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Table of Contents

Cont #	Title	Presenter	Page
13	The Beam Commissioning of BRIF and Future Cyclotron Development at CIAE	ZHANG, Tianjue	1
17	New trap technologies for in-trap recapture of HCI for mass measurements and in-trap decay spectroscopy for $2\nu2\beta$ decay	KWIATKOWSKI, Anna A.	2
21	The High Rigidity Spectrometer for FRIB	BAUMANN, Thomas	3
23	Production, Purification, and Analysis of a Ho-163 Sample for the Neutrino Mass Determination	SCHNEIDER, Fabian	4
24	Multi-reflection time-of-flight mass separation and spectrometry	WOLF, Robert	5
25	The TRIGA-SPEC experiment: coupling to the research reactor TRIGA Mainz, beamline optimization and recent results	GRUND, Jessica	6
29	The SECAR Recoil Separator for Nuclear Astrophysics	BERG, G.P.A.	7
33	On-line separators for the Dubna Superheavy Element Factory	POPEKO, Andrey	8
35	Calcium isotope enrichment by means of multi-channel counter-current electrophoresis (MCCCE) for the study of particle and nuclear physics	KISHIMOTO, Tadafumi	9
39	In-gas-jet spectroscopy of actinium isotopes	RAEDER, Sebastian	10
40	The extraction of $^{229}Th^{3+}$ from a buffer-gas stopping cell	VON DER WENSE, Lars	11
42	The low energy storage ring CRYRING@ESR project	HERFURTH, Frank	12
43	Progress in the design and construction of SPES at INFN-LNL	BISOFFI, Giovanni	13
46	On-line charge breeding using ECRIS and EBIS/T	VONDRASEK, Richard	14
49	Ion Optical Modeling of In-Flight Separators	AMTHOR, Alan	15
51	Direct measurement of nanoscale lithium diffusion in solid battery materials using radioactive tracer of ^{8}Li	ISHIYAMA, Hironobu	16
56	Harvesting Radioisotopes from an Aqueous Target at a Projectile Fragmentation Facility	PEN, Aranh	17
60	The KOBRA facility for neutron-rich beam production at RISP	CHAE, Hyunwoo	18
61	New energy-degrading scheme for low-energy reaction measurements of rare isotope beams	MATSUSHITA, Masafumi	19
63	On-line experimental results of argon gas cell based laser ion source (KEK Isotope Separation System)	HIRAYAMA, Yoshikazu	20
66	Large acceptance spectrometers and possible new developments	NAKAMURA, Takashi	21
67	Measurements of multinucleon transfer reactions of ^{136}Xe + ^{198}Pt for production of exotic nuclei	WATANABE, Yutaka	22
69	Status of the Low-Energy Super Heavy Element Facility at RIKEN	SCHURY, Peter	23
71	Wider in spectral range, narrower in line width - upgrades of the RILIS titanium:sapphire lasers for in-source spectroscopy	WENDT, Klaus	24
76	Measurement of the Ionization potential of Lr (Z=103) by online mass separation	SATO, Tetsuya	25
77	First production test of slowed-down RI beam at RIBF	SUMIKAMA, Toshiyuki	26
80	MR-TOF-MS at the FRS: Instrumental Advances, Mass Measurements and Spatial Isomer Separation for Decay Spectroscopy	PLAß, Wolfgang	27
84	Developments at the IGISOL-4 facility	GORELOV, Dmitry	28
86	New developments of ^{11}C post-accelerated beams for hadron therapy and imaging	MELO MENDONCA, Tania	29
96	The laser ion source at CERN-ISOLDE: new features - more possibilities	ROTHE, Sebastian	30
100	The Prototype Active-Target Time-Projection Chamber used with TwinSol Radioactive-Ion Beams	AHN, Tan	31
113	Thick targets for high-power ISOL facilities	BRICAULT, Pierre	32
115	Production at 1000 MeV/u, in-flight separation, thermalization and extraction of 238-U projectile and fission fragments from a cryogenic stopping cell	REITER, Moritz Pascal	33
116	Direct evidence of melting shell-gap of the neutron-rich nuclei through novel spectroscopic tool	DATTA, Ushasi	34
121	The Super Separator Spectrometer S3 and the associated focal plane detection systems SIRIUS and REGLIS3	DÉCHERY, Fabien	35
123	The Argonne Gas-filled Fragment Analyzer	SEWERYNIAK, Dariusz	36
124	JYFLTRAP at IGISOL-4: Separating isomers and nailing down nuclear masses	REINIKAINEN, Juuso	37
126	Gas-filled and vacuum mode separators for fusion reactions	GATES, Jacklyn	38
127	The CARIBU gas catcher	SAVARD, Guy	39
128	Radioactive ion beams developments from the TRIUMF resonant ionization laser ion source	LASSEN, Jens	40
132	First Measurement of the Permanent Electric Dipole Moment of Radium-225	SINGH, Jaideep	41
133	Experimental program of the Super-FRS Collaboration of the FAIR project and developments of the related instrumentation	MUKHA, Ivan	42
136	Operational Experiences in Particle Identification and Isotope Separation with BigRIPS In-flight Separator	AHN, DeukSoon	43

Cont #	Title	Presenter	Page
137	SPIRAL 1 Upgrade at GANIL: status	DUBOIS, Mickaël	44
140	Slow neutron detector WINDS for (p,n) reaction in inverse kinematics with SAMURAI spectrometer	YASUDA, Jumpei	45
147	First measurements with the Array for Nuclear Astrophysics and Structure with Exotic Nuclei	BLACKMON, Jeffery	46
150	SAMURAI in its operation phase for RIBF users	OTSU, Hideaki	47
151	The Light Ion Guide Project at the Texas A&M University Cyclotron Institute	YENNELLO, Sherry	48
152	The ISOLDE Facility and the HIE-ISOLDE project	G. BORGE, Maria J.	49
154	Time Projection Chambers for Nuclear Reaction Studies with Fast Beams	LYNCH, William	50
158	New Developments in Penning Trap Mass Spectrometry	BLOCK, Michael	51
160	TSR: a storage ring for HIE-ISOLDE	BUTLER, Peter	52
163	Neutral atom traps of rare isotopes at the precision frontier	MUELLER, Peter	53
164	High Intensity Ion Guides and Purification Techniques for Low Energy Radioactive Ion Beams	GRÉVY, Stéphane	54
165	Recent progress of in-flight separators and rare isotope beam production	KUBO, Toshiyuki	55
166	Storage rings for experiments with in-flight produced rare isotope beams	ZHANG, Yuhu	56
167	New Target Material Developments for Exotic ISOL Beams	GOTTBERG, Alexander	57
168	β-NMR on liquid media for biophysical and biological applications	STACHURA, Monika	58
173	New developments in resonance laser ionization for radioactive beams	MARSH, Bruce	59
178	The transition from Si to Gas detection media in Nuclear Physics	POLLACCO, Emmanuel	60

Poster Presentations

9	Progress of TITAN's Cooler Penning Trap for Highly Charged Ions	LASCAR, Daniel	62
10	An In-flight Radioactive Beam Separator for the ATLAS Facility	MUSTAPHA, Brahim	63
11	The SPES Target - Ion Source system	BISOFFI, Giovanni	64
12	Design of the in-flight fragment separator for the RISP	KIM, Jong-Won	65
14	High Intensity Proton Beam Transportation through Fringe Field of 70 MeV Compact Cyclotron to Beam Line Targets	ZHANG, Xu	66
15	The hydraulic and thermal numerical analysis of free surface flow for Beijing ISOL high power liquid target	GAO, Yuan	67
16	SHELS - Separator for Heavy ELement Spectroscopy	POPEKO, Andrey	68
18	Application and further improvement of the Laser Ion Source and Trap (LIST) at ISOLDE/CERN	HEINKE, Reinhard	69
19	The Deuteron Accelerator Conceptual Design for Beijing ISOL	PENG, Shixiang	70
20	Design study of a β=0.09 high current superconducting half wave resonator at Peking University	ZHU, Feng	71
22	Towards sympathetic cooler for HCI using laser-cooled Ca ions	PARK, Young-Ho	72
26	LISE++ : exotic beam production with fragment separators and their design	TARASOV, Oleg	73
27	Recent results from the TwinSol low-energy RIB facility	BECCHETTI, Fred	74
28	Extraction and low energy beam transport from a surface ion source at the TRIUMF-ISAC facility	BRICAULT, Pierre	75
30	Simulations of the University of Notre Dame Multi-Reflection Time-of-Flight Spectrograph	KELLY, James	76
32	High voltage conditioning of the electrostatic deflector of MARA	PARTANEN, Jari	77
34	Theoretical study of buffer gas cooling and ion motions in a Penning Trap, and status of LPT	TIAN, Yulin	78
36	Radioactive ion beam production at CERN-ISOLDE with nanometric, highly porous target materials - a review	RAMOS, Joao Pedro	79
37	A1900 Rigidity Calibration Based on Accelerator RF Timing	GINTER, Thomas	80
38	Off-line in-gas-laser ionization and spectroscopy (IGLIS) laboratory at KU Leuven	KUDRYAVTSEV, Yuri	81
41	Off-line production of transition metal ions for collinear laser spectroscopy at BECOLA/NSCL	MINAMISONO, K.	82
44	Probing the nature of the weak interaction with laser trapped 6He	LEREDDE, Arnaud	83
45	Development of a Gas Filled Magnet within the FIPPS project	BLANC, Aurelien	84
47	Charge breeder development for HIE-ISOLDE and future ISOL facilities.	BREITENFELDT, Martin	85
50	A Multi-Reflection Time-of-Flight Mass Spectrometer for Isobaric Purification at the University of Notre Dame	SCHULTZ, Brad	86
52	Efficient laser trapping of neutral radium atoms for electric dipole moment search	PARK, Sung Jong	86a
53	Development of a next generation RFQ beam cooler and buncher for the CANREB project at TRIUMF	BARQUEST, Brad	87
54	V_{ud} determination from light nuclide mirror transitions	BRODEUR, Maxime	88
55	A proposed method of effective collinear optical pumping for nuclear spin polarization	PARK, Sung Jong	89
57	Multi-Step Resonant Photoionization of Sn by High-Repetition-Rate Ti:Sapphire Lasers	YOON, Jin Woo	90

Cont #	Title	Presenter	Page
59	Search for efficient laser resonance ionization schemes for Ta and W using a new reference-cell in KISS	MUKAI, Momo	91
62	Principle of Isochronous Mass Spectrometry using two time-of-flight detectors	ZHANG, Yuhu	92
64	New developments in high-capacity isobaric separation with the Penning-trap based mass separator PIPERADE at DESIR	MINAYA RAMIREZ, Enrique	93
65	Development of the detector system for ?-decay spectroscopy at the KEK isotope separation system	KIMURA, Sota	94
68	The ISOLDE High Resolution Separator upgrade to a mass resolving power of 20000	BREITENFELDT, Martin	95
72	Development of a liquid Pb-Bi target for high-power ISOL facilities	HOUNGBO, Donald	96
73	Plans for Performance and Model Improvements in the LISE++ Software Suite	KUCHERA, M.P.	97
74	The Ion Conveyor for the Cyclotron Gas Stopper	VILLARI, Antonio C.C.	98
75	First experiment with the NUSTAR/FAIR Decay Total Absorption Gamma-Ray Spectrometer at the IGISOL IV facility	GUADILLA, Víctor	99
78	Off-line Tests and Performance of ORISS with an Improved RFQ Ion Cooler/Buncher	PIECHACZEK, A.	100
79	A Compact All-Permanent Magnet ECR Ion Source Injector for ReA at MSU NSCL	PHAM, Alfonse	101
81	RFQ Beam Cooler for SPES project at LNL	MAGGIORE, MARIO	102
82	Extending the capabilities of the ISOLDE RILIS by blurring the boundaries between ion sources at ISOLDE	DAY GOODACRE, Thomas	103
85	The new IGISOL off-line ion guide quadrupole mass spectrometer system and applications	POHJALAINEN, Ilkka	104
89	Status of the Isolde RFQ Beam Cooler	GILES, Tim	105
90	A Laser Ablation Source for LEBIT	IZZO, Christopher	106
91	SWIFT beam purification at LEBIT	VALVERDE, Adrian	107
93	A Novel Next-Generation Cryogenic Stopping Cell for the Low-Energy Branch of the Super-FRS	REITER, Moritz Pascal	108
94	Experimental techniques to use the (d,n) reaction for spectroscopy of low-lying proton-resonances	KUVIN, Sean	109
95	Towards a precision Penning trap measurement of the 163Ho Electron Capture Q-value	REDSHAW, Matthew	110
97	IGISOL control system modernization	KOPONEN, Jukka	111
98	Direct double beta-decay Q-value measurements at LEBIT	GULYUZ, Kerim	112
99	Advances in surface ion suppression from ISOLDE-RILIS using µs beam-gating and pulsed heating	ROTHE, Sebastian	113
101	Upgrades for the TwinSol low-energy RIB facility	O'MALLEY, Patrick	114
105	A preparation Penning trap for the project TRAPSENSOR with prospects for MATS at FAIR	CORNEJO, JUAN MANUEL	115
106	Micro Penning Traps for Continuous Magnetic Field Monitoring in High Radiation Environments	RINGLE, Ryan	116
107	Opportunities for Isotope Discovery at FRIB	BAUMANN, Thomas	117
108	Beam Thermalization in a Large Gas Catcher	SUMITHRARACHCHI, Chandana	118
109	The Ion Surfing Transport Method for Beam Thermalization Devices	GEHRING, Amanda	119
110	Mass Measurements of Rare Isotopes with a Single Ion	EIBACH, Martin	120
112	Commissioning the cryogenically cooled gas target and the ionization chamber of HELIOS	SANTIAGO-GONZALEZ, Daniel	121
114	Specifications and Design of the Electric Dipole for the SPIRAL2 Super Separator Spectrometer	NOLEN, Jerry	122
117	Specifications, Design, and Commissioning of the Superconducting Multipole Triplets for the SPIRAL2 Super Separator Spectrometer	NOLEN, Jerry	123
119	The NSCL Cyclotron Gas Stopper - entering commissioning	SCHWARZ, Stefan	124
120	Developments in magnet modeling and beam optics for the ARIS separator at FRIB	PORTILLO, Mauricio	125
122	AstroBox2 - Detector for Low-energy Beta-delayed Proton Detection	SAASTAMOINEN, Antti	126
129	Characterization and Performance of the NSCL's Large Volume Linear Gas Cell	COOPER, Kortney	127
131	The SPES-Charge Breeder and its beam line at INFN-LNL	BISOFFI, Giovanni	128
134	PILGRIM, a future MR-ToF-MS at GANIL for mass measurement and separation on exotic beams.	CHAUVEAU, Pierre	129
138	New Target Ion Source Systems at GANIL/SPIRAL 1: prospective	JARDIN, Pascal	130
142	The new JENSA gas-jet target for astrophysical radioactive beam experiments	O'MALLEY, P.D.	131
143	Status of the project TRAPSENSOR: a laser-cooled ion as a high-sensitive detector for single-ion Penning trap mass spectrometry	CORNEJO, Juan Manuel	132
144	Thermalized and ReAccelerated beam diagnostics at NSCL	WILLIAMS, Scott	133
145	Thermal, Mechanical and Fluid Flow Aspects of the High Power Beam Dump for FRIB	AVILOV, Mikhail	134
146	Status of the ReA Electron Beam Ion Trap Charge Breeder at NSCL	LAPIERRE, Alain	135
148	Experimental Test of Momentum Compression in an Achromatic Fragment Separator	HAUSMANN, Marc	136
149	Upgrade of the TAMU MDM-Focal Plane Detector with MicroMegas Technology	SPIRIDON, Alexandra	137

Cont #	Title	Presenter	Page
157	A Resonant Ionization Laser Ion Source at ORNL	LIU, Yuan	138
159	Towards high precision measurements of nuclear g-factors for Be isotopes	TAKAMINE, Aiko	139
161	Ultra fast timing detector systems to probe exotic properties of nuclei using RIB facility	DATTA, Ushasi	140
162	Installation of the Multi Reflection Time Of Flight (MR-TOF) mass separator at the ANL CARIBU facility	HIRSH, Tsviki	141
171	High-resolution laser spectroscopy with the Collinear Resonance Ionisation Spectroscopy (CRIS) experiment at CERN ISOLDE	COCOLIOS, Thomas Elias	142
172	Development of Electromagnetic and Gaseous Centrifuge Technologies for the Enrichment of Stable Isotopes	STEVENSON, Adam	143
175	New design studies for TRIUMF's ARIEL High Resolution Spectrometer	MALONEY, James	144
176	Delivering multiple, independent RIB simultaneously: Technical and operational challenges	MORTON, Colin	145
177	Electrostatic Potential Map Modelling with COSY Infinity	MALONEY, James	146
180	First direct determination of the superallowed β-decay Q-EC-value for O-14 via Penning trap mass spectrometry at the LEBIT facility	SANDLER, Rachel	147
181	The progress of the BRISOL facility	ZHANG, Tianjue	148

Oral Presentations

Oral Presentation ID: 13

The Beam Commissioning of BRIF and Future Cyclotron Development at CIAE

As an upgrade project of the existing HI-13 tandem accelerator facility, the Beijing Radioactive Ion-beam Facility (BRIF) is being constructed in China Institute of Atomic Energy (CIAE). This project consists of a 100MeV compact cyclotron for high current proton beam, a two-stage ISOL system, a superconducting linac booster and various experimental terminals. The design and construction progress of BRIF were invited to presented elsewhere [1, 2,3]. In this paper, the recent progress of BRIF will be presented briefly. The beam commissioning of the cyclotron is in progress and we got the first 100 MeV beam on July 4, 2014. The beam current was stably maintained at above 25 μA for about 9 hours on July 25, 2014, which is ready for providing CW beam on target for RIB production. 200 μA to 500 μA proton beam will be provided in the coming years. The installation of ISOL system is finished and the stable ion beam test shows it can reach a mass resolution better than 14000. It is expected to generate dozens of RIB by 100 MeV proton beam. In additions, this paper also introduce the recent progress of the pre-study of a 800 MeV, 3-4 MW separate- sector proton cyclotron, which is proposed to provide high power proton beam for several applications, such as neutron and neutrino physics, proton radiography and nuclear data measurement and ADS study as well.

[1] Tianjue Zhang et al., 100 MeV H- Cyclotron as an RIB Driving Accelerator, Proc. Of 17th International Conference on Cyclotrons and Their Applications (Invited), Oct.18-22, 2004, Tokyo

[2] Tianjue Zhang, et al., Physics problem study for a 100 MeV, 500 microAmp H- beam compact cyclotron, 10th International Computational Accelerator Physics Conference (Invited), Aug 31-Sept 4, 2009, San Francisco

[3] Tianjue Zhang, The Cyclotron Development Activities at CIAE, 10th European Conference on Accelerators in Applied Research and Technology (Invited), September 13-17, 2010, Athens, Greece

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Oral Presentation ID: 17

New trap technologies for in-trap recapture of HCI for mass measurements and in-trap decay spectroscopy for 2ν2β decay

TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) facility deploys three ion traps for Penning trap mass spectrometry of radionuclides and in-trap decay spectroscopy. The latter is performed in an electron beam ion trap (EBIT), which is radially surrounded by seven Si(Li) detectors. The magnetic field separates charged and neutral decay particles and hence eliminates 511 keV gamma rays from the annihilation of beta particles. The electron beam enhances the radial confinement of the magnetic field, thereby extending the observation period to minutes, enabling the observation of the evolution of the decay chains of the trapped isotopes. The setup has been commissioned with a branching-ratio and half-life measurement of ^{124}Cs.More recently, ion stacking has been demonstrated: Hundreds of ^{116}In ion bunches were collected in the EBIT, reaching close to its space-charge capacity of about 10**8 trapped ions. Stacking improves the statistical precision attainable with in-trap decay spectroscopy.

The other principle purpose of the EBIT is charge breeding for Penning-trap mass measurements, as the precision scales with the charge state of the ion. More generally, the use of highly charged ions (HCI) can reduce the beam-time requirements. In addition, TITAN has pioneered the use of HCI for beam purity, for example with threshold charge breeding. More recently, the EBIT has been used to enhance the beam availability at TITAN. The daughter of the beta-emitter ^{30}Mg was recaptured in the EBIT and subsequently delivered to the Penning trap for a successful mass measurement. In-trap recapture circumvents difficulties in the production of certain nuclides via the ISOL technique employed at TRIUMF-ISAC, and it can ensure population of a particular nuclear state. Recent results and developments in ion manipulation will be presented.

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Oral Presentation ID: 21

The High Rigidity Spectrometer for FRIB

The Facility for Rare-Isotope Beams (FRIB) will be the world's premier rare-isotope beam facility, producing a large fraction of the isotopes predicted to exist [1, 2]. For FRIB's rare isotope beams, optimum production yields will be achieved at energies between 170 MeV/u and 200 MeV/u. To make full use of these beams a high-acceptance beamline and a spectrometer with adequate bending power is needed.

The High Rigidity Spectrometer (HRS) will build on and expand the capabilities of the current experimental program at the S800 Spectrograph and the Sweeper Dipole Magnet by combining a large-gap dipole sweeper magnet with a spectrometer stage, both of which will be designed to handle beams of up to 8 Tm magnetic rigidity.

This charged-particle bending power will be about twice that of the existing devices and thus a good match for the rare isotope beams that will be available with FRIB. It will also enable the study of very neutron-rich systems at optimum energies.

A key feature of the HRS will be the accommodation of detector systems for charged particles, neutrons, and gamma rays. This will enable coincidence measurements of reaction products that stem from a variety of reactions such as knockout, breakup, charge exchange or Coulomb excitation [3].

This presentation will highlight some of the scientific objectives to which the HRS will contribute, and offer details of the current pre-conceptual design ideas.

[1] J. Erler et al., Nature 486, 509 (2012) and references therein
[2] A. V. Afanasjev, S. E. Agbemava, D. Ray, P.Ring, Phys. Lett. B 726, 680 (2013)
[3] "HRS - a High Rigidity Spectrometer for FRIB" whitepaper, Ed. Alexandra Gade and Remco Zegers, http://people.nscl.msu.edu/~zegers/HRS_draft.pdf (December 2014)

*) In collaboration with the FRIB HRS working group.

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Production, Purification, and Analysis of a Ho-163 Sample for the Neutrino Mass Determination

The ECHo collaboration investigates the electron capture decay (EC) of Ho-163 for determining the mass of the electron neutrino. The spectrum of the EC is recorded by metallic magnetic calorimeters (MMC) and the neutrino mass is deduced from the analysis of the endpoint region of the spectrum. The required Ho-163 samples are produced by reactor activation of enriched Er-162. Co-produced long-lived radio isotopes producing unacceptable levels of background need to be removed. By ion exchange chromatography both prior to and after the irradiation a pure Ho fraction can be obtained, leaving Ho-166m as the only remaining long-lived contamination. Resonance ionization at a mass separator offers a suitable method to further purify the sample and to implant Ho-163 into the calorimeters in a single step. This combines additional element-selectivity and high ionization efficiency, in particular regarding lanthanides, with precise control and monitoring of the implantation. The RISIKO mass separator of the LARISSA working group is an ideal tool with its existing resonance ionization laser ion source and the associated high-performance pulsed Ti:sapphire laser system. This highly element-selective method and a sector field Mass separation result in no radioactive co-implants beyond a fraction of 1 ppb with respect to Ho-163. To increase the implantation yield, a new focusing and scanning stage is currently being designed which matches the beam characteristics to the miniature geometry of the MMC. In addition to the calorimetric spectrum, an independent measurement of the EC Q-value, i.e., the mass difference between parent and daughter nuclide, is necessary as a consistency check and to quantify systematics such as solid state effects. The ideal way for a model independent Q-value measurement is by high-precision Penning- trap mass spectrometry. For this purpose the chemically purified Ho-163 sample is sufficient as the only isobar, Dy-163, is suppressed by the chemical separation. Ion production from samples with only 10^16 atoms was studied at TRIGA TRAP using an improved laser ablation ion source. Determination of the Q-value was demonstrated and the uncertainty of the atomic masses of Ho-163 and Dy-163 improved by a factor of two compared to literature. This combination of sample and ion production can now be used at SHIPTRAP to perform the measurements on a 30 eV uncertainty level, thus providing the very important input for the ECHo project.

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Oral Presentation ID: 24

Multi-reflection time-of-flight mass separation and spectrometry

Precision mass measurements of radioactive nuclides give direct insight to one of the most fundamental properties of atomic nuclei, their binding energy. Investigating this property as a function of proton and neutron number is crucial for advancing theory in describing and predicting the structure of nuclei. Furthermore, the masses of nuclei far from stability are essential for the understanding of nucleosynthesis in supernovae and neutron stars. Laboratory experiments are often extremely challenging due to the short half-lives and low production rates of the nuclides of interest. At the same time, longer-lived or stable contaminations are produced in orders of magnitude higher abundancies, demanding a high selectivity and resolving power of the mass spectrometer. ISOLTRAP at ISOLDE/CERN has already investigated over 500 isotopes on an uncertainty level down to dm/m=1x10-8 by use of Penning-trap techniques. To extend the range of accessible nuclides even further, the setup has been upgraded with a multi-reflection time-of-flight mass analyzer [1], see fig. 1. This device can be operated as a mass purifier or a mass spectrometer, which already allowed mass measurements for nuclear astrophysics applications [2] and tests of modern nuclear theory, i.e., valence-shell calculations based on three-nucleon forces [3]. The talk will give an overview of these developments and of recent further applications.

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Oral Presentation ID: 25

The TRIGA-SPEC experiment: coupling to the research reactor TRIGA Mainz, beamline optimization and recent results

Experimental data of ground-state properties of exotic nuclides are important for nuclear structure and reaction studies. They also benchmark the predictive power of astrophysical models. The TRIGA-SPEC experiment - comprising the collinear laser spectroscopy setup TRIGA-LASER and the double Penning-trap mass spectrometer TRIGA- TRAP - is built to perform high-precision measurements on fission products and long-lived transuranium nuclides. Laser-spectroscopic measurements will provide model- independent information on nuclear ground-state and excited-state properties such as magnetic dipole and electric quadrupole moments as well as the change in the nuclear charge radius. Direct mass measurements allow determining nuclear binding energies and Q-values.

The TRIGA-SPEC facility is coupled to the research reactor TRIGA Mainz. Here, fission products produced by neutron-induced fission of U-235 or Cf-249 targets are extracted by an aerosol-based gas-jet system and are guided through a skimmer system to a surface ionization ion source, which is heated by electron bombardment to temperatures of about 2000°C. We recently implemented an aerodynamic lens, which improves the transmission through the skimmer by collimating the particle beam of the gas-jet system, thereby boosting the injection efficiency into the ionizer. The 30 keV ion beam from the on-line ion source is mass separated in a 90° dipole magnet, then cooled and bunched in a radio-frequency quadrupole cooler/buncher (RFQ). The RFQ generates short bunches of low-energy ions suitable for injection into the Penning-trap and for collinear laser spectroscopy studies. In addition, an off-line laser ablation ion source, using a frequency-doubled Nd:YAG laser, is available for TRIGA-TRAP, in order to perform reactor-independent mass measurements of stable and long-lived nuclei, including transuranium element isotopes.

The latest results concerning the performance of the beamline will be presented. Furthermore an overview of current mass measurements of transuranium nuclides at the TRIGA-SPEC experiment is given.

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Oral Presentation ID: 29

The SECAR Recoil Separator for Nuclear Astrophysics

The explosive nuclear burning of hydrogen at high temperatures and densities on the surface of accreting white dwarfs and neutron stars gives rise to a number of observable nuclear explosions including Novae or X-ray bursts. Recent astronomical observations provide unprecedented information, for example, on atomic abundances in Nova ejecta and time structure of X-ray bursts. Interpretation of these data requires an understanding of the nuclear processes during the explosive events and, therefore, information on the reactions of unstable, proton-rich nuclei with hydrogen and helium.

We will present the conceptual design of the SEparator for CApture Reactions (SECAR), a recoil separator designed to achieve the sensitivity needed to measure very low (p,gamma) and (alpha,gamma) rp-process reaction rates directly at astrophysical energies in inverse kinematics and for target masses up to A= 65. This requires a large angle acceptance of ±25 mrad to transmit the full reaction distribution of the recoils and a very high mass resolution m/dm > 750 not available at existing recoil separators. SECAR will initially operate at the ReA3 rare isotope (RI) beam facility at NSCL, Michigan State University, and taking advantage of its unique capability to produce a wide range of radioactive beams. SECAR will achieve its full potential with the intense radioactive beams that can be produced at the Facility for Rare Isotope Beams (FRIB), a next generation facility currently under construction at Michigan State University.

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Oral Presentation ID: 33

On-line separators for the Dubna Superheavy Element Factory

Production cross sections of superheavy elements (SHE) with Z = 112 ÷ 118 in fusion reactions are in the range of a few picobarns or less. To get access to heavier nuclides and carry out a detailed study on their properties, a sufficient increase in the beam intensity and the development of separators providing the necessary background suppression are needed. This is the main goal of the construction at the JINR's Flerov Laboratory of a first-ever SHE factory based on the high-current heavy-ion cyclotron DC280, having an experimental hall of 1000 m2 designed in compliance with class II radiation safety requirements for work with high active targets made of transuranium isotopes. By choosing the separation principle, we have analyzed cinematic characteristics of different products for several hundred reactions leading to the formation of heavy nuclei. Unfortunately, the use of only magnetic fields is inapplicable for fusion reactions. Thus, electrostatic separators (energy selectors), velocity filters, and gas-filled systems were considered. Further analysis showed that it is reasonable to construct 3 separators optimized for specific tasks:

I. The universal gas-filled separator for the synthesis and study of properties of heavy isotopes and the investigation of reaction mechanisms. The ion-optical layout QDQQD is chosen for this set-up. The R and technical design were conducted, and the parameters of magnetic elements were determined. The negotiations with potential manufacturers are currently underway.

II. The velocity filter is chosen for a detailed spectroscopic study of heavy isotopes. This separator, named SHELS, is manufactured, equipped and installed for testing and use at the beam of the U400 cyclotron. Upon the completion of the construction of the SHE factory, it will be moved into a new experimental hall. (See special report to this conference).

III. To study radiochemical properties of SHE, extremely high suppression factors are not needed. One needs to work with thick targets at high beam intensities.

Thus, we consider different versions of a simplified gas-filled QDQ system, gas-filled solenoid or multipole magnets. Coupled with a reaction product collection (RPC) chamber or a gas catcher, this set-up will serve as a pre-separator for further chemical separation and precise mass measurements, respectively.

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Oral Presentation ID: 35

Calcium isotope enrichment by means of multi-channel counter-current electrophoresis (MCCCE) for the study of particle and nuclear physics

We developed a new method for enrichment of large amount of calcium isotopes for the future study of ^{48}Ca double beta decay. The method is the Multi-Channel Counter-Current Electrophoresis (MCCCE). We present the concept of the MCCCE where power density in migration path is the key for the efficient enrichment of large amount of materials.

In the MCCCE, ions migrate in multi-channel on a boron nitride (BN) plate by which substantial increase of the power density can be achieved. We made a tiny prototype instrument with a 10 mm thick BN plate and obtained 3 for an enrichment factor as the ratio of abundance of ^{48}Ca to ^{43}Ca over that of natural abundance. It corresponds to 6 for the enrichment factor of ^{48}Ca to ^{40}Ca. Recently we obtained 10 for the enrichment factor by using 20 mm BN plate. This remarkably large enrichment factor demonstrates that the MCCCE is a realistic and promising method for the enrichment of large amount of ions. This method can be applied to many other elements and compounds.

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Oral Presentation ID: 39

In-gas-jet spectroscopy of actinium isotopes

To perform laser spectroscopy measurements of exotic nuclides at the borders of stability, highest efficiencies in combination with a high spectral resolution are required. In this contribution we report on the first on-line results reconciling these requirements by applying the In-Gas Laser Ionization and Spectroscopy (IGLIS) technique in the supersonic gas jet produced by a de Laval nozzle installed at the buffer gas cell exit at the Leuven Isotope Separator On-Line (LISOL) facility. In the last years IGLIS was employed within the gas cell at the LISOL facility to measure magnetic moments of Cu [1] and Ag [2] isotopes. A typical spectral resolution of 5 GHz was obtained. The measurements were recently extended to the heavy mass region by resolving the hyperfine structure (HFS) of neutron deficient $^{212-215}$Ac [3]. Carrying out laser ionization in the low-temperature and low-density supersonic gas jet formed at the exit nozzle allows eliminating the pressure broadening thus improving significantly the spectral resolution [4]. A narrow bandwidth, high repetition rate laser system brought together from GANIL, Mainz University and JYFL has been used to investigate the HFS of the 438 nm atomic transition in ^{214,215}Ac. The data obtained reveals a total spectral resolution of ~400 MHz. Thus, the isotope shifts as well as the hyperfine parameters are extracted with a 25-fold higher precision than obtained for these isotopes by in-gas-cell spectroscopy. Additionally, a better spin assignment for the N=126 nuclide ^{215}Ac (T½=0.17 s) is possible. Moreover, the results show that the total ionization efficiency in the gas jet is comparable to that in the gas cell (~0.5%) and can potentially be improved up to one order of magnitude by increasing the duty cycle. Further characterization and optimization of the technique is investigated at the off-line IGLIS laboratory, being commissioned at KU Leuven. Here, the physical and technical limits of the IGLIS technique will be explored. This will ensure the best performance in spectral resolution and ionization efficiency for the future IGLIS setup [5] linked to the Superconducting Separator Spectrometer (S3) at the new radioactive ion beam facility SPIRAL2 (GANIL).

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Oral Presentation ID: 40

The extraction of $^{229}Th^{3+}$ from a buffer-gas stopping cell

Among all known nuclear isotopes, ^{229}Th possesses the lowest nuclear excitation, revealing an energy of just 7.6 eV above the ground state. This low energy is equivalent to a wavelength of the corresponding gamma-ray of about 160 nm, which is set in the VUV region and conceptually allows for the application of laser- spectroscopic methods to the nucleus. The excited state is predicted to be isomeric with a half-life of up to several hours, which would lead to an extremely sharp linewidth, making the isomeric ground-state transition of ^{229}Th an ideal candidate for a nuclear-based frequency standard.

So far, however, the energy of the isomeric state has not been measured precisely enough to allow for a direct optical access to the transition. Further, the direct observation of the isomeric ground-state decay has not been conclusively proven, so that, besides the exact energy, also the half-life and the gamma branching-ratio have to be stated as unknown.

In our approach to directly detect the isomeric ground-state transition, ^{229}Th is populated via a 2 % decay branch in the alpha-decay of ^{233}U. $^{229(m)}$Th recoil ions, as produced by a ^{233}U source, are stopped within ultrapure He in a buffergas stopping cell strictly designed to UHV standards. The ions are then extracted with the help of electric guiding fields and a supersonic Laval nozzle. Successively, a sub-mm diameter ion beam is formed by an RFQ guiding structure. Having formed an ion beam allows for a mass-purification of the extracted recoil ions with the help of a customized quadrupole mass separator, designed for high transmission. In this way, possible decays from short-lived daughters in the decay chain are highly suppressed. A search for photons and electrons originating from the isomeric deexcitation is performed behind the QMS. This concept has the advantage that a measurement of the transition can be performed within an environment of ultra-low background, which opens up the way for an unambiguous identification of the isomeric decay.

Obviously, a large combined extraction and mass-purification efficiency of ^{229}Th ions is of major importance for this concept. Measurements were performed to quantify this efficiency. Surprisingly, a large extraction efficiency of 10 % is obtained in the 3+charge state. This is the first time, that a significant extraction rate in the 3+ charge state could be observed from a buffer-gas stopping cell. This work was supported by DFG (Th956/3-1).

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Oral Presentation ID: 42

The low energy storage ring CRYRING@ESR project

The CRYRING@ESR project is the early installation of the low-energy storage ring LSR, the Swedish in kind contribution to FAIR, which was proposed as the central decelerator ring for antiprotons at the FLAIR facility. Since the modularized start version of FAIR does not include the erection of the FLAIR building, it was proposed to install the CRYRING storage ring behind the existing experimental storage ring ESR already now. This opens the opportunity to endeavor part of the low energy atomic physics with heavy, highly charged ions as proposed by the SPARC collaboration but also experiments of nuclear physics background in the NUSTAR collaboration much sooner than foreseen in the FAIR general schedule. Furthermore, since the installation of the ring will be handled mostly by FAIR standards, it will be used to test major parts of the FAIR control system for the first time and well ahead of time before it is needed to run SIS100.

Highly-charged ions up to bare uranium as produced by stripping at 400 MeV/nucleon will be stored, cooled and decelerated in the ESR. This will supply CRYRING@ESR with up to 100 millions of heavy, highly-charged ions stored at energies between several 100 keV/ nucleon and about 10 MeV/nucleon for atomic physics experiments. Rare ions for storage in CRYRING@ESR are produced and separated in the FRS and then also stored, cooled and decelerated in the ESR. This imposes a lower life time limit of several ten seconds for ions available for experiments in the storage ring. A future connection to the Super FRS at FAIR would increase the available yields of rare, heavy and highly charged ions considerably and hence also extend the physics opportunities. Furthermore, a possible connection of this kind would also allow to guide antiprotons from the FAIR antiproton production facility to CRYRING@ESR and hence bridge the present gap to the low energy physics program with antiprotons as proposed by the FLAIR collaboration.

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Oral Presentation ID: 43

Progress in the design and construction of SPES at INFN-LNL

INFN-LNL is constructing an ISOL facility delivering neutron rich ion beams at 10A MeV or beyond, making use of the linear accelerator ALPI as the secondary accelerator. The facility includes a direct ISOL target based on UCx and able to reach 1013 fission/s. In parallel, an applied physics facility will be developed, with applications in medicine and neutron production. Considering the exotic beam application, SPES is developed under the NuPECC umbrella, together with HIE-Isolde at CERN and Spiral2 at GANIL, as a second generation Exotic Beam Facility paving the way to EURISOL. The SPES project is a national facility, which was approved and funded. SPES relies on fruitful collaborations with Italian labs and Universities, European and extra-European labs.
Commissioning with the first exotic species is expected in 2018. The primary accelerator is a commercial cyclotron, which will send a 40 MeV, 200 uA proton beam onto a UCx target, connected to SIS, PIS and LIS ion sources. The extracted beam is purified through a Low Resolution Mass Separator (LMRS, i.e. a Wien filter and a dispersive dipole), a beam cooler and a High Resolution Mass Separator (HRMS) and sent to an ECR Charge Breeder to boost the exotic beam charge state. The highly charged exotic beam is further separated in a MRMS (Medium Resolution Mass Separator) and injected into a 100% duty cycle RFQ and into the existing superconducting linac ALPI, which will be refurbished and upgraded to be an efficient exotic beam accelerator. The upgrade is tuned, so as to give ~ 10 MeV/ a specific energy to ^{132}Sn, taken as the reference ion beam.
At present, the cyclotron accelerator is approaching completion, together with the building hosting it (http://www.lnl.infn.it/index.php/en/). After cyclotron commissioning, the second part of the machine which will become operational will be the one from the charge breeder to the RFQ injection, through the MRMS (phase planned in 2016). By the time of completion of the RFQ construction, the beam line from the Target-Ion-Source to the Charge Breeder, and the new ALPI injector will be completed too, and commissioning of the whole facility will start in stages.

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Oral Presentation ID: 46

On-line charge breeding using ECRIS and EBIS/T

The efficient and rapid production of a high-quality, pure beam of highly charged ions is at the heart of any radioactive ion beam facility. Whether an electron cyclotron resonance ion source (ECRIS) or an electron beam ion source/trap (EBIS/T) is used to produce these highly charged ions, their operating characteristics will set the boundaries on the range of experiments which can be performed. In addition, time structure and duty cycle have to be considered when defining the operating parameters of the accelerator system as a whole. At Argonne National Laboratory, an ECR charge breeder was developed as part of the Californium Rare Ion Breeder Upgrade (CARIBU) program. The charge breeding efficiency and high charge state production of the source is at the forefront of ECR charge breeders, but its overall performance as part of the accelerator system is limited by a pervasive background and relatively long breeding times. As such, an EBIS charge breeder has been developed and is running in an off-line configuration. It has already demonstrated good breeding efficiencies, shorter residence times, and reduced background and is scheduled to replace the ECR charge breeder in late 2015. The resultant change in duty cycle and time structure necessitates changes to the overall operation of the facility. The experiences with these breeders, as well as from several other facilities which already utilize ECRs and EBIS/Ts for charge breeding, help to define the operational characteristics of each technology – their strengths, their weaknesses, and the possible paths to improvement.

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Oral Presentation ID: 49

Ion Optical Modeling of In-Flight Separators

Realistic ion optical models are a critical component in the design and operation of the next generation of in-flight, heavy ion separators for the production and study of exotic nuclei. Current methods for detailed optical modeling of large acceptance, in-flight separators will be presented in the context of the design efforts for ARIS (the Advanced Rare Isotope Separator, to be constructed at FRIB), S3 (the Super Separator Spectrometer, being developed as part of Spiral2 at GANIL) and ISLA (the Isochronous Separator with Large Acceptance, being developed for use with re- accelerated FRIB beams from ReA). Transport, purification and focusing of secondary beams require particularly detailed consideration of the ion optical system because of the high power of the primary beams and the large phase space of the reaction products, both of which make the understanding of higher order aberrations important. Models based on either Taylor expansion methods (e.g. COSY Infinity) or ray tracing methods (e.g. Zgoubi) are used to study the detailed performance of proposed ion optical separator designs. Methods to be discussed include: the excitation-dependent modeling of magnetic dipole and multipole elements, parallel optimization techniques to speed the discovery of optimized magnet settings and design requirements for the reduction of optical aberrations, and Monte Carlo methods to simulate full beam cocktails to verify system performance for benchmark experimental cases.

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Oral Presentation ID: 51

Direct measurement of nanoscale lithium diffusion in solid battery materials using radioactive tracer of ^{8}Li

The diffusion coefficient of lithium in solid materials used in secondary Li--ion batteries is one of key factors that determine the rate at which a battery can be charged and discharged. Nevertheless, reported lithium diffusion coefficients in Li battery materials measured with various methods are largely scattered over several orders of magnitudes, for example, 6 orders for $LiCoO_2$ and 8 orders for $LiMn_2O_4$, which are commercially used as electrodes. The traditional radioactive tracer method with a serial sectioning technique can provide the most accurate diffusion coefficient in a direct way, but it cannot be applied for Li battery materials because of no availability of radioactive Li isotopes with a half-life suitable for such offline applications. We developed an in situ lithium diffusion tracing method using a short--lived radioactive ion beam of 8Li, with the half- life of 0.84 s, which immediately decays into two alpha particles. Tracing the time evolution of the changes in the energies of the alpha particles from diffusing 8Li, which is primary implanted into a sample of interest, we can extract Li diffusion coefficient directly. The method has been successfully applied to measure diffusion coefficients in Li ionic conductors (e.g [1]). The range of measurable lithium diffusion coefficient by the current method is from 10^{-6} down to 10^{-10} cm2/s. For measurements of Li diffusion coefficients in battery electrodes such as $LiCoO_2$, it is required to improve the lower limit of the detection by this method. We have proposed a new method by detecting alpha particles emitted from decaying ^{8}Li at a small angle (10 degree) relative to a sample surface that is irradiated with a low—energy (8 keV) 8Li beam. The new method has been successfully applied to measuring Li diffusion coefficients for an amorphous Li_4SiO_4-Li_3VO_4 thin film, demonstrating that the new method is sensitive to diffusion coefficients down on the order of 10^{-12} cm^2/s, corresponding with nanoscale Li diffusion of several 10 nm/s [2]. Using the new method, measurements of Li diffusion coefficients in electrode materials such as $LiMn_2O_4$ are in progress. In this presentation, we will introduce recent experimental results of our newly developed nanoscale Li diffusion measurement.

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Oral Presentation ID: 56

Harvesting Radioisotopes from an Aqueous Target at a Projectile Fragmentation Facility

A remotely-operated liquid water target system for harvesting radioisotopes at the National Superconducting Cyclotron Laboratory (NSCL) was designed and constructed as the initial step in proof-of-principle experiments to harvest useful radioisotopes from the Facility for Rare Isotope Beams (FRIB). FRIB will be a new national user facility for nuclear science to be completed in 2020 at which radioisotopes can be collected synergistically from the water in cooling-loops for the primary fragmentation target. To develop the radiochemical expertise required to harvest long-lived radioisotopes of interest in this environment, the water target system was constructed and has been successfully used to collect beams of ^{24}Na and ^{67}Cu ions produced at the NSCL. Initial experiments included collection of an analyzed ^{24}Na test beam and collection and extraction of ^{67}Cu, a radioisotope with medical applications, from both an analyzed and an unanalyzed beam. The last test run, where ^{67}Cu was delivered as a 2.6% unanalyzed beam, contained a cocktail of contaminant beam particles that had to be radiochemically separated from the isotope of interest. The collected radioisotopes were characterized using low-background gamma spectroscopy at both Hope College and Washington University. Analysis of the extraction technique indicated 95% and 74% of the delivered copper isotope from the analyzed and unanalyzed beam, respectively, was successfully removed from the water. The ^{67}Cu was subsequently utilized for labeling antibodies and biological evaluation.

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Oral Presentation ID: 60

The KOBRA facility for neutron-rich beam production at RISP

The KOBRA (Korea Broad acceptance Recoil spectrometer and Apparatus) facility, which is being designed for Rare Isotope Science Project (RISP), will be utilized to produce rare isotope (RI) beams for the study of a broad range of topics in low- energy nuclear physics. The RI beams will be produced by employing the rearrangement reaction such as (p,d) at a few MeV/nucleon and the multi-nucleon transfer reaction at ~20 MeV/nucleon (see, e.g., [1,2]). We briefly introduce the KOBRA facility and report on the present status of the development of KOBRA. In particular, we discuss estimates of RI beam intensity based on the ray-tracing code combined with a proper combination of nuclear reaction models (mainly DIT/GEMINI [1, 3]) that have been successfully applied to describe the multi-nucleon transfer reaction in the energy range 15-25 MeV/nucleon.

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Oral Presentation ID: 61

New energy-degrading scheme for low-energy reaction measurements of rare isotope beams

The recent developments of technique in providing RI beams have been made many advances in radioactive isotope science. The RI beam facility (RIBF) has expanded the variety of nuclides, which provides numerous kinds of exotic isotope beams with A > 100. However, available beams in RIBF are restricted to an energy region typically above 200 AMeV or stopped beams. The variety of reaction has not been necessarily expanded on this point. The deceleration of intense RI beams provided in RIBF enable the further research based on exotic nuclei/exotic states by probing with transfer reaction in the energy region of few ten MeV, fusion reaction in a few MeV and others. For this purpose, we has set up OEDO (Optimized Energy Degrading Optics for RI beam) project, which proposes a new energy- degrading scheme of rare isotope beams produced in RIBF by using quadrupole magnets, an RF electric deflector and a mono-energetic degrader. The application of energy degrader is a general method to degrade the beam energy, while it induces the broadening of beam spot due to the angular and momentum aberrations. In the OEDO project, a new beam line is proposed, where an RF electric deflector is employed to cancel the aberrations based on the time structure of the beam bunch corresponding to the velocities of the ions. Simulation has been performed to confirm its feasibility and that the RF deflector achieves a small beam size at a reaction target after energy deceleration to around a few ten MeV. The reaction target is considered to locate at the focal plane following the SHARAQ spectrometer, which enables the low-energy reaction spectroscopy. Regarding OEDO project, the basic idea, performance study by simulation, design and future plan is introduced in this presentation.

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Oral Presentation ID: 63

On-line experimental results of argon gas cell based laser ion source (KEK Isotope Separation System)

The beta-decay properties of nuclei with neutron magic number of N=126, which are believed to act as progenitors in the rapid neutron capture process (r-process) path forming the third peak (A~195) in the observed r-abundance element distribution, are considered critical for understanding the production of heavy elements such as gold and platinum at astrophysical sites. As a first step of our project, we are going to produce and measure the half-lives of the nuclei with Z=74-77 around N=126.

We adopted the multinucleon transfer (MNT) reaction of 136Xe beam and 198Pt target system as the production of nuclei around N=126. The reaction system is considered to be one of the best candidates to efficiently produce the nuclei around N=126. In order to accumulate the reaction products efficiently and select our interesting nuclei with high purity, we have constructed the KEK Isotope Separation System (KISS) at RIKEN RIBF facility. KISS consists of an argon gas cell based laser ion source (atomic number selection) and an isotope separation on-line (ISOL) (mass number selection), to produce pure low-energy beams of neutron-rich isotopes around N=126 and to study their beta-decay properties.

We performed the off-line tests to study the basic properties of the KISS such as an extraction time from the gas cell and mass resolving power of the ISOL, and then conducted the on-line experiments to study the thermalization and neutralization processes of reaction products in the gas cell, and to measure the extraction efficiency from the gas cell and the extracted beam purity. We successfully extracted the laser-ionized stable 56Fe (direct implantation into the gas cell of ^{56}Fe beam) atoms and ^{198}Pt (emitted from the ^{198}Pt target by elastic scattering with ^{136}Xe beam) atoms from the KISS at the commissioning on-line experiments. Then, we extracted laser-ionized unstable ^{199}Pt atoms and confirmed that the measured half-life was in good agreement with the reported value.

In this presentation, we will introduce the KISS project, the gas-cell system, the results of the KISS commissioning on-line experiments, and the perspective of the project.

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Oral Presentation ID: 66

Large acceptance spectrometers and possible new developments

Large acceptance spectrometers have played significant roles in RI-beam physics. They have been widely and successfully used for studies of exotic structures far from the stability line, reactions of astrophysical interest, heavy-ion reactions to probe the equation of state of nuclear matter, and so forth. For instance, correlation measurements, of the heavy fragment and neutron(s) after the breakup of rare isotopes, have been used to reconstruct the invariant mass of unbound states beyond the neutron drip line, such as ^{26}O. At RIBF at RIKEN, the SAMURAI facility was commissioned in 2012 as such a large acceptance spectrometer. I will present some details of the development of this facility and how it has been used for such studies. I will also discuss the on-going developments at SAMURAI. Such large acceptance spectrometers have also been developed, or will be developed, at other world-leading facilities such as GSI/FAIR and MSU/FRIB, which are also presented. I will also remark on the future prospects for large acceptance spectrometers.

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Oral Presentation ID: 67

Measurements of multinucleon transfer reactions of ^{136}Xe + ^{198}Pt for production of exotic nuclei

Multinucleon transfer (MNT) reaction between two heavy ions at energies around the Coulomb barrier is considered as a promising candidate to produce and investigate exotic nuclei. Especially in the region of neutron-rich nuclei around the neutron magic number of 126, which is difficult to access by other production methods, the MNT reaction is expected to provide a means to efficiently produce them. The nuclear region of the neutron magic number of 126 has been attracting an astrophysical interest because the waiting point nuclei on the r-process path, which are considered as progenitors of the peak at the mass number of 195 in the solar r-abundance distribution, are located there. We have been developing a gas-catcher type laser ion source named KEK Isotope Separation System, which is now on commissioning, to produce, separate and measure the nuclear properties of the neutron-rich nuclei around the neutron magic number of 126, which will be produced by the MNT reaction. We adopted the reaction system of ^{136}Xe + ^{198}Pt, which is considered to be one of the best candidates to efficiently produce the nuclei of interest. In order to investigate the feasibility of the nuclear production of the system, we have studied the collisions between ^{136}Xe and ^{198}Pt at the laboratory energy of 8 MeV/A by using the large acceptance magnetic spectrometer VAMOS++ at GANIL.

After the presentation at the last EMIS conference, where we reported on the experiments and the progress status of the analysis, we have finally fixed the cross sections for the projectile-like fragments produced by transfer reactions from -4 to +4 protons. In this presentation, we will report on the final cross sections of them, which indicate that the large contribution of the deep-inelastic transfer with large charge and mass diffusion to the large cross sections for the transfer of more than one proton.

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Oral Presentation ID: 69

Status of the Low-Energy Super Heavy Element Facility at RIKEN

A facility for ion trap-based experiments with exotic nuclei produced by fusion- evaporation reaction, particularly aimed at Super Heavy Elements (SHE), has been constructed at RIKEN. At present, the facility consists of a small cryogenic gas cell and a multi-reflection time-of-flight mass spectrograph (MRTOF). Considerations have been made for adding a decay spectroscopy station in the future.

Initial tests of the gas cell have shown that we extract ions of a variety of elements with good efficiency under room temperature operation. With optimized degrader thickness, we have seen more than 30% efficiency for the long-lived species ^{205}Fr. We have also seen efficiencies of nearly 20% for ^{215}Ac ($T_{1/2}$ = 170 ms) and ^{216}Th ($T_{1/2}$ = 26 ms), and more than 10% for ^{217}Pa ($T_{1/2}$=3.6 ms). First scientific experiments will be mass measurements via MRTOF, scheduled for early 2015. We will report on the current status and long-term goals of the facility.

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Oral Presentation ID: 71

Wider in spectral range, narrower in line width – upgrades of the RILIS titanium:sapphire lasers for in-source spectroscopy

High purity ion beams are of utmost importance for most experiments on exotic isotopes at state-of-the-art radioactive ion beam facilities. Resonant multi-step laser ionization in RILIS laser ion sources, including the LIST approach, is the appropriate technology for their creation. It provides the unique combination of highest efficiency and elemental selectivity together with lowest background and cross contaminations in the beam. Today the long-standing competition between dye laser and solid-state laser technology about optimum RILIS suitability has been reconciled by the demonstration of outstanding advantages of combined operation of both lasers systems at ISOLDE´s RILIS.Mainz University serves as off-line development and test facility for titanium: sapphire lasers, laser excitation schemes and new ion source geometries. Steadily on-going developments include further optimizations of the lasers and the ion sources units. New excitation schemes for quite a number of elements along the Periodic Table were investigated, which include Pd as well as different rare earth elements, i.e. Pr, Tb, Dy, Ho and Er. For measurements at the gas cell facilities at LLN and Jyvaeskylae the studies were extended to the actinides Ac, Th, Pa, U, Np and Pu. For the study of the alkaline elements, tunable laser emission in the green to yellow spectral range of 500 - 680 nm is required, easily achieved by conventional dye lasers but a particular challenge for state-of-the-art solid-state Titanium: sapphire lasers. These wavelengths were obtained successfully in a non-linear crystal by difference-frequency generation of the radiation of two lasers, one operating in the fundamental infrared range, and one in the frequency doubled blue range. Performance was demonstrated by two- and three-step resonance ionization spectroscopy of atomic Rydberg levels of sodium involving the famous ground state dublett at 589 nm. For high resolution in-source as well as in-jet laser spectroscopy at on-line facilities the narrowing of the laser band width is of primary relevance. Two complementary techniques are presently investigated, involving ring resonator designs: passive frequency band width reduction using two etalons complements the more extensive process of injection locking by a tunable continuous wave laser. Both approaches, which require advanced stabilization techniques, have been demonstrated by high resolution hyperfine structure investigations in Tc, Ac and Th.

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Oral Presentation ID: 76

Measurement of the Ionization potential of Lr (Z=103) by online mass separation

The Isotope Mass Separation OnLine (ISOL) has been developed for over fifty years to study short lived radioisotopes. Since then the technique has diversified and many different facilities have been constructed, with post-accelerators used for nuclear structure studies. In parallel, the field of superheavy element research has Progressed with the synthesis and investigation of more than 15 new chemical elements. These elements are produced by heavy-ion induced reactions with actinide targets, where the recoil products are stopped in gas-filled cells. While recoil mass (pre)separators are now commonly used for isotope identification or chemical studies, no heavy elements have so far been investigated exploiting the ISOL method.

Here we present the production of ^{256}Lr (Z=103) radioisotopes, and their identification after formation of an ISOL beam at JAEA, Tokai. A surface ion source has been developed and its operation parameters characterized with a series of radiolanthanides [1]. The conditions were optimized to exploit the low production rates. From the measured efficiencies, it was possible to determine the first ionization potential of Lr at an one-atom-at-a-time production rate. The experimental figure closely matches theoretical predictions obtained using state of the art computational methods [2].

This novel method could possibly be extended for other superheavy element investigations.

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Oral Presentation ID: 77

First production test of slowed-down RI beam at RIBF

RI beam factory at RIKEN provides an RI beam as a projectile fragments. Because the fragments are produced from an primary beam with 345 MeV/u, an energy of reaction- type experiments is usually higher than ~100 MeV/u. However, a low energy RI beam with 15 MeV/u is required for an investigation of the shell evolution via transfer reactions. The low energy RI beam also provides opportunities of a deep-inelastic reaction and fusion reaction.

In the present study, the low energy RI beam was produced by slowing down the projectile fragment with a momentum compression scheme proposed at the RNB8 conference [1]. The RI beam of 82Ge was produced via the in-flight fission reaction of ^{238}U with 345 MeV/u. The momentum-compressed and momentum-achromatic beam was produced at the second stage of the fragment separator BigRIPS. The energy was slowed down to ~ 15 MeV/u using five energy degraders. The beam size of 11mm phi (sigma) was achieved. We will present the slowed-down scheme and results in this conference.

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Oral Presentation ID: 80

MR-TOF-MS at the FRS: Instrumental Advances, Mass Measurements and Spatial Isomer Separation for Decay Spectroscopy

At the FRS Ion Catcher experiment at GSI, projectile and fission fragments are produced at relativistic energies with the FRS, separated in-flight, range-focused, slowed-down and thermalized in a cryogenic stopping cell and are transmitted to a multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS). The MR-TOF-MS is used to perform direct mass measurements of exotic nuclei, to provide an isobarically and isomerically clean beam for further experiments, and as a versatile diagnostics device to verify the particle identification of the FRS and analyze the ions emerging from the CSC.

The MR-TOF-MS consists of an RFQ for ion cooling and transmission, an injection RFtrap for ion bunching, a coaxial isochronous TOF analyzer, as well as a TOF detector for mass measurement and a Bradbury-Nielsen Gate for mass separation. Several novel principles have been implemented to further enhance the performance and versatility of the MR-TOF-MS, including a post-analyzer reflector. Thus extremely high resolution can be obtained as well as very short flight times. Mass resolving powers up to 600,000 (FWHM) at 50% transmission efficiency, ion capacities of more than a million ions per second and cycle frequencies as high as 400 Hz have been achieved.

Recently, the kinetic energy of the ions in the time-of-flight section of the MR-TOF- MS has been increased, yielding a mass resolving power of 220,000 at mass 133 u after only 4.6 ms. A novel RF quadrupole-based ion beam switchyard has been developed that allows merging and splitting of ion beams as well as transport of ion beams into different directions. It efficiently connects a test and reference ion source and an auxiliary detector to the system.

Mass measurements of uranium projectile and fission fragments produced at the FRS at 1000 MeV/u have been performed at mass resolving powers up to 400,000. For several nuclides, the mass was measured directly for the first time, among them the nuclides 213-Rn, 218-Rn and 217-At with half-lives of 19.5 ms, 35 ms and 32.3 ms, respectively. Mass determination with as few as 27 detected ions at ion rates of five ions per hour has been demonstrated, and mass measurement accuracies down to 0.2 ppm have been achieved. The excitation energy of several isomers and isomeric ratios were determined using mass spectrometry. For the first time, an isomeric beam was prepared using an MR-TOF-MS. This work opens up new perspectives for decay experiments with isomers.

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Oral Presentation ID: 84

Developments at the IGISOL-4 facility

The ion guide based isotope separator facility in the JYFL accelerator laboratory, the IGISOL, was recently moved to a new location next to the new high intensity proton cyclotron MCC30, thus becoming IGISOL-4, as reported in the previous EMIS conference [1]. The facility has now passed the commissioning phase, which is clearly indicated by more than 60 days of beam time delivered from the K-130 cyclotron for nuclear physics experiments at the IGISOL-4 during 2014. On top of this become the test beams from the new MCC30, which did not launch the scheduled beam delivery yet in 2014.

A major new development since [1] is the neutron converter, based on beryllium target bombarded with protons. The converter is designed to provide a high neutron flux with energy up to tens of MeV at the IGISOL-4 target position [2, 3]. This is foreseen as the best way to fully utilize the intense beams from the MCC30 in the studies of exotic neutron rich nuclei [3]. The first tests of the converter have been performed in 2014.

At the IGISOL, the neutron rich, medium mass nuclei are produced for decay spectroscopy studies via charged particle induced fission of natural uranium and thorium. Neutron induced fission is expected to give improved yields of the most neutron-rich species.

We have recently completed independent fission product yield measurements of proton induced fission of uranium and thorium. In this work we have exploited a technique utilizing the unambiguous isotope identification with JYFLTRAP [4]. In the progress of this work we have also gained better understanding of the experimental constraints and the execution of the independent fission yield measurements. The technique is now challenged in the product yield measurements of neutron induced fission of uranium.

In the presentation, the most up-to-date developments of the IGISOL-4 facility will be summarized. The performance of the neutron converter as well as the results of the first neutron-induced fission product yield measurements will be presented.

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Oral Presentation ID: 86

New developments of ^{11}C post-accelerated beams for hadron therapy and imaging

Hadron therapy was first proposed in 1946 and is by now widespread throughout the world, as witnessed with the design and construction of the CNAO, HIT, PROSCAN, MedAustron and Etoile treatment centers, among others. The clinical interest in hadron therapy lies in the fact that it delivers precision treatment of tumors, exploiting the characteristic shape (the Bragg peak) of the energy deposition in the tissues for charged hadrons. In particular, carbon ion therapy is found to be biologically more effective, with respect to protons, on certain types of tumors. Following an approach tested at NIRS in Japan [1], carbon ion therapy treatments based on ^{12}C could be combined or fully replaced with ^{11}C PET radioactive ions post-accelerated to the same energy. This approach allows providing a beam for treatment and, at the same time, to collect information on the 3D distributions of the implanted ions by PET imaging. The production of 11C ion beams can be performed using two methods. A first one is based on the production using compact PET cyclotrons with 10-20 MeV protons via $^{14}N(p,\alpha)^{11}C$ reactions following an approach developed at the Lawrence Berkeley National Laboratory [2]. A second route exploits spallation reactions $^{19}F(p,X)^{11}C$ and $^{23}Na(p,X)^{11}C$ on a molten fluoride salt target using the ISOL (isotope separation on-line) technique [3]. This approach can be seriously envisaged at CERN-ISOLDE following recent progresses made on $^{11}C^{+}$ production [4] and proven post-acceleration of pure $^{10}C_3$/6+ beams in the REX- ISOLDE linac [5]. Part of the required components is operational in radioactive ion beam facilities or commercial medical PET cyclotrons. The driver could be a 70 MeV, 1.2 mA proton commercial cyclotron, which would lead to $2x10^{10}$ $^{11}CO^{+}$/s and $2.3x10^{8}$ $^{11}C^{6+}$/spills at 1 Hz [4]. This intensity is appropriate using ^{11}C ions alone for both imaging and treatment. Here we report on the ongoing feasibility studies of such approach and future tests envisaged within the forthcoming CERN-MEDICIS facility and MEDICIS-PROMED Horizon2020 EU program.

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Oral Presentation ID: 96

The laser ion source at CERN-ISOLDE: new features - more possibilities

The Resonance Ionization Laser Ion Source (RILIS) of the CERN-ISOLDE radioactive ion beam facility is the most frequently applied ion source type. The RILIS method of step-wise resonant laser excitation and ionization of the nuclear reaction products makes it both highly selective and efficient. A continuous program of technical upgrades of the laser installation, as well as research and development of the RILIS technique is necessary to fulfil the ever-increasing demand for new, more intense, or higher purity ion beams. The 2012-2014 long shutdown (LS1) of the LHC accelerator chain suspended the operation of ISOLDE for 18 months, enabling significant RILIS upgrades and development work to be performed.

The laboratory was extended and a new, high beam quality Nd:YVO laser was added to RILIS laser system. The laser launch system for the GPS front-end with beam reference area was rebuilt and upgraded with a refined beam stabilization and monitoring system. This, in conjunction with the implementation of an autonomous machine protection system, enabled the first RILIS "on-call" operation, successfully used for four experiments during the 2014 ISOLDE on-line period. The RILIS DAQ system has been upgraded and streamlined, managing the links between RILIS, the Windmill detector system and the ISOLTRAP MRTOF-MS for in-source laser spectroscopy experiments.

In addition to these technical improvements, the RILIS capabilities have been extended to improve the efficiency, selectivity and the range of accessible elements: New ionization schemes have been investigated for holmium, mercury, lithium, barium, chromium, and germanium; laser ionization to the 2+ state has been applied for barium; and, for the first time, the RILIS has been coupled with a liquid target for the on-line production of neutron-deficient mercury beams.

In this paper we present the status of the RILIS system, a summary of the recent upgrades and new capabilities, concluding with an outlook towards the promising future areas of development.

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Oral Presentation ID: 100

The Prototype Active-Target Time-Projection Chamber used with TwinSol Radioactive-Ion Beams

The study of low-energy reactions with radioactive-ion beams has been greatly enhanced by the recent use of active-target detectors, which have high efficiency and low thresholds to detect low-energy charged-particle decays. Both of these features have been used in experiments with the Prototype Active-Target Time-Projection Chamber (PAT-TPC) to study alpha-cluster structure in unstable nuclei and 3-body charged-particle decays after implantation. Predicted alpha-cluster structures in C-14 were probed using resonant alpha scattering and the nature of the 3-alpha breakup of the Hoyle state after the beta decay of N-12 was studied. These experiments used in-flight radioactive-ion beams that were produced using the dual superconducting solenoid magnets TwinSol at the University of Notre Dame. Preliminary results from these experiments as well as the development of future radioactive beams to be used in conjunction with the PAT-TPC will be presented.

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Oral Presentation ID: 113

Thick targets for high-power ISOL facilities

The future frontier of the ISOL technique is to increase the intensity of the Radioactive Isotope Beams (RIB) by many orders of magnitude in order to satisfy challenging experiments such as Rn-EDM, Fr-PNC... and in general for radiative proton-capture in nuclear astrophysics. In the On-Line Isotope Separation (ISOL) method, the isotopes are produced by nuclear interactions of light particles impinging onto a high-Z target material. The resulting products are stopped in the bulk of the thick target that is closely coupled to the ion source, allowing them to be quickly turned into an ion beam, which can be mass analyzed and transported efficiently to experiments. The main challenges in the ISOL method come from the fact that the reaction products are stopped in the bulk of the target material. To be released, the atoms have to diffuse out of the grain to the surface, then undergo the so-called effusion process, which is a series of desorption-absorption iterations, until reaching the ion source where the neutral atoms are ionized and extracted in the form of an ion beam. To obtain the highest overall efficiency for the release out of the target to the ion source, the targets are usually operated at the highest "acceptable" temperature. The most direct method to increase the RIB intensity is to increase the driver beam intensity. At ISAC we have developed thick ISOL targets capable of withstanding high proton beam power by using composite target material and high power dissipating target container capable of dissipating 20 kW using radiative cooling. With these techniques we routinely operate refractory foil-targets and carbide targets between 35 and 50 kW incident beam power. The concepts and technical challenges of generating intense radioactive ion beams from ISOL target irradiated with high intensity proton beam are discussed. Another method to increase RIB intensity is the use of indirect ISOL method, where secondary particle beam (n or γ) interacts with a fissile target material. The decoupling of the power deposition in the system composed of a converter and ISOL target allows the operation of the ISOL-target at much lower power while the converter can be cooled without affecting the target temperature and consequently the radioactive atoms overall release efficiency. While the indirect ISOL target method can reach several hundred kW to MW driver beam power, the RIBs hence produced are limited to mainly fission products.

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Oral Presentation ID: 115

Production at 1000 MeV/u, in-flight separation, thermalization and extraction of 238-U projectile and fission fragments from a cryogenic stopping cell

At the low energy branch (LEB) of the Super-FRS at FAIR, projectile and fission fragments will be produced at relativistic energies, separated in-flight, energy- bunched, slowed-down and then thermalized in a stopping cell filled with ultra-pure helium gas. The stopping cell has been developed as a cryogenic stopping cell (CSC), operated at 70 to 90 K, featuring enhanced cleanliness and high extraction efficiencies. Using an RF carpet with fine electrode spacing enables operation at high stopping gas densities. After extraction from the CSC the ions will be delivered to the high precision low-energy experiments MATS and LaSpec. A prototype CSC for the LEB has been successfully commissioned at the FRS Ion Catcher at GSI. The FRS Ion Catcher consists of the fragment separator FRS, the CSC and a multiple-reflection time-of-flight mass- spectrometer (MR-TOF-MS).

During three FRS experiments numerous 238-U projectile and fission fragments produced at 1000 MeV/u have been stopped, thermalized and extracted from the CSC with high total efficiencies (up to 15%). For the first time 238-U fission fragments were thermalized in a stopping cell. The fragments were extracted without any significant contribution of adducts or molecular contaminants, demonstrating the excellent cleanliness of the CSC. The CSC was operated online at areal densities of up to 6.2 mg/cm^2 helium, which is about two times higher than ever reached before for a stopping cell with RF ion repelling structures (RF Carpet). Despite the high areal density the extraction time of ions from the CSC was about 30 ms, enabling the extraction of short-lived fragments, e.g. 220-Ra with a half-life of only 17.9 ms.

The ion transport along the body of the CSC and in the vicinity of the RF carpet has been studied with and without space-charge effects in detailed simulations and compared with measurements. Moreover the temperature dependence of the cleanliness and the extraction efficiency of the CSC have been investigated. As an alternative to helium, neon has been investigated as stopping gas.

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Oral Presentation ID: 116

Direct evidence of melting shell-gap of the neutron-rich nuclei through novel spectroscopic tool

Understanding the limits of existence of the quantum many body systems is an open and urgent problem in the fundamental of science. Both theoretical and experimental investigations are pursued to understand the unusual properties of the quantum many body system, the atomic nuclei, at the limit of its existence. Melting of the shell gap at magic number of the exotic nuclei is one of the important observations [1]. RIB facility provide us excellent opportunity to explore this outstanding problems. Coulomb breakup is a sensitive spectroscopic tool to probe the ground state properties [2]. Due to large spatial extension, enhanced threshold strength can be observed. The shape and magnitude of this threshold strength of the nuclei is a direct finger-print of the quantum numbers of valence nucleon and its occupation probability for that particular quantum state. The ground state properties of p_{sd} shell nuclei have been explored through kinematics complete measurement. Recently, using this method, an experiment (S306) has been performed to explore the ground state properties of a number of exotic sd−pf shell neutron-rich nuclei around (N~20) using LAND-ALADIN-FRS setup at energy 400-430 MeV/u. The shape of the differential CD cross section suggests that the predominant ground-state configurations are ^{28}Na(1+)xns,d, ^{29}Na(3/2+)xns,d for ^{29}Na(3/2+), ^{30}Na(2+) [3,5] isotopes, respectively. First time, very clear evidence of reduced shell gap between p3/2 and f7/2 shell has been observed through the data analysis of Coulomb breakup of ^{35}Al (N=22). This results clearly indicate the breakdown of magic number N=28. It is evident from present experimental data of Coulomb dissociation of ^{31}Na(N=20), ^{33}Mg (N=21) [4, 6], the ground state configuration is dominated by (~ 80 %) core excited states. This is direct evidence of sufficiently reduced shell gap at N=20 for ^{31}Na and ^{33}Mg [4,6]. I would like to present these exciting experimental results and discuss about the limitations of the present measurements. I would like to discuss how, one may overcome these limitation using future advanced instrumentation.

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Oral Presentation ID: 121

The Super Separator Spectrometer S3 and the associated focal plane detection systems SIRIUS and REGLIS3

The Super Separator Spectrometer (S3) will receive the very high intensity stable ion beams from the superconducting LINAG accelerator of SPIRAL2, with energies ranging from 0.75 to 14.5 MeV/u and currents beyond 1 pµA. 16 Letters of Intent have been submitted by a large physics community [1]. Special emphasis is on the study of rare nuclei, such as superheavy elements and neutron-deficient isotopes, produced by fusion evaporation reactions. S3 includes a rotating target to sustain the high- energy deposition, a two-stage separator (momentum achromat followed by a mass spectrometer) that can be coupled to the implantation-decay station SIRIUS or to a gas catcher.

The SIRIUS detection system [2] will includes tracking detectors and a silicon box [3] surrounded by germanium detectors to perform delayed spectroscopy. The gas catcher, combined with a set of RFQs, multi-reflection time-of-flight mass spectrometer and a last generation laser system, constitute the Low Energy Branch [4]. It will make possible ground state properties measurements or will deliver the reaction products to the DESIR facility.

S3 will combine very high transmission with high mass resolution, thanks to large aperture superconducting magnets with sextupolar and octupolar corrections. The project is in the construction phase and will be completed by end 2016. We present the current status of the main elements of the facility (target station, magnets, detection set-up, low energy branch) with a focus on the specific issues due to the handling of very high power beams (heat dissipation, induced radioactivity, beam rejection…). Included are detailed results of tracking single ions through 3D fields maps of all elements using a recently updated version of Tracewin [5] software, and the resulting performance for various physics cases and optical configurations.

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Oral Presentation ID: 123

The Argonne Gas-filled Fragment Analyzer

Gas-filled recoil separators are characterized by an unparalleled transmission for products of fusion-evaporation reactions. They also offer a very good primary beam suppression for reactions with relatively light beams impinging on heavy targets. Consequently, gas-filled separators have been playing an essential role in studies of super-heavy nuclei, which are produced with tiny cross sections and require very intense beams.

In order to extend the studies of super-heavy nuclei at ATLAS, the Argonne Gas-Filled Fragment Analyzer (AGFA) was designed and is currently under construction. It consists of a large bore quadrupole followed by a dipole with the combined function of horizontal focusing and bending of ion trajectories. Its unique features include large space in front of the separator sufficient to accommodate a 4π Ge array for in-beam gamma-ray studies and a compact focal plane to achieve a high gamma-ray detection efficiency for decay studies. AGFA will be coupled to GAMMASPHERE for in- beam gamma-ray spectroscopy, including calorimetry, of trans-Fermium nuclei. In the stand-alone mode, it will be used for decay spectroscopy, such as alpha-decay fine structure and K-isomer studies, and for new super-heavy element searches in the future. It can also be coupled with a gas catcher to produce cool beams of super- heavy ions for precision mass measurements and laser spectroscopy.

During the talk, the details of AGFA design and its parameters will be presented and plans for experimental program with AGFA will be discussed.

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Oral Presentation ID: 124

JYFLTRAP at IGISOL-4: Separating isomers and nailing down nuclear masses

The JYFLTRAP Penning trap setup [1] as a part of the IGISOL facility is not only used in high-precision atomic mass spectrometry of exotic nuclei but it also provides isomerically clean ion beams. After relocation to the new experimental hall and its commissioning, the trap setup has been mostly used as a high-resolution mass filter. Recent tests with Xe-133 that has an isomeric state at 233 keV (requiring about 2 ppm separation) showed that JYFLTRAP with present settings provides better than 1 ppm mass resolution in a two- step cleaning process requiring less than 500 ms. With the demonstration of such a high resolving power, production of Xe-133m samples for comprehensive test ban treaty organization (CTBTO) will soon commence [2]. These samples provide valuable contaminant-free calibration sources for noble gas detectors. Various post-trap spectroscopy experiments have been performed including studies of beta delayed neutron emitters with BELEN (BEta deLayEd Neutron Detector) [3] setup and measurements of beta decay strengths of fission reactor products with total absorption spectroscopy (TAS) method. In the mass measurement side, light neutron deficient nuclei masses near A=30 region were measured for nuclear astrophysics studies. Currently, cross-reference mass measurements are being carried out to study systematic characteristics of JYFLTRAP.As the further development of IGISOL-4 is concerned, the major upcoming improvements to JYFLTRAP setup will be the installation of a position sensitive MCP to enable phase-imaging ion-cyclotron-resonance (PI-ICR) technique to further improve mass measurement precision and speed. Additionally, a multi-reflection time-of-flight (MR- TOF) mass separator will be added in front of the Penning trap to provide faster isobaric purification allowing mass measurements of even shorter-lived isotopes. Due to its faster cycle, MR-TOF also boosts the purification efficiency as it allows a few orders of magnitude worse ion-of-interest to contamination ratio than the purification Penning trap. This contribution will concentrate on current status of JYFLTRAP, especially on high- resolution beam purification. Also overview and status of the on-going developments are given.

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Gas-filled and vacuum mode separators for fusion reactions

Gas-filled and vacuum mode separators have been used for studying the products of fusion-evaporation reactions since the 1960's. Most recently, these separators are being used to study heavy recoils that are produced at rates of atoms per second to atoms per year in complete fusion-evaporation reactions. Due to the low production rates, the present-day separators are highly selective and highly efficient to remove the few wanted heavy recoils from a background of 10^{13} beam ions and unwanted reaction products per second.

The next generation of radioactive and high-intensity stable ion beam facilities will pose interesting challenges for gas-filled and vacuum mode separators for fusion- evaporation reactions. At radioactive beam facilities with planned intensities of up to 10^{11} ions per second, fusion-evaporation reactions can be used to produce new isotopes of elements up to Z~106 at the rates of atoms per day. However, the beta- gamma decay rate of the beam will be as high as several Curies. For experiments trying to study nuclear properties of low-production heavy elements, highly selective separators will be required for even the 'simplest' of the reactions with radioactive beams.

At high intensity, stable beam facilities, beam intensities of 10^{13-14} ions per second would allow for detailed studies of isotopes near the next predicted spherical closed shell. However, and order of magnitude improvement in selectivity over current separators will be required to take full advantage of the higher beam intensities.

An overview of recent developments in gas-filled and vacuum mode separators for fusion reactions, with an outlook toward the next generation of accelerators, will be presented.

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Oral Presentation ID: 127

The CARIBU gas catcher

The CARIBU facility provides neutron-rich radioactive beams at low-energy or reaccelerated to energy up to 10-15 MeV/u for experiments addressing issues in nuclear physics, nuclear astrophysics and various applications. The source for these radioactive ions is a large high-intensity gas catcher used to thermalize neutron- rich recoils from the fission of a 1 Ci ^{252}Cf source. This approach provides fast and essentially universal extraction of all fission fragments and delivers a low- emittance beam suitable for high-resolution mass separation and post-acceleration. The CARIBU gas catcher operates successfully under extreme conditions with intense neutron, alpha particle and fission recoil bombardment while extracting reliably a total of 10^7 to 10^8 short-lived radioactive ions per second. The technical developments that allow this performance level will be presented, together with a detailed characterization of the results obtained thus far, and a discussion of further improvements being implemented to reach total extracted radioactive beam intensities well above 10^8 ions per second.

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Oral Presentation ID: 128

Radioactive ion beams developments from the TRIUMF resonant ionization laser ion source

Developments towards intensity and purity increases of the radioactive ion beams delivered from TRIUMF's ISAC facility by means of target ion sources coupled to the laser resonance ionization ion source (TRILIS) will be detailed. There are a number of long standing experiments in nuclear structure and nuclear astrophysics that have not been able to be conducted at present isotope separator and accelerator facilities due to one or two general shortcomings. These are: (a) the production and/or beam intensity delivered is too small, and/or (b) the purity of the delivered beam is insufficient to conduct a successful measurement. There is incremental progress at all RIB facilities towards obtaining higher beam intensities and increased beam purity. At TRIUMF our most notable improvements in the past years has been the successful prototyping and application of an ion guide as part of the resonant ionization laser ion source to increase the beam purity by introducing a suppression of isobaric beam contamination (from surface ionization) by up to 6 orders of magnitude. In addition improved laser ionization schemes for a number of elements have been developed and applied to boost overall yields of radioactive isotopes. In order to motivate the rationale and constraints of the approaches taken to obtain improved RIB delivery to experiments a general introduction to RIB production at TRIUMF's ISAC facility will be included.

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Oral Presentation ID: 132

First Measurement of the Permanent Electric Dipole Moment of Radium-225

Electric dipole moments (EDMs) are signatures of time-reversal (T), parity (P) & charge-parity (CP) violation. CP-violation beyond the Standard Model is generally believed to be required to explain the observed prevalence of matter over antimatter in the universe. Radium-225 ($T_{1/2}$ = 14.7 d, I = 1/2) is mostly sensitive to T- & P-violating interactions originating within the nucleus. The best limits on these types of exotic interactions are derived from the atomic EDM limit for Mercury-199. Because of its unusual nuclear structure (octupole deformation), Ra-225 is expected to have a physics sensitivity that is a few hundred to a few thousand times higher than Hg-199. Laser cooling & trapping techniques are performed to collect & transport the cold Ra atoms into the measurement region. An EDM measurement is then performed by searching for a linear electric field dependent shift in the nuclear spin precession frequency of Ra-225. We will report on the first measurement of the atomic EDM of Ra-225 as well as plans for future improvements. This work is supported by U.S. DOE, Office of Science, Office of Nuclear Physics, under contract DE- AC02-06CH11357.

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Oral Presentation ID: 133

Experimental program of the Super-FRS Collaboration of the FAIR project and developments of the related instrumentation

The physics program at the superconducting fragment separator Super-FRS, being operated in a multiple-stage, high-resolution spectrometer mode at radioactive-beam energies up to 1500 MeV/u for the heaviest projectiles [1], will be presented. This versatile spectrometer, coupled to the heavy-ion synchrotrons SIS18/SIS-100, will be a backbone facility of the NuSTAR collaboration of the FAIR project for research with exotic nuclei. The Super-FRS will be used for production and transmission of separated isotopes to three experimental areas, but it can also be used as a stand- alone experimental device together with ancillary detectors. Various combinations of the magnetic sections of the Super-FRS can be operated in dispersive, achromatic or dispersion-matched spectrometer modes which are suited for measurements of momentum distributions of secondary reaction products with high resolution and precision. Taking advantage of the multiple stages and flexibility of ion-optical modes, the Super-FRS is a worldwide unique instrument in the high-energy range, which allows for a variety of novel experiments in atomic, nuclear and hadron physics as well as an extension of preceding experiments at the existing fragment spectrometer FRS [2]. Among the planned experiments are the search for new isotopes and measurements of their production cross sections, studies of hypernuclei, Delta-resonances in exotic nuclei and spectroscopy of atoms characterized by bound mesons. Rare decay modes like multiple-proton or neutron emission and the nuclear tensor force observed in high- momentum components of the nucleons can also be addressed. The in-flight radioactivity measurements in the picosecond range, pioneered at the FRS, will be extended with the proposed program. Fusion, transfer and deep-inelastic reaction mechanisms with the slowed-down and energy-bunched fragment beams are proposed for the high-resolution and energy buncher modes at the Low-Energy Branch of the Super- FRS. Examples of the related experimental setups, pilot experiments and developments of the ancillary detectors will be presented.

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Operational Experiences in Particle Identification and Isotope Separation with BigRIPS In-flight Separator

The BigRIPS in-flight separator [1-3] at the RIKEN RI Beam Factory (RIBF) [4,5], which became operational in March 2007, has been used to produce a variety of rare isotope (RI) beams by using in-flight fission of a 238U beam as well as projectile fragmentation of various heavy-ion beams such as ^{18}O, ^{48}Ca, ^{70}Zn, ^{124}Xe, etc. Its major features are large ion-optical acceptances, two-stage structure, and excellent performance in particle identification [6,7]. These features of the BigRIPS separator have made it possible to efficiently produce RI beams, allowing us to expand the region of accessible rare isotopes and advance studies on exotic nuclei to a significant extent. In this paper, we will overview the RI-beam production with the BigRIPS separator, showing operational experiences in particle identification and isotope separation of RI beams. We will demonstrate background reduction and resolution improvement in particle identification and also encountered difficulties in isotope separation which are caused by large backgrounds such as charge state changing events and triton events.

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Oral Presentation ID: 137

SPIRAL 1 Upgrade at GANIL: status

The Upgrade of SPIRAL1 [1] aims to offer new radioactive ion beams to the physics community. Regarding the ion beams requested by the users, an important technical transformation was needed to make the current installation able to host new Target Ion Source Systems (TISS) suited to the production and ionization of the relevant isotopes, while preserving sufficient high charge states for post-acceleration. Part of the work has already been done: the irradiation cave has been transformed and successfully tested with two different TISSs in 2013. To match with the features of the cyclotron post-accelerator, the second part of the project consists in the installation of an efficient charge breeder, in a room surrounding the production cave which must first be transformed to be in conformity with the conclusions of a safety examination. The risk analysis related to the technical proposal has just been approved by the safety authority thus building transformations will start soon and should be completed by the end of 2015. Improvement of our charge breeder takes advantage of the experimental feed-back of existing on-line breeders (ANL/Argonne, LPSC/Grenoble). It is now built and on-line tests with stable primary ion beams are scheduled by spring 2015 at LPSC. In parallel, a TISS including a graphite target associated to a FEBIAD ion source [3], already tested on-line in 2013 [2] to produce new radioactive ions on SPIRAL1, will be optimized before using it regularly after the SPIRAL1 Upgrade commissioning. Goals, technical progress and safety status will be presented with more details.

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Oral Presentation ID: 140

Slow neutron detector WINDS for (p,n) reaction in inverse kinematics with SAMURAI spectrometer

Charge exchange (CE) reactions at intermediate energies have long been used to investigate isovector spin-transfer excitations in stable nuclei [1]. Recently, significant progress has been made to employ CE reactions to the study of unstable isotopes. The most important step was the development of the (p,n) reaction in inverse kinematics[2,3].To efficiently perform (p,n) reaction experiments in inverse kinematics, we have developed a new setup of the WINDS + SAMURAI spectrometer[4] at RIKEN RIBF. In the setup, the WINDS (Wide-angle Inverse-kinematics Neutron Detectors for SHARAQ) is used for the detection of recoil neutrons and the SAMURAI spectrometer is used for tagging the (p,n) reactions. The main advantage of the setup is as follows. All the heavy fragments with different rigidities can be detected with the large acceptance of the SAMURAI spectrometer at the same time, i.e. without changing the setting of the magnetic field. This is important especially for tagging the decay channels with multi-nucleon emission, because the momentum spread of the heavy fragments rapidly becomes larger with the increase of the number of the emitted nucleons. The first experiment by using the WINDS + SAMURAI was performed in April 2014 at RIKEN RIBF to study Gamow-Teller transition in ^{132}Sn by using (p,n) reaction. Details of the experimental setup and the current status of the data analysis will be reported.

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Oral Presentation ID: 147

First measurements with the Array for Nuclear Astrophysics and Structure with Exotic Nuclei

The Array for Nuclear Astrophysics and Structure with Exotic Nuclei (ANASEN) is an array of charged-particle detectors designed for efficient studies of nuclear reactions using radioactive ion beams. ANASEN includes about 1000 square cm of silicon strip detectors backed with CsI scintillators. ANASEN also includes an array of gas proportional and gas ionization counters that allows ANASEN to be used as an extended active gas target/detector. Positions of ions are measured in the gas and the vertex of each reaction is reconstructed on an event-by-event basis allowing good energy resolution to be achieved with thick gas targets. ANASEN targets direct measurements of (alpha,p) reactions with radioactive nuclei that are important for understanding X-ray bursts and studies of the structure of nuclei through scattering and transfer reactions. The first measurements with ANASEN in active target mode were performed at the John D. Fox Superconducting Linear Accelerator Laboratory at Florida State University and included measurements using beams of 6He, 18Ne and 19O produced by the in-flight technique using RESOLUT. ANASEN has also been used in a number of fixed target experiments including one of the first experiments with a reaccelerated beam from the ReA3 accelerator facility at the National Superconducting Cyclotron Laboratory. Results from this first series of measurements will be presented, along with capabilities and future plans with ANASEN. Support for the construction of ANASEN was provided by the U.S. National Science Foundation's Major Research Instrumentation Program.
The experimental program with ANASEN is supported by the U.S. National Science Foundation and the U.S. Department of Energy's Office of Science, Office of Nuclear Physics through Award DE-FG02-96ER40978.

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Oral Presentation ID: 150

SAMURAI in its operation phase for RIBF users

SAMURAI is one of the basic and critical devices of the RIBF facility, which provides opportunities for nuclear spectroscopic studies using RI beam, especially for reactions with multi-particle final states. It consists of a superconducting dipole magnet with 7 Tm bending power coupled with sophisticated detectors for beam tracking and detection of reaction residues. The commissioning run of SAMURAI was performed in 2012 after 5 years construction. Then SAMURAI has entered into the phase of physics experiments since then. Already in 2012, the "day-one experimental campaign" was performed with neutron-nucleus coincidence measurements. In 2013, experiments detecting two residues in coincidence on the focal plane of SAMURAI were performed. Those experiments used a SAMURAI magnet configuration rotated 30 degree rotated with respect to the beam line. DALI2 was placed at the target to detect prompt gamma rays for tagging excited states in residual nuclei of the relevant reactions. In the year 2014, two experimental programs were dedicated to detection of recoil particles from the target in inverse kinematics measurements. In parallel with conducting those experiments, SAMURAI international collaboration forms several subgroups. Developments continue in order to expand and maximize the multipurpose properties of SAMURAI. The SAMURAI-TPC subgroup also known as SAMURAI pion Reconstruction Ion Tracker, SpiRIT, collaboration is developing TPC for multi particle detection in Equation of State studies. In summer of 2014, the SpiRIT collaboration tested performances of the TPC installed in the SAMURAI chamber with the magnetic field of 0.5 T. The SAMURAI-Si subgroup is developing a Si detector system for tracking heavy reaction product and one or more protons in coincidence. The Si detectors with their new readout circuits will be tested using heavy ion beams at the HIMAC facility this year. In the near future, spectroscopy of long lived fission products (LLFP) using SAMURAI is also planned as basis for technological developments for nuclear transmutation. SAMURAI is now in operation for user experiments with further technical developments, status of these development will be discussed in the presentation. The SAMURAI collaboration welcomes new ideas of experiments including development of devices to be coupled with SAMURAI.

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Oral Presentation ID: 151

The Light Ion Guide Project at the Texas A&M University Cyclotron Institute

The Upgrade Project at the Texas A&M University Cyclotron Institute continued to advance with focus on the two major direction of production of Radioactive Ion Beams: the Light Ion Guide and the Heavy Ion Guide [1]. The Light Ion Guide entered the phase of coupling the radioactive ion production and transport section with the Charge Breeding ECR Ion Source (CB-ECRIS). Several experiments and tests were performed, using different target – beam combinations, in order to better understand the functioning of the radioactive ion production and transport with along (approx.1 m) RF-only sextupole. The long sextupole proved to work in certain conditions of Helium gas pressure in the production target cell, transporting successfully radioactive products, but in conditions suitable for high output the long sextupole was not able to transport radioactive products, due to a combination of low beam acceptance, bad vacuum and insufficient DC drag. We adopted a solution proposed by the Jyvaskyla Accelerator Laboratory, with a shorter sextupole and an extraction tube to provide the particle acceleration in the low vacuum region. Recent experiments using proton beam at 16 MeV and a natural Zn target showed that we successfully produce and transport ^{64}Ga and ^{66}Ga radioisotopes. The next step is to charge breed these radioactive products and the CB-ECRIS has to be prepared for the charge breeding mode by tuning the gas load, microwave power and the extra voltage to overcome the plasma potential. An ion gun is permanently installed in line to set-up the CB-ECRIS in charge breeding mode. A broad presentation of the entire upgrade project will be given as well as the status on the advancements of the Light Ion Guide.

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Oral Presentation ID: 152

The ISOLDE Facility and the HIE-ISOLDE project

The On-Line Isotope Mass Separator ISOLDE at the CERN Proton-Synchrotron Booster (PSB) is a facility dedicated to the production of a large variety of radioactive ion beams for many different experiments in the fields of nuclear and atomic physics, materials science and life sciences. The facility has garnered unique expertise in radioactive beams over the years since its approval fifty years ago. The ISOL method involves in this case the bombardment of a thick target with an intense proton beam, producing high yields of exotic nuclei with half-lives down to the millisecond range. By a clever combination of target and ion source units including the use of ionization lasers pure beams of 700 different nuclei of 75 elements have been produced and delivered to experiments where properties of the nuclei such as masses, radii, structure and shapes are determined. The high quality of the beams allows high-precision measurements of beta decay and particle correlations including measurement of beta-neutrino correlations in order to prove fundamental interactions in nuclei. Since more ten years ISOLDE offers the largest variety of post-accelerated radioactive beams in the world today. The post-accelerated beams expand from ^{6}He to ^{224}Ra. In a decade of physics with post- accelerated beams beautiful results have been obtained exploring, by Coulomb excitation with the Miniball HPGe-array the shape transitions in extreme neutron rich middle mass nuclei as week as transfer reaction in light nuclei.

The HIE ISOLDE upgrade (HIE stands for High Intensity and Energy), intends to improve the experimental capabilities at ISOLDE over a wide front. The main feature are to boost the energy of the beams, going in steps from currently 3 MeV/u via 5.5 MeV/u to finally 10 MeV/u, and to accommodate a roughly fourfold increase in intensity. In addition improvements in several aspects of the secondary beam properties such as purity, ionisation efficiency and optical quality are addressed. Presently the facility and the experimental equipment undergo extensive transformation to commit to the new physics challenges.

In this presentation recent ISOLDE highlights, the HIE-ISOLDE project and the day one proposed experiment for 2015 are discussed.

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Oral Presentation ID: 154

Time Projection Chambers for Nuclear Reaction Studies with Fast Beams

Time Projection Chambers (TPCs) can enable unique experimental programs and extend the scientific reach of fast radioactive beams at current and future facilities. Regardless of whether a TPC is operated as a detector or as an active-target, a TPC can provide a broad (nearly 4π) angular coverage with good energy resolution and particle identification. In active target mode, the TPC counter gas serves as both the target and the detector gas, enabling one to measure low energy particles with good energy resolution while retaining the luminosity advantage of a thick target. In this talk, I will discuss the SAMURAI Pion Reconstruction and Ion- Tracker (SπRIT) TPC recently constructed at Michigan State University and its planned experimental program within the SAMURAI dipole at the Radioactive Isotope Beam Factory (RIBF) at RIKEN to constrain the symmetry- energy term in the nuclear Equation of State (EOS). I will also discuss important applications of such TPCs as active targets to measure giant resonances, fission and charge exchange reactions, and present the concept of a solenoidal TPC to perform such experiments using the fast beams at NSCL and later at FRIB.

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Oral Presentation ID: 158

New Developments in Penning Trap Mass Spectrometry

Penning trap mass spectrometry is presently the method that provides masses of stable and short-lived nuclides with unrivaled accuracy. Even in the case of exotic radionuclides a ppm precision level has been reached in certain cases. Recent advances in gas stopping and advanced ion manipulation techniques have opened the door to access radioisotopes of essentially all elements. However, for rare isotopes in addition to a high precision, also short measurement times and highest sensitivity are crucial to maximize the reach towards nuclides far off stability. Recently several developments have been performed to address these issues. The novel phase- imaging ion-cyclotron-resonance (PI-ICR) technique for high-precision mass measurements has been developed at SHIPTRAP at GSI Darmstadt. It provides an increase in resolving power by a factor of forty and a gain in precision by a factor of five. This has been demonstrated for example in a recent measurement of the mass difference ^{187}Re-^{187}Os with a precision of only 30 eV. Nondestructive electronic detection techniques, well established for ultraprecise measurements of fundamental properties, are being extended to radionuclides and will eventually allow mass measurements with only single ions. Such systems are presently under development for TRIGATRAP, SHIPTRAP, and LEBIT. In my presentation I will summarize the recent methodical and technical developments and present selected results of recent mass measurements.

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Oral Presentation ID: 160

TSR: a storage ring for HIE-ISOLDE

It is planned to install the heavy-ion, low-energy ring TSR, currently at the Max- Planck Institute for Nuclear Physics in Heidelberg, at the HIE-ISOLDE facility in CERN, Geneva [1]. Such a facility will provide a capability for experiments with stored, cooled secondary beams that is rich and varied, spanning from studies of nuclear ground-state properties and reaction studies of astrophysical relevance, to investigations with highly-charged ions and pure isomeric beams. In addition to experiments performed using beams recirculating within the ring, the cooled beams can be extracted and exploited by external spectrometers for high-precision measurements.

The capabilities of the ring facility as well as some physics cases will be presented, together with a brief report on the status of the project.

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Oral Presentation ID: 163

Neutral atom traps of rare isotopes at the precision frontier

Laser cooling and trapping techniques offer unprecedented control of an atom's external and internal degrees of freedom. The species of interest can be selectively captured, precisely positioned, cooled close to absolute zero temperatures, and observed with high signal-to-noise ratio even down to the single-atom level. Likewise, the atom's internal electronic and magnetic state can be accurately manipulated and interrogated. Applied in nuclear physics, these techniques are ideally suited for precision measurements in the fields of testing fundamental interactions and symmetries, nuclear structure studies, and detection of rare isotopes. In particular, they offer unique opportunities in the quest for physics beyond the Standard Model when applied to specific rare isotopes that exhibit enhanced sensitivity to signals of new physics. In my talk, I will review new and on- going developments and will cover world-wide efforts to apply laser cooling and trapping of rare isotopes to experiments such as measurement of atomic parity-non- conservation, searches for permanent electric dipole moments, studies of nuclear beta decays, and ultra-trace isotope analysis.

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Oral Presentation ID: 164

High Intensity Ion Guides and Purification Techniques for Low Energy Radioactive Ion Beams

Many projects worldwide aim to increase by orders of magnitude the number of exotic nuclei, in particular produced using the ISOL technique. At the same time, more and more experimental setups require very pure secondary beams in order to perform precision experiments in the domain of the fundamental interactions but also for nuclear structure studies.

In order to achieve such requirements with high intensities radioactive ion beams, it is necessary to develop new high intensity ion guides and powerful purification devices. In this presentation, we will first give a brief overview of the different purification methods that can be applied using high resolution mass spectrometers (HRS), multi-reflection time-of- flight mass separators (MR-TOF-MS) or dedicated Penning traps. In a second part, we will focus on the ongoing developments in the framework of the SPIRAL2 project at GANIL.

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Oral Presentation ID: 165

Recent progress of in-flight separators and rare isotope beam production

New-generation in-flight separators are being developed worldwide, which include the Super-FRS separator at GSI FAIR, the ARIS separator at MSU FRIB, and the BigRIPS separator at RIKEN RIBF, in order to expand the regions of accessible rare isotopes and enlarge the scope of experimental studies on exotic nuclei far from stability. The major features of these new in-flight separators can be characterized as follows: (1) use of primary beams with high intensity and high power, (2) use of in-flight fission as well as projectile fragmentation, (3) large ion-optical acceptances which allow efficient rare isotope (RI) beam production even using in-flight fission, (4)use of large-aperture high-field superconducting magnets which allow large ion- optical acceptances, (5) multi-stage structure which allows multi-step isotope separation and particle identification under low-background conditions, (6) excellent particle identification which allows identification of charge states without measuring total kinetic energy, (7) elaborate and versatile ion optics by utilizing multi-stage structure, (8) production of low-energy RI beams, (9) combination of in- flight and ISOL schemes using a gas catcher system, (10) a variety of experimental apparatus designed and built dedicatedly for RI beam experiments, and so on. Studies of exotic nuclei are being significantly advanced by exploiting these upgraded features.
In this talk, recent progress in the development of new-generation in-flight separators and RI beam production will be reviewed, including technical issues such as those caused by the use of high-intensity primary beams.

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Oral Presentation ID: 166

Storage rings for experiments with in-flight produced rare isotope beams

Ion storage rings have been proven as powerful tools for precision experiments in atomic physics, nuclear physics and nuclear astrophysics involving unstable nuclides. In the last two decades, a variety of experiments have been conducted at the only operating facilities that are capable of providing and storing exotic ions, namely the ESR in Darmstadt, Germany and the CSRe in Lanzhou, China. Those experiments concern with mainly the ground-state properties of nuclei far from stability, such as masses and lifetimes. In this talk, a brief introduction to the facilities and the storage-ring-based experiments are presented, and selected results in nuclear physics and nuclear astrophysics are reviewed. Future experiments and improvement of the facilities are discussed.

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Oral Presentation ID: 167

New Target Material Developments for Exotic ISOL Beams

Throughout the last decades a variety of complex materials and composites has been developed ranging from metals, oxides, fluorides and carbides to higher order compounds. These materials are serving as spallation, fragmentation or fission targets in the different ISOL facilities worldwide, where mixed uranium carbide with excess graphite has become the reference material.
While the nuclear production cross-section for each isotope is determined by the driver particle, its energy and the target isotopes, the final isotope beam intensity can fall as much as 10 orders of magnitude below the production yield. These losses mostly occur due to nuclear decay or chemical depletion on the isotope's path through the thick ISOL target towards the ion source. This motion is governed by diffusion, both inside the target material and its pores and is therefore closely related to the material's chemical and microstructural properties.
Major ingredients to a high-performance target material are therefore a controlled microstructure as well as its stability in the harsh conditions inside of an ISOL target. Especially when higher driver power is desired, such as 200 kW deuterons at SPIRAL 2 (GANIL, France), 240 kW protons at ISOL@MYRRHA (SCK-CEN, Belgium) or 500 kW electrons at ARIEL (TRIUMF, Canada), special precaution must be taken in order to prevent target and structural materials from degradation. This can be achieved by combining the primary target material that often exhibits limited thermal conductivity with backing foils of higher thermal durability and conductivity serving as structural backbone and thermal contact to an appropriate heat sink. Also particle converters can relax the thermal ballast on the target by converting a primary beam of charged particles into a secondary beam of spallation neutrons (i.e. SPIRAL 2) or bremsstrahlung (i.e. ARIEL), which in turn have significantly less thermal interaction with matter. Where low to medium beam power is used, such as 8 kW at SPES (LNL-INFN, Italy) or 3 kW at ISOLDE (CERN, Switzerland) additional freedom for material development arise, since the moderate thermal load allows for a higher degree of material functionalization (even when the pulsed proton beam imposes additional constrains at ISOLDE). In the past years engineered micro and nano structures with tailored grains and pores became available and promising attempts are made to translate the success of these materials towards high-power applications.

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Oral Presentation ID: 168

β-NMR on liquid media for biophysical and biological applications

Recently β-NMR spectroscopy was successfully applied for the world's first experiments on liquid samples - an achievement which opens new avenues of research in the fields of wet chemistry and biochemistry [1]. This project was motivated by the need for finding a new experimental approach to directly study biologically highly relevant metal ions, such as Mg(II), Cu(I), Ca(II), and Zn(II), that are extremely difficult to study with conventional methods in the field.

The resonance spectrum recorded for 31Mg implanted into a liquid sample shows two clear resonances, which originate from Mg ions occupying two different coordination geometries, illustrating that this technique can in fact discriminate between different structures - the first and the most important step towards the application of β-NMR spectroscopy in chemistry. A prototype bio-β-NMR spectrometer, designed and constructed explicitly for this purpose using polarized ions at the ISOLDE-COLLAPS setup, allowed for testing different aspects, such as: different liquids, vacua and rest gases, showing that aqueous solutions can as well be investigated by this method. In a future biochemical perspective, this proof-of-principle allows the application of β-NMR for studying metal ions, which are silent in most other spectroscopic techniques in their body-like environments.

In order to exploit the potential of this technique and to satisfy the growing user demand for polarized rare isotope beams new facilities at ISAC (TRIUMF, Canada) are under intense consideration, while a permanent beamline – VITO - for performing bio-β-NMR is already being setup at ISOLDE [2]. VITO stands for Versatile Ion- polarized Techniques On-line and it will allow for laser-induced nuclear spin polarization of ions and atoms, allowing for establishing β-NMR and β-asymmetry studies in a wide range of sample environments.

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Oral Presentation ID: 173

New developments in resonance laser ionization for radioactive beams

Multi-step resonance photo-ionization is completely element selective as it exploits the unique electronic energy level structure of the chosen element. When incorporated into the Isotope Separator On-Line (ISOL) process of ion beam production, element selective laser ionization complements the subsequent charge-to- mass ratio selection, performed by an electromagnetic spectrometer, thereby greatly increasing the isotope purity of the ion beam that reaches the experiment.
Crucial to the application of resonance laser ionization at radioactive ion beam facilities is an optimization of the laser-atom interaction region so that it is well adapted to specific requirements imposed by the isotope production environment. The physical and chemical properties of the isotope of interest must be considered, as well as the nature and abundance of non-laser ionized impurities. Due to the diversity of existing and planned ISOL facilities there is no universal laser ion source design and a variety of implementations have been conceived.
At thick-target ISOL facilities, the hot-cavity surface ion source is a commonly used, convenient and effective laser ionization environment but simultaneous extraction of surface-ionized isobaric contaminants often limits the achievable ion beam purity. Several supplementary techniques may be employed to reduce this problem: selective in-target production; chemical separation before the ion source; reduced surface ionization efficiency; and active suppression of surface ions. The suitability of these methods will be summarized along with an outlook towards promising ongoing developments, particularly the exploitation of the time structure of the laser-ion bunch and laser/atom interactions inside a FEBIAD-type ion source. At thin-target ISOL and projectile fragmentation facilities a gas cell, used to capture nuclear reaction products, can be an effective laser ionization volume. Design modifications have greatly improved the laser-ion survival whilst also enabling active suppression of impurities. For resonance ionization spectroscopy applications the pressure broadening and shifts of the atomic spectral lines are problematic and must be well characterized. This issue is largely avoided if ionization takes place outside of the gas cell, within a high-velocity collimated gas jet. A comparison of these methods will be presented along with a summary of the progress in achieving compatibility with projectile fragmentation facilities.

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Oral Presentation ID: 178

The transition from Si to Gas detection media in Nuclear Physics

As of five to some ten years, the emerging radioactive beams and now multi petawatt laser facilities are sturdily transforming our base concepts in instruments in nuclear physics. The changes are fuelled by studies of nuclei close to the drip-line or exotique/extreme reactions. This physics demand high luminosity and wide phase space cover with good resolution in the registered position and induced wave-form. By exploring and judiciously modifying the micro-world of the particle/space physics instruments (Double Sided Strip Si Detectors, Micro-Pattern Gas Amplifiers, micro-electronics), we are on the path to build our "dream" experiments. In this paper, I will present a selection of instruments that highlight the present trends with silicon and the growing shift towards gas media for particle detection.

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Poster Presentations

Poster Presentation ID: 9

Progress of TITAN’s Cooler Penning Trap for Highly Charged Ions

The Penning trap cyclotron frequency is proportional to the charge state, q, so therefore measuring the larger frequencies of highly charged ions (HCIs) yields a corresponding increase in the precision of mass measurements. This was demonstrated in the mass measurement of the superallowed β-emitter $^{74}Rb^{8+}$[1]. The process of charge breeding HCIs, however, introduces a large energy spread into the ion bunch which decreases the trapping efficiency and the precision of the mass measurement as the ions probe a larger and more inhomogeneous magnetic field. The TITAN experiment [2] at TRIUMF in Vancouver has begun commissioning a Cooler Penning Trap (CPET) with the goal of sympathetically cooling HCIs generated in an electron beam ion trap (EBIT) via interactions with other trapped, charged particles.

CPET was designed with the option of using a room temperature electron plasma, H^+, or He^{2+} ions as a cooling medium, and simulations of cooling behavior have been run for each [3]. The initial program focuses on electrons and CPET’s current status with respect to trapped electron plasma will be discussed. Already, CPET has demonstrated the trapping of a self-cooling, room temperature plasma for several minutes [4]. Technical details of the effort to create nested traps that capture both positively charged HCIs and a negatively charged electron plasma in such a way that the two interact and remain confined will also be discussed.

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Poster Presentation ID: 10

An In-flight Radioactive Beam Separator for the ATLAS Facility

The Argonne In-flight Radioactive Ion Separator (AIRIS) is being proposed to enhance the radioactive beam capabilities of the ATLAS facility at ANL. In order to serve most of the experimental areas while maintaining stable beam operations, the separator consists of a magnetic chicane with a net zero-degree deflection. The chicane is made of four dipoles and four multipoles. In this design, all the beams are deflected to a middle plane away from the ATLAS beam line where a selection in magnetic rigidity is performed using slits. The selected radioactive beam is then deflected back to the ATLAS beam line. Stable beam operations are maintained by simply turning off the separator dipoles while using the quadrupoles for focusing.
For contaminants not eliminated by magnetic separation, an rf sweeper will be used to take advantage of the time separation from the beam of interest. The design of the separator has recently been completed. We will describe the AIRIS design and its expected performance.

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Presenter: Mr. MUSTAPHA, Brahim (Argonne National Laboratory)

Poster Presentation ID: 11

The SPES Target - Ion Source system

SPES (Selective Production of Exotic Species) is a project approved and financed by INFN (Istituto Nazionale di Fisica Nucleare), aimed to produce neutron-rich Radioactive Ion Beams (RIBs) according to the ISOL (Isotope Separation On Line) technique [1]. The core of the SPES facility is constituted by the TIS (Target - Ion Source) system that converts a stable proton beam into a RIB (Radioactive Ion Beam). The SPES production target is an innovative multi-foil direct target, composed of 7UCx co-axial disks [1,2]. It is impinged by a 40 MeV, 0.2 mA proton beam that generates approximately 10 to the 13 fissions per second. The nuclear reaction products get into the ion source thanks to diffusion-effusion processes [3], passing through a tubular transfer line made of Ta. In the framework of the SPES project, two different kinds of ion source will be adopted: a hot-cavity surface ion source (used for both surface and laser ionization), and a FEBIAD (Forced Electron Beam Induced Arc Discharge) ion source [4,5]. The SPES TIS system is installed inside a water- cooled vacuum chamber, and works at temperature levels approximately equal to 2000°C. High temperatures are fundamental to enhance the aforementioned diffusion- effusion processes, and to dissipate efficiently by thermal radiation the important amount of power deposited by the primary proton beam.

In this work, all the specific issues related to the SPES TIS system (including the target production, the primary beam power deposition, the steady state and the transient thermal behavior, the diffusion-effusion and ionization processes) are appropriately commented, showing the results obtained making use of both the theoretical and the experimental approaches. The characterization of the SPES ion sources in terms of efficiency and emittance is presented in detail, with an accurate description of the related experimental apparatus. A particular attention is dedicated also to safety issues that are of primary importance in the context of ISOL facilities.

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Poster Presentation ID: 12

Design of the in-flight fragment separator for the RISP

An in-flight fragment separator has been designed for the rare isotope science project (RISP) underway in Korea. The primary beam power is 400 kW at maximum, which is reflected on the radiation shielding and thereby on the separator design. The beam energy of ^{238}U is 200 MeV/u and will be increased to 400 MeV/u. Maximum magnetic rigidity of the separator is set as 9.5 Tm. Development of the major components, which includes graphite target, beam dump made of Ti-alloy, and large-aperture superconducting magnets using LTS and HTS coils, has been made. As the building design starts, configuration of the separator was finalized and the layout of the separator facility has been detailed. Comparison study with different configurations of the separator was carried out in terms of enhancing momentum resolution and beam purity. The study results will be presented as well as overall progress in the component design and prototyping for the in-flight system.

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Poster Presentation ID: 14

High Intensity Proton Beam Transportation through Fringe Field of 70 MeV Compact Cyclotron to Beam Line Targets

From the stripping points, high intensity proton beam of compact cyclotron travels through fringe field area of the machine to the combination magnet. Starting from there the beam with various energy is transferred to the switching magnet for distribution to the beam line targets. In the design of the extraction and transport system for the compact proton cyclotron facilities, such as the 70MeV in France and the 100MeV in China, the space charge effect as the beam crosses the fringe field has not been previously considered; neither has the impact on transverse beam envelope coupled from the longitudinal direction. Those have become much more important with the higher beam-power because of the beam loss problem. In this paper, based on the mapping data of 70MeV Cyclotron including the fringe field by BEST and combination magnet by CIAE, the beam extraction and transportation are investigated for the 70MeV Cyclotron used on the SPES project at INFN-LNL, including the study of the space charge effect and longitudinal and transverse coupling mentioned above, as well as the matching of beam optics using the beam line for medical isotope production as an example. In addition, the designs of the ± 30 °, ± 45° switching magnets, the 60° bending magnet, and the combination magnets for the extracted beam with the energy from 35MeV to 70MeV, and the quadrupole magnets have been made. Parts of the construction and field measurements of those magnets have been done as well. The current result shows that, the design considers the complexity factors of compact cyclotron extraction area and fits the requirements of the extraction and transport for high intensity proton beam, especially at mA intensity levels.

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Poster Presentation
ID: 15

The hydraulic and thermal numerical analysis of free surface flow for Beijing ISOL high power liquid target

Beijing ISOL is a double driver RIB facility with CARR Research reactor and deuteron LINAC, which is proposed by Peking University (PKU) and China Institute of Atomic Energy (CIAE). In this facility, the converter target is designed to produce neutron and remove the 40 MeV deuteron beam thermal power (>400 kW, >80 kW/cm2). The free surface fluid of liquid lithium has been considered as the neutron converter target of Beijing ISOL. Different simulation models and boundary conditions have been used to compute the free surface stability. The thermal numerical analyses has been carried out to investigate the energy deposition and transfers in the target.

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Poster Presentation ID: 16

SHELS - Separator for Heavy Element Spectroscopy

Over the past 15 years, the electrostatic recoil separator VASSILISSA has been used for investigations of evaporation residues (ERs) produced in heavy-ion fusion reactions. In the course of the experimental work, a bulk of data on ERs formation cross sections was collected. In 2004–2010, the isotopes of Fm, Md, No, and Lr were studied using the GABRIELA (Gamma Alpha Beta Recoil Investigations with the Electromagnetic Analyzer) detector system. These experiments showed that the efficiency of the existing set-up was not sufficient.

The goals of the modernization of the VASSILISSA electrostatic separator were to increase the transmission of asymmetric reactions, like $^{22}Ne + ^{238}U$ or $^{16}O + ^{244}Pu$ products, by the factor of 2–3 and to extend the region of reactions to be investigated up to symmetric combinations like $^{136}Xe + ^{136}Xe$. For this purpose, 3 electrostatic deflectors in the central part of the separator were replaced by a combination of two electrostatic and two magnetic deflectors. This modernization converted the energy selector VASSILISSA into the velocity filter SHELS. The new separator will be used together with the detector GABRIELA to carry out spectroscopic studies of heavy and superheavy isotopes. First tests of the set-up were performed with the beams of accelerated ^{22}Ne, ^{40}Ar, ^{48}Ca, and ^{50}Ti ions.

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Poster Presentation ID: 18

Application and further improvement of the Laser Ion Source and Trap (LIST) at ISOLDE/CERN

The investigation of short-lived and exotic nuclides far off stability at on-line mass separators such as ISOLDE at CERN is a strong means to solve relevant problems in nuclear and astrophysics. To approach the regions far-off stability of the nuclear chart ion beams of highest purity are required. Today, the Resonance Ionization Laser Ion Source RILIS has become a worldwide established standard in the ion production due to its outstanding properties, regarding e.g. elemental selectivity, efficiency and temporal beam structure. Nevertheless, in the RILIS hot cavity design significant isobaric contaminations are produced by the process of surface ionization. The Laser Ion Source and Trap LIST has been developed to entirely suppress these unwanted beam admixtures. Located immediately downstream the hot cavity, it consists of an electrostatic repelling electrode followed by a radio frequency ion guide quadrupole. Ions produced in the cavity are prevented from entering the RFQ, while only neutral atoms can pass to be ionized within the volume of the quadrupole structure by the RILIS laser radiation. Through the transversal confinement, they are guided towards the separator and subsequent experiments. In the past years, the LIST has been adapted for routine operation at ISOLDE [1] and used most recently for successful measurements on Po isotopes [2]. It has shown an impressive increase in the suppression of contaminations by more than a factor 1000, going along with only a slight loss in efficiency by a factor of 50 to 20 compared to conventional RILIS operation.Further refinement of the LIST is presently carried out at Mainz University. A number of LIST design changes were driven by unexpected minor limitations and shortcomings, observed during operation at ISOLDE. A narrow rod LIST design is supposed to decrease a still remaining deposit area for contaminants inside the RFQ structure. In addition the use of the RFQ itself as initial mass filter is developed, leading to a new mass selective operation mode, which will also help to prevent space charge limitations. Efficiency improvement is addressed by avoiding the discrete repeller electrode and directly using the electric potential gradient of the cavity itself for suppression of unwanted isobars. These new design concepts and their performance during recent off-line tests are presented.

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Poster Presentation ID: 19

The Deuteron Accelerator Conceptual Design for Beijing ISOL

Beijing ISOL is an isotope separation on line (ISOL) type rare ion beam facility for both basic science and applications, which is proposed jointly by Peking University (PKU) and China Institute of Atomic Energy (CIAE) [1]. It can be driven by a reactor or a deuteron accelerator. The driver accelerator can accelerate the deuteron beam up to 40 MeV with maximum beam current of 10 mA. Proton beam up to 33 MeV and He2+ beam up to 81.2 MeV can also be accelerated in this accelerator. The accelerator can be operated on either CW (continuous waveform) or pulse mode, and the ion energy can be adjusted in a wide range. Details will be given in this paper.
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Poster Presentation ID: 20

Design study of a β=0.09 high current superconducting half wave resonator at Peking University

Beijing ISOL is an isotope separation on line (ISOL) type rare ion beam facility for both basic science and applications. The low beta high current superconducting half wave resonator (HWR) is being developed at Peking University for Beijing ISOL deuteron driver accelerator. A β=0.09 162.5 MHz HWR cavity has been designed to accelerate several tens of mA deuteron beam. In this paper, the detailed electromagnetic design, multipacting simulation, mechanical design, beam dynamic simulation and high order mode analysis of the cavity will be given.

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Poster Presentation ID: 22

Towards sympathetic cooler for HCI using laser-cooled Ca ions

The long-term goal of the Penning trap system of RAON is to obtain an order of magnitude higher mass accuracy for short-lived rare isotopes. For that purpose, we are developing a sympathetic cooler for highly charged ions exploiting laser-cooled Ca ions. We chose the Ca ions as the coolant because the light sources for cooling Ca ions are readily available in the markets. We installed a prototype octagon chamber with Ca atom source, Paul trap, and helical resonator for high voltage RF supply etc. Laser system is composed of three extended cavity diode lasers (423, 397, 866 nm) plus one UV laser (375 nm). Optical frequency stabilization setup is made up of wavelength meter, multichannel fiber switch and PXI system with 8-channel analog outputs. Resonant ionization experiment for Ca atomic beam was performed. With the ionization signal against the laser frequency, we were able to deduce the atomic velocity distribution and the temperature of the atom source. After the successful observation of photoionization signal, we applied RF voltage to the trap electrode and cooling lasers directing to the center of the trap at 45 degree with respect to the trap axis. The number of laser cooled Ca ions was estimated to be about 100,000 from the image of laser-cooled ion bunch. Our experimental setup and the preliminary results for Ca cooling experiment will be presented in detail at the conference.

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Poster Presentation ID: 26

LISE++: exotic beam production with fragment separators and their design

The LISE++ program* is designed to predict intensities and purities for the planning of future experiments with in-flight separators, but is also essential for radioactive beam tuning where its results can be quickly compared to on-line data. This is achieved via the simulation of fragment separators through the use of different sections called "blocks" (magnetic and electric multipoles, solenoid, velocity filter, RF deflector and buncher, material in beam, drift, rotation element, and others). The code is built around a user-friendly interface that helps to seamlessly construct any fragment separator from the different blocks. The LISE++ package includes configurations of existing separators at NSCL/MSU, RIKEN, GANIL, GSI, FLNR/JINR, TAMU and others. The Projectile Fragmentation, Fusion-Evaporation, Fusion-Fission, Coulomb Fission, and Abrasion-Fission models are used in the program to simulate experiments at beam energies above the Coulomb barrier.

Since the LISE++ code presentation at the EMIS 2007 conference, important improvements were performed in the analytical and Monte Carlo calculations of transmission, and accuracy of reaction product distributions. Large progress has also been achieved in ion-beam optics with the introduction of elemental blocks that enable a new type of configuration, labeled "extended (or elemental)" in addition to the classic "sector" configuration. Optical matrices can now be calculated within the LISE++ code (up to second order), directly input by the user, or linked to COSY maps (up to fifth order). This enables a detailed analysis of the transmission, useful for fragment separator design, and is a powerful tool to calculate angular acceptances, and display ion-beam optics characteristics. In the latest version of the program, export/import of TRANSPORT files is now possible, with minimization of quadrupole fields following user constraints.

The future development of LISE++ will be announced in this presentation, and will be discussed in detail in a poster presentation.

* O.B.Tarasov and D.Bazin, Nuclear Instruments and Methods in Phys.Research B 266 (2008) 4657–4664

The LISE++ package which includes also the PACE4, Global, Charge, Spectroscopic calculator codes can be downloaded freely from the following site: http://lise.nscl.msu.edu.

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Poster Presentation ID: 27

Recent results from the TwinSol low-energy RIB facility

The University of Michigan(UM)-University of Notre Dame (UND) TwinSol low-energy radioactive ion beam (RIB) facility at the UND tandem van de Graaff accelerator is a 2nd generation low-energy RIB facility that has been in active use for over 15 years. Its initial configuration was subsequently modified by transporting the secondary beam through a shielding wall into a large, low background room where most of the recent experiments have been performed. A large (1m) scattering was built together with a large neutron wall (17 m flight path), and recently a special deuterated scintillator array developed to permit a variety of measurements involving charged particles and neutrons, especially near or below the Coulomb barrier. The deuterated scintillator array developed is particularly well suited to RIB measurements as it can provide neutron energy spectra without need for long-path ToF. A variety of intense, low-energy RIBs have been produced using high cross section transfer reactions with solid or gas cell production targets, with the beam purified using a mid-plane absorber between the two solenoid magnets. Measurements have included ^{6}He, ^{8}B, ^{7}Be etc. break up, fusion, and transfer reactions, most recently a $^{7}Be(d,n)$ measurement. A TPC built by the MSU RIB group as a prototype for a larger device being constructed for the ReA and FRIB facilities at MSU has been tested and successfully used for a number of measurements using the TPC as an active-target tracking detector to produce excitation functions. Several of the measurements have yielded some unusual results that only would be seen easily using a TPC with its multi-body tracking capabilities. Future improvements to the TwinSol facility are planned and will be described.

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Poster Presentation ID: 28

Extraction and low energy beam transport from a surface ion source at the TRIUMF-ISAC facility

A large fraction of radioactive beams produced and delivered at TRIUMF's isotope and accelerator facility, ISAC, are using either a surface ion source or a resonant ionization laser ion source, which share a common design. To characterize the operation of the ion sources, simulations were performed to determine the ion beam optics and beam envelope properties of the extracted beam. Furthermore ion-optics calculations were performed to determine the transmission though the mass separator magnet and the subsequent emittance of the beam. The recent addition of a channeltron to the Allison emittance meter scanner now allows us to measure emittances for ion beams with intensities as low as 10^5 ions/sec. This is particularly useful for establishing high resolution, high throughput mass separator tunes for radioactive isotope beams. This paper describes the modification to the Allison emittance meter allowing emittance measurement of low intensity beams and we will show typical emittance scans for the surface ion source and the resonant laser ionized source for different source parameters. The observed results are compared to the simulations and discussed.

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Poster Presentation ID: 30

Simulations of the University of Notre Dame Multi-Reflection Time-of-Flight Spectrograph

A multi-reflection time-of-flight mass spectrograph (MR-ToF) is currently being designed for the future University of Notre Dame radioactive ion beam facility. This device will be used to provide isobarically pure ion bunches to experiments. We are currently designing an off-line testing setup for the MR-ToF. To characterize and optimize the MR-ToF, and to guide the design, we performed the series of simulations that will be presented.

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Poster Presentation ID: 32

High voltage conditioning of the electrostatic deflector of MARA

A new vacuum-mode recoil spectrometer MARA (Mass Analyzing Recoil Apparatus) [1] has been built in JYFL. The spectrometer has a designed first-order m/q resolving power of 250. What sets this FMA-like [2] device apart from its siblings is the single- deflector ion-optical configuration QQQEM. Collimators and slit systems are used to reduce the background components caused by scattered beam and recoils with unwanted m/q. The deflector is designed for a maximum electric rigidity of 14 MV, achievable with 500 kV across the gap. The primary beam is dumped in a separate beam dump, the anode is split to facilitate this.

The geometry, materials and their finishing are of utmost importance when constructing a device used in such high voltages. A cylindrical vacuum chamber is used in MARA because of its mechanical simplicity and clearance from the electrodes and the large vacuum volume is pumped with cryo- and turbomolecular pumps. The electropolished titanium electrodes are oversized to achieve a uniform field with a simple electrode geometry.

The high voltage conditioning process of such a device is a time-consuming process and has therefore been automated. The conditioning logic is heavily influenced by the systems in use at CARP [3] and SHIP [4] and follows a three-limit approach.

The factory conditioning, as well as the first conditioning at JYFL, were prime opportunities to tune the conditioning parameters. The conditioning proceeded well when pre-breakdown currents in the order of tens of microamperes were seen. These currents were accompanied with increases in radiation and vacuum levels, indicating that the voltage was indeed reaching the electrodes and field emission was taking place. The results got and the parameters used in the first conditioning are reported.

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Poster Presentation ID: 34

Theoretical study of buffer gas cooling and ion motions in a Penning Trap, and status of LPT

The suitable energy range of viscous damping force (VDF) model, hard sphere collision (HSC) model, and realistic interaction potential (RIP) model have been investigated by comparing the stopping ranges from the simulated data with those from SRIM code. Using the VDF model, together with the Runge–Kutta method, ion motions in an ideal Penning Trap and different excitation conditions have been calculated, and, the recommendatory ranges of helium gas pressure and driving rf amplitude for quadrupolar excitation have been shown.
The Lanzhou Penning Trap (LPT), which is at the Institute of Modern Physics, Chinese Academy of Sciences, is an ion trap aims at direct accurate mass measurements on fusion-evaporation products. All subsystems including LPT beam line, test/reference ion source, vacuum system, special radio frequency (RF) power supplies, detector system, control and data-acquisition system have been tested, and the shoot-through efficiency without magnetic field has been measured. Test works with superconducting magnet will be started in recent future, besides, some new sub-system like a multi- reflection time-of-flight mass spectrometer/separator and a gas ion collection system have also been planned.

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Poster Presentation ID: 36

Radioactive ion beam production at CERN-ISOLDE with nanometric, highly porous target materials – a review

After isotope production, in the bulk of the target material, the beam intensities in ISOL facilities are mainly defined by: the release from the target material, ionization, mass separation and transport efficiencies. Although production can be up to 1E10 /s, by far the most limiting step is the release of the isotopes from the target itself, where release efficiencies can go down to 1E-6 or even less, especially in the case of very short lived isotopes. Apart from this, beam intensities are sometimes decreasing over time, which can be due to the target material degradation. For those reasons, the target material research at ISOL facilities is crucial to deliver stable, high intensity and new exotic beams. The stabilization of open porous, nanostructured materials at high temperatures is the key to improve release efficiencies by reducing the isotope diffusion times, assuming this process is limiting the release. The nanomaterial target family [1] at ISOLDE has been extended, with novel nano materials operated last year. Nano calcium oxide [2,3] has been operated and has delivered significant intensities of 31Ar even at room temperature. A new material was added to the ISOLDE target material collection - titanium carbide and carbon black nanocomposite [4] - which displayed no decrease of yields as opposed to the previously used Ti foils targets. For the first time, a target exclusively made of multiwall carbon nanotubes (MWCNT) was operated and showed indications of the first 8B beams.With ~70% of the beam time at ISOLDE, the development of uranium carbide with excess carbon (UCx) target represent the most significant gains for the facility. A composite made of UCx and MWCNT was developed, showing high and stable yields on almost all measured isotopes [5]. Using the same recipe, a nanometric lanthanum carbide-MWCNT composite was successfully developed and tested to provide high and stable beams of neutron-deficient Ba and Cs isotopes. These materials will be reviewed in terms of synthesis, material characteristics, time-structure and release rates of selected isotopes. From the release results the modelling of physical parameters (effusion and diffusion) will be shown [6].

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Poster Presentation ID: 37

A1900 Rigidity Calibration Based on Accelerator RF Timing

The A1900 fragment separator, located at the National Superconducting Cyclotron Laboratory of Michigan State University, is used to select rare isotopes produced in fragmentation reactions for delivery to downstream experiments. The increasing demand for studies using gas-stopping techniques [1] requires that the energy of the delivered fragments, as given from the beam rigidity measured in the separator, be determined with greater precision than was previously needed. To this end, various test beams with precisely-measured energies have been used to improve the rigidity calibration to an accuracy level of ±0.1% covering a range from 1.5 to 4.5 Tm. A time-of-flight technique to measure the energy of the test beams is described and results given. In this technique, a barium fluoride detector is moved between two positions along the beam path to measure the arrival time of beam particles with respect to the cyclotron RF signal. Also presented is the application of these results to achieve an improved rigidity calibration of the A1900 separator.

This work is supported by the U. S. National Science Foundation under grant No. PHY-11-02511.

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Poster Presentation ID: 38

Off-line in-gas-laser ionization and spectroscopy (IGLIS) laboratory at KU Leuven

The in-gas laser ionization and spectroscopy (IGLIS) technique developed at KU Leuven is used at the Leuven isotope separator on line (LISOL) facility to produce short-lived radioactive beams in different regions of the chart of nuclides using light and heavy-ion induced fusion or fission reactions. In this technique, the nuclear reaction products recoiling out of a thin target are thermalized and neutralized in a high pressure noble gas, then resonantly ionized by the laser beams in a two-step process, extracted from the ion source, accelerated and mass separated. In this way isobaric and isotopic selectivity is achieved. High efficiency and selectivity of the ion source [1] allows performing in-gas cell resonance ionization spectroscopy of exotic atoms. Using this method the nuclear magnetic moments of copper [2], silver [3] and actinium [4] isotopes produced in fusion-evaporation reactions have been measured. As it was shown in recent on-line experiments with actinium isotopes, implementation of resonance laser ionization in the supersonic gas jet allows increasing the spectral resolution by more than one order of magnitude in comparison with in-gas- cell ionization spectroscopy [5]. To obtain the maximum efficiency and the best spectral resolution, properties of the supersonic jet and the laser light have to be correctly chosen [6]. To perform these studies a new off-line IGLIS laboratory, including a new high repetition rate laser system and a dedicated off-line mass separator, has been established under European Research Council (ERC) HELIOS grant [7]. The specifications of the different systems developed for the IGLIS laboratory will be discussed and first results of high-resolution spectroscopy in the supersonic gas jet will be presented. An optimized IGLIS setup to perform laser ionization spectroscopy including high repetition lasers will be installed at the Super Separator Spectrometer (S3), which will be coupled to the superconducting linear accelerator of the SPIRAL2 facility at GANIL [8].

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Poster Presentation ID: 41

Off-line production of transition metal ions for collinear laser spectroscopy at BECOLA/NSCL

The production of stable isotopes using off-line ion sources for online reference measurements and development of atomic transition schemes is a critical aspect in collinear laser spectroscopy (CLS). A Penning Ionization Gauge (PIG) ion source [1] has been installed for offline production of metal beams at the BEam COoler and LAser spectroscopy (BECOLA) facility [2] at the National Superconducting Cyclotron Laboratory at Michigan State University. BECOLA is a CLS facility aimed at measuring hyperfine spectra for determining charge radii and electromagnetic moments of radioactive isotopes for nuclear structure studies. The PIG ion source is located downstream of the radio-frequency-quadrupole (RFQ) beam cooler and buncher [3]. Mass filtering of the PIG emissions was achieved by operating the separate cooling and bunching sections of the RFQ at differing RF frequency and amplitude, and He buffer-gas pressures. The performance characteristics of the PIG ion source for production of light transition metal ions Fe, Ni, V, and Co for CLS studies will be discussed.
This work was supported in part by NSF Grant Nos. PHY-11-02511 and PHY-12-28489.

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Poster Presentation ID: 44

Probing the nature of the weak interaction with laser trapped ^{6}He

Radioactive beams coupled with atom and ion trapping techniques are a powerful combination for precision experiments to search for physics beyond the Standard Model (SM). 6He isotopes are particularly interesting to constrain tensor-like contributions to the weak interaction by studying their β decay. So far, such couplings have been experimentally ruled out at the 9% level but are excluded in the V-A description of the weak interaction by the SM. The beta-neutrino angular correlation parameter aβν, in the case of ^{6}He, is exclusively sensitive to exotic tensor components and can be measured accurately by a β/recoil-ion coincidence measurement. Our goal is to measure aβν at the 0.1% level by analyzing the momentum distribution of the recoiling daughter nuclei. This uncertainty would be an order of magnitude better than the precision of the current best measurement. Short-lived ^{6}He atoms ($T_{1/2}$ = 807 ms) are produced on-line via the 2H(7Li,3He)6He reaction @ 18 Mev using the Tandem Van de Graaff accelerator at the University of Washington in Seattle. Recent upgrades on our liquid Li target allow us to routinely produce 2x1010 6He/s with a high reliability. 6He atoms are then loaded into a double-magneto- optical trap apparatus where the β decays are studied by detecting the β particles with a multi-wires proportional chamber and a scintillator/PMT assembly in coincidence with the 6Li recoiling nuclei with a position sensitive microchannel plate detector. To achieve our goal, production rates, trapping efficiency and trap lifetime are optimized, and our detection setup has been carefully studied to reduce and control all systematic effects. The apparatus will be presented along with its performances and preliminary results. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract numbers DE-AC02-06CH11357 and DE-FG02-97ER41020.

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Poster Presentation ID: 45

Development of a Gas Filled Magnet within the FIPPS project

The accurate knowledge of the fission product properties of actinides is important for the studies of innovative nuclear fuel cycles and also for the understanding of the fission process. Until now fission models cannot predict the fission yields with an acceptable accuracy. A collaboration between LPSC (Laboratoire de Physique Subatomique et de Cosmologie), ILL (Institut Laue-Langevin) and CEA (Commissariat à l'Energie Atomique et aux Energies Alternatives) is pursuing a measurement program performed at the LOHENGRIN spectrometer at ILL (Grenoble, France) that is dedicated to the thorough characterization of fission yields in mass A, nuclear charge Z, kinetic energy E_k and spin J. To assess this last quantity, so far only an indirect method through isomeric ratio measurements has been used at the LOHENGRIN spectrometer.
Nevertheless the evaluation of the fission fragment spin distributions can be done also directly via the measurement of prompt neutron and γ spectra per isotope. The FIPPS (FIssion Product Prompt γ-ray Spectroscopy) project at ILL aims at combining a powerful γ ray detection array with a gas-filled recoil separator for one of the fission products. The combined spectrometer will give access to new nuclear spectroscopy information of neutron-rich nuclides by tagging the complementary fragment and new insight into the fission process via combined measurements of mass A, nuclear charge Z, kinetic energy E_k and excited states.
To optimize the design of the gas-filled separator in terms of acceptance and resolving power, we performed preparatory experiments using the second dipole magnet of the LOHENGRIN fission fragment separator. Using mass and energy separated fission fragment beams we studied the transmission, energy acceptance, energy loss and resolving power in A and Z with helium and nitrogen gas filling at pressures ranging from 2 mbar to 40 mbar. For instance, with the given magnet properties the best separation was reached with He at pressures around 40 mbar, corresponding to an overall energy loss of 50% in the gas. In parallel we developed a Monte Carlo simulation code to reproduce the obtained results. This code is now used for the detailed design of the gas-filled separator of the FIPPS project. In this talk experimental and simulation results will be presented along with the current status of the FIPPS project.

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Poster Presentation ID: 47

Charge breeder development for HIE-ISOLDE and future ISOL facilities.

In this paper we report on our results from the design study of an advanced EBIS- based Charge Breeder (ECB) . The ECB should fulfill the requirements of the HIE- ISOLDE upgrade, and if possible be adapted for ion injection into TSR@ISOLDE , as well as serve as an early prototype of a future EURISOL ECB. Fulfilling the HIE-ISOLDE/TSR@ISOLDE specifications requires simultaneous increase in electron beam energy, current and current density in order to provide the requested beams with proper charge state, high intensity and with a specified pulse repetition rate.
We have carried out a study on the technical requirements of the ECB from the charge breeding performance point of view. The obtained parameters were optimized to comply with technical limitations arising from the electron beam technology and plasma physics in an ECB.
A prototype electron gun of BNL design was built at CERN for the future ECB. It has been tested in cooperation with BNL and undergone a couple of development iterations. Until now, we have reached approximately 50% of the required electron current and energy specification for an HIE-ISOLDE ECB. The gun is undergoing further development in order to improve the beam quality, allow for an increase in current and energy, and to validate the beam compression performance.

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Poster Presentation ID: 50

A Multi-Reflection Time-of-Flight Mass Spectrometer for Isobaric Purification at the University of Notre Dame

One of the most significant problems in the production of rare isotopes is the simultaneous production of contaminants, often times isobaric. Thus, a high-resolution beam purification method is required which is compatible with both the low yield and short half-life of the desired radionuclide. A multi-reflection time-of-flight mass spectrometer (MR-TOF-MS) meets all these criteria, in addition to boasting a smaller footprint relative to traditional separator dipole magnets. Such a device is currently under construction at the University of Notre Dame and will be coupled to the IG-ISOL source in the upcoming cyclotron facility. The motivation, conceptual design and a status report will be presented.

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Poster Presentation ID: 52

Efficient laser trapping of neutral radium atoms for electric dipole moment search

Recently it has been suggested that radium is an excellent candidate for next generation fundamental symmetry tests. Since the first trapping of radium atoms [1] at the Argonne National Laboratory, the worldwide efforts have been devoted to improving the electric dipole moment (EDM) sensitivity. For the Ra EDM experiment, high efficiency of trapping is of foremost importance to achieve the projected sensitivity goals. The number of atoms in the trap is limited due to the large leakage into metastable D states from the cooling transition and the loss mechanism from collisions with the background gases and with other elements in the atomic beam. We propose a setup consisting of an efficient Zeeman slower, an optical atomic beam deflector, and an Egg-MOT, which provides a large capture velocity for trapping of Ra-225 atoms [2]. Furthermore, the pure slow atomic beam produced by the optical atomic beam deflector can maximize the number of trapped atoms and their lifetime in a ultra-high vacuum chamber by minimizing the collisional loss. Our proposed setup allows for the search for a permanent electric dipole moment based on laser-cooled and trapped radium atoms with improved sensitivity.

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Poster Presentation ID: 53

Development of a next generation RFQ beam cooler and buncher for the CANREB project at TRIUMF

A new RFQ-based ion beam cooler and buncher is under development as part of the CANREB project at TRIUMF. The CANREB project requires an RFQ buncher that will efficiently accept continuous beams of rare isotopes from the ARIEL or ISAC target, by way of a high resolution mass spectrometer (HRS), with energies up to 60 keV and deliver bunched beams to an EBIS for charge breeding. The CANREB RFQ incorporates design considerations to facilitate ease of use over a wide range of ion masses, and is intended to accommodate incident beam rates as high as 108 pps, delivering beam bunches at 100 Hz. Many design concepts to be implemented in the CANREB RFQ have been developed and tested through the development and commissioning of a beam cooler and buncher [1] for the BECOLA facility [2] at Michigan State University, including a novel DC electrode shape in the cooling region, the technique used to couple RF and DC to the RFQ electrodes, and the design of the cooling region which reduces the risk of RF discharge in the buffer gas. The efforts to commission the BECOLA beam cooler and buncher demonstrated the success of many new beam cooler design concepts, while also suggesting avenues for further tailoring of the design for the needs of the CANREB project. An overview of the CANREB RFQ design concept will be presented, informed by results from both ion optical simulations as well as commissioning efforts with the BECOLA beam cooler and buncher.

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Poster Presentation ID: 54

V_{ud} determination from light nuclide mirror transitions

Thanks to extensive experimental efforts that led to a precise determination of important super-allowed pure Fermi transition experimental quantities, we now have a very precise value for V_{ud} that leads to a stringent test of the CKM matrix unitarity. Despite this achievement, measurements in other less precise systems remain relevant as conflicting results could uncover unknown systematic effects or even new physics. One such system is the super-allowed mixed transition, which can also help refine the same theoretical corrections used for pure Fermi transitions and hence improve the accuracy of V_{ud}. However, as a corrected Ft-value determination from these systems requires the more challenging determination of the Fermi Gamow- Teller mixing ratio, only five transitions, spreading from ^{19}Ne to ^{37}Ar, are currently fully characterized. There are several ongoing efforts to determine the mixing ratios for medium-mass nuclei. Measuring transitions in lighter nuclei, such as ^{17}F, ^{15}O, ^{13}N and ^{11}C pose new challenges as their longer half-lives, ranging from 1 to 22 minutes, conflict with the time constraints present at the large radioactive ion beam facilities where these nuclei are typically produced. We will present a proposed ion trapping experiment to measure these transitions at the TWINSOL facility of the University of Notre Dame where time constraints are less stringent.

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Poster Presentation ID: 55

A proposed method of effective collinear optical pumping for nuclear spin polarization

Collinear optical pumping technique is a very useful tool to produce spin-polarized radioactive isotope beams. Unlike the case of stable alkali atomic beams, the experimental results of lithium-8 have shown the limited nuclear spin polarization [1,2] although the rate equation formalism predicts almost 100% polarization [2,3]. We propose the laser frequency ramping method by means of position-dependent Zeeman splitting which can efficiently polarize nuclear spin of atoms/ions in an accelerator beamline [4]. This minimizes a quantum phenomenon, coherent population trapping, which limits the optical pumping efficiency in the polarized beamline for radioactive nuclear spin polarization. We numerically solve the density matrix equations to consider the lithium-8 atomic system interacting with two circularly polarized laser beams in the presence of time-dependent magnetic field. From numerical results, we find that optimum frequency ramping allows efficient optical pumping for a short interaction time, e.g., 2 μs.

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Poster Presentation ID: 57

Multi-Step Resonant Photoionization of Sn by High-Repetition-Rate Ti:Sapphire Lasers

RAON is a heavy ion accelerator being built in Korea. It will have both the Isotope Separator On-Line (ISOL) and the In-flight Fragmentation (IF) facilities. For efficient and Z-selective ionization, the resonance ionization laser ion source (RILIS) will be included in the RAON ISOL facility. Recently, we have installed the laser system, composed of all solid state Ti:sapphire lasers developed at Mainz University and an high power Nd:YAG laser supplied by Lee Laser. Three Ti:sapphire lasers are pumped by a 10 kHz, 100 W, Q-switched, frequency doubled, diode pumped, Nd:YAG laser. Infrared beams in the 700-950 nm range are emitted by Ti:Sapphire lasers, and ultraviolet beams can be generated in the frequency doubling and tripling units. We carried out the multi-step resonant photoionization experiments with stable Sn atoms. Thermally generated Sn atoms were resonantly ionized by laser pulses in a reference atomic beam chamber designed by the LARISSA group at Mainz University. In this presentation, preliminary results of the resonant photoionization spectroscopy with stable Sn atoms and current status of the laser ion source development for RAON will be presented.

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Poster Presentation ID: 59

Search for efficient laser resonance ionization schemes for Ta and W using a new reference-cell in KISS

In KISS (KEK Isotope Separation System) [1], laser resonance ionization [2] is employed for the element-selective ionization of multi-nucleon transfer reaction products around N = 126. We searched for efficient laser resonance ionization schemes for tantalum (Z = 73) and tungsten (Z = 74), which will be studied in KISS.
In laser resonance ionization technique, an atom is element-selectively excited by the first step laser with a wavelength of λ1. By irradiating the atom with a second- step laser of wavelength λ2, the atom then transits from the excited state to an auto-ionization state (AIS), which is located above ionization potential. The AIS's, through which the ionization efficiency is more than one order of magnitude higher than that via an atomic continuum states, are searched for in general. Our goal is to achieve the laser ionization efficiency more than 15% in the KISS gas cell which is filled with an argon gas of 50 kPa. The ionization schemes of tantalum and tungsten were studied using a reference-cell. The reference-cell consists of the two-step acceleration electrodes, the drift tube, a channeltron and a filament. The lasers were focused to a spot of a few mm2 between the ion-acceleration electrodes. Neutral atoms were evaporated by heating the filament and ionized by laser irradiation between the electrodes. Ions were accelerated by the electric field and detected by a channeltron at about 30 cm away from the ionization region. The ions were mass-analyzed by measuring the time-of- flight (TOF). However, we could not search for the high efficient laser ionization schemes. We are going to search for efficient laser ionization schemes in the same elements using a newly designed reference-cell. The new reference-cell was designed to separate the isotopes of A ~ 180 with the mass resolution of ~ 330. It is achieved by adjustment of the distances between the electrodes and the drift distance (56 cm) to converge the position distribution of the atoms in the ionization region. It makes possible to study of the ionization scheme, the ionization efficiency and the isotope shift in each isotope. We will study the power broadening and the pressure broadening of the excited states and the AISs to obtain the more realistic ionization efficiency in the KISS gas cell.

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[2] Y. Hirayama et al.: J. Phys. B: At. Mol. Opt. Phys. 47 (2014) 075201.

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Poster Presentation ID: 62

Principle of Isochronous Mass Spectrometry using two time-of-flight detectors

The Isochronous Mass Spectrometry (IMS) is a storage-ring-based technique suitable for precision mass measurement of short-lived exotic nuclei produced by relativistic beam fragmentation. Several experiments employing the IMS with one time-of-flight (TOF) detector have been successfully conducted at the experimental storage ring CSRe in Lanzhou, China [1]. In these experiments, the typical magnetic rigidity (Bρ) acceptance of the CSRe is around $\pm 2\times 10^{-3}$ and the momentum compaction factor is about 0.51. The experimental results show that the spectral resolving power of the revolution-time spectrum of the stored ions are not constant over the whole spectrum, and only a part of the whole spectrum corresponding to $\Delta T/T<0.8\ \times 10^{-5}$ are used for further mass determination.

In order to improve the mass resolving power of the current IMS technique so as to make use of the whole measured revolution-time spectrum, one approach is to limit the momentum spread of the ions to the level of $\Delta p/p=5\times 10^{-5}$ before the injection into the ring [2]. The drawback of this method is that the transmission efficiency of the secondary beam is greatly reduced due to smaller transmission acceptance through the fragment separator [2].

In order to bypass this shortage, an additional velocity measurement of the stored ions in the ring was proposed [3]. In this paper we report the realization of this novel idea in CSRe, namely an upgraded isochronous mass spectrometry with two TOF detectors installed in the straight section of the CSRe. A series of simulated data generated from a dedicated program [4] were analysed using the new method. The velocity precision of the two TOF detector system was assumed to be $dv/v\approx 1.6\times 10^{-4}$ in the simulation. With the additional information of velocity, the revolution-time of all injected ions were corrected to the corresponding revolution-time on the reference orbit. The resulting mass resolving power was greatly improved, especially for nuclides with Lorentz factor far away from the transition point of the CSRe.

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Poster Presentation ID: 64

New developments in high-capacity isobaric separation with the Penning-trap based mass separator PIPERADE at DESIR

The DESIR (decay, excitation and storage of radioactive ions) facility at GANIL will receive a large variety of exotic nuclei at low energy (up to 60 kV) with extremely high intensities. However, the production methods of radioactive beams are non-selective limiting the purity of the beams of interest. Moreover the high precision needed for nuclear structure and astrophysics studies using beta decay spectroscopy, laser spectroscopy and trap-based experiments at DESIR requires highly pure samples of exotic nuclei. The aim of the double-Penning-trap mass separator PIPERADE is to deliver large and very pure samples of exotic nuclei to the different experiments in DESIR. New excitation schemes and the large inner diameter of the first trap will face the space charge effects and allow trapping of up to 10^5 ions per pulse. The purification cycle will be performed in a few hundred of milliseconds so that short- lived nuclei can be sorted. Furthermore, in order to extract the nuclides of interest from the large amount of isobaric contaminants, a resolving power of 10^5 is mandatory. Afterwards the ions of interest will be accumulated in the second trap until they constitute a considerable pure sample for the measurements. The future developments and the status of the project will be presented.

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Poster Presentation ID: 65

Development of the detector system for β-decay spectroscopy at the KEK isotope separation system

The KEK Isotope Separation System (KISS) has been developed to study the β-decay properties of the neutron-rich nuclei around neutron number N = 126 which are essential for understanding how the heavy, noble-metal elements, such as gold and platinum, are formed in the r-process. It is desirable that the detector system for β-decay spectroscopy at the KISS should be highly efficient for low-energy β-rays because the nuclei of interest have Q-values of around 2 MeV. In addition, the system should be operated under a low-background environment because of the low production rates of these nuclei. Though the tolerable count rate of the background depends on the production rates, our ultimate goal is set around several 10 counts per day, allowing access to the waiting point nuclei, progenitor of gold and platinum in the r-process.

The detector system of the KISS consists of β-ray telescopes, Ge detectors, and a tape transport system. For efficiently counting low-energy β-rays with low background, the β-ray telescopes are composed of three double-layered thin plastic scintillators which act as ΔE-ΔE counters; the thickness of the first ΔE counters is 0.5 mm and that of the second ΔE counters is 1 mm. The solid angle subtended by the β-ray telescopes is, in total, as large as 90% of 4π.

In order to reduce the background events which was considered to originate from cosmic rays and environmental γ radiations, we installed a veto counter system and shields with low-activity lead blocks. The veto counter system, consisting of seventeen bar-shaped plastic scintillators surrounding the β-ray telescopes, was constructed to reduce the cosmic rays. The configurations of scintillators was designed based on the Geant4 simulation, and a designed value of the veto efficiency was 92% for 1 GeV muon.

For further reduction of the background, we have started to made a new first ΔE counter for the β-ray telescopes. In this presentation, we will introduce the present status of the detector system of the KISS.

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Poster Presentation ID: 68

The ISOLDE High Resolution Separator upgrade to a mass resolving power of 20000

ISOLDE/CERN is one of the leading facilities in production of exotic beams. With its upgrade in the HIE-ISOLDE project an increase in primary beam intensity and energy is envisaged. Together with developments in target and ion source technology a significant increase in intensity of the exotic beam expected. Note, in the worst case after the ion source this is a cocktail beam containing radionuclides from all over the nuclide chart. The current magnetic separation with the high resolution separator (HRS) can suppress contaminations almost completely when the masses differ to the beam of interest by $\Delta m/m > 1/2000$ (ion-source emittance dependent).
This will not be sufficient anymore for the user experiments and also because of radioprotection consideration; an increase of mass resolving power $R = m/\Delta m$ to better than 20000 with a complete suppression of the contaminants is required, which is ion source independent. Here we present a concept of a new separator, which consists of three stages; a magnetic pre-separator, a radio frequency quadrupole (RFQ) for improvement of the transversal emittance, and a magnetic HRS including its surrounding electrostatic optics. We will focus on the discussion of the magnet for the HRS. Here a 120 degree magnet with a bending radius of 1.25m has been chosen. The magnetic rigidity is 0.625T (B-field of 0.5T) to allow for separation of molecules of up to a mass of 300u. The magnet comprises a yoke in wedged H-type configuration for stability and precision. Pole face conductors are implemented to achieve the required inhomogeneous parameters for focusing and compensation of aberration. In a first step the concept has been derived analytically. It has been refined with the OPERA 2D software and been tested with the ray-tracing module of OPERA 3D using a conservative estimate of the radial emittance after the RFQ of 3π mm mrad.

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Poster Presentation ID: 72

Development of a liquid Pb-Bi target for high-power ISOL facilities

In the context of the forthcoming next generation of Radioactive Ion Beams (RIBs) facilities based on the Isotope Separation On Line (ISOL) method, the development of production targets capable of dissipating the high power deposited by the primary beam is a major challenge. The concept of a high-power target based on a Lead Bismuth Eutectic (LBE) loop incorporating a heat-exchanger, a pump and a release chamber was proposed during EURISOL DS in 2005-2009. The partners within the ongoing LIEBE project (CEA, CERN, IPUL, PSI, SCK•CEN, SINP) are collaborating since 2012 on the development of this target, with the realization of a prototype and online tests at CERN-ISOLDE in 2016. The prototype could become a production unit for ISOLDE, accommodating a possible primary proton beam upgrade under discussion at CERN, and can easily be adapted for the EURISOL 100-kW beam power.In this target the irradiated Pb-Bi containing short-lived isotopes is promptly spread into a shower of droplets, thereby reducing by two orders of magnitude the diffusion length of isotopes. Yet, ensuring an efficient release of isotopes is still of crucial importance and several delay-inducing processes have to be optimized. This requires design-optimization of both the irradiation volume and the release chamber. LBE evacuation from the irradiation volume of this target is one such process that needs to be carefully studied. The optimization of the flow of liquid Pb-Bi in the compact and complex geometry of the irradiation volume will be discussed in this presentation. Three-dimensional computer simulation results pertaining to the initial design geometries have revealed issues such as long residence time due to irradiated LBE recirculation, non-uniform distribution of LBE-velocity vectors at outlet apertures and regions with pressure dropping below the vapor pressure of LBE. Thorough analysis of the results led to successively-improved target-design options. Two different optimized target geometries were eventually obtained and will be presented. Calculations of the thermo-mechanical effects of the impact of a proton pulse will be presented for the optimized geometries. Under the assumptions of a rigid irradiation- volume container and not accounting for potential cavitation effects, temperature and pressure fields inside the irradiation volume have been determined. The presentation will further include an overview of the activities within LIEBE and the status of the project.

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Poster Presentation ID: 73

Plans for Performance and Model Improvements in the LISE++ Software Suite

LISE++ is the standard software used at in-flight separator facilities for predicting beam intensity and purity. LISE++ simulates nuclear physics experiments where fragments are produced then selected with a spectrometer. The use of LISE++ in most facilities is to predict and identify the composition of Radioactive Nuclear Beams [1]. Intensity and purity of a desired beam can be predicted, along with the separator magnet settings. The LISE++ package allows simulation of isotope production, separation, ion optical transport through magnetic and electric systems, and ion interactions in matter. The suite includes utilities for simulation of experiments. A set of modifications are planned to improve the functionality of the code.

The modifications include a transportation to a modern graphics framework and updated compilers to aid in the performance and sustainability of the code. To accommodate the diversity of our users, we extend the software from Windows to a cross platform application. The calculations of beam transport and isotope production are becoming more computationally intense with the new large scale facilities. For example, the FRIB separator will have around fifty magnetic elements and ten points of beam interactions with matter. In order to perform the calculations in acceptable time, code optimization and parallel methods are applied. Planned new features include new types of optimization, for example, optimization of ion optics, improvements in reaction models, and new event generator options. In addition, LISE++ interface with control systems are planned. Computational improvements as well as the schedule for updating this large package will be discussed.

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Poster Presentation ID: 74

The Ion Conveyor for the Cyclotron Gas Stopper

The Ion Conveyor is a new apparatus devoted to transport ions fast and efficiently under moderate gas pressure. Such a device is particularly useful for long transition regions from relatively high pressures into vacuum. At the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University an Ion Conveyor will be used to extract rare isotopes from a new device to thermalize fast ions produced by the A1900 separator, called the Cyclotron gas Stopper [1,2]. Fast Ions (E/u ~ 100 MeV/u) produced by the A1900 are energy degraded and stopped in a gas-filled reverse- cyclotron filled with helium at ~100 mbar pressure, where they are collected and guided to a small exit orifice by traveling radio-frequency (RF) electric fields [3]. The transport of ions between the center of the cyclotron chamber and the external surface of the magnetic yoke, approximately 1 m distance with a strongly decreasing magnetic field, will use an Ion Conveyor with entrance and exit RF-carpets to span pressures between 100 and ~0.1 mbar. The concept of the Conveyor is based on similar devices used in mass spectrometry of heavy biochemical clusters [4]. The Ion Conveyor we developed for light and heavy ions is made by concentrical electrodes with central opening of 10 mm spaced by 1.4 mm and fed with a RF electric field in the range of 200 to 1000 kHz in traveling wave mode. This allows the ions to be transported rapidly and efficiently through the decreasing magnetic field, over the required distance. The present contribution describes the simulations, the mechanical design, the electronic circuitry, as well as the results obtained in off-line tests of the full-size Ion Conveyor for alkali ions. Measured efficiency in excess of 80% was demonstrated.

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Poster Presentation ID: 75

First experiment with the NUSTAR/FAIR Decay Total Absorption Gamma-Ray Spectrometer at the IGISOL IV facility

A new Total Absorption Gamma-Ray Spectrometer for beta-decay studies (DTAS) has been developed within the DESPEC experiment of the NUSTAR collaboration [1]. The instrument has been designed [2] to determine accurately the beta-decay intensity distribution for exotic nuclei produced in high-energy reactions, which will be separated and identified by means of the Super Fragment Separator at the future FAIR facility. DTAS has a modular construction with up to 18 large NaI(Tl) detector modules (module dimension: 25cmx15cmx15cm) which can be assembled in a 4pi geometry with little dead material around the AIDA implantation detector, a stack of double sided Si strip-detectors [2].We have recently performed the first experiment with this setup at the upgraded IGISOL IV (Jyväskylä, Finland) facility. The low energy radioactive beams have been further purified with the JYFLTRAP Penning trap [3]. The experiment aimed to study fission products of relevance in neutrino physics and reactor decay heat time evolution. The measurements allowed us to perform a careful characterization of the detector and to study the overall performance of the setup. The results of this work will be presented, including the performance of the gain stabilization system, the correction of electronic pulse pileup, the sensitivity to neutrons and the calibration of the response of the spectrometer to decay radiation by means of Geant4 Monte Carlo simulations.

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Poster Presentation ID: 78

Off-line Tests and Performance of ORISS with an Improved RFQ Ion Cooler/Buncher

ORISS (Oak Ridge Isomer/Isobar Spectrometer/Separator) is a Time-of-Flight (ToF) based high resolution and high transmission instrument. Designed for decay spectroscopy experiments, the performance goals are a mass resolving power (FWHM) of 400,000 and a transmission of 50%. As a separator, it will provide isobarically pure samples of any rare isotope and of many isomers. As a spectrometer, it will measure masses in many cases where low production rates and/or contaminations limit the use of a Penning trap. The UNIRIB universities and staff continue to explore ways to utilize ORISS at NSCL and TRIUMF. At NSCL, ORISS would accept beams from the stopping gas cell located behind the A1900 fragment separator or the He Jet system and be used for mass measurements and decay spectroscopy experiments.
Presently, ORISS is tested offline at the former HRIBF facility. The Radio-Frequency ion cooler/buncher, which serves as an ion injector, and the multi-reflection section, where the mass dispersion occurs, were tested separately. The cooler/buncher converts the incoming ion beam of typically 125 eV and 60 mm mrad emittance into bunches, which are then injected into the multi-reflection section for mass analysis.
In the past year, significant improvements were made to the cooler/buncher, such as increased mechanical precision, higher RF amplitudes and frequencies, and a modified internal pressure distribution of the He buffer gas. As a result, a transmission of the cooler/buncher of > 50% has been achieved, and is being further optimized. At the exit of the cooler/buncher, a ToF spectrum is registered, and ToF peaks with a FWHM of 9 ns for mass A = 133 have been recorded and are being optimized.The overall ORISS system performance is expected to meet our design goals. The ion optics of the multi-reflection section was tested previously and is well understood. From the results presented here, we predict a total ORISS transmission of comparable size (> 50%) and a mass resolving power of > 200,000. During ion injection and multi- reflection, no ion losses except through collisions with residual gas atoms are expected, which we estimate to be small. The ToF-peak broadening as a function of the number of laps is well understood from our ion optical model and previous measurements, and allows us to predict very high mass resolving power.Measurements of transmission, mass resolving power, beam acceptance, throughput and space charge effects will be presented.

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Poster Presentation ID: 79

A Compact All-Permanent Magnet ECR Ion Source Injector for ReA at MSU NSCL

The design of a compact all-permanent magnet electron cyclotron resonance (ECR) ion source injector for the superconducting heavy ion linac rare isotope ReAccelerator Facility (ReA) at the Michigan State University (MSU) National Superconducting Cyclotron Laboratory (NSCL) is currently being carried out. The ECR ion source injector is based on a Grenoble design using microwave heating with a frequency range between 12.75 GHz and 14.5 GHz. The off-line injector will augment the electron beam ion trap (EBIT) rare isotope charge breeder as stable ion beam injector for the ReA linac. The ECR ion source injector will be optimized for high charge state to provide CW heavy ion beams from hydrogen to masses up to 136Xe within the ReA charge-to-mass ratio (Q/A) operational range between 0.2 to 0.5. The ECR ion source will be mounted on a high-voltage platform that can be adjusted to provide the required injection energy of 12 keV/u into a room temperature RFQ in preparation for further acceleration. The beam line consists of a 30 kV tetrode extraction system, two mass analyzing sections, and optical matching section for injection into the existing ReA Low Energy Beam Transport (LEBT) line. The design of the ECR ion source and the associated beam lines are discussed in the proceeding.

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Poster Presentation ID: 81

RFQ Beam Cooler for SPES project at LNL

The SPES project is the new Radioactive Ion Beam facility under construction at Laboratori Nazionali di Legnaro (LNL), Italy. Neutron-rich RIBs are produced by the ISOL technique, by the interaction of a primary proton beam of 13 kW with a target of UCx. The high intensity beam is supplied by a Cyclotron able to accelerate up to 50 kW beam power (700 uA @ 70 MeV), whose installation will start on March of this year. To select the low energy RIBs with a resolution of 1/40000, a Mass Spectrometer coupled with a RFQ Beam Cooler are foreseen. The RFQ Beam cooler is designed to improve the quality of the RIBs in terms of reduction of trasversal emittance and to get very low final energy spread (1 eV). The device is under construction at LNL and the installation of the test stand started in January. The performance and the technical details of the cooler will be presented and discussed.

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Poster Presentation ID: 82

Extending the capabilities of the ISOLDE RILIS by blurring the boundaries between ion sources at ISOLDE

For the first time, the RILIS laser ion source has been combined with other ion sources at ISOLDE, offering both immediate applications and a possible direction to meet the laser ion source requirements of the future. The ISOLDE RILIS was combined with a surface ion source for the first hot cavity 2+ resonance ion-ionization and also with the VADIS (Versatile Arc Discharge Ion Source), a first step towards extending the capabilities of both the RILIS and the VADIS.

2+ resonance ion-ionization was originally developed for the case of neutron deficient barium. Resonance ion-ionization of singly surface ionized barium selectively doubles the charge to mass ratio, shifting the barium in the mass region, away from surface ionized 1+ cesium and indium isobars, to a region where surface ionization is not considered to be efficient.

Laser ionization inside the VADIS cavity was first demonstrated off-line with gallium, identifying two new modes of VADIS operation: an element selective RILIS- only mode and a combined RILIS+VADIS mode. These capabilities have since been verified on-line for the production of mercury beams as part of a feasibility study for a future in-source laser spectroscopy study of mercury isotopes. There are numerous immediate applications of these developments: it is now possible to couple a molten lead target with the laser ion source at ISOLDE; laser spectroscopy can be performed inside the VADIS cavity; and switching from VADIS mode to the element selective RILIS mode allows for signal identification. For future developments, the combination of element selective RILIS ionization with the capabilities of the VADIS source to ionize any element or perform molecular break-up, will be explored as a possible method of producing previously unavailable ion beams at ISOLDE.

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Poster Presentation ID: 85

The new IGISOL off-line ion guide quadrupole mass spectrometer system and applications

Currently the off-line testing and development setup of the IGISOL-4 facility [1] at the Accelerator Laboratory of the University of Jyväskylä, is being upgraded. The off-line station is an independently operated ion guide quadrupole mass spectrometer system that is used not only for off-line measurements, but is needed as a development and testing platform for ion guides and other IGISOL front end systems. The new IGISOL-4 facility is now fully operational and due to high demand for on-line (and indeed off-line) operation, an independent infrastructure is required to support the ongoing developments.

During the upgrade, the vacuum chambers and ion optics were reconstructed for optimized ion beam transmission and differential pumping in order to accommodate more stringent requirements for current projects which include cryogenic ion guide development and a Cf-252 fission fragment source. Characterization of a cryogenic ion guide, initiated at IGISOL-3 [2], is now being continued with the coupling of the IGISOL lightion fusion-evaporation gas cell to a cryocooler with the aim of realizing gas cell operation at temperatures down to 30 K. This is primarily motivated by the requirement for the purification of N-14 from the helium buffer gas in order to perform high-precision mass measurements of O-14, a superallowed beta emitter. Additionally, we plan to investigate gas purification and the sensitivity of extraction efficiency as a function of temperature.

The Cf-252 fission fragment source is planned to be installed in a dedicated gas cell in order to be used together with laser resonance ionization for ionization scheme development and to perform spectroscopy on refractory elements. Further studies on the elemental dependency of the extraction efficiency are also planned. Finally, the off-line rig is also well suited to probe supersonic gas jets [3], specifically the study of the effect on resonance linewidth due to the reduced temperature and pressure, as well as extraction of flow velocity and distribution of ions in the gas jet.

In this contribution we present the status of these activities and first results of the performance of the upgraded off-line station.

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Poster Presentation ID: 89

Status of the Isolde RFQ Beam Cooler

The Isolde RFQ beam-cooler[1][2][3] is now an indispensable part of the operation of the Isolde facility, providing greatly improved beam quality via reduced transverse emittance. It also has an optional function to trap ions longitudinally, delivering bunched beams to experiments which need them.

During the 2013 CERN shutdown the cooler was largely rebuilt, partly to address reliability issues, but also to correct misalignments in the injection and extraction regions. It is now possible to inject laser beams into the newly recommissioned cooler, and optical pumping of strontium-88 has been demonstrated. 422 nm light from the Isolde RILIS[4] lasers was sent into the trapping region of the cooler where ion bunches were held for 50-1000 ms, populating a metastable level. The metastable state has an enhanced neutralisation cross-section with sodium vapour, which was read out via the charge-exchange cell in the COLLAPS experiment[5]. We estimate that the population of the metastable state was approximately 50%. This demonstration paves the way to further experiments using optically-pumped ion beams[6].

We will also discuss the bunching performance of the RFQ and the effect of alternative tunes.

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Poster Presentation ID: 90

A Laser Ablation Source for LEBIT

The use of Penning traps in nuclear physics has brought unprecedented precision to nuclear mass measurements. As the only Penning trap system installed at a projectile-fragmentation facility, the LEBIT facility [1] at NSCL has played a unique role in the mass measurement field, offering access to elements that are difficult to produce at other rare-isotope-beam facilities. The high level of precision achieved with LEBIT is used for measurements vital for nuclear structure, nuclear astrophysics, and the study of fundamental interactions.

LEBIT has recently expanded its capability with the addition of a Laser Ablation Source. This source provides access to a wide range of carbon cluster ions, which cover the whole nuclear chart and have essentially no mass uncertainty by definition of the atomic mass. Carbon cluster ions therefore are ideal for rigorous testing and calibration of the LEBIT system, as well as for use as reference masses during experiments, so that the masses of ions of interest can be measured to the highest possible precision. The laser source also provides simple, efficient access to other stable and long-lived isotopes of interest. This has allowed for several measurements important for neutrino physics [2-5]. Here I will present a description of the design and capabilities of this new ion source.

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Poster Presentation ID: 91

SWIFT beam purification at LEBIT

In high precision Penning trap mass spectrometry of rare isotopes, beam purity is an important consideration when making measurements because the contamination of the ions of interest with other particles results in a shift of the measured mass. This is of particular concern at the Low Energy Beam and Ion Trap (LEBIT) facility [1] at the National Superconducting Cyclotron Laboratory - a rare isotope beam facility utilizing particle fragmentation - as molecular contaminant ions with similar charge- to-mass ratios can be created in the beam thermalization process. Previously, beam purification at LEBIT has relied on the use of dynamic capture in the Penning trap as a time-of-flight mass separator, and on dipole cleaning [2]. Dipole cleaning relies on driving contaminant ions to a sufficiently large radius so that they do not interfere with the measurement through the quick dipolar excitation of specific contaminants at their specific reduced cyclotron frequencies. This requires the identification of all contaminants, an inefficient use of rare isotope beam time. The stored waveform inverse Fourier transform (SWIFT) [3] beam purification technique, which has been recently implemented in the 9.4 T LEBIT Penning trap mass spectrometer[4], offers a method of exciting a range of frequencies, providing for broadband excitation in a user-defined mass range as an alternative to the dipole cleaning method already in use at LEBIT. We will discuss both the implementation of SWIFT at the LEBIT facility, as well as its use in recent rare isotope beam experiments.

[1] R. Ringle, G. Bollen, and S. Schwarz, Int. J. Mass Spectrom. 349-350, 87 (2013) [2] P. Schury et al, Phys. Rev. C 75, 0055801 (2007)
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Poster Presentation ID: 93

A Novel Next-Generation Cryogenic Stopping Cell for the Low-Energy Branch of the Super-FRS

The next-generation cryogenic stopping cell (CSC) for the Low-Energy Branch (LEB) of the Super-FRS is based on our experience of advanced stopping cell techniques. The stopping cell is operated at cryogenic temperatures to ensure a high purity of the stopping gas and high density operation enabled using an RF carpet with a small electrode structure size. These techniques have been implemented in the first version of the cryogenic stopping cell for the LEB, which has recently been commissioned in FRS experiments with a primary beam of ^{238}U ions at 1000MeV/u [1].

The next generation CSC consists of two main vacuum chambers, an outer chamber that provides the insulation vacuum for the inner chamber, which is operated at cryogenic temperatures (~ 70 K). The system will incorporated several novel concepts (i) the inner chamber is divided into a high-density stopping region and a low-density extraction region, (ii) ion extraction is done in vertical direction with respect to the incident fragment beam, (iii) multiple parallel extractions nozzles are used between the high and low pressure region and (iv) a dual-layer rectangular RF carpet (structure size: > 6 electrodes / mm) with electrode lines that overlap at right angles is used.

Compared to conventional stopping cells, these new design features lead to numerous advantages: (i) extremely short extraction times (~5ms), (ii) higher rate capability, (iii) minimized power dissipation, which is crucial for cryo-operation, (iv) increased areal density without compromising extraction times, efficiencies or rate capability, (v) precise measurement of the range of the ions and (vii) improved cleanliness of the CSC.

The stopping volume has a width of 25 cm, a height of 10 cm and a length of 2 m corresponding to an areal density of 40 mg/cm^2, an increase by a factor of 8 from the areal density of the present CSC. In combination with the momentum compression provided by the energy buncher of the Super-FRS, stopping efficiencies close to unity are expected for all but very light nuclei. The extraction time of the ions will be about 5 ms, shorted by a factor of 5 compared to the present CSC. The novel CSC will thus significantly improve the performance of present stopping cells and give access to very exotic and short-lived nuclei available at the Super- FRS.

[1] S. Purushothaman et al, (2013) EPL 104 42001

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Poster Presentation ID: 94

Experimental techniques to use the (d,n) reaction for spectroscopy of low-lying proton-resonances

Studies of rp-process nucleosynthesis in stellar explosions show that establishing the lowest l=0 and l=1 resonances is the most important step to determine reaction rates in the astrophysical rp--process path. At the RESOLUT facility, we have used the (d,n) reaction to populate the lowest p-- resonances in ^{26}Si, and demonstrated the usefulness of this approach to populate the resonances of astrophysical interest [1]. In order to establish the (d,n)reaction as a standard technique for the spectroscopy of astrophysical resonances, we have developed a compact setup of low- energy neutron-detectors, ResoNEUT and tested it with the stable beam reaction $^{12}C(d,n)^{13}N$ in inverse kinematics. Most recently, the detectors were included in a study of the radioactive beam reaction $^{17}F(d,n)^{18}Ne$ in inverse kinematics. Performance data from these experiments will be presented.

[1]P.N. Peplowski {\it et al.} Phys.Rev.{\bf C 79}, 032801 (2009)

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Poster Presentation ID: 95

Towards a precision Penning trap measurement of the ^{163}Ho Electron Capture Q-value

The results of solar, atmospheric, and reactor neutrino oscillation experiments have provided strong evidence for a non-zero neutrino mass. However, these measurements determine only the difference between the squared-masses of the neutrino mass eigenstates. The absolute neutrino mass scale is still unknown. Beta-decay experiments utilizing ^{3}H and ^{187}Re have obtained the most stringent upper limits on the (anti) electron neutrino mass of 2 eV. An emerging alternative method for a direct neutrino mass determination is based on calorimetric electron capture spectroscopy (ECS) of ^{163}Ho. The ECHO collaboration in Europe, and the NUMECS collaboration in the USA aim for sub-eV sensitivity to the electron neutrino mass using this method. In both the beta-decay and EC experiments the neutrino mass is determined from a fit to data near the end-point of the decay energy spectrum. The end-point energy for zero neutrino mass, which corresponds to the Q-value for the decay, is a free parameter in the fit. Hence, an independent measurement of the Q-value is extremely important for interpreting experimental results and checking for possible systematic effects.
At CMU we are developing a high-precision double Penning trap mass spectrometer: the Central Michigan University HIgh Precision Penning trap (CHIP-TRAP), which will employ a simultaneous cyclotron frequency comparison technique using pairs of ions confined in two separate traps. This will reduce the effect of magnetic field fluctuations. The Q-value, defined as the mass difference between parent and daughter atoms, can be determined via $Q = m_p - m_d = (m_p - m_e)(1 - R)$, where $R = f_{c,p}/f_{c,d}$ is the cyclotron frequency ratio for ions of the parent and daughter species. CHIP-TRAP will utilize ions of 163Ho and the daughter ^{163}Dy produced by a laser ablation ion source. This will minimize the amount of ^{163}Ho, which must be synthesized, required for the measurement. A Q-value determination to ~1 eV is required for the ^{163}Ho ECS experiments, corresponding to a fractional precision of ~5 parts-per-trillion in the cyclotron frequency ratio. In this presentation we will describe the current status of CHIP-TRAP, and of tests of ion production via laser ablation of the stable 165Ho isotope.

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Poster Presentation ID: 97

IGISOL control system modernization

Since 2010 a lot has happened in the IGISOL research facility [1] at the Accelerator laboratory of the University of Jyväskylä. The facility has moved to a completely new target hall. The facility area has increased by multifold and the length of the ion transport line has grown to about 50 metres with several measurement setups and extension possibilities. Now the facility can have accelerated ions from two different cyclotrons. The facility has evolved to much more complex system including hundreds of manual, pneumatic and electronic devices. The facility is now known as IGISOL4.

The move of the IGISOL research facility gives perfect opportunity to examine the operational factors of the facility with modern perspective. As the complexity of the facility has increased the safety, usability and maintainability issues require more attention. All these aspects overlap in modern facility-wide control system which enables user and device level safety, introduces a whole new level of user operations, and makes system maintenance and further development more straightforward.

The previous IGISOL3 control system was already partly relying on modern digital design [2] in which devices are operated remotely by dedicated hardware and software. In IGISOL4 this concept is taken a step further since as many devices as possible are to be included to the software-based remote control system. In IGISOL4 the main architecture of the control system hardware involves ethernet as the main communication medium which gives good integration of wide range of devices. In the hierarchy of hardware architecture the highest level includes PCs as the main control system units with main control logic. The middle level includes semi-intelligent devices such as function generators. The lowest level of hardware includes dummy fieldside devices like valves. The software architecture of the IGISOL4 control system is relying on EPICS ecosystem as the backbone. EPICS communicates through ethernet via Channel Access protocol. EPICS is a powerful tool which forms a versatile real-time database from the facility process variables and in such offers a clean interface between higher and lower level hardware and software.

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Poster Presentation ID: 98

Direct double beta-decay Q-value measurements at LEBIT

Experimental searches for the neutrinoless double-β (0νββ) decay [1] have become of great interest after the confirmation of nonzero neutrino mass by neutrino oscillation experiments. This process is forbidden in the Standard Model and proposed to only occur if the neutrino is its own antiparticle. An observation of 0νββ-decay would enable one to determine the absolute neutrino mass scale. The Q-value of the decay, which is defined as the difference between the masses of parent and daughter atoms, is an important parameter that enters into the equation.

The Low Energy Beam and Ion Trap (LEBIT) facility [2] at the National Superconducting Cyclotron Laboratory (NSCL) utilizes Penning trap mass spectrometry (PTMS) which has proven to be a powerful technique for performing high precision atomic mass measurement. We have recently performed precise Q-value measurements on some stable 0νββ-decay candidates produced by the laser ablation source and the plasma ion source of the LEBIT facility. Our recent double beta-decay Q-value measurements of 48-Ca [3,4], 96-Zr [5], 82-Se [6] isotopes, and the neutrinoless double electron capture candidate 78-Se [7] and their contribution to direct decay searches will be presented.

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[3] M. Redshaw, G. Bollen, M. Brodeur, S. Bustabad, D. L. Lincoln, S. J. Novario, R. Ringle, S. Schwarz, Phys. Rev. C 86 (2012) 041306.
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Poster Presentation ID: 99

Advances in surface ion suppression from ISOLDE-RILIS using µs beam-gating and pulsed heating

The RILIS - Resonance Ionization Laser Ion Source - is the most commonly used ion source type at CERN-ISOLDE. While it is both efficient and highly element-selective its application to certain experiments is limited by the presence of isobaric contaminants due to the surface ionization of neighbouring elements. Different approaches have been demonstrated varying degrees of efficacy in tackling this problem: suppressing the production of surface ions by selecting low work function cavity materials, the use of a surface ion repeller, and the use of a pulsed electrostatic ion deflector to deviate the DC beam of surface ions away from the pulsed beam of laser-ions, referred to as beam-gating.

In this paper we will present recent results from the ongoing developments in ion beam purification using the microsecond beam-gating technique and its planned adaptation towards ISOLDE on-line conditions. By increasing the voltage across the hot cavity through the use of a high resistivity graphite tube, the bunch-length of laser ions extracted from the cavity can be reduced to below 5 µs, as observed during off-line tests. Combined with microsecond beam-gating, this enables a 20-fold selectivity improvement with minimal loss of the ions of interest. A further increase in the voltage across the ionizer can be realized by applying a pulse-width modulated (PWM) heating current whilst maintaining the same time-averaged electrical power level. The results of these tests will be presented, along with details of the cavity materials used and possible solutions to the technical challenges that they impose. Some additional promising applications of this new laser-ion source cavity configuration, with a view to a further increase in ion beam purity, will also be introduced.

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Poster Presentation ID: 101

Upgrades for the TwinSol low-energy RIB facility

TwinSol, a pair of coupled, superconducting solenoids, was one of the first devices capable of producing beams of radioactive nuclei. A primary beam from the UND accelerator is used to bombard a primary target producing a secondary beam in flight. TwinSol is used to gather, separate, and focus the recoils. Since it was commissioned at the University of Notre Dame (UND) in 1997, at least 58 publications have reported data from its use. There are hundreds of collaborators from many different countries that use this facility. Currently, plans are in place at the UND to provide several upgrades to TwinSol including a multi-cell gas production target and the possible addition of a third solenoid. Upgrades currently in the works will be discussed along with future plans.

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Poster Presentation ID: 105

A preparation Penning trap for the project TRAPSENSOR with prospects for MATS at FAIR

Most of the Penning traps for precision measurements (MT) at Radioactive Ion Beam (RIB) facilities make use of another Penning trap located upstream in the experimental set up, to perform isobaric separation (PT) and deliver cooled samples of the ions to be measured in the MT. The PT for the project TRAPSENSOR at the University of Granada has been built to prepare ions produced off-line, with a laser- desorption ion source, using firstly the buffer-gas cooling technique [1]. It will be also used as a platform to investigate the induced image-current technique in a specific frequency range. The system has been built following the geometrical specifications given in the Technical Design Report for the MATS facility at FAIR [2], so as to allow performing later other cooling mechanisms on the ions ensemble (singly or multiply charged) and reaching lower final temperatures. So far, cooling resonances have been obtained for several isotopes, with mass-to-charge rations ranging from 40 to about 200, with specifications similar to those PTs already in operation at RIBs. In this contribution the PT will be described, with the associated infrastructure, i.e., the cold head system to run it at low temperature (about 40 K), and the electronic detection circuit. The measurements obtained so far will be also presented.

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Poster Presentation ID: 106

Micro Penning Traps for Continuous Magnetic Field Monitoring in High Radiation Environments

The establishment of next generation rare isotope beam facilities, such as the Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU), requires new and improved instrumentation to deal with the anticipated high-radiation environment associated with the interaction of high-power beams with matter. One important piece of instrumentation is a precise, radiation-resistant, magnetic field probe. NMR probes, which are currently used extensively to measure magnetic fields, have a limited lifetime in these environments. Therefore, a radiation-tolerant replacement is needed. Specifically, we propose to employ Penning trap mass spectrometry for high-precision magnetic field measurements. Our Penning microtrap will be radiation-compatible as all electronic components will be maintained at a safe distance and shielded.Penning trap mass spectrometers can determine magnetic fields by measuring the cyclotron frequency of an ion with known mass and charge. We have developed a high- precision "minitrap" magnetometer [1] to be used for constant monitoring of strong magnetic fields used at the Low Energy Beam and Ion Trap (LEBIT) facility [2] at the National Superconducting Cyclotron Laboratory (NSCL). The minitrap magnetometer design has pushed the limits of what, with reasonable effort, can be achieved using conventional machining processes. In order to broaden the use of this novel approach to magnetic field probes, we have partnered with Translume [3], a company that specializes in manufacturing microstructures in fused-silica glass using lasers. This partnership will allow us to develop low-cost, reliable ion trap assemblies. Further miniaturization will also make integration of the device easier, and reduce deleterious effects due to magnetic field gradients.

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510 (2013).
[3] http://www.translume.com

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Poster Presentation ID: 107

Opportunities for Isotope Discovery at FRIB

The discovery of an isotope is not only a prerequisite for the future investigation of its nuclear structure, but it also helps us to delineate the limits of nuclear binding and thus has direct implications for fundamental questions in nuclear physics and nuclear astrophysics. Besides the roughly 300 stable isotopes there are about 2700 that have been identified so far, but there are still several thousand to be discovered [1]. Isotope discoveries are closely linked to the experimental equipment available, and for rare isotope beams this means that a new generation of accelerator facility offers opportunities for discovery. With its high intensity primary beam of 200 MeV/u and 400 kW, FRIB will make a large number of rare isotopes available for the first time. Besides offering the needed particle yields, the 3-stage fragment separator ARIS [2] will also provide the selectivity that is required to identify these very rare isotopes. Expected production yields for a wide range of rare isotopes were calculated using the the code LISE++ and planned performance parameters [3, 4]. A comparison between recent isotope discoveries and expected particle yields indicates the range of isotopes that can likely be detected. The presentation will highlight recent isotope discoveries at NSCL's Coupled Cyclotron Facility and deduce how far the limits can be pushed with the Facility for Rare Isotope Beams. This work was supported by NSF Grant PHY-11-02511. [1] M. Thoennessen, B. Sherrill, Nature 473 (2011) 25-26 doi:10.1038/473025a [2] M. Hausmann et al., Nucl. Instr. Meth B 317 (2013) 349-353 doi:10.1016/j.nimb.2013.06.042 [3] O. B. Tarasov, D. Bazin, Nucl. Instr. Meth. B 266 (2008) 4657 doi:10.1016/j.nimb.2008.05.110 [4] G. Bollen, M. Hausmann, B. M. Sherrill, O. B. Tarasov, <http://groups.nscl.msu.edu/frib/rates/fribrates.html>

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Poster Presentation ID: 108

Beam Thermalization in a Large Gas Catcher

Thermalization in a buffer gas provides a method to transform fast exotic beams produced by projectile fragmentation at the National Superconducting Cyclotron Laboratory (NSCL) into low-energy beams. The process includes slowing down the fast exotic beams in solid degraders combined with momentum compression and removing the remaining of kinetic energy by collisions with the buffer gas [1]. The beam thermalization area at the NSCL was reconfigured to accommodate two new momentum compression beam lines, a large Radio-frequency (RF) gas catcher constructed by Argonne National Lab [2] and a low-energy beam transport system. A large variety of exotic isotopes produced by the A1900 fragment separator was thermalized in the 1.2 m long gas catcher filled with helium at ~100 mbar. The ions were guided to an extraction nozzle with a combination of electrostatic and RF potentials and ejected by the gas flow. A novel RF ion guide was used for low-velocity transport of the ions into ultrahigh vacuum [3]. Finally, the ions were modestly accelerated for transport to various experiments. Twelve fragments ranging from ^{14}O to ^{76}Ga were used to study the thermalization process in the gas catcher. The combined stopping and extraction efficiencies were measured varying from 0.05% to 40% depending on the study case. The operational status of the beam thermalization area and gas catcher characterization results will be presented.

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Poster Presentation ID: 109

The Ion Surfing Transport Method for Beam Thermalization Devices

Projectile fragments can be slowed and thermalized in buffer gas to supply rare ions to low energy experiments. I will present studies of "ion surfing" [1], a method for transporting ions through gas-filled devices that uses a RF gradient to repel the ions from the walls. Instead of relying on a fixed potential gradient to guide the thermal ions through the length of the cell, the ions are transported by a traveling wave superimposed on the RF field. The traveling wave is formed by an oscillating sinusoidal field applied to repeating sets of four electrodes. The field on each subsequent electrode is offset by 90 degrees in phase. Transport efficiency and velocity measurements were performed for rubidium and potassium ions over a wide range of conditions. With the optimal parameters currently attainable, >90% efficient transport over 10 cm at 80 mbar was observed for Rb and K ions with max velocities of 75 m/s and 50 m/s, respectively [2]. The measurements were conducted with an arrangement of curved electrodes in preparation for the cyclotron gas cell at the National Superconducting Cyclotron Laboratory at Michigan State University. I will present the results of the measurements and comparisons to detailed simulations.

[1] G. Bollen, Int. J. Mass Spect. 299 (2011) 131
[2] M. Brodeur, A.E. Gehring, et al., Int. J. Mass Spect. 336 (2013) 53

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Poster Presentation ID: 110

Mass Measurements of Rare Isotopes with a Single Ion

Several scientific applications require high-precision mass data. In particular calculations of the astrophysical r-process, nuclear structure studies, tests of nuclear mass models, and fundamental interactions are examples with very high impact. Mass measurements of radioactive nuclides are particularly challenging as the production rates decrease with increasing distance from stability Rare isotopes are produced at the National Superconducting Cyclotron Laboratory (NSCL) by relativistic heavy-ion fragmentation and in-flight separation. This fast, chemically-insensitive production technique provides access to nuclei far from stability. The new Facility for Rare Isotope Beams (FRIB) under construction at MSU will provide even more exotic isotopes. High-precision mass measurements of rare isotopes are performed at NSCL by the Penning trap mass spectrometer LEBIT, being the only one worldwide located at a fast beam facility, using the well-known time of flight ion cyclotron resonance (TOF-ICR) technique. This very universal technique requires minimal effort to change from one ion species to another. However, a single resonance curve requires on the order of 100 detected ions. As one moves further from the valley of beta stability, production rates of the exotic isotopes typically decline and a more sensitive technique is needed in order to access rare isotopes being delivered at rates of about 1 ion/hour, or less. Thus, the Single Ion Penning Trap project (SIPT) is being developed at NSCL allowing for high-precision mass measurements with a single ion employing the narrow-band Fourier-Transform Ion Cyclotron Resonance (FT-ICR) technique. It aims for mass measurements in the neutron-rich region where half-lives are usually sufficiently long for FT-ICR measurements. SIPT is being implemented in a 7-T superconducting magnet sharing the beam line with LEBIT. An optimal signal-to- noise ratio is ensured by employing a superconducting NbTi resonator coil, and by cooling the trap and detection electronics down to 4.2K with a pulsed-tube cooler. With this combination of isotope production by fragmentation, and the complementary use of mass measurements with FT-ICR at SIPT as well as TOF-ICR at LEBIT, the reach of Penning trap mass spectrometry will be greatly enhanced at the NSCL now, and at FRIB in the future.

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Poster Presentation ID: 112

Commissioning the cryogenically cooled gas target and the ionization chamber of HELIOS

The HELIcal Orbit Spectrometer (HELIOS) has been used to successfully study reactions in inverse kinematics with both stable and radioactive beams; however, initial studies were limited to solid targets. In addition, in the original implementation of HELIOS a telescope of silicon detectors was used for recoil detection and, while it provided particle identification information for recoils with A<30, such a device is limited to rates of ~10 kHz and covers a relatively small solid angle. To broaden the scope of nuclear reactions accessible with HELIOS and to increase recoil detection capabilities, two devices have been developed: a cryogenically cooled gas target, which allows for the study of reactions in inverse kinematics using for example 3He or 4He targets, and a high-rate ionization chamber that captures a much larger fraction of the recoils than the silicon telescope and is capable of detecting heavy recoils with A<150 at rates of up to 500 kHz. The technical details of the new devices are presented and results from the commissioning experiments are discussed.

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Poster Presentation ID: 114

Specifications and Design of the Electric Dipole for the SPIRAL2 Super Separator Spectrometer

The Super Separator Spectrometer (S3) is a large acceptance mass separator which is under construction for use with intense heavy ion beams at the SPIRAL2 facility at GANIL. It is a two-stage separator comprising a momentum achromat followed by a mass separator. The mass separation stage uses a combination of one electric dipole for energy dispersion and one magnetic dipole for momentum dispersion to create m/q dispersion at the final focal plane. The specifications required to achieve the desired separator resolution, acceptance, and rigidity are: dipole horizontal gap=20 cm, radius of curvature rho=4 m, bend angle θ=22 degree, electric field E=3 MV/m (+/- 300 kV), vertical acceptance 25 cm. Extensive electrostatic simulations have been done to support a mechanical design with peak surface fields limited to 8 MV/m on the electrodes and much smaller surface fields along the support insulators. The anode has a gap and an external Faraday cup to collect beam transmitted by the 1st stage. The electrodes are profiled to achieve the required vertical extent of the good field region with minimum height of the electrodes. The positive and negative high voltage power supplies are being designed starting from the concept high voltage multipliers integrated with the electric dipole's vacuum chamber as currently being used at the ATLAS FMA separator and the ISAC2 EMMA separator. These supplies are being designed for peak voltages of +/- 480 kV to a) make sure they operate reliably at required voltages by conditioning to at least 20% higher, and b) to possibly operate at higher than the base-line requirement of +/- 300 kV if the design peak fields can be exceeded in practice.

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Poster Presentation ID: 117

Specifications, Design, and Commissioning of the Superconducting Multipole Triplets for the SPIRAL2 Super Separator Spectrometer

The Super Separator Spectrometer (S3) is a large acceptance mass separator which is under construction for use with intense heavy ion beams at the SPIRAL2 facility at GANIL. It is a two-stage separator comprising a momentum achromat stage with two bends by magnetic dipoles to form a fully achromatic image at its focal plane and a mass spectrometer stage with one electric dipole for energy dispersion and one magnetic dipole for momentum dispersion to create m/q dispersion while being achromatic in momentum at the final focal plane. Each of the four bends are preceded and followed by magnetic quadrupole triplets. Seven are superconducting multipole triplets (SMT) while the one following the first magnetic dipole is an open-sided copper-coil multipole to permit the high-power primary beam to exit and be captured by a Faraday cup. In this presentation we present the design requirements and results of commissioning the first SMT. To achieve the desired high angular, momentum, and charge-state acceptance of S3 the SMTs are designed with a warm-bore aperture of 30 cm and each of the singlets contains sextupole and octupole correcting coils in addition to the quadrupole coils. Each quadrupole singlet also contains a dipole coil for steering corrections, with the first and third singlets of each triplet having vertical dipole correctors wired in series while the central singlet has a horizontal steerer. To avoid large multipole error terms in the fringe fields of these large aperture multipoles a new coil configuration has been implemented*. The cryostats of the SMTs are complex due to the large number of leads and vertical space limitations of the S3 vault.

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*P. Walstrom, NIM A519 (2004) 216

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Poster Presentation ID: 119

The NSCL Cyclotron Gas Stopper - entering commissioning

At the NSCL rare isotopes are produced by projectile fragmentation at energies on the order of 100 MeV/u for a wide range of research. Linear gas stopping cells have been used successfully at NSCL for a decade to slow down these beams to the keV-energy range; first for use with low-energy high precision experiments such as the Penning- trap mass spectrometer LEBIT and the collinear laser spectroscopy setup BECOLA, and more recently, for NSCL's re-accelerator ReA.

A gas-filled reverse cyclotron is currently under construction by the NSCL. Simulations indicate that very efficient stopping and fast extraction will be possible even for light and medium-mass ions, which are difficult to efficiently thermalize in linear gas cells. The device is based on a 2.6T maximum-field three- sectored cyclotron-type magnet to confine the injected beam while it is slowed down in ~100 mbar of high-purity LN2-temperature helium gas. Once thermalized, the beam will be transported to the center of the device by a traveling-wave RF-carpet system, extracted along the symmetry axis with an ion conveyor and accelerated to a few tens of keV of energy for delivery to the users.

The magnet with its pair of superconducting coils has been constructed on a 60kV-HV platform and is currently being commissioned. The magnet's two cryostats use 3 cryo- refrigerators each and liquid-nitrogen cooled thermal shields to cool the coils to superconductivity. This concept, chosen not to have to rely on external liquid helium, has been working well. First measurements of axial and radial field profiles confirm field calculations.

The individual RF-ion guiding components for low-energy ion transport through the device have been tested successfully. The beam stopping chamber with its 1m-diameter RF carpet system is currently being prepared for installation inside the magnet and will be coupled to the extraction conveyor for a full low-energy transport test in early 2015.

The design and the predicted performance of the machine will be summarized and an update on its commissioning status given.

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Poster Presentation ID: 120

Developments in magnet modeling and beam optics for the ARIS separator at FRIB

The Advanced Rare Isotope Separator (ARIS) at the future Facility for Rare Isotope Beams (FRIB) at Michigan State University will produce high-intensity rare isotope beam by in-flight separation of reaction products from fragmentation and fission of primary beams with energies of 200 MeV/u and higher and with up to 400 kW of beam power. ARIS will use a variety of bending and focusing magnets, as well as wedged- shaped energy degraders, in order to separate contaminants and efficiently transport the rare-isotope beam of interest. Due to the large emittances of many of the products, detailed and accurate knowledge of fields is required by the beam physics model to support efficient operation. The compact design and high acceptance requirements causes the contribution of fringe fields to be large, hence requiring detailed knowledge of the magnet field distributions. As magnet designs of different magnets are being completed, detailed simulated field distributions are becoming available. The fields are analyzed to extract a relatively small set of parameters used in the beam physics simulations that emulate the fields. The residuals between the field data and emulated fields are minimized by applying fitting and Fourier analysis algorithms.

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Poster Presentation ID: 122

AstroBox2 - Detector for Low-energy Beta-delayed Proton Detection

Over the past years we have done several studies of beta-delayed proton emitters of astrophysical interest by implanting the nuclei of interest into Si detectors of various segmentations [1-5]. In these studies it was realized that shrinking the physical detection volume of elements in Si detector did not reduce the beta- background enough to create a background free spectrum in the typical energy range of astrophysically interesting decays (Ep ~ few hundred keV). To further reduce the beta-background a novel detector, AstroBox, based on Micro Pattern Gas Amplifier Detector (MPGAD) was developed [6].

We are now building an upgraded version of this detector, AstroBox2. The major change to the first version is the change of geometry of the MPGAD pad structure. The earlier cylindrical symmetry of the pads has been replaced by a set of rectangular pads that are arranged into a geometry along the beam axis to improve implantation control. The new detector chamber design has several technical improvements that enhance the overall usability of the setup.

In this presentation a description of the AstroBox2 detector and results from the commissioning tests are given, and future physics experiments discussed.

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Poster Presentation ID: 129

Characterization and Performance of the NSCL's Large Volume Linear Gas Cell

Beam thermalization plays a pivotal role in the ability of projectile fragmentation facilities to produce low-energy ion beams. The National Superconducting Cyclotron Laboratory (NSCL) employs a beam thermalization technique that involves first passing high-energy beams through solid degraders to remove the bulk of the beam's kinetic energy. The remaining kinetic energy is then dissipated through collisions with buffer gas atoms of a large volume linear gas cell that was constructed at Argonne National Lab (ANL). A series of initial commissioning experiments for the gas cell were conducted using 76Ga beams produced at approximately 90 MeV/u in the A1900. The fast beams were delivered to the gas cell in a new momentum compression beam line and the range distributions, extraction efficiency as well as the overall efficiency of the system were measured as a function of the incident intensity. The data were compared to predictions from the LISE++ code [1], stopping and range of ions in matter (SRIM) [2], and then particle-in-cell (PIC) calculations [3] of the space charge produced by the stopping were used in SIMION calculations [4] of the ion migration in the cell. The calculated efficiencies have been completed and generally agree with the observed behavior of the gas cell. Both the experimental and simulated results for the linear gas cell's performance will be presented and discussed.

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Poster Presentation ID: 131

The SPES-Charge Breeder and its beam line at INFN-LNL

The Selective Production of Exotic Species (SPES) facility is under construction at INFN-LNL: aim of this project is the production, ionization and post-acceleration of radioactive ions to perform forefront research in nuclear physics. Radioactive species will be produced by fissions induced by a proton beam impinging on an UCx target: the proton beam will be delivered by a normal conducting cyclotron (built by the Best Company) with a maximum energy of 70 MeV and 0.7 mA of maximum current. The radioactive species will be ionized in the so called Target-Ion-Source system, extracted as a 1+ beam, cooled in RFQ cooler and purified by the isobars contaminants through an High Resolution Mass Spectrometer. In order to allow post acceleration with the superconducting linac ALPI at INFN-LNL (up to 10 MeV/u for A/q=7), an ECR- based charge breeding (CB) technique was chosen: in particular the SPES-CB will be developed by the LPSC Grenoble on the basis of the Phoenix booster. The SPES-CB will be equipped with a complete test bench totally integrated with the SPES beam line: in particular, in order to avoid beam contaminations induced by the impurities present inside the SPES-CB and to have high transmission for a beam of very low intensity, special attention was paid not only on the transport efficiency but also to the resolution of the spectrometer downstream the charge breeder. To this scope, a Medium Resolution Mass Spectrometer (MRMS) was designed on the basis of the one employed for CARIBU at ANL. In the following paper the technical aspects connected with SPES-CB, its beam line and the transport of highly charged radioactive ions will be described.

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Poster Presentation ID: 134

PILGRIM, a future MR-ToF-MS at GANIL for mass measurement and separation on exotic beams.

PILGRIM is a Multi-Reflection Time Of Flight Mass Spectrometer (MR-ToF-MS) currently under development at GANIL for the S3 collaboration (Super Separator Spectrometer) and dedicated to the study of very heavy and super heavy nuclei. MR-ToF-MS devices have been proven effective for isobaric separation (Resolving power over 10^5 [1]) and high precision mass measurement (mass error down to a few 10^-7 [2]) within a few tens of milliseconds. These features make such a device extremely interesting for ensuring isobaric beam purity and mass measurement of very exotic, short lived nuclei. PILGRIM is to be set up in the future low energy branch of the S3-Spiral2 project and may also be used as a beam purifier in front of the double Penning trap PIPERADE at DESIR-Spiral2.

An electrostatic 90 degree quadrupole deflector is also currently on study and will be placed between a RFQ cooler-buncher (beam preparation) and PILGRIM. The study focuses on conserving the beam features and especially the Time-of-Flight spread of an ion bunch as it directly impacts the Resolving Power of a MR-ToF-MS device.

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Poster Presentation ID: 138

New Target Ion Source Systems at GANIL/SPIRAL 1: prospective

SPIRAL1 facility is currently under transformation [1] in order to extend the range of radioactive ion beam offered to users. It will be able to host a larger variety of Target Ion Source Systems by the end of 2016, needed to fulfill the production requirements related to the chemical variety of the isotopes demanded by the physicists. The extent of the transformation is limited by the frame of the safety regulation and by the existing facility. Nevertheless, several combinations of mono-charged or multi-charged ECR, FEBIAD and surface ionization sources with new target materials [2] will become possible. Some of these combinations are already under test. Next ones will be presented versus scientific priorities and technical possibilities.

[1]: M. Dubois et al, contribution to this conference.
[2]: P. Delahaye et al, contribution to this conference.

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Poster Presentation ID: 142

The new JENSA gas-jet target for astrophysical radioactive beam experiments

New radioactive beam facilities are enabling the study of many astrophysical reactions on exotic beams for the first time. To take full advantage of these new capabilities, however, we need to also advance target technology. Particularly important to the study of astrophysical reaction rates is the creation of localized and dense targets of hydrogen and helium. The Jet Experiments in Nuclear Structure and Astrophysics (JENSA) gas jet target has been constructed for this purpose. JENSA was originally constructed at Oak Ridge National Laboratory for testing and characterization, and has now moved to the ReA3 reaccelerated beam hall at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University for use with radioactive beams. The JENSA target will be presented along with the first commissioning and science results.

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Poster Presentation ID: 143

Status of the project TRAPSENSOR: a laser-cooled ion as a high-sensitive detector for single-ion Penning trap mass spectrometry

Penning traps are used at many facilities to perform direct high-precision mass measurements on stable and/or radioactive nuclides. For stable or long-lived nuclides, the developments are going mainly in the direction of improving precision. In the case of very exotic nuclei, an important objective is to enhance sensitivity. This motivates further work on conventional techniques, initially applied to stable isotopes, and to develop new ones. In this scenario, we are developing a novel technique at the University of Granada in the framework of the project TRAPSENSOR. This technique is based on the detection of a single ion stored in a Penning trap by monitoring the fluorescence of a laser-cooled $^{40}Ca^{+}$ ion, which is connected to the ion of interest through electrical image charges these ions induce in a common electrode [1]. An important aim of the project is to perform measurements on ions produced with very low yield as for example superheavy elements [2,3]. The full experimental set-up comprises a laser-desorption ion source [4], a Penning-trap system consisting of a preparation trap and double micro-trap system housed in a 7-T superconducting solenoid, and a high-performance laser arrangement [5]. In this contribution, the status of the project will be presented, underlining technical features with prospects for other experiments, and the results achieved so far.

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Poster Presentation ID: 144

Thermalized and ReAccelerated beam diagnostics at NSCL

The National Superconducting Cyclotron Laboratory at Michigan State University produces rare isotope beams using the fast fragmentation technique. A recent expansion of the facility enables low energy (< 60 keV) and post-accelerated (< 3MeV/A) beams to be delivered to experiments. The first stage is thermalization in a helium-filled linear gas cell. Depending on the chemistry of the beam species being extracted, the beam may be singly or doubly charged atomic or molecular ions. In order to select the correct mass the low energy beam transport (LEBT) dipole magnet follows the gas cell. The beam can be further transported to the electron-beam ion trap (EBIT) charge breeder and the ReA superconducting linac to provide post-accelerated beams around the Coulomb barrier. Energies up to 3 MeV/A are currently available and a future expansion is planned to provide up to 12 MeV/A for ^{238}U.

Both the gas cell and the EBIT can produce stable backgrounds orders of magnitude higher in intensity than the isotope of interest. Scanning the fields in the LEBT magnet and the charge-over-mass (Q/A) separator following the EBIT provides selectivity, but the diagnostics giving feedback to this process must be able to provide information on the intensity and species of the isotopes on the single-ion- counting level.

NSCL has installed a wide array of beam diagnostics devices, both traditional and detector-based. These devices include Faraday cups for measuring current in the low 10s of pA, with dedicated setups capable of 100s of fA, microchannel plate (MCP) detectors for imaging the beam profile, with observation possible in the low 10s of Hz and decay counters sensitive only to the radioactive portion of the beam. The decay counters give information on the beam species through half-life measurements, with further identification available through the measurement of gamma rays using NaI and germanium detectors. After post-acceleration, the energy of the beam components can be measured with silicon detectors utilizing scattering from gold foils, and in-beam silicon detectors, which allows the beam composition to be measured based on their masses only.

This contribution will discuss the array of traditional and radioactive beam diagnostics available at the laboratory, and show data obtained during the operation and characterization of the gas cell and ReA facilities.

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Poster Presentation ID: 145

Thermal, Mechanical and Fluid Flow Aspects of the High Power Beam Dump for FRIB

The Facility for Rare Isotope Beams (FRIB) under construction at Michigan State University is based on a 400 kW heavy ion accelerator and uses in-flight production and separation to generate rare isotope beams. The first section of the fragment separator houses the rare isotope production target and a primary beam dump to absorb unreacted primary beams. The experimental program will use ion beams from 16O to 238U with as much as 300 kW in remaining beam power needing to be absorbed by the dump. A rotating water-cooled thin-shell metal drum was chosen as the basic concept for the beam dump. Extensive thermal, mechanical and fluid flow analyses were performed to evaluate the effects of high power density in the beam dump shell and water. Results of the simulations of the beam dump with different design options will be discussed. A design modification to the initial flow pattern resulted in a substantial increase in the wall heat transfer coefficient, for example. Detailed evaluation of different materials for the shell were done. Many properties must be optimized simultaneously: low beam power deposition in the shell, mechanical strength, fatigue strength, and radiation resistance. A titanium alloy, Ti-6Al-4V, is presently considered to be the best choice, and is the subject of specific tests, such as heavy irradiation studies. In this talk we will present simulation results for different design options, the current status of material studies, and the results from a beam dump full-scale mock- up mechanical test.

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Poster Presentation ID: 146

Status of the ReA Electron Beam Ion Trap Charge Breeder at NSCL

The rare isotope beam re-accelerator facility ReA3 of the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) employs an electron beam ion trap (EBIT) as charge breeder and injector. After breeding, the highly charged rare isotope beams are injected into an achromatic Q/A separator for ion species selection and then re-accelerated to energies of several MeV/u in a room temperature radiofrequency quadrupole accelerator and a subsequent superconducting linear accelerator.
Recent commissioning measurements investigated the performance of the EBIT charge breeder. The electron beam current density was determined to be j = 454 A/cm2 for an 800 mA electron beam in a 4 T magnetic field by an x-ray imaging technique [1]. This current density allowed for a charge breeding efficiency with continuous ion injection of about 5 % for stable $^{39}K^{15+}$ ions [2]. Further studies focused on the energy spread of the extracted ions as well as the time structure of the ion bunches [3]. Several different ion extraction schemes were investigated to modify the ion bunch time structure: a slow voltage ramp spreading the bunch to up to 10 ms, aiming for a continuous-like ion beam and a scheme employing a fast switch for extracting a train of short (2 µs) pulses. These schemes provide more flexibility in fulfilling the timing requirements of different experiments at the end stations of ReA. In 2013, 37K17+ ion beams have been charge bred and re-accelerated for the first successful delivery of radioactive beams to the ANASEN detector array [4]. The latest developments at ReA include the installation of a cooler / buncher in front of the EBIT. This device allows for the injection of bunched ion beams into the charge breeder in addition to the so far utilized continuous injection mode. An overview of the facility and the status of the EBIT, including first results from the cooler / buncher commissioning will be presented.

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Poster Presentation ID: 148

Experimental Test of Momentum Compression in an Achromatic Fragment Separator

The efficient collection of projectile fragments and fission fragments with in-flight separators in many cases requires a large momentum acceptance. For example, the planned Advanced Rare Isotope Separator (ARIS) [1] at the future Facility for Rare Isotope Beams at Michigan State University has a 10% momentum acceptance. Such broad momentum distributions can be compressed using appropriately shaped energy degraders [2], and these energy degraders can be used to generate mass-separation at the sametime [3]. Here we report on an experimental test of this momentum-compression scheme using the A1900 fragment separator [4] at the National Superconducting Cyclotron Laboratory with dedicated wedge-shaped energy degraders and a matching beam optics setting. The energy distribution of the beam after momentum compression was measured with a stack of semiconductor detectors.

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Poster Presentation ID: 149

Upgrade of the TAMU MDM-Focal Plane Detector with MicroMegas Technology

MicroMegas is a relatively new detector technology that operates as a two stage parallel plate avalanche chamber. It consists of a small amplification gap (50-300 um) and a much larger drift gap (on the order of cm) separated by a thin electroformed micromesh. It has been shown to provide gains of up to 105.[1] We have previously used this technology at our Institute in the AstroBox [2], to detect very low-energy protons from beta-delayed proton emitters. During these decay experiments, we observed that this device also detected the incoming energetic heaver ions with good resolution for particle identification (PID). This latter result was the starting point for the upgrade of the focal plane detector sitting at the back of the Multipole-Dipole-Multipole spectrometer at Texas A Cyclotron Institute. It has been used primarily to study scattering and transfer reactions involving nuclei with A≤26. Above that mass, we encountered significant difficulties with the PID due to the insufficient resolution of both the dE and E signals. A detailed description of the MDM-detector can be found in ref [3]. Briefly, dE is the energy lost by particles in gas and is measured by 3 Al anode plates. Currently, the first two plates connected produce a signal we call ΔE1 with energy resolution of 10-15%. The third plate, ΔE2, gives a signal that is too noisy to be of any use. For this reason, we decided to replace this anode with a MicroMegas plate of identical size.

We tested the new setup with three beams, ^{16}O, ^{22}Ne and ^{28}Si. Preliminary results indicate a definite improvement in dE detection. We operated the Micromegas without issues at a gas pressure range of 30-100 Torr. Energy resolution varies from 5-6% at higher pressure to 10-11% at lower pressure. For all three beams, we obtained improved Z separation.We will continue testing with heavier ions, while using the upgraded system for experiments in the A=28 region. Specifically, we will continue studying nucleon capture reactions that present an interest in explosive nucleosynthesis, ^{27}Al(n,γ), as well various peripheral transfer reaction for optical potential model studies, ^{22}Ne(n, γ), ^{28}Si(n, γ). In the future, the modified detector is also intended to be used in similar experiments with radioactive ion beams.

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Poster Presentation ID: 157

A Resonant Ionization Laser Ion Source at ORNL

Multi-step resonance laser ionization has become an essential tool for the production of isobarically pure radioactive ion beams at the Isotope Separator On-Line (ISOL) facilities around the world. A resonant ionization laser ion source (RILIS) had been developed [1] for the former Holifield Radioactive Ion Beam Facility (HRIBF) of Oak Ridge National Laboratory (ORNL). The RILIS employs the widely-used hot-cavity ion source and all-solid-state Ti:Sapphire lasers. The laser system consists of three grating-tuned lasers and individual pump lasers, especially designed for stable and simple operation. The RILIS has been installed at the Injector for Radioactive Ion Species 2 [2], the second ISOL production platform at the former HRIBF, and has successfully provided beams of neutron-rich 78,83-86Ga isotopes for beta decay studies [3]. The features, advantages, limitations, on-line implementation, and performance of the RILIS in off-line and on-line operations will be presented.

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Poster Presentation ID: 159

Towards high precision measurements of nuclear g-factors for Be isotopes

We have worked on the development of an online trap system including prototype SLOWRI for the highly energetic Be isotope ions provided by the RIKEN projectile fragment separator RIPS. The direct measurements of the hyperfine structure constants of the atomic ground states for $^{7}Be^{+}$ and $^{11}Be^{+}$ ions were performed with high precisions of 500 ppb and 30 ppb, respectively [1]. In order to study the magnetization distribution of 11Be through its Bohr-Weisskopf effect, which the one halo neutron bears the primary responsibility for, the nuclear g-factor is also required to be determined with a higher precision than an order of 10 ppm. We propose the measurements of the nuclear g-factors of utilizing laser-microwave double resonance and laser-microwave-rf triple resonance methods for laser-cooled and trapped radioactive Be isotope ions. Beryllium isotope ions will be produced at BigRIPS, decelerated at SLOWRI [2], and then online-trapped into a linear rf trap. From the measurement of both of the electron spin flip and the nuclear spin flip transitions in the Zeeman splitting under a strong magnetic field of around 0.5 T, the nuclear g-factor and the hyperfine constant will be determined simultaneously with a high precision as already demonstrated for ^{9}Be ions [3]. With this method, the nuclear g-factor of ^{11}Be is expected to be determined with an enough precision to deduce its hyperfine anomaly. This is also essential to determine the nuclear g-factor of ^{7}Be which cannot be accessible by the beta-NMR method. The detailed experimental setup and procedure will be presented.

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Poster Presentation ID: 161

Ultra fast timing detector systems to probe exotic properties of nuclei using RIB facility

Recent RIB facilities combined with advance detector systems provides us unique opportunity to probe the exotic properties of the nuclei with unusual neutron to proton ratio. The studies of these properties enlighten new directions in understanding fundamental laws of quantum many body systems. In this presentation, we want to discuss the unique utilization of three different types of ultra-fast timing detector systems to probe exotic properties of nuclei using radioactive ion beam facilities. These three different types of ultra fast timing detectors (�t≤150 ps) are plastic scintillators array, inorganic scintillators (viz.,LaBr3) and special type of gas detector (multi-gap resistive plate chamber, MMRPC [1]). First two types of detector systems are commercially available and detector response mechanism is similar. Though depending upon light output and its decay constant, the utilities are different for optimum uses. Ultra fast timing plastic scintillators array are used in many large scale experiments for charge, time of flight and position measurements of charged particles or nuclei. However, these detectors are also used for detecting neutrons. Due to fast decay time and high light output inorganic scintillators, like LaBr3 etc. are very useful for detecting gamma-rays. These detectors are unique solution with good timing (dt~150-250ps) and energy resolution (de~3%) [2]. We have studied the response of the charge particle of this type detector [1]. Thus, these types of detector can be utilized to explore rare processes for physics beyond standard models. The response mechanism of MMRPC is different than other two ultra fast timing detectors and this detector was developed with specific design at SINP, Kolkata [1]. These types of detector systems are better economical solution than commercially available ultra fast scientillators with PMT or photodiode. This MMRPC detector can be used for both TOF and position of both charge particle and neutrons (dt<100ps). In this presentation, the response, limitation of the detectors systems and particular utilities will be discussed. In addition to that, the some specific physics experiment using those detectors with results will be discussed.

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Poster Presentation ID: 162

Installation of the Multi Reflection Time Of Flight (MR-TOF) mass separator at the ANL CARIBU facility

The low-energy beam line at the Californium Rare Isotope Breeder Upgrade (CARIBU) [1] was recently upgraded with the installation of a Multi Reflection Time-Of-Flight (MR- TOF) mass separator. The MR-TOF is a scaled-up version of the ISOLDE MR-TOF [2], realizing the same operation principle of a single in-trap lift electrode. The mass separation is performed by multiple reflections of the ions between two electrostatic mirrors, composed from 6 pairs of voltage-adjustable electrodes, in which different masses are separated by their time of flights in the kilometers-long folded trajectory. Fission product beams from CARIBU 252Cf source are extracted, thermalized, accelerated, and mass separated in the CARIBU gas catcher, RFQ cooler and the compact isobar separator that provides a mass resolving power of around 14000. The ~36 keV beam is then injected into the RFQ cooler-buncher that delivers pulsed beams of ~3 keV to the MR-TOF. A high mass-resolving power can be achieved in the MR-TOF by reflecting the ions back and forth in the device, and the desired mass is selected by using a fast Bradbury-Nielsen Gate (BNG) to deflect contaminate ions in the ejected beam. To achieve high mass selectivity, precise voltages, to the level of ppm, have to be applied to the 6 pairs of electrodes. The optimization of the mirror voltages, as well as emittance matching, has been performed via SIMION simulations, showing a potential mass resolving power of more than 50000 following 1000 cycles.The higher mass-separated beams provided by the MR-TOF and delivered to the Canadian Penning Trap (CPT) will provide access to further measurements of neutron-rich nuclei along the astrophysical r-process path [3].

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Poster Presentation ID: 171

High-resolution laser spectroscopy with the Collinear Resonance Ionisation Spectroscopy (CRIS) experiment at CERN ISOLDE

The Collinear Resonance Ionisation Spectroscopy (CRIS) experiment at CERN ISOLDE is used for the study of nuclear electromagnetic moments and changes in the mean-square charge radii by means of multi-step, high-resolution, resonance ionisation laser spectroscopy [1]. Thanks to the high selectivity of the technique, it can also be used to separate isobaric beams and even purify isomers with a demonstrated mass resolving power greater than 5.10^6 [2]. The CRIS technique combines the high detection efficiency of resonance ionisation with the high resolution of collinear laser spectroscopy. The use of a decay spectroscopy station [3] enhances the performances of the system by allowing the assignment of different hyperfine components with respect to the characteristic decay patterns of different isomers [2]. Additionally, it can be used to study decay properties of these nuclei in unprecedented clean conditions. Altogether, the CRIS experiment has successfully performed laser spectroscopy on very exotic francium isotopes down to ^{202}Fr with beams of intensities as low as 100 ions / s [4]. A new laser laboratory now completes the CRIS experiment: a 200 Hz Nd:YAG laser system allows spectroscopy with a 5 ms duty cycle to be performed, giving access to the shortest-lived nuclei available at ISOLDE without decay losses; a cw tuneable laser system (dye & Ti:Sa available) with second harmonic generation offers a resolution comparable to collinear fluorescence laser spectroscopy. In this contribution, the status of the CRIS beam line at ISOLDE, its new laser laboratory, and its recent achievements including high-resolution studies on francium isotopes will be presented.

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Poster Presentation ID: 172

Development of Electromagnetic and Gaseous Centrifuge Technologies for the Enrichment of Stable Isotopes

The Enriched Stable Isotope Production Facility (ESIPF) is being established at Oak Ridge National Laboratory (ORNL) by the US Department of Energy, Office of Nuclear Physics, to restart domestic production of enriched stable isotopes. This facility will help meet the enriched stable isotope needs of the medical, industrial, research, national security, and other scientific communities. The ESIPF development strategy is to modernize and improve two mature isotope separation technologies: Electromagnetic Isotope Separation (EMIS) and Gas Centrifuge Isotope Separation (GCIS). The ESIPF will use the high-throughput / low-enrichment GCIS technology to magnify the throughput of the low-throughput / high-enrichment EMIS technology to reach high enrichment for selected isotopes in less time than achievable with EMIS alone. In addition, the ESIPF isotope separators have been designed to support a wide range of elements rather than being highly optimized for a single isotope. The efficiency gained by combining these two enrichment technologies can be illustrated by a case study for enriching molybdenum 100 (^{100}Mo; natural abundance 9.6%) and molybdenum-98 (^{98}Mo; natural abundance 24%) to obtain approximately 50 g of each (100 g total) with an isotopic assay greater than 98%. Using a production-class EMIS device by itself is projected to require approximately 75% of that device's annual production capacity. Pre-enrichment of the natural Mo feedstock using a small GCIS cascade comprised of fewer than 10 units decreases the annual capacity demands of both EMIS and GCIS to less than 20% of their projected annual capacities. An ongoing research and development project that builds on the results obtained from an ORNL 10 mA prototype EMIS will provide a modernized, higher-throughput, high-resolution, production-class EMIS device for use in the ESIPF. The prototype EMIS device currently being operated at ORNL has enriched 10's of milligrams of nickel and molybdenum isotopes to enrichments of up to 99.9% in a single pass. Results of the prototype EMIS device will be presented.

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Poster Presentation ID: 175

New design studies for TRIUMF's ARIEL High Resolution Spectrometer

As part of its new Advanced Rare IsotopE Laboratory (ARIEL), TRIUMF is designing a novel High Resolution Spectrometer (HRS) to separate rare isotopes. The HRS has a 180 degree bend, separated into two 90 degree magnetic dipoles, bend radius 1.2m, with an electrostatic multipole corrector between them. Second order correction comes mainly from the dipole edge curvatures, but is intended to be fine-tuned with a sextupole component and a small octupole component in the multipole. This combination is expected to achieve the 1:20000 resolution for a 3um (horizontal) by 6um (vertical) emittance. A review of the design is presented including the study of limiting factors affecting separation, issues related to setup and beam tuning and maintaining beam stability over a reasonable experiment time frame. Simulation results are presented showing a design for the HRS dipole magnets that achieves both the radial and integral field flatness goals of $<1\cdot10^{-5}$. Field simulations from OPERA models of the dipole magnets are used in COSY INFINITY to find and optimize the transfer maps to 3rd order and study residual nonlinearites to 8^{th} order.

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Poster Presentation ID: 176

Delivering multiple, independent RIB simultaneously: Technical and operational challenges

ISAC is an ISOL-type facility at which RIB are produced by direct reactions of 480–500 MeV protons on a thick target in one of two target stations. Like other ISOL-type facilities, ISAC is limited to the production and delivery of a single RIB at any given time (though an additional stable beam from an offline source may be delivered in parallel). ARIEL, the Advanced Rare-IsotopE Laboratory, will provide for the production and delivery of one, and ultimately two, additional RIB, the first produced by photofission on actinide targets using electrons from a new superconducting electron linac and the second by direct and indirect reactions with protons from TRIUMF's main cyclotron. This will allow for the simultaneous delivery of two, and ultimately three, independent RIB to experimental areas at ARIEL and ISAC, with stable-beam delivery still possible beyond that.

The shift from single-user to multi-user operation will introduce significant technical and operational challenges that RIB facilities have not yet had to address. Almost all aspects of facility operation, including scheduling (beam, target, and maintenance), personnel requirements, and technical considerations such as the development of high-level applications, will become more complex as the first RIB from ARIEL targets become available. The anticipated impact of multi-user operation will be discussed and proposals for addressing the issues associated with it presented.

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Poster Presentation ID: 177

Electrostatic Potential Map Modelling with COSY Infinity

COSY Infinity is a differential-algebra based simulation code which allow accurate calculation of transfer maps to arbitrary order. COSY's existing internal procedures were modified to allow electrostatic elements to be specified using an array of field potential data from the midplane. Additionally, a new procedure was created allowing electrostatic elements and their fringe fields to be specified by an analytic function. This allows greater flexibility in accurately modelling electrostatic elements and their fringe fields. Applied examples of these new procedures are presented including the modelling of a shunted electrostatic multipole designed with OPERA, a parallel plate electrostatic bender, and the effects of different shaped apertures in an electrostatic beam line.

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Poster Presentation ID: 180

First direct determination of the superallowed β-decay Q_{EC}-value for ^{14}O via Penning trap mass spectrometry at the LEBIT facility

The conserved vector current (CVC) hypothesis asserts that the vector part of the weak interaction is independent of the nuclear interaction. This means that the vector coupling constant Gv is truly a constant and does not require renormalization. This constant, when combined with the purely leptonic muon decay constant G_F determines the up-down matrix element V_{ud} of the Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix. Measurements of the f t values of super-allowed $0^+ \rightarrow 0^+$ transitions allow G_v to be determined. A precise determination of V_{ud} has been, and continues to be, an important component of the test of the unitarity of the CKM quark-mixing matrix and the search for physics beyond the standard model. To determine an ft value, the decay half-life, the branching ratio for the 0+ → 0+ transition, and the QEC values need to be known.

Low-Z, superallowed β-emitters like ^{14}O are particularly significant for setting limits on the existence of scalar currents. While the CVC hypothesis states that Ft should be the same for all superallowed $0^+ \rightarrow 0^+$ β-decays, if there is a scalar interaction, an additional term approximately inversely proportional to Q_{EC} would be present in Ft. As Q_{EC}-values are smaller for lower-Z isotopes, these isotopes would be most sensitive to the presence of a scalar current, showing the largest deviation in Ft. To date, 14 Ft values are used to calculate the world average [1]. Of these 14 decays, only ^{14}O has not been measured in a Penning trap, despite multiple attempts at other facilities. At LEBIT [2] we have performed the first direct measurement of the ground state β-decay Q_{EC} value. This measurement provides an order of magnitude improvement in precision, and it no longer makes a significant contribution to the uncertainty of its associated Ft value. Together with future reductions in the uncertainties of the other major contributors, particularly the half-life and branching ratio, more stringent limits will be placed on the existence of scalar currents in the electroweak interaction.

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The progress of the BRISOL facility

The Beijing Radioactive ion beam facility Isotope Separator On-Line (BRISOL) is a radioactive ion beam facility based on a 100MeV cyclotron providing 100μA proton beam bombarding the thick target to producing radioactive nuclei, which is transferred into ion source to producing singly ion beam. The construction and installation of BRISOL was completed in Mar., 2014, after a long time designing and manufacture. The ion source, separator and the beam-line was tested by $^{39}K^+$ stable beam, and the ^{39}K ion beam from BRISOL was firstly accelerated by Tandem in Feb., 2015. The first radioactive ion beam of 38K+ was produced by bombarding CaO target by 100MeV proton beam in Apr., 2015. The test result and the current status of the BRISOL will be presented in detail in this paper

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