International Nuclear Target Development Society Conference

October 8th-12th 2018

Michigan State University-FRIB
East Lansing, Michigan, USA

Contact:
Email: intds2018@frib.msu.edu
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FRIB

MICHIGAN STATE UNIVERSITY

International Nuclear Target Development Society Conference 2018

8-12 October 2018

Facility for Rare Isotope Beams

East Lansing, Michigan, USA

indico.fnal.gov/e/intds2018

NOTES

CONTENTS

Welcome!

The 29th INTDS Conference 2018, organized by the International Nuclear Target Development Society (http://www.intds.org/) brings together scientists and engineers from the international community for nuclear targetry.

Themes for the conference include:

- Thin films and foils preparation techniques
  - *Laser PVD, nano – and other innovative technologies, …*
- Beam charge strippers (foil, liquid, gas, plasma)
  - *Foil, liquid, gas, plasma strippers*
- Isotopically enriched and radioactive targets
  - *Expensive isotopes, long-lives isotopes, targets for superheavy ion production*
- Targets for high intensity beams
  - *Radiation damage, thermomechanical constraints, …*
- Target characterization
  - *Nano – and microstructure, physical properties, radiation resistance*
- Targets for special applications (medical, industrial, controlled fusion)
  - *Medical, industrial, controlled fusion*
- Cryogenic and polarized targets

Sincerely,

INTDS Conference 2018 Local Organizing Committee (LOC)

WORKSHOP ORGANIZATION

Key Contacts

Frederique Pellemoine, Chair
Wolfgang Mittig, Co-chair
Ana Lesage, Conference Administrator

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A. Lesage

VENUE & WORKSHOP HOTELS

Venue
Facility for Rare Isotope Beams at Michigan State University
640 South Shaw Lane, East Lansing, Michigan 48824, USA
Main phone: +1-517-355-9671

Conference Hotels
Residence Inn by Marriott
2841 Hannah Blvd., East Lansing, Michigan 48823, USA
+ 1-517-657-2875

Kellogg Hotel
219 S. Harrison Road, East Lansing, Michigan 48824, USA
+1-517-432-4000

Other Local Hotels
TownePlace Suites
2855 Hannah Blvd., East Lansing, Michigan 48823, USA
+1-517-203-1000

Candlewood Suites
3545 Forest Road, Lansing, Michigan 48910, USA
+1-517-351-8181

Radisson Hotel Lansing
111 N. Grand Avenue, Lansing, Michigan 48933, USA
+1-517-482-0188

USEFUL INFORMATION

Emergency Phone Numbers:

MSU Campus Police	911
Fire	911
Ambulance	911

Transportation
Some hotels may offer a shuttle that can be scheduled through the hotel's front desk.

Capital Area Transportation Authority (CATA) www.cata.org – local busses

Taxis:

- iCab Car Service +1-517-215-7910
- Spartan Cab +1-517-482-1444
- Green Cab Company +1-517-643-1905

Hospitals and Urgent Care Facilities in East Lansing/Lansing
Sparrow Hospital - 1215 E. Michigan Ave., Lansing, Michigan 48912 - +1-517-364-1000
Lansing Urgent Care - 505 N. Clippert St., Lansing, Michigan 48912 - +1-517-333-9201

Banking and Currency Exchange
The currency used in the United States is the U.S. dollar ($). Exchange offices are located in the airports. Banks and ATMs are well distributed throughout the East Lansing and Lansing areas.

Lost and Found
A lost-and-found service will be available at the registration desk.

INTERNET AND OTHER SERVICES

Wireless Internet
Wireless Internet access is available to all participants at Facility for Rare Isotope Beams (FRIB).

Connect to “MSUnet Guest 3.0” – No password is required.

REGISTRATION

Hours and Location
The registration desk will be open at the following times.

Day	Times
Monday, 8 October	8 a.m. – 5:30 p.m.
Tuesday, 9 October	8 a.m. – 5:30 p.m.
Wednesday, 10 October	8 a.m. – 12 p.m.
Thursday, 11 October	8 a.m. – 5 p.m.
Friday, 12 October	8 a.m. – 12:30 p.m.

Your registration fee includes entry to all technical sessions of the conference, morning and afternoon coffee daily, lunches – Monday – Friday, an abstract book, a souvenir, and the following social events:

Welcome Reception (Sunday, 7 October) – appetizers only
Excursion and Banquet (Wednesday, 10 October) – lunch and dinner included
FRIB Tour (Thursday, 11 October)

A buffet lunch will be provided for all participants on Monday, Tuesday, and Thursday. A boxed lunch will be provided to all participants on Wednesday and Friday.

Security and Insurance
Participants are advised not to leave their belongings unattended.
The conference organizers cannot accept liability for personal injuries sustained or for loss or damage to participants' (or companions') personal property during the workshop.

Workshop Nametags
Participants are required to wear their nametag during all INTDS Conference 2018-sponsored events.

Luggage Storage
Your hotel will provide luggage storage for their guests on arrival and departure days. You may also bring luggage with you on your departure day, and INTDS Conference 2018 staff will store it for you until your departure time.

SOCIAL PROGRAM AND FRIB SITE TOUR

Summary of Events

Date	Event	Venue
Sunday, 7 October	Welcome Reception	MSU Wharton Center
Wednesday, 10 October	Excursion and Banquet	Henry Ford/ Greenfield Village Detroit Princess
Thursday, 11 October	FRIB Tour	FRIB

Transportation will be provided for the excursion and banquet. Bus boarding will begin in front of FRIB at 12:30 p.m.

Social Events

Sunday, 7 October (6 p.m.– 8 p.m.)
Welcome Reception
The welcome reception will be held at the MSU Wharton Center. All registrants are invited to attend. It is a 5-minute walk from the FRIB Laboratory to the Wharton Center.

Wednesday, 10 October (12:30 p.m. – 11 p.m.)
Excursion
Two options are possible for the excursion at Dearborn, Michigan. We will leave FRIB at approximately 1 p.m. Boxed lunches will be served on the way to the destination.
Option A: Henry Ford Museum
Option B: Greenfield Village

Conference Banquet
The conference dinner (cruise on a steam boat) will take place on Wednesday, 10 October, from 7 – 9:30 p.m. on the Detroit Princess, following the excursion at the Henry Ford Museum or Greenfield Village.

Thursday, 11 October (10 a.m.)
FRIB Tour

Please note the following for the tour:

- Photos, videos, bags, food or beverages, high-heel shoes, open-toed shoes and sandals, and minors under the age of 16 are not allowed on the tour route.
- All visitors must wear long pants (no shorts, capris, or dresses).

During the tour, there are 56 stairs to climb down and up, and also long walks. Persons with pacemakers, defibrillators, electronic medicine dispensers, hearing aids or metal implants, persons with reduced mobility or otherwise incapacitated, and persons suffering from claustrophobia should contact the organizers.as Accommodations will be made where necessary for tour participation. Participation in the tour is at the visitors' own risk. Please secure all belongings as you will remain fully responsible for their safety.

During the tour:

- Do not touch any equipment
- Do not take pictures or videos
- Do not go beyond posted barriers and stay with tour group
- Follow all directions and rules given by the tour guide

Tour participants will be split into tour groups. Please stay with your tour group at all times.

Conference participants at public events hosted at FRIB are required to disclose citizenship/permanent residency. Persons with citizenship/residency from Country Group E (currently Cuba, Iran, North Korea, Sudan, and Syria) or participants associated with an organization on the Department of Commerce Entity list are ineligible to access any radiation-restricted area of the laboratory, which prevents participation in FRIB tours. Direct questions to FRIB Chief of Staff Bob Patterer (patterer@frib.msu.edu).

Extra Tickets
Tickets for the banquet and FRIB tour are limited. Any remaining tickets will be available at the registration desk.

Oral Presentations
Oral presentation will be held in 1200 FRIB Laboratory.

Presentation time:

Invited talks:	30 minutes plus 10 minutes for discussion
Regular talks:	15 minutes plus 5 minutes for discussion

The organizers will provide a Windows7 PC and RGB cable.
Presentation slides should be provided as PowerPoint or pdf file for smooth operation.
Speakers are asked to identify themselves to the chairperson of the session and upload the final version of their talk during the preceding coffee break.
Speakers can use their own laptop but should check the compatibility with the available system well in advance of the session. If needed, speakers should bring adapting connectors (e.g. for Macintosh laptops).

The oral presentation listing is current as of printing and may not reflect late changes.

Oral Presentations

0

High Power Beam Dump Drum for FRIB Primary Beam: Challenge and Solutions

Author(s): PELLEMOINE, Frederique[1]
Co-author(s): AVILOV, Mikhail [1] ; MITTIG, Wolfgang [2;] AMROUSSIA, AIDA[3;] BOEHLERT, Carl [3]
[1] *Michigan State University - Facility for Rare Isotope Beams*
[2] *Michigan State University-NSCL*
[3] *Michigan State University*

The Facility for Rare Isotope Beams (FRIB) at Michigan State University in East Lansing is building a heavy ion accelerator to produce rare isotopes by the fragmentation method. The Linac will accelerate primary ion beams from Oxygen to Uranium to energies above 200 MeV/u with a beam power of up to 400 kW. For the rare isotope production, the in-flight technique and fragment separation is used. Only a fraction of the primary beam will be converted into rare isotopes and 300 kW of unreacted primary beam power needs to be absorbed in the beam dump. The concept of the beam dump for FRIB is based on a rotating thin-wall drum filled with water. The drum is made of Ti-6Al-4V alloy and had an outer wall thickness of 0.5 mm. Flowing water is used to both cool the wall and to stop the beam inside the drum. The high power and the use of heavy ions leads to high power densities in the materials used. Effective water cooling is required to dissipate the power deposited in the wall, which for the heaviest ^{238}U beam can reach up to 70 kW. Extensive thermal, mechanical and fluid flow analysis have been performed, taking into account the beam power deposited in the water and the drum wall. To validate the simulations, a thermal and mechanical test with a beam dump ¼-scaled mockup with a high energy electron beam was performed at the Budker Institute of Nuclear Physics in Novosibirsk. The results of tests, simulations and material studies will be discussed in this paper. This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan and Michigan State University.

Track Classification: 5 - Targets for high intensity beams

2

Progress on Fabrication of Glow Discharge Polymer Shells as ICF Targets at CAEP

Author(s): HE, Xiaoshan[1;] CHEN, Guo[1]
Co-author(s): LI, Jun [1;] HE, Zhibing [1]
[1] *Research Center of Laser Fusion, China Academy of Engineering Physics*

The glow discharge polymer (GDP) shells are used as the ablators for inertial confinement fusion (ICF) targets. In order to avoid the preheat of DT by high energetic X-rays, the shells have to be doped with a small quantity of high Z material. The doped GDP shells are fabricated exclusively by plasma polymerization technology, which is well known today and largely used. But the shells for laser fusion targets have many stringent characteristics. Although this process of coating shells has been done for years, there is still need for the research to prepare GDP shells meeting all the specifications. An investigation of the chemical structure, surface morphology, and doped concentration of GDP shells is described. The experimental results have shown that 1 at% to 5 at% silicon concentration and 1 at% to 3 at% germanium was attained, respectively. Besides, the gas-phase analysis and the characterization of the GDP plasma were obtained by the Quadrupole Mass Spectrometer (QMS) and Langmuir probe during the deposition process. The results have shown that the rf power significantly affected the carbon bonds, microstructures and surface roughness of the GDP shells. By adjusting the rf powers, the structures were modified, and in some case, the surface roughness decreased dramatically.

Track Classification: 1 – Thin films and foils preparation techniques

4

A Progress on Nanostructured Array Targets in Nano-plasmas Research

Author(s): LI, Xibo[1]
Co-author(s): LUO, Jiangshan [1] ; DU, Kai [1]
[1] *Research Center of Laser Fusion, China Academy of Engineering Physics*

Nano-plasmas generated by intense radiation encompass elements of both high energy density physics and nanoscale science, which leads to the many interesting and unusual physical effects.[1] Interactions of short-pulse, high-intensity relativistic lasers with nanometer-scale targets are actively studied to generate high-energy ions, extreme UV, and coherent radiation. This Colloquium paper explores a recent progress on the array nanostructure targets and their applications in high intensity beams and energy interactions. Ultra-high electron energies and densities have been reported in many literatures which achieved through high-intensity irradiation of oriented nano-array structures.[2-5] We discuss and analyse the mechanism and related enhanced effects by using nanostructure array targets generated from laser-produced plasma, such as the large surface area and thin nanowall structure enlarges the region of interaction with the laser pulse, the nanospaces in array structure promote electron oscillation and ion collisions, and the low thermal conductivity increases plasma temperature, etc. For nano-array targets, the effect of photo-excitation lead to generate hot electrons and strong magnetic fields. Through the inter- actions of non-equilibrium, many-body coulomb interaction, thermal and non-thermal effect, nanostructured array targets have been widely used in the field of particle accelerators, compact syncrotrons, sources of THz, infrared, X-ray radiation, etc..

Our research group in Research Center of Laser Fusion (RCLF) has set up a physically self-assembled Oblque Angle Deposition (OAD) and Glancing Angle Deposition (GLAD) technique with dynamic shadowing growth (DSG) in physical vapor atmosphere. We have designed and fabricated different lightweight nanostructured array targets with the characterized properties for their interactions with intense radiation, such as nano-rod/nano-column and triangular patterned array targets with band-gap turing, porous structure, low density, different distance, doping and composite multilayer 3D nanostructures. Under the irradiation of 50 fs 3 x 10^{18} W/cm^2 intense laser pulse, we compared the difference of high intensity beams and energy interactions by using generally Cu foil film and nanostructured array Cu targets by glancing angle deposition technique. The experimental results show that the intensity of Kα X-ray and laser-energy conversion efficience can be transferred more effectively to the electrons in the well-separated and oriented nanostructure array targets.

References:

[1] Kostya (Ken) Ostrikov, Farhat Beg, and Andrew Ng; Colloquium: Nanoplasmas generated by intense radiation, Rev. Mod. Phys. 88 (2016) 011001.

[2] Sudipta Mondal, Indrani Chakraborty, Saima Ahmad, Daniel Carvalho, Prashant Singh, Amit D. Lad, V. Narayanan, Pushan Ayyub, and G. Ravindra Kumar; Highly enhanced hard x-ray emission from oriented metal nanorod arrays excited by intense femtosecond laser pulses, Phys. Rev. B 83 (2011) 035408.

[3] K A Ivanov, A V Brantov, S I Kudryashov, S V Makarov, D A Gozhev, R V Volkov, A A Ionin, V Yu Bychenkov and A B Savel'ev; Enhanced relativistic laser–plasma coupling utilizing laser-induced micromodified target, Laser Phys. Lett. 12 (2015) 046005.

A Andreev, K Platonov, J Braenzel, A Lübcke, S Das, H Messaoudi, R Grunwald, C Gray, E McGlynn and M Schnürer; Relativistic laser nano-plasmonics for effective fast particle production, Plasma Phys. Control. Fusion 58 (2016) 014038.

[4] Michael A. Purvis, Vyacheslav N. Shlyaptsev, Reed Hollinger, Clayton Bargsten, Alexander Pukhov, Amy Prieto, Yong Wang, Bradley M. Luther, Liang Yin, Shoujun Wang and Jorge J. Rocca1; Relativistic plasma nanophotonics for ultrahigh energy density physics, Nature Photonics 7 (2013) 796-800.

Track Classification: 1 – Thin films and foils preparation techniques

5

Design of a Thin Internal ^{12}C Target for Antiproton Interactions Inside the HESR Ring at FAIR

Author: YOUNIS, Hannan[1]
Co-Authors: Y.Alil, F. Iazzi[2]; M. Ajaz[3]; Kamal Hussain Khan[4]
[1] *COMSATS University Islamabad Pakistan*
[2]*Department of Applied Science and Technology, Politecnico di Torino INFN-Sezione di Torino Italy*
[3]*Department of Physics, Abdul Wali Khan University, Mardan, Pakistan*
[4]*Department of Physics, Women University of Kashmir Bagh, Pakistan*

In the future complex FAIR (Facility for Antiproton and Ion Research) experiments, the HESR (High Energy Storage Ring) will provide antiprotons as projectiles in the momentum range of 1.5-15 GeV/c [1]. These antiproton projectiles are very helpful in study of charm and strangeness of Double hyper nuclei physics. The FAIR project will supply intense beam of antiprotons from the HESR ring [2]. For carrying all these nuclear reactions, it is essential to insert an internal target in HESR. In particular for the production of systems with double strangeness a solid ^{12}C target will be used. By inserting a nuclear target inside the antiproton ring will leads into two main drawbacks: a large background on the detectors due the overwhelming amount of annihilations and a strong depletion of the beam due to the all the hadronic and coulomb interactions of the antiprotons with ^{12}C nuclei [2]. An appropriate target with precise thickness can minimize these undesirable effects. In this regard, a thin diamond target with two-wire shape prototypes have been analyzed [3]. The wire shaped diamond target has been obtained using Femto-Edged laser. Mechanical properties of nuclear target like hardness, purity and thickness of the nuclear targets have been tested by using back scattering technique. For this purpose the target is irradiated with 1.5 MeV beams of protons. Further these prototypes have been submitted to Micro-Raman Spectroscopy in order check the phase change in the target. The use of a very thin Diamond target, together with beam steering techniques, seems to be a satisfactory solution to the above problems and will be described hereafter. Keywords: Double Hyper-nuclei; Diamond Target; Femto-Edged Laser; Ion Storage Ring; micro-Raman Spectroscopy.

Reference: [1] Iazzi F et al. 2011 Proc of Sci.(STORI11) 020 [2] W. Erni et al. 2013 Eur. Phys. J. A 49 25 [3] H. Younis et al. 2014 JINST 9 P04012

Track Classification: 1 – Thin films and foils preparation techniques

6

The Study of Fabrication High Z Coatings by Magnetron Sputtering for ICF Target

Author(s): LIU, Yansong[1]
Co-author(s): HE, Zhibing [1]
[1] *Research Center of Laser Fusion, China Academy of Engineering Physics*

Fusion promises to offer a clean, inexpensive, efficient, and abundant source of energy for future. As we all know, Inertial Confinement Fusion (ICF) is an alternative way to achieve ignition and utilize fusion energy. In ICF experiment, high-Z materials are needed to improve the implosion and lead to more energy release, or yield, from the target. Among different high-Z materials, as a high-atomic number (high-Z) and refractory material, tungsten has attracted great interest for its potential use in ICF, due to its excellent thermal and electrical properties [1-3].

In this paper we report the development of tungsten coatings to produce high Z shells focusing on production, surface morphology and uniform properties of tungsten shells. Through surface modification and deposition adhesion layer on running pan, the crack problems of the tungsten film on running Pan were solved successfully. By reducing the adhere force between mandrel and Pan, the surface morphology of the tungsten shells was improved. By controlling the sputtering heat effect, we successfully fabricated tungsten shells on PAMS mandrels. The copper atoms with appropriate amounts were found to form a supersaturated solid solution with tungsten, which can serve to refine the grains of these coatings and to smooth their surface.

We are able to control the tungsten coating rate and therefore coating thickness. We could routinely produce uniform 5-10μm tungsten coatings both on PAMS mandrels, SiO_2 mandrels and GDP mandrels with a Δwall ≤ 0.2μm. Typical surface roughness values for coated shells having a 2μm tungsten coating were 30 to50 RMS, while surface roughness values for coated shells having a 5μm tungsten coating were 80 to 100 RMS. Though drill 20μm diameter hole on tungsten coating (PAMS mandrel) by ns laser, and annealed at 310°C in vacuum, we can get hollow tungsten shells without PAMS mandrel successfully. Besides tungsten coating, we also give an introduction and progress for fabrication of all kinds of metal coatings and films by magnetron sputtering in Laser Fusion research center.

References:

[1] D.G. Czechowicz, J. A. Dorman, J. C. Geronimo and C. J. Chen, Tungsten sputter coating development to produce high /Z shells, Fusion science and technology, 51, 631, 2007.
[2] E. H. Stephens, A. Nikroo, D. T. Goodin and R. W. Petzoldt, Optimizing high-Z coatings for inertial fusion energy shells, Fusion science and technology, 43, 346 ,2003.
[3] J. L. Huang, Y. S. Liu and K, Du, et.al, Microstructure Evolution of Copper-Doped Tungsten Coatings for Inertial Confinement Fusion Application, Fusion science and technology,71,187,2017.

Track Classification: 1 – Thin films and foils preparation techniques

7

Multi-jet Gas Cooling of In-beam Foils or Specimens: CFD Predictions of the Convective Heat-transfer Coefficient (LA- UR-18-27366)

Author(s): STEYN, Gideon[1] ; VERMEULEN, Christiaan[2]

[1] *iThemba LABS*

[2] *Los Alamos National Laboratory*

Metallic foils are often employed as windows for gas and liquid targets. They are also used to isolate the beamline vacuum from target materials at accelerator facilities. These beam exit windows normally consist of two closely spaced foils through which a high flow-rate gas is circulated to remove the heat induced by the beam. Helium-cooled Havar windows are popular in radionuclide production applications as these foils have excellent mechanical strength even at elevated temperatures and can be thin enough to cause minimal energy degradation to the beam. At the 2016 INTDS Conference, we presented a paper on single-jet gas cooling of beam windows [1] in which we pointed out that certain empirical relations based on dimensional analysis have good predictive power. In addition, more advanced modelling based on computational fluid dynamics (CFD) proved useful to gain a better understanding of the turbulence and heat transfer inside such window assemblies. We also presented an experimental set-up designed to measure convective heat-transfer coefficients with a single gas jet. We also had in our possession a set of measured data for multi-jet impingement heat transfer, which we did not present because we did not know how to interpret those results at that time. We are now in a better position to present that work as well as corresponding CFD simulations to assist with the interpretation.

One reason why we struggled to understand multi-jet cooling was because we tried to implement a strategy based on correlations between dimensionless hydrodynamic quantities and geometric ratios, which worked well in the case of single jets. This was attempted for multi-jet heat transfer by many authors over the years, with limited success. In 1970, however, a seminal study [2] concluded that power functions of dimensionless parameters cannot be correlated with experimental results in the case of multi-jet heat transfer. We now know that even decades after that enlightening publication, various groups still tried.

In this presentation, we will discuss various aspects of multi-jet gas cooling and present our own results on this topic for the first time.

[1] G.F. Steyn, C. Vermeulen, Single-jet gas cooling of in-beam foils or specimens: Prediction of the convective heat-transfer coefficient. AIP Conf. Proc. 1962 (2018) 030020.

[2] D.M. Kercher, W. Tabakoff, Heat transfer by a square array of round air jets impinging perpendicular to a flat surface including the effect of spent air. J. Eng. Power 92 (1970) 73–82.

Track Classification: 5 – Targets for high intensity beams

8

Uranium Carbide Target Development

Author(s): CHOWDHURY, SANJIB[1]
Co-author(s): STORA, Thierry [2] ; GONÇALVES, António [3]
[1] *Early Stage Researcher*
[2] *CERN*
[3] *Professor*

Background: Radioactive ion beams at ISOLDE, CERN, are produced by the interaction between an intense proton beam with a thick target material [1]. The target should operate at high temperatures and must instantly release the isotopes. Bulk, micrometric, UCx-based targets are the current reference at ISOLDE, but a significant increase on the release and yields of exotic isotopes can be obtained from submicron and nanostructured porous target materials. Key isotopes for cancer research are ^{211}At and ^{212}Bi. ^{211}At would be the most important alpha particle-emitting radionuclide if widely available, emitting alpha particles without high energy beta particles, which are advantages over ^{131}I. ^{212}Bi can be used in targeted alpha therapy. Therefore, we need high yield productions of such isotopes. Nanograin UCx target materials can be the solution. Key Method: Electrospinning is a process of making fiber from viscous solutions under voltage. It is a top-down technique based on electrospun of polymer in solution into ultrafine fibers [2]. In the electrospinning process, a high voltage is used to originate a charged jet of polymer solution out of the orifice. Before reaching the collector solvent evaporates and the interconnected webs are collected on a metallic collector. There are two electrodes connected to oppositely charged power supply. The polymer solution at the tip of the needle held by its surface tension is subjecte to the high electric field. There is an induction charge appears on the surface of the liquid. A hemispherical shape is formed of the viscous solution at the tip of the needle due to mutual charge repulsion, which acts just oppositely to the surface tension. If the voltage increased more the hemispherical surface elongates and transforming to a conical shape known as the Taylor Cone. Further increasing the electric field, a critical value is obtained with which repulsive force overcomes the surface tension and the fluid jet is ejected from the tip of the Taylor cone. After discharging of the polymer solution, it undergoes 1) bending instability and 2) elongation process allows and results in the jet to become thin and long leaving a solidified fiber on the collector. Experiments and Results: Uranium precursor nanofibers were prepared by electrospinning method. The solutions for electrospinning were prepared by dissolving three different types of Uranium precursors (acetate, acetylacetonate and formate) and cellulose acetate in glacial acetic acid and 2,4-pentanedione solvents in 1:1 ratio. The effect of the solution characteristics, including the concentrations of the starting materials and the C/U ratio, on the as-spun materials were investigated. The consequence of other electrospinning process parameters, like voltage and distance to targets were also studied. The fibers were heated at 550°C to decompose the polymer. A slowly heating (1°C/min) was used to keep the fiber form. The decomposed material was further heat-treated at 1750°C in the induction furnace to reduce the oxide. The final material has grains of 2-5nm in size. The electrospun precursors and the heat-treated materials were characterized by scanning electron microscopy, X-ray diffraction, thermogravimetry and transmission electron microscopy.

References: [1] Nanostructured Target for Isotope Production. Stora, T.; Da Visitacao, S.F.; Mathot, S.; Bowen, P. September 29, 2009, U.S. Patent 20110235766 A1. [2] Electrospinning jets and polymer nanofibers. Darrell H. Reneker, Alexander L. Yarin. 10, May 13, 2008, Polymer, Vol. 46, pp. 2387-2425.

Track Classification: 6 – Target Characterization

9

Manufacturing and Characterization of Targets in IFIN-HH: Developing an Interdisciplinary Body of Knowledge

Author(s): MITU, Andreea[1]
[1] *IFIN-HH*

The target laboratory in IFIN-HH was developed to respond to the necessity of thin films ranging from tens of nanometers to a few micrometers, which are used for nuclear physics experiments at our 9MV Tandem accelerator. In order to fulfill the specific requirements, our laboratory is endowed with high quality equipment for evaporation-condensation, cold rolling, electron gun and pulsed laser deposition techniques, the latter being outsourced for the moment. The target characteristics define its quality and represent a key element for a successful experiment. Consequently X-ray Diffraction (XRD), Atomic Force Microscopy (AFM), and Scanning Electron Microscopy/ Energy Dispersive X-ray (SEM/EDX) analyses are performed in collaboration with specialized departments from our institute. Progress is also foreseen from the nuclear forensics laboratory, which is currently under development in our institute. It will be dedicated to identification and characterization of nuclear materials, but also non-radioactive ones with the same type of equipment integrated in a single spot. Among the complementary methods for characterization this lab shall provide in addition to those already available, we mention the high quality optical microscopy system, which we are looking forward to use starting next year. Detailed and specific information about all the aforementioned techniques is given and finally the plan for our process and performance in the new configuration is presented. It appears the manufacturing process combined with the characterization techniques offer a strong perspective for target development methods.

Track Classification: 1 – Thin films and foils preparation techniques

10

Investigation of Charge Strippers for High Intensity Uranium Ions

Author(s): KUBOKI, Hironori[1]
Co-author(s): HARADA, Hiroyuki [1] ; SAHA, Pranab [1]
[1] *J-PARC*

Recently, simulation studies for U beam acceleration at J-PARC has been in progress aiming to provide the world's highest intensity U beam [1, 2]. A planned new booster synchrotron would realize multi charge acceleration applying a charge stripping injection technique. Charge stripping section is installed at the booster injection and U beams are injected and stripped simultaneously enhancing their charge states from U^{30+}-U^{35+} to around U^{60+} [3]. The U charge states are distributed after the charge stripper according to the charge distribution determined by the stripper material and the ion velocity. The distribution width is very important and should be as narrow as possible because the beams with the charge states beyond the acceptance lead to beam loss in the booster during acceleration. In general, distribution widths would be narrower in carbon foil (solid) than in gases [4], however, we are afraid that foil strippers could withstand heat load by the high intensity beam irradiation. In this study, we investigate the possibility to deal with heat deposition by the high intensity U beam in the cases of applying flowing liquid as well as solid foil strippers.

References
[1] P.K. Saha, H. Harada, M. Kinsho, M. Yamamoto, and H. Sako, "First Simulation Results of Heavy-Ion Acceleration in the RCS of J-PARC", Proceedings of HIAT'15, (2015), TUM2CO2, pp. 127-129.
[2] H. Harada et al., to be published.
[3] H. Kuboki et al., "Investigation of Charge Stripping Scheme for Uranium Ions at 1–20 MeV/nucleon", AIP Conference Proceedings 1962, (2018) 030006.
[4] H. Kuboki et al., "Charge-state distribution of ^{238}U in nitrogen gas and carbon foil at 14 and 15 MeV/nucleon", Phys. Rev. Accel. Beams 14, (2011) 053502.

Track Classification: 2 – Beam charge stripers (foil, liquid, gas, plasma)

11

Preparing Enriched Stable Isotope Targets at Oak Ridge National Laboratory

Author(s): ZACH, Mike[1]
[1] *Oak Ridge National Laboratory*

Since the 1960s, the U.S. Department of Energy (DOE) Isotope Program, through the Stable Isotope Group at the Oak Ridge National Laboratory (ORNL), has been developing and supplying enriched stable isotope targets for nuclear, medical, academic, and industrial research around the world. This Group maintains the DOE inventory of enriched stable isotopes, provides customer quotations, and dispenses isotopes through the National Isotope Development Center's Isotope Business Office located at ORNL. Chemical and pyrochemical techniques are used to prepare enriched stable isotopes from this inventory in the desired chemical and physical form. Metallurgical, ceramic, or vacuum processing methods are then used to prepare the isotopes in a wide range of physical forms—from powders, thin films, foils, and coatings to large fabricated shapes—to meet the needs of experimenters. Significant characterization capabilities are also available to assist in the preparation and evaluation of these custom materials. This work is part of the DOE Isotope Program, Office of Nuclear Physics within the DOE Office of Science. A goal of this program is to enable research and development. My goal is to transform any material in our inventory into whatever form is needed to optimize the user's success. This presentation will focus on the custom preparation of enriched stable isotope targets and other research materials.

Track Classification: 1 – Thin films and foils preparation techniques

12

Progress Status of Fabrication of Stripper Foils for 3 GeV RCS of J-PARC in Tokai-site

Author(s): YOSHIMOTO, Masahiro[1]
Co-author(s): NAKANOYA, Takamitsu [1] ; YAMAZAKI, Yoshio [1] ; SAHA, Pranab [1] ; MICHIKAZU, Kinsho [1]
[1] *Japan Atomic Energy Agency / J-PARC center*

In the 3-GeV Rapid Cycling Synchrotron (RCS) of the Japan Proton Accelerator Research Complex (J-PARC), we adopted thick Hybrid type Boron-doped Carbon (HBC) stripper foil for the multi-turn H- charge-exchange injection. The HBC stripper foil developed at KEK has been successfully demonstrated to improve the foil lifetime significantly. Early manufacturing process of the stripper foil in the J-PARC had been carried out in following two steps: foil fabrication in KEK Tsukuba-site and foil preparation in JAEA Tokai-site. However, to proceed with the foil manufacturing in a same place efficiently, the carbon discharge arc-evaporation system for HBC stripper foil was removed from the Tsukuba-site and relocated in the Tokai-site.

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

13

Measurement of Radioactivation and Evaluation of Activated Nuclides due to Secondary Particles Produced in Stripper Foil in J-PARC RCS

Author(s): YOSHIMOTO, Masahiro[1]
Co-author(s): OKABE, Kota [1] ; HARADA, Hiroyuki [1] ; KINSHO, Michikazu [1]
[1] *Japan Atomic Energy Agency / J-PARC center*

Multi-turn charge-exchange beam injection is key technique to achieve the high intensity proton beam accelerators. In the J-PARC RCS, 400MeV H- beams from the LINAC are injected to the stripper foils so that the most of beams are converted to protons. The stripper foil is irradiated not only by the injected H- beams but also by the circulating protons. The high energy and intense beam irradiation into the foil generates secondary neutrons and protons via nuclear reactions. These secondary particles cause high residual activation around the stripper foil. Therefore, an activation analysis method using sample pieces is considered to identify the species of the secondary particles, their energies and emission angles. In the presentation, we report the result of the evaluation of this activation analysis with PHITS codes.

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

14

"Thermal Spike" Model Applied to Thin Targets Irradiated with Heavy Ion Beams at Low Energy

Author(s): STODEL, Christelle[1]
Co-author(s): TOULEMONDE, Marcel [2] ; CLEMENT, Emmanuel [3]
[1] *Grand Accélérateur National d'Ions Lourds*
[2] *CIMAP*
[3] *CNRS-GANIL*

During some experiments at GANIL, it was observed that some targets were soon deteriorated at very low intensity of heavy ion beam while the estimated temperature at equilibrium was far below the melting point of the material. An explanation of this observation would be the induced tracks due to irradiation of targets with heavy ion beams which result from the quench of the liquid phase of the material along the ion path. The model "thermal spike" described in [1], [2], [3] [4] was then applied to the experimental systems, the simulations enable to calculate the internal energy of target atoms and so their transient temperature along the ion track. We propose to discuss about this model and its application to the experimental systems.

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Track Classification: 5 – Targets for high intensity beams

15

Recent Advances in Transcurium Actinide Target Production at Oak Ridge National Laboratory

Author(s): MYHRE, Kristian[1]
Co-author(s): SIMS, Nathan [1] ; VAN CLEVE, Shelley [1] ; BOLL, Rose [1]
[1] *Oak Ridge National Laboratory*

Oak Ridge National Laboratory (ORNL) has been involved for many years in the production of actinide targets for numerous applications, such as the continued study and discovery of super-heavy elements (SHE). Researchers at the ORNL Radiochemical Engineering Development Center (REDC) are currently producing targets with Cf material enriched in Cf^{251}. The targets will be irradiated with a Ca^{48} beam on the U-400M heavy ion cyclotron at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. One of the main goals for the experiments is to synthesize new isotopes of the heaviest element known, Oganesson. Enriched Cf^{251} material was previously recovered and purified at REDC from decayed Cf^{252} sources, electrodeposited onto Ti foil, and irradiated at JINR. These target segments developed a film during irradiation and were returned to ORNL. Analysis of the film showed that it contains a silicon-based material. The mixed Cf material was recovered and purified in preparation for electrodeposition using a non-silicon containing target segment design. Recent results related to the production of the improved target segments will be discussed.

Track Classification: 1 – Thin films and foils preparation techniques

16

Production and Characterization of Rare Isotopes Targets at PSI: Present Status and Future Prospects

Author(s): MAUGERI, Emilio Andrea[1]
Co-author(s): HEINITZ, Stephan [1] ; DRESSLER, Rugard [1] ; SCHUMANN, Dorothea [1]
[1] *Paul Scherrer Institut*

This contribution presents the production and the characterization of rare isotopes targets, at the Paul Scherrer Institut, for neutron cross section measurements in energy ranges of interest for nuclear physics and astrophysics. Particular emphasis is given to the chemical characterization of the starting material, which can drastically influence the outcome of the entire cross section measurement. In this respect, a recent example of nuclear cross section measurement failure is presented. The importance of the target characterization, in terms of deposited activities and spatial distributions, for a correct evaluation of cross section measurements, is addressed as well. In this context, two methods developed at PSI, based on alpha spectrometry coupled with the advanced alpha-spectroscopy simulation program, and gamma spectroscopy coupled with a screaming device and radiographic imaging, respectively, is presented.

Track Classification: 3 – Isotopically enriched and radioactive targets

17

Measurements with the Stripping Foil Test Stand in the Linac4 Transfer Line

Author(s): WETERINGS, Wilhelmus[1]
Co-author(s): BRACCO, Chiara [1] ; JORAT, Louise [1] ; NOULIBOS, Remy [1] ; VAN TRAPPEN, Pieter [1]
[1] *CERN*

In 2020, after the CERN accelerators complex Long Shutdown 2 (LS2), a novel Linac4 (L4)-to-PS Booster (PSB) charge-exchange injection system will allow to transform the L4 160 MeV H beam into H+ which will be injected into the four PSB superposed rings. For this, a 200 μg/cm^2 carbon stripping foil will convert negative hydrogen ions (H−) into protons by stripping off the electrons. L4 is now performing operational reliability runs, which include a stripping foil test stand installed in the L4 transfer line. These tests will permit to gain experience on the fragile foils, test different foil materials and thicknesses, measure the efficiency and lifetime of the foils, and evaluate the foil changing mechanism as well as the interlocking functions. This paper briefly describes the stripping foil test stand setup, before reporting on the obtained important test results.

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

18

Graphene Stripper Foils for Nuclear Physics Research and Medical Isotope Cyclotrons

Author(s): PAVLOVSKY, Igor[1]
Co-author(s): FINK, Richard [1]
[1] *Applied Nanotech Inc.*

Applied Nanotech, Inc., (ANI) offers free-standing graphene foils for electron stripping of charged beams in heavy ion accelerators. The foils are produced by pressure filtration of a reduced graphene oxide aqueous dispersion (Ref. 1). ANI offers graphene films with diameters up to 25 cm (13 cm diameter typical) and area densities of 0.1 to 3.0 mg/cm^2 are standard. Higher mass density foils are available on custom orders. Foils with an area density of approximately 0.4 mg/cm^2 have demonstrated lifetimes under proton beam bombardment that were significantly longer than those typically observed with amorphous carbon foils. Although the typical configuration is a stationary foil, these graphene foils can be easily handled and mounted on a mandrel for rotation at high angular frequencies. Rotating the foil during beam irradiation effectively distributes the area of thermal loading from the beam and improves radiative cooling of the foil, resulting in improved handling of high power loads. These same graphene foils were also tested under 11 MeV negative hydrogen ion beams in various Siemens Eclipse cyclotrons that are used in production of the fluorine-18 isotope in the ^{18}O (p,n) => ^{18}F reaction for the radiopharmaceuticals industry (Ref. 2). The foils of the same area density have demonstrated the lifetime over 18,000 μA h at a typical beam current of 70 to 100 μA. The high thermal conductivity of graphene helps mitigate thermally induced damage to the foils. These foils also serve as a basis for fabricating unique isotope targets.

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Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

19

Methods of Targets' Characterization

Author(s): STODEL, Christelle[1]
[1]*Grand Accélérateur National d'Ions Lourds*

The characterization of targets before, after as well as if possible during irradiation, is essential for the success of experiments in nuclear physics and the accuracy of the results (for example for cross-section measurements). The relevant parameters such as absolute thickness, homogeneity of the layer, variation across the active area, purity of the target have to be determined and controlled as accurately as possible. I propose to report the experimental and commonly used methods characterizing targets, and to review them with an emphasis ontheir range of validity.

Track Classification: 6 – Targets Characterization

20

Extrusion of Hydrogen Ice for Thin Targets

Author(s): GILLIBERT, Alain[1]
Co-author(s): GHELLER, Jean-Marc [2] ; POLLACCO, Emmanuel [3]
[1] *CEA/IRFU/SPhN*
[2] *CEA/IRFU/DACM*
[3] *CEA/IRFU/DPhN*

We have developed a new device for production of thin hydrogen cryogenic targets. Gas at room temperature is introduced in the cryostat and cooled down near the triple point to create a volume of hydrogen in an amorphous phase. When the required volume is obtained, and endless screw is used to generate the mechanical pressure (around 100 bars) necessary for extrusion of hydrogen through a nozzle, the geometry of which will define the final geometry, a hydrogen ribbon in our case. Then the ribbon can flow with gravity in the vacuum of a reaction chamber in a continuous way. In the reaction chamber at room temperature, the hydrogen ribbon is subject to sublimation and a powerful pumping device has to be installed to eliminate hydrogen gas and maintain the room pressure. Two different domains, at least, are concerned by such a target: nuclear physics with direct reactions and laser-hydrogen interaction for production of proton beams. In both cases, the effective target thickness has to be smaller or equal 50 microns. A very small thickness is a challenge for the nozzle technology and the extrusion process.

Track Classification: 8– Cryogenic and polarized targets

21

Contact Free Measurement of Carbon Stripper Foil Thickness Variation for IsoDAR Experiments

Author(s): DRESSLER, Rugard[1]
Co-author(s): DÖLLING, Rudolf [1] ; CALABRETTA, Luciano [2]
[1] *Paul Scherer Institute*
[2] *Laboratori Nazionali del Sud*

The proof whether or not sterile neutrinos exist will have main impact not only to particle and nuclear physics but also to astrophysics and cosmology related subjects [1]. It was discussed over the last decades that the existence of sterile neutrinos may explain various observed anomalies connected with measurements of $\bar{\nu}_\mu$and $\bar{\nu}_e$ratios [2, 3]. The Decay At rest Experiment for δ_{CP} At a Laboratory for Underground Science (DAEδALUS) [4] under development is dedicated to lock for CP violations during the oscillations of such low energetic neutrinos. In an early stage the main focus from experimental point of view is given to Isotope Decay At Rest (IsoDAR) experiments. These experiments will produce an intense flux of $\bar{\nu}_e$via the decay of ^{8}Li created by neutron capture of ^{7}Li. The needed neutrons itself will be produced by capture reaction of protons with a ^{9}Be target. In the proposed experiment a 60 MeV/amu 5 mA H^+ molecular beam [5] is extracted from a cyclotron and immediately afterwards stripped to a proton beam to minimize the beam losses along the transport line and to reduce the magnetic rigidity of the beam and, therefore, the cost of the magnetic beam-line components. A minimal carbon foil thickness of 280 μ/cm^2 is required to achieve a dissociation efficiency of 1-10^{-9}.
We will present here a test of the lifetime of an amorphous carbon foil of 71 μ/cm^2 performed at the Paul Scherrer Institute (PSI) using the transfer line between the Injector 2 and the Ring cyclotron. The 72 MeV proton beam with about 1.7 mA was used. A significant thinner carbon foil than needed for the optimal dissociation efficiency was selected to minimize the beam losses along the transport line during the regularly beam production. An accumulated central beam charge density up to 224 mAh/cm^2 was applied stepwise to two different spots of the stripper foil. The foil thickness was contact free measured before and after irradiation at several positions via the energy loss of α-particles emitted from a collimated ^{241}Am source passing the stripper foil [6].
We will discuss the experimental setup, the estimation of the deduced beam parameters, the observed foil damage as well as the practical boundary conditions.

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Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

22

The Argonne Target Library

Author(s): GREENE, John[1]
Co-author(s): GOTT, Matthew [1] ; GORDON, Gavin [1]
[1] *Argonne National Laboratory*

As part of the proposal to DOE-NP for the Center for Accelerator Target Science (CATS) initiative, one of the objectives was to develop an inventory of existing targets that will serve as a pool available to the community. Targets collections have been recovered from Yale University due to the closing of their Tandem Accelerator Facility. In addition, accumulated targets from target preparation in the Physics Division over several decades have also been assembled with the intent of providing them to whomever would have a use for them. Space has now become available to compile, catalog and house these collections. Thus, the Argonne Target Library has been established and its progress and outlook will be discussed in detail.

Track Classification: 3 – Isotopically enriched and radioactive targets

23

Rhenium and Iridium Targets Prepared Using a Novel Graphene Loading Technique

Author(s): GREENE, John[1]
Co-author(s): GOTT, Matthew [1] ; FINK, Richard [2] ; PAVLOVSKY, Igor [2]
[1] *Argonne National Laboratory*
[2] *Applied Nanotech Inc.*

For accelerator targets, graphene films are an excellent material choice due to their high thermal conductivity, high temperature tolerance, low outgassing, mechanical integrity, and ease of handling. A variety of targets have been produced using graphene material as a backing or a host matrix. One of the unique advantages of the graphene film fabrication process is the capability to embed target materials, including refractory metals, in the nanoparticle form into a host graphene matrix during target preparation. Targets of natIr and natRe have been fabricated as nanoparticle loaded graphene targets for use in nuclear physics research. We hope to obtain beam time to evaluate target performance as well as production yields and nuclear decay properties via the natRe(a, 2n)^{186}Ir and natIr(a, 3n)^{194}Au reactions, respectively. These rhenium and iridium targets will be irradiated using the ATLAS accelerator and gamma rays measured in-place using the high-precision gamma-ray spectroscopy capabilities of Gammasphere and further analyzed using a multi-parameter detector system. Future plans include the preparation of isotopic targets of these two elements.

Track Classification: 7 – Targets for special applications (medical, industrial, controlled fusion)

24

Method Development for Producing Thin ^{14}C Foils

Author(s): GOTT, Matthew[1]
Co-author(s): GREENE, John [1] ; FINK, Richard [2] ; PAVLOVSKY, Igor [2]
[1] *Argonne National Laboratory*
[2] *Applied Nanotech Inc.*

Thin, isotopic ^{14}C foils are of great interest to the nuclear physics community as neutron-rich targets. Historically, these foils have been extremely difficult to prepare and an effort is underway to make them readily available. The stock material of ^{14}C available at Argonne contains a number of oxide impurities (SiO_2, MgO, and Al_2O_3), which affect the composition and stability of the fabricated foil. A simple, robust method was developed (using natC as a surrogate) to purify the ^{14}C material while minimizing loss and potential spread of the material. Thin foils were fabricated using the purified carbon, the unpurified carbon/oxide mix, and purchased high-purity carbon powder. A comparison of the resulting foils and the methodology for purifying the ^{14}C stock at Argonne will be discussed.

Track Classification: 3 – Isotopically enriched and radioactive targets

25

Second Generation Degrader Foil for the CARIBU Project

Author(s): GOTT, Matthew[1]
Co-author(s): Mr. GREENE, John [1] ; SAVARD, Guy [1] ; DIGIOVINE, Brad [1] ; ZABRANSKY, Bruce [1]
[1] *Argonne National Laboratory*

The Californium Rare Ion Breeder Upgrade (CARIBU) project utilizes ^{252}Cf to access species not produced in the low-energy fission of uranium as well as producing elements that are difficult to extract using standard ISOL techniques. CARIBU provides beams of neutron rich species to the Argonne Tandem Linear Accelerator System (ATLAS) which are accelerated up to ~10 MeV/u for nuclear physics experiments. The electroplated ^{252}Cf source is positioned in front of a large helium gas catcher, where the incoming particles are stopped and stripped of electron(s) to a 1+ or 2+ ion. Within this gas catcher, the ions first pass through a gold cover foil to contain self-sputtering recoil emissions. The ions next pass through an aluminum degrader foil where much of their residual energy is reduced so as to be stopped in the gas catcher. In the past, a less than ideal cylindrical shaped degrader was utilized to due to production limitations. This resulted in non-uniform energy loss as the ions passed through the degrader. With the advent of 3D printing, a new hemispherical degrader was prepared to enable a more uniform energy loss. The design, production, and assembly of the new degrader will be discussed.

Track Classification: 7 – Targets for special applications (medical, industrial, controlled fusion)

26

Preparation and Characterization of ^{10}B Targets at JRC- Geel

Author(s): VANLEEUW, David[1]
Co-author(s): SIBBENS, Goedele [1] ; HEYSE, Jan [1] ; ZAMPELLA, Mariavittoria [1]
[1] *European Commission JRC-Geel*

Measurements of neutron-induced cross sections to generate nuclear data are a core activity of the JRC-Directorate G for Nuclear Safety and Security in Geel. Thin ^{10}B layers are of great importance in this activity as they are used to measure the absolute neutron flux in the beam by means of the $^{10}B(n,\alpha)\ ^{7}Li$ reaction cross-section as standard reference. After a period of reduced activity and in line with a renewed interest for nuclear data, the demand for high quality ^{10}B targets increased. In this paper we describe the design and features of a new e-beam evaporator specifically customized for the preparation of boron targets as replacement of the old dysfunctional equipment. Several ^{10}B targets of varying thicknesses were prepared and characterized as part of the factory acceptance tests and implementation in the JRC-Geel target preparation laboratory. Differential substitution weighing was applied for mass determination and in order to calibrate the thickness monitor. Comparative time of flight measurements relative to ^{10}B and ^{235}U standard targets were conducted in the GELINA accelerator facility at the JRC-Geel site as second methodology for the determination of ^{10}B areal density. The morphology of the layers was assessed by means of Scanning Electron Microscopy (SEM). The determination of impurities was realized by means of Energy Dispersive X-ray (EDX). Finally, two boron targets were prepared in the frame of the measurement of the neutron induced fission cross-section of ^{230}Th at the neutron time-of-flight facility in CERN.

Track Classification: 1 – Thin films and foils preparation techniques

27

Target Development of Oxidizing Metals at IUAC

Author(s): STHUTHIKKATT REGHU, Abhilash[1]
Co-author(s): HOSAMANI, M M [2] ; KABIRAJ, D [1]
[1] *Inter University Accelerator Centre*
[2] *Karnatak University*

Target development laboratory at IUAC provides nuclear targets to many accelerator based experiments in India. Target development of materials which get oxidized readily and its preservation are always a challenging task. Targets of oxidizing materials viz; Pb, Li, Ca, Gd, Sm, Ba, Ce, Pr, Bi, Er, Eu and Nd are frequently fabricated in IUAC [1-5]. Minimizing the exposure of target materials to atmosphere before and after the target preparation plays the most important role in development of readily oxidizing targets. Since many of these isotopically enriched materials are rarely available, preservation of targets for longer duration for future use is also important. Recent developments at IUAC in target fabrication of oxidizing materials will be discussed in the report.

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[5] R. Mahajan et al. Vacuum 150 (2018) 203-206

Track Classification: 1 – Thin films and foils preparation techniques

28

Target Development of High Melting Point Metals

Author(s): STHUTHIKKATT REGHU, Abhilash[1]
Co-author(s): KABIRAJ, D [1]
[1]*Inter University Accelerator Centre*

Thin target development of high melting point metals by vacuum evaporation is a challenging job as it needs more heat to evaporate the metals. Target development laboratory at Inter-University Accelerator Centre (IUAC) frequently delivers targets of high melting metals viz; Ir, W, Hf, Mo and Ta in the thickness range of 100-800μg/cm^2 for accelerator based experiments in India [1-3]. Methods adopted to minimize the radiant heating of substrate due to the high power e-gun source, minimizing the stress developed in the targets during evaporation and details of electron beam based evaporation facility in IUAC are discussed in the report.

References

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[3] T. Banerjee et al. Vacuum 144 (2017) 190-198

Track Classification: 1 - Thin films and foils preparation techniques

29

Electromagnetic Separation of Photonuclear Reaction Products for Rare Isotope Targets

Author(s): HORKLEY, Jared[1]
Co-author(s): BUCHER, Brian [1] ; CARNEY, Kevin [1]
[1] *Idaho National Laboratory*

Highly enriched monoisotopic targets have been produced by Idaho National Laboratory (INL) using electromagnetic isotope separators. In 2008 INL refurbished a Scandinavian-type 90 ° sector mass separator for laboratory scale stable isotope enrichment. In 2012, a second separator of similar design was refurbished and later certified to produce radioactive monoisotopic targets, including those derived from transuranic elements. In conjunction with isotope separation efforts, INL collaborates with Idaho State University's Idaho Accelerator Center with their fleet of high-current, electron linacs capable of yielding gamma-rays of up to 48 MeV to produce photon-induced fission and activation products via the (γ, f), (γ, xn), and (γ, xp) processes. A third, smaller mass separator has been constructed and is being tuned to couple to a linac, facilitating in situ production and separation of rare, short and long-lived isotopes. Thus far, isotope separation and/or target production has been demonstrated for natural isotopes of Ar, Kr, Sr, La, Ba, and Sm. Ion beams have also been produced and measured with natural W and Th, photonuclear-synthesized U^{237}, natural U, and Np^{237}. Beam currents produced by the isotope separators range from several nanoamps up to 30 microamps and isotopic enrichment greater than 99% can be attained in a single pass. Target dimensions and thicknesses can be tailored using simple collimation and Faraday cup ion detection.

Track Classification: 3 – Isotopically enriched and radioactive targets

30

Microstructured Targets for Enhanced X-Ray and Particle Emission Fabrication and Characterization

Author(s): SCHAUMANN, Gabriel[1]
Co-author(s): ROTH, Markus [1] ; TEBARTZ, Alexandra [1] ; ABEL, Torsten [1] ; EBERT, Tina [1] ; SANDER, Steffen[1]
[1] *Technische Universität Darmstadt*

Intense electromagnetic fields generated by tightly focused, energetic and short laser pulses are amenable to accelerate charged particles across just a few hundred micrometers to MeV energies. Laser driven electron and ion acceleration is a very effective approach to generate high number particle bunches with short duration and excellent emittance, though typically a broad energy spectrum and large divergence. Such compact laser driven accelerators benefit from recent developments of tabletop high intensity laser systems with an increased repetition rate. Currently 10Hz operation is feasible, future systems with 1kHz and more are envisioned. Typical nuclear scattering experiments at traditional accelerator facilities usually work with a single target which can be used for an entire experimental campaign or, e.g. for stripper foils, is only to be exchanged from time to time. In contrast targets for high power laser matter interaction are for single use only. In order to benefit from the increased repetition rate of the driver, it is vital to develop efficient targetry techniques that are amenable to high number production, automated characterization and robotic handling of individual components. Targets are inherently small to prohibit excess waste production and mitigate material cost. Still they can be of complex geometrical shape, e.g. to positively influence the particle beam divergence or enhance the conversion efficiency from laser light into particle and X-Ray emission. This presentation will outline different fabrication and characterization techniques at TUD target laboratory to the audience, specifically exemplified by micro structured silicon targets – also known as "black silicon". This project has received funding from BMBF under the grant 05P15RDFA1

Track Classification: 6 – Target Characterization

31

Medical Isotope Collection from ISAC Targets

Author(s): KUNZ, Peter[1]
Co-author(s): ANDREOIU, Corina [2] ; CERVANTES, Marla [1] ; EVEN, Julia [3] ; GARCIA, Fatima [2] ; GOTTBERG, Alexander [1] ; LASSEN, Jens [1] ; RADCHENKO, Valery [1] ; RAMOGIDA, Caterina [1] ; ROBERTSON, A.K.H. [1] ; SCHAFFER, Paul [1]
[1] *TRIUMF*
[2] *Simon Fraser University*
[3] *KVI-CART, University of Groningen*

The Isotope Separation and Acceleration (ISAC) facility[1] at TRIUMF provides a wide range of radioactive isotope beams (RIB) by irradiating ISOL-type (Isotope Separation OnLine) targets with a 480 MeV proton beam from the TRIUMF H- cyclotron. The majority of the available beamtime is used for basic research in the fields of nuclear astrophysics, nuclear structure and material science. A more recent application is the generation of pure exotic isotope samples from proton-irradiated targets for pre-clinical medical research towards therapeutic and diagnostic applications[2]. The focus has been so far on the production of isotopes for targeted alpha therapy (TAT) from composite uranium carbide targets3. Samples of 225Ac, 224Ra and 209/211At (generated from ^{213}Fr and ^{211}Fr beams) have been collected. Another source for TAT and Auger Therapy isotopes are high-power tantalum metal foil targets. They produce high-intensity lanthanide beams4. In a first proof-of-principle test, a ^{165}Tm/Er sample was collected and characterized.
The RIB collection takes place at the ISAC Implantation Station (IIS) where a compact vessel, in which mass-separated RIB are implanted on a target disc at energies between 20-55 keV, is attached to the beamline. It features ion beam positioning and current monitoring capabilities and allows for sealed transport of the accumulated activity under vacuum.
A chemical etching procedure was developed to retrieve >95% of activity from the implantation target. Taking advantage of the fact that the RIB implantation energy is lower than the typical alpha decay recoil energy, the production of very pure samples of alpha decay products such as ^{213}Bi and ^{212}Pb was investigated as an alternative to common ion exchange separations.
To accommodate the demand of an increased number or uranium carbide targets for the new ARIEL facility1 which features two additional target stations and a symbiotic medical isotope target, the carbothermal reduction process to fabricate composite uranium carbide targets3 was modified. A simplified, faster process that combines reduction to UC[2] and sintering of composite ceramic target discs in one step was developed[7].
The performance of ISAC targets is frequently assessed with yield measurements[5] and Geant[4] simulations6, using the latest hadronic cascade models. The combination of measurement data and simulation results is used to extrapolate yield rates and to determine release properties.
This presentation provides an overview of medical isotope collection from ISAC targets, associated target materials and yields. It concludes with a brief outlook towards future developments related to the ARIEL facility.

References
1. Dilling, J. ISAC and ARIEL: The TRIUMF radioactive beam facilities and the scientific program. (Springer, 2014).
Hoehr, C. et al. Medical Isotope Production at TRIUMF – from Imaging to Treatment. Physics Procedia 90, 200–208 (2017). Kunz P, Bricault P, Dombsky M, Erdmann N, Hanemaayer V, Wong J, et al. Composite uranium carbide targets at TRIUMF: Development and characterization with SEM, XRD, XRF and Ledge densitometry. Journal of Nuclear Materials. 2013 Sep;440(1–3):110–6. Kunz P, ISAC Yield Database, 2018. URL: http://mis.triumf.ca/science/planning/yield/beam.
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4. Cervantes, M. et al. A NEW PRODUCTION PROCESS FOR UCx TARGETS FOR RADIOACTIVE ISOTOPE BEAMS AT TRIUMF. Proceedings of the 9th Int. Particle Accelerator Conf., IPAC2018, Vancouver, BC, Canada (2018). doi:10.18429/jacow-ipac2018- thpml131

Track Classification: 7 – Targets for special applications (medical, industrial, controlled fusion)

32

Development of High-density Highly Oriented Graphite Stripper

Author(s): HASEBE, Hiroo[1]
Co-author(s): OKUNO, Hiroki [1] ; TATAMI, Atsushi [2] ; TACHIBANA, Masamitsu [2] ; MURAKAMI, Mutsuaki [2] ; IMAO, hiroshi [1] ; FUKUNISHI, Nobuhisa [1] ; KASE, masayuki[1] ; KAMIGAITO, osamu [1]
[1] *RIKEN*
[2] *Kaneka Corporation*

In 2014, we found that high-density highly oriented Multilayer Graphene (MG) sheets provided by Kaneka Corporation [1] can be applied as stripper disks for heavy ion acceleration at RIKEN RIBF. These MG sheets are prepared from heat treated polyimide films at temperature up to 3000 °C. They have been used for uranium and various heavy ion beam operations since 2015 [2], nevertheless, no significant damage caused by beam irradiation has been found for the moment. Kaneka tried to fabricate thinner MG sheets with thickness of 1-10 μm and thinner sheets began to be available as a result of their research and development. We tested and evaluated these thinner MG sheets as stripper foils at RIBF. We have clarified, as a result of the SEM and EPMA analysis, the reasons why the MG sheets have high quality and long life times, and also found the difference in characteristic with carbon foils fabricated by an evaporation technique. The results will be represented.

References

[1] A. Tatami et al., AIP Conference Proceedings 1962, 030005 (2018). [2] H. Hasebe et al., AIP Conference Proceedings 1962, 030004 (2018).

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

33

Uranium-Targets for Heavy-ion Accelerators

Author(s): LOMMEL, Bettina[1]
Co-author(s): STEINER, Jutta [2] ; YAKUSHEVA, Vera [2] ; KINDLER, Birgit [1] ; CELIK AYIK, Elif [2] ; HUEBNER, Annett [2]
[1] *GSI Helmholtzzentrum für Schwerionenforschung*
[2] *GSI Helmholtz Centre for Heavy-Ion Research*

Uranium targets are a very important for the accelerator-based research of nuclear properties. Depending on the reaction to be studied and on the conditions during the experiments different restrictions on the target material have to be met as for example durability, melting temperature, reactivity or compound partners contributing to the reaction. Therefore we are developing processes to produce Uranium targets in the elemental form as well as in different compounds. Here we report on the production and application of targets from metallic Uranium, UF_4 and UO_2

Track Classification: 1 - Thin films and foils preparation techniques

34

Surface and Thickness Measurement in the Targetlab of GSI

Author(s): KINDLER, Birgit[1]
Co-author(s): LOMMEL, Bettina [1] ; CELIK AYIK, Elif [1] ; HUEBNER, Annett [1] ; STEINER, Jutta [1]; YAKUSHEVA, Vera [1]
[1] *GSI Helmholtz Centre for Heavy-Ion Research*

For characterization of targets and foils prepared at the target laboratory as well as for characterization of e.g. degrader or windows of internal customers different analytical devices are available. Besides a lot of standard the target laboratory of GSI holds a 3D-measurement system (MicroProf ®) equipped with optical sensors for measuring surface parameter as well as total thickness variations contact-free. In the talk the measuring principle as well as the possibilities and features of the MicroProf® system are explained and some different applications are shown.

Track Classification: 6 – Target Characterization

35

Preventing Damage to Floating Foils Caused by Rayleigh- Taylor Instabilities

Author(s): STONER, John, Jr.[1]
Co-author(s): STONER, Robert B. [1] ; STONER, Constance G. [1]
[1] *ACF-Metals*

An evaporated metal foil target is often produced on a layer of water- soluble parting agent previously applied to a massive substrate. The foil is then floated onto a water surface by immersing the substrate into a water bath and is picked up later if the foil survives. During the foil's release, a significant fraction of the dissolved parting agent remains close to the floating foil, as a "heavy" thin layer of solution having higher density than water. This layer of parting agent solution and the lower-density water bath below it form a gravitationally unstable configuration known as a Rayleigh-Taylor instability. If the foil is sufficiently thin, its mass and elastic properties can be ignored, and the motion of the liquids is controlled by only the liquids' properties. This system can spontaneously adjust itself toward stability in several ways, one of which involves rotating a cylindrical liquid cell having a horizontal axis, and its cylindrical surface tangent to the surface. This motion moves part of the heavy layer from the top surface downward. The target maker detects this occurrence by the motions of the foil floating on the top of the bath; if the foil is frail, these motions may result in the crumpling, wrinkling, or tearing of the foil. We have observed such behavior with aluminum foils having thickness of 40 nm on NaCl parting agent, and have successfully implemented methods to prevent such damage.

Track Classification: 1 – Thin films and foils preparation techniques

36

Meeting the Needs of a Growing Stripper Foil Community with a Dedicated User Forum

Author(s): STONER, Constance[1]
Co-author(s): STONER, John [1]
[1] *Arizona Carbon Foil Co., Inc. ACF-Metals*

The Arizona Carbon Foil Co., Inc. (ACF-Metals) has been providing carbon foils to the international accelerator and cyclotron community for almost 50 years. One major component, included with the actual product, has been the personal attention, the one-on-one consultation time, that users have with our in-house Physicist and Target Specialists. The opportunity to discuss experiments, trouble shoot, and get meaningful feedback has been a viable component to the whole ACF-Metals offering. Now, as the community is experiencing greater demands and growth in a variety of fields that use carbon foils, ACF-Metals.com has developed a User Forum to meet many of those needs. Users from all over the world can ask questions specific to their equipment, application, and production involving extractor foils. The opportunity to share important techniques with other users at all levels of experience, creating a gateway between the product, the users, and experts in their respective fields. This talk will include actual questions from users and responses, a demonstration of the forum site, and a similar alternate source for users. We invite discussion on goal setting for the target making community in reaching out to foster the target makers and users, including possible topics and revisions to the forum to maximize its effectiveness.

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

37

Radium Targets for the Reactor Production of Alpha-emitting Medical Radioisotopes

Author(s): Dr. COPPING, Roy[1]
[1] *Oak Ridge National Laboratory*

Radium 226 ($t_{1/2}$ = 1600 years) can be irradiated in a reactor to produce a variety of important medical radioisotopes. These isotopes can be chemically separated and purified after irradiation, and the radium can be recycled for future use. Since radium is highly radioactive, there are unique challenges with using radium as a target material. Also, the chemical properties of radium are not yet fully explored, so stable surrogate materials, such as barium, are used to develop the process. To irradiate radium at the Oak Ridge National Laboratory (ORNL) High Flux Isotope Reactor, it must be in a stable chemical form and in a safe and thoroughly certified target configuration.
Recent efforts at ORNL have focused on the identification and preparation of several radium compounds to be used as target material for irradiation followed by chemical processing to extract the desired product and recover the radium material. Radium in a stable chemical form can be blended into an aluminum pellet cermet and contained within a welded aluminum capsule. Due to the radioactive properties of radium, the material must be handled in a hot cell, which required design, testing, and construction of in-cell welding and certification capability to seal and certify target capsules. The development of a suitable radium target material, pellet fabrication process and capsule welding will be discussed.

Track Classification: 3 – Isotopically enriched and radioactive targets

38

Target Preparation for Neutron-induced Cross-section Experiments

Author(s): SIBBENS, Goedele[1]
Co-author(s): MOENS, André [1] ; OBERSTEDT, Stephan [1] ; VANLEEUW, David [2] ; ZAMPELLA, Mariavittoria [1] ; HEYSE, Jan [1] ; LEWIS, David [1]
[1] *EC JRC-Geel*
[2] *European Commission JRC-Geel*

Neutron cross-section measurements require samples, called “targets”, with specific properties depending on the reaction being studied and the quantities being measured. The target characteristics influence the results of these measurements and can have a strong impact on the total uncertainty in neutron cross-section data, which are important for the nuclear industry and in research. This paper gives an overview of the main techniques applied in the target preparation laboratory at JRC-Geel for production and characterization of targets for neutron-induced cross-section measurements. The use of these targets is demonstrated with a few examples of total and reaction cross-section experiments. In addition, on-going investigations are presented.

Track Classification: 3 – Isotopically enriched and radioactive targets

39

Target Preparation for Nuclear Chemistry Experiments at Los Alamos National Laboratory

Author(s): BOND, Evelyn[1]
Co-author(s): BREDEWEG, Todd [1] ; ZHAO, Xinxin [1] ; RUSEV, Gencho [1]
[1] *Los Alamos National Laboratory*

Targets for nuclear chemistry experiments such as neutron-induced capture and fission require thin, uniform, and adherent deposits. Thin metal foils are often used as substrates and electrodeposition has been used to prepare actinide, lanthanide and transition metal deposits on these substrates. However, deposits on thin non-metallic substrates such as carbon foils or plastic films are desired for high-resolution fission-fragment spectroscopy. We have been exploring methods to prepare deposits on these substrates by electrodeposition or vacuum evaporation. We will discuss recent efforts in the preparation and characterization of targets by vacuum evaporation and electrodeposition. LA-UR-18-28293

Track Classification: 1 – Thin films and foils preparation techniques

40

Operational Experience of the High-power Production Target System for BigRIPS Separator

Author(s): YANAGISAWA, Yoshiyuki[1]
Co-author(s): YOSHIDA, Koichi [1] ; KUBO, Toshiyuki [1]
[1] *RIKEN Nishina Center*

The high-power production target system of the superconducting RI beam separator BigRIPS [1,2,3] at RI beam factory (RIBF) was constructed in 2007 and has been successfully operated since then with the beam powers up to 8 kW. The system was designed to withstand the energy loss of 22 kW in a Be target of 5.4mm (1g/cm^2) thickness for a ^{238}U beam at 345 MeV/nucleon and 1 particle μA (82 kW in a beam power). The spot size of the primary beam at the production target is about 1 mm in a diameter. Therefore the power density in the target becomes high with 28 kW/mm^2 on the target surface and with 5.2 kW/mm^3 in the target volume. A water-cooled rotating disk target was developed to cope with such high power density. Stationary targets mounted on a water-cooled ladder were also provided for low intensity beams.
In the meeting, operational experiences of the water cooled rotating targets as well as the stationary targets will be presented together with the temperature measurements of the beam spot for various beam powers up to 8 kW. The maintenance system of the target will also be discussed.

References
[1] A. Yoshida et. al.: Nucl. Instr. Meth. A 521, 65 (2004).
[2] A. Yoshida et. al.: Nucl. Instr. Meth. A 590, 204 (2008).
[3] A. Yoshida et. al.: Nucl. Instr. Meth. A 655, 10(2011).

Track Classification: 5 – Targets for high intensity beams

41

Thermal Model Simulation of the High Power Target System for BigRIPS Separator

Author(s): YOSHIDA, Koichi [1]
Co-author(s): YANAGISAWA, Yoshiyuki[1]; KORKULU, Zeren[1]; KUBO, Toshiyuki [1]
[1] *RIKEN Nishina Center*

Thermal model simulations using the finite element analysis code ANSYS have been performed for the high power production target system [1,2,3] of BigRIPS separator at RI beam factory (RIBF). In order to evaluate the cooling capacity of the target system, the model simulation is particularly important since available beam power of the RIBF is limited about 1/8 of the goal beam power of 82 kW which corresponds to ^{238}U beam at 345 MeV/nucleon and 1 particle μA. Simulation models of the water-cooling rotating disk as well as the stationary target mounted on a water cooled ladder were constructed in the ANSYS code. Temperatures of the beam spot were calculated in various beam intensities and thermal conditions (various heat transfer coefficents) and compared with the observed beam-spot temperatures of the target system.
In the meeting, details of the simulations and results of the comparisons will be presented and discussed.

References
[1] A. Yoshida et. al.: Nucl. Instr. Meth. A 521, 65 (2004).
[2] A. Yoshida et. al.: Nucl. Instr. Meth. A 590, 204 (2008).
[3] A. Yoshida et. al.: Nucl. Instr. Meth. A 655, 10 (2011).

Track Classification: 5 – Targets for high intensity beams

42

Calcium Targets for Production of the Medical Sc Radioisotopes in Reactions with p, d or α Projectiles

Author(s): STOLARZ, Anna[1]
Co-author(s): SITARZ. M[1]; SZKLINIARZ. K[2]; JASTRZĘBSKI. J [1]; TRZCIŃSKA. A [1]; ZIPPER. W [2]; CHOIŃSKI. J [1]
[1] *University of Warsaw*
[2] *University Silesia*

The scandium radioisotopes for medical application can be produced in reactions of calcium with proton, deuteron or alpha projectiles and in reaction of titanium with protons. Majority of our studies was performed using reaction of Ca, both natural and enriched material, with various projectiles. The research quantities of scandium radioisotopes are produced at HIL UW with two charged particle accelerators: the heavy ion cyclotron U200P for reaction with α-particles and medical high current PETtrace cyclotron for studying the reactions with protons and deuterons. Enriched isotopic calcium material is commercially available as calcium carbonate which can be, and was, used directly or can be converted into other calcium compounds or into metallic form. Each form can be used for production of Sc isotopes and pros and cons of use of each target chemical form will be discussed.

Track Classification: 7 – Targets for special applications (medical, industrial, controlled fusion)

44

Construction Status of the FRIB Lithium Charge Stripper

Author(s): KANEMURA, Takuji[1]
Co-author(s): MARTI, Felix [1]; LAVERE, Michael [1]; MADENDORP, Randall [1] ; MOMOZAKI, Yoichi [2]
[1] *Facility for Rare Isotope Beams, Michigan State University*
[2] *Argonne National Laboratory*

The Facility for Rare Isotope Beams (FRIB) at Michigan State University is building a heavy ion linac to produce rare isotopes by the fragmentation method. The linac will accelerate ions up to U to energies above 200 MeV/u with beam powers up to 400 kW. At energies between 16 and 20 MeV/u the ions will be stripped to higher charge states to increase the energy gain downstream in the linac. The main challenges in the stripper design are due to the high power deposited by the ions in the stripping media (~ 30 MW/cm^3) and radiation damage if solids are used. For that reason self-recovering stripper media must be used. The FRIB baseline choice is a high-velocity (~ 50 m/s) thin film (~ 10 μm) of liquid lithium [1].
On the basis of the collaboration work with Argonne National Laboratory, the construction of the lithium stripper module was initiated at FRIB. Main and unique features of the system that have been added since the development at ANL are a spiral DC electromagnetic pump enabling continuous circulation of liquid lithium, and a double containment system to prevent/mitigate lithium-related hazards. The pump was originally designed at ANL, but modified by FRIB for the lithium application. It is equipped with Sm-Co permanent magnets and supplied with a DC current of several hundred amps. The Lorenz force created by the interaction between electric and magnetic fields along the long spiral tube generates a high discharge pressure. Pump performance test results confirmed that our pump can create a desired flow of ~ 10 cc/s at ~ 1.4 MPa. Regarding the hazard controls associated with the use of liquid lithium, lithium-air reaction and resulting lithium fire were our concerns. To prevent and mitigate this hazard, we employed a double containment system: the primary lithium loop is completely enclosed by the secondary containment vessel filled with inert argon gas. Because of this unique configuration, any lithium leaks from the primary loop will not be considered fire hazards and such leaks will be detected by various leak detection mechanisms. This assures no lithium fire takes place in case that lithium leaks out of the primary loop.
So far the module has been assembled, and the primary lithium loop has been loaded and charged with all the necessary amount of lithium (~ 5 liters). After all of those works, the lithium was melted with heaters and successfully circulated with the electromagnetic pump.

[1] Thin-film liquid-lithium stripper for the RIA driver linac. DOE RIA R&D proposal (2003).
*This work is supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

45

The Synthesis of Deuterated Polyethylene Targets

Author(s): KHESWA, Ntombizonke[1]
Co-Author(s): Dinoko, TDS[1]**;** Wiedeking. M[1]
[1] *iThemba LABS*

In most of nuclear physics experiments conducted at iThemba LABS, a particle beam from the separated sector cyclotron (SSC) impinged upon a target material, either self-supporting or on a backing. The methods currently used to manufacture these target materials include vacuum evaporation system with various heating sources, one using electrons and the other using resistive heating. Mechanical rolling system is available also for rolling the material to the required thicknesses. In this contribution, the method to synthesise deuterated polyethylene (d4) targets is described. Polyethylene targets were prepared before in other laboratories, for example by dissolving polyethylene resin into hot xylene (Arnison, 1966) or using a hot presser (Kusuhara, 1970). The method used for this contribution was adapted from the one by Arnison (1966), with further heat treatment of substrate as the modification to enhance the strength of the films and easy release from the substrate without the application of the parting agent. Polyethylene targets with various thicknesses were successfully manufactured.

Track Classification: 1 – Thin films and foils preparation techniques

46

Encapsulated Sulfur Targets

Author(s): KHESWA, Ntombizonke[1]
Co-Author(s): JONGILE, S.[1,2]**;** PAPKA, P.[1,2]**;** WIEDEKING, M[1]; LEMASSON, A[3]; SITHOLE, M[1,5]; MAKHATHINI, L.[1,2]; KHESWA, B.V[1,6]; MAQABUKA, B.[1,6]; SORLIN, O.[3]; BRITS, C.P.[1,2]; MTHEMBU, S.H.M.[1, 4]
[1] *iThemba LABS*
[2] *Stellenbosch University*
[3] *GANIL*
[4] *University of Zululand*
[5] *Univeristy of the Western Cap*
[6] *University of Johannessburg*

A new method was developed to produce enriched Sulfur targets. This was made possible by inserting sulfur in-between two 0.5 mm Mylar foils ($C^{10}H^{8}O^{4}$). The aim is to ensure that sulfur targets reduces by no more than 50% of the initial thickness within 24 hours under the equivalent of 10 J of integrated energy deposition by a proton beam. There is no loss of enriched material while making the target, as all the material is deposited within the surface area to be exposed to the beam. The targets were frequently swivelled in order to expose each part of the target to the beam and achieved homogeneous irradiation. Thickness of 0.4 mg/cm^2 targets were produced decreasing by a factor of two over 8 hour period irradiation using a 3 MeV proton beam of 6 nA intensity (nearly 30 J).

Track Classification: 1 – Thin films and foils preparation techniques

47

An Isotope Harvesting Beam-dump for the NSCL

Author(s): SEVERIN, Gregory[1]
[1] *Michigan State University*

The process of harvesting isotopes from beam dumps and other activated materials at accelerator facilities is becoming an important tool for accessing difficult-to-produce radionuclides (e.g. ERAWAST at PSI). At FRIB, the unique design of the water-filled beamstop will allow rapid access to the multitude of short- and long-lived isotopes that are formed as a result of stopping fast heavy ion beams in water. Currently, at the NSCL we are developing an isotope harvesting program from an analogous target (beam stop) fabricated from the same materials. Preliminary experiments are giving some clues about the environment inside of the beam dump and the effect of heavy-ion radiolysis on the water chemistry. Overall the program can be viewed as a way to make a nuclear target out of the beam dump, rather than throwing away the production capacity of unreacted beams.

Track Classification: 7 – Targets for special applications (medical, industrial, controlled fusion)

48

Use of Ion Irradiation to Emulate Radiation Damage in Reactor Core Materials

Author(s): WAS, Gary[1]
[1] *University of Michigan*

Reactor core materials in both thermal and fast reactors, as well as fusion first wall and blanket materials must withstand irradiation to high doses at high temperature. While test reactors have traditionally been used to evaluate and down select materials that can be used in such harsh environments, they are becoming increasingly scarce, prohibitively expensive, and are much too slow to support the launch of new reactor concepts. Accelerator based irradiation techniques overcome all of these deficiencies as these accelerators are quite common, they can achieve damage levels in days that take years in a reactor, and therefore, they are very inexpensive. The Michigan Ion Beam Laboratory at the University of Michigan is configured to provide a radiation environment that is representative of a reactor core. This is accomplished by the use of multiple accelerators to create radiation damage simultaneously with the simulation of gas production by transmutation. A new 300 keV transmission electron microscope interfaced to two beamlines will provide the capability to observe the evolution of radiation damage and the impact of gas production by transmutation as it occurs. Beam current, irradiation temperature and maintenance of an ultraclean, high vacuum provide for a high degree of control of the irradiation parameters as well as reproducibility. A description of the laboratory and its capabilities will be presented, and some results of the application of accelerators to radiation damage in metallic alloys will be discussed.

Track Classification: 5 - Targets for high intensity beams

50

Production and Distribution of Isotopically Enriched and Radioactive Isotopes for Research

Author(s): HART, Kevin[1], STRACENER, Daniel[1]
[1] *Oak Ridge National Laboratory*

The US Department of Energy, Office of Nuclear Physics, Isotope Program has a mission to produce and distribute enriched stable and radioactive isotopes for research. Part of this effort is located at Oak Ridge National Laboratory and includes the Enriched Stable Isotope Prototype Plant, Radiochemical Engineering Development Center, High Flux Isotope Reactor, and various other facilities related to production and dispensing of stable and radioisotopes. The ORNL Isotope Program also includes capabilities to fabricate targets and sources including wires, thin films and other custom forms. This talk will provide an overview of ORNL Isotope Program activities including recent developments of electromagnetic and gas centrifuge capabilities for production of enriched stable isotope products. Most recent stable isotope separations have concentrated on ^{96}Ru ^{100}Mo, ^{98}Mo, and ^{176}Yb. Stewardship of the US stockpile of enriched stable isotopes (e.g. ^{48}Ca) continues with the emerging production capacity addressing those isotopes that have become depleted or that are in short supply.

ORNL Isotope Program activities related to radioisotope production include reactor-based production of various isotopes, such as ^{75}Se, ^{252}Cf, ^{133}Ba, and ^{63}Ni that are primarily used in industrial applications and medical radioisotopes important in cancer therapy such as ^{225}Ac, ^{227}Ac, ^{188}W, ^{212}Pb, ^{89}Sr, and ^{223}Ra. Other radioisotopes of interest that are produced and/or distributed through the ORNL Isotope Program include ^{244}Pu, ^{249}Bk, ^{251}Cf, ^{248}Cm, and ^{254}Es in support of super-heavy element research and other fundamental scientific research.

Track Classification: 3 – Isotopically enriched and radioactive targets

51

AT3PC: Active Tritium Target TPC Conceptual Design of a Novel Time Projection Chamber Detector for Reactions Using Tritium

Author(s): AYYAD, Yassid[1]
Co-author(s): Macchiavelli, Augusto[2]
1 *Research Center for Nuclear Physics*
2 *LBNL*

Pairing correlations play a crucial role in determining the properties and structure of atomic nuclei. The evolution of these correlations in exotic nuclei has received much attention in recent years, as new accelerator facilities are providing unique radioactive beams for study. Of particular interest is the role of neutron-neutron pairing in neutron-rich isotopes, where the effects of weak binding and continuum coupling are important. Clearly, the best tool to study these correlations is the (t,p) transfer reaction, particularly suited to probe the 2n pair density. Due to the compelling capabilities that time projection chambers (TPC) offer, it seems natural to explore the use of a tritium gas target TPC, with an equivalent thickness around 100 times larger than typical solid targets, enabling experiments with exotic beams with a very low intensity (of the order of 100 pps). In this work, we propose to develop a dedicated TPC featuring two separated and isolated gas regions: an inner cell deployed along the beam direction, that will contain the gas target of interest, such as tritium ($^{3}H2$) or ^{3}He or other rare and expensive gases, and an outer volume for tracking purposes. The AT3PC is intended to operate inside a solenoid magnet to enable the reconstruction of the energy of the particle through the magnetic rigidity. In this work, we will present the preliminary conceptual design and comprehensive simulations.

Track Classification: 3 – Isotopically enriched and radioactive targets

54

The Irradiation Study of Multilayer Carbon Stripper Foils by Ar Beam

Author(s): Jiang, Wen[1]
Co-author(s): Mittig, Wolfgan[2] ; Pellemoine, Frederique[3]; Stetch, Edward[4]; Robertson, Daniel[4]; Tan, Ahn[4]; Kumar, Nalin[5]
1 *Purdue University*
2 *Michigan State University – NSCL*
3 *Michigan State University – Facility for Rare Isotope Beams*
4 *University of Notre Dame – Department of Physics*
5 *UHV Technologies, Inc., Lexington, KY 40511-1162*

Irradiation performance of multilayer HBC foils which layers are more thank 20 were observed for the first time, and different types of carbon stripper foils were irradiated under a series of irradiation conditions (intensities, fluences) systematically. 8 types of carbon stripper foils were irradiated by Ar beam under different intensities and fluences. 100 layers HBC foil performed best among all the tested foils upon irradiation, which is believed to be due to their structural stability. Multilayer foils performed generally better than the monolayer ones. The existence of boron layer helped to increase the resistance of the foils to irradiation damage, elongating their lifetimes. The swelling of the irradiated DLC type 1 foil and 100 layers HBC foil are measured by alpha particle test. The 100 layers HBC foils relatively stable in size upon irradiation, while the swelling as well as degree of inhomogeneity of DLC foils decrease with the icreasing of fluence at 1.4 μAe intensity, providing the evidence to the structural stability of 100 layers of HBC foils.

Track Classification: 2 – Beam charge strippers (foil, liquid, gas, plasma)

55

An Overview of Target Fabrication at LLNL

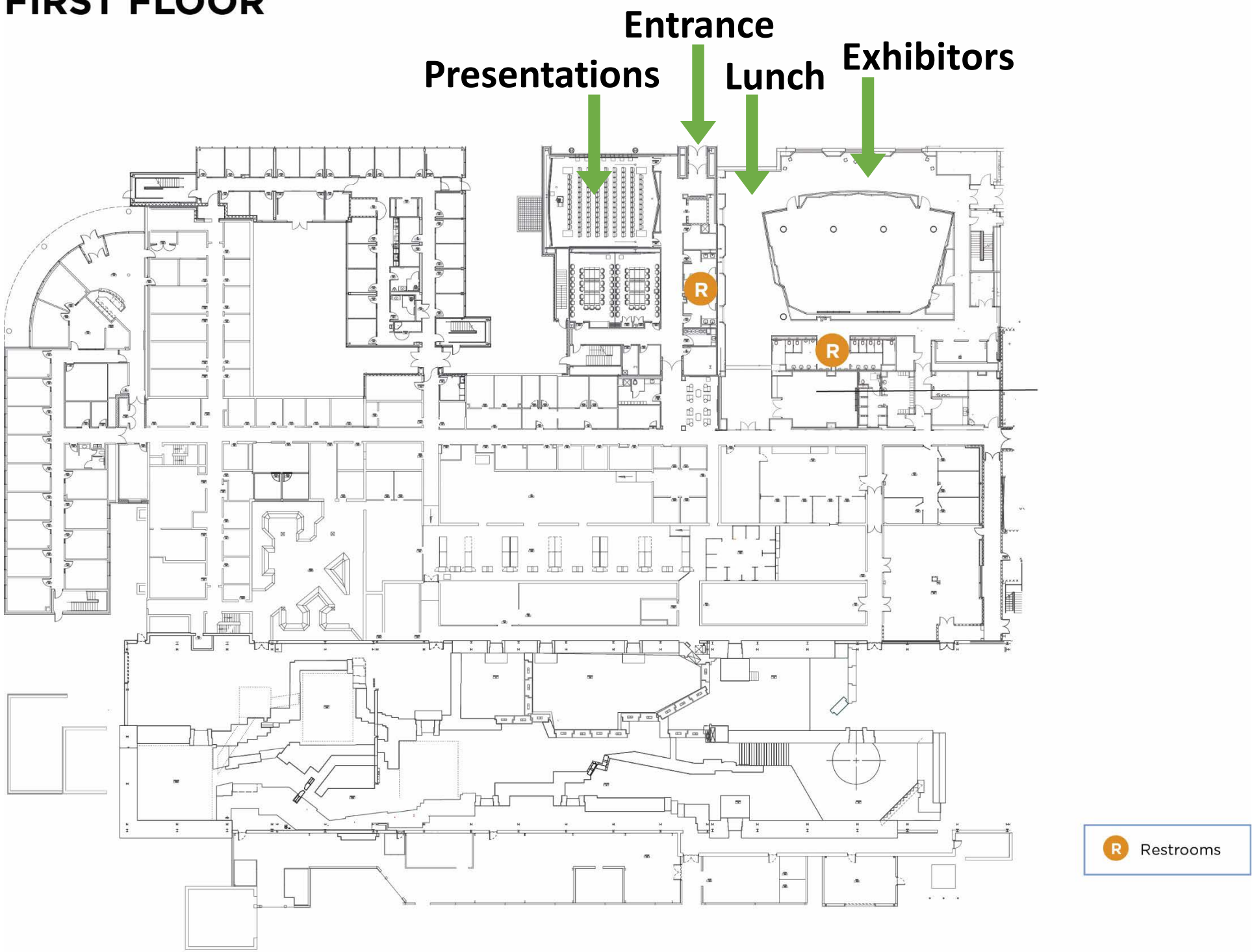
Author(s): Bhandarkar, Suhas[1]
1 *Lawrence Livermore National Laboratory*

Targets are critical elements of wide-ranging mission-oriented fusion and basic high energy density science research efforts that use ulta-high power lasers like the one located at the National Ignition Facility (NIF). The Target Fabrication program at Lawrence Livermore National Lab is a core competency where multiple disciplines such as preceision and materials integration engineering and high resolution metreology are consolidated to produce diverse target types that range from the simple to complex and exquisite micro-assemblies that operate at deep cryogenic condictions. This presentation will seek to highlight these capablilities and the sustained progress they enable in the study of inertial confinement physics and the challenging quest for ignition. This work was performed under the auspices of the US Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

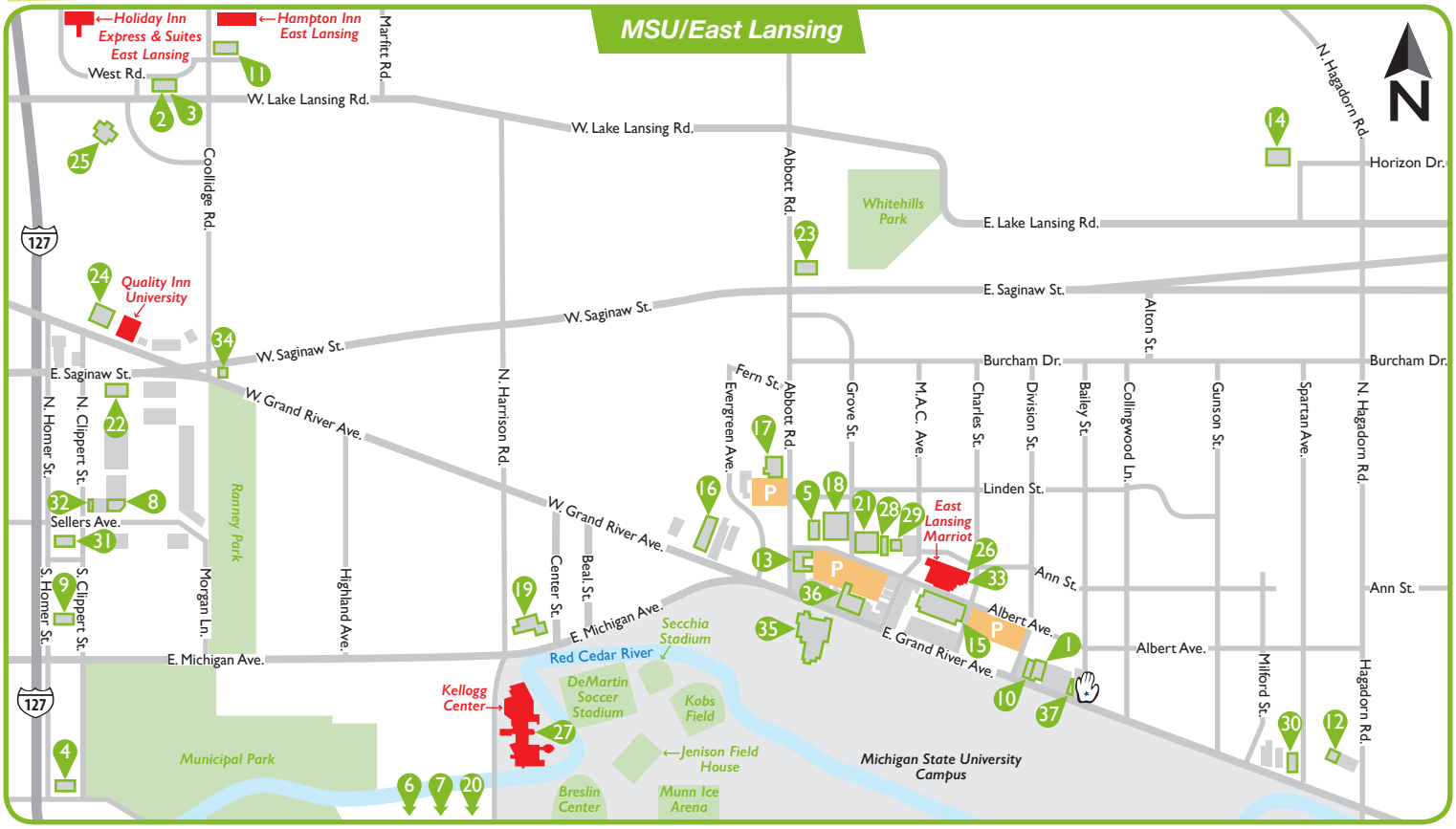
Track Classification: 7 – Targets for special applications (medical, industrial, controlled fusion)

NOTES

FIRST FLOOR



EAST SIDE DINING GUIDE



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5 Black Cat Bistro
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6 Gigi's Cupcakes
1020 Trowbridge Rd.
East Lansing, 48823 | (517) 679–3982 **$**

7 MSU Dairy Store
220 Trowbridge Rd.
East Lansing, 48824 | (517) 355–1855 **$**

8 Panera Bread—Frandor
310 N. Clippert St.
Lansing, 48912 | (517) 332–9183 **$$**

9 Sugar Shack
215 N. Clippert St.
Lansing, 48912 | (517) 316–2009 **$**

10 Velvet A Candy Store
507 E. Grand River Ave.
East Lansing, 48823 | (517) 337–2639 **$**

BAR & GRILL

11 Applebee's
2450 Coolidge Rd.
East Lansing, 48823 | (517) 336–5926 **$**

12 Bagger Dave's Burger Tavern
1351 E. Grand River Ave.
East Lansing, 48823 | (517) 492–5052 **$**

13 Beggar's Banquet
218 Abbot Rd.
East Lansing, 48823 | (517) 351–4573 **$**

14 Buddies Pub & Grill
3048 E. Lake Lansing Rd.
East Lansing, 48823 | (517) 333–9212 **$**

15 Buffalo Wild Wings—East
360 Albert Ave.
East Lansing, 48823 | (517) 333–2999 **$**

16 Crunchy's
254 W. Grand River Ave.
East Lansing, 48823 | (517) 351–2506 **$**

17 Dublin Square
327 Abbot Rd.
East Lansing, 48823 | (517) 351–2222 **$**

18 Harper's Brew Pub
131 Albert Ave.
East Lansing, 48823 | (517) 333–4040 **$**

19 Harrison Roadhouse
720 Michigan Ave.
East Lansing, 48823 | (517) 337–0200 **$**

20 Hobie's Cafe & Pub
930 Trowbridge Rd.
East Lansing, 48823 | (517) 351–3800 **$**

21 HopCat—East
300 Grove St.
East Lansing, 48823 | (517) 816–4300 **$**

22 Red Lobster Restaurant
3130 E. Saginaw St.
Lansing, 48912 | (517) 351–0610 **$**

23 Reno's Sports Bar & Grill—East
1310 N. Abbot Rd.
East Lansing, 48823 | (517) 351–7366 **$**

24 Spare Time Entertainment Center/Grand River Bar & Grill
3101 E. Grand River Ave.
Lansing, 48912 | (517) 337–2695 **$**

25 Spartan Hall of Fame Café
1601 W. Lake Lansing Rd.
East Lansing, 48823 | (517) 337–4680 **$**

FINE DINING

26 Bistro 43 & The Great Room
300 M.A.C. Ave.
East Lansing, 48823 | (517) 337–4440 **$$**

27 State Room Restaurant & Lounge
219 S. Harrison Rd.
East Lansing, 48824 | (517) 432–4000 **$$**

ITALIAN/GREEK

28 Field House
213 Ann St.
East Lansing, 48823 | (517) 332–8300 **$**

MEXICAN/SOUTHWESTERN

29 El Azteco—East
225 Ann St.
East Lansing, 48823 | (517) 351–9111 **$**

30 Los Tres Amigos—East
1227 E. Grand River Ave.
East Lansing, 48823 | (517) 853–5800 **$**

31 Qdoba Mexican Grill—Frandor
301 N. Clippert St.
Lansing, 48912 | (517) 664–2994 **$**

QUICK CASUAL

32 Halo Burger
310 N. Clippert St., Ste. 1
Lansing, 48912 | (517) 203–5263 **$**

33 Leo's Coney Island—MSU
333 Albert Ave., Ste. 100
East Lansing, 48823 | (517) 708–8580 **$**

34 Lou & Harry's—Grill & Bakery
1429 W. Saginaw St.
East Lansing, 48823 | (517) 351–1066 **$**

35 MSU Union/Dairy Store
49 Abbot Rd.
East Lansing, 48824 | (517) 355–3460 **$**

36 Noodles & Company—East
205 E. Grand River Ave.
East Lansing, 48823 | (517) 332–4040 **$**

37 Sweet Lorraine's Fabulous Mac n' Cheez!
547 E. Grand River Ave.
East Lansing, 48823 | (517) 325–0850 **$**

P Parking

East Lansing Visitors Center


Spartan Hall of Fame Café

$ Entreé under $15

$$ Entreé over$15

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