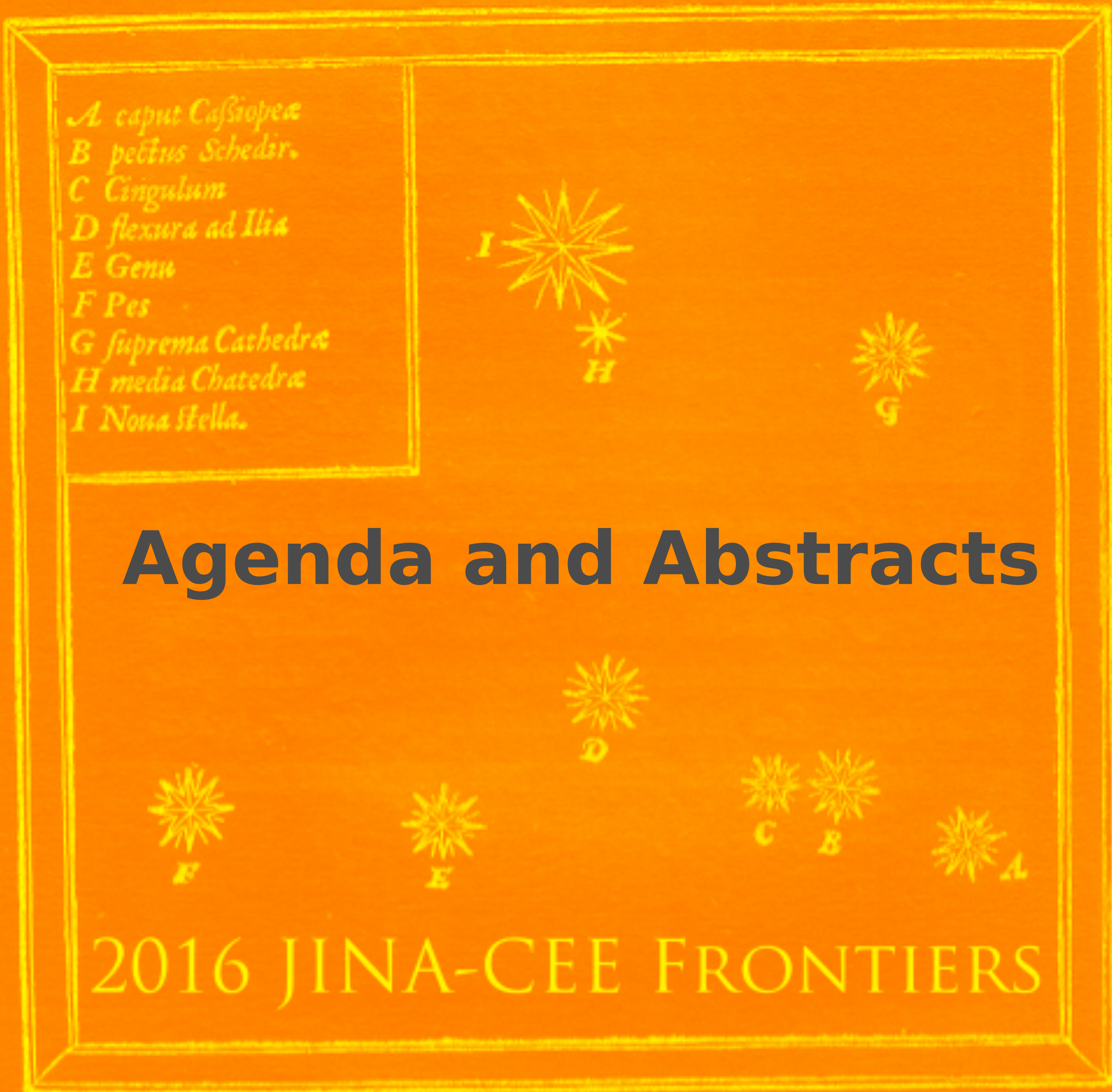
Agenda and Abstracts



2016 JINA-CEE Frontiers

Confirmed Invited Speakers:
Almudena Arcones (TU Darmstadt), Andrew Davis (U. Chicago), Sebastian George (MPIK), Brian Grefenstette (CalTech), Terese Hansen (Copenhagen), Alex Heger (UMN/MoCA), and Hye Young Lee (LANL)

Conference Committee:
Zach Meisel (UND), Alexander Long (UND), Mackenzie Barton-Rowledge (UW), Kathy Burgess (UND), Ryan Connolly (MSU), Lisa Duffey (MSU), Patrick O'Malley (UND), Wei Jia Ong (MSU), Ilka Petermann (ASU), Ingo Tews (UW), and Jinmi Yoon (UND)

March 29th - 31st, 2016
Gillespie Center
University of Notre Dame
http://indico.fnal.gov/event/Frontiers2016

JINA-CEE

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University of Notre Dame

We acknowledge support from the Institute for Structure and Nuclear Astrophysics, the University of Notre Dame Department of Physics and JINA-CEE.

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1 Organizing Committee

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Alex Long, Vice-chair (University of Notre Dame)

Mackenzie Barton-Rowledge (University of Washington)

Kathy Burgess (University of Notre Dame)

Ryan Connolly (Michigan State University)

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Ilka Petermann (Arizona State University)

Ingo Tews (University of Washington)

Jinmi Yoon (University of Notre Dame)

JINA-CEE Frontiers in Nuclear Astrophysics 2016 (Mar 28-31)

Student & Post-Doc Day: Mon, Mar 28, 16

9:00	**Opening remarks**
	Session 1: Experimental Equipment and Techniques
9:15	**Rashi Talwar**: Bubble Chamber : A new approach towards understanding the $^{12}C(\alpha,\gamma)^{16}O$ reaction
9:30	**James deBoer**: Characterizing neutron background reactions for CASPAR
9:45	**Alex Dombos**: Total absorption spectroscopy of neutron-rich nuclei around the A=100 mass region
10:00	**Tony Ahn**: Development of a neutron long-counter system for astrophysical (α,n) reaction studies
10:15	**Justin Browne**: Commissioning of the JENSA Gas Jet Target with $^{4}He(p,p)^{4}He$
10:30	**Brad Schultz**: Construction of a multi-reflection time-of-flight mass spectrometer at the University of Notre Dame
10:45-11:00	**Break**
	Session 2: Compact Objects 1
11:00	**Oleg Korobkin:** Evolution of the gamma- and X-ray radioactive source in macronovae/kilonovae from compact mergers
11:15	**Ermal Rrapaj:** Microscopically constrained mean field models from chiral nuclear thermodynamics
11:30	**Max Katz:** Mergers and Collisions of White Dwarfs on Adaptive Meshes
11:45-13:00	**Lunch**
	Session 3: Compact Objects 2
13:00	**Farrooh Fattoyev**: Exploring the Role of Nuclear Symmetry Energy in Large Scale Quantum Simulations of Nuclear Pasta
13:15	**Matthew Caplan**: Phase Diagrams, Thermal Conductivities, and Electrical Conductivities of Nuclear Pasta
13:30	**Mackenzie Barton-Rowledge**: An Exotic Battery: Neutron Star Heating from New Physics Annihilations
13:45	**Stephan Stetina**: Superfluid Hydrodynamics from Field Theory
14:00-14:30	**Break**
	Session 4: Nuclear Reactions & Structure
14:30	**Stephanie Lyons**: Low-Energy $^{20}Ne(p,\gamma)^{21}Na$ Cross-section Study with the 5U-4 St. Ana Accelerator
14:45	**Cathleen Fry**: Constraining resonance strengths for $^{30}P(p,\gamma)^{31}S$ with lifetime measurements
15:00	**Stylianos Nikas**: Impact of Parametrization on (n, γ) calculations using the statistical model of Hauser-Feshbach
15:15	**Bryce Frentz**: Alpha Cluster States in ^{16}O
15:30	**Gwenaelle Gilardy**: ^{7}Li : a cosmological problem from a nuclear physics perspective
15:45	**Nishanth Sasankan**: BBN and CMB Constraints on Dark Radiation Revisited
16:00-16:30	**Break**
16:30-17:30	**Carreer Panel**
17:30	**End of Student/Post-Doc Day**

JINA-CEE Frontiers in Nuclear Astrophysics 2016 (Mar 28-31)

Tue, Mar 29, 16		Wed, Mar 30, 16		Thu, Mar 31, 16	
8:00-9:00	**Registration & Coffee**	**8:00-9:00**	**Coffee**	**8:00-9:00**	**Coffee**
	Session 1: Chair Chris Wrede		**Session 4:** Chair Jason Clark		**Session 7:** Chair Remco Zegers
9:00	**Opening Remarks**	**9:00**	**Brian Grefenstette**: Nuclear astrophysics with NuSTAR: Bringing the high energy sky into focus	**9:00**	**Hye Young Lee:** Neutron-induced reaction studies at Los Alamos Neutron Science center for improving nuclear data in astrophysics
9:15	**Andrew Davis**: Nuclear Astrophysics with presolar grains	**9:30**	**Xilu Wang**: Fermi and Swift as supernova alarms: Alert, localization, and diagnosis of future galactic Type-Ia explosions	**9:30**	**Yong-Zhong Qian**: Neutrinos and Nucleosynthesis
9:45	**Michael Bennett**: ^{31}Cl β-decay and the ^{30}P(p,γ)^{31}S reaction rate in nova nucleosynthesis	**9:45**	**Karen Ostdiek:** First half-life measurement of ^{60}Fe using the direct decay of ^{60m}Co and accelerator mass spectrometry	**9:45**	**Maxime Brodeur**: High precision mass measurements for nuclear astrophysics
10:00	**Ian Roederer**: New observational constraints from ancient stars on the origins of heavy elements	**10:00**	**Olga Liliana Caballero**: Neutrino emission from neutron star mergers with microscopical equations of state	**10:00**	**Robert Andrassy**: 3D hydrodynamic simulations of O-shell convection
10:15	**Iris Dillmann**: The nuclear astrophysics program at TRIUMF	**10:15**	**Daniel Robertson**: The CASPAR facility for underground nuclear astrophysics	**10:15**	**Michael Deaton**: The matter neutrino resonance around black hole accretion disks
10:30-11:00	**Coffee Break**	**10:30-11:00**	**Coffee Break**	**10:30-11:00**	**Coffee Break**
	Session 2: Chair Brian Fields		**Session 5:** Chair Carla Fröhlich		**Session 8 :**
11:00	**Terese Hansen**: Recent observational results for metal poor stars	**11:00**	**Almudena Arcones**: Nucleosynthesis in supernovae and neutron star mergers	**11:00**	5min summaries from approx. 10 unconference breakout groups
11:30	**Rana Ezzeddine**: Iron abundance analysis of ultra-metal poor stars using non-LTE	**11:30**	**Jorge Pereira**: Theoretical uncertainty of (α,n) reaction rates relevant for the nucleosynthesis of heavy elements in neutrino-drive winds	**11:50**	**Closing remarks**
11:45	**Falk Herwig**: Observations, simulations, and nuclear physics of the i-process	**11:45**	**Anna Frebel**: A single prolific r-process event preserved in an ultra-faint dwarf galaxy		**End of Conference**
12:00	**Paul Woodward:** 3D simulation of hydrogen ingestion in a very low metallicity AGB star, a potential site for i-process nucleosynthesis	**12:00**	**Grant Matthews**: In search of the site for r-process nucleosynthesis		
12:15	**Brian O'Shea:** Modelling galactic chemical evolution in a cosmological context	**12:15**	**Farheen Naqvi**: First total-absorption spectroscopy measurement on the neutron-rich Cu isotopes		
12:30-14:00	**Lunch buffet**	**12:30-14:00**	**Lunch buffet**		
	Session 3: Chair Ed Brown		**Session 6:** Chair Pavel Denisenkov		
14:00	**Sebastian George**: Nuclear astrophysics with rings and traps	**14:00**	**Alexander Heger**: Recent advances in X-ray burst modelling		
14:30	**Alex Deibel:** New Urca cooling pairs in the neutron star ocean and their effect on superbursts	**14:30**	**Yang Sun**: Shell-model study of isospin-symmetry breaking and the impact in the rp-process		
14:45	**Alessandro Roggero**: Thermal conductivity in the neutron star crust	**14:45**	**Melina Avila**: Measuring key α-induced reaction rates with the MUSIC detector		
15:00	**Chris Sullivan**: The sensitivity of core-collapse supernovae to nuclear electron capture	**15:00-18:00**	**Unconference (coffee)**		
15:15	**Caroline Robin**: Nuclear Response theory for spin-isospin excitations in a relativistic framework				
15:30	**Evan Scannapieco**: Modelling the pollution of pristine gas in the early universe				
15:45	**Tsung-Han Yeh**: Primordial deuterium predictions cry out for an updated d(p,γ)^{3}He rate				
16:00-16:30	**Coffee Break**				
16:30-18:00	**Poster Session (beer/wine & hors d'oeuvre)**				
18:00	**End of Day 1**	**18:00-20:00**	**Conference banquet (beer/wine)**		

3 Abstracts student/ postdoc day

March 28, 2016

3.1 Session 1

Rashi Talwar
Bubble Chamber : A new approach towards understanding the $^{12}C(\alpha,\gamma)^{16}O$ reaction

Our current technical capabilities for direct measurement of some of the most important nuclear reactions at astrophysically relevant energies have reached their limits. Adopting ideas from dark matter search experiments, we have found that a superheated liquid in a bubble detector is sensitive to recoils produced by γ-ray beams impinging on the nuclei in the liquid. Such a target-detector system has a density factor of four orders of magnitude higher than conventional gas targets and is practically insensitive to the γ-ray beam itself. Also, since photodisintegration reactions have approximately two orders of magnitude higher cross-sections than direct particle capture reactions, such a technique can pave the way towards measuring these reactions within the stellar Gamow window. In an effort to study the $^{16}O(\gamma,\alpha)^{12}C$ system using the bubble chamber technique, the first test of the superheated N_2O liquid with a low-energy bremsstrahlung beam at JLab has been completed. This test has been performed to understand the background contributions from ^{17}O and ^{18}O nuclei in N_2O. The experimental technique, results and future plans will be presented. This work has been supported by the US Department of Energy, Office of Nuclear Physics, under contract number DE-AC02-06CH11357 and by Jefferson Science Associations, LLC, under contract number DE-AC05-06OR23177.

James deBoer
Characterizing neutron background reactions for CASPAR

The compact accelerator system for performing astrophysical research (CASPAR) is an underground low-background facility for measuring cross sections at very low energies. In this environment the background neutron flux is suppressed by about 1,000-10,000 compared to surface levels. At these levels the major neutron background for most experiments will be beam induced. At the low energy range of CASPAR, less than 1 MeV beam energy, the Coulomb penetrability dominates the cross section. Therefore, low atomic number reactions will have the largest cross sections. Boron and Beryllium are common contaminants in almost all solid target material and backings. Additionally, these elements can find their way onto the slits and collimators of the beam lines. A high efficiency neutron detector like a ^{3}He counter often gives no energy information making different sources of neutrons hard to distinguish. It is thus very important to have good estimates of the cross sections of these background reactions when attempting measurements of higher atomic number reactions such as ^{13}C(α,n)^{17}O and ^{22}Ne(α,n)^{26}Mg. In this presentation I will discuss recent measurements of the ^{11}B(α,n)^{14}N and ^{10}B(α,n)^{13}N cross sections at the University of Notre Dame's nuclear science laboratory. Preliminary results using both a 3He counter and a deuterated scintillator array from the U of M will be presented.

Alex Dombos

Total absorption spectroscopy of neutron-rich nuclei around the A=100 mass region

Accurate modeling of the r-process requires knowledge of properties related to the β-decay of neutron-rich nuclei, such as β-decay half-lives and β-delayed neutron emission probabilities. These properties are related to the β-decay strength distribution, which can provide a sensitive constraint on theoretical models. Total absorption spectroscopy is a powerful technique to accurately measure quantities needed to calculate the β-decay strength distribution. In an effort to improve models of the r-process, the total absorption spectra of neutron-rich nuclei in the mass region around A=100 were recently measured using the Summing NaI(Tl) (SuN) detector at the NSCL in the first ever total absorption spectroscopy measurement performed in a fragmentation facility. Total absorption spectra will be presented and the extracted β-decay feeding intensities will be compared to theoretical calculations.

Tony Ahn

Development of a neutron long-counter system for astrophysical (α,n) reaction studies

The low abundances of Z = 38 - 47 range in metal poor stars has been recently studied and (α,xn) reactions were proposed as the main reaction pathway for early nucleosynthesis in the wind with the condition of (n,γ)-(γ,n) equilibrium and temperatures between 3.5 and 5.5 GK. Although recent sensitivity studies showed that uncertainties in (α,xn) reaction rates directly affect calculated abundances with an impact that is comparable to that from astrophysical uncertainties, current reaction rate uncertainties are relatively large since little experimental data exists for (α,xn) cross sections involved in nucleosynthesis calculations. We are developing the Heavy ion Accelerated Beam induced (Alpha,Neutron) Emission Ratio Observer (HabaNERO) for future important (α,xn) reaction studies including ^{75}Ga(α,xn)^{78}As. The HabaNERO is a neutron long counter system which consists of 80 gas-filled BF3 and 3He proportional tubes oriented in rings along the beam axis embedded in a polyethylene matrix. The configuration of the tubes in the matrix is determined by both a high average neutron detection efficiency and the efficiency as a function of energy to be as constant as possible from En = 0.1-19.5 MeV, since neutron energy information will be lost due to neutron moderation. Details of the detector design and a status report on the development will be presented. We will also discuss plans to utilize this system for experiments of α,xn) reactions using radioactive ion beams.

Justin Browne

Commissioning of the JENSA Gas Jet Target with ^{4}He(p,p)^{4}He

The JENSA gas jet target is a dense, localized, windowless gas target designed to study H- and He-induced reactions. It has been successfully installed at the National Superconducting Cyclotron Laboratory, and the first commissioning experiment has been performed. In this experiment, the areal density profile of a Helium jet was determined using a proton beam.

Andrew Nystrom

Precision Mass Measurements at the Canadian Penning Trap using a Phase-Imaging Technique

Precision mass measurements at Penning Trap facilities have traditionally used a time-of-flight (TOF) technique to measure the cyclotron frequency of ions and use them to determine their masses. At the Canadian Penning Trap (CPT) located at Argonne National Laboratory, this technique is able to provide mass measurements to a precision of about δm/m = 10-8 with measurement times as low as 200ms. However, a new phase-imaging technique, that is used to determine the cyclotron frequency by projecting the radial ion motion on a position-sensitive detector, is being implemented at the CPT. It provides at least a tenfold gain in resolving power while allowing for measurement times of less than 100ms, permitting measurements of more exotic neutron-rich nuclei from CARIBU with respect to the TOF technique. Details of its commissioning at the CPT will be discussed alongside with some of the most recent neutron-rich mass measurements.

Brad Schultz

Construction of a multi-reflection time-of-flight mass spectrometer at the University of Notre Dame

One of the most significant problems in the production of rare isotopes is the simultaneous production of contaminants, often times isobaric. Thus, a high-resolution beam purification method is required which is compatible with both low yield and short half-life of the desired radionuclide. A multi-reflection time-of-flight mass spectrometer meets all these criteria. Such a device has been constructed at the University of Notre Dame and will be installed in the ATLAS facility at Argonne National Lab for use as an isobaric purifier. The motivation, design and a status report will be presented.

3.2 Session 2

Oleg Korobkin

Evolution of the gamma- and X-ray radioactive source in macronovae/ kilonovae from compact mergers

Mergers of two neutron stars or a neutron star and a black hole produce radioactive outflows, containing a mixture of heavy r-process elements. Radioactive heating in these outflows will power a macronova/ kilonova transient, which, if observed, could provide information about astrophysical environment of the mergers. Accurate light curve calculations for macronovae / kilonovae are essential to distinguish them from a variety of background sources. They in turn depend on the accurate estimates of radioactive heating in the freshly synthesized r-process elements. In this presentation, I will combine the yields of r-process nucleosynthesis with radiation data for individual nuclides to produce comprehensive picture of the gamma- and X-ray emission due to radioactivity in various components of merger ejecta. Prospects of detection of macronova remnants in X-ray and gamma-ray bands will also be discussed.

Ermal Rrapaj

Microscopically constrained mean field models from chiral nuclear thermodynamics

We explore the use of mean field models to approximate microscopic nuclear equations of state derived from chiral effective field theory across the densities and temperatures relevant for simulating astrophysical phenomena such as core-collapse supernovae and binary neutron star mergers. We consider both relativistic mean field theory with scalar and vector meson exchange as well as energy density functionals based on Skyrme phenomenology and compare to thermodynamic equations of state derived from chiral two- and three-nucleon forces in many-body perturbation theory. Quantum Monte Carlo simulations of symmetric nuclear matter and pure neutron matter are used to determine the density regimes in which perturbation theory with chiral nuclear forces is valid. Within the theoretical uncertainties associated with the many-body methods, we find that select mean field models describe well microscopic nuclear thermodynamics. As an additional consistency requirement, we study as well the single-particle properties of nucleons in a hot/dense environment, which affect e.g., charged-current weak reactions in neutron-rich matter. The identified mean field models can be used across a larger range of densities and temperatures in astrophysical simulations than more computationally expensive microscopic models.

Max Katz
Mergers and Collisions of White Dwarfs on Adaptive Meshes

Observational evidence has been mounting in recent years for the case that white dwarf mergers and collisions are potential progenitors of Type Ia supernovae. This exciting development has resulted in a number of studies focused on computationally modeling these events, using both particle-based codes and grid-based codes. It has become clear that for both mergers and collisions, spatial and temporal resolution plays a key role in obtaining accurate results. Additionally, there are important questions to be resolved about whether detonations observed in these numerical simulations are true physical phenomena or are numerically seeded. Accurate initial conditions also play a key role for the mergers in particular. We have used the compressible hydrodynamics code CASTRO, built on the BoxLib adaptive mesh refinement library, to simulate these binary systems, in particular focusing on the role targeted mesh refinement can play in ensuring both accurate small-scale nuclear burning and accurate large-scale system dynamics. In this talk I will describe the code improvements that have been made to CASTRO for the purpose of studying binary white dwarf systems, and we will discuss what our simulation results imply for the future of computational modeling of white dwarf mergers as Type Ia supernova progenitors.

3.3 Session 3

Farrooh Fattoyev
Exploring the Role of Nuclear Symmetry Energy in Large Scale Quantum Simulations of Nuclear Pasta

Matter in Neutron Star crusts and Supernovae contain regions of complex and exotic nuclear geometries collectively referred to as "nuclear pasta". By employing a set of self-consistent microscopic nuclear energy density functionals we present the first results of large scale quantum simulations of pasta phases with A $= 2000$ nucleons at baryon densities $0.03 < \rho < 0.10$ fm^{-3}, proton fractions $0.05 < Y_p < 0.40$, and zero temperature. The full quantum simulations allow us to study the role of various components of nuclear interaction in the nuclear pasta formation. In particular, we explore the role and impact of the nuclear symmetry energy on these pasta configurations.

Matthew Caplan

Phase Diagrams, Thermal Conductivities, and Electrical Conductivities of Nuclear Pasta

We report on recent large scale classical molecular dynamics simulations of nuclear pasta. Due to recent advances in supercomputing we are now able to simulate nuclear matter at a wide range of temperatures, densities, and proton fractions, thereby assembling a phase diagram for nuclear pasta. Additionally, we study electron transport in the crust by calculating the static structure factor of nucleons in the pasta. This allows us to calculate the thermal and electrical conductivity of nuclear pasta, and we find that the presence of defects in nuclear pasta decrease the thermal and electrical conductivity of the crust.

Mackenzie Barton-Rowledge

An Exotic Battery: Neutron Star Heating from New Physics Annihilations

Usual supernova exclusions of new particles come from energetic constraints during the supernova; however, exotic particles that are pair-produced during the supernova at rates less than the critical cooling constraints–often because they are heavy–can be trapped in the neutron star's gravitational potential and may later annihilate into standard model particles, heating the cold neutron star years or millennia after the supernova.

Stephan Stetina

Superfluid Hydrodynamics from Field Theory

Multi component hydrodynamic models are a useful tool to describe a large variety of observable phenomena in compact stars such as pulsar glitches or the r-mode instability. Depending on the ground state of matter inside a compact star such a hydrodynamic description might be fairly complicated, in particular in the presence of superfluid phases. In order to relate the phenomenology of compact stars to underlying microscopic physics it is therefore crucial to understand in detail how the effective hydrodynamic description emerges from a quantum field theory. We show how the non-dissipative hydrodynamic parameters can be derived from a scalar quantum field theory. In addition sound modes and instabilities will be discussed in this approach.

3.4 Session 4

Stephanie Lyons

Low-Energy ^{20}Ne(p,γ)^{21}Na Cross-section Study with the 5U-4 St. Ana Accelerator

In stars whose temperature is greater than 0.05 GK, hydrogen burning can proceed via the NeNa cycle, which is important for the nucleosynthesis of Ne, Na, and Mg isotopes. The first reaction in this cycle is ^{20}Ne(p,γ)^{21}Na, which also has the slowest proton capture reaction rate [1], thereby influencing the rest of the cycle and, potentially, abundances of the other nuclei that are synthesized in the cycle. The stellar reaction rate for ^{20}Ne(p,γ)^{21}Na is dominated by direct capture and the high energy tail of a subthreshold resonance. The aim of this work is to understand the direct-capture component of this reaction. Using Notre Dame's recently commissioned 5U-4 accelerator, the ^{20}Ne(p,γ)^{21}Na cross-section has been measured relative to the 1169 keV resonance at low energies. The resonance strength of the 1169 keV resonance was also independently determined. Improvements to previous cross-section measurements will be discussed [2]. [1] Iliadis et. al. The Astrophysical Journal Supplement Series 134, 151 (2001) [2] Rolfs et. al. Nuclear Physics A 241, 480 (1975)

Cathleen Fry

Constraining resonance strengths for ^{30}P(p,γ)^{31}S with lifetime measurements

In classical novae, the ^{30}P(p,γ)^{31}S reaction potentially acts as a bottleneck in nucleosynthesis flow to higher masses. Knowledge of this reaction rate is necessary for the modeling of elemental and isotopic ratios in classical novae, which affect proposed nova thermometers and presolar grain identification, respectively. While most of the resonance energies are known experimentally, the corresponding resonance strengths are not yet known. As a step towards determining experimental resonance strengths, we plan to measure the lifetimes of these resonances, using the Doppler Shift Lifetime (DSL) setup at TRIUMF. A measurement of the lifetimes of these states will provide the total widths of these resonances, and can be used along with the spins and proton branching ratios to determine resonance strengths.

Stylianos Nikas

Impact of Parametrization on (n,g) calculations using the statistical model of Hauser-Feshbach

We explore the impact of different parametrizations of the Hauser-Feshbach formula for (n,γ) reactions. We focus on captures of neutrons on nuclei a few neutrons away from stability and near closed shells. Results were compared with experimental data when possible. The main parameters affecting reaction rates from H-F calculations of (n,γ) reactions are identified and presented.

Bryce Frentz

Alpha Cluster States in ^{16}O

The reaction ^{13}C(α,n)^{16}O and the subsequent breakup of ^{16}O was measured the University of Notre Dame Nuclear Science Laboratory in order to explore the α-cluster states above the 4α-decay threshold in ^{16}O. The charged particles were detected using four double-side strip detectors with 256 total channels and 12 deuterated liquid scintillators were used to detect neutrons. Locating and understanding these states is crucial in understanding the stellar evolution through helium burning. Details of the experimental setup, data analysis, and preliminary results will be presented. This work was supported by the National Science Foundation under Grants PHY-1419765 and PHY-0969456.

Gwenaelle Gilardy

^{7}Li : a cosmological problem from a nuclear physics perspective

The primordial abundance discrepancy in the lithium 7 between the prediction from the cosmological observations, like the cosmic microwave background, and the stellar abundances is one of the main astrophysical sources of concern for big bang nucleosynthesis. While various solutions are proposed, the focused of this work is on a nuclear origin. This motivated the study of ^{7}Li(α,γ)^{11}B. The 5U accelerator of the Nuclear Science laboratory at the University of Notre Dame was used to accelerate an α beam on a LiF target. The Ge-detectors Online Array for Gamma Ray Spectroscopy in Nuclear astrophysics (Georgina) was used to detect γ rays from three resonances at 401, 814 and 953 keV in ^{11}B. Preliminary results will be presented.

Nishanth Sasankan
BBN and CMB Constraints on Dark Radiation Revisited

The effect of dark radiation on BBN and CMB has been studied earlier. We revisit this study, since new data has been available for light element abundances and Plank has updated data on CMB. Dark radiation is a construct of the RS model in brane world cosmology. Derivation of the Friedmann equation in RS model results in an addition of a radiation like term to the standard equation. We constrain the amount of dark radiation using CMB data and observational limit of light element abundance.

4 Abstracts main conference

March 29 - 31, 2016

4.1 Session 1

Andrew Davis
Nuclear astrophysics with presolar grains

The isotopic, chemical, and petrologic properties of presolar grains from meteorites provide unique insight into nucleosynthesis in and dust formation around asymptotic giant branch (AGB) stars, core collapse supernovae, and other types of dying stars. Recent progress include Ba and Sr isotopic constraints on the distribution of carbon-13 within the carbon-13 pockets of AGB stars and Fe and Ni isotopic constraints on galactic chemical evolution.

Michael Bennett
^{31}Cl β-decay and the ^{30}P(p,γ)^{31}S reaction rate in nova nucleosynthesis

The ^{30}P(p,γ)^{31}S reaction rate is critical for identifying the origin of presolar nova grains [1], modeling the final isotopic abundances of ONe nova nucleosynthesis [2], and calibrating proposed nova thermometers [3]. Unfortunately, this rate is essentially experimentally unconstrained because the strengths of key ^{31}S proton capture resonances are not known, due to uncertainties in their spins and parities. Using a ^{31}Cl beam produced at the National Superconducting Cyclotron Laboratory, we have populated several ^{31}S states for study via β decay and observed their radiative decay [4]. Based on isospin mixing with the nearby isobaric analog state, we have unambiguously identified a new I $=$ 0, Jπ $=$ 3/2$+$ ^{31}S resonance in the middle of the Gamow Window. Results of the study will be presented and the potential effects of this resonance on the ^{30}P(p,γ) ^{31}S reaction rate will be discussed. [1] J. Jose, M. Hernanz, S. Amari, K. Lodders, and E. Zinner, Astrophys. J. 612, 414 (2004). [2] J. Jose and A. Coc, Nucl. Phys. News 15, 17 (2005). [3] L. N. Downen, C. Iliadis, J. Jose, and S. Starrfield, Astrophys. J. 762, 105 (2013). [4] M. B. Bennett et al., Phys. Rev. Lett. (Accepted 2016)

Ian Roederer
New observational constraints from ancient stars on the origins of heavy elements

Understanding the origin of the elements is one of the major challenges of modern astrophysics. I will quickly highlight new observations of heavy elements in ancient stars that provide new constraints on nucleosynthesis in the earliest generations of stars. (1) The recently-discovered Reticulum 2 dwarf galaxy is unlike any other known galaxy, in that most of its stars contain three orders of magnitude more r-process material than any other low-luminosity galaxy in the Local Group. (2) New ultraviolet spectroscopy from the Hubble Space Telescope (HST) reveals possible evidence (super-solar [As/Ge] ratios, among others) for operation of the intermediate neutron-capture process (i process) in massive stars, super-AGB stars, or low-mass AGB stars in the early Galaxy. (3) Other new observations from HST reveal new opportunities to detect phosphorus, sulphur, and zinc—elements never before detected in carbon-enhanced stars with [Fe/H] $<$ -3.8 that may have formed from the remnants of Pop III stars. The constraints derived from these observations are central to the mission of JINA-CEE, and I am actively seeking new opportunities for collaboration in the nuclear astrophysics community.

Iris Dillman
The nuclear astrophysics program at TRIUMF

The present Nuclear Astrophysics program at TRIUMF includes the long-standing DRAGON and TUDA setups for reaction rate measurement, the TITAN Penning trap for mass measurements, and since last year also the GRIFFIN spectrometer and its auxiliary detectors for decay spectroscopy. The new EMMA recoil spectrometer is presently under construction. I will give an overview about the present and future experimental program at these facilities, and close with a look to RIKEN where the BRIKEN neutron detection setup will start to measure the beta-delayed neutron emission probabilities and half-lives of almost 100 isotopes in late 2016.

4.2 Session 2

Terese Hansen
Recent observational results for metal poor stars

The first heavy elements beyond hydrogen and helium were produced by the first generations of stars to form in the Universe. These presumably massive stars, with main-sequence lifetimes of a few million years, died in supernovae explosions and can no longer be directly observed. What can be observed are the low-mass stars that formed from the gas clouds these supernovae enriched with their ejecta. These extremely ([Fe/H] $<$ -3), ultra ([Fe/H] $<$ -4), and hyper ([Fe/H] $<$ -5) metal-poor stars provide a fossil record of the chemical composition of the Galaxy at the time and place of their birth. High-resolution spectroscopic observations of large samples of such stars have been analysed in the past decades, in an effort to disentangle the chemical fingerprints of the different nucleosynthesis pathways in operation at the earliest times, such as hydrostatic burning, explosive nucleosynthesis, and neutron-capture processes. I will present a review of the recent observational results for metal-poor stars, including results from long-term radial-velocity monitoring of highly r-process-element enhanced (r-II) stars and carbon-enhanced metal-poor (CEMP) stars with and without neutron-capture overabundances (CEMP-s and CEMP-no stars), the discovery of numerous r-II stars in the ultra faint dwarf galaxy Recticulum II, the bimodal distribution of absolute carbon abundances among CEMP stars, and evidence for neutron-capture element production at the earliest times in our Galaxy.

Rana Ezzeddine

Iron abundance analysis of ultra-metal poor stars using non-LTE

Iron abundance plays a vital role in all stellar spectroscopic studies. It is usually used as a proxy for the total metal content, due to its wealth of lines in most stellar spectra. Additionally, excitation equilibrium of FeI lines and ionization equilibrium between FeI and FeII lines is commonly used to determine the fundamental atmospheric parameters of the star. Hence accurate modelling of iron spectral lines is required to ensure an accurate characterization of the star as well as accurate chemical abundance measurements of elements other than iron. We present line-by-line non-LTE iron abundance determination for a sample of ultra metal-poor stars, using a new complete iron model atom that we built with the most up-to-date atomic data. Our results show a better agreement between FeI and FeII abundances for a chosen set of stellar parameters and a much less scatter of Fe abundances vs excitation potential than LTE values. This re-confirms the increasing need for using non-LTE spectral line synthesis in all future stellar spectroscopic studies.

Falk Herwig

Observations, simulations, and nuclear physics of the i-process

I will review our present knowledge of the i process. The i process is a neutron capture process with neutron densities of $\sim 10^{15}\mathrm{cm}^{-3}$, in-between that of s- and r-process conditions. Possible observational manifestations have been identified in pre-solar grains, open clusters, CEMP-stars and post-AGB stars. Stellar production sites include mixing of H into He-shell flash convection zones in low-Z AGB and super-AGB stars, post-AGB stars and rapidly accreting white dwarfs as well as possibly some massive stars. Important aspects of the i process nucleosynthesis can be studied in simple one-zone simulations and slightly more sophisticated 1D mutli-zone simulations. I will discuss how recent 3D hydrodynamic simulations have shown that the astrophysical site of Hingestion into He-convection zones defies the assumptions of conventional 1D stellar evolution simulations. Clearly more sophisticated nucleosynthesis simulation methods are needed, and are presently developed. Finally, i-process yields may be of importance on a galactic chemical evolution scale. To understand the i process quantitatively better emerges as an important ingredient of a holistic approach to the question of how the elements rise in the early universe. The i process proceeds very close to yet parallel to the valley of stability, which poses numerous nuclear physics challenges that may be addressed with unstable beam facilities.

Paul Woodward

3-D simulation of hydrogen ingestion in a very low metallicity AGB star, a potential site for i-process nucleosynthesis

I will report on recent simulations with Stou Sandalski at Minnesota and Falk Herwig's team at the University of Victoria carried out on the Blue Waters machine at NCSA. These new simulations focus on an AGB star of the early universe, in contrast to the very late thermal pulse star, Sakurai's object, that I reported on last year. This new case has a lower driving luminosity and a larger convection zone above the helium burning shell than we find in Sakurai's object. Nevertheless, we expect the burning of hydrogen entrained into this convection zone to be a site for the i-process. The differences from the case of Sakurai's object make this simulation more challenging. Techniques that we are using to address the new computational challenges will be presented. Our simulation results show large deviations from 1-D behavior leading to burning of the ingested hydrogen-rich gas in a sequence of increasingly violent events. We have captured the flow at about 2000 time levels on a grid that is well resolved in radius but with only 80 triangular cells tessellating the sphere in the two angular dimensions. This data will be used to determine from a 3-D analysis the nucleosynthetic signature of such a hydrogen ingestion event in an AGB star of the early universe.

Brian O'Shea
Modeling galactic chemical evolution in a cosmological context

In this talk, I will present results from recent efforts by the JINA galactic chemical evolution collaboration to develop chemical evolution models that take into account the dynamic nature of galaxy formation. A galaxy like the Milky Way is built by the merging together of generation after generation of galaxies – many thousands of progenitors in total, each of which has its own unique properties, and the traces of these ancestors can be seen in the chemical abundances observed in stars in our Galaxy. Our theoretical framework combines cosmological simulations of galaxy formation, models of stellar evolution, and statistical techniques to compare to modern stellar surveys such as SEGUE, APOGEE, and Gaia-ESO. I will highlight some recent results, make connections to other projects going on within JINA (particularly nuclear experiments and astronomical observations) and talk about the capabilities of this framework and our plans for the future.

4.3 Session 3

Sebastian George
Nuclear astrophysics with rings and traps

Storage rings were primarily developed for the field of high-energy physics, while ion traps were first employed in atomic and molecular physics. Nowadays both of them are key instrumentations of nuclear astrophysics when connected to a radioactive ion beam facility. Their long storage times are perfectly suited conducting lifetime measurements as well as performing precision mass spectroscopy on astrophysical relevant nuclei and their long-lived isomers. The experimental capabilities have been successively extended to in-ring reaction studies in a quasi background-free environment. State of the art experiments and future perspectives will be discussed.

Alex Deibel
New Urca cooling pairs in the neutron star ocean and their effect on superbursts

In a low-mass X-ray binary, low-level accretion onto the neutron star primary may trigger a superburst in the neutron star's ocean. Superbursts are long and energetic X-ray bursts thought to be powered by the unstable ignition of carbon approximately 100 meters below the surface. Recent reaction network calculations of nuclear burning on accreting neutron stars find that electron-capture/beta-decay cycling “Urca" pairs are robustly produced in X-ray burst and superburst nuclear burning. When compressed deeper into the star by further accretion, Urca pairs in the neutron star's ocean and crust cool the interior through powerful neutrino emission. We find that Urca cooling pairs lower the ocean's steady state temperature in accreting neutron stars and unstable carbon ignition must occur deeper than it would in the absence of Urca pairs. In this presentation, we will discuss the newly identified Urca pairs in the neutron star's ocean and the observational consequences of Urca cooling on superbursts.

Alessandro Roggero

Thermal conductivity in the neutron star crust

In this talk I will present our recent results for the thermal conductivity of electrons in the strongly-correlated multi-component plasma expected in the outer layers of neutron stars, using Path Integral Monte Carlo (PIMC) techniques, where we find an increased scattering rate compared to earlier calculations based on simple electron-impurity scattering. These findings directly impact our interpretation of thermal relaxation observed in accreting neutron stars.

Chris Sullivan

The sensitivity of core-collapse supernovae to nuclear electron capture

An open source weak-rate library aimed at investigating the sensitivity of astrophysical environments to variations of electron-capture (EC) rates on medium-heavy nuclei has been developed. With this library, the sensitivity of the core-collapse and early post-bounce phases of core-collapse supernovae (CCSNe) to nuclear EC was examined. The EC rates were adjusted by factors consistent with uncertainties indicated by comparing theoretical rates to those deduced from charge-exchange and β-decay measurements. To ensure a modelindependent assessment, sensitivity studies across a comprehensive set of progenitors and equations of state were performed. Variations of the protoneutron star inner-core mass and peak electron-neutrino luminosities were observed to be 5 times larger when varying the EC rates than what is observed when fixing the rates and utilizing a wide array of progenitor models. Furthermore, the simulations were found to be particularly sensitive to the reduction in rates for neutron-rich nuclei near the $N = 50$ closed neutron shell. As measurements for medium-heavy ($A>65$) and neutron-rich nuclei are sparse, and because accurate theoretical models that account for nuclear structure considerations of individual nuclei are not readily available, rates for these species may be overestimated. In this talk, I will describe the impact this overestimate may have to the core-collapse trajectory, the detailed sensitivity of the core-collapse and bounce phases of CCSNe to EC rates, and I will suggest specific areas of focus for future experimental and theoretical efforts.

Caroline Robin

Nuclear response theory for spin-isospin excitations in a relativistic framework

Nuclear spin-isospin response theory has various applications extending across the fields of nuclear structure and nuclear astrophysics. A precise description of such modes of excitation is needed to compute rates of weak interaction processes such as beta-decay, neutrino scattering or electron capture, which are important for astrophysical modeling. In this talk we present a theoretical approach to nuclear charge-exchange response. It is based on the relativistic Lagrangian that explicitly includes effective meson degrees of freedom to describe the static nucleon-nucleon interaction. At the same time, emergent collective phenomena are quantified consistently by means of an additional energy-dependent interaction induced by the nuclear medium polarization. Pion-nucleon interaction is considered with the free-space coupling constant [1,2]. The recent developments introduce pairing correlations of the superfluid type, which are needed for a correct description of open-shell nuclei. New results of calculations for Gamow-Teller resonances in medium-mass nuclei will be presented and discussed. [1] T. Marketin, E. Litvinova, D. Vretenar, P. Ring, Phys. Lett. B 706, 477 (2012). [2] E. Litvinova, B.A. Brown, D.-L. Fang, T. Marketin, R. G. T. Zegers, Phys. Lett. B 730, 307 (2014).

Evan Scannapieco

Modeling the pollution of pristine gas in the early universe

The properties of Population III (Pop III) stars are thought to be very different than those of later stellar generations, because cooling is dramatically different in a media with metallicities below a critical value, Zc. As Zc is very small, the mixing efficiency of metals plays a crucial role in determining the Pop III transition. I will describe a comprehensive theoretical and numerical investigation of the pollution of pristine gas in turbulent flows. Our data show that the evolution of the pristine fraction of gas with $Z<Z_c$ can be well approximated by a "self-convolution" model, with two free parameters. Carrying out a suite of numerical simulations, we are able to provide accurate fits to these parameters as a function of Mach number and the ratio between the critical metallicity and the average metallicity in the flow. I will show how these results can be used to construct subgrid models for tracking the evolution of the first stars in large cosmological numerical simulations.

Tsung-Han Yeh
Primordial deuterium predictions cry out for an updated d(p,γ)^{3}He rate

Big-bang nucleosynthesis (BBN) describes the dynamic interplay among lightest nuclides during early minutes of the Universe. Standard BBN has a single free parameter: the cosmic baryon density, now measured with high precision via observations of the cosmic microwave background. Using the 2015 results from Planck, we present precise BBN predictions of primordial light element abundances. The concordance between the BBN abundance predictions and astronomical observations of helium-4 and deuterium ensures the non-trivial success of the hot big-bang cosmology and probes non-standard physics scenarios. However, while the highredshift deuterium abundance is observed with 1.6% uncertainty, we show that the theoretical uncertainty is $\sim$5% (1σ variance), the dominant part of which comes from the uncertainty of empirical d(p,γ) ^{3}He rate.Moreover, the experimental data at the BBN energy range (especially 50 200 keV) are sparse and dated. Consequently, some recent studies instead adopted theoretical ab initio calculations for the crucial d(p,γ) ^{3}He rate. We will show that the theoretical versus experimental rate data lead to significant discrepancies in the deuterium abundance, with important implications for BBN. To settle this controversy, new and reliable d(p,γ)^{3}He measurements around 100 keV are essential.

4.4 Session 4

Brian Grefenstette
Nuclear astrophysics with NuSTAR: Bringing the high energy sky into focus

Understanding the origin of supernova explosions remains one of the outstanding problems in astrophysics. This is true of both explosions resulting from the collapse of a massive star as well as the thermonuclear explosions (Type Ia) that are commonly used as "standard candles" in cosmology. X-ray and gamma-rays produced promptly during these explosions as well as those produced in the decay of radioactive elements found in supernova remnants can be used to study the energetics of the explosion. I will provide an overview of recent high energy X-ray observations of supernovae and supernova remnants using the Nuclear Spectroscopic Telescope Array (NuSTAR). The NuSTAR Small Explorer (SMEX) mission, launched June 13, 2012, is the first focusing high-energy X-ray telescope in orbit. Covering the hard X-ray band from 3–79 keV, NuSTAR provides more than a 100-fold improvement in sensitivity, more than a 10-fold improvement in angular resolution and source positioning capability, and significantly improved spectral resolution compared to previous instruments that have operated in this band. This has enabled a unique set of observation tools for studying supernovae and the ejecta left behind by the explosions. I will review recent results from NuSTAR and place them in the context of theoretical models.

Xilu Wang
Fermi and Swift as supernova alarms: Alert, localization, and diagnosis of future galactic Type-Ia explosions

A Galactic SNIa event could go entirely unnoticed to us due to the large optical and near-IR extinction in the Milky Way plane, low radio and X-ray luminosities, and a weak neutrino signal. But the recent SN2014J confirms that Type Ia supernovae emit nuclear γ-ray lines, from the ^{56}Ni $\rightarrow$ ^{56}Co $\rightarrow$ ^{56}Fe radioactive decay. The energy released in these decays powers the SNIa UVOIR light curve at times after $\sim$1 week, leading to an exponential decline. Importantly for Swift and Fermi, these decays are accompanied by γ-ray line emission, with distinct series of lines for both the ^{56}Ni and ^{56}Co decays, spanning 158 keV to 2.6 MeV. These lines are squarely within the Fermi GBM energy range and 56Ni 158 keV line emission occurs within the Swift BAT energy range. The Galaxy is optically thin to γ-rays, so the SN line flux will suffer negligible extinction. Both GBM and BAT have continuous and nearly all-sky coverage. Thus GBM and BAT are ideal to serve as Galactic SNIa monitors and early warning systems. To illustrate the GBM and BAT capabilities, we use a simple model for SNIa γ-ray emission and transfer to estimate MeV light curves and spectra. Our work is constrained and calibrated by SN2014J MeV data, which suggest $\sim$10% of the 56Ni is in an optically thin shell surrounding the rest of the initially opaque ejecta. We show that the supernova signal emerges as distinct from the GBM background within days after the explosion in the SN2014J shell model. Therefore if a Galactic SNIa were to explode, there are two possibilities of confirming and sounding the alert: 1) Swift BAT discovers the SNIa first and localizes it within arcminutes; 2) Fermi GBM finds the SNIa first and localizes it to within 1 degree, using the Earth occultation technique, followed up by BAT to localize it within arcminutes. After the alert of either BAT or GBM, Swift localizes it to take spectra in optical, UV, soft and hard X-rays simultaneously with both XRT and UVOT instruments.

Karen Ostdiek
First half-life measurement of ^{60}Fe using the direct decay of ^{60m}Co and accelerator mass spectrometry

Radioisotopes, produced in stars and ejected through core collapse supernovae (SNe), are important for constraining stellar and early Solar System (ESS) models. The presence of these isotopes, specifically ^{60}Fe, can identify progenitors of SN types, give evidence for nearby SNe, and can be a chronometer for ESS events. The ^{60}Fe half-life, which has been in dispute in recent years, can have an impact on calculations for the timing for ESS events, the distance to nearby SN, and the brightness of individual, non-steady state ^{60}Fe gamma ray sources in the Galaxy. To measure such a long half life, one needs to simultaneously determine the number of atoms in and the activity of an ^{60}Fe sample. We have undertaken a half-life measurement at Notre Dame and have successfully measured the activity of our ^{60}Fe sample using the isomeric decay in ^{60}Co rather than the traditional ^{60}Co grow-in decay. This will then be coupled with the results of the ^{60}Fe concentration measurement of our sample using Accelerator Mass Spectrometry (AMS). I will present the most recent results of both the activity and the AMS measurements.

Olga Liliana Caballero
Neutrino emission from neutron star mergers with microscopical equations of state

Neutron-star mergers are interesting for several reasons: they are proposed as the progenitors of short gamma-ray bursts, they have been speculated to be a site for the synthesis of heavy elements, and they emit gravitational waves possibly detectable at terrestrial facilities. The understanding of the merger process, from the pre-merger stage to the final compact object-accreting system involves detailed knowledge of numerical relativity and nuclear physics. In particular, key ingredients for the evolution of the merger are neutrino physics and the matter equation of state. We present some aspects of neutrino emission from binary neutron star mergers showing the impact that the equation of state has on neutrinos and discuss some spectral quantities relevant to their detection such as energies and luminosities far from the source.

Daniel Robertson
The CASPAR facility for underground nuclear astrophysics

The drive of low-energy nuclear astrophysics laboratories is to study the reactions of importance to stellar burning processes and elemental production through stellar nucleosynthesis, over the energy range of astrophysical interest. As laboratory measurements approach the stellar burning window, the rapid drop off of cross-sections is a significant barrier and drives the need to lower background interference. The natural background suppression of underground accelerator facilities enables the extension of current experimental data to lower energies. An example of such reactions of interest are those thought to be sources of neutrons for the s-process, the major production mechanism for elements above the iron peak. The reactions ^{13}C(α,n)^{16}O and ^{22}Ne(α,n)^{25}Mg are the proposed initial focus of the new nuclear astrophysics accelerator laboratory (CASPAR) currently under construction at the Sanford Underground Research Facility, Lead, SD.

4.5 Session 5

Almudena Arcones
Nucleosynthesis in supernovae and neutron star mergers

Where in the universe are heavy elements synthesized? The favored candidates are core-collapse supernovae and neutron star mergers where extreme conditions enable the rapid neutron capture process (r-process). Recent advances in hydrodynamic simulations with improved microphysics can be combined with observations of the oldest stars to bring new insights about the astrophysical sites where heavy elements are produced. In nuclear physics, a new era for extreme neutron-rich isotopes is starting with new facilities world wide. Nucleosynthesis in core-collapse supernovae and neutrino-driven winds produces elements up to silver. While neutron star mergers present an exciting possibility for the production of all r-process elements (from the first to the third peak). Moreover, the radioactive decay of neutron-rich nuclei triggers an electromagnetic signal in mergers known as kilonova. This was potentially observed in 2013 after a short gamma ray burst, associated with a neutron star merger. Only by combining nuclear physics experiment and theory, with long-time simulations of supernovae and neutron star mergers, will we be able to understand the origin of heavy elements.

Jorge Pereira
Theoretical uncertainty of (a,n) reaction rates relevant for the nucleosynthesis of heavy elements in neutrino-driven winds

Neutrino-driven winds from nascent neutron stars following Supernovae explosions have been proposed as a possible source of "light" r elements (from Sr through Ag with A$\sim$88-110). In these events, (α,n) reactions involved in the so-called α-process are key to move matter beyond the iron group towards the region of heavier proton number. We have investigated the theoretical uncertainty of calculated reaction rates for the most relevant

(α,n) reactions in the α-process. We will discuss the most important sources of uncertainty, including those arising from nuclear-physics inputs and from technical aspects of the reaction codes.

Anna Frebel
A single prolific r-process event preserved in an ultra-faint dwarf galaxy

The heaviest elements in the periodic table are synthesized through the r-process, but the astrophysical site for r-process nucleosynthesis is still unknown. The major current candidates are ordinary core-collapse supernovae and neutron star mergers. Ancient, metal-poor ultra-faint dwarf galaxies contain a simple fossil record of early chemical enrichment that provides the means to study clean signatures of nucleosynthesis events, and thus, can yield unique information on the origin of these processes. Previously, extremely low levels of neutroncapture elements were found in the metal-poor stars in ultra-faint dwarf galaxies which supported supernovae as the r-process site. Based on Magellan/MIKE high-resolution spectroscopy, we have determined chemical abundances of nine stars in the recently discovered ultra-faint dwarf Reticulum II. Seven stars display extremely enhanced r-process abundances, comparable only to the most extreme r-process enhanced metal-poor stars found in the Milky Way's halo. The enhancement is also 2-3 orders of magnitude higher than that of stars in any of the other ultra-faint dwarfs. This implies the neutron-capture r-process material in Reticulum II was synthesized in a single prolific event that is incompatible with r-process yields from ordinary core-collapse supernovae but consistent with that of a neutron star merger. This would be the first signature of a neutron star merger in the early universe which holds the key to finally identifying the r-process production site. Furthermore, such a single r-process event is a uniquely stringent constraint on the metal mixing and star formation history of this ultra-faint dwarf galaxy. (accepted for publication in Nature, http://arxiv.org/abs/1512.01558)

Grant Matthews
In search of the site for r-process nucleosynthesis

It has been known for more than half a century that about half of the elements heavier than iron are produced via rapid neutron capture in the r-process. Indeed, the basic physical conditions for the r-process are well constrained by simple nuclear physics. In spite of this simplicity, however, the unambiguous identification of the site for the r-process nucleosynthesis has remained elusive. Parametrically, one can divide current models for the r-process into three scenarios roughly characterized by the number of neutron captures per seed nucleus (n/s). This parameter, in turn is the consequence of a variety of conditions such as time-scale, baryon density, average charge per baryon, and entropy. In this talk we summarize various proposed sites for the rprocess along with their short comings. Insight from a variety of nuclear physics measurements and astronomical observations is summarized. A paradigm is proposed whereby one may be able to quantify the relative contributions of each astrophysical site.

Farheen Naqvi
First total-absorption spectroscopy measurement on the neutron-rich Cu isotopes

The first β-decay studies of the isotope ^{74}Cu using the Total Absorption Spectroscopy (TAS) technique will be reported. The β-decay properties of neutron-rich nuclei are one of the essential nuclear physics inputs required to simulate and understand the astrophysical r process. The region around ^{74}Cu is identified in sensitivity studies as playing an important role in weak r process and influencing the A = 80 abundance peak. Comparing the β-decay strength distributions in the daughter Zn will provide a stringent constraint to the theoretical models used in astrophysical calculations. The Cu isotopes are also good candidates to probe the single-particle structure in the region because they have one proton outside the Z = 28 shell. The experiment was performed at the National Superconducting Cyclotron Laboratory (NSCL) employing the TAS technique with the Summing NaI(Tl) detector, while β electrons were measured in the NSCL beta-counting system. The experimentally obtained total absorption spectra for ^{74}Cu will be presented and the implications of the extracted beta- feeding intensities will be discussed.

4.6 Session 6

Alexander Heger
Recent advances in x-ray burst modeling

Type I X-Ray bursts (XRBs) occur on the surface of accreting neutron stars in binary star systems. They have typical recurrence times of hours to days for the most common variety, but there are also intermediateduration bursts and superburst with recurrence times of the order of years. The bursts, their nuclear reactions, and their nuclear physics in general are a very rich topic. In the regular type hydrogen-rich bursts, both the αp- and rp-process occur. They are hence sensitive to nuclei far from the line of stability, as they can be made with new and upcoming facilities such as FRIB. Unlike production of exotic nuclei in massive stars, supernovae, and binary neutron star mergers, the exotic nuclei play a key role in the energetics of the bursts and their observable light curves. Therefore, our understanding and modelling of these bursts depends on accurate experimental and nuclear determination of the nuclear reaction rates involving these nuclei. I will give an overview on X-ray burst simulations with special focus on time-dependent multi-zone models and of the different outcomes based on a range of astrophysical model parameters such as accretion rates and accretion compositors, and sensitivity to nuclear reaction rate uncertainties. The results are based on a large grid of models compiled over the years. This is complemented by targeted studies for specific regimes and input physics parameters, such as heating and nuclear reaction rates.

Yang Sun

Shell-model study of isospin-symmetry breaking and the impact in the rp-process

Isospin is a fundamental concept in particle and nuclear physics. In nuclei, the Coulomb force and other isospin non-conserving (INC) forces break both charge symmetry and charge independence. The Coulomb displacement energy (CDE) is a measure of charge-symmetry breaking while the triplet displacement energy (TDE) is regarded as a measure of breaking in charge independence. We show that the characteristic behavior of CDE and TDE can be reproduced if the INC nuclear force with J = 0 and T = 1 are introduced into large-scale shell model calculations [1]. Theoretical one- and two-proton separation energies are predicted for mirror nuclei with masses A = 42-95, and locations of the proton drip-line can thereby be suggested. Mirror energy differences (MED) and triplet energy differences (TED) in the T = 1 analogue states are other probes of isospin-symmetry breaking. Experimental data for excited states in mirror nuclei are valuable information [2,3]. We show that the INC nuclear forces have significant effect also on MED and TED in the upper fp-shell [4]. There are indications that isospin-symmetry breaking in CDE-TDE for masses and MED-TED for excited states may have the same origin. Possible impact of isospin-symmetry breaking on the rp-process nucleosynthesis is discussed. This work is collaborated with K. Kaneko, T. Mizusaki, and S. Tazaki. Research at SJTU is supported by the National Natural Science Foundation of China (No. 11135005) and by the 973 Program of China (No. 2013CB834401). [1] K. Kaneko, Y. Sun, T. Mizusaki, S. Tazaki, Phys. Rev. Lett. 110 (2013) 172505 [2] P. Ruotsalainen et al., Phys. Rev. C 88 (2013) 041308(R).. [3] P. J. Davies et al., Phys. Rev. Lett. 111 (2013) 072501. [4] K. Kaneko, Y. Sun, T. Mizusaki, S. Tazaki, Phys. Rev. C 89 (2014)

Melina Avila

Measuring key α-induced reaction rates with the MUSIC detector

Understanding stellar evolution is one of the primary objectives of nuclear astrophysics. Reaction rates involving α-particles are often key nuclear physics inputs in stellar models. For instance, there are numerous (α,p) reactions fundamental for the understanding of X-ray bursts and the production of ^{44}Ti in core-collapse supernovae. Furthermore, some (α,n) reactions are considered as one of the main neutron sources in the s-process. However, direct measurements of these reactions at relevant astrophysical energies are experimentally challenging because of their small cross section and intensity limitation of radioactive beams. The active target system MUSIC offers a unique opportunity to study (α,p) and (α,n) reactions because its segmented anode allows the investigation of a large energy range in the excitation function with a single measurement. Recent results on the direct measurement of (α,n) and (α,p) measurements in the MUSIC detector will be discussed. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract number DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

4.7 Session 7

Hye Young Lee

Neutron-induced reaction studies at Los Alamos Neutron Science Center for improving nuclear data in astrophysics

Available experimental nuclear inputs used in nucleosynthesis network calculations are limited to the accessible measurements of stable or radioactive nuclei, leaving thousands of reactions that rely on theoretically predicted reaction rates. The Hauser-Feshbach (HF) formalism is widely used to predict these reaction rates, however difficulties like renormalizations of calculated (n,γ) cross sections to experimental data or shape disagreements of (n,p) cross sections below 6 MeV among different HF codes have arisen. At Los Alamos Neutron Science Center (LANSCE), where neutrons are produced in the energy range of thermal energies to several hundreds of MeV, the direct measurement capability of neutron-induced charged particle reactions using the LENZ instrument (Low Energy NZ) has been developed to investigate (n,p) and (n,α) cross sections in close comparison with the Monte Carlo HF calculation, CoH. We also explored the total cross section measurement capability for providing nuclear structure information, which can be complementary to other direct measurements near charged-particle thresholds. I will present the progress of these ongoing projects at LANSCE for the interest of nuclear astrophysics.

Yong-Zhong Qian
Neutrinos and Nucleosynthesis

I will review the roles of neutrinos in nucleosynthesis from the big bang to supernovae and neutron star mergers. The importance of neutrino oscillations and other nuclear input will be highlighted. Implications for observations will be discussed.

Maxime Brouder
High precision mass measurements for nuclear astrophysics

I will discuss about the importance of high precision mass measurements for nuclear astrophysics, more specifically for explosive nucleosynthesis process. I will present recent and future development that will allow to extend our reach towards more exotic nuclei of relevance to the rapid neutron capture process.

Robert Andrassy
3D hydrodynamic simulations of O-shell convection

I am reporting on our team's progress in investigating fundamental properties of convective shells in the deep stellar interior during advanced stages of stellar evolution. We have performed a series of 3D hydrodynamic simulations in 4pi spherical geometry of convection in conditions similar to those in the O-shell burning phase of massive stars. We focus on characterizing the convective boundary and the mixing of material across this boundary. Results from 7683 and 15363 grids are encouragingly similar (typically within 20%). Several global quantities, including the rate of mass entrainment at the convective boundary and the driving luminosity, are related by scaling laws. We characterize the fluctuations of quantities such as the velocities in the simulations and investigate the effect of several of our assumptions, including the treatment of nuclear burning that drives the convection as well as that of entrained material from above the convection zone. The latter has potentially important implications for pre-supernova nucleosynthesis.

Michael Deaton
The matter neutrino resonance around black hole accretion disks

We are studying neutrino flavor transformations in typical neutron star merger environments. Here the high neutrino densities and geometric effects of the disk introduce transformation behaviors qualitatively different from those seen in supernovae. Discovered in thin disk models assuming flat space, the matter neutrino resonance (MNR) may behave differently around thick disks, or in the strongly-curved spacetime near a black hole. I'll present what we have learned about the MNR using a phenomenological model motivated by hydrodynamical simulations of post-merger disks around a black hole.

5 List of Posters

1. Anirudh Chiti
Chemical Abundances of Stars in the Sculptor Dwarf Spheroidal Galaxy

The study of the chemical abundances of metal-poor stars in the Sculptor dwarf spheroidal galaxy provides a venue to constrain paradigms of chemical enrichment and galaxy formation, as dwarf galaxies are thought to be the building blocks of larger systems in current hierarchical galaxy formation scenarios. Here we present metallicity and carbon abundance measurements of over 250 stars in Sculptor from medium-resolution ($R \sim 2000$) spectra taken with the Magellan/Michigan Fiber System (M2FS) mounted on the Magellan-Clay 6.5m telescope at Las Campanas Observatory. We identify 13 extremely metal-poor stars ([Fe/H] $<$ -3.0) of which 11 appear carbon-enhanced ([C/Fe] $>$ 0.7). Our results indicate that Sculptor has a larger cumulative CEMP star fraction than the halo for stars below [Fe/H] = -2.0 ($\sim$31% vs. $\sim$20%). This is possibly due to our selection bias towards extremely metal-poor stars. The high CEMP star fraction in Sculptor further suggests it to be a defining characteristic of the low metallicity Sculptor population and that the early chemical evolution of Sculptor was driven by either fallback supernova with large [C/Fe] abundance ratios or massive rotating stars with large CNO yields. Within the paradigm of hierarchical structure formation, it thus appears plausible that various halo CEMP stars have their origin in early dwarf galaxy analogs of Sculptor.

2. Benoit Cote
Connecting Nuclear Physics and Stellar Evolution to the Chemical Evolution of Galaxies (1/2)

I will present our JINA/NuGrid numerical pipeline designed to build permanent connections between the different areas involved in the field of galactic chemical evolution (GCE), which are nuclear physics, stellar evolution, observation, and galaxy evolution. I will briefly present the results of some of our experiments, such as quantifying the propagation of uncertainties into GCE predictions using a Monte Carlo approach, evaluating the impact of the stellar grid resolution in GCE applications, and measuring of the impact of modeling assumptions in GCE models using Markov Chain Monte Carlo calculations. I will focus on highlighting the challenges that we are currently facing in understanding how the elements are created and distributed inside galaxies. This includes the difficulty to reproduce the chemical evolution of heavy elements and the multiple observational constraints associated with core-collapse supernovae. This presentation will serve to set the stage for the GCE break-out session (ROS-GCE: 'r'-process, observational, and supernova needs for the JINA GCE project) that we plan to propose in order to discuss those challenges.

3. Benoit Cote
Connecting Nuclear Physics and Stellar Evolution to the Chemical Evolution of Galaxies (2/2)

I will present our JINA/NuGrid numerical pipeline designed to build permanent connections between the different areas involved in the field of galactic chemical evolution (GCE), which are nuclear physics, stellar evolution, observation, and galaxy evolution. I will briefly present the results of some of our experiments, such as quantifying the propagation of uncertainties into GCE predictions using a Monte Carlo approach, evaluating the impact of the stellar grid resolution in GCE applications, and measuring of the impact of modeling assumptions in GCE models using Markov Chain Monte Carlo calculations. I will focus on highlighting the challenges that we are currently facing in understanding how the elements are created and distributed inside galaxies. This includes the difficulty to reproduce the chemical evolution of heavy elements and the multiple observational constraints associated with core-collapse supernovae. This presentation will serve to set the stage for the GCE break-out session (ROS-GCE: 'r'-process, observational, and supernova needs for the JINA GCE project) that we plan to propose in order to discuss those challenges.

4. Pavel Denisenkov
Nuclear and stellar physics uncertainties in the modelling of the i-process nucleosynthesis in post-AGB and rapidly-accreting white dwarf stars

The H-rich material accreted, rapidly enough, onto a carbon-oxygen white dwarf in a close binary system burns under stationary conditions, resulting in an accumulation of a He shell. Later on, when the He shell experiences a thermal flash, convection driven by the flash may penetrate the H-rich envelope, ingesting H into the He convective shell. This may trigger the i process of neutron capture by heavy isotopes with a density of neutrons intermediate between those characteristic for the s and r processes. The resulting nucleosynthesis goes along the path that is 4 or 5 neutrons away from the valley of stability. The i process may also occur in a single post-AGB star if it experiences the very late thermal pulse of its He shell. I will present and discuss the results of our recent analysis of nuclear and stellar physics uncertainties that can affect theoretical predictions of the i-process nucleosynthesis yields from these stars.

5. Patrick Fasano

Modern Plunger Control with Low-Cost Microcontrollers

The plunger technique provides a valuable tool for measuring lifetimes of excited states in the 1-100 ps range. The plunger consists of a thin foil target and stopper foil separated by some controllable distance; beam-induced reactions occur in the target and the resulting nucleus of interest leaves the target foil and is completely stopped by the stopper foil. The Notre Dame Nuclear Science Laboratory has a plunger device which is approximately 30 years old. In the Notre Dame plunger apparatus, the separation between foils is measured via capacitance between the foils and is used to control the position of three dc motors. Our work has focused on a complete rebuild of the plunger vacuum systems and control electronics including a low-cost microcontroller-based feedback loop for precisely controlling servo motors with quadrature encoder outputs. Results will be presented from the commissioning experiment to measure the lifetime of the 0.87-MeV state of ^{17}O via the ^{16}O(d,p) reaction in inverse kinematics. This work has been funded in part by the National Science Foundation under grant number PHY-1419765; and the generosity of Diane and Bryant Hichwa, administered through the University of Notre Dame College of Science.

6. Carl Fields

On The Origin of The Elements: The Spectacular Role of White Dwarfs

We investigate properties of carbon-oxygen white dwarfs (WD) to the composite uncertainties in the nuclear reaction rates using the stellar evolution toolkit, Modules for Experiments in Stellar Astrophysics (MESA). The first Monte Carlo (MC) stellar evolution studies using complete stellar models are performed for a 3 solar mass model evolved from the pre main-sequence (pre-MS) to the first thermal pulse (1TP). We survey the WD mass, composition, and structure properties as a function of 26 STARLIB reaction rates covering hydrogen and helium burning. In general, we find that the ^{12}C$(\alpha,\gamma)^{16}$O reaction dominates the global and core properties causing a variation of M $\approx$ 0.008 to 0.03 solar mass for the core mass, t1TP $\approx$ 7 to 20 Myr for the age, Xc(^{12}C) $\approx$ 0.02 to 0.26, and Xc(^{16}O) $\approx$ 0.06 to 0.32 from the arithmetic mean value at 1TP. We also perform MC stellar evolution studies for a fixed rate distribution of ^{12}C$(\alpha,\gamma)^{16}$O and find, in this case, the properties are most affected the ^{14}N(p,γ)^{15}O and triple-α reaction. Lastly, we consider a grid of 1 to 6 solar mass models evolved from the pre-MS to the final WD to probe the sensitivity of the initial-final mass relation to experimental uncertainties in the H and He reaction rates.

7. Cathleen Fry

Constraining resonance strengths for $^{30}P(p,\gamma)^{31}S$ with lifetime measurements

In classical novae, the ^{30}P(p,γ)^{31}S reaction potentially acts as a bottleneck in nucleosynthesis flow to higher masses. Knowledge of this reaction rate is necessary for the modeling of elemental and isotopic ratios in classical novae, which affect proposed nova thermometers and presolar grain identification, respectively. While most of the resonance energies are known experimentally, the corresponding resonance strengths are not yet known. As a step towards determining experimental resonance strengths, we plan to measure the lifetimes of these resonances, using the Doppler Shift Lifetime (DSL) setup at TRIUMF. A measurement of the lifetimes of these states will provide the total widths of these resonances, and can be used along with the spins and proton branching ratios to determine resonance strengths.

8. Mayukh Gangopadhyay

Constraints on Supersymmetric Inflation

Inflation is one of the most discussed cosmological problems in last few decades. There are different classes of inflation models. With the recent advanced astronomical observations from WMAP and PLANCK some classes of inflation models are almost ruled out. On the other hand Supersymmetry is one of the most discussed theories in particle physics. But it has a very good motivation from primordial inflation. Supersymmetry can explain naturally the existence of scalar inflation also it can help to maintain the flatness of the inflation potential through the cancellation of radiative corrections. Now inflation has connections with supergravity in different models such as chaotic, hybrid, new, topological and so on. Thus Supersymmetric Inflation is one of the prime candidates to explain the mysteries of the early universe. Now Supersymmetry itself is highly constrained by experimental particle physics. In this work we are trying to understand Supersymmetric inflation and chances of its discovery in recent or future observations and experiments.

9. Benjamin Guerin

Fake or Fortune: Examining Art Pigments via XRF and Raman Spectroscopy

This project is focused on the implementation of X-ray flourescence (XRF) and Raman spectroscopy methods of non-destructive composition analysis. XRF occurs when a material is bombarded by X-rays, exciting component atoms. When these atoms deexcite, the photon emitted carries a characteristic energy. Raman spectroscopy relies on the inelastic scattering of photons. A laser is used to excite molecules to higher vibrational modes. When the molecules de-excite, the spectrum of the emitted photons is the Raman spectrum. This spectrum can then be compared to databases of known Raman spectra to determine what the material is. While XRF is a popular method for pigment analysis, it is not enough on its own since it only identifies specific elements. Both these methods were used to analyze a collection of leaflets from what is thought to be a mid-15th century copy of a popular Christian devotional book, the book of hours. A common modern practice is to cut these books apart and sell the individual leaflets as pieces of art. Notre Dame's curator of ancient and medieval manuscripts, David Gura, hopes to reunite all the pages from this particular copy. We used these two methods to verify the legitimacy of the leaflets he has already procured. Our hope is to make these tools of analysis available to other departments who might benefit as well as possibly construct a mobile setup for off-campus applications. This project was supported by the University of Notre Dame Rare Books and Special Collections Department and the National Science Foundation under contract number PHY-1419765.

10. Matt Hall
A Measurement of the Nuclear Levels in ^{19}Ne using GODDESS

A direct way to test nova explosion models is to observe γ rays created in the decay of radioactive isotopes produced in the nova. One such isotope, ^{18}F, is believed to be the main source of observable 511- keV γ rays. The main destruction mechanism of ^{18}F is thought to be the ^{18}F(p,α)^{15}O reaction, and the uncertainty in the reaction rate is attributed to uncertainties in the energies, spins, and parities of the nuclear levels in 19Ne above the proton threshold. A ^{3}He beam was used at Argonne National Lab in an effort to understand the levels in ^{19}Ne via the ^{19}F(^{3}He,t)^{19}Ne reaction. Gammasphere ORRUBA Dual Detectors for Experimental Structure Studies (GODDESS) was used to measure γ rays from the decay of 19Ne in coincidence with the reaction tritons. Preliminary data from the experiment will be presented. This research was supported by the National Science Foundation, the US DOE Office of Nuclear Physics and the National Nuclear Security Administration.

11. Madison Harris
Simulations for a new detector of low-energy β-delayed protons at NSCL

Our current understanding of classical novae is limited by uncertainties in certain key nuclear reaction rates. Of particular interest is the reaction rate of ^{30}P(p,β)^{31}S, which is a potential nucleosynthesis bottleneck in classical novae. In order to reduce the uncertainty in that and other key reaction rates, a new detector based on micro pattern gas amplifier technology is being designed at the National Superconducting Cyclotron Laboratory on the campus of Michigan State University. Through the detection of β-delayed proton emission from ^{31}Cl in the new detector, we will be able to measure the proton branching ratios of 31S resonances providing a key component of the ^{30}P(p,γ)^{31}S resonance strengths. To aid in the design of the detector, Geant4 simulations of this device have been run to determine the behavior of protons of different energies in a variety of gases and under different pressures. More specifically, we have investigated the energy deposition of protons as a function of position in the detector in order to study how various pad geometries affect efficiency and the background due to βparticles. Most recently, we have been optimizing the detector's geometry by examining how various pad sizes and an outer ring to veto high energy protons affect both efficiency and background.

12. Jun Hu

Measurement of the ^{1}H(^{17}F,α)^{14}O cross section at TwinSol

The ^{14}O(α,p)^{17}F reaction is important during the ignition phase of X-ray bursts, but significant uncertainties in this reaction rate have persisted due to uncertainties in the properties of excited states in ^{18}Ne and the unmeasured direct reaction cross section. The ^{1}H(^{17}F,α)^{14}O reaction, the time-inverse of the ^{14}O(α,p)^{17}F g.s. reaction, was studied using a radioactive ^{17}F beam produced by the TwinSol separator at the University of Notre Dame. Some preliminary results will be represented.

13. Max Katz

Mergers and Collisions of White Dwarfs on Adaptive Meshes

Observational evidence has been mounting in recent years for the case that white dwarf mergers and collisions are potential progenitors of Type Ia supernovae. This exciting development has resulted in a number of studies focused on computationally modeling these events, using both particle-based codes and grid-based codes. It has become clear that for both mergers and collisions, spatial and temporal resolution plays a key role in obtaining accurate results. Additionally, there are important questions to be resolved about whether detonations observed in these numerical simulations are true physical phenomena or are numerically seeded. Accurate initial conditions also play a key role for the mergers in particular. We have used the compressible hydrodynamics code CASTRO, built on the BoxLib adaptive mesh refinement library, to simulate these binary systems, in particular focusing on the role targeted mesh refinement can play in ensuring both accurate small-scale nuclear burning and accurate large-scale system dynamics. In this presentation I will describe the code improvements that have been made to CASTRO for the purpose of studying binary white dwarf systems, and we will discuss what our simulation results imply for the future of computational modeling of white dwarf mergers as Type Ia supernova progenitors.

14. Zidu Lin
Neutrino Pasta Scattering in Supernovae

Nuclear pasta involves non-spherical shapes of nuclear matter. Various phases of nuclear pasta involving complex shapes of nuclear matter are expected in supernovae and neutron stars. Neutrinos can scatter coherently from these shapes because supernova neutrino wavelengths are comparable to the pasta size. We calculate the static structure factor describing neutrino pasta scattering from large-scale MD simulations involving 51200 nucleons and simulation times of 7.8*108 fm/c. Our results for the neutrino opacity can eventually be included in supernova simulations.

15. Jonas Lippuner
Influence of neutrinos on r-process nucleosynthesis in black hole–neutron star mergers

During a black hole–neutron star merger, baryonic material can be dynamically ejected. Because this ejecta is extremely neutron-rich, the r-process rapidly synthesizes heavy nuclides as the material expands and cools. This can contribute to galactic chemical evolution of the r-process elements and lead to a short- lived optical transient, called a kilonova, powered by the radioactive decay of the heavy nuclides. We use the nuclear reaction network SkyNet to model r-process nucleosynthesis under varying levels of neutrino irradiation by post-processing tracer particles in the ejecta of a full numerical relativity simulation of a black hole–neutron star merger. We find the ejected material robustly produces the second and third r- process peaks, whose abundances remain unchanged even for very high neutrino luminosities, due to the rapid velocities of the outflow. Nonetheless, we find that neutrinos can have an impact on the detailed abundance pattern by significantly enhancing the amount of material produced in the first peak around A$\sim$78. Electron neutrinos are captured by neutrons to produce protons while neutron capture is occurring. These protons rapidly form low-mass seed nuclei, a fraction of which eventually ends up in the first peak after neutron capture ceases.

16. Diego Lonardoni
Hyperons in neutron stars: a strange puzzle

The onset of hyperons in the core of neutron stars and the consequent softening of the equation of state have been questioned for a long time. We tackle the problem within a quantum Monte Carlo computational scheme. We first show that a repulsive three-body hyperon-nucleon force is needed to correctly describe the systematics of Λ-hypernuclei. Then, we employ the same potential to determine the equation of state and the mass-radius relation of an infinite system of neutrons and Λ particles. We find dramatic effects on the predicted maximum mass depending on the details of the three-body hyperon-nucleon force. Our results suggest that stronger constraints on the hyperon-neutron force are necessary in order to properly assess the role of hyperons in neutron stars.

17. Alex Long

An indirect study of the stellar ^{34}Ar(α,p)^{37}K reaction rate through high-precision ^{40}Ca(p,t)^{38}Ca reaction measurements

The ^{34}Ar(α,p)^{37}K reaction is believed to be one of the last in a sequence of (α,p) and (p,γ) reactions within the Tz = +1, sd-shell nuclei, known as the αp-process. This process is expected to heavily influence the shape and rise times of luminosity curves coming from type 1 X-ray bursts (XRB's). With very little experimental information known on many of the reactions within the αp-process, stellar rates are calculated using a statistical model, such as Hauser-Feshbach. Questions on the applicability of a Hauser-Feshbach model of the ^{34}Ar(α,p)^{37}K reaction arise due to level density considerations in the compound nucleus, ^{38}Ca. We have performed high energy-resolution zero-degree ^{40}Ca(p,t)^{38}Ca measurements with the K=600 spectrograph at iThemba LABS in order to identify levels above the α-threshold in ^{38}Ca. States identified in this work were then used to determine the ^{34}Ar(α,p)^{37}K reaction rate based on a narrow resonance formalism. Comparisons are made to two standard Hauser-Feshbach model predicted rates at XRB temperatures.

18. Patrick O'Malley

TwinSol Prospects for Nuclear Astrophysics

TwinSol, a pair of coupled, superconducting solenoids, was one of the first devices capable of producing beams of radioactive nuclei. A primary beam from the University of Notre Dame (UND) accelerator is used to bombard a primary target producing a secondary beam in flight. TwinSol is used to gather, separate, and focus the recoils. Since it was commissioned at the UND in 1997, at least 58 publications have reported data from its use. There are hundreds of collaborators from many different countries that use this facility. Several upgrades have been performed for TwinSol, including a multi-cell gas production target and a mounting system for silicon strip detector arrays. Other upgrades currently underway will be discussed along with plans for measurements of astrophysical interest.

19. Rodney Orford
High-precision mass measurements at the Canadian Penning trap mass spectrometer through a phase-imaging ion-cyclotron-resonance technique

The Canadian Penning trap mass spectrometer (CPT) is currently located in the CARIBU facility at Argonne National Laboratory where intense radioactive beams of neutron-rich nuclei are produced from the spontaneous fission of ^{252}Cf. The scarcity of nuclear data, including masses, on the neutron-rich side of the valley of stability has limited the accuracy and progression of calculations relating to the astrophysical rapid neutron capture process of nucleosynthesis. Since its move to CARIBU in 2010, the CPT has successfully measured the masses of more than 110 isotopes by measuring the cyclotron frequency of ions through a time-of-flight (TOF) technique. An upgrade to a position-sensitive microchannel plate detector at the CPT has allowed for the determination of masses by recording the phases of radial motion of trapped ions. This phase-imaging method is intrinsically more efficient than the TOF technique, and provides an order of magnitude improvement in mass-resolving power without a loss in precision. Preliminary results from a recent exploratory measurement campaign aimed at previously unmeasured neutron-rich rare-earth isotopes will be shown.

20. David Perez Loureiro
Development of a low-background proton detector for studying low energy resonances relevant in stellar nucleosynthesis

Classical novae and type I x-ray bursts are explosive events that occur in close binary systems containing a compact object, either a white dwarf (novae) or a neutron star (x-ray bursts). Our current understanding of nucleosynthesis and energy generation in these astrophysical scenarios is limited by the uncertainties in particular thermonuclear reaction rates. Two key reactions are ^{30}P(p,γ)^{31}S, which is a potential nucleosynthesis bottleneck in classical novae, and ^{15}O(α,γ)^{19}Ne, the initial break-out channel from the Hot CNO cycle, which triggers the nucleosynthesis of heavier elements in type I x-ray bursts. A method to constrain these two reaction rates is to determine the charged-particle branches of key resonances using the β-delayed particle emission from proton-rich precursor nuclei, like ^{31}Cl and ^{20}Mg. A new gaseous detector is being developed at the National Superconducting Cyclotron Laboratory at Michigan State University to detect these low-energy charged particles. During the conceptual design stage of the project, a Geant4-based simulation was created to define its geometry and optimize its performance by modeling the interactions of positrons and β-delayed charged particles within the detector's active volume. While a calorimetric low granularity pad-plane will be sufficient to study the ^{30}P(p,γ)^{31}S reaction via ^{31}Cl(βp)^{30}P, the installation of a high-granularity pad plane will provide multi-particle detection capabilities, which will allow the first investigation of the ^{15}O(α,γ)^{19}Ne reaction via ^{20}Mg(βpα)^{15}O.

21. Ilka Petermann
On the (non-)monotonicity of pre-supernova models

Studies of pre-supernova models have a revealed a non-monotonic behavior with respect to properties such as the density structure, compactness or iron core mass. We aim at understanding this behavior in analyzing detailed models computed with the stellar evolution code MESA and study its implications on the final fate of massive stars.

22. Sherwood Richers
Equation of State Dependence of Gravitational Waves from Rapidly-Rotating Core Collapse

We carry out axisymmetric simulations of rotating core-collapse, exploring over 92 precollapse rotational configurations and 18 different finite-temperature microphysical equations of state (EOS) using the general-relativistic hydrodynamical code CoCoNuT. Our focus is on gravitational wave (GW) emission. We find that the GW wave signature depends systematically on the rotation rate of the inner core at bounce and the compactness of the protoneutron star (PNS), set by the EOS and rotation. The GW signal from core bounce is almost independent of the EOS. However, the frequency of the post-bounce ring down signal from the fundamental quadrupole oscillation mode of the PNS is dependent on both rotation and the EOS, increasing with rotation rate and compactness. We will discuss the origin of the EOS-dependent f-mode frequency variation and its potential observability with Advanced LIGO.

23. Christian Ritter
Convective-reactive nucleosynthesis in low-mass and massive stars

Convective-reactive events in stellar evolution may give rise to unusual and unique nucleosynthesis pathways. An example is the i process that occurs in the convective-reactive ingestion of H into He-shell flash convection. Present nucleosynthesis models are based on 1D stellar evolution simulations which are not able to account for the complex, global oscillatory instabilities revealed by 3D hydrodynamic simulations. In order to simulate nucleosynthesis according to such 3D simulations with the required large number of species (>1000) we adopt a new advective-reactive post-processing approach similar to the 1D post-processing for the yield calculations, but in 3D. We show first results of this advective 3D post- processing (A3DPP) of the i-process site of the post-AGB star Sakurai's object. Another example of convective-reactive nucleosynthesis is the O-C shell merger in massive stars. Based on multi-zone nucleosynthesis models we discuss the strong production of K, Cl, and Sc. This hydrodynamic nuclear production site may address the general deficiency of K and Sc in chemical evolution models. Like the H- ingestion phase of evolution 3D hydrodynamic simulations will eventually be required for realistic predictions.

24. Ermal Rrapaj

Microscopically constrained mean field models from chiral nuclear thermodynamics

We explore the use of mean field models to approximate microscopic nuclear equations of state derived from chiral effective field theory across the densities and temperatures relevant for simulating astrophysical phenomena such as core-collapse supernovae and binary neutron star mergers. We consider both relativistic mean field theory with scalar and vector meson exchange as well as energy density functionals based on Skyrme phenomenology and compare to thermodynamic equations of state derived from chiral two- and three-nucleon forces in many-body perturbation theory. Quantum Monte Carlo simulations of symmetric nuclear matter and pure neutron matter are used to determine the density regimes in which perturbation theory with chiral nuclear forces is valid. Within the theoretical uncertainties associated with the many-body methods, we find that select mean field models describe well microscopic nuclear thermodynamics. As an additional consistency requirement, we study as well the single-particle properties of nucleons in a hot/dense environment, which affect e.g., charged-current weak reactions in neutron-rich matter. The identified mean field models can be used across a larger range of densities and temperatures in astrophysical simulations than more computationally expensive microscopic models.

25. Stou Sandalski

Nucleosynthetic Advection Post-Processing on a Tetrahedral Grid

The intermediate neutron process or i-process is characterized by nucleosynthesis driven by the entrainment and burning of H in the He-convection zone of AGB and post-AGB stars. Understanding the i- process and its signature abundances requires tracking many nuclear species as they are transported around the star and their concentrations evolve. However tracking a sufficient number of elements with high resolution 3D hydro is prohibitively expensive partly due to the large number of nucleosynthetic calculations that would need to be performed for each one of the large number of simulation cells. Our approach is to perform the hydrodynamic calculations in high resolution on a cartesian grid using the two fluid PPMstar code then to resample the velocity and concentration information onto a low resolution tetrahedral grid. During post-processing the grid is loaded from disk and we assign concentrations for the rest of the species of interest to each tetrahedral cell and track the evolution of their concentrations using the NuGrid framework. At each post-processing time step the re-sampled velocity field is used to advect the individual elements and then nucleosynthesis is performed to update the concentrations. This approach will allow us to study the sites of the i-process at a reasonable cost.

26. Rick Sarmento

Following the Cosmic Evolution of Pristine Gas - The transition from Pop III to Pop II and the chemical evolution of early stars

We study the enrichment of the primordial gas in turbulent flows and the subsequent effect on Population III and Population II star formation rates, overall metallicity and likely metal composition. Our enhancements to the large-scale cosmological code RAMSES (Teyssier 2002) allow us to trace the evolution of the metallicity as well as the pristine gas fraction (gas with $Z < Z_{crit}$) of simulation cells while modeling supernova (SN) induced turbulent mixing. Additionally, we track primordial metals, ZP. This material is generated by Pop III stars and likely has abundance ratios much different from later stellar generations. We find that by modeling metal free star formation in unmixed regions of gas at least as many Pop III stars are formed within metal-enriched protogalaxies as are formed in purely metal free- objects. Finally, using a simple model for Pop III SNe ejecta (Heger 2016), we find good agreement between our Pop II star's chemical composition and a representative sample of MW CEMP stars studied by Keller et al. (2014).

27. Konrad Schmidt

Structure examinations of the JENSA gas jet target

The Jet Experiments in Nuclear Structure and Astrophysics (JENSA) gas jet target enables the direct measurement of previously inaccessible reactions with reaccelerated radioactive beams at the National Superconducting Cyclotron Laboratory (NSCL), USA.

JENSA is going to be the main target for the recoil separator for capture reactions (SECAR) at the Facility of Rare Isotope Beams (FRIB). Commissioning and first experiments at Oak Ridge National Laboratory (ORNL) showed a highly localized, pure gas target with a density of about 1019 atoms per square centimeter. Results from recent examinations of the jet structure at NSCL will be presented. This research is supported by the U. S. Department of Energy and the National Science Foundation.

28. Christopher Seymour
Inelastic α Scattering Reactions and the P-Process

Production of proton-rich elements beyond the iron peak is attributed to p-process nucleosynthesis. The p-process is thought to proceed via photodisintegration reactions which can occur in astrophysical environments like supernovae. Network calculations of abundances for p-process nuclei depend highly on the photodisintegration reaction rates, of α-emitting reactions in particular. Studying the associated elastic and inelastic α scattering reactions will help improve our understanding of the α optical potentials. Scattering data around or below the Coulomb barrier are scarce, but needed to test statistical models that use these nuclear potentials to calculate the photodisintegration reaction rates. α scattering measurements were carried out in 2011 at Notre Dame, using the FN tandem accelerator and an array of 32 silicon diode detectors with excellent angular and energy resolution. New experimental angular distributions of the 2+ inelastic cross sections for several nuclei near Z=50 are presented.

29. Sabrina Strauss
β-Delayed Neutron Emission using the β Paul Trap

The path of the r process is dependent on multiple environmental factors, including the neutron density at the site of the process. The neutron density is affected by β delayed neutron (BDN) emission, a type of exotic decay that occurs in nuclei with β decay Q-values greater than the neutron separation energy. There are two important quantities that affect r process simulations: the BDN emission probability, and the neutron energy distribution. Existing techniques only measure one of the two quantities at a given experiment. At Argonne National Laboratory, we have developed a new technique for studying BDN emission, and getting both the probability and energy spectrum simultaneously, using the β Paul trap (BPT) to detect the recoiling ion, in lieu of the neutron. Eight isotopes were studied at Californium Rare Isotope Breeder Upgrade (CARIBU) using the BPT. The trapping technique allows for multiple, independent calculations of the probability by having 3 independent ways to calculate the total number of decays. Results from the calculations using the β-γ coincidence data will be presented.

30. Sean Sweany
Probing Neutron Star Properties from Heavy Ion Collisions

The symmetry energy contribution in the nuclear equation of state (EOS) can be used to learn about properties in the interior of neutron stars, like the composition of the star as well as its radius. So far constraints have been made on the EOS in symmetric nuclear matter in a range from 1 to 4.5 times saturation density while constraints on asymmetric nuclear matter above saturation density are not well determined [1][2]. Heavy ion collisions (HIC) have been used to probe the density dependence of the equation of state so as to gain better constraints for asymmetric matter [2]. At NSCL, we use the HiRA (High Resolution Array), an array of 20 charged particle telescope to measure fragment isotopes produced in HIC help to provide constraints on the EOS. Each of the HiRA telescope consists of a 32 strip, single- sided ΔE detector, and a 32 strip double-sided E detector. Finally, behind the two strip Si detectors is a 2 by 2 array of 4cm long CsI crystals [3]. We are currently in the process of upgrading the HiRA array from the 4 cm long CsI crystals to 10 cm long ones. The longer crystals will allow us to detect higher energy fragments from HIC and be able to better constrain the nuclear equation of state at density above the saturation density. [1] M.B. Tsang et al. Phys. Rev. Lett. 102, 122701 (2009). [2] D.D.S Coupland, W.G. Lynch, M.B. Tsang, P. Danielewicz, Y. Zhang, Phy. Rev. C 84, 054603 (2011). [3] M.S. Wallace, NIM A 583 (2007) 302-312.

31. Rachel Taverner
Applications of the ^{88}Sr(t,3He+γ) reaction

The charge-exchange group at the NSCL is interested in extracting Gamow-Teller transition strengths from medium- and heavy-mass nuclei for the purpose of calculating weak reaction rates, specifically electron capture rates. These rates are, in turn, used in simulations of astrophysical phenomena, including those of core-collapse supernovae, in which pf and sdg shell nuclei play an important role. Because these simulations also rely heavily on theoretical calculations, because it is impossible to experimentally determine rates for all nuclei, it is important to have accurate models with which to generate these weak rates. Shell model calculations are used to generate Gamow-Teller strengths for a wide range of nuclei. In an effort to reach heavier mass regions, a core of Strontium-88 is used. The calculations assume that this core is inert, and the upcoming ^{88}Sr(t,3He+γ) experiment at the NSCL aims to determine whether this assumption is valid.

32. Jinmi Yoon

Carbon Plateaus Among Carbon-Enhanced Metal-Poor Stars

Several recent studies have suggested the existence of bi-modality in the distribution of absolute carbon abundances, A(C), among carbon-enhanced metal-poor (CEMP) stars – most CEMP-s stars belong to a high-C band (A(C)$\sim$8.25), while most CEMP-no stars reside on a low-C band ($\sim$6.5). The number of CEMP stars considered by the individual studies is, however, quite small, so we have compiled all available high- resolution spectroscopic data as well as several medium-resolution results for CEMP stars, in order to further investigate the existence of the claimed carbon bi-modality, and to consider what can be learned about the progenitors of CEMP-s and CEMP-no stars based on the A(C) distribution.

6 List of Participants

LAST	first	institute
AHN	Sunghoon (Tony)	NSCL
ANDRASSY	Robert	University of Victoria
ARCONES	Almudena	TU Darmstadt
AVILA	Melina	Argonne National Laboratory
AYOUB	Sara	Michigan State University
BARTON-ROWLEDGE	Mackenzie	University of Washington
BEERS	Timothy	University of Notre Dame
BENNETT	Michael	Michigan State University
BRODEUR	Maxime	University of Notre Dame
BROWNE	Justin	NSCL
BROWN	Edward	Michigan State University
CABALLERO	Olga Liliana	University of Guelph
CAPLAN	Matthew	Indiana University
CHHAYA	Kamal	Government Science College
CHITI	Anirudh	MIT
CHOMIUK	Laura	Michigan State University
CLARK	Jason	Argonne National Laboratory
CONNOLLY	Ryan	Michigan State University
COTE	Benoit	Michigan State University
COUDEF	Manoel	University of Notre Dame
DAVIS	Andrew	The University of Chicago
DEATON	Michael	North Carolina State University
DEBOER	Richard	225 Nieuwland Science Hall
DEIBEL	Alex	Michigan State University
DENISENKOV	Pavel	University of Victoria
DILLMANN	Iris	TRIUMF
DOMBOS	Alex	MSU/ NSCL
EZZEDDINE	Rana	MIT/ Michigan State University
FASANO	Patrick	University of Notre Dame
FATTOYEV	Farrooh	Indiana University
FIELDS	Brian	University of Illinois
FIELDS	Carl	Arizona State University
FREBEL	Anna	MIT

FRENTZ	Bryce	University of Notre Dame
FROHLICH	Carla	North Carolina State University
FRY	Brian	University of Illinois
FRY	Cathleen	MSU/ NSCL
GANGOPADHYAY	Mayukh	University of Notre Dame
GASTIS	Panagiotis	Central Michigan University
GEORGE	Sebastian	Max-Planck-Institut für Kernphysik
GILARDY	Gwenaelle	Bordeaux University/ Notre Dame
GLASSMAN	Brent	NSCL
GREFENSTETTE	Brian	California Institute of Technology
GUERIN	Benjamin	University of Notre Dame
HAGER	Ulrike	NSCL
HALL	Matthew	University of Notre Dame
HANSEN	Terese	Carnegie Observatories
HARRIS	Madison	Michigan State University/ NSCL
HEGER	Alexander	School of Physics and Astronomy Monash University
HERWIG	Falk	University of Victoria
HINNEFELD	Jerry	Indiana University South Bend
HOLMBECK	Erika	University of Notre Dame
HONG	Jun	Michigan State University , NSCL
HOROWITZ	Charles	Indiana University
HU	Jun	University of Notre Dame
KATZ	Max	Stony Brook University
KILBURN	Micha	University of Notre Dame
KOROBKIN	Oleg	Los Alamos National Laboratory
LEE	Duane	Vanderbilt/ Fisk University
LEE	Hye Young	Los Alamos National Laboratory
LENTNER	Geoffrey	University of Notre Dame
LIN	Zidu	Indiana University Bloomington
LIPPUNER	Jonas	Caltech
LONARDONI	Diego	NSCL/ MSU; LANL
LONG	Alexander	University of Notre Dame
LYONS	Stephanie	University of Notre Dame
MATHEWS	Grant	University of Notre Dame
MCLAUGHLIN	Gail	North Carolina State University
MEISEL	Zach	University of Notre Dame
NAQVI	Farheen	NSCL
NIKAS	Stylianos	Central Michigan University

NYSTROM	Andrew	University of Notre Dame
O'SHEA	Brian	Michigan State University
OMALLEY	Patrick	University of Notre Dame
ONG	Wei Jia	Michigan State University, NSCL
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