# FORTHCOMING INSTITUTE CONFERENCES

## MAY 2015 – JULY 2017

### 2015

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<td>18–22 May</td>
<td>Nuclear Physics in Astrophysics VII: 28th EPS Nuclear Physics Divisional Conference</td>
<td>York, UK</td>
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<td>1–3 June</td>
<td>Theory Meets Experiment: Molecular Nanoscience and Applications</td>
<td>London, UK</td>
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### 2017

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See [www.iop.org/conferences](http://www.iop.org/conferences) for a full list of IOP one-day meetings.

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Web [www.iop.org/conferences](http://www.iop.org/conferences)
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Scientific programme

Sunday 17 May

16:00 – 18:00  Conference registration at The Royal York Hotel

Monday 18 May

08:00  Registration

09:00  Welcome address

Session 1 – Explosive scenarios

09:20  Invited presentation – Modeling type Ia supernova explosions
Fritz Roepke, Universität Würzburg, Germany

09:50  PUSHing 1D CCSNe to explosions: Model and SN 1987A
Carla Frohlich, North Carolina State University, USA

10:10  Multidimensional hydrodynamics simulations to improve our understanding of stellar evolution
Philipp Edelmann, Heidelberger Institut für Theoretische Studien, Germany

10:30  Morning refreshment break

Session 2 – Explosive scenarios

11:00  Invited presentation – Neutrino-nucleus reactions and their role in supernova dynamics and nucleosynthesis
Karlheinz Langanke, GSI Helmholtzzentrum für Schwerionenforschung, Germany

11:30  First results from the last measurement concerning $^{19}$Ne spectroscopic properties of astrophysical importance via a new method of inelastic scattering.
Florent Boulay, Grand Accélérateur National d’Ions Lourds (GANIL), France

11:50  Study of excited states of $^{35}$Ar through $\beta$-decay of $^{35}$K for nucleosynthesis in novae and X-ray bursts
Antti Saastamoinen, Texas A&M University, USA

12:10  Asymptotic normalisation coefficients from the $^{26}$Al(d,p)$^{27}$Al reaction, mirror nuclei study and application to nuclear astrophysics
Vincent Margerin, University of Edinburgh, UK

12:30  Lunch
Session 3 – Explosive scenarios

14:00 Measurement of the p-process branching point reaction $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ in inverse kinematics with DRAGON
Jennifer Fallis, TRIUMF, Canada

14:20 Study of the low energy $\alpha$-nucleus optical potential using a (p,$\alpha$) reaction
György Gyürky, Institute for Nuclear Research (Atomki), Hungary

14:40 Post-processing nucleosynthesis simulations for the production of the light p-nuclei
Kathrin Göbel, Goethe University Frankfurt, Germany

15:00 Investigation of the reaction $^{56}\text{Fe}(n,\gamma)^{57}\text{Fe}$ at FAIR
Tanja Heftrich, Goethe-University Frankfurt, Germany

15:20 Afternoon refreshment break

Session 4 – Explosive scenarios

16:00 Type Ia supernovae from exploding oxygen-neon white dwarfs
Kai Marquardt, University of Würzburg, Germany

16:20 Gamma-ray line diagnostics of supernova explosions – SN2014J and Cas A
Thomas Siegert, Max Planck Institut für Extraterrestrische Physik, Germany

16:40 Using stellar observations to trace the formation processes of Mo, Ru, Pd, and Ag.
Camilla Hansen, DARK Cosmology Centre, Denmark

17:00 Close of day one

17:15 Welcome reception at The Royal York Hotel

18:00 – 19:30 Whisky tasting at The Royal York Hotel
Tuesday 19 May 2015

08:30 Registration

Session 5 – Nuclear structure, reactions and theory

09:00 Invited presentation – Nuclear astrophysics with indirect methods
Carlos Bertulani, Texas A&M University, USA

09:30 Mirror nuclei and insights into cross-sections for reactions of astrophysical interest
David Jenkins, University of York, UK

09:50 New direct investigations of the $^{19}$F($p,\alpha^{0}$)$^{16}$O reaction down to 200 keV
Ivano Lombardo, University of Napoli Federico II / INFN-Napoli, Italy

10:10 Theoretical cross sections in the $^{12}$C(α,γ)$^{16}$O reaction
Masahiko Katsuma, Osaka City University, Japan

10:30 Morning refreshment break

Session 6 – Nuclear structure, reactions and theory

11:00 Talk title tbc
Presenter tbc

11:20 Microscopic description of r-process nuclei fission properties
Samuel Andrea Giuliani, Technische Universität Darmstadt, Germany

11:40 Beyond BCS pairing in high-density neutron matter
Arnau Rios Huguet, University of Surrey, UK

12:00 $\alpha$-induced reaction cross sections in the mass range $A \approx 20 – 50$: a critical review
Peter Mohr, Diakonie-Klinikum, Germany

12:20 Lunch and exhibition

Session 7 – Galactic chemical evolution / Big bang nucleosynthesis

14:00 Invited presentation – Primordial nucleosynthesis after Planck
Brian Fields, University of Illinois, USA

14:30 Search for resonant states in $^{10}$C and $^{11}$C and their impact on the primordial $^7$Li abundance
Faïrouz Hammache, Institut de Physique nucléaire d’Orsay, France

14:50 Trojan Horse cross section measurements and their impact on primordial nucleosynthesis
Rosario Pizzone, INFN LNS, Italy
15:10  Nuclear forces towards the drip-line viewed from the study of neutron-rich F isotope  
Olivier Sorlin, GANIL, France

15:30  Afternoon refreshment break

Session 8 – Galactic chemical evolution / Big bang nucleosynthesis

16:00  Invited presentation – Galactic chemical evolution: Strengths, weaknesses, and hidden secrets  
Brad Gibson, University of Central Lancashire, UK

16:30  Subclasses of type Ia Supernovae as the origin of [alpha/Fe] ratios in dwarf spheroidal galaxies  
Chiaki Kobayashi, University of Hertfordshire, UK

16:50  The key role of SNIa at different metallicities for galactic chemical evolution of p-Nuclei  
Claudia Travaglio, INAF - Astrophysical Observatory Turin, Italy

17:10  Poster and Exhibitors session

19:30  Close of day two
Wednesday 20 May 2015

08:30 Registration

Session 9 – Neutron stars and equation of state

09:00 Invited presentation - The quest for the equation of state of high-density stellar matter
Stefan Typel, GSI Helmholtzzentrum für Schwerionenforschung, Germany

09:30 Neutron star equations of state with optical potential constraint
Sofija Antic, GSI Helmholtzzentrum für Schwerionenforschung, Germany

09:50 The origin of lighter heavy elements in neutrino-driven winds and of heavy r-process elements in neutron star mergers
Almudena Arcones, Technische Universitaet Darmstadt and GSI Helmholtzzentrum für Schwerionenforschung, Germany

10:10 Neutrino-driven wind from neutron star merger remnants
Albino Perego, Technische Universitaet Darmstadt, Germany

10:30 Morning refreshment break

Session 10 – Exotic Nuclei

11:00 Invited presentation – Measurement of beta-delayed neutron emitters for astrophysics and reactor physics
Iris Dillmann, TRIUMF, Canada

11:30 Measurement of 40 new β-decay half-lives across the n=82 shell gap: Implications for the astrophysical r-process
Giuseppe Lorusso, National Physical Laboratory, UK

11:50 Beta-decay of proton-rich nuclei beyond $^{72}$Kr; implications for the astrophysical rp-process
Laura Sinclair, University of York, UK

12:10 First experimental indication of β-delayed neutron emission for very exotic nuclei beyond N=126
Roger Caballero-Folch, Universitat Politècnica de Catalunya (UPC), Spain / TRIUMF, Canada

12:30 Lunch and exhibition

14:00 Conference excursion (See http://npa7.iopconfs.org/176010 for more details)

17:00 Close of day three
Thursday 21 May 2015

08:30  Registration

**Session 11 – Stellar evolution and nucleosynthesis**

09:00  **Invited presentation – Talk title tbc**
Falk Herwig, University of Victoria, Canada

09:30  **The intermediate neutron-capture process in stars**
Marco Pignatari, University of Basel, Switzerland

09:50  **Invited presentation – Probing horrendous space kablooies through horrendous laboratory kablooies**
Anuj Parikh, Universitat Politecnica de Catalunya, Spain

10:20  **Theory of stellar convection: removing the mixing-length parameter**
Stefano Pasetto, University College London, UK

10:40  Morning refreshment break

**Session 12 - Stellar evolution and nucleosynthesis**

11:10  **Invited presentation – Nucleosynthesis in massive stars**
Georges Meynet, Geneva University, Switzerland

11:40  **Looking for the imprints of the first stellar generations in metal-poor bulge field star**
Cesar Siqueira Mello, Universidade de São Paulo, Brazil

12:00  **$^{12}$C+$^{12}$C measurements at low energies**
Lizeth Morales Gallegos, University of Edinburgh, UK / INFN-Naples, Italy

12:20  **Measurement of $^{23}$Na($\alpha$,p)$^{26}$Mg at energies relevant to $^{26}$Al production in massive stars and nucleosynthesis in SNIa**
Jessica Tomlinson, University of York, UK

12:40  Lunch and exhibition

**Session 13 - Stellar evolution and nucleosynthesis**

14:00  **Nucleosynthesis of $^{26}$Al in massive stars: New $^{27}$Al states above alpha and neutron emission thresholds**
Nicolas de Séréville, Institut de Physique Nucléaire, France

14:20  **Spectroscopic study of $^{27}$Al states above the neutron threshold via the $^{28}$Mg($^3$He,d) reaction**
Stephen Gillespie, University of York, UK
14:40 Branching ratio of the $\beta$-delayed $\alpha$-decay of $^{15}$N and its effect on the calculated $^{12}$C($\alpha,\gamma$)$^{16}$O reaction rate
Jonas Refsgaard, Aarhus University, Denmark

15:00 Low energy scattering cross section ratios of $^{14}$N(p,p)$^{14}$N
Richard deBoer, University of Notre Dame, USA

15:20 $\gamma$-process reaction studies via in-beam $\gamma$-ray spectroscopy at HORUS
Philipp Scholz, University of Cologne, Germany

15:40 Afternoon refreshment break

Session 14 – Industrial, EU funding and panel discussion

16:00 Invited presentation – Detection of MeV scale neutrinos in underground laboratories
Aldo Ianni, Laboratorio Subterrâneo de Canfranc, Spain

16:30 Industrial session, EU funding and panel discussion

17:00 Close of day four

19:00 Conference Gala dinner and drinks reception at The Merchant Adventurers' Hall
Visit: http://npa7.iopconfs.org/176010 for more information
Friday 22 May 2015

08:30 Registration

Session 15 – Tools, techniques and facilities

09:00 Invited presentation - Nuclear astrophysics at FRANZ
René Reifarth, Goethe University Frankfurt, Germany

09:30 A new method for mass measurements of exotic nuclei produced by the in-flight method at relativistic energies
Ann-Kathrin Rink, Justus-Liebig University Gießen, Germany

09:50 Photodisintegration reactions for nuclear astrophysics studies at ELI-NP
Catalin Matei, Extreme Light Infrastructure - Nuclear Physics, Romania

10:10 Nuclear Astrophysics with radioactive beams at GANIL
Francois de Oliveira, Grand Accélérateur National d’Ions Lourds (GANIL), France

10:30 Morning refreshment break

Session 16 – Low-energy and underground nuclear astrophysics

11:00 Invited presentation - Latest results from LUNA
Rosanna Depalo, Università degli Studi di Padova and INFN Padova, Italy

11:30 Direct underground measurement of the $^{17}\text{O}(p,a)^{14}\text{N}$ reaction at LUNA
Carlo Bruno, University of Edinburgh, UK

11:50 Progress of the Felsenkeller shallow-underground 5 MV accelerator for nuclear astrophysics
Daniel Bemmerer, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany

12:10 Final overview
Roland Diehl, Max Planck Institut für extraterrestrische Physik, Germany

12:40 Closing remarks

13:00 Lunch

13:00 Close of day five and conference
Poster programme

P:01 Precision mass measurements of $^{129-131}$Cd for nuclear astrophysics studies
Dinko Atanasov, Max-Planck-Institute for Nuclear Physics, Germany

P:02 The feasibility of direct measurement of the $^{44}$Ti($\alpha$,p)$^{47}$V reactions at astrophysically relevant temperatures
Daniel Bemmerer, Helmholtz-Zentrum Dresden-Rossendorf, Germany

P:03 Low energy neutron background in deep underground laboratories
Andreas Best, INFN - Laboratori Nazionali del Gran Sasso, Italy / University of Notre Dame, USA

P:04 Nucleosynthesis of Mo and Ru isotopes in neutrino-driven winds
Julia Bliss, Technische Universität Darmstadt, Germany

P:05 Background modeling and shielding of a Bismuth Germanium Oxide (BGO) detector underground
Axel Boeltzig, Gran Sasso Science Institute, Italy

P:06 Thermonuclear reaction rates for $^{17}$O+p - a low-energy, high beam current study of $^{17}$O(p, $\gamma$)$^{18}$F
Matthew Buckner, University of North Carolina, USA

P:07 Anharmonic oscillator potentials in the prolate $\gamma$-rigid regime of the collective geometrical model
Radu Budaca, Horia Hulubei National Institute of Physics / Nuclear Engineering (IFIN-HH), Romania

P:08 Nuclear astrophysics at LNL: The $^{25}$Mg($\alpha$,n)$^{28}$Si and $^{10}$B(p,$\alpha$)$^{7}$Be cases
Antonio Caciolli, University of Padua, Italy

P:09 Gravitational redshift and the singularity effect in de Sitter field
Diana Rodica Constantin, Astronomical Institute of Romanian Academy, Romania

P:10 Detection of solar neutrinos with a torsion balance with sapphire crystal
Madalina Cruceru, IFIN-HH, Romania

P:11 Structure of $^{10}$Be and $^{16}$C nuclei via break-up reactions studied with the 4$\pi$ Chimera array
Daniele Dell’Aquila, Università di Napoli Federico II / INFN Sezione di Napoli, Italy

P:12 Impact of rotation and magnetic fields in low mass AGB stars
Jacqueline den Hartogh, Keele University, UK

P:13 Improved primordial D/H calculation with re-evaluated rates
Pierre Descouvemont, Université Libre de Bruxelles (ULB), Belgium

P:14 Gamma-ray line diagnostics of the interstellar medium – $^{26}$Al, $^{60}$Fe, and e$^-$
Roland Diehl, Max Planck Institut für extraterrestrische Physik, Germany

P:15 Explosion dynamics of parametrized spherically symmetric core-collapse supernova simulations
Kevin Ebinger, Universität Basel, Switzerland
Explosive nucleosynthesis in core-collapse supernovae: The titanium problem
Marius Eichler, Universität Basel, Switzerland

Measurement of the strengths of the resonances at 417, 611, and 632 keV in the $^{22}\text{Ne}(p,\gamma)^{23}\text{Na}$ reaction
Federico Ferraro, Università degli Studi di Genova & INFN - Sezione di Genova, Italy

Towards a study of the $^{22}\text{Ne}(p,\gamma)^{23}\text{Na}$ reaction with a BGO detector at LUNA
Marcell Péter Takács, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Neutron capture cross sections of $^{86}\text{Kr}$
Stefan Fiebiger, Goethe University Frankfurt, Germany

Nuclear astrophysics experiments in the CSRe and ESR
Bingshui Gao, GSI Helmholtzzentrum für Schwerionenforschung, Germany

Carbon-12 production in stellar evolution
Ruchi Garg, University of York, UK

$^{34}\text{S}(p,\gamma)$ reaction rates studied through the $^{34}\text{S}(^3\text{He},d)^{35}\text{Cl}$ reaction
Stephen Gillespie, University of York, UK

New data on the neutron capture cross section of the s-process branching points $^{171}\text{Tm}$ and $^{147}\text{Pm}$
Carlos Guerrero, Universidad de Sevilla, Spain

Measurement of the $^{23}\text{Na}(\alpha,p)^{26}\text{Mg}$ reaction
Nicolas Hubbard, University of York, UK

Key Resonances in $^{26}\text{Mg}$ and their implications for the astrophysical s-process
Ralitsa Ilieva, University of Surrey, UK

Maxwellian neutron spectrum generation for stellar cross-section measurements
Pablo Jiménez, University of Seville, Spain

Nucleosynthesis of intermediate mass stars: Inferences from the observed abundances in photoionized nebulae of the local group
Walter Maciel, University of Sao Paulo, Brazil

Getting ready for GERDA Phase II
Werner Maneschg, Max-Planck-Institut für Kernphysik, Germany

Effectiveness of using a magnetic spectrograph with the Trojan Horse method
Spencer Manwell, McMaster University, Canada

Nucleosynthesis in the ejecta of neutron star mergers
Dirk Martin, Technische Universität Darmstadt, Germany

TACTIC - The TRIUMF Annular Chamber for Tracking and Identification of Charged Particles
Lars Martin, TRIUMF, Canada
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<td>Saad Ouichaoui</td>
<td>Université des Sciences et Technologie H. Boumediene (USTHB), Algeria,</td>
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<td>University of São Paulo, Brazil</td>
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<td>Tobias Reinhardt</td>
<td>TU Dresden, Germany</td>
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Jos Riley, University of York, UK

Isovector and pairing properties of the Gogny interaction
Rosh Sellahewa, University of Surrey, UK

Neutrino nucleosynthesis in core-collapse supernova explosions
Andre Sieverding, Technische Universität Darmstadt, Germany

Measurement of the $^{16}$O + $^{16}$O elastic scattering cross section below the coulomb barrier
Hugo Silva, Laboratório de Instrumentação, Engenharia Biomédica e Física da Radiação (LIBPhys-UNL), Portugal

Alpha-induced production cross sections of $^{77}$Kr, $^{79}$Kr and $^{77}$Br
Zuzana Slavkovská, Goethe University Frankfurt, Germany

Test of a SiPM-scintillator based muon detector at the Gran Sasso Laboratory
Ildikó Stark, Eötvös Loránd University (ELTE), Hungary

Background studies in the 148m deep Reiche Zeche mine in Freiberg, Germany
Tamás Szücs, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany

Excited nuclei, resonances and reactions in neutron star crusts
Nurgali Takibayev, Al-Farabi Kazakh National University, Kazakhstan

Simple potential model for interaction of dark particles with massive bodies
Nurgali Takibayev, Al-Farabi Kazakh National University, Kazakhstan

Study of the $^3$(p,$\gamma$)$^4$He reaction in the BBN energy range at LUNA
Davide Trezzi, Università degli Studi di Milano and INFN, Italy

Electron screening - Still an open problem
Jelena Vesic, Jozef Stefan Institute, Slovenia

The $^{14}$N(p,$\gamma$)$^{15}$O S factor at 0.4 – 1.5 MeV
Louis Wagner, Helmholtz-Zentrum Dresden-Rossendorf, Germany

The Electromagnetic Mass Analyser EMMA. A new recoil spectrometer for nuclear physics research being developed at TRIUMF, Vancouver
Matthew Williams, University of York, UK

Development of a detector in order to investigate (n, $\gamma$)-cross sections by ToF method with a very short flight path
Clemens Wolf, Goethe Universität Frankfurt, Germany

$\gamma$ – ray line cross sections in proton inelastic scattering off $^{24}$Mg, $^{28}$Si and $^{56}$Fe target nuclei over the proton energy range E = (30 – 66) MeV
Walid Yahia-Cherif, University of Sciences and Technology Houari Boumediene (USTHB), Algeria
Oral abstracts

Session 1 – Explosive scenarios

(invited) Modeling type Ia supernova explosions
F Röpke
1Heidelberger Institut für Theoretische Studien, Germany, 2Institut für Theoretische Astrophysik, Germany
Type Ia supernovae are associated with thermonuclear explosions of white dwarf stars. The stellar systems from which these events arise, however, have not been established observationally. Therefore, the way white dwarfs trigger explosion and details of the propagation of thermonuclear burning in them remain uncertain. Recent progress in modeling the explosion phase with three-dimensional simulations allows for a thorough comparison of predictions of different scenarios with astronomical data. I will give an overview of the current status and discuss uncertainties in modeling the explosion mechanism and the nuclear physics processes. Further progress in understanding Type Ia supernovae critically depends on improvements in the description of these aspects.

PUSHing 1D CCSNe to explosions: model and SN 1987A
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1North Carolina State University, USA, 2Technische Universität Darmstadt, Germany, 3Universität Basel, Switzerland
We report on a method, PUSH, for triggering core-collapse supernova explosions of massive stars in spherical symmetry. The PUSH method locally increases the energy deposition in the gain region through energy deposition by the heavy neutrino flavors and hence triggers explosions in otherwise non-exploding simulations. We calibrate PUSH such that the observables of SN 1987A are reproduced. With this setup we explore basic explosion properties (see abstract submitted by K. Ebinger), correlations with progenitor compactness, and nucleosynthesis of Ni and Ti (see abstract submitted by M. Eichler). We also make a prediction for the mass of the neutron star from SN 1987A.

Multidimensional hydrodynamics simulations to improve our understanding of stellar evolution
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Traditionally the evolution of stars has been studied using one-dimensional codes. These rely on simplifying assumptions to be able to cover the huge range of length and time scales that occur in stars. Most prominently perfect spherical symmetry and hydrostatic equilibrium are assumed. This means that all multidimensional and hydrodynamical effects, for example convection, overshooting, and shear instabilities, cannot be accounted for from first principles. To make the models more realistic it is common to introduce physically motivated prescriptions with a number of free parameters that are adjusted to match the observed behavior. One approach to remove these uncertainties is to perform resolved multidimensional hydrodynamics simulations with all the necessary physics included. These will, of course, not replace classical stellar evolution as the involved time scales are too long but the goal is to improve the prescriptions used in these codes.

We developed the Seven-League Hydro (SLH) code, a multidimensional hydrodynamics code that uses implicit time discretization. This makes it more efficient than the commonly used explicit codes for flows at low Mach numbers,
which often occur in stellar interiors. A special low Mach number discretization (Miczek et al., 2014) greatly increases accuracy for these flows. The code includes a general equation of state, radiation in the diffusion limit, and a flexible nuclear reaction network. It scales well on large supercomputers up to 100,000 cores.

We present two exemplary applications of this code involving nuclear reactions. The first is a simulation of convective overshooting in a Population III star during core He-burning. The mixing of 12C from the core into the shell above causes a great increase in the reaction rate, which has an impact on the overshooting process. The second application is directed towards classical novae. Here, the 12C-enrichment of the accreted H-layer on a white dwarf is studied with 3D simulations. The amount of increase in metallicity is important for determining candidates for possible nova outbursts.


**Session 2 – Explosive scenarios**

*(invited) Neutrino-nucleus reactions and their role for supernova dynamics and nucleosynthesis*

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The description of nuclear reactions induced by supernova neutrinos has witnessed significant progress during the recent years. On one hand this progress is due to experimental data which serve as important constraints to model calculations, on the other hand it is related to advances in nuclear modelling itself and in computer hardware. At the energies and momentum transfers relevant for supernova neutrinos neutrino-nucleus cross sections are dominated by allowed transitions, however, often with non-negligible contributions from (first) forbidden transitions. For several nuclei allowed Gamow-Teller strength distributions could be derived from charge-exchange reactions and from inelastic electron scattering data. Importantly the diagonalization shell model has been proven to accurately describe these data and hence became the appropriate tool to calculate the allowed contributions while higher multipole contributions are calculated within the framework of the Quasiparticle Random Phase Approximation.

The talk reviews recent progress achieved in calculating supernova-relevant neutrino-nucleus cross sections and summarizes the impact which these reactions have on the dynamics of supernovae and on the associated nucleosynthesis.

**First results from the last measurement concerning \(^{19}\)Ne spectroscopic properties of astrophysical importance via a new method of inelastic scattering**

F Boulay

GANIL, France

*Abstract not available.*
Study of excited states of $^{35}$Ar through $\beta$-decay of $^{35}$K for nucleosynthesis in novae and X-ray bursts

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The thermonuclear runaway in close binary systems such as novae and X-ray bursts proceeds through proton-rich nuclei and many of the radiative proton capture reactions $(p, \gamma)$ involving sd-shell nuclei close to the dripline are dominated by resonant capture. The key parameters in understanding the astrophysical reaction rates are the energies, decay widths and spins of these resonances. One of the reactions for which improved data are needed and which determines the synthesis of nuclei beyond sulfur and chlorine is the radiative proton capture $^{34}$Cl$(p, \gamma)^{35}$Ar. At the moment the properties of the excited states of $^{35}$Ar above the proton separation threshold are rather poorly known and the astrophysical reaction rate is based on statistical Hauser-Feshbach calculations.

In a recent experiment we have studied the excited states of $^{35}$Ar selectively through the $\beta$-decay of the $3/2^+$ ground state of $^{35}$K. A beam of $^{35}$K was made with MARS separator at the Texas A&M University in inverse kinematics through reaction $^{1}$H$(^{36}$Ar, $^{35}$K)2n at 36 MeV/u and implanted into a novel detector setup, capable of measuring $\beta$-delayed protons and $\gamma$-rays simultaneously. In this contribution we report preliminary results of our experiment, including several new proton groups, first direct observation of the Isobaric Analogue State of $^{35}$K ground state in $^{35}$Ar in $\beta$-decay and the improved half-life of $^{35}$K.

Asymptotic normalisation coefficients from the $^{26}$Al $(d,p)^{27}$Al reaction, mirror nuclei study and application to nuclear astrophysics

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The observations of the radioactive decay of $^{26}$Al by satellites, which were the first such observations, has triggered an intense need for understanding the mechanism responsible for its production and destruction in galactic phenomena. While the exact provenance is still unresolved, all-sky maps tracking $\gamma$-rays associated with its decay have shown that it was produced by several different astrophysical sites such as core collapse supernovae, Wolf-Rayet (WR) stars and novae. A relatively small network of reactions is responsible for the observed $^{26}$Al quantities. In hydrogen-burning environment, such as WR stars, the destruction rate is mainly determined by the $^{26}$Al$(p, \gamma)^{27}$Si reaction. As a result the occurrence of resonances above the $^{26}$Al+p threshold in $^{27}$Si has a large impact on the galactic $^{26}$Al abundance inherent to WR stars. Recently resonant states have been identified in $^{27}$Si by two spectroscopic studies [1,2], but the strength of two of those states, at 7532 and 7589 keV (resp. 70 and 127 keV) excitation (resonance) energy, remains mainly unknown. These low energy resonances are currently not reachable via direct measurement as the cross section fall off dramatically with energy. In this study, this ob-stacle is overpassed via a state of the art spectroscopic study of the mirror nucleus $^{27}$Al with the $^{26}$Al(d,p)$^{27}$Al transfer reaction. Such study allows for an indirect study of the 127 keV resonance in $^{27}$Si. It is currently understood (see, for example, Ref. [1]) that the state in $^{27}$Al, equivalent to this resonance, is at 7806 keV. Here the reaction was performed in inverse kinematics at TRIUMF, Canada, using the most intense $^{26}$Al beam yet available. We will present results for the measurement of Asymptotic Normalisation Coefficients in $^{27}$Al and the implication for the mirror system including the resonant states of the $^{26}$Al+p system.

Session 3 – Explosive scenarios

Measurement of the p-process branching point reaction $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ in inverse kinematics with DRAGON

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The reaction $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ has been identified as one of the highest priority measurements for the p-process due to the importance of its time-inverse reaction $^{80}\text{Kr}(\gamma,\alpha)^{76}\text{Se}$ [1]. The nuclide $^{80}\text{Kr}$ is a branching point of this process and so the relative rates of the $^{80}\text{Kr}$ photo-disintegration reactions will directly affect abundance of p-nuclide $^{78}\text{Kr}$. While there is no experimental data on any of these reactions, it is the theoretical $^{80}\text{Kr}(\gamma,\alpha)^{76}\text{Se}$ reaction rate which is the most uncertain. For this reason $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ was chosen as the flagship measurement of the DRAGON high mass program, the goal of which has been to expand the capabilities of the DRAGON recoil separator to study beams of mass $A > 40$. The recent measurement of the $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ reaction constitutes the first scientific results of this ongoing program. Here we report on the first two measurements of $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ at energies within the 2.0 T$_9$ Gamow window, provide description of the required upgrades to the DRAGON separator, and present results from the high mass commissioning experiments. Plans for future measurements of $^{76}\text{Se}(\alpha,\gamma)^{80}\text{Kr}$ and other p-process reactions will also be discussed.


Study of the low energy $\alpha$-nucleus optical potential using a $(p,\alpha)$ reaction

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Many recent experiments on reactions relevant for the astrophysical $\gamma$-process [1] gave an indication that the low energy $\alpha$-nucleus optical potential used in reaction rate calculations needs strong modification. The problem was mostly studied by measuring the cross section of $\alpha$-induced reactions, and unfortunately in such an experiment the optical potential could not be studied directly at low, astrophysically relevant energies. Therefore, the experiments provided only indirect evidence for the potential problem.

In the present work a $(p,\alpha)$ reaction, where the $\alpha$ particle is in the exit channel, was used for the first time to study the low energy $\alpha$-nucleus optical potential. The cross section of the $^{64}\text{Zn}(p,\alpha)^{61}\text{Cu}$ reaction was measured in the proton energy range between 3.5 and 8 MeV. In this energy range the cross section is only sensitive to the $\alpha$-nucleus optical potential and the astrophysically relevant energy range can be fully covered.

The experimental results were compared with the predictions of statistical model calculations and it was found that the models strongly overestimate the measured data when the standard optical potential of the models is used [2]. Our results provide therefore the first direct evidence that the low energy $\alpha$-nucleus optical potentials need to be modified.

Post-processing nucleosynthesis simulations for the production of the light p-nuclei

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Most of the p-nuclei between 74Se and 196Hg are produced under explosive conditions in a sequence of photodissociation reactions and subsequent β-decays starting at s- and r-process seeds[1]. Some of the light p-nuclei, e.g. the neutron magic isotope 92Mo, may also be synthesized by proton capture reactions [2]. Most of the p-nuclei are about two orders of magnitude less abundant than other stable isotopes of the same element. Relevant exceptions are the p-nuclei 92,94Mo and 96,98Ru [3]. Their production in stars is a puzzle for nuclear astrophysics since present models underproduce these p-nuclei by orders of magnitude. The production and destruction of the light p-nuclei was investigated with post-processing nucleosynthesis routines provided by the NuGrid collaboration [4].

The nucleosynthesis of the light p-nuclei, especially of 92Mo and 94Mo, was studied for a classical one-dimensional Supernova type II model [5] as well as for a two-dimensional Supernova type Ia model [2]. The most important reactions producing or destroying the p-nuclei were identified by the corresponding nucleosynthesis fluxes. The sensitivities of the isotopic abundances to the rates of these reactions were determined. We present recent results from the nucleosynthesis simulations.

Furthermore, online tools are currently being developed to display nucleosynthesis fluxes as well as local and global impacts of reactions on the final abundances. We present the tools and give an outlook for further developments.


Investigation of the reaction 59Fe(n,γ)60Fe @ FAIR

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One of the fundamental signatures for active nucleosynthesis in the Milky Way is the observation of long-lived radioactive isotopes [1], for instance 26Al with a half-life of 7.17 · 105 yr and 60Fe with half-life of 2.62 · 106 yr. The ratio of 59Fe to 26Al was constrained by RHESSI and INTEGRAL [2] [3] using high-resolution γ-ray observatories. The interpretation of these observations depends critically on the reaction rates of 60Fe under stellar conditions. While 26Al is studied extensively, very little is known about the reactions associated with the nucleosynthesis of 60Fe.

The isotope 60Fe is dominantly produced during the s-process [1]. The isotope 59Fe deter- mines the production of 60Fe since it acts as a branching point due to its rather short half-life of t1/2 = 44.495 d. Moderate neutron densities and temperatures are needed to overcome this instability gap. The corresponding astrophysical scenario is C shell burning in massive pre-supernova stars where neutron densities of 1012 cm−3 and temperatures of kT = 90 keV are reached.

The direct measurement of the production rate 59Fe(n,γ)60Fe is very difficult because of the short half-life of 59Fe. In order to evaluate the neutron capture cross section for 59Fe(n,γ)60Fe, a Coulomb dissociation experiment was
performed at the R3B/LAND setup at GSI. The unstable iron isotopes were produced by fragmentation of a 660 AMeV primary beam of $^{64}$Ni on a 4 g/cm$^2$ Be target. The dissociation cross section $^{60}$Fe($\gamma,n$)$^{59}$Fe allows to constrain the theoretical estimates of the inverse neutron capture reaction $^{59}$Fe($n,\gamma$)$^{60}$Fe via detailed balance. In order to prove this method, $^{58}$Fe($\gamma,n$)$^{57}$Fe was studied in addition to compare with the already directly measured $^{58}$Fe($n,\gamma$)$^{59}$Fe cross section.

The Coulomb dissociation measurement was performed using the neutron LAND detector. Its geometry and the time resolution allow a binning for the neutron energy of 250 keV. The s-process acts near the reaction threshold in a neutron energy regime of 25 keV - 90 keV. Therefore, the experiment delivers an integral cross section covering the astrophysically important energy range. To obtain a better neutron energy resolution, the R3B collaboration designed an improved neutron detector for FAIR, called NeuLAND. The aim is a binning of neutron energies of 20 keV, which allows for an energy-dependent measurement of ($n,\gamma$) reaction cross section for radioactive isotopes will be possible in the future.


Session 4 – Explosive scenarios

Type Ia supernovae from exploding oxygen-neon white dwarfs
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The progenitor problem of Type Ia supernovae (SNe Ia) is still unsolved. Most of these events are thought to be explosions of carbon-oxygen white dwarfs but there is also the possibility of oxygen-neon white dwarf (ONE WD) progenitors in some of the explosion scenarios. We performed two-dimensional hydrodynamic simulations with the supernova code leafs for several initial ONE WD masses below the Chandrasekhar mass, followed by a detailed nucleosynthetic postprocessing based on a 384 isotope nuclear reaction network. The results are used to calculate synthetic spectra and light curves with the radiation transfer code artis. These are then compared with observations of SNe Ia. The overall ejecta structure of our simulated detonations in sub-Chandrasekhar mass ONE WDs is similar to those from carbon-oxygen WD detonations. There are, however, small systematic deviations in the mass fractions and the ejecta velocities. Consequently, the synthetic observables of our ONE WD explosions look generally similar to those obtained from carbon-oxygen models; however, spectral features are systematically redshifted. Overall, the ONE WD explosion model compares well to the observations.

Gamma-ray line diagnostics of supernova explosions – SN2014J and Cas A
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Gamma-ray lines from radioactive decay of isotopes produced inside supernova explosions convey information about the explosion mechanism. The amount of an isotope is most directly measured through the gamma-ray flux in
characteristic lines. The expanding ejecta dynamics is reflected in the line parameters of centroid (bulk motion) and width (spread of expansion velocities).

SN2014J at only 3.3 Mpc distance is a supernova of type Ia, and was observed for several months with INTEGRAL. Characteristic lines from $^{56}$Ni ($\tau = 8.8$ d) and from $^{56}$Co decay ($\tau = 111$ d) have been measured for the first time for a SNI in this event. Their intensity variations traced over the phase from still-embedded gamma-rays to gamma-ray transparency.

The surprising discovery of $^{56}$Ni lines after only 20 days indicates that about 10% of the $^{56}$Ni is not deeply embedded, and may have been produced by an outer ignition of helium accreted from a companion star. The $^{56}$Co from within the exploding white dwarf is revealed through somewhat flickering line emission, which may indicate filamentary structure of the interior of the supernova. From comparison to 1D model light curves, we estimate a $^{56}$Ni mass of 0.5 $M_\odot$ produced in this event.

Cas A is a young (340 years) supernova remnant (SNR) of a core-collapse supernova explosion in our Galaxy at 3.4 kpc distance. $^{44}$Ti gamma-rays had first been discovered with COMPTEL from this SNR, and was measured since by several different instruments. We revisit INTEGRAL observations accumulated over the mission, and our re-analysis detects both the characteristic low-energy line from $^{44}$Sc at 78 keV and the 1157 keV line from $^{44}$Ca, attributed to the $^{44}$Ti decay chain ($\tau = 86$ y). Our results provide ejecta velocities of 4300 (2200) km s$^{-1}$ (from 78 (1157) keV lines, respectively). The total $^{44}$Ti mass produced in Cas A is re-evaluated from combined observations as 1.37 $10^{-4}$ $M_\odot$.

Using stellar observations to trace the formation processes of Mo, Ru, Pd, and Ag

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The exact formation mechanism of many heavy elements remains unknown. Models of the formation site and environment have greatly improved over the past decades, and experiments have provided new data for many of the heavy isotopes, yet a lot of information is still missing to fully describe the neutron-capture formation processes and their sites. Stellar observations combined with mass spectroscopic measurements of meteorites can help place some of the needed constraints. This in turn will help improve the models and our knowledge on the formation channels creating these heavy elements. Recent studies of Mo, Ru, Pd, and Ag showed that a different process or environment was needed to explain the production (and observationally derived abundances) of elements in the 40 < Z < 50 compared to the main r-process associated with the formation of for instance Eu. I will present an observational study of Mo - Ag, where stellar abundances are compared to meteoritic isotopic abundances (at higher metallicities $[\text{Fe/H}] > -1.5$) to extract information on differences or similarities in their production. Finally, I will briefly comment on how many formation processes seem to be needed to describe the chemical composition derived from a large sample of low metallicity ($[\text{Fe/H}] < -2.5$) stars.

Session 5 – Nuclear structure, reactions and theory

(invited) Nuclear astrophysics with indirect methods

C A Bertulani

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I discuss the present status of indirect techniques that are used to determine reaction rates for stellar burning
Mirror nuclei and insights into cross-sections for reactions of astrophysical interest
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If the proton and neutron were identical particles, then mirror nuclei would have identical nuclear structure. In reality, Coulomb and isospin non-conserving forces lift this degeneracy, leading to small differences in excitation energy of excited states in mirror nuclei of the order of 10s or 100s of keV. Predicting these mirror energy differences is challenging from a theoretical perspective as they depend sensitively on the structure of the states involved. In nuclear astrophysics, it is often necessary, due to the difficulty in making direct measurements such as \((p,\gamma)\) reactions on exotic nuclei, to place reliance on mirror symmetry to make plausible assignments of spin/parity to excited states. Detailed study of mirror symmetry and a better understanding of the underlying physics may allow this procedure to be better refined. Such information may come from nuclear structure studies which provide important insights into mirror symmetry up and down the line of \(N=Z\).

A specific example to be discussed in this talk will be mirror symmetry in the \(A=23\) nuclei, \(^{23}\text{Na}\) and \(^{23}\text{Mg}\) \(^{[1]}\). These nuclei were populated in the \(^{12}\text{C}+^{12}\text{C}\) fusion-evaporation reaction at beam energies of 16 and 22 MeV. Gamma rays emitted from excited states were detected with Gammasphere allowing extensive level schemes for \(^{23}\text{Na}\) and \(^{23}\text{Mg}\) to be obtained. Accordingly, mirror symmetry could be explored in detail as a function of spin/parity and excitation energy. The extensive data for both positive and negative parity states could be compared with the results of USD-A and PSPDF shell model calculations, respectively. The high statistics in the experiment allowed information to be obtained on proton-unbound states in both nuclei. This latter data is valuable in supporting the determination of the resonant reaction rate for the \(^{22}\text{Na}(p,\gamma)\) and \(^{22}\text{Ne}(p,\gamma)\) reactions, respectively.


New direct investigations of the \(^{19}\text{F}(p,\alpha)^{16}\text{O}\) reaction down to 200 keV
I Lombardo\(^{1,2}\), D Dell’Aquila\(^{1,2}\), A DiLeva\(^{1,2}\), I Indelicato\(^{3,4}\), M LaCognata\(^{4}\), M LaCommara\(^{1,2}\), A Ordine\(^{2}\), V Rigato\(^{5}\), M Romoli\(^{2}\), E Rosato\(^{1,2}\), G Spadaccini\(^{1,2}\), C Spitaleri\(^{3,4}\), A Tumino\(^{4,6}\) and M Vigilante\(^{1,2}\)

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The \(^{19}\text{F}(p,\alpha)^{16}\text{O}\) reaction at low energies plays an important role on various fields, including both fundamental and applied physics. It allows to study the structure of the self-conjugated nucleus \(^{20}\text{Ne}\) with the possibility of evidencing \(\alpha\)-cluster effects \(^{[1]}\). In Nuclear Astrophysics it represents, together with the \(^{19}\text{F}(p,\gamma)^{20}\text{Ne}\) reaction, the crossing point between the CNO and the NeNa cycles in stars \(^{[2]}\). Furthermore, fluorine nucleosynthesis is an open issue of modern astrophysics \(^{[3]}\), and it has been suggested that \(^{19}\text{F}(p,\alpha)^{16}\text{O}\) reactions can play an important role in hydrogen-rich environments of AGB stars in presence of extra-mixing phenomena \(^{[4,5]}\).
Despite the important role played by this reaction, very few and old direct data have been reported in the literature, leading to strong uncertainties in the evaluation of the reaction rate at stellar energies [6]. In this communication we will discuss the results of two new measurements on the $^{19}$F(p,$\alpha\alpha$)$^{16}$O reaction at low energies, in the 1.0-0.6 MeV (TTT3 accelerator in Naples, Italy [7]) and 0.6-0.2 MeV (AN2000 accelerator, LNL, Padua, Italy [8]) domains. These two experiments, together with recent results of indirect measurements with the Trojan Horse Method [4], allow to refine our knowledge on the spectroscopy of $^{20}$Ne in the 13.0-13.8 MeV excitation energy range and to obtain new results on the $S$-factor at very low bombarding energies, near to the domain of astrophysical interest.


The theoretical cross sections in the $^{12}$C($\alpha$,$\gamma$)$^{16}$O reaction
M Katsuma
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The $^{12}$C($\alpha$,$\gamma$)$^{16}$O reaction is considered as the key reaction for the carbon-oxygen ratio in the universe [1]. However, the cross section is too small to measure it at Ec.m. = 0.3 MeV, corresponding to the helium burning temperature in a star, because of the Coulomb barrier. To understand the $^{12}$C($\alpha$,$\gamma$)$^{16}$O reaction more precisely, the experimental efforts to measure the tiny cross section have been made with the various methods, including the indirect measurements. In this presentation, I will report the theoretical result of $^{12}$C($\alpha$,$\gamma$)$^{16}$O obtained from the potential model [2].

To generate the $\alpha^{+12}$C continuum state, I first show the excitation function of elastic scattering [3,4]. The appropriate strength of the internuclear potential is determined from nuclear rainbow scattering at high energies [5]. For the bound states, the potential is adjusted so as to reproduce the separation energy [6]. This method gives the appropriate wavefunctions in the peripheral region that are sensitive to nuclear reactions, and it makes a doorway state from the continuum state to the fused nuclei. The spectroscopic factors and ANCs are obtained phenomenologically. The low-energy cross section and astrophysical reaction rates are compared with the experimental results (e.g. [7]). The contribution from the narrow resonances is also considered [8]. In addition, the photodisintegration of $^{16}$O is predicted from the statistical consideration [9].

In the result, the $^{12}$C($\alpha$,$\gamma$)$^{16}$O reaction seems to be explained by the simple reaction mechanism of the direct-capture potential model. The theoretical cross section at Ec.m. = 0.3 MeV is found to be dominated by E2 transition. Likewise, the photodisintegration of $^{16}$O is dominated by the E2 excitation. The angular distribution is predicted to have the characteristic interference pattern made from the states belonging to the $\alpha^{+12}$C rotational bands [10]. The other narrow resonances may be negligible. The derived $^{12}$C($\alpha$,$\gamma$)$^{16}$O reaction rates are consistent with the results of [11].

Session 6 – Nuclear structure, reactions and theory

Microscopic description of r-process nuclei fission properties
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Fission is a crucial phenomenon to understand r-process nucleosynthesis. Metalpoor star observations suggest a very robust r-process abundance pattern for elements heavier than $Z \sim$ 50. The most likely reason to achieve such a robust pattern is fission cycling. In recent papers [1, 2] the fission properties of the Barcelona- Catania-Paris-Madrid energy-density functional [3] were compared with available experimental data. Given their encouraging results we extended the computations to the superheavy region ($84 \leq Z \leq 120$, $120 \leq N \leq 250$).

Potential energy surfaces as well as collective inertias relevant to the fission process are obtained within a mean-field approach. Spontaneous fission half-lives are computed using the semiclassical Wentzel-Kramers-Brillouin formalism. We found that certain combinations of neutron and proton number lead to an enhanced stability against the spontaneous fission process, putting forward the existence of magic numbers in the superheavy region. Finally, the agreement with other theoretical models is discussed.


Beyond BCS pairing in high-density neutron matter
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Superfluidity is a prominent phenomenon in neutron stars. The present theoretical understanding of pulsar glitches [1] and neutron star cooling [2] relies on superfluid neutron and proton dynamics. At a microscopic level, nuclei are also superfluid, as denoted in a wide range of pairing phenomena [3]. The theoretical description of pairing in neutron-star matter has often relied on a Bardeen-Cooper-Schrieffer (BCS) mean-field approach, at odds with the
strongly correlated nature of nuclear systems.

In this context, we have investigated the influence of beyond mean-field, long- and short-range correlations on pairing in neutron matter. Short-range correlations are incorporated by means of a full spectral distribution obtained in a Self-Consistent Green’s Functions calculation [4]. The effect of long-range correlations is studied by including polarization terms in addition to the bare interaction, which allow the neutrons to exchange density and spin fluctuations governed by Landau parameters [5].

We study the influence of these correlations in both the 1S0 and the 3PF2 pairing channels. In both cases, short-range correlations deplete substantially the pairing gap [6]. Long-range correlations, on the contrary, enhance pairing in the 3PF2 channel and deplete it further in 1S0. We provide results for a variety of realistic interactions. Our conclusions are particularly relevant in the context of the cooling scenarios of the young neutron star in Cassiopeia A [7].

Session 7 – Galactic chemical evolution / Big bang nucleosynthesis

(invited) Primordial nucleosynthesis after planck
B D Fields
University of Illinois, USA

We will survey the status of big-bang nucleosynthesis (BBN), which describes the production of the lightest elements during the first three minutes of cosmic time. We will emphasize the transformative influence of cosmic microwave background (CMB) experiments such as Planck in precisely determining the cosmic baryon density. Standard BBN combines this with the Standard Model of particle physics, and with nuclear cross section measurements, to make tight predictions for the primordial light element abundances. Deuterium observations agree spectacularly with these predictions, helium observations are in good agreement, but lithium observations (in metal-poor halo stars) are significantly discrepant – this is the "lithium problem." Over the past decade, the lithium discrepancy has become more severe, and very recently the solution space has shrunk. A solution due to new nuclear resonances has now been essentially ruled out experimentally. Stellar evolution solutions remain viable but must be finely tuned. Observational systematics are now being probed by qualitatively new methods of lithium observation. Finally, new physics solutions are now strongly constrained by the combination of the precision baryon determination by Planck, and the need to match the D/H abundances now measured to unprecedented precision at high redshift. Setting aside the lithium problem as possibly originating in observational or astrophysical systematics, BBN and the CMB together now sharply probe all four fundamental forces at times $t > \sim 1$ sec. We will examples include neutrino physics and other forms of “dark radiation.”

Search for resonant states in $^{10}$C and $^{11}$C and their impact on the primordial $^7$Li abundance

$^1$Université Paris Sud, France, $^2$CSNSM, IN2P3-CNRS, France, $^3$Universidade de Santiago de Compostella, Spain, $^4$University of York, UK, $^5$Nuclear Physics Institute ASCR, Czech Republic, $^6$GANIL, France, $^7$Universitat Politecnica de Catalunya, Spain, $^8$Univesidad de Huelva, Spain

The cosmological $^7$Li problem arises from the significant discrepancy of about a factor 3 between the predicted primordial $^7$Li abundance and the observed one [1]. The main process for the production of $^7$Li during Big-Bang nucleosynthesis is the decay of $^7$Be. Many key nuclear reactions involved in the production and destruction of $^7$Be were investigated in attempt to explain the $^7$Li deficit but none of them led to successful conclusions. However, some authors suggested recently the possibility that the destruction of $^7$Be by $^3$He and $^4$He may reconcile the predictions and observations if missing resonant states in the compound nuclei $^{10}$C and $^{11}$C exist [2]. Hence, a
search of these missing resonant states in $^{10}$C and $^{11}$C was investigated at the Orsay Tandem-Alto facility through $^{10}$B($^3$He,t)$^{10}$C and $^{11}$B($^3$He,t)$^{11}$C charge-exchange reactions respectively.

After a short overview of the cosmological $^7$Li problem from a nuclear physics point of view, the Orsay experiment as well as the obtained results and their impact on the $^7$Li problem [3] will be presented.


Trojan Horse cross section measurements and their impact on primordial nucleosynthesis

R G Pizzone$^1$, C Bertulani$^2$, R Spartá$^{1,2}$, C Spitaleri$^{1,2}$, M La Cognata$^1$, L Lamia$^2$ and A Mukhamedzhanov$^3$

$^1$INFN - Laboratori Nazionali del Sud, Italy, $^2$Universitádi Catania, Italy, $^3$Texas A&M University, USA

Big Bang Nucleosynthesis (BBN) nucleosynthesis requires several nuclear physics inputs and, among them, an important role is played by nuclear reaction rates. They are among the most important input for a quantitative description of the early Universe. An up-to-date compilation of direct cross sections of $^d(^d,p)^t$, $^d(^d,n)^{3He}$ and $^3He(^d,p)^4He$ reactions is given, being these ones among the most uncertain bare-nucleus cross sections.

An intense experimental effort has been carried on in the last decade to apply the Trojan Horse Method (THM) to study reactions of relevance for the BBN and measure their astrophysical S(E)-factor. The result of these recent measurements is reviewed and compared with the available direct data. The reaction rates and the relative error for the four reactions of interest are then numerically calculated in the temperature ranges of relevance for BBN (0.01<T$_9$ <10) and compared with up-to-date reaction rate compilations. Their value were therefore used as input physics for primordial nucleosynthesis calculations in order to evaluate their impact on the calculated primordial abundances of D, $^3$He and $^7$Li. These ones were then compared with the observational primordial abundance estimates in different astrophysical sites. A comparison was also performed with calculations using other reaction rates compilations available in literature.

Nuclear forces towards the drip-line viewed from the study of neutron-rich Fisotopes

O Sortin
GANIL, France

Predicting the limits of stability in nuclear matter and the evolution of shell gaps far from stability are two of the intellectual challenges of fundamental research in nuclear physics that have driven the developments of rare-isotope facilities. Besides its fundamental interest, the understanding of nuclear forces towards the neutron drip-line play is required to model the r-process nucleosynthesis, to deduce in which stellar conditions/sites it occurs, and to study the physics of the neutron star crust. To achieve these endeavours, detailed understanding of the nuclear forces under extreme conditions of isospin and binding energy are required. While the effect of continuum and shell evolutions at the proximity of the neutron drip-line are still beyond reach in the heaviest part of the chart of nuclides, these two aspects can be beautifully studied in the O-F isotopic chains. In the oxygen isotopic chain, recent experiments have shown that drip line occurs at the doubly magic $^{24}$O$_{16}$ [1-3], the $^{25,26}$O nuclei being unbound [4,5]. The role of tensor and three-body forces was proposed in [6,7] to account for the emergence of the N=16 gap and the early appearance of the drip line in the O isotopic chain, respectively. On the other hand, six more neutrons can be added in the F isotopic chain before reaching the drip line at the isotope $^{31}$F$_{22}$
[8]. One can therefore speculate that the extension of the drip line between the oxygen and fluorine chains of isotopes, as well as the odd-even binding of the fluorine isotopes, arise from a delicate balance between the proton-neutron and neutron-neutron pairing interactions, coupling to the continuum and three body forces [9].

I will present results obtained from several experiments carried out at GANIL and GSI that led to the spectroscopy of the bound and unbound states in the $^{24-26}\text{F}$ that lie around the $^{24}\text{O}$ closed core. These results were obtained using complementary experimental techniques, such as $^\alpha$- [10] and isomer-decay spectroscopies [11], in-beam $^\alpha$-ray spectroscopy using fragmentation [12,13] and knockout reactions [14]. In particular, studies of the unbound states were achieved at GSI using the tracking of incoming and outgoing particles, the analysis of momentum distributions of the knockout residues, the detection of $^\alpha \gamma \gamma$-rays from the Cristal Ball and of the neutrons from the LAND detector. Combining all these results, a unified understanding of the nuclear structure has been obtained in the F isotopic chain. This is one of the first times that the properties and the origin of resonant states could be achieved up to high energy in the continuum (beyond S$_n$ in $^{26}\text{F}$), hereby challenging the modelling of nuclear forces. A splendid agreement between experimental and theoretical levels is obtained for the bound states of all $^{24-26}\text{F}$ isotopes using state-of-the-art ab initio calculations with realistic two and three-body forces. This agreement suddenly breaks when reaching the continuum, pointing to the need of new theoretical developments there.

[14] M. Vandebrouck et al., work in progress

Session 8 – Galactic chemical evolution / Big bang nucleosynthesis

(invited) Galactic chemical evolution: Strengths, weaknesses, and hidden secrets

B K Gibson
University of Hull, UK

Galactic Chemical Evolution (GCE) has provided something of a 4th dimension to the astronomer's toolbox for disentangling the physics underpinning galaxy formation and evolution, supplementing morphology, photometry, and kinematics. In this review, I will take an overarching, if biased, look at the methodologies employed, as well as applications from planetary to cosmological, all with an eye towards identifying the successes, the failures, and hidden secrets of GCE models.
Subclasses of Type Ia Supernovae as the origin of \( \alpha/Fe \) ratios in dwarf spheroidal galaxies

C Kobayashi
University of Hertfordshire, UK

Recent extensive observations of Type Ia Supernovae (SNe Ia) have revealed the existence of a diversity of SNe Ia, including SNe Iax. We introduce two possible channels in the single degenerate scenario: 1) double detonations in sub-Chandrasekhar (Ch) mass CO white dwarfs (WDs), where a thin He envelope is developed with relatively low accretion rates after He novae even at low metallicities, and 2) carbon deflagrations in Ch-mass possibly hybrid C+O+Ne WDs, where WD winds occur at \([Fe/H]\) \(-2.5\) at high accretion rates. These subclasses of SNe Ia are rarer than ‘normal’ SNe Ia and do not affect the chemical evolution in the solar neighborhood, but can be very important in metal-poor systems with stochastic star formation. In dwarf spheroidal galaxies in the Local Group, the decrease of \([\alpha/Fe]\) ratios at \([Fe/H]\) \(-2\) to \(-1.5\) can be produced depending on the star formation history. SNe Iax give high \([Mn/Fe]\), while sub-Ch-mass SNe Ia give low \([Mn/Fe]\), and thus a model including a mix of the two is favoured by the available observations.

The key role of SNIa at different metallicities for galactic chemical evolution of p-nuclei

C Travaglio, I R Seitenzahl, F Roepke and W Hillebrandt
1INAF - Astrophysical Observatory Turin, Italy, 2Australian National University College of Physical and Mathematical Sciences, Australia, 3Universität Würzburg, Germany, 4Max-Planck Institut für Astrophysik, Germany

Abstract not available.

Session 9 – Neutron stars and equation of state

(invited) The quest for the equation of state of high-density stellar matter

S Typel
GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany

The equation of state (EoS) of high-density stellar matter is a fundamental ingredient in the description of many astrophysical objects, e.g. the structure of compact stars, the evolution of core-collapse supernovae or binary-star mergers. Since a determination of the EoS under these conditions from first principles of QCD is still out of reach, many models have been developed in order to include the most relevant aspects for astrophysical applications. A brief overview will be given in the presentation. In recent years, these theoretical approaches are challenged by constraints from laboratory experiments and astrophysical observations. The discovery of at least two compact stars with about two solar masses is particular noteworthy because it excludes many models that were thought to be suitable in the past. The determination of neutron star radii from observations is still controversial but it will be essential in the future for the advancement of the models. Similarly important are the knowledge of the nuclear symmetry energy, the question about the composition of matter at high densities or the possibility of a phase transition from hadronic to quark matter. There are many different theoretical models for the description of cold
neutron-star matter but only a limited number of global models that cover the wide ranges in density, temperature and isospin asymmetry relevant for dynamical simulations. As an example of such a model, the main features of a generalized relativistic density functional approach will be presented.

**Neutron star equations of state with optical potential constraint**

S Antic\(^1,2\) and S Typel\(^1\)

\(^1\)GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany, \(^2\)Technische Universität Darmstadt, Germany

Nuclear matter and compact neutron stars are studied in the framework of an extended relativistic mean-field (RMF) model that includes higher-order derivative and density dependent couplings of nucleons to the meson fields. Generalized Euler-Lagrange equations follow from the principle of least action and the most general expressions for current and energy-momentum tensor are derived. The equation of state (EoS) of infinite nuclear matter is obtained for different non-linear derivative coupling functions. From experimental constraints on the optical potential the appropriate energy dependence of the regulator functions is chosen. The thermodynamical consistency of the model is demonstrated.

Spherical, non-rotating stars are described with the new EoS considering charge neutrality and \(\beta\)-equilibrium conditions. The stellar structure is calculated by solving the Tolman-Oppenheimer-Volkov (TOV) equations and the results for neutron stars are shown in terms of mass-radius relations.

This work is supported by the Helmholtz Association (HGF) through the Nuclear Astrophysics Virtual Institute (NAVI, VH-VI-417).

**The origin of lighter heavy elements in neutrino-driven winds and of heavy \(r\)-process elements in neutron star mergers**

A Arcones\(^1,2\)

\(^1\)TU Darmstadt, Germany, \(^2\)GSI, Germany

We will discuss new results on nucleosynthesis in core-collapse supernovae and neutrino-driven winds that produce elements up to silver. Because the synthesis of these elements occurs closer to stability, in the near future, the nuclear physics uncertainties will be reduced by experiments. This will uniquely allow us to combine observations and nucleosynthesis calculations to constrain the astrophysical conditions in neutrino-driven winds and thus gain new insights about core-collapse supernovae. In addition, we will discuss the production of all \(r\)-process elements (from the first to the third peak) in neutron star mergers. The radioactive decay of neutron-rich nuclei triggers an electromagnetic signal in mergers known as kilonova. This was potentially observed after a short gamma ray burst, associated with a neutron star merger. Nucleosynthesis in mergers takes place far away from stability and our sensitivity studies show the importance of, in particular, nuclear masses and fission properties.

**Neutrino-driven wind from neutron star merger remnants**

A Perego\(^1,2\), A Arcones\(^1,2\), R Cabezón\(^5\), R Käppeli\(^6\), O Korobkin\(^6\), M Liebendörfer\(^3\), D Martin\(^1,2\) and S Rosswog\(^5\)

\(^1\)Technische Universität Darmstadt, Germany, \(^2\)GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany, \(^3\)University of Basel, Switzerland, \(^4\)ETH Zürich, Switzerland, \(^5\)Stockholm University, Sweden

Binary neutron star mergers are among the most extreme events happening in the Universe. These powerful events are expected to release large amounts of energy in form of neutrinos, gravitational waves and electromagnetic...
radiation, together with the ejection of a small fraction of their original mass. In particular, they are expected to be sites for r-process nucleosynthesis, as well as very promising candidates to power short-hard gamma-ray bursts (GRBs) and the newly discovered kilo/macro-novae.

In this talk, I will present results from 3D simulation of the aftermath of a binary neutron star merger. The dynamics of the disc will be investigated, as well as the neutrino emission coming from the central object and the innermost part of the accreting disc. The interaction between the disc and the neutrino radiation produces a neutrino-driven wind on a timescale of a few tens of milliseconds after the merger. Inside the wind, the electron fraction of the matter (initially extremely neutron rich) is reset by neutrino absorption. The properties of the related ejecta will be explored, with a special emphasis on the nucleosynthesis yields and on their dependences on microphysics inputs. Implication of the wind in terms for the central engine of short GRBs will also be discussed.


Session 10 – Exotic Nuclei

(invited) Measurement of beta-delayed neutron emitters for astrophysics and reactor physics
I Dillmann
TRIUMF, Canada

Beta-delayed neutron- \( \alpha n \)-emitters play an important, two-fold role in the stellar nucleosynthesis of heavy elements in the "rapid neutron-capture process" (r process). On one hand they lead to a detour of the material beta-decaying back to stability. On the other hand, the released neutrons increase the neutron-to-seed ratio, and are re-captured during the freeze-out phase and thus influence the final solar r-abundance curve.

A large fraction of the isotopes for r-process nucleosynthesis are not yet experimentally accessible and are located in the "terra incognita". With the next generation of fragmentation and ISOL facilities presently being built or already in operation, one of the main motivation of all projects is the investigation of very neutron-rich isotopes at and beyond the border of presently known nuclei. However, reaching more neutron-rich isotopes means also that neutron-emission becomes the dominant decay mechanism.

The investigation of \( \alpha n \)-emitters has recently experienced a renaissance. I will summarize the recent efforts of the BELEN collaboration at GSI Darmstadt (see talk of R. Caballero) and at the IGISOL facility in Jyväskylä. Presently, groups from Germany, Japan, Russia, Spain, and the USA merge their \( ^{3}\text{He} \)-neutron counters and combine it with the implantation detector AIDA from the UK to the largest and most efficient neutron detection setup "BRIKEN" ("Beta-delayed neutron measurements at RIKEN for nuclear structure, astrophysics, and applications"). Planned first experiments in 2015/16 will comprise the first-time measurements of 48 \( \alpha \)-delayed one-neutron and 24 \( \alpha \)-delayed two-neutron emitters in the regions around doubly-magic \(^{56}\text{Ni} \) and \(^{132}\text{Sn} \). Even some \( \alpha \)-delayed three-neutron emitters in the heavier mass region will be tackled for the first time.

In parallel to these activities, the International Atomic Energy Agency (IAEA) has approved a Coordinated Research Project in 2013 about "Beta-Delayed Neutron Emission Evaluation" to create a solid basis for the vast amount of new neutron-rich isotopes being discovered with the new generation of RIB-facilities in the next decades. I will show the outcome of the recently submitted evaluation of half-lives and neutron-branching ratios for neutron-rich isotopes between \(^{8}\text{He} \) and \(^{80}\text{Ni} \) and provide some discrepant results which will require remeasurements.
Measurement of 40 new β-decay half-lives across the n=82 shell gap: implications for the astrophysical r-process


1RIKEN Nishina Center, Japan, 2University of Brighton, UK, 3Universite Joseph Fourier Grenoble, France, 4Instituto de Estructura de la Materia, Spain, 5Peking University, China, 6University of Koln, Germany, 7University of Surrey, United Kingdom, 8Tohoku University, Japan, 9Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI), Hungary, 10Beihang University, China

The β-decay of about 40 neutron-rich nuclei with neutron number N~82 were measured at the RIBF facility for the elements Ru—Sn. The new measurements include the five r-process “classical” waiting points 127Rh82, 128Pd82, 131Ag84, 134Cd86, and 138Sn88. The nuclei of interest were produced by in-flight fission of a 238U beam with an energy of 345 MeV/u colliding a Be target. Fission fragments identified by BigRIPS and ZeroDegree were implanted into the WAS3ABi silicon detectors working in conjunction with the EURICA HPGe detector array.

The new data, which includes half-lives and β-delayed neutron emission probability, are of great significance for both nuclear structure and astrophysics. The unknown evolution of the N = 82 shell closure is, in fact, a main challenge for nuclear models, and half-life predictions across the shell gap are often diverging. Many of the measured nuclei are located deep into the r-process path predicted by most models. Thus, the new measurements allow a more reliable comparison between the solar system abundance pattern to the results of reaction network calculations.

This contribution will present the experiment, and will discuss its results and implications for nuclear models and the astrophysical r-process.

Beta-decay of proton-rich nuclei beyond 72Kr; implications for the astrophysical rp-process


1University of York, UK, 2RIKEN Nishina Center, Japan, 3National Physical Laboratory, UK, 4Peking University, China, 5University of Tokyo, Japan, 6University of Brighton, UK, 7Technische Universität München, Germany, 8University of Surrey, UK, 9University of Edinburgh, UK, 10Osaka University, Japan, 11Tohoku University, Japan, 12Beihang University, China, 13Yale University, USA

The nuclide 72Kr is a potential waiting point of the astrophysical rp-process with a beta-decay half-life of 17.1 s. However, its effective half-life in the conditions found in X-ray bursts on accreting neutron stars may significantly be reduced by the 2-proton capture reaction 72Kr(p,γ)73Rb(p,γ)74Sr.

This reaction rate is highly sensitive to the characteristics of the low-energy states of the intermediate nucleus 72Rb, and in particular 72Rb to the unknown proton-separation energy, Sp, of Rb. Furthermore, the reaction above would open a branch of the rp-process path involving nuclei such as 74Sr and 76Y, whose half-lives are not experimentally...
To understand the $^{72}$Kr rp-process bottleneck, a beta-decay spectroscopy experiment was performed at the Radioactive Isotope Beam Factory (RIBF) at RIKEN. The nuclei of interest were produced by the fragmentation of a 345 MeV/nucleon $^{124}$Xe primary beam colliding with a 555 mg/cm$^2$ $^9$Be target. The average beam intensity was 30-35 pnA. The secondary beam purification and identification was provided by the BigRIPS separator. The fragments of interest were unambiguously identified and implanted into the silicon detector WAS$^3$ABi, which recorded the subsequent $\beta$-decays as well. The $\gamma$ rays were recorded by the germanium array EURICA. Implantations were correlated with their subsequent $\beta$-decays on the basis of position and time, enabling measurement of half-lives and $\beta$-delayed $\gamma$ rays.

The half-lives of $^{73,74}$Sr and $^{76}$Y were measured for the first time. Beta-delayed protons were detected following the implantations of $^{73}$Sr that may provide a first direct measurement of Sp in $^{73}$Rb. The isotopes of $^{72,73}$Rb were also observed in BigRIPS; the upper limits for the proton decay half-lives of these isotopes could be established. These results will be presented and their astrophysical implications discussed.

First experimental indication of $\beta$-delayed neutron emission for very exotic nuclei beyond N=126

R Caballero-Folch$^{1,2}$, C Domingo-Pardo$^3$, I Dillmann$^2$ and the S410 collaboration

$^1$Universitat Politècnica de Catalunya (UPC), Spain, $^2$TRIUMF, Canada, $^3$IFIC (CSIC-University of Valencia), Spain

Abstract not available.

Session 11 – Stellar evolution and nucleosynthesis

Invited presentation – Talk title tbc

Falk Herwig

University of Victoria, Canada

Abstract not available.

The intermediate neutron-capture process in stars

M Pignatari$^{1,8}$, F Herwig$^{2,6}$, C Ritter$^{2,8}$, S Jones$^{2,6}$, P Woodward$^3$ and M Bertolli$^{4,5,6}$

$^1$University of Basel, Switzerland, $^2$University of Victoria, Canada, $^3$University of Minnesota, Minneapolis, USA, $^4$University of Tennessee, USA, $^5$Oak Ridge National Laboratory, USA, $^6$NuGrid Collaboration

The intermediate neutron-capture process (i process) was first predicted in 1977 by Cowan and Rose [1]: the isotope $^{13}$C is produced by small amounts of H ingested in He-burning layers, and in these conditions the $^{13}$C($\alpha$,n)$^{16}$O reaction is activated with neutron densities of $\sim 10^{15}$ cm$^{-3}$. The i-process stellar products were only identified for the first time in the Sakurai’s object in 2011 [2]. In these last years, we are collecting several observational evidences of the i process in different types of stars and at different metallicities. The i process might be relevant for the galactical chemical evolution of heavy elements, together with the well established slow neutron-capture process and rapid neutron-capture process [3,4]. In this contribution I present the i-process observations,
and I discuss nucleosynthesis results and present challenges that we need to tackle in order to better understand the i process in stars.


(invited) Probing horrendous space kablooies through horrendous laboratory kablooies

A Parikh\textsuperscript{1,2}

\textsuperscript{1}Universitat Politècnica de Catalunya, Spain \textsuperscript{2}Institut d’Estudis Espacials de Catalunya, Spain

Classical nova explosions, Type I X-ray bursts and Type Ia supernovae are astrophysical phenomena characterized by explosive burning. Reliable thermonuclear reaction rates are required to constrain predicted observable properties of these explosions. We discuss studies that have been performed to identify those rates that most significantly affect model predictions. Recent experimental progress and horrendous suggestions for future studies will be presented.

Theory of stellar convection: Removing the mixing-length parameter

S Pasetto\textsuperscript{1}, C Chiosi\textsuperscript{2}, M Cropper\textsuperscript{3} and E K Grebel\textsuperscript{3}

\textsuperscript{1}University College London, UK, \textsuperscript{2}University of Padua, Italy, \textsuperscript{3}Zentrum fur Astronomie der Universitat Heidelberg, Germany

Stellar convection is customarily described by the mixing-length theory, which makes use of the mixing-length scale to express the convective flux, velocity, and temperature gradients of the convective elements and stellar medium. The mixing-length scale is taken to be proportional to the local pressure scale height, and the proportionality factor (the mixing-length parameter) must be determined by comparing the stellar models to some calibrator, usually the Sun. No strong arguments exist to claim that the mixing-length parameter is the same in all stars and all evolutionary phases. Because of this, all stellar models in literature are hampered by this basic uncertainty.

We present a new theory of stellar convection that does not require the mixing length parameter. Our self-consistent analytical formulation of stellar convection determines all the properties of stellar convection as a function of the physical behavior of the convective elements themselves and the surrounding medium.

The new theory of stellar convection is formulated starting from a conventional solution of the Navier-Stokes/Euler equations, i.e. the Bernoulli equation for a perfect fluid, but expressed in a non-inertial reference frame co-moving with the convective elements. In our formalism, the motion of stellar convective cells inside convective-unstable layers is fully determined by a new system of equations for convection in a non-local and time dependent formalism.

We obtain an analytical, non-local, time-dependent solution for the convective energy transport that does not depend on any free parameter. The predictions of the new theory are compared with those from the standard mixing-length paradigm with very satisfactory results.
Session 12 - Stellar evolution and nucleosynthesis

(Invited) Nucleosynthesis in massive stars
G Meynet
University of Geneva, Switzerland

This talk will focus on the impact of rotation on the nucleosynthesis of massive stars with a strong emphasis on the first generations of very metal poor massive stars. We shall see that rotational mixing can trigger some mild mixing between the helium and hydrogen burning zones and thus can open the path to interesting and new nucleosynthetic products affecting the abundances in CNO and s-process elements in the interstellar medium at the very early phases of the evolution of galaxies. We shall discuss various observational features supporting these views. Some considerations about important nuclear reaction reactions rates in this context will be made indicating how the present uncertainties in their rates impact the results.

Looking for the imprints of the first stellar generations in metal-poor bulge field star
C Siqueira-Mello1, B Barbuy1, C Chiappini2, K Freeman3, M Ness3, E Depagne2, M Pignatari4, R Hirschi5, U Frischknecht5, G Meynet6, A Maeder6 and E Cantelli1

1Universidade de São Paulo, Brazil, 2Leibniz-Institut für Astrophysik Potsdam (AIP), Germany, 3Australian National University, Australia, 4University of Basel, Switzerland, 5Keele University, UK, 6Geneva Observatory, University of Geneva, Maillettes 51, CH-1290 Sauverny, Switzerland

Although most of the current effort in finding the chemical imprints left by the first stars in the oldest stars of the Milky Way have focused on halo very-metal poor stars, high resolution cosmological simulations have shown that at least half of the first stars should have formed in the Galactic bulge. These first objects, formed at the highest density peaks, are believed to have enriched the surrounding ISM extremely fast, so that bulge stars around [Fe/H] = -1 would trace the same early phases as halo stars around [Fe/H] = -3.

In previous works, our group was the first to find evidences of signatures of these early stellar generations in NGC 6522, the oldest globular cluster in the Milky Way, and to show that these stars were most probably fast rotating stars, or spinstars. Besides [Fe/H], the abundances of the elements [O/Fe], [Mg/Fe], [Si/Fe], [Ca/Fe] and [Ti/Fe] were provided, showing an enhancement compared to solar expected from a pure massive stars signature. Concerning elements heavier than iron, Y, Zr, Ba, La, and Eu were also reported to be enhanced, compatible with other recent measurements of heavy elements in the Galactic bulge. The measurements of upper limits for [C/Fe] were also provided, showing no enhancement for carbon.

The abundances agree with recent inhomogenous chemical evolution models where spinstars were taken into account, which indicate a moderate enhancements of the [Y/Ba] ratio at metallicities around [Fe/H] = -1. The milder enrichment found for Y compared with Ba, and the abundance scatter found for Ba and La makes the mass transfer contribution from s-process-rich AGB stars another possible scenario to explain the signature in NGC 6522. In the first case the chemical enrichment is from stars polluting the primordial material before
forming the cluster, in the second case the chemical enrichment would have been explained by stars belonging to NGC 6522.

In order to disentangle between these two scenarios, it is important to analyse the abundance pattern in bulge field stars of the lower end of the bulge metallicity distribution (MDF). Thanks to the Galactic bulge ARGOS Survey it was possible to select 11 confirmed bulge stars, with metallicities around that of NGC 6522 and estimated over solar [alpha/Fe] ratios. These stars are most probably sampling the lower end of the Bulge MDF, offering a unique opportunity to test our main hypothesis that the oldest bulge stars at one tenth the solar metallicity probe the earliest phases of the chemical enrichment of our Galaxy as well as of the Universe. In this contribution we present the analysis of five metal-poor (around [Fe/H] = -1) Bulge stars selected from ARGOS, based on UVES spectra at high resolution R=45,000 with a slit width of 0.8", covering the wavelength range 480 – 680 nm. The abundances of key elements are discussed and compared to those of NGC 6522, which brings better understanding of the problem described.

### 12C+12C measurements at low energies

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<td>University of Edinburgh, UK</td>
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12C(12C,α)20Ne and 12C(12C,p)23Na are the most important reactions during the carbon burning stage in the evolution of massive stars. Direct measurements at the relevant astrophysical energy (E_{cm} = 1.5 ± 0.3 MeV) are very challenging because of the extremely small cross sections involved and of the high beam-induced background originating from impurities in the targets. High purity, stable carbon targets are critical for measurements of these reactions cross sections at astrophysical energies.

In this work, we present a new experimental effort aiming to an improved measurement of this reaction at the laboratory CIRCE, Caserta, Italy. An extensive characterization of the targets under beam bombardment allowed to significantly reduce the beam-target induced background. An array of two-stage detectors is used to detect both alpha and protons emitted in the two exit channels of 12C+12C of interest in astrophysics. The experimental setup and its commissioning are discussed and, finally, first results at E_{cm} = 3 - 4 MeV are presented and compared to previous data.

### Measurement of 23Na(α,p)26Mg at energies relevant to 26Al production in massive stars and nucleosynthesis in SNIa

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The galactic distribution of 26Al can be mapped using gamma-ray telescopes to detect the characteristic 1.809-MeV gamma-ray produced as a result of its decay to 26Mg. These maps suggest massive stars as the main production site for 26Al, though this is still uncertain. Four reactions have been identified using post processing codes as having a significant effect on the 26Al produced during several different burning stages in massive stars, one of which is the 23Na(α,p)26Mg reaction. This reaction is influential during neon/carbon convective shell burning as it provides protons for the production of 26Al via the reaction 25Mg(p,γ)26Al. Additionally the reaction is thought to be influential during nucleosynthesis in type 1a supernovae.
Until recently astrophysical models used the theoretical non-SMOKER rate for the $^{23}\text{Na}(\alpha,p)^{26}\text{Mg}$ reaction due to insufficient experimental data in the Gamow window. A direct measurement of $^{23}\text{Na}(\alpha,p)^{26}\text{Mg}$ was performed in inverse kinematics using the TUDA scattering chamber at the TRIUMF. The measurement was made at energies of $E_{cm} = 1.7 - 3.1$ MeV, corresponding to neon/carbon convective shell burning in massive stars at $T \sim 1.25$ GK and nucleosynthesis in type 1a supernova at $T \sim 2 - 4$ GK. The astrophysical motivation, experimental setup and results will be discussed.

Session 13 - Stellar evolution and nucleosynthesis

Nucleosynthesis of $^{26}\text{Al}$ in massive stars: New $^{27}\text{Al}$ states above alpha and neutron emission thresholds


1CNRS-IN2P3/Université Paris-Sud, France, 2Université Mouloud Mammeri, Algeria, 3University of York, UK, 4Universidad de Huelva, Spain, 5Saha Institute of Nuclear Physics, India

The $^{26}\text{Al}$ radioisotope is of great importance for understanding the chemical and dynamical evolution of our Galaxy. Among the possible stellar sources, massive stars are believed to be the main producer of this radioisotope. Recent sensitivity studies [1] have shown that understanding $^{26}\text{Al}$ nucleosynthesis in massive stars requires better estimates of the thermonuclear reaction rates of the $^{26}\text{Al}(n,p)^{26}\text{Mg}$, $^{26}\text{Al}(n,\alpha)^{23}\text{Na}$ and $^{23}\text{Na}(\alpha,p)^{26}\text{Mg}$ reactions. These reaction rates depend on the spectroscopic properties of $^{27}\text{Al}$ states above the neutron and alpha thresholds. In this context, the inelastic scattering $^{27}\text{Al}(p,p')^{27}\text{Al}$ reaction was studied populating states from the ground-state up to excitation energies above the $^{26}\text{Al}+n$ threshold [2].

After a brief presentation of $^{26}\text{Al}$ nucleosynthesis in massive stars, the two experiments done at the TANDEMs of the ALTO facility (Orsay) and the MLL (Munich) will be presented. The use, in both cases, of very high-energy resolution spectrometers allowed to discover 30 new levels above the $^{23}\text{Na}+\alpha$ threshold and more than 30 new states above the $^{26}\text{Al}+n$ threshold. The experimental details and results will be discussed.


Spectroscopic study of $^{27}\text{Al}$ states above the neutron threshold via the $^{26}\text{Mg}(3\text{He},d)$ reaction

S Gillespie, N de Sereville, C J Barton, T Faestermann, J Kiener, A Laird, C Portail, J Riley and M Williams

1University of York, UK, 2Institut de Physique Nucléaire d’Orsay, France, 3Technische Universität München, Germany, 4CSNSM, France

$^{26}\text{Al}$ is believed to be responsible for the excess of $^{26}\text{Mg}$ relative to $^{24}\text{Mg}$ seen in Calcium Aluminium rich Inclusions (CAIs) [1]. As CAIs were among the first solids to condense in the early solar system, understanding the origin of $^{26}\text{Al}$ is essential to constrain the astrophysical conditions present at the formation of the solar system. Reaction network calculations [2] have shown that the $^{26}\text{Al}$ destruction reactions $^{26}\text{Al}(n,p)^{26}\text{Mg}$ and $^{26}\text{Al}(n,\alpha)^{23}\text{Na}$ in massive stars are among the most uncertain with a factor of two of accuracy required to minimize uncertainties in $^{26}\text{Al}$ production.

Knowledge of individual resonances in these reactions, corresponding to states above the neutron threshold in $^{27}\text{Al}$ will help to constrain reaction rates.
The $^{26}\text{Mg}^{(3}\text{He},d)^{27}\text{Al}$ transfer reaction was performed at the Maier-Leibnitz-Laboratorium (Garching, Germany) using the Q3D magnetic spectrometer in order to assign spin parity information to states seen above the neutron threshold in a recent $^{27}\text{Al}(p,p')^{27}\text{Al}$ inelastic scattering study[3]. The $^{26}\text{Mg}^{(\alpha},t)^{27}\text{Al}$ reaction was also studied to compare to the $^{26}\text{Mg}^{(3}\text{He},d)^{27}\text{Al}$ reaction to identify high spin states. Experimental details and results will be presented and compared to theoretical DWBA calculations performed using the FRESCO code.


Branching ratio of the $\beta$-delayed $\alpha$-decay of $^{16}\text{N}$ and its effect on the calculated $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction rate

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\textsuperscript{1}Aarhus University, Denmark, \textsuperscript{2}KU Leuven, Belgium, \textsuperscript{3}Kernfysisch Versneller Instituut, The Netherlands

Abstract not available.

Low energy scattering cross section ratios of $^{14}\text{N}(p,p)^{14}\text{N}$

R J deBoer\textsuperscript{1}, P F Bertone\textsuperscript{2,3}, D W Bardayan\textsuperscript{1}, A E Champagne\textsuperscript{2,3}, J Görres\textsuperscript{1}, M S Islam\textsuperscript{4}, P J LeBlanc\textsuperscript{1}, K V Manukyan\textsuperscript{1}, M Moran\textsuperscript{1}, K Smith\textsuperscript{1}, W Tan\textsuperscript{1}, E Uberseder\textsuperscript{2} and M Wiescher\textsuperscript{4}

\textsuperscript{1}University of Notre Dame, USA, \textsuperscript{2,3}University of North Carolina at Chapel Hill, USA, \textsuperscript{4}Triangle Universities Nuclear Laboratory, USA, \textsuperscript{4}Ball State University, USA

The slowest reaction in the first CNO cycle is $^{14}\text{N}(p, \gamma)^{15}\text{O}$, therefore its rate determines the overall energy production efficiency of the entire cycle. The cross section presents several strong resonance contributions, especially for the ground state transition. Some of the properties of the corresponding levels in the $^{15}\text{O}$ compound nucleus remain uncertain, which affects the uncertainty in extrapolating the capture cross section to the low energy range of astrophysical interest.

The $^{14}\text{N}(p, \gamma)^{15}\text{O}$ cross section can be described using phenomenological $R$-matrix [1]. Over the energy range of interest, only the proton and $\gamma$ channels are open. Since resonance capture makes significant contributions to the $^{14}\text{N}(p, \gamma)^{15}\text{O}$ cross section, resonant proton scattering data can be used to provide additional constraints on the $R$-matrix fit of the capture data.

A 4 MV KN Van de Graaff accelerator was used to bombard protons onto a windowless gas target containing enriched $^{14}\text{N}$ gas over the proton energy range from $E_p = 1.0$ to 3.0 MeV. Scattered protons were detected at $\theta_{lab} = 90, 120, 135, 150,$ and 160° using ruggedized silicon detectors. In addition, a 10 MV FN Tandem Van de Graaff accelerator was used to accelerate protons onto a solid Adenine target, of natural isotopic abundance, evaporated onto a thin self-supporting carbon backing, over the energy range from $E_p = 1.8$ to 4.0 MeV. Scattered protons were detected at 28 angles between $\theta_{lab} = 30.4$ and 167.7° using silicon photodiode detectors.

Relative cross sections were extracted from both measurements. While the relative cross sections do not provide as much constraint as absolute measurements, they reduce the dependence of the data on significant systematic uncertainties, which are more difficult to quantify [2]. The data are fit simultaneously using an $R$-matrix analysis and level energies and proton widths are extracted. Even with relative measurements, the statistics and large angular...
The relative cross sections provide a consistent set of data that can be used to better constrain a full multichannel $R$-matrix extrapolation of the capture data. In particular, the broad resonance at $E_{\text{cm}} = 2.21$ MeV can interfere with the $E_x = 6.79$ MeV subthreshold state, affecting the extrapolation of the capture cross section to the region of astrophysical interest. A preliminary discussion of a global fit which includes both the scattering and capture data will also be presented.


**γ-process reaction studies via in-beam γ-ray spectroscopy at HORUS**

P Scholz, J Mayer, L Netterdon and A Zilges

University of Cologne, Germany

The γ process [1] as a huge network of photodisintegration reactions is an important part in the nucleosynthesis of the proton-rich nuclei which cannot be produced via neutron-capture processes [2]. Reaction-network calculations of the γ process are almost completely based on theoretical predictions for reaction rates in the scope of the Hauser-Feshbach statistical model. The accuracy of these theoretical reaction rates are strongly influenced by the adopted models for nuclear physics input-parameters like particle+nucleus optical-model potentials (OMP), γ-ray strength functions, and nuclear-level densities. Precise cross section measurements at astrophysically relevant energies help to constrain adopted models and, therefore, to reduce the uncertainties in the theoretical predicted reaction rates.

Several charged particle induced reactions were studied within the last years by our group addressing the improvement of adopted models for α- or proton-OMPs as well as the γ-ray strength function. These cross-section measurements were performed by applying either the well-known activation technique using the Cologne Clover Counting Setup [3,4,5] or the in-beam technique with HPGe detectors using the highly efficient HORUS γ-ray spectrometer [6].

The recently studied $^{112}\text{Sn}(\alpha,\gamma)^{116}\text{Te}$ reaction at HORUS was the first successful measurement of an α- capture reaction on a heavy nucleus applying the in-beam method with HPGe detectors. The obtained cross sections could not be reproduced by statistical model calculations based on widely used models for nuclear physics input-parameters but required local modifications which lead to an excellent reproduction of the measured values. In addition, the modification have also found to be very successful in describing cross-section values of the $^{112}\text{Sn}(\alpha,p)$ reaction as well as of α-induced reactions on $^{106}\text{Cd}$ and $(\alpha,n)$ reactions on $^{115,116}\text{Sn}$. The recently performed in-beam measurement of the $^{108}\text{Cd}(\alpha,\gamma)^{112}\text{Sn}$ reaction at HORUS is a promising candidate for further investigations related to the α- OMP in particular for the Sn/Cd region.

This talk, will present the experimental setup at HORUS in Cologne as well as the results of the recently studied reactions and their input on the α-OMP at astrophysically relevant energies.

**Session 14 – Industrial, EU funding and panel discussion**

*(invited)* Detection of MeV scale neutrinos in underground laboratories

A Ianni

Laboratorio Subterráneo de Canfranc, Spain

Neutrinos in the energy range of 1 – 10 MeV can be detected in underground facilities. Namely, solar neutrinos, reactor neutrinos, geo-neutrinos and neutrinos from core collapse supernovae can be searched for by means of high radiopurity massive liquid scintillators. This talk will mainly focus on solar neutrinos and geo-neutrinos. A general introduction on detection techniques will be given. Observation of p-p solar neutrinos will be discussed. The production of these neutrinos together with deuteron is very slow and drives the evolution of the sun in a timescale of billions of years. Being the average energy of p-p neutrinos equal to 267 keV, detection of these neutrinos in realtime is extremely difficult. An extreme level of radiopurity is required to perform such measurement. In the talk the main characteristics of underground detectors for low energy neutrino searches and main background sources and background reduction methods will be presented. Perspective for future measurements will be discussed.

**Session 15 – Tools, techniques and facilities**

*(invited)* Nuclear astrophysics at FRANZ

R Reifarth

Goethe-Universität Frankfurt am Main, Germany

The ‘Frankfurter Neutronenquelle am Stern-Gerlach-Zentrum’ (FRANZ), which is currently under development, will be the strongest neutron source in the astrophysically interesting energy region in the world. It will be about three orders of magnitude more intense than the well-established neutron source at the Research Center Karlsruhe (FZK). Measurements of neutron-induced cross sections are therefore possible on isotopes with half lives down to a few months.

Since the neutron production is based on the \(7\text{Li}(p,n)\) reaction, a 2MV high-power linear accelerator will be the heart of the facility. It is therefore also planned to use the high proton beams directly to determine proton-induced cross sections of astrophysical interest.

The broad portfolio of possible experiments and their astrophysical impact will be discussed during the presentation.
A new method for mass measurements of exotic nuclei produced by the in-flight method at relativistic energies

A-K Rink¹, S Ayet San Andres², T Dickel², J Ebet¹, H Geissel¹,², E Haettner², C Hornung¹, I Miskun², W R Plaß¹,², S Purushothaman², M P Reiter¹, C Scheidenberger¹,², H Weick², P Dendooven³, F Heisse², S Pietri², M Diwisch¹, F Greiner¹, C Jesch¹, N Kalantar-Nayestanaki³, R Knöbel², J Lang¹, W Lippert¹, I Moore³, A Pikhtelev⁵, I Pohjalainen⁴, A Prochazka², M Ranjan³, M Takechi², J S Winfield², X Xu² and M I Yavor⁵

¹Justus-Liebig-Universität Gießen, Germany,²GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany,³University of Groningen, The Netherlands,⁴University of Jyväskylä, Finland, ⁵Russian Academy of Sciences, Russia

Nuclear masses and lifetimes are essential input for network calculations of the r-process. A special challenge is to extend the measurements to nuclides far from stability, where the r-process proceeds. A new method to perform efficient mass measurements of such exotic nuclei has been developed and successfully applied at the FRS Ion Catcher at GSI.

The exotic nuclei are produced in-flight, separated and range bunched at the fragment separator (FRS), thermalised in 80 K cold helium stopping gas in a cryogenic stopping cell (CSC), extracted and transferred to a multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS). Mass measurements of uranium projectile and fission fragments produced by bombarding a beryllium target at 1000 MeV/u have been performed with mass resolving powers up to 400000. For several nuclides, the mass was measured directly for the first time, among them the nuclides ²¹³Rn, ²¹⁸Rn and ²¹⁷At with half-lives of 19.5 ms, 35 ms, 32.5 ms. Mass determination with as few as 27 ions at rates of five ions per hour has been demonstrated. Accuracies down to 0.2 ppm have been achieved for mass measurements. The excitation energies of several isomers and isomeric ratios for fission products like ¹³⁴mXe, ¹³⁵mI, ¹³⁶mI were determined by mass spectrometry. For the first time, a pure isomeric beam was prepared using an MR-TOF-MS. This work opens up new perspectives for mass measurements of very neutron-rich nuclides at GSI and FAIR. Additionally isomers, which can be thermally populated in the r-process at high temperatures, may be of relevance for the nucleosynthesis.

Photodisintegration reactions for nuclear astrophysics studies at ELI-NP

C Matei, D Balabanski and O Tesileanu

Extreme Light Infrastructure – Nuclear Physics (ELI-NP) /Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Romania

Extreme Light Infrastructure – Nuclear Physics facility (ELI-NP) will come online in Bucharest-Magurele, Romania in 2018 and will consist of two components: a very high intensity laser and a very intense brilliant γ beam. ELI- NP will allow either combined experiments between the high-power laser and the γ beam or stand-alone experiments.

We present the physics cases and experimental facilities proposed at ELI-NP to measure capture reactions by means of the inverse photodisintegration reaction.

The ¹²C(α,γ)¹⁶O radiative capture reaction is one of the most important reactions in nuclear astrophysics as its reaction rate strongly influences the present C/O ratio in the Universe. We propose to measure the total cross
section and angular distributions in the $^{16}\text{O}(\gamma,\alpha)$ reaction using a Time Projection Chamber detector with electronic readout.

Several other reactions, such as $^{24}\text{Mg}(\gamma,\alpha)^{20}\text{Ne}$ and reactions on heavy nuclei relevant in the p-process ($^{74}\text{Se}, ^{78}\text{Kr}, ^{84}\text{Sr}$), are central to stellar evolution and will be investigated with a proposed Silicon Strip Detector array. The status of the experimental facilities and first-day experiments will be presented in detail.

**Nuclear astrophysics with radioactive beams at GANIL**

F de Oliveira Santos  
GANIL, France

Several experiments using radioactive beams were performed at GANIL in order to progress in our understanding of certain astrophysical phenomena. A first direct measurement of reaction cross section was performed at relatively low energy [1]. This experiment, the simultaneous measurement of the $\text{H}(^{18}\text{F},\alpha)^{15}\text{O}$ and $\text{H}(^{18}\text{F},p)^{18}\text{F}$ reactions, is related to the cosmic $\gamma$-ray emitter $^{18}\text{F}$ and Novae phenomena. In another experiment, the inelastic scattering reaction $\text{H}(^{19}\text{Ne},p)^{19}\text{Ne}^*$ was used to populate states in $^{19}\text{Ne}^*$. The scattered protons were detected using the VAMOS spectrometer in coincidence with proton or alpha particles emitted from $^{19}\text{Ne}^*$ and detected with a DSSSD. Analysis of the particle-particle angular correlation can be used to determine spin of the states [2]. Super-screening effect in superconductor was study in another experiment. Using beams of high intensity, good quality and high purity obtained in the SPIRAL1 facility, a very accurate measurement of $^{19}\text{O}$ and $^{19}\text{Ne}$ lifetimes was obtained in different substratum [3]. A change of the lifetime was expected. This study is related to the electron screening effects, which is important at low energy in nuclear reactions during stellar hydrostatic combustion phases. The isotope $^{56}\text{Fe}$ is another cosmic $\gamma$-ray emitter, which radiation was observed by spacecrafts, and the reaction $^{56}\text{Fe}(n,\gamma)^{57}\text{Fe}$ was identified as an important reaction for the understanding of its abundance. This reaction was studied at GANIL via the measurement of the transfer reaction $^{56}\text{Fe}(d,p)$ [4]. The measurement of radiative alpha capture reactions is very important in the understanding of the origin of the p-nuclei, medium mass proton rich stable nuclei which origin is probably Supernovae SNII. A series of $(\alpha,\gamma)$ reactions experiments performed in inverse kinematics and using the Wien Filter of LISE as a recoil separator is proposed.

Besides this continuous activity performed in experimental nuclear astrophysics at GANIL, new ideas of experiments are proposed with the future beams that will be available with the new SPIRAL2 facility.

[2] F. Boulay (see abstract)  

**Session 16 - Low-energy and underground nuclear astrophysics**

*(invited)* Latest results from LUNA  
R Depalo  
Università degli studi di Padova and INFN, Italy (*for the LUNA collaboration*)

Cross sections of nuclear reactions relevant for astrophysics are crucial ingredients to understand the energy generation inside stars and the element nucleosynthesis. At astrophysical energies, nuclear cross sections are often
too small to be measured in laboratories on the Earth’s surface where the signal would be overwhelmed by the cosmic-ray induced background.

The Laboratory for Underground Nuclear Astrophysics, located at Gran Sasso National Laboratories (Italy), is currently running the only underground accelerator in the world. The very low background achieved at LUNA allows to perform uniquely sensitive experiments.

In the last years, new measurements have been performed at LUNA concerning several astrophysical scenarios from the big bang to asymptotic giant branch stars and classical nova explosions.

An overview of the current status and latest results of the LUNA experiment will be given.

Direct underground measurement of the $^{17}\text{O}(p,\alpha)^{14}\text{N}$ reaction at LUNA

C G Bruno

University of Edinburgh, UK (for the LUNA Collaboration)

The $^{17}\text{O}(p,\alpha)^{14}\text{N}$ reaction plays a key role in the nucleosynthetic processes of several astrophysical scenarios. In particular, this reaction influences the abundance of the rare isotope $^{17}\text{O}$, which can be used to trace and constrain extra mixing processes occurring in AGB stars. Extra mixing processes, such as the Cool Bottom Process (CBP), are not very well understood [1] and new nuclear input may help improve the agreement between stellar models and observations [2]. At temperatures of astrophysical interest, the $^{17}\text{O}(p,\alpha)^{14}\text{N}$ reaction is dominated by a narrow resonance at $E_p = 70$ keV in the laboratory frame.

Measuring this resonance is extremely challenging because of its weakness ($\omega\gamma \sim \text{neV}$), and both direct [3,4] and indirect [5] measurements have been performed. However, ref. [3] was partially retracted [6] and ref. [4] was later re-analysed as well [7]. The picture painted in the literature is still incomplete.

An experimental campaign aimed at measuring the 70 keV resonance in $^{17}\text{O}(p,\alpha)^{14}\text{N}$ has recently been completed at the underground LUNA-400 accelerator in Gran Sasso Laboratory, Italy. The thick target yield technique was employed. Protons were accelerated on a solid $\text{Ta}_2\text{O}_5$ target, enriched in $^{17}\text{O}$, and the alpha particles produced were detected by an array of eight silicon detectors positioned at backward angles [8]. Final results on efficiency measurements, target contaminants and target stability under beam will be presented. Preliminary results on the strength of the $E_p = 70$ keV resonance in $^{17}\text{O}(p,\alpha)^{14}\text{N}$ will be discussed.

References:

Progress of the Felsenkeller shallow-underground 5 MV accelerator for nuclear astrophysics

D Bemmerer and K Zuber

1Helmholtz-Zentrum Dresden-Rossendorf, Germany, 2Technische Universität Dresden, Germany
In the case of astrophysically important reactions, cross section measurements at or near the Gamow energy require high-intensity accelerators, long running times of typically one year per experiment, and ultra low background [1]. The highly successful LUNA 0.4 MV accelerator in Gran Sasso, Italy, has pioneered this field with data on several nuclear reactions of stellar hydrogen burning and of Big Bang nucleosynthesis. As a result, there is a call for one or more new underground accelerators with higher beam energy, able to address also helium and carbon burning and the neutron sources for the astrophysical s-process [2].

Such an accelerator is being installed at the Felsenkeller underground site in Dresden, Germany. It is shielded from cosmic radiation by 45 m of rock, reducing the muon flux by a factor of 40. An intercomparison exercise has shown that at Felsenkeller, the background in a typical nuclear astrophysics γ-ray detector is competitive to the deep-underground case in the crucial 6-8 MeV γ-ray energy range, if an additional muon veto is used.

A high-current 5 MV Pelletron accelerator that was previously used in York, UK, has been bought for this purpose. It is being fitted with an internal ion source to provide intensive H+ and He+ beams in addition to the existing external sputter ion source. The site construction progress will be shown. The laboratory will be open to outside users, who are invited to form a user consortium.

P:01 Precision mass measurements of $^{129-131}$Cd for nuclear astrophysics studies


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The rapid neutron capture process (r-process) is the proposed mechanism for the creation of more than 50% of elements heavier than iron up to bismuth and all thorium and uranium observed in the solar system abundance. While generic scenarios for the r-process can be proposed, experimental input from nuclear physics is greatly needed. The path of the r-process proceeds through very exotic and short-lived neutron-rich isotopes, where experimental data is still missing. Valuable observed quantities constraining r-process calculations are binding energy, half-lives, neutron capture cross section etc. The Penning-trap mass spectrometer ISOLTRAP, situated at ISOLDE/CERN, is primarily dedicated to precision mass measurements of radioactive isotopes from which their binding energy can be determined. In recent experiment, ISOLTRAP measured the masses of the neutron-rich Cd isotopes in the A = 130 region. In this contribution the current ISOLTRAP setup will be presented as well as the techniques for mass measurements of Cd isotopes. Furthermore we will discuss their impact on nuclear astrophysics.

P:02 The feasibility of direct measurement of the $^{44}$Ti($\alpha$, p)$^{47}$V reactions at astrophysically relevant temperatures

T Al-Abdullah, D Bemmerer, Z Elekes and D Schumann

1Hashemite University, Jordan, 2Helmholtz-Zentrum Dresden-Rossendorf, Germany, 3Institute for Nuclear Research of the Hungarian Academy of Sciences, Hungary, 4Paul Scherrer Institute, Switzerland

Understanding the synthesis of radioactive $^{44}$Ti in the alpha-rich freeze-out following core-collapse supernovae may help to better interpret such explosive events. The gamma-ray lines from the decay of $^{44}$Ti have been observed by space-based gamma-ray telescopes from two supernova remnants. It is believed that the $^{44}$Ti($\alpha$, p)$^{47}$V reaction dominates the destruction of $^{44}$Ti. A possible technique to determine its reaction rate at astrophysically relevant energies in forward kinematics will be presented. Two important concerns are considered to make this study possible: The amount of stable Ti in the radioactive target and the degree of radioactive contaminations in the experimental setup due to sputtered $^{44}$Ti atoms after intensive irradiations. Several online and offline measurements in parallel with Monte Carlo simulations were performed and the results will be discussed.
P:03 Low energy neutron background in deep underground laboratories
A Best1,2, J Goerres2, M Junker1, K L Kratz1, A Long2, K Smith2 and M Wiescher2
1INFN, Italy, 2University of Notre Dame, USA, 3Max-Planck-Institute for Chemistry, Germany

The natural neutron background influences the maximum achievable sensitivity in most deep underground nuclear, astroparticle and double-beta decay physics experiments. Reliable neutron flux numbers are an important ingredient in the design of the shielding of new large-scale experiments as well as in the analysis of experimental data.

Using a portable setup of 3He counters and polyethylene moderators we measured the thermal and epithermal neutron flux at the Kimballton Underground Research Facility, the Soudan Underground Laboratory, on the 4100 ft and the 4850 ft levels of the Sanford Underground Research Facility, at the Waste Isolation Pilot Plant and at the Gran Sasso National Laboratory. Absolute neutron fluxes at these laboratories are presented and the consequences for future underground measurements of neutron producing reactions for nuclear astrophysics is discussed.

P:04 Nucleosynthesis of Mo and Ru isotopes in neutrino-driven winds
J Bliss1 and A Arcones1,2
1Technische Universität Darmstadt, Germany, 2GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany

Neutrino-driven winds from nascent neutron stars in core-collapse supernovae are an exciting astrophysical site for the synthesis of elements between Sr and Ag.

We have performed a systematic nucleosynthesis study to identify the necessary conditions for the synthesis of the Mo and Ru isotopes. Molybdenum and ruthenium have raised interest because the origin of their highly abundant p-nuclides in the solar system is still under debate. Moreover, available data of SiC X grains exhibit a different isotopic ratio of 95Mo and 97Mo than in the solar system. We present here the wind conditions that lead to the production of 92,94Mo, 96,98Ru and to the peculiar composition of 95,97Mo found in SiC X grains.

P:05 Background modeling and shielding of a Bismuth Germanium Oxide (BGO) detector underground
A Boeltzig1, A Best2, M Junker2, G Imbriani3, A Di Leva3 and C Savarese1
1Gran Sasso Science Institute, Italy, 2Laboratori Nazionali del Gran Sasso, Italy, 3Università degli Studi di Napoli Federico II, Italy

The Laboratory Underground for Nuclear Astrophysics (LUNA) is an accelerator facility to measure nuclear cross sections of astrophysical interest. Its location underground at the Gran Sasso National Laboratories greatly reduces the cosmic ray induced background. A detailed understanding of the remaining background in the detector is crucial for the analysis of measurements and the design of measures for further background suppression.

The work presented here focuses on non-beam-induced backgrounds in a segmented BGO detector in use at LUNA. These backgrounds are mainly caused by the environmental gamma ray and neutron flux and the intrinsic radioactivity of the detector itself. The main region of interest for this work is determined by the Q-values of reactions scheduled to be measured at LUNA in the near future: 18O(p,γ)19F and 23Na(p,γ)24Mg with Q = 8.0 MeV and Q = 11.7 MeV respectively.

A model for the different background contributions based on detector simulations was developed. The results of these studies for the bare detector and for a setup utilizing a newly constructed massive lead shield are presented.
Comparison between simulations and measurements are shown and possible further improvements of the setup are discussed.

**P:06 Thermonuclear reaction rates for $^{17}\text{O}+\rho$ - a low-energy, high beam current study of $^{17}\text{O}(\rho, \gamma)^{18}\text{F}$**

M Q Buckner, C Iliadis, K J Kelly, L N Downen, A E Champagne, J M Cesaratto, C Howard and R Longland

University of North Carolina, USA

Hydrogen burning of oxygen isotopes occurs in classical novae, low-mass stars, and asymptotic giant branch (AGB) stars. Reliable thermonuclear reaction rates for hydrogen burning of the oxygen isotopes—when coupled with oxygen elemental and isotopic abundances derived from stellar spectra and the analysis of presolar grains—can constrain stellar models. A new measurement of the $^{17}\text{O}(\rho, \gamma)^{18}\text{F}$ reaction within the $H^+$ bombarding energy range $E_{\text{lab}} = 170−530$ keV was performed at the Laboratory for Experimental Nuclear Astrophysics (LENA). This in-beam measurement was made with substantially higher beam intensities ($I_{\text{p, max}} \approx 2$ mA) than previous work, and a sophisticated $\gamma\gamma$-coincidence spectrometer was used. Additionally, a novel spectral analysis method was applied based on the decomposition of different contributions to the measured pulse-height spectrum. The $^{17}\text{O}(\rho, \gamma)^{18}\text{F}$ reaction was studied within the classical nova Gamow window, and the cross section was measured at much lower energies than previous in-beam measurements. A new direct capture S-factor at zero energy and new $E_{\text{lab}} = 193$ and 518 keV resonance strengths were determined. These new values and all consistent results from previous measurements contributed to the new $^{17}\text{O}+\rho$ thermonuclear reaction rates that will be presented. This work has been accepted for publication by Physical Review C.

**P:07 Anharmonic oscillator potentials in the prolate $\gamma$-rigid regime of the collective geometrical model**

R Budaca

Horia Hulubei National Institute of Physics and Nuclear Engineering, Romania

An analytical expression for the energy spectrum of the ground and $\beta$ bands was obtained in the axially symmetric $\gamma$-rigid regime of the Bohr-Mottelson Hamiltonian with a harmonic oscillator potential in the $\beta$ shape variable amended with a higher order anharmonicity term. The anharmonic terms are considered of quartic [1] and sextic [2] types. The particular structure of the model space facilitates the exact separation of angular variables from the $\beta$ variable, leading to a differential Schrodinger equation with an anharmonic potential and a centrifugal-like barrier. The Schrodinger equation for a quartic potential is not exactly solvable, while that for the sextic potential is quasi exactly solvable for certain family of shapes which however is not the case of the present problem. Thus, the corresponding eigenvalues are approximated by an analytical formula derived on the basis of the JWKB approximation [3], which depends on a single parameter except the scale. This approximation has a finite convergence radius which is determined in respect with exact numerical results [4,5].

Studying the behavior of the potential and of the whole energy spectrum as function of the free parameter, one establishes the present model’s place between other $\gamma$-rigid models [2,6]. The experimental realization of the model is found in a variety of vibrational-like nuclei exhibiting some regularity regarding the order of the considered anharmonicity.

P:08 Nuclear astrophysics at LNL: The $^{25}$Mg($\alpha$,n)$^{28}$Si and $^{10}$B(p,$\alpha$)$^{7}$Be cases

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The National Laboratory of Legnaro (LNL) has a long experience in Nuclear Physics measurements. Recently a new effort to perform Nuclear Astrophysics studies has been initiated. This effort started with the collaboration of LNL with the LUNA (Laboratory for Underground Nuclear Astrophysics) collaboration for the study of targets. After that in 2012, thanks to a fruitful collaboration between nuclear astrophysicist and nuclear physics groups involved in neutron detection, the study of the $^{25}$Mg($\alpha$,n)$^{28}$Si reaction was developed in order to help solving the $^{26}$Al puzzle. For the first time the angular distributions of neutrons emitted by this reaction were studied deeply founding discrepancies between the previous studies in literature.

In 2014 the study of $^{10}$B(p,$\alpha$)$^{7}$Be was performed in order to give a precise normalization to the indirect measurements. This study was done by measuring the activated samples and it is still under analysis. A report of the status of the two experiments will be given in this contribution.

P:09 Gravitational redshift and the singularity effect in de Sitter field

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We analyze the gravitational redshift in de Sitter field to continue the study of this topic in the post-Newtonian potential fields. An important consequence of this approach is that we obtain $\Lambda<0$ as an existence condition by calculation required. Also in the general relativistic approximation, we identify a “black hole effect” namely we obtain for the Cauchy horizon a gravitational radius noted by us $\rho_{d'S}$. We discuss about it versus $R_M$ - the gravitational radius of Maneff’ scaled field - and $\rho_S$ - the radius which occurs in the Schwarzschild problem.

P:10 Detection of solar neutrinos with a torsion balance with sapphire crystal

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The solar neutrinos (antineutrinos) are detected with a dedicated torsion balance in the case when they interact coherent on stiff crystals (sapphire with high Debye temperature $\sim 1000$K and lead with $\sim 100$K Debye temperature). The balance consists in two equal masses of lead and sapphire, of 25g. An autocollimator coupled to this balance measures small rotation angles of the balance. The force with which neutrino flux interacts with these crystals is between $10^{-5}$ and $10^{-8}$, comparable with that reported in Weber’s experiments[1]. A diurnal effect is observed for solar neutrinos due to the rotation of the Earth around its own axes. The solar neutrino flux obtained at the site of our experiment is $\sim 3.8*10^{10}$neutrinos/cm$^2$*s[2]. Experimental data for neutrinos signals from this high sensitivity torsion balance, are presented and discussed[3].

The study of cluster states in neutron rich Beryllium and Carbon isotopes is an important topic in Nuclear Physics due to the possible formation of molecular nuclear states [1]. These particular states are characterized by highly deformed structures in which alpha clusters are bounded by valence neutrons [1,2]. We performed a spectroscopic study of $^{10}$Be and $^{16}$C isotopes via projectile break-up reactions, by using radioactive beams produced at the INFN – Laboratori Nazionali del Sud (LNS) FRIBs facility [3,4] and the Chimera 4π multi-detector array [5]. The good granularity of the Chimera device and the complete azimuthal angle coverage allowed us to identify and track each break-up fragment of the reactions H,D,C($^{10}$Be*, $^{6}$He+4He), H,D,C($^{16}$C*, $^{6}$He+$^{10}$Be), H,D,C($^{16}$C*, $^{4}$He+$^{6}$He+4He). By measuring their energies, masses and flight directions, we reconstructed $^{10}$Be and $^{16}$C relative energy spectra. They indicate the possible presence of excited states strongly characterized by clustering phenomena. From the analysis of the first reaction, above mentioned, we found peaks corresponding to some excited states of $^{10}$Be known in literature and a new possible state of $^{10}$Be at 13.5 MeV of excitation energy. From the study of the corresponding $^{4}$He-$^{4}$He angular correlations we estimated that the 13.5 MeV state can be a high spin (possibly 6$^+$) state, in agreement with [6]. In this case, it may represent the missing member of a $^{10}$Be rotational band, proposed in [2]. Finally, from binary ($^{4}$He+$^{10}$Be) and ternary ($^{4}$He+$^{6}$He+$^{4}$He) cluster decompositions of $^{16}$C we found, respectively, the indication of possible new states at about 20.6 MeV and 34 MeV. A new experiment, with improved angular resolution and better statistics, will be performed in the next month at LNS by using the Farcos array [7] to improve $^{16}$C spectroscopy.

P:12 Impact of rotation and magnetic fields in low mass AGB stars

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After core helium burning in stars with an initial mass of 1.5-3 solar masses, starts the AGB phase. In this phase, the s-process takes place, which is believed to be at the origin of half of all elements heavier than iron. Rotation and magnetic fields play a key role in stars but their impact on the AGB phase is debated and still uncertain.

We have calculated stellar evolution models with MESA for stars with an initial mass of 1.65 solar masses, to investigate the effect of the extra mixing. Our models include both rotation and the Tayler-Spruit dynamo. We will show how the extra mixing contributes to the total diffusion coefficient and how it will affect the transport of angular momentum and the s-process nucleosynthesis.

When comparing the results to observations, we find that the final core spin of the rotating magnetic models is closer to the observed values than that of the rotating non-magnetic models. The preliminary results of the s-process nucleosynthesis suggest the same trend.

P:13 Improved primordial D/H calculation with re-evaluated rates

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The main goal of this work is to improve the precision on big bang nucleosynthesis (BBN) D/H calculations to match new very precise observations by i) updating reaction rates involving Deuterium and ii) improving numerical BBN calculations.

Deuterium most primitive abundance is determined from the observation of very few cosmological clouds at high redshift on the line of sight of distant quasars. Recently, Cooke et al. [1] have made new observations and reanalysis of existing data, that lead to a new average value of D/H = (2.53 ±0.04) ×10−5, lower and with smaller uncertainties than in previous determinations. Deuterium BBN predictions are marginally compatible with BBN predictions of D/H = (2.656 ±0.067) ×10−5 [2], (2.54 ±0.17) ×10−5 [3] and (2.64±0.08) ×10−5 [4]. If such a precision of 1.6% in observations is confirmed, great care should be paid to nuclear cross sections affecting Deuterium nucleosynthesis.

The 2H(d,n)3He, 2H(d,p)3H and 2H(p,γ)3H reactions, are the most influential on D/H predicted abundance. According to Di Valentino et al. [5], the 2H(p,γ)3H reaction rate uncertainty now dominates the error budget on D/H predictions. We have re-evaluated these three reaction rates taking into account new measurements and using theoretical models to fit the experimental data. To better determine the rate uncertainties, we had to consider the significant dispersion in absolute normalization factors, from one experiment to the other.

Finally, it has been shown [6] that Gear’s backward differentiation method for nuclear reaction network integration gave more accurate results in various astrophysical contexts. We recently implemented this method in our BBN code aiming at a better precision, in particular, on calculated primordial D/H.

Gamma-ray line diagnostics of the interstellar medium – $^{26}$Al, $^{60}$Fe, and $e^+$


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Gamma-ray lines from radioactive decay in the interstellar medium (ISM) of isotopes produced by stars and supernovae convey information about the nucleosynthesis sources in our Galaxy, and about how ejecta are mixed into interstellar gas. $^{26}$Al ($\tau = 1.04$ My) and $^{60}$Fe ($\tau = 2.65$ My) are accumulated in the ISM from many sources, most likely massive stars and their supernovae. These eject such long-lived radio-isotopes at times several My after star formation, when the stellar wind (for $^{26}$Al) and the core-collapse supernova explosion (both isotopes) release the nuclear fusion products from their sources into the ISM. The amount of an isotope is most-directly measured through the gamma-ray flux in characteristic lines, and reflects the integrated activity of massive stars; thus it can be converted into a massive-star census, or a star formation or supernova rate, measured in penetrating gamma-rays from the Galaxy and from specific stellar associations therein.

$^{26}$Al observations accumulated over the INTEGRAL mission have revealed spectra from along the inner Galactic ridge and from several bright regions along the Galaxy. Comparisons with population synthesis models and their predicted $^{26}$Al yields, kinetic energy injection, and ionizing luminosity have been exploited to relate the stellar census of a massive-star group to observed gamma-ray brightness, ISM cavity sizes, and free free emission. For the Scorpius-Centaurus association, the U Sco subgroup of stars is at the right age to appear as the main source of $^{26}$Al, while in HI data we find cavities attributed to the older associations and Lower Centaurus Crux. From spatially separated spectra along the inner Galaxy, we traced systematic variations of $^{26}$Al gamma-ray line centroids according to Doppler shift from large-scale galactic rotation. Comparing the velocity results for $^{26}$Al to other objects in the Galaxy, specifically molecular gas (CO) and masers, we find a surprising velocity excess by about 200 km s$^{-1}$ of $^{26}$Al over other objects. We interpret this as $^{26}$Al ejecta travelling in superbubbles of sizes up to kpc, which are moreover asymmetrically distributed around the parental stellar groups and extend away from spiral arms into the interarm regions. This results in decaying $^{26}$Al to on average travel more frequently into forward rotation directions away from spiral arms, providing this extra velocity while emitting gamma rays. We discuss the implications of such a superbubble geometry for ejecta and kinetic-energy recycling in interstellar gas and the Galaxy as a whole.

$^{60}$Fe observations are being re-analyzed using an improved instrumental background treatment. We show previous results from the Galaxy’s $^{60}$Fe sources, and discuss prospects of the new re-analysis which also adds more data. Similarly, characteristic gamma rays from positrons annihilating in interstellar gas with main energy 511 keV and a continuum towards lower energies is being re-analyzed, using a variety of background approaches, and attempting to associate emission regions to characteristic structures in the Galaxy.
P:15 Explosion dynamics of parametrized spherically symmetric core-collapse supernova simulations

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We trigger explosions in otherwise non exploding models with the PUSH method (see abstract submitted by C. Fröhlich). It taps the energy reservoir provided by the heavy neutrino flavours to locally increase the energy deposition in the gain region, mimicking in spherically symmetric simulations the effects of large multi-dimensional hydrodynamical instabilities. Here, we investigate characteristics of the explosion energy, such as the different energy contributions and their evolutions. We confine the progenitor mass range to 18 – 21 solar masses, which corresponds to the typical values of the progenitor mass reported for SN1987A. Furthermore, we study the dependence on the progenitor structure, where we find that the compactness of the progenitor star strongly influences the explosion dynamics.

P:16 Explosive nucleosynthesis in core-collapse supernovae: The titanium problem

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Based on a new mechanism to drive spherically symmetric core-collapse supernovae (PUSH; see abstract submitted by K. Ebinger and C. Fröhlich), we perform full network nucleosynthesis calculations for different progenitors. Comparison to observations of $^{56-58}$Ni ejecta masses of SN 1987A [1,2] reveals the necessity of fallback in our model. However, the ejected titanium masses in our calculations are lower than the values inferred from observations. We demonstrate the sensitivity of ejecta composition on the progenitor structure and the mass cut. Furthermore, we show the dependence of $^{44}$Ti production on hydrodynamic quantities and discuss possible solutions to the well-known problem of titanium underproduction [3,4].


P:17 Measurement of the strengths of the resonances at 417, 611, and 632 keV in the $^{22}$Ne(p,γ)$^{23}$Na reaction

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The $^{22}$Ne(p,γ)$^{23}$Na reaction is part of the NeNa cycle of hydrogen burning. This cycle plays a key role in the nucleosynthesis of the elements between $^{20}$Ne and $^{27}$Al in red giant stars, asymptotic giant stars and classical nova explosions [1,2]. The strengths of the resonances at proton energies above 400 keV are still affected by high uncertainty [3,4]. In order to reduce this uncertainty, a precision study of the most intense resonances between 400 keV and 700 keV has been performed at the HZDR 3 MV Tandetron. The target, made of $^{22}$Ne implanted in a 0.22 mm thick Ta backing, has been characterized using the 1222 keV and 458 keV resonances, well known in literature [4,5]. Subsequently, the strengths of the resonances at 417, 611, and 632 keV were determined. Two HPGe detectors equipped with active anti-Compton shielding have been used. – Supported by the European Union
Towards a study of the $^{22}$Ne(p,$\gamma$)$^{23}$Na reaction with a BGO detector at LUNA

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The $^{22}$Ne(p,$\gamma$)$^{23}$Na reaction takes part in the neon-sodium cycle of hydrogen burning. This cycle is active in asymptotic giant branch stars as well as in novae and contributes to the nucleosynthesis of neon and sodium isotopes. In order to reduce the uncertainties in the predicted nucleosynthesis yields, new experimental efforts to measure the $^{22}$Ne(p,$\gamma$)$^{23}$Na cross section directly at the astrophysically relevant energies are needed.

The Laboratory for Underground Nuclear Astrophysics (LUNA) at INFN-LNGS provides a unique opportunity to study this reaction due to its location under the Gran Sasso massif. The experimental approach applied is based on differentially pumped gas target system and a high-current electrostatic accelerator.

In the first, recently completed phase of the LUNA $^{22}$Ne(p,$\gamma$)$^{23}$Na experiment, selected low-energy resonances have been studied with two high-purity germanium detectors. The second phase will be based on a $4\pi$ bismuth germanate summing detector and aims to address the lowest-energy resonances (below 200 keV proton beam energy) as well as the direct capture.

In this poster, the preparations for the BGO based experimental phase will be presented, focusing on characterization of the new gas target chamber with respect to the pressure and temperature profile. Initial data will be shown.

Neutron capture cross sections of $^{85}$Kr

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Neutron capture and $\beta^-$ decay are competing branches of the s-process nucleosynthesis path at $^{85}$Kr, which makes it an important branching point. The knowledge of its neutron capture cross section is therefore an essential tool to constrain stellar models of nucleosynthesis. The goal is the measurement of the $^{85}$Kr (n,$\gamma$) cross section via the time of flight method.

For this, several methods for the production of $^{85}$Kr will be investigated. One of these is the irradiation of a $^{82}$Se target with an $\alpha$-beam. Here, the produced $^{85}$Kr stays trapped inside the crystalline structure of the selenium. Due to technical difficulties and low yields, another method is the use of reactor produced $^{85}$Kr.

For future measurements of the neutron capture cross section of $^{85}$Kr at FRANZ (Frankfurter Neutronenquelle am Stern-Gerlach-Zentrum), the goal is the use of a target with a high isotopic purity to reduce the background. For this, $^{85}$Kr is believed to be a great problem.
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P:20 Nuclear astrophysics experiments in the CSRe and ESR

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Nuclear masses and decay rates of highly-charged ions are important parameters for modelling evolution of stars and paths of nucleosynthesis processes on the nuclidic chart. However, many of the nuclei are not readily accessible in the laboratory, they have to be produced, separated and stored for extended periods of time while preserving the highly-charged state. For the storage purpose, heavy ion storage rings are usually used. Two of such rings in operation at present are the Experimental Storage Ring (ESR) at GSI, in Darmstadt and the Cooling Storage Ring (CSRe) at IMP in Lanzhou. By tuning the CSRe into the isochronous mode [1], masses of nuclei with short half-lives down to hundreds of microseconds can be accurately measured using a time of flight detector. A series of successful measurements have been performed in the last years. Recently also the detection of gamma decays of nuclear isomers in highly-charged ions is being considered in the CSRe. While the CSRe mainly focuses on short-lived nuclei, mass and life-time measurements of longer-lived nuclei can routinely be done in the ESR by means of the Schottky mass spectrometry [1]. A bundle of experiments have been performed in the ESR during the past two decades studying masses and beta-decays of highly-charged ions with lifetimes of up to several years. A planned experiment in the ESR is the determination of the bound-state beta-decay probability of bare 209Fr161+, which can help to address the problem of solar pp-neutrino flux [2] and the s-process nucleosynthesis in stars [3]. A similar technique as applied in the case of bare 163Dy66+ nuclei [4] will be exploited in this experiment.


P:21 Carbon-12 production in stellar evolution

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12C is produced in massive stars via the triple-alpha process. The precise evaluation of the rate of this reaction is required to be able to understand the subsequent stages in the stellar nucleosynthesis and the elemental abundances in the universe. The triple-alpha process occurs through a resonance in the 12C nucleus, famously known as the Hoyle-state. Theoretically, the Hoyle state, which can be thought of as a cluster of three alpha particles, should have the first rotational excitation state with spin-parity 2+ and the energy 9-11 MeV [1-5] above the ground state of 12C. Knowledge of this state is required to understand the debated structure of the 12C nucleus in the Hoyle state. Also, at higher temperatures in stars, the reaction rate of the triple-alpha process has a large dependency on the energy level of this second excited 2+ state.

In the experiment, the states of interest were populated by the beta decay of 12N to 12C which subsequently breaks into three alpha particles. The coincident detection of the decay beta-particle with all three alpha particles from the subsequent breakup will provide the information on the angular correlation in the decay and breakup, which will be used to establish the spin-parity of the state. The experiment was performed at IGISOL facility at JYFL, Jyväskylä,
Finland. The alpha particles from the breakup were detected using a cubic array of thin Double-Sided Silicon Strip Detectors (DSSSDs), surrounding the breakup site. Thick Silicon detectors were used to detect the beta particles from the decay.


P:22 $^{34}$S($^{3}$He,d)$^{35}$Cl reaction rates studied through the $^{34}$S($^{3}$He,d)$^{35}$Cl reaction
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The $^{34}$S/$^{32}$S isotopic ratio has been proposed as a possible diagnostic to identify presolar grains from classical novae. Elemental abundances of grains are broadly in agreement with nucleosynthesis predictions for novae, however uncertainties in certain reactions cannot discount other origins such as type II supernovae. The $^{34}$S($p$,$\gamma$) reaction rate must be constrained by studying states in the 6-7 MeV region in $^{35}$Cl to use the $^{34}$S/$^{32}$S isotopic ratio as a diagnostic.

The $^{34}$S($^{3}$He,d)$^{35}$Cl reaction was measured at the Maier-Leibnitz-Laboratorium (Garching, Germany) using the Q3D magnetic spectrometer. Many new $^{35}$Cl levels have been observed within the 6 - 7 MeV region. Proton spectroscopic factors have been extracted for the first time for levels above the $^{34}$S + p threshold, spanning the energy range required for calculations of the thermonuclear $^{34}$S($p$,$\gamma$)$^{35}$Cl rate in classical nova explosions.

P:23 New data on the neutron capture cross section of the s-process branching points $^{171}$Tm and $^{147}$Pm
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The neutron capture cross sections of unstable isotopes acting as branching points in the s-process are crucial in stellar nucleosynthesis network calculations, but they are very challenging to measure due to both the difficulty in producing a sample with enough material and the background associated to the activity of such isotopes. Recently, the combination of a renewed effort for producing samples with enough mass and the availability of the upgraded n_TOF facility at CERN (Geneva, Switzerland) have open the door to time-of-flight cross section measurements that were not feasible before.

In particular, a sizable amount of $^{171}$Tm ($\sim 3$ mg) and $^{147}$Pm (0.3 mg) has been produced at ILL (Grenoble, France) and chemically processed at PSI (Villigen, Switzerland). The measurement of the capture cross section of $^{171}$Tm took place in Autumn 2014 and preliminary results are already available, while the measurement of $^{147}$Pm will take place in Spring 2015. The samples, the experiments, the preliminary results and the prospects for future measurements are presented in this paper.
Measurement of the $^{23}$Na($\alpha$,p)$^{26}$Mg reaction

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Within the C/Ne convective shell of a massive star the $^{23}$Na($\alpha$,p) reaction is the second most important source of protons for the $^{25}$Mg($p,\gamma$)$^{26}$Al reaction, one of the sites of galactic $^{26}$Al production. Sensitivity studies have shown that an increase of the $^{23}$Na($\alpha$,p) reaction by a factor of 10 will result in a factor 3 change in the $^{26}$Al abundance [1]. The $^{23}$Na($\alpha$,p) reaction has been measured in forward kinematics by Kuperus in 1964 [2] and Whitmire and Davids in 1974 [3], and recently in inverse kinematics in 2014 by Almaraz-Calderon et al [4], with the latter determining a rate nearly 80 times greater than the former two, and 40 times greater than the current recommended rate from theoretical models. The large discrepancy between the two results is hard to explain as a result of a change in stoichiometry of the target of the early experiments: to underestimate the cross section by a factor of 80 would require that the target be composed of only a few percent sodium. The present investigation investigates and clarifies this cross section and reaction rate discrepancy.

In this experiment the $^{23}$Na($\alpha$,p) reaction is measured in forward kinematics using the 5 MeV Van de Graaff accelerator at Aarhus University, with a NaCl target. The protons produced are measured using segmented detectors placed at 150°-170° and 60°-120°. The detectors are also capable of measuring the elastically scattered alpha particles off the target, which provide continuous measurements of the target thickness and stoichiometry. Cross sections have been measured with beam energies between 2 and 3.14 MeV, which overlaps with the new and previous measurements. Additionally the p1 channel has been measured to a lower energy than previous measurements, and angular distributions have been directly measured over a wide range of angles.


Key resonances in $^{26}$Mg and their implications for the astrophysical $s$-process

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The astrophysical $r$- and $s$- processes are responsible for the production of elements heavier than iron. The $s$-process involves a series of neutron captures slower than the average $\beta$-decay rates of unstable nuclei. The main component of the $s$-process is expected to produce stable nuclei with masses $A > 90$, while its weak component is expected to produce nuclei with $60 \leq A \leq 90$. The weak component of the $s$-process takes place during the Helium burning phase of massive stars ($M \gtrsim 13M_\odot$), where the temperature becomes as high as $T \sim 0.2$ GK. In these environments, the $^{22}\text{Ne}(\alpha, \gamma)^{26}\text{Mg}$ reaction is the primary source of neutrons for the $s$-process. However, $^{22}\text{Ne}(\alpha, \gamma)^{26}\text{Mg}$ competes with $^{21}\text{Ne}(\alpha, \gamma)^{25}\text{Mg}$ in the destruction of $^{22}\text{Ne}$ without producing any neutrons. The isotopic abundances in massive stars are very sensitive to variations in the flux of neutrons produced in this reaction. Therefore, accurate measurement of the reaction rate of both processes is required in order to predict the $s$-process yield in these astrophysical conditions. The $^{23}\text{Ne}(\alpha, \gamma)^{26}\text{Mg}$ reaction is expected to be dominated by individual resonance states between $S_\alpha$ and $S_\gamma$ in $^{26}\text{Mg}$ ($E_\gamma = 10615-11093$ keV). Consequently, a precise investigation of the excited levels of $^{26}\text{Mg}$ is crucial for an accurate measurement of the rate of the reaction. A detailed $\gamma$-ray spectroscopy study of $^{26}\text{Mg}$ was performed by populating its excited states and detecting their subsequent decays.
with the Gammasphere array. Excited levels in $^{26}$Mg, including ones in the range of astrophysical importance, have been identified and angular distribution information has been extracted. These implications of these states for the astrophysical $\alpha$-process will be presented.

**P:26 Maxwellian neutron spectrum generation for stellar cross-section measurements**

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Neutron capture processes are the main responsible for the nucleosynthesis of the main part of the heavy elements beyond iron [1]. Neutrons produced inside the stars via ($\alpha$,n) reactions are quickly thermalized through elastic scattering, and their velocities are represented by a Maxwell- Boltzmann distribution (or maxwellian in unit of energy). A maxwellian-averaged cross-section (MACS) or stellar cross-section of the involved isotopes is therefore a key parameter for modeling the stellar nucleosynthesis processes. As shown by Beer & Käppeler [2] and later improved by Ratynski & Käppeler [3], a neutron field with an energy spectrum close to a maxwellian at kT=25 keV (quasi-maxwellian, R2≈0.9) can be generated using the $^7$Li(p,n)$^7$Be reaction at 1912 keV proton energy. Then it is possible for many isotopes to use the activation technique for measuring an experimental cross section with this spectrum. However, in order to obtain the MACS, a correction taking into account the difference between this quasi-maxwellian spectrum and a true stellar (maxwellian) one must be carried out. For this correction, the knowledge or assumption of the energy dependency of the cross-section of the isotope is mandatory, and also for extrapolation to kT different from 25 keV. This method has been extensively used for MACS measurements of many isotopes relevant to the s-process [4] [5]. Recently, it has been showed [6] that it is possible to generate a closer maxwellian neutron spectrum at kT=30 keV (R2>0.995 fit) if we shape the energy profile of the incident proton beam. Introducing a foil degrader in the proton beam, before the Lithium target, with a proper combination of proton energy and foil thickness the proton energy beam is shaped to a Gaussian distribution [7]. This energy-shaped proton beam impinging on the Lithium target produces a neutron field with a maxwellian at kT=30 keV energy spectrum. Moreover, simply adjusting the proton beam energy with the same thickness of the degrader, maxwellian spectra at different kT from 30 to 60 keV can be generated [8]. In this work we discuss the method, and preliminary results of a measurement of the MACS of $^{197}$Au(n,$\gamma$) are shown.

P:27 Nucleosynthesis of intermediate mass stars: Inferences from the observed abundances in photoionized nebulae of the Local Group

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Photoionized nebulae, comprising HII regions and planetary nebulae, are excellent laboratories to investigate the nucleosynthesis and chemical evolution of several elements in the Galaxy and other galaxies of the Local Group. Since these nebulae have intense emission lines of elements such as H, He, C, N, O, S, Si, etc., the abundances of these elements can be derived to a high degree of accuracy, which frequently cannot be reached in stars. As a consequence, these objects are extremely useful to investigate the abundances of the elements that are clearly affected by the evolution of the progenitor stars, which is the case of He, C, and N in planetary nebulae, but also to fine-tune the nucleosynthesis processes involving elements that are probably not affected by the evolution of the progenitor star in an important way, such as O, Ne, S, and Ar. Some recent investigations have stressed that the abundances of O and Ne can in fact be modified by nuclear processes during the AGB phase of intermediate mass stars, so that evidences of these processes can in principle be observed by comparing the abundances of the younger HII regions and the older planetary nebulae.

In this work we consider a large sample of photoionized nebulae in several galaxies of the Local Group, and derive abundance correlations involving the chemical elements mentioned above. Our purpose in this investigation is threefold: (i) to compare the abundances of HII regions and planetary nebulae in each system in order to investigate the differences derived from the age and origin of these objects, (ii) to compare the chemical evolution in different systems, such as the Milky Way, the Magellanic Clouds, and other galaxies of the Local Group, and (iii) to investigate to what extent the nucleosynthesis contributions from the progenitor stars affect the observed abundances in planetary nebulae, especially for oxygen and neon, which places constraints on the amount of these elements that can be produced by intermediate mass stars. (FAPESP/CNPq)

P:28 Getting ready for GERDA phase II

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The GERmanium Detector Array (GERDA) at the Gran Sasso Underground Laboratory (LNGS) searches for the neutrinoless double beta decay (0vbb) of Ge-76. According to a novel shielding design bare Germanium detectors enriched in Ge-76 are operated in a 64 m³ liquid argon (LAr) cryostat which is surrounded by a 3 m thick ultrapure water inside a stainless steel tank.

In GERDA Phase I, the collaboration succeeded to suppress the background by one order of magnitude compared to former 0vbb Ge experiments. The results based on an exposure of 20 kg*years were reported in 2013 [1] achieving the best half-life limit for 0vbb decay in Ge-76 so far. In the upcoming GERDA Phase II the sensitivity is planned to be improved by one order of magnitude (beyond 10^26 years) by collecting 100 kg*years and lowering the background level by another factor of 10. The present talk summarizes the current status of the detector upgrades needed to reach the physics goal. This includes the procurement and characterization of 30 new detectors (20 kg in total) with improved energy resolution and enhanced event type identification ability, the development of new detector holders, cold front end electronics, signal and high voltage cables of very low mass and high radiopurity, and contact bonding procedures. Further it encompasses the installation of photomultiplier tubes (PMT) and fibers connected to Silicon PMTs which read out scintillation light produced by background events in LAr.

P:29 Effectiveness of using a magnetic spectrograph with the Trojan Horse method

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The Trojan Horse method relies on performing reactions in a specific kinematic phase space that maximizes contributions of a quasi-free reaction mechanism. The hallmark of this method is that the incident particle can be accelerated to energies that are high enough to overcome the Coulomb barrier of the target, but once inside the target nucleus the relative motion of the clustered nuclei allow the reaction of interest to proceed at energies below this Coulomb barrier [2,3]. This method allows the experimentalist to probe reactions that have significance in astrophysics at thermal reaction energies that would otherwise be impossible.

Traditionally the Trojan Horse method has been applied with the use of silicon detectors to observe the reaction products. In this study, performed at the IPN-Orsay ALTO Tandem Accelerator, we apply the Trojan Horse method to a well studied reaction [1] to examine the potential benefits of using a split- pole magnetic spectrograph to detect one of the reaction products. The reaction we consider here is $^7\text{Li} + p \rightarrow \alpha + \alpha$ via the three-body $^7\text{Li} + d \rightarrow \alpha + \alpha + n$ reaction. The three-body reaction was measured in two ways: initially with two silicon detectors, and then with one silicon detector and the splitpole magnetic spectrograph. The experimental design, early results, and limitations are discussed.


P:30 Nucleosynthesis in the ejecta of neutron star mergers

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Neutron star mergers (NSMs) are a unique site in astrophysics. They are the most promising scenario for the origin of heavy elements in the universe. Extremely neutron-rich as well as explosive conditions favour the production of elements up to uranium via the rapid neutron capture process (r-process). Moreover, coalescing neutron stars represent also a major source of gravitational waves and are the best candidates to explain short gamma-ray bursts.

NSMs comprise three kinds of neutron-rich ejecta: dynamic ejecta due to gravitational torques and hydrodynamic processes, neutrino-driven winds and evaporating matter from the accretion disk by viscous heating as well as recombination of free nucleons into $\alpha$-particles.

We carried out nucleosynthesis calculations based on a recent simulation of the neutrino- driven wind from a NSM [1]. Elements up to the second r-process peak ($A \approx 130$) are created in the disk ejecta [2]. These yields complement the robust formation of heavy elements including the third r-process peak ($A \sim 195$) in the dynamic ejecta. Our results also reveal dependencies on the observation angle and the black hole formation time.

P:31 TACTIC - The TRIUMF Annular Chamber for Tracking and Identification of Charged Particles

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The fact that no stable nuclides of mass 8 exist impedes the reaction flow towards higher masses in a variety of different astrophysical environments. While in hydrostatic stellar burning the gap is bridged by the reaction $3\alpha \rightarrow ^{12}\text{C}$ via the so-called Hoyle-state, other scenarios, such as Big Bang Nucleosynthesis and the formation of r-process seeds in supernovae do not have the required Helium-density for this, and must thus proceed via radioactive intermediaries. One important step for which experimental data is required in such models is the reaction $^8\text{Li}(\alpha,n)^{11}\text{B}$.

While several experiments have measured a cross section for this reaction, there is significant disagreement between the results, and they all suffer from severe rate limitations. To address this, a new time projection chamber (TPC) was built to measure and identify the charged reaction product $^{11}\text{B}$. The design includes a blind central region to avoid rate saturation due to detected beam particles. The detector is operated with a modern digitizing data acquisition system, allowing the recording of full signals.

An in-depth characterization of the detector was performed using data from a $^{148}\text{Gd}$ alpha source and some test runs with a stable ion beam. Both energy resolution and tracking accuracy were found to agree with theoretical predictions and Geant4 simulations. The $^8\text{Li}$ beam rate capability of the system is predicted to be of the order of $10^5$ s$^{-1}$, several orders of magnitude higher than previous measurements of the same reaction, while still maintaining a high detection efficiency of 60% to 70%.

P:32 Manganese abundances in the stars with metallicities -1.0 < [Fe/H] < 0.3

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The manganese abundances in the atmospheres of the F-G-K-type dwarf stars that belong to the thin and thick disc populations (in the metallicity range -1.0 < [Fe/H] < 0.3) were estimated. The observations were conducted using the 1.93 m telescope at Observatoire de Haute-Provence (OHP, France) equipped with the echelle type spectrographs ELODIE and SOPHIE. The abundances were derived under the LTE approximation; the synthetic spectrum for the manganese lines was computed accounting for the hyperfine structure. The correlation between the abundance of the investigated element and metallicity [Fe/H] in the Galactic thin and thick disc stars was analyzed.

P:33 Borromean rings and exotic nuclei

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Borromean rings are three rings which are linked together, but two of the three cannot be linked. In nuclear physics, recent research indicates that the ring nature is revealed in several exotic nuclei such as $^{22}\text{C}$: there are no low-lying states in $^{21}\text{C}$ and the nucleus is unbound [1], while $^{22}\text{C}$ is loosely bound and the upper bound of its 2n separation energy is 0.329 MeV [2]. To explore the Borromean ring concept, we adopt a 3body cluster model and hyperspherical formalism. As to reaction observables we use the eikonal framework. In this talk, we present our
In the earlier work [1] the results of experimental and theoretical studies for the elastic and inelastic scattering of α-particles from $^{13}$C target nuclei in a wide energy range, including the new experimental data obtained from the cyclotron JYFL Jyvaskyla (Finland) at energy 65 MeV are presented. Theoretical analysis of the angular distributions for $\alpha + ^{13}$C inelastic scattering: $1/2^-$ (8.86 MeV) and $1/2^+$ (3.09 MeV) $^{13}$C excited states performed in the framework of the distorted wave method and the modified diffraction pattern showed a significant increase in the radius for these excited states in comparison with the value obtained for the ground state. In the current work we continue the investigation of the nature of $^{13}$C excited states at low energies.

The experimental angular distributions measurements for the elastic and inelastic scattering of α-particles from $^{13}$C target nuclei were performed in the isochronous cyclotron U-150M located in Institute of Nuclear Physics (INP NNC RK) using an accelerated α-particles beam of an energy 29 MeV.

Angular distributions of α-particles elastically and inelastically scattered from $^{13}$C nuclei at energy $E_{\text{lab}}=29$ MeV: ground state (0.0 MeV), $1/2^-$ (8.86 MeV) and $1/2^+$ (3.09 MeV) were measured in the angular range $\theta_{\text{lab.}}=10^\circ$ – $80^\circ$ with increments of $1^\circ$ – $2^\circ$. Energy resolution of the detector at small angles is $\sim 290$ keV, and at large angles is $\sim 350$ keV. The experimental data at this energy showed a well-developed diffraction scattering pattern.

In addition to our experimental data at $E_{\text{lab}}=29$ MeV, $\alpha + ^{13}$C elastic scattering was analyzed at different energies from literature: 65 MeV [1], 54.1 and 48.7 MeV [2], 35 MeV [3] and 26.6 MeV [4]. The theoretical predictions were performed using both empirical Woods-Saxon and double folding optical model potentials. The comparison between the experimental data and the theoretical predictions is fairly good overall the whole angular range. We managed from obtaining physically reasonable parameters for the interaction potentials. Analysis of inelastic scattering data were performed using the obtained optimal potential parameters and the nuclear rotational model was used to include the transition to the concerned excited state.

Investigation of interaction processes of nitrogen isotopes with 1p shell nuclei

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The study of the interaction of heavy ions with 12C, 16O, 27Al nuclei at energies close to Coulomb barrier is of interest both from the point of view of establishing reliable values of the parameters of the internuclear potential interaction of heavy ions and to study the mechanisms of cluster gears in scattering processes [1].

Earlier studies of the scattering of ions 12C and 16O from 12C, 16O [1] and 11B nuclei [2] at energies close to the Coulomb barrier have shown that the formation of the experimental scattering cross sections is not only due to purely potential scattering, but also due to exchange mechanism associated with the cluster structure of these nuclei. So for the 12C + 16O system alpha cluster exchange process is clearly seen, and for the 12C + 11B system - proton exchange.

The purpose of this study is to determine the impact of the mechanisms of cluster transfer in scattering cross sections formation in interaction of nitrogen ions with 12C, 16O, 27Al nuclei.

Experiments were carried out at the cyclotron DC-60 RSE INP EAC MINT RK. The energy of the accelerated nitrogen ions was 1.5 and 1.75 MeV/nucleon. Measurements of differential scattering cross sections were made in the range of angles 30º - 140º in center of mass frame. The particles were detected by silicon detectors with sensitive layer thickness of 100 microns. The targets were thin films made of 12C and Al2O3 with thicknesses of 20-40 µg/cm2. The thickness of the target was determined with an error of not more than 5%. The energy resolution of the registration system was 250-300 keV, which is mainly determined by the energy spread of the primary beam. In general, the absolute error of the data did not exceed 10%.

Any oscillations and enhancements are not observed in the experimental cross sections. This is probably due to the fact that in the systems under study the cross sections are formed by purely potential scattering and there is no contribution of any exchange processes.

Analysis of the scattering cross sections of nitrogen ions from aluminum showed that at a given energy, they do not differ from the Rutherford scattering cross sections. Processes 14N + 16O and 14N + 12C were analyzed within the standard optical model using the computer program FRESCO.

As it follows from the figures, the experimental angular distributions can be adequately reproduced by the theoretical curves calculated using the optical model in the whole measured angular range, indicating the dominance of potential scattering mechanism in the formation of the elastic process cross section for 14N + 12C, 14N + 16O and 14N + 27Al nuclear systems.

The resulting potentials can be used for model calculations of yields of nuclear reactions necessary for astrophysical applications.


P:36 Study of elastic and inelastic scattering of alpha particles from $^{11}$B nuclei in the energy range of 29-54 MeV

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Study of nuclear reactions is of special interest as it could provide us with useful information about the nuclear structure, potential parameters, deformation parameters and transition probabilities. The $\alpha$-nucleus interaction is an essential tool for the understanding of nuclear structure and nuclear reactions. The concept of the $\alpha$-particle mean field has been widely used to unify the bound and scattering $\alpha$-particle states in a similar way to use of the nuclear mean field to calculate the properties of bound single particle states and also the scattering of unbound nucleons by nuclei.

We have measured the angular distributions for the elastic and inelastic scattering of $^4$He from $^{11}$B in the isochronous cyclotron U-150 M INP RK. The extracted $\alpha$-particles beam has been accelerated to energies 29 MeV and then directed to $^{11}$B target of thickness $\sim$ 32.9 $\mu$g/cm$^2$. The experimental results were analysed within the framework of both the optical model using different complex potential and the double folding potential obtained with different density-dependent NN interactions which give the corresponding values of the nuclear incompressibility $K$ in the Hartree-Fock calculation of nuclear matter. The theoretical calculations for the concerned excited states were performed using the CC coupled channel method implemented in code FRESCO. We extracted the optimal deformation parameters for the $5/2^-$ and $7/2^-$ states.

In addition to our experimental data for $^4$He+$^{11}$B at energy 29 MeV, we also analyzed the experimental data for this nuclear system at other energies (40 and 50 MeV) [1] and (48.7 and 54.1 MeV) [2].


P:37 Role of nuclear reactions on stellar evolution of intermediate-mass stars

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The evolution of intermediate-mass stars (8 - 12 solar masses) represents one of the most challenging subjects in nuclear astrophysics. Their final fate is highly uncertain and strongly model dependent. They can become white dwarfs, they can undergo electron-capture or core-collapse supernovae or they might even proceed towards explosive oxygen-burning and a subsequent thermonuclear explosion. We believe that an accurate description of nuclear reactions is crucial for the determination of the pre-supernova structure of these stars and show that weak rates involving sd-shell nuclei are of particular importance. We argue that due to the possible development of an oxygen-deflagration, a hydrodynamic description has to be used. We implement a nuclear reaction network with $\sim$ 200 nuclear species into our implicit hydrodynamic code AGILE. The reaction network considers all relevant nuclear electron captures and beta-decays. For selected relevant nuclear species, we include a set of updated reaction rates based on shell-model calculations, for which we discuss the role for the evolution of the stellar core, at the example of selected stellar models. We find that the final fate of these intermediate-mass stars depends sensitively on the density threshold for weak processes that deleptonize the stellar core.
Results of the first cross-section measurement of the $^{72}\text{Ge}(p,\gamma)^{73}\text{As}$ reaction will be reported. The proton capture reaction on $^{72}\text{Ge}$ is relevant for the astrophysical p-process and was identified in a sensitivity study as one of the important reactions required to estimate the abundances of the light p-nuclei. The $\gamma$-summing technique was employed using the Summing NaI(Tl) detector (SuN) from the National Superconducting Cyclotron Laboratory. The experiment was performed at the University of Notre Dame using a 1.8 to 3.6 MeV proton beam. In order to test the predictive power of different theoretical calculations in the region, experimental values are compared to the results given by the nuclear reaction code TALYS. The theoretical uncertainties in the cross section arising from different combinations of nuclear level densities, $\gamma$-ray strength functions and optical model potentials were reduced to < 18% by the experimental data. The recommended reaction rates from the standard astrophysical libraries, BRUSLIB and REACLIB, are found to be in good agreement with the experimental results.

The s-process in massive stars produces heavy elements beyond iron up to $A \sim 90$ (the weak s-process) and possibly reaches up to heavy nuclei including Ba ($A \sim 138$) in very metal-poor stars. In the study of s-process nucleosynthesis, we perform nuclear reaction network calculations for comparison with several observed abundances. The present study focuses on the reliability of these nucleosynthesis calculations in the context of nuclear physics uncertainties, i.e., $(n,\gamma)$-reactions and $\beta$-decay. For the purpose of robust quantitative evaluation, we employ Monte-Carlo simulations with randomly varying relevant nuclear reaction rates on the basis of different stellar evolution models.

In this presentation, we show results on s-process nucleosynthesis, based on a wide range of parameters, that cover stellar environments from solar-metallicity to very metal-poor stars. We found that the adopted range of estimated uncertainty for $(n,\gamma)$ rates, which are tens of percents, affects the production of nuclei along the s-process path up to Sr for solar- metallicity star models. While, metal-poor stars exhibited different responses to the fi s-process products with heavier elements up to Ba isotopes. This indicates that the physical uncertainty of neutron captures significantly affects the fi abundances of s-process calculations. We also show that this uncertainty has even qualitative difference in the production of heavier s-process nuclei when the effect of rotation-induced mixing are strong enough for metal-poor stars. Additionally, besides the impact of the $(n,\gamma)$-reaction, we discuss the effect of $\beta$-decay at stellar temperatures. Focusing on the contribution of excited states to decay rates, we specify key important temperature-dependent $\beta$-decay rates, which have a strong impact on s-process branch points.
P:40 Production of iron-group isotopes in magneto-rotational induced core-collapse supernovae

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Core-collapse supernovae with rapid rotation and strong magnetic fields have been studied, which are focused on the production sites for the r-process elements, as well as the central engine of gamma-ray bursts, X-ray flashes and hypernovae etc. Recent nucleosynthesis studies have revealed that energetic jet-like explosions induced by strong magnetic fields may eject neutron-rich matter, which achieve suitable conditions for the r-process nucleosynthesis. While, other elements including iron group isotopes, which are expected to be produced by explosive nucleosynthesis, are not investigated well in previous studies. In this presentation, basing on hydrodynamical simulation of magneto-rotational supernovae, we show the amounts of several key important radioactive nuclei, i.e., Ni isotopes, Fe isotopes, ⁴⁴Ti, which are important for connection to optical observation of several supernova events. We also discuss the role of these supernova scenario in the galactic chemical evolution using ejected mass of iron.

P:41 The white dwarf’s carbon fraction as a secondary parameter of Type Ia supernovae

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Binary stellar evolution calculations predict that Chandrasekhar-mass carbon/oxygen white dwarfs (WDs) show a radially varying profile for the composition with a carbon depleted core. Many recent multi-dimensional simulations of Type Ia supernovae (SNe Ia), however, assume that the progenitor WD has a homogeneous chemical composition.

In my presentation, I will show recent results from hydrodynamics simulations and corresponding nucleosynthesis computations as well as synthetic spectra and light curves which are compared to observations. Using these simulations, we explore the impact of different initial carbon profiles of the progenitor WD on SNe Ia in the Chandrasekhar-mass delayed detonation model. The main conclusions are that carbon depleted models result in weaker explosions and produce less ⁵⁶Ni. Moreover, for a series of models with different compositions, we are not able to reproduce the width–luminosity relation of SNe Ia. Hence, the carbon mass fraction is probably only a secondary parameter in the family of SNe Ia.

P:42 Towards an activation cross section measurement of the ¹⁷O(p, 𝛾)¹⁸F reaction in a wide energy range

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The CNO cycle is one set of fusion reactions in stars that converts hydrogen to helium. This hydrogen burning process occurs in several sites and stages of stellar evolution, such as red giants, asymptotic giant branch (AGB) stars, massive stars, and classical novae. One of the important reactions in the CNO-III cycle is the ¹⁷O(p, 𝛾)¹⁸F [1]. The only available total cross section measurement in a wide energy range for this reactions dates back to several decades ago [2] which makes the theoretical extrapolation to astrophysical energies more difficult and introduces uncertainty. Therefore, the aim of the present work is to provide precise total cross section data in the energy range between about 500 keV and the 2 MeV using the activation method. The experimental campaign at the new
The elucidation of the production and destruction processes of Lithium, Beryllium and Boron light elements both in stellar and interstellar media is of crucial interest in connection with several astrophysical problems. In addition to the rarity of the Li, Be and B elements in the solar system (the Li-Be-B problem), some of these problems are, e.g., the origin and interactions of cosmic rays, galactic chemical evolution and gamma-ray astronomy. Important efforts have been made previously in order to improve our knowledge of these problems, and the current work dealing with the $^7$Li($p,\alpha$)$^4$He nuclear reaction enters this framework. This reaction contributes to the depletion of lithium in stellar interiors and, consequently, the corresponding rate needs to be determined with the highest possible precision at stellar temperatures. Several experiments have been carried out for performing direct measurements of the astrophysical S(E)-factor of this reaction. This method would yield more accurate results if the reduced widths involved in theoretical expressions fitted to experimental data were known with high precision. Alternatively, this goal may be more easily attained, for instance, via a DWBA theoretical analysis of angular distribution experimental data for the $^7$Li($^3$He,d)$^8$Be transfer reaction where the two J$^{\pi}$ = 2+ astrophysically relevant states of $^8$Be at Ex = 16.626 MeV and 16.922 MeV are produced with high cross sections. In this work, the angular distributions for these states and the 1+ state at 17.640 MeV have been measured at the IPN-Orsay tandem accelerator for $E_{^7}$Li = 20 MeV using a high energy resolution position sensitive detection system on the line of the split-pole electromagnetic spectrometer. The measured cross section data have been carefully analyzed within the DWBA theory, extracting relevant values of the nuclear level spectroscopic and asymptotic normalization factors that are reported and discussed here in comparison to previous ones from the literature.

P:44 Measurements of the $^6$He+p resonant scattering

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The spectroscopy of light nuclei such as $^6$Li, and others is still a relatively unexplored field and the ability to produce these nuclei in reactions induced by exotic nuclei is motivating. In particular the $^6$Li has an excited state at 11.24MeV J$^p$ = 3/2$+$ which is the Isobaric Analog State of the $^7$Li ground state. We present results of an experiment $^4$He+CH$_2$ performed in the RIBRAS[1] double solenoid system. The $^6$He secondary beam was produced by the $^8$Be($^7$Li,$^4$He) reaction at incident $^7$Li energy of 24MeV. A thick 12mg/cm$^2$ CH$_2$ foil was used as a secondary target and as absorber in the midway scattering chamber between the two solenoids. We observed the protons, deuterons, tritons and $^\alpha$ particles produced in reactions of the $^6$He beam and the CH$_2$ target. Measurements of the elastic scattering p($^6$He,p) have been performed at three different angles, namely 0, 20, and 25 degrees in the laboratory system, to observe states $^7$Li of the $^7$Li[2] around excitation energies of E$_{^7}$Li $\approx$ 10.4 − 11.8MeV. Excitation functions have been obtained for those angles which correspond to 180, 140, and 130 degrees in the center of mass system. We have fitted those excitation functions using the Breit-Wigner function. We also compare the
P:45 Beta-decay rates of heavy neutron rich nuclei

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For nucleosynthesis calculations of the r-process it is important to know beta-decay half-lives of short-lived neutron rich nuclei. In present report we will discuss the calculations of these characteristics for extended number of neutron-rich nuclei, and their difference from previous predictions.

For beta-decay rates predictions for neutron-rich nuclei the models of beta strength-function are usually used \cite{1, 2, 3}. In this work we used the beta-strength function model in which strength-function was derived in the framework of quasi-classical approach, based on the finite Fermi-systems theory. On the basis of this model the consequent calculations of neutron emission and beta-delayed fission probabilities were derived recently for actinides \cite{4}. The consistent calculations of beta-decay rates based on the same model needed for the r-process nucleosynthesis were calculated as well. New calculations became actual when it was shown \cite{5} that the values of beta-decay rates strongly affect on abundances of rare earth elements, forming in nucleosynthesis in very high neutron environment with fission cycling. And exact calculations in the framework of the quasi-classical model of beta-strength function confirmed the proposition \cite{5}, that translead nuclei has beta-decay rates shorter, than beta-decay rates predicted earlier \cite{2}.

After the comparison with other predictions and experimental data was done it was shown that accuracy of beta-decay half-lives of short-lived neutron rich nuclei is increasing with increasing of neutron excess and is sufficiently good for modeling of nucleosynthesis of heavy nuclei in the r-process. And that is more important for the r-process, for nuclei heavier lead the half-lives of neutron-rich nuclei turned out in 10 times in average less, than other predictions \cite{2} proposed. Some of our results mentioned here were also summarized in \cite{4} and in \cite{6}.

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\end{thebibliography}

P:46 $^{12}\text{C}$ problem in type I x-ray bursts: Nuclear reaction rate study with a reduced network

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Regular bursts have been observed in binary systems containing a neutron star with an accretion flow of matter from the companion star. These bursts are so-called type I X-ray bursts and occur due to thermonuclear explosions in the accreted shell of the neutron stars. Observations have shown that after thousands of X-ray bursts a rare superburst...
event may take place. These superbursts are thought to be triggered by unstable carbon-burning from the ashes of the previous X-ray bursts. Most simulations of superbursts are not able to reproduce the observed behaviour.

We investigated the influence of reaction rate changes to the nucleosynthesis during X-ray bursts with a reduced network. We performed these simulations with a general relativistic hydrodynamics code coupled with the nuclear reaction network solver [1,2].


P:47 Towards semiconductor-based photosensors for NeuLAND

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For upcoming large-scale scintillator-based time-of-flight detectors like NeuLAND at FAIR fast and efficient photosensors are needed. Recent developments in the field of semiconductor based photosensors, so called Silicon Photomultipliers (SiPMs), indicate that they could be a potential alternative for this type of application.

SiPMs with active surfaces ranging from 1 x 1 mm² to 6 x 6 mm² from several manufacturers were studied using inhouse developed preamplifiers. The standalone response of the SiPMs was studied with a picosecond laser system. Subsequently, the timing response of a coupled system of SiPM and plastic scintillator was studied at the 30 MeV electron accelerator ELBE. The data are compared with Monte Carlo simulations.

P:48 Review of the 18F+p reactions and their impact on γ-ray spectroscopy for nova explosions

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18F is an unstable nuclei produced via the H-CNO cycle in novae. Its half-life of 110 minutes makes it one of the strongest observable source of gamma rays during the few hours of the explosion. Detection of this radiation would provide a direct test of current hydrodynamic models, which are currently underestimating global properties such as the total ejected mass. Abundance estimates of 18F are therefore important for determining the maximum distance gamma-ray spectroscopy remains a viable technique for observation of novae.

18F is destroyed by proton capture through unbound states in 19Ne. These reactions contribute the most uncertainty in abundance calculations of 18F. Due to the presence of a wide 3/2+ resonance at 665 keV above the proton threshold in the 18F+p channel, interference effects between other 3/2+ states create a large cross section uncertainty in the energy window of interest. Recent measurements of states above and below the threshold however have questioned several 3/2+ spin parity assignments and thus their interference contribution.

The subject of this work has been to re-evaluate the remaining uncertainty in the Gamow window, highlighting states for further measurement in future experiments. R-matrix calculations have been performed using the Azure2 code for both the alpha and gamma decay channels, giving new estimates for cross sections and reaction rates. The effects of a postulated broad resonance at -410 keV have also been investigated. The results of these calculations and the changes to the expected reaction rate for 18F+p and its subsequent decay channels will be presented along with implications for future studies of 19Ne.
P:49 Isovector & pairing properties of the Gogny interaction
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Pairing in nuclear matter has observable implications for the dynamics of neutron stars [1]. The Gogny force is a finite-range phenomenological interaction that has been widely used to study nuclei [2]. We analyse the isovector properties of this phenomenological force and study the corresponding equations of state of neutron stars [3]. Mass-radius relationships calculated with the Gogny interactions are presented. Neutron star matter pairing gaps generated with the Gogny interaction are presented for various partial waves. The implications of the calculated gaps are explored in the context of neutron star cooling [4] with a consistent set of equations of state and pairing gaps.


P:50 Neutrino nucleosynthesis in the outer layers of supernovae
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Abstract not available.

P:51 Measurement of the $^{16}$O + $^{16}$O elastic scattering cross section below the coulomb barrier
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In recent decades, the processes of fusion of $^{16}$O were studied both theoretically [1,2] and experimentally [3,4,5,6,7,8], because the fusion reaction $^{16}$O+16O is essential for understanding the nuclear burning processes in advanced stages of stellar evolution, contributing significantly to the production of heavier elements. However, the lowest center-of-mass energy reached in these previous studies was around 6.5 MeV, but at this energy the discrepancies between the different experimental results at sub-barrier energies are around a factor of 3. Moreover, the theoretical calculations are not enable to fit both elastic scattering cross sections and fusion S-factors. In the aim of the study of the $^{16}$O+16O fusion reaction, we present the experimental elastic scattering cross section in the region of astrophysical interest. For this purpose, we used the 3.0 MV Tandem Accelerator placed at the Ion Beam Laboratory at CTN (Sacavém - Portugal) with a new technique of targets production for Nuclear Astrophysics purposes.

Measurements of reaction cross sections help to constrain models predicting stellar reaction rates and can therefore improve our understanding of the stellar nucleosynthesis. The production cross sections of $^{77,79}$Kr and $^{77}$Br following the $\alpha$-irradiation of natural selenium were determined between the $\alpha$-energies of 11 MeV and 15 MeV using the activation technique.

The irradiation of nat Se targets with He$^2+$ ions extracted from a cyclotron was conducted at Physikalisch-Technische Bundesanstalt in Braunschweig. The spectroscopic analysis of the reaction products was performed using a HPGe detector. As the $\alpha$-beam was stopped inside the targets, the thick target yields were determined. The corresponding energy-dependent cross sections were calculated from the difference of the thick target yields at various beam energies. The determined values were compared to theoretical predictions based on the TALYS code.

The aim of the present work is to determine the characteristics of a scintillation detector by measuring cosmic muons above and underground at the Gran Sasso National Laboratory. To check the consistency of the applied method, we evaluated the flux and angular intensity from the measured muon data and compared them with the results of more precise measurements from the literature.

The detector has been designed for demonstrational purposes and had never been involved in scientific research before. It is a compact, layered detector using plastic scintillation bars and Silicon photomultipliers (SiPM). The detector does not provide energy information. In the underground laboratory we had to deal with a very low rate of muons (6 orders of magnitude less than on the surface). For this reason we optimized the trigger configuration. During the evaluation process we designed and optimized a maximum-likelihood line fit method which is able to deal with the high dark count rate and the relatively poor efficiency of the detector. We also carried out simulations to calculate the actual fit and intensity from the measured ones.

Background studies in the 148m deep Reiche Zeche mine in Freiberg, Germany

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A very low background level is a key requirement for underground nuclear astrophysics experiments. A detailed gamma-background study with two escape-suppressed HPGe detectors has been performed at a medium deep underground site, namely the Reiche Zeche mine (148m) in Freiberg, Germany [1]. The new data complement a data set with the same detector at other underground sites [2,3].

Now, detailed background data are available at the Earth’s surface and at underground sites with depths of 45m, 148m, 1400m from one and the same escape-suppressed HPGe detector. This allows to investigate the effect of the active and passive shielding on the high energy ($E_\gamma > 3\ MeV$) laboratory background. A detailed interpretation of the behaviour of different background components as a function of the underground depth will be presented.

In addition to this work with gamma-ray detectors, the neutron background has been studied by $^3$He counters from the BELEN neutron detector, equipped with polyethylene moderators of various thicknesses in the Felsenkeller laboratory (45m). By mean of the varied moderation, spectral information of the neutron flux is derived. The same detectors and same method were used previously deep underground in Canfranc/Spain (850m) to measure the neutron flux and spectrum [4]. This allows a direct comparison of the two sites.


Excited nuclei, resonances and reactions in neutron star crusts

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Processes, reactions and few-body effects that occur in the overdense crystalline structures of neutron star envelopes are considered in this work. We studied matter transformation in neutron star envelopes taking into account complex of reactions, processes and effects expected in such regions.

So, analyses of electron capture reactions for isotopes of carbon, aluminum, iron and zinc showed that subsidiary reactions of electron capture cycles are different for even-even and odd-even nuclei. For instance, for the nucleus $^{24}_{\text{Mg}}$ or $^{56}_{\text{Fe}}$, each pair of successive reactions of the daughter nucleus has the energy threshold below that of the mother nucleus. A daughter nucleus in such reactions occurs mainly in the excited state [1]. However, in the case of $^{23}_{\text{Na}}$ or $^{57}_{\text{Fe}}$ the threshold of each subsequent reaction is higher than the threshold of the previous one. Therefore, the reactions of electron capture by odd nuclei with formation of daughter excited nuclei are unlikely.

The excited nucleus cannot reach the ground state, since the overdense crystalline structure does not allow the nucleus to emit gamma. Tunneling effect between excited nuclei and interactions between nuclear phonons [2] and phonons in the overdense crystalline structure can lead to formation of highly excited nuclei. When density of the excited nuclei reaches a certain critical value, the highly excited nuclei can induce reactions and processes to...
produce neutrino-antineutrino pairs and gammas of high energy to beat out nucleons off their neighbouring nuclei. Thus, free neutrons appear in this layer and interact with nuclei fixed in the crystalline nodes. Some of these neutrons can stimulate neutron structure resonances [3, 4]. The neutron resonances can result in oscillations of pressure and density in certain layers of crust crystalline in the neutron star envelopes.

Periodic enhancement of these processes and the character and the rate of reactions will directly depend on the elemental composition of the primary neutron star matter. Resonance processes and reactions that occur in the overdense crystalline structure may lead to periodic ejections of neutrino radiation from the neutron star and other extraordinary phenomena.


P:56 Simple potential model for interaction of dark particles with massive bodies

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A simple model for interaction of dark particle with matter based on resonance behavior in a three-body system is proposed. The model describes resonant amplification of effective interaction between two massive bodies at large distances between them. The phenomenon is explained by catalytic action of a third dark particle rescattering at a system of two heavy bodies. This simple potential model allows solving the three-body problem analytically. The solutions distinctly demonstrate the resonance dependence of the effective interaction between two massive bodies at large distances. We consider two heavy stellar objects as a system of one massive body located in a center of a galaxy and another stellar body located at the galaxy’s periphery orbiting the center of the galaxy.

Resonant amplification of the effective interaction between the two heavy bodies imitates increase in their mass while their true gravitational mass remains unchanged. Such increased interaction leads to more pronounced gravitational lensing of bypassing light. So, the model can describe main effects and phenomena in the dark matter problem. It is shown that effective interaction between the heavy bodies is changed at larger distances and can transform into repulsion contributing in that case to the dark energy action [1]. In reality, the nature of interactions between dark particles and a heavy body can be more complex and the catalytic action may happen to be far from simple.

Study of the $^2H(p, \gamma)^3He$ reaction in the BBN energy range at LUNA

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Using Big Bang Nucleosynthesis (BBN) with the recent cosmological parameters obtained by the Planck collaboration, a primordial deuterium abundance value $D/H = (2.65 \pm 0.07) \times 10^{-5}$ is obtained [1]. This one is in tension with astronomical observations on metal-poor damped Lyman alpha systems where $D/H = (2.53 \pm 0.04) \times 10^{-5}$ [2]. In order to reduce the BBN calculation uncertainty, a measurement of the $^2H(p, \gamma)^3He$ cross section in the energy range 10-300 keV with a 3% accuracy is thus desirable [1].

Thanks to the low background of the underground Gran Sasso Laboratories (LNGS), and to the experience accumulated in more than twenty years of scientific activity, LUNA (Laboratory for Underground Nuclear Astrophysics) [3] [4] planned to measure the $^2H(p, \gamma)^3He$ fusion cross section at the BBN energy range in 2015-2016. A feasibility test of the measurement has been recently performed at LUNA. The results obtained as well as the setup R&D for the final measurement campaign will be shown. Possible cosmological and theoretical nuclear physics outcomes from the future LUNA data will be also discussed.


Electron screening - Still an open problem

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Reliable cross section data at low energies are crucial for precise determination of thermonuclear reaction rates. However, stellar environments cannot be reproduced in a laboratory and the influence of electronic environment on nuclear reaction rates in such conditions cannot be experimentally deduced. Therefore, it is of significant importance to measure the bare cross sections as well as possible. The probability for tunneling through the Coulomb barrier depends on its height exponentially and even small changes to the barrier caused by electrons surrounding the reactants in laboratory experiments have a significant effect on the fusion cross section. As a result, the measured cross sections are enhanced compared to cross sections for bare nuclei. Experimental studies of various nuclear reactions in metallic environments have shown the expected cross section enhancement at low energies [1-5]. However, the enhancements in metallic targets were significantly larger than expected from the adiabatic limit, which is thought to provide the theoretical maximum for the magnitude of electron screening. Although studied for more than two decades, this discrepancy is still not understood under laboratory conditions. Therefore the value of electron screening potential cannot be deduced theoretically and its size has to be measured for each metallic environment and each target separately.

Recently, we performed an extensive experimental campaign, with an aim to study the electron screening in the laboratory for various nuclear reactions and involving both low and high Z targets. The $^3H(^6Li,\alpha)^4He$ fusion reaction was studied for hydrogen implanted Pd, Pt, Zn and Ni targets. Large electron screening, of a few keV was observed in all targets. On the contrary, no large electron screening was observed in the following proton induced reactions: $^{55}Mn(p,\gamma)^{56}Fe$, $^{55}Mn(p,n)^{55}Fe$, $^{113}Cd(p,n)^{113}In$, $^{115}In(p,n)^{115}Sn$, $^{50}V(p,n)^{50}Cr$ and $^{51}V(p,\gamma)^{52}Cr$. Moreover, no shift in resonance energy for metallic compared to insulator environment was observed for the studied (p,n) and (p,\gamma) reactions. The above results posed a question on the validity of the measurements that showed large electron
screening potentials in nuclear reactions involving high Z targets and point to a dependence of the electron screening potential on the position of the target nuclei in metallic lattice. In a continuation of our experimental campaign, we aim to further investigate the $^1H(^6Li,\alpha)^4He$ reaction in order to thoroughly investigate the stated hypothesis. In addition, we will also focus on studies of electron screening in the $^1H(^{19}F,\alpha\gamma)^{16}O$ reaction in different environments (in both normal and inverse kinematics) and hopefully try to answer some of the still open questions. A review of previous results, as well as newly obtained results will be presented.


P:59 The $^{14}N(p, \gamma)^{15}O$ S factor at 0.4 – 1.5 MeV

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For solar model calculations precise knowledge of the relevant fusion cross sections is needed. In the solar core the rate of the CNO cycle is dominated by the bottleneck $^{14}N(p,\gamma)^{15}O$ reaction, because this is the slowest reaction of the cycle. A proton beam with energies of 0.4 - 1.4 MeV at the 3 MV Tandetron of Helmholtz-Zentrum Dresden-Rossendorf was used to study the non-resonant cross section of $^{14}N(p,\gamma)^{15}O$. The contribution presents the characterization of the used TiN targets with Elastic Recoil Detection Analysis (ERDA), new data for the S factor of $^{14}N(p,\gamma)^{15}O$ and combined with data of experiments at other proton energies [1], [2] a R-Matrix fit for capture to the excited state at 6.79 MeV to achieve a more accurate extrapolation to the astro-physically relevant cross section at the Gamow-window of the reaction.


P:60 The Electromagnetic Mass Analyser EMMA. A new recoil spectrometer for nuclear physics research being developed at TRIUMF, Vancouver

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EMMA (Electromagnetic Mass Analyser) is a recoil mass spectrometer currently being assembled within the ISAC-II high energy experimental hall at TRIUMF, Vancouver. The design of EMMA has been optimised for both efficiency and selectivity, possessing large acceptances in angle, mass, and energy without sacrificing the required beam suppression and mass resolving power. Accurate measurements of position, energy loss, residual energy, and time of flight will allow EMMA to uniquely identify transmitted recoils. Recoils will be accepted within a large range of m/q (+/- 4%) and energy (+/-20%), which together with a large angular acceptance of 20msr would result in high detection efficiencies approaching 50% for the recoil nuclei of many fusion-evaporation and radiative capture reactions. These capabilities of large acceptance, beam rejection at 0°, and high selectivity are likely to make EMMA, and an instrument of exceptional quality for nuclear physics research.
Though ideally suited for fusion evaporation reactions, EMMA is also well suited for measuring projectile-like recoils from transfer reactions in inverse kinematics, with excellent geometric efficiency approaching unity for strongly forward focussed transfer reactions such as (d,p), (d,t) and (p, 3He). EMMA’s capabilities will be further augmented by the use of particle and gamma-ray detector arrays at the target position for recoil-particle-gamma coincidence measurements. Experimental set-ups involving EMMA can therefore offer new insight into interesting reaction channels that would otherwise be too weak to observe. In summary, this presentation aims to give an overview on the current status of EMMA, as well as an outlook of progress for the near future and expected capabilities.

P:61 Development of a detector in order to investigate (n,\gamma)-cross sections by ToF method with a very short flight path
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Under the conditions of the slow-neutron-capture-process (s-process) the beta-minus-decay rate und the neutron-capture rate of 85Kr lie within the same range. Consequently, this isotope is a branching-point. For this reason the exact knowledge of the (n,g)-cross section enables us to draw conclusions of the inside of stars during their red giant phase. Unfortunately 86Kr can only be used in small targets inside a gamma detector. Hence, the neutron flux of current experiments is too small to determine the cross section. Thus, we try to decrease the flightpath of the neutrons of FRANZ to a few centimeters in order to increase the neutron flux so that the determination of the cross section is possible. Indeed this effects a higher intensity of the gamma-flash and the neutron induced background. Therefore I optimize the geometrie, the szintillator material and the moderator by GEANT3 simulations.

P:62 \gamma-ray line production cross sections in proton inelastic scattering off 24Mg, 28Si and 56Fe target nuclei over the proton energy range E\gamma = (30 – 66) MeV
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New laboratory experimental data for highly accelerated charged particles with velocity E > 25 MeV/amu in interaction with astrophysically relevant target nuclei are essential for modeling the \gamma-ray emission in various astrophysical sites and supporting gamma astronomy studies. Such nuclear data are especially needed for simulating the violent nuclear collisions taking place, e.g., in solar flares and in the interaction of low energy cosmic rays with constituent nuclei of the interstellar medium. In this context, we have measured nuclear \gamma-ray line production cross sections for swift protons inelastically scattered off various target nuclei abundant on the solar surface and corona and in the ISM. The experiment has been carried out at the separate-sector cyclotron of iThemba LABS in Somerset West (Cape Town, South Africa) over the proton energy range E\gamma = (30 – 66) MeV using the line of the AFRODITE reaction chamber and associated large solid angle array of Ge-clover \gamma-ray detectors. Partial results for the 24Mg, 28Si and 56Fe target nuclei are reported herein and discussed. They are compared to scarce previous experimental data [1,2,3,4] and to the predictions of the Talys computer code [5] for modern nuclear reactions. In particular, our data consistently extend to higher proton energies those measured at the Orsay [1] and Washington [2] tandem accelerators.
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