Poster

Surface characterisation of ^{14}N implanted targets

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The $^{14}\mathrm{N}(p,\gamma)^{15}\mathrm{O}$, being the slowest reaction in the hydrogen burning CNO cycle [1], controls energy generation in it. But measurement of the cross-section of this reaction is hampered by the presence of ^{15}N impurity in the target. The ^{14}N implanted targets have a ^{15}N depletion of about two orders of magnitude [2]. In the present work, we discuss the preparation and characterisation of primarily the surface properties of a ^{14}N implanted target for upcoming Facility for Research in Experimental Nuclear Astrophysics (FRENA) with a high current 3 MV Tandetron accelerator at Saha Institute of Nuclear Physics, Kolkata.

The ^{14}N implanted target with thick Ta backing has been prepared by using 75 keV ^{14}N ions with 3^+ charge state from an ECR ion source at Tata Institute of Fundamental Research, Mumbai. No special treatment of the backing was undertaken to reduce contaminants. The backing material and implantation energy have been selected on the basis of simulation studies on sputter yields etc. We have utilised XPS, Raman spectroscopy, SEM and EDX methods to detect presence of elements as light as Boron (B) from the few nm ($\simeq$ 10nm) depth of the target surface. The results indicate the presence of low Z impurities in the target. So another ^{14}N implanted target with some special treatment of the backing have been prepared to reduce the contaminants. Characterization of this target is being done to estimate the reduction in the impurity concentration by these special efforts.

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[2] S. Suethe et. al,, Nucl. Instr. and Meth. A **260**, 33 (1987); H.Y. Lee, Nucl. Instr. and Meth. B **267**, 3539 (2009); J. Cruzet. al,, Nucl. Instr. and Meth. B **267**, 478 (2009).

Poster

Coulomb dissociation of ^{14}B and ^{15}B to constrain the astrophysical r-process

Sebastian Altstadt for the S393-Collaboration[1]

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To constrain the astrophysical r-process the importance of light elements in the reaction network has to be clarified. Model calculations of r-process nucleosynthesis in a neutrino-driven wind scenario with a short dynamical timescale indicate, that light, neutron-rich nuclei may have a crucial influence on final r-process abundances [1]. However, nuclear reaction rates of unstable nuclei far from stability are rarely known. Therefore, a kinematically complete measurement was performed with the LAND set-up at GSI. To obtain the neutron capture cross sections of ^{13}B and ^{14}B, which are supposed to be on the main flow path among the light-mass nuclei [2], the time-reversed reactions were measured via Coulomb dissociation. At the current status the analysis provides the integral cross sections of $^{15}B(\gamma, n)^{14}B$ and $^{14}B(\gamma, n)^{13}B$ as first preliminary results.

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[1] M. Terasawa et. al, The Astrophysical Journal **562**, 470-479 (2001).

[2] T. Sasaqui et. al, The Astrophysical Journal **634**, 1173-1189 (2005).

Talk

Direct measurement of the d(α,γ)^{6}Li cross-section at astrophysical energies

Michael Anders[1] and Daniel Bemmerer[1]

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Standard Big Bang nucleosynthesis predicts a very low abundance of the minor lithium isotope ^{6}Li, which is instead believed to be produced by cosmic rays over time. However, recently ^{6}Li has been detected in very old metal-poor stars, leading to the question whether its Big Bang production might be stronger than believed. The key reaction for ^{6}Li production in the Big Bang is d(α,γ)^{6}Li. Using the deep underground LUNA 400 kV accelerator at the Gran Sasso Laboratory in Italy, a direct measurement of the cross section is underway. The contribution will report on this experiment, collected data, methods to analyze them, and preliminary results.

Overview talk

Underground laboratories

Daniel Bemmerer[1]

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(Dated: January 13, 2012)

The precision of models describing astrophysical scenarios, like for example our Sun, depends among other factors on our understanding of the underlying nuclear reactions. Unfortunately, usually there are no experimental cross section data at the astrophysically relevant energies, and one has to rely on uncertain extrapolations to estimate the reaction rate. This is so because at these energies, the cross section is so low that the signal counting rate in a detector is much lower than the background. Underground laboratories address this problem, because they offer a much lower background rate in γ-ray and neutron detectors when compared to facilities at the surface of the Earth due to the suppression of cosmic-ray induced muons. Therefore, accelerator-based cross section measurements may be performed at much lower energies underground. For reactions involving light nuclei, this allows to greatly approach or for some scenarios even reach the astrophysically relevant energy range, reducing or even removing the uncertainties caused by extrapolations. The only underground accelerator worldwide is the Laboratory Underground for Nuclear Astrophysics (LUNA) 0.4 MV accelerator at Gran Sasso, Italy. Its past, present, and future scientific program will be discussed, including many reactions of stellar hydrogen burning and the Big Bang. Based on the success of LUNA, there is a call for a higher-energy accelerator underground, and several projects are being developed worldwide.

Overview talk

Measuring Reaction Rates for Nova Nucleosynthesis

Shawn Bishop[1]

[1] *Technische Universität München*

Novae are the result of a thermonuclear runaway on the surface of a white dwarf (WD) progenitor, within a binary star system. These objects come in two classes: so-called carbon-oxygen novae and oxygen-neon novae. Theoretical nova models comparing the nucleosynthetic output of the each nova-type show that, within the burning zone of the ONe-type, the composition mass-flow reaches as high as calcium, and the resulting abundances between neon and calcium ($20 < A < 40$) are $\approx$100 times greater, or more, than those produced in CO novae. This makes ONe-novae more interesting than CO-novae because, within this mass range exist three gamma -ray emitting isotopes which are, themselves, potential targets of gamma-ray astronomy. Additionally, several presolar grains have been discovered to carry isotopic signatures of potential ONe nova parentage. Because the reactions in novae involve proton capture onto nuclei that are within 2 to 3 mass units from stability, these objects are the only explosive phenomena in which the reaction rates can almost all be measured/constrained. This presentation will present results and discuss direct and indirect methods for measuring (p,γ) reaction rates for nova nucleosynthesis.

Talk

Measurement of ^{17}O(p,γ)^{18}F resonance at $E = 183.3$ keV with the LUNA accelerator

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(for the LUNA collaboration)

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[2] *Center for GeoTechnologies, Via Vetri Vecchi, 34 - 52027 San Giovanni Valdarno, Arezzo, Italy*

The ^{17}O+p thermonuclear reaction plays a major role in the hydrogen burning in a number of different stellar sites. In particular, the isotopic abundances of ^{17}O and ^{18}F in Nova nucleosynthesis are regulated by ^{17}O(p,α)^{14}N and ^{17}O(p,γ)^{18}F reaction rates. Recent results on the of the ^{17}O(p,γ)^{18}F resonance at $E = 183.3$ keV are in disagreement within each other. This resonance has been measured in LUNA by using both the activation and the gamma prompt technique. In this contribution, an overview of the experiment will be presented and the data analysis will be discussed.

Talk

^{4}He(^{3}He, γ) ^{7}Be cross section at E_{CM} of 900-2800 keV measured at a 5MV tandem accelerator

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[1] *Instituto de Estructura de la Materia-CSIC, Madrid, Spain*

The rate of the ^{4}He(^{3}He,γ)^{7}Be is one of the main source of uncertainty in determining the primordial ^{7}Li and the high energy solar neutrino flux. Due to the low reactions rates at energies of astrophysical interests (Gamow peak 23 keV) direct measurements are experimentally impossible. Thus, models use the extrapolation of the astrophysical factor S_{34}(E) at zero energy from the measurements at higher energies. For the range of 1.5 MeV to 3 MeV center of mass energy data from Ref. [1] and Ref. [2] show big discrepancies resulting [3] in one of the biggest error contribution among the nuclear inputs parameters.

New independent measurements would help to constrain the S_{34}(E) factor at high energies and thus improve the extrapolation to the S_{34} (0). We report here on an experiment performed at the Centro de Microanlisis de Materiales (CMAM), a 5 MeV Tandem accelerator in Madrid, using the activation method utilizing the same experimental setup as was used at Weizmann Institute [4]. A ^{3}He beam with laboratory energies between 2.3- 5.3MeV was impinging on a ^{4}He gas target of 55 Torr pressure. The recoiling ^{7}Be atoms were collected onto Cu catchers, and the subsequent beta delayed gamma radiation was measured off-line using a low-background HPGe station. Further, we will give some details from a complementary experiment using the direct recoil detection method that was recently performed with the DRAGON spectrometer at TRIUMF.

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[3] E. G. Adelberger et al , Rev. Mod Phys. **83 No. 1**, 195 (2011).

[4] B. S. Nara Singh et al., Phys. Rev. Lett **93**, 262503 (2004).

Talk

Lifetime measurement of the 6.79 MeV state in ^{15}O with the AGATA Demonstrator

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[2] *INFN, Sezione di Padova, Padova, Italy.*

[3] *Dipartimento di Fisica dell'Università di Padova.*

[4] *Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany*

[5] *Physikalisch-Technische Bundesanstalt, Braunschweig, Germany*

[6] *ATOMKI, Debrecen, Hungary.*

[7] *The Andrzej Soltan Institute for Nuclear Studies, Warsaw, Poland*

Recent determinations of the solar photosphere composition lead to discrepancies between standard solar model predictions and helioseismological measurements. This puzzle, known as the solar composition problem, may be solved using the CNO neutrino flux to derive the metallicity of the solar core.

The ^{14}N(p,γ)^{15}O reaction is the slowest one of the CNO cycle and thus it determines the total rate of energy and neutrinos production. The reaction cross section is influenced by a sub-threshold resonance corresponding to the 6.79 MeV level in ^{15}O and the width of this resonance is one of the main sources of uncertainty in the extrapolation of the cross section in the Gamow peak energy window.

Preliminary results of a new lifetime measurement of the 6.79 MeV state with the Doppler Shift Attenuation Method will be discussed. The level of interest was populated by the ^{14}N(^{2}H,n)^{15}O reaction at 32 MeV beam energy and the gamma rays emitted in its decay to the ground state were detected using the AGATA Demonstrator array. The sensitivity of the line shape to lifetimes in the fs range is investigated for both ^{15}O and ^{15}N levels comparing the experimental peaks in the gamma ray spectrum with detailed Monte Carlo simulations of the reaction mechanisms and of the gamma ray emission and detection.

Poster

The Search for Supernova-Produced Radionuclides in Deep-Sea Sediments with AMS

Jenny Feige,[1] Anton Wallner,[1,2] Stephan R. Winkler,[1]
Silke Merchel,[3] L. Keith Fifield,[2] and Gunther Korschinek[4]

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[2] *The ANU, Department of Nuclear Physics, Canberra, Australia*

[3] *Helmholtz-Zentrum Dresden-Rossendorf, Germany*

[4] *TU Munich, Physik Department, Germany*

We will search for supernova-produced radionuclides in deep-sea sediment cores originating from the Indian Ocean. We aim to measure the long-lived radionuclides ^{26}Al ($t_{1/2}$ = 0.7 Myr), ^{60}Fe ($t_{1/2}$ = 2.6 Myr), ^{53}Mn ($t_{1/2}$ = 3.7 Myr) and ^{244}Pu ($t_{1/2}$ = 80 Myr) at different laboratories in sediment samples with high time resolution. A positive signal will also confirm a previous finding of an enhanced ^{60}Fe content in a ferromanganese crust [1]. The above mentioned radionuclides are commonly synthesized in massive stars and ejected by supernova (SN) explosions. If such a SN event happens in the solar vicinity, the expanding SN envelope might hit the solar system and leave certain traces in terrestrial archives. An indication to recent SN activity is the existence of a cavity consisting of thin, hot gas in the local interstellar medium, embedding our solar system. This superbubble, called the Local Bubble, was presumably produced by 14-20 SN explosions starting ~14 Myr ago [2].

Because SNe and their ejecta are a site for dust formation, there might be a chance of finding such radionuclides in dust particles deposited in such terrestrial archives, like deep-sea sediments. The measurements will be carried out with accelerator mass spectrometry (AMS) utilizing laboratories with the highest sensitivities for these long-lived radionuclides.

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Talk

High power targets for FRANZ

M. Fonseca[1] and S. Schmidt[1]

[1] *Goethe Universität Frankfurt, Germany*

The FRANZ (Frankfurt neutron source at the Stern-Gerlach Zentrum) facility currently under construction at the Goethe University Frankfurt offers the possibility of energy-dependent neutron capture cross section measurements and activation experiments in an energy range relevant to the astrophysical s-process. Taking advantage of the high proton beam, cross sections of (p,γ) reactions for the p-process will also be measured.

At this facility, neutrons will be produced via the ^{7}Li(p,n)^{7}Be reaction by bombarding a thin ^{7}Li layer with a pulsed proton beam of up to 2 mA average current. As proton energies range from 1.8 to 2.2 MeV the beam power will be 4 kW. For activation experiments, a proton beam of up to 20 mA is available, which can also be used for p-induced reactions. The enormous heat load of up to 100 kW/cm^{-2} on the target has to be handled. Therefore, a high power target for neutron production as well as a target for (p,γ) reactions will be developed to withstand the expected power.

The heat distribution for the neutron production target has been simulated with the fluid dynamics code ANSYS. In order to validate the surface temperature as predicted by simulations, a high power setup at GSI in collaboration with the Super-FRS Group was used. The current status on target design covering the layout of the cooling system and first thermal performance test results at GSI will be presented.

A precise knowledge of the target composition is an essential ingredient to an absolute cross section measurement and has to remain stable under beam bombardment during the experiment. In order to verify the stability, RBS (Rutherford Backscattering Spectrometry) can be used.

Poster

A project for a nuclear astrophysics accelerator under the Pyrenees

L.M. Fraile[1] and the CUNA collaboration

[1] *Grupo de Fsica Nuclear, Universidad Complutense de Madrid, 28040 Madrid*

The direct measurement of reaction cross-sections of stellar nuclear reactions is hindered by experimental difficulties, particularly the very small cross-section values at the Gamow peak and the high background arising from the cosmic ray interactions. At the Earth's surface the low signal to background ratio can be overcome up to a certain limit by active and passive shielding and by a suitable choice of the experimental technique. But attaining the required sensitivity at low energies requires a further reduction of the background, as can be achieved at underground laboratories.

The Canfranc Underground Laboratory provides an excellent site for a unique accelerator-based nuclear astrophysics facility. With a depth of 2400 meters water equivalent it offers a reduction of the neutron flux down to the level of $2 \cdot 10{-}2$ $m^{-2}s^{-1}$ and a reduction of the muon flux to about $3 \cdot 10^{-2}$ $m^{-2}s^{-1}$. Under these conditions, the CUNA collaboration intends to develop an experimental nuclear physics programme, with the main purpose of studying the 13C(,n)16O and $^{22}Ne(\alpha,n)^{25}Mg$ reactions. These reactions have been identified as the dominant stellar neutron sources for the s-process and are therefore essential for the production of half of the elements above iron by slow neutron capture in stellar environments.

In 2011 a Preliminary Design Study for the construction of the new hall housing the nuclear astrophysics accelerator has been developed. It addresses the underground civil works, the building and construction, the installation of all services and facilities, and will serve as a basis for the technical Construction Project. The new hall will be located inside the Canfranc railway tunnel, on the Spanish side at around 2400 m from the tunnel entrance. The poster will address the Physics case, the ongoing background measurements and simulations, the hall design study and future prospects of the facility.

Talk

A new method for studying broad ^{12}C resonances using small accelerators and compact setups

Hans O. U. Fynbo[1] and Kasper L. Laursen[1]

[1]*Department of Physics and Astronomy, Aarhus University, Denmark*

We present a new method for studying broad resonances in ^{12}C, which is feasible at university labs. We populate a resonance above the region of interest and select gamma-decays of this resonance to lower lying resonances. The gamma-decay is identified by measuring the final state in complate kinematics. Thus the gamma-ray is not directly measured. This method makes it possible to identify gamma-decay to broad resonances, which is otherwise very difficult due to either background from overlapping states with different spin-parity, or due to the response of conventional gamma-detectors.

By choosing the first resonance appropriately one can enhance the selectivity for each state of interest by using the selection rules of gamma-decay.

Our first case using this method is a search for the first 2^+ resonance in ^{12}C, which has been the object of countless studies throughout the years. We will present clear evidence for a 2^+ resonance near 11-12 MeV and tentative evidence also for a resonance at 9-10 MeV.

The method might also work for studying resonances in ^{16}O of importance for the ^{12}C(α, γ) reaction.

Poster

Investigation of particle-nucleus optical potentials for *p*-process nucleosynthesis

Jan Glorius,[1] J. Goerres,[2] M. Knoerzer,[3] R. Reifarth,[1]
A. Sauerwein,[4] K. Sonnabend,[1] and M. Wiescher[2]

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[2] *Department of Physics, University of Notre-Dame, USA*

[3] *Institut für Kernphysik, TU Darmstadt, Germany*

[4] *Institut für Kernphysik, Universität zu Köln, Germany*

The p-process reaction network involves about 1000 nuclei and more than 10,000 reactions. Photon-induced as well as particle-induced reactions play an important role in this network. For elements heavier than Calcium reaction rates have to be calculated within the Hauser-Feschbach model. Therefore, it is mandatory to verify and improve the predictive power of these calculations studying the influence of the underlying nuclear physics. An investigation of optical particle-nucleus potentials is carried out via activation measurements of the four reactions ^{165}Ho(α,n), ^{166}Er(α,n), ^{169}Tm(p,n) and ^{175}Lu(p,n). All reactions exhibit strong sensetivities to the charged particle width of the respective entrance channel. The experimentally determined cross sections are compared to theoretical predictions of different codes using several optical potential parametrizations. Preliminary results of the investigation will be presented.

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Talk

Spatial and Time Correlated Detection of the Decay Chain of Radioactive Nuclei

C. Granja,[1] J. Jakubek,[1] U. Köster,[2] M. Platkevic,[1] and S. Pospisil[1]

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[2]*Institute Laue Langevin, Grenoble, France*

The quantum counting Timepix pixel detector enables to detect single radioactive ions and register their subsequent charged-particle decay chain in the same detector. The per-pixel energy and time sensitivity together with high granularity and configurability of the detector operation allow applying not only time but also spatial coincidence techniques for high selectivity and suppression of unwanted events. We can thus follow and visualize the life history of a single nucleus implanted into the semiconductor sensor. Experiments were done with radioactive ion beams from the fission fragment mass separator Lohengrin at the ILL Grenoble. The technique is demonstrated by the registration of the decay sequence

$$^{8}\mathrm{He} \rightarrow ^{8}\mathrm{Li} \rightarrow ^{8}\mathrm{Be} \rightarrow \alpha + \alpha. \quad (1)$$

Decay lifetimes of μs and longer can be measured.

This research was carried out in frame of the Medipix Collaboration

Poster

Mo(γ,n) and real photons for the validation of CD

Kathrin Göbel[1] and the S295 collaboration

[1] *Goethe Universität Frankfurt, Germany*

Most of the p-nuclei between ^{74}Se and ^{196}Hg are produced in explosive conditions by sequences of photo dissociations and β-decays. The region of A $\approx$ 100 is the borderline between the *rp*- and γ-process. In order to study the production of *p*-nuclei in this region, the experimental examination of by statistical model calculations predicted reaction rates involved in network calculations has to be performed.

At small-scale accelerators photo dissociation reactions with the stable isotopes ^{92}Mo and ^{100}Mo have been investigated. The cross sections were determined using real photons provided by the bremsstrahlung setups at ELBE and S-DALINAC.

However, most nuclei involved in photo dissociation reactions in stellar nucleosynthesis networks are unstable and cannot be prepared as a target. Therefore the (γ,n) reaction has to be studied in inverse kinematics by a beam of the radioactive nuclei in the Coulomb field of a high-Z target nucleus.

The (γ,n) cross sections of the isotopes ^{92,93,94,100}Mo have been measured using Coulomb Dissociation at the SIS/FRS/LAND setup at GSI in 2005. To establish the accuracy of this method, the cross sections of the stable isotopes ^{92}Mo and ^{100}Mo were compared to the results from the experiments with real photons mentioned above. The feasibility of the Coulomb Dissociation method was proven.

First results of the ^{94}Mo(γ,n)^{93}Mo cross section by Coulomb Dissociation will be presented.

Overview Talk

Proton- and Alpha-induced reactions

György Gyürky[1]

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About 99 % of our Universe is made of Hydrogen and Helium. Since practically no other elements have been synthsized in the big-bang, all heavy elements what we observe in Nature, have been produced by nuclear reactions involving these two elements. Therefore, low energy nuclear reactions induced by protons and alpha-particles play a central role in nuclear astrophysics.

Owing to the relatively low interaction energies encountered in different stellar environments, charged particle induced reactions take place well below the Coulomb-barrier resulting in low reaction cross sections. The experimental study of these reactions is thus challenging. In this review talk some experimental aspects of proton and alpha-induced reaction studies will be discussed through the examples of some recent experiments from various sub-fields of nuclear astrophysics.

Poster

^{60}Fe(n,γ)^{61}Fe at TRIGA reactor, Mainz and future possibilities at FRANZ

T. Heftrich,[1] M. Mikorski,[1] C. Beinrucker,[1] F. Käppeler,[2] K. Landwehr,[1] C. Lederer,[3] R. Reifarth,[1] C. Ritter,[1] S. Schmidt,[1] K. Sonnabend,[1] and T. Thomas[1]

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[2] *Forschungszentrum Karlsruhe*

[3] *Universität Wien*

One of the fundamental signatures for active nucleosynthesis in our galaxy is the observation of long-lived radioactive elements using γ-ray observatories such as INTEGRAL. Of particular importance are the two long-lived radioactive isotopes ^{26}Al and ^{60}Fe the production of which is thought to be associated with the nucleosynthesis in Helium shell burning phase in AGB stars where temperatures of $kT = 30$ keV are reached as well as with the nucleosynthesis in hot carbon or oxygen shell burning in massive pre-supernova stars at temperatures of $kT = 90$ keV. While the reactions of ^{26}Al have been studied extensively, very little is known about the reactions associated with the nucleosynthesis of ^{60}Fe. The destruction rate ^{60}Fe(n,γ)^{61}Fe at temperatures of $kT = 25$ meV was measured directly via an activation experiment at the TRIGA reactor in Mainz, Germany. Because of the short half life of ^{61}Fe ($t_{1/2}$=5.98 min) the experiment was performed in a sequence of cycles. The resulting γ-ray detection was measured with two Clover type HPGe detectors facing each other in close geometry. The ^{60}Fe sample was extracted from a Cu beam dump previously irradiated with high energy protons at Paul Scherrer Institut PSI. At the Frankfurt Neutron Source (FRANZ), which was recently founded at the University of Frankfurt, it will be possible to measure the destruction rate of ^{60}Fe(n,γ)^{61}Fe at a temperature of $kT = 90$ keV which refers to the temperature of astrophysical interest.

First results of the activation experiment at TRIGA as well as the new possibilities at the FRANZ to perform a measurement of the destruction rate ^{60}Fe(n,γ)^{61}Fe at $kT = 90$ keV will be presented.

Overview talk

Neutron-induced reactions

Michael Heil[1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung GmbH*

Neutron capture cross sections in the keV energy range are important for many applications such as accelerator driven systems (ADS), neutron boron therapy, radiation hardness tests of materials, and nuclear astrophysics. This contribution will focus on the need of neutron capture cross sections for the understanding of nucleosynthesis processes in stars. Experimental methods and techniques which allow neutron capture measurements with small-scale accelerators will be discussed. This includes the 4π BaF_2 detector setup at the former Van de Graaff accelerator at FZ Karlsruhe and the new FRANZ facility at the Goethe University Frankfurt.

Poster

(γ,n)-rates of short-lived carbon isotopes with the LAND/R3B setup

Marcel Heine[1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung GmbH*

Recent research has shown that (n,γ) rates on light nuclei can have an influence on the neutron balance during the r-process. Especially neutron-rich carbon isotopes play an important role in r-process nucleosynthesis network calculations, which include light nuclei since these nuclei are on the major flow-paths [1]. In particular ^{18}C is of interest, because it can be interpreted as a waiting point. The ^{17}C(n,γ)^{18}C rate could so far only be estimated theoretically and has an uncertainty of a factor of 10 [2]. At the LAND/R3B setup at GSI we ^{18}C have measured the time reversed reaction of ^{17}C(n,γ)^{18}C via Coulomb-breakup of a ^{18}C beam. The kinematically complete measurement allows extracting the differential cross-section with respect to the excitation energy by using the invariant-mass method. The validity of this approach could be shown in the past for the reaction pair ^{14}C(n,γ)^{15}C and ^{15}C(γ,n)^{14}C, where the neutron capture reaction has been investigated directly at a Van de Graaff accelerator [3] and the g-induced reaction via Coulomb-breakup at RIKEN and at GSI. Such tests based on experiments on small-scale accelerators are a necessary prerequisite for reliable cross section determinations far off the valley of stability.

[1] M. Terasawa et. al, Astroph. Journal **562**, 470 (2001)

[2] T. Sasaqui et. al, Astroph. Journal **634**, 1173 (2005)

[3] R. Reifarth et. al, Physical Review C **77**, 015804 (2008)

Overview talk

Astrophysics with spallation sources

Franz Käppeler[1]

[1] *Karlsruhe Institute of Technology*

During the last decade an increasing number of nuclear astrophysics experiments have been performed at spallation neutron sources, which are characterized by a number of attractive features. In particular the combination of high neutron flux, wide energy range, and low background provide the basis for measurements on small and/or radioactive samples. An overview of the spallation sources operated at Los Alamos, CERN, and J-PARC is followed by illustrative examples to highlight the potential of these facilities. Finally, the existing spallation sources and further upgrades are compared with advanced low-energy accelerators.

Poster

Nucleosynthesis simulations in AGB stars

Alexander Koloczek[1] and the NuGrid collaboration

[1] *Goethe University, Frankfurt am Main*

In order to understand the origin of the elemental distribution in the universe, one has to be able to track the nucleosynthesis back to the big bang. After the big bang nucleosynthesis the universe consisted mainly of Hydrogen and Helium. This elemental composition will be altered by stars through fusion. At some point fusion stops being efficient so that stars can only build up higher elements by neutron capture. One site for this to take place is in AGB stars (Asymptotic Giant Branch Stars) with the s-process (slow neutron capture).

In order to calculate the s-process in stars, one needs not only the stellar model but also a complete reaction network, which has to be fed with experimental data. The NuGrid collaboration developed a tool to post-process nucleosynthesis after the stellar model has been calculated. This way, the computing time can be reduced and different reaction networks can easily be used for the same stellar model.

Here we present sensitivity studies which show the effect of changes in the reaction network on the elemental distribution in the star. This helps to identify crucial reaction rates which should be measured in future experiments.

Overview talk

Astrophysics with rare isotope beams at TRIUMF

R. Krücken[1]

[1] *TRIUMF, Vancouver, VT6 2A3, BC, Canada*

The ISAC facility at TRIUMF is a high power ISOL facility which provides high intensity rare isotope beams for studies of questions in laboratory nuclear astrophysics, nuclear structure, and fundamental symmetries. A wide range of state-of-the-art experimental facilities is available for the investigation of nuclear properties as well as direct and indirect studies of astrophyiscal reactions. This contribution will provide an overview of the ISAC facility and its capabilities. It will discuss a number of recent experimental studies relevant to various aspects in stellar and explosive burning. Also perspectives for studying nuclei along the r-process path will be discussed using the neutron-rich beams from proton and photon induced fission with the upcoming ARIEL facility.

Talk

TACTIC: The TRIUMF Annular Chamber for Tracking and Identification of Charged particles

Edward Martin[1]

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The development of radioactive ion beams (RIBs) has enabled the measurement of many nuclear astrophysically important reactions directly for the first time. TACTIC (the TRIUMF Annular Chamber for Tracking and Identification of Charged particles) has been designed and built with the main purpose of measuring these reactions.

TACTIC is a cylindrical time projection chamber, which can fully track reaction products from their reaction vertex to their stop point inside the detector, gaining information on particle energy, energy loss and angle of emittance. Due to its geometry, TACTIC is ideal for measuring low energy, low cross-section, alpha induced reactions, and is able to utilise the maximum beam intensity currently available from RIB facilities. Because the target gas is also used as the detector gas, there needs to be no window between target and detector, so reaction products lose little energy before entering the detection volume.

At present, the main focus is to measure the cross-section of the ^{8}Li(α,n)^{11}B reaction. This reaction has been shown to provide an alternative nucleosynthesis pathway to ^{12}C, playing a pivotal role during the initial stages of the r-process in core-collapse supernovae.

In this talk, I will cover the design and operation of TACTIC, as well as physics motivation and the current status of the ^{8}Li(α,n)^{11}B reaction.

Poster

Towards a measurement of the ^{22}Ne(p,γ)^{23}Na cross-section at LUNA

Marie-Luise Menzel[1] and Dr. Daniel Bemmerer[1]

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The ^{22}Ne(p,γ)^{23}Na reaction takes part in the so called neon-sodium-cycle of hydrogen burning. This cycle is important at higher temperature than those experienced in the sun and plays a role in explosive hydrogen burning in an astrophysical nova. In addition, this reaction possibly depletes the supply of ^{22}Ne in the accreting white dwarf preceeding a supernova of type Ia. The rate of this reaction depends on the strengths of several resonances in the energy range of the LUNA 0.4 MV accelerator which have never been observed in direct experiments. A related study is under preparation at LUNA. The poster will show the experimental set-up and planned measurement strategy.

Overview talk

The Accelerator Based Neutron Source FRANZ

Oliver Meusel[1]

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Accelerator based neutron sources have several advantages compared with nuclear reactors. As an example the Frankfurt neutron source "FRANZ" already under construction will use the ^{7}Li(p,n) reaction for neutron production. It consists of a linear accelerator (LINAC) which gives the opportunity to adjust the neutron flux, neutron energy distribution and the timing of the pulsed neutron production by changing the properties of the primary proton beam.

FRANZ comprises two experimental areas that allow different types of neutron capture measurements. The compressor mode offers time of flight (TOF) measurements in combination with a 4π BaF_2 detector array. The proton beam will be compressed to a 1ns pulse with a peak current of about 9.6A and a repetition rate of 250kHz.

The activation mode uses a continuous neutron flux. The primary cw proton beam will have a current up to 8mA for the use on solid targets and up to 30mA on liquid metal targets as a later option.

The different components of the accelerator and its impact on the proton beam parameters will be described. Preliminary experimental results of proton beam production will be presented together with numerical simulations of beam transport and compression.

Talk

Experimental facilities for reaction studies in Nuclear Astrophysics in Cologne

Lars Netterdon,[1] Michael Elvers,[1] Janis Endres,[1] Ulrich Giesen,[2] Andreas Hennig*,[1] Anne Sauerwein*,[1] and Andreas Zilges[1]

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In order to improve *p*-process network calculations, experimentally determined nuclear physics input parameters like α + nucleus optical model potentials are of crucial importance. Due to the astrophysically relevant low interaction energies, cross sections for α-induced reactions are typically located in the μb range. Here the activation method has, if it is applicable, some advantages compared to in-beam measurements, *e.g.*, the very efficient background reduction. Therefore, we developed a new counting setup at the Institute for Nuclear Physics in Cologne equipped with two clover-type HPGe detectors each with a relative efficiency of 120 % at E_γ =1332 keV compared to a standard 7.62 cm × 7.62 cm NaI detector. A high detection efficiency and the possibility to measure coincidences between the eight leafs of the detectors gives access to cross sections in the μb range [1]. In this contribution we illustrate the counting setup and present preliminary cross sections of the reaction ^{168}Yb(α,n)^{171}Hf, that was measured at the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, Germany.

Supported by the DFG under contract ZI 510/5-1

*AH and AS are members of the Bonn-Cologne Graduate School of Physics and Astronomy

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[1] A. Sauerwein *et al.*, Phys Rev. C **84**, 045808 (2011).

Poster

$^{12}C +^{12}C$ Fusion Reaction at Low Energies

Carine Tsimba Nsangu[1]

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The $^{12}C +^{12}C$ reaction plays a key role in different astrophysical scenarios: from the hydrostactic carbon burning where the uncertainty in the reaction rate of this reaction is directly related to the uncertainty in the mass range determining two extremely different endpoints of stellar evolution, to its role in TP AGB stars, Type Ia supernovae and possible role in superbursts. Considerable effort has therefore been devoted over the years to measure the $^{12}C +^{12}C$ reaction at astrophysically relevant energies:1-3MeV. The lowest measured energy is 2.1 MeV, major discrepencies persists in the actual data. The present work analyses the $^{12}C +^{12}C$ reaction data which was performed in the energy range Ecm=3.40MeV to 4.02MeV. The experiment was carried out with TUDA chamber at TRIUMF using charged particle detection.

Talk

Experiments to constrain nucleosynthesis in hydrogen-burning environments

Anuj Parikh[1]

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Thermonuclear charged-particle reaction rates are required to constrain nucleosynthesis in both explosive hydrogen-burning phenomena, such as classical nova explosions and type I X-ray bursts, as well as during different stages of stellar evolution characterized by strong stellar winds (e.g., asymptotic giant branch and Wolf-Rayet stars). We review desired measurements in these environments with an emphasis on the role that facilities with small-scale accelerators may play in better determining the necessary rates.

Overview talk

Data acquisition in nuclear physics - from past to future

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The need of data acquisition systems in nuclear physics came along with the discovery of scintillators in the beginning of the 20th century.

While the first glimpse into this whole new world was done with the most basic tools, the need for more data and/or faster counting motivated the development of a wide variety of techniques. With the widespread use of electronics, the development of computers and powerful accelerators, the known territory could be and still is steadily expanded.

Yet, the need of more accurate cross section data for an increasing number of isotopes still persists. Although many of the stable isotopes have already been assessed with sufficient precision, the measurement of many other important nuclei suffers from either limited sample material, small cross sections or background from radiactive samples.

More intense ion or neutron beams of future facilities help to overcome these problems but heavily increase the amount of resulting data and require still-to-be-developed data acquistion systems.

This talk aims at illuminating the evolution of data acquisition in nuclear physics and gives an outlook on future systems.

Poster

Measurement of low energy neutrons with scintillation detectors

Moritz Pohl,[1] J. Glorius,[1] Susanne Kräckmann,[1] Christoph Langer,[1] Attila Krasznahorkay,[2] R. Reifarth,[1] and K. Sonnabend[1]

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The Low Energy Neutron detector Array (LENA) is a newly developed tool for the detection of neutrons with energies down to 100keV, an energy region quite important to nuclear astrophysics. It consists of several scintillating plastic bars, with a readout photomultiplier on each end. LENA was mainly developed for the s405 and s408 experiments at the LAND/R3B setup at GSI, but can also be used in several other experiments.

Whenever the detection of neutrons in a wide energy range is crucial to the understanding of the reactions under investigation, detectors like LENA can come into play. This could take place e.g. in the detection of neutrons in fission experiments, direct measurement of neutrons in (γ,n) reactions or at the upcoming FRANZ setup at Goethe University Frankfurt. This facility offers interesting experimental opportunities with its intense neutron beam, e.g. to study charge exchange reactions like (p,n) as well as (n,n) or other neutron induced reaction types. Scintillation detectors like LENA provide scientists with good time and position resolution combined with an easy handling due to its compact physical dimensions, which makes them a ideal tool for small scale experimental setups.

Overview talk

Differences between Nuclear Reactions in Stars and in the Laboratory

T. Rauscher[1]

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Three main nucleosynthesis processes involve nuclei close to stability: hydrostatic burning in stars, the s-process, and (partially) the γ-process. (The latter process starts with photodisintegration of stable nuclei but the main nucleosynthesis path then involves mainly radioactive nuclei a few units away from stability.) Laboratory experiments measure reaction cross sections by impinging a (mostly) monoenergetic projectile beam on a target whereas the central quantity for nucleosynthesis studies is the astrophysical reaction rate under stellar plasma conditions. The reaction rate involves an integration over a Maxwell-Boltzmann energy distribution of the projectiles and thermally excited target nuclei. While the computation of stellar rates from experimental cross sections is straightforward for light nuclei, the situation changes drastically above Fe where nuclear and thermal effects additionally influence the reaction rate. These additional effects are independent of the stability of a nucleus, although thermal effects may well modify the lifetime of a nucleus. They can only be assessed by theory in general, although selected experiments may provide specific information for a limited number of nuclei. Another important aspect is the fact that the cross sections and rates exhibit different sensitivities to nuclear structure at different energies. Therefore a measurement outside the astrophysically relevant energy range may not yield any information to better constrain the astrophysical rate. It should be further noted that also electron captures and decays are modified in the stellar plasma, by thermal excitation and/or by the full ionization of the atoms. Mainly focussing on the s- and the γ-process, I will discuss these effects and give a general overview of the limits and possibilities of experimentally constraining reaction rates above Fe, which are especially important when highly precise rates are sought after. I will also address common misconceptions on thermal modification of the reaction rates and their impact on photodisintegration rates.

Overview talk

Research at small-scale accelerators

René Reifarth[1]

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Nuclear-astrophysics related research at small-scale accelerators is typically performed at universities. In addition to important research that can not be carried out similarly cost efficient at big national research laboratories, the opportunities for involvement and education of young students, in particular at bachelor and master level, is a major advantage.

However, in contrast to the big collaborations like R^3B or EXL, no such platform is established for the research community at small-scall accelerators. One of the reasons for this circumstance is certainly the diversity of the research field. It ranges from charged-particle induced reactions above and below ground, in direct and inverse kinematics over neutron-induced reactions in time of flight and integral experiments to γ-induced experiments with real photons.

The 496. Wilhelm und Else Heraeus-Seminar on Astrophysics with modern small-scale accelerators brings together scientists with experience or collaborations in the field of nuclear astrophysics and in particular with smaller machines suited for university labs. The latest developments will be shared, common interests determined and future projects with high visibility developed.

Overview talk

Acclerator Mass Spectrometry

Georg Rugel[1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

Accelerator Mass Spectrometry (AMS) is presently one of the most sensitive techniques for the detection of long-lived radioisotopes at very low abundances. In recent years more isotopes can be measured via AMS and many isotopes ratios can be determined relatively precise. The main fields of applications are climate history and environmental processes where radioisotopes act as natural tracers. In earth sciences and archaeology AMS provides valuable dating tools. Radioisotopes commonly measured are ^{10}Be, ^{14}C, and ^{26}Al. Accelerators with intermediate energies of 3–6 MeV also allow sensitive detection of ^{36}Cl and ^{41}Ca. More exotic isotopes like ^{44}Ti, ^{53}Mn, ^{55}Fe, ^{59}Ni, ^{60}Fe, ^{63}Ni, ^{79}Se have been measured for astrophysical reasons.

An overview on recent AMS measurements with a focus on nuclear astrophysics will be given.

The technique of AMS at different laboratories will be shown. The new facility DREAMS at the Helmholtz–Zentrum Dresden–Rossendorf with an 6 MV tandem accelererator and the unique facility at Munich of the Technische Universität München and the Ludwig Maximilians Universität München will be described in more detail.

Talk

Experiments to study optical-model potentials

Anne Sauerwein,[1] Hans-Werner Becker,[2] Harald Dombrowski,[3] Michael Elvers,[1] Janis Endres,[1] Ulrich Giesen,[3] Jens Hasper,[1] Andreas Hennig,[1] Lars Netterdon,[1] Thomas Rauscher,[4] Karl Oskar Zell,[1] and Andreas Zilges[1]

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One aim of experimental p-process studies is the improvement of descriptions for optical-model potentials. The ^{141}Pr(α,n)^{144}Pm reaction is especially well suited to test the α+^{141}Pr optical-model potential for the application in the astrophysical p process [1]. This reaction was investigated at 8 different α-particle energies between 11 MeV and 15 MeV with the activation method. The $\gamma\gamma$ coincidence technique using the different segments of a clover-type detector for efficient background suppression was applied.

The experimentally determined S factors were compared to Hauser-Feshbach statistical model calculations using different optical-model potentials. Furthermore, a local potential was constructed to improve the description of the data.

This project has been supported by the Deutsche Forschungsgemeinschaft under the contract ZI 510/5-1. M. Elvers, A. Hennig, and A. Sauerwein are members of the Bonn-Cologne Graduate School.

[1] A. Sauerwein et al., Physical Review C **84**, 045808 (2011).

Talk

The $^{40}Ca(\alpha,\gamma)^{44}Ti$ Reaction Studied by Activation

Konrad Schmidt,[1,2] Chavkat Akhmadaliev,[1] Michael Anders,[1] Daniel Bemmerer,[1] Konstanze Boretzky,[3] Antonio Caciolli,[4] Zoltn Elekes,[1] Zsolt Fülöp,[5] György Gyürky,[5] Zoltan Halasz,[5] Roland Hannaske,[1] Arnd Junghans,[1] Michele Marta,[1,3] Ronald Schwengner,[1] Tams Szücs,[5] Andreas Wagner,[1] and Kai Zuber[1,2]

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The radioactive nuclide ^{44}Ti is believed to be produced in the α-rich freezeout preceding supernova explosions. The γ-lines from its decay have been observed in space-based γ-observatories for the Cassiopeia A supernova remnant. The rates of the nuclear reactions governing the production and destruction of ^{44}Ti should therefore be known with precision. Using the α-beam of the 3.3 MV Tandetron of Helmholtz-Zentrum Dresden-Rossendorf, the strengths of the $^{40}Ca(\alpha,\gamma)^{44}Ti$ resonance triplet at 4.5 MeV α-energy have been re-studied by activation. The samples have been analyzed in the Felsenkeller underground γ-counting facility. Preliminary data on lower-lying resonances will be presented, as well.

Talk

Flash-ADC-based Data Acquisition at the Frankfurt neutron source "FRANZ"

S. Schmidt,[1] C. Beinrucker,[1] M. Gilbert,[1] T. Heftrich,[1] K. Landwehr,[1] M. Mikorski,[1] R. Plag,[1] R. Reifarth,[1] C. Ritter,[1] and K. Sonnabend[1]

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In the modern picture of nucleosynthesis, heavy element production is explained via numerous processes, each of which accounts for a certain part of the nuclide chart. Among these, the r-process and the s-process are the most dominant processes, each being responsible for nearly half of the observed isotopic abundance. For both of these processes, a very important ingredient is the stellar neutron capture cross-section of the involved nuclei. While the conditions of the r-process cannot be reproduced under laboratory conditions, the s-process is accessible to specifically designed small-scale accelerators. The FRANZ accelerator currently under construction in Frankfurt will measure cross-sections of nuclides relevant to the s-process, thus continuing the work at Forschungszentrum Karlsruhe. There, several racks of analog electronic devices were required to provide readout for the time of flight measurements, which involved a segmented γ calorimeter consisting of 42 BaF_2 crystals. At FRANZ, due to the increased proton current and, consequently, the higher event rate, analog readout may become even more expensive and complicated. Using digital flash-ADCs, the readout will require much less space while allowing for higher event rates. In this talk, we will highlight the strengths and weaknesses of flash-ADC based readout, and review our experience with flash-ADC based data acquisition at a Ge detector setup.

Overview talk

Photon-induced reactions

Kerstin Sonnabend[1]

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Photon-induced reactions – like (γ,n), (γ,p), and (γ,α) – play an important role in the nucleosynthesis of the p nuclei. These proton-rich, in general very low-abundant isotopes cannot be produced by neutron capture reactions. Complete network calculations on p-process nucleosynthesis include a large number of reaction rates, *i.e.*, one relies theoretical predictions of the rates, usually performed in the framework of the Hauser-Feshbach statistical model. The reliability of these calculations should be tested experimentally for selected isotopes.

Activation experiments can be performed with low amounts of sample material because of their high sensitivity and selectivity. If the samples are activated with bremsstrahlung spectra – as provided, *e.g.*, by the Darmstadt High Intensity Photon Setup (DHIPS) or at the ELBE accelerator at Dresden – the usage of different electron energies and, thus, different endpoint energies of the continuous-energy photon spectra enables to derive the ground-state (γ,n) reaction rates via a superposition method without any assumption on the shape of the cross section for adjustable temperatures. The activation yield is usually determined by high-resolution γ spectroscopy at different setups optimized to the energies and branchings of the expected decay lines.

If the laboratory cross section has to be extracted from the data the continuous-energy distribution of the bremsstrahlung spectra necessitates a deconvolution that can lead to large uncertainties close to the reaction threshold due to the low reaction yield. To avoid this problem, Laser Compton-Backscattered (LCB) photons can be used providing an energy resolution of several 100 keV. In-beam measurements are performed at the National Institute of Advanced Industrial Science and Technology in Japan. Recently, the beam intensities available at the High Intensity γ-ray Source (HIγS) at the Duke Free Electron Laser Laboratory (DFELL) reached values to enable the usage of the activation technique also close to the reaction threshold.

An overview of the different facilities including recent results will be presented.

Talk

Experimental Setup for Trojan Horse Method in Nuclear Astrophysics

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Direct measurements of nuclear reactions at astrophysical energies is strongly inhibited, due to the small cross-sections involved and to the presence of electron screening, which prevents us from measuring the relevant bare astrophysical S(E)-factor. In order to overcome these experimental difficulties, indirect methods, e.g. the Coulomb dissociation, the Asymptotic Normalization Coefficients method and the Trojan Horse Method (THM) have been applied over the years whenever direct approaches alone could not provide definitive information. In particular the Trojan Horse Method has proved to be particularly suitable for acquiring information on charged-particle induced cross-sections at astrophysical energies, since it allows to overcome the Coulomb barrier of the two-body entrance channel. Briefly describing the method, a projectile a strikes a target nucleus A, whose wave fuction has a large amplitude for a s-b cluster configuration. Under a ppropriate kinematical conditions, the particle a interacts only with the part b of the target nucleus A, while the other part s behaves as spectator to the process a+b(+s) $\rightarrow$ c+d(+s). The basic features of the Trojan Hors Method are discussed. Some recent applications, aimed to extract the bare nucleus astrophysical S_b(E)-factors for two-body processes ^{11}B+p $\rightarrow$ ^{8}Be+α, ^{10}B+p$\rightarrow$ ^{7}Be+α, ^{19}F+p$\rightarrow$ ^{16}O+α, ^{6}Li+n$\rightarrow$ α+^{3}H, will be presented giving particular attention to the experimental setup (accelerators, scattering chamber and detection system) used in the experiments.

Poster

Indirect measurements of the ^{18}F(α,p)^{21}Ne reaction with TUDA

Jessica Tomlinson[1]

[1] *University of York, UK*

The ^{18}F(α,p)^{21}Ne reaction rate is important in predicting the stellar abundance of ^{19}F and ^{21}Ne in AGB stars, however there are still large uncertainties in the cross section at the relevant temperature conditions. An experiment was carried out at TRIUMF using the TUDA scattering chamber to measure the time reversed reaction cross section ^{21}Ne(p,α)^{18}F using a gas H_2 target for the first time. The direct reaction cross section can then be calculated and the reaction rate found, reducing the uncertainty in the measured value. The poster will discuss the astrophysical importance of this reaction, previous results obtained and experimental set up for measuring this time reversed reaction.

Poster

Cross section measurements with the Karlsruhe $4\pi BaF_2$ detector using a 3.7 MV Van de Graaff accelerator

Mario Weigand,[1] Stephan Walter,[2] Franz Käppeler,[2] Ralf Plag,[3] and Rene Reifarth[1]

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The cosmic abundance distribution of elements and isotopes is related to the reaction rates of the different synthesis processes. Most of the elements heavier than iron have been and still are synthesized in neutron-induced in stars of different stages. However, some isotopes are primarily formed in the so-called p-process because they are shielded from the much more effective neutron-induced reactions. The qualitative description of the p-process requires large reaction networks. The most important components here are the proton-, alpha- and gamma-induced reactions and the associated β^+-decays.

At the Karlsruhe Institute of Technology (KIT) proton capture events have been observed with the Karlsruhe 4π-BaF_2-detector, which consists of up to 42 spherically arranged BaF_2-crystals. The protons were accelerated with a pulsed 3.7 MV Van de Graaff accelerator to an energy of 3 MeV.

An overview of the experimental setup and the experimental data will be presented.

Overview talk

Challenges and limits of experiments with small accelerators

Michael Wiescher[1]

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The field of nuclear astrophysics provides a broad range of experimental and theoretical challenges to the physicist. Nucleosynthesis in explosive environments requires the use of radioactive beams to study nuclear reactions as well as nuclear decay, and the properties of nuclei and nuclear matter far off stability. The build-up of heavy elements in quiescent burning requires the development and use of intense neutron sources based on nuclear reaction or spallation processes to simulate the neutron flux anticipated for stellar environments. The formation of light particles in quiescent burning during stellar evolution is of particular interest, since it provides the seed for subsequent quiescent f explosive burning events. A reliable interpretation of the nucleosynthesis during the different stages of stellar evolution relies on the careful study of nuclear reaction processes associated with stellar hydrogen, helium, and carbon burning towards the corresponding stellar temperature range. This requires long-term measurements of reactions at exceedingly low energies with cross sections in the sub-picobarn range. Measurements are not only handicapped by exceedingly low count rates but also by natural and beam induced radiation background. This talk will present two new facilities presently designed for low energy experiments, the St.ANA low energy heavy ion beam accelerator at the University of Notre Dame, designed for radiative capture studies utilizing inverse kinematics techniques, and the DIANA light ion beam accelerator facility at the Sandford Underground Research Facility SURF at Homestake Mine in South Dakota. The design and the expectations for the two facilities will be discussed on a numbers of examples such as the ^{22}Ne(α, γ) and the ^{22}Ne$(\alpha$,n) reactions, which are key processes for the neutron production for the weak and main s-process. Finally, challenges for measurements projected for the actual stellar energy range will be summarized, which may require new technical developments in the future.

Talk

A multi-reflection time-of-flight mass separator for high-resolution beam purification at ISOLTRAP

Robert N. Wolf[1] and the ISOLTRAP collaboration

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High-precision Penning-trap mass measurements of short-lived nuclei are performed with ISOLTRAP at the on-line isotope separator ISOLDE/CERN. Exotic nuclides with half-lives below 100 ms and production yields of less than 1000 ions per second have been studied with a relative mass uncertainty routinely reaching $1{\cdot}10^{-8}$. They range from light systems - such as ^{17}Ne - to heavy ones - such as ^{233}Fr, thus giving insight into numerous physics topics. Recently, ISOLTRAP has delivered data for nuclear- structure studies concerning shell closures and residual interaction e.g. in the regions of closed shells around N=50, N=82, N=126. Valuable input has also been provided for neutron and proton rapid capture processes in stellar environments with isotopes of Se, Br, Ag, Rb, Kr, Cd, Xe, Rn. In addition, new mass values improved the study of the electroweak interaction based on super-allowed beta emitters such as ^{22}Mg, ^{26m}Al, ^{38}Ca, and ^{74}Rb. An important prerequisite of precision mass measurements with Penning traps is the availability of purely isobaric ion ensembles. To enhance the purity of radioactive ion beams, a multi-reflection time-of-flight mass separator (MR-TOF MS) developed at the University of Greifswald has recently been implemented at the ISOLTRAP setup. The MR-TOF MS consists of two electrostatic ion-optical mirrors between which the ions of interest oscillate and are separated from contaminant ions of different mass-over-charge ratios m/q. A mass resolving power of R = 200,000 and a contaminant reduction of four orders of magnitude by use of a Bradbury-Nielsen ion gate have been achieved. The performance of the combined setup (including an RFQ ion buncher, the MR-ToF MS and the two Penning traps) in both offline tests as well as in first applications with radioactive ion beams will be presented. Furthermore, the physics case and recent result of mass measurements of neutron-rich Zinc will be shown.