Nuclear Physics in Astrophysics - III

XXI International Nuclear Physics Divisional Conference of the European Physical Society

Dresden, Germany, 26 – 31 March 2007

Preliminary program and abstracts

(as of March 8, 2007)

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Preliminary program as of March 8, 2007

Time	Monday 26/03/2007	Tuesday 27/03/2007	Wednesday 28/03/2007	Thursday 29/03/2007	Friday 30/03/2007
08:30 – 10:30	Registration	**Topic 2** p. Descouvemont, Brussels (p. 24) A. Wallner, Vienna (p. 25) F. Strieder, Bochum (p. 26) A. Formicola, Gran Sasso (p. 27) C. Bordeanu, Bucharest (p. 28)	**Topic 3** H. Utsunomiya, Kobe (p. 44) G. Kiss, ATOMKI (p. 45) K. Sonnabend, Darmstadt (p. 46) M. Paul, Jerusalem (p. 47) I. Mishustin, FIAS (p. 48)	**Topic 4** D. Vretenar, Zagreb (p. 54) N. Auerbach, Tel Aviv (p. 55) N. Tsoneva, Gießen (p. 56) K. Boretzky, GSI (p. 57) Bao-An Li, TAMU (p. 58)	**Topic 4** Z. Elekes, ATOMKI (p. 69) N. Aoi, RIKEN (p. 70) M. Hass, Weizmann (p. 71) D. Schumann, PSI (p. 72) Y. Fujita, Osaka (p. 73)
10:30 – 11:00	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
11:00 – 13:00	**Opening** 11:00 – 11:30 E. Grosse, FZD Dresden H. Freiesleben, TU Dresden and EPS Nuclear Physics Board **Topic 1** R.H. Cyburt, MSU (p. 11) G. Mangano, Naples (p. 12) N. Christlieb, Uppsala (p. 13)	**Topic 2** M. Heil, Frankfurt/GSI (p. 29) M. Mosconi, FZK Karlsruhe (p. 30) M. Lugaro, Utrecht (p. 31) K. Czerski, Sczcecin (p. 32) G. Ruprecht, TRIUMF (p. 33)	**Topic 3** M. Krticka, Prague (p. 50) T. Rauscher, Basel (p. 49) A. Wagner, FZD Dresden (p. 51) I. Dillmann, FZK Karlsruhe (p. 52) A. Juodagalvis, Vilnius (p. 53)	**Topic 5** R. Lacey, Stony Brook (p. 59) D. Blaschke, Wroclaw (p. 60) J. Stachel, Heidelberg (p. 61) A. Illarionov, SISSA (p. 62) J. Schaffner-Bielich, Frankfurt (p. 63)	**Topic 5** F. Burgio, Catania (p. 74) p. Senger, GSI (p. 75) I. Vidana, Barcelona (p. 76) C. Fuchs, Tübingen (p. 77) G. Pagliara, Frankfurt (p. 78)
13:00 – 14:00	Lunch	Lunch	Lunch	Lunch	Lunch
14:00 – 16:00	**Topic 1** T. Dent, Heidelberg (p. 14) H. Abele, Heidelberg (p. 15) G. Gyürky, ATOMKI (p. 16) J. Cruz, Lisbon (p. 17) S. Typel, GANIL (p. 18)	**Topic 2** S. Romano, LNS Catania (p. 34) A. Mukhamedzhanov, TAMU (p. 35) M. La Cognata, LNS Catania (p. ??) R. Alvarez, Aarhus (p. 37) B.Z. Kozlovsky, Tel Aviv (p. 38)	**14:45 Meet at Terrassenufer**, get on boat for the excursion to Pillnitz Castle	**Poster session** • Poster session • Presentation of industrial partners • Presentation of candidates for NPA-4 conference to EPS Nuclear Physics board	**Topic 6** K. Eitel, FZK Karlsruhe (p. 79) G. Martinez-Pinedo, GSI (p. 80) D. Nadyozhin, Moscow (p. 81) M. Liebendörfer, Basel (p. 82)
16:00 – 16:30	Coffee break	Coffee break		Coffee break	Coffee break
16:30 – 18:30	**Topic 3** R. Diehl, MPE Garching (p. 19) C. Vockenhuber, TRIUMF (p. 20) K.-L. Kratz, Mainz (p. 21) C. Angulo, Louvain (p. 22) D. Galaviz, Madrid (p. 23)	**Topic 3** J. José, Barcelona (p. 39) G. Baur, FZJ Jülich (p. 40) V. Demetriou, Demokritos (p. 41) M. Sharma, Kuwait (p. 42) L. Kern, Darmstadt (p. 43)		**Topic 4** T. Neff, GSI (p. 64) A. Jokinen, Jyväskylä (p. 65) F. Herfurth, GSI (p. 66) M. Matos, MSU (p. 67) M. Hempel, Frankfurt (p. 68)	**Topic 6** N. Paar, Zagreb (p. 83) V. Dexheimer, Frankfurt (p. 84) R. Surman, Schenectady (p. 85) A. Kelic, GSI (p. 86) **Closing remarks** F. Käppeler, FZK Karlsruhe
	18:30 Welcome Reception 20:00 Public Lecture by C. Rolfs (Bochum)		19:00 Dinner on the boat 21:00 Return to Terrassenufer		

Topic 1 – Big bang Nucleosynthesis

Talks

Topic 2 – Stellar nucleosynthesis and low cross section measurements

Talks

Posters (Thursday 14:00 - 16:00)

Topic 3 – Explosive Nucleosynthesis and Nuclear Astrophysics with Photons

Talks

Posters (Thursday 14:00 - 16:00)

Topic 4 – Nuclei far from Stability and Radioactive Ion Beams

Talks

Posters (Thursday 14:00 - 16:00)

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Posters (Thursday 14:00 - 16:00)

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Topic 6 – Neutrinos in Nuclear Astrophysics

Talks

Posters (Thursday 14:00 - 16:00)

TALKS

1 Big bang Nucleosynthesis

Monday 11:30 - 12:00

Big Bang Nucleosynthesis

Richard H. Cyburt

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Big bang nucleosynthesis (BBN) remains one of the many successes of the hot big bang cosmology. BBN accurately predicts the primordial light element abundances of deuterium, helium and lithium. The general concordance between the predicted and observed light element abundances provides a direct probe of the universal baryon density. Another major success of the hot big bang model, the cosmic microwave background (CMB) and its anisotropy spectrum, particularly that measured by the WMAP satellite, examine this concordance by independently measuring the cosmic baryon density. Using regularly updated nuclear input is key to making accurate BBN abundance predictions. The case will be made for further mearsurements of nuclear cross sections and observations of light element abundances. With a clear understanding of theory and observations, BBN becomes a sharp probe of nuclear and particle astrophysics. The physics of the "large" can say something about the physics of the "small".

Monday 12:00 - 12:20

Relativistic energy density in the Universe

G. Mangano[1]

[1] *INFN, Italy*

I will discuss the present bounds on the relativistic energy density in the Universe parametrized in terms of the effective number of neutrinos N using, comparing the constraints from Big Bang Nucleosynthesis (BBN) predictions for 4He and Deuterium abundances with the most recent data on Cosmic Microwave Background (CMB) temperature anisotropies and polarization, Large Scale galaxy clustering from the Sloan Digital Sky Survey (SDSS) and 2dF, luminosity distances of type Ia Supernovae, Lyman-alpha absorption clouds (Ly-alpha), the Baryonic Acoustic Oscillations (BAO) detected in the Luminous Red Galaxies of the SDSS and finally. The results are in slight tension with the standard value as well as with the BBN range, though the discrepancy is slightly below the 2-sigma level; I will emphasize the impact of an improved upper limit (or measurement) of the primordial value of 3He abundance in clarifying the issue of whether the value of N at early (BBN) and more recent epochs coincide. I will also shortly report on the impact of an extended nuclear network on the CNO element yields in standard BBN. The scenario of a metal-free Early Universe, which is important for the Population III star phenomenology, is confirmed with unprecedented accuracy.

Monday 12:20 - 12:50

Constraints on Big Bang Nucleosynthesis from observations of metal-poor stars

Norbert Christlieb[1]

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In the atmospheres of stars, to a large extend the chemical composition of the gas cloud from which the star has formed is preserved. The most metal-poor stars (i.e., stars that have a deficiency of the elements heavier than helium with respect to the amount of these elements in the Sun) have ages comparable to the age of the Universe; i.e., they belong to the first few generations of stars that have formed after the Big Bang. Therefore, we can infer from these stars the chemical composition of the early Universe.

Of particular interest are observations of the abundances of ^{6}Li and ^{7}Li in metal-poor low-mass stars in a certain effective temperature range, because they have convection zones that do not reach deep enough into the interior of the star for Li to be destroyed by proton capture. Hence these stars provide us with information on the amount of ^{7}Li produced in Big Bang Nucleosynthesis (BBN), and the amount of ^{6}Li produced in the early Universe.

I will review recent observations of ^{6}Li and ^{7}Li in metal-poor stars and discuss possible consequences for BBN. I will also discuss possible solutions for the discrepancy between the ^{7}Li abundance seen in metal-poor stars and the primordial abundance inferred from the value of the baryon density of the Universe, as determined from recent observations of the cosmic microwave background radiation with the Wilkinson Microwave Anisotropy Probe, and standard BBN models.

Monday 14:00 - 14:20

Big Bang Nucleosynthesis as a probe of fundamental "constants"

Thomas Dent[1], Steffen Stern[1], Christof Wetterich[1]

[1] *Theoretische Physik, Universität Heidelberg, Philosophenweg 16, Heidelberg 69120, Germany*

Nucleosynthesis is the earliest and most sensitive probe of the values of many fundamental particle physics parameters. We have found the leading dependence of primordial abundances on all relevant physical parameters of the standard BBN code, including binding energies and nuclear reaction rates. This enables us to set limits on possible variations of fundamental parameters, under reasonable theoretical assumptions about how these affect quantities in nuclear physics. We find that Lithium-7 is expected to be significantly more sensitive than other species. Our work also indicates which areas of nuclear theory should be developed to probe values of „constants“ with more accuracy.

Monday 14:20 - 14:40

A new determination of the axial vector coupling constant g_A

Hartmut Abele[1]

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We report on a new, precise determination of the axial vector constant g_A. As a result of correlation coefficient measurements in neutron β-decay, the ratio of the weak axial-vector and vector coupling constant is now known with a precision of 7×10^{-4}, and we recommend the improved value as a standard, to be used in solar neutrino flux calculations, neutron star formation and big-bang nucleosynthesis.

Monday 14:40 - 15:10

The ^{3}He(α,γ)^{7}Be reaction studied by activation at LUNA

Gy. Gyürky[1] for the LUNA collaboration

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The ^{3}He(α,γ)^{7}Be reaction plays an important role both in primordial nucleosynthesis of ^{7}Li and in stellar hydrogen burning. The primordial abundance of ^{7}Li is an important test of big bang nucleosynthesis model calculations and presently the models are not able to reproduce the observed ^{7}Li abundance. Additionally, the reaction rate of ^{3}He(α,γ)^{7}Be is the major nuclear physics source of uncertainty in the predicted fluxes of the high energy ^{7}Be and ^{8}B neutrinos from the sun. Therefore the precise measurement of the ^{3}He(α,γ)^{7}Be cross section in (or close to) the relevant energy regions is of great importance.
The LUNA collaboration has launched an experimental program on the ^{3}He(α,γ)^{7}Be reaction in Italy's Gran Sasso underground laboratory to measure high precision cross section of the reaction by detecting both the prompt γ-radiation from the reaction (on-line method) and the decay of the produced ^{7}Be (activation). The experimental technique and the results of the activation method is presented in the talk. Using a windowless gas target, high beam intensity, and low background γ-counting facilities, the ^{3}He(α,γ)^{7}Be cross section has been determined for the first time in a very low energy range directly relevant to big bang nucleosynthesis between $E_{c.m.} = 106$ and 169 keV with a total uncertainty of 4 % [1,2]. The consequences for calculated primordial nucleosynthesis and solar neutrino fluxes are discussed.

[1] D. Bemmerer et al., Phys. Rev. Lett. **97**, 122502 (2006).
[2] Gy. Gyürky et al., Phys. Rev C (submitted).

Monday 15:10 - 15:30

Experimental study of proton induced nuclear reactions in ^{6,7}Li

J. Cruz[1,2], H. Luis[2], M. Fonseca[2], Z. Fülöp[3], G. Gyürky[3], F. Raiola[4], K.U. Kettner[5], M. Aliotta[6], J.P. Ribeiro[2], A.P. Jesus[1,2], C. Rolfs[4]

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[5] *Fachhochschule Bielefeld, Germany*
[6] *School of Physics, University of Edinburgh, UK*

The ^{7}Li(p,α)^{4}He and ^{6}Li(p,α)^{3}He astrophysical bare S-factor and electron screening have been studied at $E =$ 25 to 1740 keV and E = 24 to 580 keV, respectively. The bare S-factor shows good agreement with previous data yielding $S_b(0) = 59.7 \pm 1.3$ keV b for the ^{7}Li reaction and $S_b(0) = 3.52 \pm 0.08$ MeV b for the ^{6}Li reaction. Angular distributions measurements for the ^{7}Li(p,α)^{4}He reaction indicate that for energies above $\approx$ 1100 keV proton f waves, in addition to p waves, should be taken into account for the theoretical description of the entrance channel of this reaction.
The electron screening in the ^{7}Li(p,α)^{4}He reaction has been studied for different environments [1]: Li_2WO_4 insulator, Li metal, and PdLi alloys. For the insulator a screening potential energy of U_e = 78 $\pm$ 151 eV was observed, consistent with previous work [2] and atomic-physics models predictions. However, for the Li metal and the PdLi alloys we find large values of $U_e = 1031 \pm 59$ eV and 3528 $\pm$ 330 eV, respectively. These values can be explained by the Debye screening model applied to the quasi-free metallic electrons in these samples. Similar results have been found for the ^{6}Li(p,α)^{3}He reaction supporting the hypotesis of the isotopic independence of the electron screening effect [1]. The data together with previous ([3],[4]) and more recent ([5]) experimental data verify the Debye scaling $U_e \propto Z_t$ (target atomic number).
The ability of the Debye model to explain (and predict) the high U_e values observed in metallic environments is important for stellar evolution and BBN models since, by showing that laboratory measurements are well understood, we can rely on the cross sections input parameters for these models.

[1] J. Cruz, *et al.* , Phys. Lett. B**624**, 181 (2005).
[2] S. Engstler, G. Raimann, C. Angulo, U. Greife, C. Rolfs, U. Schröder, E. Somorjai, and B. Kirch, Z.Phys. A**342**, 471 (1992).
[3] F. Raiola,*et al.* , J. Phys. G**31**, 1141 (2005).
[4] D. Zahnow, *et al.* , Z. Phys. A **359**, 211 (1997).
[5] K.U. Kettner, *et al.* , J. Phys. G**32**, 489 (2006).

Monday 15:30 - 16:00

The Significance of Nuclear Reaction Theory for Analysing Coulomb Breakup Experiments of ^{8}B and ^{6}Li

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The Coulomb dissocation method is an indirect approach to determine low-energy cross sections of radiative capture reactions from high-energy breakup reactions. In contrast to direct experiments, the cross sections, that are relevant to nuclear astrophysics, are obtained by converting the measured three-body dissociation cross sections with the help of nuclear reaction theory. The breakup mechanism has to be well understood in order to determine reliably the cross sections of interest.

In this contribution, the input from nuclear reaction theory in the analysis of experimental breakup data is discussed for two examples. In particular, the relevance of different electromagnetic multipole contributions, higher-order effects, nuclear breakup contributions and the simulation of the actual experiments are considered.

The low-energy astrophysical S factor of the ^{7}Be(p,γ)^{8}B reaction is relevant to the determination of the solar high-energy neutrino flux. The cross section has been measured in several direct experiments allowing a comparison with results from indirect Coulomb breakup experiments. It is shown that are careful analysis of the GSI dissociation experiment with a high-energy 254 A MeV ^{8}B secondary beam [1] leads to a S factor that is consistent with the most precise direct data [2].

The major source of uncertainty for the abundance of ^{6}Li in Big-Bang nucleosynthesis is the cross section of the ^{2}H(α,γ)^{6}Li reaction. There are no direct data available in the energy range of astrophysical interest ($E \leq 400$ keV) and the experimental information relies on a Coulomb dissociation experiment with a 26 A MeV ^{6}Li beam [3]. However, the indirectly determined astrophysical S factor shows discrepancies with theoretical predictions and an independent measurement is highly desirable. The current status in the analysis of the GSI breakup experiment with a 150 A MeV ^{6}Li will be presented.

[1] F. Schümann et al., Phys. Rev. C **73**, 015806 (2006).
[2] A. R. Junghans et al., Phys. Rev. C **68**, 065803 (2003).
[3] J. Kiener et al., Phys. Rev. C **44**, 2195 (1991).

3 Explosive Nucleosynthesis and Nuclear Astrophysics with Photons

Monday 16:30 - 17:00

Observing Cosmic Nuclei with Gamma-ray Telescopes

Roland Diehl

Max Planck Institut für extraterrestrische Physik, D-85748 Garching, Germany

Nucleosynthesis events in cosmic objects create new nuclei, admixtures of radioactive isotopes being part of the matter ejected into interstellar space by these events. Gamma-rays are emitted in radioactive decays, and can be measured with space-based gamma-ray telescopes [1]. Four mission years of INTEGRAL have led to discoveries of new sources and to detailed astronomical refinements of already-known gamma-ray line emission. As part of the main science objectives of INTEGRAL's spectrometer SPI, diffuse emission from annihilation of positrons has presented a new puzzle, as the Galactic distribution of their presumed sources does not agree with the gamma-ray image. Recent massive-star nucleosynthesis is traced throughout the Galaxy with radioactivites seen in ^{26}Al [2] and now also ^{60}Fe gamma-rays [3]; precision line spectroscopy now reveals Doppler shifts for the ^{26}Al line, separately for different parts of the Galaxy [4]. This provides new insights into the dynamics of hot interstellar gas. The processes generating new atomic nuclei in stars and supernovae are reflected in the abundances of the ejected radioactivities. For individual supernovae, measurements of ^{44}Ti with its 85-year decay time probes the symmetry of the supernova interior [5]. We will discuss the recent spectroscopic information on these gamma-ray lines and their broader implications.

[1] Diehl R., Prantzos N., Ballmoos P., Nucl. Phys A, **777c**, 70 (2006).
[2] Diehl, R., *et al.*, Astron.Astroph. **449**, 1025 (2006).
[3] Wang, W., *et al.*, Astron.Astroph. *submitted* (2007).
[4] Diehl, R., *et al.*, Nature, **439**, 45 (2006).
[5] Vink, J., Adv.Sp.Res. **35**, 976 (2005).

Monday 17:00 - 17:20

^{40}Ca(α,γ)^{44}Ti and the production of ^{44}Ti in supernovae

C. Vockenhuber[1], C.O. Ouellet[2], L.-S. The[3], L. Buchmann[1], J. Caggiano[1], A.A. Chen[2], J.M. D'Auria[4], B. Davids[1], L. Fogarty[1], D. Frekers[5], A. Hussein[6], D.A. Hutcheon[1], W. Kutschera[7], D. Ottewell[1], M. Paul[8], M.M. Pavan[1], J. Pearson[2], C. Ruiz[1], G. Ruprecht[1], M. Trinczek[1], A. Wallner[7]

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The direct observation of ^{44}Ti ($t_{1/2} = 58.9 \pm 0.3$ yr) in supernova remnant Cas A by γ-ray satellites provides an excellent tool for studying core collapse supernovae. ^{44}Ti is produced during the alpha-rich freeze-out just above the collapsing core and thus allows a comparison with supernova models. Although the main production reaction ^{40}Ca(α,γ)^{44}Ti has been studied partly in the past by prompt γ-ray measurements and recently by off-line counting of ^{44}Ti nuclei with Accelerator Mass Spectrometry, there are still uncertainties of the reaction rate in the relevant temperature regime of $T_9 \sim 1.0 - 2.5$.
At the recoil mass spectrometer DRAGON, located at the ISAC facility at TRIUMF (Vancouver, Canada), we studied the reaction in inverse kinematics using a high-purity ^{40}Ca beam with energies of $0.6 - 1.2$ MeV/amu impinging on a windowless He gas target. ^{44}Ti recoils are identified directly in an ion chamber after separation of the majority of the ^{40}Ca beam by the recoil mass spectrometer and by using γ-ray coincidences (detected by a high-efficiency BGO detector array surrounding the gas target).
Results of the present measurement and plans for studying other key reactions involving radioactive beams, which now dominate the uncertainty of understanding the nucleosynthesis of ^{44}Ti, will be presented.

Monday 17:20 - 17:40

Rapid neutron-capture nucleosynthesis: How to run an r-process, at what astrophysical site, and how to terminate it?

K.-L. Kratz[1,2], J.J. Cowan[3], K. Farouqi[2], B. Pfeiffer[2], C. Sneden[4], F.-K. Thielemann[5], and J.W. Truran[6]

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[6] *Department of Astronomy and Astrophysics and Enrico Fermi Institute, University of Chicago, IL 60637, USA*

Nucleosynthesis theory predicts that about half of the chemical elements above Fe are formed in explosive scenarios by the rapid neutron-capture process (r-process). A correct modeling of this process requires the knowledge of nuclear properties very far from β-stability and a detailed description of the stellar conditions.
With updated experimental and theoretical nuclear-physics data, we have performed detailed r-process parameter studies within the site-independent „waiting-point“ model of (n,γ)–(γ,n) approximation in order to first obtain general astrophysical constraints from various r-process signatures. These indicators include the solar-system isotopic abundances ($N_{r,\odot}$), so-called „FUN“anomalies in meteoritic inclusions, and the recent elemental abundances in ultra-metal-poor (UMP) halo stars and globular clusters. Based on these results, after understanding the necessary nuclear-structure input, its associated uncertainties, and the resulting abundance deficiencies, in the next step we have performed large-scale, full dynamical r-process network calculations, still in a parameterized way , but within the realistic, site-specific scenario of the neutrino-driven wind in type II supernova (SNII) cores. An r-process „strength formula“has been deduced, correlating the astrophysical parameters Y_e, S, T and Y_n/Y_{seed}, which defines the model space within which a full r-process is possible. All major results from the earlier classical „waiting-point“ calculations were in principle confirmed and quantified.
From the combined results we draw the following conclusions for the operation of a successful r-process:
(1) Elemental abundances in UMP halo stars clearly indicate the existence of (at least) two types of r-processes, a primary „main“ and a secondary „weak“ r-process, which probably occur at different stellar sites and at different times during Galactical evolution.
(2) The robustness of the „main“ r-process originates mainly from the nuclear-structure behavior at the „quenched“ N=82 and N=126 shell closures. These two bottle-necks in the r-process matter flow determine the neutron number density (entropy) range for an r-process.
(3) The amount of matter necessary to synthesize the „correct“ Th and U chronometer yields relative to the rare-earth and 3rd peak elements seems to be naturally constrained by the observed trend of decreasing r-abundances with mass number. Fits to both the $N_{r,\odot}$ and UMP halo-star observables imply that fission recycling in SNII scenarios is of minor importance.

Monday 17:40 - 18:10

Experimental approaches to nuclear reactions involved in explosive environments

Carmen Angulo

Université catholique de Louvain, Louvain-la-Neuve, Belgium

Explosive stellar environments are currently among the most exciting topics in nuclear astrophysics. Due to the high temperatures and short reaction time scales, reactions on unstable nuclei play a crucial role in energy generation and nucleosynthesis in these events. In spite of the recent remarkable developments in radioactive ion beam production and experimental techniques, substantial uncertainties still exist in nuclear reaction rates on unstable nuclei. In this talk, I will review experimental methods that have recently been exploited to study reactions important in explosive binaries, highlight some key examples of recent results, and outline remaining experimental challenges [1].

[1] J.C. Blackmon, C. Angulo, A.C. Shotter, Nucl. Phys. A **777**, 531 (2006).

Monday 18:10 - 18:30

Experimental efforts and new results along the *rp* process path

D. Galaviz[1,2,3,*], M. Amthor[3,4], D. Bazin[2], B. A. Brown[2,4], A. Cole[2,3], T. Elliot[2,4], A. Estrade[2,4], Zs. Fülöp[5], A. Gade[2], T. Glasmacher[2,4], R. Kessler[6], G. Lorusso[2,4], M. Matos[2,3], F. Montes[2,4], W. Müller[2], J. Pereira[2,3], H. Schatz[2,3,4], B. Sherrill[2,3,4], F. Schertz[6], Y. Shimbara[2,3], E. Smith[7], A. Tamii[8], M. Wallace[2,4], and R. G. T. Zegers[2,3,4]

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One of the problems faced by the modeling of the astrophysical proton capture process (*rp* process) [1,2] is the reliable determination of (p,γ) reaction rates. Under high temperature (T $\approx$ 2 GK) and density ($\rho \geq 10^5$ g/cm^3) conditions, the process runs close to the proton drip-line via series of (α,p) and (p,γ) reactions, and subsequent β^+ decays, creating proton-rich nuclei. The thermonuclear explosions on the surface of a neutron star in a binary system with a main sequence star, known as Type I X-ray bursts, are proposed as one of the astrophysical sites where the *rp* process happens [1,3]. The modeling of these astrophysical objects, and the correct description of their observables (i.e. light emission curve), relies on a correct nuclear physics input.
In low mass regions ($A \leq 40$) far from stability, proton capture rates are dominated by a few resonances, and therefore statistical methods can not be applied [4]. In order to reduce the uncertainties in the determination of resonant proton capture rates, a powerful experimental technique had been developed at the National Superconducting Cyclotron Laboratory at the Michigan State University using exotic beams to determine precisely the excitation energy levels of nuclei located along the *rp* process path [5].
This work presents the new experimental information obtained for the nucleus ^{30}S, located in a bottleneck region for the *rp* process [6], as well as the impact of the new results in astrophysical network calculations.

[1] R. K. Wallace, S. E. Woosley, Astrophys. J. Suppl. **45** (1981) 389.
[2] H. Schatz *et al.*, Phys. Rep. **294** (1998) 167.
[3] L. Bildsten, astro-ph/0001135 (2000).
[4] T. Rauscher *et al.*, Phys. Rev. C **56** (1997) 11613.
[5] R. R. C. Clement *et al.*, Phys. Rev. Lett. **92** (2004) 172502.
[6] H. Schatz *et al.*, Phys. Rev. C **72** (2005) 065804.

*This work was supported by the US National Science Foundation under grants PHY-0216783 (JINA) and PHY-0606007 (NSCL).

2 Stellar Nucleosynthesis and Low Cross Section Measurements

Tuesday 08:30 - 09:00

Cluster Models in Nuclear Astrophysics

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The main problems in nuclear astrophysics [1] are: (*i*) for charged-particle reactions, the energies are usually much lower than the Coulomb barrier, and the corresponding cross are therefore very small, and (*ii*) several important scenarios involve radioactive nuclei. Consequently, a theoretical model is often required to complement experimental information.

Clustering is a well known phenomenon in light nuclei. In low-energy reactions, cluster states also play a crucial role. In reactions involving low level-densities, different cluster models are used for astrophysical applications: the R-matrix theory [2], the potential model [3], and microscopic cluster models [4]. A short overview is presented, and recent examples are discussed. New results obtained with the Generator Coordinate Method on the $^{12}C(\alpha,\gamma)^{16}O$ E2 S-factor are shown.

[1] D.D. Clayton, Principles of Stellar Evolution and Nucleosynthesis, University of Chicago Press, 1983.
[2] F.C. Barker, Nucl. Phys. **A588**, 693 (1995).
[3] T.A. Tombrello, Nucl. Phys. **71**, 459 (1965).
[4] P. Descouvemont, J. Phys. **G19**, S141 (1993).

Tuesday 09:00 - 09:20

Measurement of the stellar cross sections of ^{9}Be(n,γ)^{10}Be and ^{13}C(n,γ)^{14}C via AMS

Anton Wallner[1], Laurent Coquard[2], Iris Dillmann[2], Oliver Forstner[1], Robin Golser[1], Michael Heil[3], Franz Käppeler[2], Walter Kutschera[1], Alberto Mengoni[4], Michael Paul[5], Alfred Priller[1], Peter Steier[1], Christof Vockenhuber[6] and Michael Wiescher[7]

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Neutron-rich scenarios in nucleosynthesis received particular attention during recent years. Both, short time-scale r-process and neutron-rich Big-bang scenarios lead, in particular, also to the production of the long-lived radionuclides ^{10}Be and ^{14}C via neutron capture reactions on ^{9}Be and ^{13}C, respectively.
No experimental data are published for the ^{9}Be(n,γ)^{10}Be reaction in the energy range relevant for astrophysical scenarios. Predictions for ^{9}Be(n,γ) in the energy range of astrophysical interest are extrapolated from thermal energies and exhibit large discrepancies. The neutron-capture reaction on ^{13}C is considered to play an important role in nucleosynthesis. In stars it may act as a neutron poison during the phase of heavy element nucleosynthesis. In addition, inhomogeneous big-bang nucleosynthesis calculations rely on this cross section because the mass flow to intermediate mass nuclei proceeds through this reaction. Existing data disagree in the astrophysical relevant energy region between 10 and 250 keV.
Since these (n,γ) cross sections are expected to be very small (some tens of μbarn), a sensitive detection method is required. The combination of activation technique and AMS has been applied for measuring these capture cross sections in the relevant energy region.
Samples have been irradiated in a quasi-stellar Maxwellian neutron spectrum of kT=25 keV produced with the ^{7}Li(p,n)^{7}Be reaction at the 3.7-MV Van de Graaff accelerator of the Forschungszentrum Karlsruhe. The subsequent AMS measurements were performed at VERA. The main challenge in AMS is the detection of rare isotope species in the presence of strong isotopic and isobaric interferences. To this end extensive background studies were necessary to demonstrate the required sensitivity for the cross-section measurements.
After a brief overview of research activities relevant to nuclear astrophysics at VERA we will report in detail on the measurement of the ^{9}Be(n,γ)^{10}Be and ^{13}C(n,γ)^{14}C cross sections. The new data are compared with model calculations and with previous measurements.

Tuesday 09:20 - 09:50

Reaction data in helium and carbon burning

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The capture reaction ^{12}C$(\alpha,\gamma)^{16}$O takes place in the helium burning of Red Giants and determines not only the nucleosynthesis of elements up to the iron region but also the subsequent evolution of massive stars, the dynamics of a supernova, and the kind of remnant after a supernova explosion. For these reasons, the cross section should be known with a precision of at least 10%. In spite of tremendous experimental efforts in measuring the cross section over nearly 40 years, one is still far from this goal. This situation is similar for many other key reactions. The experimental data basis for the reaction ^{12}C$(\alpha,\gamma)^{16}$O will be reviewed with a focus on the results of recent measurements with recoil mass separators [1,2]. This approach to measure the capture cross sections involves a two-sided differentially pumped gas target and a recoil mass separator as detection system. This combination allows a direct observation of the produced recoils in inverse kinematics and requires an efficient recoil separator to filter out the incident beam particles from the recoils. The separator must not only have a high filtering power but also a high transmission of the recoils between the gas target and the end detector. Such measurements using the recoil mass separator ERNA at the 4MV Dynamitron Tandem Laboratory at the Ruhr-Universität Bochum, Germany, allowed collecting data with high precision over a wide range of energy. The total cross section of ^{12}C$(\alpha,\gamma)^{16}$O and, in addition, ^{3}He$(\alpha,\gamma)^{7}$Be (pp-chain) were measured by a direct and ungated detection of the ^{16}O and ^{7}Be recoils. The data represent new information for the determination of the astrophysical S(E) factor.
The fusion reactions ^{12}C(^{12}C,α)^{20}Ne ($Q = 4.62$ MeV) and ^{12}C(^{12}C,p)^{23}Na ($Q = 2.24$ MeV) are referred to as carbon burning in stars, following the hydrogen and helium burning stages. These reactions represent key processes in nuclear astrophysics since they influence not only the nucleosynthesis of ^{20}Ne and ^{23}Na but also the explosion of a star, i.e. type Ia supernovae. Thus, the cross section of these reactions must be known with high accuracy down to the Gamow energy $E_G = 1.5 \pm 0.3$ MeV for a temperature of 5×10^8 K. Previous experiments obtained useful data over a wide range of energies down to the center-of-mass energy $E = 2.5$ MeV using charged-particle or γ-ray spectroscopy. However, below $E = 3.0$ MeV the reported cross sections are rather uncertain, because at these energies the presence of ^{1}H and ^{2}H contamination in the C targets hampered the measurement of the ^{12}C+^{12}C processes in both particle and γ-ray studies. In a recent experiment [3] at the Ruhr-Universität Bochum the fusion reactions ^{12}C(^{12}C,α)^{20}Ne and ^{12}C(^{12}C,p)^{23}Na have been studied from $E = 2.10$ to 4.75 MeV by γ-ray spectroscopy using a C target with ultra-low hydrogen contamination. The deduced astrophysical $S(E)^*$ factor exhibits new resonances at $E \leq 3.0$ MeV, in particular a strong resonance at $E = 2.14$ MeV, which lies at the high-energy tail of the Gamow peak. The resonance increases the present non-resonant reaction rate of the α channel by a factor of 5 near $T = 8 \times 10^8$ K. Due to the resonance structure, extrapolation to the Gamow energy $E_G = 1.5$ MeV is quite uncertain.

[1] D. Schürmann et al., Eur. Phys. J. **A26**, 301 (2005).
[2] C. Matei et al., Phys. Rev. Lett. **97**, 242503 (2006).
[3] T. Spillane et al., Phys. Rev. Lett. (submitted).

Tuesday 09:50 - 10:10

Measurement of ^{25}Mg(p, γ)^{26}Al resonance strengths via gamma spectrometry

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for LUNA collaboration

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The Comptel instruments performed the first mapping of the Galaxy in the light of 1.809 MeV photons, triggering considerable interest in determing the sources of interstellar ^{26}Al. The predicted ^{26}Al is too low compared to the observation, for a better understanding more accurate rates for the ^{25}Mg(p, γ)^{26}Al reaction are required. The ^{25}Mg(p, γ)^{26}Al reaction has been investigated at the resonances at $E_p = 775, 435, 390, 317$ keV at Ruhr-Universität-Bochum using a Tandem accelerator and a 4π NaI detector. In addition the resonance at $E_p = 197$ keV has been measured at Laboratori Nazionali del Gran Sasso, deep underground laboratory, exploiting the strong suppression of cosmic background. This low resonance has been studied with the 400 kV LUNA accelerator and a HPGe detector. The results of the resonance strenghts will be reported and the next measurement at the resonance E_p=95 keV with 400kV LUNA accelerator and a 4π BGO summing detector will be discussed.

Tuesday 10:10 - 10:30

Saltmine Underground Accelerator Lab for Nuclear Astrophysics

C. Bordeanu[1], C. Rolfs[2], F. Negoita[1], R. Margineanu[1]

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To understand the stars in the Universe (such as our Sun), one must know precisely the microscopic processes, i.e. the nuclear fusion reactions, taking place at this centers, which intern are the sources of the stellar energy production and the concurrent synthesis of the elements. In spite of a tremendous experimental effort over the last 50 years, one is still far away from the required knowledge of these reactions.
To improve the situation, one must minimize the background induced in the detectors, which are used to study the fusion reactions. The background at an accelerator laboratory at the Earth surface consists of cosmic rays and natural radioactivity in the rocky materials. However, at an underground laboratory such as the salt mine Praid (300m bellow the surface) both background contributions are reduced by at least two order of magnitudes, which promises a quantum jump towards reaching the goals. We propose to install a high current 4 million volts accelerator and associated equipment (such as novel efficient detectors) in the salt mine, where enough space is available.
The installation of an underground acceleration laboratory has been recommended as one of the top priorities by the European NUPPEC committee [1].

[1] ECOS Report $http : //www.nupecc.org/ecos/ECOS_Report_20060912.pdf$; NuPECC Roadmap $http : //www.nupecc.org/pub/NuPECC_Roadmap.pdf$.

Tuesday 11:00 - 11:30

Neutron capture cross section measurements for s-process nucleosynthesis

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In the last 50 years considerable progress has been made in the understanding of various processes responsible for the nucleosynthesis of the elements in stars. However, recent observations seem to reveal the need for additional processes, not considered so far. In order to answer this question a good characterization of the individual processes and their abundance contributions is necessary. This was so far only possible for the the main *s* process in low-mass AGB stars, which is largely responsible for the production of about half of the elemental abundances in the mass range $90 \leq A \leq 209$. The weak *s* process, which produces elements with $A \leq 90$, however, is much less understood. In this respect, more accurate neutron capture cross sections in the mass range $56 \leq A \leq 90$ are indispensable. Also, neutron captures on abundant light elements with $A < 56$ play an important role, since they act as neutron poisons and affect the stellar neutron balance. In this context, the impact of new results for neutron capture cross sections on light and medium mass nuclei is discussed.

Tuesday 11:30 - 11:50

Nuclear physics for the Re/Os clock

Marita Mosconi[1], M. Heil[1], F. Käppeler[1], R. Plag[1], A. Mengoni[2,3], K. Fujii[4], C. Domingo Pardo [1],G. Aerts[5], R. Terlizzi[6], R. Gallino[7], and the n_TOF collaboration

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[2] *International Atomic Energy Agency, NAPC-Nuclear Data Section* [3] *CERN, Geneva, Switzerland* [4] *Istituto Nazionale di Fisica Nucleare, Trieste, Italy*
[5] *CEA/Saclay - DSM, Gif-sur-Yvette, France* [6] *Istituto Nazionale di Fisica Nucleare, Bari, Italy* [7] *Dipartimento di Fisica Generale, Università di Torino, Italy*

Dating the age of the universe by the β-decay of ^{187}Re ($t_{1/2} = 42.3$ Gyr) requires the accurate assessment of the s-process reaction flow. The daughter nucleus ^{187}Os as well as its immediate s-only neighbor ^{186}Os are shielded from the r process. Therefore, the radiogenic contribution to ^{187}Os can be derived via the local approximation of the s-process, which is well justified in this mass region: $(\langle\sigma\rangle \mathrm{N}_s)_{187} = (\langle\sigma\rangle \mathrm{N}_s)_{186}$. Accordingly, accurate Maxwellian averaged (n, γ) cross sections have to be known for ^{186}Os and ^{187}Os over the full range of s-process temperatures. Because ^{187}Os has low lying excited states, which are significantly populated during the s-process, the effect of neutron captures on these excited states has to be properly corrected. The input for the corresponding Hauser-Feshbach calculations can be constrained by deriving the strength functions from a detailed resonance analysis of the measured (n, γ) cross sections as well as by an additional measurement of the inelastic scattering cross section for the first exited level, which dominates the competition between the capture and scattering channels. This contribution reports on measurements of the neutron capture cross sections of ^{186}Os, ^{187}Os, and ^{188}Os from the eV region to 1 MeV at the CERN/n_TOF facility and of the inelastic scattering cross section of ^{187}Os around 30 keV at the Karlsruhe 3.7 MV Van de Graaff accelerator. Based on these results and on a detailed resonance analysis, improved Maxwellian average cross sections were obtained for thermal energies between 5 and 100 keV. The implications of these results for the Re/Os clock will be discussed.

Tuesday 11:50 - 12:20

New discoveries and challenges for the *s* process in AGB stars

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Approximately half of the solar abundances of nuclei heavier than iron are created in the deep layers of asymptotic giant branch (AGB) stars via *slow* neutron captures (the *s* process). Freshly made heavy elements, such as Zr, Ba and Pb, are carried to the stellar surface by recurrent mixing episodes and shed into the interstellar medium via strong stellar winds, thus contributing to the chemical evolution of galaxies. Neutron sources available for the *s* process in AGB stars are: the ^{13}C$(\alpha, n)^{16}$O and the ^{22}Ne$(\alpha, n)^{25}$Mg reactions. The ^{13}C$(\alpha, n)^{16}$O reaction is activated at a temperature around 90 million degrees and is believed to represent the main neutron source in AGB stars of masses below $\simeq 4$ solar masses. However, it is still much debated by which mechanism enough ^{13}C can be produced in these stars to match the observed *s*-process enhancements. Hence, the amount of ^{13}C is usually taken as a free parameter in theoretical models. Recently, new constraints on the amount of this neutron source have been produced by two independent approaches: (i) high-precision measurements of the isotopic composition of heavy elements in single presolar silicon carbide (SiC) grains from AGB stars, and (ii) the modelling of stellar population synthesis including the *s* process and comparison of the results to spectroscopic observations. Both these methods indicate that the range of ^{13}C amount needed to explain the observations at solar metallicity is much smaller (a factor of $\simeq 2$) than believed before (a factor of $\simeq 50$). On the other hand, a somewhat lower ^{13}C amount appears to be needed to cover observations at lower metallicities. The ^{22}Ne$(\alpha, n)^{25}$Mg reaction is instead activated at a temperature around 300 million degrees and is believed to be the main neutron source in stars of mass above $\simeq 4$ solar masses. This neutron source produces a high neutron density resulting in a relatively high production of neutron-rich isotopes. The first observations of Zr and Rb in massive AGB stars in our Galaxy are finally producing constraints also on the *s*-process in these environments, together with the discovery of the first presolar grain to have possibly originated in one of these stars. I will present and discuss the new data, together with related challenges and opportunities.

Tuesday 12:20 - 12:40

First Measurement of the Enhanced Electron Screening in d+d Reactions under UHV Conditions

K. Czerski[1,2], A. Huke[2], L. Martin[2], N. Targosz[1] , D. Blauth[3], A. Górska[1], P. Heide[2], H. Winter[3]

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Observation of enhanced electron screening in metallic environments is of fundamental importance for strongly coupled astrophysical plasmas. Generally, experimental screening energies determined by different groups for many metals are much larger than the theoretical predictions. However, a comparison between experimental and theoretical data is rather ambiguous because of some systematic errors in experiments. One of the most important is the uncertainty resulting from oxidation of the target surface during the measurements. Here, we present results of the first experiment studying d+d nuclear reactions in a deuterized Zr target under ultra high vacuum (UHV) conditions. The total cross sections and angular distributions of the $^{2}H(d,p)^{3}H$ and $^{2}H(d,n)^{3}He$ reactions have been measured using a deuteron beam of energies between 8 and 30 keV provided by the electron cyclotron ion source with an excellent long term stability of 1 eV. The atomic cleanness of the target surface has been assured by combinig Ar sputtering of the target and Auger spectroscopy. Due to application of an on-line analysis method, the homogeneity of the implanted deuteron densities could be sustainably monitored. The determined screening energy for Zr is significantly larger than the values obtained in previous experiments. A possible reason for the large discrepancy between the experimental and theoretical screening energy values will be discussed.

Tuesday 12:40 - 13:00

On the possible influence of electron screening on the lifetime of radioactive nuclei

G. Ruprecht[1], C. Vockenhuber[1], C. Ruiz[1], L. Buchmann[1], J. Pearson[1], D. Ottewell[1], K. Czerski[2], A. Huke[2]

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The decay rate of ^{22}Na implanted in aluminium has been measured at room temperature and at 9 Kelvin. The rate should increase by 40 % according to [1], and by about 6% according to [2]. In the latter publication an increase of only (1.2 ± 0.2)% has been measured and the deviation has been assigned to an incomplete implantation of ^{22}Na in the palladium sheet. Contrary, the source used for our measurements has been made by a 70-MeV proton beam penetrating an aluminum sheet, therefore the ^{22}Na was produced deep inside the metal via the reaction ^{27}Al(p, ^{6}Li)^{22}Na and the full effect should be visible when cooling the sample. However, an enhanced decay rate could not be confirmed on a level of parts of a percent. Possible explanations for these contradicting results will be discussed.

[1] C. Rolfs, public lecture for SLENA, Kolkata, India, Jan., 2006
[2] Limata et al., Eur. Phys. J. A, **28**, 251(2006)

Tuesday 14:00 - 14:30

The Trojan Horse Method in Nuclear Astrophysics: recent results

S. Romano[1,2], C. Spitaleri[1,2], S. Cherubini[1,2], V. Crucilla[1,2], M. Gulino[1,2], M. La Cognata[1,2], L. Lamia[1,2], R.G. Pizzone2, S.M.R. Puglia[1,2], G.G. Rapisarda[1,2], M.L. Sergi[1,2], A. Tumino[1,2]

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Direct approaches to the study of charged particle induced reactions in astrophysics are severely hampered by the presence of the Coulomb Barrier, so that reaction cross sections have been measured in only a very few favourable cases within, or close to, the relevant Gamow energy window. More often, experimental data at energies around the barrier have to be extrapolated down to thermal energies in order to obtain the astrophysical S(0)-factor. Moreover the energies which characterize the nuclear processes in the astrophysical context are so low that the presence of atomic electrons must be taken into account (electron screening effect). Anyway the different physical conditions make electron shielding in stellar plasma and in laboratory very dissimilar. In both cases such effect leads to an increase of S(E) with decreasing energies, when compared to the bare nucleus case. This enhancement factor strongly depends on the electron screening potential. Various indirect methods have been applied whenever direct approaches do not provide further information. In recent years the Trojan-Horse Method (THM) was successfully applied to study several astrophysically relevant two-body reactions by using appropriate three-body break-up reactions. The method has proven to be particularly suited for acquiring information on charged-particle induced reaction cross-sections at astrophysical energies, since it allows to overcome the Coulomb-barrier of the two-body entrance channel. One can briefly describe the method as follows (more details can be found in ref. [1,2]). The Trojan Horse Method (THM), is based on the quasi-free break-up mechanism. A suitable three-body reaction is selected as a mean to investigate the two-body reaction of astrophysical interest. In the process it is assumed that the interaction between a projectile and the Trojan Horse particle, which may be described in terms of two clusters, involves only one cluster leaving the other one as a spectator. If the break-up of the target occurs in the nuclear field, the hindering Coulomb Barrier is overcome. Because of the three-body nature of the process, a continuous two body energy range can be explored in a single measurement. Appropriate kinematic conditions allow one to select the interaction energies as close as possible to the relevant Gamow energy. Thus the THM can be applied to determine the energy dependence of the bare nucleus astrophysical S(E)-factor, without Coulomb suppression as well as electron screening effect. The application of the method will be presented together with recent results.

[1] C. Spitaleri et al., Phys. Rev. C60, 055802 (1999).
[2] C. Spitaleri et al., Phys. Rev. C69, 055806 (2004).

Tuesday 14:30 - 14:50

Indirect techniques in nuclear astrophysics

A.M. Mukhamedzhanov[1]

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In this talk two different indirect nuclear techniques to get astrophysical information using radioactive and stable beams will be addressed: the asymptotic normalization coefficient method (ANC) and Trojan Horse method (THM). 1. The asymptotic normalization coefficient (ANC) method has proven to be a powerful indirect technique to get astrophysical S factors. Often this method requires the use of radioactive beams. The ANC method is especially powerful when subthreshold states contribute to the process. It is believed that the ^{13}C$(\alpha, n)^{16}$O reaction is a major source of neutrons for the s-processes in the low-mass stars at the asymptotic giant branch (AGB). I will demonstrate the first application of the ANC method to determine a very important astrophysical factor for astrophysical rearrangement reaction. The ^{13}C$(\alpha, n)^{16}$O reaction proceeds through the subthreshold state 6.356 MeV in ^{17}O, just 3 keV below the threshold ^{13}C+α. The astrophysical factor is governed by the ANC for the ^{13}C+$\alpha \rightarrow {}^{17}$O(6.356MeV, $1/2^+$) virtual synthesis. The ANC for this state has been measured using the sub-Coulomb α-transfer ^{13}C(^{6}Li,d)^{17}O(6.356 MeV, $1/2^+$ and the S factor for ^{13}C$(\alpha, n)^{16}$O has been calculated down to zero energy. Our astrophysical factor $S(0)$ is ten times and the reaction rates are of a factor of three smaller than the NACRE compilation. It is the first accurate determination of the astrophysical factor for the neutron generator in the AGB stars. I will also present the first estimation of the astrophysical factor and reaction rates for the ^{12}N(p,/gamma)^{13}O reaction, which can be important for the CNO cycle processes bypassing the triple alpha process in the very massive low-metallicity stars. I will demonstrate how the ANC technique can be used to determine not only the direct capture term of the astrophysical factor but also the interference of the direct and resonant terms. 2. The second indirect technique, the TTrojan Horsemmethod, is another nice demonstration of nuclear physics application for nuclear astrophysics. It allows one to extract the astrophysical factors for direct and resonant nuclear reactions between bare nuclei at astrophysically relevant energies and determine the electron screening potential by comparing the THM data with direct measurements. I will demonstrate how to obtain from the measured THM reaction cross section $a+A \rightarrow y+b+B$ the astrophysical factor for the binary resonant reaction $x+A \rightarrow y+b+B$, where $a = (yx)$, using the recently developed off-shell R matrix approach for the off-energy-shell resonant processes. The determination of the astrophysical factor for the ^{15}N$(p, \alpha)^{12}$C reaction using the THM reaction $d+{}^{15}$N $\rightarrow n+\alpha+{}^{12}$C recently measured at Texas A&M University in collaboration with Catania National Lab will be presented. Until now the THM has been applied exclusively for nuclear rearrangement reactions. I will address the future perspectives of the THM including its application for the crucial (p,γ) and (α,γ) radiative capture reactions. For the first time I will address a novel approach to determine the astrophysical factors for the radiative capture.

Tuesday 14:50 - 15:10

Indirect Measurement of the $^{18}O(p,\alpha)^{15}N$ Reaction Rate through the THM

M. La Cognata[1,2], A. Tumino[1,2], C. Spitaleri[1,2], R. Tribble[3], L. Trache[3], T. Al-Abdullah[3], A. Banu[3], S. Cherubini[1,2], V. Crucillá[1,2], C. Fu[3], V. Goldberg[3], M. Gulino[1,2], L. Lamia[1,2], A. Mukhamedzhanov[3], R.G. Pizzone[1,2], S.M.R. Puglia[1,2], G.G. Rapisarda[1,2], S. Romano[1,2], M.L. Sergi[1,2], G. Tabacaru[3], S. Tudisco[1,2], S. Typel[4], Y. Zhai[3]

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^{19}F is one of the few naturally occurring isotopes whose nucleosynthesis is still uncertain. SNe, AGB and WR stars are its most likely source [1]. In particular fluorine abundances observed in giants can constrain AGB star models [2]. The $^{18}O(p,\alpha)^{15}N$ reaction rate can bias fluorine yield from AGB stars since it produces ^{15}N nuclei later burnt to 119F during a thermal pulse [3]. Experimental ^{19}F abundances are not reproduced by current AGB models [2]. This can be ascribed to the large uncertainties characterizing ^{19}F nucleosynthesis. The study of meteorite grains can provide useful clues to understand its production as they allow to investigate isotopic ratios of a number of key elements (C, N, O, Al). Anyway, even if $^{12}C/^{13}C$ for both MS and A+B grains (constituting about 98% of the total number of grains) can be justified according to present AGB models (including HBB for A+B grains), only the largest $^{14}N/^{15}N$ ratios can be reproduced [4]. A possible explanation might require a revised rate for the $^{18}Op,\alpha)^{15}N$ reaction, as already pointed out elsewhere [5]. In the present work, a preliminary indirect investigation of the $^{18}O(p,\alpha)^{15}N$ reaction via the THM is reported, focusing on the extraction of the resonance parameters of the 656 keV resonance. Even though a non negligible discrepancy is found, no change in the reaction rate is apparent in the astrophysically relevant temperature range.

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Tuesday 15:10 - 15:30

Triple charged-particle decays of resonances illustrated by ^{12}C-states

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The importance of the triple-α process is well known in nuclear astrophysics. The process leads from three free α-particles via a low-lying resonance into the ground state of ^{12}C. The inverse of the crucial part of this process is the decay of a resonance of ^{12}C into the continuum of three α-particles, perhaps via intermediate states of ^{8}Be [1]. The principle of detailed balance relates direct and inverse processes. Similar processes involving three charged particles occur at specific waiting points for the *rp*-process.

The breakup of a physical system into a three-body continuum with Coulomb interaction is not yet a well understood problem of few body physics, although it has been studied over many years. The main difficulty lies in constructing correct asymptotic wave functions when no binary bound states exist. We have developed a method to investigate decays of resonance states into continuum three particle final states [2]. We assume that the decay mechanism is independent of how the initial state was formed, e.g. from beta-decay or in a reaction. The decay is described in analogy with α-decay, assuming that the three fragments are formed before entering the barrier at sufficiently small distances to allow the three-body treatment. The hyperspherical adiabatic expansion, combined with the complex rotation method, is an efficient technique to compute bound states and resonances.

We use the 12 low-lying resonances of ^{12}C as illustration. They have angular momenta varying from 0 to 6 and both parities. Illustrative examples are the 0^+ and 1^+ states. The 0^+ states are often approximated by α-cluster structures preferentially decaying sequentially, whereas the directly decaying 1^+ states are more complicated. Still for both cases the decays into three α-particles is determined at intermediate and large distances. The crucial observables to test these conjectures are the momentum distributions of the particles after the decay. In the figures we show the single α-particle energy distributions from the second 0^+ resonance at 4.3 MeV and the first 1^+ resonance 5.4 MeV both energies are measured with respect to the 3α-threshold. The agreement with measured distributions is remarkably good in view of the fact that these results rely on tails of wavefunction accurately determined at root mean square radii around 100 fm. The corresponding distribution for the lowest 0^+ resonance at 0.38 MeV above the 3α-threshold is extreme but well reproduced. In conclusion, we provide a reliable method to deal with the three-body decays of many-body resonances.

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Tuesday 15:30 - 16:00

Gamma-Ray Spectroscopy from Solar Flares

B. Z. Kozlovsky[1]

[1] *Tel-Aviv University, Isreal*

The satellite REESSI (Ramaty High Energy Spectroscopic Imager) is the first satellite to observe simultaneously high resolution imaging and spectroscopy of Solar Flares X-rays to 17 MeV gamma rays with high time resolution. I will discuss the gamma ray observations and will demonstrate the methods by which Gamma-Ray spectroscopy (yields and shapes of the nuclear gamma-ray lines) can be used to determine the accelerated particle spectra and composition and the physical conditions and composition within the flare medium.

3 Explosive Nucleosynthesis and Nuclear Astrophysics with Photons

Tuesday 16:30 - 17:00

10 Gyr of Classical Nova Explosions

Jordi Jose[1]

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Classical novae are stellar explosions in cataclysmic binary systems, consisting of a compact white dwarf star (CO or ONe-rich) and a low-mass, main-sequence companion (typically, a K or M dwarf, of solar composition). The system is close enough (orbital periods between 1 - 15 hrs), hence allowing mass transfer episodes driven by overflows of the companion star. This matter flow forms an accretion disk that surrounds the white dwarf, and ultimately accumulates on its surface (at a rate M = 10^{-9}–10^{-10} M_{sun} yr^{-1}), building up an envelope in semi-degenerate conditions until a violent thermonuclear runaway (hereafter, TNR) ensues. Classical novae are believed to be major sources on the synthesis of the Galactic ^{15}N, ^{17}O and ^{13}C, with a minor contribution on a number of additional species, mainly ^{7}Li and ^{26}Al. But there are reasons to believe that these nucleosynthetic features have varied during the overall 10 Gyr of Galactic history. In this talk, I will review recent progress on the characterization of primordial novae, that is novae exploding in primordial cataclysmic binaries, and will compare their expected nucleosynthetic output with that characteristic of classical novae. Emphasis will be made on the dominant nuclear paths during the explosion as well as on the associated nuclear uncertainties.

Tuesday 17:00 - 17:20

Direct reactions with exotic nuclei and nuclear astrophysics

Gerhard Baur[1], Stefan Typel[2]

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Intermediate energy Coulomb excitation and dissociation is a useful tool for nuclear structure and astrophysics studies [1]. Low-lying electric dipole strength in light neutron rich nuclei was discovered by this method. The effective-range theory of low-lying strength in halo nuclei is a very suitable theoretical description [2]. The ^{7}Be(ρ,γ)^{8}B reaction plays a key role in the determination of the solar neutrino flux and ^{8}B Coulomb dissociation is a suitable method to study its astrophysical S factor [3]. It is also a good method to study proton capture reactions in rp-process nuclei. Using this method low-lying electric dipole strength in ^{130}Sn and ^{132}Sn was found [4], sometimes called pygmy resonance. Coulomb dissociation is expected to be a useful tool to investigate neutron capture rates in r-process elements at the future radioactive beam facilities, which can be strongly influenced by this pygmy resonance. Another indirect approach to nuclear astrophysics is the Trojan-horse method [5,6]. Due to the high beam energy electronic screening effects are negligible and the bare astrophysical S factor is determined. This sheds light on the screening problem at very low energies. It is pointed out that the Trojan-horse method is also a suitable tool to investigate subthreshold resonances [7].

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Tuesday 17:20 - 17:50

The alpha-nucleus optical potential in astrophysics applications: status and perspectives

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The *p* process of nucleosynthesis is responsible for the production of the stable neutron-deficient nuclei heavier than iron observed in the solar system. The most favoured scenarios proposed for the *p* process involve the photodisintegration through a series of (γ,n), (γ,p), (γ,α) reactions of intermediate and heavy elements at high temperatures (2–3 billion degrees Kelvin) that can be achieved only during the explosive burning phases of massive stars.

The calculations involve extended networks of about 20000 reactions on 2000 nuclei, a very small fraction of which can or have been measured in the laboratory. As a result, the calculations rely largely on predictions of the statistical model which have shown to depend strongly on the α-nucleus optical model potential (OMP).

Considerable effort has been devoted in recent years to improve our knowledge of the behaviour of the α-nucleus OMP at low energies relevant to explosive stellar environments. A review of recent experimental and theoretical developments will be presented. New measurements of α-elastic scattering and α-related reactions will be compared with the most recent global α OMP available. The impact of the new OMP on other processes such as α decay will also be discussed.

Tuesday 17:50 - 18:10

Effective Field Theory and Shell Structure for Nuclear Astrophysics

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The shell structure of nuclei with extreme isospin is of paramount importance to understanding nucleosynthesis of heavy nuclei. Nuclei in the extreme regions of the periodic table and especially neutron-rich waiting-point nuclei as well as the r-process nucleosynthesis of heavy nuclei put a heavy premium and constraints on development of appropriate nuclear forces [1]. Within the framework of the relativistic mean-field theory, we will discuss development of various Lagrangian models for nuclei and nuclear matter. Using the effective field theoretical approach, properties of nuclei in the r-process region with vector self-coupling of omega meson [2,3], with coupling between σ and ω mesons and other relevant models will be discussed [4]. Results of network chain calculations for r-process nucleosynthesis will be presented for various models. We will show as to how various models also affect the compressibility of nuclear matter and the equation of state of nuclear matter for neutron star structure.

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Tuesday 18:10 - 18:30

First experiments on *p*-process nuclei at the FRS/LAND setup*

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Within the stable nuclei there are 35 heavy isotopes which cannot be produced in neutron capture reactions. To understand the synthesis of these so-called *p* nuclei, broad reaction-network calculations are performed. As an input to these, photodissociation rates are of importance.
To be able to investigate also instable proton-rich nuclei, experiments in inverse kinematics have been done at the FRS/Land setup (GSI). The excitation results from the exchange of virtual photons in the Coulomb field of the heavy target nuclei.
In first experiments the (γ,n)-reaction rates of the isotopes ^{100}Mo, ^{94}Mo, ^{93}Mo and ^{92}Mo have been investigated. In this mass region, data from experiments with real photons already exists, which can be used for comparison.
* This project has been supported by DFG (SFB 634) and BMBF (06 DA 115 and 06 DA 129 I).

Wednesday 08:30 - 09:00

Nuclear Astrophysics with Photons: What can we do with and for photons?

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Laser Compton backscattering (LCS) produces quasi-monochromatic photons in the MeV energy domain. LCS photons have enabled us to perform a variety of nuclear astrophysics experiments at the National Institute for Advanced Industrial Science and Technology (AIST), a synchroton radiation facility in Japan [1]. Measured there were photoneutron cross sections of direct relevance to the p-process nucleosynthesis ($^{180}Ta^{m}$ and ^{138}La) and radiative capture processes for light nuclei (deuterium and ^{9}Be), and of indirect relevance to the s-process branching (^{185}W and ^{80}Se) and the Re-Os cosmochronology. A review of these measurements is given. The LCS photon source is indicative of a new way of studying nuclear astrophysics at non-traditional nuclear physics facilities [2]. Currently efforts of developing new photons sources are underway at SPring-8 and NewSUBARU. A *blackbody synchrotron radiation* at SPring-8 [3,4] and a new generation of LCS photons at NewSUBARU may provide us with an unprecedented research opportunity of studying (γ,α) and (γ,p) reactions.

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Wednesday 09:00 - 09:20

Investigation of proton capture reaction cross sections on light p-nuclei

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The stable proton-rich nuclei with charge number $Z \geq 34$ are called p-nuclei. The natural isotopic abundance of these nuclei is 10-100 times less than the more neutron-rich isotopes, because they are separated by unstable short-lived nuclei from the s- or r-process path. It is generally accepted that the main stellar mechanism synthesizing these nuclei — the so-called p-process — is initiated by (γ,n) photodisintegration reactions on preexisting more neutron-rich seed nuclei [1,2]. As the neutron separation energy increases along this path towards more neutron deficient isotopes, (γ,p) and (γ,α) reactions become stronger and process the material towards lower masses [3,4].
Despite considerable experimental and theoretical efforts in recent years, there are still open questions about the nature of the p-process and the synthesis of the p-isotopes. One of the main uncertainties in p-process nucleosynthesis is associated with the origin of the light Mo, Ru, In, and Sn p-nuclei with a fairly large abundance which cannot be explained in the framework of standard p-process nucleosynthesis models. In order to build up an experimental nuclear reaction database [5] we started a systematic investigation of (p,γ) reactions on light p-nuclei [6,7] using the activation method. As a continuation of this study here the cross sections of the ^{70}Ge(p,γ)^{71}As, ^{76}Ge(p,n)^{76}As and ^{106,108}Cd(p,γ)^{107,109}In reactions measured in the astrophysical relevant energy region are presented. The experiments were carried out at the Van de Graaff and cyclotron accelerators of ATOMKI. The cross sections have been derived by measuring the decay γ-radiation of the reaction products. The results are compared to the predictions of Hauser-Feshbach statistical model calculations using the code NON-SMOKER [8].

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Wednesday 09:20 - 09:50

Nuclear Astrophysics with Real Photons: Experiments at the S–DALINAC and beyond

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Photodesintegration rates – like (γ,n), (γ,p), and (γ,α) – play an important role in the nucleosynthesis of the so-called *p* nuclei. These proton-rich, in general very low-abundant isotopes cannot be produced by neutron capture reactions. Complete network calculation on *p*-process nucleosynthesis include several hundred isotopes and the corresponding reaction rates. Therefore, theoretical predictions of the rates, normally in the framework of the Hauser-Feshbach theory, are necessary for the modelling. The reliability of these calculations should be tested experimentally for selected isotopes.

At the superconducting linear electron accelerator S–DALINAC, Darmstadt, a High Intensity Photon Setup (HIPS) is available [1]. The monoenergetic electron beam is converted into a continuous bremsstrahlung spectrum with energies up to the electron energy and an intensity of about 10^8 photons per (keV s cm^2). Naturally composed targets are activated with different bremsstrahlung spectra to derive the (γ,n) reaction rate via a superposition method without any assumption on the shape of the cross section [2]. The activation yield is determined by high-resolution γ spectroscopy at two setups optimized to the energies of the expected decay lines. Another setup is provided at the ELBE accelerator at the Forschungszentrum Rossendorf, Dresden. Here, photons with higher energies are available with comparable intensities [3].

If the photoactivation yields an isotope with inadequate characteristics for γ spectroscopy, *i.e.* the half-life is too long and/or the γ branching is too weak, the activation yield can be determined by accelerator mass spectroscopy [4]. This method enables to measure ratios of 10^{-15} of produced nuclei to reference nuclei.

In addition, the recently constructed NEPTUN tagger system will allow direct measurements of photodissociation cross sections [5]. The aspired energy resolution is better than 0.25% in the energy range of 8 to 20 MeV. Neutrons will be detected from the lowest energies up to several MeV to cover the interesting energy range of *p*-process nucleosynthesis. Therefore, neutron detectors of liquid scintillator material enriched with ^{10}B will be combined with standard neutron detectors to permit the required neutron-to-photon discrimination in the full energy range.

To expand the measurements to unstable nuclei, Coulomb dissociation in inverse kinematics can be used. The particles in the radioactive beam are excited in the Coulomb field of a heavy target and decay by neutron emission. At the FRS/LAND-setup at GSI, Darmstadt, kinematically complete measurements are possible and have already been performed for a number of molybdenum isotopes [6].

This work is supported by the DFG under contract SFB 634 and the BMBF (06 DA 129 I).

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Wednesday 09:50 - 10:10

Ultra-sensitive detection of p-process nuclide ^{146}Sm produced by (γ, n), $(p, pn\epsilon)$ and $(n, 2n)$ reactions

N. Kinoshita[1], T. Hashimoto[1], T. Nakanishi[1], A. Yokoyama[1], H. Amakawa[2], T. Mitsugashira[3], T. Ohtsuki[4], N. Takahashi[5], I. Ahmad[6], J.P. Greene[6], D.J. Henderson[6], C.L. Jiang[6], M. Notani[6], R.C. Pardo[6], N. Patel[6], K.E. Rehm[6], R. Scott[6], R. Vondrasek[6], L. Jisonna[7], P. Collon[8], D. Robertson[8], C. Schmitt[8], X.D. Tang[8], Y. Kashiv[9] and M. Paul[9]

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Among the stable nuclides, there exists only very few nuclides, classified as p-process nuclides, which cannot be produced by neutron captures alone *e.g.* ^{144}Sm). Nuclear processes believed to be responsible for their formation of these neutron-deficient nuclides include photonuclear and ν-induced nuclear reactions. The p-process also produces several interesting long-lived ($t_{1/2} \geq 1$ Myr) nuclides. Of these nuclides, ^{146}Sm ($t_{1/2}= 1.0\times10^8$ yr) is maybe the most interesting because of evidence for its *in situ* decay in meteorites, showing that live ^{146}Sm was present in the Early-Solar system with important implications on our understanding of its formation and of the early dynamics of Earth's interior. We are developing a technique of ultra-sensitive detection of ^{146}Sm by accelerator mass spectrometry. ^{146}Sm was produced via the reactions (γ, n), $(p, pn\epsilon)$ and $(n, 2n)$ on ^{147}Sm. Preliminary results demonstrate for the first time the capability of identifying unambiguously ^{146}Sm through separation and discrimination of its stable ^{146}Nd isobar and other background ions. We consider applying the detection method to an independent determination of ^{146}Sm half-life and to the measurements of cross sections of low-energy nuclear reactions producing long-lived nuclides in the vicinity of ^{146}Sm .

Wednesday 10:10 - 10:30

Formation of heavy and superheavy nuclei in supernova explosions

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In this talk I discuss properties of hot stellar matter at sub-nuclear densities which is formed in supernova explosions. I emphasize that thermodynamic conditions there are rather similar to those created in the laboratory by intermediate-energy heavy-ion collisions [1,2]. Theoretical methods developed for the description of multi-fragment final states in such reactions can be used also for description of the stellar matter. I present main steps of the statistical approach to the equation of state and nuclear composition [3], dealing with an ensemble of nuclear species instead of one äveragennucleus. I shall also present results concerning the structure and stability of nuclei embedded in the hot and dense stellar matter, calculated within a microscopic model [4]. The emphasis is made on possible formation of heavy and superheavy nuclei in supernova environments. The main conclusions of this study are:

• Statistical equilibrium approach is very useful for describing equation of state and composition of supernova matter. It can easily incorporate the empirical information concerning properties of hot heavy nuclei.

• Survival of hot heavy nuclei may significantly influence the explosion dynamics through both the energy balance and the electron and neutrino capture reactions.

• Statistical mechanism can explain gross features of element abundances. It provides ßeednnuclei for further nuclear transformations in r- and rp-processes.

• Formation of heavy and superheavy elements (SHE) is favored by electron screening and reduction of symmetry energy in hot and dense stellar matter.

• If long-lived SHE do indeed exist, they may be produced in supernova environments and injected in space in the course of explosions. If their life times are longer than 10^6 years, they may even reach the Earth and searched for in cosmic rays.

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Wednesday 11:00 - 11:30

Nucleosynthesis in deep layers and shells of exploding massive stars

T. Rauscher[1]

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Massive stars end their life after a series of central and shell burning episodes in gigantic type II supernova explosions. The shockwave triggered by the core collapse (and perhaps supported by neutrino emission from the newly formed proto-neutron star) gives rise to additional nuclear burning on its way outward, altering abundances produced in the previous hydrostatic burning phases, and also permits additional nucleosynthesis processes. An example for the former is the γ-process in explosive O/Ne shell burning [1,2]. Examples for the latter are the r process [3], producing about half of the nuclides beyond Fe, and the recently postulated νp process [4], allowing to produce light p-elements which seem to be underproduced in the γ-process. Neutrinos can play an important role in affecting nucleosynthesis processes in the deep layers of the exploding star, such as the r- and the νp-process [4,5,6].
An overview of explosive scenarios in massive stars is given with some exemplary reactions and emphasizing remaining uncertainties in both astrophysical models and nuclear physics inputs.

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Wednesday 11:30 - 12:00

What do we really know about photon strength functions?

Milan Krtička[1]

[1] *Charles University in Prague*

Existing experimental data on γ decay of medium-weight and heavy nuclei at excitation energies E_{ex} well above the pairing gap , typically at E_{ex} ¿ Δ + 1MeV, indicate strongly that the role of structural effects is small and that this decay is predominantly governed by the extreme statistical model. In line with the paradigm of photon strength and the validity of Brink hypothesis the average properties of the γ decay can be unambiguously characterized by a set of photon strength functions (PSFs) for various multipolarities of the emitted γ radiation and the level density function. PSFs are directly related to the photoabsorption cross sections $\sigma_{\gamma abs}$. It is well known that in the case of E1 radiation these cross sections are dominated by the giant dipole electric resonance. However the shape and size of $\sigma_{\gamma abs}$ as a function of ray γ-energy E_γ below the neutron separation energy are known rather poorly. The available information on $\sigma_{\gamma abs}(E_\gamma)$ in this energy region comes not from photoabsorption experiments, but almost exclusively from studying the related PSFs, employing the data from the reactions inducing the γ emission. Available information on PSFs for γ-ray energies below about 10 MeV obtained from different experiments will be combined and discussed within existing models of PSFs. It will be shown that none of existing widely-used models seems to be able to describe PSFs reasonably in a broad range of nuclei. Emphasis will be laid on possible resonance-like structures in PSFs at low energies.

Wednesday 12:00 - 12:20

Experiments with real photons for nuclear astrophysics

A. Wagner[1], N. Benouaret[1], R. Beyer[1], F. Dönau[1], M. Erhard[1], E. Grosse[1;2], A.R. Junghans[1], K. Kosev[1], C. Nair[1], G. Rusev[1], K.D. Schilling[1], R. Schwengner[1]

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Explosive stages in the evolution of massive stars lead to temperatures which cause photon-induced disintegration of nuclei producing e.g. the so-called p-process nuclei and possibly modifying the r-process path.
In order to obtain a detailed understanding of those processes an experimental program has been initiated at the new superconducting electron accelerator ELBE at the Forschungszentrum Dresden-Rossendorf. Real photons from intense bremsstrahlung production with energies up to 20 MeV have been used to excite nuclei below and above the particle separation energies. For the first time the smooth transition from photon scattering to photo-disintegration has been investigated in detail experimentally. The chain of all stable molybdenum isotopes ^{92,94,96,98,100}Mo and the N=50 closed shell nuclei ^{88}Sr, ^{89}Y, ^{90}Zr have been studied. The influence of the tail of the giant dipole resonance at energies well below 10 MeV is discussed which leads to important consequences on cosmic element production in sufficiently hot environments.
Experimentally, the correction on non-groundstate transitions (branching) and feeding from higher excited states turned out to be significant and was treated statistically in the scope of γ-cascade simulations as discussed in [1].
Beyond the particle separation energies, charged particle production has been studied in the photoactivation experiments ^{92}Mo$(\gamma,p)^{91}$Nb, ^{92}Mo$(\gamma,\alpha)^{88}$Zr, and ^{144}Sm$(\gamma,\alpha)^{140}$Nd. Both, ^{92}Mo and ^{144}Sm are significantly underproduced in state-of-the-art nucleosynthesis network calculations [2].

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Wednesday 12:20 - 12:40

p-process simulations with an updated reaction library

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The nucleosynthesis of elements heavier than iron is dominated by neutron captures in the s and r processes but 32 stable isotopes between ^{74}Se and ^{196}Hg cannot be formed in that way. These isotopes are shielded from the reaction flow of the s process and the β-decay chains of the r process and are thought to be produced in the so-called „p process“ by photodisintegration of heavier seed nuclei.
The most favoured astrophysical site for the p process is explosive O/Ne burning during SNII explosions [1] which reproduces the solar abundances of the bulk of p isotopes within a factor of $\approx$3 [2]. However, this and most of the other proposed scenarios suffer from an inappropriate reproduction of the most abundant p isotopes, ^{92,94}Mo and ^{96,98}Ru, due to lack of seed nuclei with $A>$90. This problem could be solved by inclusion of the recently proposed νp process [3], but other underproductions still remain.
Since the largest part of the p-process reaction network lies in the region of proton-rich unstable nuclei, most of the reaction rates are not accessible by experimental techniques and have to be inferred from statistical model calculations. The current status of the experimental p-process database included in the KADoNiS project [4] and the results of a p-process simulation with an updated reaction library [5] will be outlined. The simulations were carried out with a parameterized shock front model for a SNII explosion of a 25 $M_{\odot}$ star in which the p-prozess zone was subdivided into 14 layers of the O/Ne shell [6]. The reaction network comprises 1814 nuclei with over 60000 reactions. In a first step we updated all (n,γ) and $(\gamma$,n) cross sections by inclusion of the latest KADoNiS version 0.2. The result is an even larger underproduction for most p isotopes caused by a decrease of the reaction flow from the abundant stable Pb and Bi isotopes. Further steps will be focussed on the inclusion of the available experimental information on charged-particle reactions.

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Wednesday 12:40 - 13:00

Extended Pool of Electron-capture Rates for Core-Collapse Supernovae Simulations

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The reasons of supernova explosions are not understood well yet. Massive stars end their lives by bursting away their matterial, however, not in realistic simulations [1,2]. As computational facilities get faster, more complex processes can be taken into account and the modelling can be performed at a greater detail. Improved nuclear physics plays a role in improving the understanding of this phenomenon as well [3,4]. Large-scale shell model and shell model Monte-Carlo calculations combined with the Random Phase Approximation yielded two complementary pools of electron- capture [3,5] and neutrino-nucleus [6] reaction rates for the iron group nuclei and beyond. Recently, the SMMC+RPA (LMS) pool was extended to include more neutron-rich nuclei to improve its predictions [7]. This presentation would focus on the features of this new, enlarged pool of electron-capture rates.

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4 Nuclei far from Stability and Radioactive Ion Beams

Thursday 08:30 - 09:00

Exotic nuclear structure: relativistic mean-field and beyond

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Self-consistent relativistic mean-field models have been successfully applied in the description of a variety of nuclear structure phenomena, not only in spherical and deformed nuclei along the valley of β-stability, but also in exotic nuclei with extreme isospin values and close to the particle drip-lines [1]. This framework has recently been extended to include additional correlations related to the restoration of rotational symmetry and particle number, and fluctuations of quadrupole deformation [2,3]. A new model has been developed which uses the generator coordinate method to perform configuration mixing calculations of angular momentum and particle-number projected wave functions, generated in the relativistic mean-field model with point-coupling effective interactions. This approach enables a quantitative description of the evolution of shell-structure, deformation and shape coexistence phenomena in nuclei with soft potential energy surfaces.
The relativistic (proton-neutron) quasiparticle random-phase approximation (RQRPA) has been employed in studies of dynamical aspects of exotic nuclear structure. New and interesting results include the evolution of low-lying dipole strength in neutron-rich nuclei and the isotopic dependence of the pygmy dipole resonance [4], the relation between the neutron skin of nuclei and the excitation energies of Gamow-Teller resonances and isobaric analog states [5], the prediction of the occurrence of pygmy dipole resonances in proton-rich nuclei [6], and the calculation of beta-decay rates of r-process nuclei [7].

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Thursday 09:00 - 09:20

Tests of time reversal symmetry in radioactive nuclei

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An effective method to test time reversal invariance in the non-strange sector is to measure parity and time reversal violating (T-P-odd) electromagnetic moments, (such as the static electric dipole moment).
Parity and time reversal violating components in the nuclear force may produce P-T-odd moments in nuclei which in turn induce such moments in atoms. After a short general introduction, we will discuss the possibility to improve very significantly the limits on time reversal invariance. Studying of time reversal violation in the non-strange sector has important consequences in understanding the matter anti-matter asymmetry in the universe. Some present and future experiments, in the newly constructed or planned Rare Isotope Facilities will test this idea. This and recent theoretical results will be briefly discussed.

Thursday 09:20 - 09:40

Low-energy Dipole Excitations in Nuclei at the $N = 50, 82$ and $Z = 50$ Shell Closures as Signatures for a Neutron Skin.

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Low-energy dipole excitations have been investigated theoretically in $N = 50$ ^{88}Sr and ^{90}Zr, N=82 isotones and the $Z = 50$ Sn isotopes. For this purpose a method incorporating both HFB [1] and multi-phonon QPM theory [2] is applied [3]. A concentration of one-phonon dipole strength located below the neutron emission threshold has been calculated in these nuclei. The fragmentation pattern of the low-energy dipole excitations was investigated in QPM calculations including up to three phonon components [4]. The analysis of the corresponding neutron and proton dipole transition densities allows to assign a genuine pattern to the lowenergy excitations and making them distinct from the conventional GDR modes. Analyzing also the wave function structure of the states we can identify these excitations as Pygmy Dipole Resonance (PDR) modes, recently studied also in Sn [5] and $N = 82$ [6] nuclei. In all cases a close connection between the total PDR strengths and the neutron skin thickness defined by the relative difference of neutron and proton rms radii for ^{88}Sr and ^{90}Zr nuclei was found. These observations agree very well with our previous results for the $Z = 50$ Sn isotopes and the $N = 82$ isotones. The results for $N = 50$ are exploratory for an experimental project designed for the bremsstrahlung facility at the ELBE accelerator.

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Thursday 09:40 - 10:10

Electromagnetic Excitation of Exotic Nuclei – Dipole Strength and Neutron Skins

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The properties of exotic nuclei are ideally studied in inverse-kinematics experiments at high beam energies using the FRS-LAND facilities at GSI. The LAND reaction setup allows exclusive measurements of all projectile-like particles following the excitation of the projectile in a high-Z target (Pb). At a beam energy of about 500 AMeV electromagnetic excitations are dominated by dipole transitions, and the Coulomb excitation cross sections can be transformed into photoabsorption cross sections using the method of equivalent photons within a semi-classical approach.
In an experiment utilizing secondary beams of neutron-rich Sn isotopes $^{129-133}$Sn and neighbouring nuclei with similar A/Z ratio a substantial fraction of dipole strength at energies below the giant dipole resonance (GDR) is observed. For ^{130}Sn and ^{132}Sn this strength is located in a peak-like structure around 10 MeV and exhibits a few percent of the Thomas-Reiche Kuhn (TRK) sum-rule strength [1]. Several calculations (see, e.g., [2,3]) predict the appearance of dipole strength at low excitation energies in neutron-rich nuclei. This low-lying strength is often referred to as pygmy dipole resonance (PDR) and, in a macroscopic picture, is discussed in terms of a collective oscillation of excess neutrons out of phase with the core nucleons. For the odd Sn isotopes a substantial amount of dipole strength is found at even lower excitation energies, allowing for a direct comparison with results obtained from real-photon scattering measurements in stable nuclei below the particle threshold [4]. Recent random-phase-approximation calculations show a strong correlation of the PDR strength to the density dependence of the symmetry energy and thus a link to the neutron skin size [5,6]. Consequences from the experimental findings in ^{130}Sn, ^{132}Sn and ^{208}Pb [7] for the neutron-skin sizes, the symmetry energy and the neutron equation of state (EoS) will be discussed. Constraints on the EoS of infinite neutron matter are highly desirable for a description of the largest system of neutron matter known in nature, the neutron star.
The Coulomb-excitation method allows to determine cross sections for the inverse capture processes (n,γ), (p,γ) in exotic nuclei, which are relevant in astrophysical scenarios. As an example, the capture cross section for ^{14}C(n,γ)^{15}C was determined from a LAND-FRS experiment including a separation of ground-state and excited-state contributions [8].
An outlook will be given on a series of experiments aimed at studying the (γ,p) cross sections which will be carried out in 2007 after the upgrade of the LAND setup. The experimental opportunities at the future R^{3}B setup at FAIR will be discussed in the context of astrophysical questions.

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Thursday 10:10 - 10:30

Constraining the Equation of State of Neutron-Rich Nuclear Matter with Heavy-Ion Reactions Induced by Rare Isotopes

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The ultimate goal of studying isospin physics via heavy-ion reactions with neutron-rich (stable and/or radioactive) nuclei is to explore the isospin dependence of in-medium nuclear effective interactions and the equation of state (EOS) of neutron-rich nuclear matter, particularly the isospin-dependent term in the EOS, i.e., the density dependence of the symmetry energy [1]. Since the latter is very important for both nuclear physics and astrophysics [2], to pin down the symmetry energy of neutron-rich nuclear matter has been the main focus of the intermediate energy heavy-ion community [3]. During the last decade, significant progress has been achieved both experimentally and theoretically in this field [4]. In particular, a number of experimental phenomena/observables have been identified as sensitive probes of the density dependence of the nuclear symmetry energy [5]. Experimental studies have confirmed several interesting isospin-dependent effects and allowed us to constrain stringently the symmetry energy at sub-saturation densities [6,7]. Impacts of a constrained density dependence of the symmetry energy on properties of neutron stars have also been studied and were found to be very useful for the astrophysical community [8,9]. The construction of various radioactive beam facilities around the world provides a unique opportunity to constrain the isospin dependence of in-medium nuclear effective interaction and the EOS of neutron-rich matter. In this talk, we will report our latest results in constraining the symmetry energy at high densities using heavy-ion reactions induced by high energy rare isotopes to be available at RIKEN and FAIR.

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5 Dense Matter in Neutron Stars and Relativistic Nuclear Collisions

Thursday 11:00 - 11:30

Constraints for the Thermodynamic Potential and the Transport Coefficients of the Quark Gluon Plasma

Roy A. Lacey[1]

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Considerable evidence now favors the formation of the quark-gluon plasma (QGP) in energetic collisions between heavy nuclei at ultra-relativistic energies, and in the interior of neutron stars. A major current challenge is to obtain more quantitative information about the properties of the QGP and the subsequent hot hadronic matter, as well as on the process of hadronization itself. I will (a) review several recent elliptic flow, and „QCD sonic boom“ measurements which validates the fact that the new state of nuclear matter is comprised of constituents having the quantum numbers of quarks and anti-quarks in chemical equilibrium; and (b) show that the results from these measurements allow reliable estimates of several transport coefficients – its sound speed c_s, shear viscosity to entropy ratio η/s, diffusion coefficient (D_c), sound attenuation length (Γ), etc. I will also discuss observations which may signal the critical end point for hot and dense QCD matter.

Thursday 11:30 - 11:50

Equation of state at high densities and modern compact star observations

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Recently, observations of compact stars have provided new data of high accuracy which put strong constraints on the high-density behaviour of the equation of state of strongly interacting matter otherwise not accessible in terrestrial laboratories [1]. The evidence for neutron stars with high mass ($M = 2.1 \pm 0.2\ M_\odot$ for PSR J0751+1807) and large radii ($R > 12$ km for RX J1856-3754) rules out soft equations of state and has provoked a debate whether the occurence of quark matter in compact stars can be excluded as well. In this contribution it is shown that modern quantum field theoretical approaches to quark matter [2] including color superconductivity and a vector meanfield allow a microscopic description of hybrid stars which fulfill the new, strong constraints [3,4]. For these objects color superconductivity turns out to be essential for a successful description of the cooling phenomenology in accordance with recently developed tests [5]. We present implications for the QCD phase diagram to be explored in future generations of nucleus-nucleus collision experiments at low temperatures and high baryon densities such as CBM @ FAIR.

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Thursday 11:50 - 12:20

Exploring the QGP at LHC with Hard Probes in ALICE

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Recent results from the Relativistic Heavy Ion Collider RHIC at Brookhaven on hard probes will be reviewed and discussed in terms of probing the quark-gluon plasma. The talk will discuss how this program will be pursued in ALICE at the LHC in light of the present understanding of the RHIC data.

Thursday 12:20 - 12:40

Gap energy of superfluid neutron matter at zero temperature

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Superfluidity in neutron matter has been a fascinating topic in many–body physics and astrophysics ever since Migdal proposed the possibility of superfluid matter in neutron stars. The $^1S_0$ pairing in neutron matter has been investigated in presence of realistic two– and three–nucleon interactions. We have adopted the Argonne $v_{8'}$ NN and the Urbana IX 3N potentials. Quantum Monte Carlo theory, specifically the Auxiliary Field Diffusion Monte Carlo method, and Correlated Basis Function theory are employed in order to get quantitative and reliable estimates of the gap. They both fully take into account the medium modifications due to the interaction induced correlations. The two methods are in good agreement up to the maximum gap density and both point to a slight reduction with respect to the standard BCS value. In fact, the maximum gap is about 2.5 MeV at $k_F \sim 0.8 fm^{-1}$ in BCS and $2.3 - 2.4$ MeV at $k_F \sim 0.6 fm^{-1}$ in correlated matter. At higher densities the Quantum Monte Carlo gap becomes close to BCS. In general, the computed medium polarization effects are much smaller than those previously estimated within *all theories*. Truncations of Argonne $v_{8'}$ to simpler forms give the same gaps in BCS, provided the truncated potentials have been refitted to the same NN data set. Differences among the models appear in the correlated theories, most of the reduction being attributable to the tensor force. The three–nucleon interaction provides an additional increase of the gap of about 0.35 MeV.

Thursday 12:40 - 13:00

Is a soft nuclear equation of state ruled out by pulsar data?

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There has been a tremendous activity recently with regard to the properties of dense nuclear matter in relativistic nuclear astrophysics of compact stars and in heavy-ion physics. The maximum mass of neutron stars is intimately related to the underlying stiffness of the nuclear equation of state.
More than 1600 pulsars, rotating neutron stars, are presently known. New timing measurements of binary pulsars point towards large masses and correspondingly to a nuclear equation of state usually considered to be rather stiff. For the white dwarf–pulsar system J0751+1807 a mass of $M = 2.1 \pm 0.2 M_\odot$ (1σ) and $M = 1.6 - 2.5 M_\odot$ (2σ) was found by Nice et al. [1]. Özel derives a mass limit $M \geq 2.10 \pm 0.28 M_\odot$ from x-ray bursts of the neutron star EXO 0748–676 [2] stating that soft equations of state are ruled out.
On the other hand, particle production and collective effects in heavy-ion collisions are also considered to be a probe of the underlying nuclear equation of state. Recent investigations of the subthreshold production of kaons come to the conclusions that the nuclear equation of state should be extremely soft above normal nuclear matter density [3].
We investigate in detail this apparent paradox by considering several families of nuclear equations of state, with regard to compression modulus and symmetry energy, and their impact on the properties of compact stars taking into account the recent data on kaon production in heavy ion collisions [4]. In particular, the role of the density region relevant for subthreshold production and the related Schrödinger equivalent potentials are delineated. In addition, the importance of hyperons in dense neutron star matter with regard to known hypernuclear properties are contrasted with pulsar mass measurements. Finally, the influence of a possible quark phase on the mass-radius relation of compact stars is discussed, in particular in response to the recent analysis by Özel (see [5]).

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4 Nuclei far from Stability and Radioactive Ion Beams

Thursday 16:30 - 17:00

Towards microscopic calculations of nuclear reaction rates

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Low-energy nuclear reactions play an important role in many astrophysical scenarios. In many cases experimental data are not available at energies important for the astrophysical processes. Theoretically such reactions have been studied mainly in two approaches. In potential models the participating nuclei are considered as point articles that interact via potentials that fit the experimental data on bound state properties and scattering data. In microscopic cluster models the many-body problem is described in the language of nucleons interacting via nucleon-nucleon potentials. While this is a microscopic approach uncertainties arise due to restricted model spaces, especially for description of the system in the interaction region, and simplistic interactions. In recent years the application of $ab-initio$ methods like the Green's Function Monte Carlo (GFMC) or the No-Core Shell Model (NCSM) on reaction problems is actively pursued. In these methods the same realistic two- and three-nucleon interactions that are used for the description of bound states are also used for reaction processes. However these calculations are very challenging and especially the description in the asymptotic region suffers from statistics in the Monte Carlo techniques or exploding model spaces and wrong asymptotics in the harmonic oscillator basis. With the Fermionic Molecular Dynamics (FMD) model [1] we aim at a consistent description of bound states, resonances and scattering states starting from realistic nucleon-nucleon interactions. The important short-range central and tensor correlations are treated explicitly with the Unitary Correlation Operator Method [2], providing an effective low-momentum interaction. As no explicit three-body forces are included up to now an empirical two-body correction term is added to the correlated interaction. The FMD wave functions are built with Slater determinants of Gaussian wave packets that are projected on parity, angular momentum and total linear momentum. Bound state wave functions are given as linear combinations of projected Slater determinants. The FMD model has been used successfully [3] for light nuclei where shell structures, clustering and halos can be described due to the flexibility of the Gaussian single-particle basis. The FMD basis is also well suited for the description of scattering processes. For the description of the asymptotic scattering states FMD bound states are joined, taking the distance as a generator coordinate. Additional configurations are added in the interaction region. To obtain resonance or scattering states appropriate boundary conditions have to be included. We will present first calculations for the ^{3}He$(\alpha,\gamma)^7$Be radiative capture process. We study the bound states and resonances in this system and how they evolve with increasing model space sizes. As another example fusion cross sections in neutron-rich oxygen isotopes will be shown. These are important for pycnonuclear reactions in the crust of neutron stars.

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Thursday 17:00 - 17:30

Precision measurements with ion traps for nuclear astrophysics

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In nuclear astrophysics, the binding energies are among the most important ingredients for reliable calculations. They affect the rates of the relevant reactions and they influence the time-scale and energy production of nucleosynthesis. In high temperature conditions, they adjust the balance, which defines the process paths.
At JYFL we have introduced a unique combination of Penning trap technology and IGISOL-technique, which allows precision studies of atomic masses of short-lived exotic isotopes without target-ion source chemistry related restrictions [1]. Thus the isotopes of refractory elements, like Zr, Mo, Tc and Ru could be for the first time extracted as ion beams and transported to the Penning trap.
A Penning trap is well suited for mass spectroscopy, since frequencies of radial eigenmotions in the trap sum up to a cyclotron motion, the frequency which in the given magnetic field is mass dependent $f_c = \frac{1}{2\pi}\frac{q}{m}B$. By measuring periodically the cyclotron frequency of the unknown isotope and a well known reference ion, it is possible to deduce the mass of the unknown isotope by applying relation

$$\frac{f_{c,ref}}{f_c} = \frac{m - m_e}{m_{ref} - m_e}$$

. Resulting accuracy depends on the excitation time, but typical accuracy of atomic mass determination for studies reviewed here is in the range of few keV.
The JYFLTRAP facility has succesfully been used to study the masses (which lead to the Q-values) of neutron-deficient elements from Z=40 to Z=50 in the vicinity of the expected rp-process path [2]. The data collected at JYFLTRAP improves the information in these masses which were with few exceptions obtained from the beta end-point measurements or by estimating the systematic trends in neighboring nuclides. Consequently, the mass surface of this region was rather poorly determined prior to our work.
We have also measured more than a hundred atomic masses of fission products at JYFLTRAP. Studied neutron-rich nuclei ranges from Ge (Z=32) to Pd (Z=46) [3,4,5]. Some of the most exotic isotopes measured were ^{121}Pd, ^{118}Rh, ^{110}Mo, ^{105}Zr, ^{97}Rb and ^{92}Br. It is worth of noticing that the latter one is located in the r-process path in certain scenarios.
The studied mass regions offer an interesting playground also to look for nuclear structure signatures in the mass surface, relevant also for the astrophysical predictions. The results are discussed in comparison with other spectroscopic information and theoretical studies. In addition, we will compare our results with the recent Atomic Mass Evaluation [6] and selected mass predictions used in astrophysical calculations [7].

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[3] U. Hager et al., Phys. Rev. Lett. **96**, 042504 (2006).
[4] S. Rahaman et al., Eur. Phys. J. A, submitted (2007).
[5] U. Hager et al., Phys. Rev. C, submitted (2007).
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Thursday 17:30 - 17:50

Precise Mass Measurements of Rare Nuclei - The Penning Trap Mass Spectrometers ISOLTRAP and SHIPTRAP

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[4] *CERN, Genève, Switzerland* [5] *Max-Planck Institut für Kernphysik, Heidelberg, Germany*
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The mass of an atomic nucleus contains the binding energy that brings the nucleus into existence. Its precise measurement gives access to many phenomena. A systematic investigation of the nuclear binding energy reveals nuclear structure and is a prerequisite for nuclear models. An independent and very precise determination of reaction enthalpies, i.e. Q-values, yields necessary data for fundamental tests as for instance the test of the CVC hypothesis and for reaction network calculations in nuclear astrophysics. Mass measurements of short-lived radioactive nuclei are provided by the Penning trap mass spectrometers SHIPTRAP and ISOLTRAP with relative uncertainties between $1 \cdot 10^{-7}$ and $1 \cdot 10^{-8}$.
ISOLTRAP is installed at ISOLDE at CERN in Geneva where radionuclides are produced by fission, spallation, or fragmentation of nuclei in a thick target bombarded with a 1 GeV proton beam. The nuclei diffuse out of the hot target and are subsequently ionized, accelerated to 60 keV and mass separated. The mass separated ions are then electrostatically decelerated and stopped in a buffer-gas filled linear radio frequency quadrupole (RFQ) trap in order to prepare ion bunches at low energy ideally suited for efficient capture in a Penning trap.
SHIPTRAP at GSI in Darmstadt is installed after the Separator for Heavy Ion Products (SHIP). The radionuclei are produced in fusion-evaporation reactions at a few MeV/u energy. The reaction products are separated from the primary beam in the velocity filter SHIP. The energy of the reaction products is then degraded from around 100 keV/u down to a few 10 keV/u in a μm-thin titanium window before they are stopped in 50 mbar helium in a buffer-gas cell. After extraction from the buffer-gas cell, the radioactive ions are accumulated in a linear RFQ trap to prepare the efficient transfer to a Penning trap.
At both spectrometers the ions are then injected into a purification Penning trap for accumulation and mass selective cooling with a resolving power up to $m/\Delta m = 105$. After the transfer of the purified ion ensemble to a second (high-precision) Penning trap the ion cyclotron frequency $\nu_C = qB/(2\pi m)$ and hence their mass, is determined. This is done with a resolving power of up to 106, enough to separate low-lying isomeric states.
This presentation will summarize the recent results obtained at ISOLTRAP and SHIPTRAP and their relevance for modern nuclear-physics subjects. Examples are the measurements of the ground-state proton emitter ^{147}Tm, the $0^+ \to 0^+$ β emitter ^{38}Ca, the r-process nucleus ^{81}Zn, the possible proton-halo nucleus ^{17}Ne, and ^{35}K for a test of the isobaric-multiplet mass equation.

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Thursday 17:50 - 18:10

TOF-Bρ Mass Measurements of Very Exotic Nuclides for Astrophysical Calculations at the NSCL

M. Matoš[1,2], A. Estrade[1,2,3], M. Amthor[1,2,3], D. Bazin[1], A. Becerril[1,2,3], T. Elliot[1,2,3], D. Galaviz[1,2], A. Gade[1,3], G. Lorusso[1,2,3], J. Pereira[1,2], M. Portillo[1], A. Rogers[1,2,3], H. Schatz[1,2,3], D. Shapira[4], E. Smith[2,5], A. Stolz[1], M. Wallace[6]

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Atomic masses play a crucial role in many nuclear astrophysics calculations. The lack of experimental values for relevant exotic nuclides triggered a rapid development of new mass measurement devices around the world. In the past years, mostly the stored ion techniques have been applied.
In contrast to the numerous Penning trap devices [1], other direct methods, using mostly the Time-of-Flight (TOF) technique, are implemented at a limited number of facilities.
The TOF mass measurements offer a complementary technique to the most precise Penning trap measurements, the latter being limited by the rate, half-lives and the chemistry of the ions of interest. With the minimum rate requirement of the order of 0.01 particles/s and the measurement time shorter than 1 ms, the TOF mass measurements access the most exotic nuclei. An entire region of the chart of nuclides that could not be reached by other techniques can be covered in just one experimental run, producing important data for astrophysical calculations, test of the mass models, and more.
The NSCL facility offers an ideal infrastructure for TOF mass measurements of very exotic nuclei. We have recently implemented a TOF-Bρ technique and performed mass measurements of neutron-rich nuclides in the Fe region, important for r-process calculations, and for calculations of processes occurring in the crust of accreting neutron stars.
At the NSCL, a primary beam of ^{86}Kr was accelerated in the K500 and K1200 coupled superconducting cyclotrons to an energy of 100 MeV/u. A secondary radioactive beam was then produced by fast fragmentation on 47 mg/cm^2 and 94 mg/cm^2 Be targets. The projectiles were separated in the A1900 fragment separator [2]. For this experiment a 58 m long time-of-flight path was used. Fast plastic scintillation detectors provided a timing resolution of about σ=30 ps, the relative magnetic rigidity Bρ was measured at the momentum dispersive focal plane of the S800 spectrograph [3] by position sensitive micro-channel plate (MCP) detectors [4].
Details of the experimental technique will be presented. Results from this first experiment, future plans and their impact on the astrophysical network calculations will be discussed.

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[2] A. Stolz, et al., Nucl. Instrum. Methods Phys. Res. **B241** (2005) 858.
[3] D. Bazin, et al., Nucl. Instrum. Methods Phys. Res. **B204** (2000) 629.
[4] D. Shapira, et al., Nucl. Instrum. Methods Phys. Res. **A454** (2000) 409.

Thursday 18:10 - 18:30

The outer crust of nonaccreting cold neutron stars

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The properties and composition of the outer crust of nonaccreting cold neutron stars are studied by applying the model of Baym, Pethick and Sutherland [1], which was extended by the higher order corrections of the atomic binding, screening, exchange and zero-point energy [2, 3]. The most recent experimental nuclear data from the atomic mass table of Audi, Wapstra, and Thibault from 2003 [4] is used. Extrapolation to the drip line is utilized by a comprehensive set of different state-of-the-art theoretical nuclear models: finite range droplet, relativistic nuclear field and non-relativistic Skyrme Hartree-Fock parameterizations with and without inclusion of axial and triaxial deformations. The different nuclear models are compared with respect to the neutron drip line, magic numbers, equation of state and the sequence of ground state nuclei appearing in the outer crust. Finally, for different neutron star configurations the mass-radius relation and the corresponding nuclear composition of the outer crust is presented.

[1] G. Baym, C. Pethick, and P. Sutherland, Astrophys. J. **170**, 299 (1971).
[2] S. B. Rüster, and M. Hempel, and J. Schaffner-Bielich, Phys. Rev. C **73**, 035804 (2006).
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Friday 08:30 - 09:00

Study of shell closures in light neutron-rich nuclei

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Radioactive nuclei are often involved in reactions which are important for nuclear astrophysics. The study of these reactions leads to the better understanding of the synthesis of elements. In this respect, magic nuclei (as well as shell closures) are crucial since they represent stable regions of isotopes in the nuclear chart.

Recently, we have found indirect and direct evidence for the disappearance of the N=20 shell closure and the formation of new magic numbers in the light neutron-rich area of nuclei by investigating the structure of ^{27,28}Ne and ^{23}O isotopes, which will be discussed in the present talk.

Friday 09:00 - 09:30

Physics Program at RIKEN RI Beam Factory

AOI Nori

RIKEN Nishina Center for Accelerator-Based Science, Japan

Experiments at RIKEN RI Beam Factory (RIBF) [1] will start soon in the summer of 2007. At RIBF, a wide range of short-lived RI beams will be produced using the large acceptance in-flight separator BigRIPS [2], with which the projectile fragments as well as the fission fragments of uranium can be efficiently collected. The capability of producing extremely neutron-rich or proton-rich nuclei will open opportunities for various fields of science. Among them, application to the astrophysics is one of the promising subjects, because unstable nuclei relevant to explosive stellar reaction chains such as *r*-process or *rp*-process will be accessible. In this paper, physics programs being considered at RIBF will be presented with an emphasis of nuclear astrophysics.

[1] Y. Yano, "RI Beam factory Project at RIKEN", Proc. 17th Int. Conf. on Cyclotrons and Their Applications, Tokyo, Japan, pp. 169-173 (2004).
[2] T. Kubo, Nucl. Instr. and Meth. in Phys. Res. B 204 (2003) 97.

Friday 09:30 - 09:50

Production targets of light radioisotopes for nuclear astrophysics and basic nuclear science studies.

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[3] *Hebrew University, Jerusalem, Israel*

The $^{14}O(\alpha,p)^{17}F$ and $^{15}O(\alpha,\gamma)^{19}Ne$ reactions play a central role in understanding the nuclear physics aspects of the astrophysical phenomenon of x-ray bursts [1]. Intense beams of the radioactive $^{14,15}O$ nuclei are very hard to come by, in spite of concentrated efforts [2], and as a consequence there have been numerous publications in the last several years aimed at studies of the inverse reaction $^{17}F(p,\alpha)^{14}O$, albeit with very limited success [3,4]. A measurement of the cross section for this reactions is therefore urgently needed for a critical evaluation of the astrophysics modeling of the phenomenon of x-ray bursts. In this context, we discuss the large fluxes of light radio-nuclei that can be produced by protons and deuterons from currently constructed super-conducting Linacs, impinging on a specially-designed appropriate target. By using a particular beam-target combination, one can produce many different light radioisotopes to serve in various nuclear astrophysics and basic nuclear research. In particular, with a deuteron beam at 40 MeV at few mA impinging on a ^{14}N target, reaction-yield simulations demonstrate that yields up to 10^{13} and 10^{14} atoms/s of ^{14}O and ^{15}O, respectively, can be achieved. Such intense beams will be shortly available at, e.g., the SPIRAL-II facility at GANIL, France and at the SARAF accelerator at SOREQ, Israel.

We present the various simulations that have been used to produce the estimates above, as well as target design scenarios (see also [2,5]). We outline the experimental steps that are necessary in order to obtain these goals within the framework of future activities of the SPIRAL-II and SARAF facilities.

[1] M. Wiescher et al., Phil. Trans. R. Soc. London, A**436**, 2105 (1998); and references therein.

[2] J. Powell et al., Nucl. Inst. Meth. B**204**, 440 (2003).

[3] P.J. Woods et al., proposal to the ISOLDE (CERN) INTC Committee, 2003.

[4] B. Harss et al., Phys. Rev. C**66**, 055802 (2002).

[5] S. Lapi et al., Nucl. Instr. Meth. B**204**, 444 (2003).

Friday 09:50 - 10:10

Accelerator Waste as a Source for Exotic Radionuclides

Dorothea Schumann[1]

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Long-lived exotic radionuclides such as 60-Fe, 26-Al, 44-Ti or 10-Be are of great interest in several fields of research like basic nuclear physics, astrophysics and/or radioactive ion beam techniques. Some examples for the use of such rare isotopes in the research area of nuclear astrophysics are the application of 44-Ti for investigations of core collapse supernovae or studies of several neutron capture reactions on radioactive isotopes like the 60-Fe(n,gamma)61-Fe reaction at stellar energies. The direct production of these nuclides in sufficient amounts is, in some cases, nearly impossible, in others very time consuming and extremely expensive. Until very recently, no concerted effort had been made to reclaim such radionuclides for future use from activated components of particle accelerators. This is due, in large part, to the small amounts of suitably irradiated material. Nowadays, this situation changed drastically with the construction of new large accelerator facilities, spallation neutron sources and radioactive-beam-facilities, as for example are described in the EURISOL project [1]. The Paul Scherrer Institute operates the most powerful spallation neutron source (SINQ) in Europe, driven by a high power proton accelerator, the 590-MeV ring cyclotron with a proton beam current up to 1.8 mA. Previous radiochemical analysis showed that beam dumps, shielding and target materials from these facilities contain long-lived radionuclides in such high amounts, that chemical separation for several applications seems to be attractive. It was found that the isotopes 60-Fe, 26-Al, 10-Be, 44-Ti and probably many others can be separated already now in amounts of 10e16 - 10e18 atoms [2]. At the moment, PSI can provide about 500g of proton-irradiated copper stemming from a former beam dump, as well as irradiated graphite targets with a high content of 7-Be and 10-Be. Additionally, the first lead targets, already irradiated at the spallation neutron source, SINQ, will be ready for use in the near future. With these materials, provision of several interesting long-lived radionuclides (7-Be, 10-Be, 26-Al, 44-Ti, 53-Mn, 60-Fe and many others) will be possible after chemical separation in quantities sufficient for scientific studies to be conducted in several disparate research fields. A first exploratory workshop on this topic (ERAWAST - Exotic Radionuclides from Accelerator Waste for Science and Technology) was held in 2006 at PSI. In the present contribution, an overview on the possibilities for mmining exotic radionuclidesffrom accelerator waste at PSI is given. Some selected chemical separation procedures are presented.

[1] http://ganil.fr/eurisol/
[2] D. Schumann et.al. LCH-Annual Report, PSI 2006, in print

Friday 10:10 - 10:30

Gamow-Teller transitions in pf-shell nuclei relevant to supernova explosion

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Berta RUBIO[2], and Valencia-Surrey-Osaka-Leuven β-decay collaboration

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Gamow-Teller (GT) transitions in pf-shell nuclei play important roles at the core collapse stage of type II supernovae. Pair-created high energy neutrinos produced at temperatures of several GK make violent processes on pf-shell nuclei via spin-isospin transitions including GT transitions. Therefore, accurate studies of the GT transition strengths B(GT)s (1) for the transitions up to high excitations, and also (2) for the transitions starting from unstable nuclei, are requested.
Direct information on B(GT)s can be derived from β-decay measurements, and several far-from-stability pf-shell nuclei have been studied. Although half-lives $T_{1/2}$ can be measured rather accurately, GT transitions to higher excited states are difficult to measure: the feedings to higher excited states are hindered in β decays by the phase-space factor f. On the other hand, charge-exchange reactions, like (^{3}He, t) reaction at 0° and at 420 MeV, yield cross-sections that are proportional to B(GT) values for individual transitions up to high excitations [1], but absolute values cannot be derived directly.
Assuming the isospin symmetry for the strengths of $T_z = \pm 1 \rightarrow 0$ mirror GT transitions, we performed a unique "merged analysis" [2] to determine absolute B(GT) values starting from $T_z = \pm 1$ mirror pf-shell nuclei. First, precise $T_z = +1 \rightarrow 0$ (relative) GT strength distributions were obtained from the high-resolution (^{3}He, t) spectra (energy resolution $\approx$ 30 keV) measured at RCNP, Osaka on $A = 42 - 58$, $T_z = +1$ target nuclei. The feeding ratios of the $T_z = -1 \rightarrow 0$ mirror β decays were deduced by multiplying the f-factors of the β decays with the obtained distributions. These feeding ratios were then normalized by the $T_{1/2}$ values of the β decays to obtain B(GT)s of the transitions.
In this merged analysis, accurate $T_{1/2}$ values play important and crucial roles. In order to increase the accuracy of the $T_{1/2}$ values and also to measure branching ratios, we study β decays of $T_z = -1$ pf-shell nuclei [3].
Extension of the merged analysis to the far exotic $T_z = \pm 2 \rightarrow \pm 1$ analogous GT transitions in pf-shell nuclei is also discussed.

[1] Y. Fujita et al., Phys. Rev. C **67**, 064312 (2003).
[2] Y. Fujita et al., Phys. Rev. Lett. **95**, 212501 (2005).
[3] B. Rubio et al., Experimental proposals at Louvain la Neuve and at GSI.

5 Dense Matter in Neutron Stars and Relativistic Nuclear Collisions

Friday 11:00 - 11:30

The Equation of State of dense matter : from nuclear collisions to neutron stars

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The equation of state (EOS) of nuclear matter is the fundamental input to build models of neutron stars according to the Einstein's general theory of relativity. In fact, typical stellar properties like masses, radii, rotational periods, etc., strongly depend on the equation of state at densities up to one order of magnitude larger than the saturation value. Due to the large densities attainable in the core, in massive neutron stars a hadron-quark phase transition may be expected.
The determination of the nuclear EOS over such a wide density range is a formidable task. For that, the theoretical predictions based on microscopic many-body calculations with different methods must be confronted with the analysis of the data on ordinary nuclei (saturation point, compressibility and symmetry energy at saturation and so on), hints coming from heavy ion laboratory experiments and the interpretations of observational data on pulsars and supernovae events.
In my talk, I will present an analysis of the different informations and constraints on the nuclear EOS coming from the fields just mentioned. The main emphasis will be on the theoretical prospect, with input and indications coming from a variety of laboratory experiments and observational data.

Friday 11:30 - 12:00

What do we learn about dense nuclear matter from heavy-ion collision experiments?

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Nucleus-nucleus collisions provide the unique opportunity to create and to investigate dense nuclear matter in the laboratory. The collision experiments address fundamental aspects of strong-interaction physics: the nuclear equation-of-state at high baryon densities, and the modification of hadron properties in the dense nuclear medium. The experimental results are relevant for our understanding of the dynamics of core-collapse supernovae, and of the structure of neutron stars. In particular, strange particles are promising diagnostic probes of dense nuclear matter. Existing experimental data, their theoretical interpretations, and future experiments will be discussed.

Friday 12:00 - 12:20

Effects of color superconductivity on the nucleation of quark matter in neutron stars

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[2] *Dipartimento di Fisica, Università di Pisa and INFN Sezione di Pisa, Largo Bruno Pontecorvo 3 I-56127 Pisa, Italy*

We study the nucleation of quark matter drops at the center of cold deleptonized neutron stars [1]. These drops can be made up of unpaired quark matter or color-superconducting quark matter, depending on the details of the equation of state for quark and hadronic matter. The nature of the nucleated phase is relevant in determining the critical mass M_{cr} of hadronic stars above which a transition to a quark star (strange or hybrid) is possible. We investigate the dependence of M_{cr} upon the parameters of the quark model (the Bag constant B, the pairing gap Δ, and the surface tension σ of the quark-hadron interface) for different parametrizations of the hadronic equation of state. For a large part of the parameter space corresponding to hybrid stars, the critical mass is very close to (but smaller than) the maximum mass of hadronic stars, so compatible with a "mixed" population of compact stars (pure hadronic up to the critical mass and hybrid above the critical mass). For very large B the critical mass is never lower than the maximum mass of hadronic stars, impliying that quark stars cannot form through the mechanism studied here. The energy released in the convertion is sufficient for powering a gamma ray burst.

[1] I. Bombaci, G. Lugones and I. Vidaña, Astron. and Astrophys. **462**, 1017 (2007).

Friday 12:20 - 12:50

Recent progress constraining the nuclear equation of state from astrophysics and heavy ion reactions

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The quest for the nuclear equation of state (EoS) at high densities and/or extreme isospin is one of the long-standing problems of nuclear physics. Ab inito calculations for the nuclear many-body problem make predictions for the density and isospin dependence of the EoS far away from the saturation point of nuclear matter [1]. On the other hand, in recent years substantial progress has been mode to constrain the EOS both, from the astrophysical side and from accelerator based experiments. Heavy ion experiments support a "soft" EoS at moderate densities [2] while recent neutron star observations require a "stiff" high density behaviour. Both constraints are discussed and shown to be in agreement with the predictions from many-body theory [3].

[1] E. van Dalen, C. Fuchs, A. Faessler, Phys. Rev. Lett. **95**, 022302 (2005).
[2] C. Fuchs, A. Faessler, E. Zabrodin, Y.M. Zheng, Phys. Rev. Lett. **86**, 1974 (2001).
[3] T. Klähn et al., Phys. Rev. C **74**, 035802 (2006).

Friday 12:50 - 13:10

Temporal structure of Gamma-Ray-Bursts and quark deconfinement in Compact stars

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We discuss the temporal structure of the Gamma-Ray-Bursts (GRBs) light curves and we analyse the occurrence of quiescent times which are long periods within the prompt emission in which the inner engine is not active [1,2,3]. We show that if a long quiescent time is present, it is possible to divide the total duration of GRBs into three periods: the pre-quiescence emission, the quiescent time and the post-quiescence emission. We then discuss a model of the GRBs inner engine based on the formation of quark phases during the life of an hadronic star [4,5]. Within this model the pre-quiescence emission is interpreted as due to the deconfinement of quark inside an hadronic star and the formation of 2SC quark matter or unpaired quark matter (UQM). The post-quiescence emission is due to the conversion of 2SC (or UQM) into the Color-Flavor-Locking (CFL) phase [6]. The temporal delay between these two processes is connected with the nucleation time of the CFL phase in the 2SC (UQM) phase and it can be associated with the observed quiescent times in the GRBs light curves.

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6 Neutrinos in Nuclear Astrophysics

Friday 14:00 - 14:30

Measurement of neutrino-nucleus interactions in the energy regime of supernovae

Klaus Eitel[1]

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The **KA**rlsruhe **R**utherford **M**edium **E**nergy **N**eutrino experiment situated at the ISIS spallation source of the Rutherford Appleton Laboratory, UK, investigated in the years 1990 to 2001 in great detail and with a signal:background ratio up to 100:1 neutral- and charged-current reactions on ^{12}C, ^{13}C and Fe making use of the unique features of neutrino production at ISIS. With neutrino energies up to 53 MeV, the ISIS neutrino flux was ideally suited to measure cross sections of neutrino-nucleus interactions in a regime of neutrino-induced nucleosynthesis processes in supernovae.
We report results of the KARMEN experiment on neutrino-nucleus reactions including a short review of the achieved search on neutrino oscillations and prospects of future neutrino experiments at spallation sources. An outlook on current activities determining the absolute neutrino mass with 0.2 eV sensitivity with the KATRIN experiment will be given.

Friday 14:30 - 15:00

Nuclear Physics Aspects of supernovae evolution and nucleosynthesis

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In this talk I will review different aspects of supernovae evolution and nucleosynthesis where nuclear physics plays a important role. Weak interactions on nuclei govern the evolution during the collapse of massive stars and the spectra of the emitted neutrinos during the explosion. These neutrinos determine if the ejected matter is proton or neutron rich. Proton-rich ejecta constitute the site a new kind of rp-process that is catalyzed by antineutrino absorptions in protons and that we denote as νp-process. The r-process is expected to occur in neutron rich ejecta. Depending in the conditions even the heavier r-process elements can be produced. In this case fission can play a major role in understanding the production of r-process elements.

Friday 15:00 - 15:20

Neutrino-induced nucleosynthesis in supernovae: synthesis of light elements and neutrino-driven r-process

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We report those results of our neutrino-nucleosynthesis project that concerns the neutrino-induced production of light and heavy elements in the supernova helium shell. We have used two nuclear kinetics codes [1]. The first one calculates the nuclear kinetics for the light nuclides from D, ^{3}H, ^{3}He, ... through ^{24}Mg. The second code controls the nuclear kinetics for the heavier nuclides up to $Z = 60$ (Nd). Both the codes are consistently connected by an iterative exchanging with free neutrons and protons.

The main source of free neutrons and protons is assumed to be the neutrino-helium spallation: ^{4}He$(\nu,\nu'\mathrm{n})^3$He; ^{4}He$(\nu,\nu'\mathrm{p})^3$H.

Moreover, the inelastic ν scattering off ^{12}C, ^{13}C, ^{14}N, ^{16}O, and ^{20}Ne was taken into account: ^{12}C$(\nu,\nu'^3\mathrm{He})^9$Be; ^{12}C$(\nu,\nu'\mathrm{n})^{11}$C; ^{12}C$(\nu,\nu'\mathrm{p})^{11}$B; ^{13}C$(\nu,\nu'^4\mathrm{He})^9$Be; ^{14}N$(\nu,\nu'\alpha)^{10}$B; ^{16}O$(\nu,\nu'\mathrm{n})^{15}$O; ^{16}O$(\nu,\nu'\mathrm{p})^{15}$N; ^{20}Ne$(\nu,\nu'\mathrm{n})^{19}$Ne; ^{20}Ne$(\nu,\nu'\mathrm{p})^{19}$F. Here ν stands for μ and τ neutrino and antineutrino. Finally, the $\bar{\nu}_\mathrm{e}$-proton capture was included: p$(\bar{\nu}_\mathrm{e},\mathrm{e}^+)$n.

The presupernova models were taken from [2]. The temporal behavior of the temperature, density, and radius of shocked material were described by analytical formulae from [3].

We show that in the case of the poor-metal supernova models the outer half of the helium shell turns out to be good site to obtain the neutrino-driven “weakrr-process up to $A \approx 130$. Simultaneously, the helium shell remains to be good site for the neutrino-induced production of light isotopes ^{7}Li and ^{11}B, both for the poor-metal models and ones of solar metallicity.

We show also that if the inner half of the presupernova helium shell, enriched with ^{12}C due to convective-core He-burning, undergoes possible intrusion of hydrogen shortly before the explosion then appreciable amount of ^{13}C can be created and the subsequent release of neutrons in the reaction ^{13}C$(\alpha,\mathrm{n})^{16}$O ignited in the shock-heated material can strengthen the r-process. This revives the old idea of possible importance of this reaction for r-process in supernova helium shell [4,5,6]. At the same time, the ^{13}C-enriched environment is favorable for the neutrino-induced production of ^{9}Be through the reaction ^{13}C$(\nu,\nu'^4\mathrm{He})^9$Be.

Some of our results mentioned here were also summarized in [7].

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Friday 15:20 - 15:50

Nuclear Physics with Spherically Symmetric Supernova Models

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Few years ago, Boltzmann neutrino transport led to a new and probabely the last generation of spherically symmetric models of stellar core collapse and postbounce evolution. After the failure to proof the principles of the supernova explosion mechanism, these sophisticated models continue to illuminate the close interaction between high-density matter under extreme conditions and the transport of leptons and energy in general relativistically curved space-time [1]. We emphasize that very different input physics is likely to be relevant for the different evolutionary phases, e.g. nuclear structure for weak rates in collapse, the equation of state of bulk nuclear matter during bounce, multidimensional plasma dynamics in the postbounce evolution, and neutrino cross sections in the explosive nucleosynthesis [2]. We illustrate the complexity of the dynamics by preliminary 3D MHD high-resolution simulations [3] based on multi-group neutrino diffusion. With established spherically symmetric models we show that typical features of the different phases are reflected in the predicted neutrino signal and that a consistent neutrino flux leads to electron fractions larger than 0.5 in neutrino-driven supernova ejecta [4].

[1] M. Liebendörfer, M. Rampp, H.-Th. Janka, A. Mezzacappa, ApJ **620**, 840 (2005).
[2] G. Martinez-Pinedo, M. Liebendörfer, D. Frekers, Nucl. Phys. A **777**, 395 (2006).
[3] M. Liebendörfer, U.-L. Pen, C. Thompson, PoS (NIC-IX) 132 (2006).
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Friday 16:30 - 17:00

Neutrino-nucleus reactions in the relativistic quasiparticle RPA

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Semileptonic weak interaction rates of spherical nuclei are studied in the framework based on the relativistic quasiparticle random-phase approximation (RQRPA), derived in the small amplitude limit of the time-dependent Relativistic Hartree-Bogoliubov (RHB) model. The RQRPA configuration space is based on the RHB canonical single-nucleon basis, including two-quasiparticle pairs formed from the fully or partially occupied states of positive energy in the Fermi sea, and the empty negative-energy states from the Dirac sea. The RHB+RQRPA is formulated with effective interactions with explicit density-dependent meson-nucleon couplings. Of particular interest of the present study are neutrino reactions with nuclear targets relevant for the nuclear astrophysics and calibration of solar and supernovae neutrino detectors. In addition to the Isobaric analog states and Gamow-Teller transitions, charge-changing excitations of various multipolarities and all transition operators arising from the weak-interaction Hamiltionian are also taken into account. Exploratory studies provide perspectives of such an approach in systematic and consistent predictions of the neutrino-nucleus cross sections throughout the nuclide chart.

Friday 17:00 - 17:20

Neutron Stars in a Chiral Model with Finite Temperature

V. Dexheimer[1], S. Schramm[1], H. Stöcker[1]

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We investigate nuclear matter and neutron stars in a hadronic chiral model approach. The model includes the lowest Flavor-SU(3) multiplets for baryons and mesons and the parameters are determined to yield good results for saturated nuclear matter as well as for finite nuclei. The influence of baryonic resonances is discussed. We determine the global properties of a neutron star, such as its mass and radius. We study protoneutron star properties by taking into account trapped neutrinos and temperature effects. As an extension of the model we investigate the effects of a phase transition to a quark phase in the core of the star, by including quark degrees of freedom in the chiral model.

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[2] D. Zschiesche et al., J. Phys. G **31**, 935 (2005).

Friday 17:20 - 17:50

Neutrinos and Nucleosynthesis in Supernovae and Gamma-Ray Bursts

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Neutrinos play an important and often pivotal role in a variety of nucleosynthesis processes, from big bang nucleosynthesis to the r-process. Here we present a overview of these processes, paying particular attention to those thought to occur in the intense neutrino flux of the core-collapse supernova. Recent work on the influence of neutrinos on element formation in the related extreme environment of the gamma-ray burst will also be discussed.

Friday 17:50 - 18:20

Role of the fission in r-process nucleosynthesis - Needed input

Aleksandra Kelić[1] and Karl-Heinz Schmidt[1]

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Fission can have an important influence on the termination of the r-process and on the abundances of long-lived actinides, which are relevant for determinating the age of the Universe. Fission can also influence the abundances of nuclei in the region $A \sim 90$ and 130 due to the fission cycling. Studies on the role of fission in the r process began forty years ago [1]. Meanwhile, extensive investigations on beta-delayed, neutron-induced and neutrino-induced fission have been performed. One of the common conclusions from all this work is that the influence of fission on the r process is very sensitive to the fission-barrier heights of heavy r-process nuclei with $A > 190$ and $Z > 84$, since they determine the calculated fission probabilities of these nuclei. Moreover, information on mass- and charge-distributions of fragments formed in the fission of these heavy r-process nuclei is essential if one wants to calculate r-process abundances. Unfortunately, experimental information is only available for nuclei in a limited region of the nuclide chart, and for heavy r-process nuclei one has to rely on theoretical predictions. Recently, important progress has been made in developing full microscopic approaches to nuclear fission. Nevertheless, due to the complexity of the problem, this type of calculations is still difficult to apply to heavy nuclei and, moreover, the precision of these models is often still low. In this contribution, we will concentrate on the status of experimental and theoretical knowledge on fission which is needed as input for r-process calculations. We will discuss in details the heights of fission barriers and the fragment formation in fission. Firstly, using available experimental data on saddle-point and ground-state masses, we will present a detailed study on the predictions of different models concerning the isospin dependence of saddle-point masses [2]. Secondly, we will present a model for calculating mass- and charge-distributions of fission fragments that can correctly predict the transition from double-humped to single-humped distributions with decreasing mass of the fissionning system and increasing excitation energy as seen in experimental data.

[1] P.A. Seeger, W.A. Fowler and D.D. Clayton, Astrop. J. **11** Suppl., S121 (1965).
[2] A. Kelić and K.-H. Schmidt, Phys. Lett. B **643**, 362 (2005).

POSTERS

7 Poster session

Low-Threshold Proton-Recoil Detectors for nELBE

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For experiments at the new neutron source nELBE at the superconducting electron accelerator ELBE, where neutrons in the kinetic energy region from some tens of keV to a few MeV will be produced by bremsstrahlung, neutron-time-of-flight detectors have been developed. These detectors are made from the plastic scintillator material EJ-200. Efficiency calibration showed more than 10 % efficiency for kinetic energies down to 30 keV. The calibration was done at the „accelerator facility for fast neutron research“ at Physikalisch-Technische Bundesanstalt in Braunschweig, using pulsed quasi-monoenergetic neutron fields with a well-determined fluence. The low detection threshold was obtained by coincident readout of two Hamamatsu R2059-01 photomultiplier tubes per scintillator and by triggering just below the single-photo-electron peak of these photomultiplier tubes, which additionally gives a well-reproduceable detection threshold.

[1] R. Beyer et al., Nucl. Instr. Meth. A, in press, DOI:10.1016/j.nima.2007.02.096.

Electron Screening in Alpha Decay

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Strongly enhanced electron screening observed recently in d+d fusion reactions and some other low energy nuclear reactions in metallic environments results mainly from quasi free valence electrons. Since the alpha decay probability depends on the penetration through the Coulomb barrier, the alpha decay half-lives should be smaller in metallic environments compared to those in insulators. Theoretical calculations of the electron screening in alpha decay based on the results obtained for the d+d reactions will be presented as motivation for future experimental studies. Contrary to previous calculations, the effects of dynamic screening and screening within nuclei will be included. This leads to a significant reduction of half-live differences between metallic and insulating environments.

Measurement of the ^{206}Pb(n, γ) cross section and its implications in stellar nucleosynthesis

C. Domingo-Pardo[1,2], et al. (The n_TOF Collaboration)

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[2]*Instituto de Física Corpuscular, CSIC-Universidad de Valencia, Spain*

The neutron capture cross section of ^{206}Pb has been measured at the CERN n_TOF spectrometer using a setup of two small C_6D_6 detectors. In the energy interval from 1 eV to 620 keV the cross section is dominated by resonances, which were analyzed via the R-matrix analysis code SAMMY. In the relevant energy ranges for stellar nucleosynthesis, i.e., at thermal energies of $kT = 8$ keV and $kT = 23$ keV the Maxwellian average cross section determined here differs by 20% and 9%, respectively, from the values reported in previous measurements [1]. These discrepancies have been understood in terms of the lower neutron sensitivity of the new setup and the minimization of angular distribution effects in the detection of the capture γ-rays. From the new cross section the s-abundance of ^{206}Pb could be now reliably determined as 70(4)%. This result is of importance in order to test and constrain r-process abundance calculations in the actinide region, because the r-process portion of ^{206}Pb is dominated by α-back decays of short lived transbismuth isotopes.

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Isospin dependence of quark deconfinement in Heavy Ion Collisions and in Compact Stars

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We study the transition from hadronic matter to a mixed phase of quarks and hadrons at high baryon and isospin densities, reached in heavy-ion collisions. We study in detail the formation of a drop of quark matter in the mixed phase and we discuss the effects on the quark drop nucleation probability of the finite size and finite time duration of high density region [1]. We apply this technique to the interpretation of the recent analysis of heavy ion scattering at energies of $2-10$ A GeV [2], indicating a significant reduction of the nuclear incompressibility. We fix the parameters of the MIT bag model to reproduce the observed reduction of the incompressibility. Finally, we discuss the implications of our results for the structure and formation of compact stars [4,5].

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[2] V.N. Russkikh, Yu.B. Ivanov, Phys. Rev. C **74**, 034904 (2006).
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NEPTUN - The low-energy photon tagger at S-DALINAC

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A new low-energy photon tagger is installed at the superconducting electron linear accelerator S-DALINAC at Darmstadt University of Technology. NEPTUN is a tool for the investigation of the photoresponse of atomic nuclei with very high energy resolution. The energy of the tagged photons ranges from 8 MeV to 20 MeV, therewith it covers the particle threshold and the low-energy tail of the giant dipole resonance (GDR) of many stable isotopes. The tagger is designed to tag 10^4 photons per second and keV. The high energy resolution of 25 keV allows to compare and extend our current investigations at lower energies [1,2].
It is vital for a precise measurement of (γ,n) reaction rates close above the neutron threshold. The cross section in this energy region is the basis for our astrophysical activities in studying the s and p processes [3]. NEPTUN will complete and extend the data taken from our activation experiments. In November and December 2006 first test experiments at NEPTUN were sucessfully done.
This project has been supported by DFG (SFB 634) and BMBF (06 DA 129 I).

[1] T. Hartmann *et al.*, Phys. Rev. Lett. 93 (2004) 192501
[2] A. Zilges *et al.*, Phys. Lett. B 542 (2002) 43
[3] K. Sonnabend *et al.*, Phys. Rev. C70 (2004) 035802

Photoactivation of ^{92}Mo and investigation of the short-lived isomer in ^{91}Mo with the new pneumatic delivery system at ELBE

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The photodisintegration cross section of the nucleus ^{92}Mo is important for p-process nucleosynthesis. The superconducting electron accelerator ELBE at Forschungszentrum Dresden-Rossendorf provides the possibility to investigate photodisintegration with bremsstrahlung using the photoactivation technique.
The reaction $^{92}\mathrm{Mo}(\gamma,\mathrm{p})^{91}\mathrm{Nb}$ was studied using the decay of $^{91\mathrm{m}}$Nb with a 60.9 d half-life at ELBE [1].
Now the reaction $^{92}\mathrm{Mo}(\gamma,\mathrm{n})^{91}\mathrm{Mo}$ has been probed using the new pneumatic delivery system to determine the activity of $^{91\mathrm{m}}$Mo (half-life: 65 s).
Since the isomer $^{91\mathrm{m}}$Mo decays also into $^{91\mathrm{m}}$Nb it was necessary to measure this process to separate the (γ,n) from (γ,p) contributions.

[1] M. Erhard, C. Nair et al., PoS (NIC-IX) 056 (2006)

Topology of “white”stars in relativistic fragmentation of light nuclei in nuclear emulsion

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In the present paper, experimental observations of the multifragmentation processes of light relativistic nuclei carried out by means of emulsions are analysed. Events of the type of “white” stars in which the dissociation of relativistic nuclei is not accompanied by the production of mesons and by the target-nucleus fragments are considered.
A distinctive feature of the charge topology in the dissociation of the Ne, N, Mg, Si, and S nuclei is an almost total suppression of the binary splitting of nuclei to fragments with charges higher than 2. The growth of the nuclear fragmentation degree is revealed in an increase in the multiplicity of singly and doubly charged fragments with decreasing charge of the non-excited part of the fragmenting nucleus.
The processes of dissociation of stable Li, Be, B, C, N, and O isotopes to charged fragments were used to study special features of the formation of systems consisting of the lightest α, d and t nuclei.

A new experimental set up for low cross section measurements

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The evolution of stars is mainly governed by nuclear reactions which occur in the kern at very high temperature. Among these reactions, the CNO cycle, first described by Bethe in 1939 [1], governs the energy production in stars heavier than 2 solar masses during the hydrogen burning. Four reactions from the CNO cycle consume one proton. Those reactions have been largely studied in direct kinematics. And particularly the slowest one, the ^{14}N(p,γ)^{15}O reaction [2], that determines the rate of helium production by the CNO cycle.
Usually, those reactions are studied by working in direct kinematics. But a background, due to other reactions induced by protons on impurities, interferes with the gamma rays coming from the studied reaction. This is much unappreciated if one is interested in low cross section measurements. To overcome this problem, we propose to investigate those reactions in reverse kinematics. Thus we carried out a hydrogen standard. It must be stable under ion irradiation and cannot contain deuterium as (d,p) and (d,n) reactions have much higher cross sections than the (p,γ) ones. This standard was produced by ion implantation of ^{1}H in silicon as it is well known that hydrogen is stable in this state [3]. Moreover, with this technique, we can separate hydrogen and deuterium.
We have investigated the ^{13}C(p,γ)^{14}N reaction by measuring the 511 keV resonance to validate our standard. A detailed study concerning all the experimental set up was done to determine the optimal conditions of future investigations. A work in UHV is necessary and we will use a new efficient HPGe detector placed at 0 $^\circ$. It will be surrounded with a lead castle to reduce the natural background and surmounted with a scintillator detector to suppress the cosmic radiation background.

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[2] LEMUT A. et al., Phys. Lett. B **634** 483 (2006).
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Study of the production of kaons in the collisions of nucleons

Damian Gil[1] for the COSY-11 collaboration

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Kaon and antikaon production cross sections in nucleon-nucleon interactions constitute one of the most serious uncertainties in the transport models used for studies of particles production in heavy-ion collisions. Informations about processes occurring during such collisions are gained, in particular, by the registration of the K^+ and K^- mesons which were created in the fireball region. However, in order to learn, from the observed kaon yields and momentum distibutions, about dense baryonic matter and properties of strange particles immersed in it, knowledge of their creation in the elementary nucleon-nucleon collisions is indispensable.

In some papers [1], authors apply the kaon in-medium properties extracted from heavy-ion data to the study of neutron star properties. As they found, the maximum mass of neutron stars is about $2M_\odot$, which is reduced to about $1.5M_\odot$ once kaon condensation as constrained by heavy-ion data is introduced.

Poster shows experimental results from COSY-11 installation, where the total cross section for the reaction pp $\rightarrow ppK^+K^-$ has been determined at four excess energies below the ϕ production threshold: $Q = 6$MeV (with very low statistics), 10MeV, 17MeV, and 28MeV.

The new data show a significant enhancement of the total cross section compared to pure phase space expectations and calculations within a one boson exchange model.

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Photon-plasmon transition 2S-1S in the positronium and astrophysical applications

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The positronium Ps is an exotic hydrogen isotope with the atomic mass M=2m 1 milli-amu and ground state binding energy of E=6,8 eV. The hfs states of Ps differ in spin S, lifetime t and mode of annihilation: para-Ps S=0; 2γ annihilation) and ortho-Ps, S=1; 3γ annihilation). As a rule, probabilities of the cascade radiation transitions are more than the annihilation probability. The ortho-Ps atom has a metastable state 23s1 and probability of two-photon radiation transition from this state into 1S state ($1.8 \cdot 10^{-3}$ s^{-1}) is significantly less than probability of the three-photon annihilation directly from 2S level ($8.9 \cdot 10^{5}$ s^{-1}), i.e. it is usually supposed that the ortho-Ps annihilates from 2S state. Another situation may take place in plasma, where it is arisen the competition process of destruction of the metastable level - the photon-plasmon transition 2S-1S with emission of photon and Langmuir quanta. In this paper we carried out calculation of the probabilities of the photon-plasmon transitions in the Ps within the energy QED approach. The approach represents the decay probability as an imaginary part of energy shift dE, which is defined by S-scattering matrix of second (and higher) orders. Standard S-matrix calculation with using an expression for tensor of dielectric permeability of the isotropic plasma and dispersion relationships for transverse and Langmuir waves [2] allows getting the corresponding probability P(ph-pl). Numerical value of P(ph-pl) is $5.2 \cdot {*}10^{6} \cdot$U, where U is a density of the Langmuir waves energy. Our value is correlated with estimate, available in literature P=$6 \cdot {*}10^{6} \cdot$U. Comparison of the obtained probability with the life time $t(3\gamma)$ allows getting the condition of predominance of the photon-plasmon transition over three-photon annihilation. It is very important that considered transition may control the population of 2S level and search of the long-lived Ps state can be used for diagnostics of the plasma turbulence and other astrophysical applications.

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Studies of the ^{12}C nucleus in an implantation experiment using β-decay of ^{12}N and ^{12}B

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^{12}C is the fourth most abundant element in the universe and plays a major role in nuclear synthesis in stars. The triple alpha reaction in red giant stars is the key to spanning the A = 5-8 mass gap and serves as a starting point for synthesis of heavier elements. Information about states in ^{12}C is important to nuclear astrophysics, since it will increase our understanding of stellar nucleosynthesis processes.

The structural properties of the ^{12}C nucleus are not fully understood. Some can be explained by mean-field theory and others by a model describing ^{12}C as a cluster of 3 alpha particles, but neither provide a complete description. New ab-initio calculations have been published and the results are promising giving good agreement with experimental data in the literature. New experimental data are important to test these models.

In a recent experiment which took place at KVI in Groningen, the Netherlands, β-decay of ^{12}N and ^{12}B was used to populate states in ^{12}C. The beams were implanted in a segmented detector and thus made it possible to measure absolute branching ratios to the populated states directly. Using a segmented detector increases the statistics by orders of magnitude compared to previous experiments, and should increase the precision of the branching ratios significantly. By implanting the beam in the detector is also possible to measure the lowest energy particles including break-up of the Hoyle state just 0.38 MeV above the 3 alpha threshold. Preliminary results of the analysis will be presented including absolute branching ratios, B_{GT} values, $\log ft$ values and asymmetry parameters for the populated states.

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Nuclear quadrapole moments, hyperfine structure constants for heavy and superheavy ions. Radiation transition probabilities between hfs components for ions of Fe in Supernova

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A great interest to problem has been stimulated by inaugurating the heavy-ion synchrotron storage cooler ring combination SIS/ESR at GSI. With this facility, which allows to produce, store and cool fully stripped heavy ions beams up to U92+, new ways are opened in atomic and nuclear physics. Paper is devoted to calculation of the spectra, energy shifts and widths, hyper fine structure (fs) parameters for some hadronic (pion, kaon) atoms and super heavy ions. The separated problem is calculation of the radiation transition probabilities between hfs components for ions of Fe in Supernova 1987. A new, QED perturbation theory [1] allows an accurate account of relativistic, correlation, nuclear, radiative effects. One of the main purposes is establishment of a quantitative link between quality of the nucleus structure modelling and accuracy of calculating energy and spectral properties. Zeroth approximation is generated by the effective functional, constructed on the basis of the comprehensive gauge invariance procedure [1]. The wave functions zeroth basis is found from the Klein-Gordon (pion atom) or Dirac (kaon) equation. The potential includes the effective core potential, electric and polarization potentials of a nucleus (the Fermi and Gauss models of nucleus are used). For low orbits there are important effects due to the strong hadron-nuclear interaction (pion atom). The energy shift is connected with length of the hadron-nuclear scattering (scattering amplitude under zeroth energy). The magnetic inter-electron interaction is accounted in the lowest (on alpha parameter; alpha is the fine structure constant), the Lamb shift polarization part- in the Uhling-Serber approximation, self-energy part of the Lamb shift is accounted for effectively with using the Green functions method. We carried out calculation of the energy levels, hyperfine structure intervals, nuclear quadrupole moments for heavy and superheavy H- and Li-like ions, atoms of Hg, Ra and X(118) and the shifts and widths of transitions (2p-1s,3d-2p, 4f-3d) in some pionic and kaonic atoms (Kr , $K\text{-}^{-}$He etc.). We present the results of calculating the radiation transition probabilities between hfs components for ions of Fe in Supernova 1987 too.

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Towards global optical α potentials: Study of the ^{89}Y$(\alpha,\alpha)^{89}$Y elastic scattering

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The stable proton-rich nuclei with charge number Z$\geq$34 are the so-called p-nuclei [1]. It is generally accepted that the main stellar mechanism synthesizing these nuclei — the so-called p-process — is initiated by (γ,n) photodisintegration reactions on preexisting more neutron-rich seed nuclei. As the neutron separation energy increases along this path towards more neutron deficient isotopes, (γ,p) and (γ,α) reactions can take place.
The modelling of the astrophysical p-process requires a reaction network of thousands of nuclear reactions. The reaction rates on heavy nuclei necessary for obtaining p-nuclei abundances are calculated from Hauser-Feshbach type statistical models. For reactions involving α particles, one of the most important input parameters for the calculation is the α-nucleus optical potential that needs to be known in the low energy region relevant for the p-process. The optical potentials are usually taken from global parameterizations which, however, are tested experimentally only at much higher energies. It is therefore necessary to test the global optical potentials at low energies. In recent years, elastic α scattering experiments have been performed on several isotopes at ATOMKI, Debrecen and the results have been compared with model predictions [2-5]. However, all these measurements have been carried out on even-even nuclei.
In the present work, angular distributions of elastic α scattering on the odd Z, neutron magic nucleus, ^{89}Y have been measured at energies of 15.5 and 18.6 MeV with high precision. The measured angular distributions are compared with predictions using different global optical potentials. Based on the experimental differential cross sections, a local optical potential has been also constructed for ^{89}Y using double folding and Woods-Saxon potentials for the real and imaginary parts of the potential, respectively. An analysis was carried out also in order to obtain an optical potential able to describe the whole systematics of elastic scattered alpha particles on ^{89}Y [6].
Comparison with the previous elastic α scattering experiment on ^{92}Mo [3] allows us to investigate the behavior of the α-nucleus optical potential parameters as a function of the proton number for N=50 semi-magic nuclei. Results are compared with the predictions using different global optical potential parameter sets.

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Measurement of $^{3}He(\alpha,\gamma)^{7}Be$ cross section with ERNA Recoil Separator

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The $^{3}He(\alpha,\gamma)^{7}Be$ reaction plays an important role in the interpretation of the results of the solar neutrino experiments, since the estimate of the oscillation parameters relies on the solar neutrino spectrum, calculated by solar models. The high energy component in this spectrum is mainly produced by the decay of ^{7}Be and ^{8}B. The uncertainty in the $^{3}He(\alpha,\gamma)^{7}Be$ cross section is also one of the largest contributions to the uncertainty on the predicted primordial ^{7}Li abundance in Big Bang Nucleosynthesis calculations.
Previous measurements of the $^{3}He(\alpha,\gamma)^{7}Be$ cross section have been performed detecting the capture γ-rays or, alternatively, measuring the activity of the synthesized ^{7}Be. While the results of the two different approaches agree on the energy dependence of the astrophysical S factor, they disagree in the extrapolated $S_{34}(0)$ value at a 3σ level.
A novel approach uses the European Recoil separator for Nuclear Astrophysics (ERNA) to detect directly the ^{7}Be ions produced in the reaction and, additionally, the coincident capture γ-rays. The experiment and results are presented.
Supported by DFG(Ro 429/35-3) and INFN

Nuclear beam experiments at the Dubna Nuclotron

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An overview of the experiments with nuclear beams at the Dubna Nuclotron is given [1,2]. Present status of the nuclear beams accelerated at the Nuclotron is shortly characterized. Some selected experimental and methodical results obtained in the experiments performed with internal and extracted nuclear Nuclotron's beams at the VBLHE during last years are presented. Future plans of the investigations at the Nuclotron are discussed also.

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Neutron capture cross section of ^{76}Ge

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The (n, γ) cross section of ^{76}Ge is important for s-process nucleosynthesis in Red Giant Stars as well as for obtaining reliable background estimates in double beta decay experiments. So far, this reaction has been described only by theoretical data. The present measurement was based on the activation technique. Neutrons were produced at the Karlsruhe Van de Graaff accelerator via the ^{7}Li$(p, n)^{7}$Be reaction. For proton energies just above threshold, one obtains a neutron spectrum similar to a Maxwellian distribution for $kT = 25$ keV. A set of samples was irradiated in this quasi-stellar neutron spectrum together with gold foils for normalization of the neutron flux. The results obtained at $kT = 25$ keV are presented and an extrapolation to lower and higher thermal energies is suggested.

The ^{100}Mo(γ,n) cross section close above the threshold

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We measured the ^{100}Mo(γ,n) cross section directly above the neutron threshold. This energy region is relevant for *p*-process nucleosynthesis, where photons from a thermal photon bath of $T_9 \approx 2-3$ induce photodissociation reactions. Close to the valley of stability (γ,n) reactions dominate the *p*-process path, whereas further away from stability the *p*-process path branches out via (γ,p) and/or (γ,α) reactions. We used the activation method with bremsstrahlung at our High Intensity Photon Setup. This setup is located directly behind the 10 MeV injector of the superconducting electron accelerator S-DALINAC [1]. In addition with an experimental campaign at the FRS/LAND-setup at GSI as well as at the ELBE accelerator in Rossendorf [2] one wants to investigate the overabundance of the neutron deficient Mo- and Ru-isotopes. A precise knowledge of the *p*-process contributions to the abundances in the $A \approx 100$ region is mandatory to understand the impact of exotic processes like the *rp*- and νp-process [3,4] on nucleosynthesis.
This work is supported by DFG (SFB 634) and BMBF (06 DA 129 I).

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Photodisintegration studies of the type (γ, α) on astrophysically relevant p-nuclei ^{92}Mo and ^{144}Sm

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In explosive stellar environments like supernovae, the temperatures are high enough for the production of heavy neutron deficient nuclei, the so-called p-nuclei. These are thought to be produced in such scenarios either through chains of photodisintegration reactions like (γ,n), (γ,p) and (γ, α) on heavy seed nuclei [1]. In this context, the knowledge of the cross sections for the prediction of the p-nuclei abundances is of crucial importance and to forward in this direction astrophysically relevant p-nuclei are studied via photon-induced reactions using the bremsstrahlung facility of the superconducting electron accelerator ELBE of the research centre FZ Dresden-Rossendorf [2].
Photodisintegration measurements on the astrophysically relevant p-nuclei ^{92}Mo and ^{144}Sm have been performed via the photoactivation technique with bremsstrahlung end-point energies from 10.0 to 16.5 MeV. All the three types of photodisintegration reactions were observed for both nuclei and in particular the (γ, α) reactions of the mentioned nuclei were studied for the first time. The poster will mainly emphasize on the preliminary results from the(γ, α)reactions on the above mentioned nuclei. The bremsstrahlung facility and the experimental area are designed to facilitate the studies under optimized background conditions.
To probe the interesting investigations on short-lived nuclei a new pneumatic delivery system has been built recently which enables a fast access time. First experiments on the short-lived decays following the reaction ^{144}Sm(γ,n) will also be included as a subsection. The activation yields from all measurements are compared with calculations using cross sections obtained from recent Hauser-Feshbach models [3,4].

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The bulk viscosity of quark matter in compact stars

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We present our results for the bulk viscosity of spin-1 color-superconducting quark matter in compact stars. We show that color superconductivity may act to increase the bulk viscosity. Moreover, in the presence of strange quarks, it is shown that, contrary to the general expectation, the semi-leptonic *Urca* type processes can significantly enhance the bulk viscosity. Finally, we discuss the effect of the bulk viscosity on the r-mode instabilities for strange stars.

Asymmetric neutrino emission in quark matter and pulsar kicks

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The puzzling phenomenon of pulsar kicks, i.e. the observed large escape velocities of pulsars out of supernova remnants, is examined for compact stars with a strange quark matter core. The direct Urca process in quark matter is studied in the presence of a strong magnetic field. Conditions for an asymmetric emission of the produced neutrinos are worked out in detail, giving constraints on the temperature, the strength of the magnetic field and the electron chemical potential in the quark matter core. In addition, the neutrino mean free paths for quark matter and a possible hadronic mantle are considered.

Studies of light nucleus clustering in relativistic multifragmentation processes

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We give an overview of results and prospects of nuclear clustering studies on the grounds of the observations of interactions of light stable and radioactive nuclei with an initial energy above 1 A GeV in nuclear emulsions. Thank to the best spatial resolution and the full solid angle acceptance provided by nuclear emulsions, such an approach allows one to obtain unique and evident observations reflecting cluster -like features in light nuclear structures.

The importance of this research for the physics of few body nuclear systems and the related problems of nucleosynthesis is noted. The discussed explorations are provided with the beams of the Synchrophasotron and Nuclotron of JINR, Dubna.

The expected results would make it possible to answer some topical questions concerning the cluster structure of light nuclei.

Peripheral fragmentation of relativistic ^{8}B nuclei in photoemulsion

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The results of investigations dealing with the charge topology of the fragments produced in peripheral dissociation of relativistic ^{8}B nuclei in emulsion are presented [1]. 52 events of peripheral dissociation of the ^{8}B nucleus were selected from the events which do not involve the production of the target-nucleus fragments and mesons ("white" stars). A leading contribution of the ^{8}B→^{7}Be+p mode having the lowest energy threshold was revealed on the basis of those events. Information on the relative probability of dissociation modes with a larger multiplicity was obtained. The dissociation of a ^{7}Be core in ^{8}B indicates an analogy with that of the free ^{7}Be nucleus.

Some amount of "white" stars with Q=6 due to ^{10}C admixture in the composition of the beam was found also. The ^{10}C nuclei could be produced through a ^{10}B→^{10}C charge exchange in the target intended for the ^{8}B generation and could be captured to a second beam because of a small difference in the magnetic rigidity as compared with ^{8}B (about 4%) and their proper momentum dispersion. This fact points to a possible formation of a ^{10}C beam (^{10}B→^{10}C) under the conditions which are convenient for performing investigations in emulsion.

The transverse momentum distributions of the fragments from the ^{8}B→^{7}Be+p dissociation mode were obtained. Their small average value, $<P_t>=$ 45.6 MeV/c, in the c.m.s. suggests a low binding energy of the external proton in the ^{8}B nucleus. For the events in which a transverse momentum of less than 60 MeV/c is transferred to the ^{8}B nucleus there appears a strong azimuthal angle correlation between ^{7}Be and p.

In the present report the invariant approach is used to analyse the fragmentation of ^{8}B nuclei at energy 1.2 A GeV in emulsion. The new data extracted from emulsions exposed ^{8}B nuclei confirmed the advantages of the emulsion technique in obtaining unique information on the decay of light nuclei.

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Ground state capture in ^{14}N(p,γ)^{15}O studied above the 259 keV resonance at LUNA

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The cross section of the ^{14}N(p,γ)^{15}O reaction directly influences the rate of the CNO cycle of hydrogen burning. In a previous LUNA experiment the capture to the ground state and several excited states in ^{15}O have been measured and used in an R-matrix fit [1,2] in order to extrapolate reliably the cross section to stellar energies. The data for the ground state capture had been affected by the true coincidence summing effect in a large volume HPGe detector placed in close geometry [1], limiting the precision of its extrapolation. A new measurement of the cross section for capture to the ground state in ^{15}O is presently running at LUNA in Gran Sasso (Italy). A clover HPGe detector is used to reduce the summing correction. We concentrate on energies above the Ecm = 259 keV resonance, where the R-matrix fit can be constrained by precision data.

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Indirect Study of the ^{15}N(p,α)^{12}C reaction at sub-Coulomb energies via the Trojan-horse method applied to the ^{2}H(^{15}N,α^{12}C)n process

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The astrophysically relevant ^{15}N(p,α)^{12}C has been investigated at very low sub-Coulomb energies down to 20 keV by means of the Trojan-horse Method [1,2,3] applied to the ^{2}H(^{15}N,α^{12}C)n reaction at E_{beam}=60 MeV. The reaction rate of this two-body process is considered among the primary sources of uncertainty in predicting the fluorine abundance in AGB stars [4,5], whose chemical evolution is strongly influenced by the reactions belonging to the production/destruction path of ^{19}F. In particular, the ^{15}N(p,α)^{12}C reaction competes with the ^{18}O(p,α)^{15}N reaction since it removes both protons and ^{15}N nuclei from ^{19}F production chain. The astrophysical S(E)-factor for the ^{15}N(p,α)^{12}C process was extracted by selecting the quasi free mechanism from the chosen ^{2}H(^{15}N,α^{12}C)n reaction, and compared to the direct data available down to 70 keV. A good agreement is found. Below 70 keV, where no direct data exist, the Trojan Horse S(E)-factor provides a rate which confirms that obtained through the extrapolation procedure. An independent R-matrix calculation has been performed in this relevant region, introducing also destructive interference terms between ^{16}O levels with $J^{\pi}=1^{-}$. The novelty of this calculation is the introduction of the $J^{\pi}=1^{-}$ sub-threshold state at 9.585 MeV excitation energy. The result of the calculation strongly confirms the behavior of Trojan Horse data.

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A fermionic molecular dynamics technique for nuclear matter

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At subnuclear densities, nuclear matter can arrange itself in a variety of complex configurations. This can be the case in the crust of neutron stars and in core-collapse supernovae. These slablike and rodlike structures, were dubbed as nuclear pasta [1] and can be modelled using molecular dynamics techniques [2,3].
We present an approach, based on fermionic molecular dynamics [4], to model nuclear matter at subnuclear densities. The dynamical evolution of an antisymmetric ground state is studied under the assumption of periodic boundary conditions. Adding the concepts of antisymmetry, spin and probability distributions to classical molecular dynamics, brings the dynamical description of nuclear matter to a quantum mechanical level.
Applications of this model vary from the investigation of macroscopic observables and the equation of state, to the study of the response of nuclear matter to external probes.

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Fragmentation of relativistic ^{7,9}Be, ^{8}B, ^{9}C nuclei in peripheral collisions in nuclear track emulsion

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Possibilities of the nuclear emulsion technique for the study of the systems of several relativistic fragments produced in the peripheral interactions of relativistic nuclei are discussed [1]. A detailed study of the nuclear fragment ensembles makes it possible to go on to the search for complicated quasi-stationary states of fragments. In the nuclear scale of distances and excitations they can possess properties which make them analogous to dilute quantum gases in atomic physics at ultra-cold temperatures. The proof of the existence of such systems can find some important applications for the problems of nuclear astrophysics. In this respect, the fragment jets are a microscopic model of stellar media [2-5].

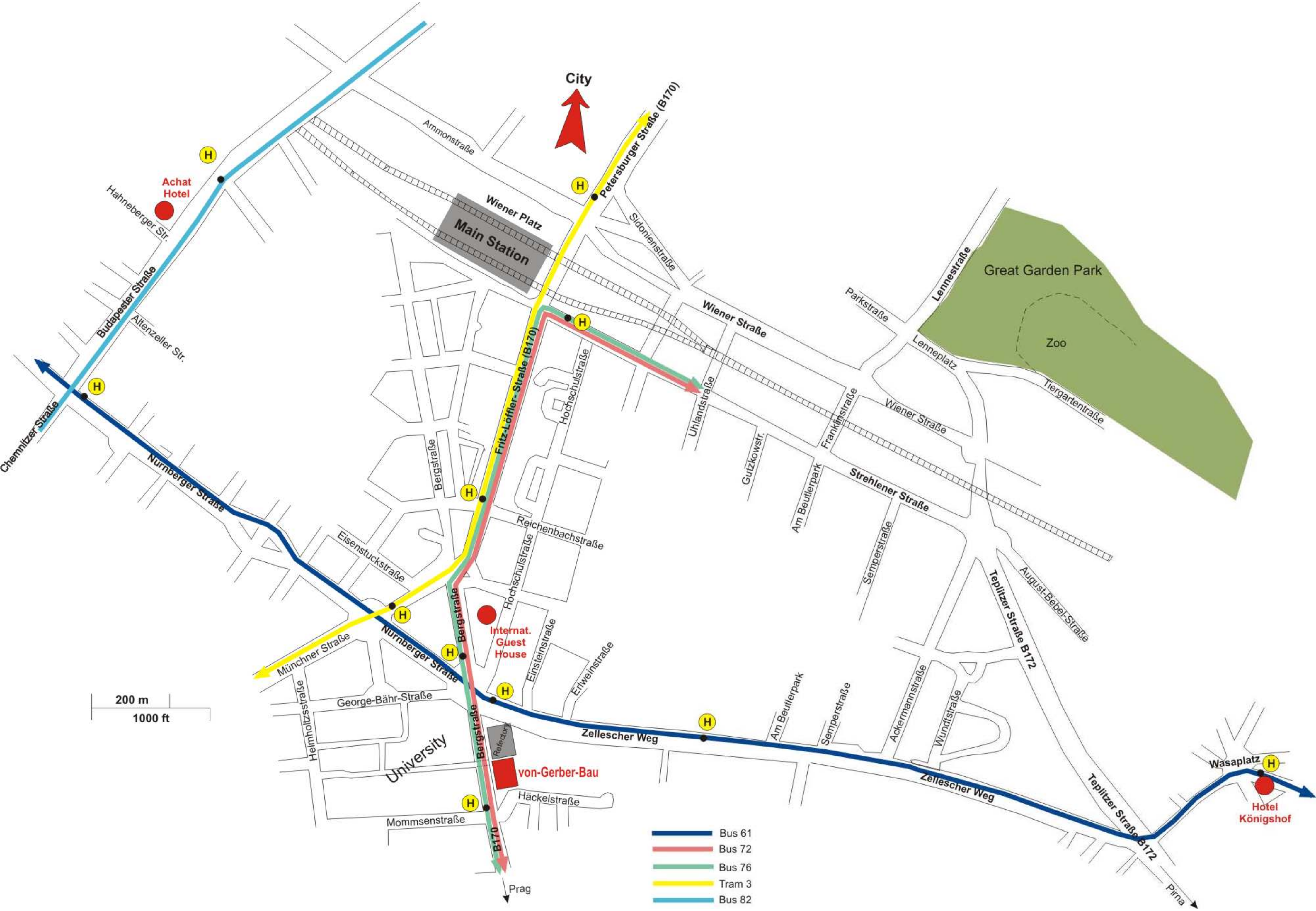
Nuclei of ^{7}Li were accelerated at the JINR Nuclotron. After the charge-exchange reaction involving these nuclei at an external target a second ^{7}Be beam of energy 1.23A GeV was formed. This beam was used to expose photo-emulsion chambers. More than 10% of the ^{7}Be events are associated with the peripheral interactions in which the total charge of the relativistic fragments is equal to the charge of the ^{7}Be and in which charged mesons are not produced. The present paper gives the channels of the ^{7}Be fragmentation to charged fragments. The particular features of the relativistic ^{7}Be fragmentation in such peripheral interactions are explained by the ^{3}He+^{4}He 2-cluster structure of the ^{7}Be nucleus [6].

The results of investigations of the relativistic ^{9}Be nucleus fragmentation in emulsion which entails the production of two He fragments of an energy of 1.2 A GeV are presented. The results of the angular measurements of the ^{9}Be→2He events are analyzed. The ^{9}Be→^{8}Be+n fragmentation channel involving the ^{8}Be decay from the ground (0^{+}) and the first excited (2^{+}) states to two α particles is observed to be predominant [7].

The results of investigations dealing with the charge topology of the fragments produced in peripheral dissociation of relativistic ^{8}B nuclei in emulsion are presented. 55 events of peripheral dissociation of the ^{8}B nucleus were selected from the events which do not involve the production of the target-nucleus fragments and mesons. A leading contribution of the ^{8}B→^{7}B+p mode having the lowest energy threshold was revealed on the basis of those events. Information on the relative probability of dissociation modes with a larger multiplicity was obtained. The dissociation of a ^{7}Be core in ^{8}B indicates an analogy with that of the free ^{7}Be nucleus [8].

New data on ^{9}C are expected to be presented.

[1] Web site of the BECQUEREL project: http://becquerel.jinr.ru.
[2] N. P. Andreeva et al., Eur. Phys. J. A 27, s01, 295-300(2006).
[3] http://arxiv.org/abs/nucl-ex/0605015
[4] http://arxiv.org/abs/nucl-ex/0605022
[5] http://arxiv.org/abs/nucl-ex/0610023
[6] http://arxiv.org/abs/nucl-ex/0605014.
[7] http://arxiv.org/abs/nucl-ex/0605018.
[8] http://arxiv.org/abs/nucl-ex/0605013.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Wiener Platz
Achat Hotel
Internat. Guest House
von-Gerber-Bau
Refectory
University
Hotel Königshof
Great Garden Park
Zoo
Chemnitzer Straße
Budapester Straße
Hahneberger Str.
Altenzeller Str.
Ammonstraße
Petersburger Straße (B170)
Sidonienstraße
Wiener Straße
Parkstraße
Lennestraße
Lenneplatz
Tiergartenstraße
Fritz-Löffler- Straße (B170)
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Wasaplatz
Häckelstraße
Mommsenstraße
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Bus 76
Tram 3
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