HK 62: Nukleare Astrophysik

Zeit: Freitag 14:00–16:15 Raum: RW 2

Gruppenbericht HK 62.1 Fr 14:00 RW 2

Study of the ^{2}H(α,γ)^{6}Li reaction and recent progress at LUNA — •Daniel Bemmerer for the LUNA-Collaboration — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

In addition to the well-known ^{7}Li problem of Big Bang nucleosynthesis, observations of ^{6}Li in very metal poor stars hint at a possible Big Bang ^{6}Li problem. Network calculations show that the ^{2}H(α,γ)^{6}Li reaction dominates ^{6}Li production in the Big Bang, but there are no direct experimental data on this reaction at relevant energies. An experiment on this reaction is underway at the 400 kV underground accelerator LUNA in Gran Sasso/Italy, and preliminary data will be shown. In addition, recent LUNA work on the ^{15}N(p,γ)^{16}O, ^{17}O(p,γ)^{18}F, and ^{25}Mg(p,γ)^{26}Al reactions and a planned ^{22}Ne(p,γ)^{23}Na study will be briefly discussed, and an outlook will be given. – Supported in part by INFN and by DFG (BE 4100/2-1).

Gruppenbericht HK 62.2 Fr 14:30 RW 2

High resolution (^{3}He,t) reaction on the $\beta\beta$ decaying nucleus ^{136}Xe — •Peter Puppe[1], Dieter Frekers[1], Annika Lennarz[1], Jan Thies[1], and Michael Holl[2] — [1]Inst. f. Kernphysik, 48149 Münster — [2]Inst. f. Theor. Physik, 48149 Münster

A (^{3}He,t) charge-exchange reaction experiment on the $\beta\beta$ decaying nucleus ^{136}Xe has been performed at an incident energy of 420 MeV. The objective was to identify the Gamow-Teller (GT) strength distribution in ^{136}Cs in an attempt to understand the long $2\nu\beta\beta$ decay half-life of ^{136}Xe. The measurements have been carried out at the Grand Raiden spectrometer of the RCNP in Osaka, where an energy resolution of 42 keV was achieved. A new gas cell with thin windows made of polyethylene naphthalate has been employed as a target.

We find that the GT^{-} strength distribution even at low excitation energies exhibits a rather normal behaviour compared to neighbouring nuclei like ^{128,130}Te. A number of well isolated states up to about 4 MeV concentrated in two separate clusters have been resolved carrying a total B(GT^{-}) strength of order unity. We argue that assuming exceptionally weak transitions from the GT^{+} side would be a rather improbable cause for the long half-life, whereas phase-cancelation effects for the $2\nu\beta\beta$ decay nuclear matrix elements seem to be a more natural and likely scenario. The data are confronted with the half-life measurement recently communicated by the EXO-Collaboration [1] and with recent theoretical calculations. The impact of phase cancellation on the neutrinoless decay will also be discussed.

[1] N. Ackerman et al., Phys. Rev. Lett. 107, 212501 (2011)

HK 62.3 Fr 15:00 RW 2

Properties of Nuclei in Dense Matter and Equation of State — •Stefan Typel[1], Thomas Klähn[2], and Gevorg Poghosyan[3] — [1]GSI, Darmstadt, Germany — [2]IFT, University of Wrocław, Poland — [3]SCC, KIT, Karlsruhe, Germany

The detailed chemical composition of dense matter is relevant for simulations of astrophysical objects such as neutron stars or core-collapse supernovae. It depends strongly on the density and temperature of the environment and affects the thermodynamic properties encoded in the equation of state. In many applications, a simple nuclear statistical equilibrium description is used assuming an ideal mixture of nuclei with experimental masses in chemical equilibrium. However, the binding energies of nuclei are modified considerably in a medium. We calculate the change of nuclear properties with density and temperature in a relativistic density functional approach using the Thomas-Fermi approximation in a spherical Wigner-Seitz cell. Both the stabilization and the dissolution of nuclei are observed depending on the thermodynamic conditions. A parametrization of the binding energy shifts can be employed in the construction of improved equation of state tables. The results are also of interest for the analysis of fragment distributions in heavy-ion collisions.

HK 62.4 Fr 15:15 RW 2

Constraining mean-field models of the nuclear matter equation of state at low densities — •Maria Voskresenskaya and Stefan Typel — GSI, Darmstadt

The description of thermodynamical properties and the composition of dense nuclear matter for astrophysical applications requires the knowledge of the equation of state in a wide range of densities and temperatures. In this work we extend a generalized relativistic mean-field (gRMF) model with density dependent couplings by considering bound states of nuclei and two-nucleon scattering correlations as explicit degrees of freedom in the thermodynamical potential. These quasiparticles are characterized by medium dependent effective resonance energies with temperature dependent effective degeneracy factors. The model interpolates between the correct low-density limit, the model independent virial equation of state (VEoS), and the RMF description around nuclear saturation density where clusters are dissolved. From the comparison of the fugacity expansions of the VEoS and the gRMF model consistency relations between the quasiparticles properties, the nucleon-nucleon scattering phase shifts and the meson-nucleon couplings of the gRMF model at zero density are derived. Relativistic effects are found to be important at temperatures that are typical in astrophysical applications. The example of neutron matter is studied in detail for different temperatures.

HK 62.5 Fr 15:30 RW 2

Quark Stars in the Quark-Meson-Model — •Margit Maly, Rainer Stiele, and Jürgen Schaffner-Bielich — Institute for Theoretical Physics, Heidelberg University, Philosophenweg 16, Heidelberg, D-69120

Compact stellar objects are nature's laboratory for probing QCD in the high density, low temperature regime. For exploring the properties of compact stars made of pure quark matter, we use an effective model for the quark interaction respecting the chiral symmetry of the original QCD-Lagrangian. This linear sigma model including quark degrees of freedom is complemented by an repulsive interaction coming in through vector meson exchange. By varying the free parameters of the model one can set up several different equations of state which result in various mass-radius-relations for quark stars.

By using the recent new mass limit for compact stars from pulsar PSR J1614-2230 of $M=(1.97 \pm 0.04)M_{\odot}$, we constrain the possible parameter space of our model and discuss implications for the possible existence of selfbound quark stars.

HK 62.6 Fr 15:45 RW 2

Fission-Fusion: a new Reaction Mechanism for Nuclear Astrophysics based on Laser-Ion Acceleration* — •P.G. Thirolf[1], D. Habs[1,2], K. Allinger[2], J. Bin[2], W. Ma[2], J. Schreiber[1], and H. Wong[2] — [1]LMU München — [2]MPI f. Quantenoptik, Garching

High power short-pulse lasers with peak powers presently reaching up to PW levels routinely reach focal intensities of 10^{18} - 10^{21} W/cm^{2}. These lasers are able to produce a variety of secondary radiation, from relativistic electrons to multi-MeV/nucleon ion beams. Compared to ion beams generated by conventional accelerators, laser-accelerated ion bunches can reach ultra-high densities around solid-state density, exceeding classical ion beams by up to 10^{15}. These properties will allow to investigate a new reaction mechanism, 'fission-fusion', opening the perspective to generate extremely neutron-rich fusion products e.g. towards the N=126 waiting point of the r process path. Laser-accelerated ^{232}Th ions pass through a second Th foil, where target-like and beam-like Th nuclei will desintegrate into heavy and light fission fragments. Due to the high beam density, subsequent fusion between two light (neutron-rich) fission fragments can occur, resulting in a very neutron rich fusion product. A new EU-funded large-scale research infrastructure ELI-NP (Extreme Light Infrastructure) will be built until 2016 in Bucharest for high-power laser-based nuclear physics. This facility with an unprecedented laser intensity of 10^{24} W/cm^{2} will allow to exploit the new fission-fusion reaction mechanism.

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HK 62.7 Fr 16:00 RW 2

Integrated nucleosynthesis in neutrino-driven winds — •Lutz Huther[1,2], Tobias Fischer[1,2], Gabriel Martinez-Pinedo[1,2], and Karlheinz Langanke[1,2,3] — [1]TU Darmstadt, Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [3]Frankfurt Institute for Advanced Studies, Frankfurt

The neutrino driven wind from core collapse supernova is considered as one of the sources of elements heavier than iron. However, its contribution to different elements and its dependence with progenitor mass

has not yet been determined. We perform a detailed nucleosynthesis study based on recent long-time simulations using Boltzmann neutrino transport. These simulations have been performed for stars of different progenitor masses (8.8, 10.8 and 18.0 $M_{\odot}$) and for times of several tens of seconds after the onset of the explosion. The ejected matter is always proton rich. Using an extended nuclear network that includes all relevant nuclear and weak processes, we have determined the integrated nucleosynthesis outcome and its sensitivity to the progenitor mass. We show that proton rich winds can account for the metal-poor star observations of light r-process elements, $Z < 56$. Furthermore depending on the late time dynamics of the ejecta, we find that after the freeze-out of proton captures at temperatures around 1 GK, there is a phase dominated by neutron captures that drives material to the neutron rich side of stability. During this phase the elemental abundances do not change, but the resulting isotopic abundances are in agreement with solar system abundances.