HK 25: Nuclear Astrophysics III

Time: Wednesday 13:45–15:30 Location: PHIL A 602

Group Report HK 25.1 Wed 13:45 PHIL A 602

Collisional Radiative Data for non-LTE Kilonova Radiative Transfer — •Andreas Flörs[1], Ricardo Silva[2], and Gabriel Martínez-Pinedo[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Laboratório de Instrumentação e Física Experimental de Partículas (LIP), Lisboa, Portugal

Recent infrared spectroscopy from the James Webb Space Telescope (JWST) has transformed kilonova studies, with detailed nebular-phase spectra now available for AT 2023vfi, the second spectroscopically observed kilonova and the counterpart to GRB 230307A. Observations reveal rich mid-infrared emission, with features tentatively attributed to r-process elements such as tellurium. These data extend well beyond what was possible for the first kilonova AT2017gfo and highlight the need for robust atomic and collisional data to interpret kilonova spectra in the non-local thermodynamic equilibrium (non-LTE) regime.

Non-LTE radiative transfer modelling of kilonovae relies on comprehensive collisional-radiative datasets, including electron impact excitation and forbidden transitions for heavy ions. In this talk, I will present calibrated large-scale collisional-radiative atomic structure calculations for lanthanide ions, and show how their inclusion in radiative transfer models improves agreement with JWST observations of AT2023vfi. These results enable more robust elemental abundance determinations and provide new constraints on r-process nucleosynthesis.

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HK 25.2 Wed 14:15 PHIL A 602

Analysis of Coulomb Breakup of Clustered Nuclei for the Determination of Radiative Capture Cross Sections: The case of $\alpha(d,\gamma)^6Li$ — •Monica Sanjinez Ortiz and Pierre Capel — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany

In the study of nucleosynthesis, the cross section of radiative capture reactions involving charged particles plays a fundamental role. However, the direct experimental measurement of these cross sections is difficult at low energy. Coulomb breakup of nuclei on a heavy target has been considered as an alternative method to infer the low-energy cross sections in an indirect way, as it can be understood as the time reversed process of radiative captures. Two Coulomb breakup experiments to infer the $\alpha(d,\gamma)^6Li$ radiative capture cross section have been performed in the past. With a fully dynamical reaction model, we report here on a new theoretical analysis of these experiments. Our results indicate that the breakup of ^6Li onto ^{208}Pb at 150 A MeV and 26 A MeV is characterized by marked Coulomb-nuclear interferences. Moreover, the analysis points towards a nuclear dominated process at forward angles as Coulomb breakup is suppressed due to the α-d clustered structure of ^6Li. Consequently, extracting radiative capture cross sections from data at these energies is unfeasible. The forward Coulomb breakup suppression may be a general feature of breakup processes involving N=Z clustered nuclei. We underscore the importance of alternative indirect methods for the determination of cross sections for astrophysics such as photodissociation induced by electrons.

HK 25.3 Wed 14:30 PHIL A 602

Simulation and Analysis of Three-α Decay in ^{12}C with Geant4 — •Timo Biesenbach[1], David Werner[1], Peter Reiter[1], Alessandro Salice[1], Joe Roob[1], Konrad Arnswald[1], Maximilian Droste[1], Madalina Enciu[3], Pavel Golubev[2], Hannah Kleis[1], Nikolas Königstein[1], Dirk Rudolph[2], and Luis Sarmiento[2] — [1]University of Cologne, Institute for Nuclear Physics, Cologne — [2]Lund University, Department of Physics, Lund, Sweden — [3]TU Darmstadt, Institute of Nuclear Physics, Darmstadt

The branching ratios of direct and sequential three-α decay modes of the 0_2^+ Hoyle state in ^{12}C provide a sensitive probe of its internal structure and play a key role in our understanding of stellar nucleosynthesis. A high-statistics experiment was conducted at the 10 MV FN Tandem Accelerator at the University of Cologne using inelastic scattering via the $^{12}C(\alpha,\alpha')$ reaction at an incident energy of 27 MeV. The decay products were detected with the Lund–York–Cologne Calorimeter, which combines high angular resolution with large acceptance of Si strip detector arrays. To enable a precise interpretation of the data, the experiment was modelled within the Geant4 Monte Carlo framework. The simulation incorporates the full experimental geometry, detector response, beam characteristics, target properties, and relevant physical processes. By performing a detailed comparison between the measured observables and the simulated decay scenarios, the branching ratio of the direct decay component is extracted. These results provide constraints on the three-body decay dynamics of the Hoyle state.

HK 25.4 Wed 14:45 PHIL A 602

Proof-of-principle neutron photo-dissociation measurement in the ^{7}Li(e,e'n)^{6}Li reaction — •Davud Sokolovic[1], Jan Butz[1], Pierre Capel[2], Tanja Heftrich[1], Michael Heil[3], Carolin Grün[1], Samira Ikerkourn[1], Felix Panholzer[1], and Concettina Sfienti[2] — [1]Goethe-Universität, Frankfurt am Main, Deutschland — [2]Johannes Gutenberg-Universität, Mainz, Deutschland — [3]GSI, Darmstadt, Deutschland

As neutron capture processes are fundamental to our understanding of the element abundance distribution in the universe, measurements of (n,γ) in direct kinematics are essential. For many nuclei, these measurements are not easily accessible due to low reaction rates or strong backgrounds from competing channels. Thus, time-reversed reactions induced by virtual photons provide a complementary approach to determine neutron capture cross sections via detailed balance.

In this talk, the concept and first steps of a proof-of-principle neutron photo-dissociation measurement in the $^7Li(e,e'n)^6Li$ reaction at the Mainz Microtron (MAMI) are presented including GEANT4 simulation studies used to map electromagnetic and photonuclear backgrounds and to optimise the placement of a lithium-glass neutron detector.

The kinematic strategy is chosen to mimic an s-wave entrance channel into a p-wave bound state, favouring an $E1$ transition to the ground state. In view of these requirements, DICEBOX simulations are performed to estimate ground-state branching ratios and identify further target candidates. The status of the analysis will be reported.

HK 25.5 Wed 15:00 PHIL A 602

Investigating BBN cross sections: Characterization of the DT neutron generator in Dresden and the new ASTRO beam line — •Max Osswald[1], Daniel Bemmerer[2], Björn Lehnert[1], Steffen Turkat[1], Frederik Uhlemann[1], and Kai Zuber[1] — [1]TU Dresden — [2]Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

The Deuterium-Tritium neutron generator of TU Dresden can provide several milliamperes of proton and deuteron beams with energies of up to 350 keV. So far the accelerator was used to generate monoenergetic 14 MeV neutrons for fusion research via the $^3H(d,n)^4$He reaction with up to 10^{12} n/s.

This contribution will present the feasibility studies and modifications required to transform this neutron production facility into a laboratory, which in addition will also be used for nuclear astrophysics, i.e. investigations of reactions relevant for Big Bang Nucleosynthesis (BBN). Key parameters such as beam characterization, energy calibration, and operational limits will be reported, providing the basis for future high-precision cross-section measurements. In addition, the new ASTRO beam line and the collaborative effort to use the ELISSA silicon strip detector array in Dresden will be introduced for the first time. These upgrades enable forthcoming studies of the $d(d,p)^3$H and $d(d,n)^3$He reactions, which currently limit our understanding of the primordial deuterium abundance in BBN models.

HK 25.6 Wed 15:15 PHIL A 602

Geant4 simulation towards the measurements of $^2\mathbf{H}(d,p)^3\mathbf{H}$ and $^2\mathbf{H}(d,n)^3\mathbf{He}$ reactions at the DT generator of TU Dresden — •Frederik Uhlemann, Björn Lehnert, Max Osswald, Steffen Turkat, and Kai Zuber — Institut für Kern- und Teilchenphysik, TU Dresden

The $^2H(d,p)^3$H and $^2H(d,n)^3$He reactions are critical for determining the primordial deuterium abundance D/H after Big Bang nucleosynthesis. Improved cross section data for these channels would reduce the uncertainty on the cosmic baryon density $\Omega_b h^2$. The resulting value could reach a precision comparable to that of the CMB, while remaining fully independent. This would improve our understanding of early universe physics and provides a powerful cross-check for en-

tirely independent fields of (astro-)physics.
The Deuterium-Tritium neutron generator of TU Dresden is a unique facility in Europe that was mainly used for fusion research so far. Based on its new ASTRO beam line, this facility will be capable to measure these two reaction channels from 10 keV to 350 keV, which covers the entire energy range relevant for BBN. Measurements of the two deuterium reactions using solid targets are planned. This talk will focus on Geant4 simulations for this campaign, with a focus on the setup, utilized targets and detectors.