HK 35: Heavy-Ion Collisions and QCD Phases VI

Time: Wednesday 17:30–19:00 Location: HS 3 Chemie

HK 35.1 Wed 17:30 HS 3 Chemie

Study of (anti)deuteron production in proton-proton collisions with ALICE at the LHC — •Rutuparna Rath for the ALICE Germany-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, GmbH, Darmstadt, Germany

The measurement of (anti)nuclei production in small collision systems, such as proton-proton (pp) collisions, provides valuable insights into the nucleosynthesis mechanisms in our Universe. Antinuclei can form through two primary processes: the interaction of cosmic rays with the interstellar medium or the decay/annihilation of dark matter candidates. The coalescence model is commonly employed to describe the production of nuclei, where light nuclei are formed from the overlap of nucleon phase-space distributions with the Wigner density of the bound state. Light (anti)nuclei have been extensively studied in small collision systems using ALICE at the LHC. In this contribution, we present results on (anti)deuteron production in pp collisions at various center-of-mass energies. The coalescence parameter, B_2, which quantifies the probability of coalescence, is analyzed within the framework of modern coalescence models.

Furthermore, utilizing the extensive dataset collected by ALICE during Run 3, new results on (anti)deuteron production in pp collisions are reported. These measurements enable, for the first time, the determination of the coalescence parameter and source radii for the lowest energy (900 GeV) achieved yet from the LHC run in small collision systems, providing deeper constraints on their dependence on the initial state.

HK 35.2 Wed 17:45 HS 3 Chemie

Decoding light (anti)nuclei formation with femtoscopy in ALICE — Laura Fabbietti, Bhawani Singh, Dimitar Mihaylov, Maximilian Mahlein, and •Marcel Lesch for the ALICE Germany-Collaboration — TU München, Garching, Germany

The formation of light (anti)nuclei in ultra-relativistic nuclear collisions remains one of the longest-standing puzzles in hadronic physics. In recent years, two primary theoretical frameworks have been proposed to address this question. Statistical hadronization models posit that light (anti)nuclei emerge directly from a thermalized medium alongside all other hadrons. In contrast, coalescence models describe light (anti)nuclei formation due to nucleons fusing together after freeze-out. However, both models can successfully describe key observables, such as deuteron yields. To further investigate this puzzle, we present recent results from ALICE on p–$\pi^\pm$ and d–$\pi^\pm$ femtoscopy in pp collisions at $\sqrt{s} = 13$ TeV. Understanding the pion-multinucleon (d–$\pi^\pm$) system begins with a detailed study of p–$\pi^\pm$ correlations, which serve as a baseline for the pion-nucleon dynamics. These correlations exhibit pronounced resonance structures, providing insights into the life of Δ resonances produced in ultra-relativistic nuclear collisions. Similar structures are observed in d–$\pi^\pm$, revealing residual correlations from pions and nucleons that stem from a common Δ decay before the deuteron formation. These findings suggest that pion-assisted fusion processes play a significant role in light (anti)nuclei production, offering new perspectives on this long-standing puzzle.

Funded by the DFG under Grant SFB 1258.

HK 35.3 Wed 18:00 HS 3 Chemie

A Realistic Coalescence Model for Nuclei Production — •Maximilian Mahlein — Technische Universität München

Understanding the formation of (anti)nuclei in high-energy collisions has attracted large interest over the last few years. According to the coalescence model, nucleons form independently and then bind together after freeze-out if they are close in phase-space. A recent advancement of the model is the Wigner function formalism, which allows the calculation of the coalescence probability based on the distance and relative momentum of the constituent nucleons. The interest in explaining nuclear formation processes extends beyond standard model physics, with implications for indirect Dark Matter searches. Understanding the production mechanism of antinuclei is crucial for correctly interpreting any future measurement of antinuclear flux in space, as it would allow for the differentiation of the background originating from collisions between high-energy Cosmic Rays and the stationary Interstellar Medium. In this presentation, we provide a comprehensive overview of the state-of-the-art coalescence formalism, not only for deuterons but also for the more intricate case of A=3 nuclei. This represents a significant advancement, as previous efforts primarily focused on modeling the formation of deuterons. The model is tested for pp collision data measured by ALICE. Our approach introduces a novel aspect by implementing this model into a purpose-built Monte Carlo generator called ToMCCA offering exceptional adaptability while maintaining superior performance compared to general-purpose event generators. This work was funded by the BMBF 05P24W04 ALICE.

HK 35.4 Wed 18:15 HS 3 Chemie

He-3 inelastic cross section & nuclei production in Run3 — •Rafael Manhart for the ALICE Germany-Collaboration — Technische Universität München

This study focuses on two areas of nuclear and particle physics explored with ALICE at the LHC. First, the inelastic hadronic cross section of Helium-3, previously measured within a limited momentum range in fixed-target experiments, is investigated. Expanding this range up to 10 GeV/c, using data from ALICE, provides critical insights into light nuclei interactions and benchmarks theoretical models. Complementary measurements of deuterons serve as validation for the applied methodology, leveraging the advanced capabilities introduced in the LHC Run 3 campaign. Second, the production of light (anti)nuclei in high-energy hadronic collisions is examined. These measurements are instrumental in understanding the astrophysical sources of antinuclei and evaluating theoretical production mechanisms, which remain a topic of scientific debate. By comparing new data from Pb*Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV from Run 3 with results from Run 2, this contribution provides a comprehensive analysis of (anti)nuclei production up to A=3. These advancements offer enhanced precision and scope, significantly contributing to the interpretation of antinuclei observations in astrophysical and experimental contexts.

This work was funded by the BMBF 05P24W04 ALICE.

HK 35.5 Wed 18:30 HS 3 Chemie

Measurement of ^{3}H and ^{3}He production in pp collisions with ALICE at the LHC — •Matthias Herzer for the ALICE Germany-Collaboration — Institut für Kernphysik, Goethe Universität, Frankfurt, Germany

The production of (anti)nuclei in pp collisions at the LHC has become a major topic in the high-energy heavy-ion physics community. In fact, there is a huge overlap between different research directions, from astrophysics, particle and nuclear physics. For instance, the observation of antinuclei in space is considered as possible signature for dark matter, since they would originate from collisions of potential dark matter candidates among each other. We will present the study of the production of ^{3}H and ^{3}He in pp collisions at 13.6 TeV in data sets that were taken in LHC Run 3. Furthermore, we will show the measurement of the ratio of these nuclei. This is an important test of isospin symmetry, which is expected to hold at LHC energies, but can not be tested directly since neutrons are not accessible experimentally. Moreover, the ratio of ^{3}H and ^{3}He can be an important test of nuclei production models such as the coalescence model.

HK 35.6 Wed 18:45 HS 3 Chemie

CBM Performance for Λ Yield Analysis using Machine Learning Techniques — •Axel Puntke for the CBM-Collaboration — Universität Münster

The Compressed Baryonic Matter (CBM) experiment at FAIR will investigate the QCD phase diagram at high net-baryon densities ($\mu_B >$ 500 MeV) with heavy-ion collisions in the energy range of $\sqrt{s_{NN}} =$ 2.9 - 4.9 GeV. Precise determination of dense baryonic matter properties requires multi-differential measurements of strange hadron yields, both for the most copiously produced K^s_0 and Λ as well as for rare (multi-)strange hyperons and their antiparticles.

In this talk, the analysis of the Λ baryon yield measurement is presented. It is based on simulated events from the SMASH heavy-ion event generator, which are transported through the CBM setup using GEANT4 with subsequent detector response simulation. The Λ hadrons are then reconstructed using methods based on a Kalman Filter algorithm that has been developed for the reconstruction of particles via their weak decay topology. The large combinatorial background is suppressed by applying selection criteria tuned to the topology of the decay. This selection is optimized by training a machine learning model based on boosted decision trees. A routine is implemented to extract multi-differentially Λ yields corrected for detector acceptance and efficiency. The yield extraction analysis chain is validated by comparison with the simulated data from the transport step described above.