Production of antinuclei in high-energy collisions at the LHC

The research program, developed within the framework of the H2020-ERC-STG CosmicAntiNuclei project, is aimed at studying nucleosynthesis mechanisms in hadronic collisions, with applications to cosmic ray physics and indirect dark matter searches in space. The main goal is to clarify the formation mechanism of (anti)nuclei via coalescence, through precision measurements of antinuclei with A=3 and particle correlations.

The planned activities include the analysis of large data samples collected during LHC Run 3 with the ALICE detector, a contribution to the calibration and performance studies for the ALICE Time-Of-Flight (TOF) detector, the optimization of particle identification algorithms for antinuclei, and the implementation of coalescence models for simulating the production of (anti)nuclei with A=3 in Monte Carlo generators.
More specifically, the research fellow is expected to contribute

- to the study of light antinuclei production in high-energy collisions at the LHC through measurements of production rates and yield ratios relative to that of antiprotons and other light antinuclei.
- to the modeling of cluster formation mechanisms through the development of an "afterburner" package based on the coalescence approach, to be used in cascade with general-purpose Monte Carlo event generators such as PYTHIA and EPOS.

This development will also be instrumental for investigate a newly proposed decay channel of the Lambda_b baryon into antideuteron or antihelium by means of simulations. By coupling a coalescence-based model developed within CosmicAntiNuclei with the PYTHIA event generator, the final production of bound states will be simulated at the end of the full decay chain of Lambda_b. The feasibility for a first measurement of such decay channel will be explored through dedicated detector simulations of the current and future ALICE apparatus setup.

The fellow will be involved in data analysis using the ALICE O2Physics framework and distributed computing resources. Given the key role of particle identification based on Time-of-Flight (TOF) detector information for the relevant observables, involvement in offline activities for ALICE-TOF (data quality control, calibration, performance studies) and data preparation is foreseen.
For this project, the research fellow will join the ALICE-TOF group at DIFA-INFN, and the team involved in the CosmicAntiNuclei project.

In summary, the activities include:

- detector calibration and quality control activities, evaluation of detector performance for the TOF
- data analysis
- software development (C++/Python, ALICE O2Physics framework)
- modelling of production of antinuclei (coalescence, statistical hadronization)
- detector simulation
- application of the results obtained within the context of the CosmicAntiNuclei project.

Activity plan

The fellow, expected to have a solid experience with the ALICE O2Physics software framework, is foreseen to analyze the existing 2022, 2023 and 2024 data samples as well as to contribute to software development as necessary. We expect the analysis to be the focus of the first nine months of the project, whereas the remaining time should be devoted to preparing for the public release of the results. In parallel, the fellow is expected to contribute to the development of the model of nucleus formation based on the coalescence approach. Predictions will be extracted working on modelling in parallel to the data analysis and will be released at the same time as data.

During the duration of the project, the fellow will participate to the ALICE-TOF related activities, meetings of the ALICE Collaboration at CERN, international workshops and conferences and contribute to the publications by the CosmicAntiNuclei team and the ALICE Collaboration.