Simulation of the production of light antinuclei in high-energy interactions

The research programme is framed in the H2020-ERC-STG CosmicAntiNuclei project, finalized to the study of nucleosynthesis mechanisms in hadronic collisions, with applications for cosmic ray physics and indirect dark matter searches in space. The project aims at clarifying the formation mechanism of (anti)nuclei via the coalescence process through its simulation in Monte Carlo generators and comparison with measurements of light (anti)nuclei production at the LHC.

The research fellow will join the ALICE-TOF group at DIFA-INFN, and the team involved in the CosmicAntiNuclei project. The main activity of the fellow will be the simulation of light nuclear cluster formation via coalescence starting from the input of the event generators commonly employed in high-energy physics, such as PYTHIA and EPOS, etc. This will be achieved by developing a library for a "coalescence afterburner" to simulate the formation of these bound states according to a state-of-the-art Wigner-function coalescence approach. A first version of the afterburner is currently being developed within the research group and the research fellow is expected to build on this. First will be the implementation of deuteron and antideuteron formation via nucleon coalescence in the final state. Secondly, the results of the simulation will be compared with currently available data from the ALICE experiment as a function of collision energy, charged-particle multiplicity and source size at LHC energies. Third, the possibility to extend the model to the formation of three-nucleon states as (anti)triton and (anti)helium will be explored.

In summary, the activities include:

- Software development (C++/Python)
- Simulation of high-energy pp collision events with Monte Carlo event generator
- Analysis of simulated data
- Comparison of model results with data from ALICE
- Application of the results obtained within the context of the CosmicAntiNuclei project.

Activity plan
In the first two months of the year, the fellow will be introduced to the current version of the software library being developed within the group and will analyze a large sample of Monte Carlo pp collision events generated using PYTHIA/EPOS to characterize the nucleon source and momentum distribution in detail. Based on that, the (anti)deuteron production will be simulated using the afterburner and compared to data from the LHC.
The following six months will be devoted to improving the model to include a more realistic description of the particle source and nuclear wave function while carrying out a systematic comparison of the model to the data from ALICE at the LHC. In particular, one of the main goals of the project is to enable the comparison with the newest (anti)nuclei production and proton source studies using the LHC Run 3 data and the ALICE detector, which are ongoing within the CosmicAntiNuclei project.
The last four months of the project will be devoted to the extension of the model to the simulation of three-nucleon states for future applications to the study of (anti)helium production.

During the entire duration of the project, the fellow will also join ALICE-related and project-related activities, including collaboration meetings that might take place at CERN or at the Technical University of Munich, which is a partner in the ERC project. The fellow will also participate to international workshops and conferences and contribute to the publications by the CosmicAntiNuclei team.