Nuclear Physics from Particle Physics

A new theoretical analysis connects the results of high-energy particle experiments at the Large Hadron Collider with three-proton correlations inside nuclei.

By **Charles Day**

How triplets of protons and neutrons behave is an important ingredient in theories of dense nuclear matter. Directly observing that behavior is beyond the reach of terrestrial labs. However, Alejandro Kievsky of Italy's National Institute of Nuclear Physics and his collaborators have now demonstrated that it can be inferred from particle collisions recorded by the ALICE experiment at CERN's Large Hadron Collider in Switzerland [**1**].

Last year, the ALICE experiment reported the results of smashing together beams of protons at an energy of 13 TeV. The kaons, protons, and deuterons that reached ALICE's detectors carried with them correlations that arose when the particles sprang to life from a volume a few femtometers across. To determine what happens in that tiny volume, Kievsky and his collaborators analyzed the case of three squished-together nucleons (neutrons and protons) and worked out what detectable correlations would ensue after they flew apart. The effort required determining the source function, which described the initial state of the three nucleons, and the scattering wave function, which described their ensuing spatial distribution.

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The researchers modeled the three-body source function in terms of the hyperradius, a generalized coordinate depending on the three nucleon–nucleon distances. Calculating the scattering wave function entailed casting the problem in terms of a generalization of spherical harmonics known as hyperspherical harmonics. By expanding the scattering wave function in partial waves, the researchers could simultaneously handle the short-range strong nuclear force and the long-range Coulomb force. Accurately treating the latter force was crucial in describing the asymptotic behavior in the most challenging case of all three nucleons being protons.

Kievsky and his collaborators' analytical framework can cope with triplets of protons, neutrons, and combinations of the two. It can also handle deuterons and mesons. "We have opened the door to a new way of studying three-body systems," he says. Indeed, he and his collaborators are looking forward to analyzing the correlations among two protons and a Λ baryon already measured by ALICE.

Charles Day is a Senior Editor for ***Physics Magazine***.

REFERENCES

1. A. Kievsky *et al.*, "*nnn* and *ppp* correlation functions," **Phys. Rev. C 109, 034006 (2024).**