Successor of the COMPASS experiment will measure fundamental properties of the proton and its relatives

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The COMPASS experiment. Credit: CERN

Protons are one of the main building blocks of the visible universe. Together with neutrons, they make up the nuclei of every atom. Yet, several questions loom about some of the proton's most fundamental properties, such as its size, internal structure and intrinsic spin. In December 2020, the CERN Research Board approved the first phase ("phase-1") of a new experiment that will help settle some of these questions. AMBER, or Apparatus for Meson and Baryon Experimental Research, will be the next-generation successor of the Laboratory's COMPASS experiment.

COMPASS receives particle beams from CERN's Super Proton Synchrotron and directs them onto various targets to study how quarks and gluons form hadrons (such as protons, pions and kaons) and give these composite particles their distinctive properties. Using this approach, COMPASS has obtained many important results, including several results linked to the proton's spin structure and a measurement of the pion's polarisability; the polarisability of a hadron is the degree to which its constituent positive and negative electric charges can be separated in an electric field.

AMBER will build on COMPASS's legacy and take it to the next level. By upgrading existing COMPASS components and introducing new detectors and targets, as well as using state-of-the-art read-out technology, the team behind AMBER plans to take three kinds of measurements in the experiment's first phase.

First, by sending muons, heavier cousins of the electron, onto a hydrogen target, the AMBER team plans to determine with high precision the proton's charge radius—the extent of the spatial distribution of the particle's electric charge. This measurement would help resolve the proton radius puzzle, which emerged in 2010 when a new measurement of the proton radius was found to be substantially different from the previously accepted measurements.

Second, by directing protons onto proton and helium-4 targets, AMBER will determine the little-known production rate of antiprotons, the antimatter counterparts of protons, in these collisions. These measurements will improve the accuracy of predictions of the flux of antiprotons in cosmic rays, which are needed to interpret data from experiments searching for evidence of dark matter in the flux of antiproton cosmic rays.

Third, by focusing pions on nuclear targets, AMBER will measure the momentum distributions of the quarks and gluons that form the pion. These measurements will cast light on the particle dynamics that holds the pion together and ultimately on the origin of the masses of hadrons, which is known technically as the emergence of hadron mass.

Further insights into the emergence of hadron mass are anticipated from studies of the internal structure of kaons in the second phase ("phase-2") of AMBER. These studies require the beamline that feeds COMPASS to be upgraded to deliver a charged-kaon beam of high energy and intensity.

Combining AMBER's pion and kaon results will lead to a better understanding of the interplay between nature's two mass-generating mechanisms: the mechanism that gives hadrons their masses and the Higgs mechanism, which endows massive elementary particles with mass.

More information: COMPASS experiment: home.cern/science/experiments/compass

Provided by CERN

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