Experiment brings precision to a cornerstone of particle physics

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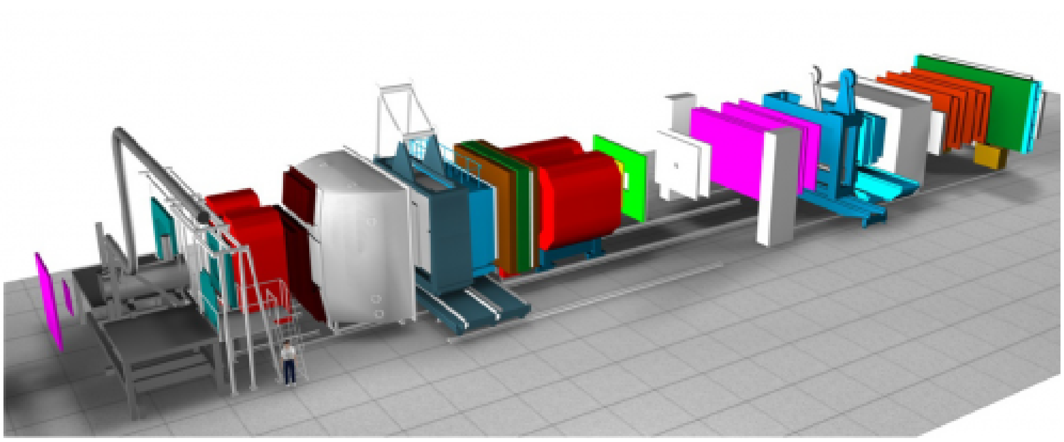

Artistic view of the 60 m long COMPASS two-stage spectrometer. The two dipole magnets are indicated in red.

In a paper published yesterday in the journal *Physical Review Letters*, the COMPASS experiment at CERN reports a key measurement on the strong interaction. The strong interaction binds quarks into protons and neutrons, and protons and neutrons into the nuclei of all the elements from which matter is built. Inside those nuclei, particles called pions made up of a quark and an antiquark mediate the interaction. Strong interaction theory makes a precise prediction on the polarisability of pions – the degree to which their shape can be stretched. This polarisability has baffled scientists since the 1980s, when the first measurements appeared to be at odds with the theory. Today's result is in close agreement with theory.

"The theory of the strong interaction is one of the cornerstones of our understanding of nature at the level of the fundamental particles," said Fabienne Kunne and Andrea Bressan, spokespersons of the COMPASS experiment, "so this result, in perfect agreement with the theory, is a very important one."

"Despite the high energies available at CERN, the experiment is a big challenge, as the pion polarisability is tiny and its effect hard to isolate," said Jan Friedrich, researcher at the Technische Universität München and leading scientist in the project.

Everything we see in the universe is made up of fundamental particles called quarks and leptons. Quarks are bound together in groups of three to make up the building blocks of the nuclei of elements – protons and neutrons. The hydrogen nucleus, for example, consists of a single proton, whereas the nucleus of a gold atom consists of 79 protons and 118 neutrons. Flitting between the protons and neutrons in a nucleus are pions, which mediate the strong force binding the nucleus together. These pions are made up of a quark and an antiquark, themselves held tightly bound by the strong force. This makes their deformability, or polarisability, a direct measure of the strong binding force between the quarks.

To measure the polarisability of the pion, the COMPASS experiment shot a beam of pions at a target of nickel. As the pions approached the nickel on average at distances twice the radius of the particles themselves, they experienced the very strong electric field of the nickel nucleus, which caused them to deform, and change trajectory, in the process emitting a particle of light called a photon. It is by measuring the photon energy and the deflection of the pion for a large sample of 63000 pions that the polarisability could be measured. The result reveals that the pion is significantly stiffer than shown by previous measurements, as expected from strong interaction theory.

"This result is admirably complementary to the studies of fundamental interactions performed at the LHC and a testimony to the diversity and strength of CERN's research programme," said CERN Director General Rolf Heuer. "While the Higgs boson – proposed by Brout, Englert and Higgs – accounts for the masses of the fundamental particles, thereby allowing composite objects such as us to exist, the bulk of our mass comes from the binding energy of the strong interaction holding them together."

More information: "Measurement of the Charged-Pion Polarizability" *Phys. Rev. Lett.* 114, 062002 – Published 10 February 2015 DOI: dx.doi.org/10.1103/PhysRevLett.114.062002

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