New tool for proton spin

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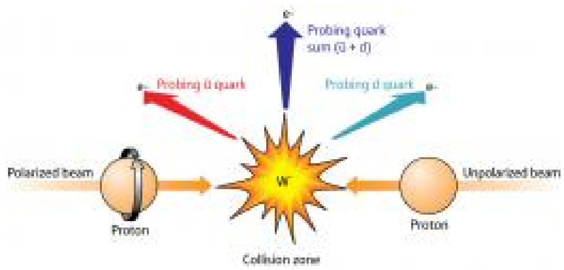

Figure 1: When two beams of protons collide (center), the electrons (e-) produced by the W- boson-mediated interactions provide information about the different ‘flavor’ quarks of a proton, such as the anti-up (ū) quark and the down (d) quark. Credit: Brookhaven National Laboratory

How the particles that constitute a proton give rise to is to its rotation, or ‘spin’, is an intriguing open question of contemporary particle physics. A technique that could provide some answers has been developed using the world’s only polarized proton–proton collider. The work was published by the PHENIX Collaboration, which includes researchers from the RIKEN Brookhaven National Laboratory (BNL) Research Center in Upton, USA.

Nowadays, the most popular theory for subatomic particles is the Standard Model: a menagerie of fundamental particles including quarks, which come in six different types or flavors, and four fundamental forces. These forces include the ‘weak’ force that is mediated by particles called W bosons, which are created, albeit only briefly, when protons collide. The researchers discovered that these W bosons are a sensitive probe of the quarks that make up a proton.

To investigate proton spin, the PHENIX team fired two beams of high-energy protons at one another using the Relativistic Heavy Ion Collider at BNL. “Most of the interactions that take place when the protons collide are ‘strong’ interactions,” explains Okada. “But our experiment was sensitive enough to detect ‘weak’ interactions too.” The researchers identified two such weak reactions: detection of an electron indicated the decay of a negatively charged W boson (Fig. 1); and detection of a positron—a positively charged electron—indicated the decay of a positively charged W boson. By counting the number of resulting electrons and positrons, the researchers could calculate the probability of each type of interaction.

The PHENIX team then performed two experiments simultaneously. In one, they made protons spin parallel to the axis of the beam; and in the other, they made them spin in the opposite direction. The difference in the rate of weak interactions in each experiment provided information about the spin direction of the quarks in the proton. “The asymmetry of the production rates is connected to the probability that the spin of a particular flavor of quark is aligned to the proton spin direction,” says Okada. This approach could soon be extended to identify the spin contribution of all the proton’s quarks.

Next the team hopes to improve the sensitivity of the experiment. “This time, we only caught electrons and positrons that emerged at 90 degrees to the beam axis,” explains Okada. “We are preparing new detectors to extend this detection region for a more complete analysis.”

More information: Adare, A., et al. Cross section and parity-violating spin asymmetries of W± boson production in polarized p + p collisions at $\sqrt{s}$ = 500 GeV. Physical Review Letters 106, 062001 (2011).

Provided by RIKEN

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