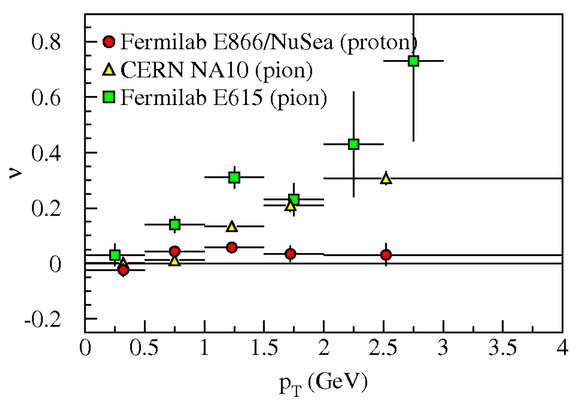
The proton is like a spinning top with a total angular momentum of ½ ħ. It is not, however, a fundamental particle, and its constituents (known as quarks, antiquarks and gluons) also have an intrinsic spin. The proton's spin (½ ħ) must be the sum of its constituents' intrinsic spin and angular momentum from their movement inside the proton. Measuring the individual elements of the proton's spin has been a challenge. Measurements show that the net spin of the quarks and antiquarks is only a fraction of the total. The angular momentum of the gluons is near zero, but it is poorly measured.

The third element of the proton's spin arises from the motion of the quarks inside the proton. The orbital motion may give rise to something know as the Boer-Mulders distribution. We can about learn the orbital motion through the angular distributions resulting from quark-antiquark annihilation in a process know as Drell-Yan scattering. In Drell-Yan scattering, the transverse motion of the quarks (produced by their orbital paths) will create an angular distribution proportional to *cos2φ*. We have examined angular distributions from proton-deuterium collisions and found that there is no *cos2φ* component in these Drell-Yan data. However, experiments using beams of pions (particles made up of a quark and an *antiquark*) found a substantial *cos2φ* component, which became even more prominent as the transverse motion of the quarks increased.

What is the difference between a proton or pion beam? The proton does not contain valence *antiquarks*—the pion does. Thus, the proton sees only the target's antiquarks, present as "sea" quarks. The pion, however, sees both the quarks and antiquarks in the target. The new analysis clearly shows that the angular momentum of the "sea" quarks is not likely to contribute to the proton's spin. This result was published in 2007 by Physical Review Letters.



The *cos2φ* component (υ) of the Drell-Yan angular distribution plotted versus transverse momentum (p_T). The new proton data shown by the red circles are consistent with zero, while the pion data (green squares and yellow triangles) are both nonzero. This effect is most pronounced at large p_T.

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