E97-110: The GDH Sum Rule and the Spin Structure of ^{3}He and the Neutron Using Nearly Real Photon

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The nucleon spin has been of central interest ever since the EMC experiment found that at high Q^2 quarks carry only a small fraction of the nucleon spin. The Bjorken sum rule, which relates the deep inelastic scattering spin structure function at high Q^2 to the nucleon axial coupling constant, was tested in the last 20 years of spin structure experiments at high energy laboratories. At the other extreme, $Q^2 = 0$, there is another fundamental sum rule, the Gerasimov-Drell-Hearn (GDH) sum rule, which relates the nucleon spin structure to its anomalous magnetic moment. The GDH sum rule is based on very general principles and is valid not only for the nucleon but also for any nucleus.

How does the spin structure evolve with Q^2 (especially at low Q^2) and what is the connection between the GDH and the Bjorken sum rules? Recent theoretical developments in the generalization of the GDH sum rule, based on the same general assumptions as the GDH sum rule, provide the framework for understanding and answering the above questions. The GDH and the Bjorken sum rules are the two limiting cases, at $Q^2 = 0$ and $Q^2 = \infty$, of the generalized GDH sum rule. The generalized GDH sum rule has been calculated at small Q^2 with Chiral Perturbation Theory and calculations have also been done for high Q^2 with higher order QCD (twist) expansions. The transition from the high Q^2 (pQCD region, quark-gluon picture) regime to the low Q^2 (non-perturbative region, coherent hadron picture) regime may be calculated in the future with lattice QCD calculations. This will provide, for the first time, the possibility that hadron structure can be described by a fundamental theory in the entire kinematic regime.

Experimental tests of the GDH sum rule have only recently become possible. This experiment, E97-110, is an extension of experiment E94-010. The experiment will measure the spin structure and the generalized GDH sum for the neutron with a polarized ^{3}He target. Using the new septum magnets, we will be able to reach a small angle, 6°, and hence very low Q^2. The Q^2 range is from 0.01 to 0.5 GeV^2. The energy transfer range is from elastic to nearly the beam energy, covering the quasielastic, resonances and the deep-inelastic regions. We will measure the slope of the generalized GDH at $Q^2 = 0$, which Chiral Perturbation Theory predicts to be positive while phenomenological quark models predict it to be negative. We will also attempt to extrapolate to $Q^2 = 0$, the real GDH sum rule, which will complement real photon tests of the GDH sum rule.

It has been shown that while the extraction of the neutron spin structure functions froom ^{3}He in the resonance region depends on the nuclear model used, the extraction of the neutron GDH sum has much less model dependence. This experiment provides an interesting test of the ^{3}He structure by comparison of the GDH sum on ^{3}He with that on the neutron. In the zeroth order approximation that polarized ^{3}He is a polarized neutron target, one can deduce that the big difference in the ^{3}He and neutron sum rules is from the "nuclear" contribution below the pion threshold. This experiment will be able to test and study that "nuclear" contribution.