1 Summaries of Experimental Activities

1.1 E08-027

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1.1.1 Introduction

The inclusive scattering spin structure functions g_1 and g_2 are fundamental spin observables which characterize the deviation of the nucleon's spin-dependent properties from point-like behavior. Historically, measurements of g_1 provided direct tests of QCD via the Bjorken sum rule, and also revealed that only a small fraction of the nucleon spin is carried by the valence quarks. In general, measurement of the spin structure functions (SSF) allow insight into QCD via sum rule predictions, provide benchmarks for chiral perturbation theory (χPT) and lattice gauge theory calculations, and are needed to quantify higher twist effects and quark-hadron duality.

Recently, it has become apparent that poor knowledge of the SSFs (which are purely QCD quantities) at low Q^2 limits the precision of QED calculations of simple bound systems, such as the hydrogen-like atom [1, 2]. Energy levels in these systems can be measured to fantastic precision. As a result, the corresponding QED calculations have been pushed to a level where the finite size of the nucleon, as characterized by the structure functions and elastic form factors (FF), has become a leading uncertainty. Of particular interest, researchers from PSI [2] have obtained a value for the proton charge radius $\langle R_p \rangle$ via measurements of the Lamb shift in muonic hydrogen, which differs significantly from the value from elastic electron proton scattering. The deviation in $\langle R_p \rangle$ would have many troubling consequences, such as requiring a sizable shift in the fundamental Rydberg constant, so all aspects of the PSI calculations are being re-examined. The main uncertainties in the PSI results originate from the proton polarizability and from different values of the Zemach radius. These quantities are determined from integrals of the SSF and elastic form factors, which due to kinematic weighting, are dominated by the low Q^2 region. It is prudent to question whether these uncertainties are underestimated, since g_2^p is largely unmeasured, and g_1^p data extends only down to $Q^2 \approx 0.05$ GeV^2. The Zemach radius, is similarly dominated by the low Q^2 behavior of the proton elastic form factors G_E and G_M.

At low and moderate Q^2, data on the g_2^p structure function is conspicuously absent. The lowest momentum transfer that has been investigated is 1.3 GeV^2 by the RSS collaboration [3]. The absence of g_2^p data is also unsatisfying in light of the intriguing results found in the transverse neutron data: The SLAC E155 collaboration found their data to be inconsistent with the proton Burkhardt-Cottingham (BC) sum rule at $Q^2 = 5.0$ GeV^2, while the JLab E94-010 collaboration found that the neutron BC sum rule held below $Q^2 = 1.0$ GeV^2. Even more compelling, it was found that state-of-the-art next-to-leading order χPT calculations are in agreement with data for the generalized spin polarizability γ_0^n at $Q^2 = 0.1$ GeV^2, but exhibit a significant discrepancy [4] with the longitudinal-transverse polarizability δ_{LT}^n. This is surprising since δ_{LT} was expected to be more suitable than γ_0 to serve as a testing ground for the chiral dynamics of QCD [6, 7] due to it's relative insensitivity to resonance contributions. It is rare to find such striking disagreement with theory, and g_2^p data at low Q^2 will be invaluable in establishing the reliability and range of χPT. As discussed above, lack of knowledge of the g_2^p structure function at low Q^2 is also one of the leading uncertainties in calculations of the hyperfine splitting of the hydrogen atom [1], and the Lamb shift in muonic hydrogen [2]. In particular, the g_2^p contribution to these calculations is dominated by the region below 0.4 GeV^2 where no data currently exists and where E08-027 will measure.

1.1.2 The Experiment

E08-027 was approved by PAC33 with A$^-$ rating to run in JLab's Hall A. We will perform an inclusive measurement at forward angle of the proton spin-dependent cross sections in order to determine the g_2^p

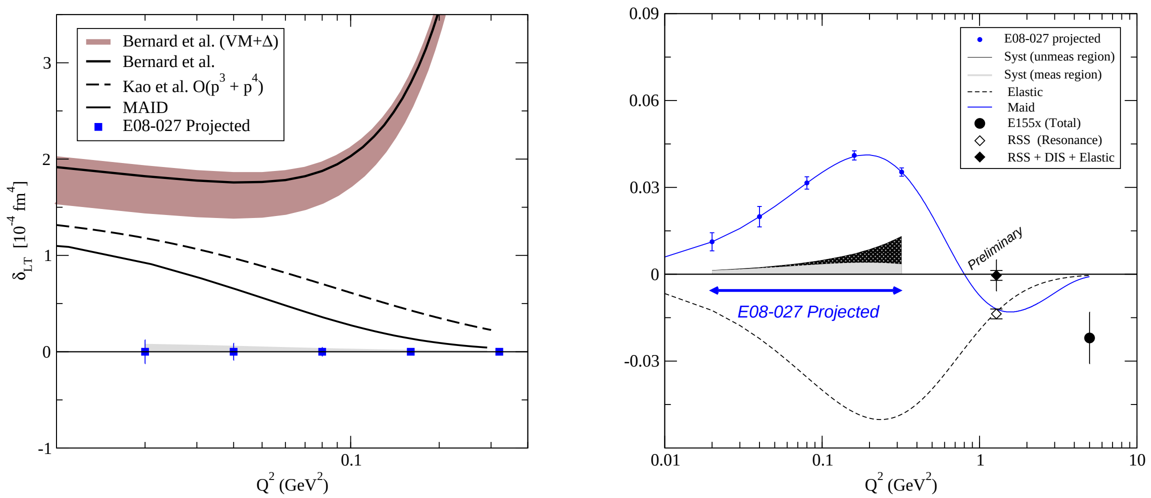

Figure 1: **Left:** Projected uncertainties for δ_{LT}. χPT predictions from Bernard *et al.* [6], and Kao *et al.* [7]. **Top Right:** Projected uncertainties for $\Gamma_2^p(Q^2)$. The light and dark bands on the horizontal axis represent the experimental systematic, and the uncertainty arising from the unmeasured ($x \to 0$, $x = 1$) contributions to Γ_2, respectively.

structure function and the longitudinal-transverse spin polarizability δ_{LT} in the resonance region for $0.02 < Q^2 < 0.4$ GeV^2. To reach the lowest possible momentum transfer, a pair of room temperature septa magnets will be used to allow detection of scattered electrons at 6°. Dynamical Nuclear Polarization (DNP) will be used to polarize a solid ammonia target maintained in a liquid helium bath at 1 K in a 5 Tesla field. This will represent the first use of a DNP target in Hall A. See Fig. 1 for the expected uncertainties on the spin polarizability δ_{LT} and the first moment of g_2.

E08-027 complements two other related experiments : EG4 which will measure the proton g_1 structure function, and E08-007 which will measure the proton form factor ratio G_E/G_M in the same kinematic region as E08-027. Together, these experiments will provide the definitive measurement of proton structure at low Q^2. Because of the similarities in technique and equipment, the E08-027 and E08-007 collaborations are highly cooperative and the two experiments will run simultaneously. E08-007 will focus on elastic scattering, while E08-027 measures the inelastic data. Installation begins in May 2011, and the experimental run will extend into 2012.

References

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