1 Summaries of Experimental Activities

1.1 E08-027

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1.1.1 Motivation

The deviation of the nucleon's spin dependent properties from point like behavior in inclusive scattering can be described by the spin structure functions (SSF) g_1 and g_2. While g_1 can be expressed in terms of quark distribution functions, g_2 contains contributions from higher order interactions, and so has no simple interpretation in the quark-parton model. Measurements of g_2 for the proton, specifically at low to moderate Q^2, are scarce; currently, the lowest momentum transfer investigated is 1.3 GeV^2, by the RSS collaboration [1].

The data from this experiment will provide insight on several outstanding physics puzzles, such as why Chiral Pertubation Theory (χPT) calculations fail to predict the behavior of the longitudinally-transverse spin polarizability (δ_{LT}) [3]; a surprising outcome as δ_{LT} is seen as a good test of QCD dynamics due to its insensitivity to the delta resonance [4, 5]. Additionally, they will provide a test of the Burkhardt-Cottingham Sum rule, which says that the integral of g_2 over the Bjorken scaling variable x tends to zero. This sum rule has been satisfied for the neutron, but the lack of data for g_2^p leaves this sum rule largely untested for the proton. Furthermore, a lack of knowledge of the SSF at low Q^2 is a limiting factor of QED calculations of bound-state systems, such as the hydrogen atom. The energy levels of the hydrogen atom can be measured to very high accuracy, to the point where the leading uncertainty of the corresponding QED calculations comes from the finite size of the nucleon as characterized by the SSF and elastic form factors. Finally, recent results from PSI [2] for the proton charge radius $\langle R_p \rangle$ via measurements of the lamb shift in muonic hydrogen suggest a discrepancy from the value obtained from elastic electron-proton scattering. The leading uncertainty in these calculations comes from differing values of the Zemach radius, determined from integrals of the SSF and elastic form factors.

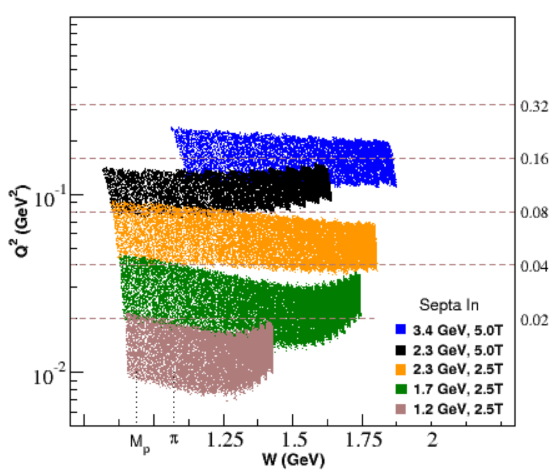


Figure 1: Achieved kinematic coverage during the experimental run period. The vertical axis on the right hand side is the extrapolation to constant Q^2.

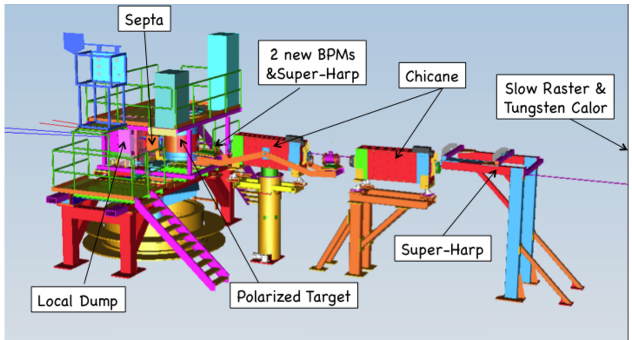


Figure 2: Installation of the g_2^p experiment in Hall A. The 3^{rd} arm detector was located on the left-hand side of the bottom target platform.

1.1.2 The Experiment

The g_2^p experiment ran successfully from March-May of 2012. An inclusive measurement was performed in the low Q^2 region $0.02 < Q^2 < 0.20$ GeV^2 (see figure 1) at forward angles to obtain the proton spin-dependent cross sections. From these data the g_2^p structure function will be extracted along with the longitudinally-transverse spin polarizability δ_{LT}. This experiment required a large scale installation in Hall A, as shown in figure 2. A solid ammonia target was polarized through the process of Dynamic Nuclear Polarization (DNP). In order to compensate for the the deflection of the beam by the large target magnetic field, a pair of chicane magnets was installed upstream of the target. To reach the small scattering angle of 5.69° necessary for this kinematic range, a septum magnet was installed downstream of the target. New beamline diagnostics (BPM and BCM) were required due to the low beam current (50-100nA) used throughout the run. For certain kinematics, a local beam dump was necessary, located just downstream of the septum magnets. Finally, a new scintillator detector, the 3^{rd} arm, was developed specifically for this experiment as a cross check of the product of the beam and target polarization. The 3^{rd} arm was placed on the target platform to collect elastically scattered protons at large scattering angles to provide a measurement of the elastic proton asymmetry.

1.1.3 Status of Analysis

HRS Detector efficiencies are needed as a correction to the cross section. The VDCs provide tracking information for both arms of the HRS, which provides good position and angle reconstruction. However, due to the high event rate, it is possible that multiple particles will pass through the drift chambers simultaneously; as many as 30% of events can have multiple track for certain kinematic settings. This presents a large uncertainty to the cross section if left uncorrected. The multitrack events are carefully examined and resolved, bringing the systematic uncertainty down to below ∼1% for all kinematic settings. The total vdc efficiency can be seen in figure 3. Efficiencies from the other spectrometer detectors, including the s1 and s2m trigger scintillators, gas Cherenkov, and lead glass calorimeters were seen to be high (∼99% or higher) throughout the run, indicating good detector performance. PID cuts were determined to minimize the amount of residual pion contamination and maintain and overall detection efficiency of 99%.

The optics calibration without target field has been updated to include beam positions obtained from fitting the focal plane data. Forward and reverse transport functions between the target and focal plane, used to describe the magnetic field system without the target field, were fitted with simulation data from the SNAKE Model. These functions have been incorporated into the g_2^p simulation package to describe the trajectories of outgoing electrons. A comparison between simulation results and optics data at the target plane is being done; the quantities match well, but more tuning to refine the comparison results is currently underway. Additionally, efforts are being focused on optics analysis with the target field on. Due to problems with the right-HRS septum magnet during the run, multiple calibrations will be needed to correspond to the different magnet coil configurations.

A Monte-Carlo simulation program was developed to simulate the physics of the HRS together with the

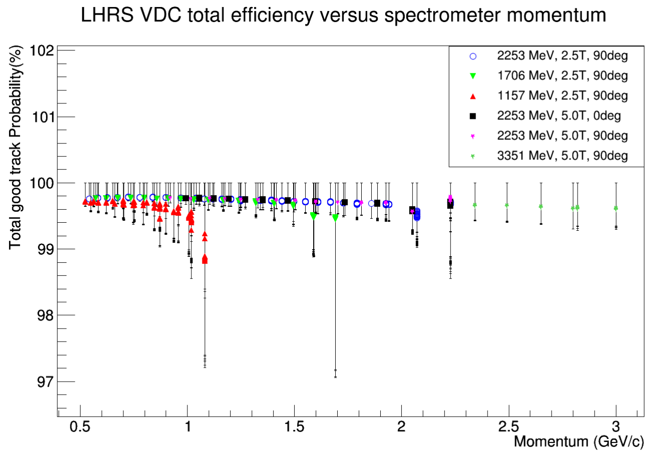
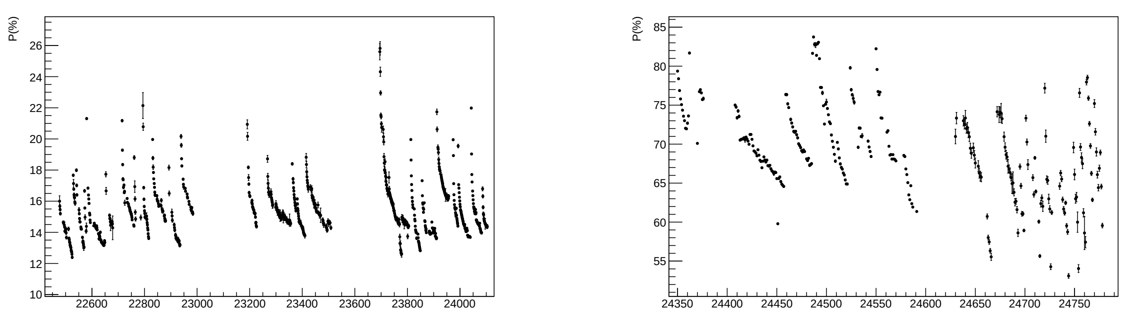


Figure 3: Total VDC efficiency for all lhrs runs, after multitrack events have been accounted for. The efficiency is $> 99\%$ for most kinematic settings.

target and septum fields. The program is based on the Hall A Single Arm Monte-Carlo (SAMC) package and is extended to work with the target field. The simulation setup has been tuned with our experimental configuration, including two target field settings and several different versions of the septum field model. The programs also include several different cross section models and fittings in the elastic and resonance kinematic regions. The package will be used in the optics calibration with target field and the spectrometer acceptance study.

Beam position information is very important for optimization of the optics. For the straight through calibration, two harps were used to determine the beam position at the four-antennae BPMS. During the course of the run, the BPMB division (attenuation) was changed; present efforts are focused on determining a different calibration method to account for this change. Additionally, a study is underway to understand and account for the fluctuation of the pedestal throughout the run period. The g_2^p experiment is using the same helicity scheme set up by the QWEAK experiment. Both the helicity flip rate and the DAQ rate are high, so a new standalone package was developed to decode the helicity information under these conditions.



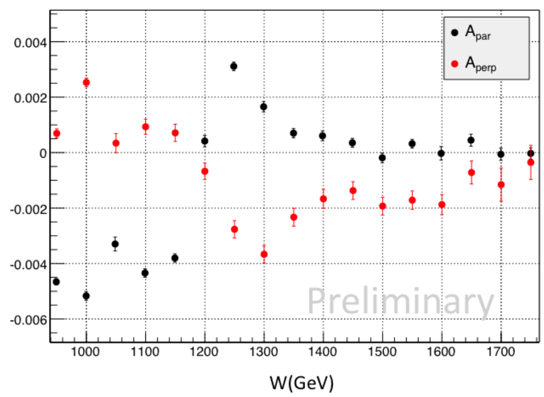
(a)

(b)

Figure 4: Run by run polarization results for (a) the 2.5T magnetic field setting and (b) the 5.0T magnetic field setting.

A precise measurement of the target polarization is needed to extract the physics asymmetry. During this experiment two different target fields, 2.5T and 5T, were necessary to achieve the desired kinematic range. The calibration constants, used to convert the measured NMR signal into a useable polarization, have been calculated for all ammonia samples and applied to the data to determine the average polarization on a run-by-run basis. The final run polarizations can be seen in figure 4. An average polarization of 70% for the 5T field setting and 15% for the 2.5T field setting were observed. Polarization uncertainties due to measurement precision and statistical fluctuations have been calculated to less than 5%.

Once beam position calibrations, optics with target field and acceptance studies have been completed, the cross section can be extracted. Studies are underway to calculate the packing fraction and dilution factor, which will determine the percentage of electrons that were not scattered from a proton in the ammonia target. Analysis of data taken with the $3^r d$ arm, which which be used as a cross check of the beam and target polarization, is also on going. Preliminary physics asymmetries and yields can be seen in figure 5.



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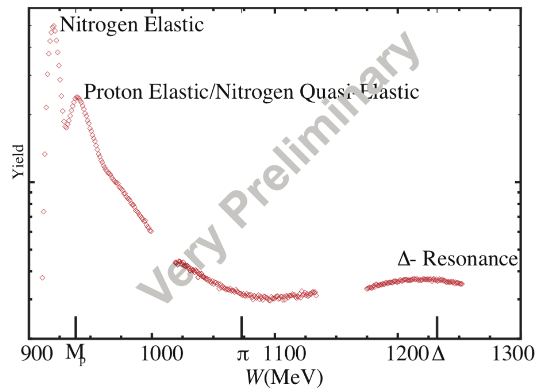

(b)

Figure 5: Preliminary results: (a) Physics asymmetries for the longitudinal and transverse magnetic field setting and (b) yields showing the nitrogen and proton elastic peaks.

References

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