Electron Scattering from a Polarized Deuterium Target at BLAST

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The deuteron, the simplest nucleus, is an ideal arena for testing models of the nucleon-nucleon (NN) interaction and exploring the low-energy behavior of Quantum Chromodynamics (QCD). The Bates Large Acceptance Spectrometer (BLAST) Experiment[1] was designed to use both a tensor and vector polarized deuterium target[2] in combination with a longitudinally polarized electron beam for the simultaneous measurement of the vector (A^V_{ed}) and tensor (A^T_d) asymmetry. These asymmetries allow for the determination of the analyzing powers, T_{20} and T_{21}, and spin correlation coefficients, T_{10} and T_{11}, from which the elastic form factors can then be extracted.[3]

The average spin angle of the BLAST target for the 2004(2005) run was oriented at a $32^o(47^o)$ with respect to the beamline. This unique configuration allows for the spin asymmetries:

$$A^V_{ed} = \sqrt{\frac{3}{2}}(\cos\theta_d T_{10} - \sqrt{2}\sin\theta_d\cos\phi_d T_{11}) \tag{1}$$

$$A^T_d = \frac{\sqrt{3}(\cos^2\theta_d - 1)}{\sqrt{8}}T_{20} - \frac{\sqrt{3}\sin 2\theta_d\cos\phi_d}{2}T_{21} + \frac{\sqrt{3}\sin^2\theta_d\cos 2\phi_d}{2}T_{22} \tag{2}$$

to be measured simultaneously for the scenario where the Q^2 vector is parallel and perpendicular to the spin angle, and therefore permitting the independent determination of T_{20}, T_{21}, T_{10} and T_{11} from the same dataset.

Parameterization III by Abbott *et al.*[4] of the world form factor data is used to subtract the small T_{22} contribution from the measured A^T_d and to determine the tensor polarization at the two lowest Q^2 bins. The BLAST analyzing powers T_{20} and T_{21}, plotted in Figs. 1 and 2,[5] are in good agreement with the existing world data while providing comparable or improved statistical precision between 2 and 4 fm^{-1}.

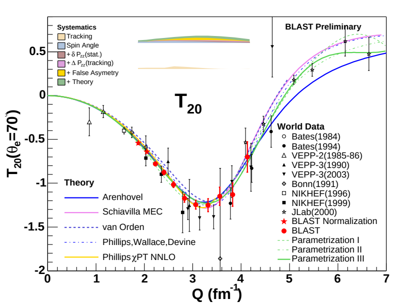

Fig. 1. Measured tensor analyzing power T_{20} compared to existing data and theoretical calculations

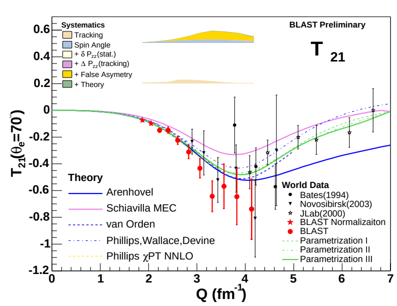

Fig. 2. Measured tensor analyzing power T_{21}.

Analogously, the measured vector asymmetries allow for the first time the extraction of the spin coefficients T_{11} and T_{10}, shown in Fig. 3.[6] While the statistical precision for the vector observables is lower than for T_{20}, the BLAST results are again in close agreement with calculations from the parameterizations of world data by Abbott[4] and predictions from theory.

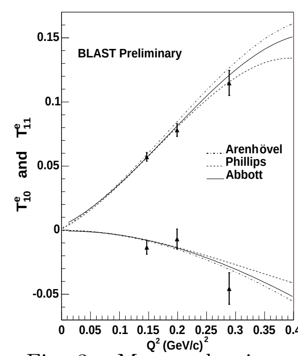

Fig. 3. Measured spin correlation coefficients T_{10} (neg) and T_{11} (pos)

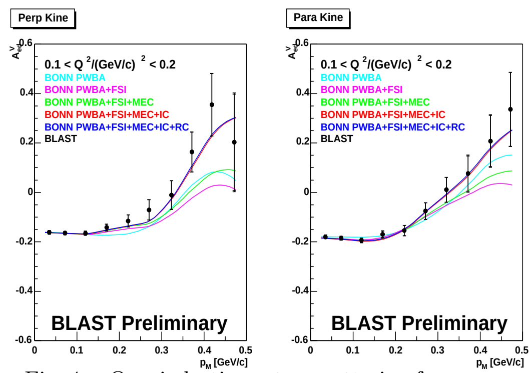

Fig. 4. Quasi-elastic proton scattering from a vector polarized deuterium target

Quasi-elastic proton scattering from vector polarized deuterium provides additional, but complementary, information about NN interactions, particularly at higher values of missing momentum (p_M). The vector asymmetry, $A^V_{ed}(p_M)$, is negative and flat if the deuteron orbital angular momentum is set to zero in the Plane Wave Impulse Approximation (PWIA). However, several effects, such as the D-state contribution, final state interactions (FSI), meson exchange currents (MEC), isobar contributions (IC), and relativistic effects (RC) can cause the asymmetry to change sign. Figure 4 shows the behavior of the BLAST A^V_{ed}[7] as a function of p_M for for $Q^2 = 0.1 - 0.2\ (GeV/c)^2$ for both the perpendicular and parallel orientations. The agreement between data and predictions from the Plane Wave Born Approximation[8] (PWBA), a model which incorporates the NN exchange effects with the PWIA framework, is excellent and clearly shows the strong role these effects play for $p_M > 0.2\ GeV/c$. The dependence of the PWBA curves on various potentials, such as Born, Paris and V18, was tested and shown to be negligible within the statistical error of the data.

References

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