GLUON POLARIZATION AND CHARM PRODUCTION AT SLAC *

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After a decade of precise spin structure measurements at SLAC, the laboratory has approved a set of new experiments that would use polarized coherent bremsstrahlung photon beams with energies between 5 and 45 GeV. One of the goals of this program is to measure the nucleon gluon distribution using the photon-gluon fusion process for $0.12 < x < 0.19$.

1 Introduction

The origin of spin in the nucleon can be summarized by the simple sum rule $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$, in which $\Delta\Sigma$ is the number of quarks with spin aligned along the nucleon spin minus those anti-aligned, ΔG is the equivalent quantity for gluons, and L_z is the quark plus gluon orbital angular momentum. The last decade of deep-inelastic spin structure function measurements has obtained $\Delta\Sigma = 0.23 \pm 0.07$ from the first moment of g_1, and $\Delta G = \int_0^1 g(x)dx = 1.6 \pm 0.8 \pm 1.1$ from global next-to-leading-order (NLO) fits to g_1 [1]. At present, ΔG is extremely uncertain and L_z is completely unknown. Although measuring generalized parton distributions under certain kinematic limits can yield L_z, a precise measure of ΔG would by inference do the same. Therefore, new measurements of ΔG are the key to understanding the spin in the nucleon.

Direct measurements of ΔG include a reported value of $\Delta G/G = 0.41 \pm 0.18$ from high p_T jets for $0.06 < x < 0.28$ at HERMES[2], and several planned or running experiments. COMPASS[3] will measure the reaction $\mu + d \to c\bar{c}$ with a LiD target. Using low-Q^2 data from a 160 GeV beam, they will detect D and $\bar{D}$ mesons, and also high p_T jets. RHIC[4] will measure gluon Compton scattering $q + g \to \gamma + X$ as well as gluon fusion $g + g \to \text{jet} + \text{jet}$. E161 at

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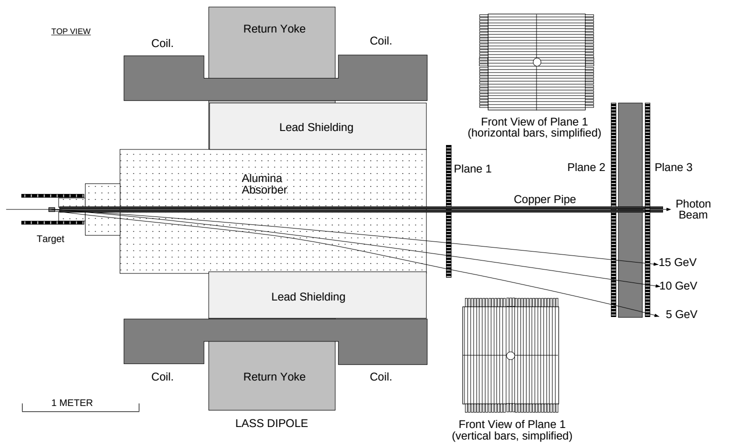

Figure 1: Muon spectrometer for E161. Decay muons are studied by removing some of the shielding following the target.

SLAC[5] plans to use 35-45 GeV circularly polarized photons in the reaction $\mu + d \rightarrow c\bar{c}$ from a LiD target, identified by a single μ^+ (μ^-) from D ($\bar{D}$) decay.

2 SLAC Experiment E161 and the Real Photon Program

In the fall of 2000 three proposals using a proposed polarized coherent bremsstrahlung facility were approved by the SLAC EPAC.

E159[5], "Measurement of $\Delta^{\gamma N}(k)$ and the High Energy Contribution to the Gerasimov-Drell-Hearn Sum Rule," will determine for the first time the difference between right- and left-handed polarized photoabsorption for photon energies between 4 and 40 GeV. If the Gerasimov-Drell-Hearn sum rule is to be satisfied, this cross section difference must change sign at high energies. E159 will provide extensive data that will constrain the GDH sum. Total cross sections will be determined by identification of at least one hadron produced from polarized $^{15}NH_3$ and $^{15}ND_3$ targets.

E160[5], "Measurement of the A-dependence of J/ψ and ψ' photoproduction," is designed to explore the interplay of pQCD and color transparency in the creation and interaction of J/ψ and ψ' particles in nuclei, to understand why vector-meson dominance and geometrical expectations for $\sigma_{\rm tot}^{\psi N}$ are

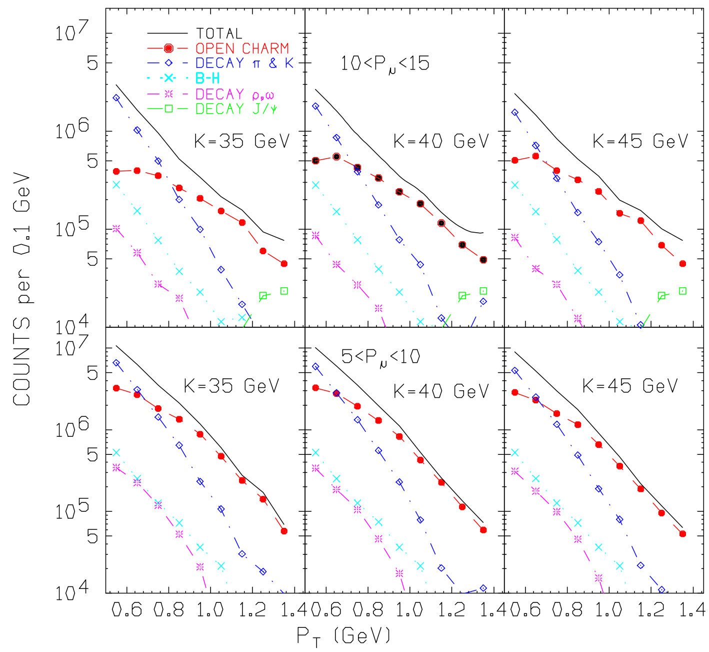

Figure 2: Expected single-μ events in counts per 0.1 GeV versus p_T for three beam energies $k = 35, 40, 45$ GeV. Top row: $10 < p_\mu < 15$ GeV; bottom row: $5 < p_\mu < 10$ GeV; total (solid line), open charm (solid dots), π and K decay (diamonds), Bethe-Heitler (crosses), J/ψ (squares), η, ρ, ω, ϕ decays (stars).

at odds, and to constrain causes for J/ψ suppression in relativistic heavy-ion collisions. The measurement consists of reconstructing J/ψ's from $\mu^+\mu^-$ pairs produced in Be, Al, Cu, Pb targets by 15, 25, and 35 GeV photons. It will produce t-distributions, α from $\sigma_A \propto A^\alpha$, and ψ-nucleon cross sections $\sigma_{\rm tot}^{\psi N}$ as a function of beam energy and nucleon number A.

E161[5], "Measurement of the Gluon Spin Distribution using Polarized Open Charm Photoproduction," will determine the polarized gluon distribution of the nucleon, and discriminate between models of $\Delta G(x)$ by making precise measurements complementary to COMPASS, HERMES, STAR and PHENIX. Asymmetries for longitudinal beam and target polarizations, as a function of muon (transverse) momenta p_μ ($p_{T\mu}$), will yield $\Delta G(x)$ for $0.1 < x < 0.2$. Open charm production is relatively clean because the detected charmed mesons are direct descendants from the c and $\bar{c}$ quarks of the hard process.

The experimental strategy for measuring ΔG at SLAC is to use an isoscalar target (^{6}LiD) cooled to 300mK in a B Field of 6.5 T, and polarized to 70% using 182 GHz dynamic nuclear polarization. The electron beam (85% polarization, 10^{12} electrons per second) produces a coherent bremsstrahlung photon beam (75–80% circular photon polarization) using a diamond radiator. The spectrometer (Fig. 1) consists of a high magnetic field, hodoscopes with good position and time resolution, and an absorber that eliminates all but muons. After vetoing $\mu^+\mu^-$ pairs, one can expect $> 10^5$ high-p_T charm events per day.

Table 1

particle	D^+	D^0	D_s^+	Λ_c^+	D^-	$\bar{D}^0$	D_s^-	Λ_c^-
production(%)	19	63	8	8	21	71	6	2
decay to μ^+(%)	37	47	8	4				
decay to μ^-(%)					40	53	5	1

Table 1 shows the relative number of charmed hadrons produced in the fragmentation of charmed quarks, and the fraction of single muons of each charge originating from the parent charmed hadron. These values were calculated using PYTHIA 5.7 for 40 GeV incident photons, a deuteron target and $p_T > 0.5$ GeV. Single muon production is dominated by decays of the $D^\pm$ and D^0 mesons. Fig. 2 shows the PYTHIA estimates of the different processes contributing to single muon events.

The above arguments are predicated on the assumption that associated production does not dominate. For large photon energies the hadronization of $c\bar{c}$ is isolated from the target fragments. At E161 energies, however, hadronization can include the coupling of charmed quarks with target remnants. Rates of producing $\Lambda_c = udc$ and $\bar{\Lambda}_c = \bar{u}\bar{d}\bar{c}$ differ, since Λ_c can be created from a ud diquark in the target. The production and decay of Λ_c has been studied by counting the relative number of muons produced from the difference in rates of events with a Λ_c and a $\bar{\Lambda}_c$ using HERWIG 6.1 and PYTHIA 5.7. The μ^+ comes from D (c) mesons ($\approx 2\%\Lambda_c$ associated production), whereas the μ^- comes from $\bar{D}$ ($\bar{c}$) mesons ($\approx 20\%\Lambda_c$ associated production). The Λ_c's spin comes from the c quark; therefore, production depends neither on the polarization of c, nor the polarization of the target fragments. E161 will measure the differences in μ^+ and μ^- asymmetries to correct for Λ_c contamination.

Fig. 3 shows expected statistical errors for various experiments. E161 sta-

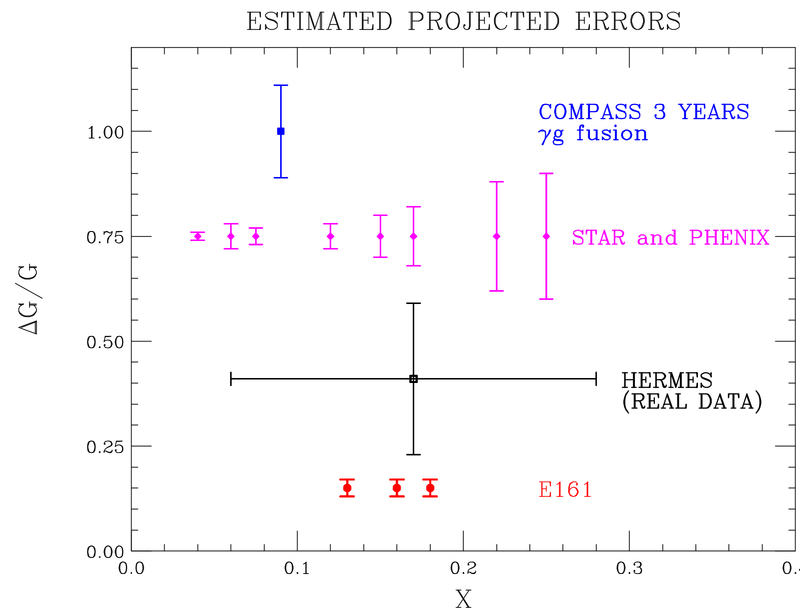

Figure 3: Estimated accuracy of $\Delta G/G$ measurements. Each data set is arbitrarily shifted on the y-axis.

tistical errors are small because of a spectrometer/detector design that makes effective use of the high luminosity and low duty factor at SLAC.

The Real Photon Program at SLAC is currently delayed indefinitely due to severe budget constraints. If money is eventually forthcoming, SLAC will be able to make a unique contribution to our understanding of ΔG.

References

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