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FUTURE SPIN EXPERIMENTS AT SLAC

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Abstract. A series of three photo-production experiments using a new polarized coherent quasi-mono-energetic photon beam have been approved at SLAC. Experiment E159 will measure the high energy end of the GDH sum rule. E160 will measure the A dependence of J/ψ and ψ' to determine ordinary nuclear attenuation and compare with that observed in heavy ion collisions. E161 will measure the gluon polarization in the nucleon using open charm production.

THE PHOTON BEAM

The three approved experiments require a mono-energetic high intensity photon beam and two of them require that the beam be longitudinally polarized. This beam will be produced using collimated coherent bremsstrahlung of a polarized electron beam hitting an oriented diamond crystal. The electron beams will have energies from 9.9 to 48.5 GeV; an intensity of up to 5×10^{10} electrons per pulse; repetition rate of 120 Hz; pulse length of 500 nsec; and polarization of about 83%. Typical photon beam energy spectra are shown in Fig. 1. The coherent peak is produced by constructive interference of the photons produced at different planes of the diamond crystal. Different orientations of the crystal produce peaks at different energies and intensities. Each experiment has different criteria for optimum results. The beamline elements for E160 are shown in Fig. 2.

E159: THE GDH SUM RULE

The Gerasimov-Drell-Hearn (GDH) sum rule [1] is one of the most fundamental relations in hadronic physics, and its experimental test is one of the major challenges for photo-production experiments over the next decade. The GDH sum rule relates the difference in total hadronic photo-absorption cross sections for left- ($\sigma_A^{\gamma N}$) and right-handed ($\sigma_P^{\gamma N}$) circularly polarized photons interacting with longitudinally polarized nucleons to the square of the nucleon's anomalous magnetic moment κ,

$$\int_{k_\pi}^{\infty} \frac{dk}{k} \Delta\sigma^{\gamma N}(k) = \frac{2\pi^2 \alpha \kappa^2}{M^2} \tag{1}$$

where k is the photon energy, $\Delta\sigma^{\gamma N}(k) = \sigma_P^{\gamma N}(k) - \sigma_A^{\gamma N}(k)$, M is the nucleon mass, and k_π is the threshold energy needed to produce at least one pion. An alternate notation is $\Delta\sigma^{\gamma N} = \sigma_{3/2}^{\gamma N} - \sigma_{1/2}^{\gamma N}$, where 1/2 (3/2) refers to the spin of the nucleon-photon system. Experimental data is need up to high energies to measure the complete integral. SLAC

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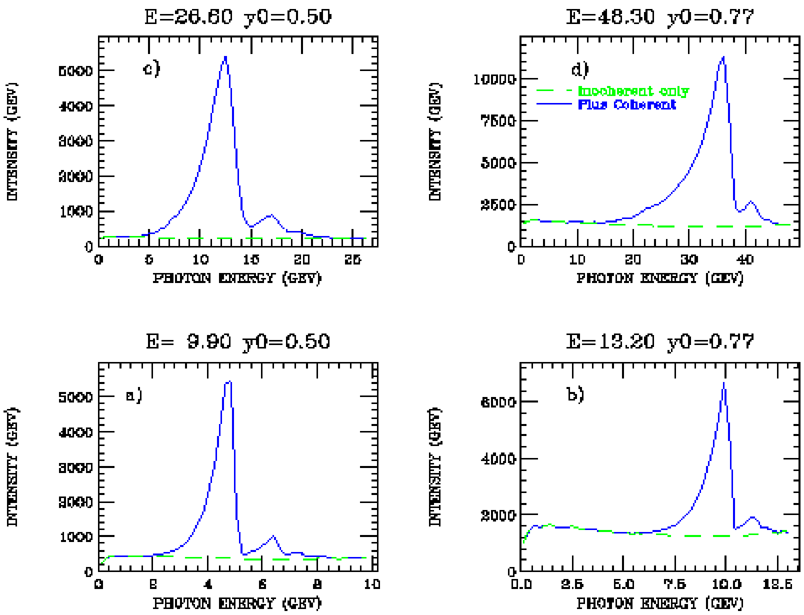

FIGURE 1. Calculated intensity (flux times energy) for collimated coherent bremsstrahlung at four settings. The dashed lines are incoherent radiation only, while the solid lines include coherent contributions.

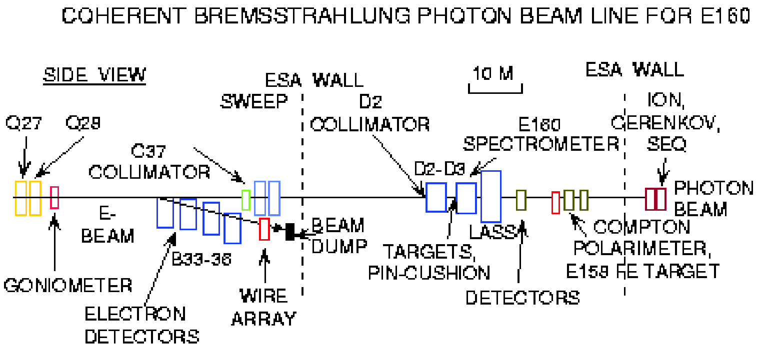

FIGURE 2. Overall view of the main components of the photon beam (horizontal scale is approximate, vertical scale is exaggerated)

is the only place where measurements above 6 GeV can presently be done. Numerically, the GDH sum rule prediction is 204 μb for the proton, 232 μb for the neutron, and 219 μb (-15 μb) for the average isoscalar (ISO-vector) combinations. The fundamental meaning of the sum rule is that any particle with a non-zero anomalous magnetic moment must have an excitation spectrum and internal structure. The energy scale at which the sum rule is saturated gives an indication of the energy scale beyond which nucleonic excitations become asymptotically spin-independent. Many authors [2] have analyzed the connection between the GDH sum rule, valid for real photons

($Q^2 = 0$), and the analogous sum rules for virtual photons, in particular the equally fundamental Bjorken Sum Rule [3] for $Q^2 \to \infty$, which has been the the subject of intense experimental study in the past decade. A generalized GDH Sum Rule can be formed that smoothly connects the $Q^2 = 0$ and large Q^2 limits. The goal of the present proposal is to augment the large body of data recently acquired at SLAC with virtual photons, with new data using real photons. This will provide valuable $Q^2 = 0$ anchor points for the study of spin-dependent photo-absorption cross sections in the 5 to 40 GeV energy range, thought to be responsible for much of the ISO-vector sum rule strength. Because there are no existing data in this energy region, it will be an exciting experimental venture, with surprising results certainly possible. Such was the case with the $Q^2 > 0$ measurements, which have concluded that the Ellis-Jaffe sum rules for the proton (p) and neutron (n) are strongly violated, although the more fundamental ISO-vector ($p - n$) Bjorken Sum Rule rule has been validated within experimental errors. Data from this proposal will compliment the vast body of spin-averaged data on $\sigma^{\gamma N}(k)$. Measurements of the spin degree of freedom will help to gain insight into underlying reaction mechanism for photo-absorption, such as the role of reggeon exchange and a possible pomeron cut contribution. A good understanding of soft Regge physics is essential for the interpretation of the Q^2-dependence of data taken with virtual photons. The energy region of 5 to 40 GeV accessible at SLAC extends the upper limit of integration by about an order of magnitude, which will likely be high enough if $\Delta\sigma^{\gamma N}$ is smoothly decreasing in strength with increasing energy. However, as in the resonance region, specific degrees of freedom for nucleon excitations can come in to play to cause oscillations in the magnitude of $\Delta\sigma^{\gamma N}$ which may well be significant. As an example, the SLAC energy range spans charm threshold. It is entirely possible that $\Delta\sigma^{\gamma N}$ is approximately constant in the SLAC energy range, which would imply that excitations at even higher energies play a crucial role in preventing the GDH integral from becoming divergent.

E160: PROPAGATION OF J/ψ AND ψ' IN NUCLEAR MATTER

The search for J/ψ suppression in heavy ion collisions is generally regarded as one of the most compelling signatures for the onset of the quark-gluon plasma [4](e.g. Fig.3 This search is one of the main goals of the newly constructed RHIC facility. However, modeling this suppression requires accurate knowledge of the J/ψ-nucleon and $\psi\prime$-nucleon cross section. The best way to measure this quantity is through the A-dependence of photo-production.

The cross section is dominated by quasi-elastic production. In this process, a photon undergoes a hard $\gamma N \to J/\psi N$ interaction with a nucleon in a nucleus with a kinematically dependent production time (or equivalently distance) scale. It takes a significantly longer time for the J/ψ to evolve from the point-like configuration of the hard interaction, to a full on-shell physical J/ψ particle. This formation time should be small compared to the nuclear radius R_A in order to use Glauber theory extract to the physical J/ψ-nucleon cross section. By varying both the production time. the formation time and the distance to be traveled in the nuclear medium (radius of nucleus) we can get

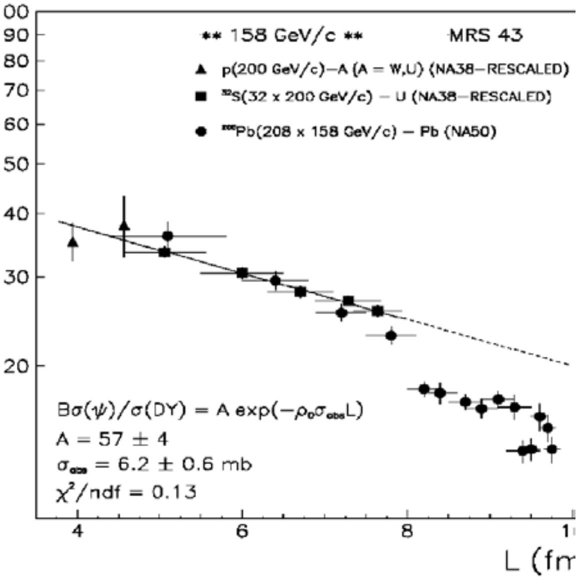

FIGURE 3. Suppression of J/ψ in heavy ion collision from NA50

a complete description of the propagation of the J/ψ in ordinary matter. We will use 4 different target materials and photon beam energies of 15, 25 and 35 GeV to span the relevant parameter space.

E161: THE GLUON POLARIZATION IN THE NUCLEON

To complete our understanding of the components of the nucleon spin it is necessary to make an accurate measurement of the contribution of the gluon. The unpolarized parton distributions have been measured over the last 30 years by many experiments. More recently the polarized up and down quark distributions have been measured in Deep Inelastic Scattering. The gluon spin density in the nucleon is poorly known since it comes mostly from the pQCD evolution of the DIS data. Current models differ widely. They indicate that the gluon spin makes very large contributions to the nucleon spin and cannot be ignored. Experiments at CERN, RHIC and SLAC will measure the gluon spin directly using a variety of theoretical and experimental techniques which complement one another in the *x* range covered and experimental and theoretical challenges.

At SLAC the gluon spin density within the nucleon will be determined by measuring the asymmetry of polarized photo-production of open charmed quarks from a polarized target. The hard scattering process is dominated by photon-gluon fusion and has been calculated to next to leading order in pQCD. Other mechanisms for producing charm are suppressed because of the large ($\sim$ 1.5 GeV) mass of the charm quark. Intrinsic charm contributions to the nucleon are expected to be very small at our kinematics. At photon energies above 40 GeV effects from associated production of Λ_c are estimated to be small. The highly polarized quasi-mono-chromatic photon beam will interact with

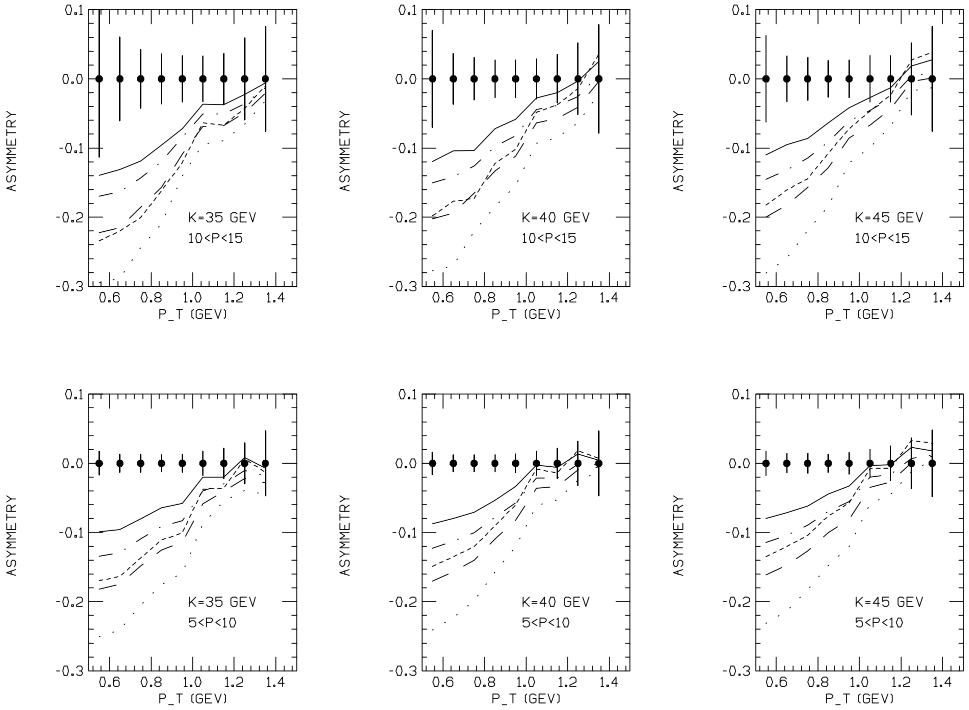

FIGURE 4. Estimated uncertainties for the asymmetry in open charm photo-production compared to various models of $\Delta g(x)$

longitudinally polarized nucleons in LiD. A polarization of greater than 60% will be attained using a temperature of 300 mK, and a 6.5 T magnetic field.

The open charm final state will be tagged by decays of D mesons into high transverse momentum muons. The parallel/anti-parallel asymmetry for producing open charm is closely related to the fundamental polarized gluon spin density $\Delta g(x)$. The asymmetry for single muons will be measured as a function of muon momentum, muon transverse momentum, and photon beam energies with sufficient precision to discriminate among models of $\Delta g(x)$ that differ from each other by as little as 10% in the range $0.1 < x < 0.2$. Significant constraints will be placed on both the shape and magnitude of $\Delta g(x)$ as illustrated in Fig. 4 The projected errors are significantly smaller than for other experiments that plan to make direct measurements of $\Delta g(x)$.

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