Proton Spin Physics with STAR at RHIC

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In late 1999, we were asked by Professor S. Vigdor of Indiana University to join a new spin physics program at RHIC using the STAR detector. The previous summer, the NSF had approved funding to construct an endcap electromagnetic calorimeter (EEMC) to be added to the STAR detector. The EEMC will provide STAR with the ability to study electromagnetic final states in the pseudo-rapidity range 1.08 < 0 < 2, supplementing the barrel electromagnetic calorimeter, which will cover -1 < 0 < 1 once it is completed. While the EEMC will enhance STAR's ability to observe electromagnetic final states in relativistic Au-Au collisions, the primary motivation is to allow STAR to measure photons produced in quark-gluon Compton scattering during *p-p* and *p-A* collisions. When used in conjunction with the polarized proton beam at RHIC and STAR's existing ability to observe jets with high efficiency, the STAR detector with the EEMC will be the best system available anywhere in the world for measuring the gluon contribution to the proton spin. Following discussions with DOE and the STAR management, our group was approved for membership in STAR in May, 2000, by a vote of the STAR Council.

The main physics argument that makes STAR ideal for measurements of the gluon properties of the nucleon is that most of the high-p_T photons that are produced directly in *p-p* collisions at RHIC energies originate from quark-gluon interactions, effectively via the Compton scattering process *qg* 6 *q*(. This process has a sizable longitudinal double-spin analyzing power A_{LL}. By observing photon-jet coincidences in *p-p* scattering, one can reconstruct the kinematics of the underlying *qg* 6 *q*(reactions and infer the longitudinal momentum fractions of the incident partons, x_1 and x_2. If reactions with $x_1 >> x_2$ are singled out for study, the event sample is strongly biased in favor of $x_1 = x_q$ and $x_2 = x_($. The spin of the valence quarks in the proton has been studied at moderate and large *x* in previous polarized deep-inelastic scattering experiments, so measurements of A_{LL} in photon-jet coincidences will make it possible to unravel the gluon contribution to the proton spin as a function of the gluon momentum fraction $x_($ and to determine the integral contribution)*G* to ±0.5. The experiment will also measure the *x* dependence of the polarization of *u* and *d* quarks in the proton at large *x* and of $\underline{u}$ and $\underline{d}$ antiquarks in the proton at small to moderate *x* via simultaneous, complementary measurements of A_L in *W*-boson production and A_{LL} in Drell-Yan scattering. This information is crucial if we eventually hope to understand the properties of baryons such as the proton from basic QCD. In addition, the observation of photon-jet coincidences in *p-A* collisions at RHIC will measure the *A*-dependence of the nuclear gluon distribution, a crucial input to the interpretation of relativistic heavy ion collisions.

The EEMC is essential for these measurements. It provides STAR with electromagnetic coverage in the forward direction, which is needed to have good acceptance for photon-jet and Drell-Yan events with $x_1 >> x_2$. A_{LL} is also largest when the photons are produced in the forward direction, maximizing the sensitivity to the gluon spin. The EEMC will be a traditional sampling calorimeter, divided into 720 projective towers to provide high granularity in 0 and N. Each projective tower will consist of 24 plastic scintillator tiles, read out by individual wavelength-shifting fibers, separated by 23 Pb radiators. The 24 optical fibers from a given tower will be routed to a common photo-multiplier tube for optical summing and read-out. In addition, the first, second and last plastic scintillator tiles in each tower will contain a second wavelength-shifting fiber. These three fibers, representing the pre-shower and post-shower detectors, will be read out individually to provide information about the longitudinal evolution of the electromagnetic showers for gamma-B^0 and electron-hadron discrimination. In addition, the EEMC will contain a shower maximum detector, consisting of 7200 triangular plastic scintillator strips read out by individual wavelength-shifting fibers, to measure the locations of the photons and to provide additional gamma-B^0 discrimination. Overall, there will be 720 traditional photo-multiplier tubes to read out the tower signals and 576 16-pixel multi-anode phototubes to read out the pre-shower, post-shower and shower maximum detectors.

As part of our contribution to the STAR collaboration, we have agreed to design and construct the magnetic shields for the photo-multiplier tubes that will be used to read out the scintillators in the EEMC. The phototubes will be mounted on the back of the STAR pole tip, in a region where the fringe field ranges from 200 to over 1000 Gauss. We have developed a scheme to mount the phototubes in 108 individual steel boxes, each of which will contain either 12 standard PMT's or 12 multi-anode PMT's. 60 boxes will be used for read-out of the tower PMT's, 36 will be used for read-out of the shower maximum detector, and 12 will be used for read-out of the pre-shower and post-shower detectors. These boxes will support the optical connectors needed to couple the fiber bundles from the EEMC to the phototubes and contain the optical fiber routing necessary to multiplex the fibers to the appropriate PMT's, in addition to providing the magnetic shielding and cooling necessary for the tubes to operate. At present, we have conceptual designs for the photo-multiplier tube boxes and for "tiling" the boxes onto the STAR pole tip. We will complete the design this spring and build prototype boxes during the summer for installation on STAR. The schedule calls for the prototype boxes to be tested during the Fall, 2001, running period at RHIC. After that, we will build half the boxes in time for the Summer, 2002, RHIC shut-down when the first half of the EEMC is to be installed at Brookhaven. The rest of the EEMC is to be installed during a RHIC shut-down in Summer, 2003.