Recent Results from HERMES

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Abstract

HERMES is a third-generation spin structure experiment which aims to perform a complete program of spin structure studies of the proton and neutron. One of the principal strengths of the experiment is the measurement of semi-inclusive, as well as inclusive, spin asymmetries, which will extend our knowledge of the polarization of the individual quark flavour components of the nucleon far beyond what is possible with purely inclusive measurements. In addition, HERMES collects high statistics event samples with unpolarized targets, and has made new measurements of fragmentation functions and of the flavour structure of the nucleon sea using these data. An overview of the present status of the experiment and various ongoing analyses is presented.

I. The HERMES Experiment

Nucleon Spin Structure

Spin is a relatively new degree of freedom with which to study the structure of hadrons. The principal experimental approach used to date is the measurement of double spin asymmetries in the deep-inelastic scattering (DIS) of polarized lepton beams from polarized nuclear targets. The asymmetry formed by flipping the relative orientation of beam and target spin is related to the spin structure function g_1 of the target. In the lowest order parton model, this structure function can be expressed in the following simple way:

$$g_1 = \frac{1}{2} \sum_f e_f^2 \Delta q_f(x) \tag{1}$$

where the index f refers to quark flavour, e_f is the quark charge, and $\Delta q_f(x) \equiv q_f^{\uparrow}(x) - q_f^{\downarrow}(x)$ is the polarized parton distribution function.

In 1988, a measurement of the spin structure function g_1^p of the proton by the EMC collaboration [1] suggested that the polarization of the quark constituents of the proton account for less than 15% of of the total spin of the nucleon. Since then, experiments at SLAC and CERN have repeated such measurements. The total spin of the quarks is extracted by combining measurements of g_1 on the proton, deuteron, and ^{3}He with measured values of the F and D parameters describing hyperon beta decay (observables also related to hadronic spin structure). The global analysis of ref. [2], performed under the assumption of SU(3) flavour symmetry, yields a value 0.31 ± 0.07 for $\Delta\Sigma$, the total fraction of the nucleon spin provided by the quark helicities.

Such SU(3) flavour symmetric analyses also suggest that the strange quarks in the nucleon carry a slight negative polarization, whose magnitude amounts to about 10% of the nucleon spin. It is of great importance to confirm this rather suprising result in a less model-dependent analysis, and also to explore the polarization of the light quark sea.

To achieve these goals, one must turn to the measurement of *semi-inclusive* asymmetries, where both the scattered beam lepton and particles in the hadronic final state are detected. Such asymmetries provide additional "flavour tagging" information about the flavour of the struck quark, which is related to the flavour composition of final state hadrons through fragmentation functions [3]. Hadrons with high energy fraction $z = E_h/\nu$ are especially likely to contain a parton of the same flavour as the struck quark. Explicitly, the spin asymmetry for the production of a hadron h takes the following parton model form:

$$A_1^h(x,z) = \frac{\Sigma_f e_f^2 \Delta q(x) D^{f/h}(z)}{\Sigma_f e_f^2 q(x) D^{f/h}(z)}(1+R) \tag{2}$$

By measuring such semi-inclusive asymmetries for several hadronic species and targets, one can separate the individual flavour components of quark polarization, and in particular obtain information about the quark sea.

The HERMES Experiment

HERMES is a third-generation spin structure experiment which aims to perform a complete program of inclusive and semi-inclusive spin structure measurements on the proton and neutron. The experiment has been running at the HERA storage ring in Hamburg, Germany since 1995. HERMES measures the scattering of polarized 27.5 GeV positrons or electrons from polarized internal gas targets. Undiluted species of polarized gas are fed into a cooled target cell located directly in the beam vacuum. An optically pumped ^{3}He target was used during the 1995 data taking period, while an atomic beam source (ABS) provided polarized hydrogen for the 1996 and 1997 running periods. The ABS will supply polarized deuterium for data collection in 1998 and 1999.

The circulating HERA electron beam is naturally polarized in a transverse orientation by the continuous emission of synchrotron radiation. Spin rotators installed on either side of the HERMES experimental area produce the longitudinal polarization necessary for the asymmetry measurements. The beam polarization is monitored by two independent polarimeters, respectively located outside and inside the spin rotators.

The HERMES detector is a forward, open-geometry spectrometer providing large acceptance and good particle identification. A detailed description of the spectrometer is provided in reference [4].

II. Inclusive Measurements

Spin Structure Functions

Figure 1a shows the spin structure function g_1^n measured by HERMES from the 1995 data on ^{3}He [5]. Our result for g_1^p is shown in 1b, based on the 1997 H data set [6]. The proton measurement is consistent with world data, and of comparable precision to the published results from SLAC experiment E-143. The neutron measurement is also consistent with data from SLAC and SMC, and will be supplemented by HERMES data on deuterium during the 1998 and 1999 running periods.

Gerasimov-Drell-Hearn Sum Rule

The Gerasimov-Drell-Hearn (GDH) sum rule [8] relates two quantities relevant to the spin structure of the nucleon: the anomalous magnetic moment of the nucleon (κ), and the difference between the total photoabsorption cross-section in the $J = 1/2$ and $J = 3/2$ spin states.

$$I_0 \equiv \int_0^\infty \left[\sigma_{1/2}(\nu) - \sigma_{3/2}(\nu)\right] \frac{d\nu}{\nu} = -\frac{2\pi^2\alpha}{M^2}\kappa^2 \tag{3}$$

It is as yet prohibitively difficult to make a direct measurement of this quantity with real photons. There is also strong interest in a generalized form of the above integral [9], which may be addressed by electron scattering experiments:

$$I(Q^2) \equiv \int_{Q^2/2M}^\infty \left[\sigma_{1/2}(\nu,Q^2) - \sigma_{3/2}(\nu,Q^2)\right] \frac{d\nu}{\nu} = \frac{8\pi^2\alpha}{M} \int_0^1 \frac{g_1(x,Q^2) - \gamma^2 g_2(x,Q^2)}{\nu\sqrt{1+\gamma^2}} \frac{dx}{x} \tag{4}$$

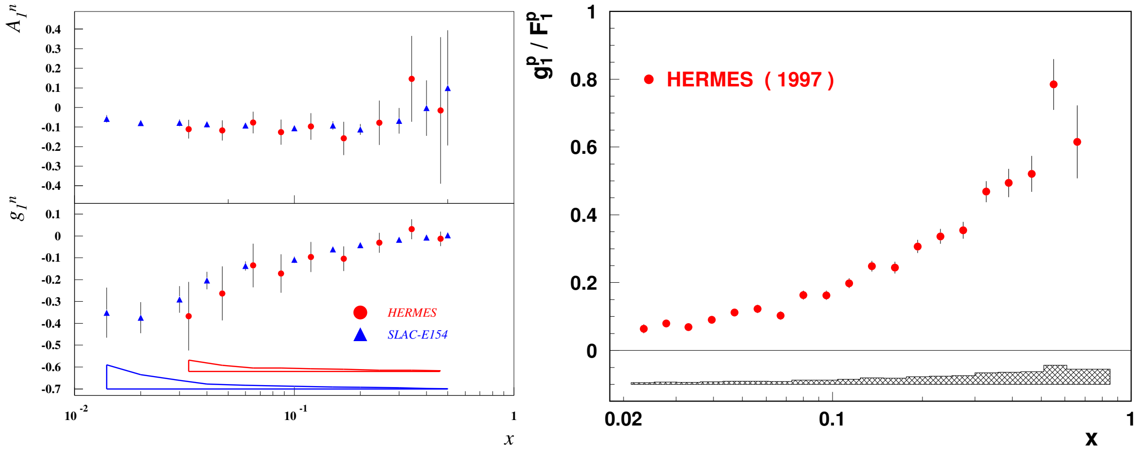

Figure 1: (a) A_1^n and g_1^n as measured by HERMES (1995 data) [5] and E154[7]. (b) g_1^p/F_1^p as measured by HERMES (1997 data) [6].

where $\gamma^2 \equiv Q^2/\nu^2$. The GDH integral I_0 is recovered by taking the $Q^2 = 0$ limit of $I(Q^2)$. Each measurement of the inclusive spin structure functions yields a portion of the integral $I(Q^2)$. HERMES can contribute the "DIS portion", for W^2 values above 4 (GeV/c)^2. Other experiments, at facilities such as Jefferson Lab, will be needed to supply the resonant contribution at lower W. However, at the intermediate Q^2 values of the HERMES measurement, the DIS part of the integral is expected to be dominant. The open geometry of HERMES and its consequent continuous kinematic coverage in ν and Q^2 is of particular advantage to the measurement of this quantity, as compared with the slender bands in phase space within which other measurements have been made.

Preliminary results on I_n^{DIS} and I_p^{DIS} versus Q^2 are shown in figure 2. The neutron and proton results are obtained from the 1995 and 1996 data sets respectively, within the kinematical limits $0.8 \leq Q^2 \leq 10$ (GeV/c)^2, $\nu < 23.4$ GeV, and $W^2 > 4$ GeV. The plotted circles represented the actual measured value within these kinematic limits, while the square and triangular points represent two possible extrapolations of the measurement to the $\nu \to \infty$ limit. The theoretical uncertainty surrounding this extrapolation is clearly a dominant complication in the interpretation of the results.

To place the data in context, the value of the GDH sum I_0 expected in the $Q^2 \to 0$ limit is of order -200. A dramatic turnover of the integral at low Q^2 must therefore occur for the sum rule to be satisfied.

III. Semi-inclusive Measurements

Quark Polarizations

As mentioned above, semi-inclusive asymmetries measured for different hadronic species and targets can be combined to yield information about the polarization of individual quark flavours in the nucleon. The inclusive spin asymmetries A_1 are also included in such an analysis. Equation 2 can be rewritten in a convenient form for this purpose:

$$A_1^h = \Sigma_f P_f^h(x,z) \frac{\Delta q_f(x)}{q_f(x)} \tag{5}$$

In this way, the spin-dependent quantities of interest are isolated, and the remaining "purity matrix" P_f^h depends only on the unpolarized parton distribution functions $q_f(x)$ and the fragmentation

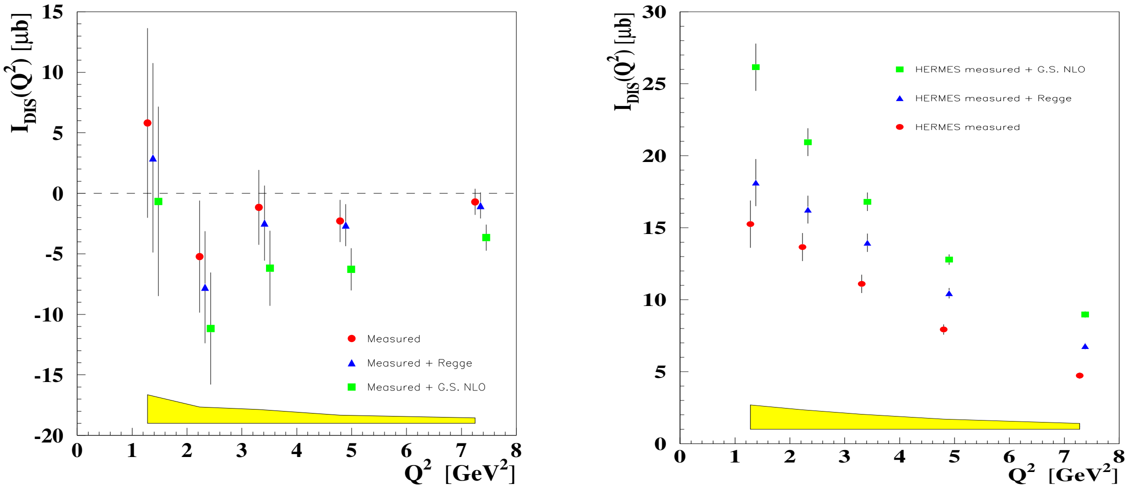

Figure 2: Preliminary HERMES measurement of the GDH integrals $I(Q^2)$. The left and right panels show the results for the neutron and proton respectively. The circles indicate the measurement made within the kinematic limits of HERMES. The square and triangular points show two possible extrapolations of the integrals to the $\nu \to \infty$ limit.

functions $D^{f/h}(x,z)$. The quark purities P_f^h are the coefficients of the resulting system of linear equations, and can be interpreted as the conditional probability that a quark of flavour f was struck in an event which produced a hadron h.

The matrix elements P_f^h can conveniently be calculated by means of a Monte Carlo simulation. The purities are thus dependent on the particular models used in the simulation for the unpolarized quark distributions and for the fragmentation process. Numerous systematic checks of these dependences have been performed. In particular, several fragmentation models, such as the Lund string model and independent fragmentation formalism, have been used, with a variety of parameters. The purities are found to be rather insensitive to these variations, and in the end, such dependences are responsible for only a third of our conservative preliminary estimate of the systematic uncertainty. Conversely, the use of a Monte Carlo simulation circumvents the need to make simplifying approximations, such as the x-independence or target-independence of the fragmentation functions.

The preliminary results shown here are the result of a purity matrix analysis of six separate asymmetry measurements. These are the inclusive asymmetry A_1 and the semi-inclusive asymmetries A_1^{h+} and A_1^{h-} (for positive and negative hadron production), measured from two polarized targets: ^{3}He (1995 data) and H (1996 data). Due to the statistical limitations of the data collected to date and the nature of the purity matrix itself, it is not presently possible to make a significant extraction of more than three independent quark polarizations. Consequently, an assumption must be made about the relationship between the various sea quark polarizations. Two assumptions have been made. One is of flavour-independent quark spin distributions:

$$\frac{1}{6}\Delta\overline{q} = \Delta u_{\rm sea} = \Delta\overline{u} = \Delta d_{\rm sea} = \Delta\overline{d} = \Delta s = \Delta\overline{s} \tag{6}$$

The other is of flavour-independent *fractional* quark polarization:

$$\frac{\Delta\overline{q}}{\overline{q}} = \frac{\Delta u_{\rm sea}}{u_{\rm sea}} = \frac{\Delta\overline{u}}{\overline{u}} = \frac{\Delta d_{\rm sea}}{d_{\rm sea}} = \frac{\Delta\overline{d}}{\overline{d}} = \frac{\Delta s}{s} = \frac{\Delta\overline{s}}{\overline{s}} \tag{7}$$

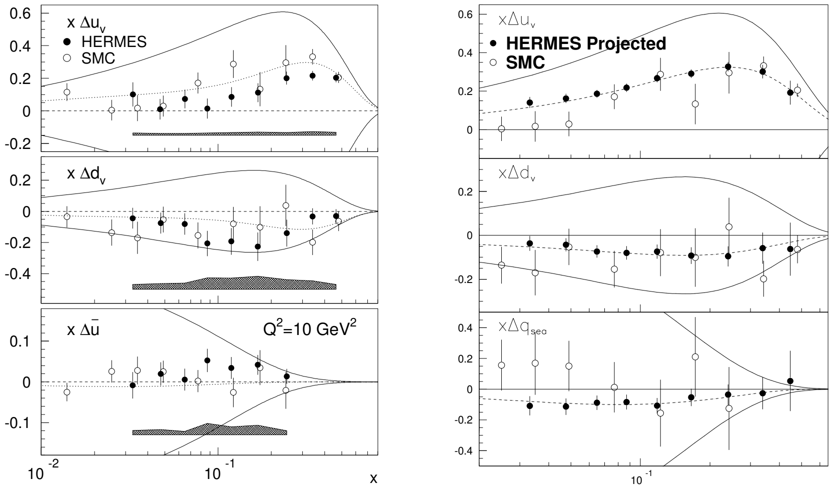

Figure 3: (a) Preliminary quark polarizations extracted by HERMES from 1995 and 1996 data. (b) Conservative projection of HERMES accuracy including forthcoming data from 1998 and 1999. In both figures, the open points are the data from SMC [10], and the dashed curves are the theoretical model of [11]. The solid outer curves indicate the limits on the quark distributions imposed by the unpolarized parton distribution functions.

The choice between these two assumptions is found to have negligible influence on the result.

HERMES preliminary results are shown in figure 3a, for the valence quark polarizations $x\Delta u_v(x)$ and $x\Delta d_v(x)$, and for the sea polarization $x\Delta q_{\rm sea}(x)$. Overlaid on the HERMES points are the results published by the SMC collaboration [10], also based on semi-inclusive hadron asymmetries. The results are statistically consistent with each other. However, the HERMES data do hint at a discrepancy with the theoretical model of [11], particularly in the region $x \simeq 0.1$. The data indicate a weaker polarization of the u valence quarks, a stronger negative d_v polarization, and a possible positive sea quark polarization in this region.

HERMES sensitivity to the quark polarizations is presently limited by the relative lack of high quality neutron data, as compared to the proton measurements of 1996 and 1997. Our ability to extract the quark polarizations will be greatly enhanced by the addition of the deuterium data to be collected during 1998 and 1999, as well as the 1998 upgrade of the threshold Cerenkov detector to a RICH (see section IV). A conservative projection of our ultimate accuracy is shown in figure 3b, superimposed with the data from SMC and with the theoretical model of ref [11]. As is shown, the HERMES data will be of sufficient precision to measure even the modest d_v and $\overline{q}$ polarizations predicted by this model.

Fragmentation Functions

The process by which a scattered quark fragments into a series of colour singlet hadrons is a fundamental one of which there is, at present, little theoretical understanding. The process is traditionally expressed in terms of fragmentation functions $D^{f/h}(z, Q^2)$, which represent the multiplicity of hadrons of type h which are created when a quark of flavour f is struck or produced in a hard scattering process. The best data available on these functions comes from high energy e^+e^- collider experiments, which have no sensitivity to the flavour of quark from which each jet of hadrons originates. The only measurement of fragmentation functions from deep-inelastic scattering comes from the EMC experiment [12]. HERMES has already collected charged pion samples which are

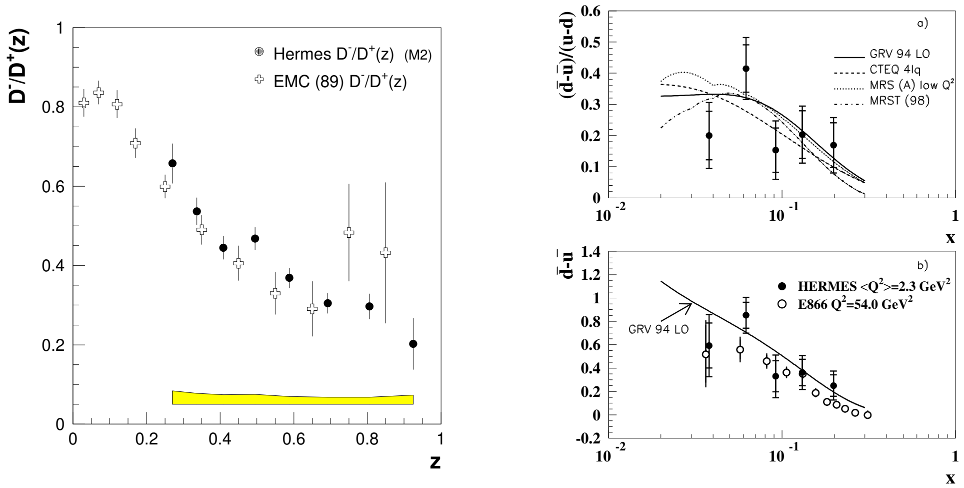

Figure 4: (a) Preliminary HERMES results on the ratio D^+/D^-, superimposed with the EMC data of ref. [12]. (b) HERMES measurement of the flavour asymmetry of the light quark sea [15]. Superimposed are the Drell-Yann measurements of [14] and [16].

larger by a factor of 5 than those used in the EMC measurement, and so hopes to make a significant contribution to our knowledge of these functions.

The measured quantity needed for this study is the multiplicity of hadrons h produced at a given value of $z \equiv E_h/\nu$ in a DIS event. This observable can be expressed as follows:

$$\frac{1}{N_e}\frac{dN^h}{dz} = \frac{1}{\sigma_{tot}}\frac{d\sigma(eN \to e'hX)}{dz} = \frac{\int\int dx dQ^2\ \Sigma_f e_f^2 q_f(x,Q^2) D_f^h(z,Q^2)}{\int\int dx dQ^2\ \Sigma_f e_f^2 q_f(x,Q^2)} \tag{8}$$

In an analysis similar to the quark polarization extraction described above, equation 8 is seen to be linear in the fragmentation functions, with coefficients dependent only on the rather well-known unpolarized parton distribution functions (PDF's). Again, the coefficients are determined by Monte Carlo simulation. Variations in the choice of PDF parametrization yield systematic uncertainties of less than 2%. More challenging is the correction of the measured fragmentation functions for the hadrons missed by the HERMES spectrometer acceptance. This correction factor is also determined by Monte Carlo simulation, and is dependent not only on the accuracy with which the detector is modelled, but also on the fragmentation model used to extrapolate the observed hadrons into the unmeasured regions of phase space. The correction factor can be quite large, varying from 3 to about 9 across the kinematic range of the measurement.

As no spin-dependent observables enter into equation 8, the high-statistics samples of unpolarized data collected at HERMES can be used. Results extracted separately from H, D, and ^{3}He targets were found to agree, and so the data sets are combined in the analysis presented here. The specific measurements used are the multiplicities for the production of positive and negative pions. The pions are identified by means of the threshold Cerenkov counter, and are consequently restricted to momenta above 4 GeV/c.

As only two independent observables are measured, only two fragmentation functions may be extracted. As was done in the EMC analysis of [12], charge conjugation invariance and isospin symmetry of the fragmentation functions are assumed:

$$D^+ \equiv D_u^{\pi^+} = D_d^{\pi^-} = D_{\overline{u}}^{\pi^-} = D_{\overline{d}}^{\pi^+} \tag{9}$$
$$D^- \equiv D_u^{\pi^-} = D_d^{\pi^+} = D_{\overline{u}}^{\pi^+} = D_{\overline{d}}^{\pi^-} = D_{s,\overline{s}}^{\pi}$$

The "favoured" fragmentation function D^+ characterizes events where the detected hadron h contains a quark of the same flavour as the struck quark. The function D^- characterizes all other events and is termed "disfavoured".

Figure 4a shows the HERMES preliminary result on the ratio of favoured to disfavoured fragmentation functions. The systematic error on the ratio is dominated by the assumption of equation 9, whose influence was evaluated in various models of the fragmentation process. Of particular interest is the behaviour of the D^+/D^- ratio in the limit $z \to 1$. The early independent fragmentation model of [13] predicted a rather simple dependence, $(1-z)/(1+z)$, which goes to zero at the $z=1$ limit where the observed hadron carries the entire energy of the virtual photon. The EMC data suggested that this relation might be insufficient, an observation which is confirmed to much higher precision by the HERMES data.

Flavour Asymmetry of the Light Quark Sea

In the same way that polarized quark distributions may be extracted from the measurement of semi-inclusive hadron asymmetries, charged hadron multiplicities may be used to extract unpolarized parton distributions. Although these are generally well constrained by the large database of F_2 and F_3 measurements, the flavour ratio $\overline{u}/\overline{d}$ of the light quark sea has eluded the grasp of DIS experiments. The violation of the Gottfried Sum Rule indicated by the F_2^n and F_2^p measurements of NMC suggested that the sea was not, in fact, isospin symmetric, an effect not predicted by the naive quark-parton model. However, this measurement was explained in many different ways and cannot be considered a direct measurement of the sea flavour asymmetry.

The first direct confirmation of $\overline{u}/\overline{d} < 1$ came from the Drell-Yann experiment NA51 [14], which measured a single point at $x \simeq 0.2$. However, the experiment was not able to provide any indication of the x-dependence of the asymmetry.

The HERMES measurement of the sea flavour asymmetry [15] is shown in figure 4b. The result is based on unpolarized data on charged pion production collected from H and D targets, and uses the fragmentation functions measured within the HERMES acceptance from ^{3}He data only. In this way, no correlations exist between the pion samples and fragmentation functions used in the analysis. The results show a clear excess of $\overline{d}$ quarks over $\overline{u}$ quarks in the sea, and a pronounced x-dependence which indicates an increasingly flavour-symmetric sea as x increases toward 1. It is also clear from this result that the majority of the Gottfried Sum Rule violation does indeed come from a $\overline{u}/\overline{d}$ asymmetry.

This effect has been seen independently in the Fermilab Drell-Yann experiment E866 [16]. It is important to note that the two results are complementary, since they are are determined from different physical processes and are directly sensitive to different quantites. HERMES measures $(\overline{d}-\overline{u})/(u-d)$, while the Drell-Yann experiments determine $\overline{u}/\overline{d}$.

IV. Detector Upgrades in 1998

The HERA accelerator schedule featured an extended shutdown period of 6 months at the beginning of this year. This provided the opportunity for the upgrade of the HERMES experiment with several new devices. The shorter one to two month shutdown planned for winter of 1998/1999 will permit the installation of further new detectors.

The RICH Upgrade

The most complex and significant of the HERMES 1998 upgrades is the replacement of the threshold Cerenkov detector with a Ring-Imaging Cerenkov (RICH). Two such devices (one each for the upper and lower halves of the spectrometer) were constructed and successfully installed during the shutdown. The RICH detectors employ a dual radiator system consisting of an array of clear aerogel tiles (n = 1.03) followed by a volume of heavy C_4F_{10} gas (n = 1.0014). The two thresholds provided by this system enable the identification of pions, kaons, and protons across the entire momentum range of the experiment, from 2 to 20 GeV/c. The Cerenkov photons are intercepted by a thin spherical mirror of optical quality, formed from eight contiguous segments, and are reflected onto hexagonal arrays of 3/4" phototubes. Particles traversing the radiators produce in general two cones of Cerenkov photons, which are imaged onto the phototube array as rings of hits. The radii of these rings provide a continuous mass measurement for the particles, when combined with the momentum information supplied by the tracking system. The two RICH detectors together employ 3868 phototubes, whose signals are discriminated and read out by a PCOS IV system.

As mentioned above, the RICH will permit the identification of all stable hadronic species across the complete momentum range of the experiment. By contrast, the threshold Cerenkov counter that was in place for the years 1995 through 1997 permitted the identification of pions only, above a momentum threshold of 6 GeV/c (in 1995) and 4 GeV/c (in 1996-1997). As the pion spectrum from deep inelastic scattering is strongly peaked at low momenta, the yield of positively identified pions available to HERMES will be dramatically increased by the presence of the RICH. This will provide a higher statistics sample for the measurement of pion asymmetries, to be used in the determination of the quark polarizations. The ability to identify kaons and protons as well will provide additional independent asymmetries with which to constrain the quark polarizations. The kaon asymmetries, in particular, enhance our sensitivity to the strange quark component of the sea, and will hopefully permit a first direct measurement of the strange quark polarization.

With the exhanced particle identification of the RICH, the ability to reconstruct unstable particles from their decay products will be greatly improved. The measurement of charmed particles in a spin-dependent experiment is a particularly exciting prospect, as it provides the opportunity for access to the as yet unmeasured gluon polarization in the nucleon. The only two-particle decay mode of the D^0 meson is to a kaon and pion. Simulations indicate that the RICH will reduce background in this channel by a factor of 15, making it possible to identify a significant D^0 signal at HERMES. Finally, the RICH will provide HERMES with the ability to measure fragmentation functions to kaons and protons as well as pions. The samples we expect to collect will greatly improve on the only existing measurement of these quantities from EMC [12].

Charm

The HERMES Charm Upgrade consists of a series of new detectors, designed to enhance the ability of the experiment to measure charm production. The interest in this measurement is twofold. First, HERMES is kinematically placed near the charm threshold. Knowledge of charm production in this region is currently very limited, and is of considerable theoretical interest. Second, as the charm content of the nucleon is, at best, very small, charm production proceeds predominantly through the photon-gluon fusion process, rather than through single quark scattering. Consequently, the spin asymmetry of charm production is directly proportional (at leading order) to the fractional polarization of the gluon field, $\Delta G/G$. As is now known, quark polarization accounts for only about 30% of the nucleon spin. The rest must come from either the gluon polarization, or from the orbital angular momentum of quarks and/or gluons. The measurement of $\Delta G/G$ is clearly the next step to take in the experimental study of nucleon spin structure.

The HERMES charm upgrade will be accomplished in two phases. Phase I comprises two new detectors which were installed during the 1998 shutdown. The first is a system of hodoscopes placed behind a 1 m thick iron absorber wall, for the identification of muons. Muons feature prominently in the decay modes of charmed hadrons, via the semi-leptonic decay of the charm quark in the case of singly charmed particles, and via the dilepton decay mode of the J/ψ . This detector system provides muon identification in both the "standard" (existing) spectrometer acceptance, and in the "frame gap" region presently occupied by the frames of the detectors. Because of the large mass of charmed hadrons, their decay products frequently appear at angles which lie outside the present acceptance of the HERMES spectrometer. The second detector installed in 1998 is the Forward Quadrupole Spectrometer (FQS), consisting of a series of tiny vertical-drift chambers placed inside the aperture of two beam quadrupoles downstream of the experiment. This device will measure beam leptons scattered at the low angles characteristic of low Q^2 events. The proximity of HERMES to the charm threshold is at once an intersting region to measure and an experimental challenge, because of the low cross-sections which exist in this region. Consequently, in order to make a charm measurement of significant statistical precision, HERMES must measure down to the real photoproduction limit where the cross-section is sharply peaked. The FQS will enable the determination of the vertex kinematical variables ν and Q^2 for a portion of these events.

Phase II of the charm upgrade will consist of the installation of two planes of Limited Streamer Tubes, located behind the iron poles of the HERMES spectrometer magnet. The iron of the magnet itself will thus serve as an absorber, for the identification of muons at angles outside both the "standard" and "frame gap" acceptance regions. The LST chambers will be installed during the 1998/1999 winter shutdown of the accelerator.

The charm upgrade will enhance the charm detection ability of HERMES in two channels. First is the $J/\psi \to \mu^+\mu^-$ decay mode. Second is the mode $D^0, \overline{D^0} \to K\mu X$, a partially reconstructed channel which relies on the combination of strange quark and muon as a unique signature of charm quark decay. The presence of the RICH is vital to the feasibility of this channel, and in addition provides a third measurable decay mode, $D^0, \overline{D^0} \to K\pi$.

V. Other physics

An overview has been presented here of the current status and some analyses of the HERMES experiment. However, the HERMES program includes numerous additional physics topics, which can be mentioned only briefly in this report.

One of these is the study of spin-dependent Λ production. The Λ baryon is a weakly-decaying resonance, and because of the parity-violating nature of its decay, it is "self-analyzing", in the sense that the angular distribution of its decay products (in the channel $\Lambda \to p\pi^-$) is directly related to the spin of the Λ in the final state. Because of this extra polarization information, interesting spin-dependent studies can be made using a polarized beam and an unpolarized target. In the backward ($x_F > 0$) hemisphere (also termed the target fragmentation region), Λ polarization measurements yield information about the spin structure of the Λ [17]. This structure is closely related to that of the proton and neutron, by an SU(3) rotation in the space of the three lightest quark flavours. In the forward ($x_F > 0$) or current fragmentation region, one can study the spin dependence of fragmentation [18]. The question at issue is to what extent the spin of the virtual photon is transmitted, through the fragmentation process, to the spin of the Λ. Nothing is known at present about a possible spin dependence of the fragmentation functions.

Extensive studies of vector meson production are underway at HERMES. These are discussed in further detail in the proceedings of one of the parallel sessions at this workshop. Our sample of diffractive ρ^0 mesons will yield the production cross section in the interesting region of intermediate Q^2 and W which marks the transition between various models of diffractive meson production (vector meson dominance, and "hard" and "soft" Pomeron exchange). Preliminary results on the spin-density matrix elements for ρ^0 production are already available. In addition, HERMES has collected a sample of diffractive ϕ and J/ψ particles whose cross-sections are being analyzed.

In 1997, HERMES recorded several days worth of events using an unpolarized ^{14}N target. These data have yielded a preliminary result on the nuclear transparency of ρ^0 production, a measurement which investigates the coherence length of the fluctuation of a virtual photon into a vector meson. The initial state interaction of the rho with the nuclear medium allow one to measure this coherence length against the ruler provided by the nuclear radius. In addition, the study of the ν and Q^2 dependences of the transparency may yield information on colour transparency, a prediction of perturbative QCD that postulates reduced final state interactions with increasing Q^2 in exclusive processes.

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