NEW RESULTS ON SPIN DENSITY MATRIX ELEMENTS FOR ρ^0 AT HERMES

BOHDAN MARIANSKI
ON BEHALF OF THE HERMES COLLABORATION
Andrzej Soltan Institute for Nuclear Studies, Warsaw
Hoza 69, Poland
E-mail: bohdan@fuw.edu.pl

Spin Density Matrix Elements (SDMEs) have been determined from exlusive diffractive ρ^0 production at 27.5 GeV in the HERMES experiment. Beam polarization dependent and independent SDMEs have been extracted from the data on hydrogen and deuterium targets accumulated in the years 1996 - 2000 in the HERMES kinematic region $1 < Q^2 < 5$ GeV^2, $3.0 < W < 6.3$ GeV. Kinematic dependences of the 15 unpolarized SDMEs on Q^2 are also presented.

1. Introduction

In exclusive meson leptoproduction the spin transfer from the virtual photon to the vector meson is commonly described [1] in terms of Spin Density Matrix Elements (SDMEs - $r_{ij}^{\alpha\beta}$).These matrix elements can be experimentally accessed through measurements of angular distributions of the produced vector meson and its decay pions.The angular distribution of the scattered lepton and of the decay products $W(cos\Theta, \phi, \Phi, r_{ij}^{\alpha\beta})$ is described in terms of the following angles: Φ is the angle between the scattering plane and the ρ^0 production plane, Θ, ϕ are polar and azimuthal angles of the decay π^+ in the vector meson rest frame with z-axis aligned opposite to the outgoing nucleon momentum in the γ^*p center-of-mass system. SDMEs are usually described in the center-of-mass system of the virtual photon and proton by the helicity amplitudes $T_{\lambda_V \lambda'_N, \lambda_\gamma \lambda_N}$ where λ_V (λ_γ) is the helicity of the vector meson (virtual photon) and λ_N, λ'_N denote the helicities of incident and outgoing nucleon, respectively. The full expression for the decay angular distribution is given in Ref. [1] in terms of SDMEs $r_{ij}^{\alpha\beta}$, which are related to the spin density matrix elements $\rho^{\alpha}_{\lambda_V \lambda'_V}$ of the vector meson:

$$\rho^{\alpha}_{\lambda_V \lambda_{V'}} = \frac{1}{2N_\alpha} \sum_{\lambda_\gamma \lambda_{\gamma'}} T_{\lambda_V \lambda_\gamma} \Sigma^{\alpha}_{\lambda_\gamma \lambda'_\gamma} T^{*}_{\lambda'_V \lambda'_\gamma}. \tag{1}$$

Here N_α denotes a normalization factor, $\Sigma^{\alpha}_{\lambda_\gamma \lambda'_\gamma}$ with $\alpha = 0, 1, \ldots, 8$ are nine hermitian matrices defined in Ref. [1], summation over final nucleon helicities and averaging over initial proton helicities being always implied.

It is not possible to separate directly the contributions from longitudinal and transverse photons, as all HERMES data are taken at the same energy of the lepton beam. Hence, only certain combinations of the matrix elements $\rho^{\alpha\beta}_{ij}$ can be experimentally determined:

$$
\begin{aligned}
r^{04}_{\lambda_V \lambda'_V} &= (\rho^{0}_{\lambda_V \lambda'_V} + \epsilon R \rho^{4}_{\lambda_V \lambda'_V})/(1+\epsilon R), \\
r^{\alpha}_{\lambda_V \lambda'_V} &= \rho^{\alpha}_{\lambda_V \lambda'_V}/(1+\epsilon R), \quad \alpha = 1,2,3, \\
r^{\alpha}_{\lambda_V \lambda'_V} &= \sqrt{R}\rho^{\alpha}_{\lambda_V \lambda'_V}/(1+\epsilon R), \quad \alpha = 5,6,7,8.
\end{aligned}
\tag{2}
$$

Here R is the longitudinal-to-transverse cross section ratio and ϵ is the polarization parameter of the virtual photon .

2. The Hermes Experiment

The HERMES experiment at DESY uses a 27.5 GeV longitudinally polarized positron beam and hydrogen or deuterium gas targets internal to the HERA storage ring. The HERMES spectrometer is described in detail in Ref. [2]. Part of the data was collected with longitudinally polarized targets. Since the target polarization is not exploited in the present analysis, an average over both target polarization states is taken. The average beam polarization for the proton (deuteron) data set was 0.53 (0.53) for both positive and negative beam helicities after requiring $0.3 < P_{beam} < 0.8$. The exlusive ρ^0 events were selected in the same procedure as in Refs. [3,4].

3. Extraction of SDMEs

The SDMEs are obtained directly from the measured quantities by minimizing the difference between the 3-dimensional $(\cos\Theta, \phi, \Phi)$ decay angle matrix of the data and a sample of fully reconstructed Monte Carlo events, using the maximum likelihood method. An $8 \times 8 \times 8$ binning is used for the variables $\cos\Theta$, ϕ, Φ. The Monte Carlo events were generated with uniform angular distributions and are reweighted in an iterative procedure with the angular distribution $W(cos\Theta, \phi, \Phi, r^{\alpha\beta}_{ij})$ [1], where the matrix elements are treated as free parameters. The best fit parameters are determined using a binned maximum log-likelihood method. The number of events in each bin is assumed to obey a Poisson distribution. The minimization itself and the error calculation were performed using the MINUIT package.

4. Results

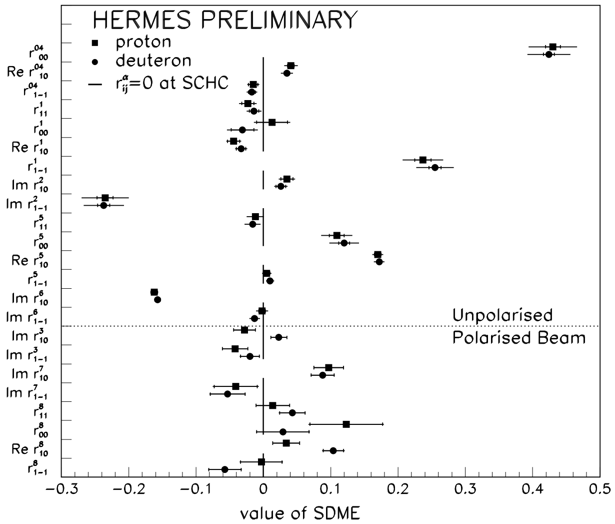

Figure 1. The 23 Spin Density Matrix Elements extracted from ρ^0 data, full squares for proton and full circles for deuteron. The sections of the vertical line denote the prediction for the case of the s-channel helicity conservation assumption. The inner error bars represent the statistical uncertainties as given by MINUIT, while the outer error bars indicate the statistical and systematic uncertainties added in quadrature.

The extracted SDMEs for the kinematic region $1.0 < Q^2 < 5.0$ GeV^2 $3.0 < W < 6.3$ GeV and $0.03 < x_{Bj} < 0.25$, are presented for the proton and deuteron data sample in Fig. 1. All unpolarized SDMEs measured on the proton agree with those on the deuteron within one standard deviation of the combined uncertainty. The statistical uncertainties are larger for the eight polarized SDMEs (in the bottom of the plot) due to the dilution by the non-unity lepton beam polarization (0.53). All these SDMEs are analyzed without the assumption of s-channel helicity conservation.

The sections of the central vertical line in Fig.1 indicate those SDMEs which are expected to be zero under s-channel helicity conservation.The gaps in the central vertical line correspond to elements which are not restricted by SCHC to be zero (r^{04}_{00}, Re$\{r^1_{1-1}\}$, Im$\{r^2_{1-1}\}$,Re$\{r^5_1$ Im$\{r^6_{10}\}$, Im$\{r^7_{10}\}$ and Re$\{r^8_{10}\}$) and which are found indeed to be nonzero. From Fig.1 we observe that the results indicate a significant violation of SCHC. The unpolarized SDMS which have significantly non-zero values are the following: r^5_{00}, Re$\{r^{04}_{10}\}$ Re$\{r^1_{10}\}$, Im$\{r^2_{10}\}$.The polarized elements Im$\{r^3_{10}\}$,

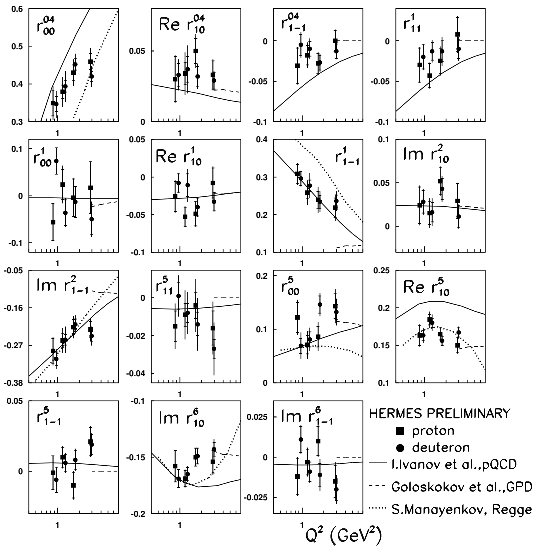

Figure 2. The Q^2 - dependence of the unpolarized SDMEs for proton (full squares) and deuteron (full circles) compared with theoretical calculations. The inner error bars represent the statistical uncertainty, while the outer ones indicate the statistical and systematic uncertainties added in quadrature.

$\{r^8_{00}\}$, $\mathrm{Im}\{r^7_{1-1}\}$ are also found to be non-zero.These results emphasize the violation of SCHC and indicate contributions of spin-flip amplidudes to exclusive ρ^0 production at intermediate energies.

The Q^2-dependence of the 15 unpolarized SDMEs obtained for proton and deuteron data in four bins of Q^2 (0.7 - 1.0 - 2.0 -5.0) GeV^2 is shown in Fig. 2. It is compared to calculations performed using three different approaches, based on pQCD k_T factorization [5], Regge phenomenology [6], and on a pQCD GPD-based approach [7]. Agreement is found for the majority of the unpolarized matrix elements.

References

1. K.Schilling and G.Wolf, *Nucl. Phys.* **B61**, 381 (1973).
2. HERMES Coll.H.Ackerstaff et al, *NIM A* **417**, 230 (1998).
3. Airapetian et al., *Eur.Phys.J C* **17**, 3898 (2000).
4. K.Ackerstaff et al, *Eur.Phys.J C* **18**, 303 (2000).
5. I.P Ivanov, N,N. Nikolaev, A.A.Savin, *hep-ph0501034* , DESY preprint 04-243
6. S.I.Manayenkov, *Eur.Phys.J C* **33**, 397(2004).
7. S.V. Goloskokov and P.Kroll, *Eur. phys.J.C* **42**, 4492 (2005).