Diffractive ρ^0 production at COMPASS experiment

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The helicity structure of the diffractive leptoproduction of ρ mesons, $\mu + N \to \mu + N + \rho$, is studied and preliminary results on several spin density matrix elements and $R = \sigma_L/\sigma_T$ for incoherent exclusive ρ^0 production from COMPASS 2002 data are presented. The elements r^{04}_{00}, r^{04}_{1-1}, $\Im m\ r^3_{1-1}$, r^1_{1-1} and R are measured at $< W >= 10$ GeV in a wide range of Q^2, $0.01 < Q^2 < 10$ GeV^2. The data are consistent with a substantial increase of R with Q^2 and a weak violation of SCHC, in agreement with other high energy experiments.

1. INTRODUCTION

A study of exclusive leptoproduction of vector mesons is a part of the COMPASS physics program. Here we present preliminary results of the analysis of angular distributions for exclusive incoherent ρ^0 production and subsequent decay $\rho^0 \to \pi^+\pi^-$. The studied reaction is

$$\mu + N \to \mu' + N' + \rho^0, \tag{1}$$

where N is a quasi-free nucleon from any of the nuclei of the COMPASS polarised target.

The angular distributions allow to determine ρ^0 spin density matrix elements (SDME) [1], which carry information on the spin structure of the production amplitudes. In particular, SDMEs allow to test the s-channel helicity conservation (SCHC) and to determine $R = \sigma_L/\sigma_T$, the ratio of the longitudinal to transverse virtual photon cross section for the studied process.

2. THE COMPASS DETECTOR

A high intensity positive muon beam from the CERN SPS, of 160 GeV/c momentum and -76% average polarisation, impinge on a double-cell ^{6}LiD polarised target. The beam traverses two 60 cm long target cells, in which the target material is polarised in opposite directions. Polarisation directions in each taget cell are reversed frequently.

The COMPASS detector consists of two high resolution magnetic spectrometers equipped with tracking detectors, calorimetry and muon identification. The first, large angle spectrometer is equipped with the RICH detector. A more detailed description of the COMPASS apparatus can be found in ref. [2].

3. EVENT SAMPLE

For the present analysis all COMPASS 2002 data taken with the longitudinally polarised target were used. For an event to be accepted for further analysis we required it to originate inside the target, have reconstructed beam and scattered muon tracks and have only two addional tracks, which correspond to charged pions from the decay of ρ^0. A cut on the invariant mass of two pions, $0.5 < m_{\pi\pi} < 1$ GeV, selects the ρ^0. As the slow recoil target particles are not detected, in order to select exclusive events we use the cut on the missing energy, $-2.5 < E_{miss} < 2.5$ GeV, and on the transverse momentum of ρ^0 with respect to the direction of virtual photon, $p_t^2 < 0.5$ GeV^2. Here $E_{miss} = (M_X^2 - M_p^2)/2M_p$, where M_X is the missing mass of an unobserved recoiling system and M_p is the proton mass. Coherent interactions on the target nuclei are removed by a cut $p_t^2 > 0.15$ GeV^2. To avoid large corrections for acceptance, smearing and misidentification of events the following cuts are applied: $Q^2 > 0.01$ GeV^2, $\nu > 30$ GeV and $E_{\mu'} > 20$ GeV.

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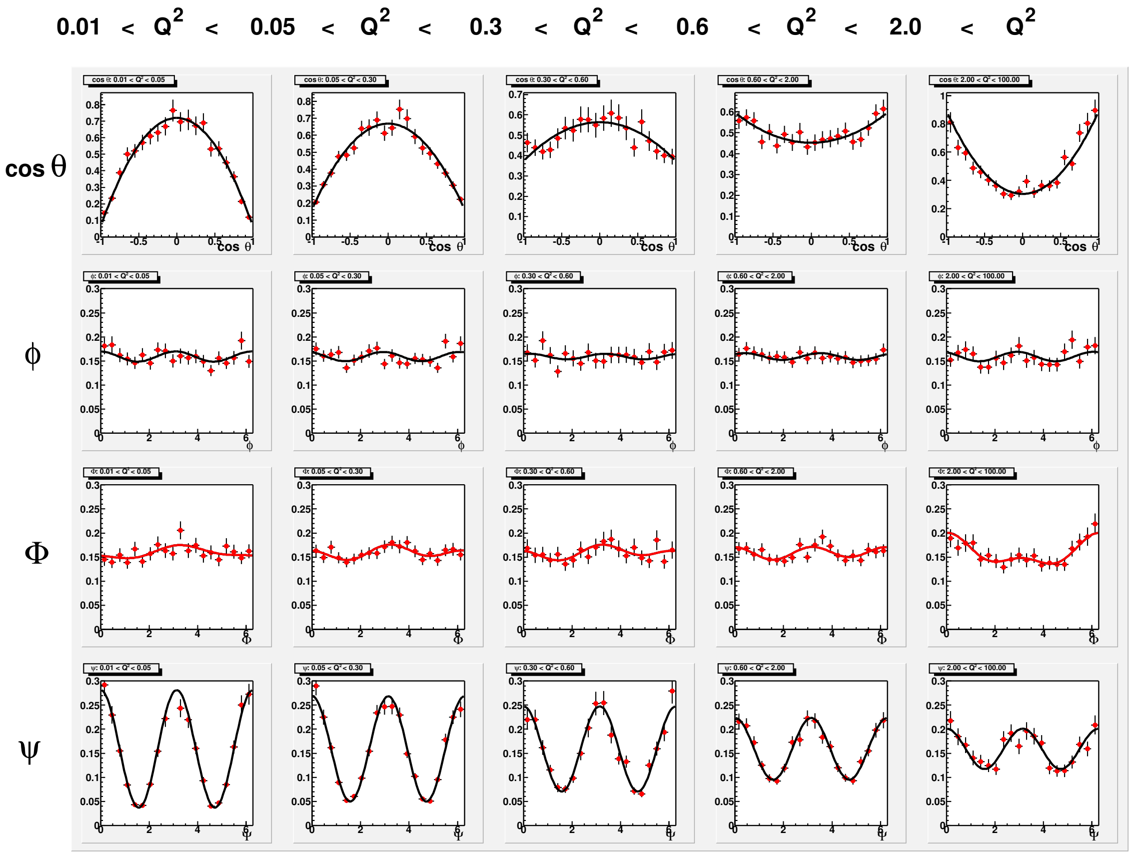

Figure 1. Angular distributions as a function of $\cos\theta$, ϕ, Φ and ψ for five bins of Q^2.

The data with opposite target polarisations are merged resulting in the average target polarisation close to 0. After all selections the sample consists of about 700 000 events, of which about 6000 events at $Q^2 > 2\,\mathrm{GeV}^2$. The average W is equal to 10.4 GeV.

4. FORMALISM

The ρ^0 angular distribution $W(\cos\theta, \phi, \Phi)$ is studied in the s-channel helicity frame [1]. The ρ^0 direction in the virtual photon-nucleon centre of mass system is taken as the quantisation axis. The angle θ is the polar angle and ϕ the azimuthal angle of the positive decay meson in the ρ^0 centre of mass system. The angle ϕ is then that between the decay plane and the ρ^0 production plane (the γ^*-ρ^0 plane). The angle Φ is that of the ρ^0 production plane with respect to the lepton scattering plane.

The hypothesis of s-channel helicity conservation (SCHC) assumes that the helicity of the virtual photon is retained by the ρ^0, in which case the angular distribution reduces to $W(\cos\theta, \psi)$, where $\psi = \phi - \Phi$ is the angle of the ρ^0 decay plane with respect to the lepton scattering plane.

The detailed formalism for the angular distribution can be found in [1], where the authors consider the case of the vector meson production by polarised lepton on unpolarised target. In principle, 23 spin density matrix elements can be determined experimentally from the three-dimensional distribution $W(\cos\theta, \phi, \Phi)$. They contain information on the helicity amplitudes for the process

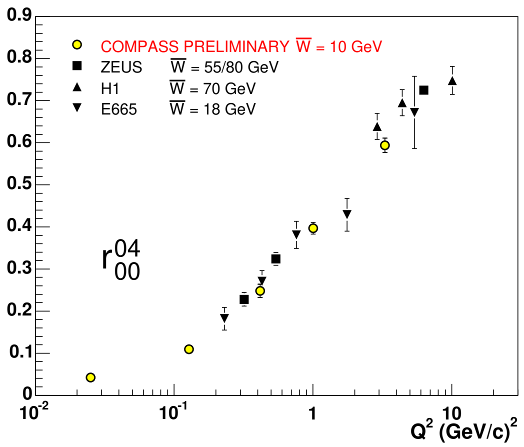

Figure 2. Q^2 dependence of r^{04}_{00}.

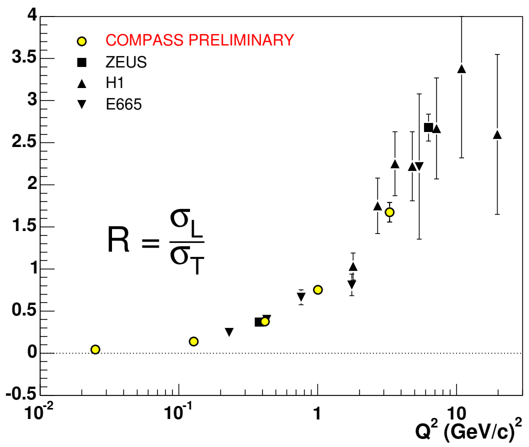

Figure 3. Q^2 dependence of R.

$\gamma^* N \to \rho^0 N$.

In this analysis we consider only single-dimensional projections of $W(\cos\theta, \phi, \Phi)$. For $\cos\theta$, ϕ and ψ they are given by the following formulae

$$W(\cos\ \theta) = \frac{3}{4}[(1 - r^{04}_{00}) + (3\, r^{04}_{00} - 1)\cos^2\theta]\ , \quad (2)$$

$$W(\phi) = \frac{1}{2\pi}[1 - 2r^{04}_{1-1}\cos 2\phi + P_\mu\sqrt{1-\epsilon^2}\ 2\,\Im m\ r^3_{1-1}\sin 2\phi]\ , \quad (3)$$

$$W(\psi) = \frac{1}{2\pi}[1 + 2\epsilon\ r^1_{1-1}\cos 2\psi]\ . \quad (4)$$

In above equations the r's are the spin density matrix elements for exclusive ρ^0 production, P_μ is the polarisation of muon beam and ϵ is the virtual photon polarisation parameter [1].

One should mention that for Eq. 4 to be valid one must assume SCHC, in contrast to Eq. 2 and 3, which are general.

5. RESULTS

The angular distributions extracted from the data were corrected for acceptance, efficiency and smearing effects using the full MC simulation of the apparatus. The corrected angular distributions for 5 Q^2 bins are shown in Fig. 1. The curves are results of the fits with the SDMEs as fitted parameters.

The element r^{04}_{00}, which is determined from $\cos\theta$ distribution, is shown as a function of Q^2 and compared to the published data of H1 [3], ZEUS [4] end E665 [5] experiments in Fig. 2. Only statistical errors are shown. The results of the experiments are in a fair agreement. The COMPASS results have substantially smaller statistical errors than the other experiments, except ZEUS. In addition the Q^2 range covered by COMPASS extends one decade down from the lowest Q^2 measured in other experiments.

The element r^{04}_{00} can be interpreted as a fraction of longitudinal (helicity 0) ρ^0 in the sample. If SCHC holds, R can be obtained using

$$R = \frac{1}{(\epsilon + \delta)}\ \frac{r^{04}_{00}}{1 - r^{04}_{00}}\ , \quad (5)$$

where δ is the correction [1] to the ratio of the longitudinal and transverse virtual photon fluxes, which is due to the finite lepton mass.

The COMPASS results on Q^2 dependence of R are compared to other experiments in Fig. 3. At small Q^2 the production by transverse photons (σ_T) dominates, while with increasing Q^2 a contribution of the production by longitudinal photons (σ_L) takes over.

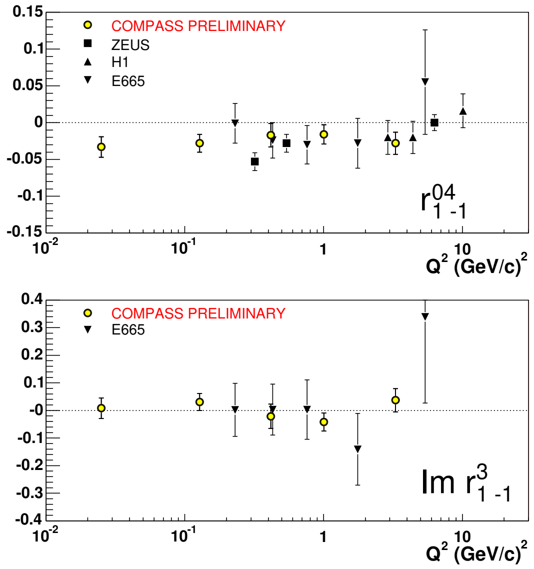

Figure 4. Q^2 dependence of r^{04}_{1-1} and $\Im m\, r^{3}_{1-1}$.

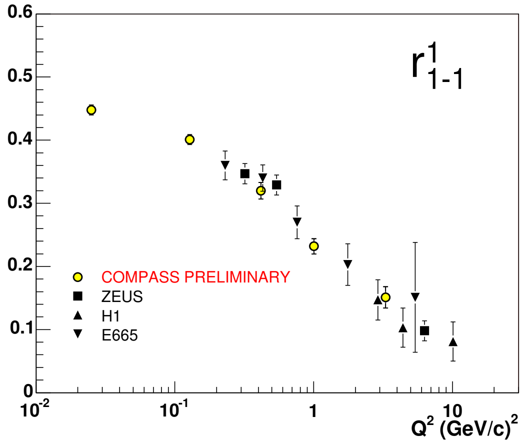

Figure 5. Q^2 dependence of r^{1}_{1-1}.

From ϕ distribution one could determine two matrix elements r^{04}_{1-1} and $\Im m\, r^{3}_{1-1}$. COMPASS preliminary results are compared to other experiments in Fig. 4. Note, that $\Im m\, r^{3}_{1-1}$ could be accessed only with polarised lepton beams. COMPASS measurements exhibit small negative values of r^{04}_{1-1} (≈ -0.03) approximately independent of Q^2, whereas $\Im m\, r^{3}_{1-1}$ is consistent with 0. The non-zero value of r^{04}_{1-1} indicates a small contribution of amplitudes with helicity flip.

Finally, ψ distribution allows to determine element r^{1}_{1-1}. The results for r^{1}_{1-1} as a function of Q^2 are compared to other experiments in Fig. 5. All data are in a fair agreement.

6. SUMMARY AND OUTLOOK

The preliminary results from the analysis of angular distributions for exclusive incoherent ρ^0 production from COMPASS 2002 data are presented. The matrix elements r^{04}_{00}, r^{04}_{1-1}, $\Im m\, r^{3}_{1-1}$, r^{1}_{1-1} and R are measured at $< W >= 10$ GeV in a wide range of Q^2, $0.01 < Q^2 < 10$ GeV^2. The data are consistent with a substantial increase of R with Q^2 and a weak violation of SCHC in agreement with other high energy experiments.

The studies of background and other sources of systematic effects are in progress. The statistical accuracy of the present results is dominated by the limited MC sample used for calculations of corrections to the data. More MC production is foreseen in the future. The statistical accuracy will further improve significantly by including 2003 and 2004 data.

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