RESULTS ON EXCLUSIVE ρ^0 PRODUCTION FROM COMPASS

D. NEYRET, ON BEHALF OF THE COMPASS COLLABORATION
DAPNIA/SPhN, CEA Saclay, F-91191 Gif sur Yvette Cedex, France

Study of the ρ^0 spin density matrices $r^{\alpha}_{\lambda\lambda'}$ using exclusive incoherent ρ^0 production events is performed by the COMPASS collaboration. An overview of this analysis is presented, and preliminary results from the 2002 data are shown. These results are compatible with the previous experiments but with a better statistical accuracy and cover a higher range in Q^2. The ratio R of the longitudinal to transverse virtual photon polarization cross sections for the studied process is deduced from r^{04}_{00}. The non-zero value of r^{04}_{1-1} indicates a weak violation of the s-channel helicity conservation.

1. Introduction

A study of the exclusive incoherent vector-meson production events is done by the COMPASS collaboration. The goal of such analysis is to measure the elements of the ρ^0 spin density matrices $r^{\alpha}_{\lambda\lambda'}$, in order to test the s-channel helicity conservation (SCHC), to measure the ratio of the longitudinal to transverse virtual photon polarization cross sections for the studied process, and to get access to the longitudinal cross section related to Generalized Parton Distributions at high Q^2.

2. Formalism Of The Exclusive ρ^0 Production

We study ρ^0 exclusive production with $\mu + N \to \mu' + N' + \rho^0$, where ρ^0 decays in $\pi^+\pi^-$. The cross section is proportional to the product of both leptonic and hadronic tensors $L_{\mu\nu}T^{\mu\nu}$. One defines then a photon density matrix $\rho(\gamma)$ [1] proportional to the leptonic tensor, and, from $\rho(\gamma)$ and the hadronic tensor, a ρ^0 density matrix $\rho(V)_{\lambda\lambda'}=1/2\ T\rho(\gamma)T^+$ expressed on the ρ^0 helicity basis. The photon density matrix can be decomposed over nine independent virtual photon polarization states α. $\alpha = 0$ corresponds to the unpolarized transverse photons, 1 and 2 to the two linear polarizations, 3 to the circular photons, 4 to the longitudinally polarized photons, and 5 to 8 are the interference terms between transverse and longitudinal amplitudes. One defines the ρ^{α} matrices as the contribution to the ρ^0 density matrix $\rho(V)$ for these nine states. These matrices provide informations on the spin characteristics of the hadronic tensor T. In particular, one could test the s-channel helicity conservation hypothesis (SCHC), which means that the helicity of the virtual photon is entirely transfered to the outgoing vector meson. Assuming SCHC, it is possible to determine the value of the ratio $R = \sigma_L / \sigma_R$ of the longitudinal and the transverse cross section.

3. ρ^0 Production Studies At COMPASS

The ρ^{α} matrices can all be extracted from the angular distributions of the ρ^0 production events $W(\cos\theta, \phi, \Phi)$ [1] where the three independent angles are: Φ

between the leptonic scattering and ρ^0 production planes, ϕ between the ρ^0 production and $\rho^0 \rightarrow \pi^+ + \pi^-$ decay planes, and θ the polar angle between the ρ^0 momentum direction and the produced π^+ momentum, in the vector-meson rest frame. The ρ^0 and ρ^4 matrices can be distinguished with a Rosenbluth method using two beam energies to separate the contribution of longitudinally and transversally polarized virtual photons. This is not yet done at COMPASS. One measures then $r^{04}_{\lambda\lambda'}$ which is proportional to a linear combination of ρ^0 and ρ^4. We define also for homogeneity $r^{\alpha}_{\lambda\lambda'}$ directly proportional to the ρ^{α} matrices. For these preliminary results we don't use the full $W(\cos\theta, \phi, \Phi)$ distribution, the analysis is limited to the one-dimensional distributions $W(\cos\theta)$, $W(\phi)$ and $W(\psi)$, where $\psi = \phi - \Phi$. From these ones a few of the r^{α} matrix elements can be determined already:

$$W(\cos\theta) = \frac{3}{4}((1 - \boldsymbol{r^{04}_{00}}) + (3\boldsymbol{r^{04}_{00}} - 1)\cos^2\theta) \qquad W(\psi) = \frac{1}{2\pi}(1 + 2\epsilon \boldsymbol{r^{1}_{1-1}} \cos 2\psi)$$

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

In the above expression SCHC was used to obtain $W(\psi)$. The r^{04}_{00} matrix element allows to determine the value of the ratio $R=\sigma_L/\sigma_T$, if we assume the validity of SCHC. In parallel SCHC can be tested from the values of r^{04}_{1-1} and $\Im m\, r^{3}_{1-1}$ matrix elements, which should be equal to zero if it is verified.

4. Selection Of The Exclusive ρ^0 Events

The COMPASS experiment studies the interaction of beam of 160 GeV polarized muons (76% polarization) on a ^{6}LiD target. The detector is composed of two high resolution spectrometers equipped with tracking systems and calorimetry. A more precise description of the COMPASS detector can be found in [2].

Different criteria are applied to select exclusive ρ^0 production events. The topological selections will require an initial and scattered μ, and two remaining tracks for the charged pions from the decayed ρ^0. The slow recoil target particles are not detected. Several cuts are applied on hadron tracks: a cut on the invariant mass of the two pions ($0.5 < m_{\pi\pi} < 1$ GeV) identifies the ρ^0, the exclusivity of the interaction is insured by cuts on missing energy and transverse momentum ($-2.5 < E_{missing} < 2.5$ GeV, $p^2_t < 0.5$ GeV^2), and coherent interactions on nuclei are rejected by a cut on transverse momentum ($p^2_t > 0.15$ GeV^2). Kinematics regions where the systematics effects are too large are rejected ($E_{\mu'} > 20$ GeV, $Q^2 > 0.01$ GeV^2, $\nu > 30$ GeV). After all selections, the average value of W is 10.4 GeV.

5. Correction For Experimental Effects

The event generator used in the Monte-Carlo used for this analysis is based on DIPSI [3] which is dedicated to exclusive vector-meson production. Based on a perturbative QCD model from M.G. Ryskin, it has been used in ZEUS experiment

[4] at DESY on a large range on Q^2, in particular at a low Q^2 as an effective tool. For this analysis, it has been tuned to reproduce data from NMC [5] and E665 [6] experiments.

Monte-Carlo events have been used to correct data for acceptance, efficiency and smearing effects. For each kinematical bin, corrections functions have been determined using the numbers of generated and reconstructed events in this bin. These functions have been found to be approximately uniform as a function of the angles. Different Q^2 distributions of the generated events have been tested, but the differences obtained on the correction functions have been below 2%, well below the statistical errors of the Monte-Carlo.

6. Results

Some matrix elements are extracted from the one-dimensional angular distributions of the COMPASS 2002 data in five bins in Q^2 from 0.01 up to 10 GeV^2. The average value of W, taking into account all the selection applied on the data, is around 10.4 GeV. Figure 1 shows the matrix element r^{04}_{00} determined from the cos θ distribution as a function of Q^2. It is compared to the published data of H1 [7], ZEUS [4] and E665 [6] experiment. Only statistical errors are shown. COMPASS data are in a good agreement with previous experiments but with a much smaller statistical errors, except for ZEUS. COMPASS covers also a larger range at low Q^2 up to $2.5.10^{-2}$ GeV^2. Using the measurement of r^{04}_{00} one can determine the value of the ratio $R=\sigma_L/\sigma_T$, if the SCHC hypothesis holds. Figure 2 shows the measurements of the ratio R, which are in agreement with other experiments. One can remark that at low Q^2 the production by transverse photons dominates, but becomes smaller than the longitudinal photons contribution at high Q^2.

From the ψ distribution one could extract r^1_{1-1} matrix element, assuming the validity of SCHC. It is shown in figure 3 and compared to other experiments, with the same conclusions as for r^{04}_{00}. The r^{04}_{1-1} and $\Im m\, r^3_{1-1}$ matrix elements are determined from the ϕ distribution. They are shown in figure 4 and compared with the previous experiments. $\Im m\, r^3_{1-1}$ is not available from the HERA experiments, as its measurement requires a polarized lepton beam. One can note that if $\Im m\, r^3_{1-1}$ is consistent with 0, it is not the case for r^{04}_{1-1}. The measured values of the later one indicate a small contribution of amplitudes with helicity flip, which means a mild violation of SCHC.

7. Conclusion

A first determination of several ρ^0 density matrix elements from the COMPASS 2002 data has been performed, leading to the measurement of r^{04}_{00}, r^1_{1-1}, r^{04}_{1-1}, $\Im m\, r^3_{1-1}$ and R. These measurement have been done at an average value of W of 10.4 GeV and in a large Q^2 range between 0.01 and 10 GeV^2. These results are in good agreement with the previous experiment ZEUS, H1 and E665, with a better statistical accuracy and a larger Q^2 range. The data confirm an increase of R with Q^2, and indicate a weak violation of SCHC.

This analysis will be continued with more statistics using the 2003 and 2004 data, which will allow us to extend the high Q^2 range up to 25 GeV^2. Also the three-dimensional angular distribution $W(\cos\theta, \phi, \Phi)$ will be used to extract all the $r^{\alpha}_{\lambda\lambda'}$ spin density matrices.

References

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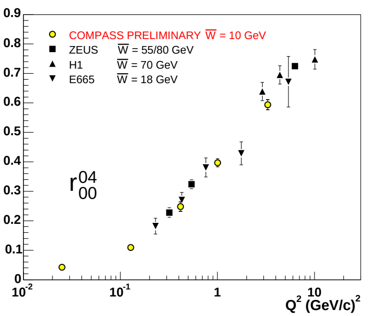

Figure 1: Measured r^{04}_{00} (see text)

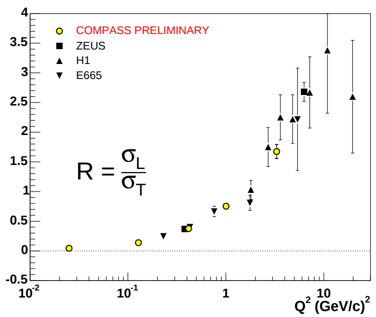

Figure 2: Ratio of $R=\sigma_L/\sigma_T$ extracted from r^{04}_{00}

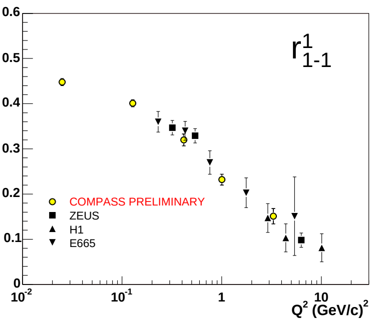

Figure 3: Measured $r^{1}_{1\text{-}1}$ (see text)

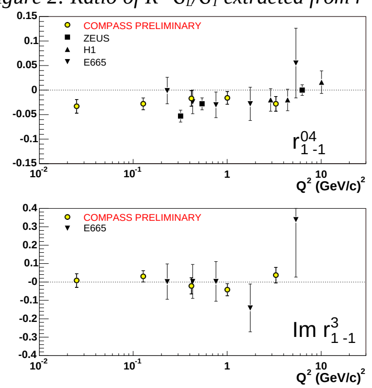

Figure 4: Measured $r^{04}_{1\text{-}1}$ and $\Im m\ r^{3}_{1\text{-}1}$ (see text)