Exclusive ρ^0 production off transversely polarized protons at COMPASS

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In this work we present the measurement of the transverse target spin asymmetry in the exclusive ρ^0 production using the high energy 160 GeV muon beam and the COMPASS spectrometer at CERN. This will constitute an essential step to get information about Generalized Parton Distributions.

1 Physics Motivations

Exclusive vector meson production has played an important role in studying strong interaction and gained a renewed interest, as it can give access to Generalized Parton Distributions (GPDs) and thus to a wealth of information on the nucleon structure. Moreover it was pointed out that vector meson production on a transversely polarised target is sensitive to the nucleon helicity-flip GPD E [1, 2]. This GPD offers unique views on the orbital angular momentum carried by partons in the proton through the Ji sum rule[3] and on the correlation between polarisation and spatial distribution of partons [4].

Exclusive ρ^0 production off the proton has been carried out in 2007 at CERN by the COMPASS collaboration using the high energy 160 GeV muon beam and the transversely polarised NH_3 target. The studied reaction is $\mu + N \to \mu' + \rho^0 + N'$ where N is a quasi-free proton from the NH_3 polarised material. The reaction can be described in terms of the virtual photoproduction process $\gamma^* + N \to \rho^0 + N'$.

In the limit of large Q^2 at fixed x_B and small momentum transfer t, the $\gamma^* p$ amplitude factorizes into the convolution of a hard-scattering subprocess with GPDs in the nucleon and the light-cone distribution amplitude of the produced mesons. The factorization theorem [5, 6] shows that the leading transitions in the large Q^2 limit have both the virtual photon and the produced meson longitudinally polarised, all other transitions being suppressed by at least one power of $1/Q$.

2 Selection of exclusive ρ^0 production

The COMPASS experiment uses the 160 GeV/c polarised muon beam of the CERN SPS. Muons are scattered off transversely polarised nucleons in a three-cell solid-state NH_3 target. The three cells are polarised in opposite directions and polarization is reversed frequently. The scattered particles and the decay products of the ρ are detected in two high resolution magnetic spectrometers [7]. For an event to be selected we require incident and scattered muon tracks with only two additional tracks, which correspond to charged pions from the decay of the ρ^0. A cut on the invariant mass of two pions, $|M_{\pi\pi} - M_{\rho^0}| < 0.3$ GeV/c^2, is applied to identify the ρ^0 (Fig.1. upper left plot). In order to select exclusive events as the slow recoiling target particles are not detected, we use cuts on the missing energy, $-2.5 < E_{miss} < 2.5$, GeV (Fig.1. upper right plot) and on the transverse momentum of ρ^0 with respect to the virtual photon direction, $p_T^2 < 0.5$ (GeV/c)^2, (Fig.1. bottom plot).

Here $E_{miss} = (M_X^2 - M_p^2)/2M_p$ where M_X is the mass of the undetected system and M_p the proton mass. Coherent interactions on the target nuclei are removed by a cut $p_T^2 > 0.05$ $(\mathrm{GeV}/c)^2$. After all selections the 2007 data sample consists of about 223 000 events, with $Q^2 > 1$ $(\mathrm{GeV}/c)^2$. Distributions of x_{Bj} and Q^2 for the full 2007 data sample are presented in Fig.2. The remaining non-exclusive background in the whole sample is about 30% and will be rejected in a further step.

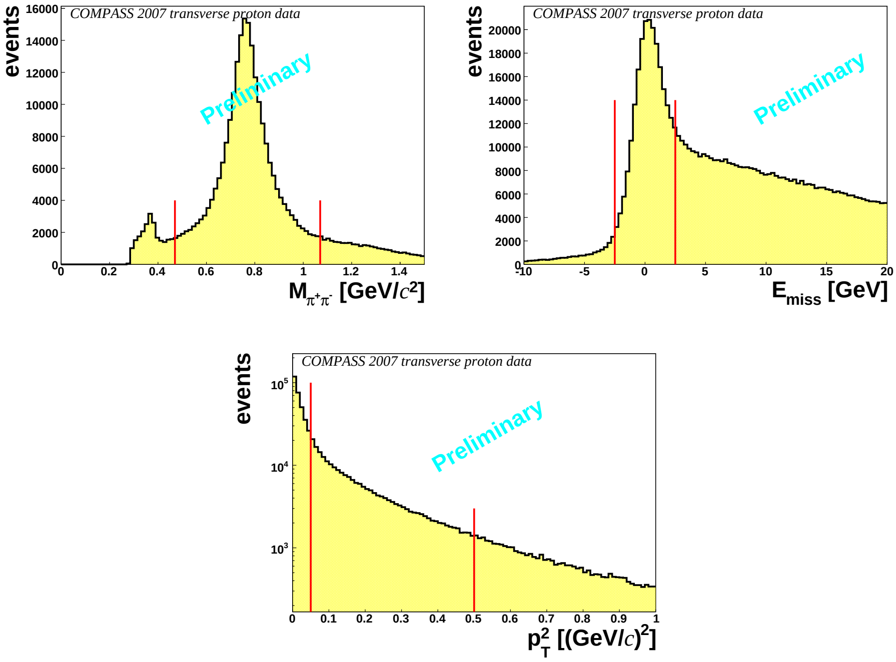

Figure 1: Distributions of invariant mass $M_{\pi^+\pi^-}$ (upper left plot), missing energy E_{miss} (upper right plot), and transverse momentum of ρ^0 with respect to the virtual photon direction p_T^2 (bottom plot).

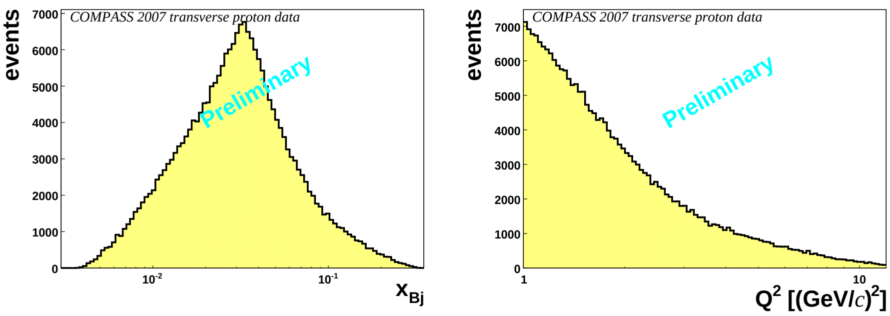

Figure 2: Distributions of x_{Bj} (left plot) and Q^2 (right plot) for the full 2007 data sample.

3 Transverse target spin asymmetry

Counting rates are expressed as a function of the angle $(\phi - \phi_S)$ between the spin of the target and the production plane (Fig. 3). The transverse target spin asymmetry is then defined by $A_{\rm UT}^{sin(\phi-\phi_S)} = \frac{\sigma(\phi-\phi_S)-\sigma(\phi-\phi_S+\pi)}{\sigma(\phi-\phi_S)+\sigma(\phi-\phi_S+\pi)}$ and represents the asymmetry of the cross section between the $(\phi - \phi_S)$ direction and the opposite one $(\phi - \phi_S + \pi)$.

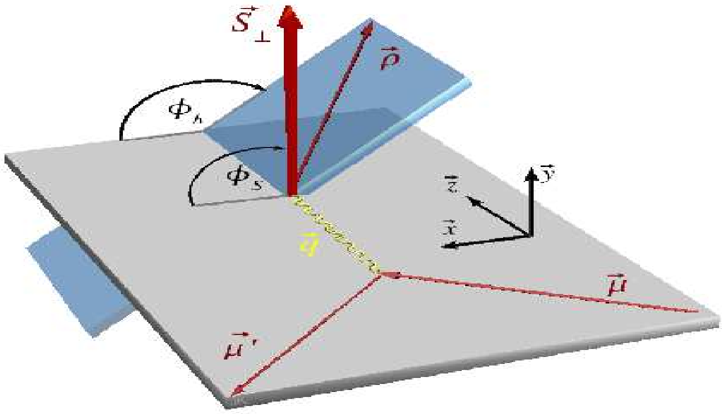

Figure 3: Definition of ϕ ($\equiv \phi_h$) and ϕ_S for the exclusive ρ^0 production

With the three cells of the COMPASS target and the two polarization configurations, we have six sets of data for each bin of $(\phi - \phi_S)$. To cancel systematic effects, we extract the asymmetry from a double ratio [8] of counting rates:

$$\begin{aligned} r &= \frac{(N^+_{up}(\phi - \phi_S) + N^+_{down}(\phi - \phi_S)) \cdot N^+_{middle}(\phi - \phi_S)}{(N^-_{up}(\phi - \phi_S + \pi) + N^-_{down}(\phi - \phi_S + \pi)) \cdot N^-_{middle}(\phi - \phi_S + \pi)} \\ &= \frac{(1 + f < P_T > A_{\rm UT}^{sin(\phi-\phi_S)} \cdot sin(\phi - \phi_S))^2}{(1 - f < P_T > A_{\rm UT}^{sin(\phi-\phi_S)} \cdot sin(\phi - \phi_S))^2} \end{aligned} \quad (1)$$

where *up* (or *down* or *middle*) refers to the target cell, + (or −) refers to the target polarisation, f is the dilution factor and $< P_T >$ the average target polarisation. Then we extract the asymmetry $A_{\rm UT}^{sin(\phi-\phi_S)}$ by fitting the ratio r.

Results and future steps in analysis

The asymmetry $A_{\rm UT}^{sin(\phi-\phi_S)}$ is found consistent with zero with the NH_3 (proton) target in the investigated Q^2, x_{Bj} and p_T^2 range (Fig. 4). In a previous analysis of the 2002-03-04 data sample using on a transversely polarized Li^6D (deuteron) target without coherent rejection, the asymmetry $A_{\rm UT}^{sin(\phi-\phi_S)}$ was also found to be compatible with zero (Fig. 5). Cancellation between proton and neutron was thus expected, and the new results on a proton target only show that the genuine asymmetry on the proton is also rather small, consistent with zero within the error bars.

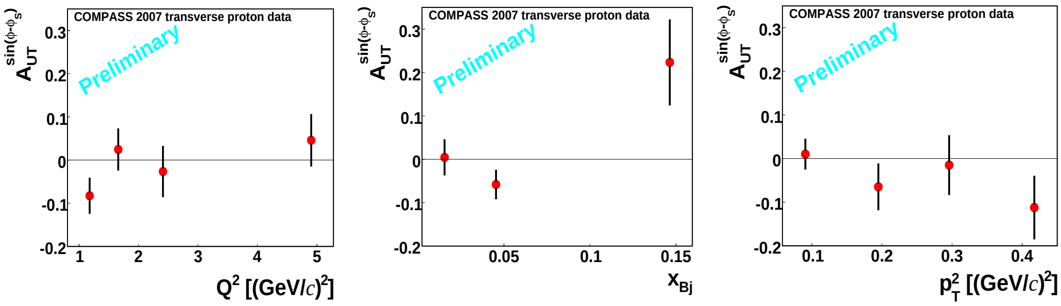

Figure 4: Transverse target spin asymmetries for proton data as a function of Q^2 (left), x_{bj} (middle) and p_T^2 (right)

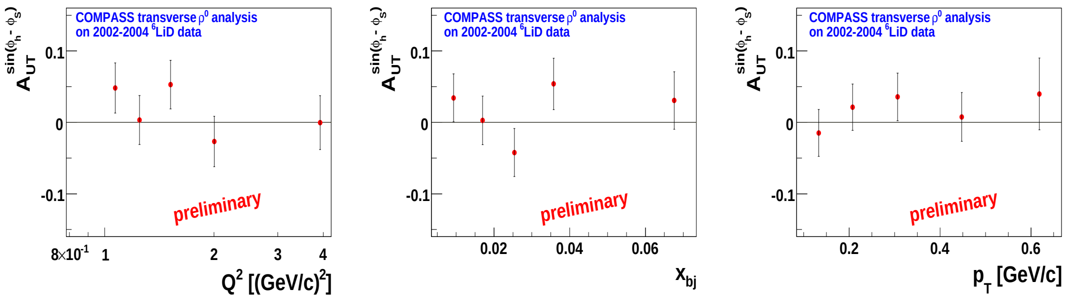

Figure 5: Transverse target spin asymmetries for deuteron data as a function of Q^2 (left), x_{bj} (middle) and p_T (right)

The HERMES collaboration [10] has also measured this asymmetry with a proton target and obtained the same result within similar accuracy. Theoretical predictions have been done by Goloskokov and Kroll for $A_{UT}^{sin(\phi-\phi_s)}$. A value of -0.02 is predicted for ρ production on the proton while it is higher around -0.1 for ω production [11, 12, 13].

To complete the analysis, the non-exclusive background has to be subtracted. Moreover longitudinal and transverse virtual photon contributions have to be separated. A detailed method to extract the asymmetry for longitudinal photons was proposed by Diehl and Sapeta [9]: the contributions of longitudinal and transverse ρ^0 can be estimated from the angular distribution of pions in the ρ^0 decay. By assuming the s-channel helicity conservation, we can determine the contribution from longitudinal photons. This final step of the analysis needs both background and acceptance correction, based on a complete simulation will be performed.

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