Exclusive meson production at COMPASS

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Abstract. Recent and planned measurements of exclusive meson production at COMPASS are discussed. In particular, results on transverse target spin asymmetry $A_{UT}^{\sin(\phi-\phi_S)}$ for exclusive ρ^0 production are presented. This asymmetry is sensitive on the 'elusive' GPDs E, which are related to the orbital angular momentum of quarks. First observation of exclusive π^0 meson production at COMPASS is also reported.

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INTRODUCTION

Hard exclusive electro- and muoproduction of mesons on nucleons has played an important role in studies of strong interactions and recently gained renewed interest as it allows access to Generalised Parton Distributions [1, 2, 3, 4, 5]. The GPDs provide a novel and comprehensive description of the partonic structure of the nucleon and contain a wealth of new information. For instance the GPDs give a description of the nucleon as an extended object, referred to as 3-dimensional nucleon tomography [6, 7, 8], and give access to the orbital angular momentum of quarks [2, 3]. Depending on the quark content and the quantum numbers of the meson (π^0 , ρ^0 , ϕ , ...), there exists sensitivity to various types of GPDs and different quark flavours.

Recent measurement of the transverse target spin asymmetry $A_{UT}^{\sin(\phi-\phi_S)}$ for exclusive ρ^0 meson production on protons and deuterons at COMPASS is presented is this paper. This asymmetry is sensitive on the GPDs E, which are related to the orbital angular momentum of quarks. First observation of exclusive π^0 meson production at COMPASS, which is sensitive on the transversity GPDs H_T and E_T, is also reported. Planned measurements of exclusive meson production, which are a part of the approved COMPASS-II proposal, are discussed at the end of the paper.

EXCLUSIVE ρ^0 PRODUCTION

Exclusive vector meson production on transversely polarized target is sensitive on the GPDs E. The sensitive observable is the azimuthal asymmetry $A_{UT}^{\sin(\phi-\phi_S)}$. Here, UT refers to unpolarized beam and transversely polarized target and $\sin(\phi-\phi_S)$ indicates the type of azimuthal modulation of the cross section. The angle ϕ is the angle between the lepton plane, defined by the momenta of incoming and scattered leptons, and the hadron plane, defined by the momenta of virtual photon and produced meson. The angle

ϕ_S is the angle between the lepton plane and the direction of the target spin.

To determine transverse target spin asymmetry $A_{UT}^{\sin(\phi-\phi_S)}$ for exclusive production of ρ^0 meson the data taken in 2003-2004 with polarized deuterons and in 2007, 2010 with polarized protons were analysed. Each selected event contains a primary vertex with only one incoming and one outgoing muon track and with only two outgoing hadron tracks with opposite charges. It is assumed, that the outgoing hadron tracks come from the pions. The ρ^0 resonance is selected by the cut on the reconstructed invariant mass $0.5 < M_{\pi\pi} < 1.1$ GeV/c^2. Because recoiled target particle in undetected, the exclusivity is checked by the missing energy $E_{\rm miss} = (M_x^2 - M_p^2)/2M_p$, where M_p is the mass of the proton and M_x is the missing mass. For exclusive events the reconstructed values of $E_{\rm miss}$ are close to zero. To select these events the cut $-2.5 < E_{\rm miss} < 2.5$ GeV is used. The cuts $0.05 < p_T^2 < 0.5$ (GeV/c)^2 for the proton target and $0.1 < p_T^2 < 0.5$ (GeV/c)^2 for the deuteron target are also used, where p_T^2 is the squared transverse momentum of ρ^0 candidate with respect to the virtual photon direction. The lower cut on p_T^2 suppresses a contribution from the coherent production on the target nuclei, while the upper one provides a further reduction of non-exclusive background.

For the selected sample the kinematic region is defined by the following cuts: $1 < Q^2 < 10$ (GeV/c)^2, $0.1 < y < 0.9$ (the fraction of incoming muon energy lost in the laboratory system), $0.003 < x_{Bj} < 0.35$, $W > 5$ GeV (the total energy in the virtual photon - nucleon center of mass system) and p_T^2 cuts as indicated above. The asymmetry was extracted using the binned likelihood method after subtraction of remaining semi-inclusive background. Details of the analysis can be found in Ref. [11].

The $A_{UT}^{\sin(\phi-\phi_S)}$ asymmetry measured for protons and deuterons is shown in Fig. 1 as a function of x_{Bj}, Q^2 and p_T^2. Note, that this is first measurement of the asymmetry for deuteron target. The asymmetries both for proton and deuteron are small and consistent with zero. Blue curve in Fig. 1 is the prediction of the GPD model of P. Kroll and S. V. Goloskokov [9]. The model reasonably well reproduces the experimental result. It predicts that the orbital angular momenta of up and down quarks are comparable but have opposite sign and in case of ρ^0 meson approximately cancel out. In contrast, the model predicts large asymmetry for ω meson, due to the different combination of up and down quarks.

EXCLUSIVE π^0 PRODUCTION

As it was shown in Ref. [10], exclusive pseudoscalar meson production is sensitive on the transversity GPDs H_T and E_T, which give essential contribution to the cross section. The analysis is motivated also by the study of potential experimental background to Deeply Virtual Compton Scattering (DVCS), which will be extensively studied in the GPD program at COMPASS-II.

The data used in this analysis come from 2009 DVCS test run with muon beam, a 40 cm long unpolarized hydrogen target and a 1 m long recoil proton detector (RPD). The RPD consists of two scintillator barrels, which surround the target. It provides both tracking and particle identification. The later is possible due to the correlation of time of flight between two barrels with energy deposited in the outer barrel.

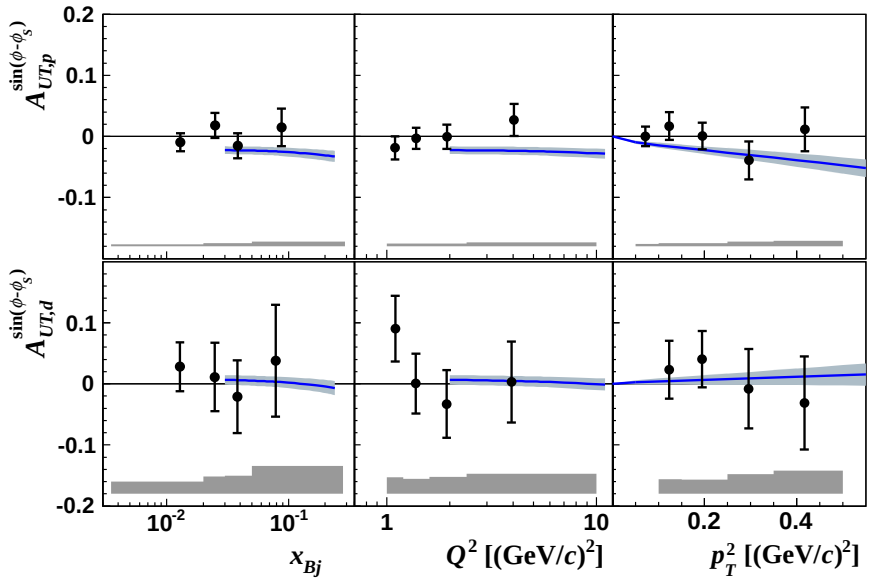

FIGURE 1. Transverse target spin asymmetries $A_{UT}^{\sin(\phi-\phi_S)}$ for the proton (upper) and the deuteron (lower) as a function of x_{Bj}, Q^2 and p_T^2. The curves show the predictions of the GPD model [9].

Each selected event contains a primary vertex with only one incoming and one outgoing muon tracks. In addition, only two clusters in the electromagnetic calorimeter in the large angle section of the COMPASS two-stage spectrometer with energy exceeding 5 GeV and one proton track in the RPD are required. To select exclusive events, the azimuthal angle ϕ and the transverse momentum p_T of the proton are compared to the corresponding values calculated using the scattered muon and the two observed photons, and the following cuts are applied: $E_{\rm miss} < 7$ GeV, $|\Delta\phi| < 30$ deg and $|\Delta p_T| < 0.34$ GeV/c. Alter all cuts 23 events are selected. Note, that this is the first measurement of exclusive π^0 meson production at hight energy DIS experiment. An analysis aiming at the determination of the absolute cross section is in progress.

FUTURE MEASUREMENTS AT COMPASS-II

The GPD program at COMPASS will be continued. The COMPASS-II proposal [12] of the new measurements has been already approved by CERN. Measurement of exclusive meson production is one of the main goals of this proposal, together with the measurement of DVCS. The data for the GPD program will be taken during 2012 pilot and in 2016-2017.

The GPD program at COMPASS-II will explore intermediate region of Bjorken scaling variable, $0.01 < x_{Bj} < 0.1$, and large photon virtuality, $Q^2 < 12$ GeV/c, where both the sea and the valence quarks contribute. This region will be covered only by COMPASS-II before availability of new electron-hadron colliders. Due to the unique M2 beam line of the CERN SPS, data will be taken with muon beams of both charges. This feature is important for the DVCS measurement, as it allows to extract the imaginary

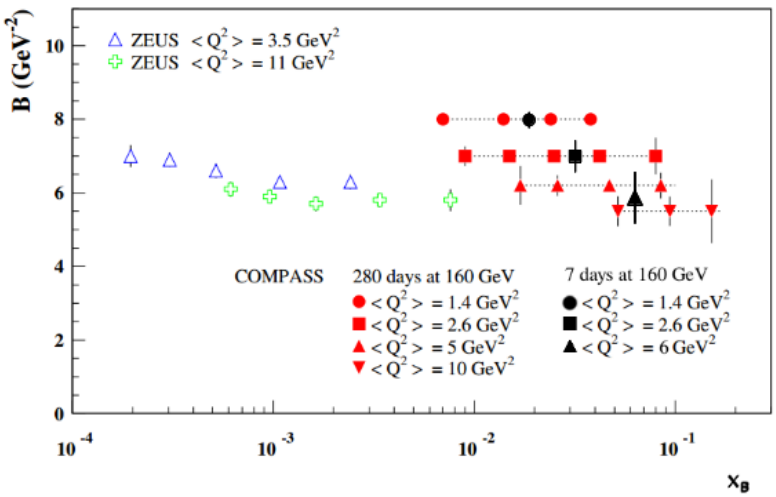

FIGURE 2. The projection of measurement of slope b for 2012 pilot and 2016-2017. Also existing data points from ZEUS in a similar Q^2 range are shown.

and real parts of the DVCS amplitudes.

To provide high luminosity a new 2.5 m long liquid hydrogen target is built, which will be surrounded by a 4 m long recoil proton detector, called CAMERA. Also a large angle electromagnetic calorimeter, which will cover high x_{Bj} region for the DVCS measurement, is constructed.

For the COMPASS-II proposal projections of expected results were made. One of the projections shows expected precision of the measurement of slope b of Mandelstam variable t distribution as a function of x_{Bj} for exclusive ρ^0 meson production. The slope is related to the transverse size of the nucleon, and thus it can be used for the nucleon tomography. The projection of measurement of slope b in three Q^2 bins for 2012 pilot and in four bins for 2016-2017, together with existing data points from ZEUS in a similar Q^2 range, is shown in Fig. 2.

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