Exclusive ρ^0 and ϕ production from COMPASS

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Preliminary results on exclusive ρ^0 and ϕ production from the COMPASS 2002 run are presented. The data were obtained by scattering polarized muons of 160 GeV energy on a polarized ^{6}LiD target in the kinematic range $10^{-3} < Q^2 < 10$ (GeV/c)^2 and $7.5 < W < 16$ GeV. The final large statistics data will allow to reduce significantly errors on both unpolarized and polarized observables for both exclusive channels. In addition, an extended range of low Q^2 will enable comprehensive studies in the region close to the photoproduction. As examples, we discuss the t'-dependent skewing of the two-pion invariant mass distribution and the decay angular distributions.

1 Introduction

In this paper we discuss the potential of the COMPASS experiment [1] to study the exclusive ρ^0 and ϕ production in the range of small and large Q^2 and present first preliminary results based on 1/6 of the data from the year 2002. Using a 160 GeV muon beam which scatters on a ^{6}LiD target we investigate the elastic vector meson (VM) production passing via coherent $\mu + A \to \mu + A + VM$ scattering, where A is the nucleus, which remains intact in the final state and incoherent $\mu + N \to \mu + N + VM$ scattering, where N is the target nucleon, which can be either free or bound in the nucleus. We study reactions with ρ^0 or ϕ mesons in the final state decaying via the hadronic mode ($\pi^+\pi^-$ and K^+K^- respectively). The high beam luminosity results in the large statistics which even with one year of data taking will allow to reduce significantly the errors on both unpolarized and polarized observables. In addition, an extended range of low Q^2, compared to other fixed target experiments, will allow to explore the region close to the photoproduction.

2 Selection of the sample

The track reconstruction efficiency is lower for soft particles, thus we may expect distortions of kinematic variable distributions when one of the mesons

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from VM decay is slow. To minimize such effects, we apply a cut on the energy transfer: $\nu > 30\,\mathrm{GeV}$.

In addition, a cut on the minimum energy of the scattered muon has been applied to reduce the contamination due to the triggers caused by muons from the decay of final state hadrons: $E_{\mu'} > 20\,\mathrm{GeV}$.

To decrease the contribution of non-exclusive background in the sample we apply a cut on the transverse momentum transfer: $-t' < 0.5\ (\mathrm{GeV/c})^2$.

In order to suppress not-exclusive events which exhibit the topology of exclusive events a cut on the missing energy ΔE has been applied, where $\Delta E = (M_X^2 - M_p^2)/2M_p$ and M_X is the missing mass of undetected final state particles. ΔE is a measure of exclusivity. At this stage we require for an event to have a reconstructed primary vertex inside of the target volume with four tracks. They are beam track, scattered muon and two hadrons of opposite charge. The distribution of ΔE for the preselected sample is shown in Fig.1.

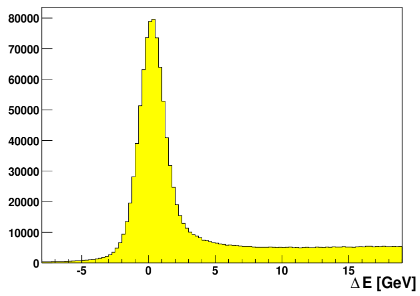

Figure 1: The missing energy in primary vertex after all selection cuts.

We define the sample of exclusive events by requiring $-2 < \Delta E < 2.5\,\mathrm{GeV}$.

The invariant masses of the VM were calculated assuming a decay $\rho^0 \to \pi^+\pi^-$ or $\phi \to K^+K^-$, respectively, without applying particle identification. The total numbers of events for certain mass intervals in the preselected sample are presented in table 1.

meson	mass cut	statistics (1/6 of 2002)
ρ^0	$0.5 < m_{\pi\pi} < 1\,\mathrm{GeV}$	$1.3 \cdot 10^6$
ϕ	$\lvert m_{KK} - m_\phi \rvert < 9\,\mathrm{MeV}$	$42 \cdot 10^3$

Table 1: The preselected sample statistics.

3 First results

In this section we present the raw data distributions. No acceptance for geometric acceptance were included and no attempt was made to take into account the errors in the kinematic reconstruction. The Monte Carlo study, needed to evaluate these effects, is in progress. The kinematic range, accessible for COMPASS and corresponding to the selection criteria is

$$\begin{aligned} 10^{-3} &< Q^2 < & 10\ (\mathrm{GeV/c})^2, \\ 7.5 &< W < & 16\ \mathrm{GeV}. \end{aligned}$$

One can see that the sample is dominated by quasi-real photoproduction and that the energy W is outside of the photon-nucleon resonance region.

As it is usual for the region near to photoproduction we observe a skewing of the ρ^0 invariant mass distribution compared to the relativistic Breit-Wigner shape. The enhancement of events at low masses and the depletion at large masses can be described by the Söding model [2] as an interference between resonant ρ^0 production and "Drell-type" background processes. This background is coming from the fluctuations of the virtual photon into two pions which scatter diffractively on the proton. The mass spectrum has been fitted with an expression corresponding to the coherent sum of resonant and non-resonant $\pi^+\pi^-$ production [3].

Fig.2 shows the results of the fit for different intervals of t' (top row) and Q^2 (bottom row). The non-exclusive contribution extracted from the fit is subtracted from all histograms. One observes that the distortion due to the interference term decreases with increase of $-t'$. That can be explained by absorptive corrections due to the rescattering of the two-meson system as a whole off the target [4]. The non-resonant dipion contribution is also reduced when Q^2 increases.

The angular distributions of the VM decay products give a direct indication of the polarization of the VM. We present the polar angle distributions that determine the fractions of the vector mesons produced with longitudinal polarization (helicity 0). We demonstrate also azimuthal angular distributions which could be used for testing the consistency of the data with the hypothesis of s–channel helicity conservation (SCHC).

ρ^0 and ϕ are vector mesons which decay into two spinless hadrons. Their spin state will be reflected in the orbital angular momentum of decay mesons. The detailed formalism can be found in [5]. Usually the VM decay angular distribution $W(\cos\theta, \phi, \Phi)$ is studied in the s-channel helicity frame, which is the most convenient for describing the VM decay after photo- and electroproduction [6]. In this analysis we consider only one-dimensional projections of

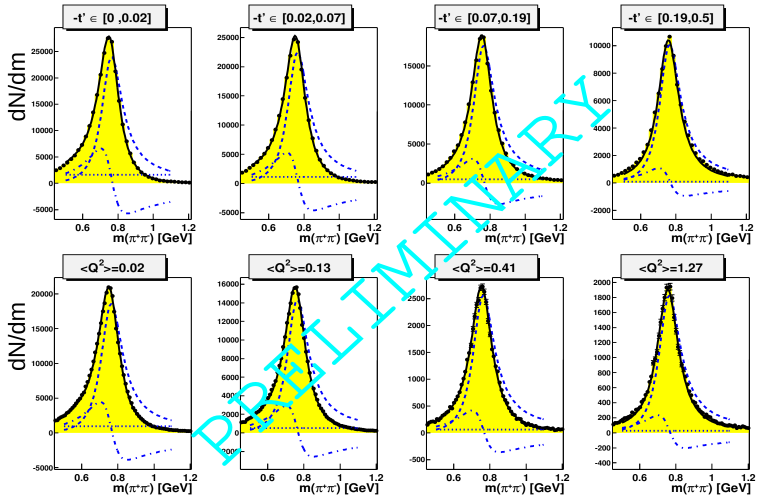

Figure 2: The fit of ρ^0 invariant mass distribution according to Söding parameterization. *Dashed line* corresponds to relativistic p-wave Breit-Wigner resonant contribution, *dotted line* – non-resonant part, *dashed-dotted* – interference term. No acceptance corrections were applied.

the angular distributions.

In this paper we split our Q^2 interval into four slices[1]. Fig.3 shows the $\cos\theta$ and ψ distributions for the ρ^0 case ($\psi = \phi - \Phi$). One can see that at small Q^2 the distribution of $\cos\theta$ has $\sin^2\theta$ - like dependence which indicates that production of transversely polarized (helicity ± 1) VM dominates. At large Q^2, when the contribution from interaction of longitudinally polarized photons dominates, the distribution changes the curvature and has $\cos^2\theta$ - like shape. The modulation in ψ relates to the contribution from the production of transverse photons. The fact that it peaks at 0 and π indicates that the decay mesons are mainly emitted in the muon scattering plane. The assumption of SCHC and natural parity exchange in t channel applies constrain on ψ modulation amplitude resulting to the vanishing of the latter in the region of longitudinal VM production (high Q^2).

One can see that COMPASS is capable to cover continuously the kinematic

[1]For the current analysis we apply the cut $Q^2 > 0.05$ (GeV/c)^2 to remove events with small scattering angles where angular smearing effect become essential.

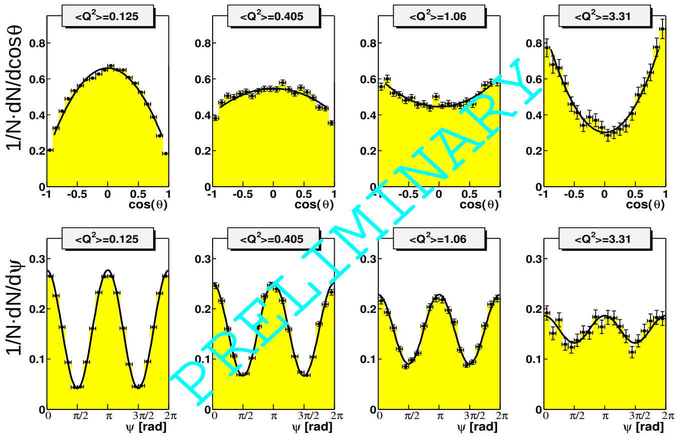

Figure 3: ρ^0 angular distributions for different Q^2 intervals. No acceptance and angular smearing corrections were applied. Only statistical errors are shown.

range from quasi-real photoproduction to hard pQCD.

4 Conclusion

The large statistics expected in COMPASS will allow to reduce significantly the errors on unpolarized and polarized observables for exclusive ρ^0 and ϕ channels. In addition, the extended range of low Q^2, compared to other fixed target experiments, will allow to explore the region close to the photoproduction.

References

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