Diffractive electroproduction of ρ^0 mesons at 27.5 GeV

The HERMES collaboration

Electroproduction of ρ^0 mesons has been studied at an incident positron beam of 27.5 GeV. From data taken on Hydrogen (^{1}H) and Deuterium (^{2}H) and ^{3}He targets the nuclear transparency has been determined. The measurement of the polar decay angular distribution confirms the results of previous measurements. The evaluation of the cross section and target asymmetry for ρ^0 production is in progress.

1 Introduction

Diffractive ρ^0 production has been studied at HERMES, a deep inelastic positron scattering experiment at DESY. By comparing the ρ^0 production rate on ^{3}He to that on ^{1,2}H, nuclear transparencies were determined. Also measured were the angular distributions of the decay products of the ρ^0 meson, the $\pi^+ \pi^-$ pair, which provide information about the validity of s-channel helicity conservation and the various helicity-transfer amplitudes describing vector-meson electroproduction [1]. In this paper the preliminary results of the 1995 data on ^{3}He are presented. An overview of diffractive ρ^0 production can be found in reference [2].

2 The HERMES Experiment

The HERMES experiment at DESY uses the 27.5 GeV polarised positron beam at HERA. The polarised positrons scatter from a polarised internal gas target, which in 1995 was ^{3}He. Also a limited amount of unpolarised ^{1}H and ^{2}H data were collected.
The HERMES spectrometer comprises a dipole magnet together with microstrip gas counters, proportional chambers and drift chambers for track reconstruction. Scattered positrons and forward going hadrons within an angular acceptance of 40 to 220 mrad are reconstructed. A lead glass calorimeter, two rows of hodoscope scintillators and a transition radiation detector provide positron-hadron separation. Additionally, a gas Čerenkov detector provides pion identification above a threshold of 6 GeV. Two small calorimeters monitor the

luminosity by measuring the coincidence yield of Bhabha scattering from the target.

3 Data analysis

Only those events are selected in which both the scattered positron and two hadrons with opposite charge are detected in the spectrometer.
Exclusive ρ^0 events are selected by comparing the invariant mass of the incoming and outgoing nucleon, i.e. by requiring the missing mass to be close to zero. We distinguish *coherent* scattering from the entire nucleus from *incoherent* scattering from individual nucleons by requiring $-t'$, the transverse momentum squared of the ρ^0 meson with respect to the virtual photon, to be smaller or larger than 0.05 GeV^2, respectively. Further cuts on $-t'$ and the energy transfer ν are used to remove background. The contribution of ϕ production is removed by requiring that M_{KK}, the invariant mass evaluated under the assumption that both hadrons are kaons, is larger than m_ϕ. After applying these cuts, about 10,000 ρ^0 mesons are obtained.

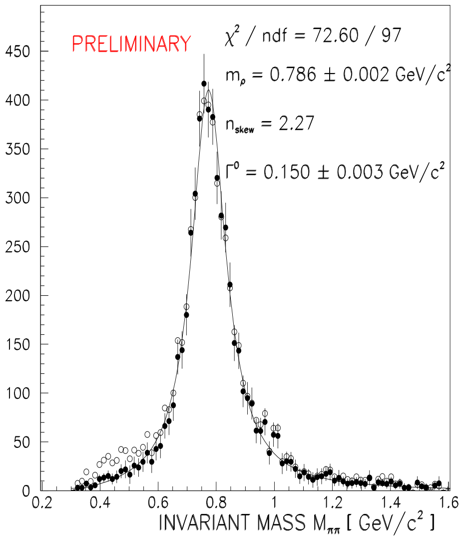

Figure 1: Mass spectrum. The open circles correspond to the data before acceptance correction, the closed circles correspond to the data after acceptance correction.

After subtracting background and applying an acceptance correction, the invariant mass spectrum is evaluated under the assumption that the two detected hadrons are pions. The spectrum is shown in figure 1 together with the results of a fit, described by a skewed relativistic Breit-Wigner resonance [3] with a Ross-Stodolsky skewing factor [4]:

$$\frac{d\sigma}{dM_{\pi\pi}} = \frac{M_{\pi\pi} m_\rho \Gamma_\rho}{(M_{\pi\pi}^2 - m_\rho^2)^2 + m_\rho^2 \Gamma_\rho^2} \left(\frac{m_\rho}{M_{\pi\pi}}\right)^{n_{\rm skew}} \; ; \; \Gamma_\rho = \Gamma_0 \left(\frac{\sqrt{M_{\pi\pi}^2 - 4m_\pi^2}}{\sqrt{m_\rho^2 - 4m_\pi^2}}\right)^3 \frac{m_\rho}{M_{\pi\pi}}.$$

The free parameters in the fit are the position (m_ρ), the width (Γ_0) and the skewing parameter (n_{skew}) of the ρ^0-mass peak. The fitted values, which are shown in figure 1, compare fairly well to the values from the Particle Data Book [5], i.e. $m_\rho = 768.5 \pm 0.6$ MeV and $\Gamma_0 = 150.7 \pm 1.2$ MeV. The fitted value of m_ρ is somewhat larger, which is likely due to an unseparated contribution from the $\omega(782)$ meson.

4 Nuclear Transparency

The nuclear transparency is defined as the ratio of the cross section for incoherent scattering from a nuclear target, normalised by A, and the cross section for a hydrogen target: $T_A \equiv \frac{\sigma_A}{A \cdot \sigma_H}$. The nuclear transparency can be less than unity due to initial and final state interactions (ISI and FSI) of the vector meson inside the nucleus. The probability for ISI and FSI effects increases with atomic number.

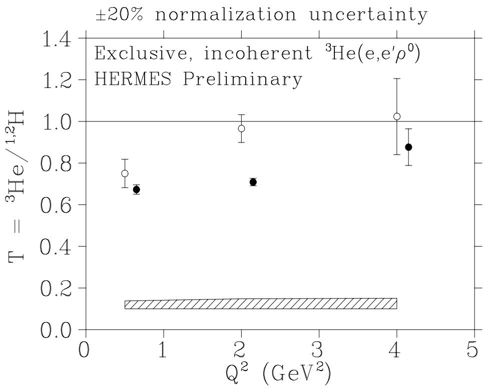

Figure 2: Nuclear Transparency for ^{3}He.

The Color Transparency ansatz [6] leads to a rise of nuclear transparency with increasing Q^2 and ν. On the other hand, reduction in the ISI for small coherence length [7] would result in a rise of nuclear transparency with increasing Q^2 and with *decreasing* ν. Hence, one would like to measure the nuclear transparency for different Q^2 and ν bins to distinguish between these two effects.

Since only a limited amount of ^{1}H and ^{2}H data were taken in 1995, the data for these two targets are combined, assuming that the nuclear transparency for ^{2}H is close to unity:

$$T_{^3He} = \frac{N_{^3He}}{N_{^1H} + N_{^2H}} \cdot \frac{L_{^1H} + 2\,L_{^2H}}{3\,L_{^3He}}$$

with N_A the number of events and L_A the time integrated luminosity on a particular gas type.

In figure 2 the preliminary measurement of the nuclear transparency for ^{3}He are shown for the HERMES 1995 data (open circles). These data are compared to a prediction (filled circles) based on interpolating the fit $T_A = A^{\alpha(Q^2)-1}$

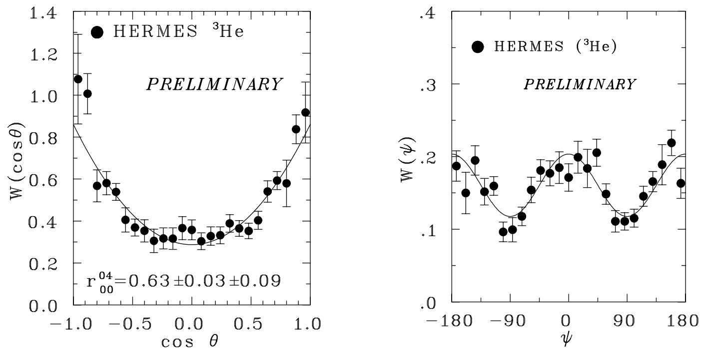

Figure 3: Angular distributions of $\cos(\theta)$ and Ψ as obtained from the HERMES 1995 data on ^{3}He.

from the E665 ^{1,2}H, C, Ca, Pb ρ^0 production data[8] to A=3. The preliminary HERMES data are closer to unity than the E665-based prediction.

5 Angular distributions

One can express the cross section for exclusive diffractive ρ^0 production in terms of the polarisation states of the ρ^0 meson, the incident beam, the virtual photon and the target. For a longitudinally polarised lepton beam, the production cross section can be expressed in terms of the polar decay angles (θ, ϕ) of the ρ^0 meson in the ρ^0 center of mass frame and the angle between the production plane and the lepton scattering plane Φ in the $\gamma^* p$ center of mass frame (See reference [1]). There is an additional dependence on the target polarisation; in this analysis, however, a sum over both spin states is performed. Under the assumption of s-channel helicity conservation (SCHC) [1], the cross section can be written as a function of only two angles: θ and $\Psi \equiv \phi - \Phi$.
After integrating over all angles except for the one that is considered, one obtains the following expressions for the θ and Ψ distributions:

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

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

The density matrix element r^{04}_{00} represents the longitudinal polarisation of the ρ^0 meson. Within the framework of SCHC, r^1_{1-1} is the linear polarisation of the ρ^0 meson. Assuming SCHC and using $R = \sigma_L/\sigma_T$ and $\epsilon = \Gamma_L/\Gamma_T$ one obtains:

$$R = \frac{1}{\epsilon}\frac{r^{04}_{00}}{1 - r^{04}_{00}}.$$

Assuming - in addition - natural parity exchange in the t-channel, one obtains:

$$r^{1}_{1-1} = \frac{1}{2}(1 - r^{04}_{00}).$$

In order to evaluate the various angular distributions, a multidimensional acceptance correction was carried out. Subsequentially, all events are projected onto a particular angular coordinate. Figure 3 shows the resulting $\cos(\theta)$ and Ψ distributions. From the $\cos(\theta)$ distribution, a value for r^{04}_{00} was derived: $r^{04}_{00} = 0.63 \pm 0.03 \pm 0.09$, which is averaged over a Q^2 range from 1 to 12 $(\mathrm{GeV/c})^2$. In figure 4 the value of r^{04}_{00} is compared to the results of other experiments. The HERMES measurement is consistent with existing data. Determination of r^{04}_{00} and r^{1}_{1-1} as a function of Q^2 is in progress.

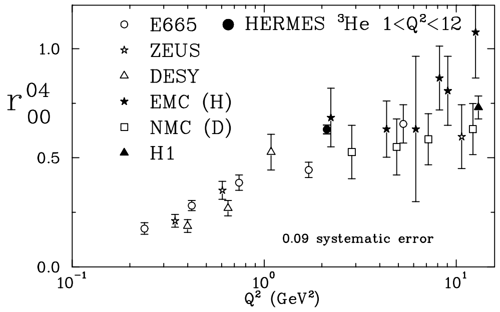

Figure 4: HERMES measurement of r^{04}_{00} as a function of Q^2 compared with data from DESY [9], EMC [10], NMC [11], ZEUS [12 13], H1 [14] and E665 [15]

6 Conclusions and outlook

A clean sample of diffractive exclusive ρ^0 events has been extracted from the HERMES 1995 data on ^{3}He. A measurement of the nuclear transparency on ^{3}He has been obtained. Combining 1995 and 1996 data (on ^{1}H) may enable a measurement of the nuclear transparency with sufficient accuracy to distinguish between effects due to the coherence length variation and possible effects due to color transparency.

Angular distributions can be measured at HERMES with high statistical accuracy which will enable a test of SCHC in our kinematic range. A preliminary result for the matrix element r^{04}_{00} is shown to be consistent with existing data. The analysis of the target spin dependence of ρ production is in progress. This will enable the extraction of helicity transfer amplitudes which depend on beam and target polarisation.

References

1. K. Schilling and G. Wolf, *Nucl. Phys. B*, **61**, 381 (1973)
2. T.H. Bauer, R.D. Spital, D.R. Yennie, F.M. Pipkin, *Reviews of Modern Physics*, **50**, 261 (1978)
3. J.D. Jackson, *Il Nuovo Cimento*, **34**, 1644 (1964)
4. M. Ross, L. Stodolsky, *Phys. Rev.*, **149**, 1172 (1966)
5. Review of Particle Properties, *Phys. Rev. D*, **54**, 1 (1996)
6. S.J. Brodsky, A.H. Mueller, *Phys. Lett. B*, **206**, 685 (1988)
7. B.Z. Kopeliovich, J. Nemchik, N.N. Nikolaev, B.G. Zakharov, *Phys. Lett. B*, **324**, 469 (1994)
8. M.R. Adams et al. (E665 collaboration), *Phys. Rev. Lett.*, **74**, 1525 (1995)
9. P. Joos et al., *Nucl. Phys. B*, **113**, 53 (1976)
10. J.J. Aubert et al. (EMC), *Phys. Lett. B*,, **161**, 203 (1985)
11. M. Arneodo et al. (NMC), *Nucl. Phys. B*, **429**, 503 (1994)
12. M. Derrick et al. (ZEUS), *Phys. Lett. B*, **356**, 601 (1995)
13. O. Lukina (ZEUS), Ref. pa 02-053, Contribution to the XXVIII Conference on High Energy Physics, Warsaw, 1996
14. S. Aïd et al. (H1), *Nucl. Phys. B*, **468**, 3 (1996)
15. M.R. Adams et al. (E665 collaboration), *Z. Phys. C*, **74**, 237 (1997)