VECTOR MESON PRODUCTION AT HERMES

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Exclusive electroproduction of ρ^0, ϕ, ω and J/ψ mesons is described. The measured decay angle distributions provide information on the elements of the spin density matrix of the ρ^0 meson. The data are in agreement with the hypothesis that the reaction is dominated by helicity conserving amplitudes with natural parity exchange, and are used to extract a measure of $R \equiv \sigma_L/\sigma_T$ in the range $0.5 < Q^2 < 4$ GeV^2. Also exclusive incoherent electroproduction of the ρ^0 meson was studied by using ^{1}H, ^{2}H, ^{3}He, and ^{14}N targets. The ratio of the ^{14}N to ^{1}H cross sections per nucleon, known as the nuclear transparency, decreases with increasing coherence length of the virtual photon's hadronic fluctuations. The data are interpreted as the first explicit demonstration of the effect of l_c on initial state interactions.

HERMES is an internal gas target experiment located in the East Hall of the HERA storage ring complex at DESY. The HERMES spectrometer [1] has been constructed with acceptance sufficient to allow the detection of scattered leptons in coincidence with quark fragmentation products. It consists of two identical halves having acceptance $40 < \Theta < 220$ mrad with momentum resolution $\leq 1\%$, and identification of electrons with efficiency $> 97\%$ at hadron contamination $< 1\%$. In addition Cherenkov detector provides pion identification in the momentum range from 5.6 (4) GeV/c up to 19.8 (16) GeV/c in 1995 (1997, 1998) years.

The ρ^0, ϕ, ω and J/ψ mesons are identified by their decay products in the following channels: $\rho^0 \to \pi^+\pi^-(100\%)$, $\omega \to \pi^+\pi^-\pi^0$; $\pi^0 \to \gamma\gamma(88\%)$, $\phi \to K^+K^-(49\%)$, $J/\psi \to e^+e^-, \mu^+\mu^-(6\% + 6\%)$. The numbers in brackets indicate the branching ratios. Approximate numbers of detected elastic events in the years 1995-1997 are: $\rho^0 \sim 11000$, $\omega \sim 300$, $\phi \sim 1200$. About 100 J/ψ has been detected, without the separation of different production mechanisms because scattered positron was usually not detected.

The extraction of matrix elements from measured angular distributions of diffractive ρ^0 at HERMES allows the testing of S-Channel Helicity Conservation (SCHC) and natural parity exchange [2]. A detailed desciption of the analysis of experimental data is in [3].

Briefly, if SCHC is valid and the $t-$channel exchange particle in a diffractive exclusive ρ^0 production reaction has natural parity $P = (-1^J)$, then the matrix elements r^{04}_{00} and r^1_{1-1} extracted from the measured distributions should be correlated: $r^1_{1-1} = \frac{1}{2}(1 - r^{04}_{00})$. These are derived from fits of two angular distributions: the decay angle θ, which is the polar angle of the direction of flight of the positive decay pion, and the difference $\Psi \equiv \phi - \Phi$ between the ρ^0

decay and production planes ϕ and the lepton scatterring and ρ^0 production planes Φ. They are related to r^{04}_{00} and r^1_{1-1} via
$W(\cos\theta) = \frac{3}{4}\left[1 - r^{04}_{00} + (3r^{04}_{00} - 1)\cos^2\Theta\right]$ $\qquad W(\Psi) = \frac{1}{2\pi}\left[1 + 2\epsilon r^1_{1-1}\cos 2\Psi\right]$
In Fig. 1 we present the Q^2 dependences of above parameters based on 1995 data. Their correlation allows one to conclude that HERMES data are consistent with SCHC and natural parity exchange in the $t-$channel.

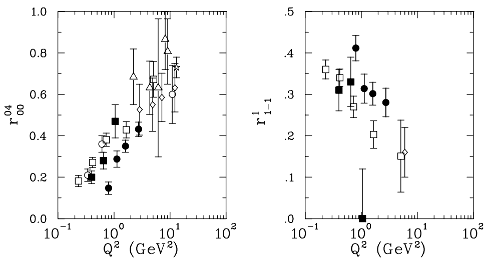

Figure 1: The spin density matrix elements for r^{04}_{00} and r^1_{1-1} are shown (full circles with statistical errors only). Previous measurements (with statistical errors only) from DESY, NMC, EMC, ZEUS and H1 are shown for comparison. The notation of the points is the same as in Fig. 2.

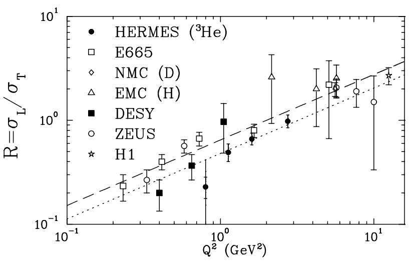

Figure 2: The ratio $R \equiv \sigma_L/\sigma_T$ determined from the measured values of r^{04}_{00}. The inner error bars represent the statistical error. The outer error on the lowest HERMES Q^2 point includes the systematic error added linearly. The dashed (dotted) line represents a simultaneous fit according to fit of the world data to data with average W above (below) 10 GeV.

The measured spin density matrix elements can be used for the determination of the Q^2 dependence of the ratio of longitudinal to transverse ρ^0 production cross sections $R \equiv \sigma_L/\sigma_T = \frac{1}{\epsilon}\frac{r^{04}_{00}}{1-r^{04}_{00}}$ where ϵ is the virtual photon polarization parameter[3]. Results for $R(Q^2)$ are presented in Fig. 2. The world data are fit to the form: $R(Q^2) = c_0(W) \cdot \left[\frac{Q^2}{M^2_\rho}\right]^{c_1}$, with $c_1 = 0.63 \pm 0.04$, one value of $c_0 = 0.46 \pm 0.03$ for the data from high energy muon beams and collider experiments spanning $6 < W < 140\,\mathrm{GeV}$ (EMC, NMC, E665, Zeus, and H1), and another $c_0 = 0.34 \pm 0.03$ for data with lower beam energy covering $2 < W < 6.5\,\mathrm{GeV}$ (DESY and HERMES). The Q^2 dependence of R is consistent with previous experiments, exhibiting a monotonic increase with Q^2 and marked disagreement with the VDM prediction $c_1 \equiv 1$. However, the data taken together with low energy data from DESY and compared with world data at higher energy suggest enhanced transverse strength at lower energy for fixed Q^2.

Also measured at HERMES was the reduction of the incoherent exclusive ρ^0 production cross section in nuclear medium (nuclear transparency) due to initial and final state interactions, as a function of the propagation distance or coherent length $l_c = 2\nu/(Q^2 + M^2_{q\bar{q}})$. At HERMES kinematics ($0.4 < Q^2 < 6$ GeV^2, $9 < \nu < 20$ GeV) this coherence length ($0.6 < l_c < 8$ fm) spans from well below to beyond the nuclear dimensions: $R_A = 2.1, 1.9, 2.5$ fm for ^2H, ^3He, ^{14}N. The variations of ν, Q^2 and A are used to probe the dependence on l_c of the measured nuclear trancparency: $T_A = \frac{\sigma_A}{A\sigma_H} = \frac{N_A L_H}{A N_H L_A} < 1$, where L_A is the luminosity determined from the DIS rate, N_A is the number of exclusive events at $t'_l < -t' < 0.4\ GeV^2$ and $t'_l = 0.02 - 0.09\ GeV^2$ is chosen for each $A > 1$ so that the coherent contribution is less then 5% . Non-exclusive background is excluded by the requirement $-2 < \Delta E < 0.6\ GeV$.

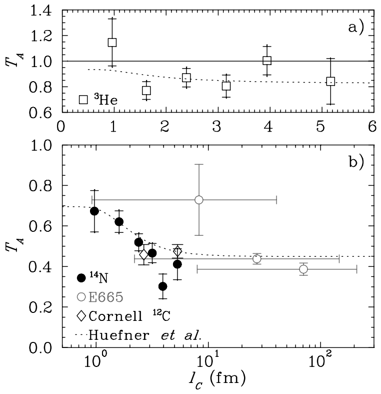

Figure 3: Nuclear transparency T_A as a function of l_c for a) ^{3}He and b) ^{14}N targets compared with previous experiments [4]. The error bars are statistical. The E665 data corresponds to broad ranges in l_c (horizontal error bars). The curve is from a calculation [5].

The resulting value of deuterium transparency $T_{^2H} = 0.970 \pm 0.024_{stat} \pm 0.040_{syst}$ is independent of l_c. The nuclear transparency for ^{3}He (open square) and ^{14}N (filled circle) is shown as a function of the coherence length l_c in Fig. 3. Strong hadronic initial state interactions (ISI) of $q\bar{q}$ states with the nuclear medium are small at $l_c \ll R_A$ and only final state interactions (FSI) reduce T_A from unity there: $T_{FSI} \approx T_{^{14}N}(l_c < 2fm) = 0.681 \pm 0.060$. ISI and FSI are saturated at $l_c \gg R_A$: $T_{ISI}T_{FSI} \approx T_{^{14}N}(l_c > 3.6fm) = 0.401 \pm 0.054$. The results are interpreted as a evidence that in the lab frame the exclusive ρ^0 is formed as a direct fluctuation of the virtual photon; the strength of the initial state interactions increases with increasing coherent length l_c of the fluctuation until it approximately equals the strength of the ρ^0 final state interactions.

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4. G.N. McClellan et at, Phys.Rev. Lett. 23, 554, (1969), M.R. Adams et at, Phys.Rev. Lett. 74, 1525, (1995).
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