DIFFRACTIVE EXCLUSIVE ELECTROPRODUCTION OF ρ^0 MESONS AT HERMES*

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Recent Hermes measurements are presented on the coherent and incoherent part of the cross section for the exclusive diffractive production of ρ^0 mesons. Based on data taken with a variety of targets, ^{1}H, ^{2}H,^{3}He,^{14}N, ^{20}Ne and ^{84}Kr, the method to extract the coherent to incoherent cross section ratios as a function of coherence length $l_{\rm coh}$ and momentum transfer Q^2 will be presented. The measurement of those ratios could contribute to the study of how quark–antiquark pairs interact with the nuclear medium. Using the ^{1}H and ^{14}N targets, the nuclear transparency of ρ^0 production has been measured as a function of coherence length. The data have been analysed to search for a possible onset of color transparency and are compared with recent theoretical calculations.

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1. Introduction

Exclusive electroproduction of ρ^0 mesons from nuclei is considered to be an excellent tool to investigate the properties of elementary particles interacting with nuclear matter, such as the phenomena of a *"shrinking photon"* [1], and Color Transparency (CT) [2], a QCD phenomenon which connects the transverse size of particle with its cross-section. The *"size"* of the hadronic components of a virtual photon at high negative four-momentum transfer squared, Q^2, was conjectured to be smaller than the size of a normal hadron, thereby accounting for the pointlike behavior and the diminished absorption of virtual photons in nuclear interactions compared to real photons.

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In QCD, the reaction amplitudes for exclusive interactions at large momentum transfer are expected to be dominated by components of the photon wavefunction with small transverse size, which give rise to diminished final state interactions in the nuclear medium.

2. Event selection and kinematic reconstruction

The data were obtained during the 1995-2000 running periods of the HERMES experiment using ^{1}H, ^{2}H, ^{3}He, ^{14}N, ^{20}Ne, and ^{84}Kr gas targets in the 27.5 GeV HERA positron storage ring at DESY. The HERMES detector is described in detail in Ref. [3]. The scattered e^+ and the h^+h^- pair were detected and identified in the HERMES forward spectrometer. The ρ^0 production sample was extracted from events with exactly three tracks: a scattered positron and two oppositely-charged hadrons. A more detailed and comprehensive description of extracting exclusive diffractive ρ^0 can be found in Ref. [4]. Here we only describe the method of extracting the ratio of coherent to incoherent cross sections based on nuclear data. After extracting the exclusive $-t' = t - t_{\rm min}$ distributions, where t is the four-momentum transfer squared between the vector meson and nucleon, and $|t_{\rm min}|$ is the minimum $|t|$ allowed by the kinematics, we see that they exhibit the rapid falloff expected for diffractive processes, and that they have two components (coherent(when nucleus left in ground state) and incoherent(scattering off a quasifree nucleon from nucleus without break up)) for nuclear targets and only one component(coherent) for hydrogen. The cross-section is therefore approximated with the sum of coherent and incoherent contributions as:

$$\frac{d\sigma}{dt} = b_N \mathrm{e}^{b_N t'} + R_A b_A \mathrm{e}^{b_A t'}, \tag{1}$$

where b_N is the nucleon and b_A is the nuclei diffractive slope, respectively. This yields the first observable, the coherent to incoherent full cross-section ratio, $R_A = \frac{\sigma_{\rm coh}}{\sigma_{\rm incoh}}$.

The coherent (incoherent) nuclear transparency is defined as:

$$Tr^{\rm coh(incoh)} = \frac{\sigma^A_{\rm coh(incoh)}(Q^2)}{A\sigma_{\rm H}(Q^2)}, \tag{2}$$

where H refers to ^{1}H and A is the nucleus atomic number. Note that for the extraction of R_A, there is no need to measure the absolute luminosity, as both measurements are done with the same target and the same beam, while for the nuclear transparency analysis, which was performed as:

$$Tr^{\rm coh(incoh)} = \frac{\sigma^A_{\rm coh(incoh)}(Q^2)}{A\sigma_{\rm H}(Q^2)} = \frac{N_A L_{\rm H}}{A N_{\rm H} L_A}, \tag{3}$$

L_A and L_{H}, the luminosities (multiplied by detector and tracking efficiencies) for nuclear and hydrogen target, respectively, had to be measured individually.

3. Study of systematic effects

The systematic uncertainties for the measured ratios were determined by varying the event selection criteria or the analyses procedures. These uncertainties include: the uncertainties arising from finite vertex resolution, the background subtractions that were performed to determine ρ^0 mass spectrum and the $-t'$ distribution. Ratios extracted in parallel for the $-t'$ and P_t^2 spectra provided a measure of the extraction uncertainty. Monte-Carlo generator DIPSI [5] was used to calculate the detector acceptance. there different diffractive slope parameters and relativistic (nonrelativistic) Breit–Wigner mass distributions were used as input parameters. Finally, corrections($\approx 15\%$) were applied to the ratios due to "Pauli blocking" [6] for incoherent scattering. For the nuclear transparency measurement the DIS positron cross-section was used as a luminosity measure in addition to the standard Bhabha luminosity measurement. The overall systematic uncertainty was determined by adding the above uncertainties in quadrature.

4. Results

In Fig. 1, the measured diffractive slope parameter for different targets and the fit result are presented. From earlier measurements of strong interaction nuclear radii [7] an $A^{2/3}$ dependence is expected as confirmed by the present data and the fit through the data.

TABLE I

Fitted common slope parameter of the Q^2-dependence of the nitrogen to hydrogen ratio with statistical and systematic uncertainties given separately. The results are compared to theoretical predictions [8].

Data sample	Measured Q^2 slope (GeV^{-2})	Prediction (GeV^{-2})
Coherent	$0.081 \pm 0.027 \pm 0.011$	0.060
Incoherent	$0.097 \pm 0.048 \pm 0.008$	0.053

Fig. 2 displays the coherent to incoherent cross section ratio *versus* Q^2. A strong Q^2 dependence can be observed.

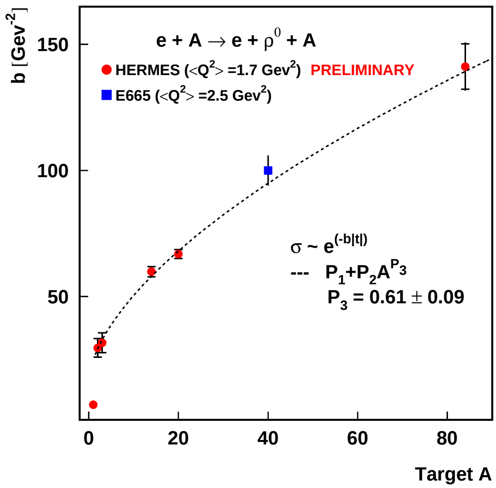

Fig. 1. A dependence of the diffractive slope parameter b. The dashed line is the result of the fit. Also shown a point from E665 Fermilab Collaboration for calcium [9]

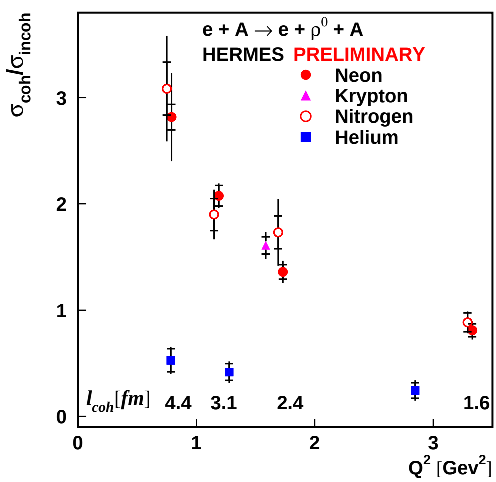

Fig. 2. Q^2 dependence of the coherent to incoherent cross-section ratio. For each data point, the corresponding $l_{\rm coh}$ values are given.

Fig. 3 presents the A dependence of the coherent to incoherent cross-section ratio. Note that it reaches saturation, which means that multiple scattering inside the nucleus is not growing linearly with A [6]. In Fig. 4 the published [4] incoherent transparency versus $l_{\rm coh}$ are compared with the new coherent transparency result. As one can see the coherent transparency

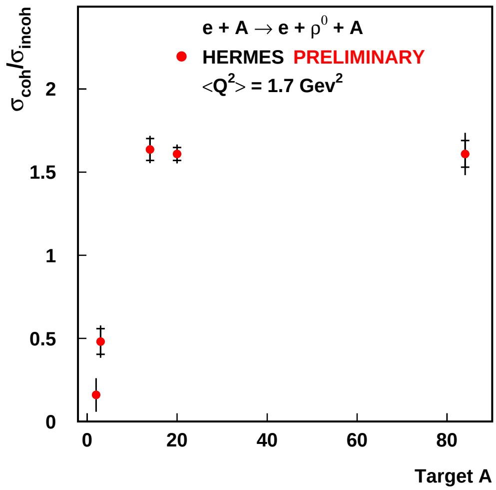

Fig. 3. A dependence of the coherent to incoherent cross-section ratio.

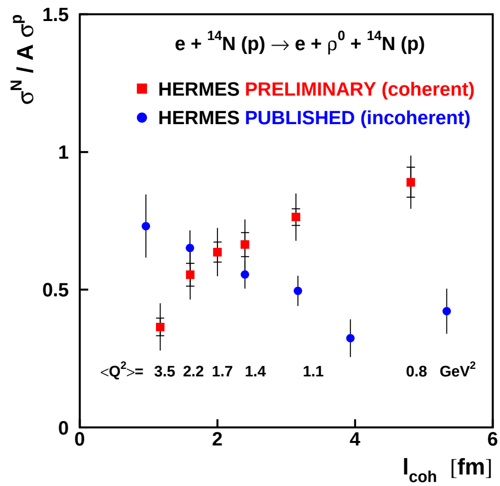

Fig. 4. Nuclear Transparency for coherent and incoherent scattering on nitrogen target. For each data point, the corresponding Q^2 value is indicated.

result shows a distinct $l_{\rm coh}$ dependence. To separate CT from coherence length effects a two dimensional analysis was performed where, for fixed $l_{\rm coh}$, a slope of the Q^2 dependence was extracted. A positive slope of the Q^2 dependence is evidence for CT according to Ref. [8]. Indeed, the results presented here support the CT assumption as shown in Fig. 5 for coherent ρ^0 production. The results are also summarized in Table I for both coherent and incoherent ρ^0 production.

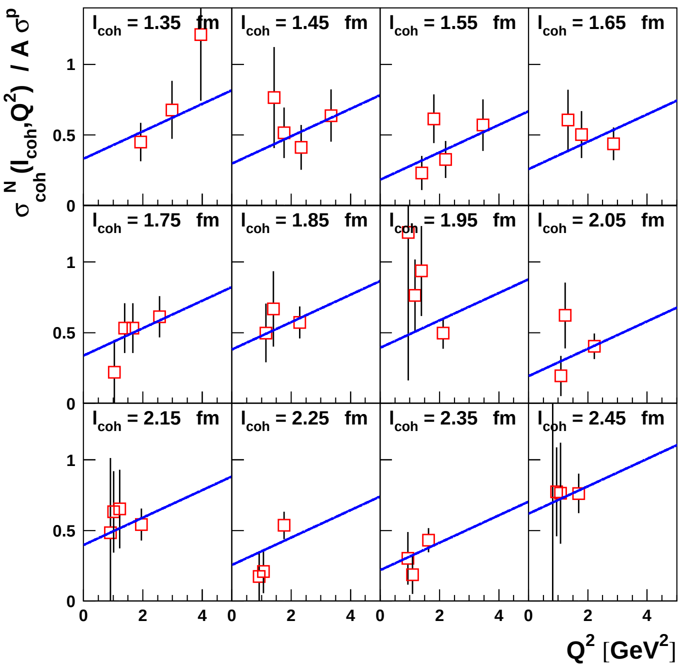

Fig. 5. Nuclear transparency as a function of Q^2 in specific coherence length bins (as indicated in each panel) for coherent ρ^0 production on nitrogen. The straight line is the result of the *common* fit of the Q^2-dependence. The error bars include only statistical uncertainties.

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