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DIFFRACTIVE CHARMONIUM PRODUCTION IN COLLISIONS OF 920 GeV PROTONS WITH NUCLEI* **

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We present preliminary results on the diffractive charmonium production at the HERA-B experiment. An excess of the events with a large rapidity gap between J/ψ and the outgoing proton system is observed, while a much smaller excess of that between J/ψ and the outgoing nucleus system is found. The A-dependence for the events with the large rapidity gap is measured. The search for the Double Pomeron Exchange charmonium production results in the upper limits on the proton–carbon cross-section times the radiative branching fraction of $\sigma^{\mathrm{DPE}}_{\chi_{c0}} \times \mathrm{BR} < 0.5$nb and $\sigma^{\mathrm{DPE}}_{\chi_{c1,2}} \times \mathrm{BR} < 1.1$nb at 90% C.L. The upper limits cover part of the region of the theoretical expectations.

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The diffraction is a process with an exponentially not suppressed rapidity gaps in the final state. In addition in the hard diffraction heavy particles or jets are produced. The hard diffraction allows to study an interplay between the long- and short-distance scales in QCD.

Using data collected by the HERA-B experiment we have searched for a diffractive charmonium production. The measurement of an A-dependence of the process is important for the understanding of the nuclear effects. In addition, Higgs searches in a Double Pomeron Exchange (DPE) process

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are planned at TEVATRON and LHC [1]. Since the production of heavy particles in DPE has not been observed yet, the observation of the DPE charmonium production at HERA-B would be an important step towards the understanding of the Higgs DPE production.

The diffractive events are selected using a requirement of large rapidity gaps. It is not possible to use the reconstructed outgoing proton system for the selection, since HERA-B has a limited acceptance in the forward direction.

HERA-B is a fixed target experiment which uses an internal target at the HERA proton ring. The 920GeV protons interact with carbon, tungsten and other targets, with $\sqrt{s_{pN}} = 41.6$ GeV. The HERA-B detector is a magnetic spectrometer with a wide angular coverage of $15 < \theta_x < 220$ mrad (bending direction) and $15 < \theta_y < 160$ mrad. The components used in this analysis include a silicon strip vertex detector (VDS), honeycomb drift chambers, a large acceptance 2.13T·m magnet, a finely segmented "shashlik" electromagnetic calorimeter (ECAL) and a muon system. The detector has a dedicated trigger to select di-lepton pairs. The detailed description of the HERA-B detector and the trigger system can be found in [2, 3]. The collected data sample contains about 170,000 reconstructed J/ψ s in the muon channel and about 150,000 in the electron channel. The analysis reported here is based on 86% of the $J/\psi \to \mu^+\mu^-$ data sample. Additional requirement of one primary vertex per event is applied.

For the Monte Carlo (MC) simulation a PYTHIA 5.7 event generator is used in combination with FRITIOF 7.02, as described in [3]. The MC generator does not contain the diffractive charmonium production. Full simulation of the detector is performed.

1. J/ψ production with the large rapidity gaps

We define multiplicity as a number of track segments, reconstructed in VDS plus the number of ECAL clusters minus 2 for $\mu^+\mu^-$ from J/ψ. The clusters produced by the charged tracks with segments in VDS are not counted. The number of reconstructed J/ψ s as a function of multiplicity is plotted in figure 1(a), dots correspond to data, histogram corresponds to MC. An excess in data over MC at low multiplicity is observed. This excess is suppressed, if the signal in Small Angle scintillator Counters (SAC) is required, as shown in figure 1(b). SAC cover the angular range of $2.3 < \theta < 9.6$ mrad, which corresponds to the pseudo-rapidity range of $5.3 < \eta < 6.8$. Since the requirement of the signal in SAC suppresses the events with the rapidity gap in the forward direction, the observation suggests that the excess is due to such events.

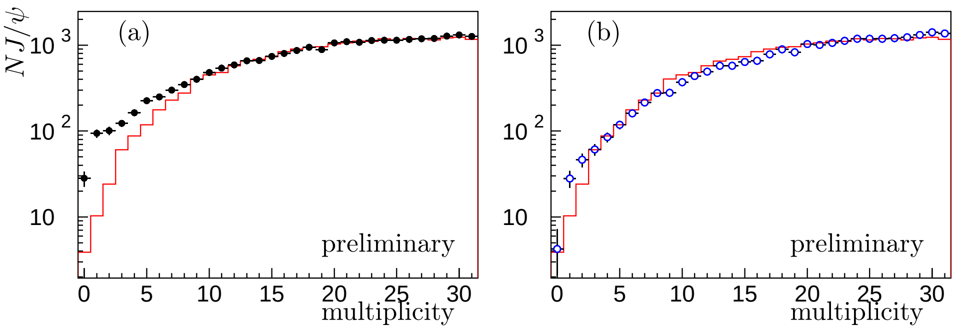

Fig. 1. (a) The number of reconstructed J/ψ s as a function of multiplicity. (b) The same as (a) but in data the signal in Small Angle scintillator Counters is required. The dots correspond to data, the histograms correspond to MC.

Figure 2(a) shows the distribution of J/ψ s in the rapidity gap size for the forward rapidity gaps (a) and for the backward rapidity gaps (b). There

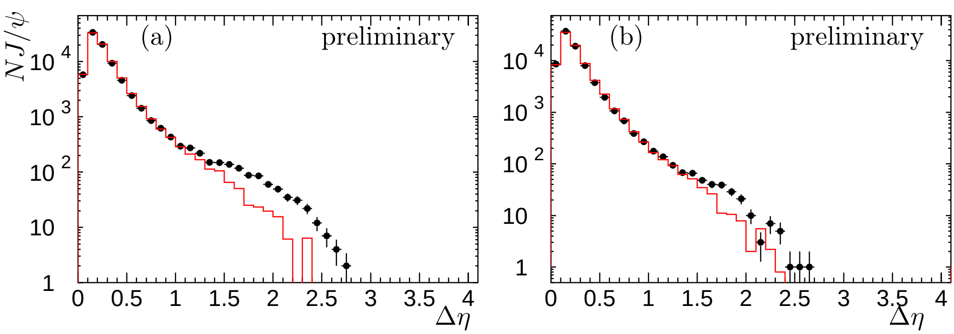

Fig. 2. The distribution of J/ψ s *vs* the size of the rapidity gap in forward direction (a) and in backward direction (b). The dots correspond to data, the histograms correspond to MC.

is a clear excess in data over MC for the forward direction, while there is only a small excess for the backward direction.

In the diffractive process the rapidity gap is a result of the Pomeron exchange. The cross section of the process with the Pomeron exchange between J/ψ and the nucleus (the backward rapidity gap) is expected to be larger than that with the Pomeron exchange between J/ψ and the proton (the forward rapidity gap). This is due to the fact, that in case of the nucleus both coherent (nucleus remains intact) and non-coherent (nucleus is broken) diffraction contribute. However we do not see an excess of the corresponding events with the large rapidity gap between J/ψ and the nucleus. It remains to be understood why.

It is interesting to measure the A-dependence for the events with the large rapidity gap. Usually the A-dependence is parameterized by the power law:

$$\sigma_{pA} = \sigma_{pN} \times A^{\alpha}\,.$$

The carbon and tungsten data samples are used to measure the parameter α. The number of J/ψ s in the two samples is normalized based on the E866 measurement of α [4]. This allows to avoid the determination of the integrated luminosity on every target in our preliminary measurement. To calculate α we assume that the acceptance ratio for the carbon and tungsten targets does not depend on the rapidity gap size. The resulting α as a function of rapidity gap size on both sides of J/ψ is shown in figure 3. For diffractive production α is expected to be close to 0.3, as it is a peripheral proton–nucleus interaction, for inclusive production α is close to 1. For forward rapidity gaps α is approaching 0.3 for large gap sizes, which is consistent with the diffraction. For backward rapidity gaps α is higher than 0.3, which implies that there is still a substantial contribution from a non-diffractive background.

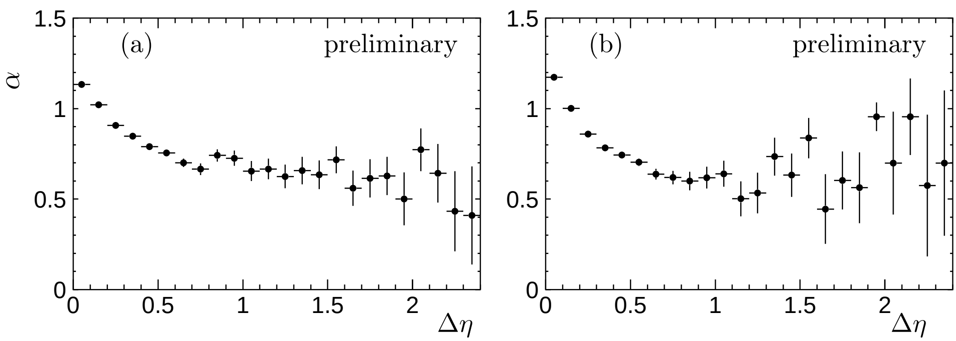

Fig. 3. The A-dependence parameter α as a function of rapidity gap size, (a) for the forward rapidity gaps and (b) for the backward rapidity gaps.

2. Search for the DPE charmonium production

We search for the DPE charmonium production:

$$pA \to p'^{(*)} + \chi_c + A'^{(*)}\,.$$

Pluses denote the large rapidity gaps on both sides of χ_c. The J/ψ state can not be produced in DPE due to its negative C-parity. The χ_{c1} and χ_{c2} states are suppressed compared to χ_{c0} [5]. However branching fraction $\mathrm{BR}\,(\chi_c \to J/\psi\gamma)$ is much smaller for χ_{c0} than for χ_{c1} and χ_{c2}, therefore it is not known which χ_c state will dominate in the $J/\psi\gamma$ final state.

As the outgoing proton and nucleus systems miss the acceptance of the detector, the signature of the process is an almost empty event with 3 particles only: μ^+, μ^- forming J/ψ and a photon forming χ_c. In our definition, the multiplicity of such events is equal to one. The mass difference $\Delta m = m(\mu^+\mu^-\gamma) - m(\mu^+\mu^-)$ for events with multiplicity=1 is plotted in figure 4. The histogram is fitted to a Gaussian corresponding to the χ_{c0}

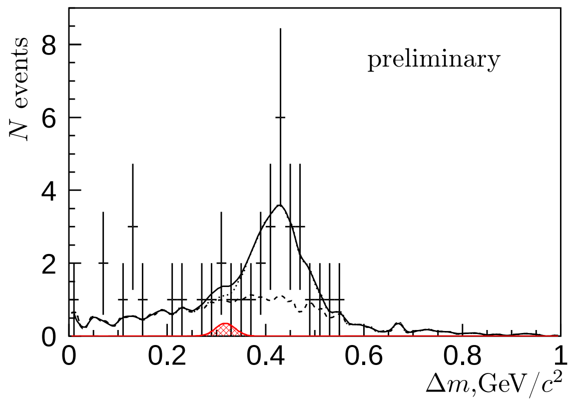

Fig. 4. The mass difference $\Delta m = m(\mu^+\mu^-\gamma) - m(\mu^+\mu^-)$ for the events with the multiplicity = 1.

signal plus a Gaussian corresponding to the $\chi_{c1,2}$ signal plus a function describing background shape determined from the event mixing. The mean and width of the Gaussians are taken from the MC simulation. An enhancement at the expected position of $\chi_{c1,2}$ states is seen. No signal of χ_{c0} is seen. From the fit results, an upper limit on χ_{c0} DPE production is set, using the method from [6]:

$$\sigma^{\mathrm{DPE}}(\chi_{c0}) \times \mathrm{BR}\,(\chi_{c0} \to J/\psi\gamma) < 0.5\mathrm{nb/carbon\ nucleus},\ 90\%\mathrm{C.L.}$$

The signal of $\chi_{c1,2}$ in the events with multiplicity=1 might be due to the background from inclusive production with a fluctuation of the multiplicity. To check this we plot the ratio $N(\chi_{c1,2})/N(J/\psi)$ (not corrected for the efficiency) as a function of multiplicity (see figure 5). The DPE signal would be an enhancement in the multiplicity=1 bin. As no enhancement is seen, we fit the distribution with a constant, the first bin being excluded. Based on the deviation of the first point from the fitted mean, an upper limit on $\chi_{c1,2}$ DPE production is set:

$$\sigma^{\mathrm{DPE}}(\chi_{c1,2}) \times \mathrm{BR}\,(\chi_{c1,2} \to J/\psi\gamma) < 1.3\ \mathrm{nb/carbon\ nucleus},\ 90\%\mathrm{C.L.}$$

To estimate $\sigma^{\mathrm{DPE}}(\chi_{c0})$ at HERA-B we use the existing predictions for TEVATRON and recalculate them for the HERA-B energy [7]. The resulting

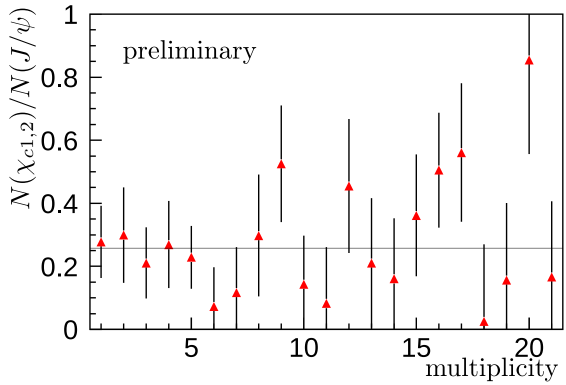

Fig. 5. The ratio $N(\chi_{c1,2})/N(J/\psi)$ (not corrected for the efficiency) as a function of multiplicity.

value is

$$\sigma^{\rm DPE}(\chi_{c0}) \times {\rm BR}\,(\chi_{c0} \rightarrow J/\psi\gamma) = 0.01 - 0.3{\rm nb/nucleon}\,,\ 90\%{\rm C.L.}$$

The existing upper limit from the WA102 experiment [8] is an order of magnitude higher than the theoretical predictions:

$$\sigma^{\rm DPE}(\chi_c) \times {\rm BR}\,(\chi_c \rightarrow J/\psi\gamma) < 2{\rm nb/nucleon}\,.$$

To compare our preliminary result with the expectations we assume $\alpha^{\rm DPE} = 0.3$. Then our upper limit *per nucleon* is:

$$\sigma^{\rm DPE}(\chi_{c0}) \times {\rm BR}\,(\chi_{c0} \rightarrow J/\psi\gamma) = 0.23{\rm nb/nucleon}$$

which covers part of the theoretically predicted region.

In summary, an excess of the events with the large rapidity gap between centrally produced J/ψ and the outgoing proton system is observed in data compared to MC. A much smaller excess of that between J/ψ and the outgoing nucleus system is found. If the excess is attributed to diffraction then we expect an even larger number of events with the Pomeron exchange between produced J/ψ and nucleus. It remains to be understood why we do not see an excess corresponding to such events. The A-dependence for the events with the large rapidity gaps in forward direction is consistent with the expectations for the diffractive production with $\alpha \sim 0.3$. For the events with the large rapidity gap in the backward direction α is higher which points to a higher contribution of background inclusive production in these events. We improve the existing upper limits on the DPE χ_c production by an order of magnitude.

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