HEAVY FLAVOUR PRODUCTION AT HERA-B

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HERA-B is a fixed target experiment operating at the 920 GeV/c ($\sqrt{s} = 41.6$ GeV) HERA proton beam at DESY. During the 2002/2003 HERA-B run, about 300.000 J/ψ were acquired in both e^+e^- and $\mu^+\mu^-$ decays with different nuclear targets. This allows for the first time the study of charmonium production (including also ψ' and χ_c states) in the negative Feynman x (x_F) region, and will provide important input for testing charmonium production mechanisms. Moreover, results will be presented also on nuclear suppression, on J/ψ polarization, on D and Υ mesons production and on the $b\bar{b}$ cross section.

1. Introduction

HERA-B is currently addressing a wide panorama of physics topics, ranging from strange, charmed and beauty hadron production to hard photon studies and pentaquark searches. The program of measurements devoted to the verification of perturbative QCD includes the hadronic productions of charmonium, bottonium, open charm and open beauty. Improvements with respect to the previous experimental situation are represented by the high energy of the experiment (the highest among the fixed-target ones), the wide kinematical acceptance, covering negative x_F values, and the possibility to select final states both in electrons and muons channels. The understanding of the mechanisms of particle production in an ordinary nuclear state is crucial for the correct interpretation of the J/ψ suppression [1] for which there is not yet a general consensus on the quark-gluon plasma formation.

2. HERA-B results

A complete description of the apparatus is given in [2]. The total data sample consists of 150 million dilepton triggered events (requiring the presence of at least two candidates in the electromagnetic calorimeter or in the muon detector) and 210 million minimum bias (requiring only the presence of detected photons in the RICH). The total suppression of the dilepton trigger is about $50 \cdot 10^3$ allowing a final archive rate of about 100 Hz. By running the muon and the electron triggers in parallel it is possible to perform all the analyses in both leptonic channels, providing significant consistency checks of the results.

A detailed study has been performed on the J/ψ, $\psi(2S)$ and χ_c mesons. About 300000 J/ψ and 5000 $\psi(2S)$ have been reconstructed both in e^+e^- and $\mu^+\mu^-$ channels and for two different materials (carbon C and tungsten W). The study of the J/ψ production and decay includes the measurement of the normalized differential distributions with respect to the transverse momentun p_T (fig.1a) and x_F (fig.1b) of the J/ψ and the lepton decay angle (fig.1c for the Gottfried-Jackson [3] frame) for the polarization studies.

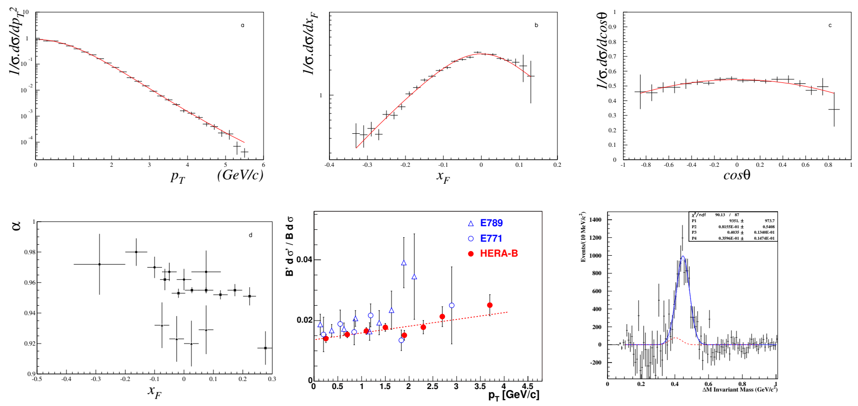

Figure 1. (a-b-c) Normalized J/$\psi \rightarrow e^+e^-$ production cross sections with respect to the p_T (a), x_F (b) and cos_theta (c) variables for the events acquired with carbon targets. (d): α distribution with respect to x_F together with the results of E866 (square) and Na50 (triangle). (e): distribution of the $\psi(2S)$ over J/ψ production ratio with respect to p_T together with the results of E771 (open circle) and E789 (open triangle). (f): $\chi_c \rightarrow \mu^+\mu^-\gamma$ peak background subtracted. All plots are preliminary.

The p_T distributions has been fitted with the curve [4]: the preliminary values obtained for $< p_T >$ are 1.24 ± 0.01 GeV/c and 1.29 ± 0.01 GeV/c respectively for C and W, confirming the tendency of an increasing $< p_T >$ for heavier targets as already seen by previous experiments [5].

The x_F distribution has been fitted with the function proposed in [6] in which the shape is described by a single "slope" parameter: the range of variation for the slope indicated by the fit ($5 \div 6.5$) includes the spread of preliminary evaluation performed with muon and electron data and for different target materials. The distributions will be the first measurements in the negative x_F range [5] and are crucial for the study of the nuclear effects of the J/ψ production (A-dependence). A preliminary indication of the possibilities of this study is given by distribution shown in fig.1d for the suppression parameter α; it has been measured a constant behaviour confirmed also (in a similar x_F region) by E866 [7] and Na50 [1] experiments. For the determination of the J/ψ polarization, the distribution of the variable $\cos\vartheta$, defined in the Gottfried-Jackson frame is fitted with the standard function $\approx 1 + \lambda cos^2\theta$. The preliminary results evaluated with different targets, indicates a preference for longitudinal rather that transverse polarization. The analysis also includes the evaluation of dependence of the polarization (expressed in several different frames) on the variables p_T and x_F.

The comparison between $\psi(2S)$ and J/ψ production can further contribute to the understanding of nuclear absorbtion processes: different cross section behaviours of the two charmonium states may in fact be interpreted in terms of the bigger size and lower binding energy of the $\psi(2S)$ with respect to the J/ψ state. Preliminary results for the yield ratio are (0.0163 ± 0.0010) for C and (0.0162 ± 0.0011) for W target. These values are in agreement with the world average value of about 0.016 (see [1] and ref. therein) and with the apparent independence of the target atomic weight and of the production energy shown by previous results. The $\psi(2S)$ to J/ψ ratio is also measured as a function of x_F and p_T (see fig.1e) extending the current experimental panorama. The fraction of J/ψ from the $\psi(2S)$ results $(7.0 \pm 0.4)\%$.

The fraction of J/ψ from the χ_c (R_{χ_c}) has been measured reconstructing about $15k$ χ_c candidates via the $J/\psi\gamma$ decay (see fig.1f for the only muon channel). A preliminary results gives $R_{\chi_c} = 0.21 \pm 0.05_{stat}$, in agreement with the previous value published by HERA-B[8]. These results favour the NRQCD expectation, but more stringent tests and better precision are needed for a final conclusion.

Measurements of open charm cross sections have been performed on the minimum bias sample. The D-meson production cross sections have been evaluated by reconstructing the signals $D^0 \to K^-\pi^+$, $D^+ \to K^-\pi^+\pi^+$ and $D^{\star+} \to D^0\pi^+$ (charge conjugates are here always implied) obtaining respectively 189 ± 20, 198 ± 12 and 43 ± 8 candidates. Preliminary numbers for the three cross sections, with statistical and systematic uncertainties, are $\sigma_{D^0} = 56.3 \pm 8.5 \pm 9.5$ μb/nucleon, $\sigma_{D^+} = 30.2 \pm 4.5 \pm 5.8$ μb/nucl and $\sigma_{D^{\star +}} = 27.8 \pm 5.2 \pm 3.9$ μb/nucl [9]; the precision obtained by HERA-B is comparable or better than the previous measurements.

The Beauty production was studied with the measurement of the $b\bar{b}$ and the Υ cross-sections relative to the J/ψ production. Only two measurements of the $b\bar{b}$ production cross section in $p - Nucleus$ interactions have been previously reported [10]. The b-hadrons are detected in the inclusive channels $J/\psi X$ reconstructing about 80 candidates and obtaining $\sigma(b\bar{b}) = 14.9 \pm 2.2_{stat} \pm 2.4_{syst} nb/N$ [11]. The fraction of J/ψ from the b quarks results $(0.065 \pm 0.011)\%$. The production of hidden beauty was studied measuring the cross section of the Υ without distinction between the three states $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$. About 100 Υ mesons have been reconstructed in both $\mu^+\mu^-$ and $e + e^-$ decay channel simultaneously. The measured cross section at mid rapidity is 4.5 ± 1.1 pb/N [12] in agreement with respect to the previous experimental measurements.

3. Conclusions

A brief panorama of the studies performed at HERA-B on the heavy flavor production has been presented. Due to the high statistics many analyses have been performed using different nuclear targets for the investigation of the production processes. The high acceptance of the apparatus has permitted to obtain results in an extended range with respect the previous experimental panorama and its versatility has allowed the study the charmonium and the beauty production both in the electron and muon decay channels.

References

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