SELECTED HERA-B RESULTS*

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The preliminary results on the measurement of the $D^+, D^0, J/\psi, b\bar{b}$, Υ production cross sections performed by the HERA-B experiment in 920 GeV pA interactions are presented.

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1. Introduction

HERA-B is a forward spectrometer which makes use of the HERA 920 GeV/c proton beam at DESY [1]. The large acceptance of the HERA-B spectrometer coupled with high-granularity particle identification devices and a precision vertex detector allow to perform detailed studies of complex multi-particle final states. The physics program is focused on the study of the quarkonium production (*e.g.* $J/\psi, \psi(2S)$ and χ_c) and its A dependence and heavy flavor production (D-, B- and Υ- mesons).

The data samples used in the analysis were collected between October 2002 and March 2003. During the data taking period two different triggers were used: the minimum bias (MB) and the dilepton trigger. 164 M dilepton triggered events were recorded containing about 300 000 J/ψ mesons (approximately equally distributed in both decay channels $J/\psi \to \mu^+\mu^-$ and $J/\psi \to e^+e^-$). Furthermore, for other charmonium states a quite large statistics could be achieved: $N(\psi(2S)) \approx 5\,000$ and $N(\chi_c) \approx 15\,000$.

The data sample of 210M MB events was recorded within two weeks in the 2002 HERA running period at a high data acquisition rate of about 1 000 Hz.

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Having successfully accumulated these data sets, the HERA-B Collaboration decided in the early 2003 to finish data taking activities at the end of this short running period and to fully concentrate on the analysis of the data taken.

2. Minimum bias data

The MB data sample was analyzed with the aim to measure the inclusive production cross section of $V^0(K^0_s, \Lambda$ and $\bar{\Lambda})$, open charm mesons and J/ψ.

The trigger required at least 20 hits in a RICH detector (compared to an average of 33 for full ring from a $\beta = 1$ particle) or an energy deposit of at least 1 GeV in an electromagnetic calorimeter and was sensitive to $\varepsilon^{\rm MB}_{\rm trig} > 97\,\%$ [2].

2.1. Open charm production

Signals of $D^0 \to K^-\pi^+$, $D^+ \to K^-\pi^+\pi^+$ and $D^{*+} \to D^0\pi^+$ (and charge conjugate decays) were fully reconstructed. To select a well-defined detached secondary vertex associated with the selected primary vertex, lifetime cuts were applied.

The preliminary results on D^0, D^+ and D^{*+} cross sections and the signal yields for these decays are summarized in Table I. The total cross sections were calculated by extrapolating over the full $x_{\rm F}$ range assuming $d\sigma/dx_{\rm F} \propto (1- \mid x_{\rm F} \mid)^{(7.7\pm1.4)}$ parametrization.

TABLE I

Results on D^0, D^+ and D^{*+} production cross sections.

	events	$-0.1 < x_{\rm F} < 0.05$	full $x_{\rm F}$
$\sigma(D^0)\mu b$/nucl	194 ± 20	$21.4 \pm 3.2_{\rm stat} \pm 3.6_{\rm sys}$	$56.3 \pm 8.5_{\rm stat} \pm 9.5_{\rm sys}$
$\sigma(D^+)\mu b$/nucl	92 ± 11	$11.5 \pm 1.7_{\rm stat} \pm 2.2_{\rm sys}$	$30.2 \pm 4.5_{\rm stat} \pm 5.8_{\rm sys}$
$\sigma(D^*+)\mu b$/nucl	49 ± 10	$10.0 \pm 1.9_{\rm stat} \pm 1.4_{\rm sys}$	$27.8 \pm 5.2_{\rm stat} \pm 3.9_{\rm sys}$

The measured production cross sections have been used to determine the ratio of neutral and charged D meson production rates. The result for the D^+/D^0 ratio is $0.54 \pm 0.11 \pm 0.14$ and for the D^{*+}/D^0 ratio is $0.49 \pm 0.12 \pm 0.10$. The expected theoretical value for the ratio of charged to neutral D mesons is approximately equal to 0.42. The result is much better in agreement with theory for the ratio of D^{*+}/D^0 for which the expected theoretical value is approximately equal to $1/2$.

2.2. J/ψ production cross section.

The MB triggered sample collected by the HERA-B experiment in interaction of 920 GeV/c protons with carbon, titanium and tungsten targets has been used to determine the production cross section of J/ψ mesons. In this data sample we find 100 ± 12 $J/\psi \to \mu^+\mu^-$ and 57 ± 13 $J/\psi \to e^+e^-$ decays. Correcting for the efficiency of the selection criteria within the range in rapidity of $-1.25 < y < +0.35$ and combining the both final states, we calculate the visible cross sections per nucleus within the detector acceptance. Using $\sigma_{pA}^{J/\psi} = \sigma_{pN}^{J/\psi} \times A^{0.96\pm0.01}$ to parameterize the A-dependence, and extrapolating this measurement to the full rapidity range (0.631 ± 0.010), the total production cross section per nucleon is $\sigma_{pN}^{J/\psi} = 663\pm74\pm46$ nb/nucleon.

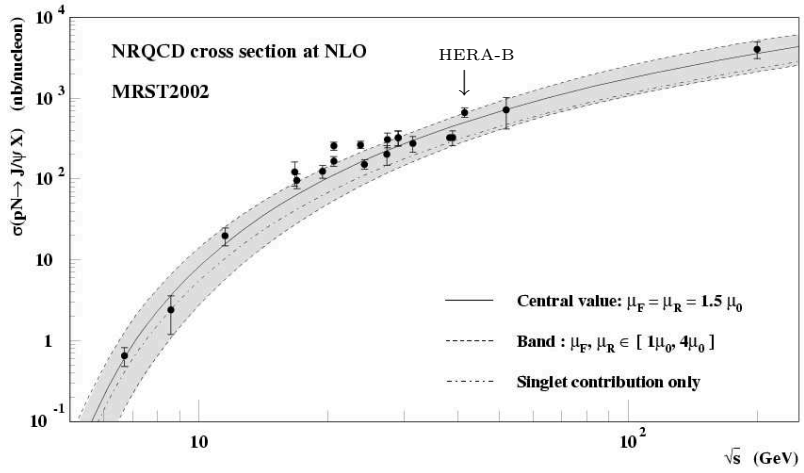

Fig. 1. J/ψ production cross section in proton-induced interactions.

The comparison of our measurement with other experiments is shown in Fig. 1. It is obvious that the experimental results are far from being consistent. Also shown in the figure is a fit to the published data on proton-induced J/ψ and $\psi(2S)$ production in the context of a next-to-leading order NRQCD calculation [3]. At $\sqrt{s} = 41.6$ GeV, the fit gives a cross section of $\sigma_{J/\psi}^{\rm fit} = 502 \pm 44$ nb/nucleon which is in agreement with the HERA-B result.

3. Dilepton trigger data

The dilepton triggered events have been analyzed to measure the p_T and $x_{\rm F}$ distributions of produced J/ψ mesons, the fraction of J/ψ produced from $\psi(2S)$ and $\chi_{\rm c}$ decays, the $b\bar{b}$ production cross section and also the

Υ production cross section. In a part of the dilepton sample both carbon and tungsten targets were operated simultaneously. This sample is being used to measure the A-dependence of J/ψ-production.

3.1. Open beauty production

The HERA-B experiment can measure the $b\bar{b}$ cross section via inclusive bottom quark decays into J/ψ by exploiting the longitudinal separation of $J/\psi \to l^+l^-$ decay vertices from the J/ψ produced directly on the target. In the analysis, $b \to J/\psi \to l^+l^-$ decays were selected in both muon and electron channels and a combined $b\bar{b}$ production cross section was measured. To minimize the systematic errors the measurement is performed relative to the prompt J/ψ production cross section. In order to determine the number of detached J/ψ candidates an un-binned likelihood fit of the dilepton invariant mass distributions after detachment cuts was performed. The results obtained are 46.2 ± 8.2 and 36.9 ± 8.1 events respectively for the muon and electron channel [4]. Combining the results in the e^+e^- and $\mu^+\mu^-$ channels, we obtain the value for the cross section ratio in the HERA-B acceptance:

$$R_{\Delta\sigma} = \frac{\Delta\sigma(b\bar{b})}{\Delta\sigma(J/\psi)} = 0.032 \pm 0.005_{\text{stat}} \pm 0.004_{\text{sys}} \,. \tag{1}$$

Here, $\Delta\sigma$ represents the cross section in the HERA-B acceptance. In order to compare these results to other measurements and to theoretical predictions, we extrapolate the $R_{\Delta\sigma}$ to the full x_{F} range and then, using the prompt J/ψ production cross section of $\sigma^{\text{fit}}_{J/\psi} = 502 \pm 44$ nb/nucleon, we

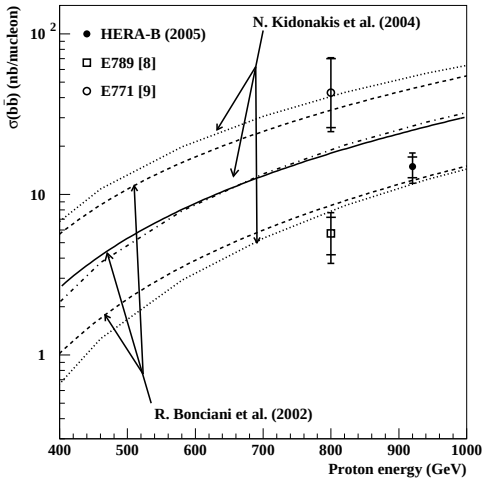

Fig. 2. Comparison of the available $\sigma(b\bar{b})$ measurement.

obtain the $b\bar{b}$ cross section of $14.9 \pm 2.2_{\text{stat}} \pm 2.4_{\text{sys}}$ nb/nucleon. Comparing to the other available experimental results (see Fig. 2), the present value is within 1.6σ of the E789 value (after rescaling to the same $\sqrt{s}$) [5] and 1.8σ below the rescaled E771 measurement [6].

3.2. Production cross section of Υ

The Υ mesons are reconstructed via leptonic decays $\Upsilon \to l^+l^-$ [7]. The signal is visible in both muon and electron final states with mass resolution between 140–160 MeV. The results of the both $\mu-$ and $e-$subsamples are in good agreement. The background shapes are described by a combination of combinatorial background and Drell–Yan events, whereas the Υ signal shapes are taken from MC.

As in the $b\bar{b}$ analysis, the production cross section is determined relative to the prompt J/ψ cross section. Combining the muon and electron channels, we obtain

$$R_{J/\psi} = \frac{\text{BR}\,(\Upsilon \to l^+l^-) \cdot d\sigma(\Upsilon)/dy|_{y=0}}{\sigma(J/\psi)} = (9.0 \pm 2.1) \times 10^{-6}\,. \qquad (2)$$

Using the J/ψ cross section of $\sigma^{\text{fit}}_{J/\psi} = 502 \pm 44$ nb/nucleon the Υ production cross section times branching ratio at mid rapidity of $\text{BR}(\Upsilon \to l^+l^-) \times d\sigma(\Upsilon)/dy|_{y=0} = 4.5 \pm 1.1$ pb/nucleon is obtained.

The comparison of our measurement with other experiments is shown in Fig. 3. The dotted line in Fig. 3 shows fits to predictions of next-to-leading order (NLO) calculations from Ref. [8] in the framework of the colour evaporation model (CEM) using the MRST HO parton distribution functions [9]. Our result, scaled for $\sqrt{s}$ dependence, lies half-way between those of E605 [10] and E772 [11].

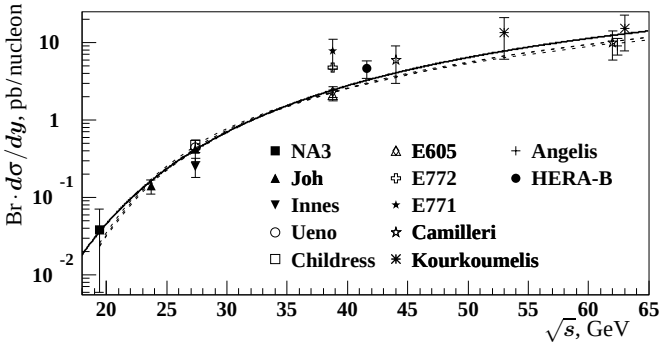

Fig. 3. $\text{BR} \cdot d\sigma(\Upsilon)/dy|_{y=0}$ for Υ production as function of the center-of-mass energy.

4. Summary

A brief overview on the measurements performed by the HERA-B experiment in the field of heavy flavor production in pA interactions has been given here. In most cases the presented results improve the precision of previous measurements and provide useful input for QCD models and reference measurements for heavy-ion experiments.

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