Charmonium Production at HERA-B

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The HERA-B experiment collected data in two periods during the years 2000 and 2002/3. Results based on 2000 data has been published recently. Here we report on the ongoing charmonium analyses in addition.

1 The Physics of Charmonium Production

Although the $J/\psi$ meson had been discovered almost 30 years ago, its hadronic production mechanism is still lacking a consistent theoretical understanding. Many new results on $J/\psi$ production appeared within the last decade, from the failure of the colour singlet model [1] to reproduce the production rate in $p\bar{p}$ collisions [2], to the claim that quark-gluon plasma related $J/\psi$ suppressions had been observed in heavy ion collisions [3]. In addition, there is a variety of results from HERA in the different kinematical regimes of $ep$ scattering [4]. The failure of the colour singlet model has stimulated intense theoretical interest in the mechanism of $J/\psi$ production. The inclusion of a colour octet $c\bar{c}$ state is common to several of the new theoretical models. NRQCD, the theoretically most rigorous approach, factorizes the charmonium production into a short distance hard part and a long distance matrix element which is claimed to be universal [5]. While NRQCD in leading order can accommodate the $J/\psi$ yield in $p\bar{p}$ collisions, the successful application to $ep$ data is less straightforward, and higher order corrections may be necessary [6]. Furthermore, the predicted transverse $J/\psi$ polarization is not observed in $p\bar{p}$ data [7]. Another unsettled question of $J/\psi$ production is the anomalous suppression in heavy ion collisions and a better understanding of the conventional $J/\psi$ suppression mechanism is desirable. The new HERA-B data on charmonium production and its $A$ dependence may therefore help to understand the underlying physics.
The HERA-B Experiment

HERA-B is a fixed target experiment operating at the HERA storage ring at DESY. Charmonium states are produced in inelastic collisions by inserting wire targets into the halo of the HERA proton beam. The c.m.s. energy is $\sqrt{s} = 41.6$ GeV. The detector is a magnetic spectrometer with a dedicated $J/\psi$ trigger sensitive to the muon and the electron decay channel. The detector components of interest to the charmonium analysis are the silicon vertex detector (VDS), the honeycomb drift chambers (OTR), the electromagnetic calorimeter (ECAL) and the muon system (MUON). The HERA-B target stations houses 8 target wires of different materials which can be moved independently [8]. The target materials cover a wide range in the nuclear mass number $A$ from carbon to tungsten.

The experiment took data in two periods: in the year 2000 during commissioning a sample of 8600 $J/\psi$, mainly with carbon and titanium wires, and a sample of about 300000 $J/\psi$ in the years 2002/2003 (3 month of data taking), mainly with carbon and tungsten wires. On average the experiment took 25-30 $J/\psi h^{-1}$ in the year 2000 but 1000-1500 $J/\psi h^{-1}$ in 2002/2003. This
shows the large improvement achieved in detector and trigger performance by
the detector upgrade that took place during the shutdown for the HERA lu-
minosity upgrade.

The experiment was originally designed to investigate CP violation in $B^0 \rightarrow J/\psi K^0$ decays and is therefore well suited for $J/\psi$ studies. Charmonium spec-
troscopy and the nuclear dependence of charmonium production are a central
part of the present physics program. Beside the triggered sample the experiment collected about 220 million minimum bias events. In addition to subjects like strangeness and open charm production, this sample is large enough to
study the $J/\psi$ production cross section without trigger bias.

3 Expectations for $J/\psi$ Production Measurements at HERA-B

![Figure 2: Expectations for the muon channel. Left: number of $J/\psi$ versus $x_F$
for carbon and tungsten targets (uncorrected HERA-B data). Right: expected
statistical error in the muon channel on $\alpha$ for the $J/\psi$ versus $x_F$ compared to
data from E866 [9].]

The A dependence of charmonium production can be studied with the
HERA-B carbon and tungsten data samples. The result is presented by the
parameter $\alpha$ defined in $\sigma_{pA} = \sigma_{pN}A^\alpha$. Due to its large angular coverage the
HERA-B detector allows us to study the $J/\psi$ production at negative values
of $x_F$ (Feynman $x$) and thereby to extend the existing measurements into a
range of about $-0.3 < x_F < 0.15$. Examples for the raw $x_F$ distributions of
the available data for carbon and tungsten targets are shown in Fig. 2 together
with the expected statistical error on $\alpha$ in different $x_F$ bins. In addition to the
$J/\psi$ a clear $\psi'$ signal can be observed in the same data sample. The ongoing
studies concentrate on a careful evaluation of the detector and trigger related systematic errors.

4 J/ψ Production via χc Decays

The relative χc production cross section with respect to the J/ψ is given by the ratio \( R_{\chi_c} = \sum_{i=1}^{2} \sigma(\chi_{ci}) Br_i / \sigma(J/\psi) \), where \( \sigma(\chi_{ci=0,1,2}) \) is the cross section for the different χc states and \( Br_i \) is the corresponding branching ratio for the radiative decay: \( \chi_{ci} \rightarrow J/\psi \gamma \). The signal for this radiative decay is visible in the mass difference \( \Delta M = M(J/\psi \gamma) - M(J/\psi) \). HERA-B has published a first measurement based on the 2000 data sample in both leptonic decay channels and the combined result \( R_{\chi_c} = 0.32 \pm 0.06 \pm 0.04 \) is consistent with earlier NRQCD calculations (Fig. 3, see [10] for more details). In addition Fig. 3 shows the χc signal in the new data for the muon channel after background subtraction. The increase in statistics of almost 2 order of magnitude in the new data will allow for an improved measurement and first results are available for the electron and the muon decay channel independently.

5 Outlook

The main topics in charmonium physics at HERA-B are the production cross sections of J/ψ, ψ′ and χc and their A dependence. Beyond this there are
many ongoing analyses on a variety of different subjects as double $J/\psi$ and diffractive $J/\psi$ production, $J/\psi$ polarization, hadronic $\psi'$ decays and many other subjects. Many new Results are expected in the near future.

References


[8] For more information on target, vertexing and the measurement of the $b\bar{b}$ cross section see M. Braun in this proceedings.
