ZEUS Results on Charm and Beauty Production from HERA II Data

DIS’05

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On Behalf of the ZEUS Collaboration

- D*± Production in Deep Inelastic Scattering
- D± Production
- Beauty Production with Dijets + Muon
- Outlook
**Motivation: Charm Production in DIS from HERA I**

- Probe QCD in detail
- Directly sensitive to gluon in proton

### Graphical Representation

![Graph showingcharm production](image)

- Differential cross sections
  - Sensitivity to the gluon
  - Can further constrain gluon proton pdf
**Motivation: Charm Production in DIS from HERA I**

Golden Decay of $D^{*\pm}(2010)$:

$$D^{*\pm} \rightarrow D^0 \pi_{s}^{\pm} \rightarrow K^{\mp} \pi^{\pm} \pi_{s}^{\pm}$$

Kinematic Region:

$$1.5 < Q^2 < 1000 \text{ GeV}^2 ; \ 0.02 < y < 0.7$$

$$1.5 < P_T < 15 \text{ GeV} ; \ |\eta(D^*)| < 1.5$$

- 96-97 Data (37 pb$^{-1}$)
- 98-00 Data (82 pb$^{-1}$)
  - $e^+ p$: 65 pb$^{-1}$; $e^- p$: 17 pb$^{-1}$

5545 $D^{*\pm}$ Mesons
Golden Decay of $D^{*\pm}(2010)$:

$$D^{*\pm} \rightarrow D^{0}\pi^{\pm}_{S} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}_{S}$$

Kinematic Region:

- $1.5 < Q^2 < 1000 \text{ GeV}^2$; $0.02 < y < 0.7$
- $1.5 < P_T < 15 \text{ GeV}$; $|\eta(D^*)| < 1.5$

- Cross Sections ($ep \rightarrow eD^{*}X$):
  - $\sigma(e^-p) = 9.37 \pm 0.44^{+0.59}_{-0.52} \text{ nb}$
  - $\sigma(e^+p) = 8.20 \pm 0.22^{+0.39}_{-0.36} \text{ nb}$
  - $\sigma(e^-p) > \sigma(e^+p)$

- Assumed to be a statistical fluctuation
Motivation: Charm Production in DIS from HERA II

Golden Decay of $D^{*\pm}(2010)$:

$$D^{*\pm} \rightarrow D^0 \pi^\pm_s \rightarrow K^\mp \pi^\pm \pi^\pm_s$$

Kinematic Region:

- $1.5 < Q^2 < 1000 \text{ GeV}^2$
- $0.02 < y < 0.7$
- $1.5 < P_T < 15 \text{ GeV}$
- $|\eta(D^*)| < 1.5$

- Production rate, $r=N/L$
- $Q^2 > 1.5 \text{ GeV}^2$:
  $$r(e^- p) / r(e^+ p) = 1.12 \pm 0.06$$
- $Q^2 > 40 \text{ GeV}^2$:
  $$r(e^- p) / r(e^+ p) = 1.67 \pm 0.21$$
- $\sigma(e^- p) / \sigma(e^+ p)$ increases with $Q^2$
- Assumed to be a statistical fluctuation
HERA II

- Regular production running for HERA II since October 2003
- Situation 2 weeks ago: HERA delivered $\sim 150 \text{ pb}^{-1}$

- Almost equal amounts of positron and electron luminosity
  - Have a look at the ratio of charm cross sections again
Golden Decay of $D^{\star \pm}(2010)$:

$$D^{\star \pm} \rightarrow D^0 \pi_{S}^{\pm} \rightarrow K^{\mp} \pi^{\pm} \pi_{S}^{\pm}$$

Kinematic Region:
$$5 < Q^2 < 1000 \text{ GeV}^2 ; 0.02 < y < 0.7$$
$$1.5 < P_T < 15 \text{ GeV} ; |\eta(D^{\star})| < 1.5$$

- 03-05 Data (73 pb$^{-1}$)
  - $e^+ p$: 40 pb$^{-1}$
  - $e^- p$: 33 pb$^{-1}$
- $D^\star$ Candidates:
  - $p_T (K, \pi) > 0.4$ GeV
  - $p_T (\pi_S) > 0.12$ GeV
- Signal from wrong charge subtraction
  - $1.80 < M(D^0) < 1.92$ GeV
  - $143 < \Delta M < 148$ MeV
**D* Signal - Positrons**

**ZEUS**

- **ZEUS 03-04 (prel.) e⁺p 40 pb⁻¹**
- **Wrong Charge**

- 1240 ± 64 D* Mesons
- rate = 30.7 ± 1.8 / pb⁻¹
- Q² > 40: rate = 6.4 / pb⁻¹

29th April 2005

Richard Hall-Wilton, UCL
• 1118 ± 60 D* Mesons
• rate = 33.5 ± 1.8 / pb$^{-1}$
• $Q^2 > 40$: rate = 6.3 / pb$^{-1}$
Ratio $\frac{\sigma(e^- p)}{\sigma(e^+ p)}$ vs $Q^2$

ZEUS

- ZEUS 98-00
- ZEUS (prel.) 03-05
Kinematic Region:

$5 < Q^2 < 1000 \text{ GeV}^2; 0.02 < y < 0.7$

$1.5 < P_T < 15 \text{ GeV}; |\eta(D^*)| < 1.5$

- 98-00 Data (82 pb$^{-1}$)
  - $e^+ p$: 65 pb$^{-1}$
  - $e^- p$: 17 pb$^{-1}$

- 03-05 Data (73 pb$^{-1}$)
  - $e^+ p$: 40 pb$^{-1}$
  - $e^- p$: 33 pb$^{-1}$

$r(e^- p) / r(e^+ p)$:

- $Q^2 > 1.5$ (5) GeV$^2$
  - 98-00 Data: $1.12 \pm 0.06$
  - 03-05 Data: $30.7/33.5=0.92$

- $Q^2 > 40$ GeV$^2$
  - 98-00 Data: $1.67 \pm 0.21$
  - 03-05 Data: $6.4/6.3=1.02$

Slight excess seen previously is not confirmed
- Charm is produced equally in $e^+ p$ and $e^- p$ collisions
Silicon MicroVertex Detector

Central Tracking Detector (CTD)

Straw Tube Tracker (STT)

Micro Vertex Detector (MVD)
Charm and beauty mesons have long lifetimes. Can be tagged via separated vertex or impact parameter. Have a look at $D^+$ Mesons and Dijet events containing Muons. Assign a sign to impact parameter using the Muon or $D^+$ direction.
• $D^{+}$ Candidate
• $Q^2 = 160 \text{ GeV}^2$
• $P_T = 5.1 \text{ GeV}$
**D± Photoproduction**

- **03-04 Data:** 15 pb\(^{-1}\)
- **p\(_T\)(D±) > 3.7 GeV**
- Cutting on significance gives large improvement in signal
- **151 ± 28 D± Mesons**
**D\(\pm\) Production in DIS**

- 03-04 Data: 10 pb\(^{-1}\)
- \(p_T(D^{\pm}) > 2\) GeV
- 191 \(\pm\) 33 D\(\pm\) Mesons

- Background reduced by factor 45, whilst signal reduced by only factor 2.7

▷ Cutting on significance gives large improvement in Signal:Background Ratio
Dijet + Muon Selection

- 03-04 Data: $31 \text{ pb}^{-1}$
- Photoproduction, $Q^2 < 4 \text{ GeV}^2$, $0.2 < y < 0.8$
- $p_T^{\mu} > 0.75 \text{ GeV}$
- $|\eta^{jet}| < 2.5$
- Massive jets, $p_{T}^{jet_{1,2}} > 7, 6 \text{ GeV}$
- 8010 muon candidates associated to a jet
**Dijet + Muon Selection — Control Plots**

**ZEUS**

- **ZEUS (prel.) 03-04 (31 pb⁻¹)**
  - beauty MC
  - beauty+charm+lf MC

- **beauty fraction:** $16.1 \pm 2.7 \%$

**Candidates**

- $p_T^{\mu-jet}$ vs. $p_T$ for different ranges of kinematic variables.
- $\eta^{\mu-jet}$ vs. $\eta^\mu$ for different ranges of kinematic variables.

**29th April 2005**
Beauty Fraction; 2 Methods

- Determine beauty fraction using $P_{T}^{rel}$ method
- Beauty fraction $16.1 \pm 2.1 \%$

![Graph showing beauty fraction distribution](image)

- Muon impact parameter
  - Excess in dijet data in positive direction
  - Indication of beauty component
  - Subtract negative from positive side
Monte Carlo (charm+beauty) describes reasonably the subtracted data distribution

Beauty normalisation taken from fit to $P_{T}^{rel}$
**Dijet Event with 2 Associated Muons**

- **Muon 1:**
  - \( P_{rel}^T = 1.24 \text{ GeV} \)
  - IP = 250 \( \mu \text{m} \)

- **Muon 2:**
  - \( P_{rel}^T = 2.05 \text{ GeV} \)
  - IP = 330 \( \mu \text{m} \)
Summary and Outlook

● Charm production in DIS investigated using 73 pb$^{-1}$ of HERA II data
  ▶ Twice as large sample e$^-$p data as HERA I
  ▶ Ratio of charm production in e$^+$p to e$^-$p collisions equal
  ▶ Previous excess in e$^-$p data NOT confirmed

● First results utilising silicon microvertex detector

● Lot of data on tape, plenty more coming
  ▶ Many more results to come!