

# ZEUS Results on Charm and Beauty Production from HERA II Data

DIS'05

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**Richard Hall-Wilton**

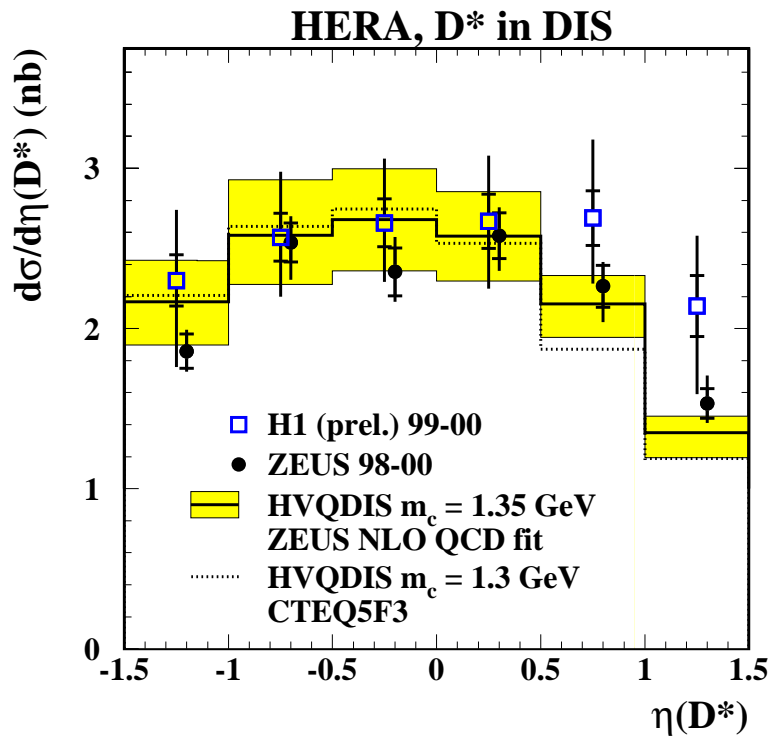
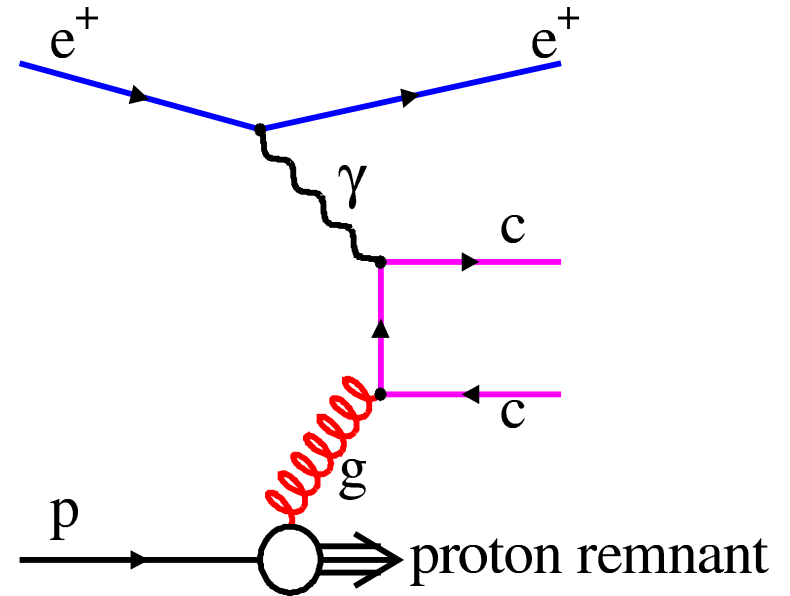
On Behalf of the ZEUS Collaboration

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- $D^{*\pm}$  Production in Deep Inelastic Scattering
- $D^{\pm}$  Production
- Beauty Production with Dijets + Muon
- Outlook

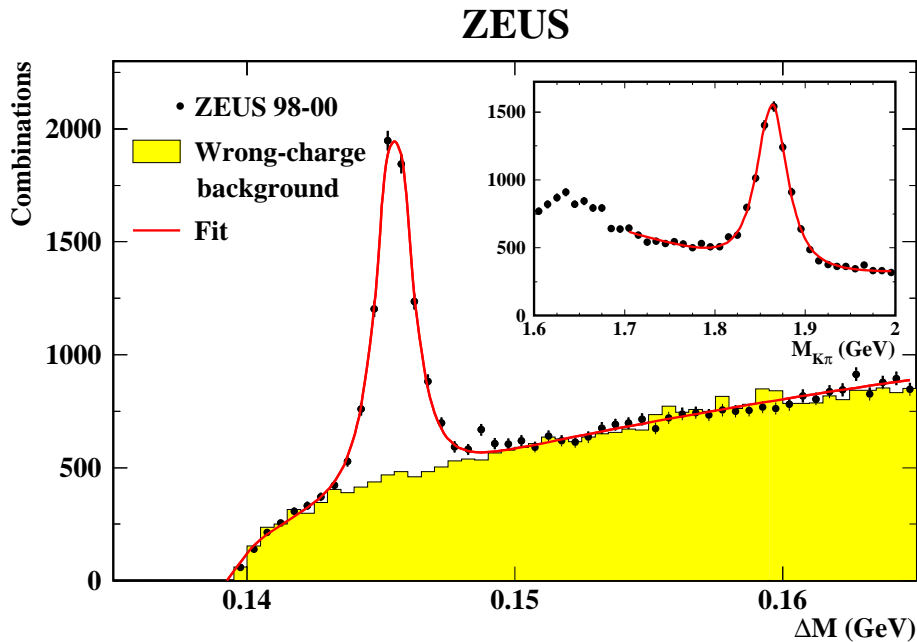
## Motivation: Charm Production in DIS from HERA I

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



- 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 ( $37 \text{ pb}^{-1}$ )

- ▷ Eur. Phys. J. C12 (2000), 35

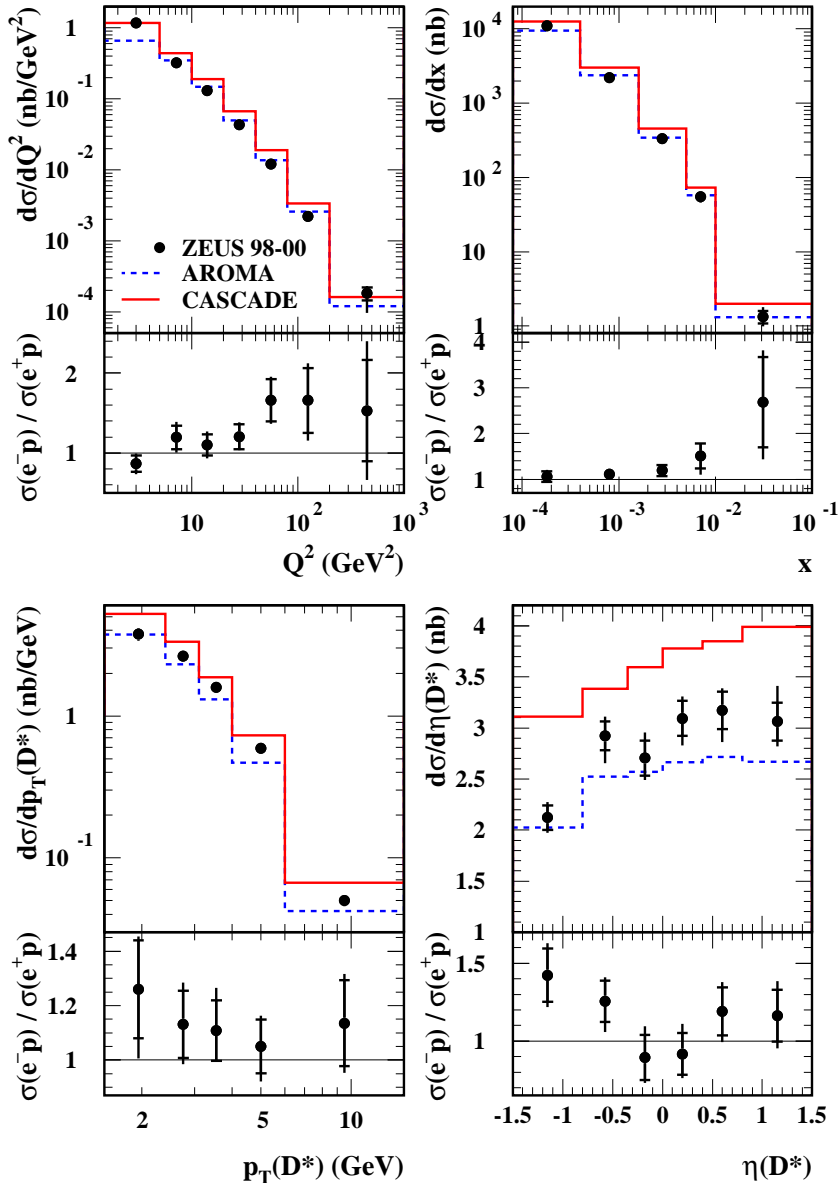
- 98-00 Data ( $82 \text{ pb}^{-1}$ )

- ▷  $e^+p$ :  $65 \text{ pb}^{-1}$ ;  $e^-p$ :  $17 \text{ pb}^{-1}$

- ▷ Phys. Rev. D70 (2004) 12008

## Motivation: Charm Production in DIS from HERA I

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

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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 ( $ep \rightarrow eD^*X$ ):

▷  $\sigma(e^-p) = 9.37 \pm 0.44^{+0.59}_{-0.52} \text{ nb}$

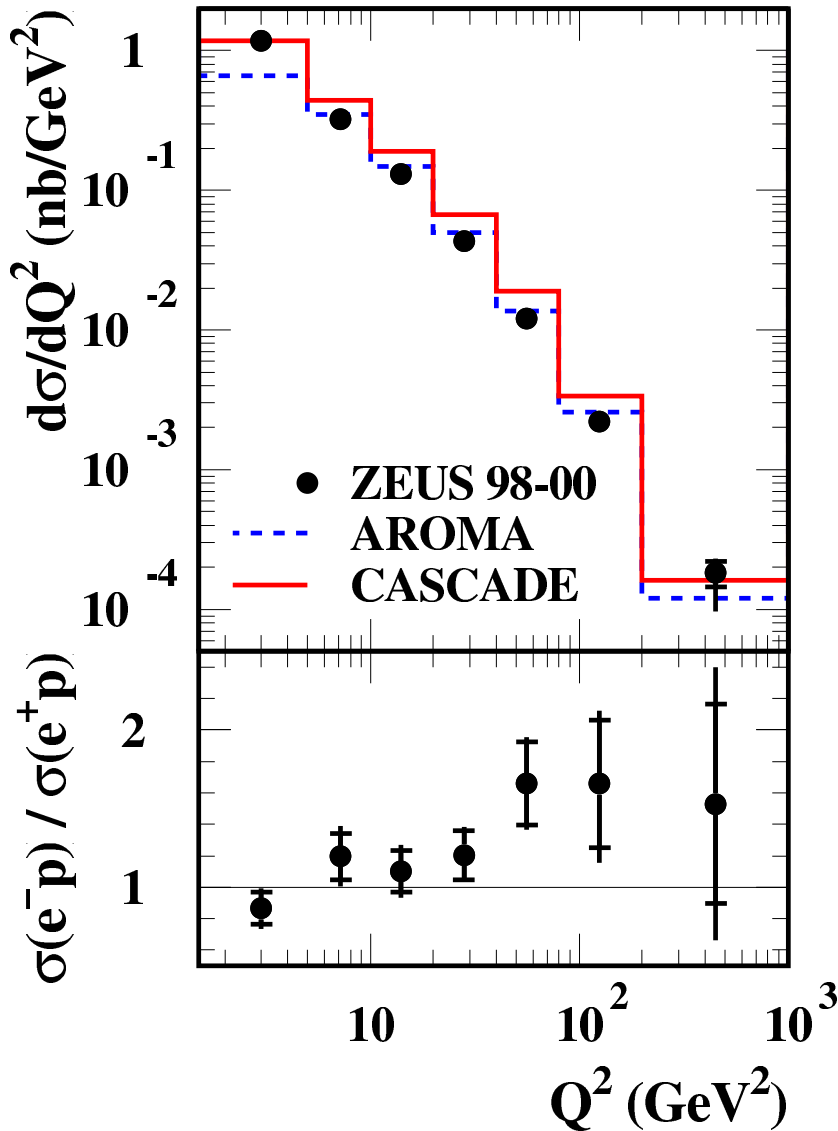
▷  $\sigma(e^+p) = 8.20 \pm 0.22^{+0.39}_{-0.36} \text{ nb}$

▷  $\sigma(e^-p) > \sigma(e^+p)$

● Assumed to be a statistical fluctuation

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

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

Kinematic Region:

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

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

● Production rate,  $r=N/L$

▷  $Q^2 > 1.5 \text{ GeV}^2$ :

$$r(e^-p) / r(e^+p) = 1.12 \pm 0.06$$

▷  $Q^2 > 40 \text{ GeV}^2$ :

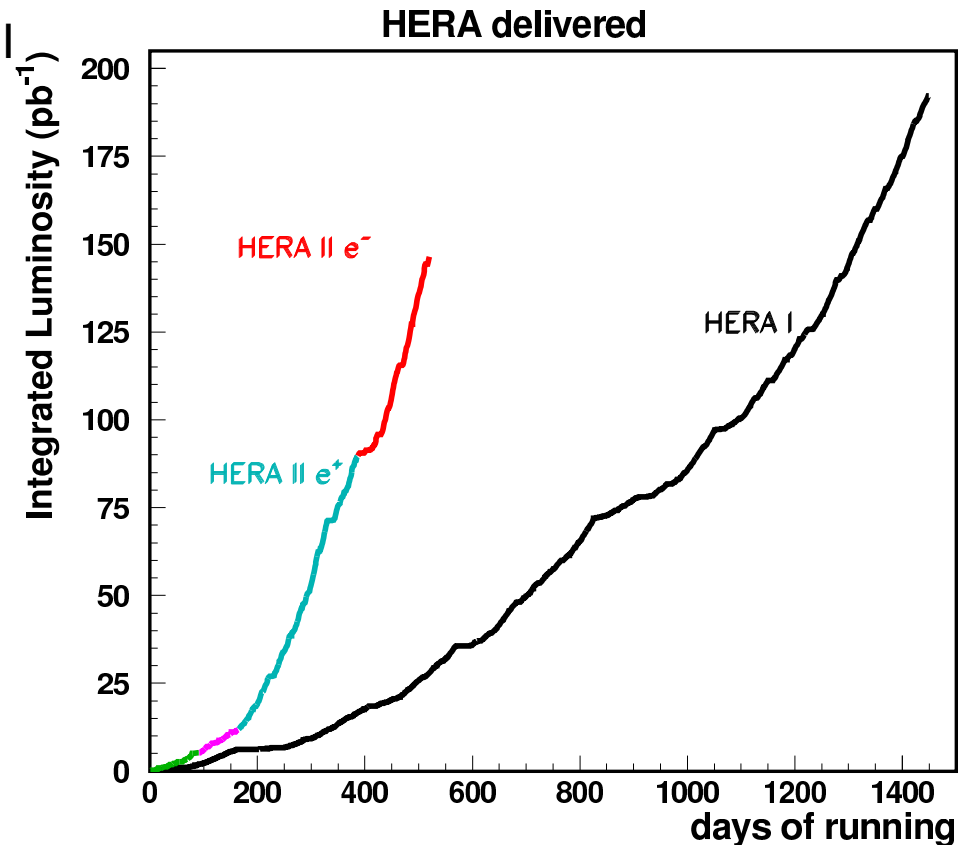
$$r(e^-p) / r(e^+p) = 1.67 \pm 0.21$$

▷  $\sigma(e^-p) > \sigma(e^+p)$  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

## Event Selection

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

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

Kinematic Region:

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

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

- 03-05 Data ( $73 \text{ pb}^{-1}$ )

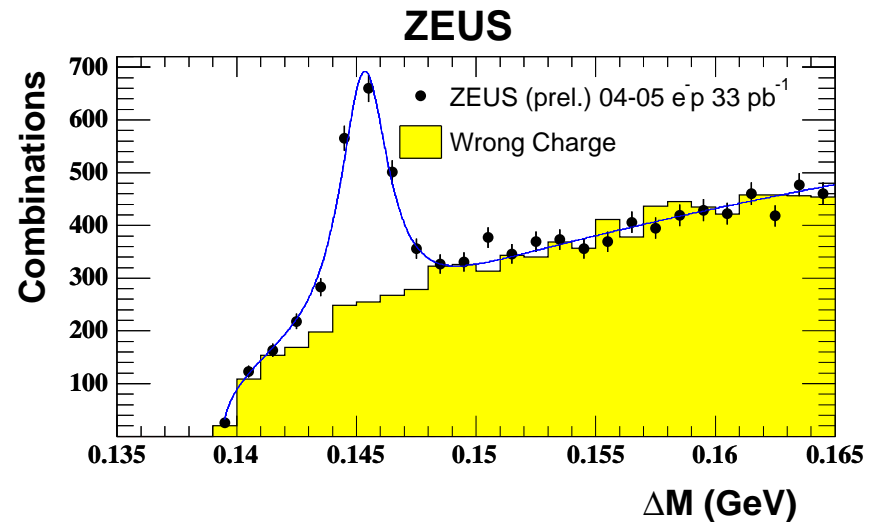
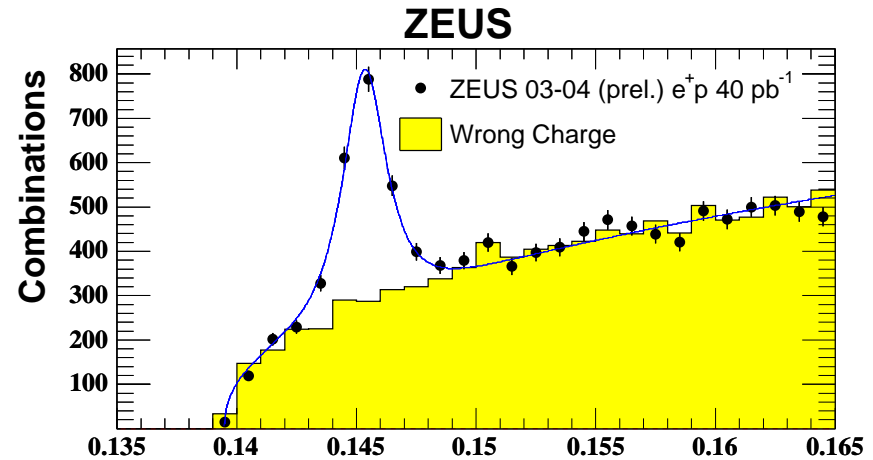
- ▷  $e^+ p$ :  $40 \text{ pb}^{-1}$

- ▷  $e^- p$ :  $33 \text{ pb}^{-1}$

- $D^*$  Candidates:

- ▷  $p_T(K, \pi) > 0.4 \text{ GeV}$

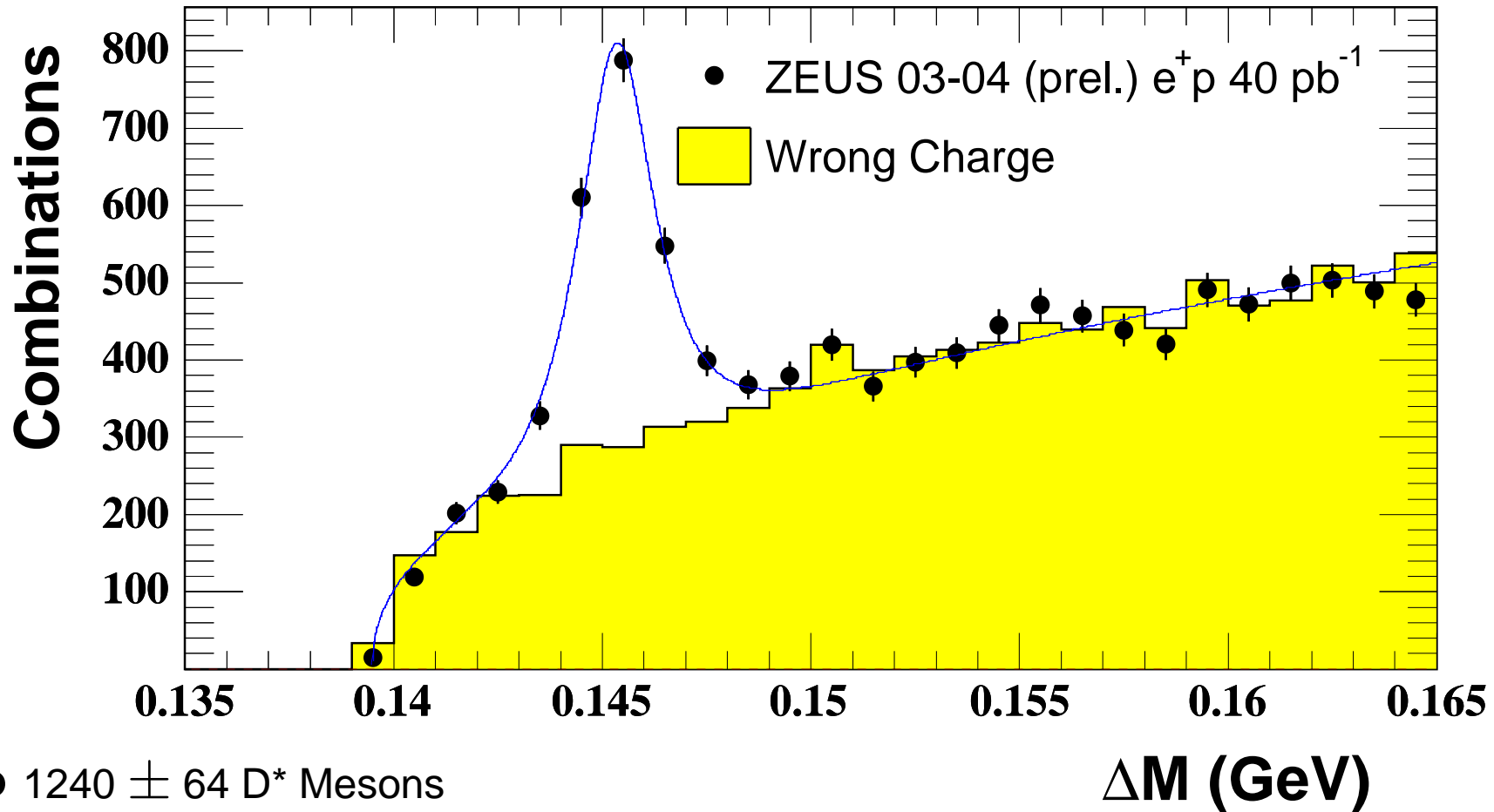
- ▷  $p_T(\pi_s) > 0.12 \text{ GeV}$



- Signal from wrong charge subtraction

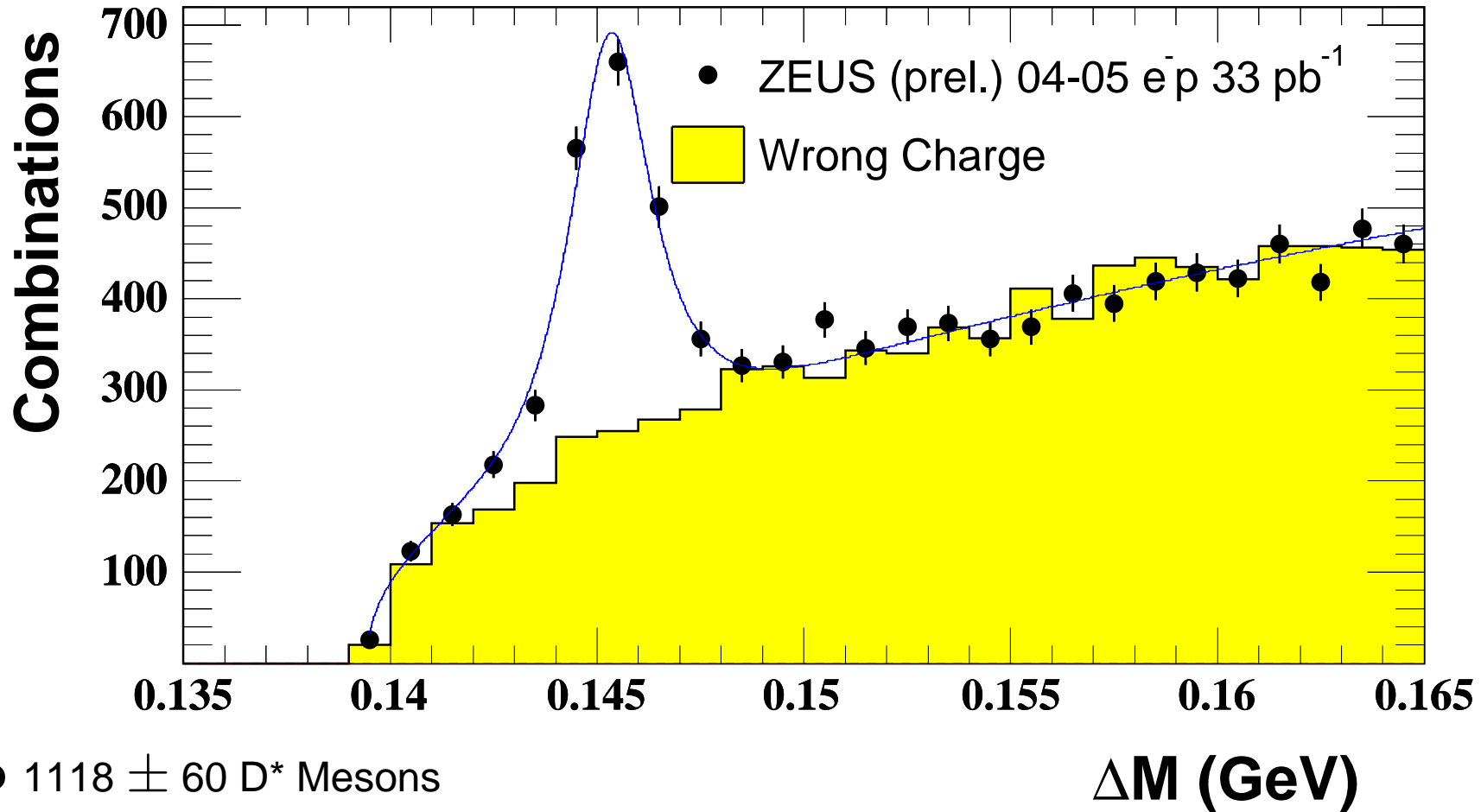
- ▷  $1.80 < M(D^0) < 1.92 \text{ GeV}$

- ▷  $143 < \Delta M < 148 \text{ MeV}$

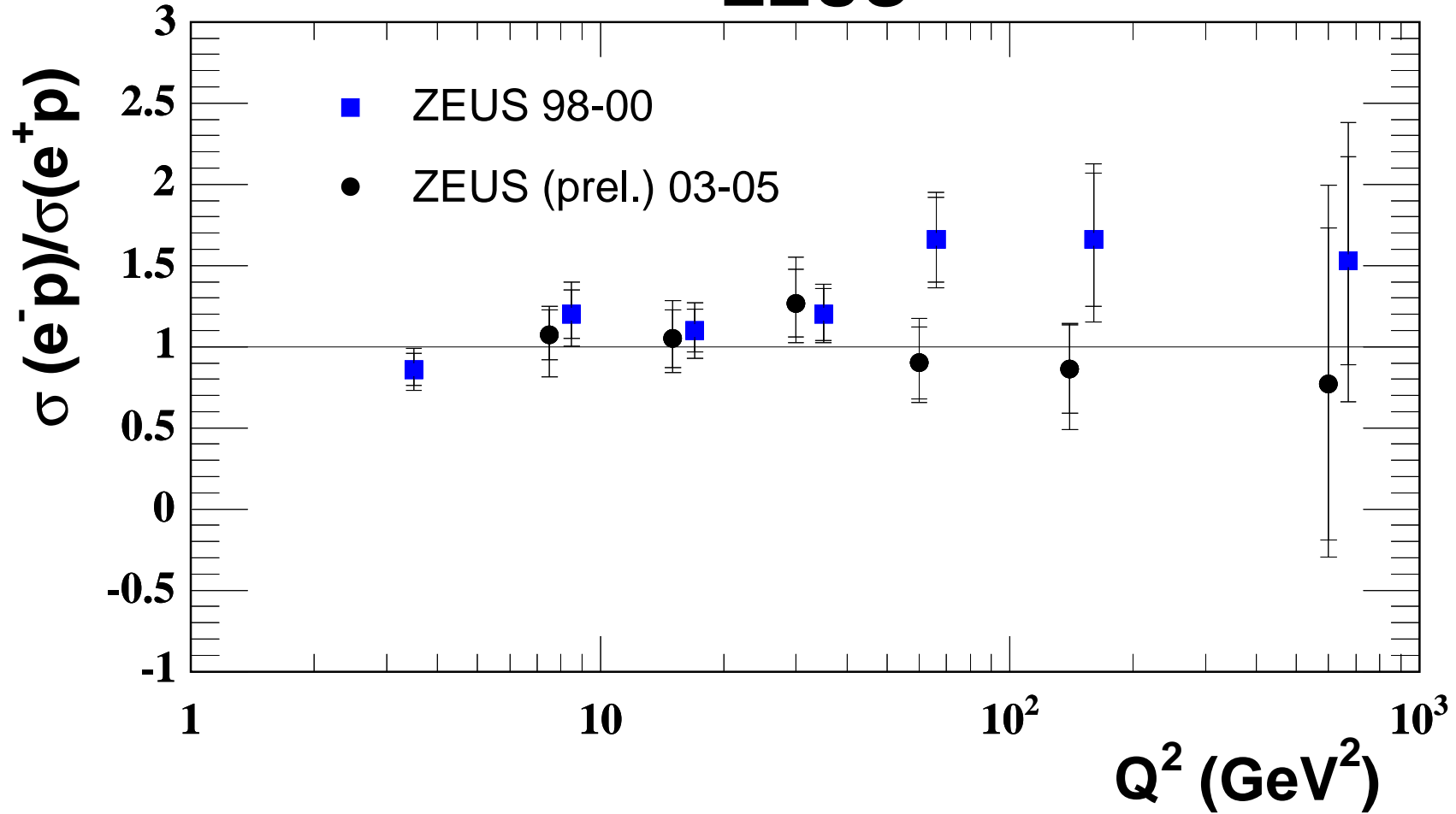
***D\* Signal - Positrons*****ZEUS**

- $1240 \pm 64$   $D^*$  Mesons
- rate =  $30.7 \pm 1.8 / \text{pb}^{-1}$
- $Q^2 > 40$ : rate =  $6.4 / \text{pb}^{-1}$



***D\* Signal - Electrons*****ZEUS**

- $1118 \pm 60$   $D^*$  Mesons
- rate =  $33.5 \pm 1.8 / \text{pb}^{-1}$
- $Q^2 > 40$ : rate =  $6.3 / \text{pb}^{-1}$

**Ratio  $\sigma(e^- p) / \sigma(e^+ p)$  vs  $Q^2$** **ZEUS**

## Ratio $\sigma(e^- p) / \sigma(e^+ p)$ vs $Q^2$

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<sup>-1</sup>)

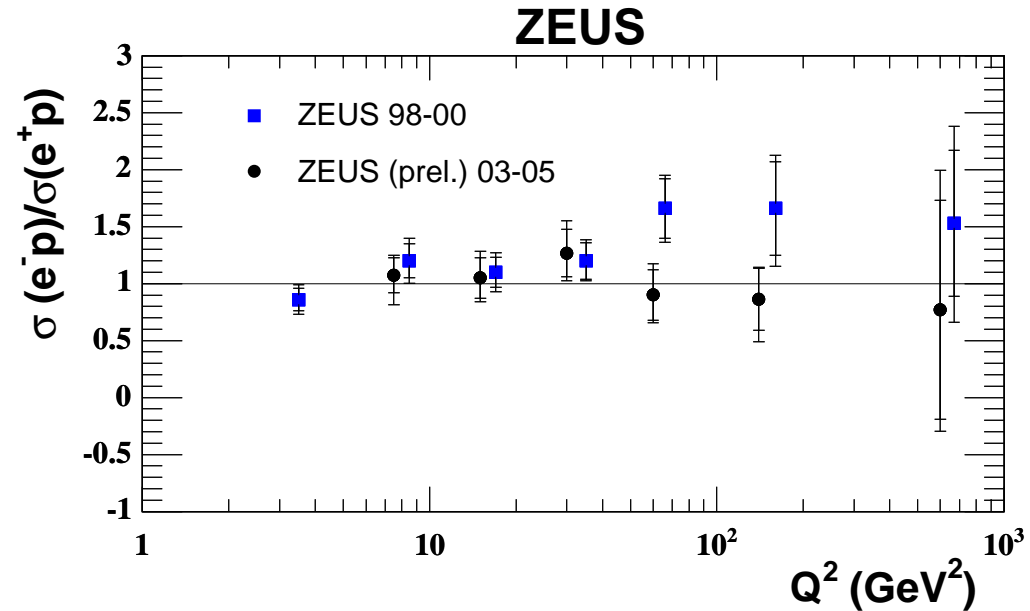
▷ e<sup>+</sup>p: 65 pb<sup>-1</sup>

▷ e<sup>-</sup>p: 17 pb<sup>-1</sup>

● 03-05 Data (73 pb<sup>-1</sup>)

▷ e<sup>+</sup>p: 40 pb<sup>-1</sup>

▷ e<sup>-</sup>p: 33 pb<sup>-1</sup>



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

$Q^2 > 1.5$  (5) GeV<sup>2</sup>

$Q^2 > 40$  GeV<sup>2</sup>

98-00 Data

$1.12 \pm 0.06$

$1.67 \pm 0.21$

03-05 Data

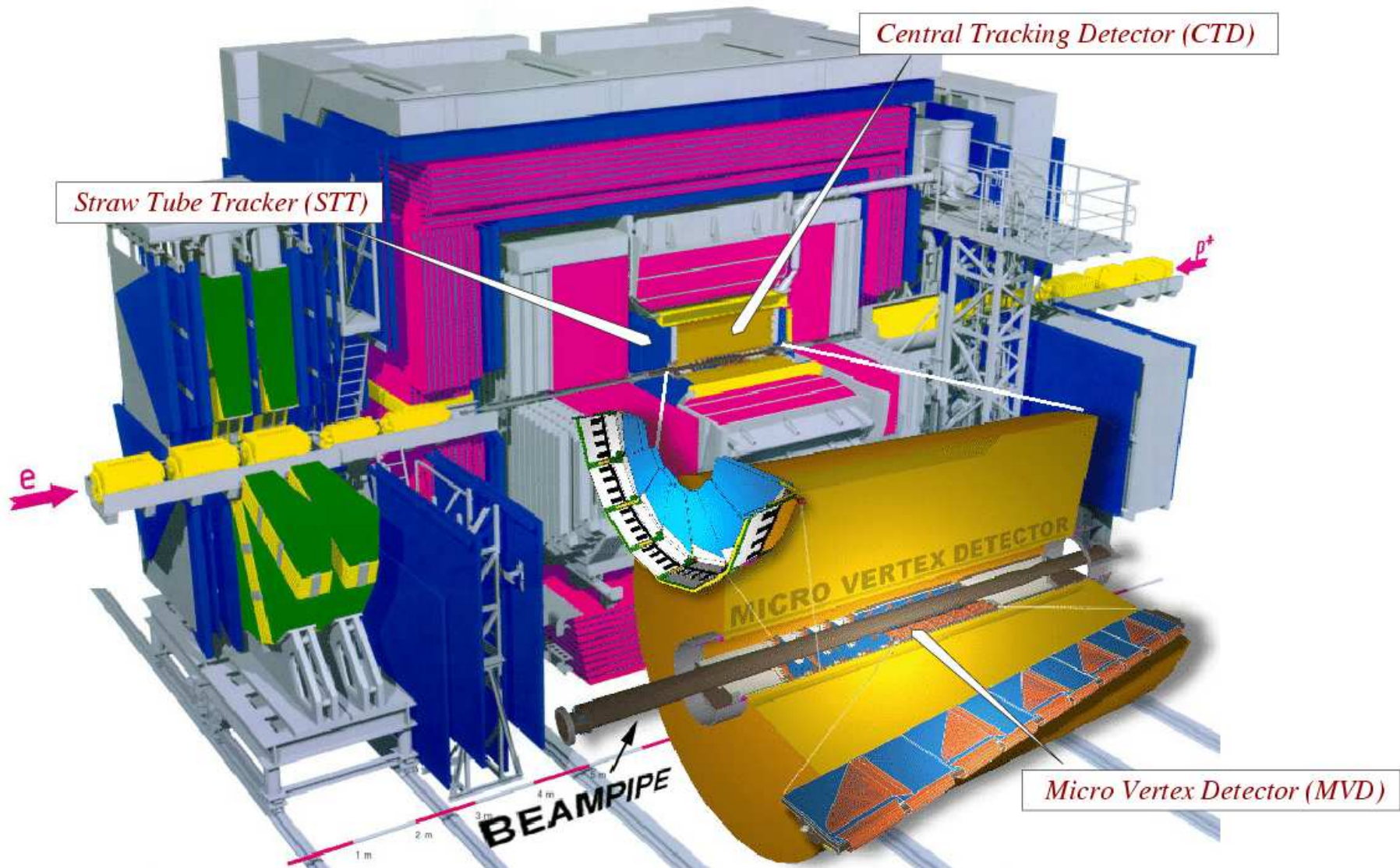
$30.7/33.5=0.92$

$6.4/6.3=1.02$

● Slight excess seen previously is not confirmed

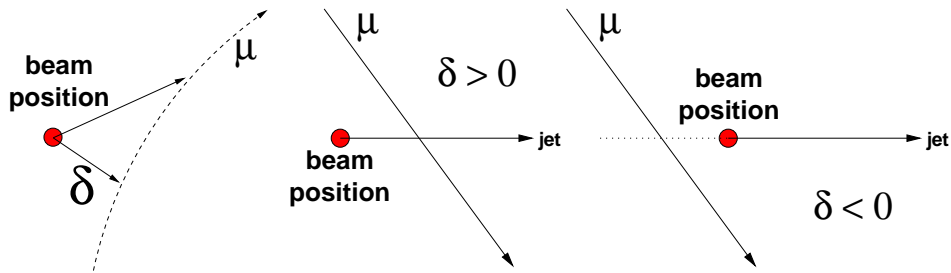
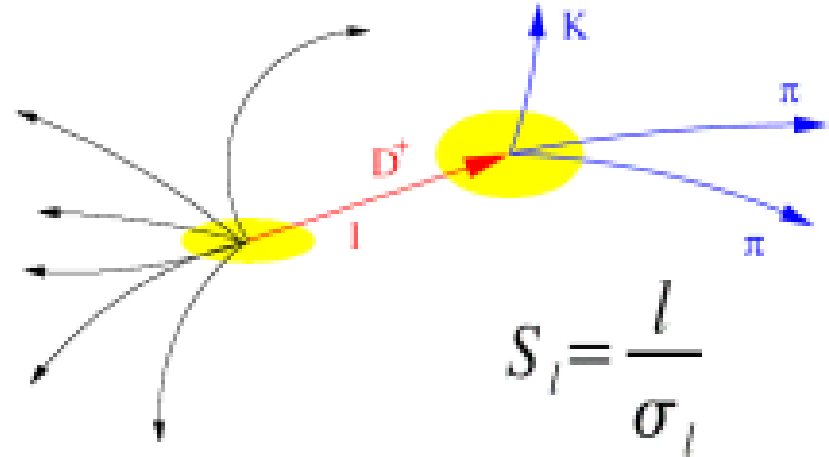
▷ Charm is produced equally in e<sup>+</sup>p and e<sup>-</sup>p collisions

# Silicon MicroVertex Detector

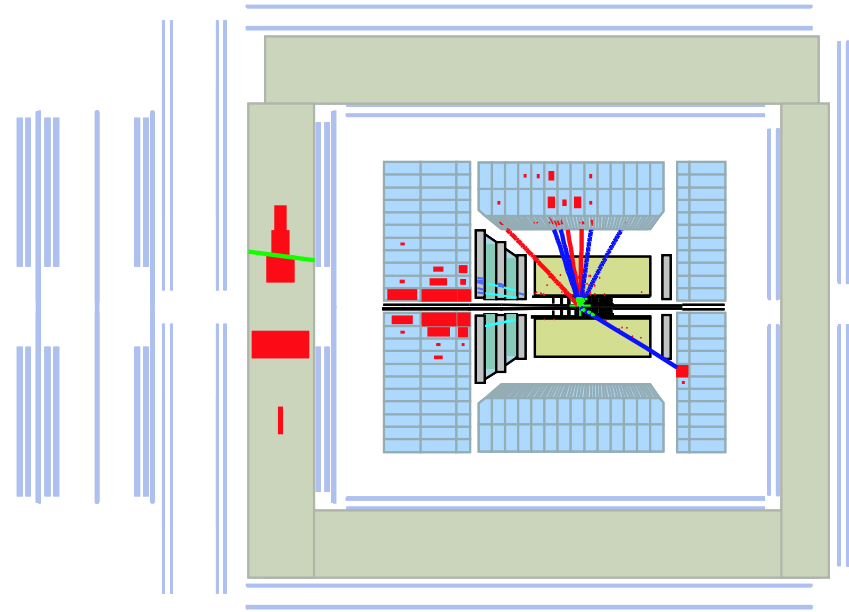
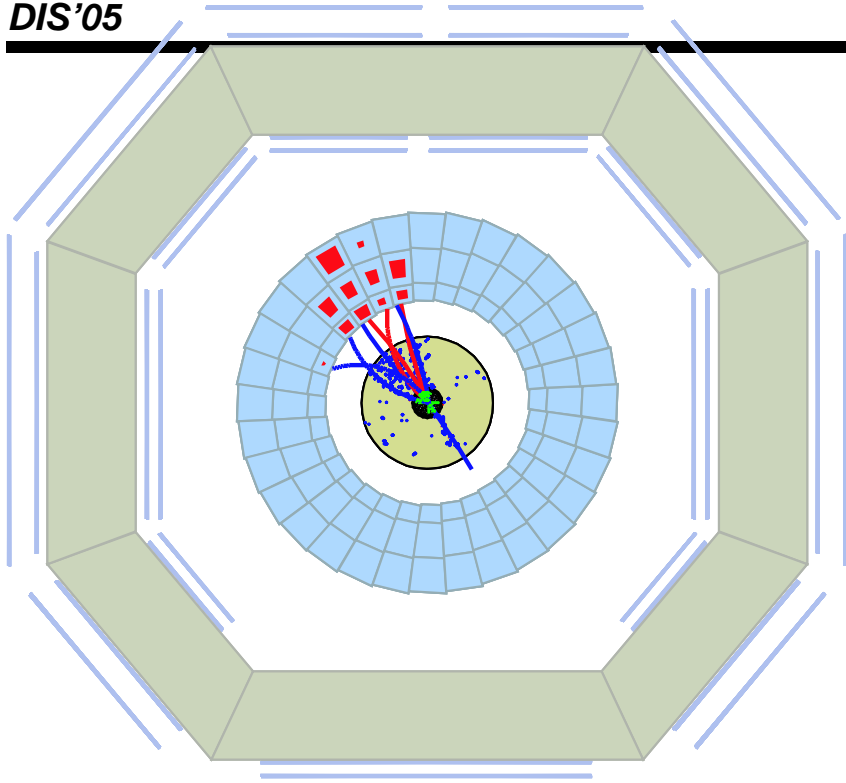


## Impact Parameters and Secondary Vertices

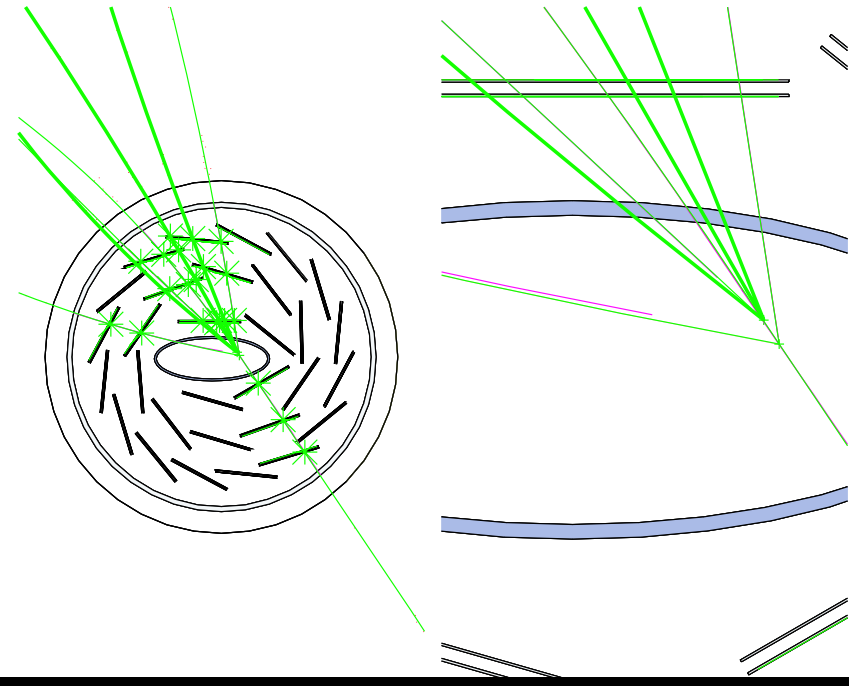
- Charm and beauty mesons have long lifetimes
- Can be tagged via separated vertex or impact parameter



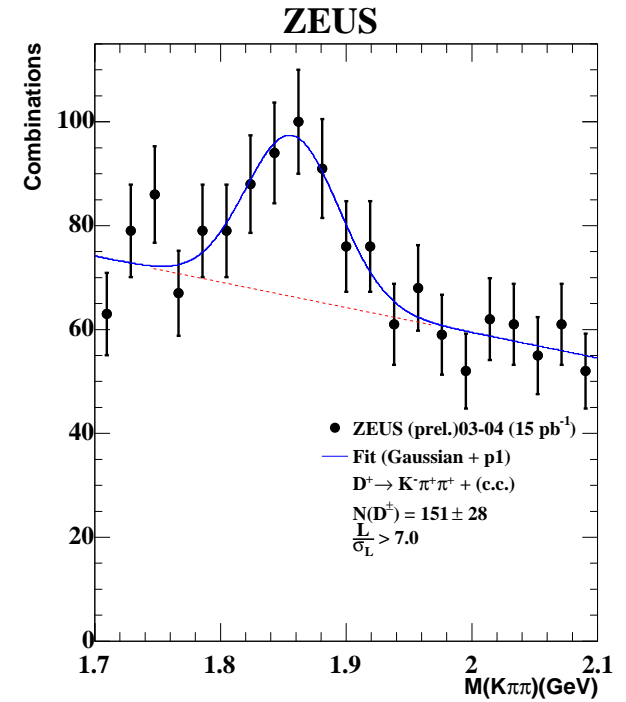
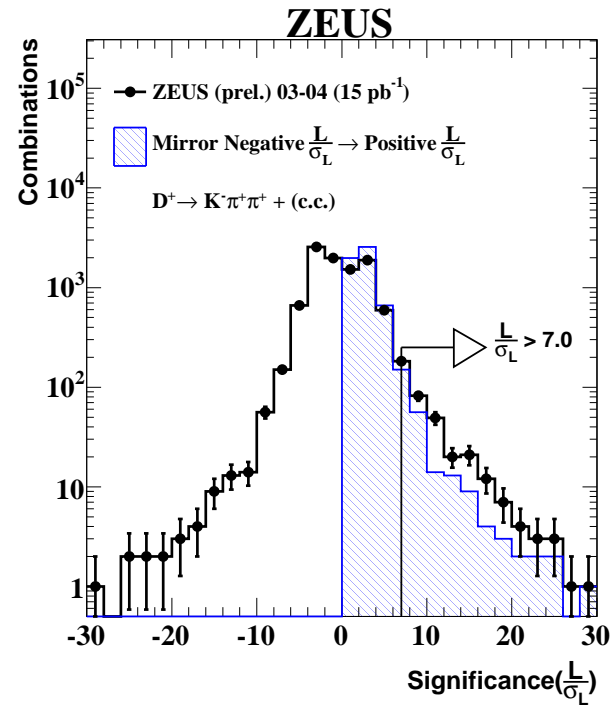
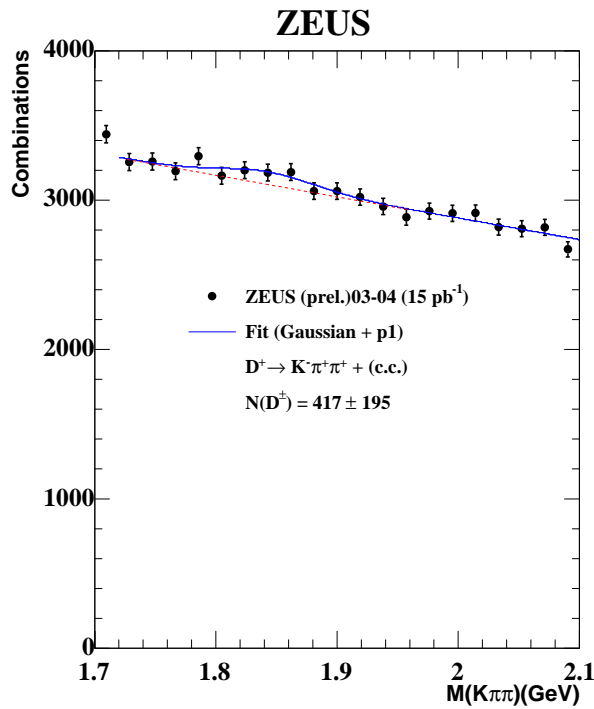
- Have a look at  $D^+$  Mesons and Dijet events containing Muons
- Assign a sign to impact parameter using the Muon or  $D^+$  direction



- $D^+$  Candidate
- $Q^2 = 160 \text{ GeV}^2$
- $P_T = 5.1 \text{ GeV}$

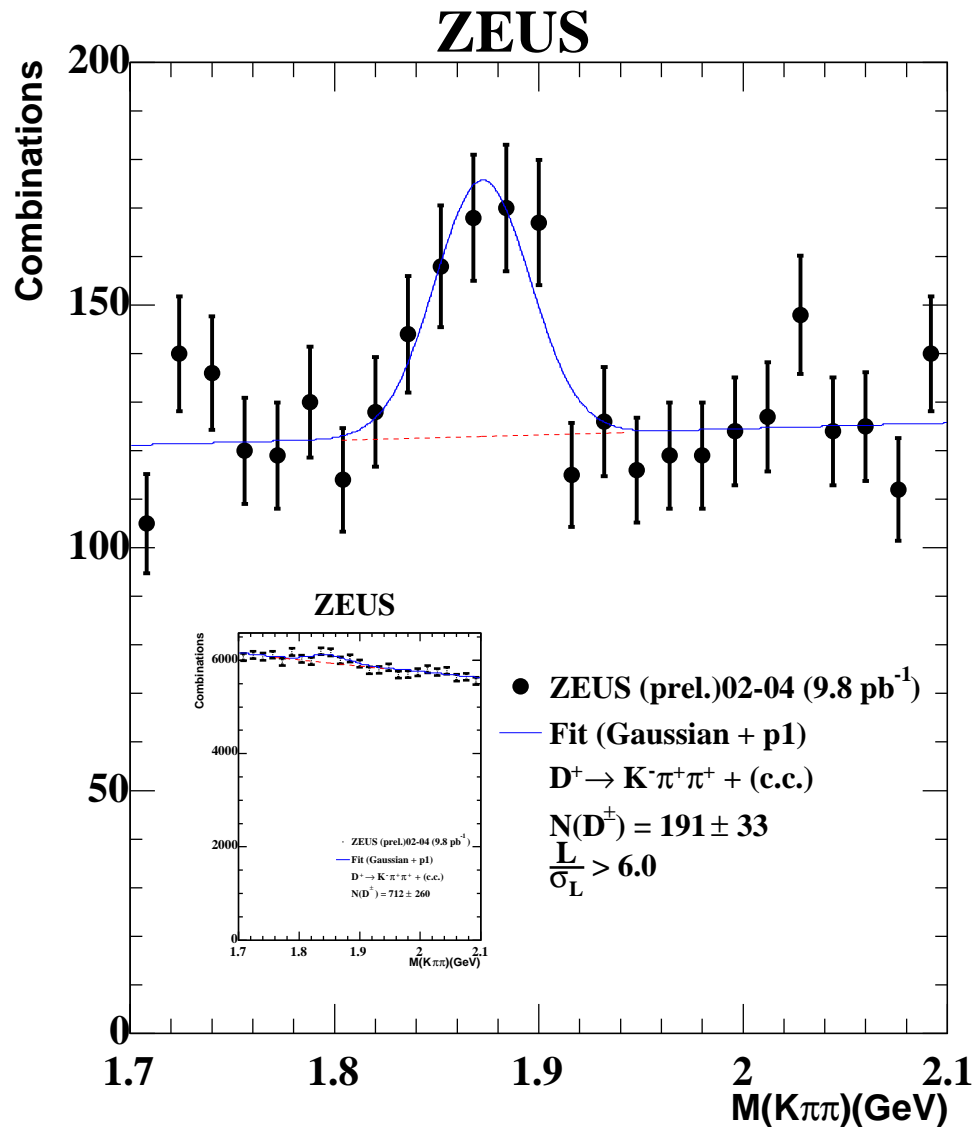


# $D^\pm$ Photoproduction



- 03-04 Data:  $15 \text{ pb}^{-1}$
- $p_T(D^\pm) > 3.7 \text{ GeV}$
- Cutting on significance gives large improvement in signal
- $151 \pm 28 D^\pm$  Mesons

# $D^\pm$ Production in DIS



▷ Cutting on significance gives large improvement in Signal:Background Ratio

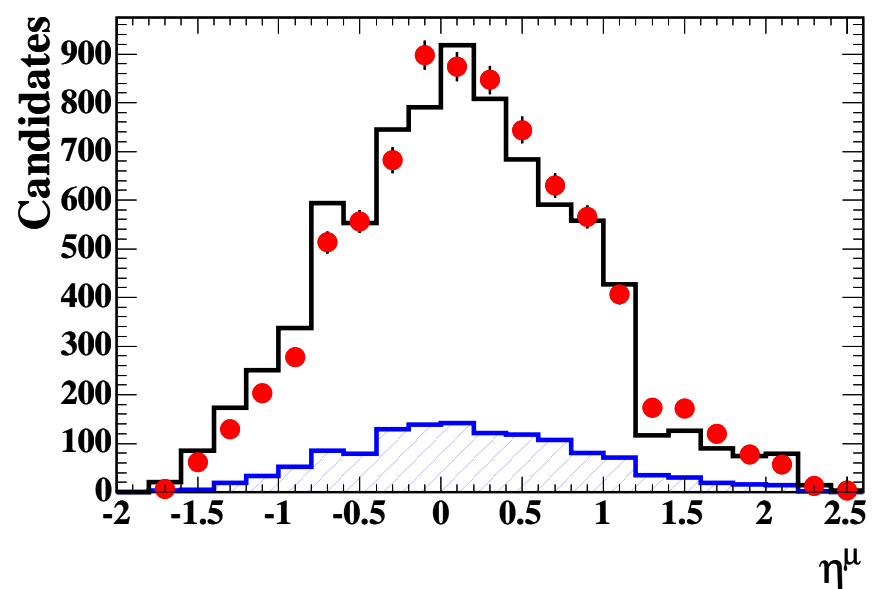
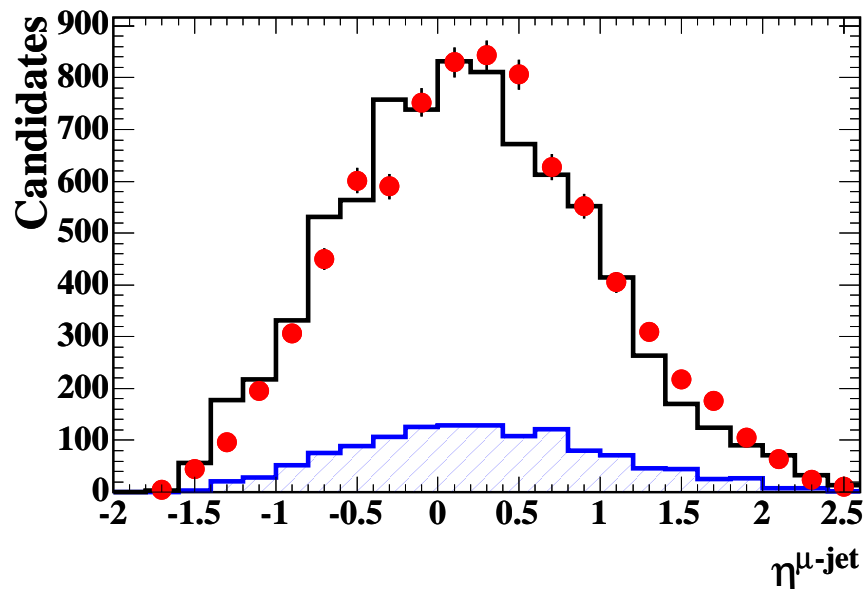
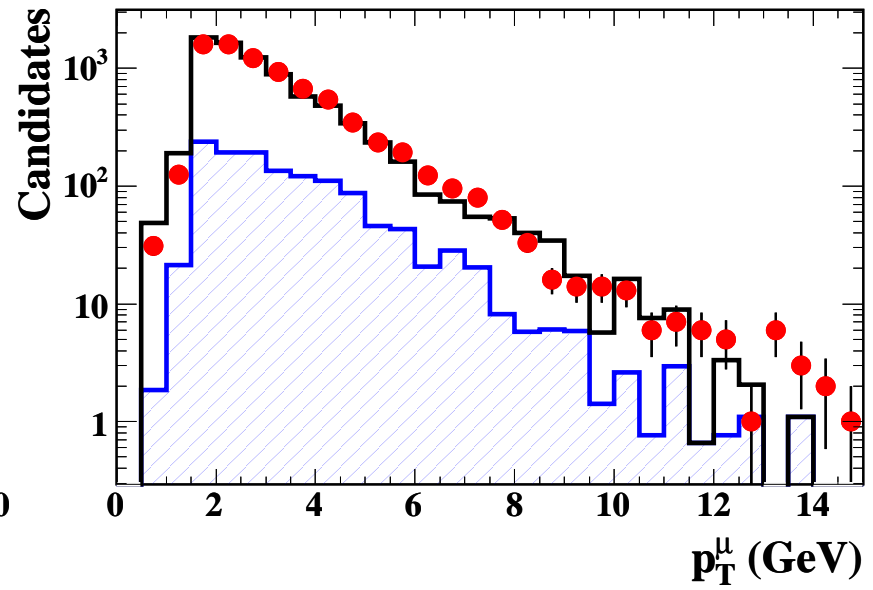
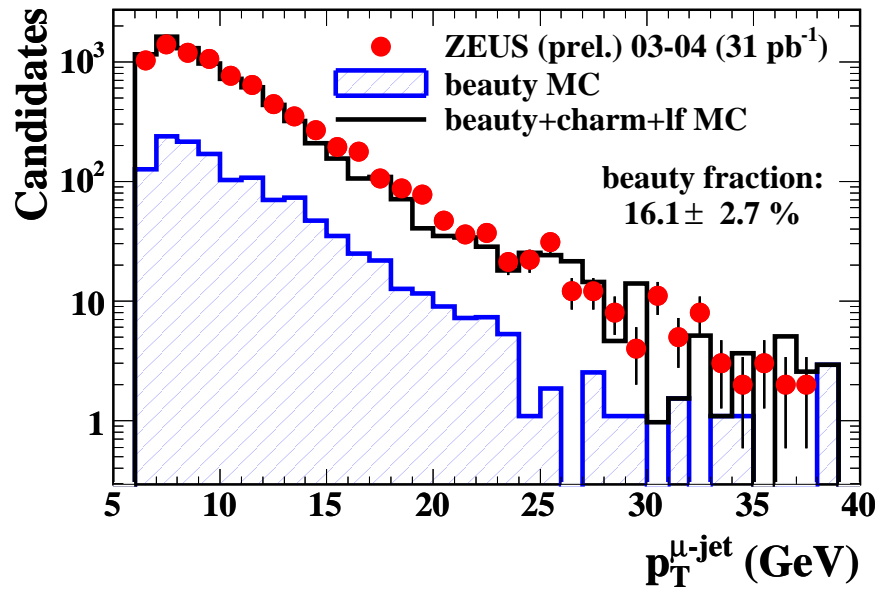


## Dijet + Muon Selection

- 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,  $p_T^{jet1,2} > 7, 6 \text{ GeV}$
- 8010 muon candidates associated to a jet

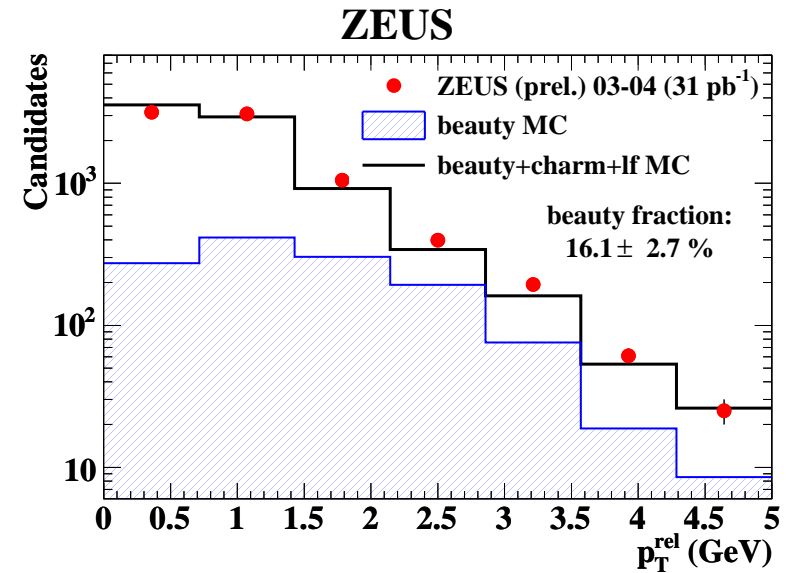
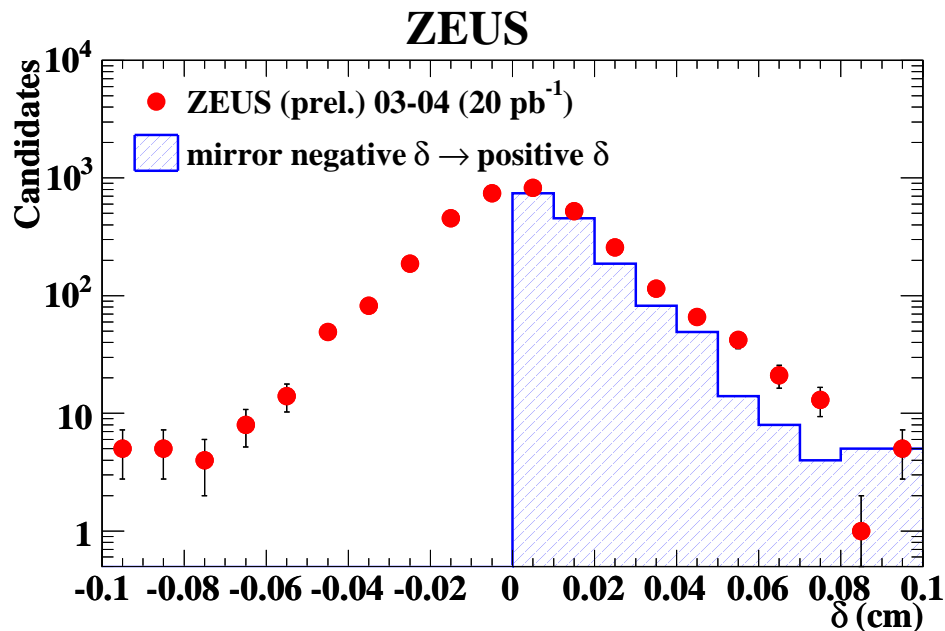
# Dijet + Muon Selection — Control Plots

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## Beauty Fraction; 2 Methods

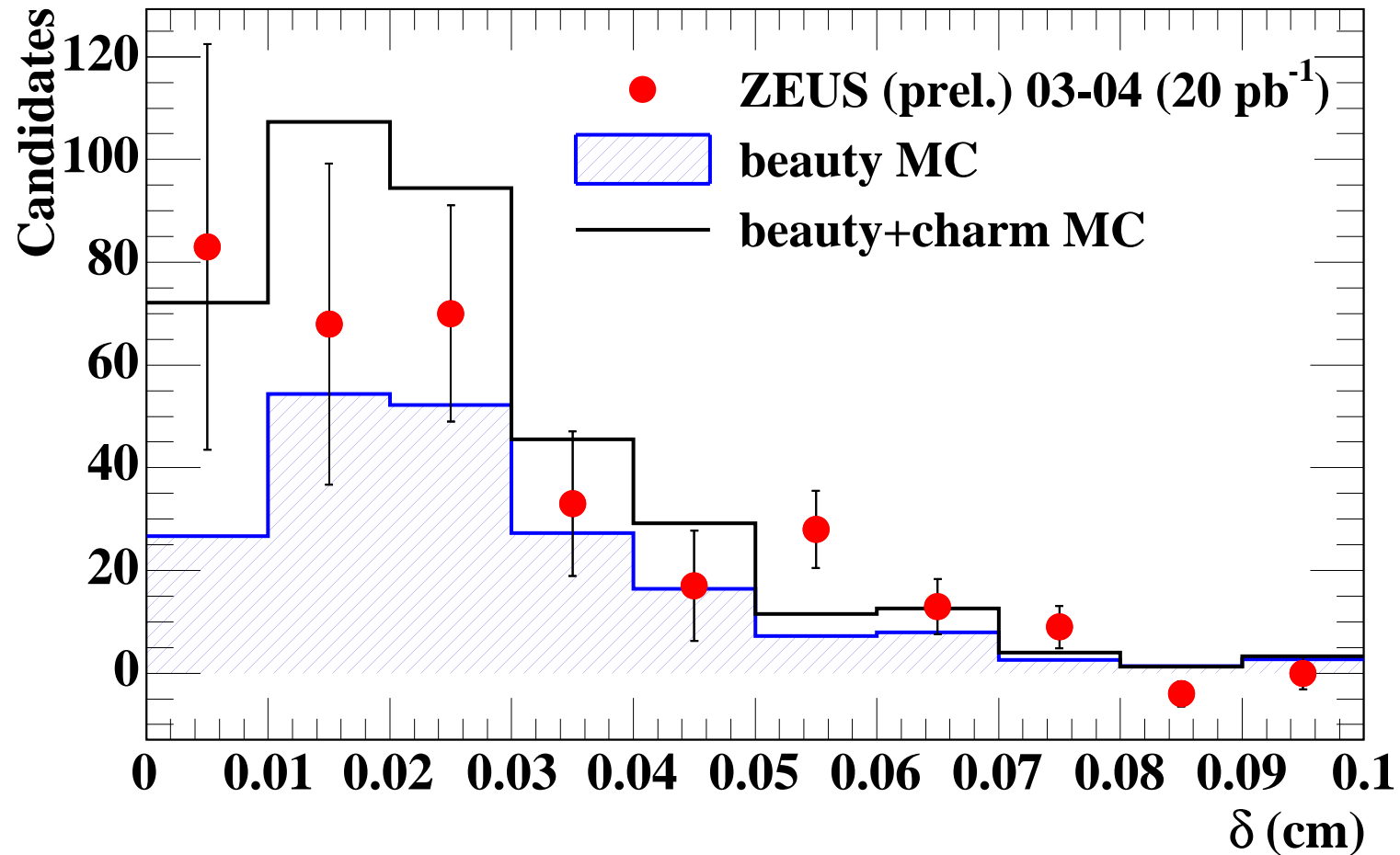
- Determine beauty fraction using  $P_T^{rel}$  method
- Beauty fraction  $16.1 \pm 2.1 \%$



- Muon impact parameter
  - ▷ Excess in dijet data in positive direction
  - ▷ Indication of beauty component
  - ▷ Subtract negative from positive side

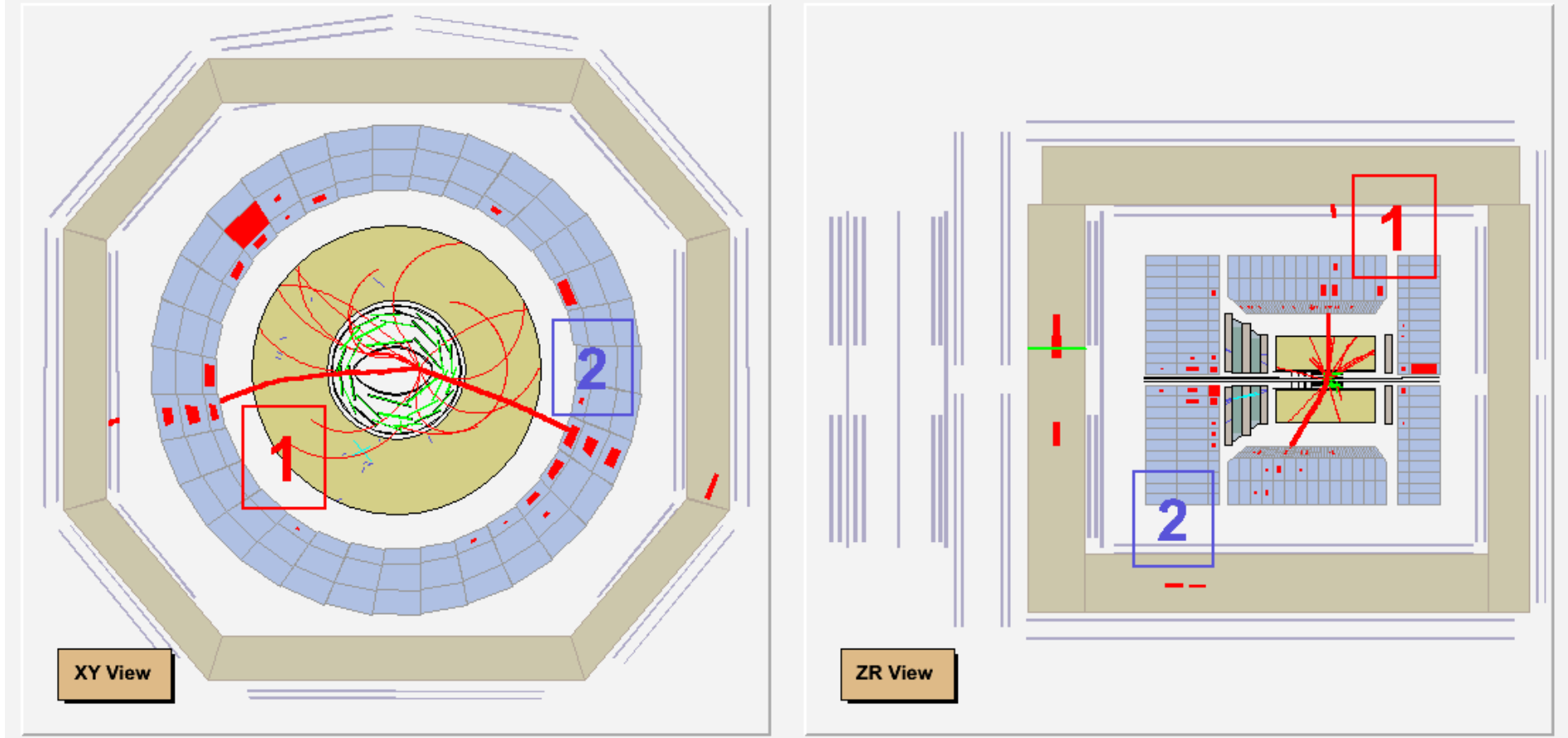
## Beauty Fraction - Impact Parameter Method

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- 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:

- ▷  $P_T^{rel} = 1.24 \text{ GeV}$

- ▷ IP =  $250 \mu\text{m}$

- Muon 2:

- ▷  $P_T^{rel} = 2.05 \text{ GeV}$

- ▷ IP =  $330 \mu$

## Summary and Outlook

- Charm production in DIS investigated using  $73 \text{ pb}^{-1}$  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!

