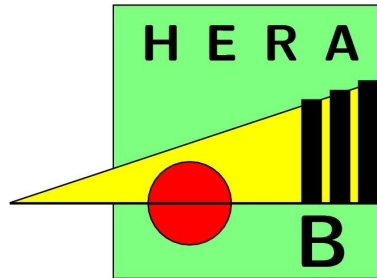


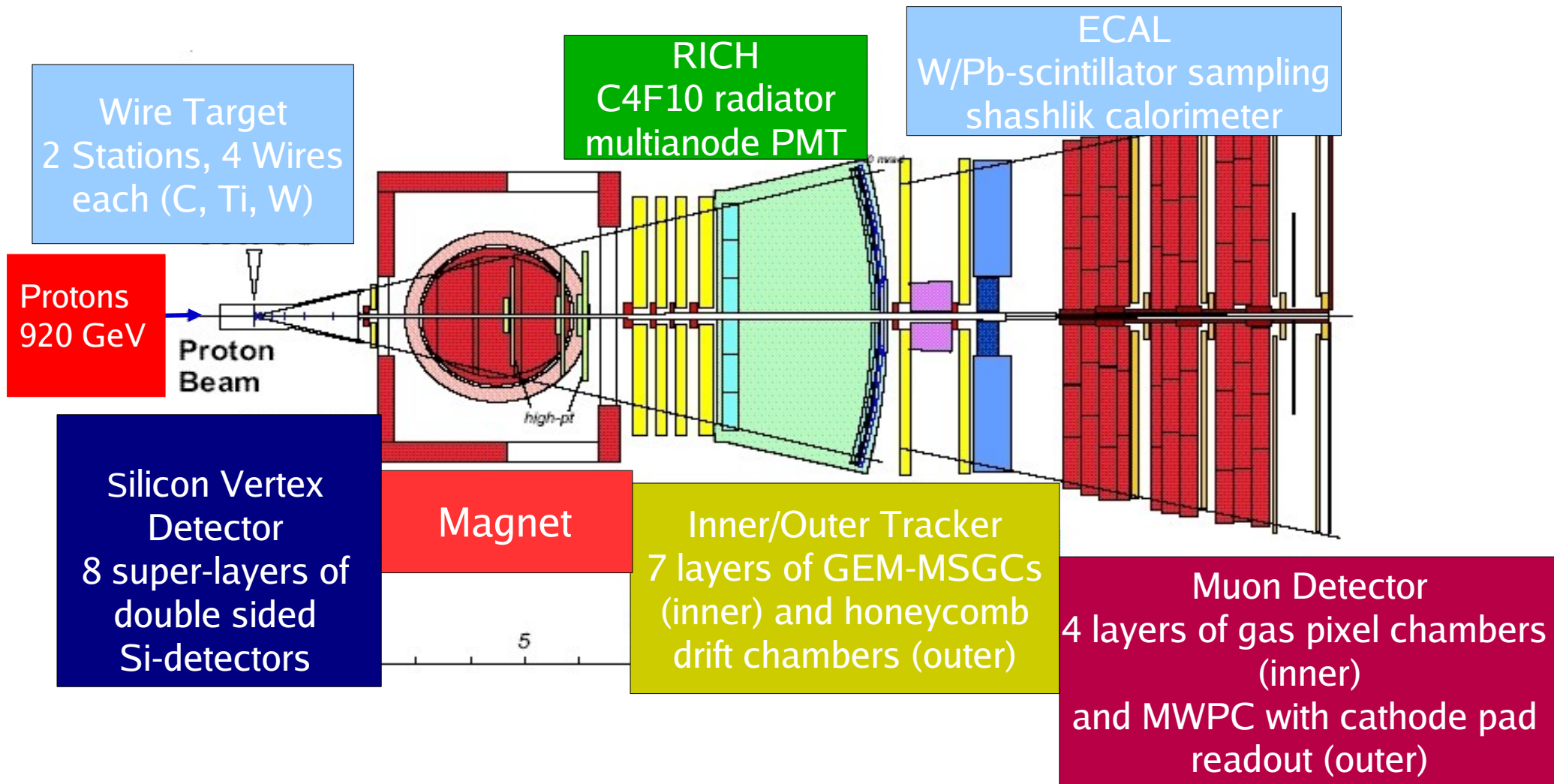
# *Selected HERA-B Results*



Victor Egorychev, ITEP (Moscow)  
For the HERA-B Collaboration

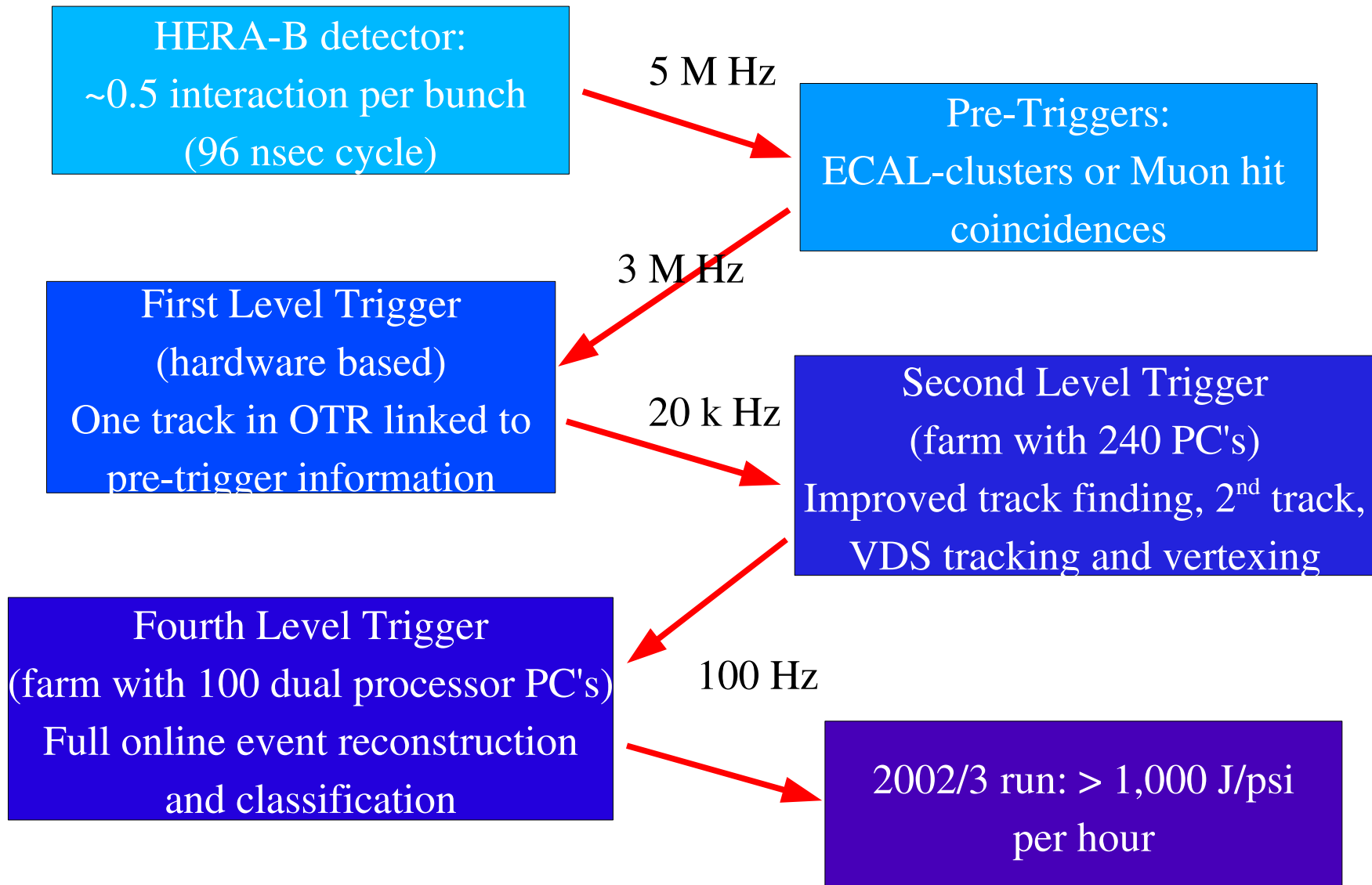
Cracow, 3 – 8 July 2006

# The HERA-B detector



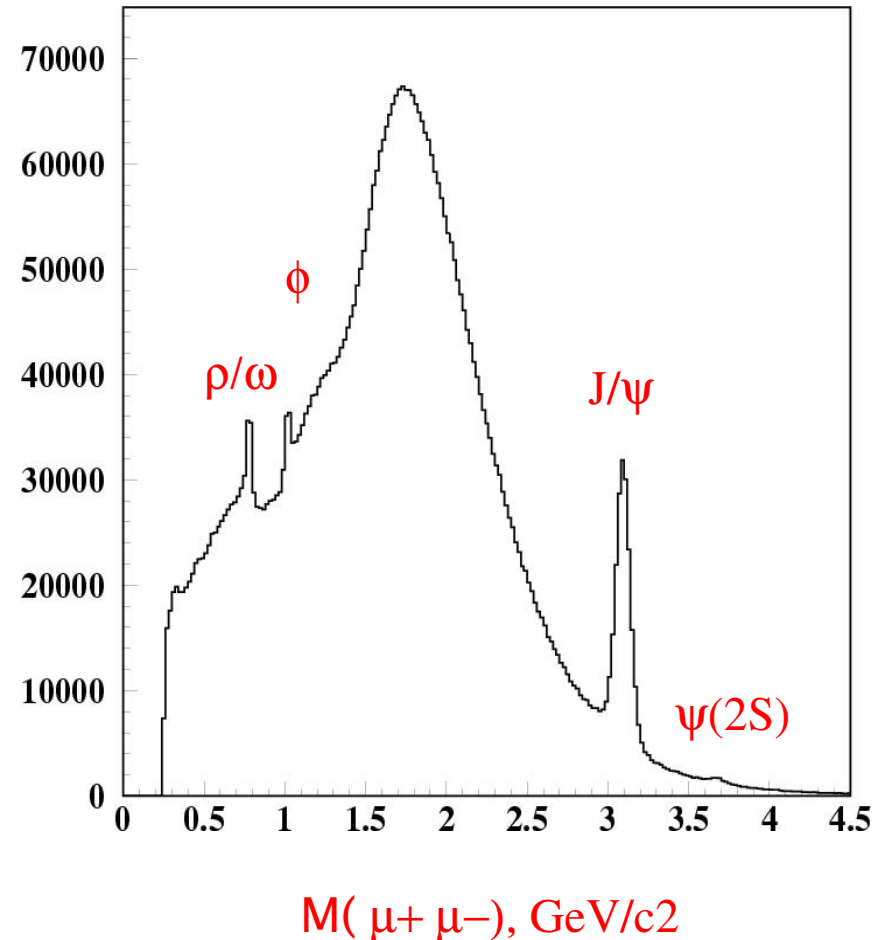
The HERA-B **fixed-target spectrometer** operated at the **920 GeV proton beam** of the HERA storage ring at DESY and featured a vertex detector and extensive tracking and particle identification systems (RICH, MUON, ECAL)

# *Dilepton Trigger and DAQ system*



# *Relevant data sample*

- Data taking finished in March 2003
- 164 M di-lepton trigger events (ee/mu mu)
  - 300,000  $J/\psi$
  - 15,000  $\chi_c$
  - 5,000  $\psi(2S)$
- 210 M minimum bias events



# *Physics topics*

- $J/\psi$  A-dependence  
 $P_T$  distribution  
 $X_F$  distribution
- $\Psi(2S) / J/\psi$  production ratio
- $\chi_c / J/\psi$  production ratio
- FCNC  $D0 \rightarrow \mu\mu$  Br limit
- $b\bar{b}$  cross section
- $\Upsilon$  production
- $J/\psi$  production cross section
- Strangeness and hyperon productions
- Pentaquark search
- $\Lambda$  polarization
- Deuteron/anti-deuteron production
- Open charm production

Most of analyses already published

# *Open and Hidden*

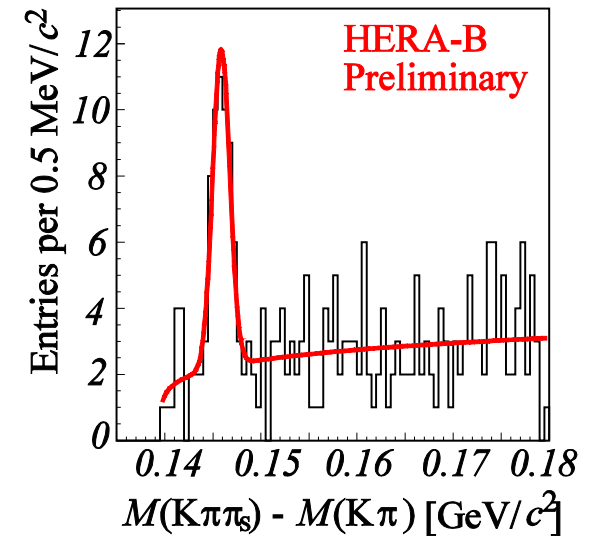
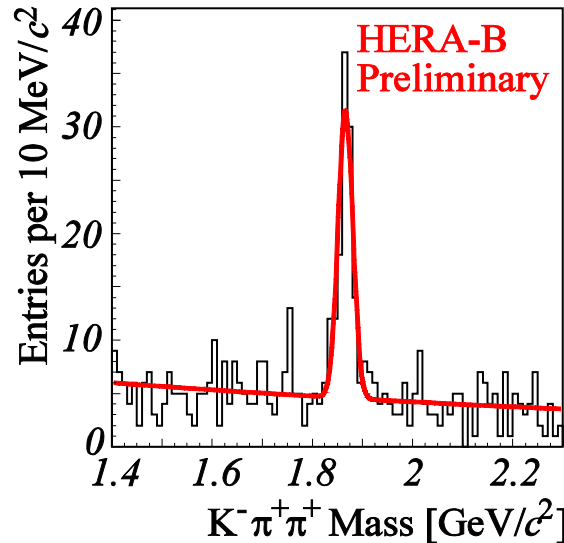
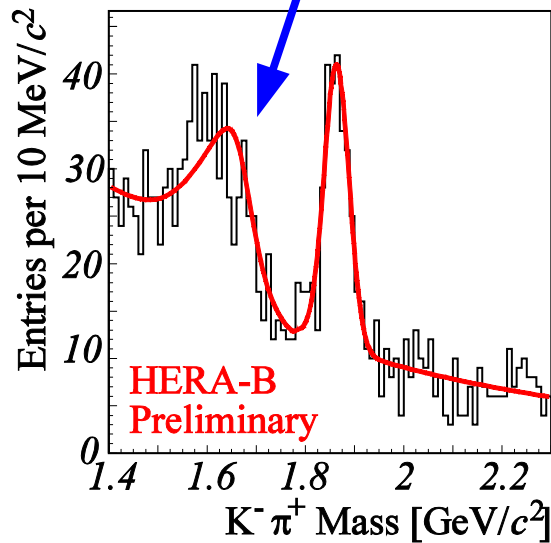


*Charm production at HERA-B*

# Open charm production

Reflection of not fully reconstructed charm decay

From Minimum Bias data analysis



$$N_{D^0} = 194 \pm 20$$

$$N_{D^+} = 92 \pm 11$$

$$N_{D^{*+}} = 49 \pm 10$$

(charge conjugate decays are also included)

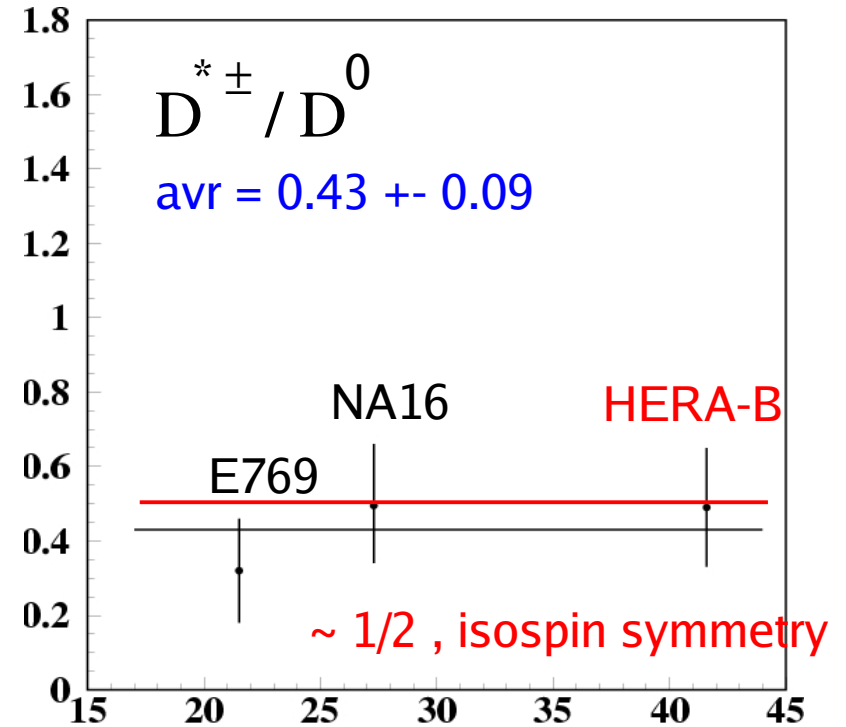
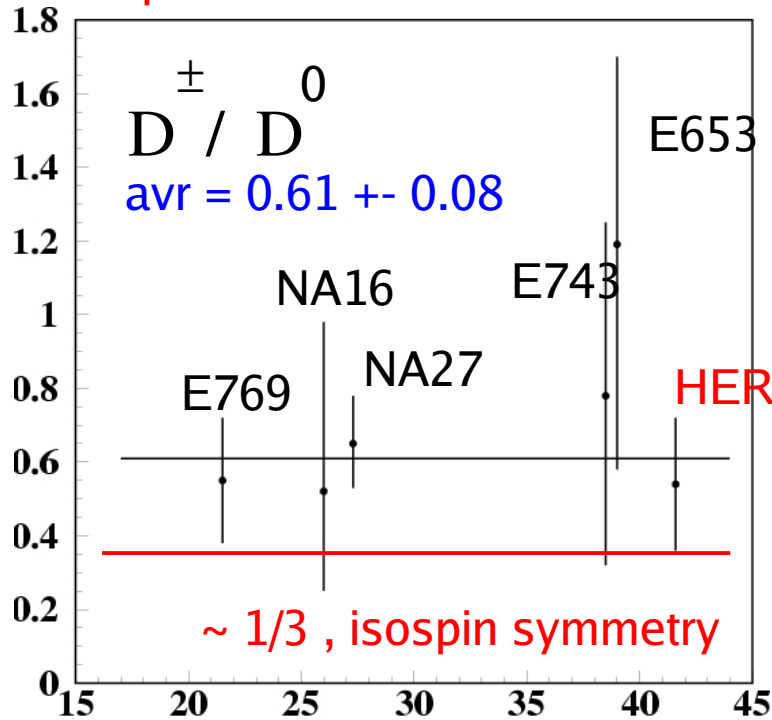
Production cross section for  $D^0$ ,  $D^+$  and  $D^{*+}$   
 Production ratios  $D^+ / D^0$  or  $D^{*+} / D^0$   
 particle-antiparticle production asymmetry

$$\sigma_D = \frac{N_D}{\epsilon \text{ BR } \Sigma (A_i L_i)}$$

Assuming A dependence with  $\alpha = 1$

# Open charm production

Experimental situation is unclear

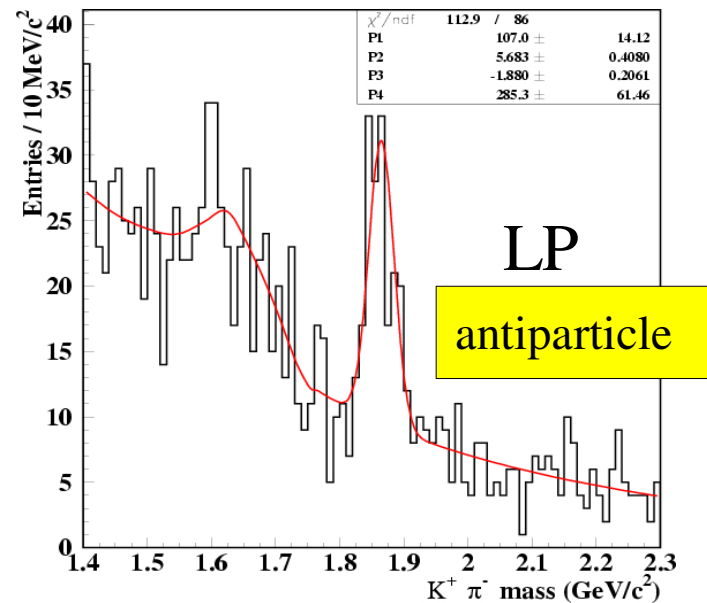
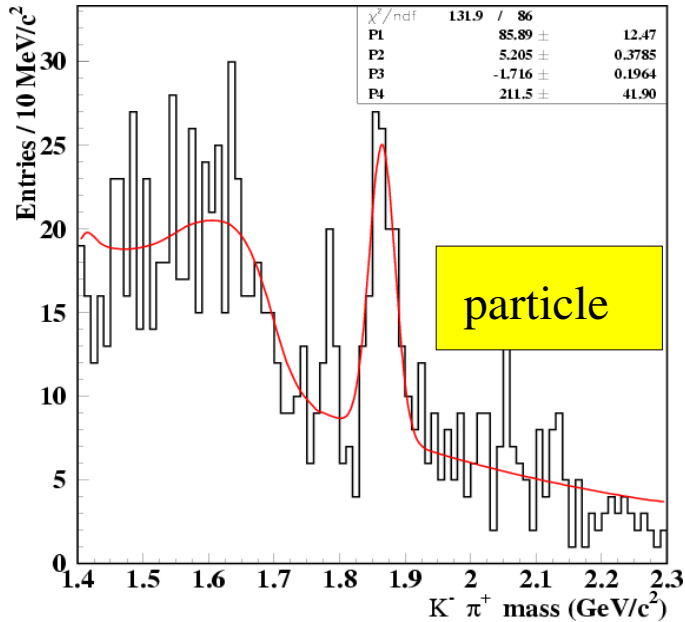


$\sqrt{s}$ , GeV

Preliminary	$-0.1 < x_F < 0.05$	full $x_F$ range
$\sigma_{D^0}$ [ $\mu\text{b}/\text{nucl}$ ]	$21.4 \pm 3.2 \pm 3.6$	$56.3 \pm 8.5 \pm 9.5$
$\sigma_{D^+}$ [ $\mu\text{b}/\text{nucl}$ ]	$11.5 \pm 1.7 \pm 2.2$	$30.2 \pm 4.5 \pm 5.8$
$\sigma_{D^{*+}}$ [ $\mu\text{b}/\text{nucl}$ ]	$10.0 \pm 1.9 \pm 1.4$	$27.8 \pm 5.2 \pm 3.9$
Ratio $\sigma_{D^+} / \sigma_{D^0}$		$0.54 \pm 0.11 \pm 0.14$
Ratio $\sigma_{D^{*+}} / \sigma_{D^0}$		$0.49 \pm 0.12 \pm 0.10$



# Open charm production



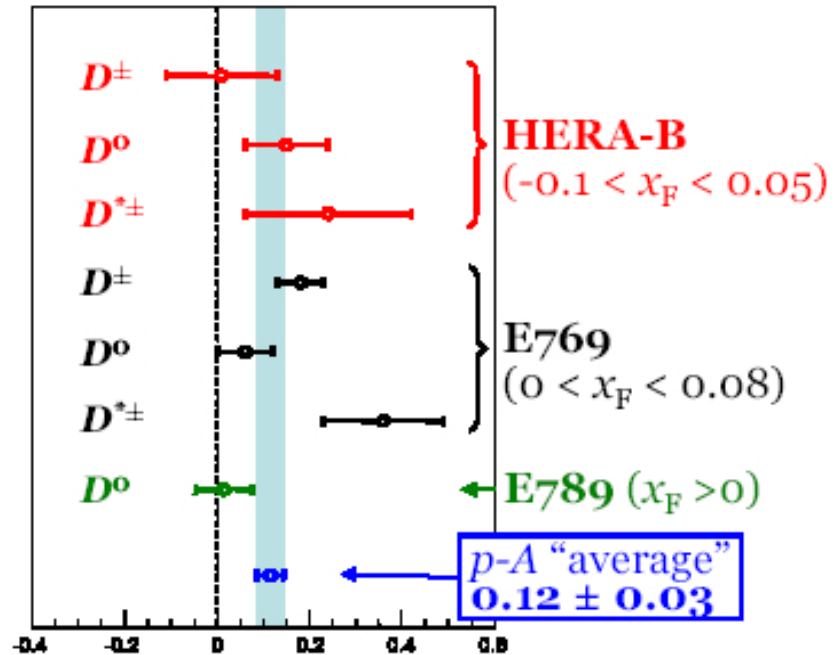
“Leading-Particle” asymmetry:

$$A = \frac{\sigma_{LP} - \sigma_{nonLP}}{\sigma_{LP} + \sigma_{nonLP}}$$

Asymm (preliminary)

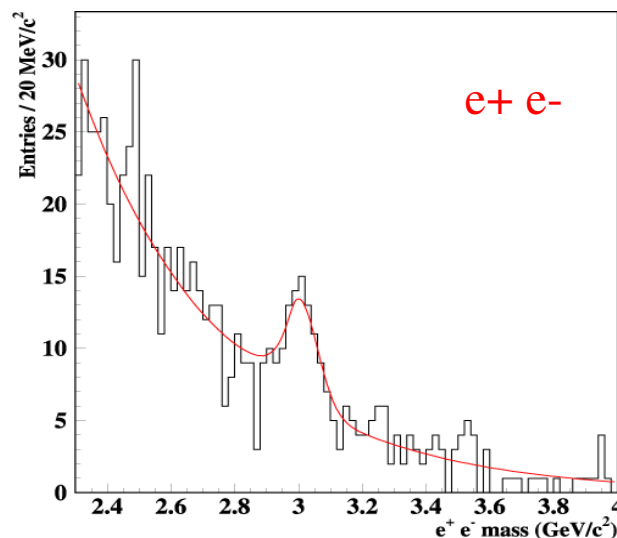
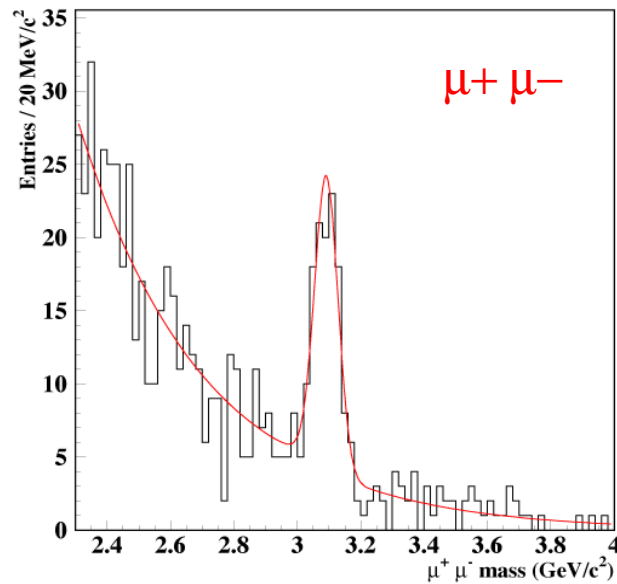
$D^\pm$	0.01 ± 0.12
$D^0$	0.15 ± 0.09
$D^{*\pm}$	0.24 ± 0.18

LP has a light quark in common with the beam particle



# *J/ψ production cross section*

From Minimum Bias data analysis



- relatively low statistics, but **no trigger uncertainty**
- important for cross section normalization of di-lepton triggered data

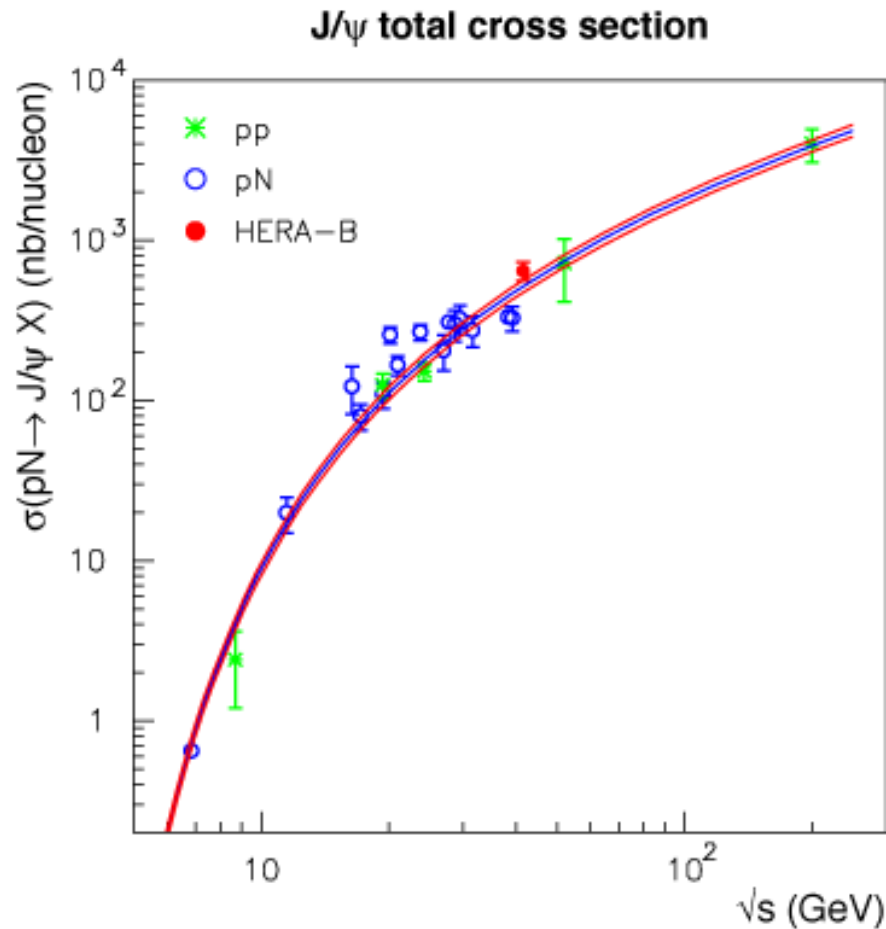
$$\sigma_{J/\psi} = \frac{N_{J/\psi}}{\varepsilon \cdot \text{BR} \cdot \sum (A_i^\alpha L_i)}$$

**HERA-B**

$$\sigma_{J/\psi} = 663 \pm 74 \pm 46 \text{ nb/nucleon}$$

**HERA-B** ~ 1.7 x higher than E771/E789 extrapolated to this energy region

# $J/\psi$ production cross section



- Fit of cross section data currently studied with F.Maltoni *et al.* using NRQCD model
- Fit rather stable w.r.t. changes in model input (PFD's, ME's,...)
- **Biggest problem – inconsistent exp. data**

$$\sigma_{J/\psi}^{\text{fit}} = 502 \pm 44 \text{ nb/nucleon}$$

in agreement with **HERA-B result**

hep-ex: 0512029, 2006

*Open and*

*Hidden*



*Beauty production at HERA-B*

# Open beauty production

$$pA \rightarrow \mathbf{bb} + X$$

$$b(b) \rightarrow \mathbf{B} \rightarrow J/\psi + X$$

$$J/\psi \rightarrow \mu^+\mu^- ; e^+e^-$$

$$R_{\Delta\sigma} = \frac{n_B}{n_{J/\psi}} \frac{1}{\epsilon_R \epsilon_{\Delta Z}^B \text{Br}(bb \rightarrow J/\psi X)}$$

- Measure number of  $J/\psi$  from B meson decays relative to the prompt  $J/\psi$  inside kinematic acceptance
- To minimize trigger/reconstruction uncertainties
- Only needed to count detached and direct  $J/\psi$
- Average decay length of B mesons at HERA-B  $\sim 9$  mm, to be compared with dilepton vertex resolution of  $\sim 0.5$  mm

# Open beauty production

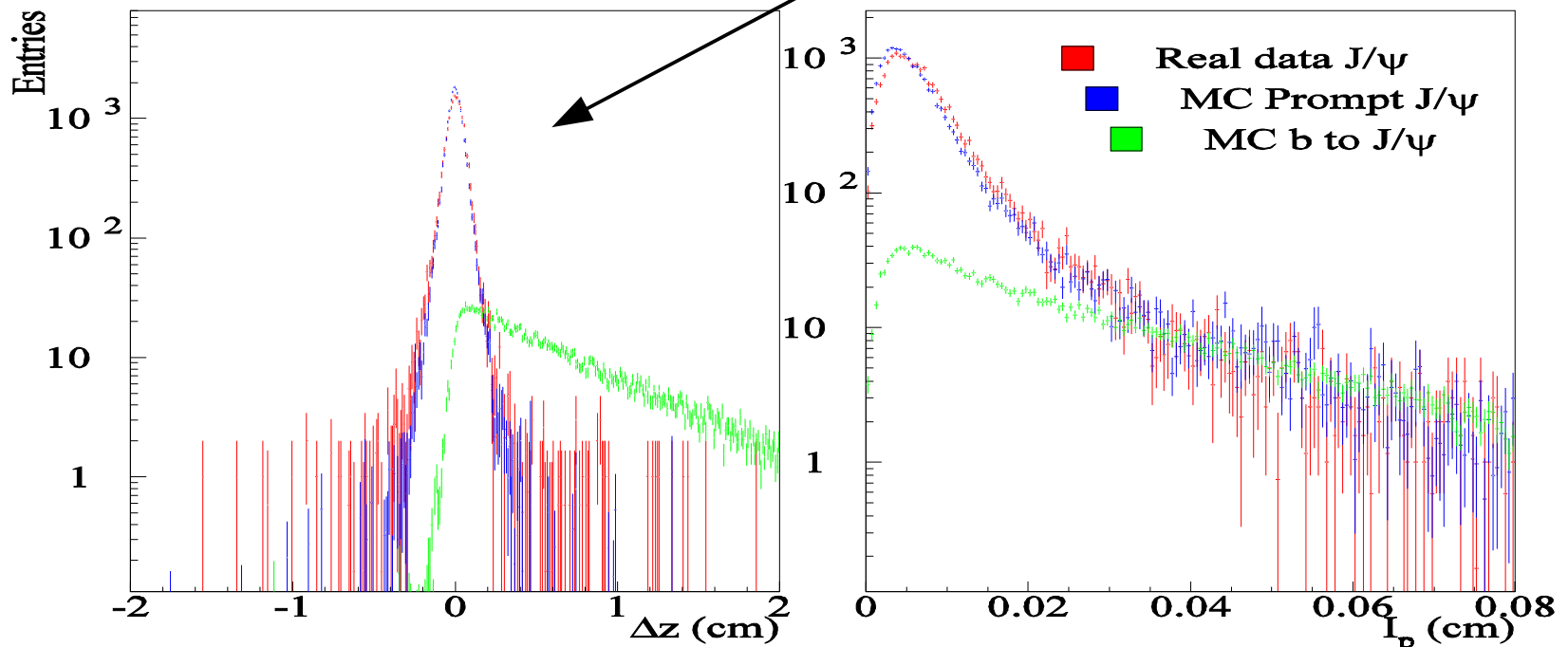
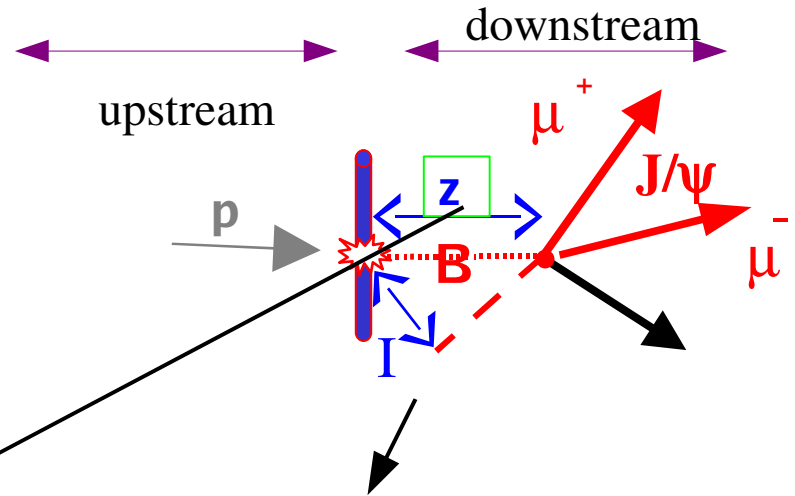
$b\bar{b}$  events identified via **detached vertex**

analysis:

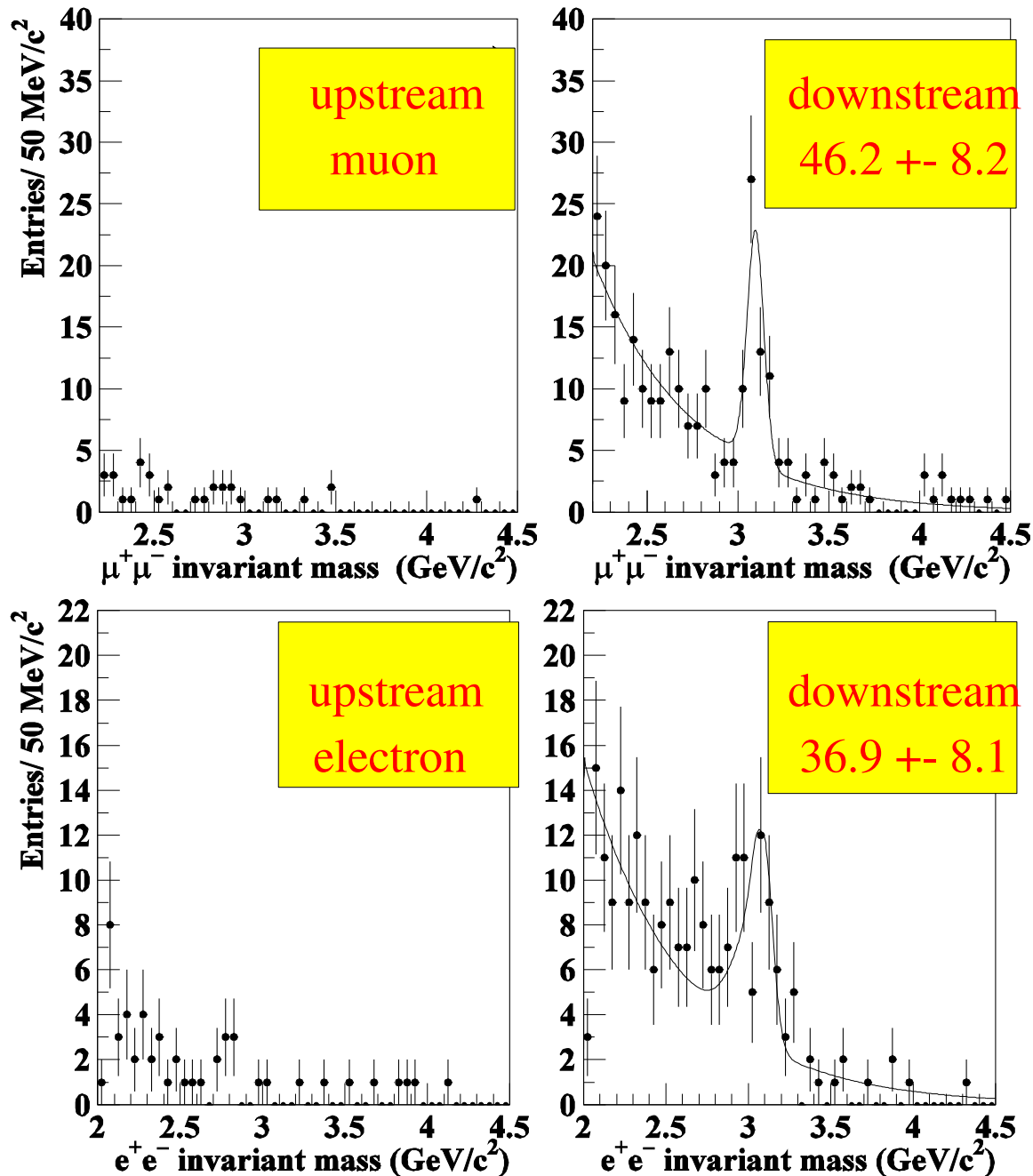
- decay length ( $Z$ )
- impact parameter ( $I$ )

MC tuned to match experimental distribution

Background from MB and prompt  $J/\psi$  has smaller  $I$  and  $Z$



# Open beauty production



- C,W,Ti targets
- Full statistics
- Unbinned likelihood fit
- Upstream from target (unphysical region)
- Downstream from target (signal region)
- Background:
  - combinatorial
  - B/D semileptonic decays
  - no prompt  $J/\psi$

# Open beauty production

In HERA-B kinematic range ( $-0.15 < x_F < 0.15$ ,  $0 < P_T < 6$  GeV)

$$R_{\Delta\sigma} = 0.032 \pm 0.005_{\text{(stat)}} \pm 0.004_{\text{(syst)}}$$

syst error mainly from  $\text{Br}(b \rightarrow J/\psi X)$

$$\frac{f_{J/\psi}}{f_B} = \frac{0.83 \pm 0.01}{0.906 \pm 0.005}$$

$$\sigma_{b\bar{b}} = R_{\Delta\sigma} \cdot \sigma_{J/\psi} \cdot \frac{f_{J/\psi}}{f_B}$$

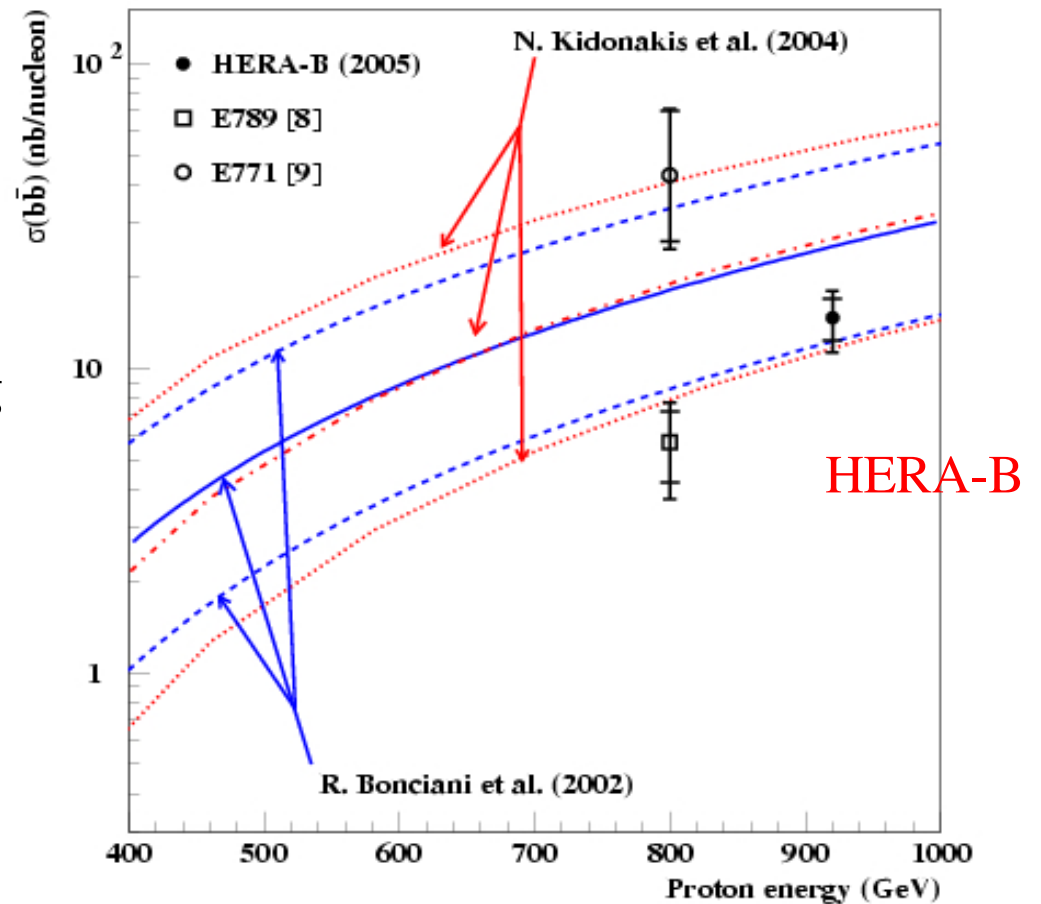
$$\sigma_{b\bar{b}} = 14.9 \pm 2.2 \text{ (stat)} \pm 2.4 \text{ (syst) nb/N}$$

Normalizing to  $\sigma_{J/\psi} = 502 \pm 44$  nb/nucleon (Maltoni et al)



# Open beauty production

- Previous measurements (E789, E771) do not agree with each other
- The present value is within  $1.5 \sigma$  of the E789 experiment (after rescaling to the same  $\sqrt{s}$ )
- $1.8 \sigma$  below the rescaled E771 measurement
- theoretical uncertainty:
  - renormalization and factorization scales
  - $b$ -quark mass



Phys. Rev. D73: 052005, 2006

# *Upsilon (hidden beauty) production*

$$\rho A \rightarrow \Upsilon + X$$

$$\Upsilon \rightarrow \mu^+ \mu^- ; e^+ e^-$$

- Measurement relative to prompt  $J/\psi$ 
  - Less sensitive to systematic effects
- Prompt  $J/\psi$  cross section  $\sigma(J/\psi) = 502 \pm 44$  nb/nucleon obtained in the global fit of  $J/\psi$  production data (Maltoni et al)

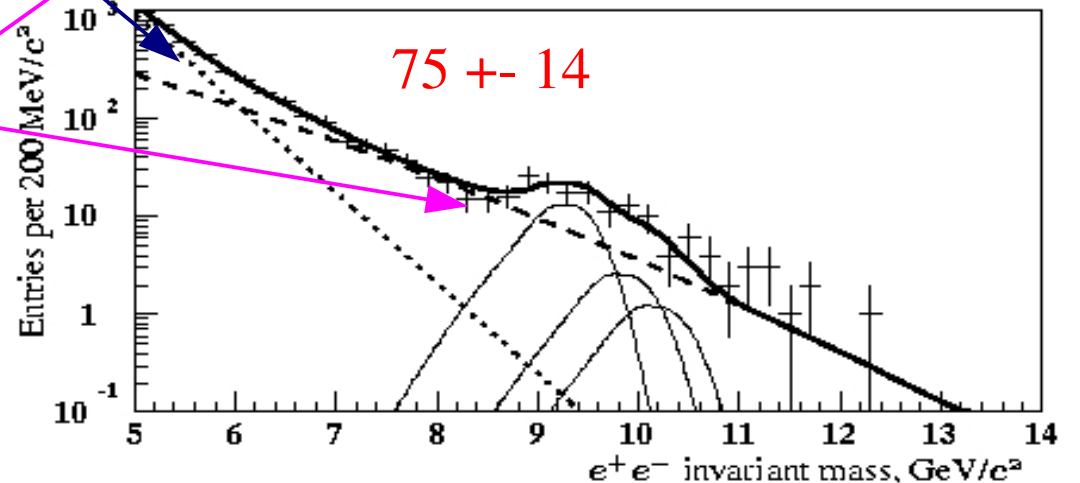
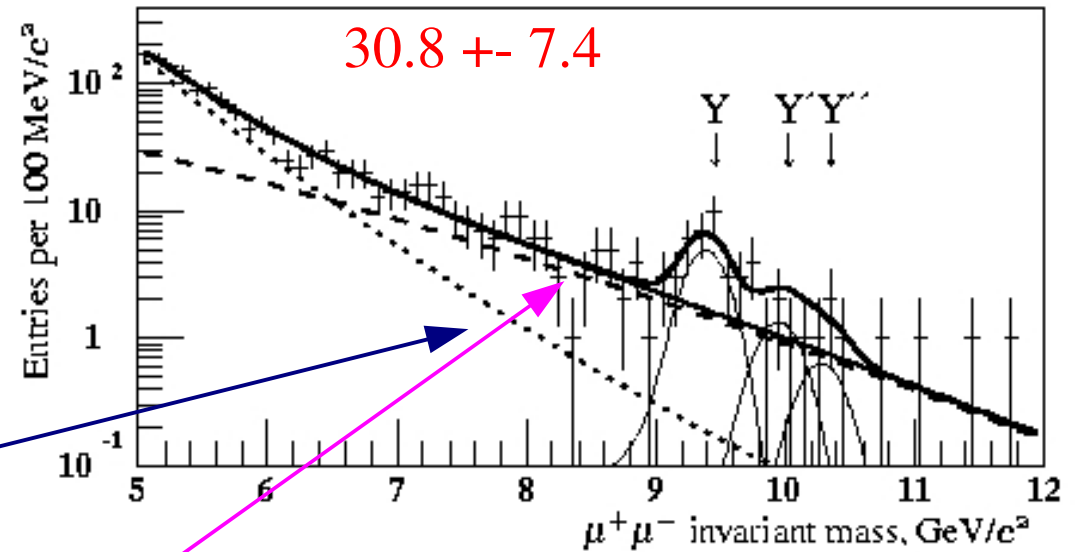
# Upsilon production

- 25% W + 75 % C (targets)
- Mass resolution between 140 and 160 MeV/c<sup>2</sup>
- Background:

Random combinatorial:  
estimated from like sign  
pairs in data

Drell-Yan: shape  
estimated from MC

- Relative production of  
different  $\Upsilon(1S) / \Upsilon(2S) / \Upsilon(3S)$   
states is fixed to E605 results



# *Upsilon production*

$$R_{J/\psi} = \frac{\text{Br}(\Upsilon \rightarrow l^+ l^-) \cdot d\sigma(\Upsilon) dy \Big|_{y=0}}{\sigma(J/\psi)}$$

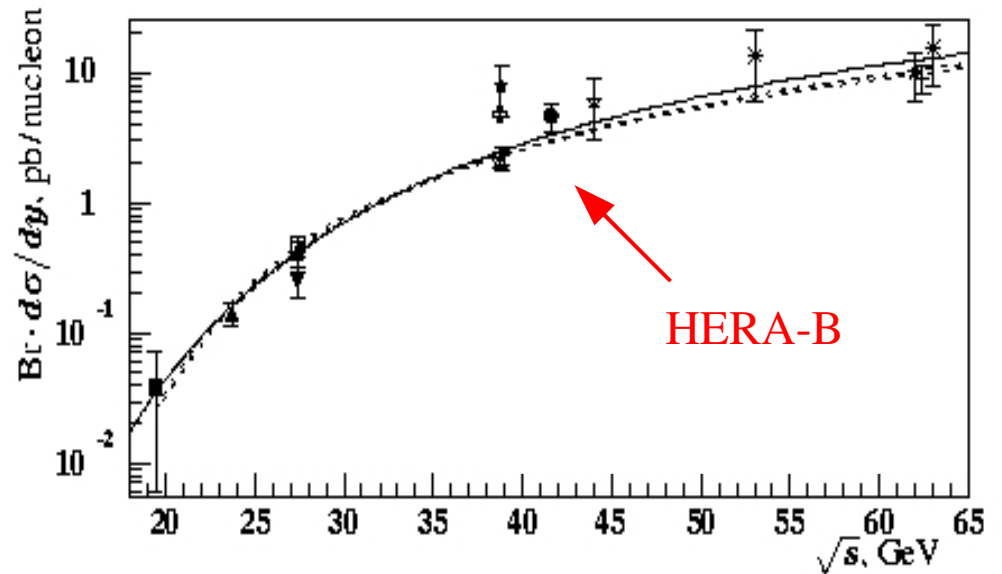
$$R_{J/\psi} = (9.0 \pm 2.1) \times 10^{-6}$$

$$\text{Br}(\Upsilon \rightarrow l^+ l^-) \cdot d\sigma(\Upsilon) dy \Big|_{y=0} = 4.5 \pm 1.1 \text{ pb/N}$$

Normalizing to  $\sigma_{J/\psi} = 502 \pm 44 \text{ nb/nucleon}$  (Maltoni et al)

# *Upsilon production*

- Good agreement with CEM prediction
- The present value is half way between of E605 and E772 results



Phys. Lett. B638: 13-21, 2006

$$\text{Br} (\Upsilon \rightarrow l^+ l^-) \cdot d\sigma (\Upsilon) dy \Big|_{y=0} = 4.5 \pm 1.1 \text{ pb/N}$$

Normalizing to  $\sigma_{J/\psi} = 502 \pm 44 \text{ nb/nucleon}$  (Maltoni et al)

# Conclusions

- HERA-B collected ~300 k  $J/\psi$  and 210 M mbias events on various nuclei
- **Final results presented on:**
  - $J/\psi$  production cross section
  - Open and hidden beauty cross section
- **Final results** on other topics are expected by the end of Y2006

