Open and Hidden Charm production in 920 GeV Proton-Nucleus Collisions

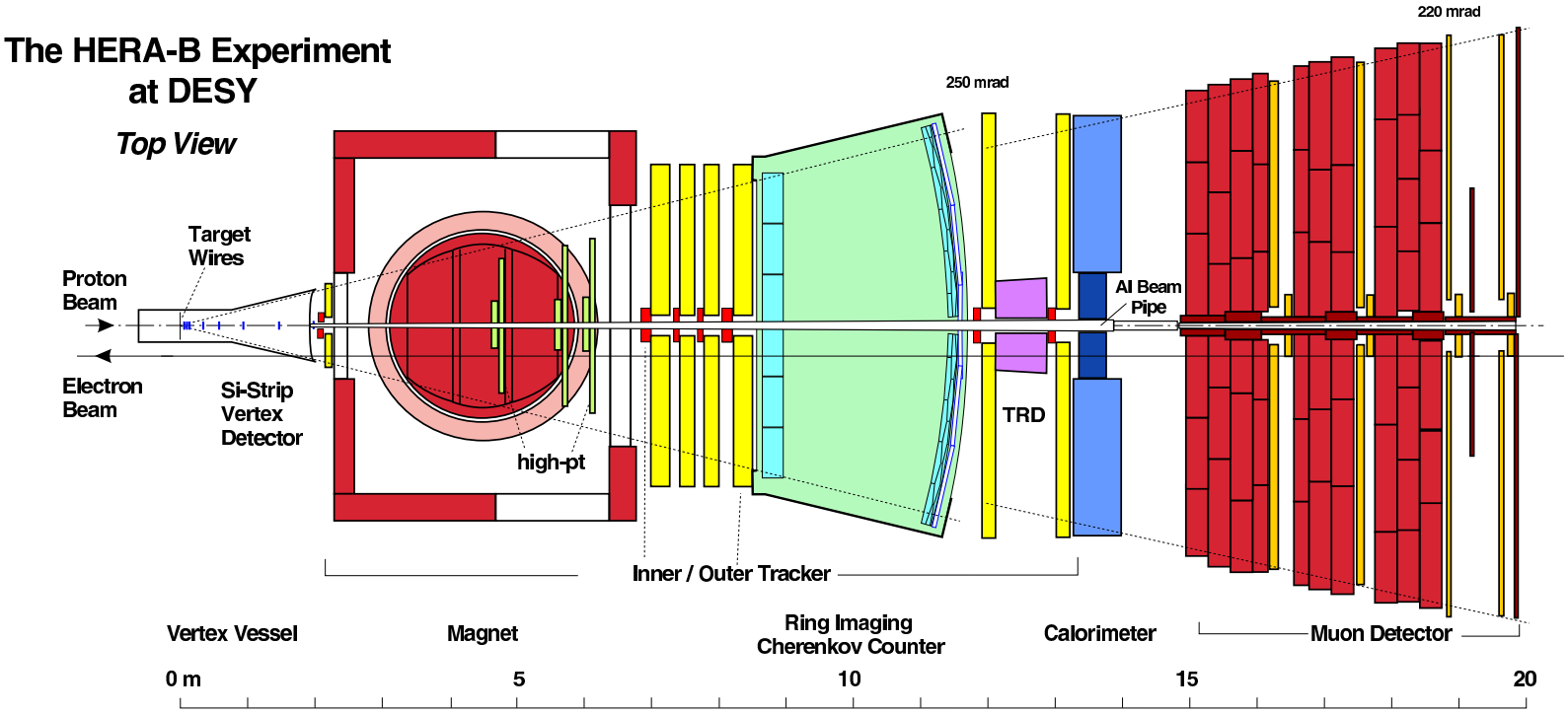
Marko Starič (HERA-B Collaboration)
Jožef Stefan Institute, Ljubljana, Slovenia

Štrbské Pleso, 14 - 18 April 2004
DIS 2004

- HERA-B detector
- Open charm production
- Charmonium production
- Conclusions

The HERA-B Detector

- Fixed target detector at e-p ring HERA, DESY
- High rate forward spectrometer ($<$40MHz)
- Wire targets (different materials) in proton beam halo
- Proton beam at 920 GeV/c ($\sqrt{s}$ = 41.6 GeV)
- High resolution vertexing
- Very good particle ID for e, μ, π, K and p
- Hardware track trigger for lepton pairs ($J/\psi \rightarrow l^+l^-$)



Marko Starič (HERA-B Collaboration)
Jožef Stefan Institute, Ljubljana, Slovenia

Data Sample

Data taking period: November 2002 - March 2003

Trigger modes:

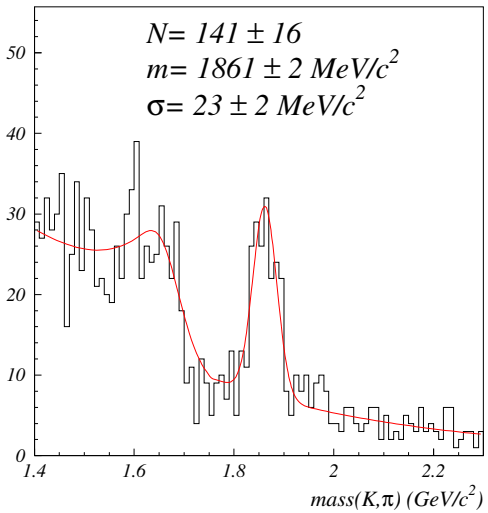
- Di-lepton trigger:
  - 150M events
  - ∼300k J/ψ collected
  - achieved J/ψ rates: 1200 - 1400 /hour
  - → study of charmonium production
- Interaction trigger (hits in RICH or energy in ECAL):
  - 210M events
  - achieved logging rates: 1000 Hz (1.7 Tb/day)
  - → study of open charm production

All results are preliminary

Open Charm - Introduction

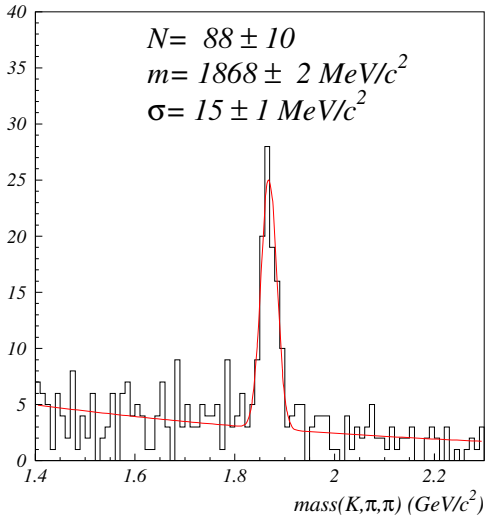
- With 150M interaction trigger events, open charm signals observed:

$D^0 \to K^-\pi^+ + c.c.$



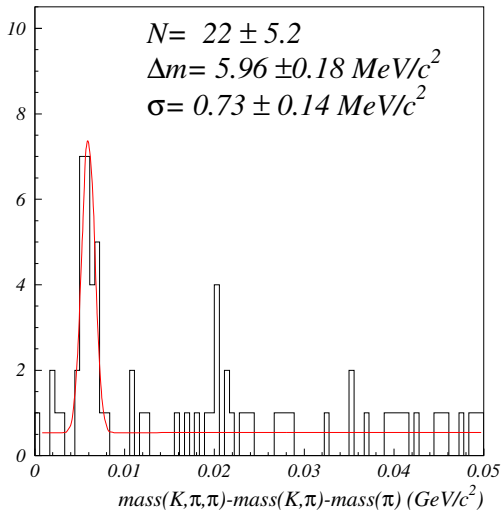
$N_D = 141 \pm 16$

$D^+ \to K^-\pi^+\pi^+ + c.c.$



$N_D = 88 \pm 10$

$D^{*+} \to D^0\pi^+ + c.c.$



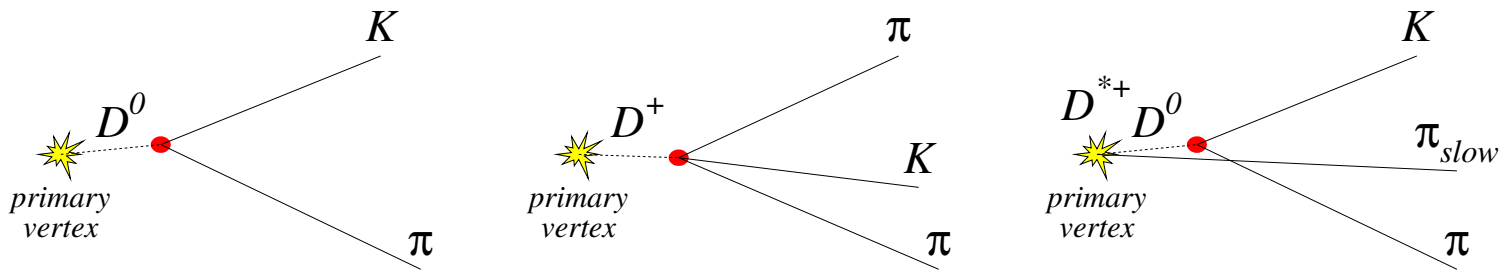
$N_D = 22 \pm 5.2$

- Preliminary results on total production cross sections for D^0, D^+ and D^{*+}
- Preliminary results for production ratios D^+/D^0 and D^{*+}/D^0

Open Charm - Data analysis

To select events the following criteria were used:

- *Event selection:* $\geq$1 prim. vertex reconstructed
- *Particle ID:* identification of K and π in RICH
- *Tracks form a common vertex:* prob(χ^2,ndf) > 0.01
- *Vertex of D^0 (D^+) is detached :*
  - cut on significance of distance to primary vertex $\Delta z/\sigma_z > 6(10)$
  - cut on significance of K and π impact parameter to primary $\Delta b/\sigma_b > 4$
- *D meson comes from primary vertex:* $\Delta b/\sigma_b < 3$
- *D^{*+}: reconstructed $D^0 \rightarrow K\pi$ with mass within ± 50MeV of D^0 table mass*



Open Charm - Efficiency

- Cross-section per nucleon:

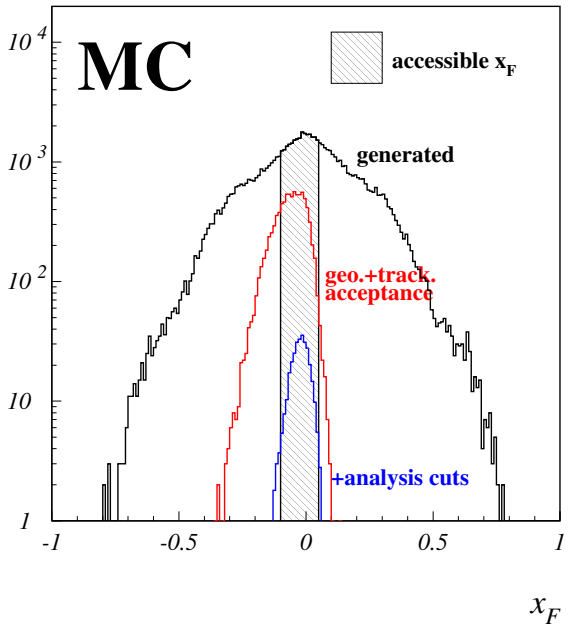
$$\sigma_D = \frac{N_D}{\epsilon \cdot br \cdot \sum A_i L_i}, \qquad \sum A_i L_i = 10985 \mu b^{-1}$$

(linear A-dependency, $\sigma_{pA} = \sigma_{pN} \cdot A$, assumed)

- MC used for efficiency determination
  PYTHIA 5.7 - $pN \rightarrow Q\bar{Q}X$
  FRITIOF 7.02 - the remaining part

- Efficiency for $D^0 \rightarrow K^-\pi^+$:
  overall: **0.6%**
  main losses:
  $\rightarrow$ detector acceptance ($\approx$10%)
  $\rightarrow$ detached vertex ($\approx$10%)

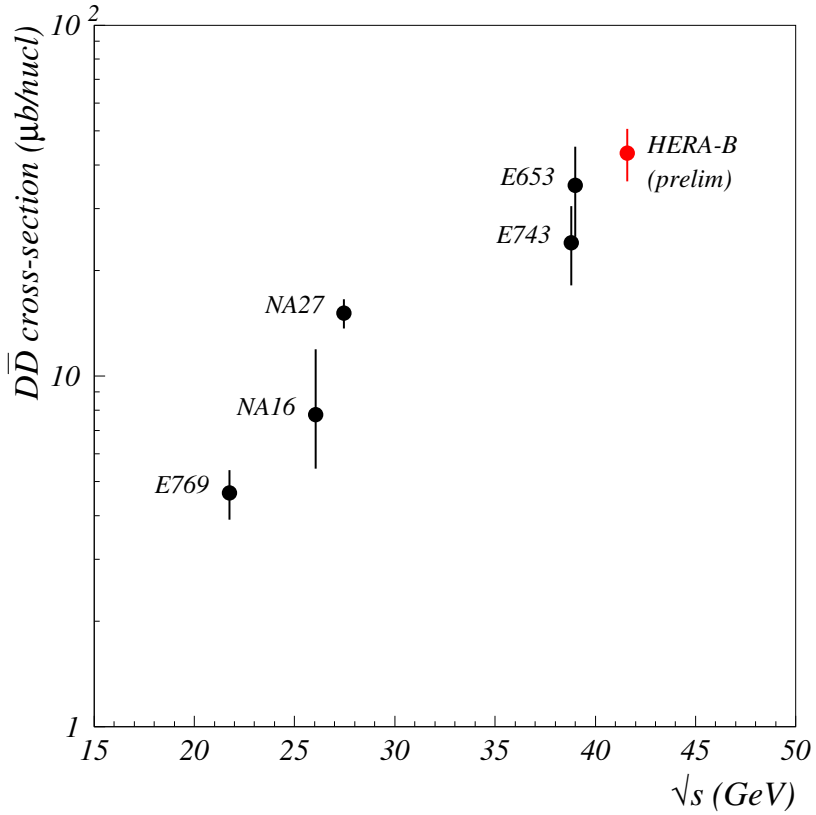
- Accessible kinematic range: $x_F \in [-0.1, 0.05]$



Open Charm - Cross sections

- Cross sections per nucleon in μb - preliminary

	$-0.1 < x_F < 0.05$	full x_F
$\sigma(D^0)$	$21.4 \pm 3.2 \pm 3.6$	$56.3 \pm 8.5 \pm 9.5$
$\sigma(D^+)$	$11.5 \pm 1.7 \pm 2.2$	$30.2 \pm 4.5 \pm 5.8$
$\sigma(D^{*+})$	$10.3 \pm 2.8 \pm 1.5$	$28.5 \pm 7.6 \pm 4.2$



$\longleftarrow$ $D\bar{D}$ cross section:

$$\sigma(D\bar{D}) = \frac{\sigma(D^0) + \sigma(D^+)}{2}$$

(other data points from *C. Lourenco and H. Wohri, CERN-EP/2003-xxx*)

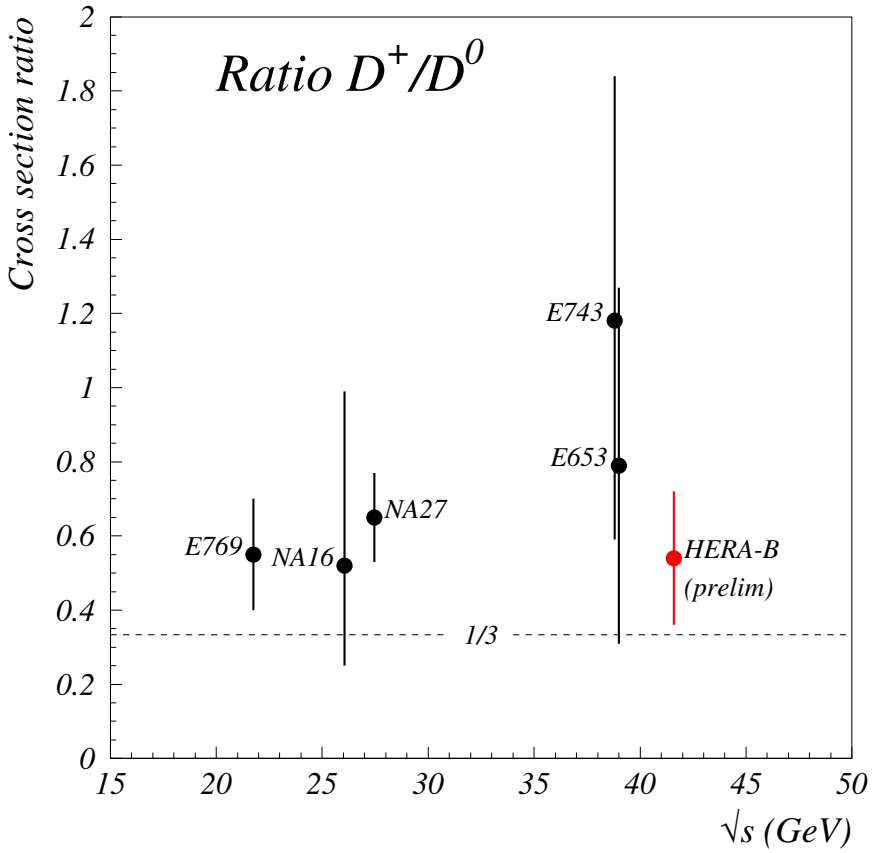
Open Charm - Cross section ratios

- A simple model based on isospin invariance, polarization states of D and D^* and $Br(D^* \to D)$ predicts:

$$R(D^+/D^0) \approx 1/3$$
$$R(D^{*+}/D^0) \approx 1/2$$

- Our preliminary results

	ratio
$R(D^+/D^0)$	$0.54 \pm 0.11 \pm 0.14$
$R(D^{*+}/D^0)$	$0.51 \pm 0.15 \pm 0.10$

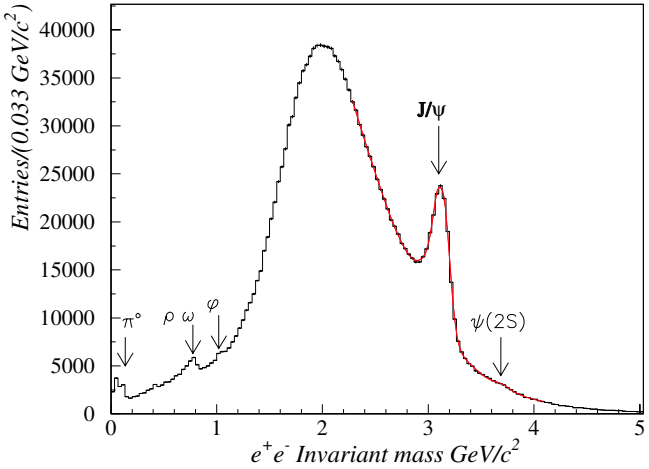


(other data points from *C. Lourenco and H. Wohri, CERN-EP/2003-xxx*)

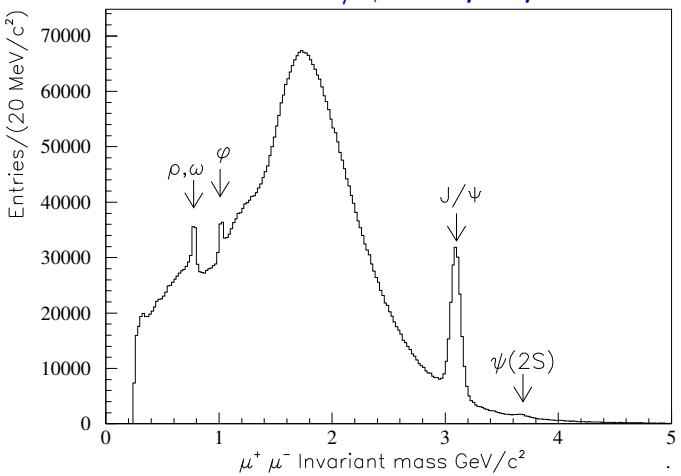
Charmonium - Introduction

Di-lepton trigger data

~150 000 $J/\psi \to e^+e^-$



~150 000 $J/\psi \to \mu^+\mu^-$

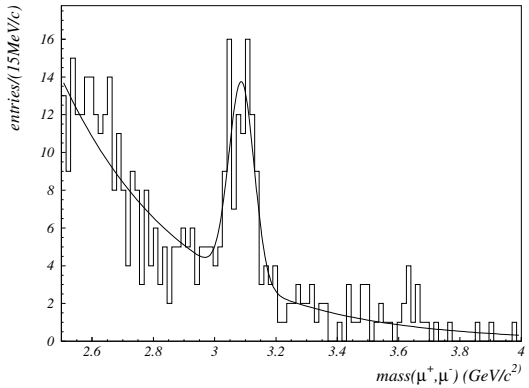


Topics

- J/ψ differential distributions
  - p_t distribution
  - x_F distribution
  - A-dependence
- $\psi(2s)$ production
- $\chi_c/J/\psi$ production ratio

Interaction trigger data

~100 $J/\psi \to \mu^+\mu^-$

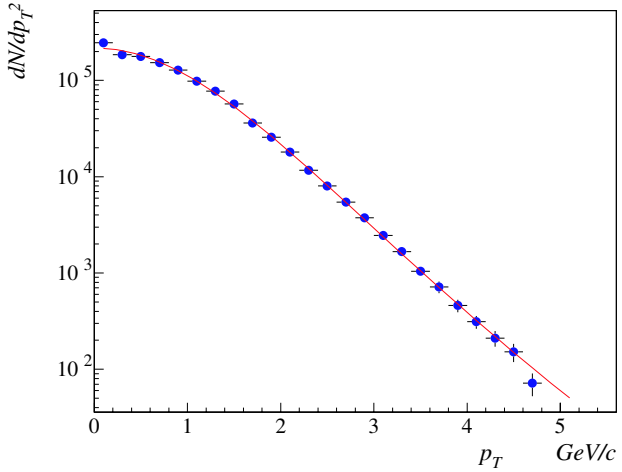


$\to J/\psi$ production cross section

Marko Starič (HERA-B Collaboration)
Jožef Stefan Institute, Ljubljana, Slovenia

p_t distribution of J/ψ

80% of e^+e^- sample



Parametrization:

$$\frac{d\sigma}{dp_t^2} = \beta \cdot [1 + (\frac{35\pi p_t}{256 < p_t >})^2]^{-6}$$

$\rightarrow$ wide range in p_t

Preliminary results for $< p_t >$:

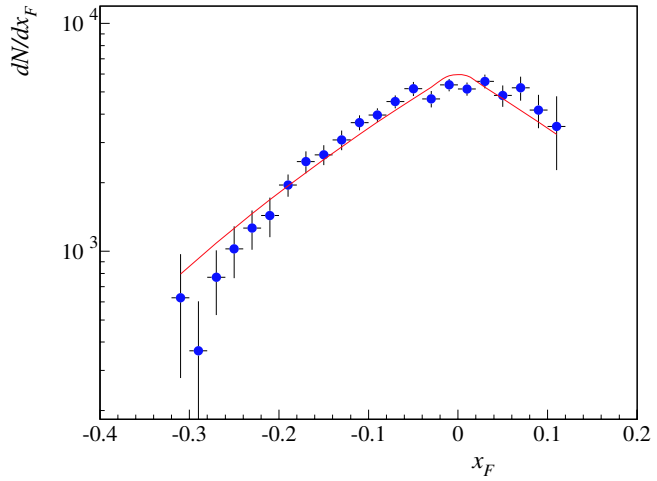
Target	Exp.	p_t range	$< p_t > (e^{\pm})$	$< p_t > (\mu^{\pm})$	error
C 920	HERA-B	≤ 4.8	1.22	1.22	0.01*
W 920	HERA-B	≤ 4.8	1.29	1.29	0.01*
Si 800	E771	≤ 3.5		1.20	0.01
Au 800	E789	≤ 2.6		1.29	0.009

* statistical error only

$\rightarrow$ confirmation of p_t-broadening with increased atomic number

x_F distribution of J/ψ

10% of e^+e^- sample



Parametrization:

$$\frac{d\sigma}{dx_F} = \beta \cdot (1 - |x_F|)^c$$

(is it adequate to describe exp. data ?)

$\rightarrow$ negative x_F range accessible

Preliminary results for exponent c:

Target	Exp.	x_F range	$c(e^{\pm})$	$c(\mu^{\pm})$	error
C, W 920	HERA-B	-0.35 : 0.15	5 - 6.5		0.3*
Si 800	E771	-0.05 : 0.25		6.54	0.23
Au 800	E789	-0.03 : 0.13		4.91	0.18
Cu 800	E789	0.30 : 0.95		5.21	0.04

* statistical error only

Analysis still ongoing $\rightarrow$ only range in c presented (10% of e^+e^- sample used)

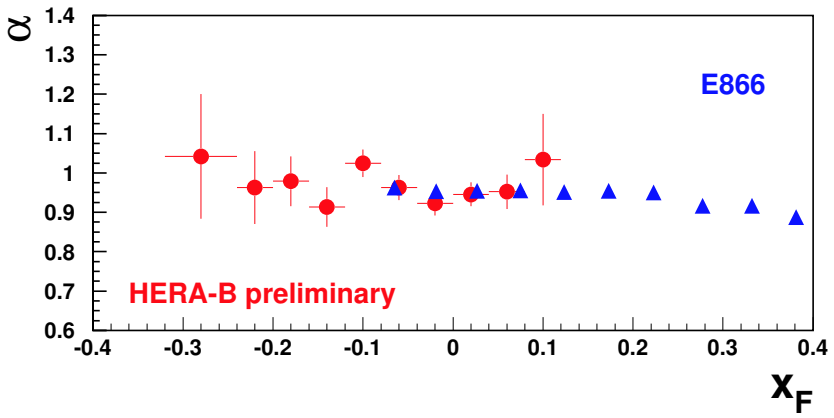
A-dependence of J/ψ

- Simultaneous measurements with C and W target
  → HERA-B well suited to study A-dependence of J/ψ production
- Parametrization of cross section:

$$\sigma_{pA} = \sigma_{pN} \cdot A^{\alpha}, \qquad \alpha = \frac{1}{log(A_W/A_C)} \cdot log(\frac{N_W}{N_C}\frac{\mathcal{L}_W}{\mathcal{L}_C}\frac{\epsilon_W}{\epsilon_C})$$

- Theoretical predictions for $x_F < 0$
  NRQCD: α is decreasing with decreasing x_F
  BCKT: α is increasing with decreasing x_F

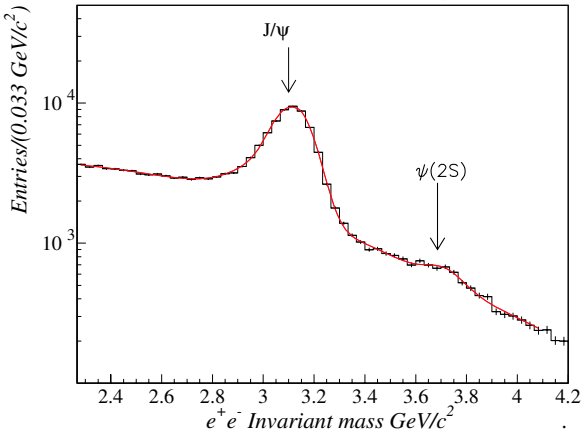
25% of e^+e^- sample

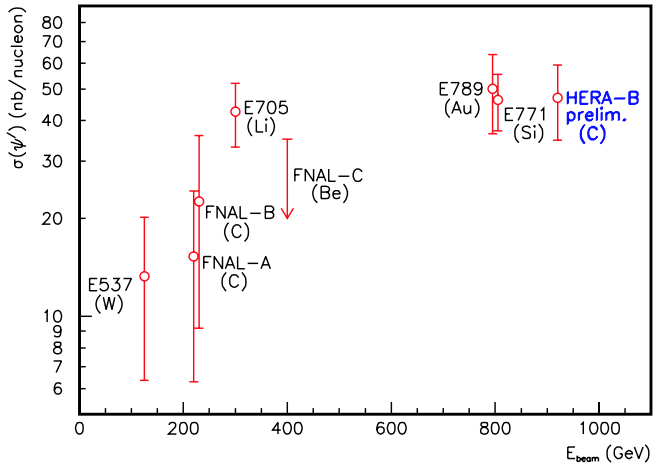


- Ratio of efficiencies includes full detector + trigger simulation
- Ratio of luminosities under investigation
  → normalized to E866 result

$\psi(2s)$ production

30% of e^+e^- sample





Cross section ratio:

$$R_{\psi(2s)} = \frac{N_{\psi(2s)}}{N_{J/\psi}} \cdot \frac{Br(\psi(2s) \to e^+e^-)}{Br(J/\psi \to e^+e^-)} \cdot \frac{\epsilon_{\psi(2s)}}{\epsilon_{J/\psi}}$$

Preliminary result (carbon target):

$$R_{\psi(2s)} = 0.13 \pm 0.02$$

Cross section:

$$\sigma_{\psi(2s)} = R_{\psi(2s)} \cdot \sigma_{J/\psi}$$

With $\sigma_{J/\psi}$ from E771 and E789:

$$\sigma_{J/\psi} = (357 \pm 8 \pm 27) nb/nucl$$

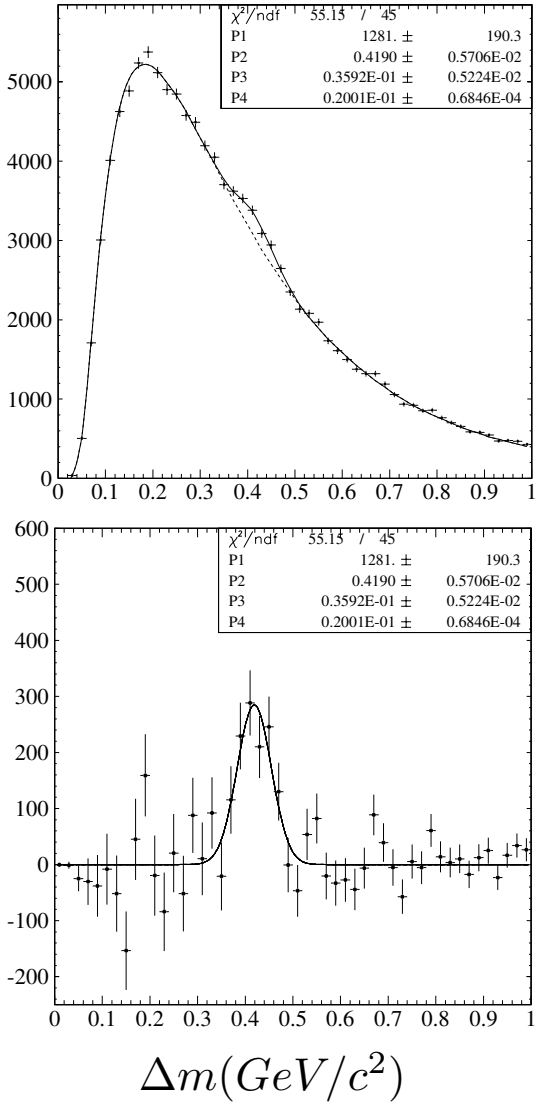
Preliminary result (carbon target):

$$\sigma_{\psi(2s)} = (46 \pm 12) nb/nucl$$

Systematic studies ongoing. Muon channel gives compatible result.

$\chi_c/J/\psi$ production ratio

$\chi_c \to \gamma J/\psi$ (15% of $\mu^+\mu^-$)



Production ratio:

$$R_{\chi_c} = \frac{\sum_{i=1}^{2} \sigma(\chi_c) \cdot Br(\chi_c \to J/\psi)}{\sigma(J/\psi)} = \frac{N_{\chi_c}}{N_{J/\psi}} \cdot \frac{\epsilon_{J/\psi}}{\epsilon_{\chi_c}\epsilon_\gamma}$$

(ECAL resolution does not allow to separate χ_{c1} and χ_{c2} states)

Results of 2000 (Phys.Lett. B561(2003)61):

$$N(\chi_c) = 370 \pm 74 \quad (\mu^+\mu^-, e^+e^-)$$

$$R(\chi_c) = 0.32 \pm 0.06 \pm 0.04$$

$\to$ in good agreement with NRQCD prediction.

Preliminary results of 2002/03:

$$N(\chi_c) \approx 1300 \quad (15\% \ \ of \ \ \mu^+\mu^-)$$

$$R(\chi_c) = 0.21 \pm 0.05$$

Expect to get $N(\chi_c) \sim 15000$ for full sample.

Conclusions

- Large dilepton sample (both e^+e^- and $\mu^+\mu^-$) allows for detailed study of J/ψ and $\psi(2s)$ production
- Large minimum bias sample allows for competitive measurement of open charm production cross sections
- Quality of data is very good
- HERA-B has large acceptance (negative x_F) and good particle identification
- Analysis of 2002/2003 data in progress
- Preliminary results presented