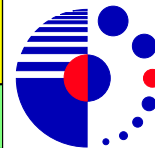
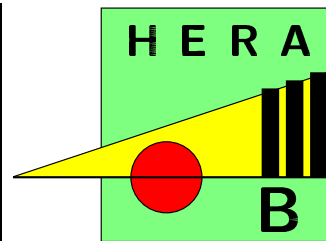

Charmonium Production at HERA-B *DIS2003 - St. Petersburg*

Dirk Krücker
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Humboldt University Berlin



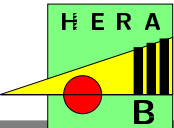
bmb+f - Förderschwerpunkt

HERA - B

Großgeräte der physikalischen
Grundlagenforschung

Content

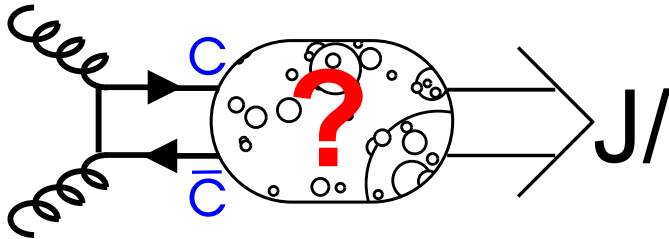
- Charmonium and HERA-B
- A Short Overview
- The HERA-B Detector
- Data Sample 2000 and 2002/2003
- Results
- Outlook



Charmonium Production



No direct connection between solid theory and experiment.



We have to tell stories on what is going on in between:

F^ψ , $\langle \mathcal{O}_n^\psi \rangle$; absorption ...

Many new experimental results within the last decade.

- Failure of the Colour Singlet Model at Tevatron.
 - NRQCD
 - CEM
- NA50 anomalous J/ψ suppression
 - QGP or just
 - absorption in nuclear matter
- Many results from HERA
 - Consistent picture?

Models for Charmonium Production

● CEM:

$$\frac{d\sigma^\psi}{dx_F} = F^\psi \int_{2m_c}^{2m_D} dM_{c\bar{c}} \frac{d\sigma[c\bar{c}]}{dM_{c\bar{c}} dx_F} \text{ col. \& spin averaged}$$

Same composition of singlet and octet states to different charmonia.

$$x_F := \frac{p_{\parallel}}{p_{max}}$$

● NRQCD:

$$\frac{d\sigma^\psi}{dx_F} = \sum_{\substack{n=\text{col.}, \\ \text{ang. mom.}}} C_{c\bar{c}}[n] \langle \mathcal{O}_n^\psi \rangle$$

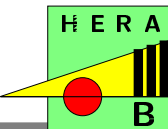
Ratio of singlet and octet predicted.

J/ψ production predominantly colour octet,

χ_c predominantly colour singlet.

Different pre-resonant $c\bar{c}$ states will interact differently in nuclear matter.

⇒ Different A-dependence.

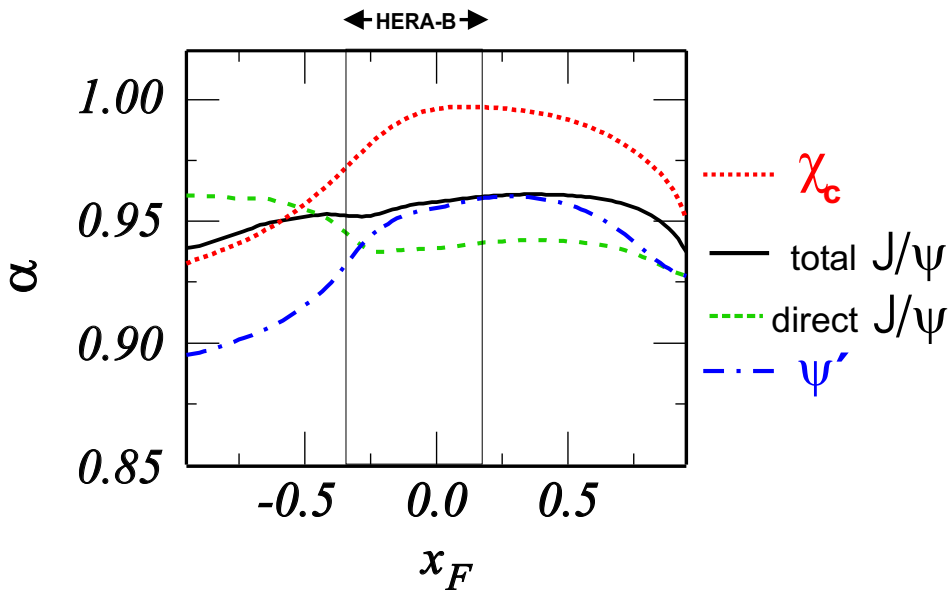


Charmonium A-Dependence

A-dependence parameterized as

$$\sigma_{pA} = \sigma_{pN} A^\alpha$$

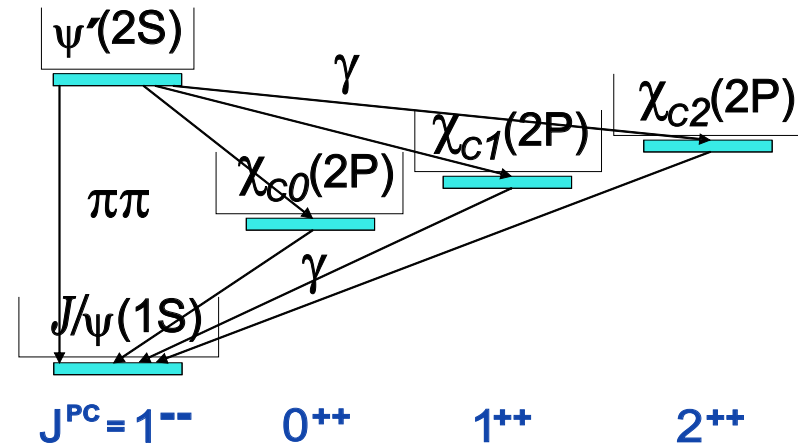
Nuclear effects: $\alpha \neq 1$



NRQCD at 920 GeV

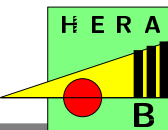
R. Vogt, Nucl.Phys.A700(2002)539

$$x_F = \frac{p_{\parallel}}{p_{max}}$$



30...40% J/ψ from radiative χ_c decays and hadronic ψ' decays.

$\Rightarrow$ Needs measurement of χ_c contribution and A-dependence.



HERA-B Physics Program

The HERA-B **ABC**

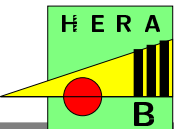
- A.** A-dependence of charmonia production
- B.** $b\bar{b}$ production cross section
 $\implies$ See talk by M.Bräuer
- C.** Charmonium spectroscopy: J/ψ , ψ' , χ_c

In addition

220 million minimum bias events:

strangeness production, open charm, ...

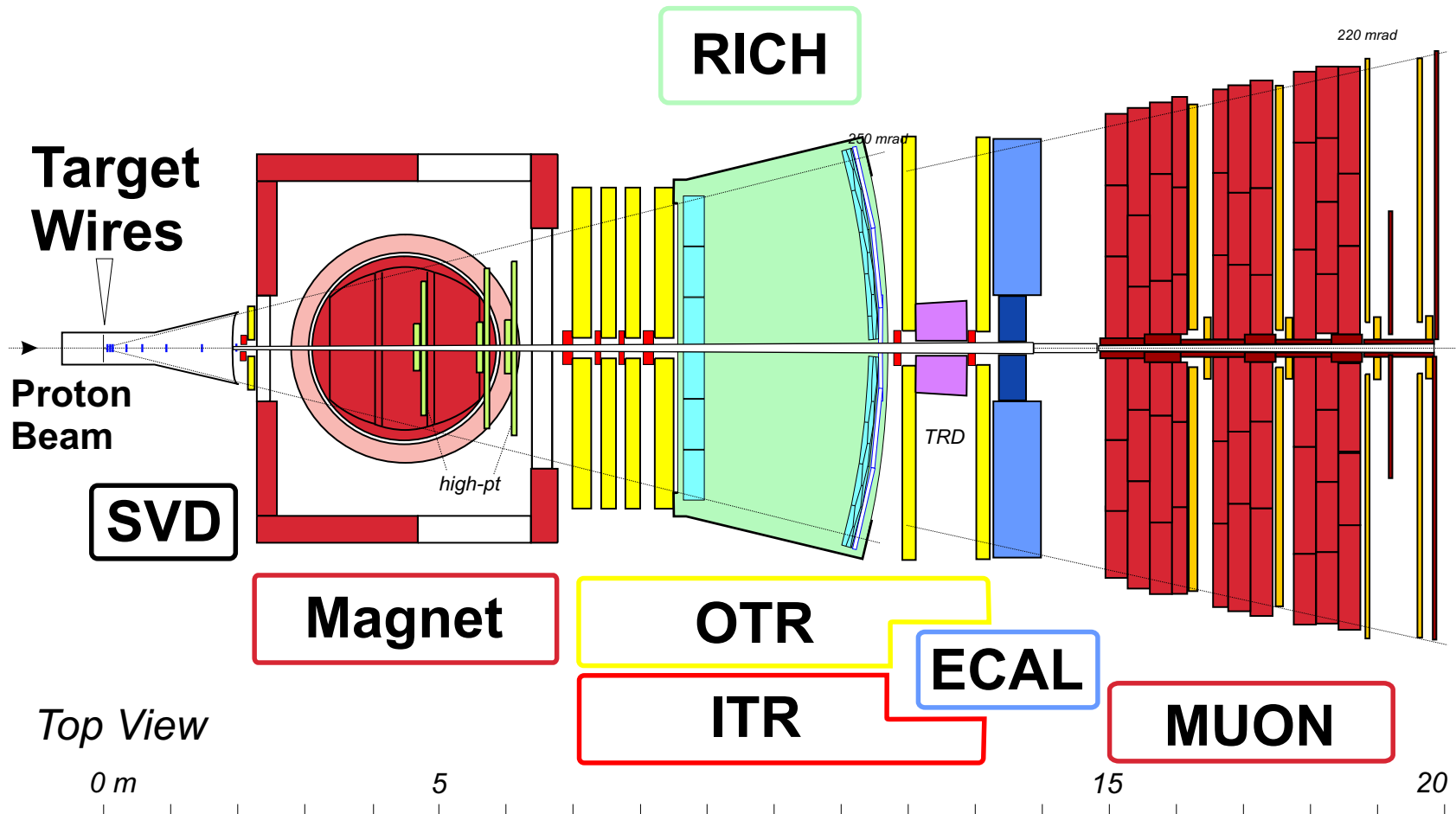
J/ψ production cross section



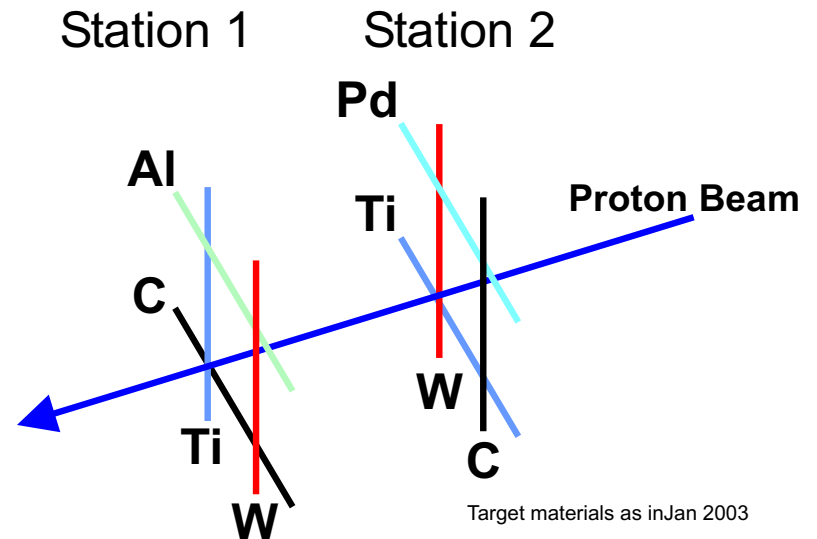
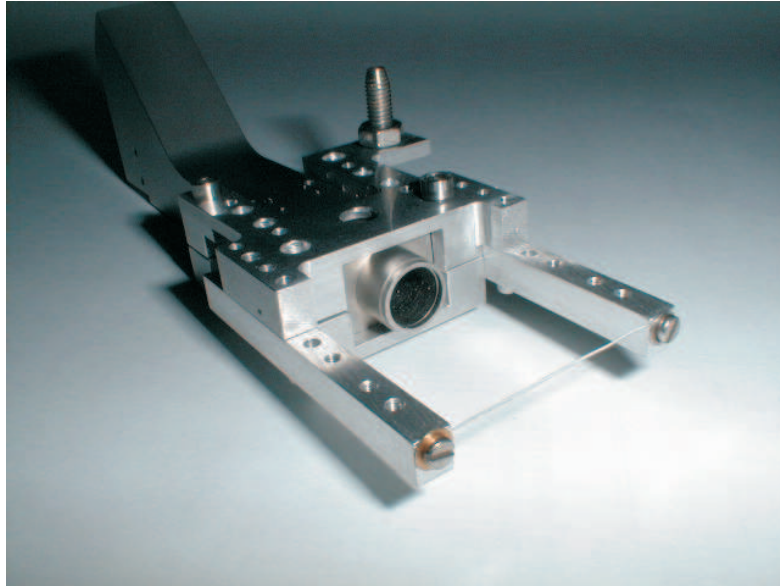
The HERA-B Detector

A Fixed Target Spectrometer at the HERA Proton Beam

$$\sqrt{s} = 41.6 \text{ GeV}$$

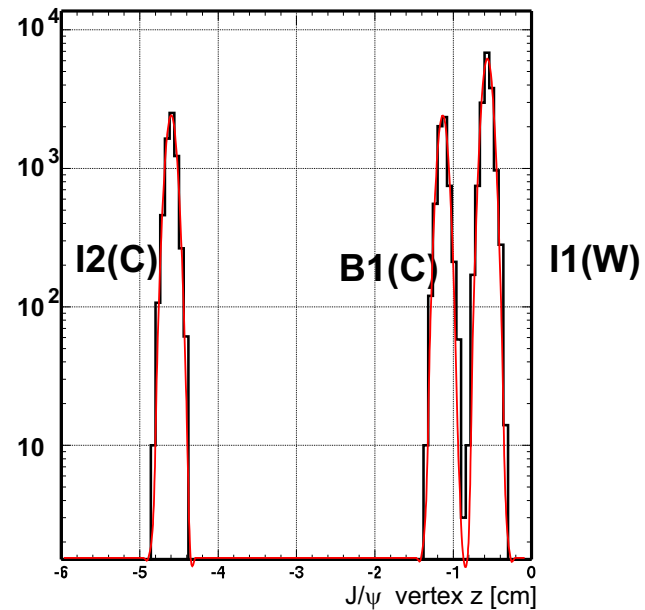
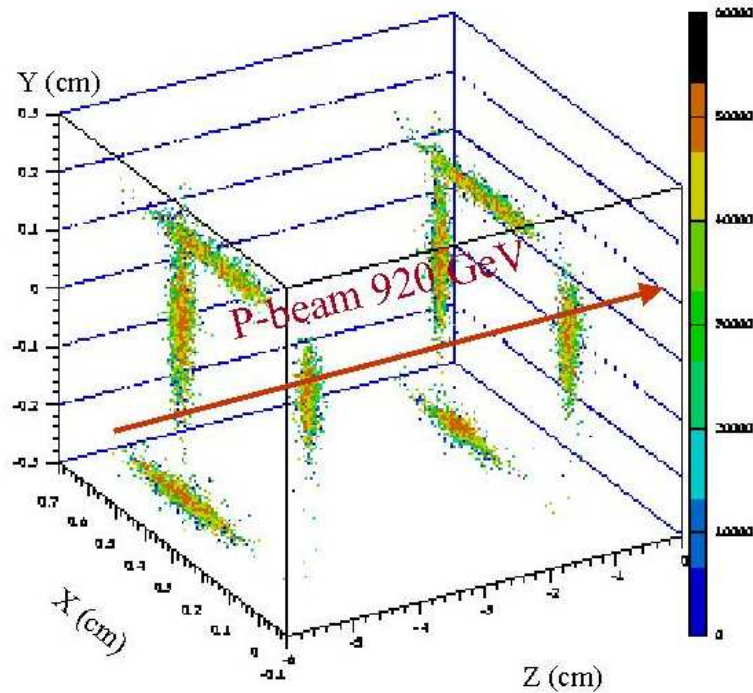


Target



- Different targets can be used simultaneously.
A-dependence measurements $\Rightarrow$ control of systematic errors.

Target



- Events from different wires can be separated easily

Trigger

**HERA-B Detector: on average
 $\frac{1}{2}$ interaction per proton bunch**

5 MHz

**Pretriggers: ECAL cluster or
MUON hit coincidence**

3 MHz

**FLT: track based hardware trigger
(track finding behind magnet)**

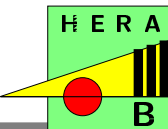
20 kHz

**SLT (PC farm): track finding,
SVD, vertexing**

100 Hz

4LT (PC farm): online reconstruction

Year	J/ψ h^{-1}
2000	25-30
2002/3	1000-1500

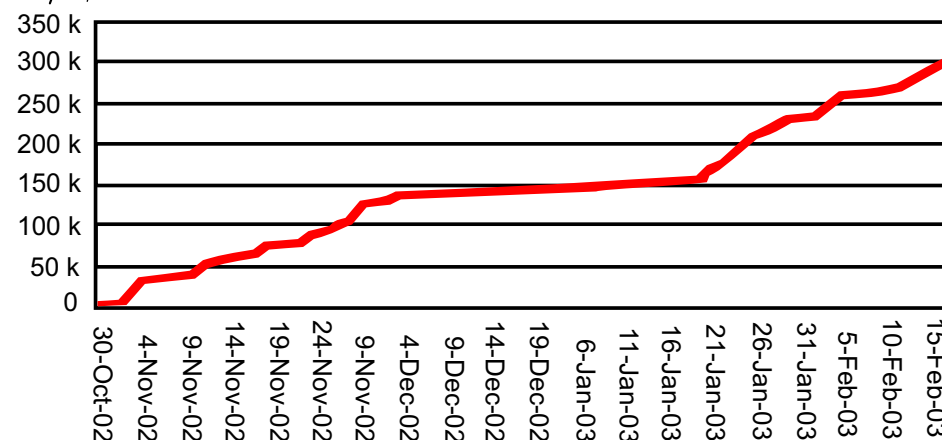


Data Sets with Di-Lepton Triggers

2000: short physics run during HERA-B commissioning: runs with 1 and 2 target wires, mainly carbon and titanium, $\approx 8600 J/\psi$'s

2002/2003: 3 Months of data taking: runs with 1 and 2 target wires, mainly carbon and tungsten, $\approx 300000 J/\psi \rightarrow l^+ l^-$

J/ψ 's collected in 2002/2003

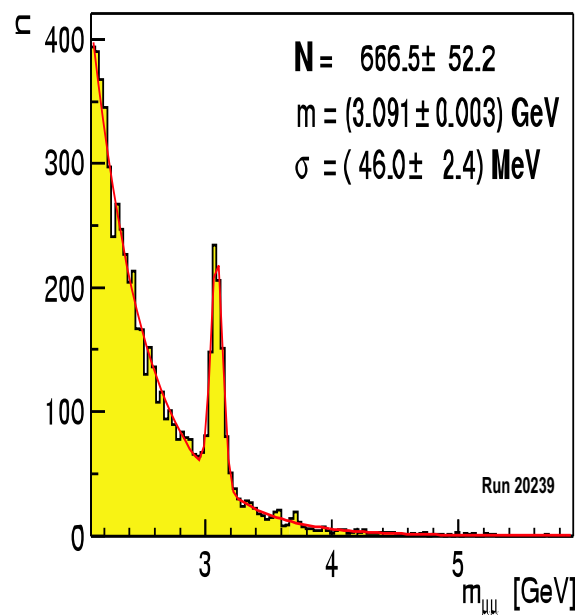


Many improvements for 2003/2003

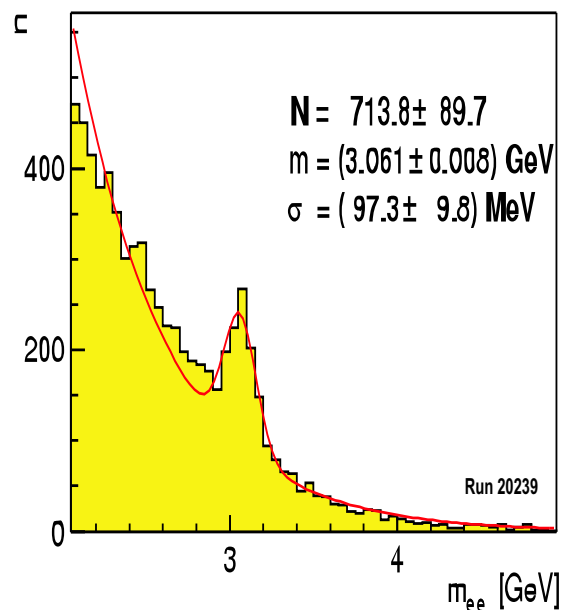
- Less material in magnet area
- ECAL: less noise, improved calibration
- Improved tracking efficiency, trigger, ...

Detector performance in 2002/2003

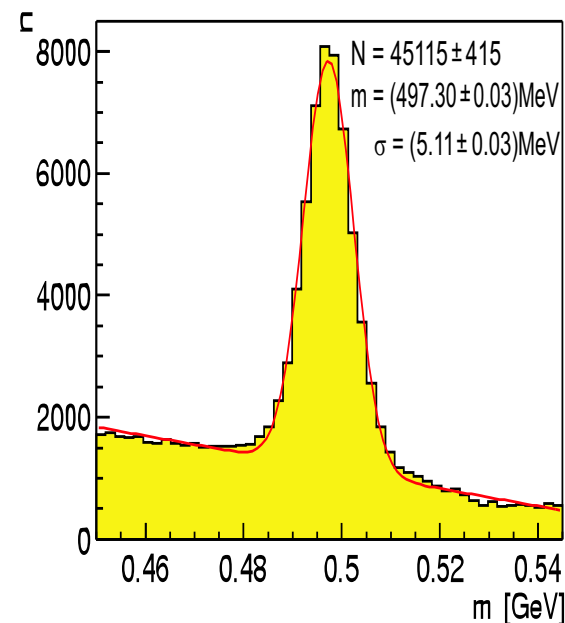
Online data quality, e.g :



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

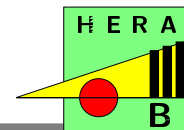


$J/\psi \rightarrow e^+ e^-$



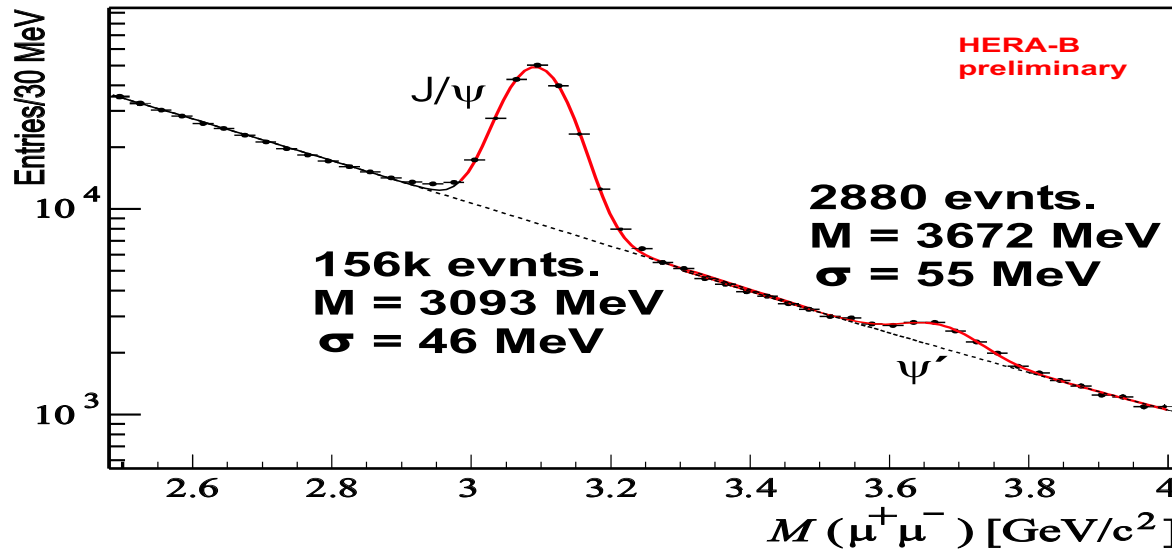
K_s^0 width as expected from Monte Carlo

Physical signals as seen during data taking

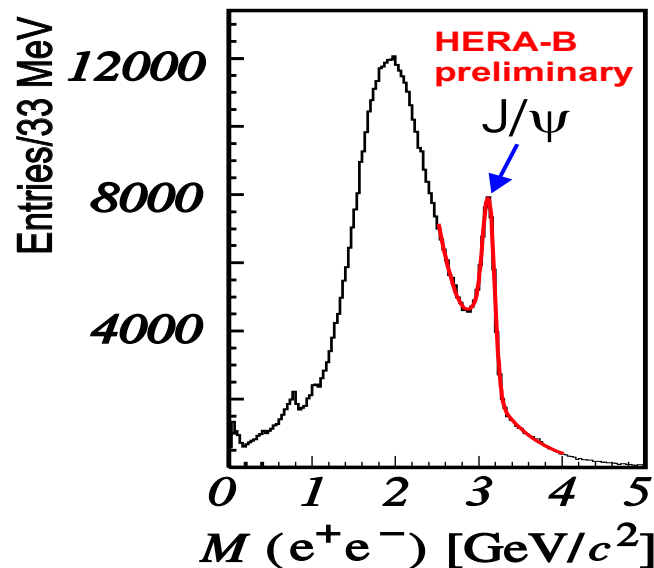


Invariant Mass of Lepton Pairs in 2002/2003

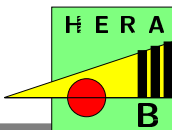
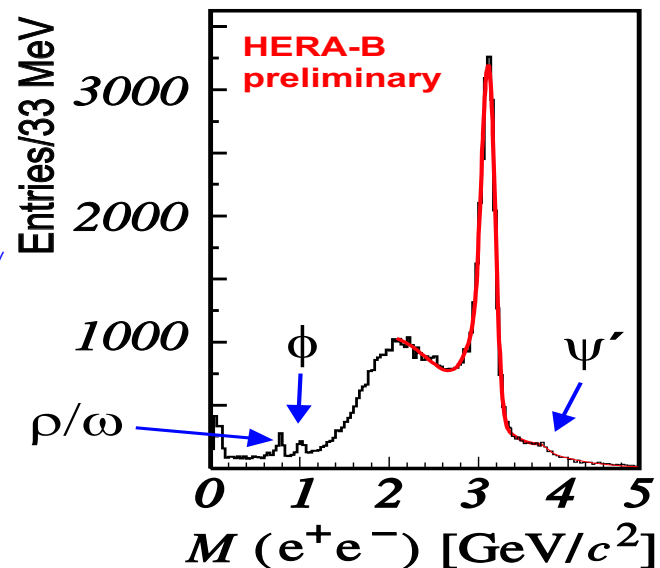
Muons



Electrons

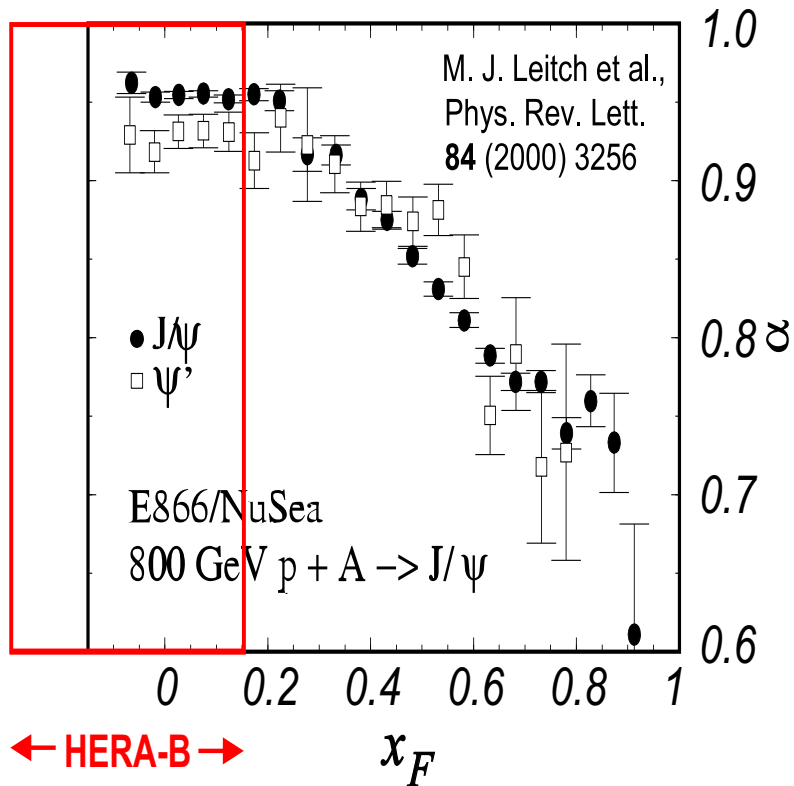


1 brems-
strahlung γ



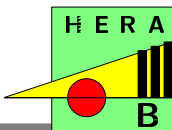
Expectations for the A-Dependence Measurement

Existing measurement
from E866



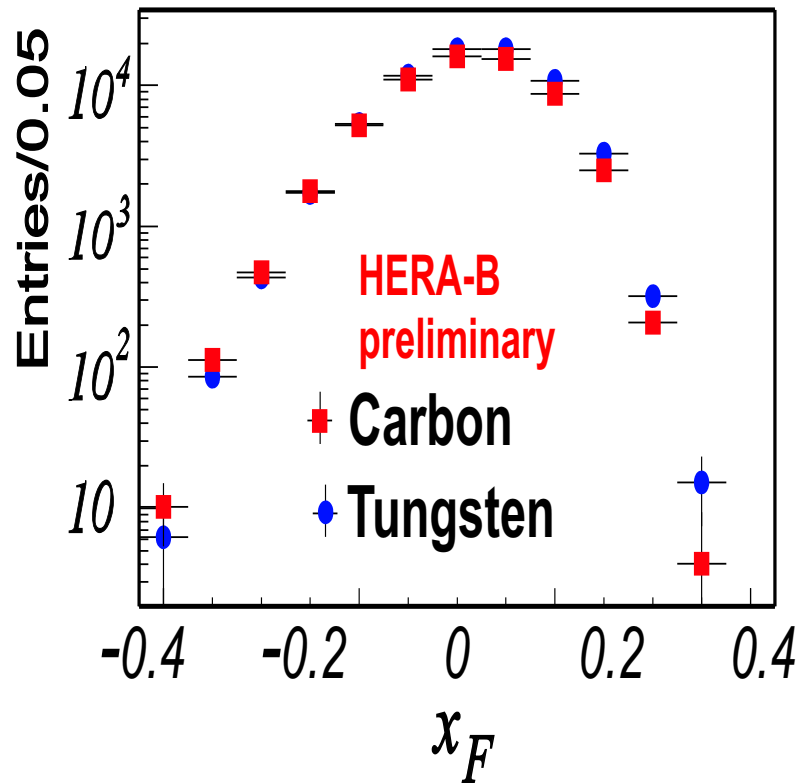
HERA-B:

- extension to $-0.3 < x_F < 0.15$
- A-dependence of J/ψ , ψ' and χ_c

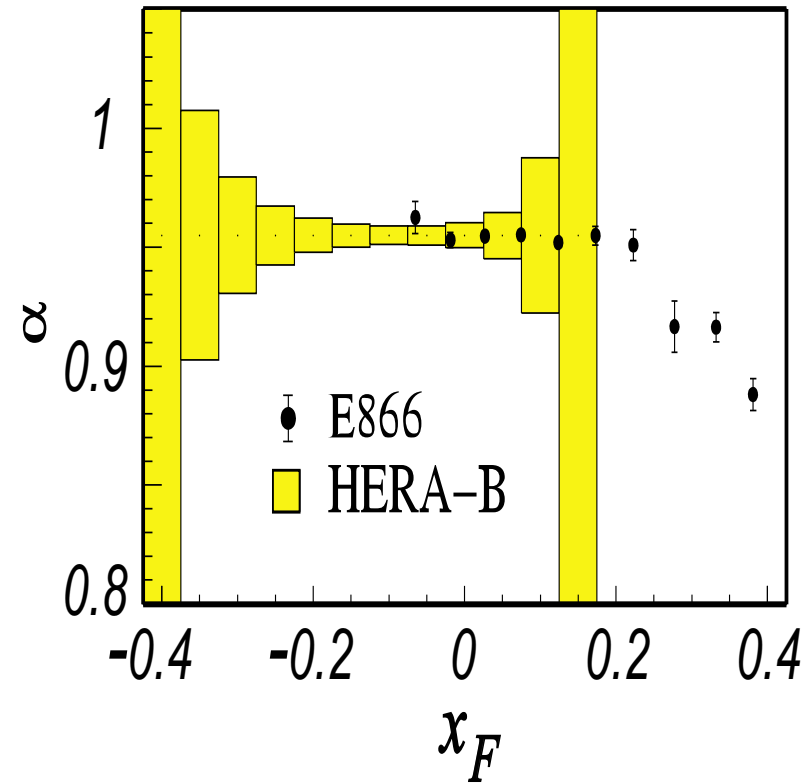


Expectations for the A-Dependence Measurement

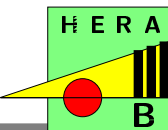
● J/ψ x_F -distribution.
Uncorrected! 2002/3



● Expected statistical error on α .



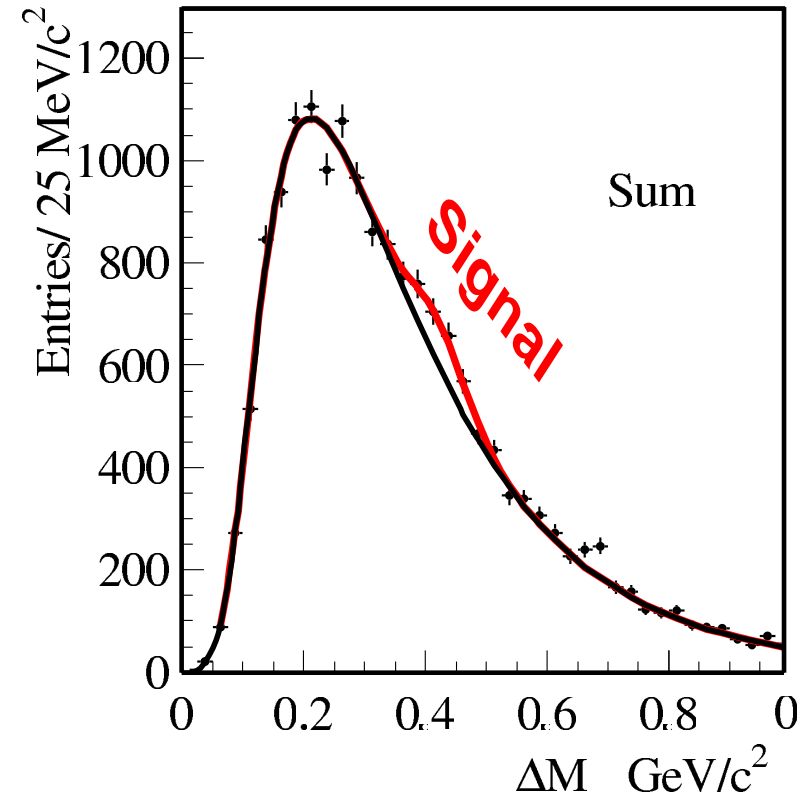
Ongoing analysis ...



J/ψ Production via χ_c Decays

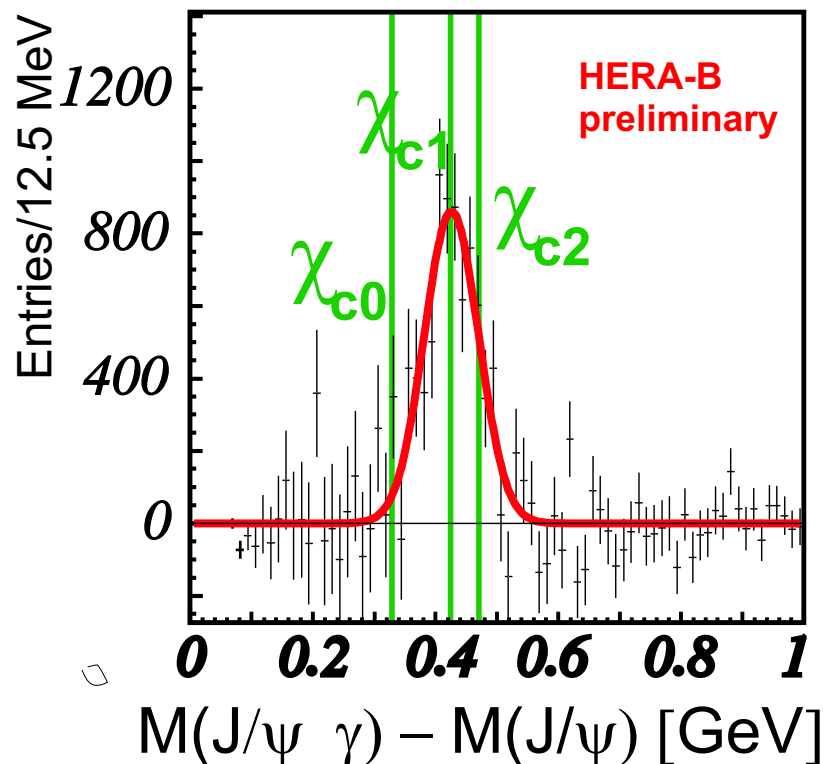
- Radiative decay
 $\chi_c \rightarrow J/\psi \gamma \rightarrow l^+ l^- \gamma$
- Signal in
 $\Delta M = M(J/\psi \gamma) - M(J/\psi)$
- Large combinatorial backgr. from photon candidates (ECAL cluster)
- Mixture χ_{c1}, χ_{c2}
– χ_{c0} negligible
-

$$R_{\chi_c} = \frac{\sum_{i=1}^2 \sigma(\chi_{ci}) Br(\chi_{ci}) \rightarrow J/\psi \gamma}{\sigma(J/\psi)}$$



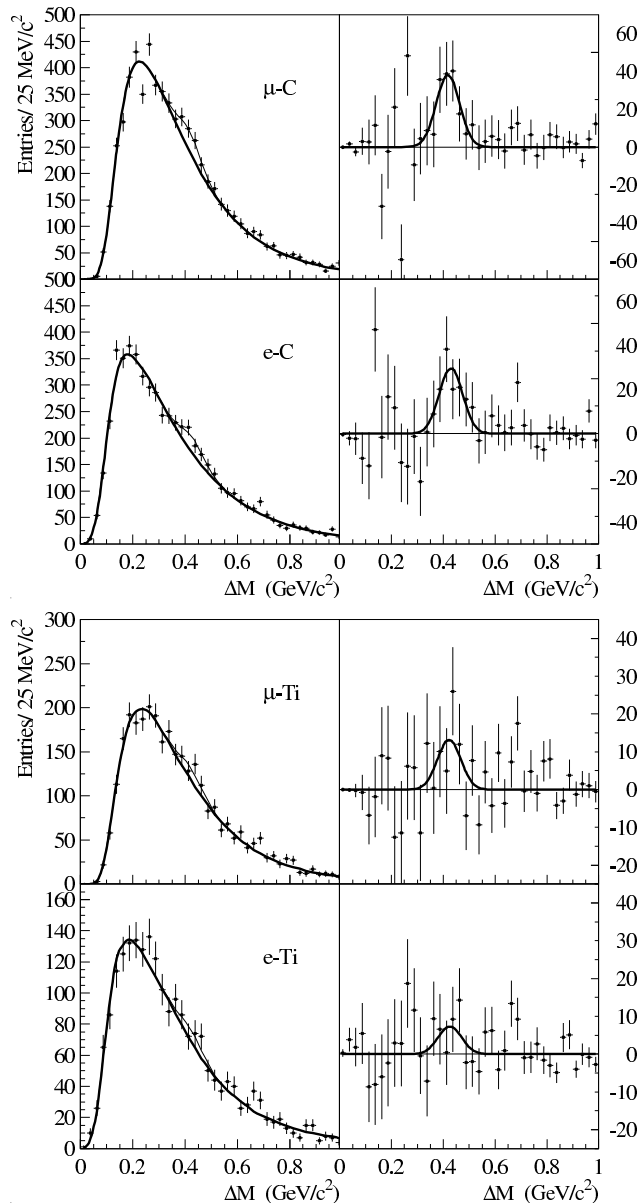
Decays of χ_c in 2002/2003

- ≈ 7600 events
(full sample
 $\approx 20000 \chi_c$)
- mixture χ_{c0} , χ_{c1} and
 χ_{c2}
- Mass: 3518 MeV
- Width: 44 MeV



Ongoing analysis ...

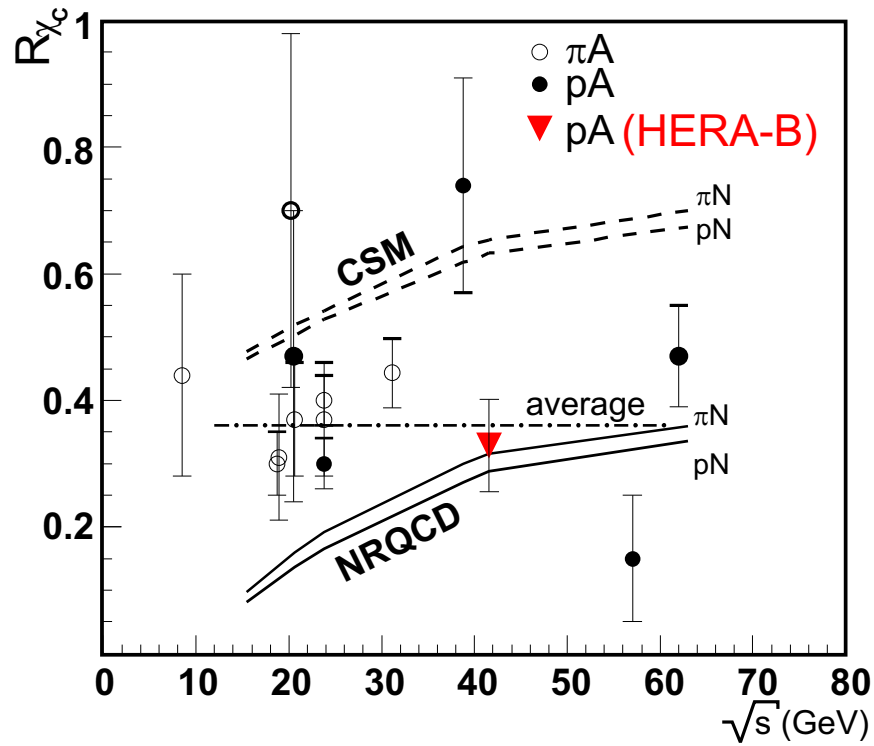
χ_c in 2000 Data



- Background estimated by event mixing
- Signal in electron and muon decay channel for titanium and carbon
- Result on R_{χ_c} based on sum: $\sum_{all} \approx 370 \chi_c$

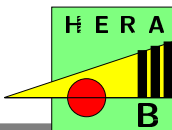
J/ψ Production via χ_c Decays in 920 GeV pA Interactions

Phys.Lett.B



$$R_{\chi_c} = \frac{\sum_{i=1}^2 \sigma(\chi_{ci}) Br(\chi_{ci} \rightarrow J/\psi \gamma)}{\sigma(J/\psi)}$$

HERA-B 2000: $\langle R_{\chi_c} \rangle = 0.32 \pm 0.06_{stat} \pm 0.04_{sys}$



Summary

- First results based on 2000 data published
 $\langle R_{\chi_c} \rangle = 0.32 \pm 0.06_{stat} \pm 0.04_{sys}$
- About 300000 J/ψ 's and 20000 χ_c 's in 2002/2003
Many ongoing analyses

Outlook

Many other ongoing analyses

J/ψ differential distributions, A-dependence, Polarization

χ_c studies

Ratio of ψ' to J/ψ for different A

$\psi' \rightarrow l^+ l^- \pi \pi$

$\psi' \rightarrow l^+ l^- \eta$

$J/\psi K^+ K^-$ correlations

Hidden charm decaying into $J/\psi \pi^0$

Double J/ψ production

Double charm production

J/ψ production in diffractive events

Low mass resonances ...

New results coming soon

