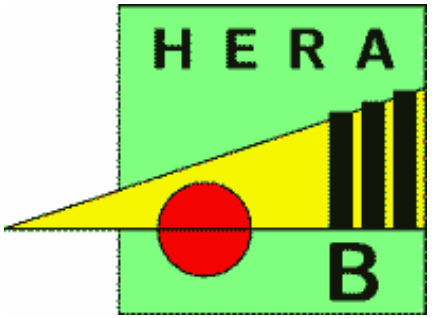
Diffractive Charmonium Production at HERA-B



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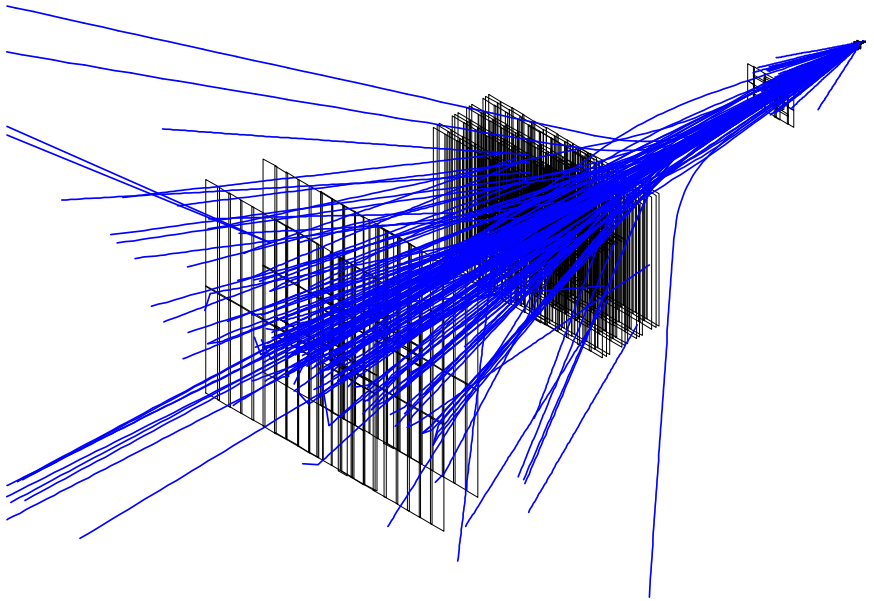
for the HERA-B Collaboration

Xth Blois Workshop on Elastic and Diffractive Scattering
Hanasaari, Helsinki, June 23rd-27th, 2003

Outline

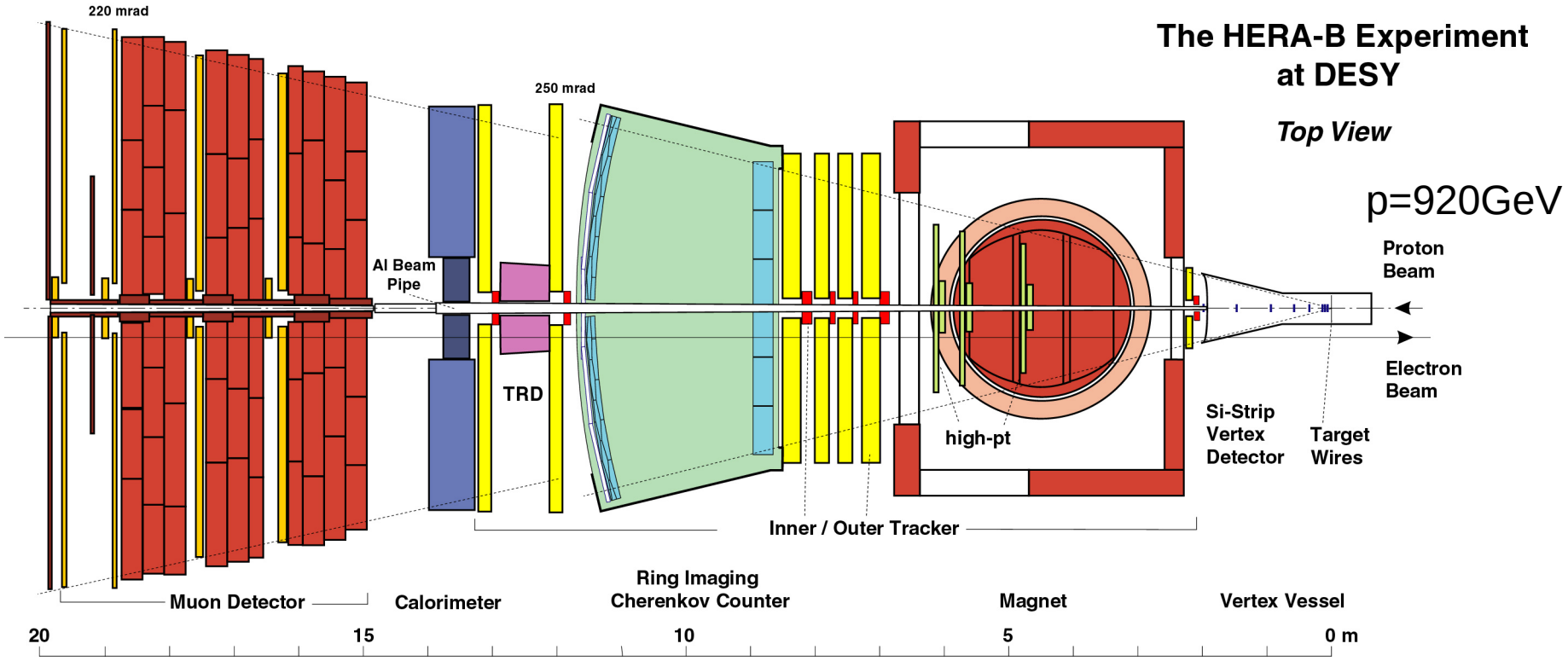
- HERA-B detector
- Data taking periods: 2000 and 2002/2003
- Physics to address with new data sample
- Diffractive charmonium production
  - Signal
  - Upper limits
- Concluding remarks



HERA-B Detector

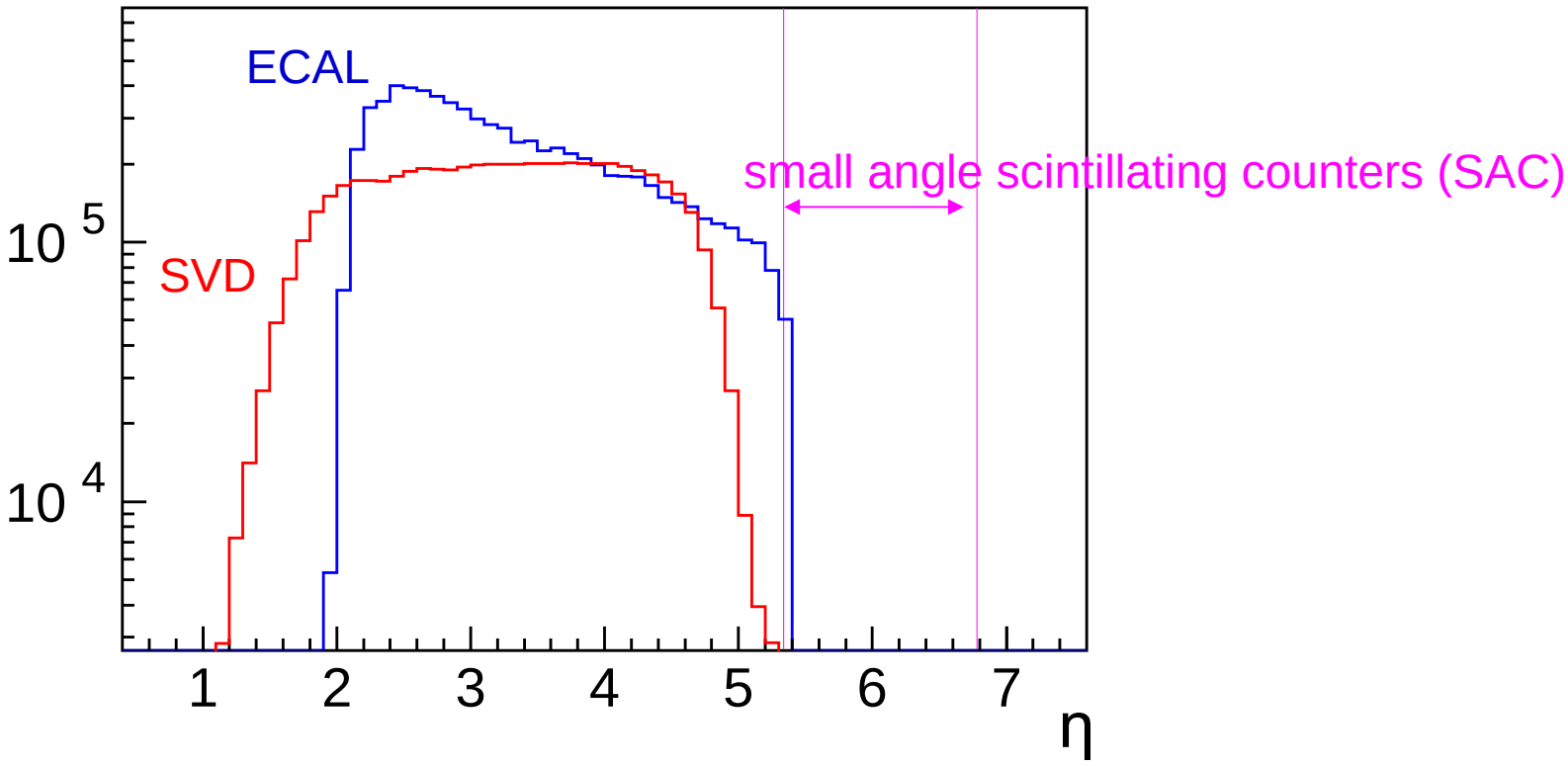
- Fixed target experiment with open geometry, operated at HERA proton ring in DESY.
- Target wires are inserted in halo of proton beam. C,W,..
- $\sqrt{s}$=41.6 GeV
- Originally designed as B-factory.
- $\sigma_{J/\psi}/\sigma_{total} \sim 10^{-5}$, $\sigma_{bb}/\sigma_{total} \sim 10^{-6}$
  $\Rightarrow$ very selective trigger on lepton pairs
  $\Rightarrow$ high interaction rate: 5MHz
  $\Rightarrow$ total data flow 1TB/sec.

Schematic View of HERA-B Detector



HERA-B Rapidity Coverage

- Charged tracks: Silicon Vertex Detector (SVD)
- Neutrals: Electromagnetic Calorimeter (ECAL)



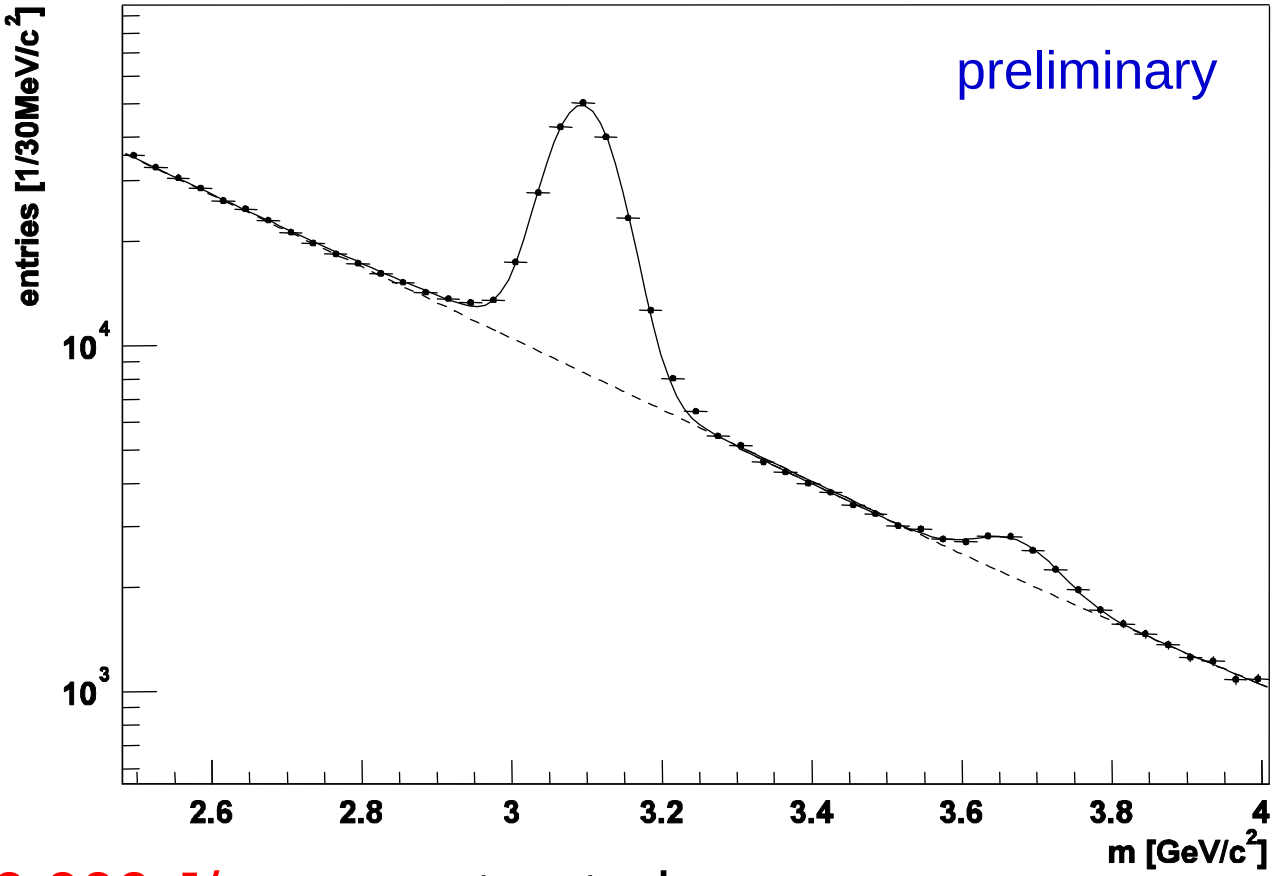
Year 2000 Data Sample

- HERA-B detector was commissioned during year 2000, short physics run before HERA lumi upgrade shutdown.
- In total ~9,000 J/ψ in electron and muon channels.
- 2 papers published:
  - Eur. Phys. J. C26 (2003) 345 (hep-ex/0205106)
    Measurement of the bb production cross section in 920GeV fixed target proton nucleus collisions
  - Phys. Lett. B561 (2003) 61 (hep-ex/0211033)
    J/ψ production via χ_c decays in 920GeV pA interactions
- One more paper based on minimum bias sample:
  - Eur. Phys. J. C, DOI 10.1140/epjc/s2003-01200-y (hep-ex/0212040)
    Inclusive V^0 production cross sections from 920GeV fixed target proton-nucleus collisions

2002/2003 Run

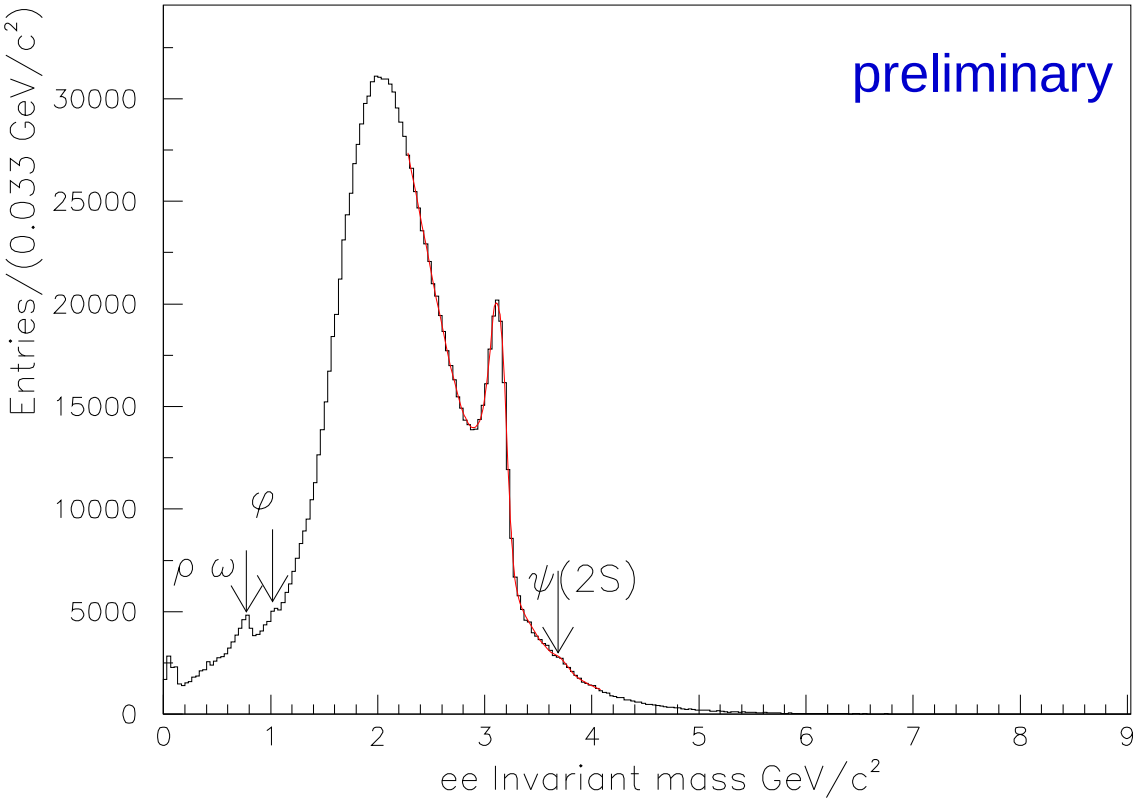
- During lumi upgrade shutdown in 2001 detector and trigger were geatly improved $\Rightarrow$ J/ψ rate in 2002/2003 reached 1000-1500 per hour (x40 increase compared to 2000).
- Accelerator commissioning was slow $\Rightarrow$ we got much less beam-time than expected $\Rightarrow$ J/ψ statistics is 1/10 of aim.
- Collected sample of 150M di-lepton triggers allows to perform many interesting studies.
- In addition data samples with other triggers:
  - 270M minimum bias
  - 10M hard photon (E_T>3GeV)
  - 80M „Glueball“ (low multiplicity minimum bias)

$\mu^+\mu^-$ Mass Spectrum, 2002/2003 Data



- ~170,000 J/ψ reconstructed
- 2,800 ψ(2S) reconstructed

e^+e^- Mass Spectrum, 2002/2003 Data



- ~100,000 J/ψ reconstructed (2/3 of sample)
- S/B ratio greatly improved compared to year 2000

Physics Program 2002/2003

HERA-B ABC (lepton trigger):

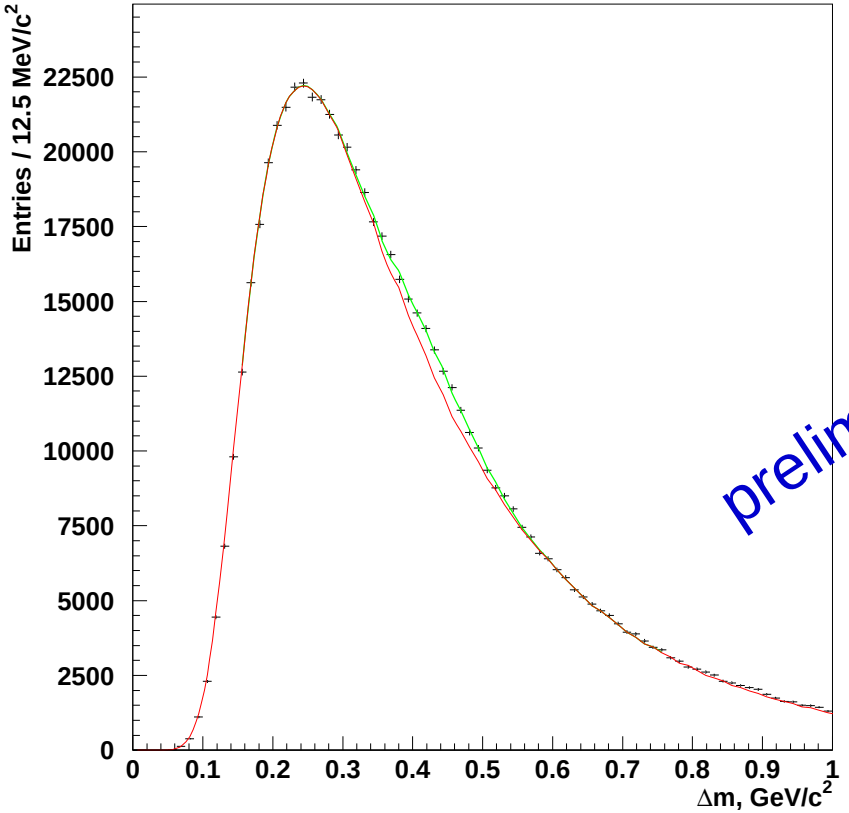
- A-dependence of charmonium production as a function of Feynman-x.
- B cross section.
- Charmonium production ratios: J/ψ, χ_c, ψ(2S).
- Many other items: Υ, Drell-Yan, double charmonium, associated charm, upper limit BR($D^0 \rightarrow \mu^+\mu^-$),..

Other triggers:

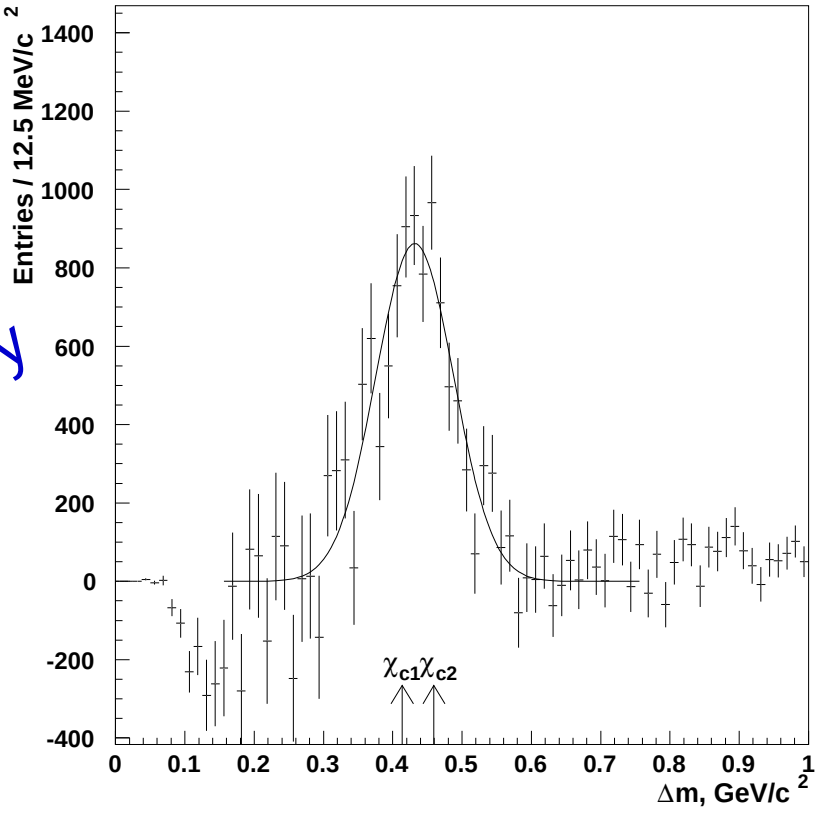
- open charm, J/ψ total cross section, V^0, K*, φ, Hyperon production, Λ polarisation, hard photon, glueball,..

χ_c Production

- Reconstruct $\chi_c \rightarrow J/\psi\ \gamma$ $\Delta m = m(l^+ l^- \gamma) - m(l^+ l^-)$.



preliminary



- ~10,000 $\chi_c \rightarrow \mu^+ \mu^- \gamma$, similar statistics in $\chi_c \rightarrow e^+ e^- \gamma$.
- Large combinatorial background, shape from event mixing.

Diffractive charmonium production

Motivation

- Diffraction is important for studies of soft interactions.
- Diffractive Higgs searches are planned at TEVATRON.

Data

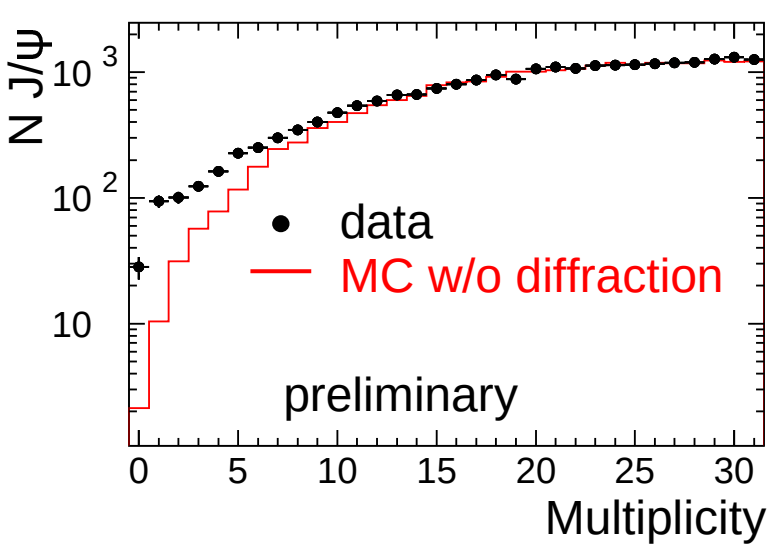
- 86% of $J/\psi \rightarrow \mu^+\mu^-$ sample.
- Events with one primary vertex only (62%).
- Carbon wire only (69%) $\Rightarrow$ 63,000 reconstructed J/ψ.

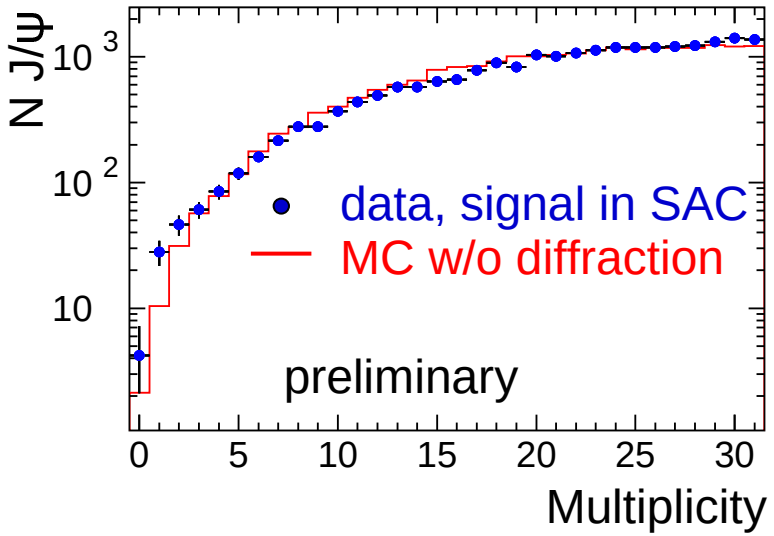
Monte Carlo

- HERA-B standard: PYTHIA for hard interaction + FRITIOF for underlying event (pA). No diffractive J/ψ production.
- MC with diffraction: Soft Color Interaction model (SCI)
  A.Edin, G.Ingelman, J.Rathsman Phys.Lett **B366** (1996) 371.

Multiplicity in Events with $J/\psi \rightarrow \mu^+\mu^-$

- Multiplicity ≡ #ECAL clusters + #VDS segments – $2(\mu^+\mu^-)$

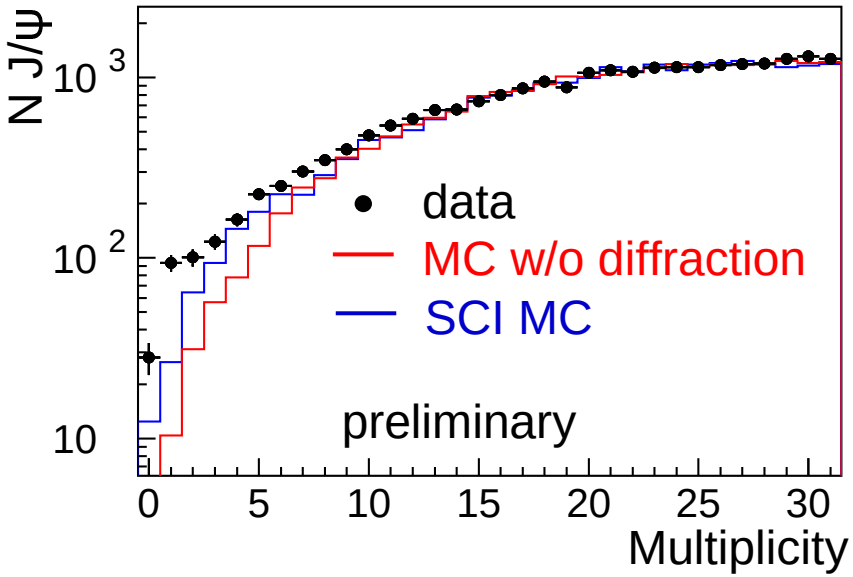




- Discrepancy between data and MC at small multiplicities.
- Excess is suppressed if signal in small angle counters is required ⇔ no rap. gap ⇒ origin of excess is diffraction.

Multiplicity in Events with $J/\psi \rightarrow \mu^+\mu^-$

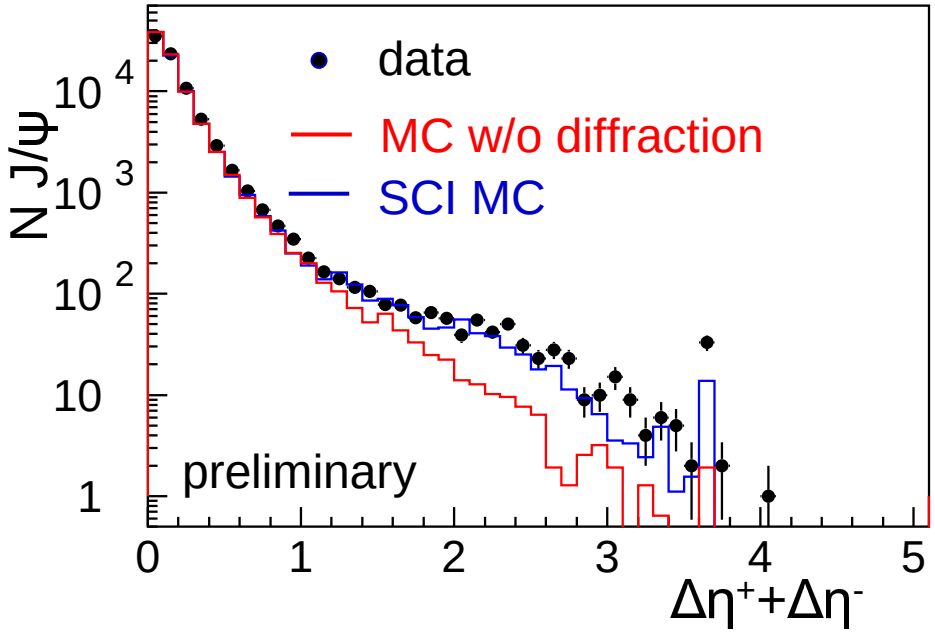
- SCI model describes data better.



- SCI describes pN interactions. We admixed inelastic events generated by FRITIOF to correct for higher multiplicity in pA.

Rapidity Gaps in Events with J/ψ

- Sum of rapidity gaps on both sides of J/ψ ($\Delta\eta^+ + \Delta\eta^-$).



- „Shoulder“ in rapidity gap distribution in data, reproduced by SCI MC, not reproduced by MC w/o diffraction
  ⇒ presence of diffraction.

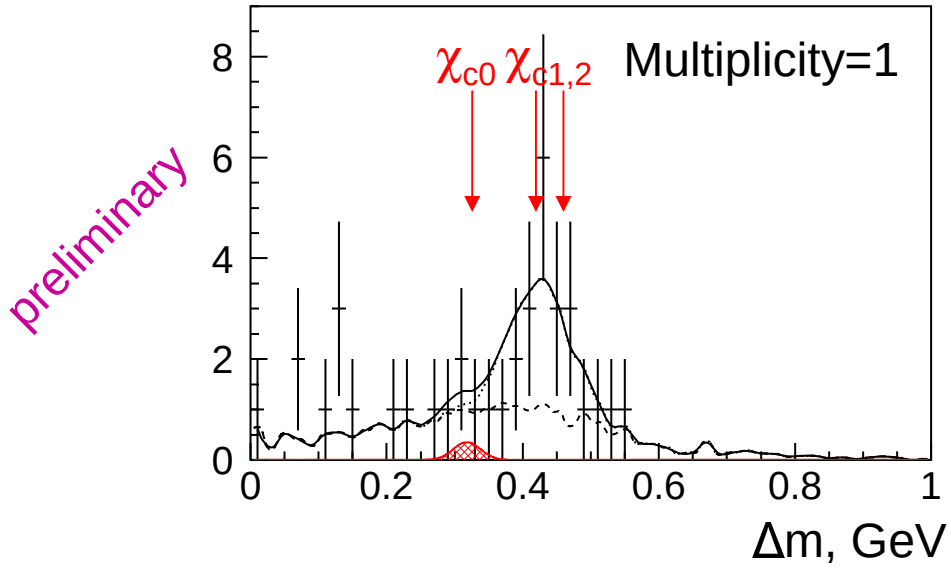
Search for DPE χ_c Production

- $p\ A \rightarrow p' + \chi_c + A'$
- J/ψ can not be produced
- χ_{c1}, χ_{c2} are suppressed compared to χ_{c0}
- BR($\chi_c \rightarrow$J/ψ γ): χ_{c0}=1.02%, χ_{c1}=31.6%, χ_{c2}=18.7%.
- One can observe any of three χ_c states in DPE.

Experimentally:

- p´, A´ are not detected. Signature is χ_c signal in events with $\mu^+ \mu^- \gamma$ only (Multiplicity=1).
- Plot $\Delta m = m(\mu^+ \mu^- \gamma) - m(\mu^+ \mu^-)$ for Multiplicity=1.
- Additional cuts: p_T(J/ψ)<1GeV, veto in small angle counters.

Search for DPE χ_{c0} Production



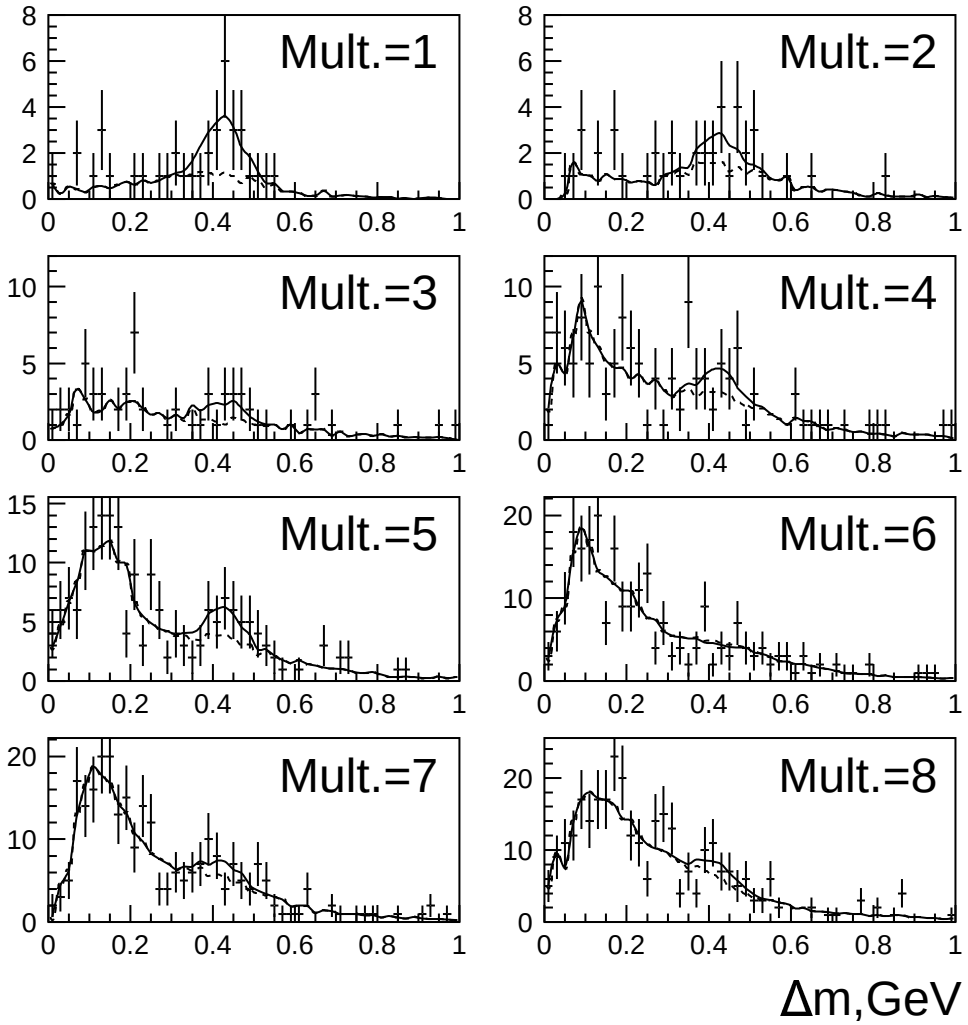
- Signal of χ_{c1}, χ_{c2}.
- No signal of $\chi_{c0} \Rightarrow$ set upper limit: $N(\chi_{c0})=0.9\pm2.0<4.2$ CL90%

(Feldman-Cousins tables)

Very preliminary !

$$\sigma^{DPE}(\chi_{c0})\times Br = \frac{\sigma(J/\psi)\, N(\chi_{c0})}{N(J/\psi)\, \varepsilon(\text{pile-up})\, \varepsilon(\gamma)\, \varepsilon(\text{veto})\, \varepsilon_R} < 0.5\text{nb/Carbon nucleus}$$

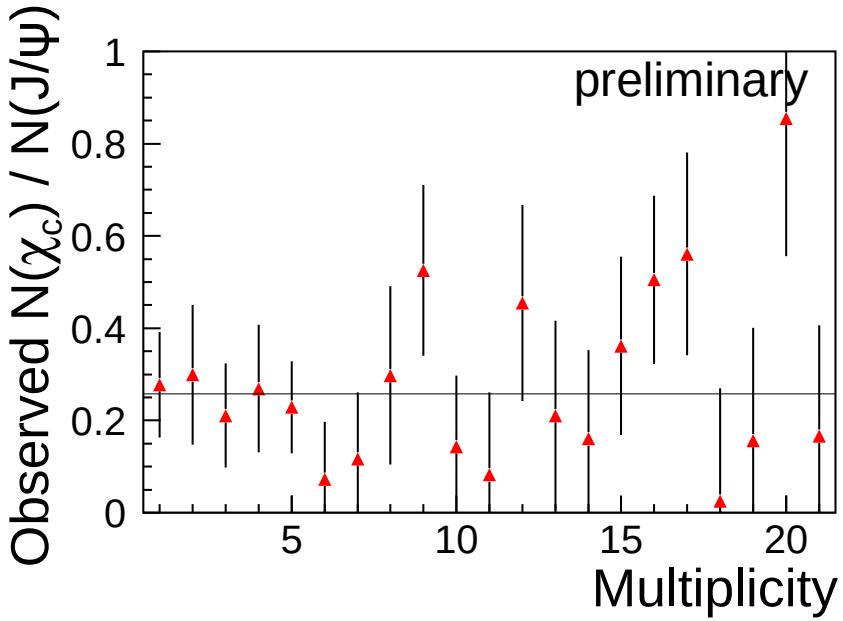
Δm Spectrum in Multiplicity Bins



preliminary

Search for DPE $\chi_{c1,2}$ Production

- Plot observed $N(\chi_{c1,2})$ / $N(J/\psi)$.



Excess over average in 1st bin = 0.16σ

$\Rightarrow N_1^{excess}(\chi_{c1,2}) / N_1(J/\psi) < 0.22$ (Feldman-Cousins tables)

$N_1(J/\psi)=49$

$\Rightarrow N_1^{excess}(\chi_{c1,2}) < 11$ 90% CL

$$\sigma^{DPE}(\chi_{c1,2})\times Br = \frac{\sigma(J/\psi)\, N_1^{excess}(\chi_{c1,2})}{N(J/\psi)\, \varepsilon(\text{pile-up})\, \varepsilon(\gamma)\, \varepsilon(\text{veto})\, \varepsilon_R} < 1.3\text{nb/Carbon nucleus}$$

Very preliminary !

χ_c DPE Production: Expectations

Expectations:

- A.Kaidalov (talk at „HERA-B Workshop on Future Perspectives“):
  $\sigma^{DPE}(\chi_{c0}) \times BR(\chi_{c0} \rightarrow J/\psi\, \gamma) = 0.1 \div 0.3$nb/nucleon
- M.Ryskin (private communications):
  $\sigma^{DPE}(\chi_{c0}) \times BR(\chi_{c0} \rightarrow J/\psi\, \gamma) = 0.007 \div 0.13$nb/nucleon

Upper limit:

- WA102 $\sigma^{DPE}(\chi_c) \times BR < 2$nb, 90%CL

To compare our preliminary result with expectations assume $\alpha^{DPE}=0.4 \Rightarrow$

- $\sigma^{DPE}(\chi_{c0}) \times Br < 0.18$nb/nucleon, 90% CL

Conclusions.

- HERA-B detector was in good shape in 2002/2003.
- Collected data sample is smaller than anticipated but sufficient to make many interesting measurements.
- We observe evidences for diffractive charmonium production.
- We expect to improve upper limit on χ_c DPE production by an order of magnitude.
- HERA-B has stopped data taking after 2002/2003 run.
- Some collaborators are looking for options to continue data taking with existing detector
(Glueball, open charm, direct photons).