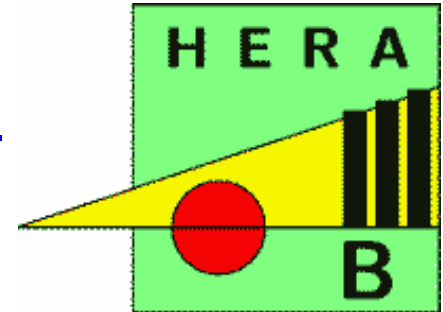


XXXIII International Symposium on Multiparticle Dynamics
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Diffractive Charmonium Production in pA Collisions at 920GeV

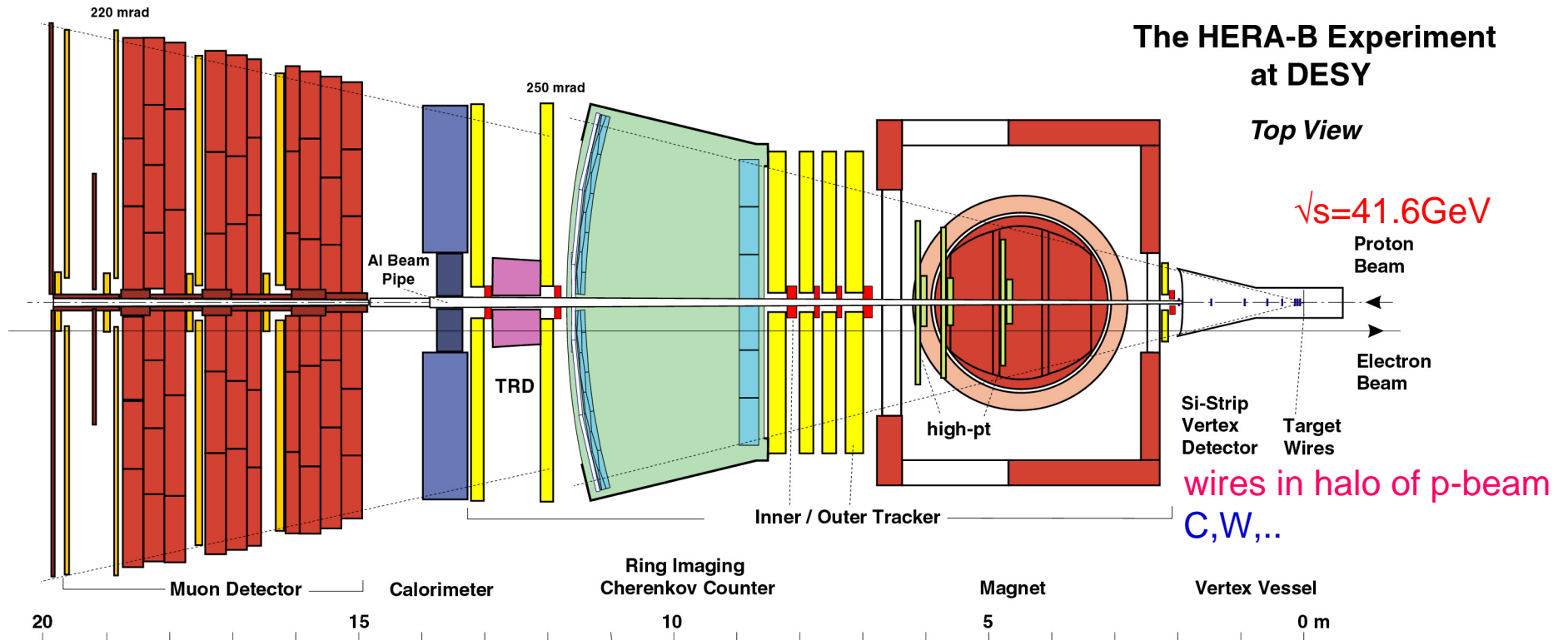


Roman Mizuk (ITEP, Moscow)
for the HERA-B Collaboration

Outline

- HERA-B detector
- Collected data sample & physics issues to address
- Evidence for charmonium production with large rap. gaps
- Search for DPE charmonium production

Schematic View of HERA-B Detector



- Precise vertexing, momentum/energy measurement, PID.
- Powerful trigger system, high interaction rate: **5MHz**
 - $\sigma_{J/\psi}/\sigma_{\text{total}} \sim 10^{-5}$, $\sigma_{\text{bb}}/\sigma_{\text{total}} \sim 10^{-6}$

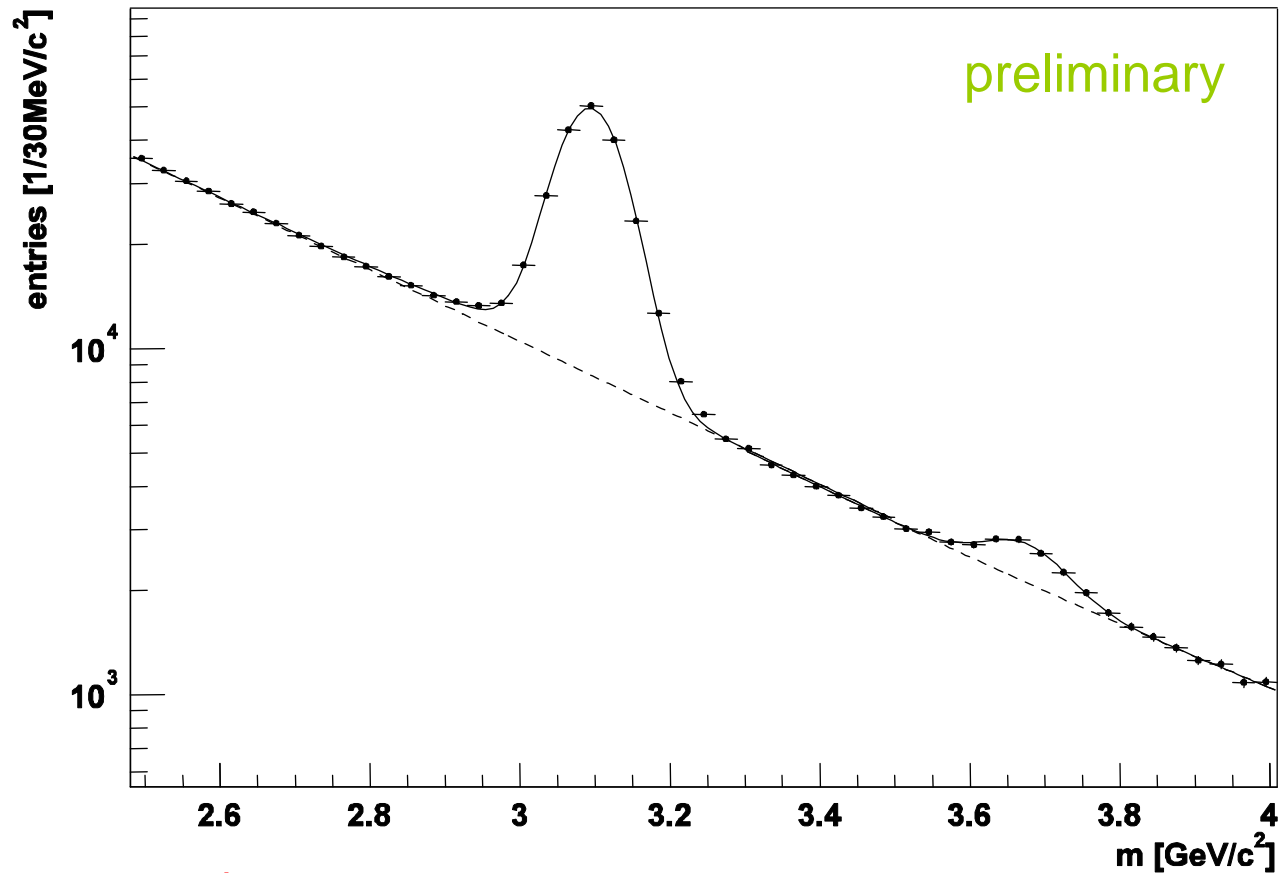
Year 2000 Data Sample

- HERA-B detector was commissioned in 2000.
- Short physics run in 2000 before HERA lumi upgrade shutdown. Collected $\sim 9,000$ J/ψ in e and μ 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. C29 (2003) 181 (hep-ex/0212040)
Inclusive V^0 production cross sections from 920GeV fixed target proton-nucleus collisions

2002/2003 Run

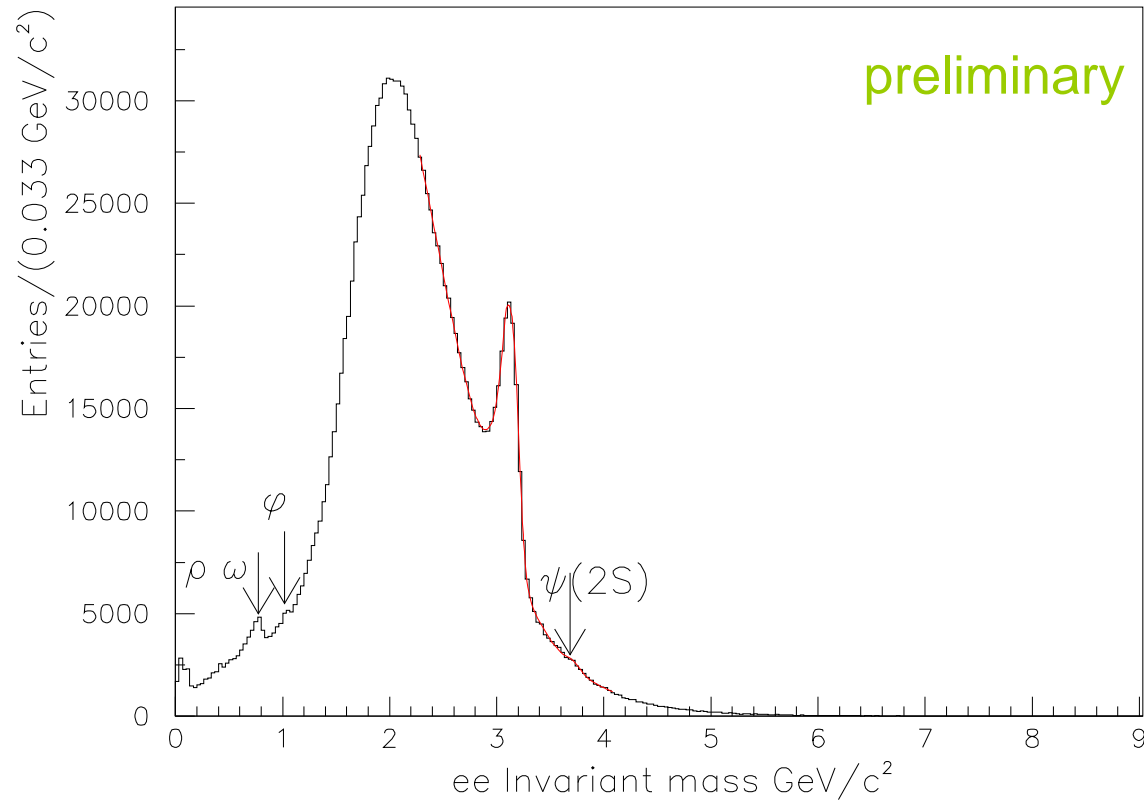
- HERA lumi upgrade shutdown in 2001:
detector and trigger system were greatly improved
⇒ increased J/ψ rate by x40 in 2002/2003 run, reached goal of 1000 J/ψ per hour.
- Accelerator commissioning was slow ⇒ less beam-time than expected ⇒ J/ψ statistics is 1/10 of aim.
- New sample contains 320k J/ψ (x40 statistics of run 2000)
⇒ many interesting studies.
- In addition data samples with other triggers:
 - 270M minimum bias
 - 10M hard photon ($E_T > 3\text{GeV}$)
 - 80M „Glueball“ (low multiplicity minimum bias)

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



- $\sim 170,000$ J/ψ reconstructed
- $2,800$ $\psi(2S)$ reconstructed

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



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

Physics Program 2002/2003

Triggered data:

- A-dependence of charmonium production, especially at negative x_F .
- B cross section.
- Charmonium production ratios: J/ψ , χ_c , $\psi(2S)$.
- Many other items: Υ , Drell-Yan, double charmonium, associated charmonium and charm, diffractive charmonium, $D^0 \rightarrow \mu^+ \mu^-$, ..

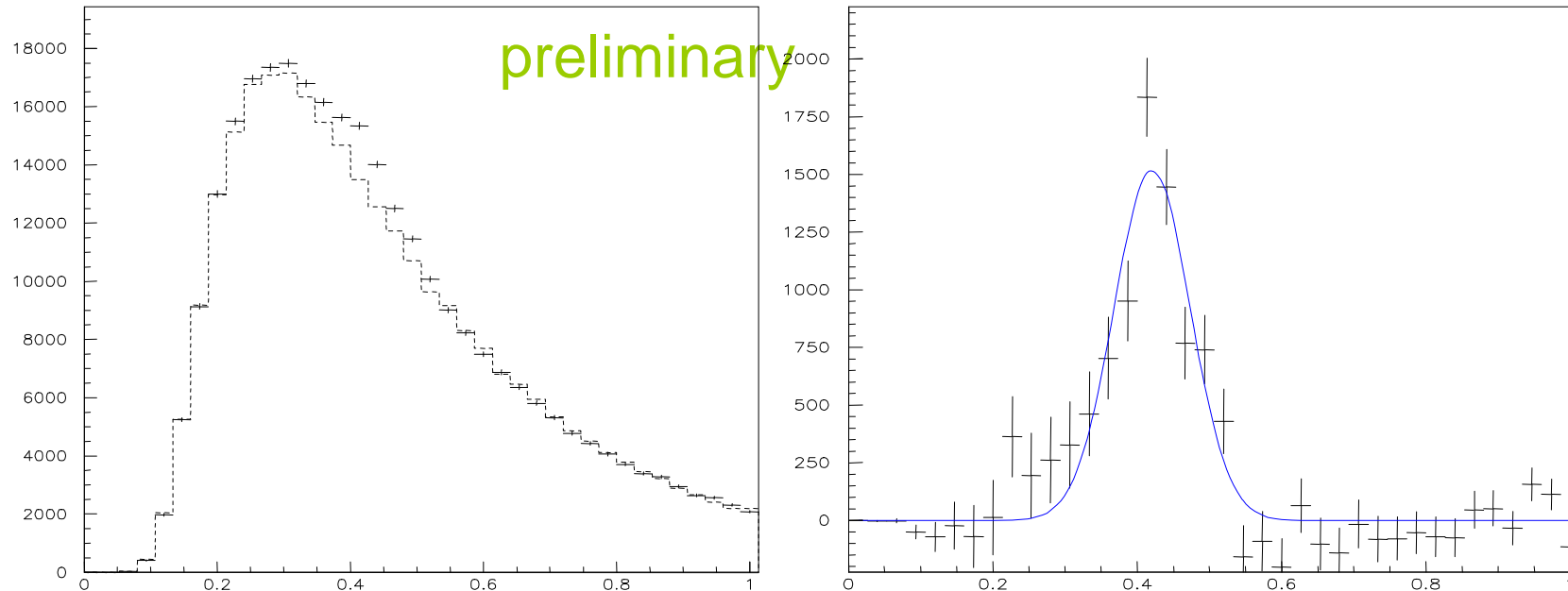
Minimum bias data sample:

- V^0 , K^* , ϕ , Hyperon production, Λ polarisation, open charm, ..

Hard photons, glueball

χ_c Production

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



- Shape of combinatorial background from event mixing.
- $\sim 8,000 \chi_c \rightarrow \mu^+ \mu^- \gamma$, similar statistics in $\chi_c \rightarrow e^+ e^- \gamma$.

Diffractive Charmonium Production

Why at HERA-B?

- Nuclear dependence of diffractive charmonium production
← understanding of nuclear effects.
- DPE Higgs production searches are planned at TEVATRON
← proof of principle.

Data:

- 86% $J/\psi \rightarrow \mu^+\mu^-$ sample.

Monte Carlo:

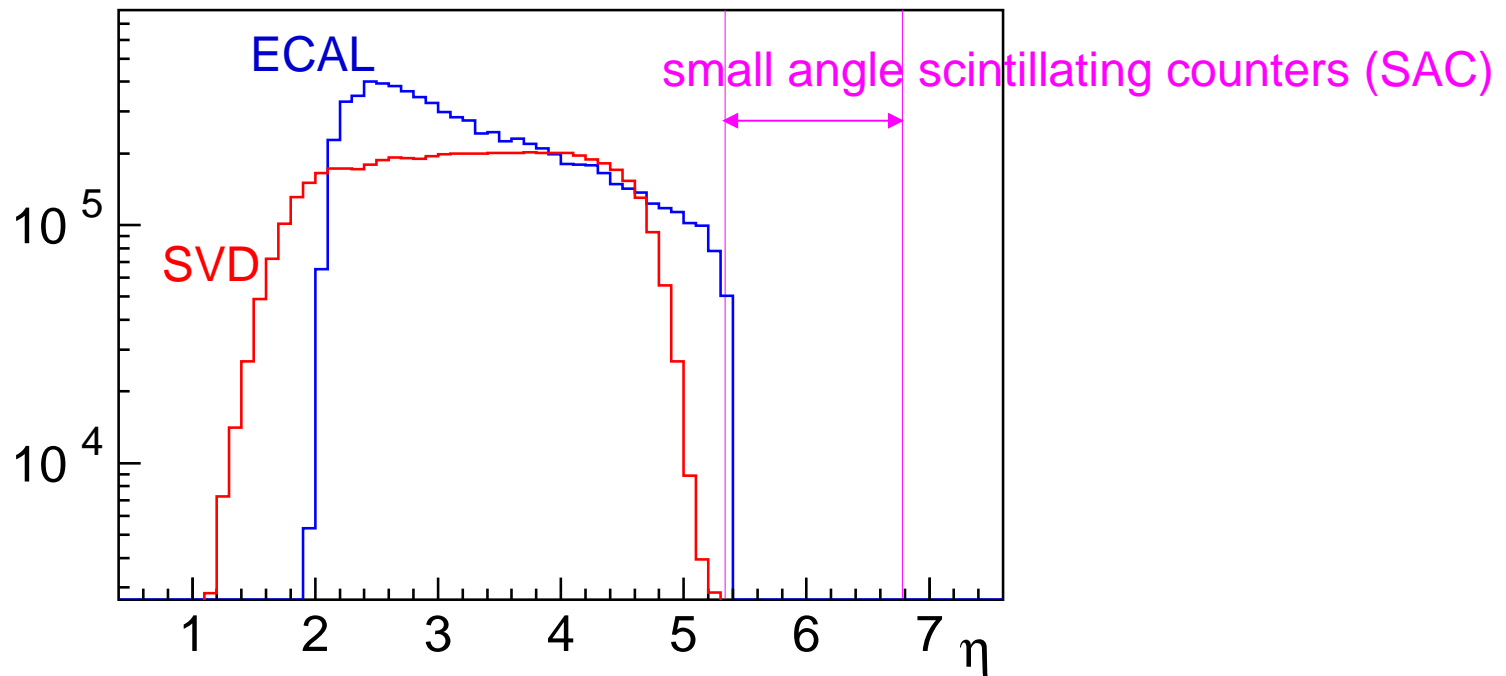
- PYTHIA for hard interaction + FRITIOF for underlying event.

Method:

- Not possible to detect forward proton.
- Selection based on rapidity gaps on both sides of J/ψ .

HERA-B Rapidity Coverage

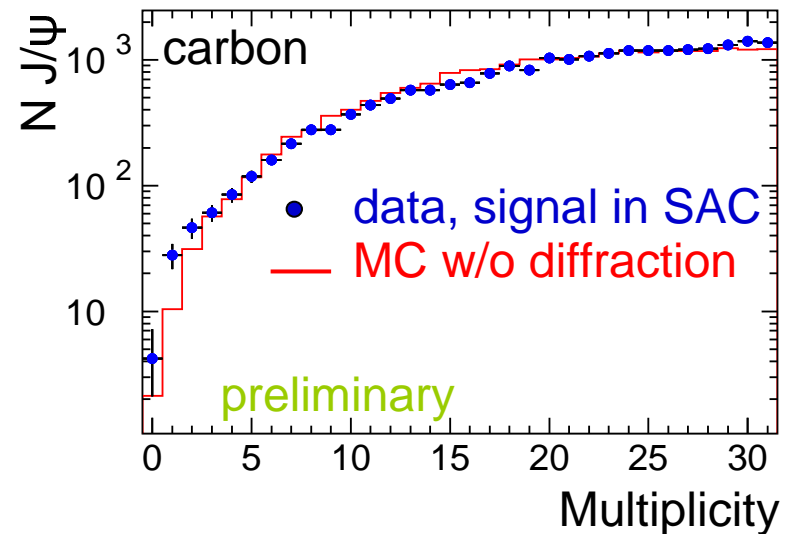
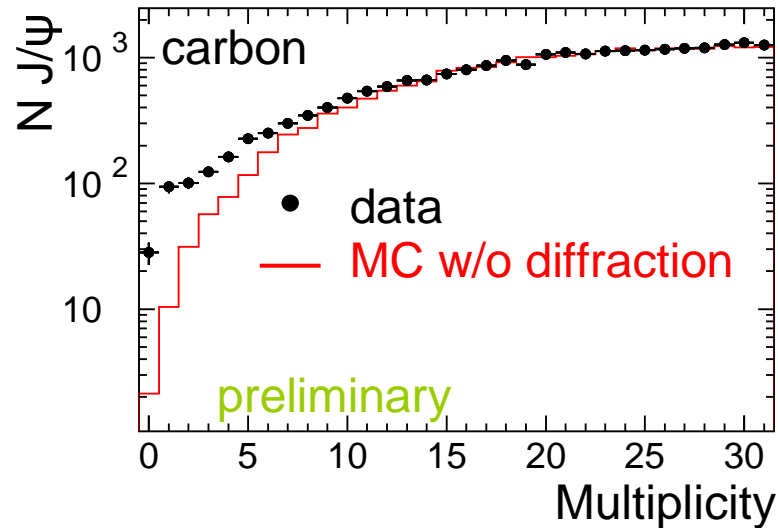
- Charged tracks: Silicon Vertex Detector (SVD)
- Neutrals: Electromagnetic Calorimeter (ECAL)



- Large rapidity gaps \equiv small multiplicities.

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

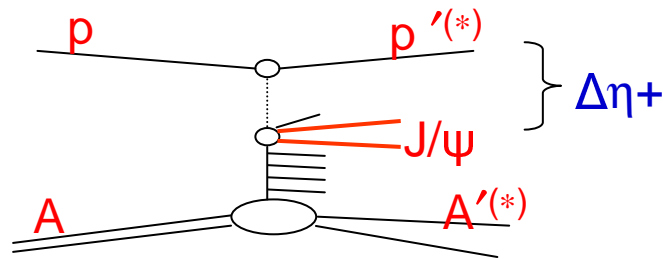
Multiplicity \equiv #ECAL clusters + #VDS segments $- 2(\mu^+\mu^-)$



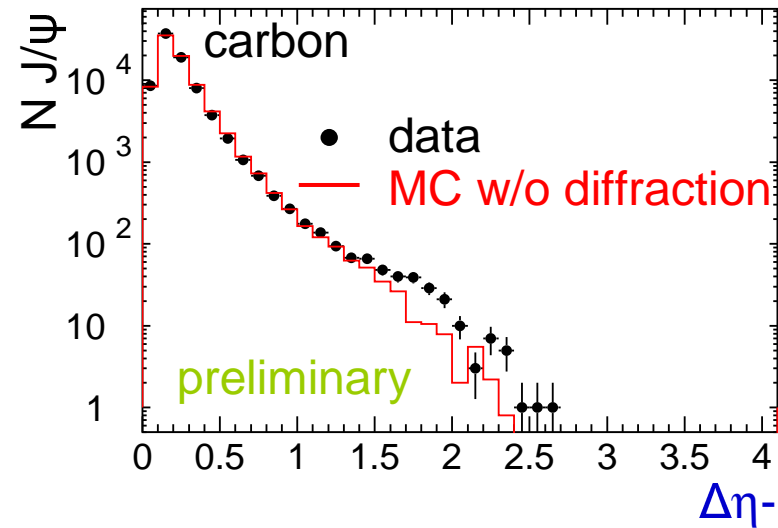
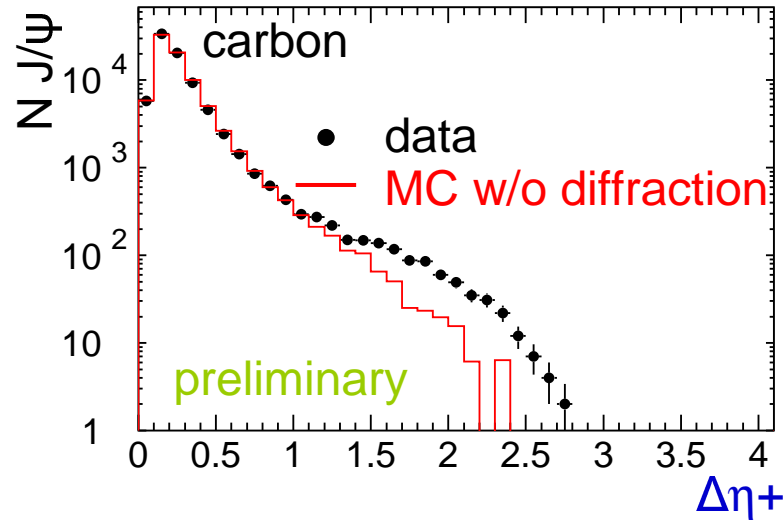
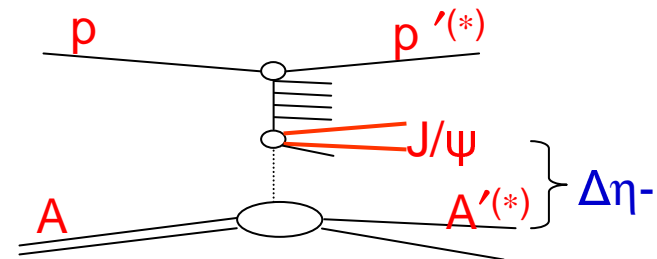
- Excess in data over MC at small multiplicities.
- If signal in small angle counters is required excess disappears
 \Rightarrow excess is due to events with rapidity gaps in forward direction.

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

r.g. in forward direction



r.g. in backward direction

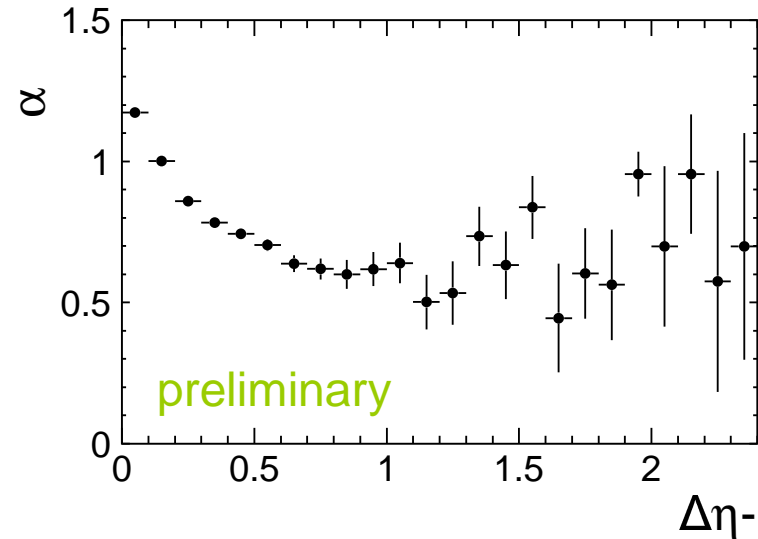
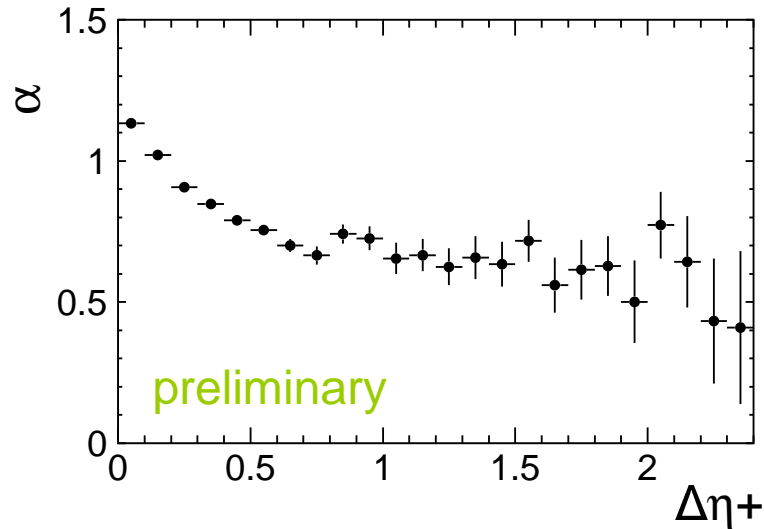


- Excess for r.g. in forward direction is larger than in backward.
- For diffractive production of J/ψ expect opposite
 \Leftarrow coherent diffraction (A' is intact) \Rightarrow to be understood

A-dependence for Events with Rap.Gaps

$$\sigma_A = \sigma_1 A^\alpha$$

materials : C and W



- Absolute normalization from E866 measurement ($\alpha=0.955$).
- For diffractive production expect $\alpha \sim 0.3$ (peripheral pA), for inclusive production $\alpha \sim 1$.
- Considerable contribution from inclusive production for events with large $\Delta\eta_-$.

Search for DPE χ_c Production

- Double Pomeron Exchange (DPE):

$$p A \rightarrow p' (*) + \chi_c + A' (*)$$

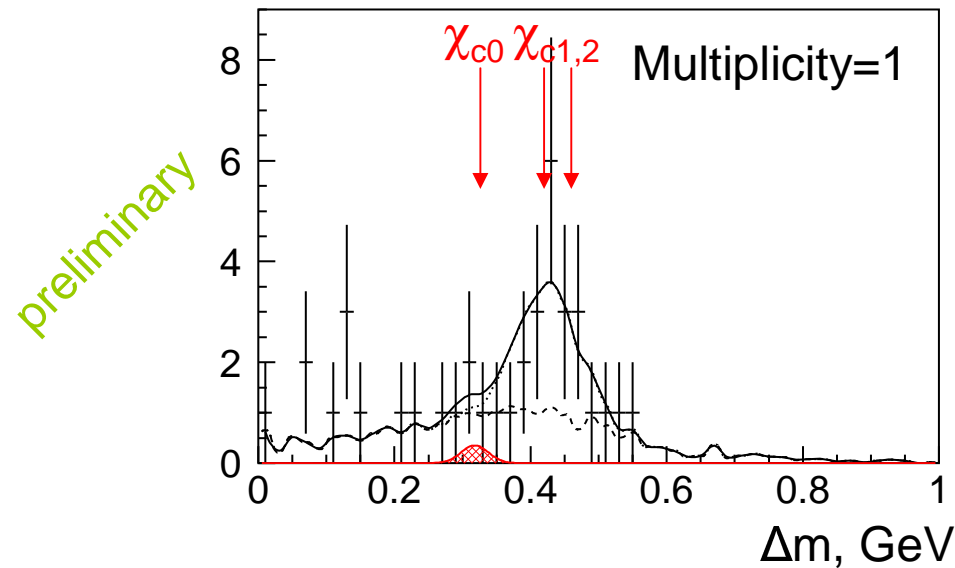
- J/ ψ can not be produced in DPE (C=-1).
- Production of χ_{c1} , χ_{c2} is suppressed compared to χ_{c0} .
- BR($\chi_c \rightarrow J/\psi \gamma$): $\chi_{c0}=1.02\%$, $\chi_{c1}=31.6\%$, $\chi_{c2}=18.7\%$.
- One can observe any of three χ_c states in DPE.

Experimentally:

- $p' (*)$, $A' (*)$ are not detected. Signature is χ_c signal in events with $\mu^+ \mu^- \gamma$ only (Multiplicity=1).
- Cuts: $p_T(J/\psi) < 1 \text{ GeV}$, veto in small angle counters.

Search for DPE χ_{c0} Production

- Plot $\Delta m = m(l^+ l^- \gamma) - m(l^+ l^-)$ for events with Multiplicity=1.

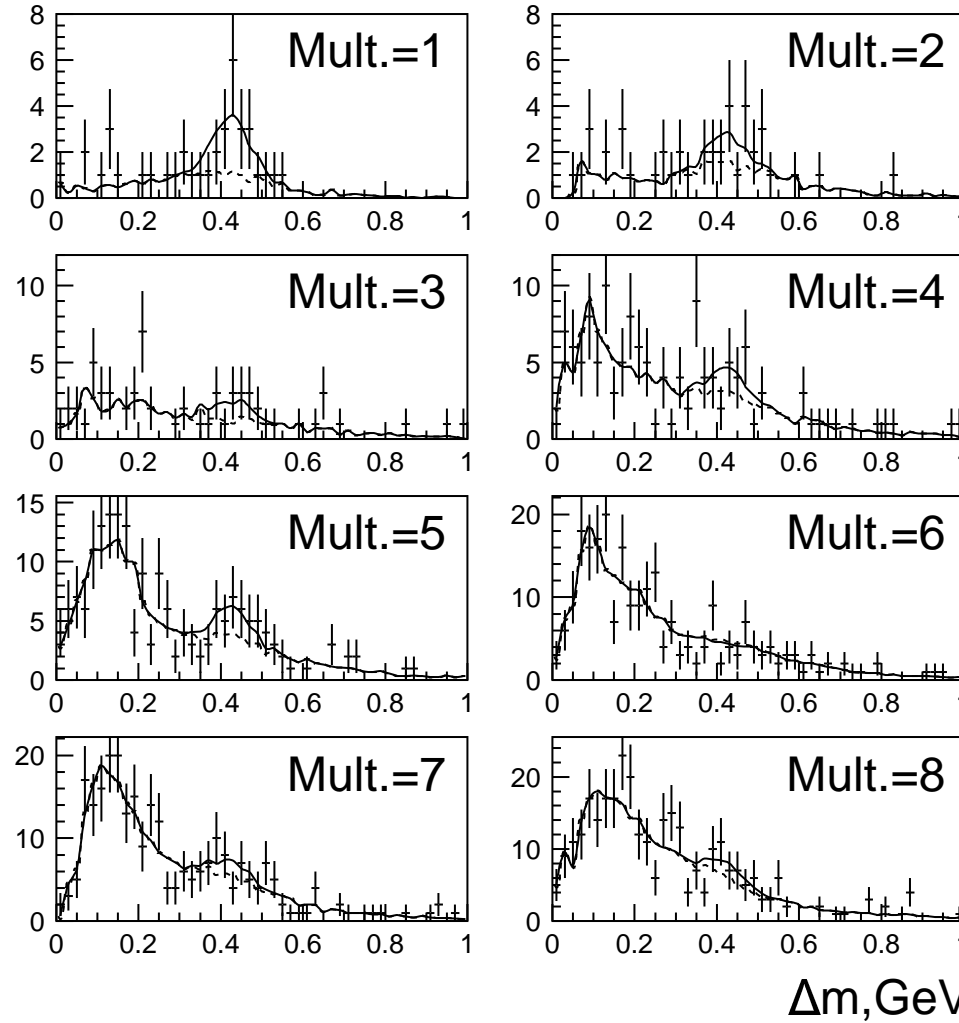


- Signal of χ_{c1} , χ_{c2} .
- No signal of χ_{c0} .

$\Rightarrow \sigma^{\text{DPE}}(\chi_{c0}) \times \text{Br}(\chi_{c0} \rightarrow J/\psi \gamma) < 0.5 \text{ nb/carbon nucleus, 90\% CL}$

very preliminary

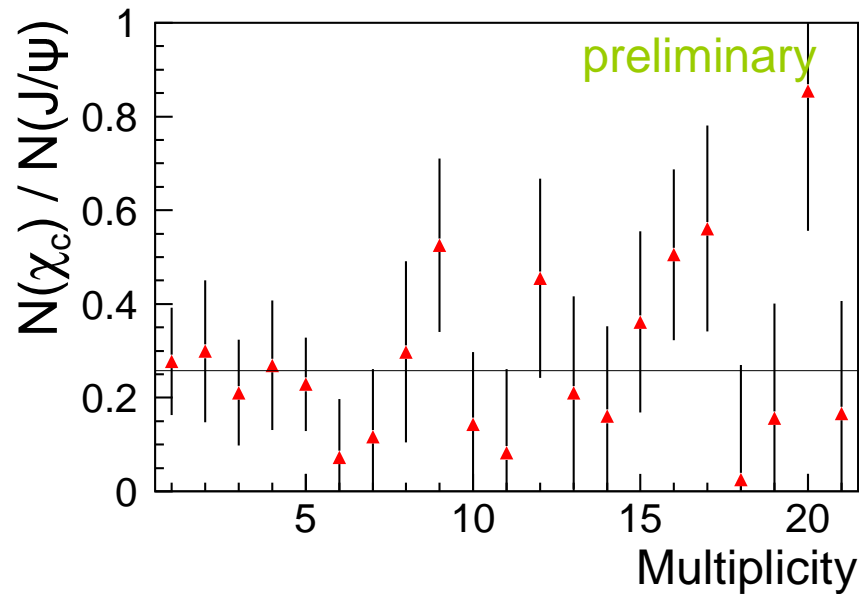
Δm Spectrum in Multiplicity Bins



preliminary

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

- Plot ratio $N(\chi_{c1,2}) / N(J/\psi)$ in Multiplicity bins (not corrected).



- No significant enhancement at Multiplicity~1
 $\Rightarrow \sigma^{\text{DPE}}(\chi_{c1,2}) \times \text{Br}(\chi_c \rightarrow J/\psi \gamma) < 1.3 \text{ nb/carbon nucleus, 90\% CL}$
very preliminary

χ_c DPE Production: Expectations

Expectations:

- For HERA-B can be recalculated from existing predictions for TEVATRON (A.Kaidalov, M.Ryskin)
- Large uncertainty:
 $\sigma^{\text{DPE}}(\chi_{c0}) \times \text{BR}(\chi_{c0} \rightarrow \text{J}/\psi \gamma) = 0.01 \div 0.3 \text{ nb/nucleon}$

Previous measurements:

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

To compare our preliminary result with expectations assume $\alpha^{\text{DPE}} = 0.3 \Rightarrow$

- HERA-B : $\sigma^{\text{DPE}}(\chi_{c0}) \times \text{Br} < 0.23 \text{ nb/nucleon}, 90\% \text{ CL}$

Conclusions

- HERA-B experiment reached planned J/ψ rate in 2002/3 run.
- Collected data sample is smaller than anticipated, sufficient to make many interesting measurements.
- We observe evidences for charmonium production with large rapidity gaps in forward direction.
- We set upper limits on DPE χ_c production cross section.
- HERA-B has stopped data taking after 2002/3 run.
- Some collaborators are looking for options to continue data taking with existing detector (charmonium, glueball, open charm, direct photons).