



Some considerations on the MPD and SPD performance for heavy flavour studies

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Contributors

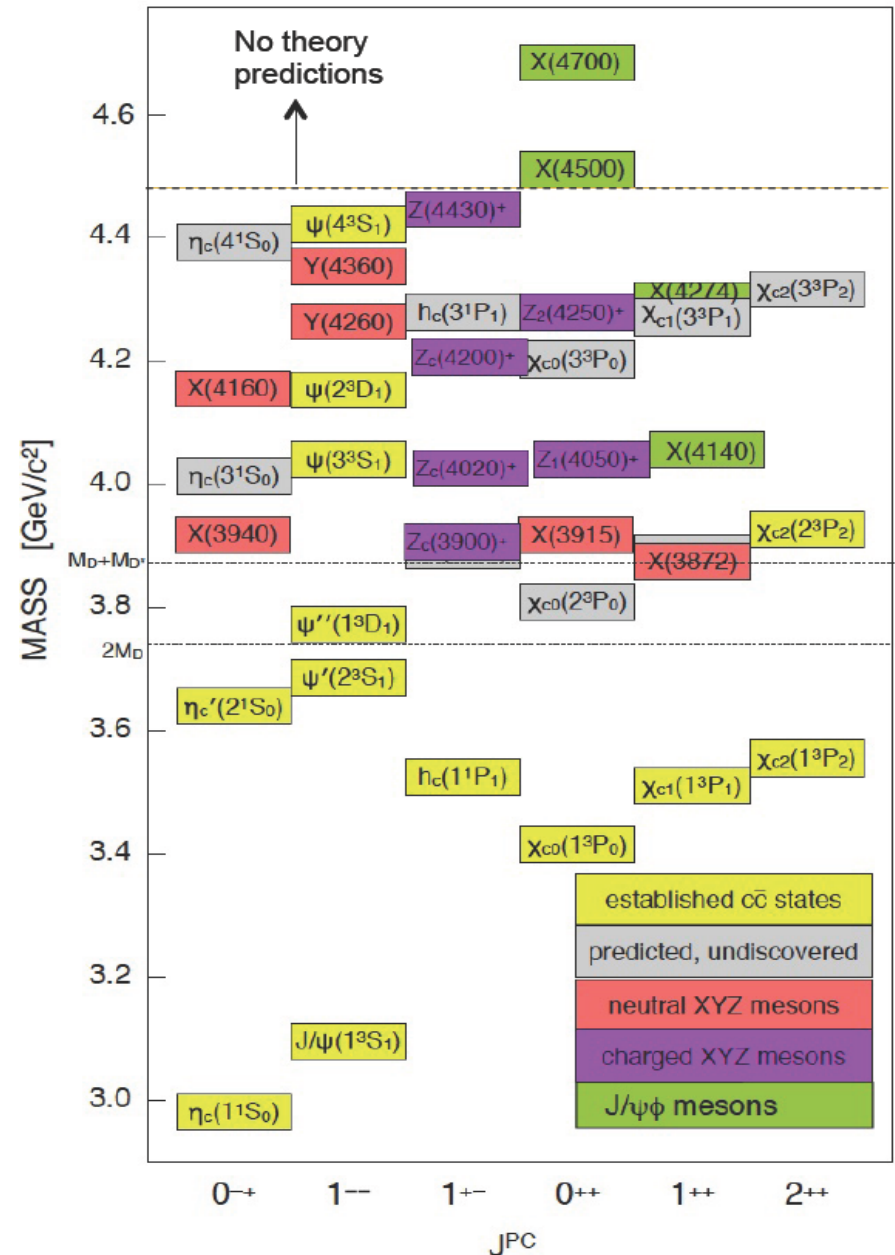
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Outline

1. *Motivation*
2. *NICA complex and MPD detector*
3. *Software used*
4. *Charm in pp*
5. *Charm in pA*
6. *Charm in AA*
7. *Summary / conclusions*

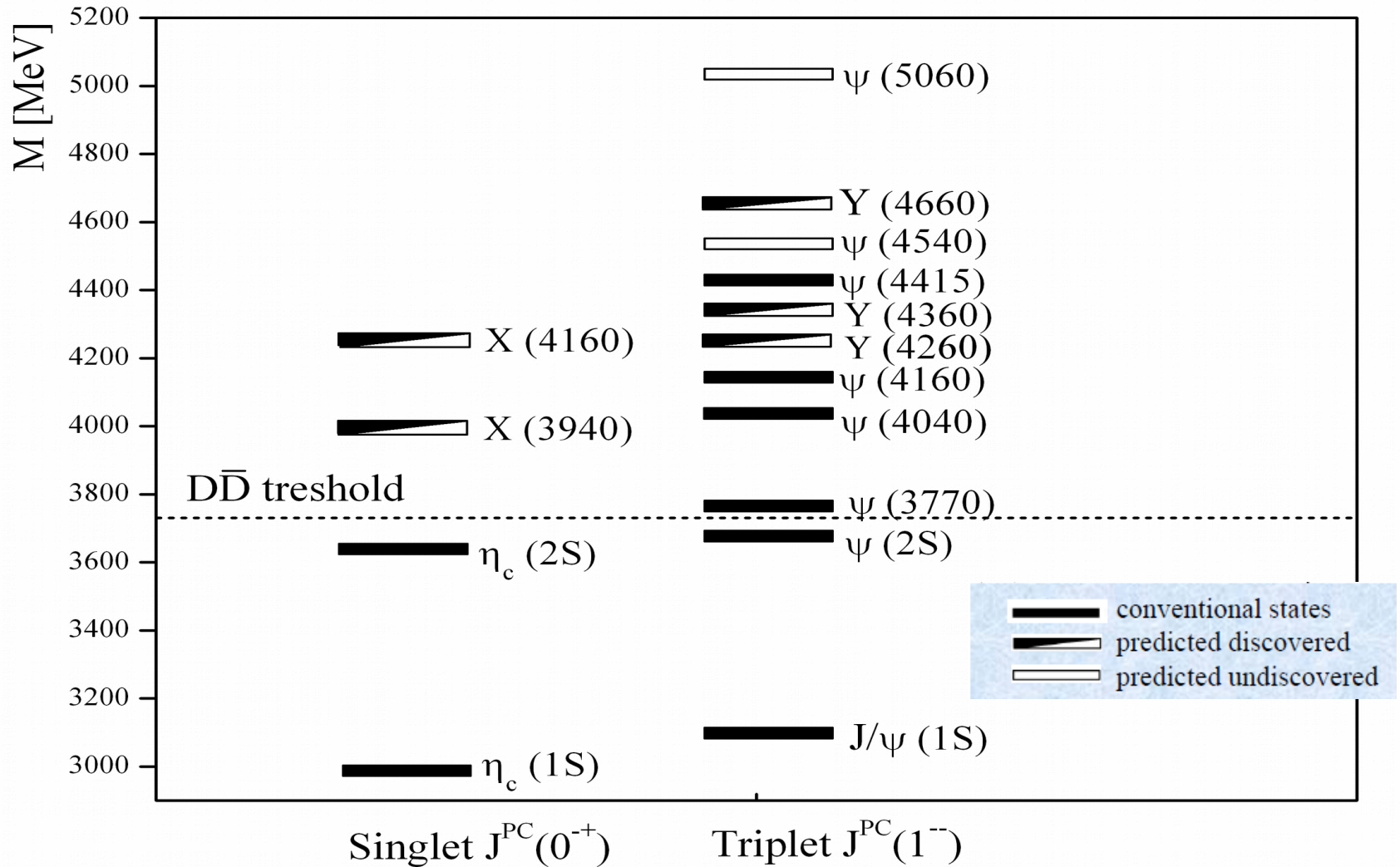
Motivation

- Predicted neutral charmonium states compared with found $c\bar{c}$ states, & both neutral & charged exotic candidates
- Based on Olsen [\[arXiv:1511.01589\]](https://arxiv.org/abs/1511.01589)
- Added 4 new $J/\psi\phi$ states



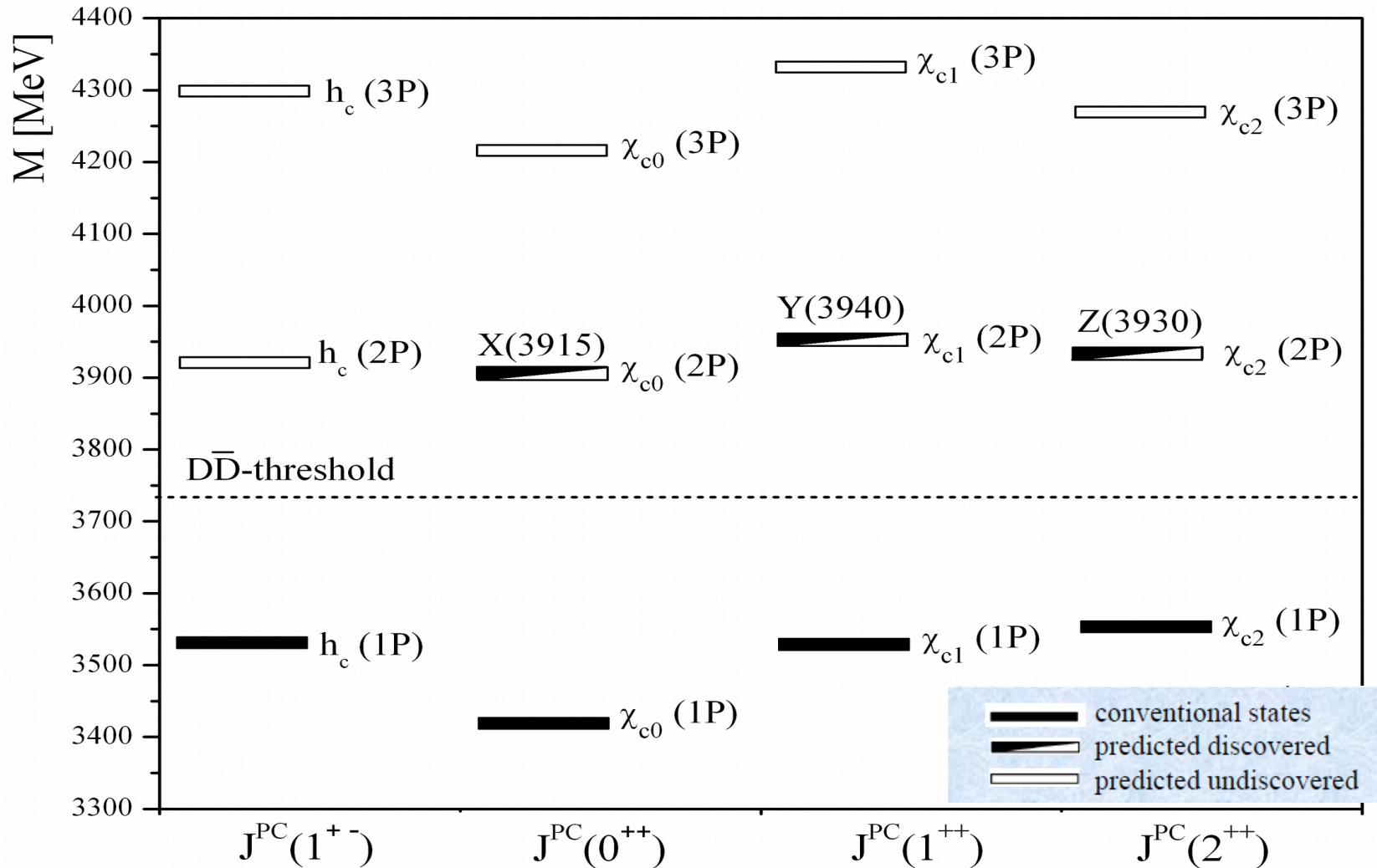
Motivation

THE SPECTRUM OF SINGLET (1S_0) AND TRIPLET (3S_1) STATES OF CHARMONIUM

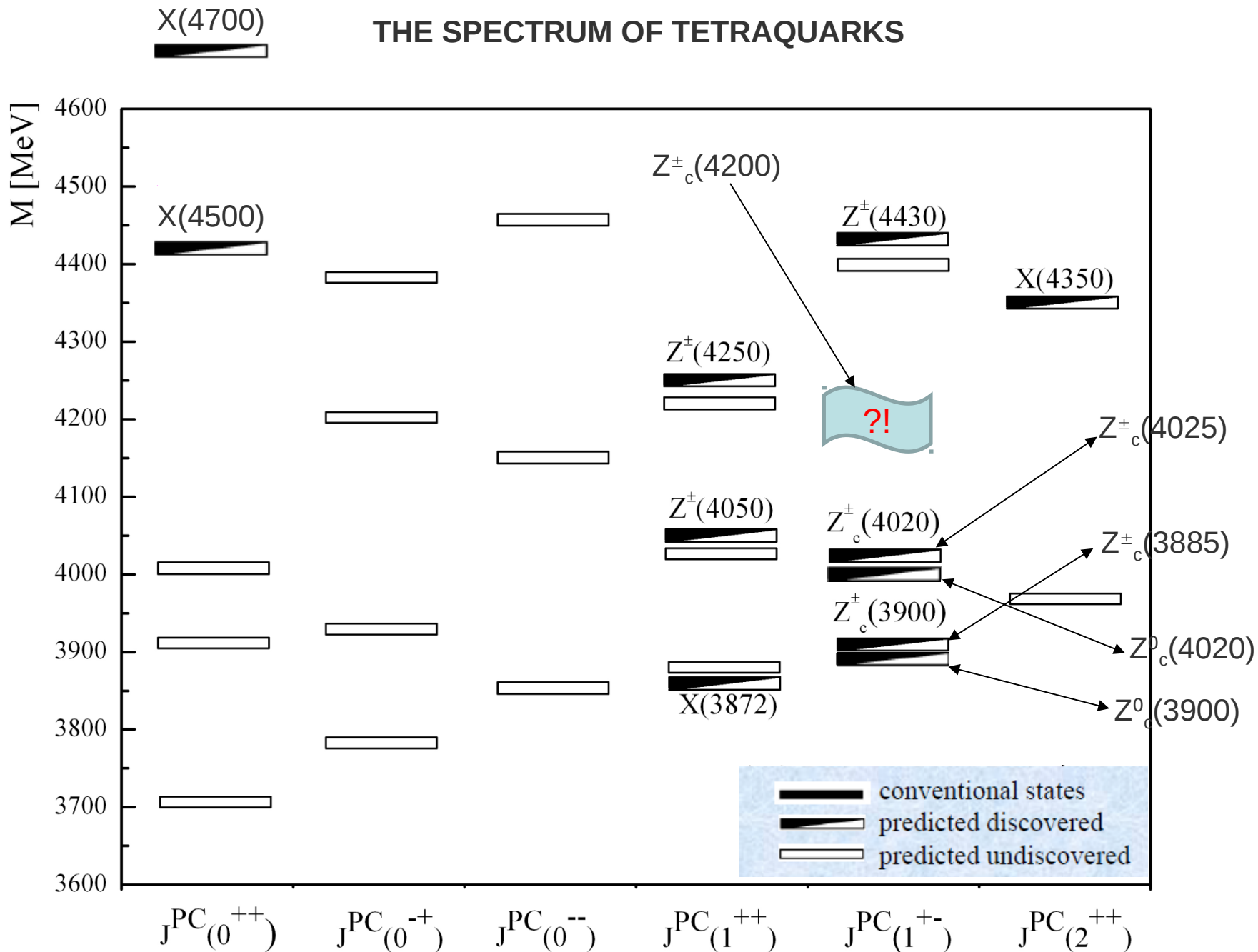


Motivation

THE SPECTRUM OF SINGLET (1P_1) AND TRIPLET (3P_J) STATES OF CHARMONIUM



THE SPECTRUM OF TETRAQUARKS



Motivation

To look for different charmonium-like states (conventional and exotic) in pp and pA collisions to obtain complementary results to the ones from e^+e^- and $p\bar{p}$ interactions

Charmonia measurements

Phys.Lett. B438 (1998) 35-40

EUROPEAN LABORATORY FOR PARTICLE PHYSICS

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Charmonia production in 450 GeV/c proton induced reactions

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NA38 Collaboration

Abstract

Absolute J/ψ and ψ' production cross sections have been measured at the CERN SPS, with 450 GeV/c protons incident on a set of C, Al, Cu and W targets. Complementing these values with the results obtained by experiment NA51, which used the same beam and detector with H and D targets, we establish a coherent picture of charmonia production in proton-induced reactions at SPS energies. In particular, we show that the scaling of the J/ψ cross section with the mass number of the target, A , is well described as A^α , with $\alpha^\psi = 0.919 \pm 0.015$. The ratio between the J/ψ and ψ' yields, in our kinematical window, is found to be independent of A , with $\alpha^{\psi'} - \alpha^\psi = 0.014 \pm 0.011$.

Accepted by Physics Letters B

J/ψ , ψ' and Drell-Yan production in pp and pd interactions at 450 GeV/c

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NA51 Collaboration

J/ψ and ψ' production cross-sections are measured in pp and pd collisions at 450 GeV/c at the CERN-SPS. The Drell-Yan cross section for muon pairs in the mass range $[4.3 - 8.0]$ GeV/c² is also determined in the same experiment.

Charmonia measurements

NA38 (1998)

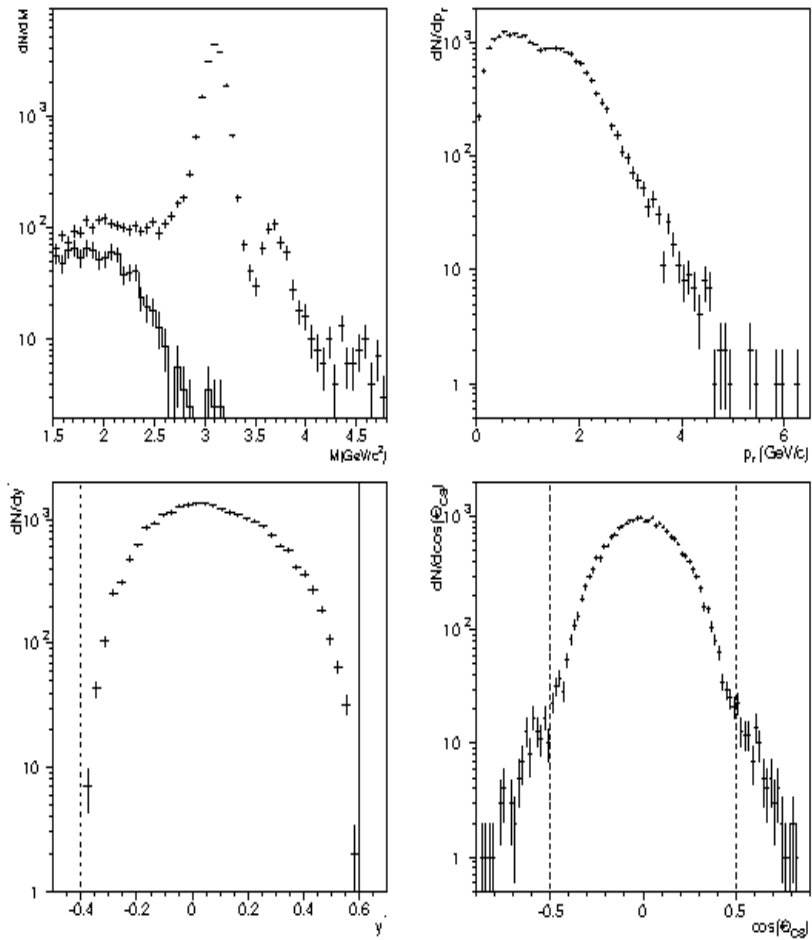


Figure 1: Dimuon mass, transverse momentum, rapidity and $\cos(\theta_{CS})$ distributions, for the p-Cu (10.1) data set. The dimuon mass figure includes the background distribution.

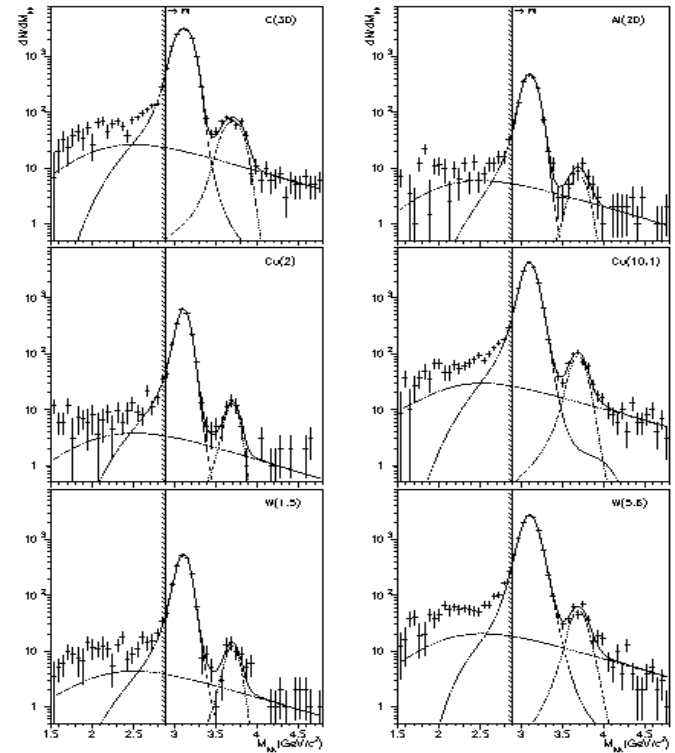


Figure 2: Mass spectra, after background subtraction, for the six data sets. The three components of the fit, performed in the mass window above 2.9 GeV/c², are also shown.

Charmonia measurements

NA38

NA51

Table 4: J/ψ and ψ' absolute cross sections, in the dimuon channel, for the measured p-A reactions. Systematic uncertainties, not included, amount to 7%.

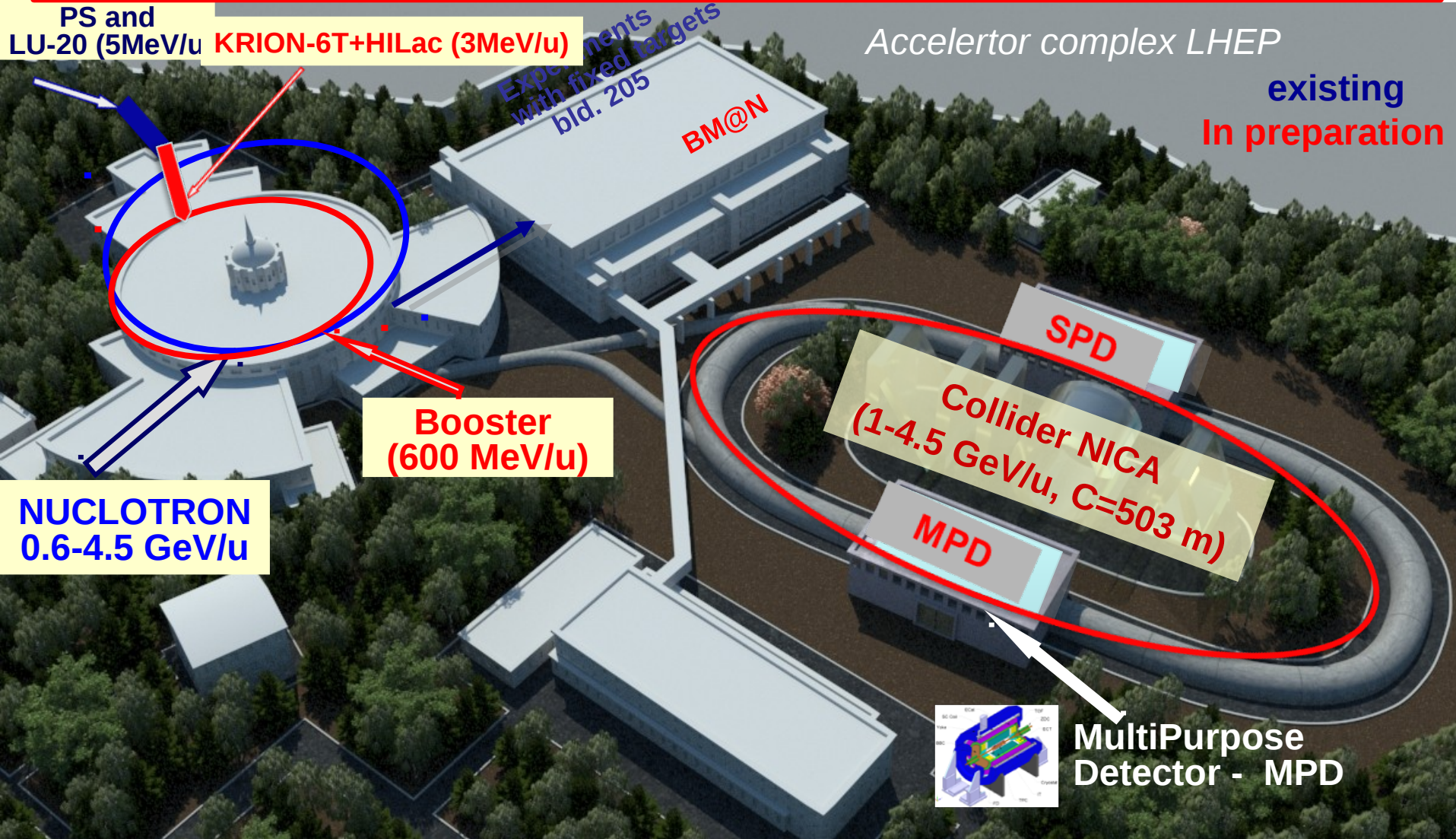
	\mathcal{L} (nb ⁻¹)	N^ψ	$B_{\mu\mu}^\psi \sigma^\psi$ (nb)	$B_{\mu\mu}^{\psi'} \sigma^{\psi'}$ (nb)
C	2232.5	15014 ± 140	55.8 ± 0.6	1.06 ± 0.07
Al	136.4	1851 ± 48	112.1 ± 2.8	1.52 ± 0.39
Cu (2)	63.0	2083 ± 51	267.8 ± 6.3	4.66 ± 0.31
Cu (10.1)	518.4	16522 ± 140	263.5 ± 2.4	4.58 ± 0.29
W (1.5)	25.4	1896 ± 48	606.1 ± 14.8	9.63 ± 0.77
W (5.6)	136.7	11533 ± 118	692.6 ± 7.4	11.00 ± 0.87

Target	H2	D2
N_ψ	301236 ± 601	312204 ± 630
$N_{\psi'}$	5705 ± 127	6219 ± 131
N_{DY}	1910 ± 44	2120 ± 46
$B\sigma_\psi$ (nb)	5.50 ± 0.01 ± 0.36(0.06)	11.32 ± 0.03 ± 0.75(0.13)
$B'\sigma_{\psi'}$ (nb)	0.086 ± 0.002 ± 0.006(0.003)	0.188 ± 0.004 ± 0.015(0.006)
σ_{DY} (pb)	25.3 ± 0.6 ± 1.8(0.5)	55.0 ± 1.2 ± 3.9(1.2)
$B'\sigma_{\psi'}/B\sigma_\psi$ (%)	1.60 ± 0.04 ± 0.02	1.72 ± 0.04 ± 0.025
$B\sigma_\psi/\sigma_{DY}$	54.7 ± 1.0 ± 1.3	53.8 ± 1.0 ± 0.5

Table 3: Numbers of J/ψ , ψ' and Drell-Yan events in the mass range [4.3–8.0] GeV/ c^2 as well as the corresponding cross sections. B and B' are the branching ratios of the decay of J/ψ and ψ' resonances into two muons. Ratios of cross sections are also given. In the case of the ratio $B\sigma_\psi/\sigma_{DY}$, Drell-Yan pairs are taken in the mass range [2.9–4.5] GeV/ c^2 in order to allow the comparison with other data from the NA38 experiment. Finally, the numbers given in parenthesis correspond to the fraction of systematic error which has to be taken into account in the comparison of the two targets.

Complex **NICA**

Collider basic parameters: *beams: from p to Au;*
 $L \sim 10^{27} \text{ cm}^{-2} \text{ c}^{-1}$ (Au), $\sqrt{s_{NN}} = 4-11 \text{ GeV}$; $\sim 10^{32} \text{ cm}^{-2} \text{ c}^{-1}$ (p), $\sqrt{s} = 12-26 \text{ GeV}$;



The MPD apparatus

Magnet: 0.5 T superconductor

Tracking: TPC, ECT, IT

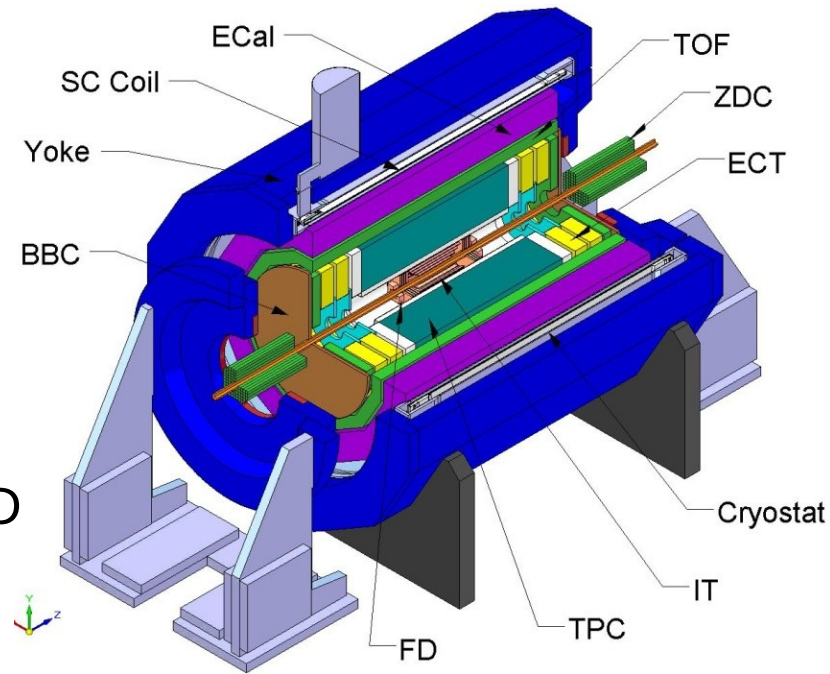
Particle ID: TOF, ECal, TPC

T_0 , Triggering: FFD

Centrality, Event plane: ZDC

Stage 1: TPC, Barrel TOF& ECal, ZDC, FFD

Stage 2: IT + EndCaps (tracker, TOF, ECal)



Detector features:

- Minimal dead time, event rate capability up to ~ 6 kHz.
- Hermeticity, homogeneous acceptance: 2π in azimuthal angle.
- Highly efficient 3-D track reconstruction ($|\eta| < 2$), high resolution vertexing.
- Powerful PID: π/K up to 1.5 GeV/c, K/p up to 3 GeV/c, ECal for γ , $e^{+/-}$.
- Careful event characterization: impact parameter & event plane reconstruction.

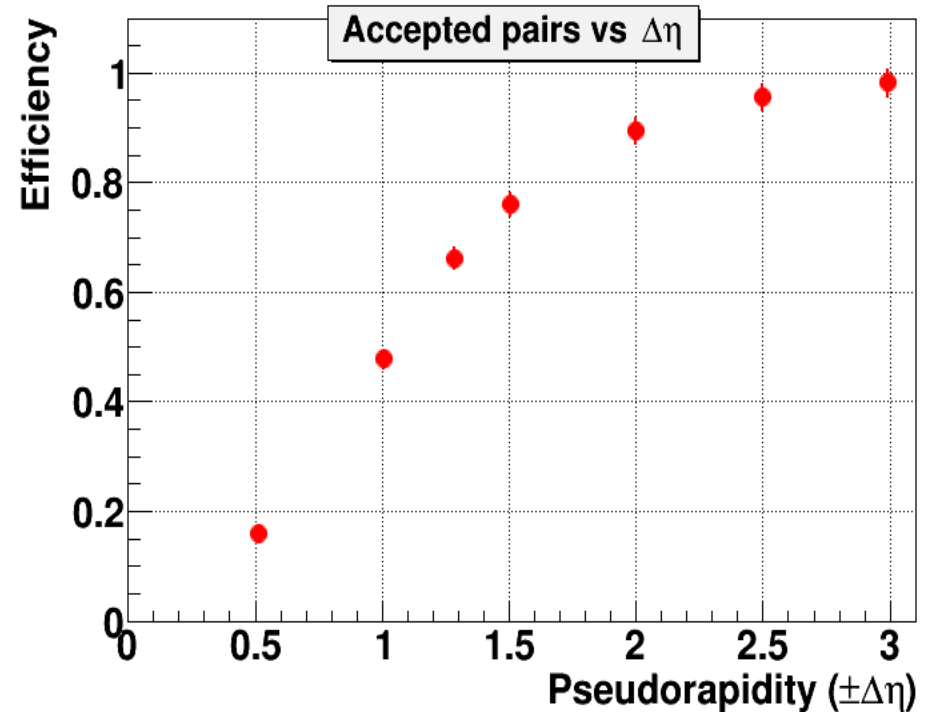
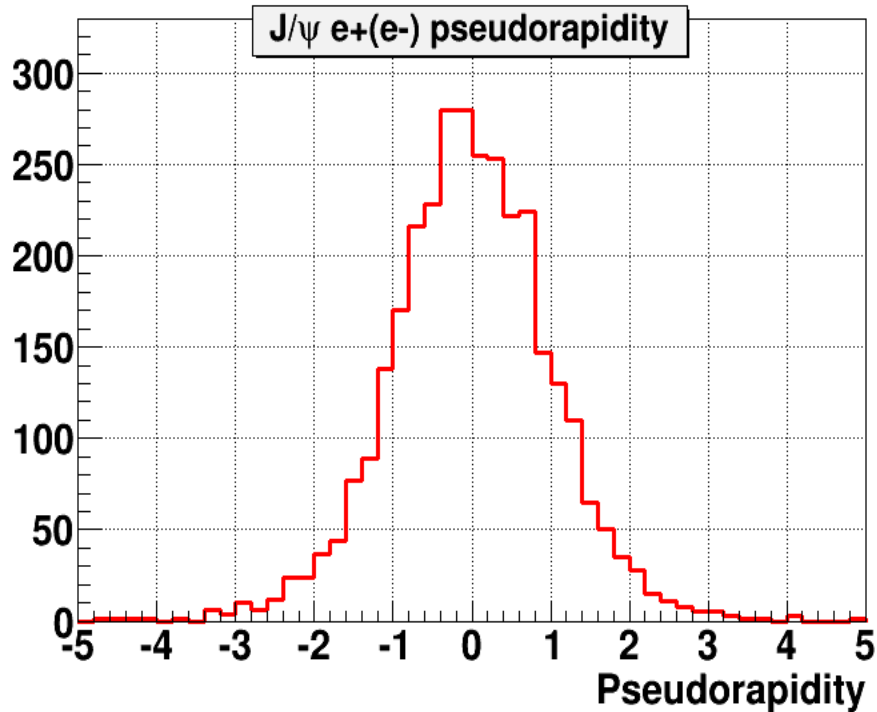
Software

- 1. MpdRoot as a framework*
- 2. Pythia8, UrQMD3.3 generators*
- 3. MpdRoot Geant3 transport*
- 4. MpdRoot TPC Kalman filter – based track and vertex reconstruction*

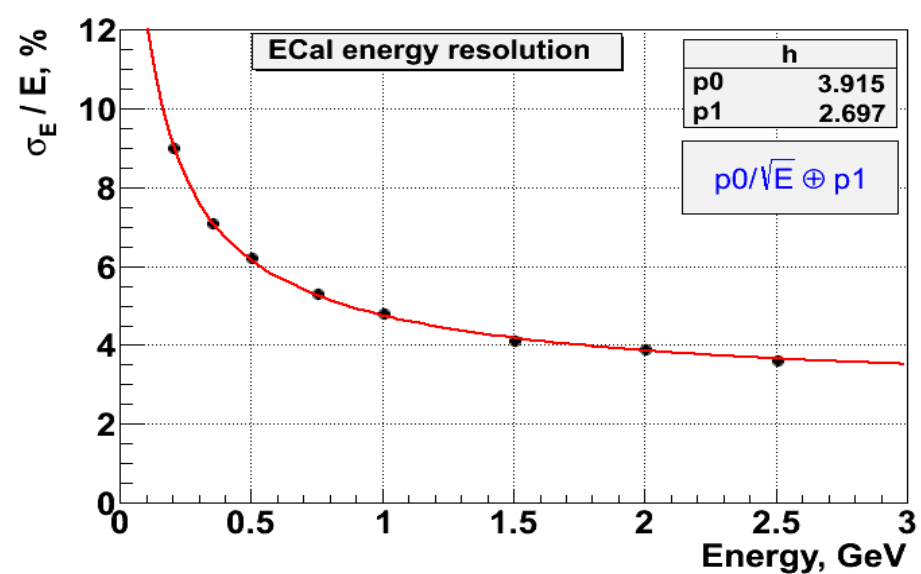
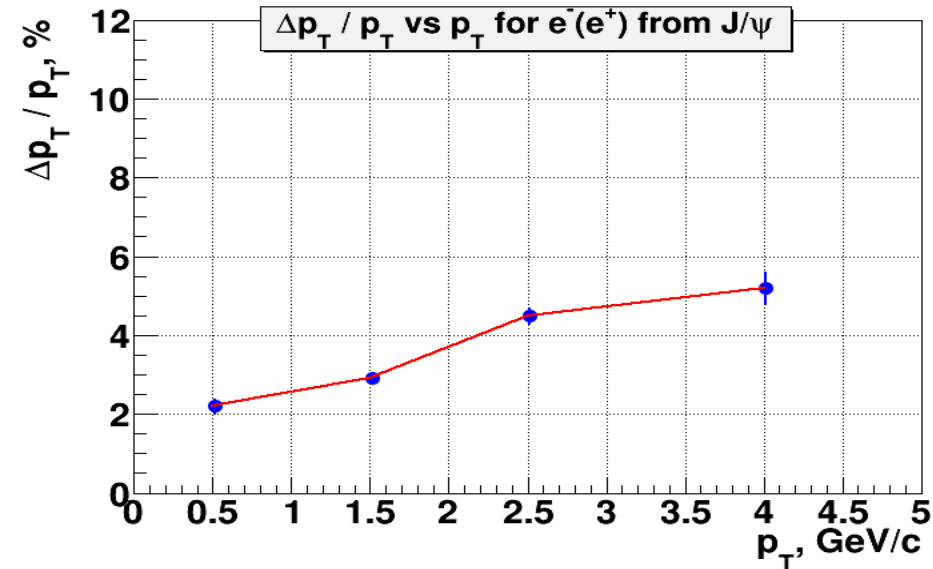
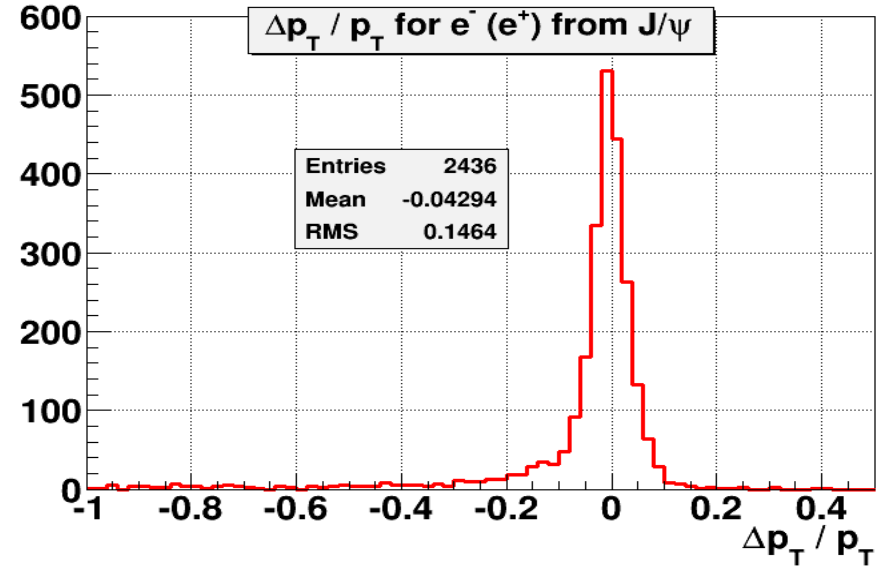
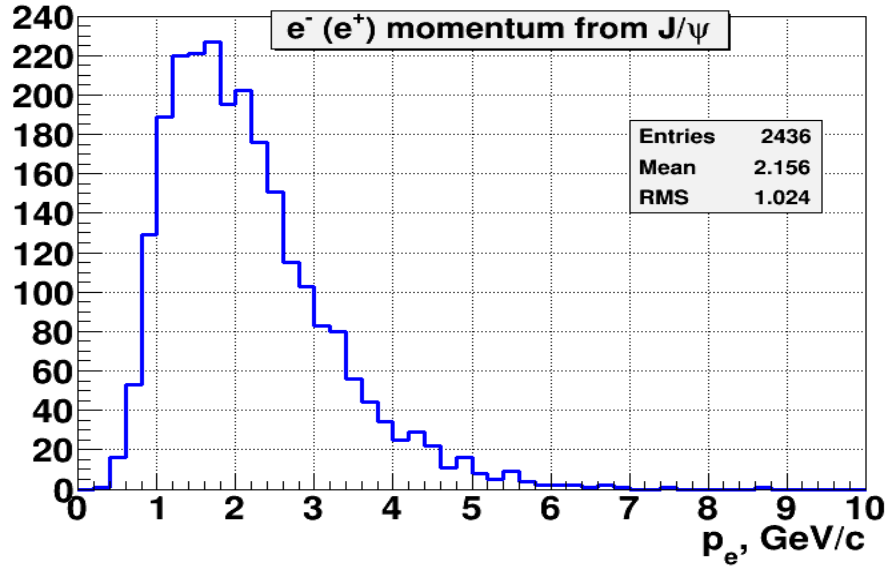
Running conditions

1. $p+p$ at $\sqrt{s} = 25 \text{ GeV}$
2. Luminosity $L = 10^{29} \text{ cm}^{-2}\text{c}^{-1}$
3. Running time 10 weeks: integrated luminosity $L_{int} = 604.8 \text{ nb}^{-1}$
4. Decay channel $J/\psi \rightarrow e^+e^-$ (branching ratio $\sim 6\%$)

Detector acceptance for $e^+(e^-)$ from J/ψ



Momentum resolution for $e^+(e^-)$ from J/ψ

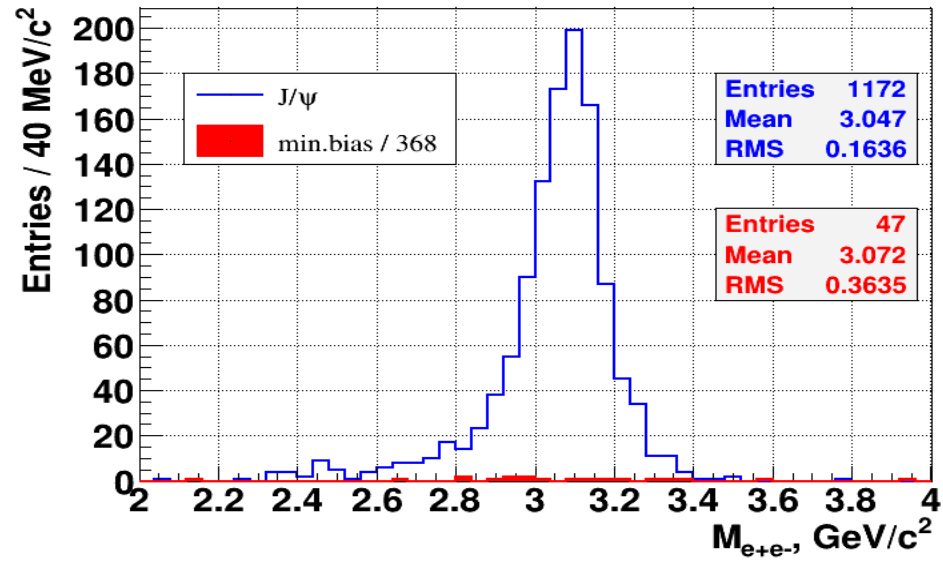
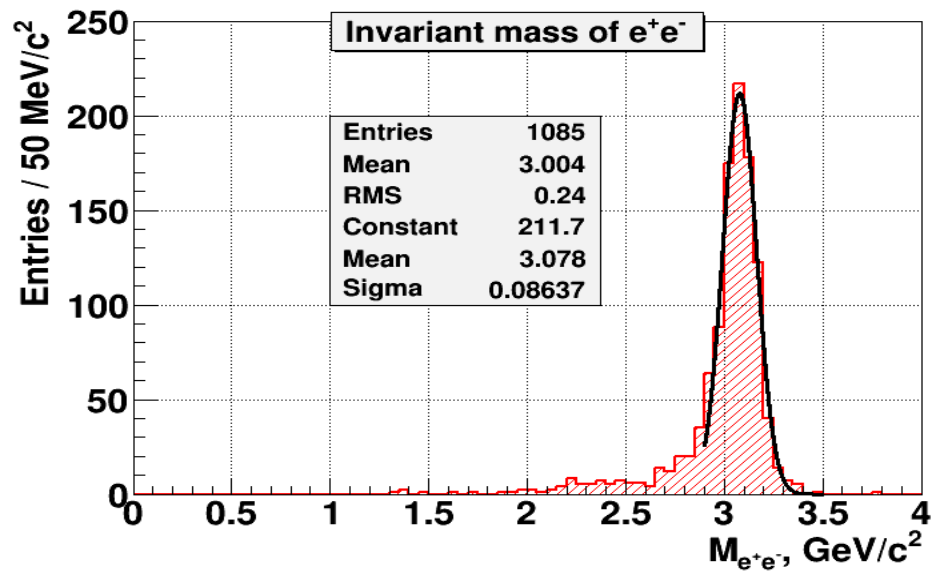


Expectations for J/ψ

1. X-section $\sigma_{J/\psi}$ from Pythia8 108.7 nb

2. Statistics: $N_{J/\psi} = L_{int} \cdot \sigma_{J/\psi} \cdot Br_{J/\psi \rightarrow e^+e^-} \cdot Eff_{\Delta\eta=\pm 1.5} =$
 $604.8 \cdot 108.7 \cdot 0.06 \cdot 0.8 = 3156$

Invariant mass: $e^- + e^+$



7 weeks

Reconstructed invariant mass $J/\psi\pi^+\pi^-$ (from CDF)

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week ending
13 AUGUST 2004

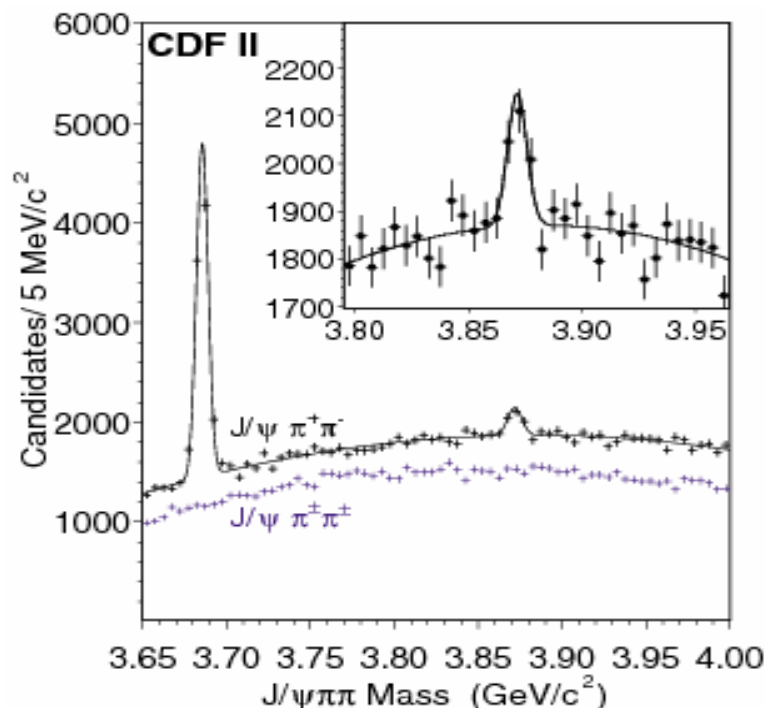


FIG. 1 (color online). The mass distributions of $J/\psi\pi^+\pi^-$ and $J/\psi\pi^+\pi^+$ candidates passing the selection described in the text. A large peak for the $\psi(2S)$ is seen in the $J/\psi\pi^+\pi^-$ distribution as well as a small signal near a mass of 3872 MeV/c². The curve is a fit using two Gaussians and a quadratic background to describe the data. The inset shows an enlargement of the $J/\psi\pi^+\pi^-$ data and fit around 3872 MeV/c².

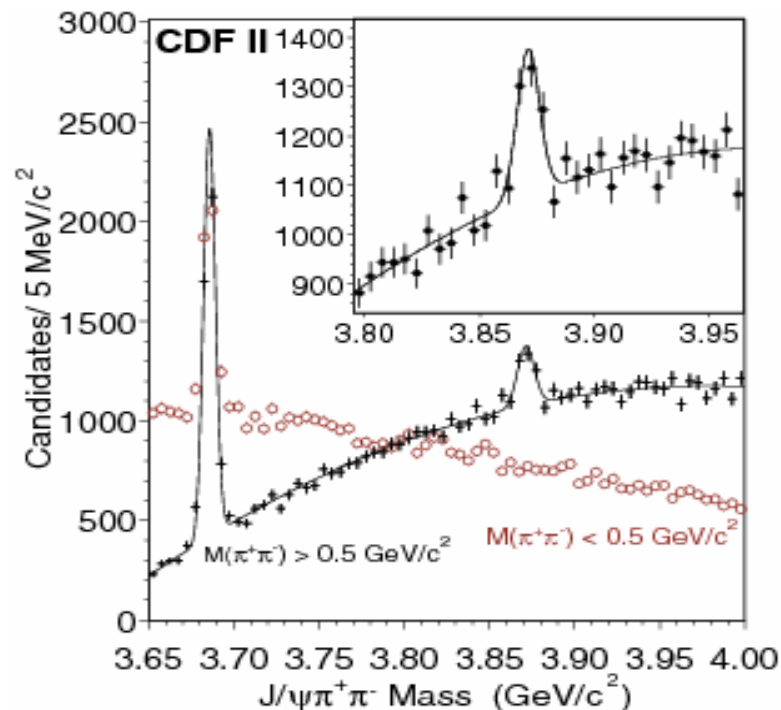


FIG. 2 (color online). The mass distributions of $J/\psi\pi^+\pi^-$ candidates with $m(\pi^+\pi^-) > 0.5$ GeV/c² (points) and $m(\pi^+\pi^-) < 0.5$ GeV/c² (open circles). The curve is a fit with two Gaussians and a quadratic background. The inset shows an enlargement of the high dipion-mass data and fit.

Requiring $M(\pi^+\pi^-) > 0.5$ MeV/c² reduces the back-

X(3872) state

1. X-section in Pythia8 for X(3872) is 4 nb (X(3872) \equiv $\psi(3770)$ with mass 3.872 GeV)

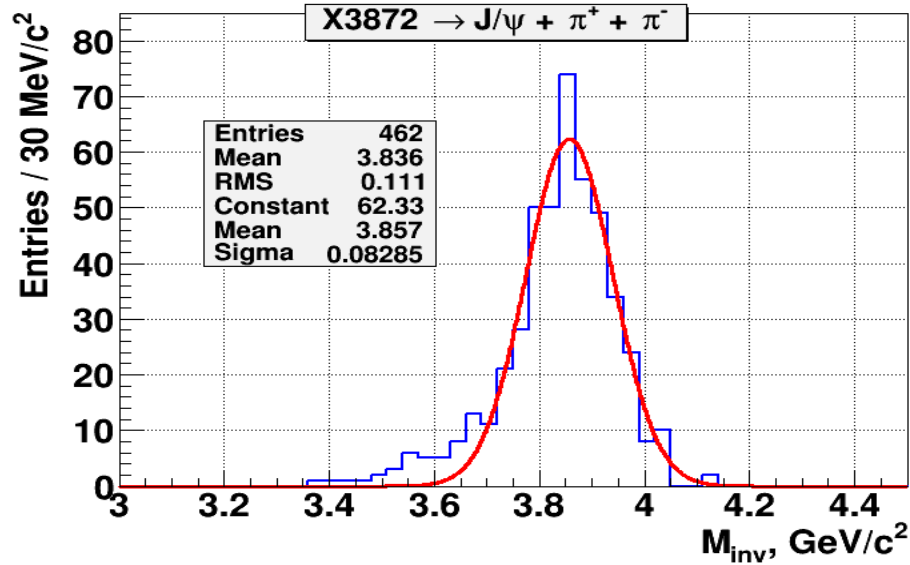
2. $Br(X3872 \rightarrow J/\psi \rho^0) = 5.0\%$

$Br(X3872 \rightarrow e^+e^- \pi^+\pi^-) = 0.3\% \rightarrow X\text{-section} = 12.2 \text{ pb}$

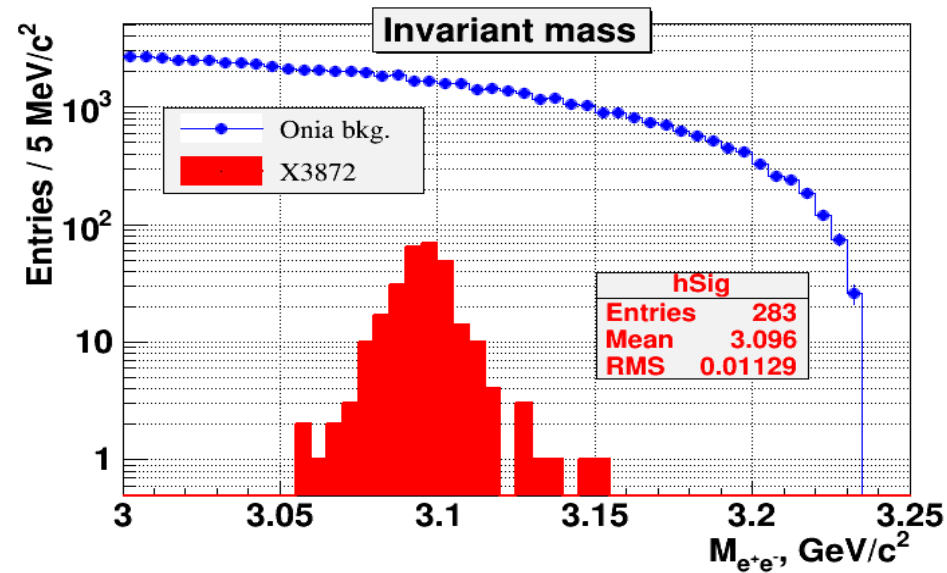
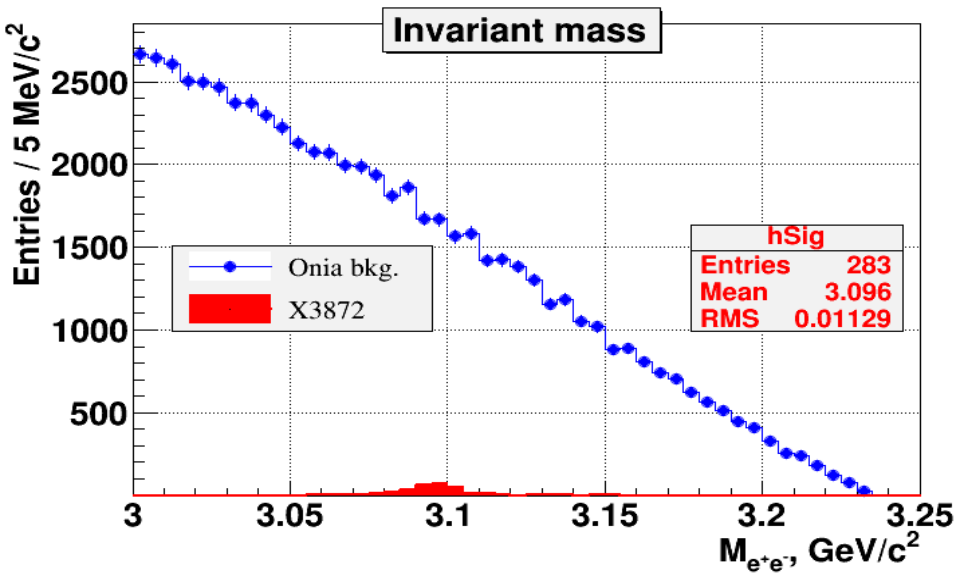
1000 events at $L = 10^{31} \text{ cm}^{-2}\text{s}^{-1}$: 95 days

$10^{32} \text{ cm}^{-2}\text{s}^{-1}$ and 10 months: 31600 events

$X(3872) \rightarrow J/\psi + \rho^0$

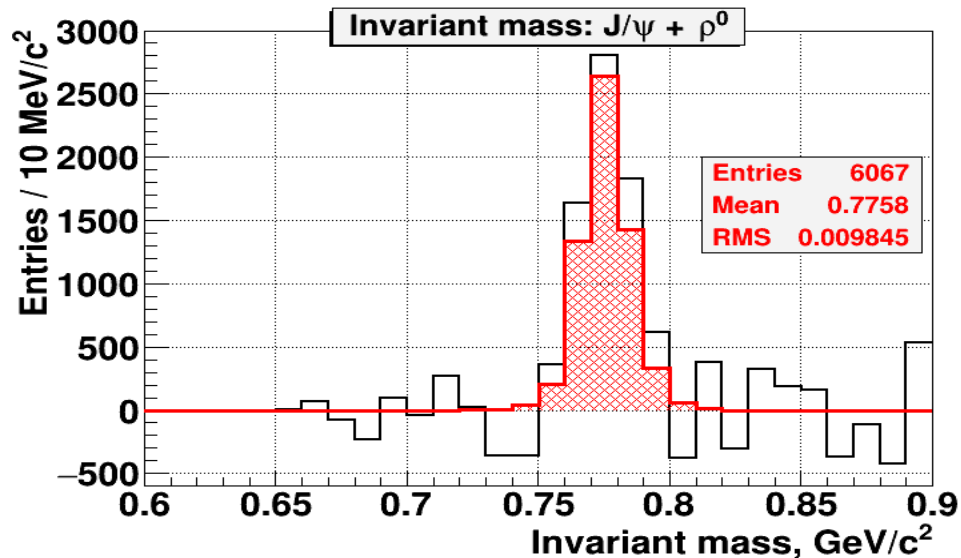
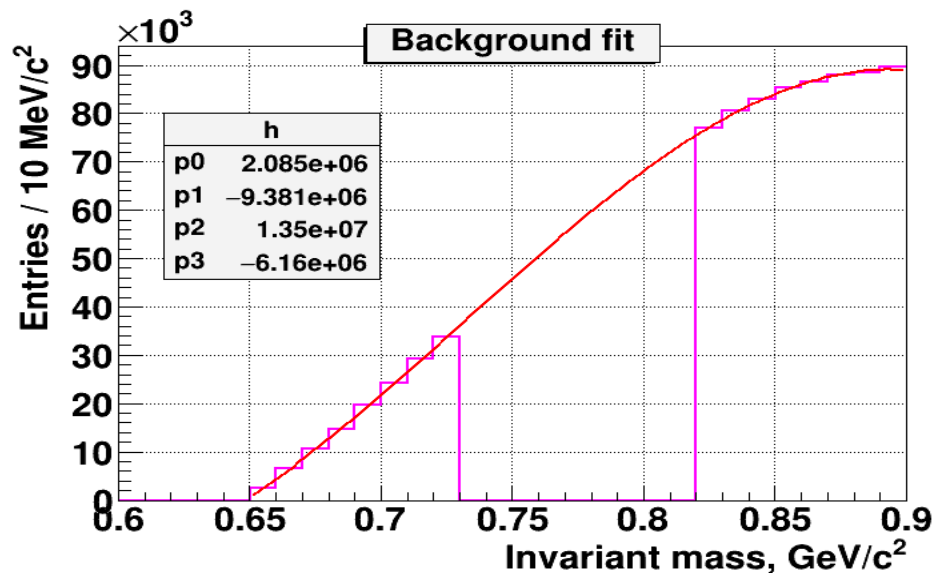
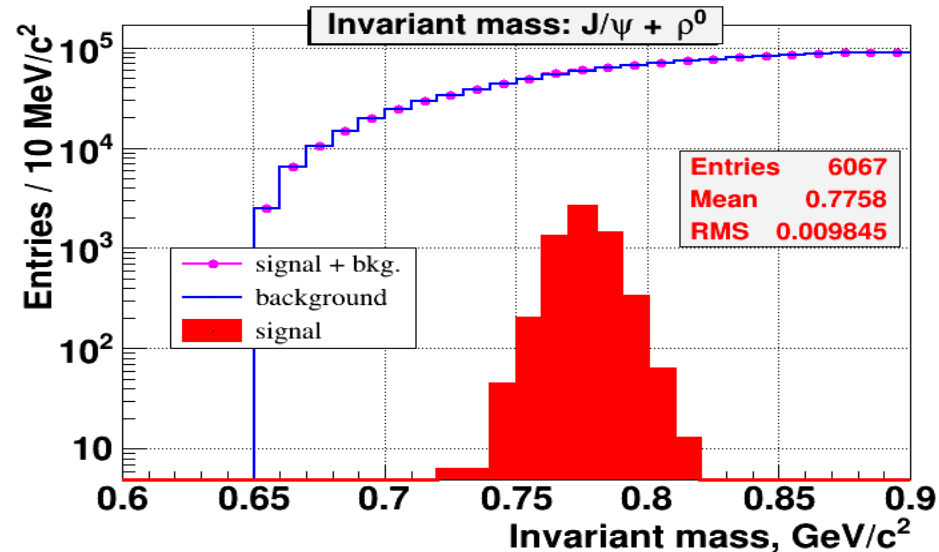
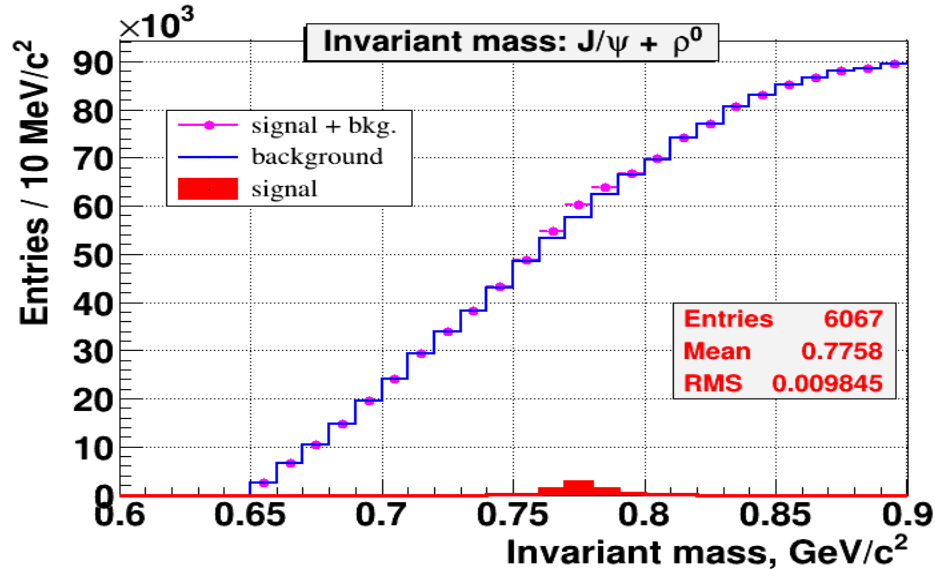


Using mass-constrained fit of X(3872), obtain mass of decay J/ ψ



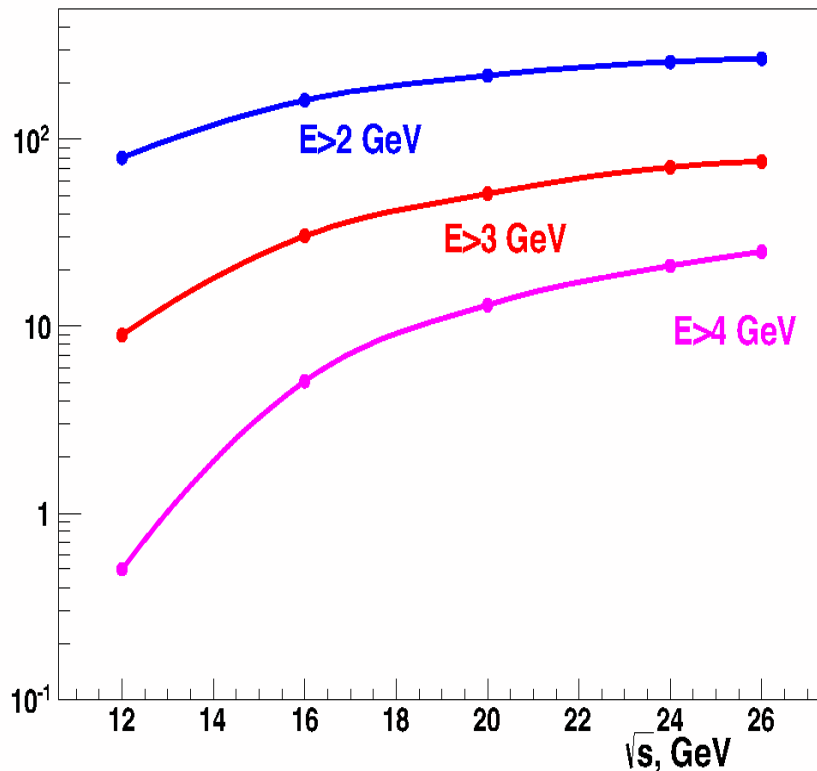
$X(3872) \rightarrow J/\psi + \rho^0$

Using mass combination: $M_{e^+e^-\pi^+\pi^-} - M_{e^+e^-}$

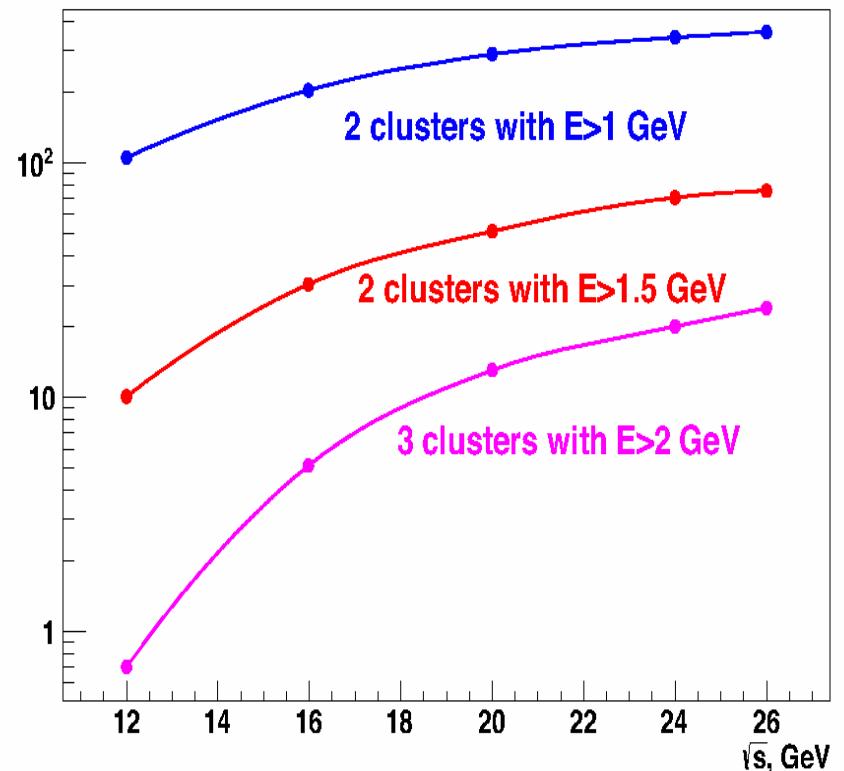


Trigger rate estimates (from SPD)

Rate, kHz ($L=10^{32} \text{ cm}^{-2} \text{ s}^{-1}$)



Rate, kHz ($L=10^{32} \text{ cm}^{-2} \text{ s}^{-1}$)



A.Guskov

X(3872) in p+p and p+A at NICA

Probing the X(3872) meson structure with near-threshold pp and pA collisions at NICA

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† *E-mail: solsensnu@gmail.com*

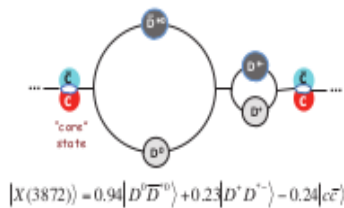


Figure 1: The X(3872) in a hybrid picture. The numerical values come from re

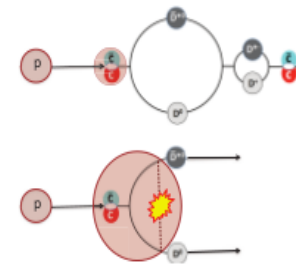
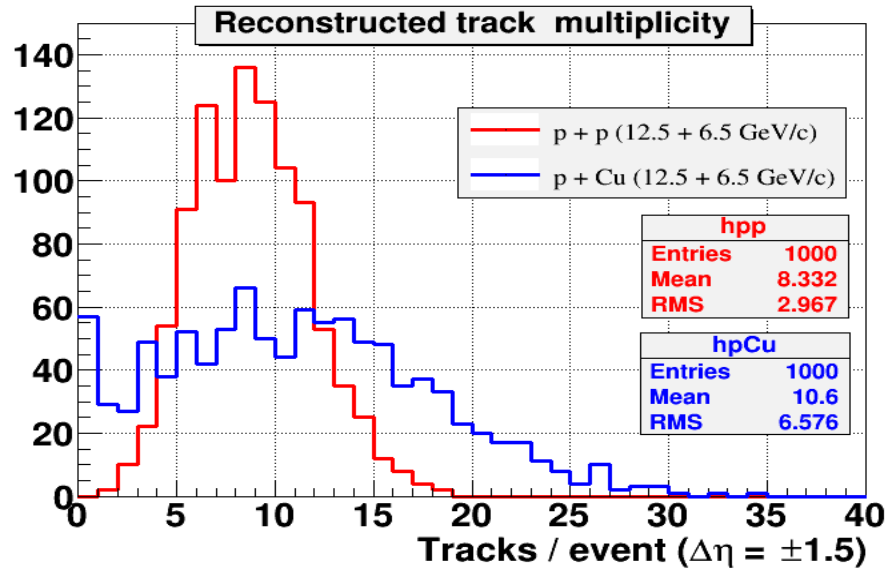
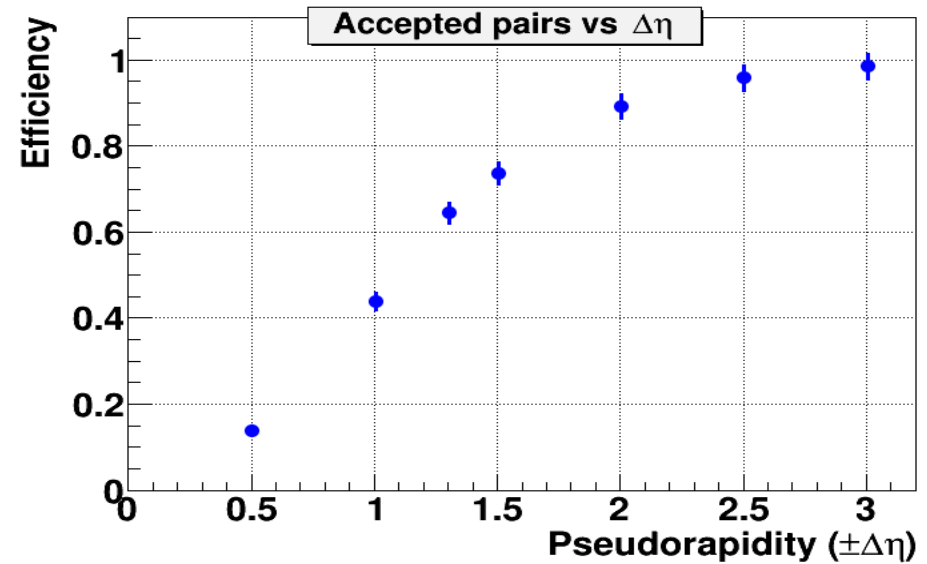
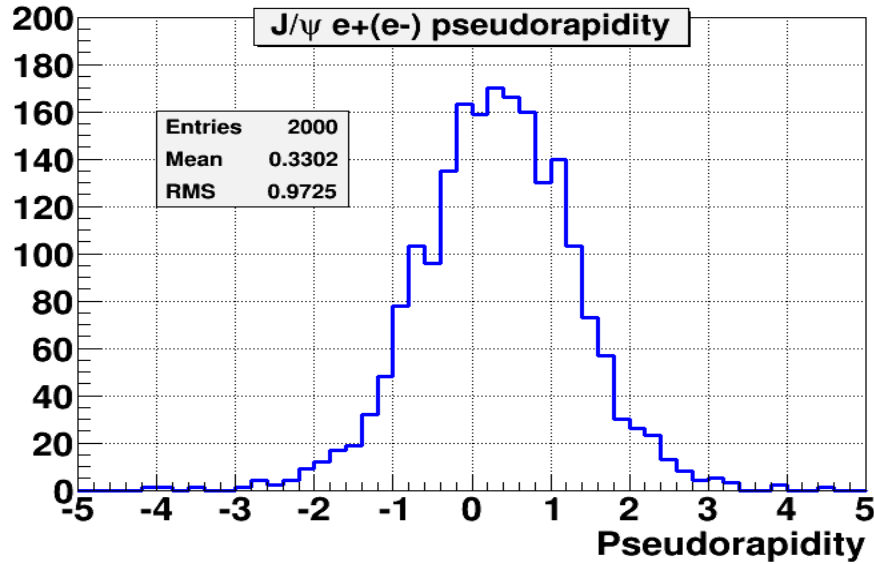


Figure 2: **(Top)** X(3872) production on a proton target ($r_{\text{rms}} \simeq 1$ fm). Here the X(3872) escapes the target region before it establishes a significant DD^* component. **(Bottom)** X(3872) production on a nuclear target. Here the presence nuclear material disrupts the (< 200 keV) coherence between the well separated D^0 and D^{*0} (represented by the dashed line).

Asymmetric system: p+p (p+Cu) 6.5+12.5 GeV



Pythia8 predictions for X(3872)

1. X-section of $\psi(3770)$ with $m = 3.872$ GeV at pp 12.5+6.5 GeV: 1.3 nb

2. X-section at pCu: $1.3 * A (=63) = 81.9$ nb

3. $Br(X(3872) \rightarrow J/\psi \pi^+\pi^-) = 5.00\%$

$Br(X(3872) \rightarrow D^+D^-) = 40.45\%$

$Br(X(3872) \rightarrow D^0D^0\bar{D}^0) = 54.55\% \Rightarrow D^0D^0\bar{D}^0\pi^0 = 35.29\%$

4. $Br(D^{+-} \rightarrow K^-\pi^+\pi^+) = 9.2\%$, $Br(D^0 \rightarrow K^-\pi^+) = 3.8\%$

5. $\sigma(pCu) * Br(J/\psi \pi^+\pi^-) * Br(e^+e^-) = 81.9 * 0.05 * 0.06 = 0.246$ nb

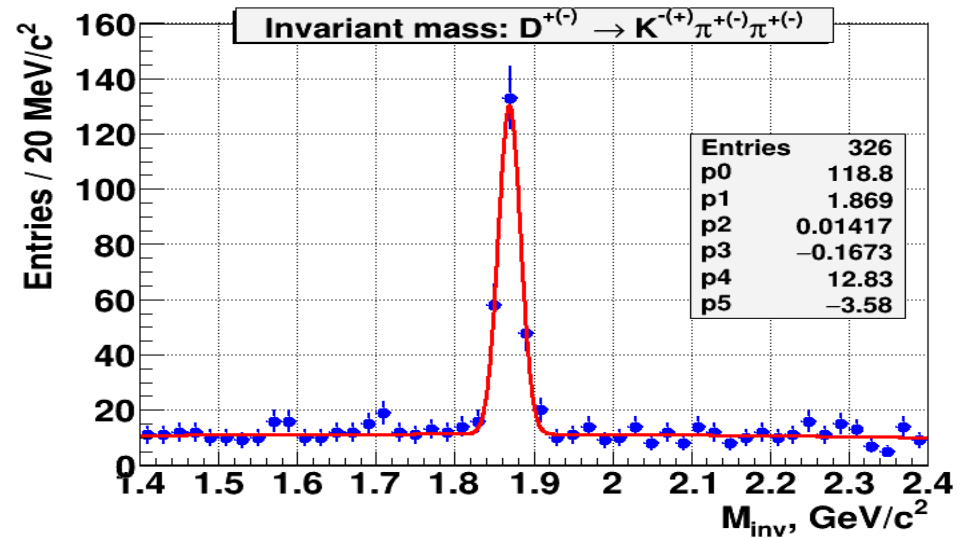
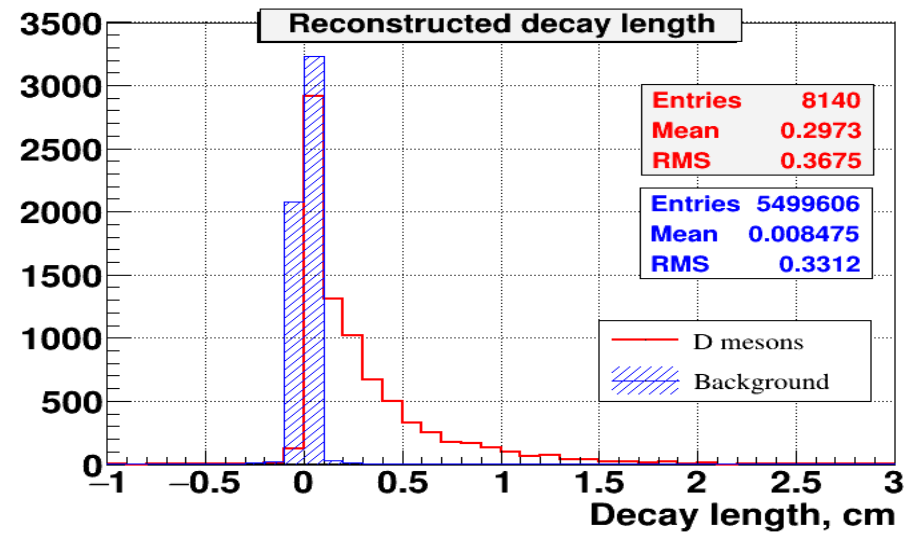
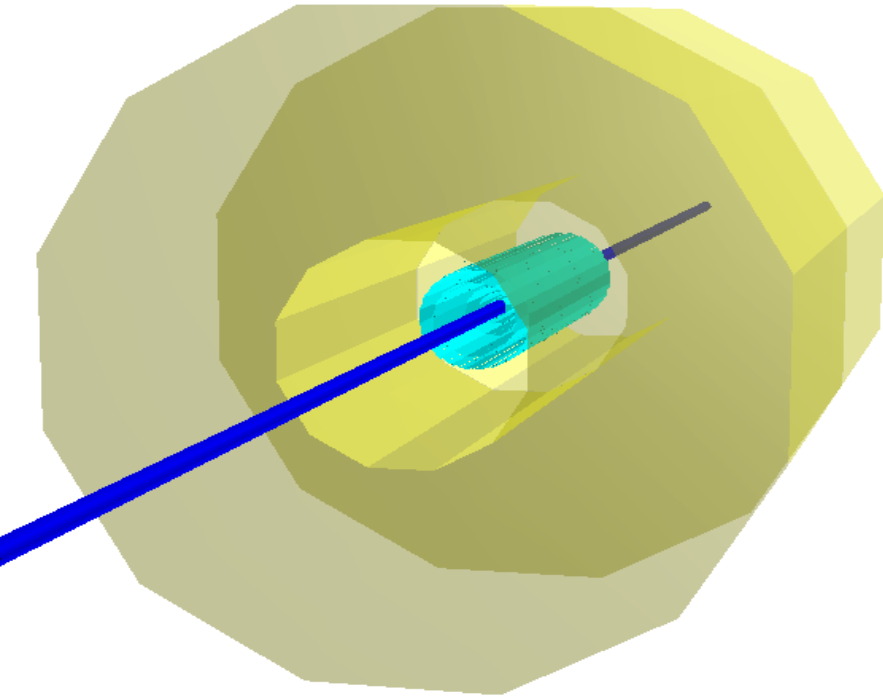
$\sigma(pCu) * Br(D^+D^-) * Br(K\pi\pi)^2 = 81.9 * 0.4045 * 0.092 * 0.092 =$
0.280 nb

$\sigma(pCu) * Br(D^0D^0\bar{D}^0\pi^0) * Br(K\pi)^2 = 81.9 * 0.3529 * 0.039 * 0.039 =$
0.044 nb

0.280 nb $\Rightarrow L = 5.9 \times 10^{29}$ (1000 events / 10 weeks)

MPD Inner Tracking System (ITS)

MAPS (Monolithic Active Pixel Sensors)





Interaction rate estimates



$$\text{In [1]: } \sigma_{pAt} = \pi \cdot r_0^2 \cdot (A^{1/3} - a / A^{1/3})^2, \quad (1)$$

$$r_0 = 1.3 \text{ fm}, \quad a \approx 0.3$$

Table 1. [2]

A_t	$A_t^{1/3}$	$\sigma_m (pA_t),$ mb	Estimate to Eq. 1,
55Fe	3.8	745 ± 20	740

Table 2.

$\sigma_{pCu} (mb)$	$L (cm^{-2}s^{-1})$	Rates (kHz)
818	10^{27}	0.818
818	10^{28}	8.18
818	10^{29}	81.8

[1] T.F. Hoang, B. Cork, and H.J. Crawford, Z. Phys. C 29, 611 (1985).

[2] V. Kolesnikov, private communication

Charm in AA

1. *J/ψ polarization studies*
2. *Open charm selection via hadronic decays*

Summary / Conclusions

The MPD and SPD detector provide good opportunities for the reconstruction and identification of charged and neutral particles.

They can obtain some valuable information on the charm production in pp , pA and AA collisions.

For hadronic decays the silicon ITS should greatly enhance the research potential (reconstruction and selection). For pp and pA at high luminosity it can be also used for triggering and pile-up resolving.