Some considerations on the MPD performance for heavy flavours

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Outline

1. Motivation

2. NICA complex and MPD detector

3. Software used

4. Charm in pp

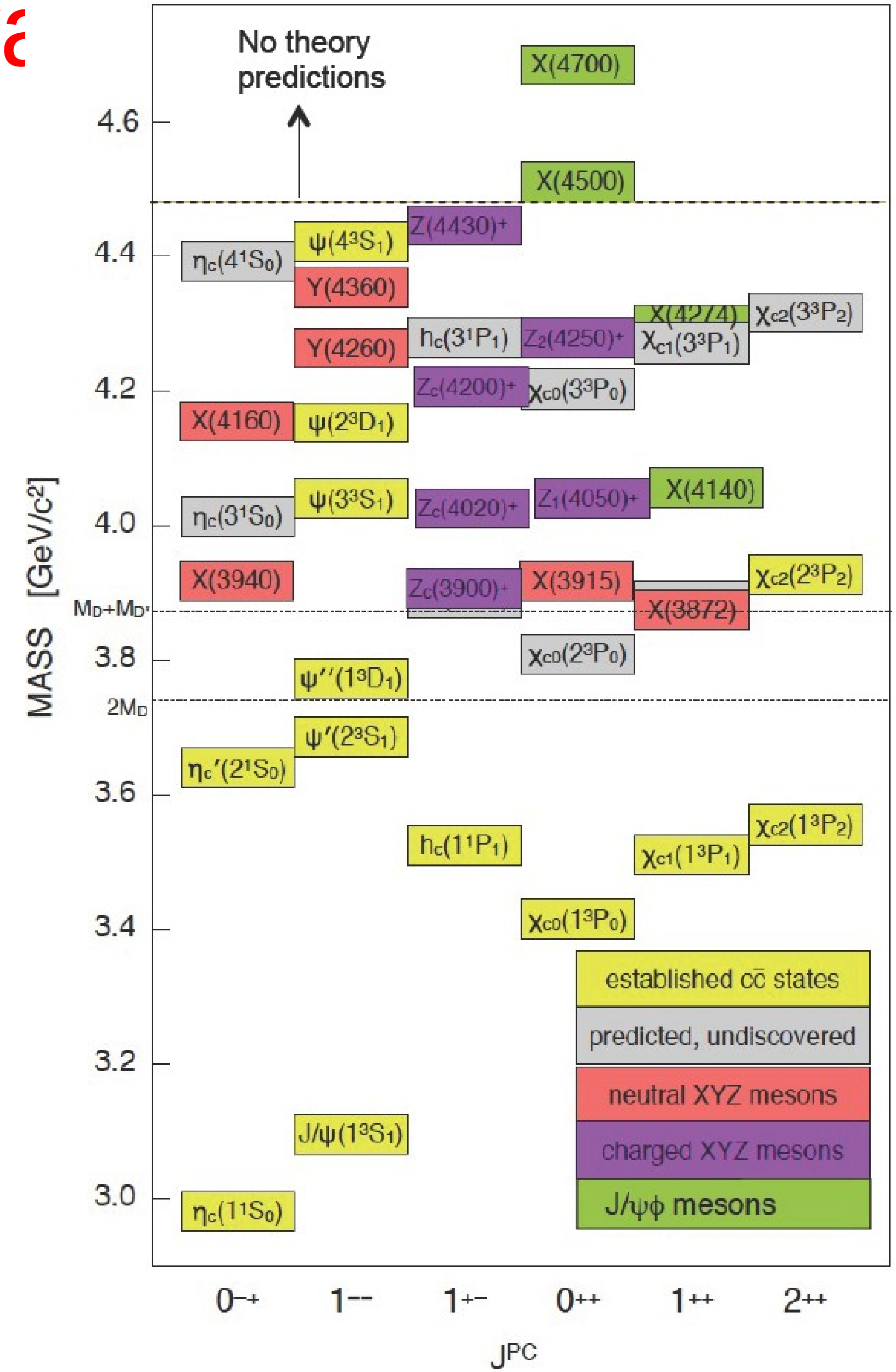
5. Charm in pA

6. Charm in AA

7. Summary / conclusions

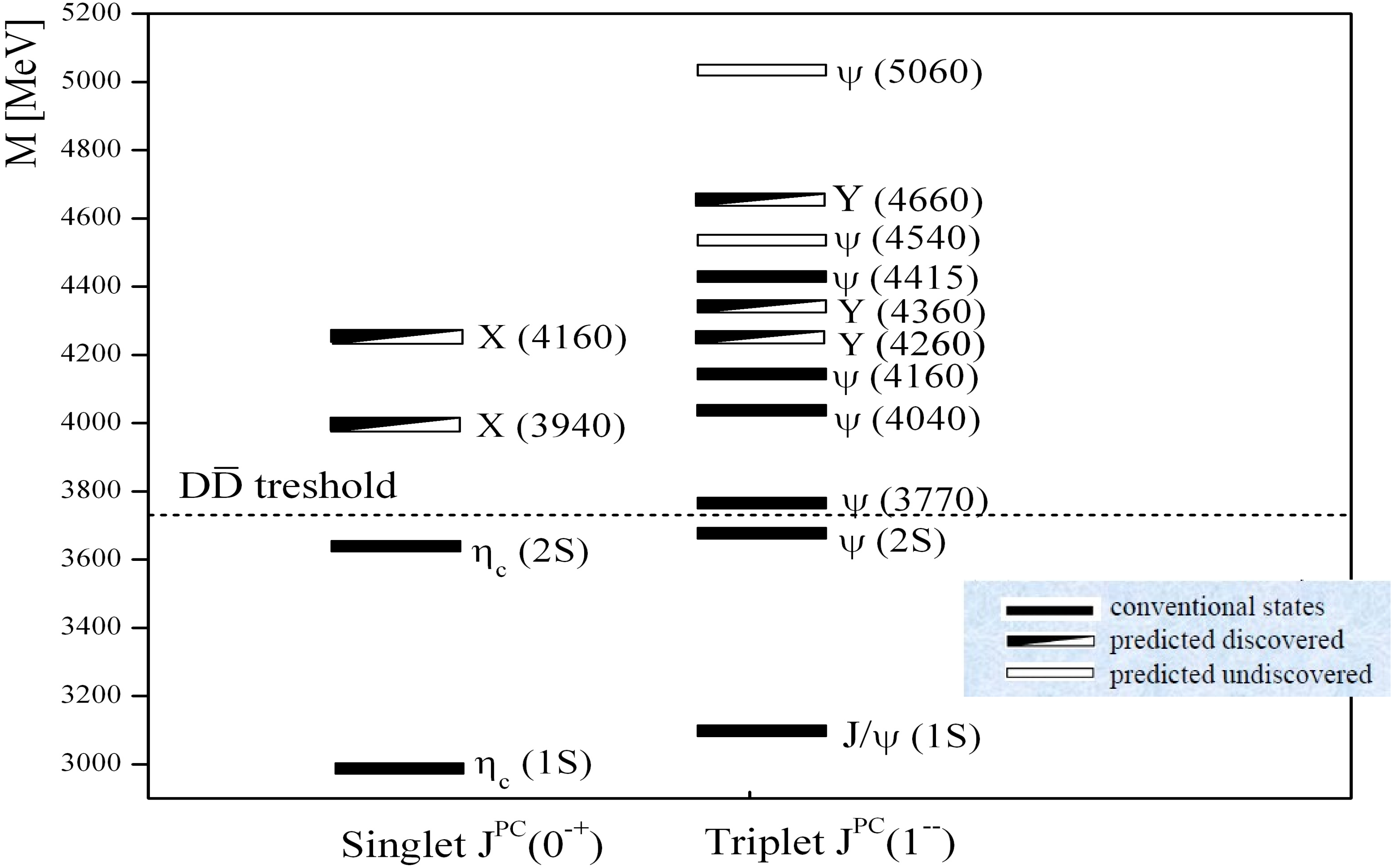
Motiva

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



Motivation

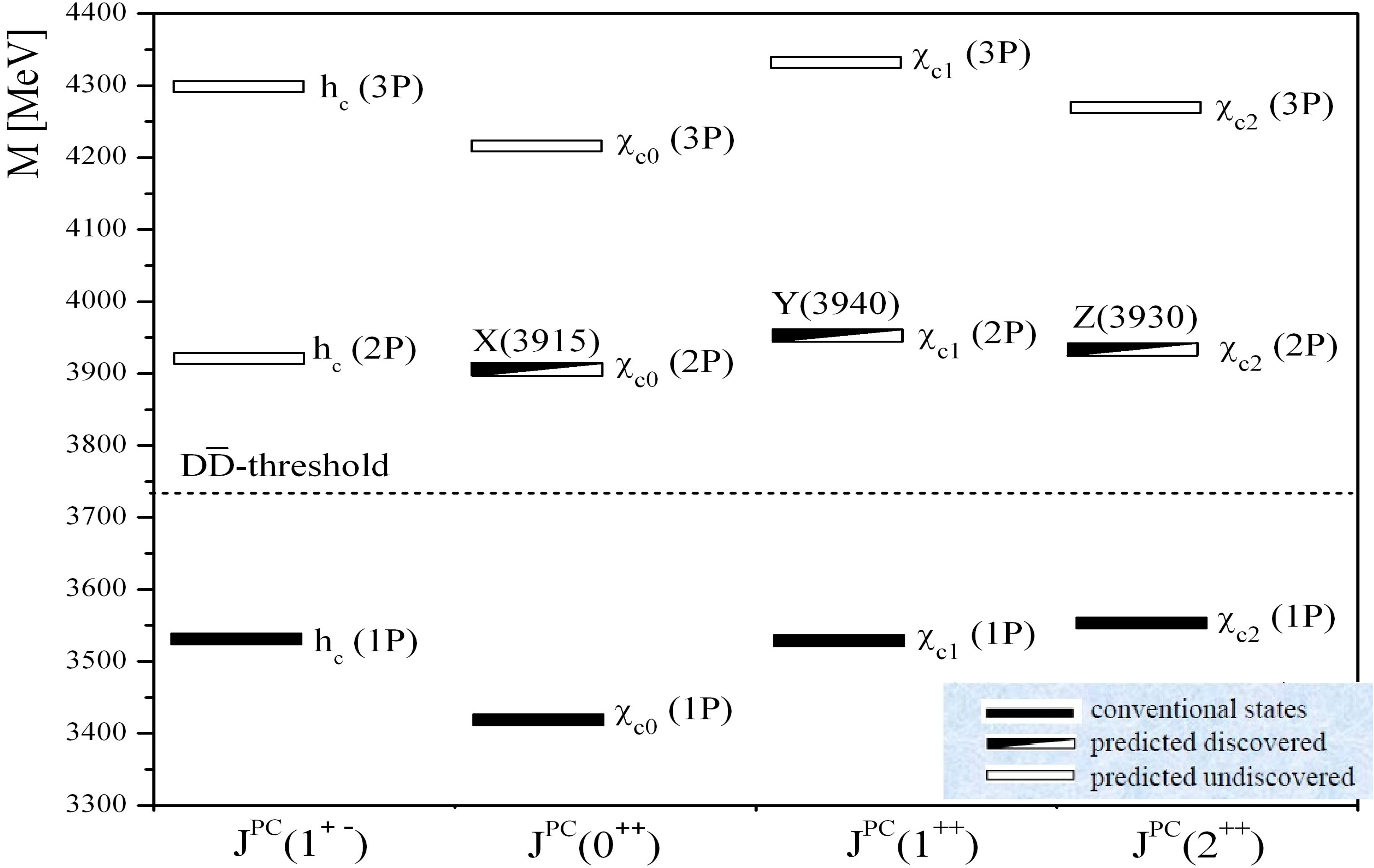
THE SPECTRUM OF SINGLET ($^1S_0$) AND TRIPLET ($^3S_1$) STATES OF CHARMONIUM



M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen, Yadernaya Fizica, V.77, N.1, pp. 1 - 5 (2014) / Phys. At. Nucl., V.77, N.1, pp. 126 -130 (2014)

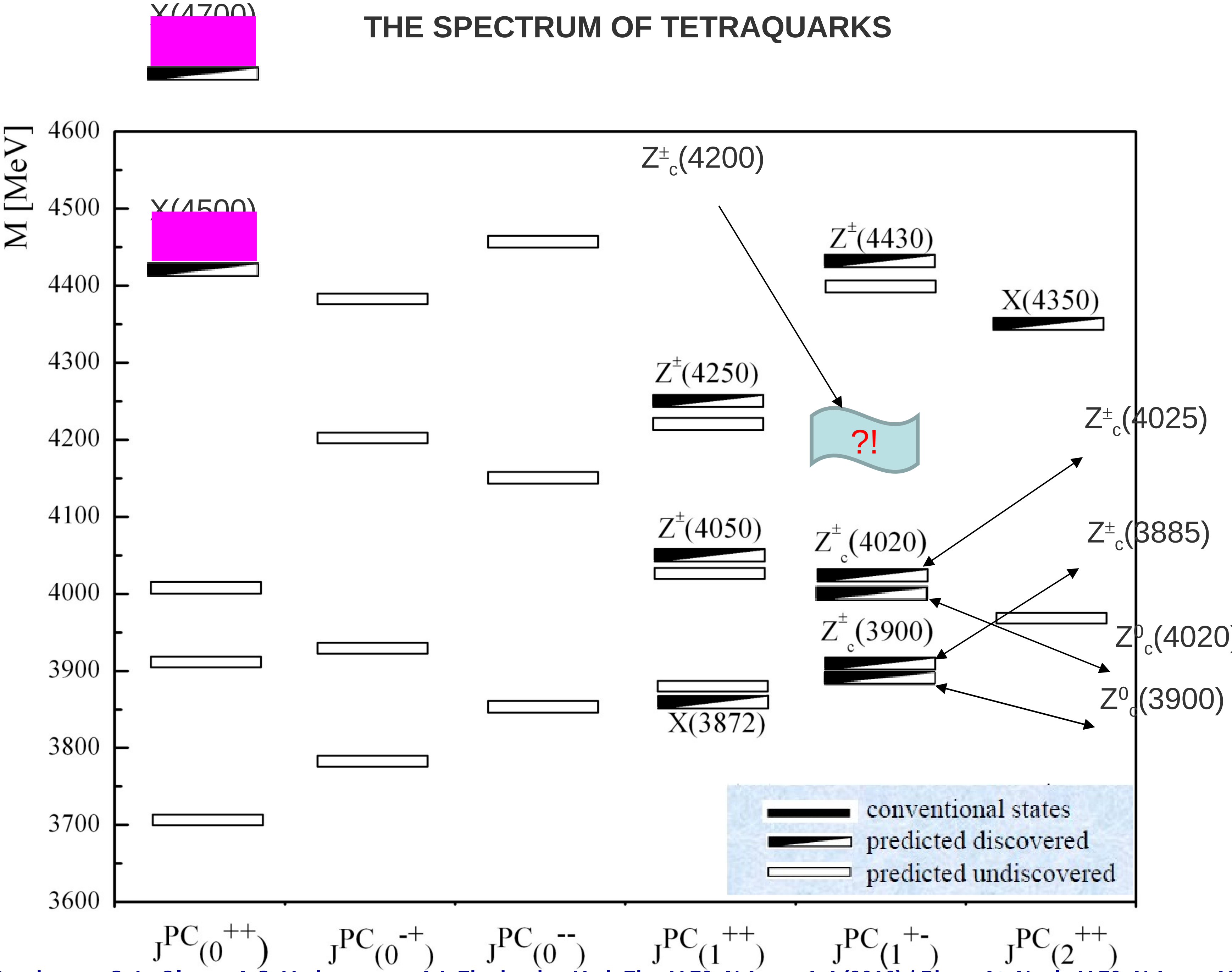
Motivation

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



M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen , Yadernaya Fizica, V.77, N.1, pp. 1 - 5 (2014) / Phys. At. Nucl., V.77, N.1, pp. 126 -130 (2014)

THE SPECTRUM OF TETRAQUARKS



M.Yu. Barabanov, S. L. Olsen, A.S. Vodopyanov, A.I. Zinchenko, Yad. Fiz., V.79, N.1, pp. 1-4 (2016) / Phys. At. Nucl., V.79, N.1, pp. 126 – 179 (2016)

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 *ppbar* interactions

Charmonia measurements

Phys.Lett. B438 (1998) 35-40

EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CERN–EP / 98–161
October 19, 1998

Charmonia production in 450 GeV/c proton induced reactions

M.C. Abreu[1,a)], C. Baglin[2)], A. Baldit[3)], M. Bedjidian[4)], P. Bordalo[1,b)], A. Bussière[2)], P. Busson[5)], J. Castor[3)], T. Chambon[3)], C. Charlot[5)], B. Chaurand[5)], D. Contardo[4)], E. Descroix[4,c)], A. Devaux[3)], O. Drapier[4)], B. Espagnon[3)], J. Fargeix[3)], R. Ferreira[1)], F. Fleuret[5)], P. Force[3)], L. Fredj[3)], J. Gago[1,b)], C. Gerschel[6)], P. Gorodetzky[7,d)], J.Y. Grossiord[4)], A. Guichard[4)], J.P. Guillaud[2)], R. Haroutunian[4)], D. Jouan[6)], L. Kluberg[5)], R. Kossakowski[2)], G. Landaud[3)], C. Lourenço[1,8)], R. Mandry[4)], F. Ohlsson-Malek[4,e)], J.R. Pizzi[4)], C. Racca[7)], S. Ramos[1,b)], A. Romana[5)], P. Saturnini[3)], S. Silva[1)], P. Sonderegger[8,b)], X. Tarrago[6)], J. Varela[1,b,f)], F. Vazeille[3)]

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/c^2 is also determined in the same experiment.

Charmonia measurements

NA38

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}	$B^{\psi}_{\mu\mu}\sigma^{\psi}$ (nb)	$B^{\psi'}_{\mu\mu}\sigma^{\psi'}$ (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

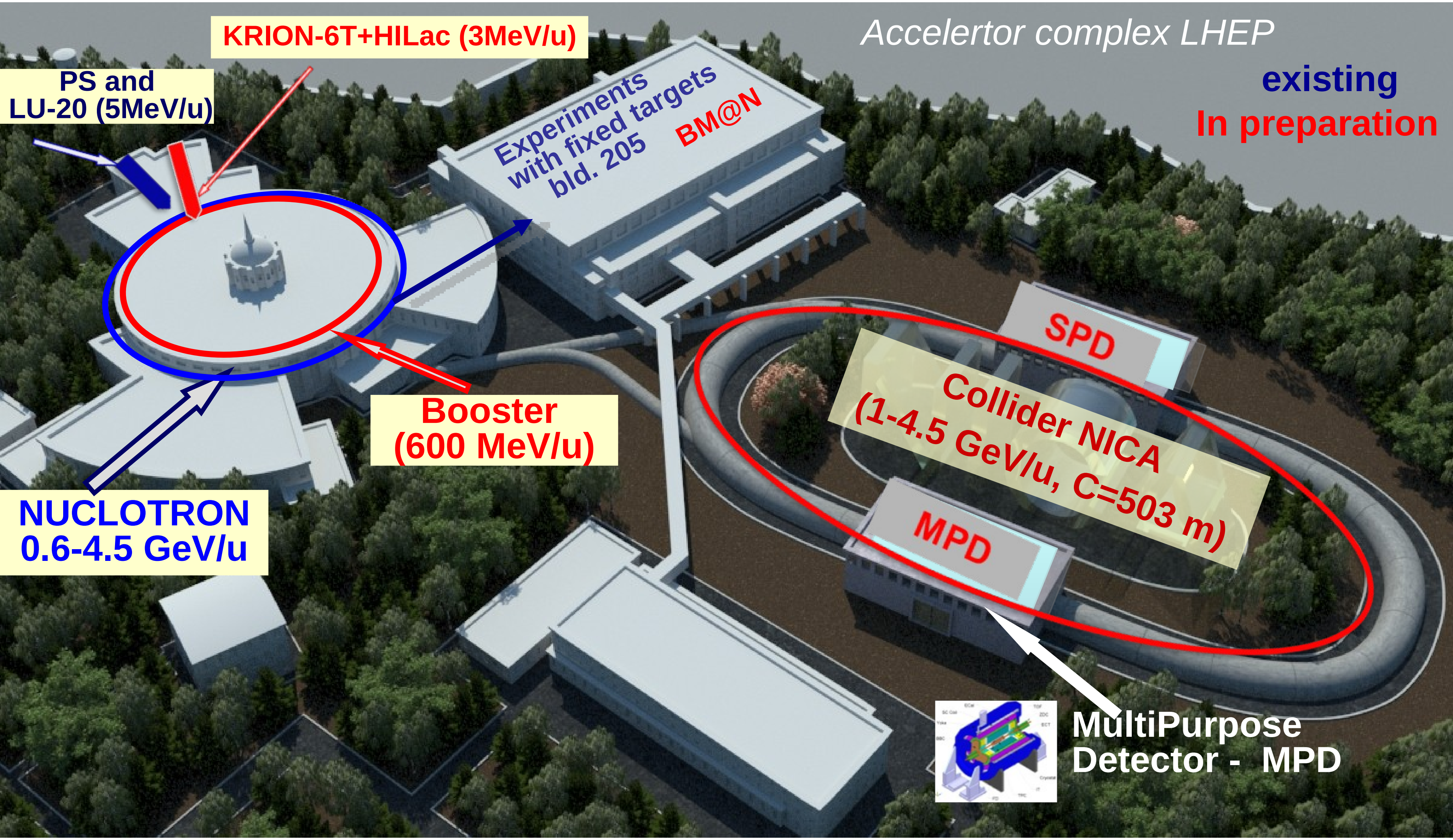
NA51

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)	$5.50 \pm 0.01 \pm 0.36(0.06)$	$11.32 \pm 0.03 \pm 0.75(0.13)$
$B'\sigma_{\psi'}$ (nb)	$0.086 \pm 0.002 \pm 0.006(0.003)$	$0.188 \pm 0.004 \pm 0.015(0.006)$
σ_{DY} (pb)	$25.3 \pm 0.6 \pm 1.8(0.5)$	$55.0 \pm 1.2 \pm 3.9(1.2)$
$B'\sigma_{\psi'}/B\sigma_{\psi}(\%)$	$1.60 \pm 0.04 \pm 0.02$	$1.72 \pm 0.04 \pm 0.025$
$B\sigma_{\psi}/\sigma_{DY}$	$54.7 \pm 1.0 \pm 1.3$	$53.8 \pm 1.0 \pm 0.5$

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

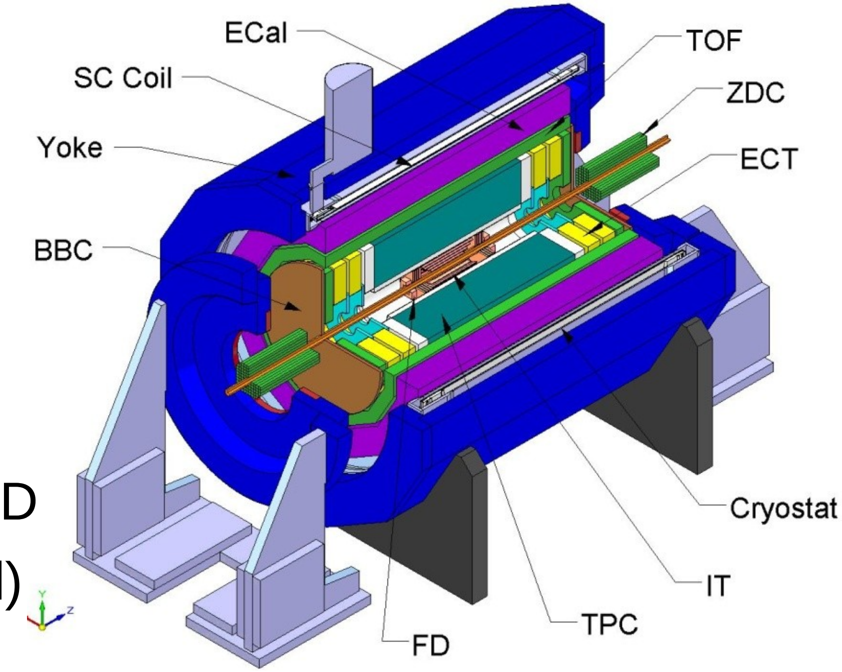
Collider basic parameters: ***beams: from*** **p to Au;**
L~10^{27} cm^{-2} c^{-1} (Au), $\sqrt{s_{NN}}$ = 4-11 GeV; ~10^{32} cm^{-2} c^{-1} (p), $\sqrt{s}$ = 12-26 GeV;



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:

- Hermeticity, homogeneous acceptance: 2π in azimuthal angle.
- Highly efficient 3-D track reconstruction (|η|<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.
- Minimal dead time, event rate capability up to ~ 6 kHz.

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

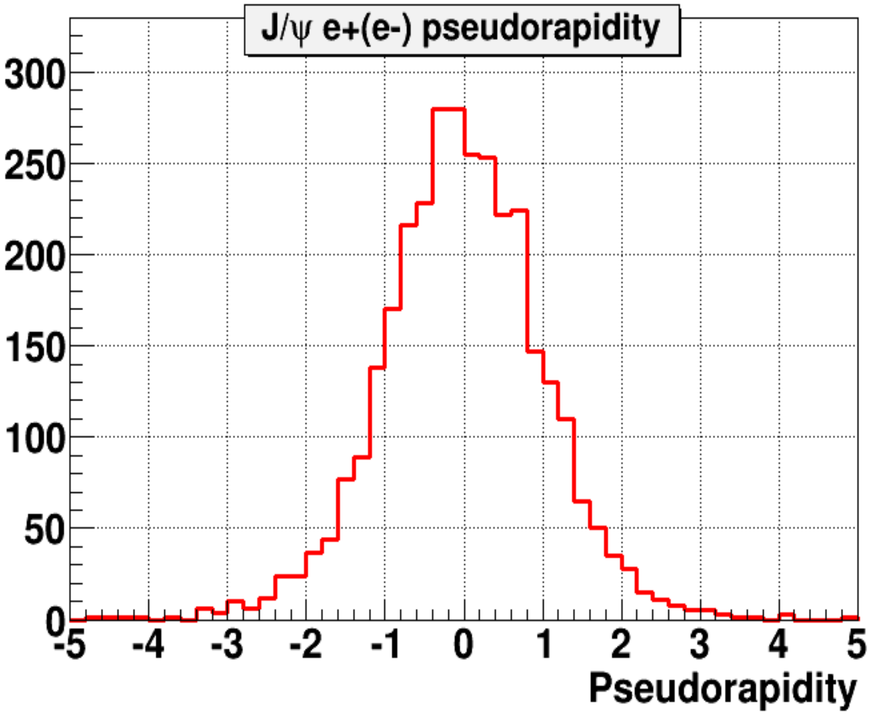
1. *p+p at $\sqrt{s}$ = 25 GeV*

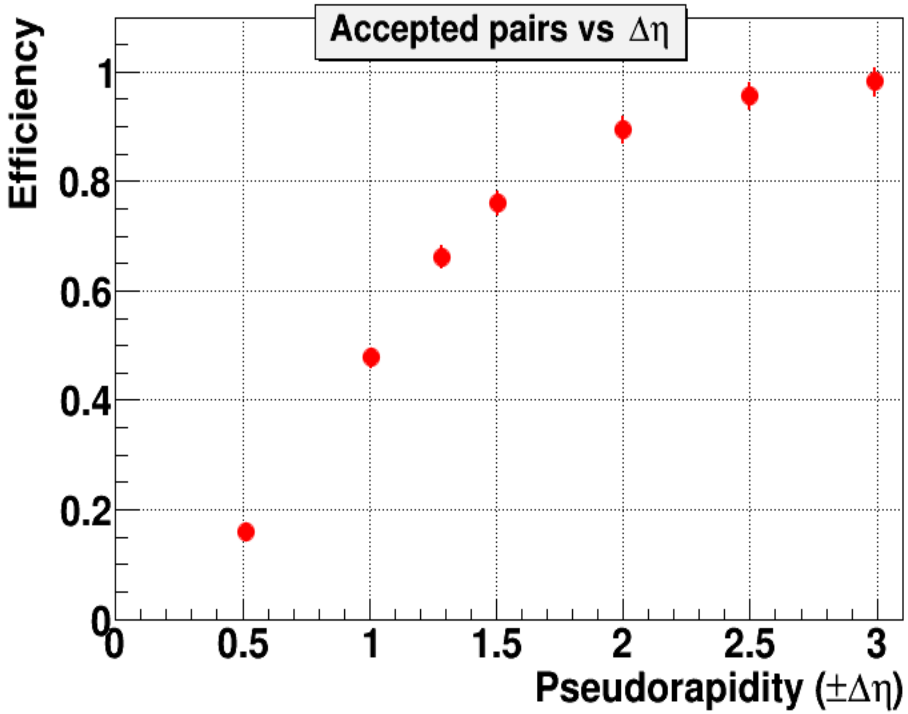
2. *Luminosity L = 10^{29} $cm^{-2}c^{-1}$*

3. *Running time 10 weeks: integrated luminosity L_{int} = 604.8 nb^{-1}*

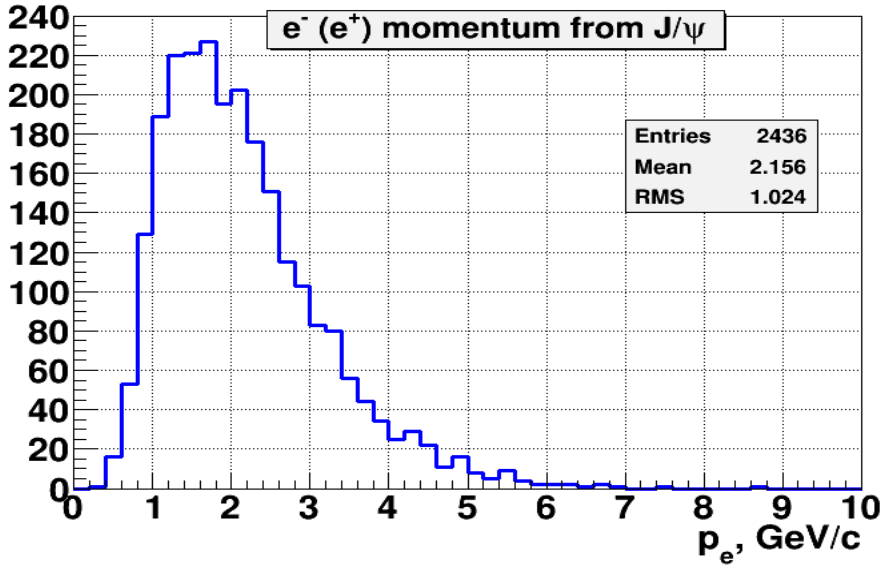
4. *Decay channel $J/\psi \rightarrow e^+e^-$ (branching ratio ~6%)*

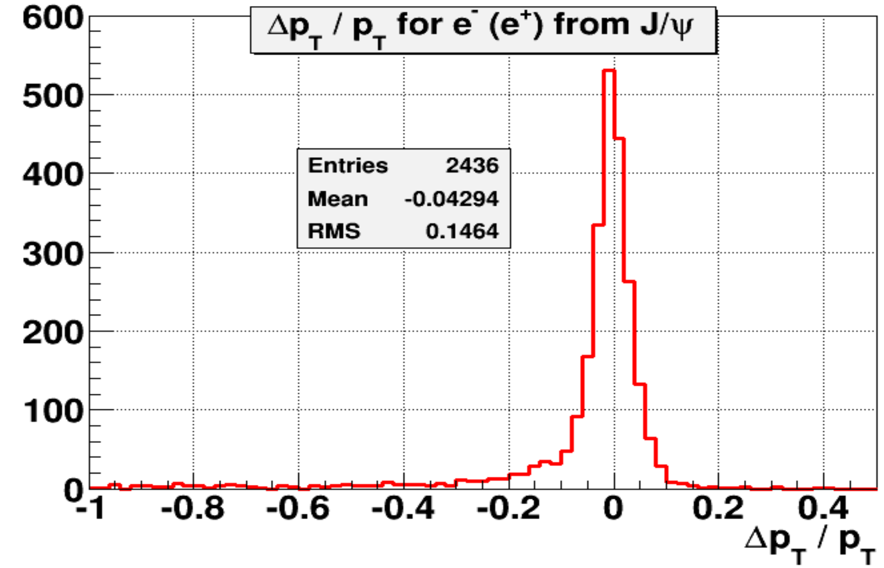
Detector acceptance for e+(e-) from J/ψ

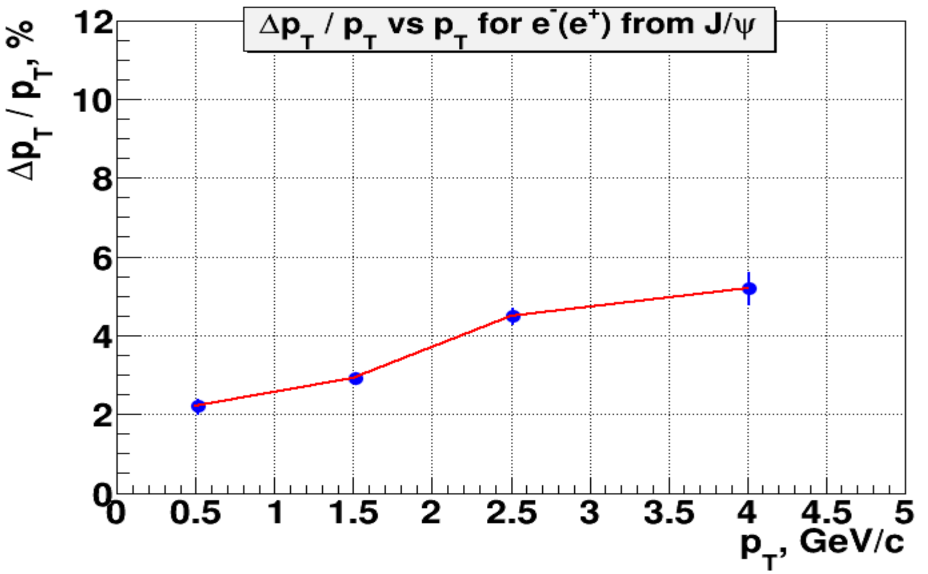


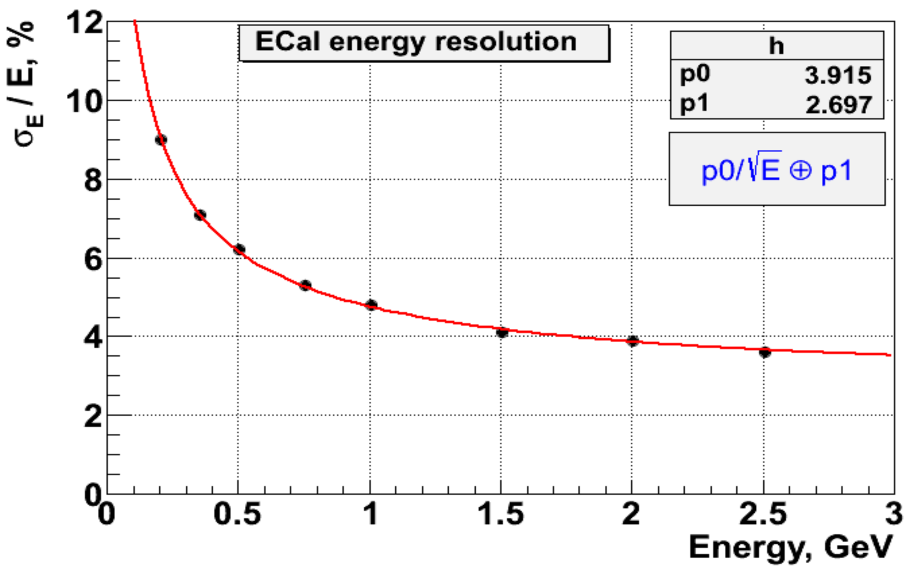


Momentum resolution for e+(e-) from J/ψ







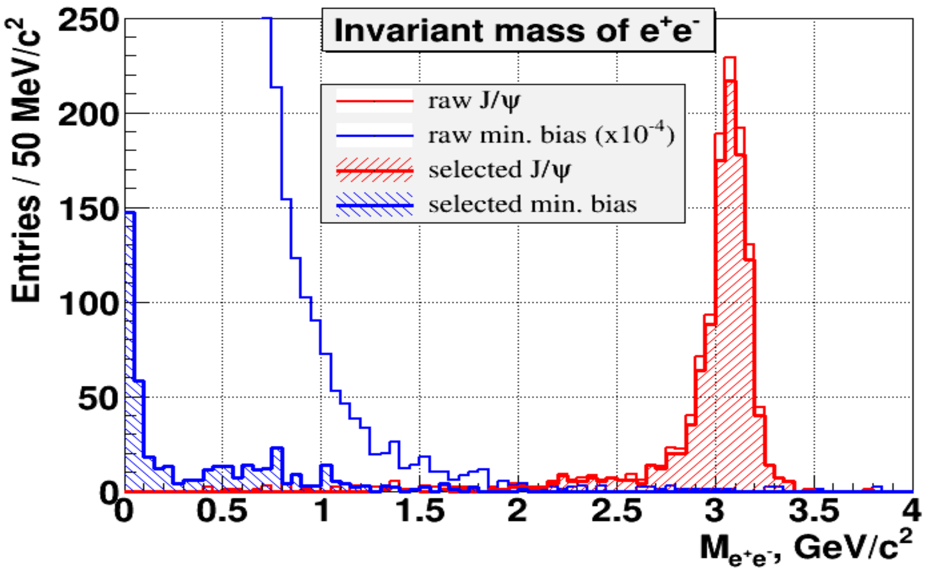


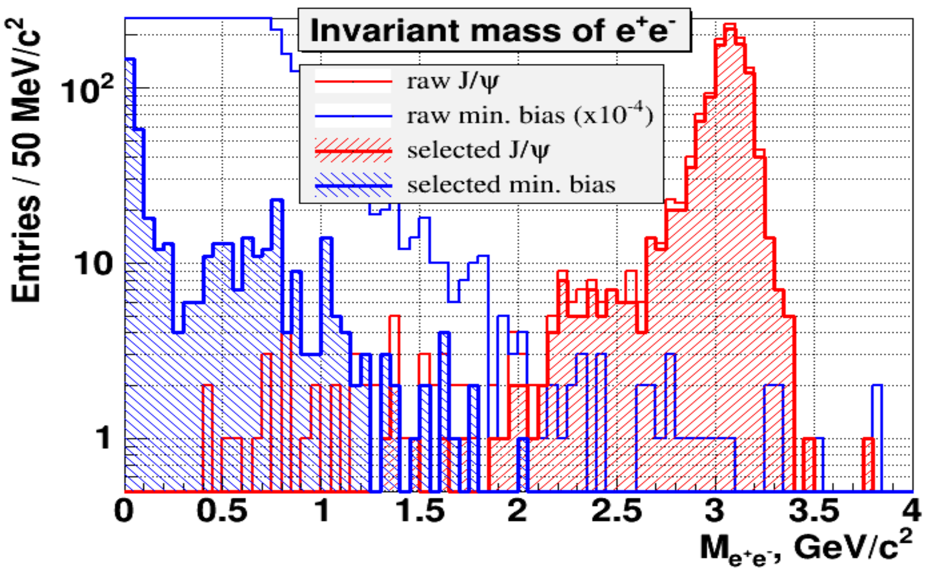
Expectations for J/ψ

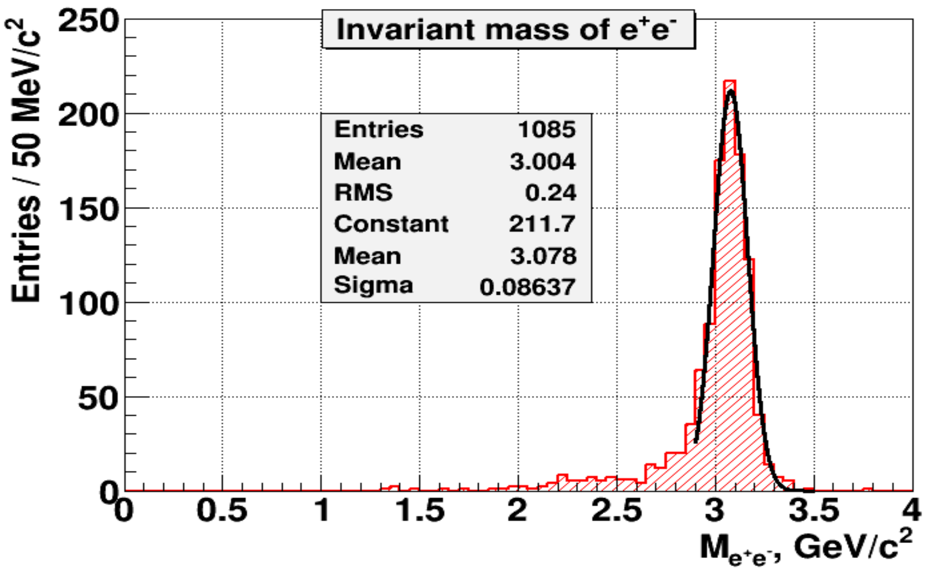
1. *X-section* $\sigma_{J/\psi}$ *from Pythia8 108.7 nb*

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

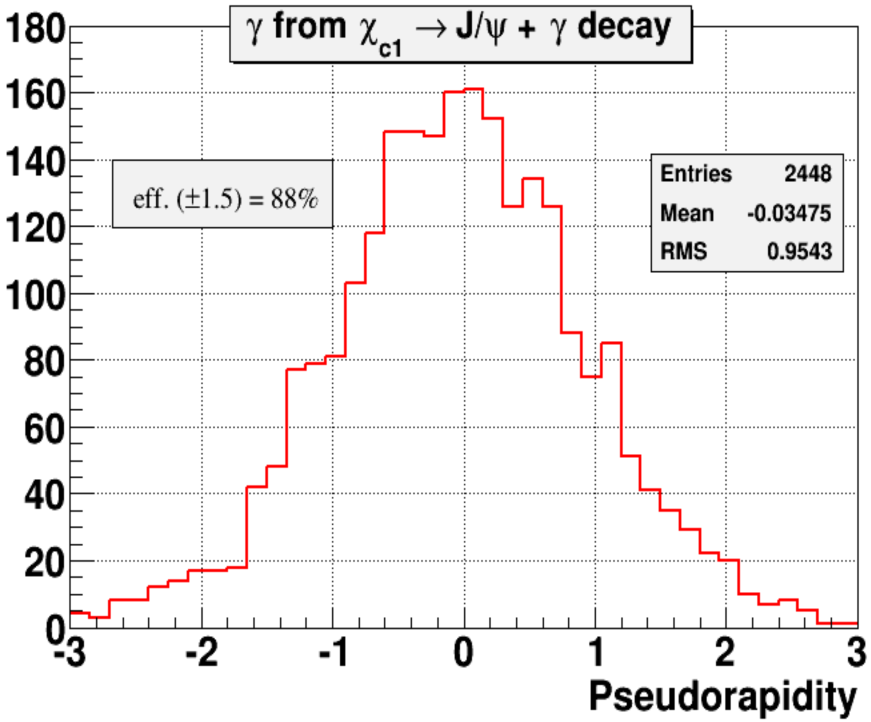
Invariant mass: $e^- + e^+$

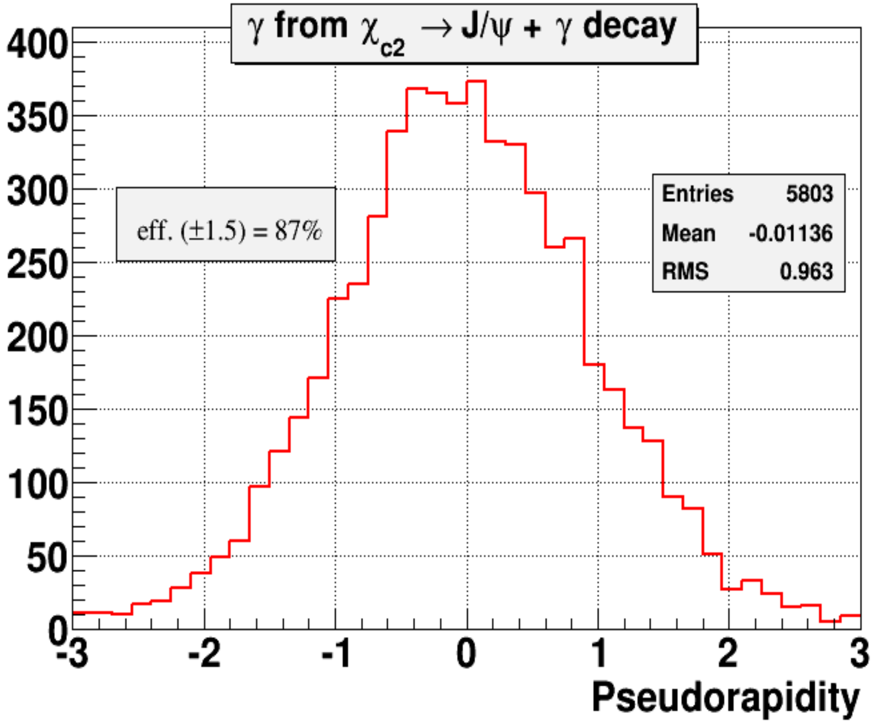






Detector acceptance for γ

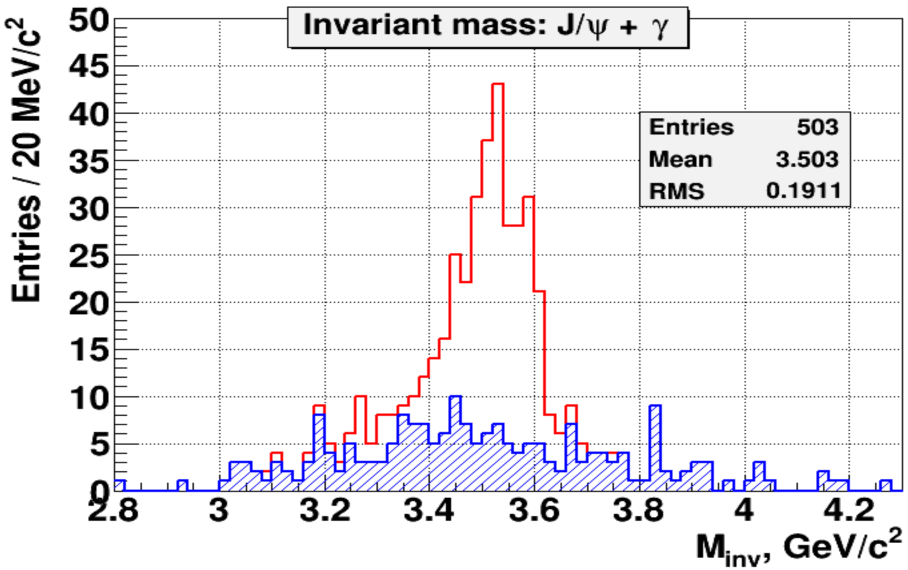


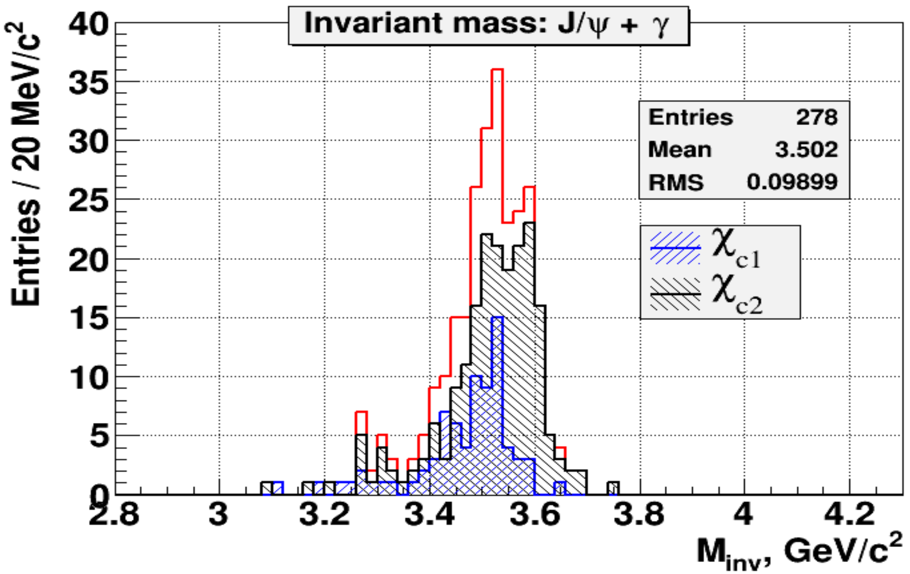


Expectations for χ_{c1} and χ_{c2}

1. X-section $\sigma_{\chi c1}$ from Pythia6 13.7 nb
2. Statistics: $N_{\chi c1} = L_{int} \cdot \sigma_{\chi c1} \cdot Br_{\chi c1 \to \gamma J/\psi} \cdot Eff._{\Delta\eta=\pm 1.5} \cdot Br_{J/\psi \to e+e-} \cdot Eff._{\Delta\eta=\pm 1.5} =$
$604.8 \cdot 13.7 \cdot 0.27 \cdot 0.9 \cdot 0.06 \cdot 0.8 = 97$
3. X-section $\sigma_{\chi c2}$ from Pythia6 66.6 nb
4. Statistics: $N_{\chi c2} = L_{int} \cdot \sigma_{\chi c2} \cdot Br_{\chi c2 \to \gamma J/\psi} \cdot Eff._{\Delta\eta=\pm 1.5} \cdot Br_{J/\psi \to e+e-} \cdot Eff._{\Delta\eta=\pm 1.5} =$
$604.8 \cdot 66.6 \cdot 0.14 \cdot 0.9 \cdot 0.06 \cdot 0.8 = 244$

Invariant mass: J/ψ + γ





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

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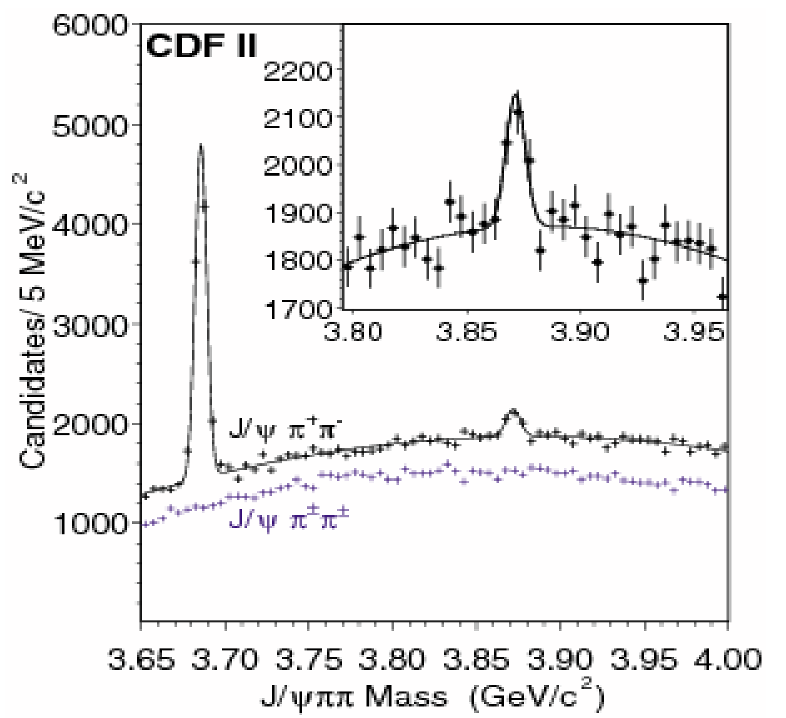


FIG. 1 (color online). The mass distributions of $J/\psi\pi^+\pi^-$ and $J/\psi\pi^\pm\pi^\pm$ candidates passing the selection described in the text. A large peak for the $\psi(2S)$ is seen in the $J/\psi\pi^+\pi^-$ distribution as well as a small signal near a mass of 3872 MeV/c^2. The curve is a fit 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/c^2.

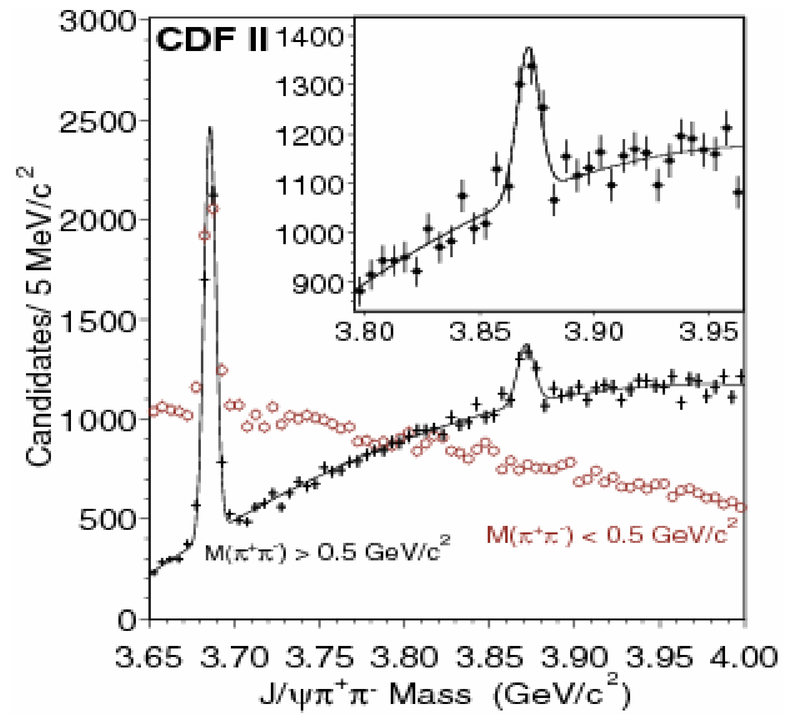


FIG. 2 (color online). The mass distributions of $J/\psi\pi^+\pi^-$ candidates with $m(\pi^+\pi^-) > 0.5$ GeV/c^2 (points) and $m(\pi^+\pi^-) < 0.5$ GeV/c^2 (open circles). The curve is a fit with two Gaussians and a quadratic background. The inset shows an enlargement of the high dipion-mass data and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

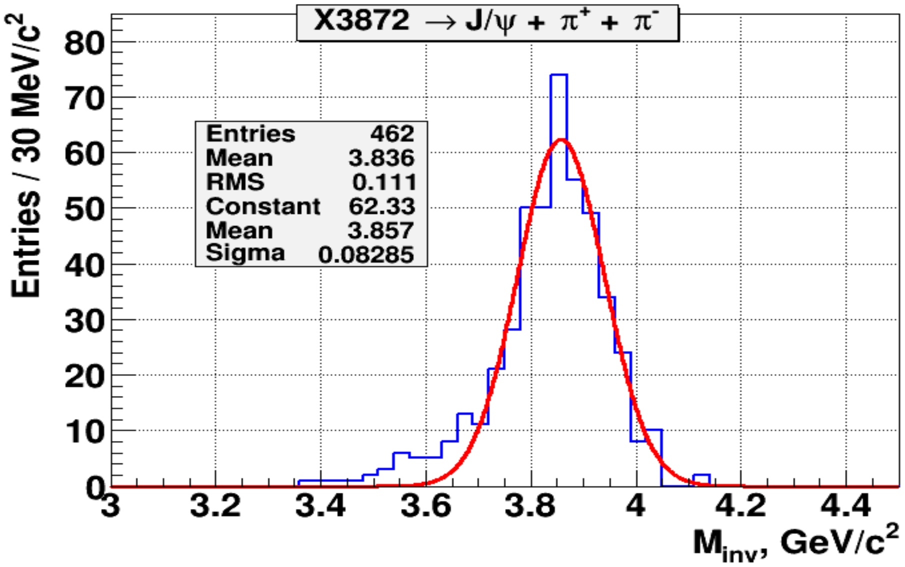
Requiring $M(\pi^+\pi^-) > 0.5$ MeV/c^2 reduces the back-

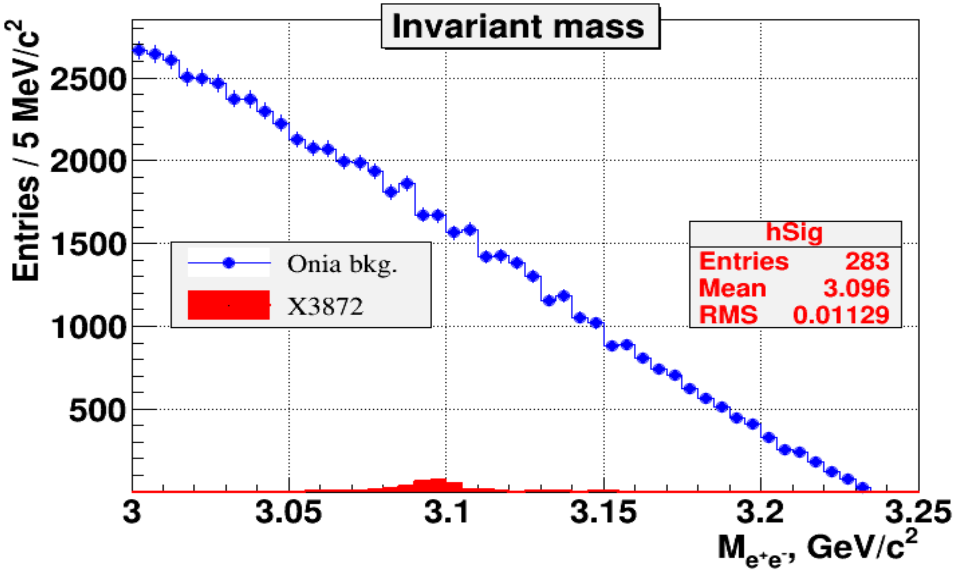
X(3872) state

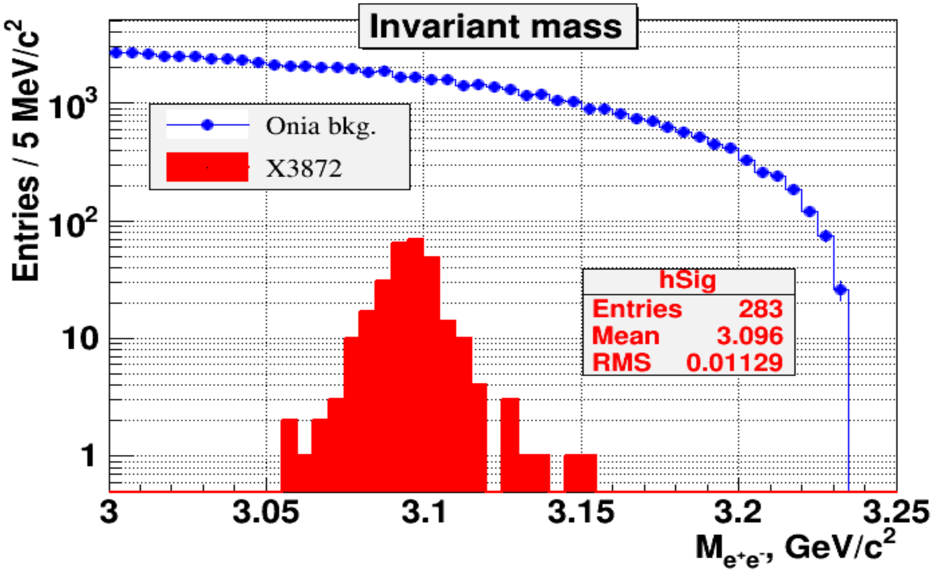
1. X-section in Pythia8 for X(3872) is 4 nb (X(3872) $\equiv \psi$(3770) with mass 3.872 GeV)

2. Br (X3872 $\rightarrow$ J/ψ ρ^0) = 5.0%
Br (X3872 $\rightarrow$ e+e- $\pi+\pi-$) = 0.3% $\rightarrow$ X-section = 12.2 pb
1000 events at L = 10^{30} $cm^{-2}s^{-1}$: 950 days

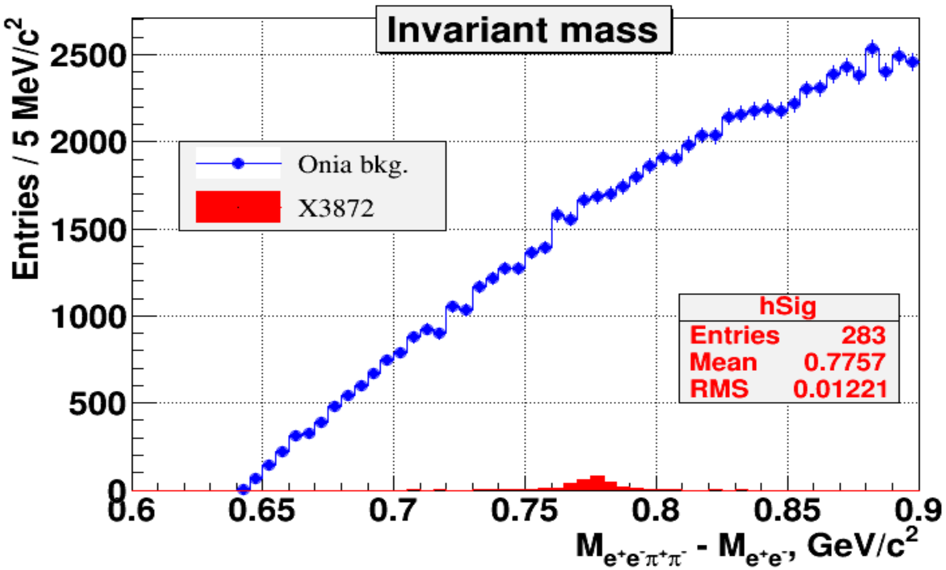
$X(3872) \to J/\psi + \rho^0$

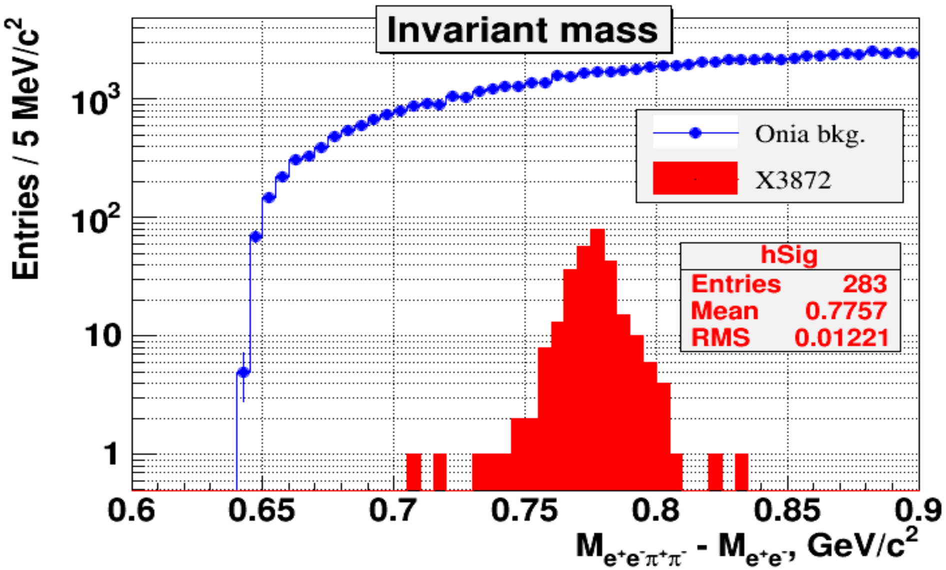




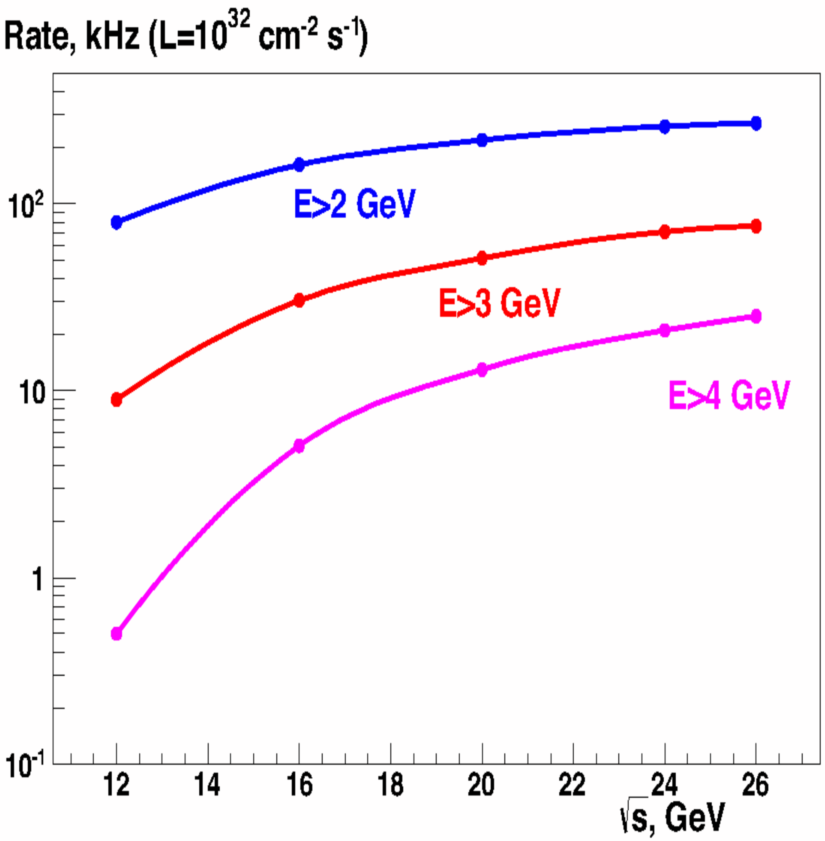


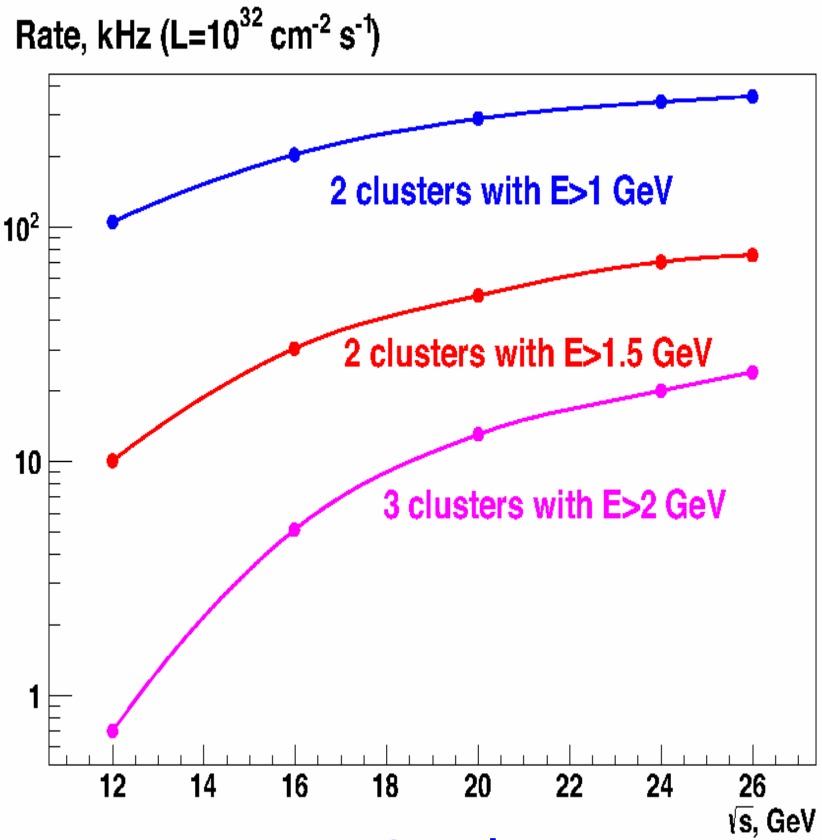
$X(3872) \to J/\psi + \rho^0$





Trigger rate estimates (from SPD)





A.Guskov

Trigger and pile-up resolving in ITS

"A Monte-Carlo study of the NICA/MPD inner tracking system main characteristics"

D.Zinchenko, E.Nikonov, A.Zinchenko

Mathematics. Computing. Education.
XXV International Conference
Dubna, Russia, 29 January – 3 February 2018

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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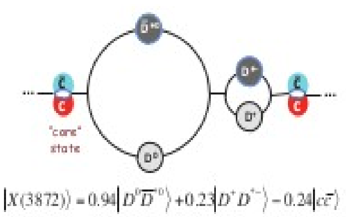


Figure 1: The $X(3872)$ in a hybrid picture. The numerical values come from re

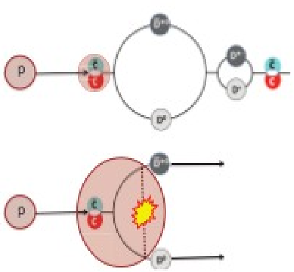
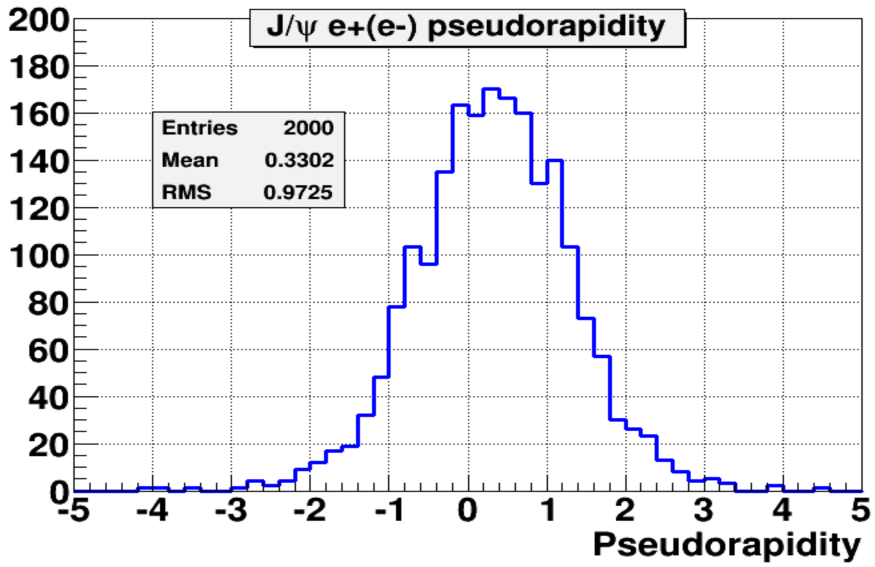
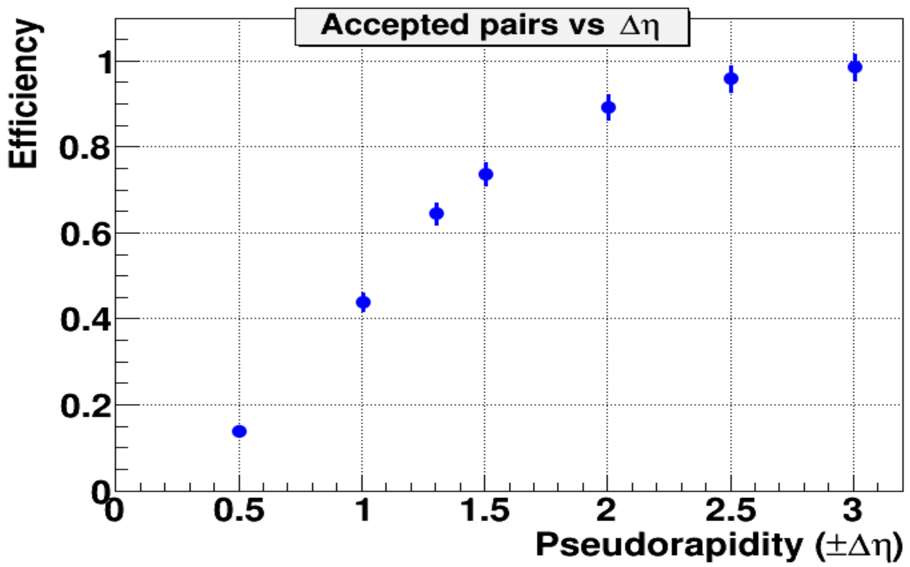
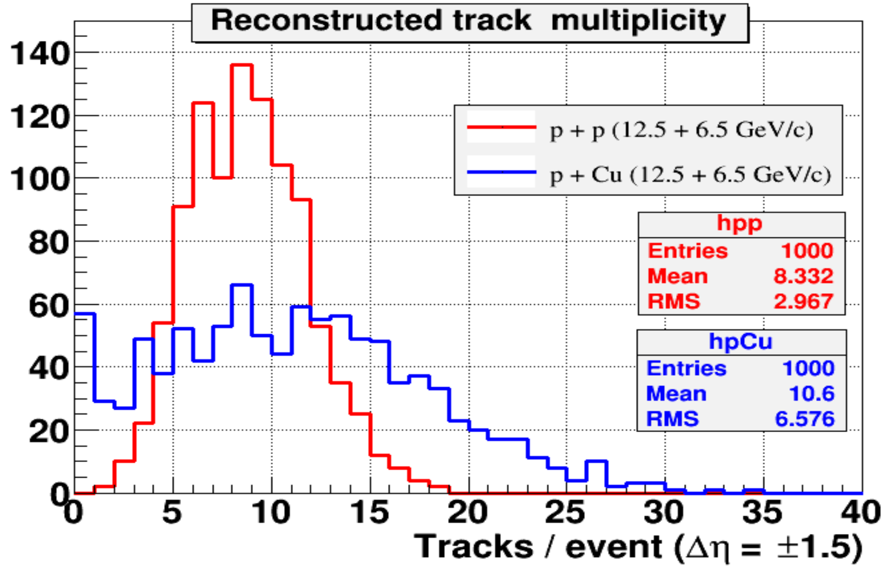


Figure 2: (**Top**) $X(3872)$ production on a proton target ($r_{\mathrm{rms}} \simeq 1$ fm). Here the $X(3872)$ escapes the target region before it establishes a significant $D\bar{D}^*$ component. (**Bottom**) $X(3872)$ production on a nuclear target. Here the presence nuclear material disrupts the (< 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 ψ(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/ψ $\pi+\pi-$) = 5.00%
Br (X(3872)$\rightarrow D^+D^-$) = 40.45%
Br (X(3872)$\rightarrow D^0D^{*0}$bar) = 54.55%

4. Br (D+->K-$\pi+\pi+$) = 9.2%, Br (D0->K-$\pi+$) = 3.8%

*5. σ(pCu) * Br(D+D-) * Br(K$\pi\pi$) = 81.9 * 0.4045 * 0.092 * 0.092 = 0.280 nb*

0.280 nb => L = 5.9 x 10^{29} (1000 events / 10 weeks)

Interaction rate estimates

In [1]: $\sigma_{pA_t} = \pi \cdot r_0^2 \cdot (A_t^{1/3} - a / A_t^{1/3})^2$, (1)

$r_0 = 1.3$ *fm*, $a \approx 0.3$

$\sigma_{pCu} = \pi \cdot 1.3^2 \cdot (4 - 0.3/4)^2 = 818$ *mb*

Table 1. [2]

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

Table 2.

σ_{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

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Charm in AA

1. J/ψ polarization studies

2. Open charm selection via hadronic decays

Summary / Conclusions

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

It 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.

Contributors

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