Prospects for X(3872) Detection at Panda

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for the PANDA Collaboration

This talk:
only MC

12th International Conference
on Meson-Nucleon Physics and the Structure of the Nucleon
05/31-06/04, 2010
College of William and Mary
Williamsburg, Virginia

Bundesministerium für Bildung und Forschung

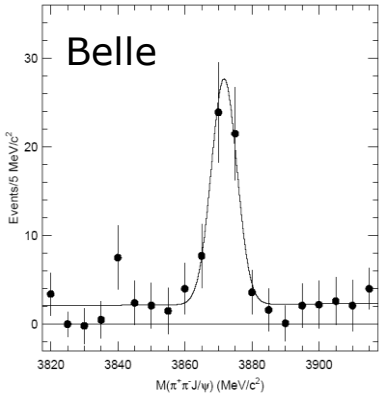
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

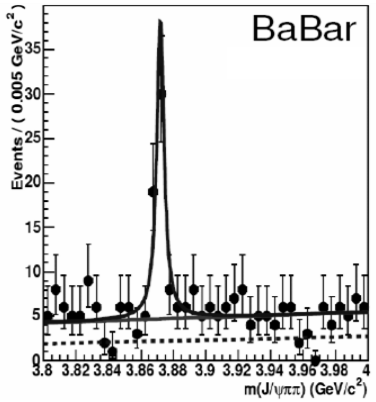
HIC for FAIR
Helmholtz International Center

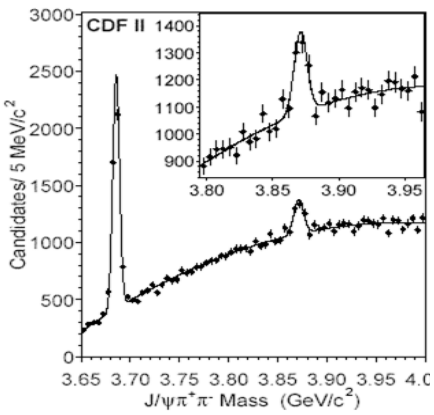
The X(3872)

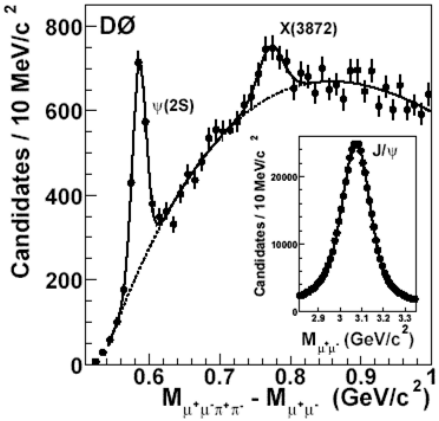
Belle, Phys. Rev. Lett.91(2003)262001
CDF-II, Phys. Rev. Lett.93(2004)072001
D0, Phys. Rev. Lett.93(2004)162002
BaBar, Phys. Rev. D71(2005)071103

- A charmonium(-like) state found in X(3872) → J/ψ π^+ π^-
- Observation of decay into J/ψ γ → C=+1
- interesting properties: breaks isospin in the decays J/ψρ(→ π^+ π^-), J/ψω(→ π^+ π^- π^0) → is it charmonium?
- Within Δm<1 MeV of the DD* threshold → S-wave molecular state?
- (to be) investigated at Belle, BaBar, CDF-II, D0 BES-III, Belle-II, …
- However: width is unknown Γ<2.3 MeV (Belle)





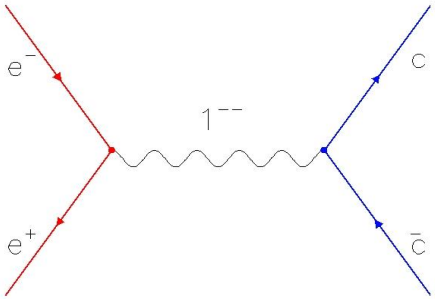


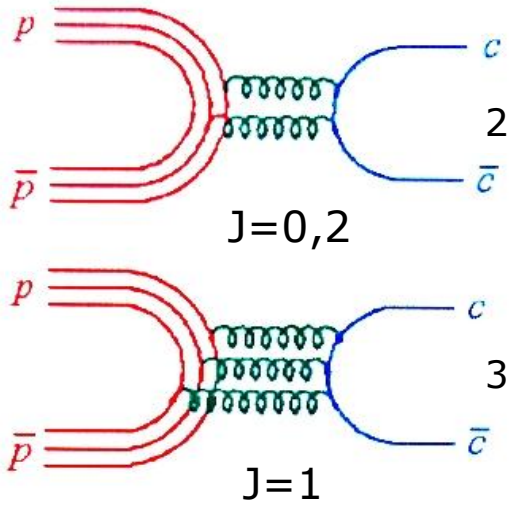


See also Plenary Talks by E. Braaten and S. L. on Tuesday

Charmonium Production in $\bar{p}p$ collisions

- X(3872) has C=+
- In e^+e^- collisions only $J^{PC}=1^{--}$ can be produced directly in $\bar{p}p$ collisions any quantum number



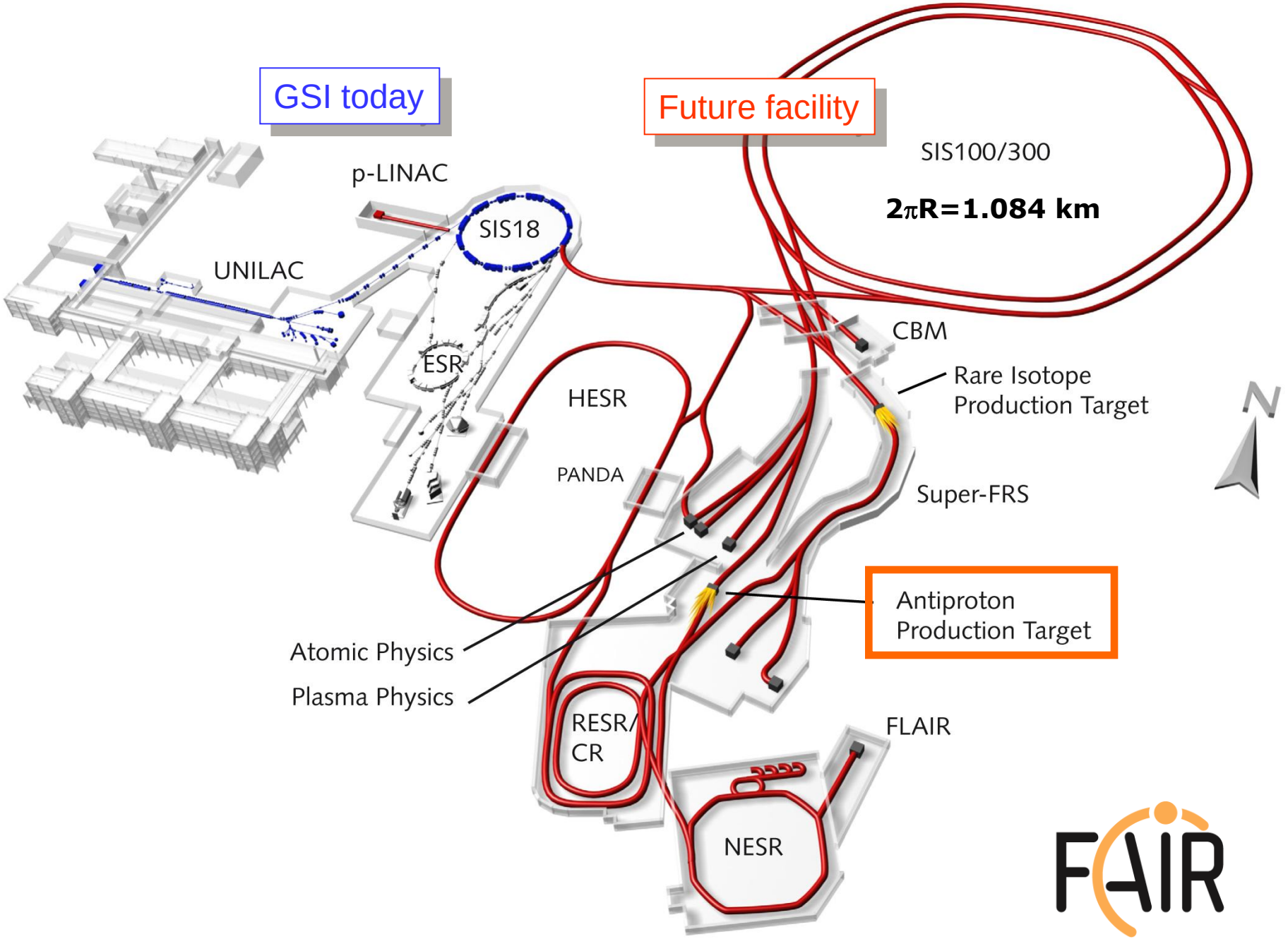


2 gluons: 0−+, 0++, 2++

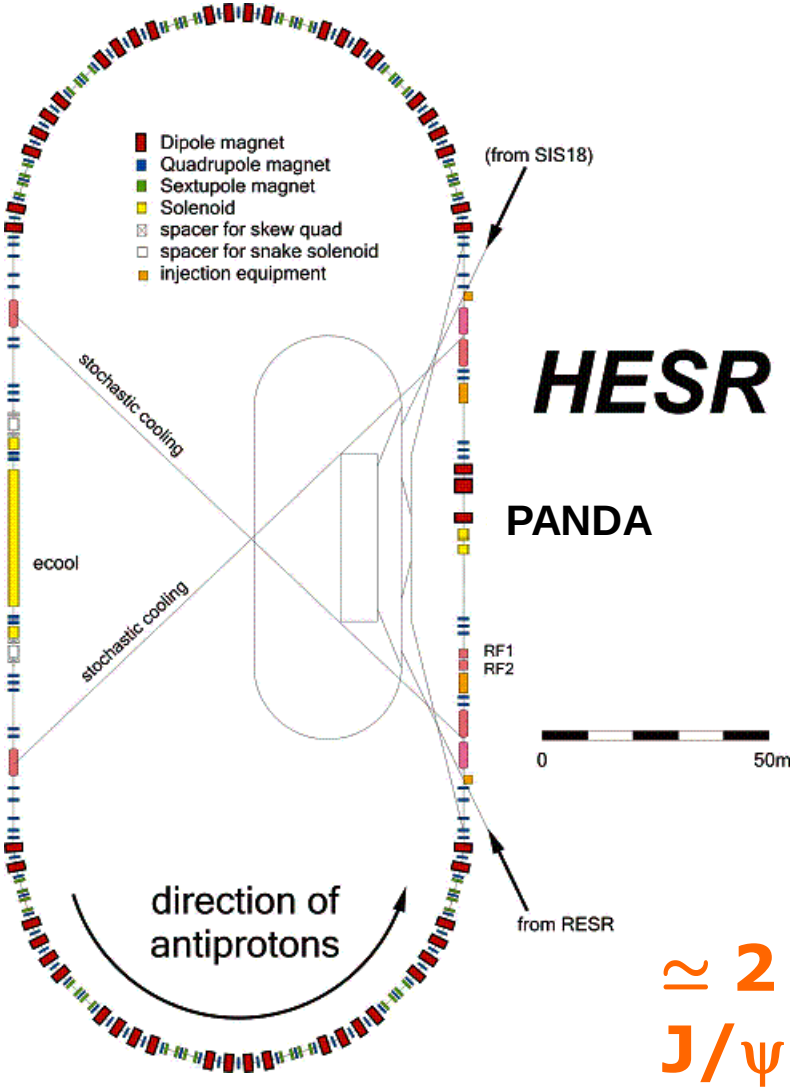
3 gluons: 1−−, 1+−

- Resonance scan with a cooled antiproton beam: the width of the X(3872) could be measured

→ Panda Experiment at FAIR


GSI today
Future facility
SIS100/300
2πR=1.084 km
p-LINAC
SIS18
UNILAC
ESR
HESR
PANDA
CBM
Rare Isotope
Production Target
Super-FRS
N
Antiproton
Production Target
Atomic Physics
Plasma Physics
RESR/
CR
FLAIR
NESR
FAIR

HESR (High Energy Storage Ring)



For Anti-Protons

High intensity mode

- $10^{11}\ \bar{p}$
- $\delta p/p \approx 10^{-4}$ (stochastic cooling)

High resolution mode

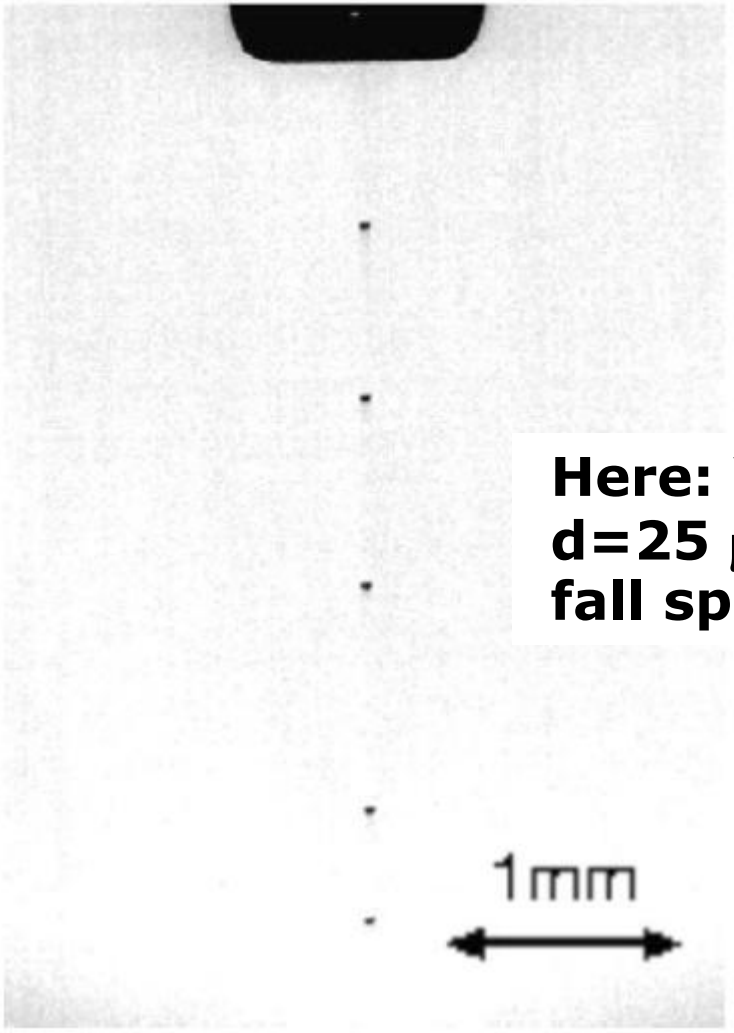
- $10^{10}\ \bar{p}$
- $\delta p/p \approx 10^{-5}$ (e^- cooling)

Internal targets

- $\mathcal{L} = 2 \cdot 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Pellets
- Cluster jet
- Nuclei: Be, C, Si, Al

$\simeq$ 2 x 10^9 J/ψ per year

The Pellet Target



Here: WASA Target
d=25 μm
fall speed ≥ 60 m/s

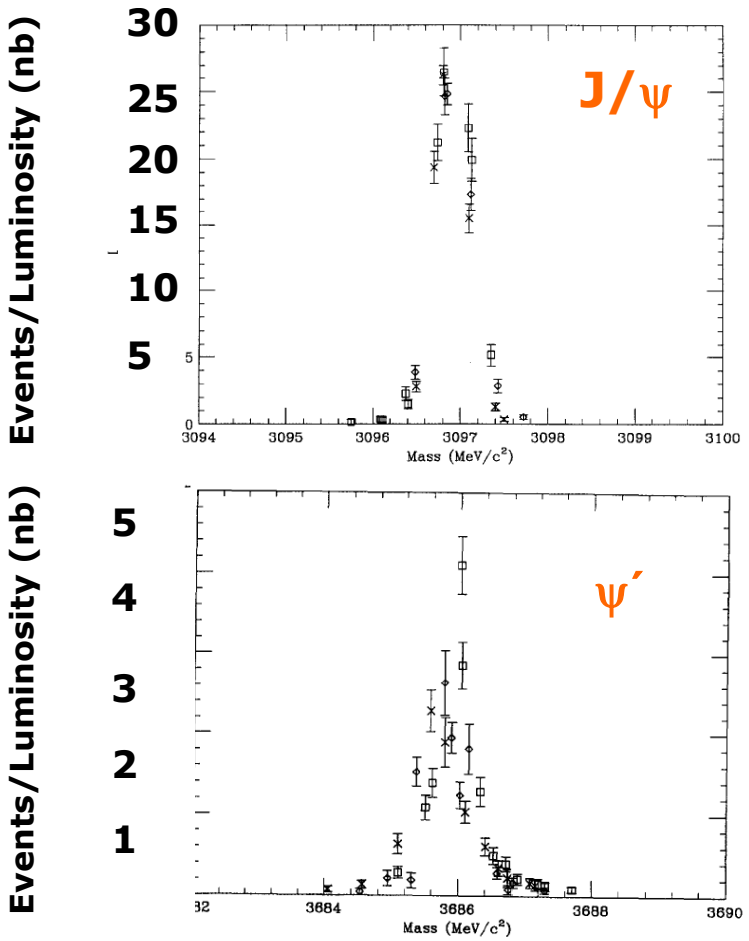
Example of Charmonium Width Measurements

Γ (J/ψ) = 99 $\pm$ 12 $\pm$ 6 keV
Γ (ψ') = 306 $\pm$ 36 $\pm$ 16 keV
by FERMILAB E760 and E835

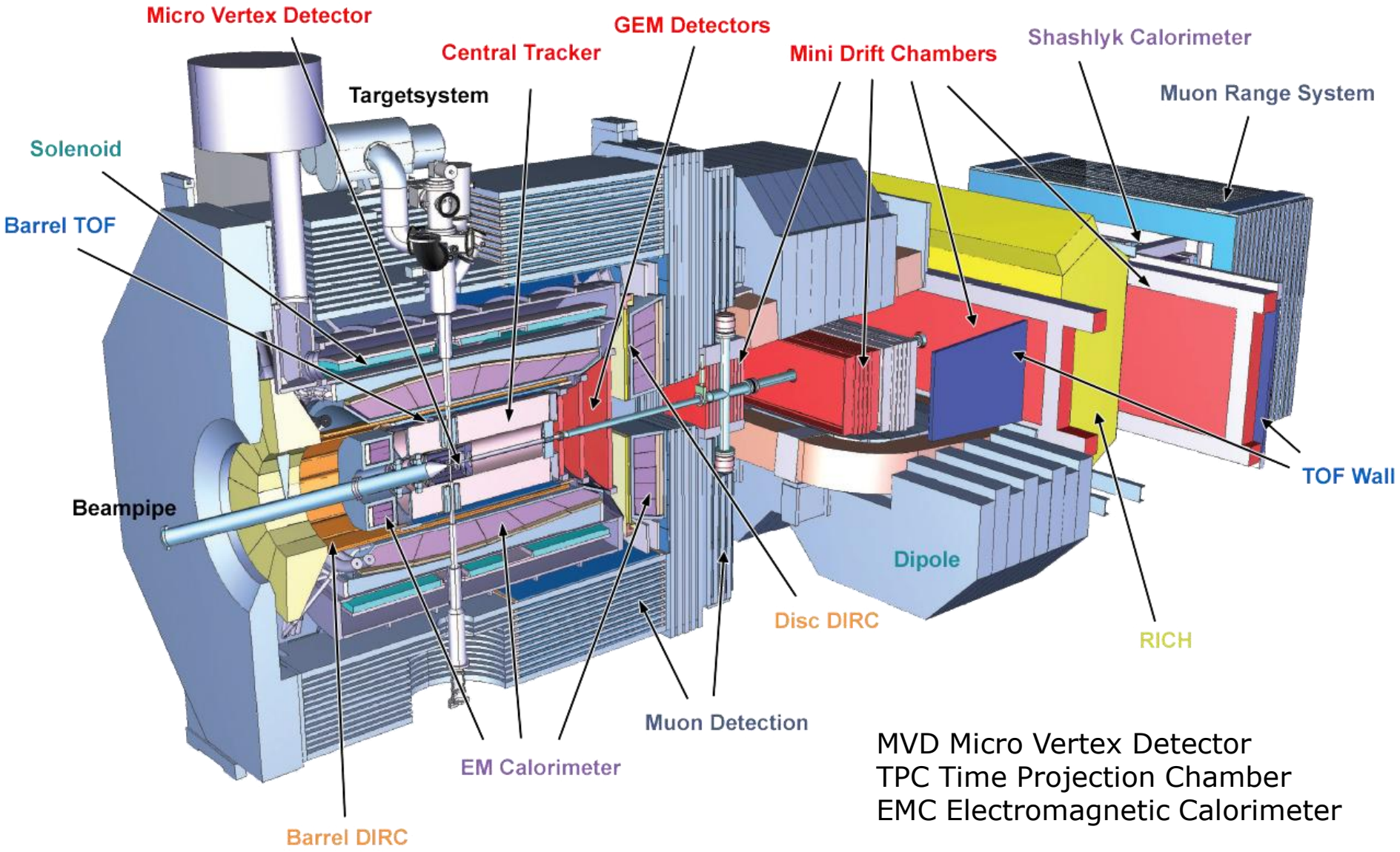
beam momentum resolution
$\Delta p/p$, 2×10^{-4}
$\rightarrow$ $\sqrt{s}$ FWHM resolution $\simeq$0.5 MeV

$\sigma \times$ BR (J/ψ) $\simeq$ 630 nb

Phys. Rev. D 47(1993)772



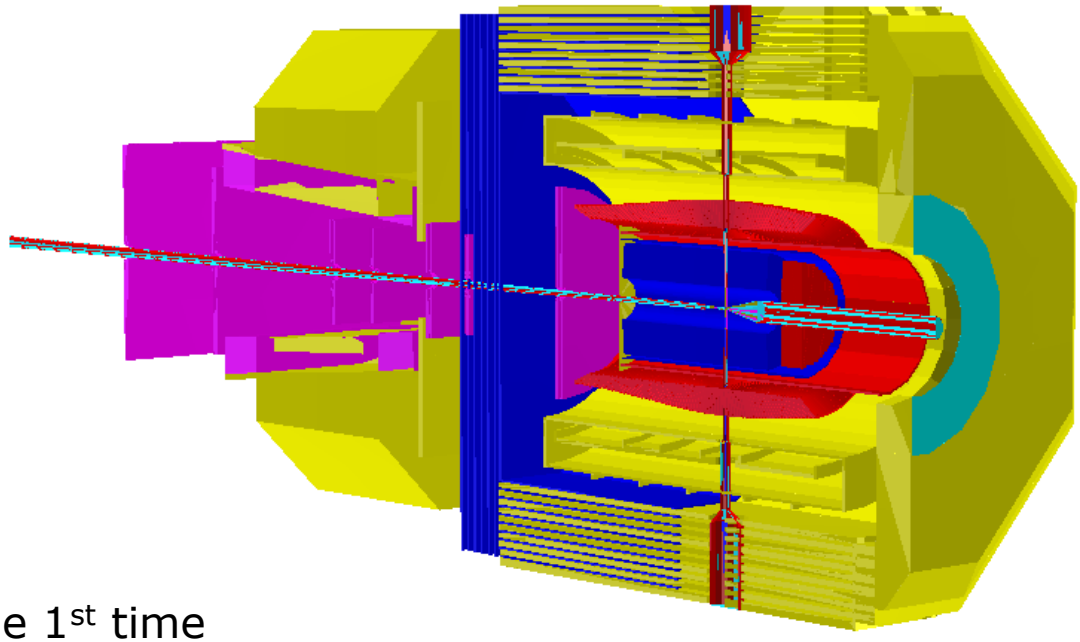
Panda Experiment



MVD Micro Vertex Detector
TPC Time Projection Chamber
EMC Electromagnetic Calorimeter

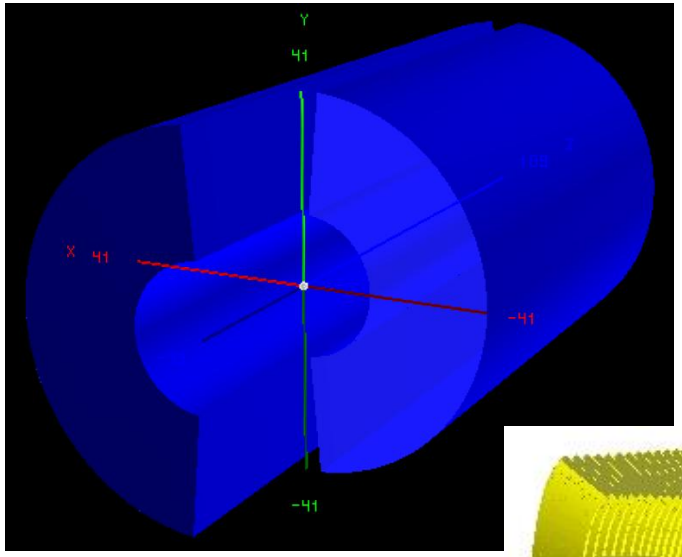
PandaRoot Framework

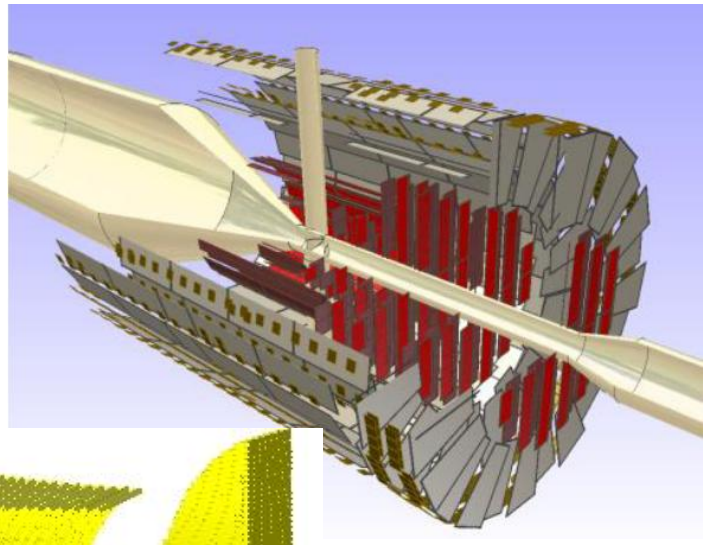
- Simulation,
  Digitization
  Reconstruction,
  Analysis
- 43,000 geometry volumes
- $\geq$ 400,000 lines of C++ code
- Transport engines:
  Geant3, Geant4, FLUKA
- Event Generators:
  EvtGen, DPM, PYTHIA, UrQMD
- $\geq$ 20 Linux platforms
- Improvements since
  Panda Physics Book
  arXiv:0903.3905
  - X(3872) simulations for the 1st time
  - detailed field maps
  - track finder and track fitter
  - final state radiation
    PHOTOS, Comp. Phys. Comm. 79(1994)291-308

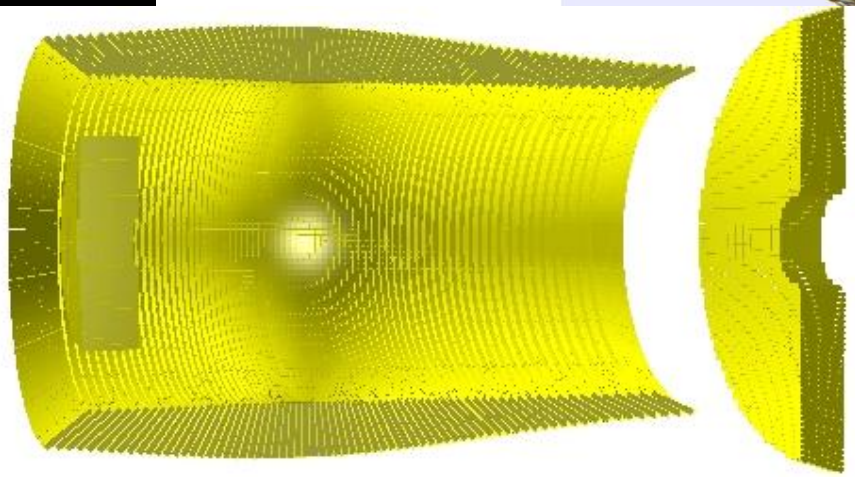


For further information
http://panda-wiki.gsi.de/cgi-bin/view/Computing/PandaRoot

PandaRoot Implementation of relevant Detectors







TPC

135 padrows
135,169 pads of 2x2 mm^2

EMC

~17,200 crystals
PbWO4 (radiation hard, fast τ_{decay}~6 ns)
28 X_0

MVD

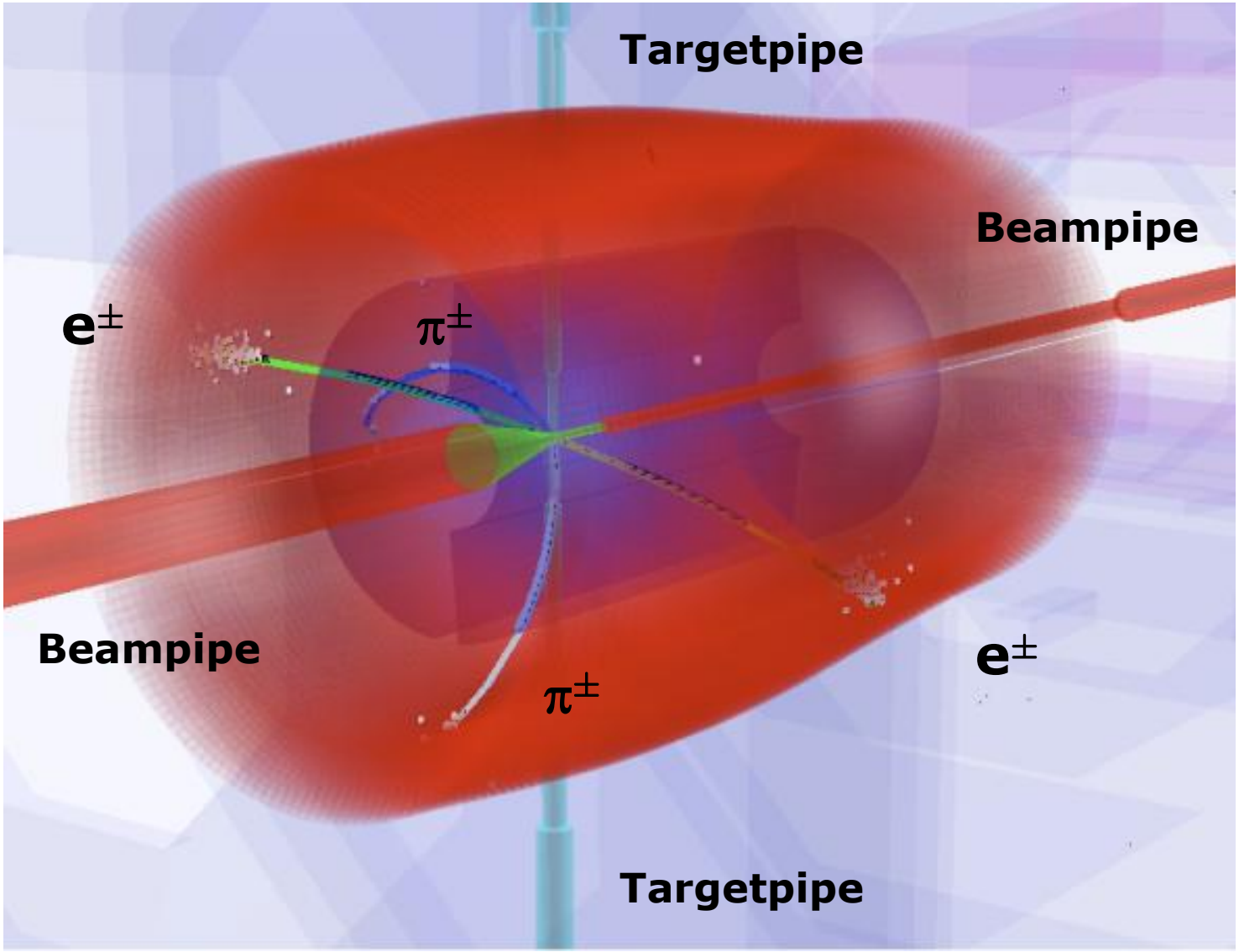
120 pixel modules
100x100 μm^2 pixel size
~10^7 readout channels

400 strip modules
~0.5 m^2 active area
7x10^4 readout channels

Estimated Rates for X(3872) Formation at Panda

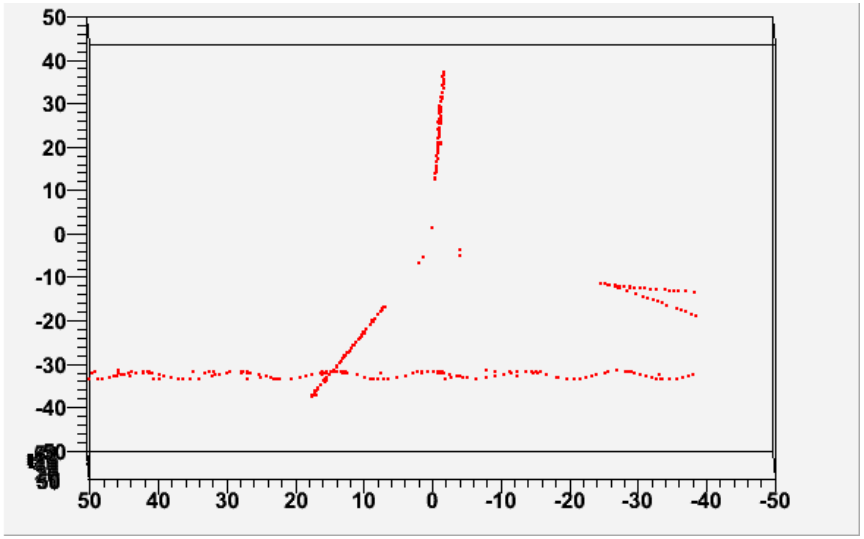
- p_{beam}=6.99100 GeV/c
- Baseline assumption: σ_{peak} = 50 nb
- If X is a loosely bound DD* state
  Chen, Ma, Phys. Rev. D77(2008)097501
  cross section estimate $\leq$443 nb
- Branching fractions of decays of X(3872) into
  DD* : $J/\psi\ \pi^+\ \pi^-$: $J/\psi\ \gamma$
  assumed as 9:1:0
- $J/\psi \rightarrow e^+\ e^-$ and $\mu^+\ \mu^-$
  BR $\simeq$ 6% each
- Reconstruction efficiency $\simeq$ 50%
  (track reconstruction efficiency for low momentum $\pi^{\pm}$)
  $\rightarrow$ 250 pb
- high resolution mode $\Delta p/p = 10^{-5}$ is
  low luminosity mode: $L=2\times10^{31}\ cm^{-2}\ s^{-1}$
- duty factor = 50%
- L_{int}= 0.86 pb^{-1}/day
- 20 points for resonance scan
  2 days/point
- Yield $\simeq$ 215 events of $X\rightarrow J/\psi\ \pi^+\ \pi^-$ per day at peak

X(3872)→ J/ψ π^+ π^- Event, PandaRoot Simulation

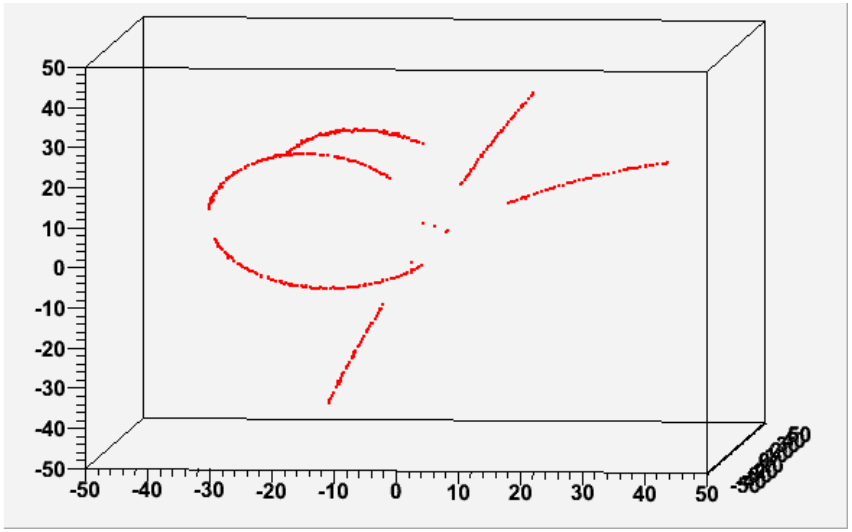


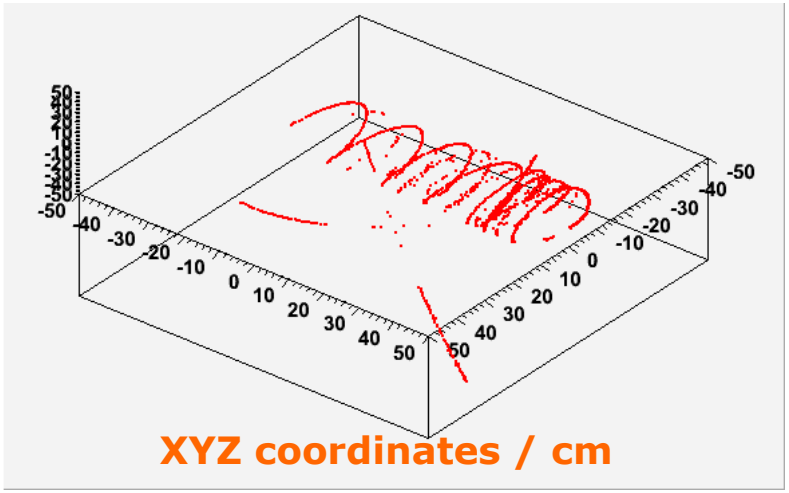
X(3872) Events in Panda MVD+TPC
PandaRoot Simulation

XYZ coordinates / cm



XYZ coordinates / cm



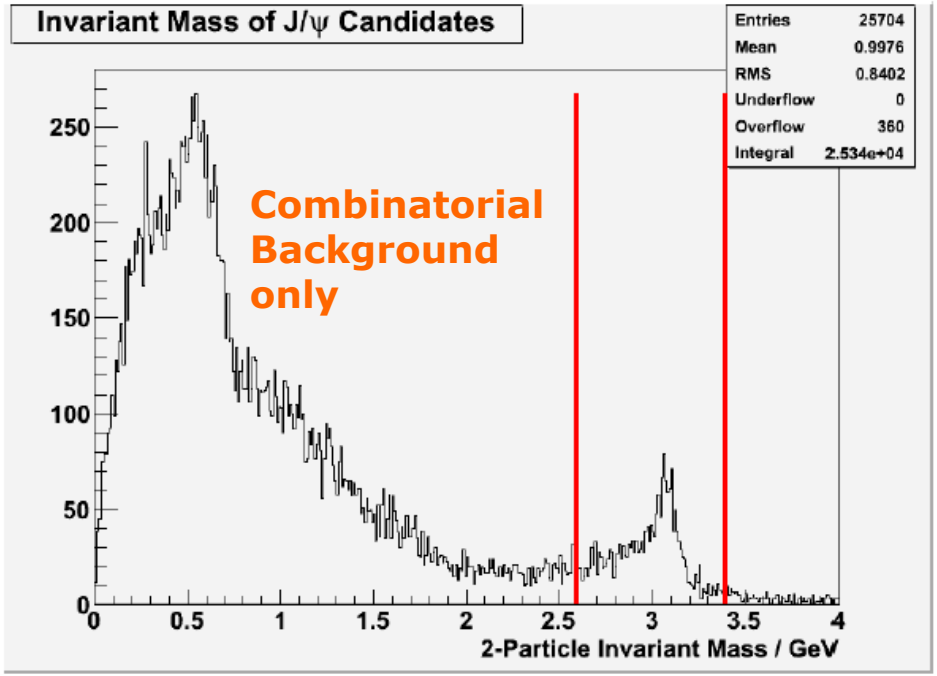


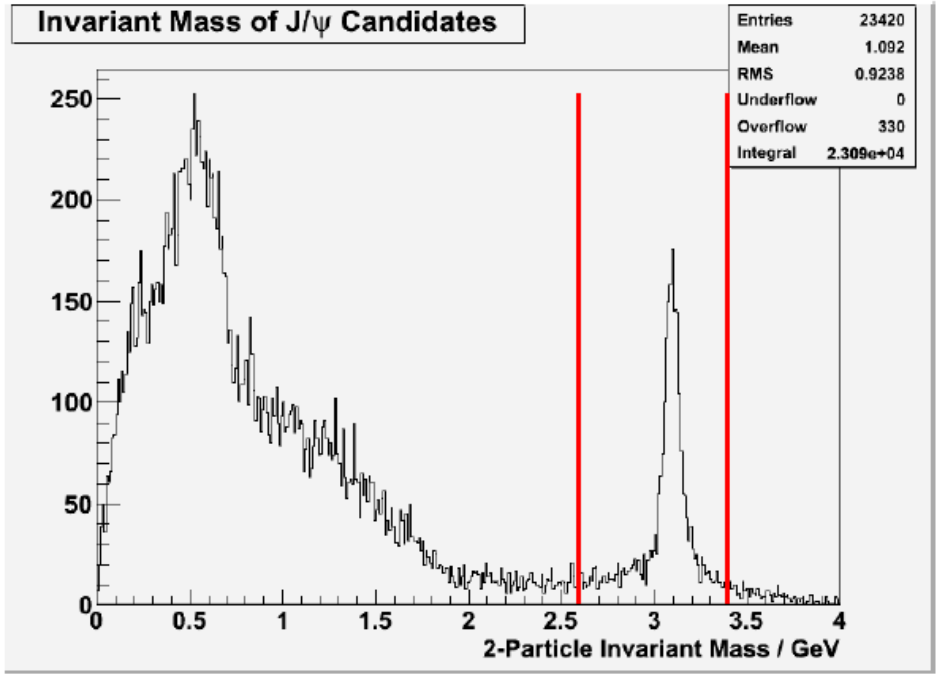
XYZ coordinates / cm

Beampipe Interaction

Comparison of $e^+ e^-$ and $\mu^+ \mu^-$ final states

2-particle invariant mass





J/ψ decay into e^+e^-

Radiative Tail due to Final state radiation (PHOTOS)

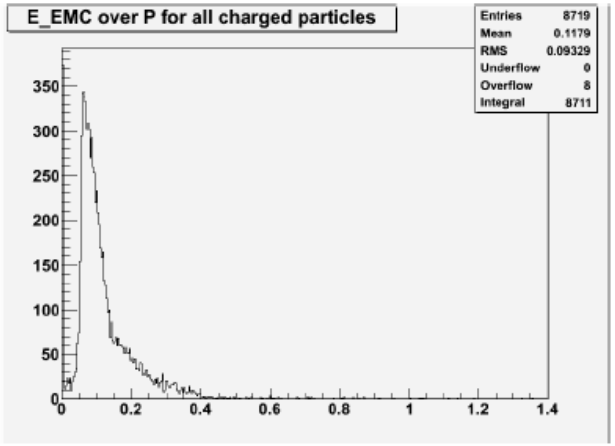
J/ψ decay into $\mu^+\mu^-$

Particle Indentification (PID)

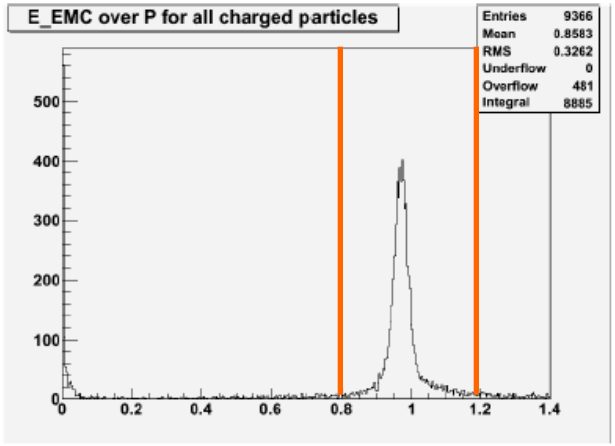
Using E_{EMC}/p_{track} (requires track-cluster matching)

E_{EMC} is deposited cluster energy

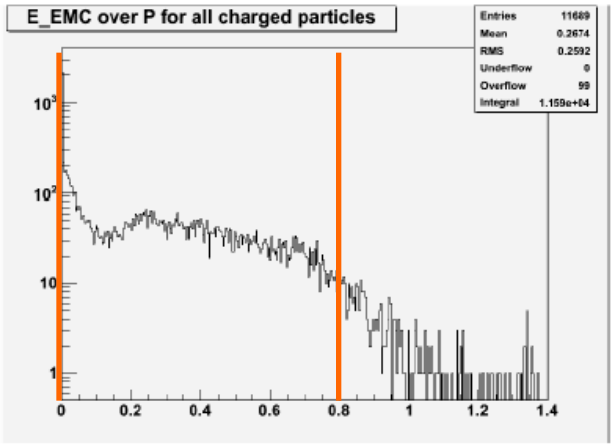
P_{track} is reconstructed track momentum (TPC + MVD)



$J/\psi \to \mu^+\mu^-$ VLL



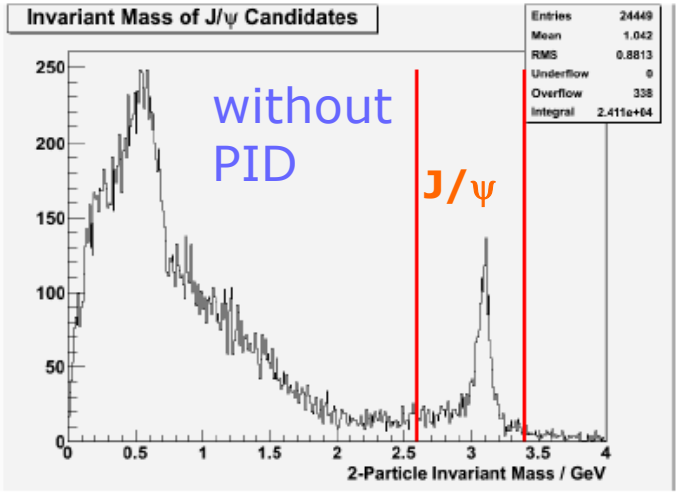
$J/\psi \to e^+e^-$ VLL



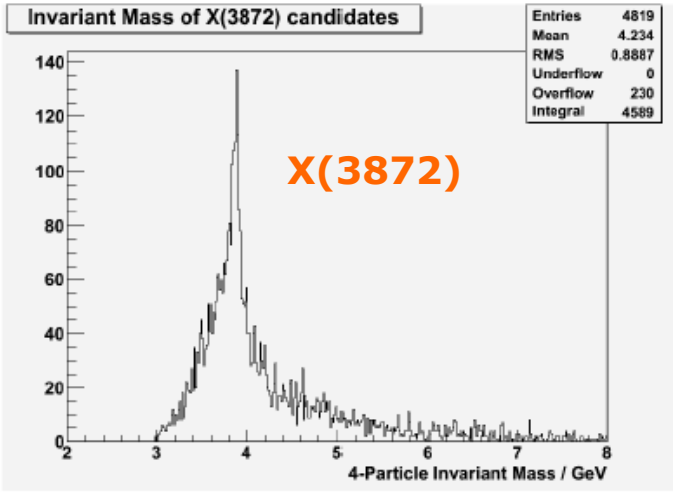
$\psi' \to J/\psi\, \pi^+\, \pi^-$,
no J/ψ decay

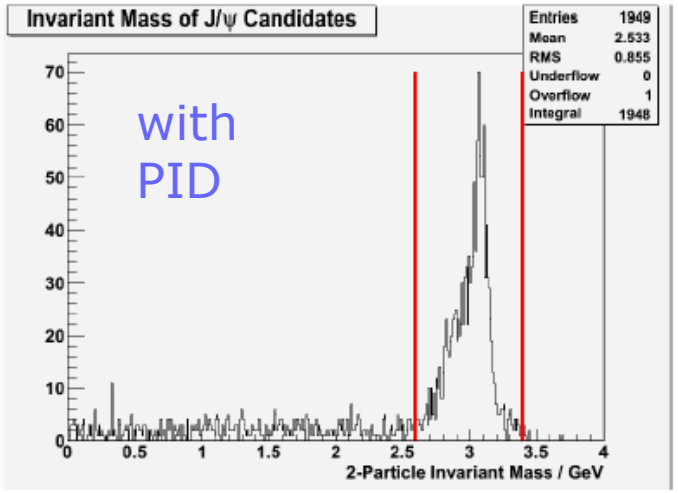
Example MC Results for X(3872)→ J/ψ π^+ π^-

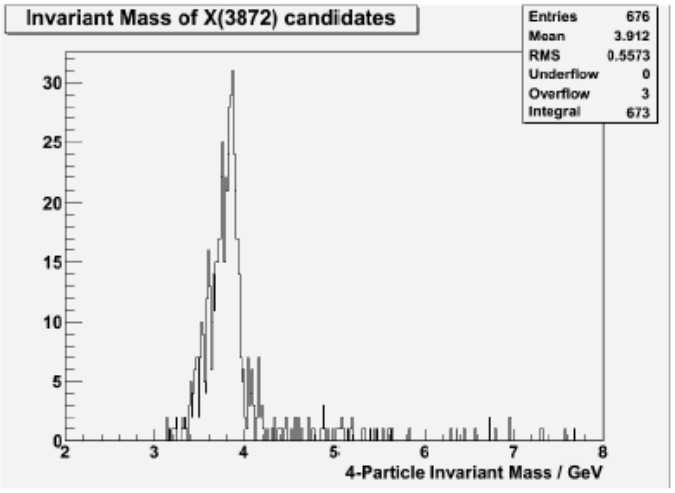
2-particle invariant mass



4-particle invariant mass

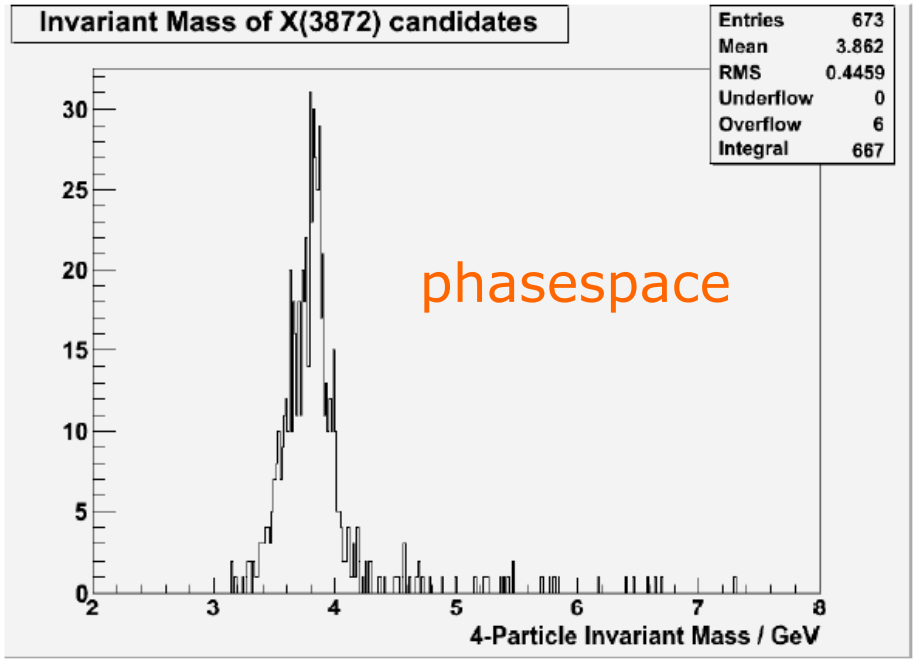


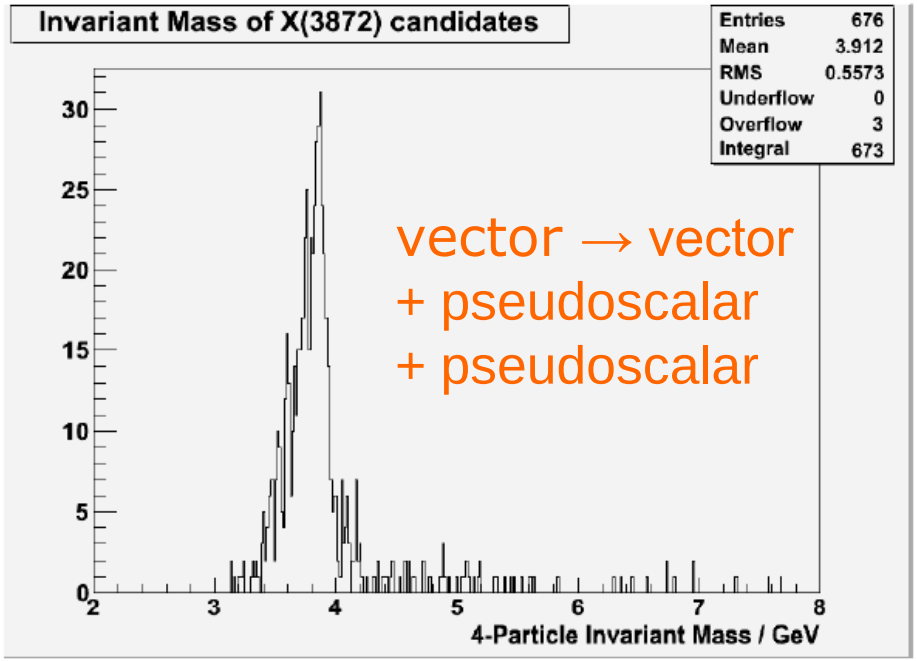




Variation of Angular Distributions

- Tentative quantum number assignment of X(3872) is 1++
  → vector
- Panda is fixed target experiment
  cms frame → lab frame
- Negligible effect on reconstruction efficiency (<1%)
- → Lorentz boost dominates acceptance



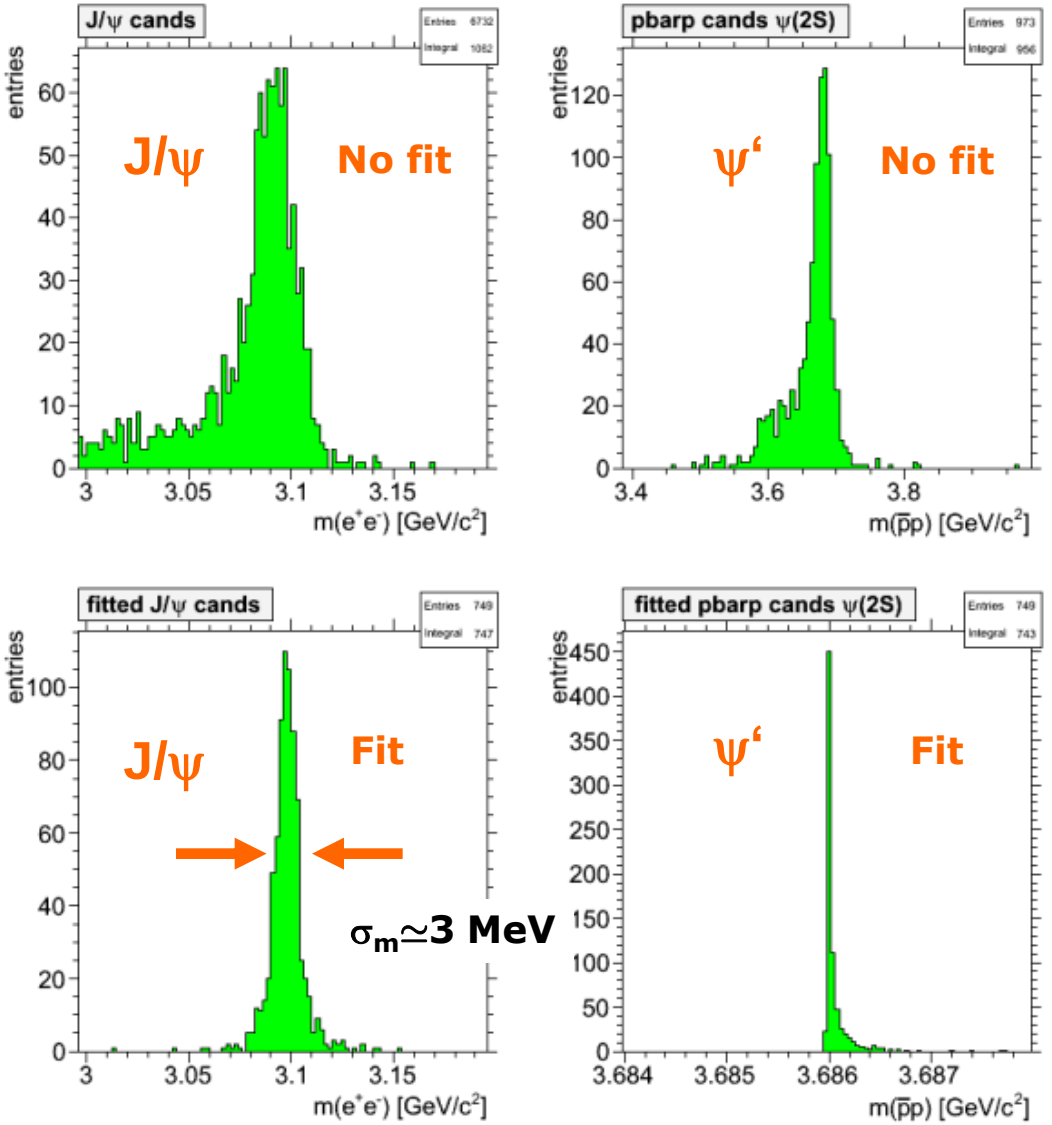


Kinematic Fit: Vertex Constraint and Mass Constraint

Example:
reference mode

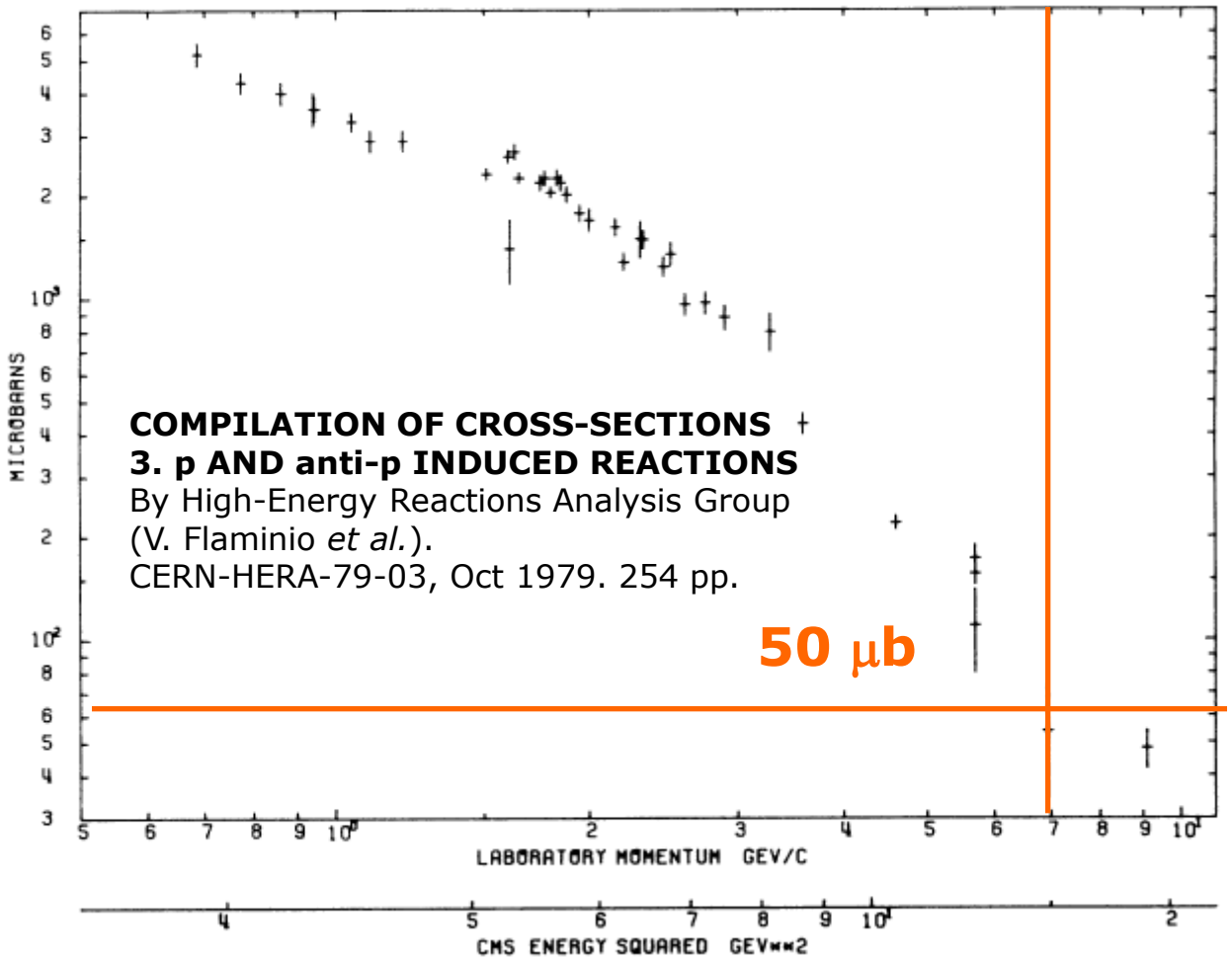
$\psi' \rightarrow J/\psi \ \pi^+ \pi^-$

↑ **Constraint**



Background: $p\ \bar{p} \rightarrow 2\ \pi^+\ 2\ \pi^-$

$\sigma_{total}\ (\ \bar{p}p\ ) \simeq 70$ mb



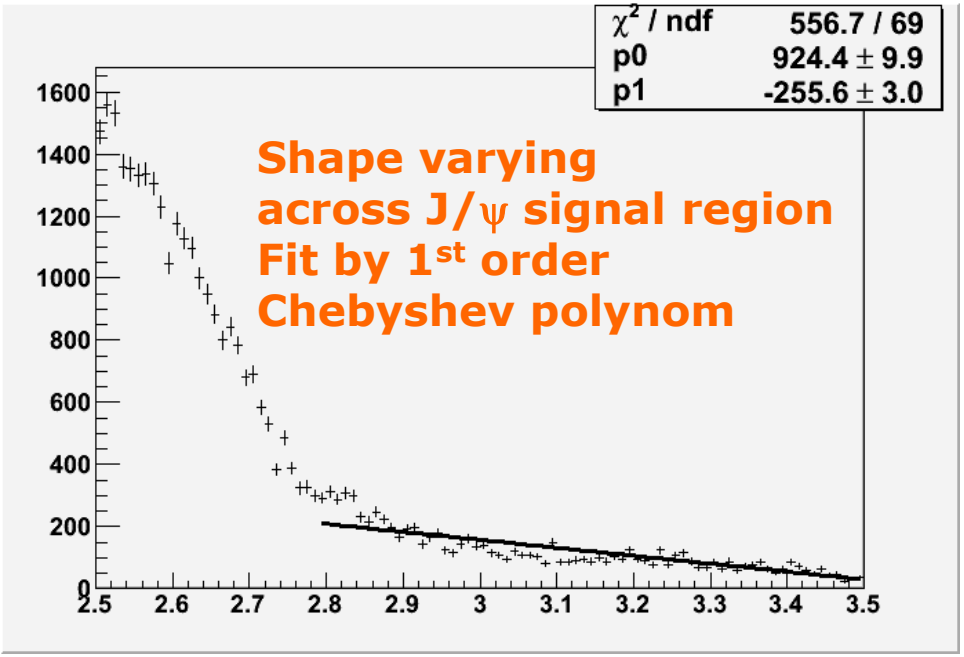
Shape of Background
Dual Parton Model (DPM)

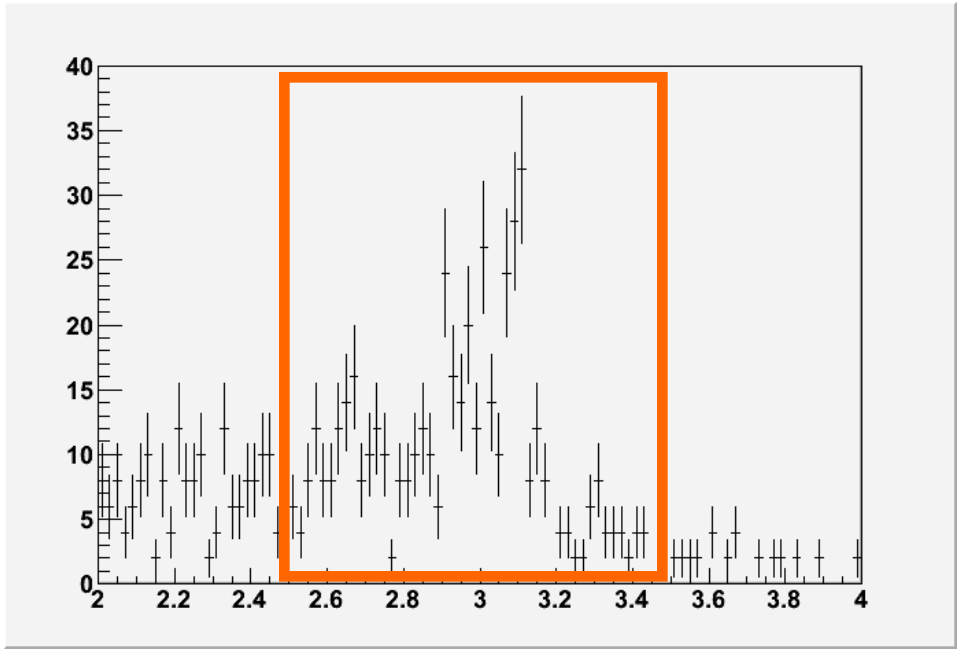
Capella, Sukhatme, Tan, Tran Thanh Van
Phys. Rept. 236(1994)225
Kaidalov, Volkovitsky,
Z. Phys. C63(1994)517
Uzhinsky, Galoyan
hep-ph/0212369

Kinematic situation favourable

→ background decreases just below J/ψ mass

2 days data taking



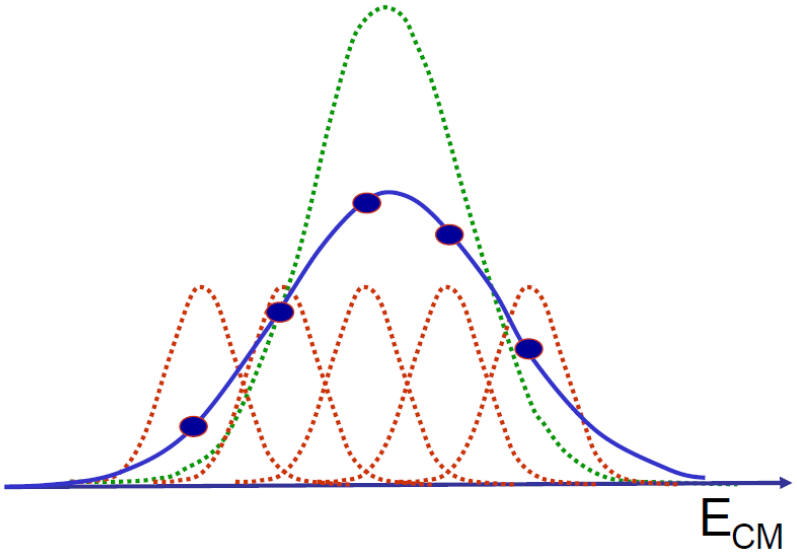


Scan of a Resonance R

Convolution of resonance width and beam resolution

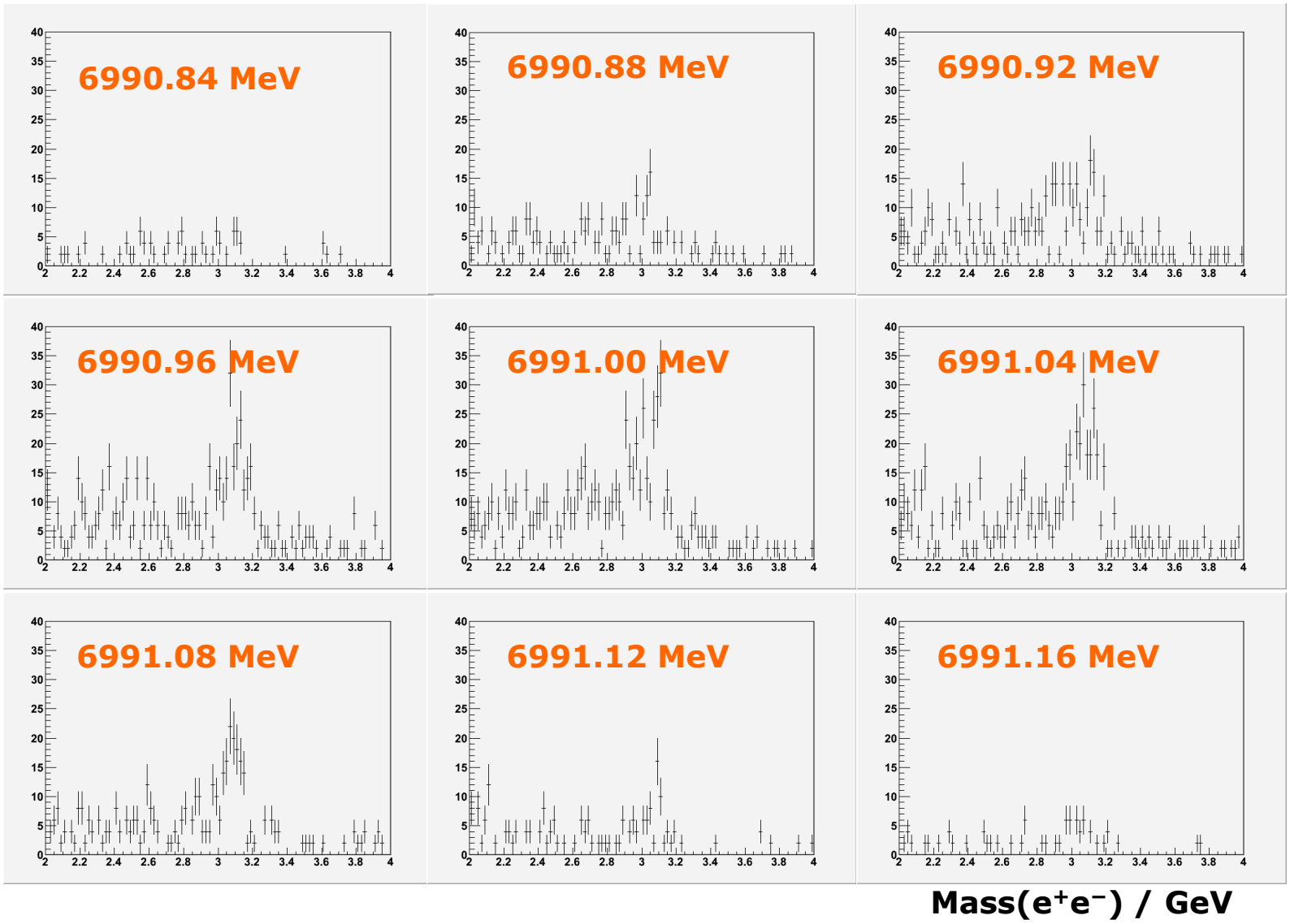
$$\sigma(E_{cm}) = \int_0^\infty \sigma_{BW}(E')G(E' - E_{cm})dE'$$

$$\sigma_{BW}(E_{cm}) = \frac{(2J+1)}{(2S+1)(2S+1)} \frac{4\pi(\hbar c)^2}{(E_{cm}^2 - 4(m_p c^2)^2)} \times \frac{\Gamma_R^2 BR(\overline{p}p \to R)BR(R \to f)}{(E_{cm} - M_R c^2)^2 + \Gamma_R^2/4}$$



MC, X(3872) Scan, each 2 days, $\Delta p/p = 10^{-5}$ mode

Tagged J/ψ yield, 2-particle invariant mass / GeV

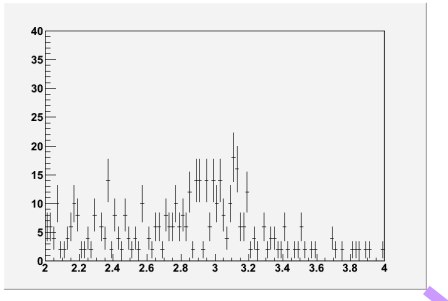


X(3872) Excitation Function, MC

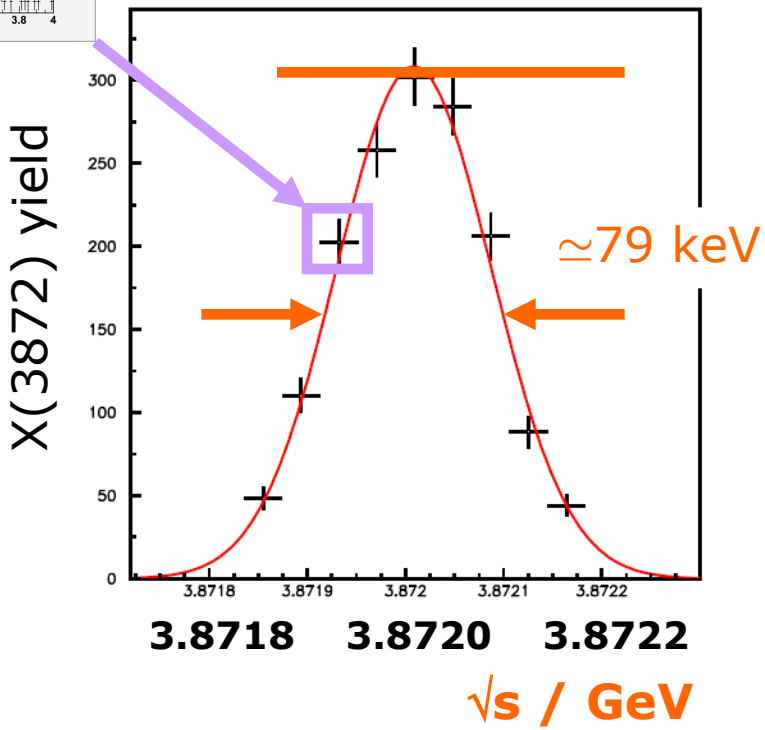
- Exclusive final state

  $p\ \bar{p} \rightarrow X(3872)$

- each data point
  2 days
  data taking
- full background
- Preliminary result:
  fitted width is ~20% larger than input,
  but $\sigma(\sqrt{s})$ still $\leq$100 keV
  (this would be a syst. error on the width of X(3872))
- Unfolding
  (integral equation)
  is ongoing work
  (Master Thesis, Univ. Gießen)
- Preliminary estimate for Panda
  $\Gamma \geq 168$ keV for $\Delta p/p = 10^{-4}$



Reconstruction efficiency ≃72%



Preliminary
stat. errors only

Summary

- For the 1st time, MC simulations for X(3872) production at Panda have been performed
- Detailed simulation and reconstruction:
  - final state radiation
  - vector → vector angular distribution
  - track finder and track fitter
  - PID by track and cluster matching
  - background with dual parton model
- Preliminary results are encouraging
- Extraction of width is ongoing (integral equation)

see also:

- M. Sudol, Session 4E, Tuesday
  Formfactors at Panda
- Ulrich Wiedner, Plenary, Friday
  Status of FAIR