BES-3 and possible benefit from it for PANDA at JINR

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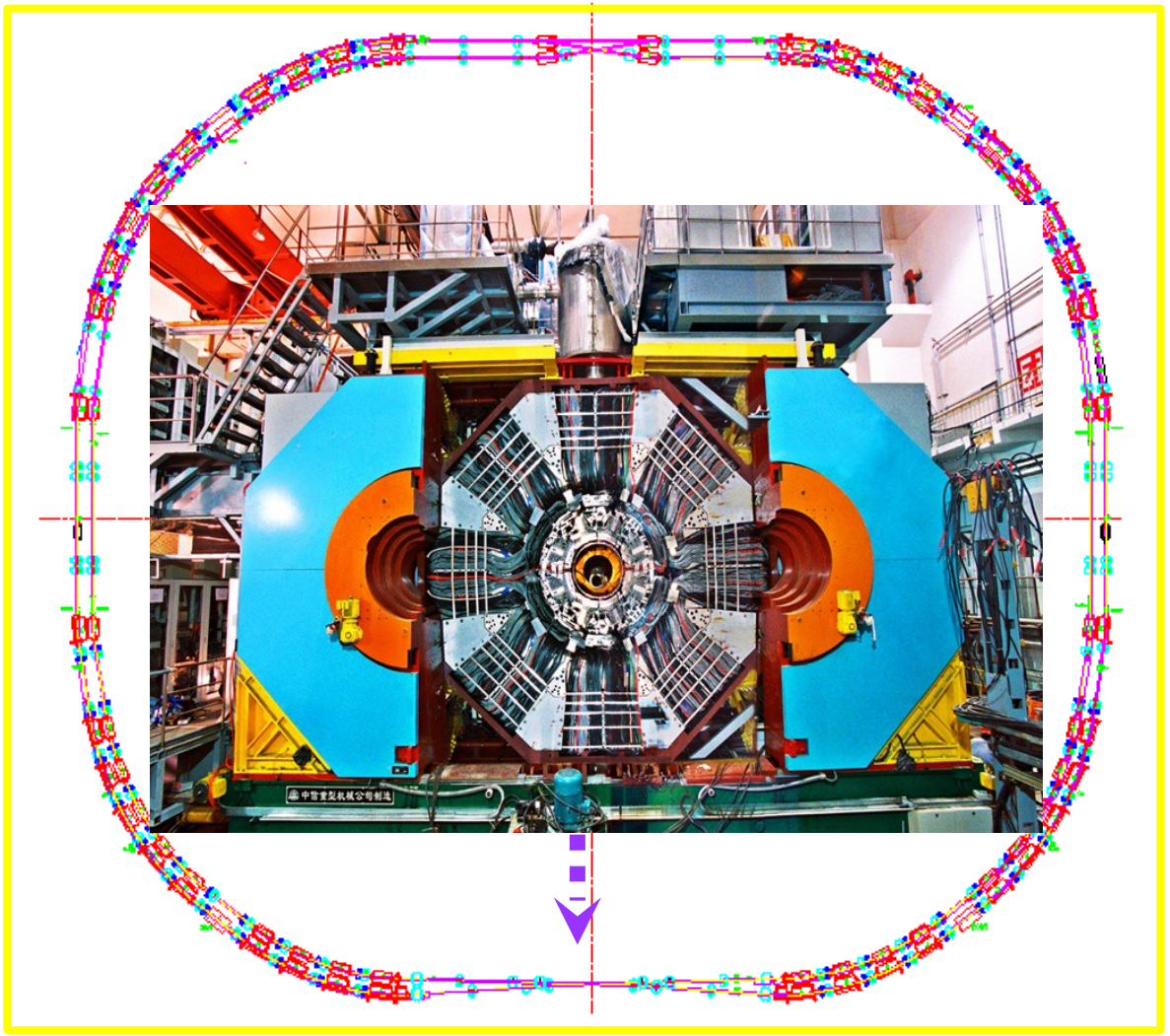
Outline

- JINR group in BES-3
- Light hadron spectroscopy
- Heavy hadron spectroscopy

The BES-III experiment

China, Germany, Italy, Japan, JINR, Korea, Netherlands, Pakistan, Russia, Sweden, Turkey, USA



Site:
IHEP CAS, Beijing, China

BEPC-II beam energy:
1.0-2.3 GeV

Design luminosity
1 x 10^{33}/cm^2/s @ψ(3770)

Achieved luminosity:
0.65 x 10^{33}/cm^2/s

Project timeline:

2004 – Start of BEPC upgrade

2006 - The detector installation

2007 - BEPCII/BESIII commissioning

2009 – Start of physics data taking

Physics research program

Light hadron physics

-meson & baryon spectroscopy
-exotic states
-two-photon physics

Charmonium physics

- precision spectroscopy
- transitions and decays

QCD & τ -physics

- precision *R*-measurement
- τ decays
- *p* & *n* form-factors

Charm physics

- semi-leptonic form factors
- f_D & f_{Ds} decay consts.
- CKM matrix: V_{cd}, V_{cs}
- D^0-$\overline{D}^0$ mixing and *CPV*

Precision mass measurements

- τ mass
- D^0, D^+ & D_s masses

XYZ physics

-*Y(4260), Y(4360)*
- searches for new states

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Data samples after 4 years of data taking

J/ψ	1.2 x10^9 events	world largest sample
ψ'	0.6 x10^9 events	world largest sample
ψ(3770)	~2.9 fb^{-1}	world data sample X 3
$D_s\bar{D}_s$ @ 4.01 GeV	~0.5 fb^{-1}	unique data
Y (4260)	~2.2 fb^{-1}	unique data
Y (4360)	~0.6 fb^{-1}	unique data
τ mass scan	24 pb^{-1}	

More than 40 papers based on these data !

Light hadron spectroscopy

LHS at BES-3 (1st of 3)

- Goals
  - Extra meson states
  - Missing baryon states
  - Search for exotic states in light hadron sector: glueballs, hybrids, multiquarks
- Method
  - J/Ψ, Ψ' decays as a source of light hadrons
  - PWA as a main analysis tool

LHS at BES-3 (2nd of 3)

- Main results
  - Observation of pp mass enhancement in $J/\Psi,\Psi' \to \gamma p\bar{p}$ Chinese Phys. C 2010, 34(4), Phys. Rev. Lett. 431 108, 112003 (2012)
  - Confirmation of the X(1835) and observation of X(2120),X(2370) in J/ψ->γπ+π -η' Phys.Rev.Lett. 106 (2011) 072002
  - New $N^*(2300),N^*(2570)$ in $\Psi' \to \pi^0 p\bar{p}$ Phys. Rev. Lett. 110, 022001 (2013)
  - PWA of $J/\Psi \to \gamma\eta\eta$ Phys. Rev. D. 87, 092009 (2013)
  - PWA of $J/\Psi \to \gamma\varphi\omega$ Phys.Rev. D87 (2013) 032008
  - PWA of $\Psi' \to \eta p\bar{p}$ Phys. Rev. D 88, 032010 (2013)

LHS at BES-3 (2nd of 2)

- Activity of JINR group
  - PWA of $J/\Psi \to K^+K^-\pi^0$, $K_S K^\pm\pi^\pm$
  - combined PWA of $J/\Psi \to \gamma\pi\pi, \gamma KK, \gamma\eta\eta$

JINR group learned to master PWA in collaboration with Bonn-Gatchina team leaded by A.Sarantsev

Gatchina PWA

- Developed in 1993-2000 to analyze Crystal Barrel data at LEAR
  - f0(1500), f0(1370), a0(1450), a2(1700), f2(1560) had been discovered
- Used successfully to analyze γp data of CB-ELSA, SAPHIR, CLAS, GRAAL, SPRING8, TAPS, and $\gamma\gamma$ at L3
- Since 2008 used in BES-3
- Significant effort was made to optimize the procedure for speed

Advantages of the method

- Covariant tensor formalism is used – the method is fully relativistic
- Based on the operator expansion technique

A.V.Anisovich et al, J. Phys. G: Nucl.Part.Phys. 28 15-32 (2002)

- allows to include higher states (like 4^+ etc) without drop of performance
- The method is specially designed for the combined fit of several reactions
- Partial waves are investigated either as a sum of Breit-Wigner resonances or a multichannel K-matrix
- The calculation of rescattering effects in multiparticle reactions is straightforward

PWA at JINR

- Use this method to analyze BES-3 data
- Detailed study of fit stability
- Several optimizations have been made
- A new technique to account for detector resolution is developed and implemented
- PWA program adapted for use on Linux → can treat large data samples at computer farms
- Can cope with 1B of J/Ψ decays at BES-3

PWA@BES-3 vs PWA@PANDA

BES3

- Huge statistics
- Clear initial state
- Clean experimental conditions

PANDA

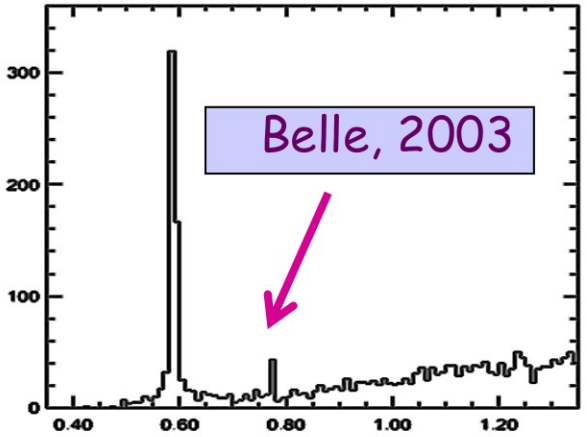
- Huge statistics
- Direct production of initial states other that 1^{--}
- Complicated initial state

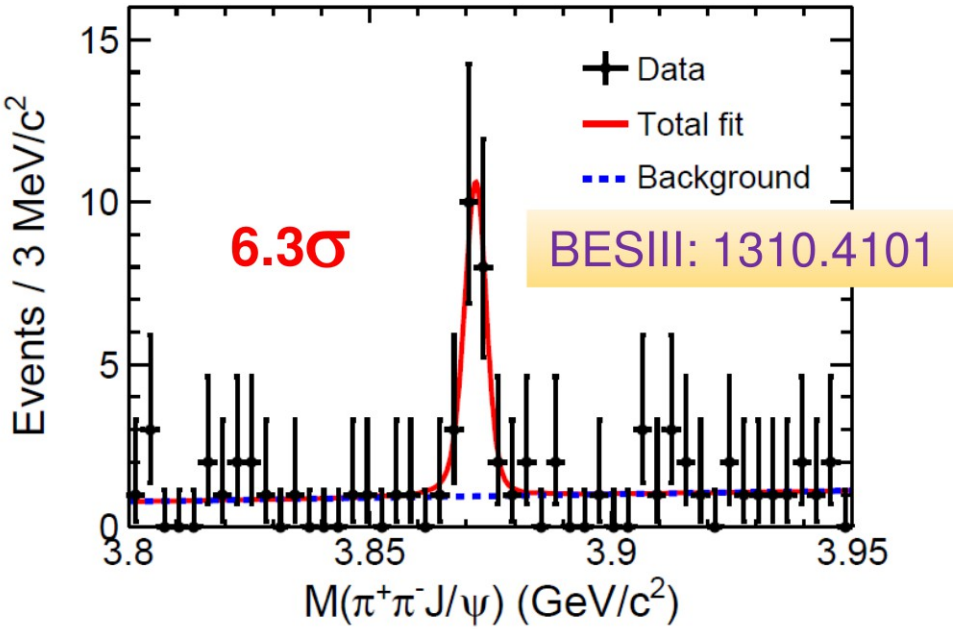
Possible inputs for PANDA

- Very few PWA analyses at BES-III will be limited by statistics of J/Ψ, Ψ' by the time when PANDA starts operation
- Dynamics of rare decays
- PWA using sources other than J/Ψ, Ψ' (like χ_{cJ} or possibly XYZ states)
- Development of PWA technique itself will be necessary (non-resonant contributions, background treatment, number of particles >3, etc)

Heavy hadron spectroscopy

Observation of $e^+e^- \to \gamma X(3872)$





- $J^{PC}=1^{++}$ [LHCb: arXiv:1302.6269]
- Nature:
  - Loosely $\bar{D}^0 D^{*0}$ bound state?
  - Mixture of excited χ_{c1} and $\bar{D}^0 D^{*0}$ bound state?
  - Many other possibilities (if it is not χ'_{c1}, where is χ'_{c1}?)

M= 3871.9±0.7±0.2 MeV
[PDG: 3871.68 ±0.17 MeV]

$\sqrt{s}$ (GeV)	$N^{\rm obs}$	ϵ (%)	$1+\delta$	$\sigma^B \cdot \mathcal{B}$ (pb)
4.009	< 1.4	25.5	0.861	< 0.12
4.229	9.6 ± 3.1	31.5	0.799	$0.29 \pm 0.10 \pm 0.02$
4.260	8.7 ± 3.0	30.5	0.814	$0.36 \pm 0.13 \pm 0.03$
4.360	< 5.1	21.1	1.023	< 0.39

seems it is from Y(4260) decays

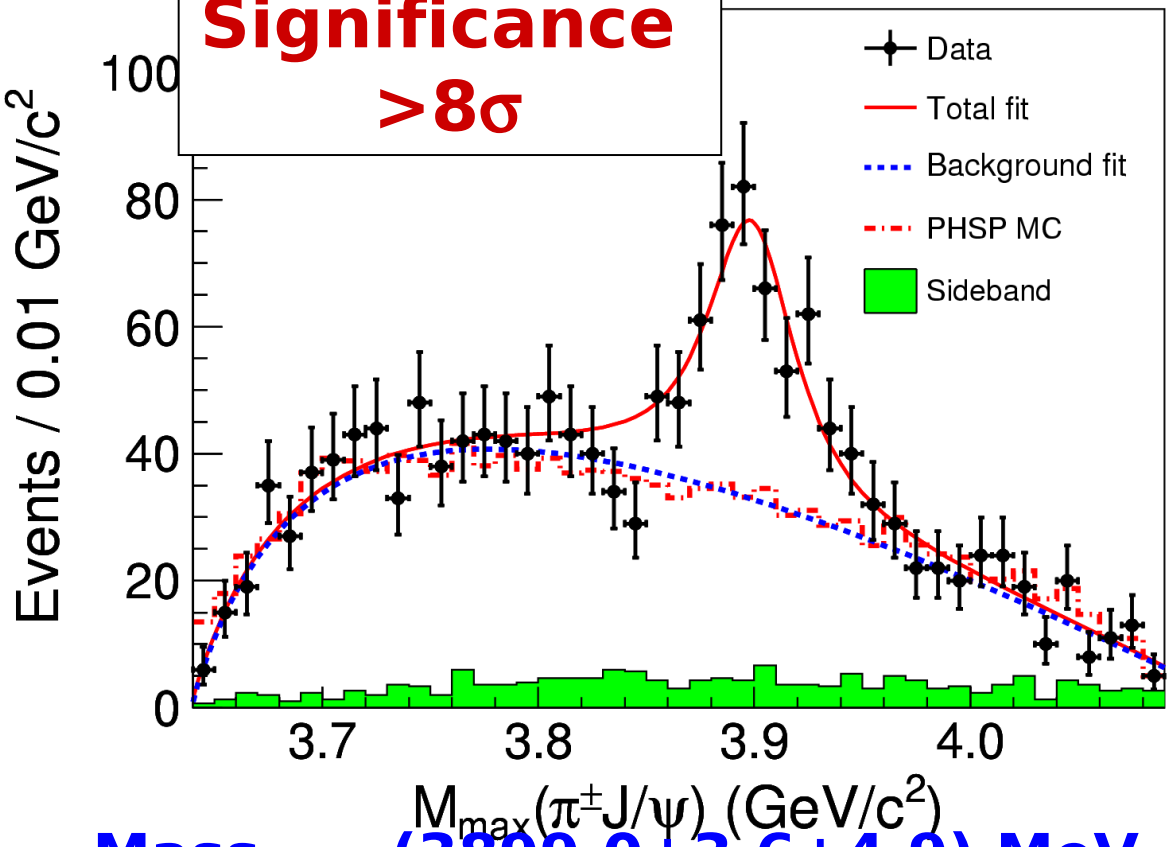
The $Z^{\pm}_c(3900)$ observation @BESIII

$e^+e^- \to Y(4260) \to \pi^{\pm} Z_c^{\pm} \to \pi^+ (\pi^- J/\psi)$ at $\sqrt{s}$=4260 MeV

24 March 2013

BESIII: Phys.Rev.Lett. 110 (2013) 252001

Confirmed by
BELLE: arXiv:1304.0121
Cleo-C: arXiv:1304.3036



Mass = (3899.0±3.6±4.9) MeV

Width = (46±10±20) MeV

A structure around 3.9 GeV/c is observed in the $\pi^{\pm}$ J/Ψ mass spectrum.

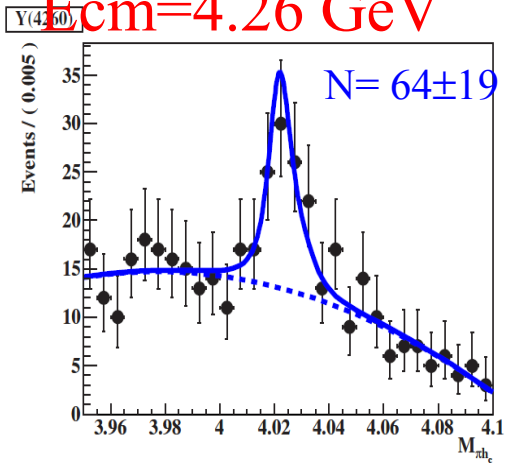
If interpreted as a particle, it carries charge and couples to charmonium.

A strong evidence that unconventional hadrons do exist!

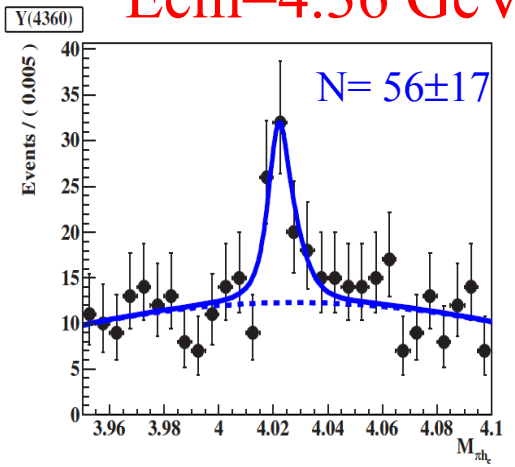
Observation of $Z^{\pm}_c(4020)$ and $Z^{\pm}_c(4025)$

$e^+e^- \to Zc^{\pm}(4020) \to \pi^{+}\pi^{-}hc(1P)$

Ecm=4.26 GeV



Ecm=4.36 GeV

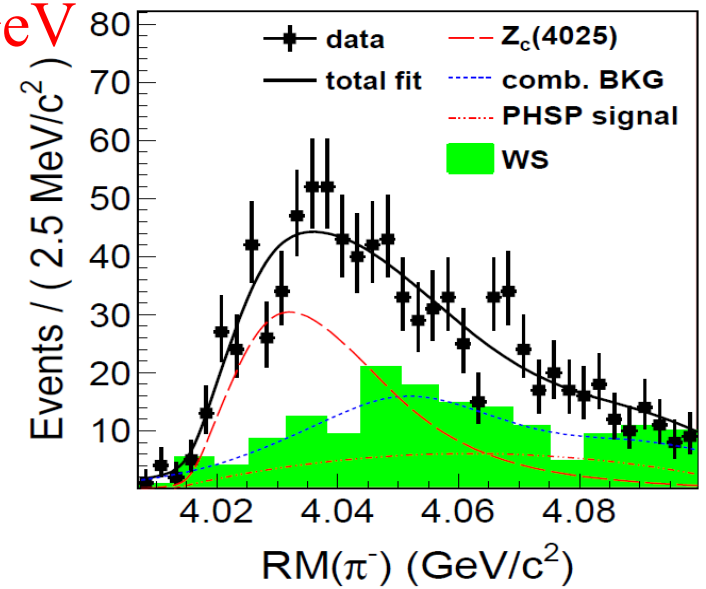


arXiv:1309.1896

M(4020) = 4021.8±1.0±2.5 MeV
Γ(4020) = 5.7±3.4±1.1 MeV
Significance 6.4 σ

$e^+e^- \to Zc^{\pm}(4025) \to \pi^{\pm}(D^*D^*)^{\pm}$

Ecm=4.26 GeV



M(4025) = 4026.3±2.6±3.7 MeV
Γ(4025) = 24.8±5.6±7.7 MeV
Significance >10 σ

arXiv: 1308.2760

Possible inputs for PANDA

- BES-III will likely explore in detail the region sqrt(s)<4.5 GeV before PANDA starts
- But, BES-III is limited by $J^{pc}=1^{--}$ (Y(4260), Y(4360) so far)
- So, the most attracting is a prospect of direct production of XYZ states with $J^{pc}\neq1^{--}$
- Another interesting prospect is to go higher than 4.5 GeV
- Discoveries are expected in a short term after PANDA starts operation (driven by findings of BES-III and B-factories)
- Precision study depends on experimental conditions

Thank you!