Recent Results on Light Hadron Spectroscopy at BESIII

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QCD and High Energy Interaction
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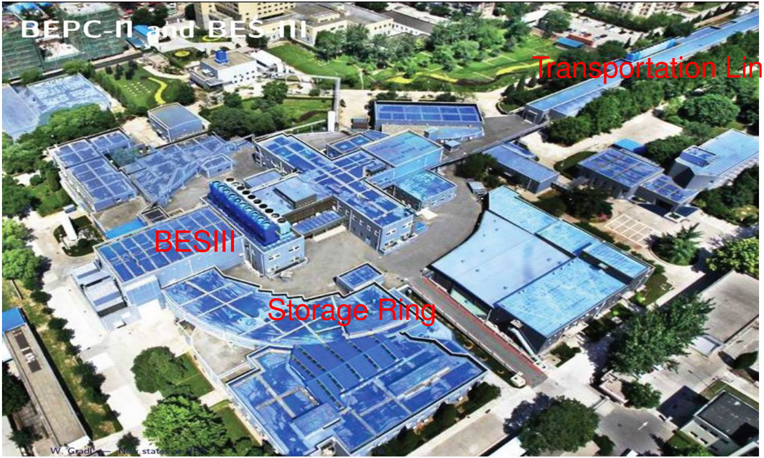
Outline

1. The BEPCII/BESIII Project
2. Recent results on Light Hadron Spectroscopy
   - $p\bar{p}$ mass threshold structure
   - Confirmation of $X(1835)$ and observation of two new structures in $J/\psi \to \gamma\pi\pi\eta'$
   - Observation of $J/\psi \to \omega X(1870)(X(1870) \to a0(980)^{\pm}\pi^{\mp})$
   - Observation of $\eta(1405) \to f_0(980)\pi^0$ in $J/\psi \to \gamma 3\pi$
   - Precision measurement of the branching ratios of $J/\psi(\psi(2S)) \to \pi^+\pi^-\pi^0$
3. Summary

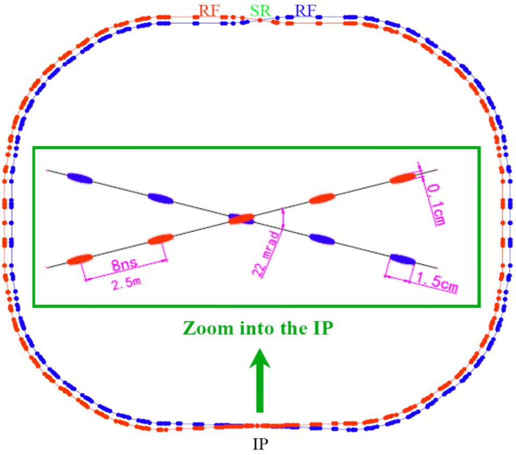
Overview of BEPCII and BESIII



2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BEPCII/BESIII data taking

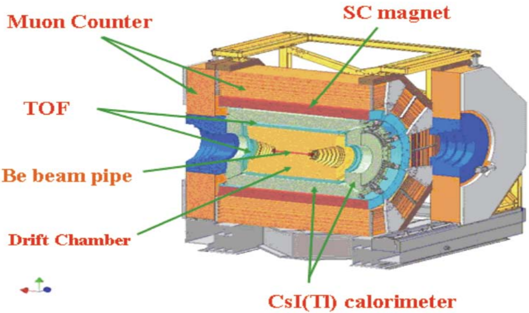
BEPCII storage rings

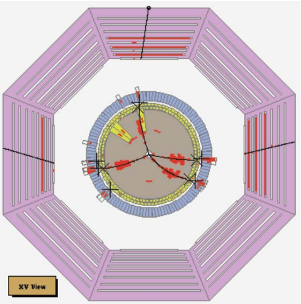
BEPCII(the Beijing Electron Positron Collider)



Beam energy:
1.0-2.3GeV
Design Luminosity:
$1 \times 10^{33} cm^{-2} s^{-1}$
Record Luminosity:
$6.492 \times 10^{32} cm^{-2} s^{-1}$
Energy spread:
5.16×10^{-4}
Optimum energy:
$1.89 GeV$
No.of bunches:
93
Bunch length:
$1.5 cm$
Total current:
$0.91 A$
Circumference:
$237 m$

The BESIII Detector

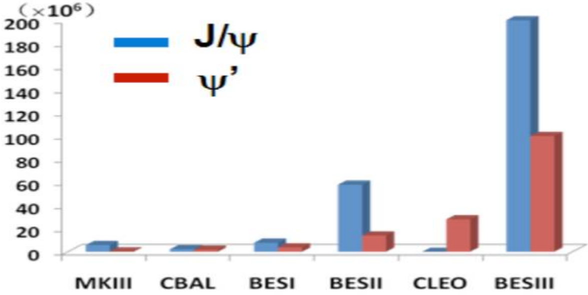




BESIII(the Beijing Spectrometer)

- MDC:43 layers; $\sigma(p)/p = 0.5\%@1GeV$; $\sigma(dE/dx) < 6\%$; $\sigma_{xy} = 130um$
- TOF:$100ps$ for Barrel;$110ps$ for Endcap
- EMC:$\sigma(E)/E = 2.5\%@1GeV$
- MUC:9 layers of RPC for barrel, 8 for endcap

Data taking



Data collected(Apr.14,2009-July.28,2009):
$106M\psi(2S)$,$226MJ/\psi$,$42.3pb^{-1}$ at $3.65GeV/c^2$
More physics data will be taken in the following years.

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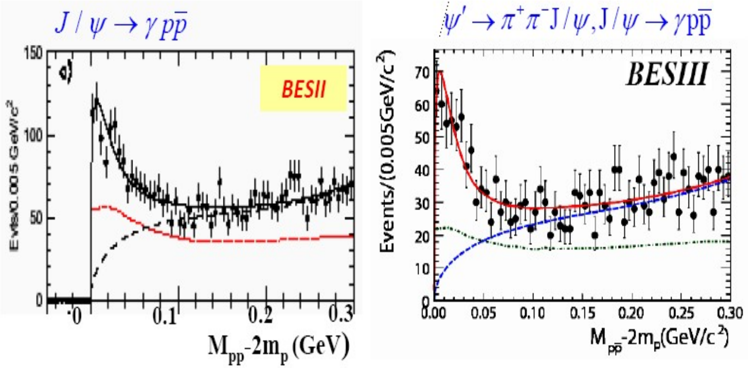
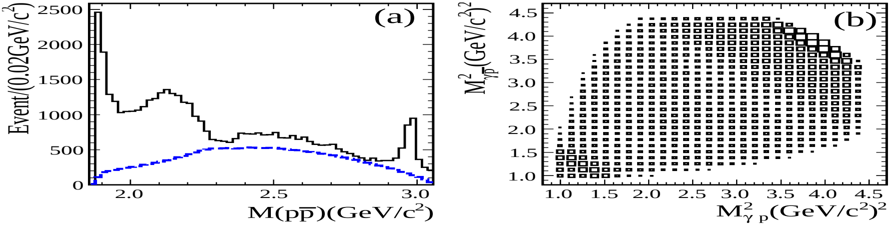
$p\bar{p}$ mass threshold structure in $J/\psi \to \gamma p\bar{p}$



What could it be? $p\bar{p}$ bound state or Final state interaction effect(FSI) or some of both?

PWA $p\bar{p}$ mass threshold structure in $J/\psi \to \gamma p\bar{p}$

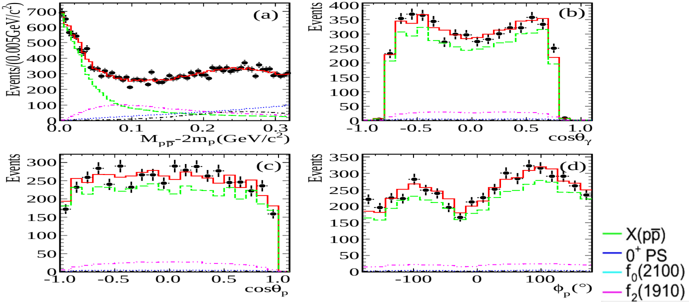


Evident narrow $p\bar{p}$ mass threshold enhancement in J/ψ decays.
Partial Wave Analysis (PWA)($M_{p\bar{p}} < 2.2GeV$):

- Concentrate on dealing with the mass threshold structure, especially to determine the J^{PC} .
- Convariant tensor amplitudes (S. Dulat and B. S. Zou, Eur.Phys.J A 26:125, 2005).
- Include the Juich-FSI effect (A. Sirbirtsen et al. Phys.Rev.D 71:054010, 2005).
- Four components: $X(p\bar{p})$, $f_2(1910)$, $f_0(2100)$ and 0^{++}phase space.

PWA results and projections in $J/\psi \to \gamma p\bar{p}$

arXiv: 1112.0942,Submitted to PRL.



θ_γ :polar angle of γ in the J/ψ center of mass system; θ_p and ϕ_p are the polar angle and azimuthal angle of p in the $p\bar{p}$ center of mass system,respectively.

$J^{pc} = 0^{-+}$

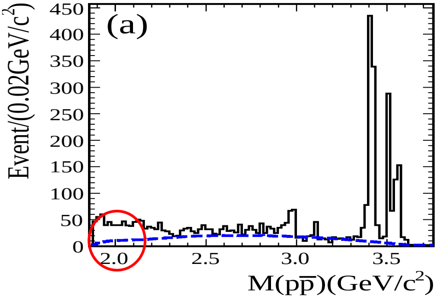
Inclusion of Julich-FSI model:

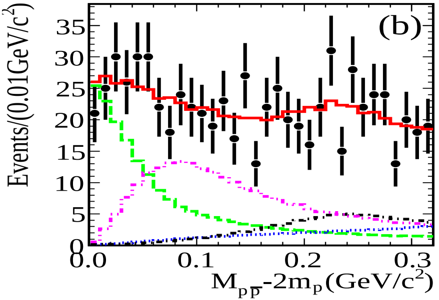
$M = 1832^{+19}_{-5}(stat.)^{+18}_{-17}(syst.) \pm 19(model)MeV/c^2$

$\Gamma = 13 \pm 39(stat.)^{+10}_{-13}(syst.) \pm 4(model)MeV/c^2(\Gamma < 76MeV/c^2$ at the $90\%C.L)$

$Br(J/\psi \to \gamma X)Br(X \to p\bar{p}) = (9.0^{+0.4}_{-1.1}(stat.)^{+1.5}_{-5.0}(syst.) \pm 2.3(model)) \times 10^{-5}$

PWA $p\bar{p}$ mass threshold structure in $\psi(2S) \to \gamma p\bar{p}$





$Br(\psi(2S) \to \gamma X)Br(X \to p\bar{p}) = (4.57 \pm 0.36(stat.)^{+1.23}_{-4.07} \pm 1.28(model)) \times 10^{-6}$

The production ratio R:

$$R = \frac{Br(\psi(2S) \to \gamma X(p\bar{p}))}{Br(J/\psi \to \gamma X(p\bar{p}))} = (5.08^{+0.71}_{-0.45}(stat.)^{+0.67}_{-3.58}(syst.) \pm 0.12(model))\%$$

It is suppressed compared with 12%rule.

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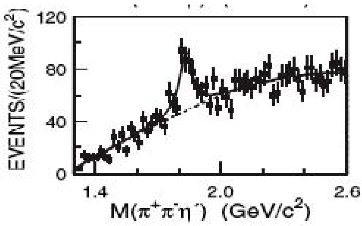
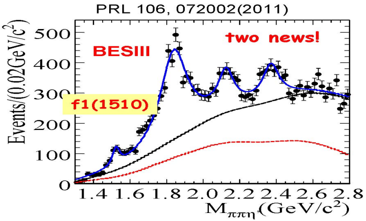
Confirmation of $X(1835)$ and observation of two new structures in $J/\psi \to \gamma\pi^+\pi^-\eta'$

BESII: PRL 95,262001(2005)

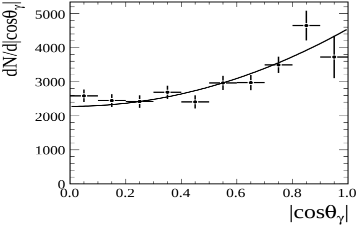
BESIII: PRL 106, 072002(2011)





	BESII results:	BESIII results:
$X(1835)$	$\sim 7.7\sigma$ $M = 1833.7 \pm 6.1 \pm 2.7 MeV$ $\Gamma = 67.7 \pm 20.3 \pm 7.7 MeV$	$> 20\sigma$ $M = 1836.5 \pm 3.0^{+5.6}_{-2.1} MeV$ $\Gamma = (190.1 \pm 9.0^{+38}_{-36}) MeV$
$X(2120)$		7.2σ $M = 2122.4 \pm 6.7^{+4.7}_{-2.7} MeV$ $\Gamma = 83 \pm 16^{+31}_{-11} MeV$
$X(2370)$		6.4σ $M = 2376.3 \pm 8.7^{+3.2}_{-4.3} MeV$ $\Gamma = 83 \pm 17^{+44}_{-6} MeV$

Confirmation of $X(1835)$ and observation of two new structures in $J/\psi \to \gamma\eta'\pi^+\pi^-$



For radiative J/ψ decays to a pseudoscalar meson, θ_γ should be distributed according to $1 + \cos^2\theta_\gamma$. $X(1835)$ consistent with $J^{pc} = 0^{-+}$
Wheter or not $X(p\bar{p})$ and $X(1835)$ are the same states?

Nature of new structures?

It is the first time resonant structures are observed in $2.4GeV$ region. It is interesting since:LQCD predicts lowest lying pseudoscalar glueball around $2.4GeV$ and $J/\psi \to \gamma\pi\pi\eta'$ decay is a good channel for finding 0^{-+} glueballs.(PRD73,014516(2006) Y.Chen et al)
Nature of $X(2120)/X(2370)$: glueball? η/η' excited states?

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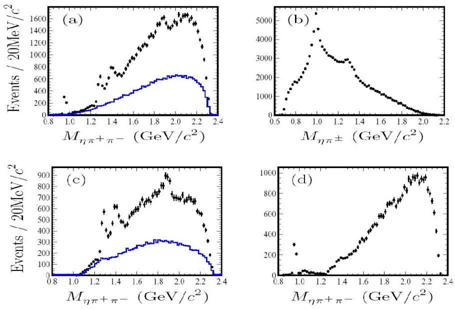
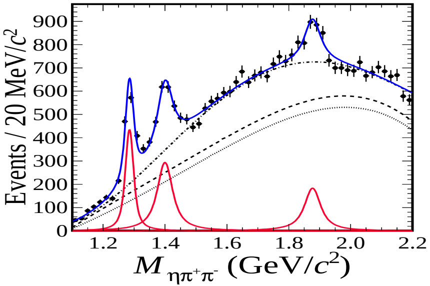
$X(1870)$ in $J/\psi \to \omega X(X \to a0(980)^{\pm}\pi^{\mp})$

Phys. Rev. Lett. 107, 182001 (2011)





The $f1(1285)(> 10\sigma), \eta(1405)(> 10\sigma)$ and $X(1870)(7.2\sigma)$ decay primarily via $a0(980)\pi$ mode.

First observation of the process $J/\psi \to \omega X(1870)$ in which $X(1870) \to a_0(980)^{\pm}\pi^{\mp}$

Fitted result of $f1(1285), \eta(1405)$ and $X(1870)$

$$Br(J/\psi \to \omega X, X \to a_0^{\pm}(980)\pi^{\mp})$$

Resonance	Mass(MeV/c^2)	Width(MeV/c^2)	Branch ratio(10^{-4})
$f_1(1285)$	$1285.1 \pm 1.0^{+1.6}_{-0.3}$	$22.0 \pm 3.1^{+2.0}_{-1.5}$	$1.25 \pm 0.10^{+0.19}_{-0.20}$
$\eta(1405)$	$1399.8 \pm 2.2^{+2.8}_{-0.1}$	$52.8 \pm 7.6^{+0.1}_{-7.6}$	$1.89 \pm 0.21^{+0.21}_{-0.23}$
$X(1870)$	$1877.3 \pm 6.3^{+3.4}_{-7.4}$	$57 \pm 12^{+19}_{-4}$	$1.50 \pm 0.26^{+0.72}_{-0.36}$

Nature of $X(1870)$

$J^{pc} = 0^{-+}$? It is $X(1835)$? Need PWA!

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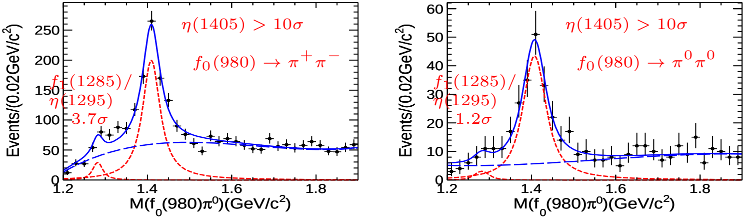
First observation of $\eta(1405) \to f_0(980)\pi^0$ in $J/\psi \to \gamma f_0(980)\pi^0$

arXiv:1201.2737, Submitted to PRL. Helicity analysis indicates that peak at $1400MeV$ is from $\eta(1405) \to f_0(980)\pi^0$(isospin violated decays), not from $f_1(1420)$



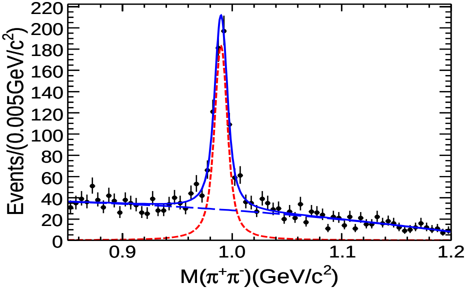
$$Br(J/\psi \to \gamma\eta(1405) \to \gamma\pi^0 f_0(980) \to \gamma\pi^0\pi^+\pi^-) = (1.50 \pm 0.11(stat) \pm 0.11(sys)) \times 10^{-5}$$
$$Br(J/\psi \to \gamma\eta(1405) \to \gamma\pi^0 f_0(980) \to \gamma\pi^0\pi^0\pi^0) = (7.10 \pm 0.82(stat) \pm 0.72(sys)) \times 10^{-6}$$

Large Isospin-violating decay rate:

$Br(\eta(1405) \to f_0(\pi^+\pi^-)\pi^0)/Br(\eta 1405 \to \pi^+\pi^-\eta) \sim 7.5\%$,

$Br(\eta(1405) \to f_0(980)\pi^0)/Br(\eta(1405) \to a_0(980)\pi) \sim 25\%$ A possible explanation is KK^* loop(J.J.Wu et al, arXiv:1108.3772)

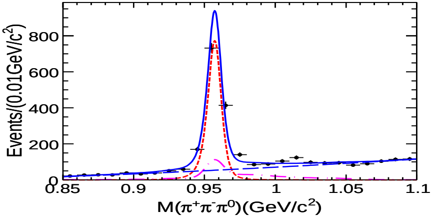
Anomalous lineshape of $f_0(980)$ in $J/\psi \to \gamma f_0(980)\pi^0$

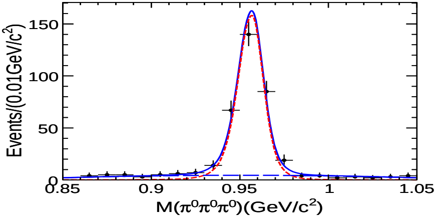


$f_0(980) \to \pi^+\pi^-$:
$m = 989.9 \pm 0.4 MeV/c^2$
$\Gamma = 9.5 \pm 1.1 MeV/c^2$

The measured width of the $f_0(980)$ is much narrower than the world average(PDG2010,$\Gamma 40 - 100 MeV/c^2$)!

New results on $\eta' \to 3\pi$





New results:

$Br(\eta' \to \pi^+\pi^-\pi^0) = (3.83 \pm 0.15 \pm 0.39) \times 10^{-3}$(PDG2010,$(3.6^{+1.1}_{-0.9}) \times 10^{-3}$)

$Br(\eta' \to 3\pi^0) = (3.56 \pm 0.22 \pm 0.34) \times 10^{-3}$(PDG2010,$(1.68 \pm 0.22) \times 10^{-3}$)

For the decay $\eta' \to 3\pi^0$, it is two time larger than the world average value.

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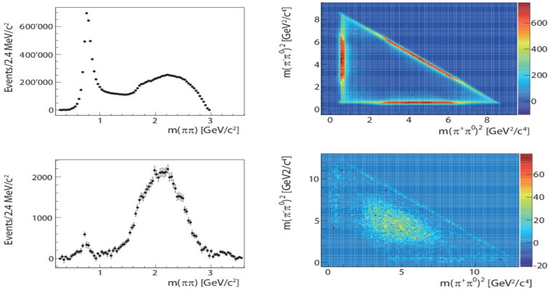
Branching ratios of $J/\psi(\psi(2S)) \to \pi^+\pi^-\pi^0$

arXiv: 1202.2048



The Dalitz plot with backgrounds subtracted and corrected for efficiency

- $Br(J/\psi \to \pi^+\pi^-\pi^0) = (2.137 \pm 0.004(stat.)^{+0.058}_{-0.056}(syst.)^{+0.027}_{-0.026}(norm.)) \times 10^{-2}$ (dominated by $\rho(770)$)
- $Br(\psi(2S) \to \pi^+\pi^-\pi^0) = (2.14 \pm 0.03(stat.)^{+0.08}_{-0.07}(syst.)^{+0.09}_{-0.08}(norm.)) \times 10^{-4}$ (a small $\rho(770)$ and most of events are around $2.2GeV$ in di-pion mass)

$\rho\pi$ puzzle

$$Q_h = \frac{Br(\psi(2S) \to hadrons)}{Br(J/\psi \to hadrons)} \simeq \frac{Br(\psi(2S) \to e^+e^-)}{Br(J/\psi \to e^+e^-)} \simeq 12\%$$

The ratio of these two branching fractions:

$$\frac{Br(\psi(2S) \to \pi^+\pi^-\pi^0)}{Br(J/\psi \to \pi^+\pi^-\pi^0)} = (1.00 \pm 0.01(stat.)^{+0.06}_{-0.05}(syst.))\% << 12\%$$

$J/\psi \to \pi^+\pi^-\pi^0$ decays are dramatically different from $\psi(2S) \to \pi^+\pi^-\pi^0$ decays!

Summary

- PWA to $J/\psi \to \gamma p\bar{p}$ and J^{pc} of the mass-threshold enhancement is 0^{-+}. The produce branching ratio for $X(p\bar{p})$ in $\psi(2S)$ decay is first measured.
- Confirmation of $X(1835)$ and observation of two new structures $X(2120)$ and $X(2370)$ in $J/\psi \to \gamma\pi\pi\eta'$
- First observation of the process $J/\psi \to \omega X(1870)$ in which $X(1870) \to a_0(980)^{\pm}\pi^{\mp}$ in $J/\psi \to \omega\pi\pi\eta$
- First observation of $\eta(1405) \to f_0(980)\pi^0$ in $J/\psi \to \gamma 3\pi$
- Precision measurement of the branching ratios of $J/\psi \to \pi^+\pi^-\pi^0$ and $\psi(2S) \to \pi^+\pi^-\pi^0$. $J/\psi \to \pi^+\pi^-\pi^0$ decays are dramatically different from $\psi(2S) \to \pi^+\pi^-\pi^0$ decays

Thanks

Thanks for your attention!