RECENT RESULTS ON LIGHT HADRON SPECTROSCOPY AT BES

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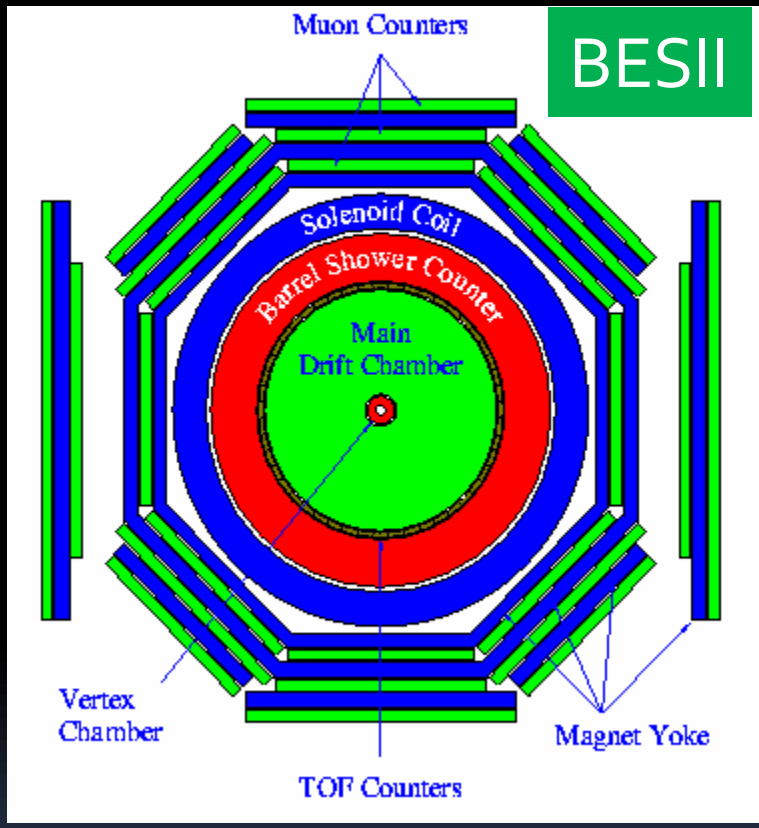
Thanks to Fred, Haibo, and many other BESIII members

BEPC and BESII



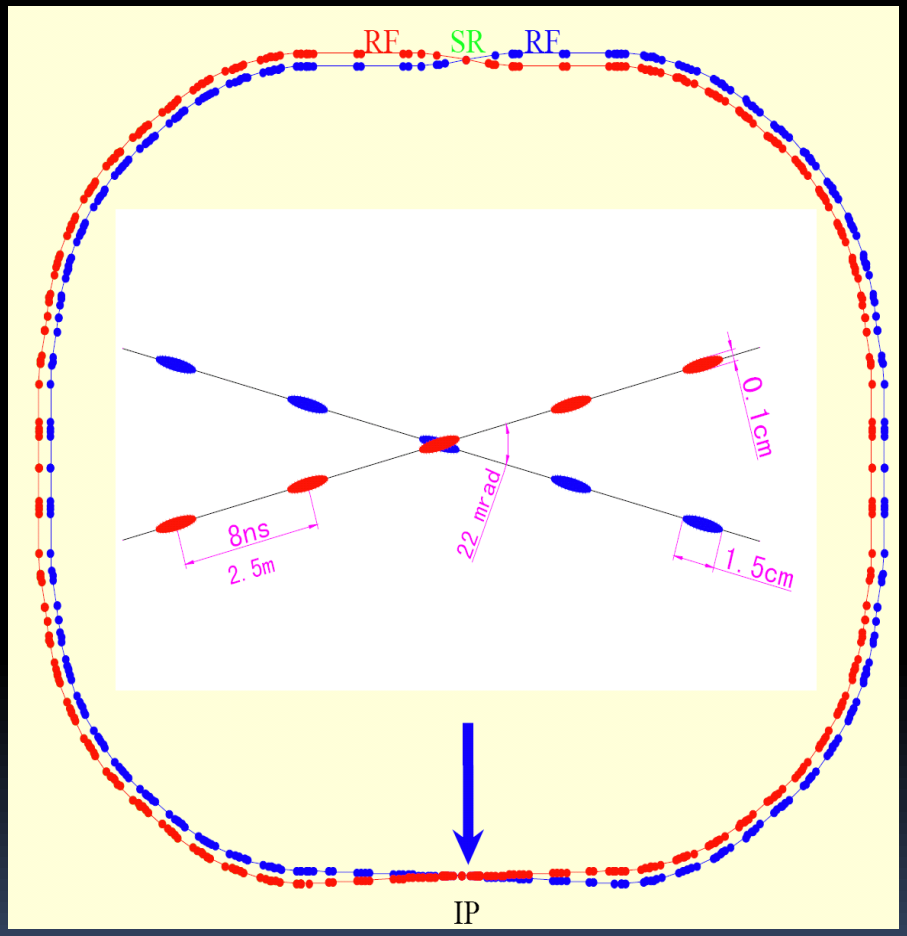
Beijing Electron Positron Collider

CM energy ranges from 2 to 5 GeV

Luminosity at J/ψ ~ $5 \times 10^{30} cm^{-2} s^{-1}$

BEPC II

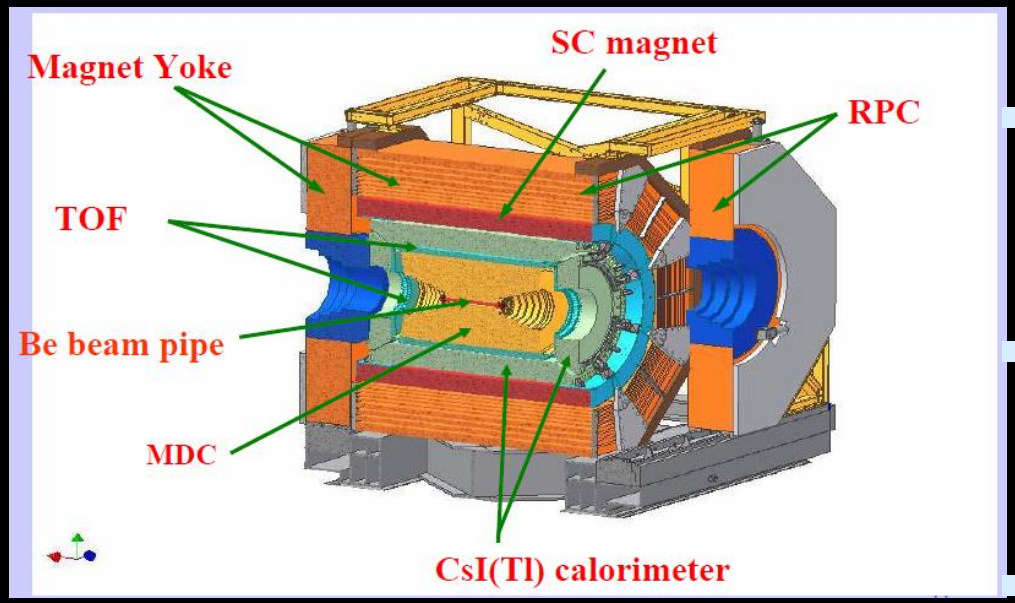
A high lumonisity double-ring collider

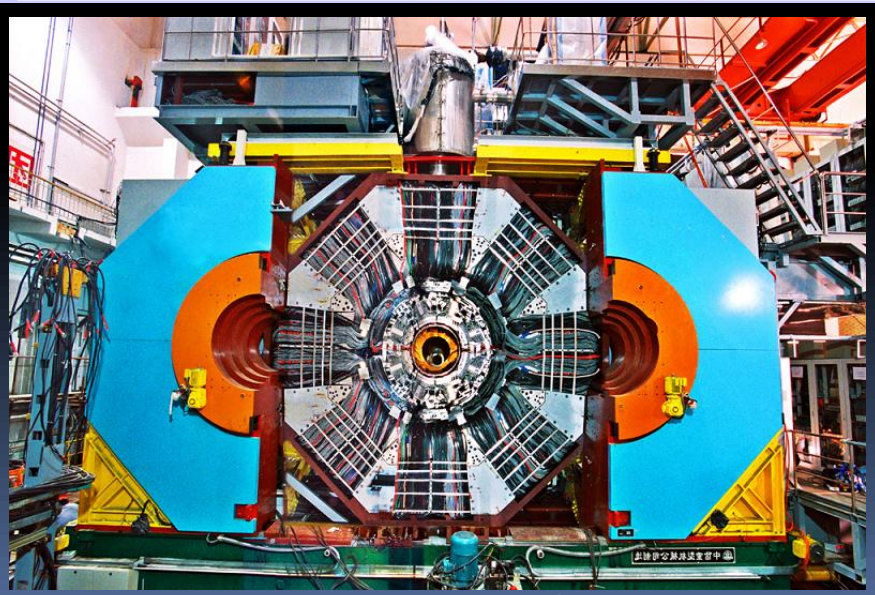


Beam energy: 1.0 – 2.3 GeV
Luminosity: $1x10^{33}$ cm^{-2} s^{-1}
Optimum energy: 1.89 GeV
No. of bunches: 93
Bunch length: 1.5 cm
Total current: 0.91 A
SR mode: 0.25A @ 2.5 GeV

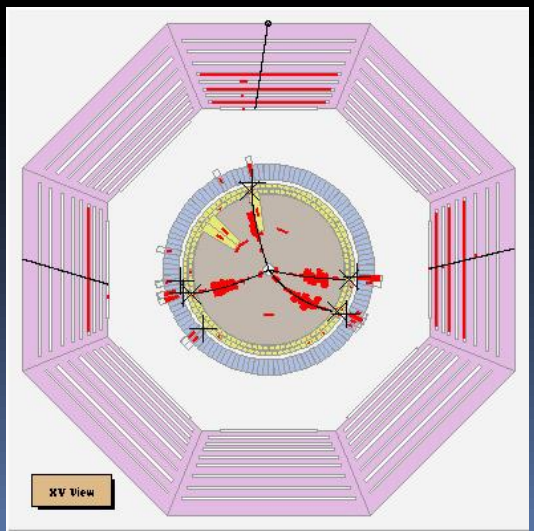
Beam magnets

BESIII

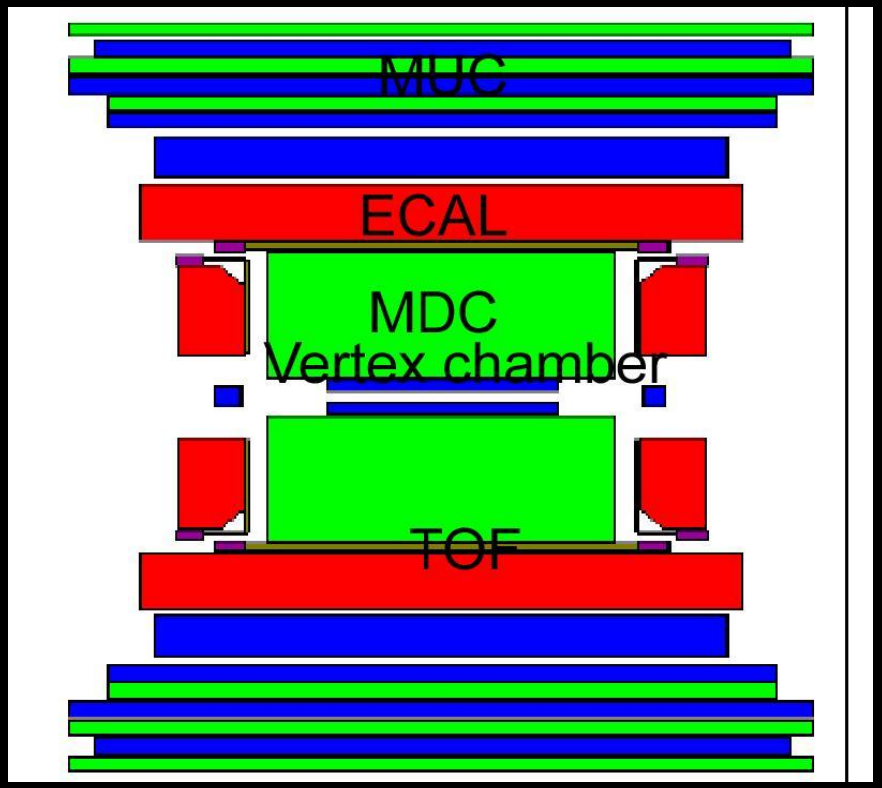




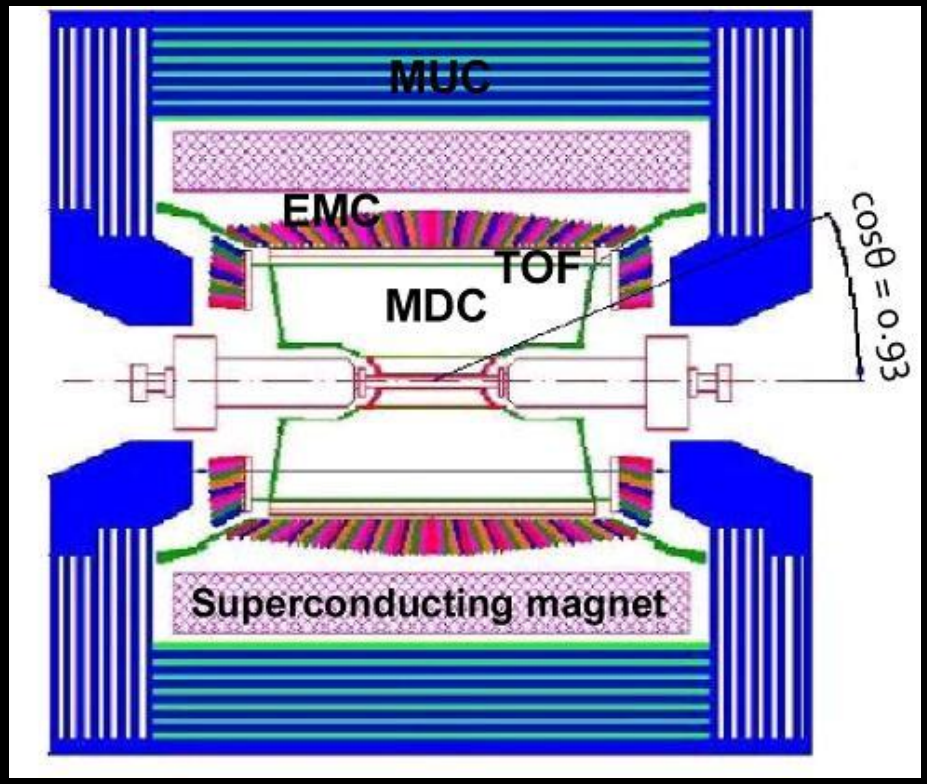
- July 18, 2008:
  First e+e- collision event at BESIII
- Apr. 14, 2009:
  106 M ψ(2S) events (x4 CLEOc)
- July 28, 2009:
  ~226 M J/ψ events (x4 BESII)
- June 1, 2010:
  ~0.8 fb^{-1} at ψ(3770)



BES II @ BEPC



BES III @ BEPC II



	BESII	BESIII
MDC	$\sigma(p)/p = 1.78\,\% \cdot \sqrt{1+p^2}$ $dE/dx_{reso} = 8\,\%$	$\sigma(p_t)/p_t = 0.32\,\% \cdot p_t$ $dE/dx_{reso} < 6\,\%$
TOF	180 ps (for bhabha)	90 ps (for bhabha)
EMC	$\sigma(E)/E = 22\% \cdot \sqrt{E}$	$\sigma(E)/E = 2.3\,\% \cdot \sqrt{E}$
MUC	3 layers for barrel	9 layers for barrel, 8 for endcap

Light Hadron Spectroscopy

- Establish spectrum of light hadrons
- Search for non-conventional hadrons

- BESIIII advantages:
  - Gluon rich
  - Clean environment
  - Important J^{PC} filter, and isospin filter

observation of charged κ @BESII

- κ was first found in Kπ scattering data
- However, its phase shift is much less than 180° and it cannot be filled into any nonets of ordinary $q\bar{q}$ mesons. There have been hot debates on the existence of κ.

In recent years:

- FNAL E791 found evidence of neutral κ in $D^+ \to K^-\pi^+\pi^+$

$$M = 797 \pm 19 \pm 43\ \mathrm{MeV/c^2}, \Gamma = 410 \pm 43 \pm 87\ \mathrm{MeV/c^2}$$

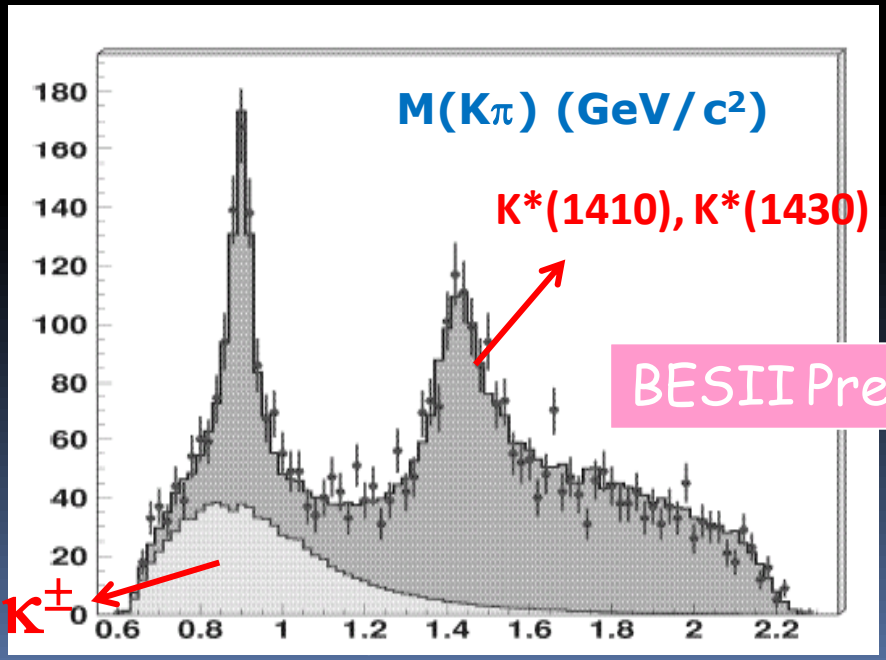
- CLEO $D^0 \to K^-\pi^+\pi^0$ data find no evidene of κ
- FOCUS data on $D^+ \to K^-\pi^+\mu^+\upsilon$ required K^{*0} interfere with either a constant amplitude or a broad 0^+ resonance in Kπ.
- BESII observed neutral κ in $J/\psi \to K^{*0}K\pi \to K^+K^-\pi^+\pi^-$ in 2006.

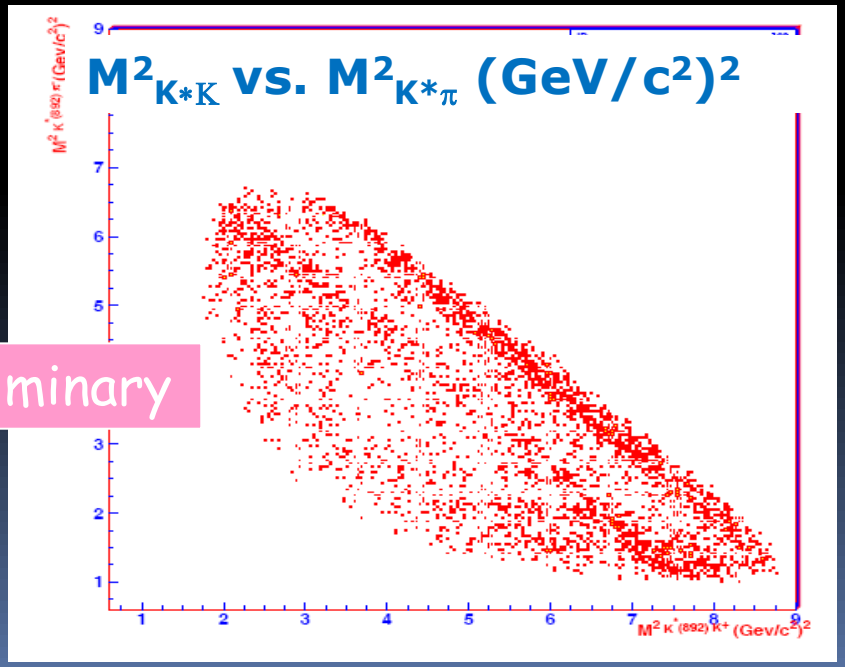
neutral κ pole:

$$m + i\frac{\Gamma}{2} = (841 \pm 30^{+81}_{-73}) - i(309 \pm 45^{+48}_{-72})\ \mathrm{MeV/c^2}$$

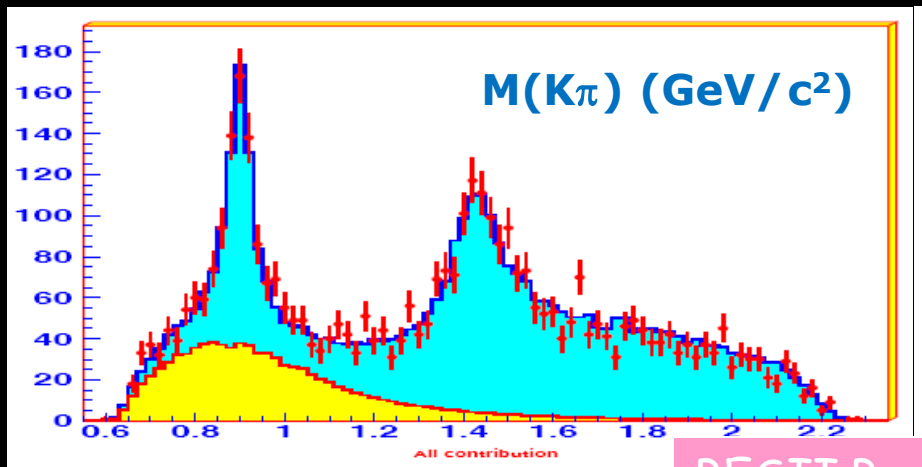
The existence of charged κ is expected

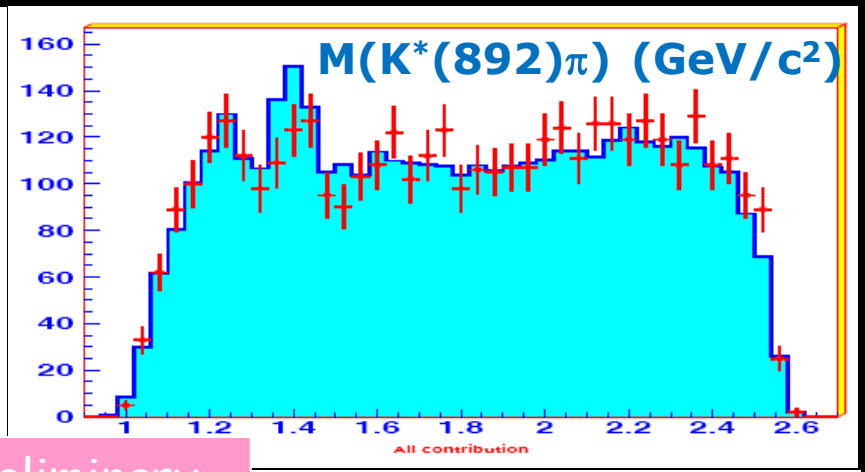
- CLEO reported the necessity of $\kappa^{\pm} \to K^{\pm}\pi^0$ in $D^0 \to K^+K^-\pi^0$
- However, no charged κ is needed in BABAR data.
- BESII studied charged κ in $J/\psi \to K^{*\pm}\kappa^{\mp} \to K_s\pi^{\pm}K^{\mp}\pi^0$



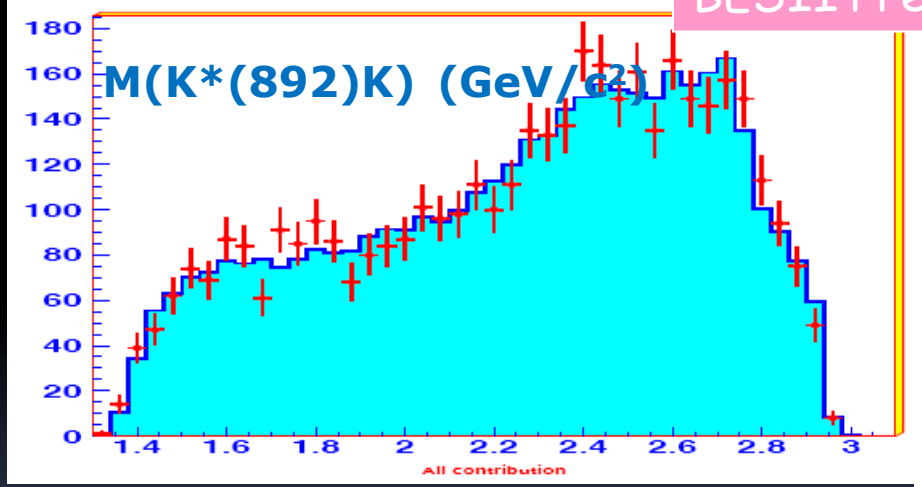


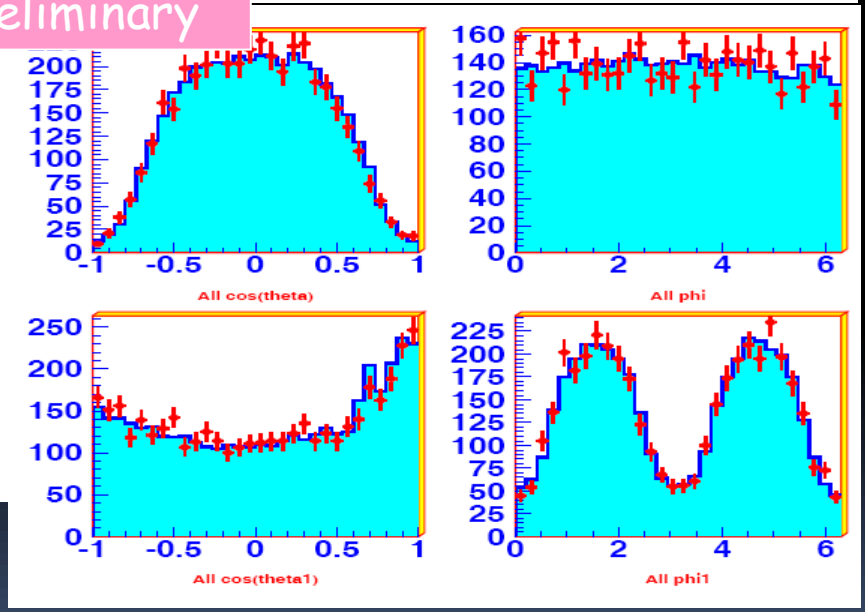
Partial wave analysis results





BESII Preliminary





Resonance parameters of charged κ

BESII Preliminary

charged κ	Constant BW	BW with ρ	Zheng
Mass(MeV)	$810\pm68^{+15}_{-24}$	$884\pm40^{+11}_{-22}$	$1165\pm58^{+120}_{-41}$
Width(MeV)	$536\pm87^{+106}_{-47}$	$478\pm77^{+71}_{-41}$	$1349\pm500^{+472}_{-176}$
pole(MeV)	$(849\pm77^{+18}_{-14})$ $-i(256\pm40^{+46}_{-22})$	$(849\pm51^{+14}_{-28})$ $-i(288\pm101^{+64}_{-30})$	$(839\pm145^{+24}_{-7})$ $-i(297\pm51^{+50}_{-18})$

neutral κ	Constant BW	BW with ρ	Zheng
Mass(MeV)	$745\pm26^{+14}_{-91}$	$874\pm25^{+12}_{-55}$	$1140\pm39^{+47}_{-80}$
Width(MeV)	$622\pm77^{+61}_{-78}$	$518\pm65^{+27}_{-87}$	$1370\pm156^{+409}_{-148}$
pole(MeV)	$(799\pm37^{+16}_{-90})$ $-i(290\pm33^{+25}_{-38})$	$(836\pm38^{+18}_{-87})$ $-i(329\pm66^{+28}_{-46})$	$(811\pm74^{+17}_{-83})$ $-i(285\pm20^{+18}_{-42})$

PL B633 (2006) 681

- Different parameterizations of κ give consistent results on the pole of charged κ
- The pole position for charged κ is consistent with that for neutral κ within the error.

$\bar{p}p$ threshold enhancement @BESII

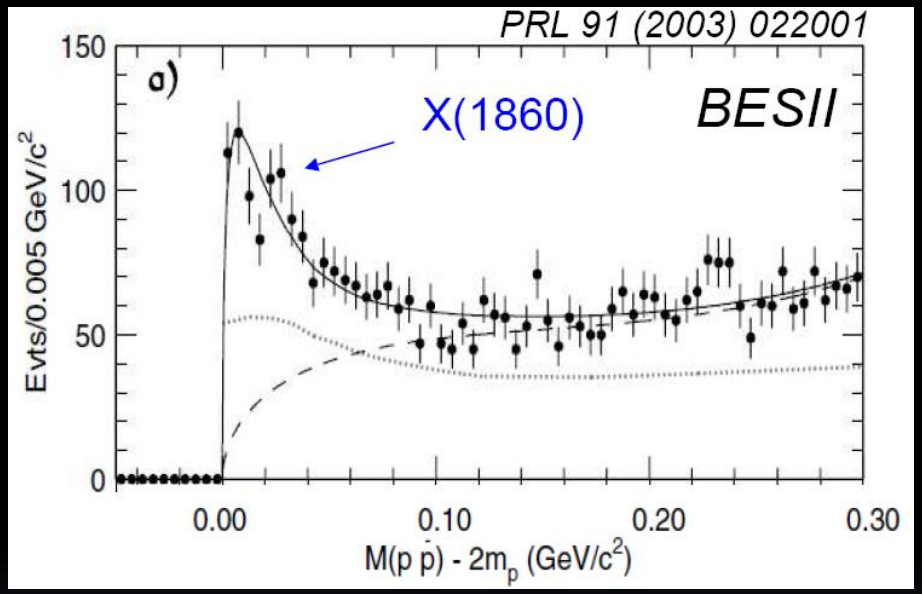
$$J/\psi \to \gamma p\bar{p}$$

- If fitted with a S-wave resonance

  M = 1859 $^{+3}_{-10}$ $^{+5}_{-25}$ MeV/c²

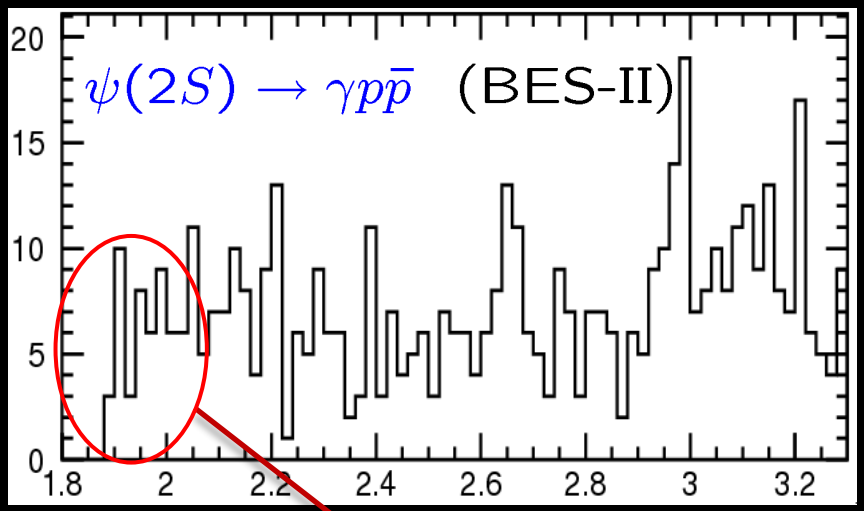
  Γ < 30 MeV/c² (90% CL)

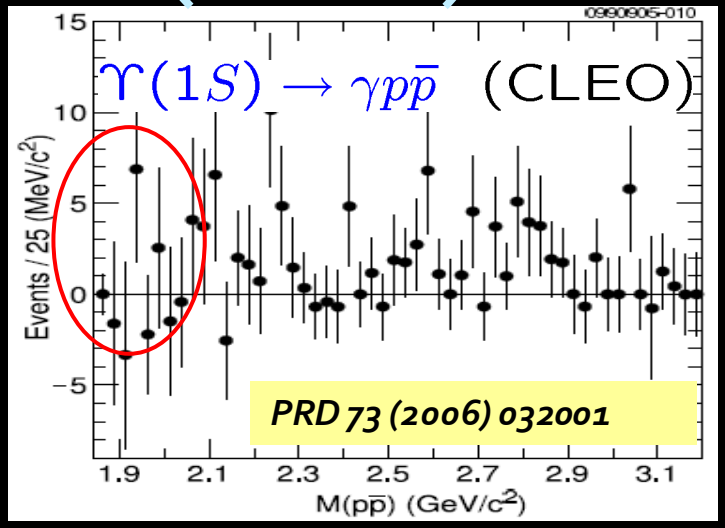
- Theoretical speculation:
  - $\bar{p}p$ bound state?
  - FSI effect?
  - ……



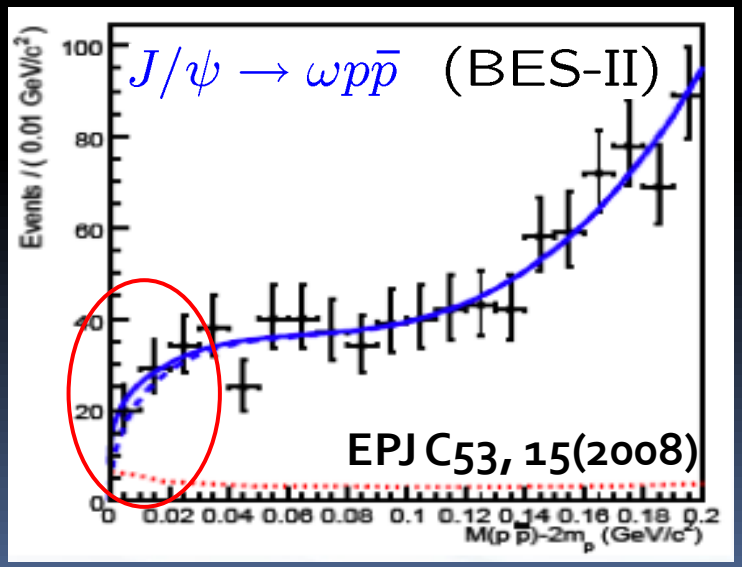
Non-observation of X(1860)

PRL 99 (2007) 011802



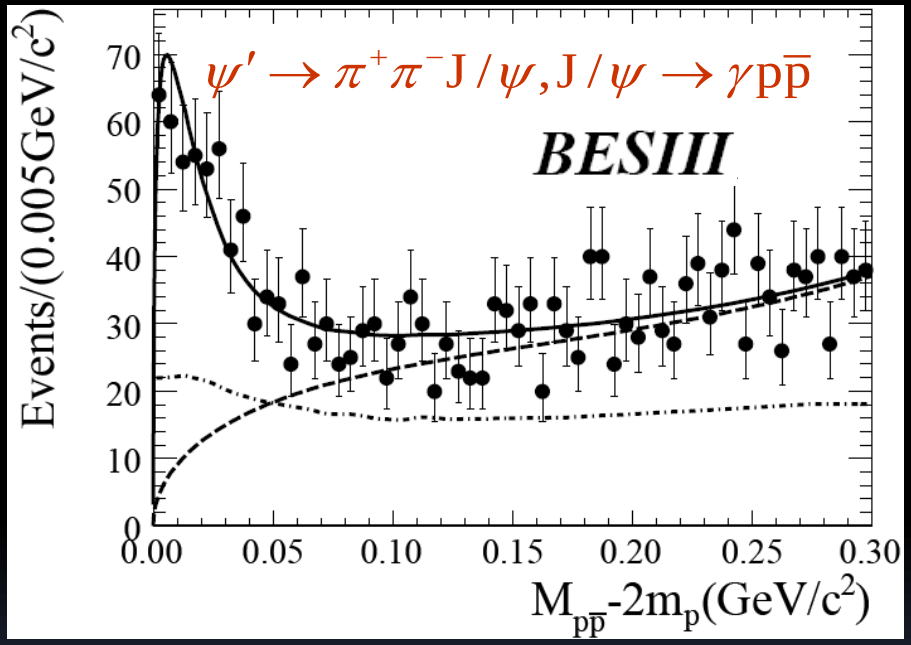


No significant signal of X(1860) found (only 2σ significance)



$\bar{p}p$ threshold enhancement @BESIII

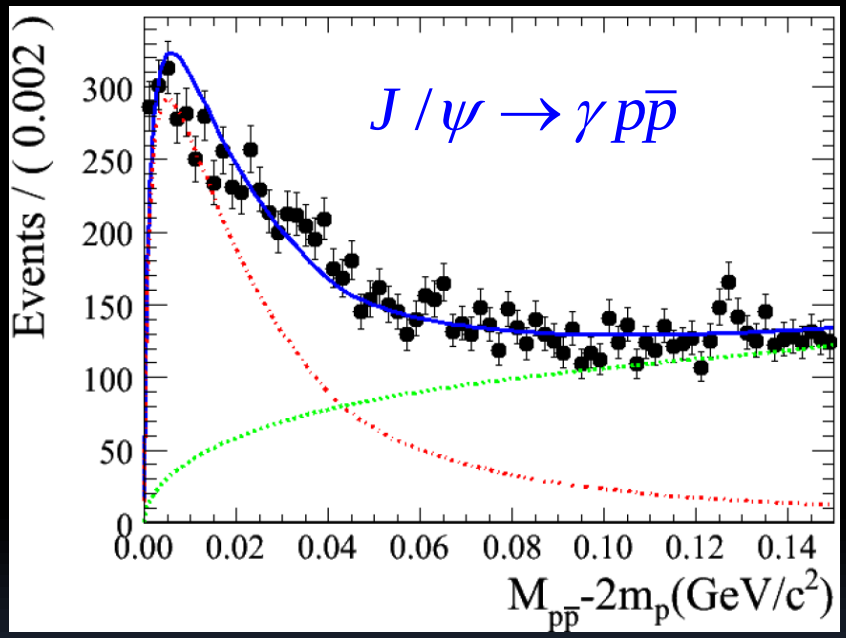
Chinese Physics C 34(2010)421



M=1861 $^{+6}_{-13}$ $^{+7}_{-26}$ MeV/c²

Γ < 38 MeV/c² (90% CL)

BESIII preliminary



M=1861.6 ± 0.8 MeV/c²

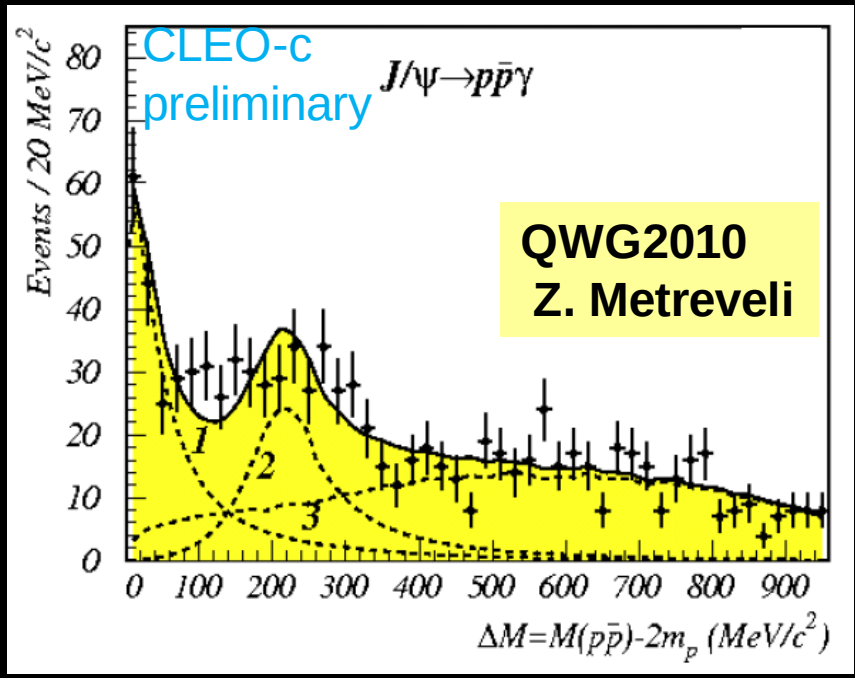
Γ < 8 MeV/c² (90% CL)

Consistent observation by BESIII !

$\bar{p}p$ threshold enhancement @CLEOc

- CLEO-c does the same fit as that BES, they obtain
  $M(R_{thr})= 1861^{+6}_{-16}$ (MeV/c²),
  $\Gamma(R_{thr}) = 0^{+32}_{-0}$ (MeV/c²)
  which agree with BESII results.
- CLEO-c fit with three contributions: $R_{thr}+f_0(2100)+PS$
  $M(R_{thr})= 1837^{+10}_{-12}{}^{+9}_{-7}$(MeV/c²),
  $\Gamma(R_{thr}) = 0^{+44}_{-0}$ (MeV/c²)
  CL = 26.1%

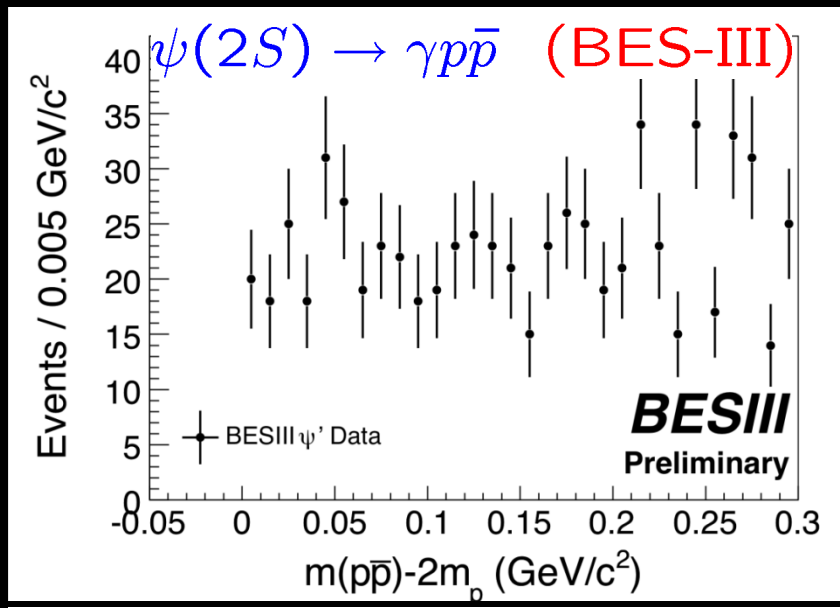
  BES considered 2nd and 3rd parts as systematic errors.

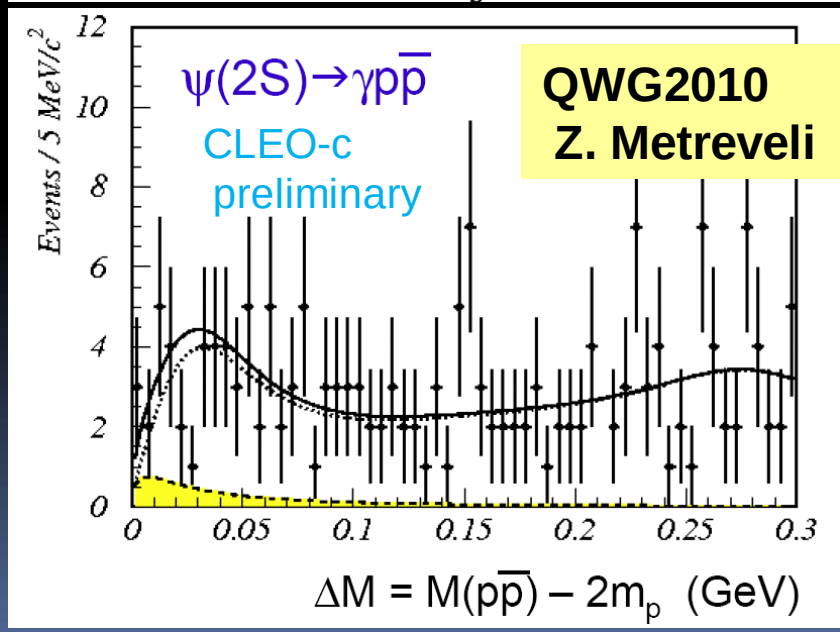


The central value of the mass is close to the resonance mass reported by BES with M(R) = 1833.7±6.1±2.7 MeV/c², observed in $J/\psi\to\gamma R$, $R\to\pi^+\pi^-\eta'$ [PRL 95 (2005) 262001]

X(1860) in ψ(2S) decays (preliminary)

- Check also for enhancement in ψ(2S) decays (high statistics)
  confirmation of no observation of enhancement in ψ(2S) channel
  ⇒ pure FSI effect unlikely
- B(ψ(2S)→γR)xB(R→ $\bar{p}p$)
  - CLEO-c fit assuming
    M=1859MeV, Γ=20MeV
    < 1.6 x 10-6 @90% CL
  - BESII result:
    PRL 99(2007)011802
    < 5.4 x 10-6 @90% CL

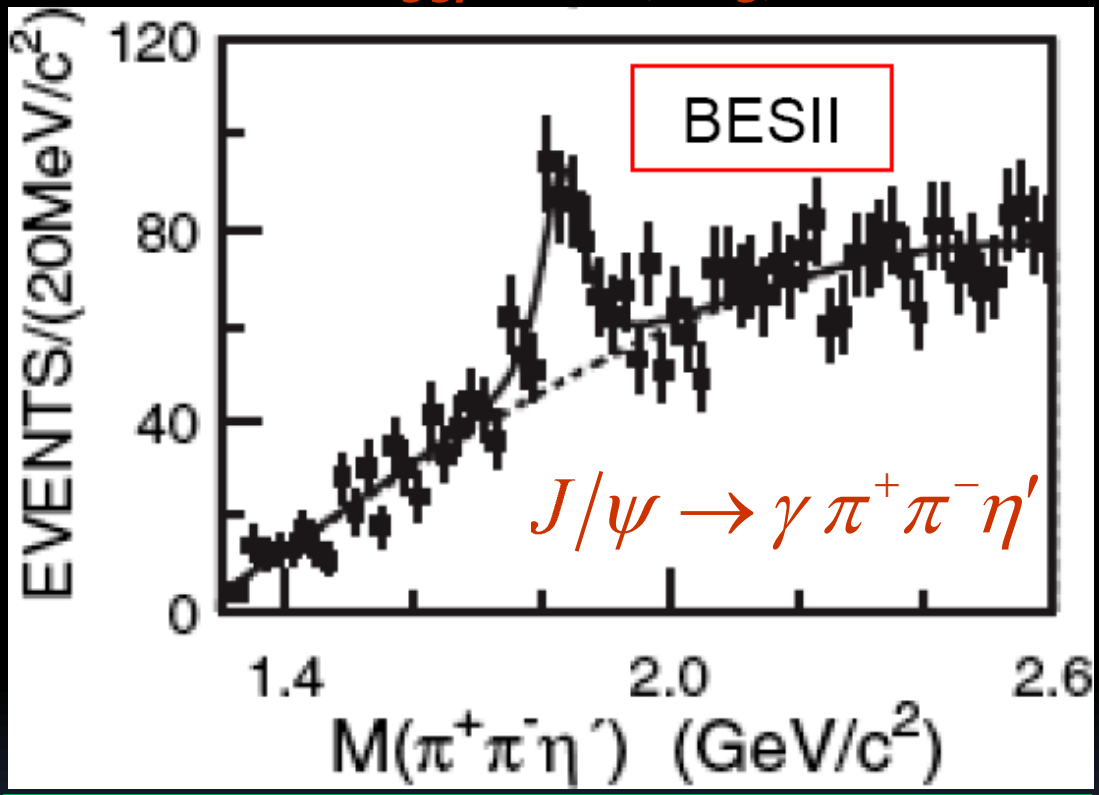




X(1835) at BESII

- The X(1860) should be detected in other decay modes.
- G.J. Ding and M.L. Yan suggest $\eta'\pi\pi$ to be a favorable mode. (PR C72, 015208 (2005))
  - there is gluon content in pp
  - η' has strong coupling to gluons
- Confirmation of X(1835) is necessary with BESIII ~230M J/ψ data sample

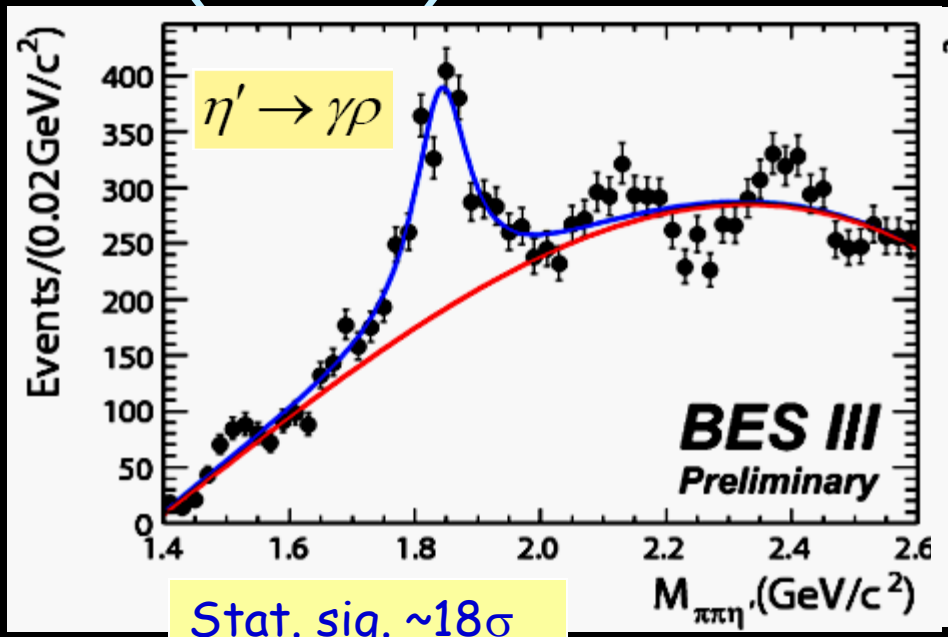
PRL 95,262001(2005)



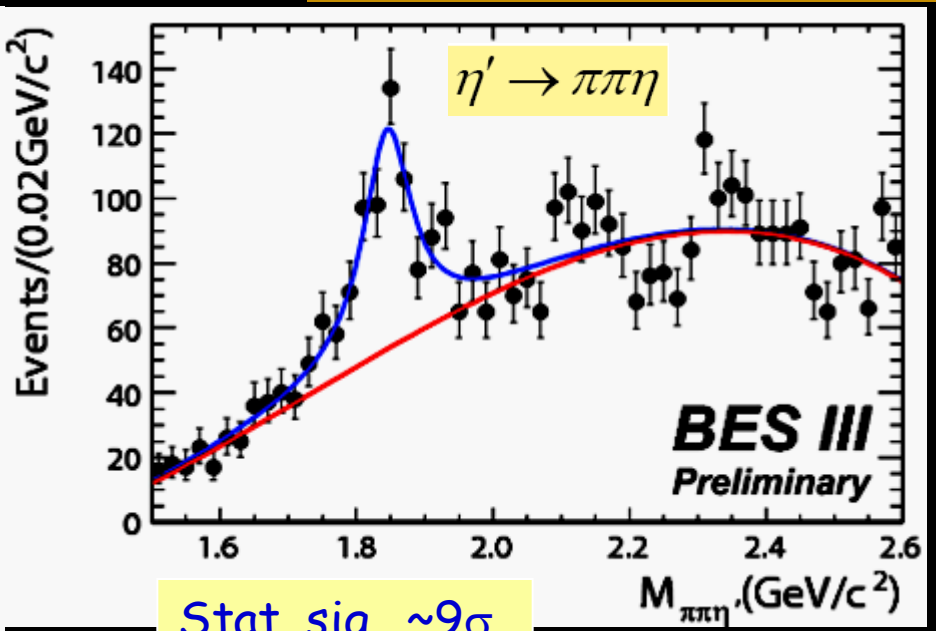
M = 1833.7 ± 6.1 ± 2.7 MeV/c²
Γ = 67.7 ± 20.3 ± 7.7 MeV/c²
B(J/ψ→γX) x B(X→$\pi^+\pi^-\eta'$) = (2.2±0.4±0.4) x 10^{-4}
sig. = 7.7σ

X(1835) at BESIII

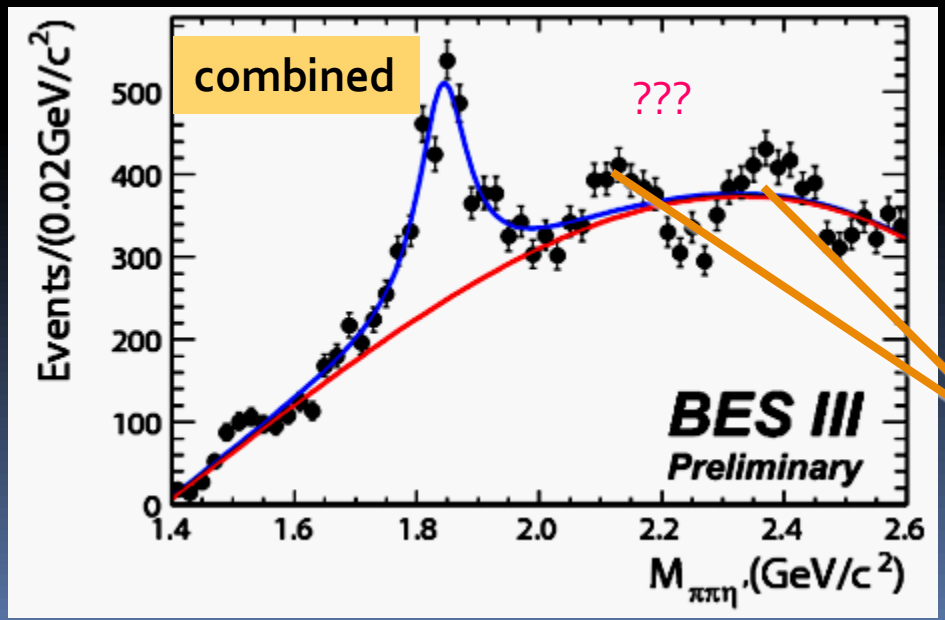
BESIII preliminary



Stat. sig. ~18σ



Stat. sig. ~9σ



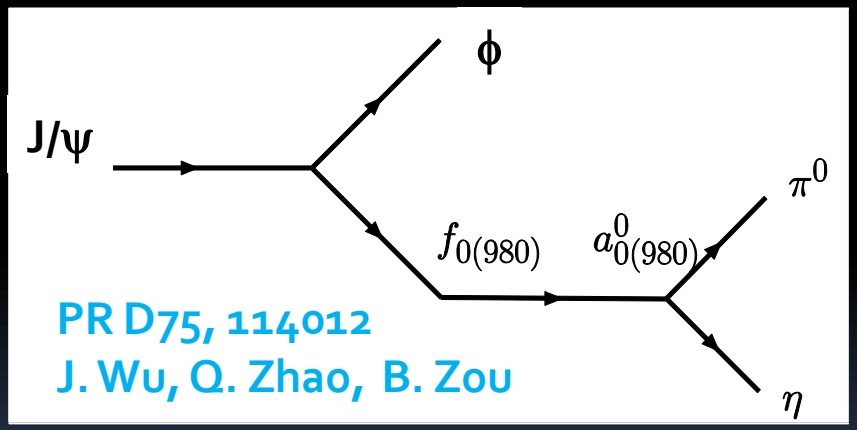
M = 1842.4 ± 2.8(stat.) MeV/c²
Γ = 99.2 ± 9.2 (stat.) MeV/c²
Fit result: Stat. sig. ~ 21σ

X(1835) confirmed by BESIII

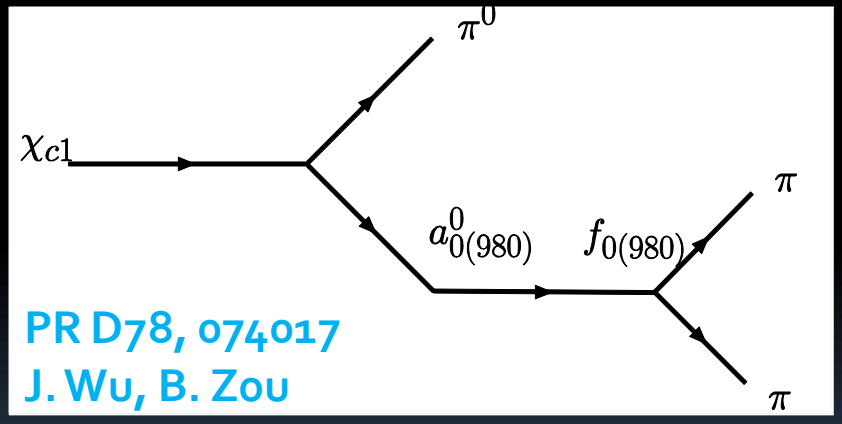
The possibility that there are two new resonances is under further study.

$a_0(980)$ – $f_0(980)$ mixing

- Light scalar mesons f_0 and a_0 are still controversial.
- Described as quark-antiquarks, four quarks, KK-bar molecule, qq-bar g hybrids, etc.
- Study of mixing important to clarify their nature.
- $J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi$ and $\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0$ provide complementary information:



PR D75, 114012
J. Wu, Q. Zhao, B. Zou



PR D78, 074017
J. Wu, B. Zou

$$\xi_{fa}(s) = \frac{d\Gamma_{X\to Yf_0(980)\to Ya_0(980)\to Y\pi^0\eta(s)}}{d\Gamma_{X\to Yf_0(980)\to Y\pi\pi(s)}}$$

$$\xi_{af}(s) = \frac{d\Gamma_{X\to Ya_0(980)\to Yf_0(980)\to Y\pi\pi(s)}}{d\Gamma_{X\to Ya_0(980)\to Y\pi^0\eta(s)}}$$

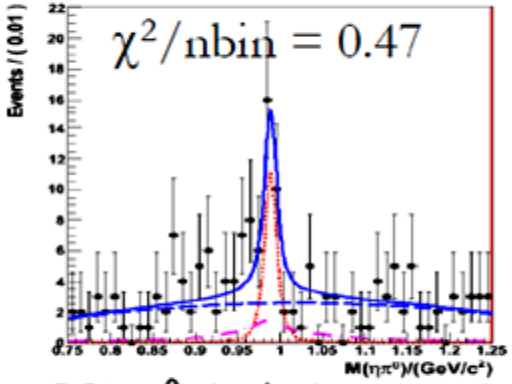
Mixing intensity

$a_0(980)$ – $f_0(980)$ mixing

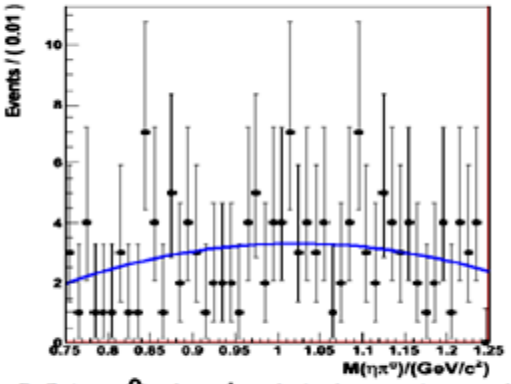
BESIII preliminary

Mixing peaks expected at ~991 MeV/c^2 with 8 MeV/c^2 width.

$J/\psi \to \phi f_0 \to \phi a_0$



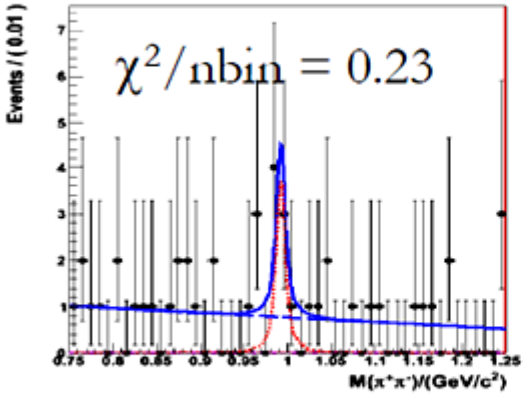
$M(\eta\pi^0)$ in ϕ signal region



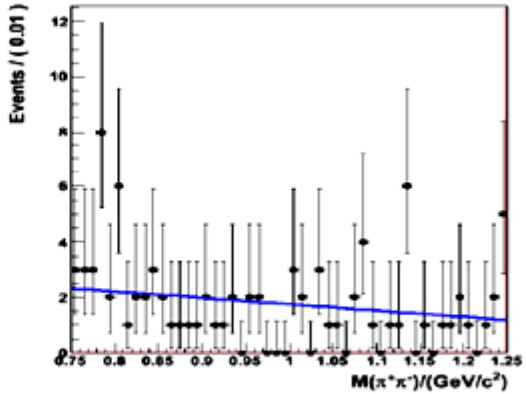
$M(\eta\pi^0)$ in ϕ sideband region

- $N(\text{mixing}) = 24.7 \pm 8.6$ (< 36.7 @ 90% C.L.), $S = 3.3\,\sigma$;

$\chi_{c1} \to a_0\pi^0 \to f_0\pi^0$



$M(\pi^+\pi^-)$ in χ_{c1} signal region



$M(\pi^+\pi^-)$ in χ_{c1} sideband region

- $N(\text{mixing}) = 6.5 \pm 3.2$ (< 12.1 @ 90% C.L.), $S = 2.0\,\sigma$;

$a_0(980)$ – $f_0(980)$ mixing

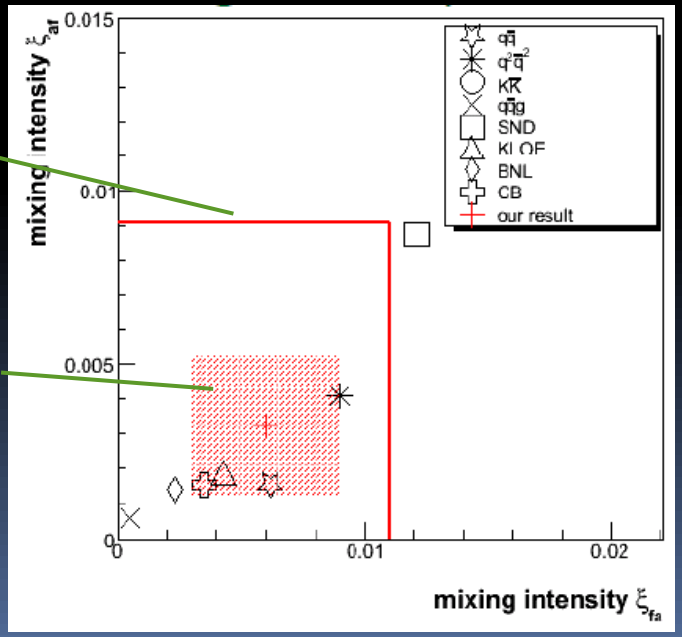
- **Mixing intensity**

BESIII preliminary

- ξ_{fa} = (0.6±0.2(stat.)±0.2(sys.))%
  (<1.1% @90% C.L.)
- ξ_{af} = (0.32±0.16(stat.)±0.12(sys.))%
  (<0.91% @90% C.L.)

our upper limit

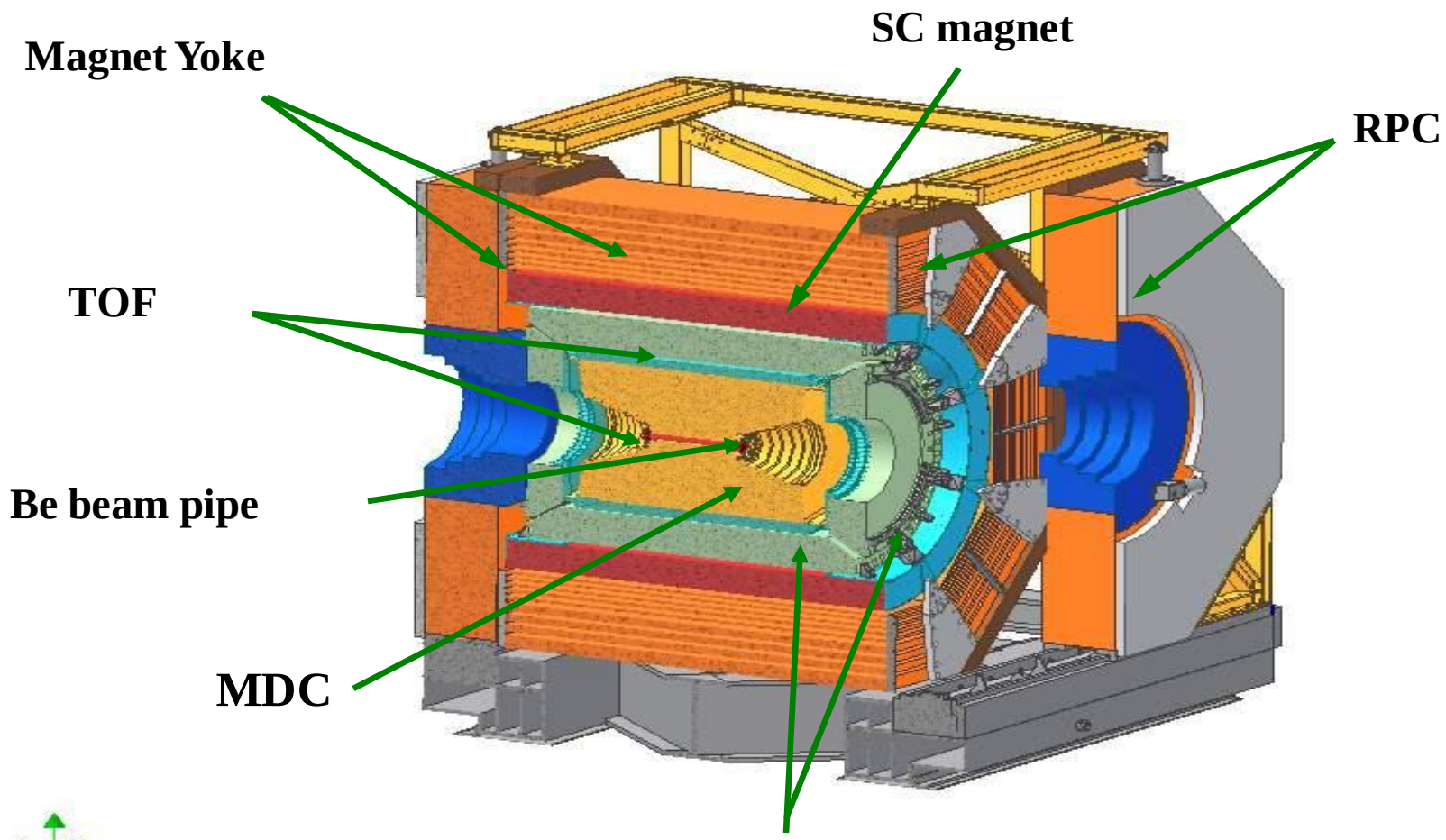
our measurement



Summary

- BEPCII/BESIII had been successfully constructed and commissioned with excellent performance
- 100 M $\psi(2S)$ and 230 M J/ψ events samples have been accumulated, >800 pb^{-1} at $\psi(3770)$ so far in 2010.
- charged κ is observed at BESII
- $\bar{p}p$ threshold enhancement is confirmed at BESIII
- X(1835) is confirmed at BESIII
- $a_0(980) - f_0(980)$ mixing is meausred
- More exciting results are expected

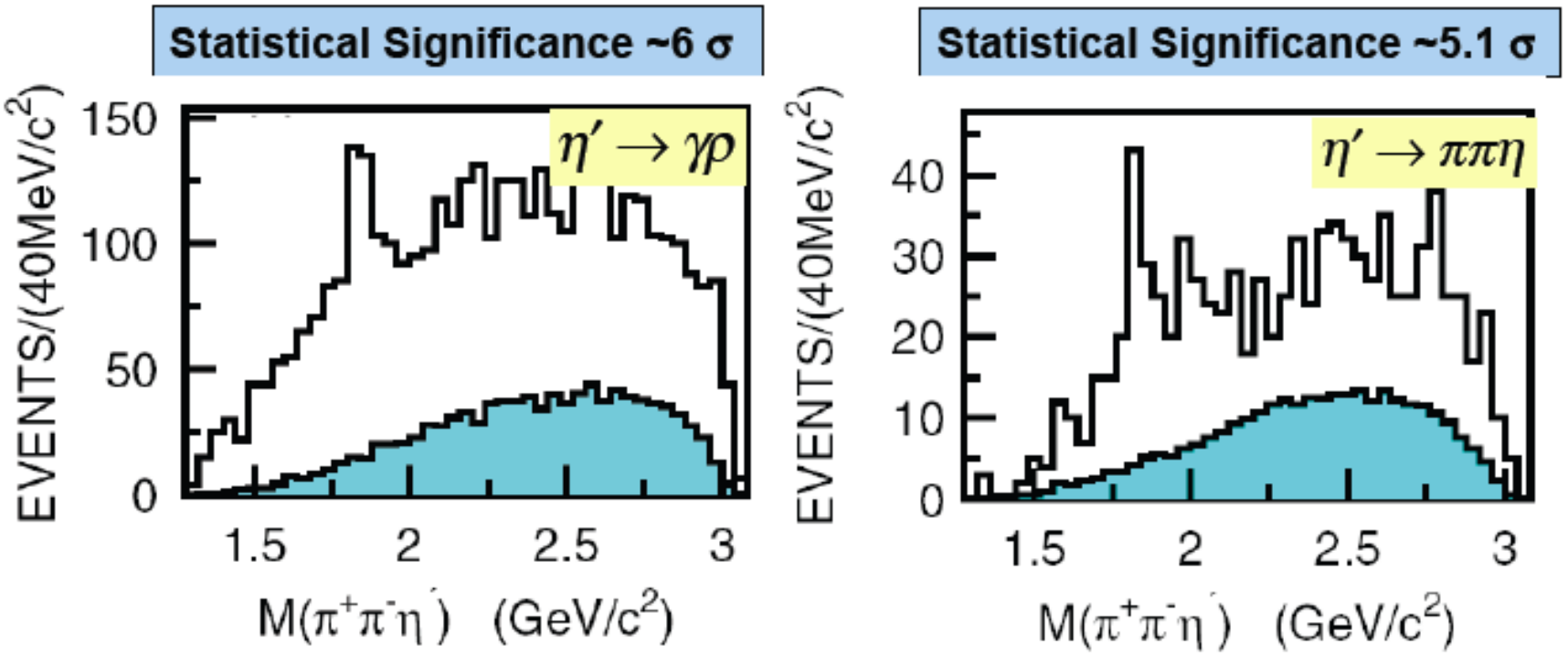
Thank you!


Magnet Yoke
SC magnet
RPC
TOF
Be beam pipe
MDC
CsI(Tl) calorimeter

BESIII Performance

Sub-detectors			design	measurement
MDC	Momentum resolution (1 GeV)		0.5 – 0.7 %	0.58%
	dE/dx resolution		6 – 8 %	6.0 %(hadron) 5.3% (Bhabha)
EMC	Energy resolution (1 GeV)		2.5 – 3.0 %	2.5%
	Spatial resolution		5 – 7 mm	6 mm
TOF	Time resolution	Barrel	80 – 90 ps	80 ps (Bhabha)
		Endcap	100 – 110 ps	100 ps (Di-muon)
MUC	$\delta_{R\Phi}$=1.4 cm~1.7 cm			< 1.7 cm

Observation of X(1835) in $J/\psi \to \gamma\pi^+\pi^-\eta'$ at BESII



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