

Recent results from BESIII

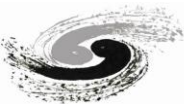
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La Thuile 2010, 28 Feb. ~ 06 March, 2010

Outline

- Introduction of BEPCII & BESIII
- Recent BESIII Results
 - the threshold enhancement & X(1835);
 - observation of h_c
 - observation of $\chi_{cJ} \rightarrow VV$;
 - measurement of $\text{Br}(\chi_{c0,2} \rightarrow \pi^0\pi^0)$,
 $\text{Br}(\chi_{c0,2} \rightarrow \eta\eta)$
- Summary



Beijing Electron Positron Collider II (BEPCII) @ IHEP



Beijing Spectrometer

BESI: 1989 - 1998

BESII: 1999 - 2004

$L \sim 5 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$ @ J/ψ

$E_{\text{beam}} \sim 1 - 2.5 \text{GeV}$

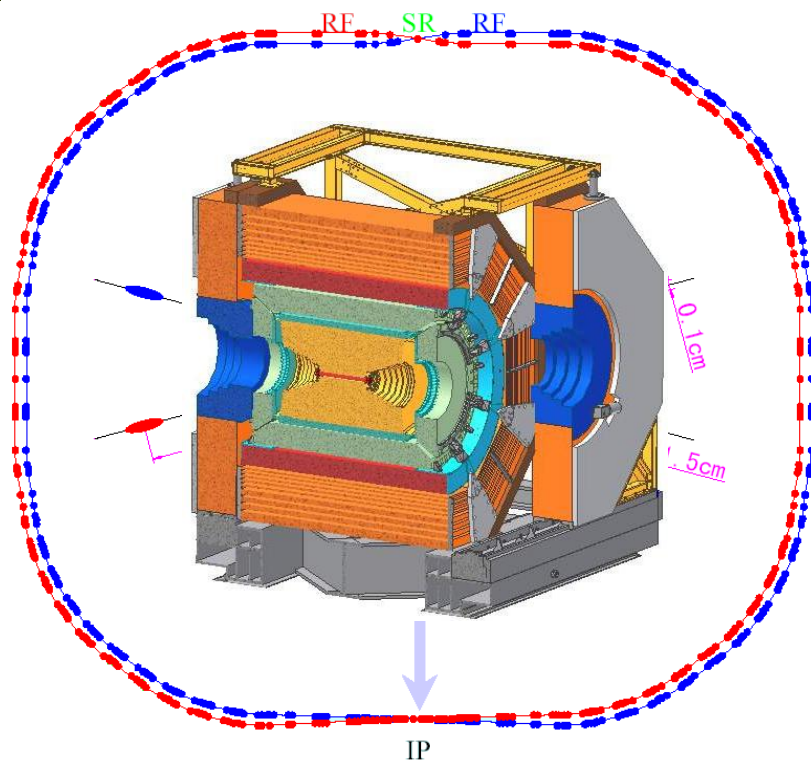
BESIII: 2008 -

Physics run from
March 2009,

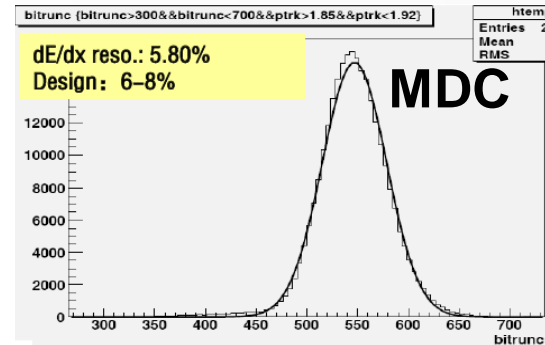
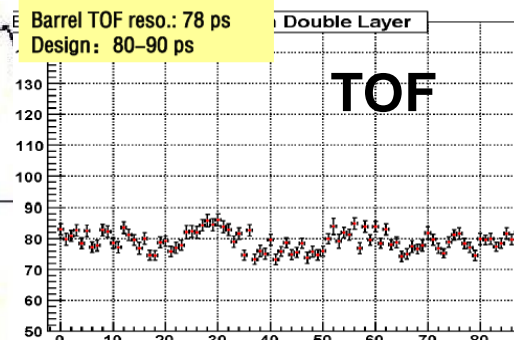
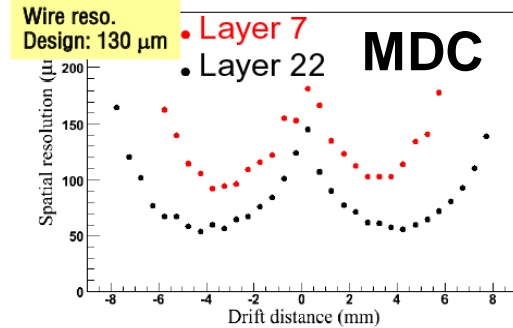
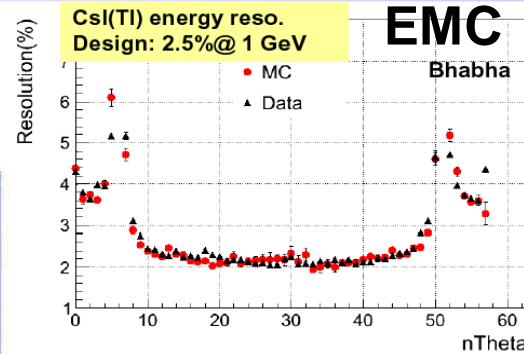
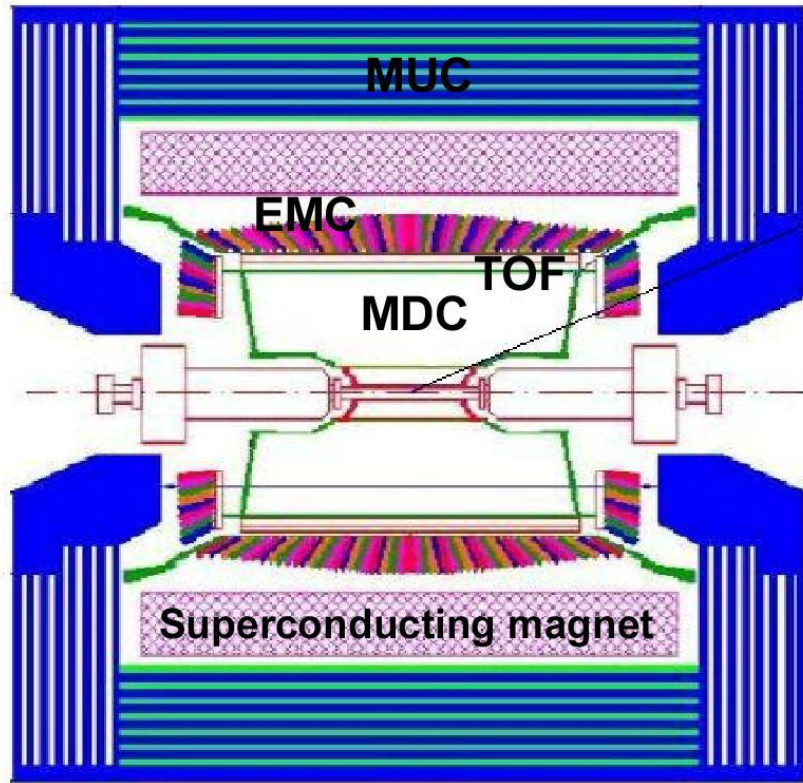
$\sim 110 \text{M } \psi(2\text{S}), \sim 220 \text{M } J/\psi$

BEPCII

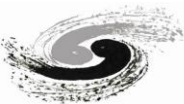
- Beam energy:
 - 1.0-2.3 GeV
- Luminosity:
 - $1 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$
- Optimum energy:
 - 1.89 GeV
- Energy spread:
 - 5.16×10^{-4}
- No. of bunches:
 - 93
- Bunch length:
 - 1.5 cm
- Total current:
 - 0.91 A



BESIII @ BEPCII



- MDC: $\sigma(p_T)/p_T = 0.32\% \pm 0.37\%$
@ 1 GeV
 $dE/dx_{\text{reso}} < 6\%$
- TOF: 80 ps (for bhabha, barrel)
- EMC: $\sigma(E)/E = 2.3\% \times \sqrt{E}$
- MUC: 9 layers for barrel,
8 layers for endcap

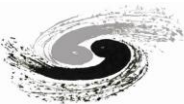


Physics potential at BESIII

- Light hadron spectroscopy *IJMP A V24 No 1 (2009) supp*
 - Full spectra: normal & exotic hadrons **QCD**
 - How quarks form a hadron? **Non-pQCD**
- Charm physics
 - CKM matrix elements **SM & beyond**
 - D \bar{D} mixing & CPV **SM & beyond**
- Charmonium physics
 - Spectroscopy & transition **pQCD & non-pQCD**
 - New states above open charm thresholds **exotic hadrons ?**
 - pQCD: $\rho\pi$ puzzle **a probe to non-pQCD or ?**
- Tau physics & QCD
 - Precision measurement of the tau mass & R value
- Search for rare & forbidden decays

The physics window is precision charm physics & the search for new physics.

- **High statistics: high luminosity machine + high quality detector**
- **Small systematic error: high quality detector.**



Milestones of BESIII

April 30, 2008: Move the BESIII to IP

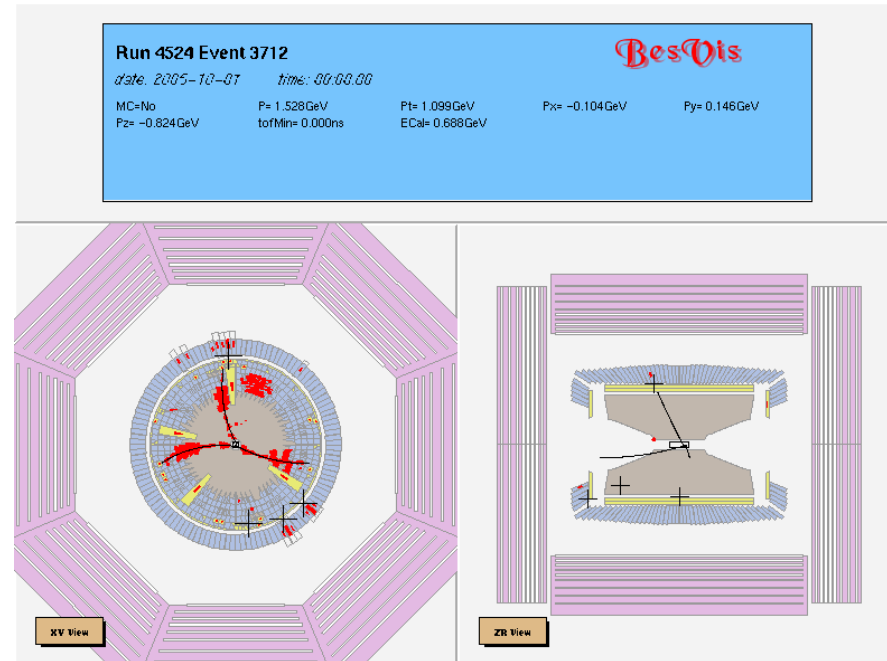
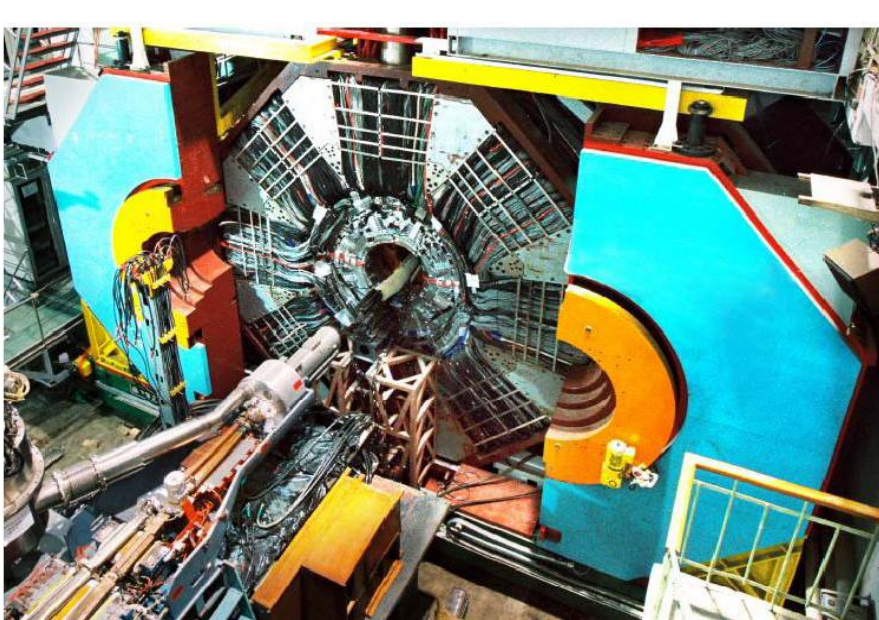
July 19, 2008: First e^+e^- collision event

April 14, 2009: $\sim 110\text{M}$ $\psi(2\text{S})$ events collected
($\times 4$ CLEOc)

May 30, 2009: 42 pb^{-1} at continuum collected

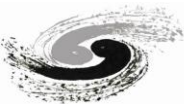
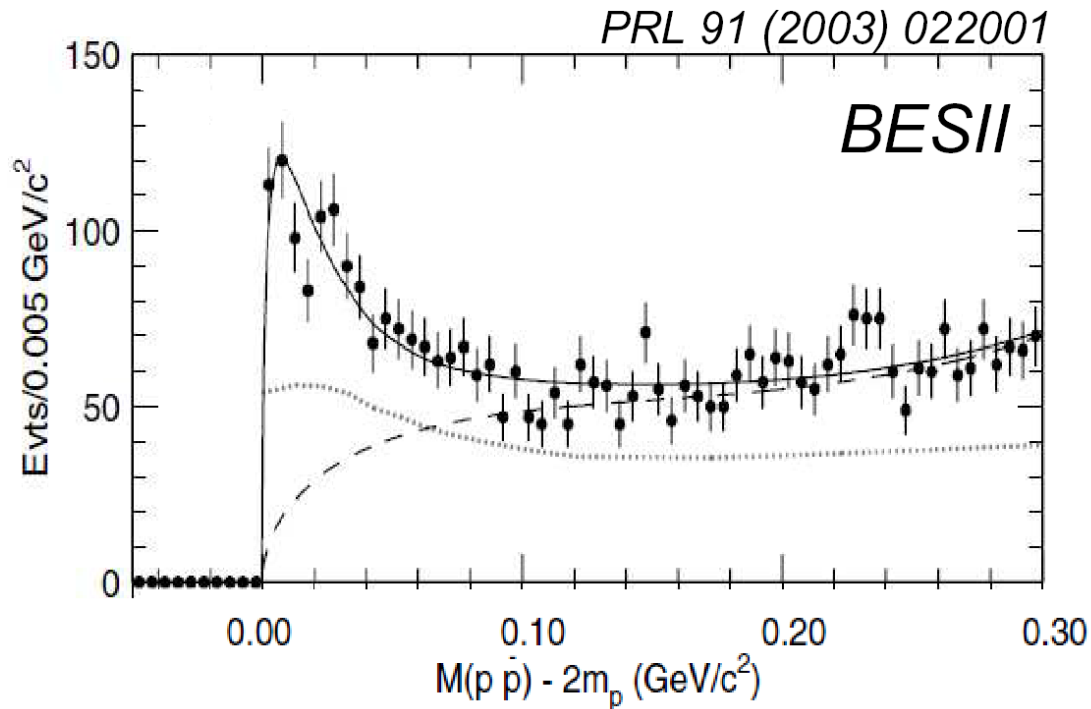
July 28, 2009: $\sim 220\text{M}$ J/ψ events collected
($\times 4$ BESII)

Peak Lumi. @ May
2009:
 $3.2 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$
 $\rightarrow \times 5$ CESRc @ ψ''
 $\rightarrow \times 30$ BEPC

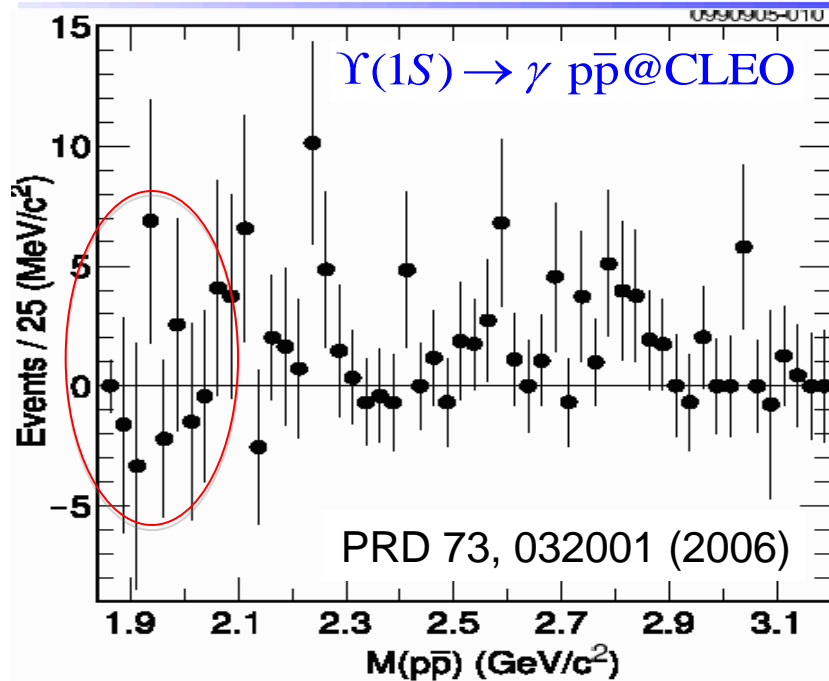


$p\bar{p}$ Threshold Enhancement @ BESII

- BESII observed $p\bar{p}$ enhancement close to threshold
- $J/\psi \rightarrow \gamma p\bar{p}$

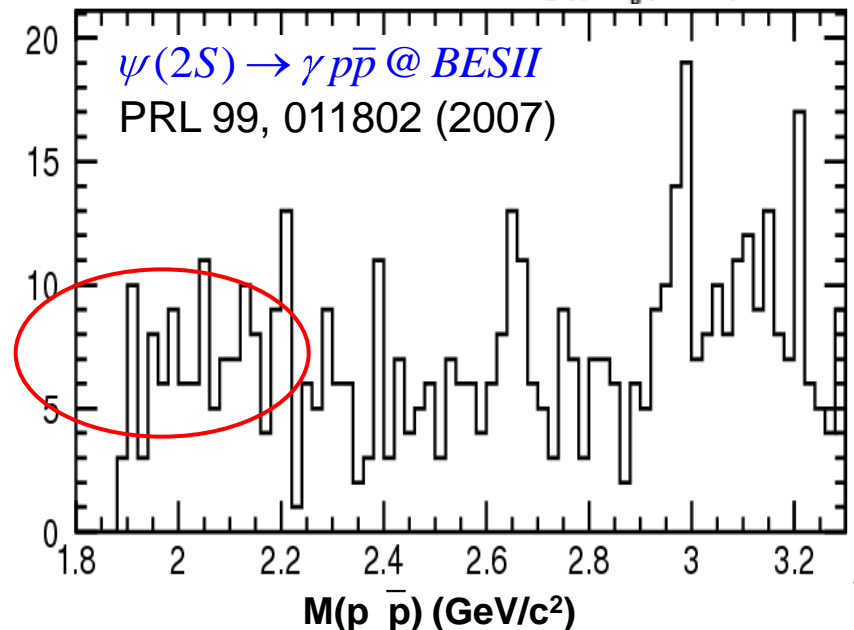
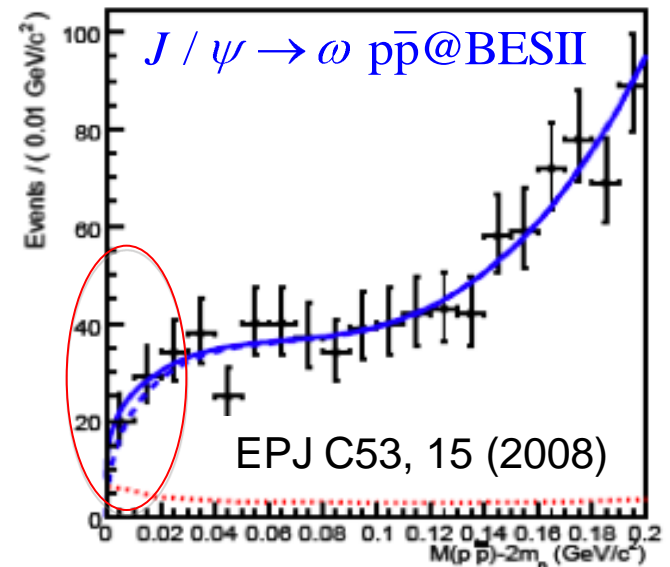


No $p\bar{p}$ Threshold Enhancement

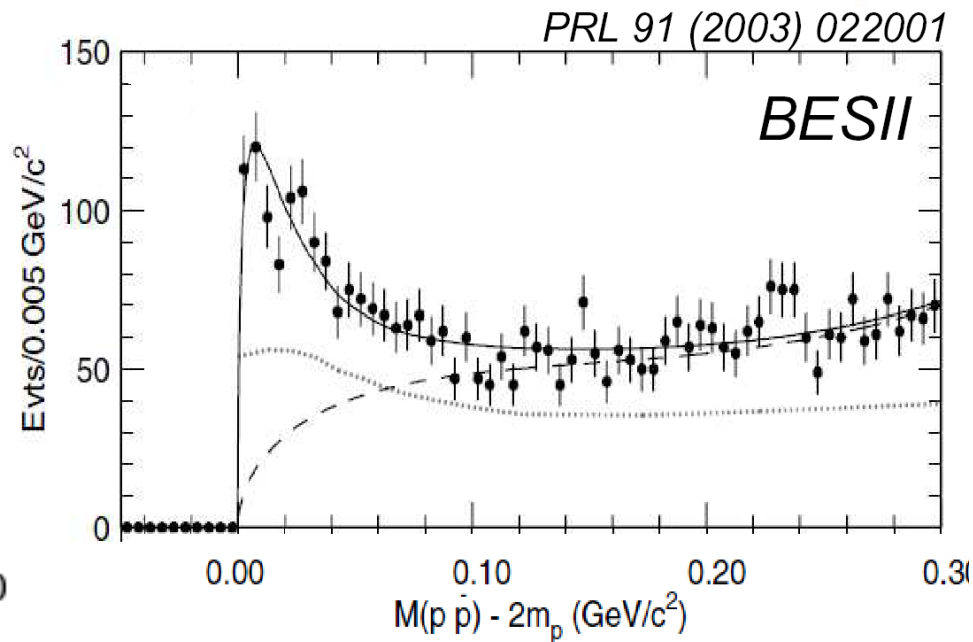
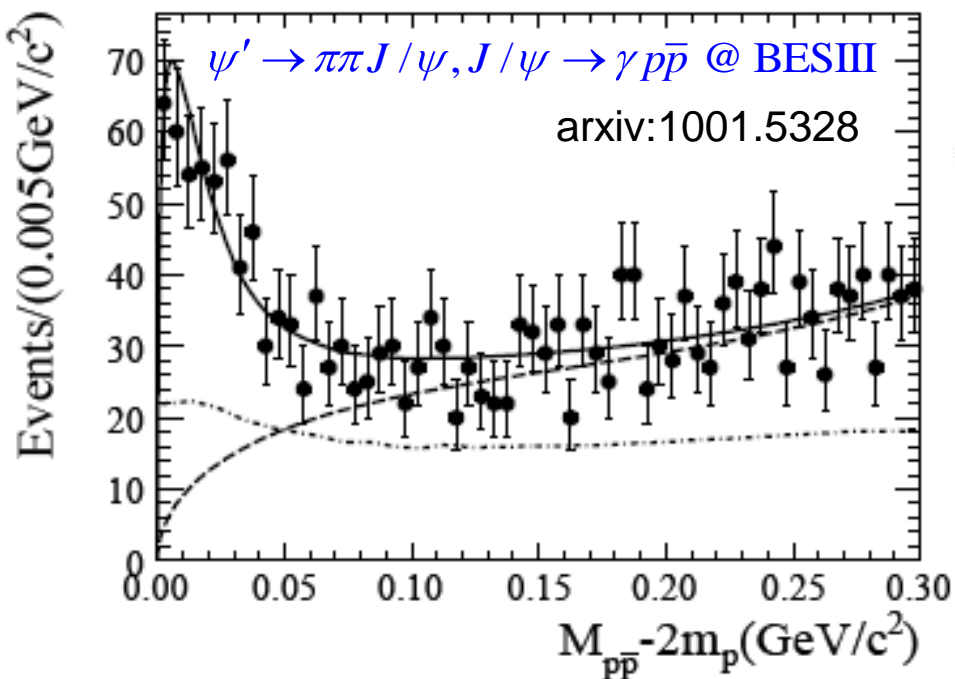


No significant narrow strong enhancement near threshold

Any model trying to interpret the mass threshold enhancement should also answer why it is not observed in other places, especially in those radiative decays.



$p\bar{p}$ Threshold Enhancement @ BESIII

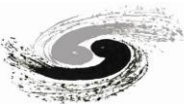


**BESIII: Fitted with a S-wave BW,
 $M=1861^{+6}_{-13}$ (stat) $^{+7}_{-26}$ (syst) MeV/c²
 $\Gamma < 38$ MeV/c² (90% CL)**

BESII:

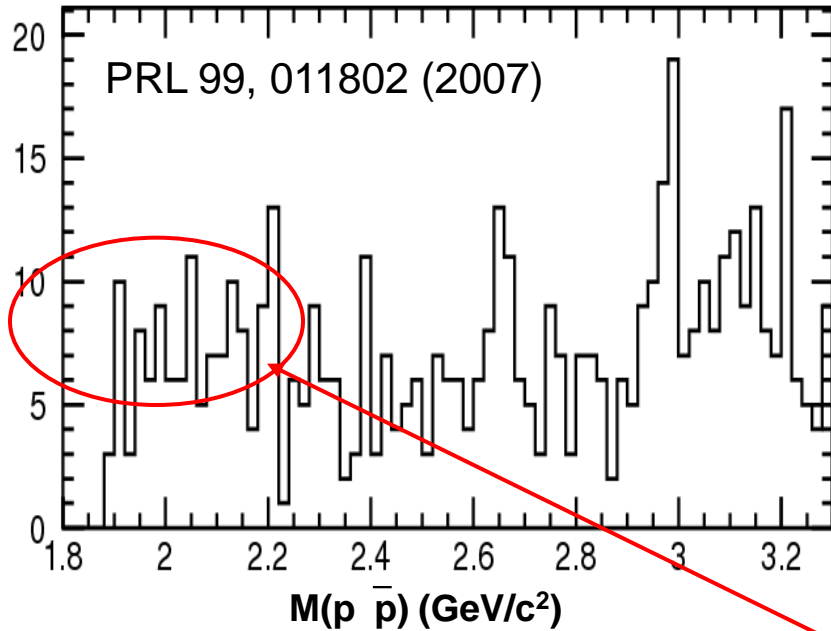
**$M=1859^{+3}_{-10}$ $^{+5}_{-25}$ MeV/c²;
 $\Gamma < 30$ MeV/c² (90% CL)**

arxiv:1001.5328,
 accepted by Chinese Physics C

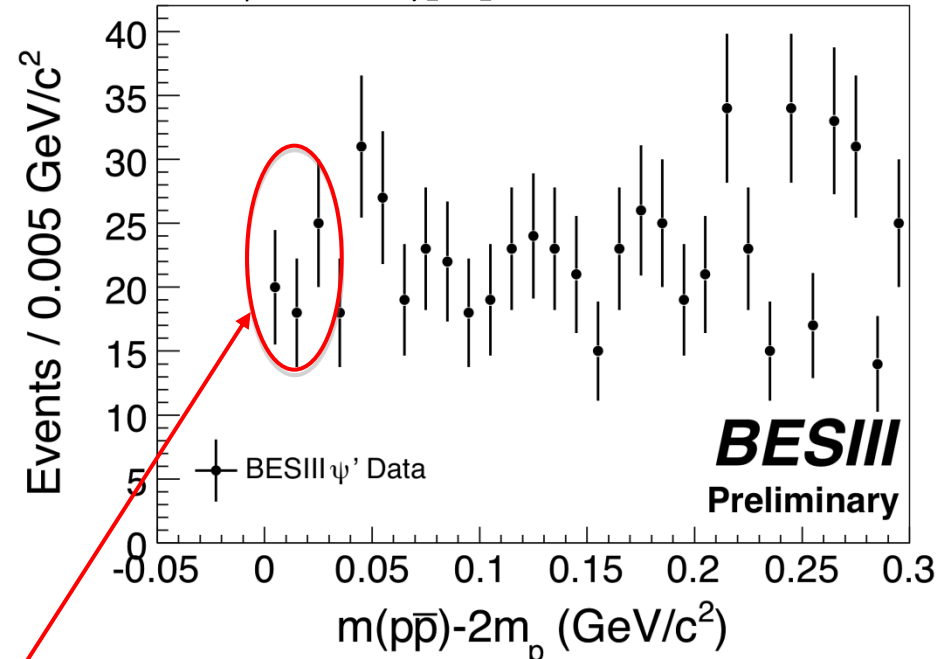


No $p\bar{p}$ Threshold Enhancement in $\psi' \rightarrow \gamma p\bar{p}$ @ BESIII

$\psi(2S) \rightarrow \gamma p\bar{p}$ @ BESII



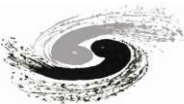
$\psi(2S) \rightarrow \gamma p\bar{p}$ @ BESIII



No significant narrow strong enhancement near threshold

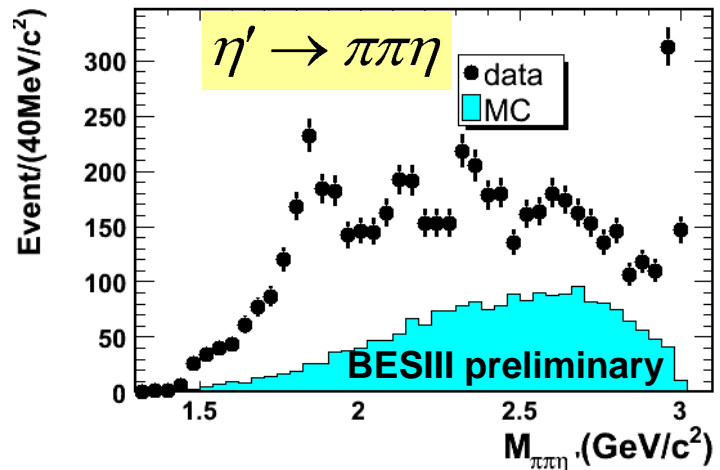
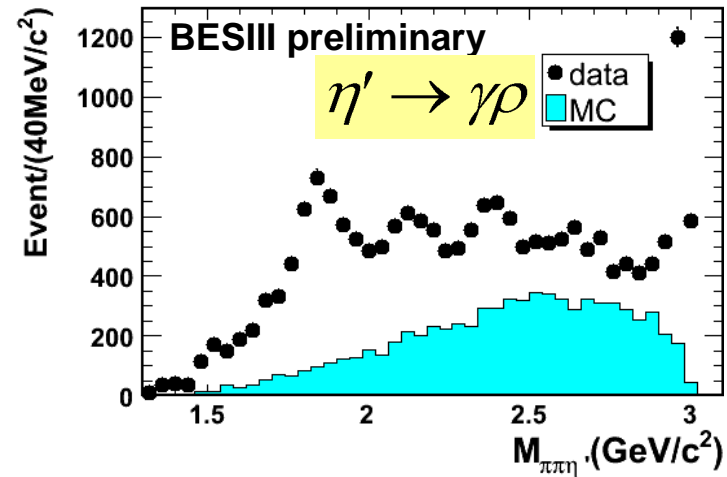
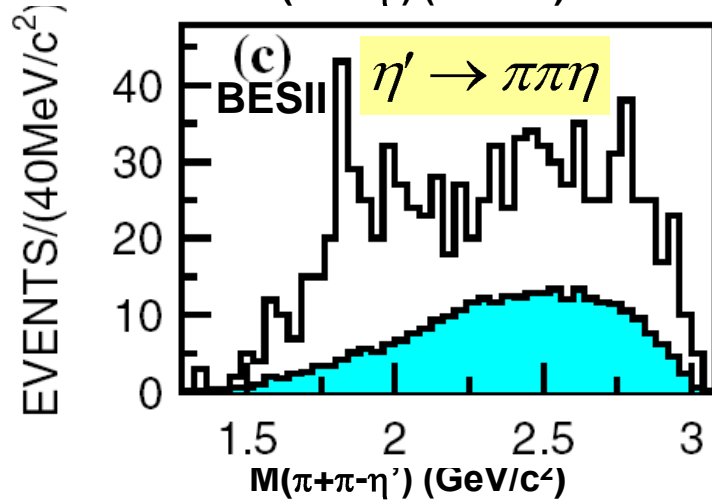
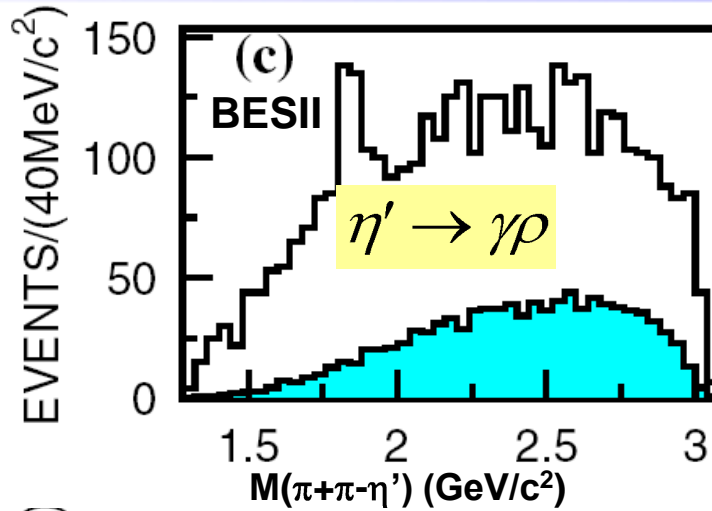
**Consistent with
BESII result**

- whether the enhancement is the $p\bar{p}$ bound state
- the measurement of $J/\psi \rightarrow \gamma \eta \pi \pi \pi$ is suggested by
 - G.J.Ding and M.L.Yan, Phys. Rev. C 72, 015208 (2005)



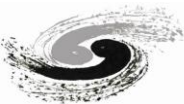
X(1835) from $J/\psi \rightarrow \gamma \eta' \pi^+ \pi^-$

PRL 95,262001(2005)

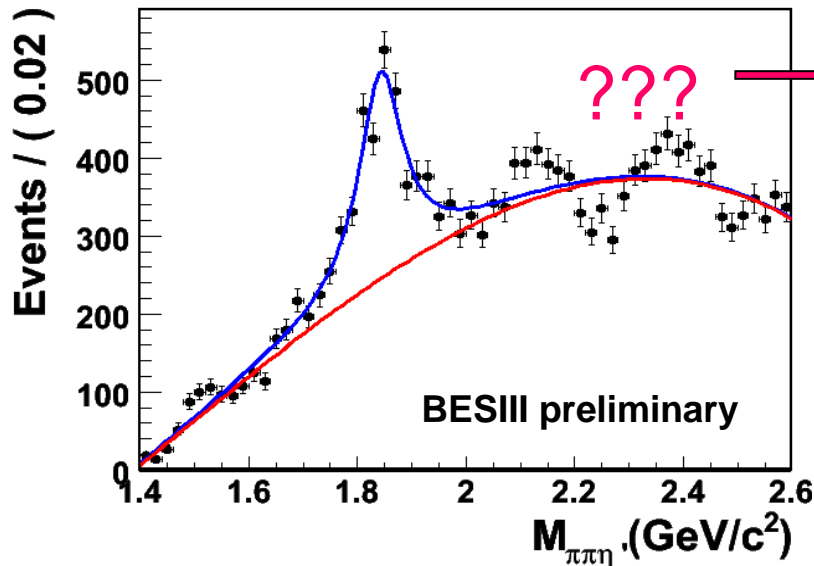


- $\eta' \rightarrow \gamma \pi \pi$: significance $\sim 6\sigma$
- $\eta' \rightarrow \eta \pi^+ \pi^-$: significance $\sim 5.1\sigma$

- $\eta' \rightarrow \gamma \rho$: significance $\sim 18\sigma$
- $\eta' \rightarrow \eta \pi^+ \pi^-$: significance $\sim 9\sigma$



Combined mass spectrum of the two decay modes



Structures at higher mass region???

BESIII fit results

(statistic significance $\sim 21\sigma$):

$$M = 1842.4 \pm 2.8(\text{stat}) \text{ MeV}$$

$$\Gamma = 99.2 \pm 9.2(\text{stat}) \text{ MeV}$$

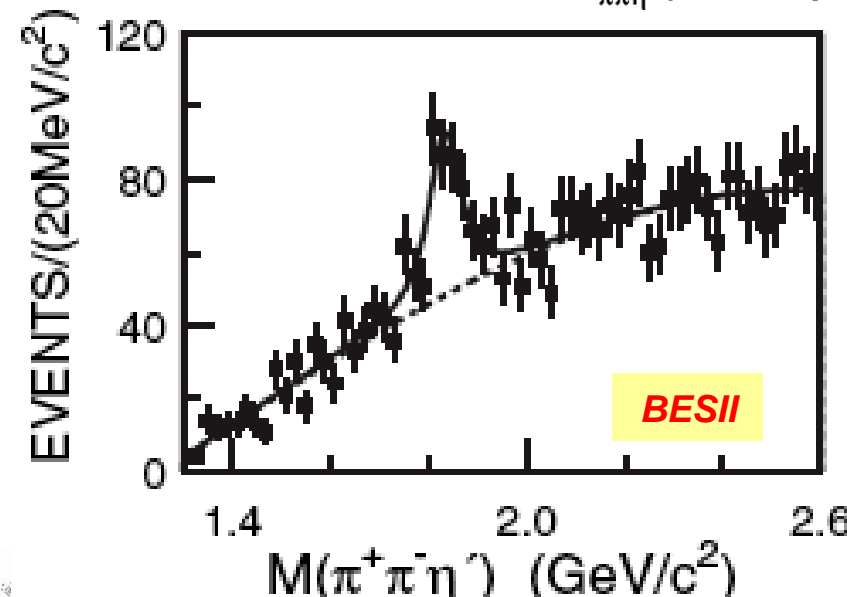
BESII fit results

(statistic significance $\sim 7.7\sigma$):

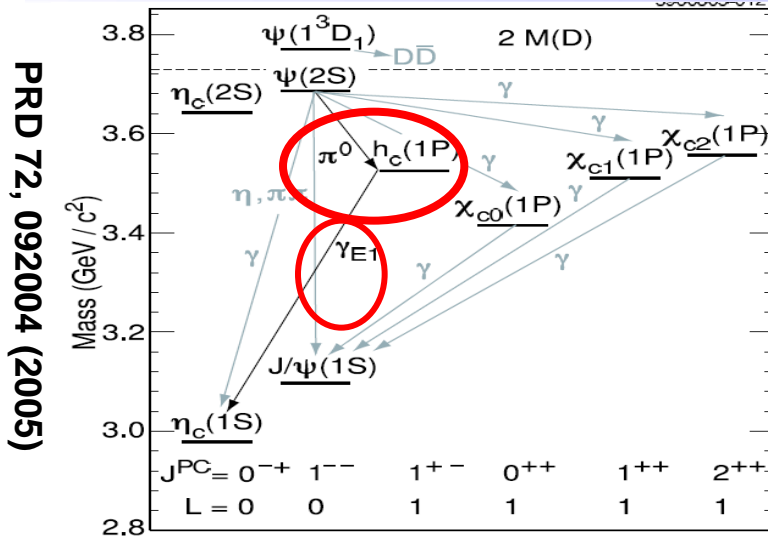
$$M = 1833.7 \pm 61(\text{stat}) \pm 2.7(\text{syst}) \text{ MeV}$$

$$\Gamma = 67.7 \pm 20.3(\text{stat}) \pm 7.7(\text{syst}) \text{ MeV}$$

- **X(1835) is confirmed in BESIII**
- **the significance improved as statistics increases**
- LQCD predicts the glueball mass of $0^{++} \sim 2.3\text{GeV}$
- For 0^{++} glueball, it may have similar property as η_c (mainly decay to $\pi\pi\eta'$)



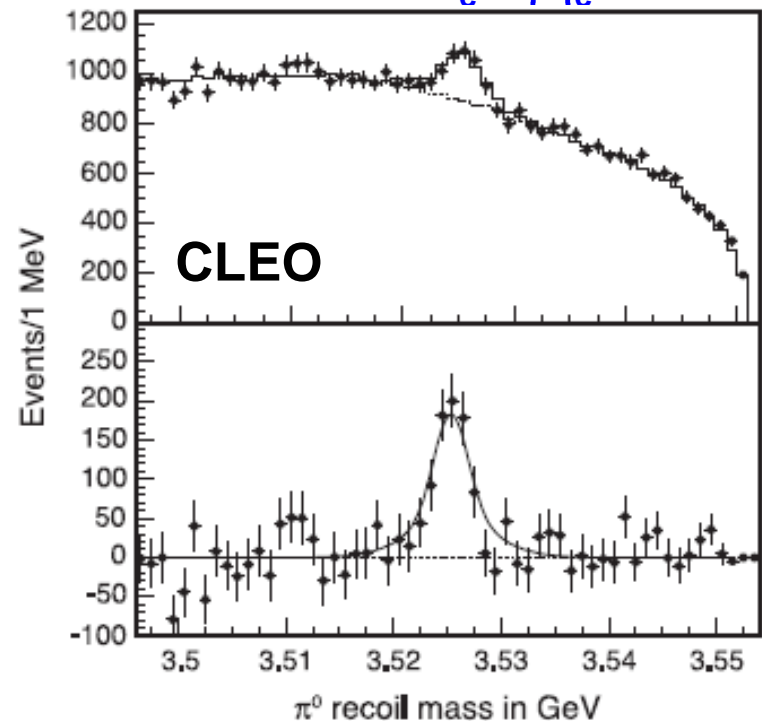
$h_c(1P_1)$ in charmonium family



- The $c\bar{c}$ singlet state h_c was predicted by theory long time ago.
- In 2008, h_c was observed by CLEO_c in charmonium decays
- h_c only observed in the process of $\psi(2S) \rightarrow \pi^0 h_c$
- the main decay mode of h_c : the E1 transition $h_c \rightarrow \gamma \eta_c$.

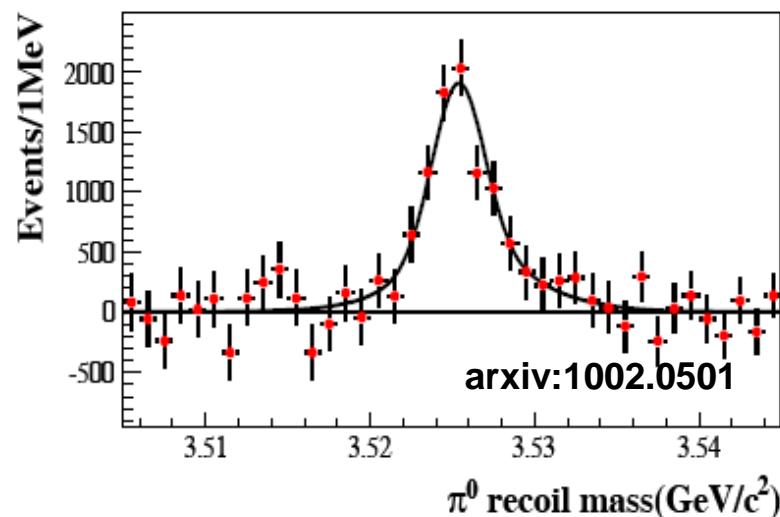
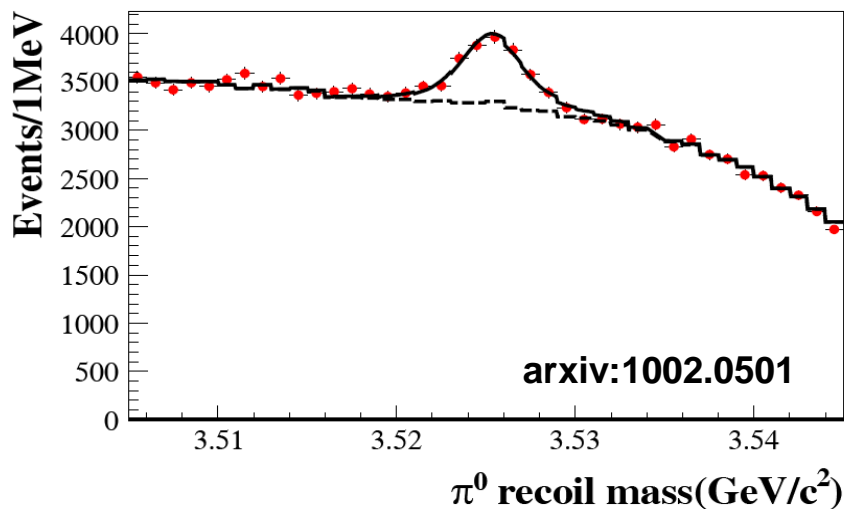
- CLEOc first measurement of h_c
 - $\psi(2S) \rightarrow \pi^0 h_c, h_c \rightarrow \gamma \eta_c$, E1-tagged

	Inclusive	Exclusive
Counts	1146 ± 118	136 ± 14
Significance	10.0σ	13.2σ
$M(h_c)$ (MeV)	$3525.35 \pm 0.23 \pm 0.15$	$3525.21 \pm 0.27 \pm 0.14$
$\mathcal{B}_1 \times \mathcal{B}_2 \times 10^4$	$4.22 \pm 0.44 \pm 0.52$	$4.15 \pm 0.48 \pm 0.77$



CLEO: PRL 101, 182003(2008)

E1-tagged $\psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma \eta_c$ at BESIII



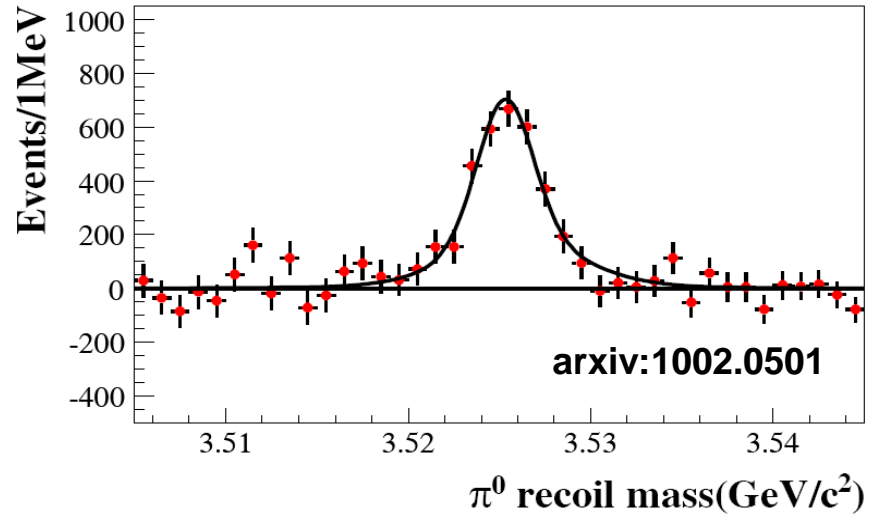
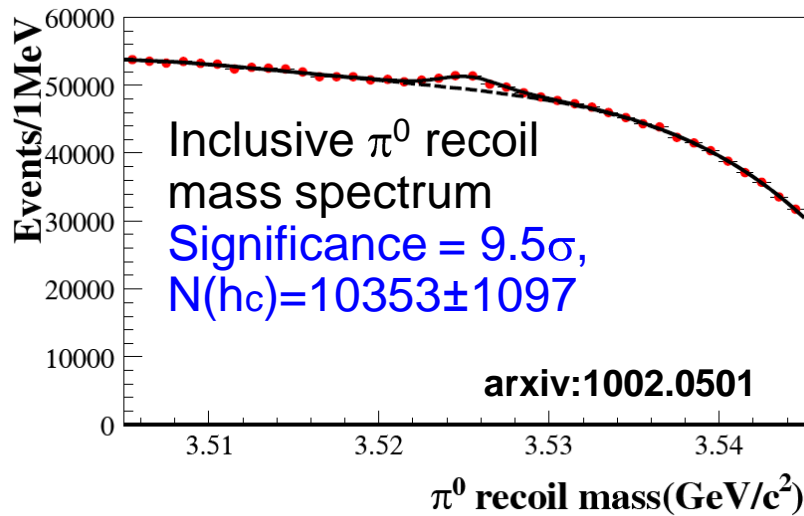
- Select E1-photon to tag h_c
- A fit of Double Gaussian signal + sideband BG yield:
 - **Significance = 18.6σ ,**

E1-photon -tagged	$\text{Br}(\psi' \rightarrow \pi^0 h_c) \times \text{Br}(h_c \rightarrow \gamma \eta_c) (\times 10^{-4})$	$M(h_c)$ (MeV)	$\Gamma(h_c)$ (MeV)
BESIII	$4.58 \pm 0.40 \pm 0.50$	3525.16 ± 0.16	0.89 ± 0.57
CLEO	$4.22 \pm 0.44 \pm 0.52$	$3525.35 \pm 0.23 \pm 0.15$	----

BESIII: [arxiv:1002.0501](#) submitted to PRL

CLEO: PRL 101, 182003(2008)

h_c Measurement in inclusive $\psi' \rightarrow \pi^0 h_c$



- Select inclusive π^0
- A fit of Double Guassian signal + 4th poly. BG yield:

Combined inclusive & E1-photon-tagged spectrum

the first measurement:

$$\text{Br}(\psi' \rightarrow \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$$

$$\text{Br}(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$$

Theoretical predictions of branching ratios:

$$\text{Br}(\psi' \rightarrow \pi^0 h_c) = (0.4 - 1.3) \times 10^{-4}$$

$$\text{Br}(h_c \rightarrow \gamma \eta_c) = 48\% \text{ (NRQCD)}$$

$$\text{Br}(h_c \rightarrow \gamma \eta_c) = 88\% \text{ (PQCD)}$$

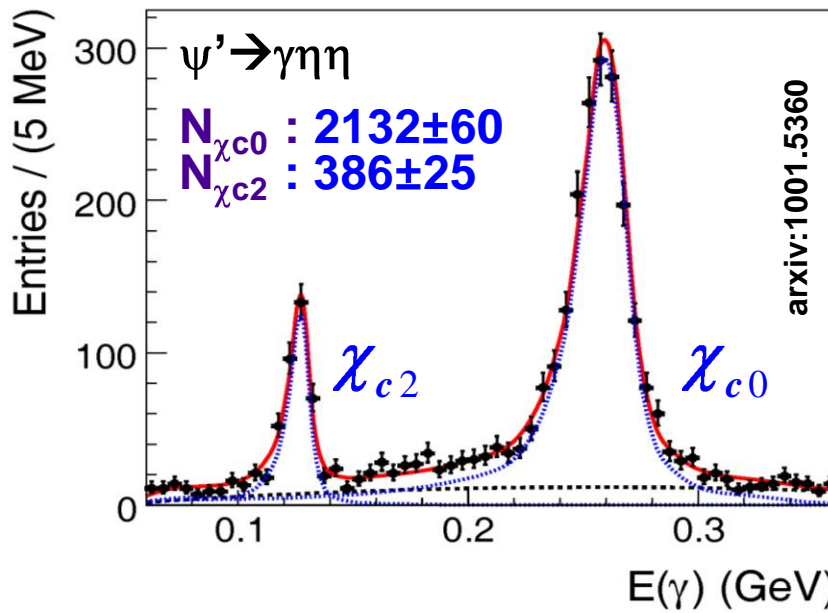
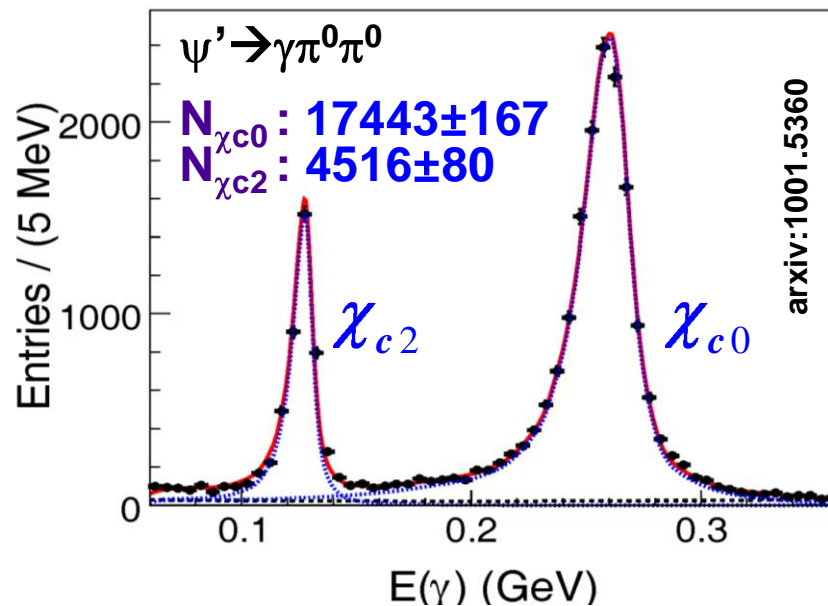
(Y.P.Kuang, PRD 65,094024 (2002))

$$\text{Br}(h_c \rightarrow \gamma \eta_c) = 38\%$$

(S. Godfrey & J.Rosner, PRD 66,014012(2002))

Study of $\psi' \rightarrow \gamma \pi^0 \pi^0$, $\gamma \eta \eta$ ($\eta \rightarrow \gamma \gamma$, $\pi^0 \rightarrow \gamma \gamma$)

- Radiative decay of charmonium to $\pi^0 \pi^0, \eta \eta$ are interesting channels for glueball searches.
- Exclusive decays of χ_{cJ} are good laboratory to test the color-octet mechanism in P-wave charmonium decays.
- BR of χ_{cJ} to $\eta \eta, \eta' \eta, \eta' \eta'$ determine the ratio of contributions from SOZI and DOZI graphs.

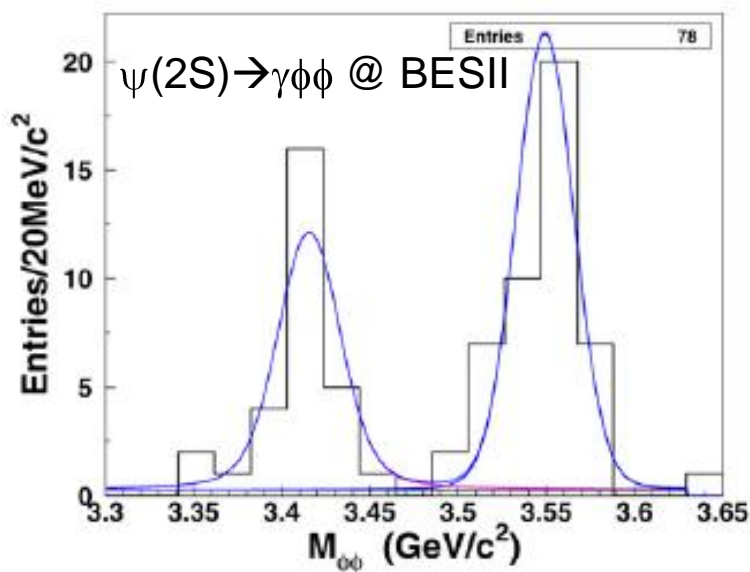


Mode		χ_{c0}	χ_{c2}
$\pi^0 \pi^0$	BESIII	$3.23 \pm 0.03 \pm 0.23 \pm 0.14$	$0.88 \pm 0.02 \pm 0.06 \pm 0.04$
	CLEOc [2]	$2.94 \pm 0.07 \pm 0.32 \pm 0.15$	$0.68 \pm 0.03 \pm 0.07 \pm 0.04$
	PDG [10]	2.43 ± 0.20	0.71 ± 0.08
$\eta \eta$	BESIII	$3.44 \pm 0.10 \pm 0.24 \pm 0.13$	$0.65 \pm 0.04 \pm 0.05 \pm 0.03$
	CLEOc [2]	$3.18 \pm 0.13 \pm 0.31 \pm 0.16$	$0.51 \pm 0.05 \pm 0.05 \pm 0.03$
	PDG [10]	2.4 ± 0.4	< 0.5

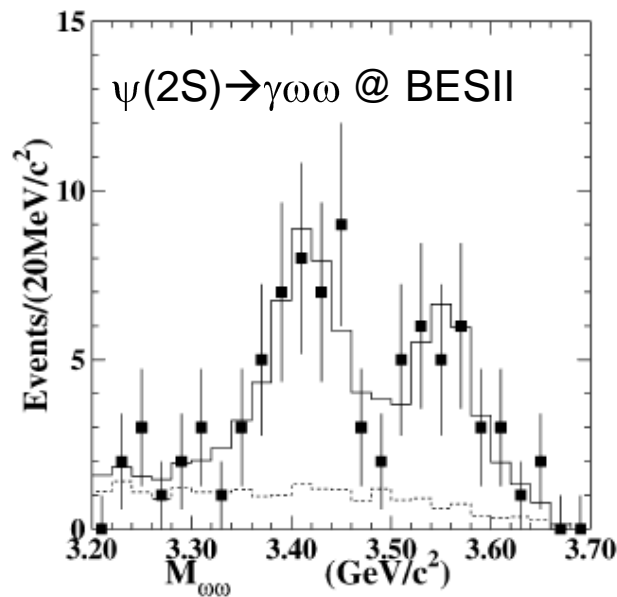
arxiv:1001.5360, accepted by PRD

Study of $\chi_c \rightarrow VV$, $V = \omega, \phi$

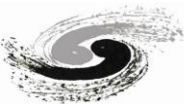
- $\chi_{cJ} \rightarrow \phi\phi$ and $\chi_{cJ} \rightarrow \omega\omega$ Singly OZI suppressed
- $\chi_{c1} \rightarrow \phi\phi$ and $\chi_{c1} \rightarrow \omega\omega$ is only allowed for L=2, suppressed ?
- $\chi_{cJ} \rightarrow \phi\omega$ is doubly OZI suppressed, not measured yet



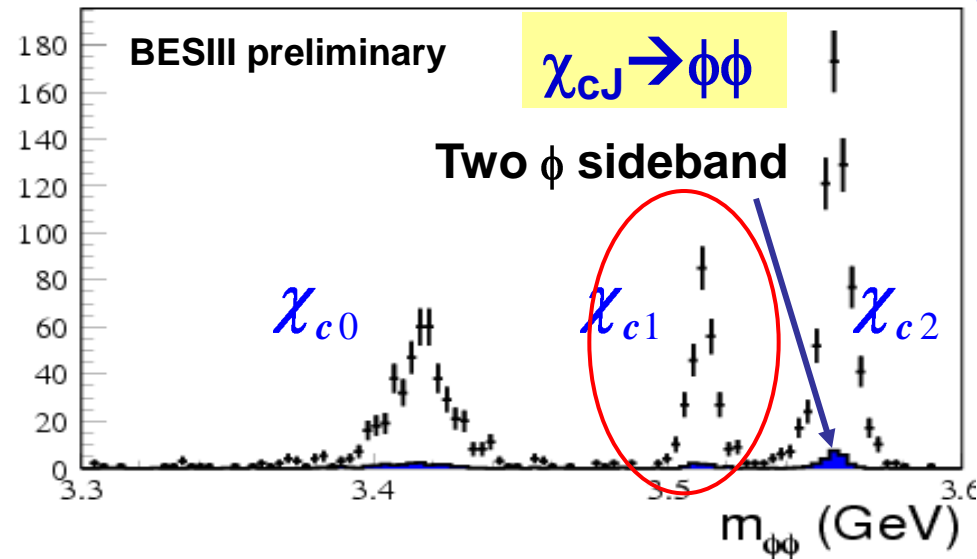
PLB 642,197(2006)
PLB 630,7 (2005)



BR(10^{-3})	χ_{c0}	χ_{c2}
$\phi\phi$	0.93 ± 0.20	1.5 ± 0.3
$\omega\omega$	2.3 ± 0.7	2.0 ± 0.7



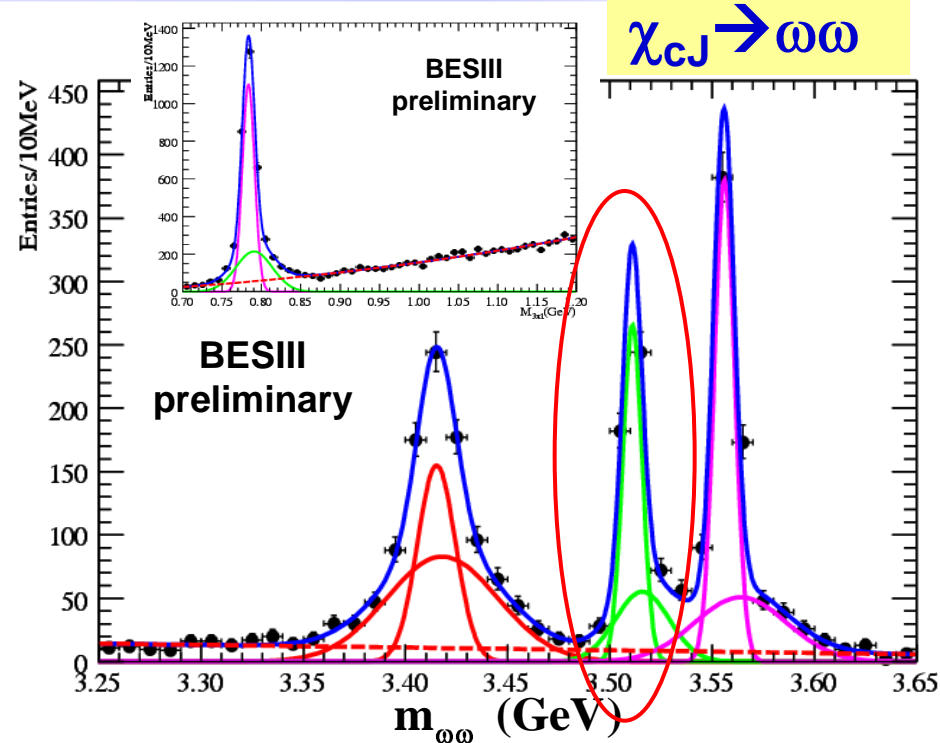
Study of $\chi_{cJ} \rightarrow \phi\phi$ & $\chi_{cJ} \rightarrow \omega\omega$



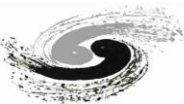
Branching fraction

channel	($\times 10^{-4}$)	PDG($\times 10^{-4}$)
$\chi_{c0} \rightarrow \phi\phi$	8.0 ± 0.4	9.3 ± 2.0
$\chi_{c1} \rightarrow \phi\phi$	4.2 ± 0.3	— — —
$\chi_{c2} \rightarrow \phi\phi$	11.3 ± 0.4	15.4 ± 3.0

- the first measurement of $\chi_{c1} \rightarrow \phi\phi$ and $\chi_{c1} \rightarrow \omega\omega$

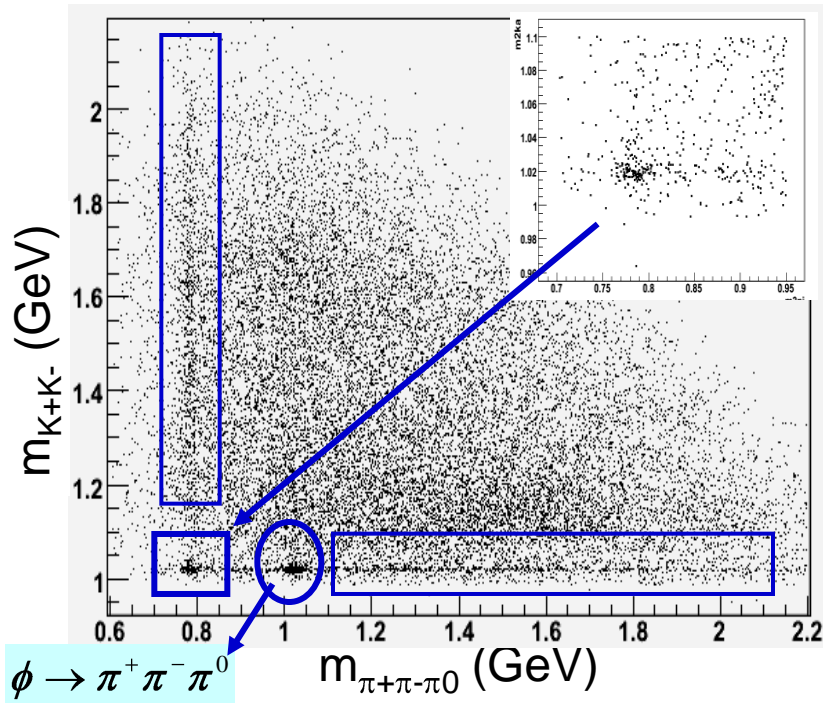


- $\omega\omega$ signals are clearly observed
- backgrounds and non-resonance contributions are studied with two- ω sidebands and continuum data, very low.



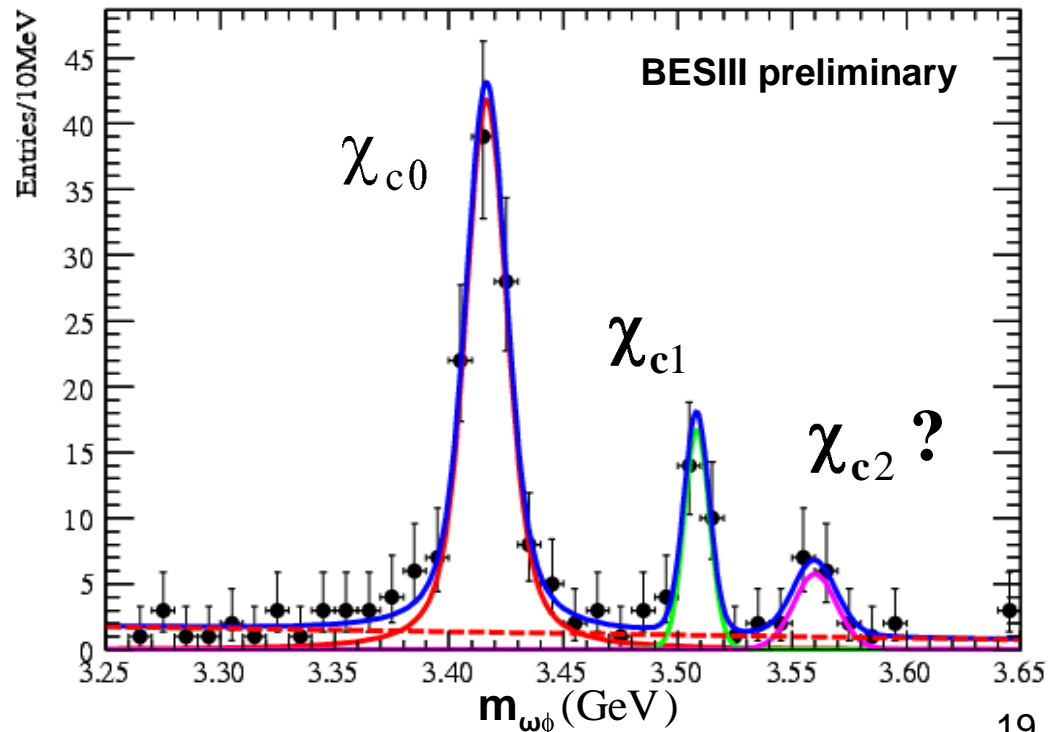
First observation of $\chi_{cJ} \rightarrow \omega\phi$

m_{KK} versus $m_{\pi^+\pi^-\pi^0}$ for Data



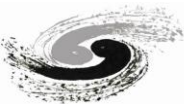
- $\chi_{c0,1} \rightarrow \phi\omega$ OZI doubly suppressed
- surprisingly the doubly suppressed decay is first observed!

- $\omega\phi$ signals are clearly observed
- backgrounds and contributions from non-resonances are studied with ω & ϕ sidebands, and continuum data.



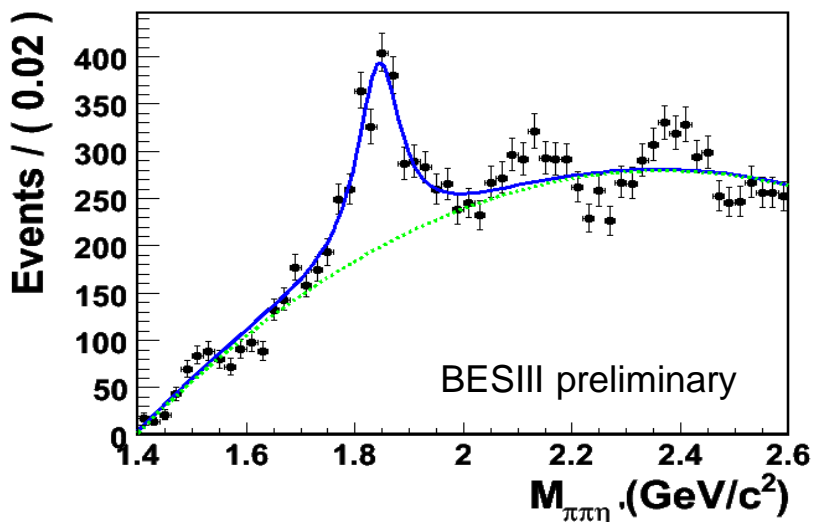
Summary

- **BESIII has been in operation since 2008:**
 - $\sim 110M$ ψ' events collected
 - $\sim 220M$ J/ψ events collected
- **Recent physics results at BESIII are presented:**
 - Confirmation of $p \bar{p}$ threshold enhancement and $X(1835)$;
 - Observation of h_c from $\psi' \rightarrow \pi^0 h_c$:
 - first measurement: $\text{Br}(\psi' \rightarrow \gamma h_c)$ & $\text{Br}(h_c \rightarrow \gamma \eta_c)$
 - $M(h_c)$, $\Gamma(h_c)$;
 - Observation of $\chi_{cJ} \rightarrow VV$
 - $\chi_{cJ} \rightarrow \phi\phi, \omega\omega$; first observation: $\chi_{c1} \rightarrow \phi\phi, \omega\omega$;
 - first observation: $\chi_{cJ} \rightarrow \omega\phi$;
 - Measurement of $\text{Br}(\chi_{c0,2} \rightarrow \pi^0\pi^0)$, $\text{Br}(\chi_{c0,2} \rightarrow \eta\eta)$
- **More exciting results are coming.**



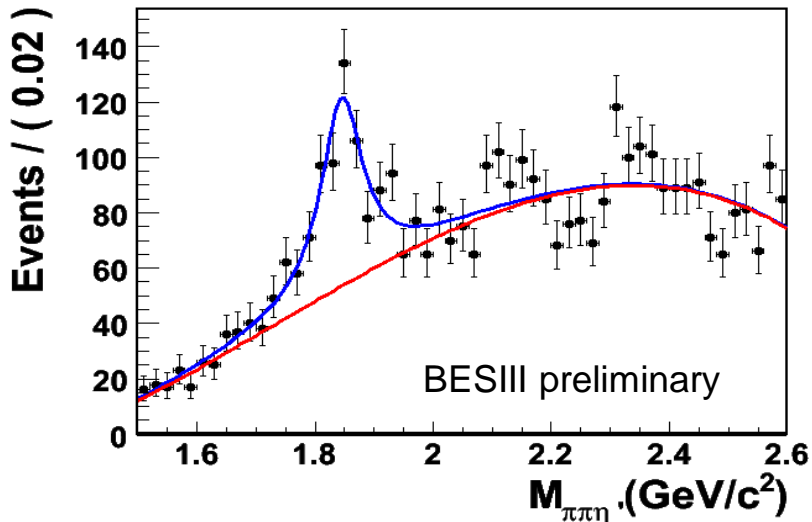
Back up

X(1835) @ BESIII from $J/\psi \rightarrow \gamma \eta' \pi^+ \pi^-$



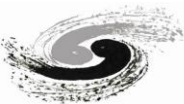
$J/\psi \rightarrow \gamma \eta' \pi^+ \pi^-, \eta' \rightarrow \gamma \rho$

- $M \sim 1835 \text{ MeV}$
- significance $\sim 18\sigma$



$J/\psi \rightarrow \gamma \eta' \pi^+ \pi^-, \eta' \rightarrow \eta \pi^+ \pi^-$

- $M \sim 1835 \text{ MeV}$
- significance $\sim 9\sigma$



BESIII Prospects

BESIII will take $\psi(3770)$ data for ~5 months until this summer

In following 6 years or more, we expect to get:

- **~10B J/ ψ events,**
- **~3B ψ' events,**
- **~20fb⁻¹ $\psi(3770)+\psi(4040)+\psi(4160)$,**
- **R scan/resonance scan: 2.0-4.6GeV (months),**
- **tau physics (months)**

Possible upgrades:

- **Luminosity: crab waist, bunch spacing, ...**
- **Beam Energy: $E_{\max} = 4.6 \text{ GeV} \rightarrow 5 \text{ GeV}$**
- **e- Polarization**
- **Detector: TOF, inner DC, ...**

