BESIII Results

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For the BES Collaboration

3rd International Workshop on Theory, Phenomenology and Experiment in Heavy Flavour Physics

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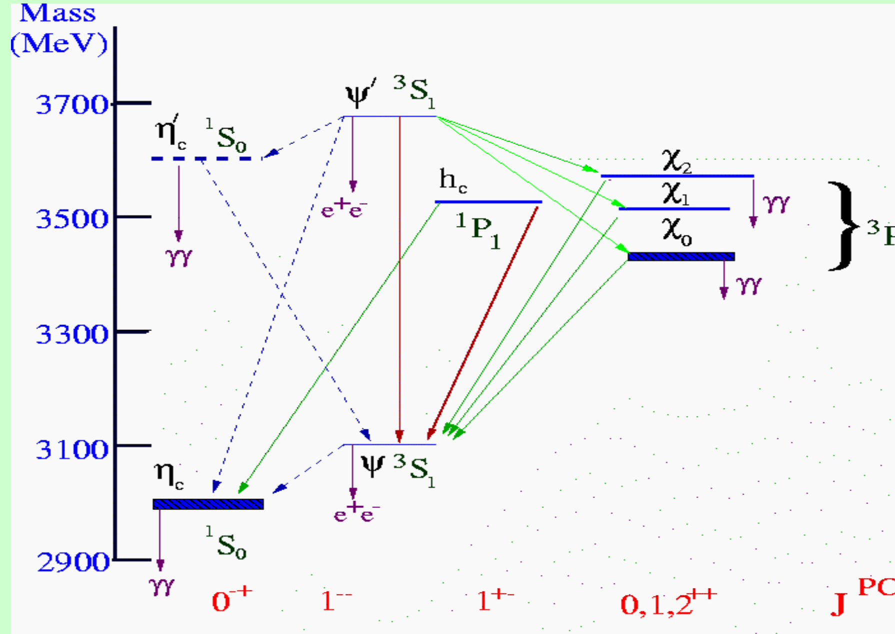
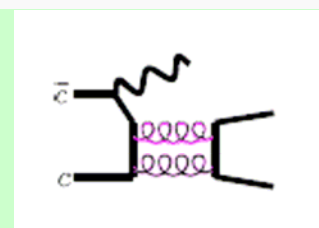
OUTLINE

- **Introduction**
- **BEPCII/BESIII**
- **Physics results**
  - χ_{cJ}
  - $\psi(2S) \to \gamma\gamma J/\psi$
  - h_c
  - **X(1860) & X(1835)**
  - $f_0(980) - a_0(980)$ **mixing**
- **Summary**

Physics of tau – charm region

- Light hadron spectroscopy.
- Charmonium: J/ψ, $\psi(2S)$, $\eta_C(1S)$, $\chi_{C\{0,1,2\}}$, $\eta_C(2S)$, $h_C(^1P_1)$, $\psi(1D)$, etc.
- New Charmonium states above open charm threshold (X, Y, Z).
- In J/ψ and $\psi(2S)$ hadronic decays:
  - ➢ Exotics : hybrids, glueballs, and other exotics.
  - ➢ Baryons and excited baryons.
  - ➢ Mesons and mixing of quarks and gluons.
- Electromagnetic form factors and precise R values.
- High precision tau and charm physics near threshold. Tau mass.

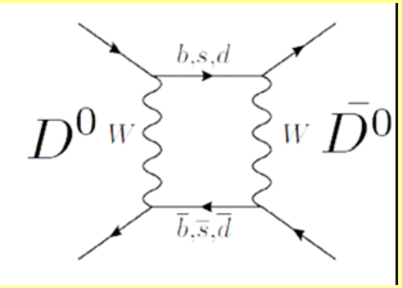




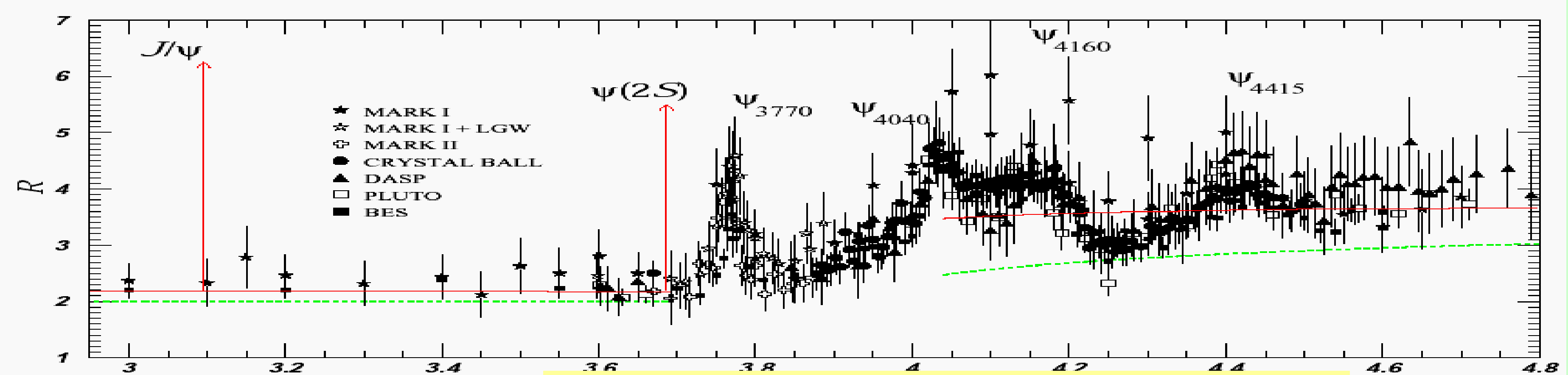
$$\begin{pmatrix} e & \mu & \tau \\ \nu_e & \nu_\mu & \nu_\tau \end{pmatrix} \qquad \begin{pmatrix} u & c & t \\ d & s & b \end{pmatrix}$$

Physics of tau – charm region

- **Open charm factory :**
  - Absolute BR measurements of D and Ds decays
  - Rare D decay
  - D^0 - D^0bar mixing
  - Quantum correlations (ψ ’’)
  - CP violation, strong phase.
  - f_{D+}, f_{Ds}, form factors in leptonic D decays
  - Can provide calibrations and tests of lattice QCD.
  - precise measurement (~1.6%) of CKM (Vcd, Vcs)
  - light meson spectroscopy in D^0 and D^+ Dalitz plot analyses.



- **Search for new physics.**



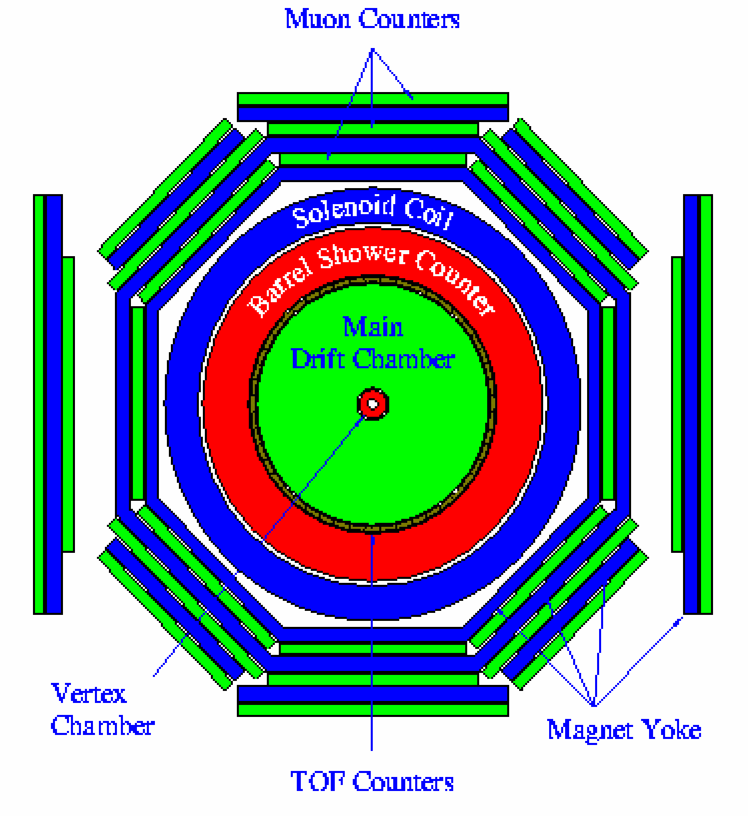
Very rich and interesting energy region.

The Beijing Electron Positron Collider (BEPC)

BEPC/BESII

CM Energy ranges from 2 to 5 GeV

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



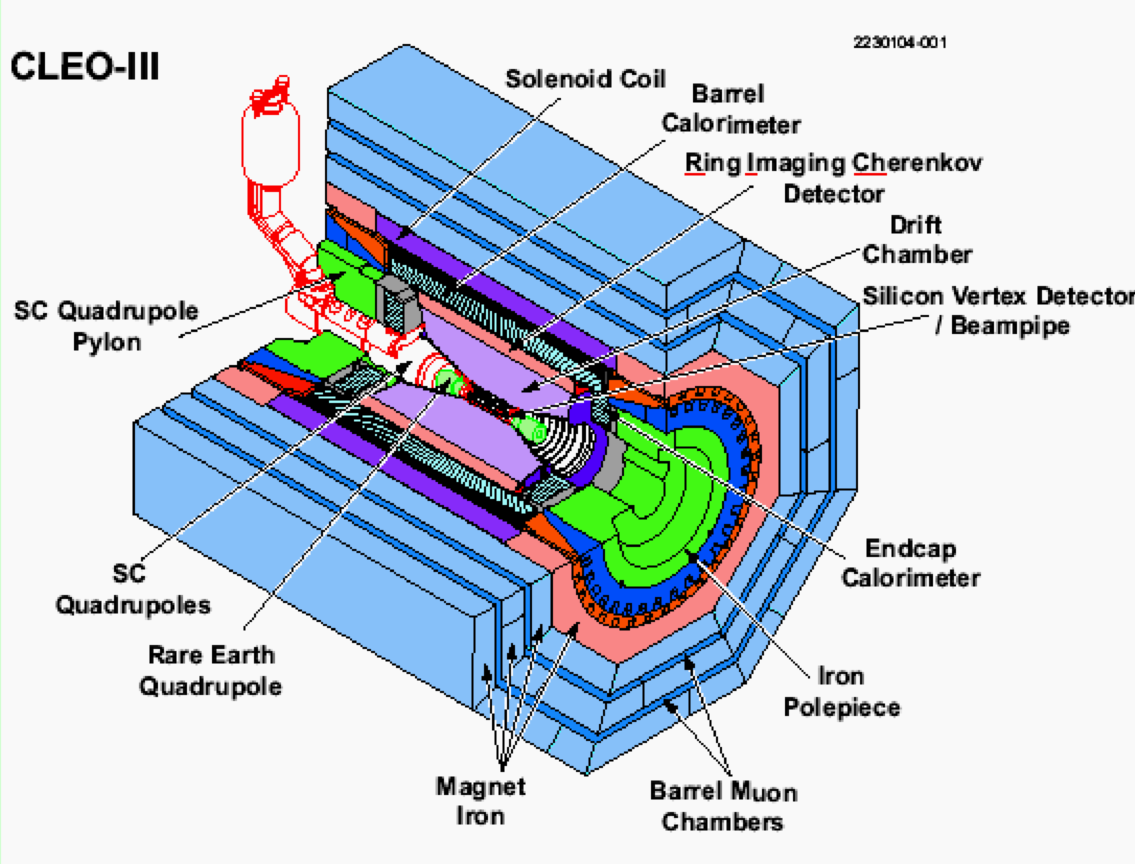
BESII detector removed in 2004.

CLEO-c

Late comer to tau – charm energy region.

- **Lowered CESR CM energy in 2003 to run in tau-charm region.**
- **Stopped in 2008.**
- **Peak luminosity**

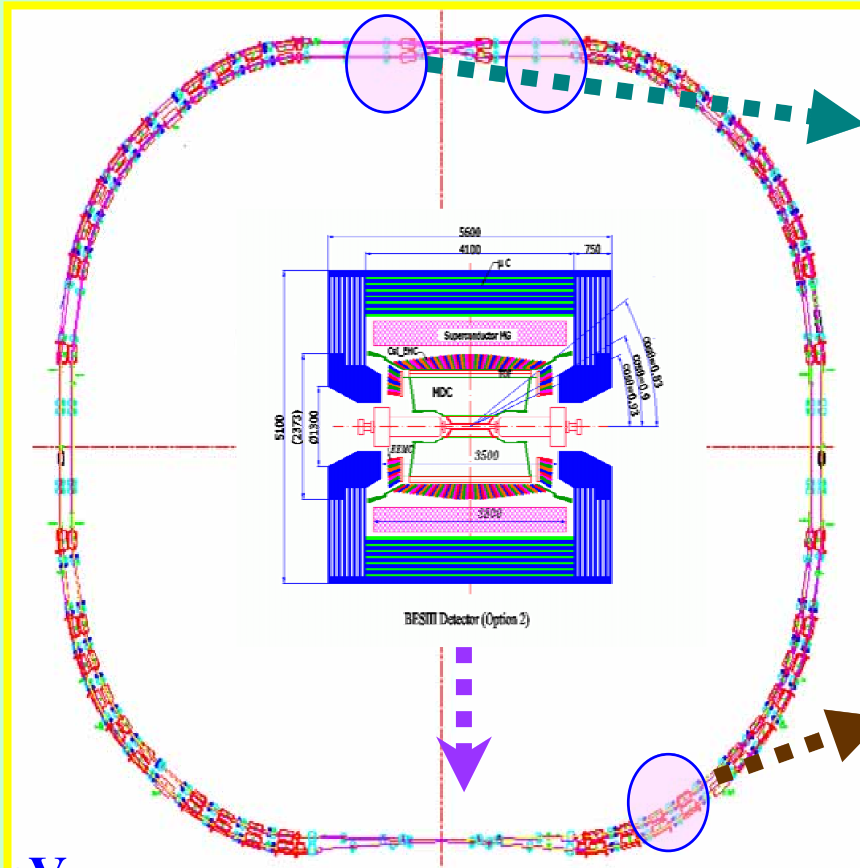
  $\sim 0.6 \times 10^{32}\ pb^{-1}\ s^{-1}$.
- **Int. Luminosity at $\psi(3770)$ $\sim 800\ pb^{-1}$.**
- **$\psi(2S)$: ~25 M.**
- **Well understood, state of the art detector.**
- **BESIII has a comparable detector and higher luminosity. Unique e^+e^- experiment at tau-charm energy region.**



BEPCII: a high luminosity double–ring collider

Beam energy:
1.0-2.3 GeV
Luminosity:
1×10^{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

22 mrad crossing angle



Use many bunches and SC mini-beta.

SC RF

Beam magnets

BEPCII/BESIII Milestones

Beginning of 2004, construction starts

Mar. 2008: Collisions at 500 mA × 500 mA, Lum.: 1

Apr. 30, 2008: Move BESIII to IP

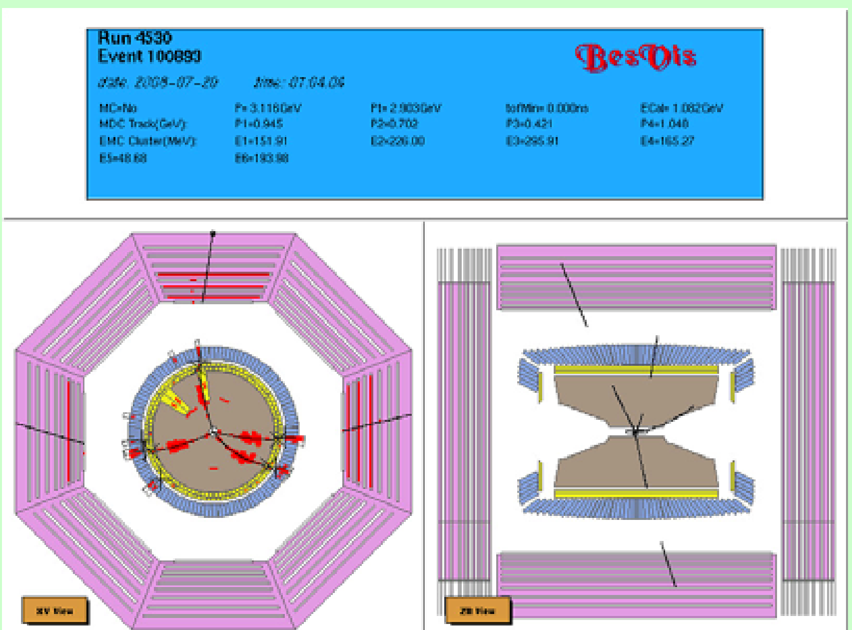
July 18, 2008: First e^+e^- collision event in BESIII

Apr. 14, 2009 BESIII 106 M ψ(2S) events (42.3pb^{-1} at 3.65GeV)

July 28, 2009 ~226 M J/ψ events

June 27, 2010 ~930 pb^{-1} at ψ(3770), with ~70pb^{-1} scanning in ψ(3770) energy region.

Record Luminosity
$3.2 \times 10^{32} cm^{-2}s^{-1}$ or
5 × CESRc
30 × BEPC

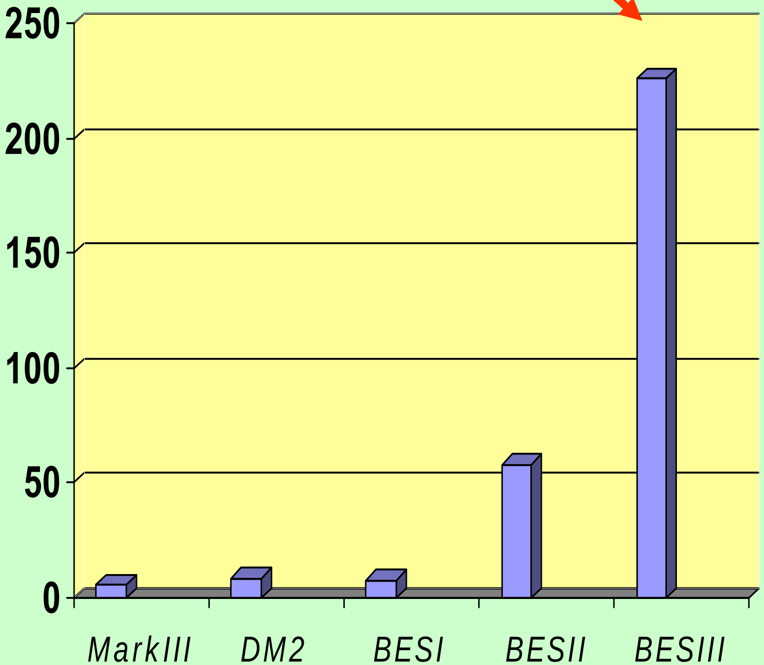


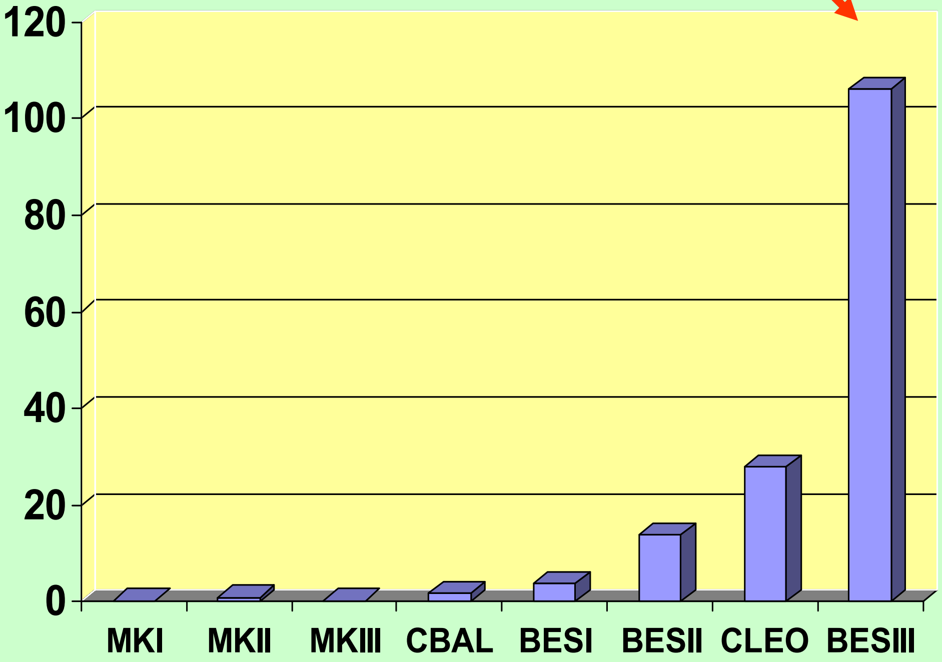
First collision event

May 15, 2008: detector at IP; installing SC quads and beam pipe.

World J/ψ and ψ(2S) Samples ($\times 10^6$)

BESIII: J/ψ 2009 – ~226M   ψ(2S) 2009 – 106M





BESII: J/ψ 58M   ψ(2S) 14M

BES-III

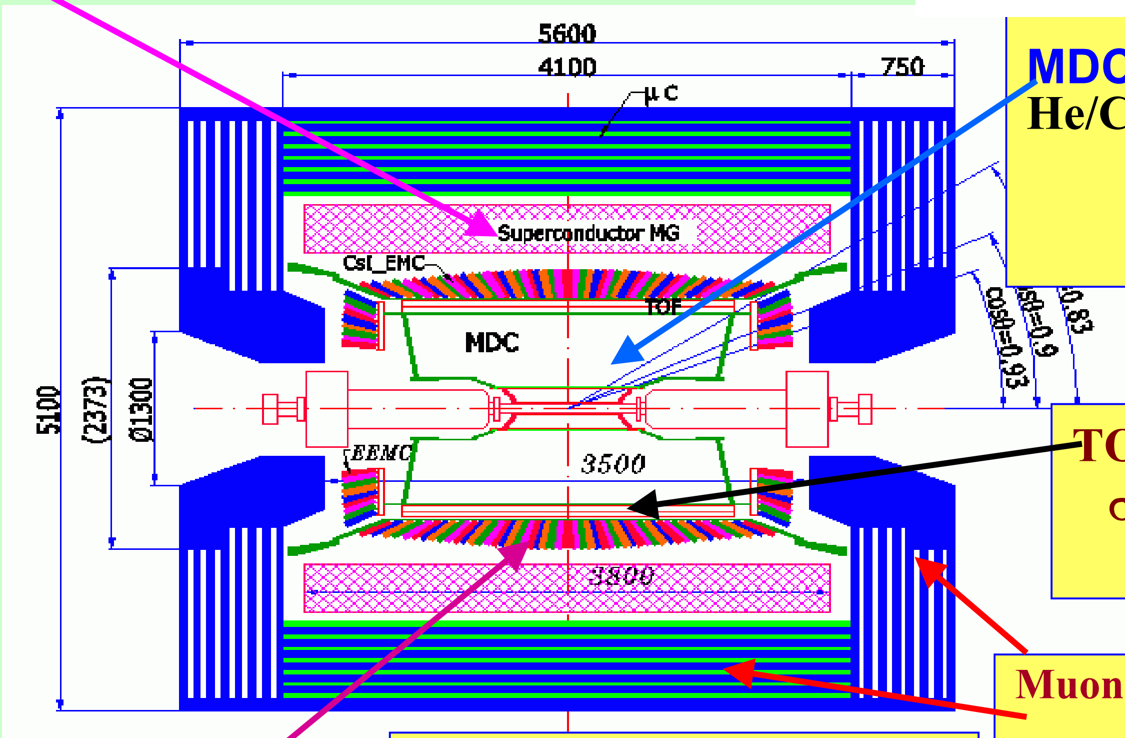
BESIII detector: all new !

CsI calorimeter

Precision tracking

Time-of-flight + dE/dx PID

Magnet: 1 T Super conducting



MDC: small cell & Gas:
He/C3H8 (60/40), 43 layers
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σ_T = 100 ps Barrel
110 ps Endcap

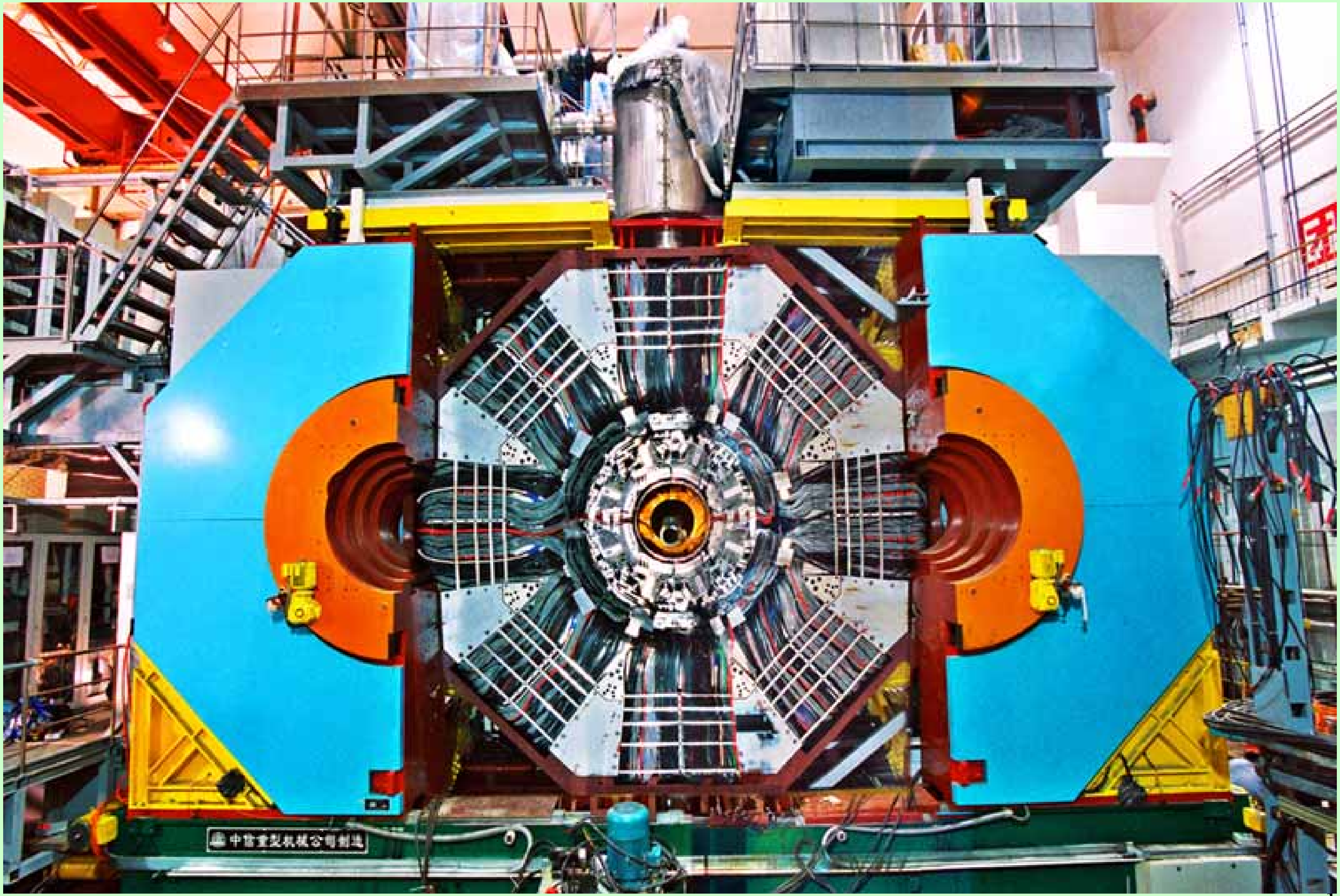
Muon ID: 9 layers RPC
8 layers for endcap

EMC: CsI crystal, 28 cm
$\Delta E/E$ = 2.5% @1 GeV
$\sigma z = 0.6\ \mathrm{cm}/\sqrt{E}$

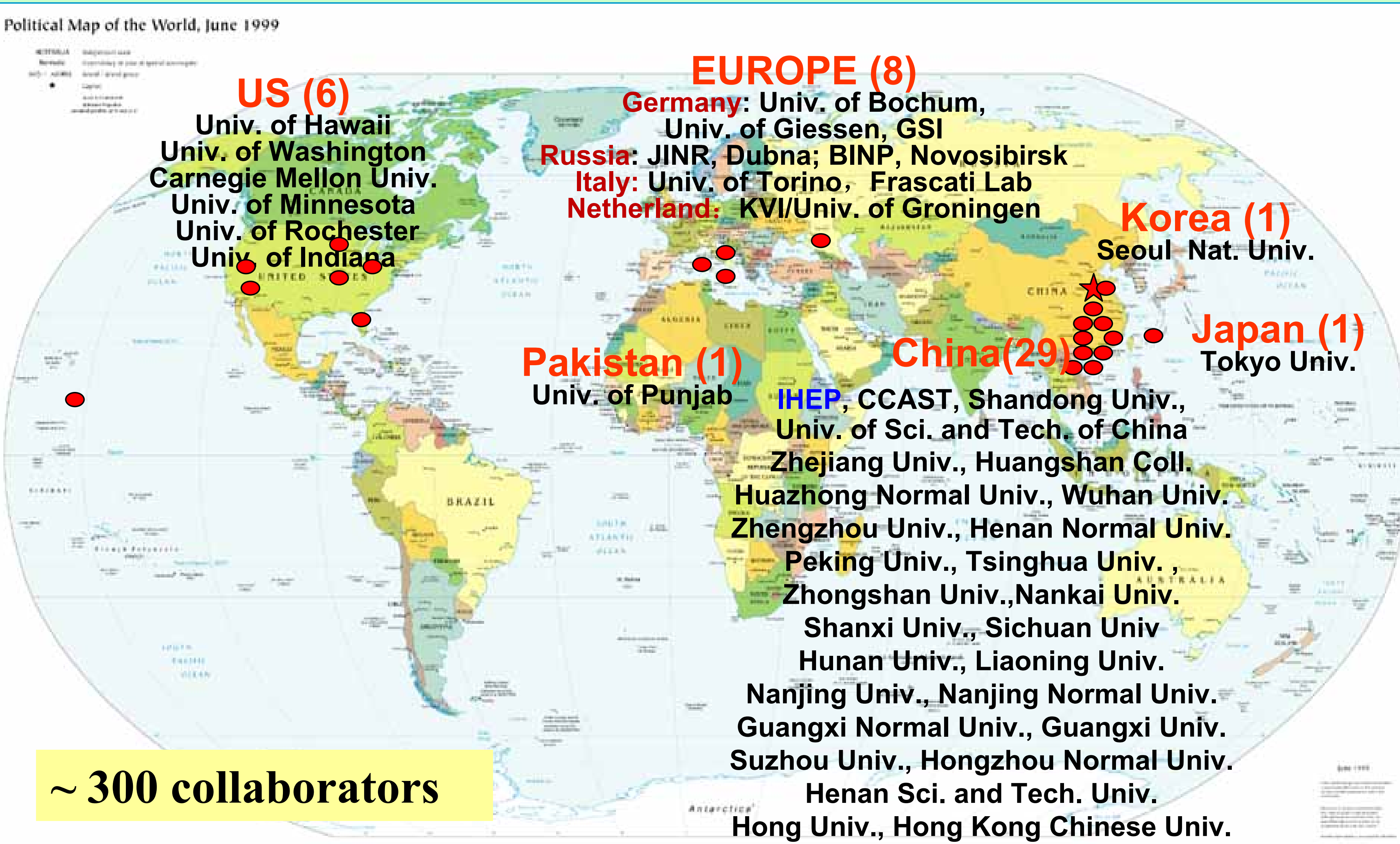
Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

The detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.

April 2008 - Installation complete



BESIII collaboration： 46 Institutes



US (6)
Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

EUROPE (8)
Germany: Univ. of Bochum,
Univ. of Giessen, GSI
Russia: JINR, Dubna; BINP, Novosibirsk
Italy: Univ. of Torino， Frascati Lab
Netherland： KVI/Univ. of Groningen

Korea (1)
Seoul Nat. Univ.

Japan (1)
Tokyo Univ.

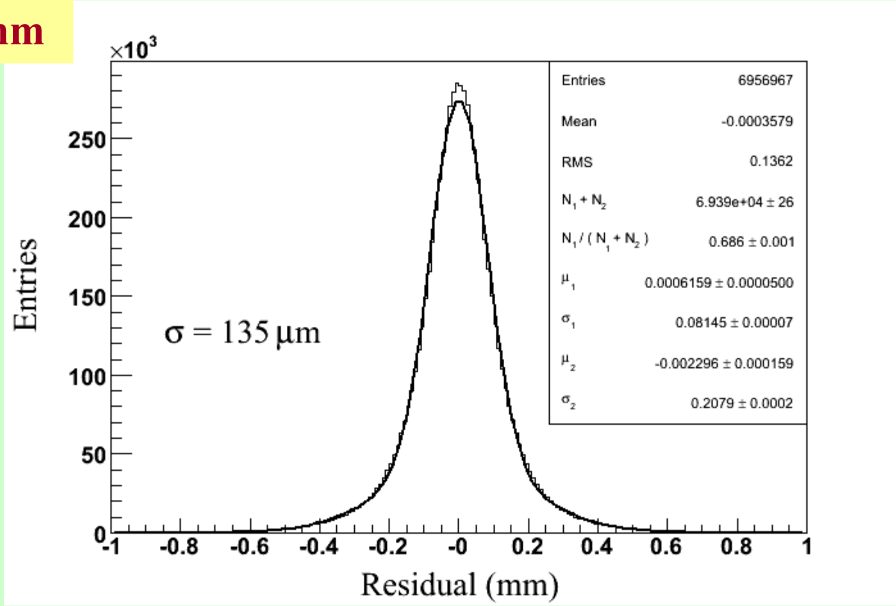
Pakistan (1)
Univ. of Punjab

China(29)
IHEP, CCAST, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hongzhou Normal Univ.
Henan Sci. and Tech. Univ.
Hong Univ., Hong Kong Chinese Univ.

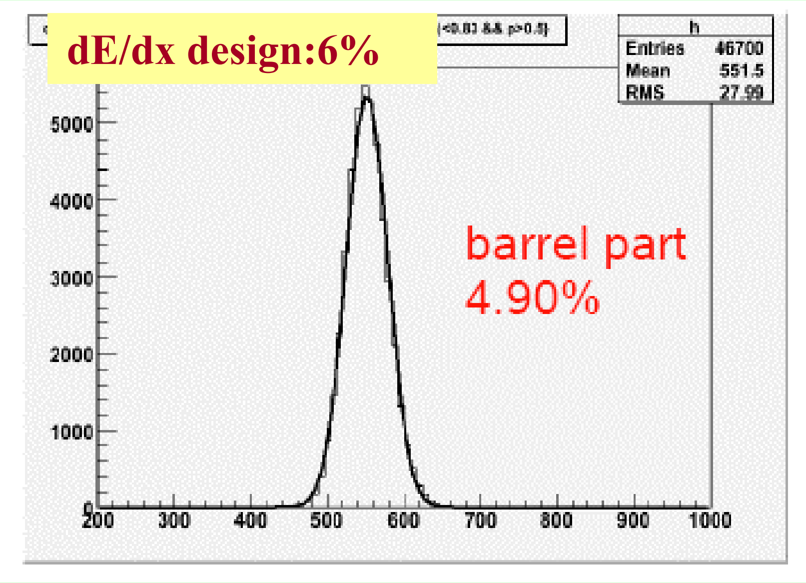
~ 300 collaborators

Detector performance **MDC**

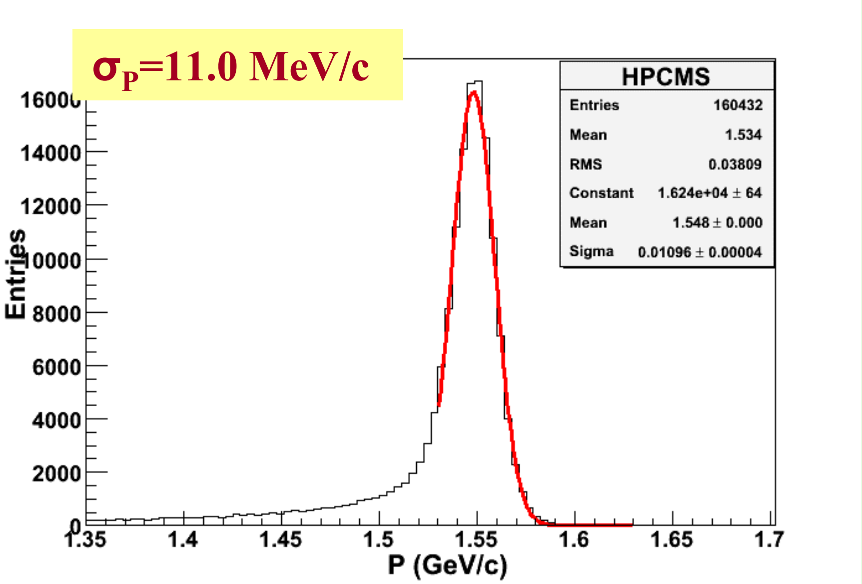
Wire reso. design：130mm



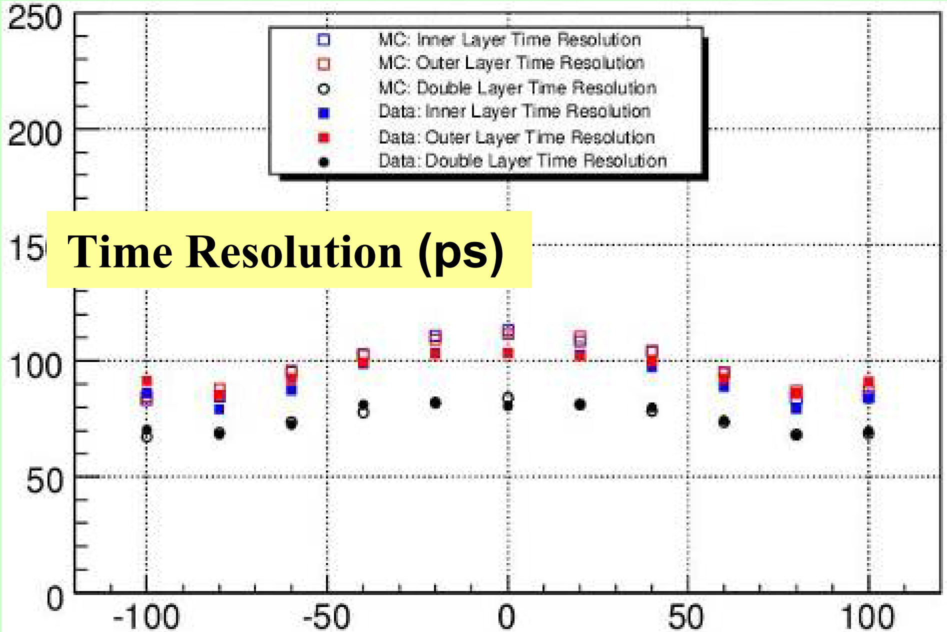
dE/dx design:6%

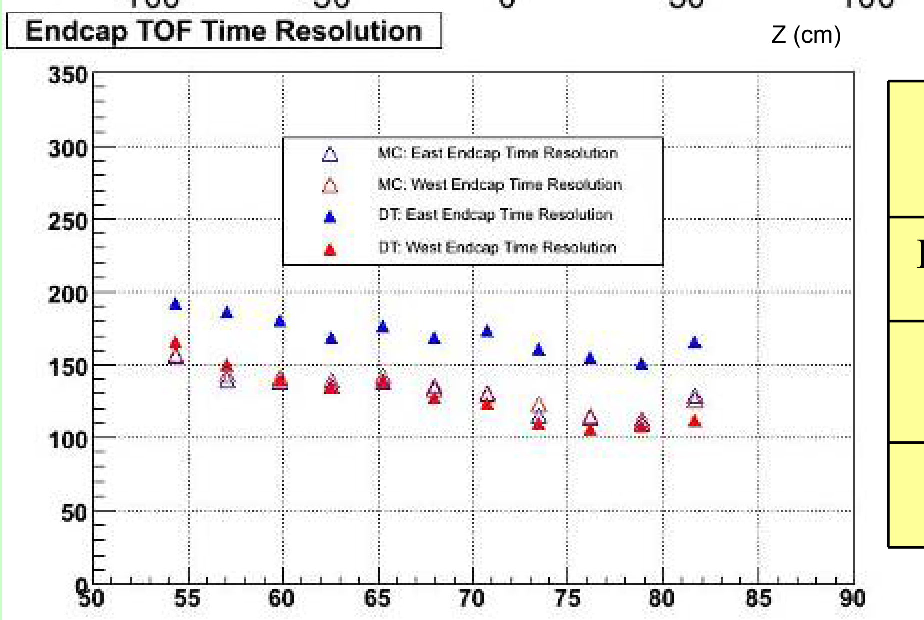


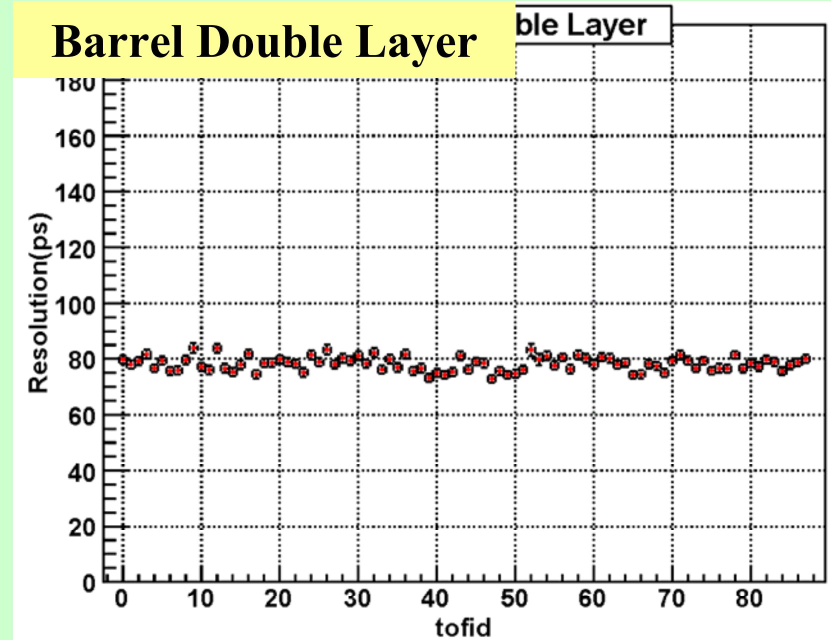
σ_P=11.0 MeV/c



TOF, Top time resolution



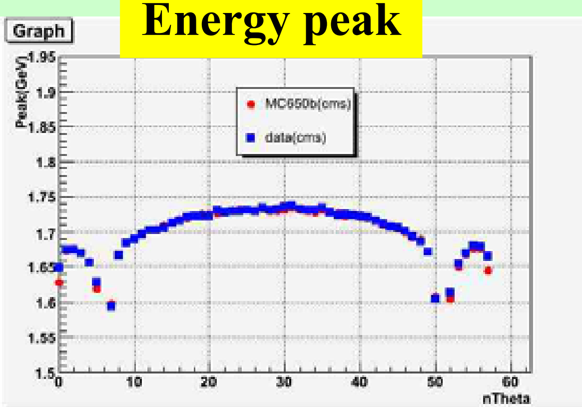


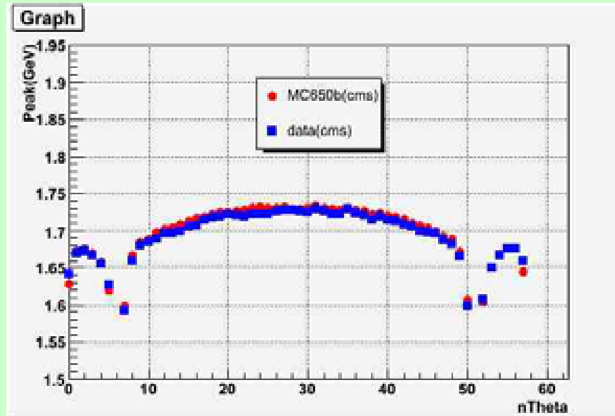


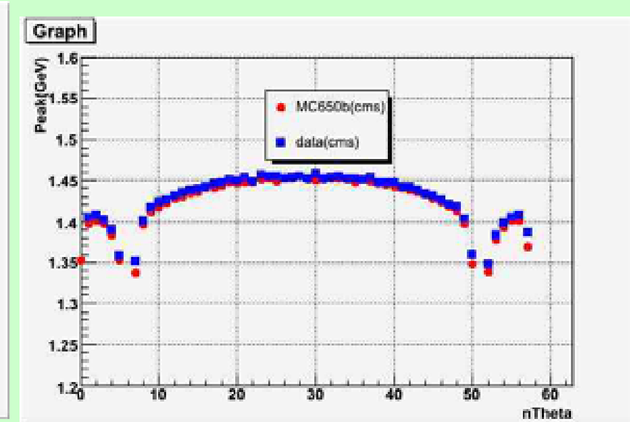
Time Resolution (ps)	Design Target	Bhabha	Dimu
Barrel Single Layer	100~110	98.0	95.3
Barrel Double Layer	80~90	78.9	76.3
Endcap	110~120	136.4	95.0

Energy peak and resolution in CMS in different runs

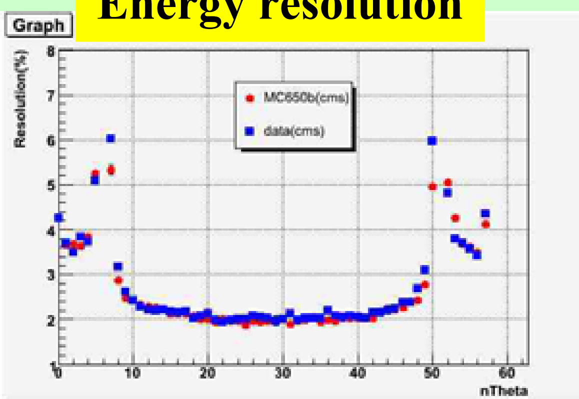
Energy peak

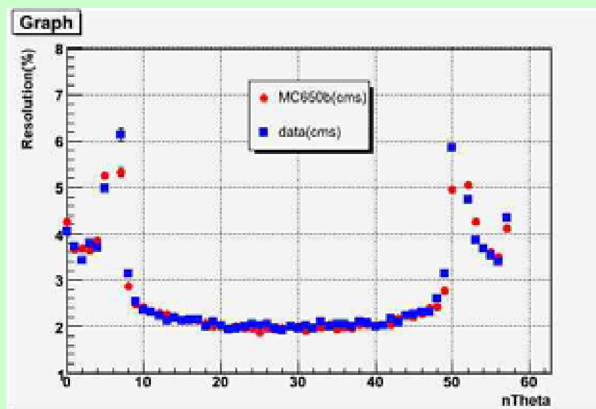


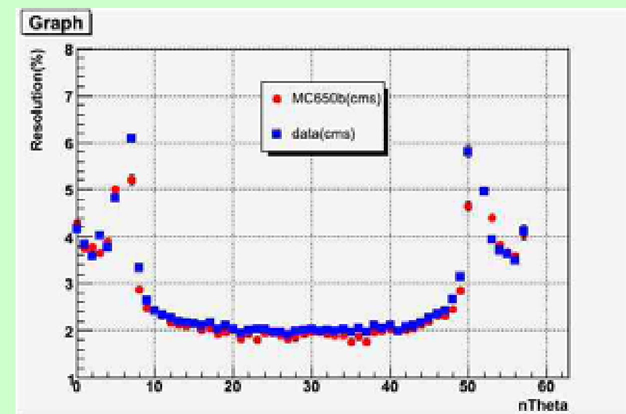




Energy resolution





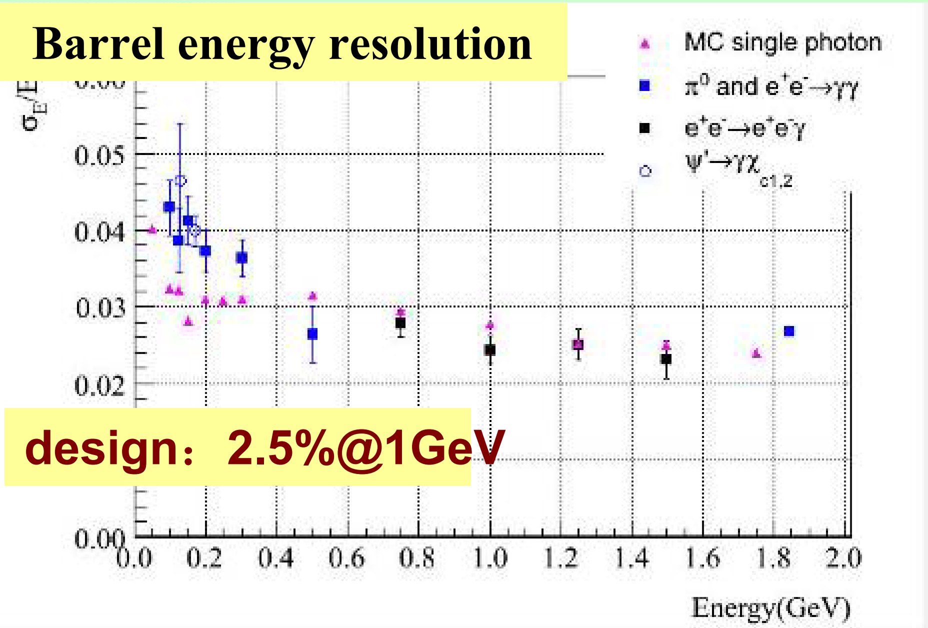


8447(3.686GeV) 9680(3.65GeV) 10138(3.097GeV)

DATA and MC consist very well for Bhabha events, after the calibration with Bhabha

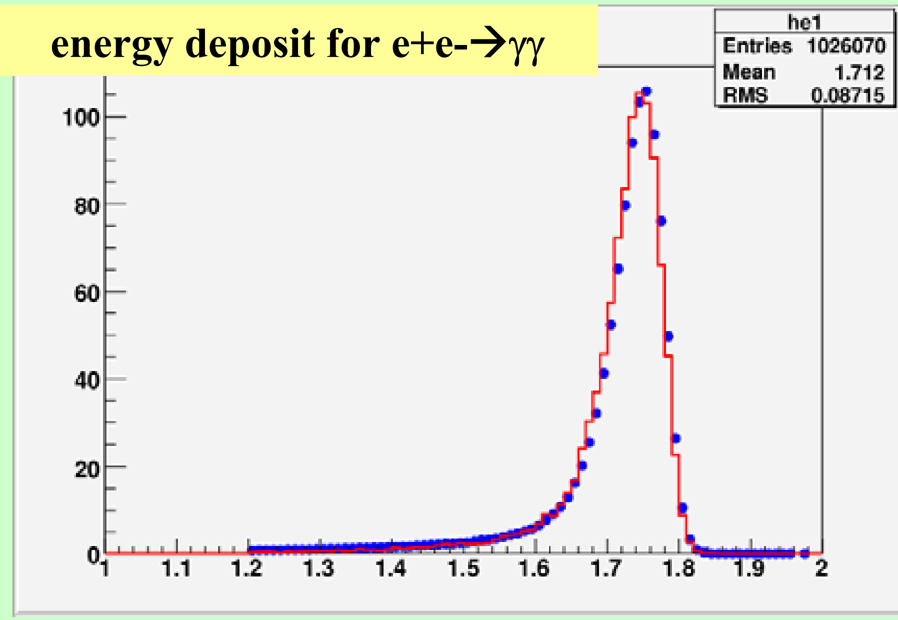
EMC Performance reach/exceed design

Barrel energy resolution



design：2.5%@1GeV

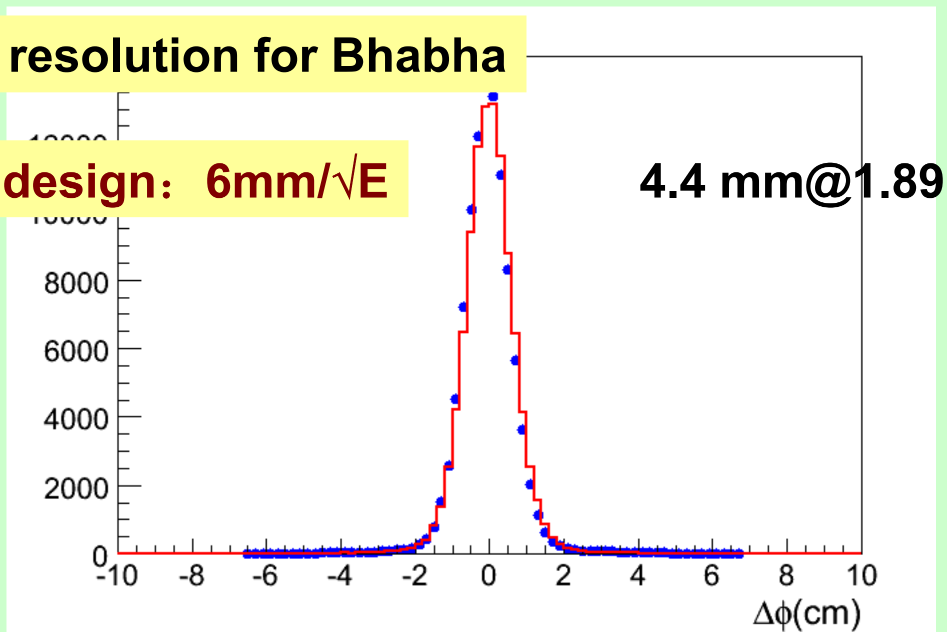
energy deposit for e+e-→γγ



Position resolution for Bhabha

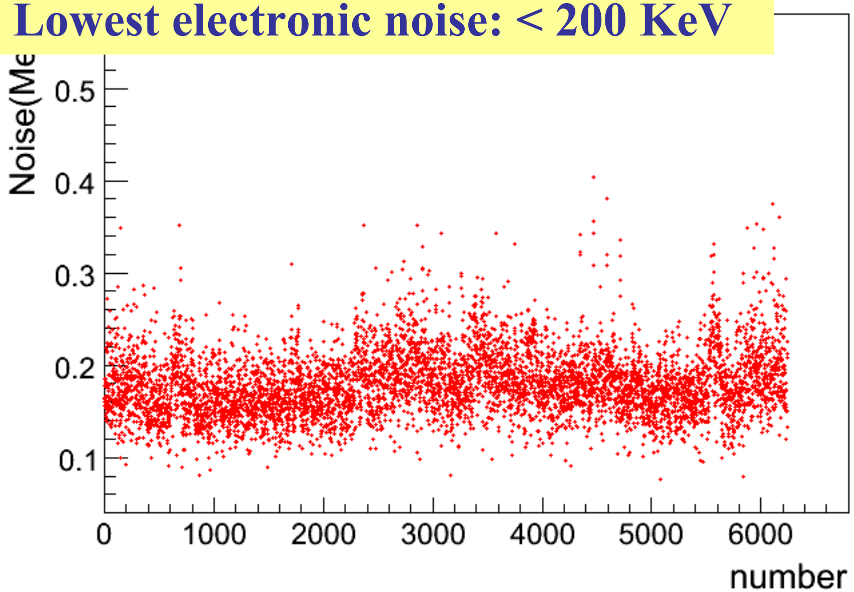
design：6mm/√E

4.4 mm@1.89 GeV

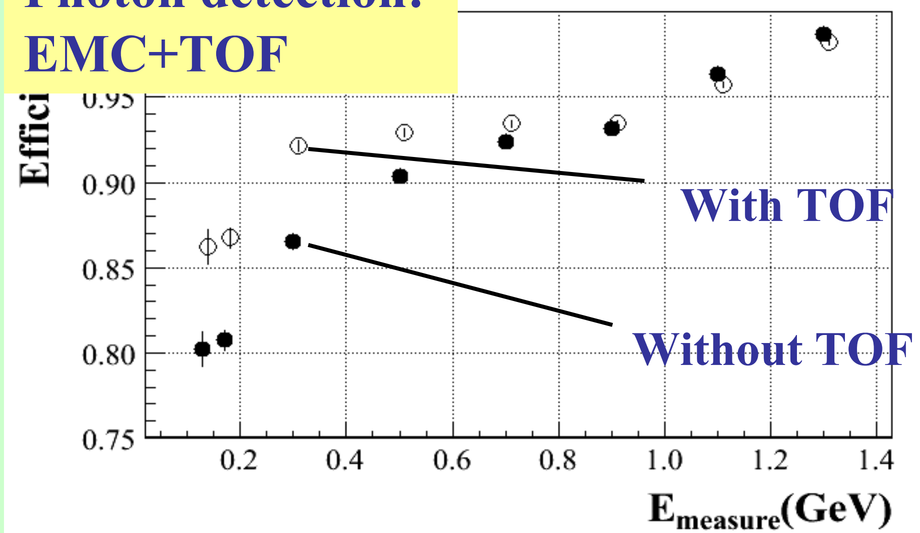


Nice features of BESIII EMC

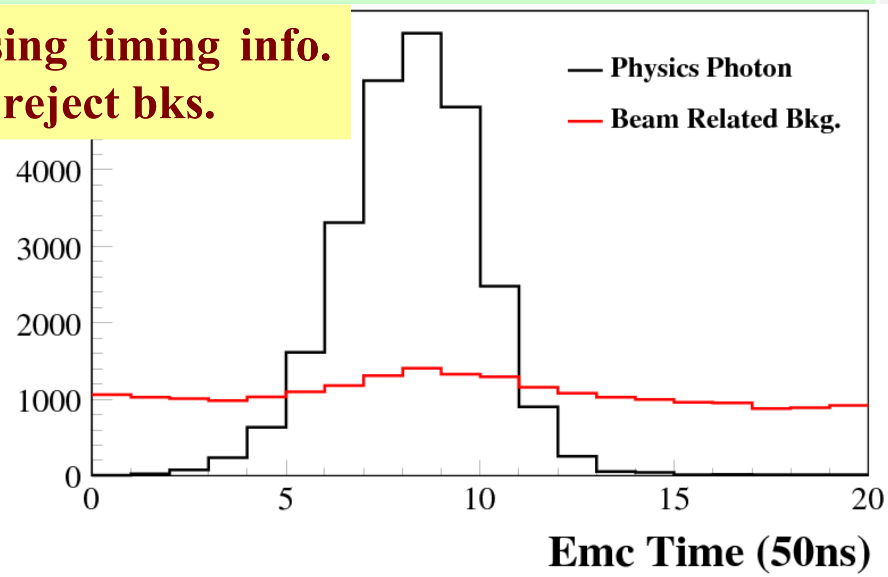
Lowest electronic noise: < 200 KeV



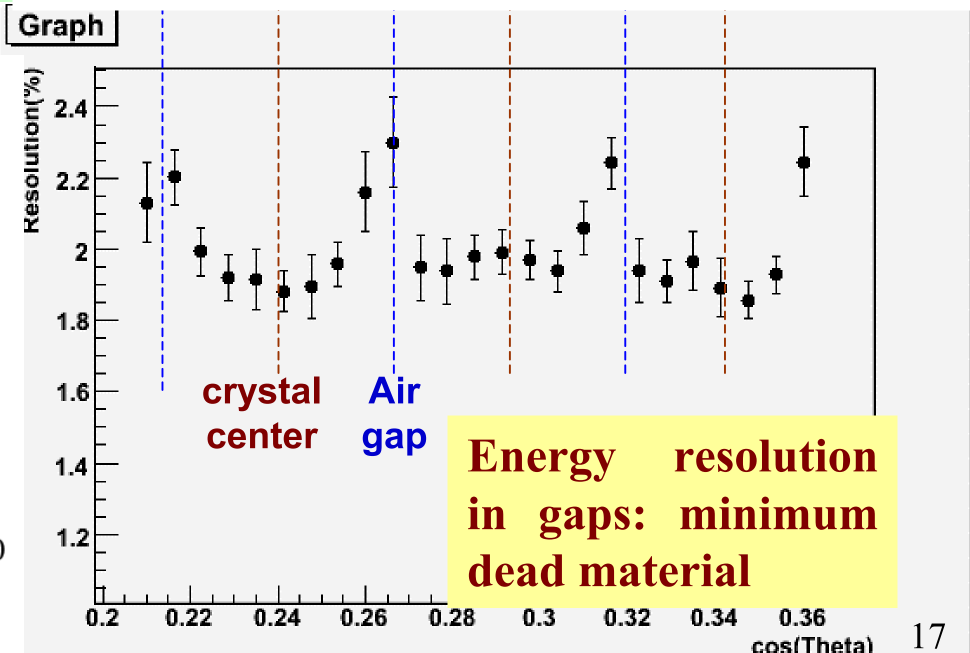
Photon detection: EMC+TOF



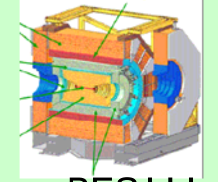
Using timing info. to reject bks.



Energy resolution in gaps: minimum dead material

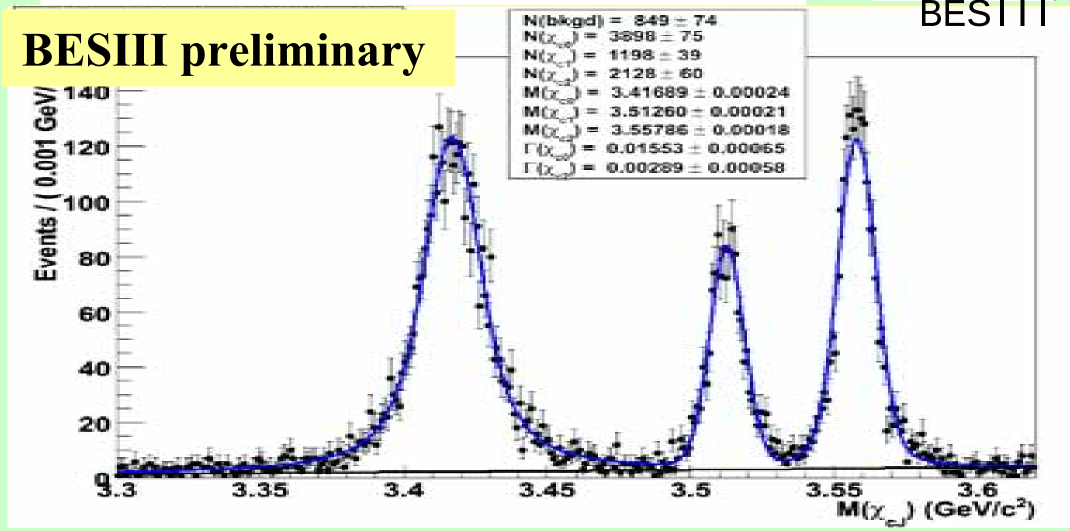


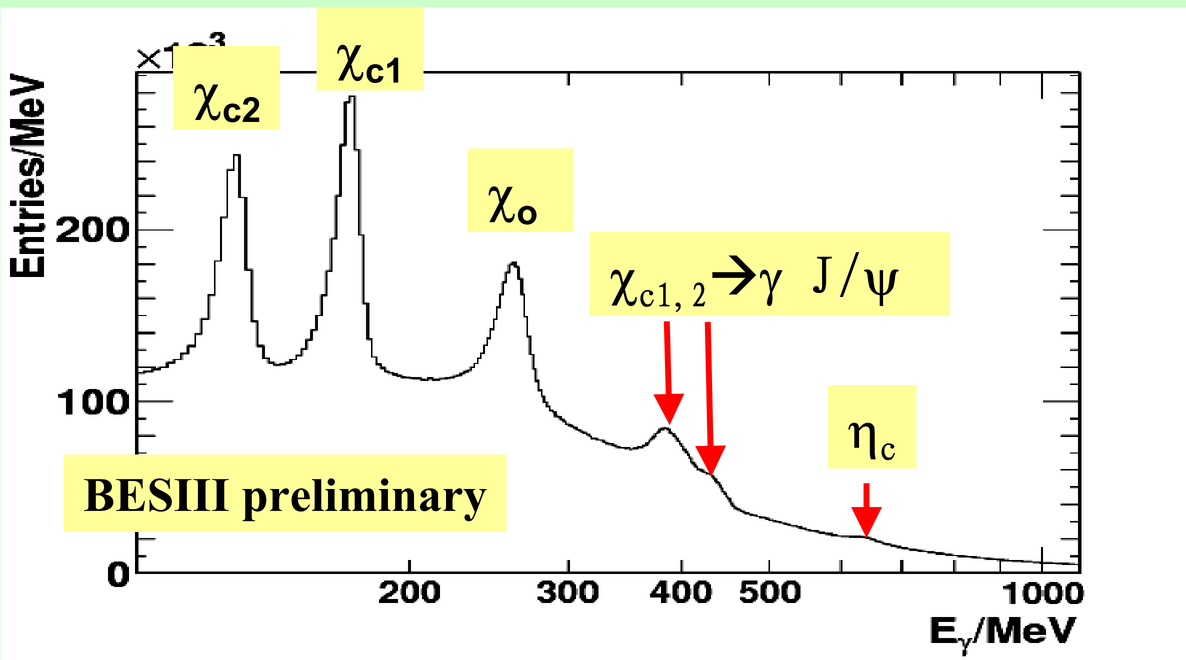
Radiative decays: ψ(2S)→γX

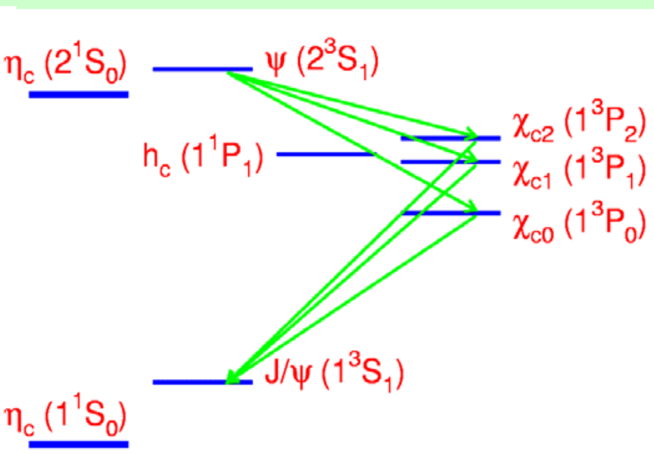


$$\psi(2S) \to \gamma\chi_{cJ} \to \gamma 2\pi^+ 2\pi^-$$

- Clean exclusive signal
- High statistics
- Clear inclusive photon spectrum
- Excellent photon resolution







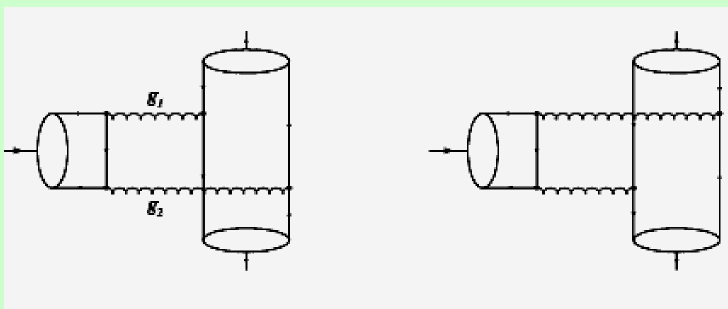
χ_{cJ} decays

- Good place to study gluonium: $\chi_c \to gg \to (q\bar{q})(q\bar{q})$.

  C. Amsler and F. E. Close,Phys. Rev. D 53, 295 (1996).

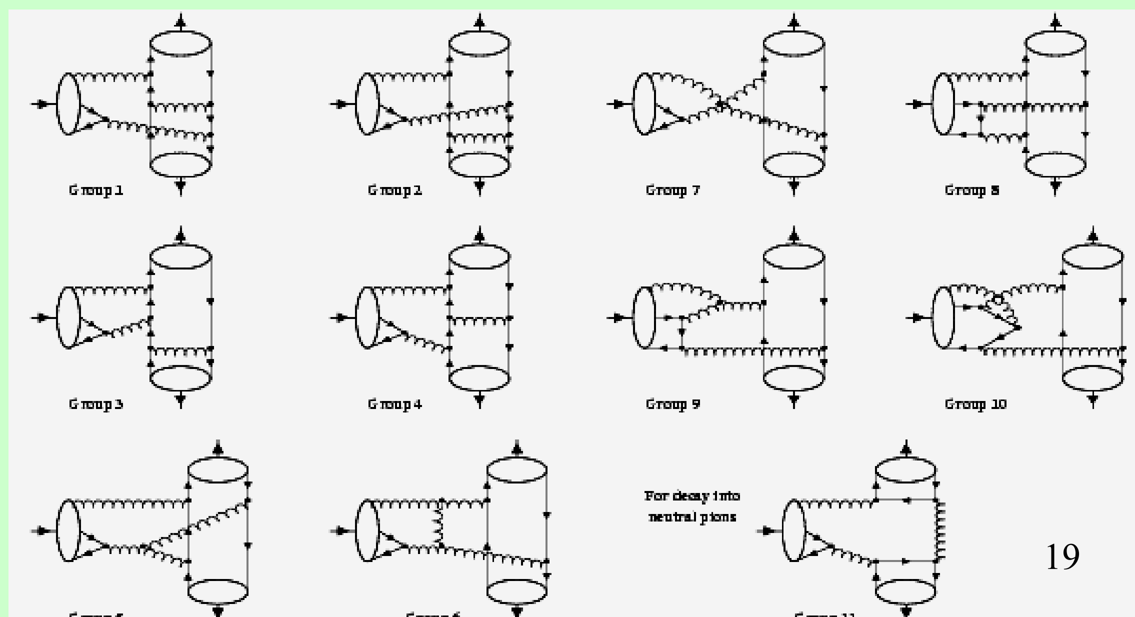
- Color octet mechanism can be tested.

  G. T. Bodwin *et al*., Phys Rev. Lett. **D51**, 1125 (1995).
  H.-W. Huang and K.-T. Chao, Phys. Rev. **D54**, 6850 (1996).
  J. Bolz *et al*., Eur. Phys. J. C **2**, 705 (1998).



Color singlet graphs ($q\bar{q}$) for $\chi_{CJ} \to \pi\pi$.

Color octet graphs ($\bar{q}qg$)



χ_{cJ} decays

- Test of color singlet/octet models in χ_{cJ} decays

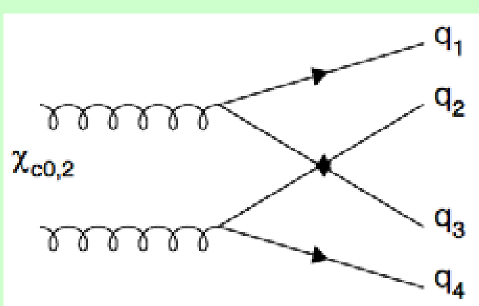
decay width	theory[3]	PDG08
$\Gamma[\chi_{c0} \to \pi^o \pi^o]$ / keV	23.5	25 ± 2
$\Gamma[\chi_{c2} \to \pi^0 \pi^0]$ / keV	1.93	1.4 ± 0.2
$\Gamma[\chi_{c0} \to \eta\eta]$ / keV	32.7	25 ± 4
$\Gamma[\chi_{c2} \to \eta\eta]$ / keV	2.66	

J. Bolz et. al., Eur. Phys. J. C 2:705 (1998)

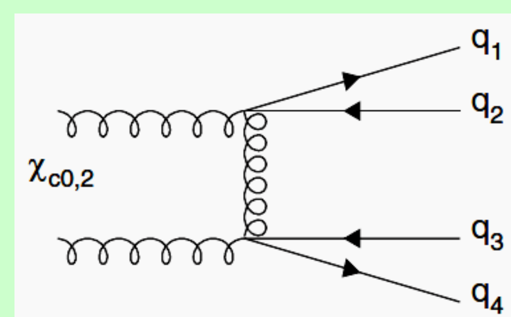
- Study of higher mass resonances (η and η') offers possibility to investigate doubly-OZI suppressed decays, which may compete with the singly-OZI suppressed decays.

Q. Zhao, Phys. Lett. B **659,** 221 (2008).

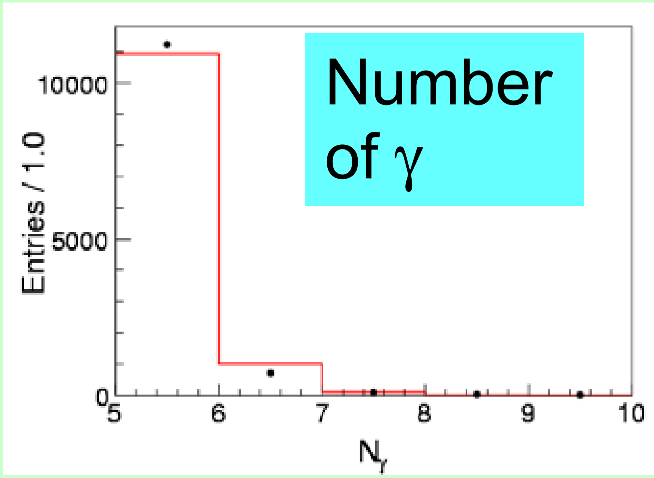
SOZI

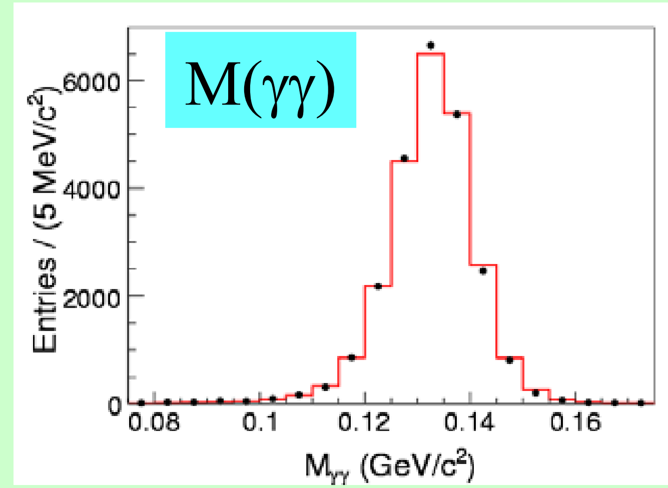


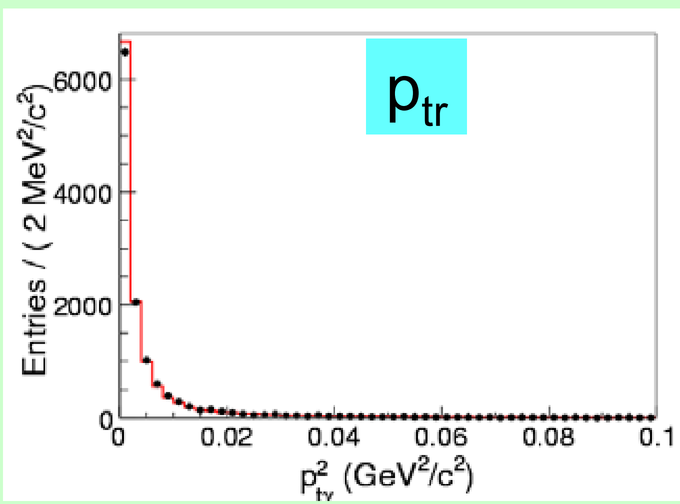
DOZI

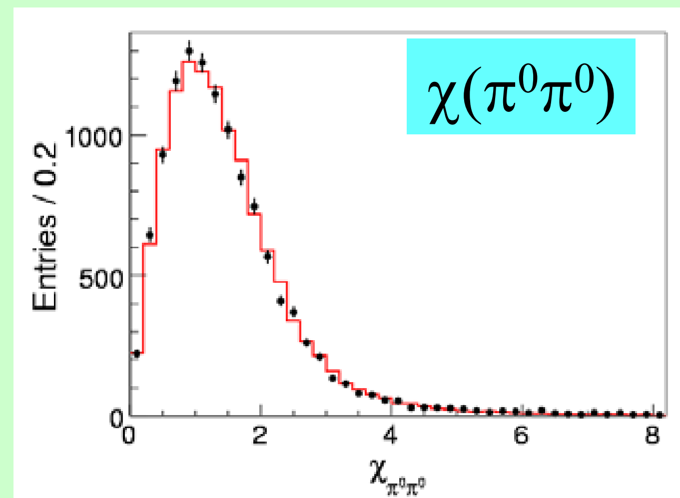


Study of $\psi(2S) \rightarrow \gamma\chi_{cJ}$; $\chi_{cJ} \rightarrow \pi^0\pi^0$, $\eta\eta$



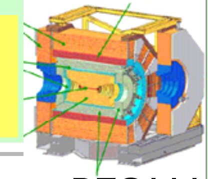






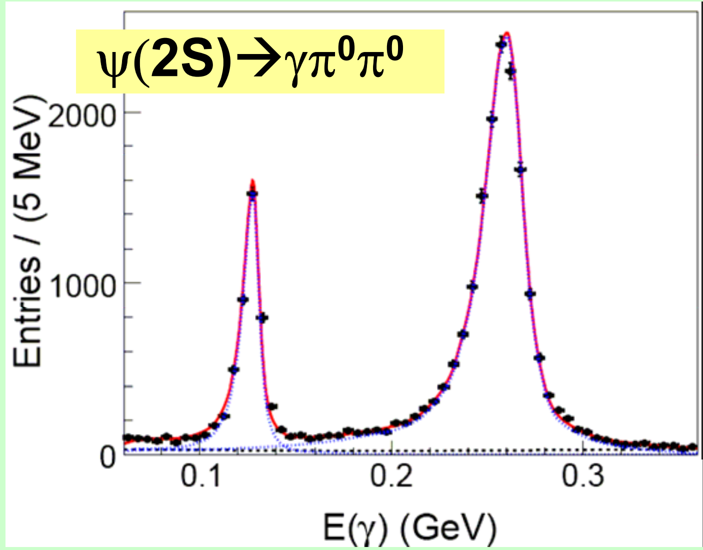
Good agreement between data & MC

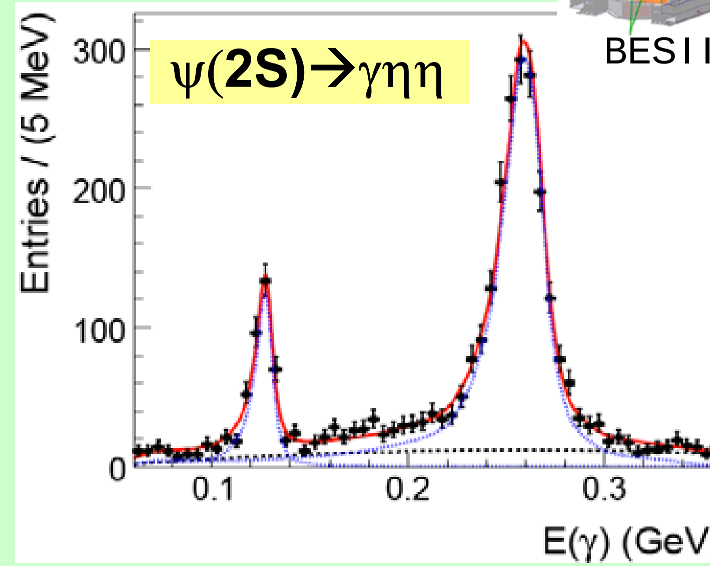
Study of $\psi(2S) \to \gamma\chi_{cJ};\ \chi_{cJ} \to \pi^0\pi^0,\ \eta\eta$



$(\eta,\ \pi^0 \to \gamma\gamma)$

BESIII:
PRD 81, 052005 (2010).





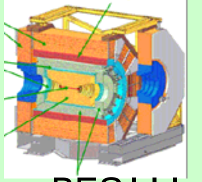
$\chi_{c1} \to \pi\ \pi$, $\eta\eta$ not allowed by parity conservation.

Decay mode		χ_{c0} (10^{-3})	χ_{c2} (10^{-3})
$\pi^0\pi^0$	BESIII	**3.23±0.03±0.23±0.14**	**0.88±0.02±0.06±0.04**
	PDG08	2.43±0.20	0.71±0.08
	CLEOc	2.94±0.07±0.32±0.15	0.68±0.03±0.07±0.04
$\eta\eta$	BESIII	**3.44±0.10±0.24±0.20**	**0.65±0.04±0.05±0.03**
	PDG08	2.4±0.4	< 0.5
	CLEOc	3.18±0.13±0.31±0.16	0.51±0.05±0.05±0.03

CLEOc:
PRD 79, 072007 (2009).

CLEOc used their own branching ratios for $\psi \to \gamma\chi_{cJ}$.

$\chi_{cJ} \to 4\pi^0$ from $\psi \to \gamma\chi_{cJ}$ decays



- **Branching fraction excluding $Ks \to \pi^0\pi^0$**

$Br(\chi_{c0} \to 4\pi^0) = 3.42 \pm 0.07 \pm 0.45) \times 10^{-3}$

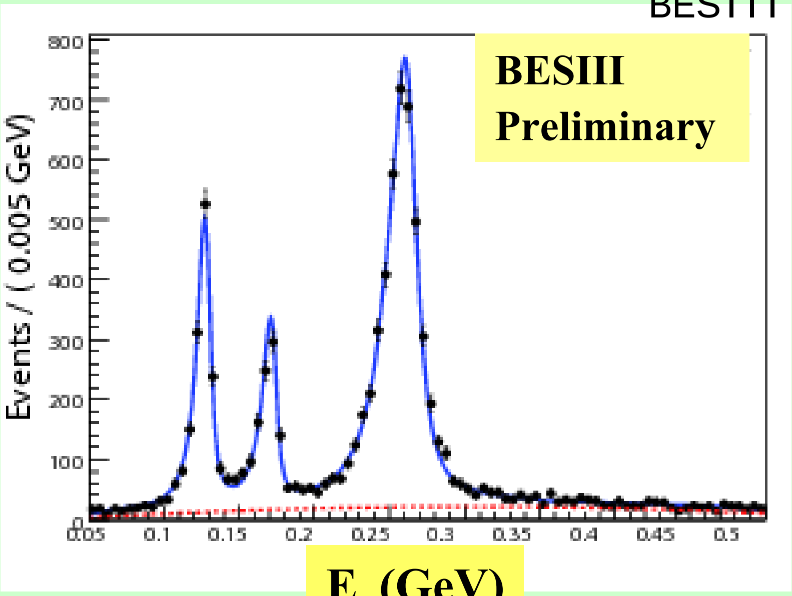
$Br(\chi_{c1} \to 4\pi^0) = 0.60 \pm 0.03 \pm 0.09) \times 10^{-3}$

$Br(\chi_{c2} \to 4\pi^0) = 1.13 \pm 0.04 \pm 0.15) \times 10^{-3}$

- **Branching fraction for $\chi_{cJ} \to KsKs$**

$Br(\chi_{c0} \to K_S K_S) = 4.1 \pm 0.4(\text{stat.})) \times 10^{-3}$

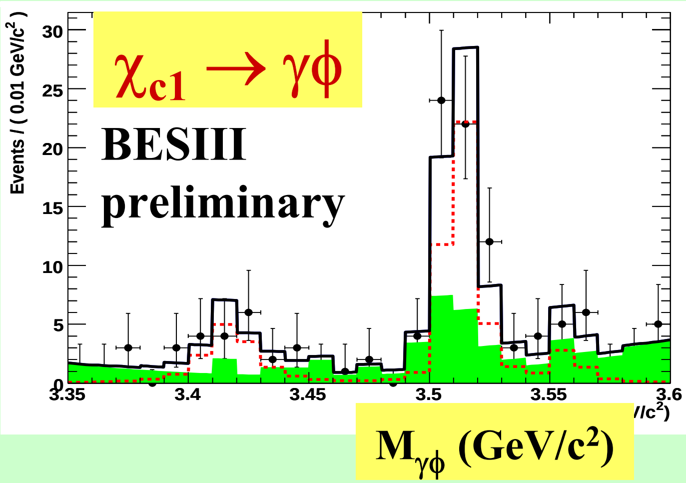
$Br(\chi_{c2} \to K_S K_S) = 0.6 \pm 0.2(\text{stat.})) \times 10^{-3}$

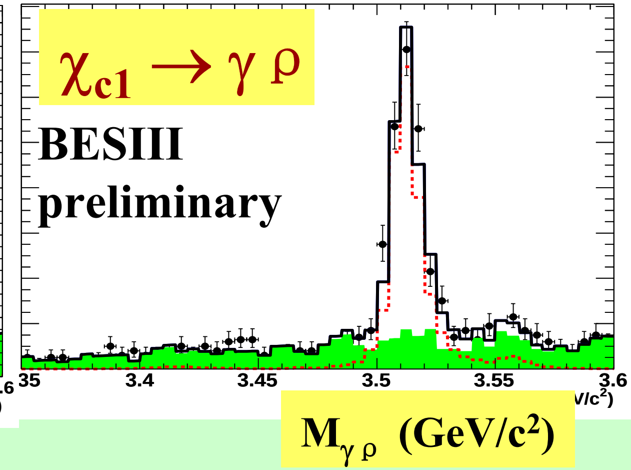


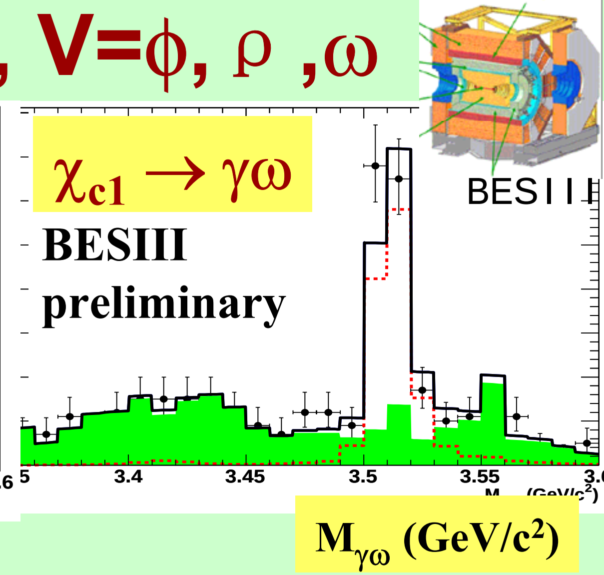
$B(\chi_{c0} \to K_S K_S)$	$\chi_{c0}\ (10^{-3})$	$\chi_{c2}\ (10^{-3})$
BESIII	$4.1 \pm 0.4_{stat}$	$0.6 \pm 0.2_{stat}$
PDG08	2.82 ± 0.28	0.65 ± 0.08
CLEOc	$3.49 \pm 0.08 \pm 0.18 \pm 0.17$	$0.53 \pm 0.03 \pm 0.03 \pm 0.03$

CLEO Collaboration, Phys. Rev. D79: 072007 (2009).

Measurements of $\chi_{cJ} \to \gamma V$, $V = \phi, \rho, \omega$







These decays are important for evaluating theoretical techniques.

B (10^{-6})	BESIII	CLEOc	pQCD
$\chi_{c0} \to \gamma\phi$	< 14.8	< 6.4	0.46
$\chi_{c1} \to \gamma\phi$	$27.3 \pm 5.5_{stat}$	< 26	3.6
$\chi_{c2} \to \gamma\phi$	< 7.8	< 13	1.1
$\chi_{c0} \to \gamma\rho^0$	< 9.5	< 9.6	1.2
$\chi_{c1} \to \gamma\rho^0$	$241 \pm 14_{stat}$	$243 \pm 19 \pm 22$	14
$\chi_{c2} \to \gamma\rho^0$	< 19.7	< 50	4.4
$\chi_{c0} \to \gamma\omega$	< 11.7	< 8.8	0.13
$\chi_{c1} \to \gamma\omega$	$73.5 \pm 7.6_{stat}$	$83 \pm 15 \pm 12$	1.6
$\chi_{c2} \to \gamma\omega$	< 5.8	< 7.0	0.5

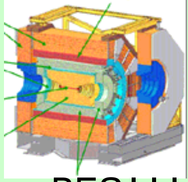
BESIII: Only statistical errors are shown

- $\chi_{c1} \to \gamma\phi$ observed for first time.
- pQCD predictions ×10 too low.
- Difference may be explained by non-perturbative QCD "loop corrections". D.Y Chen *et al*, arXiv:1005.0066v2[hep-ph].

CLEOc: PRL 101, 151801 (2008)

pQCD: Y.J. Gao et al., hep-ph/0701009

Measurements of $\chi_{cJ} \rightarrow \gamma V$, $V=\phi, \rho, \omega$



Helicity angle θ is the angle between the vector meson direction in the χ_{c1} rest frame and a daughter meson in the vector meson rest frame (ρ and ϕ) or the normal to the decay plane in the ω rest frame.
Longitudinal polarization (transverse) exhibits a $\cos\theta^2$ ($\sin\theta^2$) dependence.

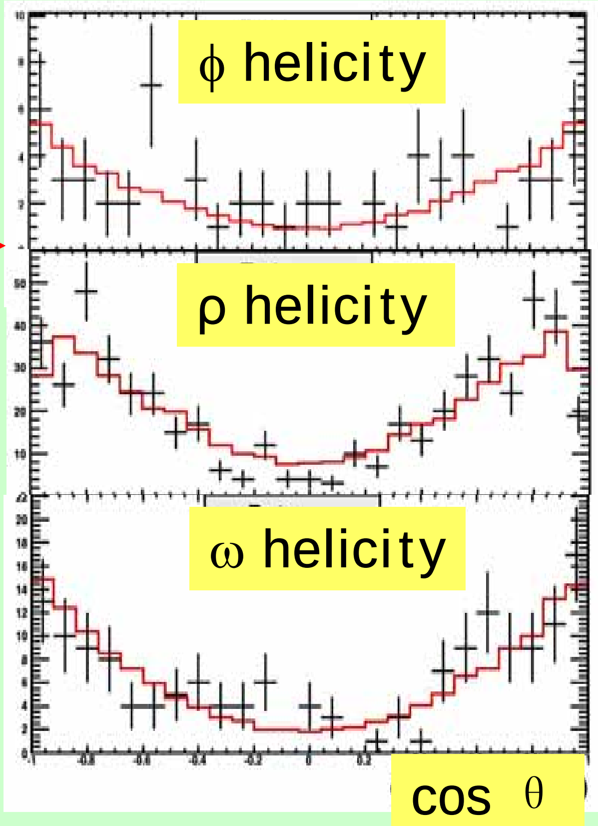
Longitudinal polarization dominant in $\chi_{c1} \rightarrow \gamma V$ decays.

CLEO-c determines ratio of transverse to longitudinal polarization (f_T) :

$$f_T = 0.078^{+0.048+0.002}_{-0.036-0.022} \quad \text{for } \chi_{c1} \rightarrow \gamma \rho$$

$$f_T = 0.47^{+0.37+0.11}_{-0.24-0.23} \quad \text{for } \chi_{c1} \rightarrow \gamma \omega$$

CLEOc: PRL 101, 151801 (2008)



BESIII preliminary

Study of $\chi_{cJ} \to VV$, $V = \omega,\phi$

Important laboratory to test QCD:

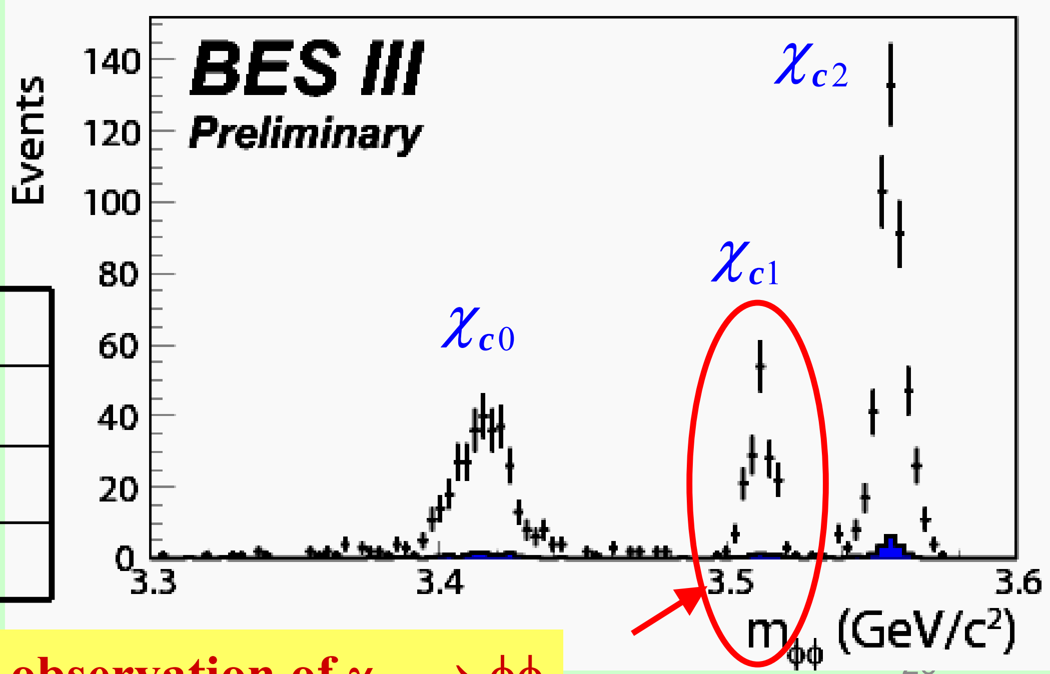
- **Previous measurements from BESII.**
- **They do not show expected helicity suppression.**

BR(10^{-3})	χ_{c0}	χ_{c2}
$\to \phi\phi$	$0.94 \pm 0.21 \pm 0.13$	$1.70 \pm 0.30 \pm 0.25$
$\to \omega\omega$	$2.29 \pm 0.58 \pm 0.41$	$1.77 \pm 0.47 \pm 0.36$

BESII, PLB 642, 197 (2006)

BESII, PLB 630, 7 (2005)

BESIII sees clear $\chi_{cJ} \to \phi\phi$
$\to$ 4K signals

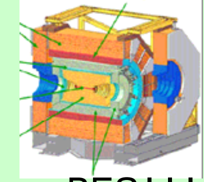


BR(10^{-3})	BESIII	PDG08
$\chi_{c0} \to \phi\phi$	0.80 ± 0.04	0.93 ± 0.20
$\chi_{c1} \to \phi\phi$	0.42 ± 0.03	----
$\chi_{c2} \to \phi\phi$	1.15 ± 0.04	1.54 ± 0.30

Errors statistical only.

First observation of $\chi_{c1} \to \phi\phi$

Study of $\chi_{cJ} \to VV$, $V = \omega,\phi$

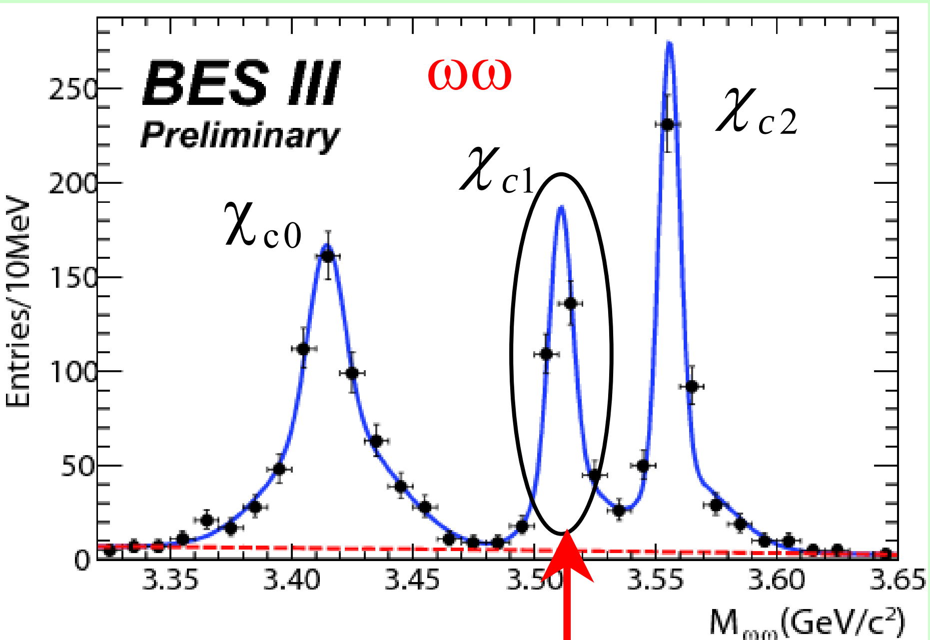


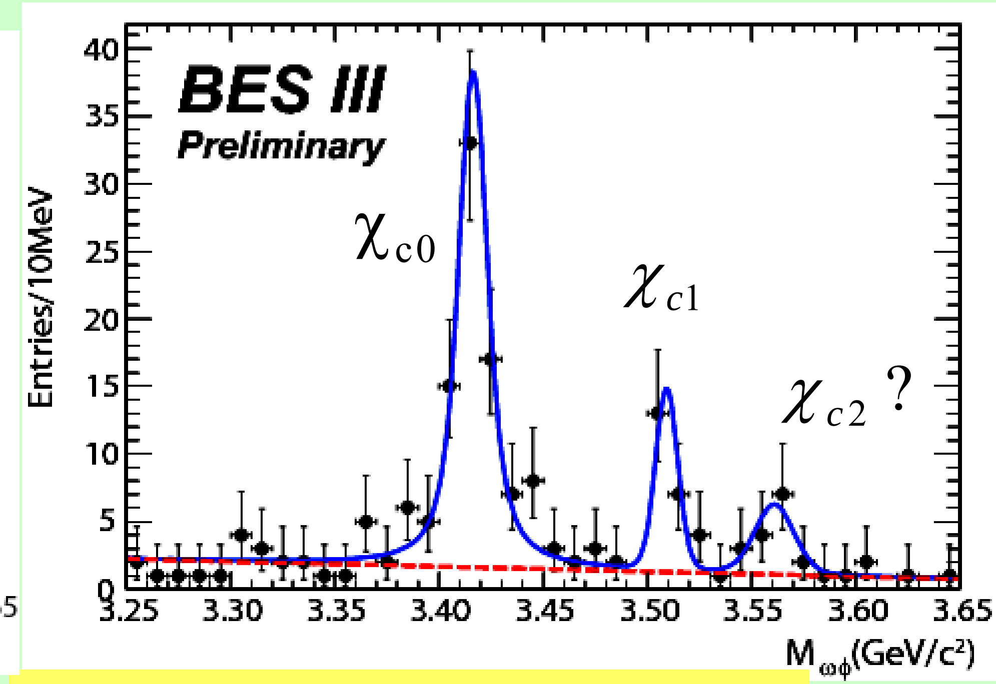
BESIII

- $\chi_{c1} \to \phi\phi$ (and $\omega\omega$) should be highly suppressed because C-parity requires L = 2.

And clear $\chi_{cJ} \to \omega\omega$
$\to 2(\pi^+\pi^-\pi^0)$

And clear $\chi_{cJ} \to \omega\phi$
$\to (\pi^+\pi^-\pi^0)(KK)$





First observation of $\chi_{c1} \to \omega\omega$.

Doubly OZI suppressed $\chi_{cJ} \to \omega\phi$ signals are observed for the first time.

First observation of $\psi(2S) \to \gamma\gamma J/\psi$

- Two photon transitions are well known in excitations of molecules, atomic hydrogen, and positronium.

A. Quattropani *etal,* PRA **25**, 3079 (1982).
F. Bassani *etal,* PRL **39**, 1070 (1977).
A. Quattropani *etal,* PRL **50**, 1258 (1983).

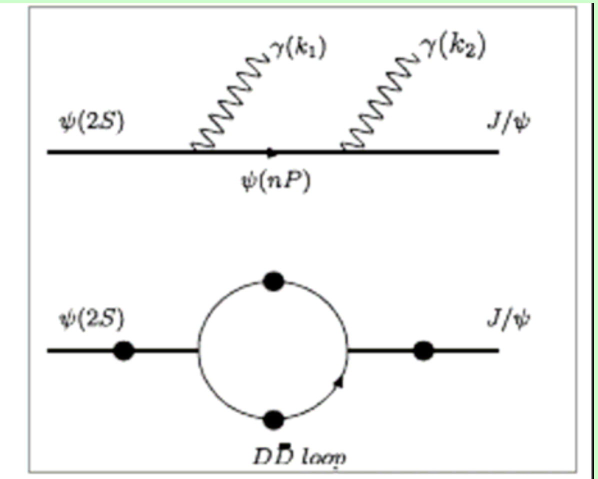
- CLEO observed two photon transitions in Upsilon(3S) $\to$ Upsilon(2S).

F. Butler *etal,* PRD **49**, 40 (1994).

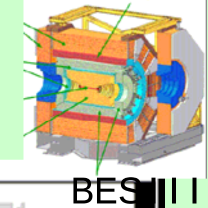
- Never been observed in the charmonium system.
- Observation helpful to understanding QCD.

Theoretically:

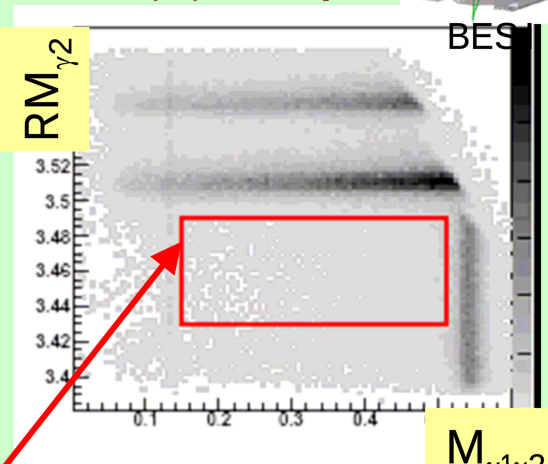
- potential models give discrete spectra ($\psi(2S) \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi$)
- coupled channel models can give continuous spectra.
- theoretical work ongoing.



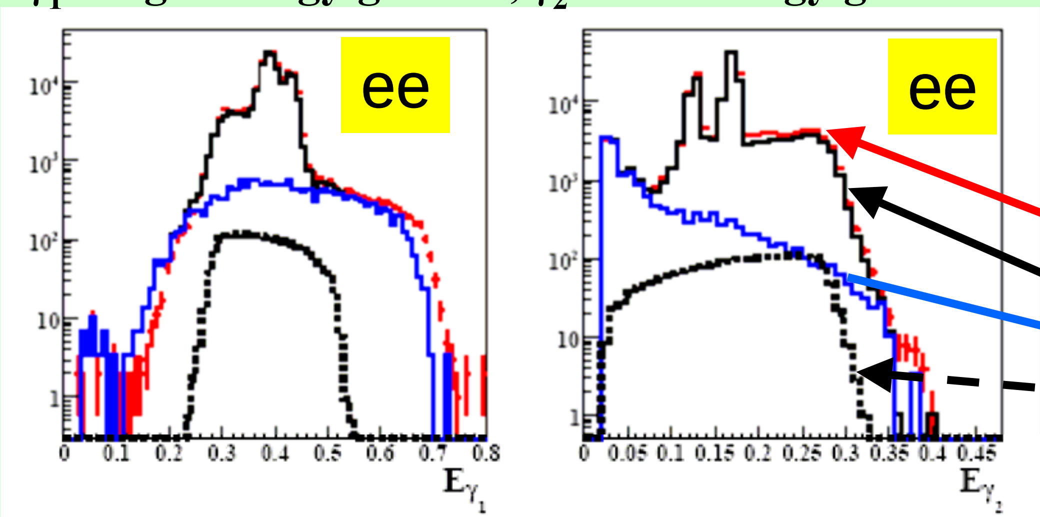
First observation of $\psi(2S) \to \gamma\gamma J/\psi$



- select $\psi(2S) \to \gamma\gamma J/\psi$, $J/\psi \to l^+l^-$ events.
- $J/\psi \to ee$ channel ($\mu\mu$ similar):



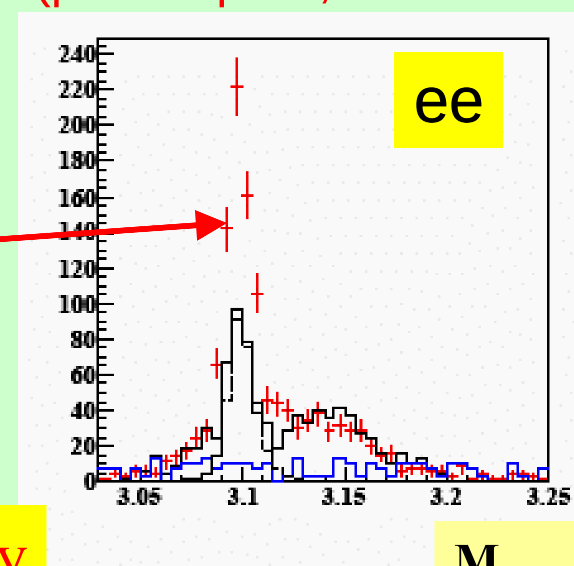
γ_1 - high energy gamma, γ_2 - low energy gamma



data
background MC + continuum
continuum only
signal (phase space; BR = 1 x 10^{-3})

- select events in box to enhance signal.
- see clear excess over BG + continuum in $M_{J/\psi}$ distribution. Significance > 10σ

$B(\psi(2S) \to \gamma\gamma J/\psi)$ [both ee and $\mu\mu$]
$= (1.02 \pm 0.05\ ^{+0.19}_{-0.20}) \times 10^{-3}$



preliminary

$h_c(^1P_1)$

$M(h_C)$ important to learn about hyperfine (spin-spin) interaction of P wave states.

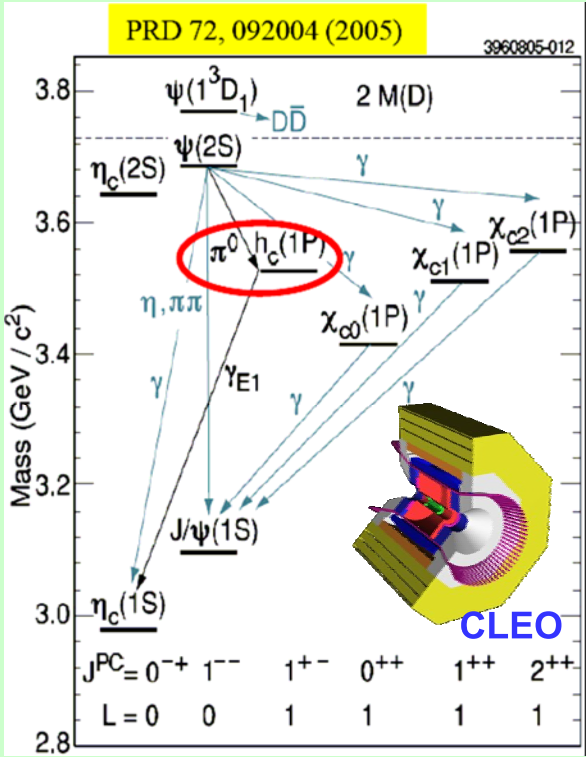
Hyperfine or triplet-singlet splitting determined by spin-spin term in QCD potential models.

h_c:

- **1st seen by E835 and CLEO in 2005**
  - **E835: Evidence in $pp \rightarrow h_c \rightarrow \gamma\eta_c$**
  - **CLEO: Observation in $\psi(2S) \rightarrow \pi^o h_c$; $h_c \rightarrow \gamma\eta_c$**
- **CLEOc in 2008: 25 M $\psi(2S)$ events**

Combining with earlier CLEO results:

$M(h_C)_{AVG} = 3525.20 \pm 0.18 \pm 0.12\ MeV/c^2$
$(B_1 \times B_2)_{AVG} = (4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$

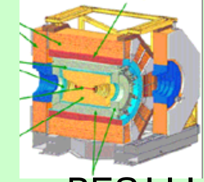


Using the spin weighted centroid of ^3P_J states, $<M(^3P_J)>$, to represent $M(^3P_J)$: $\Delta M_{hf}(1P) = <M(^3P_J)> - M(^1P_1) = 0.08 \pm 0.18 \pm 0.12$ MeV

Consistent with lowest order expectation of 0.

PRL 101, 182003 (2008).

BESIII h_c: Tagged $\psi(2S) \to \pi^0 h_c$, $h_c \to \gamma \eta_c$



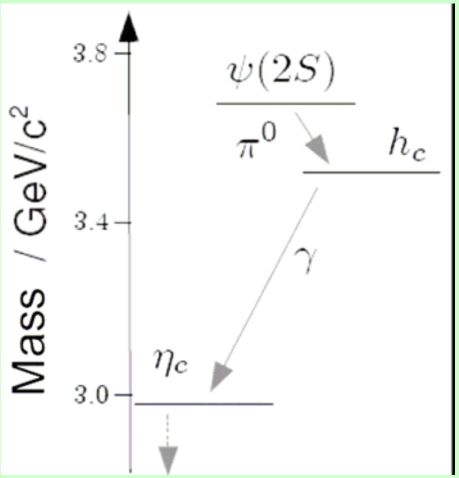
- **Select events with E1-photon to tag $h_c \to \gamma\, \eta_c$**
- **Plot mass recoiling from inclusive π^0 ($\psi(2S) \to \pi^0 h_c$)**
- **Fit with double-Gaussian signal x BW + sideband bkg:**

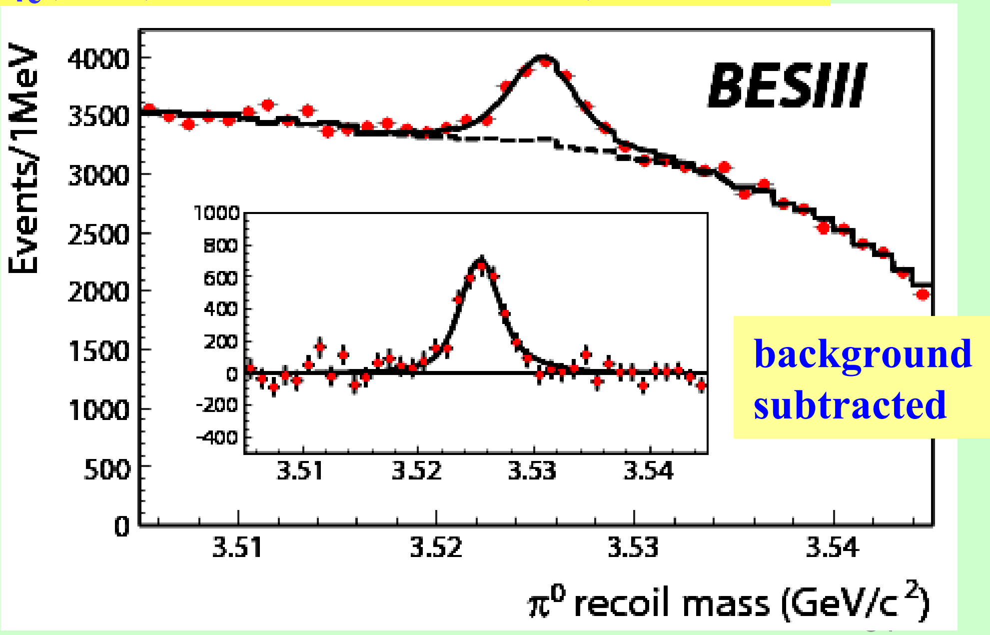
$M(h_c) = 3525.40 \pm 0.13 \pm 0.18$ MeV/c^2

$\Gamma(h_c) = 0.73 \pm 0.45 \pm 0.28$ MeV/c^2 (< 1.44 MeV/c^2 @ 90% CL)

(First measurement)

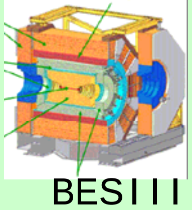
$Br(\psi(2S) \to \pi^0 h_c) \times Br(h_c \to \gamma\eta_c) = (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$





BES Collab., PRL 104, 132002 (2010)

BESIII h_c : Inclusive $\psi(2S)\rightarrow\pi^0 h_c$

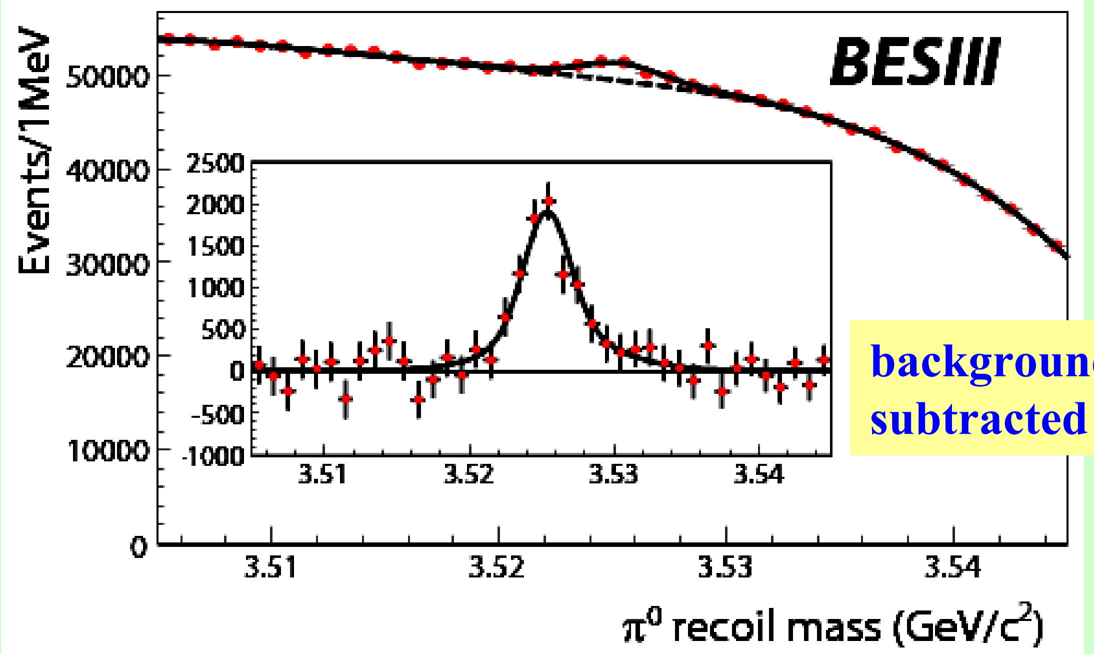


- Select inclusive π^0 (untagged)
- Plot mass recoiling against π^o.
- Fit with double-Gaussian x BW signal + 4th Poly. bkg
  (mass and width fixed to tagged values)
- Combine with tagged results to determine:

  $Br(\psi(2S)\rightarrow\pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$ (First measurement)

  $Br(h_c\rightarrow\gamma\eta_c) = (54.3 \pm 6.7 \pm 5.2)$ % (First measurement)

BES Collaboration, PRL 104, 132002 (2010)



background subtracted

h_c : analysis summary

BES Collaboration, PRL 104, 132002 (2010)

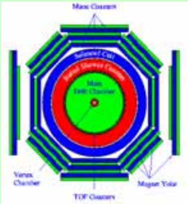
	BESIII	CLEOc	Th(Kuang)
$Br(\psi(2S)\to \pi^0 h_c) \times Br(h_c\to\gamma\eta_c)$ [10^{-4}]	$4.58\pm0.40\pm0.50$	$4.16\pm0.30\pm0.37$	
M [MeV/c^2]	$3525.40 \pm0.13\pm0.18$	$3525.20 \pm0.18\pm0.12$	
Γ [MeV]	$0.73\pm0.45\pm0.28$ < 1.44 @ 90%CL		1.1 (NRQCD) 0.51 (PQCD)
$\Delta M_{hf}(1P)$ [MeV/c^2]	$0.10\pm0.13\pm0.18$	$0.08\pm0.18\pm0.12$	

CLEO-c Collaboration, PRL 101, 182003 (2008)

	BESIII	theoretical predictions
$Br(\psi'\to \pi^0 h_c)$ [10^{-4}]	$8.4\pm1.3\pm1.0$	4 – 13 Kuang
$Br(h_c\to\gamma\eta_c)$ [%]	$54.3\pm6.7\pm5.2$	41 (NRQCD) Kuang 88 (PQCD) Kuang 38 Godfrey, Rosner

Theoretical predictions: Kuang, PRD65, 094024 (2002), Godfrey & Rosner, PRD 66, 014012 (2002).

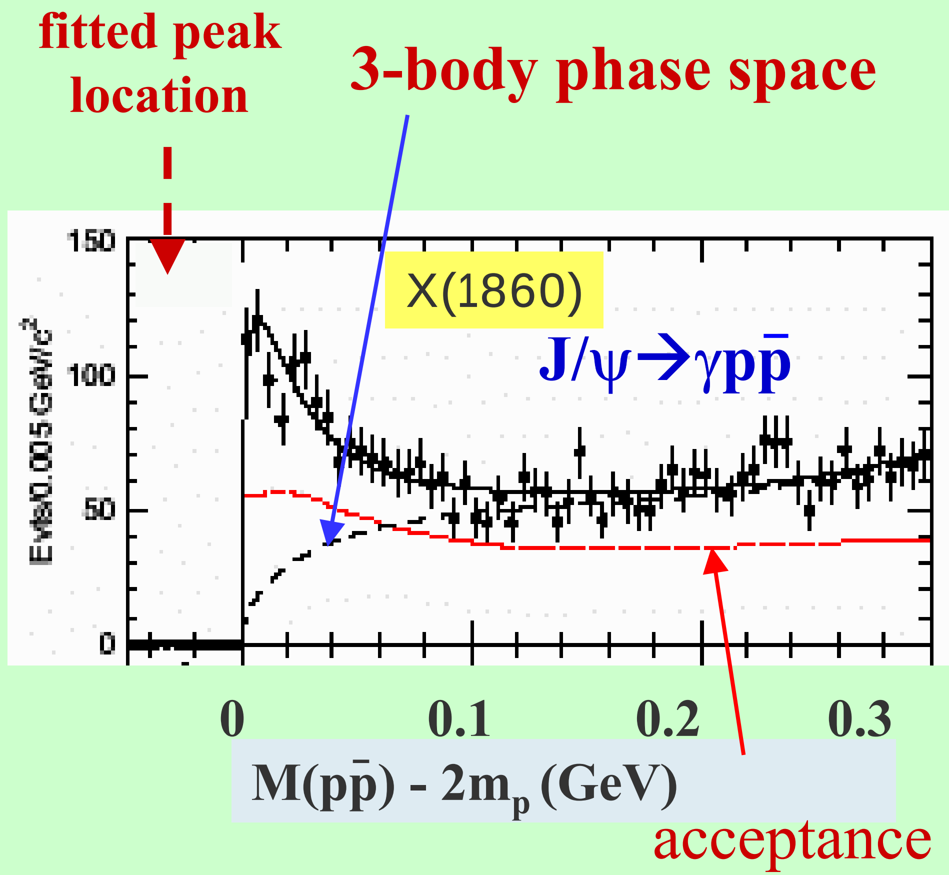
Threshold enhancement in $J/\psi \to \gamma p \bar{p}$



- **BESII**: enhancement seen near threshold in M_{pp} in $J/\psi \to \gamma\, p\, \bar{p}$.
- **If fitted with an *S* -wave resonance:**

$$M = 1859\,^{+3}_{-10}\,^{+5}_{-25}\ \mathrm{MeV}/c^2$$

$$\Gamma < 30\ \mathrm{MeV}/c^2\ (90\%\ \mathrm{CL})$$



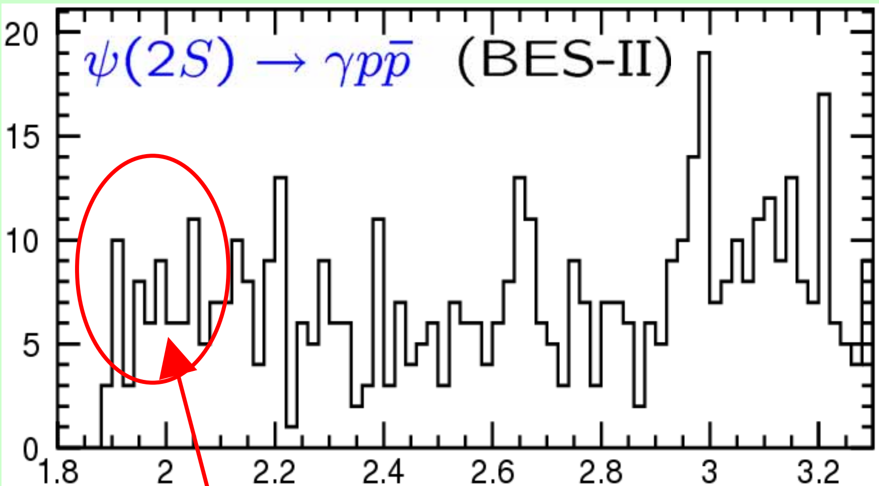
Phys. Rev. Lett. 91, 022001 (2003)
162 citations

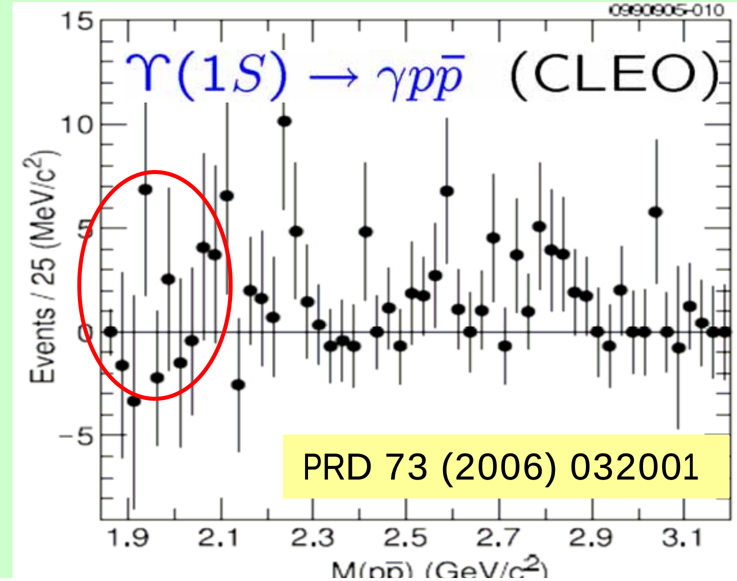
"The BES Particle"
Klempt: Glueballs, Hybrids, and Pentaquarks

$p\bar{p}$ threshold enhancement

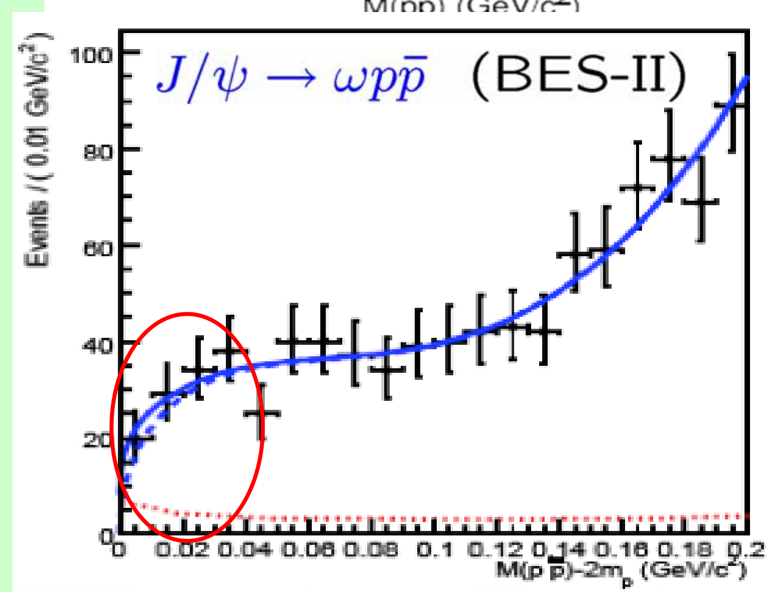
Several *non*-observations...

PRL 99 (2007) 011802



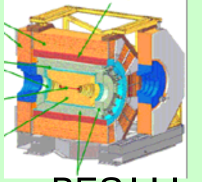


No significant signal of X(1860) found (only 2σ significance)

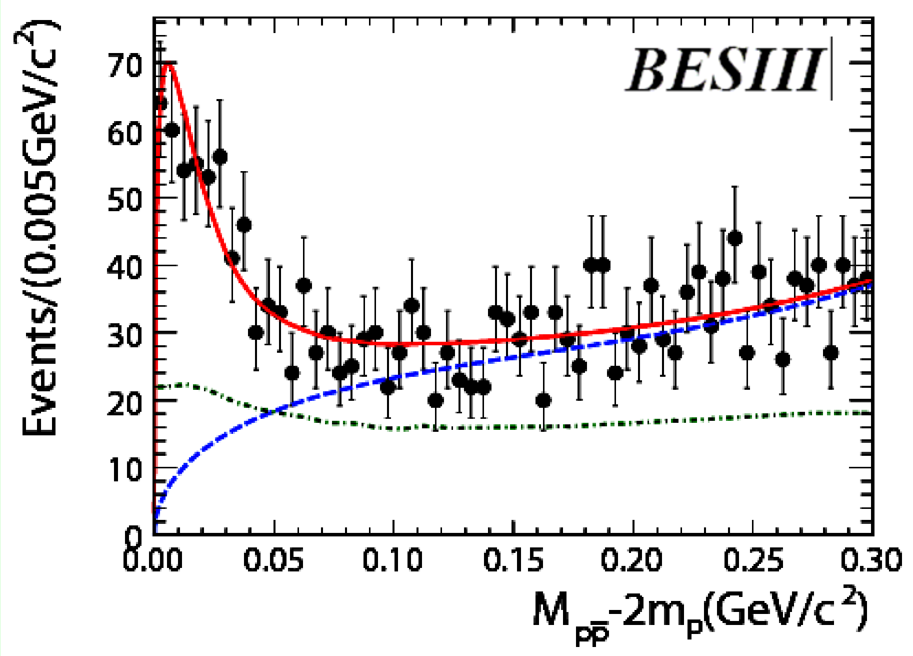


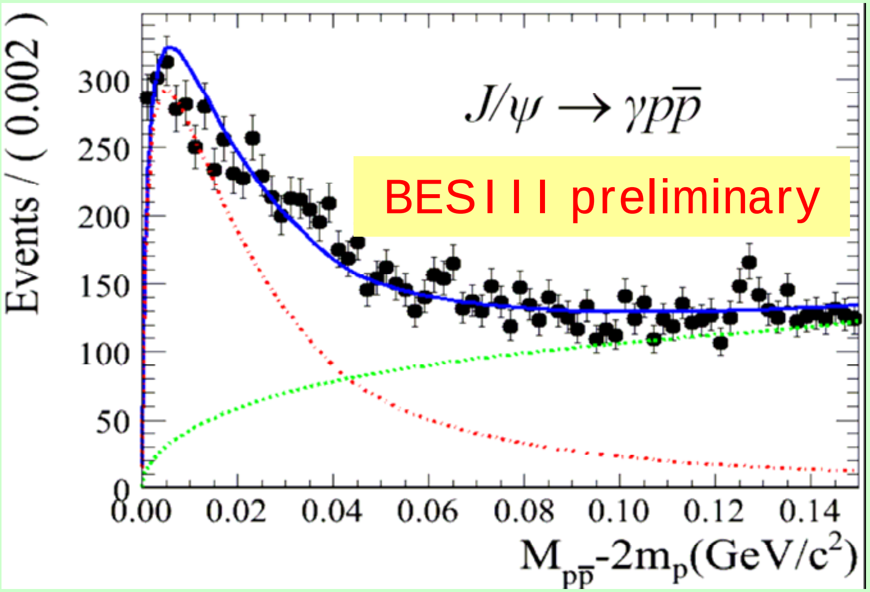
EPJ C53 (2008) 15

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



$\psi' \to \pi^+\pi^- J/\psi, J/\psi \to \gamma p\bar{p}$





$M = 1861\,^{+6}_{-13}\,^{+7}_{-26}$ MeV/c^2

$\Gamma < 38$ MeV/c^2 (90% CL)

$M = 1861.6 \pm 0.8$ MeV/c^2

$\Gamma < 8$ MeV/c^2 (90% CL)

Published in
Chinese Physics C 34, 421 (2010)

Consistent observation by BESIII !

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

QWG2010
Z. Metreveli

- **CLEO-c does fit the same as BES and obtains:**

$$M(R_{thr}) = 1861^{+6}_{-16}\ \text{(MeV)},\quad \Gamma(R_{thr}) = 0^{+32}_{-0}\ \text{(MeV)},$$

$$B_1(J/\psi \to \gamma R_{thr}) \times B_2(R_{thr} \to p\bar{p}) = (5.9^{+2.8}_{-3.2}) \times 10^{-5}$$

agrees with BESII results [PRL91(2003)022011].

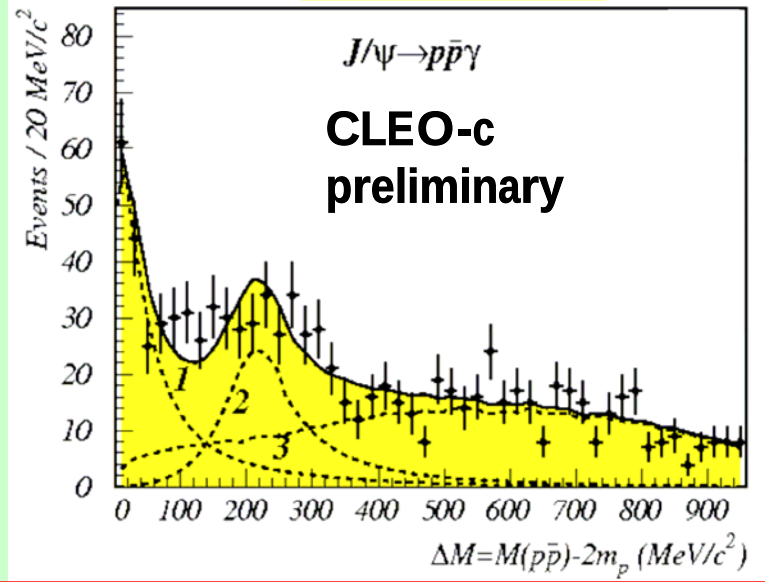
- **CLEO-c fits with three contributions:**

$$\underset{(1)}{R_{thr}} + \underset{(2)}{f_0(2100)} + \underset{(3)}{PS}$$

$$M(R_{thr}) = 1837^{+10}_{-12}{}^{+9}_{-7}\ \text{(MeV)},$$

$$\Gamma(R_{thr}) = 0^{+44}_{-0}\ \text{(MeV)},\qquad CL = 26.1\%$$

$$B_1(J/\psi \to \gamma R_{thr}) \times B_2(R_{thr} \to p\bar{p}) = (11.4^{+4.3}_{-3.0}{}^{+4.2}_{-2.6}) \times 10^{-5}$$



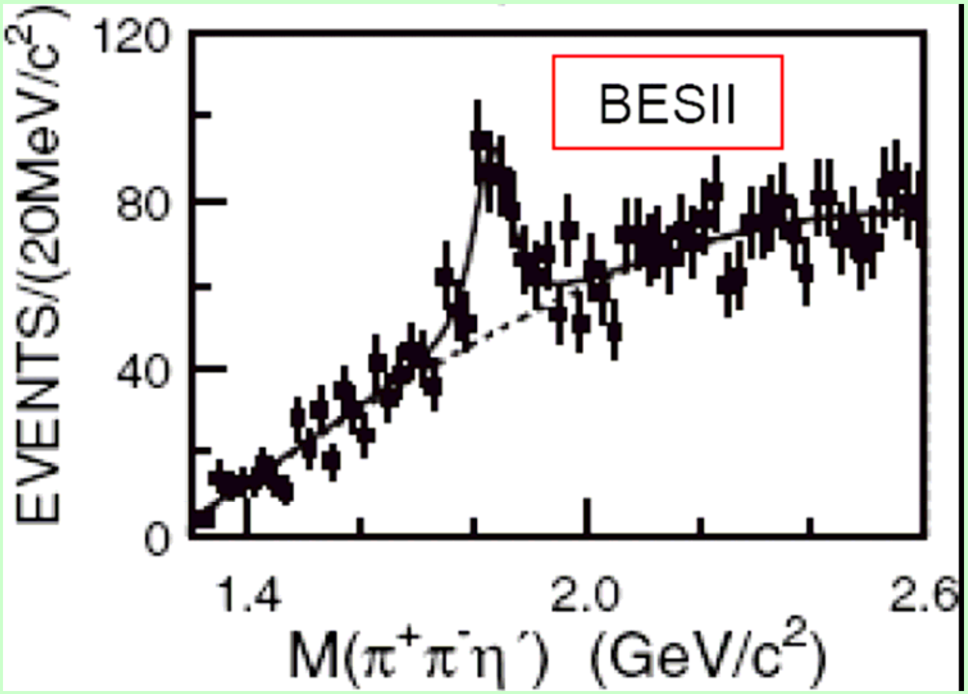
The central value of the mass is close to the sub-threshold resonance mass reported by BES with $M(R) = 1833.7 \pm 6.1 \pm 2.7$ (MeV), observed in $J/\psi \to \gamma R$, $R \to \pi^+\pi^-\eta'$ [PRL 95 (2005) 262001].

BES considered these (2) and (3) as systematic errors.

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. (Hep-ph/0502127)
  - there is gluon content in $p\bar{p}$
  - η' has strong coupling to gluons
- Confirmation of X(1835) is necessary with BESIII 226M J/ψ data sample

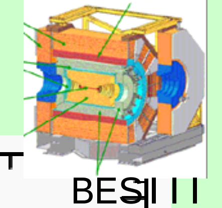
$$J/\psi \to \gamma \pi^+ \pi^- \eta'$$

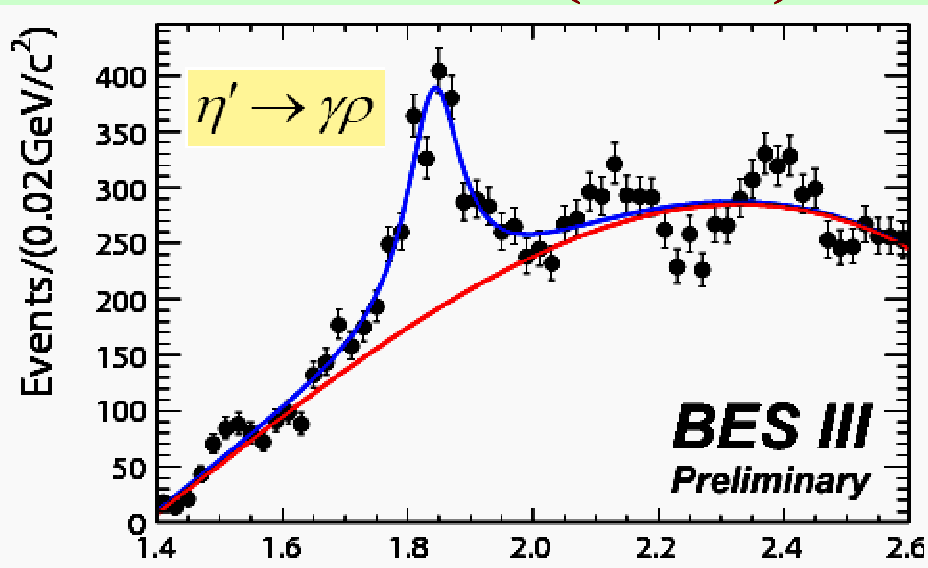


The $\pi^+\pi^-\eta'$ mass spectrum for η' decaying into $\eta'\to\pi^+\pi^-\eta$ and $\eta'\to\gamma\rho$

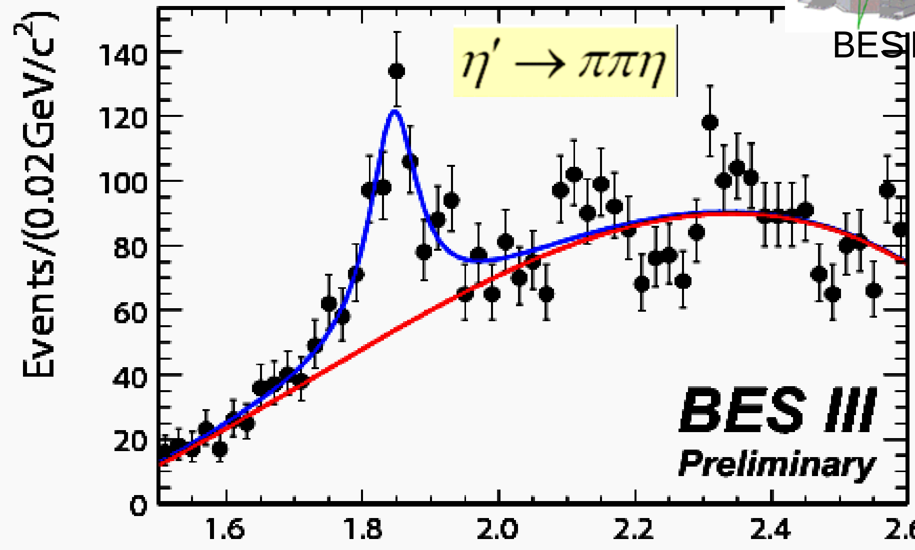
PRL 95, 262001 (2005)

X(1835) at BESIII

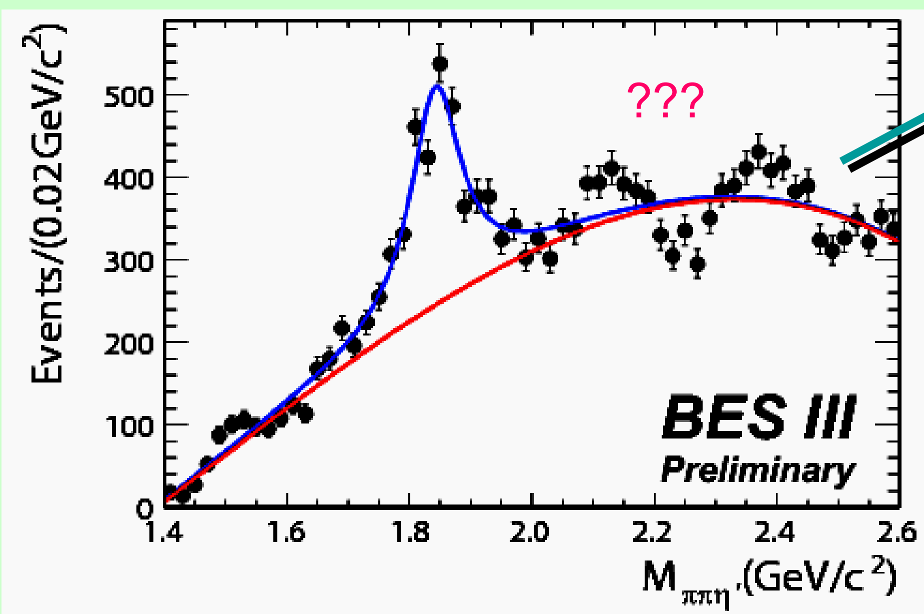




Stat. sig. ~18σ



Stat. sig. ~9σ



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

$$M = 1842.4 \pm 2.8(stat) MeV$$

$$\Gamma = 99.2 \pm 9.2(stat) MeV$$

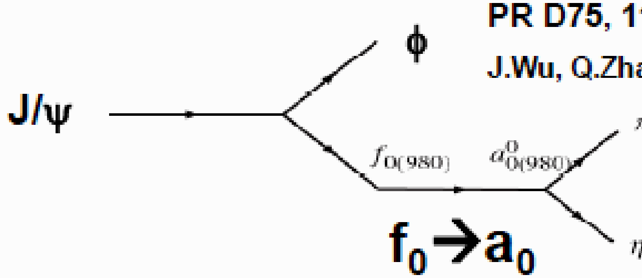
Fit result: Stat. sig. ~ 21 σ

X(1835) confirmed by BESIII

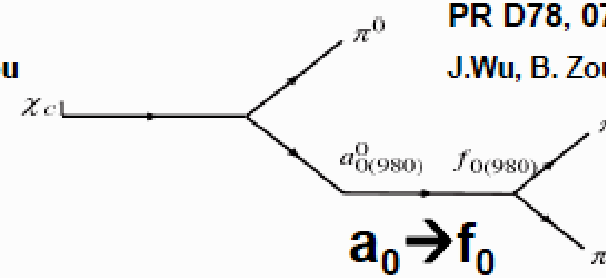
$a_0(980) – f_0(980)$ mixing

- 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 is 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



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

$$= \left|\frac{g_{a_0^0K^+K^-}g_{f_0K^+K^-}}{g_{a_0^0\pi^0\eta}g_{f_0\pi^0\pi^0}}\right|^2 \frac{|\rho_{K^+K^-}(s)-\rho_{K^0\bar K^0}(s)|^2}{3\rho_{\pi\pi}(s)\rho_{\pi\eta}(s)}$$

$$\times \frac{1}{\left|\frac{m_a^2-s}{\Gamma^a_{\pi\eta}\sqrt{s}} - i\left[\left|\frac{g_{a_0^0K^+K^-}}{g_{a_0^0\pi^0\eta}}\right|^2\left(\frac{\rho_{K^+K^-}(s)}{\rho_{\pi\eta}(s)}+\frac{\rho_{K^0\bar K^0}}{\rho_{\pi\eta}}\right)+1\right]\right|^2}$$

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

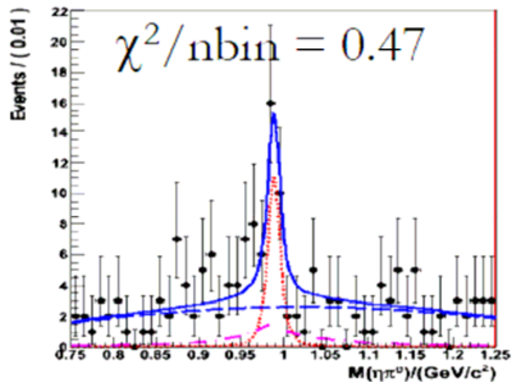
$$= \left|\frac{g_{a_0^0K^+K^-}g_{f_0K^+K^-}}{g_{a_0^0\pi^0\eta}g_{f_0\pi^0\pi^0}}\right|^2 \frac{|\rho_{K^+K^-}(s)-\rho_{K^0\bar K^0}(s)|^2}{3\rho_{\pi\pi}(s)\rho_{\pi\eta}(s)}$$

$$\times \frac{1}{\left|\frac{m_f^2-s}{\Gamma^f_{\pi\pi}\sqrt{s}} - i\left[\left|\frac{g_{f_0K^+K^-}}{g_{f_0\pi^0\pi^0}}\right|^2\left(\frac{\rho_{K^+K^-}(s)}{3\rho_{\pi\pi}(s)}+\frac{\rho_{K^0\bar K^0}(s)}{3\rho_{\pi\pi}(s)}\right)+1\right]\right|^2}$$

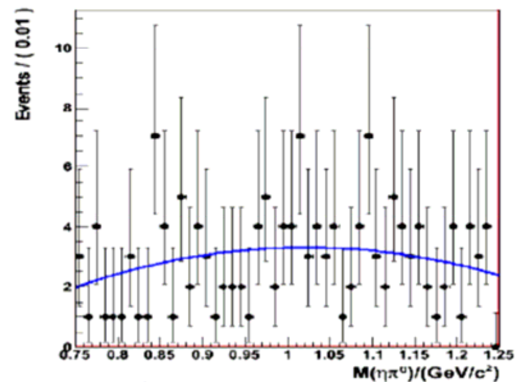
$a_0(980) - f_0(980)$ mixing

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

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



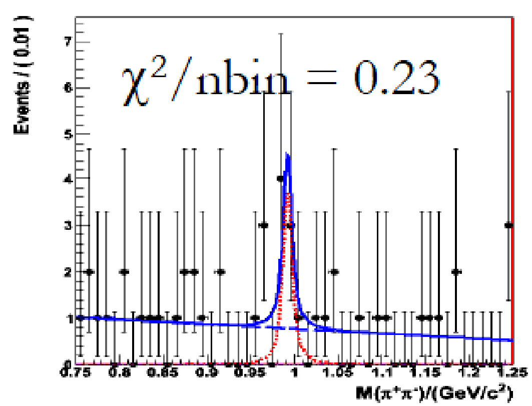
M($\eta\pi^0$) in ϕ signal region



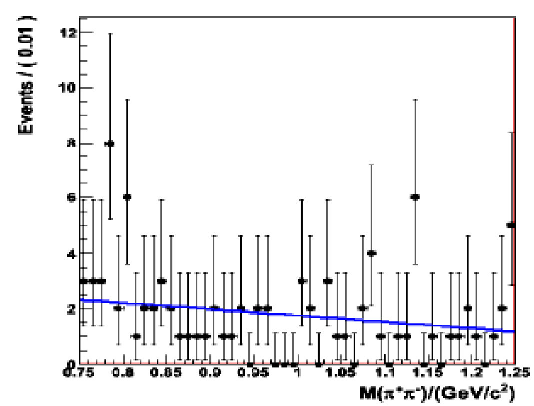
M($\eta\pi^0$) in ϕ sideband region

- N(mixing) = 24.7±8.6 (< 36.7 @ 90% C.L.), S = 3.3 σ ;

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



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



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

- N(mixing) = 6.5±3.2 (< 12.1 @ 90% C.L.), S = 2.0 σ ;

$a_0(980) – f_0(980)$ mixing

Branching ratio and mixing intensity ξ_{fa}

$J/\psi \to \phi f_0(980) \to \phi a_0(980) \to \phi\eta\pi^0$

efficiency = (18.5±0.2)%

Nobs = 24.7 ±8.6

(< 36.7@90% C. L., by Bayesian approach)

$Br(J/\psi \to \phi f_0(980) \to \phi a_0(980) \to \phi\eta\pi^0) = (3.1 \pm 1.1(stat.) \pm 0.8(sys.)) \times 10^{-6}$

$< 5.5 \times 10^{-6}$ @90% C. L., lowering the efficiency by $1\sigma_{sys}$ (to be conservative)

$Br(J/\psi \to \phi f_0(980) \to \phi\pi\pi) = (5.4 \pm 0.9) \times 10^{-4}$ (BESII)

mixing intensity

BESIII Preliminary

$\xi_{fa} = Br(J/\psi \to \phi f_0(980) \to \phi a_0(980) \to \phi\eta\pi^0) / Br(J/\psi \to \phi f_0(980) \to \phi\pi\pi)$

$= (0.6 \pm 0.2(stat.) \pm 0.2(sys.))\%$ (< 1.1% @ 90% C. L.)

Uncertainty of $Br(J/\psi \to \phi f_0(980) \to \phi\pi\pi)$ included

$a_0(980) - f_0(980)$ mixing

Branching ratio and mixing intensity ξ_{af}

$\psi(2S) \rightarrow \gamma\chi_{c1}$, $\chi_{c1} \rightarrow a_0(980)\pi^0$, $a_0(980) \rightarrow f_0(980)$, $f_0(980) \rightarrow \pi^+\pi^-$

efficiency = $(22.3\pm0.2)\%$

Nobs = 6.5 ± 3.2

(< 12.1@90% C. L., by Bayesian approach)

$Br(\psi(2S) \rightarrow \gamma\chi_{c1}) \times Br(\chi_{c1} \rightarrow a_0(980)\pi^0 \rightarrow f_0(980)\pi^0 \rightarrow \pi^+\pi^-\pi^0)$

$= (2.8 \pm 1.4(\mathrm{stat.}) \pm 0.5(\mathrm{sys.}))\times 10^{-7}$

$< 5.5 \times 10^{-7}$ @90% C. L., lowering the efficiency by $1\sigma_{sys}$ (to be conservative)

$Br(\psi(2S) \rightarrow \gamma\chi_{c1}) = (8.8\pm0.4)\%$(PDG);

$Br(\chi_{c1} \rightarrow a_0(980)^+\pi^- + c.c. \rightarrow \eta\pi^+\pi^-) = (2.0 \pm 0.7(\mathrm{stat.}) \pm 0.1(\mathrm{sys.})) \times 10^{-3}$ (PDG);

$Br(\psi(2S) \rightarrow \gamma\chi_{c1}, \chi_{c1} \rightarrow a_0(980)\pi^0, a_0(980) \rightarrow \eta\pi^0) = 8.8 \times 10^{-5} \times (1 \pm 35\%)$

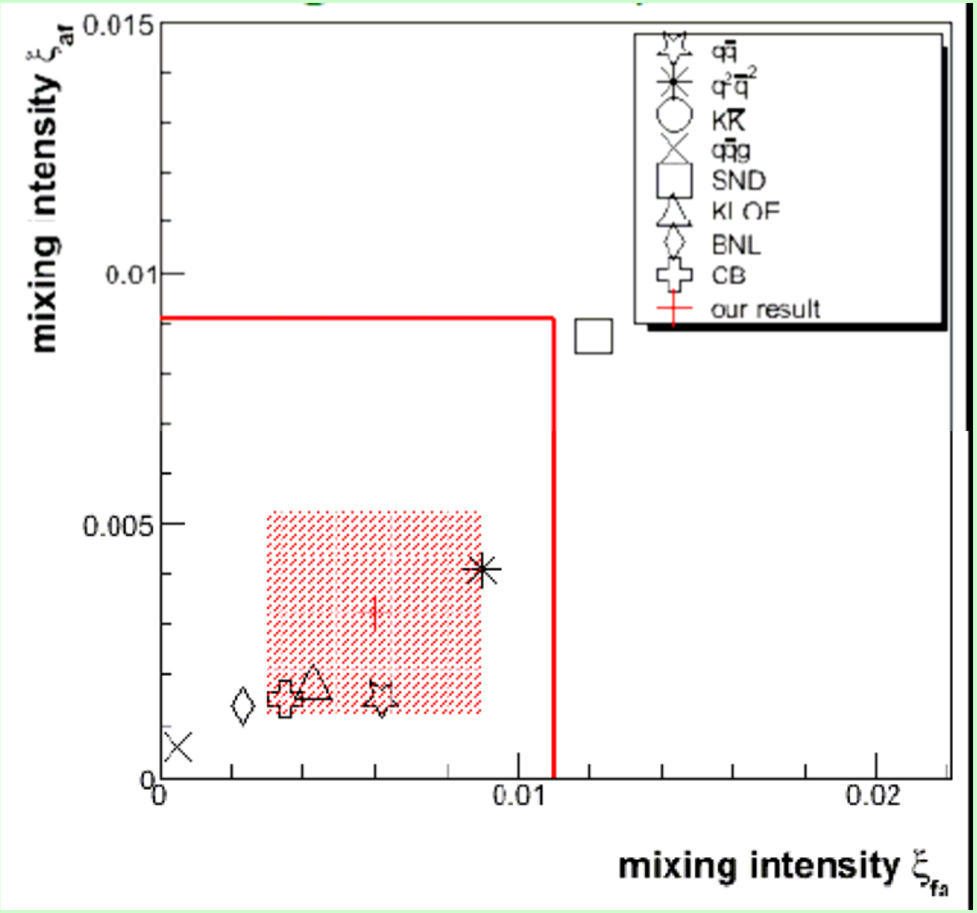
mixing intensity

$\xi_{af} = (0.32 \pm 0.16(\mathrm{stat.}) \pm 0.12(\mathrm{sys.}))\%$ (< 0.91% @ 90% C. L.)

BESIII Preliminary

$a_0(980) - f_0(980)$ mixing

Mixing intensity ξ_{fa} and ξ_{af}



Shaded region: Our measurement

Red line:

Upper limit

BESIII Preliminary

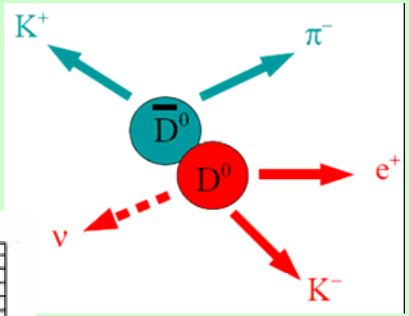
Charm meson production

- **Threshold productions at 3.773, 4.03, 4.17 GeV**

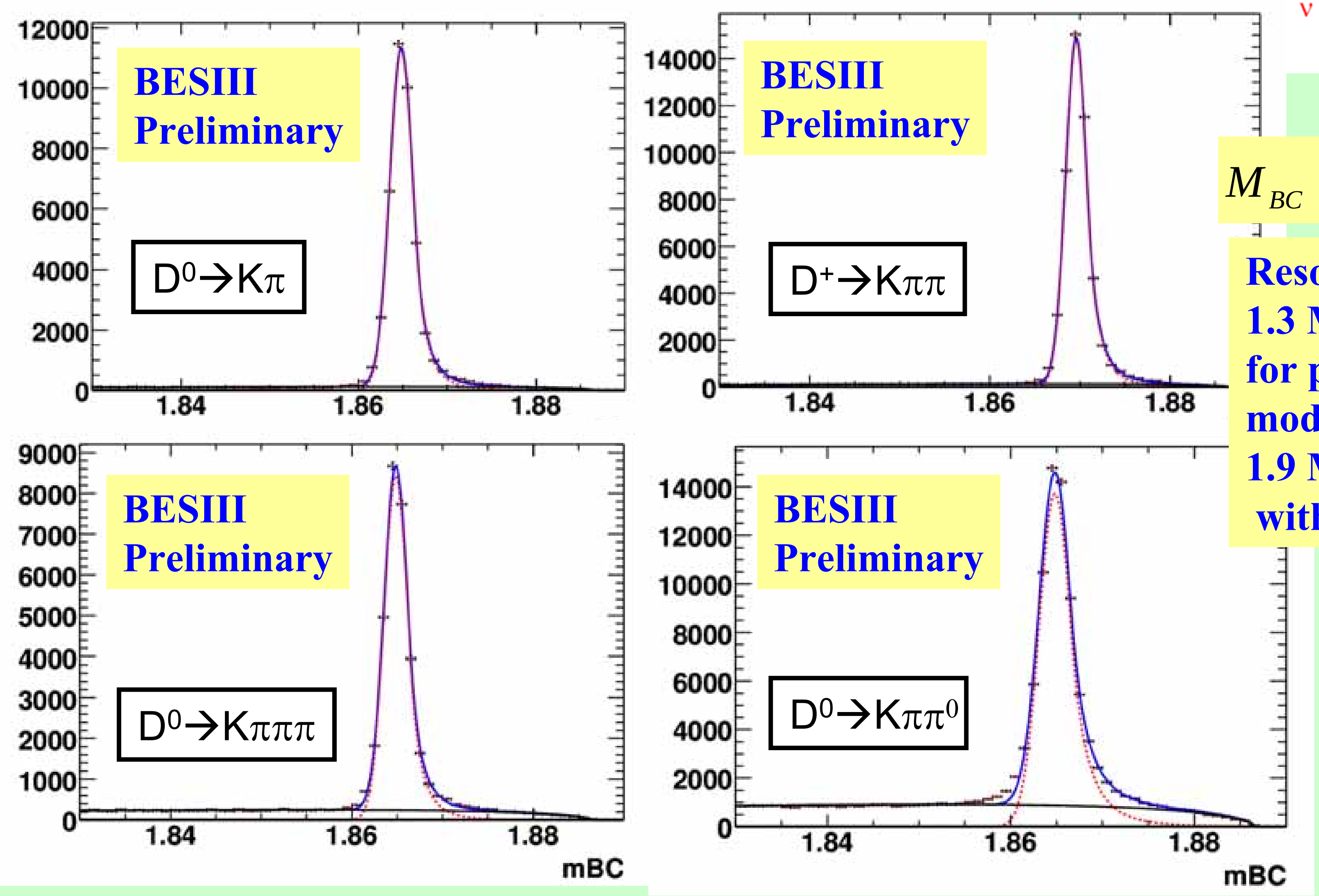
$$e^+e^- \to D\overline{D}, D_s D_s, D_s D_s^*$$

- **Quantum Coherent of $D\overline{D}$ meson pair**
- **Double Tag techniques: (partial-) reconstruct both D mesons**
- **Charm events at threshold are very clean**

Clean single tag at BESIII



@ψ(3770) with 420pb^{-1} first clean single tagging sample:



$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$

Resolution:
1.3 MeV
for pure charged modes;
1.9 MeV for modes with one π^0.

Scan data around ψ（3770）

- About 70 pb^{-1} of data were taken at 65 energy points in the energy region from 3.65 to 3.89 GeV.
- Three ψ(3686) energy scan data samples were collected for BEPC-II energy calibration, …
- Separated beam data were taken for three hours, which will be used to study the beam associated background.

➢ To more precisely measure the line shape of cross sections for $e^+e^- \to$ hadrons in the energy range from 3.72 to 3.89 GeV

➢ To measure B[ψ(3770)→non-DD] and B[ψ(3770)→LH]

➢ To measure line-shape for $\sigma(e^+e^- \to DD)$ and $\sigma(e^+e^- \to LH)$

➢ To measure ψ(3770) resonance parameters precisely

➢ To measure inclusive decay of ψ(3770) to K^0, K^{0*}, φ, J/ψ, etc.

to understand the nature of ψ(3770)

Summary

- **BEPCII/BESIII completed successfully:**
  - **Peak Luminosity of 3.2×10^{32} achieved.**
  - **106 M $\psi(2S)$ and ~226 M J/ψ events obtained in 2009.**
  - **~930 pb^{-1} at $\psi(3770)$ so far in 2010, with some energy scan data.**

- **Some nice results are obtained with the data: χ_{CJ}, hc, light hadron spectroscopy**

- **More results will come soon**

Thanks