Recent Results from BESIII

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Outline

- Status of BEPCII/BESIII
- Results from Charmonium data samples
- Summary

physics at BESIII

This Talk

Charmonium physics:
- Spectroscopy
- transitions and decays

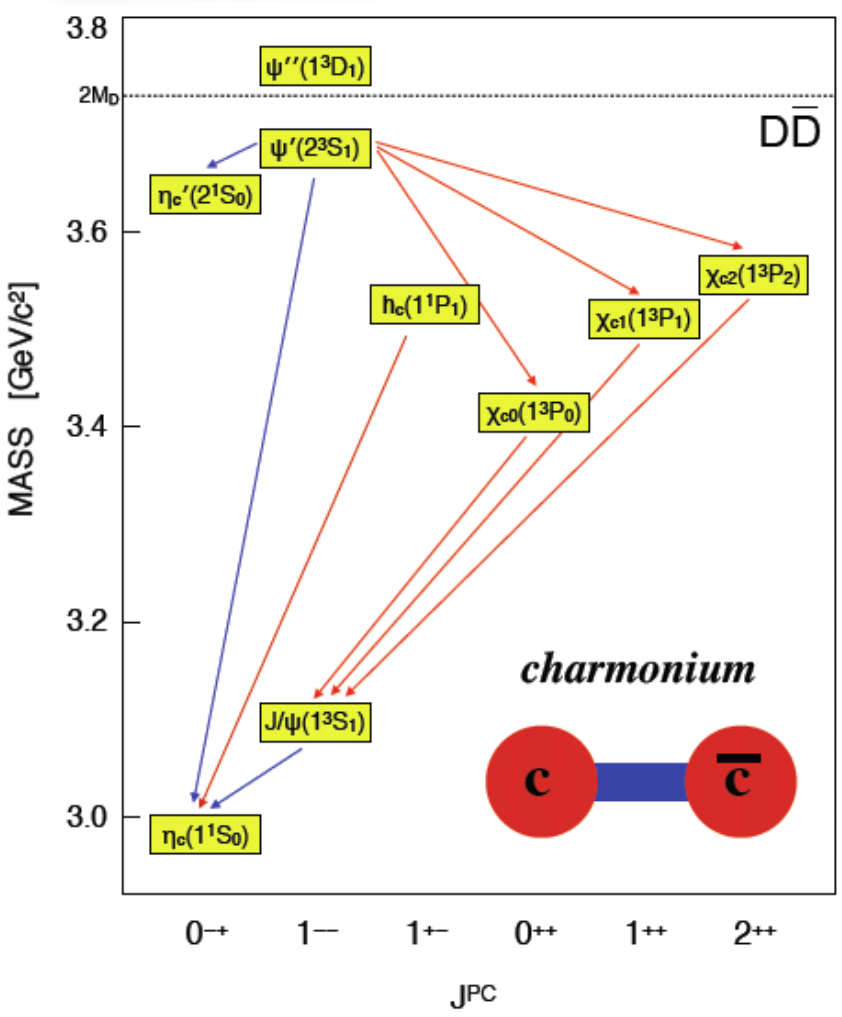
Light hadron physics:
- meson & baryon spectroscopy
- glueball & hybrid
- two-photon physics
- e.m. form factors of nucleon

Charm physics:
- (semi)leptonic + hadronic decays
- decay constant, form factors
- CKM matrix: Vcd, Vcs
- D^0-D^0bar mixing and CP violation
- rare/forbidden decays

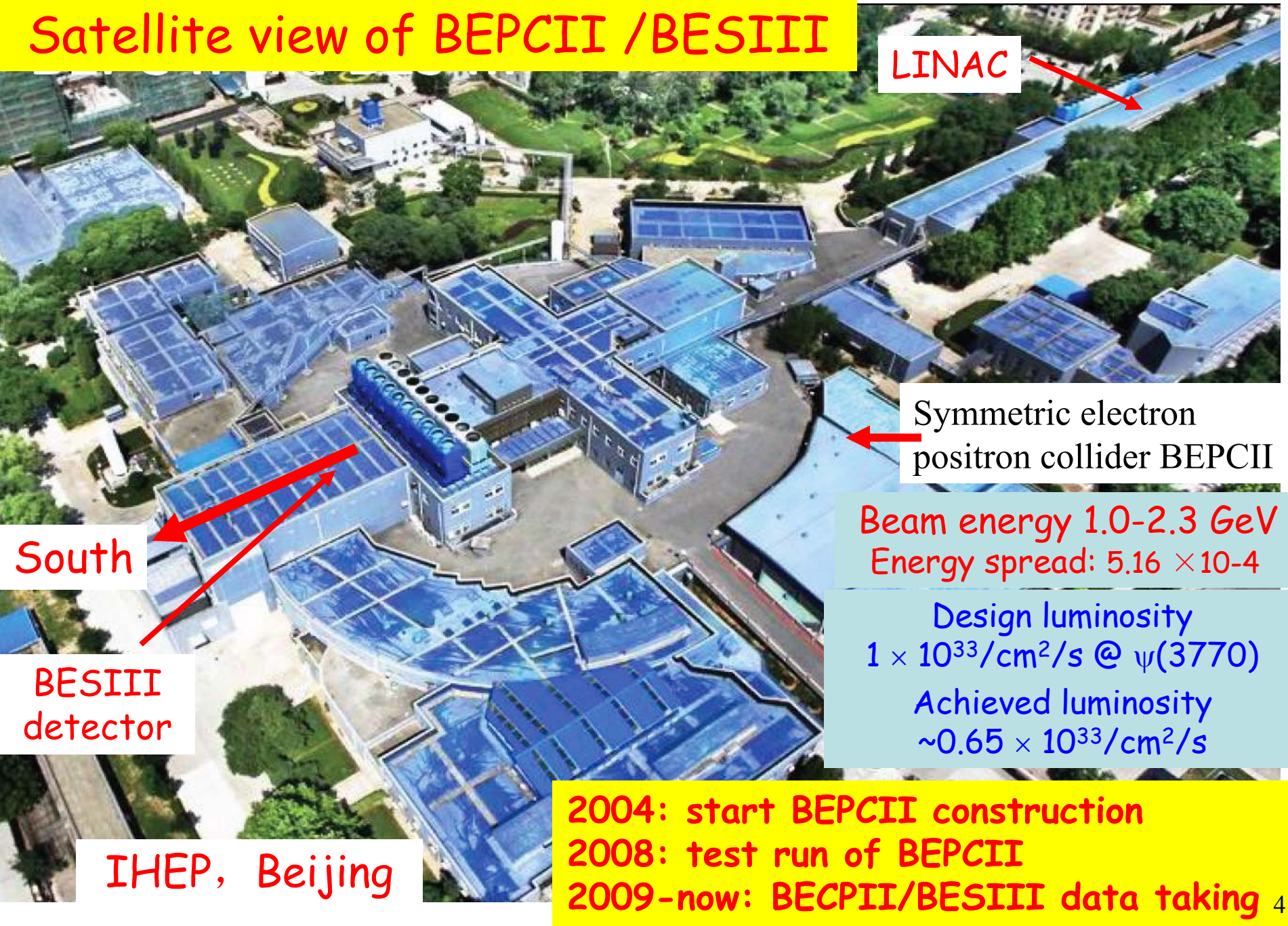
Tau physics:
- Tau decays near threshold
- tau mass scan

…and many more.

arXiv:0809.1869 [hep-ex]
IJMP A V24, No1(2009)supp



Satellite view of BEPCII /BESIII



Beam energy 1.0-2.3 GeV
Energy spread: 5.16 ×10-4

Design luminosity
$1 \times 10^{33}/cm^2/s$ @ $\psi(3770)$

Achieved luminosity
$\sim 0.65 \times 10^{33}/cm^2/s$

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

BESIII Detector

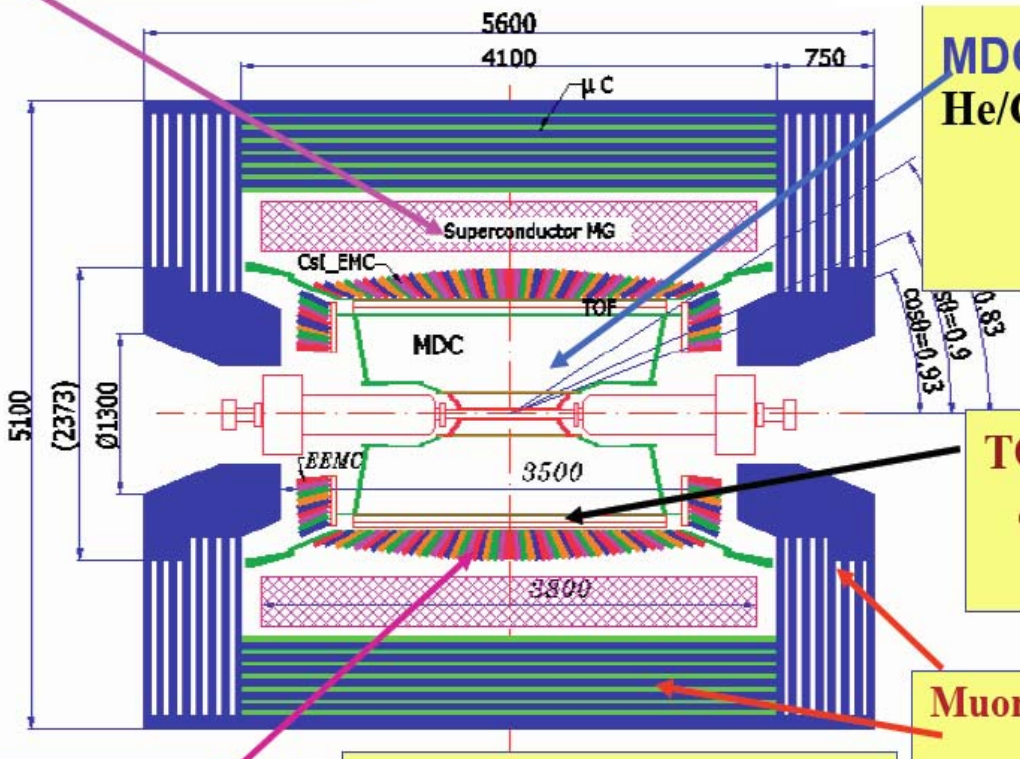
BESIII detector: all new !

CsI calorimeter

Precision tracking

Time-of-flight + dE/dx PID

Magnet: 1 T Super conducting



MDC: small cell & Gas:
He/C_3H_8 (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
ΔE/E = 2.5% @1 GeV
σz = 0.6 cm/√E

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

BESIII Data samples

- So far BESIII has collected :
  - 2009: 220 Million J/ψ
  - 2009: 106 Million ψ'
  - 2010-11: ~2.9 fb^{-1} ψ(3770) (3.5 × CLEO-c 0.818fb^{-1})
  - May 2011: ~0.5fb^{-1} @4010 MeV (one month) for Ds and XYZ spectroscopy
- BESIII will also collect:
  - more J/ψ, ψ', ψ(3770)
  - data at higher energies （for XYZ searches, R scan and Ds physics）

Year	Running Plan
2012	J/ψ: 1 billion / ψ(2S): 0.5 billion (approved)
2013	4170 MeV: Ds decay R scan (E > 4 GeV)
2014	ψ(2S)/τ / R scan (E > 4 GeV)
2015	ψ(3770): 5-10 fb^{-1} (our final goal)

Red: be approved by BESIII Collaboration

Released results of BESIII

- **Charmonium Spectroscopy and Transitions**
  - Properties of the h_c *(PRL 104, 132002 (2010))*
  - $\psi' \to \gamma\ \gamma\ J/\psi$ *(submitted soon)*
- **Charmonium Decays**
  - $\chi_{cJ} \to \pi^0\pi^0,\ \eta\ \eta$ *(PRD 81, 052005 (2010))*
  - $\chi_{cJ} \to \gamma\ \rho\ ,\ \gamma\ \omega\ ,\ \gamma\ \phi$ *(PRD83,112005(2011))*
  - $\chi_{cJ} \to \omega\ \omega\ ,\ \phi\ \phi\ ,\ \omega\ \phi$ *(submitted to PRL)*
  - $\psi' \to \gamma\ \pi^0,\ \gamma\ \eta\ ,\ \gamma\ \eta'$ *(PRL 105, 261801 (2010))*
  - $\chi_{cJ} \to 4\pi^0$ *(PRD 83, 012006 (2011))*
  - η , $\eta'$and $\eta_c \to \pi\ \pi$ *(submitted to PRD)*
  - Observation of $\chi_{cJ} \to ppK^+K^-$ *(PRD83,112009(2011))*
- **Light Quark States**
  - $a_0(980) - f_0(980)$ mixing *(PRD 83, 032003 (2011))*
  - $\eta' \to \eta\pi^+\pi^-$ matrix element *(PRD 83, 012003 (2011))*
  - X(1860) in $J/\psi \to \gamma$ (pp) *(Chinese Physics C 34, 4 (2010))*
  - X(1835) in $J/\psi \to \gamma\ (\eta'\pi^+\pi^-)$ *(PRL 106, 072002 (2011))*
  - X(1870) in $J/\psi \to \omega\ (\eta\ \pi^+\pi^-)$ *(submitted to PRL)*

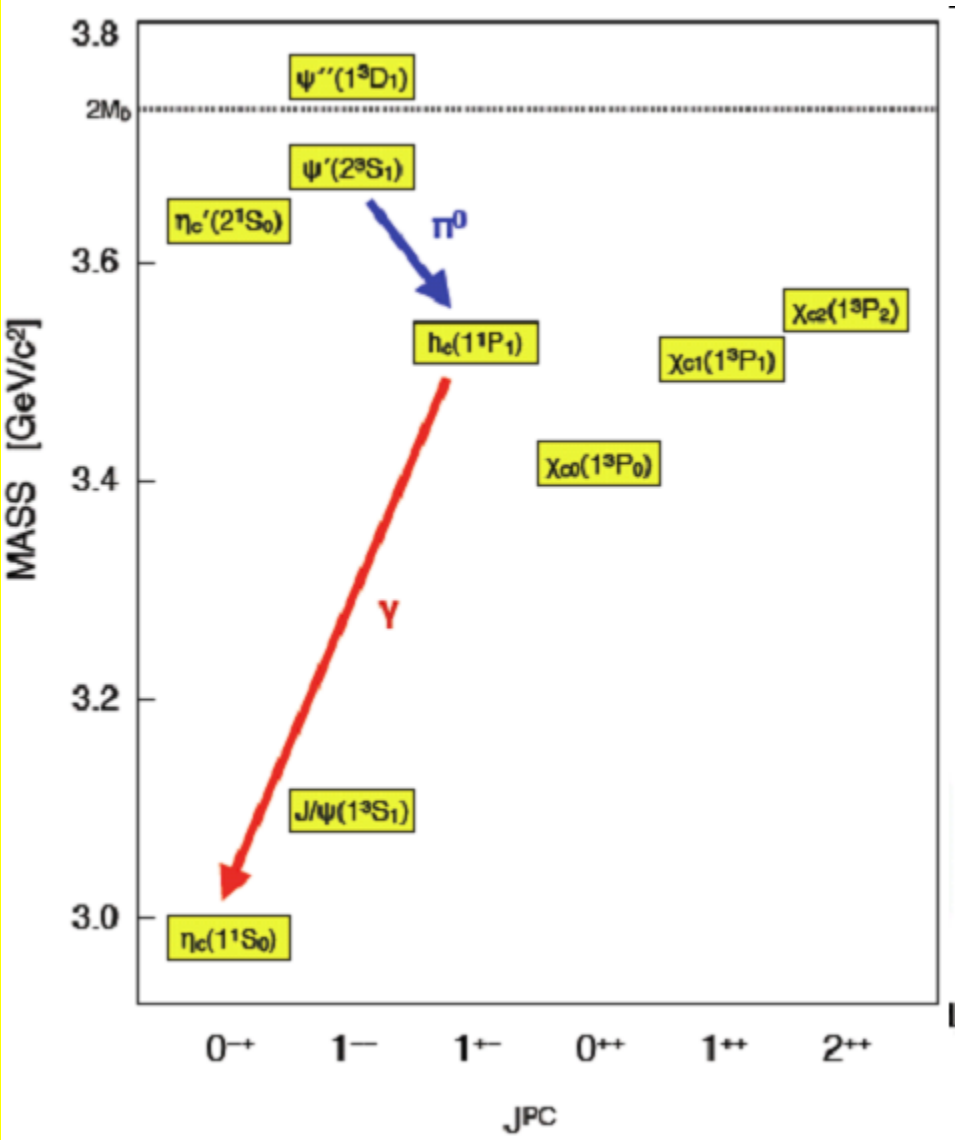
10 papers published

More than 20 analyses are under internal review!

Observation of h_c at BESIII

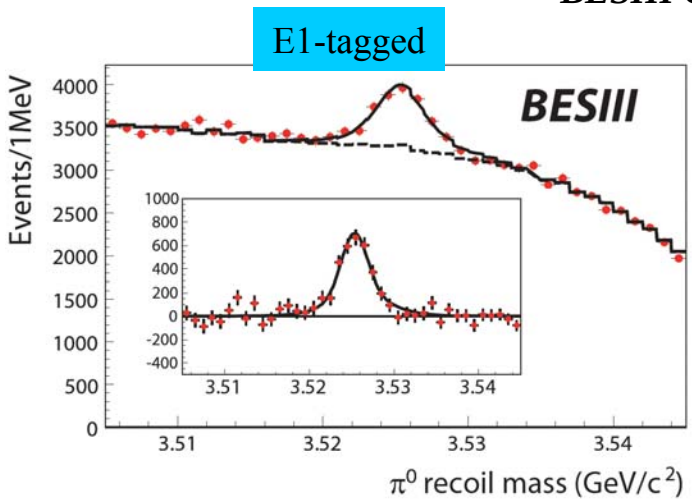
Property of h_c (1p1)

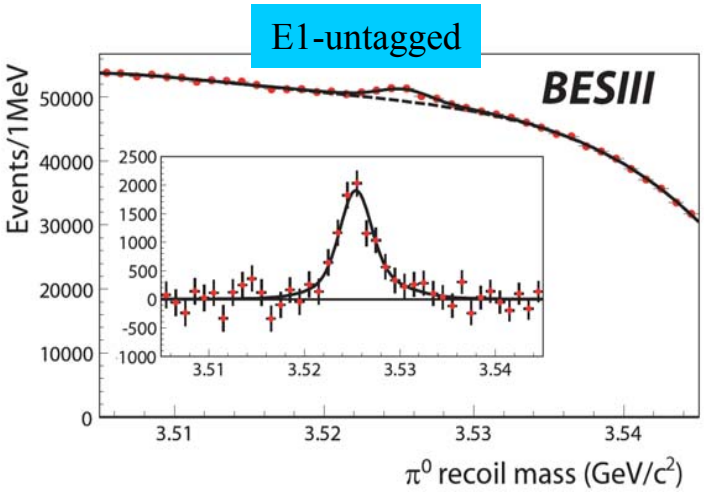
- First evidence: E835 in
  $pp \rightarrow h_c \rightarrow \gamma\eta_c$ (PRD72,092004(2005))
- CLEO-c observed h_c in
  $ee \rightarrow \psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$
  $\Delta M_{hf}(1P)=0.08\pm0.18\pm0.12$ MeV/c^2
  (PRL104,132002(2010))
- Study isospin forbidden transition:
  $B(\psi' \rightarrow \pi^0 h_c)$
- Measure as well the E1 transition:
  $B(h_c \rightarrow \gamma\eta_c)$
- $M(h_c)$ gives access to hyperfine splitting of 1P states:
  $\Delta M_{hf}(1P)=M(h_c)-1/9(M(\chi_{c0})+3M(\chi_{c1})+5M(\chi_{c2}))$



Observation of h_c at BESIII (inclusive)

BESIII Collaboration: PRL104, 132002, (2010)





- Select inclusive π^0 ($\psi' \rightarrow \pi^0 h_c$)
- Select E1-photon in $h_c \rightarrow \gamma\eta_c$ (E1 tagged) or not (E1 untagged)
- E1-tagged selection gives

  $M(h_c)=3525.40\pm0.13\pm0.18$MeV

  ($\Delta M_{hf}(1P)=0.10\pm0.13\pm0.18$MeV/$c^2$)

  $\Gamma(h_c)=0.73\pm0.45\pm0.28$MeV (first measurement)

  (<1.44MeV at 90% CL)

  $Br(\psi' \rightarrow \pi^0 h_c) \times Br(h_c \rightarrow \gamma\eta_c) =$

  $(4.58\pm0.40\pm0.50) \times 10^{-4}$
- E1-untagged selection gives

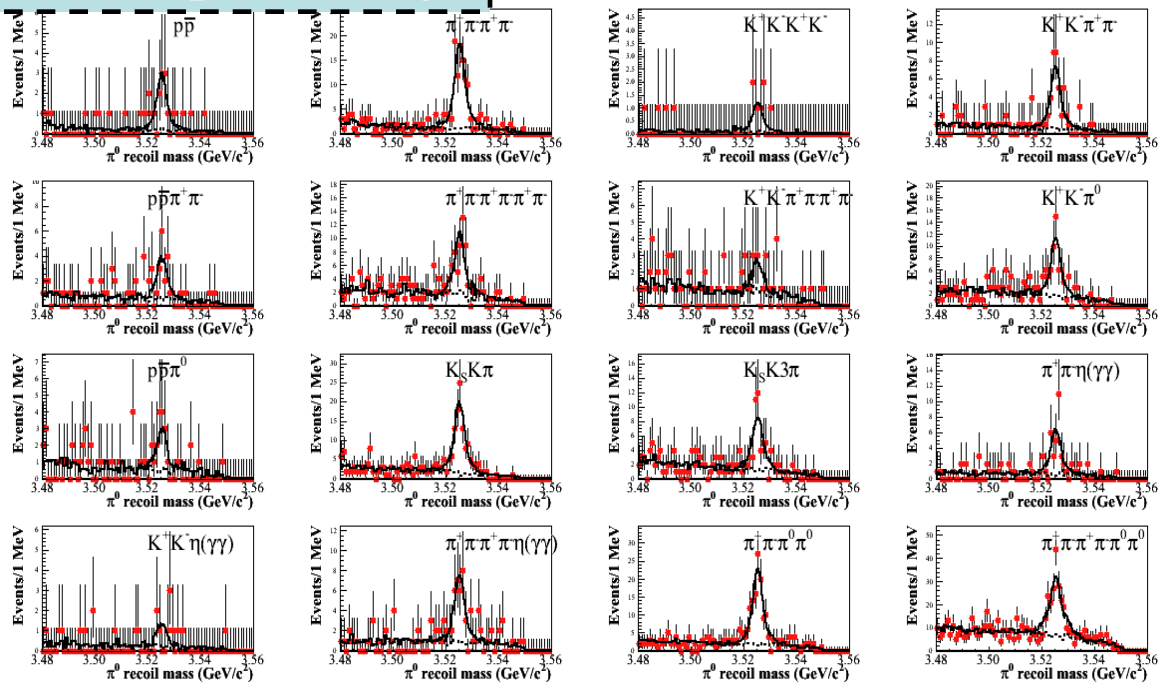
  $Br(\psi' \rightarrow \pi^0 h_c) = (8.4\pm1.3\pm1.0) \times 10^{-4}$
- Combining branching fractions leads to

  $Br(h_c \rightarrow \gamma \eta_c) = (54.3\pm6.7\pm5.2)\%$

  (first measurement)

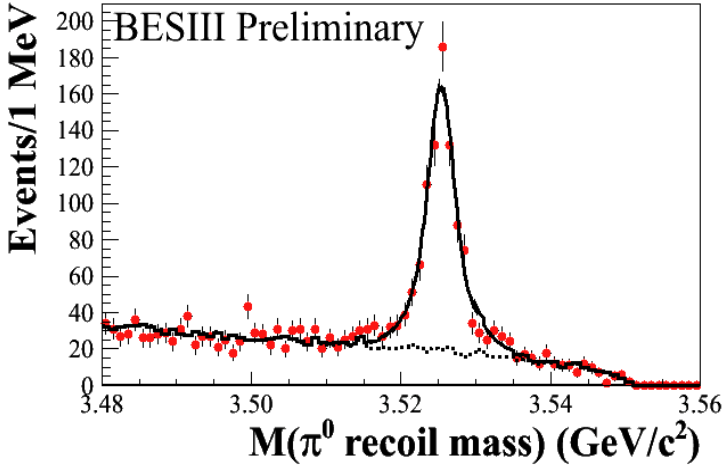
Measurements of the h_c properties at BESIII (exclusive)

BESIII preliminary



$\psi' \to \pi^0 h_C$, $h_C \to \gamma \eta_C$,
η_C is reconstructed exclusively with 16 decay modes

Summed π^0 recoil mass



Simultaneous fit to π^0 recoiling mass:
$M(h_c)$ = 3525.31±0.11±0.15 MeV
$\Gamma(h_c)$ = 0.70±0.28±0.25 MeV
N = 832±35
χ^2/d.o.f. = 32/46

BESIII preliminary

Consistent with BESIII inclusive results PRL104,132002(2010)

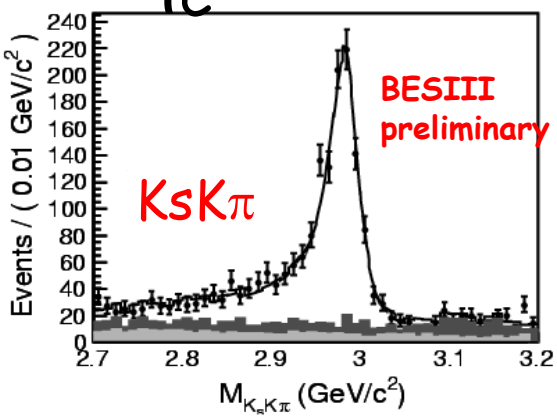
CLEOc exlusive results
$M(h_c)$=3525.21±0.27±0.14 MeV/c^2
N = 136±14
PRL101, 182003(2008)

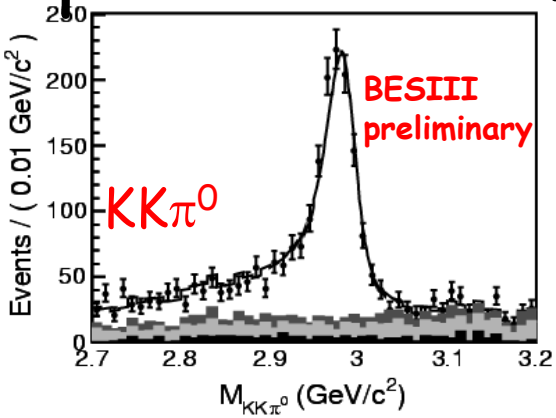
Measurement of the η_c resonance parameters from $\psi' \to \gamma\eta_c$

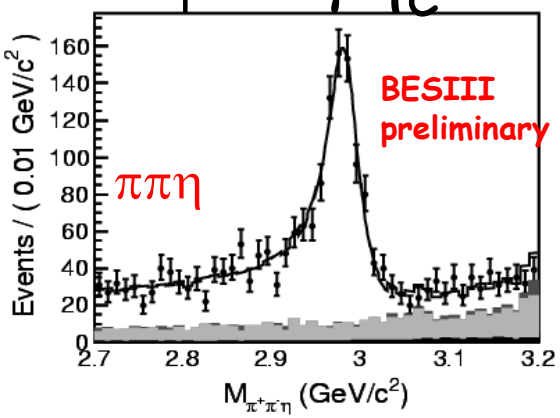
Introduction

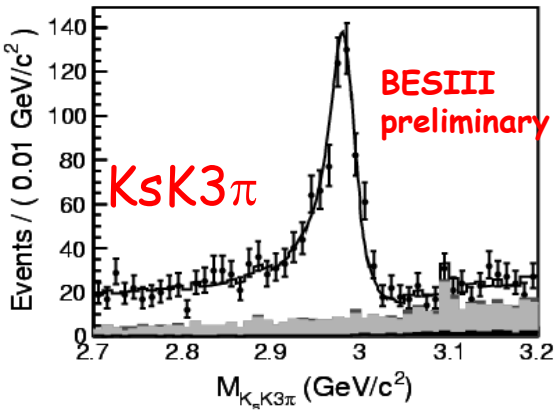
- The lowest lying S-wave spin singlet charmonium η_c was discovered in 1980 by MarkII.
- Earlier experiments using J/ψ radiative transition gives $M(\eta_c)\sim2978.0 MeV/c^2$, $\Gamma(\eta_c)\sim10 MeV$.
- Recent studies using the two-photon processes gives $M(\eta_c)=2983.1\pm1.0\ MeV/c^2$, $\Gamma(\eta_c)=31.3\pm1.9\ MeV$.
- The most recent study from CLEO-c pointed out the distortion of the η_c line shape in ψ′ decays.
- Measurement of the η_c properties at BESIII
  - ◆Data sample: 106M ψ′events, 45pb^{-1} continuum data at 3.65 GeV
  - ◆Decay modes X_i: KsKπ, $K^+K^-\pi^0$, $\eta\pi^+\pi^-$, KsK3π, $K^+K^-\pi^+\pi^-\pi^0$, $3(\pi^+\pi^-)$, where Ks→$\pi^+\pi^-$, η→γγ, π^0→γγ

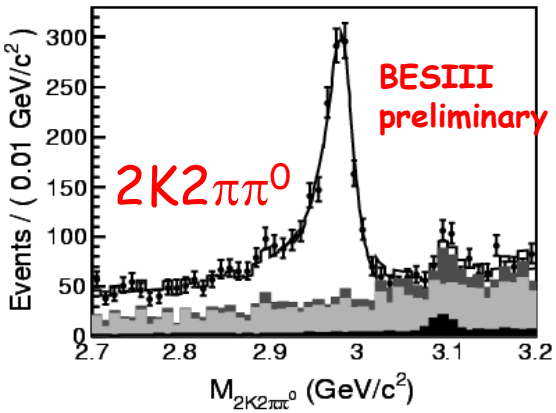
η_c resonance parameters from $\psi' \to \gamma\eta_c$

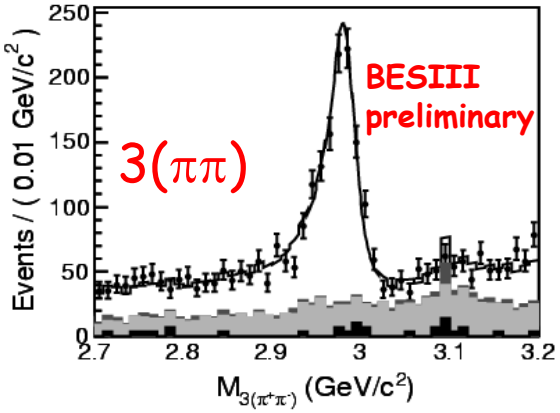












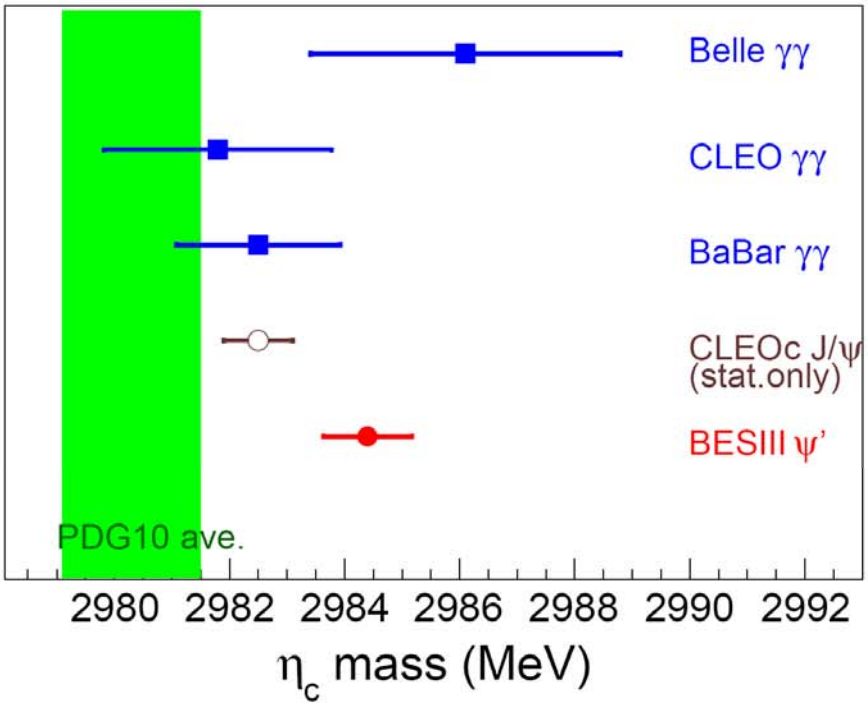
Simultaneous fit with r-BW by considering **the interference between η_c and non-η_c decays**, as well as the energy dependence of phase space:

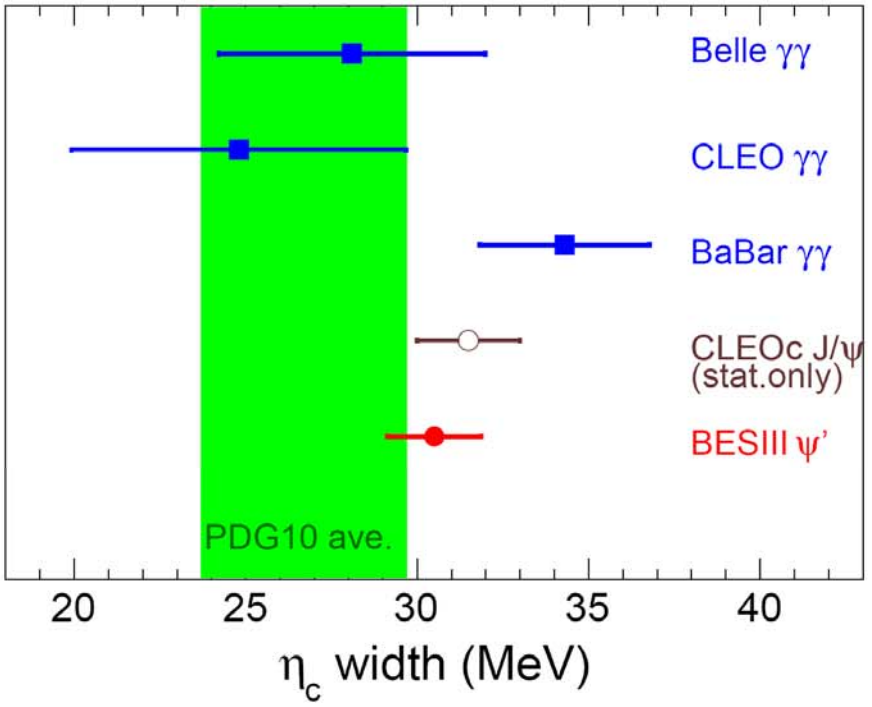
mass: $2984.4 \pm 0.5_{stat} \pm 0.6_{sys}$ MeV/c^2
width: $30.5 \pm 1.0_{stat} \pm 0.9_{sys}$ MeV
ϕ: $2.35 \pm 0.05_{stat} \pm 0.04_{sys}$ rad

ϕ: relative phase between η_c decay and non-resonant component under the signal region by assuming all non-η_c is 0^{-+}, and an universal phase for different modes is used.

Comparison of the mass and width for η_c

The world average in PDG2010 was using earlier results





BESIII results include both stat. and syst. errors, which is the most precision measurement.

First observation of the M1 transition $\psi' \rightarrow \gamma\eta_c(2S)$

Introduction

- First "observation" by Crystal Ball in 1982 (M=3.592, B=0.2%-1.3% from $\psi' \to \gamma X$, never confirmed by other experiments.)

- Published results about $\eta_c(2S)$ observation:

Experiment	M [MeV]	Γ [MeV]	Process
Belle [1]	$3654 \pm 6 \pm 8$	—	$B^{\pm} \to K^{\pm}\, \eta_c(2S), \eta_c(2S) \to K_S K^{\pm}\pi^{\mp}$
CLEO [2]	$3642.9 \pm 3.1 \pm 1.5$	$6.3 \pm 12.4 \pm 4.0$	$\gamma\gamma \to \eta_c(2S) \to K_S K^{\pm}\pi^{\mp}$
BaBar [3]	$3630.8 \pm 3.4 \pm 1.0$	$17.0 \pm 8.3 \pm 2.5$	$\gamma\gamma \to \eta_c(2S) \to K_S K^{\pm}\pi^{\mp}$
BaBar [4]	$3645.0 + 5.5^{+4.9}_{-7.8}$	—	$e^+e^- \to J/\psi c\bar{c}$
PDG [5]	3638 ± 4	14 ± 7	—

Combined with the results based on two-photon processes from BaBar and Belle reported at ICHEP 2010, the world average $\Gamma(\eta_c(2S))=12 \pm 3$ MeV

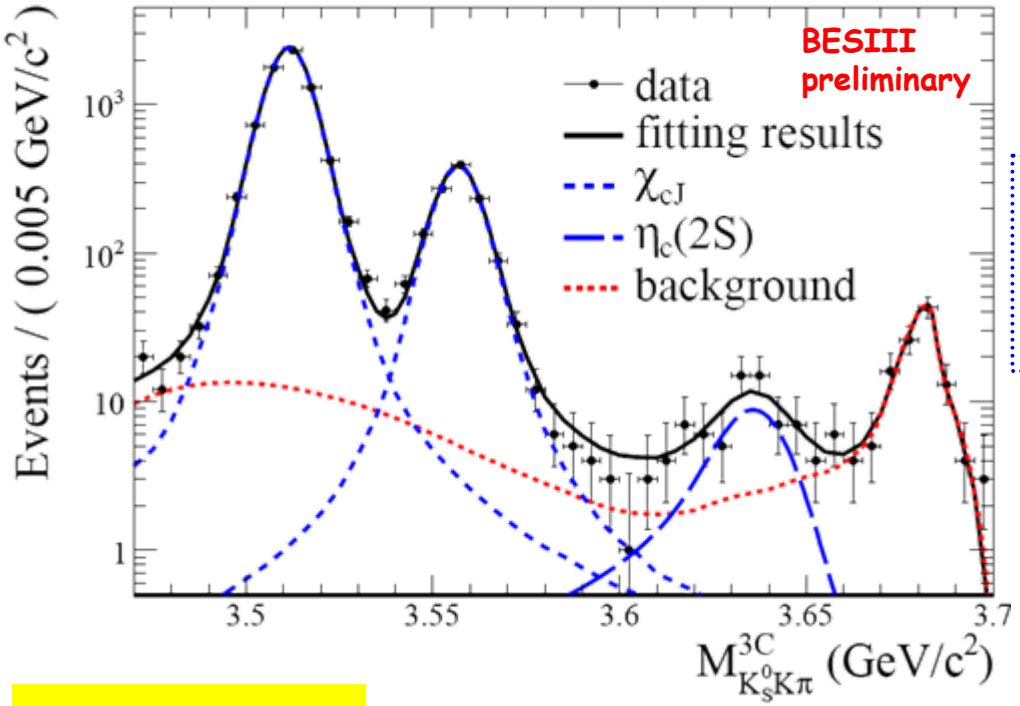
- The M1 transition $\psi' \to \gamma\eta_c(2S)$ has not been observed.

(experimental challenge : search for real photons ~50MeV,)

- Better chance to observe $\eta_c(2S)$ in ψ' radiative transition with ~106M ψ' data at BESIII.

- Decay mode studied: $\psi' \to \gamma\eta_c(2S) \to \gamma K_S K\pi$ ($K^+K^-\pi^0$ etc. in progress)

Observation of $\eta_c(2S)$ in $\psi' \to \gamma\eta_c(2S), \eta_c(2S) \to K_s K\pi$



With 106M ψ' events:

BESIII fit results:

$M(\eta_c(2S)) = (3638.5 \pm 2.3 \pm 1.0)$ MeV/c^2
$N(\eta_c(2S)) = 50.6 \pm 9.7$
Statistical significance larger than 6.0σ!

$Br(\psi' \to \gamma\eta_c(2S) \to \gamma K_s K\pi) = (2.98 \pm 0.57_{stat} \pm 0.48_{sys}) \times 10^{-6}$

+

$Br(\eta_c(2S) \to KK\pi) = (1.9 \pm 0.4 \pm 1.1)\%$
From BABAR(PRD78,012006)

$Br(\psi' \to \gamma\eta_c(2S)) = (4.7 \pm 0.9_{stat} \pm 3.0_{sys}) \times 10^{-4}$

CLEO-c: <7.6×10^{-4}
PRD81,052002(2010)

Potential model: (0.1–6.2)×10^{-4}
PRL89,162002(2002)

Mass fitting:

χ_{cJ}: MC shape ⊗ a Gaussian

$\eta_c(2S)$ signal:

$$(E_\gamma^3 \times BW(m) \times damping(E_\gamma)) \otimes Gauss(0, \sigma)$$

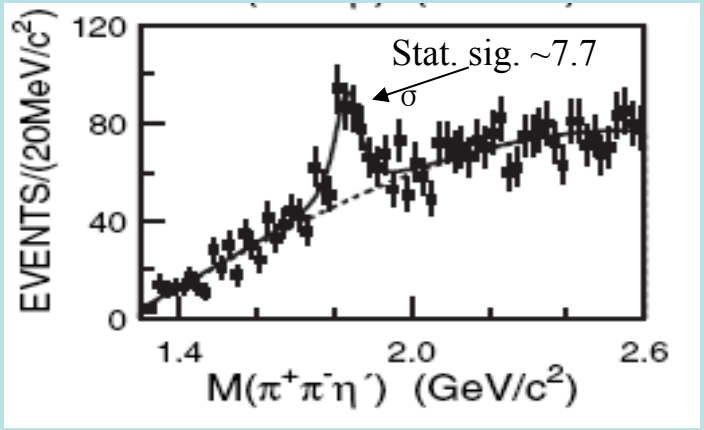
M1 transition

$$\frac{E_0^2}{E_\gamma E_0 + (E_\gamma - E_0)^2}$$

$\Gamma(\eta_c(2S))$ fixed to 12MeV (world average)

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

Confirmation of X(1835) and two new structures

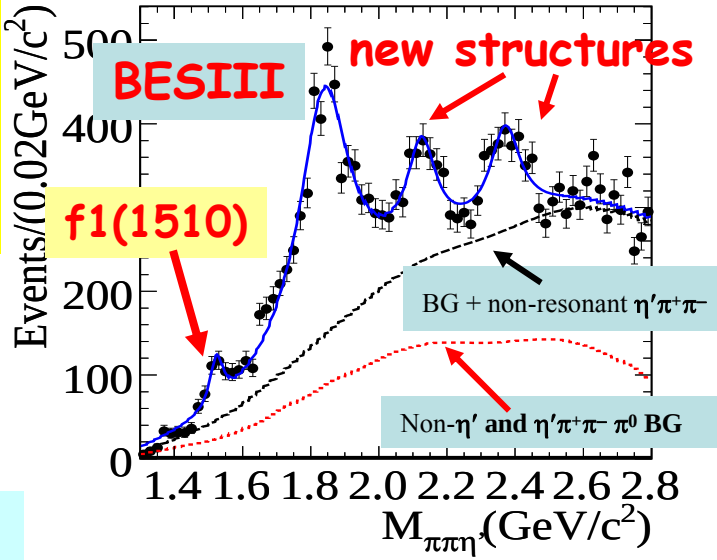


BESII PRL 95,262001(2005)

Decay modes:
$J/\psi \to \gamma\eta'\pi^+\pi^-$
$\eta' \to \eta\pi^+\pi^-$
$\eta' \to \gamma\rho$

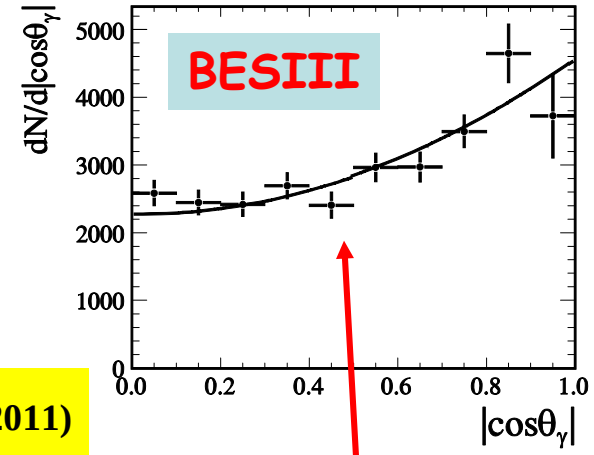
BESIII: 225M J/ψ events, new structures!

PRL 106, 072002(2011)



BESIII results:

Resonance	M(MeV/c^2)	Γ(MeV/c^2)	Stat.Sig.
X(1835)	$1836.5 \pm 3.0^{+5.6}_{-2.1}$	$190.1 \pm 9.0^{+38}_{-36}$	>20 σ
X(2120)	$2122.4 \pm 6.7^{+4.7}_{-2.7}$	$83 \pm 16^{+31}_{-11}$	7.2 σ
X(2370)	$2376.3 \pm 8.7^{+3.2}_{-4.3}$	$83 \pm 17^{+44}_{-6}$	6.4 σ



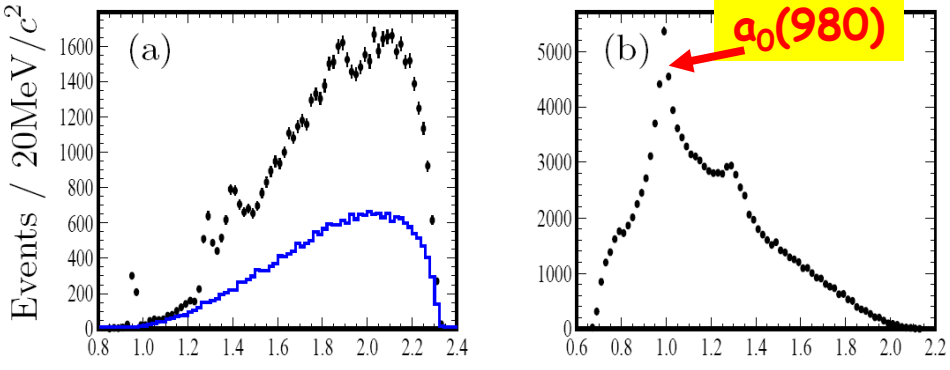
Nature of X(2120)/X(2370): (PRD82,074026,2010, PRD**83:114007,2011**)
pseudoscalar glueball ? η/η′ excited states?

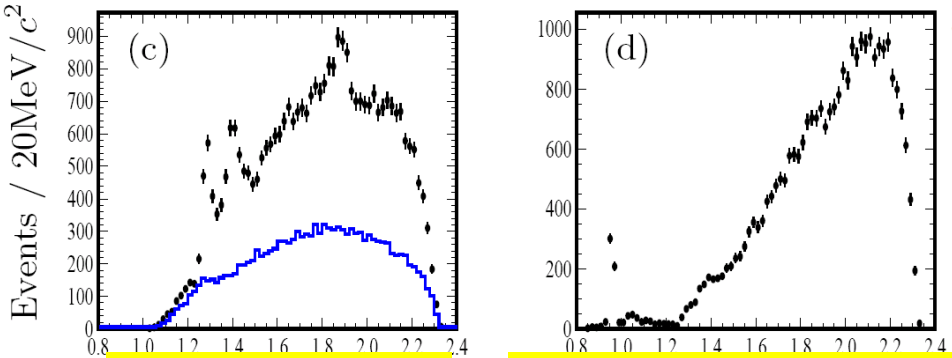
X(1835) consistent with 0^{-+}, but the others are not excluded

An amplitude analysis could help with interpretation for the additional new structures!

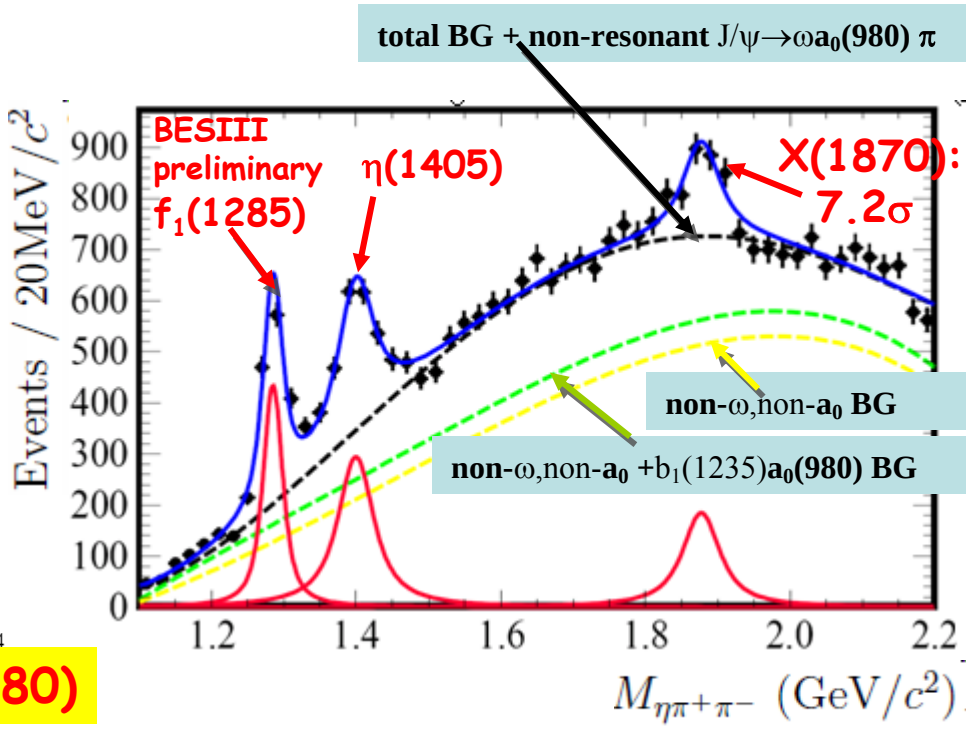
Observation of X(1870) in $J/\psi \to \omega X, X \to a_0(980)\pi$

X(1870) in $J/\psi\to\omega X$, $X\to a_0^{\pm}(980)\pi^{\mp}$ [hep-ex]1107.1806





Decay mode: $J/\psi\to\omega\eta\pi^+\pi^-$, $a_0(980)$ reconstructed in $\eta\pi^{\pm}$



BESIII fit results: 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})
$f_1(1285)$	$1285.1 \pm 1.0^{+1.6}_{-0.3}$	$22.0 \pm 3.1^{+2.0}_{-1.5}$	$1.25 \pm 0.10^{+0.19}_{-0.20}$
$\eta(1405)$	$1399.8 \pm 2.2^{+2.8}_{-0.1}$	$52.8 \pm 7.6^{+0.1}_{-7.6}$	$1.89 \pm 0.21^{+0.21}_{-0.23}$
$X(1870)$	$1877.3 \pm 6.3^{+3.4}_{-7.4}$	$57 \pm 12^{+19}_{-4}$	$1.50 \pm 0.26^{+0.72}_{-0.36}$

Identification of X(1870): 0^{-+}(?) It is X(1835)? Need PWA!

Summary

- BESIII is successfully operating since 2008:
  1. recorded huge data samples at J/ψ, ψ' and $\psi(3770)$.
  2. more data (also at higher energies) in future.

- Charmonium spectroscopy and transitions:
  1. measured the h_c resonance parameters (inclusive & exclusive).
  2. measured the $\eta_C(1S)$ parameters precisely in $\psi' \to \gamma\eta_c(1S)$.
  3. first observed of $\eta_c(2S)$ in $\psi' \to \gamma\eta_c(2S)$ decay.

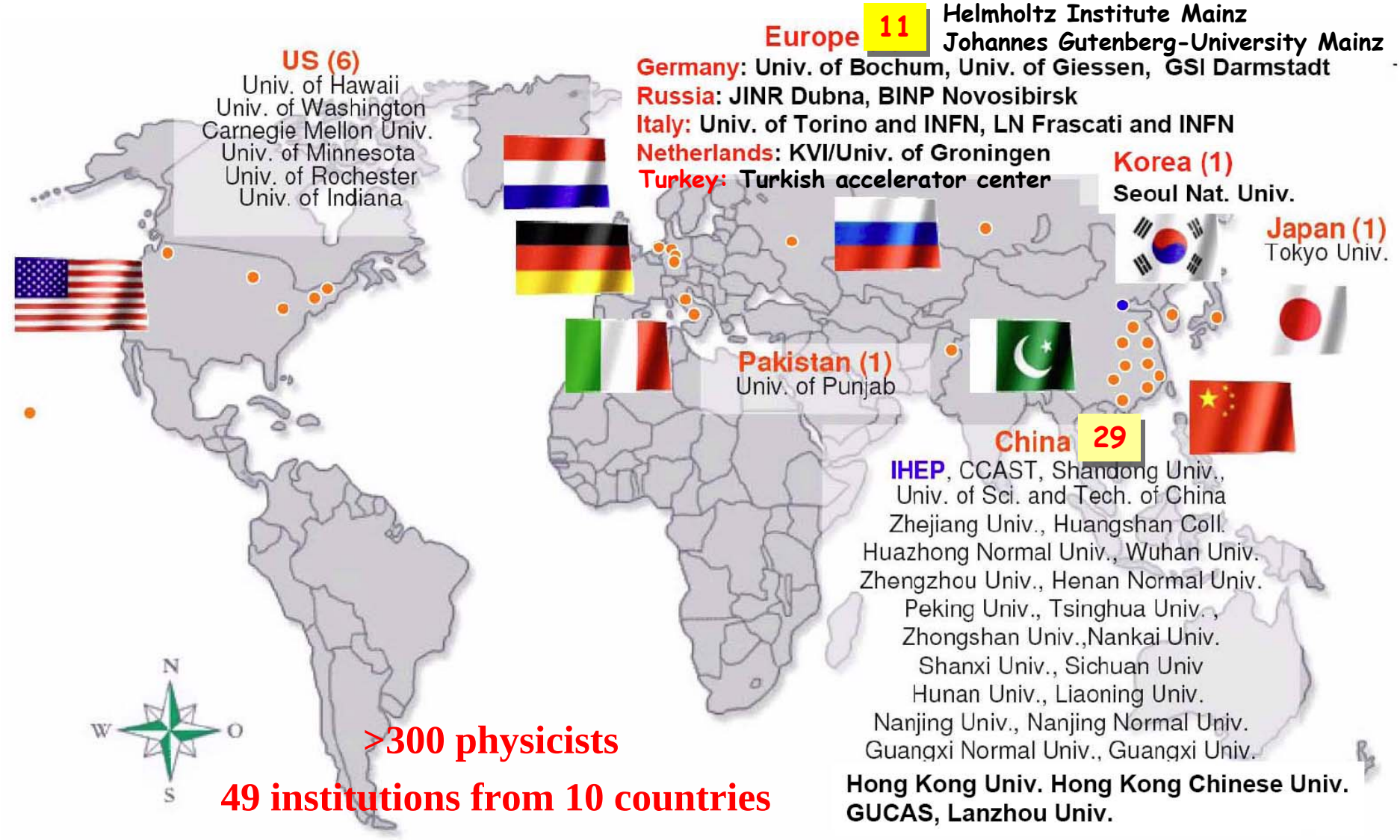
- Light quark states
  1. confirmed X(1835) with two new structures in $J/\psi \to \gamma\pi\pi\eta'$.
  2. observed a new structure X(1870) in $J/\psi \to \omega\pi\pi\eta$.

- **We expect rich physics results in the coming years from BESIII.**

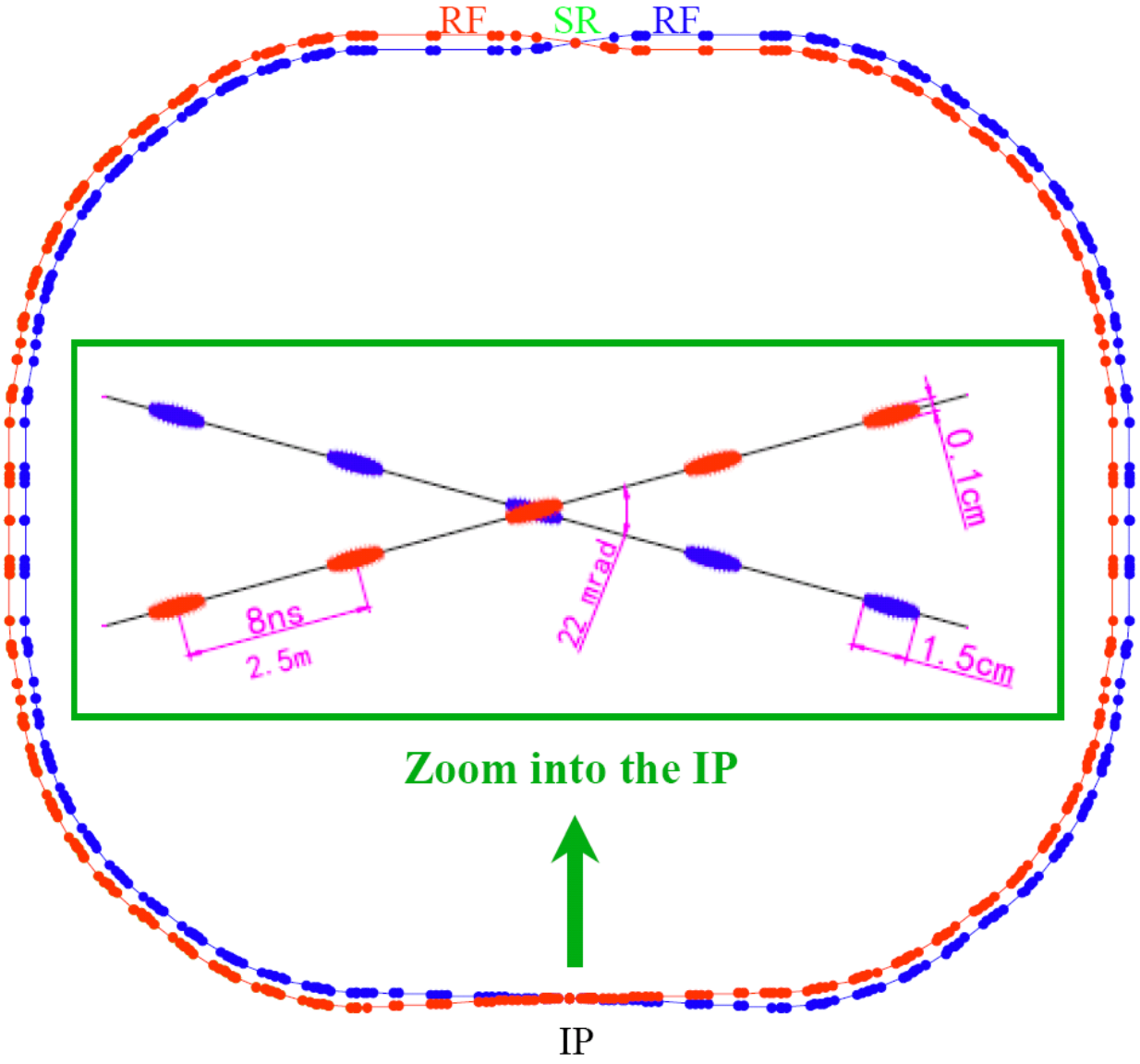
Thank you!

Backups

BESIII Collaboration



BEPCII storage rings



Beam energy:
1.0-2.3 GeV
Design Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
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
Circumference:
237m

Fitting function $\psi' \to \gamma\eta_c$

$$\sigma \bigotimes (\epsilon |e^{i\phi} f_1 \mathcal{S} + \alpha Non|^2 f_2) + BKG$$

- **S**: signal function (BW with mass width floated)
- **Non**: non-resonant γX_i PDF (a 2nd-order Chebychev function with free parameters)
- **BKG**: the sum of other backgrounds $\pi^0 X_i$ + other rare ψ' decays + continuum, fixed in the fitting
- ϕ: interference phase
- α: the strength of the non-resonant
- ε: mass-dependent efficiency
- σ: experimental resolution
- $\mathbf{f_1^2 f_2}$: M1 form factor ($E_\gamma^4 E_\gamma^3 = E_\gamma^7$)

Preliminary: relative phase between η_c decays and non-η_c background

mode	yield	ϕ_i (stat.)	χ^2/ dof
$K_S K\pi$	880.4	2.9±0.3	1.1
$KK\pi^0$	948.4	2.4±0.4	0.9
$\pi\pi\eta$	573.4	2.2±0.2	1.2
$K_S K3\pi$	432.3	2.3±0.2	0.7
$2K2\pi\pi^0$	1033.6	2.6±0.2	1.2
6π	664.4	2.5±0.1	1.1
combined	4532.5	2.35±0.05	-

ϕ_i values from each mode are consistent within 3σ:
➔ use a common phase in the simultaneous fit.

Fitting function $\psi' \rightarrow \gamma\eta_c(2S)$

- $\eta_c(2S)$ signal:

$\Gamma(\eta_c(2S))$ fixed to 12MeV (world average)

$$(E_\gamma^3 \times BW(m) \times damping(E_\gamma)) \otimes Gauss(0, \sigma)$$

M1 transition

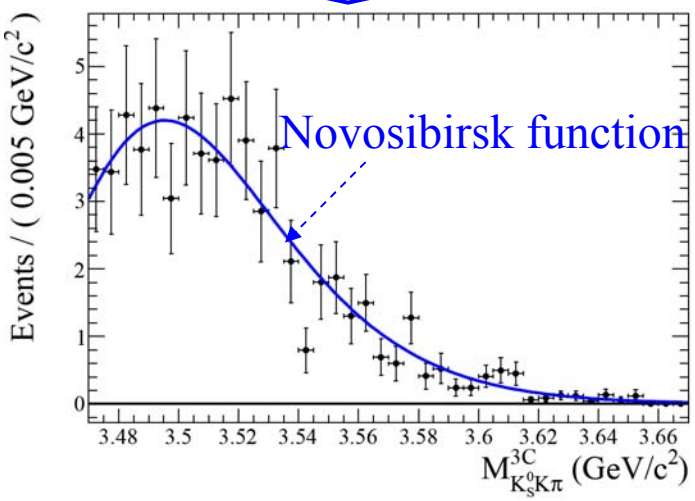
$$\frac{E_0^2}{E_\gamma E_0 + (E_\gamma - E_0)^2}$$

Fixed to the linear Extrapolation from $\sigma(\chi_{cJ})$

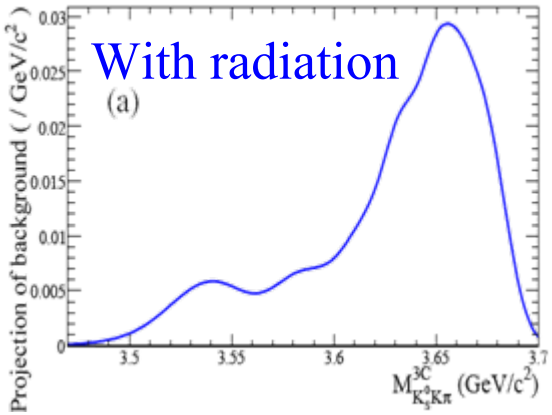
- χ_{cJ}: MC shape ⊗ a Gaussian

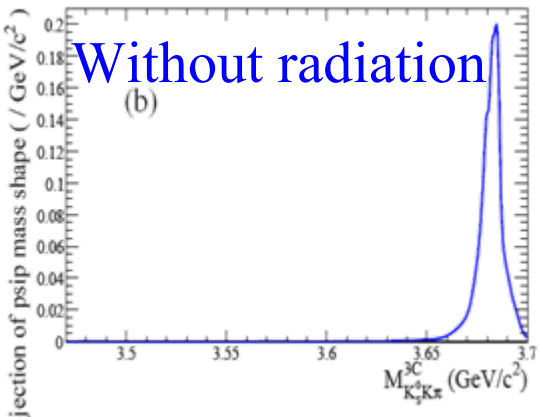
- BG from $\pi^0 K_S K\pi$:

Measurement + scaling with MC simulation



- BG from $\psi' \rightarrow K_S K\pi(\gamma_{FSR})$ & continuum ($K_S K\pi(\gamma ISR)$):

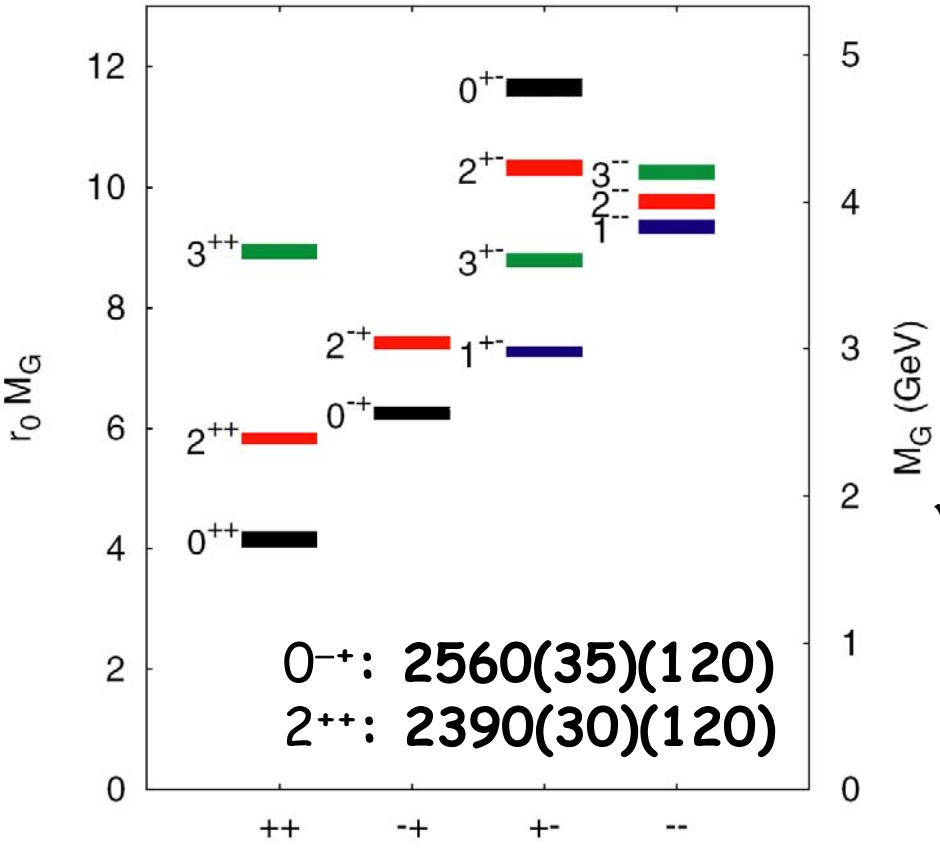




Ratio of the two is fixed in the final mass fitting

Nature of new structures in $J/\psi\to\gamma\eta'\pi^+\pi^-$?

PRD73,014516(2006) Y.Chen et al



✓It is the first time resonant structures are observed in the 2.3 GeV/c2 region, it is interesting since:

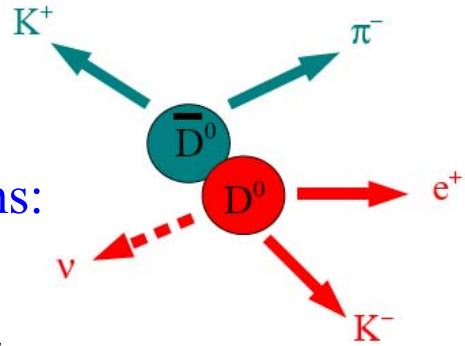
LQCD predicts that the lowest lying pseudoscalar glueball: around 2.3 GeV/c^2.

J/ψ-->$\gamma\pi\pi\eta'$ decay is a good channel for finding 0^{-+} glueballs.

✓Nature of X(2120)/X(2370)
pseudoscalar glueball ?
η/η' excited states?

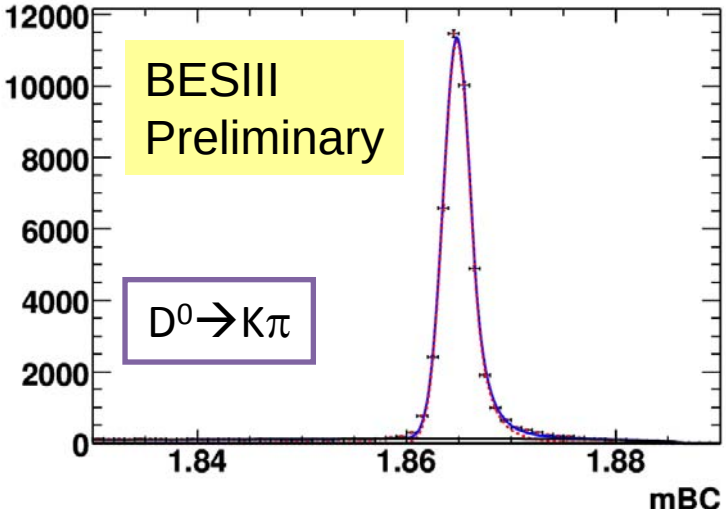
PRD82,074026,2010
J.F. Liu, G.J. Ding and M.L.Yan
PRD**83:114007,2011**
(J.S. Yu, Z.-F. Sun, X. Liu, Q. zhao),
and more…

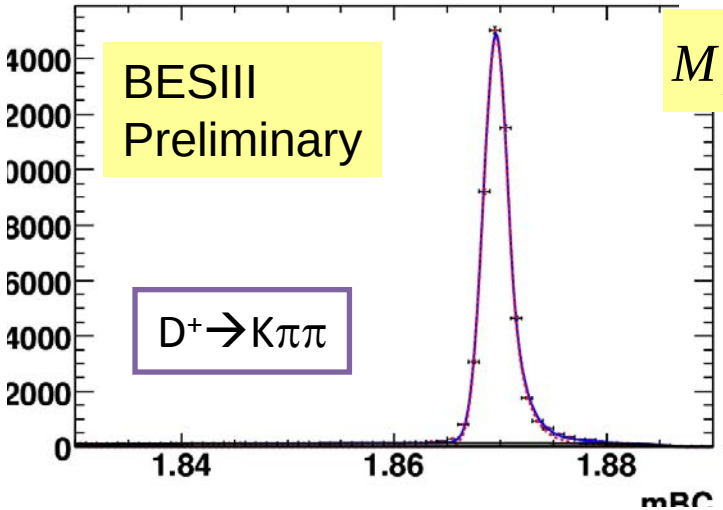
Open charm with BESIII – Stay tuned !

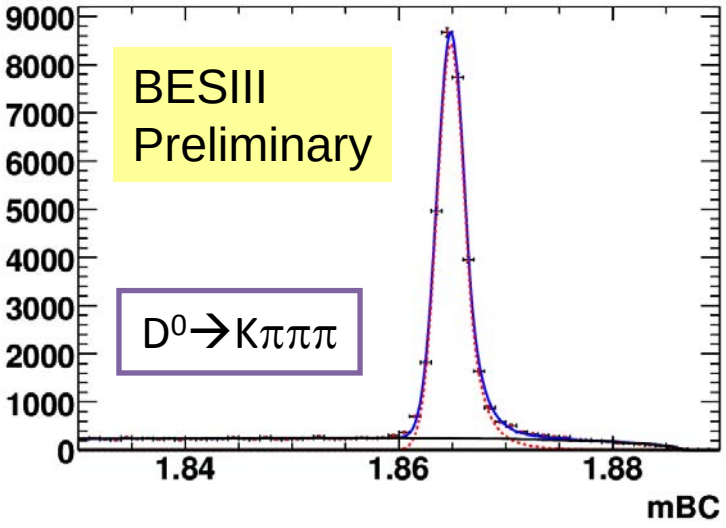


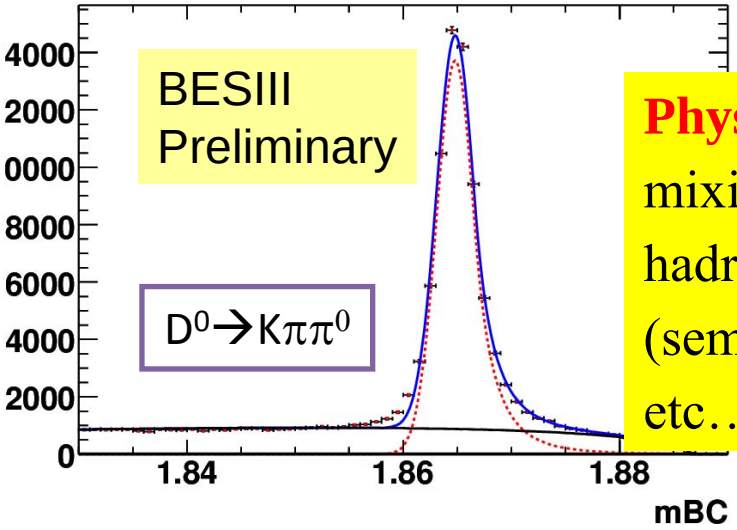
Use $\psi(3770) \rightarrow DD_{bar}$ to produce two quantum correlated D mesons:

@$\psi(3770)$ 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.

Physics:
mixing + CPV,
hadronic decays,
(semi)leptonic decays,
etc…….