Recent Results from BESIII

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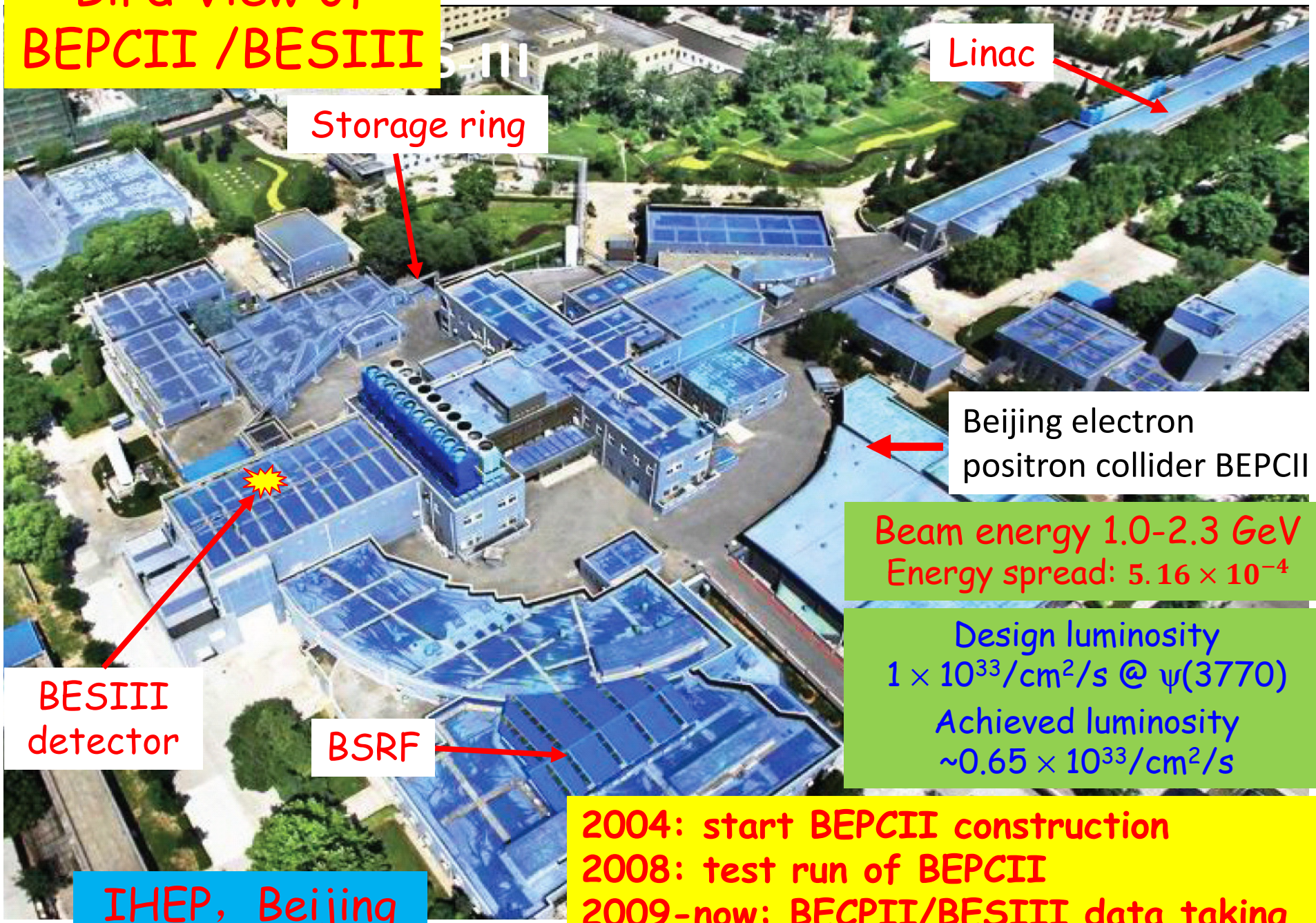
Outline

- Status of BEPCII/BESIII
- Selected Results from BESIII
  - Light Hadron Spectroscopy
  - Charmonium Transitions
  - Charm Decays
  - τ Mass Scan
- Summary

Bird View of BEPCII /BESIII

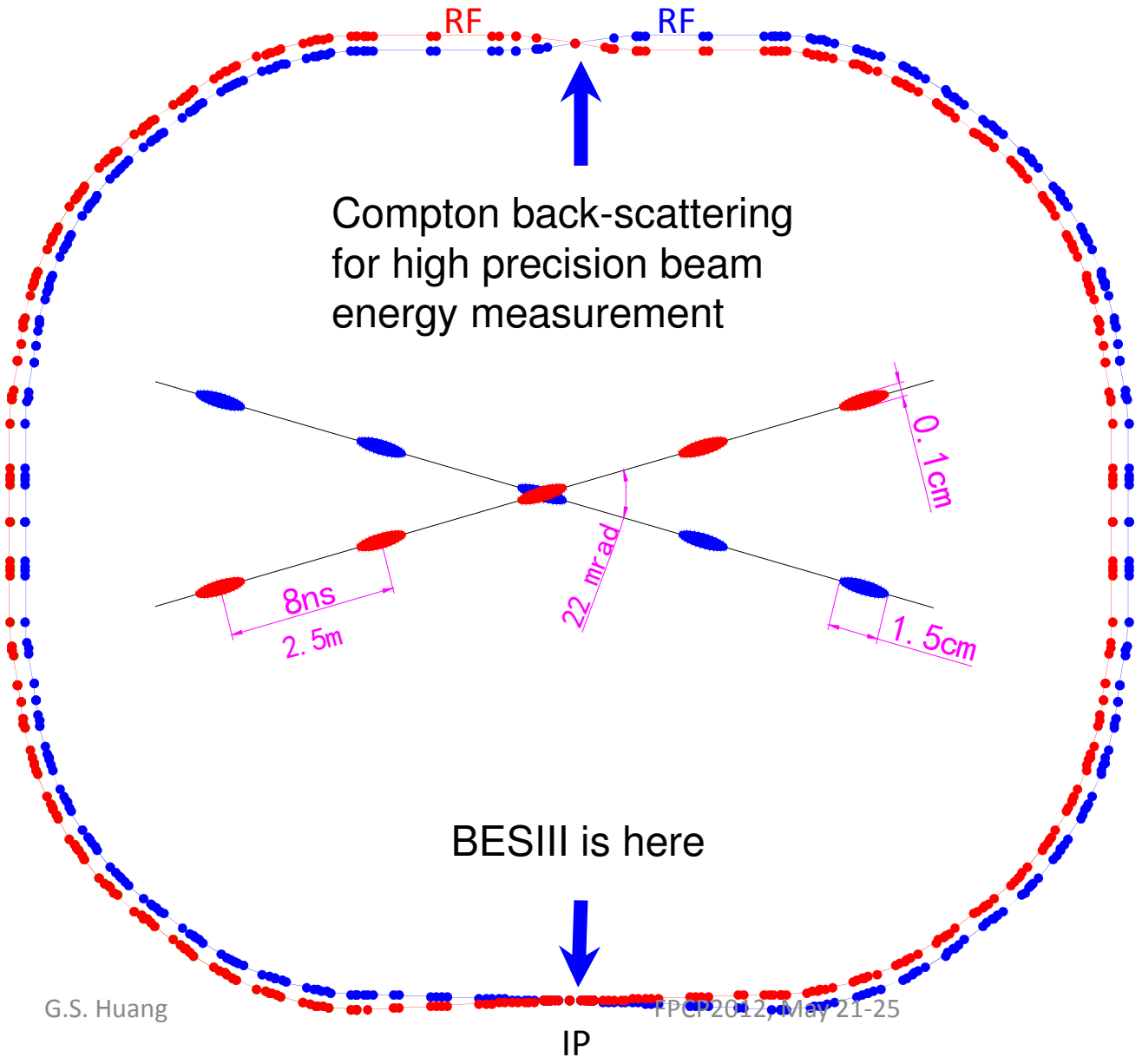


Beam energy 1.0-2.3 GeV
Energy spread: 5.16×10^{-4}

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

BEPC II: Large Crossing Angle, Double-ring



Beam energy:
1-2.3 GeV
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
SR mode:
0.25A@2.5GeV

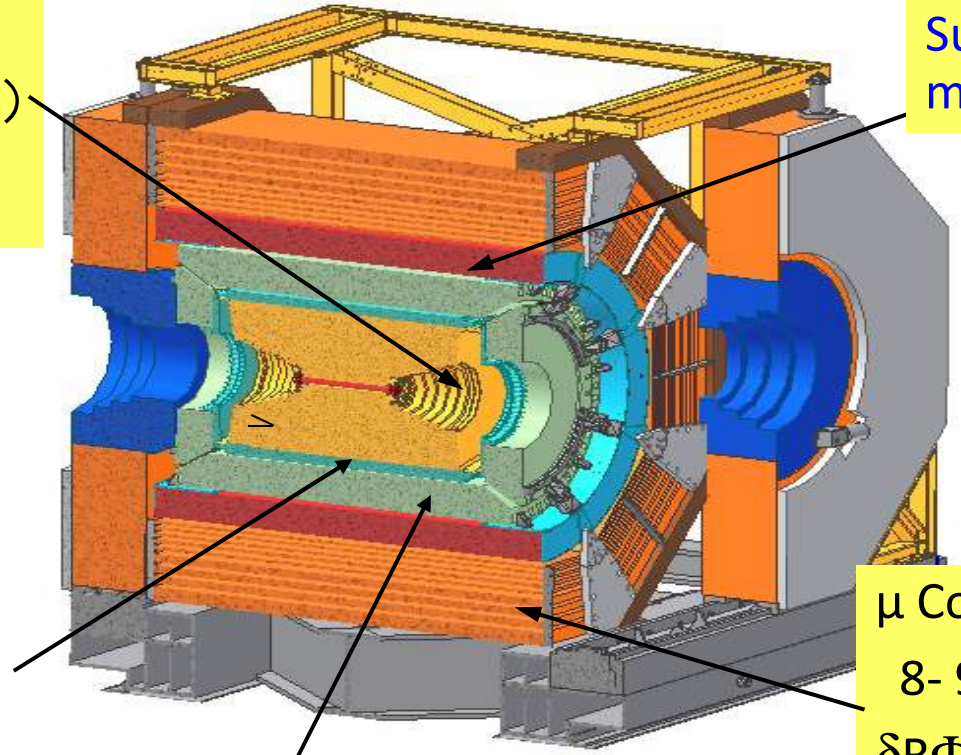
NIM A614, 345 (2010)

The BESIII Detector

Drift Chamber (MDC)

$\sigma p/p\ (^0/_0) = 0.5\%(1GeV)$

$\sigma_{dE/dx}\ (^0/_0) = 6\%$



Super-conducting magnet (1.0 Tesla)

Time Of Flight (TOF)

σ_T: 90 ps Barrel

110 ps endcap

μ Counter

8- 9 layers RPC

$\delta R\Phi$=1.4 cm~1.7 cm

EMC: $\sigma E/\sqrt{E}(^0/_0) = 2.5\ \%\ (1\ GeV)$

(CsI) $\sigma_{z,\phi}(cm) = 0.5 - 0.7\ cm/\sqrt{E}$

BESIII Commissioning

- July 19, 2008: first e^+e^- collision event in BESIII
- Nov. 2008: ~14M $\psi(2S)$ events for detector calibration
- 2009: 106M $\psi(2S)$ 4×CLEO-c
  225M J/ψ 4×BESII
- 2010: ~0.9 fb^{-1} $\psi(3770)$
- 2011: ~2.0 fb^{-1} $\psi(3770)$

  } 3.5×CLEO-c

  ~0.5 fb^{-1} @ 4.01 GeV
- 2012: tau mass scan: ~5.0 pb^{-1} ;
  $\psi(2S)$: 0.4 billion; J/ψ: 1 billion (May 22!)

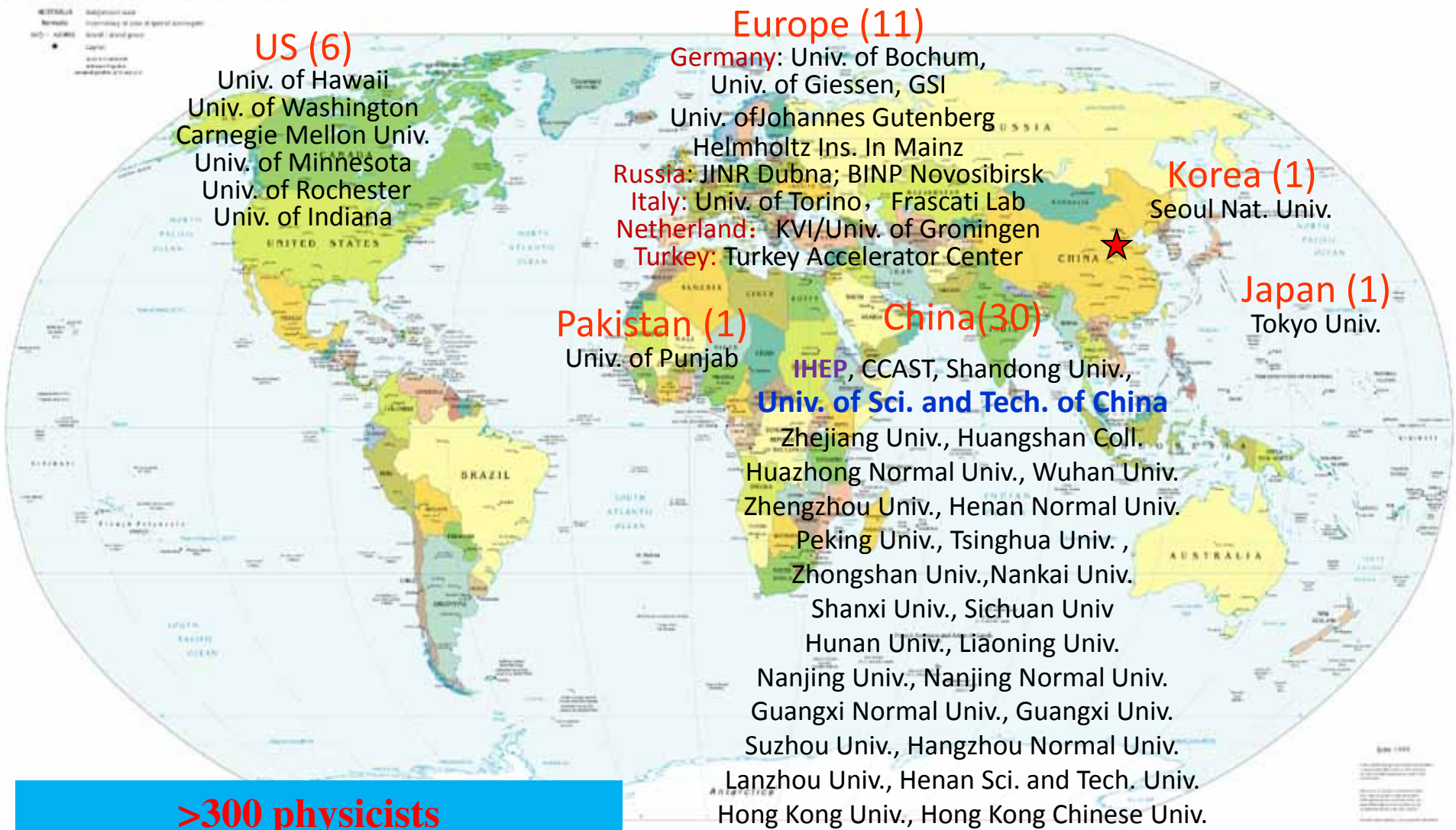
World's largest sample of J/ψ,$\psi(2S)$ and $\psi(3770)$ (and still growing)

Tentative future running plans:

2013: D_s physics (E_{cm}=4170 MeV) + R scan (E_{cm} > 4 GeV)
2014: $\psi(2S)$ / τ / R scan (E_{cm} > 4 GeV);
2015: $\psi(3770)$: 5-10 fb^{-1} for DD physics

The BESIII Collaboration

http://bes3.ihep.ac.cn



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

Europe (11)
Germany: Univ. of Bochum,
Univ. of Giessen, GSI
Univ. ofJohannes Gutenberg
Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino， Frascati Lab
Netherland： KVI/Univ. of Groningen
Turkey: Turkey Accelerator Center

Korea (1)
Seoul Nat. Univ.

Japan (1)
Tokyo Univ.

Pakistan (1)
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IHEP, CCAST, Shandong Univ.,
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Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
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Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.
Univ. of South China, GUCAS.

>300 physicists
50 institutions from 10 countries

Physics Programs @ BESIII

Light hardron physics

-meson & baryon spectroscopy
-threshold effects
-multiquark states
-glueballs & hybrids
-two-photon physics
-form-factors

Charmonium physics:

- precision spectroscopy
- transitions and decays

Charm physics:

- (semi-)leptonic decays
- f_D & f_{D_s} decay constants.
- CKM matrix: V_{cd}, V_{cs}
- D^0-D^0 mixing and *CPV*
- strong phases

QCD & τ-physics:

- precision *R*-measurement
- τ mass / τ decays

XYZ meson physics:

-$Y(4260) \rightarrow \pi\pi h_c$ decays

…

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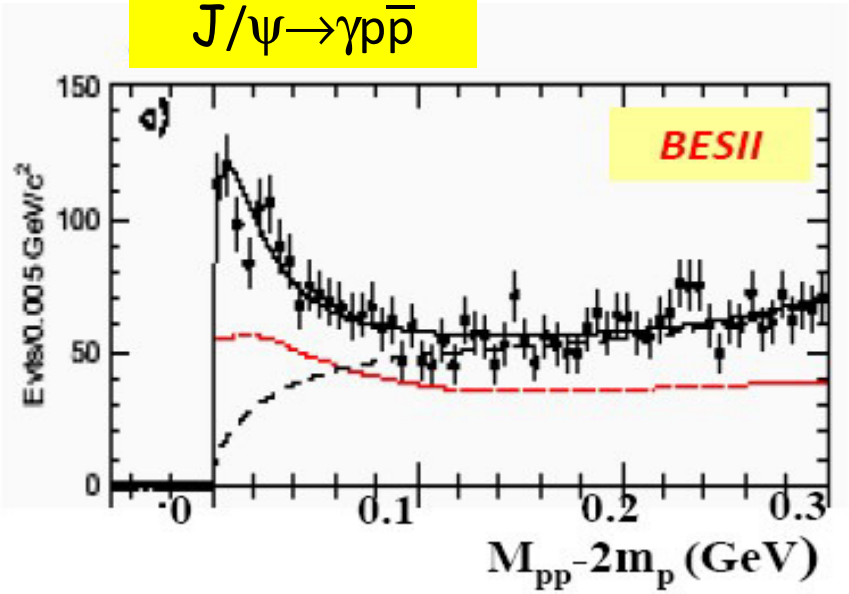
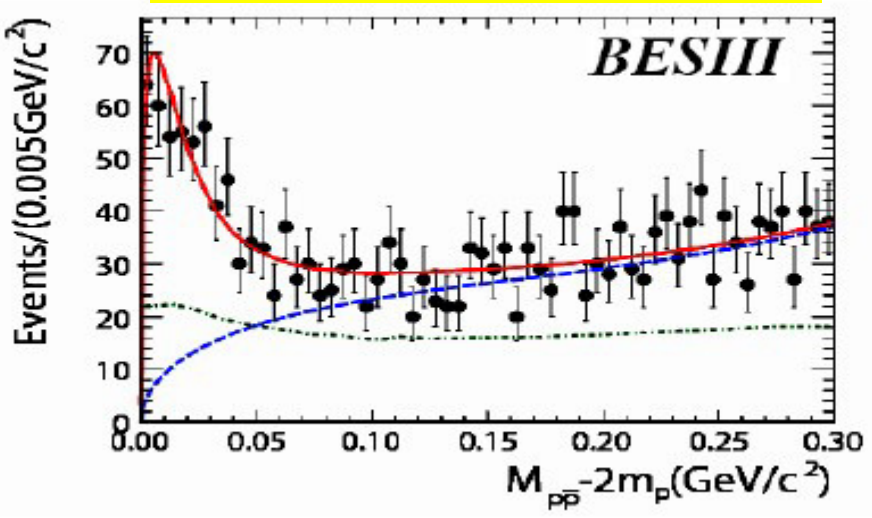
- $\eta(1405)$ in $J/\psi \to \gamma f_0(980)\pi^0$, $f_0(980) \to 2\pi$
- 3π Decays of J/ψ and $\psi(2S)$
- $\omega\phi$ threshold enhancement in $J/\psi \to \gamma\omega\phi$
- $\eta\eta$ system in $J/\psi \to \gamma\eta\eta$

Enhancement at $p\bar{p}$ threshold in $J/\psi \to \gamma p\bar{p}$

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



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



Observed at BESII in 2003 (PRL,022001)
agree with spin zero expectation
M =$1860^{+3}_{-10}{}^{+5}_{-25}$ MeV, Γ< 38 MeV (90% CL)

Confirmed at BESIII in 2010
(CPC 34,421 (2010))
M =$1859^{+6}_{-13}{}^{+6}_{-26}$ MeV, Γ< 30 MeV (90% CL)

Many possibilities:

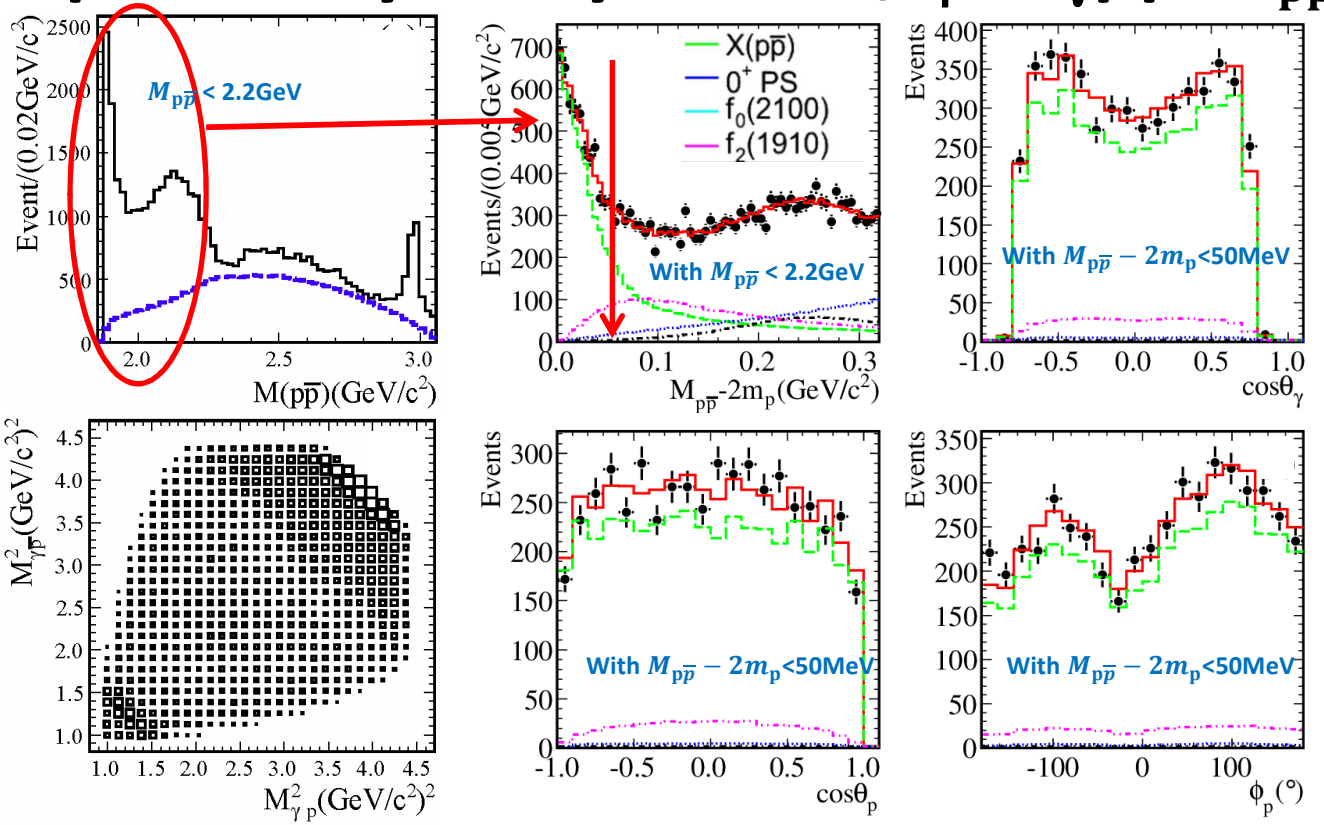
normal meson/ $p\bar{p}$ bound state/multiquark/glueball/Final state interaction effect(FSI)……

Spin-parity analysis

is essential for determining place in the spectrum and possible nature.

PRL 108, 112003 (2012)

Spin-Parity analysis of $J/\psi \to \gamma p\bar{p}$ ($M_{p\bar{p}} < 2.2$GeV)



Four components:

$X(p\bar{p})$, $f_2(1910)$, $f_0(2100)$, and 0^{++} phase space

Include the FSI effect

Fit features:

- The fit with BW and S-wave FSI(I=0) factor can well describe $p\bar{p}$ mass threshold structure.
- It is much better than that Without FSI effect (7.1σ)

Spin-parity, mass, width and Br. of $X(p\bar{p})$:

$J^{PC} = 0^{-+}$ >6.8 σ better than other J^{PC} assignments.

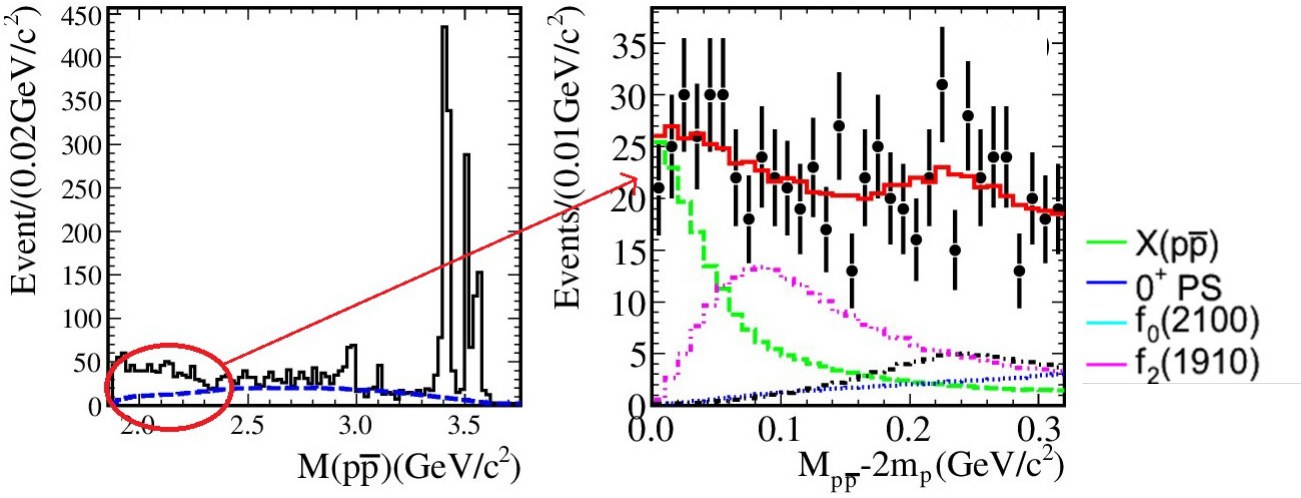
$M = 1832^{+19}_{-5}(\text{stat})^{+18}_{-17}(\text{syst}) \pm 19(\text{model})$ MeV/c^2 model: Model dependent uncertainty (Different FSI models)

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

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

PRL 108, 112003 (2012)

$\psi(2S)\to\gamma p\bar{p}$ ($M_{p\bar{p}}$< 2.2GeV)



M , Γ and J^{PC} of $X(p\bar{p})$ are fixed to the results obtained from J/ψ decays.

$$Br\left(\psi(2S)\to\gamma X(p\bar{p})\right)Br(X(p\bar{p})\to p\bar{p})$$
$$=(4.57\pm0.36(\text{stat})^{+1.23}_{-4.07}(syst)\pm1.28(\text{model}))\times10^{-6}$$

The production ratio R:

$$R=\frac{Br(\psi(2S)\to\gamma X(p\bar{p}))}{Br(J/\psi\to\gamma X(p\bar{p}))}=\left(5.08^{+0.71}_{-0.45}(\text{stat})^{+0.67}_{-3.58}(syst)\pm0.12(\text{model})\right)\%$$

It is suppressed compared with 12% rule.

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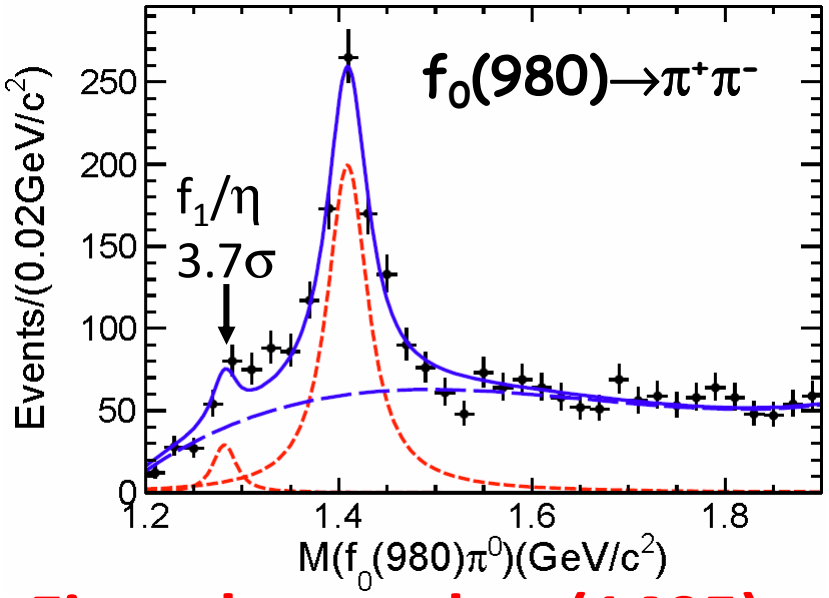
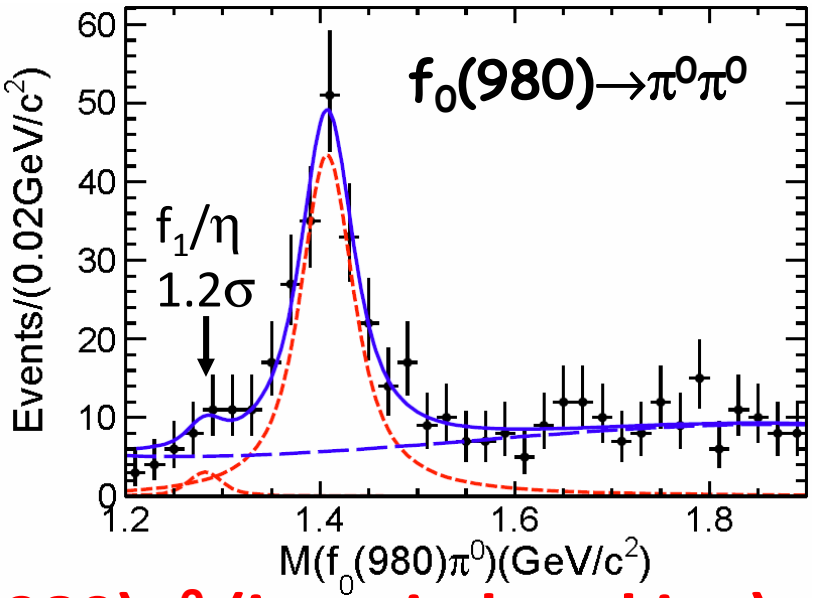
PRL 108, 182001 (2012)

$\eta(1405)$ in $J/\psi \to \gamma f_0(980)\pi^0$, $f_0(980) \to 2\pi$





First observed: $\eta(1405) \to f_0(980)\pi^0$ (isospin breaking)

- Helicity analysis indicates the peak at 1400MeV is from $\eta(1405)$, not from $f_1(1420)$

$$Br(J/\psi \to \gamma\eta(1405) \to \gamma\pi^0 f_0 \to \gamma\pi^0\pi^+\pi^-) = (1.50 \pm 0.11(stat.) \pm 0.11(syst.)) \times 10^{-5}$$

$$Br(J/\psi \to \gamma\eta(1405) \to \gamma\pi^0 f_0 \to \gamma\pi^0\pi^0\pi^0) = (7.10 \pm 0.82(stat.) \pm 0.72(syst.)) \times 10^{-6}$$

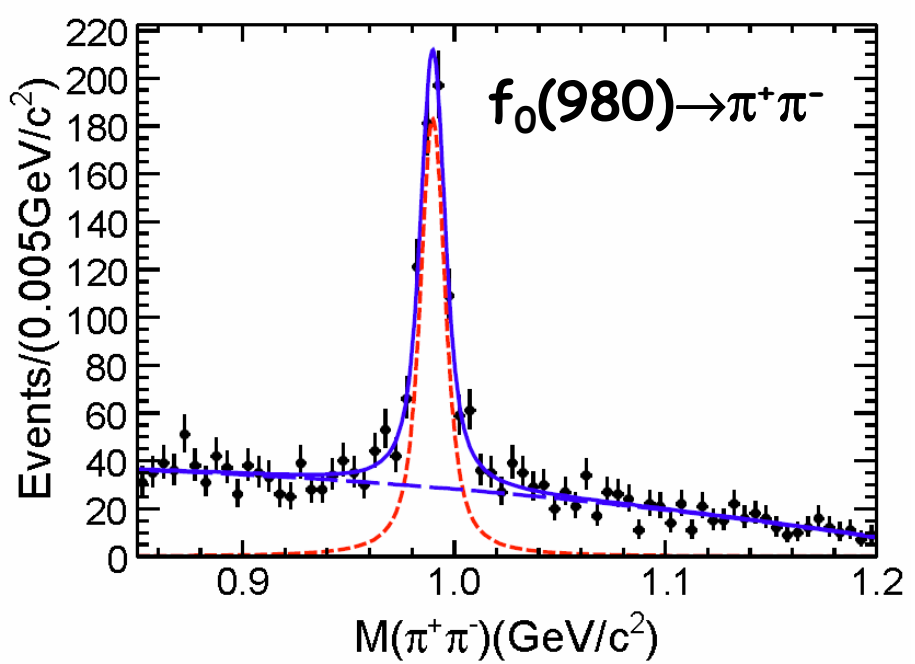
- Large Isospin-violating decay rate:

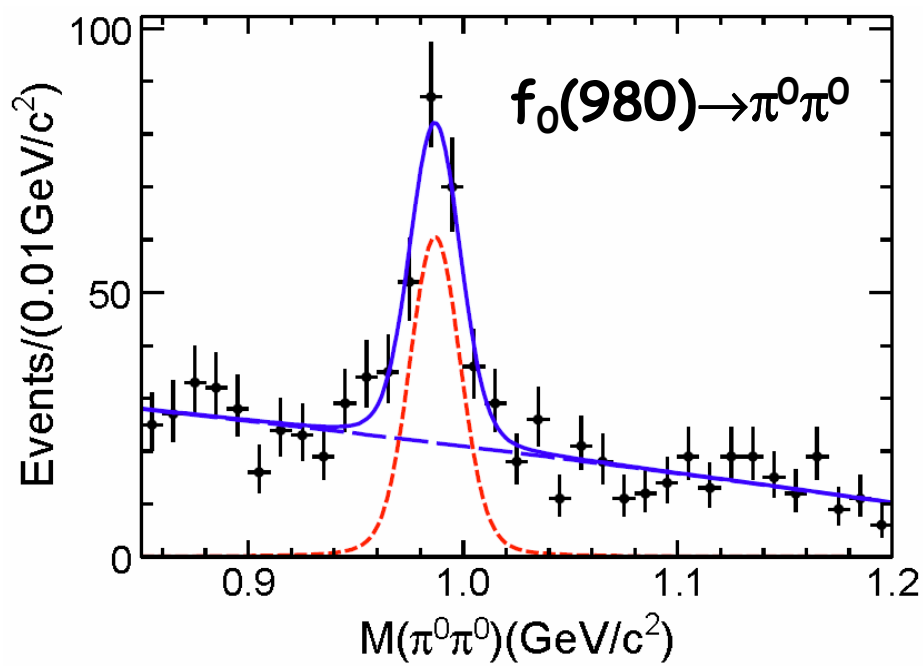
$$\frac{BR(\eta(1405) \to f_0(980)\pi^0 \to \pi^+\pi^-\pi^0)}{BR(\eta(1405) \to a_0(980)\pi^0 \to \pi^0\pi^0\eta)} \approx (17.9 \pm 4.2)\%$$

In general, magnitude of isospin violation in strong decay should be <1%.

$a_0 - f_0$ mixing alone can not explain the branching ratio of $\eta(1405) \to f_0(980)\pi^0$

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





$M = 989.9 \pm 0.4 \mathrm{MeV}/c^2$
$\Gamma = 9.5 \pm 1.1\ \mathrm{MeV}/c^2$

$M = 987.0 \pm 1.4 \mathrm{MeV}/c^2$
$\Gamma = 4.6 \pm 5.1\ \mathrm{MeV}/c^2$

Surprising result:

very narrow $f_0(980)$ width: <11.8 MeV/c^2@90% C.L.

much narrower than the world average (PDG 2010: 40-100 MeV/c^2)

A possible explanation is KK^* loop, Triangle Singularity (TS) (J.J. Wu et al, PRL 108, 081803(2012))

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PLB 710, 594 (2012)

3π Decays of J/ψ and $\psi(2S)$

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

- J/ψ is dominated by ρ
- $\psi(2S)$ is strongly populated by higher mass state absent in J/ψ decay

Precision measurement of branching fractions:

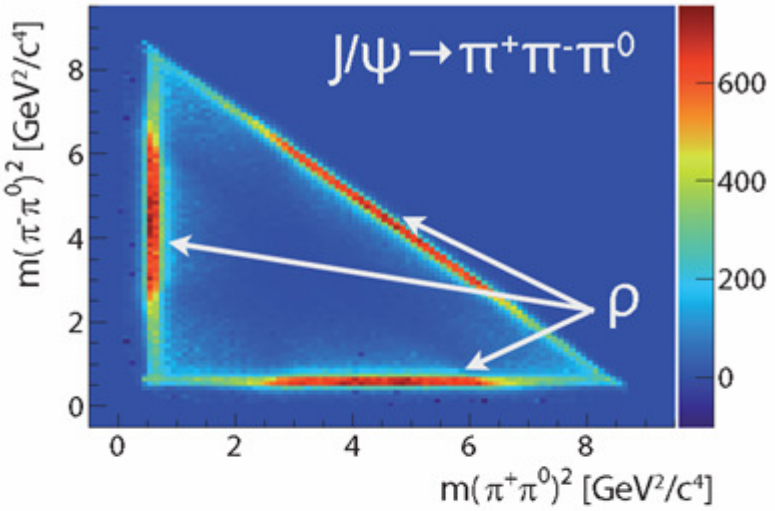
$$Br(J/\psi \to \pi^+\pi^-\pi^0) = (2.137 \pm 0.004(stat)^{+0.058}_{-0.056}(syst)^{+0.027}_{-0.026}(norm)) \times 10^{-2}$$

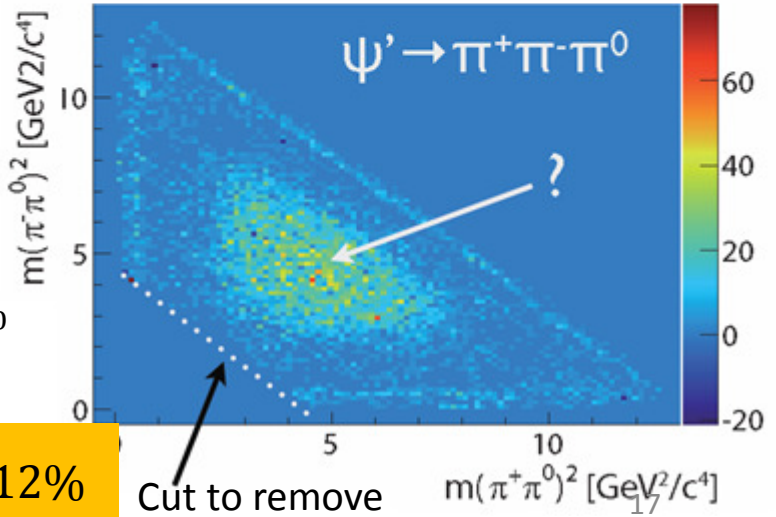
$$Br(\psi(2S) \to \pi^+\pi^-\pi^0) = (2.14 \pm 0.03(stat)^{+0.08}_{-0.07}(syst)^{+0.09}_{-0.08}(norm)) \times 10^{-4}$$

The ratio of these two branching fractions:

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

Dalitz plot with background subtracted and corrected for efficiency:





Cut to remove background

$\rho\pi$ puzzle: $Q_h = \frac{Br(\psi(2S)\to hadrons)}{Br(J/\psi\to hadrons)} \cong \frac{Br(\psi(2S)\to e^+e^-)}{Br(J/\psi\to e^+e^-)} \cong 12\%$

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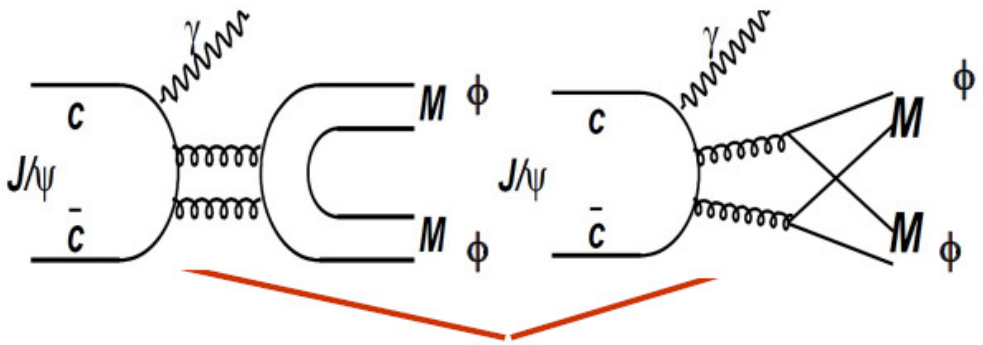
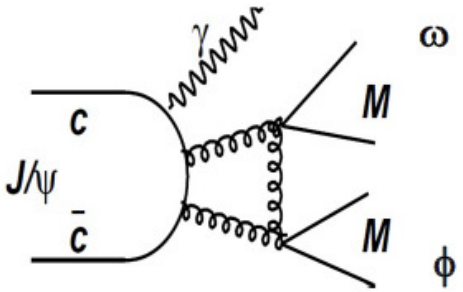
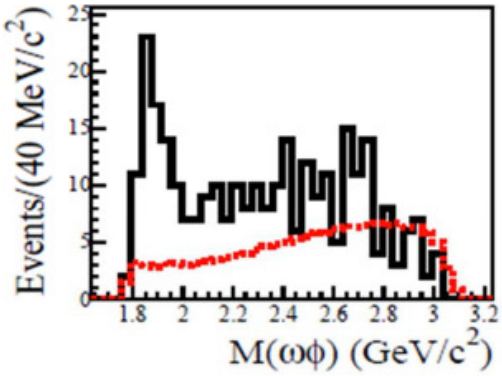
ωϕ threshold enhancement in J/ψ→γωϕ

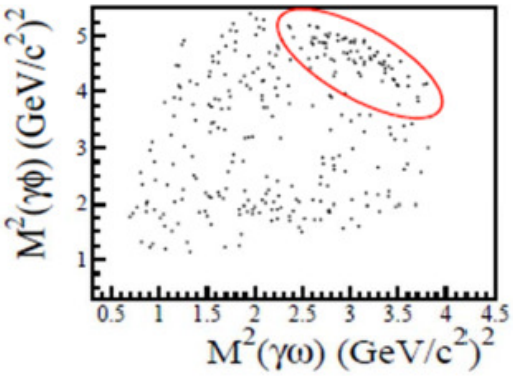




$J/\psi \to \gamma\phi\phi, \phi \to K^+K^-$ **(OZI)** $J/\psi \to \gamma\omega\phi$ **(DOZI)**

BESII





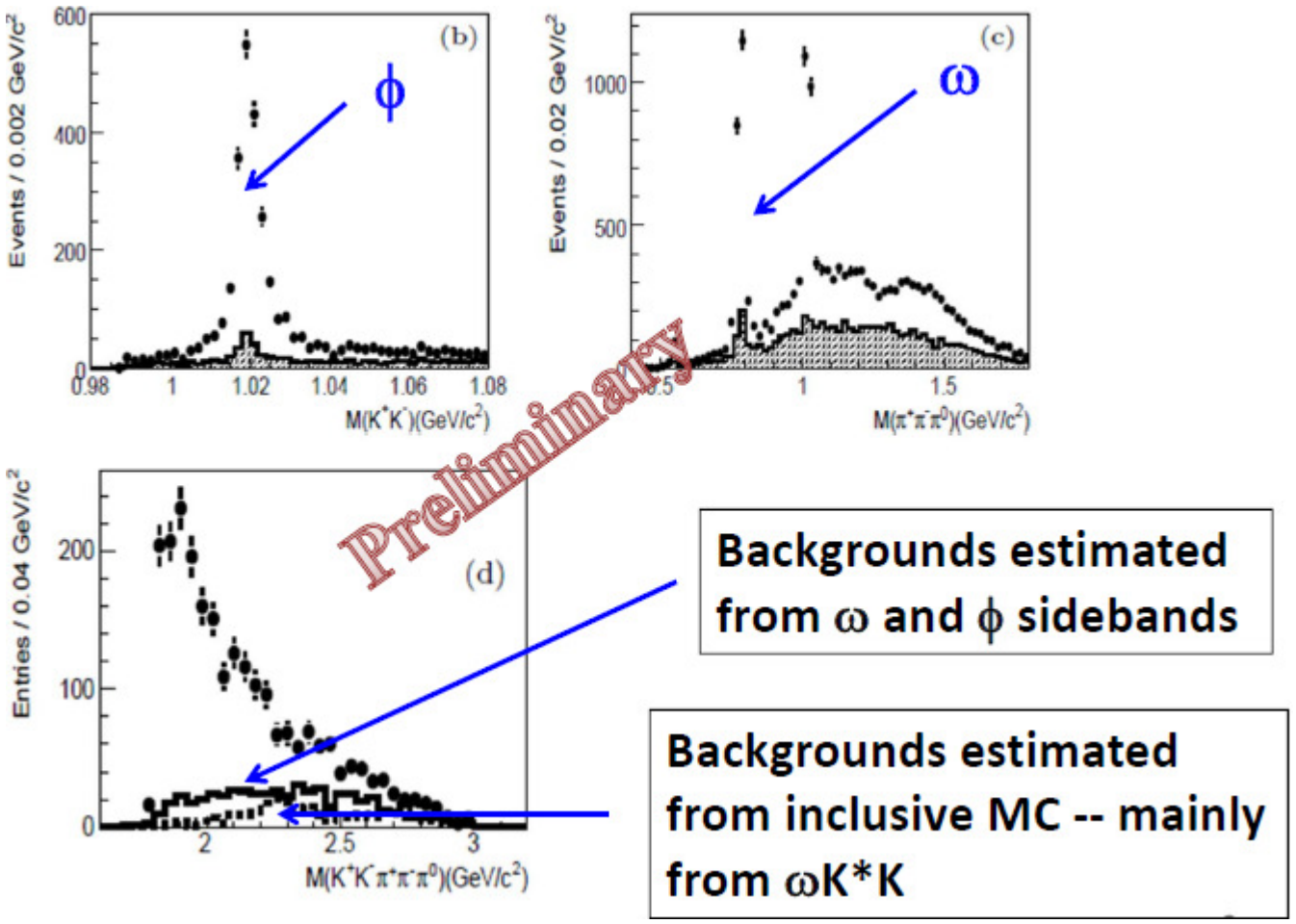
$M = 1812^{+19}_{-26} \pm 18\ \mathrm{MeV/c^2}$

$\Gamma = 105 \pm 20 \pm 28\ \mathrm{MeV/c^2}$

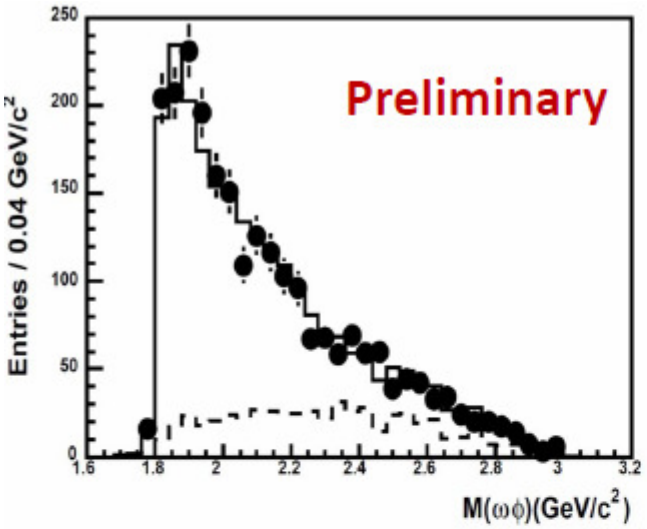
J^{PC} favors 0^{++} over 0^{-+} and 2^{++}

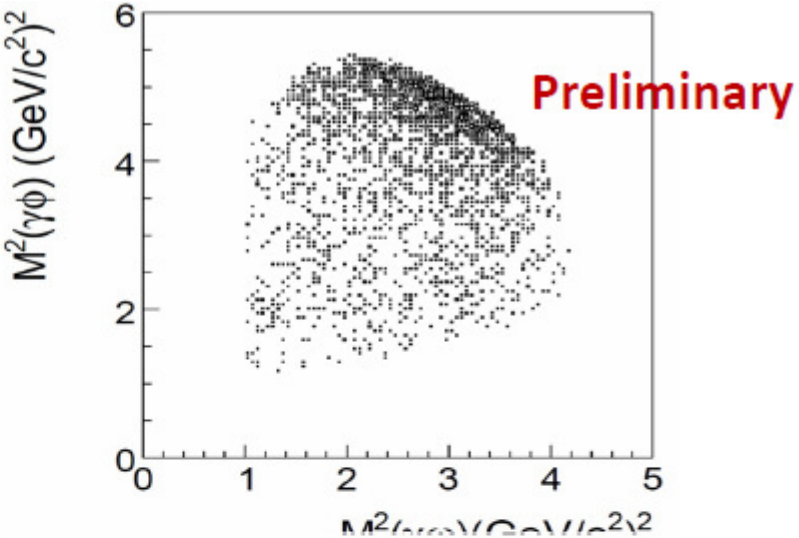
Phys. Rev. Lett. 96(2006)162002

$J/\psi \to \gamma\omega\phi$ at BESIII



Preliminary PWA Results at BESIII





Resonance	J^{PC}	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	Significance
$X(1810)$	0^{++}	1795 ± 7	95 ± 10	$> 30\sigma$
$f_2(1950)$	2^{++}	1944	472	$> 10\sigma$
$f_0(2020)$	0^{++}	[illegible]2	442	$> 10\sigma$
$\eta(2225)$	0^{-+}	2240	1903	6.4σ

Preliminary

Is X(1810) the $f_0(1710)/f_0(1790)$ or new state?

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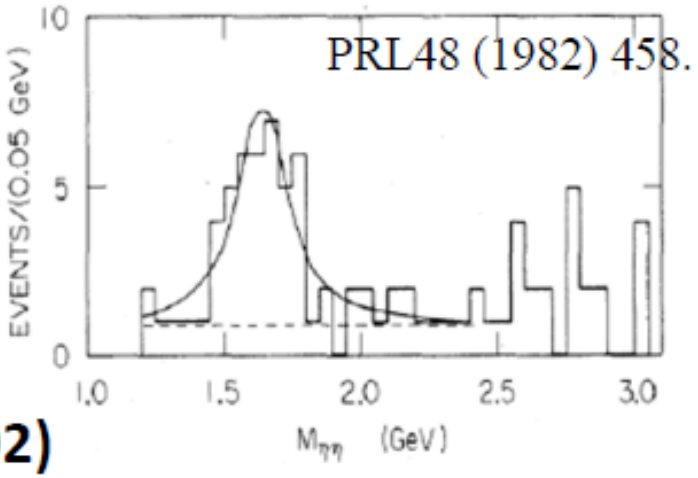
Study of ηη System



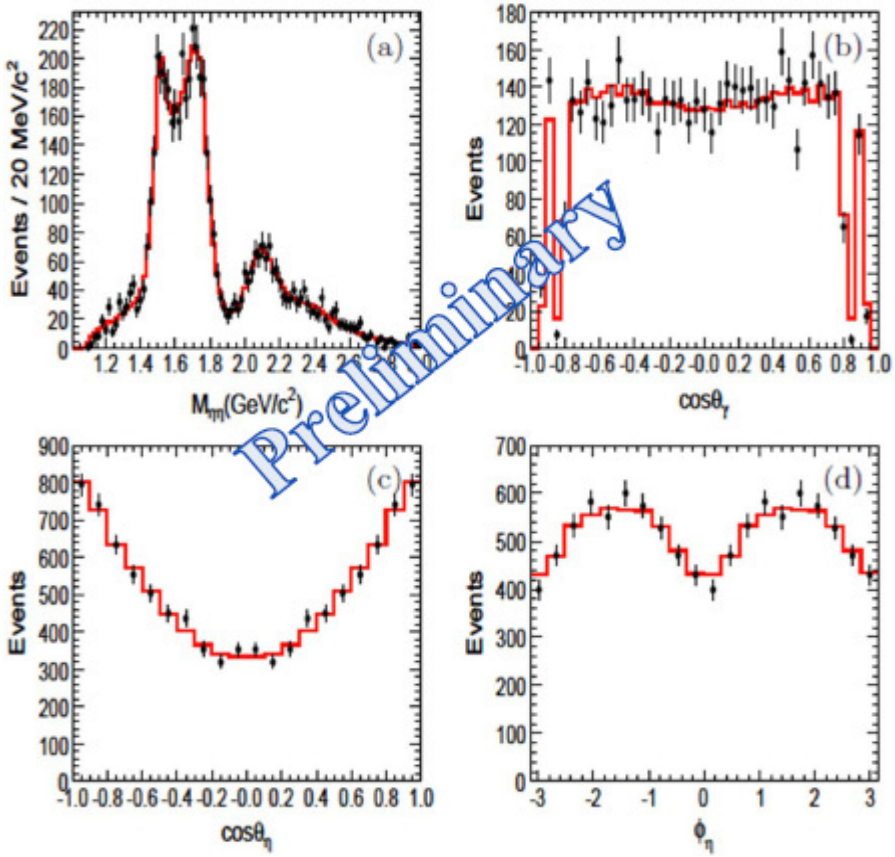
- **First observed $f_0(1710)$ from**
- **J/ψ radiative decays to ηη by Crystal Ball in 1982.**

- **Crystal Barrel Collaboration (2002) analyzed the three final states $\pi^0\pi^0\pi^0$, $\eta\pi^0\pi^0$ and $\pi^0\eta\eta$ with K matrix formalism. Found a 2^{++} (~1870), but no $f_0(1710)$.**

- **E835 (2006): ppbar → $\pi^0\eta\eta$, found $f_0(1500)$ and $f_0(1710)$.**

- **WA102 and GAMS all identified $f_0(1710)$ in ηη.**

$J/\psi \to \gamma\eta\eta$ at BESIII:
Preliminary PWA results



- $f_0(1710)$ and $f_0(2100)$ are dominant scalars
- $f_0(1500)$ exists (8.2σ)
- $f_2'(1525)$ is the dominant tensor

Resonance	Mass(MeV/c^2)	Width(MeV/c^2)	$\mathcal{B}(J/\psi \to \gamma X \to \gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+20}_{-15-74}	$136^{+41+8}_{-26-100}$	$(1.61^{+0.29+0.41}_{-0.32-1.28}) \times 10^{-5}$	$8.2\ \sigma$
$f_0(1710)$	1759^{+6+14}_{-6-25}	172^{+10+31}_{-10-15}	$(2.35^{+0.07+1.23}_{-0.07-0.72}) \times 10^{-4}$	$25.0\ \sigma$
$f_0(2100)$	2081^{+13+23}_{-13-34}	273^{+27+65}_{-24-18}	$(9.[illegible]^{+0.57+5.52}_{-0.52-2.21}) \times 10^{-5}$	$13.9\ \sigma$
$f_2'(1525)$	1513^{+5+3}_{-5-10}	75^{+12+15}_{-10-7}	$(3.41^{+0.43+1.22}_{-0.50-1.23}) \times 10^{-5}$	$11.0\ \sigma$
$f_2(1810)$	1822^{+29+61}_{-24-54}	$229^{+52+64}_{-42-[illegible]}$	$(5.38^{+0.60+3.31}_{-0.67-2.24}) \times 10^{-5}$	$6.4\ \sigma$
$f_2(2340)$	$2362^{+31+139}_{-30-59}$	$334^{+6[illegible]+164}_{-[illegible]-99}$	$(5.58^{+0.61+1.93}_{-0.65-1.81}) \times 10^{-5}$	$7.6\ \sigma$

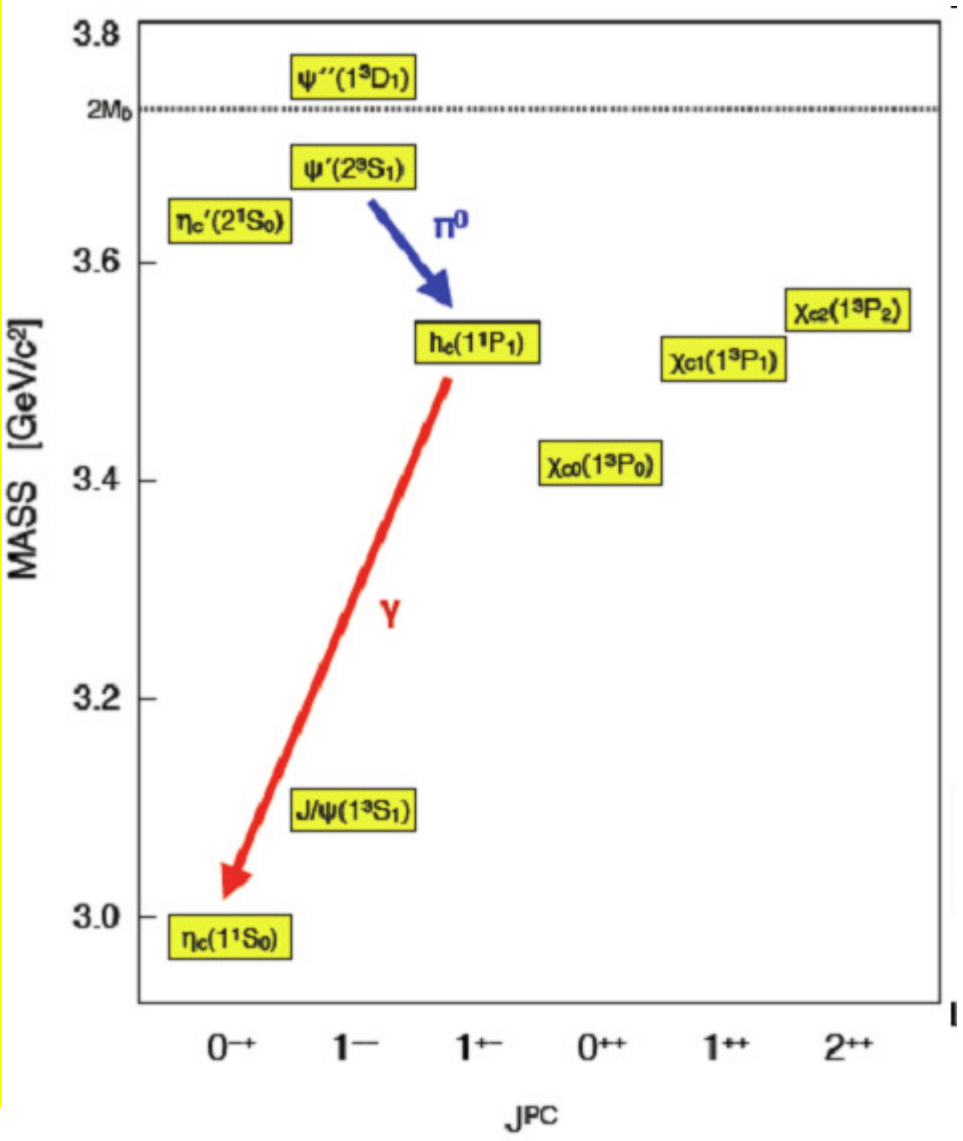
Preliminary

Recent Results on Charmonium Physics

- **Properties of h_c**
- Mass and width of η_c
- Observation of $\psi(2S) \rightarrow \gamma\eta_c(2S)$
- First evidence of $\psi(2S) \rightarrow \gamma\gamma J/\psi$

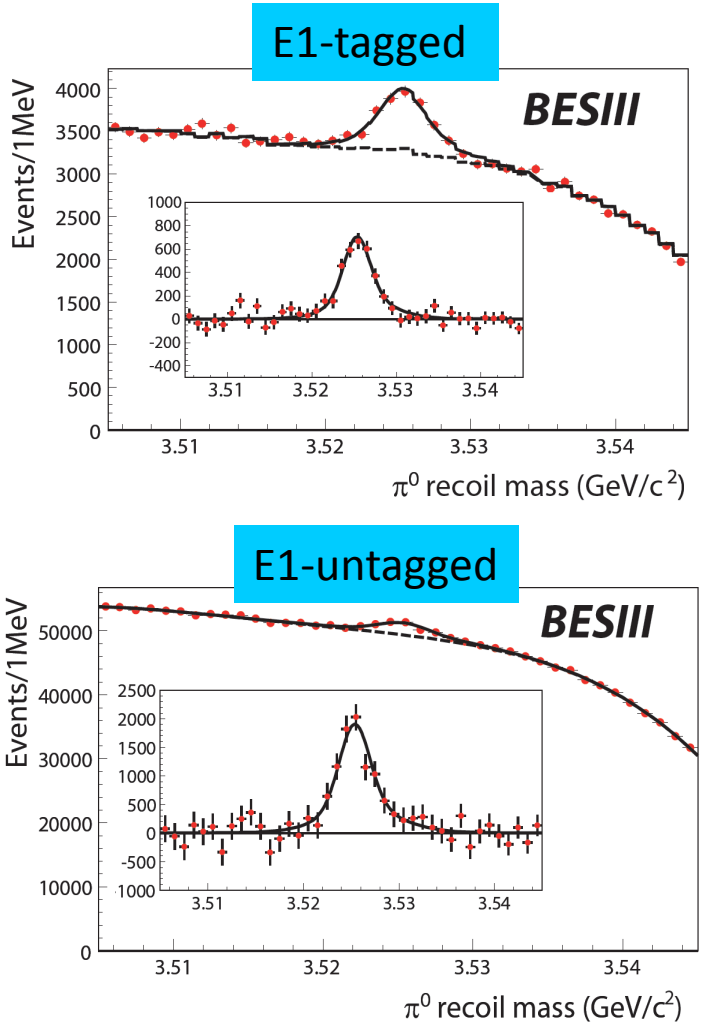
Property of h_c (1p1)

- First evidence:
  E835 in $pp \rightarrow h_c \rightarrow \gamma\eta_c$ (PRD72,092004(2005))
- CLEO-c observed h_c in
  $ee \rightarrow \psi(2S) \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$
  $\Delta M_{hf}(1P) = 0.08 \pm 0.18 \pm 0.12$ MeV/c^2
  (PRL104,132002(2010))
- Study isospin forbidden transition:
  $\psi(2S) \rightarrow \pi^0 h_c$
- Measure as well the E1 transition:
  $h_c \rightarrow \gamma\eta_c$
- $M(h_c)$ gives access to hyperfine splitting of 1P states:
  $\Delta M_{hf}(1P) = M(h_c) - 1/9(M(\chi_{c0}) + 3M(\chi_{c1}) + 5M(\chi_{c2}))$



PRL104, 132002, (2010)

Observation of h_c at BESIII (inclusive)



- Select inclusive π^0 ($\psi(2S)\rightarrow\pi^0 h_c$)
- 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)

  $Br(\psi(2S)\rightarrow\pi^0 h_c)\times Br(h_c\rightarrow\gamma\eta_c)=$

  $(4.58\pm0.40\pm0.50)\times10^{-4}$
- E1-untagged selection gives

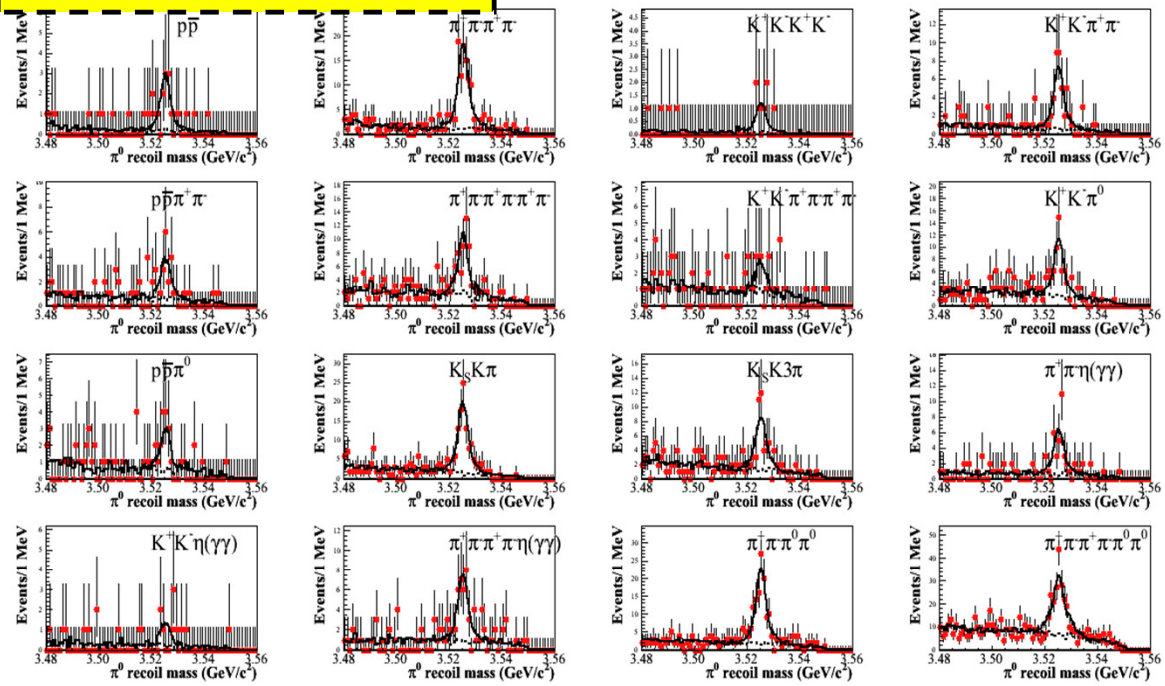
  $Br(\psi(2S)\rightarrow\pi^0 h_c)=(8.4\pm1.3\pm1.0)\times10^{-4}$
- Combining branching fractions leads to

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

  (first measurement)

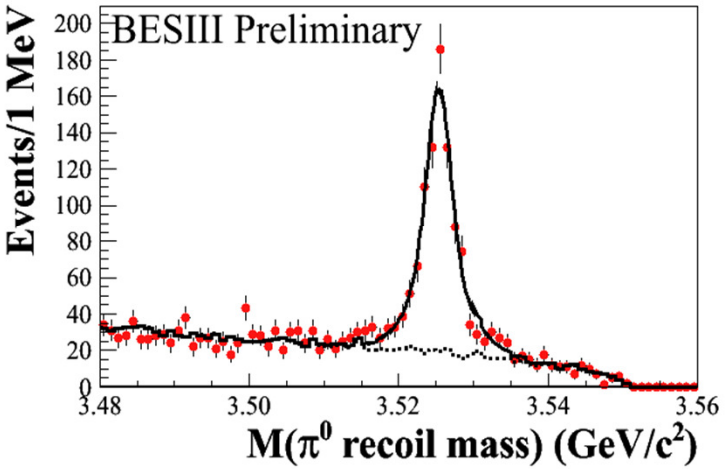
Measurements of the h_c properties at BESIII (exclusive)

BESIII preliminary



$\psi(2S)\rightarrow\pi^0 h_C$, $h_C\rightarrow\gamma\eta_C$, 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)

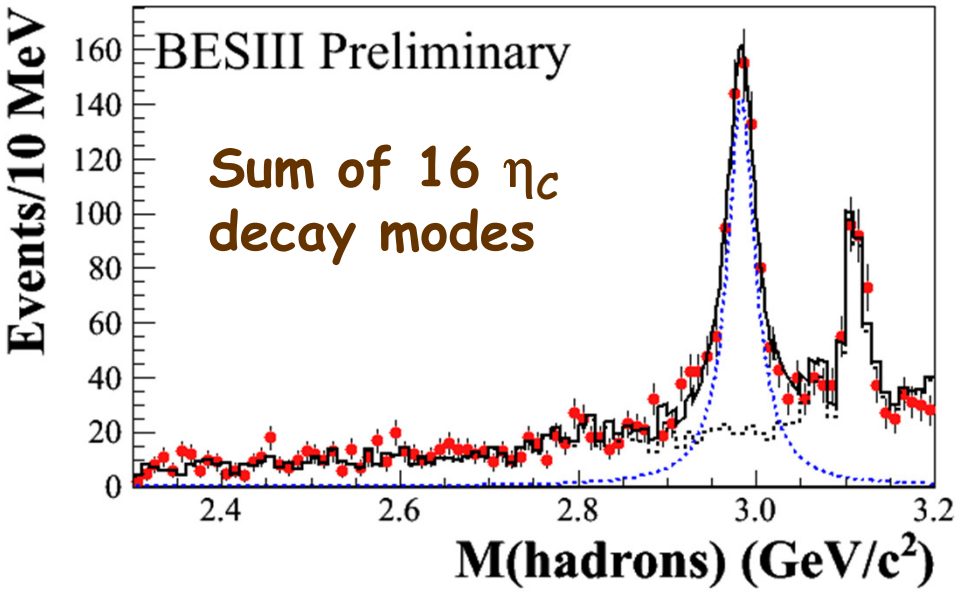
CLEOc exlusive results

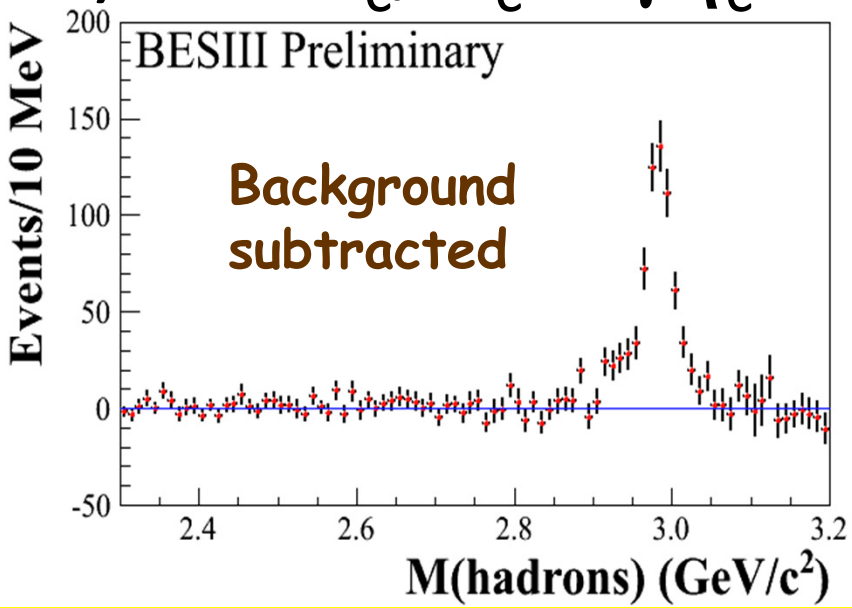
$M(h_c)$=3525.21±0.27±0.14 MeV/c^2

N = 136±14

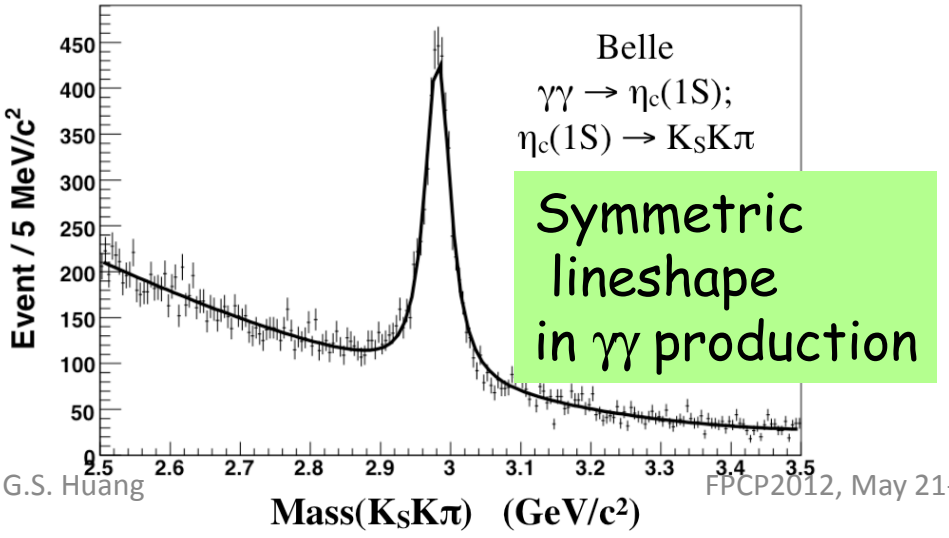
PRL101, 182003(2008)

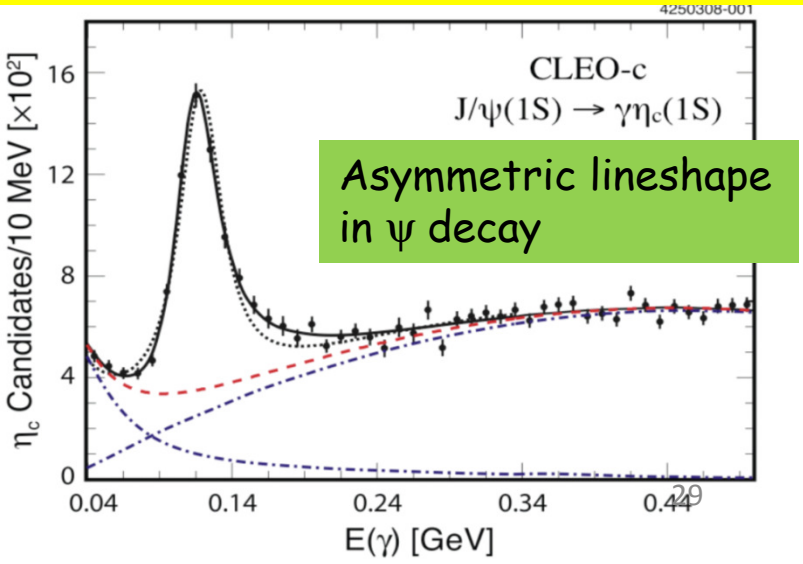
η_c lineshape from $\psi(2S)\rightarrow\pi^0 h_c$, $h_c\rightarrow\gamma\eta_c$





The η_c lineshape is not distorted in the $h_c\rightarrow\gamma\eta_c$, non-resonant bkg is small.
This channel will be best suited to determine the η_c resonance parameters.





Recent Results on Charmonium Physics

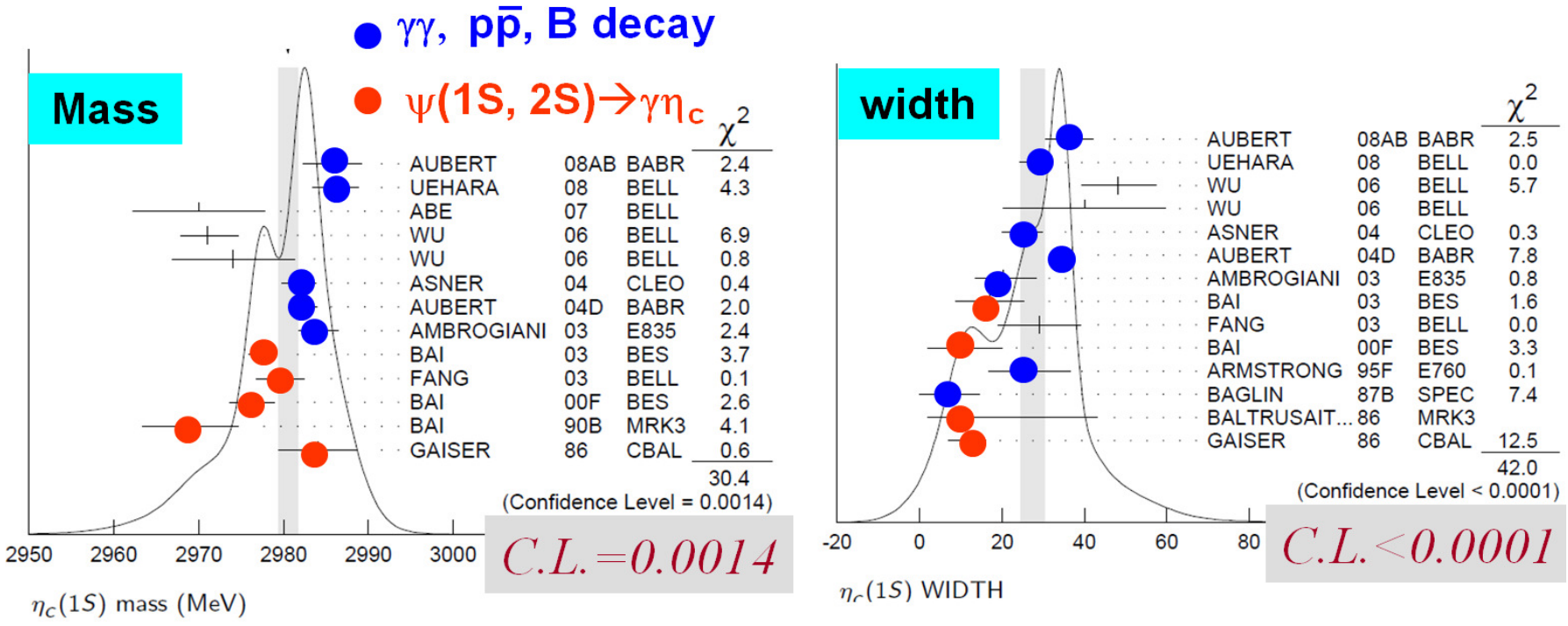
- Properties of h_c
- **Mass and width of η_c**
- Observation of $\psi(2S) \rightarrow \gamma\eta_c(2S)$
- First evidence of $\psi(2S) \rightarrow \gamma\gamma J/\psi$

$\eta_c(1S)$

- Ground state of $c\bar{c}$ system, but its properties are not well known:

  J/ψ radiative transition: $M \sim 2978.0 MeV/c^2$, $\Gamma \sim 10 MeV$

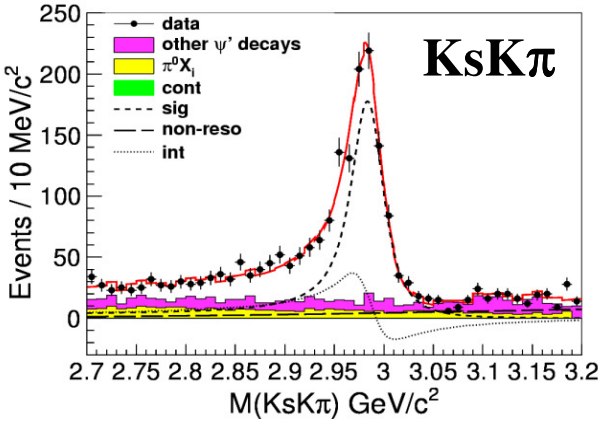
  $\gamma\gamma$ process: $M = 2983.1 \pm 1.0\ MeV/c^2$, $\Gamma = 31.3 \pm 1.9\ MeV$

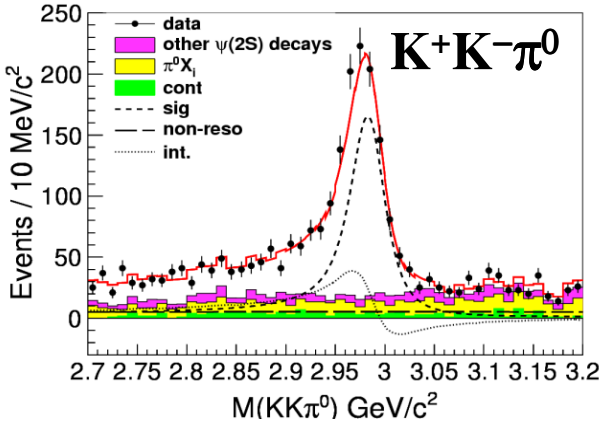


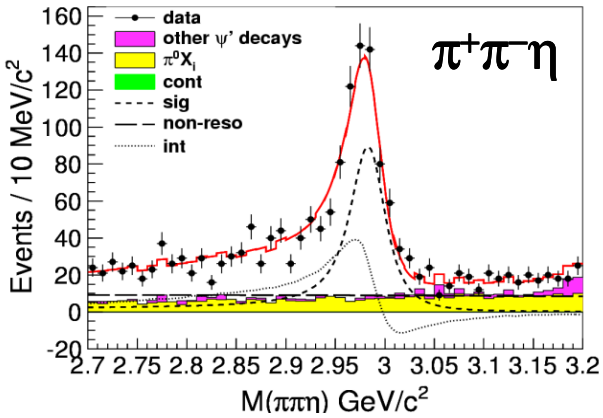
- CLEO-c found the distortion of the η_c lineshape in $\psi(2S)$ decays
- $c\bar{c}$ hyperfine splitting: $M(J/\psi)$- $M(\eta_c)$ is important experimental input to test the lattice QCD, but is dominated by error on $M(\eta_c)$

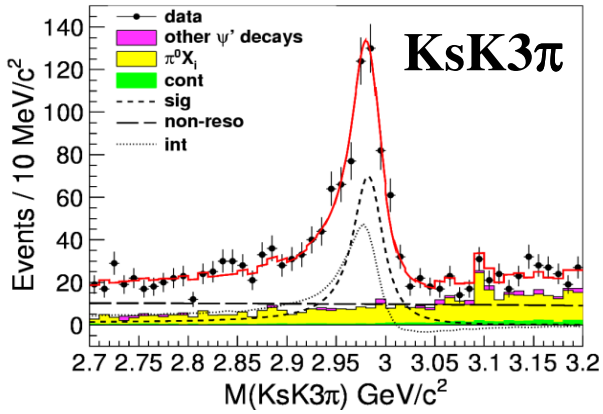
$\psi(2S) \rightarrow \gamma\eta_c$, η_c exclusive decays

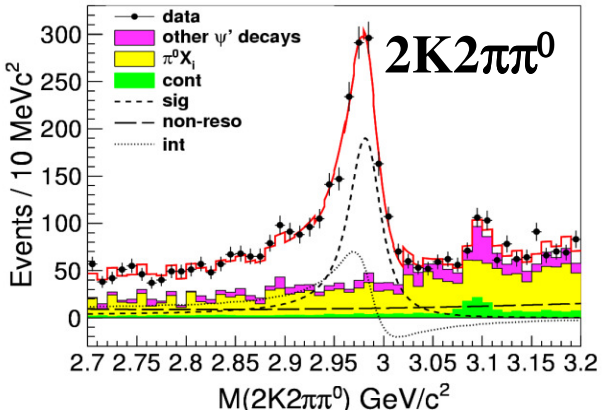
arXiv: 1111.0398 Accepted by PRL

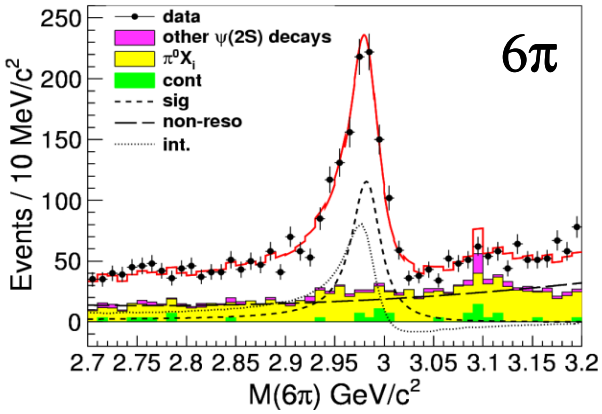












Interference with non-resonant is significant !

Relative phase ϕ values from each mode are consistent within 3σ,

➔ *use a common phase value in the simultaneous fit.*

Mass: **2984.3±0.6±0.6** MeV/c^2

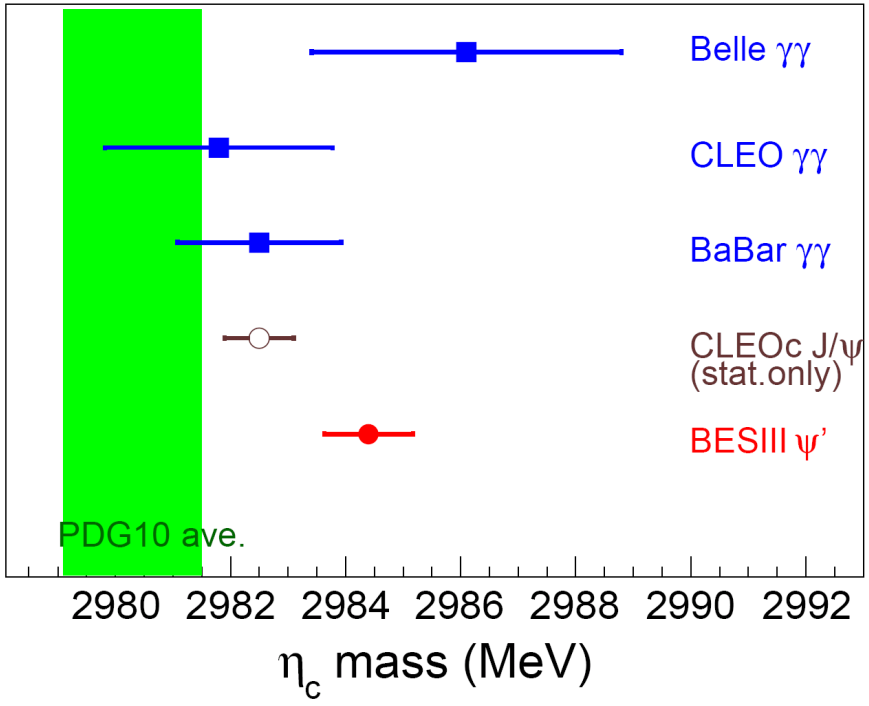
width: **32.0±1.2±1.0** MeV

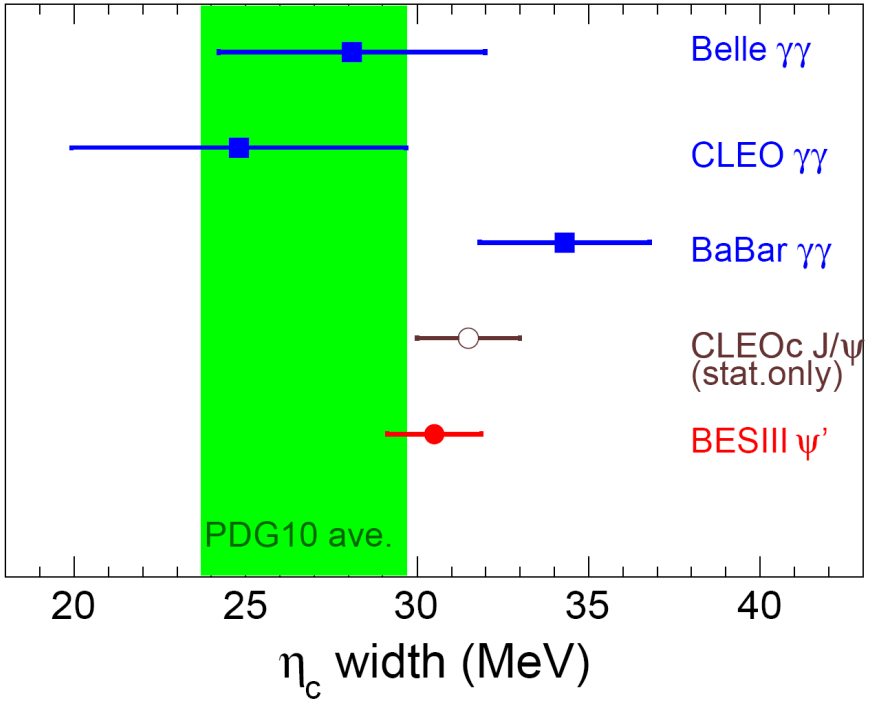
ϕ: **2.40±0.07±0.08** rad or

4.19 ±0.03±0.09 rad

Comparison of the mass and width for η_c

The world average in PDG2010 was using earlier measurements





Hyperfine splitting: $\Delta M(1S)$ = **112.6 ± 0.8** MeV

Consistent with B factory results in other production mechanisms.
Agree with lattice QCD calculations of the charmonium hyperfine splitting

Recent Results on Charmonium Physics

- Properties of h_c
- Mass and width of η_c
- **Observation of $\psi(2S) \rightarrow \gamma\eta_c(2S)$**
- First evidence of $\psi(2S) \rightarrow \gamma\gamma J/\psi$

$\eta_c(2S)$

- First "observation" by Crystal Ball in 1982 (M=3.592, B=0.2%-1.3% from $\psi(2S)\to\gamma X$, 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 $\Gamma(\eta_c(2S))=12\pm3$ MeV

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

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

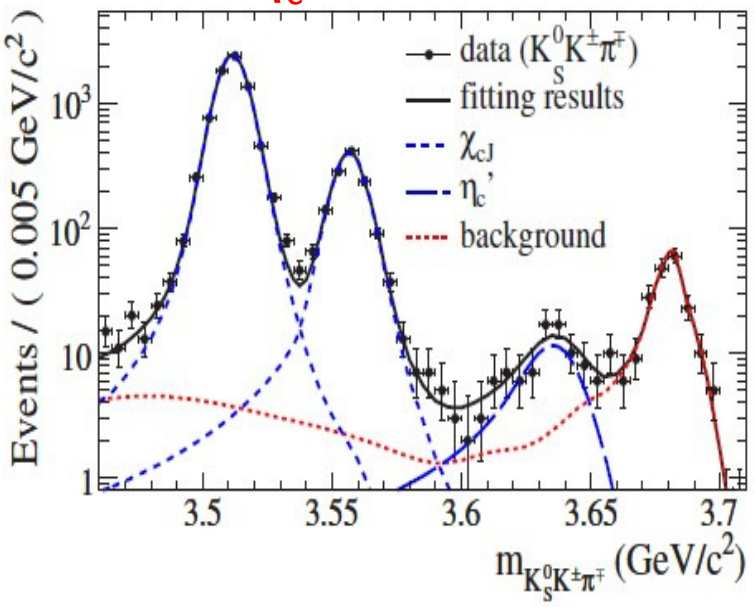
- Better chance to observe $\eta_c(2S)$ in $\psi(2S)$ radiative transition with ~106M $\psi(2S)$ data at BESIII.

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

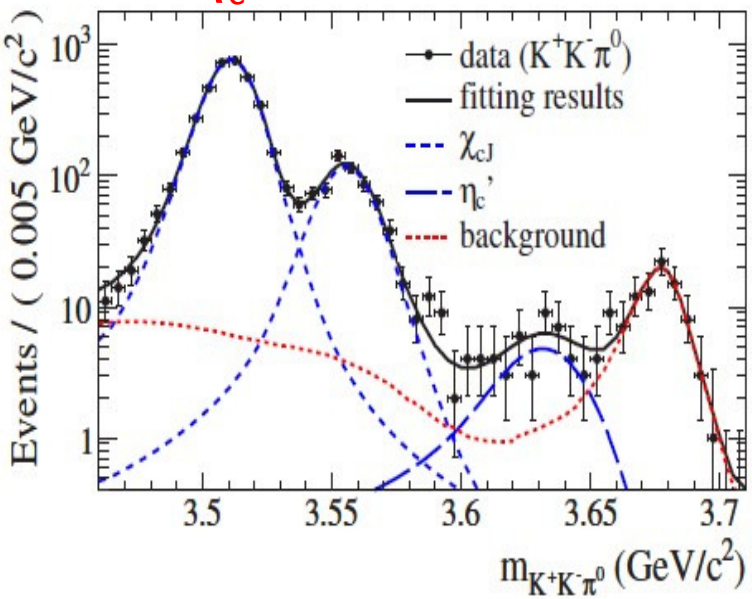
Observation of $\psi(2S) \rightarrow \gamma\eta_c(2S)$

BESIII preliminary

$\eta_c(2S) \rightarrow K_S K\pi$



$\eta_c(2S) \rightarrow K^+K^-\pi^0$



Statistical significance > 10σ

- Simultaneous fit with:
  - $\eta_c(2S)$ signal: modified BW (M1) with fixed width (Resolution extrapolated from χ_{cJ})
  - χ_{cJ} signal: MC shape smeared with Gaussian
  - BG from $e^+ e^- \rightarrow KK\pi$ (ISR), $\psi(2S) \rightarrow KK\pi$ (FSR), $\psi(2S) \rightarrow \pi^0 KK\pi$: measured from data

Preliminary results on $\psi(2S)\to\gamma\eta_c(2S)\to\gamma KK\pi$

BESIII preliminary

- $M(\eta_c(2S)) = 3637.6\pm2.9\pm1.6$ MeV/c^2
- $\Gamma(\eta_c(2S)) = 16.9\pm6.4\pm4.8$ MeV
- $Br(\psi(2S)\to\gamma\eta_c(2S)\to\gamma KK\pi)=(1.30\pm0.20\pm0.30)\times10^{-5}$

$Br(\eta_c(2S)\to KK\pi)=(1.9\pm0.4\pm1.1)\%$ from BaBar

$$Br(\psi(2S)\to\gamma\eta_c(2S))=(6.8\pm1.1_{stat}\pm4.5_{sys})\times10^{-4}$$

CLEO-c: $<7.6\times10^{-4}$ PRD81,052002(2010)

Potential model: $(0.1\text{–}6.2)\times10^{-4}$ PRL89,162002(2002)

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- **First evidence of $\psi(2S) \rightarrow \gamma\gamma J/\psi$**

$\psi(2S) \to \gamma\gamma J/\psi$

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

  *[F. Bassani etal, PRL **39**, 1070 (1977);A. Quattropani etal, PRL **50**, 1258 (1983)]*

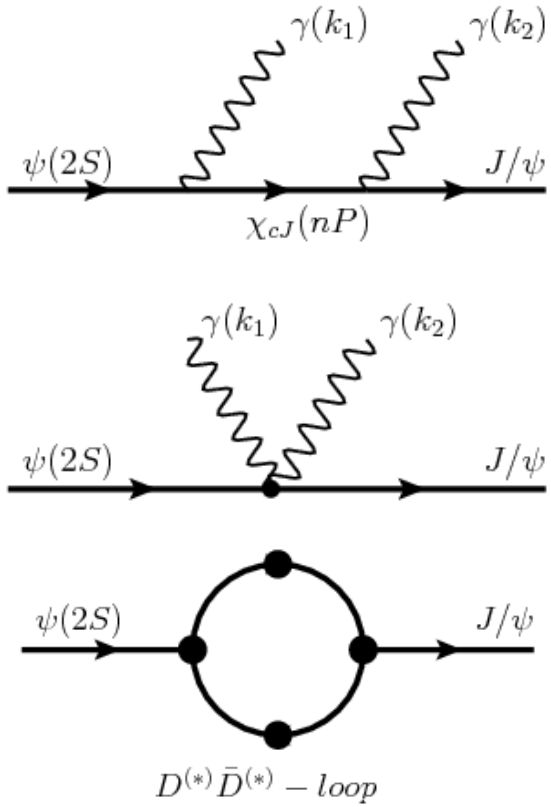
- Never been observed in the quarkonium system.

  CLEO-c: upper limit of $Br(\psi(2S) \to \gamma\gamma J/\psi)$ is 1×10^{-3} (PRD 78,011102(2008))

- Observation helpful to understand heavy quarkonium spectrum & strong interaction

Theoretically:

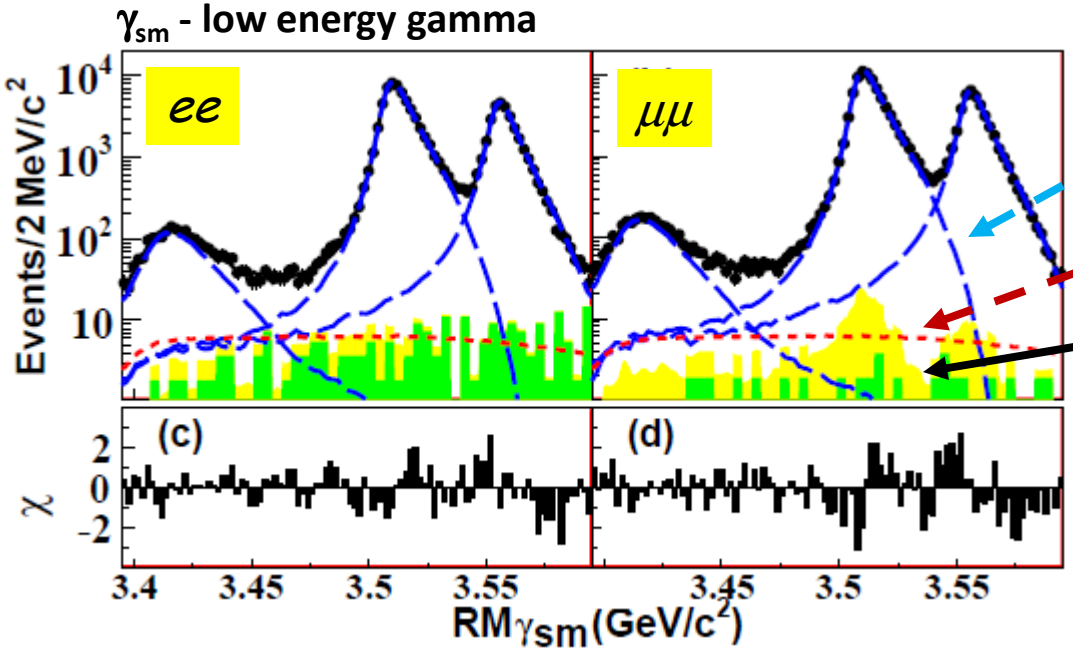
- Potential models give discrete spectra ($\psi(2S) \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi$)
- Possibility of testing the hadron-loop effect
- Coupled channel: **the hadron-loop effect also may play a important role in the continuous spectra**



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

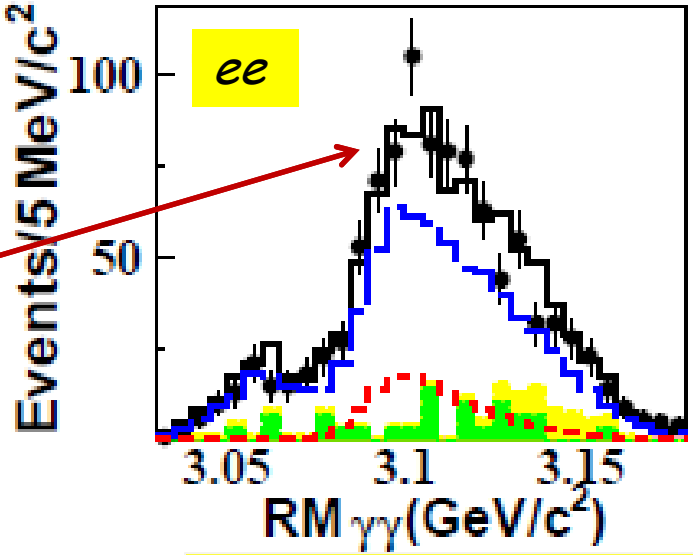
arXiv: 1204.0246 Submitted to PRL

- Select $\psi(2S) \to \gamma\gamma J/\psi$, $J/\psi \to e^+e^-$ and $\mu^+\mu^-$ events



- the χ_{cJ} components: double E1 scaling
- yields of the two-photon events
- continuum(green) + $\psi(2S)$ decay BG(yellow)

- Global fit of the two-photon process and cascade χ_{cJ} processes
- See **clear excess** over BG + continuum



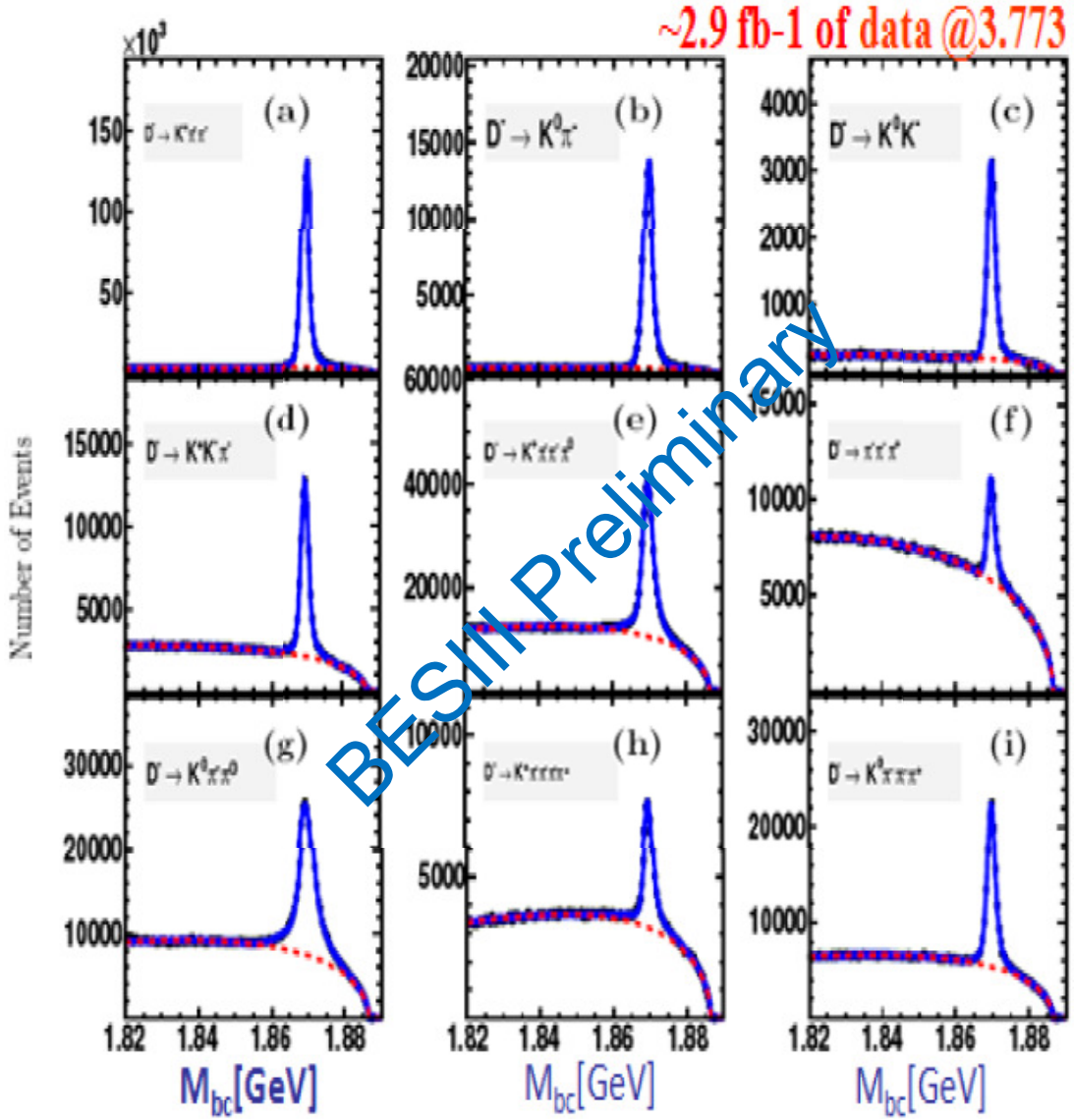
3.44<RM(γ_{sm})<3.48GeV

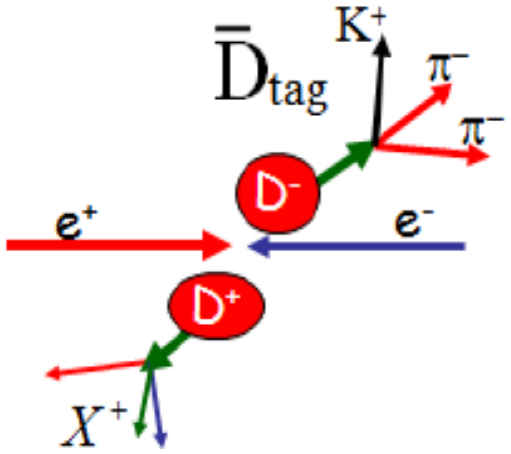
- $Br(\psi(2S) \to \gamma\gamma J/\psi) = (3.3 \pm 0.6^{+0.8}_{-1.1}) \times 10^{-4}$ (both *ee* and $\mu\mu$)
- **Significance : 3.8σ including systematics**
- $Br(\psi(2S) \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi)$ are also measured

Charm Physics (all preliminary)

- **$D^+ \rightarrow \mu^+ \nu$**
- $D^0 \rightarrow K^-/\pi^- e^+ \nu$
- Search for $D^0 \rightarrow \gamma\gamma$
- Ds tagging

D^- Tagging





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

Resolution:
1.3 MeV for pure charged modes;

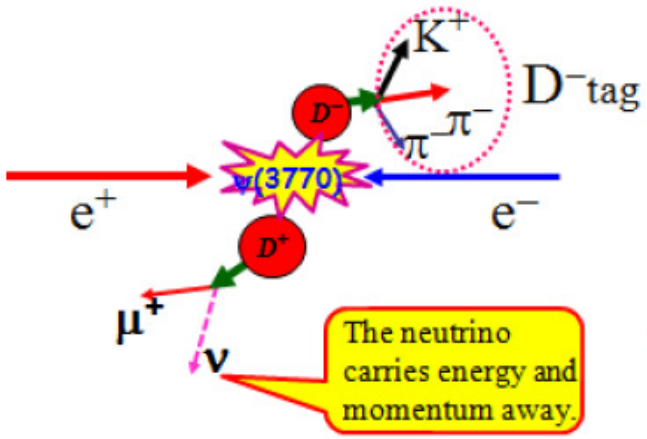
1.9 MeV for modes with one π^0.

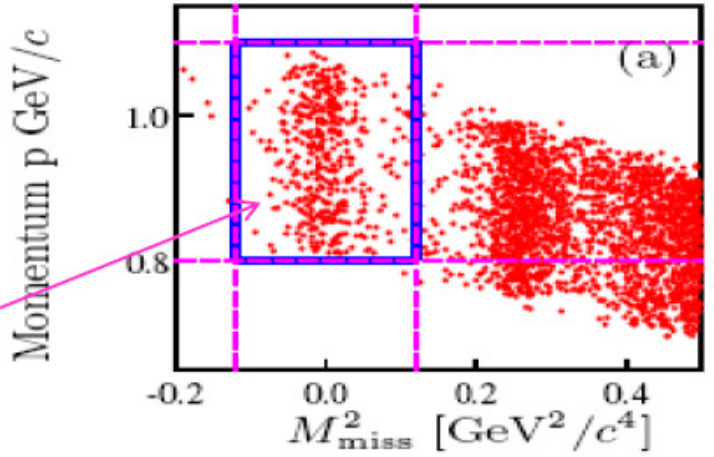
9 singly tagged modes

$N_{D^-} = (1.57 \pm 0.2) \times 10^6$

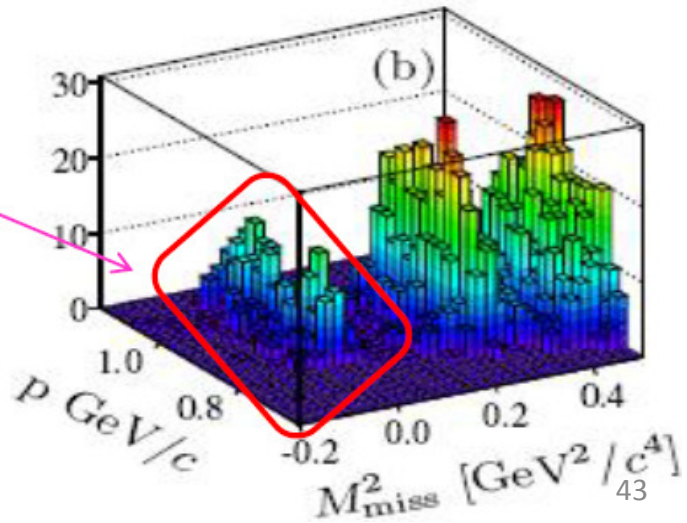
$D^+ \to \mu^+ \nu$

- **In the system recoiling against the tagged D^-, select leptonic decay for $D^+ \to \mu^+ \nu$**





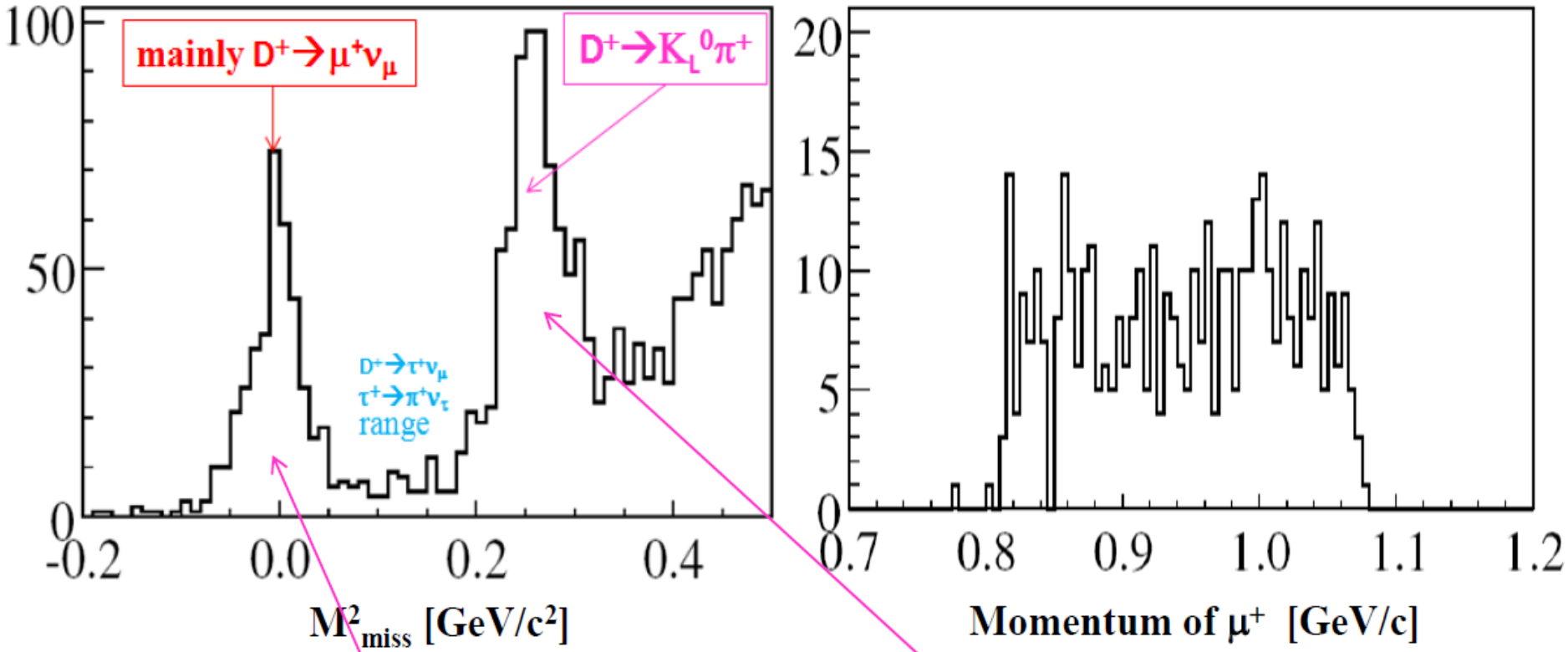
425 candidates for $D^+ \to \mu^+ \nu$



Signal selection:

- **One charged track only**
- **Positively identified μ**
- **No isolate photon**

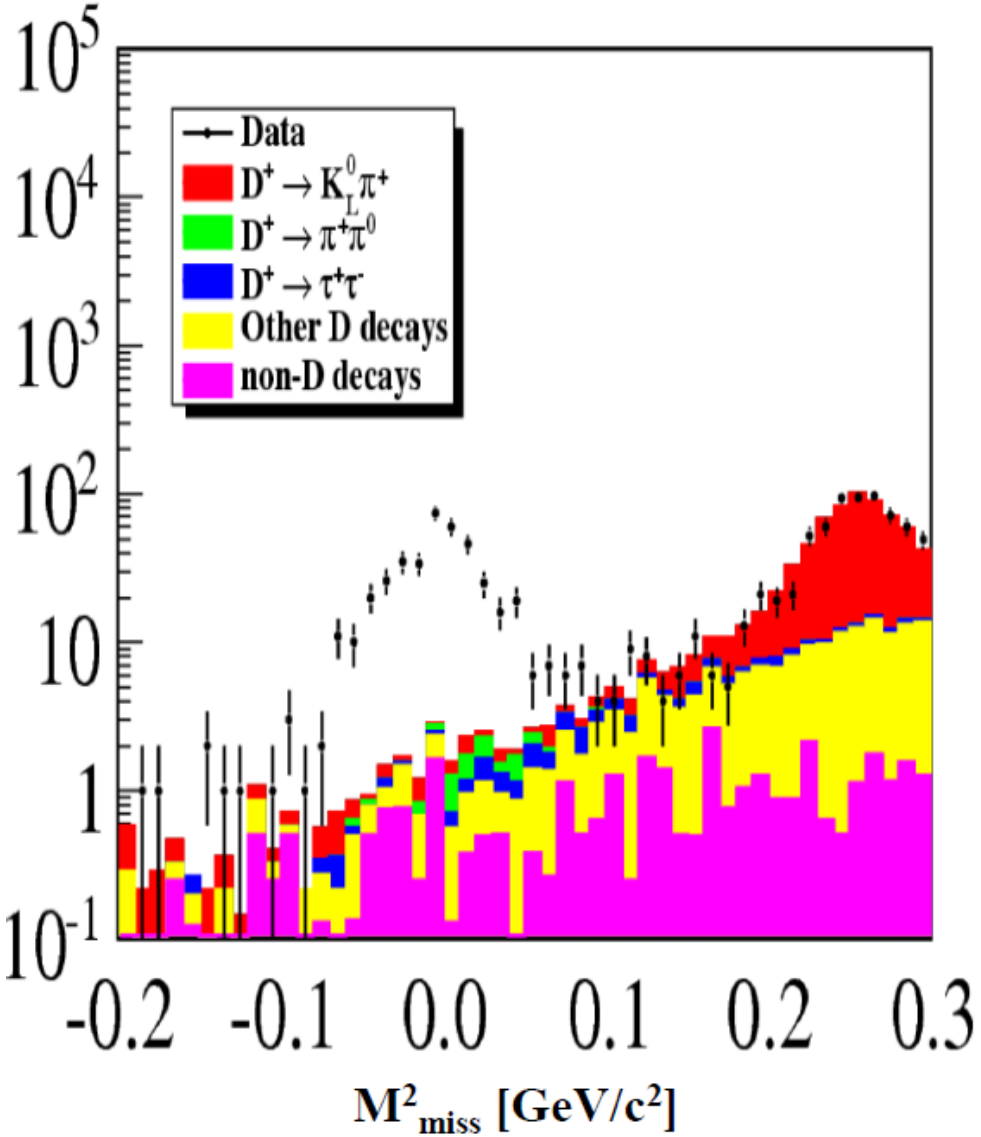
$D^+ \to \mu^+ \nu$



The K^0_L escape from the detector.

There are still some backgrounds

Backgrounds for $D^+ \to \mu^+\nu$



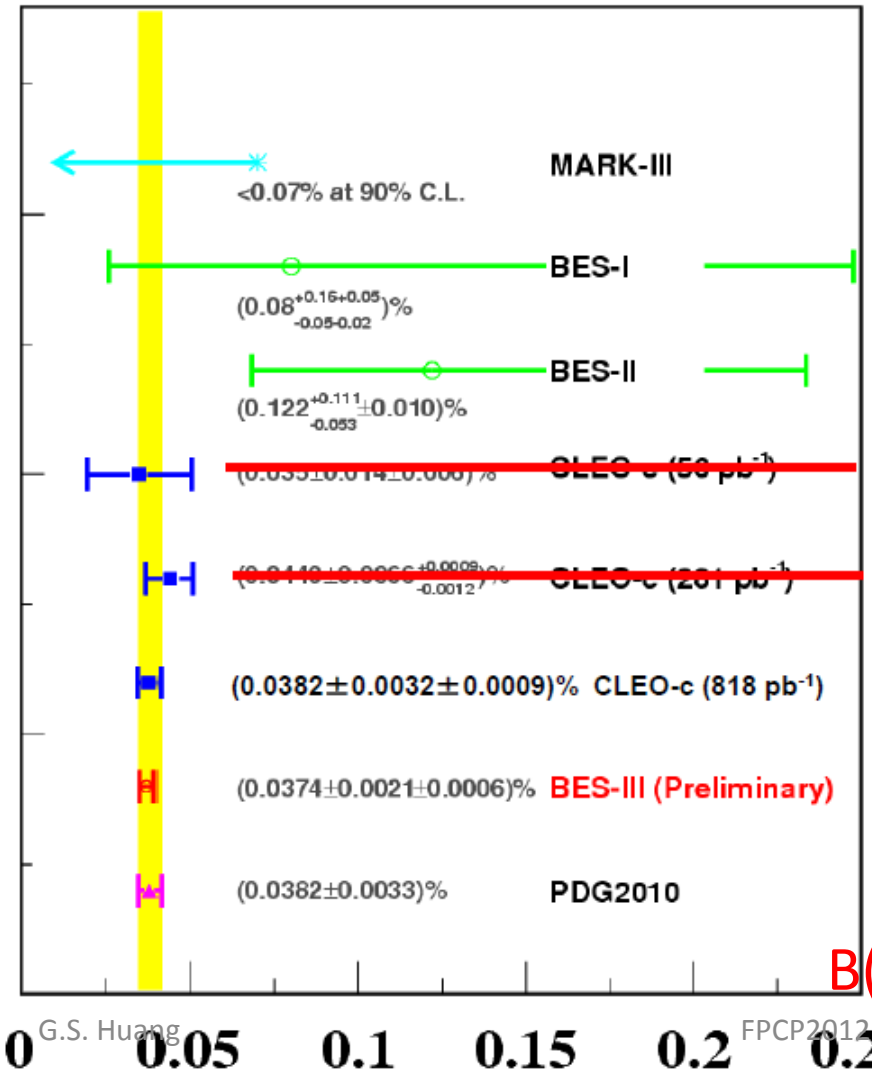
Estimated with Monte Carlo events

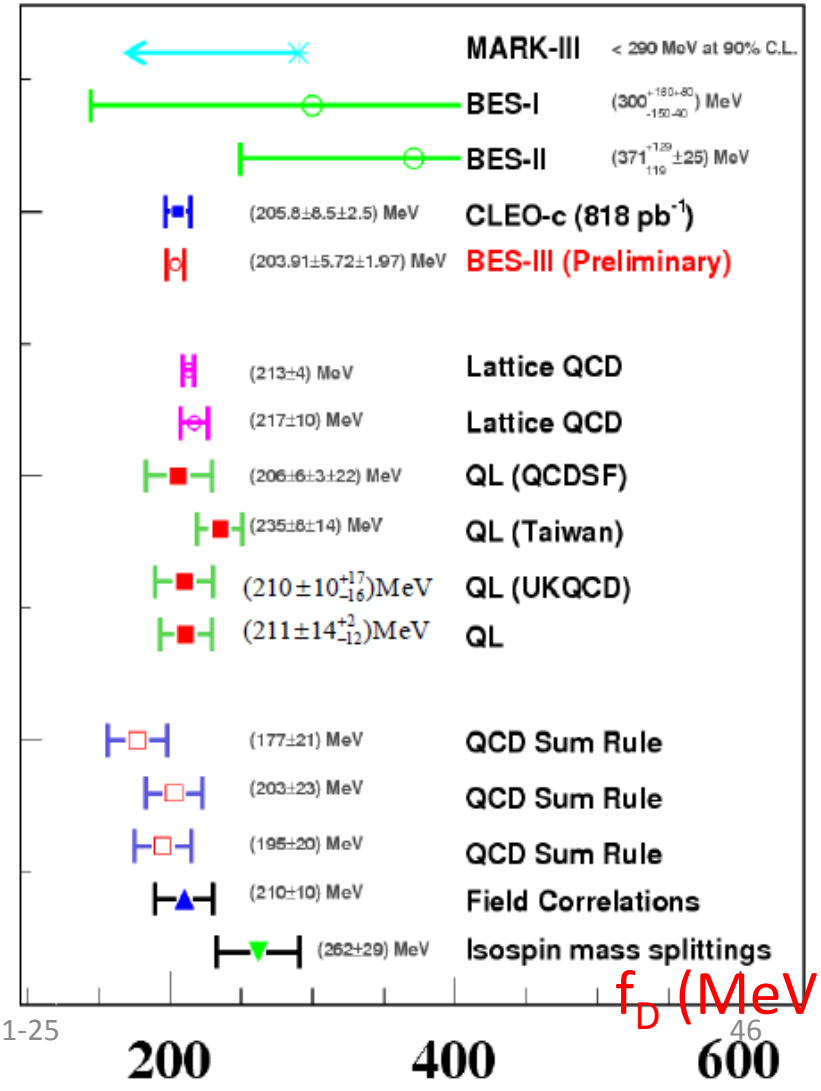
Source mode	Number of events
$D^+ \to K_L^0\pi^+$	7.9 ± 0.8
$D^+ \to \pi^+\pi^0$	3.8 ± 0.5
$D^+ \to \tau^+\nu_\tau$	6.9 ± 0.7
Other decays of D mesons	17.9 ± 1.1
$e^+e^- \to \gamma\psi(3686)$	0.2 ± 0.2
$e^+e^- \to \gamma J/\psi$	0.0 ± 0.0
$e^+e^- \to light\ hadron$ (continuum)	8.2 ± 1.4
$e^+e^- \to \tau^+\tau^-$	1.9 ± 0.5
$\psi(3770) \to non - D\bar{D}$	0.9 ± 0.4
Total	47.7 ± 2.3

$D^+ \to \mu^+\nu$: Preliminary Results

N($D^+ \to \mu^+\nu$) = 377.3 ± 20.6

B($D^+ \to \mu^+\nu$) = $(3.74 \pm 0.21^{stat} \pm 0.06^{sys})\times 10^{-4}$ f_{D^+} = $(203.91 \pm 5.72^{stat} \pm 1.97^{sys})$ MeV





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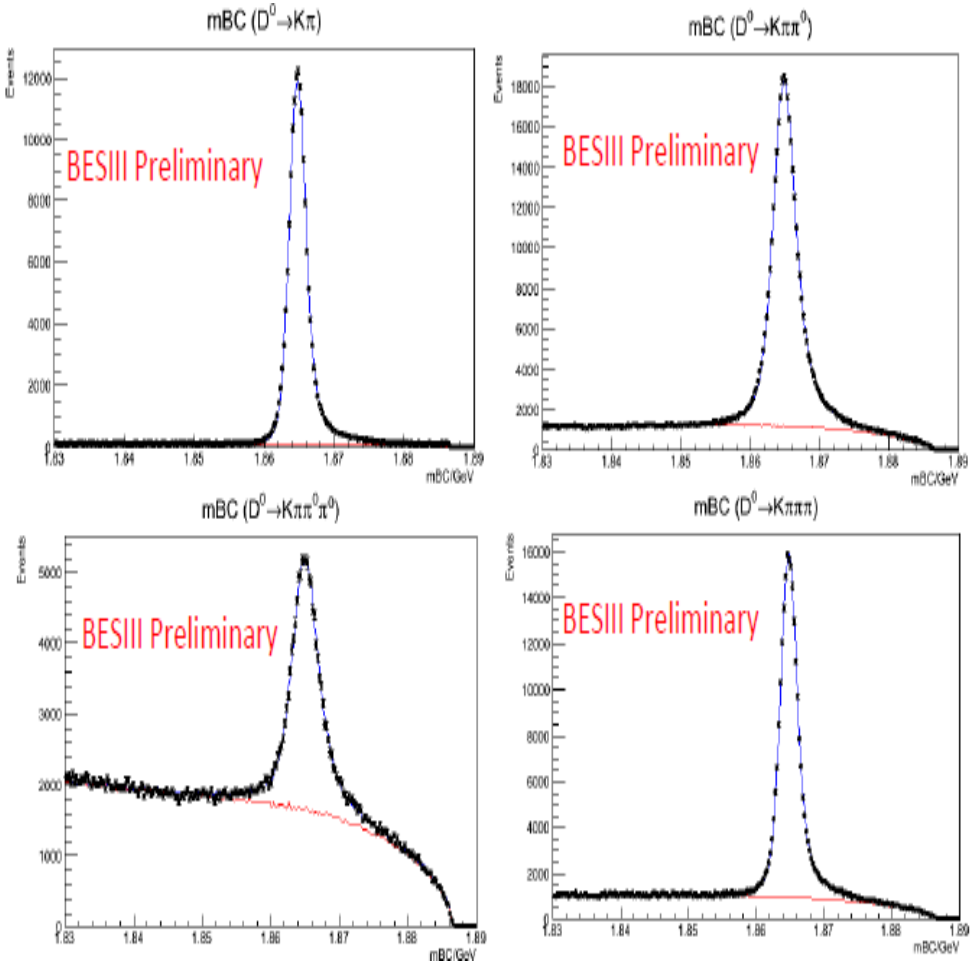
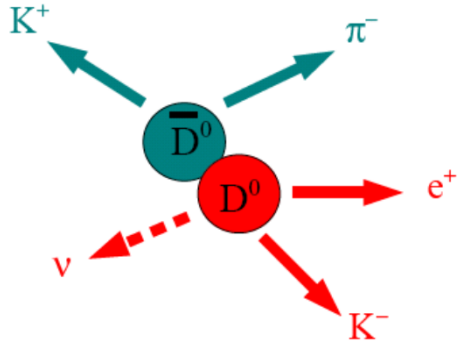
- Ds tagging

D^0 Tagging

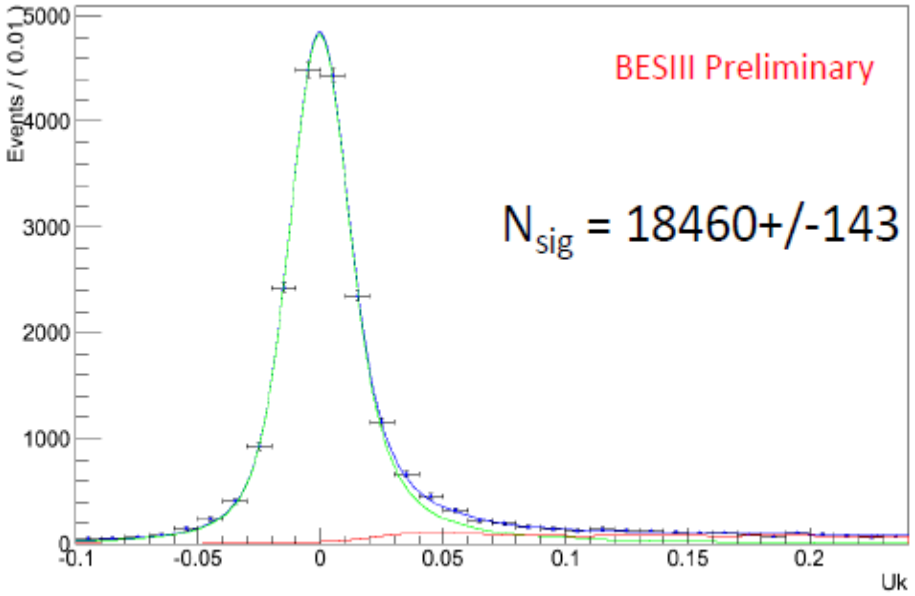




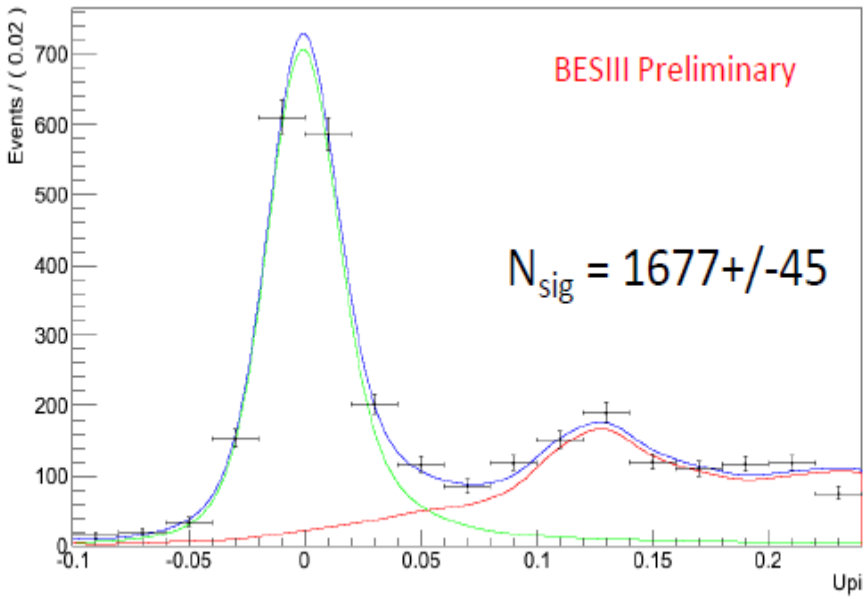
4 tag modes, 0.92 fb^{-1} data @3.773 (preliminary)

Mode	Data Yield
$D^0 \to K^-\pi^+$	$159{,}929 \pm 413$
$D^0 \to K^-\pi^+\pi^0$	$323{,}348 \pm 667$
$D^0 \to K^-\pi^+\pi^0\pi^0$	$78{,}467 \pm 480$
$D^0 \to K^-\pi^+\pi^-\pi^+$	$211{,}910 \pm 550$

$D^0 \to K/\pi\, e\, \nu$



D^0 -> K e ν



D^0 -> π e ν

Mode	measured branching fraction(%)	PDG	CLEOc
$\bar{D}^0 \to K^+ e^- \bar{\nu}$	3.542 ±0.030±0.067	3.55 ±0.04	3.50 ±0.03 ±0.04
$\bar{D}^0 \to \pi^+ e^- \bar{\nu}$	0.288 ±0.008±0.005	0.289 ±0.008	0.288 ±0.008±0.003

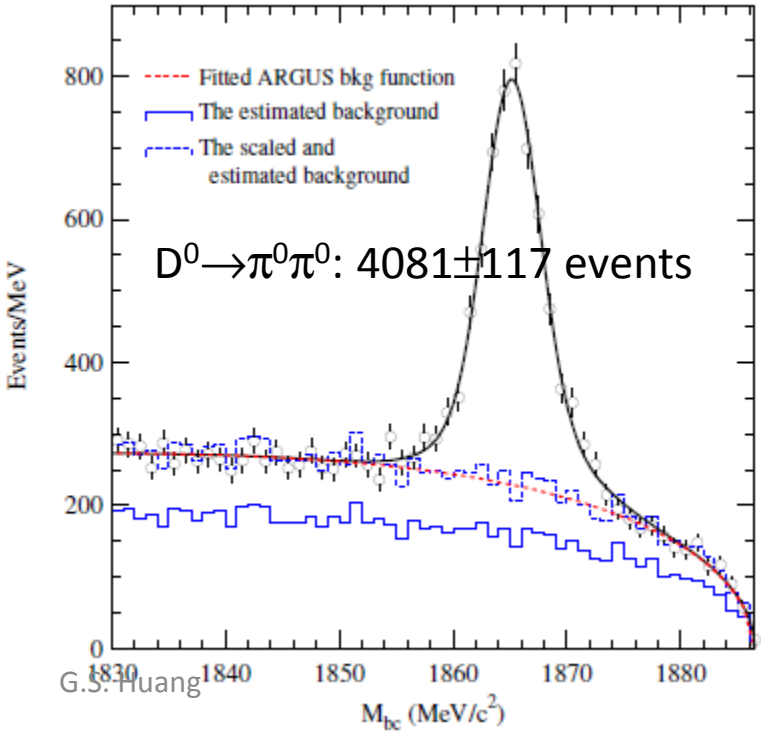
BESIII preliminary, with 0.92 fb^{-1} data, will improve with full 2.9 fb^{-1} soon. Form factor measurement ongoing.

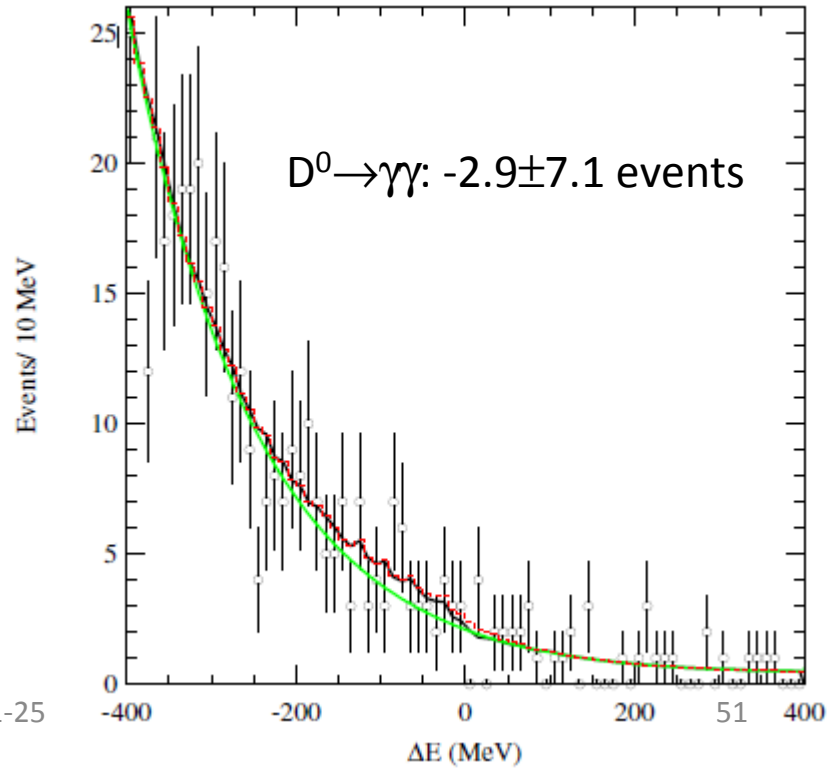
Charm Physics (all preliminary)

- $D^+ \rightarrow \mu^+ \nu$
- $D^0 \rightarrow K^-/\pi^- e^+ \nu$
- **Search for $D^0 \rightarrow \gamma\gamma$**
- Ds tagging

Search for $D^0 \to \gamma\gamma$

- Forbidden FCNC transition ($c \to u+\gamma$);
- SM prediction: $B(D^0 \to \gamma\gamma) \sim 10^{-8}$ or less;
- Results presented in $B(D^0 \to \gamma\gamma)/B(D^0 \to \pi^0\pi^0) < 5.8 \times 10^{-3}$ UL @ 90% CL, or $B(D^0 \to \gamma\gamma) < 4.6 \times 10^{-6}$ UL @ 90% CL (preliminary, to be improved);
- PDG 2.7×10^{-5}, CLEO-c preli. 8.63×10^{-6}, BaBar 2.2×10^{-6}.



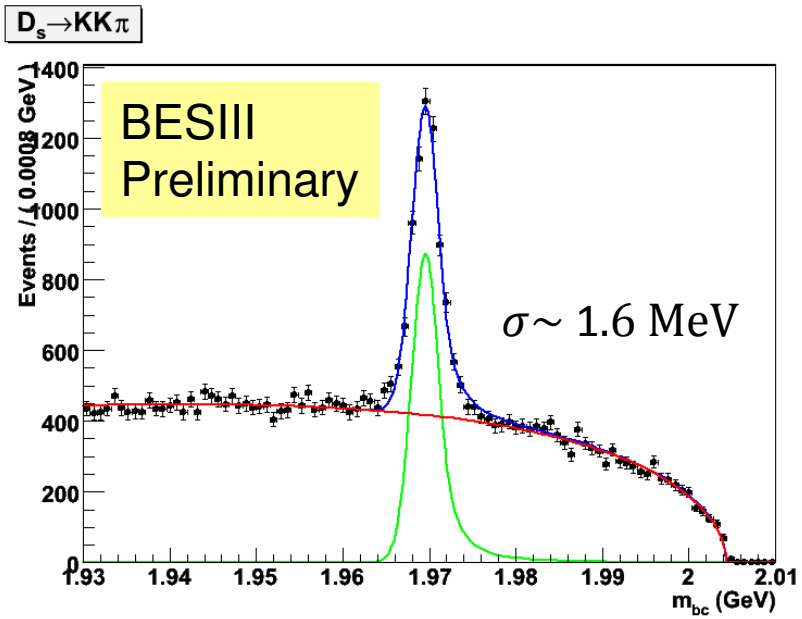


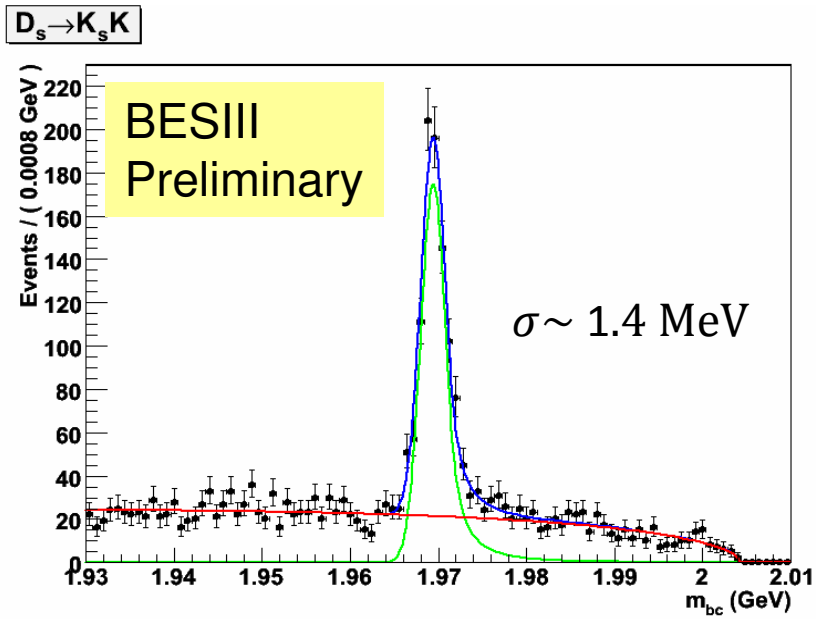
Charm Physics (all preliminary)

- $D^+ \rightarrow \mu^+ \nu$
- $D^0 \rightarrow K^-/\pi^- e^+ \nu$
- Search for $D^0 \rightarrow \gamma\gamma$
- **Ds tagging**

D_s Tag

(part of data @ 4010 MeV)





f_{Ds} (both μ and τ modes) measurement underway

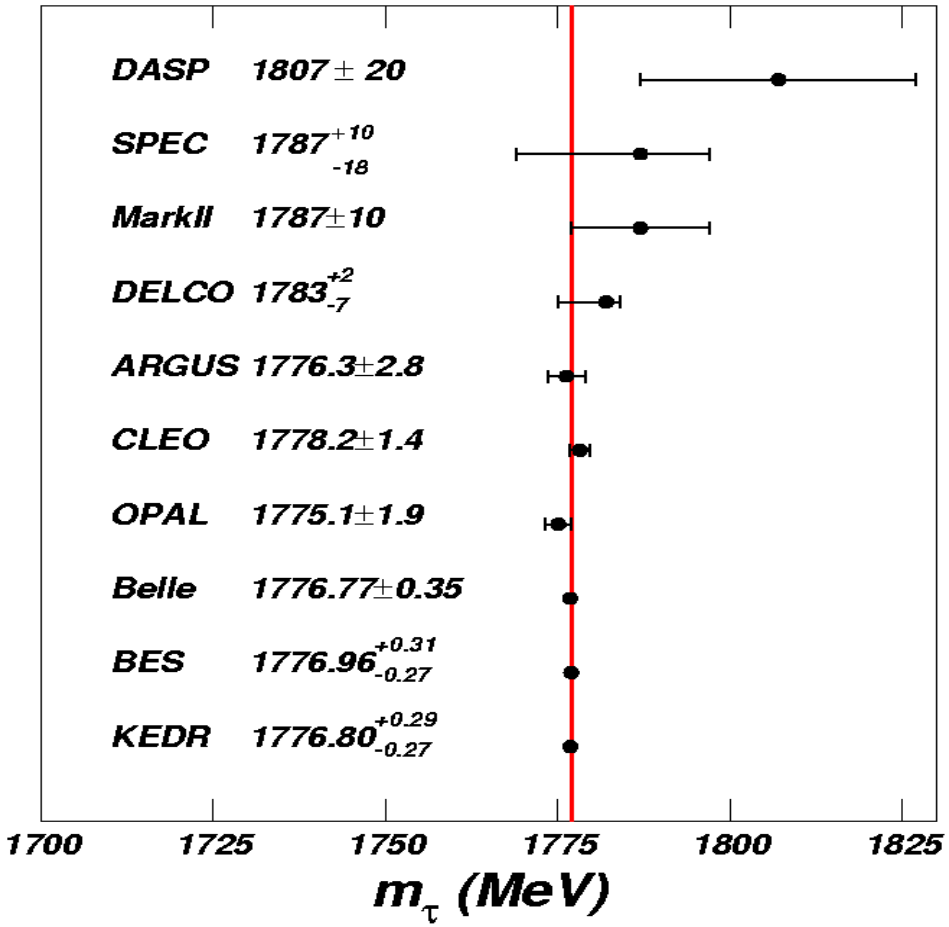
Note: this data is at 4010 MeV: ~0.3 nb of $D_s^+ D_s^-$

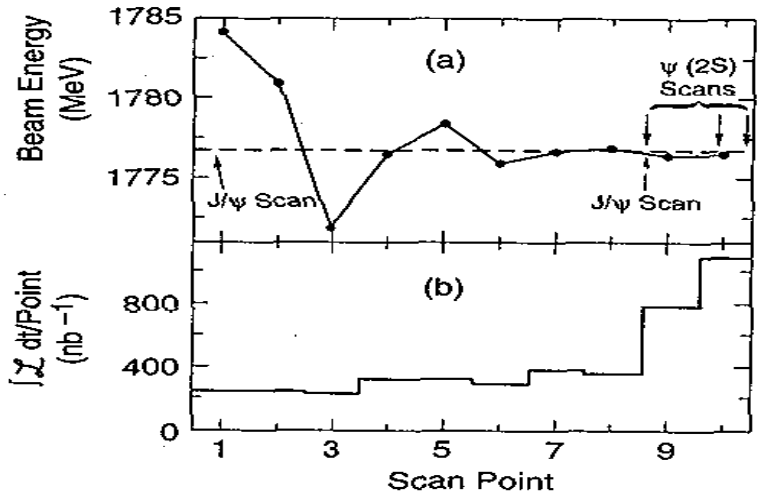
We plan to run at 4170 MeV: ~0.9 nb of $D_s^{*+} D_s^-$

pro: higher cross-section; **con**: need D_s^* transition photon ($D_s^{*+} \to \gamma D_s^+$)

τ Mass Scan

τ Mass measurement





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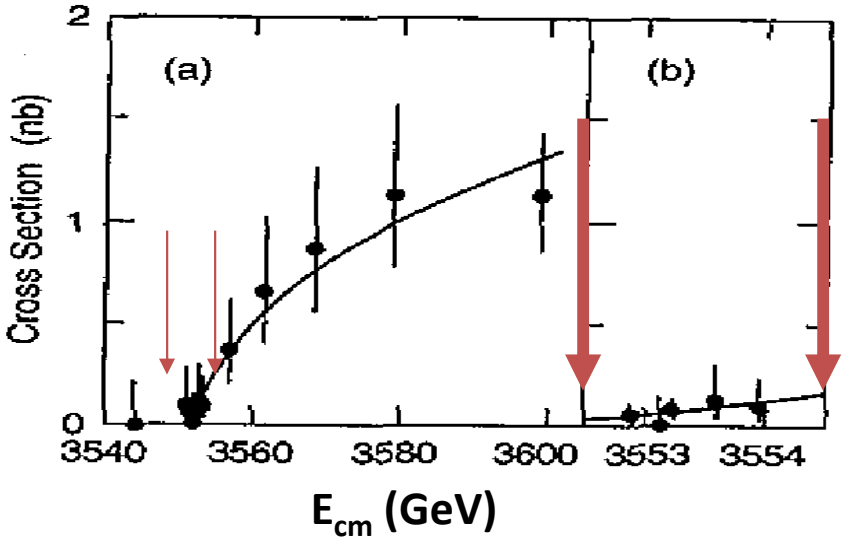
12 points, Lum.: 5 pb^{-1}



$M_\tau = 1776.96\ ^{+0.18}_{-0.21}\ ^{+0.25}_{-0.17}$ MeV

$\sigma M_\tau / M_\tau = 1.7 \times 10^{-4}$

PDG10: 1776.82±0.16 MeV

BESI results: stat. err. (0.18 / 0.21)
is compatible with syst. (0.25 / 0.17)

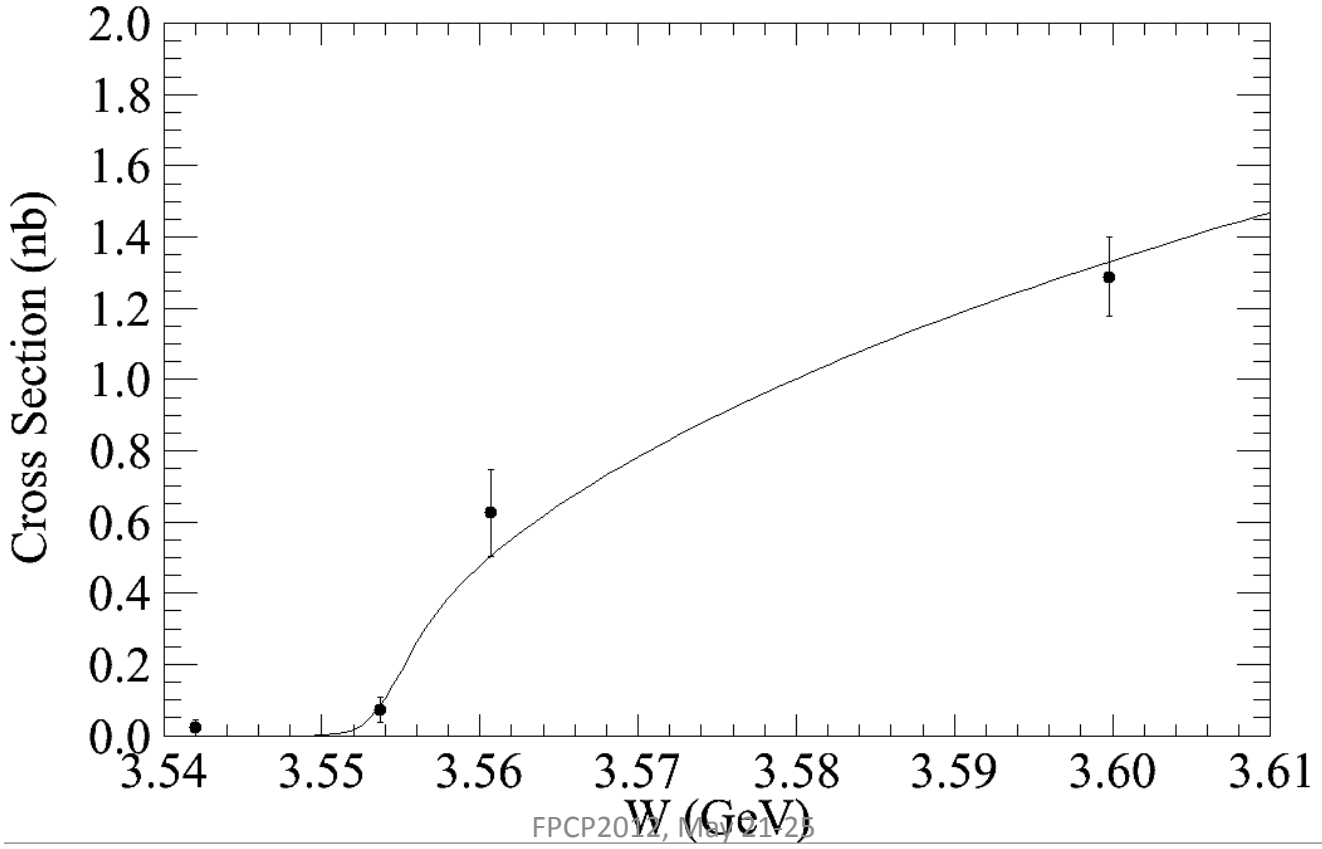
τ Mass measurement in 2012

New beam energy measurement system with a precision of 5×10^{-5};

Data at 4 energy points were taken, ~5 pb^{-1} at the τ threshold;

Expect statistical precision is ±0.3 MeV, systematic error <0.1 MeV;

More data expected later this year to reduce statistical precision to 0.1 MeV.



Summary

- BESIII is successfully operating since 2008:
  - World largest data samples at J/ψ, ψ(2S),ψ(3770), ψ(4040), still growing…
- Light quark states:
  - confirmation the enhancement at $p\bar{p}$ threshold in $J/\psi\to\gamma p\bar{p}$, $J^{PC}=0^{-+}$.
  - First observation: $\eta(1405)\to f_0(980)\pi^0$ (isospin breaking).
  - $\omega\phi$ threshold enhancement in $J/\psi\to\gamma\omega\phi$.
  - $\eta\eta$ system in $J/\psi\to\gamma\eta\eta$.
- Charmonium transitions and decays:
  - Precision measurements of h_C and $\eta_C(1S)$ properties.
  - first observation of $\eta_c(2S)$ in $\psi(2S)\to\gamma\eta_c(2S)$ decay.
  - First evidence of $\psi(2S)\to\gamma\gamma J/\psi$.
- Charm decays:
  - $D^+\to\mu^+\nu$, $D^0\to K/\pi\, e\,\nu$, $D^0\to\gamma\gamma$.
- τ mass measurement.
- **Lots of results published, more to come!**