The BES-III experiment

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for the BES-III collaboration

JINR Dubna

Spin Physics (SPIN2012)
JINR, Dubna, Russia
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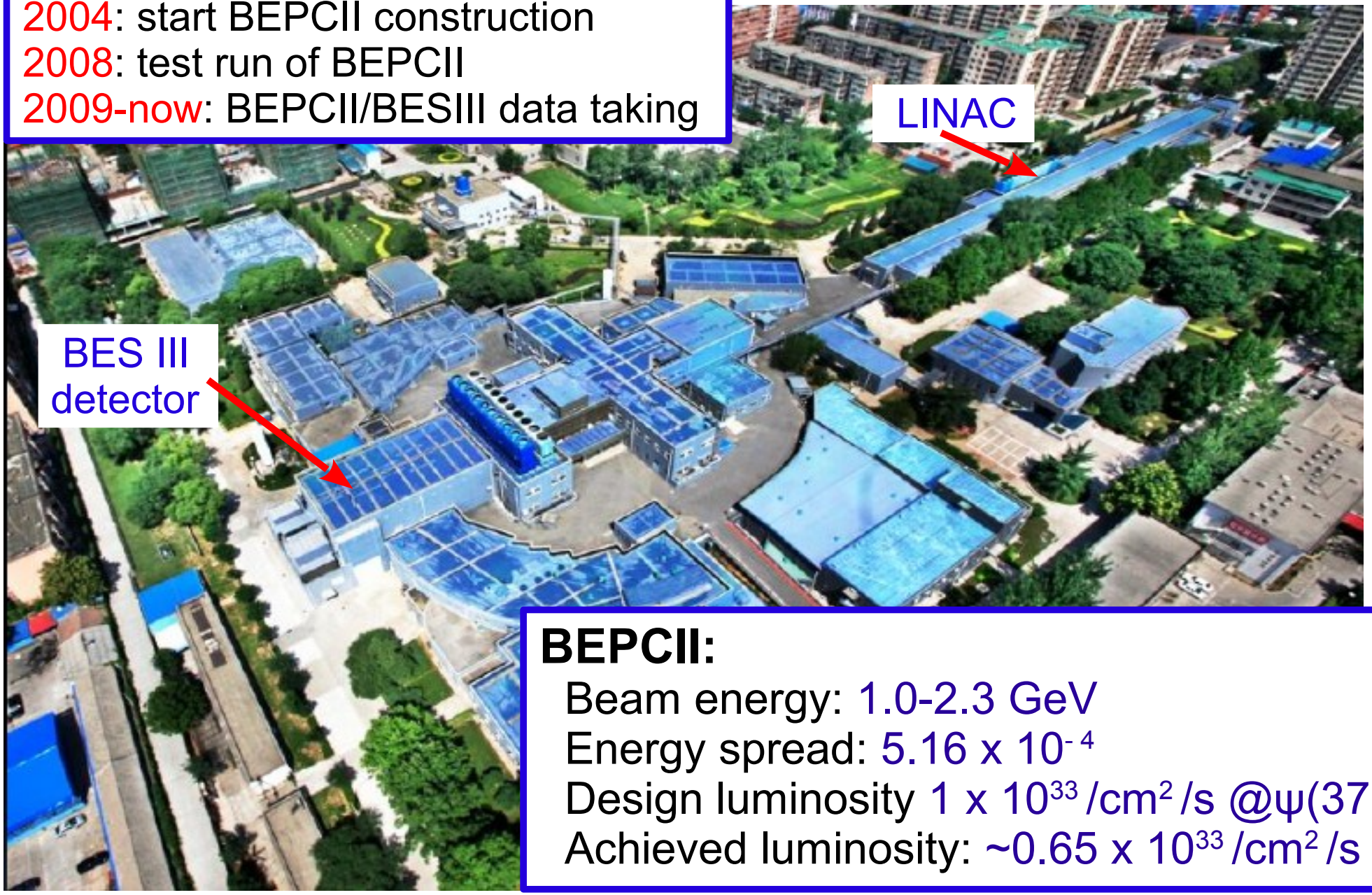
BEPCII/BESIII at IHEP (Beijing)

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



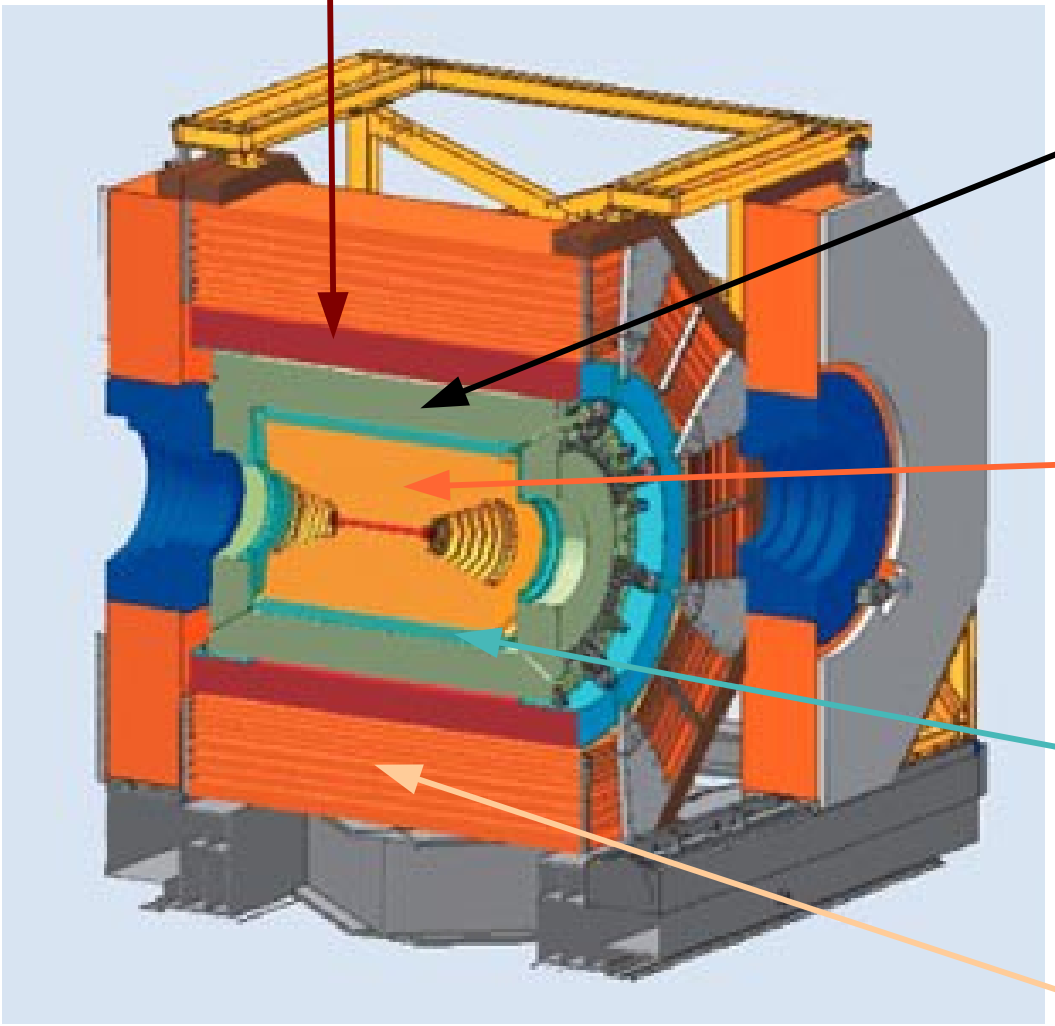
BEPCII:

Beam energy: 1.0-2.3 GeV
Energy spread: 5.16×10^{-4}
Design luminosity $1 \times 10^{33}\,/cm^2/s$ @ψ(3770)
Achieved luminosity: ~$0.65 \times 10^{33}\,/cm^2/s$

The BES-III detector

NIM A614, 345(2010)

Super conducting magnet: 1 T



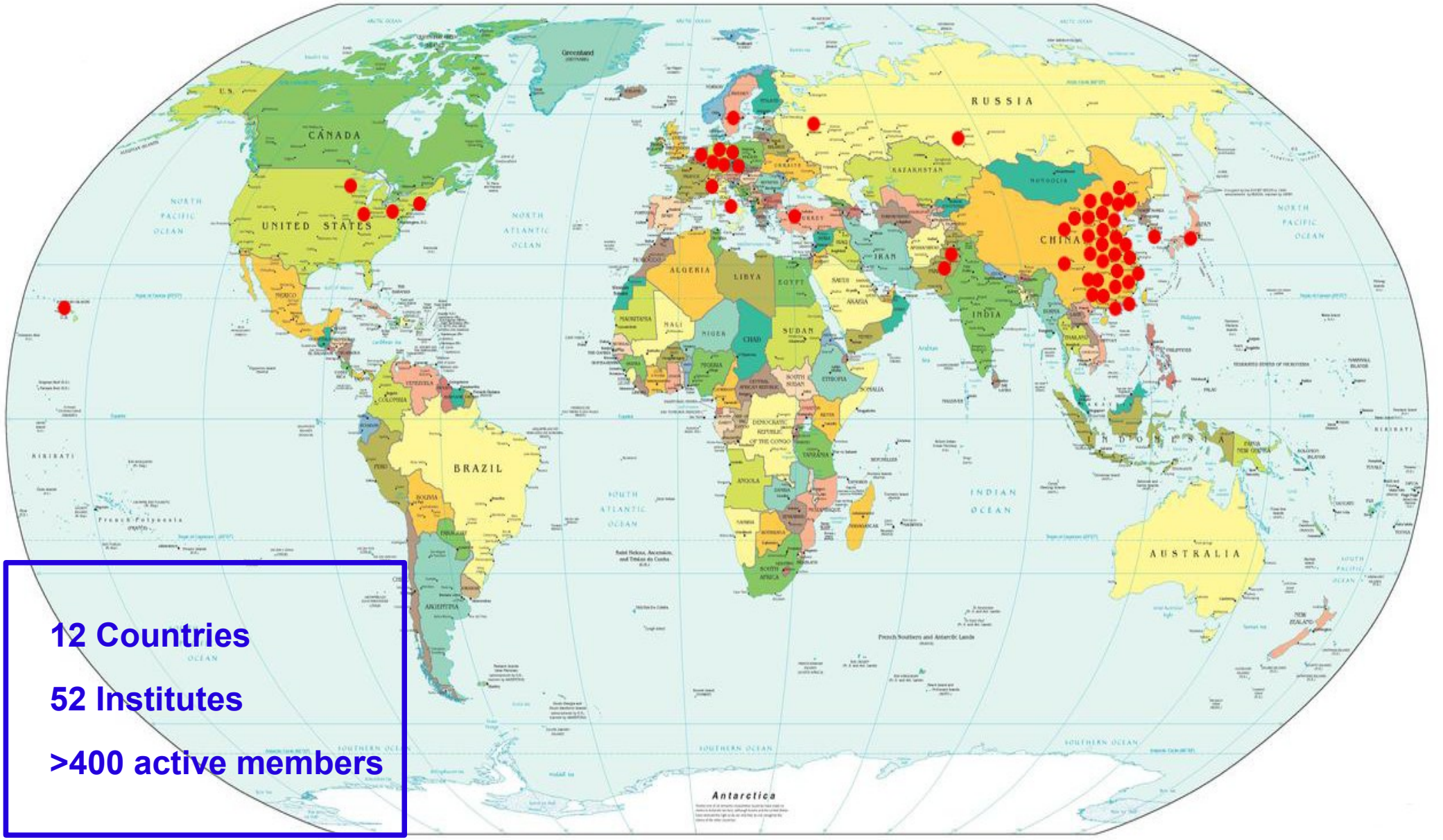
EMC: CsI cristal
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

MDC:
- Spatial resolution: σ_{xy}**= 120μm**
- Momentum resolution:**0.5% @ 1GeV**
- **dE/dx** resolution: 6%

TOF:
Time resolution: **100ps** (barrel)
110ps (endcaps)

Muon ID:
9 layers RPC, 8 for endcaps

The BES-III Collaboration



12 Countries

52 Institutes

>400 active members

The BES-III timeline

July 19, 2008: first e+e- collision event in BES-III

2009: 106M ψ(2S) (4 times of CLEO-c)

225M J/ψ (4 times of BES-II)

2010: ~0.9 fb^{-1} ψ(3770) (3.5 times of CLEO-c)

2011: ~2.0 fb^{-1} ψ(3770)

~0.5 fb^{-1} @ 4.01 GeV

2012: tau mass scan: ~5.0 pb^{-1} ;

ψ(2S): 0.4 billion;

J/ψ: 1 billion

Tentative future plans:

- 0.5 fb^{-1} @4260 MeV and 0.5 fb^{-1} @4360 MeV for "XYZ" studies
- 2.4 fb^{-1} @4170 MeV for Ds studies
- additional ψ(3770) data

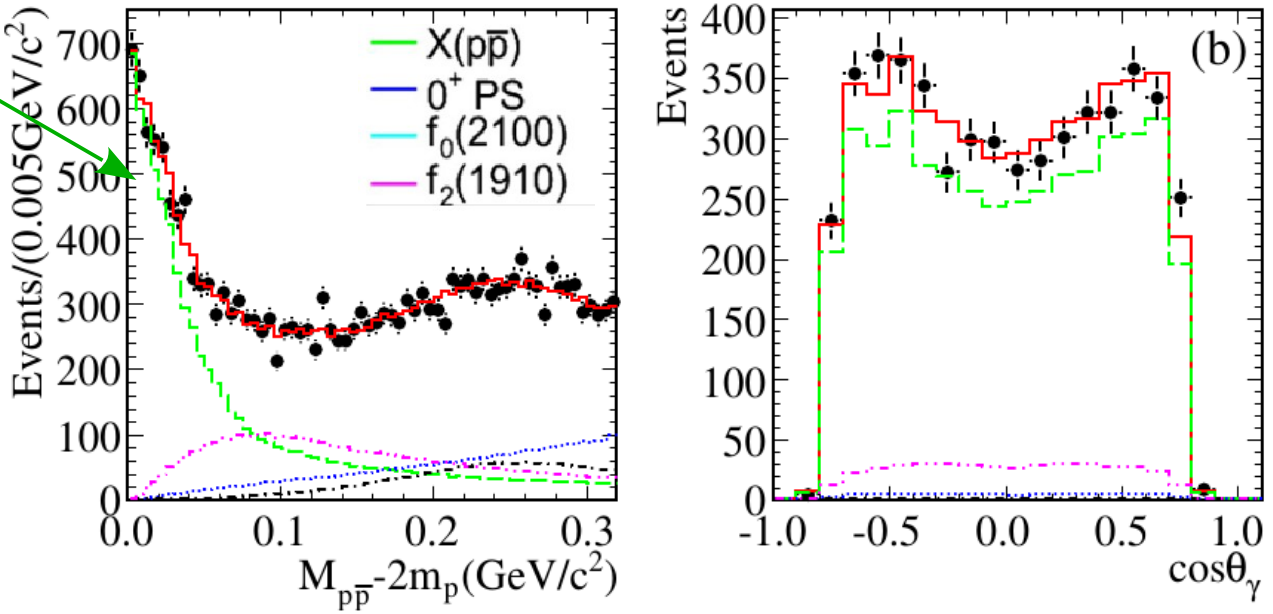
Light Hadrons Spectroscopy
(recent results)

- Spin-parity analisys of $p\bar{p}$ near threshold enhancement in $J/\psi \rightarrow \gamma p\bar{p}$, $\psi(2S) \rightarrow \gamma p\bar{p}$
- $J/\psi \rightarrow \gamma 3\pi$

$p\bar{p}$ near threshold enhancement: $J/\psi \to \gamma p\bar{p}$

Unclear nature: normal meson, pp bound sate, multiquark, glueball,...

PRL 108, 112003(2012)



Fit components: X($p\bar{p}$), $f_2(1920)$, $f_0(2100)$, 0^{++} PHSP

PWA fit features:

- Mass structure can be described by BW and FSI corrections (PRD 71, 054010 (2005))
- FSI corrections notably improve description
- Different FSI → model systematic

Fit results:

$$J^{PC} = 0^{+-} \text{ are preferable (by} > 6.8\,\sigma \text{ better than other assignments)}$$

$$M = 1832\,^{+19}_{-5}(stat)\,^{+18}_{-17}(syst) \pm 19(model)\ MeV$$

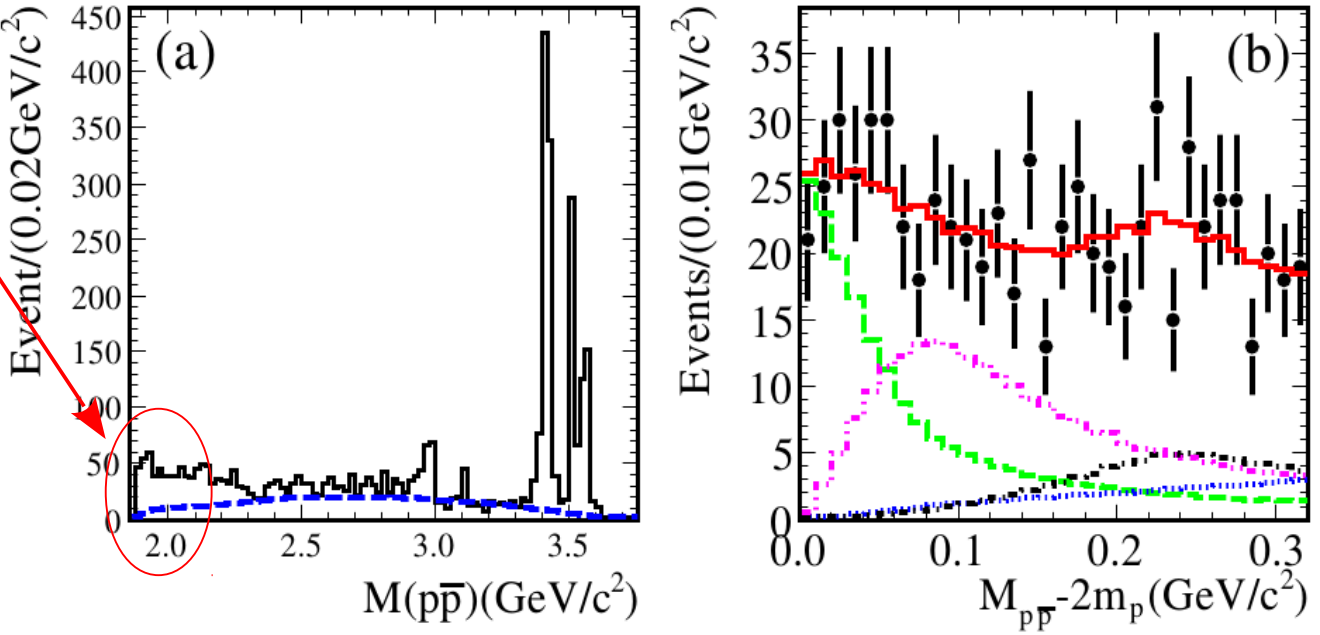
$$\Gamma < 76\ MeV \quad @90\%\ C.L.$$

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

$p\bar{p}$ near threshold enhancement: $\psi(2S) \to \gamma p\bar{p}$

PRL 108, 112003(2012)

Clearly the mass spectrum line shape is different



PWA Fit:

- mass an width and J^{PC} of $X(p\bar{p})$ are fixed to values obtained in $J/\psi \to \gamma p\bar{p}$ fit
- stat. significance >6.9σ

Fit components: $X(p\bar{p})$, $f_2(1920)$, $f_0(2100)$, 0^{++} PHSP

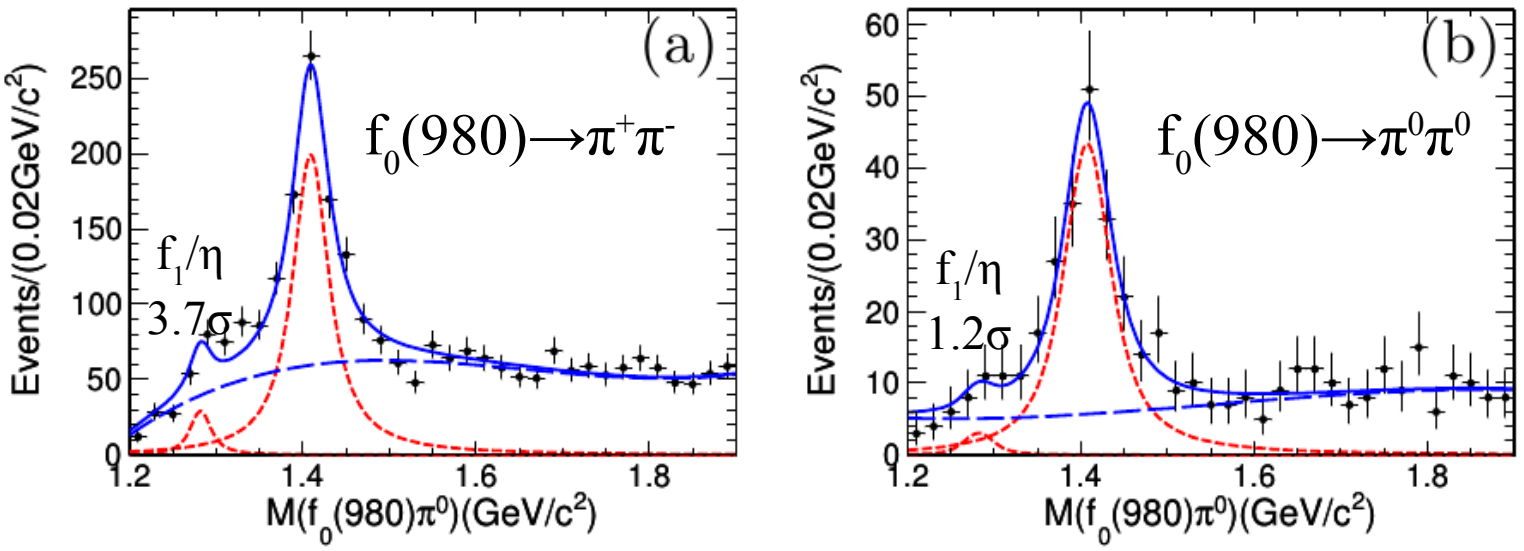
Production ratio:

$$R = \frac{Br(\psi(2S) \to \gamma X(p\bar{p}))}{Br(J/\psi \to \gamma X(p\bar{p}))} = 5.08\,^{+0.71}_{-0.45}(stat)\,^{+0.67}_{-3.58}(syst) \pm 0.12(mod)\ \%$$

$J/\psi \to \gamma\pi^+\pi^-\pi^0, \gamma 3\pi^0$

The first observation of $\eta(1405) \to \pi^0 f_0(980)$ (isospin breaking)

PRL 108, 182001 (2012)



- Helicity analysis favors $\eta(1405)$ over $f_1(1420)$
- Large isospin violating decay rate:

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

PDG2010 + Phys.Lett. B358 (1995) 389

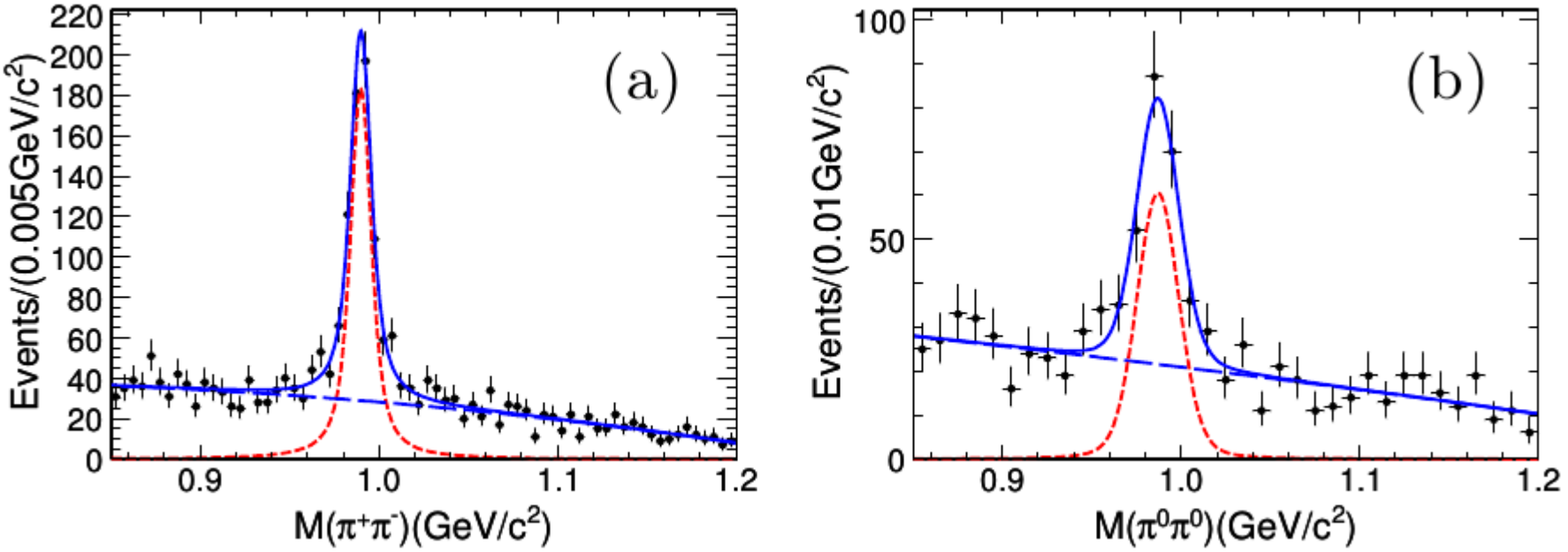
- Branching fraction for $\eta' \to \pi^+\pi^-\pi^0$, $\eta' \to 3\pi^0$ measured with precision improved by factor of 4

The magnitude of isospin violation should be <<1%
=> only $a_0(980)$-$f_0(980)$ mixing can not explain this branching (see PRD 83(2100)032203).

$J/\psi \to \gamma\pi^+\pi^-\pi^0,\ \gamma 3\pi^0$

PRL 108, 182001 (2012)

Anomalous line shape of $f_0(980)$



Surprising result:

Very narrow width: Γ<11.8 MeV @90% C.L.
(PDG gives: 40-100 MeV)

Possible explanations:
KK* loop, Triangle Singularity (PRL 108, 081803(2012))

Charmonium spectra and transitions

(recent results)

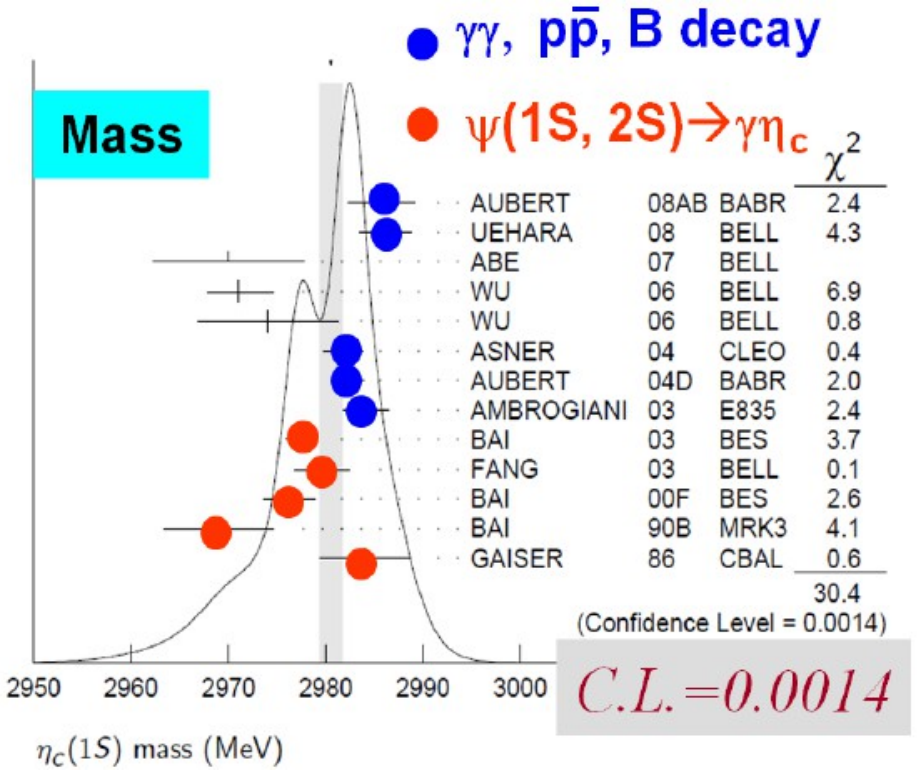
- η_c parameters precision measurement
- The first observation of M1 transition $\psi' \to \gamma\eta_c(2S)$
- The first evidence for the direct $\psi(2S) \to \gamma\gamma\ J/\psi$ transition
- The first observation of $e^+e^- \to \eta J/\psi$ at $\sqrt{s}$ = 4.009 GeV

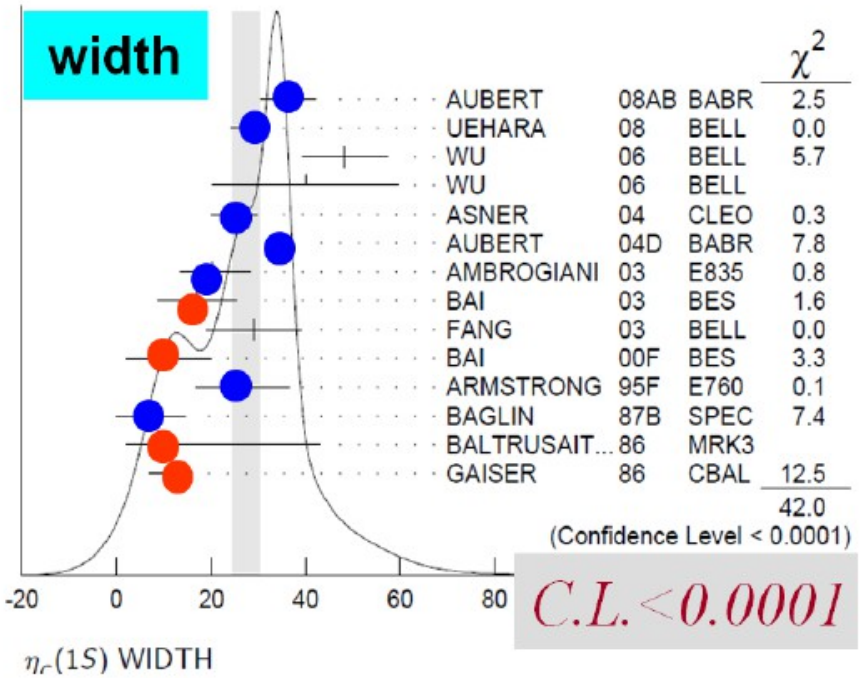
η_c resonance parameters from $\psi' \to \gamma\eta_c$

- Ground state of $c\bar{c}$ system, but mass and width are not well known:

  J/ψ, ψ(2S) radiative transitions: $M(\eta_c)$~2978.0 MeV, $\Gamma(\eta_c)$~10 MeV
  Two-photon process: $M(\eta_c)$=2983.1±1.0 MeV, $\Gamma(\eta_c)$=31.3±1.9 MeV

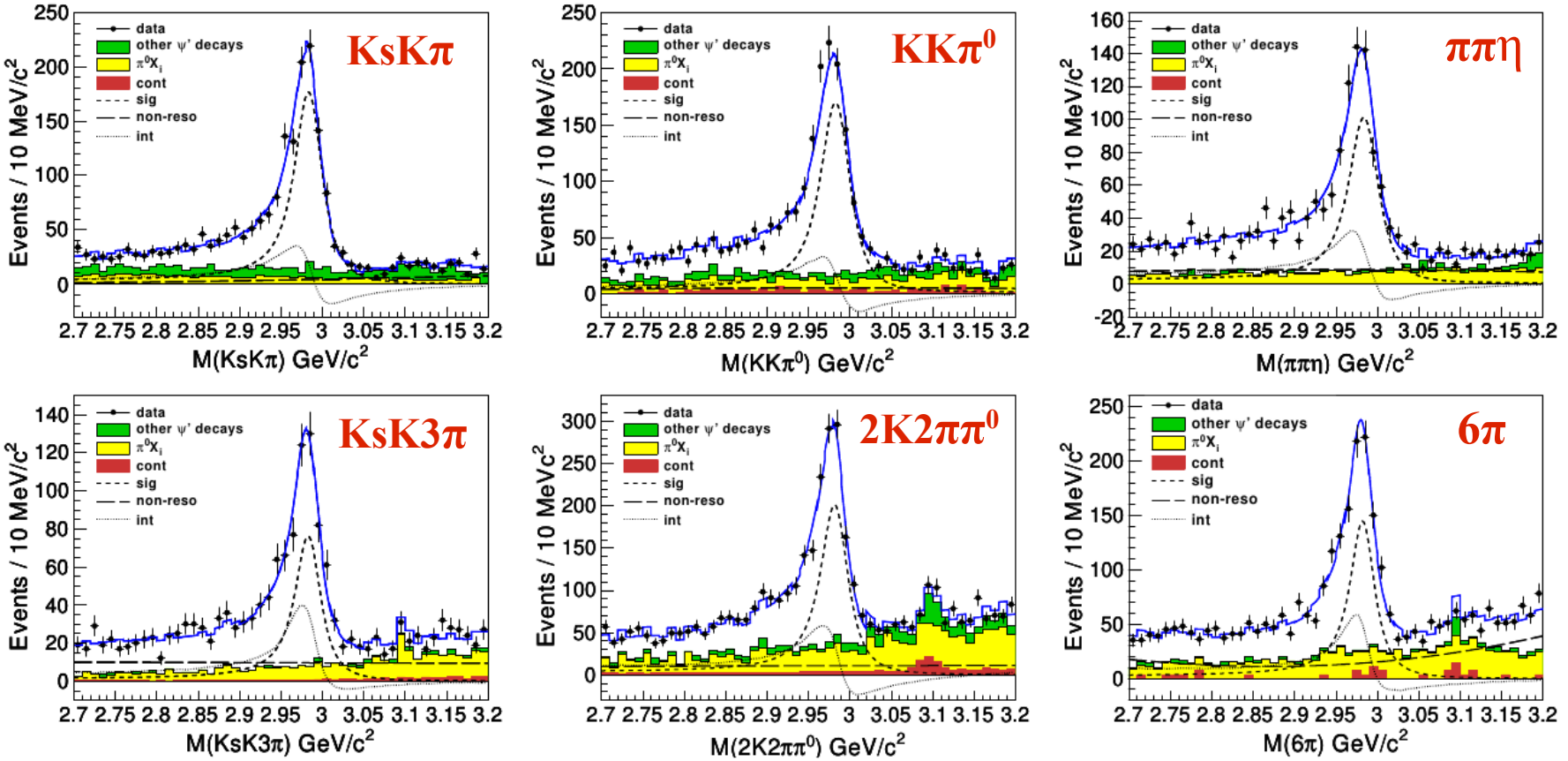
- CLEOc pointed out at the η_c line shape distortion in $\psi(2S) \to \gamma\eta_c$





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

PRL 108, 222002 (2012)



Simultaneous fit of shown η_c decay modes.

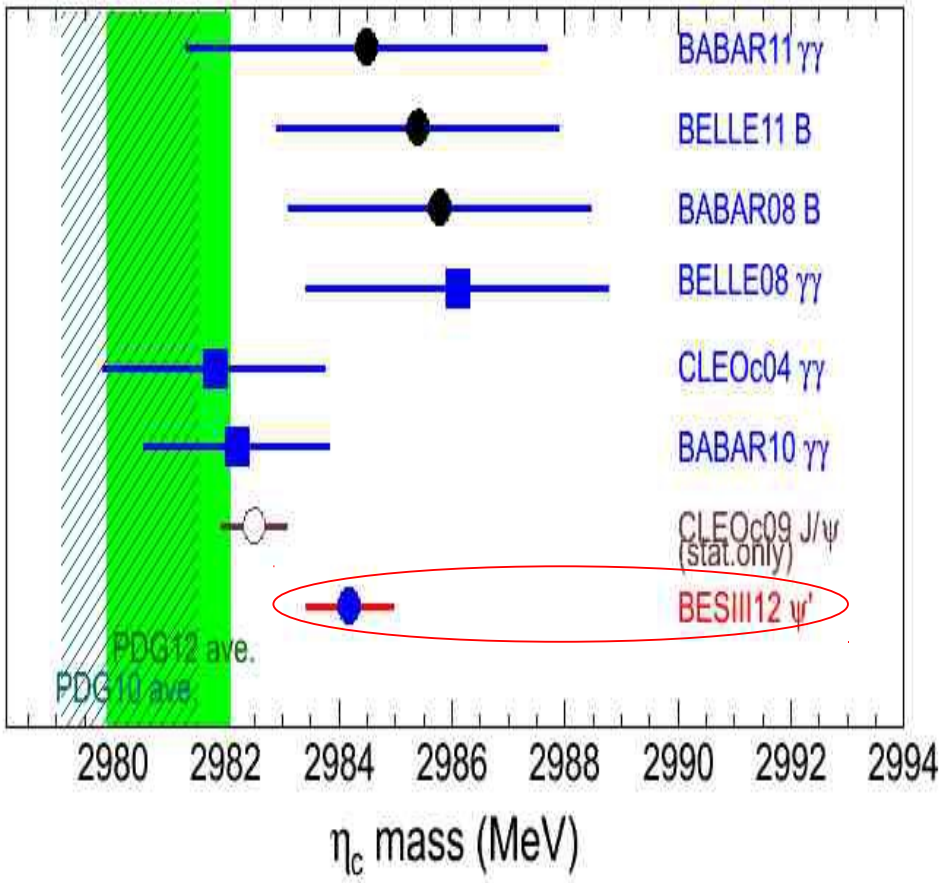
- η_c line shape: interference with non-η_c decays
- phases for different modes are consistent within 3σ, a common phase is used

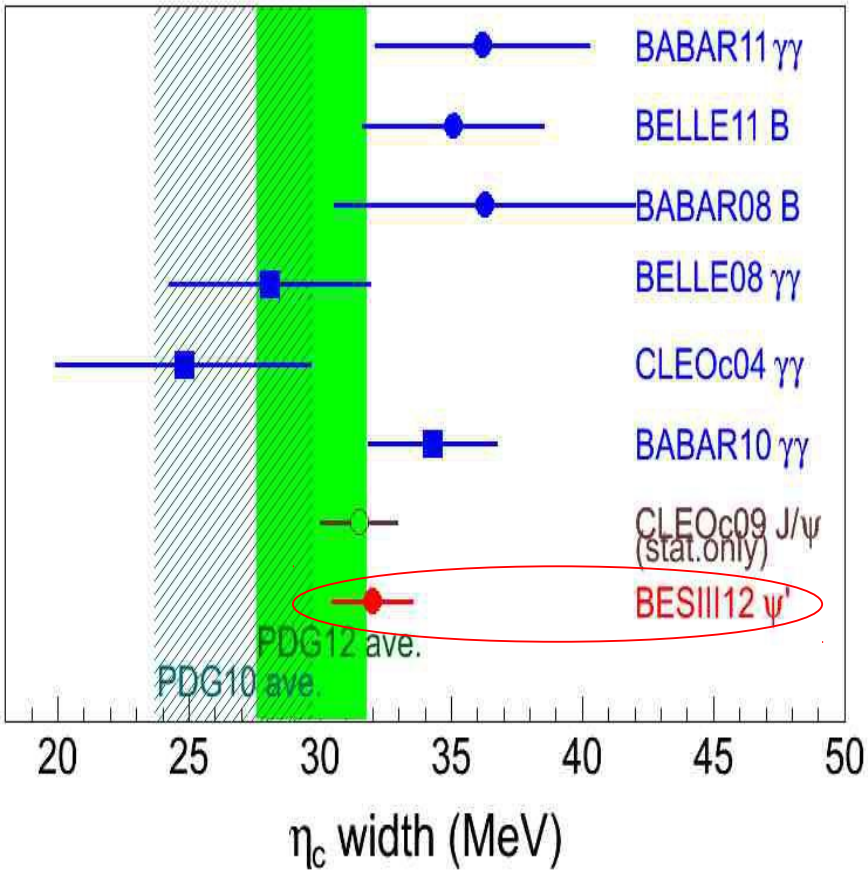
BES-III result:

$$M(\eta_c) = 2984.3 \pm 0.6 \pm 0.6\ \text{MeV}$$
$$\Gamma(\eta_c) = 32.0 \pm 1.2 \pm 1.0\ \text{MeV}$$

Currently the most precise measurements!

Comparison of the mass and width for η_c





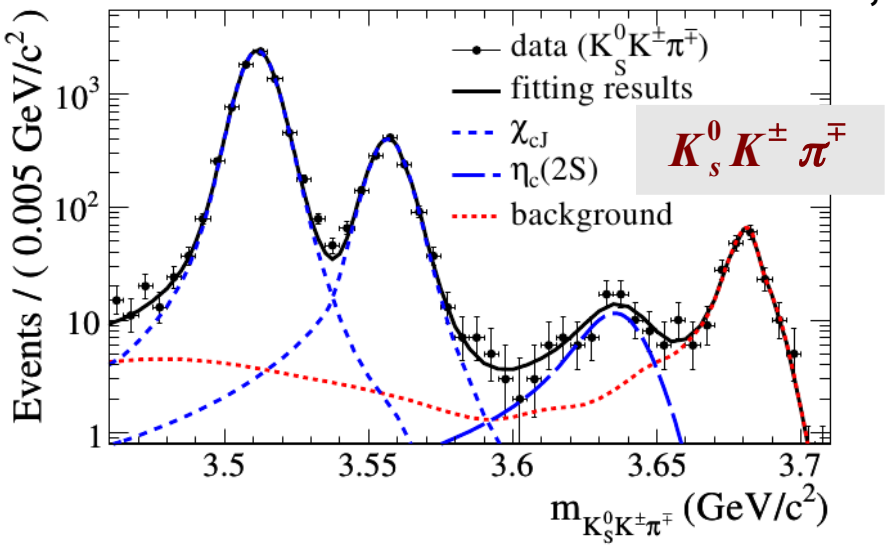
Hyperfine splitting: $\Delta M_{hf}(1S) = 112.5 \pm 0.8\ \mathrm{MeV}$

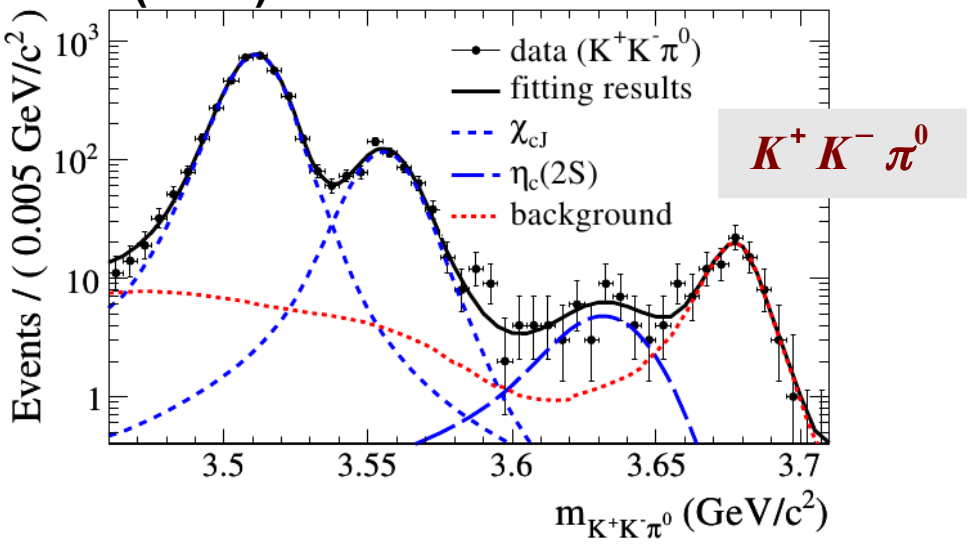
- ✔ Consistent with B factory results in other production mechanisms
- ✔ Agree with lattice QCD calculations of the charmonium hyperfine splitting

The first observation of M1 transition $\psi' \to \gamma \eta_c(2S)$

Never before observed in charmonium transitions

PRL 109, 042003 (2012)





Combined fit of two channels:

- significance >10σ
- $$M = 3637.6 \pm 2.9(stat) \pm 1.6(syst)\ MeV$$
  $$\Gamma = 16.9 \pm 6.4(stat) \pm 4.8(syst)\ MeV$$
- combined branching ratios

signal line shape:

$$\left(E_\gamma^3 \times BW(m) \times f_d(E_\gamma) \times \epsilon(m)\right) \otimes G(\delta m, \sigma)$$

M1 transition — dumping function

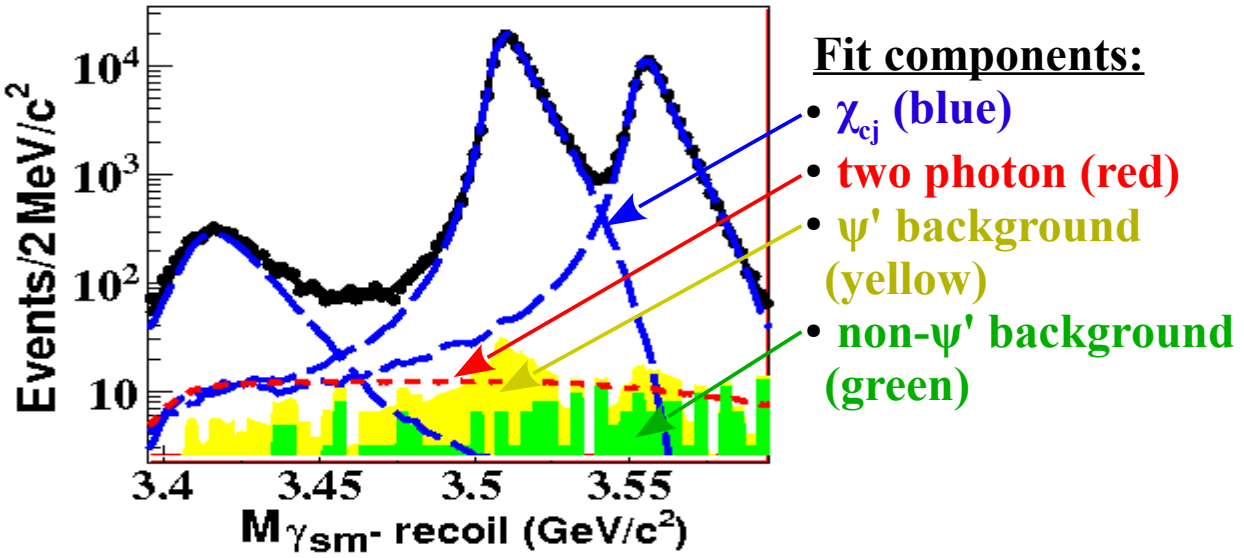
$$Br(\psi' \to \gamma \eta_c(2S)) \times Br(\eta_c(2S) \to KK\pi) = (1.30 \pm 0.20 \pm 0.30) \times 10^{-5}$$

BaBar: PRD 78 012006(2008) → $Br(\psi' \to \gamma \eta_c(2S)) = (6.8 \pm 1.1 \pm 4.5) \times 10^{-4}$

Evidence for the direct $\psi' \to \gamma\gamma J/\psi$ transition

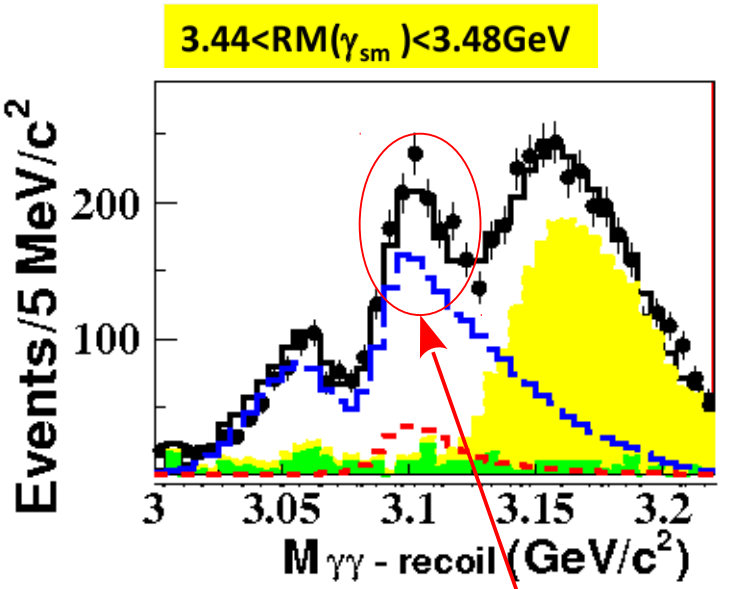
Never before observed in charmonium transitions

arXiv: 1204.0246, accepted for publication in PRL



Fit components:

- χ_{cj} (blue)
- two photon (red)
- ψ' background (yellow)
- non-ψ' background (green)



See **clear excess** over BG + continuum

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

Global fit: $Br = \left(3.1 \pm 0.6(stat)^{+0.8}_{-1.0}(syst)\right) \times 10^{-4}$

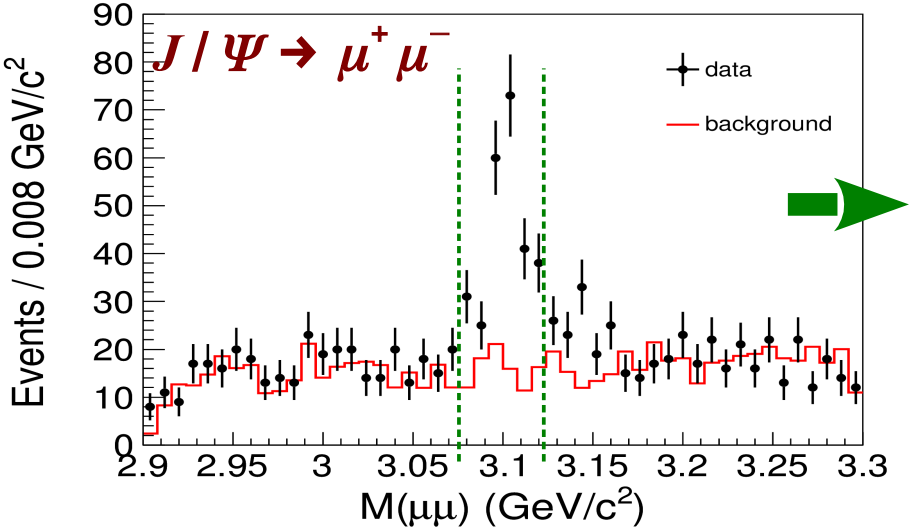
Significance: **3.8σ** (including systematics)

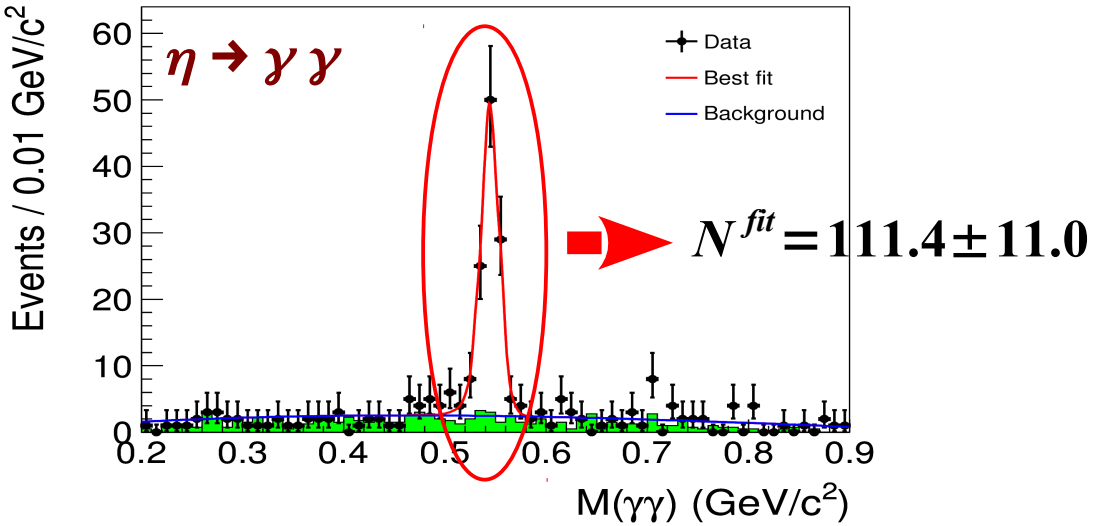
$Br\left(\Psi(2S) \to \gamma\chi_{cJ}, \chi_{cJ} \to J/\Psi\right)$ are also mesured

The first observation of $e^+e^- \to \eta J/\psi$ at $\sqrt{s}$=4.009 GeV

arXiv: 1208.1857, accepted by Phys.Rev.D

- Select $e^+e^- \to \eta J/\Psi$, $J/\Psi \to \mu^+\mu^-$ (and e^+e^-) and $\eta \to \gamma\gamma$
- Fit the η signal:





- Significance $> 10\sigma$
- Born cross-section: $\sigma^B(e^+e^- \to \eta J/\Psi) = 32.1 \pm 2.8 \pm 1.3$ pb
- Assuming the ηJ/ψ signal is from a hadronic transition of ψ(4040):

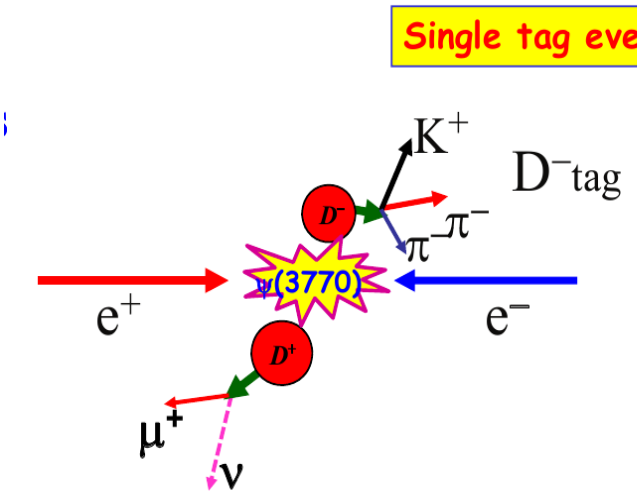
$$Br(\Psi(4040) \to \eta J/\Psi) = (5.2 \pm 0.5 \pm 0.2 \pm 0.5) \times 10^{-3}$$

Charm physics
(BES-III preliminary)

- Leptonic D^+ decays
- Semileptonic D^0 decays

Advantage of open charm at threshold

- At ψ(3770) charm production is D^+D^- or $D^0\bar{D}^0$
- About 15% of D decays are fully reconstructed
- Hadronic tag of D on one side gives "beam" of second D on the other side for leptonic/semileptonic studies. Neutrino is reconstructed from missing energy and momentum.



$$\Delta E = E_D - E_{beam}$$

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

$D^+ \to \mu^+ \nu_\mu$ (BES-III preliminary)

Nine D^- tag modes:

a) $K^+ \pi^- \pi^-$

b) $K^0 \pi^-$

c) $K^0 K^-$

d) $K^+ K^- \pi^-$

e) $K^+ \pi^- \pi^- \pi^0$

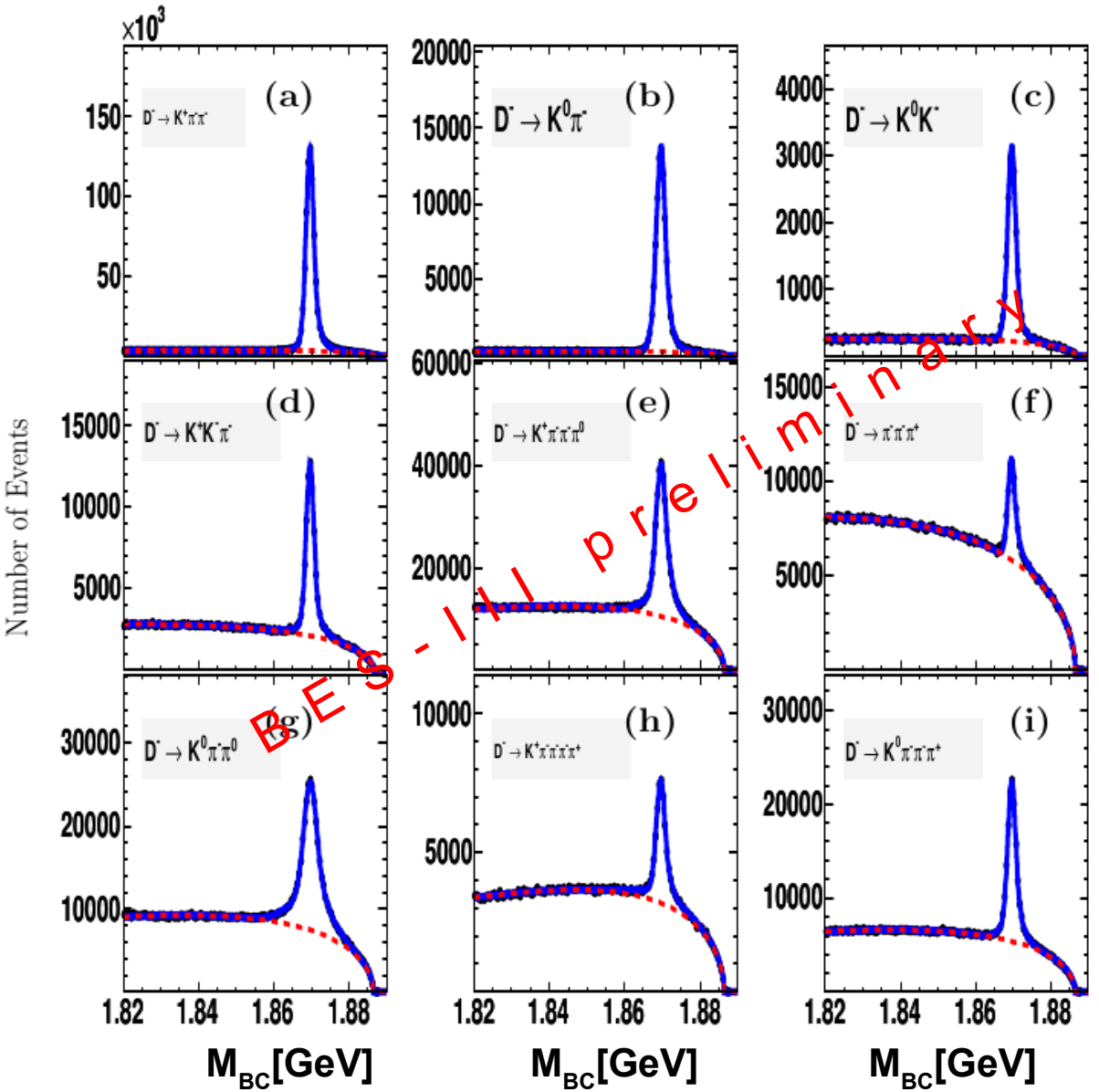
f) $\pi^+ \pi^- \pi^-$

g) $K^0 \pi^- \pi^0$

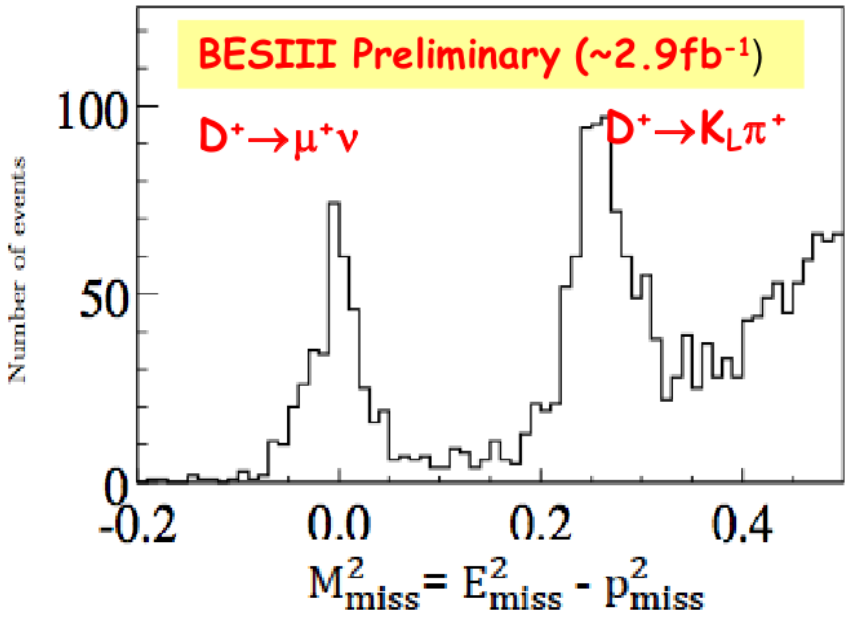
h) $K^+ \pi^- \pi^- \pi^- \pi^+$

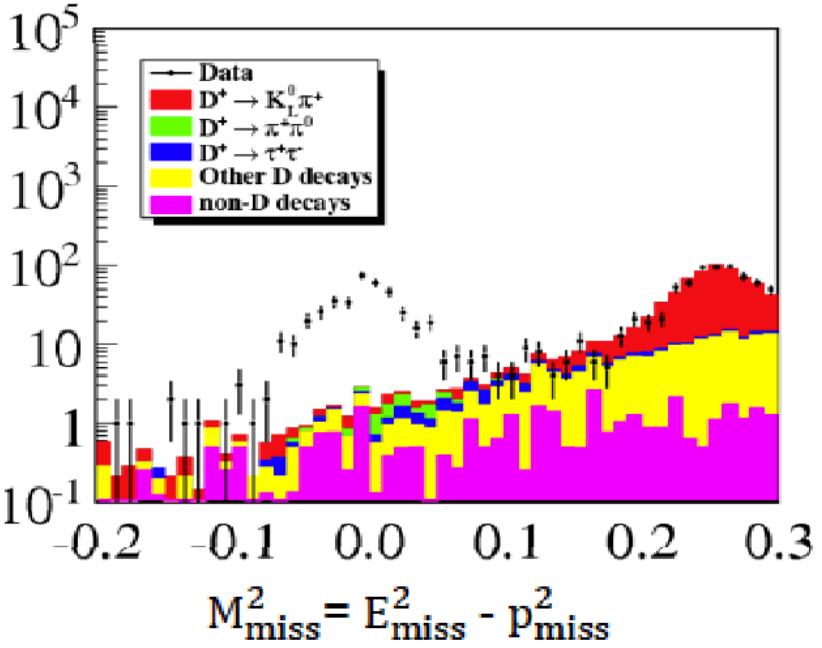
i) $K^0 \pi^- \pi^- \pi^+$

$$N_{D^-}^{tag} = (1.566 \pm 0.002) \times 10^6$$
$$\text{in } 2.9\ fb^{-1}$$



$D^+ \to \mu^+ \nu_\mu$ (BES-III preliminary)





BES-III preliminary:

$$N(D^+ \to \mu^+ \nu_\mu) = 377.3 \pm 20.6$$

$$Br(D^+ \to \mu^+ \nu_\mu) = (3.74 \pm 0.21 \pm 0.06) \times 10^{-4}$$

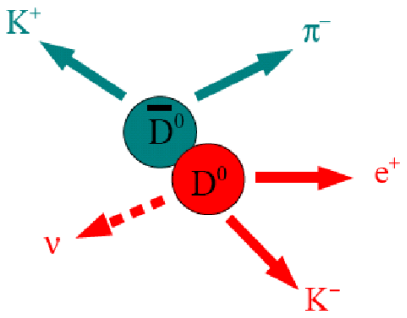
$$f_D = (203.9 \pm 5.7 \pm 2.0) \text{ MeV}$$

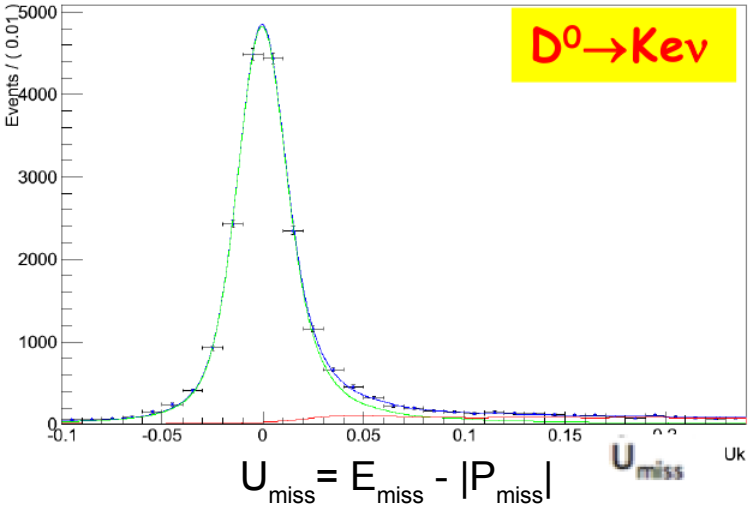
- Consistent with CLEO-c
- The error is still dominated by statistics

Semileptonic $\bar{D}^0 \to K^+(\pi^+)e^-\bar{\nu}_e$

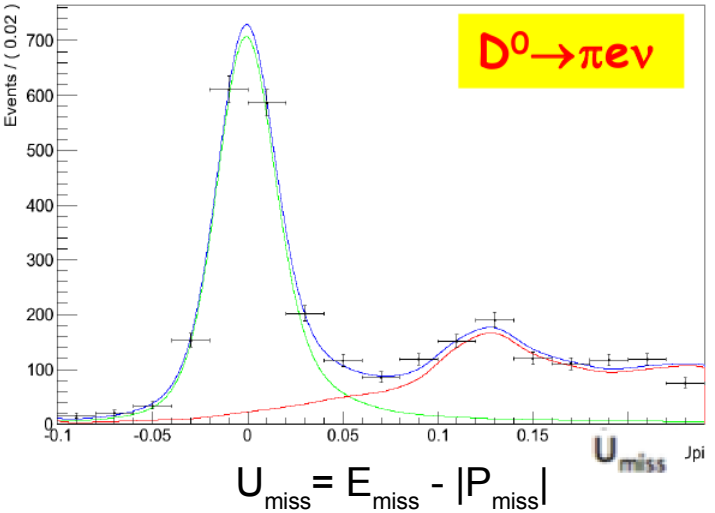
BES-III preliminary, 0.92 fb^{-1}

Four D^0 tag modes: $K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^0\pi^0$, $K^-\pi^+\pi^-\pi^+$





$U_{miss} = E_{miss} - |P_{miss}|$



$U_{miss} = E_{miss} - |P_{miss}|$

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

- Systematic uncertainties are preliminary
- Statistics will be improved with the full data set of 2.9 fb^{-1}

Summary

- **BES-III successfully takes data since 2009. World largest data samples of J/ψ, ψ(2S), ψ(3770), ψ(4040) are collected and are growing.**
- **Number of physical results are published, among recent:**
  - **PWA of $p\bar{p}$ near threshold enhancement in $J/\psi \to \gamma p\bar{p}$, $\psi(2S) \to \gamma p\bar{p}$ *(PRL 108, 112003(2012))***
  - **The first observation of η(1405) in $J/\psi \to \gamma 3\pi$ *(PRL 108, 182001 (2012))***
  - **η_c parameters precision measurement *(PRL 108, 222002 (2012))***
  - **The first observation of $\eta_c(2S)$ in charmonium transitions *(PRL 109, 042003 (2012))***
  - **First evidence for the direct $\psi(2S) \to \gamma\gamma J/\psi$ transition *(arXiv: 1204.0246, accepted for publication in PRL)***
  - **Observation of $e^+e^- \to \eta J/\psi$ at center-of-mass energy $\sqrt{s} = 4.009$ GeV *(arXiv: 1208.1857, accepted for publication in Phys.Rev.D)***
- **Preliminary charm results are presented.**
- **Expect much more results from BES-III in coming years.**