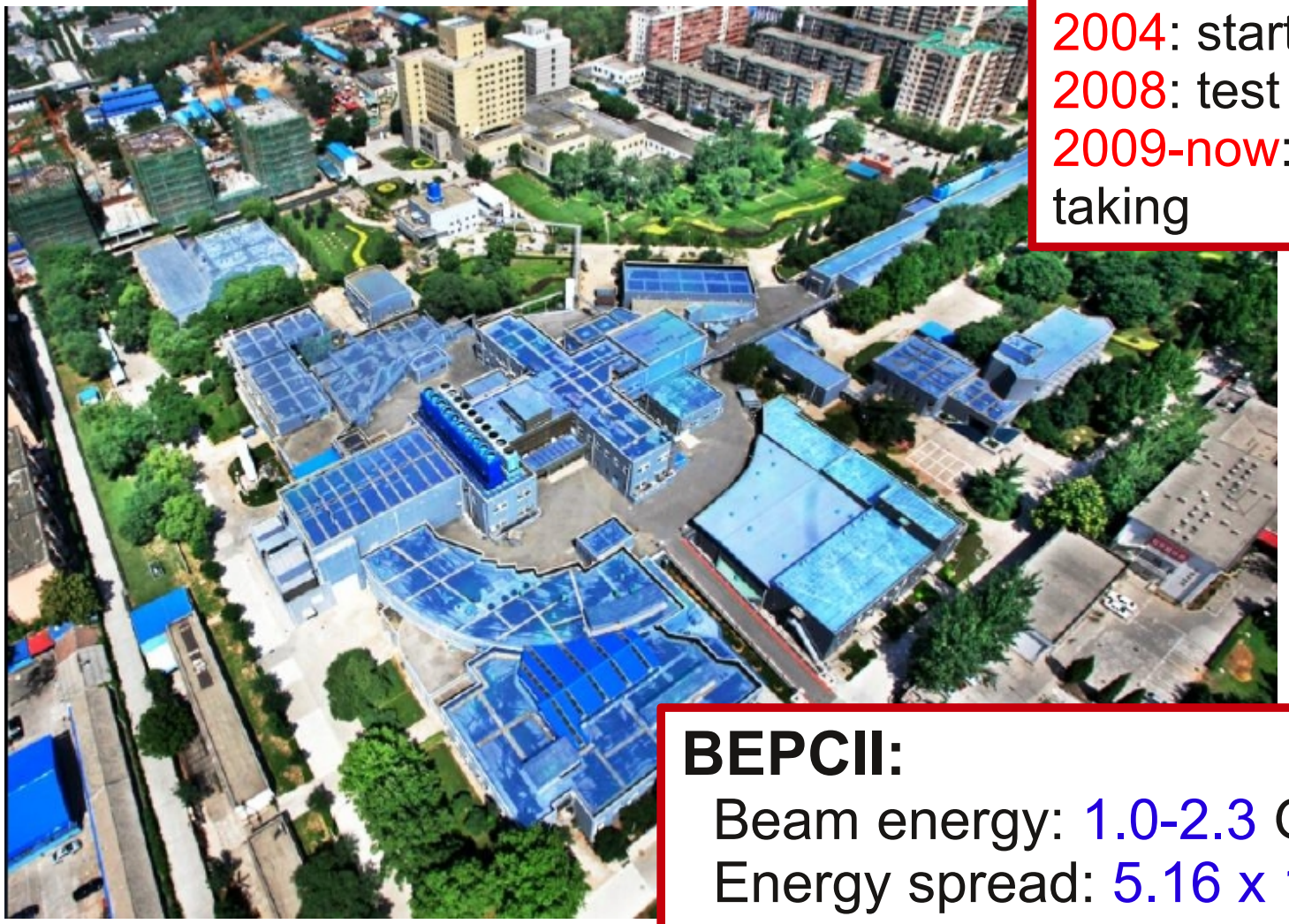
The BES-III experiment

Igor Denysenko
for the BES-III collaboration

JINR Dubna
on leave from BITP, Kiev

Hadron Structure and QCD
July 4-8, 2012, Gatchina, Russia

BEPCII/BESIII at IHEP(Beijing)



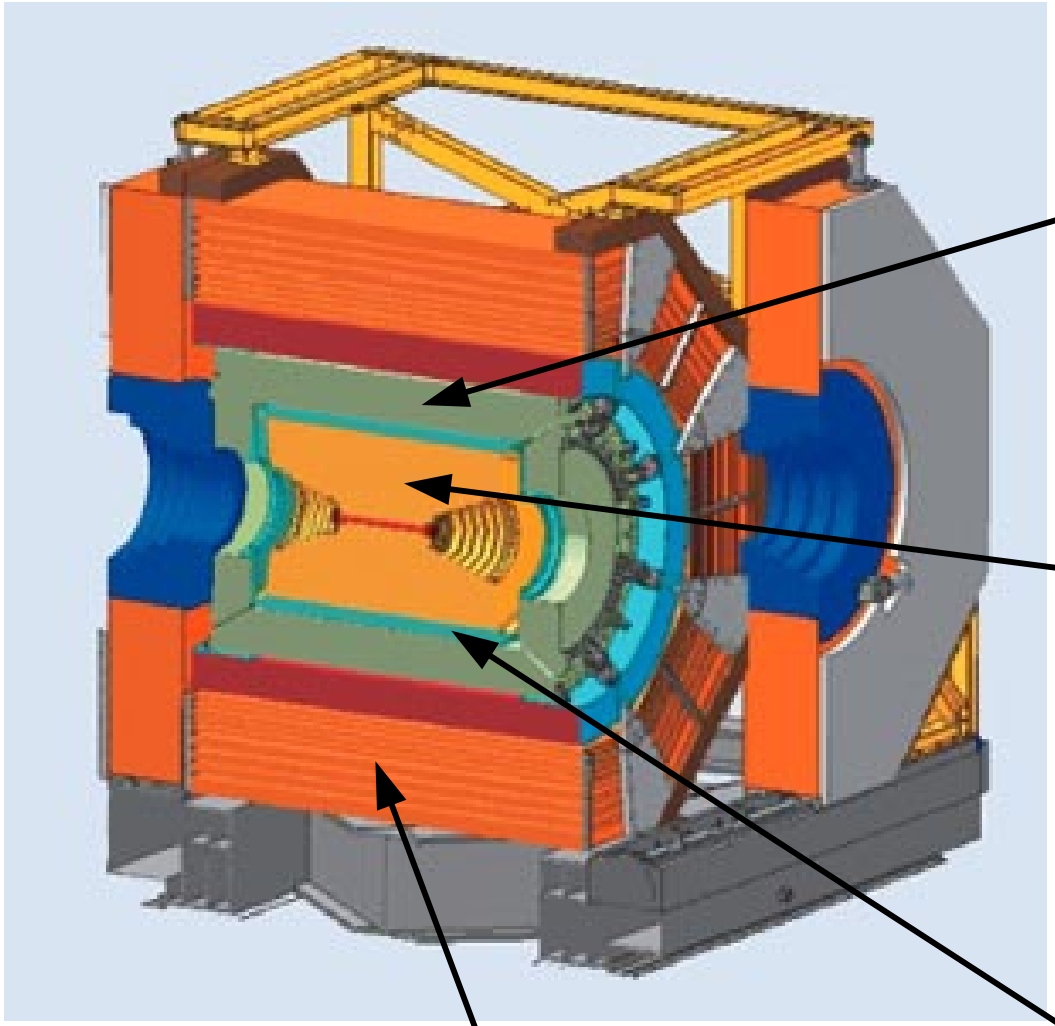
2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BEPCII/BESIII data taking

BEPCII:

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

The BES-III detector

NIM A614, 345(2010)



CsI(Tl) EMC:
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

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

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

Muon ID:
9 layers RPC, 8 for endcaps

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)

2011: ~2.0 fb^{-1} ψ(3770)

} 3.5 times of CLEO-c

~0.5 fb^{-1} @ 4.01 GeV

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

ψ(2S): 0.4 billion;

J/ψ: 1 billion

Plans for 2012-2013:

- 0.5 fb^{-1} @4.260 MeV
- tau scan
- 0.5 fb^{-1} @4.360 MeV
- R-scan

Light Hadrons Spectroscopy

(recent results)

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

pp near threshold enhancement

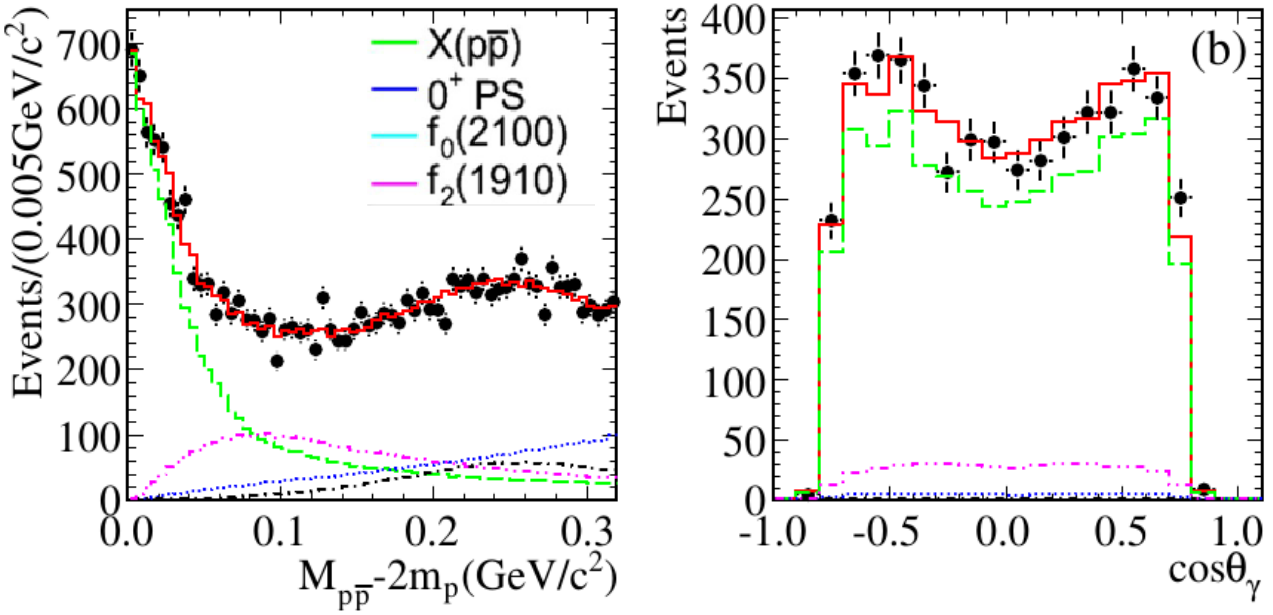
$$J/\psi \to \gamma p\bar{p}$$

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

Fit features:

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

PRL 108, 112003(2012)



Fit components: X(pp̄), $f_2(1920)$, $f_0(2100)$, 0^+ PHSP

Fit results:

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

$M = 1832_{-5}^{+19}(stat.)_{-17}^{+18}(syst.)\pm19(model)$ MeV

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

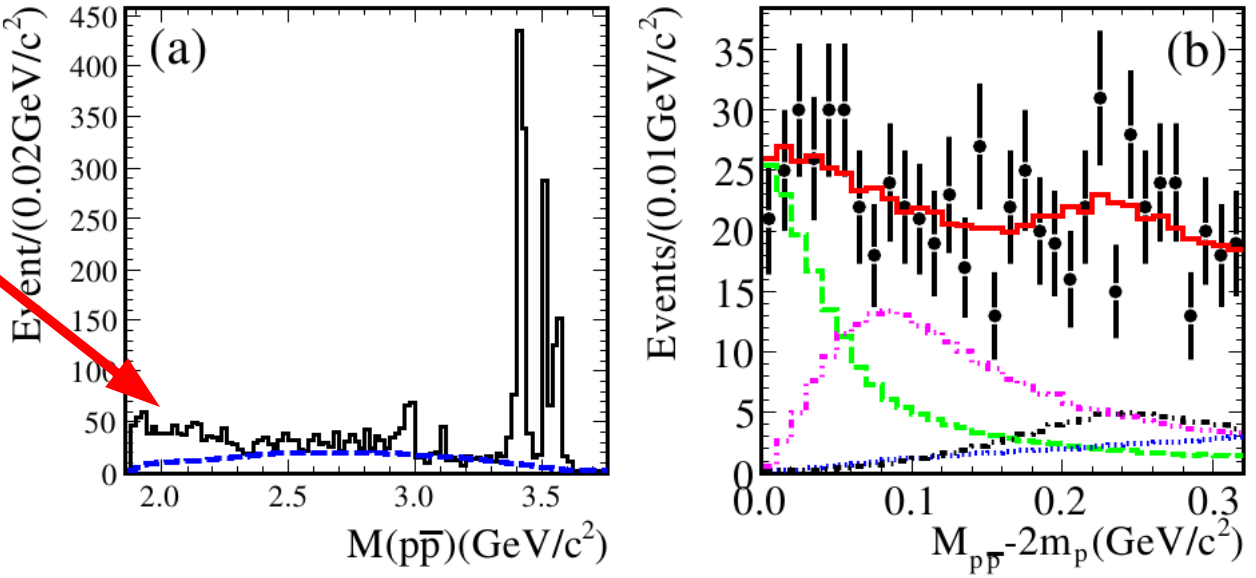
$Br(J/\psi\to\gamma X)Br(X\to pp) = (9.0_{-1.1}^{+0.4})\times10^{-5}$

pp near threshold enhancement

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

PRL 108, 112003(2012)

Clearly the mass spectrum line shape is different



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

PWA Fit:

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

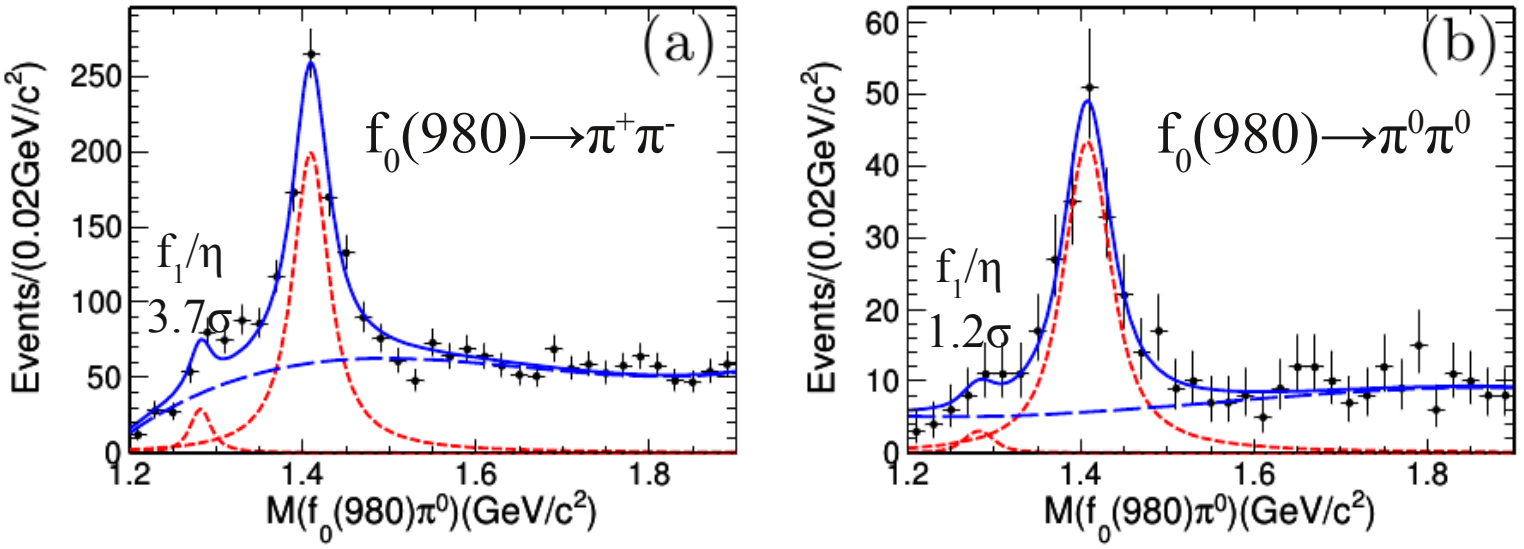
$$R = \frac{B(\psi' \rightarrow \gamma X(p\bar{p}))}{B(J/\psi \rightarrow \gamma X(p\bar{p}))}$$

$$= (5.08^{+0.71}_{-0.45}(\text{stat})^{+0.67}_{-3.58}(\text{syst}) \pm 0.12(\text{mod}))\%$$

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

PRL 108, 182001 (2012)

The first observation of $\eta(1405) \to \pi f_0(980)$, $f_0(980) \to \pi^+\pi^-, \pi^0\pi^0$



Helicity analysis strongly favors $\eta(1405)$ over $f_1(1420)$

Large isospin violating decay rate:

$$\frac{BR(\eta(1405)\to f_0(980)\pi^0\to\pi^+\pi^-\pi^0)}{BR(\eta(1405)\to a_0(980)\pi^0\to\pi^0\pi^0\eta)} \approx (17.9\pm4.2)\%$$

PDG2010 + Phys.Lett. B358 (1995) 389

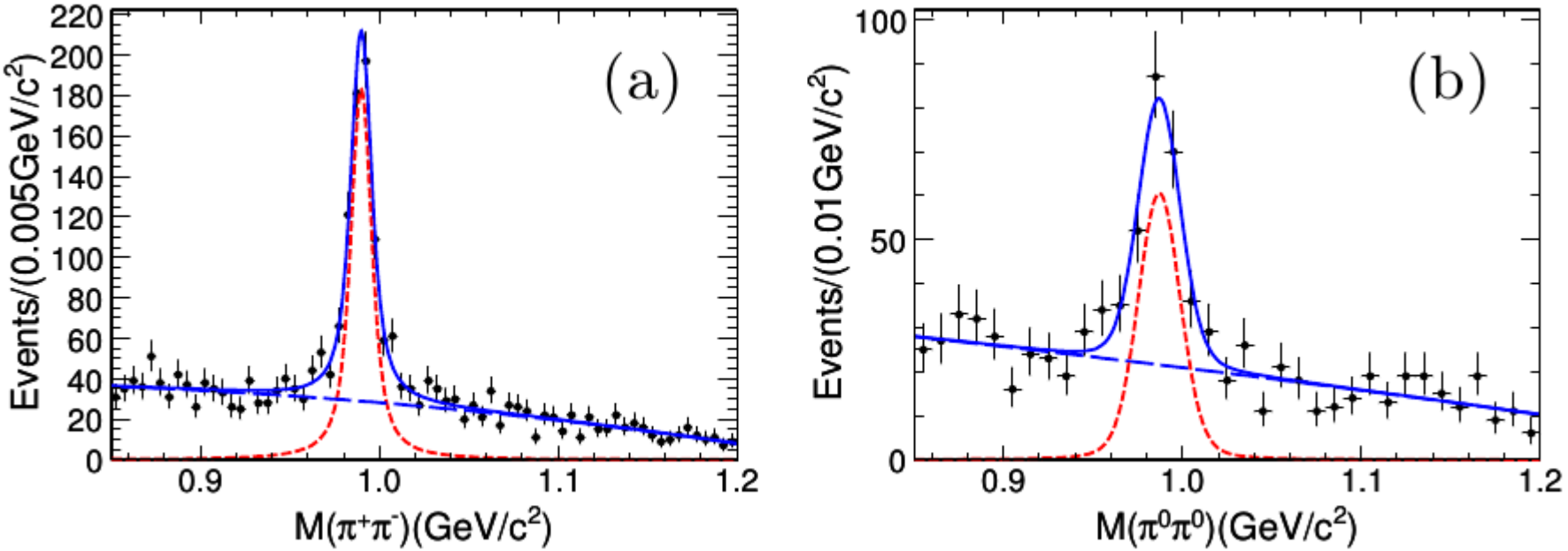
Generally, magnitude of isosping violation should be <1%.
This branching fraction cannot be explained by $a_0(980)$-$f_0(980)$ mixing alone (see PRD 83(2100)032203).

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

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

PRL 108, 182001 (2012)

Anomalous line shape of $f_0(980)$



Surprising result:

- Very narrow width Γ<11.8 MeV @90% C.L.
- Much smaller than the world average 40-100 MeV (PDG 2010)

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

Charmonium spectra and transitions

(recent results)

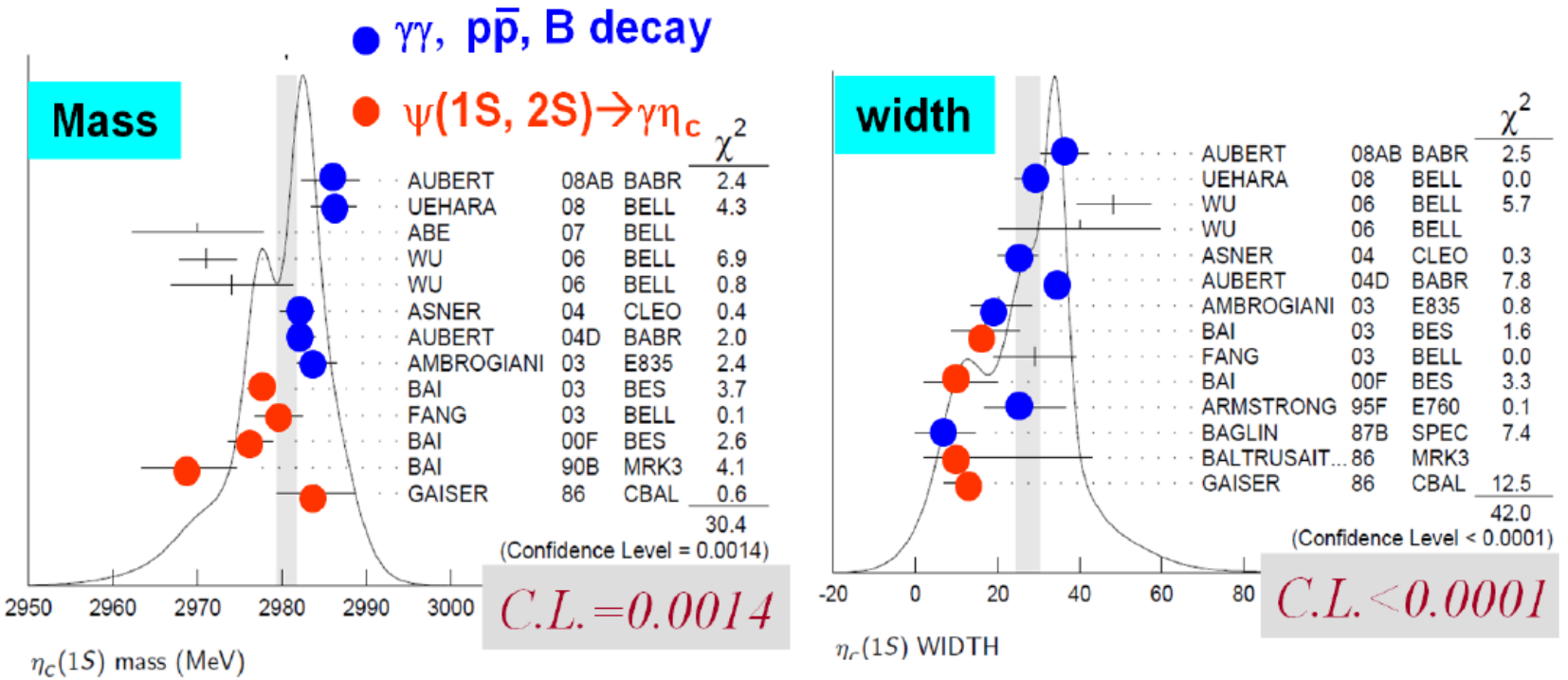
- η_c parameters precision measurement
- The first observation of M1 transition $\psi' \to \gamma\eta_c(2S)$
- The first evidence for the direct $\psi(2S) \to \gamma\gamma\ J/\psi$ transition

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

- Mass and width are known by an order of magnitude worse then for J/ψ, ψ(2S), $\chi_{c\,J}$

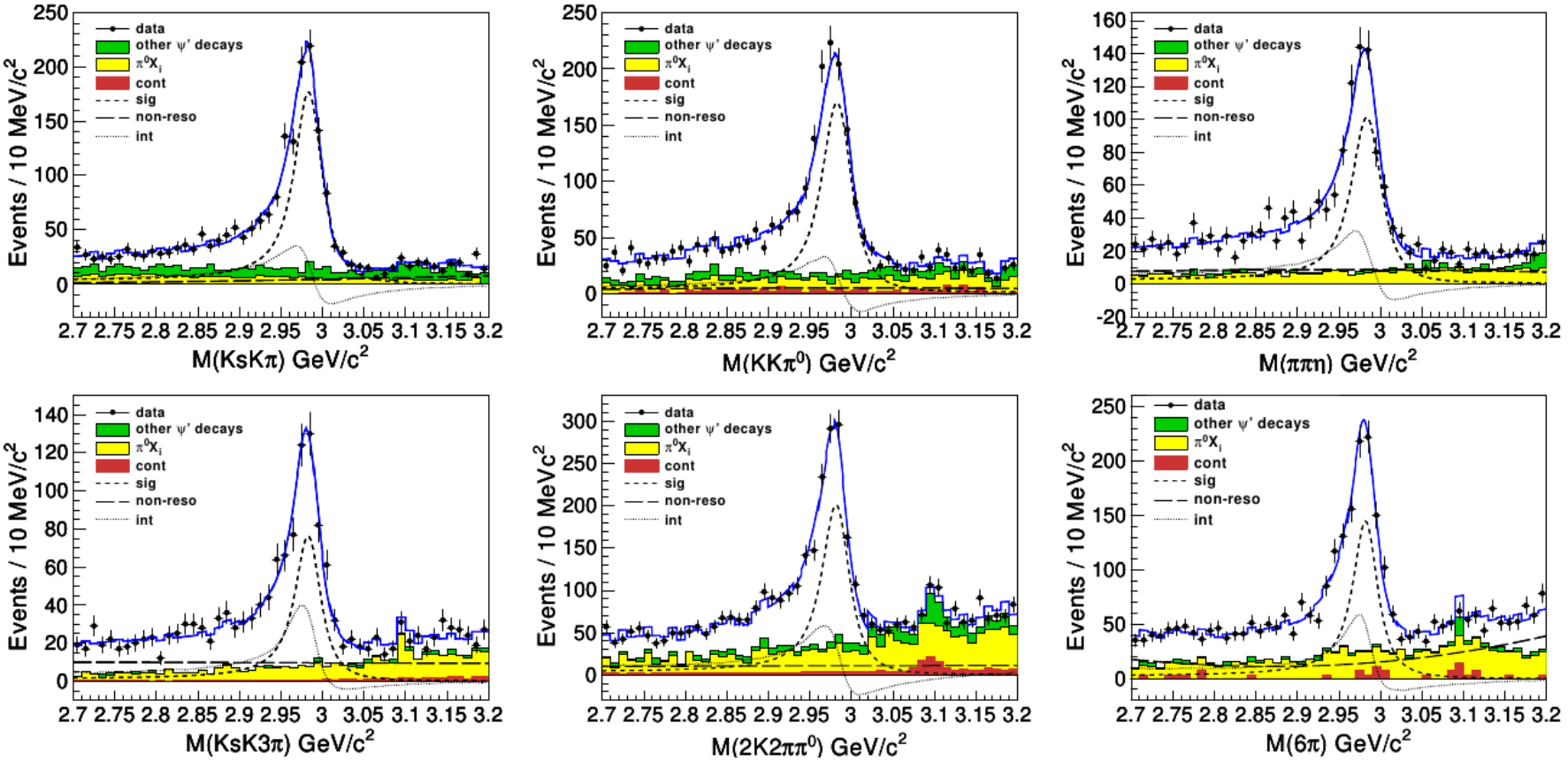
- Two series of experiments
  J/ψ and ψ(2S) radiative transitions: $M(\eta_c)$~2978.0 MeV, $\Gamma(\eta_c)$~10 MeV
  Two-photon process: $M(\eta_c)$=2983.1±1.0 MeV, $\Gamma(\eta_c)$=31.3±1.9 MeV

- CLEOc pointed out at the η_c line shape distortion in $\psi(2S) \to \gamma\eta_c$ (PRL 102, 011801 2009)



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

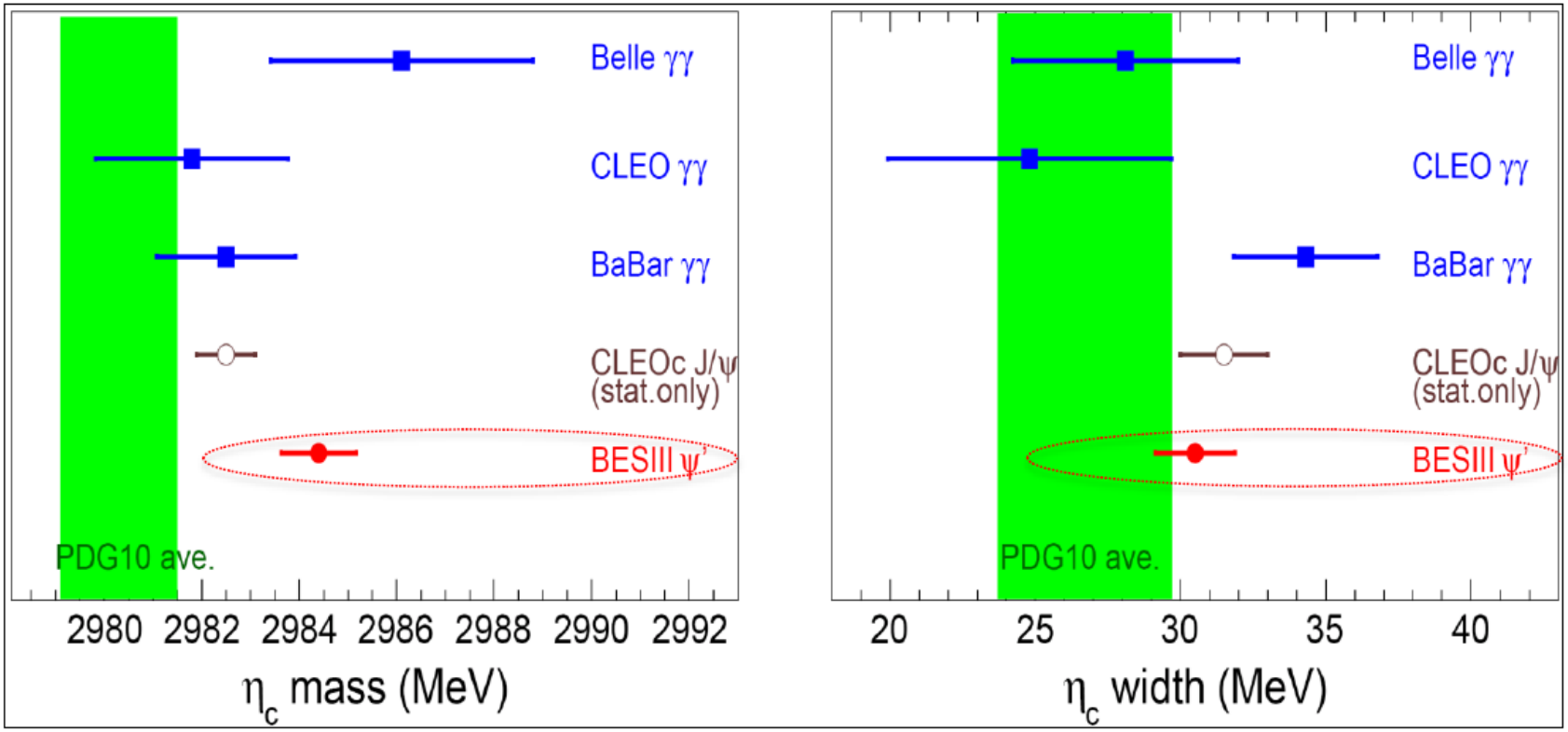
BES-III result:

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

Currently the most precise measurements!

Comparison of the mass and width for η_c

The world average in PDG2010 was using earlier measurements

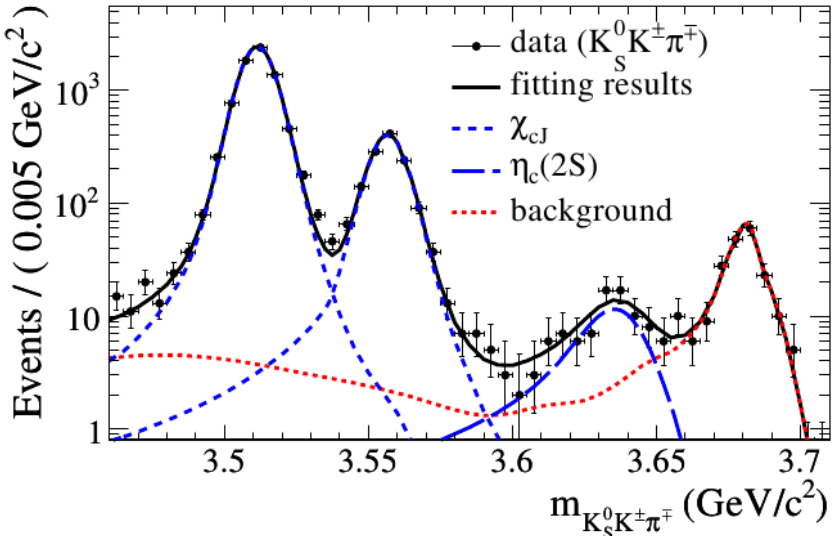


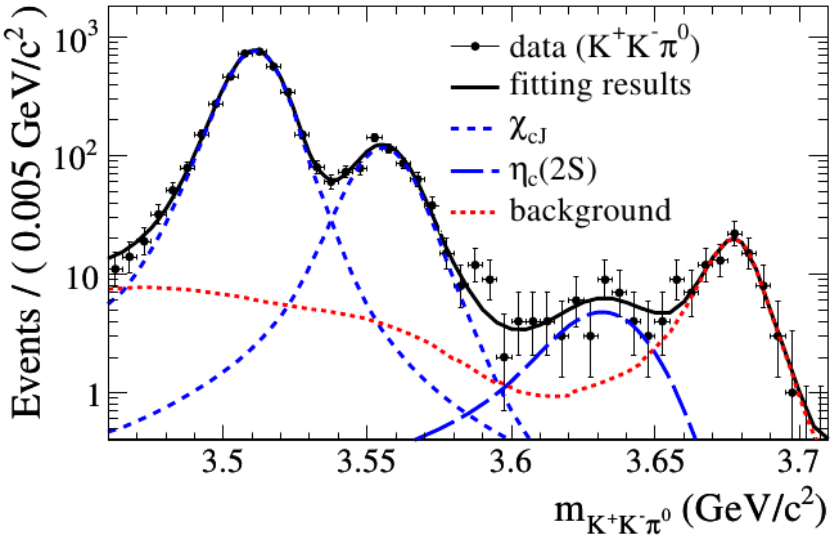
Hyperfine splitting: $\Delta M_{hf}(1S)$ = 112.6 ± 0.8 MeV/c^2

- ✓ 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 $\psi' \to \gamma \eta_c(2S)$

arXiv:1205.5103, accepted to PRL





Never before observed in charmonium transitions

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:

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

M1 transition — dumping function

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

PRD 78 012006(2008)

$$Br(\psi' \to \gamma \eta_c(2S)) = (6.8 \pm 1.1 \pm 4.5) \times 10^{-4}$$

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

arXiv: 1204.0246, submitted to PRL

Never before observed in charmonium transitions

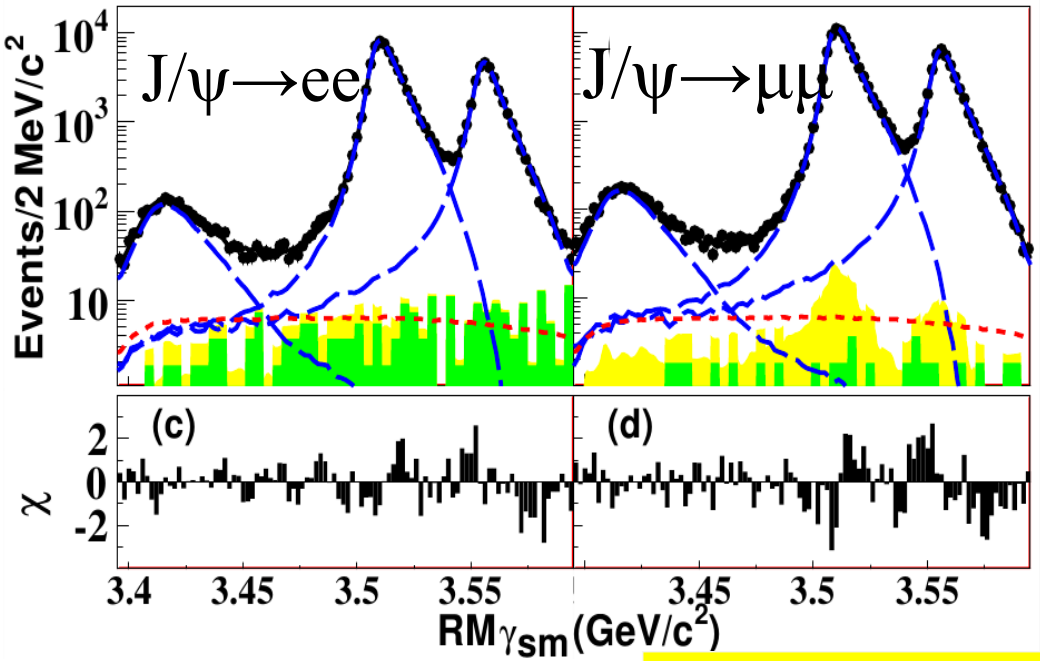
Sensitive to coupled channel effects (coupling of charmonium to DD pair)

Global fit:

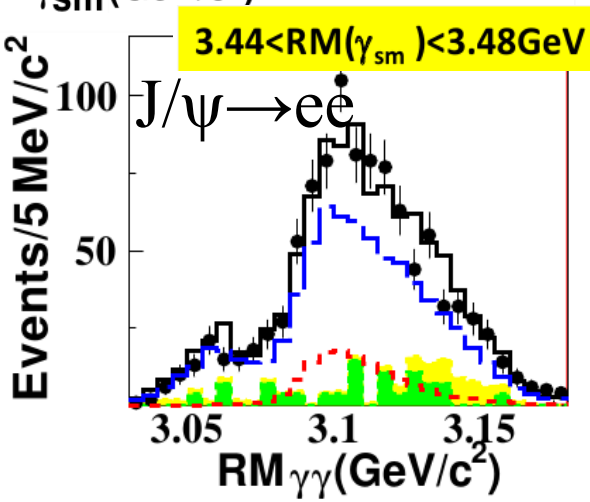
$$Br = \left(3.3 \pm 0.6(stat.)^{+0.8}_{-1.1}(syst.)\right) \times 10^{-4}$$

Significance: 3.8σ (including systematics)

Combined branching fractions $Br(\psi' \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi)$ are also measured



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



Charm physics

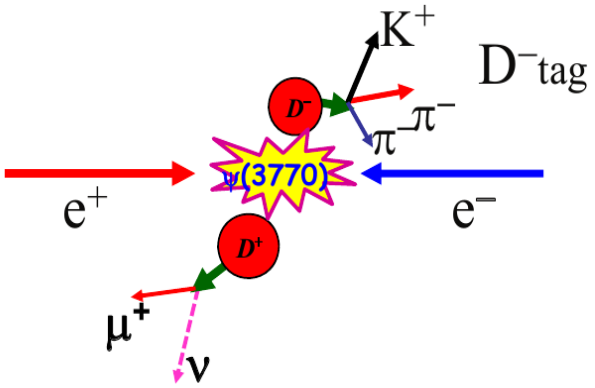
(BES-III preliminary)

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

$D^+ \to \mu^+ \nu_\mu$

BES-III preliminary

Single tag events



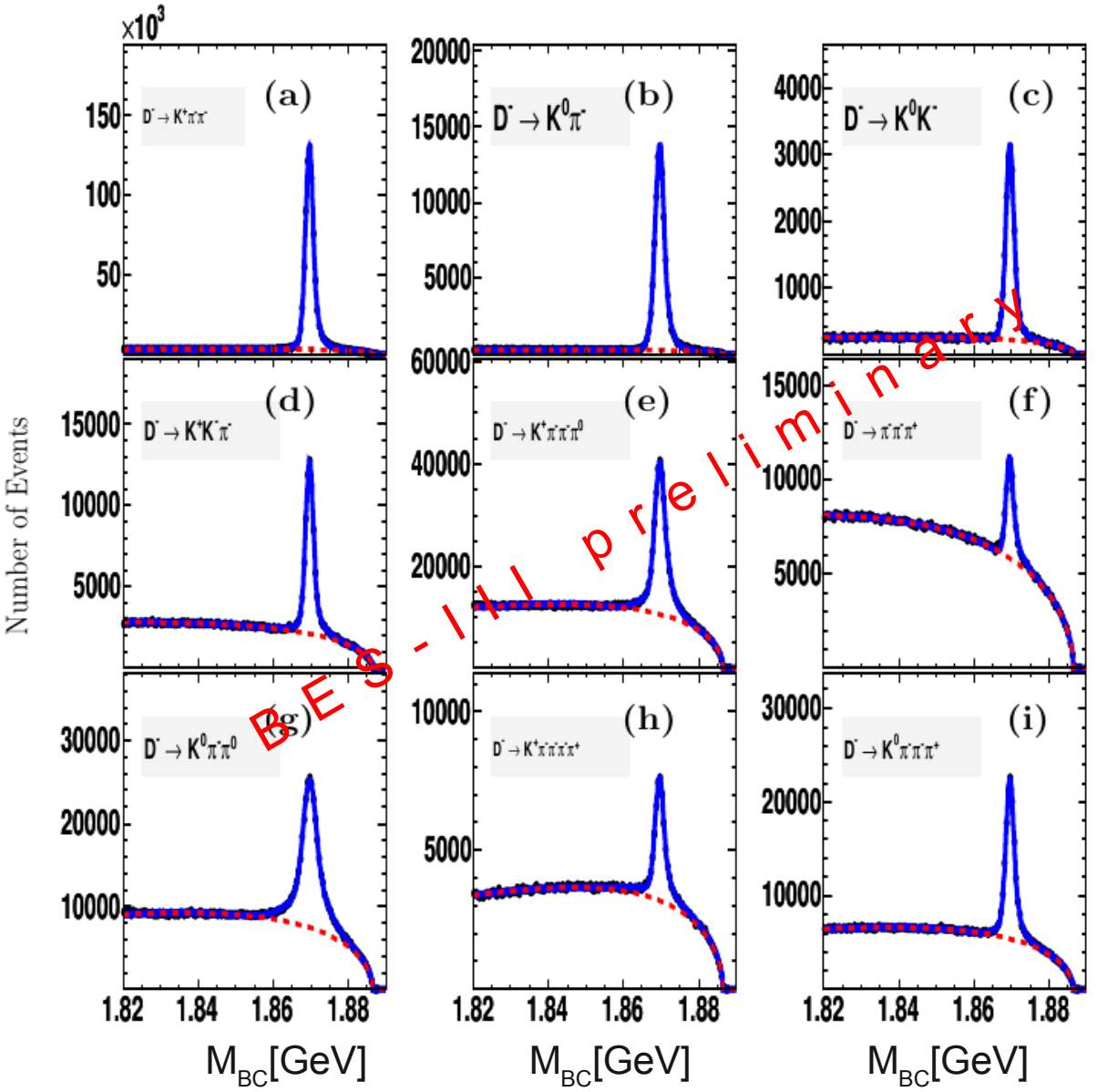
$$M_{BC} = \sqrt{E_{beam}^2 - p_D^2}$$

Resolution:

1.3 MeV for modes with charged tracks only

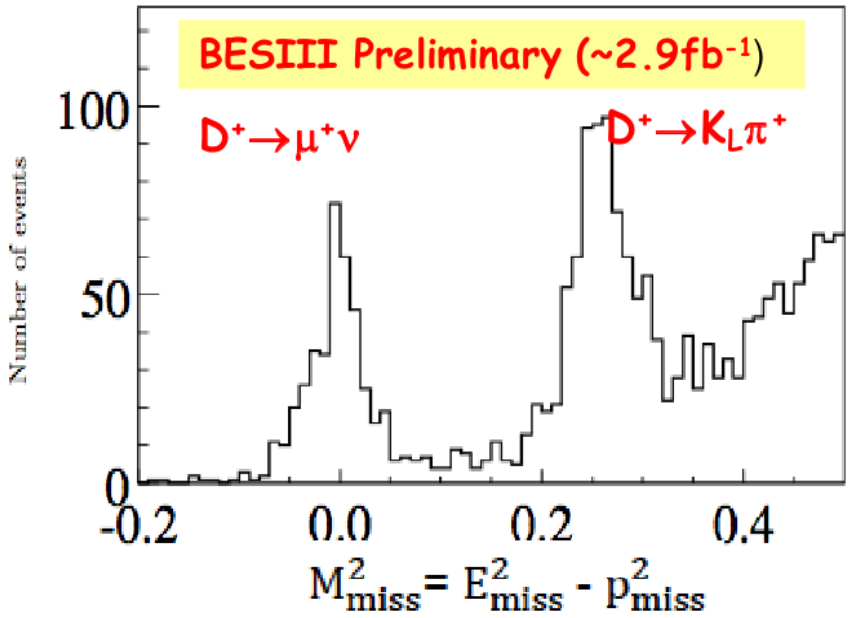
1.9 MeV for modes with one π^0

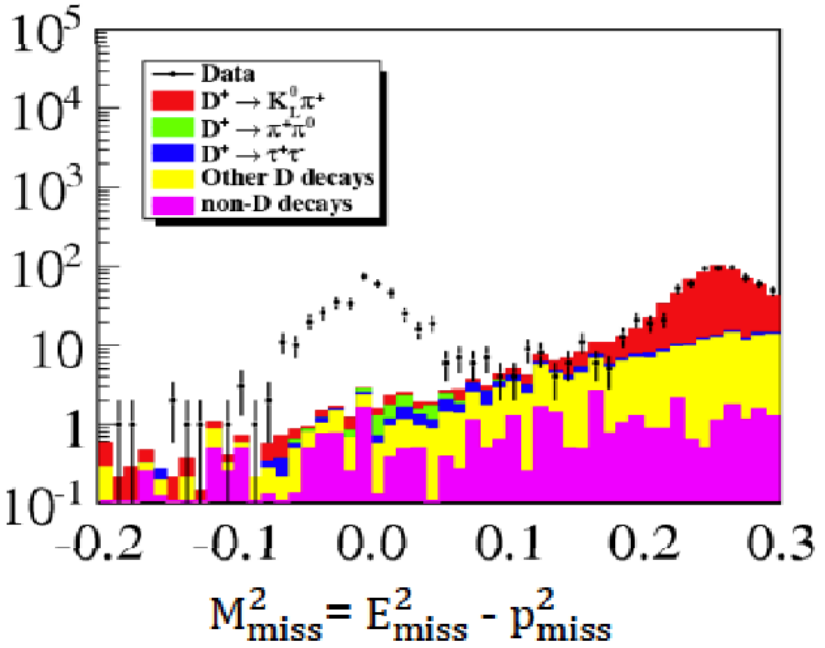
$N_{D^-} = (1.57 \pm 0.2) \times 10^6$



$D^+ \to \mu^+ \nu_\mu$

BES-III preliminary





Results:

N(D+ → $\mu^+\nu_\mu$) = 377±19.4

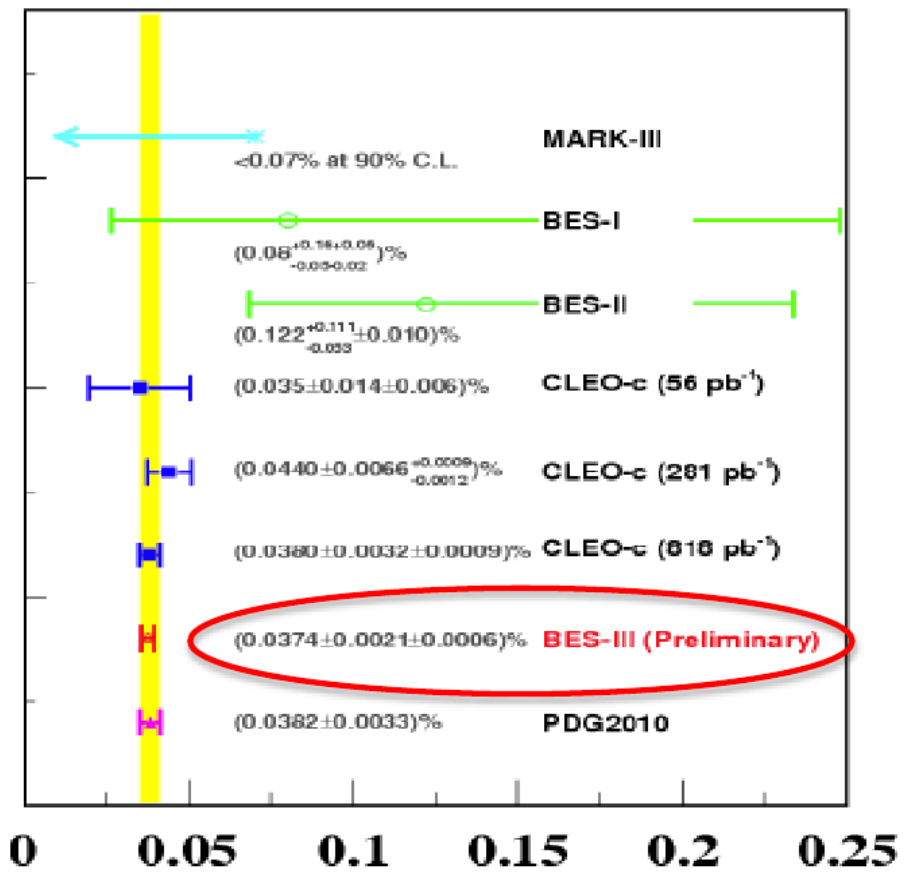
B(D+ → $\mu^+\nu_\mu$) = (3.74±0.21±0.06)×10^{-4}

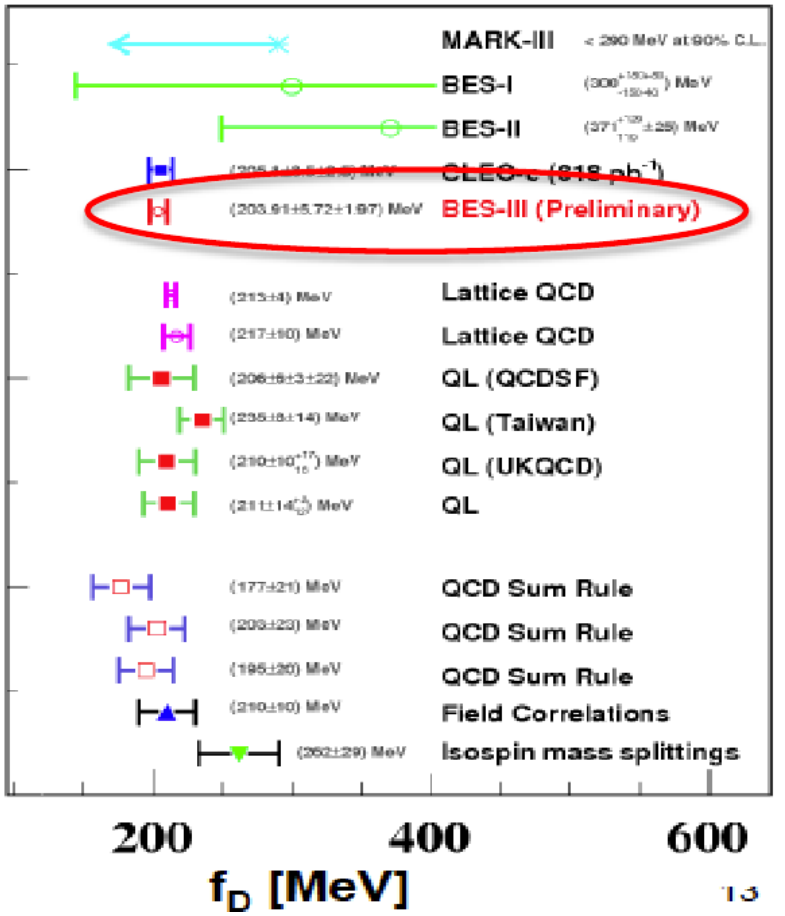
$$\Gamma(D^+ \to l^+ \upsilon_l) = \frac{G_F^2 f_{D^+}^2}{8\pi} |V_{cd}|^2 m_l^2 m_{D^+} \left(1 - \frac{m_l^2}{m_{D^+}^2}\right)^2$$

f_D = (203.91±5.72±1.97) MeV

$|V_{cd}|$ = 0.222±0.006±0.005

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

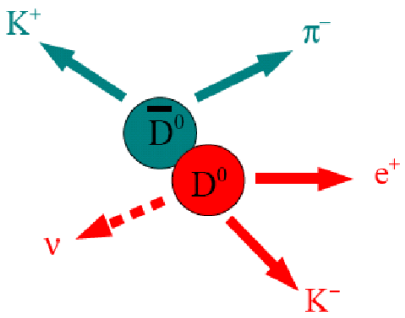


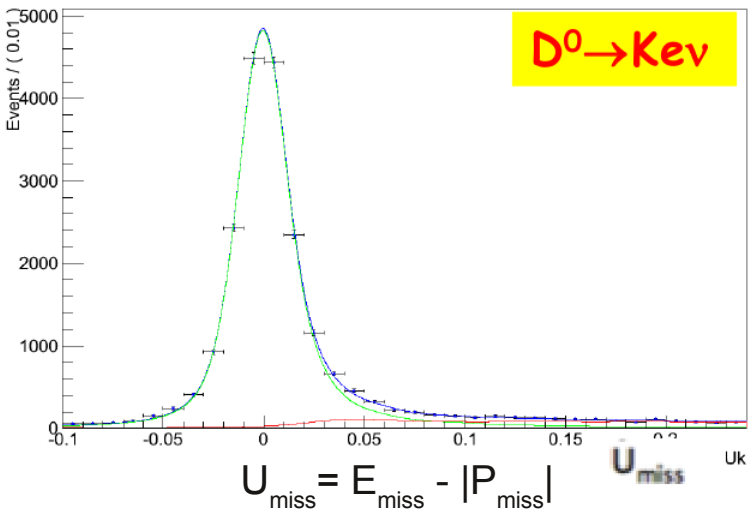


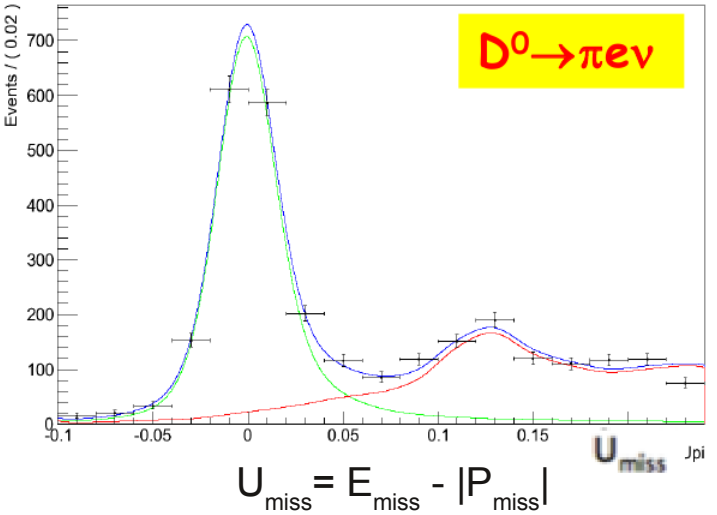
- BES-III provides the most precise measurement
- The error is still dominated by statistics

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

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







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

- Systematics are preliminary
- Statistics will be improved with the full data set of 2.9 fb^{-1}
- Preliminary results on form factors are also obtained

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 pp near threshold enhancement in J/ψ → γpp, ψ(2S) → γpp *(PRL 108, 112003(2012))*
  - The first observation of η(1405) in J/ψ → γ3π *(PRL 108, 182001 (2012))*
  - η_c parameters precision measurement *(PRL 108, 222002 (2012))*
  - The first observation of η_c(2S) in charmonium transitions (*arXiv:1205.5103, accepted to PRL)*
  - First evidence for the direct ψ(2S) → γγJ/ψ transition *(arXiv: 1204.0246, submitted to PRL)*
- Preliminary charm results are presented.
- Expect many more results from BES-III in coming years.

Thank You!

Backup

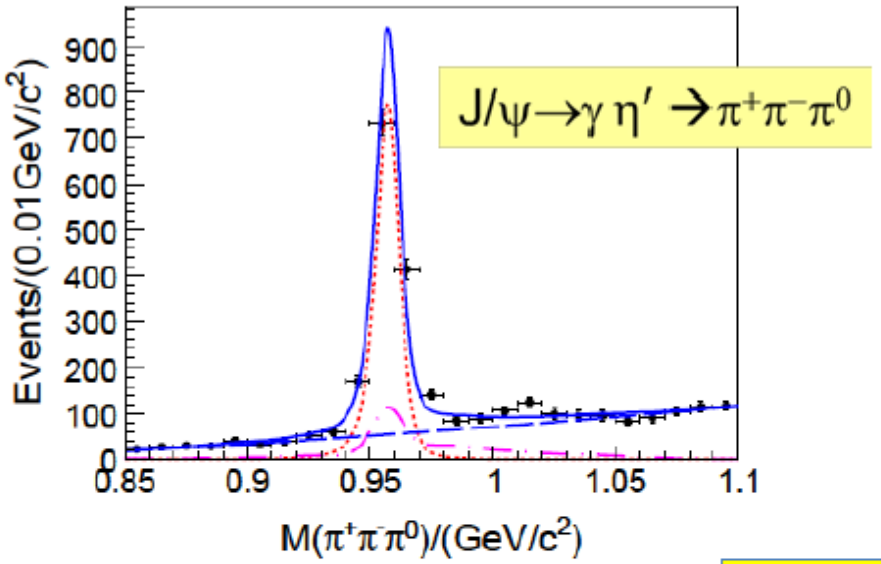
The BESIII Collaboration

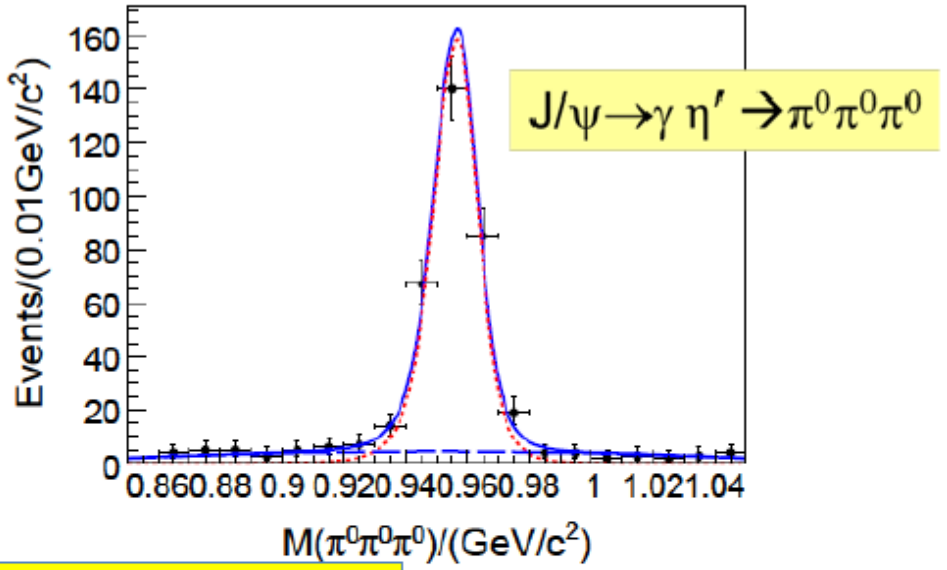
http://bes3.ihep.ac.cn

>300 physicists

50 institutions from 10 countries

New results on η'→3π





New results:

PRL 108, 182001 (2012)

$Br(\eta' \to \pi^+\pi^-\pi^0) = (3.83 \pm 0.15 \pm 0.39) \times 10^{-3}$ (PDG2010: $(3.6^{+1.1}_{-0.93}) \times 10^{-3}$)

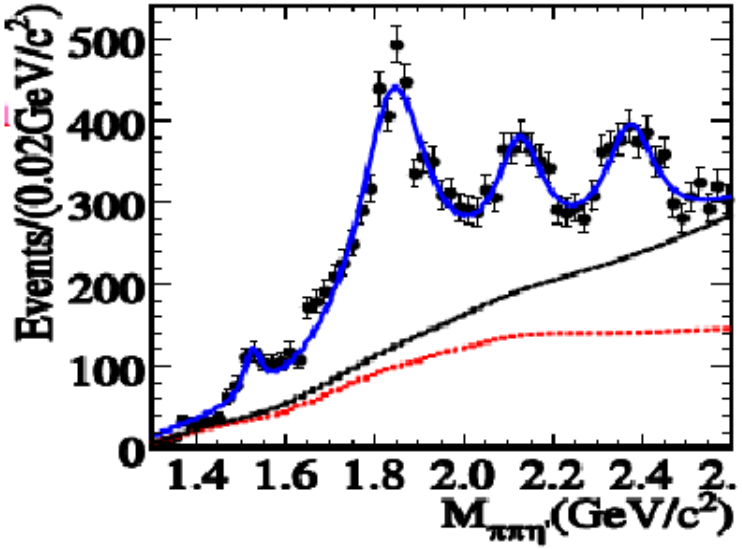
$Br(\eta' \to \pi^0\pi^0\pi^0) = (3.56 \pm 0.22 \pm 0.34) \times 10^{-3}$ (PDG2010: $(1.68 \pm 0.22) \times 10^{-3}$)

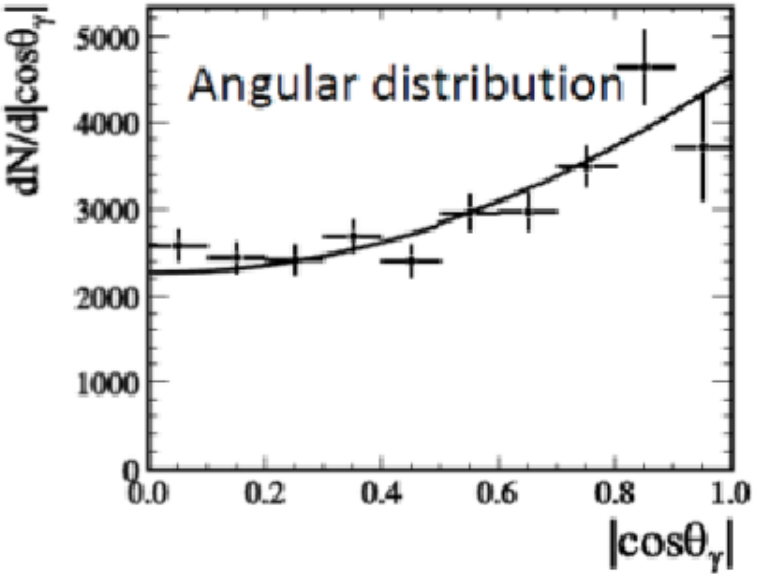
For the decay $\eta' \to \pi^0\pi^0\pi^0$, it is two times larger than the world average value.

Comparison: Isospin violations in η'→πππ :

$$\frac{BR(\eta' \to \pi^+\pi^-\pi^0)}{BR(\eta' \to \pi^+\pi^-\eta)} \approx 0.9\%, \quad \frac{BR(\eta' \to \pi^0\pi^0\pi^0)}{BR(\eta' \to \pi^0\pi^0\eta)} \approx 1.6\%$$

X(1835), X(2120), X(2370) in $J/\Psi \to \gamma\pi^+\pi^-\eta'(\gamma\rho, \pi^+\pi^-\eta)$





PRL 106, 072002 (2011)

resonance	$M(\ \mathrm{MeV}/c^2)$	$\Gamma(\ \mathrm{MeV}/c^2)$	significance
X(1835)	1836.5 ± 3.0	190.1 ± 9.0	$>> 20\sigma$
X(2120)	2122.4 ± 6.7	84 ± 16	$> 7.2\sigma$
X(2370)	2376.3 ± 8.7	83 ± 17	$> 6.4\sigma$

✓ **BESIII Results:**

— **$B(J/\psi \to \gamma X(1835))B(X(1835) \to \pi^+\pi^-\eta')=$**

$$(2.87 \pm 0.09(stat)^{+0.49}_{-0.52}(syst)) \times 10^{-4}$$

— **The polar angle of the photon is consistent with expectation for a pseudoscalar**

— **Two more structures are observed.**

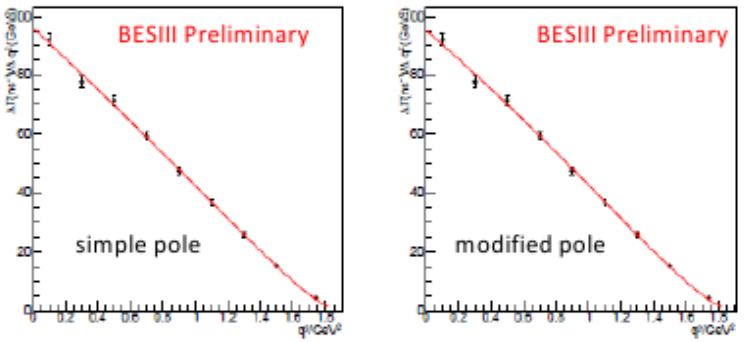
PWA is needed, interference between the resonances needs to be considered.

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

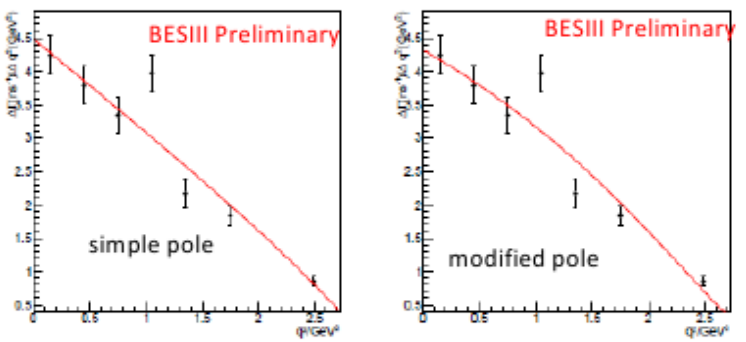
BES-III preliminary, 0.92 fb^{-1}

Form Factor Fits

$$\chi^2 = \sum_{i,j=1}^{n} (\Delta\Gamma_i - g(q^2)_i)\ C_{ij}^{-1}\ (\Delta\Gamma_j - g(q^2)_j)$$



$\overline{D}^0 \to K^+e^-\overline{\nu}_e$



$\overline{D}^0 \to \pi^+e^-\overline{\nu}_e$

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

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

Form Factor Results

BESIII Preliminary

Simple Pole	$f_+(0)\lvert V_{cd(s)}\rvert$	m_{pole}	
$D^0 \to Ke\nu$	0.729±0.005±0.007	1.943±0.025±0.003	
$D^0 \to \pi e\nu$	0.142±0.003±0.001	1.876±0.023±0.004	
Modified Pole	$f_+(0)\lvert V_{cd(s)}\rvert$	α	
$D^0 \to Ke\nu$	0.725±0.006±0.007	0.265±0.045±0.006	
$D^0 \to \pi e\nu$	0.140±0.003±0.002	0.315±0.071±0.012	
2 par. series	$f_+(0)\lvert V_{cd(s)}\rvert$	r_1	
$D^0 \to Ke\nu$	0.726±0.006±0.007	−2.034±0.196±0.022	
$D^0 \to \pi e\nu$	0.140±0.004±0.002	−2.117±0.163±0.027	
3 par. series	$f_+(0)\lvert V_{cd(s)}\rvert$	r_1	r_2
$D^0 \to Ke\nu$	0.729±0.008±0.007	−2.179±0.355±0.053	4.539±8.927±1.103
$D^0 \to \pi e\nu$	0.144±0.005±0.002	−2.728±0.482±0.076	4.194±3.122±0.448