Recent Results from BESIII

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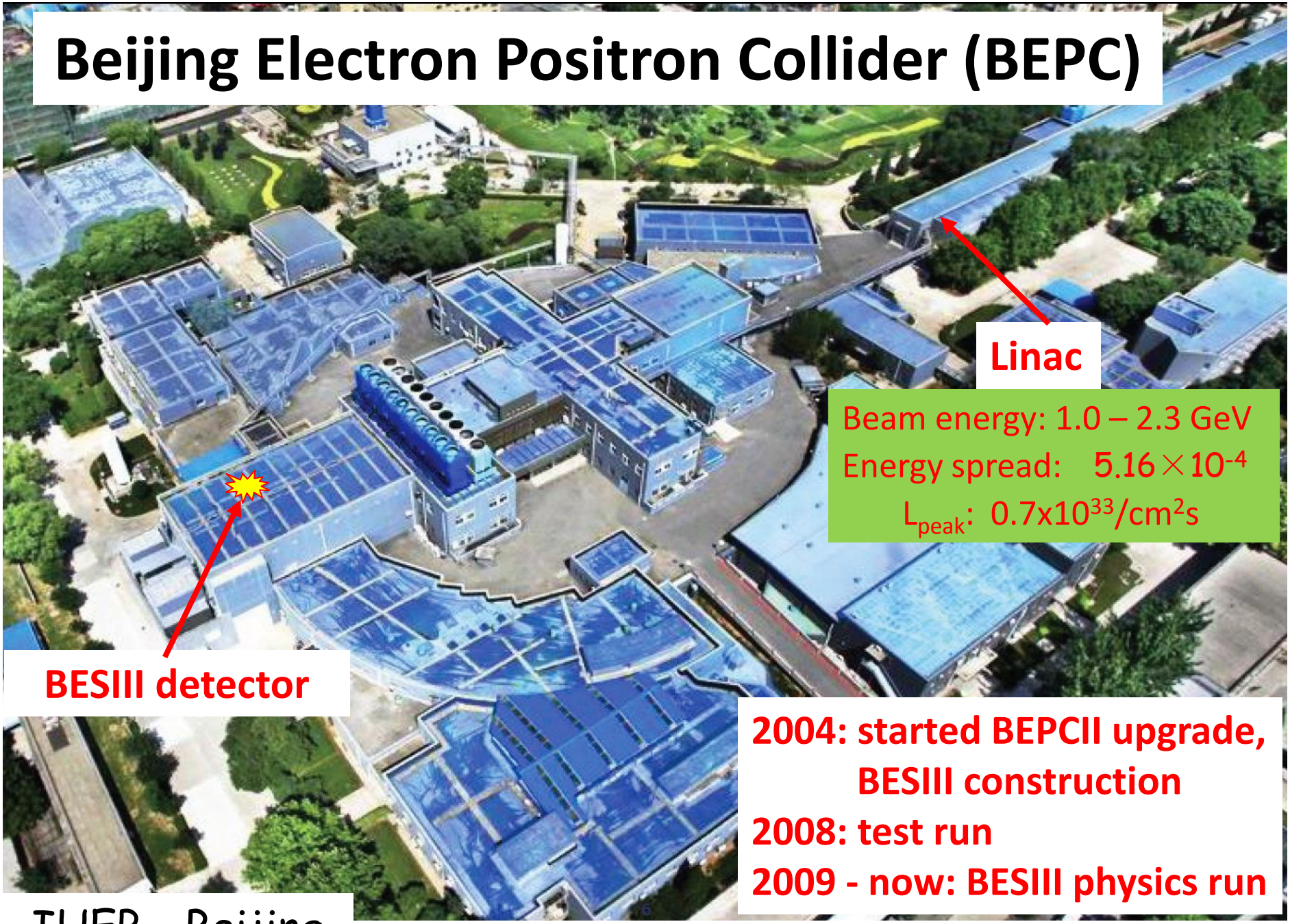
Outline

- **Status of BEPCII/BESIII**
- **Selected results from BESIII**
  - **Hadron spectroscopy**
    (XYZ, light hadron spec.)
  - **Charm decays**
- **Summary**

Beijing Electron Positron Collider (BEPC)



IHEP, Beijing

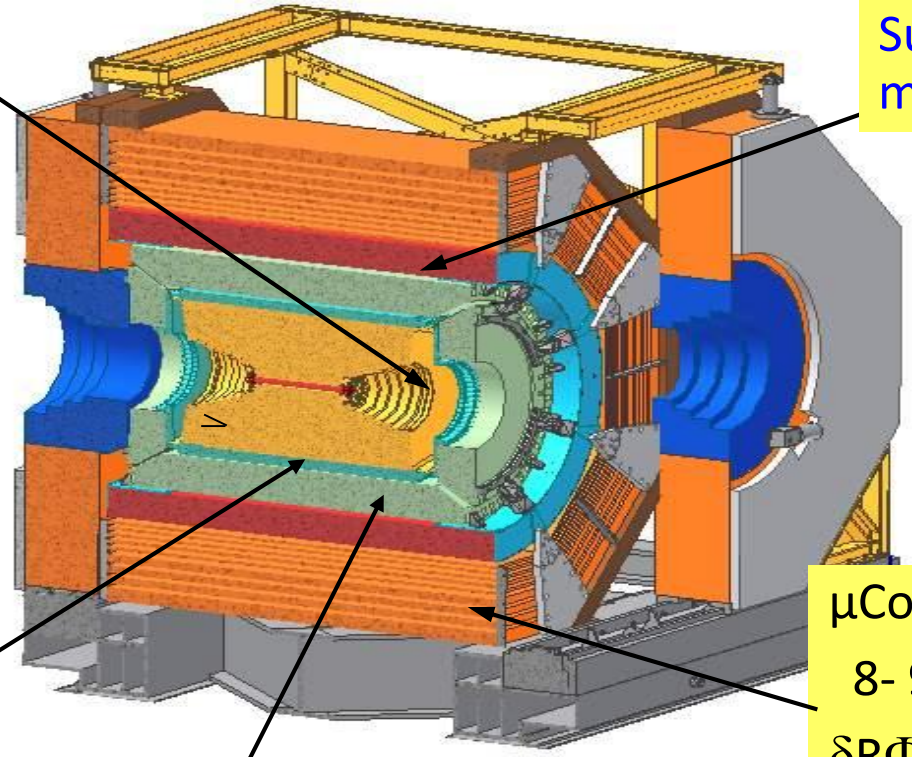
The BESIII Detector

NIM A614, 345 (2010)

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

μCounter

8- 9 layers RPC

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

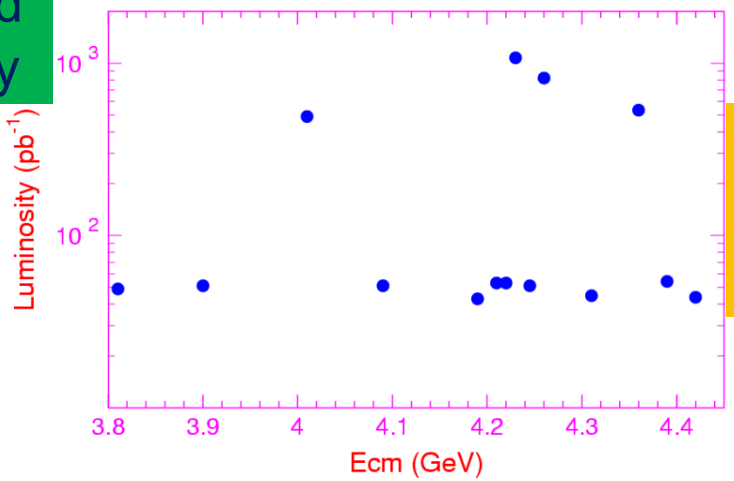
EMC: $\sigma E/\sqrt{E}(^0/_0) = 2.5\ \%\ (1\ GeV)$

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

BESIII data taking status & plan

	Previous data	BESIII now	Goal
J/ψ	BESII: 58 M	1.2 B 20* BESII	10 B
ψ’	CLEO: 28 M	0.5 B 20* CLEOc	3 B
ψ”	CLEO: 0.8/fb	2.9/fb 3.5*CLEOc	20 /fb
Above open charm threshold	CLEO: 0.6/fb @ ψ(4160)	2011: 0.5/fb@ψ(4009) 2013: 1.9/fb@4260, 0.5/fb@4360 data for lineshape	5-10 /fb
R scan	BESII	2012: R @2.23,2.4,2.8,3.4GeV 25/pb tau	

BESIII has collected 3.3/fb for XYZ study



BESIII will also collect data for high mass resonances and R measurement.

Selected results from BESIII

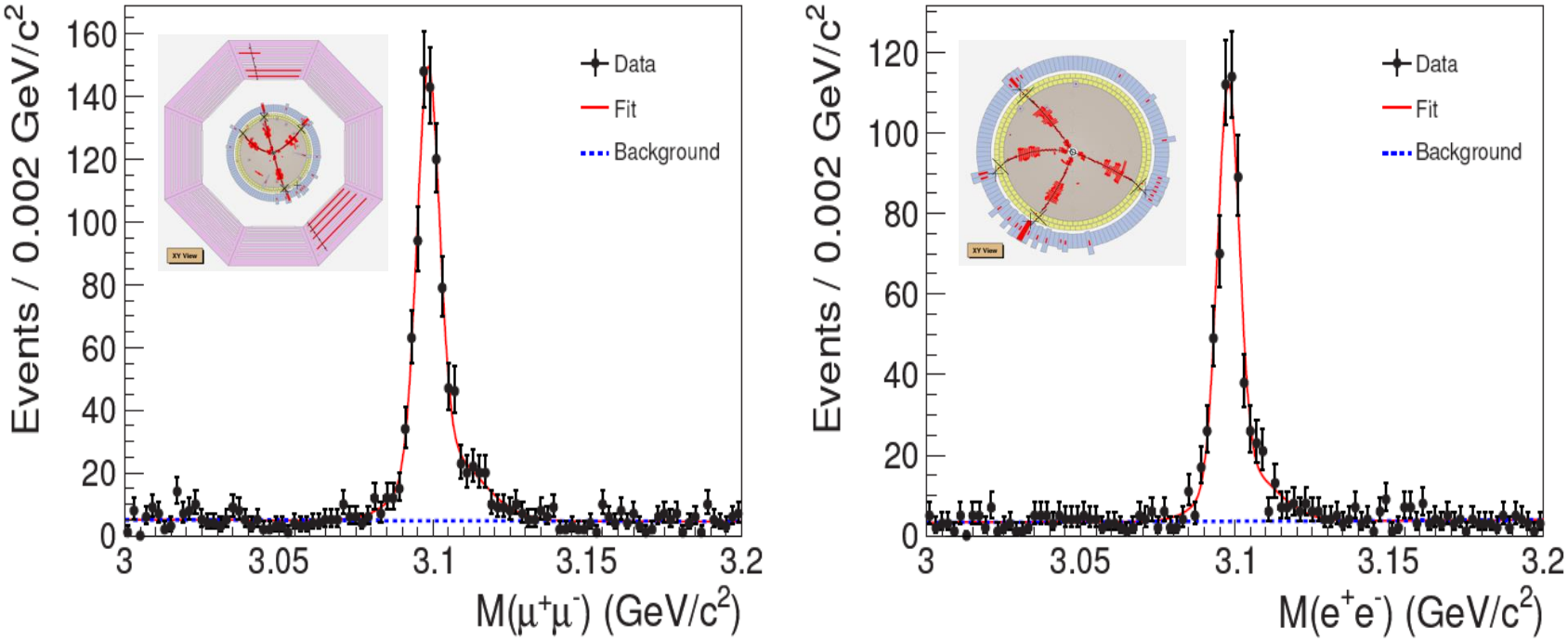
- **XYZ states (data@4260, 4360)**
  - $Z_c(3900)$, $Z_c(4020)$ & $Z_c(4025)$
  - New information on the X(3872)
- **Light hadron spectroscopy (data @J/ψ)**
  - $\eta\eta$ system in $J/\psi \to \gamma\eta\eta$
- **Charm decays (data @ψ(3770))**
  - $D^+ \to \mu^+ \nu$ and decay constant f_D
  - $D^0 \to \pi e \nu$, $D^0 \to K e \nu$ and form factor

Observation of the $Z_c(3900)$ — a charged charmonium-like structure

BESIII: PRL110, 252001 (2013)

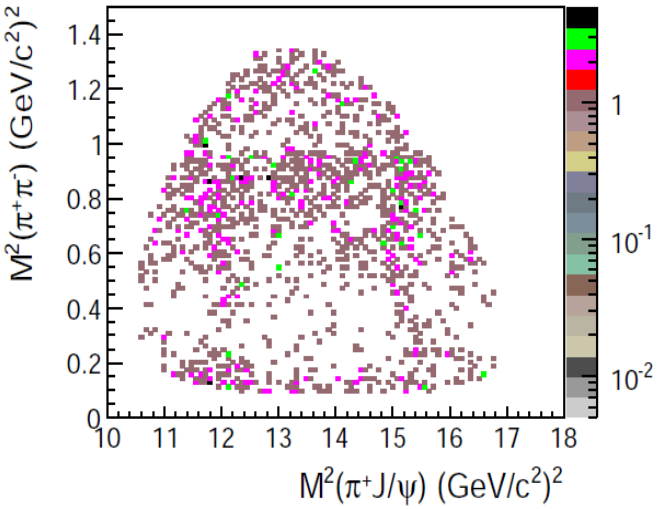
- Select $e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.26 GeV

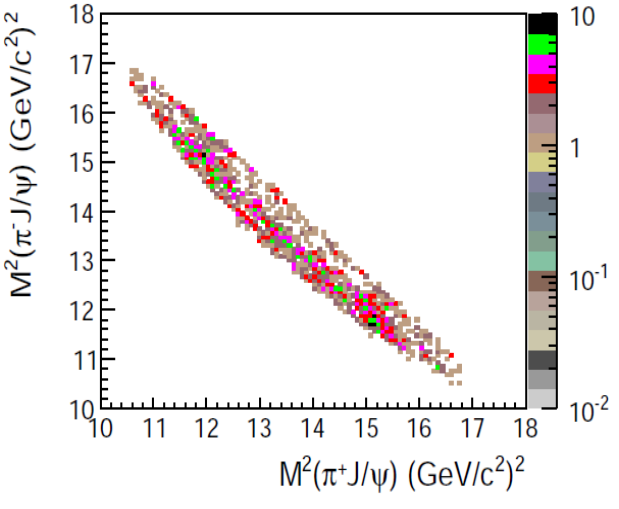
525/pb @4.26 GeV

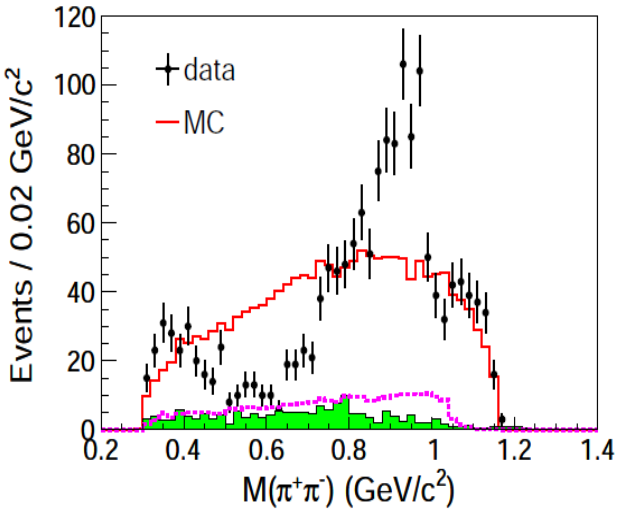


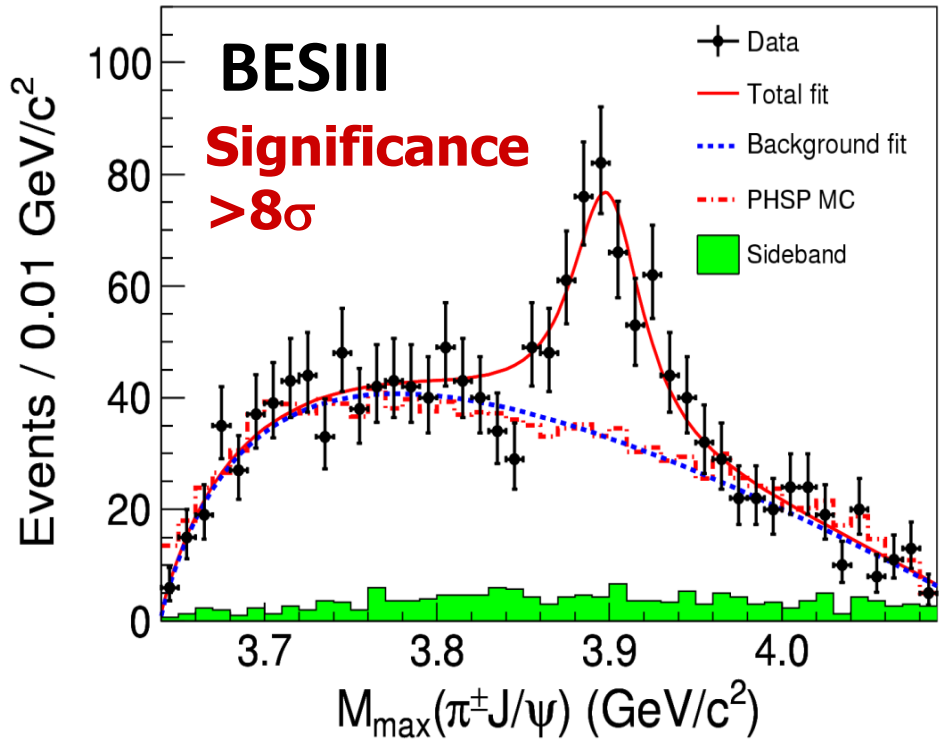
BESIII: $\sigma(e^+e^- \to \pi^+\pi^- J/\psi) = (62.9 \pm 1.9 \pm 3.7)$ pb

Agree with BaBar & Belle! Best precision!









- M = 3899.0±3.6±4.9 MeV
- Γ = 46±10±20 MeV
- 307 ± 48 events

The nature of $Z_c(3900)$?

- Couples to $c\bar{c}$, has electric charge,
- At least 4-quarks.

Theoretical interpretations:

- $\bar{D}D^*$ molecule? Tetraquark state?
- Threshold effect? …

(More experimental information needed)

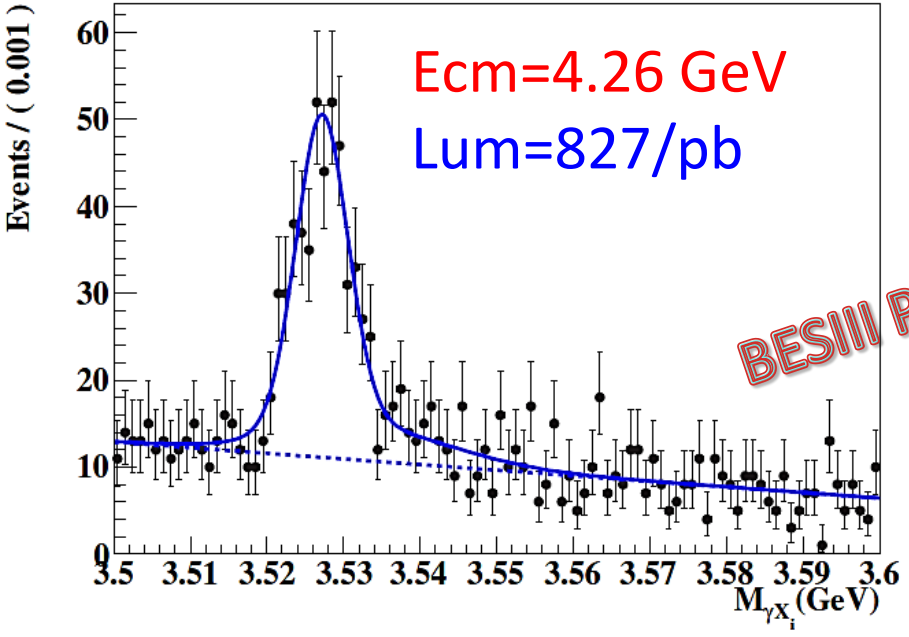
$Z_c(3900)$ also observed by Belle (PRL110,252002(2013)), and confirmed with CLEOc data (1304.3036).

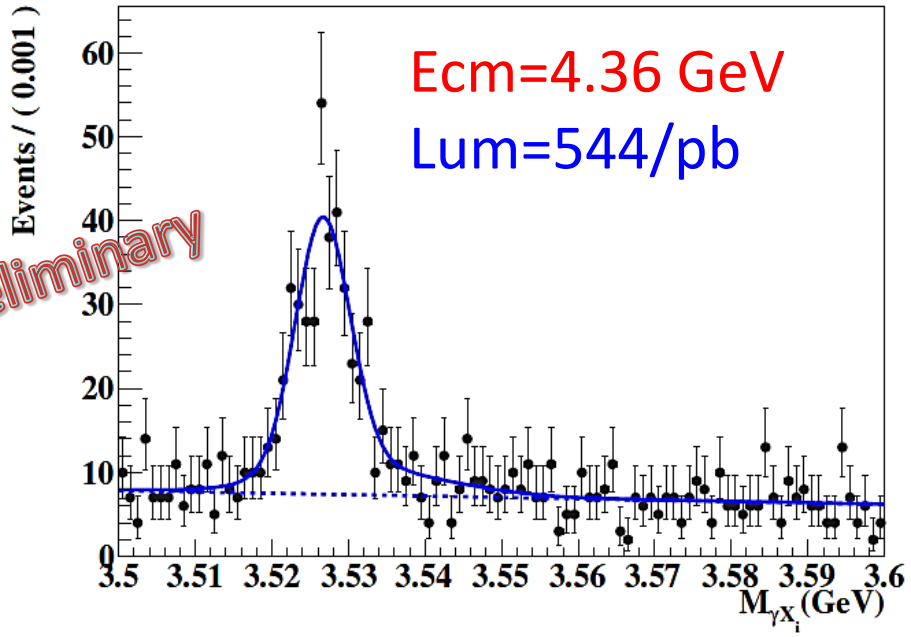
Observation of $e^+e^- \to \pi^+\pi^- h_c(1P)$

LP2013, C. Z. Yuan

$h_c \to \gamma\eta_c$, $\eta_c \to$ hadrons [16 exclusive decay modes]

- $p\bar{p}$, $\pi^+\pi^- K^+K^-$, $\pi^+\pi^- p\bar{p}$, $2(K^+K^-)$, $2(\pi^+\pi^-)$, $3(\pi^+\pi^-)$
- $2(\pi^+\pi^-)K^+K^-$, $K_S^0K^+\pi^-$+c.c., $K_S^0K^+\pi^-\pi^+\pi^-$+c.c., $K^+K^-\pi^0$
- $p\bar{p}\pi^0$, $K^+K^-\eta$, $\pi^+\pi^-\eta$, $\pi^+\pi^-\pi^0\pi^0$, $2(\pi^+\pi^-)\eta$, $2(\pi^+\pi^-\pi^0)$





BESIII Preliminary

$N(h_c)=416\pm28$

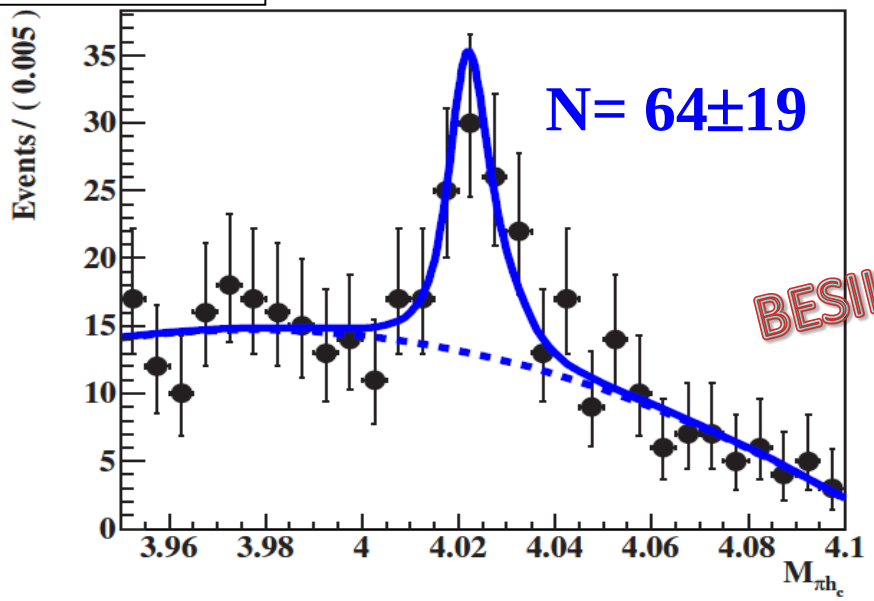
$\sigma^B = 41.0\pm2.8\pm7.4$ pb

$N(h_c)=357\pm25$

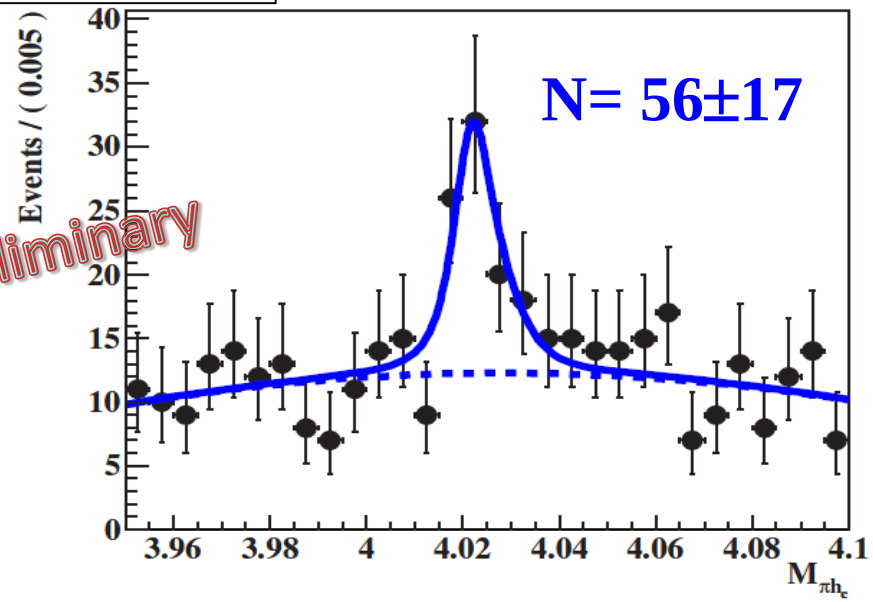
$\sigma^B = 52.3\pm3.7\pm9.2$ pb

Observation of $Z_c^{\pm}(4020)$ in $e^+e^- \rightarrow \rightarrow \pi^+\pi^- h_c(1P)$

Ecm=4.26 GeV



Ecm=4.36 GeV



BESIII Preliminary

Simultaneous fit to 4.26/4.36 GeV data and 16 η_c decay modes.

$M(Z_c(4020)) = 4021.8 \pm 1.0 \pm 2.5$ MeV

$\Gamma(Z_c(4020)) = 5.7 \pm 3.4 \pm 1.1$ MeV 6.4σ

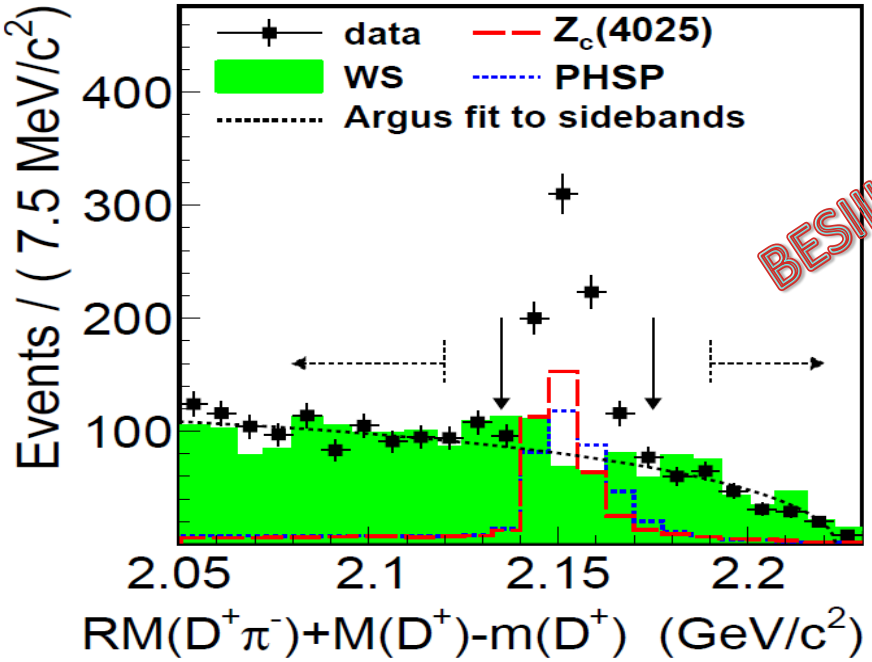
$$R = \frac{\sigma(e^+e^- \rightarrow \pi^{\pm}Z_c^{\mp} \rightarrow \pi^+\pi^- h_c(1P))}{\sigma(e^+e^- \rightarrow \pi^+\pi^- h_c(1P))} = (16.2 \pm 4.1 \pm 0.7)\% \qquad (16.6 \pm 5.2 \pm 0.8)\%$$

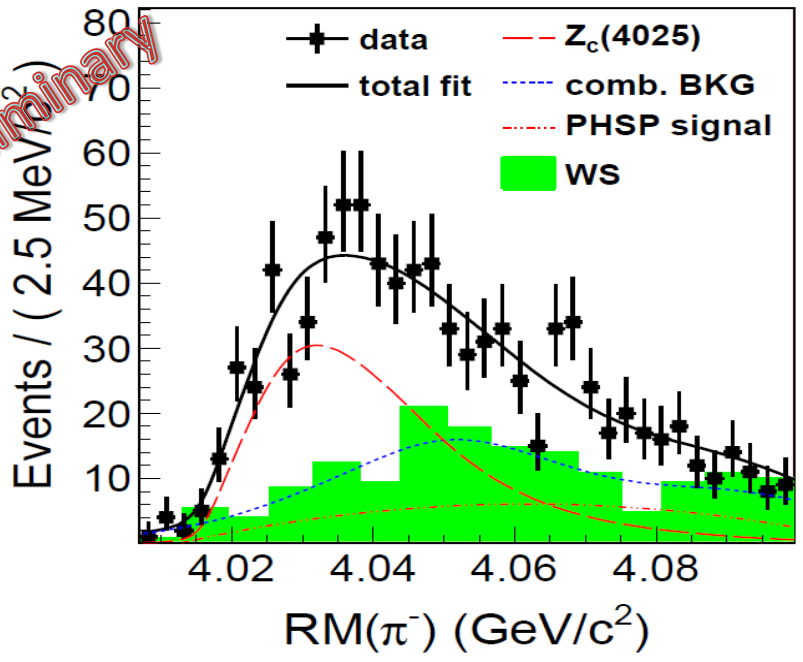
Observation of $Z_c(4025)$ in $e^+e^- \to \pi^- (D^*\bar{D}^*)^+ + c.c.$

LP2013, C. Z. Yuan

827 pb^{-1} data at Ecm=4.26 GeV

Tag a D^+ and a bachelor π^-, reconstruct one π^0 to suppress the background.





Fit to $\pi^\pm$ recoil mass yields 401±47 $Z_c(4025)$ events. >10σ

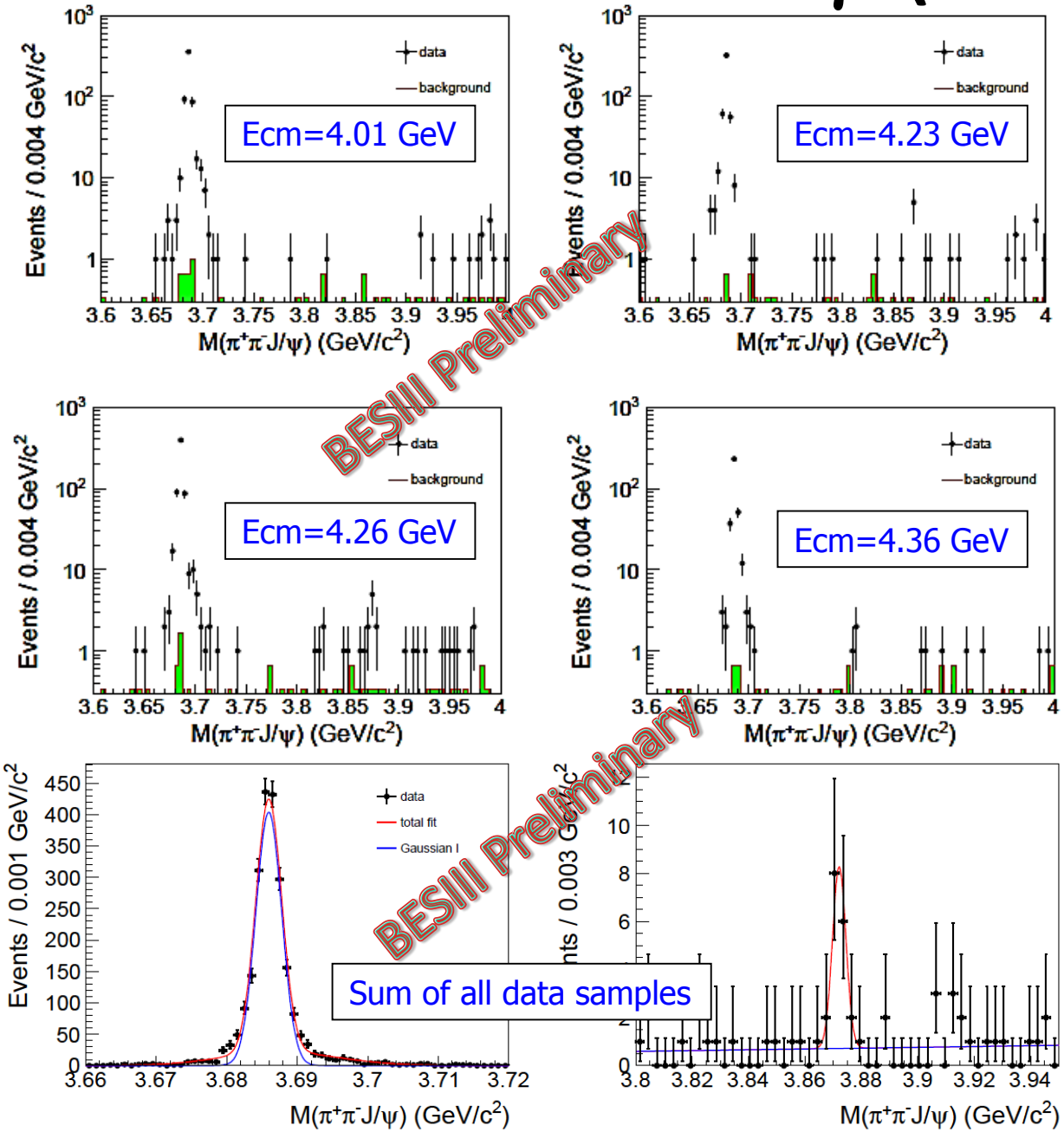
M($Z_c(4025)$) = 4026.3±2.6±3.7 MeV; $\Gamma(Z_c(4025))$ = 24.8±5.7±7.7 MeV.

$$R = \frac{\sigma(e^+e^- \to \pi^\pm Z_c^\mp \to \pi^\pm (D^*\bar{D}^*)^\mp)}{\sigma(e^+e^- \to \pi^\pm (D^*\bar{D}^*)^\mp)} = (65 \pm 9 \pm 6)\%$$

$$\sigma(e^+e^- \to \pi^\pm (D^*\bar{D}^*)^\mp) = (137 \pm 9 \pm 15)\ \text{pb}$$

Observation of $e^+e^- \to \gamma X(3872) \to \gamma\pi^+\pi^- J/\psi$

LP2013, C. Z. Yuan



ISR ψ' signal is used for rate, mass, and mass resolution calibration:

$N(\psi')=1242$;
$M=3685.96\pm0.05$ MeV;
$\sigma_M=1.84\pm0.06$ MeV

X(3872) signal at around Ecm=4.23-4.26 GeV:

$N(X(3872))=15.0\pm3.9$

5.3σ

$M(X(3872)) =$
$3872.1\pm0.8\pm0.3$ MeV
[PDG: 3871.68 ± 0.17 MeV]

Observation of $e^+e^- \to \gamma X(3872) \to \gamma\pi^+\pi^- J/\psi$

$\sqrt{s}$ (GeV)	$\sigma^B[e^+e^- \to \gamma X(3872)] \cdot \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$ (pb)
4.009	< 0.13 at 90% C.L.
4.230	$0.32 \pm 0.15 \pm 0.02$
4.260	$0.35 \pm 0.12 \pm 0.02$
4.360	< 0.39 at 90% C.L.

BESIII Preliminary

BESIII Preliminary

It seems X(3872) is from Y(4260) decays. At 4.26 GeV,

$\sigma^B(e^+e^- \to \pi^+\pi^- J/\psi) = (62.9 \pm 1.9 \pm 3.7)$ pb,

$$\frac{\sigma[e^+e^- \to \gamma X(3872)] \cdot \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)}{\sigma(e^+e^- \to \pi^+\pi^- J/\psi)} = (5.6 \pm 2.0) \times 10^{-3}$$

If we take $\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi) \sim 5\%$, (>2.6% in PDG)

$\frac{\sigma(e^+e^- \to \gamma X(3872))}{\sigma(e^+e^- \to \pi^+\pi^- J/\psi)} \sim 11.2\%$ Large transition ratio !

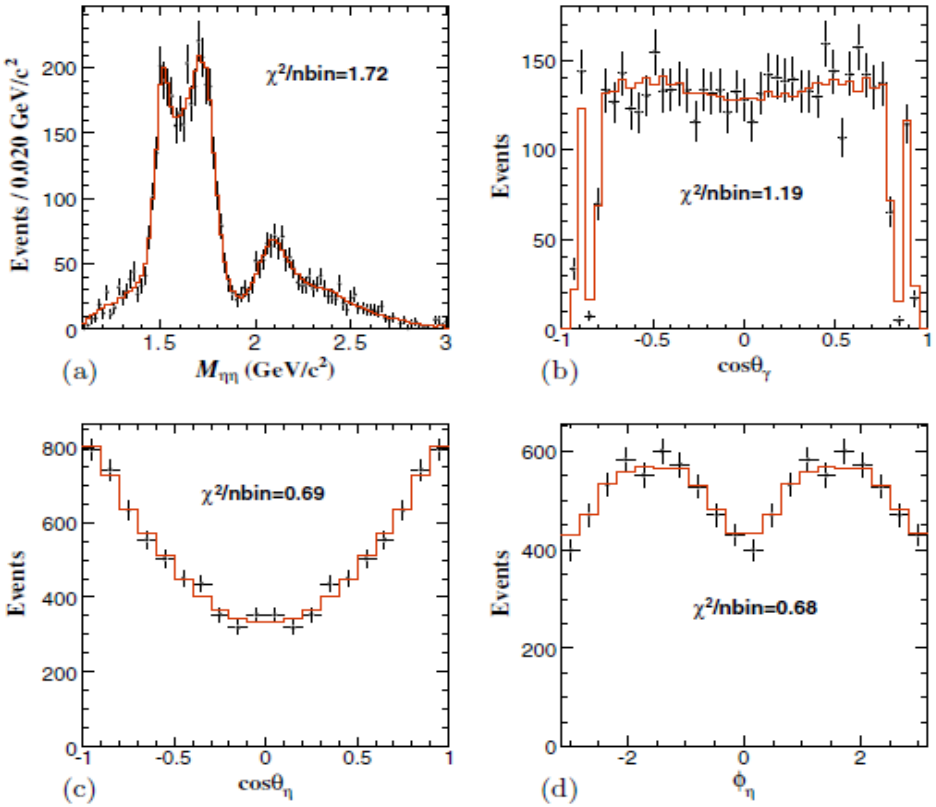
$\eta\eta$ system in J/ψ→ $\gamma\eta\eta$

BESIII: PRD 87, 092009 (2013)

LQCD： lowest mass glueball with 0^{++} is in 1.5-1.7 GeV.

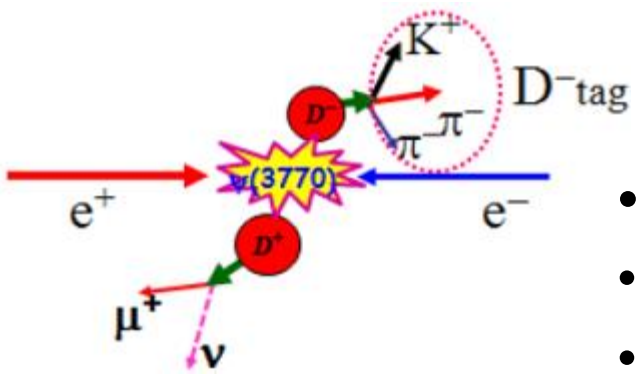
Results from Partial Wave Analysis: (based on 225M J/ψ events)

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



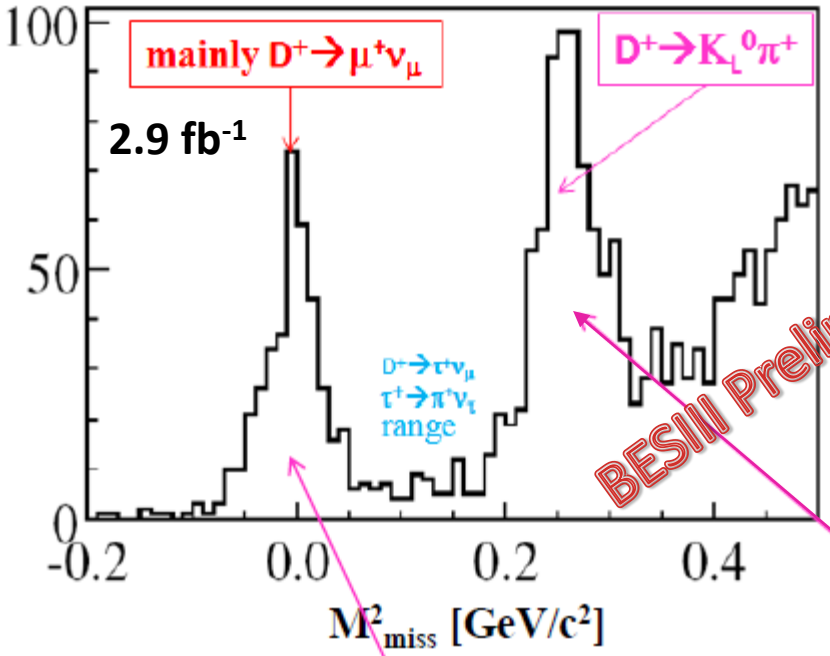
Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	$\mathcal{B}(J/\psi \to \gamma X \to \gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+23}_{-15-74}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40}) \times 10^{-5}$	8.2σ
$f_0(1710)$	$1759 \pm 6^{+14}_{-25}$	$172 \pm 10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$	25.0σ
$f_0(2100)$	$2081 \pm 13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28}) \times 10^{-4}$	13.9σ
$f_2'(1525)$	$1513 \pm 5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30}) \times 10^{-5}$	11.0σ
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35}) \times 10^{-5}$	6.4σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$	7.6σ

D^+ leptonic decays: $D^+ \rightarrow \mu^+\nu$



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

- All quantities are well measured except f_D
- Use world average $|V_{cd}|$ to extract f_D
- 9 D^- tag modes: $N_{D^-}^{tag}$ =(1.566+0.002)X10^{-6} in 2.9 fb^{-1}



Results: N(D^+->$\mu^+\nu$)= 377.3±20.6

BF($D^+ \rightarrow \mu^+\nu$) =(3.74±0.21±0.06)×10^{-4}

f_{D+} = (203.91±5.72±1.97) MeV

$|V_{cd}|$ = (0.222±0.006±0.005)

BESIII Preliminary

BESIII Preliminary

The error is still statistical dominated.

CLEOc results: PRD 78, 052003(2008)

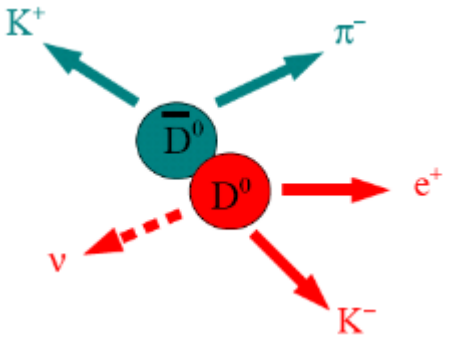
BF ($D^+ \rightarrow \mu^+\nu$) = (3.82±0.32±0.09)X10^{-4}

f_{D^+}= (205.8±8.5±2.5) MeV

There are still some backgrounds

The K^0_L escape from the detector.

Semi-leptonic decays: $D^0 \to \pi e \nu$ and $K e \nu$

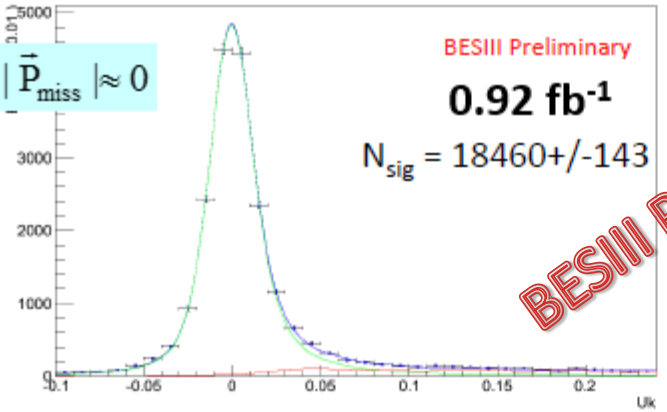


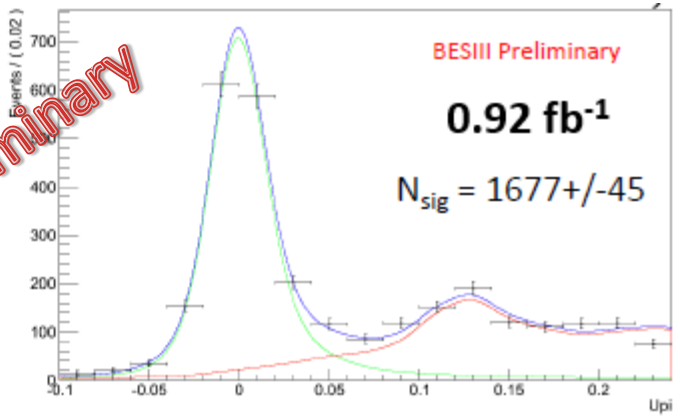
$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cx}|^2 \, p_X^3 \, |f_+(q^2)|^2$$

Only one form factor

- Measure CKM elements, Validate LQCD.
- 4 $\bar{D}^0$ tag modes: $N_{\bar{D}^0}^{tag}$ =(0.774+0.001)X10^{-6} in 0.92 fb^{-1}

$U = E_{miss} - |\vec{P}_{miss}| \approx 0$





BESIII Preliminary

$D^0 \to K e \nu$ **Fit U distribution** $D^0 \to \pi e \nu$

BESIII Preliminary

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

Good consistency with CLEOc, statistical precision comparable with only 1/3 data analyzed

Semi-leptonic decays: $D^0 \to \pi e \nu$ and $K e \nu$

Form factor results

Simple Pole	$f_+(0)\lvert V_{cd(s)}\rvert$	m_{pole}	
$D^0 \to K e\nu$	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	
$D^0 \to K e\nu$	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	
$D^0 \to K e\nu$	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
$D^0 \to K e\nu$	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

BESIII Preliminary

Form factor parameterization

$$f_+(q^2) = \frac{f_+(0)}{1 - q^2/m^2_{pole}}$$

$$f_+(q^2) = \frac{f_+(0)}{\left(1 - \frac{q^2}{m^2_{pole}}\right)\left(1 - \alpha\frac{q^2}{m^2_{pole}}\right)}.$$

$$f_+(q^2) = \frac{1}{P(q^2)\,\phi(q^2,t_0)} \sum_{k=0}^{\infty} a_k(t_0)\,\left[z(q^2,t_0)\right]^k$$

Phys. Lett. B 478 (2000) 418
Phys. Lett. B 633 (2006) 61

Summary

BESIII is successfully operating since 2008:

Recorded World's largest data samples:

- ~3.3 fb^{-1} data above open charm threshold for XYZ study
- ~0.5 Billion $\psi(2S)$ and 1.2 B J/ψ events
- ~2.9 fb^{-1} at $\psi(3770)$

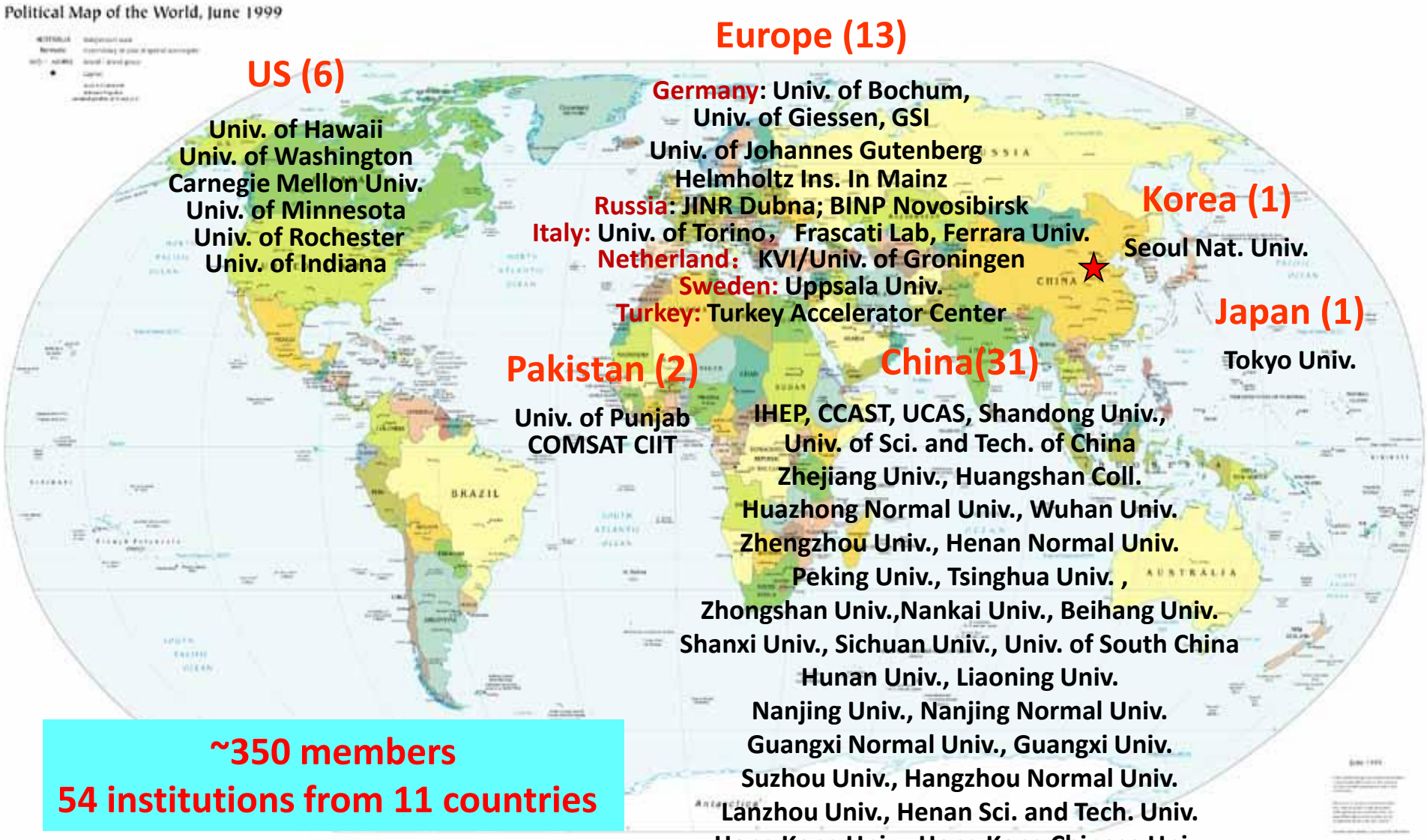
BESIII started study of the XYZ particles:

- Confirmation of exotic state with at least four quarks, $Z_c(3900)^+$
- Observation of the Z_c', $Z_c(4020)=Z_c(4025)$?
- Observation of $e^+e^- \to \gamma X(3872) \to \gamma\pi^+\pi^- J/\psi$

More results from J/ψ, $\psi(2S)$ and $\psi(3770)$ data will come soon !

Thank you !

The BESIII Collaboration



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Italy: Univ. of Torino， Frascati Lab, Ferrara Univ.
Netherland： KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

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Pakistan (2)

Univ. of Punjab
COMSAT CIIT

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