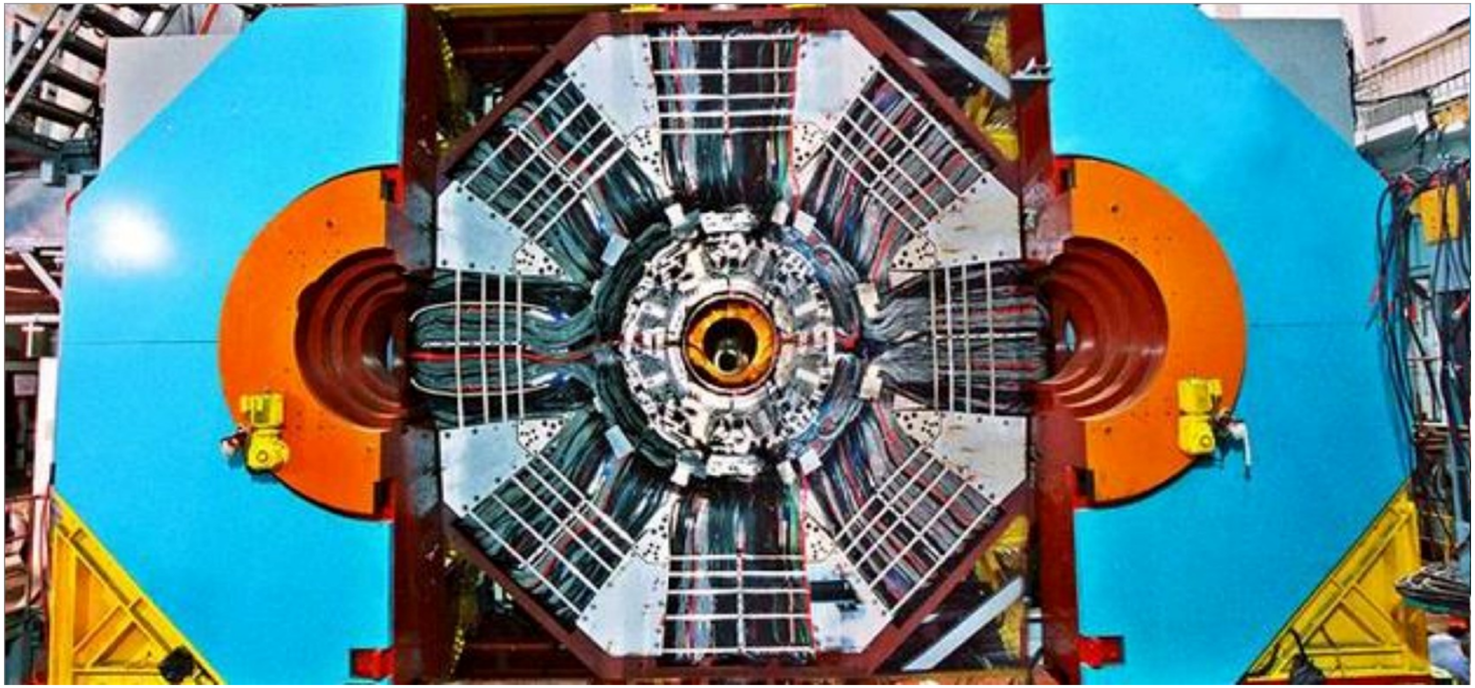


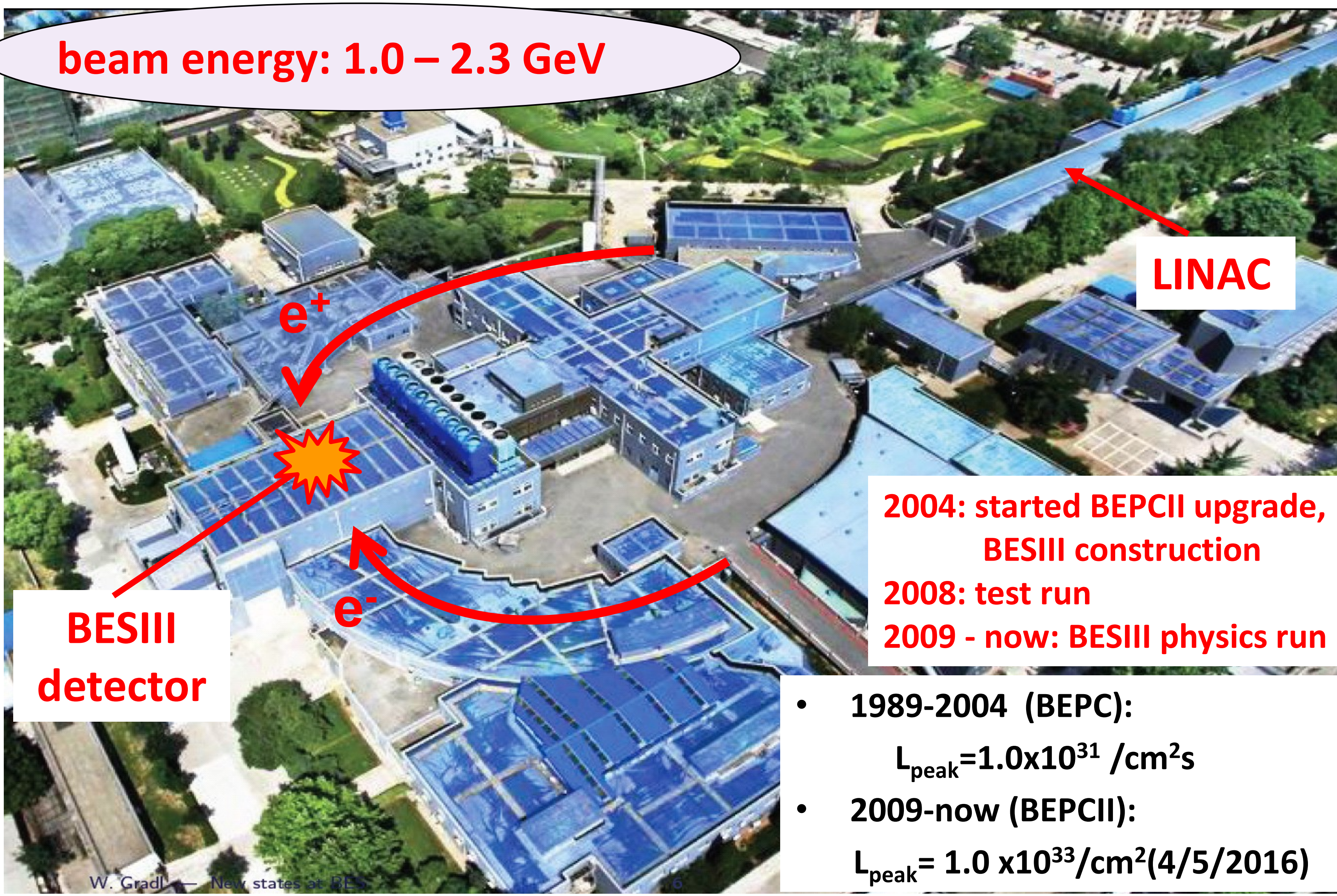
Prospects of Charm physics at BESIII and Beyond

Xiao-Rui Lyu (吕晓睿)
中国科学院大学
(On behalf of the BESIII collaboration)

Outline

- **Introduction**
- **Status of BESIII**
- **Upgrade plan**
- **Physics prospects**
- **Summary**

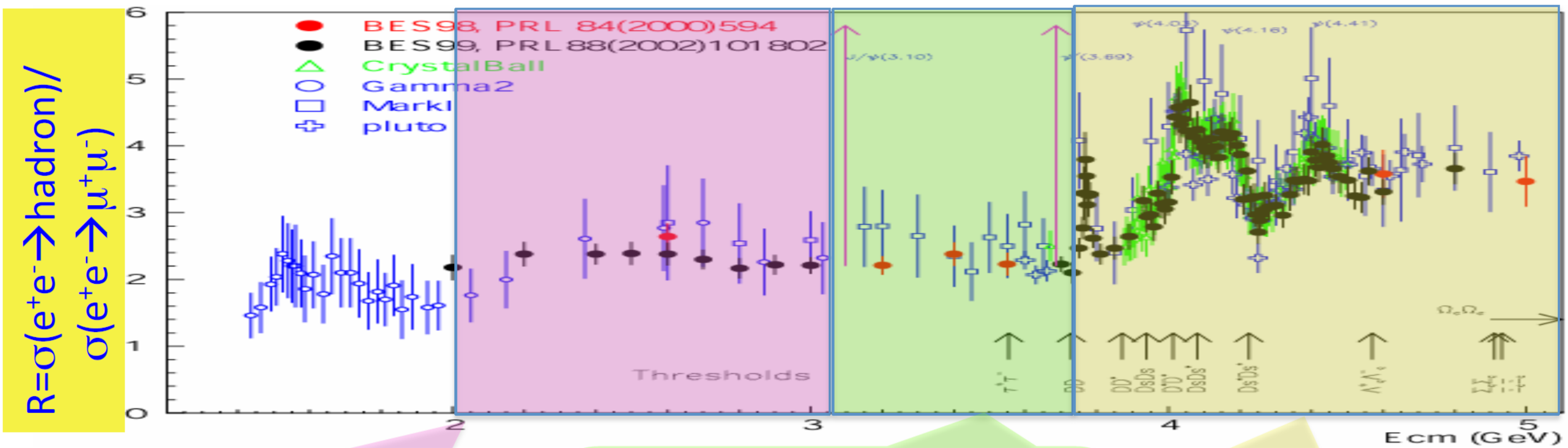
Beijing Electron Positron Collider (BEPC)



2004: started BEPCII upgrade, BESIII construction
2008: test run
2009 - now: BESIII physics run

- 1989-2004 (BEPC): L_{peak}=1.0x10^{31} /cm^{2}s
- 2009-now (BEPCII): L_{peak}= 1.0 x10^{33}/cm^2(4/5/2016)

Physics at tau-charm Energy Region



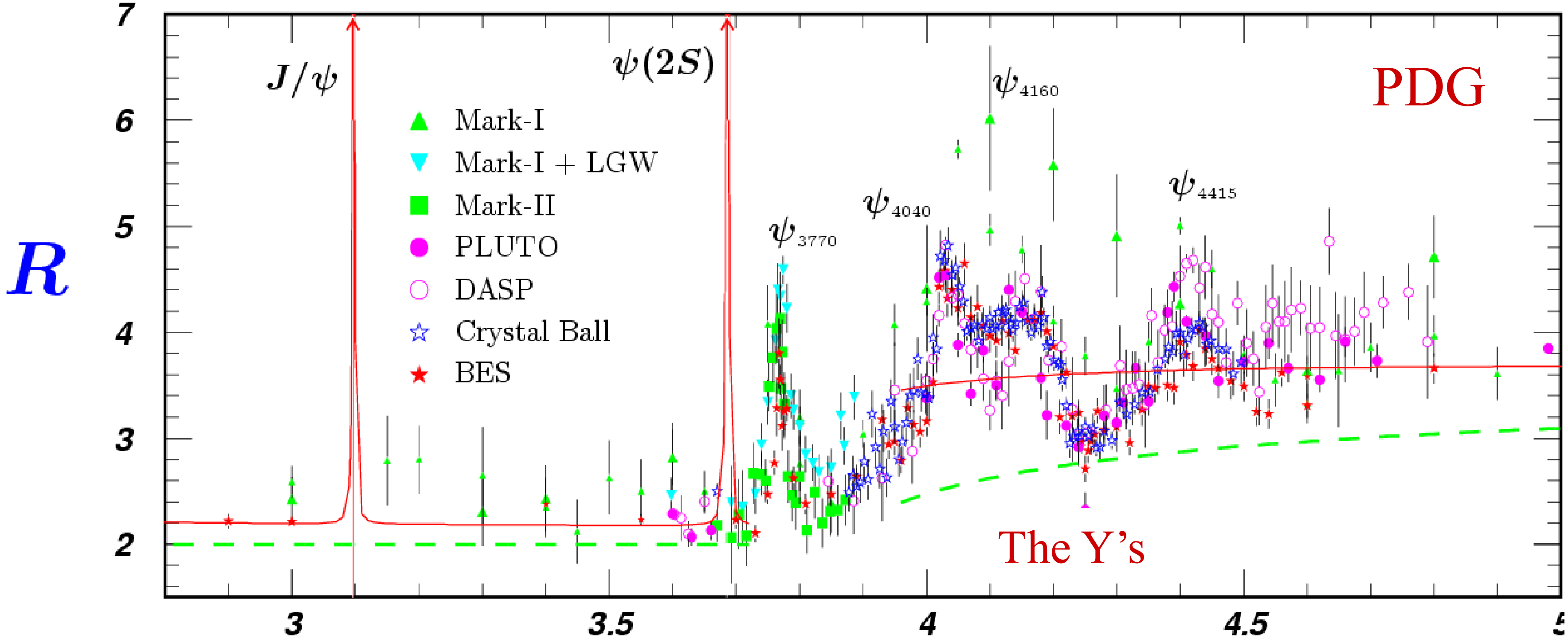
- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- D mesons
- f_D and f_{Ds}
- D_0-D_0 mixing
- Charm baryons

Features of the BEPC Energy Region

- Rich of resonances: charmonia(-like) and charmed hadrons
- Threshold characteristics (pairs of τ, D, D_s, Λ_c ...)
- Transition between smooth and resonances, perturbative and non-perturbative QCD
- Energy location of the new hadrons: glueballs, hybrids, multi-quark states

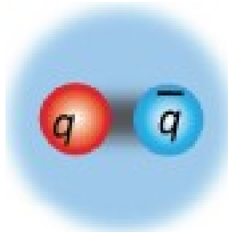


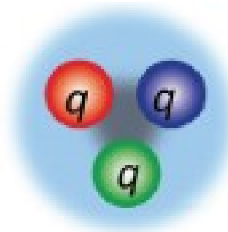
New forms of hadrons

- **Conventional hadrons consist of 2 or 3 quarks：**

Naive Quark Model：

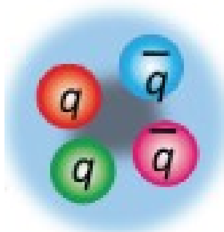
meson

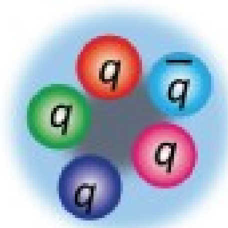




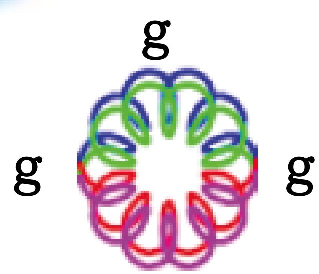
baryon

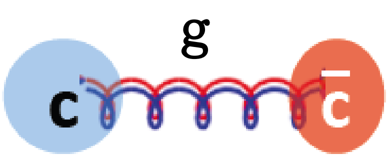
- **QCD predicts the new forms of hadrons:**
  - **Multi-quark states： Number of quarks >= 4**





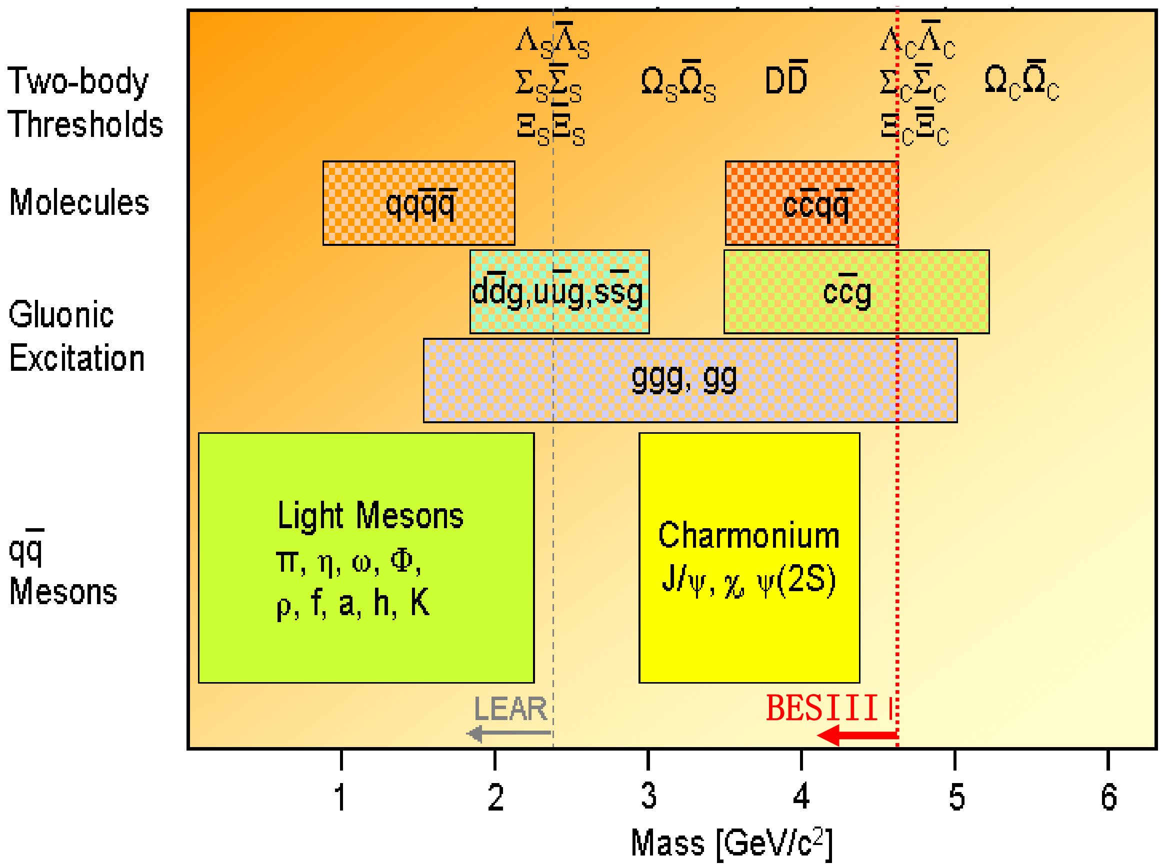
  - **Hybrids： $q\bar{q}g$， $qqqg$ …**
  - **Glueballs： gg， ggg …**





None of the new forms of hadrons is settled！

Hadron Landscape



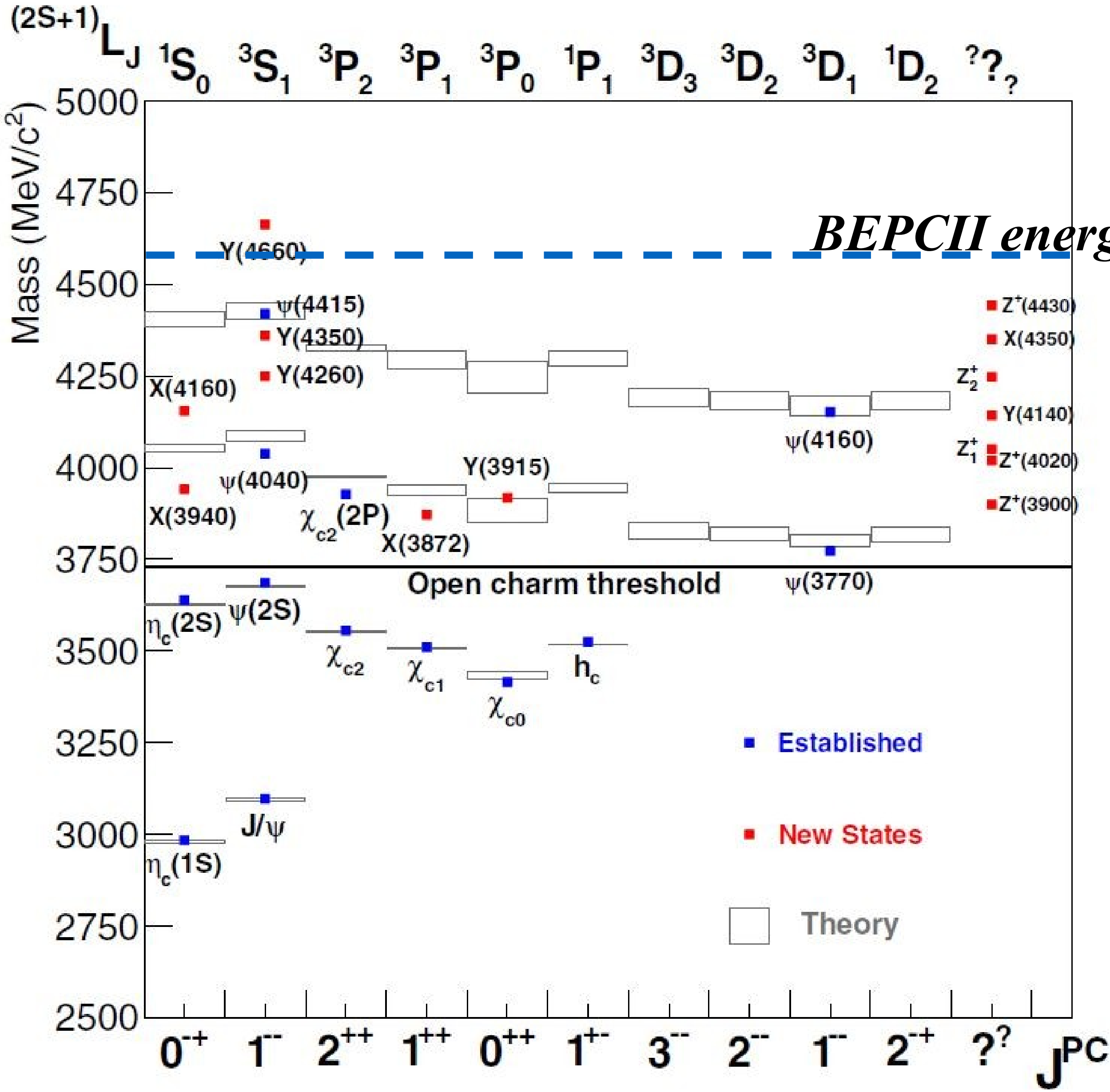
Hadron-physics challenges:

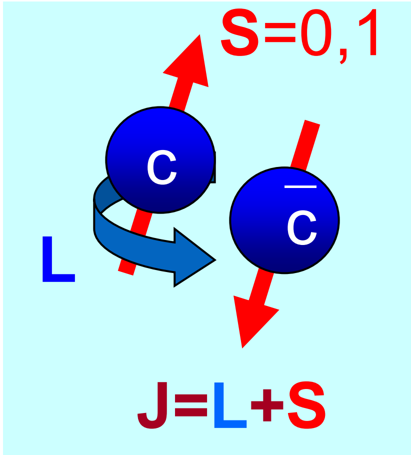
- Understanding of established states: precision spectroscopy
- Nature of exotic states: search and spectroscopy of unexpected states

At BESIII, two golden measures to study hadron spectroscopy, *esp*., to search for exotics

- Light hadrons: charmonium radiative decays (act as spin filter)
- Heavy hadrons: direct production, radiative and hadronic transitions

Charmonium Spectrum





Overpopulated observed new charmonium-like states, i.e. "XYZ".

Precision measurement of CKM elements -- Test EW theory

CKM matrix elements are fundamental SM parameters that describe the mixing of quark fields due to weak interaction.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

CKM matrix

BESIII + B factories + LQCD

Three generations of quark?

Unitary matrix?

Expected precision < 2% at BESIII

BESIII + B factories + LHCb + LQCD

- **Precision measurement of CKM matrix elements**
- **A precise test of SM model**
- **New physics beyond SM?**

δ and γ/ϕ_3 input

- *D* hadronic parameters for a final state

$$f: \ \frac{A(\bar{D}^0 \to f)}{A(D^0 \to f)} \equiv -r_D e^{-i\delta_D}$$

- Charm mixing parameters: $x = \frac{\Delta M}{\Gamma}$, $y = \frac{\Delta\Gamma}{2\Gamma}$
  - Time-dependent WS $D^0 \to K^+\pi^-$ rate $\Rightarrow$

    $y' = y\cos\delta_{K\pi} - x\sin\delta_{K\pi}$ (LHCb)
  - $\delta_{K\pi}$: QC measurements from Charm factory
- γ/ϕ_3 measurements from $B \to D^0 K$
  - $b \to u$: $\gamma/\phi_3 = \arg V^*_{ub}$
  - most sensitive method to constrain γ/ϕ_3 at present
  - GLW, ADS method
    - r_D, δ_D : QC measurements from Charm factory
  - GGSZ method
    - c_i, s_i : QC measurements from Charm factory

Time-integrated decay rates

- **No time dependent information at Charm threshold**
- **Anti-symmetric wavefuction:**

$$\Gamma^2_{ij} = \left|\langle i|D^0\rangle\langle j|\bar{D}^0\rangle - \langle j|D^0\rangle\langle i|\bar{D}^0\rangle\right|^2$$

- **Double tag rates:**

$$A_i^2 A_j^2 [1 + r_i^2 r_j^2 - 2 r_i r_j \cos(\delta_i + \delta_j)]$$

  - **CP tag: r=1, δ=0 or π; $l^{\pm}$ tag: r=0**

$$\psi(3770) \to [D^0\bar{D}^0 - \bar{D}^0 D^0]/\sqrt{2}$$
$$= -[D_{CP+}D_{CP-} - D_{CP-}D_{CP+}]/\sqrt{2}$$

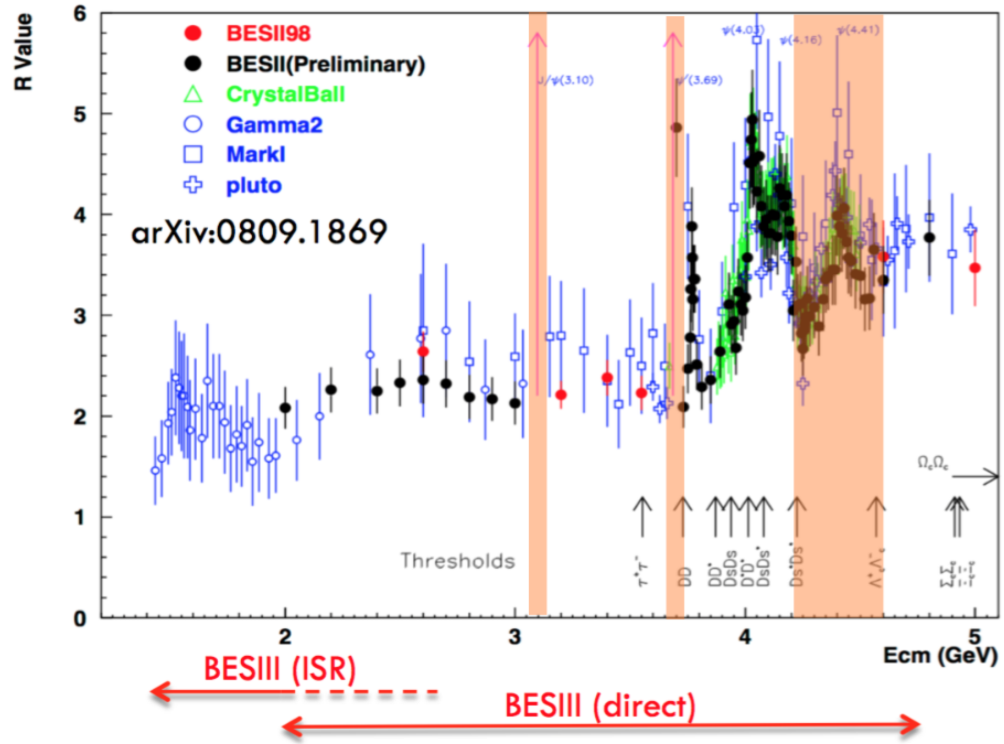
$$D_{CP\pm} = [D^0 \pm \bar{D}^0]/\sqrt{2}$$

- **Single and Double tag rates**
  - $z_f \equiv 2\cos\delta_f$, $r_f \equiv \frac{A_{DCS}}{A_{CF}}$, $R_M \approx \frac{x^2+y^2}{2}$

C-odd	f	$\bar{f}$	l^+	l^-	*CP+*	*CP-*
[redacted]						
$\bar{f}$	$1 + r_f^2(2 - z_f^2) + r_f^4$	$R_M[1 + r_f^2(2 - z_f^2) + r_f^4]$				
[redacted]						
l^-	*1*	r_f^2	*1*	R_M		
[redacted]						
CP-	$1 + r_f(r_f - z_f)$	$1 + r_f(r_f - z_f)$	*1*	*1*	*4*	*0*
[redacted]						

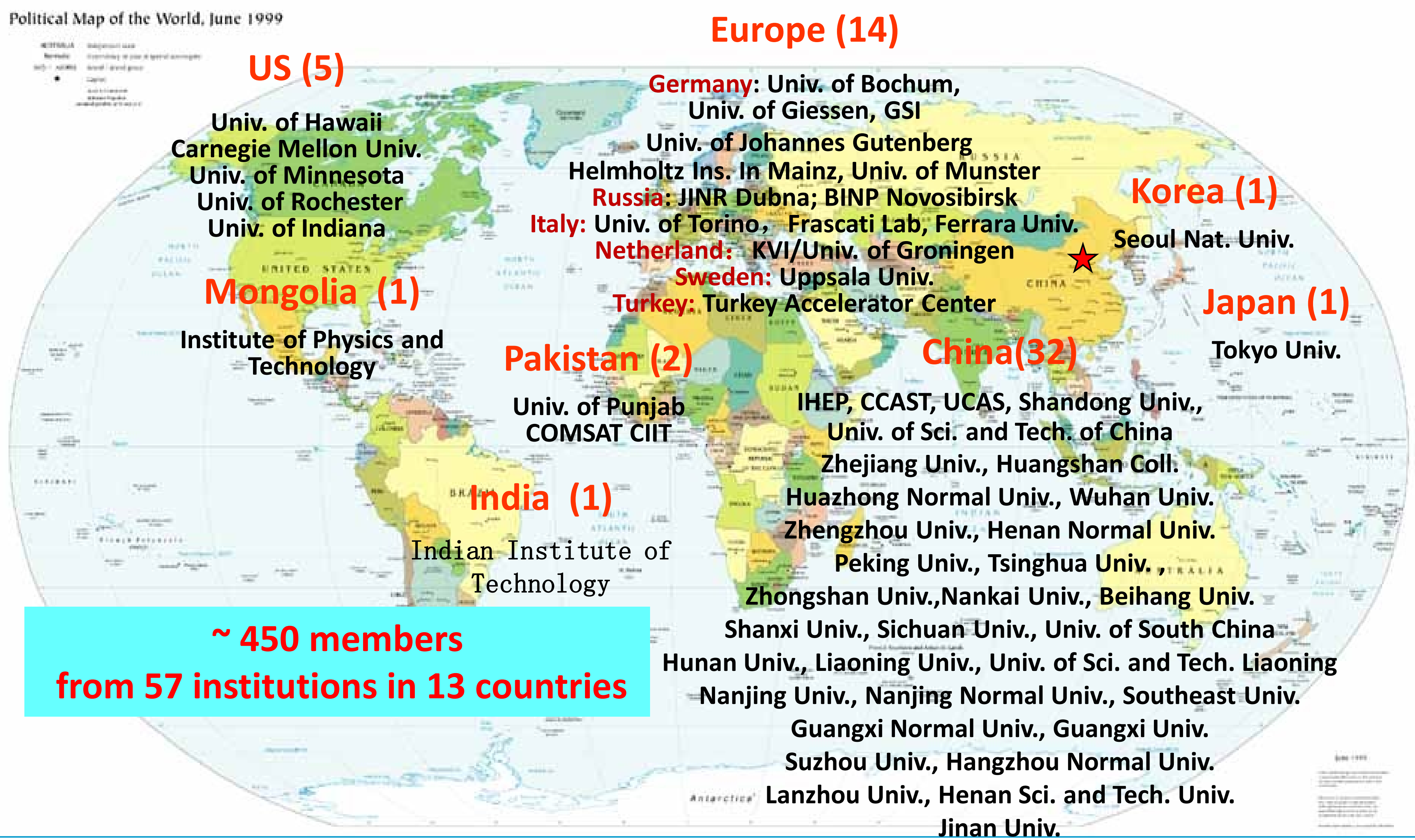
BESIII data samples

2009: 106M $\psi(2S)$
225M J/ψ
2010: 975 pb^{-1} at $\psi(3770)$
2011: 2.9 fb^{-1} at $\boldsymbol{\psi(3770)}$ *(total)*
482 pb^{-1} at **4.01 GeV**
2012: 0.45B $\boldsymbol{\psi(2S)}$ *(total)*
1.3B $\boldsymbol{J/\psi}$ *(total)*
2013: 1092 pb^{-1} at **4.23 GeV**
826 pb^{-1} at **4.26 GeV**
540 pb^{-1} at **4.36 GeV**
~50 pb^{-1} at **3.81, 3.90, 4.09, 4.19, 4.21, 4.22, 4.245, 4.31, 4.39, 4.42 GeV**
2014: 1029 pb^{-1} at **4.42 GeV**
110 pb^{-1} at **4.47 GeV**
110 pb^{-1} at **4.53 GeV**
48 pb^{-1} at **4.575 GeV**
567 pb^{-1} at **4.6 GeV**
0.8 fb^{-1} **R-scan** from 3.85 to 4.59 GeV (104 points)
2015: **R-scan** from 2-3 GeV + **2.175 GeV** data
2016: ~3fb^{-1} at 4.18 GeV (for $\mathbf{D_s}$) *JUST COMPLETED*
*2017: ~10 × 500 pb^{-1} between **4.19 and 4.30 GeV***
2017 SUBJECT TO CHANGE, OF COURSE!



+ Initial State Radiation (ISR)

BESIII Collaboration



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Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Mongolia (1)

Institute of Physics and Technology

Europe (14)

Germany: Univ. of Bochum, Univ. of Giessen, GSI
Univ. of Johannes Gutenberg
Helmholtz Ins. In Mainz, Univ. of Munster
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino, Frascati Lab, Ferrara Univ.
Netherland: KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

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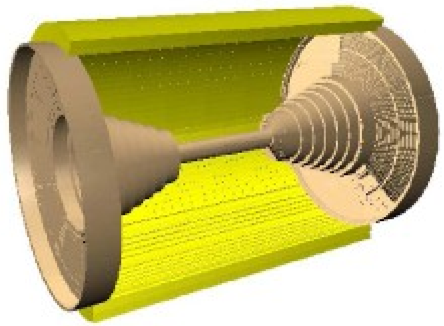
Lanzhou Univ., Henan Sci. and Tech. Univ.
Jinan Univ.

~ 450 members
from 57 institutions in 13 countries

BESIII Detector

MDC

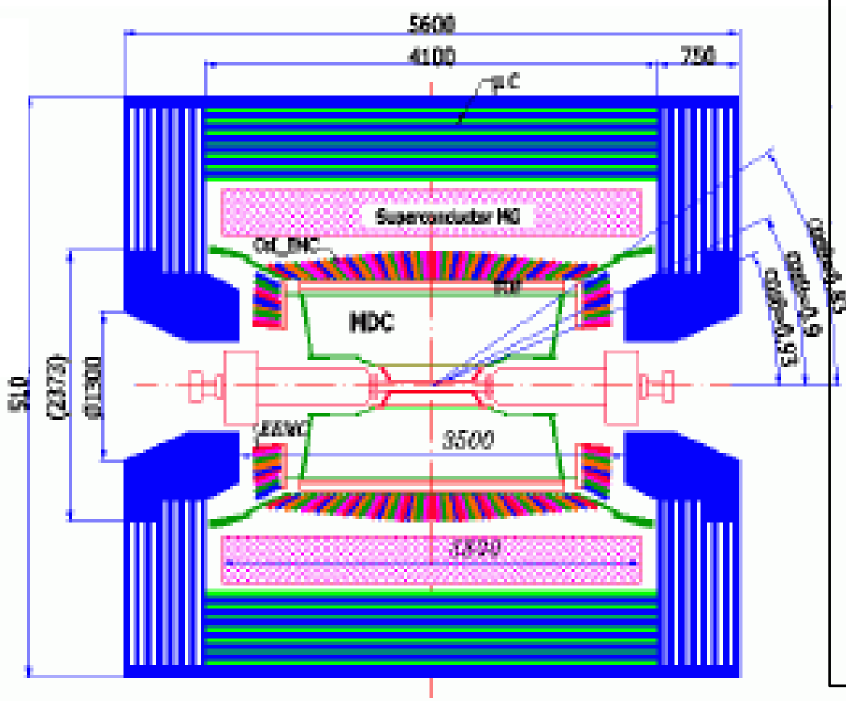


R inner: 63mm ;

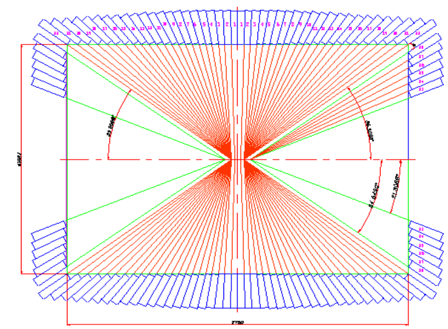
R outer: 810mm

Length: 2582 mm

Layers: 43



CsI(Tl) EMC



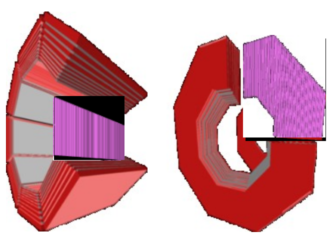
Crystals: 28 cm(15 X_0)

Barrel: |cosθ|<0.83

Endcap:

0.85 < |cosθ| < 0.93

RPC MUC



BMUC: 9 layers – 72 modules

EMUC: 8 layers – 64 modules

TOF

BTOF: two layers

ETOF: 48 crys. for each

BESIII Detector Performance

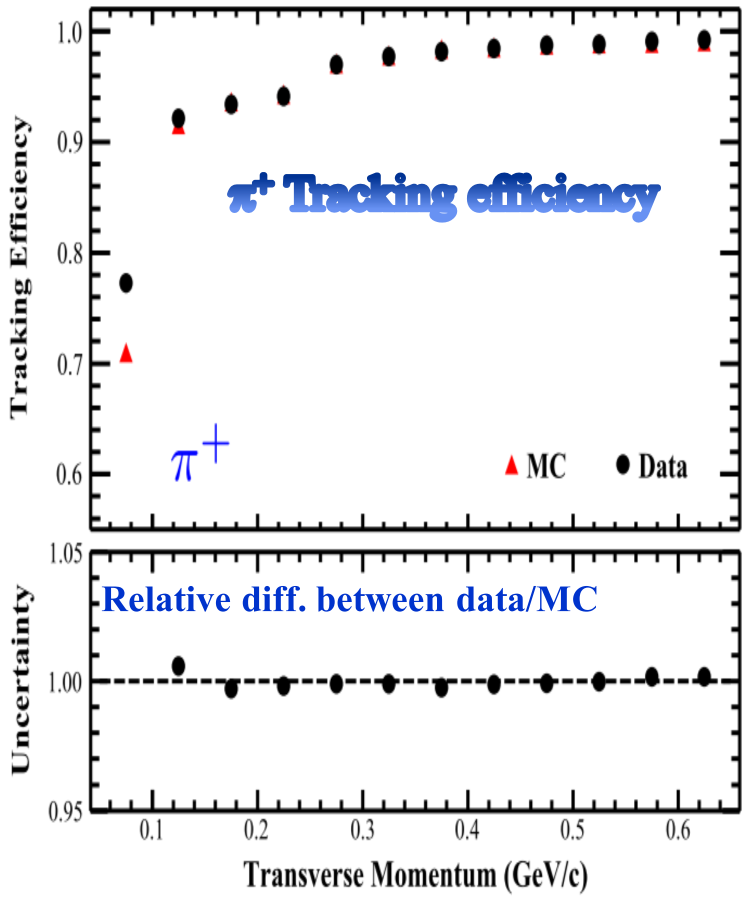
Exps.	MDC Spatial resolution	MDC dE/dx resolution	EMC Energy resolution
CLEO-c	110 μm	5%	2.2-2.4 %
BaBar	125 μm	7%	2.67 %
Belle	130 μm	5.6%	2.2 %
BESIII	115 μm	<5% (Bhabha)	2.4%

Exps.	TOF Time resolution
CDFII	100 ps
Belle	90 ps
BESIII	68 ps (BTOF) 60 ps (ETOF)

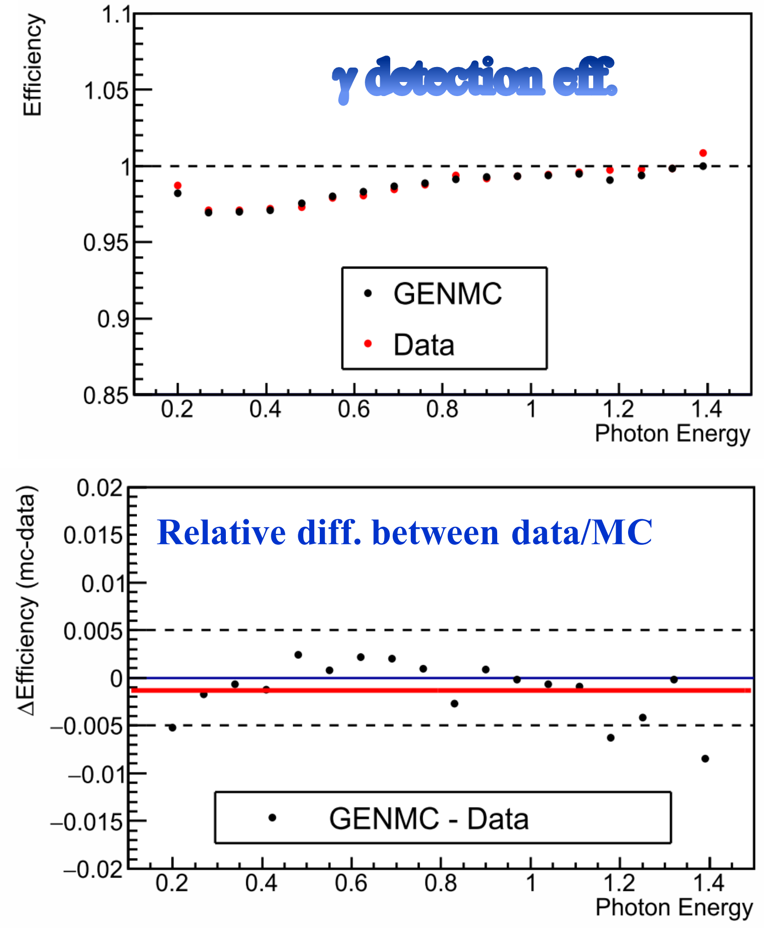
MUC: Efficiency ~ 96%
backgroun level: < 0.04 Hz/cm^2(B-MUC), < 0.1 Hz/cm^2(E-MUC)

Data/MC consistency

- **For tracking efficiency data/MC difference < 1%**



- **For photon detection efficiency data/MC difference < 1%**



Charm facilities

- Hadron colliders (huge cross-section, energy boost)
  - Tevetron (CDF, D0)
  - LHC (LHCb, CMS, ATLAS)
- e^+e^- Colliders (more kinematic constrains, clean environment, ~100% trigger efficiency)
  - B-factories (Belle, BaBar)
  - Threshold production (CLEOc, BESIII)
    - Can not compete in statistics with Hadron colliders & B-factories！！！
    - Quantum Correlations (QC) and CP-tagging are unique
    - Only D meson pairs, no extra CM Energy for pions
    - Systematic uncertainties cancellations while applying double tag technique

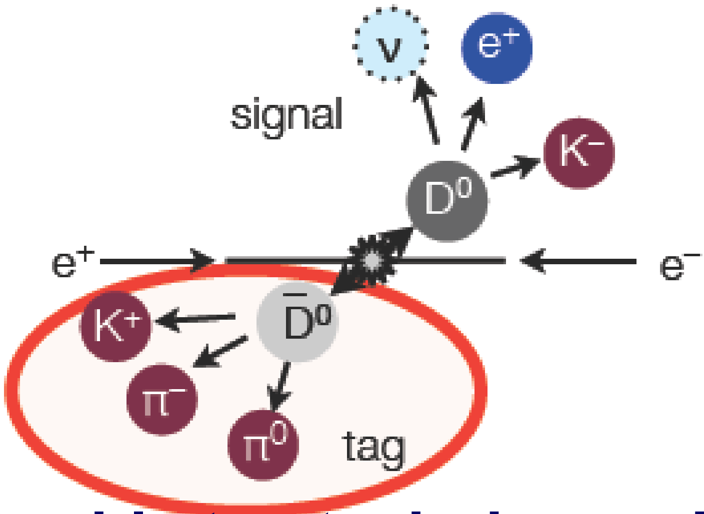
Physics at Charm threshold

- Decay constants & form factors for Charm meson
- Quantum correlations at ψ(3770)
  - CPV measurements
  - Strong phase measurements
- Rare decays
- Charm baryons
- D^0-$\underline{D}^0$ mixing & CPV @ψ(4040)

Many new BESIII results have been released!
See Hailong, Peirong, and Yu's talks.

Double Tag (DT) techniques

- 100% of beam energy converted to D pair (Clean environment, kinematic constrains ν Recon.)
- D generated in pair ⇒ absolute Branching fractions
- At ψ(3770) charm production is $\boldsymbol{D^0\bar{D}^0}$ and $\boldsymbol{D^+D^-}$
- Fully reconstruct about 15% of $D_{(S)}$ decays



$$\Delta E = E_D - E_{\text{Beam}}$$

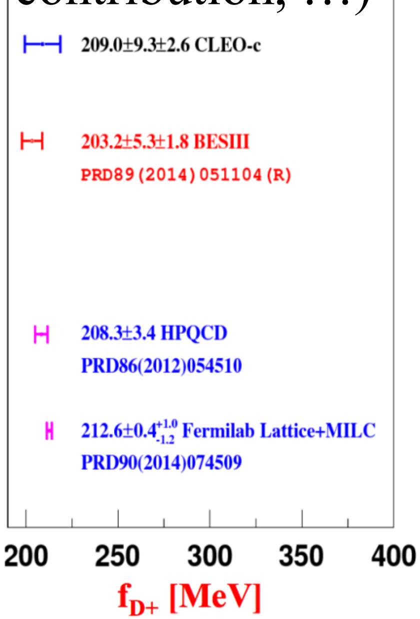
$$M_{\text{BC}} = \sqrt{E_{\text{Beam}}^2 - p_D^2}$$

◆ **Double tag techniques: Hadronic tag on one side, on the other side for leptonic/semileptonic studies. Neutrino is reconstructed from missing energy and momentum (Double tag efficiency is high.)**

$D_{(S)}$ Leptonic decays

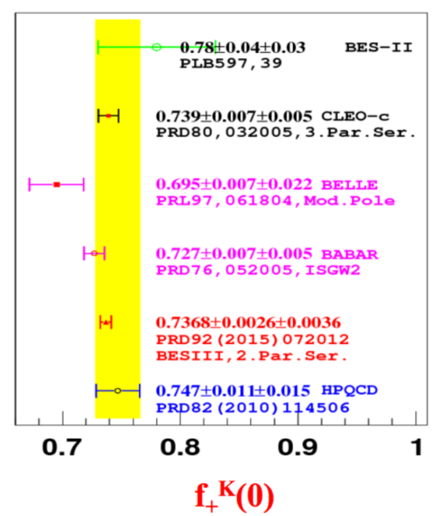
Purely Leptonic:

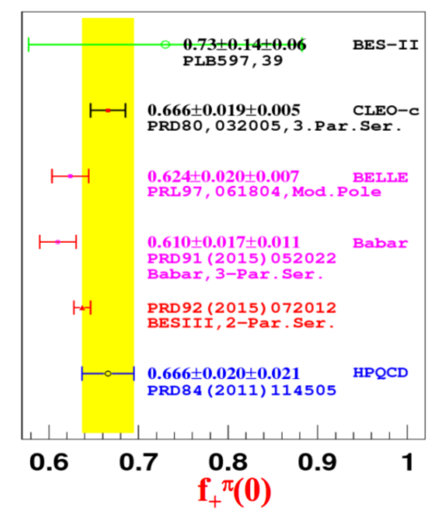
- Extract decay constant $f_{D(s)}$ incorporates the strong interaction effects (wave function at the origin)
- Multiple tests with charm: f_D, f_{Ds} and f_D/f_{Ds}
- To validate Lattice QCD calculation of $f_{B(s)}$ and provide constrain of CKM-unitarity
- Sensitive to New Physics (Charged Higgs contribution, …)



Semi-leptonic: form facotr (FF)

- $D_{(s)} \to P\, l\, \nu$ (Theoretically clean)
- Measure $|V_{cx}|$ x FF
- Charm physics:
  - CKM-unitarity $\Rightarrow |V_{cx}|$, extract FF, test LQCD
  - Input LQCD FF to test CKM-unitarity





Λ_c^+ decays

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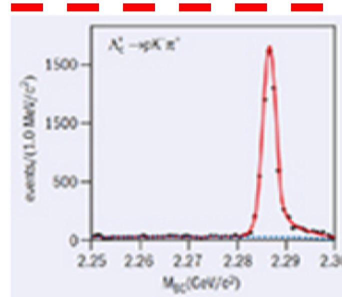
Mar 18, 2016

BESIII makes first direct measurement of the Λ_c at threshold

The charmed baryon, Λ_c, was first observed at Fermilab in 1976. Now, 40 years later, the Beijing Spectrometer (BESIII) experiment at the Beijing Electron–Positron Collider II (BEPCII) has measured the absolute branching fraction of $\Lambda^+_c \to pK^-\pi^+$ at threshold for the first time.



Beam-constrained mass distribution

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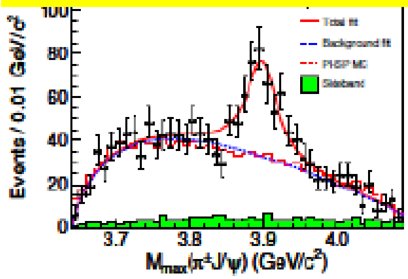
The Zc Family at BESIII

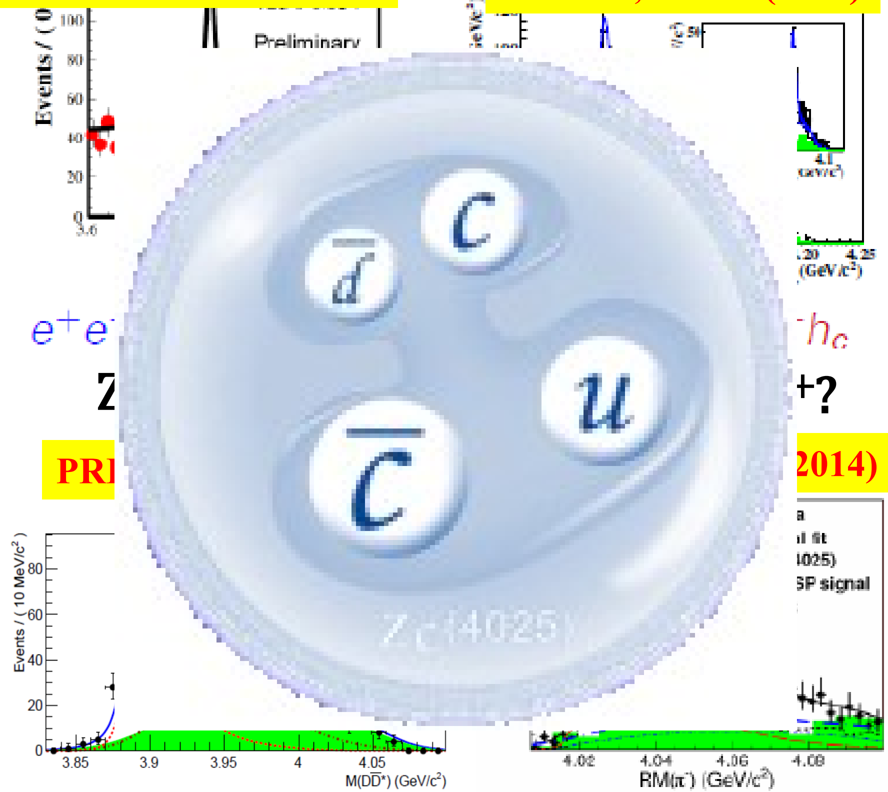
Zc(3900)$^+$?
PRL 110, 252001 (2013)



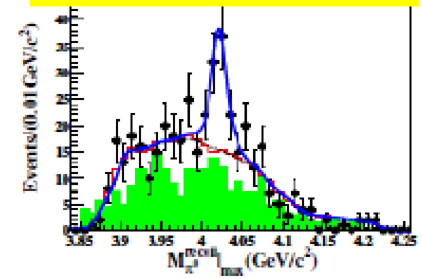
$e^+e^- \to \pi^-\pi^+ J/\psi$

Zc(3900)^0?
PRL 115, 112003 (2015)

Zc(4020)$^+$?
PRL 111, 242001(2013)

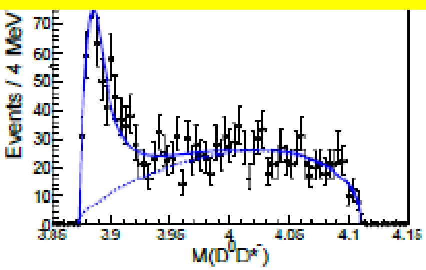


Zc(4020)^0?
PRL113,212002 (2014)



$e^+e^- \to \pi^0\pi^0 h_c$

Zc(3885)$^+$?
ST: PRL 112, 022001(2014)
DT: PRD92, 092006 (2015)

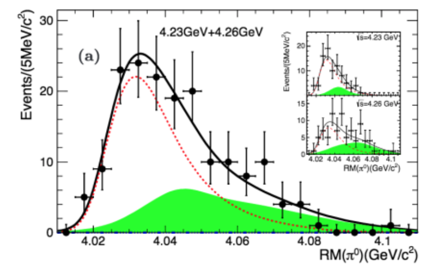


$e^+e^- \to \pi^-(D\bar{D}^*)^+$

$e^+e^- \to \pi^0(D^*\bar{D})^0$

$e^+e^- \to \pi^-(D^*\bar{D}^*)^+$

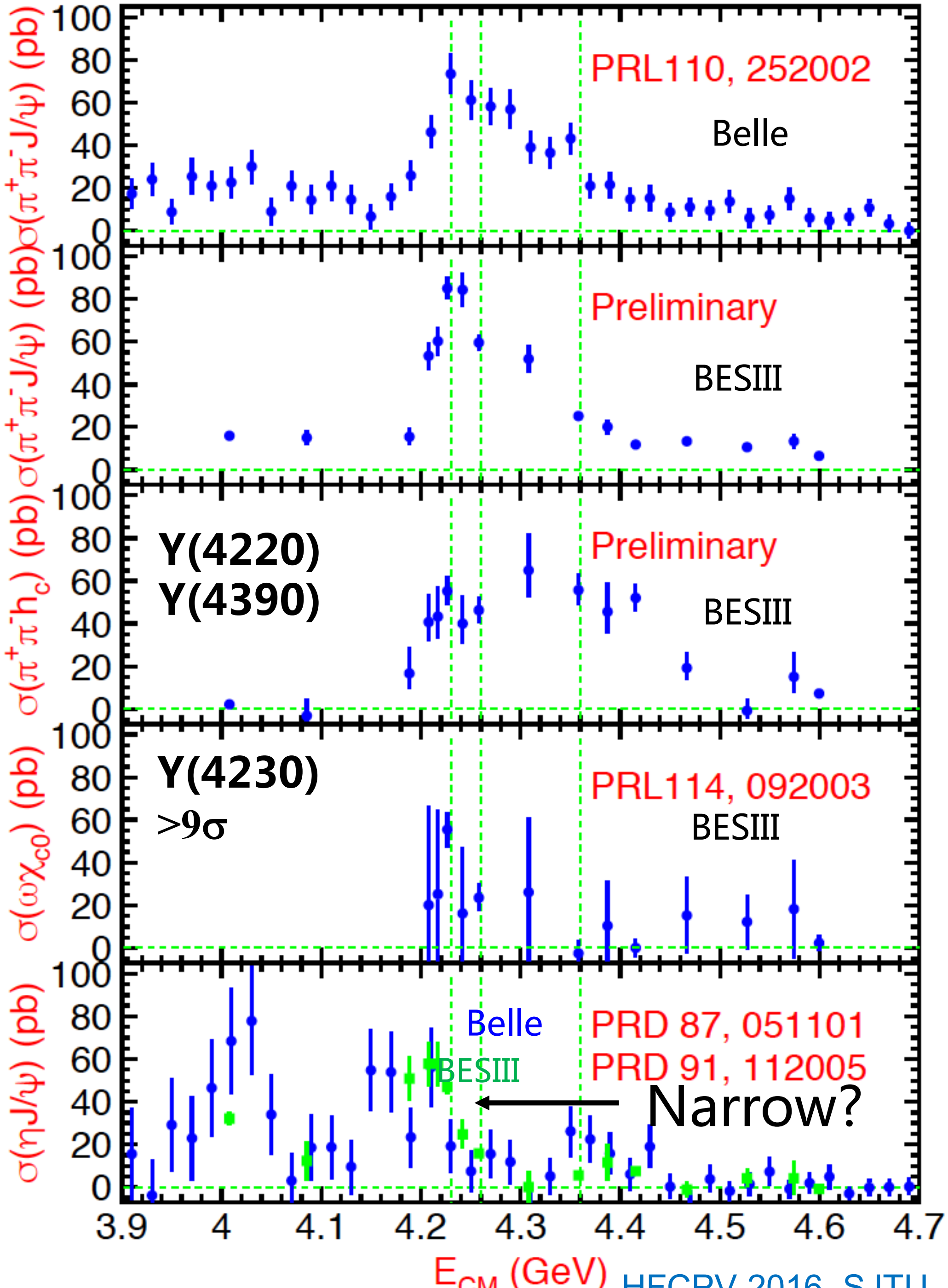
Zc(4025)^0?
PRL115, 182002 (2015)



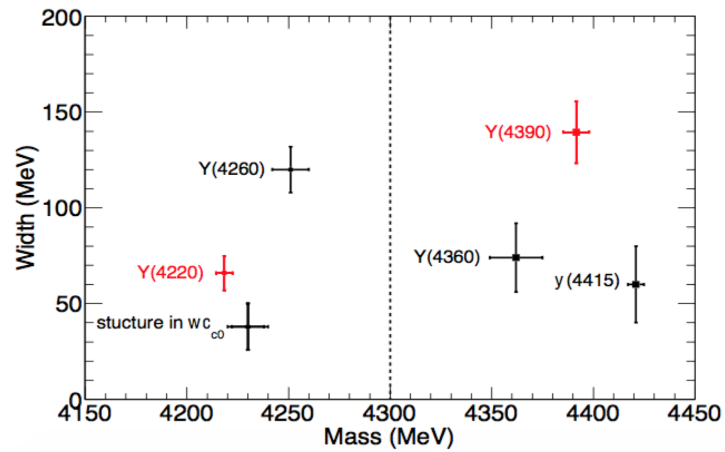
$e^+e^- \to \pi^0(D^*\bar{D}^*)^0$

Which is the nature of these states?

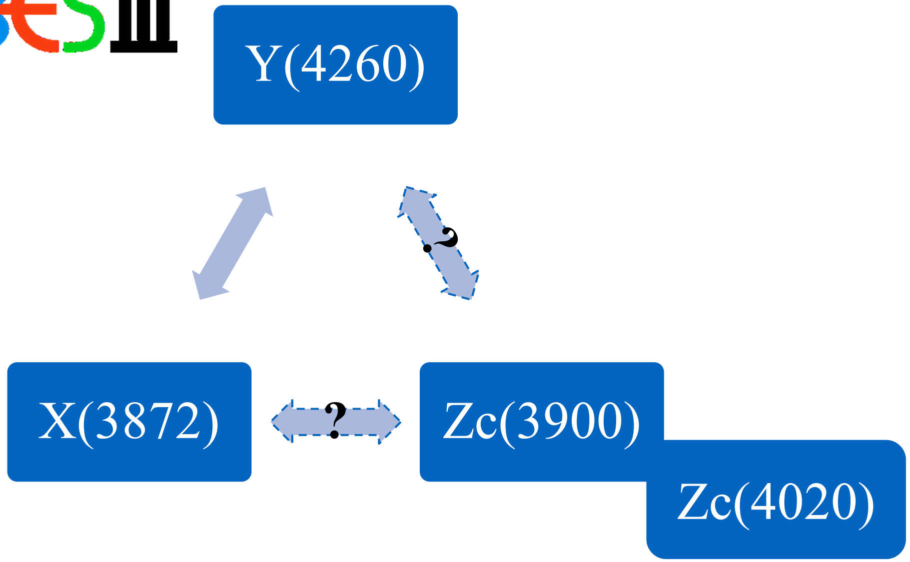
Different decay channels of the same observed states? Other decay modes?



Y(4260) → $\pi^+\pi^- J/\psi$ is observed by Babar (2005) and confirmed by Belle, known for its anomaly large decay width to $\pi^+\pi^- J/\psi$



- Revisit the Y(4260)
  -- with improved cross section measurements
- Not a single/simple BW?
- Is there any connection to $\bar{D}_s^* D_s^*$ threshold (4224 MeV) ?



Multiquark
Hybrid
Hadrocharmonium
Molecule
Threshold effects
Cusps
…

States or/and interactions???

What is the role of threshold

--Many new observations near thresholds: D*D,D*D*, D_1D, …

See reviews by Swanson (Hadron2015), Eichten (QWG2016), Zhao(MENU2016) and ref. within

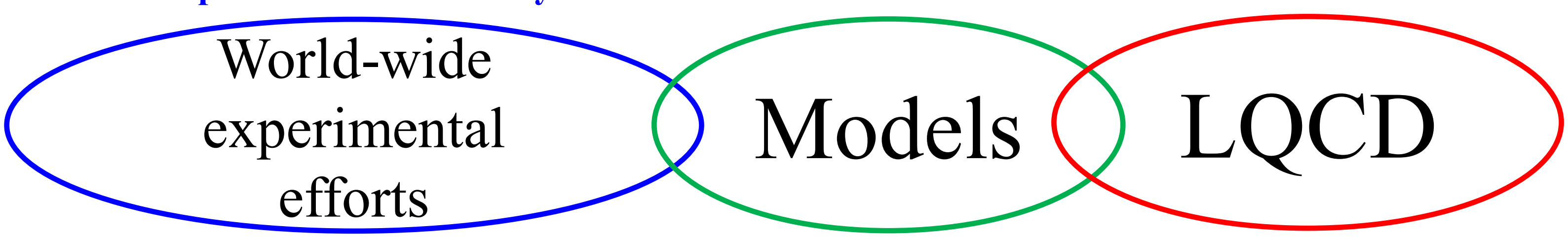
* Phase variations appear in many process: not unique for resonance

To have a complete picture, more findings are desired

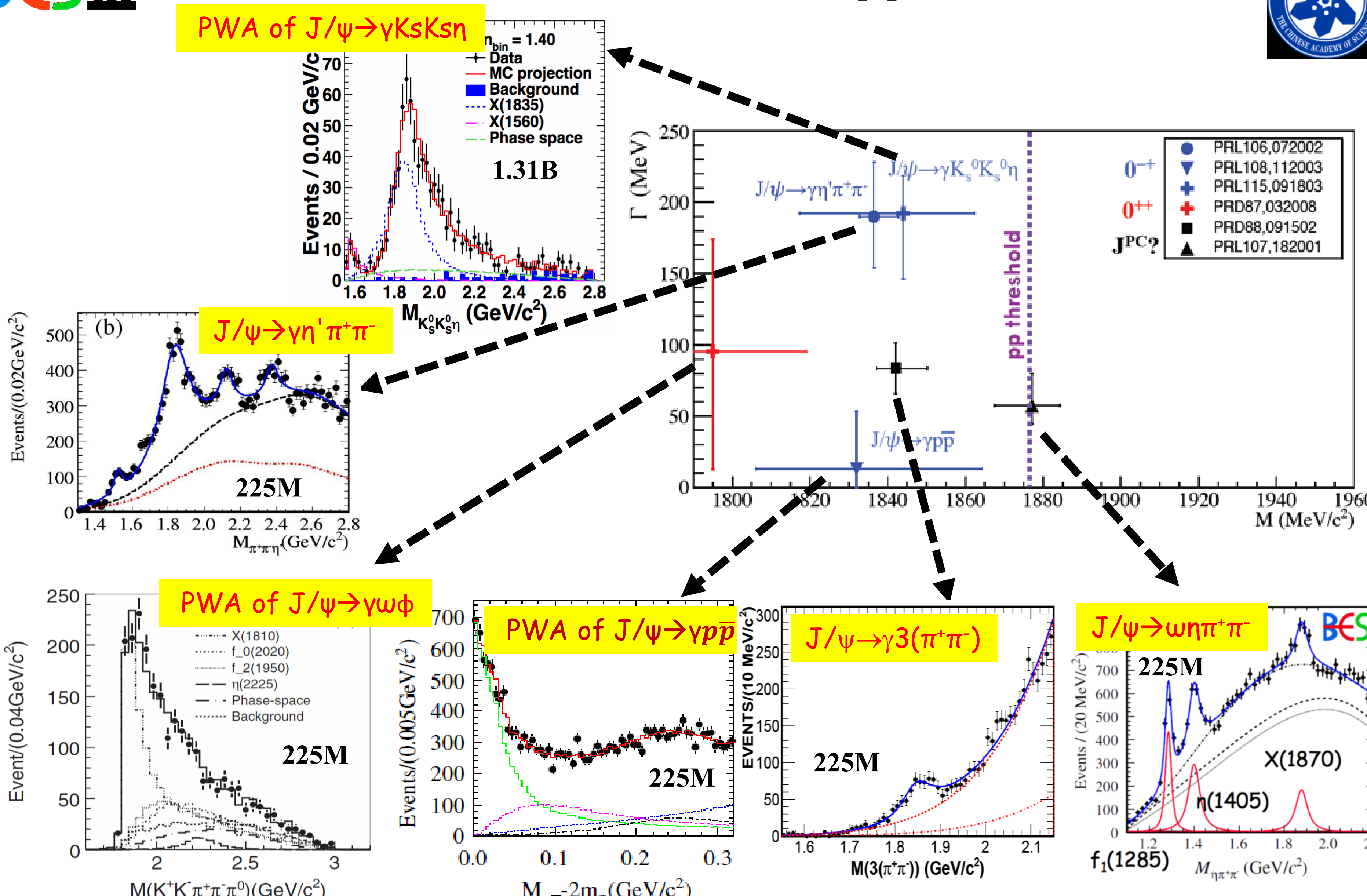
- **Energy-dependence**
- **Patterns in productions and decays**

Pole properties

For XYZ, the picture is still unclear



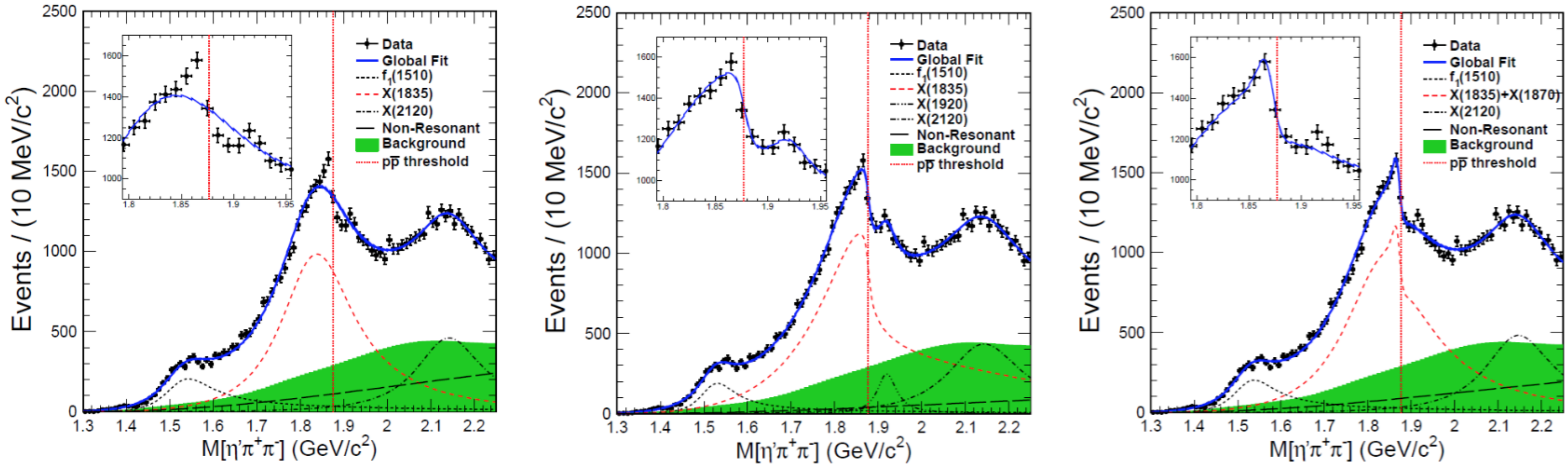
The X(18??) near the $p\bar{p}$ mass threshold



Are they the same state? It is crucial to understand their connections.

Connection of X($p\bar{p}$) and X(1835)

Phys. Rev. Lett. 117, 042002 (2016)



- Three efficiency-corrected Breit-Wigner functions
- Simple BW function fails in describing the $\eta'\pi^-\pi^+$ line shape near the threshold

MODEL 1

Threshold structure caused by the opening of additional decay mode

- Flatté formula for the shape (Phys.Lett.B**63**, 224)
- An additional BW resonance (X(1920)) is needed (5.7σ)

MODEL 2

Interference between two resonances

- Use coherent sum of two BW amplitudes for the line shape: X(1835) and a narrow resonance called X(1870)
- X(1920) not significant

- Both fits support the existence of one of
  - Broad state with strong coupling to $p\bar{p}$
  - Narrow state just below the $p\bar{p}$ mass threshold

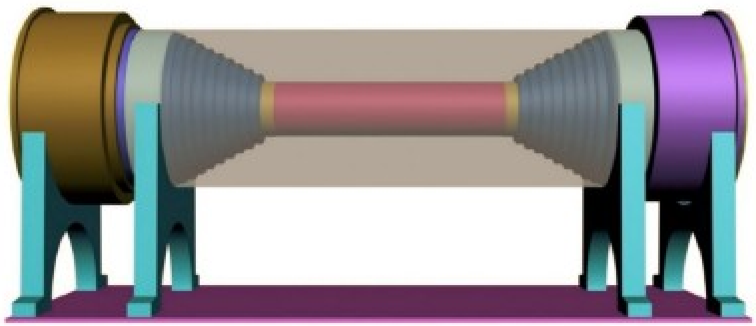
BESIII upgrade

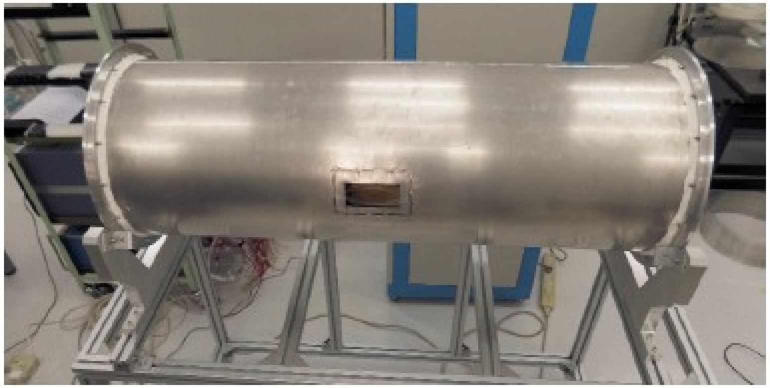
- **MDC: Malter effect found in inner chamber in 2012, add water vapor to the chamber to cure the aging problem.**
  - **New inner chamber, built by IHEP, is ready now.**
  - **CGEM as the inner chamber ongoing : Italy group in collaboration with other groups.**

- **New ETOF (built by USTC & IHEP) was installed last year to improve the time resolution.**

- **Other possible upgrade plan is under discussion**

New Inner Drift Chamber

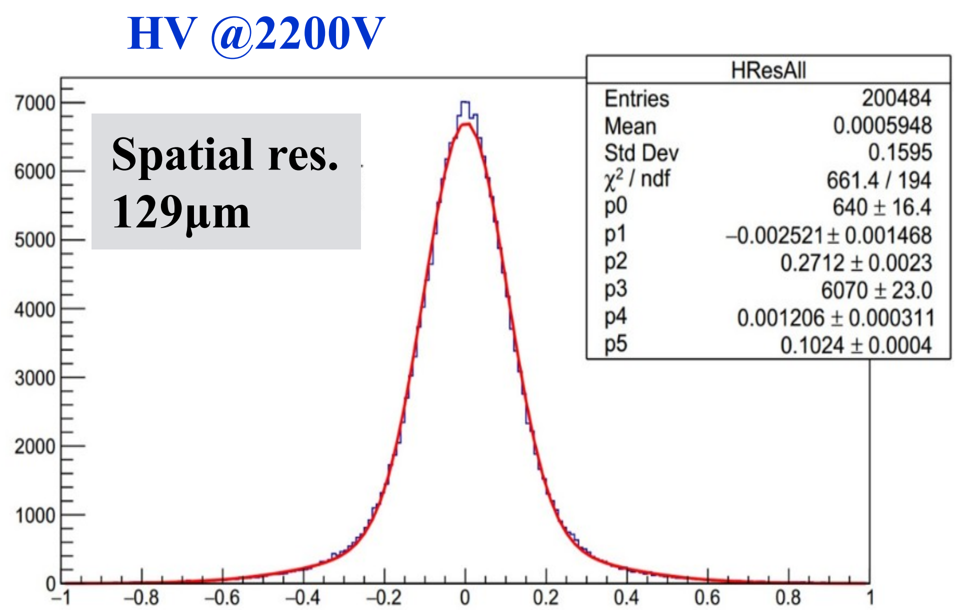


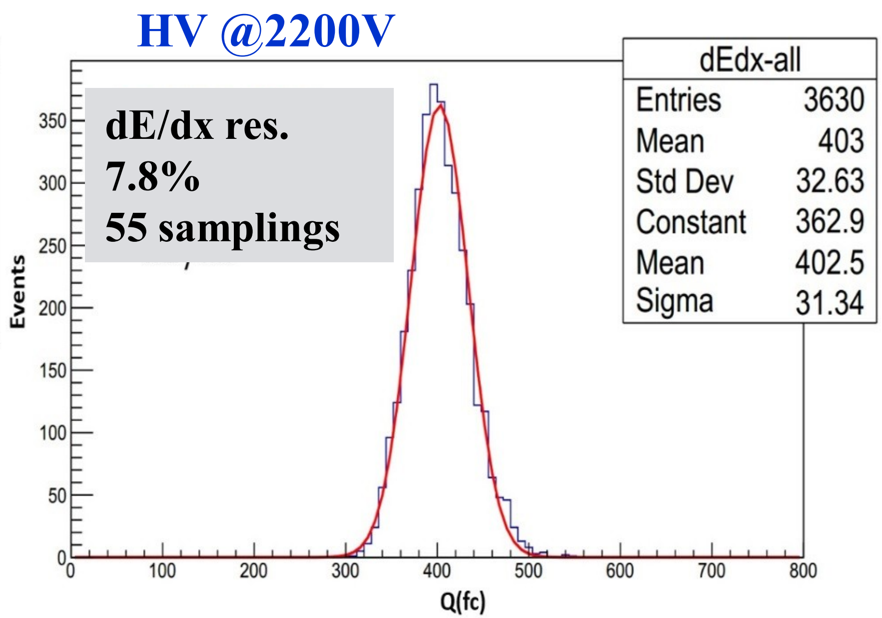


- An aluminum outer cylinder was manufactured for the chamber cosmic-ray test
- The outer cylinder was assembled after wiring had been finished

The performance of the new chamber

After half year's cosmic ray test, the efficiency > 99%

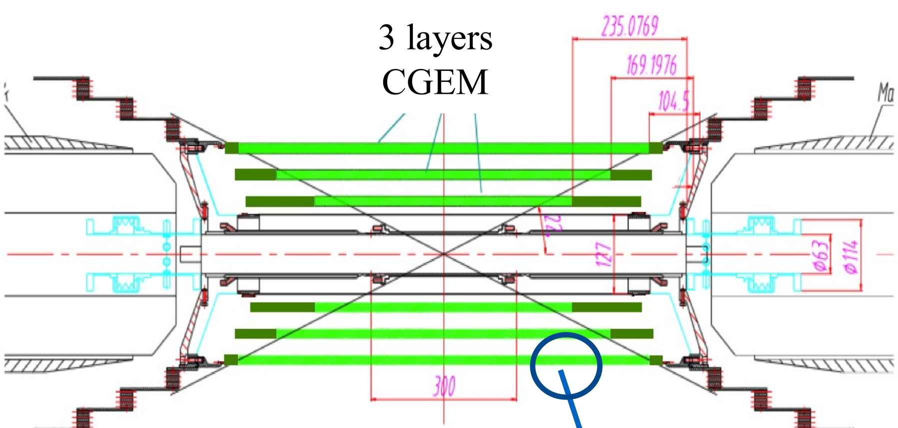




The chamber is stored in a clean room and is ready to be replaced.

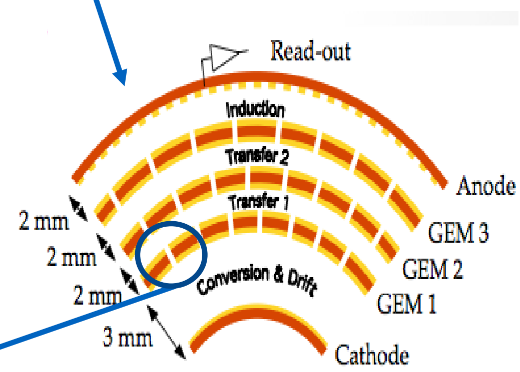
Cylindrical GEM Inner Tracker in a nutshell

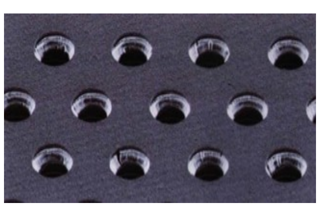
BESIII is building a cylindrical GEM detector (CGEM-IT) to replace the BESIII Inner MDC to recover some efficiency loss due to aging and to improve the secondary vertex resolution.



- **Low Material budget ≤ 1.5% of X_0 for all layers**
- **High Rate capability: ~10^4 Hz/cm^2**
- **Coverage: 93%**
- **Spatial resolution s_{rf} ~130 mm in 1 T magnetic filed**
- **Operation duration at least 5 years**

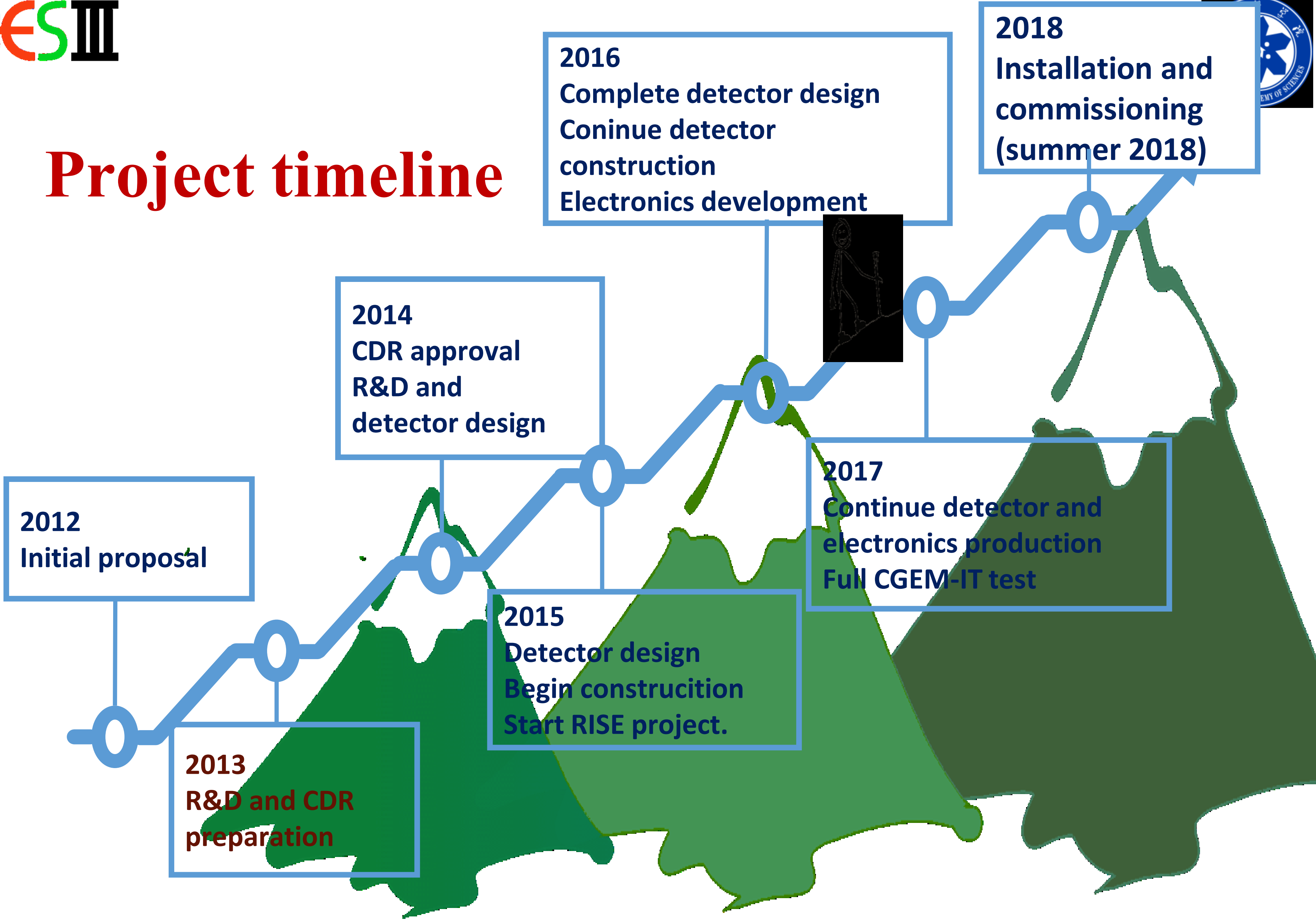
Each layer composed by a triple cylindrical GEM





The CGEM is co-funded by the European Commission Research and Innovation Staff Exchange (RISE) project 2015-2018.

Project timeline

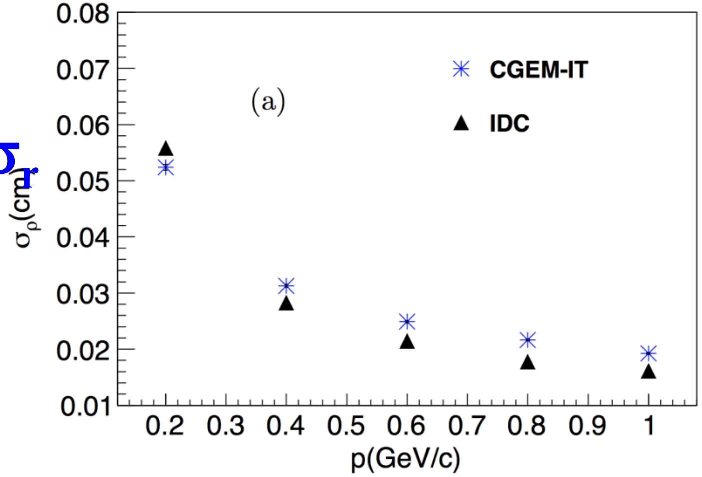


Expected performance of CGEM

Track fitting with Kalman Filter

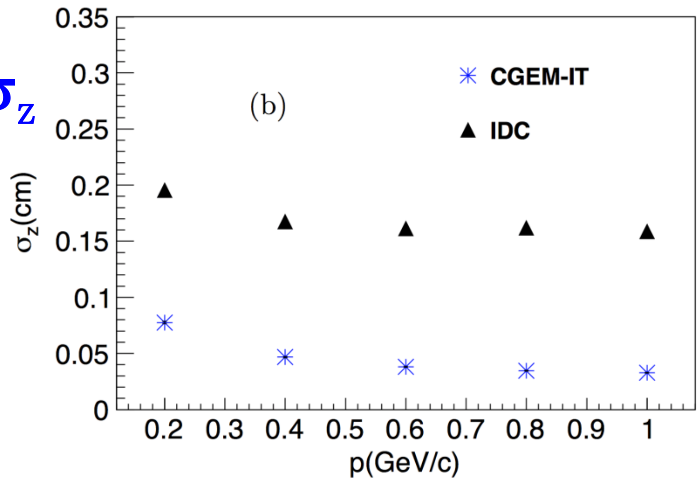
Approaching point resolution

σ_r

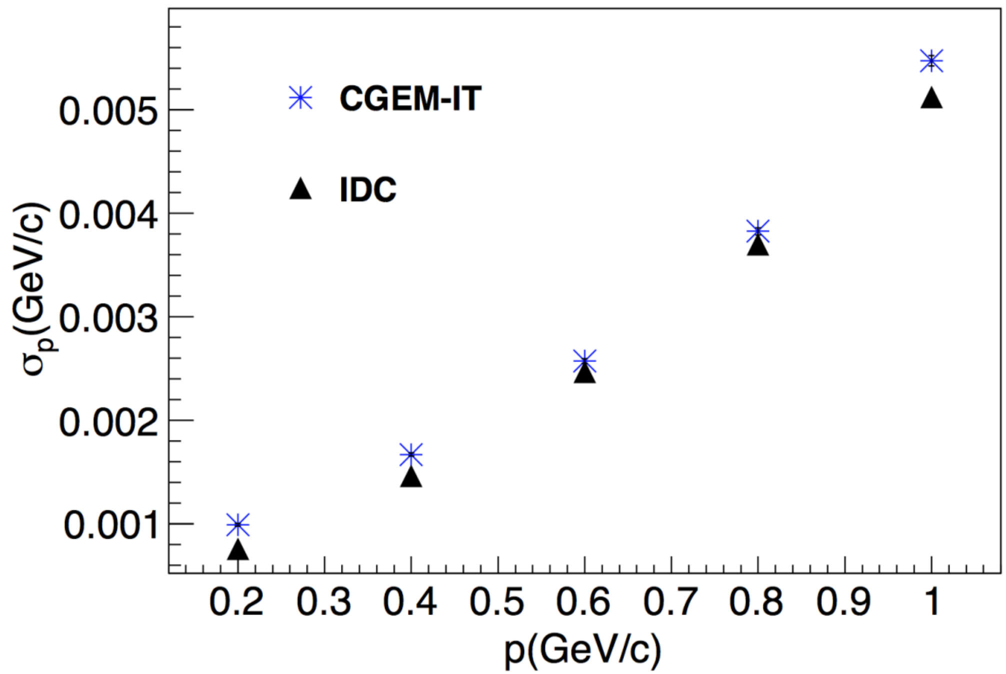


Approaching point resolution

σ_z

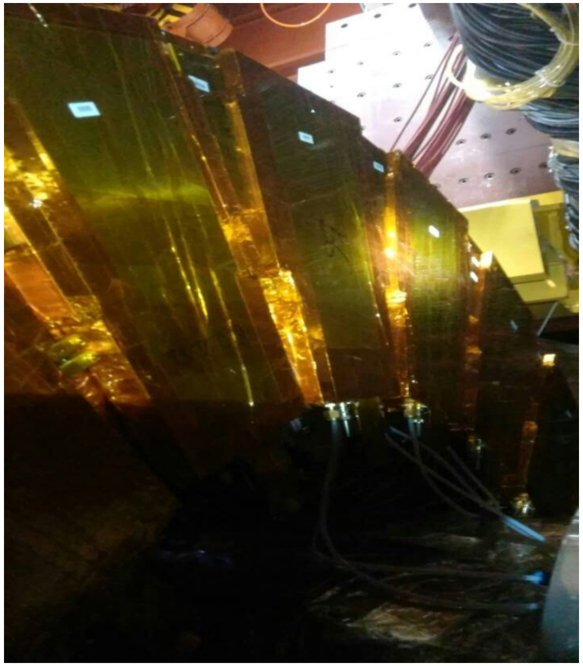


Momentum resolution

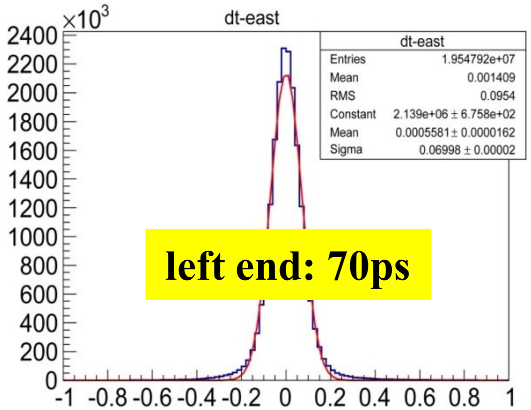


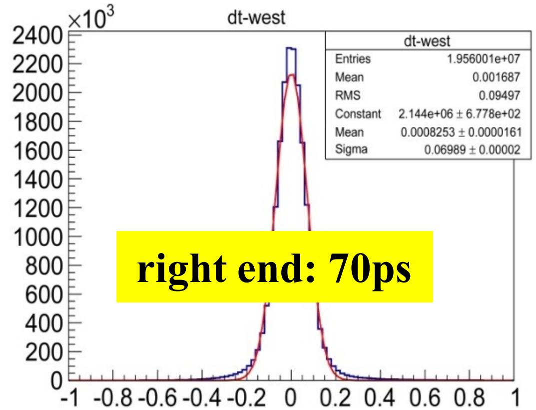
Installation of MRPC Endcap TOF

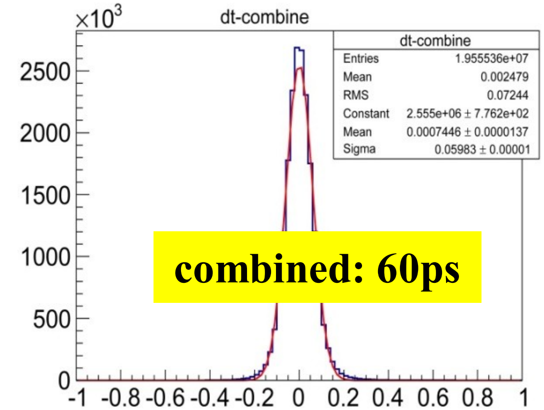
- **Scintillator Endcap TOF: time resolution for π is 138ps.**
- **New MRPC Endcap-TOF built**
- **The installation of MRPC ETOF completed in the Oct. of 2015**

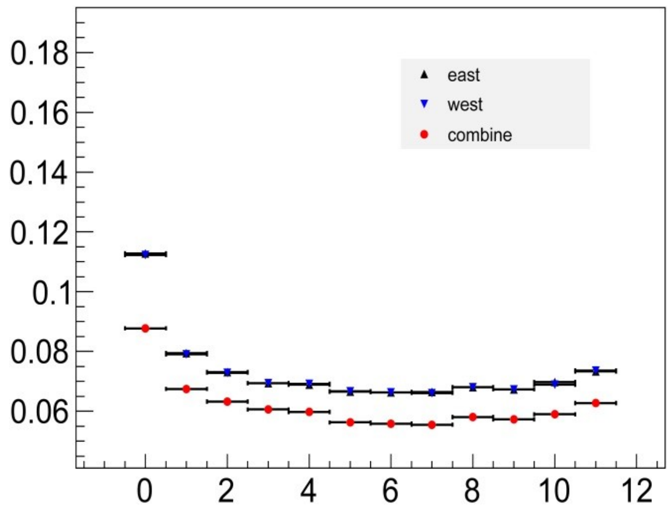


MRPC Endcap TOF

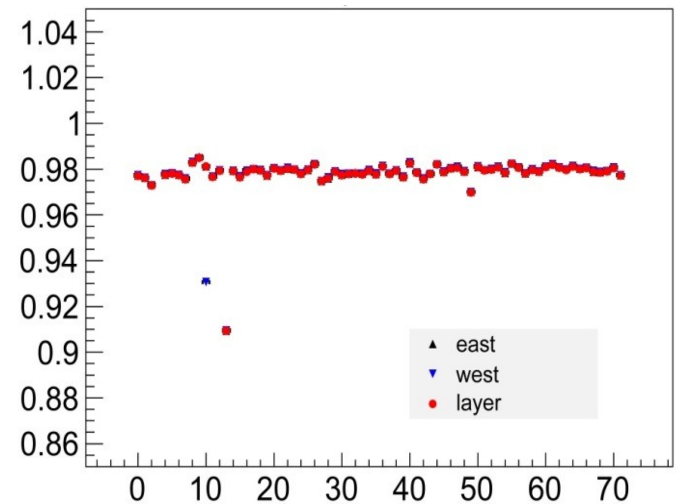








Time resolution vs Strip Number



Efficiency vs Module Number

Time resolution of 60ps achieved; Efficiency ~97%

Data/MC discrepancy

$\varepsilon_{data}/\varepsilon_{MC}-1$	2010	2016	2019?
Tracking eff./track	~2%	~1%	~0.5%
PID/track	~2%	~1%	~0.5%
Photon eff./photon	~1%	0.5-1%	~0.5%

Control of systematic errors.

Prospects of hadron spectroscopy at BESIII

- **BESIII collected world's largest samples of J/ψ, ψ(2S), ψ(3770), Y(4260), … from e^+e^- production.**
- **It will continue to run a few years.**

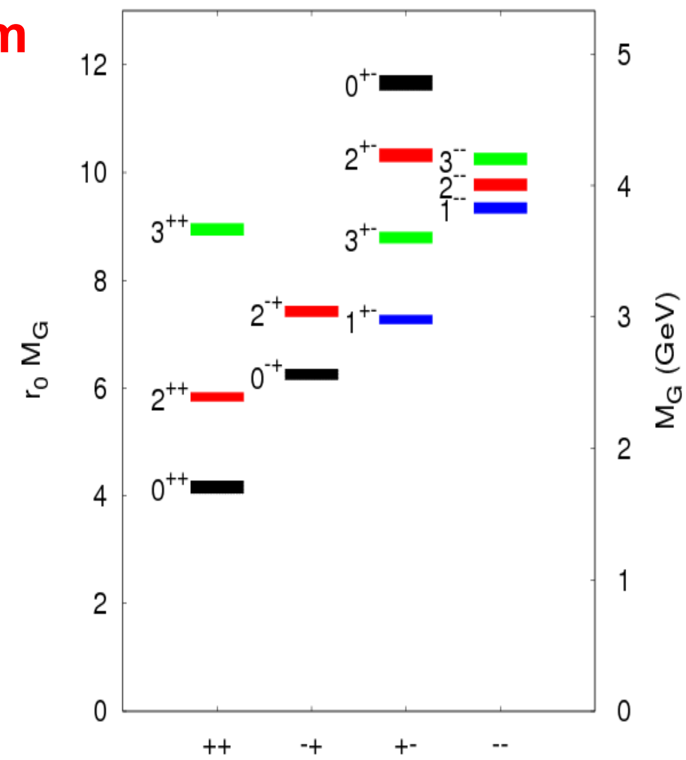
	BESIII	Goal
J/ψ	$1.3*10^9$ 21x BESII	$10*10^9$
***ψ*'**	$0.6*10^9$ 24x CLEO-c	$3*10^9$
***ψ*(3770)**	2.9 fb^{-1} 21x CLEO-c	20 fb^{-1}
Above open charm threshold	0.5 fb^{-1}@*ψ*(4040), 1.9 fb^{-1} @~4260, 0.5 fb^{-1}@4360, 1.0 fb^{-1} @4420, 0.5 fb^{-1} @4600, **scan data @4.19~4.30GeV in 2017.**	>15 fb^{-1}
R scan and tau	3.8-4.6 GeV at 105 energy points 2.0-3.1 GeV at 20 energy points	
Y(2175)	100 pb^{-1} (2015)	
ψ(4170)	3 fb^{-1} (2016)	

Opportunities for both heavy and light hadron spectroscopy

Glueballs

- **Low lying glueballs have ordinary quantum number**
  0^{++}(1.5~1.7 GeV), 2^{++}(2.3~2.4 GeV), 0^{-+}(2.3~2.6 GeV)
  mixing with qqbar mesons
- The mix of glueball with ordinary qq meson makes the situation more difficult.
- The spectrum is from unquenched LQCD calculations

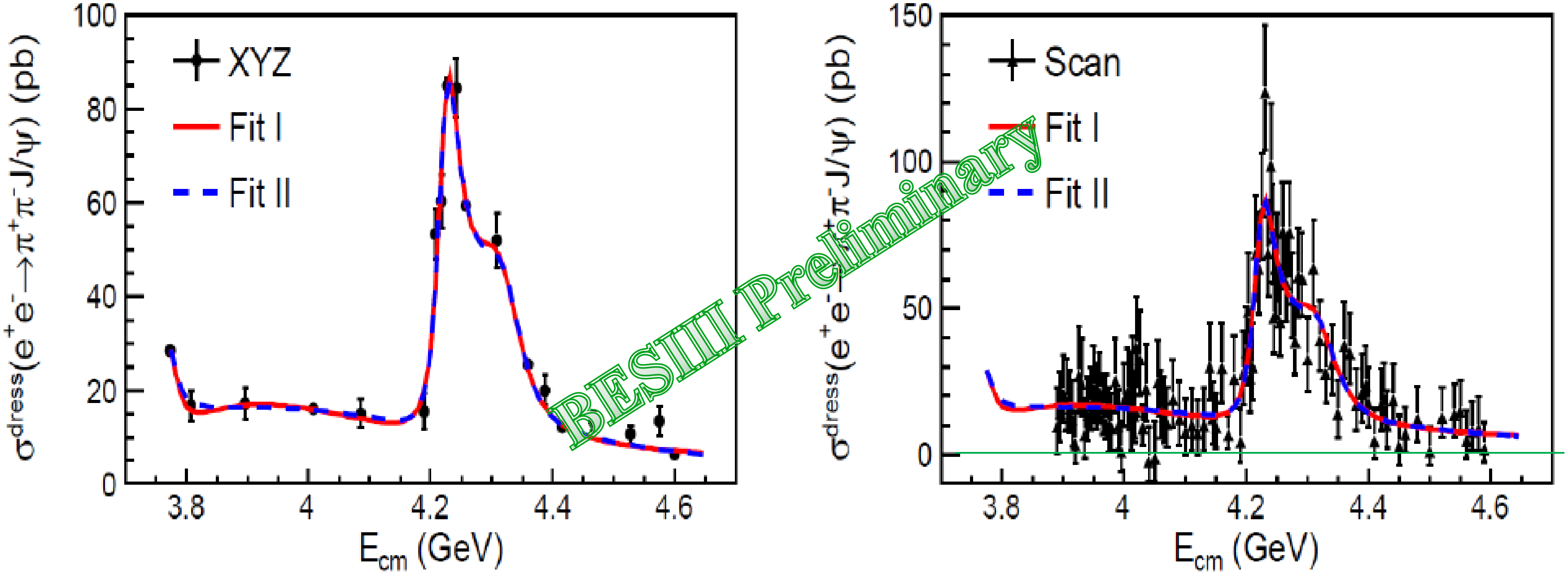
  Glueball candidates: $f_0(1500)$, $f_0(1700)$, $f_J(2220)$, ...



- **J/ψ radiative decays are believed to be an ideal place to search for glueballs.**
  - $J/\psi \to \gamma\omega\phi$ Phys.Rev. D 87,032008(2013)
  - $J/\psi \to \gamma\phi\phi$ Phys. Rev. D 93, 112011 (2016)
  - $J/\psi \to \gamma\eta\eta$ Phys. Rev. D 87, 092009 (2013)
  - $J/\psi \to \gamma\pi^0\pi^0$ Phys. Rev. D 92, 052003 (2015)

	0+	2+	0-
J/ψ→γPP			
J/ψ→γVV			
J/ψ→γPPP			

Puzzles on XYZ (one example)



Two resonances? What are they?

Prospects of charmed hadron decays

Data at 3.773, 4.18 GeV and 4.63GeV

	Systematic	Statistical	
		~3 fb^{-1}	+10 fb^{-1}
$\Delta f_{D+}/f_{D+}$	~0.9%^{BESIII}	2.6%	1.3%
$\Delta f_{Ds+}/f_{Ds+}(\mu+\tau)$	~1.4%$^{CLEO-c}$	~1.5%	~0.7%
$\Delta f_{D\to K}/f_{D\to K}$	~0.5%^{BESIII}	0.4%	0.2%
$\Delta f_{D\to\pi}/f_{D\to\pi}$	~0.7%^{BESIII}	1.3%	0.6%
$\|V_{cs}\|^{Ds+\to l+v}(\mu+\tau)$	~1.4%$^{CLEO-c}$	~1.4%	~0.7%
$\|V_{cs}\|^{D0\to K-e+v}$	2.5%^{BESIII}(2.4%^{LQCD})	0.4%	0.2%
$\|V_{cd}\|^{D+\to\mu+v}$	2.1%^{BESIII}(1.9→0.5%^{LQCD})	2.6%	1.3%
$\|V_{cd}\|^{D0\to\pi-e+v}$	4.5%^{BESIII}(4.4%^{LQCD})	1.3%	0.6%
(c_i,s_i) in $D^0\to K^0\pi^+\pi^-$	Uncertinaty for γ/ϕ_3	1%	0.5%
$\Lambda_c^+\to pK^-\pi^+$		4.8% (0.6fb^{-1}@4.6)	~2% (3fb^{-1}@4.6X)

BESIII Strong phases in D hadronic decays

Decay mode	Quantity of interest	Comments
$D \to K^0_S \pi^+\pi^-$	c_i and s_i	Binning schemes as those used in the CLEO-c analysis. With future, very large $\psi(3770)$data sets, it might be worthwhile to explore alternative binning.
$D \to K^0_S K^+K^-$	c_i and s_i	Binning schemes as those used in the CLEO-c analysis. With future, very large $\psi(3770)$data sets, it might be worthwhile to explore alternative binning.
$D \to K^\pm\pi^\mp\pi^+\pi^-$	R, δ	In bins guided by amplitude models, currently under development by LHCb.
$D \to K^+K^-\pi^+\pi^-$	c_i and s_i	Binning scheme can be guided by the CLEO model [18] or potentially an improved model from LHCb in the future.
$D \to \pi^+\pi^-\pi^+\pi^-$	F_+ or c_i and s_i	Unbinned measurement of F_+. Measurements of F_+ in bins or c_i and s_i in bins could be explored.
$D \to K^\pm\pi^\mp\pi^0$	R, δ	Simple 2-3 bin scheme could be considered.
$D \to K^0_S K^\pm\pi^\mp$	R, δ	Simple 2 bin scheme where one bin encloses the K^* resonance.
$D \to \pi^+\pi^-\pi^0$	F_+	No binning required as $F_+ \sim 1$.
$D \to K^0_S\pi^+\pi^-\pi^0$	F_+ and c_i and s_i	Unbinned measurement of F_+ required. Additional measurements of F_+ or c_i and s_i in bins could be explored.
$D \to K^+K^-\pi^0$	F_+	Unbinned measurement required. Extensions to binned measurements of either F_+ or c_i and s_i possible.
$D \to K^\pm\pi^\mp$	δ	Of low priority due to good precision available through charm-mixing analyses.

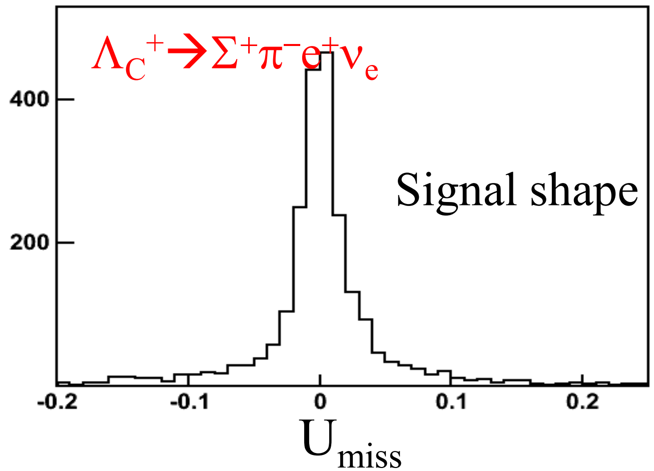
Prospects for Λ_c semi-leptonic decays

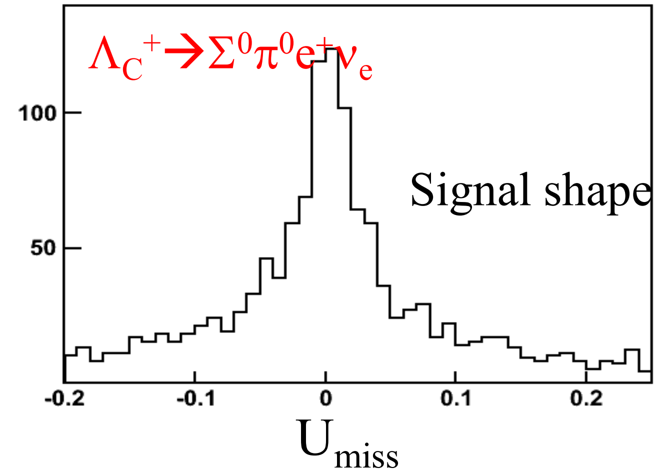
1 M Λ_c^+ pairs

- So far, only mode $\Lambda e^+ \nu_e$ is measured
- Many more semi-leptonic modes can be established at BESIII!

modes	Expected B[%]	δB/B
$\Lambda l^+ \nu_l$	3.6	5.4%
$\Lambda^* l^+ \nu_l$	0.7	17%
$(pK^-, \Sigma\pi)\ l^+ \nu_l$	0.7	17%
$n l^+ \nu_l$	0.2	30%

	SL	δB/B
D0	B(Kev)=(3.55±0.05)%	1.4%
D+	B(K0ev)=(8.83±0.22)%	2.5%
Ds	B(phiev)=(2.49±0.14)%	5.6%
Λc	B(Λev)=(2.1±0.6)% (PDG2014) =(3.63±0.43)% (BESIII) **=(3.63±0.13)% (new BESIII)**	29% 12% **3%**

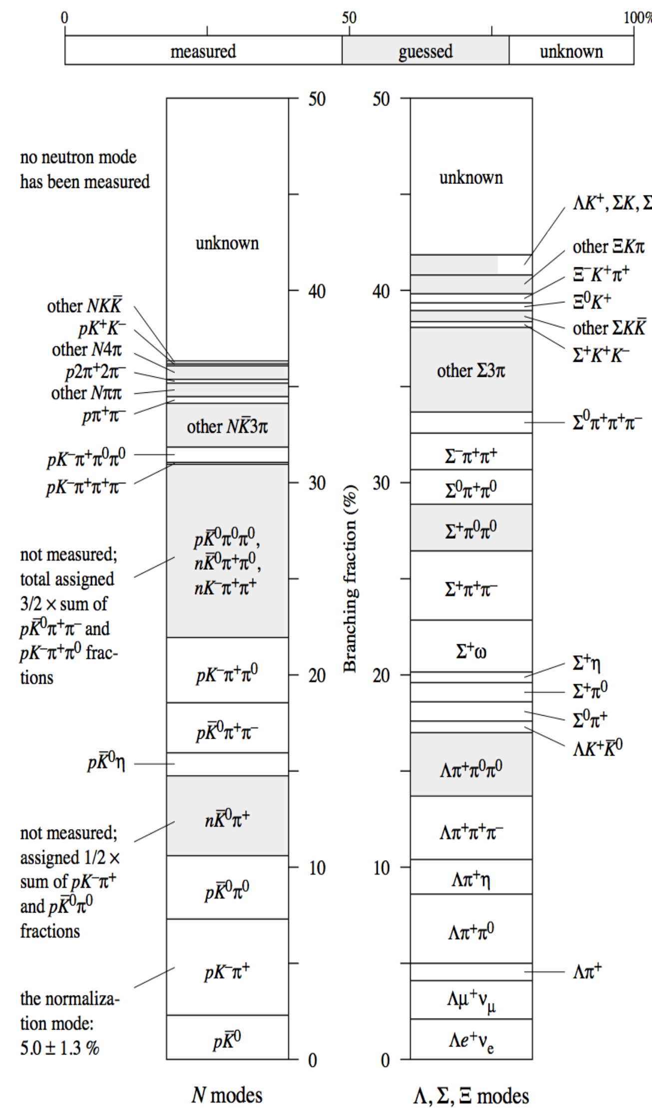




Other Relevant Λ_c^+ Potentials

10x more Λ_c^+ pairs

- **Studies on new Cabibbo-suppressed modes**
- **Many neutron modes will be firstly measured:** ***to test isospin symmetry*** PRD93, 056008 (2016)
- **Λ_c^+ hadronic weak decays**
  - ✓ Decay asymmetry parameters in two-body hadronic weak decays, such as $\Lambda_c^+ \to BP$ and $\Lambda_c^+ \to BV$ ➔ to measure the relative phase between the S- and P-wave decays
  - ✓ We can provide precise measurements on this observables
- **search for Λ_c^+ low rate decays and rare decays**
  - ✓ Weak radiative decay $\Lambda_c^+ \to \gamma\Sigma^+$; predictions of BF are $10^{-4} \sim 10^{-5}$: expected sensitivity $\sim 10^{-4}$
  - ✓ FCNC, lepton number/family violation, baryon family violation ...: expected sensitivity$\sim 10^{-5}$



We will find more the Λc-decay Mosaic!

Reaches for rare charm decays?

SM predictions and experimental reaches

10^{-0}

10^{-1}

10^{-2} Cabibbo favor

10^{-3} Single Cabibbo suppressed

10^{-4} Doubly Cabibbo suppressed

10^{-5}

10^{-6} Radiative decays

$$D^0 \to \overline{K}^{*0}\gamma / \phi\gamma / \rho\gamma / \omega\gamma$$

$$D^+ \to K^{*+}\gamma / \rho^+\gamma \quad D_S^+ \to K^{*+}\gamma / \rho^+\gamma$$

CLEO-c

BESIII

BESIII final/B factory

10^{-7} Long distance:

10^{-8} Vector meson Dominance

$$D^0 \to \gamma\gamma / VV'(\to ll) / hV(\to ll) / hh'V(\to ll)$$

LHCb

10^{-9}

Super-B

Super-τ-charm

10^{-10}

10^{-11} Short distance FCNC

$$D^0 / D^+ \to \gamma\gamma / Vl^+l^- / hl^+l^- / hh'l^+l^-$$

$$D^0 \to \mu^+\mu^-$$

10^{-12}

10^{-13}

$$D^0 \to e^+e^-$$

10^{-14}

10^{-15}

Forbidden decays: LNV, LFV, BNV

$$D \to (h)\mu^+e^-$$

$$D \to (hh)e^+e^+ / (hh)\mu^+\mu^+$$

BEPCII Future Upgrade

- Replace one cavity in summer of 2017
  - ✓ ~3 months for the replacement
  - ✓ takes time for ramping up
- A mini-workshop with BEPCII machine people
  - ✓ Top up plan ?

    Successful testing in synchrotron mode
  - ✓ Increase the beam energy? current max. energy 2.30 GeV

    Upgrade choice I: → 2.35 GeV (hardware replacement, ….

    Upgrade choice II: 2.35 GeV < E < 2.45 GeV

    bottleneck: ISPB, new magnet and power supply

    Upgrade choice III: > 2.45 GeV

    bottleneck: ISPB and SCQ
- Discussions on Crab-Waist technology
  - ✓ In maximum, luminosity can be increased by 17x

Summary

- **BESIII is successfully operating since 2008**
  – Collected large data samples in the τ-charm mass region
- **Many exciting results have been published:**
  - ✓ Study of X, Y and Z states
  - ✓ Light hadron spectroscopy in charmonium decays
  - ✓ Charmed mesons and baryons
    – best measurements: $f_{D(s)}$ & FF
    – strong phases based on neutral *D* quantum correlation
    – Λ_c physics
- **BESIII team has learned and developed technology with charm at threshold.**
- **BESIII will continue to run 6 – 8 years.**
- **BEPCII/BESIII upgrade**
  trackers, ETOF, beam energy, data taking efficiency, luminosity ...
- **Future goals**
  roughly 50M D^0, 50M D^+ , 1M Λ_c , 15M *Ds*, 100B J/ψ
- **We are working on BESIII physics survey for future BESIII potentials**
  you are welcome to join the effort.

Thank you!

谢谢！