Overview of BESIII Experiment

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Workshop on Hadron Physics in China and Opportunities Worldwide

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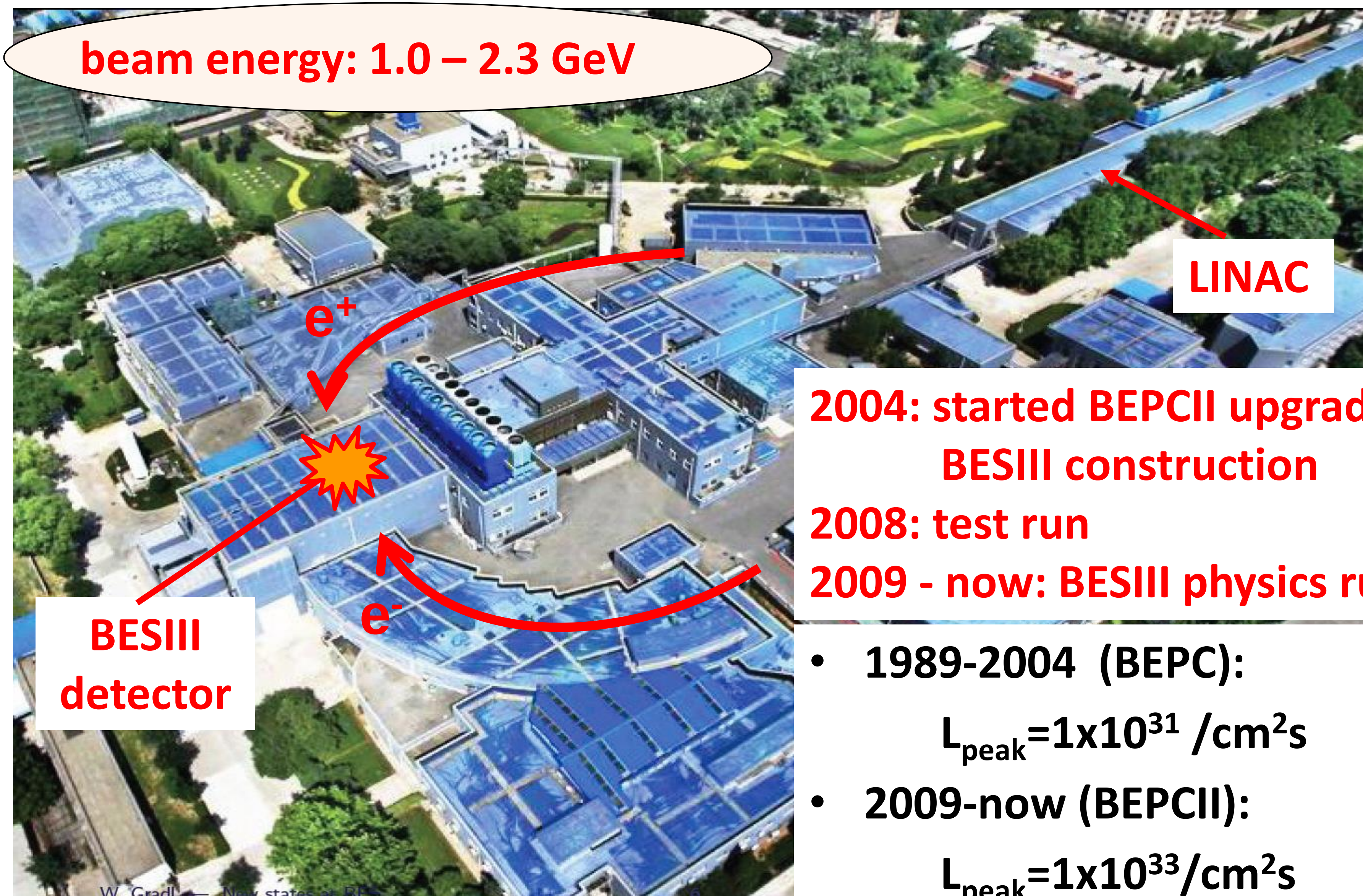
Outline

- Introduction
- Status of BESIII
- Selected results from BESIII
- Upgrade plan
- Summary

Beijing Electron Positron Collider (BEPC)



2004: started BEPCII upgrade, BESIII construction

2008: test run

2009 - now: BESIII physics run

- 1989-2004 (BEPC):

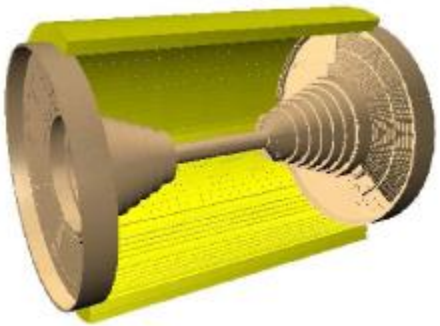
  $L_{peak}=1x10^{31}$ /cm^{2}s

- 2009-now (BEPCII):

  $L_{peak}=1x10^{33}$/cm^{2}s

BESIII Detector

MDC

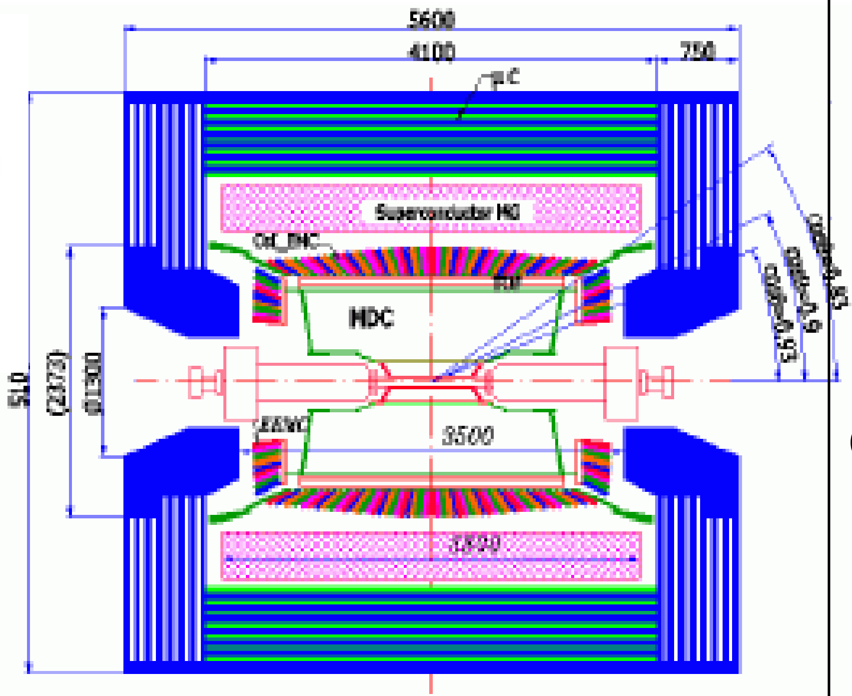


R inner: 63mm ;

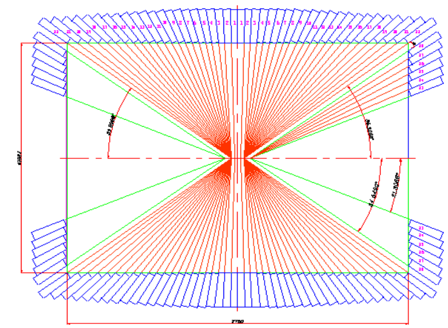
R outer: 810mm

Length: 2582 mm

Layers: 43



CsI(Tl) EMC



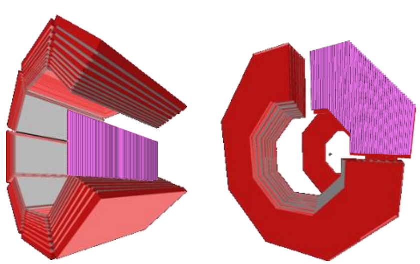
Crystals: 28 cm(15 X_0)

Barrel: $|\cos\theta|<0.83$

Endcap:

$0.85 < |\cos\theta| < 0.93$

RPC MUC



BMUC: 9 layers – 72 modules

EMUC: 8 layers – 64 modules

TOF

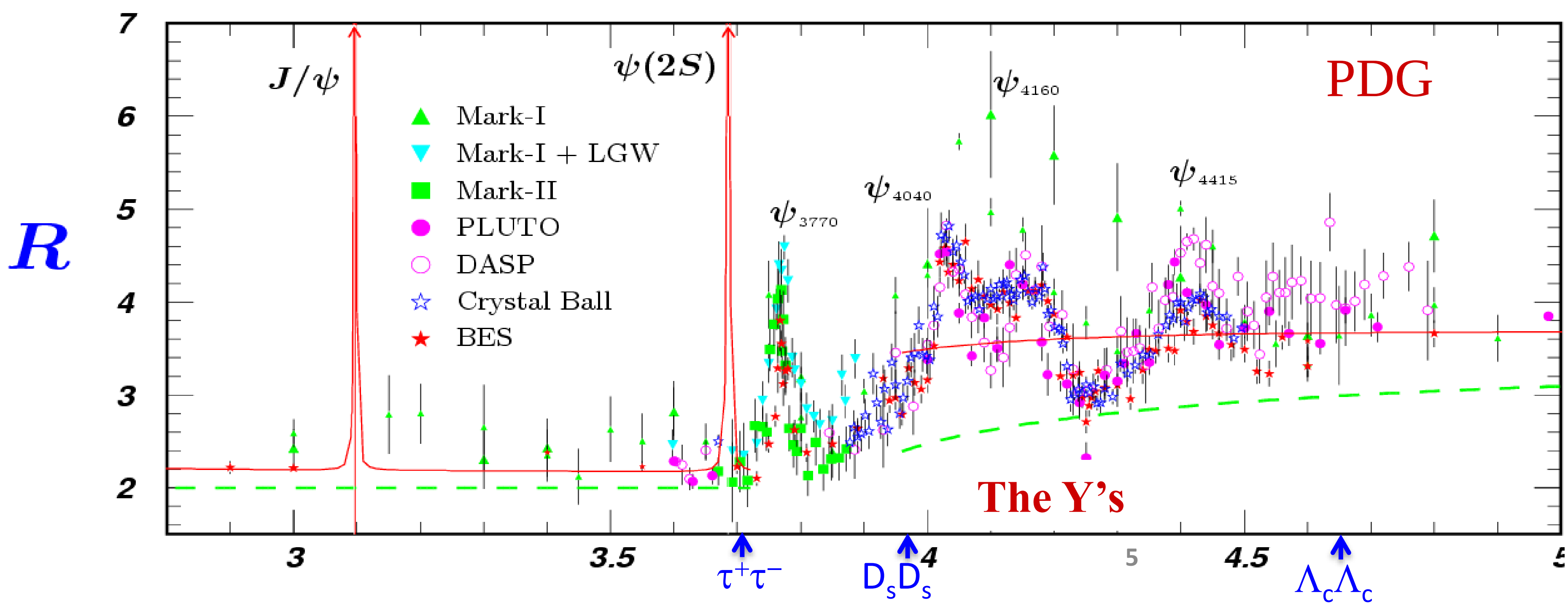
BTOF: two layers

ETOF: 48 scintillators for each

MRPC --- new ETOF

Features of the BEPC Energy Region

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

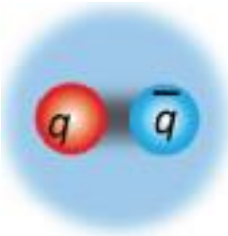


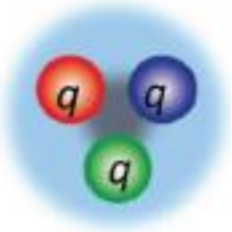
New forms of hadrons

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

Naive Quark Model：

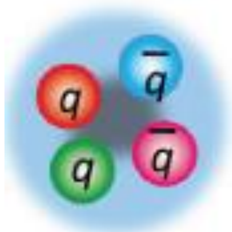
meson



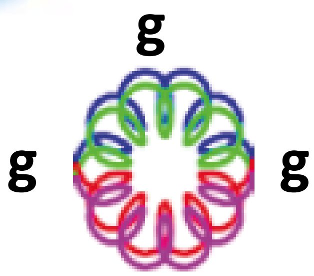


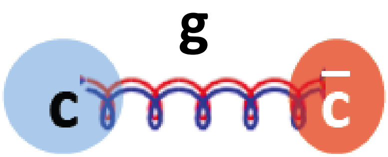
baryon

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



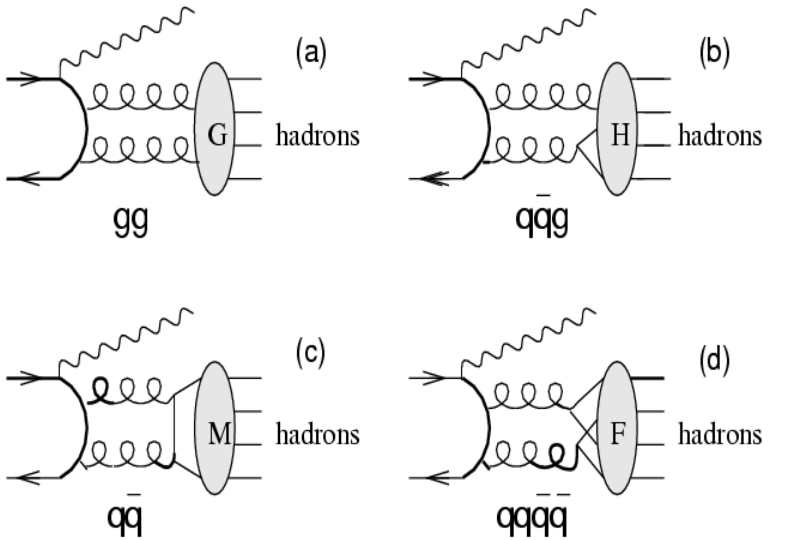
  - **Hybrids： $q\bar{q}g$， qqqg …**
  - **Glueballs： gg， ggg …**





None of the new forms of hadrons is settled !

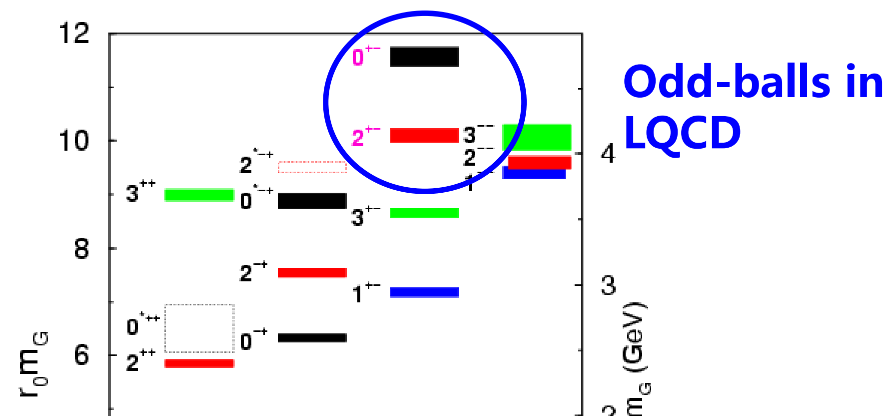
Charmonium decays provide ideal hunting ground for light glueballs and hybrids

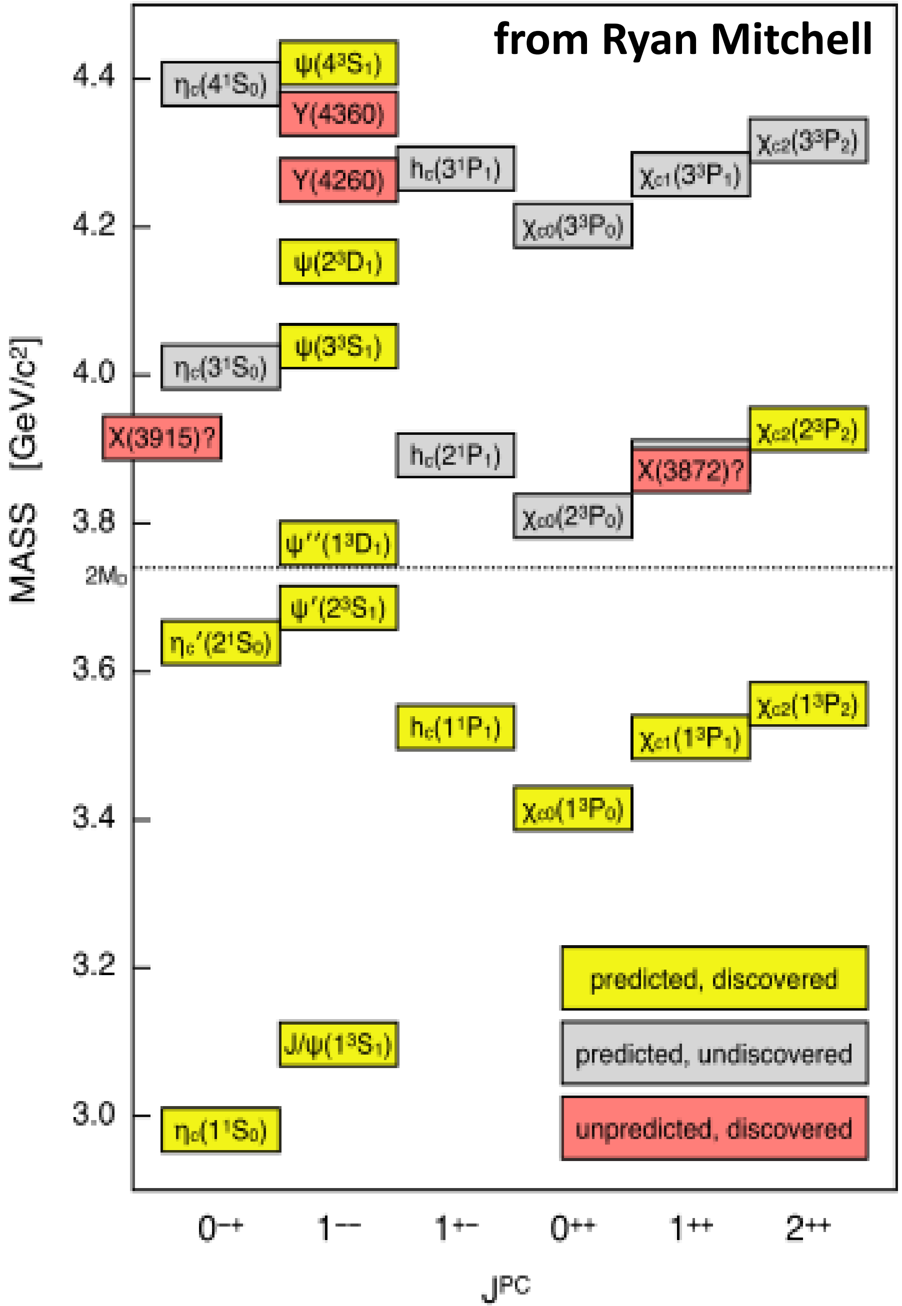


$$\Gamma(J/\psi \to \gamma G) \sim O(\alpha\alpha_s^2), \Gamma(J/\psi \to \gamma H) \sim O(\alpha\alpha_s^3),$$

$$\Gamma(J/\psi \to \gamma M) \sim O(\alpha\alpha_s^4), \Gamma(J/\psi \to \gamma F) \sim O(\alpha\alpha_s^4)$$

- "Gluon-rich" process
- Clean high statistics data samples from e+e- annihilation
- $I(J^{PC})$ filter in strong decays of charmonium





Charmonium spectroscopy

- **Charmonium states below open charm threshold are all observed**

Above open charm threshold:

- **many expected states not observed**
- **many unexpected observed**

Z(4430)
Z(4250)
Z(4050)
Z(3900)

X(3872)
XYZ(3940)

X(3915)
X(4160)
Y(4008)
Y(4140)
Y(4260)
Y(4360)
X(4350)
Y(4660)

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?

BESIII + B factories + LHCb + LQCD

Expected precision < 2% at BESIII

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

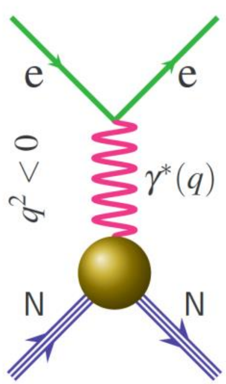
Nucleon Form Factor

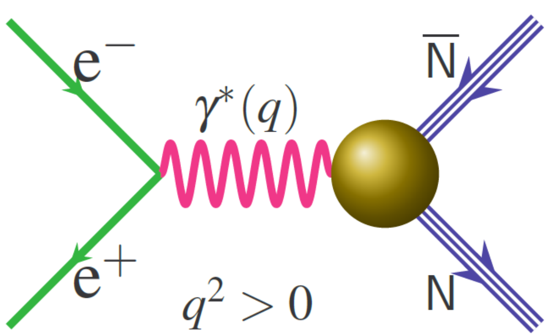
- Fundamental properties of the nucleon
  - Connected to charge, magnetization distribution
  - Crucial testing ground for models of the nucleon internal structure
  - Necessary input for experiments probing nuclear structure, or trying to understand modification of nucleon structure in nuclear medium
- Can be measured from space-like processes (eN) (precision 1%) or time-like process (e^+e^- annihilation) (precision 10%-30%)

eN → eN

$e^+e^- \leftrightarrow N\bar{N}$, $\Lambda\bar{\Lambda}$

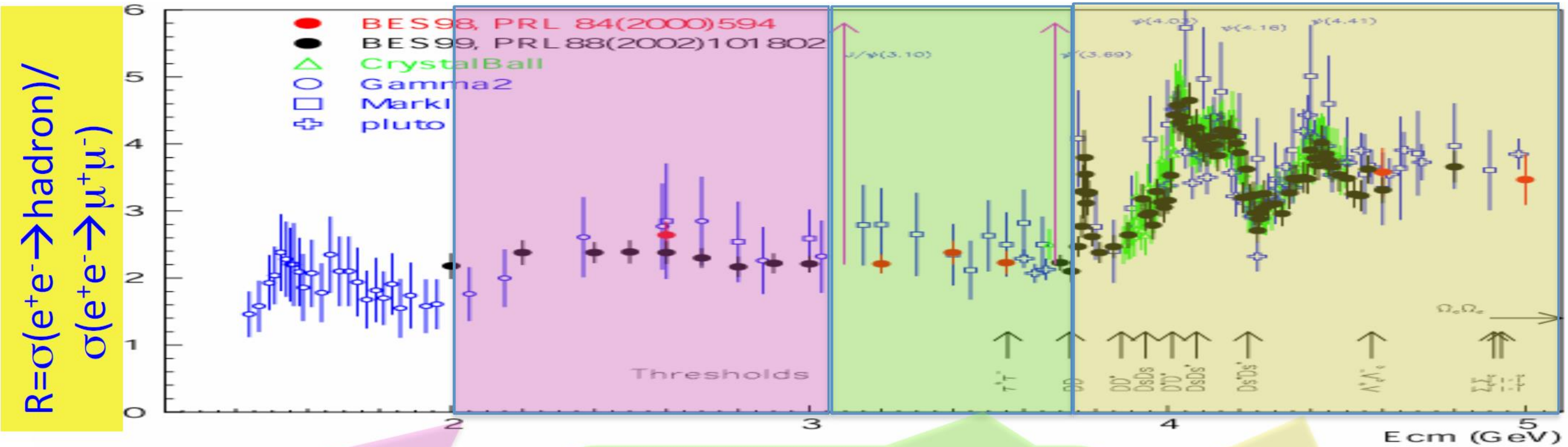
Space-like:
FF real





Time-like:
FF complex

Physics at tau-charm Energy Region

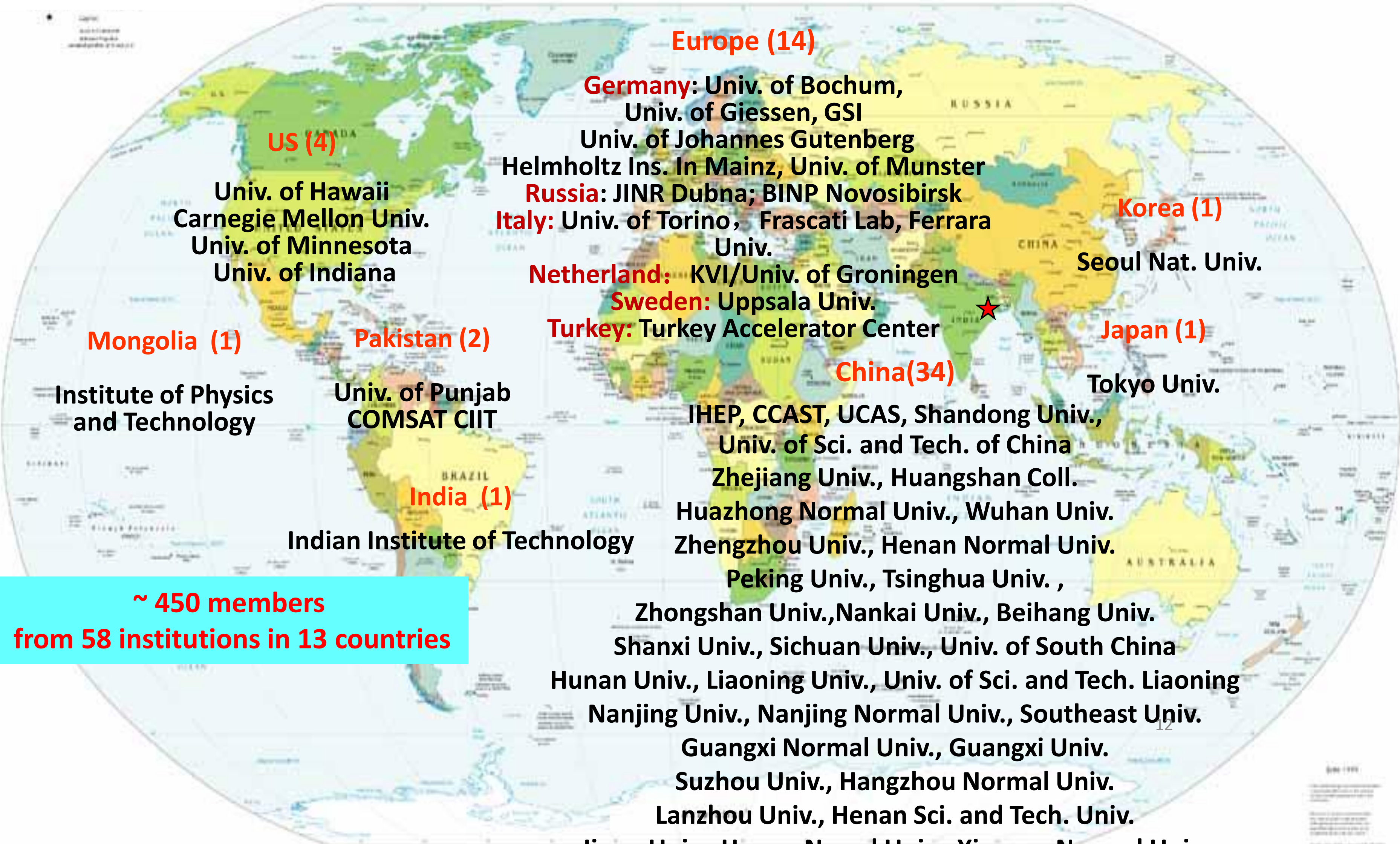


- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

- 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

BESIII Collaboration



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

US (4)

Univ. of Hawaii
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Indiana

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Mongolia (1)

Institute of Physics and Technology

Pakistan (2)

Univ. of Punjab
COMSAT CIIT

India (1)

Indian Institute of Technology

China(34)

IHEP, CCAST, UCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
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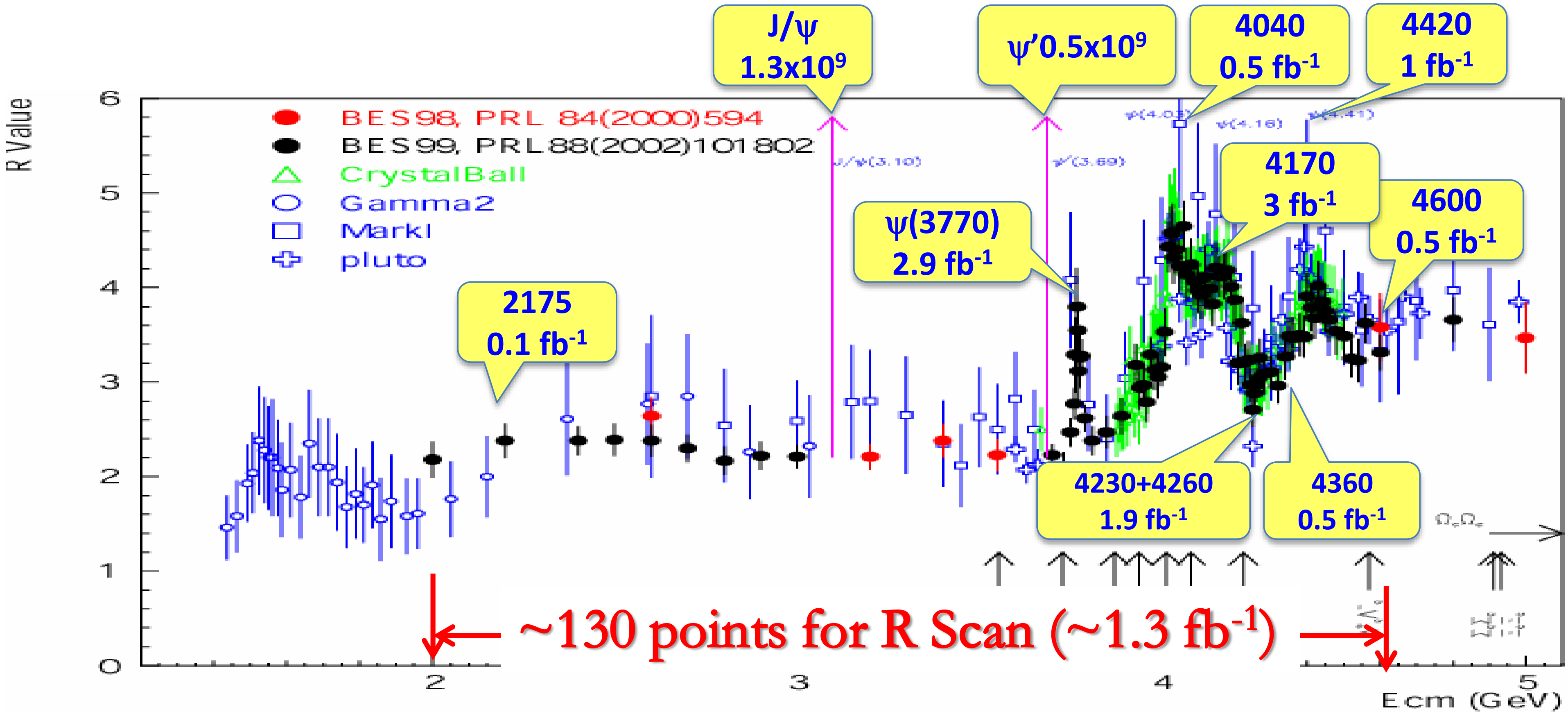
Hunan Univ., Liaoning Univ., Univ. of Sci. and Tech. Liaoning
Nanjing Univ., Nanjing Normal Univ., Southeast Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Jinan Univ., Hunan Norml Univ., Xinyang Normal Univ.

~ 450 members
from 58 institutions in 13 countries

BESIII data samples



World largest J/ψ, ψ(2S), ψ(3770), ψ(4170), Y(4260), … produced directly from e^+e^- collision

Selected results

- XYZ studies
- Light hadron spectroscopy
- Charm physics
- Λ_c absolute branching fractions

XYZ study at BESIII

Observation of $Z_c(3900)^{\pm}$

BESIII: PRL 110, 252001 (2013)

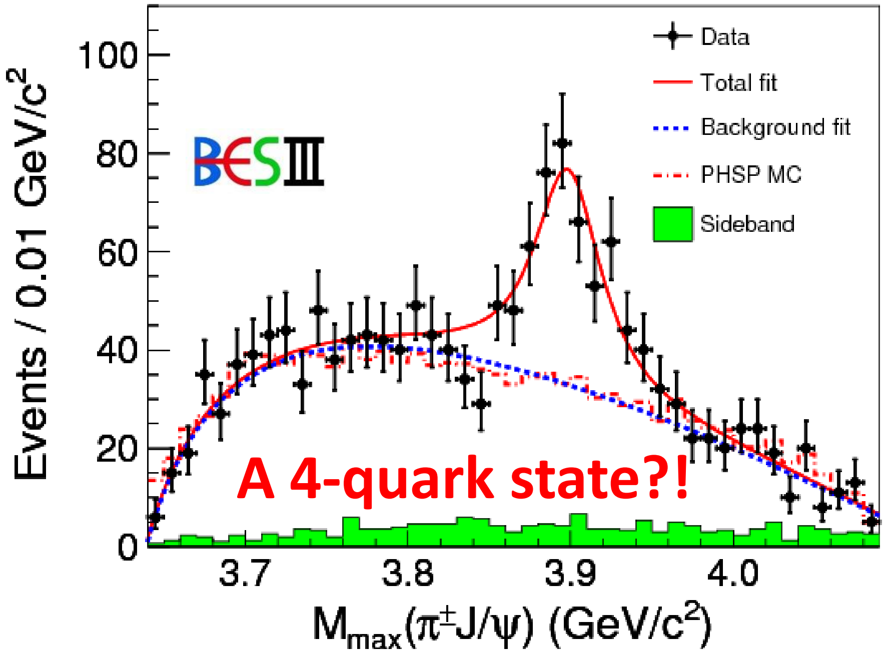
$Z_c(3900)^+$:

$$m = (3899.0 \pm 3.6 \pm 4.9)\ \text{MeV}/c^2$$

$$\Gamma = (46 \pm 10 \pm 20)\ \text{MeV}$$

Mass close to $D\bar{D}^*$ threshold

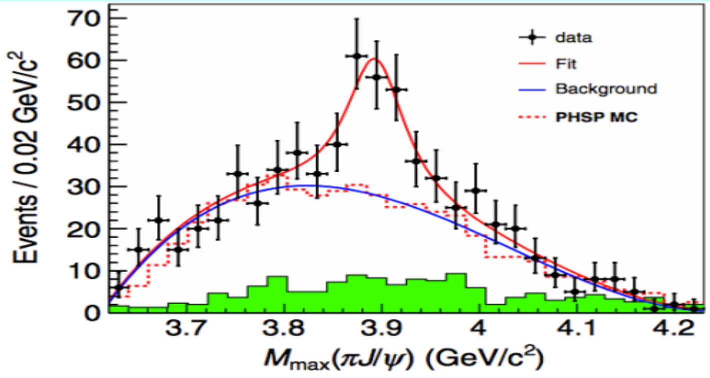
Decays to J/ψ → contains $c\bar{c}$
Electric charge → contains $u\bar{d}$



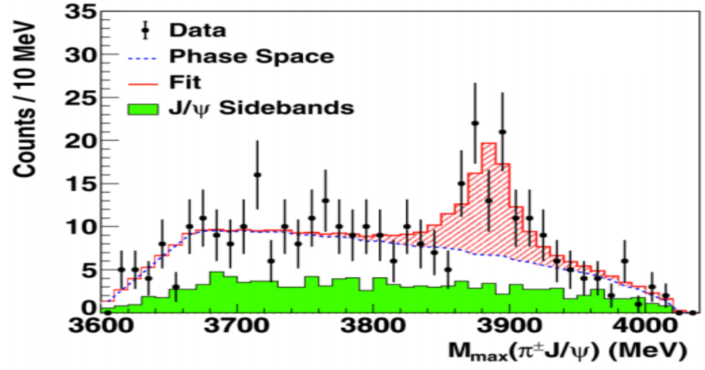
$$\sigma[e^+e^- \to \pi^+\pi^- J/\psi] = 62.9 \pm 1.9 \pm 3.7\ \text{pb at } 4.26\ \text{GeV}$$

$$\frac{\sigma[e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi]}{\sigma[e^+e^- \to \pi^+\pi^- J/\psi]} = (21.5 \pm 3.3 \pm 7.5)\%\ \text{at } 4.26\ \text{GeV}$$

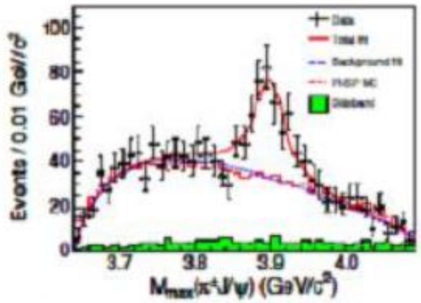
Belle with ISR data (PRL 110, 252002)



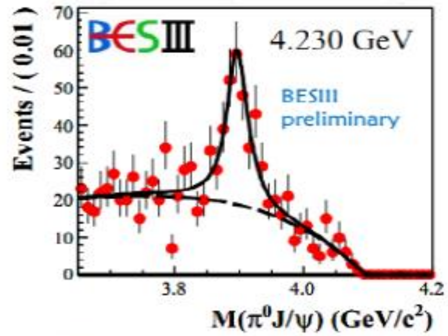
CLE0c data at 4.17 GeV (PLB 727, 366)



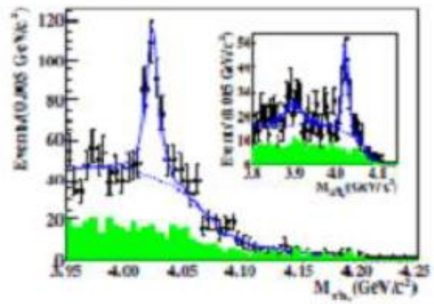
Summary of Zc's at BESIII



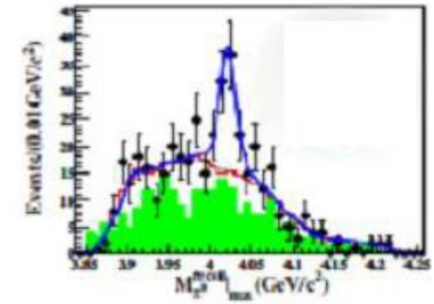
$e^+e^- \to \pi^-\pi^+ J/\psi$



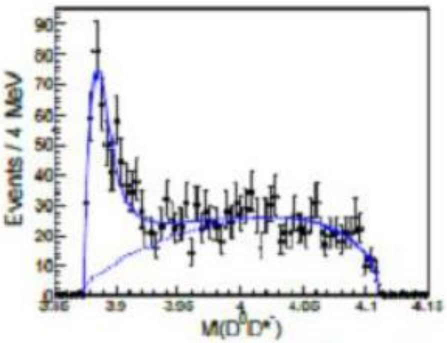
$e^+e^- \to \pi^0\pi^0 J/\psi$



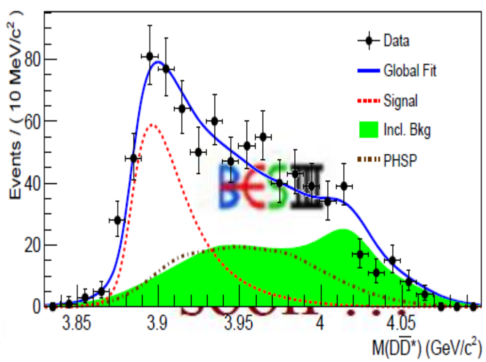
$e^+e^- \to \pi^-\pi^+ h_c$



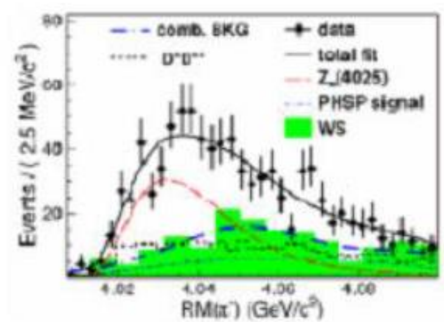
$e^+e^- \to \pi^0\pi^0 h_c$



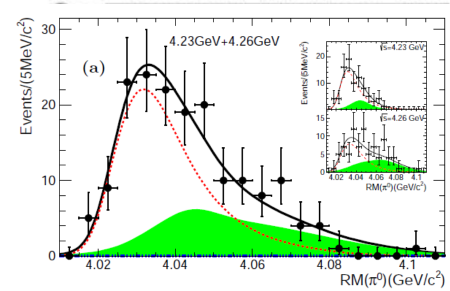
$e^+e^- \to \pi^-(D\bar{D}^*)^+$



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



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



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

$Z_c(3900)^+$?

$Z_c(3900)^0$?

$Z_c(4020)^+$?

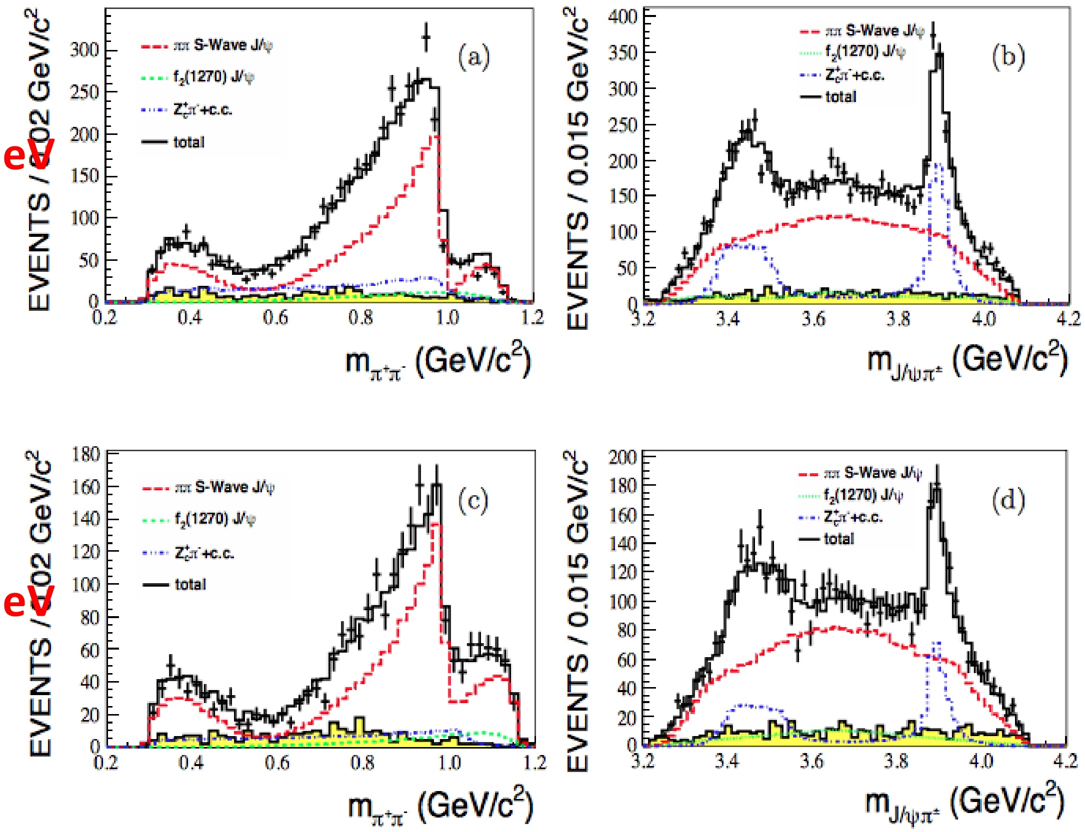
$Z_c(4020)^0$?

Summary of Zc's at BESIII

$Z_c^{\pm}(3900)$	$Z_c^{\pm}(4020)$
$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ M=3899.0±3.6±4.9MeV Γ = 46±10±20 MeV	$e^+e^- \rightarrow \pi^+\pi^- h_c$ M= 4022.9±0.8±2.7MeV Γ = 7.9±2.7±2.6 MeV
Z_c^0 (3900)	**Z_c^0(4020)**
$e^+e^- \rightarrow \pi^0\pi^0 J/\psi$ M=3894.8±2.3 MeV Γ =29.6±8.2 MeV	$e^+e^- \rightarrow \pi^0\pi^0 h_c$ M=4023.9±2.2±3.8 MeV Γ Fixed at $Z_c^{\pm}$(4020)

$Z_c^{\pm}(3885)$	$Z_c^{\pm}(4025)$
$e^+e^- \rightarrow \pi(D^*D)^{\pm}$ M=3882.2±1.1±1.5 MeV Γ =26.5±1.7±2.1 MeV	$e^+e^- \rightarrow \pi(D^*D^*)^{\pm}$ M= 4026.3±2.6±3.7 MeV Γ = 24.8±5.6±7.7 MeV
Z_c^0(3885)	**Z_c^0(4025)**
$e^+e^- \rightarrow \pi^0(D^*D)^0$ M=3885.7±5.7±8.4 MeV Γ = 35±12±15 MeV	$e^+e^- \rightarrow \pi^0(D^*D^*)^0$ M= 4025.5±4.7±3.1 MeV Γ = 23.0±6.0 ±1.0MeV

Determination of J^P of $Z_c(3900)$ from $e^+e^- \rightarrow \pi^+\pi^- J/\psi$



J^P of Zc favor 1^+ with statistical significance larger than 7.3σ over other quantum numbers.

arXiv:1706.04100 accepted by PRL

- Amplitude analysis with helicity formalism
- Simultaneous fit to data samples at 4.23GeV and 4.26GeV
- $\pi^+\pi^-$ spectrum is parameterized by σ, $f_0(980)$, $f_2(1270)$ and $f_0(1370)$

Determination of J^P of $Z_c(3900)$ from $e^+e^- \to \pi^+\pi^- J/\psi$

$Z_c : J^P$	M (MeV)	$g_1'(\mathrm{GeV}^2)$	g_2'/g_1'	$-\ln L$
0^-	3906.3 ± 2.3	0.079 ± 0.007	25.8 ± 2.9	-1528.8
1^-	3903.1 ± 1.9	0.063 ± 0.005	26.5 ± 2.6	-1457.7
1^+	3900.2 ± 1.5	0.075 ± 0.006	21.8 ± 1.7	-1569.8
2^-	3905.2 ± 2.1	0.060 ± 0.004	28.7 ± 2.7	-1516.5
2^+	3894.3 ± 1.9	0.051 ± 0.005	23.4 ± 3.3	-1316.2

- **J^P of Zc favor 1^+ with statistical significance larger than 7.3σ over other quantum numbers**

- Significance for $e^+e^- \to Z_c^+(4020)\ \pi^- + c.c \to \pi^+\pi^- J/\psi$ is ~3σ.

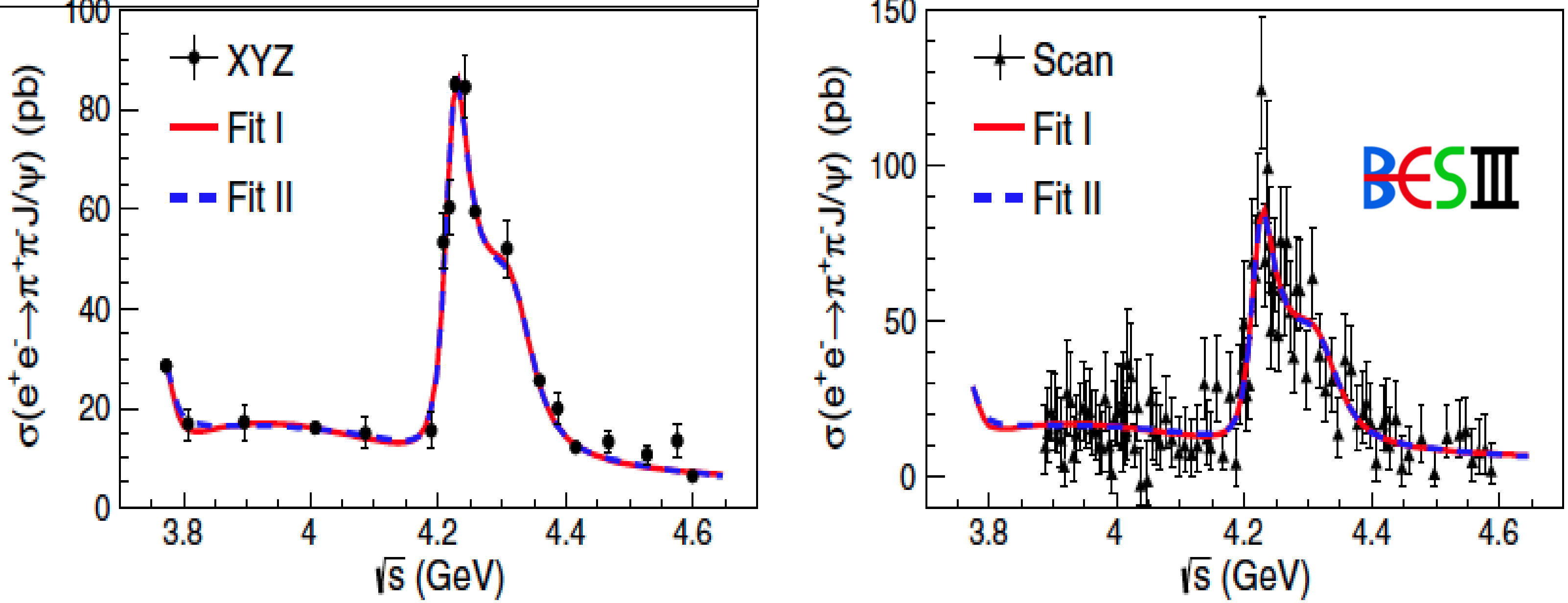
Upper limits at 90% C.L.:

$$\frac{\sigma(e^+e^- \to Z_c^+(4020)\ \pi^- + c.c \to \pi^+\pi^- J/\psi)}{\sigma(e^+e^- \to Z_c^+(3900)\ \pi^- + c.c \to \pi^+\pi^- J/\psi)} < 3.3\% \text{ at } 4.23\text{ GeV}$$

$<25.1\%$ at 4.26 GeV

Cross section measurement of $e^+e^- \to \pi^+\pi^- J/\psi$

Phys. Rev. Lett. 118, 092001 (2017)



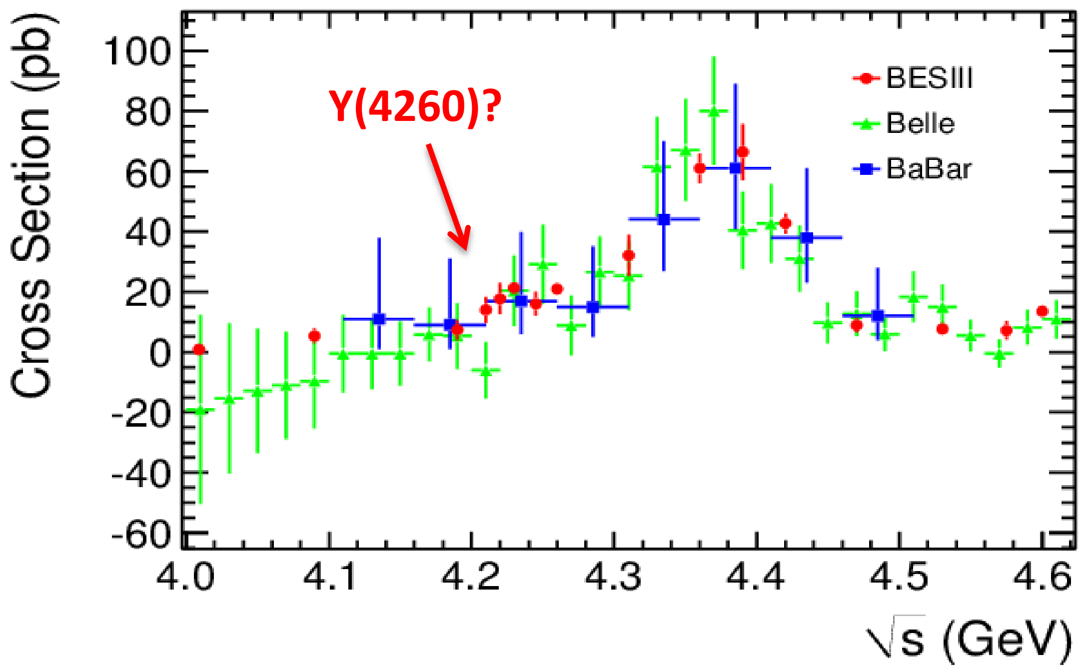
- ❑Coherent sum of two BW-like structures + one incoherent ψ(3770)
  - ➢M = (4222.0±3.1±1.4) MeV, Γ = (44.1±4.3±2.0) MeV

    Lower and narrower than previous Y(4260) PDG values
  - ➢M = (4320.0±10.4±7) MeV, Γ = (101.4±25±10) MeV

    a little bit lower than Y(4360) PDG value
- ❑Compared with one BW fit, the sig. of the second BW is 7.6σ
- ❑Y(4260) + Y(4360) ? The first observation of Y(4360)→$\pi^+\pi^- J/\psi$?

Cross section measurement of $e^+e^- \rightarrow \pi^+\pi^-\psi'$

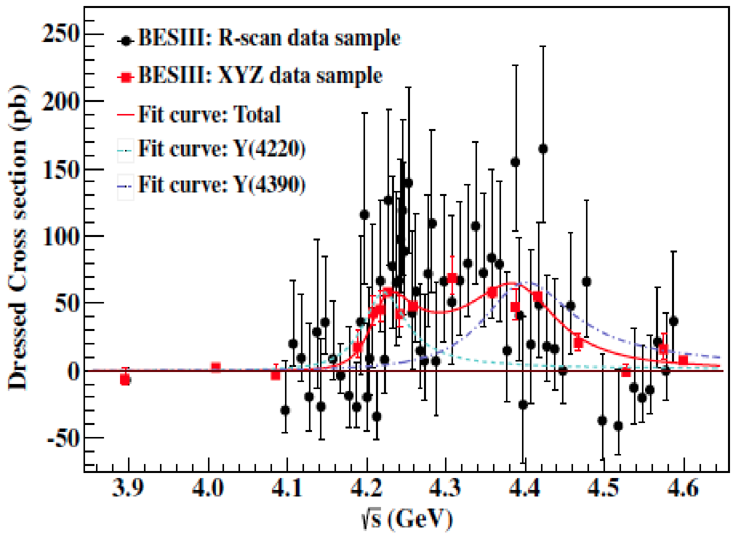
arXiv:1703.08787v1

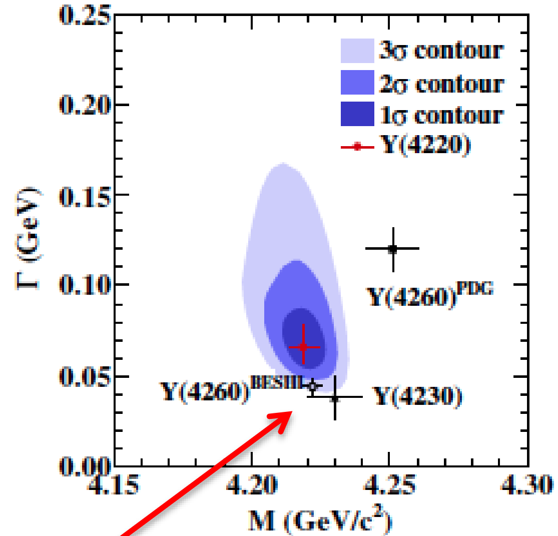


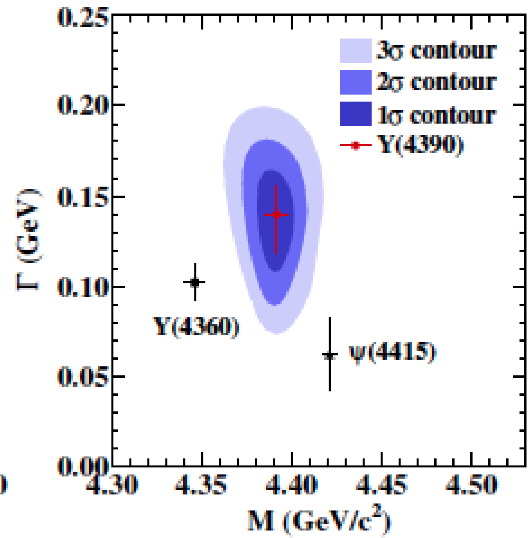
- Cross section of $e^+e^- \rightarrow \pi^+\pi^-\psi(3686)$ has been measured at 16 energy points from 4.008 to 4.600 GeV.
- A clear peak around Y(4360), consistent with the results from Belle and BaBar, but with much improved precision
- The fit on the cross section is ongoing

Cross section measurement of $e^+e^- \rightarrow \pi^+\pi^- h_c$

PRL 118, 092002 (2017)



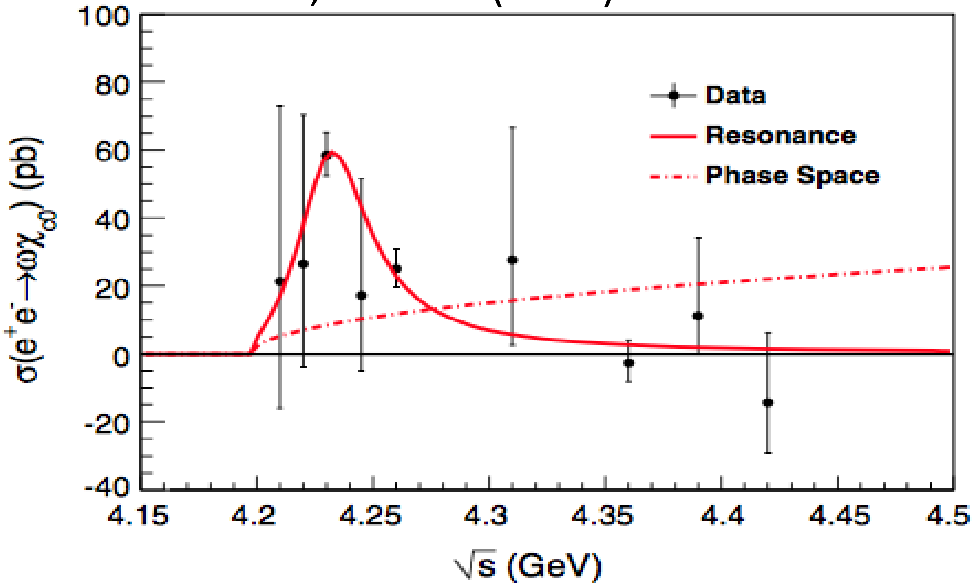


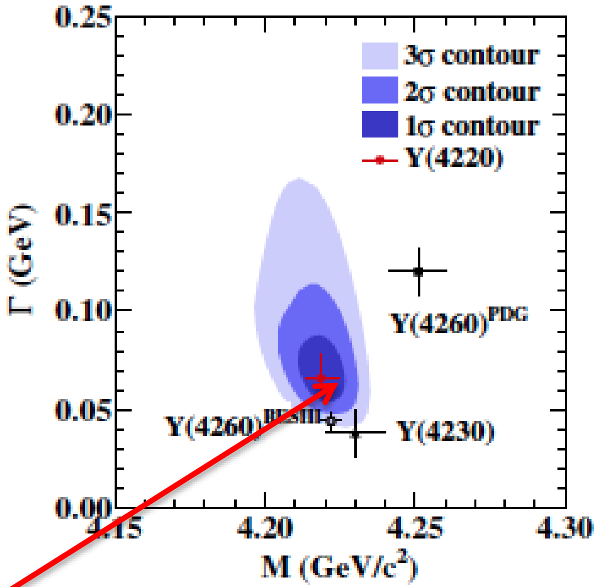


- **Fitted with coherent sum of two BW-like structures**
  - $M_1=4218.4^{+5.5}_{-4.5}\pm0.9$ MeV/c², $\Gamma_1=66.0^{+12.3}_{-8.3}\pm0.4$ MeV → Y(4220)
  - $M_2=4391.5^{+6.3}_{-6.8}\pm1.0$ MeV/c², $\Gamma_2=139.5^{+16.2}_{-20.6}\pm0.6$ MeV → Y(4390)
- **The Y(4220) here is consistent with the state observed in $\pi^+\pi^- J/\psi$ around 4222MeV**

Cross section measurement of $e^+e^- \rightarrow \omega\chi_{cJ}$

PRL 114, 092003 (2015)



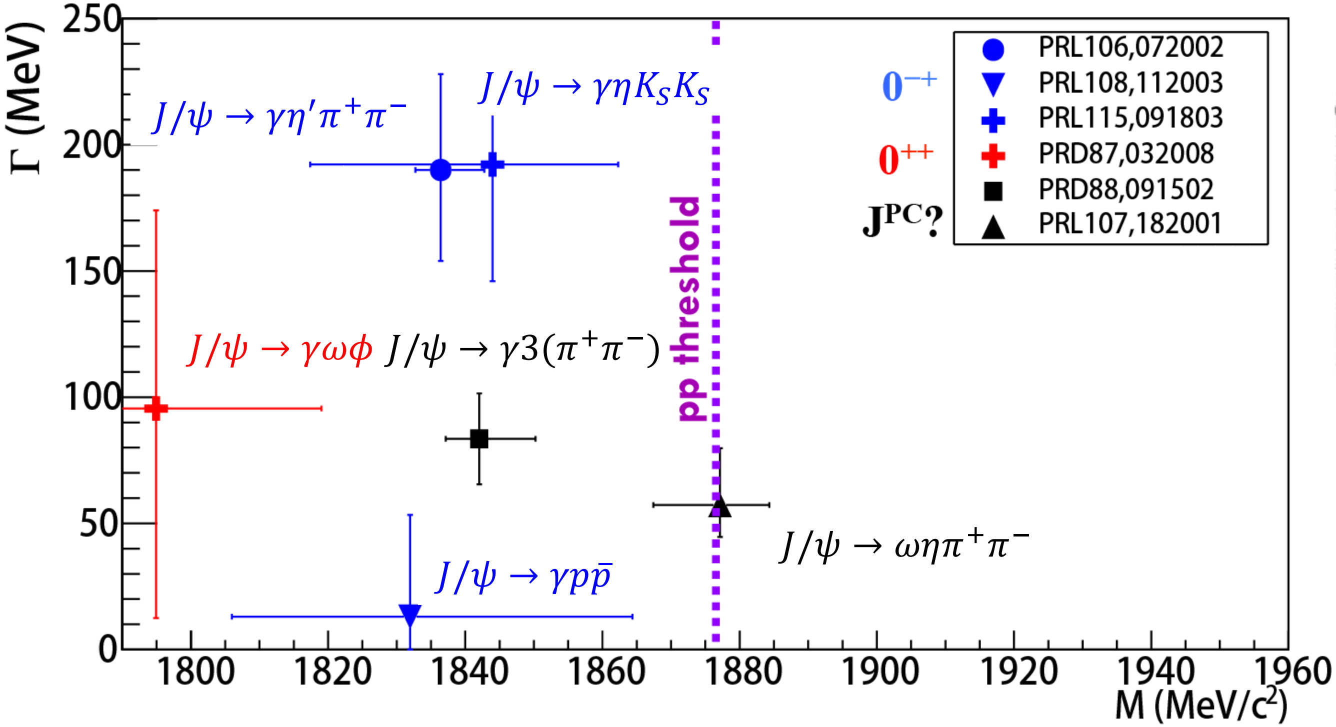


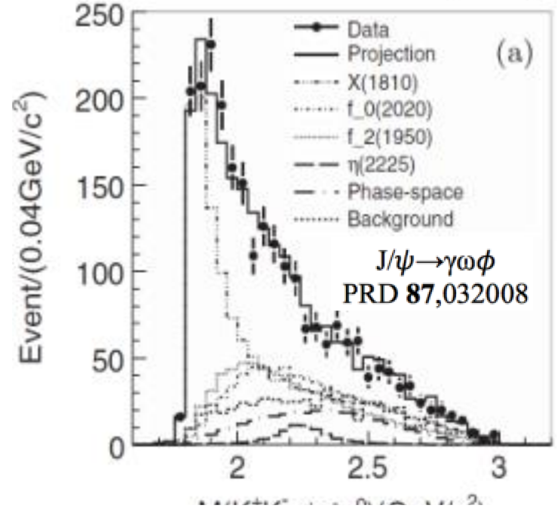
- Only $\omega\chi_{c0}$ has significant signal
- The cross section is fitted with coherent sum of a BW and a phase space term

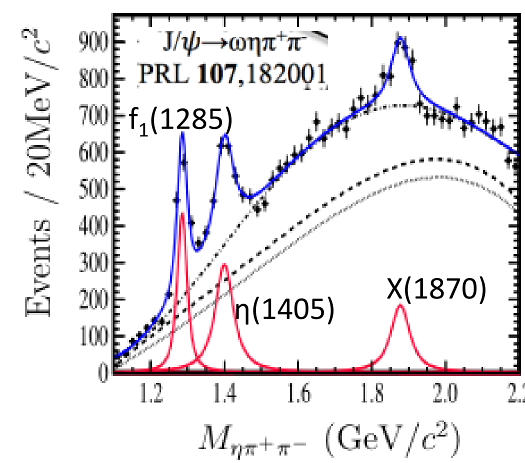
  $M = 4230 \pm 8 \pm 6$ MeV , $\Gamma = 38 \pm 12 \pm 2$ MeV
- The mass and width are compatible with the Y observed in $\pi^+\pi^- J/\psi$ and $e^+e^- \rightarrow \pi^+\pi^- h_c$

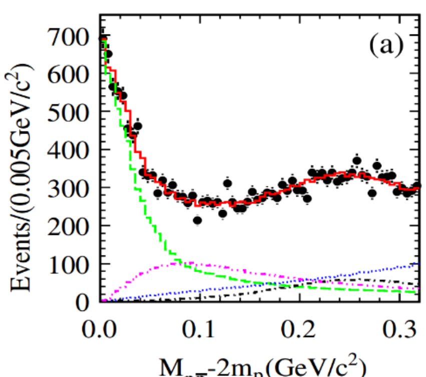
Light meson spectroscopy at BESIII

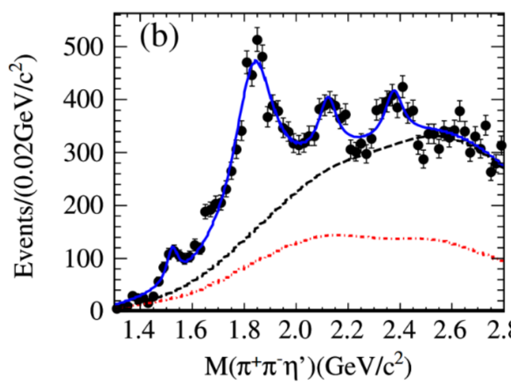
(Joint efforts with GlueX in future)

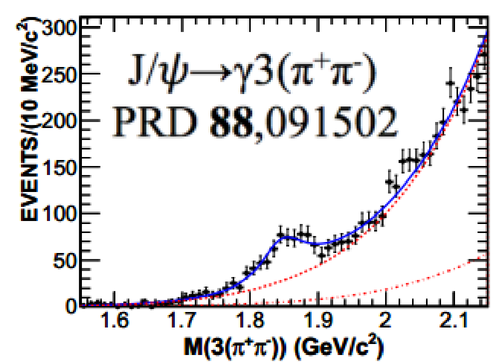










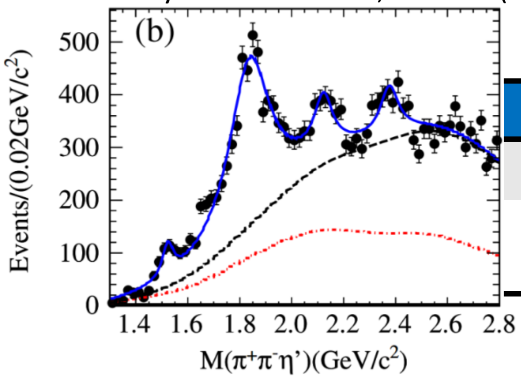


- **Any relations?**
- **What is the role of the ppbar threshold (and other thresholds)?**
- **Patterns in the production and decay modes**

Anomalous line shape of $\eta'\pi^+\pi^-$ near $p\bar{p}$ mass threshold: connection between X(1835) and X($p\bar{p}$)

X(1835) observed in $J/\psi \to \gamma\eta'\pi^+\pi^-$

Phys. Rev. Lett. 106, 072002 (2011)



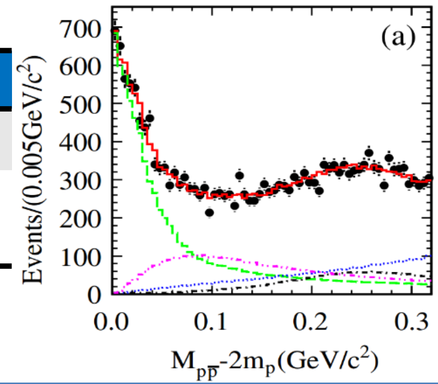
X(1835) $J^{PC}=0^{-+}$
$M = 1844 \pm 9^{+16}_{-25}$ MeV/c^2
$\Gamma = 192^{+20+62}_{-17-43}$ MeV/c^2

X($p\bar{p}$) observed in $J/\psi \to \gamma p\bar{p}$

PRL 108, 112003 (2012)

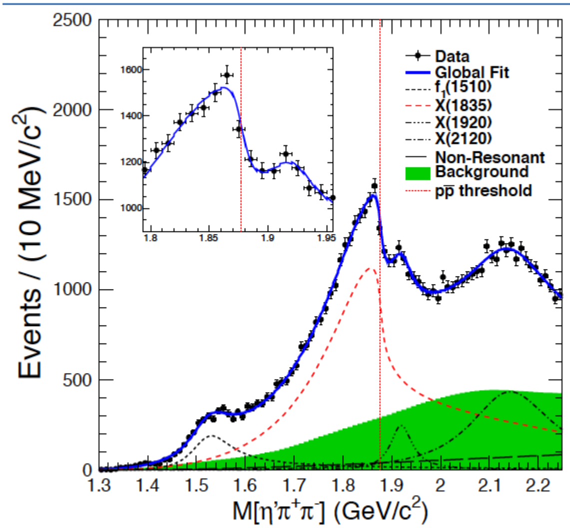
PRL 115, 091803 (2015)

X($p\bar{p}$) $J^{PC}=0^{-+}$
$M = 1832^{+19}_{-5}{}^{+18}_{-17} \pm 19$ MeV/c^2
$\Gamma = 13 \pm 19$ MeV/c^2 (< 76 MeV/c^2 @ 90% C.L.)



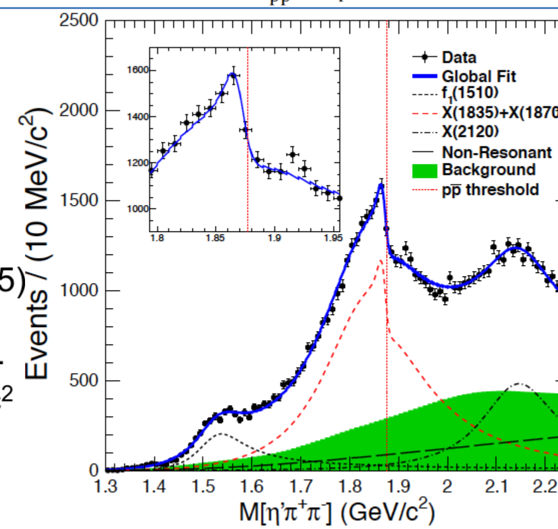
Connection is emerging

PRL 117, 042002 (2016)



Model 1:
Flatte lineshape with strong coupling to $p\bar{p}$ and one additional, narrow Breit-Wigner at ~1920 MeV/c^2

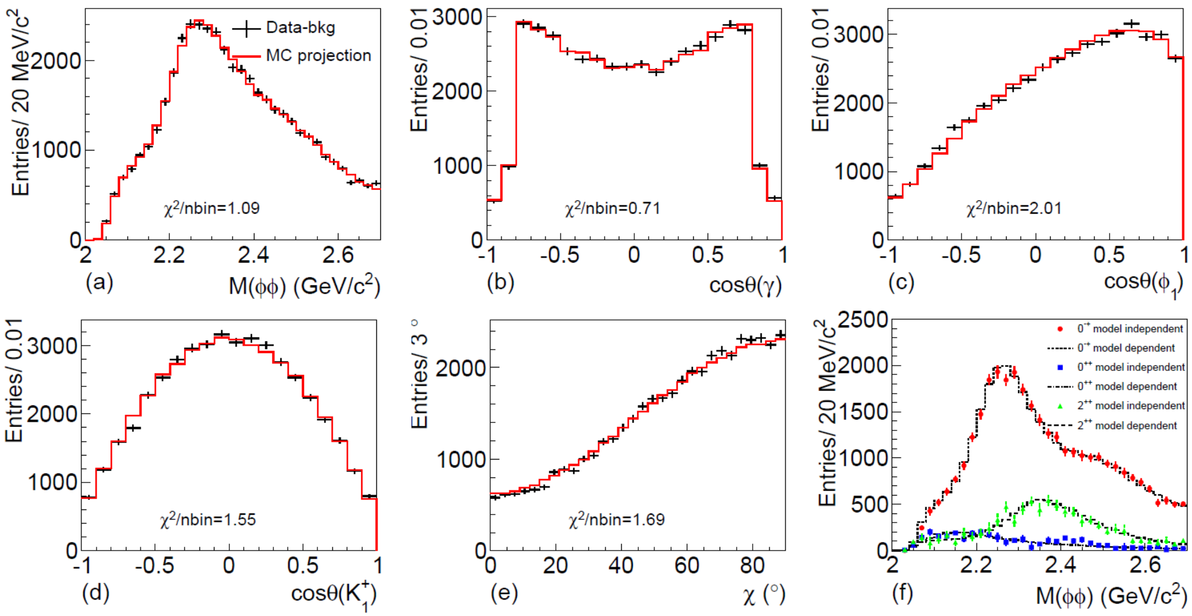
Model 2:
Coherent sum of X(1835) Breit-Wigner and one additional, narrow Breit-Wigner at ~1870 MeV/c^2



- **Suggest the existence of a state, either a broad one with strong couplings to $p\bar{p}$, or a narrow state just below the $p\bar{p}$ mass thresh.**
- **Support the existence of a $p\bar{p}$ molecule-like state or bound state**

Partial Wave Analysis of J/ψ→γϕϕ

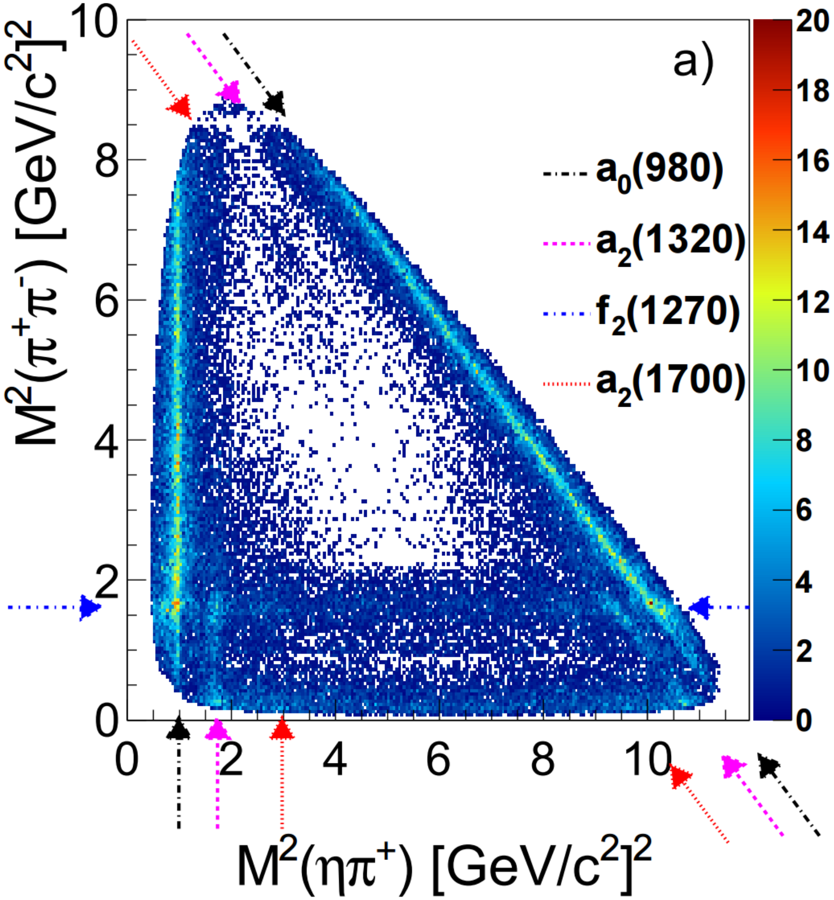
Besides η(2225) , very little was known in the sector of pseudoscalar above 2 GeV. The new experimental results are helpful for mapping out the pseudoscalar excitations and searching for 0^{-+} glueball



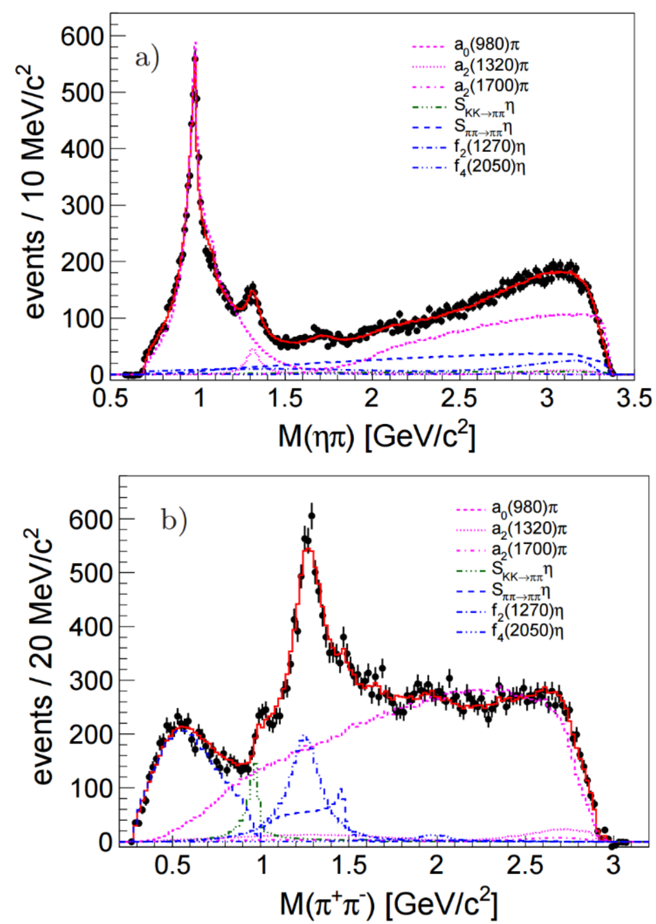
Resonance	M(MeV/c^2)	Γ(MeV/c^2)	B.F.($\times10^{-4}$)	Sig.
$\eta(2225)$	2216^{+4+18}_{-5-11}	185^{+12+44}_{-14-17}	$(2.40\pm0.10^{+2.47}_{-0.18})$	28.1σ
$\eta(2100)$	2050^{+30+77}_{-24-26}	$250^{+36+187}_{-30-164}$	$(3.30\pm0.09^{+0.18}_{-3.04})$	21.5σ
X(2500)	2470^{+15+63}_{-19-23}	230^{+64+53}_{-35-33}	$(0.17\pm0.02^{+0.02}_{-0.08})$	8.8σ
$f_0(2100)$	2102	211	$(0.43\pm0.04^{+0.24}_{-0.03})$	24.2σ
$f_2(2010)$	2011	202	$(0.35\pm0.05^{+0.28}_{-0.15})$	9.5σ
$f_2(2300)$	2297	149	$(0.44\pm0.07^{+0.09}_{-0.15})$	6.4σ
$f_2(2340)$	2339	319	$(1.91\pm0.07^{+0.72}_{-0.69})$	10.7σ
0^{-+} PHSP			$(2.74\pm0.15^{+0.16}_{-1.48})$	6.8σ

- **Dominant contribution from pseudoscalars**
    - **η(2225) is confirmed;**
    - **η(2100) and X(2500) are observed with large significance.**
- **Three tensors $f_2(2010)$, $f_2(2300)$ and $f_2(2340)$ stated in $\pi^- p$ reactions observed. A strong production of $f_2(2340)$.**
- **Model-dependent PWA results are well consistent with the results from MIPWA**

Amplitude analysis of $\chi_{c1} \to \eta\pi^+\pi^-$



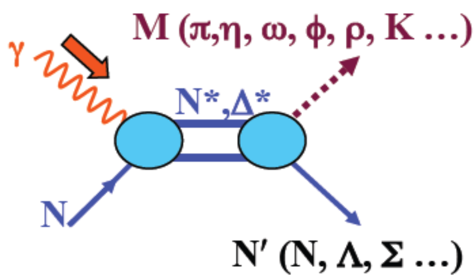
Phys. Rev. D 95, 032002 (2017)



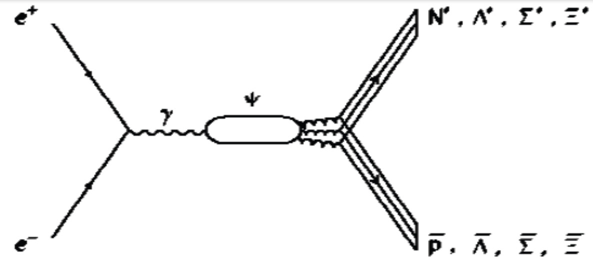
- Clear evidence for $a_2(1700)$ in χ_{c1} decays.
- First measurement of $g'_{\eta'\pi} \neq 0$ using $a_0(980) \to \eta\pi$ line shape.
- Measured upper limits for $\pi_1(1^{-+})$ in 1.4 - 2.0 GeV/c^2 region.

Charmonium decays provide novel insights into baryons --- complementary to other experiments

JLAB, MAMI, ELSA, ...



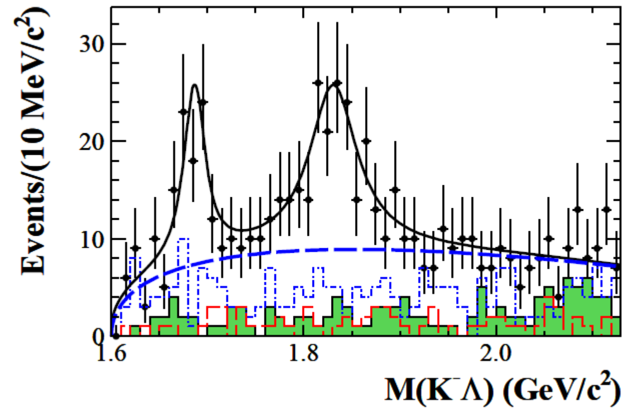
$J/\psi(\psi') \to \bar{B}BM \Rightarrow N^*, \Lambda^*, \Sigma^*, \Xi^*$



- ✓ Isospin 1/2 filter: $\psi \to N\bar{N}\pi$, $\psi \to N\bar{N}\pi\pi$
- ✓ Missing N* with small couplings to πN & γN , but large coupling to gggN : $\psi \to N\bar{N}\pi/\eta/\eta'/\omega/\phi$, $\bar{p}\Sigma\pi$, $\bar{p}\Lambda K$ …
- ✓ Not only N*, but also Λ^*, Σ^*, Ξ^*
- ✓ Gluon-rich environment: a favorable place for producing hybrid (qqqg) baryons
- ✓ Interference between N* and $\bar{N}$ * bands in $\psi \to N\bar{N}\pi$ Dalitz plots may help to distinguish some ambiguities in PWA of πN
- ✓ High statistics of charmonium @ BES III

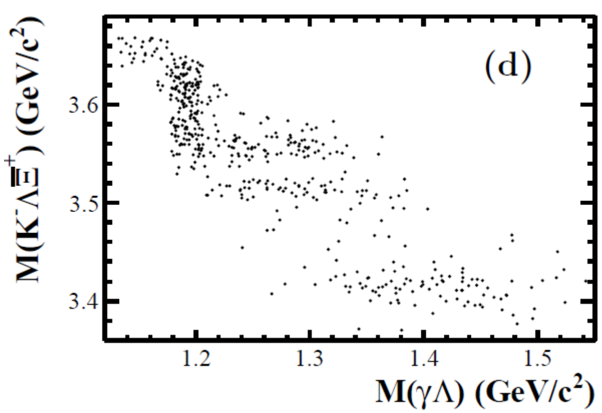
BESIII PRD91, 092006 (2015)

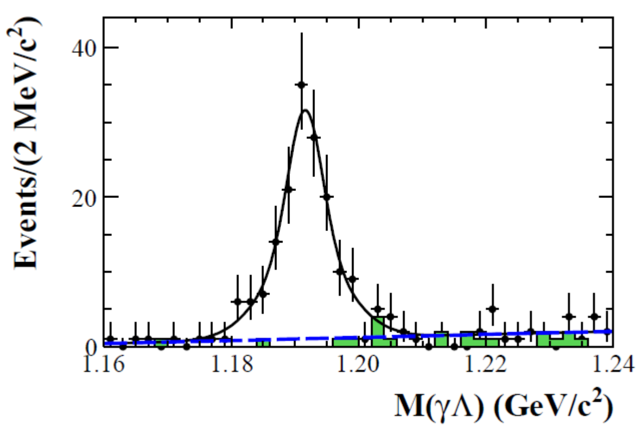
$\Xi^-(1690)$ *and* $\Xi^-(1820)$ *are* observed in $\psi' \rightarrow K^-\Lambda\bar{\Xi}^+ + c.c.$ Resonance parameters consistent with PDG values.

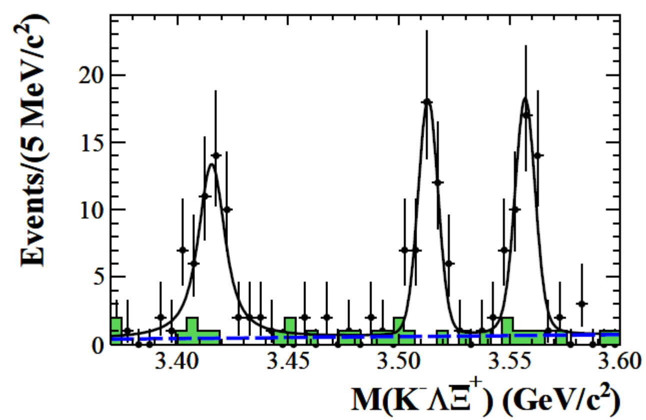


Decay	Branching fraction
$\psi(3686) \rightarrow K^-\Lambda\bar{\Xi}^+$	$(3.86 \pm 0.27 \pm 0.32) \times 10^{-5}$
$\psi(3686) \rightarrow \Xi(1690)^-\bar{\Xi}^+,\ \Xi(1690)^- \rightarrow K^-\Lambda$	$(5.21 \pm 1.48 \pm 0.57) \times 10^{-6}$
$\psi(3686) \rightarrow \Xi(1820)^-\bar{\Xi}^+,\ \Xi(1820)^- \rightarrow K^-\Lambda$	$(12.03 \pm 2.94 \pm 1.22) \times 10^{-6}$
$\psi(3686) \rightarrow K^-\Sigma^0\bar{\Xi}^+$	$(3.67 \pm 0.33 \pm 0.28) \times 10^{-5}$
$\psi(3686) \rightarrow \gamma\chi_{c0},\ \chi_{c0} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.90 \pm 0.30 \pm 0.16) \times 10^{-5}$
$\psi(3686) \rightarrow \gamma\chi_{c1},\ \chi_{c1} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.32 \pm 0.20 \pm 0.12) \times 10^{-5}$
$\psi(3686) \rightarrow \gamma\chi_{c2},\ \chi_{c2} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.68 \pm 0.26 \pm 0.15) \times 10^{-5}$
$\chi_{c0} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.96 \pm 0.31 \pm 0.16) \times 10^{-4}$
$\chi_{c1} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.43 \pm 0.22 \pm 0.12) \times 10^{-4}$
$\chi_{c2} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.93 \pm 0.30 \pm 0.15) \times 10^{-4}$

In the study of $\psi' \rightarrow \gamma K^-\Lambda\bar{\Xi}^+ + c.c.$, the branching fraction of $\psi' \rightarrow K^-\Sigma^0\bar{\Xi}^+ + c.c.$ and $\chi_{cJ} \rightarrow K^-\Lambda\bar{\Xi}^+ + c.c.$ are measured







Charm physics at BESIII

Advantage of open charm at threshold

e^+e^- colliders@threshold:

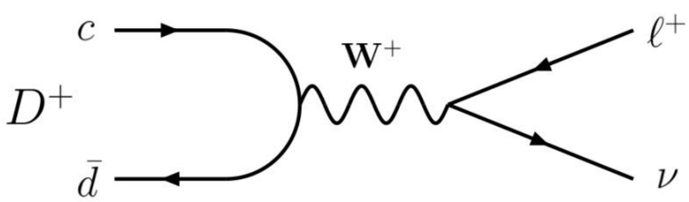
$$e^+e^- \to \psi(3770) \to D^0\bar{D}^0 \quad [C=-1] \quad \text{OR} \quad e^+e^- \to \gamma^* \to D^0\bar{D}^0\gamma \quad [C=+1]$$

Good for charm flavor physics:

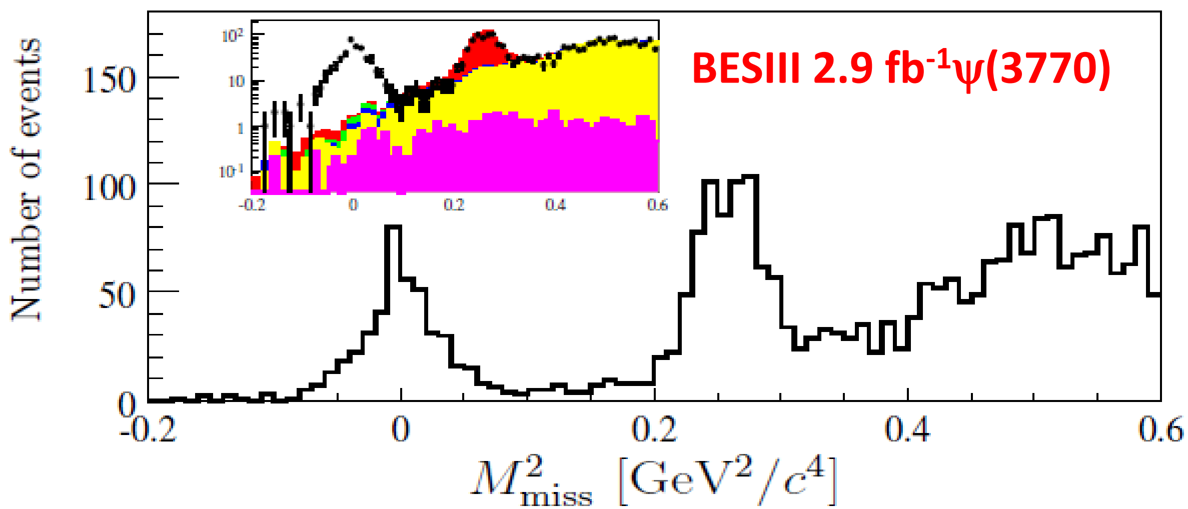
- Threshold production: clean
- Known initial energy and quantum numbers
- Both D and Dbar fully reconstructed (double tag)
- Absolute measurements

A joint effort among BESIII, LHCb and Belle-II should be formed to understand the charm decay dynamics and insight of CPV in charm sector.

$f_{D(s)+}$: Leptonic decays



$$\Gamma\left(D^+ \to \ell^+ \nu_\ell\right) = \boxed{f_D^2 \left|V_{cd}\right|^2} \frac{G_F^2}{8\pi} m_D m_\ell^2 \left(1 - \frac{m_\ell^2}{m_D^2}\right)^2$$

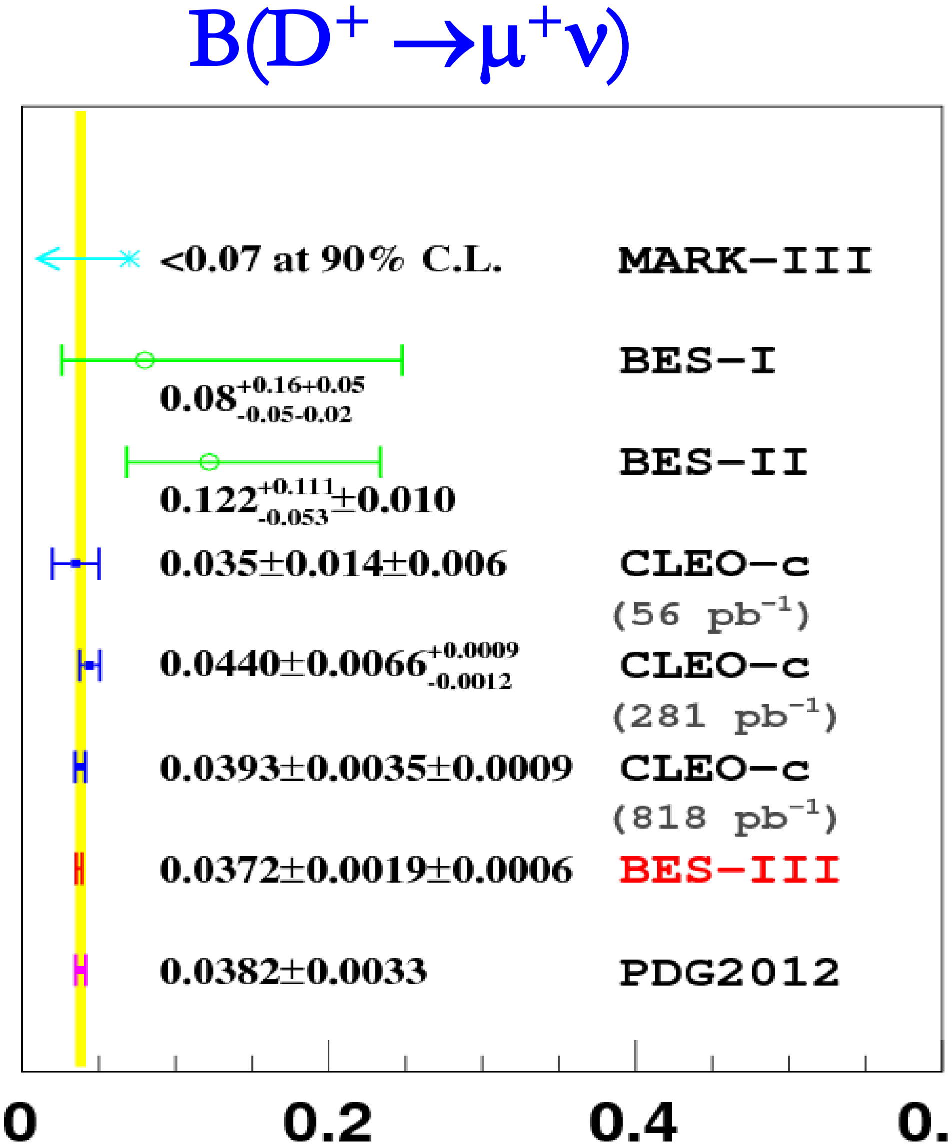


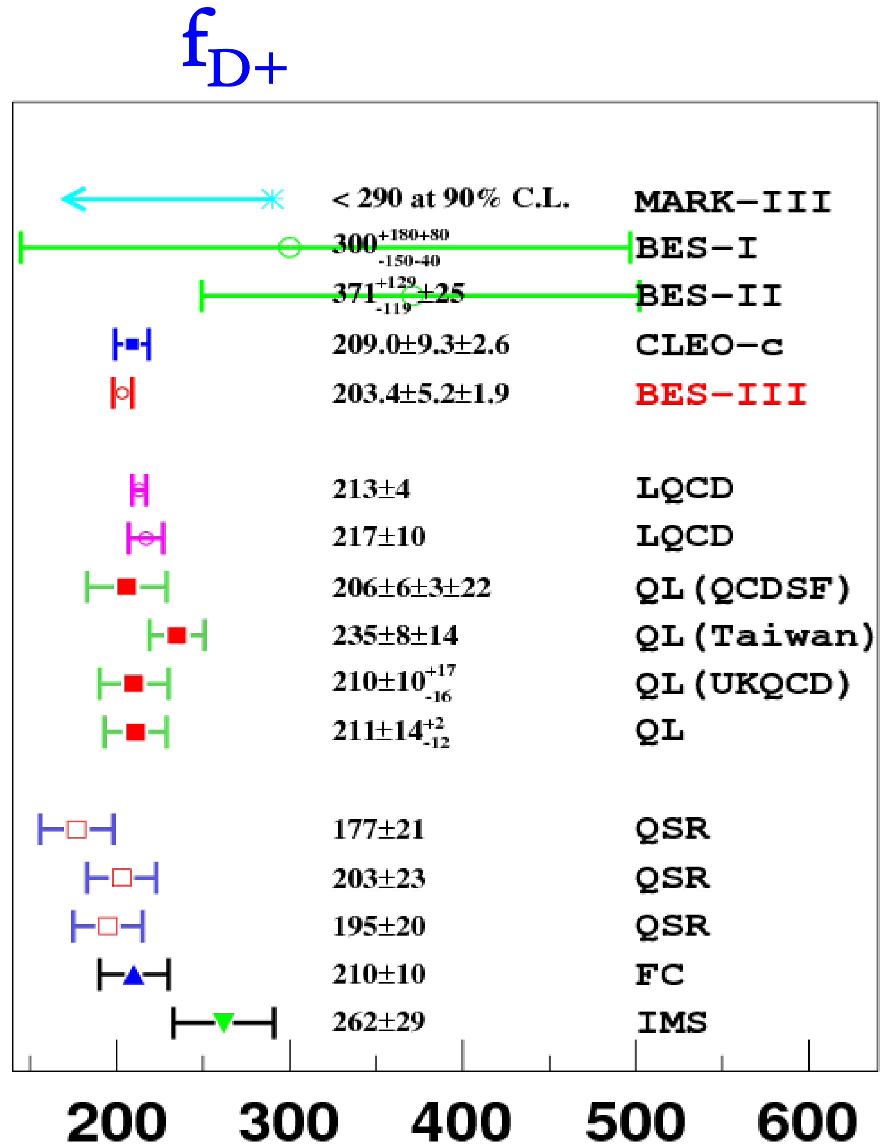
$B(D^+ \to \mu^+\nu) = (3.72 \pm 0.19 \pm 0.06) \times 10^{-4}$

f_{D+} = （203.4 ± 5.2 ± 1.9) MeV

$|Vcd| = 0.2212 \pm 0.0056 \pm 0.0047$

⇐ LQCD calculated f_D = 207±4 MeV [PRL100(2008)062002]



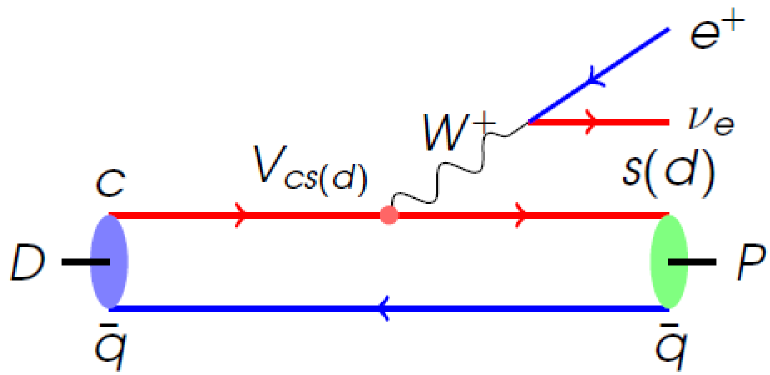


BESIII: 2.7% with 2.92fb^{-1}

BESIII final: 1.5% with 10 fb^{-1}

Semi-leptonic decays

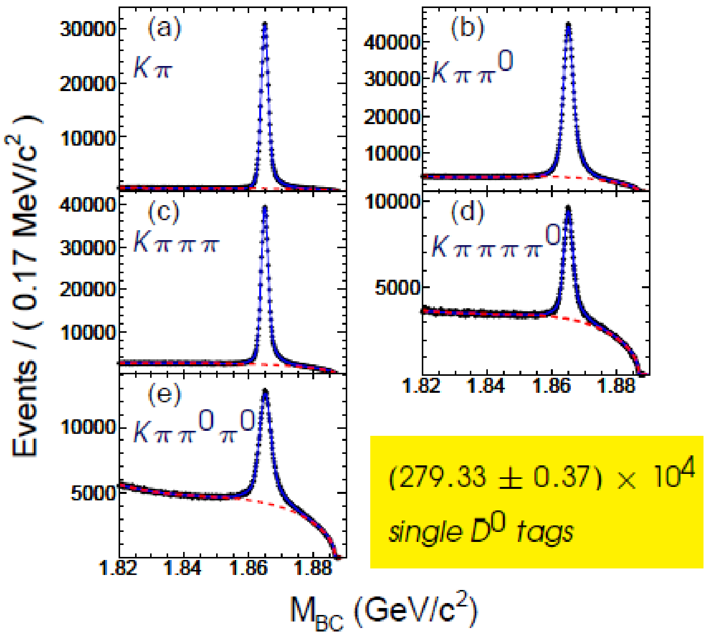
- Provide a good place to study the weak and strong interaction

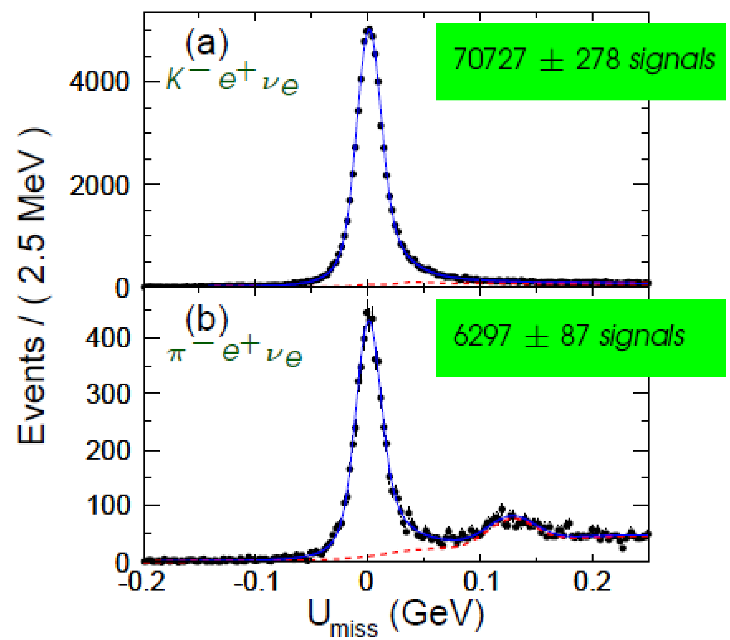


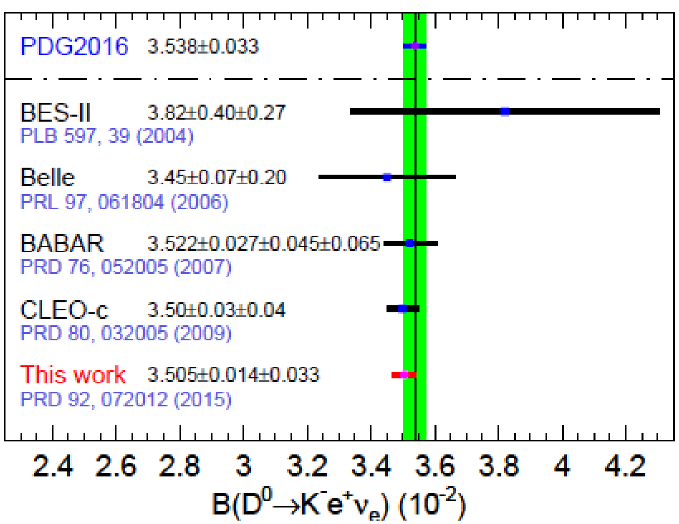
$$\frac{d\Gamma(D \to Pe\nu)}{dq^2} = \frac{G_F^2|V_{cs(d)}|^2}{24\pi^3} p^3 |f_+(q^2)|^2$$

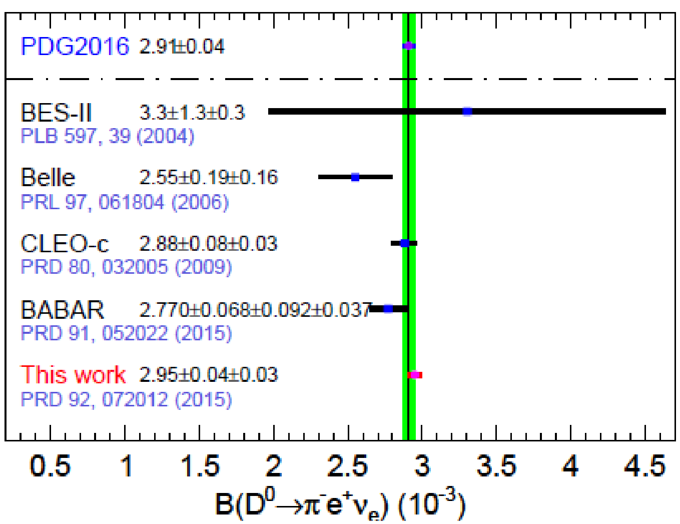
- Measure hadronic form factors $f_+^{D\to K}(0)$, $f_+^{D\to\pi}(0)$ to verify LQCD
- Extract CKM matrix elements $|V_{cs}|$ and $|V_{cd}|$

$D^0 \rightarrow K^- e^+ \nu_e$ and $\pi^- e^+ \nu_e$



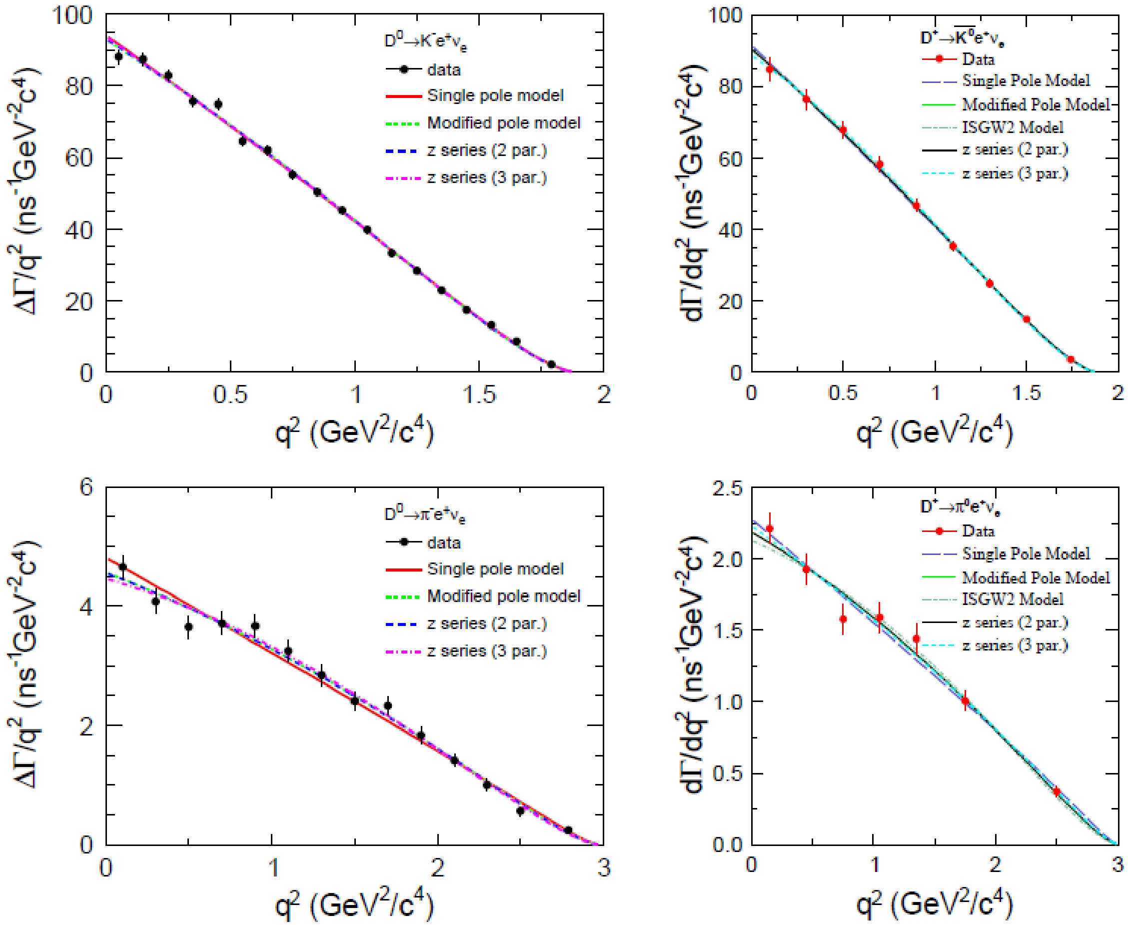






Measure partial decay rates in q^2 bins:

$$\Delta\Gamma_i = \frac{N^i_{\rm prd}}{\tau_D N_{\rm tag}} = \frac{1}{\tau_D N_{\rm tag}} \sum_j^{N_{\rm bins}} (\varepsilon^{-1})_{ij} N^j_{\rm obs}$$



Extract $f_+(0)|V_{cs(d)}|$ and other form factor parameters from measured partial decay rates in q^2 bin

Form Factor Parameterizations:

1. Single Pole $f_+(q^2) = \frac{f_+(0)}{1 - q^2/M^2_{\rm pole}}$
2. Modified Pole (BK)

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

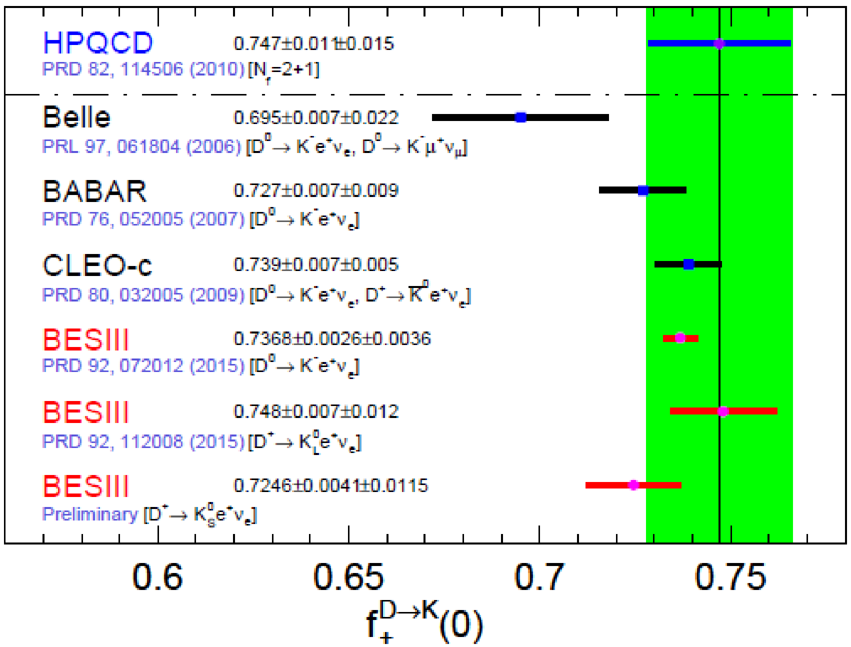
3. ISGW2

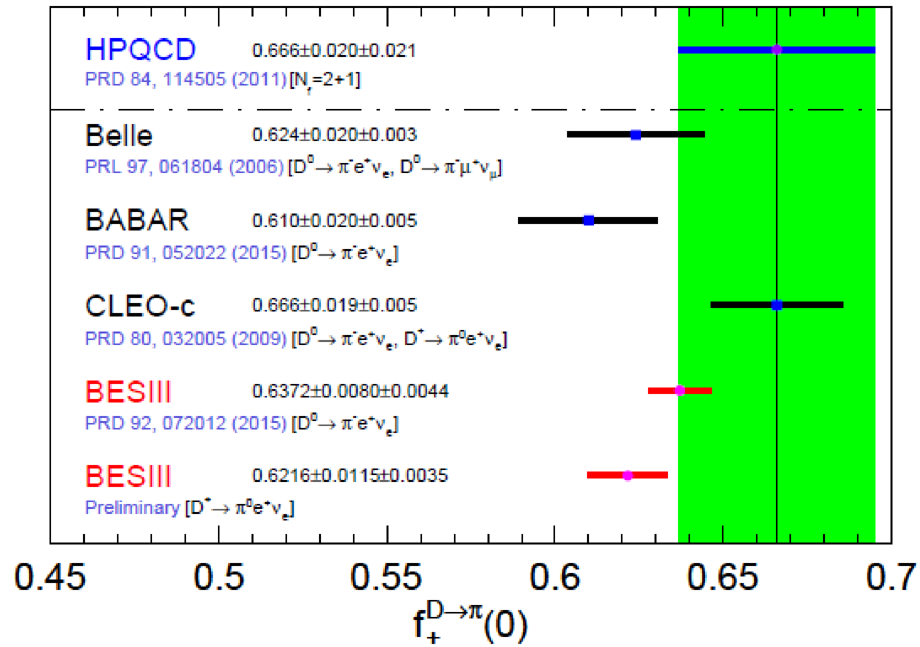
$$f_+(q^2) = f_+(q^2_{\rm max})\left(1 + \frac{r^2_{\rm ISGW2}}{12}(q^2_{\rm max} - q^2)\right)^{-2}$$

4. Series Expansion

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

- To determine $f_+^{D\to K(\pi)}(0)$, use the measurements of $f_+^{D\to K(\pi)}(0)|V_{cs(d)}|$ and the PDG values for $|V_{cs(d)}|$ (assuming CKM unitarity)

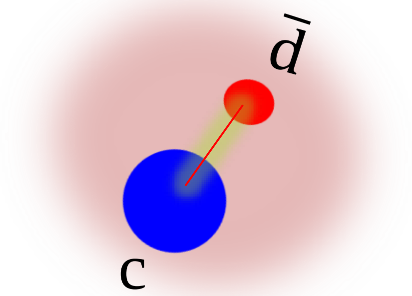


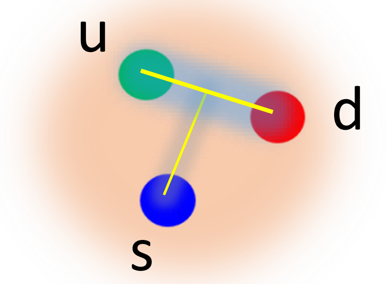


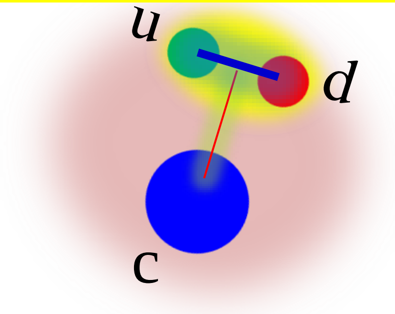
- BESIII made the best precise determinations of these two form factors
- The experimental accuracy is better than that of theoretical predictions

Λ_c study at BESIII

Λ_c^+: a heavy quark (c) with a unexcited spin-zero diquark (u-d)







Charmed meson ($D^+[c\bar{d}]$)
$m_d << m_c$ → quark (q) + heavy quark (Q)

Strange baryons ($\Lambda[uds]$)
$m_u, m_d \approx m_s$ → (qqq) uniform

Charmed baryon ($\Lambda_c[udc]$)
$m_u, m_d << m_c$ → diquark (qq) + quark (Q)

Λ_c^+ may provide complementary powerful test on internal dynamics to charmed meson.

- ☐ The lightest charmed baryon
- ☐ Most of the charmed baryons will eventually decay to Λ_c^+
- ☐ $B(\Lambda_c^+ \to pK^-\pi^+)$: dominant error for V_{ub} via b-baryon decay

Λ_c^+ experimental status

Λ_c Measurements [PDG2015]

Λ_c^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (M…	ΔB/B
Hadronic modes with a p: $S=-1$ final states					
$p\overline{K}^0$		(3.21 ± 0.30) %			9.3%
$pK^-\pi^+$		$(6.84^{+0.32}_{-0.40})$ %			5.8%
$p\overline{K}^*(892)^0$	[q]	(2.13 ± 0.30) %			14.1%
$\Delta(1232)^{++}K^-$		(1.18 ± 0.27) %			22.9%
$\Lambda(1520)\pi^+$	[q]	(2.4 ± 0.6) %			25.0%
$pK^-\pi^+$ nonresonant		(3.8 ± 0.4) %			10.5%
$p\overline{K}^0\pi^0$		(4.5 ± 0.6) %			13.3%
$p\overline{K}^0\eta$		(1.7 ± 0.4) %			23.5%
$p\overline{K}^0\pi^+\pi^-$		(3.5 ± 0.4) %			11.4%
$pK^-\pi^+\pi^0$		(4.6 ± 0.8) %			13.0%
$pK^*(892)^-\pi^+$	[q]	(1.5 ± 0.5) %			33.3%
$p(K^-\pi^+)_{nonresonant}\pi^0$		(5.0 ± 0.9) %			18.0%
$\Delta(1232)\overline{K}^*(892)$		seen			
$pK^-\pi^+\pi^+\pi^-$		$(1.5\pm1.0)\times10^{-3}$			66.7%
$pK^-\pi^+\pi^0\pi^0$		(1.1 ± 0.5) %			45.4%
Hadronic modes with a p: $S=0$ final states					
$p\pi^+\pi^-$		$(4.7\pm2.5)\times10^{-3}$			45.4%
$pf_0(980)$	[q]	$(3.8\pm2.5)\times10^{-3}$			53.2%
$p\pi^+\pi^+\pi^-\pi^-$		$(2.5\pm1.6)\times10^{-3}$			64.0%
pK^+K^-		$(1.1\pm0.4)\times10^{-3}$			36.4%
$p\phi$	[q]	$(1.12\pm0.23)\times10^{-3}$			
pK^+K^- non-ϕ		$(4.8\pm1.9)\times10^{-4}$			
Hadronic modes with a hyperon: $S=-1$ final states					
$\Lambda\pi^+$		(1.46 ± 0.13) %			8.9%
$\Lambda\pi^+\pi^0$		(5.0 ± 1.3) %			26.0%
$\Lambda\rho^+$		<6 %	CL=95%		
$\Lambda\pi^+\pi^+\pi^-$		(3.59 ± 0.28) %			7.8%
$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+}\to\Lambda\pi^+$		(1.0 ± 0.5) %			20.0%
$\Sigma(1385)^-\pi^+\pi^+$, $\Sigma^{*-}\to\Lambda\pi^-$		$(7.5\pm1.4)\times10^{-3}$			18.7%
$\Lambda\pi^+\rho^0$		(1.4 ± 0.6) %			42.8%
$\Sigma(1385)^+\rho^0$, $\Sigma^{*+}\to\Lambda\pi^+$		$(5\pm4)\times10^{-3}$			80.0%
$\Lambda\pi^+\pi^+\pi^-$ nonresonant		<1.1 %	CL=90%		
$\Lambda\pi^+\pi^+\pi^-\pi^0$ total		(2.5 ± 0.9) %			36.0%
$\Lambda\pi^+\eta$	[q]	(2.4 ± 0.5) %			20.8%
$\Sigma(1385)^+\eta$	[q]	(1.16 ± 0.35) %			30.2%
$\Lambda\pi^+\omega$	[q]	(1.6 ± 0.6) %			37.5%
$\Lambda\pi^+\pi^+\pi^-\pi^0$, no η or ω		$<9\times10^{-3}$	CL=90%		
$\Lambda K^+\overline{K}^0$		$(6.4\pm1.3)\times10^{-3}$	S=1.6		20.3%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Lambda\overline{K}^0$		$(1.8\pm0.6)\times10^{-3}$			33.3%
$\Sigma^0\pi^+$		(1.43 ± 0.14) %			10.0%
$\Sigma^+\pi^0$		(1.37 ± 0.30) %			21.9%
$\Sigma^+\eta$		$(7.5\pm2.5)\times10^{-3}$			33.3%
$\Sigma^+\pi^+\pi^-$		(4.9 ± 0.5) %			10.2%
$\Sigma^+\rho^0$		<1.8 %	CL=95%		
$\Sigma^-\pi^+\pi^+$		(2.3 ± 0.4) %			17.4%
$\Sigma^0\pi^+\pi^0$		(2.5 ± 0.9) %			36.0%
$\Sigma^0\pi^+\pi^+\pi^-$		(1.13 ± 0.31) %			27.4%
$\Sigma^+\pi^+\pi^-\pi^0$		—			
$\Sigma^+\omega$	[q]	(3.7 ± 1.0) %			27.1%
$\Sigma^+K^+K^-$		$(3.8\pm0.6)\times10^{-3}$			15.8%
$\Sigma^+\phi$	[q]	$(4.3\pm0.7)\times10^{-3}$			16.3%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Sigma^+K^-$		$(1.11\pm0.29)\times10^{-3}$			26.2%
$\Sigma^+K^+K^-$ nonresonant		$<9\times10^{-4}$	CL=90%		
Ξ^0K^+		$(5.3\pm1.3)\times10^{-3}$			24.5%
$\Xi^-K^+\pi^+$		$(7.0\pm0.8)\times10^{-3}$	S=1.1		11.4%
$\Xi(1530)^0K^+$	[q]	$(3.5\pm1.0)\times10^{-3}$			28.6%
Hadronic modes with a hyperon: $S=0$ final states					
ΛK^+		$(6.9\pm1.4)\times10^{-4}$			20.3%
$\Lambda K^+\pi^+\pi^-$		$<6\times10^{-4}$	CL=90%		
Σ^0K^+		$(5.7\pm1.0)\times10^{-4}$			17.5%
$\Sigma^0K^+\pi^+\pi^-$		$<2.9\times10^{-4}$	CL=90%		
$\Sigma^+K^+\pi^-$		$(2.3\pm0.7)\times10^{-3}$			30.4%
$\Sigma^+K^*(892)^0$	[q]	$(3.8\pm1.2)\times10^{-3}$			31.6%
$\Sigma^-K^+\pi^+$		$<1.3\times10^{-3}$	CL=90%		
…suppressed modes					
		$<3.1\times10^{-4}$	CL=90%		
…nic modes					
		(2.8 ± 0.4) %			
		(2.9 ± 0.5) %			17.2%
		(2.7 ± 0.6) %			22.2%

- **Total BFs < 65%**
- **Large uncertainties, most larger than 20%**
- **Most BFs are measured relative to $\Lambda c \to pK\pi$**

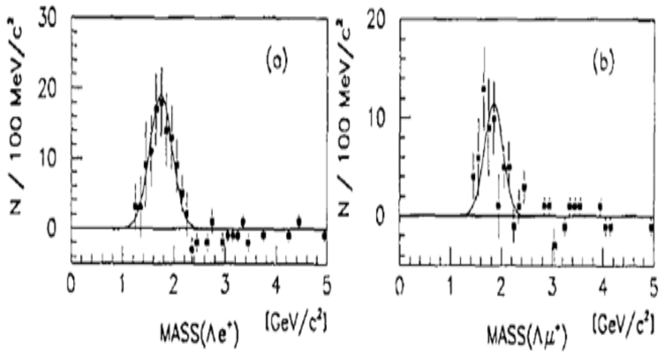
Semi-Leptonic decay $\Lambda_c^+ \to \Lambda l^+ \nu_l$

- **ARGUS first measurement :**

  Phys. Lett. B 269, 234 (1991).

$$\sigma(e^+e^- \to \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda e^+ X) = 4.20 \pm 1.28 \pm 0.71\ \mathrm{pb}$$

$$\sigma(e^+e^- \to \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda \mu^+ X) = 3.91 \pm 2.02 \pm 0.90\ \mathrm{pb}$$

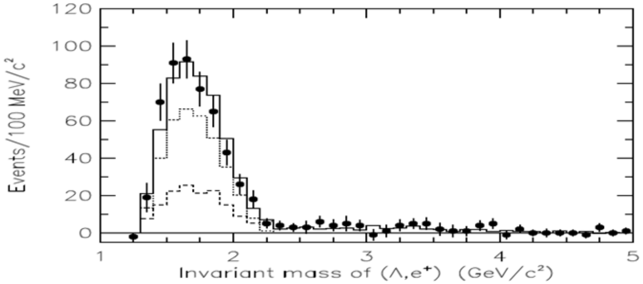


- **CLEO improved measurement :**

  Phys. Lett. B 323, 219 (1994).

$$\sigma(e^+e^- \to \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda e^+ X) = 4.87 \pm 0.28 \pm 0.69\ \mathrm{pb}$$

$$\sigma(e^+e^- \to \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda \mu^+ X) = 4.43 \pm 0.51 \pm 0.64\ \mathrm{pb}$$



- **Combined with the $\tau(\Lambda_c^+)$ and the assumption of form factors**

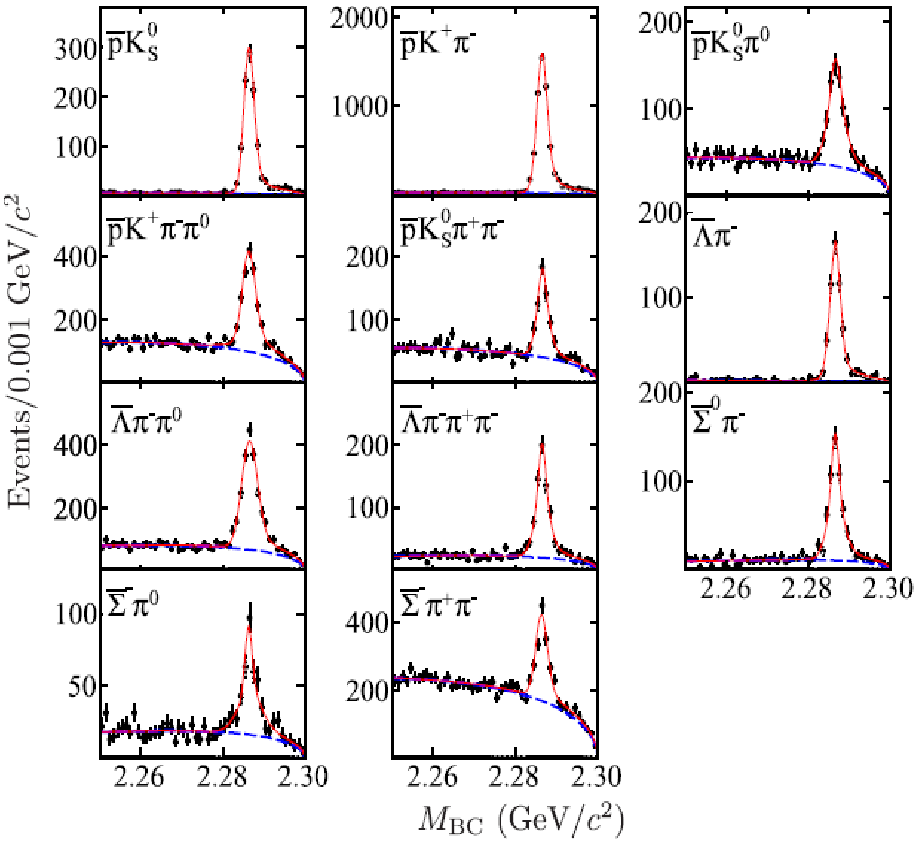
$\Lambda \ell^+ \nu_\ell$	***PDG 2015***	[r]	(2.8 ± 0.4) %
$\Lambda e^+ \nu_e$			(2.9 ± 0.5) %
$\Lambda \mu^+ \nu_\mu$			(2.7 ± 0.6) %

Not a direct measurement!

Theoretical calculations on the BF ranges from 1.4% to 9.2%

The measurement of $\Lambda_c^+ \to \Lambda l^+ \nu_l$

Double tag method **11 tag modes :** $M_{BC} = \sqrt{E_{beam}^2 - |\vec{p}_{\bar{\Lambda}_c^-}|^2}$



Mode	ΔE (GeV)	$N_{\bar{\Lambda}_c^-}$
$\bar{p}K_S^0$	[−0.025, 0.028]	1066 ± 33
$\bar{p}K^+\pi^-$	[−0.019, 0.023]	5692 ± 88
$\bar{p}K_S^0\pi^0$	[−0.035, 0.049]	593 ± 41
$\bar{p}K^+\pi^-\pi^0$	[−0.044, 0.052]	1547 ± 61
$\bar{p}K_S^0\pi^+\pi^-$	[−0.029, 0.032]	516 ± 34
$\bar{\Lambda}\pi^-$	[−0.033, 0.035]	593 ± 25
$\bar{\Lambda}\pi^-\pi^0$	[−0.037, 0.052]	1864 ± 56
$\bar{\Lambda}\pi^-\pi^+\pi^-$	[−0.028, 0.030]	674 ± 36
$\bar{\Sigma}^0\pi^-$	[−0.029, 0.032]	532 ± 30
$\bar{\Sigma}^-\pi^0$	[−0.038, 0.062]	329 ± 28
$\bar{\Sigma}^-\pi^+\pi^-$	[−0.049, 0.054]	1009 ± 57

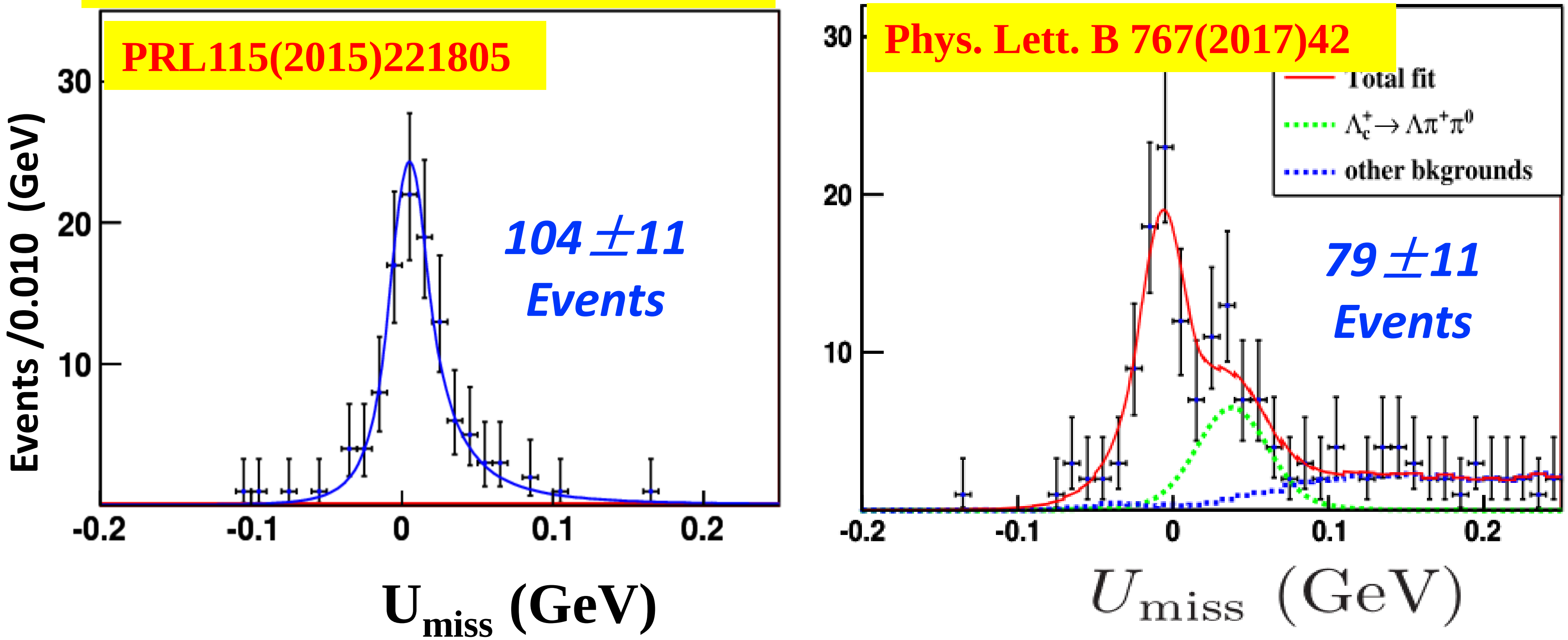
ST yields: 14415±159 events with 11 ST modes

BFs of $\Lambda_c^+ \to \Lambda l^+ \nu_l$ decay

First direct measurement, optimized variables : $U_{\text{miss}} = E_{\text{miss}} - c|\vec{p}_{\text{miss}}|$

$B(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.63 \pm 0.38 \pm 0.20)\%$

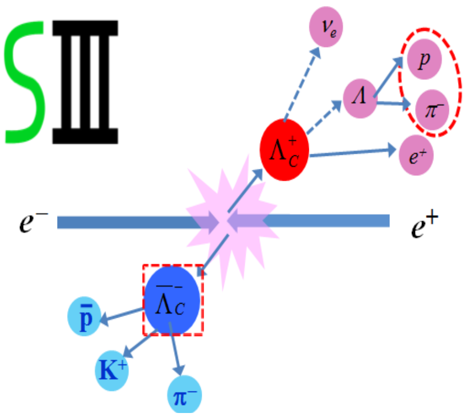
$B[\Lambda_c^+ \to \Lambda \mu^+ \nu_\mu] = (3.49 \pm 0.46 \pm 0.26)\%$



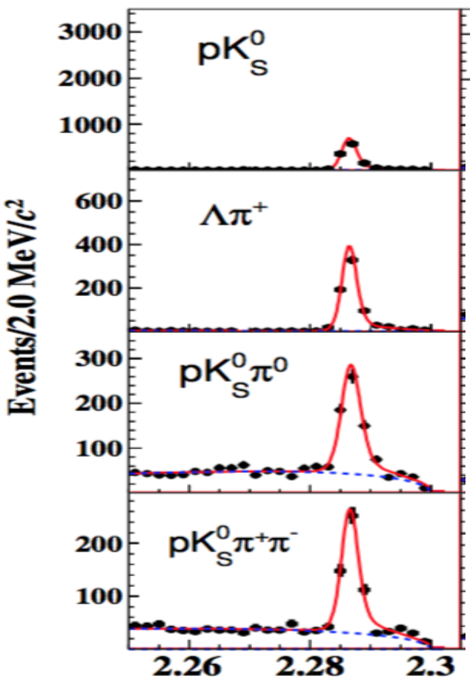
$\Gamma[\Lambda_c^+ \to \Lambda \mu^+ \nu_\mu]/\Gamma[\Lambda_c^+ \to \Lambda e^+ \nu_e] = 0.96 \pm 0.16 \pm 0.04$

Important to test and calibrate LQCD and lepton universality.

Absolute BFs of Λ_c^+ Cabibbo-Favored hadronic decays

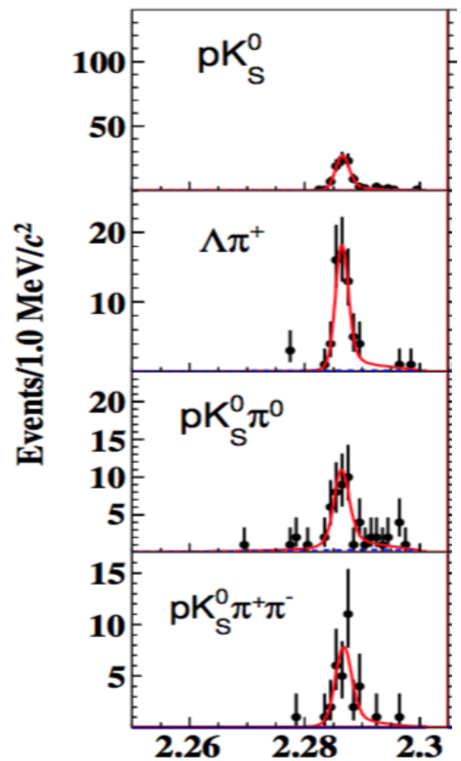


Signal Tag Variable : $M_{\rm BC} = \sqrt{E^2_{\rm beam} - |\vec{p}_{\bar{\Lambda}_c^-}|^2}$



ST yields

modes	N_i^{ST}
pK_S	1243 ± 37
$pK^-\pi^+$	6308 ± 88
$pK_S\pi^0$	558 ± 33
$pK_S\pi^+\pi^-$	454 ± 28
$pK^-\pi^+\pi^0$	1849 ± 71
$\Lambda\pi^+$	706 ± 27
$\Lambda\pi^+\pi^0$	1497 ± 52
$\Lambda\pi^+\pi^-\pi^+$	609 ± 31
$\Sigma^0\pi^+$	586 ± 32
$\Sigma^+\pi^0$	271 ± 25
$\Sigma^+\pi^+\pi^-$	836 ± 43
$\Sigma^+\omega$	157 ± 22



DT yields

Decay modes	N_{-j}^{DT}
pK_S	89 ± 10
$pK^-\pi^+$	390 ± 21
$pK_S\pi^0$	40 ± 7
$pK_S\pi^+\pi^-$	29 ± 6
$pK^-\pi^+\pi^0$	148 ± 14
$\Lambda\pi^+$	59 ± 8
$\Lambda\pi^+\pi^0$	89 ± 11
$\Lambda\pi^+\pi^-\pi^+$	53 ± 7
$\Sigma^0\pi^+$	39 ± 6
$\Sigma^+\pi^0$	20 ± 5
$\Sigma^+\pi^+\pi^-$	56 ± 8
$\Sigma^+\omega$	13 ± 3

Almost background free

PRL 116, 052001 (2016)

Results of 12 CF hadronic BFs

- Straightforward and model independent **PRL 116, 052001 (2016)**
- A least square global simultaneous fit : [CPC 37, 106201 (2013)]

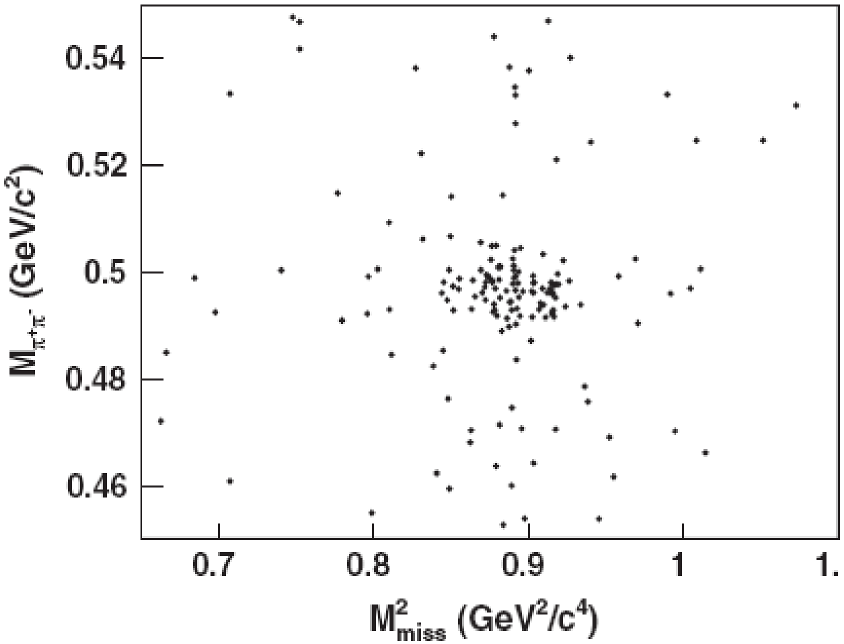
Mode	This work (%)	PDG (%)	BELLE $\mathcal{B}$
pK_S^0	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S^0\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	
$pK_S^0\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0	
$\Lambda\pi^+$	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7	
$\Sigma^0\pi^+$	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28	
$\Sigma^+\pi^0$	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0	
$\Sigma^+\omega$	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0	

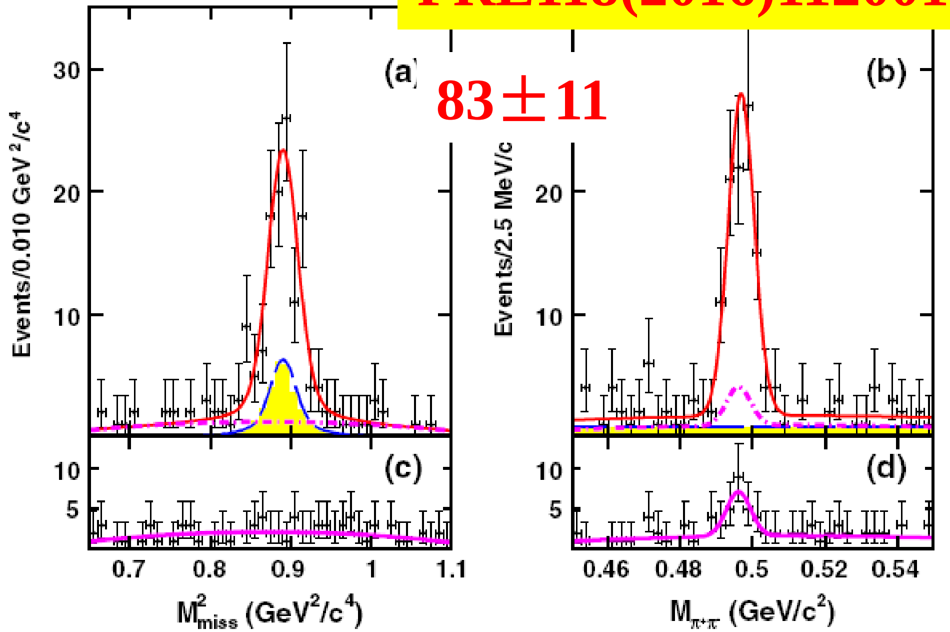
- $B(\Lambda_c^+ \to pK^-\pi^+)$: BESIII precision comparable with Belle's
- BESIII $B(\Lambda_c^+ \to pK^-\pi^+)$ is compatible with BELLE's within 2σ
- Improved precisions of the other 11 modes significantly

Observation of $\Lambda_c^+ \to nK_S^0\pi^+$

First observation of Λ_c^+ decays involving the neutron in final states.

PRL118(2016)112001





$B[\Lambda_c^+ \to nK_S^0\pi^+] = (1.82\pm0.23\pm0.11)\%$

$B[\Lambda_c^+ \to nK^0\pi^+]/B[\Lambda_c^+ \to pK^-\pi^+] = 0.62\pm0.09$

$B[\Lambda_c^+ \to nK^0\pi^+]/B[\Lambda_c^+ \to pK^0\pi^0] = 0.97\pm0.16$

The phase difference between $I^{(0)}$ and $I^{(1)}$:

$\cos\delta = -0.24 \pm 0.08$

and relative strength: $|I^{(1)}|/|I^{(0)}| = 1.14 \pm 0.11$

The relative BF of neutron-involved mode to proton-involved mode is essential to test the isospin symmetry and extract the strong phases of different final states.

Upgrade plan and physics prospects

BESIII upgrade

- New ETOF (built by USTC & IHEP) was installed in 2015 to improve the time resolution.

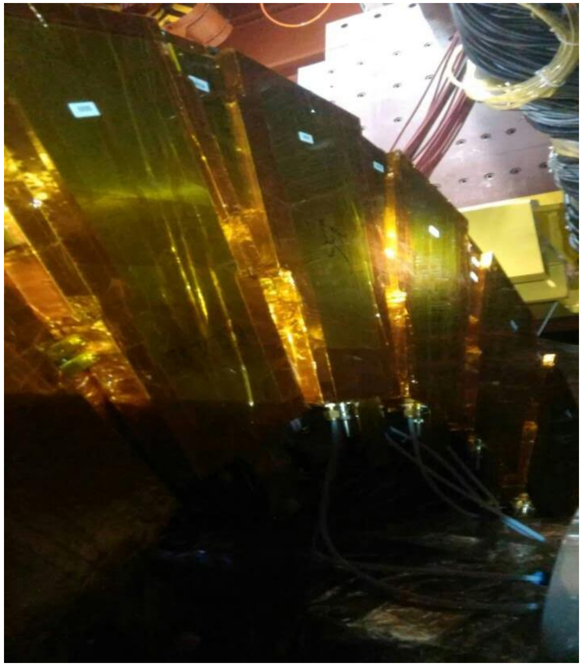
- MDC: Malter effect found in inner chamber in 2012, add water vapor to the chamber to cure the aging problem.

  - New inner chamber, built by IHEP, is ready now.
  - CGEM as the inner chamber ongoing : Italy group in collaboration with other groups.

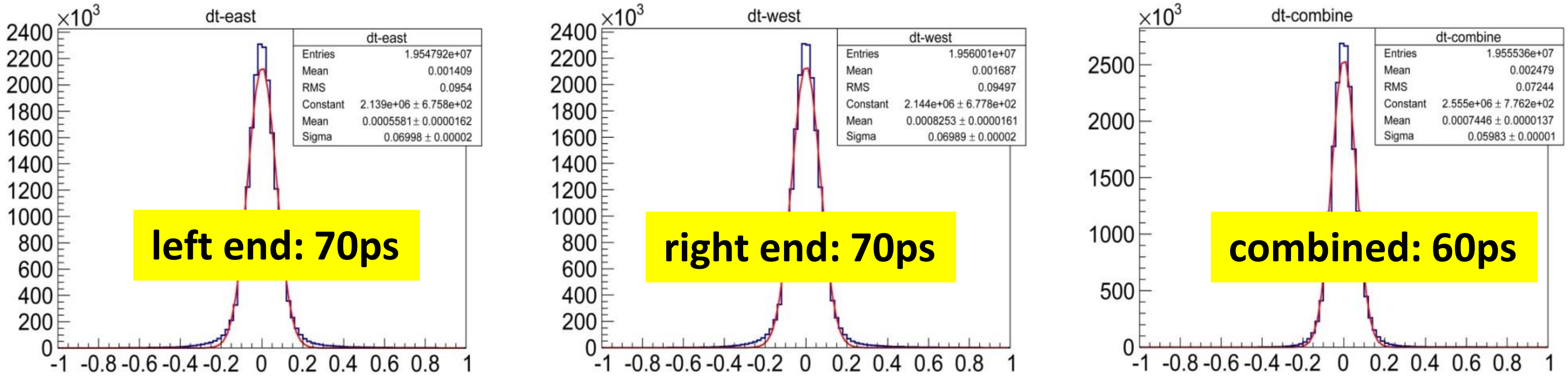
- New valve box for superconducting magnet
- Other possible upgrade plan is under discussion

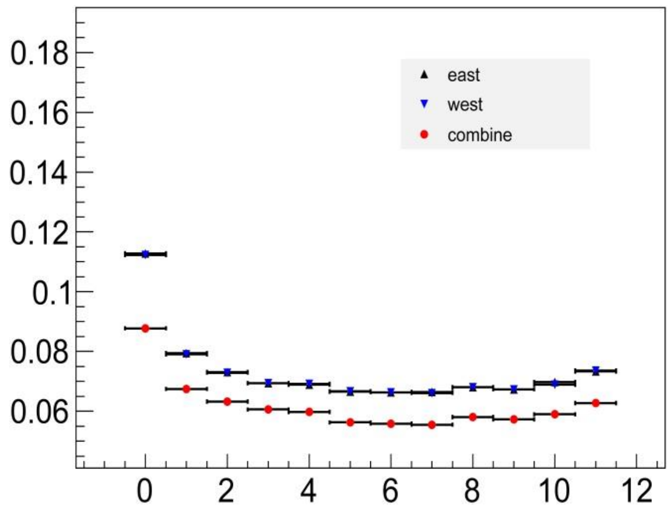
Installation of MRPC Endcap TOF

- **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**

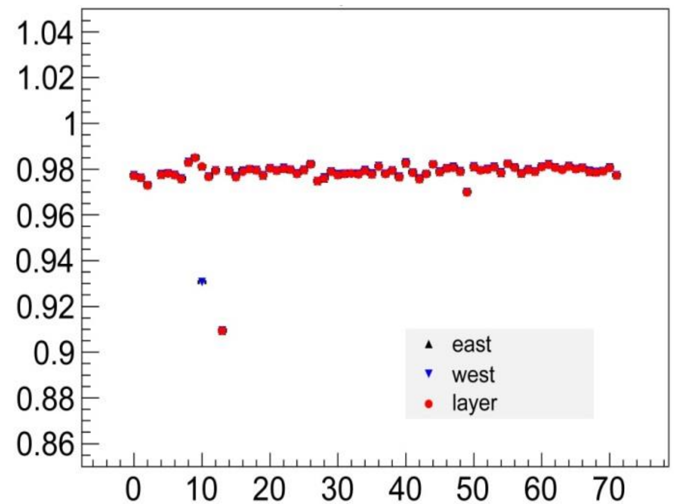


MRPC Endcap TOF





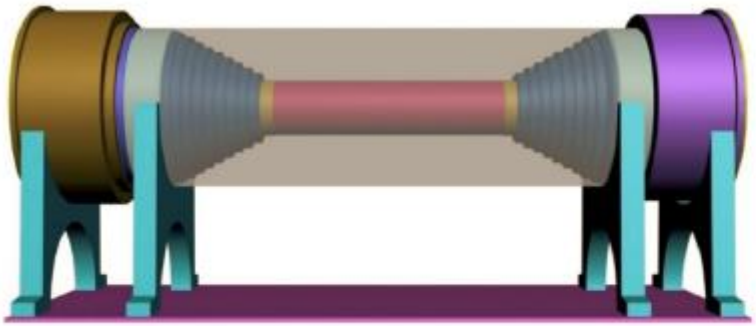
Time resolution vs Strip Number



Efficiency vs Module Number

Time resolution of 60ps achieved; Efficiency ~97%

New Inner Drift Chamber

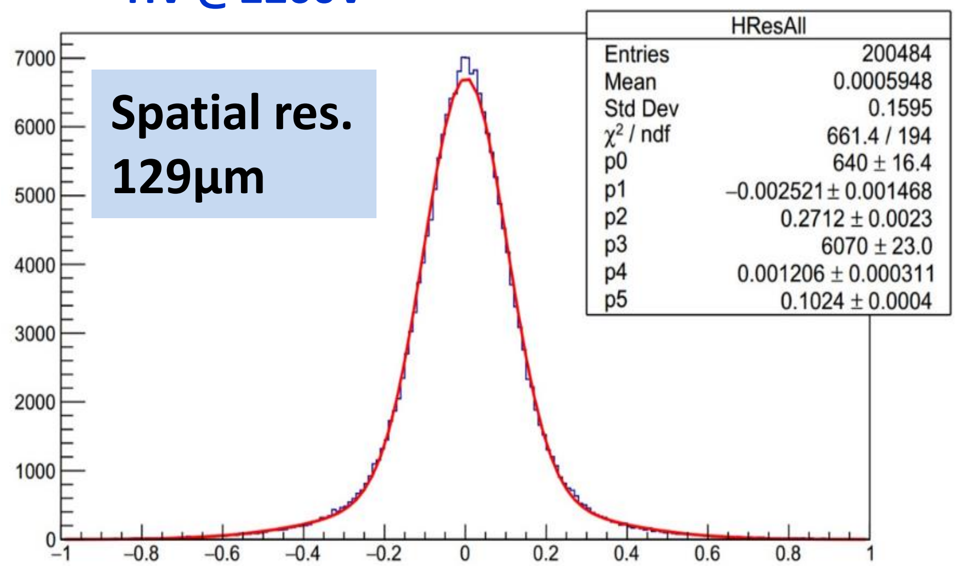


- An aluminum outer cylinder was manufactured for the chamber cosmic-ray test
- The outer cylinder was assembled after wiring had been finished

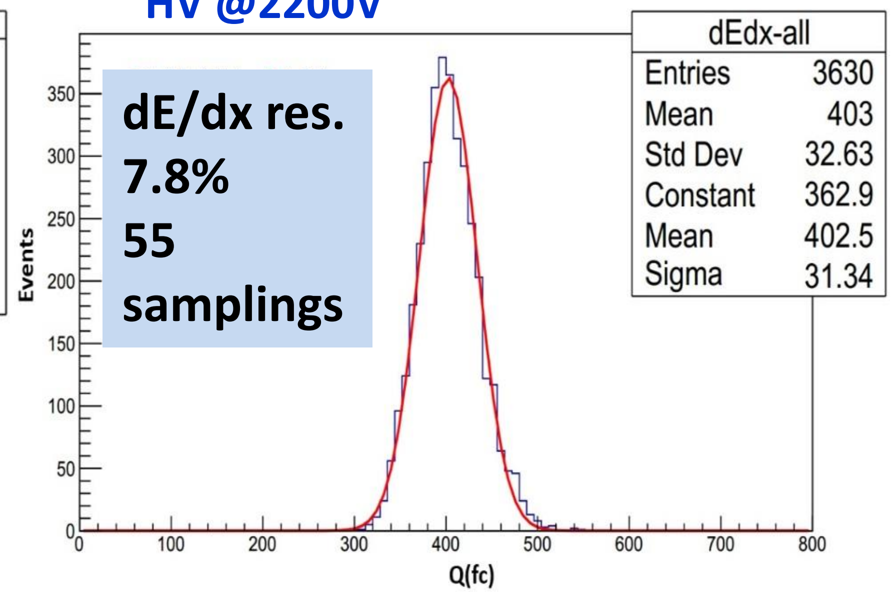
The performance of the new chamber

In cosmic ray test, the efficiency > 99%

HV @2200V



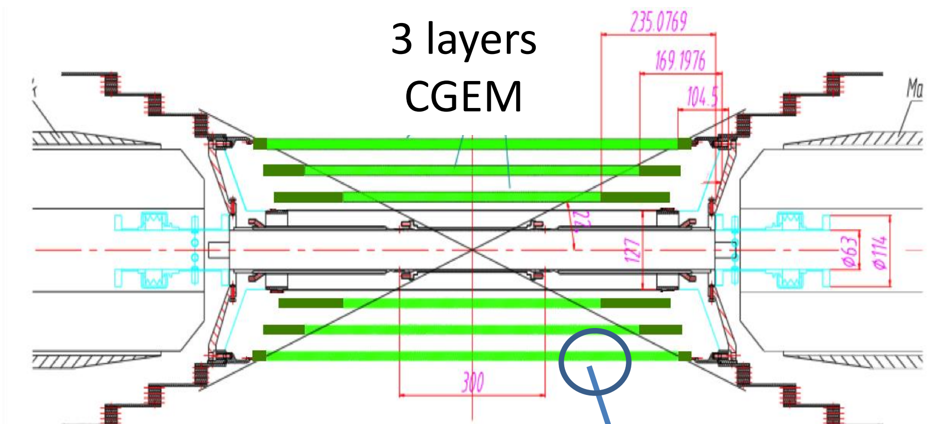
HV @2200V



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

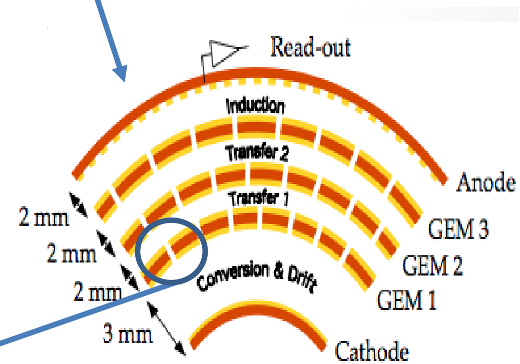
Cylindrical GEM Inner Tracker

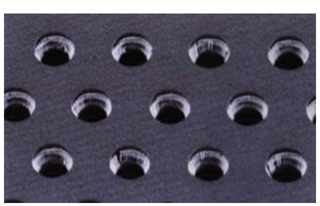
BESIII is building a cylindrical GEM detector (CGEM-IT) to replace the BESIII Inner MDC to recover some efficiency loss due to aging and to improve the secondary vertex resolution.



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

Each layer composed by a triple cylindrical GEM

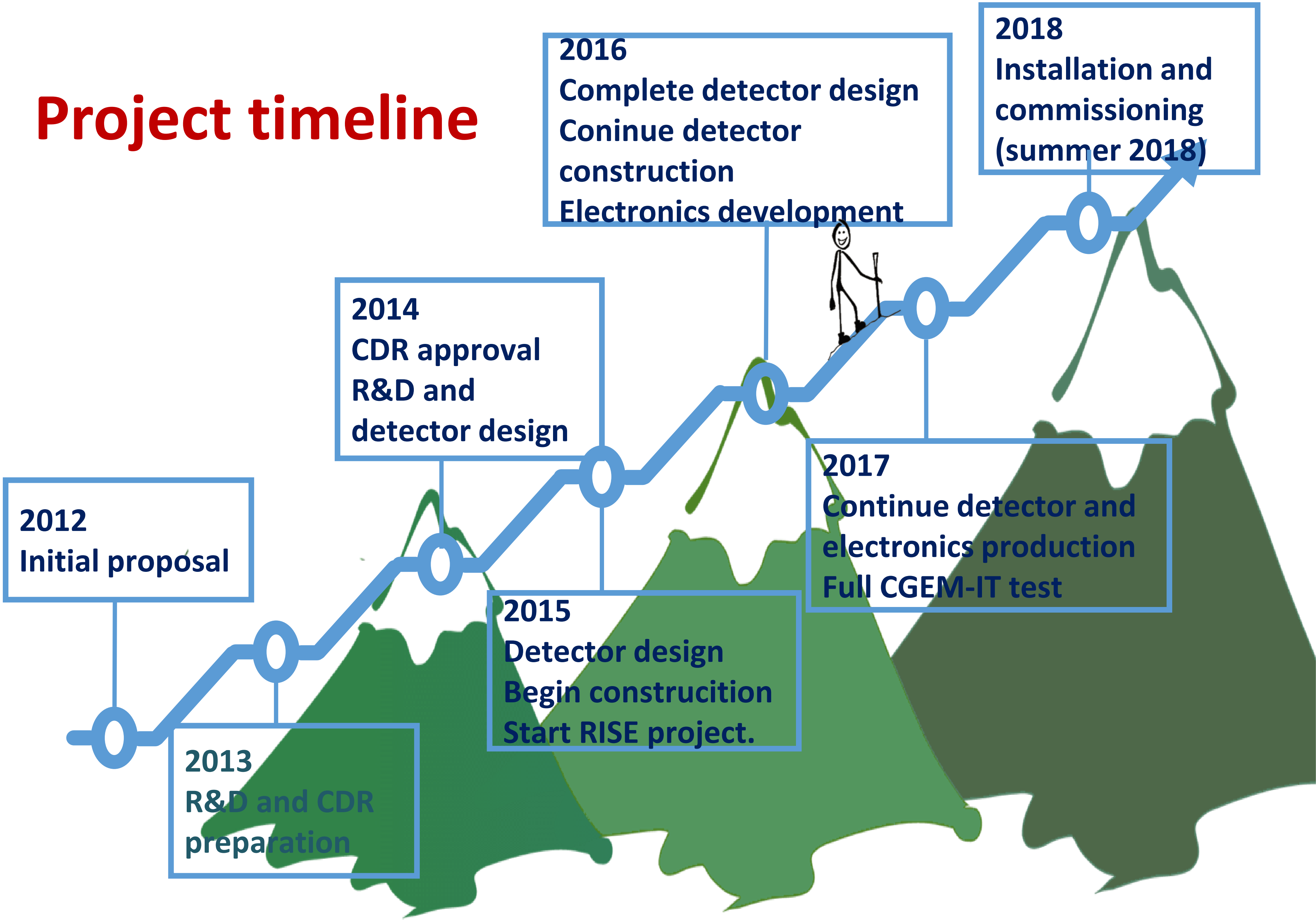




The CGEM is co-funded by the European Commission Research and Innovation Staff Exchange (RISE) project 2015-2018.

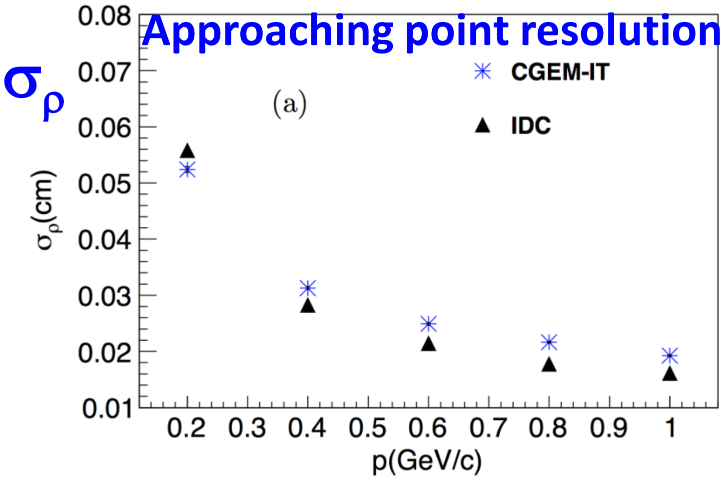
Formation of a consortium: INFN (Ferrara, Frascati, Perugia and Torino), Mainz, Uppsala, IHEP

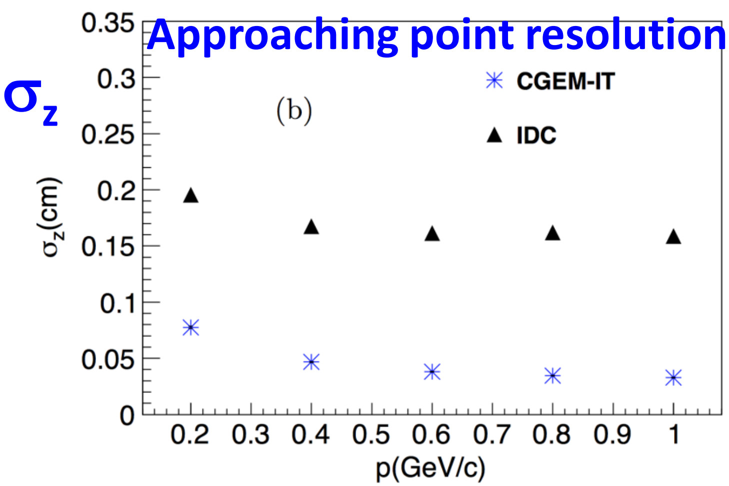
Project timeline

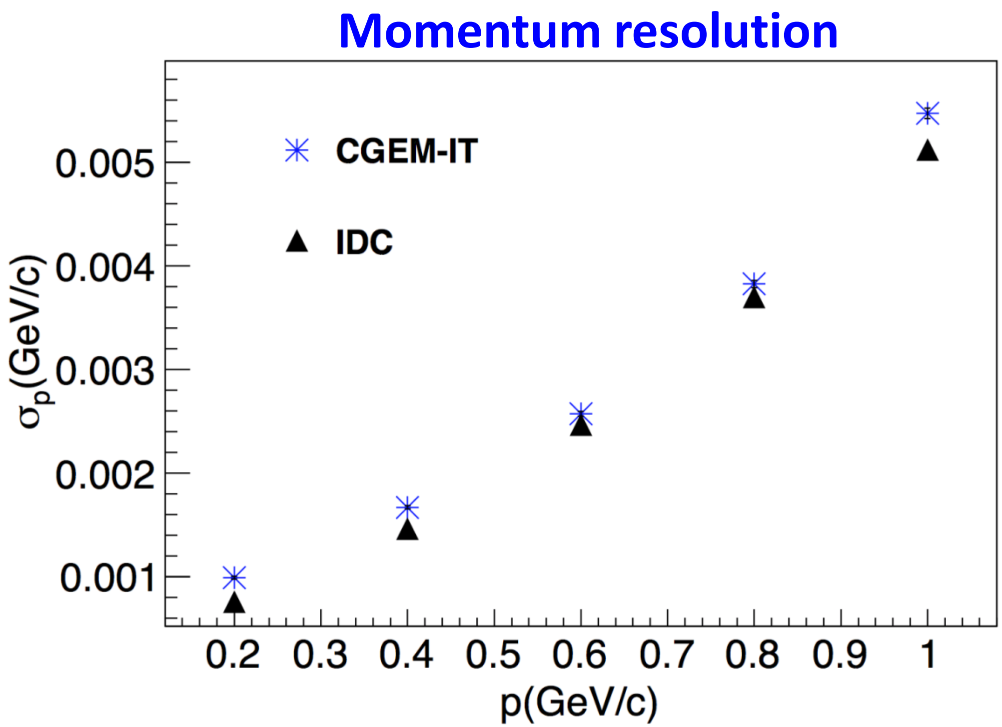


Expected performance of CGEM

Track fitting with Kalman Filter





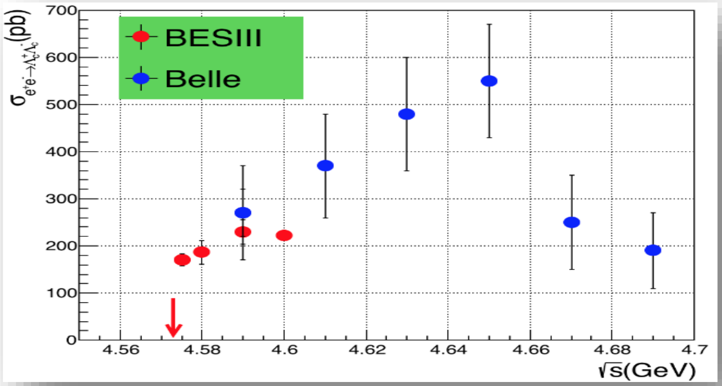


- **Will challenge BEPCII CM energy limit**

  from 2.30 →2.35→ 2.45 GeV(4.6→ 4.7→4.9 GeV)

  Funding approved (~5 M RMB)

  - Λc study



  - XYZ study: Y(4660), ...

With larger Λ_c data sample

- PWA ⇒ intermediate structures in 3-body decays
- More semileptonic decays: nlν, Λ*lν, ΣXlν …
- Decay asymmetry parameters α ⇐ $\Lambda_c^+ \to BP/BV$
- Λ_c^+ Rare decays search
  - Weak radiative decay $\Lambda_c^+ \to \gamma\Sigma^+$
  - FCNC $\Lambda_c^+ \to pl^+l^-$
  - LNV $\Lambda_c^+ \to pe\mu$

- **BEPCII Top-up project**

  funding approved (about 12M RMB)

  data taking efficiency: increased by 20-30%

BESIII data taking status & plan (run ~8-10 years)

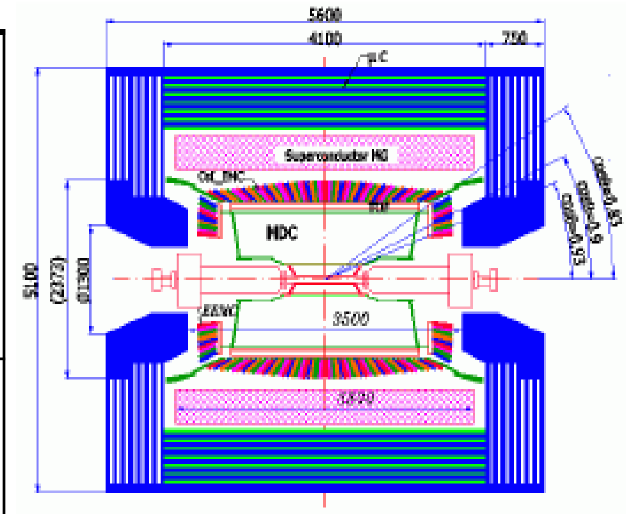
	Previous data	BESIII present & future	Goal
J/ψ	BESII 58M	1.2 B 20* BESII	10 B
ψ’	CLEO： 28 M	0.5 B 20* CLEOc	3B
ψ”	CLEO： 0.8/fb	2.9/fb 3.5*CLEOc	20 /fb
Above open charm threshold	CLEO： 0.6/fb @ ψ(4160)	0.5/fb @ ψ(4040) 2.3/fb@~4260, 0.5/fb@4360 0.5/fb@4600， 1/fb@4420 Scan from 4.19 – 4.28, 10 MeV step, 500 pb-1/point	5-10 /fb
R scan & Tau	BESII	3.8-4.6 GeV at 105 energy points 2.0-3.1 GeV at 20 energy points	
Y(2175)		100 pb^{-1}	
ψ(4170)		3 fb^{-1}	

Thank you

Backup slides

BESIII Detector

Exps.	MDC Wire resolution	MDC dE/dx resolution	EMC Energy resolution
CLEO	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)	2.3%

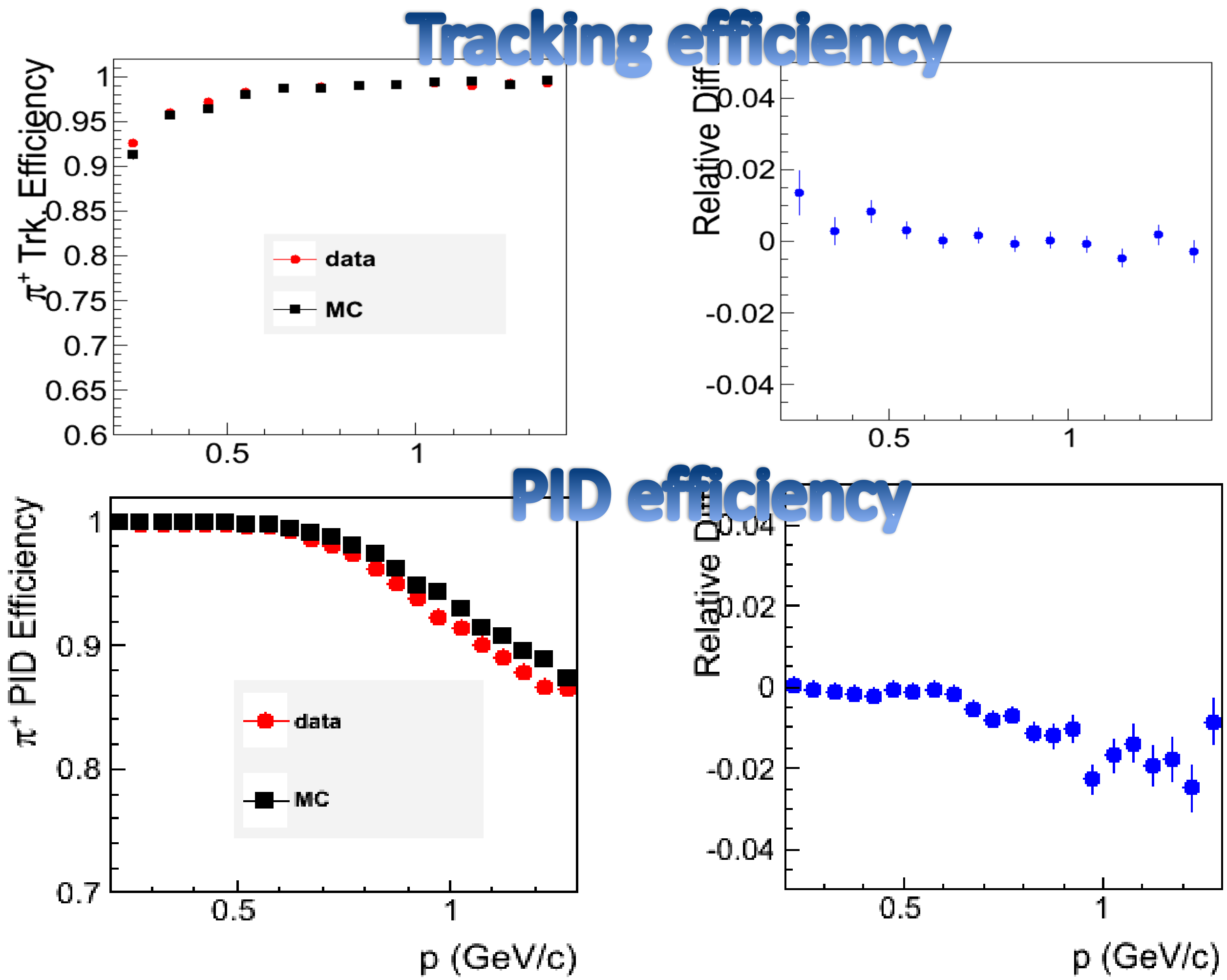


Exps.	TOF time resolution
CDFII	100 ps
Belle	90 ps
BESIII	68 ps (BTOF) 100 ps (ETOF) 60 ps (MRPC)

- New ETOF (MRPC) installed
- New Inner MDC, being built

Data/Monte-Carlo Consistency

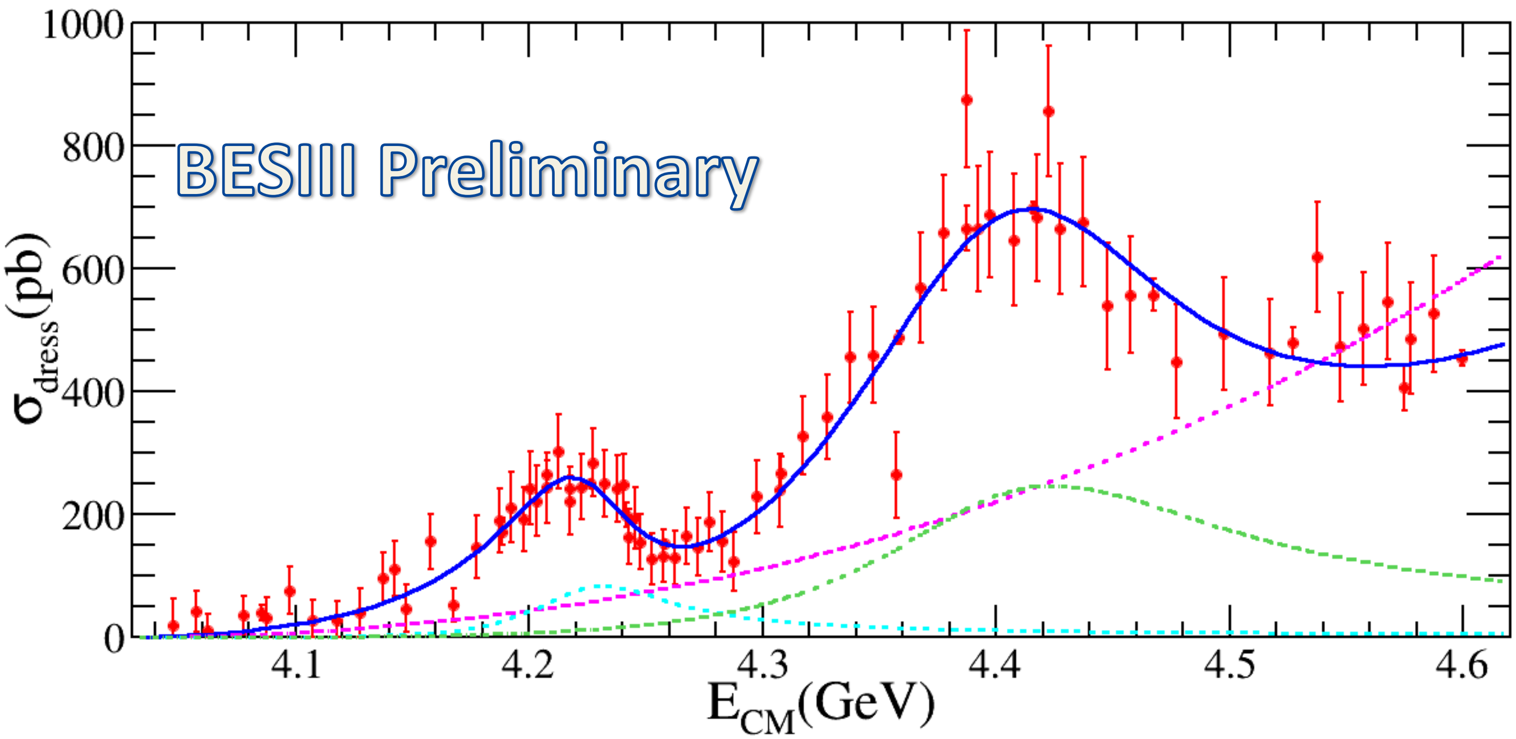
- For tracking efficiency, data/MC difference < 1%
- For particle identification efficiency, data/MC difference < 2%



$e^+e^- \rightarrow \pi^+ D^0 D^{*-}$

$$\sigma_{dress} = \frac{N^{obs}}{\mathcal{L}(1+\delta^r)B(D^0 \rightarrow K^-\pi^+)\varepsilon}$$

$$\sigma_{\text{dress}}(m) = |c \cdot \sqrt{P(m)} + e^{i\phi_1} B_1(m) \sqrt{\frac{P(m)}{P(M_1)}} + e^{i\phi_2} B_2(m) \sqrt{\frac{P(m)}{P(M_2)}}|^2$$

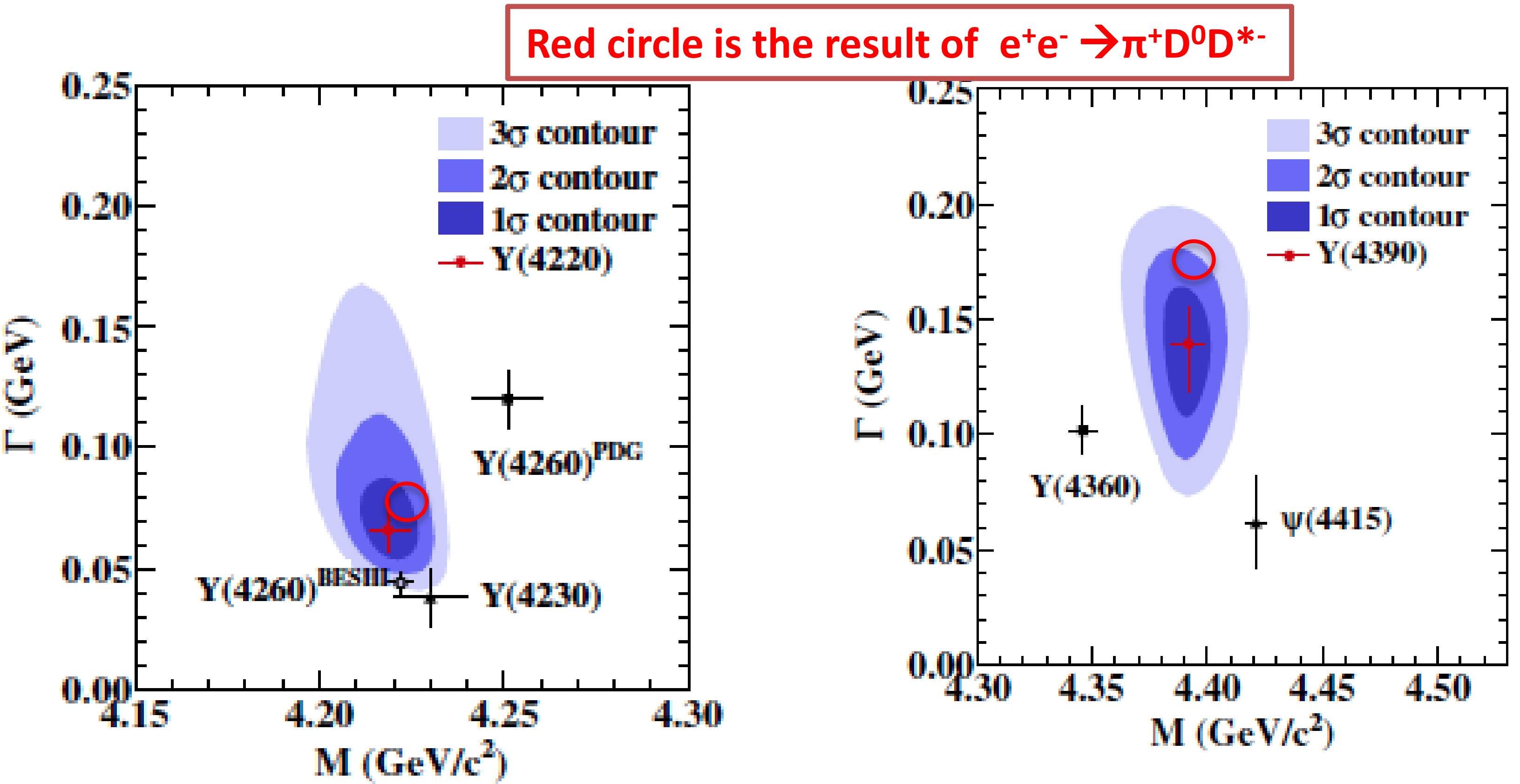


Fit with a constant (pink dashed triple-dot line) and two constant width relativistic BW functions (green dashed double-dot line and aqua dashed line).

$M(Y(4220)) = (4224.8 \pm 5.6 \pm 4.0)$ MeV/c², $\Gamma(Y(4220)) = (72.3 \pm 9.1 \pm 0.9)$ MeV.

$M(Y(4390)) = (4400.1 \pm 9.3 \pm 2.1)$ MeV/c², $\Gamma(Y(4220)) = (181.7 \pm 16.9 \pm 7.4)$ MeV.

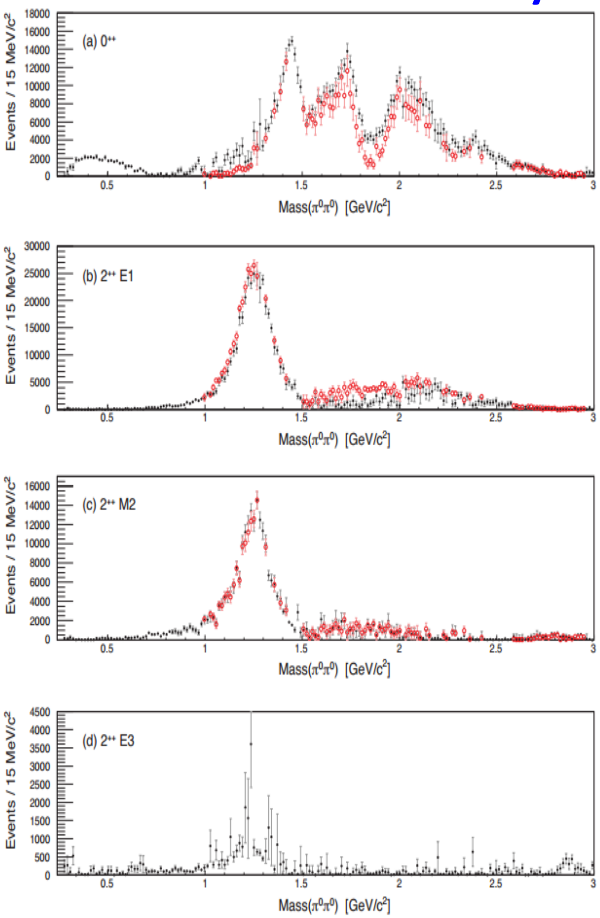
$e^+e^- \rightarrow \pi^+D^0D^{*-}$



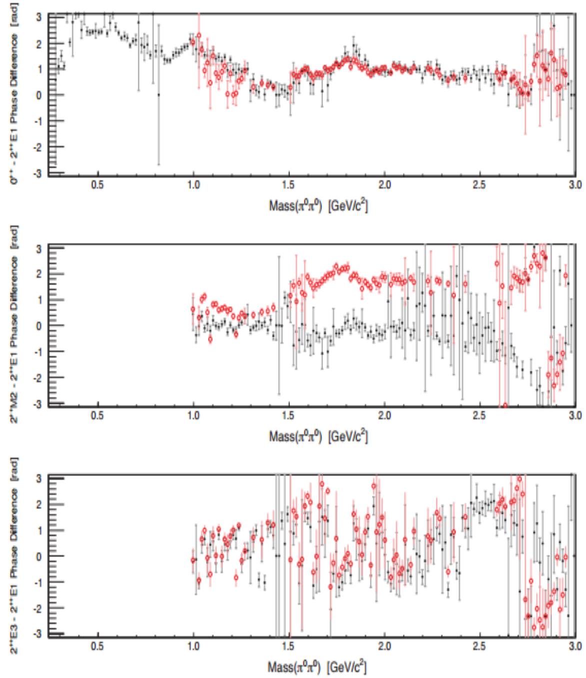
- The statistical significance of two resonances assumption over one resonance is greater than 10s.
- The resonant parameters of Y(4220) and Y(4390) states are consistent with the structures observed in $e^+e^- \rightarrow \pi^+\pi^-h_c$. The resonant parameters of Y(4220) are also consistent with those of the resonance observed in $e^+e^- \rightarrow \omega\chi_{c0}$ and $e^+e^- \rightarrow \pi^+\pi^-J/\psi$.

Model Independent PWA of $J/\psi \rightarrow \gamma\pi^0\pi^0$

Extracted Intensity



Relative Phase



- Solution 1
- Solution 2

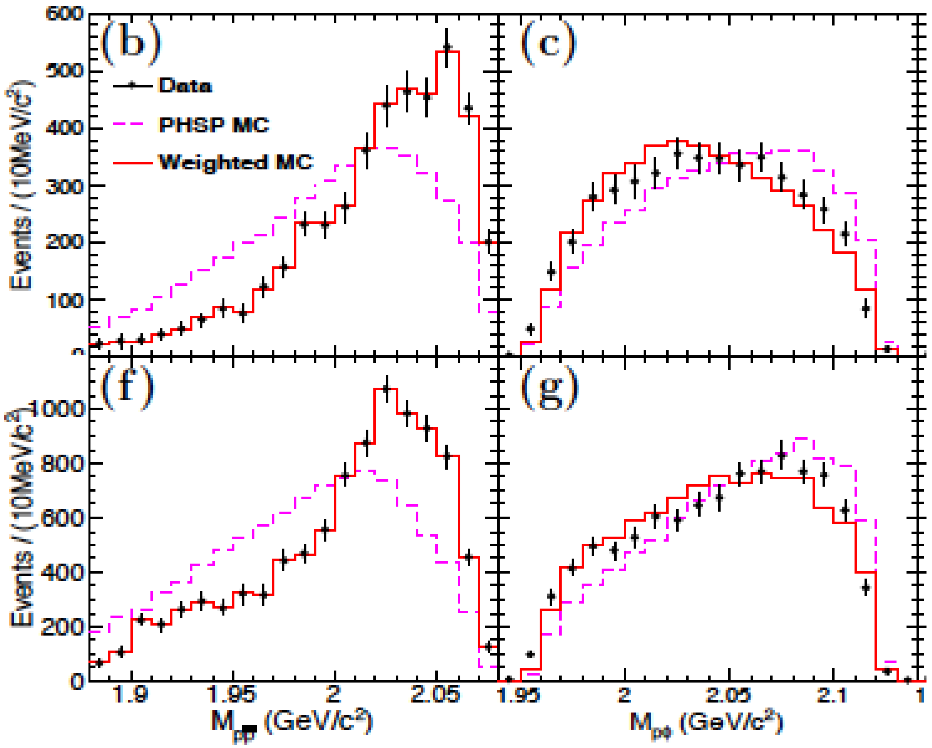
Phys. Rev. D 92, 052003 (2015)

- ✓ **Extract amplitudes in each M($\pi^0\pi^0$) mass bin**
- ✓ **Significant features of the scalar spectrum includes structures near 1.5, 1.7 and 2.0 GeV/c^2**
- ✓ **Multi-solution problem in MIPWA is usually unavoidable.**
- ✓ **Model Dependent PWA of global PWA fit is still needed to extract resonance parameters**

Measurements of $J/\psi \to \phi p \bar{p}$

BESIII Phys.Rev. D93, 052010 (2016)

No obvious threshold structure of $\bar{p}p$ or ϕp

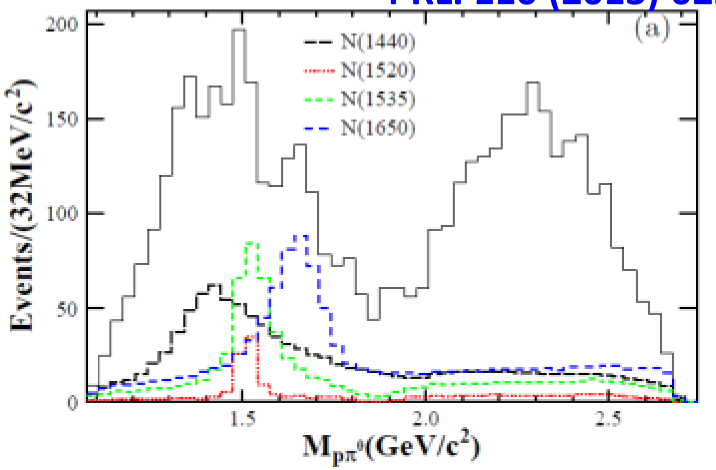


$$\mathcal{B}(J/\psi \to p\bar{p}\phi) = [5.23 \pm 0.06\,(\text{stat}) \pm 0.33\,(\text{syst})] \times 10^{-5}$$

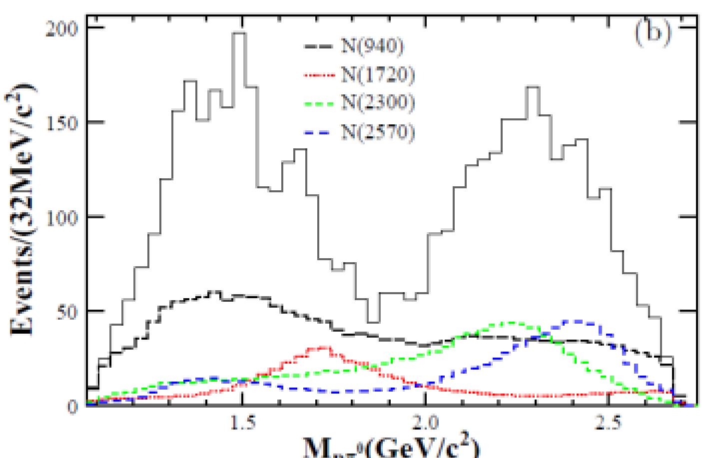
Study of N* and Ξ*

N* in $\psi' \to \pi^0 p \bar{p}$

PRL. 110 (2013) 022001

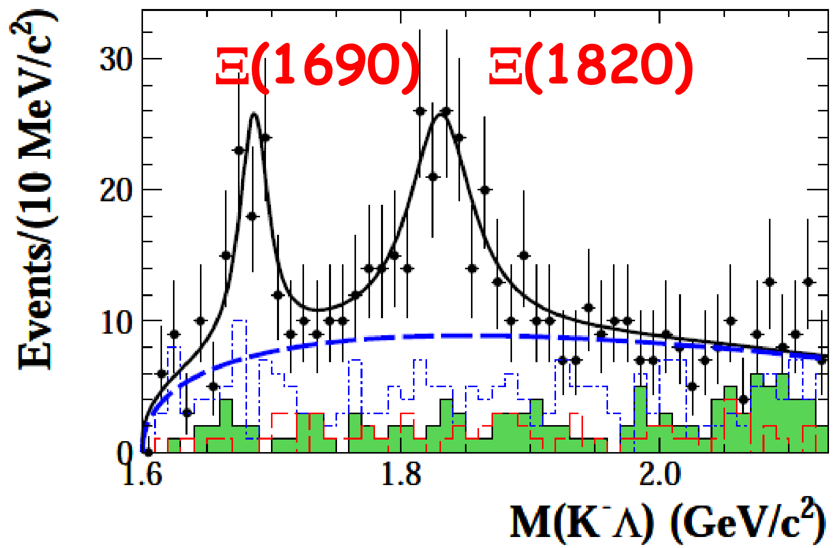


New N*s： N(2300) and N(257



Ξ* in $\psi' \to K \Lambda \Xi$

arXiv:1504.02025

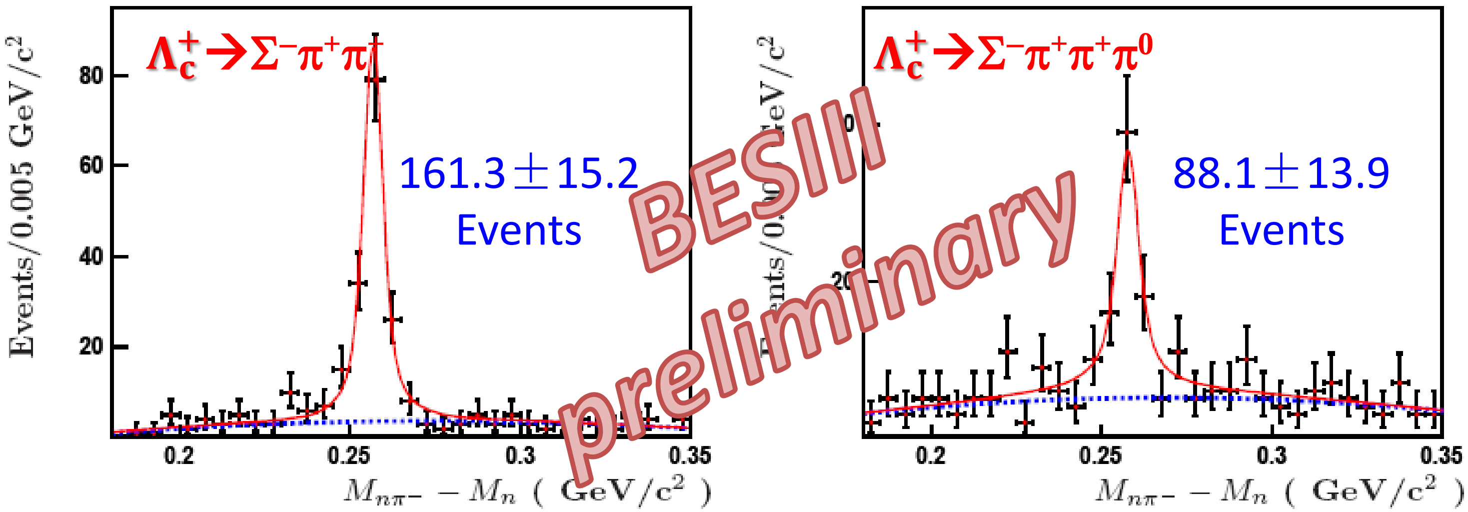


- **PWA of**
  - $J/\psi(\psi') \to \pi^0 p \bar{p}$
  - $J/\psi(\psi') \to \eta p \bar{p}$
  - $J/\psi(\psi') \to p K \bar{\Lambda}$
  - …

Measurement of $\Lambda_c^+ \to \Sigma^- \pi^+ \pi^+ (\pi^0)$

- **The total measured Λ_c^+ decay BFs is ~65%, searching for more decay modes are important**
- **Only one Λ_c^+ decay involved Σ^- is observed, B($\Lambda_c^+ \to \Sigma^- \pi^+ \pi^-$)=(2.3±0.4)%, where Σ^- dominantly decay to $n\pi^-$**

11 ST modes, 11415±159 Λ_c^+ tagged candidates



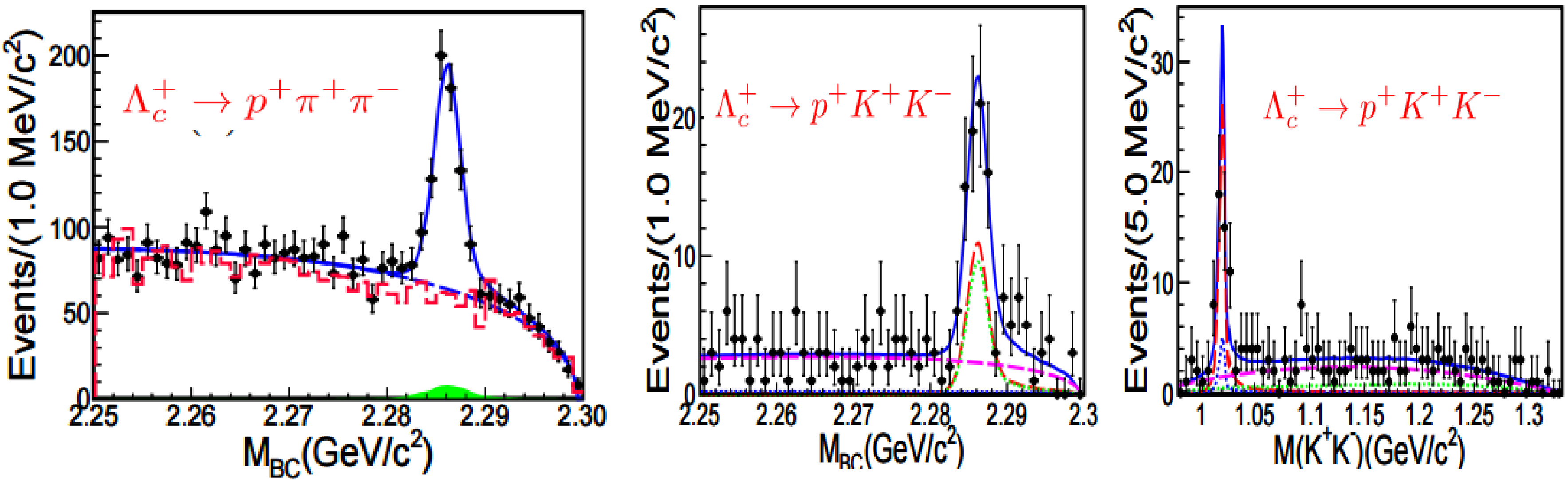
B[$\Lambda_c^+ \to \Sigma^- \pi^+ \pi^+$] =(1.81±0.17)% [Improved precision]

B[$\Lambda_c^+ \to \Sigma^- \pi^+ \pi^+ \pi^0$]=(2.11 ±0.33)% [first observation]

Statistical only, totally uncertainty <5%

Single-Cabibbo-Suppressed decay of $\Lambda_c^+ \to p\pi^+\pi^- / K^+K^-$

Sensitive to non-factorizable contributions from W-exchanged process



Decay modes	$\mathcal{B}_{\rm mode}/\mathcal{B}_{\rm ref.}$ (this work)	$\mathcal{B}_{\rm mode}/\mathcal{B}_{\rm ref.}$ ([28])
$\Lambda_c^+ \to p\pi^+\pi^-$	$(6.70 \pm 0.48 \pm 0.25) \times 10^{-2}$	–
$\Lambda_c^+ \to p\phi$	$(1.81 \pm 0.33 \pm 0.13) \times 10^{-2}$	$0.015 \pm 0.002 \pm 0.002$
$\Lambda_c^+ \to pK^+K^-$ (non-ϕ)	$(9.36 \pm 2.22 \pm 0.71) \times 10^{-3}$	$0.007 \pm 0.002 \pm 0.002$
–	$\mathcal{B}_{\rm mode}$	$\mathcal{B}$(PDG)
$\Lambda_c^+ \to p\pi^+\pi^-$	$(3.91 \pm 0.28 \pm 0.15 \pm 0.24) \times 10^{-3}$	$(3.5 \pm 2.0) \times 10^{-3}$
$\Lambda_c^+ \to p\phi$	$(1.06 \pm 0.19 \pm 0.08 \pm 0.06) \times 10^{-3}$	$(8.2 \pm 2.7) \times 10^{-4}$
$\Lambda_c^+ \to pK^+K^-$ (non-ϕ)	$(5.47 \pm 1.30 \pm 0.41 \pm 0.33) \times 10^{-4}$	$(3.5 \pm 1.7) \times 10^{-4}$

PRL117(2016)232002

first observation

improved precision

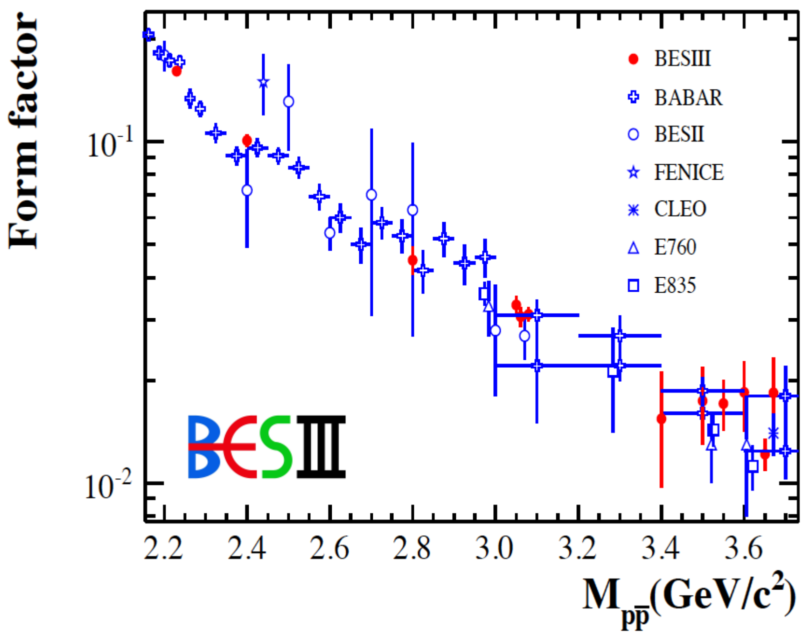
Proton FF measurement at BESIII

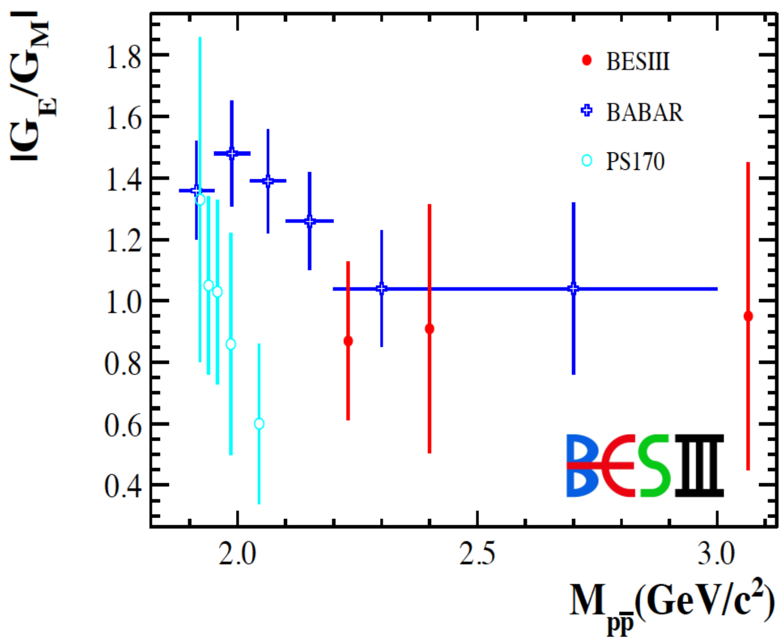
Phys.Rev. D91 (2015) 11, 112004 .

Analysis Features:

- Radiative corrections from Phokhara8.0 (scan)
- Normalization to $e^+e^- \to e^+e^-$, $e^+e^- \to \gamma\gamma$ (BABAYAGA 3.5)
- Efficiencies 60% (2.23 GeV) .... 3% (~4 GeV)
- $|G_E/G_M|$ ratio obtained for 3 c.m. energies

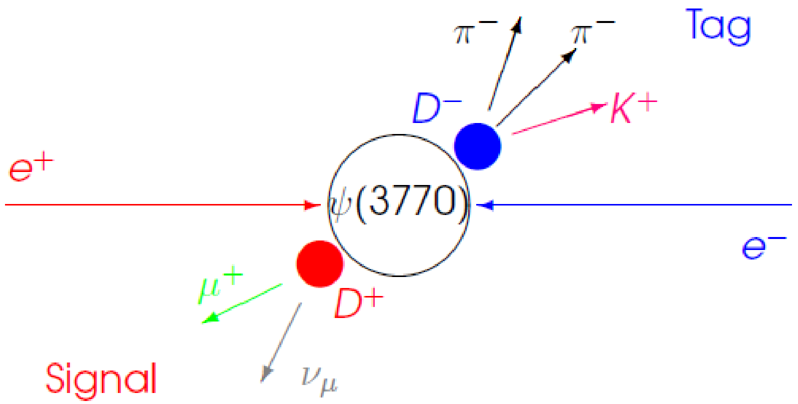
E_{cm}/GeV	L_{int} / pb^{-1}
2.23	2.6
2.40	3.4
2.80	3.8
3.05, 3.06, 3.08	60.7
3.40, 3.50, 3.54, 3.56	23.3
3.60, 3.65, 3.67	63.0





Analysis Technique

$e^+e^- \to c\bar{c} \to \bar{D}_{\rm tag}\, D_{\rm sig}$: Double-tag technique, Absolute measurement



- Tag $\bar{D}_{\rm tag}$ in hadronic decay modes

$$\Delta E = E_{\bar{D}_{\rm tag}} - E_{\rm beam}$$

$$M_{\rm BC} = \sqrt{E^2_{\rm beam} - p^2_{\bar{D}_{\rm tag}}}$$

- Reconstruct $D_{\rm sig}$ using the remaining tracks not associated to $\bar{D}_{\rm tag}$
  - $E_{D_{\rm sig}} = E_{\rm beam}$, $\vec{p}_{D_{\rm sig}} = -\vec{p}_{\bar{D}_{\rm tag}}$
  - no additional tracks/showers
  - (semi-)leptonic decay: missing neutrino, $U_{\rm miss} \equiv E_{\rm miss} - |\vec{p}_{\rm miss}| \sim 0$

$$N_{\rm tag} = 2N_{D\bar{D}}\mathcal{B}_{\rm tag}\varepsilon_{\rm tag}$$

$$N_{\rm tag,SL} = 2N_{D\bar{D}}\mathcal{B}_{\rm tag}\mathcal{B}_{\rm SL}\varepsilon_{\rm tag,SL}$$

$$\mathcal{B}_{\rm SL} = \frac{N_{\rm tag,SL}}{N_{\rm tag}}\frac{\varepsilon_{\rm tag}}{\varepsilon_{\rm tag,SL}} = \frac{N_{\rm tag,SL}}{N_{\rm tag}\varepsilon}$$

- High tagging efficiency
- Extremely clean
- Systematic uncertainties associated to tag side are mostly canceled out

- **BESIII superconducting magnet: funding approved for a new valve box (~5M RMB)**