Overview talk on BESIII physics

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KEK FF-2013

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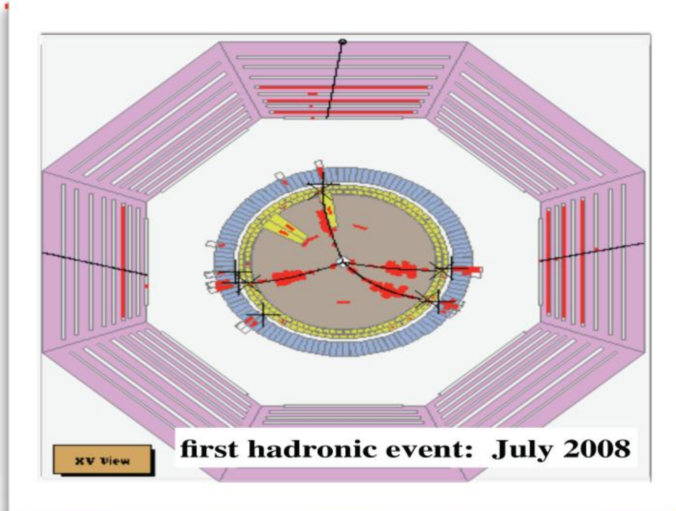
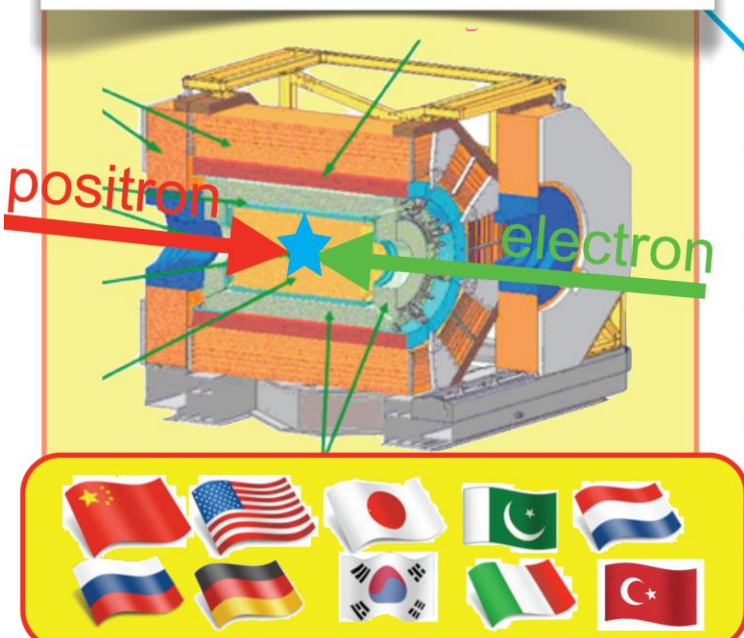
BESIII Introduction

- BESIII data samples
- BESIII detector
- BEPCII collider
- BESIII physics
- BESIII Collaboration

From 1974 till today: charmonium factories...



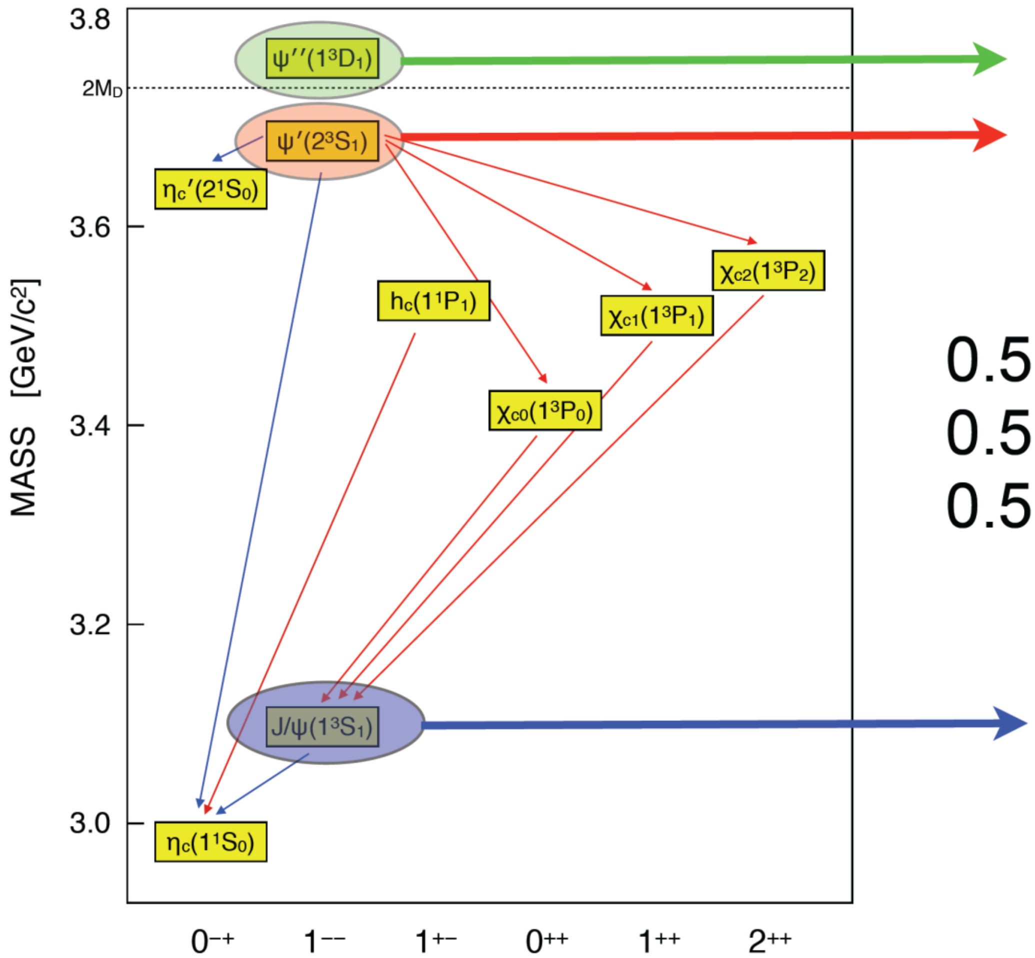


July 2008: first hadronic event
March 2009: physics data taking

BEijing **S**pectrometer - **III**

BESIII@BEPCII - breaking all records

(+data taken at 3.65 GeV and resonance scans)



~2.9 fb^{-1}

~106 million (+more)

✦~0.4 billion ψ(2S)

NEW

0.5 fb^{-1} @4010 MeV

0.5 fb^{-1} @4260 MeV

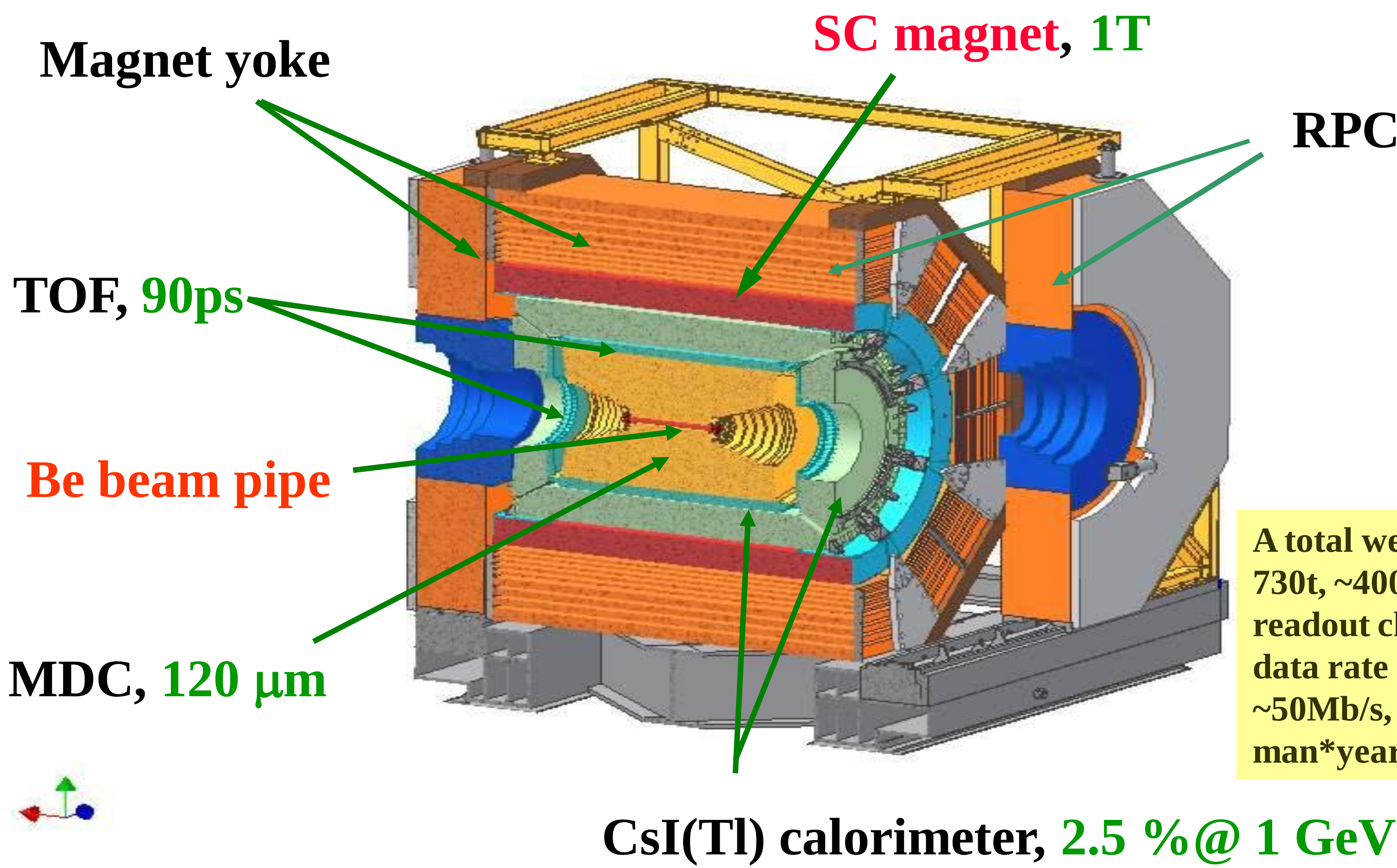
0.5 fb^{-1} @4360 MeV (ongoing!)

~225 million (+more)

✦~1 billion J/ψ

~10-20x previous generation charmonium factories

The BESIII Detector



A total weight of 730t, ~40000 readout channels, data rate 6000Hz ~50Mb/s, ~1000 man*year, 30 M$

BEPC II Storage ring: Double ring

Beam energy:
1.0-2.3 GeV

Design Luminosity:
$1 \times 10^{33}\ cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

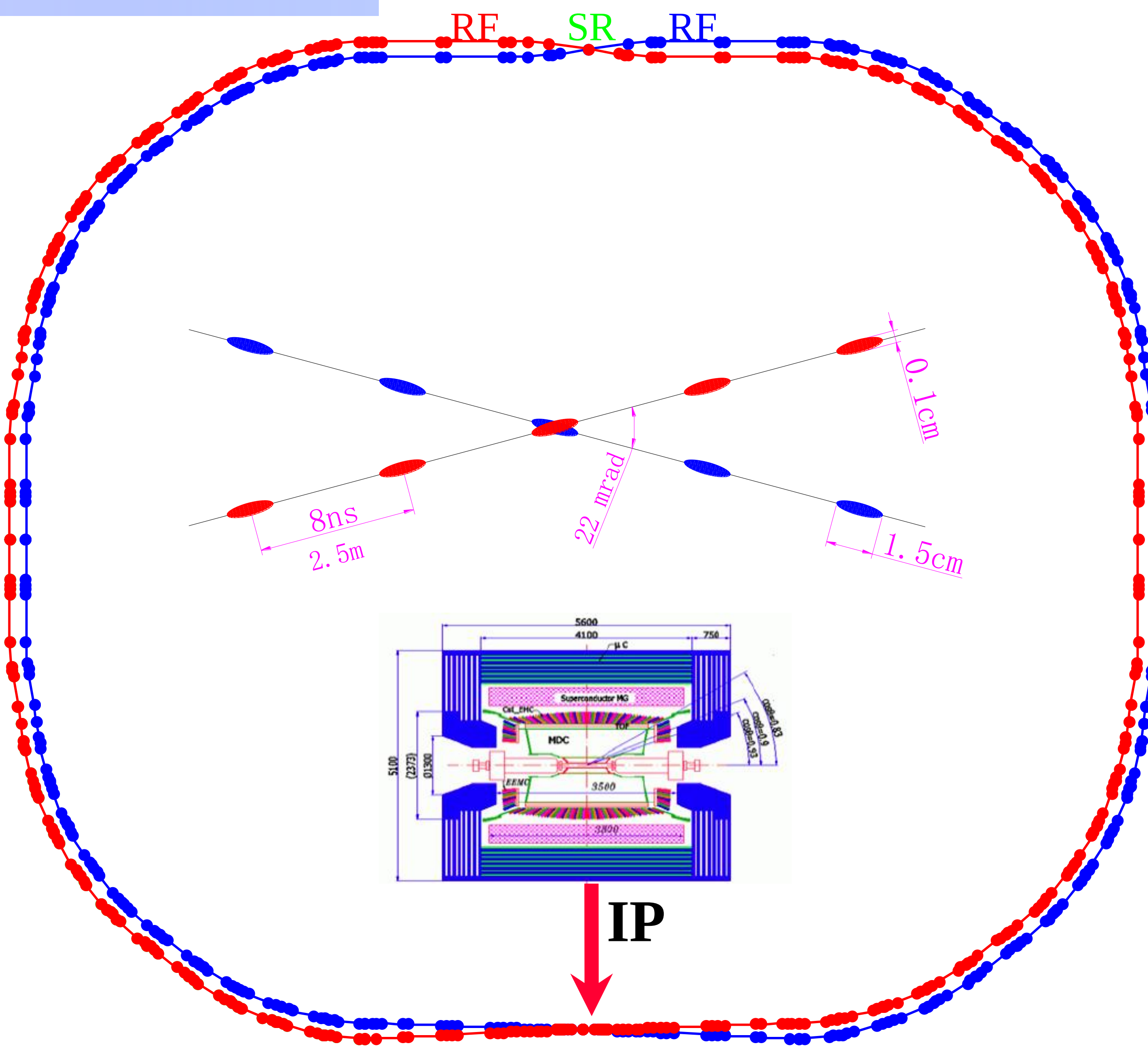
Energy spread:
5.16×10^{-4}

No. of bunches:
93

Bunch length:
1.5 cm

Total current:
0.91 A

Circumference :
237m



Physics of τ-charm region

Charmonium physics:
- Spectroscopy
- transitions and decays

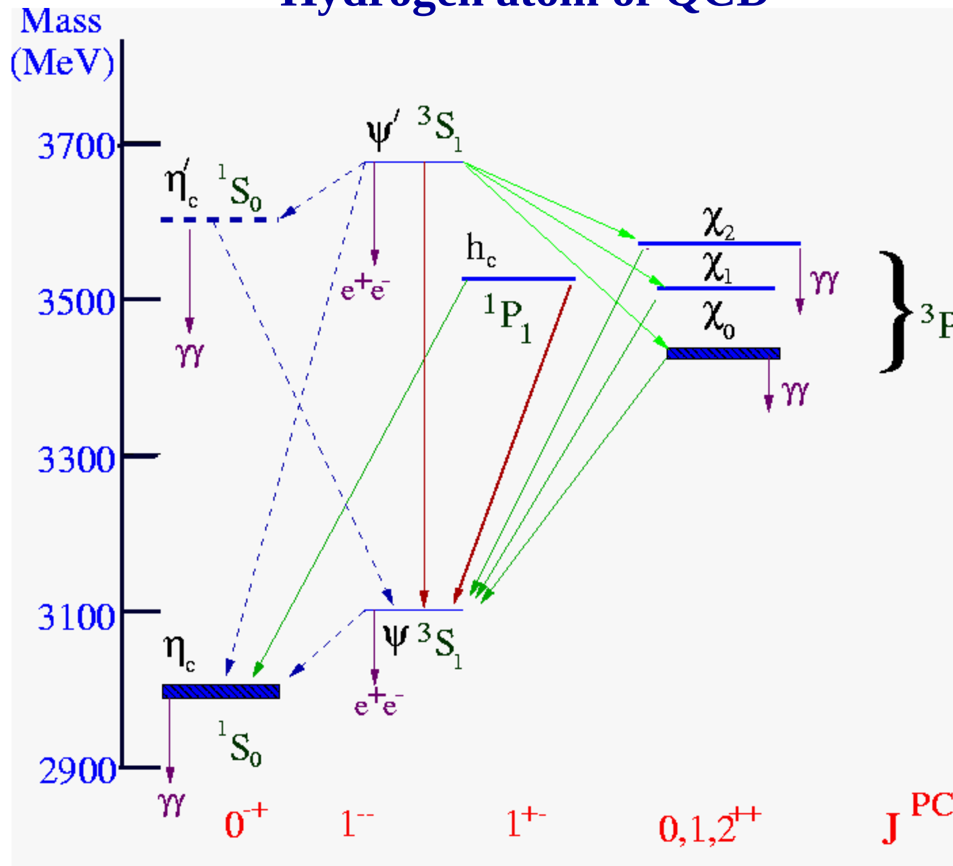
Light hadron physics:
- meson & baryon spectroscopy
- glueball & hybrid
- two-photon physics
- e.m. form factors of nucleon

Open Charm physics:
- (semi)leptonic + hadronic decays
- decay constant, form factors
- CKM matrix: Vcd, Vcs
- D^0-D^0bar mixing and CP violation
- rare/forbidden decays

Tau physics:
- Tau decays near threshold
- tau mass scan

…and many more.

"Hydrogen atom of QCD"



From discovery to precision...

- B (looks like DD for D or charm physics)
- E (looks like cc for charmonium physics)
- S (for light hadron Spectroscopy)
- T (for tau physics, looks like a Roman number “III”)

BESIII Collaboration

US (6)

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

Europe (12)

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

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Pakistan (2)

Univ. of Punjab
COMSAT CIIT

China(30)

IHEP, CCAST, GUCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.

~300 members
52 institutions from 11 countries

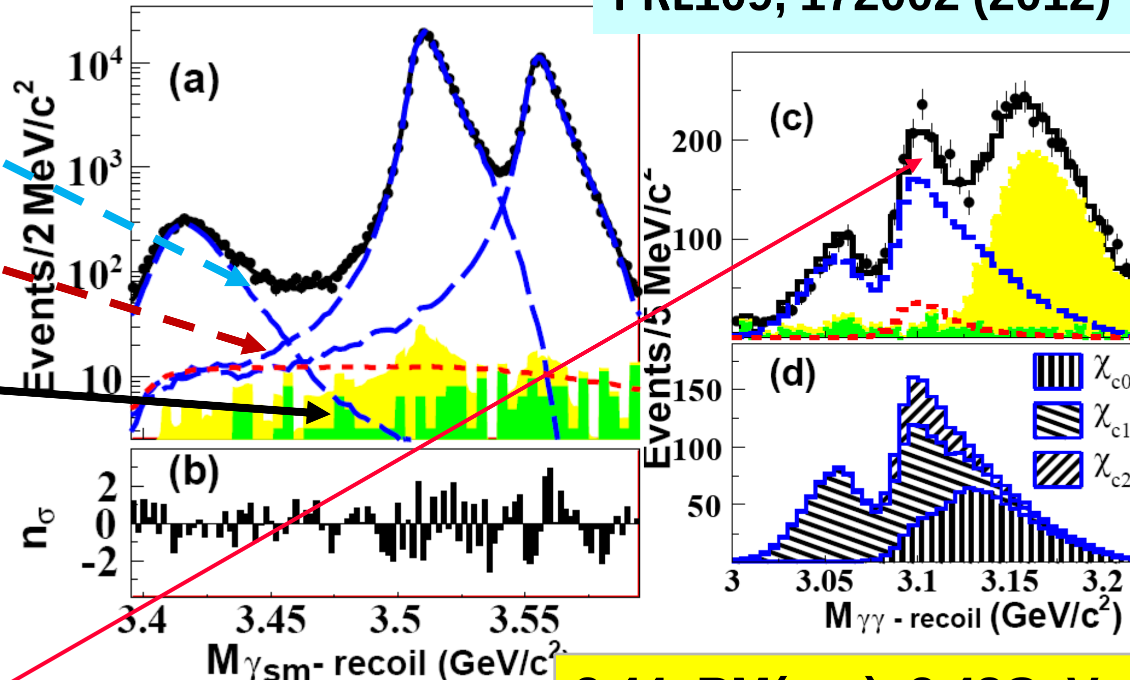
Recent results on Charmonium Spectroscopy and Transitions

- direct $\psi' \to \gamma\,\gamma\, J/\psi$ transition
- $\psi' \to \pi^0\, J/\psi$, $\eta\, J/\psi$
- $\psi' \to K^+K^-\pi^0$, $K^+K^-\eta$
- $\psi' \to p\,\underline{p}\,\pi^0$
- $\chi_{c0,2} \to \gamma\gamma$
- $\chi_{cJ} \to \Lambda\,\underline{\Lambda}\,\pi^+\pi^-$
- $\chi_{cJ} \to \Lambda\,\underline{\Lambda}$, $\Sigma^0\,\underline{\Sigma}^0$, $\Sigma^+\underline{\Sigma}^-$
- $\chi_{cJ} \to p\,\underline{n}\,\pi^-$, $p\,\underline{n}\,\pi^-\,\pi^0$
- $\eta_c(2S) \to K_sK^{+-}\,\pi^{-+}\,\pi^+\pi^-$

First evidence of $\psi' \to \gamma\gamma J/\psi$

PRL109, 172002 (2012)

- the χ_{cJ} components: double E1 scaling
- yields of the two-photon events
- continuum(green)+ ψ'-decay BG(yellow)



3.44<RM(γ_{sm})<3.48GeV

γ_{sm} - low energy gamma

- Global fit of the two-photon process and cascade χ_{cJ} processes
- See clear excess over BG + continuum

- $Br(\psi' \to \gamma\gamma J/\psi) = (3.1 \pm 0.6^{+0.8}_{-1.0}) \times 10^{-4}$ ($J/\psi \to ee$ and $\mu\mu$ mode combined)
- Significance: 3.8σ including systematics
- $Br(\psi' \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi)$ are also measured

$\psi' \to \eta J/\psi, \pi^0 J/\psi$

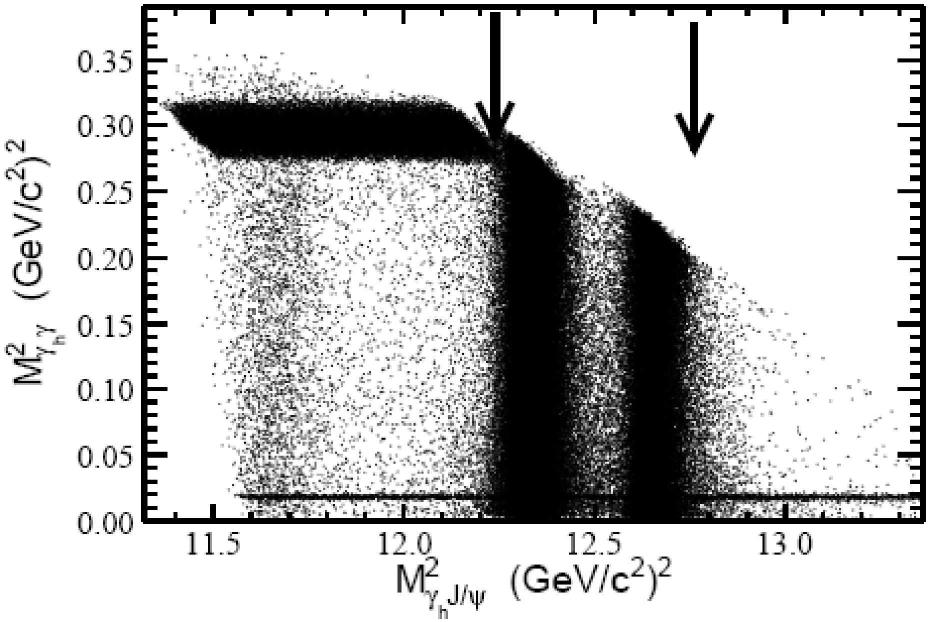
PRD 86, 092008(2012)

- **Decay final states:** $\gamma\gamma\mu^+\mu^-$ or $\gamma\gamma e^+e^-$
- $\psi' \to \pi^0 J/\psi$ isospin violation
- QCD multipole-expansion + axial anomaly $\Rightarrow$ R = 0.016

(G. A. Miller et al., Phys. Rep. 194, 1 (1990).)

- Charm-meson loops $\Rightarrow$ R = 0.11±0.06

(F. K. Guo et al., Phys. Rev. Lett., 103, 082003 (2009))



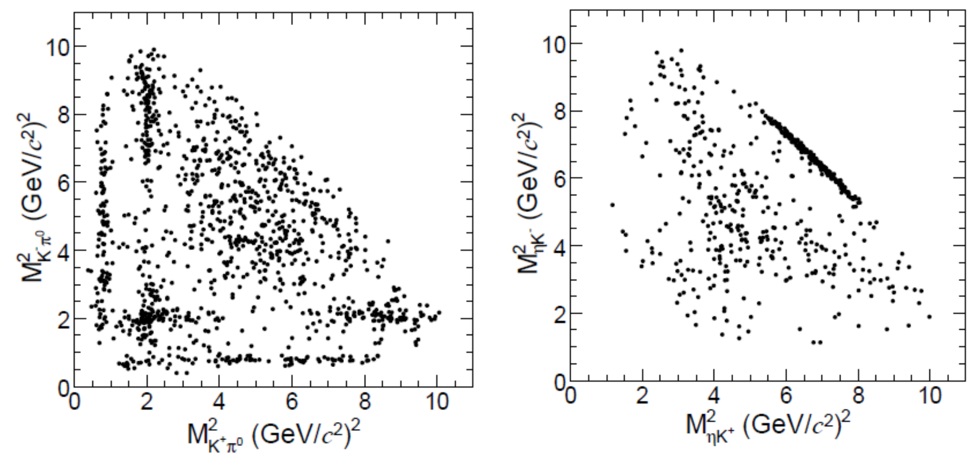
$\mathcal{B}$ or R	Combined	PDG[6]
$\mathcal{B}(\psi' \to \pi^0 J/\psi)$	—	—
$(\times 10^{-3})$	$1.26 \pm 0.02 \pm 0.03$	1.30 ± 0.10
$\mathcal{B}(\psi' \to \eta J/\psi)$	—	—
$(\times 10^{-3})$	$33.75 \pm 0.17 \pm 0.86$	32.8 ± 0.7
$R = \frac{\mathcal{B}(\psi' \to \pi^0 J/\psi)}{\mathcal{B}(\psi' \to \eta J/\psi)}$	–	—
$(\times 10^{-2})$	$3.74 \pm 0.06 \pm 0.04$	3.96 ± 0.42

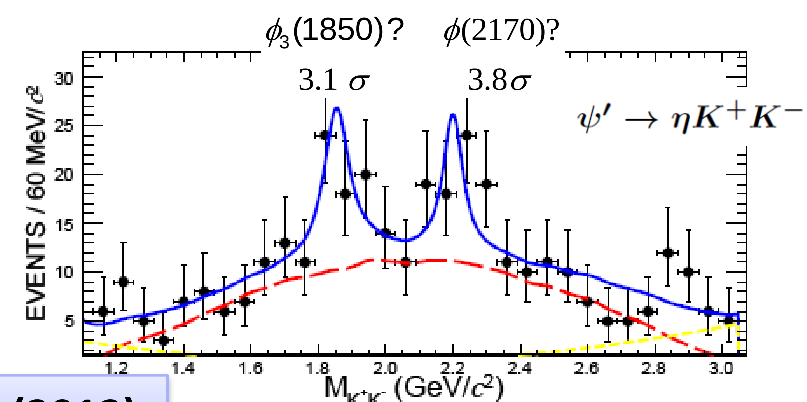
$\psi' \to K^+K^-\pi^0$, $K^+K^-\eta$

PRD 86, 072011 (2012)

- **Motivation**
  - Test 12% rule (Q_h) & Study $\rho\pi$ puzzle in $\psi' \to$ VP decays
  - Test HSR
  - Search for excited ϕ, K^* states
- **PWA applied**
  - Measured $\psi' \to KK^*$, $\phi\eta$, $\phi\pi^0$ (isospin violated)
  - Q_h in VP decays significantly deviate from 12%
- **First observation**: $\psi' \to K^+K^*_2(1430)^-$

  (HSR suppressed decay)





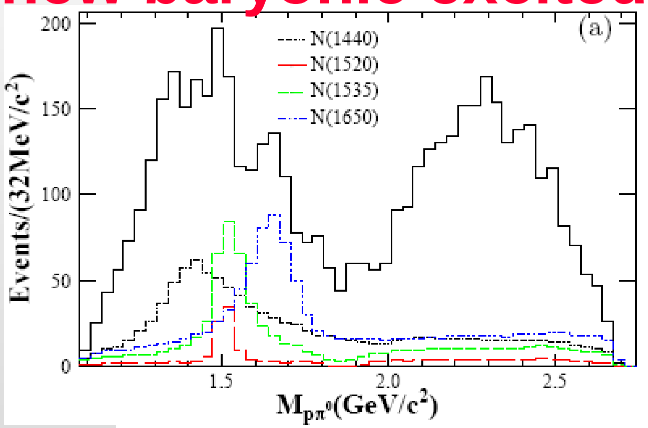
PRD 85, 074015 (2012)

BR($\psi' \to VP$)	EM	Short distance	Long distance	Strong	Total	BESIII($\times 10^{-5}$)
$K^{*+}K^- + c.c.$	7.03×10^{-6}	9.81×10^{-4}	1.33×10^{-3}	3.64×10^{-5}	1.70×10^{-5}	$3.18 \pm 0.30^{+0.26}_{-0.31}$
$\phi\eta$	2.26×10^{-6}	1.55×10^{-4}	1.73×10^{-4}	1.92×10^{-6}	2.25×10^{-6}	$3.14 \pm 0.23 \pm 0.23$
$\phi\pi^0$	9.78×10^{-8}	0	0	0	9.78×10^{-8}	<0.04

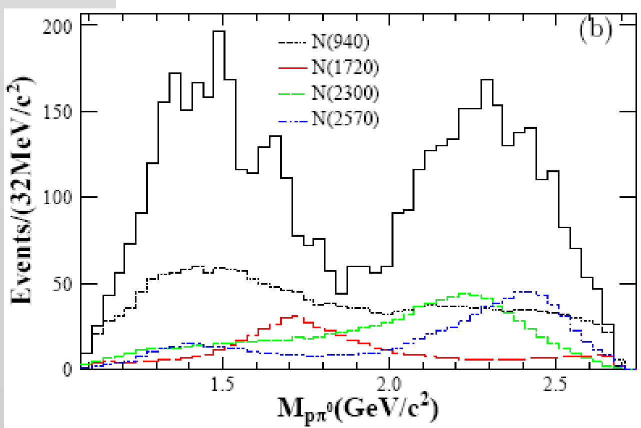
PWA of ψ' → p $\bar{p}$ π^0

PRL 110,022001 (2013)

- Non-relativistic quark model is successful in interpreting of the excited baryons
- Predicted more excited stated ("missing resonance problem")
- J/ψ (ψ') decays offers an window to search for the missing resonance
- Isospin conservation ⇒ Δ supressed
- **Two new baryonic excited states are observed !**



Resonance	M(MeV/c^2)	Γ(MeV/c^2)	ΔS	ΔN_{dof}	C.L.
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	72.5	4	11.5σ
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	19.8	6	5.0σ
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	49.4	4	9.3σ
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	82.1	4	12.2σ
$N(1720)$	1700^{+30+32}_{-28-35}	$450^{+109+149}_{-94\ -44}$	55.6	6	9.6σ
$N(2300)$	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$	120.7	4	15.0σ
$N(2570)$	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}	78.9	6	11.7σ



Resonance	N	ϵ(%)	B.F.($\times10^{-5}$)
$N(940)$	$1870^{+90+487}_{-90-327}$	27.2 ± 0.4	$6.42^{+0.20+1.78}_{-0.20-1.28}$
$N(1440)$	$1060^{+90+459}_{-90-227}$	27.6 ± 0.4	$3.58^{+0.25+1.59}_{-0.25-0.84}$
$N(1520)$	190^{+14+64}_{-14-48}	27.7 ± 0.4	$0.64^{+0.05+0.22}_{-0.05-0.17}$
$N(1535)$	$673^{+45+263}_{-45-256}$	25.5 ± 0.4	$2.47^{+0.28+0.99}_{-0.28-0.97}$
$N(1650)$	$1080^{+77+382}_{-77-467}$	26.9 ± 0.4	$3.76^{+0.28+1.37}_{-0.28-1.66}$
$N(1720)$	$510^{+27+50}_{-27-197}$	26.6 ± 0.4	$1.79^{+0.10+0.24}_{-0.10-0.71}$
$N(2300)$	$948^{+68+394}_{-68-213}$	33.8 ± 0.4	$2.62^{+0.28+1.12}_{-0.28-0.64}$
$N(2570)$	$795^{+45+127}_{-45-83}$	34.9 ± 0.4	$2.13^{+0.08+0.40}_{-0.08-0.30}$
Total	4515±93	25.5 ± 0.4	$16.5 \pm 0.3 \pm 1.5$

$\chi_{c0,2} \rightarrow \gamma\gamma$

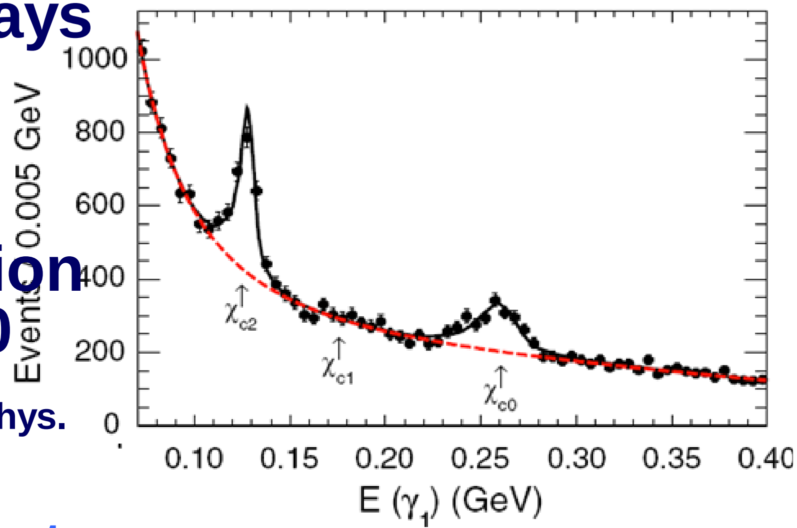
PRD85, 112008, (2012)

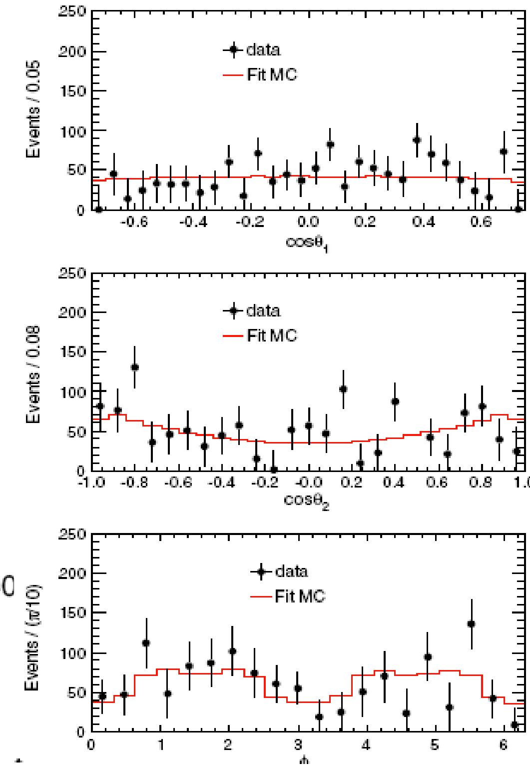
- **In analogy to the ^3P positronium decays**
  - $R \equiv \Gamma(^3P_2 \rightarrow \gamma\gamma)/\Gamma(^3P_0 \rightarrow \gamma\gamma) = 0.27$
- **First-order QCD radiative correction $\Rightarrow$ R=0.116±0.010**

(Voloshin, Prog. Part. Nucl. Phys. 61, 455 (2008))

- **First measurement of $f_{0/2} \equiv \Gamma^{\lambda=0}(\chi_{c2} \rightarrow \gamma\gamma) / \Gamma^{\lambda=2}(\chi_{c2} \rightarrow \gamma\gamma)$**
- **Relativistic potential model $\Rightarrow f_{0/2} < 0.5\%$**

(T. Barnes, in Proceedings of the IX International Workshop on Photon-Photon Collisions)



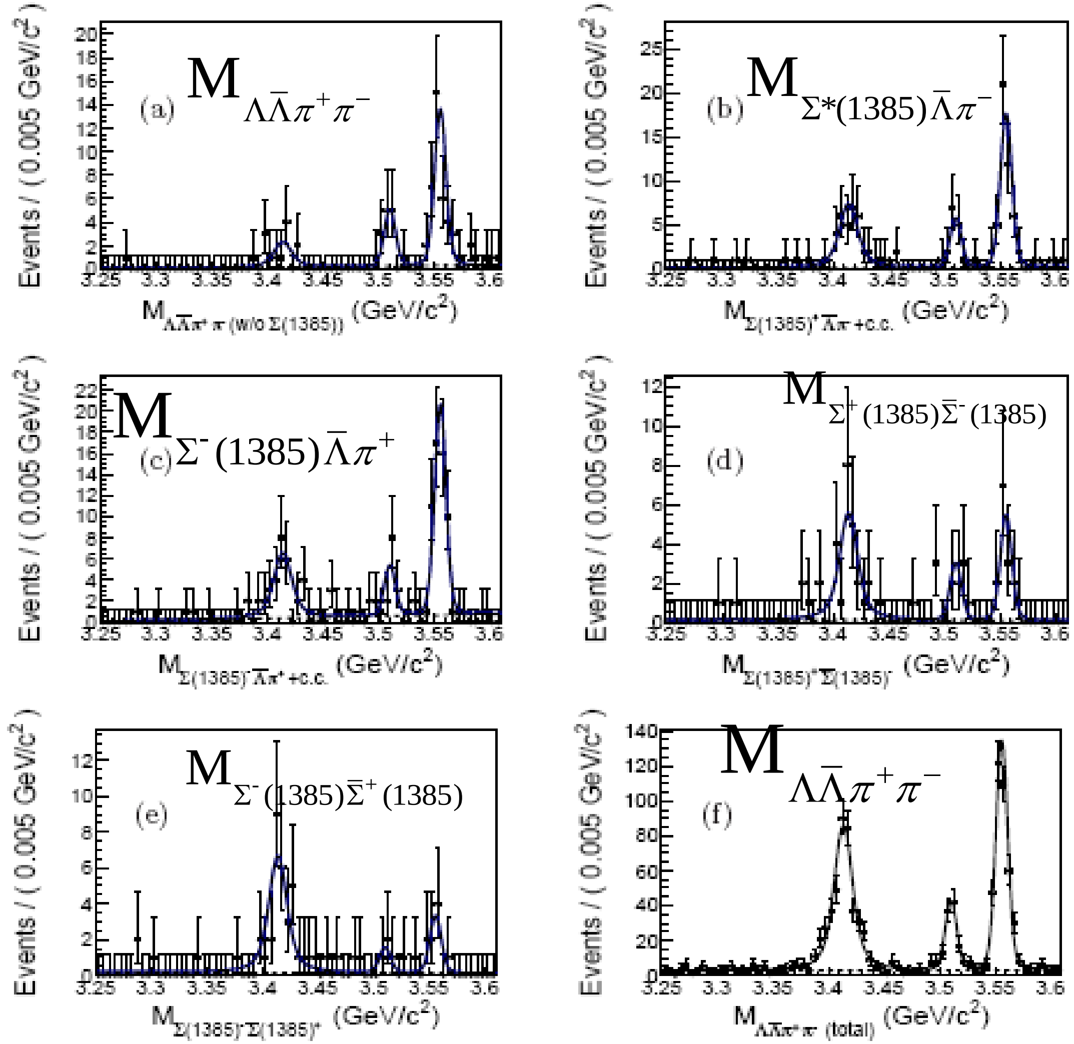


Quantity	PDG global fit results	This measurement[b]
$\mathcal{B}_1 \times \mathcal{B}_2 \times 10^5 (\chi_{c0})^c$	2.16 ± 0.18	$2.17 \pm 0.17 \pm 0.12$
$\mathcal{B}_1 \times \mathcal{B}_2 \times 10^5 (\chi_{c2})^c$	2.24 ± 0.17	$2.81 \pm 0.17 \pm 0.15$
$\mathcal{B}_2 \times 10^4 (\chi_{c0})^c$	2.23 ± 0.17	$2.24 \pm 0.19 \pm 0.15$
$\mathcal{B}_2 \times 10^4 (\chi_{c2})^c$	2.56 ± 0.16	$3.21 \pm 0.18 \pm 0.22$
$\Gamma_{\gamma\gamma}(\chi_{c0})$ (keV)	2.32 ± 0.22	$2.33 \pm 0.20 \pm 0.22$
$\Gamma_{\gamma\gamma}(\chi_{c2})$ (keV)	0.50 ± 0.05	$0.63 \pm 0.04 \pm 0.06$
$\mathcal{R}$	0.22 ± 0.03	$0.27 \pm 0.03 \pm 0.03$
$f_{0/2}$	...	$0.00 \pm 0.02 \pm 0.02$

$\chi_{cJ} \rightarrow \Lambda \bar{\Lambda} \pi^+ \pi^-$

PRD 86, 052004 (2012)

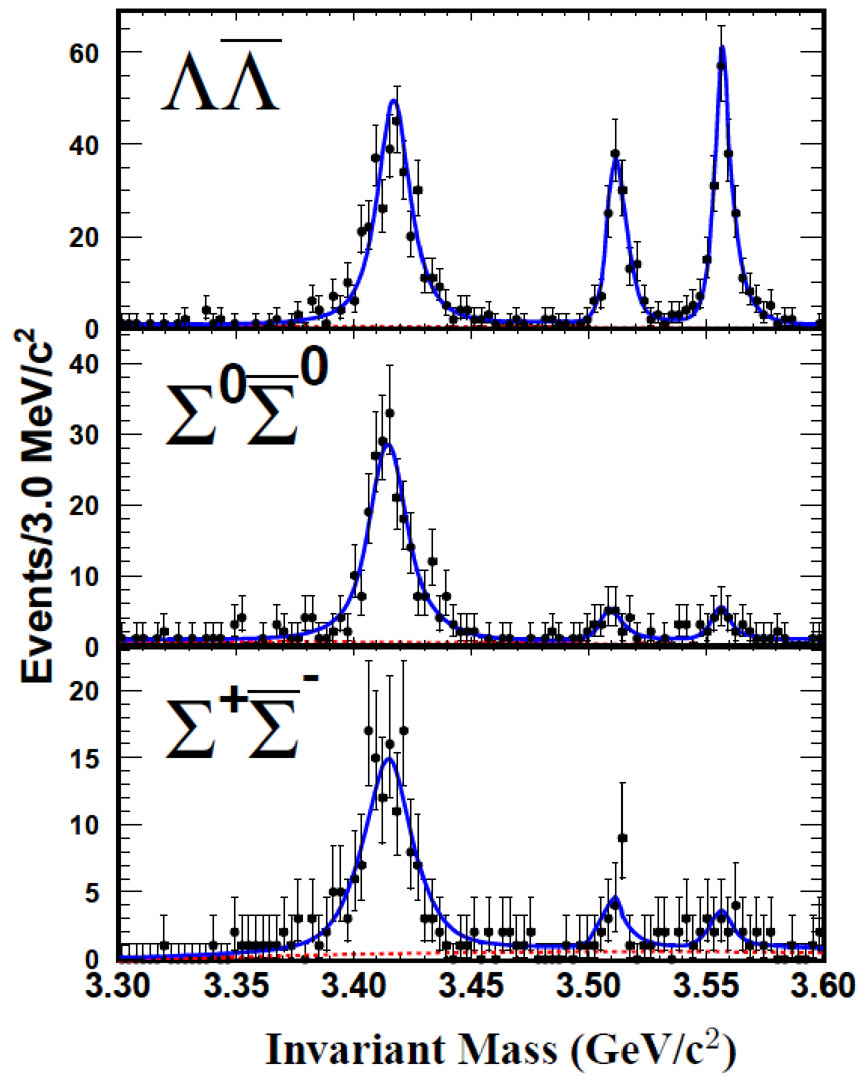
- **Color-Octet contribution: Large effect in P-wave state.**
  - **e.g. : $\chi_{cJ} \rightarrow p\bar{p}$, theoretical prediction consistent with exp.** (Wong, Nucl. Phys. A674, 185 (2000))
  - **$\chi_{cJ} \rightarrow \Lambda\Lambda$bar not consistent**
  - **What about other baryon anti-baryon decays?**
- **Experiment measured**
  - **NR: $\chi_{cJ} \rightarrow \Lambda$ Λbar $\pi^+ \pi^-$**
  - **$\chi_{cJ} \rightarrow \Sigma(1385)^+\Lambda$bar π^- +cc**
  - **$\chi_{cJ} \rightarrow \Sigma(1385)^-\Lambda$bar π^+ +cc**
  - **First evidence: $\chi_{cJ} \rightarrow \Sigma(1385)\Sigma$bar(1385)**
  - **Experiment consist with theoretical prediction**



$\chi_{cJ} \to \Lambda \bar{\Lambda}, \Sigma^0 \bar{\Sigma}^0, \Sigma^+ \bar{\Sigma}^-$ □

PRD 86, 052004 (2012)

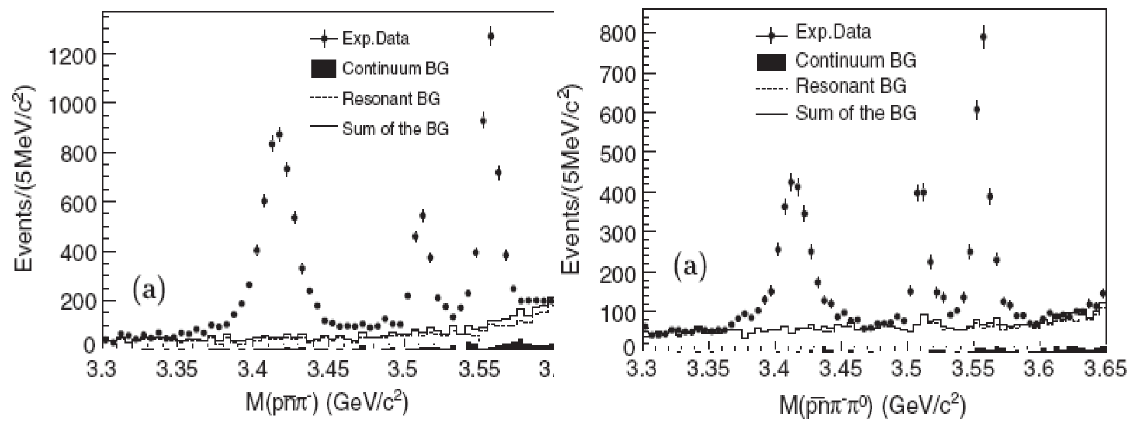
- χ_{cJ} decay properties are essential to test pQCD models and QCD-based calculations.
- many decay modes of $\chi_{cJ} \to B\bar{B}$ have not been observed yet, or measured with poor precision.
- measurements of $\chi_{cJ} \to B\bar{B}$ are helpful for understanding the HSR, which prohibits χ_{c0} decays into baryon-antibaryon pairs.

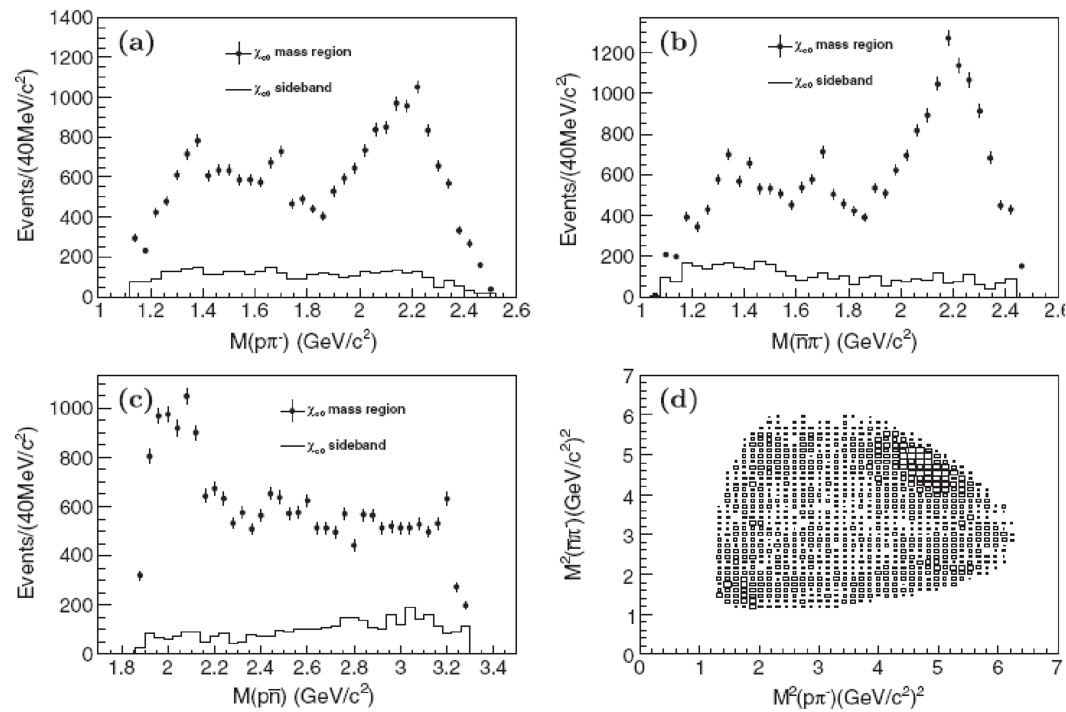


$\chi_{cJ} \rightarrow p\,\bar{n}\,\pi^-,\ p\,\bar{n}\,\pi^-\pi^0$

PRD 86, 052011 (2012)

- **Color-Octet contribution: Large effect in P-wave state.**
- **Search for N* states**
- **Experiment measured**
  - **Branching fractions for**
    $\chi_{c0,1,2} \rightarrow p\,\bar{n}\,\pi^-$ +c.c.
    $\chi_{c0,1,2} \rightarrow p\,\bar{n}\,\pi^-\pi^0$ +c.c.
    (most precise measurements)
- **Intermediate states:**
  - **N*(1400), N*(1700) in both $p\pi$ and $\bar{n}\,\pi$**
  - **Threshold enhancement of $p\bar{n}$, or N*(2190), N*(2220)?**
  - **Further detailed PWA need to be done!**

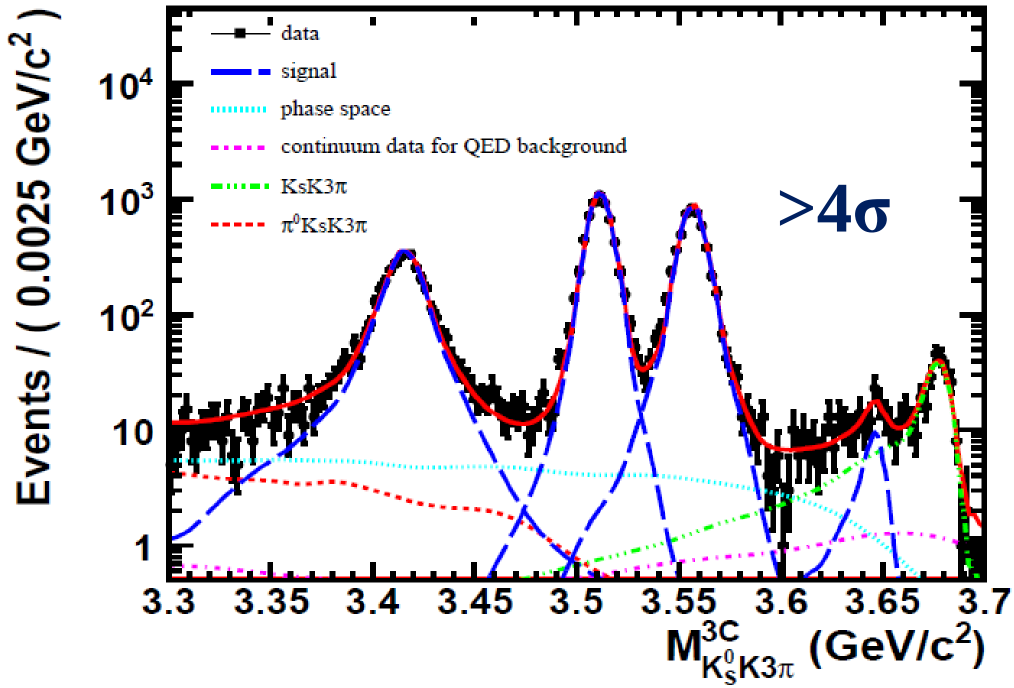




Evidence $\eta_c(2S) \rightarrow KsK^{+-} \pi^{-+} \pi^{+}\pi^{-}$

arXiv:1301.1476

- For $\eta_c(2S)$, only two measured decay Brs are available: KKbar π and $K^+K^- \pi^+ \pi^- \pi^0$
- $\psi' \rightarrow \gamma\eta_c(2S)$: M1 transition
- Search for more $\eta_c(2S)$ decay modes
- To measure the mass, width of $\eta_c(2S)$



$M=3646.9\pm1.6\pm3.6$ MeV/c^2

$\Gamma=9.2\pm4.8\pm2.9$ MeV

$B(\psi' \rightarrow \gamma\eta_c(2S))xB(KsK^{+-} \pi^{-+} \pi^{+}\pi^{-})=$
$(7.03\pm2.10\pm0.70)x10^{-6}$

The measured M and Γ are consistent with values in PRL109, 042003

Recent results on Light Hadron Spectroscopy

- $J/\psi \to \Lambda \underline{\Sigma}^0$
- PWA of $J/\psi \to \gamma\eta\eta$
- PWA of $J/\psi \to \gamma\omega\phi$

$J/\psi \to \Lambda\bar{\Sigma}^0$ + c.c.

PRD86,032008(2012)

- **PDG2010: $Br(J/\psi \to \Lambda\bar{\Sigma}^0) < 1.5 \times 10^{-4}$**
- **First observation**
- **Study isospin breaking mechanism in $J/\psi \to \Lambda\bar{\Sigma}^0$ + c.c.**
- **Search for $\Lambda(1520) \to \gamma\Lambda$**
- **Measured $\eta_c \to \Lambda\bar{\Lambda}$ (Only observed by Belle in $B \to \Lambda\bar{\Lambda}K$ before)**

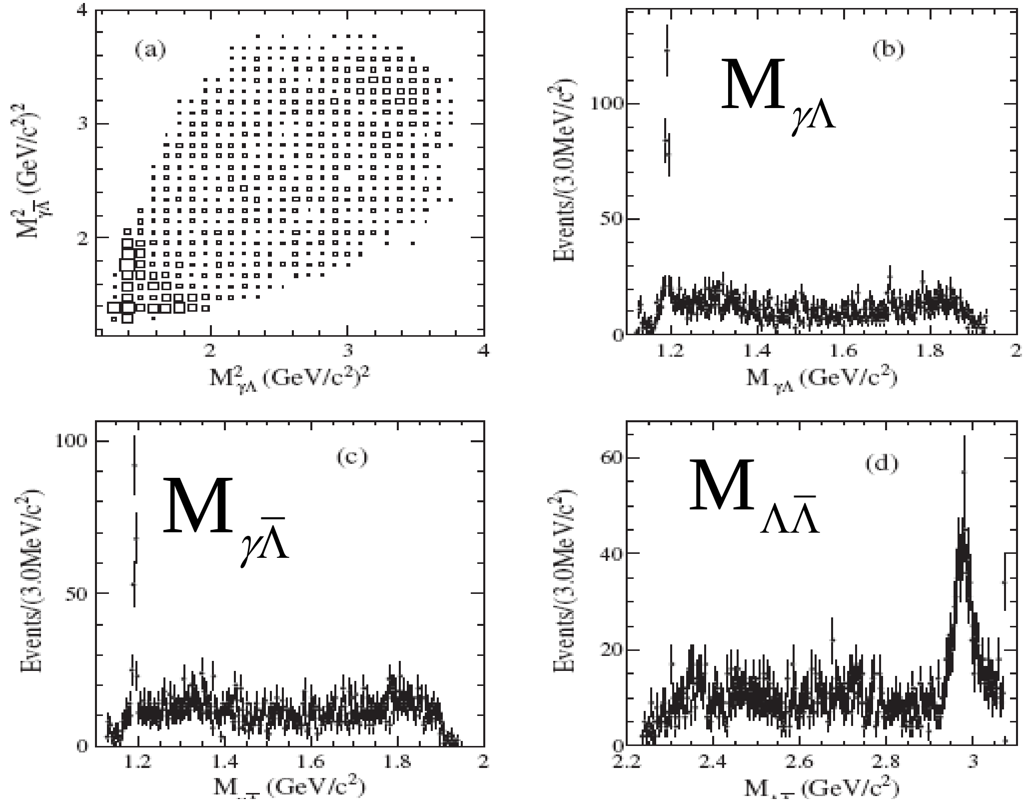


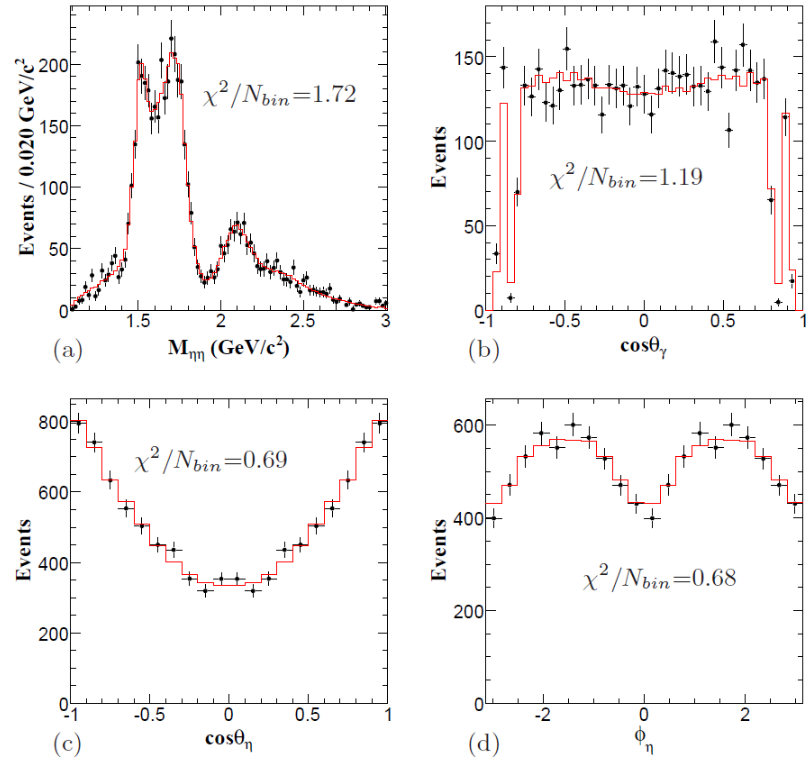
TABLE Branching fractions (10^{-5})

J/ψ decay mode	BESIII	PDG
$\bar{\Lambda}\Sigma^0$	$1.46 \pm 0.11 \pm 0.12$	<7.5
$\Lambda\bar{\Sigma}^0$	$1.37 \pm 0.12 \pm 0.11$	<7.5
$\gamma\eta_c(\eta_c \to \Lambda\bar{\Lambda})$	$1.98 \pm 0.21 \pm 0.32$	⋯
$\Lambda\bar{\Lambda}(1520)$ + c.c.$(\bar{\Lambda}(1520) \to \gamma\bar{\Lambda})$	<0.41	⋯

PWA of J/ψ → γηη

arXiv:1301.0053

- Search for glueballs, hybrids and multi-quarks
- LQCD: the lowest mass glueball with 0^{++} is in the mass region from 1.5-1.7 GeV
- the mixing with q $\bar{q}$ nonet mesons makes the identification of the glueballs difficult
- Radiative J/ψ decay is a gluon-rich process
- J/ψ radiative decay to two pseudoscalar mesons offers a very clean laboratory to search for scalar and tensor glueballs

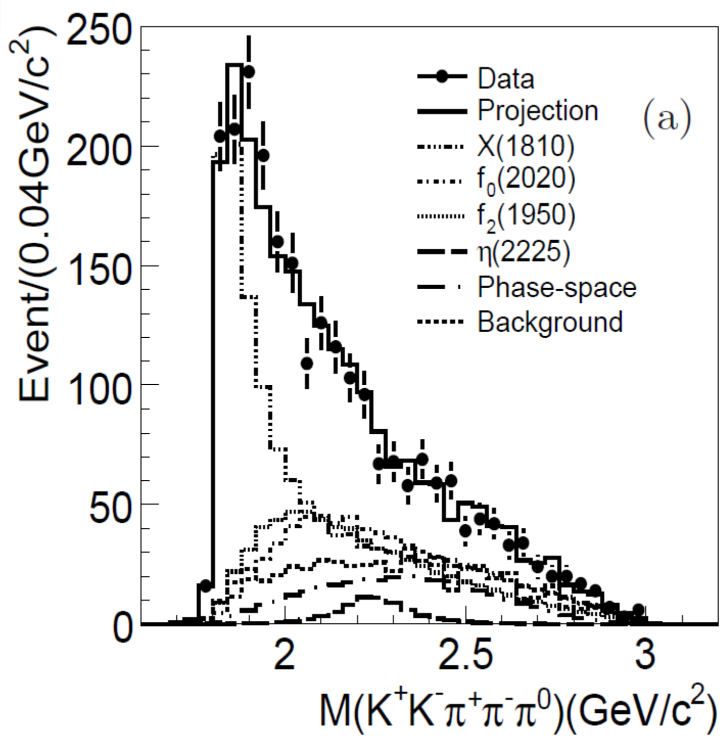


Resonance	Mass(MeV/c^2)	Width(MeV/c^2)	$\mathcal{B}(J/\psi \to \gamma X \to \gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+23}_{-15-74}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40}) \times 10^{-5}$	8.2 σ
$f_0(1710)$	$1759\pm6^{+14}_{-25}$	$172\pm10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$	25.0 σ
$f_0(2100)$	$2081\pm13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28}) \times 10^{-4}$	13.9 σ
$f_2'(1525)$	$1513\pm5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30}) \times 10^{-5}$	11.0 σ
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35}) \times 10^{-5}$	6.4 σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$	7.6 σ

PWA of $J/\psi \to \gamma\omega\phi$

arXiv:1211.5668

- X(1810) was observed in $J/\psi \to \gamma\omega\phi$ by BESII [PRL96,162002]
- PWA: 0^{++} favors 0^{-+} or 2^{++} (>10σ)
- $J/\psi \to \gamma\omega\phi$ is a doubly OZI suppressed process
- Possible interpretations: a tetraquark state, a hybrid, or a glueball state, a dynamical effect arising from intermediate meson rescattering, or a threshold cusp of an attracting resonance.



Resonance	J^{PC}	M(MeV/c^2)	Γ(MeV/c^2)	Events	ΔS	Δndf	Significance
$X(1810)$	0^{++}	1795 ± 7	95 ± 10	1319 ± 52	783	4	$> 30\sigma$
$f_2(1950)$	2^{++}	1944	472	665 ± 40	211	2	20.4σ
$f_0(2020)$	0^{++}	1992	442	715 ± 45	100	2	13.9σ
$\eta(2225)$	0^{-+}	2226	185	70 ± 30	23	2	6.4σ
phase space	0^{-+}	—	—	319 ± 24	45	2	9.1σ

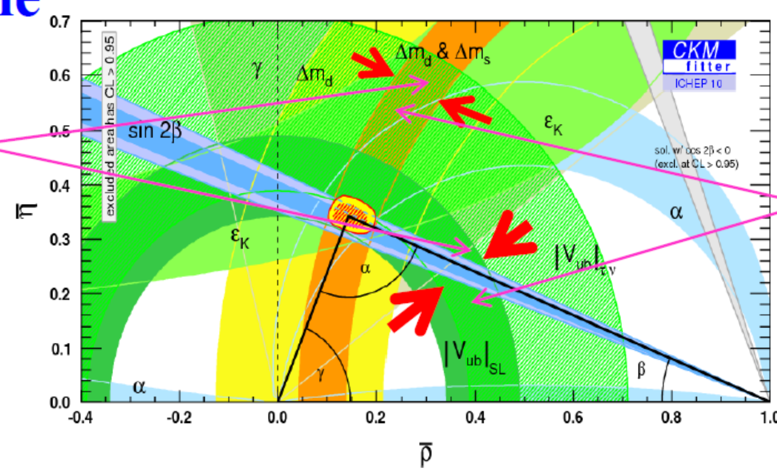
Open charm physics (all results are preliminary)

- $D^+ \to \mu^+ \nu$
- $D^0 \to K^- / \pi^- e^+ \nu$
- Search for $D^0 \to \gamma\gamma$

Leptonic and semileptonic D decays

- **D^+ leptonic decays play an important role in understanding of the SM of particle physics**
- **Unitary triangle**

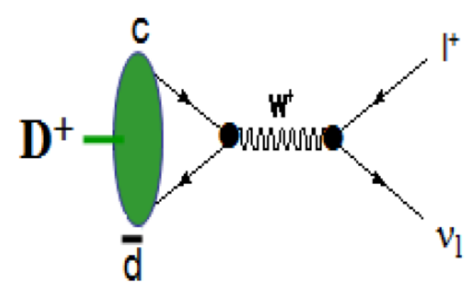
Widths of bands are dominated by errors of f_B and f_{B_s} from LQCD.



The widths of bands will be reduced if the LQCD pass the test with measured f_D, f_{Ds}.

- **f_{D+} test LQCD calculations of f_{B+}**

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



- **Reduced width of band in triangle would lead to precisely test the SM, and search for new physics beyond the SM.**

Leptonic and semileptonic D decays

- **D+ decay constant ($f_{D+} \rightarrow f_{B+}$) affect**
  - $|V_{ub}|$ extracted from $B^+ \rightarrow l^+ v$
  - $|V_{td}|$ extracted from Δm_d in $B^0 B^0$ mixing

These are used to constraint the unitary triangle

- **D^+ leptonic decay branching fractions determine**
  - $|V_{cd}|$ extracted from $D^+ \rightarrow l^+ v$

- **Precise measurement of f_{D+} together with and f_{Ds} probe New Physics**

Accumulating Evidence for Nonstandard Leptonic Deacsy of Ds Mesons

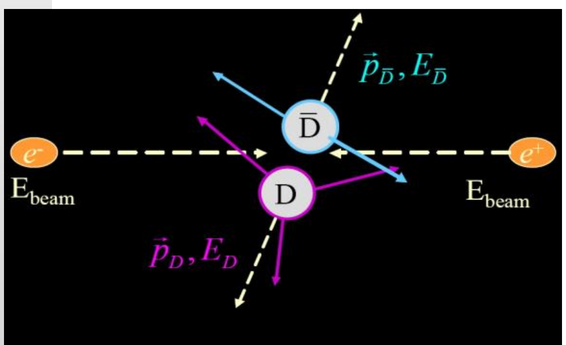
B.A. Dobressu and A.S. Kronfeld, PRL100, 241802 (2008)

R-parity violating supersymmetry, B_s mixing, and Ds$\rightarrow$lν.

A. Kundu and S. Nandi, PRD78, 015009 (2008)

ν Recon. @charm threshold

- 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 $D^0\bar{D}^0$ and D^+D^-
- Fully reconstruct about 15% of *D* decays



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

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

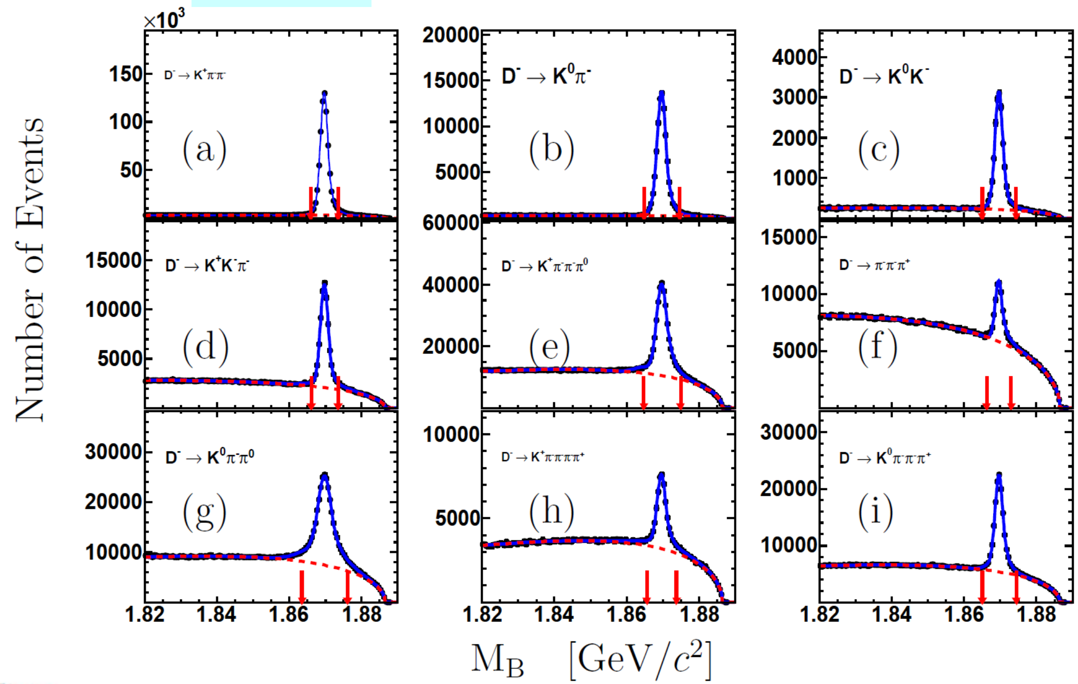
- Double tag techniques: Hadronic tag on one side, on the other side for leptonic/semileptonic studies. Neutrino is reconstructed from missing energy and momentum (Double tag efficiency is high.)

$D \to \mu\nu$ (BESIII: 2.9 fb^{-1})

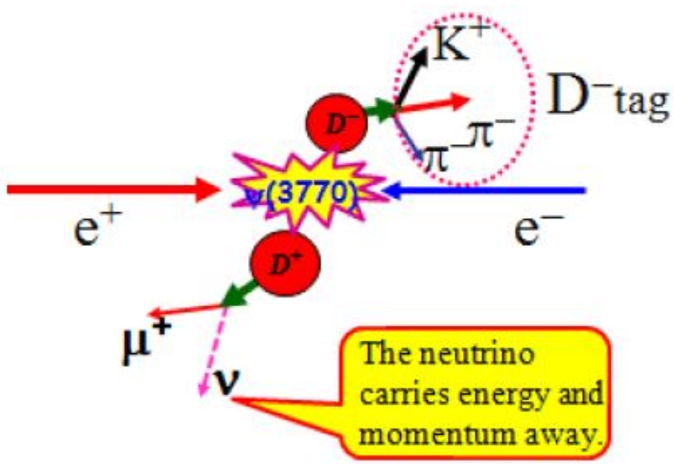
- Tag side recon.:
  - 9 decay modes
  - Kinematic variables: Beam-constrained mass and ΔE
  - (1.57±0.2) M tags found

2.9 fb^{-1}

arXiv:1209.0085

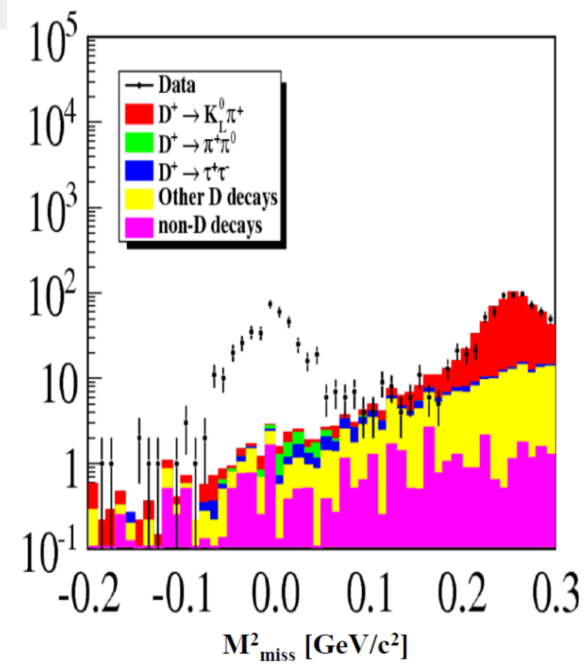


Beam-constrained mass of tag D



$D \to \mu\nu$ (BESIII: 2.9 fb^{-1})

- **Signal side reconstruction:**
  - **One charged track only**
  - **Kinematic variable: M^2_{miss}**
- **425 candidates**



BES III preliminary:

***N*($D^+ \to \mu^+\nu$) = 377.3 ± 20.6**

$$M^2_{miss} = \left(E_{Beam} - E_m\right)^2 - \left(-\vec{p}_{tag} - \vec{p}_m\right)^2 \approx 0$$

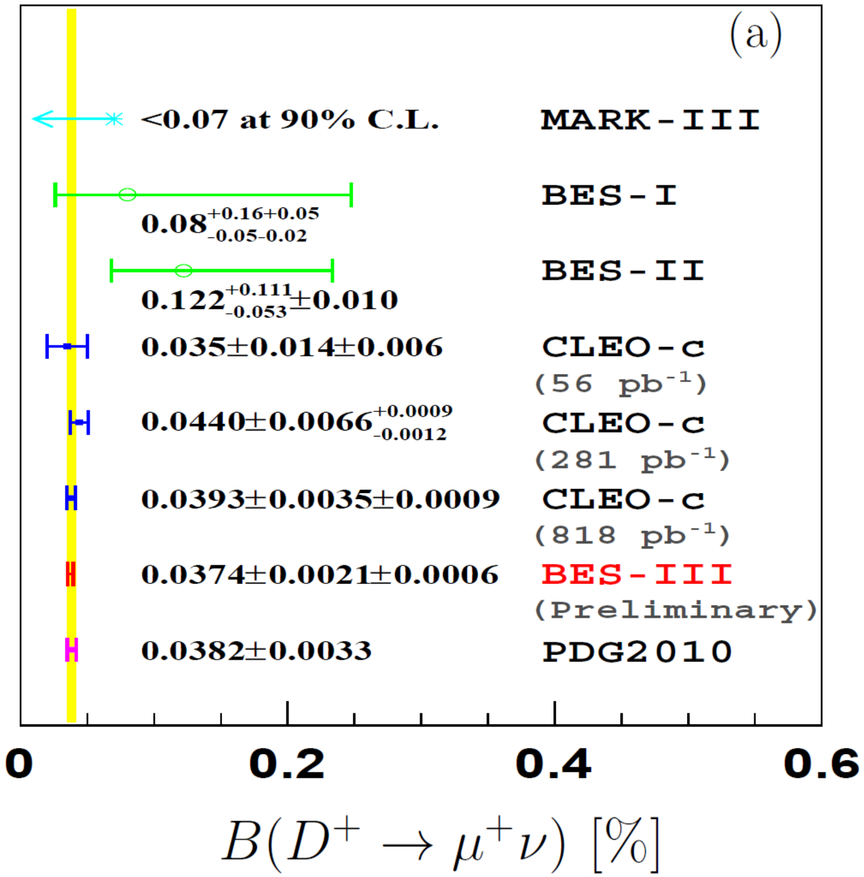
Experiment	$\mathcal{B}(D \to \mu\nu)$	f_d
BES III (preliminary)	$(3.74 \pm 0.21 \pm 0.06) \times 10^{-4}$	$(203.91 \pm 5.72 \pm 1.97)$ MeV
CLEO-c	$(3.82 \pm 0.32 \pm 0.09) \times 10^{-4}$	$(205.8 \pm 8.5 \pm 2.5)$ MeV
Average	$(3.76 \pm 0.18) \times 10^{-4}$	(204.5 ± 5.0) MeV

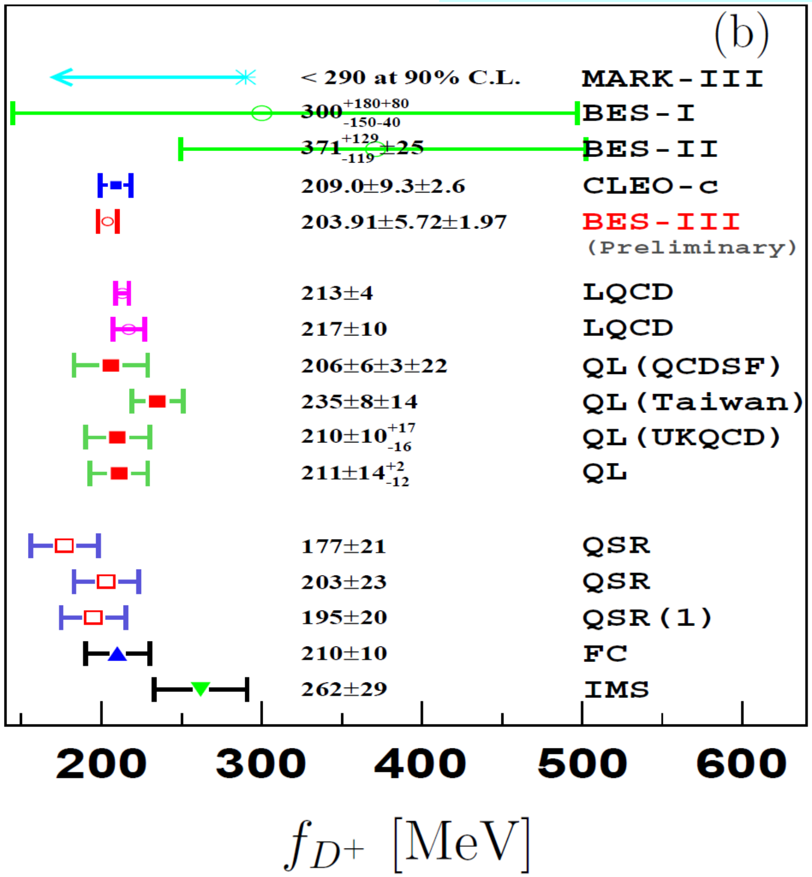
The error is still dominated by statistics, more data at threshold is needed.

$|V_{cd}| = 0.2218 \pm 0.0062 \pm 0.0047$ (BESIII Preliminary).

Comparison of Br & f_{D+}

arXiv:1209.0085



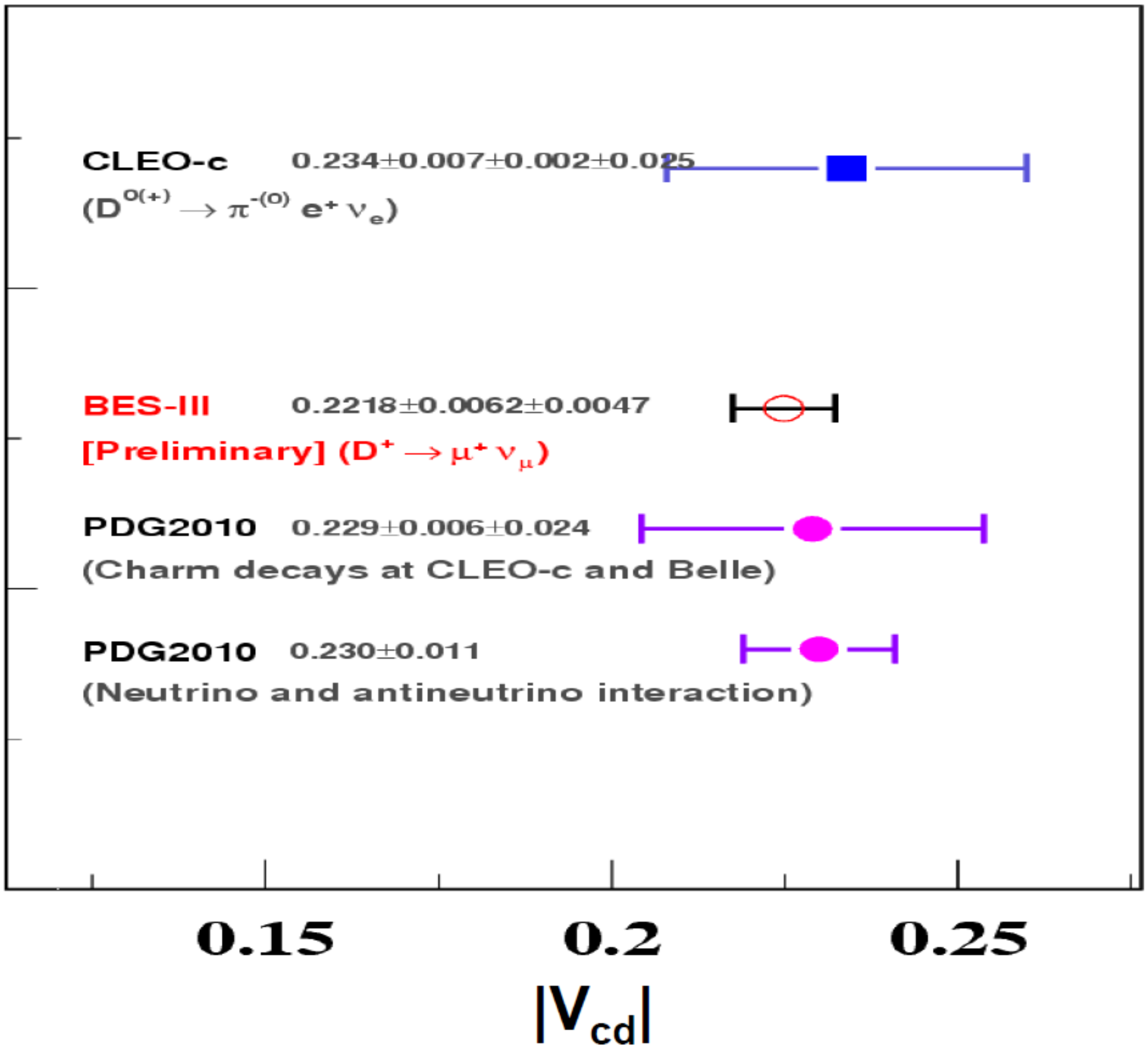


QSR: QCD sum rule

FC: Field Correlations

IMS: Isospin mass Splittings

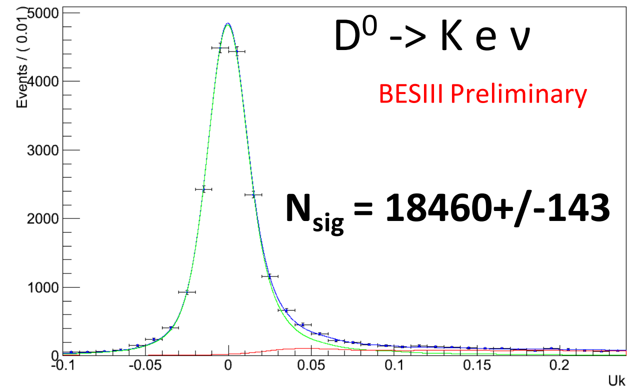
Comparison of $|V_{cd}|$

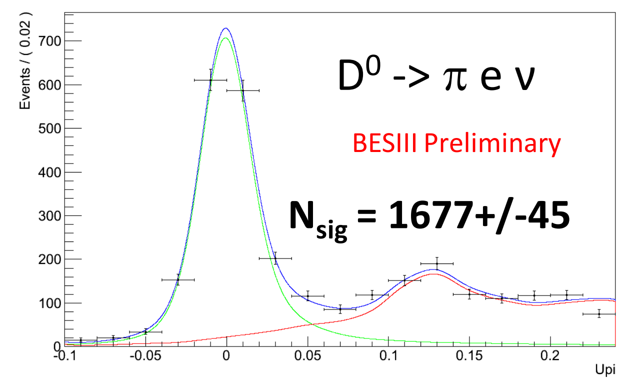


The most precise determination of $|V_{cd}|$ is from the BES-III

$D^0 \rightarrow K^-/\pi^- e^+\nu$ (BESIII: 0.9 fb^{-1})

- **BESIII Preliminary results**
- **"Partially blind" analysis (0.9 fb^{-1} analyzed so far. Full 2.9 fb^{-1} later for final results)**
- **Tag side reconstruction:**
  - **4 decay modes ($K^+\pi^-$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^0\pi^0$, $K^-\pi^+\pi^+\pi^-$)**
  - **0.77 M tags found**
- **Signal side reconstruction:**
  - **two oppositely-charged tracks**
  - **Kinematic variable: U_{miss}**
- **Systematic uncertainties are preliminary**
- **Good consistency with CLEO-c, statistical precision is comparable with only 1/3 data analyzed**



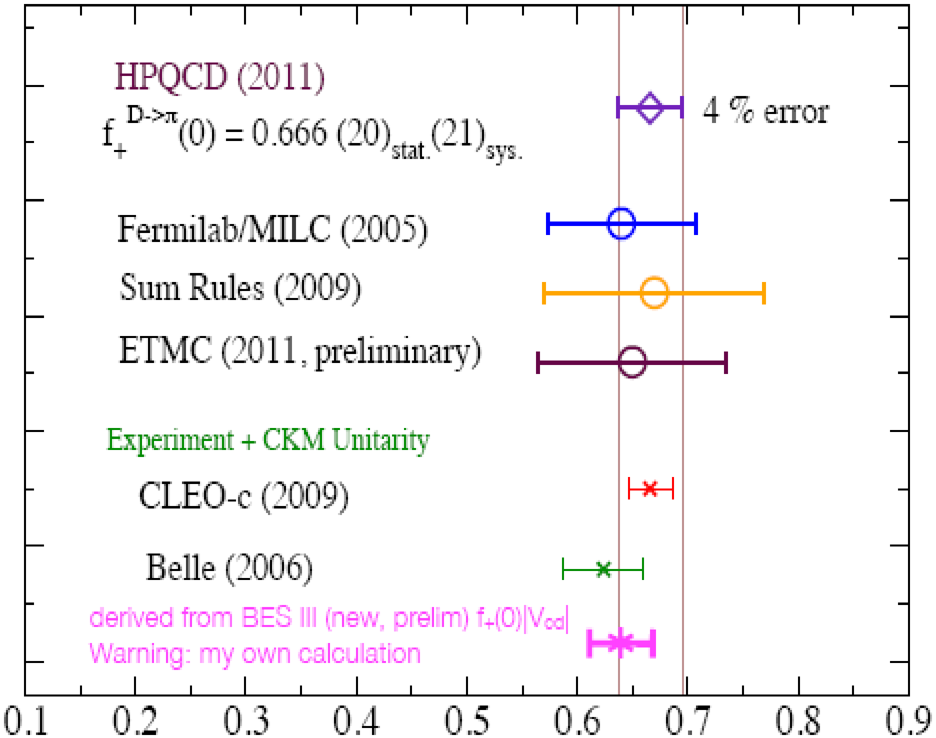


$$U = E_{miss} - |\vec{P}_{miss}| \approx 0$$

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

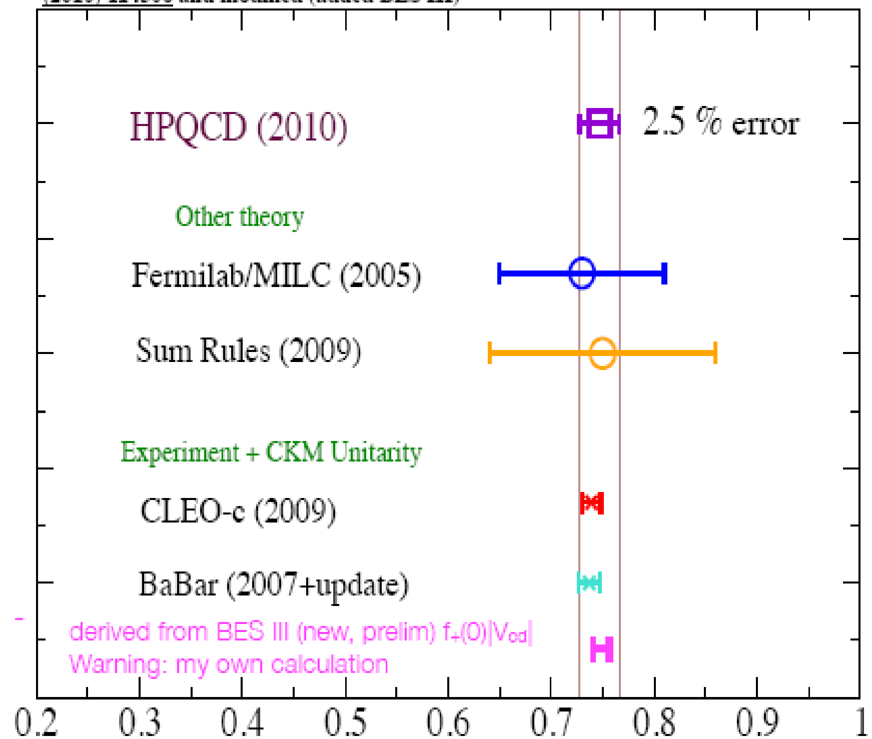
FF from experiment and theory

Taken from Na, Davies, Follana, Koponen, Lepage and Shigemitsu, Phys.Rev. D84 (2011) 114505 and modified (added BES III)



$f_+^{D\to\pi}(0)$

Taken from Na, Davies, Follana, Koponen, Lepage and Shigemitsu, Phys.Rev. D82 (2010) 114506 and modified (added BES III)



$f_+^{D\to K}(0)$

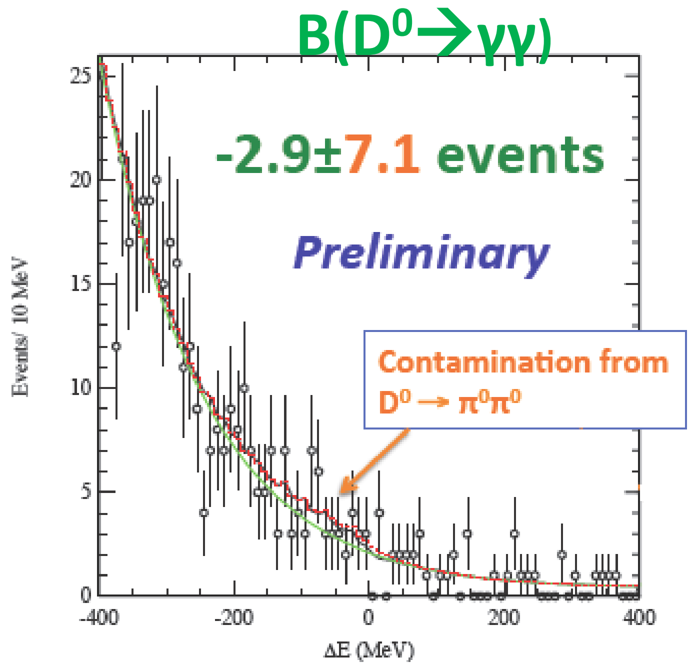
- From Jonas Rademacker at FPCP2012
- Note: BESIII result from D^0 only, CLEO-c use both D^0 and D^+

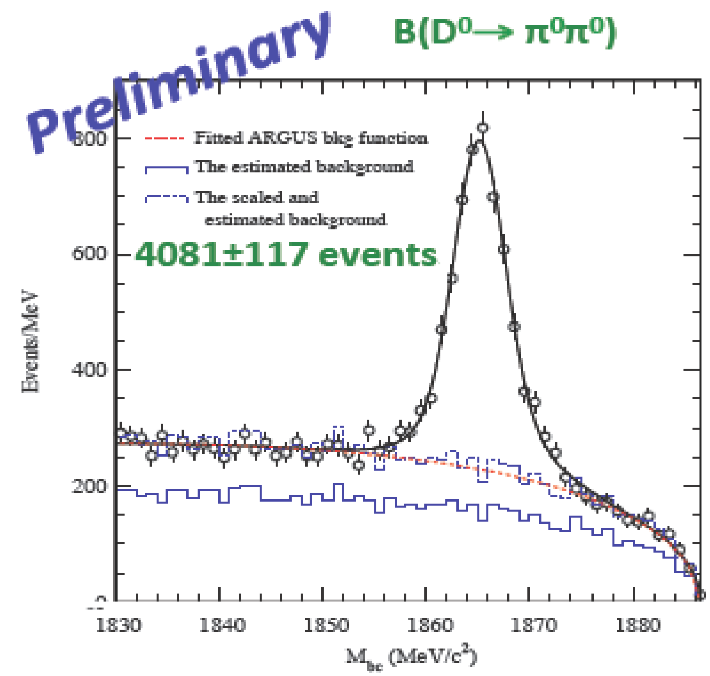
Search for $D^0 \to \gamma\gamma$

PRD64, 074008

Theoretical predictions: SM (short distance)~ 10^{-11}

Long distance ~10^{-8} (dominant)





$B(D^0 \to \gamma\gamma)/B(D^0 \to \pi^0\pi^0) < 5.8\times10^{-3}$ @90% CL, with PDG value: $B(D^0 \to \pi^0\pi^0) = 8\times10^{-4}$,

BESIII: $B(D^0 \to \gamma\gamma)) < 4.6\times10^{-6}$ @90% CL.

BaBar: $B(D^0 \to \gamma\gamma) < 2.2\times10^{-6}$ @90% CL.[PRD 85, 091107(R)]

Studies of XYZ at BESIII

- First observation of $e^+e^- \to \eta\ J/\psi$ @$\sqrt{s}$=4.009 GeV
- Expected Y(4260/4360) $\to \pi^+\pi^-\ J/\psi$
- Search for Y(4260) $\to \pi^+\pi^- h_c(1P)$ / $\gamma\eta_c$
- Search for the $h_c(2P)$
- Determine the Y(4260) lineshape

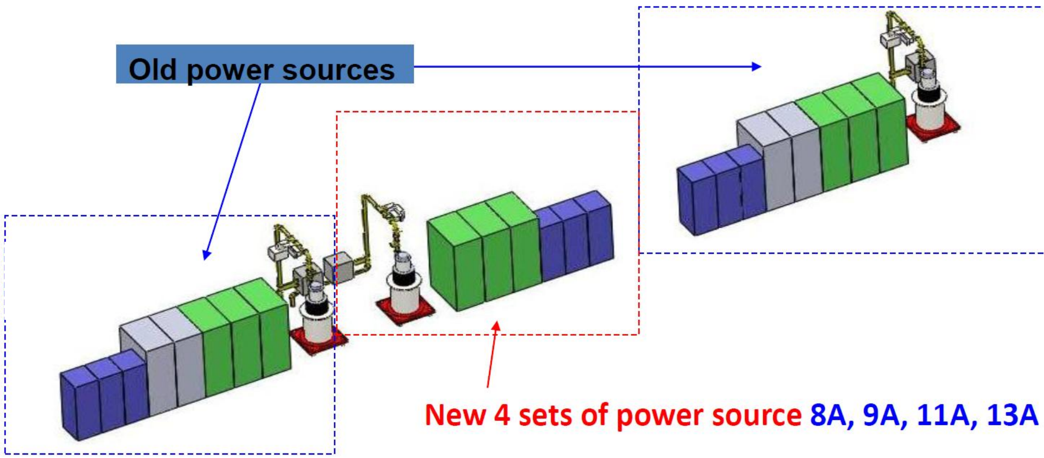
Linac upgrade

- Establish the hybrid nature of Y(4260)/Y(4360)
- Search for $h_c(2P)$ in $Y(4360) \to \pi\pi\ h_c(2P)$
- Establish the Z_c states in partial wave analyses of $Y(4260) \to \pi^+\pi^- J/\psi$
- Determine the lineshape of Y(4260)
- …..

NEW

0.5 fb^{-1} @4010 MeV
0.5 fb^{-1} @4260 MeV
0.5 fb^{-1} @4360 MeV (ongoing!)

Linac was upgrade in 2012 summer ➔ running at higher energy possible !

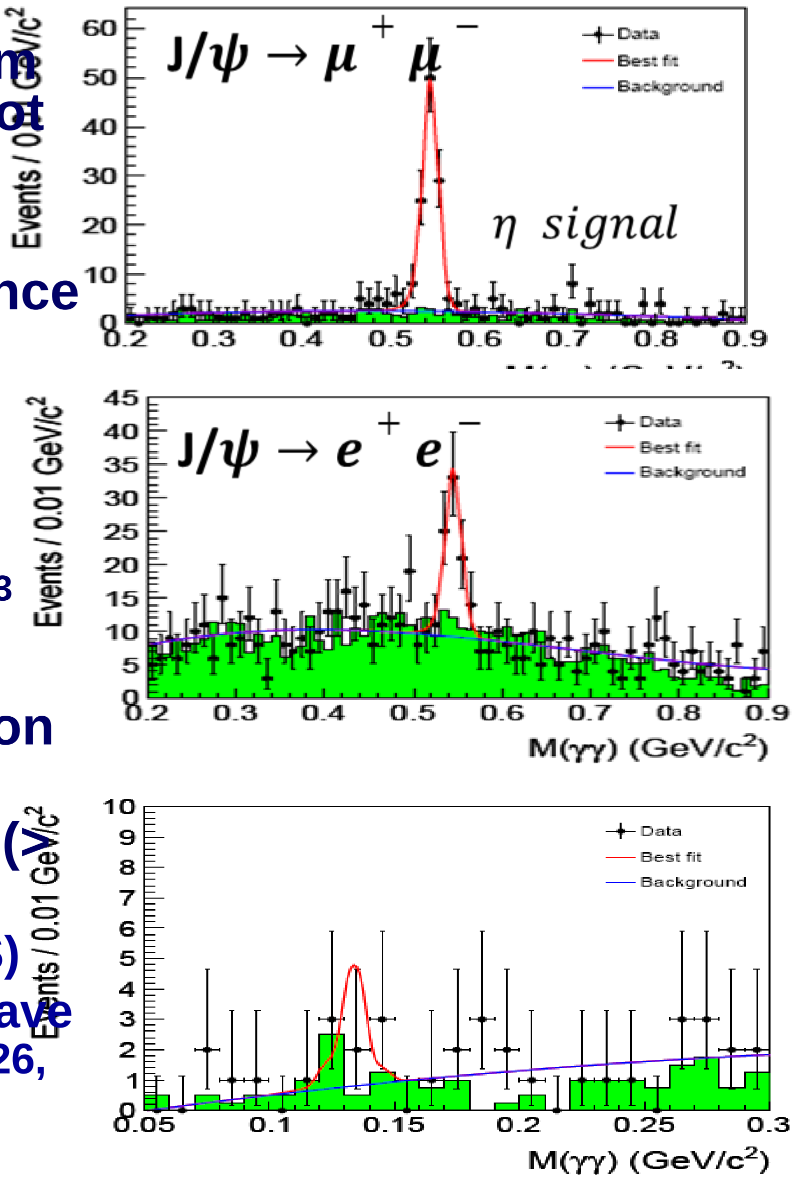


- e+ energy: 190MeV×8+70MeV+133MeV×2×3 =2.38 GeV
- e- energy: 190MeV×8+70MeV+133MeV×2×3+250MeV =2.63 GeV

$e^+e^- \to \eta J/\psi$ @4.01GeV

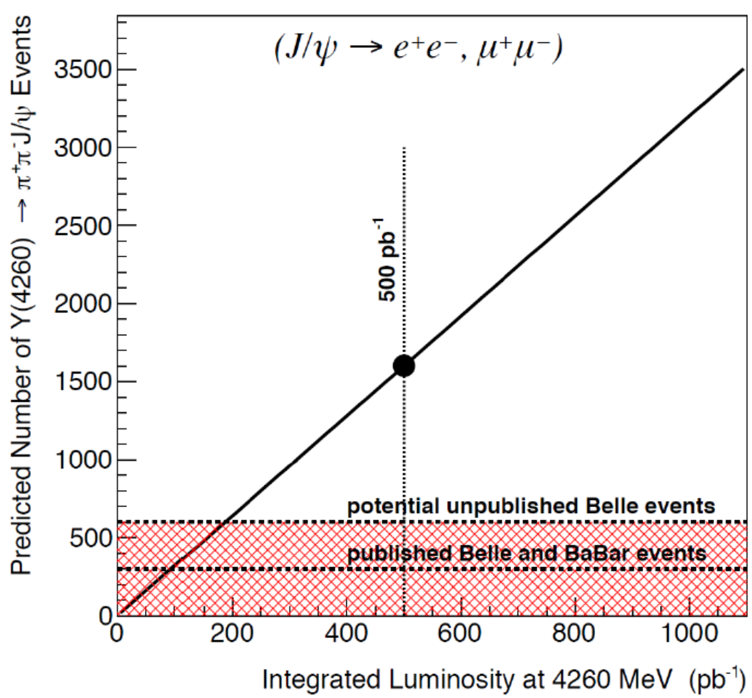
PRD86, 071101(R) (2012)

- Hadronic transition between charmonium states above open-charm threshold is not well understand
- Data sample: 478 pb^{-1} @4.01GeV
- First observation: $e^+e^- \to \eta J/\psi$ (significance > 10σ)
- Measured Born cross section:
  (32.1±2.8 ±1.3) pb
- Assume $\eta J/\psi$ from ψ(4040)
  $Br(\psi(4040)\to\eta J/\psi)=(5.2 \pm0.5\pm0.2\pm0.5)\times10^{-3}$
  $Br(\psi(4040)\to\pi^0 J/\psi) <2.8\times10^{-4}$ @90% CL
- Consistent with the theoretical calculation (Q.Wang et al., arXiv:1206.4511)
- Partial width of $\psi(4040)\to\eta J/\psi$: ~400keV (> two times $\psi(4040)\to\pi\pi J/\psi$)
  - Similar to the hadronic transition of Υ(4S) (admixture of a four-quark state in the wave function, M. B. Voloshin, Mod. Phys. Lett. A 26, 773 (2011))



Y(4260/4360) → ππJ/ψ with 0.5fb^{-1}

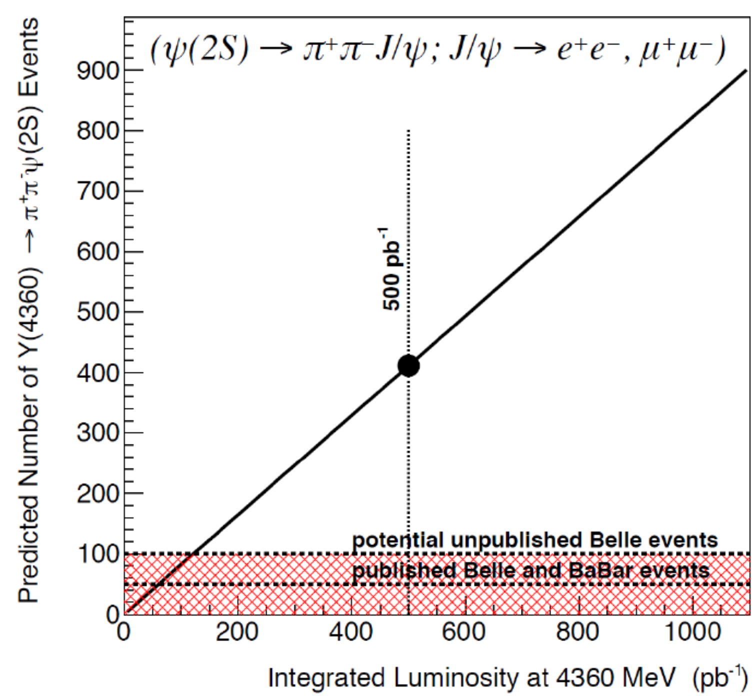
Y(4260)→ππJ/ψ



Expect 1600 events observed.

World's largest sample by a factor of >2.5

Y(4360)→ππψ(2S)



Expect 400 events observed.

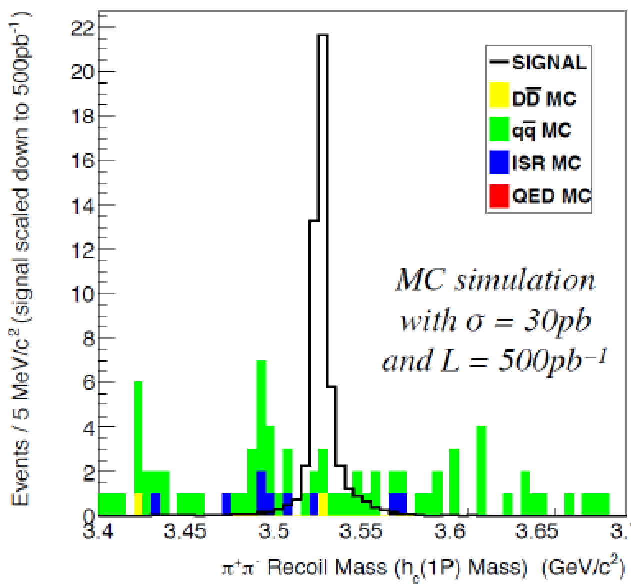
World's largest sample by a factor of >4

Allow us to perform PWA at BESIII.

$Y(4260) \rightarrow \pi\pi h_c(1P)$ / $\gamma\eta_c$ with $0.5 fb^{-1}$

Q: Is Y(4260) strongly coupling to $h_c(1P)$?

$h_c(1P) \rightarrow \gamma\eta_c$;
$\eta_c \rightarrow \gamma$ KsKπ;
assume $\sigma(\pi\pi h_c)$=30pb



greater than 5σ significance

Q: Is Y(4260) consistent with a LQCD hybrid meson?

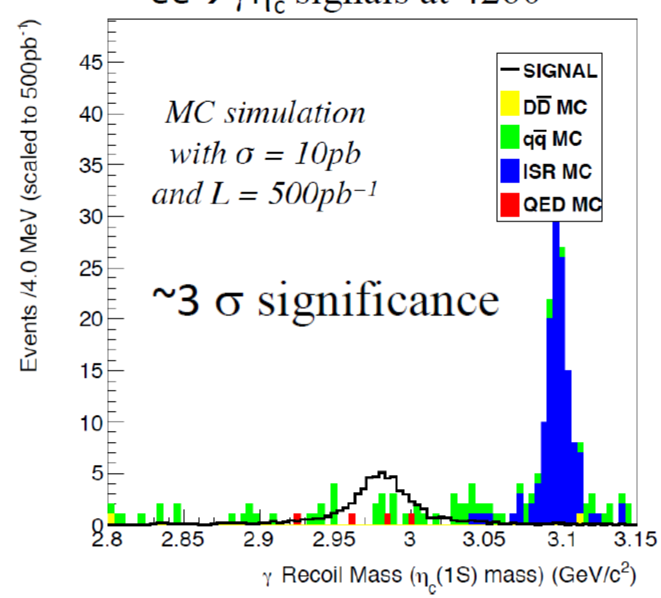
$Y(4260) \rightarrow \gamma\eta_c(1S)$ with $\eta_c(1S) \rightarrow KK\pi$

Assumed cross section: 10nb $\times$ 4.4 $\times 10^{-4}$ = 4.4pb

upper limit on $\sigma(ee \rightarrow Y(4260))$

Lattice prediction for $B(Y(4260) \rightarrow \gamma\eta_c(1S))$

$ee \rightarrow \gamma\eta_c$ signals at 4260



Search for the $h_c(2P)$

Assume $\sigma(ee \to Y(4360) \to \pi\pi h_c(2P)) =$
$\frac{1}{2}\sigma(ee \to Y(4360) \to \pi\pi\psi(2S)) = 40$pb

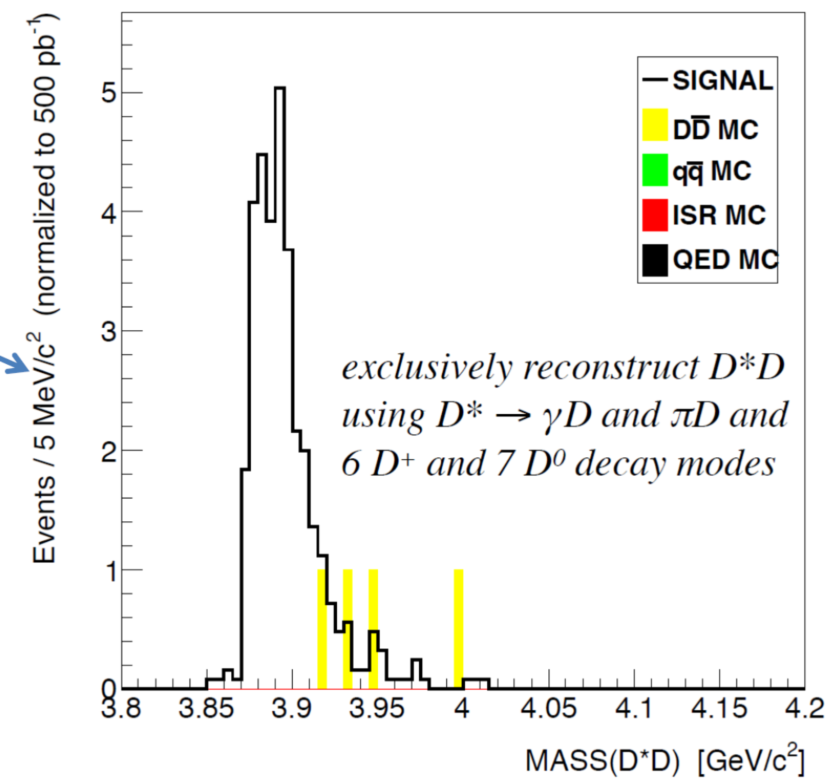
- If $M(h_c(2P)) > M(DD^*)$

  assume
  M=3892 MeV,
  Γ= 29 MeV,
  B(DD*) $\approx$100%

- If $M(h_c(2P)) < M(DD^*)$ (next page)

  assume
  M=3870 MeV,
  Γ=1MeV
  $B(\gamma\eta_c(2S))$ = 50%

$hc(2P) \to D^*D$ $(\gamma D^0 D^0 + \pi^0 D^0 D^0 + \pi^0 D^+ D^-)$



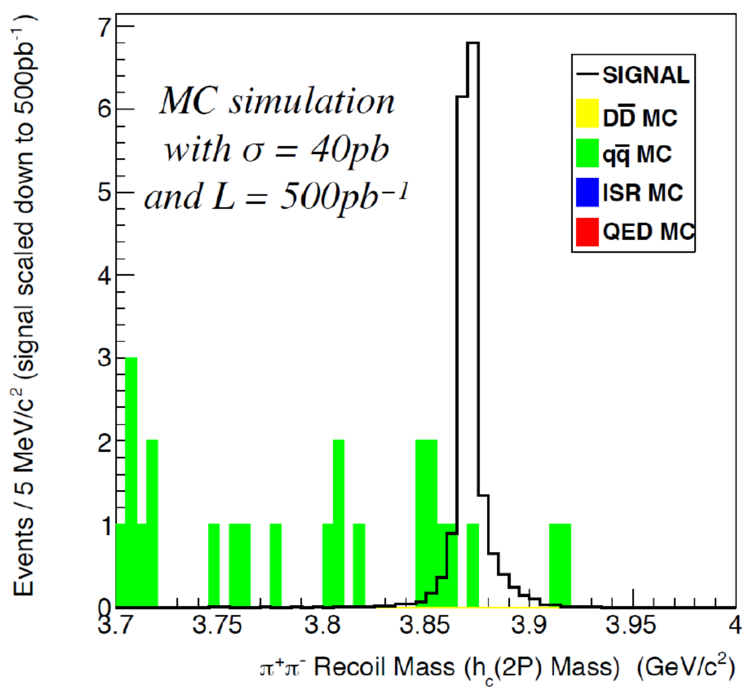
Expect 33 signal and 4 background events with 500 pb^{-1} of data at 4360

Search for the $h_c(2P)$

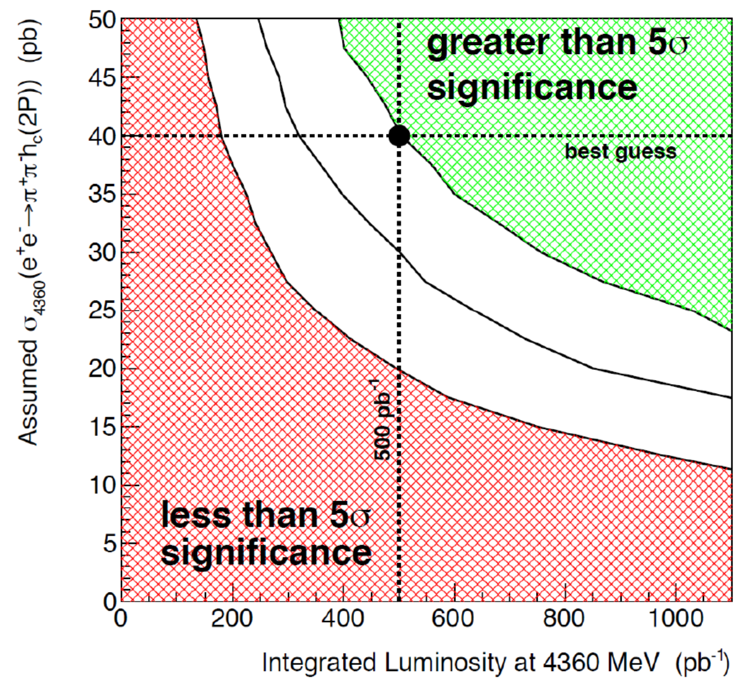
- $Y(4360) \rightarrow \pi\pi h_c(2P)$; $h_c(2P) \rightarrow \gamma\eta_c(2S)$; $\eta_c(2S) \rightarrow KK\pi$

  assume σ=40bp, M=3870MeV, Γ=1MeV, $B(\gamma\eta_c(2S))$ = 50%

$ee \rightarrow \pi\pi h_c(2P)$ signals at 4360 MeV



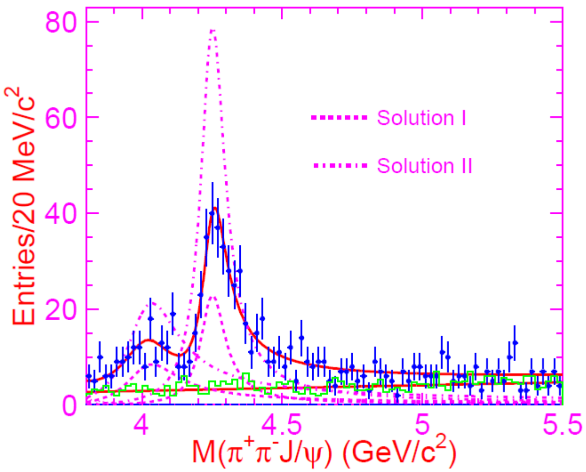
Significance of $ee \rightarrow \pi\pi h_c(2P)$ at 4360



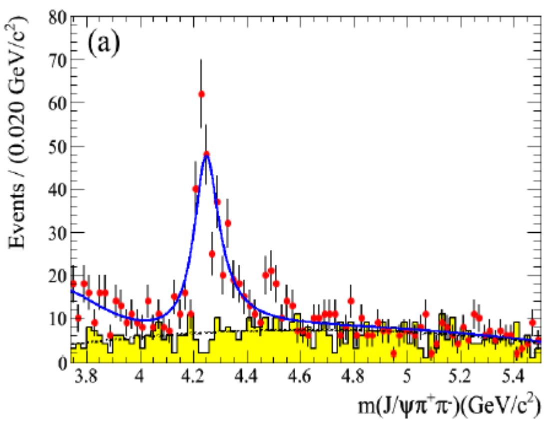
Expect more than 5σ significance with 500 pb $^{-1}$ of data at 4360 MeV

Determine the Y(4260) lineshape

Belle: PRL99,182004



BaBar: PRD86,051102

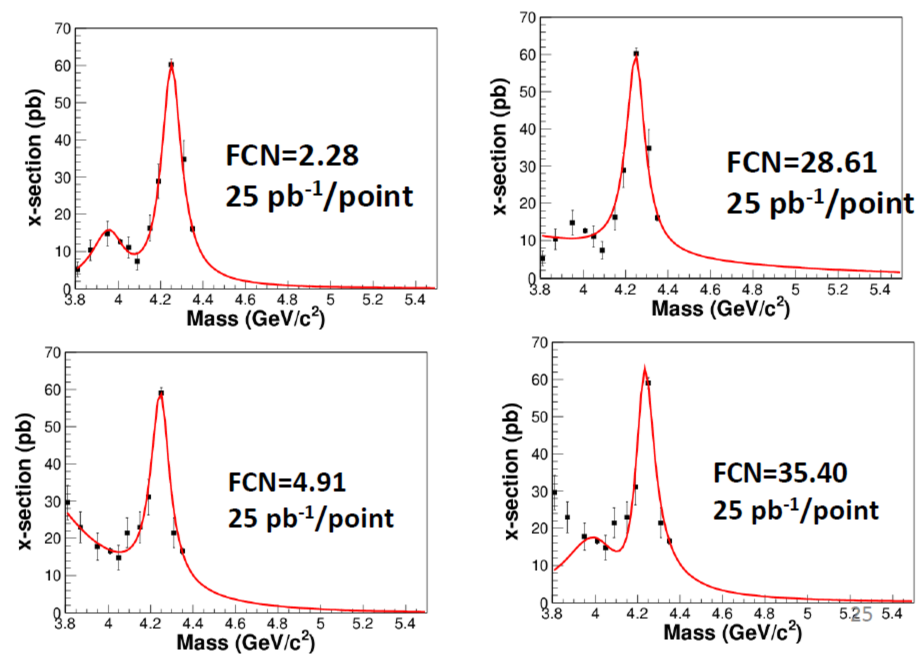


Besides the data samples @ 4040 4260 4360, 500pb^{-1} /each
Extra energy points would be needed

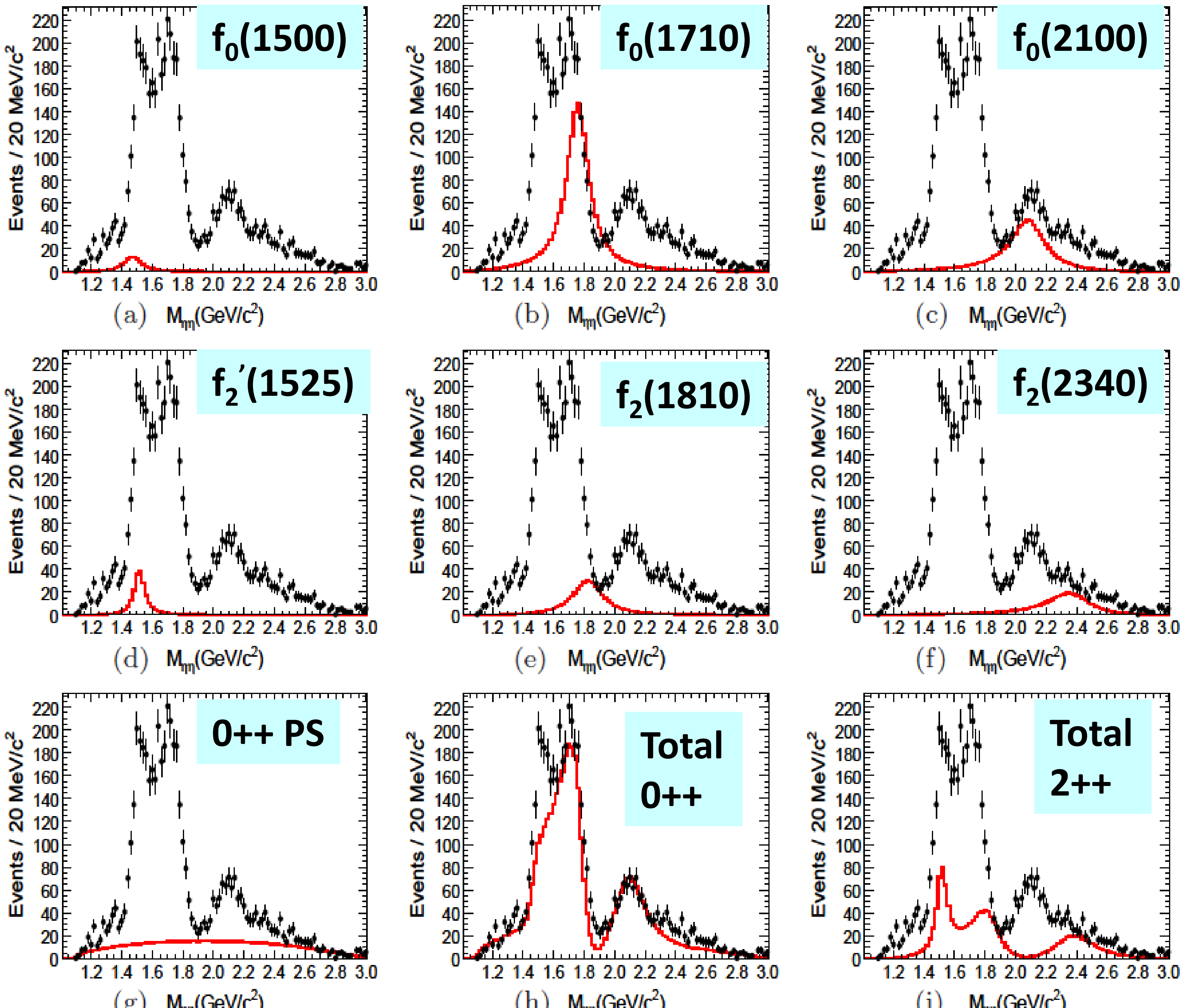
For example: (3.81, 3.87, 3.95,4.05,4.09,4.15,4.19, 4.31)

25pb-1/point

Two hypotheses can be tested by more than 5σ

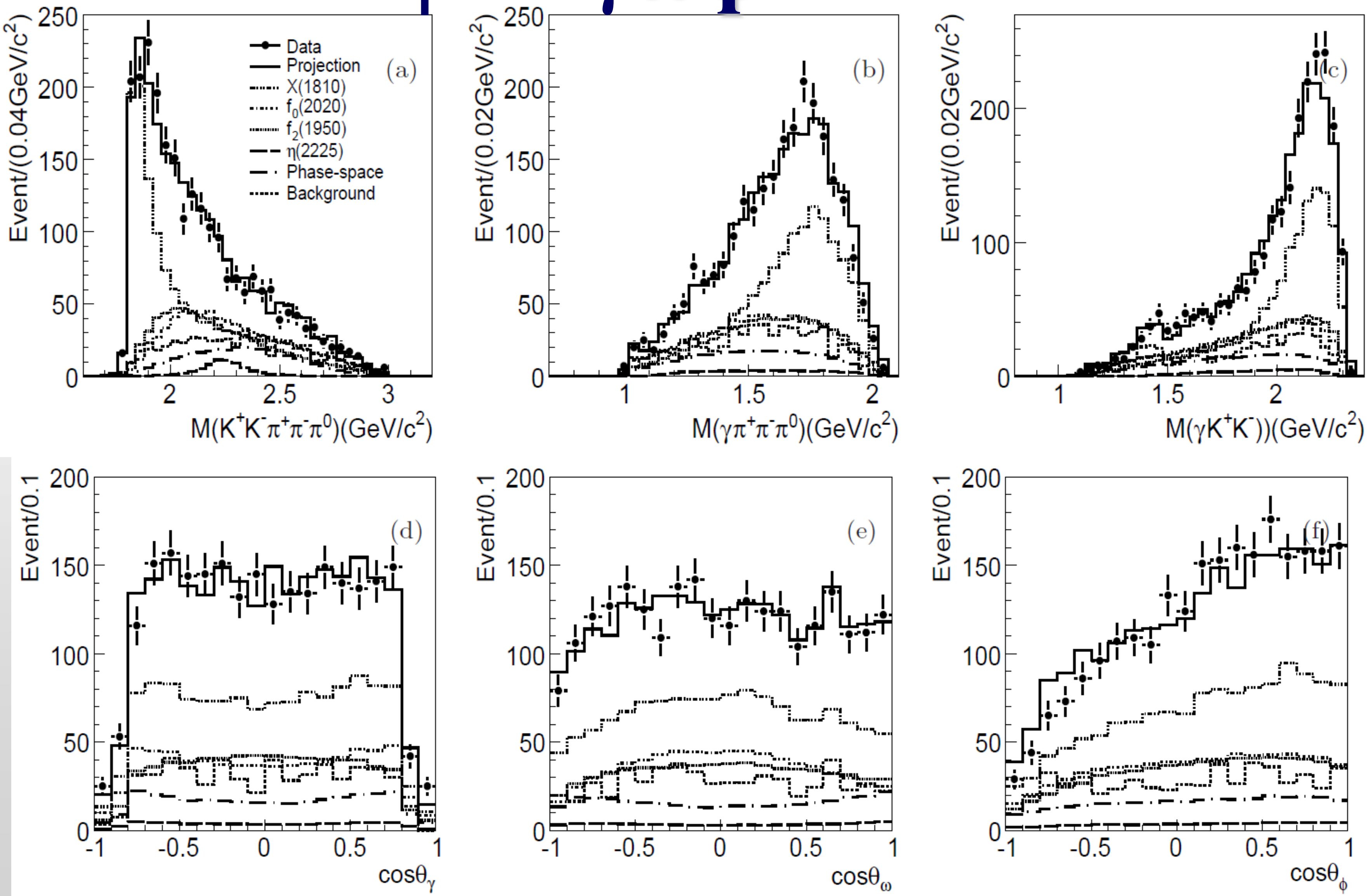


谢谢！



f0(1500)
f0(1710)
f0(2100)
f2′(1525)
f2(1810)
f2(2340)
0++ PS
Total 0++
Total 2++
Events / 20 MeV/c2
(a) Mηη(GeV/c2)
(b) Mηη(GeV/c2)
(c) Mηη(GeV/c2)
(d) Mηη(GeV/c2)
(e) Mηη(GeV/c2)
(f) Mηη(GeV/c2)
(g) Mηη(GeV/c2)
(h) Mηη(GeV/c2)
(i) Mηη(GeV/c2)

PWA of $J/\psi \rightarrow \gamma\omega\phi$

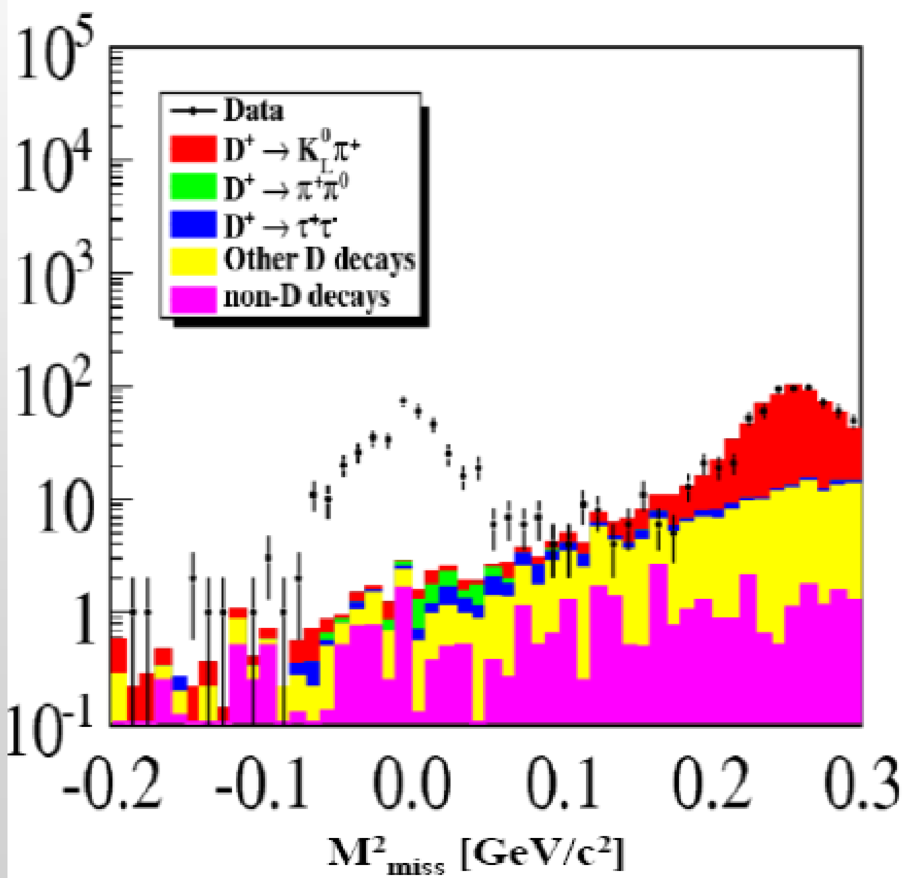


$\chi_{cJ} \to \Lambda \bar{\Lambda}, \Sigma^0 \bar{\Sigma}^0, \Sigma^+ \bar{\Sigma}^-$

TABLE III. Branching fractions (or their upper limits) of $\chi_{cJ} \to \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$ and $\Sigma^+\bar{\Sigma}^-$ (in units of 1(
The first error is statistical and the second is systematic.

Mode		χ_{c0}	χ_{c1}	χ_{c2}
$\Lambda\bar{\Lambda}$	This work	33.3±2.0±2.6	12.2±1.1±1.1	20.8±1.6±2.3
	PDG	33.0±4.0	11.8±1.9	18.6±2.7
	CLEO	33.8± 3.6±2.2±1.7	11.6±1.8±0.7±0.7	17.0±2.2±1.1±1.1
	Theory	$(93.5 \pm 20.5^a, 22.1 \pm 6.1^b)$[21]	–	$(15.2 \pm 1.7^a, 4.3 \pm 0.6^b)$[21]
		11.9~15.1[23]	3.9[22]	3.5[22]
$\Sigma^0\bar{\Sigma}^0$	This work	47.8±3.4±3.9	3.8±1.0±0.5 (< 6.2)	4.0±1.1±0.5 (< 6.5)
	PDG	42.0±7.0	<4.0	<8.0
	CLEO	44.1±5.6±4.2±2.2	<4.4	<7.5
	Theory	$(25.1 \pm 3.4^a, 18.7 \pm 4.5^b)$[21]	–	$(38.9 \pm 8.8^a, 4.2 \pm 0.5^b)$[21]
		–	3.3[22]	5.0[22]
$\Sigma^+\bar{\Sigma}^-$	This work	45.4±4.2±3.0	5.4±1.5±0.5 (< 8.7)	4.9±1.9±0.7 (<8.8)
	PDG	31.0±7.0	<6.0	<7.0
	CLEO	32.5±5.7±4.0±1.7	<6.5	<6.7
	Theory	5.5 ~ 6.9[23]	3.3[22]	5.0[22]

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



Event type	Number
$N(D^+ \to \mu^+\nu_\mu)^{\text{candidate}}$	425
N_b	$47.7 \pm 2.3 \pm 1.3$
$N(D^+ \to \mu^+\nu_\mu)$	$377.3 \pm 20.6 \pm 2.6$

- The number of backgrounds is also estimated with data.

$$N_b^{tot} = 48.9 \pm 4.8$$

- Consistent within error with N_b estimated from MC

Determination of $|V_{cs}|$ and $|V_{cd}|$

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

$f_{D(Ds)}$ can be well calculated (LQCD, …)

$\Gamma[D_{(s)}^+ \to l^+ v]$ can be well measured

One can extract CKM matrix elements $|V_{cs}|$ and $|V_{cd}|$

CKM matrix element $|V_{cd}|$

The $|V_{cd}|$ could be extracted with

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

Inserting the quantities

τ_{D+} = (1040±7) fs,
M_{D+} = (1896.60±0.16) MeV
$M_{\mu+}$ = (105.658±0.000) MeV
f_{D+} = 207±4 MeV (from LQCD)

yields

$|V_{cd}|$ = (0.222±0.006±0.005) (BES-III **Preliminary**)

From $D^+ \rightarrow \mu^+ \nu$ leptonic decay