Review of recent BESIII results

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BESIII

全国第二十届重味物理和CP破坏研讨会，16th Dec，2023，上海

Outline

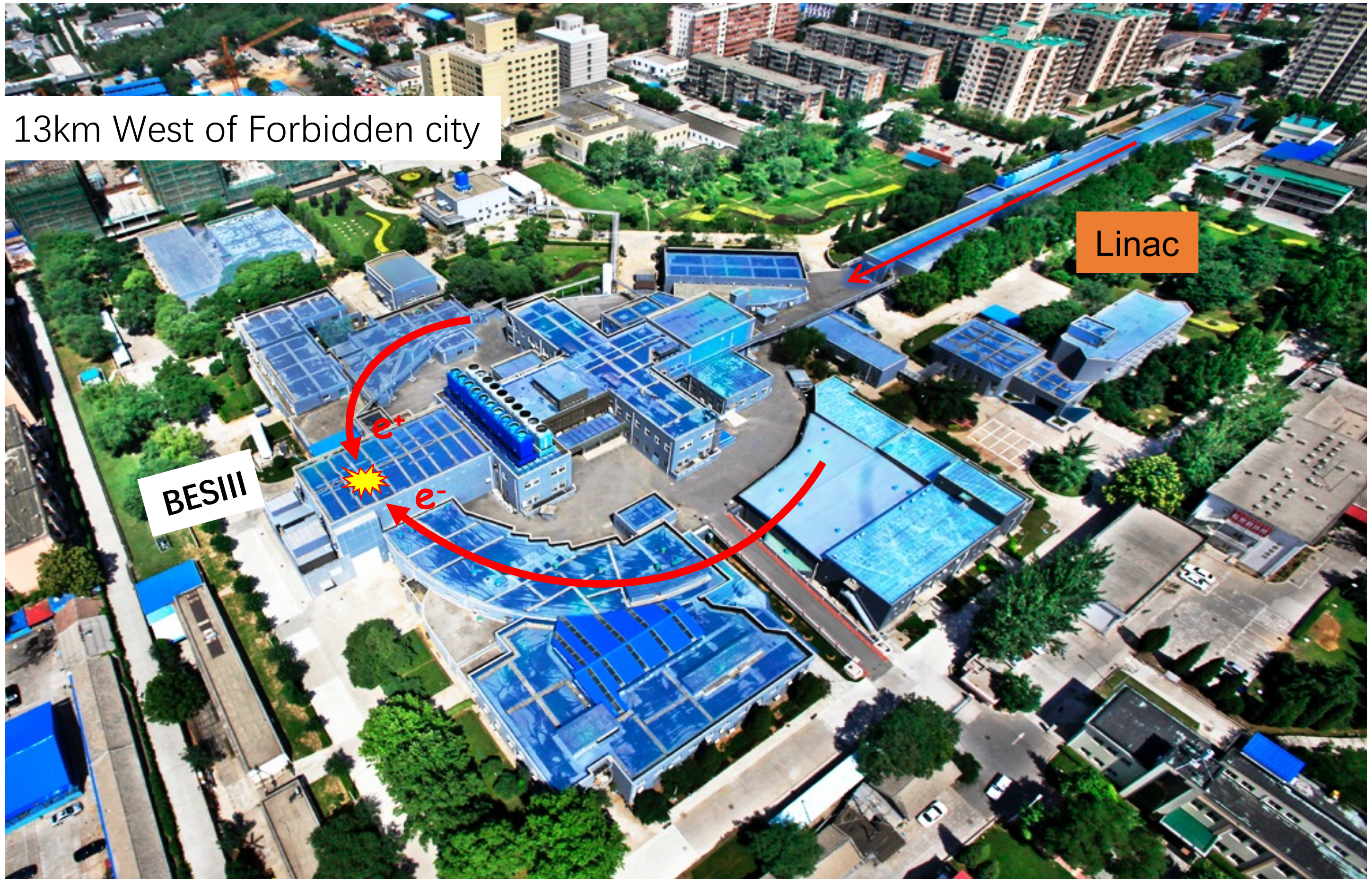
- A brief introduction to BESIII
- Heavy quarkonium spectroscopy
- D meson and Λ_c baryon decay
- New physics search
- Summary

三代北京谱仪

1988年10月24日，邓小平同志“中国要在高科技领域占有一席之地”

BEPCII

Beijing Electron Positron Collider (BEPCII)

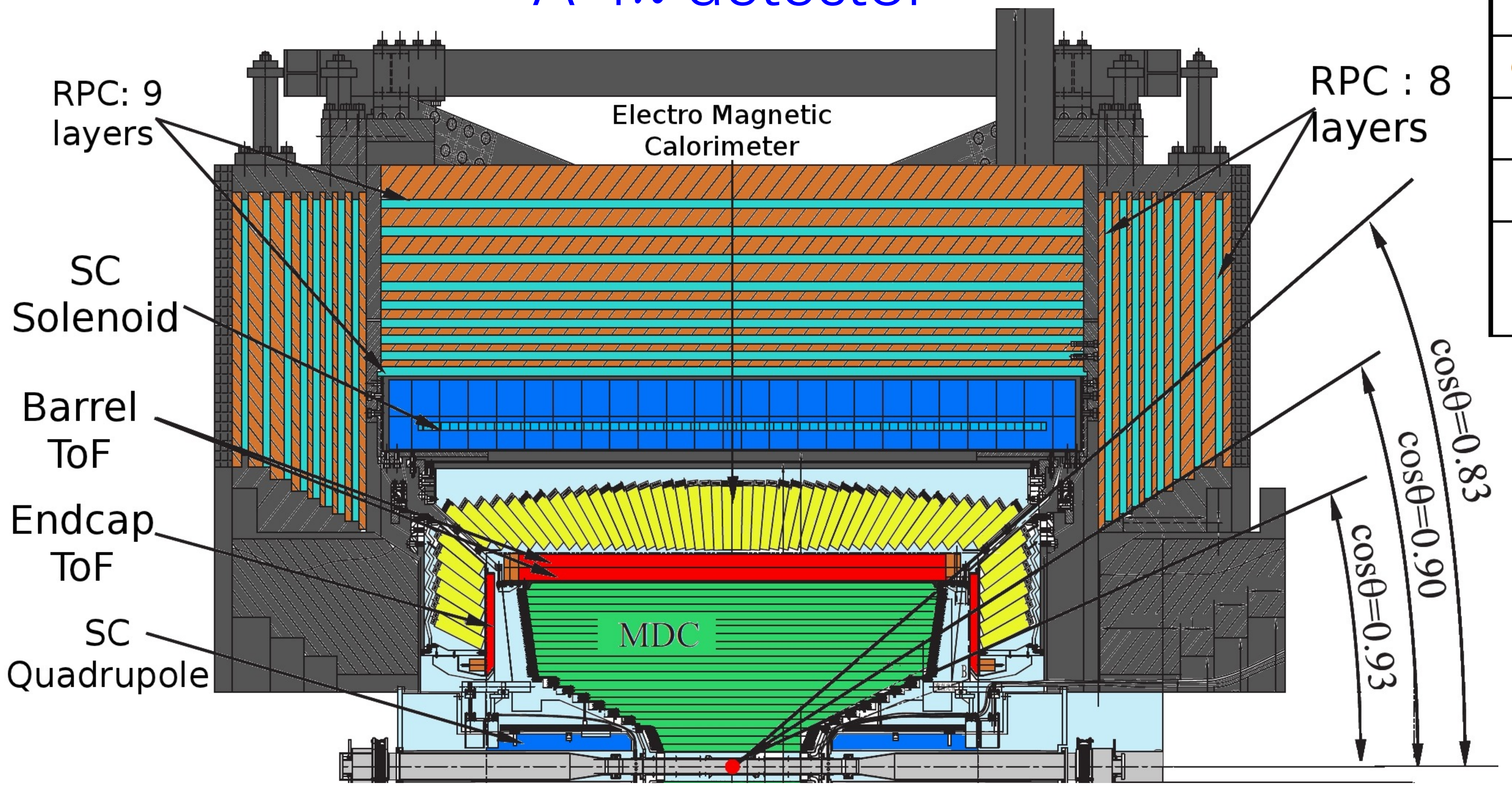


- First collision in 2008 & physics run in 2009.
- $\sqrt{s}$ = 2.0 – 4.946 GeV (tau-charm factory).
- Design Luminosity $L_D = 1\times10^{33}$ $cm^{-2}s^{-1}$ @ 3.773 GeV (2016 achieved; 2022-2023 achieved $1.1\times L_D$).
- Continuous injection (top-up mode).

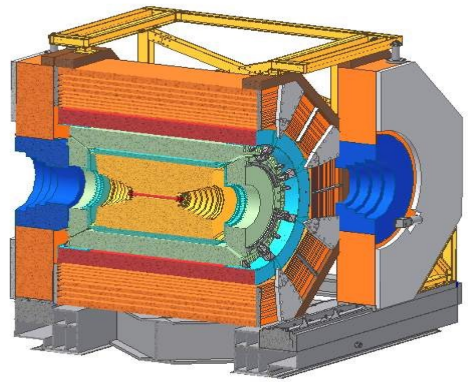
BESIII

BEijing Spectrometer (BESIII)

A 4π detector



Exps.	MDC Spatial resolution	MDC dE/dx resolution	EMC Energy resolution
CLEO-c	110 μm	5%	2.2-2.4 %
BaBar	125 μm	7%	2.67 %
Belle	130 μm	5.6%	2.2 %
BESIII	130 μm	6%	2.5%

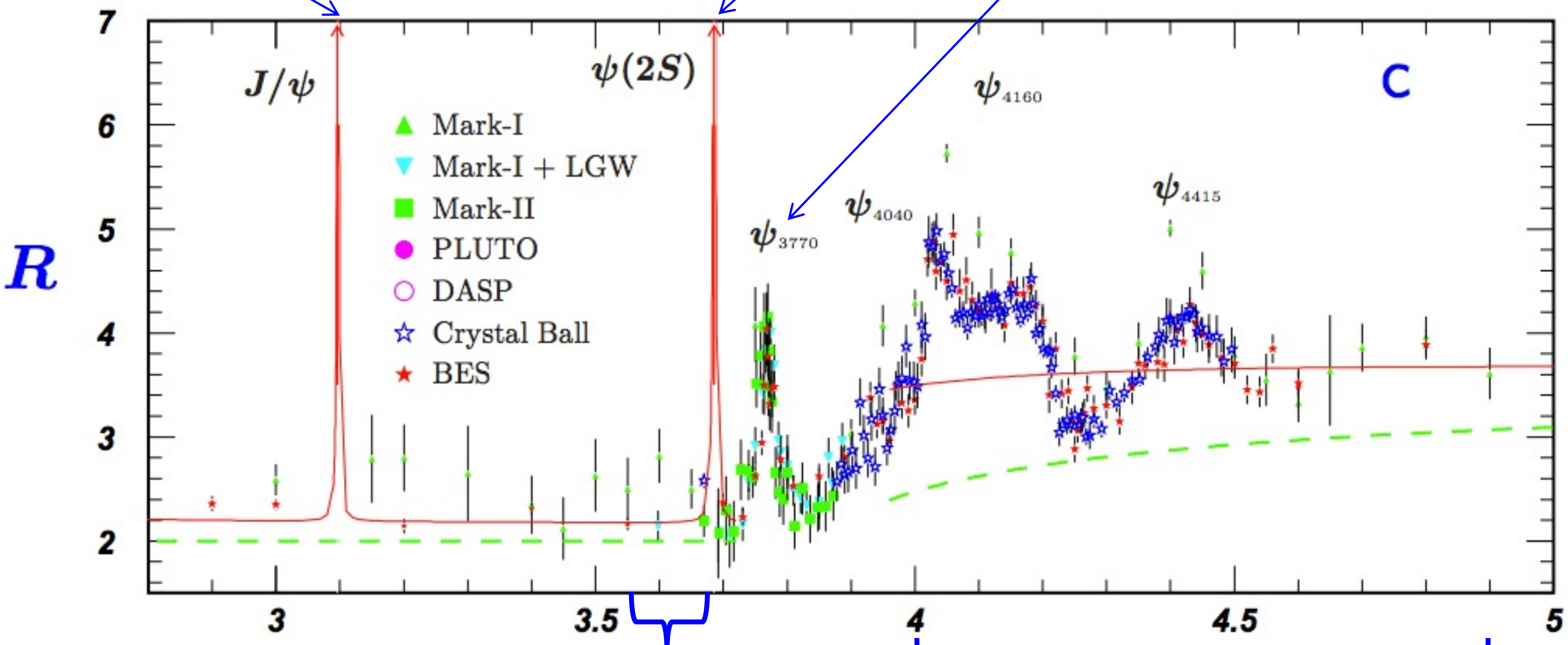


Data – On resonance & Scan

10 B J/ψ events: light hadron, hyperon

2.7 B ψ(2S) events: charmonium

20 fb^{-1} ψ(3770): D mesons

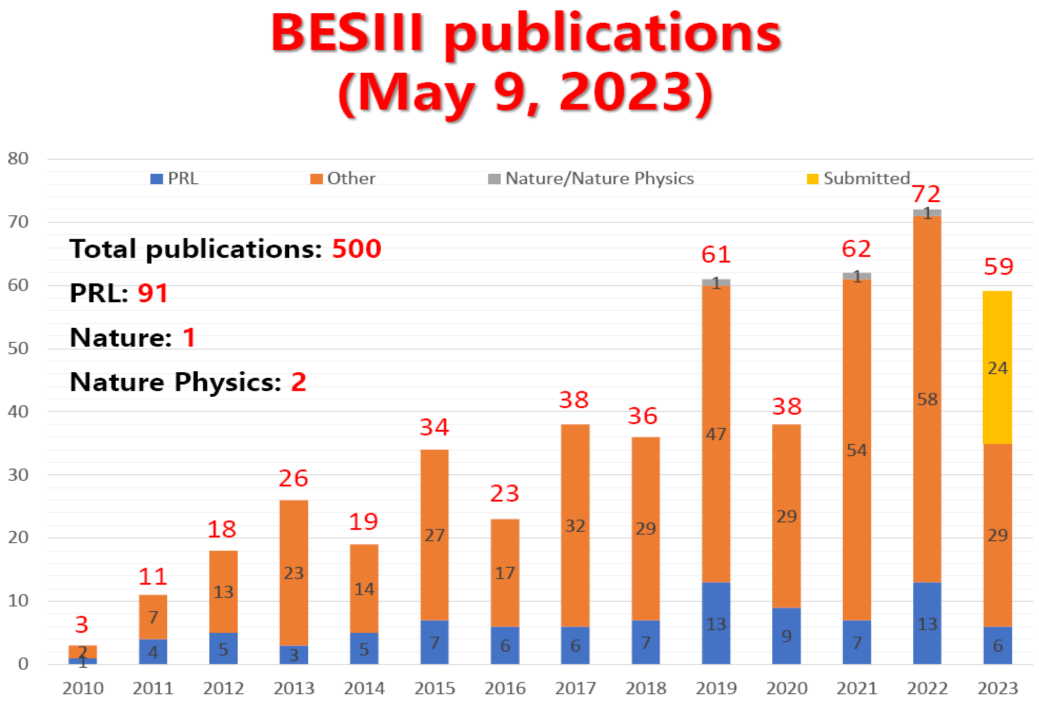


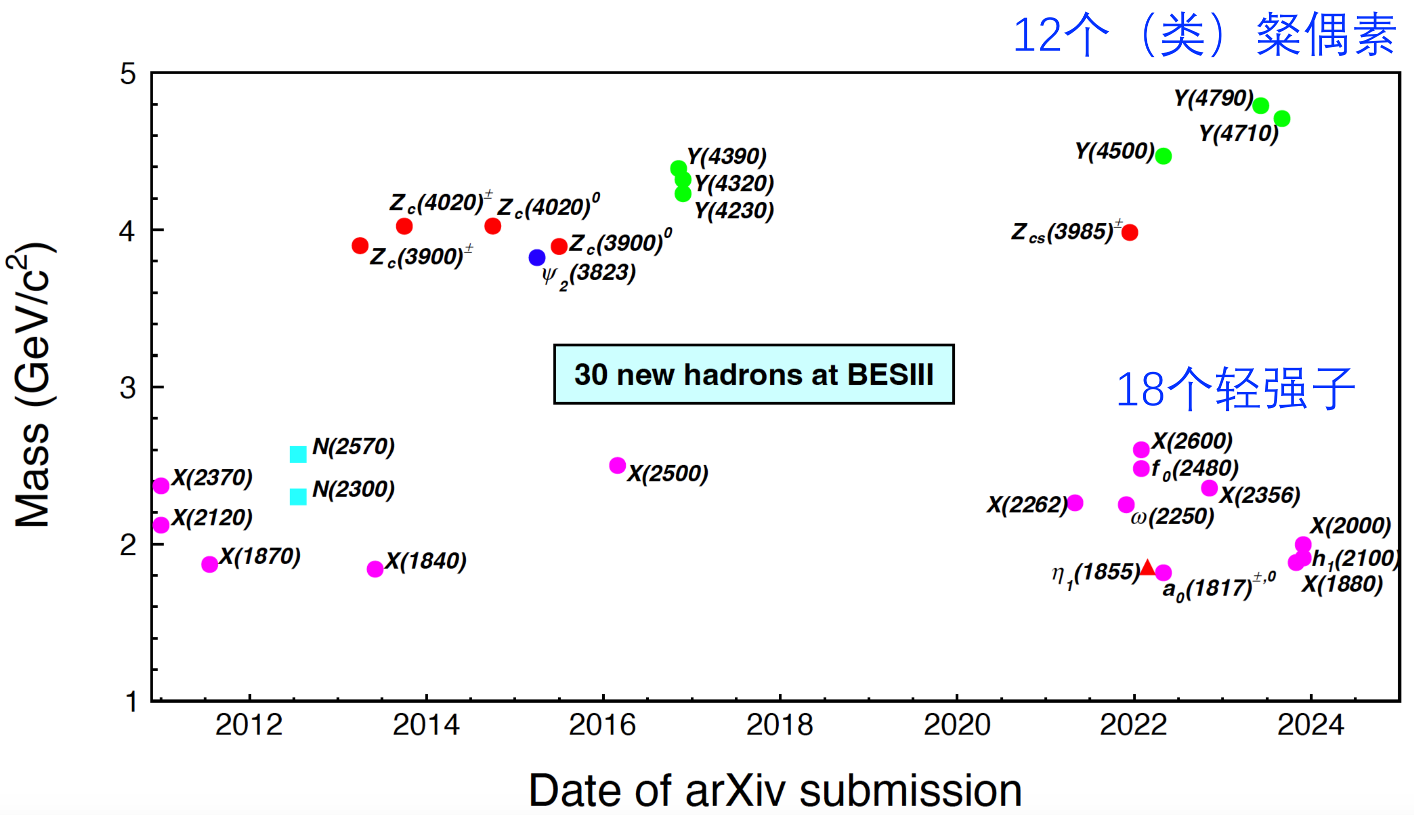
τ mass scan

Low energy scan: R-value, baryon pair

High luminosity scan: XYZ, Ds, Λ_c…

500+ publication & 30个新强子



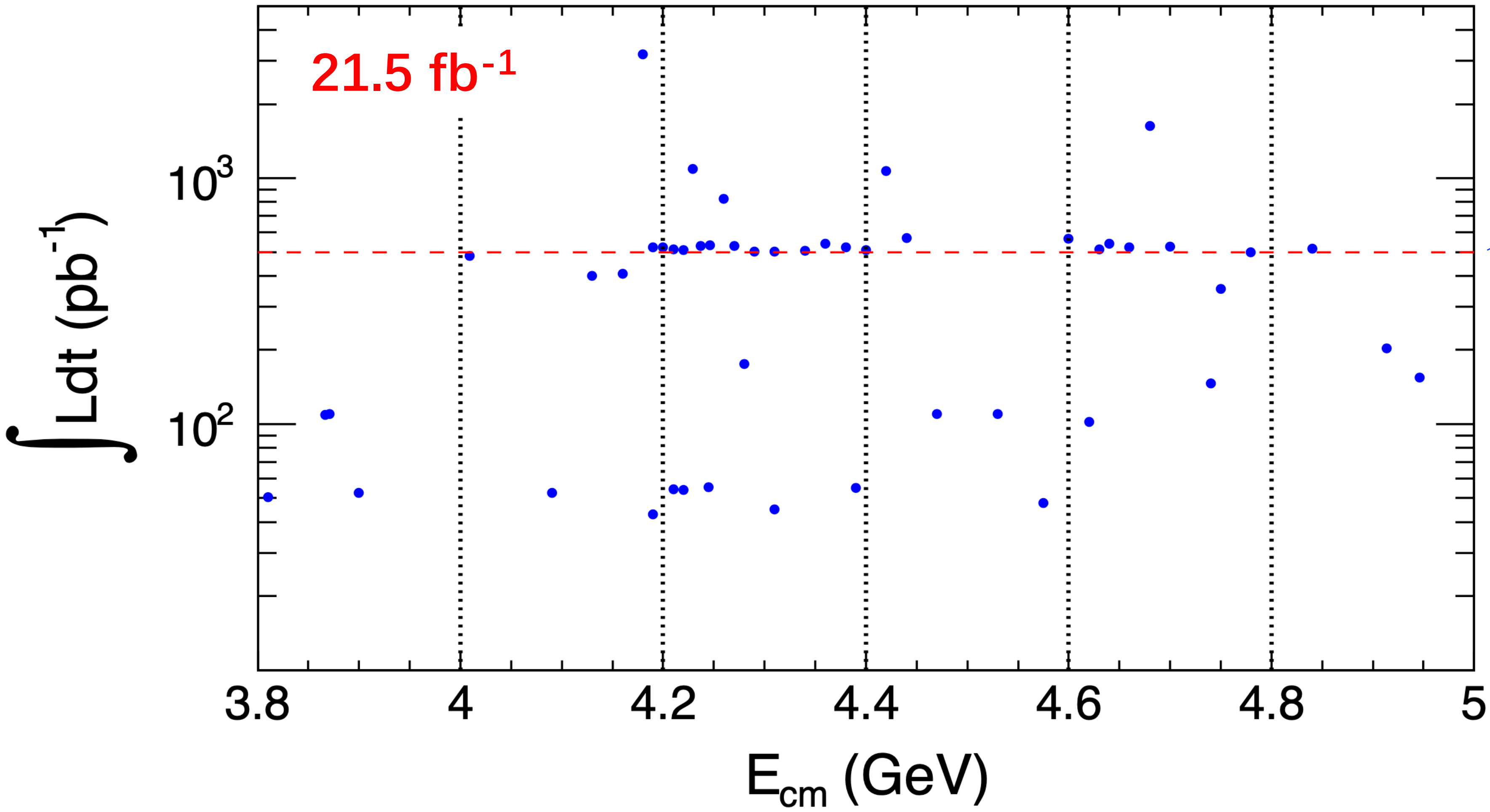


Zhiqing Liu & Ryan Mitchell, Science Bulletin 68 (2023) 2148–2150

Heavy Charmonium(-like) Spectroscopy

BESIII high luminosity scan

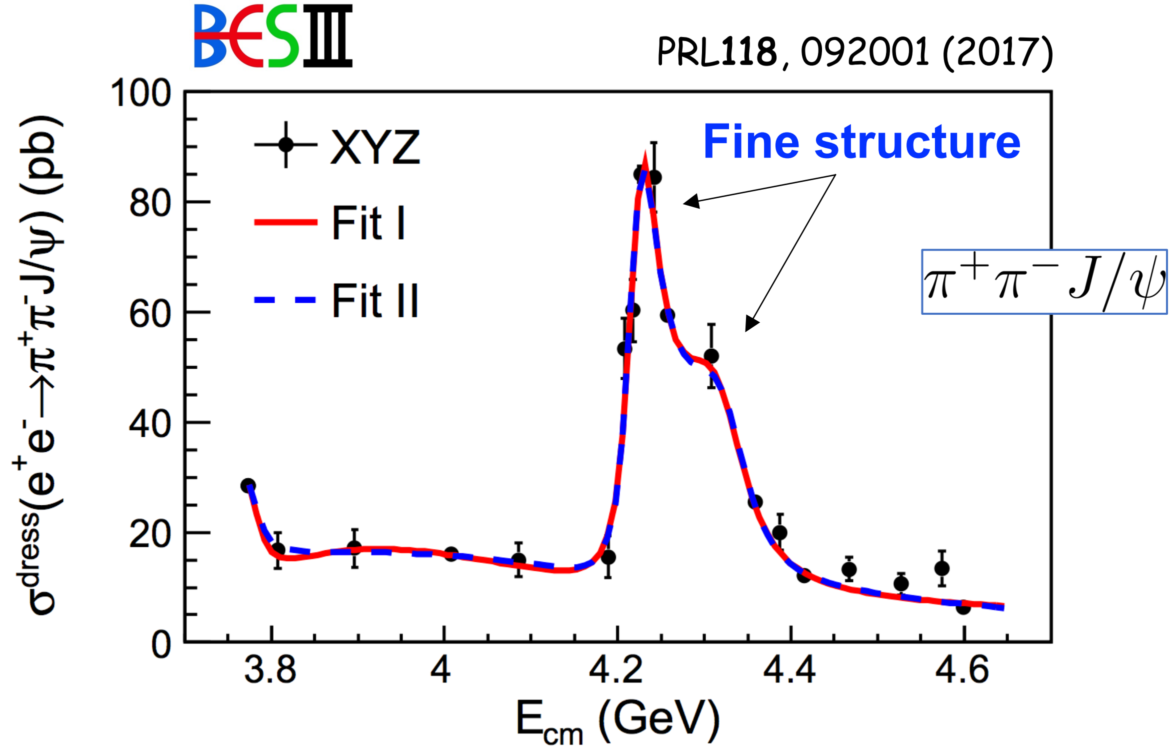
Start from 2013, 0.5 fb^{-1}/10 MeV step scan from 4 – 4.9 GeV

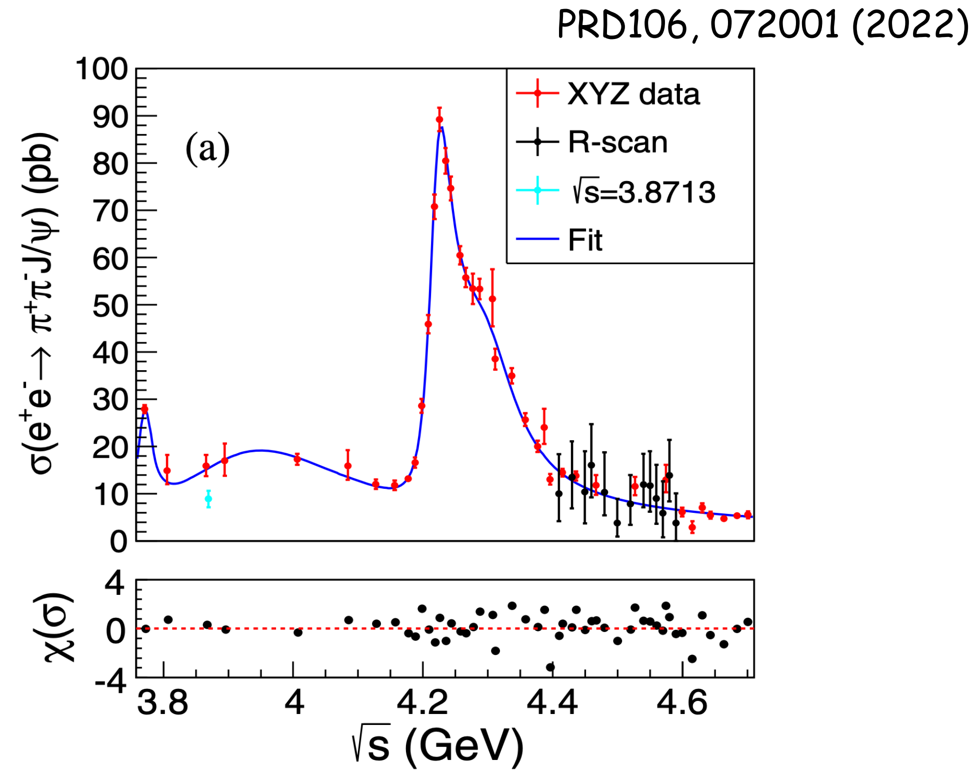


500 pb^{-1}, ~ 1 month beam time

精确扫描能够研究矢量态粒子的精细结构、向更高能量出发…

Y(4260) fine structure

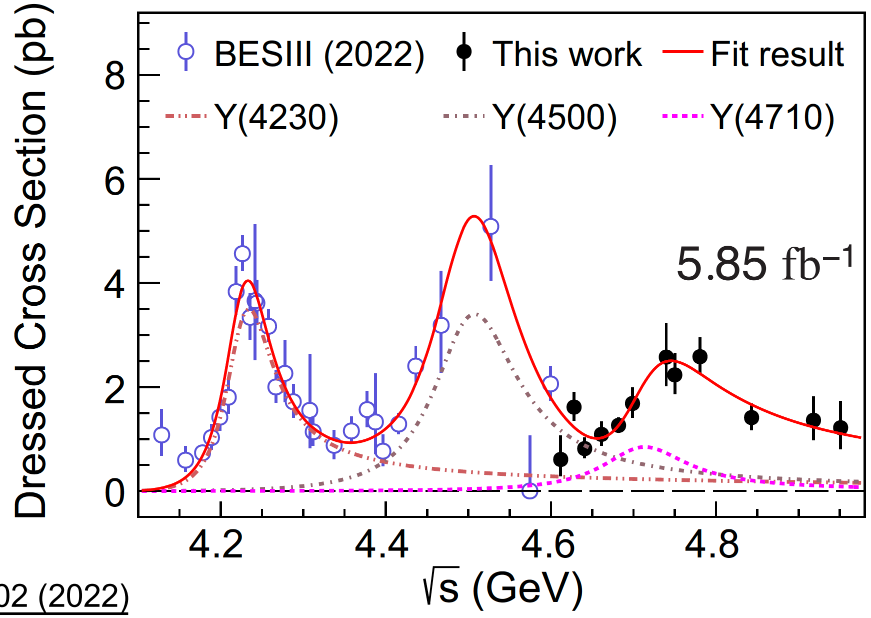




- There are fine structures in the famous "Y(4260) bump"
- Mass=(4222.0±3.1±1.4) MeV, Width=(44.1±4.3±2.0) MeV
- Most precise and significantly lower than 4.26 GeV

e+e-→K⁺K⁻J/ψ

PRL 131, 211902 (2023)

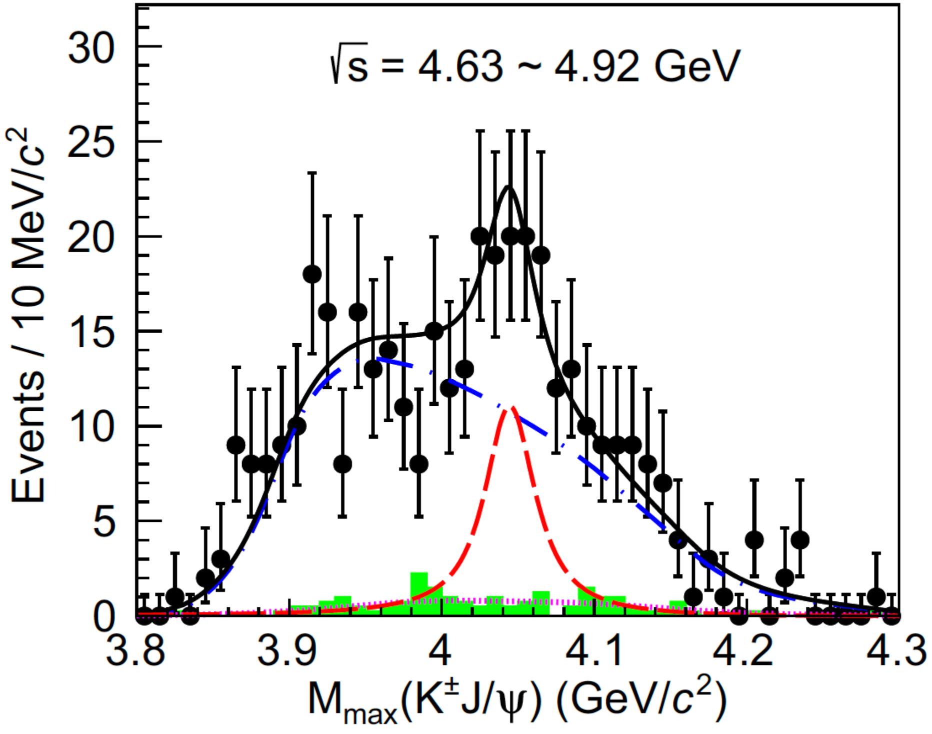


CPC 46, 111002 (2022)

	Parameters	Solution I	Solution II
$Y(4230)$	M/MeV	$4225.3 \pm 2.3 \pm 21.5$	
	Γ_{tot}/MeV	$72.9 \pm 6.1 \pm 30.8$	
	$\Gamma_{ee}\mathcal{B}$/eV	$0.42 \pm 0.04 \pm 0.15$	$0.29 \pm 0.02 \pm 0.10$
$Y(4500)$	M/MeV	$4484.7 \pm 13.3 \pm 24.1$	
	Γ_{tot}/MeV	$111.1 \pm 30.1 \pm 15.2$	
	$\Gamma_{ee}\mathcal{B}$/eV	$1.35 \pm 0.14 \pm 0.07$	$0.41 \pm 0.08 \pm 0.13$

M=(4708^{+17}_{-15}±21) MeV, Γ=(126^{+27}_{-23}±30) MeV; significance>5σ

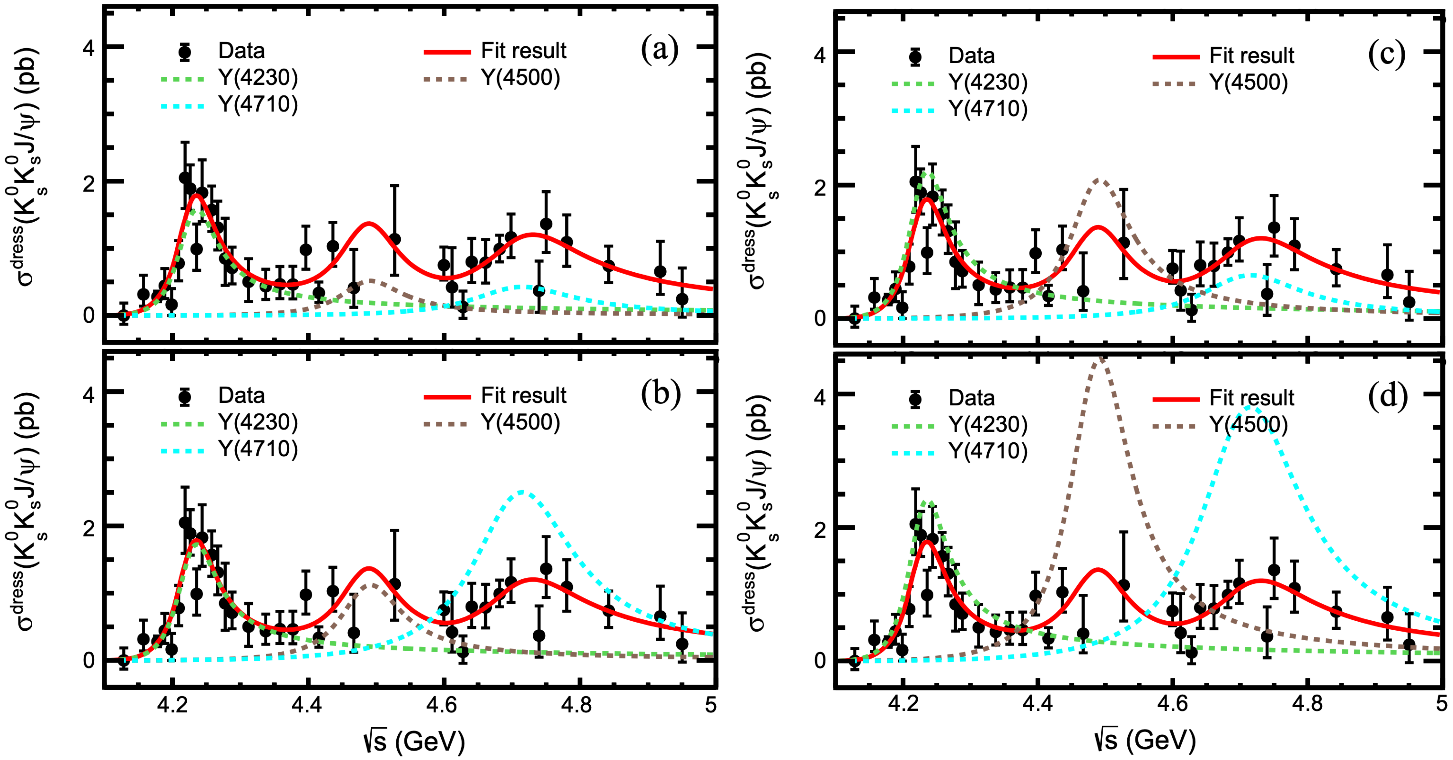
- One of the heaviest vector charmonium-like state
- Vector Hybrid, 5S charmonium, 5S-4D/6S-5D mixing



- No obvious Zcs structure (only small hint at some Ecm)

$$R_B \equiv \frac{\mathcal{B}[Z_{cs}(3985)^+ \to K^+ J/\psi]}{\mathcal{B}[Z_{cs}(3985)^+ \to (\bar{D}^0 D_s^{*+} + \bar{D}^{*0} D_s^+)]}$$ <0.03 @ 90% CL

e+e-→KsKsJ/ψ



21.2 fb^{-1}

PRD 107, 092005 (2023)

Parameter	Solution I	Solution II	Solution III	Solution IV
M_{4230} (MeV/c^2)		$4226.9 \pm 6.6 \pm 22.0$		
Γ_{4230} (MeV)		$71.7 \pm 16.2 \pm 32.8$		
$(\Gamma_{ee}\mathcal{B})_{4230}$ (eV)	$0.13 \pm 0.02 \pm 0.05$	$0.14 \pm 0.03 \pm 0.06$	$0.18 \pm 0.05 \pm 0.07$	$0.20 \pm 0.04 \pm 0.07$
M_{4500} (MeV/c^2) (fixed)		$4484.7 \pm 13.3 \pm 24.1$ [Ref. [31]]		
Γ_{4500} (MeV) (fixed)		$111.1 \pm 30.1 \pm 15.2$ [Ref. [31]]		
$(\Gamma_{ee}\mathcal{B})_{4500}$ (eV)	$0.08 \pm 0.09 \pm 0.04$	$0.17 \pm 0.14 \pm 0.05$	$0.31 \pm 0.26 \pm 0.11$	$0.68 \pm 0.24 \pm 0.18$
ϕ_{4500} (rad)	$1.02 \pm 0.57 \pm 0.56$	$1.74 \pm 1.11 \pm 0.46$	$4.26 \pm 0.76 \pm 0.91$	$4.98 \pm 0.31 \pm 0.74$
M_{4710} (MeV/c^2)		$4704.0 \pm 52.3 \pm 69.5$		
Γ_{4710} (MeV)		$183.2 \pm 114.0 \pm 96.1$		
$(\Gamma_{ee}\mathcal{B})_{4710}$ (eV)	$0.12 \pm 0.09 \pm 0.11$	$0.68 \pm 0.26 \pm 0.21$	$0.18 \pm 0.20 \pm 0.10$	$1.04 \pm 0.60 \pm 0.35$
ϕ_{4710} (rad)	$0.92 \pm 0.99 \pm 0.84$	$5.37 \pm 0.46 \pm 0.95$	$5.38 \pm 1.02 \pm 0.80$	$3.55 \pm 0.27 \pm 1.03$

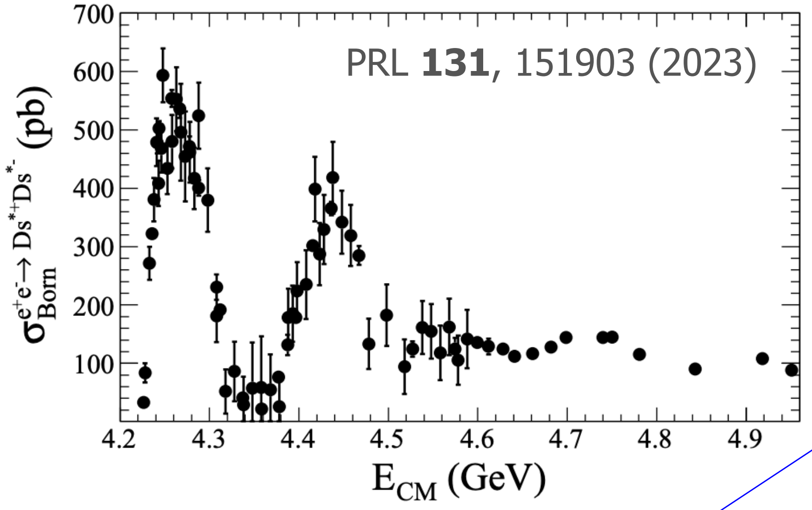
$$\sigma^{\rm dress} \equiv |BW_1 + BW_2 e^{i\phi_2} + BW_3 e^{i\phi_3}|^2,$$

M=4704.0±52.3±69.5 MeV/c2

Γ=183.2±114.0±96.1 MeV

Y(4710) statistical significance of 4.2σ

e+e-→$D_s^*D_s^*$ cross section



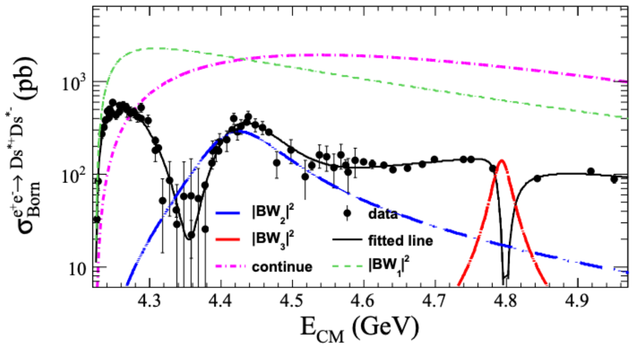
- A semi-inclusive method: D_s^*→γD_s→γKKπ

$$\left|\sum_{j=1}^{3} a_j \cdot e^{i\phi_j} \cdot BW_j(E_{\rm CM}) + \frac{a_0}{E_{\rm CM}^n}\right|^2 \beta^3(E_{\rm CM})$$

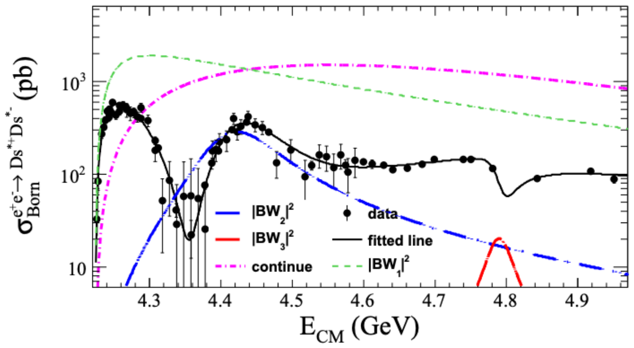
- ψ(4160) or Y(4260) [strong coupling to Ds*Ds*?]
- Consistent with ψ(4415)→first observation
- Necessarily to improve fit quality (>6.1σ)

DsDs & DsDs* is ongoing

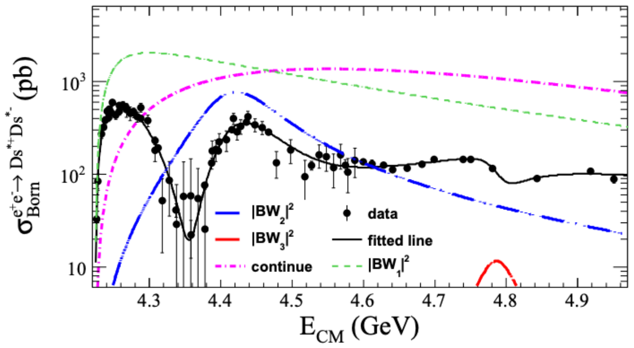
	M_1 (MeV/c^2)	Γ_1 (MeV)	M_2 (MeV/c^2)	Γ_2 (MeV)	M_3 (MeV/c^2)	Γ_3 (MeV)	significance of BW_3
Fitting result 1	4186.5±9.0	55±17	4414.5±3.2	122.6±7.0	4793.3±7.5	27.1±7.0	6.24σ
Fitting result 2	4193.8±7.5	61.2±9.0	4412.8±3.2	120.3±7.0	4789.8±9.0	41±39	6.17σ
FItting result 3	4195.3±7.5	61.8±9.0	4411.0±3.2	120.0±7.0	4786±10	60±35	6.11σ



(a) Fitting result 1



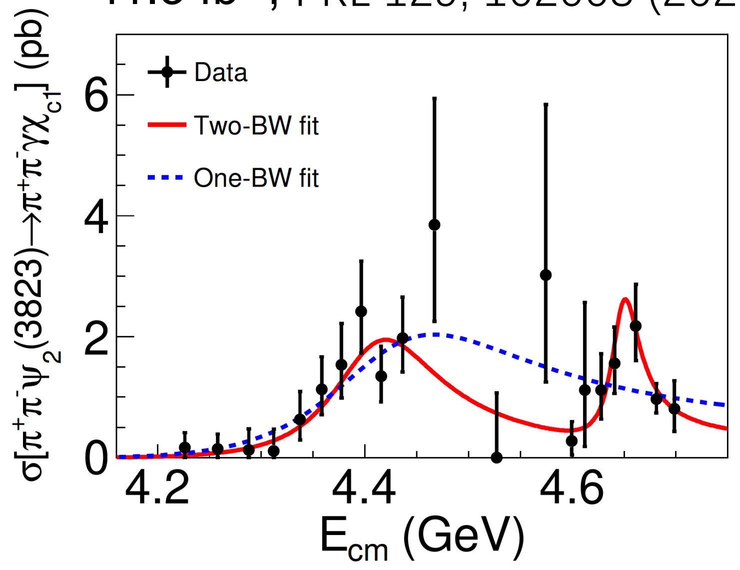
(b) Fitting result 2

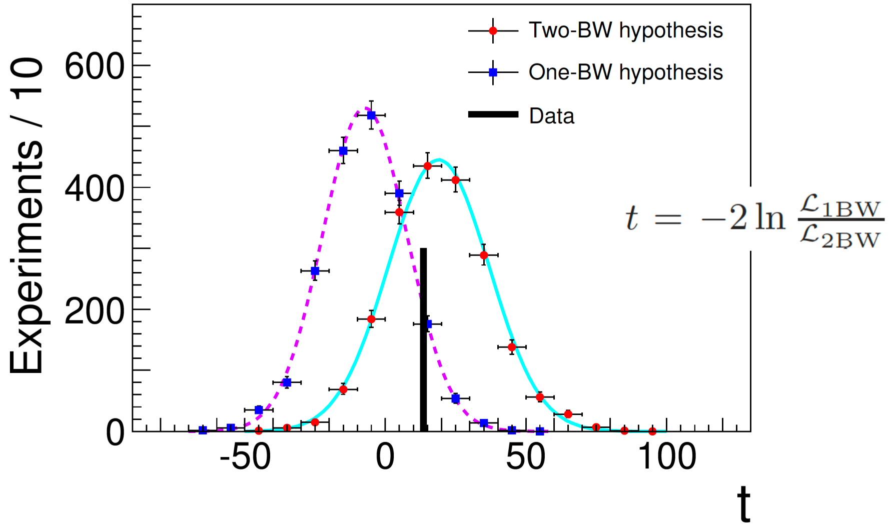


(c) Fitting result 3

Y(4660)→$\pi^+\pi^-\psi_2(3823)$

11.3 fb^{-1}, PRL 129, 102003 (2022)





- BESIII measure the E_{cm} dependent e+e-→$\pi^+\pi^-\psi_2(3823)$ cross section
- Resonance structure with >5σ significance
- One single BW resonance

  M=4417.5±26.2±3.5 MeV
  Γ=245±48±13

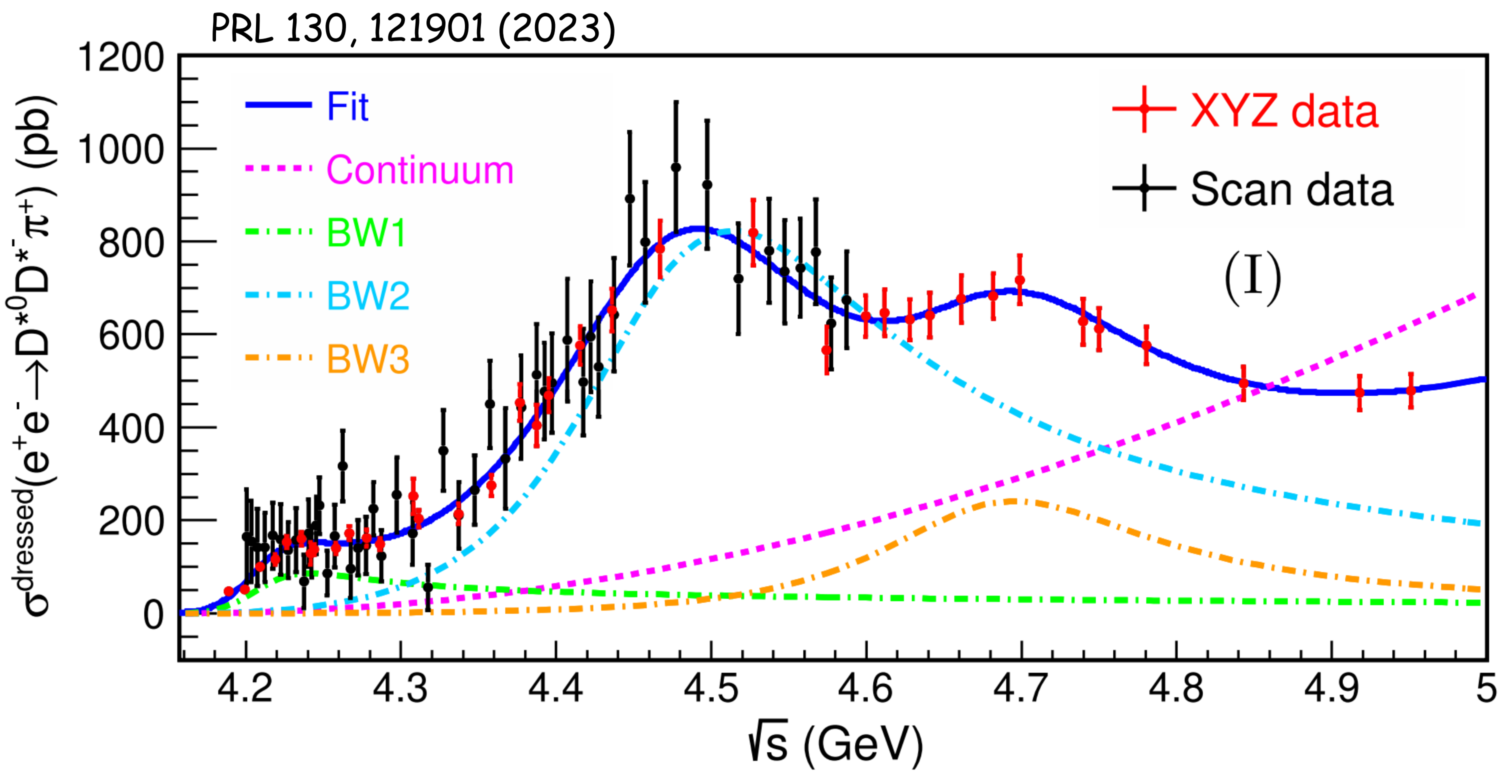
- Two coherent Y(4360)+Y(4660)

Parameters	Solution I	Solution II
$M[R_1]$	$4406.9 \pm 17.2 \pm 4.5$	
$\Gamma_{tot}[R_1]$	$128.1 \pm 37.2 \pm 2.3$	
$\Gamma_{e^+e^-}\mathcal{B}_1^{R_1}\mathcal{B}_2$	$0.36 \pm 0.10 \pm 0.03$	$0.30 \pm 0.09 \pm 0.03$
$M[R_2]$	$4647.9 \pm 8.6 \pm 0.8$	
$\Gamma_{tot}[R_2]$	$33.1 \pm 18.6 \pm 4.1$	
$\Gamma_{e^+e^-}\mathcal{B}_1^{R_2}\mathcal{B}_2$	$0.24 \pm 0.07 \pm 0.02$	$0.06 \pm 0.03 \pm 0.01$
ϕ	$267.1 \pm 16.2 \pm 3.2$	$-324.8 \pm 43.0 \pm 5.7$

$$\frac{\Gamma[\psi(4660)\to\pi^+\pi^-\psi_2(3823)]}{\Gamma[\psi(4660)\to\pi^+\pi^-\psi(2S)]} \sim 20\%$$

- $f_0(980)\psi(2S)$ molecule
- Y(4260) radial excitation
- Baryonium···

e+e-→$D^{*0}D^{*+}\pi^-$



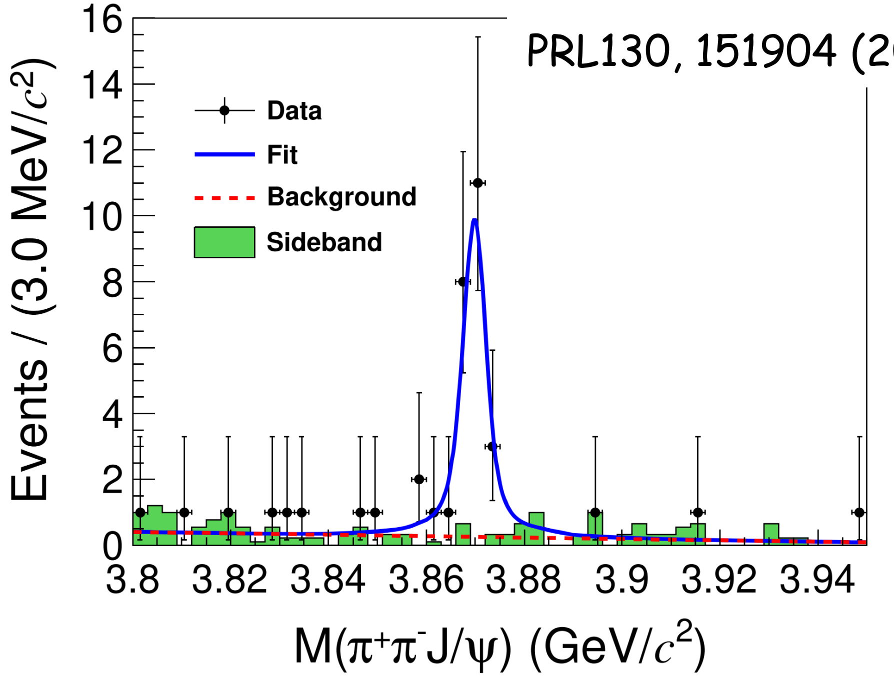
$$\sigma^{\text{dressed}}(\sqrt{s}) = C_0\left|C_1\sqrt{\Phi(\sqrt{s})} + \sum_{k=1}^{3}\text{BW}_k(\sqrt{s})e^{i\phi_k}\right|^2,$$

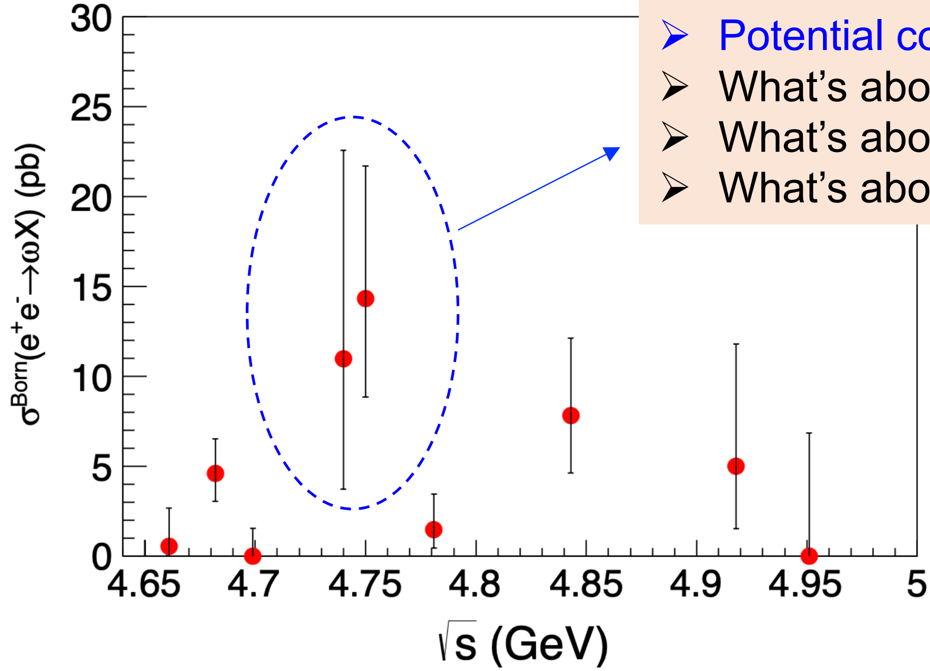
m_1=4209.6±4.7±5.9 MeV/c^2 , Γ_1=81.6±17.8±9.0 MeV; →Y(4230), coupling similar to $D^0D^{*+}\pi^-$ [Γ_{ee}>40 eV]

m_2=4469.1±26.2±3.6 MeV/c^2 , Γ_2=246.3±36.7±9.4 MeV; →Y(4500), coupling much larger than KKJ/ψ

m_3=4675.3±29.5±3.5 MeV/c^2 , Γ_3=218.3±72.9±9.3 MeV. →Y(4660), first open-charm decay

e+e-→ωX(3872) production





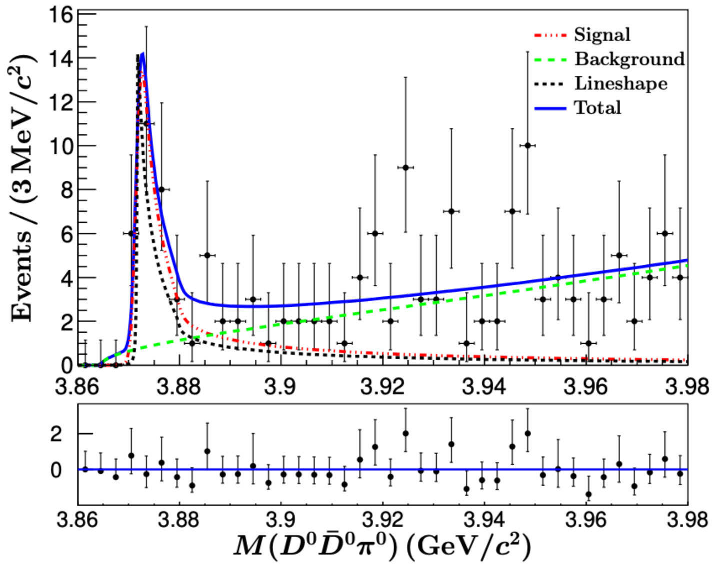
- Potential connection to Y(4710)?
- What's about e+e-→γX(3872)?
- What's about e+e-→$\omega\chi_{c1}$/ωX(3872)?
- What's about e+e-→ϕX(3872)

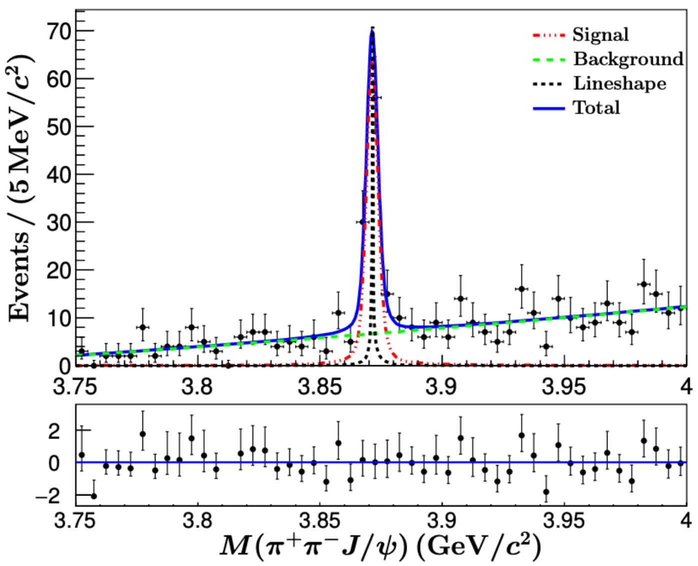
- **4.7 fb^{-1} data between 4.66 – 4.95 GeV**
- **$\omega\to\pi^+\pi^-\pi^0$ & X(3872)→$\pi^+\pi^-J/\psi$, one of the 4π could be missing to improve reconstruction efficiency**
- **New production mode: N(signal)=24.6±5.3 events, significance 7.8σ**

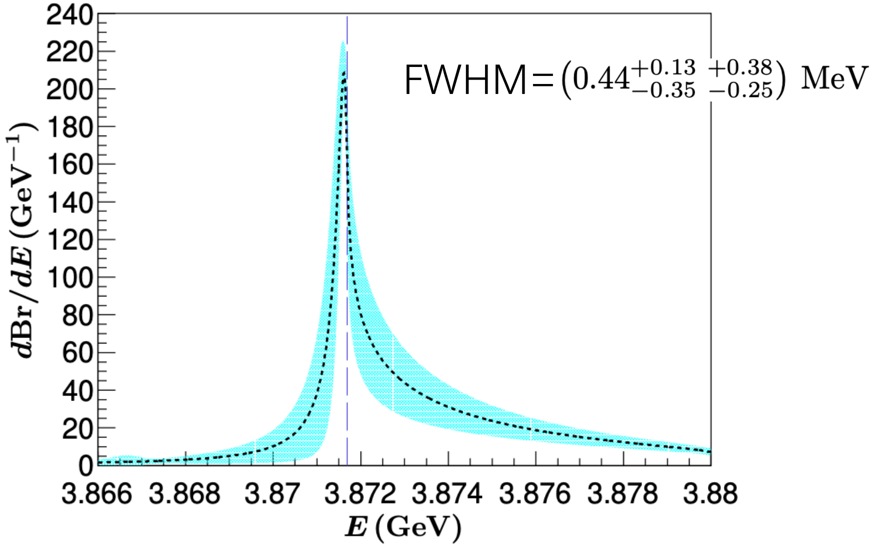
$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}$(pb^{-1})	$N_{\rm sig}$	$\epsilon(1+\delta)$ (%)	$\sigma^B(pb)$	$\sigma^B_{\rm up}(pb)$	Significance
4.661	529.63	$0.33^{+1.36}_{-0.33}$	28.3	$0.5^{+2.1}_{-0.5}\pm0.1\pm0.2$	5.6	...
4.682	1669.31	$8.00^{+3.34}_{-2.68}$	24.6	$4.6^{+1.9}_{-1.5}\pm0.4\pm1.5$	11.5	3.4σ
4.699	536.45	$0.00^{+0.95}_{-0.00}$	27.0	$0.0^{+1.6}_{-0.0}\pm0.0\pm0.0$	3.3	...
4.740	164.27	$1.67^{+1.77}_{-1.10}$	21.8	$10.9^{+11.6}_{-7.2}\pm1.0\pm3.5$	40.6	1.0σ
4.750	367.21	$5.00^{+2.58}_{-1.92}$	22.4	$14.2^{+7.4}_{-5.5}\pm1.4\pm4.5$	38.2	3.1σ
4.781	512.78	$1.00^{+1.36}_{-0.70}$	31.6	$1.5^{+2.0}_{-1.0}\pm0.2\pm0.5$	6.5	0.7σ
4.843	527.29	$4.67^{+2.58}_{-1.92}$	26.7	$7.8^{+4.3}_{-3.2}\pm0.7\pm2.5$	21.1	2.6σ
4.918	208.11	$1.00^{+1.36}_{-0.70}$	22.6	$5.0^{+6.8}_{-3.5}\pm0.4\pm1.6$	21.7	0.7σ
4.951	160.37	$0.00^{+0.95}_{-0.00}$	20.4	$0.0^{+6.8}_{-0.0}\pm0.0\pm0.0$	14.7	...

Couple channel analysis of X(3872) line shape

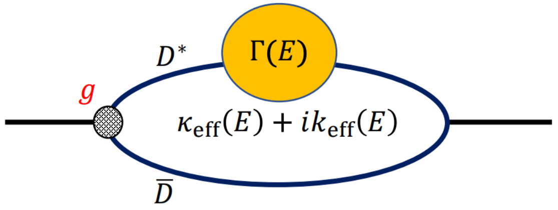
arXiv:2309.01502







Hanhart, Kalashnikova, Nefediev, PRD 81, 094028 (2010)



$$\frac{d\mathrm{Br}(D^0\bar{D}^0\pi^0)}{dE} = \mathcal{B}\frac{\mathrm{Br}(D^{*0}\to D^0\pi^0)\times g\times k_{\rm eff}(E)}{|D(E)|^2}$$

$$\frac{d\mathrm{Br}(\pi^+\pi^- J/\psi)}{dE} = \mathcal{B}\frac{\Gamma_{\pi^+\pi^- J/\psi}}{|D(E)|^2},$$

$$D(E) = E - E_X + \tfrac{1}{2}g\left[(\kappa_{\rm eff}(E) + ik_{\rm eff}(E)) + (\kappa^c_{\rm eff}(E) + ik^c_{\rm eff}(E))\right] + \tfrac{i}{2}\Gamma_0. \qquad \Gamma_0 = (1+\alpha+\beta)\Gamma_{\pi^+\pi^- J/\psi}$$

Parameters	g	Γ_0 (MeV)	M_X (MeV)
Fit results	0.16 ± 0.10	2.67 ± 1.77	3871.63 ± 0.13

$$\frac{\Gamma(X(3872)\to\pi^+\pi^- J/\psi)}{\Gamma(X(3872)\to D^0\bar{D}^{*0})} = 0.05 \pm 0.01^{+0.01}_{-0.02}$$

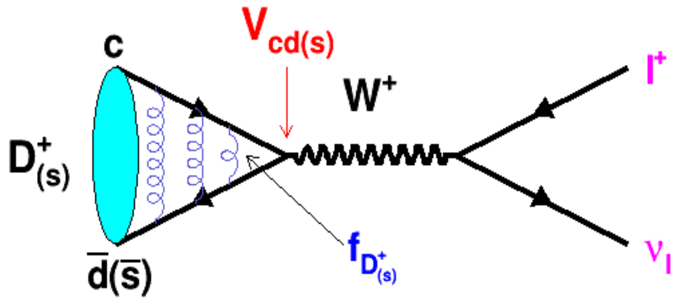
$$Z = 0.18$$

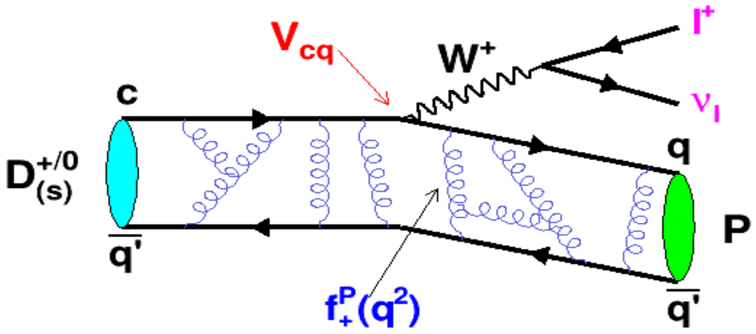
Weinberg's compositeness: Z = 1 (elementary state); Z = 0 (composite state)

D & Λ_c decay

(semi)Leptonic decay

Ideal bridge to access the strong and weak effects between quarks





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

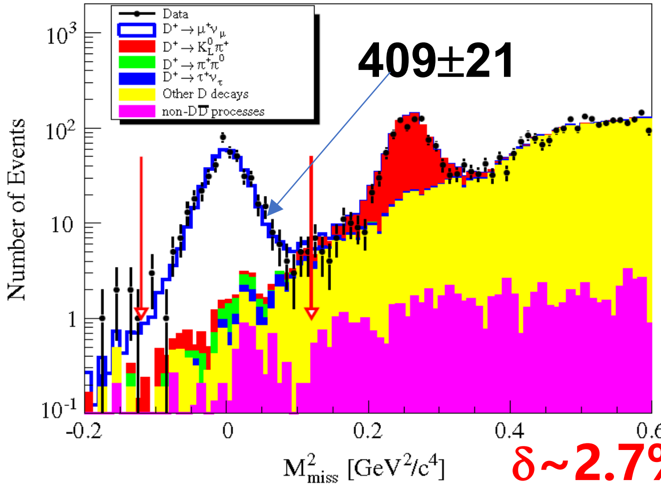
$$\frac{d\Gamma}{dq^2} = X \frac{G_F^2}{24\pi^3} |f_+^h(0)|^2 |V_{cq}|^2 |\vec{p}_h|^3$$

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

CKM matrix elements: fundamental Standard Model (SM) parameters describing the mixing of quark fields due to weak interaction

Leptonic decay of $D^+_{(s)} \to l^+\nu_l$

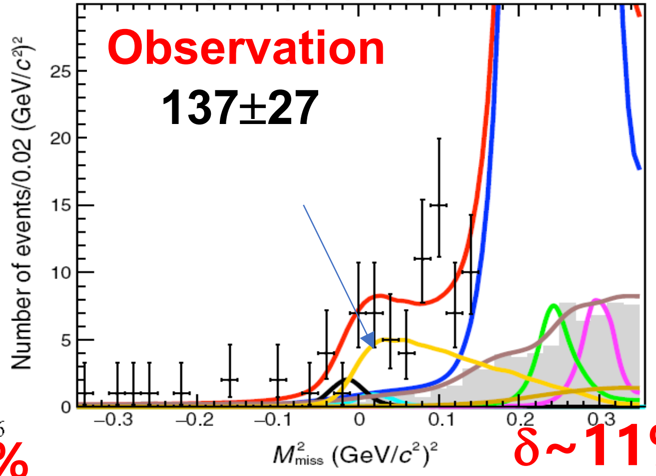
$D^+ \to \mu^+ v$ PRD89(2014)051104



δ~2.7%

$f_{D^+}|V_{cd}| = 46.7 \pm 1.2 \pm 0.4$ MeV

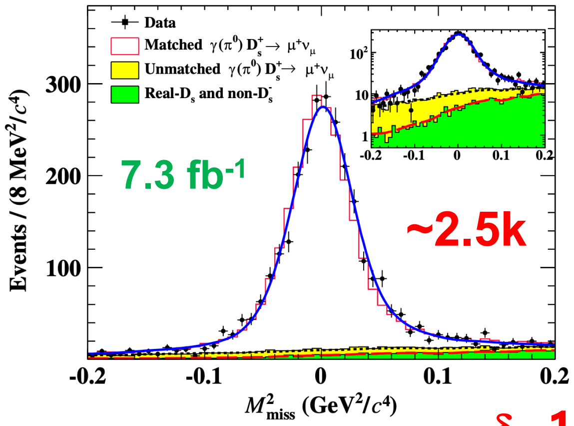
$D^+ \to \tau^+(\pi^+ v)v$ PRL123(2019)211802



δ~11%

$f_{D^+}|V_{cd}| = (50.4 \pm 5.0 \pm 2.5)$ MeV

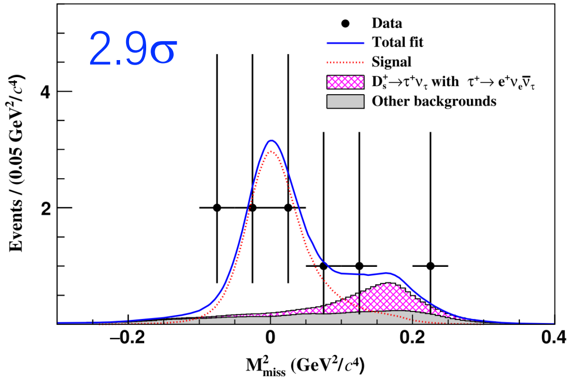
$D_s^+ \to \mu^+ v$ PRL122(2019)071802



δ~1.4%

$f_{D_s^+}|V_{cs}| = 241.8 \pm 2.5_{stat} \pm 2.2_{syst}$ MeV

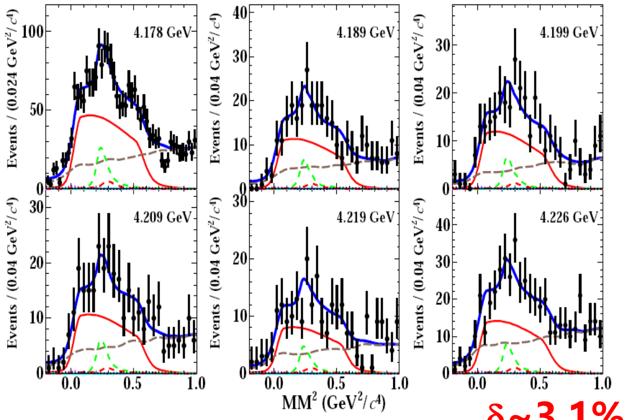
$D_s^{*+} \to e^+ v$ PRL 131, 141802 (2023)



$\Gamma[D_s^{*+}]$ input from Lattice

$f_{D_s^{*+}} = (214^{+61}_{-46\,stat} \pm 44_{syst})$ MeV

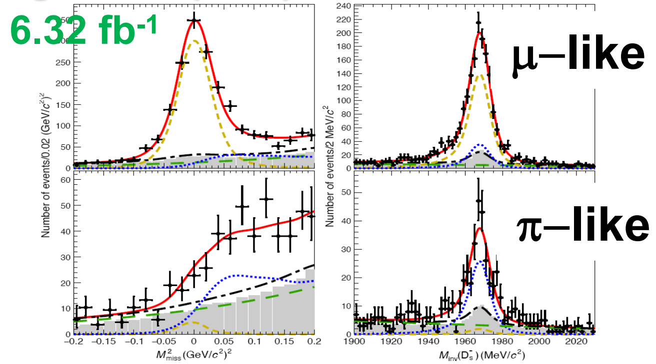
PRD104(2021)032001 $D_s^+ \to \tau^+(\rho^+ v)v$ 6.32 fb^{-1}



δ~3.1%

$f_{D_s^+}|V_{cs}| = 244.8 \pm 5.8 \pm 4.8$ MeV

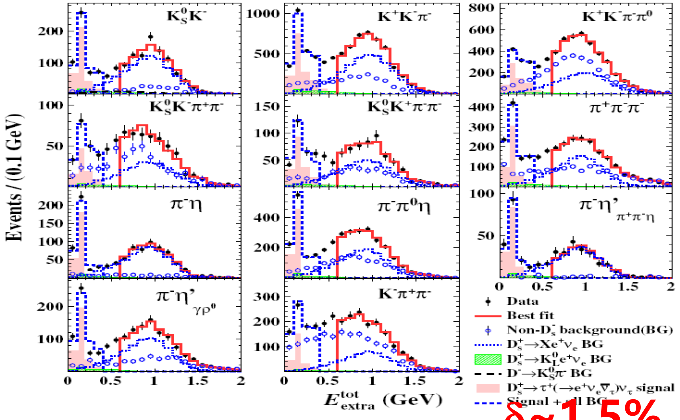
$D_s^+ \to \tau^+(\pi^+ v)v$ PRD104,052009(2021) PRD108,092014(2023)



$f_{D_s^+}|V_{cs}| = 243.0 \pm 5.8 \pm 4.0$ MeV δ~2.1%

$f_{D_s^+}|V_{cs}| = (248.3 \pm 3.9_{stat} \pm 3.0_{syst} \pm 1.0_{input})$ MeV

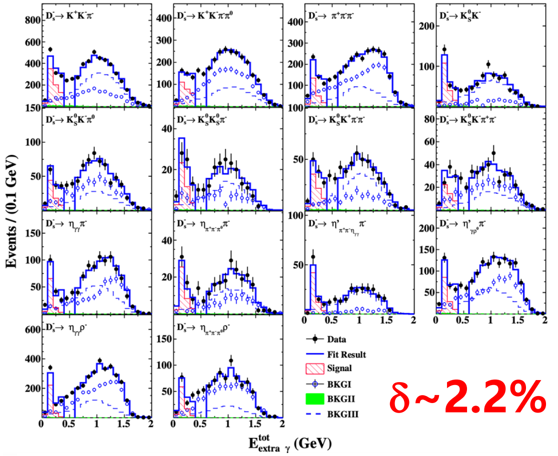
PRL127(2021)171801 $D_s^+ \to \tau^+(e^+ vv)v$ ~4.9K



δ~1.5%

$f_{D_s^+}|V_{cs}| = (244.4 \pm 2.3 \pm 2.9)$ MeV

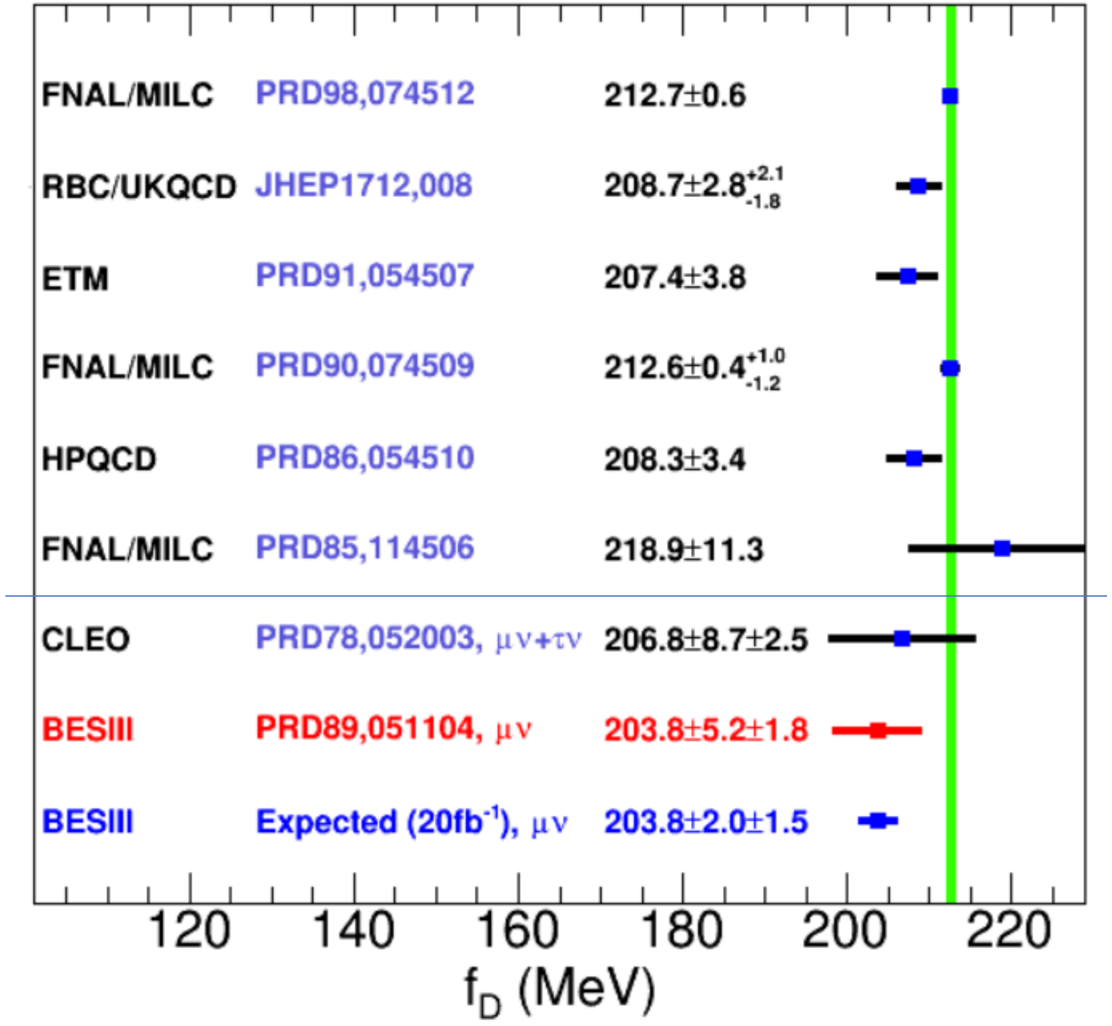
JHEP09(2023)124 $D_s^+ \to \tau^+(\mu^+ vv)v$

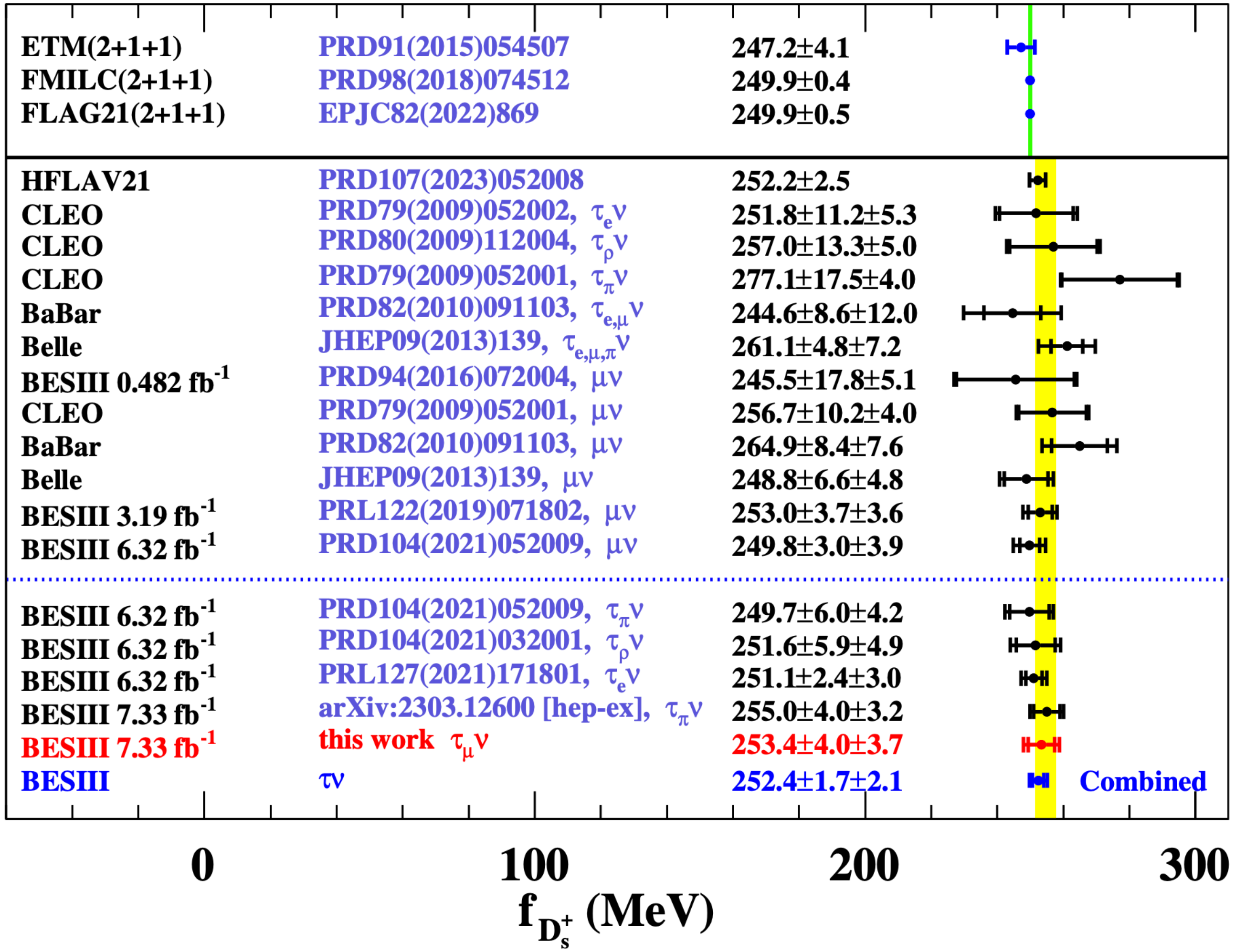


δ~2.2%

$f_{D_s^+}|V_{cs}| = (246.7 \pm 3.9_{stat} \pm 3.6_{syst})$ MeV

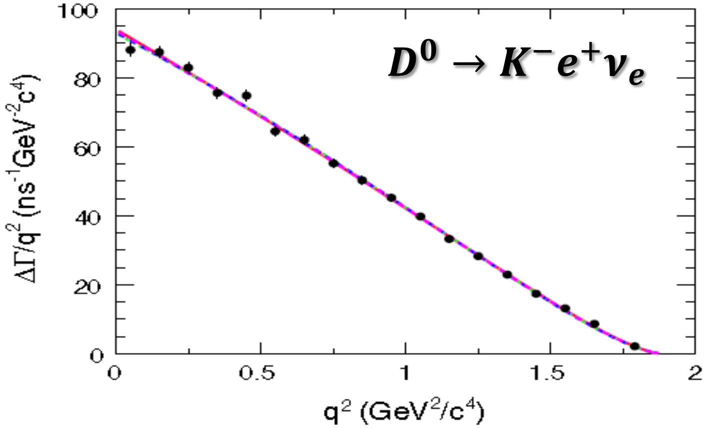
Status of f_{D^+} and $f_{D_s^+}$





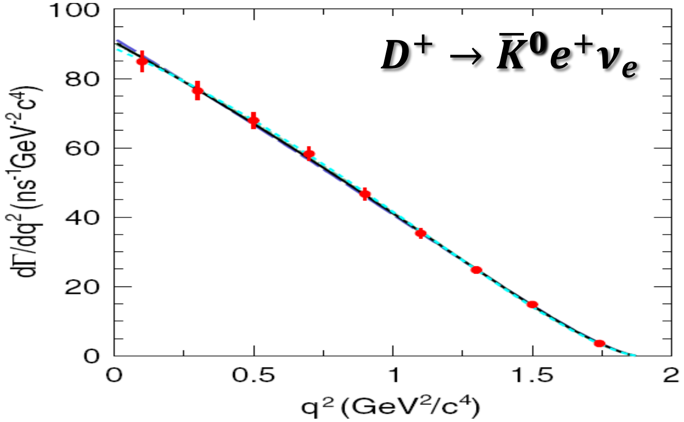
Studies of $c \to s l^+ \nu_l$ semileptonic decays

PRD92(2015)072012



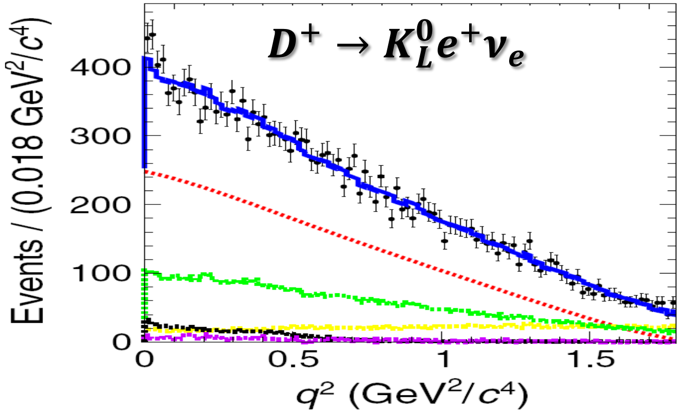
$f_+^{D\to K}(0)|V_{cs}| = 0.717(03)(04)$

PRD96(2017)012002



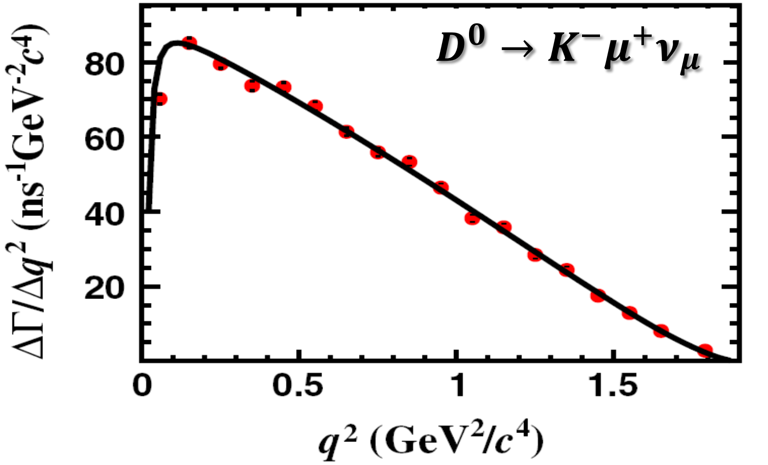
$f_+^{D\to K}(0)|V_{cs}| = 0.705(04)(11)$

PRD92(2015)112008



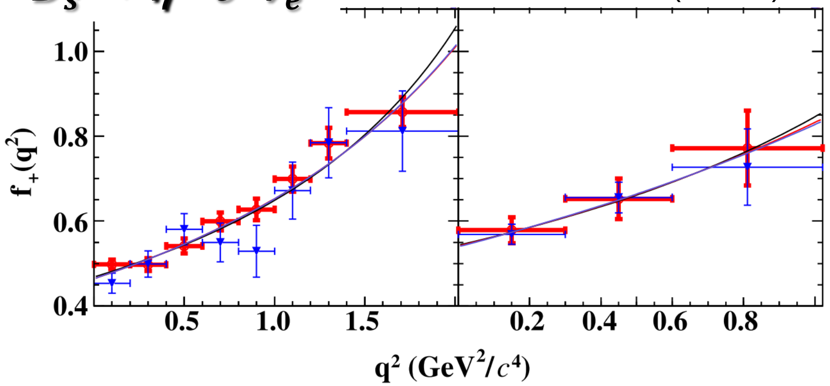
$f_+^{D\to K}(0)|V_{cs}| = 0.728(06)(11)$

PRL122(2019)011804



$f_+^{D\to K}(0)|V_{cs}| = 0.7148(38)(29)$

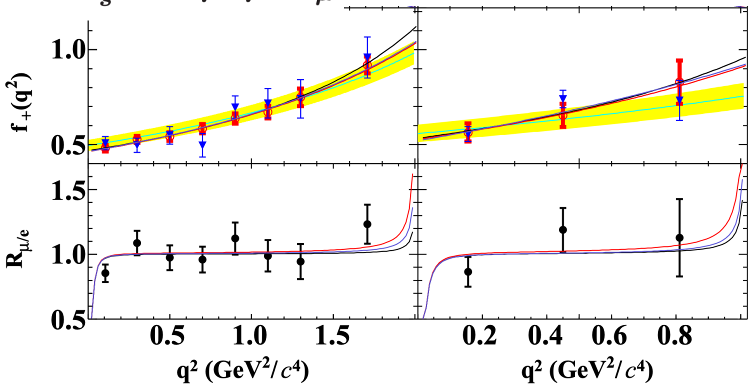
$D_s^+ \to \eta^{(\prime)} e^+ \nu_e$ PRD108, 092003 (2023)



$f_+^{\eta}(0)|V_{cs}| = 0.4519 \pm 0.0071_{\rm stat} \pm 0.0065_{\rm syst}$

$f_+^{\eta'}(0)|V_{cs}| = 0.525 \pm 0.024_{\rm stat} \pm 0.009_{\rm syst}$

$D_s^+ \to \eta^{(\prime)} \mu^+ \nu_\mu$ arXiv:2307.12852

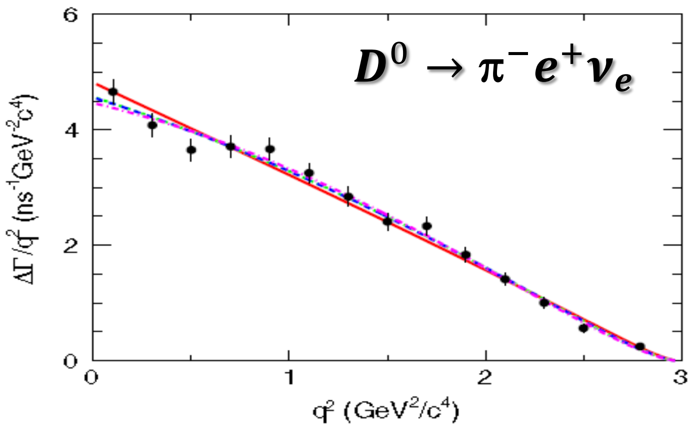


$f_+^{\eta}(0)|V_{cs}| = 0.451 \pm 0.010_{\rm stat} \pm 0.008_{\rm syst}$

$f_+^{\eta'}(0)|V_{cs}| = 0.506 \pm 0.037_{\rm stat} \pm 0.011_{\rm syst}$

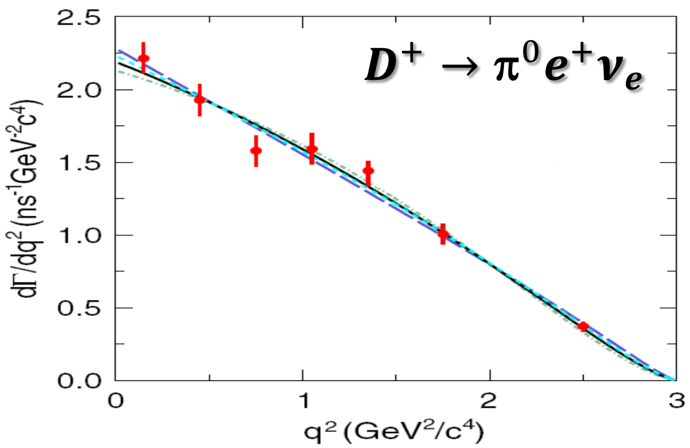
Studies of $c \to d l^+ \nu_l$ semileptonic decays

PRD92(2015)072012



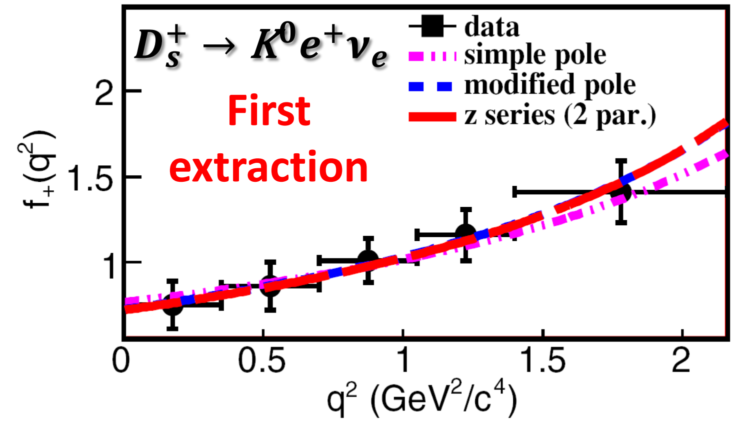
$f_+^{D\to\pi}(0)|V_{cd}| = 0.144(02)(01)$

PRD96(2017)012002



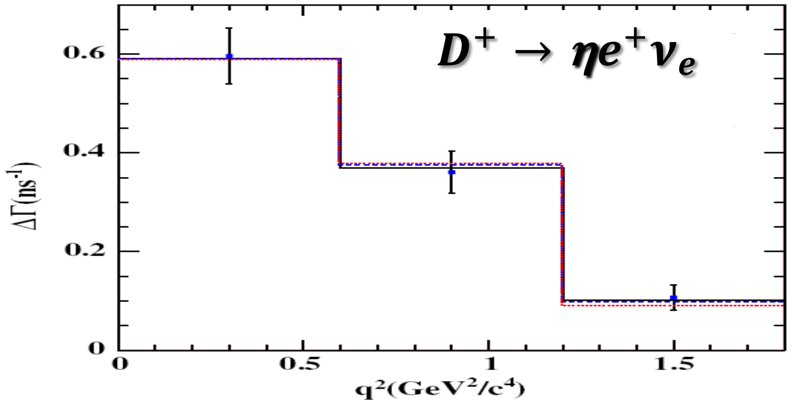
$f_+^{D\to\pi}(0)|V_{cd}| = 0.140(03)(01)$

PRL122(2019)061801



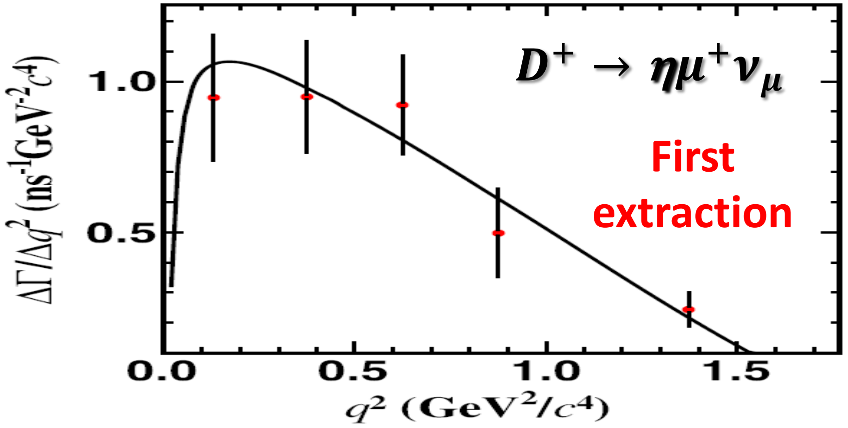
$f_+^{D_s\to K}(0)|V_{cd}| = 0.162(19)(03)$

PRD97(2018)092009



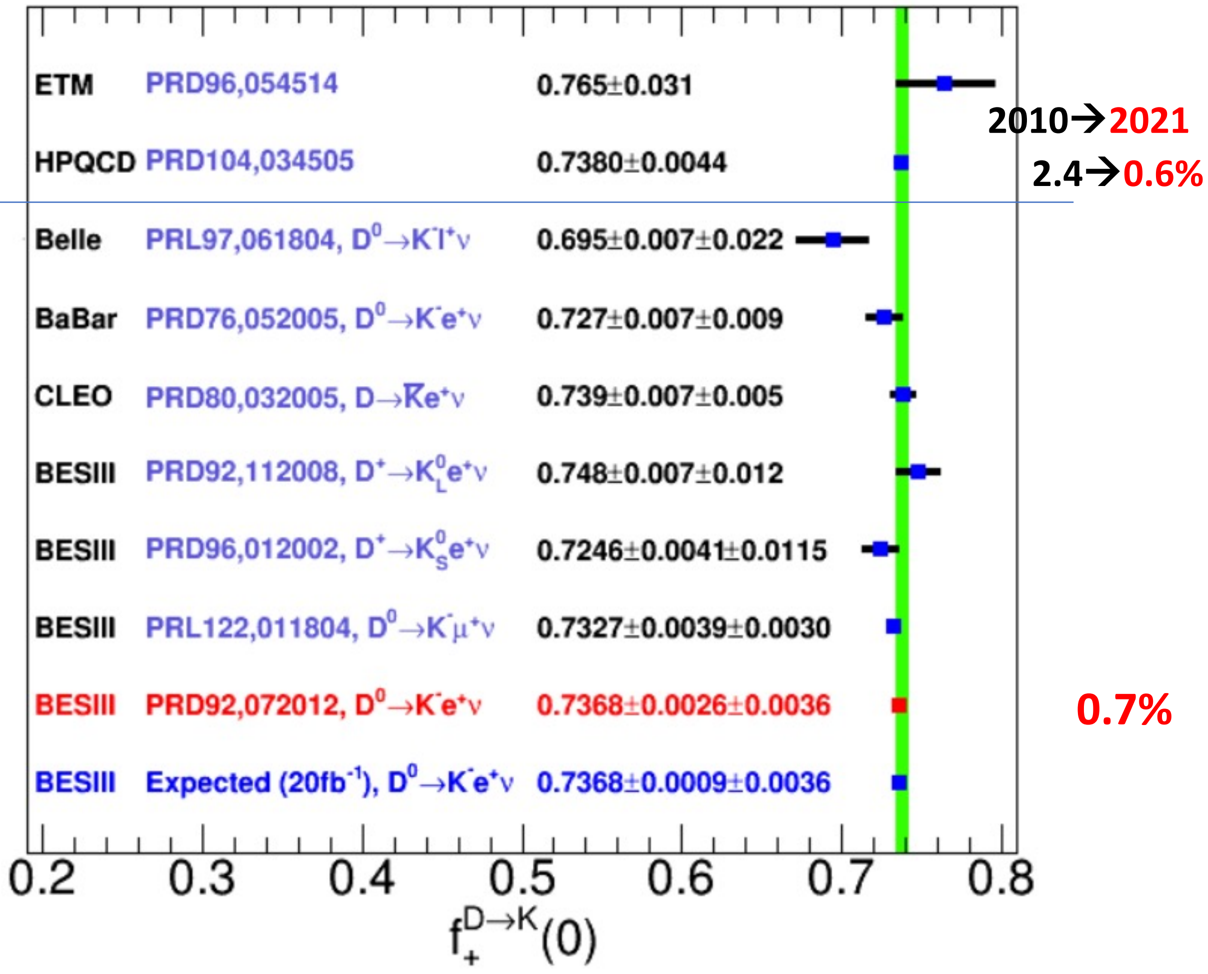
$f_+^{D\to\eta}(0)|V_{cd}| = 0.079(06)(02)$

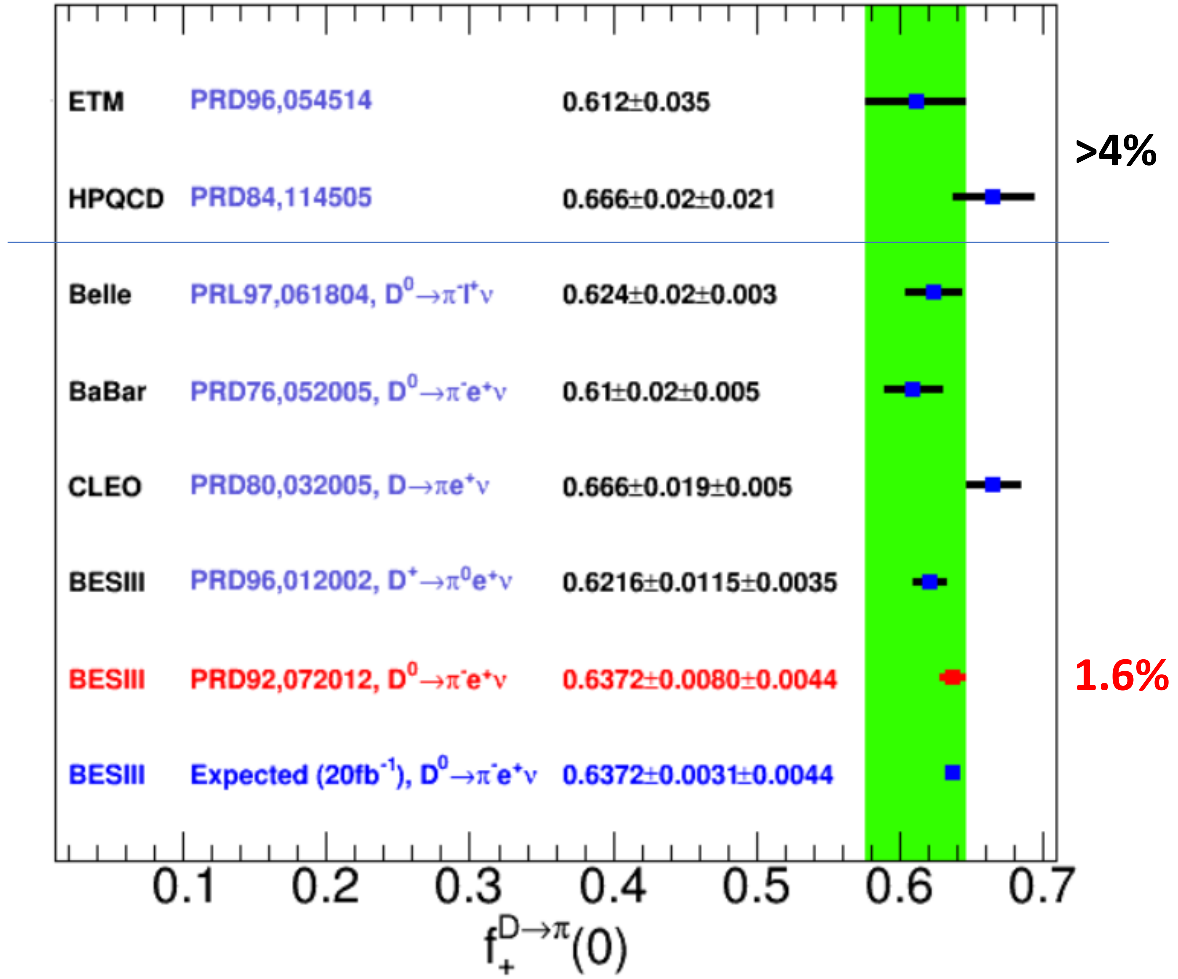
PRL124(2020)231801



$f_+^{D\to\eta}(0)|V_{cd}| = 0.087(08)(02)$

Status of $f_+^{D\to K}(0)$ and $f_+^{D\to\pi}(0)$

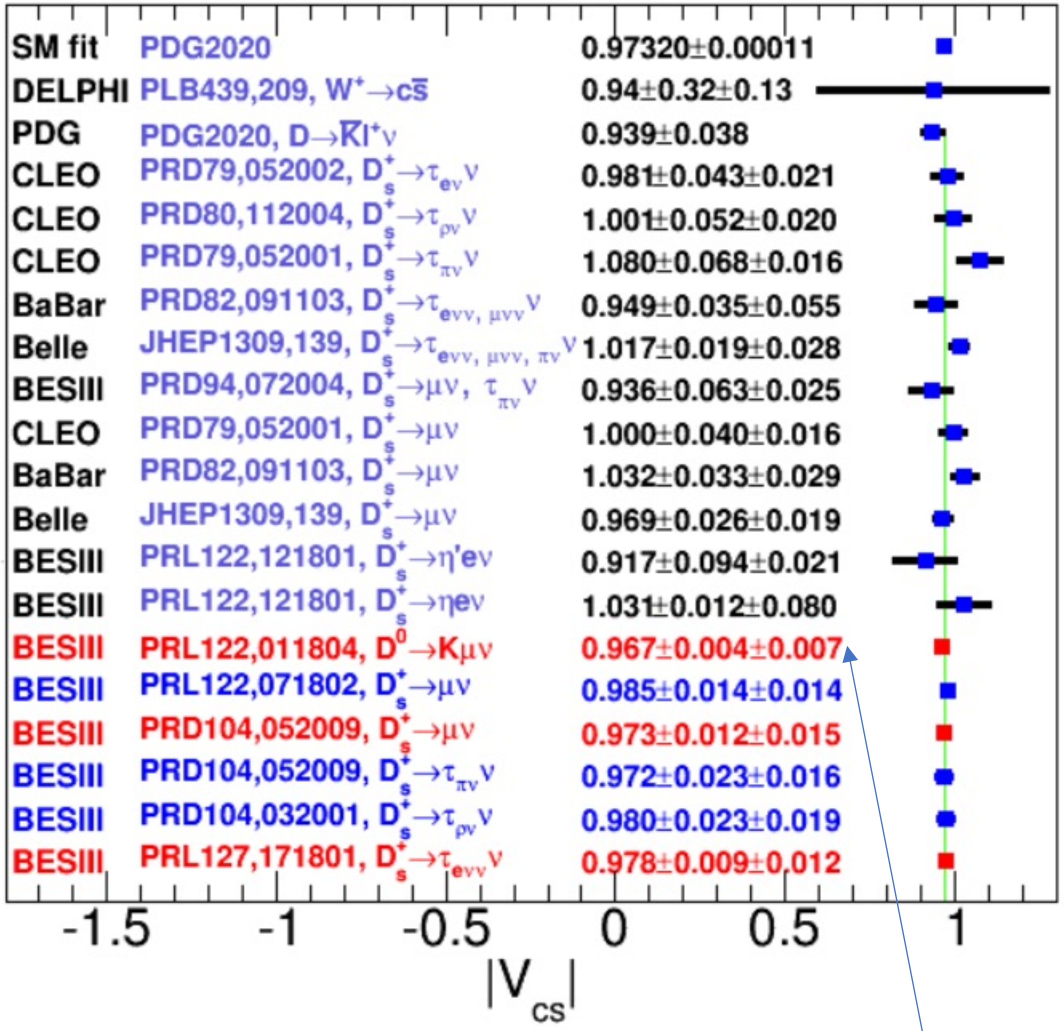


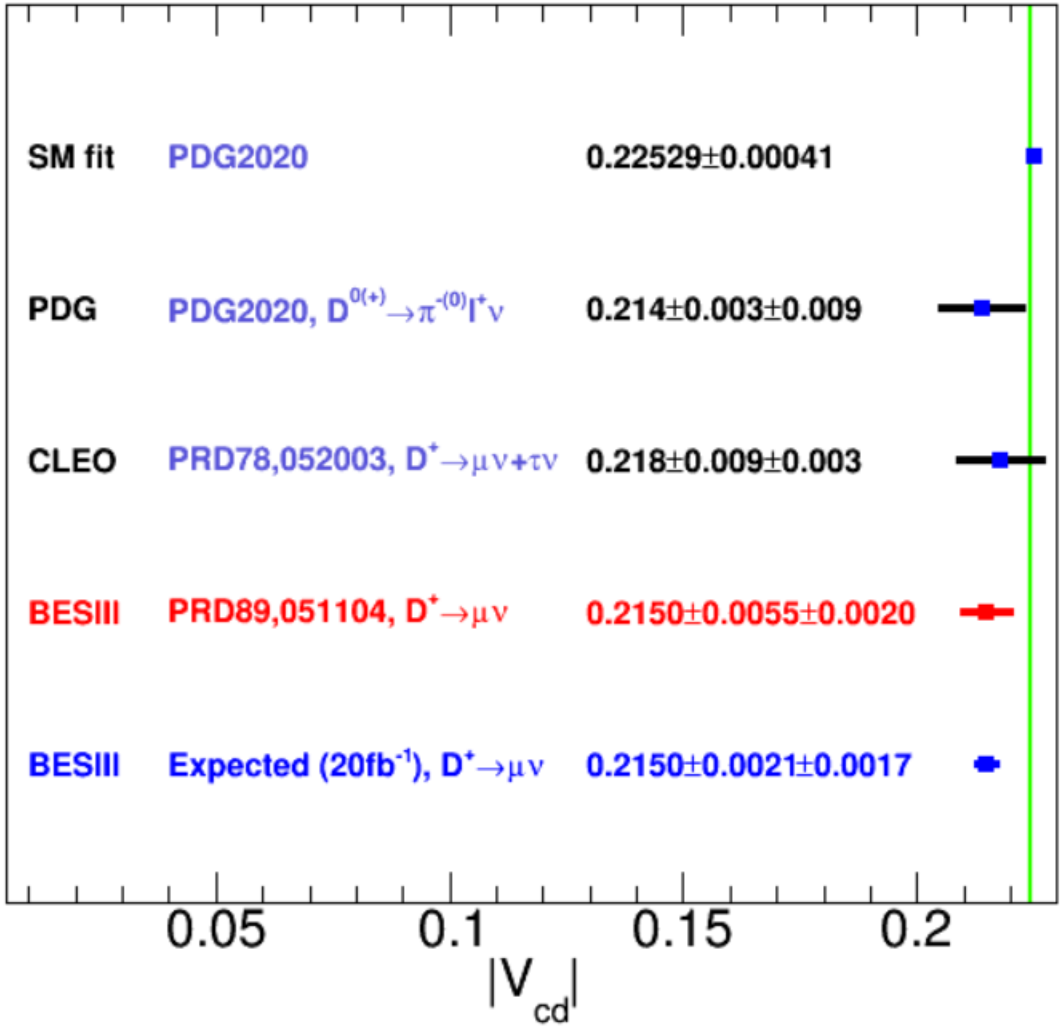


Experimental precision of $f_+^{D\to K}(0)$ is comparable to the latest LQCD precision

Experimental precision of $f_+^{D\to\pi}(0)$ is still dominated by statistical uncertainties

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

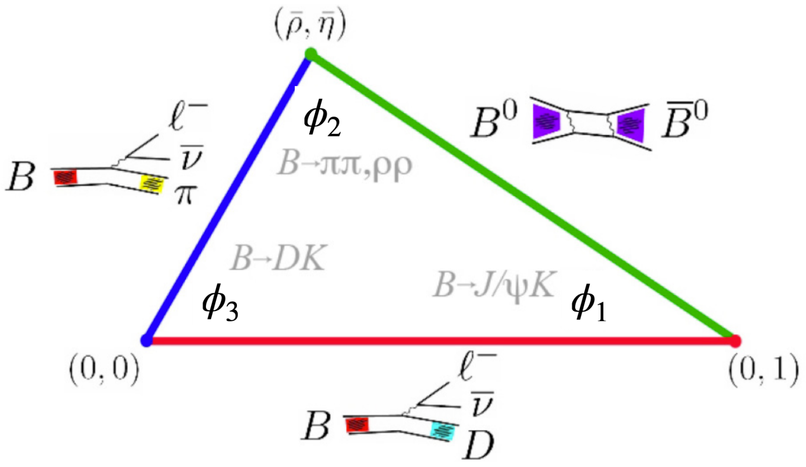




$f_+^{D\to K}(0)$@HPQCD[2021]

precision: 2.4%→0.6%

Hadronic D decays – strong phase



•In SM, CKM matrix is unitary: four free parameter, one of them is the complex phase, the **only one source** of CPV in quark sector in SM !

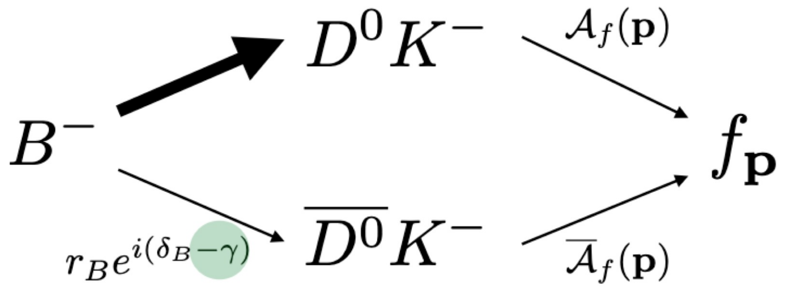
•Precisely test the CKM matrix unitary & hunt for New Physics !

$\phi_1 = \beta = \arg(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*})$, $(22.2 \pm 0.7)^\circ$ (most precise)

$\phi_2 = \alpha = \arg(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*})$,$(85.2^{+4.8}_{-4.3})^\circ$

$\phi_3 = \gamma = \arg(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*})$,$(66.2^{+3.4}_{-3.6})^\circ$(theoretically clean)

HFLAV

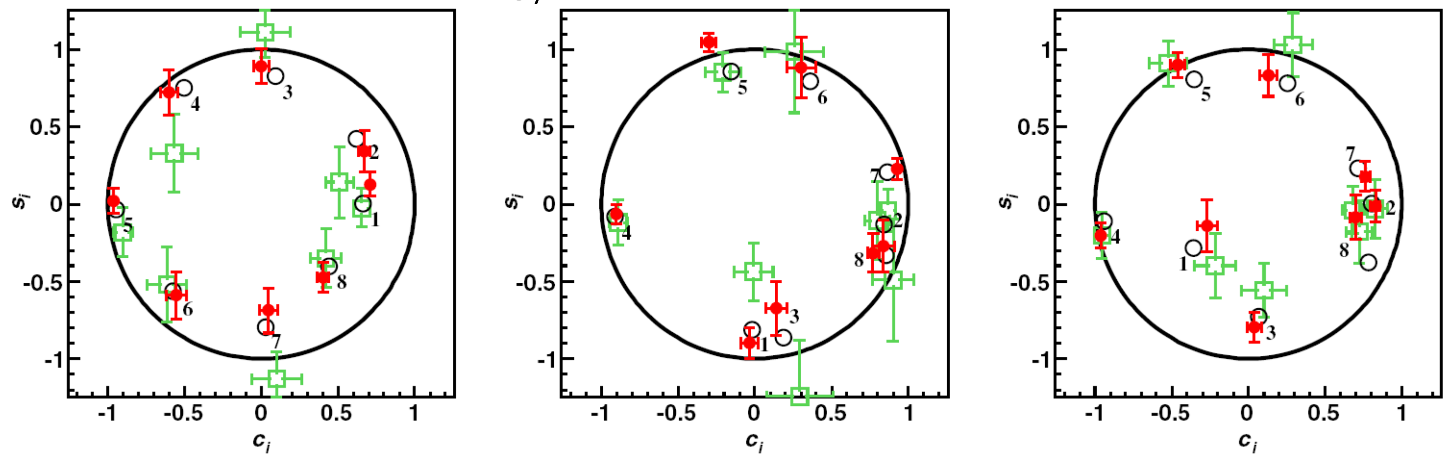


- LHCb expect 1.5° by end of Run 3 (~ 22 fb^{-1}), <1° by end of Run 4 (~ 50 fb^{-1}), ~ 0.4° in Phase II upgrade (~ 300 fb^{-1}).[arXiv:1709.10308, CERN-LHCC-2017-003]
- Belle II expect 1.5° with $50\ \text{ab}^{-1}$ [2020 snowmass].

•Need information of the D decays, e.g. strong-phase difference.
•CLEO-c and BESIII provides model-independent external inputs.

Hadronic D decays – strong phase

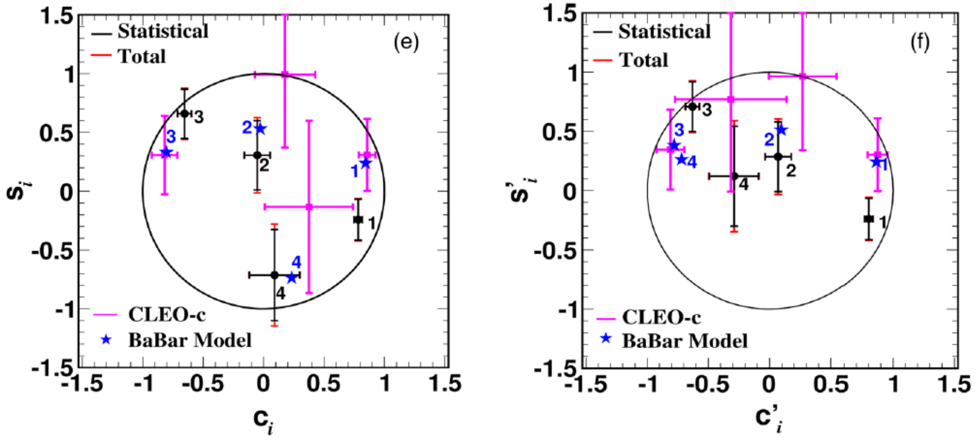
$D \rightarrow K^0_{S/L}\pi^+\pi^-$ PRL124(2020)241802



$e^+e^- \rightarrow \psi(3770) \rightarrow D^0\overline{D}^0$ quantum correlated pair production at 3.773 GeV

Constraint sensitivity on γ measurement ~ 0.7° - 1.2°

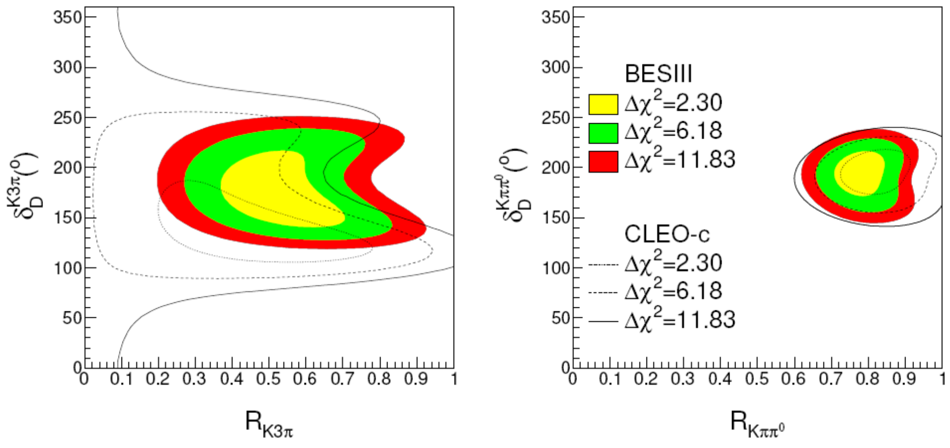
$D \rightarrow K^0_{S/L}K^+K^-$ PRD102(2020)052008



Constraint sensitivity on γ measurement ~ 1.3° – 2.3°

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

JHEP05(2021)164

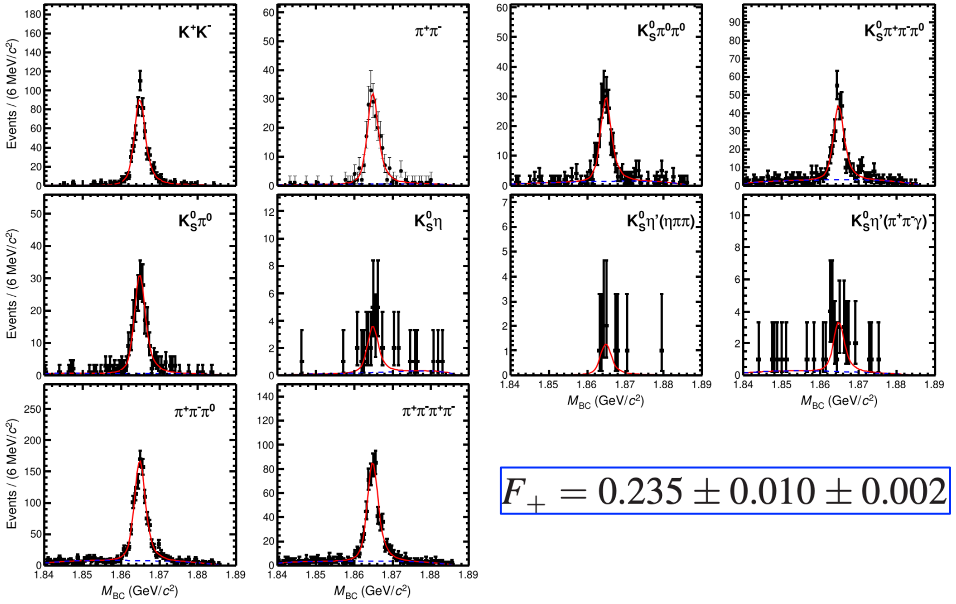


Constraint sensitivity on γ measurement ~ 6°

Hadronic D decays – strong phase

$D^0 \to K_S^0\pi^+\pi^-\pi^0$

PRD108, 032003 (2023)



$F_+ = 0.235 \pm 0.010 \pm 0.002$

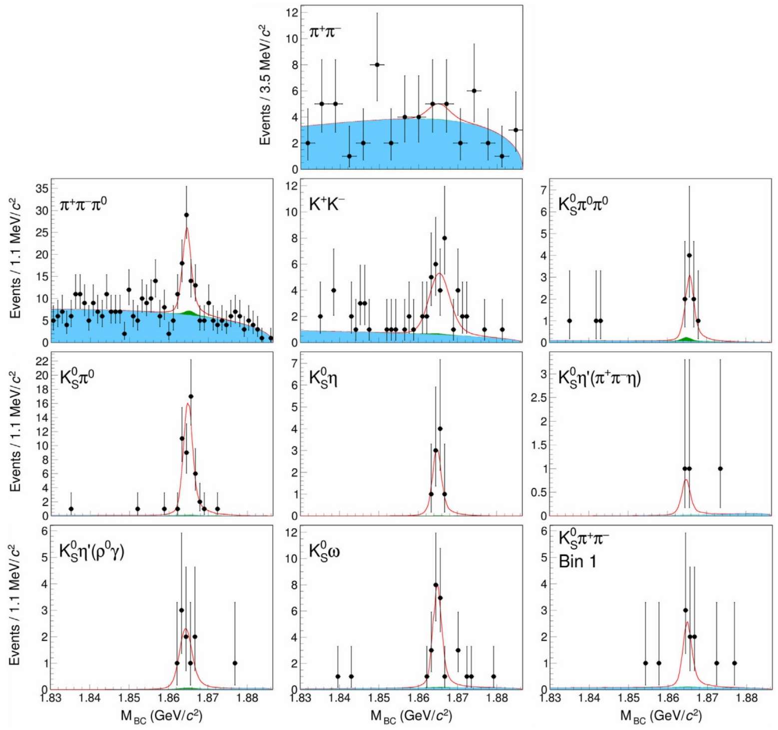
"GLW" extended strategy require CP even fraction – F_+

$$N_{\rm DT} = 2N_{D\bar{D}}\mathcal{B}(S)\mathcal{B}(T)\varepsilon(S|T) \times [1-(2F_+-1)(2F_+^T-1)]$$

$D^0 \to K^+K^-\pi^+\pi^-$

PRD 107, 032009 (2023)

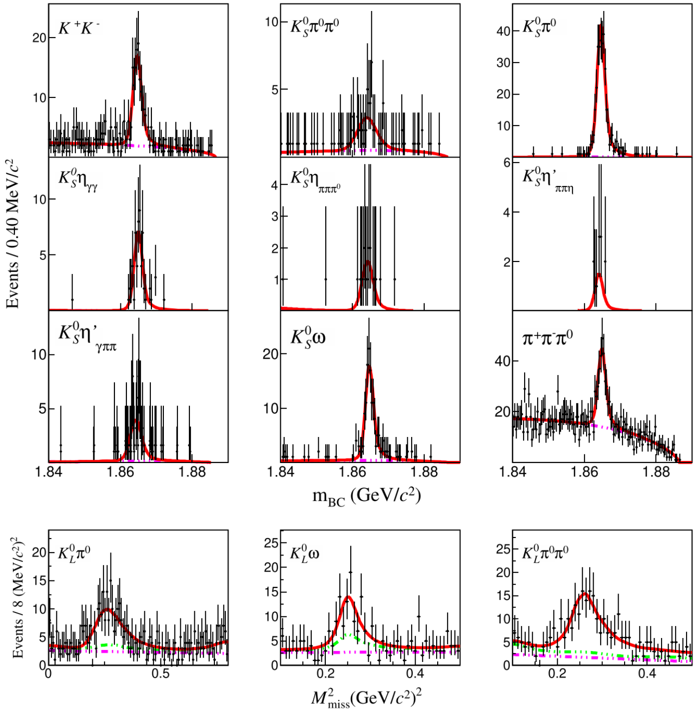
$F_+ = 0.730 \pm 0.037 \pm 0.021$



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

PRD 106, 092004 (2022)

$F_+^{4\pi} = 0.735 \pm 0.015 \pm 0.005$



Joint amplitude analysis

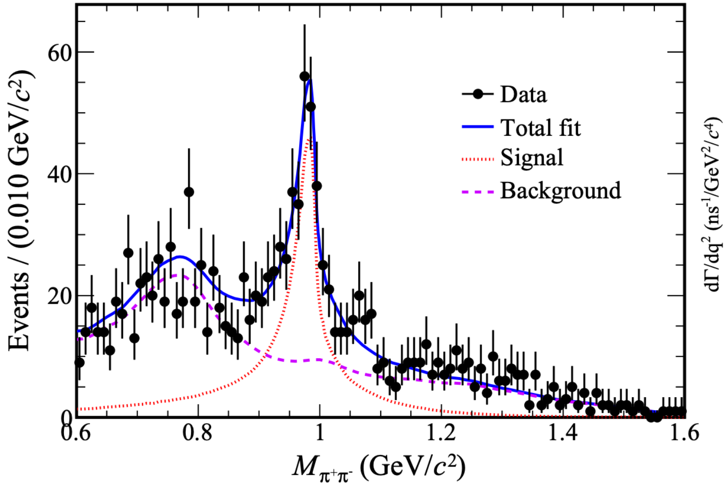
$$D^0 \to \pi^+\pi^-\pi^0\pi^0$$

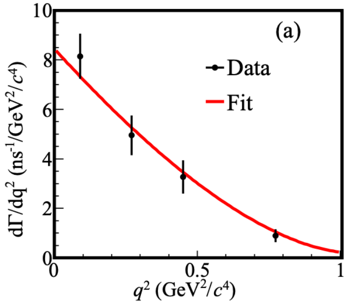
F_+ = $(68.9 \pm 1.5_{\rm stat.} \pm 2.4_{\rm syst.})\%$

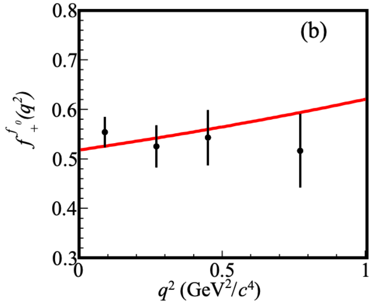
arXiv: 2312.02524

D decays – light mesons

$D_s^+ \to \pi^+\pi^- e^+\nu_e$ arXiv:2303.12927







$$f_+^{f_0}(0)|V_{cs}| = 0.504 \pm 0.017_{\rm stat} \pm 0.035_{\rm syst}$$

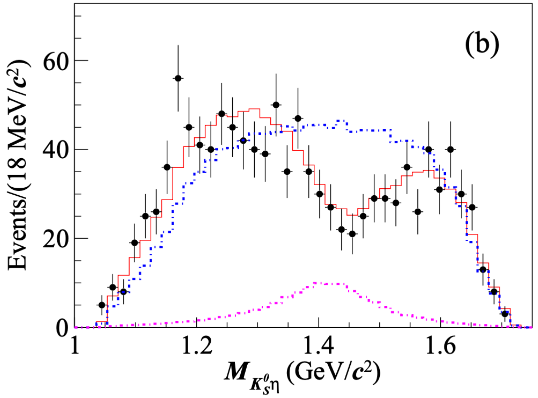
$$\mathrm{BF}(D_s^+ \to f_0(980)e^+\nu_e) = 4.22 \times 10^{-3} cos^2\phi$$

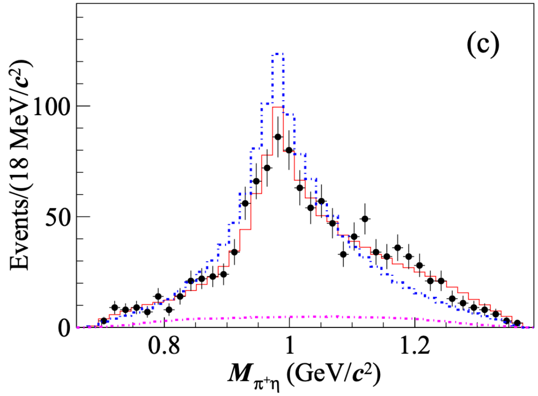
$$\sin\phi \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) + \cos\phi s\bar{s}$$

$$\phi = (19.7 \pm 12.8)^\circ$$ →ss is dominant

Further study of a0(980), f0(500)··· is ongoing

$D^+ \to K_S^0\pi^+\eta$ arXiv:2309.05760





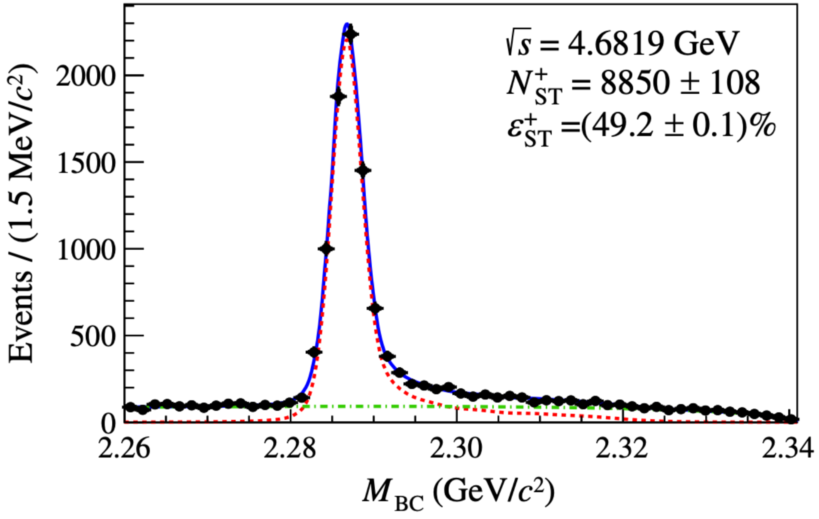
Amplitude	Phase ϕ_n (rad)	FF (%)	Significance
$D^+ \to K_S^0 a_0(980)^+$	0.0(fixed)	$105.00 \pm 0.94 \pm 1.04$	$> 10\sigma$
$D^+ \to K_0^*(1430)^0\pi^+$	$2.58 \pm 0.06 \pm 0.09$	$10.83 \pm 1.50 \pm 0.89$	$> 10\sigma$

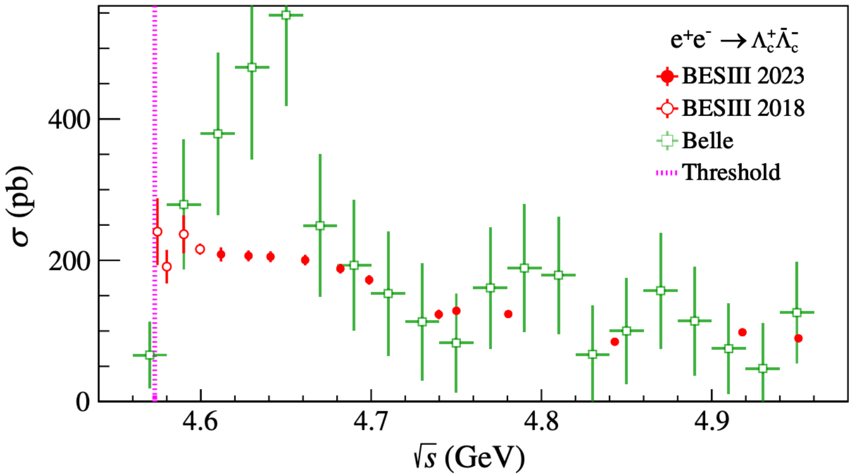
$$\mathcal{B}(D^+ \to K_S^0\pi^+\eta) = (1.27 \pm 0.04_{\rm stat.} \pm 0.03_{\rm syst.})\%$$

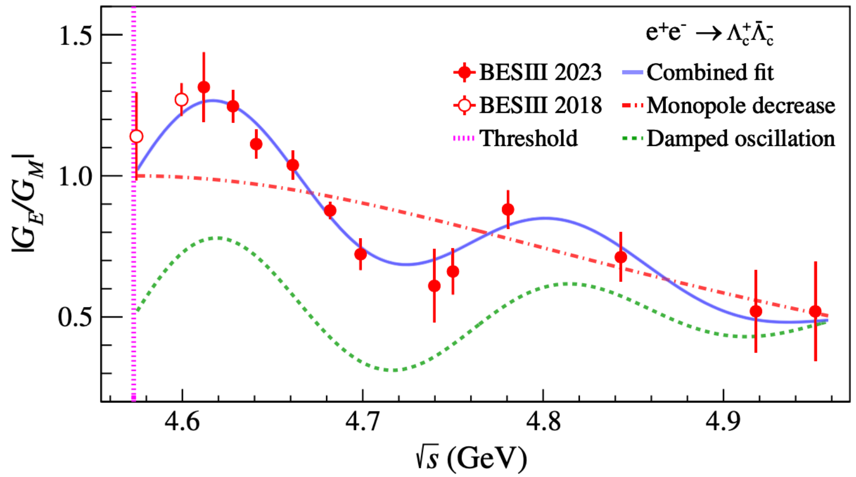
Critical information on the role of $a_0(980)$ in charmed meson decays and the nature of $a_0(980)$.

e+e-→ $\Lambda_c^+ \Lambda_c^-$ pair production

PRL 131, 191901 (2023)







- Single Tag for the golden channel
- High efficiency & low background
- Double Tag for the BF of $pK^-\pi^+$

- A plateau from threshold to 4.66 GeV (agree with previous measurement)
- No evidence for Y(4630)→ $\Lambda_c^+ \Lambda_c^-$
- A local structure near 4.75 GeV

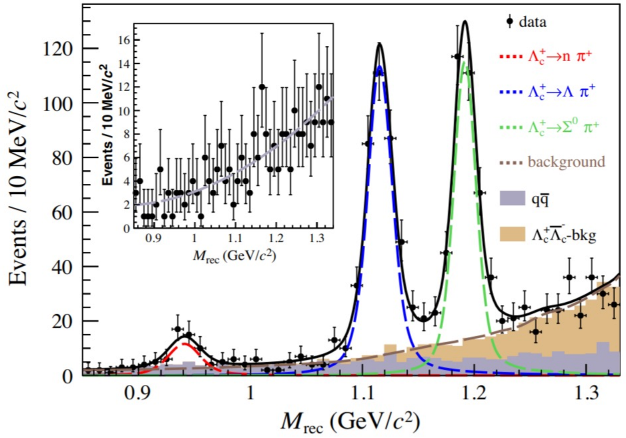
$$\alpha_{\Lambda_c} = (1-\kappa R^2)/(1+\kappa R^2)$$

$$R = |G_E/G_M| \quad \kappa = 4m^2c^4/s$$

$$|G_E/G_M|(s) = \frac{1}{1+\omega^2/r_0}[1 + r_1 e^{-r_2\omega}\sin(r_3\omega)]$$

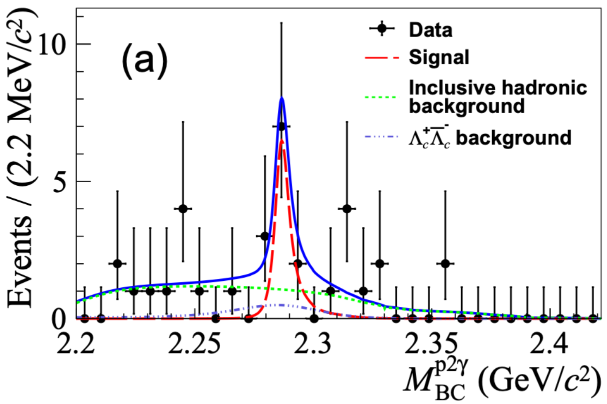
Λ_c^+ decays

Observation $\Lambda_c^+ \to n\pi^+$



PRL128(2022)142001

3.7σ evidence $\Lambda_c^+ \to p\pi^0$



arXiv: 2311.06883

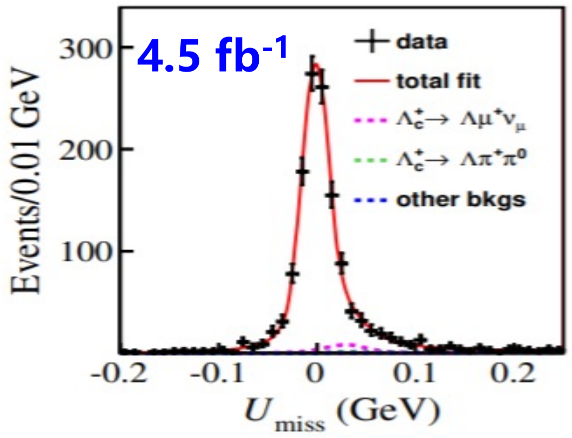
Decay	Yields	Branching fraction
$\Lambda_c^+ \to n\pi^+$	50 ± 9	$(6.6 \pm 1.2_{stat} \pm 0.4_{syst})\times10^{-4}$
$\Lambda_c^+ \to \Lambda\pi^+$	376 ± 22	$(1.31 \pm 0.08_{stat} \pm 0.05_{syst})\times10^{-2}$
$\Lambda_c^+ \to \Sigma^0\pi^+$	343 ± 22	$(1.22 \pm 0.08_{stat} \pm 0.07_{syst})\times10^{-2}$

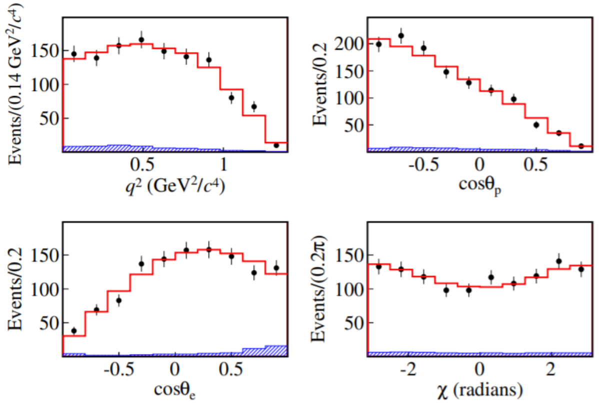
$$BF(\Lambda_c^+ \to p\pi^0) = (1.56^{+0.72}_{-0.58} \pm 0.20)\times10^{-4}$$

$$\frac{B[\Lambda_c^+ \to n\pi^+]}{B[\Lambda_c^+ \to p\pi^0]} = 4.2^{+2.2}_{-1.9}$$

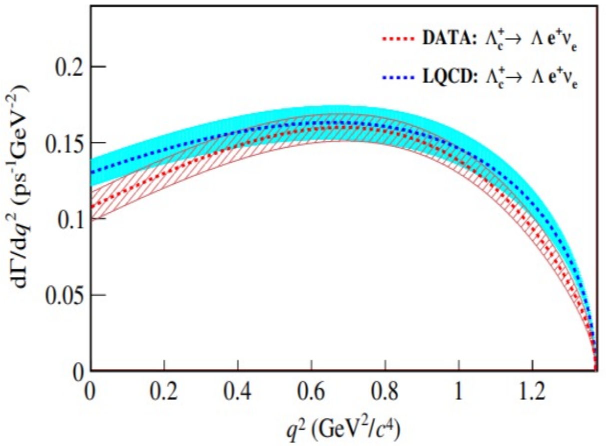
$\Lambda_c^+ \to \Lambda e^+ \nu_e$ dynamics

PRL129(2022)231803





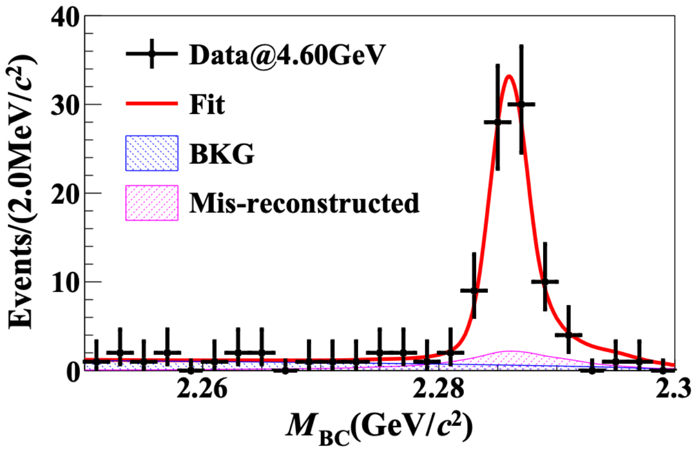
$$\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.56 \pm 0.11_{stat} \pm 0.07_{syst})\%$$

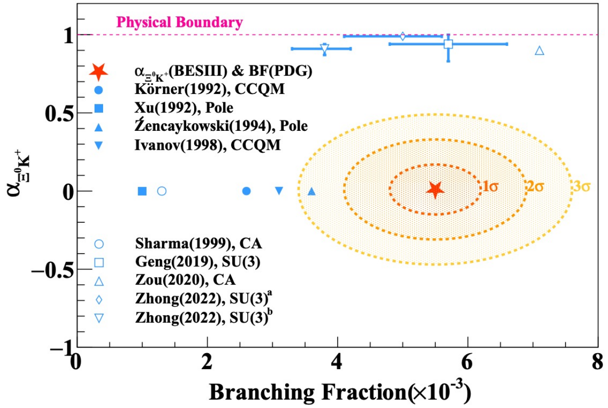


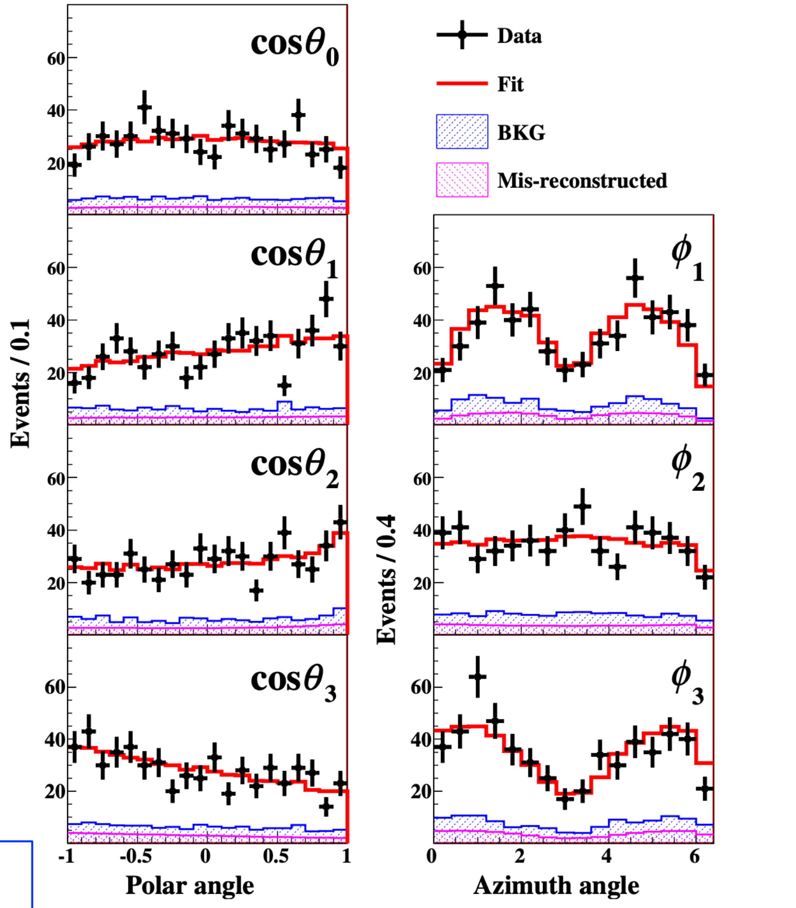
Λ_c^+ decays

$\Lambda_c^+ \to \Xi^0 K^+$

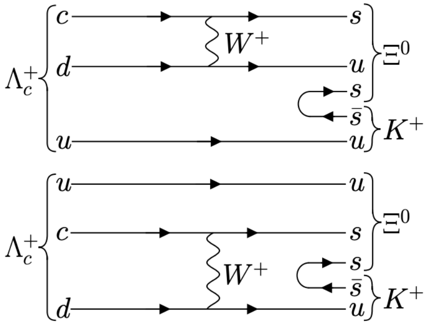
N=378±21 arXiv: 2309.02774







pure W-exchange diagram

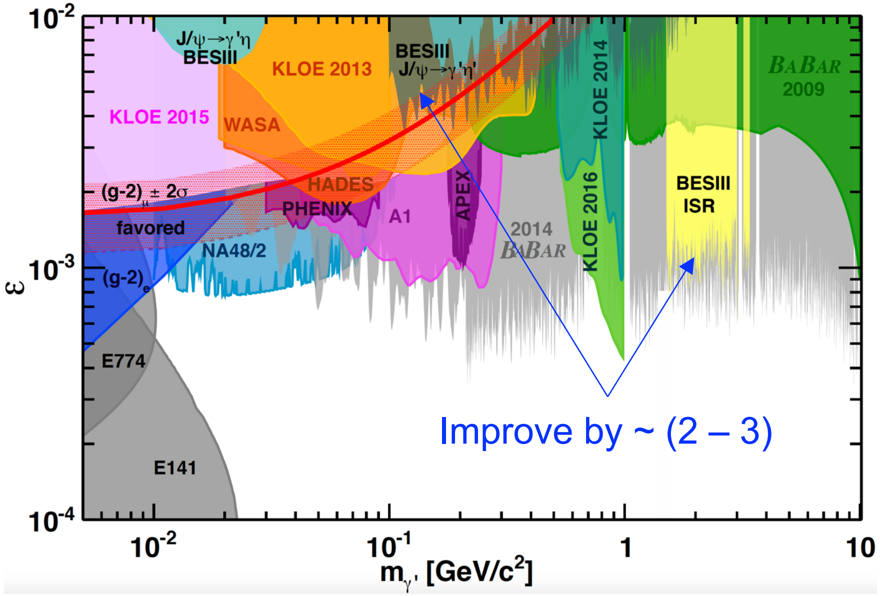


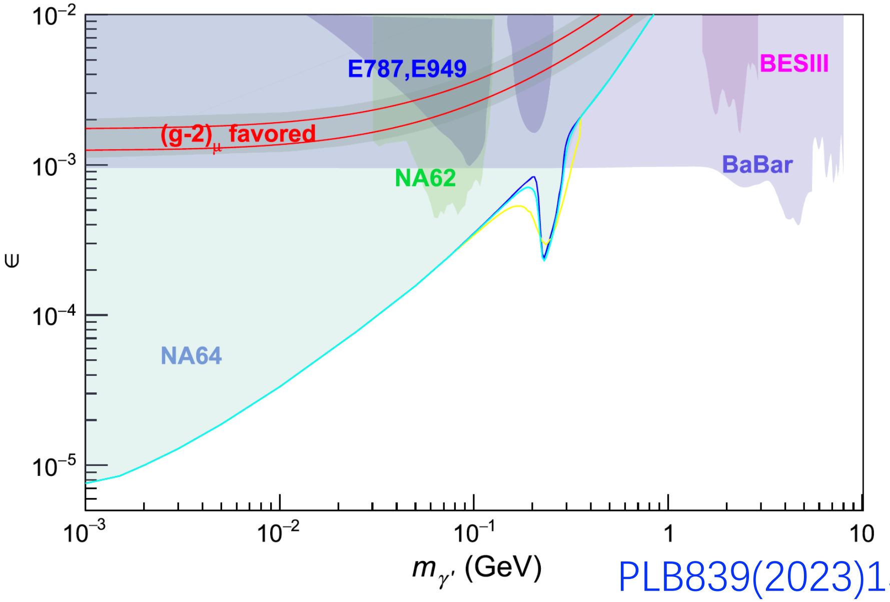
$$\delta_p - \delta_s = \arctan\frac{\sqrt{1-\alpha^2_{\Xi^0 K^+}}\sin\Delta_{\Xi^0 K^+}}{\alpha_{\Xi^0 K^+}}$$

- $\alpha_{\Xi 0K+}$= 0.01 ± 0.16(stat.) ± 0.03(syst.)
- Phase shift: (δp − δs) = [−1.55 ± 0.25(stat.) ± 0.05(syst.)] rad or [1.59 ± 0.25(stat.) ± 0.05(syst.)] rad.

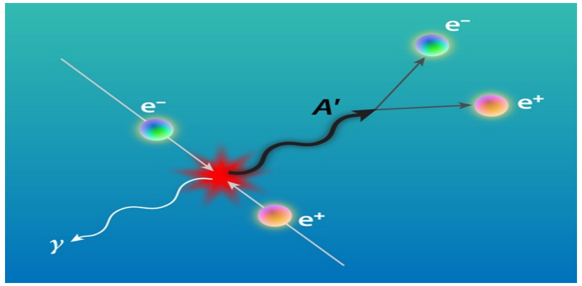
New Physics Search

Dark photon & Axion(-like)



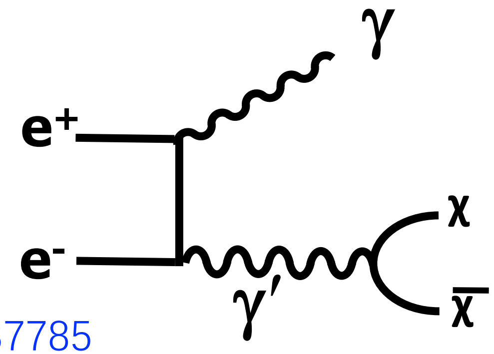


- Visible dark photon (2.93/fb @ 3.773 GeV)
- 17/fb is coming



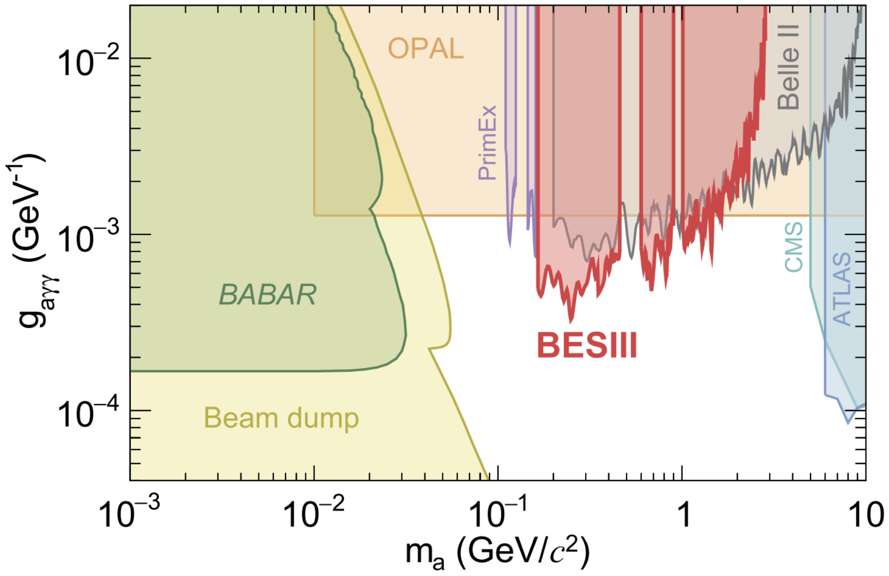
PLB 774 (2017) 252-257

- Invisible dark photon (14.9/fb> 4 GeV)
- 17/fb @ 3.773 GeV coming



PLB839(2023)137785

ALP search at BESIII [PLB 838 (2023) 137698]



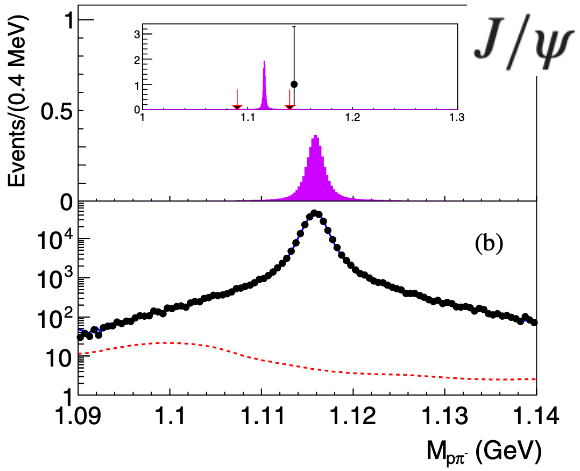
- 2.7B ψ(2S)→ππJ/ψ with J/ψ →γa
- With J/ψ decay directly (10 B)

$$g_{a\gamma\gamma} = \sqrt{\frac{\mathcal{B}(J/\psi \to \gamma a)}{\mathcal{B}(J/\psi \to e^+e^-)}\left(1 - \frac{m_a^2}{m_{J/\psi}^2}\right)^{-3}\frac{32\pi\alpha_{em}}{m_{J/\psi}^2}}$$

BNV & LFV & Z'

PRL 131, 121801 (2023) 1.3B

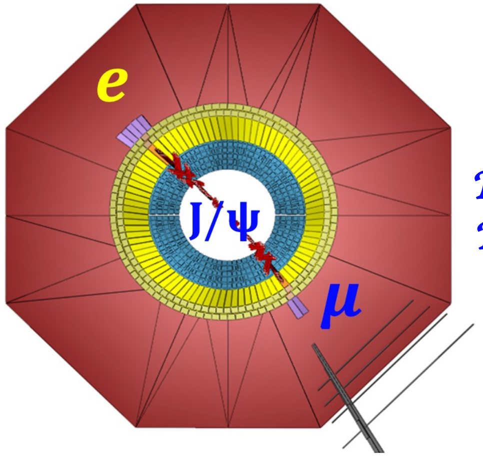
$J/\psi \to pK^-\bar{\Lambda}$



$\mathcal{P}(\Lambda) = [\mathcal{B}(J/\psi \to pK^-\Lambda + \text{c.c.})/\mathcal{B}(J/\psi \to pK^-\bar{\Lambda} + \text{c.c.})] < 4.4 \times 10^{-6}$

$$\mathcal{P}(\Lambda, t) = \sin^2(\delta m_{\Lambda\bar{\Lambda}} t) e^{-t/\tau_\Lambda}$$

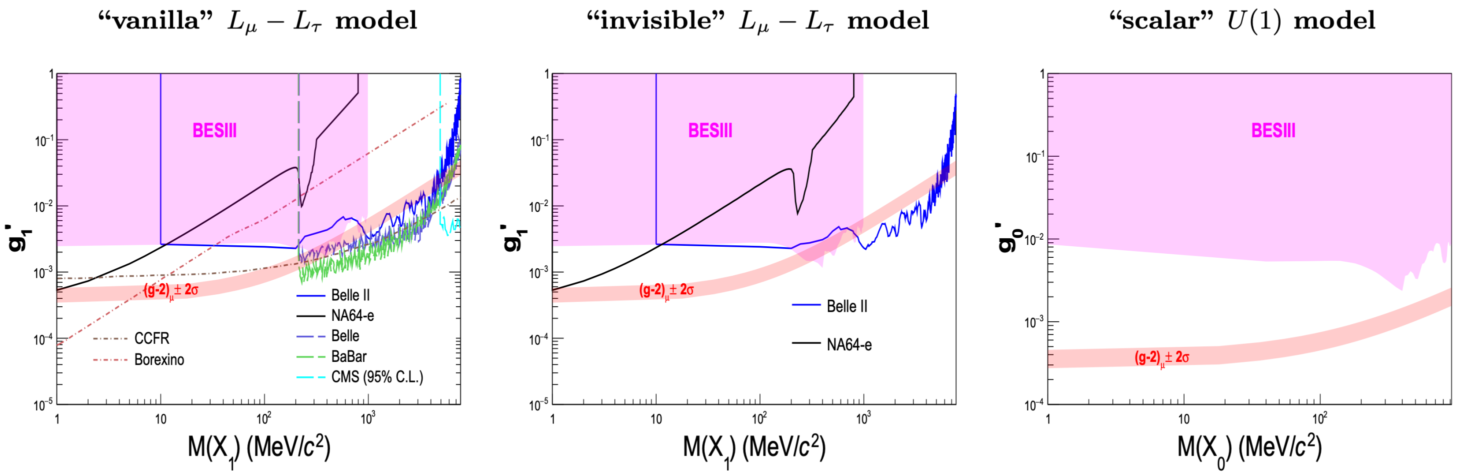
$\delta m_{\Lambda\bar{\Lambda}} < 3.8 \times 10^{-18}$ GeV



SCPMA 66, 221011 (2023)
PRD 103, 112007 (2021)

$\mathcal{B}(J/\psi \to e\mu) < 4.5\times10^{-9}$ @ 90%C. L.
$\mathcal{B}(J/\psi \to e\tau) < 7.5\times10^{-8}$ @ 90%C. L.

(9B) $J/\psi \to \mu^+\mu^- X_{0,1}$ arXiv:2311.01076

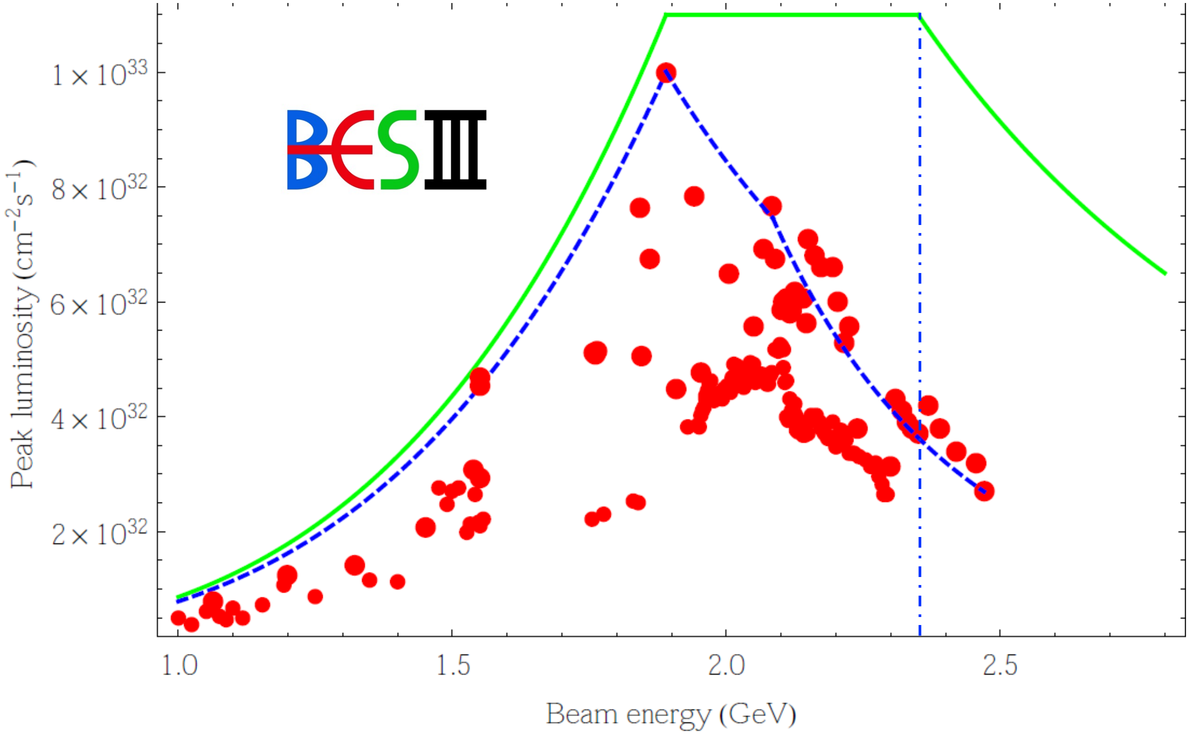


- Extra U(1) group – X0 & X1 only couple to muon & tau
- Muon from J/ψ decay is 22 times larger than QED production
- Invisible model – g_D is large, invisible decay

BEPCII-U upgrade

BEPCII-U vs. BEPCII

From Y. Zhang @ FPCP2021



BESIII White paper
Chinese Physics C Vol. 44, No. 4 (2020) 040001

Energy	Physics motivations	Current data	Expected final data
1.8 - 2.0 GeV	R values Nucleon cross-sections	N/A	0.1 fb^{-1} (fine scan)
2.0 - 3.1 GeV	R values Cross-sections	Fine scan (20 energy points)	Complete scan (additional points)
J/ψ peak	Light hadron & Glueball J/ψ decays	3.2 fb^{-1} (10 billion)	3.2 fb^{-1} (10 billion)
$\psi(3686)$ peak	Light hadron & Glueball Charmonium decays	0.67 fb^{-1} (0.45 billion)	4.5 fb^{-1} (3.0 billion)
$\psi(3770)$ peak	$D^0/D^{\pm}$ decays	2.9 fb^{-1}	20.0 fb^{-1}
3.8 - 4.6 GeV	R values XYZ/Open charm	Fine scan (105 energy points)	No requirement
4.180 GeV	D_s decay XYZ/Open charm	3.2 fb^{-1}	6 fb^{-1}
4.0 - 4.6 GeV	XYZ/Open charm Higher charmonia cross-sections	16.0 fb^{-1} at different $\sqrt{s}$	30 fb^{-1} at different $\sqrt{s}$
4.6 - 4.9 GeV	Charmed baryon/XYZ cross-sections	0.56 fb^{-1} at 4.6 GeV	15 fb^{-1} at different $\sqrt{s}$
4.74 GeV	$\Sigma_c^+\bar{\Lambda}_c^-$ cross-section	N/A	1.0 fb^{-1}
4.91 GeV	$\Sigma_c\bar{\Sigma}_c$ cross-section	N/A	1.0 fb^{-1}
4.95 GeV	Ξ_c decays	N/A	1.0 fb^{-1}

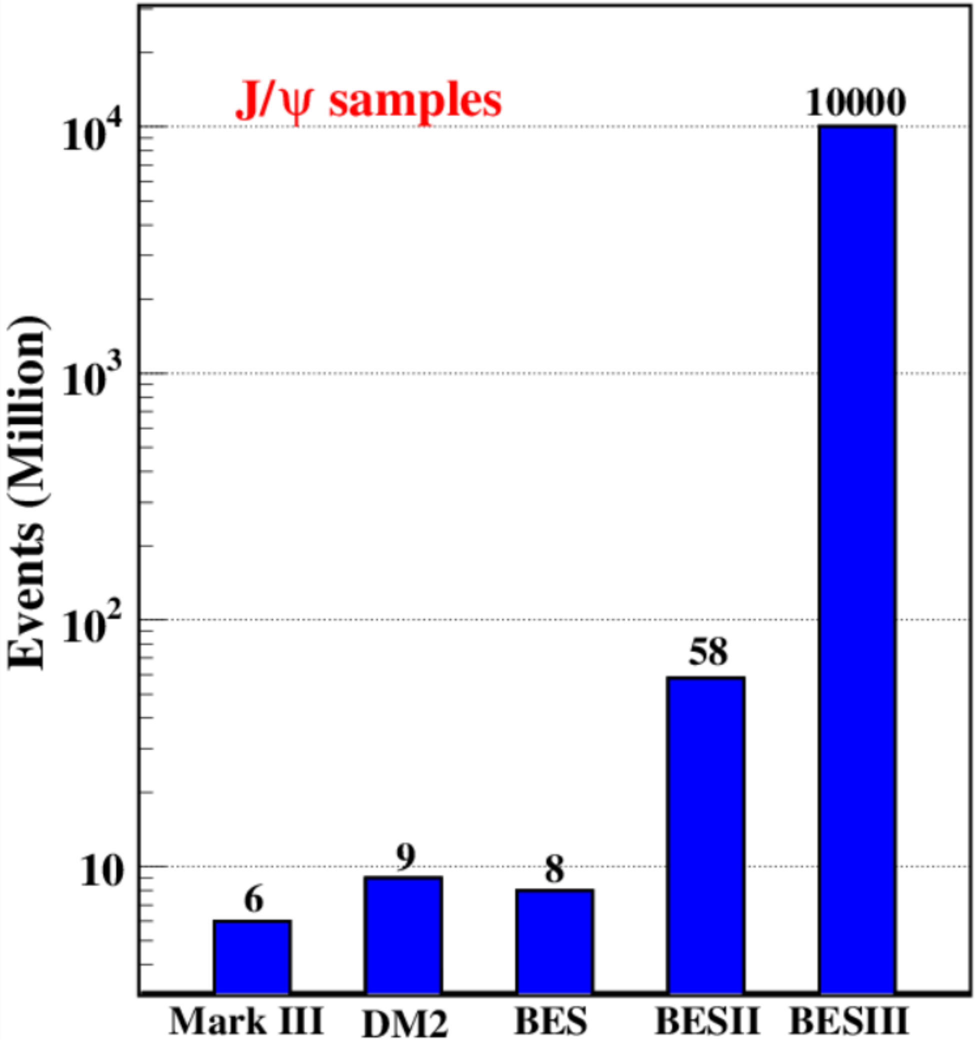
- Luminosity increased by a factor of 3 @ 2.35 GeV
- Beam energy up to 2.8 GeV
- Start running in 2025…

Summary

- BESIII is still an active and productive experiment after 15 years running.
- New Charmonium(-like)/light hadron discoveries year-by-year.
- Precise measurement of Ds properties; 20/fb $\psi(3770)$ data will greatly improve D measurement precision.
- Study of Λ_c decays make a big contribution (dominant PDG list).
- New Physics search is also popular.
- BEPCII-U upgrade will be done in 2024 & Machine commissioning in Jan. 2025

谢谢大家！

BESIII – A Hyperon/light meson factory



- Br(J/ψ→γη') ~ 5*10^{-3}, η' yield ~50 Million
- Br(J/ψ→γη) ~ 1*10^{-3}, η yield ~10 Million
- Br(J/ψ→ΛΛ) ~ 1.9*10^{-3}; Λ yield ~20 Million
- Br(J/ψ→$\Sigma^+\Sigma^-/\Sigma^0\Sigma^0$) ~ 1.2*$10^{-3}$; Λ yield ~12 Million
- Br(J/ψ→$\Xi^-\Xi^+/\Xi^0\Xi^0$) ~ 1*10^{-3}; Λ yield ~10 Million

Polarization / NP Search (CP violation, EDM) / Decay dynamics

backup