

Spectroscopy at e^+e^- colliders

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Outline

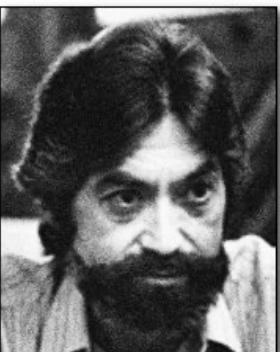
- Introduction
- Progress on $X(3872)$ & $\psi_2(3823)$ studies
- Progress on vector Y-states
- Progress on charged Z_c states
- Summary



Quark Model



1964



A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN

California Institute of Technology, Pasadena, California

Received 4 January 1964

If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way" 1-3), we are tempted to look for some fundamental explanation of the situation. A highly promised approach is the purely dynamical "bootstrap" model for all the strongly interacting particles within which one may try to derive isotopic spin and strangeness conservation and broken eightfold symmetry from self-consistency alone 4). Of course, with only strong interactions, the orientation of the asymmetry in the unitary space cannot be specified; one hopes that in some way the selection of specific components of the F-spin by electromagnetism and the weak interactions determines the choice of isotopic spin and hypercharge directions.

Even if we consider the scattering amplitudes of strongly interacting particles on the mass shell only and treat the matrix elements of the weak, electromagnetic, and gravitational interactions by means

ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^- , s^- , u^0 and b^0 exhibit a parallel with the leptons.

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" 6) and the members of the anti-triplet as anti-quarks \bar{q} . Baryons can now be constructed from quarks by using the combinations (qqq) , $(qqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(q\bar{q}\bar{q})$, etc. It is assuming that the lowest baryon configuration (qqq) gives just the representations **1**, **8**, and **10** that have been observed, while the lowest meson configuration $(q\bar{q})$ similarly gives just **1** and **8**.

AN SU_3 MODEL FOR STRONG INTERACTION SYMMETRY AND ITS BREAKING

G. Zweig *)

CERN - Geneva

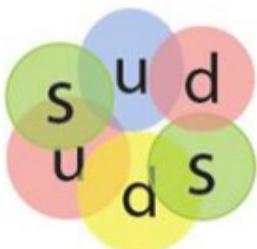
Both mesons and baryons are constructed from a set of three fundamental particles called aces. The aces

In general, we would expect that baryons are built not only from the product of three aces, AAA , but also from $\overline{A}AAA$, $\overline{A}AAAAA$, etc., where \overline{A} denotes an anti-ace. Similarly, mesons could be formed from \overline{AA} , \overline{AAA} etc. For the low mass mesons and baryons we will assume the simplest possibilities, \overline{AA} and AAA , that is, "deuces and treys".

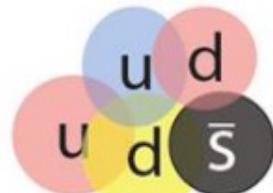
- Baryon (qqq) & meson ($q\bar{q}$)
- ($qq\bar{q}\bar{q}$) & ($qqq\bar{q}\bar{q}$) etc. → Tetraquark & Pentaquark

Exotic Hadron States

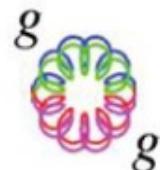
- The fundamental theory for strong interaction is QCD.
- In QCD, hadrons beyond the (qqq) baryon and ($q\bar{q}$) meson exist !
- Difficulties, i.e. do not know how to calculate a confinement problem.



dibaryon



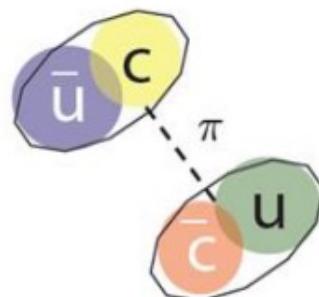
pentaquark



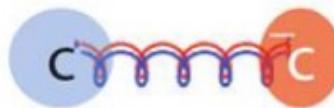
glueball



diquark + di-antiquark



dimeson molecule



$q\bar{q}g$ hybrid

XYZ particles

X(3872) GeV

X(3823)

X(3915)

X(4350)

Y(4008)

Y(4260)

Y(4140)

Y(4360)

Y(4660)

Y(4630)

...

XYZ(3940)

Z_c(3900)

Z_c(4020)

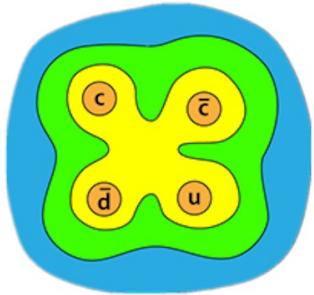
Z(4430)

Z(4250)

Z(4050)

...

- XYZ or charmonium-like states
- Not an obvious charmonium
- But charmonium in the final state



3³D₁(4.52)

2³D₁(4.19)

3¹S₀(4.06)

1³D₁(3.82)

2¹S₀(3.62)

1¹P₁(3.52)

1³P₀(3.44)

1³S₁(3.10)

4³S₁(4.45)

2¹P₁(3.96)

2³P₀(3.92)

2³P₁(3.95)

1³P₁(3.51)

1³P₀(3.44)

1³P₂(3.55)

1¹P₁(3.2+)

1¹S₀(2.97)

2¹D₂(4.21)

2³D₂(4.21)

2³D₃(4.22)

1¹F₃(4.09)

1³F₃(4.10)

1³F₄(4.11)

1³F₂(4.09)

1¹D₂(3.84)

1³D₂(3.84)

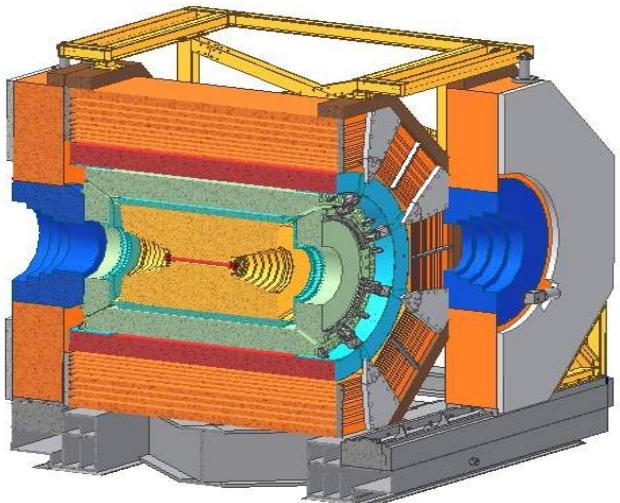
1³D₂(3.85)

Godfrey & Isgur, PRD32, 189 (1985)

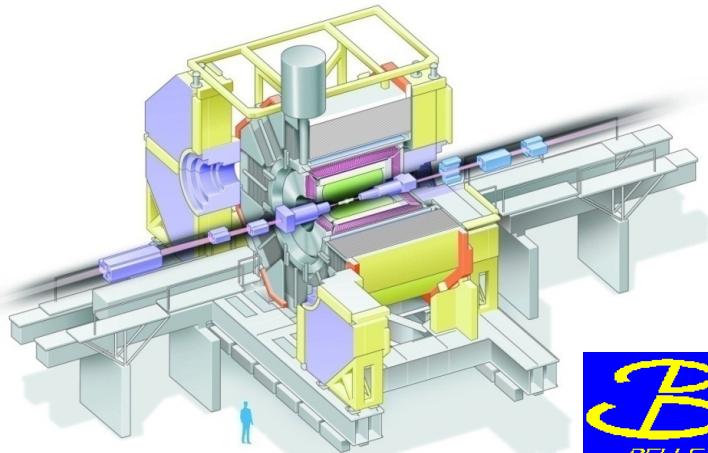
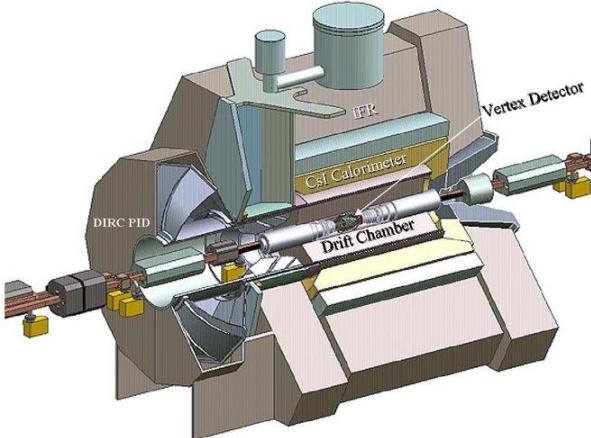
0⁻⁺ 1⁻⁻ 1⁺⁻ 0⁺⁺ 1⁺⁺ 2⁺⁺ 2⁻⁺ 2⁻⁻ 3⁻⁻ 3⁺⁻ 3⁺⁺



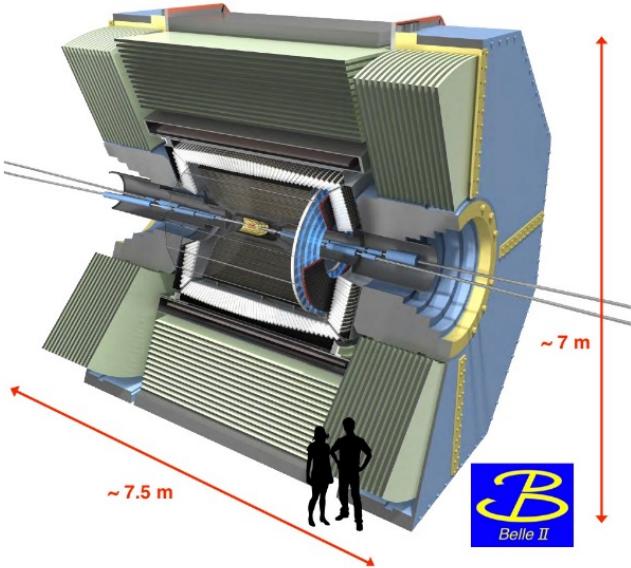
e+e- colliders



BES III



BELLE

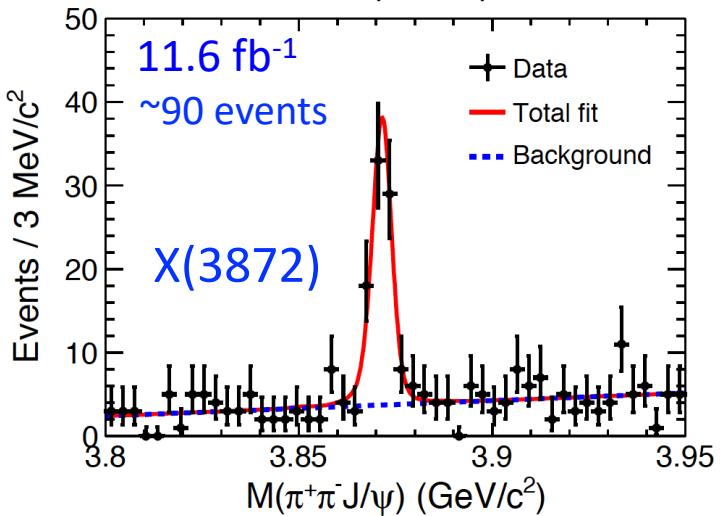
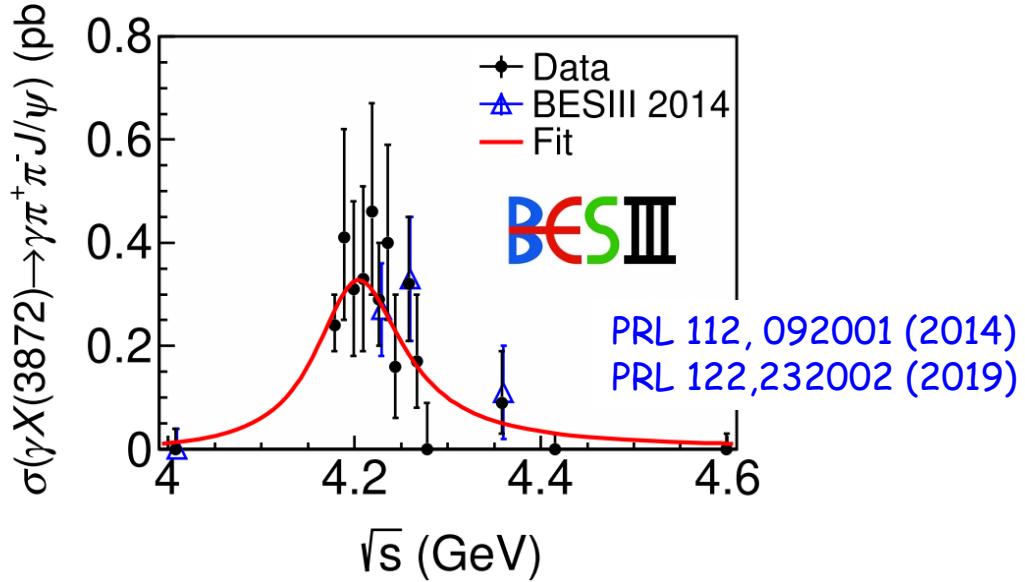
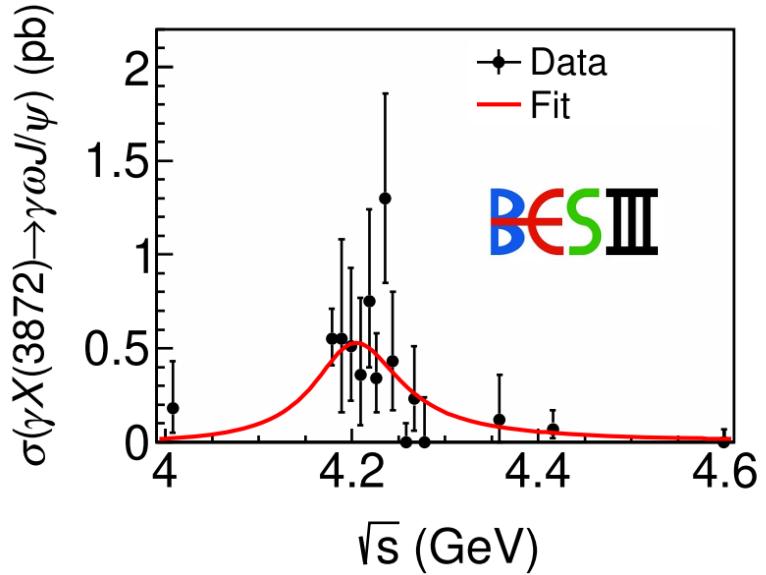


Belle II

X(3872) & $\psi_2(3823)$



$e^+e^- \rightarrow \gamma X(3872)$ production



- $e^+e^- \rightarrow \gamma X(3872)$ cross section by BESIII
- $M=4200.6^{+7.9}_{-13.3} \pm 3.0 \text{ MeV}$, $\Gamma=115^{+38}_{-26} \pm 12 \text{ MeV}$
- Agree with the $Y(4260)$ resonance

Strongly suggest the $Y(4260) \rightarrow \gamma X(3872)$ transition →
Commonality between $Y(4260)$ & $X(3872)$...

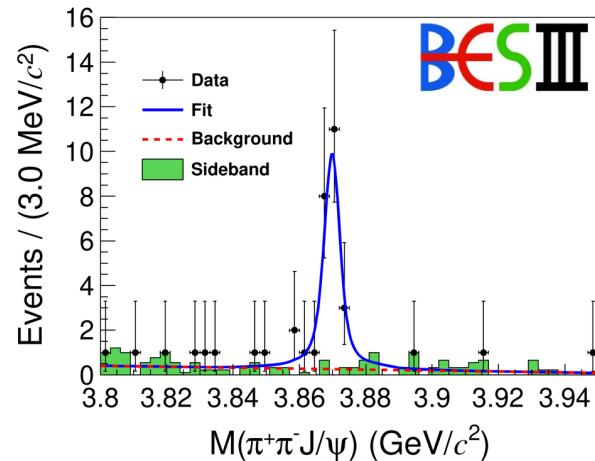
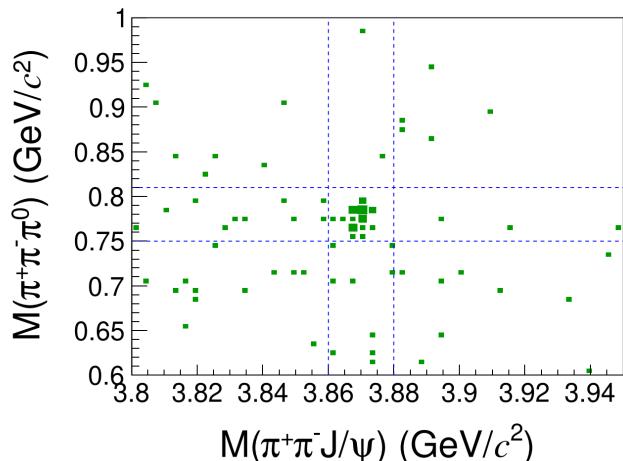
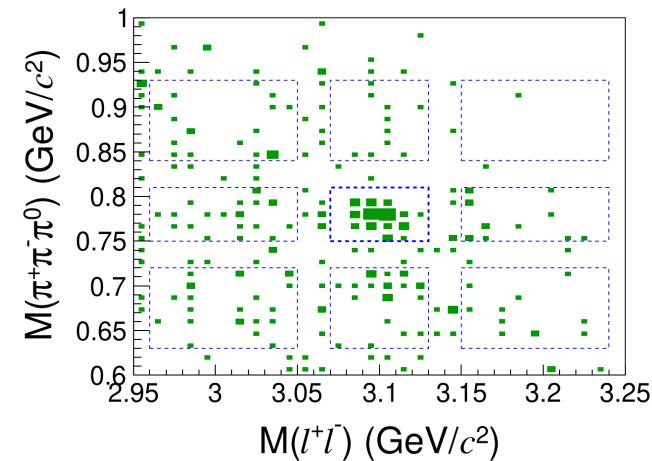
Steve Olsen et al. / Rev. Mod. Phys. 90, 015003 (2018)



$e^+e^- \rightarrow \omega X(3872)$

PRL130, 151904 (2023)

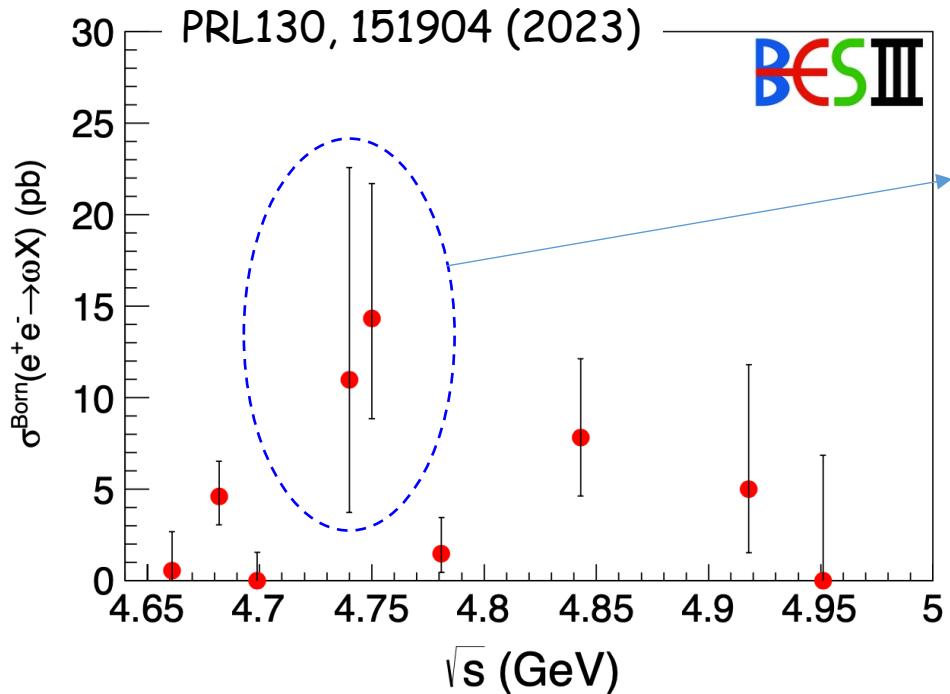
BESIII



- 4.7 fb⁻¹ data between 4.66 – 4.95 GeV (just above the $\omega X(3872)$ threshold)
- $\omega \rightarrow \pi^+\pi^-\pi^0$ & $X(3872) \rightarrow \pi^+\pi^-J/\psi$, one of the 4π could be missing to improve reconstruction efficiency
- Fit with MC shape + linear background: $N(\text{signal}) = 24.6 \pm 5.3$ events, significance 7.8σ

A new production mode at BESIII !

e⁺e⁻→ωX(3872) production



- Significantly higher near 4.75 GeV
- Potential resonance structure exist?

- What's about e⁺e⁻→γX(3872)?
- What's about e⁺e⁻→ωχ_{c1}/ωX(3872)?
- What's about e⁺e⁻→φX(3872)

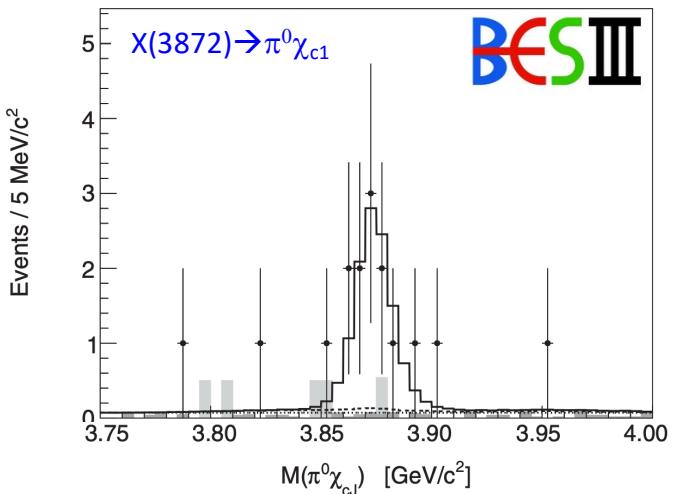
Ongoing activities...

\sqrt{s} (GeV)	$\mathcal{L}_{\text{int}}(\text{pb}^{-1})$	N_{sig}	$\epsilon(1 + \delta)$ (%)	$\sigma^B(\text{pb})$	$\sigma_{\text{up}}^B(\text{pb})$	Significance
4.661	529.63	$0.33^{+1.36}_{-0.33}$	28.3	$0.5^{+2.1}_{-0.5} \pm 0.1 \pm 0.2$	5.6	...
4.682	1669.31	$8.00^{+3.34}_{-2.68}$	24.6	$4.6^{+1.9}_{-1.5} \pm 0.4 \pm 1.5$	11.5	3.4σ
4.699	536.45	$0.00^{+0.95}_{-0.00}$	27.0	$0.0^{+1.6}_{-0.0} \pm 0.0 \pm 0.0$	3.3	...
4.740	164.27	$1.67^{+1.77}_{-1.10}$	21.8	$10.9^{+11.6}_{-7.2} \pm 1.0 \pm 3.5$	40.6	1.0σ
4.750	367.21	$5.00^{+2.58}_{-1.92}$	22.4	$14.2^{+7.4}_{-5.5} \pm 1.4 \pm 4.5$	38.2	3.1σ
4.781	512.78	$1.00^{+1.36}_{-0.70}$	31.6	$1.5^{+2.0}_{-1.0} \pm 0.2 \pm 0.5$	6.5	0.7σ
4.843	527.29	$4.67^{+2.58}_{-1.92}$	26.7	$7.8^{+4.3}_{-3.2} \pm 0.7 \pm 2.5$	21.1	2.6σ
4.918	208.11	$1.00^{+1.36}_{-0.70}$	22.6	$5.0^{+6.8}_{-3.5} \pm 0.4 \pm 1.6$	21.7	0.7σ
4.951	160.37	$0.00^{+0.95}_{-0.00}$	20.4	$0.0^{+6.8}_{-0.0} \pm 0.0 \pm 0.0$	14.7	...

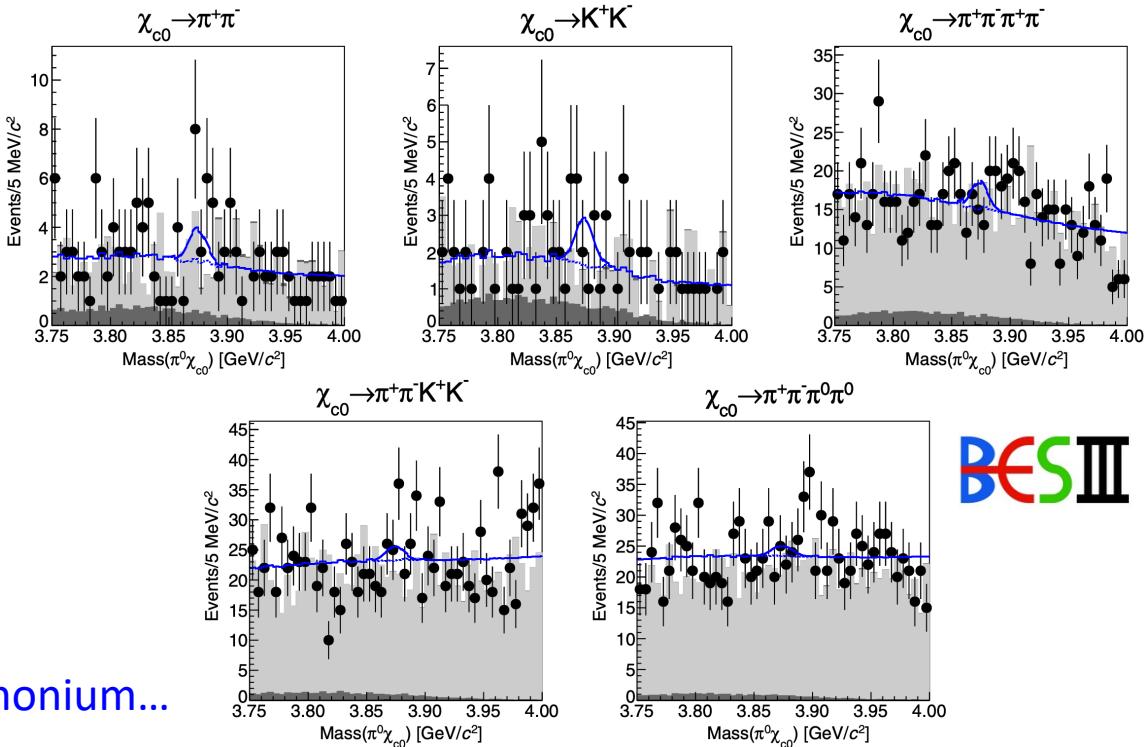


X(3872) decay

PRL122, 202001 (2019)



$$\frac{\mathcal{B}(X(3872) \rightarrow \pi^0 \chi_{c1})}{\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- J/\psi)} = 0.88^{+0.33} \pm 0.10$$



Large isospin violation, disfavor charmonium...

Technique	Interpretation	$\frac{\mathcal{B}(X(3872) \rightarrow \pi^0 \chi_{c0})}{\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- J/\psi)}$	$\frac{\mathcal{B}(X(3872) \rightarrow \pi^0 \chi_{c0})}{\mathcal{B}(X(3872) \rightarrow \pi^0 \chi_{c1})}$
Multipole expansion	Four-quark/molecule	...	2.97
Multipole expansion	$\chi_{c1}(2P)$	0.0	0.0
Effective field theory	$D^0 \bar{D}^{0*}$...	2.84–2.98
Effective field theory	$D^0 \bar{D}^{0*} + D^+ D^{-*}$	1.3–2.07	1.65–1.77
Effective field theory	$D^0 \bar{D}^{0*} + D^+ D^{-*}$...	3.72
Effective field theory	$D^0 \bar{D}^{0*} + D^+ D^{-*} + \chi_{c1}(2P)$	0.094	1.15

$$\frac{\mathcal{B}(X(3872) \rightarrow \pi^0 \chi_{c0})}{\mathcal{B}(X(3872) \rightarrow \pi^0 \chi_{c1})} < 4.5 \quad @90\%$$

PRD 105, 072009 (2022)

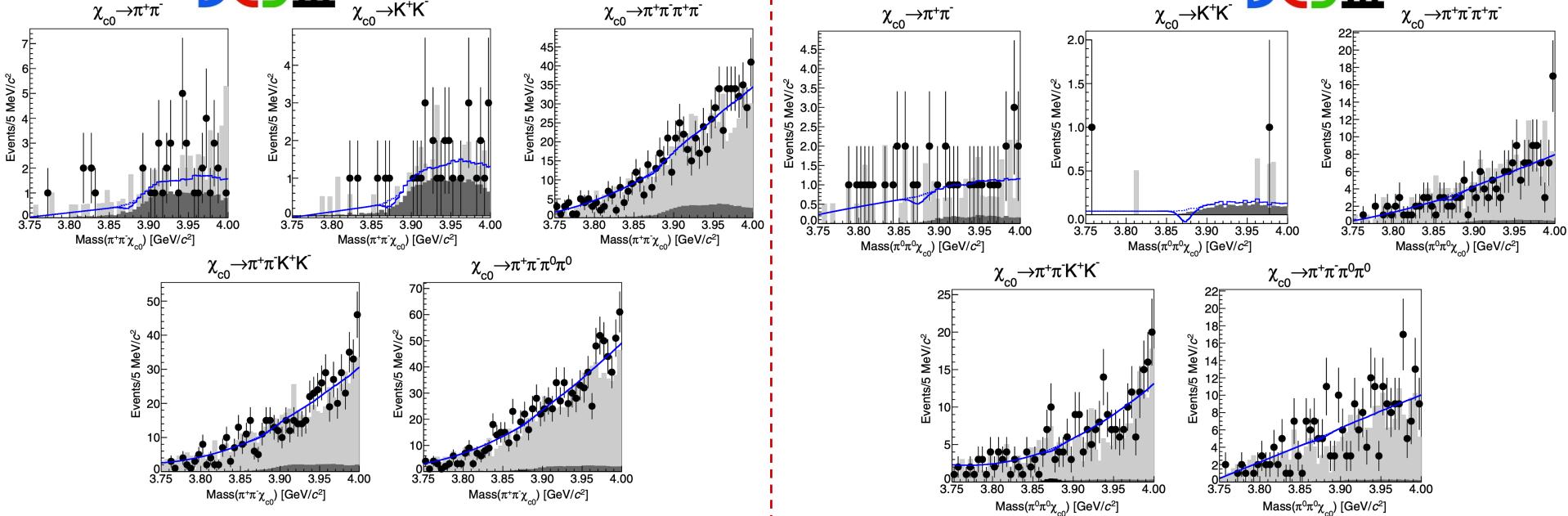


X(3872) decay

BESIII

PRD 105, 072009 (2022)

BESIII

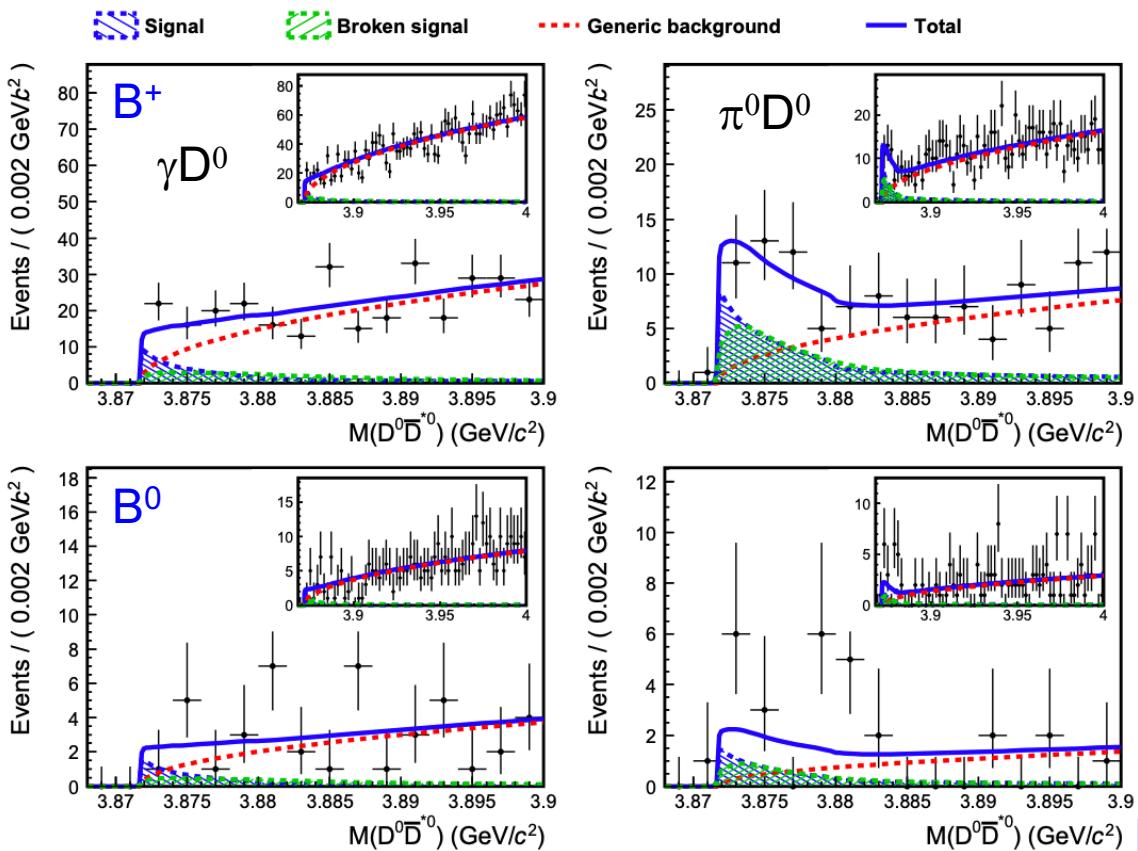


$$\frac{\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- \chi_{c0})}{\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- J/\psi)} < 0.56$$

$$\frac{\mathcal{B}(X(3872) \rightarrow \pi^0 \pi^0 \chi_{c0})}{\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- J/\psi)} < 1.7$$

@90% C.L.

$X(3872) \rightarrow D^0 \bar{D}^{*0}$ line shape



- N=90 events, BW seems better (statistics limited)
- Flatte shape: 1 free parameter g (constrain others)

$g > 0.075$ at 95% credibility

- BESIII fit $D^0 D^{*0}$ and $\pi^+ \pi^- J/\psi$ simultaneously ongoing

arXiv: 2302.02127

$$f_{\text{Flatte}}(E) = \frac{g k_{D^0 \bar{D}^{*0}}}{|D(E)|^2},$$

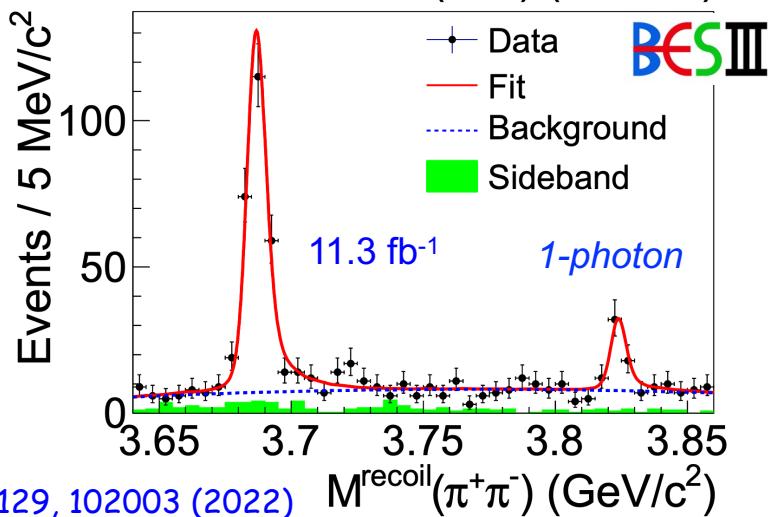
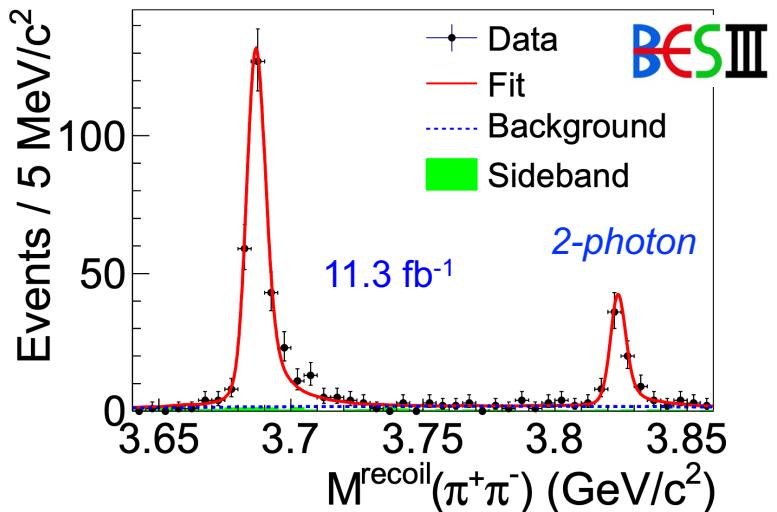
$$D(E) = \begin{cases} E - E_f - \frac{1}{2}g\kappa_{D^+ D^{*-}} + \frac{i}{2}[gk_{D^0 \bar{D}^{*0}} + \Gamma(E)] & \text{for } 0 < E < \delta, \\ E - E_f + \frac{i}{2}[g(k_{D^0 \bar{D}^{*0}} + k_{D^+ D^{*-}}) + \Gamma(E)] & \text{for } E > \delta, \end{cases}$$

$$\Gamma(E) = \Gamma_{J/\psi\rho}(E) + \Gamma_{J/\psi\omega}(E) + \Gamma_0$$

$$\frac{\mathcal{B}(B^0 \rightarrow X(3872) K^0)}{\mathcal{B}(B^+ \rightarrow X(3872) K^+)} = 1.34^{+0.47}_{-0.40}(\text{stat})^{+0.10}_{-0.12}(\text{syst})$$

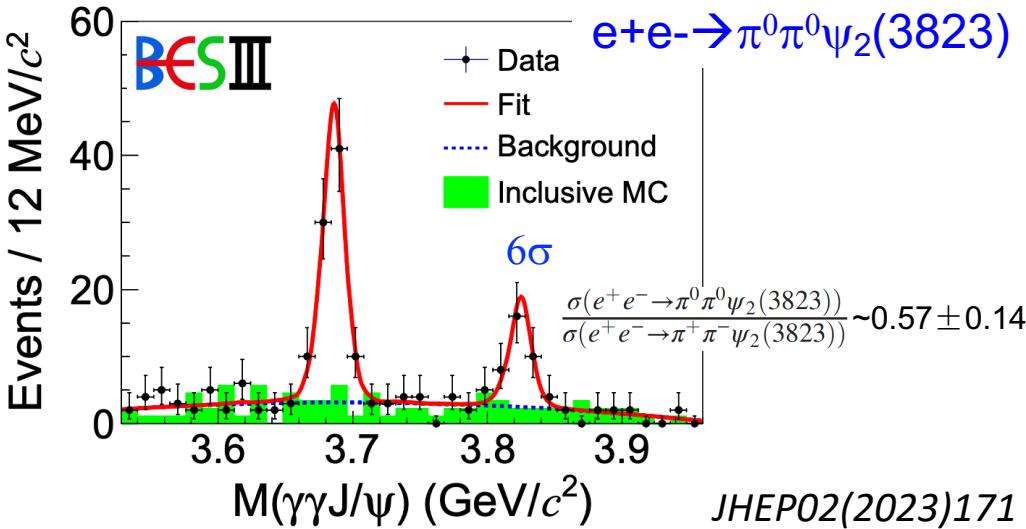
$X(3823)=\psi_2(3823)$

$e^+e^- \rightarrow \pi^+\pi^-\psi_2(3823) \rightarrow \pi^+\pi^-\gamma\chi_{c1} \rightarrow \pi^+\pi^-\gamma\gamma J/\psi$



PRL129, 102003 (2022)

- BESIII observed 120 signal events
 $m[\psi_2(3823)] = M[\psi_2(3823)] - M[\psi(2S)] + m[\psi(2S)]^{\text{PDG}}$
 $= (3823.12 \pm 0.43 \pm 0.13) \text{ MeV}/c^2$
- $\Gamma[\psi_2(3823)] < 2.9 \text{ MeV} @ 90\% \text{ C.L.}$
- Most precise measurement to date !

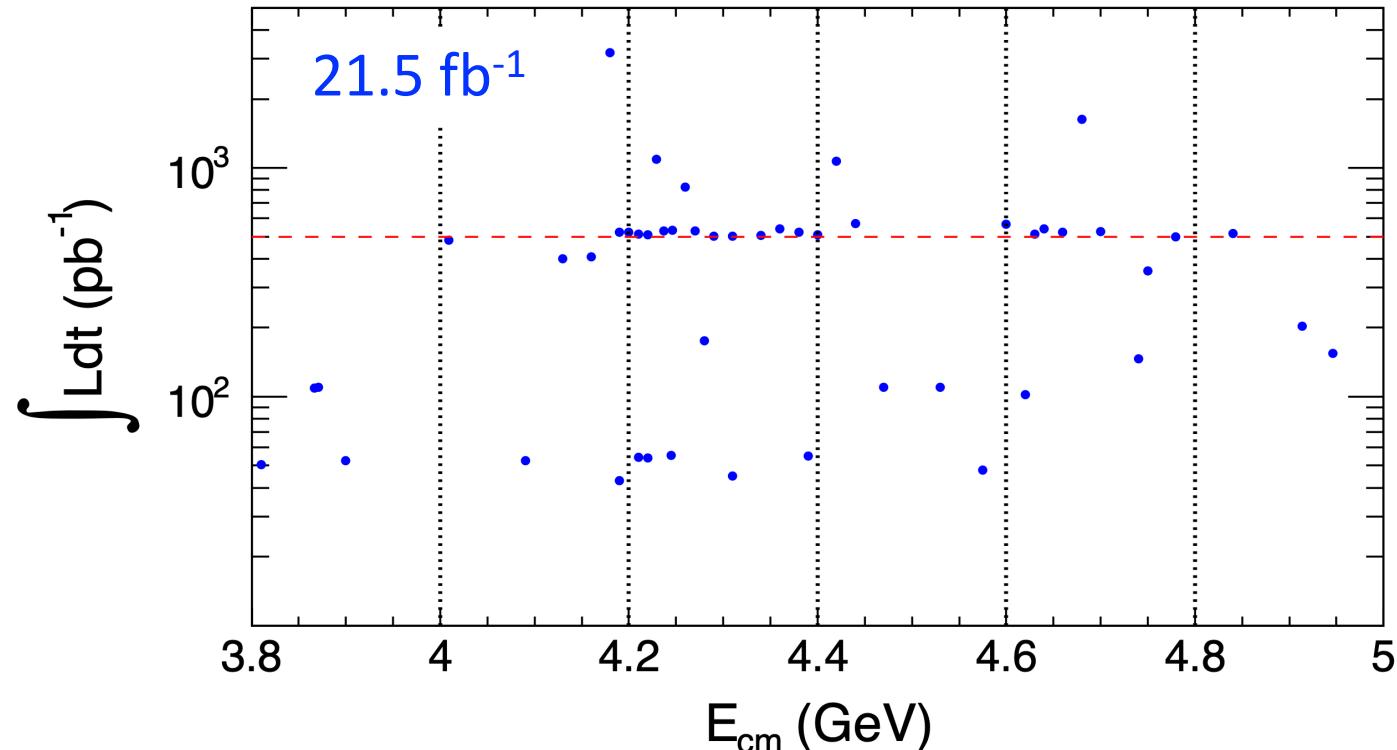


Vector Y-states

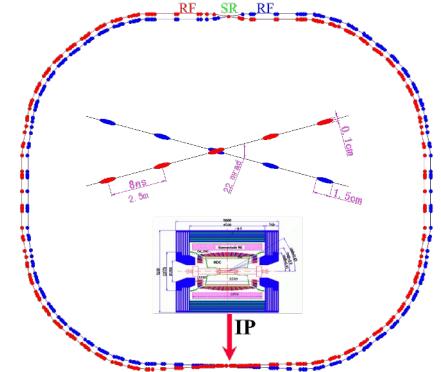


BESIII high luminosity scan

0.5 fb⁻¹/10 MeV scan from 4 – 4.6 GeV is ongoing

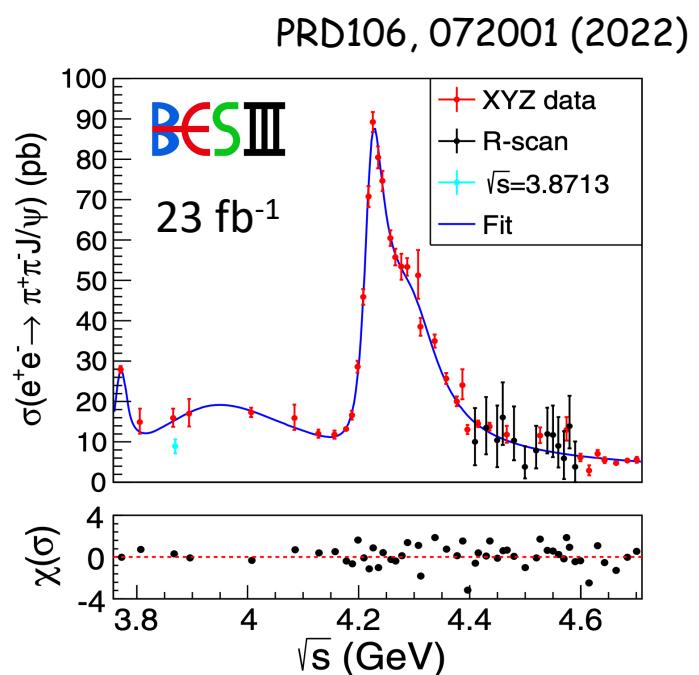
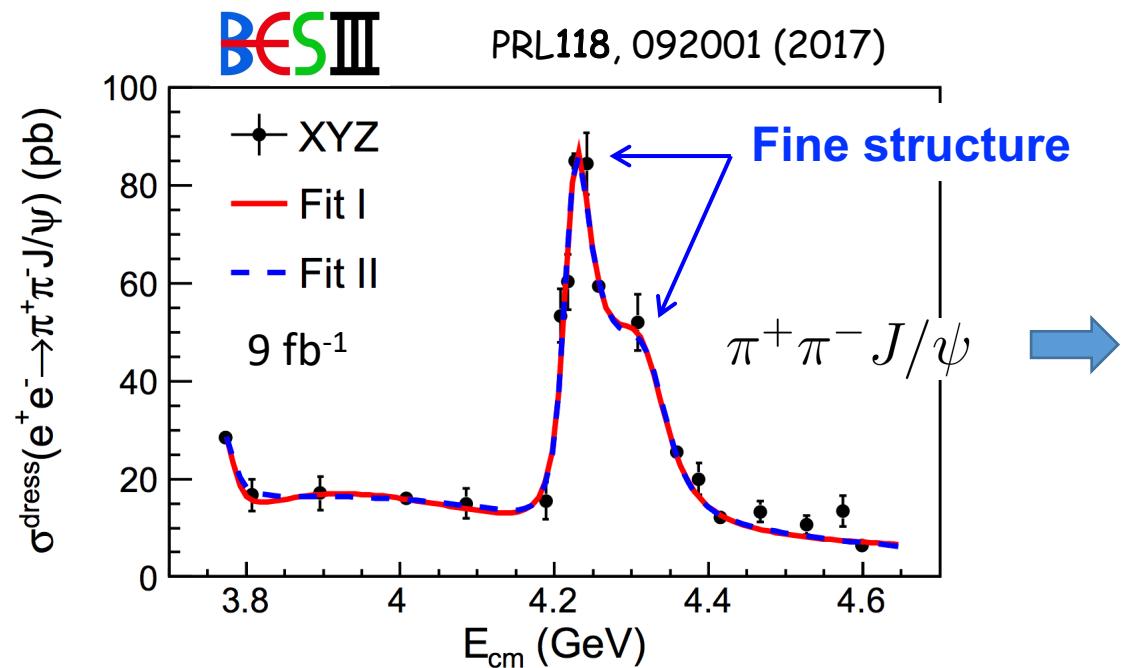


BESII



- A double ring symmetric e+e- machine in Beijing, China
- $\sqrt{s} = 2 - 4.95$ GeV (extended to 5.6 GeV with BEPCII-U)
- Design $L_D = 1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ (achieved in 2016; $1.1 \times L_D$ @ 2022-2023 run)

Y(4260) fine structure

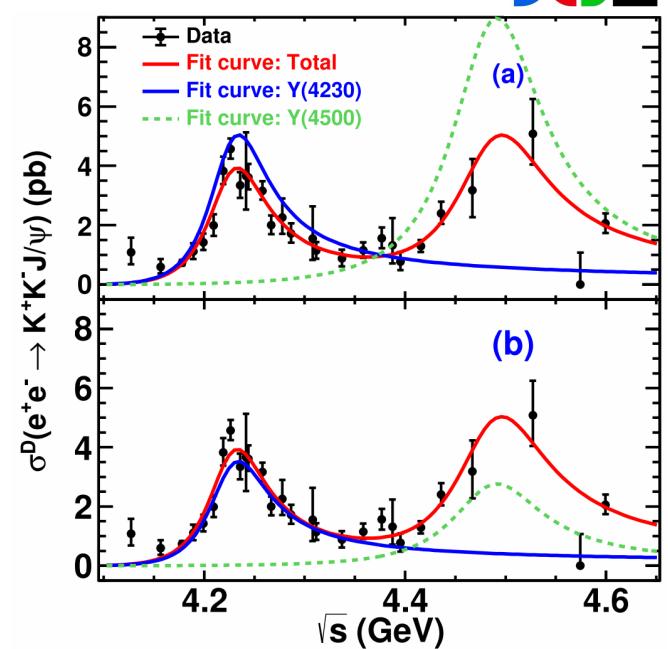


- There are fine structures in the famous “Y(4260) bump”
- Mass= $(4222.0 \pm 3.1 \pm 1.4)$ MeV, Width= $(44.1 \pm 4.3 \pm 2.0)$ MeV
- Most precise and significantly lower than 4.26 GeV

$e^+e^- \rightarrow K^+K^-J/\psi \& K_s\bar{K}_s J/\psi$

CPC 46, 111002 (2022)

BESIII



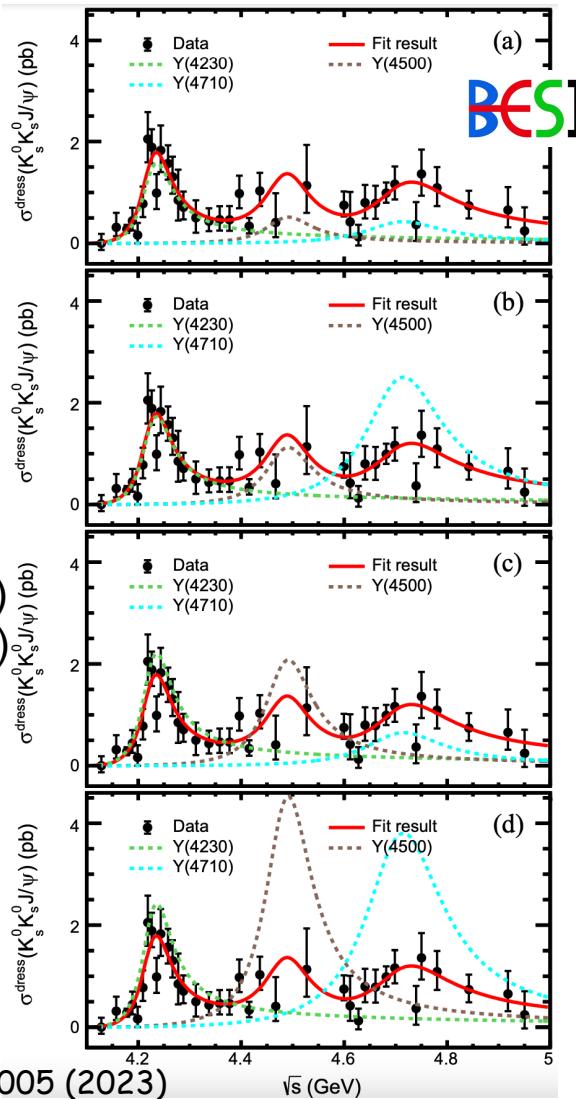
- We need a resonance $Y(4500)$ in K^+K^-J/ψ !
- 3D state?
- $K_s\bar{K}_s J/\psi$ go to higher energies & cross sections
- Evidence for $Y(4710)$ resonance

$$M = 4704.0 \pm 52.3 \pm 69.5 \text{ (MeV)}$$

$$\Gamma = 183.2 \pm 114.0 \pm 96.1 \text{ (MeV)}$$

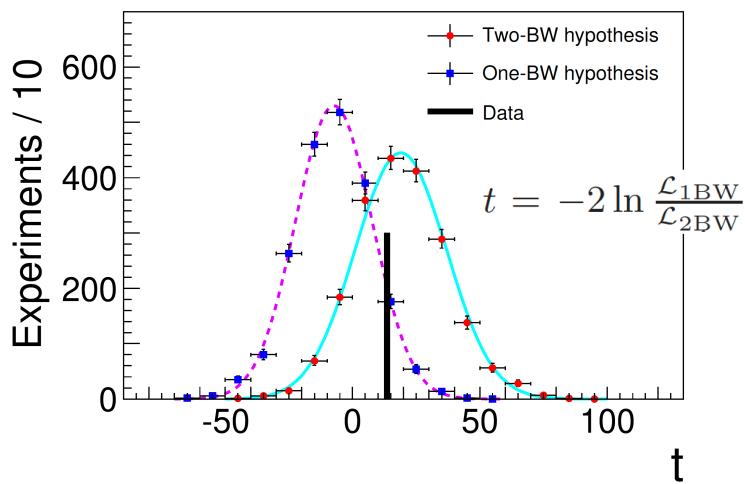
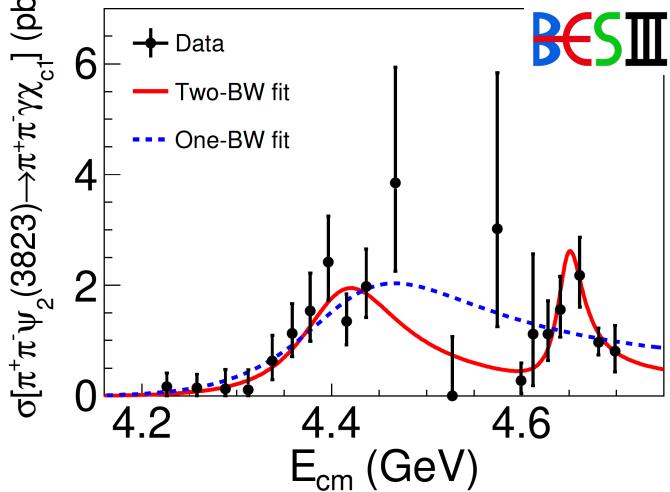
	Parameters	Solution I	Solution II
$Y(4230)$	M/MeV	$4225.3 \pm 2.3 \pm 21.5$	
	$\Gamma_{\text{tot}}/\text{MeV}$	$72.9 \pm 6.1 \pm 30.8$	
	$\Gamma_{ee}\mathcal{B}/\text{eV}$	$0.42 \pm 0.04 \pm 0.15$	$0.29 \pm 0.02 \pm 0.10$
$Y(4500)$	M/MeV	$4484.7 \pm 13.3 \pm 24.1$	
	$\Gamma_{\text{tot}}/\text{MeV}$	$111.1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

PRD 107, 092005 (2023)



$\Upsilon(4660) \rightarrow \pi^+ \pi^- \psi_2(3823)$

11.3 fb⁻¹, PRL 129, 102003 (2022)



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

$$M = 4417.5 \pm 26.2 \pm 3.5 \text{ MeV}$$

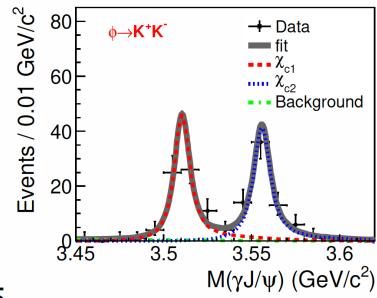
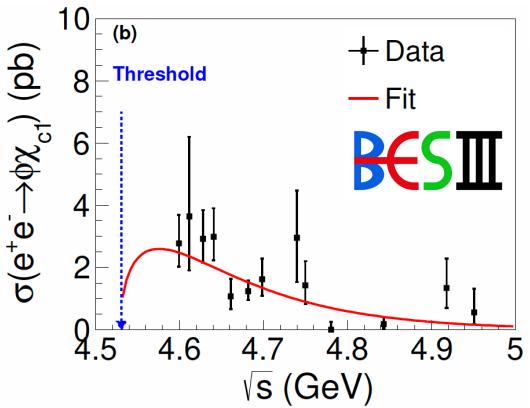
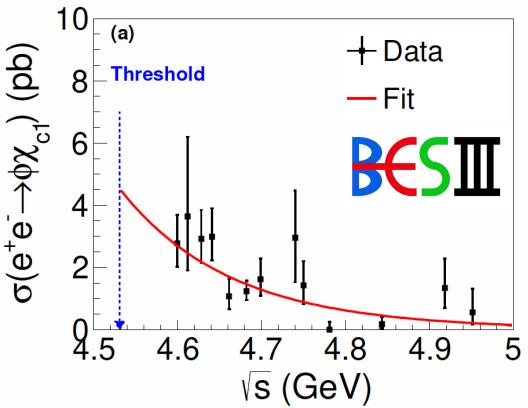
$$\Gamma = 245 \pm 48 \pm 13$$
- Two coherent $\Upsilon(4360) + \Upsilon(4660)$

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	$267.1 \pm 16.2 \pm 3.2$	$-324.8 \pm 43.0 \pm 5.7$

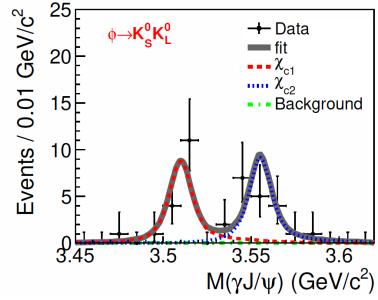
$$\frac{\Gamma[\psi(4660) \rightarrow \pi^+ \pi^- \psi_2(3823)]}{\Gamma[\psi(4660) \rightarrow \pi^+ \pi^- \psi(2S)]} \sim 20\%$$

$f_0(980)\psi(2S)$ molecule
 $\Upsilon(4260)$ radial excitation
 Baryonium...

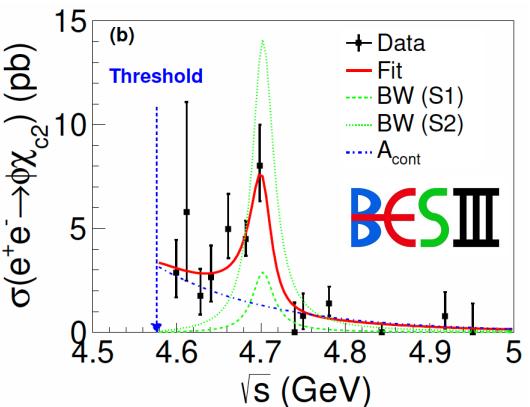
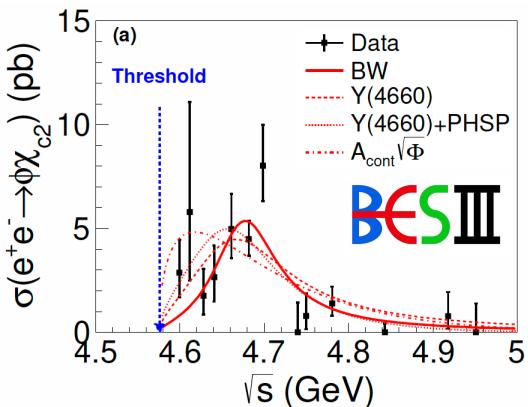
$e^+e^- \rightarrow \phi\chi_{c1}, \phi\chi_{c2}$ cross section



JHEP01(2023)132



A power law (or phase space corrected) continuum



Fit with BW or BW+Continuum

- 6.4 fb^{-1} data from 4.60 to 4.95 GeV
- Obvious $\phi\chi_{c1}, \phi\chi_{c2}$ production

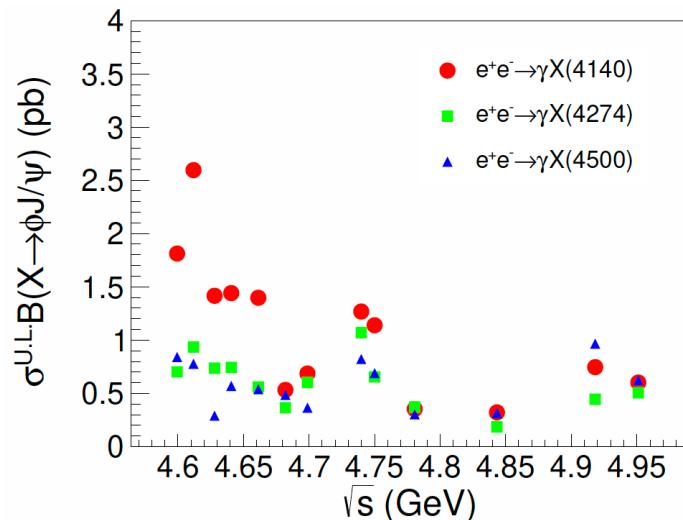
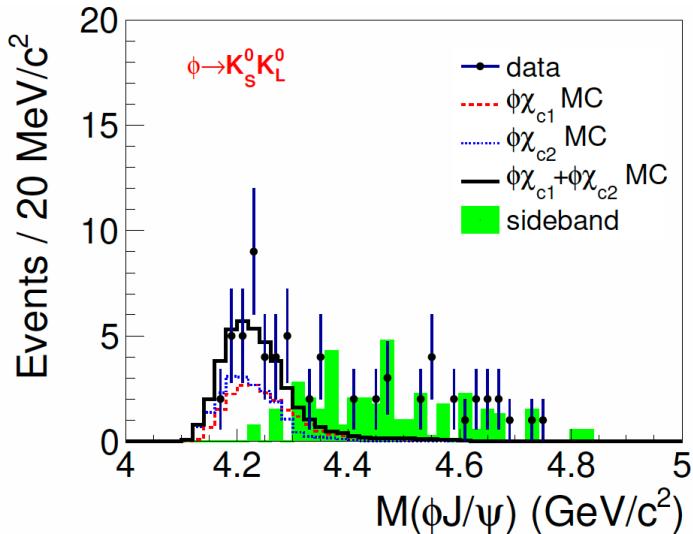
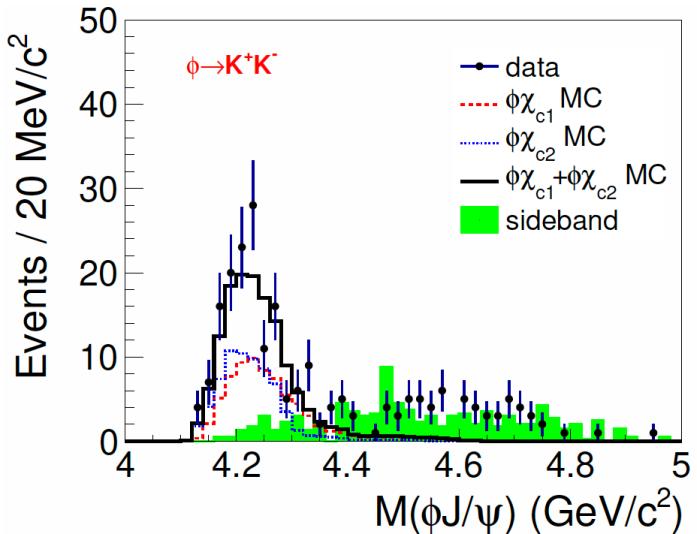
- Evidence for near threshold resonance ($\sim 3\sigma$ significance)

$$M = (4672.7 \pm 10.8) \text{ MeV}/c^2, \Gamma_{\text{tot}} = (93.2 \pm 19.8) \text{ MeV},$$

- Consistent with $\text{Y}(4660)$
- A new structure?

$$M = (4701.8 \pm 10.9) \text{ MeV}/c^2, \Gamma_{\text{tot}} = (30.5 \pm 22.3) \text{ MeV}$$

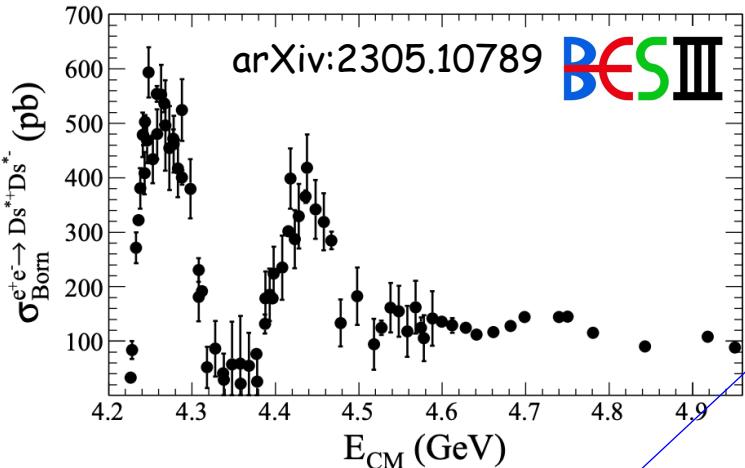
$e^+e^- \rightarrow \gamma(\phi J/\psi)$ process



- $Y(4140) \rightarrow \phi J/\psi$ by CDF
- $X(4274)/X(4500)/X(4700) \rightarrow \phi J/\psi$ by LHCb
- Events are dominant by $\phi\chi_{c1,c2}$ process
- Upper limit for production cross section



$e^+e^- \rightarrow D_s^* D_s^*$ cross section

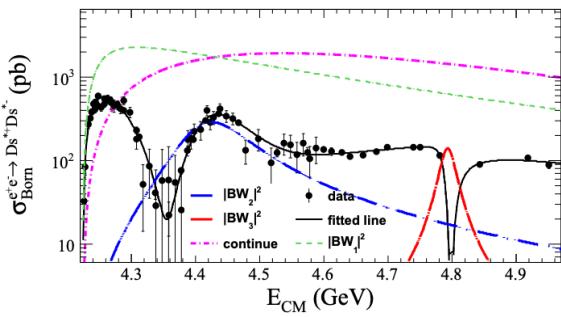


➤ A semi-inclusive method: $D_s^* \rightarrow \gamma D_s \rightarrow \gamma K K \pi$

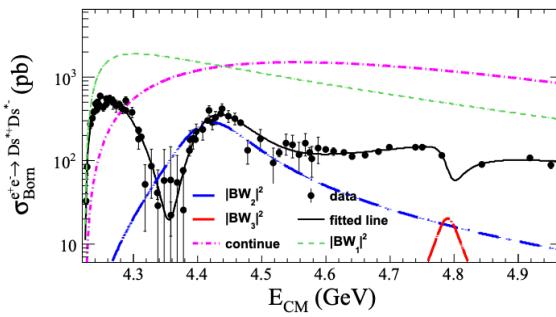
$$\left| \sum_{j=1}^3 a_j \cdot e^{i\phi_j} \cdot BW_j(E_{CM}) + \frac{a_0}{E_{CM}^n} \right|^2 \beta^3(E_{CM})$$

- $\psi(4160)$ or $Y(4260)$ [strong coupling to $D_s^* D_s^*$?]
- Consistent with $\psi(4415) \rightarrow$ first observation
- Necessarily to improve fit quality ($>6.1\sigma$)
- K-matrix method to include all channels in future.

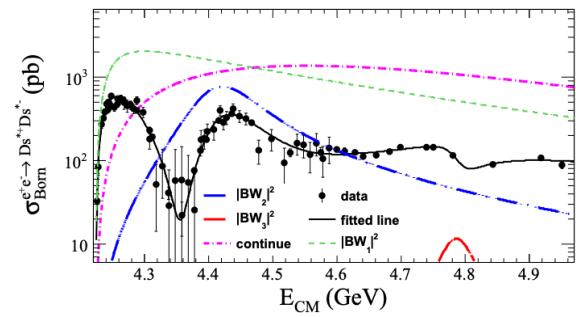
	M_1 (MeV/c ²)	Γ_1 (MeV)	M_2 (MeV/c ²)	Γ_2 (MeV)	M_3 (MeV/c ²)	Γ_3 (MeV)	significance of BW_3
Fitting result 1	4186.5 ± 9.0	55 ± 17	4414.5 ± 3.2	122.6 ± 7.0	4793.3 ± 7.5	27.1 ± 7.0	6.24σ
Fitting result 2	4193.8 ± 7.5	61.2 ± 9.0	4412.8 ± 3.2	120.3 ± 7.0	4789.8 ± 9.0	41 ± 39	6.17σ
FITting result 3	4195.3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



(a) Fitting result 1



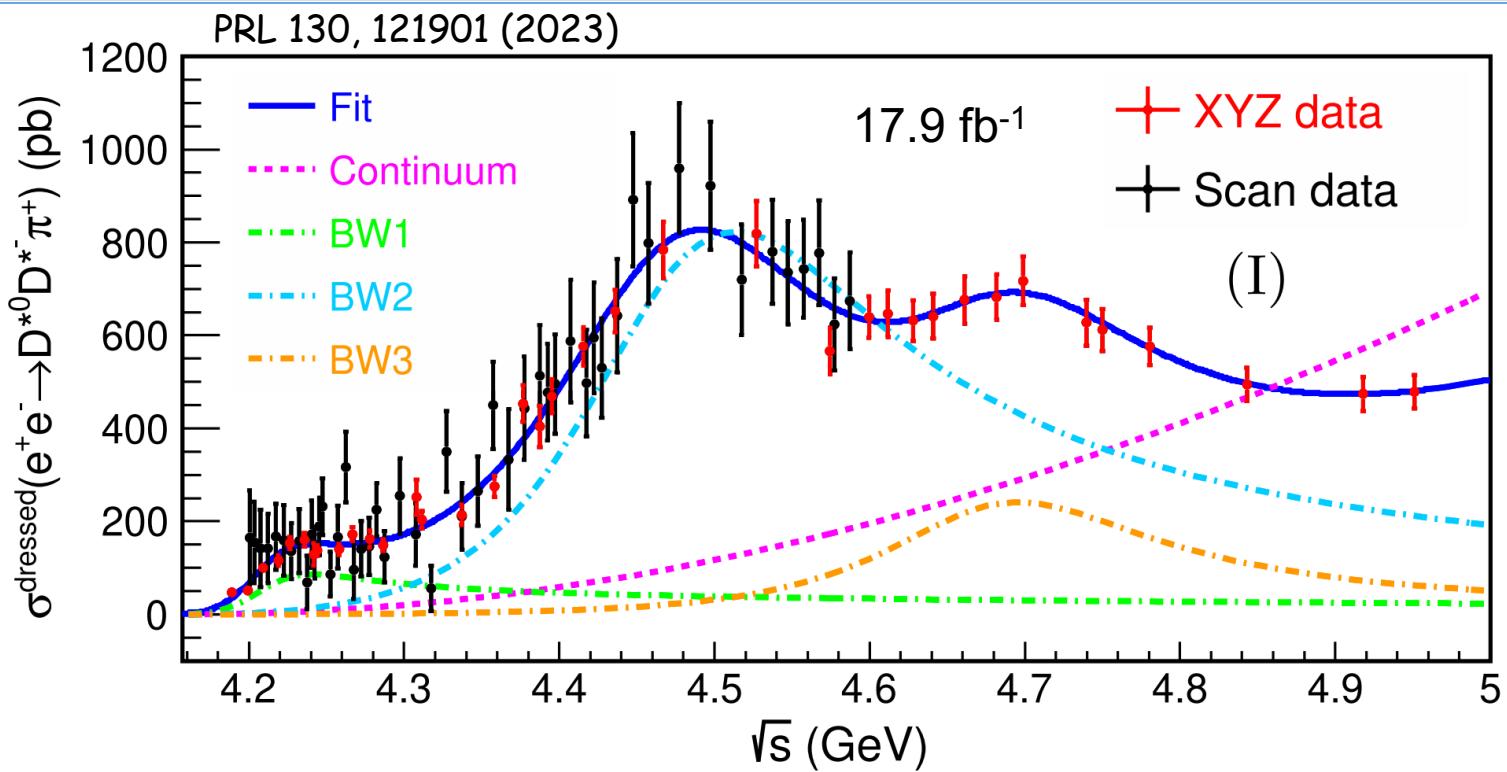
(b) Fitting result 2



(c) Fitting result 3



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



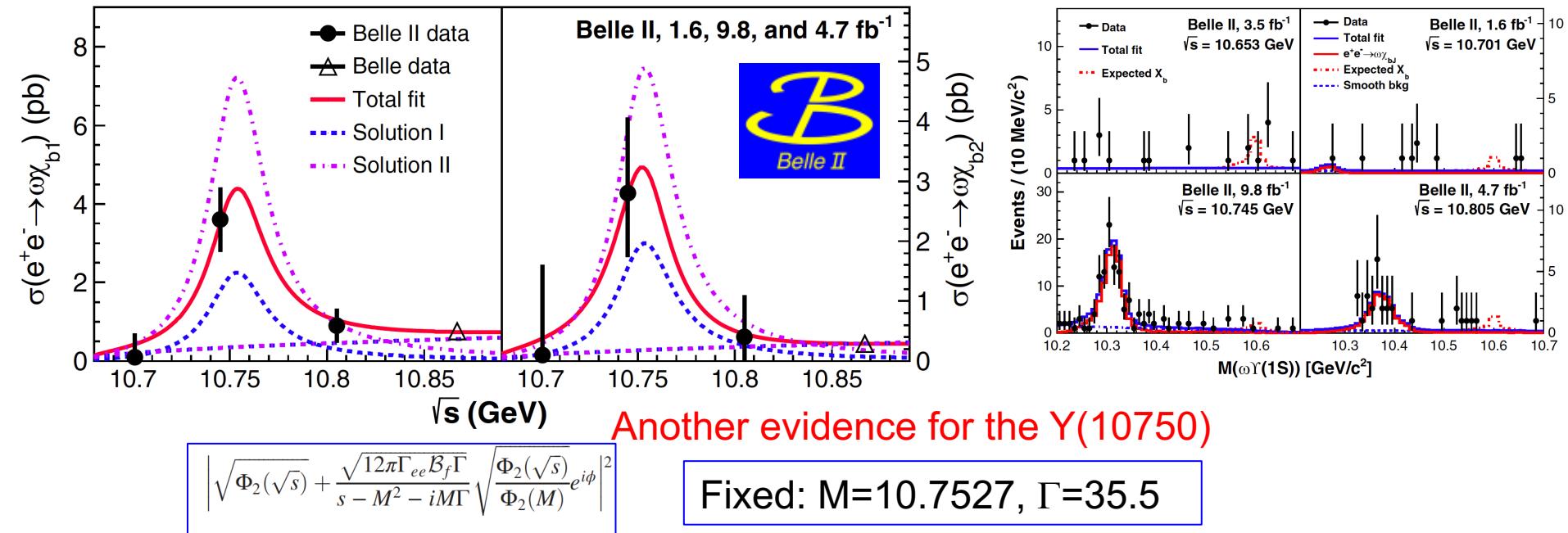
$$\sigma^{\text{dressed}}(\sqrt{s}) = C_0 \left| C_1 \sqrt{\Phi(\sqrt{s})} + \sum_{k=1}^3 \text{BW}_k(\sqrt{s}) e^{i\phi_k} \right|^2,$$

$m_1 = 4209.6 \pm 4.7 \pm 5.9$ MeV/c² , $\Gamma_1 = 81.6 \pm 17.8 \pm 9.0$ MeV; $\rightarrow Y(4230)$, large coupling to open-charm
 $m_2 = 4469.1 \pm 26.2 \pm 3.6$ MeV/c² , $\Gamma_2 = 246.3 \pm 36.7 \pm 9.4$ MeV; $\rightarrow Y(4500)$, coupling larger than KKJ/ψ
 $m_3 = 4675.3 \pm 29.5 \pm 3.5$ MeV/c² , $\Gamma_3 = 218.3 \pm 72.9 \pm 9.3$ MeV. $\rightarrow Y(4660)$, first open-charm decay

BESIII

Observation of $\Upsilon(10750) \rightarrow \omega\chi_{bJ}$

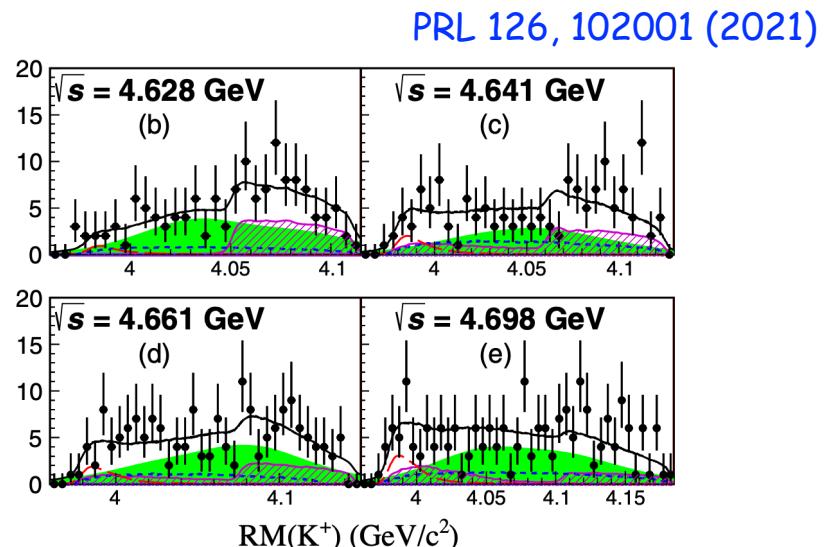
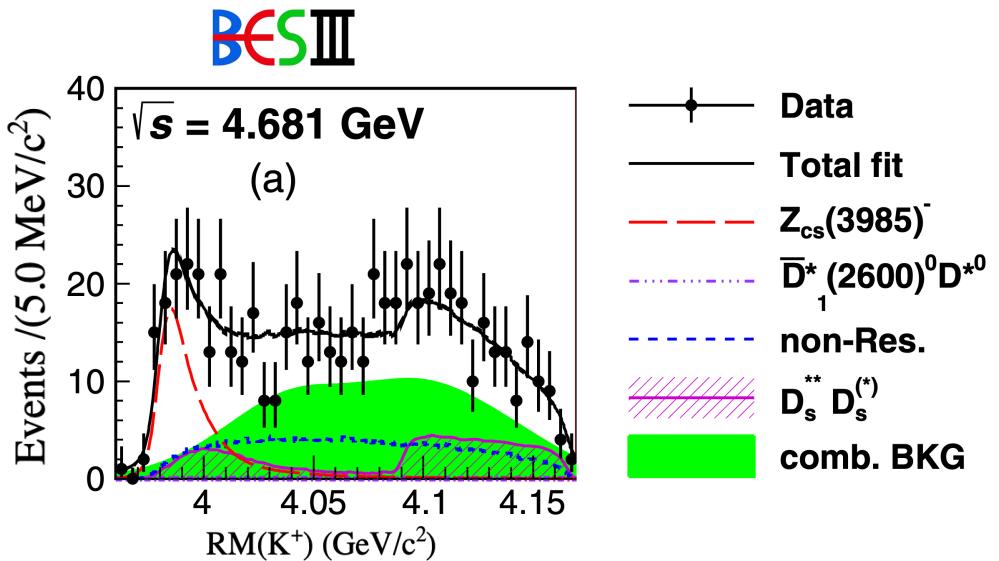
PRL130, 091902 (2023)



- Potential model 3D bottomonium ~ 10.7 GeV [$\Upsilon(10750) \rightarrow \omega\chi_{b1}/\omega\chi_{b2} = 1.3 \pm 0.6$ lower than pure D-wave (~ 15); S-D mixture (0.2)]
- $\Upsilon(10750) \rightarrow \omega\chi_{bJ}$ & $\Upsilon(10860) \rightarrow \pi\pi\Upsilon(nS)$ are two different resonance
- Hybrid, tetraquark, dynamically generated... See Alessandro's talk on Tuesday

Charged Z_{cs} states

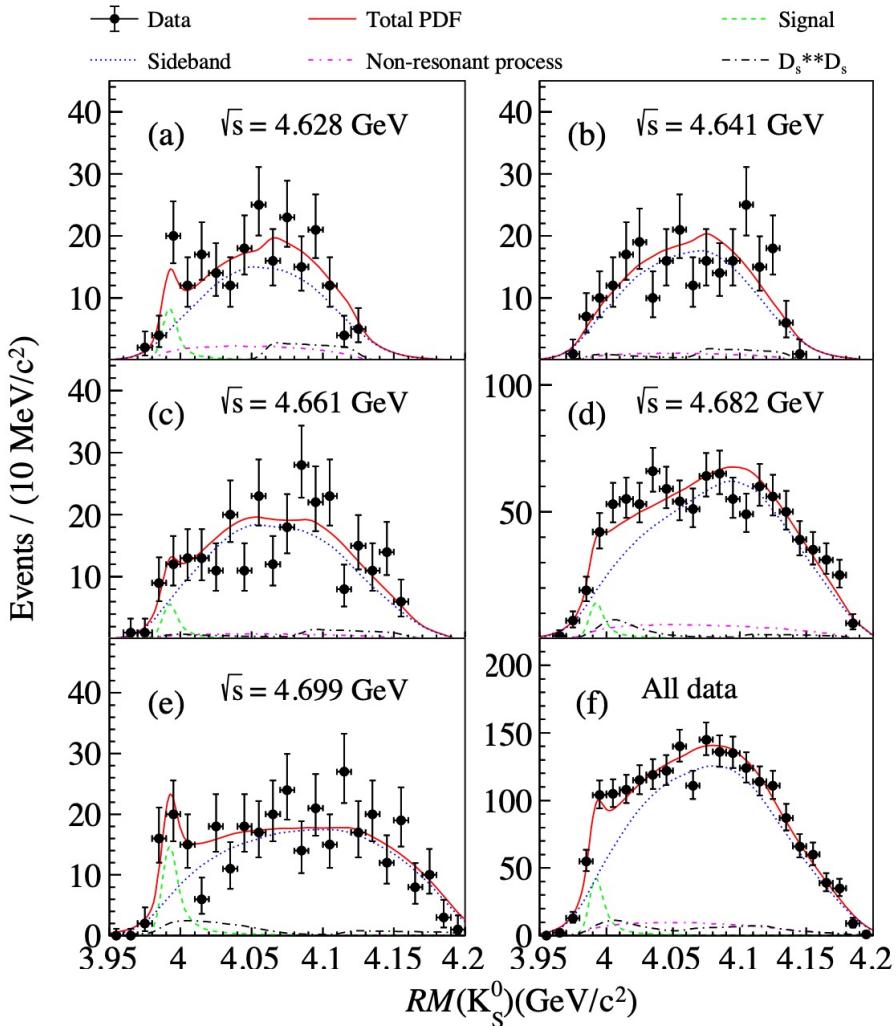
Observation of $Z_{cs}(3985)$



- Search for the Z-state with strange quark in $e^+e^- \rightarrow K^+(D_s D^*/D_s^* D^-)$
- A near threshold structure was observed at BESIII
- $M = 3982.5^{+1.8}_{-2.6} \pm 2.1 \text{ MeV}/c^2$; $\Gamma = 12.8^{+5.3}_{-4.4} \pm 3.0 \text{ MeV}$

Partner of $Z_c(3900)$ with s quark?

$Z_{cs}(3985)^0$ neutral partner



PRL 129, 112003 (2022)



- Same data set with charged channel, $e+e-\rightarrow K_s(D_sD^* + D_s^*D)$
- Evidence (4.6σ significance) for a neutral candidate $Z_{cs}(3985)^0$
- $M=(3992.2 \pm 1.7 \pm 1.6)$ MeV;
 $\Gamma=(7.7^{+4.1-3.8 \pm 4.3})$ MeV
- Iso-spin partner of $Z_{cs}(3985)^+$

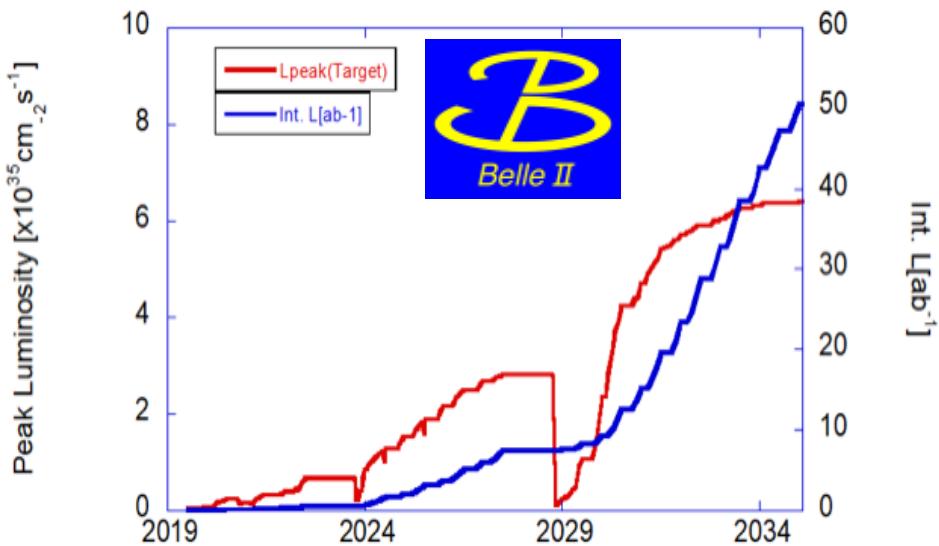
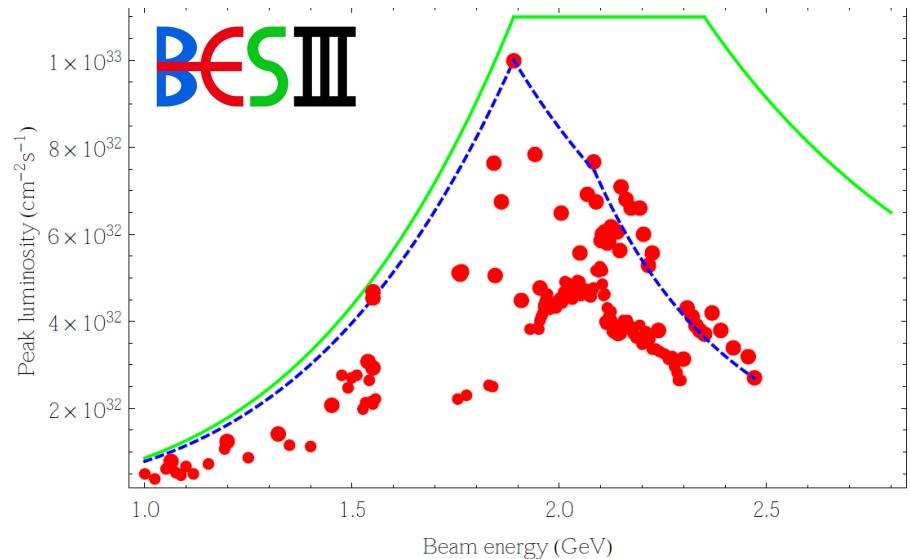
	Mass (MeV/c ²)	Width (MeV)
$Z_{cs}(3985)^0$	$3992.2 \pm 1.7 \pm 1.6$	$7.7^{+4.1}_{-3.8} \pm 4.3$
$Z_{cs}(3985)^+$	$3985.2^{+2.1}_{-2.0} \pm 1.7$	$13.8^{+8.1}_{-5.2} \pm 4.9$



Future prospect

BEPCII-U vs. BEPCII

From Y. Zhang @ FPCP2021



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

- LS1: 2022-2023 (15 month, VXD/TOP PMT replacement etc.), restart this winter
- LS2: 2026-2027 (machine improvement etc.)



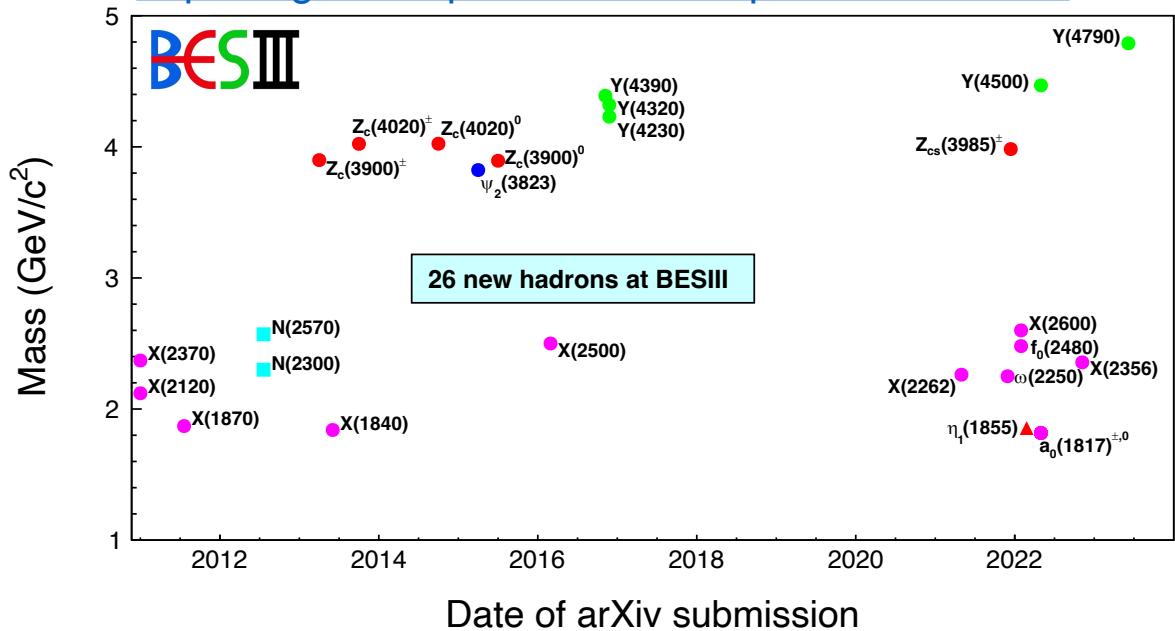
Summary

- Tremendous progress on XYZ particles in past years...
- X(3872) enters into precision line shape & properties stage
- Many new observations for vector Y-states, a multi-channel study is necessary
- Observation of SU(3) partner Z_{cs} states, a bigger particle zoo coming...



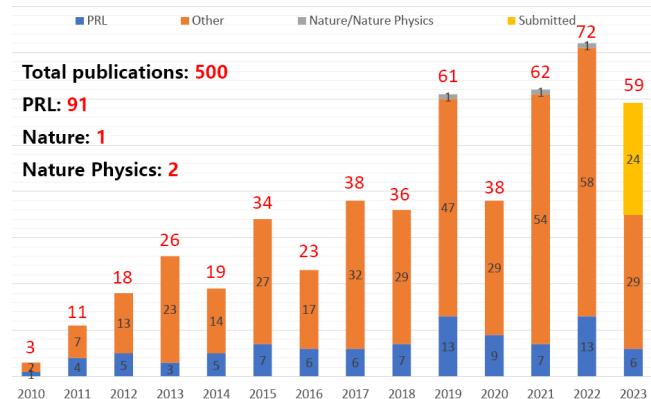
500th celebration

<http://english.ihep.cas.cn/bes/re/pu/NewParticles/>



<https://indico.ihep.ac.cn/event/19694/>

BESIII publications (May 9, 2023)

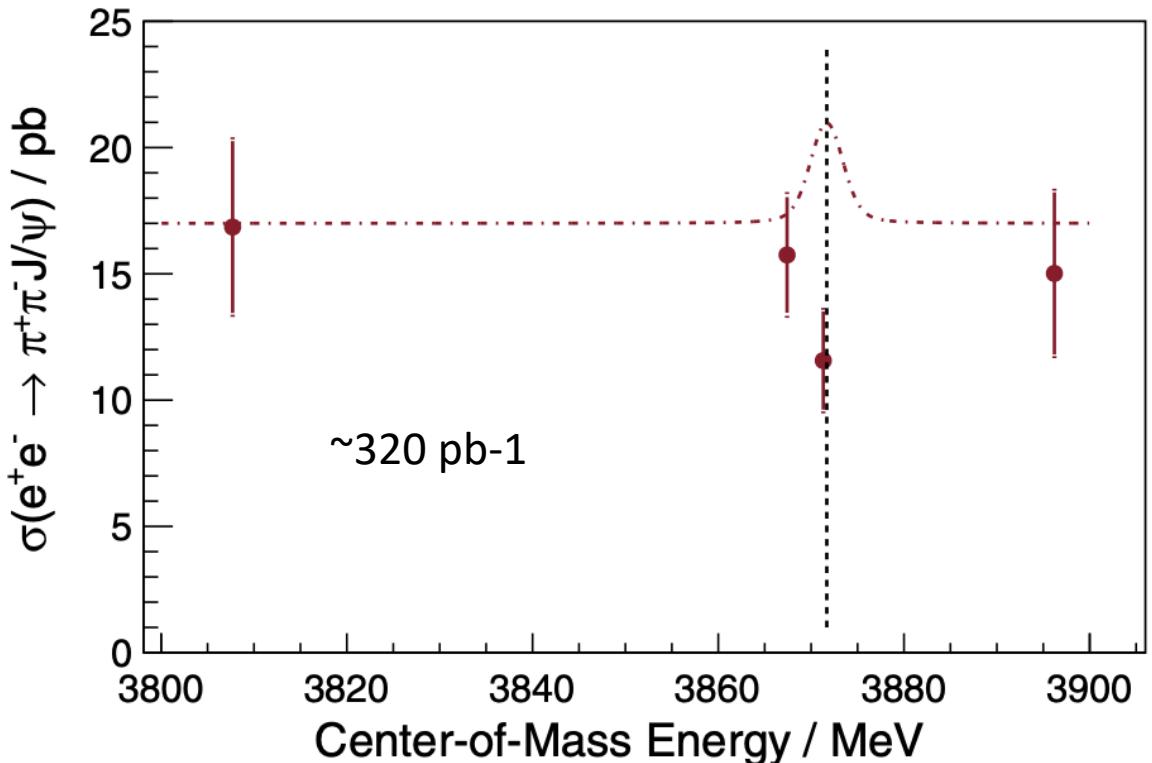
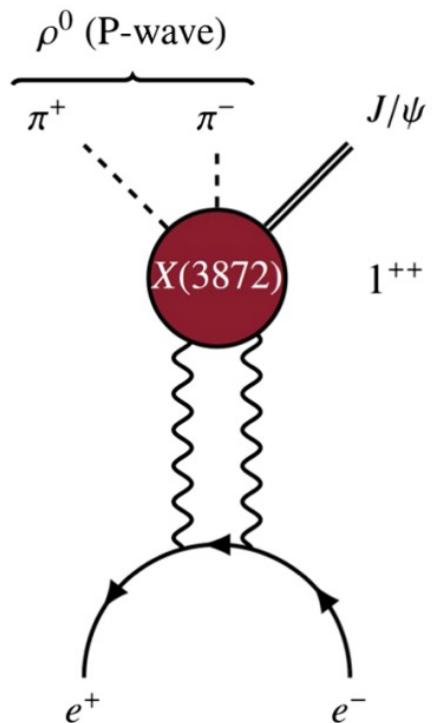


Thanks for your attention !

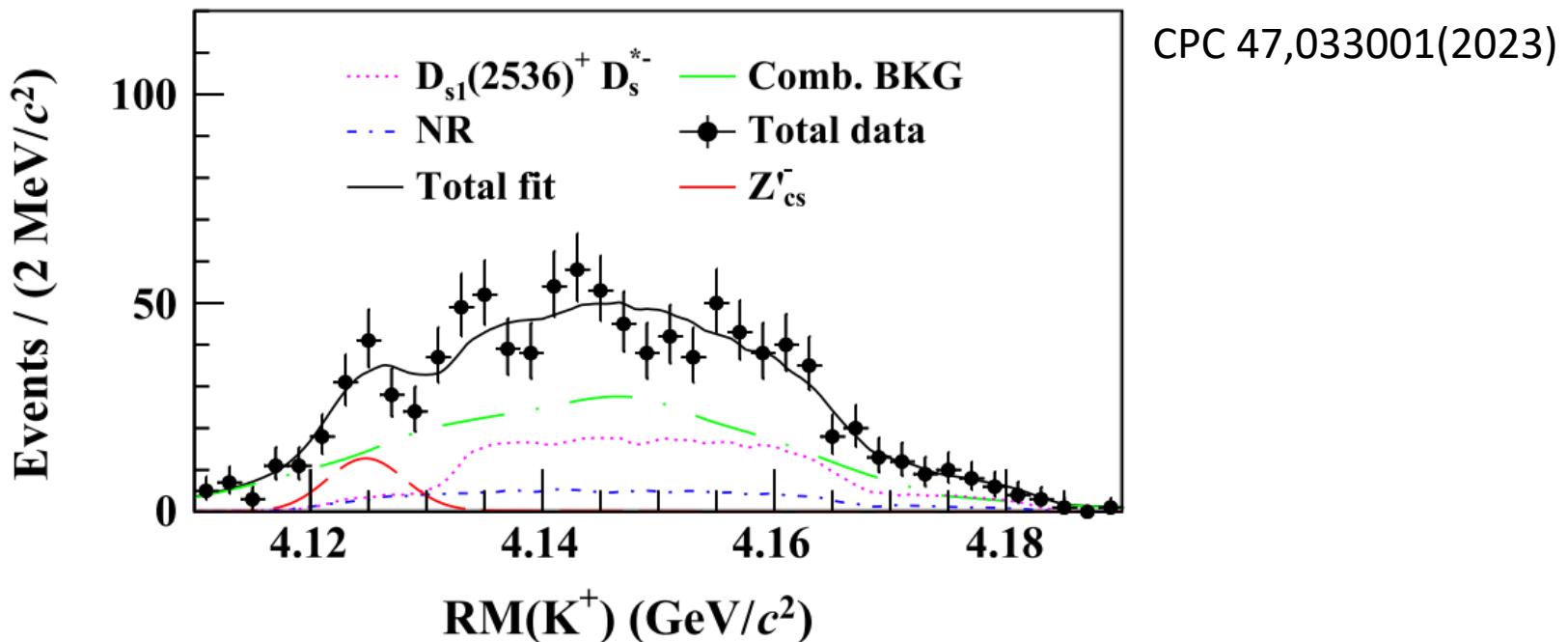


Backup

$e^+e^- \rightarrow X(3872)$



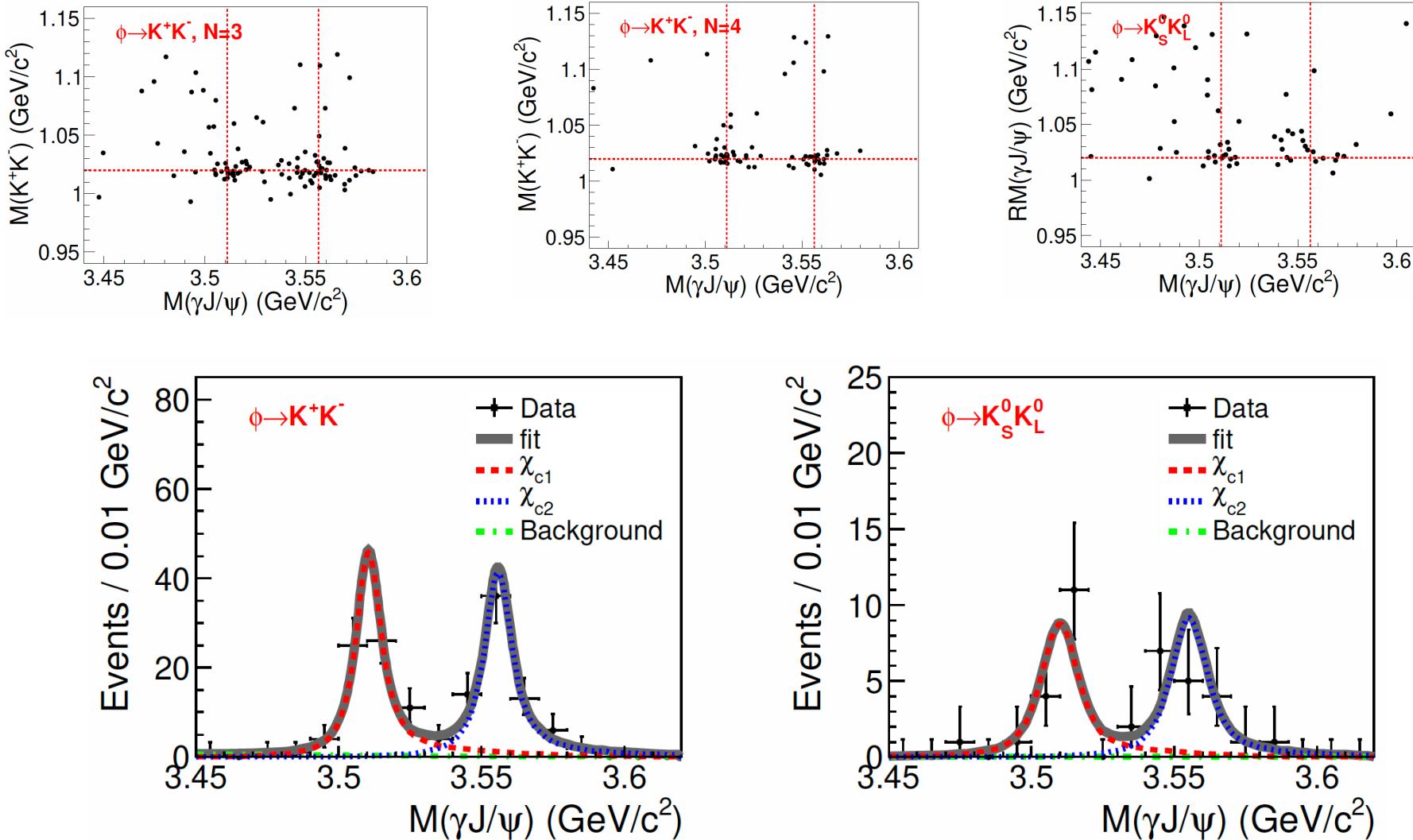
- $\Gamma_{ee}[X(3872)] < 0.32 \text{ eV} @ 90\% \text{ C.L.}$
- $\Gamma_{ee}[\chi_{c1}] = 0.12^{+0.13}_{-0.08} \text{ eV}$

$Z_{cs}' \rightarrow Ds^* D^*$


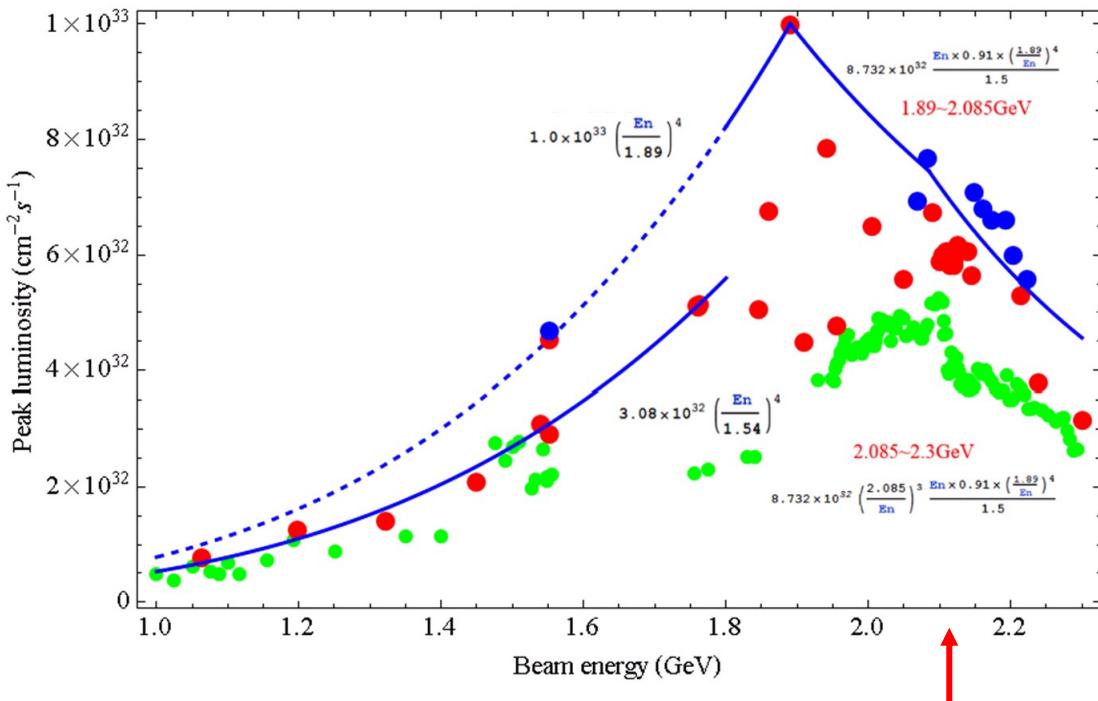
- Search for the Z_{cs}' partner in $e^+e^- \rightarrow K^+(Ds^*D^*/Ds^*D^*)^-$
- No obvious excess of events around Ds^*D^* threshold



$e^+e^- \rightarrow \gamma\phi J/\psi$ process



BEPCII Luminosity



- Center-of-Mass energy: 2.0 - 4.936 GeV
- Design Luminosity @ $\psi(3770)$: $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ (achieved in 2016)
- Energy spread: 1.1 MeV @ 3.686 GeV



BESIII experiment

A 4π detector

