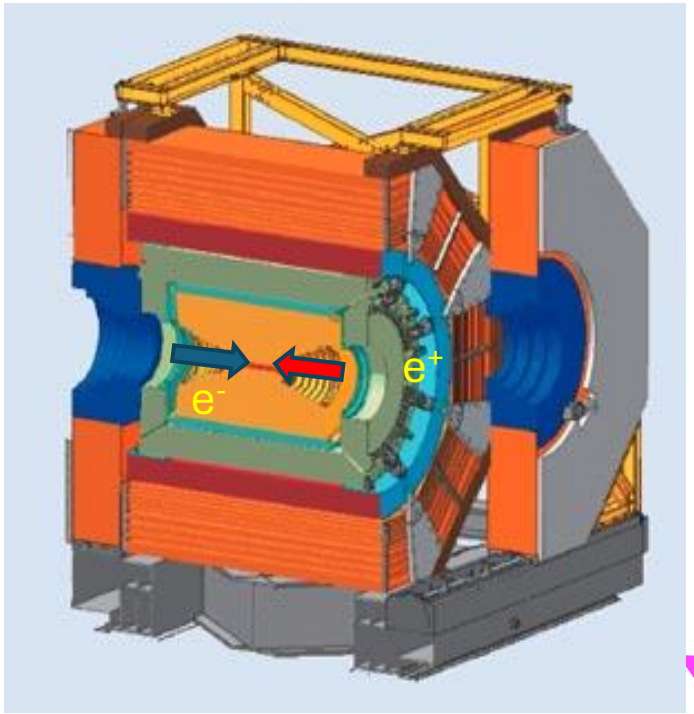
Recent results from BESIII on heavy-flavor exotica

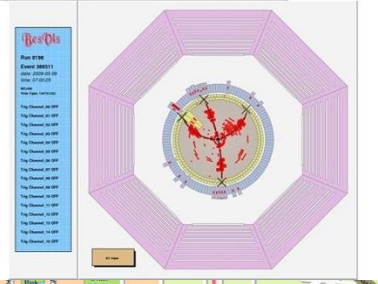
Francesca De Mori
On behalf of BESIII collaboration
Università di Torino & INFN sez. di Torino

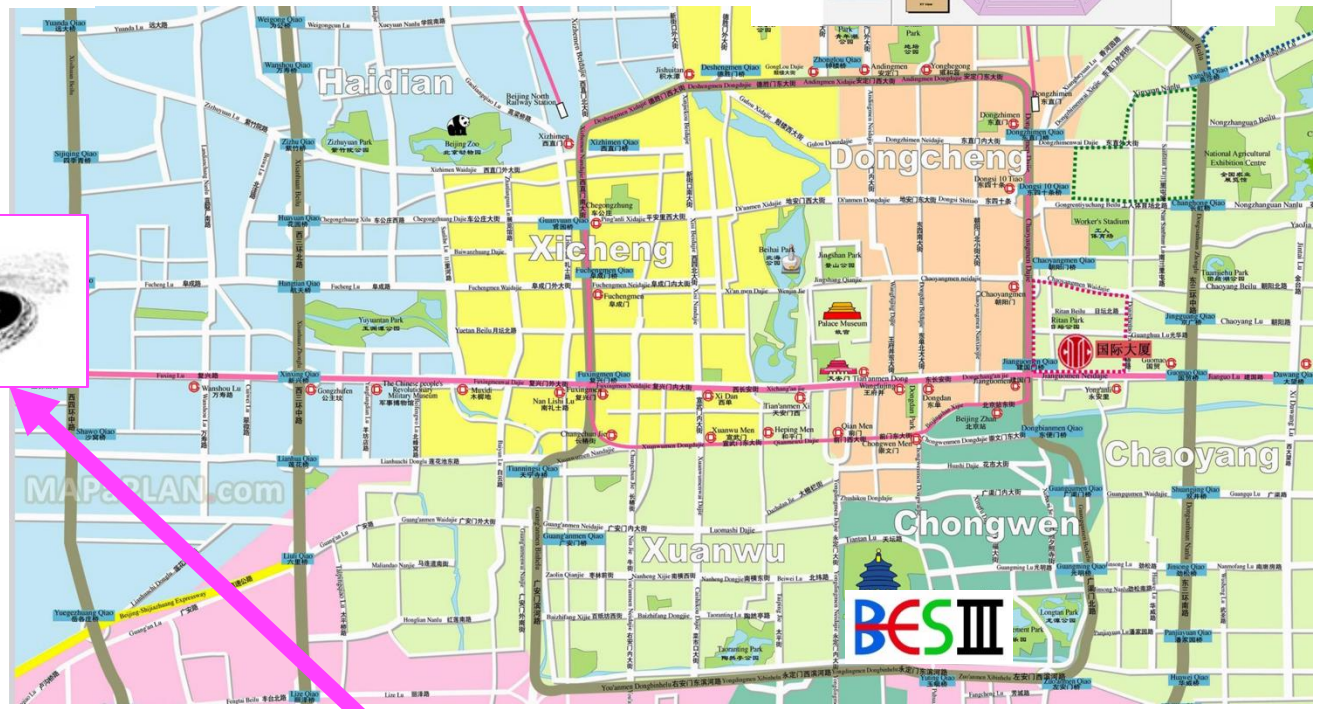
In this talk

- Introduction of charmonium-like (XYZ) states and BESIII
- Selection of results of BESIII
- Summary

BESIII @BEPCII

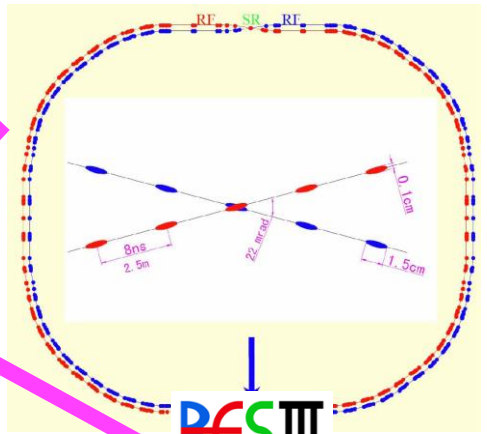


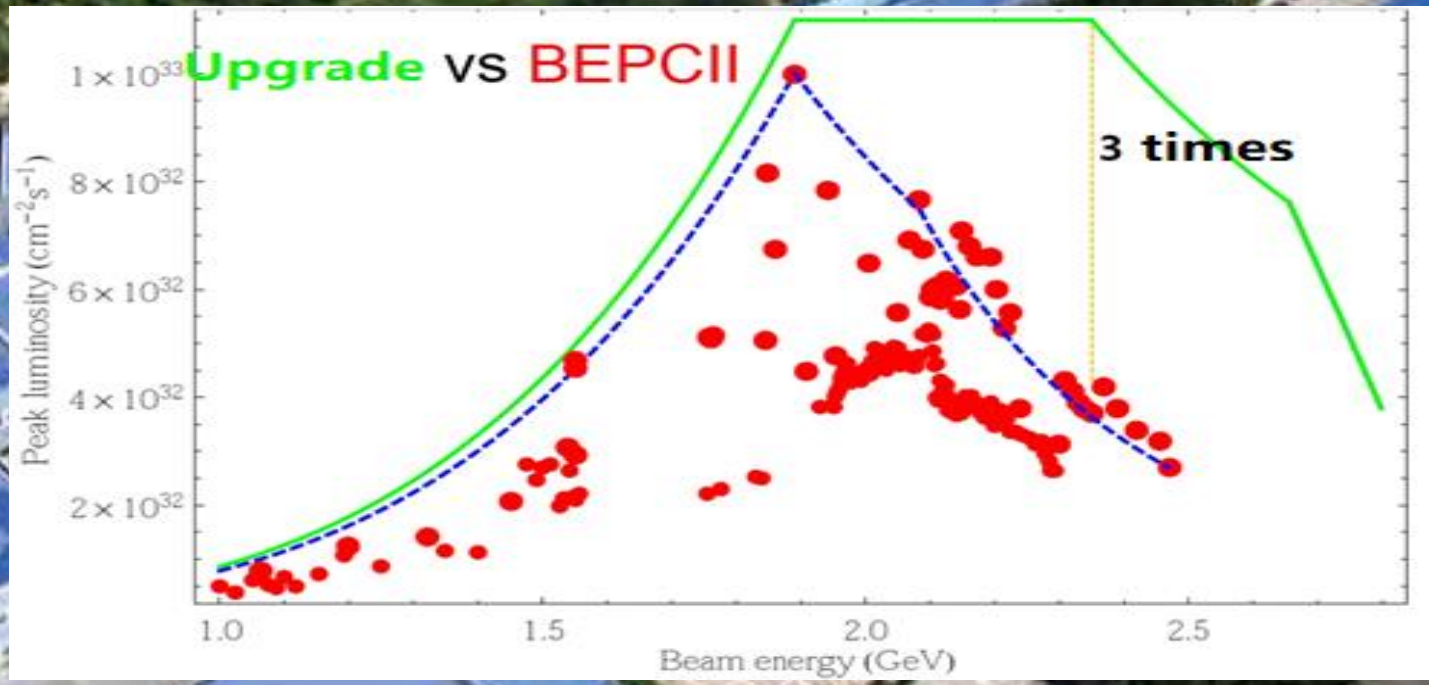




running since 2009 at the Institute of High Energy Physics in Beijing, China

Symmetric double ring collider
with tunable beam energy (CME 2-4.96 GeV)
Maximum luminosity: 1.1 10^{33} cm^{-2} s^{-1} @3770 MeV





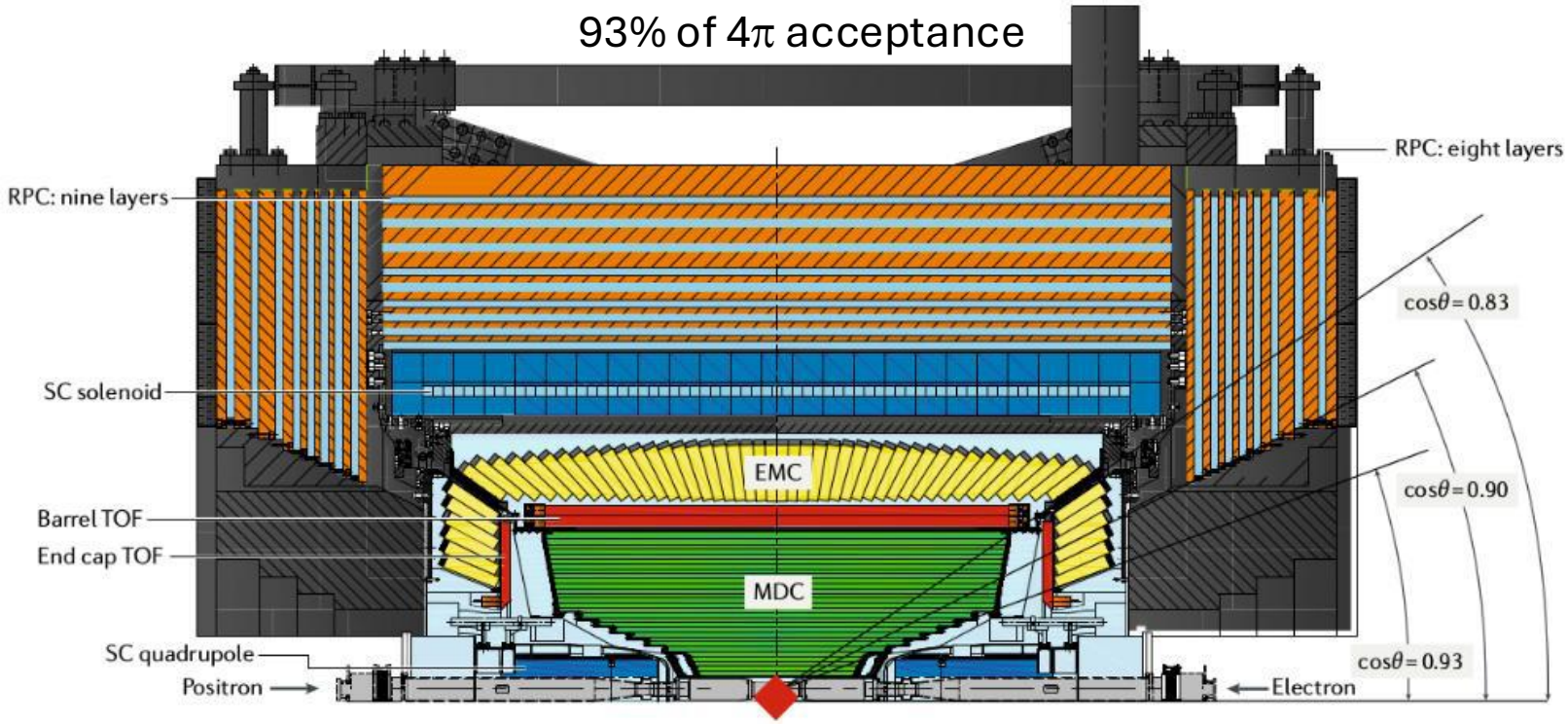
BEPCII upgrade aims to:

- **Increase luminosity by a factor 3 @2.35 GeV**
- **Increase beam energy up to 2.8 GeV (2028)**

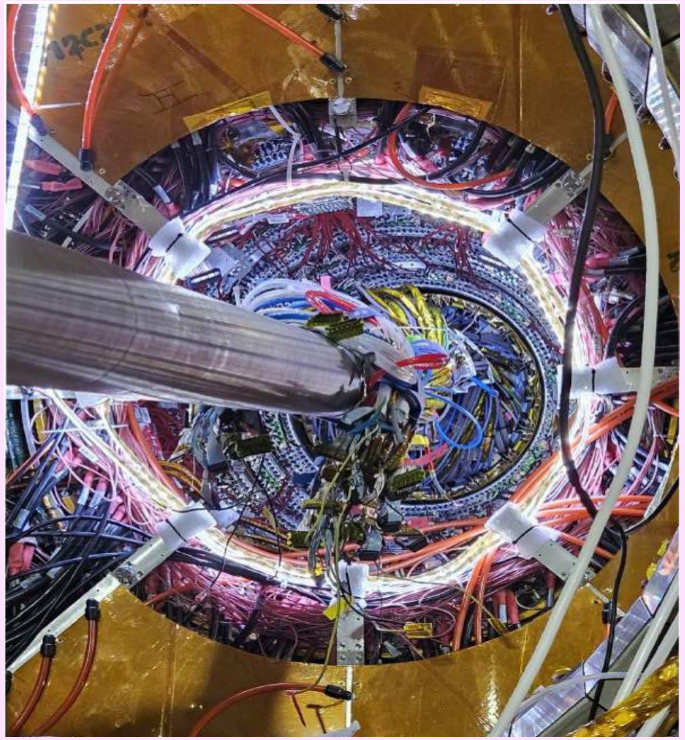
BESIII : The detector

NIM A 614-210 (2010)
Chinese Phys. C 44 040001 (2020)

93% of 4π acceptance

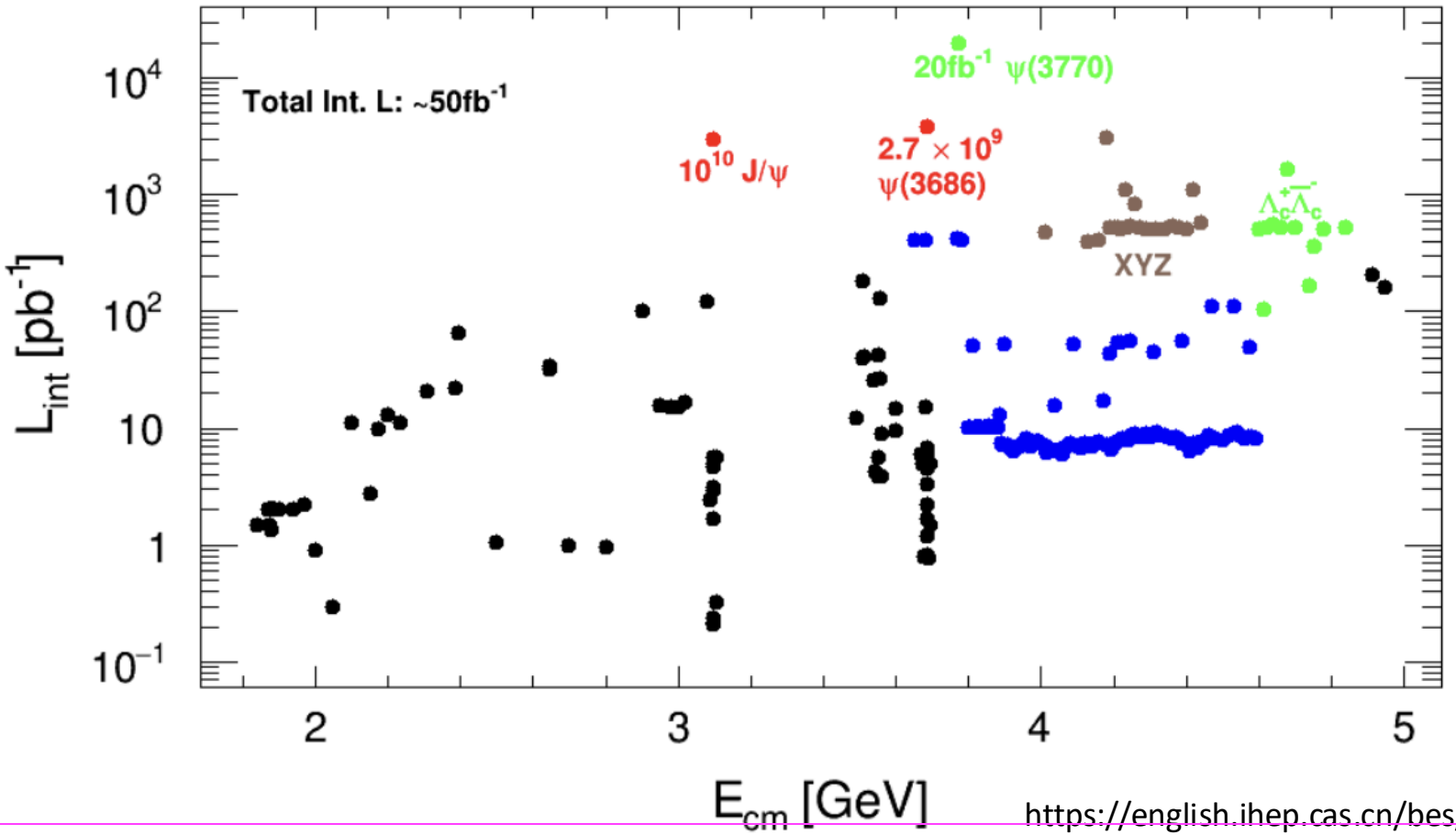


Main Drift Chamber(MDC) σ_P/P = 0.5% (1 GeV); $\sigma_{dE/dx}$ = 6%, σx=130 μm
Electromagnetic Calorimeter (EMC) CsI (Tl) $\sigma_E/\sqrt{E}$= 2.5% (1 GeV)
$\sigma_{z,\phi}$ = 0.5 - 0.7 cm/$\sqrt{E}$
μ Counter (MUC) 8 - 9 layers RPC; $\delta_{R\Phi}$ = 1.4 cm ~ 1.7 cm
Time of Flight (TOF): σ_T: 70 ps (barrel); 60 ps (endcap)
Super-Conducting Magnet :1 T



Cylindrical GEM
As NEW Inner Tracker
(since 2025)

BESIII : The data



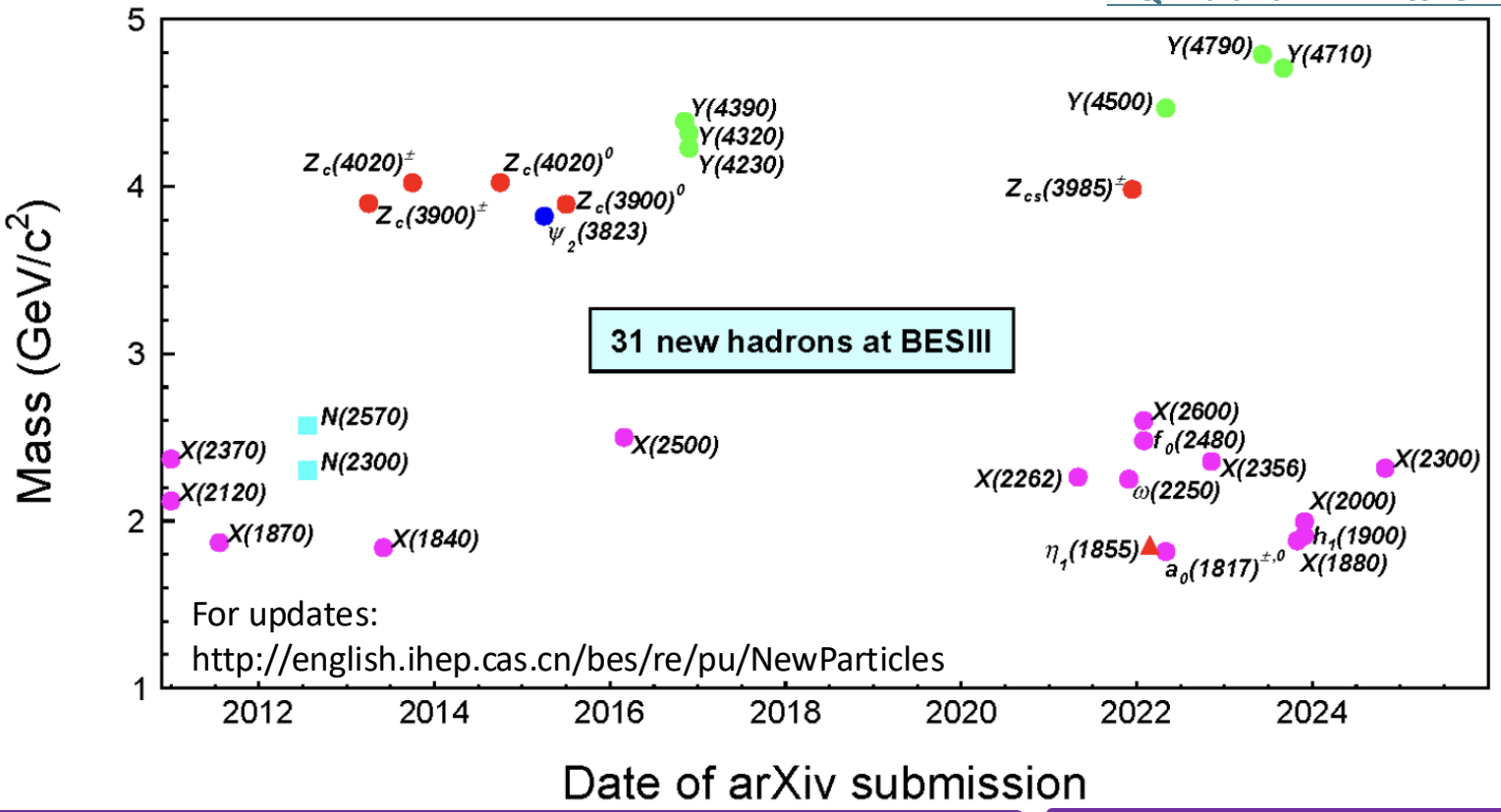
~22 fb^{-1} @ 4.0-4.9 GeV

https://english.ihep.cas.cn/bes/ui/ds/202109/t20210923_284001.html

Physics program:
light quark spectroscopy; light meson decays; hyperon physics; initial state radiation and two photon fusion; precision open charm decays; charmonium spectroscopy; spectroscopy of exotic "XYZ" states; etc. etc.

:new hadrons

Z.Q. Liu and R.E. Mitchell Science Bulletin Vol. 68, Issue 19, 2023, 2148-2150



BESIII has published about 120 XYZ relevant papers till now

- directly produced in e^+e^-
- exotic flavour combination decaying into heavy mesons
- consistent with conventiona cc meson
- new light baryon state
- exotic J^{PC}
- light states decaying into mesons

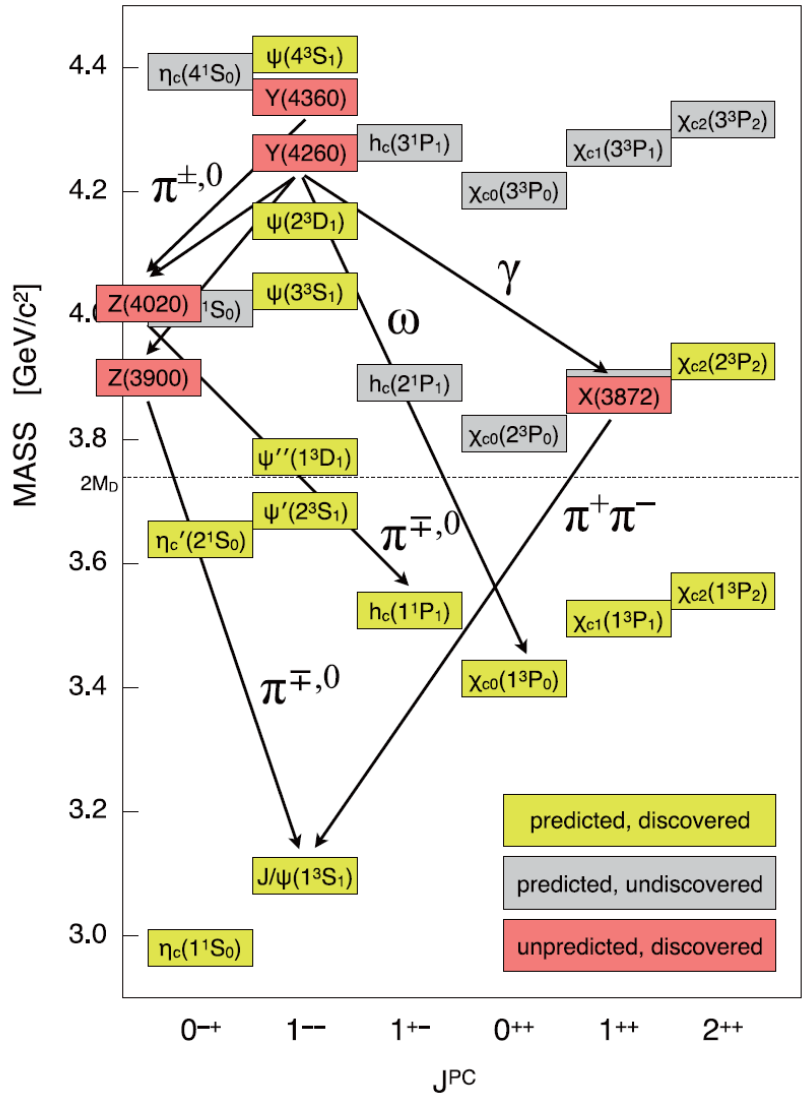
Manifestly exotic
- Quark contents more than $q\bar{q}$ or qqq
- Quantum number J^{PC} not reachable

for ordinary mesons or baryons

'Cryptoexotic'
- overpopulation of states
- mass/width not fitting in spectrum
- production and/or decay patterns

incompatible with standard mesons/baryons

Exotic hadrons Spectroscopy



$$V_{q\bar{q}} = -\frac{4}{3}\cdot\frac{\alpha_s(r)}{r} + k\cdot r$$ +spin dep.terms

Barnes *et al.*, PRD 72, 054026 (2005),
Cornell potential(not all XYZ candidates shown!)

Observed states with properties do not fit the ones of conventional charmonia (X,Y,Z) above open charm threshold by BaBar, Belle, BESIII, LHCb etc etc

X :charmonium-like states, **neither Y nor Z** observed in B decays, in proton-proton e proton-antiproton collisions ;

radiative or hadronic transition from Y

Y : charmonium-like states, $J^{PC}=1^{--}$, observed in annihilation e^+e^- o initial state radiation (ISR);

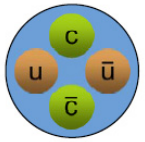
Hadronic transition from Y

Z : charmonium-like states, **I ≠ 0**, tetraquark candidates ($c\bar{c}$ + light $q\bar{q}$)

BEPCII& BESIII can be used as a Y(4230) (Y(4360)) factory.
We study the connections between
X , Y and Z and the cross-sections as CME function.

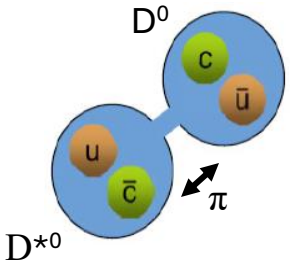
PDG, adopted a different naming scheme in 2019

Nature of XYZ states

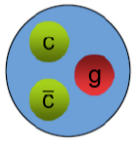


- **Tetraquarks**
  - Bound states of **4 quarks, Large number** of states expected, **Small widths** above threshold
- **Molecular states**
  - Loosely bound states of a **pair of mesons** , **Small number** of states,

  Small widths above threshold

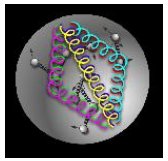


- **Hybrids**
  - Bound States with a pair of quarks and **excited gluonic** degrees of freedom
  - Lattice and model predictions for the **lowest-mass** hybrid ~ **4.2 GeV/c²**



- **Glueball**

  Bound states of gluons



- **HadroCharmonium**

Compact charmonium embedded in light quark mesonic excitation interacting by analog of Van der Waals force

- **Others: Threshold**, **cusp**, or **coupled-channel** effect
  - Produce a **cross section enhancement**

The experimental contribution

1)Establish the spectrum: search for more XYZ states, determine their properties and investigate new decays, study their production

2) Build connections: look for transitions between different states

Updates on vector states Y(aka ψ states)

Vector charmonium-(like) states sector is overpopulated with respect to predictions by the potential model, showing unusually strong BF to hidden charm Channels, like $\pi\pi J/\psi$

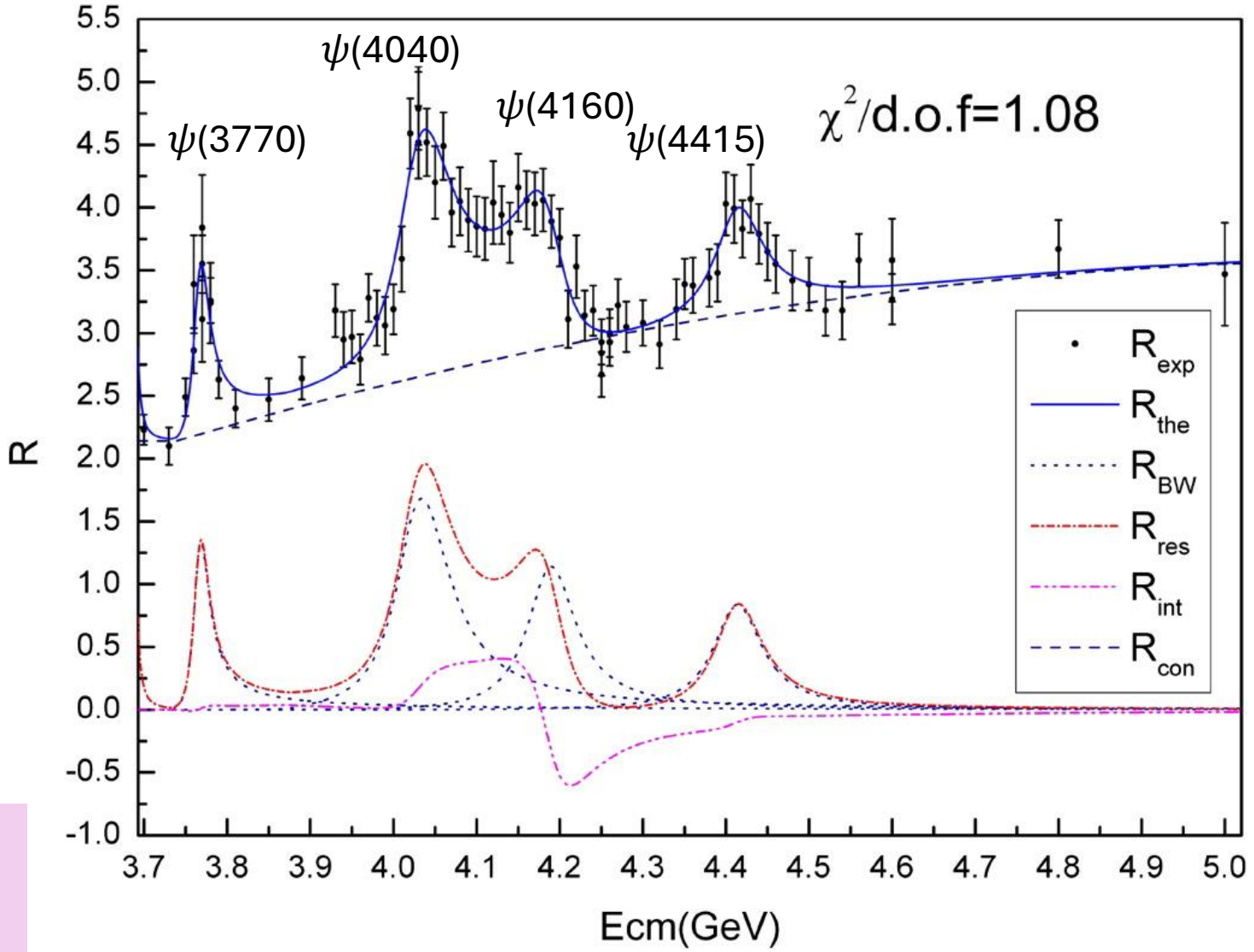
$$R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-),$$

Phys.Lett.B 660 (2008) 315-319

The system of vector states looks complete in the inclusive spectrum since 2008 (BESII) , following quark-model expectations

$$\psi(3770) \approx \psi(1^3D_1)$$
$$\psi(4040) \approx \psi(3^3S_1)$$
$$\psi(4160) \approx \psi(2^3D_1)$$
$$\psi(4415) \approx \psi(4^3S_1)$$

A R measurement in this energy region is on-going at BESIII with higher precision

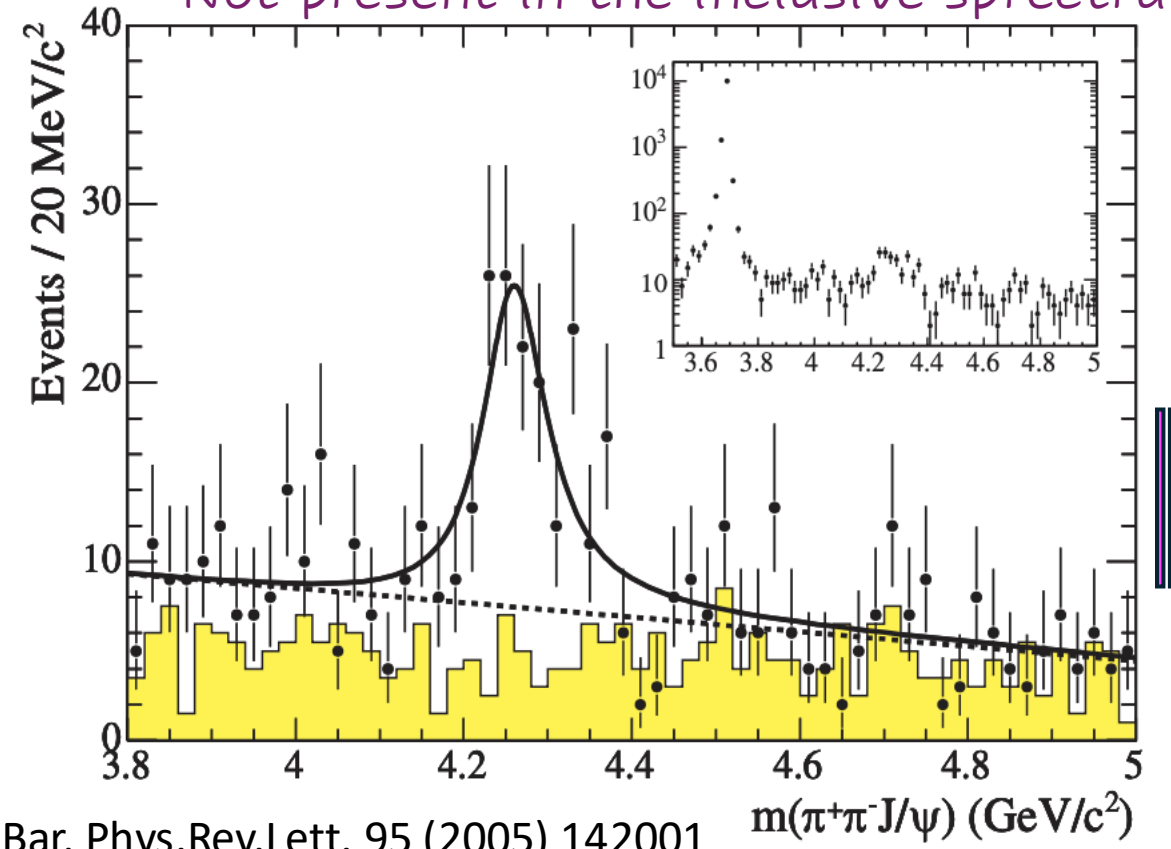


Additional states observed in esclusive channels, at least Y(4230), Y(4360), Y(4660)

Y(4230) aka ψ(4230)

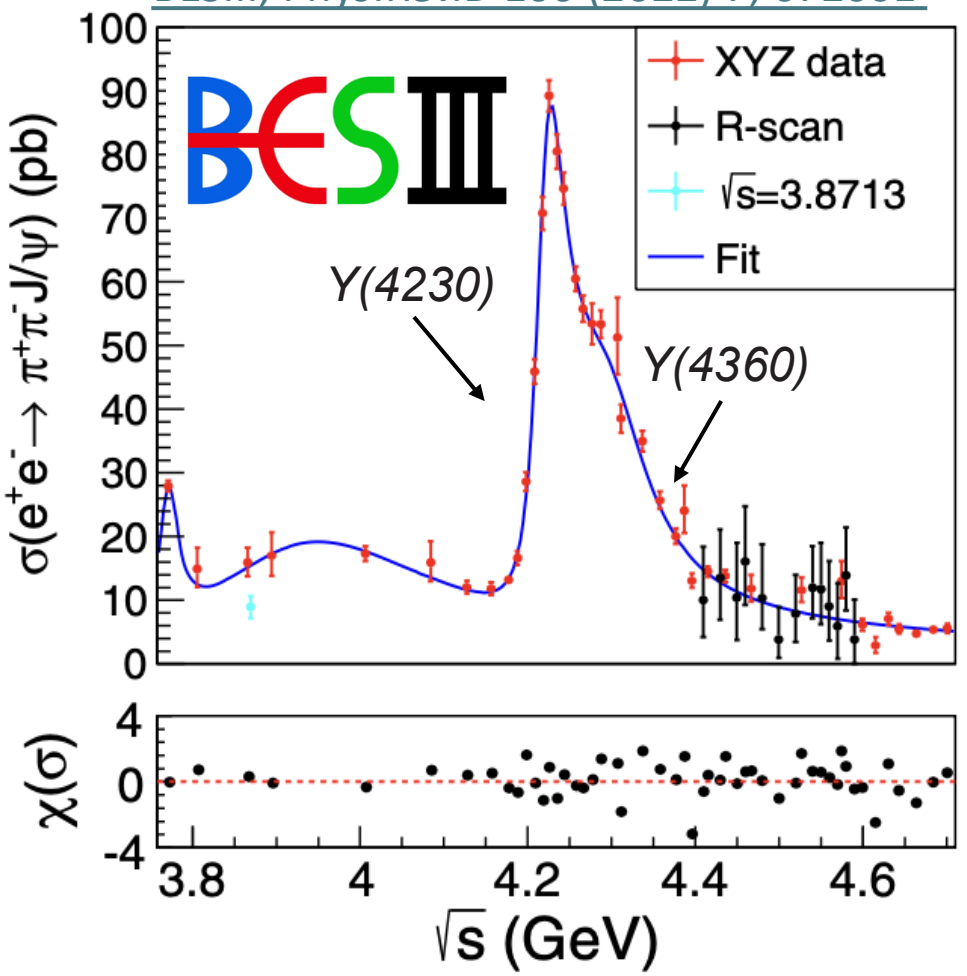
First observed (as Y(4260)) in $Y(4260) \to \pi^+\pi^- J/\psi$ by BaBar , by ISR technique

Not present in the inclusive sprectrum



BaBar, Phys.Rev.Lett. 95 (2005) 142001

BESIII, Phys.Rev.D 106 (2022) 7, 072001



Single, broad, supernumerary vector state.

DIRECT PRODUCTION in e^+e^- annihilation

Y(4230)

★ Inconsistent with all 1^{--} states in quark model

★ Open charm decays suppressed

★ Well established

★ easy production in e^+e^- annihilation

★ Proposed as exotic matter:

Hybrid? mass is close to the vector hybrid state predicted by lattice QCD.

Tetraquark?

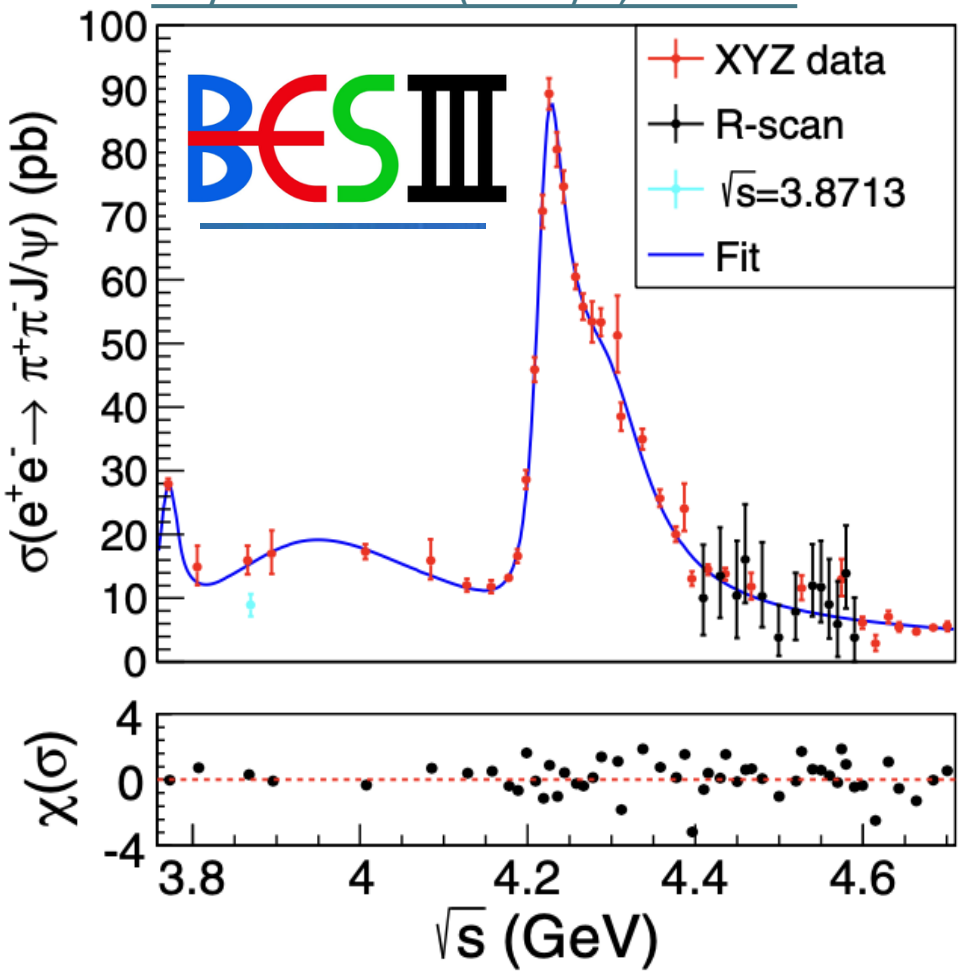
Hadronic molecule?

★ Seen in more than ten decay modes,

into charmonia and into open charm final states

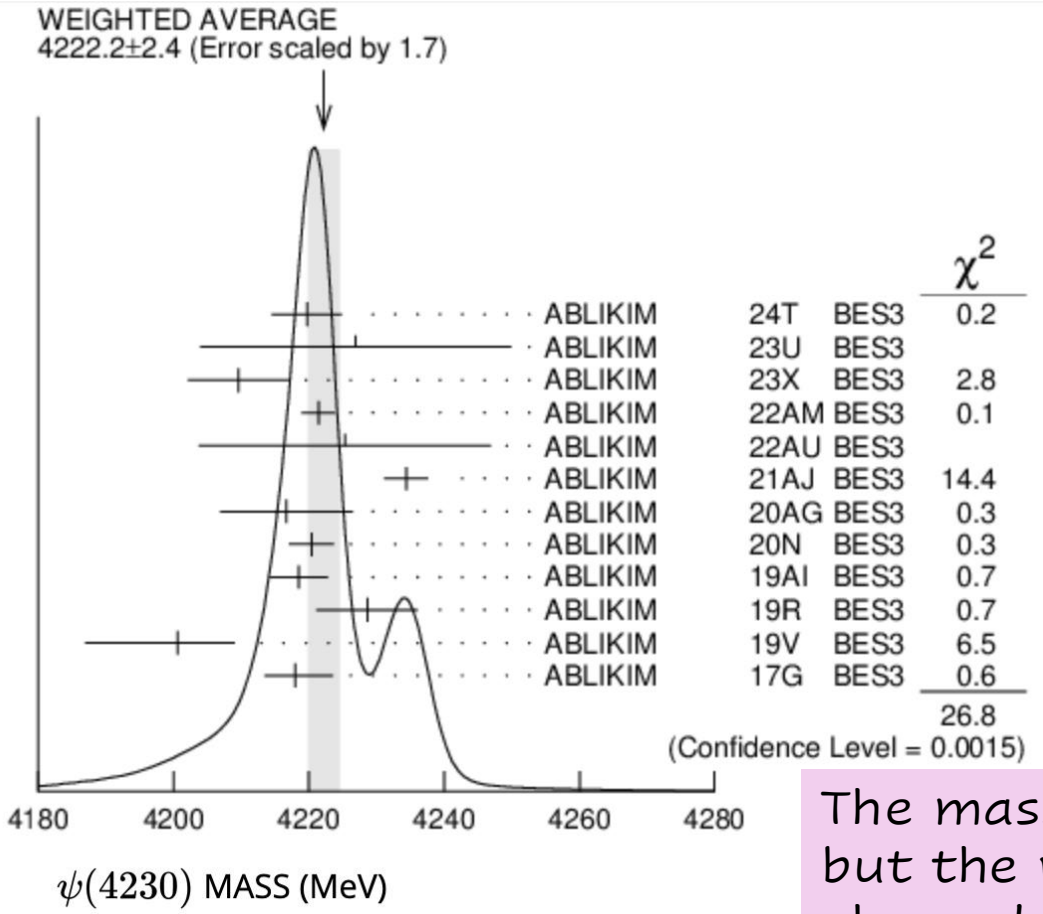
It's still a mistery!!

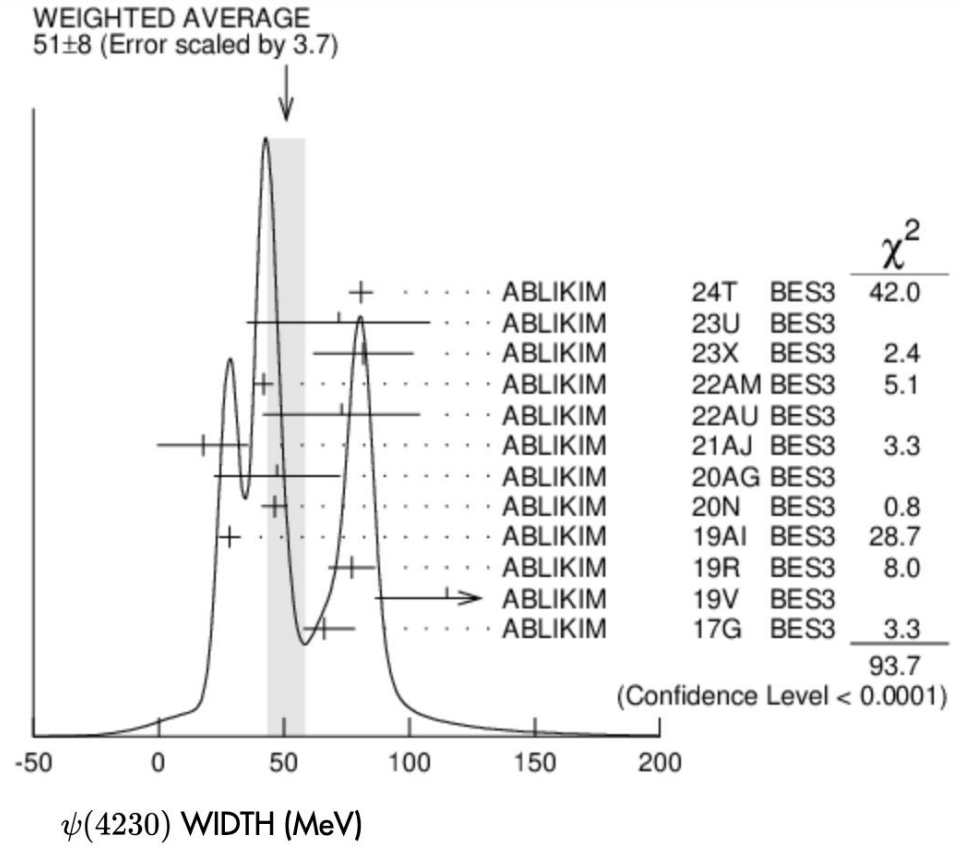
Phys.Rev.D 106 (2022) 7, 072001



$\psi(4230)$ $I^G(J^{PC}) = 0^-(1^{--})$

also known as $Y(4230)$; was $\psi(4260)$



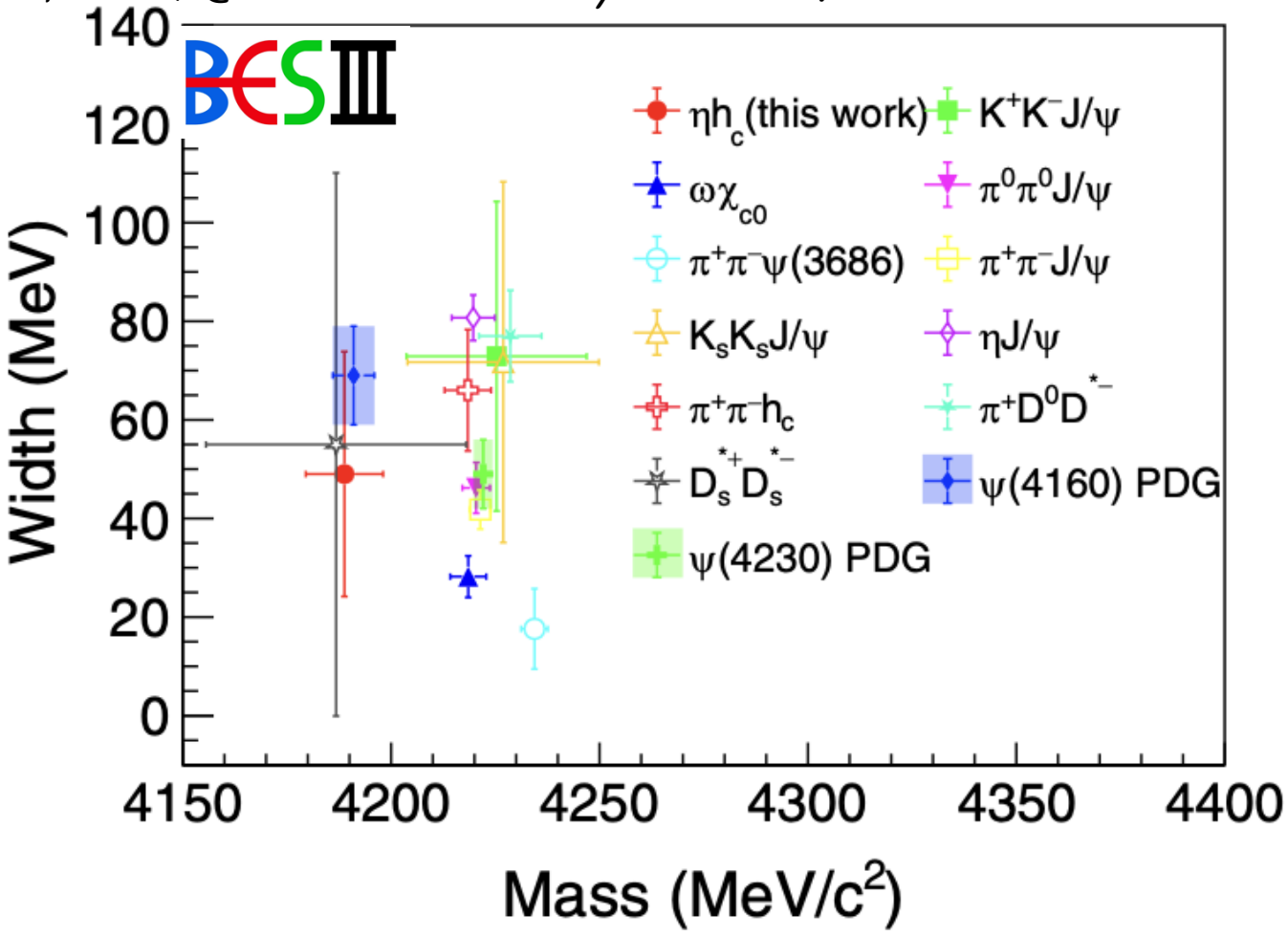


From PDG live

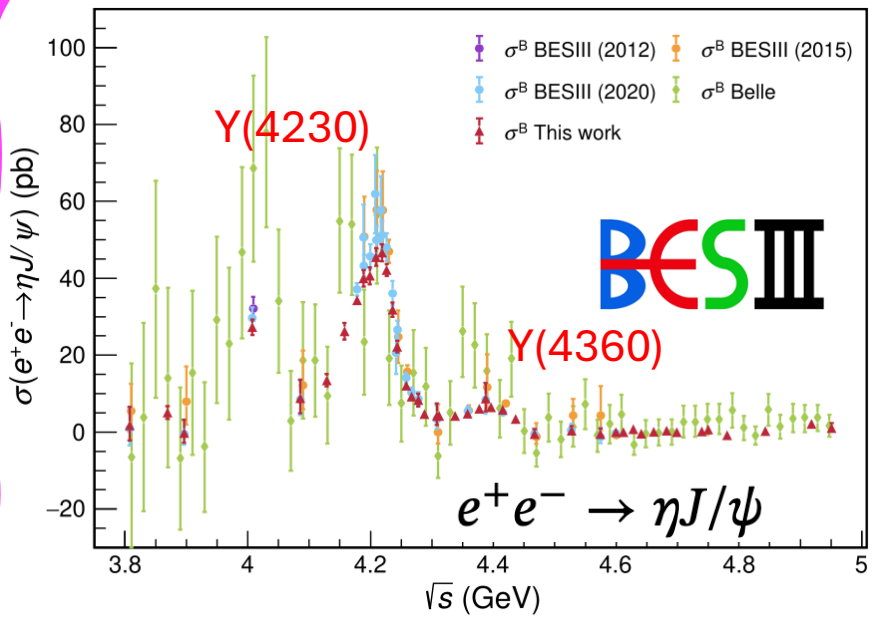
The mass is fairly consistent among exclusive channels, but the width is not! Most likely caused by coupled channels effect , interference between resonances and parametrization of the lineshape.
Coupled channels analysis is highly desirable.

Y(4230)

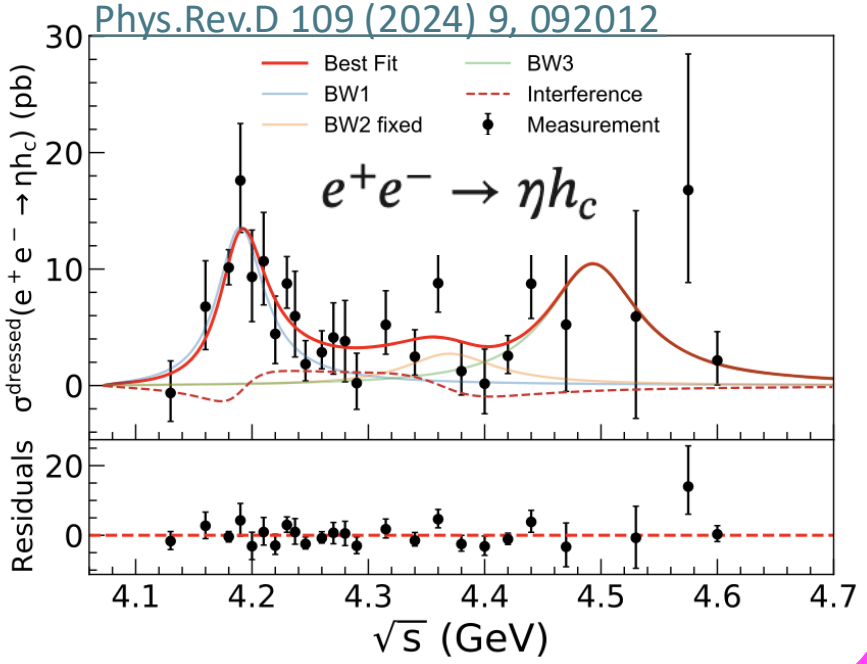
..found @ BESIII in many other exclusive channels



BESIII, Phys.Rev.D 111 (2025) 1, L011101



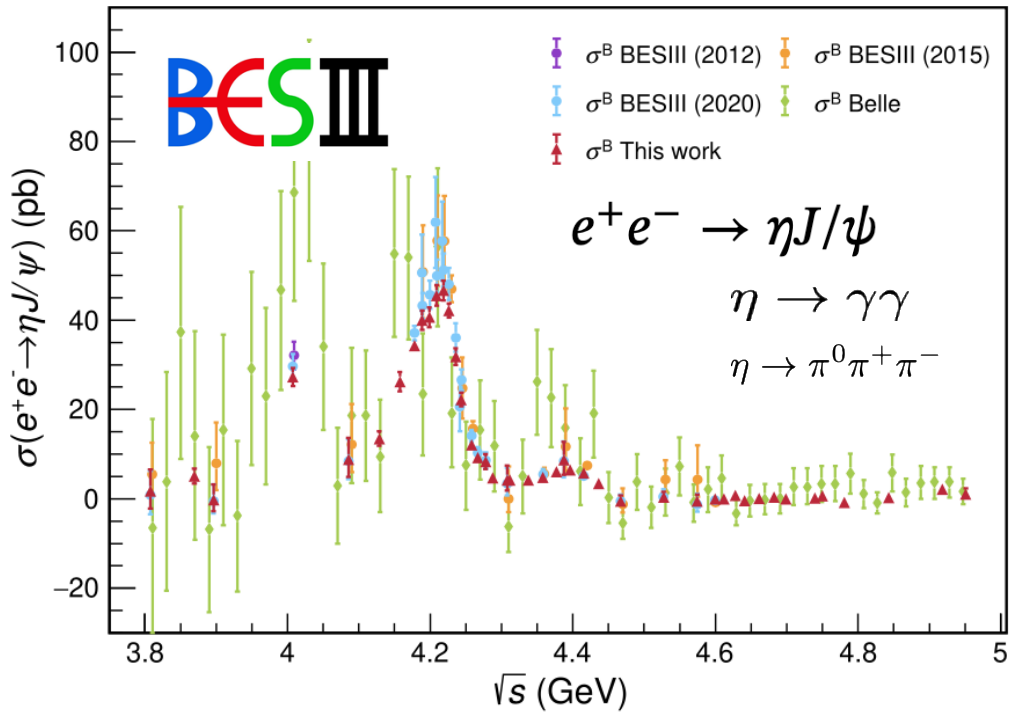
Phys.Rev.D 109 (2024) 9, 092012



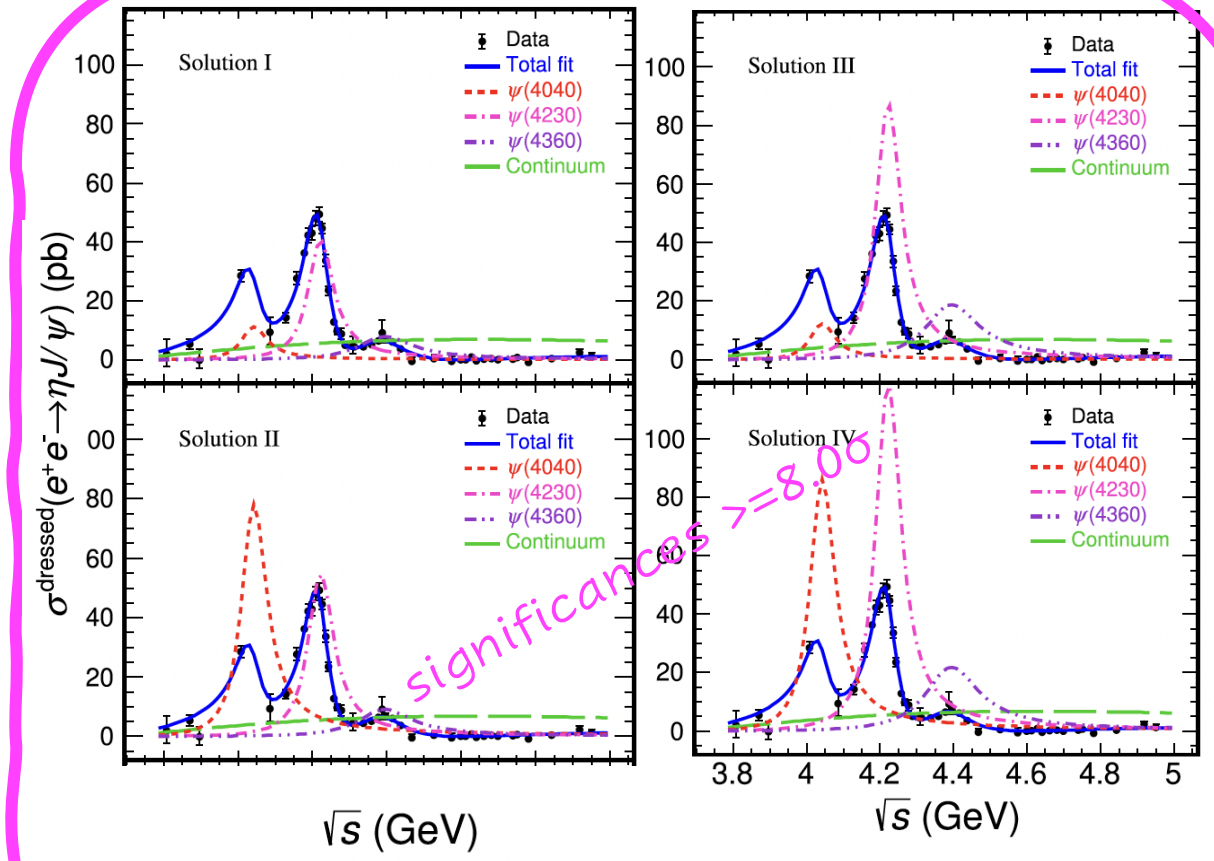
Phys.Rev.D 111 (2025) 1, L011101

Y(4230)

updated analysis of [Phys. Rev. D 102,031101 (2020)]



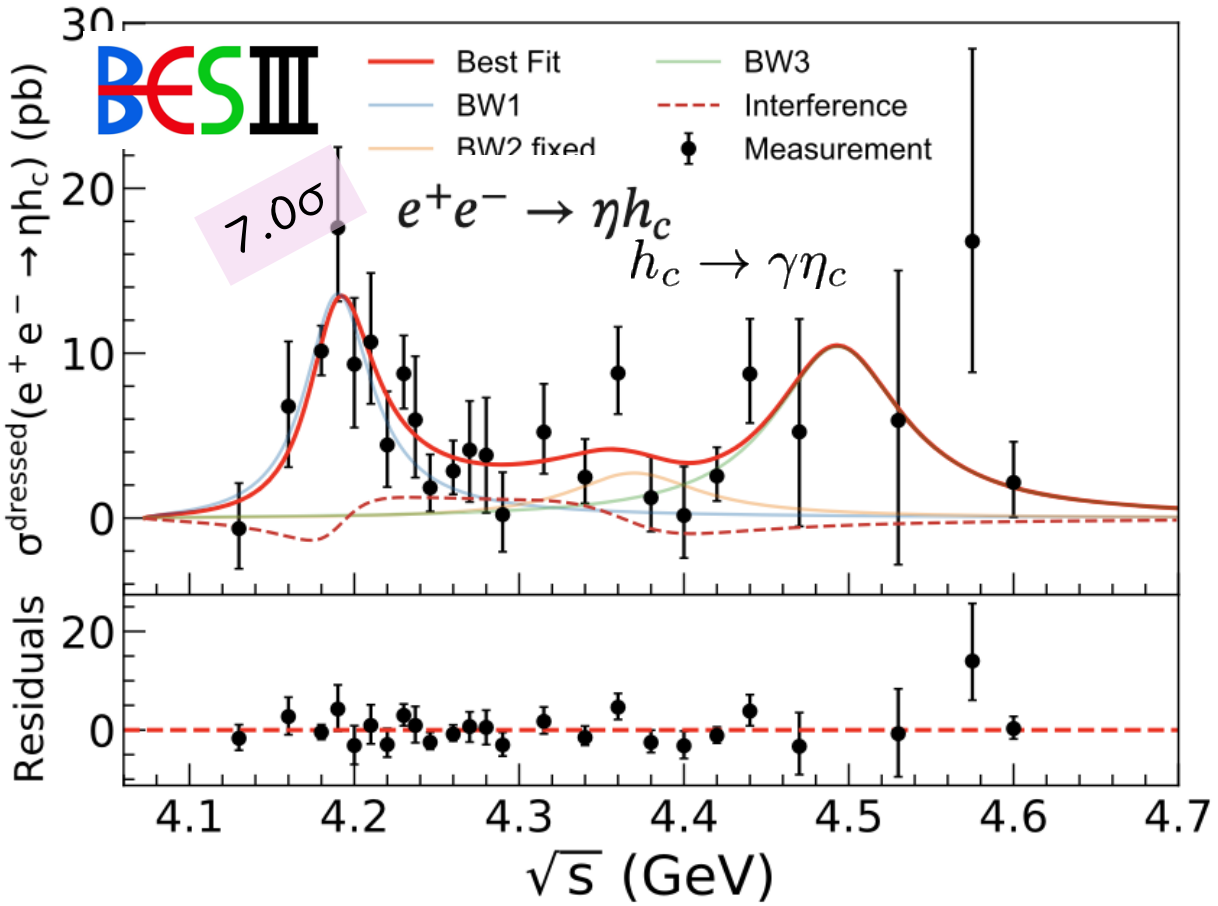
Phys.Rev.D 109 (2024) 9, 092012



3 evident peaks: Fit-model→coherent sum of three Breit-Wigner+NR , describing the structures around 4040 (assumed as $\psi(4040)$), 4220 and 4390 MeV/c^2, and a non resonant component.

Fit results for partial width unfavors for Y(4360) the molecular nature, being too low and pure charmonium for Y(4230)..too high

Y(4230)



Phys.Rev.D 111 (2025) 1, L011101

Fit function: coherent sum of R1+R2
And one independent R3
2nd BW function are fixed to those of the ψ(4360) (low statistics)
The others 2 BW with free parameters

For R1

$$M = 4188.8 \pm 4.7 \pm 8\mathrm{MeV/c^2}$$
$$\Gamma_{TOT} = (49 \pm 16 \pm 19), \mathrm{MeV}$$

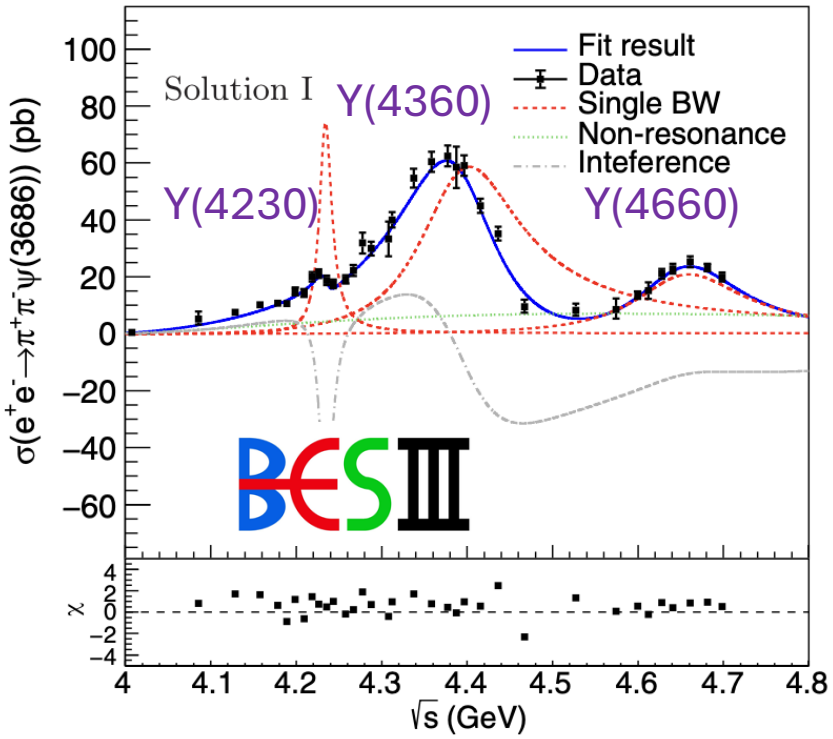
Mass still consistent with Y(4230) and with the 1^{--} hybrid charmonium predicted by the BOEFT model

Indication of two other resonant structures:
Needed coupled-channel K-matrix analysis, currently ongoing

Phys.Rev.D 111 (2025) 1, L011101

In many exclusive channels we found structures at higher mass

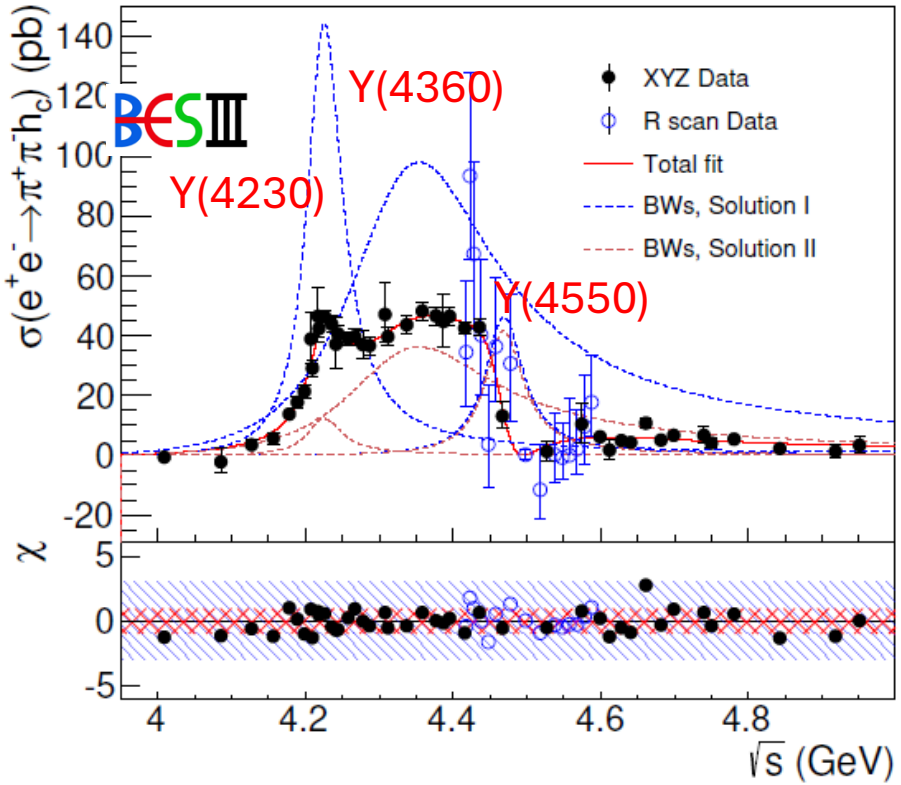
$e^+e^- \to \pi^+\pi^-\psi(3686)$



Phys.Rev.D 104 (2021) 5, 052012

first observation of Y(4660) at BESIII
Fit with three Breit-Wigner functions and a nonresonant contribution,

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

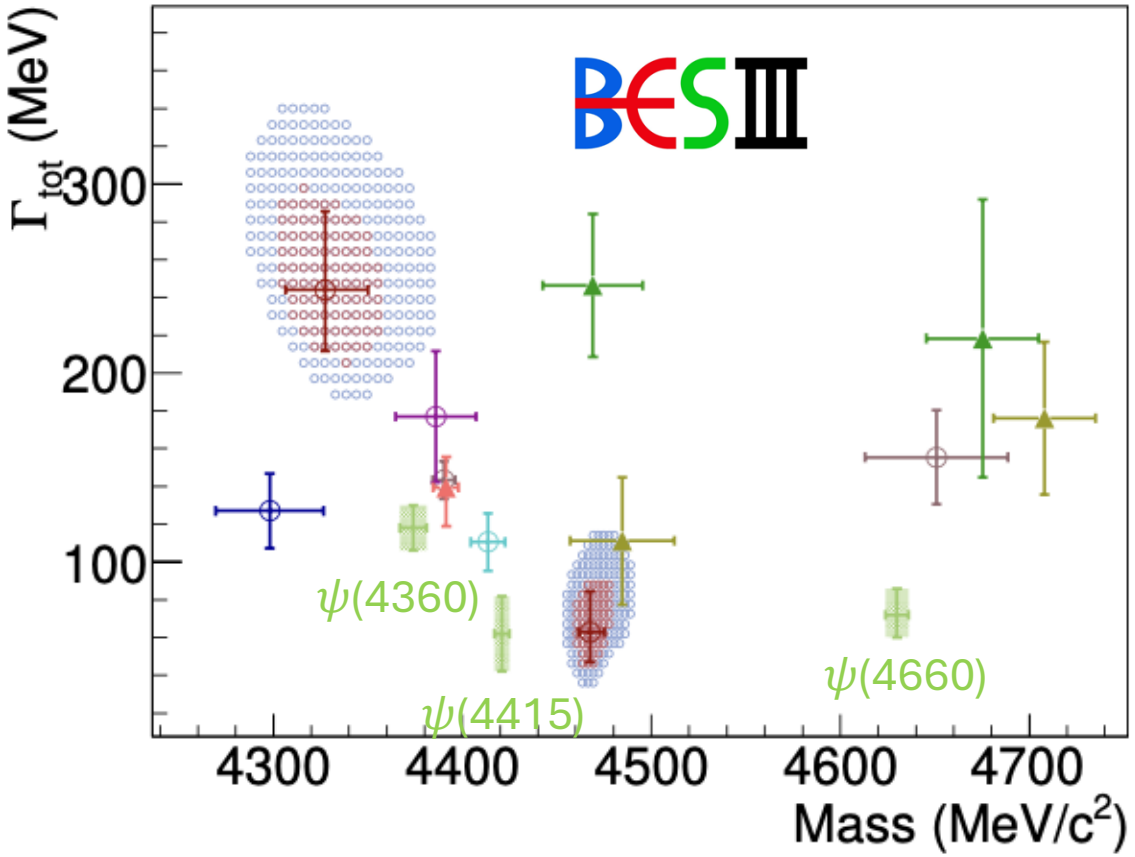


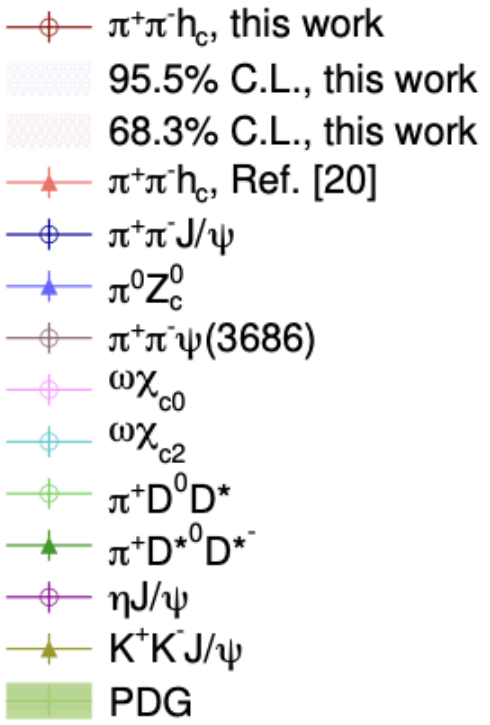
Phys.Rev.Lett. 135, 071901 (2025)

Transitions to h_c are intriguing → strong coupling is indicative of an exotic internal structure, such as hybrids

Plateau-like shape between 4.3 and 4.5 GeV. Two resonances are not enough to describe the lineshape but Y(4660) didn't show up!

RECAP (higher masses)

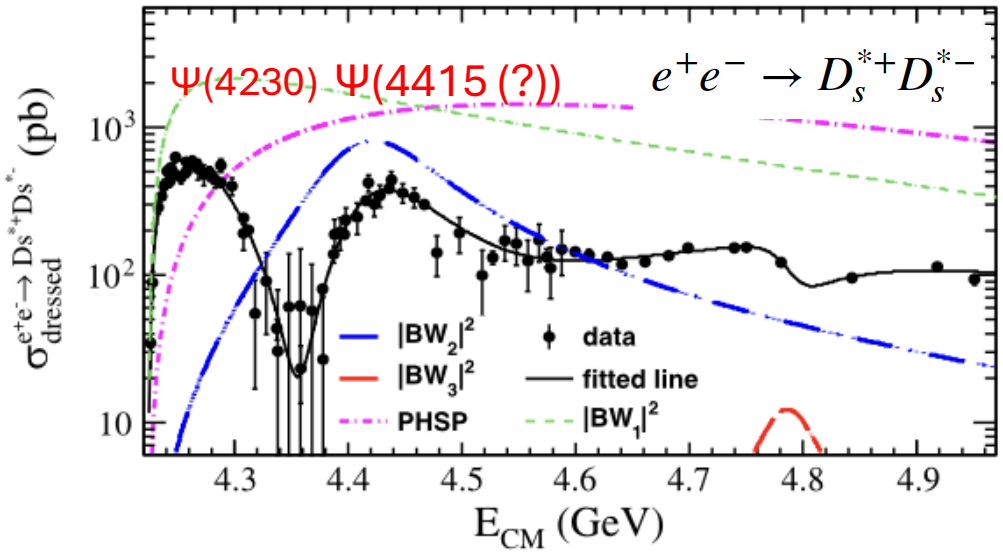




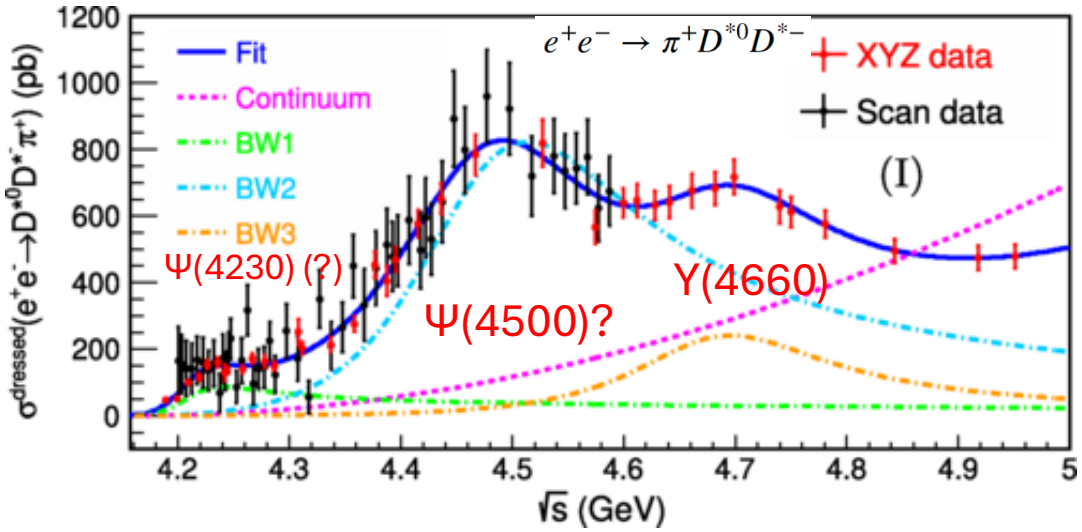
Little consistency for higher masses

PRL 135, 071901 (2025)

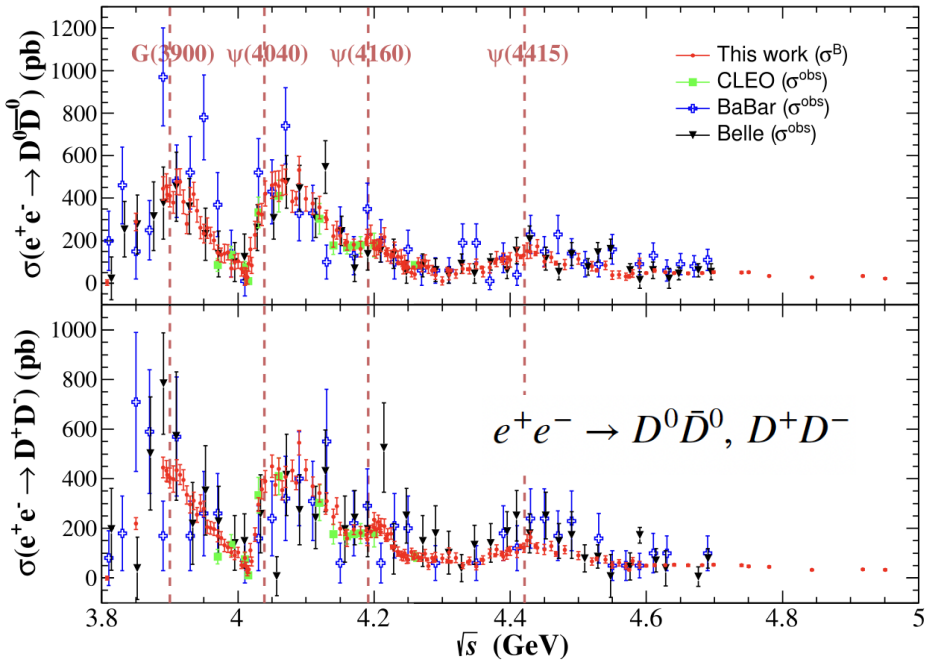
Exploring open-charm channels

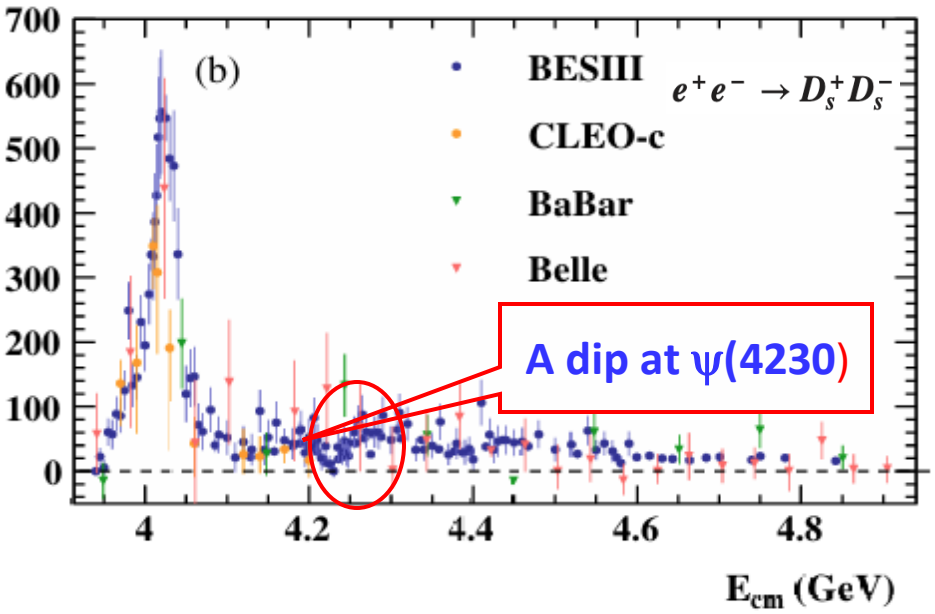


Pys.Rev.Lett. 131 (2023) 15, 151903



Phys.Rev.Lett. 130 (2023) 12, 121901





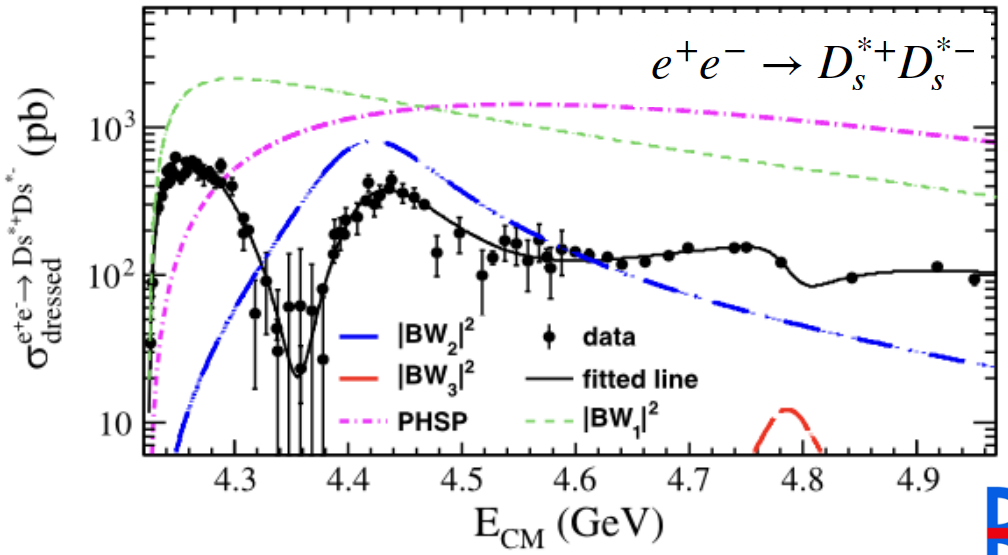
EMMI WORKSHOP, November 10-

Phys.Rev.Lett. 133 (2024) 8, 081901

Phys.Rev.Lett 133, 261902 (2024)

Exploring open charm channels

Phys.Rev.Lett. 131 (2023) 15, 151903



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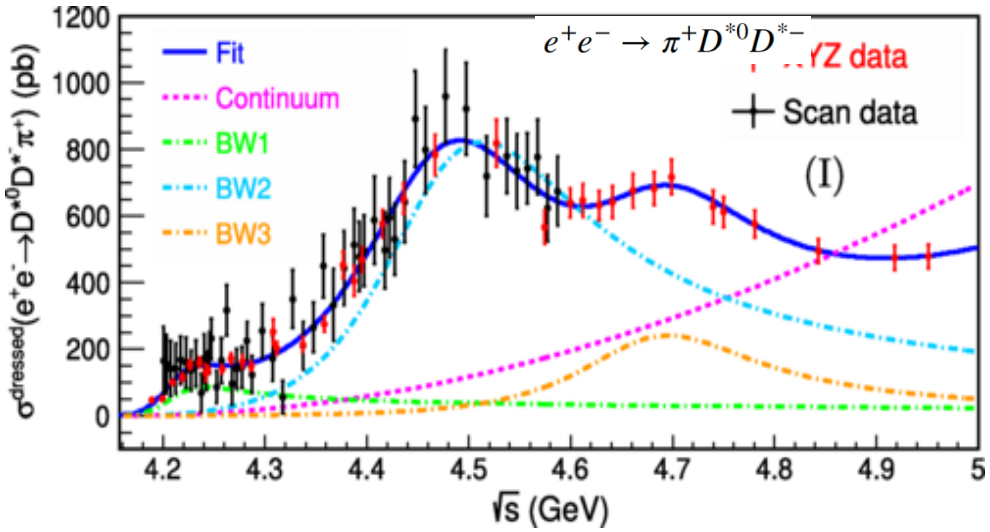
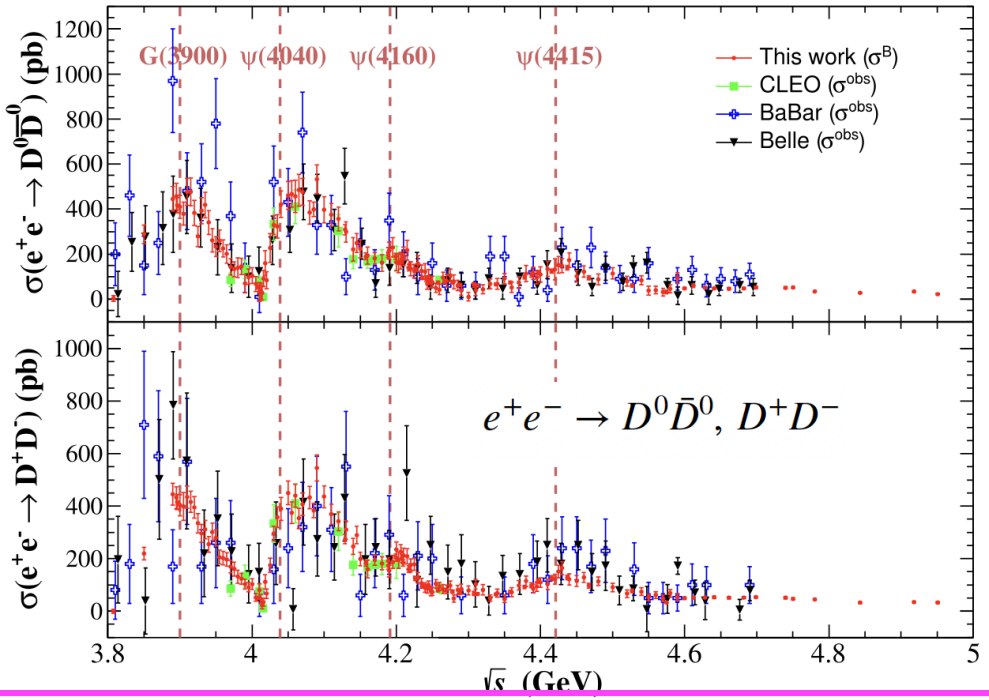


BESIII

Phys.Rev.Lett. 133 (2024) 8, 081901



More complexity is observed: Hard interpretation
Large interference terms, multi-solutions....
a global coupled-channel analysis is desirable!

A lot of work around: Hüsken et al (PhysRevD.109.114010) with K-matrix approach finds strong evidence Ψ(3770) and ψ(4040) with no need for additional poles, while Ye et al. (Phys. Rev. D 112 (2025), 01601)come to the conclusion that is a dynamically generated state

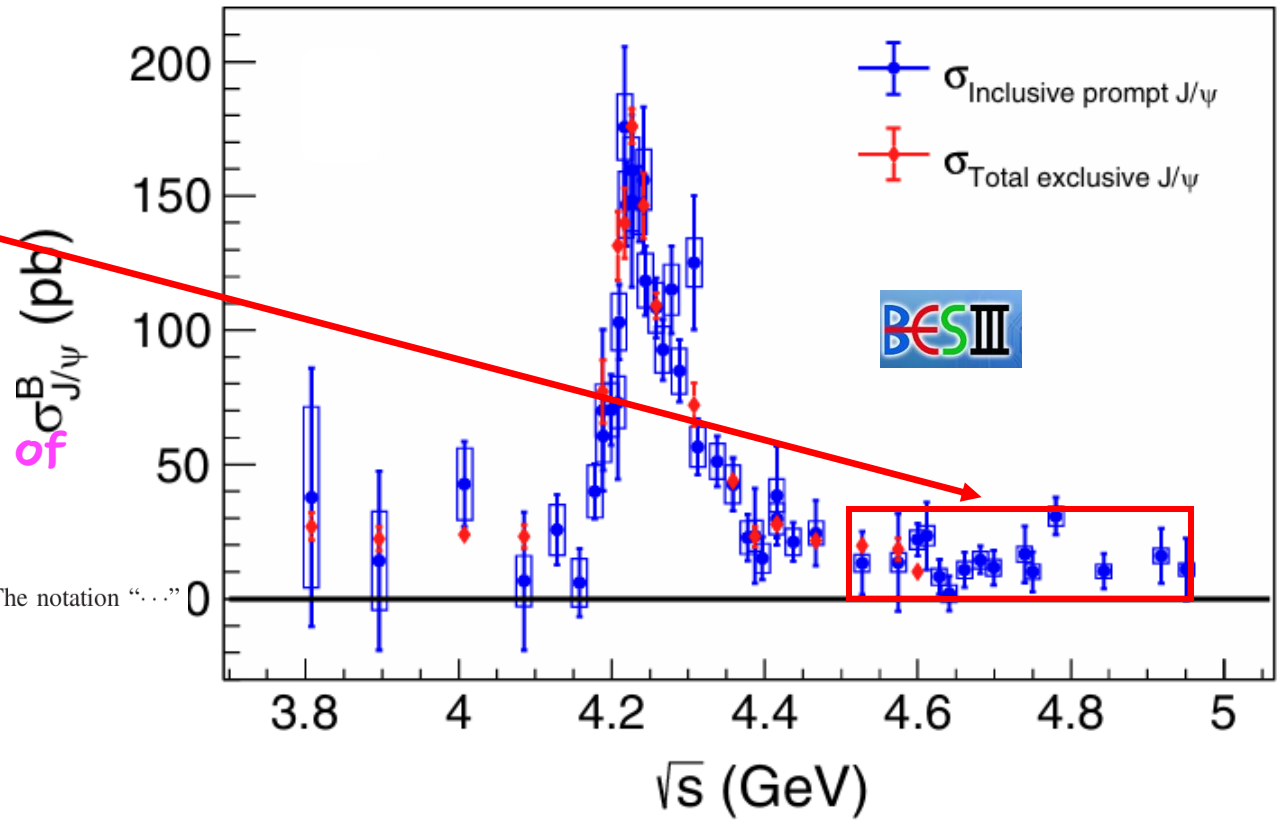
Inclusive and exclusive J/ψ production

Average value of J/ψ cross section in the region √s=4.53 to 4.95 GeV

$$\sigma = 14.0 \pm 1.7_{stat} \pm 3.1_{sys.}\ pb$$

(impact of known resonances is negligible→no-resonance hypothesis)

The comparison indicates that **no evidence of missing decays involving the J/ψ meson**



Phys.Rev.D 111, 052007 (2025)

TABLE V. The masses and widths of charmonium(like) mesons with decays into J/ψ or $\psi(3686)$ [31,39,40]. The notation "···" means that the corresponding decays have not yet seen.

$c\bar{c}$ Meson	Mass (MeV)	Width (MeV)	Decays into J/ψ
$\chi_{c1}(3872)$	3871.7 ± 0.1	1.2 ± 0.2	$\pi^+\pi^- J/\psi, \omega J/\psi, \gamma J/\psi$
$Z_c(3900)$	3887.1 ± 2.6	28.4 ± 2.6	$\pi J/\psi$
$\chi_{c0}(3915)$	3921.7 ± 1.8	18.8 ± 3.5	$\omega J/\psi$
$\psi(4040)$	4039.0 ± 1.0	80 ± 10	$\eta J/\psi$
$X(4160)$	4153 ± 23	136 ± 60	$\phi J/\psi$
$\psi(4230)$	4222.7 ± 2.6	49.0 ± 8.0	$\pi\pi J/\psi, KK J/\psi, \eta J/\psi$
$X(4350)$	4350.6 ± 5.2	13 ± 18	$\phi J/\psi$
$\psi(4360)$	4372.0 ± 9.0	115 ± 13	$\pi^+\pi^- J/\psi, \eta J/\psi$
$Y(4500)$	4485 ± 28	111 ± 34	$K^+K^- J/\psi$
$\psi(4660)$	4630.0 ± 6.0	72 ± 14	···
$Y(4710)$	4704 ± 87	183 ± 149	$K^0K^0 J/\psi$

Inclusive and exclusive $\psi(3686)$ production

- Around the $\psi(4360)$ region Excess ~23% of the $\psi(4360)_{prompt}$ inclusive cross section→something is most likely missing
- Average value of $\psi(3686)$ cross section in the region $\sqrt{s}$=4.84 to 4.95 GeV, $\sigma = 15.3 \pm 3.0\ pb$

(in the no-resonance hypothesis)

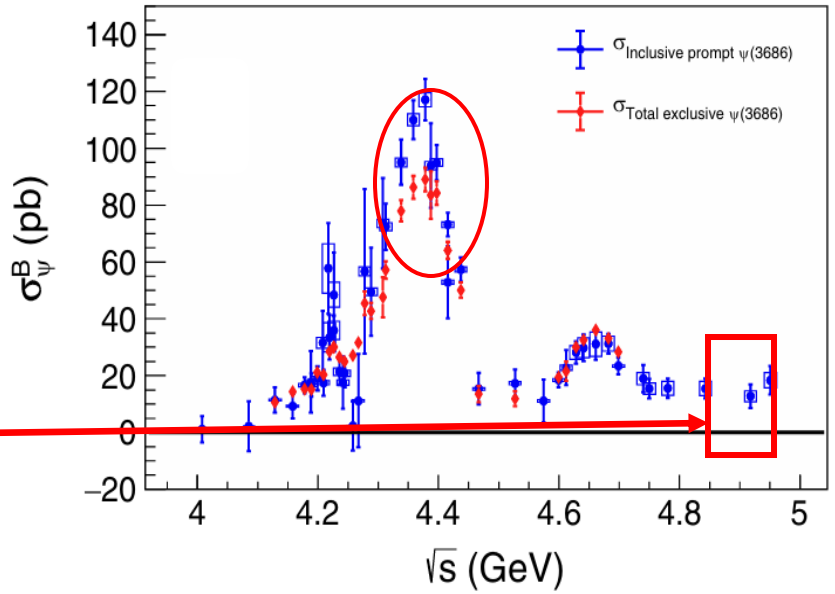
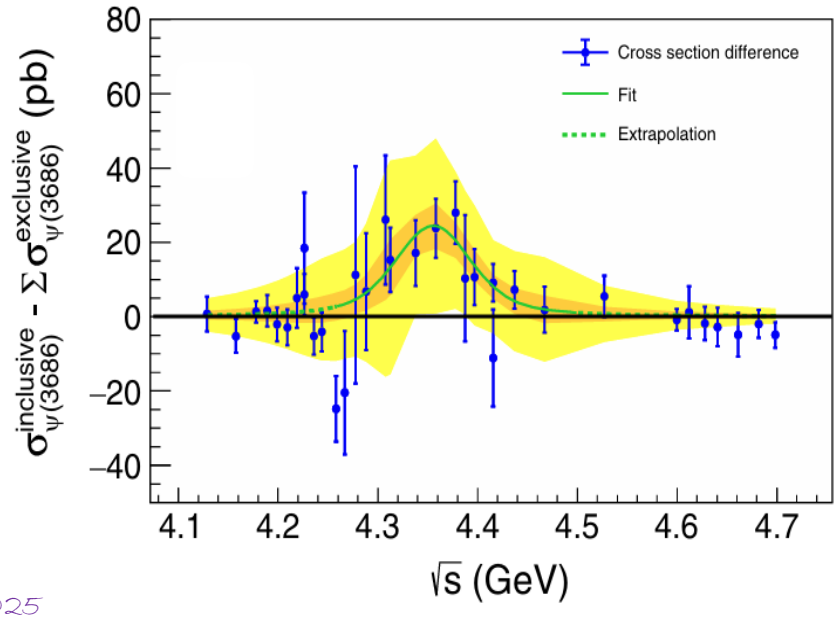


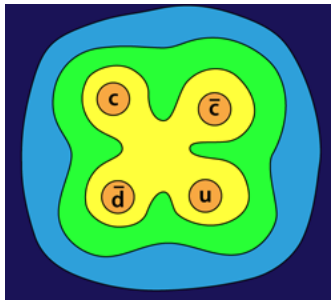
TABLE V. The masses and widths of charmonium(like) mesons with decays into J/ψ or $\psi(3686)$ [31,39,40]. The notation "..." means that the corresponding decays have not yet seen.

$c\bar{c}$ Meson	Mass (MeV)	Width (MeV)	Decays into J/ψ	Decays into $\psi(3686)$
$\chi_{c1}(3872)$	3871.7 ± 0.1	1.2 ± 0.2	$\pi^+\pi^- J/\psi, \omega J/\psi, \gamma J/\psi$	$\gamma\psi(3686)$
$Z_c(3900)$	3887.1 ± 2.6	28.4 ± 2.6	$\pi J/\psi$	...
$\chi_{c0}(3915)$	3921.7 ± 1.8	18.8 ± 3.5	$\omega J/\psi$	...
$\psi(4040)$	4039.0 ± 1.0	80 ± 10	$\eta J/\psi$	...
$X(4160)$	4153 ± 23	136 ± 60	$\phi J/\psi$	...
$\psi(4230)$	4222.7 ± 2.6	49.0 ± 8.0	$\pi\pi J/\psi, KK J/\psi, \eta J/\psi$	$\pi^+\pi^-\psi(3686)$
$X(4350)$	4350.6 ± 5.2	13 ± 18	$\phi J/\psi$	...
$\psi(4360)$	4372.0 ± 9.0	115 ± 13	$\pi^+\pi^- J/\psi, \eta J/\psi$	$\pi^+\pi^-\psi(3686)$
$Y(4500)$	4485 ± 28	111 ± 34	$K^+K^- J/\psi$	...
$\psi(4660)$	4630.0 ± 6.0	72 ± 14	...	$\pi^+\pi^-\psi(3686)$
$Y(4710)$	4704 ± 87	183 ± 149	$K^0K^0 J/\psi$	...



Phys.Rev.D 111, 052007 (2025)

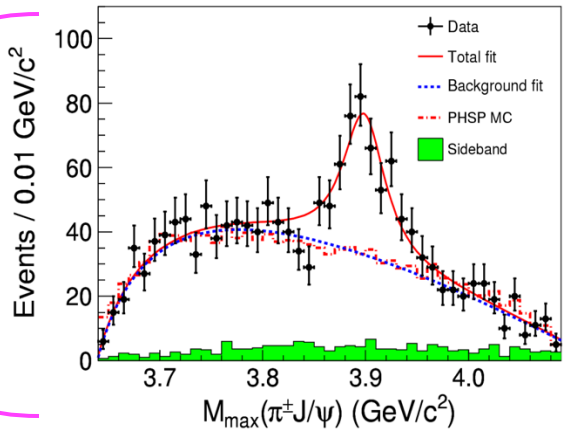
Updates on Z states



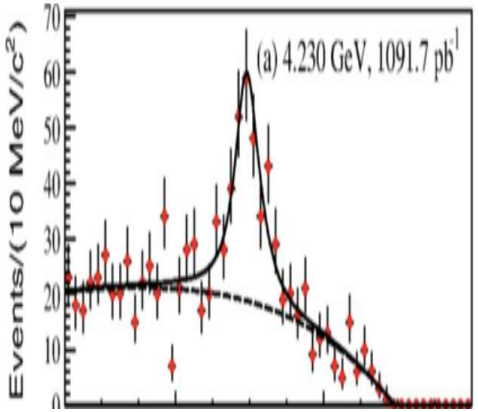
If charged, contain at least four valence-quarks, good candidate for an exotic state

Hidden charm

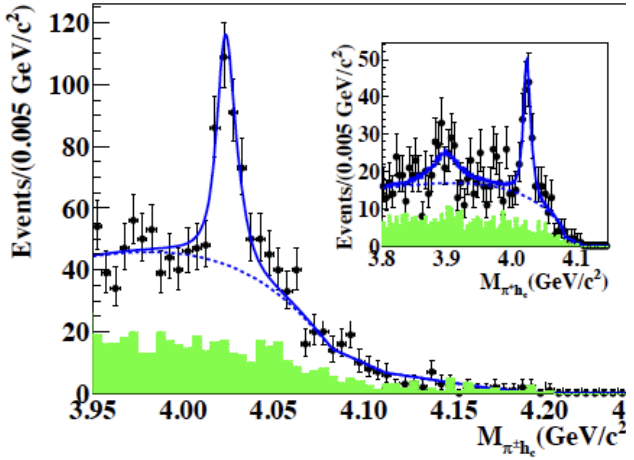
$e^+e^- \to \pi^+\pi^- J/\psi$



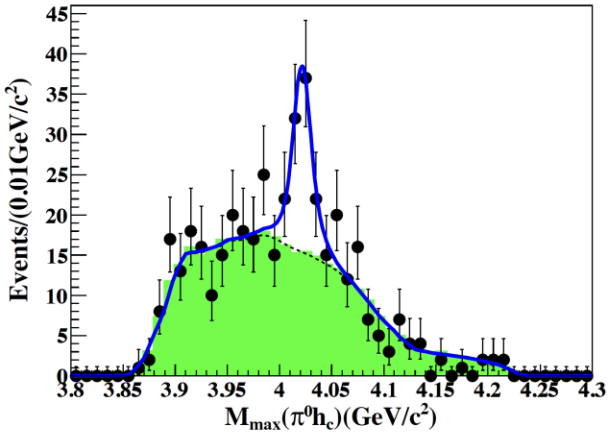
$e^+e^- \to \pi^0\pi^0 J/\psi$



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

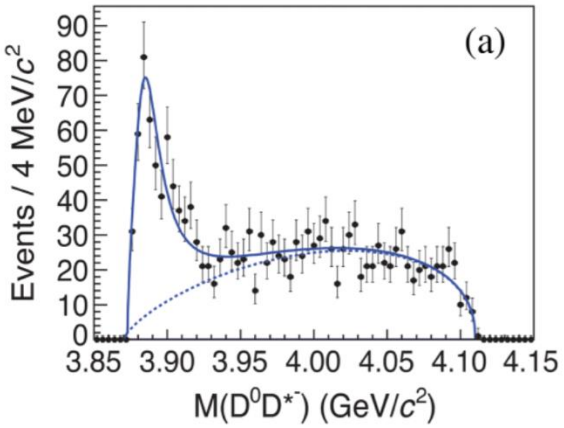


$e^+e^- \to \pi^0\pi^0 h_c$

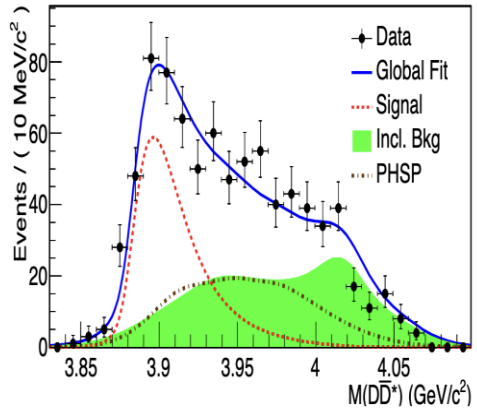


open charm

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



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

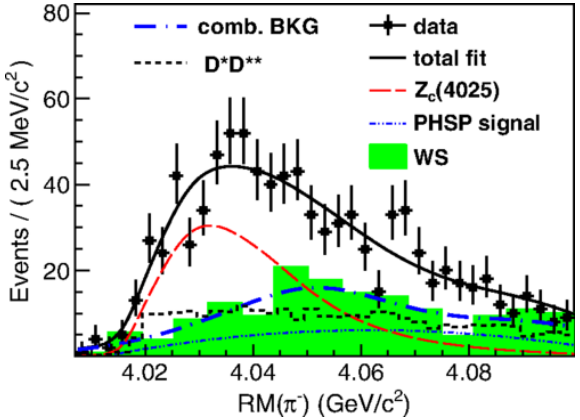


charged

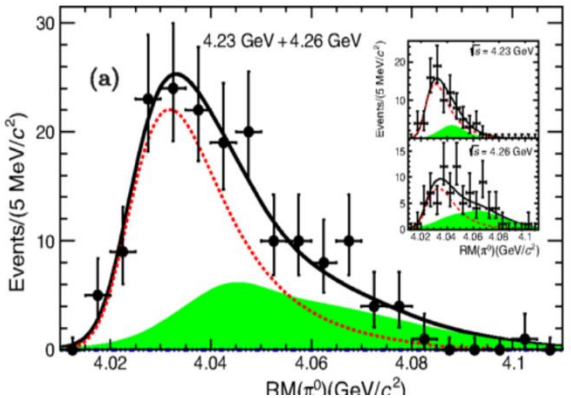
neutral

$Z_c(3900)$

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



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



charged

neutral

$Z_c(4020)$

Two isospin-triplets of charmonium-like four-quark states have been established

PRL110, 252001(2013) PRL.115.112003 (2015) PRL111, 242001 PRL113, 212002 (2014) PRL.112.022001 (2014) PRLe.115.222002(2915) PRL.112.132001 (2013) PRL.115.182002

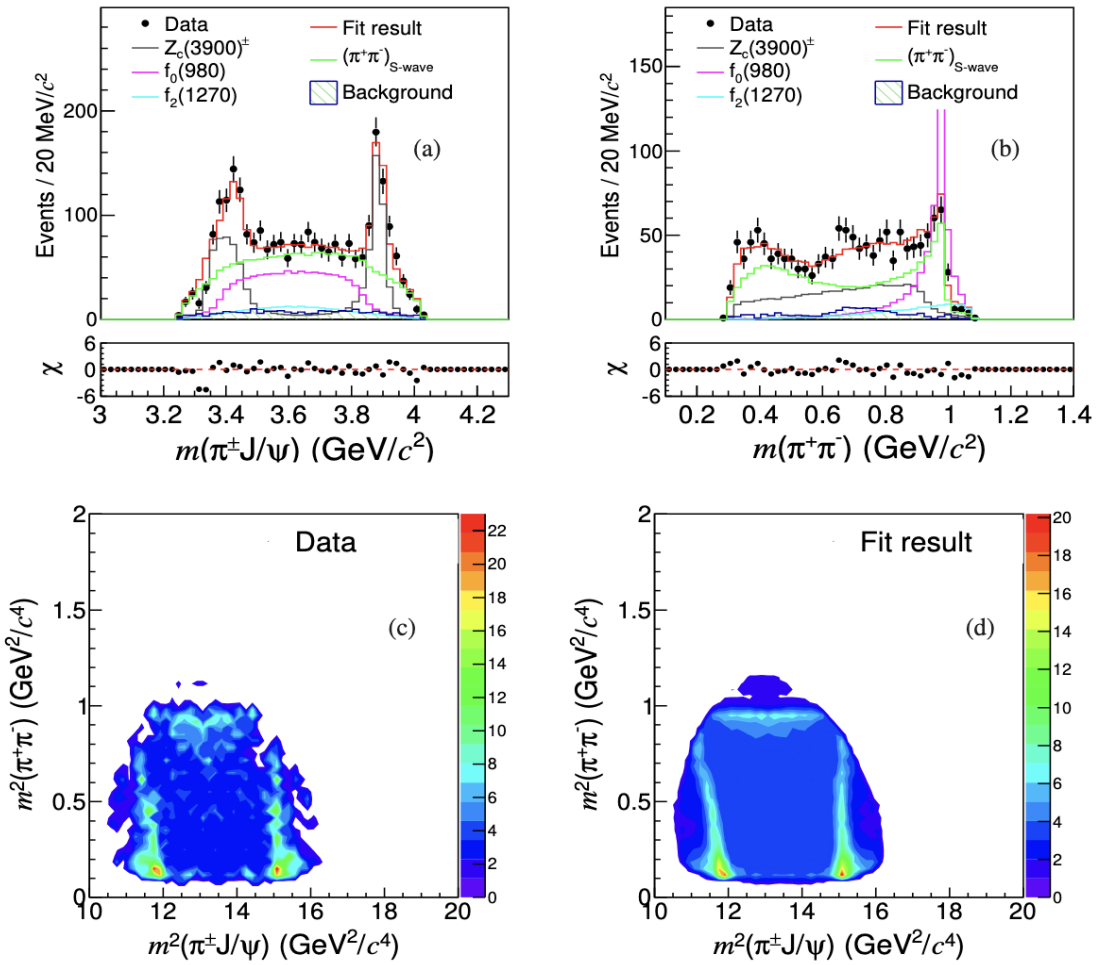
News of $Z_c(3900)$(aka $T_{cc1}(3900)$)

Charged charmonium-like state discovered in 2013 in $J/\psi\pi^{\pm}$

all data (12 fb^{-1}) between 4.1 and 4.4 GeV

https://arxiv.org/abs/2505.13222

@4.178 GeV



Partial wave analysis in helicity Formalism for $e^+e^- \to \pi^+\pi^- J/\psi$

$$e^+e^- \to \pi^{\pm} Z_c(3900)^{\mp} (\to \pi^{\mp} J/\psi)$$

$$e^+e^- \to f_J(\to \pi^+\pi^-) J/\psi$$

In simultaneous fit, $Z_c(3900)$ parameters are obtained

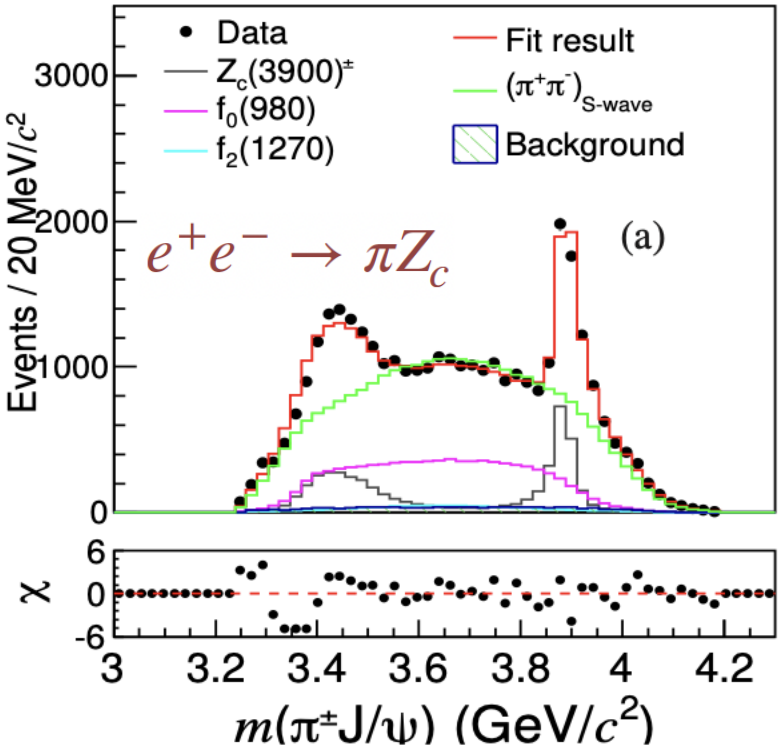
Sample	M (MeV/c^2)	Γ (MeV)
$4.1567 - 4.1989$	3883.5 ± 1.6	38.6 ± 3.6
$4.2091 - 4.2357$	3884.0 ± 1.0	37.8 ± 1.6
$4.2438 - 4.2776$	3884.9 ± 1.8	34.2 ± 3.3
$4.2866 - 4.3583$	3890.0 ± 2.3	36.1 ± 4.2
Average	$3884.6 \pm 0.7 \pm 3.3$	$37.2 \pm 1.3 \pm 6.6$

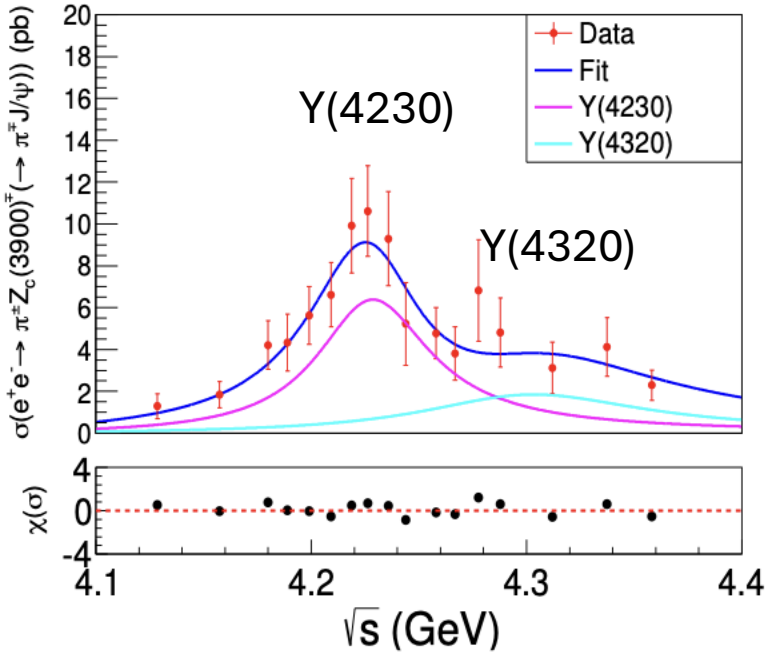
News of $Z_c(3900)$(aka $T_{cc1}(3900)$)

all data (12 fb^{-1}) between 4.1 and 4.4 GeV

https://arxiv.org/abs/2505.13222

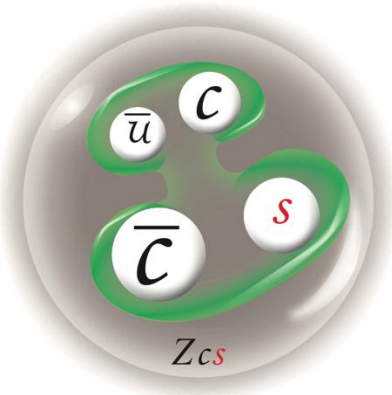
Partial wave analysis of $e^+e^- \to \pi^+\pi^- J/\psi$

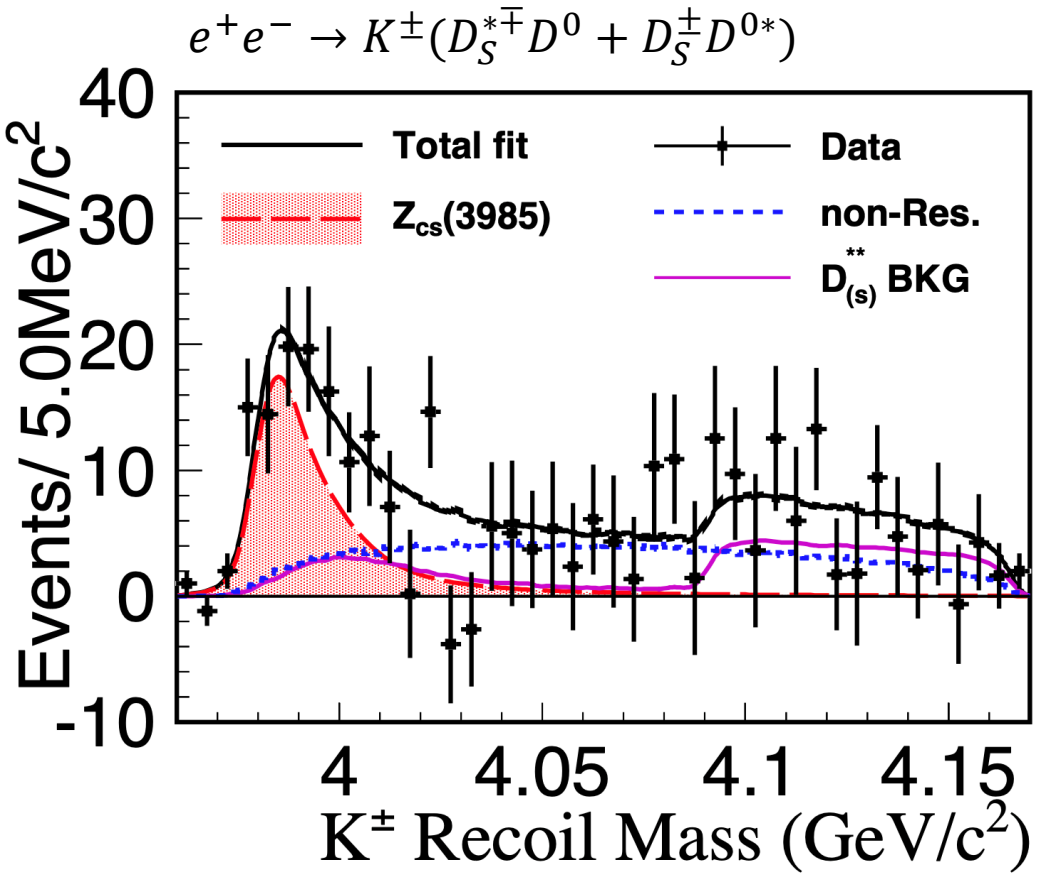




The $Z_c(3900)$ is produced at center-of-mass energies near the $\psi(4230)$, that is observed in the subprocess cross section.
For molecular/tetraquark state a strong correlation between Z_c and Y is forseen.

Hidden charm- Open strangeness $Z_{cs}(3985)$





PhysRevLett.126.102001(2021)

With SU(3) flavor symmetry→
the strange partner of $Z_C(3900)$

at least four quarks in their configurations (one s quark)
Neutral patner already found by BESIII
[PhysRevLett.129.112003(2022)]

Teatraquark candidate

LHCb then observed $Z_{cs}^+(4000) \to J/\psi K^+$
in $B^+ \to J/\psi\phi K^+$
The two states have similar mass but very different widths

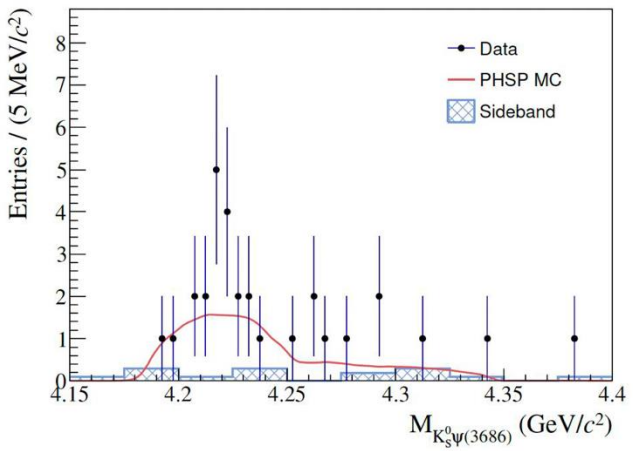
Search for $Z_{cs} \to K\psi(3686))$

arXiv: 2407.20009

Submitted to PRL

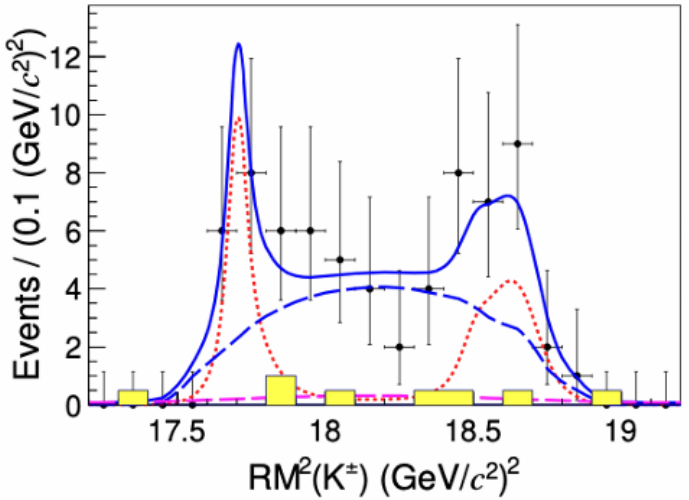
- Two best fit results assuming the presence of Z_{cs}
- Structure around 4.208 GeV/c² close to $Z_{cs}(4220)$ reported by LHCb
- Global significances: ~1σ

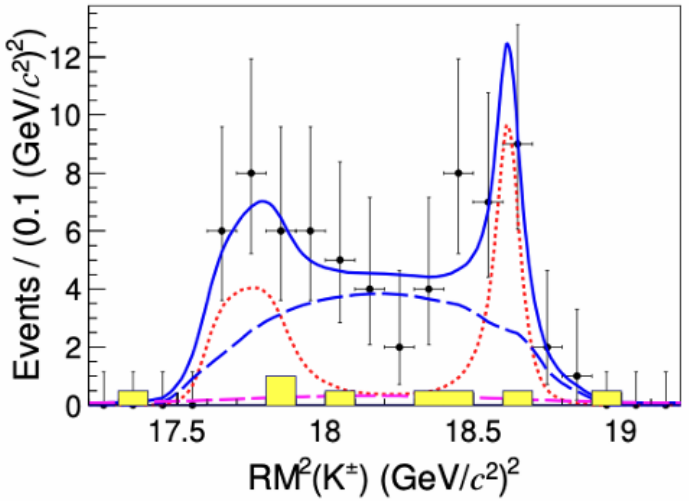
$$e^+e^- \to K_s^0 K_s^0 \psi(3686)$$



JHEP02, 120 (2025)

$$e^+e^- \to K^+K^-\psi(3686)$$

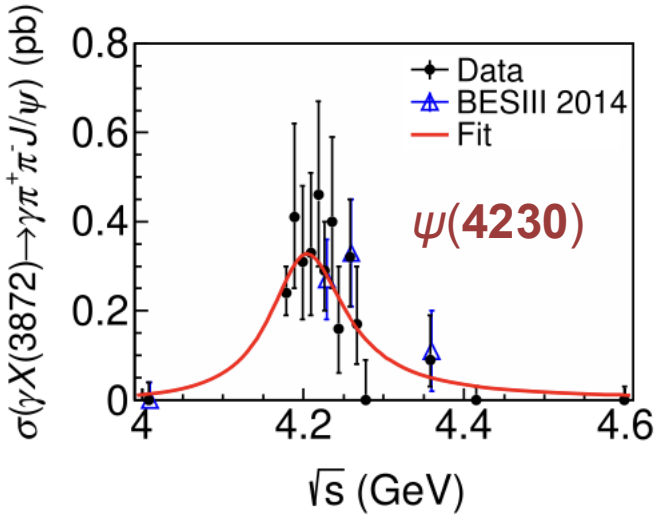




Consistent with three-body phase space

No evidence of Z_{cs} states

Updates on X states



Phys.Rev.Lett. 122 (2019) 23, 232002

BESIII produces X(3872) mainly using $e^+e^- \to \gamma X(3872)$ at center-of-mass energies around 4.2 GeV

X(3872) (aka $\chi_{c1}(3872)$)

Observed by Belle (2003) [BELLE PRL 91, 262001 (2003)],→ its internal structure is still under debate

- mass close to D_0-$\bar{D}^{0*}$ threshold
- extremely narrow state, first width measured by LHCb (2020). PDG average is 1.19 ±0.21 MeV (2020)→subMev resolution needed for clarification.😓
- isospin-violating decay pattern

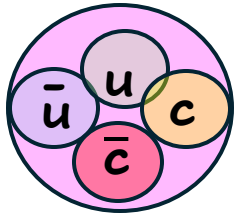
- LHCb determine the quantum numbers as $J^{PC}=1^{++}$ [LHCb PRL 110, 222001 (2013)]

- Well established production channel $Y(4230) \rightarrow \gamma X(3872)$ (BESIII) can contribute to precision studies.
- other production channels: B/Λ_b decays; pp, PbPb, e^+e^- …

X(3872) (aka $\chi_{c1}(3872)$)

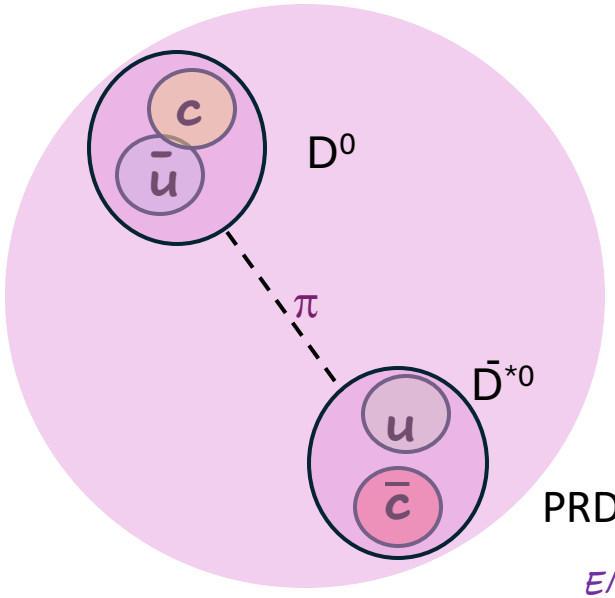
Observed by Belle (2003) [BELLE PRL 91, 262001 (2003)],→ its internal structure is still under debate; mass close to D_0-$\bar{D}^{0*}$ threshold

- CDF and LHCb determine the quantum numbers as $J^{PC}=1^{++}$ [CDF PRL 98, 132002 (2007) LHCb PRL 110, 222001 (2013)]
- Well established production channel $Y(4230) \rightarrow \gamma X(3872)$; also found $e^+e^- \rightarrow \omega X(3872)$ in BESIII [Phys. Rev. Lett. **130**, 151904 (2023)] also others B/Λ_b decays; pp, PbPb, e^+e^- …
- Charmonium interpretation disfavored→predict wrong mass with this $J^{PC}=1^{++}$
- Remaining possibilities:
- D-$\bar{D}^*$ hadron molecule:mass $X(3872) \approx D(1875)\bar{D}^*(2007)$, large & extended state
- Tetraquark: a compact four quark state
- Hybrid: mixed molecule-charmonium state (to explain production)



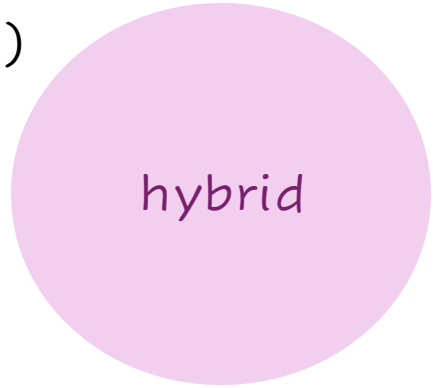
R~0,3 fm

PRD 71 (2005) 014028



R~5 fm

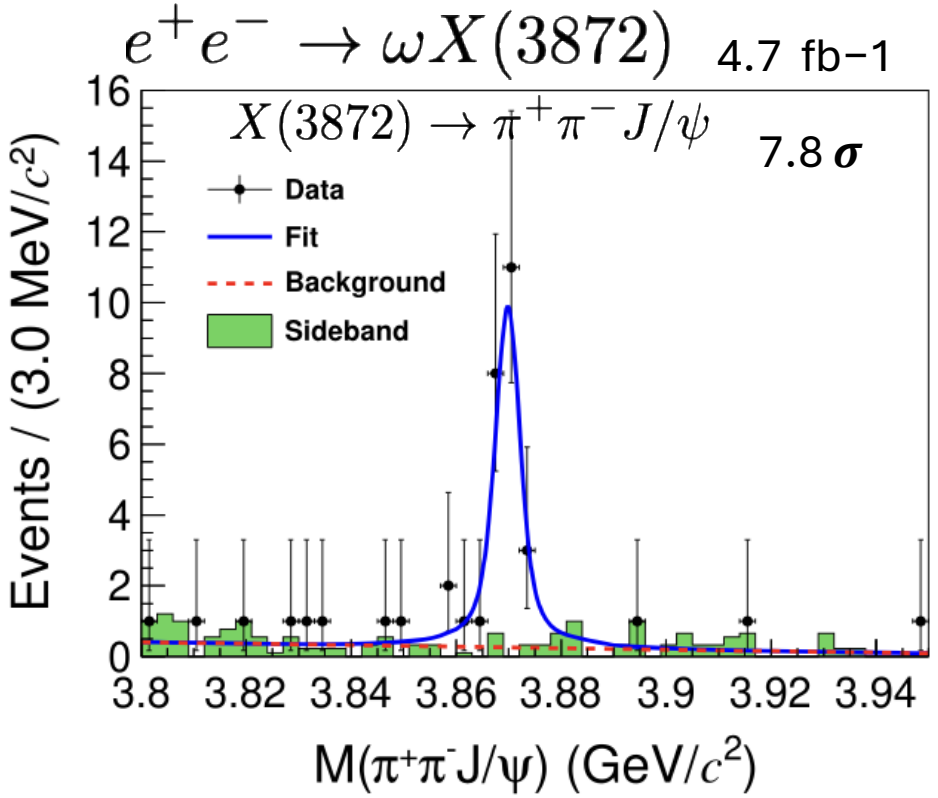
PRD71 (2005) 014028



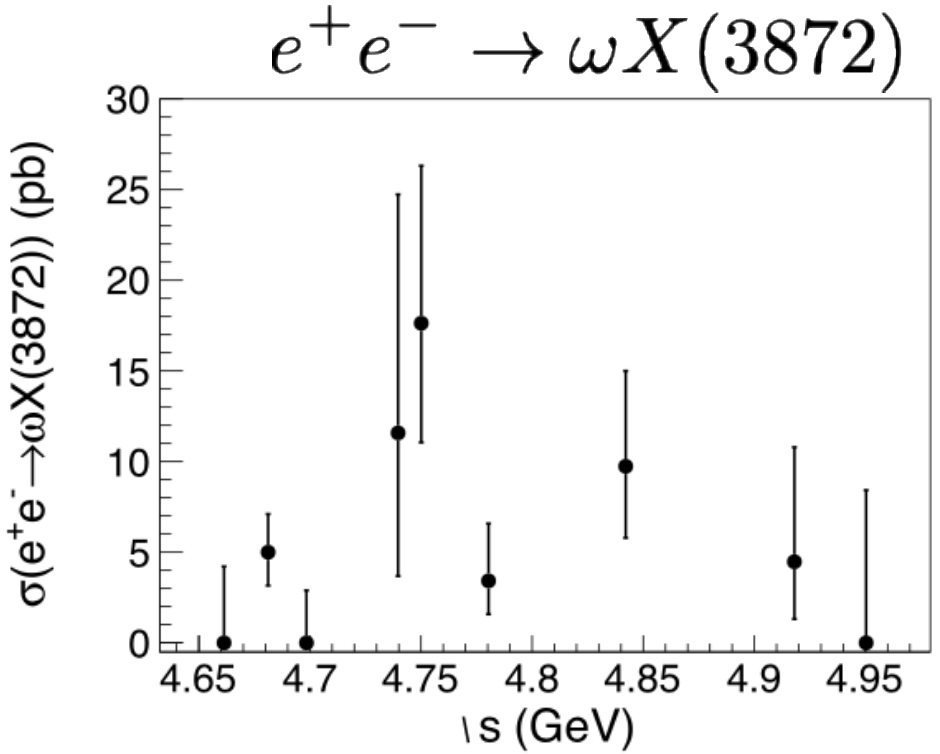
EPJA47 (2011) 101

X(3872) (aka $\chi_{c1}(3872)$):production

In 2014 BESIII first observed the production in $e^+e^- \to \gamma X(3872)$ Phys. Rev. Lett. **112**, 092001 (2014)



Phys.Rev.Lett. 130 (2023) 15, 151904



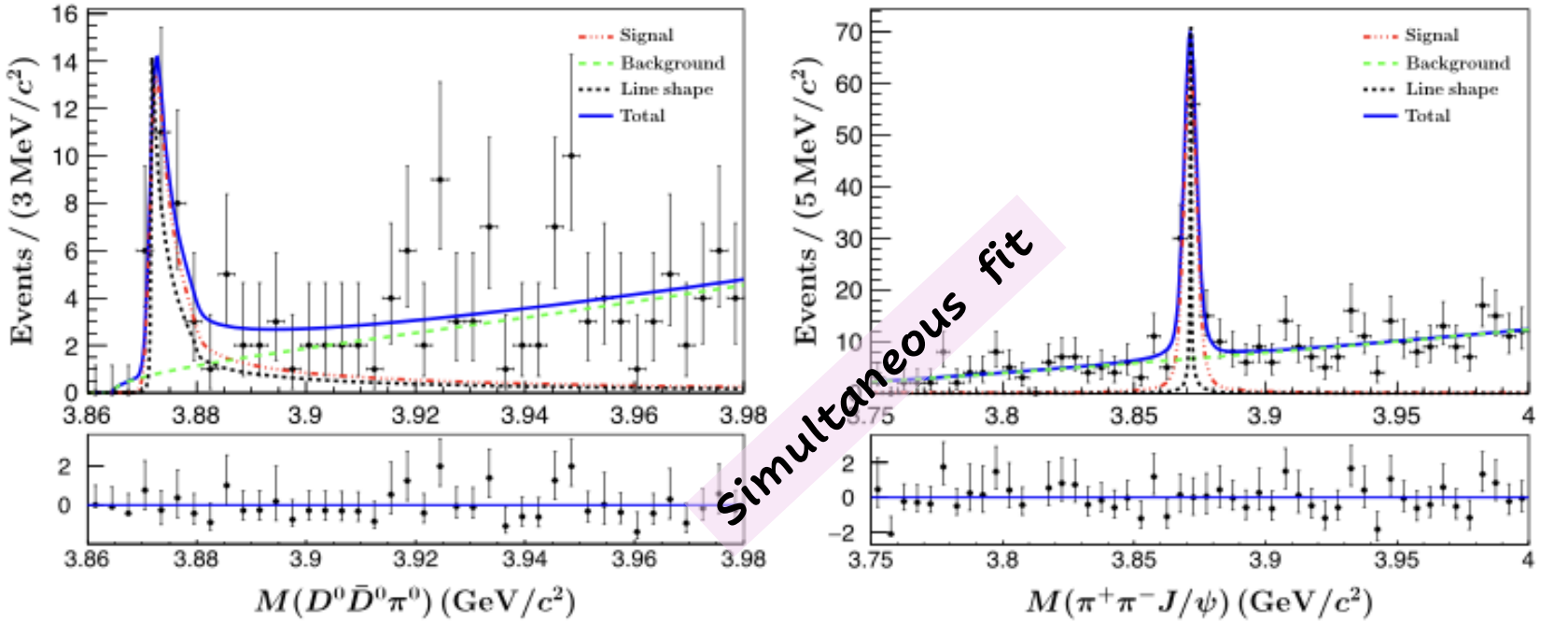
Phys.Rev.D 110 (2024) 1, 012006

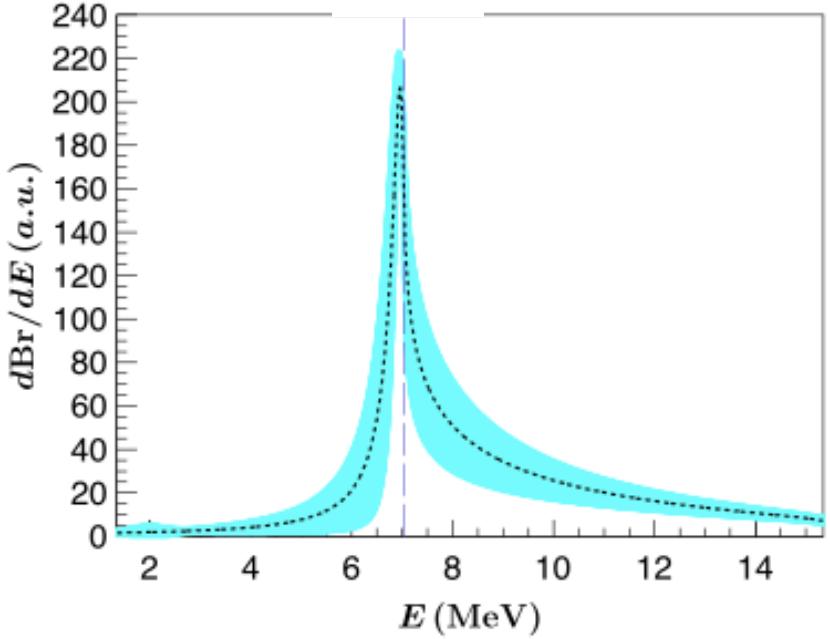
BESIII found another production process $e^+e^- \to \omega X(3872)$ at higher center-of-mass energies.
This provides cross-check for decay modes.
More data required to study the center-of-mass energy dependence of the cross section

$X(3872)$ (aka $\chi_{c1}(3872)$)

$e^+e^- \to \gamma X(3872)$

Line shape studies,coupled-channel analysis





$$X(3872) \to \bar{D}^0 D^{*0}$$

+

$$X(3872) \to \pi^+\pi^- J/\psi$$

Phys.Rev.Lett. 132 (2024) 15, 151903

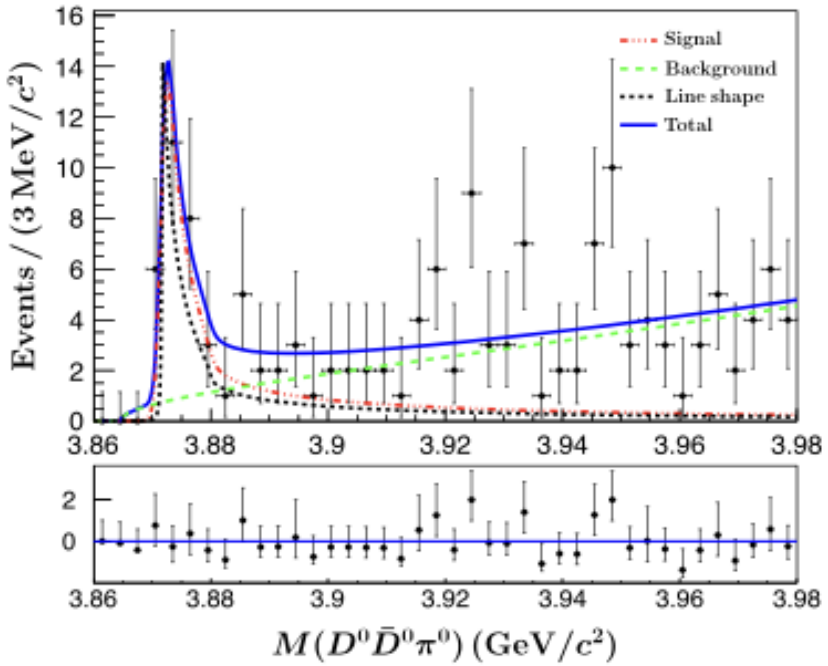
Effects of the coupled-channels and the off-shell D^{*0} are included in the parameterization.
Based on the work of Hanhart *et al.*, PRD 81,094028 (2010)):

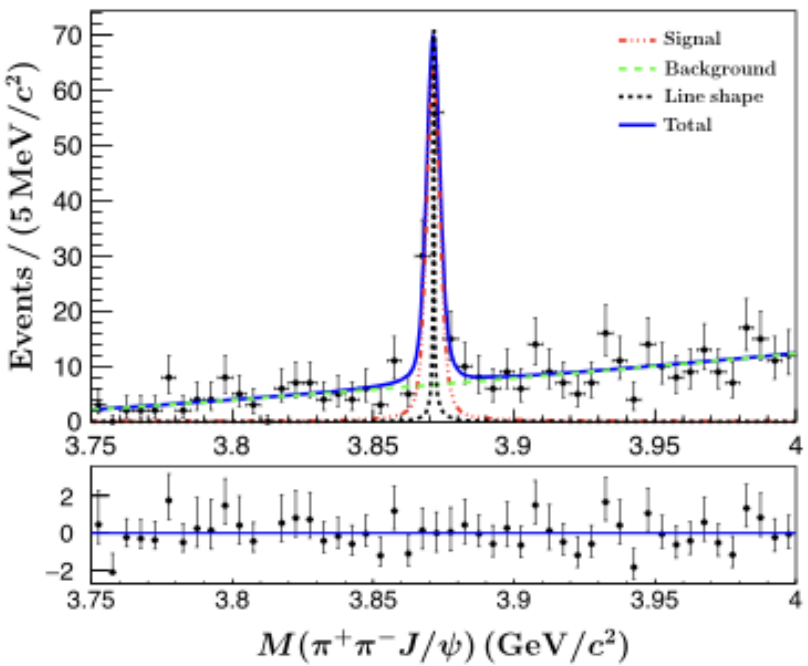
$X(3872)$ (aka $\chi_{c1}(3872)$)

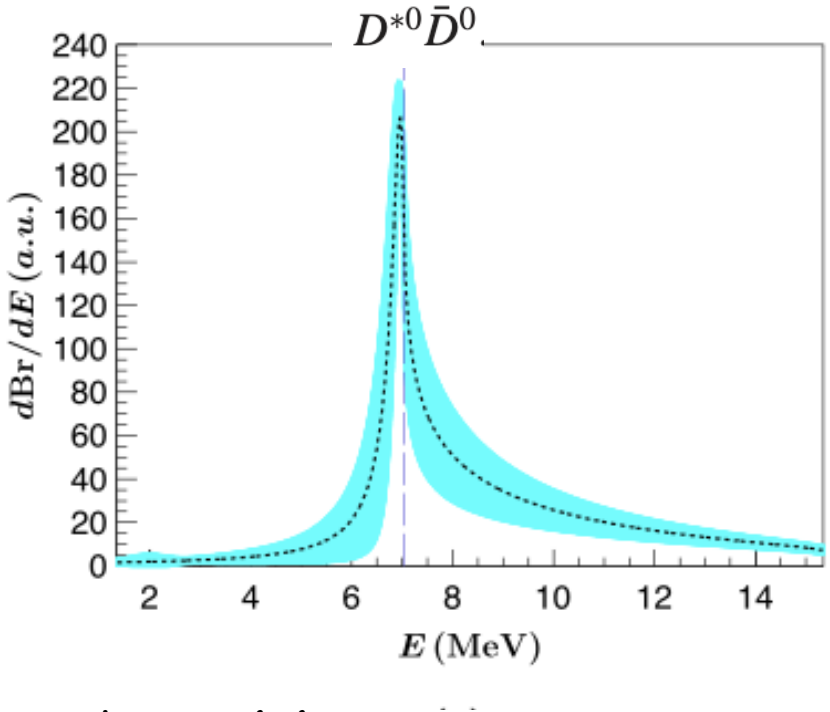
$e^+e^- \to \gamma X(3872)$

Coupled-channel analysis

Phys.Rev.Lett. 132 (2024) 15, 151903







$$X(3872) \to \bar{D}^0 D^{*0}$$

+

$$X(3872) \to \pi^+\pi^- J/\psi$$

T-matrix pole position

$$(3871.70 \pm 0.15^{+0.07}_{-0.08}) - i(0.19 \pm 0.08^{+0.14}_{-0.19})\ \text{MeV}$$

Consistent with $(\bar{D}^0 D^{*0})$ threshold

Leads to a 0.38 MeV width

results consistent with LHCb [Phys. Rev. D 102,092005 (2020)]

Additional considerations

Decay channel	BR/BR$\pi\pi J/\psi$@90%CL	Ref.
$\pi^+\pi^-\eta$	<0.12	PRD109,L011102(2024)
$\pi^+\pi^-\chi_{c1}$	<0.18	PRD109,L011101(2024)
$\gamma\ J/\psi$	<0.83	PRD110,012006(2024)
$\gamma\ \psi_2(3823)$	<0.075	PRD110,0120112 (2024)

- Disfavor the possibility of the X(3872) being a pure DD* molecular state. (expected light hadron decays suppressed)
- do not match the expectations of traditional charmonium→The X(3872) is not a pure Xc1 (2P) charmonium state.

Summary and Prospects:

- BESIII produce an abundant harvest of spectroscopy results spanning from light quark hadrons to exotic charmonia.

- In the meanwhile refined techniques, as improved parameterization methods like the K-matrix approach, will allow a deeper understanding.

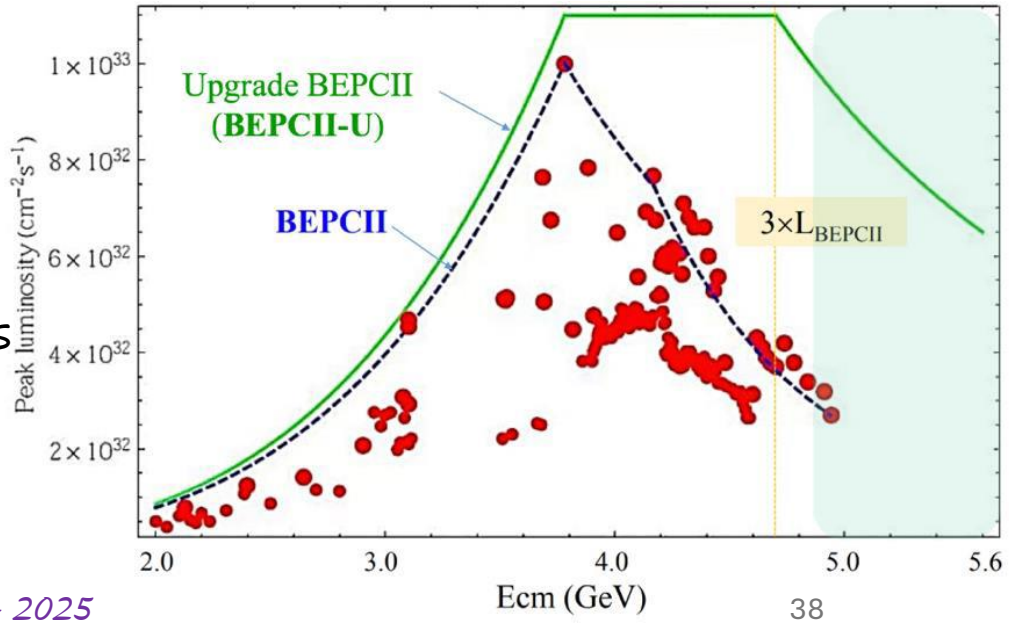
- Our aim is to elucidate the correlations between charmonium-like states and their underlying nature

- A new inner tracker (CGEM) was installed this year (2025).

- The accelerator was upgraded in 2024-2025 to reach higher luminosities and higher center-of-mass energies (to 5.6 GeV) for

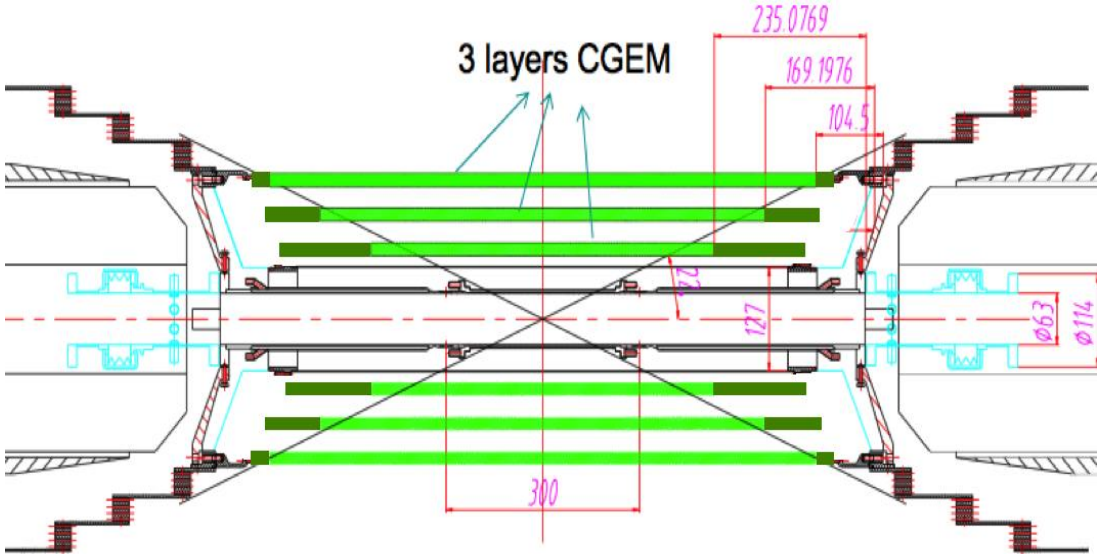
- These upgrades will allow further exciting results

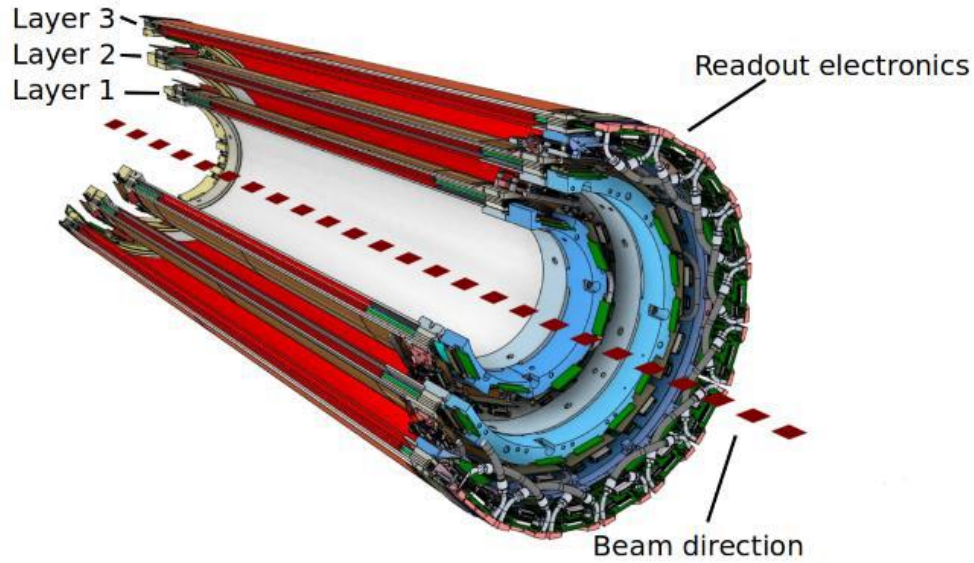
- Stay tuned!



Thank you for your attention!!!

spares





Position in ϕ e z

Each CGEM layer : triple GEM moulded in cylindrical shape

Requirements:

σ_{xy} ~ 130 mm

σ_z < 1 mm

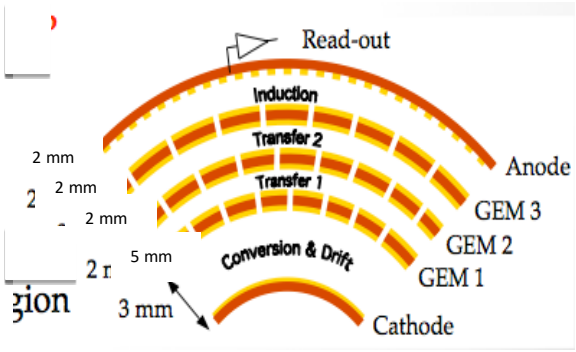
σ_{pt}/pt ~ 0.5% @ 1 GeV/c

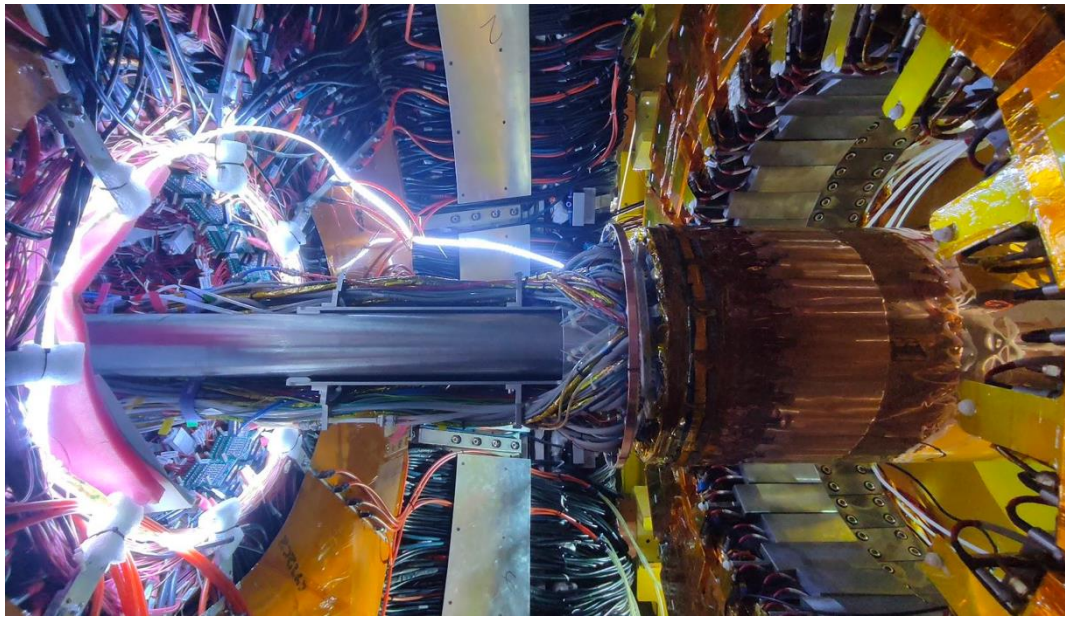
Material budget < 1.5 X_0 for all layers

Maximum rate: 10^4 Hz/cm^2

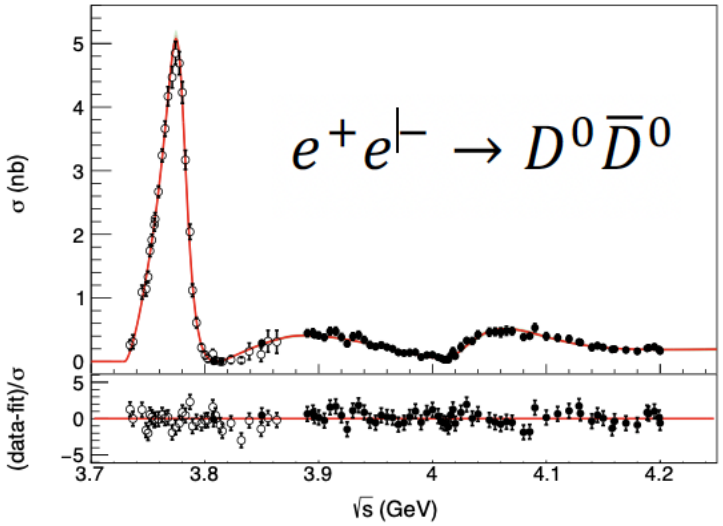
93% of 4π angular coverage

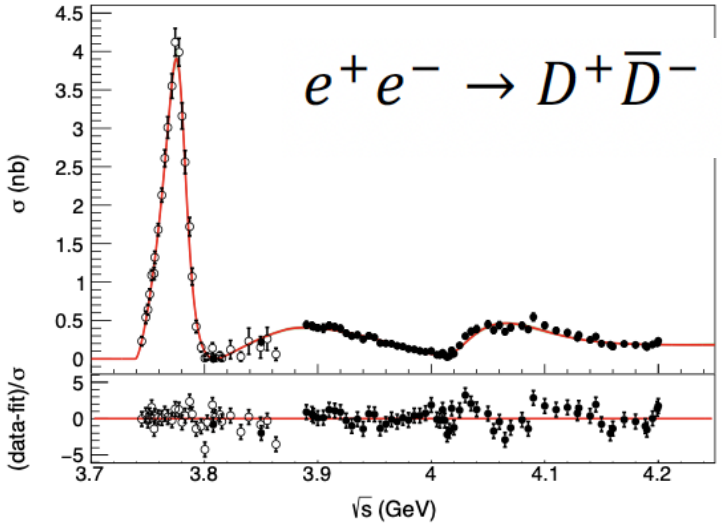
Efficiency ~ 98%

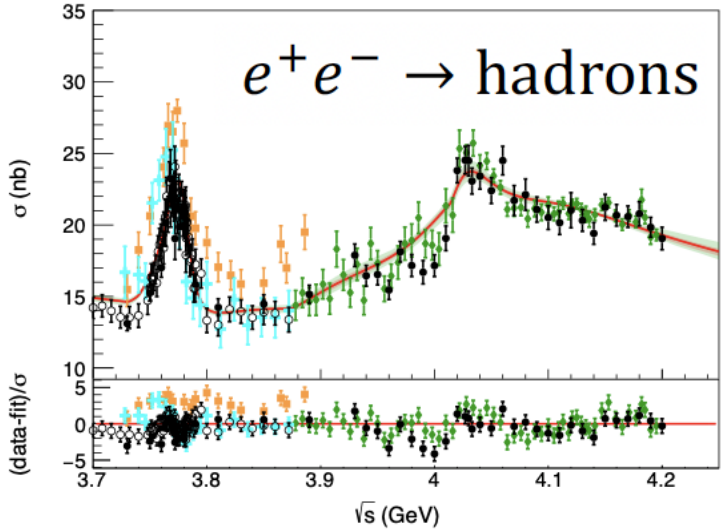


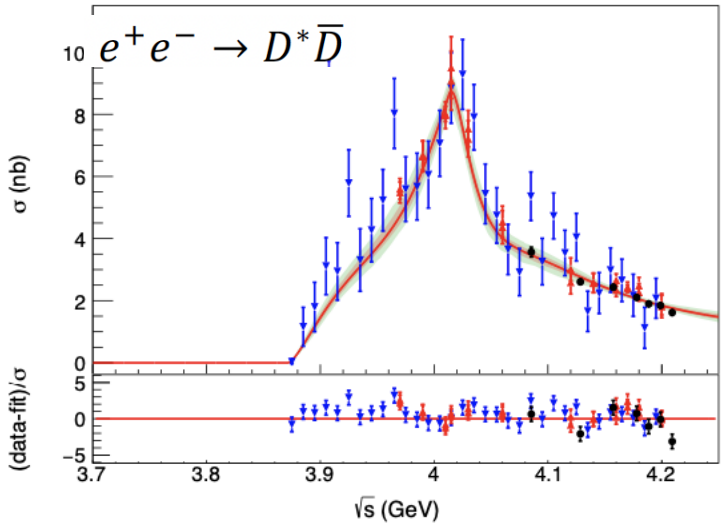


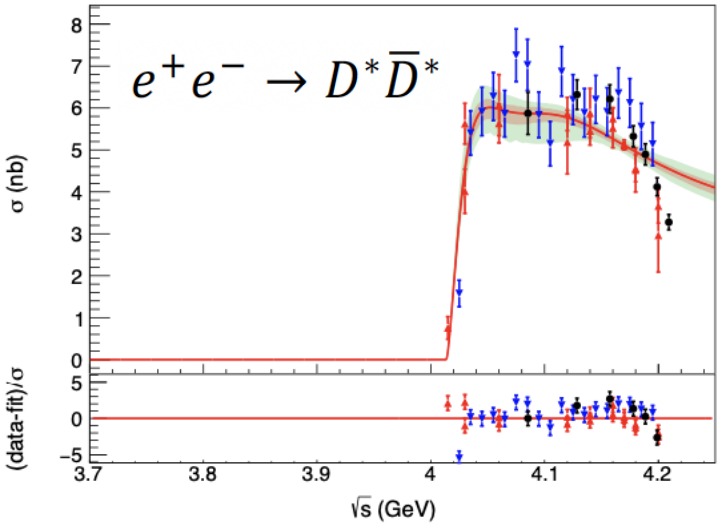
NH, R. Lebed, R. Mitchell, E. Swanson, Y.Q. Wang, C.Z. Yuan, arXiv:2404.03896











- *using two bare poles ψ(3770), ψ(4040)*
- *indeed describe peak near 3.9 GeV without the need for additional pole*
- *however, no predictive power > 4.2 GeV*

Global coupled-channel analysis of $e^+e^- \to c\bar{c}$ processes in $\sqrt{s} = 3.75 - 4.7$ GeV

S.X. Nakamura,[1,2,3,*] X.-H. Li,[2,3] H.-P. Peng,[2,3] Z.-T. Sun,[1] and X.-R. Zhou[2,3]

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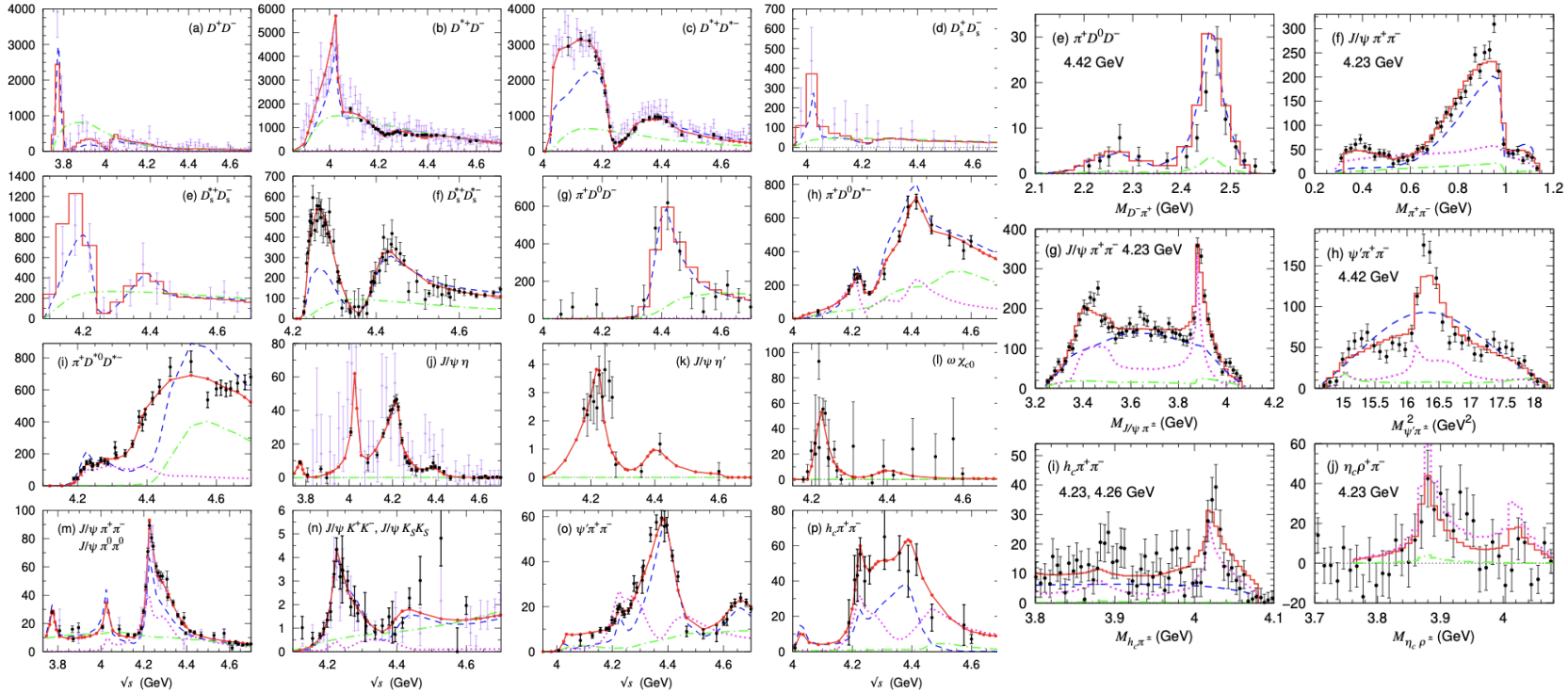

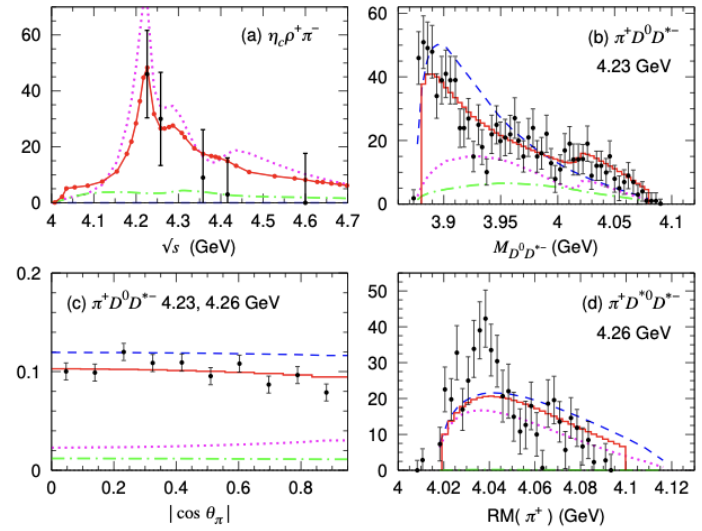

- 10 two-body, 9 three-body, and 1 four-body final states)
- *they find 7 poles (5 bare poles), but no $\psi(4160)$*
- *peak at 3.9 GeV is nonresonant*

This work		PDG [4]		
M (MeV)	Γ (MeV)	M (MeV)	Γ (MeV)	
3775 ± 2.0	28 ± 1.0	3778.1 ± 0.7	27.5 ± 0.9	$\psi(3770)$
4026 ± 0.1	25 ± 0.3	4039 ± 1	80 ± 10	$\psi(4040)$
4232 ± 1.0	114 ± 1.7	4191 ± 5	70 ± 10	$\psi(4160)$
4226 ± 0.4	36 ± 0.8	4222.5 ± 2.4	48 ± 8	$\psi(4230)$
4309 ± 0.6	328 ± 0.9	–	–	–
4369 ± 0.1	183 ± 0.2	4374 ± 7	118 ± 12	$\psi(4360)$
4394 ± 0.7	93 ± 0.9	4421 ± 4	62 ± 20	$\psi(4415)$
4690 ± 7.3	106 ± 8.8	4630 ± 6	72^{+14}_{-12}	$\psi(4660)$