QNP2022 – The 9th International Conference on Quarks and Nuclear Physics

Recent Results from BESIII

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On behalf of the BESIII Collaboration

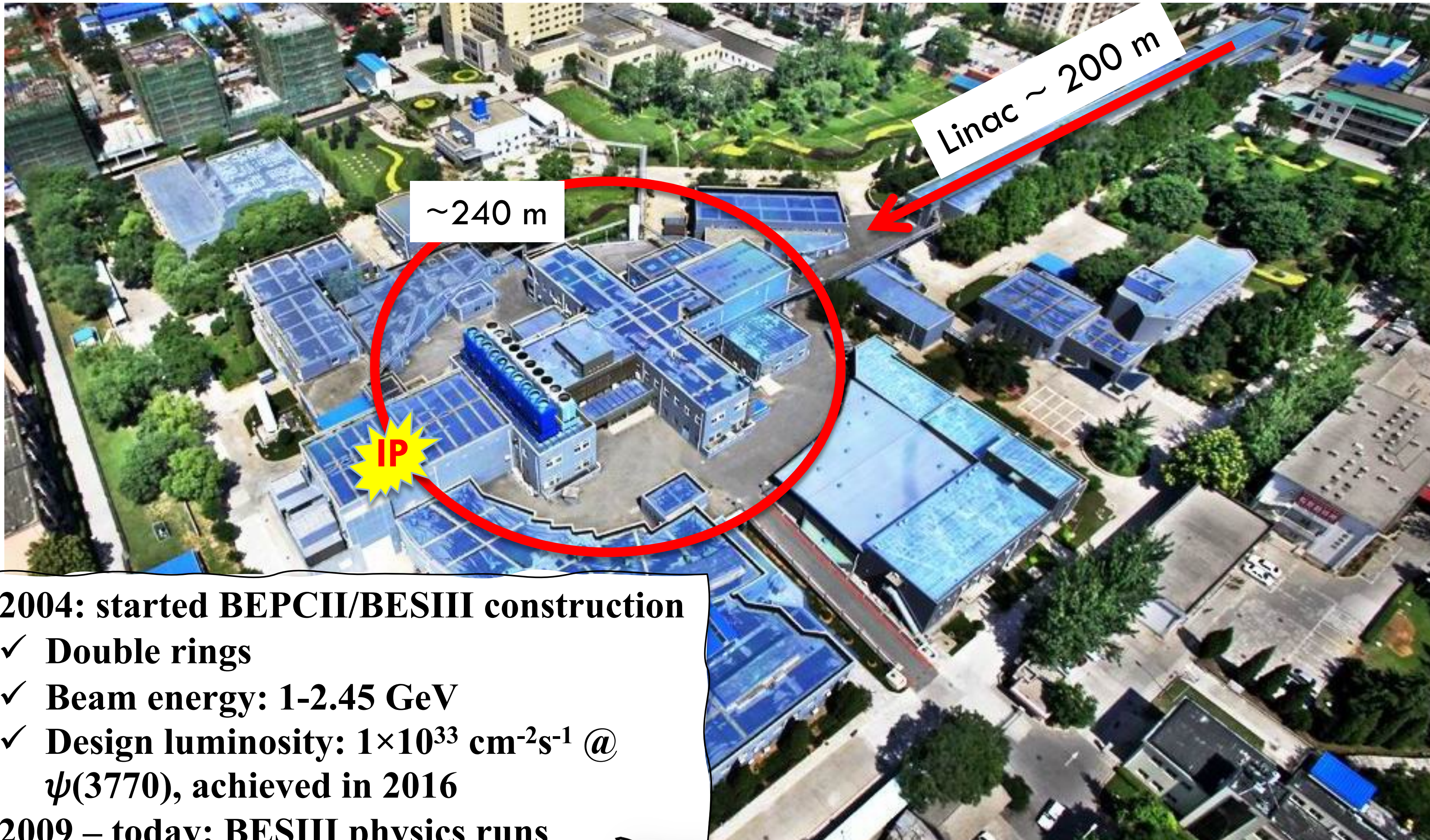
September 5-9, 2022
FSU, Tallahassee, FL, USA

Istituto Nazionale di Fisica Nucleare

Università degli Studi di Ferrara

Beijing Electron Positron Collider II

http://english.ihep.cas.cn

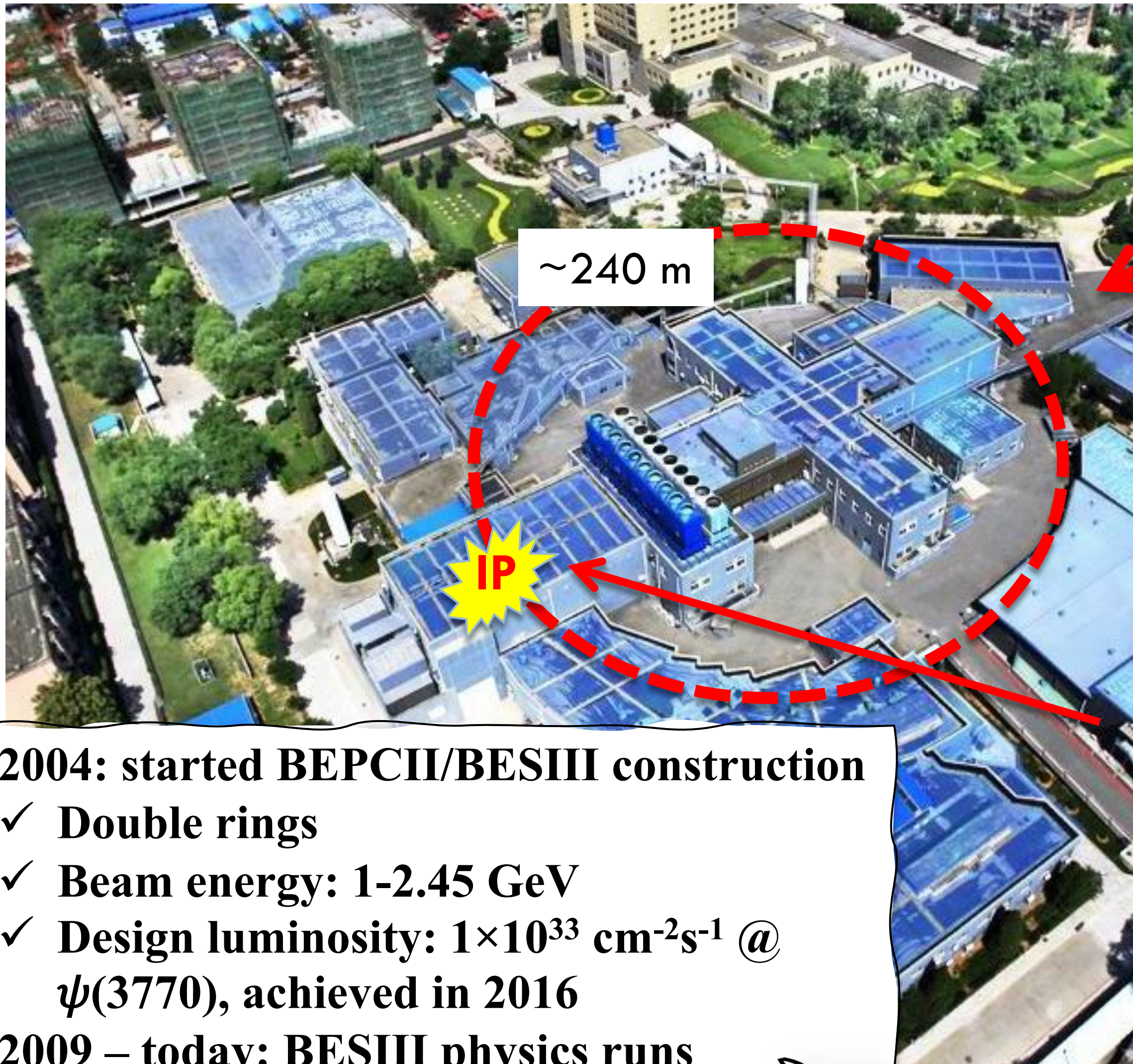


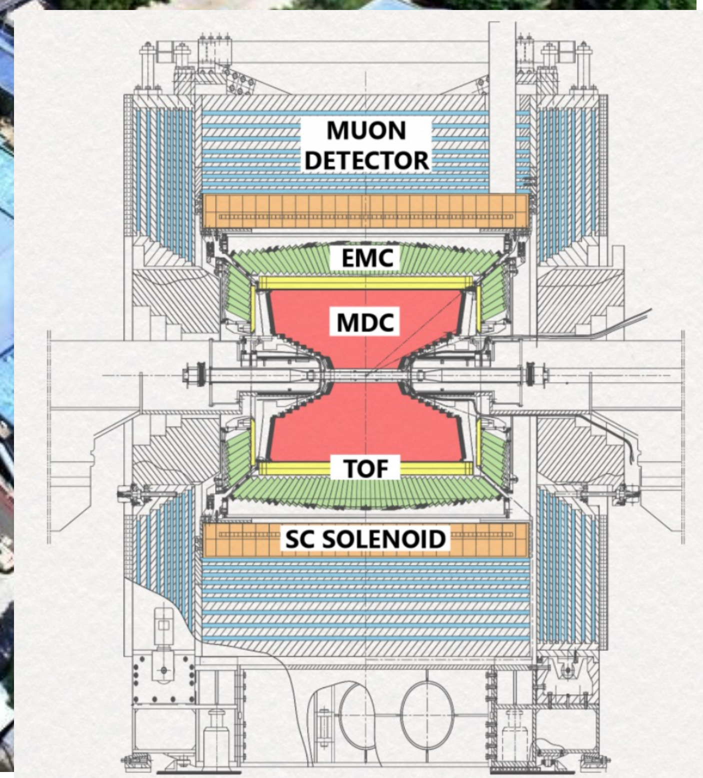
2004: started BEPCII/BESIII construction
- ✓ **Double rings**
- ✓ **Beam energy: 1-2.45 GeV**
- ✓ **Design luminosity: 1×10^{33} cm^{-2}s^{-1} @ ψ(3770), achieved in 2016**

2009 – today: BESIII physics runs

BESIII - Beijing Spectrometer III

http://english.ihep.cas.cn





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2009 – today: BESIII physics runs

Nucl. Instr. Meth. A614, 345 (2010)

BESIII dataset

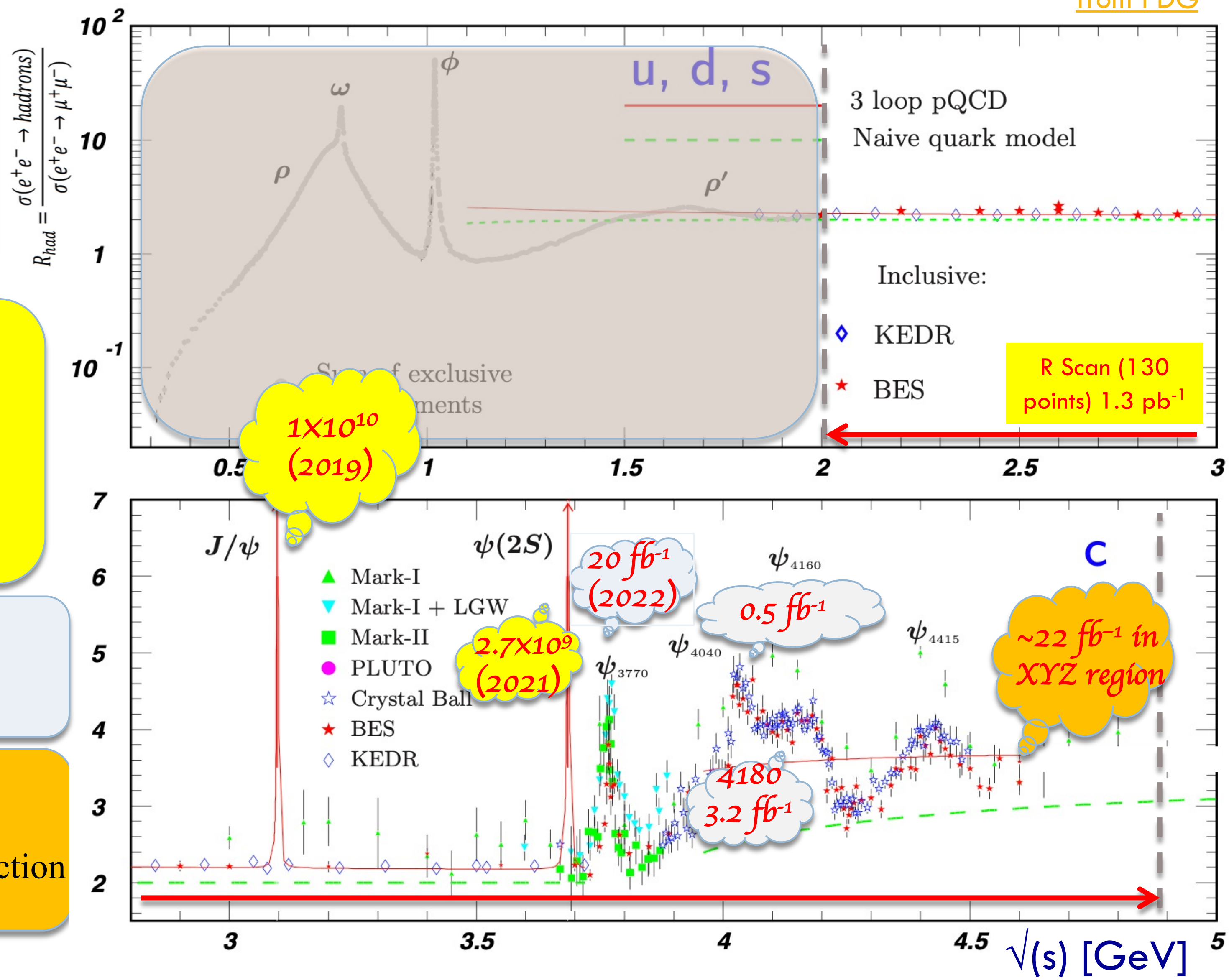
- 130 points between 2 and 4.6 GeV (~715 pb^{-1} up to 3.08 GeV for ρ*, ω*, ϕ*,… studies)

- Light hadron spectroscopy
- η/η' decays
- Hyperon physics
- Charmonium transitions

- $D^0\bar{D}^0$pairs
- $D_{(S)}$ meson decays
- ISR processes

- XYZ decays and spectroscopy
- Open charm production
- Charmed baryons
- …

from PDG



Selected BESIII results

- Light hadron Spectroscopy
  - ✓ exotic isoscalar $\eta_1(1855)$
  - ✓ new X(2600) state observed in J/ψ radiative decays
- Charmonium(-like) spectroscopy
  - ✓ Y states and $Z_{CS}(3985)$ triplet states
- $\phi(2170)$ strangeonium state

@ QNP2022

44. Light hadron spectroscopy at BESIII
Nils Huesken (Indiana University Bl...)
05/09/2022, 14:10
Hadron Spectroscopy

102. Baryons in Charmonium decays at BESIII
Prof. Rong-Gang Ping (IHEP)
06/09/2022, 15:15
Hadron Spectroscopy

109. Hyperon decays and production
He Li (University of science...)
07/09/2022, 15:25
Hadron Spectroscopy

45. XYZ particles at BESIII
Joshua Jackson
06/09/2022, 13:45
Hadron Spectroscopy

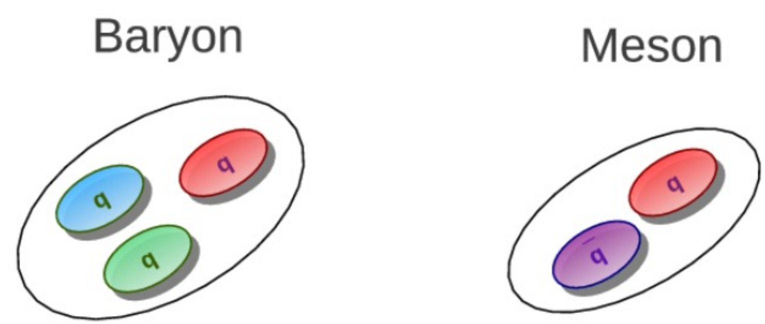
109. Hyperon decays and production
He Li (University of science...)
07/09/2022, 15:25
Hadron Spectroscopy

103. Recent result of nucleon time-like form factors at BESIII
xiaorong zhou
06/09/2022, 13:45
Hadron Structure

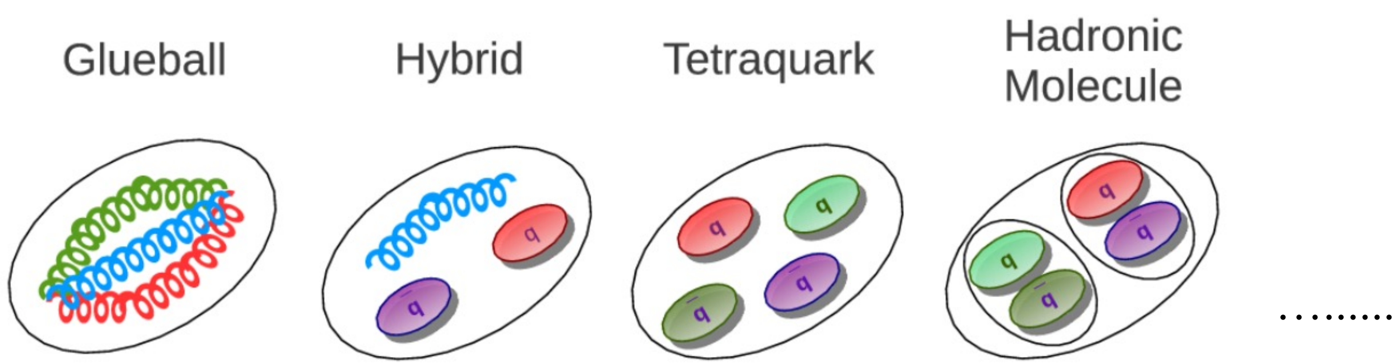
96. Light Meson Decays at BESIII
Shuangshi Fang (Institute of High Ene...)
07/09/2022, 13:25
Hadron Decays

Hadron Spectrum

<u>Naïve Quark Model:</u>
conventional hadrons
contain two or three quarks



… ***<u>but</u>*** QCD allows also different combinations of quarks and gluons: ***<u>EXOTIC</u>*** hadrons



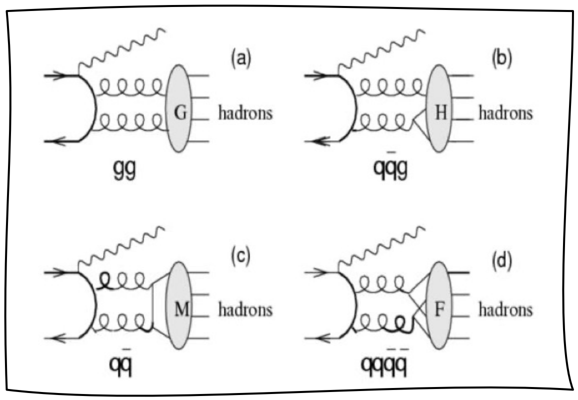
A lot of exotic states observed experimentally, but their nature is still far from being understood!!!

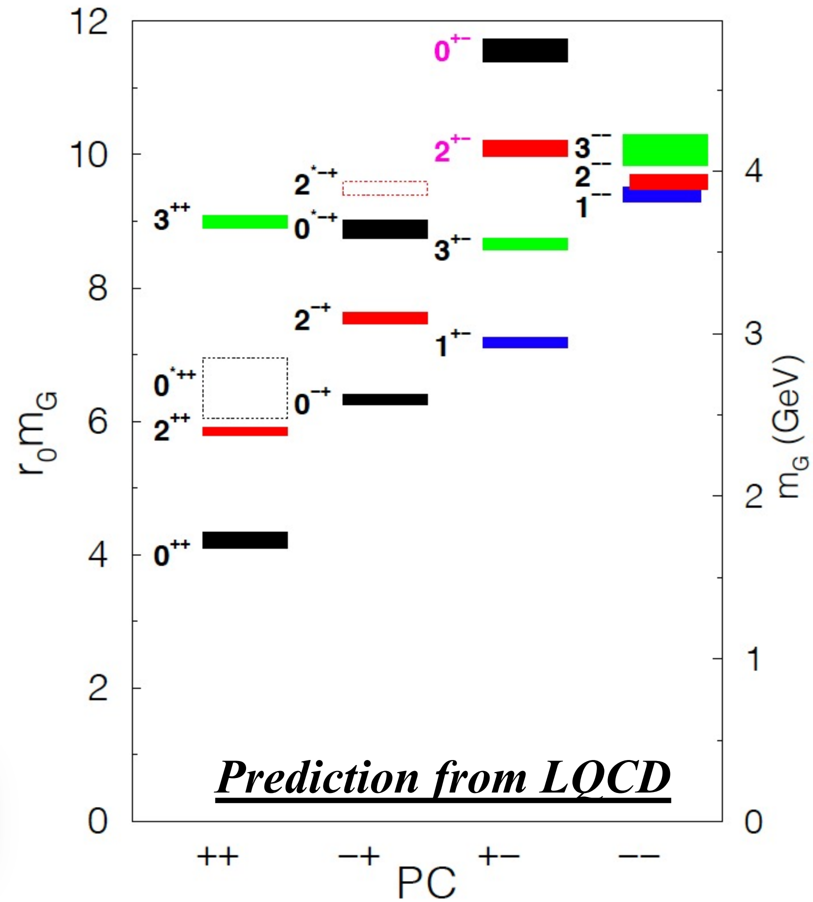
Hadron spectroscopy: establish the spectrum and study the exotic hadrons properties

Hunting for glueballs and new form of hadrons

- Charmonium radiative decays is the ideal laboratory for light glueballs and hybrids hadron studies

✓ Gluon-rich process
✓ Clean process
✓ High statistics





- ***<u>Glueballs can mix with ordinary quark-antiquark states</u>***
- Predicted large BFs for glueballs in J/ψ radiative decays

PRL**110**, 021601

$$\Gamma(J/\psi \to \gamma G_{0^{++}})/\Gamma_{\rm tot} = 3.8(9) \times 10^{-3}$$

PRL**111**, 091601

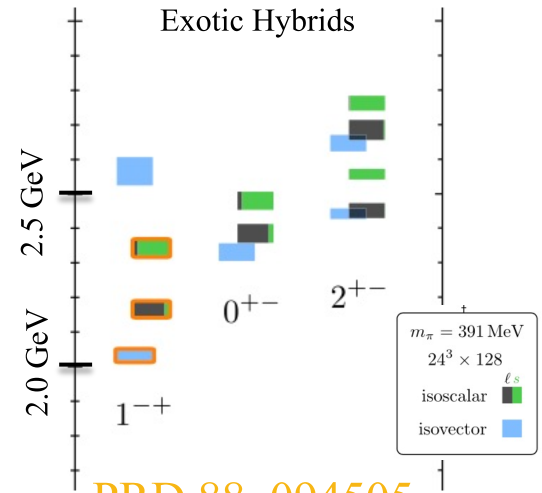
$$\Gamma(J/\psi \to \gamma G_{2^{++}})/\Gamma_{\rm tot} = 1.1(2)(1) \times 10^{-2}$$

https://doi.org/10.1142/S0218301309012124

Exotic Hybrid states

- Low-lying hybrids can have exotic quantum numbers forbidden in the conventional QCD scheme:
  $J^{PC} = 0^{+-}, 1^{-+}, 2^{+-}$
- The exotic $J^{PC} = 1^{-+}$ nonet of hybrids is predicted to be the lightest
  - Only isovector candidate observed yet: $\pi_1(1400)$, $\pi_1(1600)$ [the most extensively studied], $\pi_1(2015)$

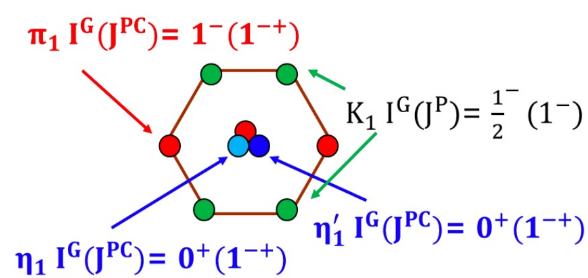
LQCD prediction for Exotic Hybrids



PRD 88, 094505

- Isoscalar 1^{-+} hybrids is important to establish the hybrid nonet
  - Can be produced in J/ψ radiative decays
  - Can decay to $\eta\eta'$ in P-wave (PRD 83,014021, PRD 83, 014006, Eur.Phys.J.Plus 135, 945)

BESIII experiment offers the ideal environment for this search
$J/\psi \to \gamma\eta\eta'$

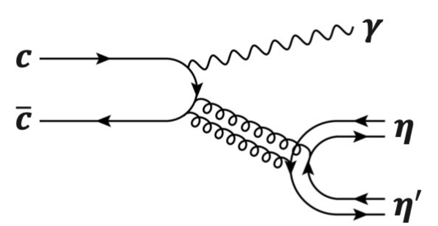


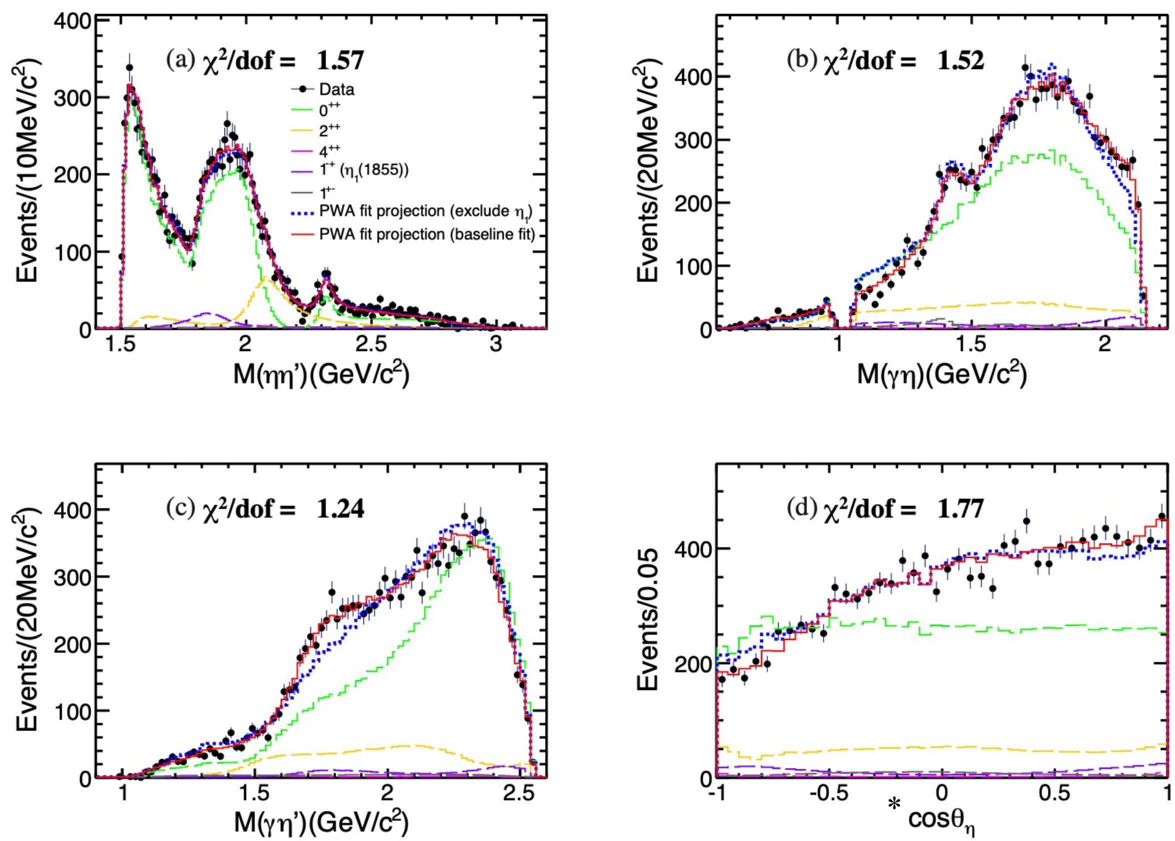
Observation of Exotic Isoscalar State $\eta_1(1855)$ in $J/\psi \to \gamma\eta\eta'$

arXiv:2202.00621
arXiv:2202.00623

PWA of $J/\psi \to \gamma\eta\eta'$ using 10 Billion of J/ψ data @ BESIII

- $\eta \to \gamma\gamma$ and $\eta' \to \gamma\pi^+\pi^-$/ $\eta\pi^+\pi^-$





*spin information

- An isoscalar 1^{-+} state, $\eta_1(1855)$, has been observed with statistical significance larger than 19σ
- Mass is consistent with LQCD calculation for the 1^{-+} hybrid (1.7 – 2.1 GeV/c^2)

$$M = (1855 \pm 9^{+6}_{-1})\ \mathrm{MeV}/c^2; \quad \Gamma = (188 \pm 18^{+3}_{-8})\ \mathrm{MeV}$$

$$\mathcal{B}(J/\psi \to \gamma\eta_1(1855) \to \gamma\eta\eta') = (2.70 \pm 0.41^{+0.16}_{-0.35}) \times 10^{-6}$$

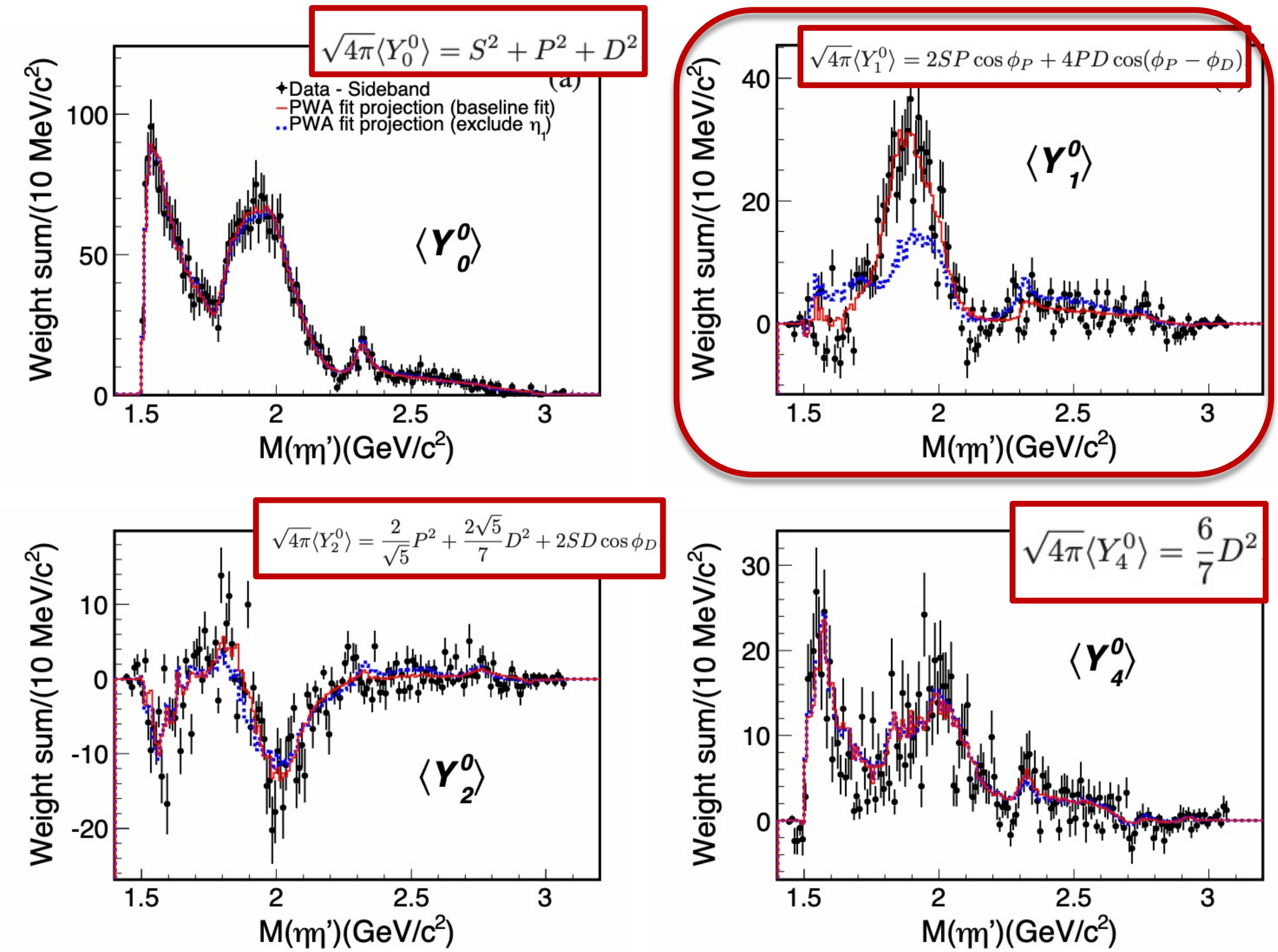
more detail from Nils Huesken talk, 09/05

Further Checks on the $\eta_1(1855)$

arXiv:2202.00621
arXiv:2202.00623

The $\cos(\theta_\eta)$ distribution can be expressed as an expansion in terms of Legendre polynomials; the coefficients $\langle Y_l^0 \rangle \equiv \sum_{i=1}^{N_k} W_i Y_l^0(\cos\theta_\eta^i)$ (called unnormalized moments of expansion), characterize the spin of the $\eta\eta'$ resonances

- Neglecting resonance contributions in the $\gamma\eta^{(')}$ subsystem, the moments are related to the spin-0 (S), spin-1 (P) and spin-2 (D) amplitudes
- Good data/PWA consistency
- Narrow structure in $\langle Y^0_1 \rangle$: $\eta_1(1855)$ P-wave component is needed



Discussion about $f_0(1500)$ and $f_0(1710)$

arXiv:2202.00621
arXiv:2202.00623

The dominant contributions in the baseline PWA are from scalar resonance:

Decay mode	Resonance	M (MeV/c^2)	Γ (MeV)	$M_{\rm PDG}$ (MeV/c^2)	$\Gamma_{\rm PDG}$ (MeV)	B.F. ($\times 10^{-5}$)	Sig.
$J/\psi \to \gamma X \to \gamma\eta\eta'$	$f_0(1500)$	1506	112	1506	112	$1.81\pm0.11^{+0.19}_{-0.13}$	$\gg 30\sigma$
	$f_0(1810)$	1795	95	1795	95	$0.11\pm0.01^{+0.04}_{-0.03}$	11.1σ
	$f_0(2020)$	$2010\pm6^{+6}_{-4}$	$203\pm9^{+13}_{-11}$	1992	442	$2.28\pm0.12^{+0.29}_{-0.20}$	24.6σ
	$f_0(2330)$	$2312\pm7^{+7}_{-3}$	$65\pm10^{+3}_{-12}$	2314	144	$0.10\pm0.02^{+0.01}_{-0.02}$	13.2σ
	$\eta_1(1855)$	$1855\pm9^{+6}_{-1}$	$188\pm18^{+3}_{-8}$	-	-	$0.27\pm0.04^{+0.02}_{-0.04}$	21.4σ
	$f_2(1565)$	1542	122	1542	122	$0.32\pm0.05^{+0.12}_{-0.02}$	8.7σ
	$f_2(2010)$	$2062\pm6^{+10}_{-7}$	$165\pm17^{+10}_{-5}$	2011	202	$0.71\pm0.06^{+0.10}_{-0.06}$	13.4σ
	$f_4(2050)$	2018	237	2018	237	$0.06\pm0.01^{+0.03}_{-0.01}$	4.6σ
	0^{++} PHSP	-	-	-	-	$1.44\pm0.15^{+0.10}_{-0.20}$	15.7σ
$J/\psi \to \eta' X \to \gamma\eta\eta'$	$h_1(1415)$	1416	90	1416	90	$0.08\pm0.01^{+0.01}_{-0.02}$	10.2σ
	$h_1(1595)$	1584	384	1584	384	$0.16\pm0.02^{+0.03}_{-0.01}$	9.9σ

$$\frac{\mathcal{B}(f_0(1500)\to\eta\eta')}{\mathcal{B}(f_0(1500)\to\pi\pi)} = (8.96^{+2.95}_{-2.87})\times 10^{-2}$$

Consistent with PDG

$$\frac{\mathcal{B}(f_0(1710)\to\eta\eta')}{\mathcal{B}(f_0(1710)\to\pi\pi)} < 1.61\times 10^{-3}$$

@90% C.L.

This suppressed decay rate supports the hypothesis that the $f_0(1710)$ has a large overlap with the ground state scalar glueball (PRD 92,121902)

Partial Wave Analysis of $J/\psi \to \gamma\eta'\eta'$

PRD 105, 072002

PWA of $J/\psi \to \gamma\eta'\eta'$ using 10 Billion of J/ψ data @ BESIII

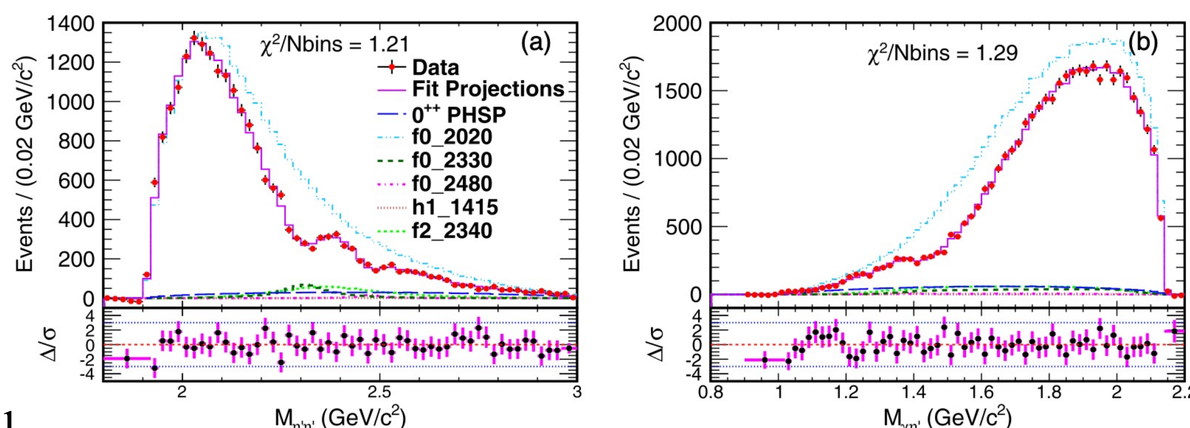
- $\eta' \to \gamma\pi^+\pi^-$ / $\eta\pi^+\pi^-$ ($\eta \to \gamma\gamma$)

Resonance	M(MeV/c^2)	Γ(MeV)	B.F.	Significance (σ)
$f_0(2020)$	$1982 \pm 3^{+54}_{-0}$	$436 \pm 4^{+46}_{-49}$	$(2.63 \pm 0.06^{+0.31}_{-0.46}) \times 10^{-4}$	$\gg 25$
$f_0(2330)$	$2312 \pm 2^{+10}_{-0}$	$134 \pm 5^{+30}_{-9}$	$(6.09 \pm 0.64^{+4.00}_{-1.68}) \times 10^{-6}$	16.3
$f_0(2480)$	$2470 \pm 4^{+4}_{-6}$	$75 \pm 9^{+11}_{-8}$	$(8.18 \pm 1.77^{+3.73}_{-2.23}) \times 10^{-7}$	5.2
$h_1(1415)$	$1384 \pm 6^{+9}_{-0}$	$66 \pm 10^{+12}_{-10}$	$(4.69 \pm 0.80^{+0.74}_{-1.82}) \times 10^{-7}$	5.3
$f_2(2340)$	$2346 \pm 8^{+22}_{-6}$	$332 \pm 14^{+26}_{-12}$	$(8.67 \pm 0.70^{+0.61}_{-1.67}) \times 10^{-6}$	16.1
0^{++} PHSP	⋯	⋯	$(1.17 \pm 0.23^{+4.09}_{-0.70}) \times 10^{-5}$	15.7

Dominant contributions

new 0^{++} state

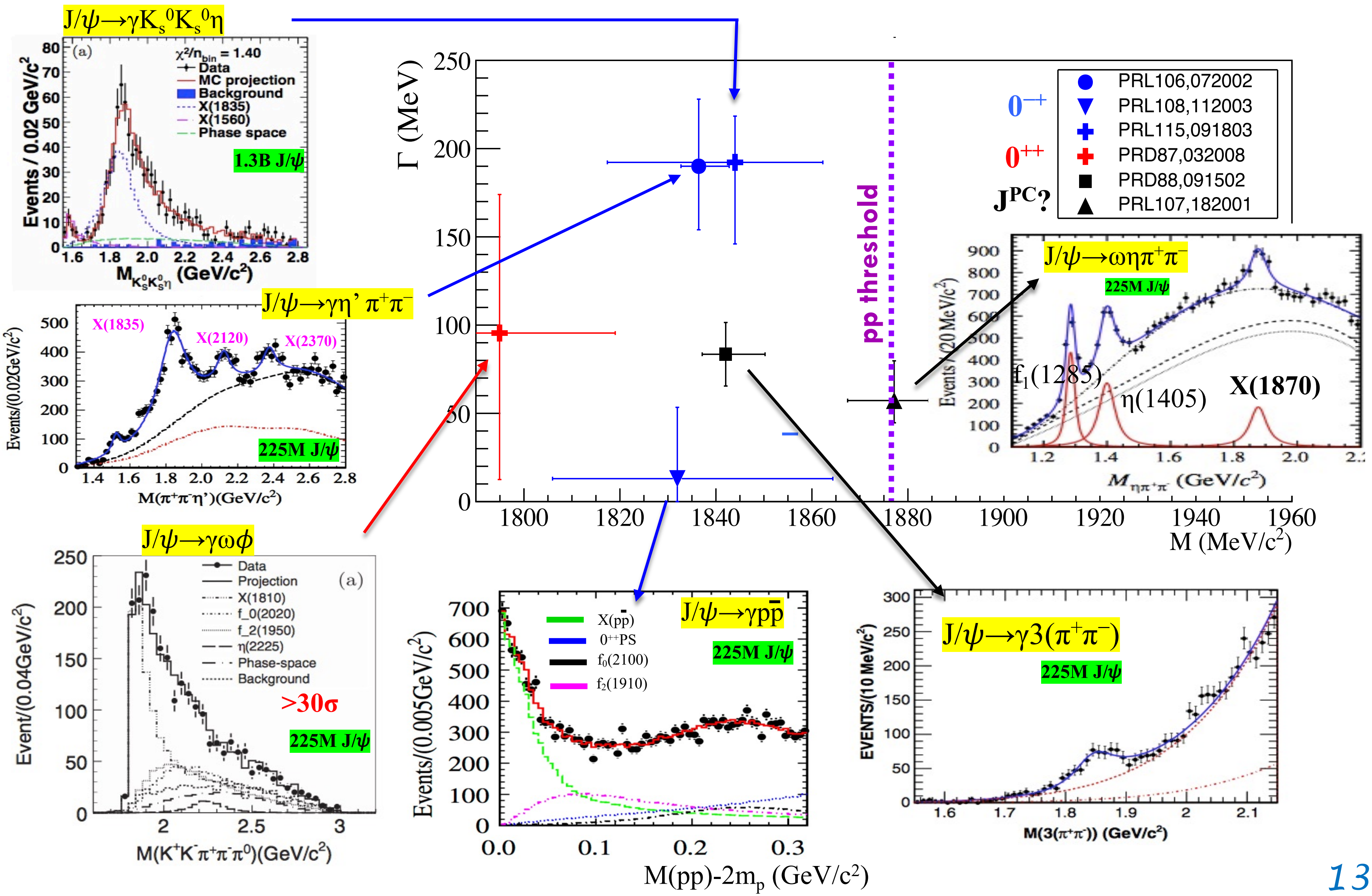
- $f_0(2020)$, $f_0(2330)$ and $f_2(2340)$ observed in $\eta'\eta'$ decay mode for the first time



$f_0(2020)$:

- Its large production rate in radiative J/ψ decay suggest a large overlap with scalar glueball
- Indication that it is a flavor singlet [Phys. Lett. B 826, 136906]

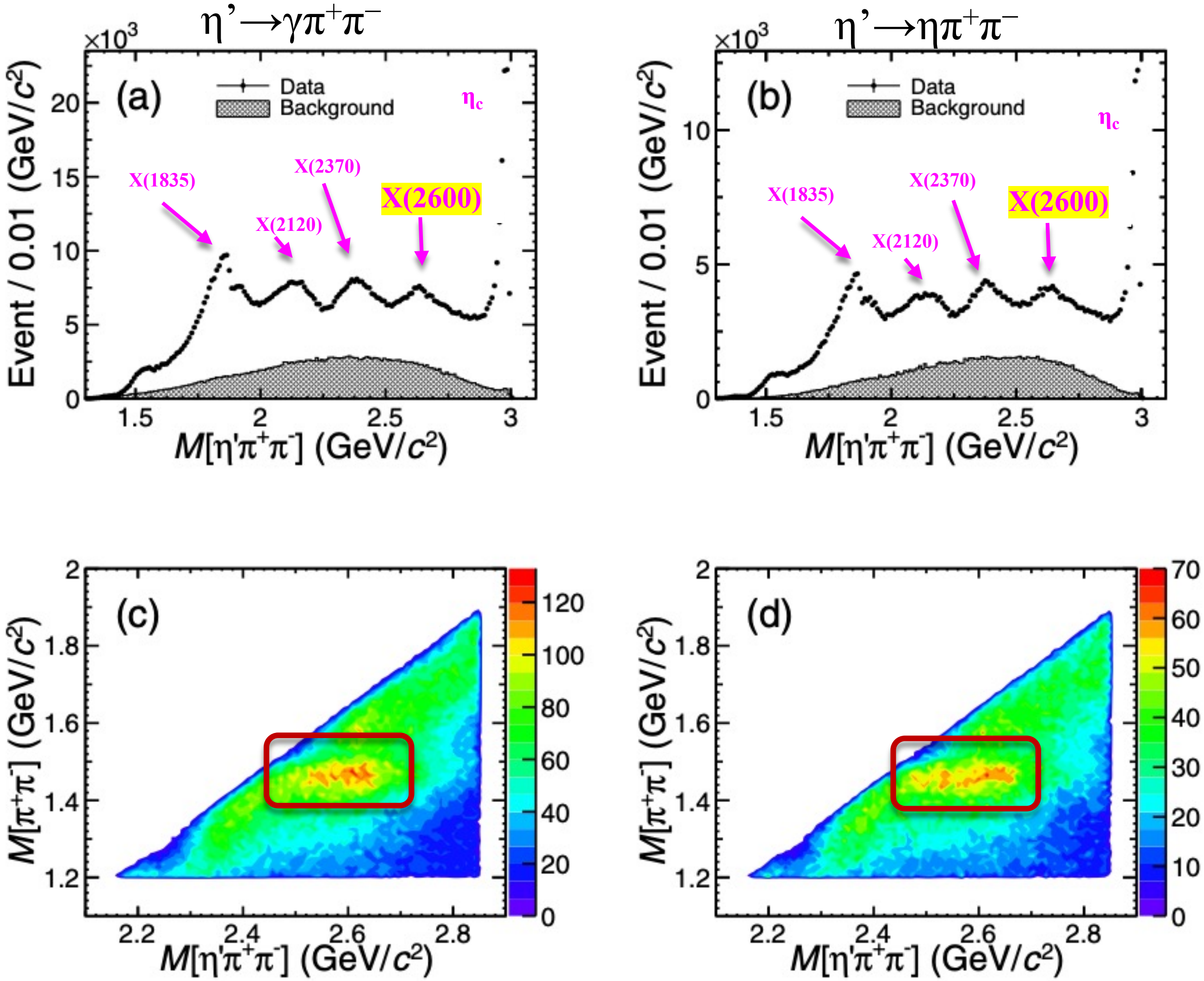
Structures between 1.8 -1.9 GeV



X(2600): A New State Observed in $J/\psi \to \gamma \pi^+ \pi^- \eta'$

10 Billion of J/ψ data @ BESIII

PRL 129, 042001



A new state in $M(\eta' \pi^+ \pi^-)$ invariant mass is observed around 2.6 GeV/c^2, which is correlated to a structure in $M(\pi^+ \pi^-)$ @ 1.5 GeV/c^2

X(2600): A New State Observed in $J/\psi \to \gamma \pi^+ \pi^- \eta'$

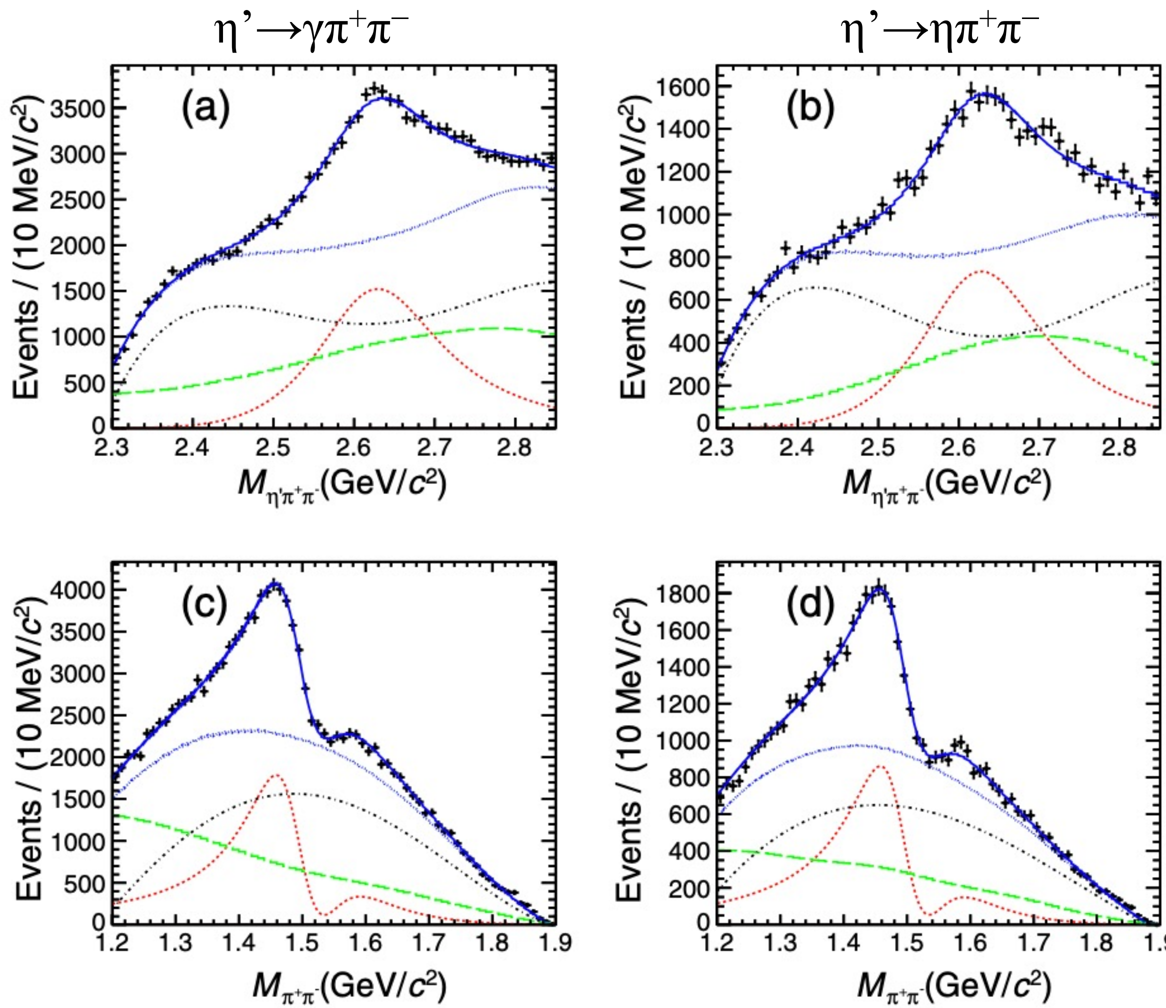
PRL 129, 042001

- Simultaneous fit to $\eta' \pi^+ \pi^-$ and $\pi^+ \pi^-$ mass spectra is performed

Resonance	Mass (MeV/c^2)	Width (MeV)
$f_0(1500)$	$1492.5 \pm 3.6^{+2.4}_{-20.5}$	$107 \pm 9^{+21}_{-7}$
$X(1540)$	$1540.2 \pm 7.0^{+36.3}_{-6.1}$	$157 \pm 19^{+11}_{-77}$
$X(2600)$	$2618.3 \pm 2.0^{+16.3}_{-1.4}$	$195 \pm 5^{+26}_{-17}$

- X(2600) resonance observed for the first time with a statistical significance greater than 20σ

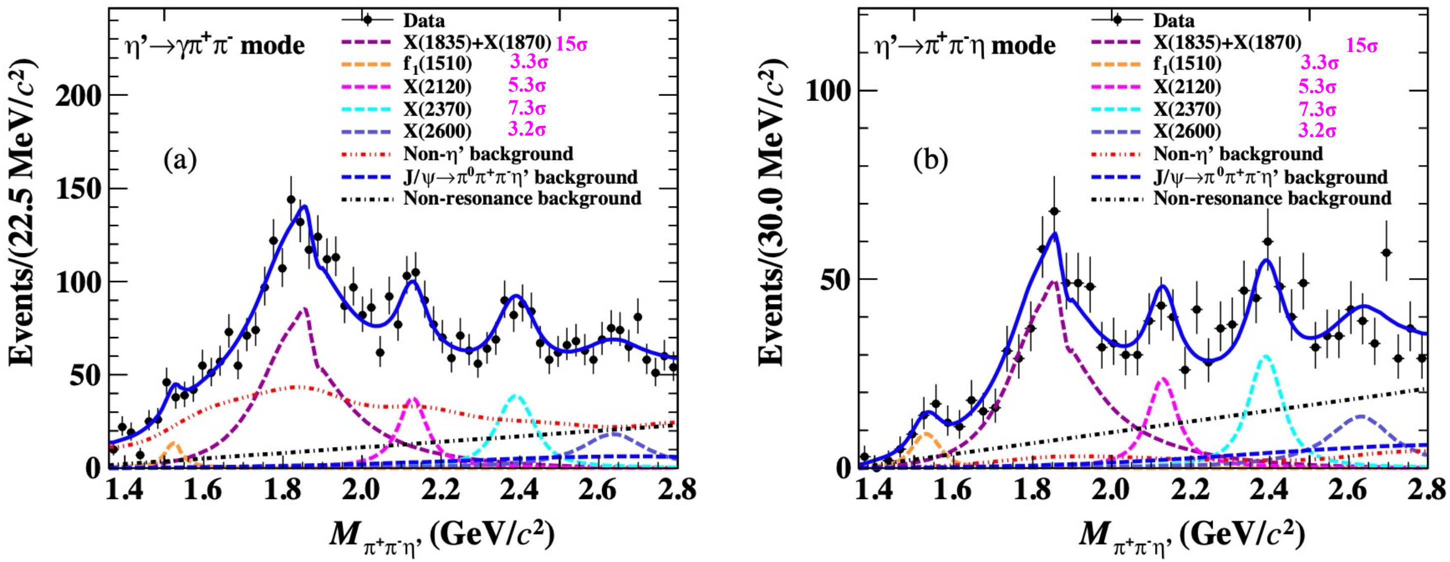
- The structure in $M(\pi^+\pi^-)$ around 1.5 GeV/c^2 can be well described with the interference between $f_0(1500)$ and the X(1540) resonances



Observation of X(1835), X(2120), X(2370) in J/ψ EM Dalitz Decays

10 Billion of J/ψ data @ BESIII

PRL 129, 022002



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

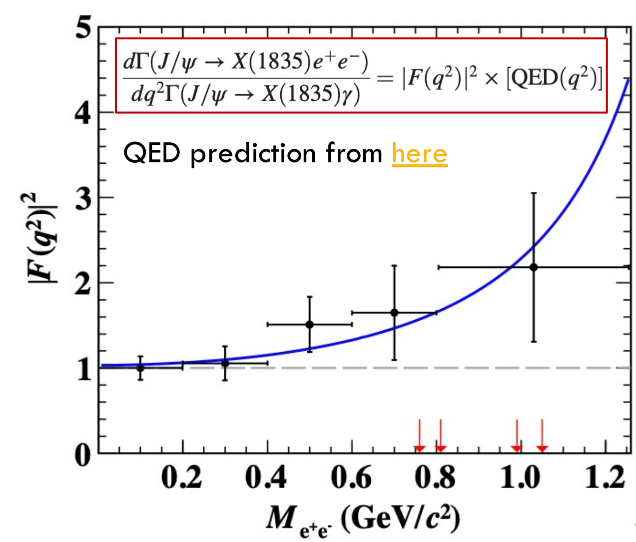
Confirmation of X(1835), X(2120) and X(2370) observed in J/ ψ radiative decays

Access to the EM transition form factor between J/ ψ and X(1835) states

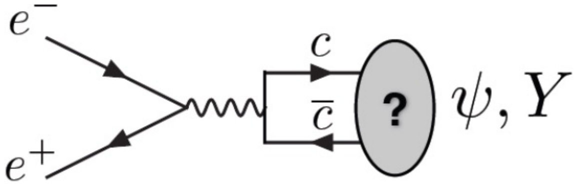
- Additional information on the internal structure of X(1835)

$$F(q^2) = \frac{1}{1 - q^2/\Lambda^2}$$

$$\Lambda = 1.75 \pm 0.29 \pm 0.05\ GeV/c^2$$

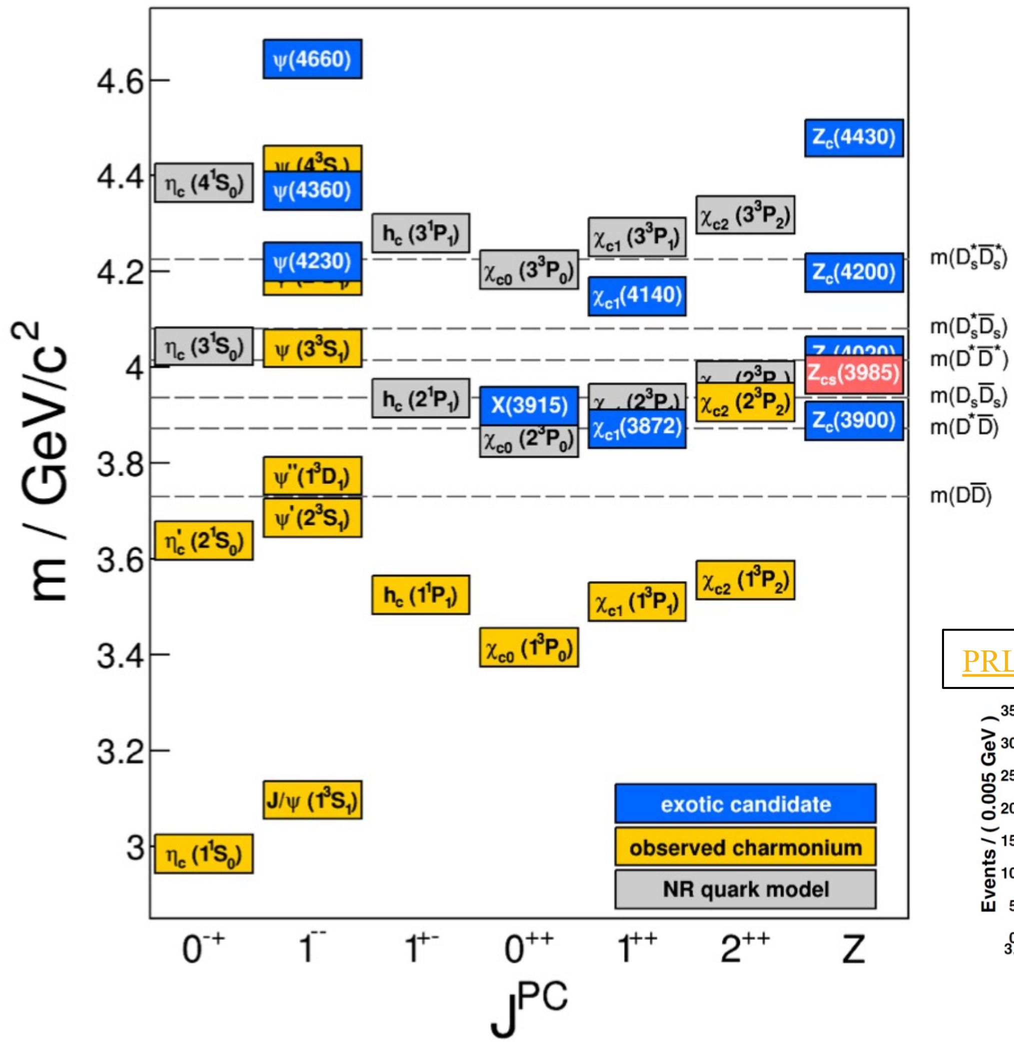


Charmonium(-like) Spectroscopy



$J^{PC} = 1^{--}$

Charmonium-like states



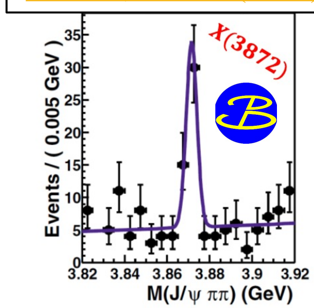
Conventional charmonia fit well with potential model calculations

$$V_{c\bar{c}} = -\frac{4}{3}\cdot\frac{\alpha_s(r)}{r} + k\cdot r$$

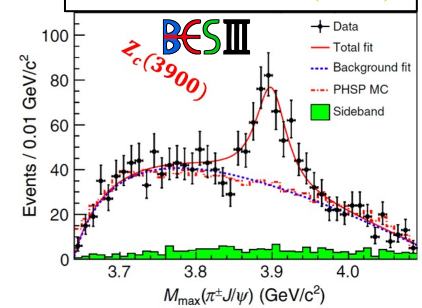
+ spin-dependent terms

Several unexpected states observed

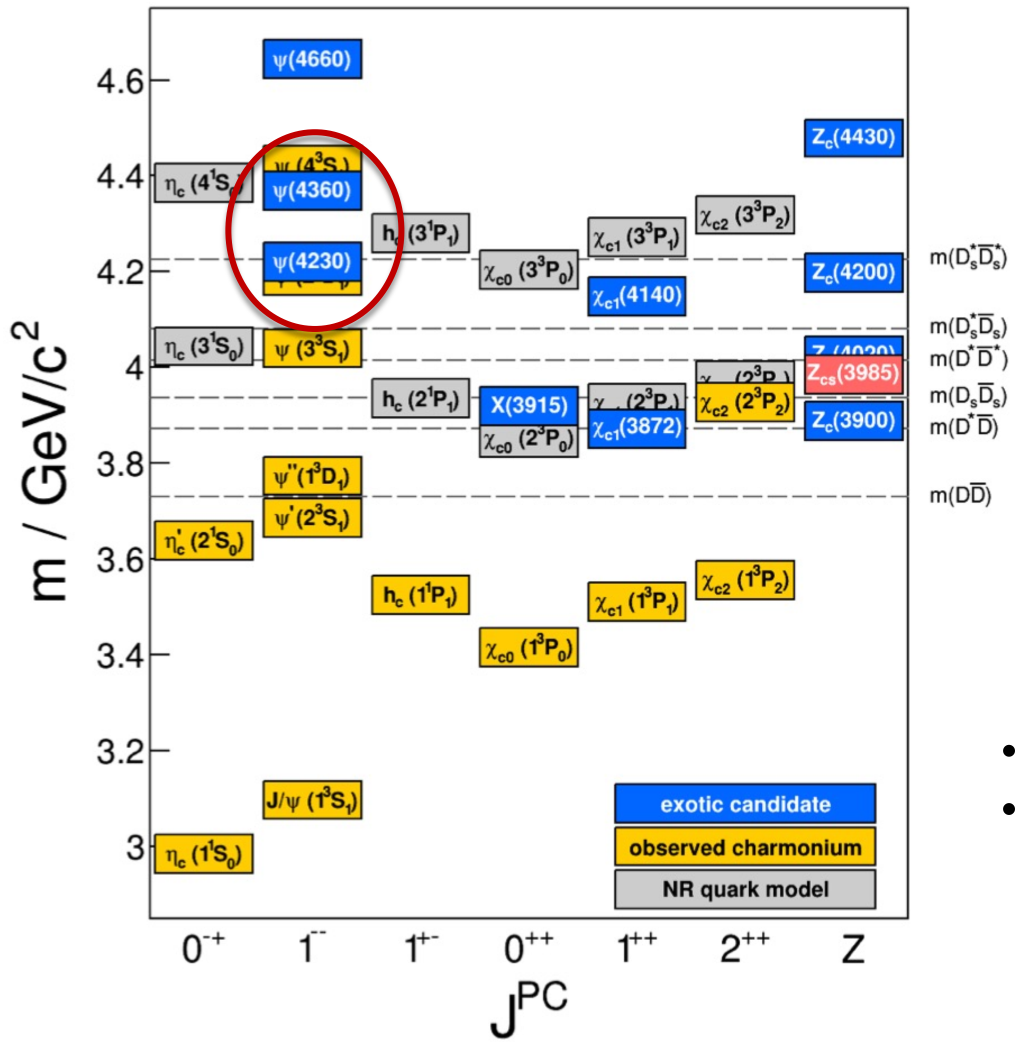
PRL 91, 262001(2003)



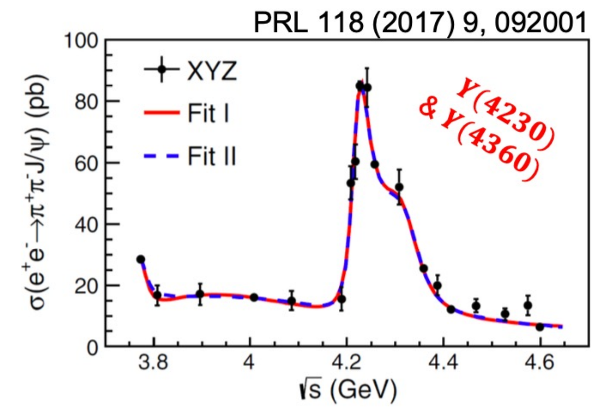
PRL 110, 252001(2013)



Vector states ψ(4230) and ψ(4360)

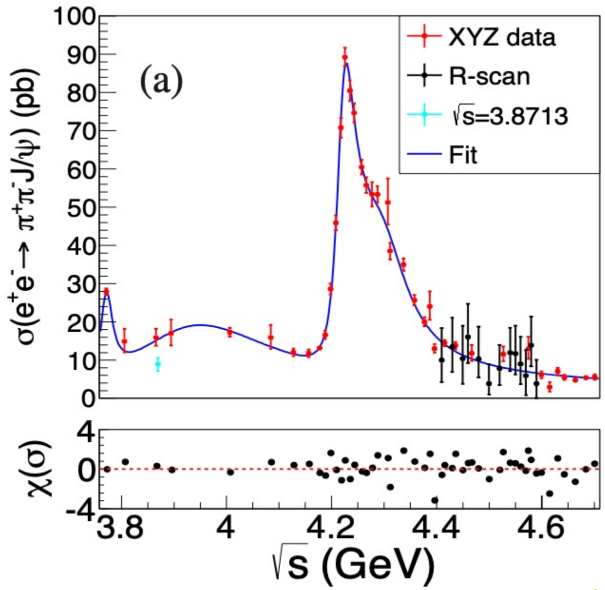


Y(4260) first seen by BaBar (PRL95, 142001); split into to states Y(4230) and Y(4360) by BESIII



- Inconsistent with simple $c\bar{c}$ scenario
- candidates for exotic:
  - Hybrid?
  - Hadronic Molecule?
  - Tetraquark?

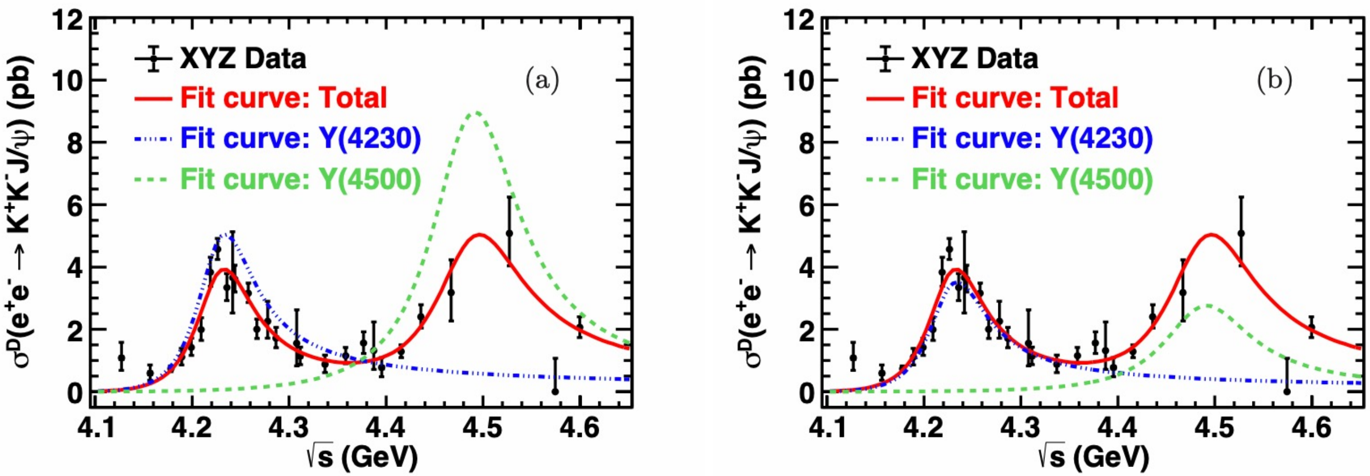
Vector states



arXiv:2206.08554 $e^+e^- \to \pi^+\pi^- J/\psi$

- **Improved** precision w.r.t previous results PRL118, 092001
- Y(4220) and Y(4320) resonances are observed with > 10σ
- Structure around 4.0 GeV is better described using a BW
- Evidence of additional structure around 4.5 GeV, identified with the $\psi(4415)$
  - it influences the evaluation of the Y(4230) parameters

arXiv:2204.07800 $e^+e^- \to K^+K^- J/\psi$

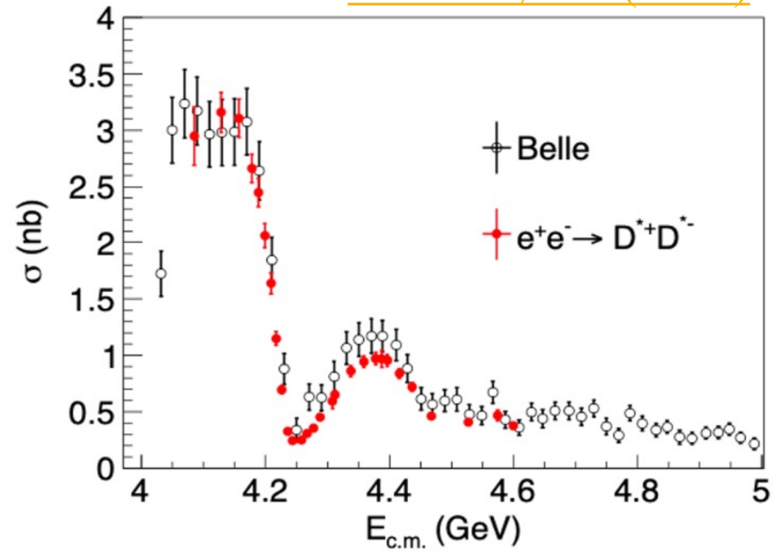


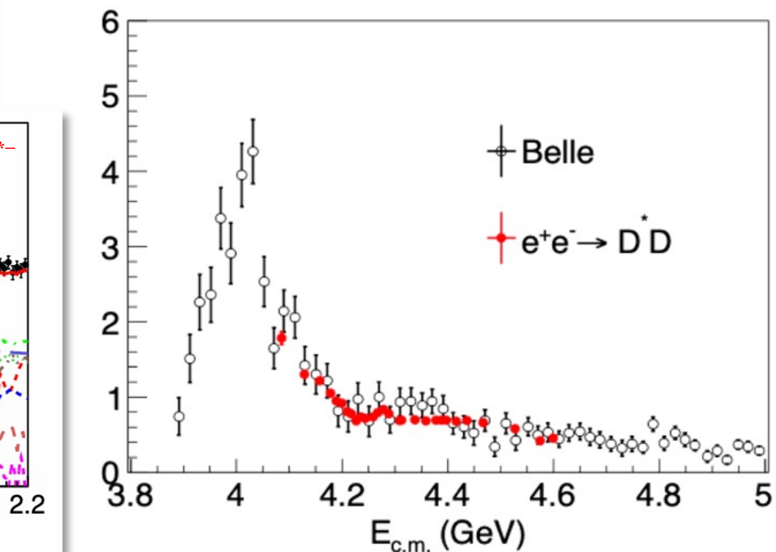
Observation of the **Y(4230)** with >5σ and **new structure Y(4500)** with >8σ

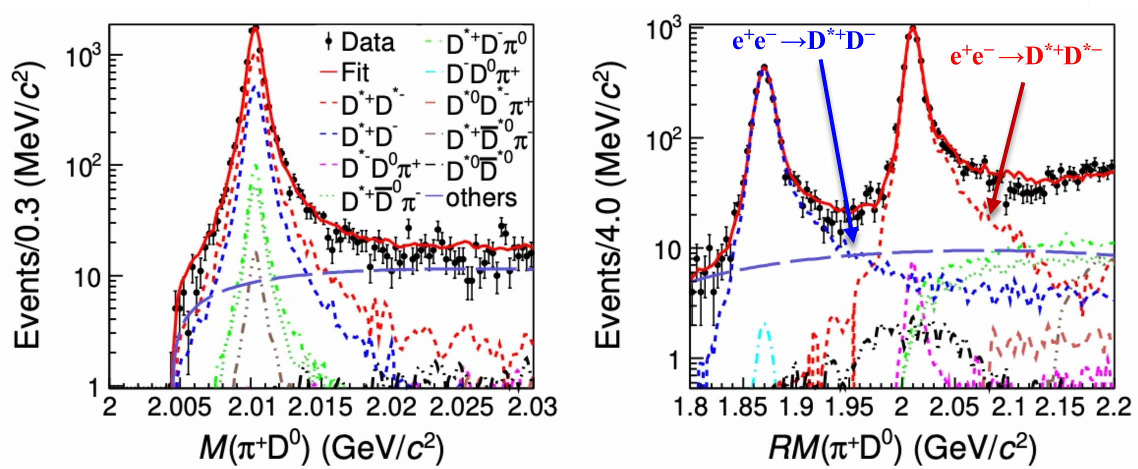
Open charm production

JHEP 05, 115 (2022)

- Measurement of $e^+e^- \to D^{*+}D^{*-}$ and $e^+e^- \to D^{*+}D^-$
- Conventional states above threshold mainly decays into open-charm mesons, while charmonium-like states mainly decay into hidden-charm final states
- Consistent with previous results with better precision
- Sophisticated models with further studies on couple-channel effects needed to understand non-trivial structure



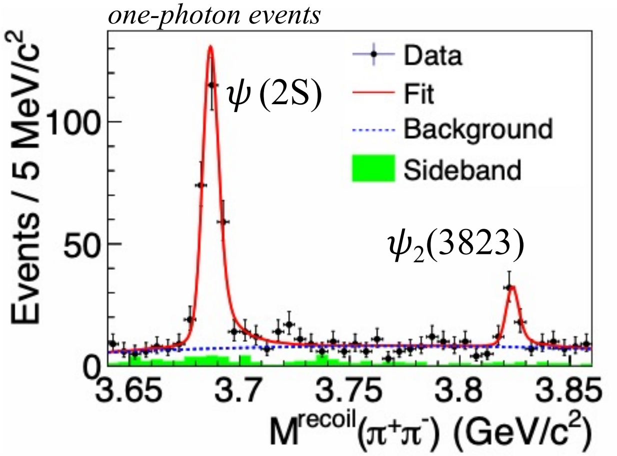


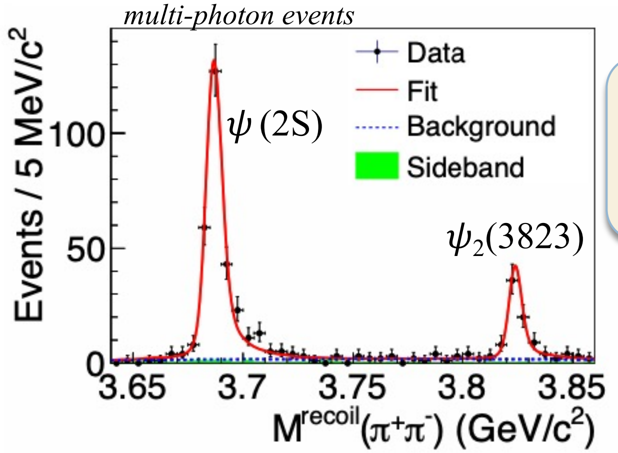


$\psi_2(3823)$ - the $\psi(1^3D_2)$ state?

arXiv:2203.05815

- $e^+e^- \to \pi^+\pi^-\psi_2(3823)$; $\psi_2(3823)\to\gamma\chi_{c1}$
  - update study of $\psi_2(3823)\to\gamma\chi_{c1}$ (PRL115,011803) allowing missing photon

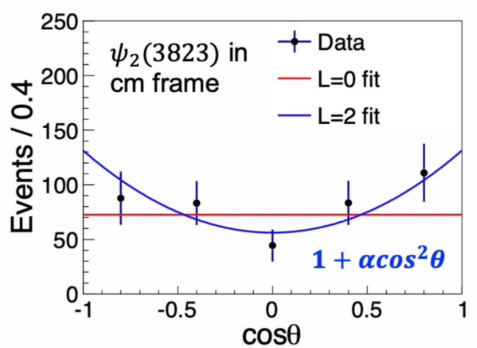




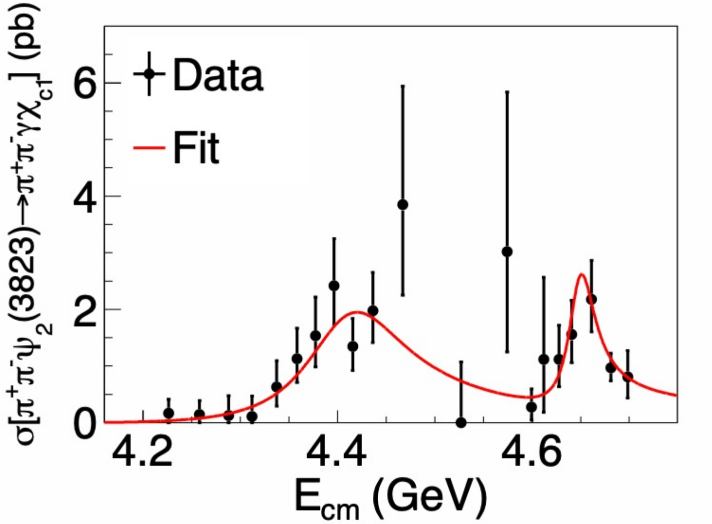
$M[\psi_2(3823)] = 3823.12 \pm 0.43 \pm 0.13\,\mathrm{MeV}/c^2$
$\Gamma[\psi_2(3823)] < 2.9\,\mathrm{MeV}$ @90% C.L.

Most precise to date

Fist observation of Y states decaying into D-wave charmonium state (two resonant structures with > 5σ)



L = 2 slightly favored over L=0

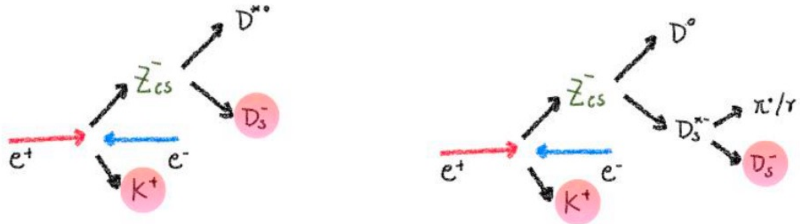


The Charged $Z_{cs}(3985)$ state

[PRL126, 102001(2021)]

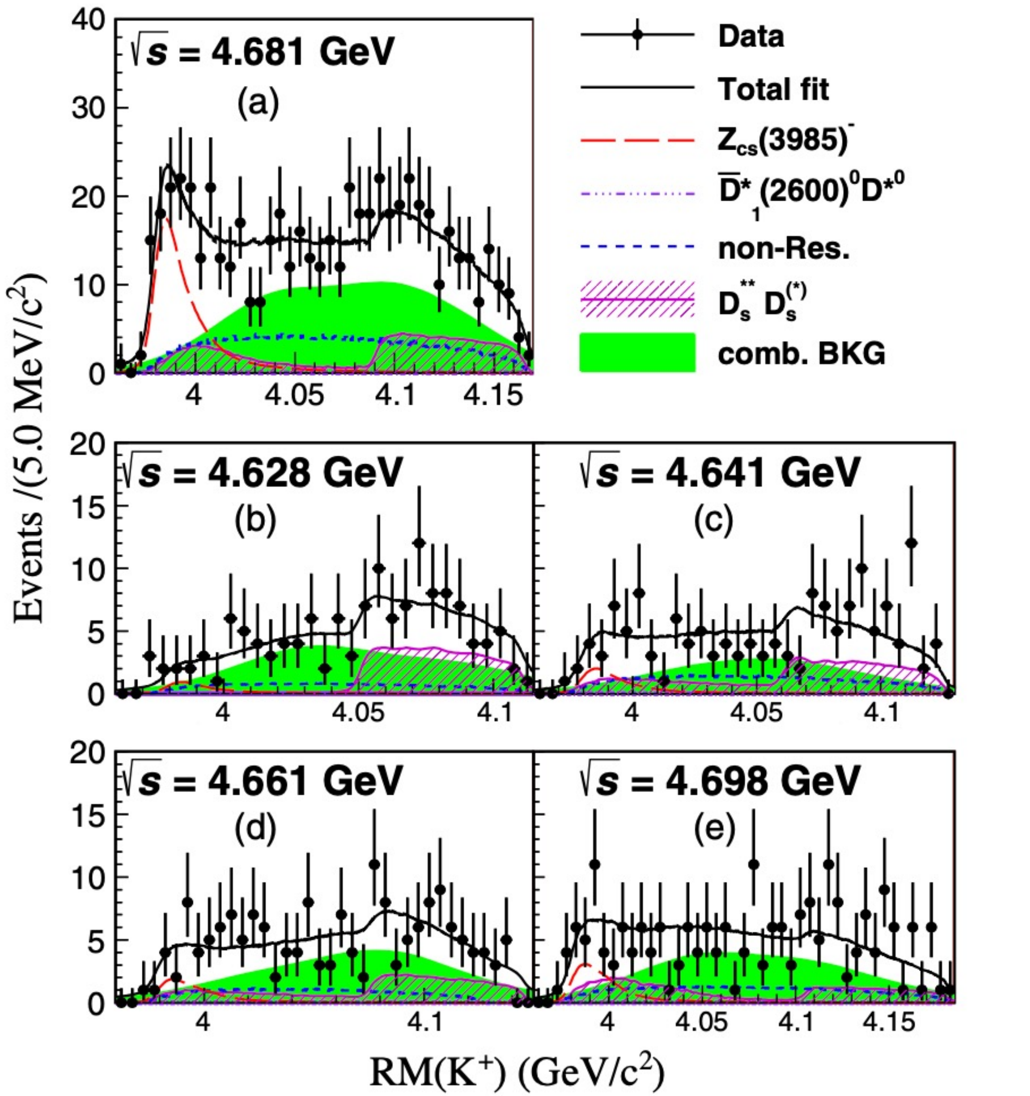
Search for the strange partner of $Z_c(3900)$

$$e^+e^- \to K^+(D_S^- D^{*0} + D_S^{*-} D^0)$$



partial reconstruction technique

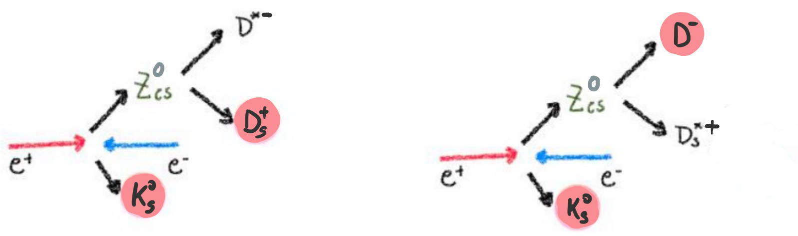
- Using 5 new datasets collected at $\sqrt{s}>4.6$ GeV
- 5.3σ excess close to threshold for data at $\sqrt{s} = 4.681$ GeV
  - Similar to $Z_{cs}(4000)$ seen by LHCb, but with different width [PRL127,082001(2021)]
- Minimal quark-content of $c\bar{c}s\bar{u}$



The Neutral $Z_{CS}(3985)$ state

arXiv:2204.13703

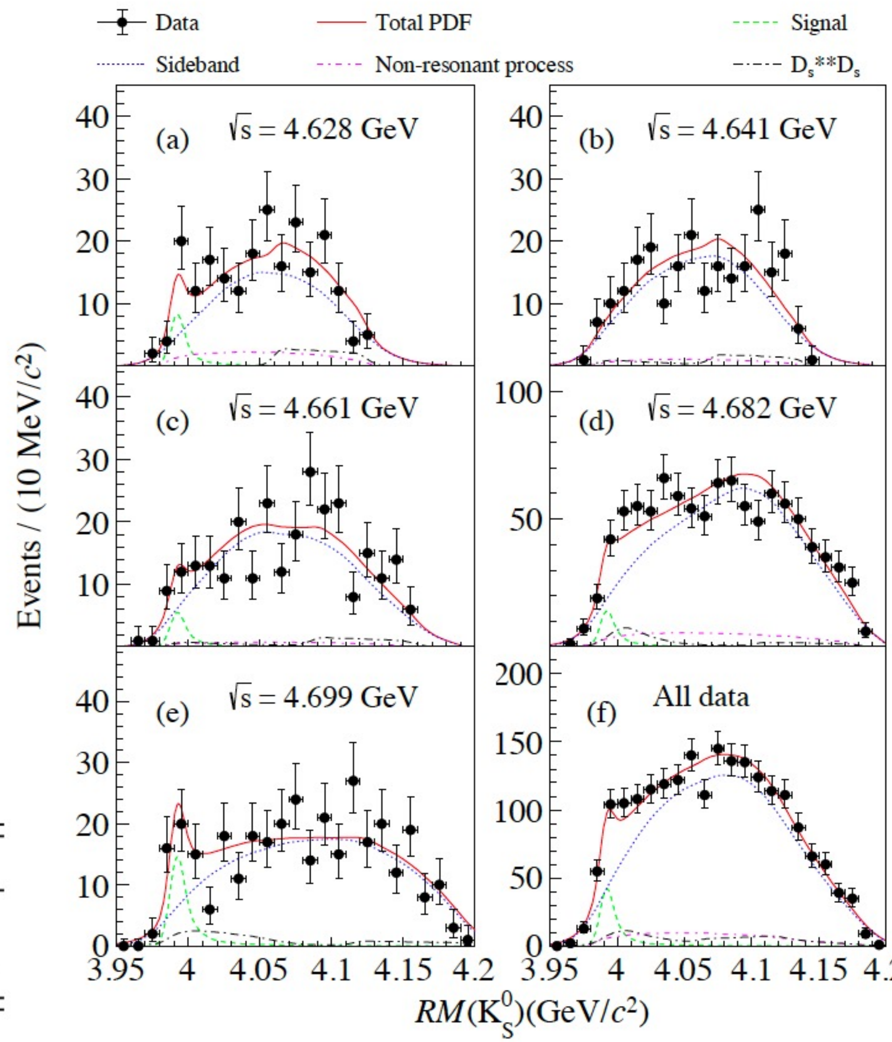
$$e^+e^- \to K_S^0(D_S^+D^{*-} + D_S^{*+}D^-)$$



partial reconstruction technique

- Evidence of neutral open-strange hidden charm state, $Z_{CS}(3985)^0$ with a significance of 4.6σ
- Minimal quark content $c\bar{c}\bar{s}d$
- $\sigma^{Born}(e^+e^- \to K^0 Z_{CS}(3985)^0)$ consistent with $\sigma^{Born}(e^+e^- \to K^- Z_{CS}(3985)^+)$ as expected under isospin symmetry

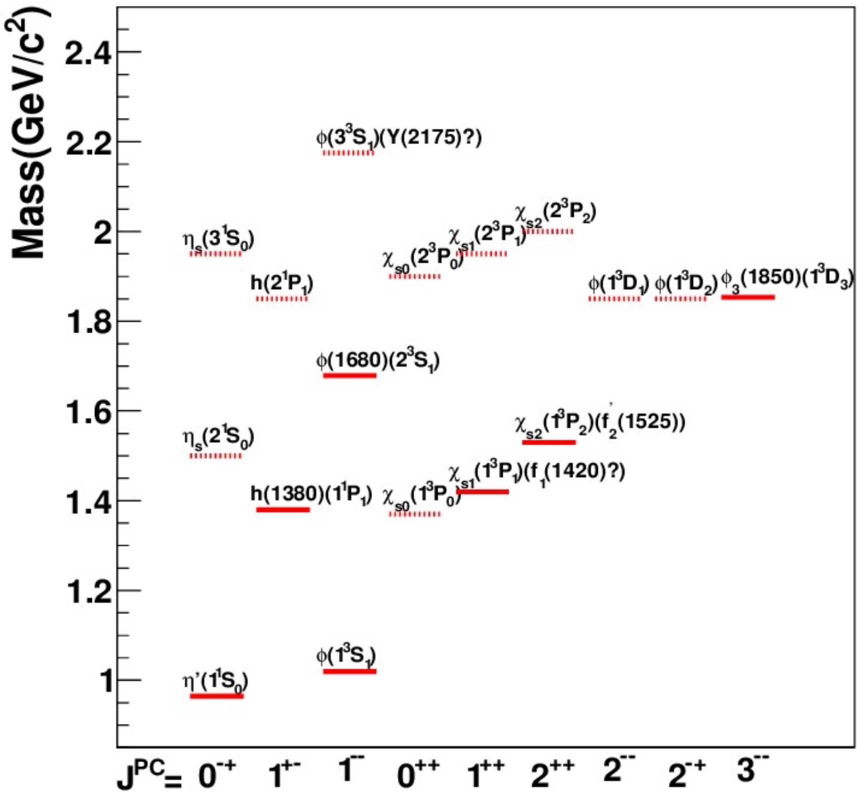
	Mass (MeV/c^2)	Width (MeV)
$Z_{cs}(3985)^0$	$3992.2 \pm 1.7 \pm 1.6$	$7.7^{+4.1}_{-3.8} \pm 4.3$
$Z_{cs}(3985)^+$	$3985.2^{+2.1}_{-2.0} \pm 1.7$	$13.8^{+8.1}_{-5.2} \pm 4.9$



Evidence of the isospin partner of the $Z_{CS}(3985)^+$

Strangeonia Spectrum

Strangeonia Spectrum



Strangeonium mesons

- Bridge between light quarks (u, d) and heavy quarks (c, b)
- Study of exotic states

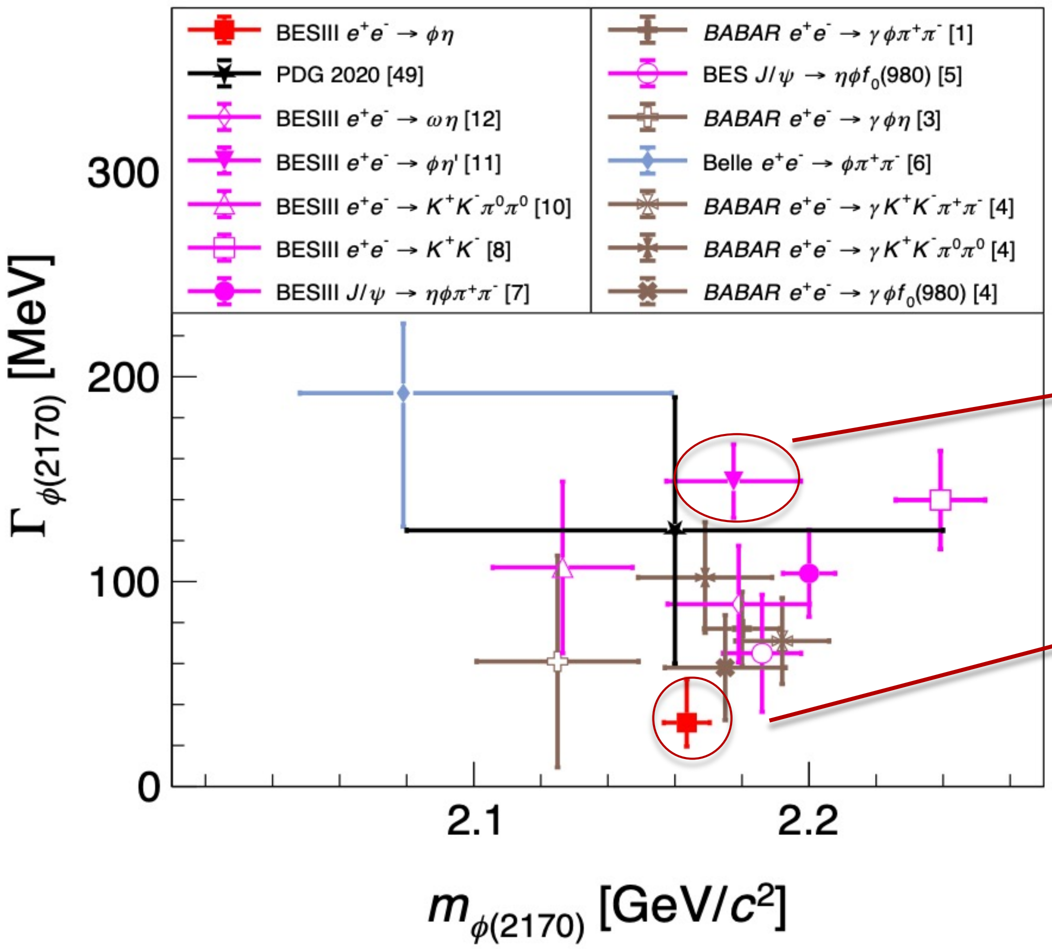
Only few states observed:

- Small BR
- Large Γ

$$e^+e^- \Rightarrow \begin{cases} Y(2175) \to \phi(1020)\pi^+\pi^- & \text{strange,} \\ Y(4260) \to J/\psi\pi^+\pi^- & \text{charm,} \\ \Upsilon(10860) \to \Upsilon(1S, 2S)\pi^+\pi^- & \text{bottom,} \end{cases}$$

- ϕ(2170)/Y(2175) observed for the first time in the ϕf_0 channel by BaBar (PRD **74**,091103; PRD **76**,031102)
  - BESIII: PRL**100**,102003(2008)
  - Belle: PRD**80**,031101 (2009)

$\phi(2170)$



[1] PRD74,091103
[3] PRD77,092002
[4] PRD86,012008
[5] PRL100,102003
[6] PRD80,031101

[7] PRD91,052017
[8] PRD99,032001
[10] PRL124,112001
[11] PRD102,012008
[12] PLB813,136059

PRD102,012008 ($e^+e^-\to\phi\eta'$)

$$M = 2177.5 \pm 4.8 \pm 19.5\ \text{MeV}/c^2$$
$$\Gamma = 149.0 \pm 15.6 \pm 8.9\ \text{MeV}$$

PRD 104, 032007 (2021) ($e^+e^-\to\phi\eta$)

$$M = 2163.5 \pm 6.2 \pm 3.0\ \text{MeV}/c^2$$
$$\Gamma = 31.1^{+21.1}_{-11.6} \pm 1.1\ \text{MeV}$$

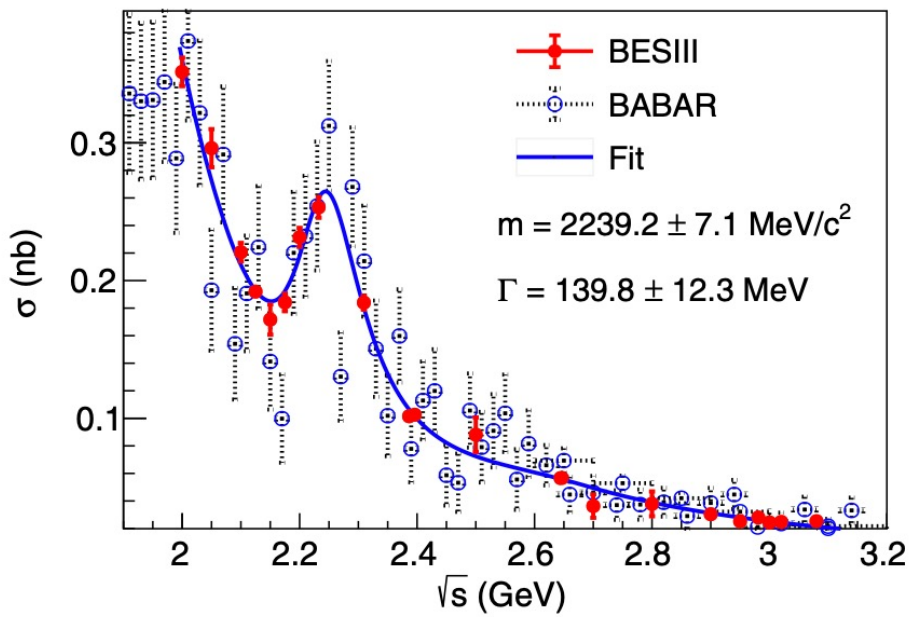
What is the $\phi(2170)$? Many interpretation

- $s\bar{s}g$ hybrid
- 2^3D_1 or 3^3S_1
- tetraquark
- molecular state $\Lambda\Lambda$
- $\phi f_0(980)$ resonance with FSI
- Three body system ϕKK

The nature of $\phi(2170)$ still not fully understood!

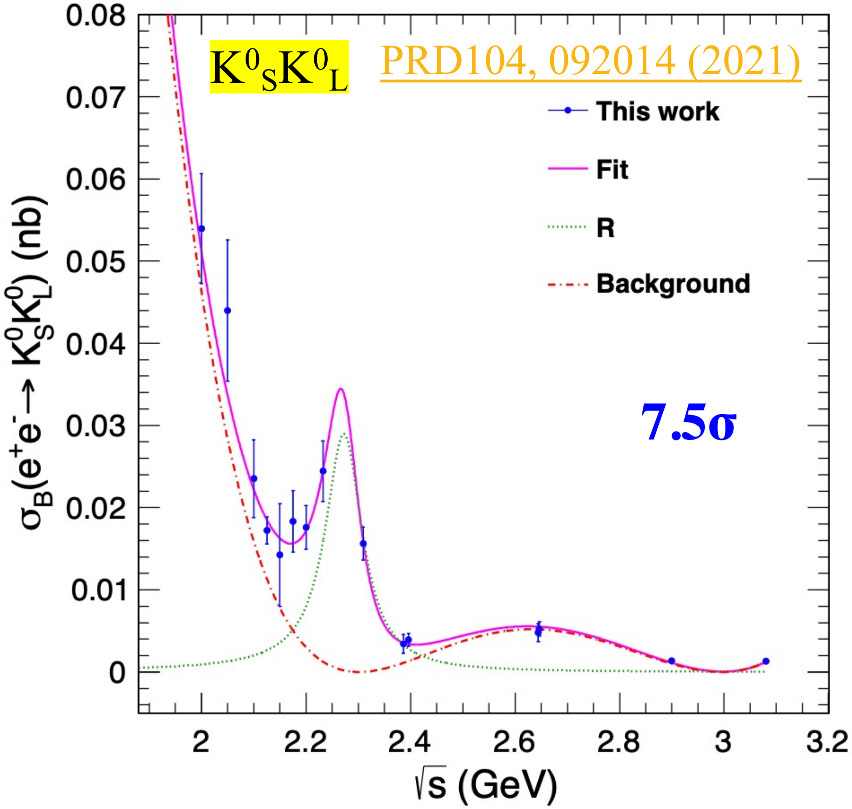
$\phi(2170)$ @ BESIII

PRD **99**, 032001 (2019)



$$M = 2239.2 \pm 7.1 \pm 11.3 \ \mathrm{MeV}/c^2$$
$$\Gamma = 139.8 \pm 12.3 \pm 20.6 \ \mathrm{MeV}$$

Consistent with BaBar PRD **88**,032012 (2018); PRD **92**,072008 (2015);



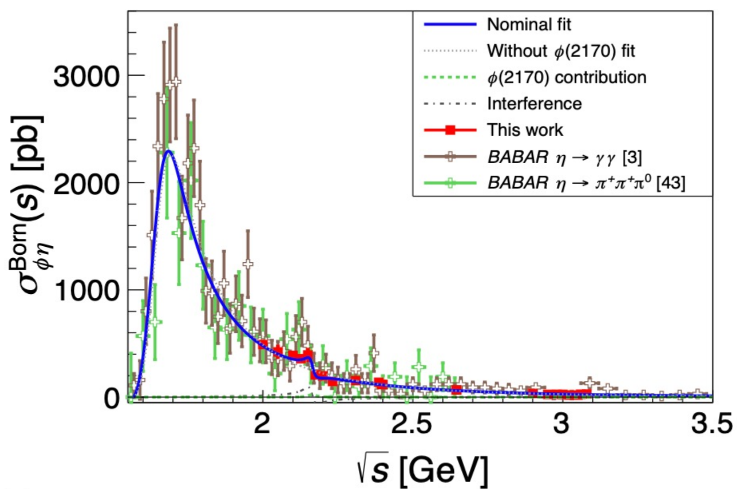
$$M = 2273.7 \pm 5.7 \pm 19.3 \ \mathrm{MeV}/c^2 \, ,$$
$$\Gamma = 86 \pm 44 \pm 51 \ \mathrm{MeV} \, ,$$

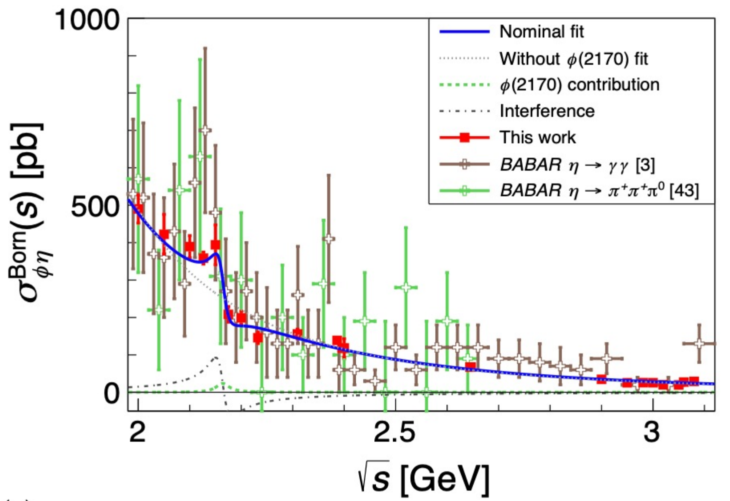
Consistent with BaBar PRD **101**,012011(2020)

$e^+e^- \to \phi\eta$ and $\phi\eta'$

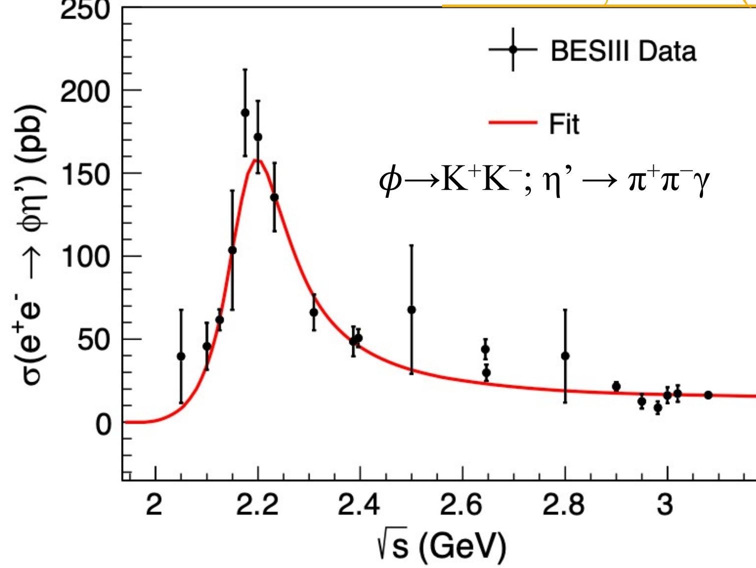
- The ratio between $\phi\eta$ and $\phi\eta'$ partial width is important observable to access $\phi(2170)$ as a $s\bar{s}g$ hybrid state
  - partial width larger in the $\phi\eta$ channel by a factor [3-200] w.r.t $\phi\eta'$

PRD **104**, 032007





PRD **102**,012008(2020)



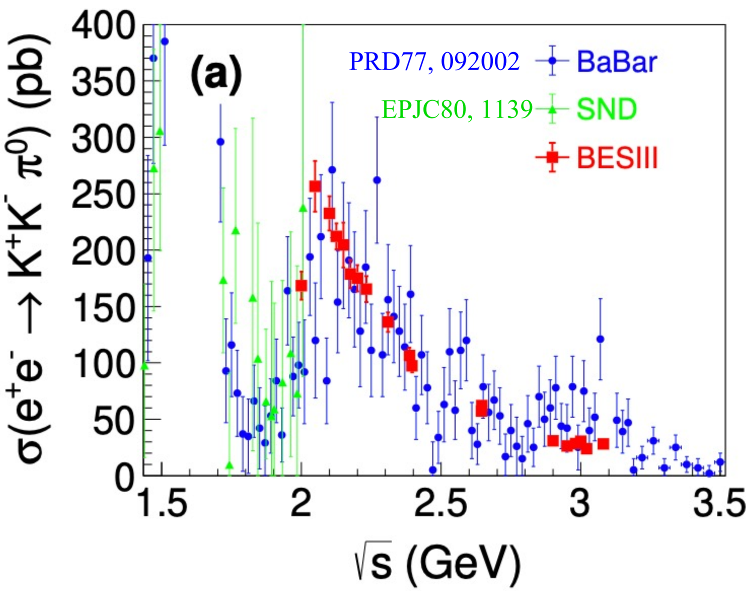
$$\frac{Br\,[\phi(2170)\to\phi\eta]\Gamma_{ee}}{Br\,[\phi(2170)\to\phi\eta']\Gamma_{ee}} = \begin{cases} 0.03^{+0.02}_{-0.01} \\ 1.42^{+0.56}_{-0.46} \end{cases}$$

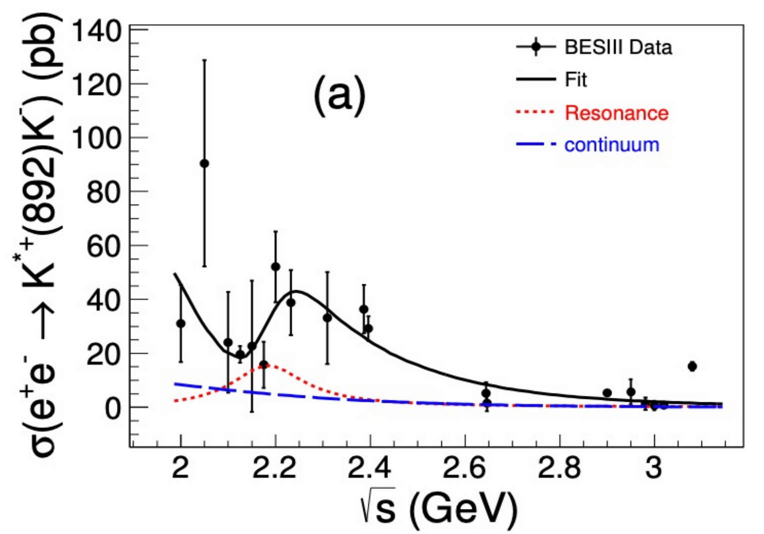
Small than prediction of the $s\bar{s}g$ hybrid model by several order o magnitude

Measurement of $e^+e^-\to K^+K^-\pi^0$ cross section

JHEP07, 045 (2022)

PWA analysis to 19 data points between 2.000 GeV and 3.080 GeV



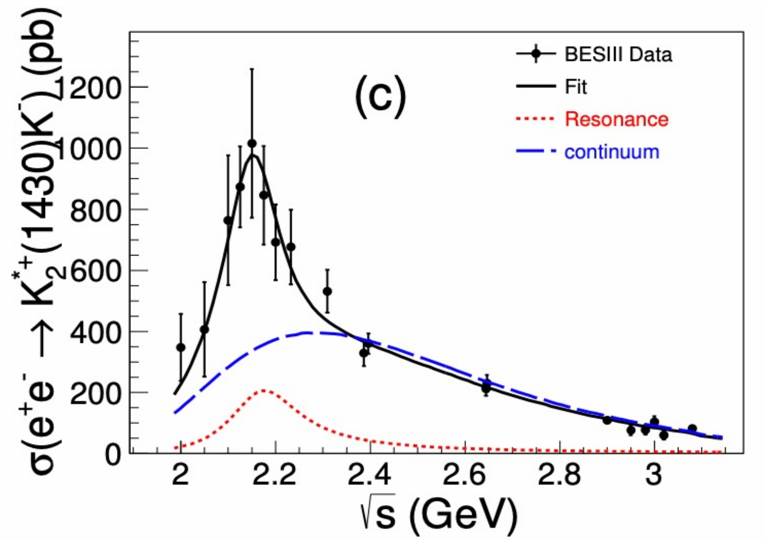


- Structure observed in the cross section of the intermediate processes $e^+e^-\to K^{*+}(892)K^-$ and $e^+e^-\to K_2{}^{*+}(1430)K^-$ with a significance of 7.1σ

$$R = \frac{\mathcal{B}r(\phi(2170) \to K_2^{*+}(1430)K^-)}{\mathcal{B}r(\phi(2170) \to K^{*+}(892)K^-)}$$

12.6±4.5 Sol1

22.7±4.1 Sol2

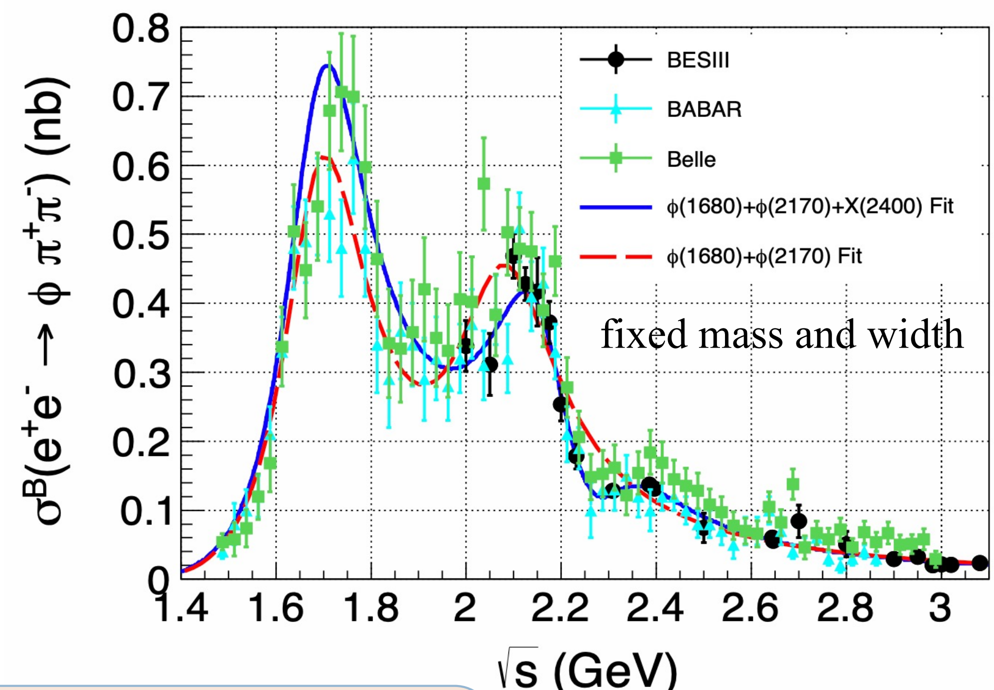


Measurement of $e^+e^- \to \phi\pi^+\pi^-$ cross section

- 22 data points between 2.000 GeV and 3.080 GeV

arXiv:2112.13219

- Clear structure ($\phi(2170)$) and enhancement (X(2400)) can be seen at around 2.1 and 2.4 GeV, respectively
  - significance of 8.5σ for the X(2400)
- Cross section consistent with previous BaBar (PRD86, 012008) and Belle data (PRD80, 031101(R))



$\phi(2170)$

$$M = 2158^{+30}_{-33} \pm 4\ \mathrm{MeV}/c^2$$

$$\Gamma = 218^{+81}_{-64} \pm 5\ \mathrm{MeV}$$

X(2400)

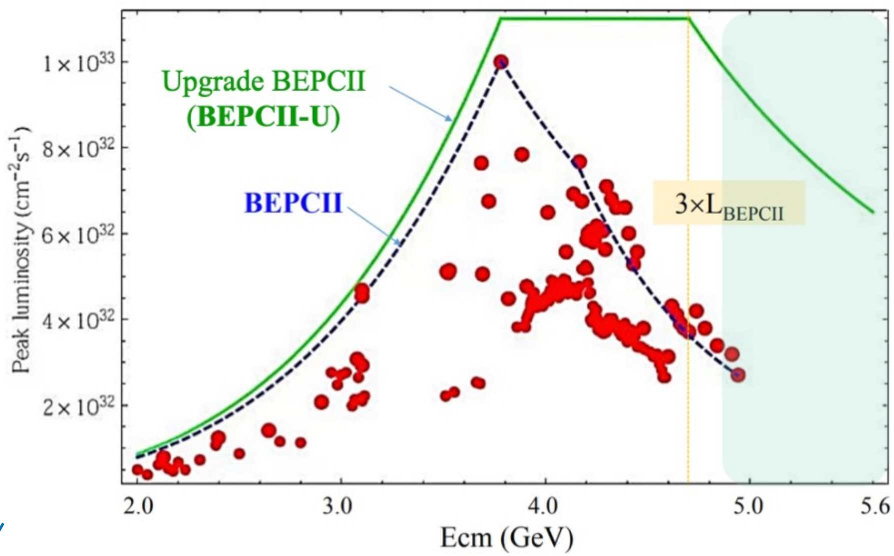
$$M = 2298^{+60}_{-44} \pm 6\ \mathrm{MeV}/c^2$$

$$\Gamma = 219^{+117}_{-112} \pm 6\ \mathrm{MeV}$$

- Independent data sample in the $\phi(1680)$ mass region is needed for further investigation
- More data points in the 2.4 GeV region for a deeper investigation of X(2400)

Summary and Outlook

- BESIII is taking data since 2008. It will continue to run ~2030
  - Selection of latest physics results (based mainly on spectroscopy) are presented
    - Observation of exotic isoscalar $\eta_1(1855)$ state and the new X(2600) state observed in J/ψ radiative decays
    - Y states and $Z_{CS}(3985)$ triplet states
    - Latest search on the $\phi(2170)$ strangeonium state
  - …. Many other not covered in this talk
- Many analysis in progress!!!
- First data at higher c.m. energies in now available ($4.7 < \sqrt{s} < 4.94$ GeV)
- Further upgrade in energy (5.6 GeV) and luminosity (BEPCII-U, 3x) planned for the next year

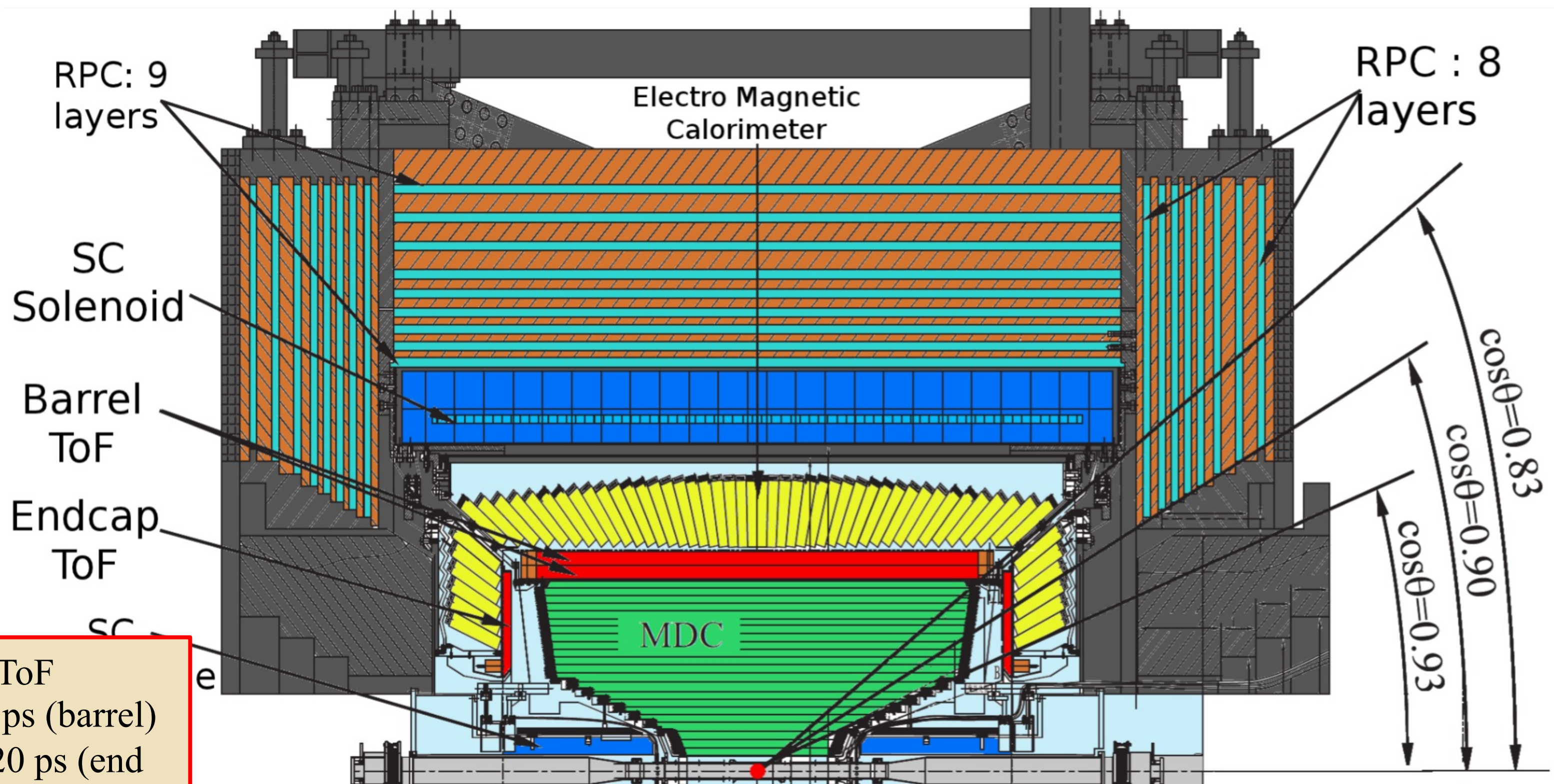


Thank you for your attention

Back-up slides

The BESIII Detector

Nucl. Instr. Meth. A614, 345 (2010)



ToF
$\sigma_t \sim 90$ ps (barrel)
$\sigma_t \sim 120$ ps (end caps)

Drift Chamber
$\sigma_{r\phi} \sim 130\ \mu m$ (single wire)
$\sigma_{pt}/p_t \sim 0.5\ \%$ @ 1 GeV

Electromagnetic CsI(Tl) Calorimeter
$\sigma_E/E < 2.5\%$ @ 1 GeV (barrel)
$\sigma_E/E < 5\%$ @ 1 GeV (end caps)
$\sigma_{xy} \sim (6\ mm)/E^{1/2}$ @ 1 GeV

RPC Muon Detector
$\Delta\Omega/4\pi=93\%$

BESIII physics programme

Light hadron physics

- Meson and baryon spectroscopy
- Multiquark states
- Threshold effects
- Glueballs and hybrids
- two-photon physics
- Form factors

XYZ meson physics

- Y(4260), Y(4360) properties
- $Z_c(3900)^+$, …

Charm physics

- Semi-leptonic form factors
- Decay constants f_D and f_{Ds}
- CKM matrix: $|V_{cd}|$ and $|V_{cs}|$
- D^0-$\overline{D}^0$ mixing, CPV
- Strong phases

QCD and τ

- Precision R measurement
- τ decay

Charmonium physics

- Precision spectroscopy
- Transitions and decays

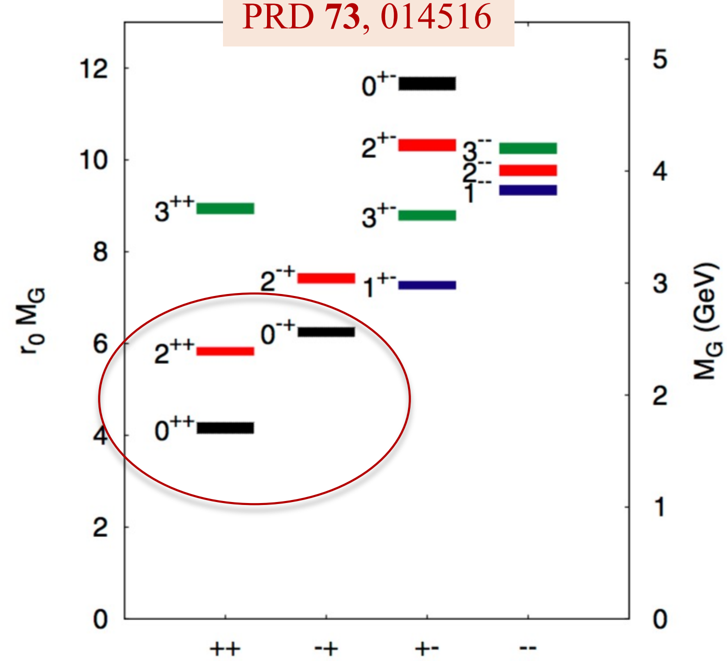
Precision mass measurements

- τ mass
- D, D^* mass

Amplitude Analyses in BESIII

- J/ψ radiative decays are ideal for searching glueballs
  - **$J/\psi \to \gamma PP$: 0^{++}, 2^{++}, …**
  - **$J/\psi \to \gamma PPP$, γVV: 0^{-+}**
- Neutral channel is much cleaner than the charged ones
- Very complicated mass spectrum in the low mass region: many broad, overlapping states complicate the study of the spectra

PRD **73**, 014516



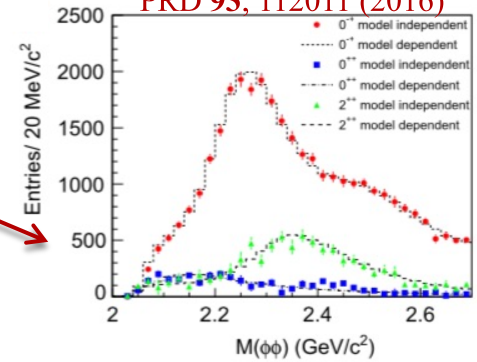
- **Amplitude analysis: toll to extract the complex amplitudes from experimental data**
  - Models with free parameters
  - Consider the kinematic of final states particles
  - Vary the parameters to maximize the likelihood
  - **Mass Dependent (MD) PWA**: model the dynamics of particle interactions as coherent sum of resonances
  - **Mass Independent (MI) PWA**: make minimal model assumptions and measure the dynamical amplitudes independently in small regions of two-meson invariant mass (PRD92, 052003 (2015))

PWA status and plans in a nutshell

	0+	2+	0−
$J/\psi \to \gamma PP$	$J/\psi \to \gamma\eta\eta$ (PRD87,092009) $J/\psi \to \gamma\pi^0\pi^0$ (PRD92,052003) $J/\psi \to \gamma K_S K_S$ (PRD98,072003) $J/\psi \to \gamma\eta\eta'$ $J/\psi \to \gamma\eta'\eta'$		
$J/\psi \to \gamma VV$		$J/\psi \to \gamma\omega\phi$ (PRD87,032008) $J/\psi \to \gamma\phi\phi$ (PRD93,112011) $J/\psi \to \gamma\omega\omega$	
$J/\psi \to \gamma PPP$			$J/\psi \to \gamma\eta'\pi\pi$ (PRL106,072002) $J/\psi \to \gamma KK\eta'$ $J/\psi \to \gamma\eta\pi^0\pi^0$

PWA Published
Ongoing
Published, no PWA

PRD **93**, 112011 (2016)

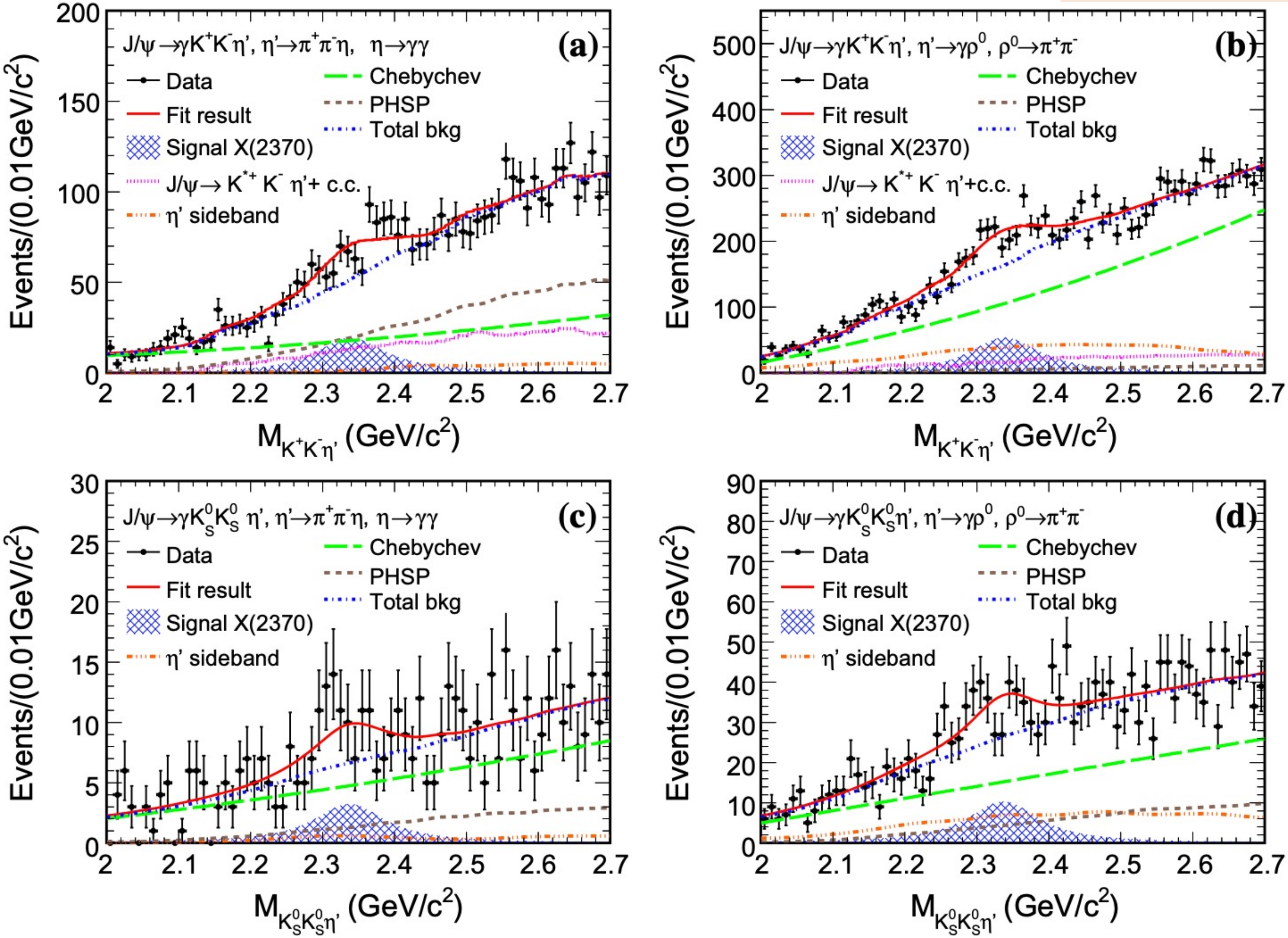


- 0++: the production rate $f_0(1710)$ is compatible with LQCD prediction for a pure gauge scalar glueball
- 2++: $f_0(2340)$ seems to be a good candidate for tensor glueball [PRL111,091601] (large production rate)
- 0−+: $\eta(2225)$ is confirmed and two additional pseudoscalar states, $\eta(2100)$ and $X(2500)$, are observed

First Observation of X(2370) in $J/\psi \to \gamma K\bar{K}\eta'$

1.3×10⁹ J/ψ @ BESIII

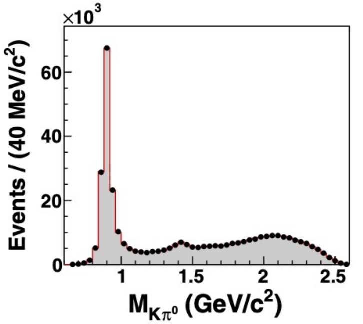
EPJC **80**, 746 (2020)



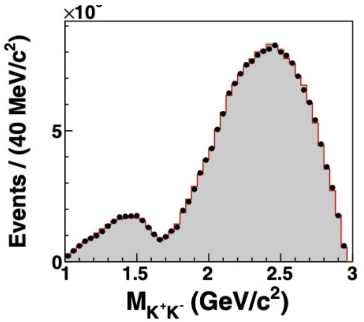
PWA of $J/\psi \to K^+K^-\pi^0$

PRD **100**,032004(2019)

J^{PC}	PDG	M (MeV/c^2)	Γ (MeV/c^2)	b (%)
1^-	$K^*(892)^\pm$	$893.6 \pm 0.1^{+0.2}_{-0.3}$	$46.7 \pm 0.2^{+0.1}_{-0.2}$	$93.4 \pm 0.4^{+1.8}_{-5.8}$
1^-	$K^*(1410)^\pm$	$1380^\star$	$176^\star$	0.26 ± 0.04
1^-	$K^*(1680)^\pm$	$1677^\star$	$205^\star$	0.20 ± 0.03
2^+	$K_2^*(1430)^\pm$	$1432.7 \pm 0.7^{+2.2}_{-2.3}$	$102.5 \pm 1.6^{+3.1}_{-2.8}$	$9.4 \pm 0.1^{+0.8}_{-0.5}$
2^+	$K_2^*(1980)^\pm$	$1868 \pm 8^{+40}_{-57}$	$272 \pm 24^{+50}_{-15}$	$0.38 \pm 0.04^{+0.22}_{-0.05}$
3^-	$K_3^*(1780)^\pm$	$1781^\star$	$203^\star$	0.16 ± 0.02
4^+	$K_4^*(2045)^\pm$	$2090 \pm 9^{+11}_{-29}$	$201 \pm 19^{+57}_{-17}$	$0.21 \pm 0.02^{+0.10}_{-0.05}$
3^-	Nonresonant	$\cdots$	$\cdots$	$\sim$1.5%



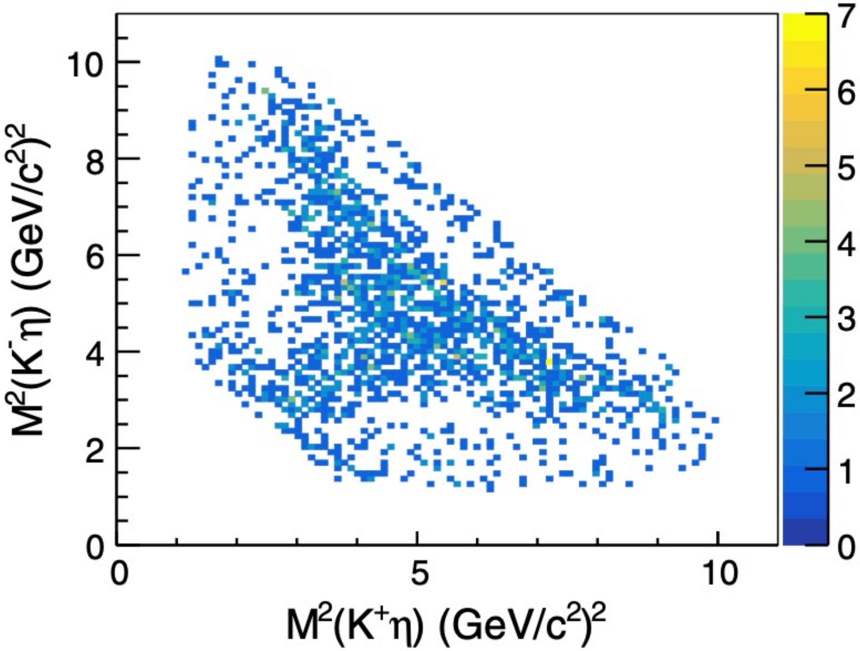
J^{PC}	M (MeV/c^2)	Γ (MeV/c^2)	b (%)
1^{--}	$1651 \pm 3^{+16}_{-6}$	$194 \pm 8^{+15}_{-7}$	$1.83 \pm 0.11^{+0.19}_{-0.17}$
1^{--}	$2039 \pm 8^{+36}_{-18}$	$196 \pm 23^{+25}_{-27}$	$0.23 \pm 0.04^{+0.07}_{-0.06}$

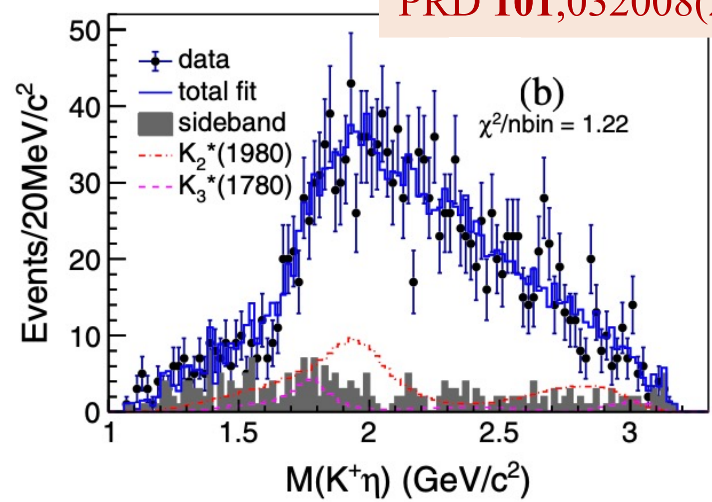


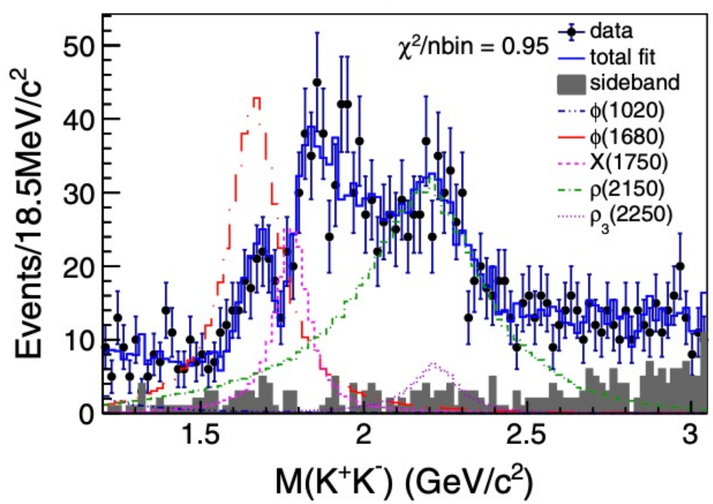
- Dominant contribution from $K^*(892)$
- First observation of $K^*_2(1980)$ and $K^*_4(2045)$ in J/ψ decays
- Two clear $J^{PC}=1^{--}$ structures observed in K^+K^- mass spectrum: possible relation with ω(1650) and ρ(2150)

PWA of $\psi(3686) \to KK\eta$

PRD **101**,032008(2020)

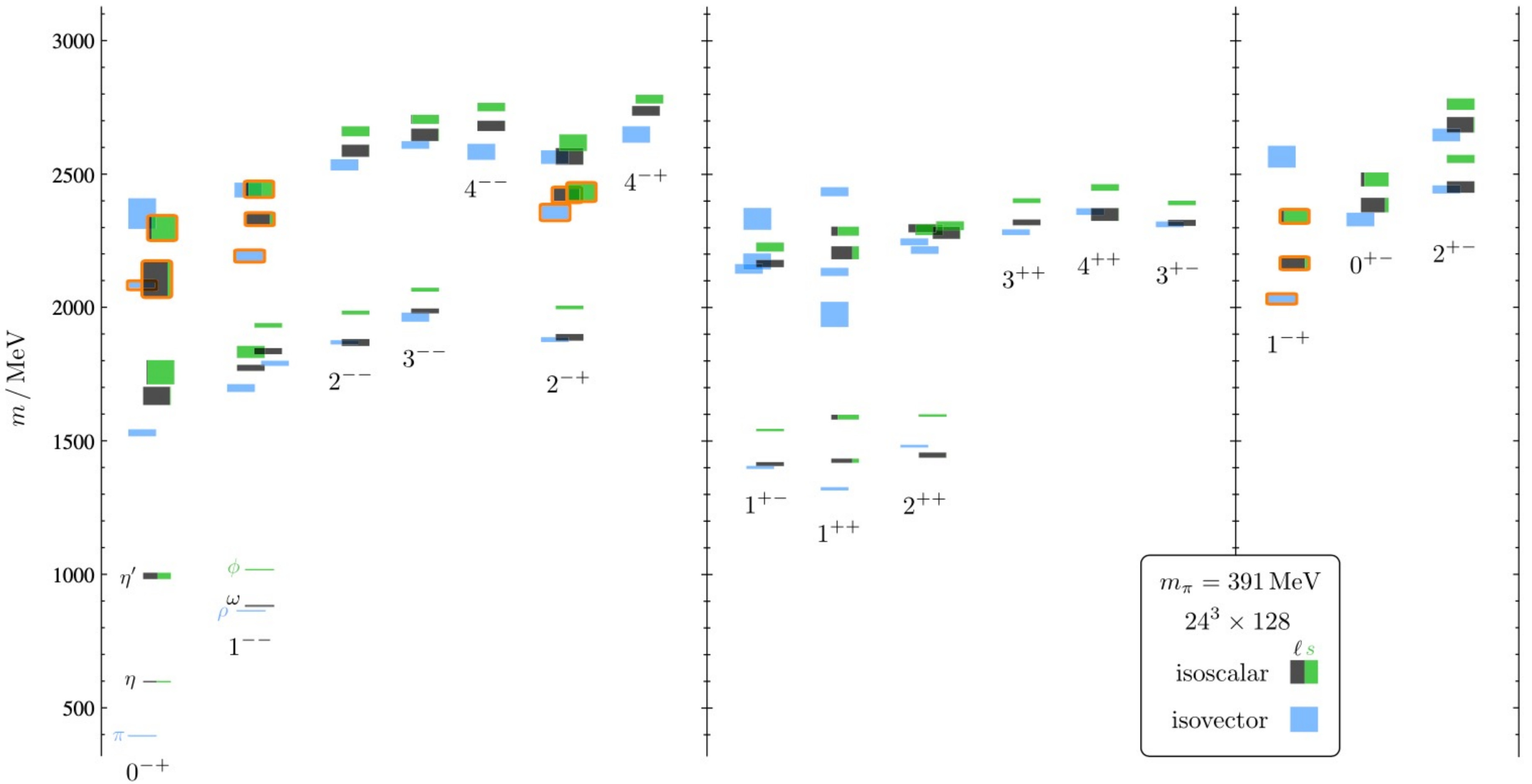






- Observation of $\phi(1680)$ in the KK mass spectra
- 1^{--} state needed to describe the dip around 1.7 GeV/c^2 in the KK mass spectra (X(1750)? but not excluded the possibility to be the ρ(1700))

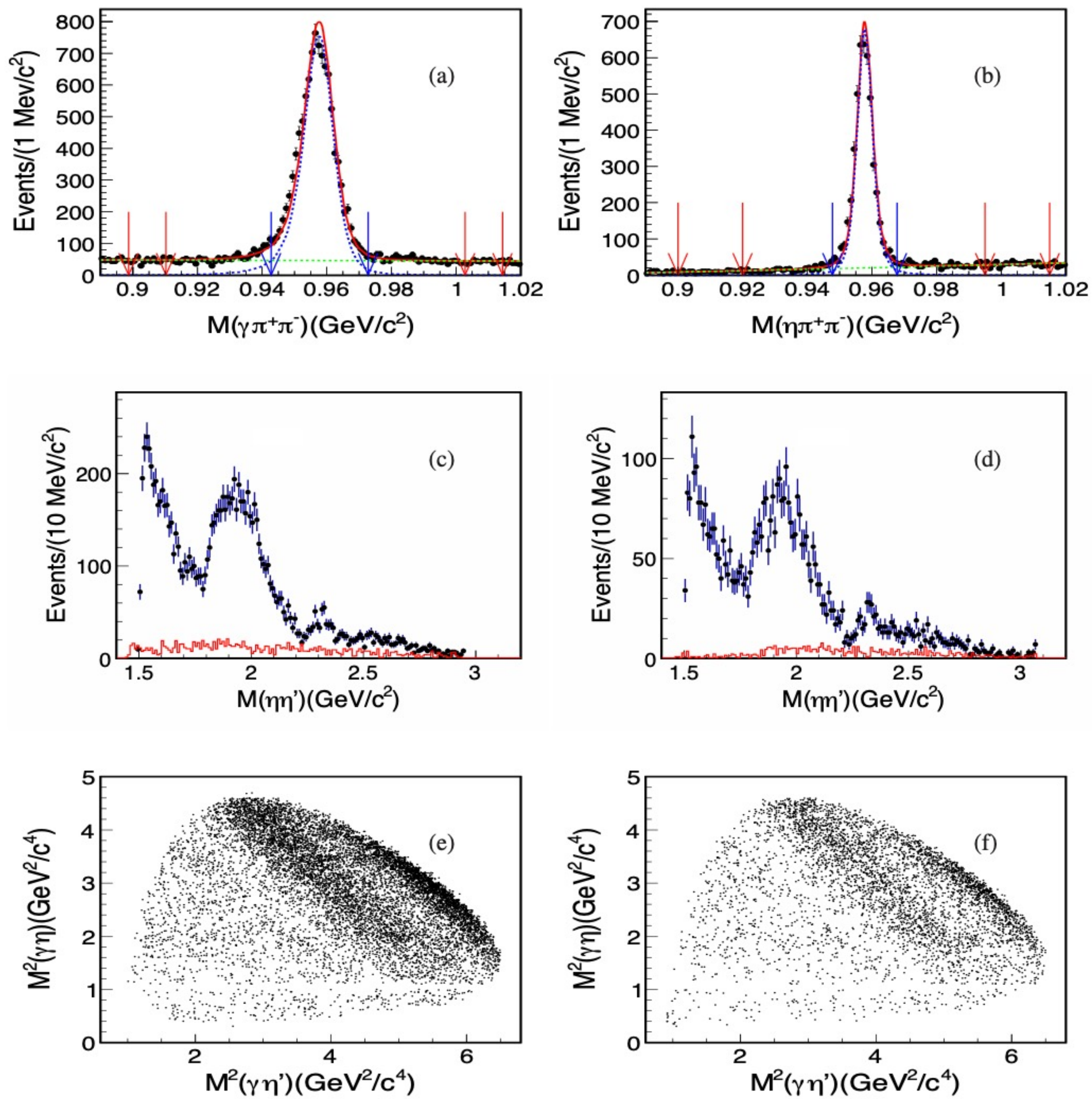
- A broad structure around 2.2 GeV/c^2 is observed, either $\phi(2170)$ or ρ(2150)?



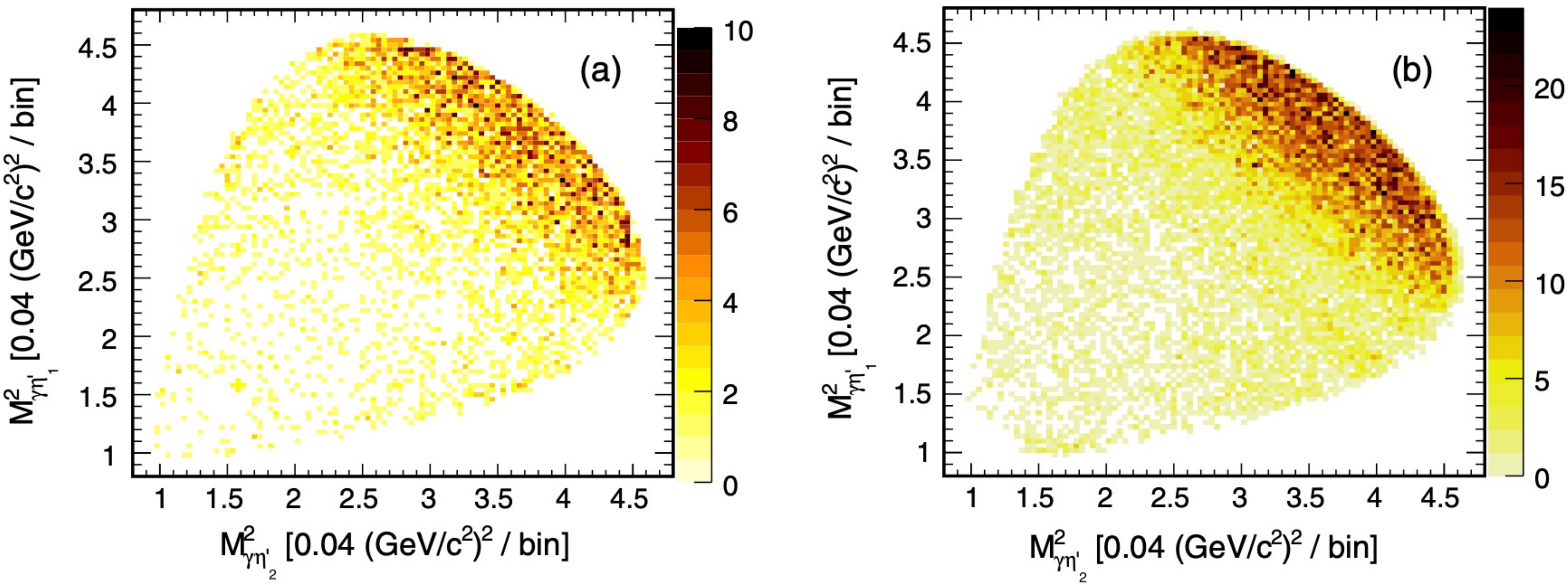
3000
2500
2000
1500
1000
500
m / MeV
η'
η
π
ϕ
ω
ρ
0^{-+}
1^{--}
2^{--}
3^{--}
4^{--}
2^{-+}
4^{-+}
1^{+-}
1^{++}
2^{++}
3^{++}
4^{++}
3^{+-}
1^{-+}
0^{+-}
2^{+-}
$m_\pi = 391$ MeV
$24^3 \times 128$
ℓ s
isoscalar
isovector

Decay mode	0^{++}	2^{++}	4^{++}
$J/\psi \to \gamma X \to \gamma\eta\eta'$	$f_0(1500)$	$f_2(1525)$	$f_4(2050)$
	$f_0(1710)$	$f_2(1565)$	$f_4(2300)$
	$f_0(1810)$[58]	$f_2(1640)$	$f_4(2283)$[57]
	$f_0(2020)$	$f_2(1810)$	
	$f_0(2100)$	$f_2(1910)$	
	$f_0(2200)$	$f_2(1950)$	
	$f_0(2330)$	$f_2(2010)$	
	$f_0(2102)$[57]	$f_2(2150)$	
	$f_0(2330)$[57]	$f_2(2220)$	
		$f_2(2300)$	
		$f_2(2340)$	
		$f_2(2240)$[57]	

	1^{--}	1^{+-}
$J/\psi \to \eta^{(\prime)} X \to \gamma\eta\eta'$	$\omega(1420)$	$h_1(1415)$
	$\omega(1650)$	$h_1(1595)$
	$\phi(1680)$	
	$\phi(2170)$	
	$\rho(1450)$	
	$\rho(1700)$	
	$\rho(1900)$	



PRD 105, 072002



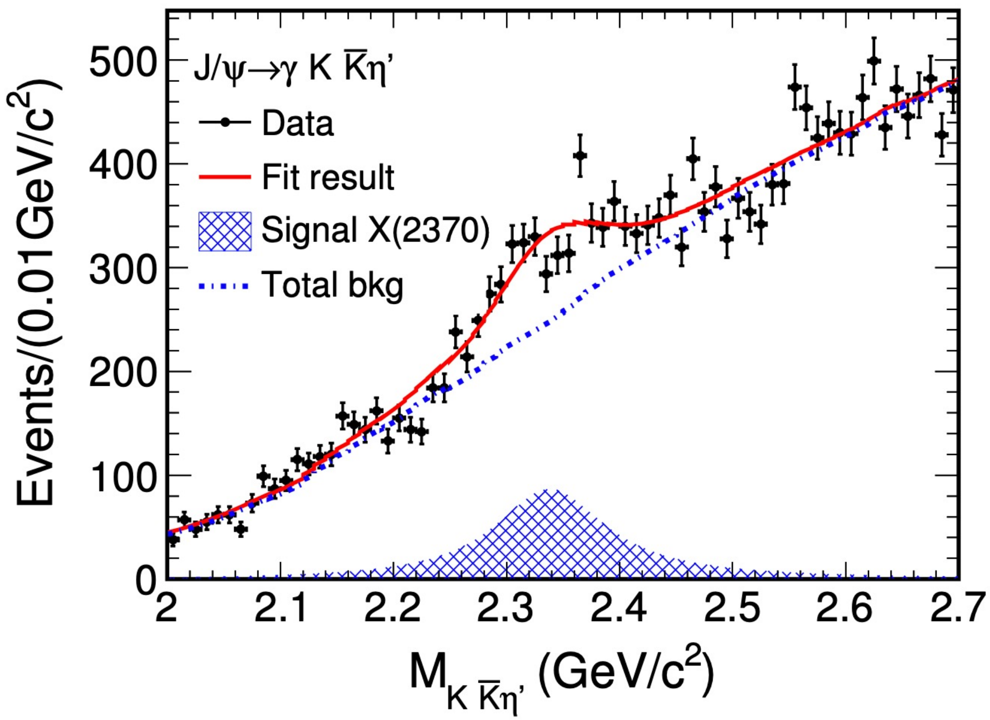
First Observation of X(2370) in $J/\psi \to \gamma K\bar{K}\eta'$

1.3×10^9 J/ψ @ BESIII

EPJC **80**, 746 (2020)

- X(2120) and X(2370) states observed in the $\pi^-\pi^+\eta'$ invariant mass spectra (PRL**106**,072002)
- The **X(2370)** measured mass is consistent with the pseudoscalar glueball candidate predicted by LQCD calculation (PRD**73**,014516)

> Simulataneus fit performed for two decay η' modes



> **No evidence of X(2120) is found**

$\mathcal{B}(J/\psi \to \gamma X(2120) \to \gamma K^+K^-\eta') < 1.49 \times 10^{-5}$

$\mathcal{B}(J/\psi \to \gamma X(2120) \to \gamma K^0_S K^0_S\eta') < 6.38 \times 10^{-6}$

> **Clear X(2370) signal observed with significance of about 8.3σ**

$$M_{X(2370)} = 2341.6 \pm 6.5 \pm 5.7\ \mathrm{MeV}/c^2 \quad \Gamma_{X(2370)} = 117 \pm 10 \pm 8\ \mathrm{MeV}$$

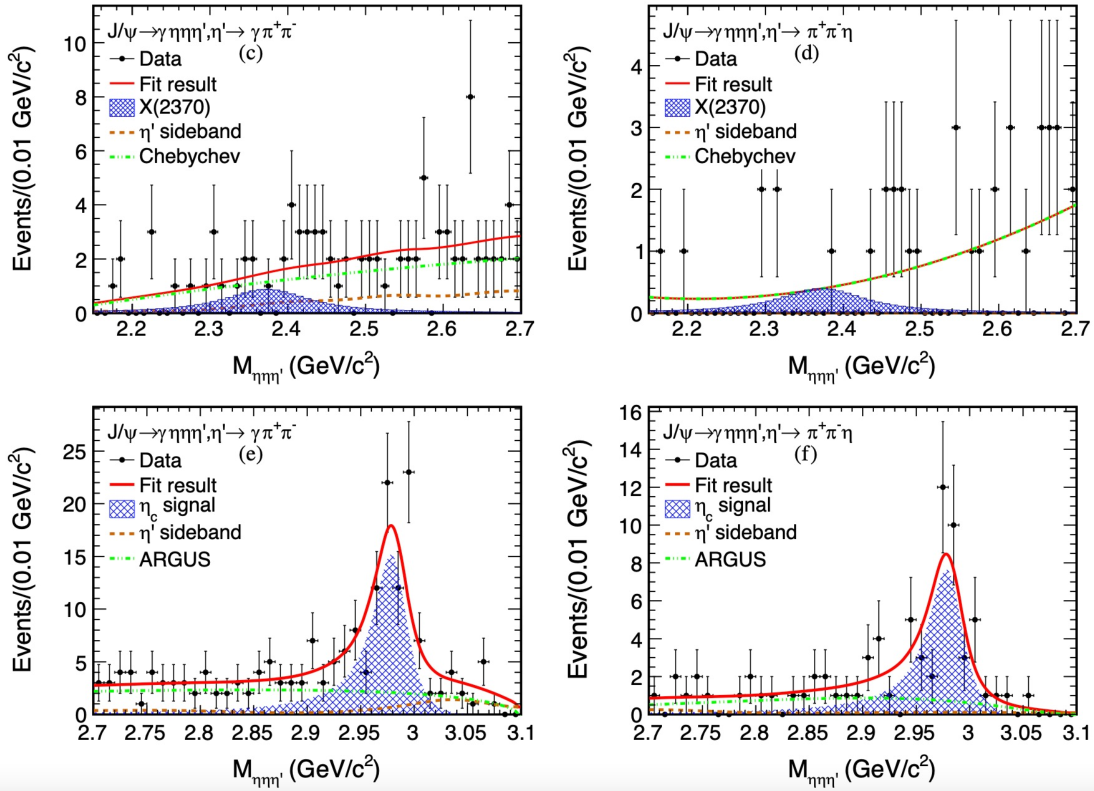
$$\mathcal{B}(J/\psi \to \gamma X(2370) \to \gamma K^+K^-\eta') = (1.79 \pm 0.23 \pm 0.65) \times 10^{-5}$$

$$\mathcal{B}(J/\psi \to \gamma X(2370) \to \gamma K^0_S K^0_S\eta') = (1.18 \pm 0.32 \pm 0.39) \times 10^{-5}$$

Search for X(2370) in $J/\psi \to \gamma\eta\eta\eta'$

PRD **103**, 012009 (2021)

1.3×10^9 J/ψ @ BESIII



Branching ratios prediction for the decay of pseudoscalar glueball with M~2.37 GeV into three pseudoscalar mesons (PRD **87**,054036 (2013))

$$\Gamma_{G\to\eta\eta\eta'}/\Gamma_G^{tot} = 0.00082$$
$$\Gamma_{G\to KK\eta'}/\Gamma_G^{tot} = 0.011$$
$$\Gamma_{G\to\pi\pi\eta'}/\Gamma_G^{tot} = 0.090$$

- **No obvious signal of X(2370)**

Simultaneous unbinned maximum likelihood fit to the ηηη' is performed and the 90% C.L. upper limit is calculated

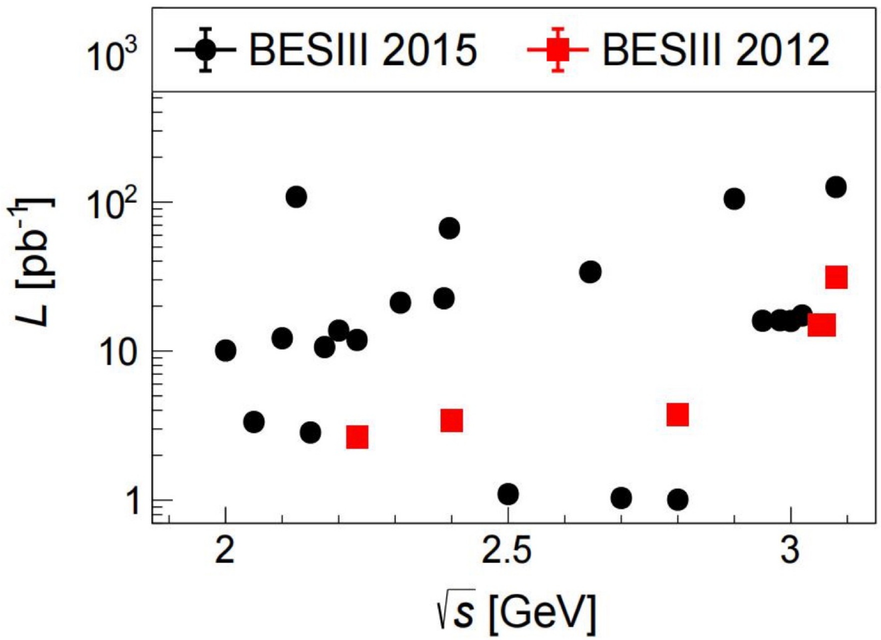
$$\mathcal{B}(J/\psi \to \gamma X(2370) \to \gamma\eta\eta\eta') < 9.2\times10^{-6}$$

(it does not contradict PRD **87**,054036)

$$\mathcal{B}(J/\psi \to \gamma\eta_c)\cdot\mathcal{B}(\eta_c \to \eta\eta\eta') = (4.86 \pm 0.62 \pm 0.45)\times10^{-5}$$

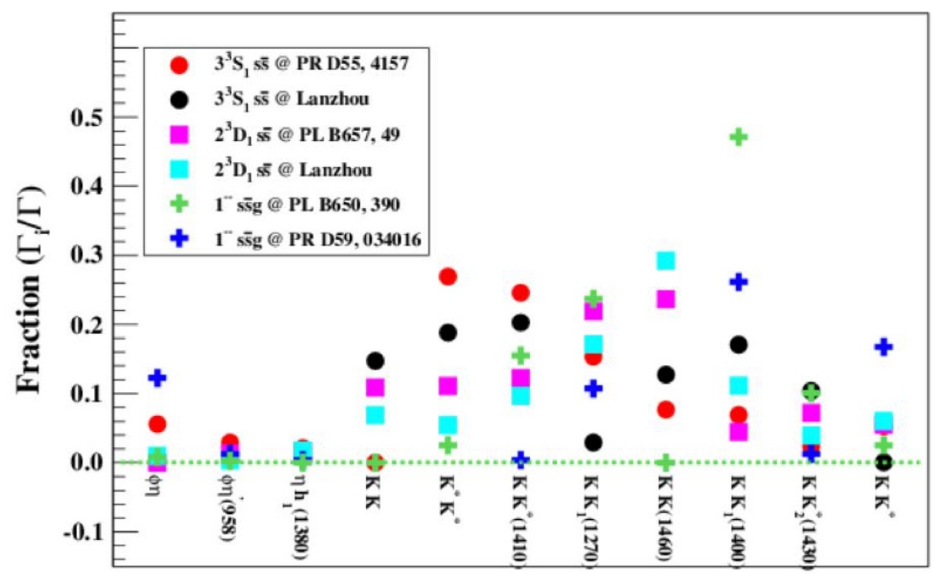
FIRST OBSERVATION in the ηηη' invariant mass spectra

$\phi(2170)$ @ BESIII



dataset

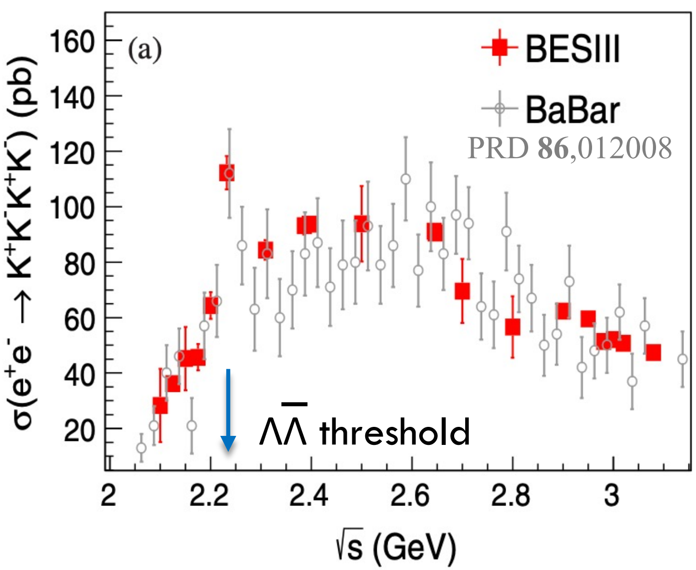
theoretical prediction



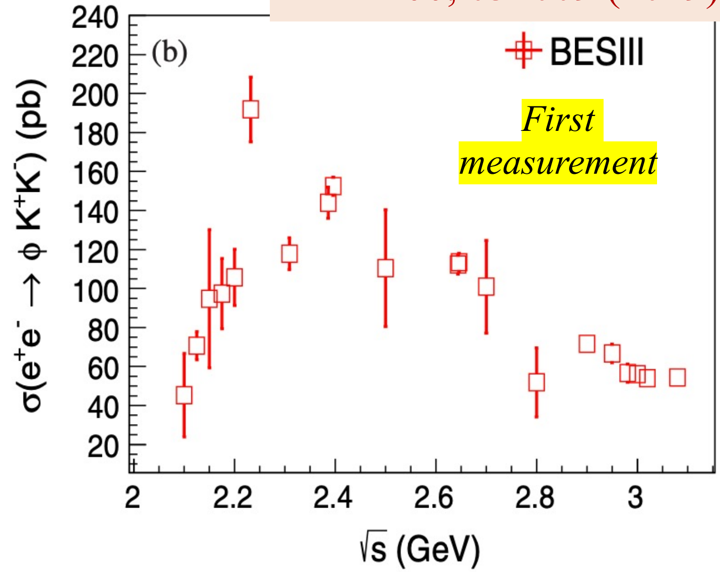
$\phi(2170)$ @ BESIII

Resonant structure in the 4K spectra, but difficult to disentangle from other final state

ϕ(2170) or new strangeonium state?



PRD **100**, 032009 (2019)



PRD **99**, 112008 (2019) - **1.3×10^9 J/ψ events**

J/ψ→$\phi\eta\eta$'

- Evidence of a structure in the $\phi\eta$' mass spectra
- Distribution of η polar angle in the J/ψ rest frame used to investigate the J^P assignment
- Significance of structure: 4.4σ for J^P = 1$^-$ and 3.8 for J^P = 1$^+$

no PDG entries

mass 5σ away from that reported on PDG