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Light Meson Spectroscopy at BESIII

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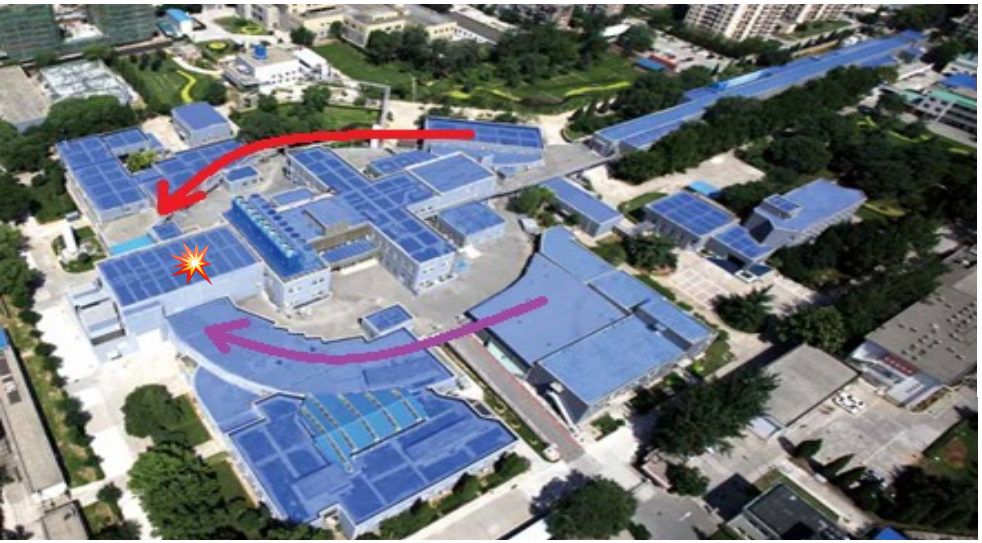
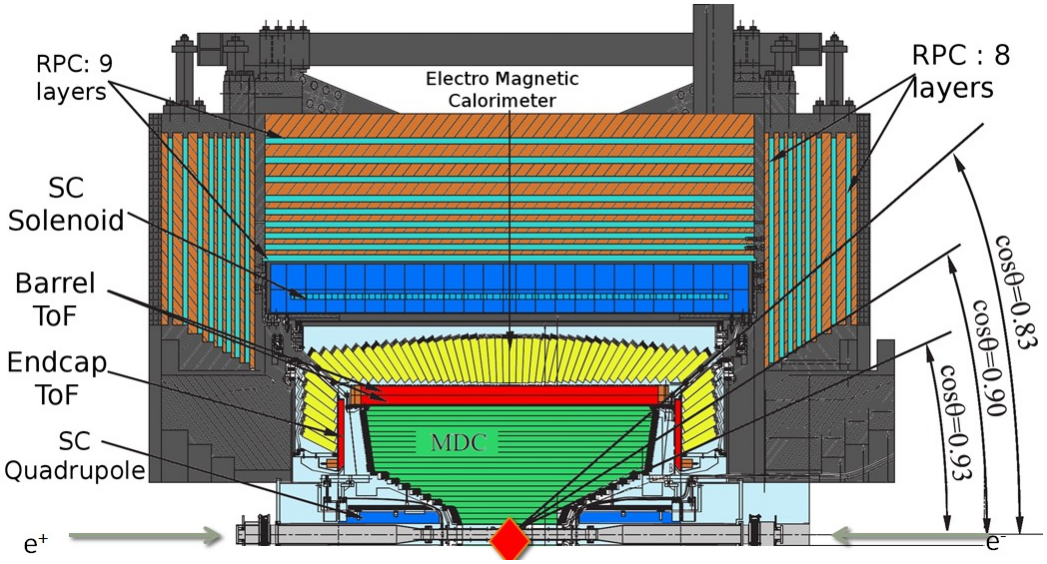
Introduction of BEPCII/BESIII

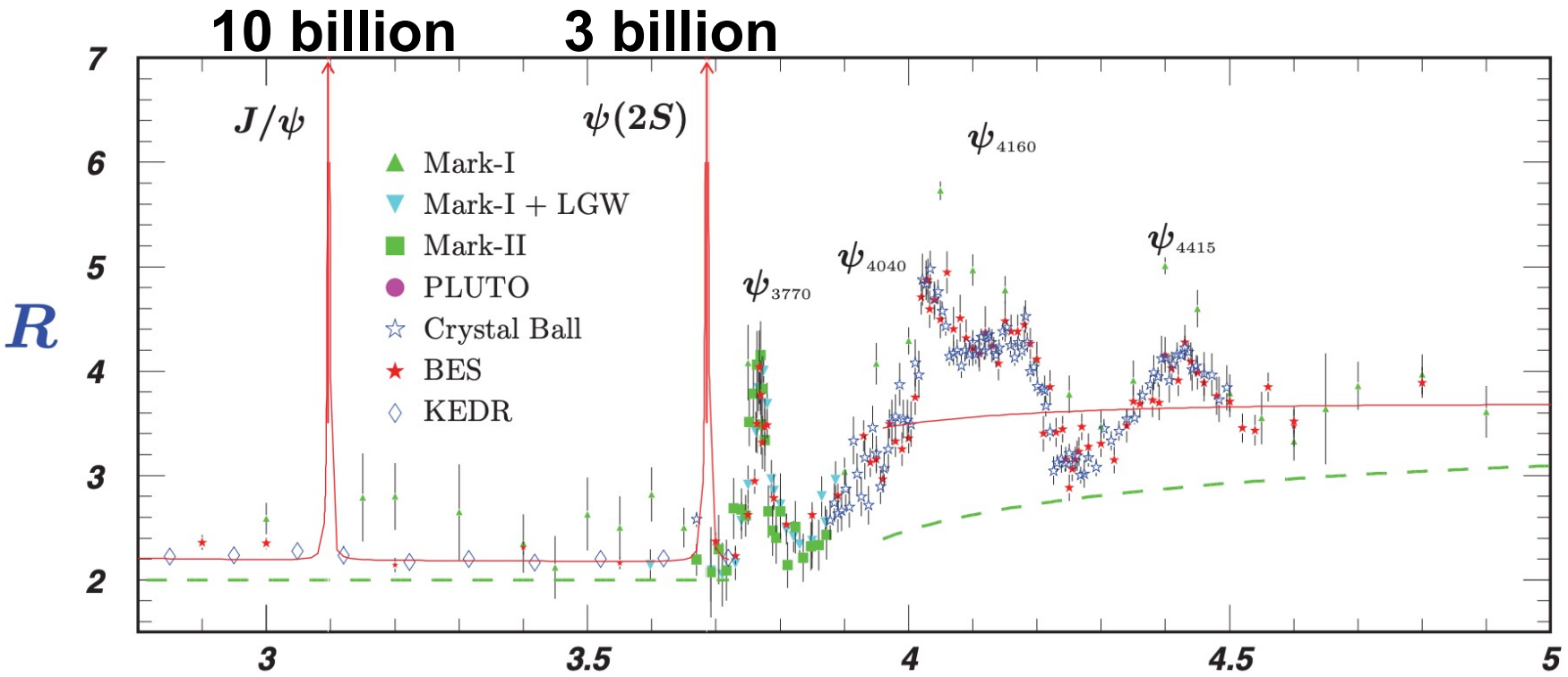


BEPC -> BEPCII
2009-now physics run
c.m. energy 2.0 – 4.95 GeV
Peak Lum. 1 x 10^{33} /cm^2/s



- MDC:$\sigma(p) = 0.5\%$@1 GeV, $\sigma\left(\frac{dE}{dx}\right) = 6\%$
- TOF:$\sigma(t) = 68\,ps(60\,ps)$ for barrel(endcap)
- EMC: $\sigma(E) = 2.5\%(5.0\%)$ @ 1 GeV in the barrel(end cap) ,$\sigma_{spatial} = 6cm$@ 1 GeV
- RPC: $\varepsilon_{\mu \mathrm{id}} > 90\%$ when $p(\mu) > 0.5$ GeV

Datasets of BESIII

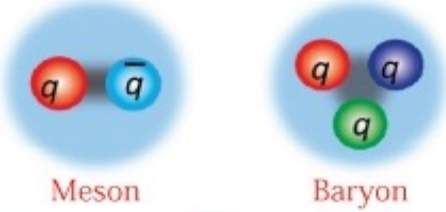


PRD.98.030001(2018)

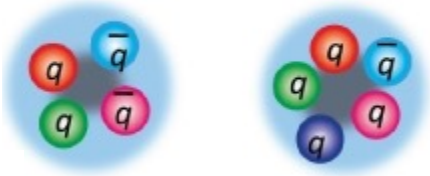
Largest J/ψ and $\psi(2S)$ dataset in the world!!

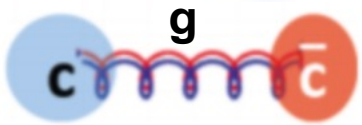
Several forms of hadrons

- **Mesons and baryons in SM model.**



- **The exotics allowed by QCD.**
  - **Multi-quarks** : number of quarks>= 4
  - **Hybrid state** : quarks + gluons
  - **Glueball** : only gluons



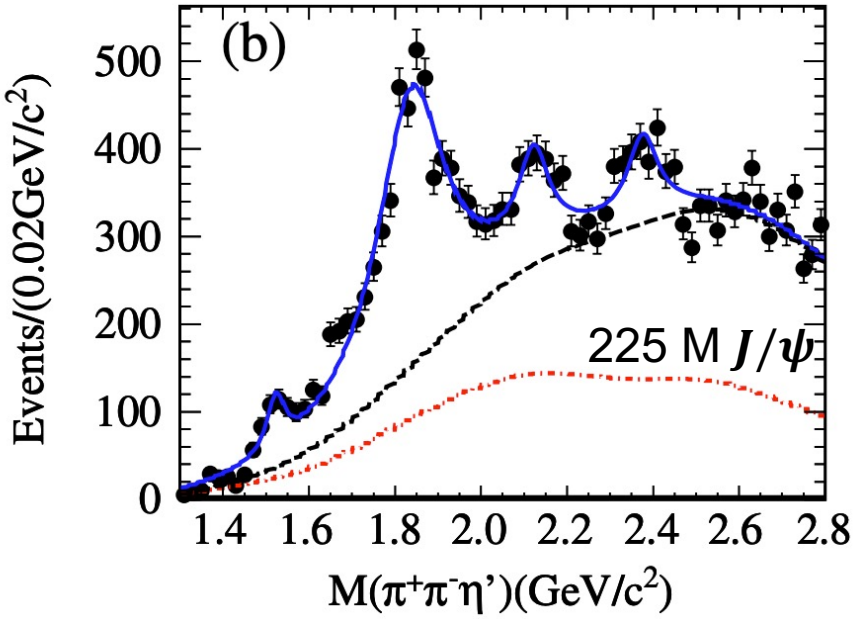


- Light meson spectroscopy is an important key to test the QCD theory. Selected results from BESIII:
  - **$X(1835)$ and $X(p\bar{p})$**
  - **Possible glueball candidates**

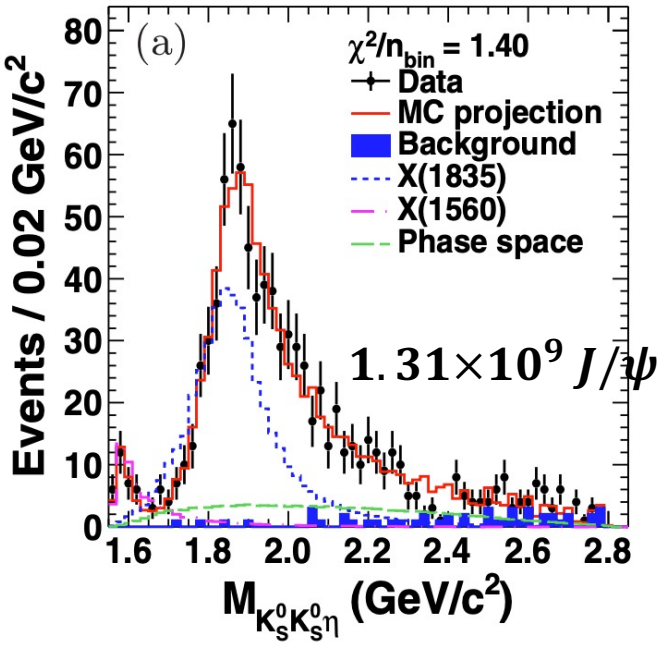
Study of the X(1835)

- First observation of the X(1835) at BESII, then confirmed by BESIII.

$J/\psi \to \gamma\pi^+\pi^-\eta'$ PRL.106.072002



$J/\psi \to \gamma K_s K_s \eta$ PRL.115.091803



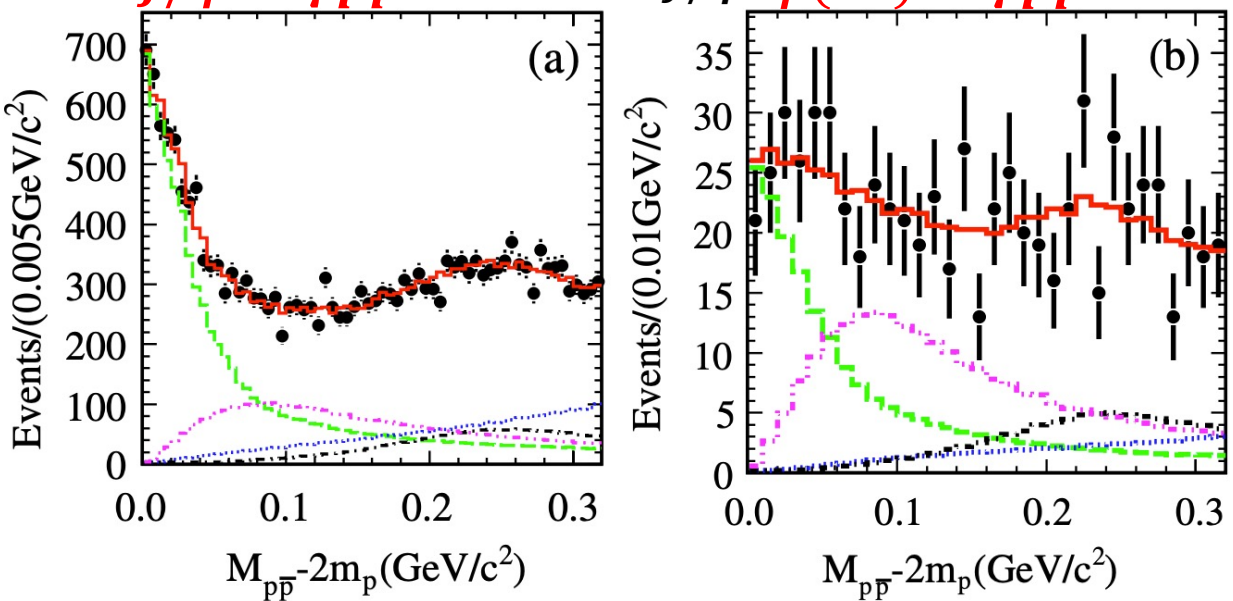
- The spin-parity is determined to be 0^{-+} in $J/\psi \to \gamma K_s K_s \eta$ channel, decays to $f_0(980)\eta$.

M = 1844±9$^{+16}_{-25}$ MeV

Γ = 192$^{+20}_{-17}{}^{+62}_{-43}$ MeV

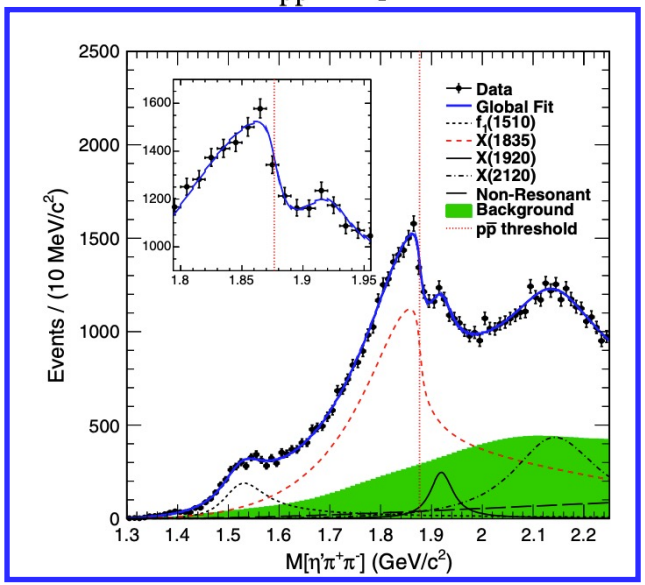
Study of the $X(p\bar{p})$

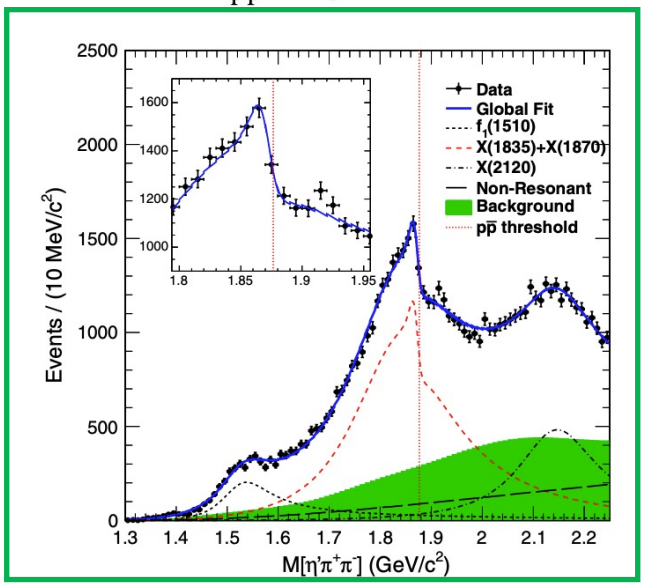
$J/\psi \to \gamma p\bar{p}$ PWA 225 M J/ψ $\psi(2S) \to \gamma p\bar{p}$ PWA



PRL.108.112003

- X($p\bar{p}$) : 0^{-+}.
- No observed in other channels, **cannot be pure FSI effect**.





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

PRL.117.042002(2016)

2-BWs, Flatte formula

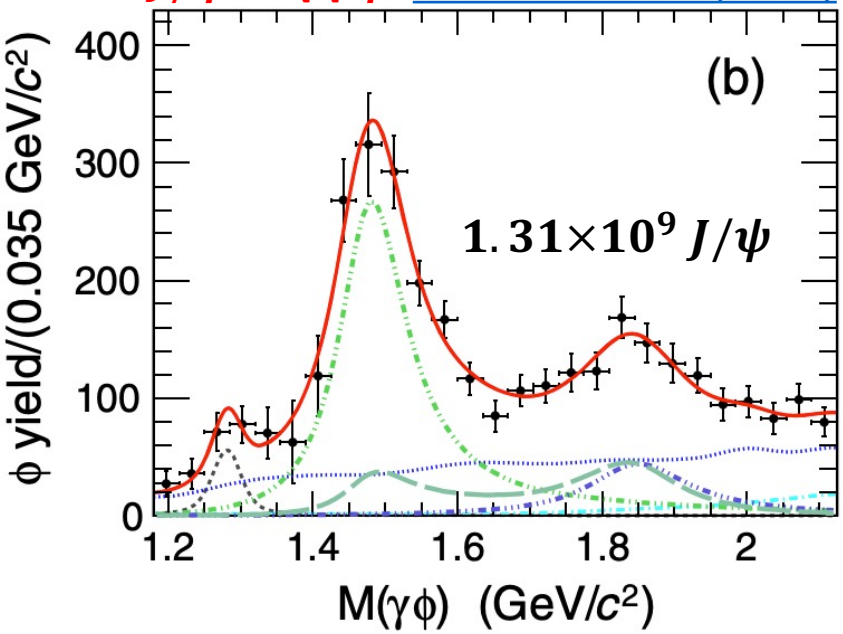
Almost equally fit quality.

- **A connection between X(1835) and $X(p\bar{p})$**, $p\bar{p}$ molecule-like or bound state.

Study of the X(1835)

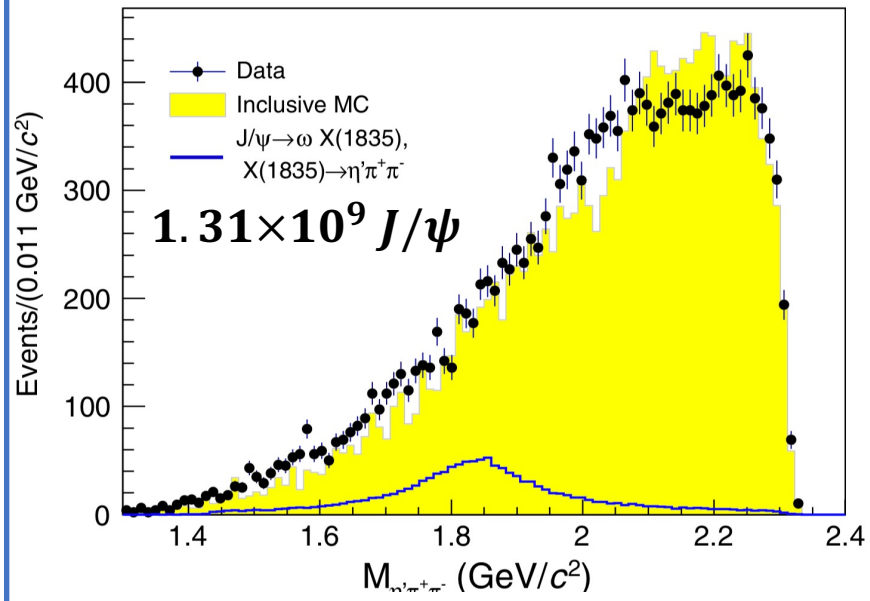
- With more statistics, we try to understand the nature of X(1835).

$J/\psi \to \gamma\gamma\phi$ PRD.97.051101(2018)



The X(1835) contains sizeable $s\bar{s}$ components from the PWA results of $J/\psi \to \gamma\gamma\phi$.

$J/\psi \to \omega\pi^+\pi^-\eta'$ PRD.99.071101(2019)

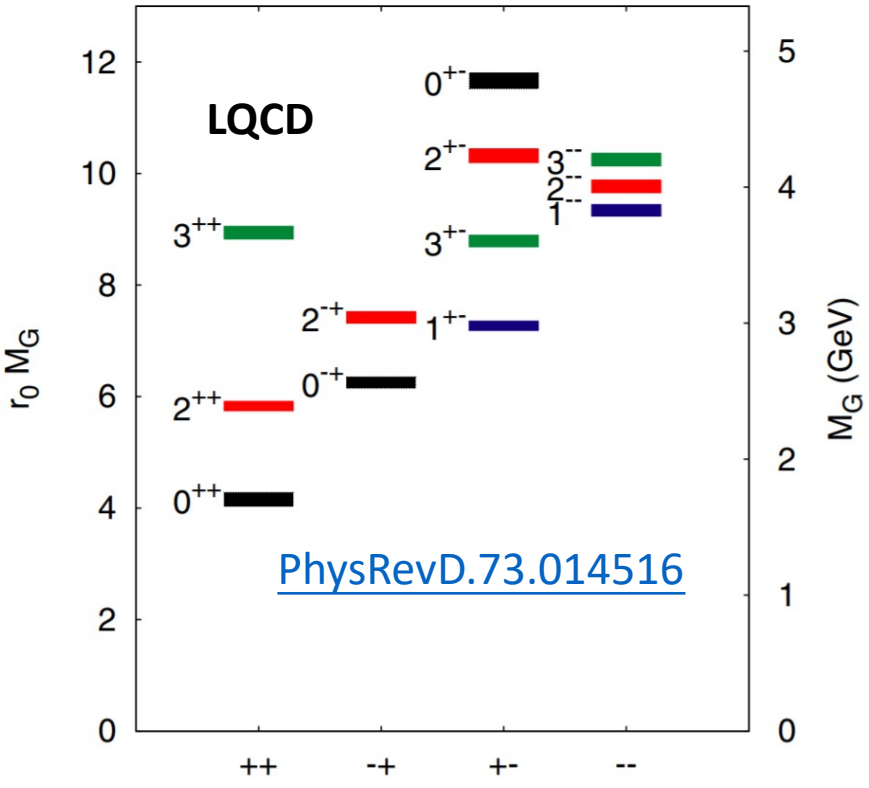


$$\mathcal{B}(J/\psi \to \omega X(1835), X(1835) \to \eta'\pi^+\pi^-) < \frac{N^{UL}}{N_{J/\psi}\cdot\epsilon'\cdot\mathcal{B}_{\rm int}\cdot(1-\sigma_{\rm sys})} = 6.2\times10^{-5}$$

No significant X(1835) is observed in the process of $J/\psi \to \omega\pi^+\pi^-\eta'$.

Possible glueball candidates

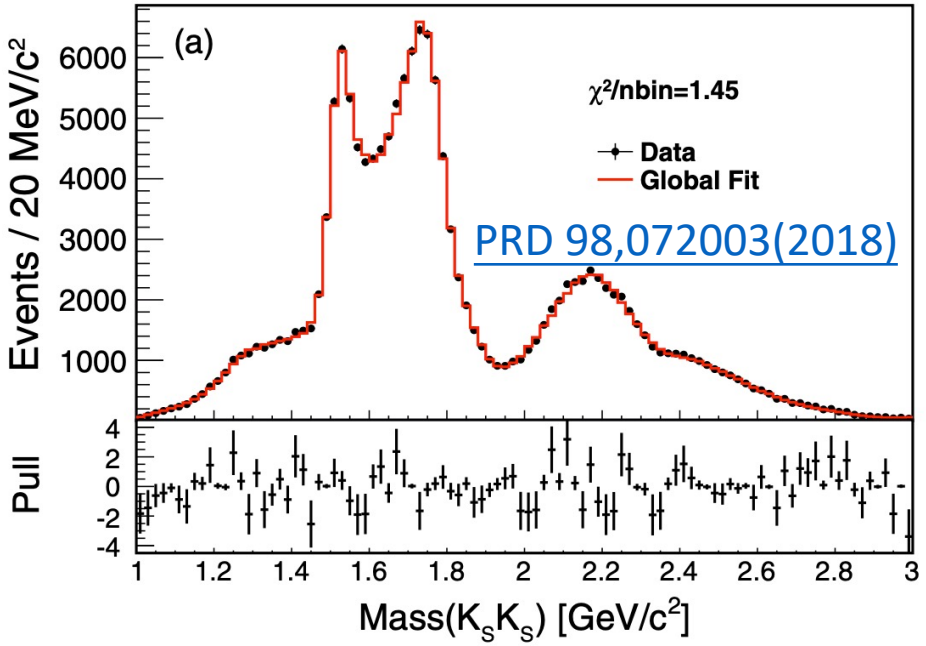
- Lattice QCD predicts the possible glueball candidates as below.



- Possible glueball candidates at BESIII.

- 0^{++}: $f_0(1500)$ and $f_0(1710)$
  - $J/\psi \to \gamma K_s K_s, \gamma\eta\eta, \gamma\pi^0\pi^0$
- 2^{++}: $f_2(2340)$
  - $J/\psi \to \gamma K_s K_s, \gamma\eta\eta, \gamma\phi\phi$
- 0^{-+}: X(2370)
  - $J/\psi \to \gamma\pi^+\pi^-\eta', \gamma K\bar{K}\eta,\ \gamma\eta\eta\eta'$

PWA of $J/\psi \to \gamma K_s K_s$

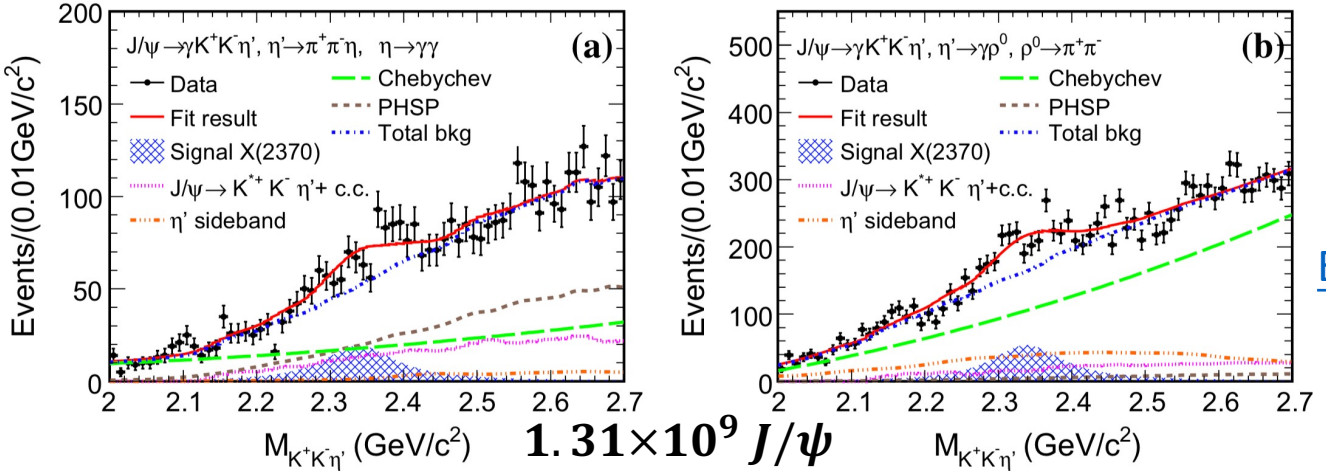


- $f_0(1710)$ has ~10 times larger production rate than $f_0(1500)$.
  - Comparable with LQCD.
  - Large overlap with scalar glueball.
- Also large contribution from $f_2(2340)$.
  - Lowest lying tensor glueball.

Resonance	M (MeV/c^2)	$M_{\rm PDG}$ (MeV/c^2)	Γ (MeV/c^2)	$\Gamma_{\rm PDG}$ (MeV/c^2)	Branching fraction	Significance
$K^*(892)$	896	895.81 ± 0.19	48	47.4 ± 0.6	$(6.28^{+0.16+0.59}_{-0.17-0.52}) \times 10^{-6}$	35σ
$K_1(1270)$	1272	1272 ± 7	90	90 ± 20	$(8.54^{+1.07+2.35}_{-1.20-2.13}) \times 10^{-7}$	16σ
$f_0(1370)$	$1350 \pm 9^{+12}_{-2}$	1200 to 1500	$231 \pm 21^{+28}_{-48}$	200 to 500	$(1.07^{+0.08+0.36}_{-0.07-0.34}) \times 10^{-5}$	25σ
$f_0(1500)$	1505	1504 ± 6	109	109 ± 7	$(1.59^{+0.16+0.18}_{-0.16-0.56}) \times 10^{-5}$	23σ
$f_0(1710)$	$1765 \pm 2^{+1}_{-1}$	1723^{+6}_{-5}	$146 \pm 3^{+7}_{-1}$	139 ± 8	$(2.00^{+0.03+0.31}_{-0.02-0.10}) \times 10^{-4}$	$\gg 35\sigma$
$f_0(1790)$	$1870 \pm 7^{+2}_{-3}$	...	$146 \pm 14^{+7}_{-15}$	...	$(1.11^{+0.06+0.19}_{-0.06-0.32}) \times 10^{-5}$	24σ
$f_0(2200)$	$2184 \pm 5^{+4}_{-2}$	2189 ± 13	$364 \pm 9^{+4}_{-7}$	238 ± 50	$(2.72^{+0.08+0.17}_{-0.06-0.47}) \times 10^{-4}$	$\gg 35\sigma$
$f_0(2330)$	$2411 \pm 10 \pm 7$	...	$349 \pm 18^{+23}_{-1}$	...	$(4.95^{+0.21+0.66}_{-0.21-0.72}) \times 10^{-5}$	35σ
$f_2(1270)$	1275	1275.5 ± 0.8	185	$186.7^{+2.2}_{-2.5}$	$(2.58^{+0.08+0.59}_{-0.09-0.20}) \times 10^{-5}$	33σ
$f_2'(1525)$	1516 ± 1	1525 ± 5	$75 \pm 1 \pm 1$	73^{+6}_{-5}	$(7.99^{+0.03+0.69}_{-0.04-0.50}) \times 10^{-5}$	$\gg 35\sigma$
$f_2(2340)$	$2233 \pm 34^{+9}_{-25}$	2345^{+50}_{-40}	$507 \pm 37^{+18}_{-21}$	322^{+70}_{-60}	$(5.54^{+0.34+3.82}_{-0.40-1.49}) \times 10^{-5}$	26σ
0^{++} PHSP	...	...	...	...	$(1.85^{+0.05+0.68}_{-0.05-0.26}) \times 10^{-5}$	26σ
2^{++} PHSP	...	...	...	...	$(5.73^{+0.99+4.18}_{-1.00-3.74}) \times 10^{-5}$	13σ

Recent results of X(2370)

- The X(2370) is first observed in the process of $J/\psi \to \gamma\pi^+\pi^-\eta'$, and now in the process of $\boldsymbol{J/\psi \to \gamma K\bar{K}\eta'}$.



$1.31\times10^9\ J/\psi$

EPJC.80.746(2020)

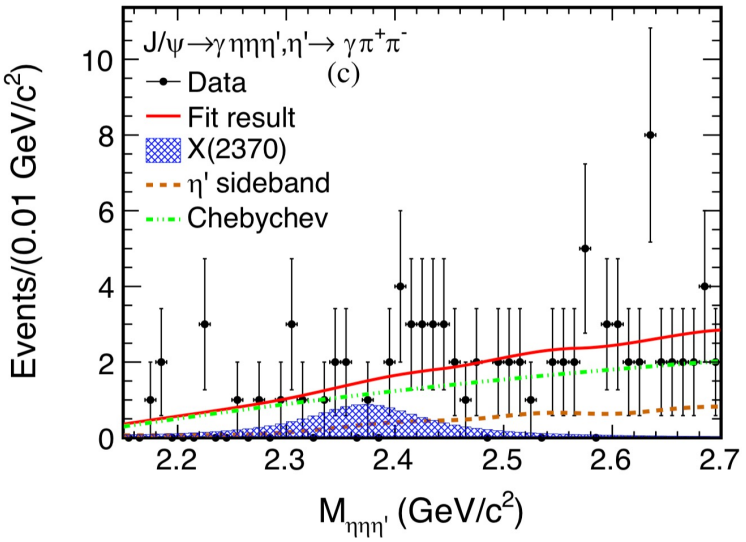
8.3σ

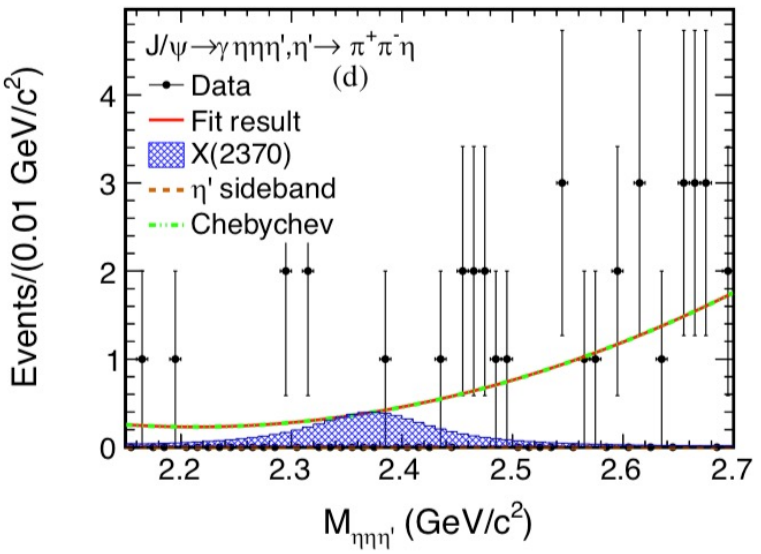
- A PWA of $J/\psi \to \gamma K_s K_s \eta'$ is ongoing to determine the J^{PC}.

Recent results of X(2370)

- The search for X(2370) is performed in the process of $J/\psi \to \gamma\eta\eta\eta'$.

$\mathbf{1.31\times10^9}\ J/\psi$ PRD.103.012009(2021)





$Br\big(J/\psi \to \gamma X(2370)\big)\times Br(X(2370) \to \eta\eta\eta') < 9.2\times10^{-6}$ at 90% C.L.

- The upper limit is not in contradiction with the pseudoscalar glueball assumption.

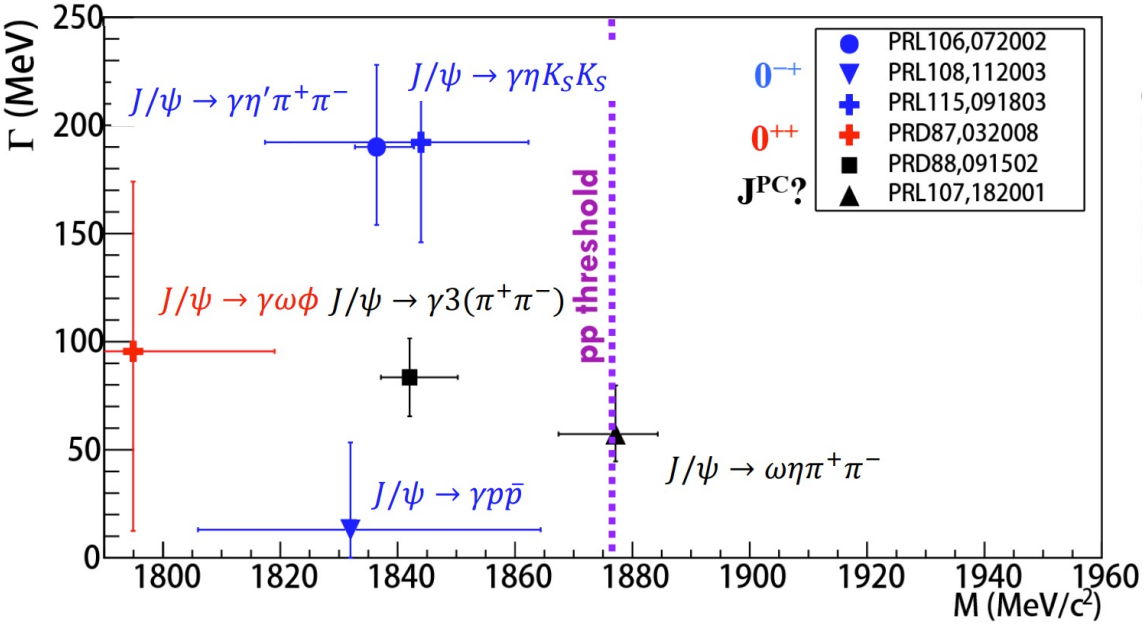
Summary

- Many interesting and important results in light meson physics at BESIII.
  - First direct connection between the X(1835) and the $X(p\bar{p})$, but a **molecule or bound state**???
  - A systematical glueball search, $f_0(1500)$, $f_0(1710)$, $f_2(2340)$ and X(2370) .
- More analyses are on the way with the 10 billion J/ψ and 3 billion $\psi(2S)$ events.

Backup

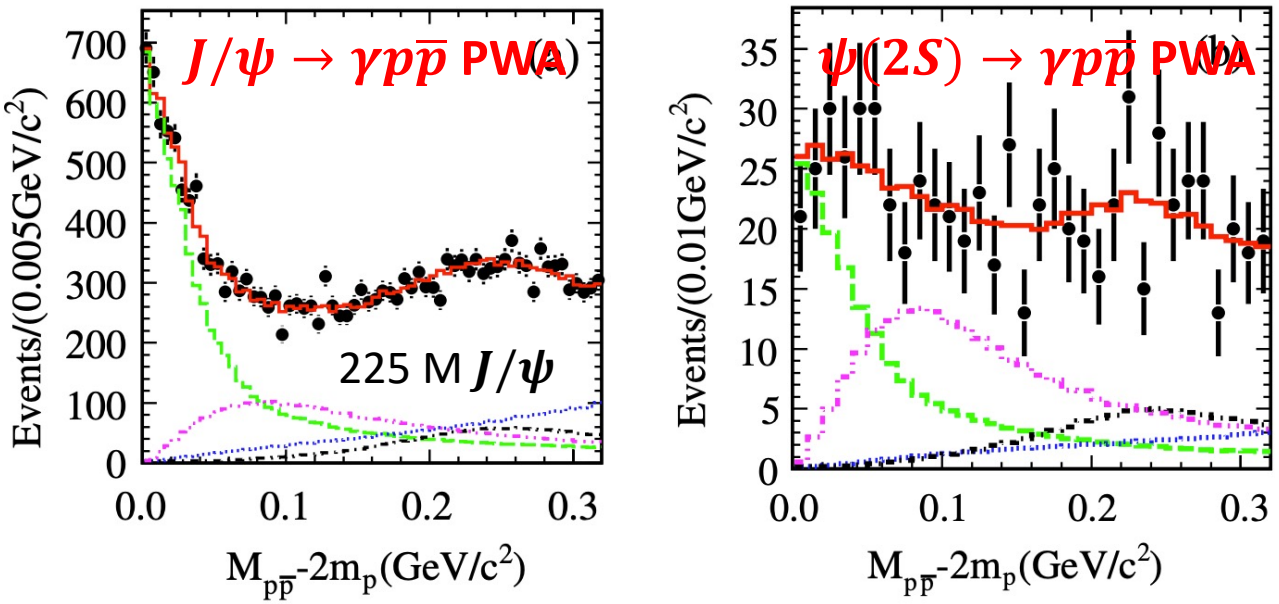
X(18xx) between 1.8~1.9 GeV

- Are they same? The masses and widths are different in several channels.
- What is the Nature of X(18xx)? **$p\bar{p}$ bound state, second radial excitation of η', pseudoscalar glueball** ?



- In the PWA of $J/\psi \to \gamma K_s K_s \eta$ and $J/\psi \to \gamma p\bar{p}$, the J^{PC} of **X(1835)** is derteminerd to be 0^{-+}.

Study of the $X(p\bar{p})$



PRL.108.112003

M = 1861±1$^{+13}_{-4}$MeV

Γ = 1±6$^{+18}_{-1}$MeV (<32MeV @90% CL)

- First observation of $p\bar{p}$ mass threshold enhancement @BESII.
- The spin-parity is determined to be 0^{-+}.
- No similar threshold structure observed in other channels, **cannot be pure FSI effect**.