Light Meson Spectroscopy at BESIII

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Institute of High Energy Physics

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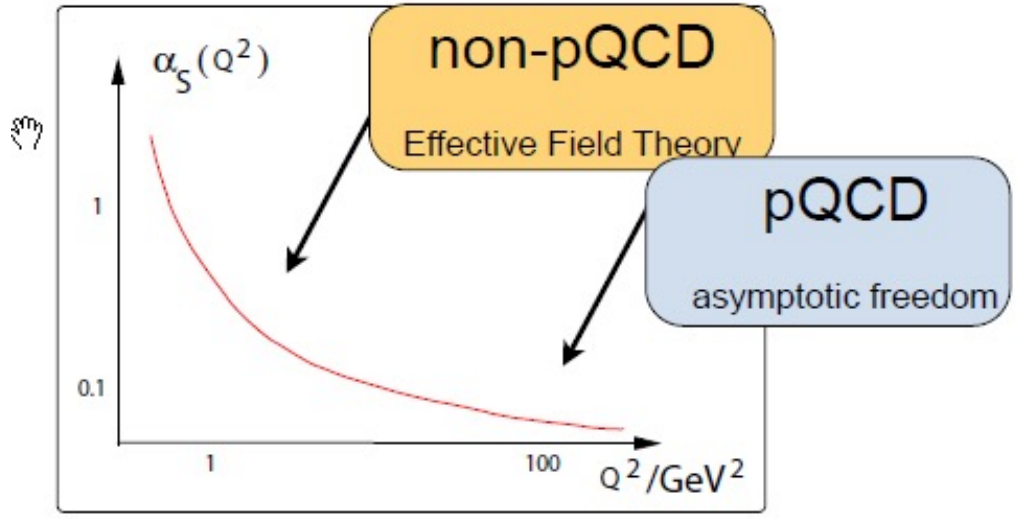
Mexico

OUTLINE

- Why light hadron physics
- Progresses at BESIII
  - Scalar, tensor and pseudoscalar mesons
  - Exotics searches
  - Strange mesons and strangeonia states
- Summary

Why light hadron physics ?



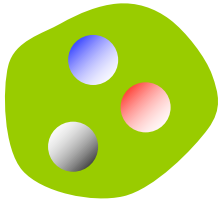
"That [intermediate distance] scale is the richest phenomenologically, and is certainly the crux region to understand...what QCD is really about. And at the heart of the subject is the hadron spectrum, in particular the spectrum built from light quarks. (...) **Without question, there is a great need... for a new round of experiments,...**"

James D. Bjorken (2000)

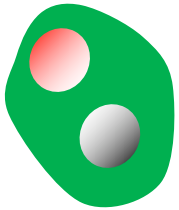
✓ QCD degrees of freedom at low energy
✓ Understanding of the quark and gluon confinement
✓ Particles beyond the QM

Light hadron spectroscopy

- Quark Model

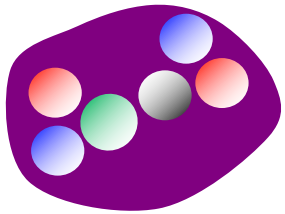


baryon

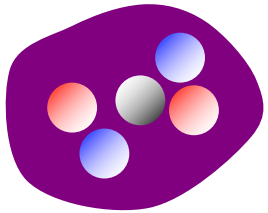


meson

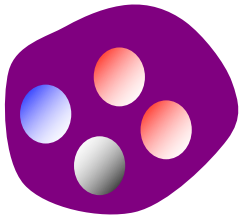
- QCD allows for hadrons beyond Quark Model



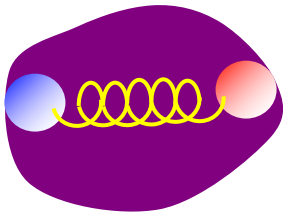
dibaryon



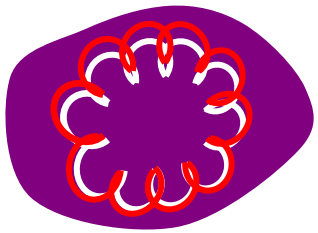
Pentaquark



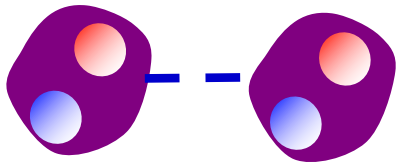
tetraquark



hybrid



glueball



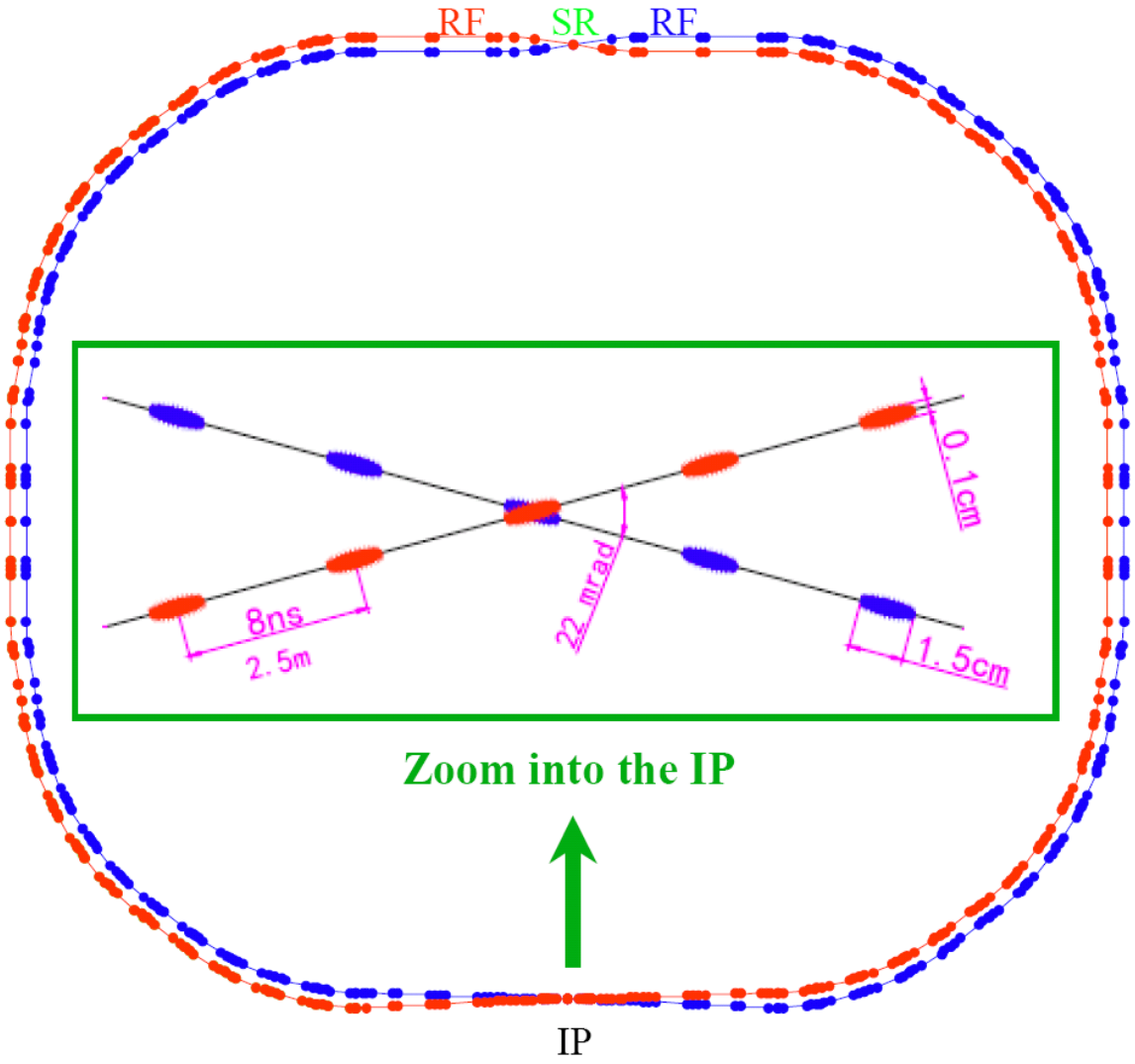
molecule

Bird view of BEPCII

BESIII physics

- Charmonium(-like) physics
- Light hadron spectroscopy
- Charm physics
- τ physics

BEPCII storage rings



Beam energy:
1.0-2.3 GeV
Design Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
(achieved on 5th April,2016)
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
Circumference：
237m

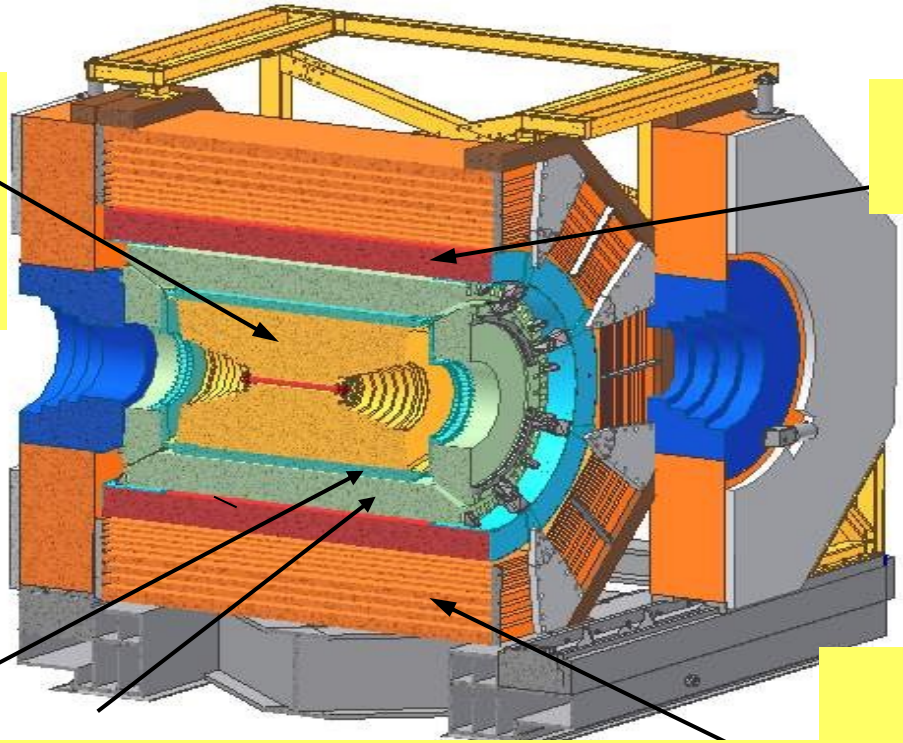
NIM A614, 345 (2010)

The BESIII Detector

Drift Chamber (MDC)

$\sigma P/P\ (^0/_0) = 0.5\%(1GeV)$

$\sigma_{dE/dx}\ (^0/_0) = 6\%$



Super-conducting magnet (1.0 tesla)

Time Of Flight (TOF)

σ_T : 90 ps Barrel

110 ps endcap

EMC: $\sigma E/\sqrt{E}\ (^0/_0) = 2.5\ \%\ (1\ GeV)$

(CsI) $\sigma_{z,\phi}(cm) = 0.5 - 0.7\ cm/\sqrt{E}$

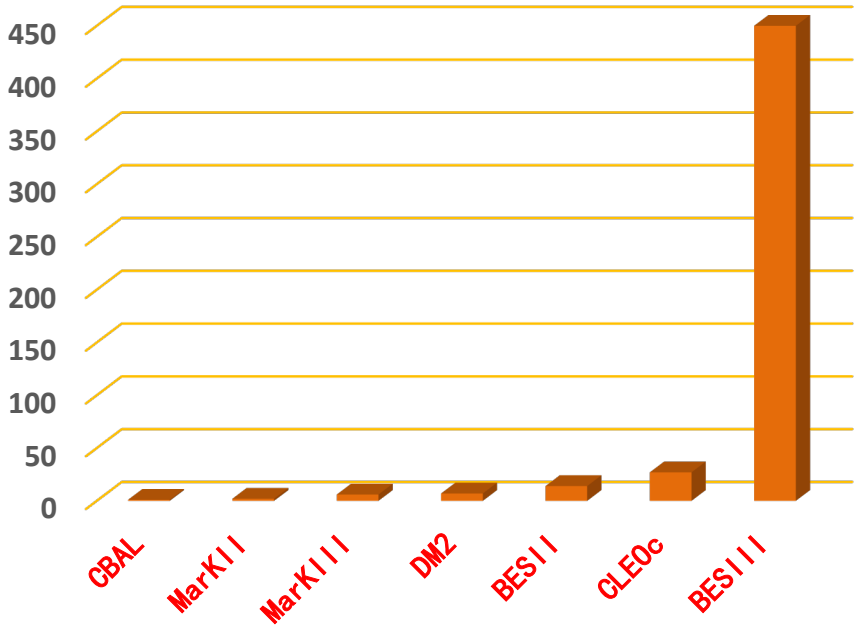
μCounter

8- 9 layers RPC

$\delta R\Phi$=1.4 cm~1.7 cm

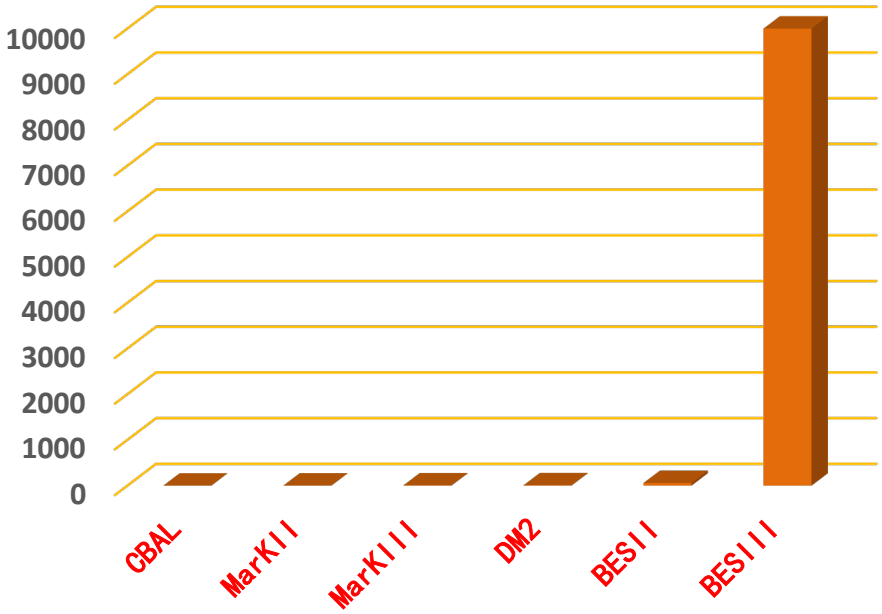
Data samples at BESIII

$\psi(3686)$ events



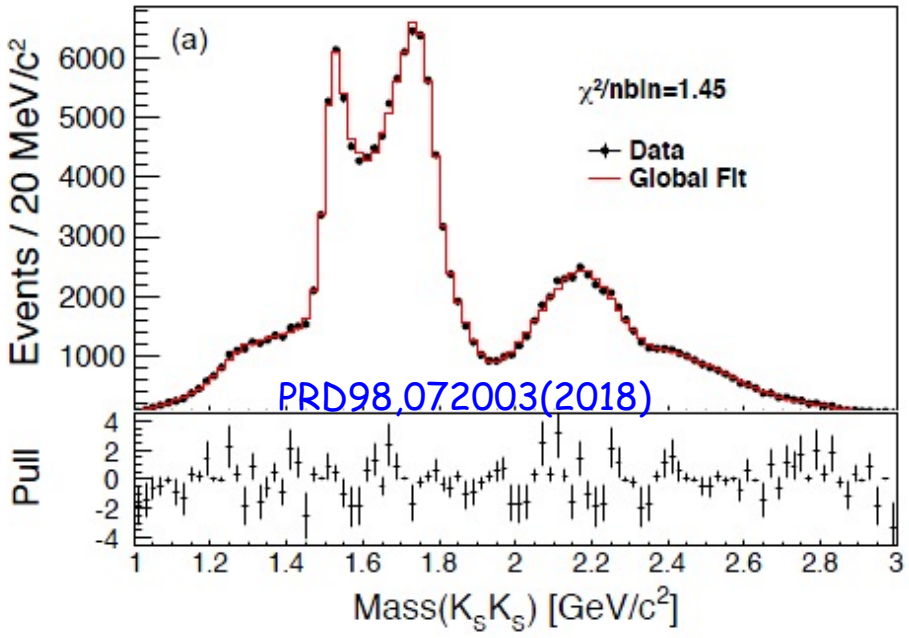
BESIII: 450 million

J/ψ events



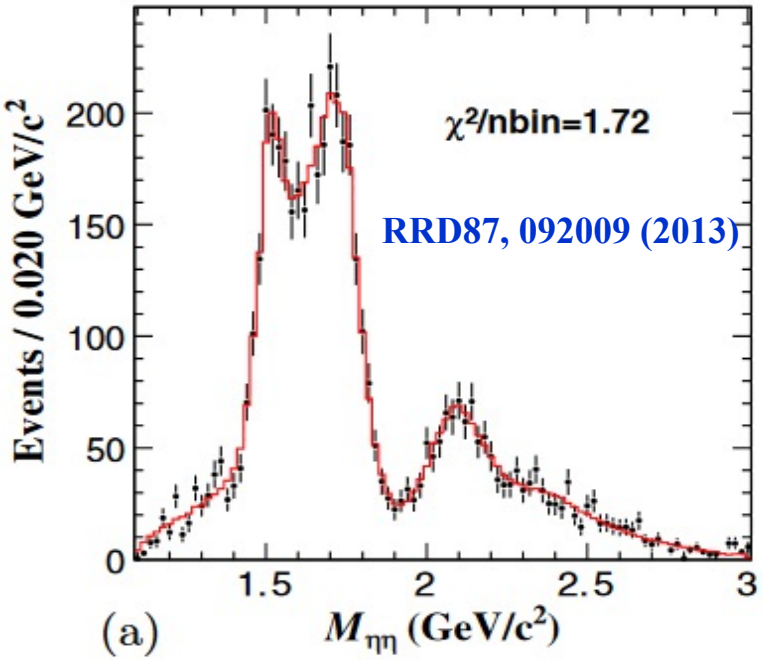
BESIII: 10 billion

PWA of J/ψ→γKsKs

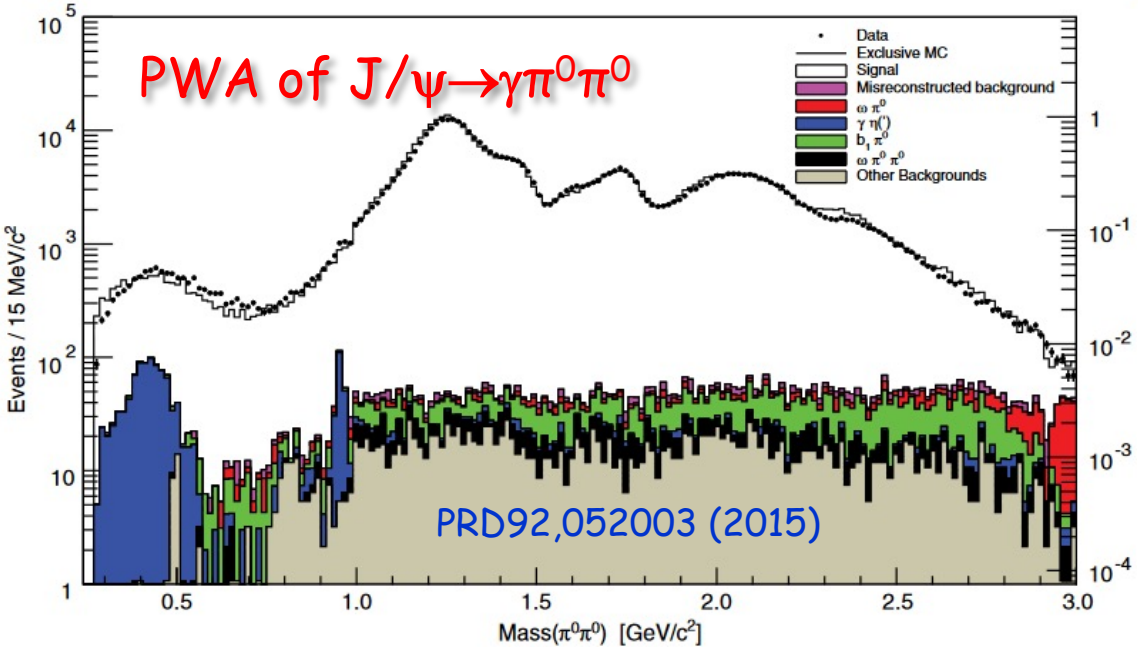


PRD98,072003(2018)

PWA of J/ψ→γηη



PWA of J/ψ→γπ⁰π⁰



PRD92,052003 (2015)

- **$f_0(1710)$ and $f_0(1500)$ are dominant**
- **$f_2'(1525)$ also seen**
- **Broad bump above 2 GeV**

About $f_0(1500)$ and $f_0(1710)$

- Clearly observed in J/ψ radiative decays
- Production rate of $f_0(1500)$ in J/ψ radiative decays is lower than that of $f_0(1710)$

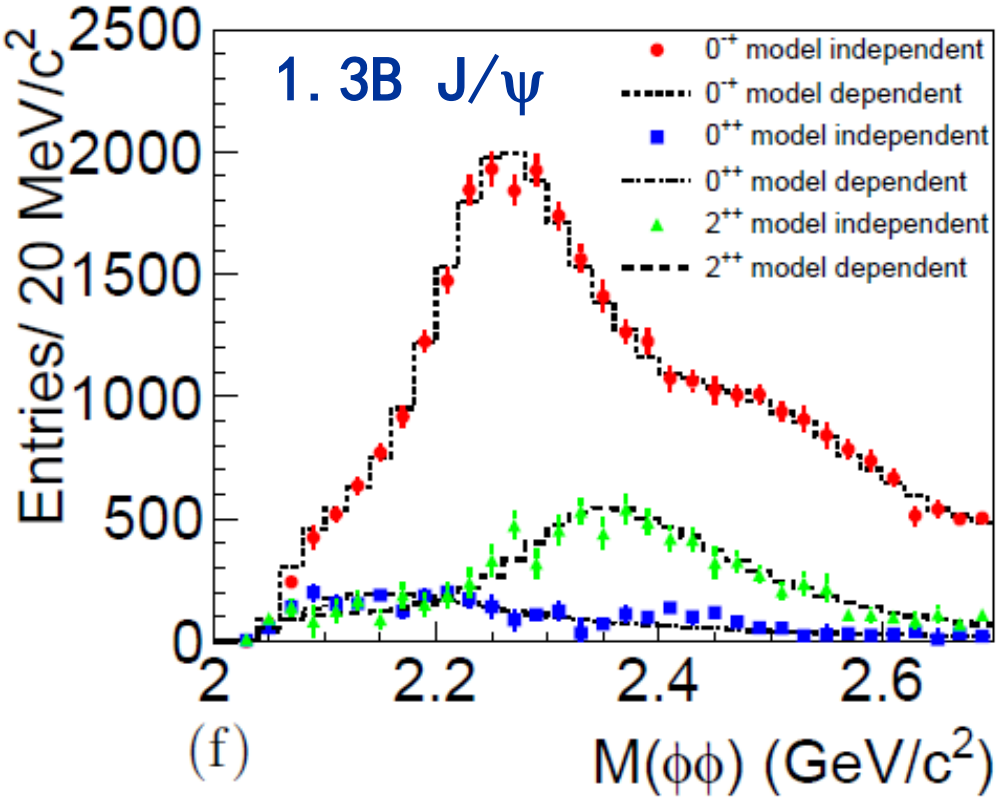
$$B(J/\psi \to \gamma f_0(1500)) \sim 3\times10^{-4}$$

$$B(J/\psi \to \gamma f_0(1710)) > 1.9\times10^{-3}$$

- $f_0(1710)$ has stronger coupling to gluons than $f_0(1500)$ → which one contains more glueball content?

PWA of J/ψ→γϕϕ

Phys. Rev. D. 93, 112011 (2016)



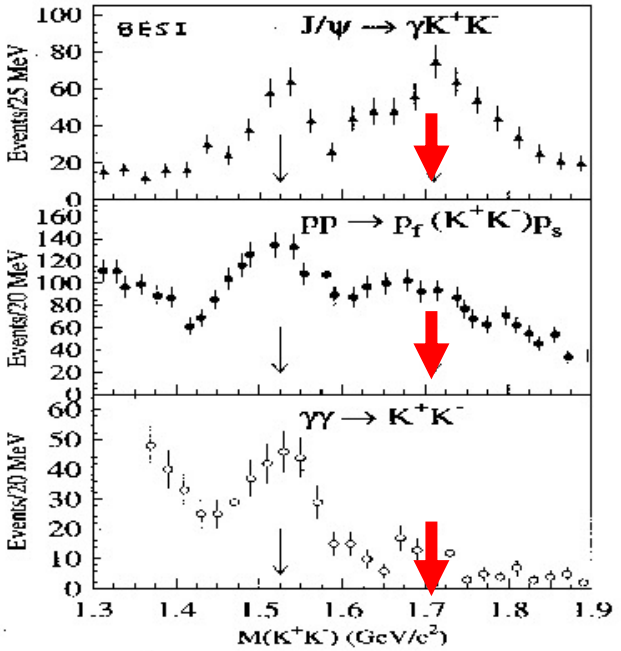
Resonance	M(MeV/c^2)	Γ(MeV/c^2)
$\eta(2225)$	2216^{+4+21}_{-5-11}	185^{+12+43}_{-14-17}
$\eta(2100)$	2050^{+30+75}_{-24-26}	$250^{+36+181}_{-30-164}$
$X(2500)$	$2470^{+15+101}_{-19-23}$	230^{+64+56}_{-35-33}
$f_0(2100)$	2101	224
$f_2(2010)$	2011	202
$f_2(2300)$	2297	149
$f_2(2340)$	2339	319
0^{-+} PHSP		

- Dominant contribution from pseudoscalars
  - η(2225) is confirmed;
  - η(2100) and X(2500) are observed

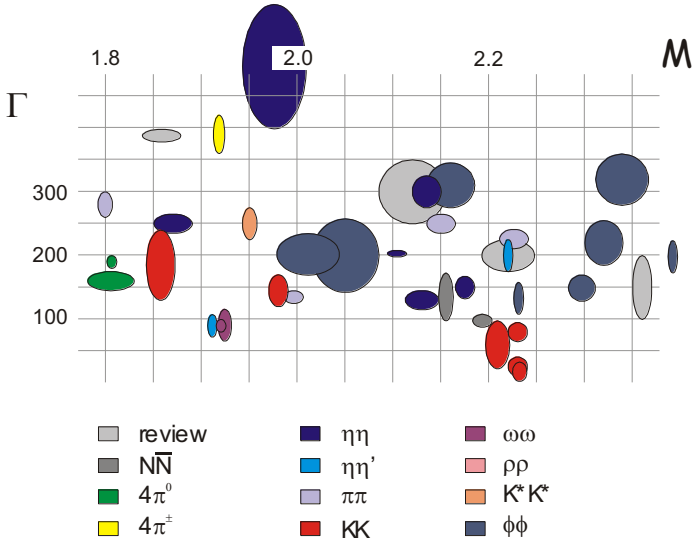
- The three tensors $f_2(2010)$, $f_2(2300)$ and $f_2(2340)$ stated in p^-p reactions are also observed

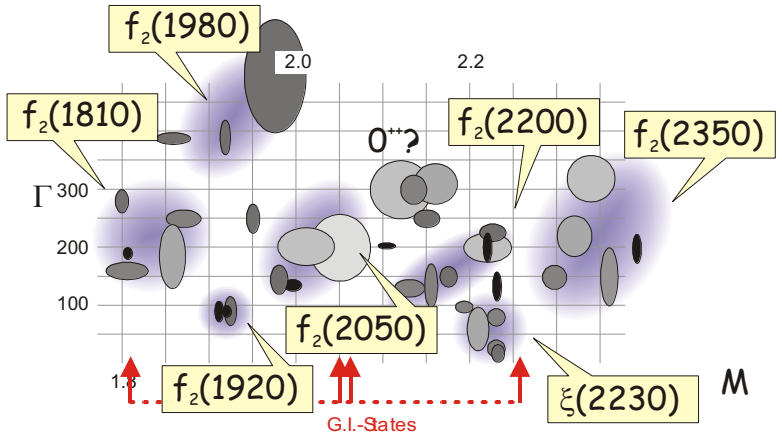
0^+ : experimental results saturated

- f_0（1710）/f_0(1790）, one or two
- Large production rate of f_0(2100) in gluon rich environment ppbar annihilations and J/psi radiative decays



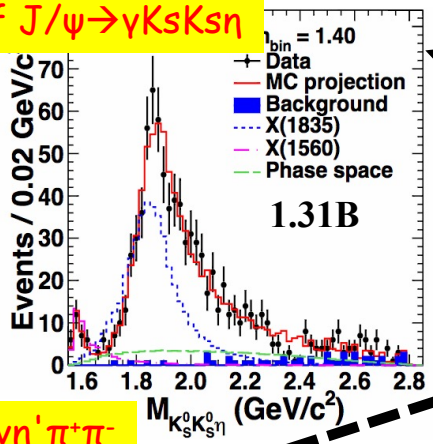
2^+: complicated situation around 2 GeV

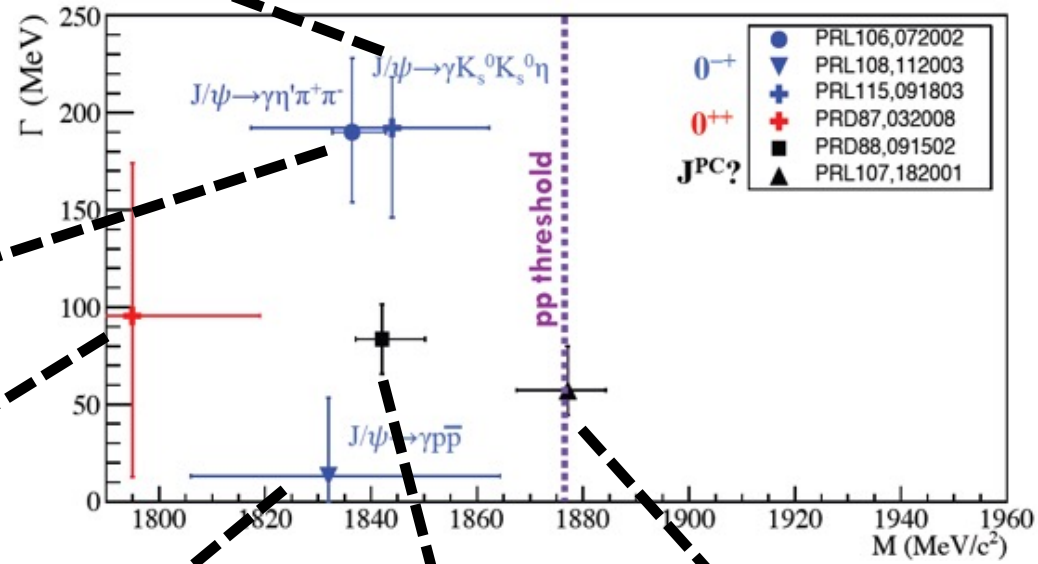




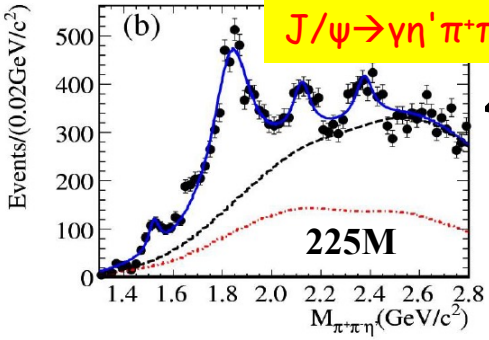
X(18??) between 1.8~1.9 GeV

PWA of J/ψ→γKsKsη

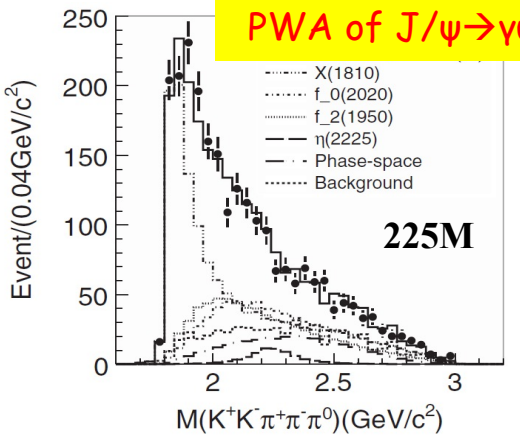




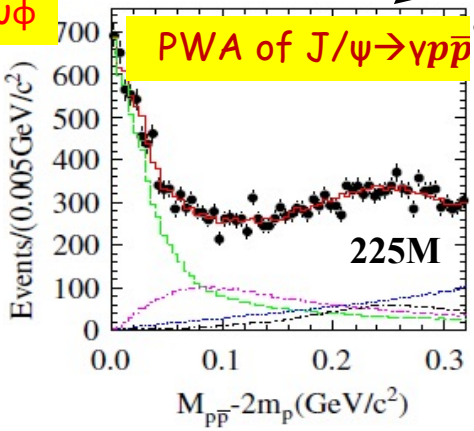
J/ψ→γη'π⁺π⁻



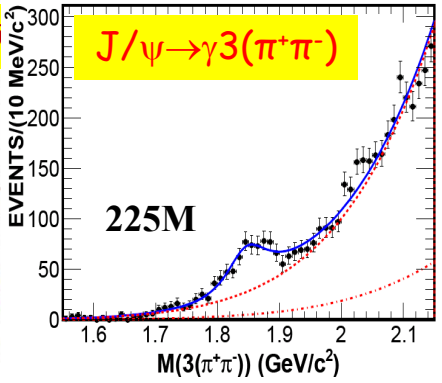
PWA of J/ψ→γωϕ



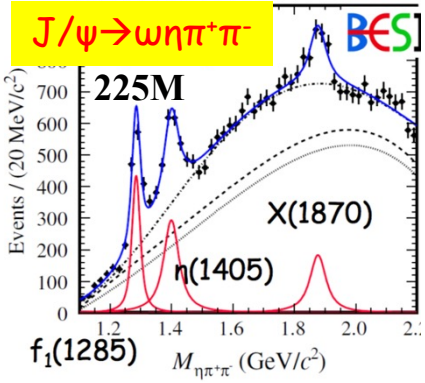
PWA of J/ψ→γpp̄



J/ψ→γ3(π⁺π⁻)



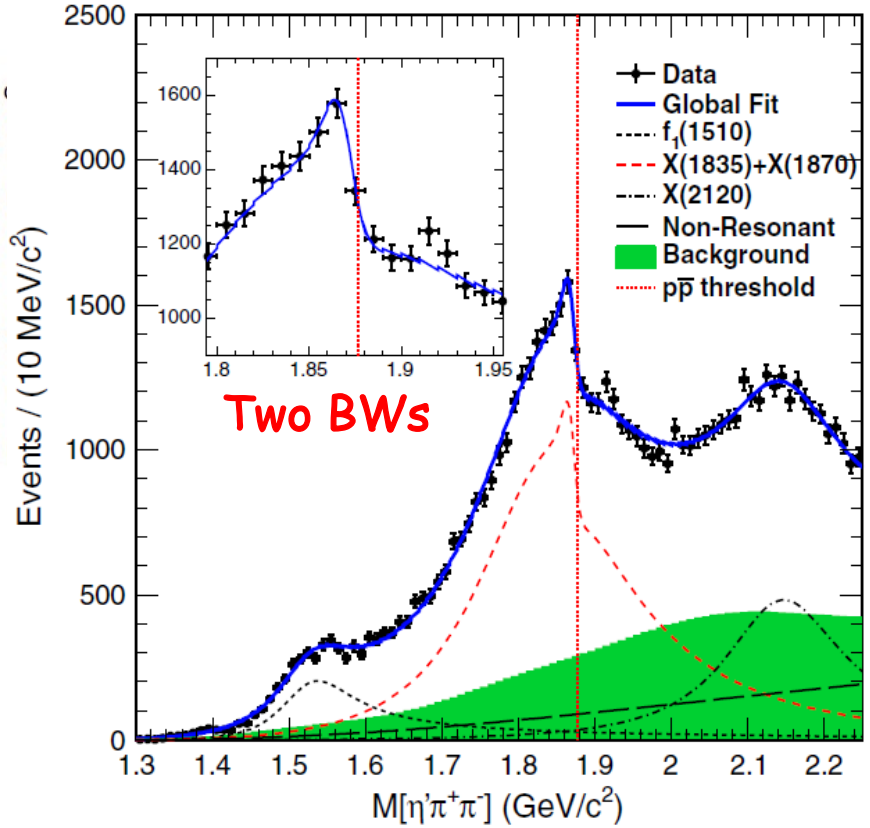
J/ψ→ωηπ⁺π⁻



Are they the same state? It is crucial to understand their connections.

Latest result on X(1835)

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

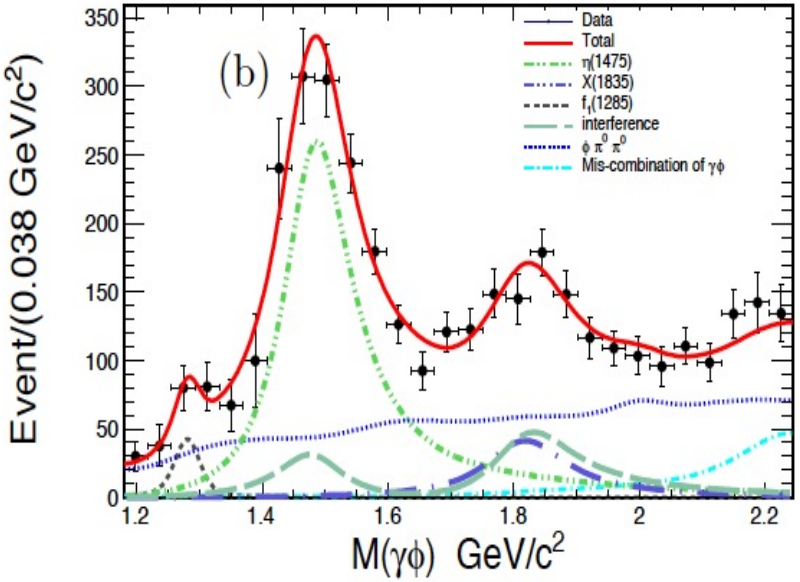


PRL 117, 042002(2016)

$M_2 = 1870.2 \pm 2.2\ ^{+2.3}_{-0.7}$ MeV/c^2

$\Gamma_2 = 13.0 \pm 6.1\ ^{+2.1}_{-3.8}$ MeV

$J/\psi \to \gamma\gamma\phi$



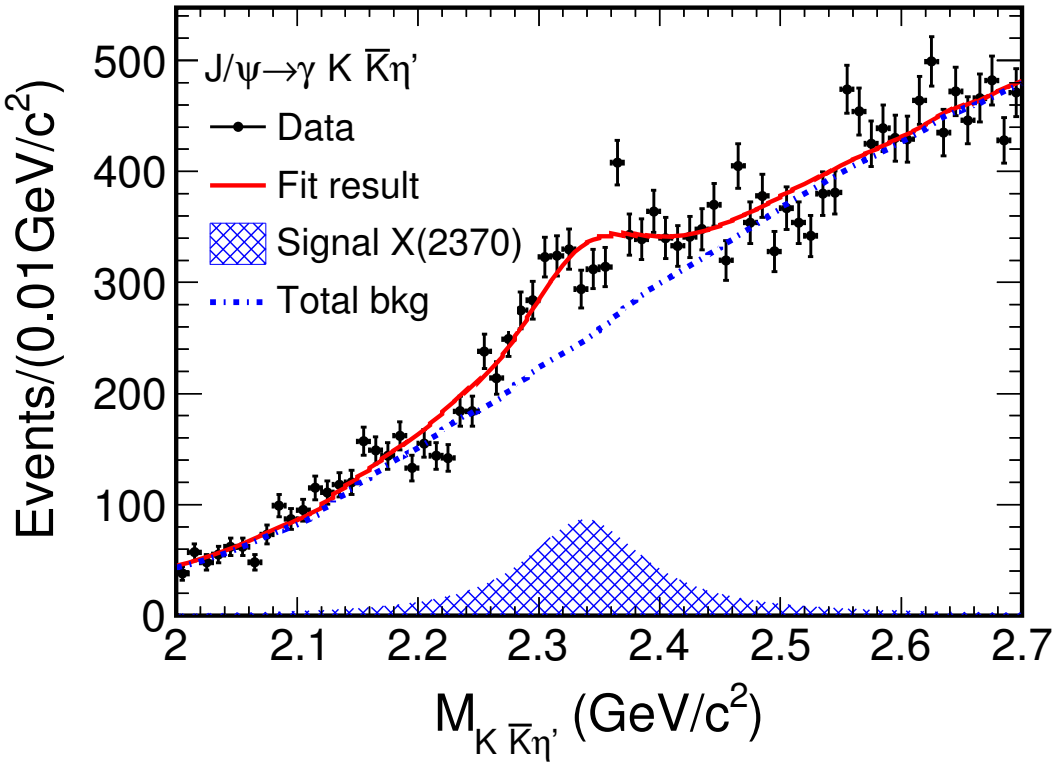
PRD97, 051101 (R) (2018)

Sizeable $s\bar{s}$ components in X(1835): more complicated than a pure $N\bar{N}$ state

Existence of a structure strongly coupling to $p\bar{p}$?

First observation of X(2370) → KKη′

EPJC80,746(2021)



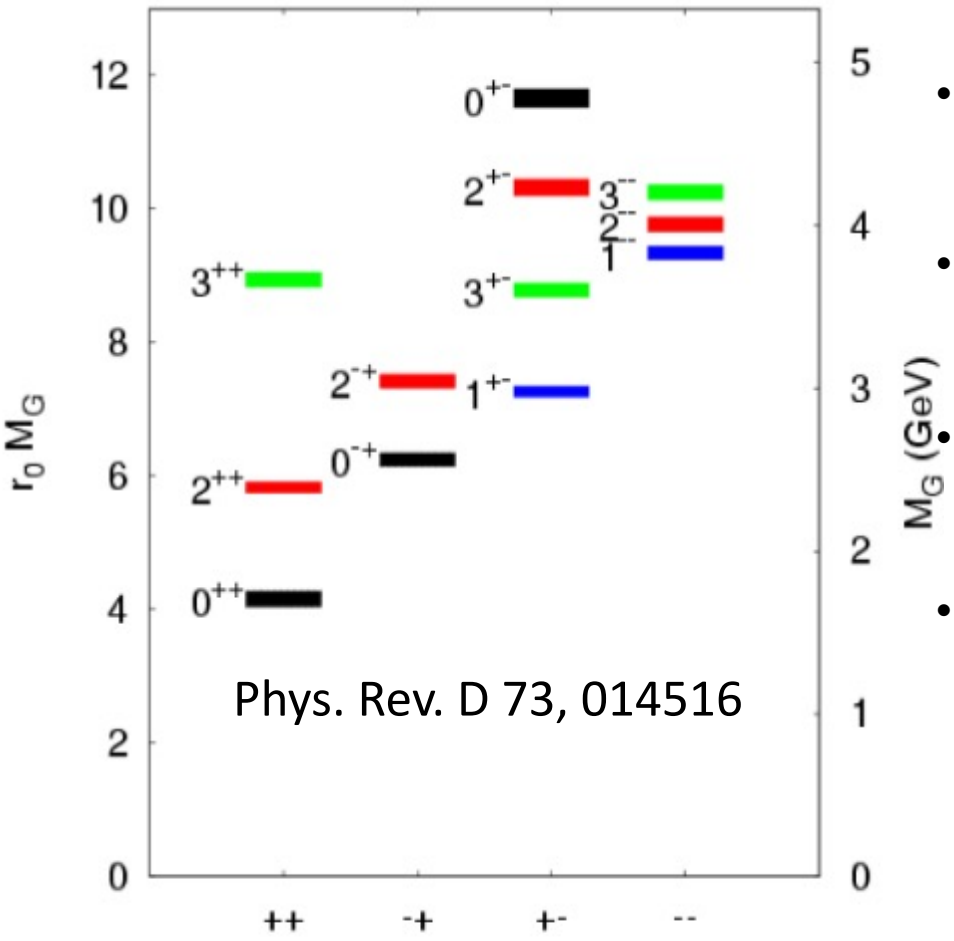
M=2341.6±6.5 ±5.7 MeV/c²
Γ = 117±10±8 MeV

- Simultaneously fit for two different η′ decay modes
- What is X(2370) ? Candidate of pseudoscalar glueball?

Lattice QCD predictions

L.-C. Gui et al. Phys. Rev. D 100, 054511 (2019)

Where is the glueball?

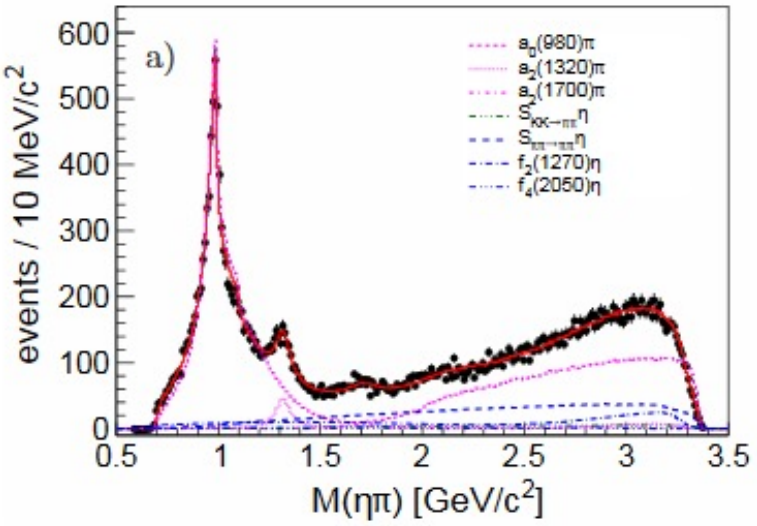


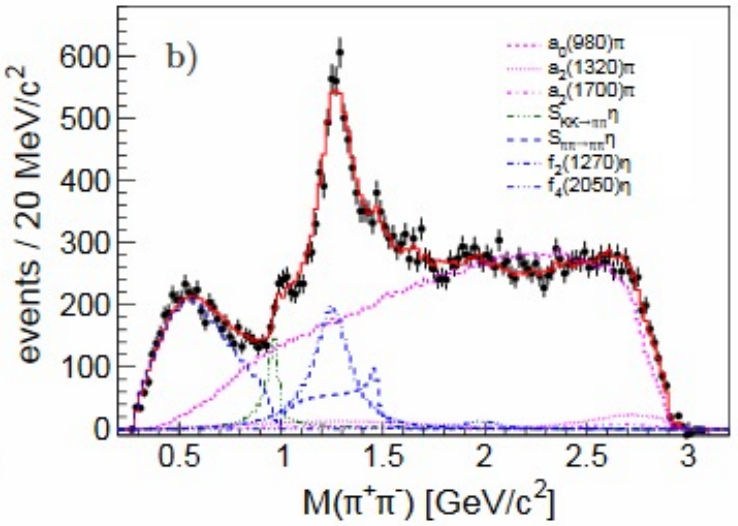
Phys. Rev. D 73, 014516

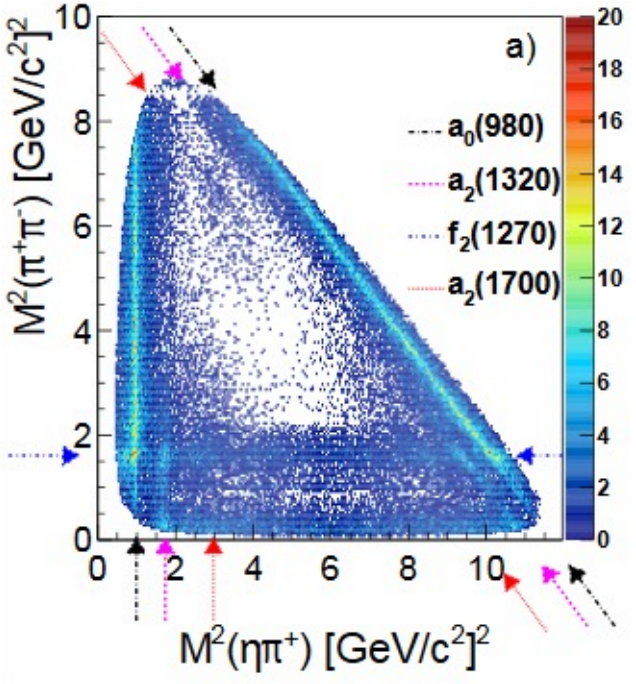
At BESIII

- $f_0(1710)$ and $f_0(2100)$ are observed in $J/\psi \to \gamma\,\eta\eta, \gamma\pi^0\pi^0$
- $f_2(2340)$ is observed in $J/\psi \to \gamma\eta\eta/\phi\phi$ $/\pi^0\pi^0$
- X(2120) and X(2370) in of $J/\psi \to \gamma\pi^+\pi^-\eta'$
- Systematic studies needed
  - $J/\psi \to \gamma\eta\eta'$
  - $J/\psi \to \gamma\eta'\eta'$
  - $J/\psi \to \phi X, \omega X$

Search exotics in $\chi_{c1} \to \eta\pi^+\pi^-$

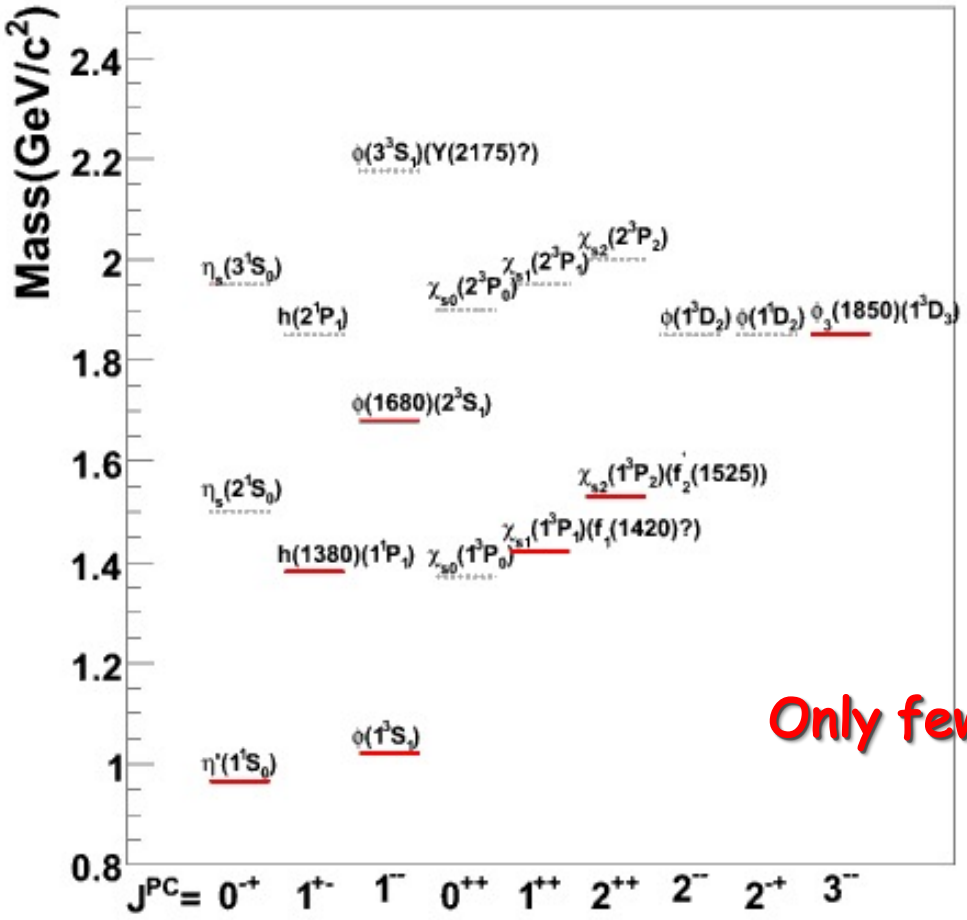






- Clear evidence for $a_2(1700)$ in χ_{c1}decays
- Upper limits for $\pi_1(1^{-+})$ in 1.4 - 2.0 GeV/c^2
- More works in progress in J/ψ and χ_{c1} decays

Strangeonia spectrum



—— identified

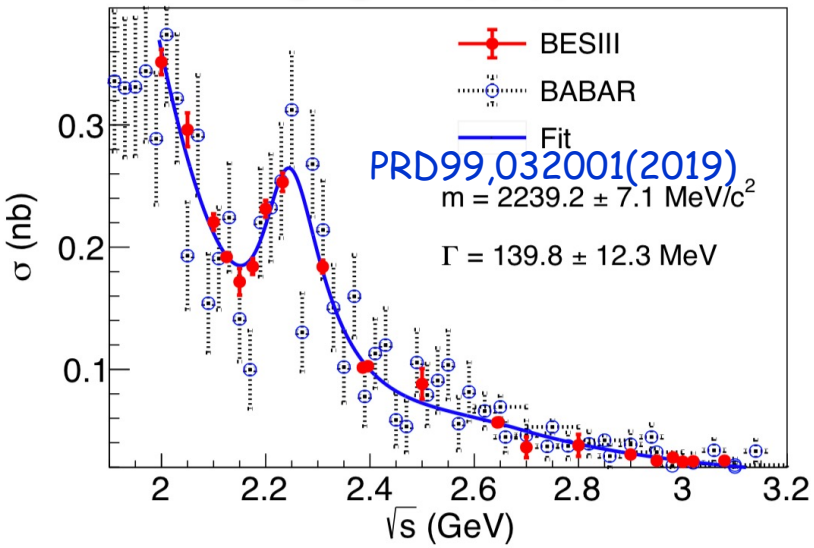
..... not identified

$s\bar{s}$ system – what do we know?

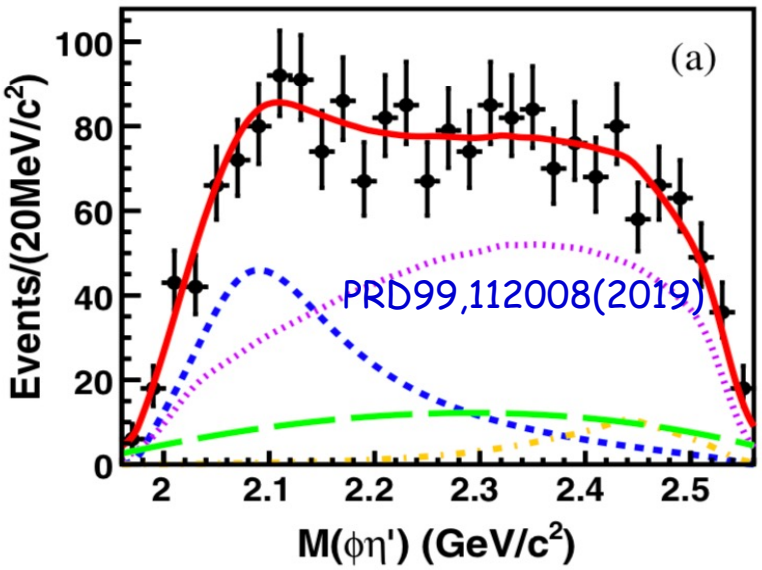
Only few of them have been identified !

$\phi(2170)$ at BESIII

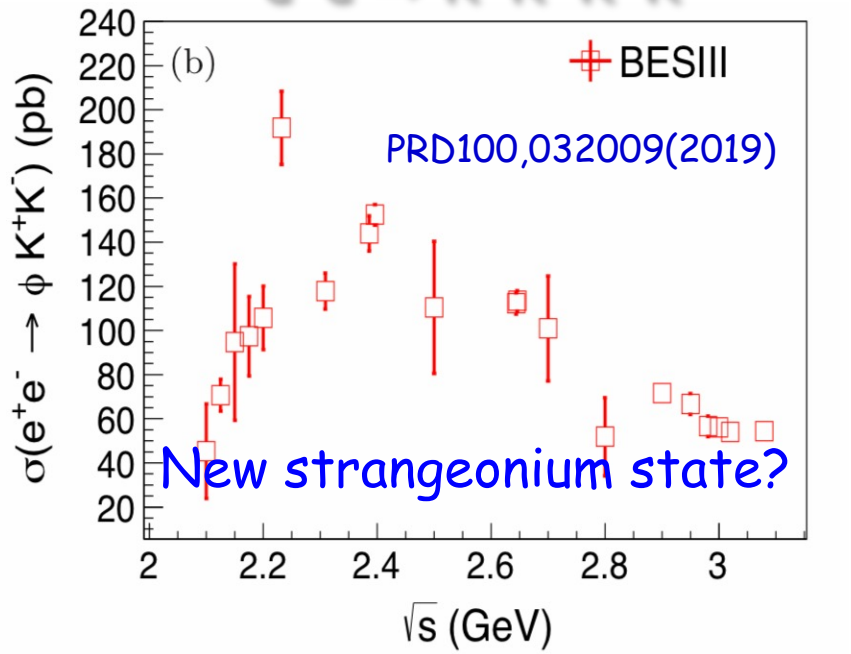
$e^+e^- \to K^+K^-$



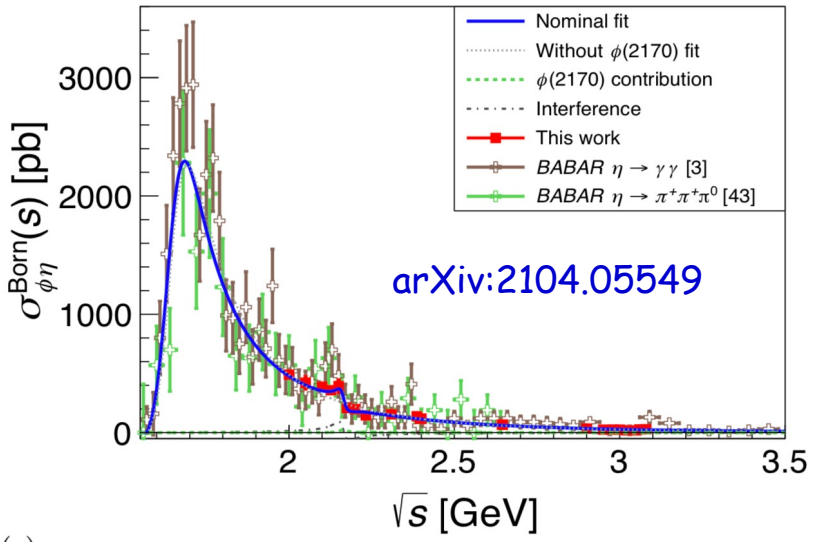
$J/\psi \to \phi\eta\eta'$



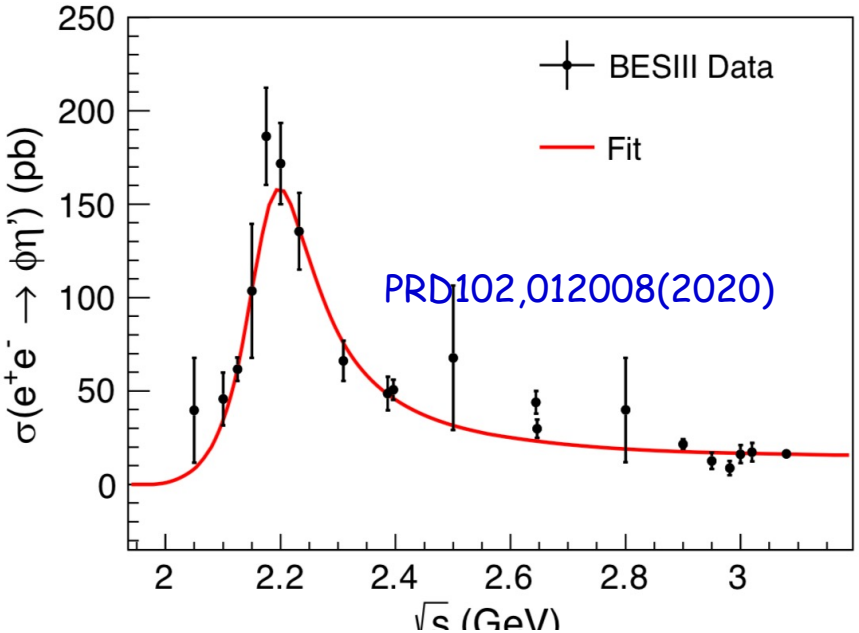
$e^+e^- \to K^+K^-\ K^+K^-$



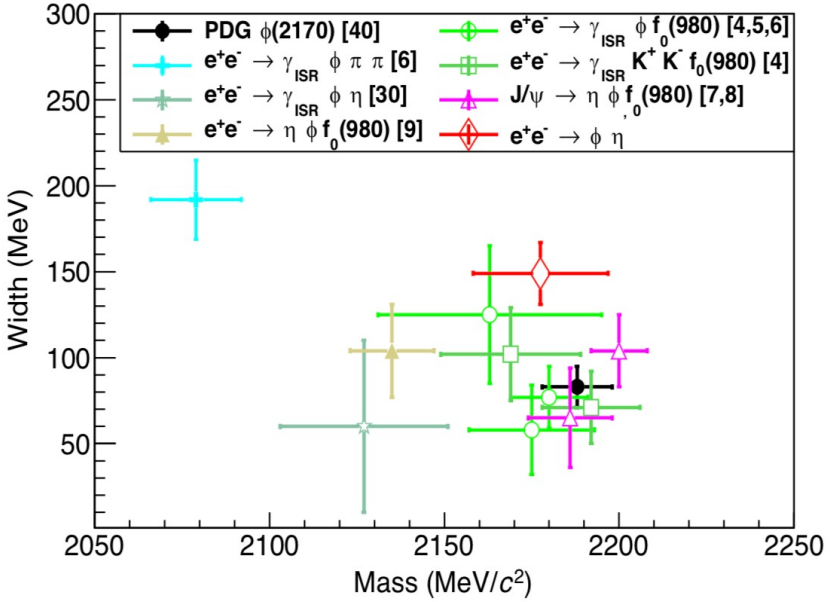
$e^+e^- \to \phi\eta$



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



Comparisons



Theorists explain $\phi(2170)$ as

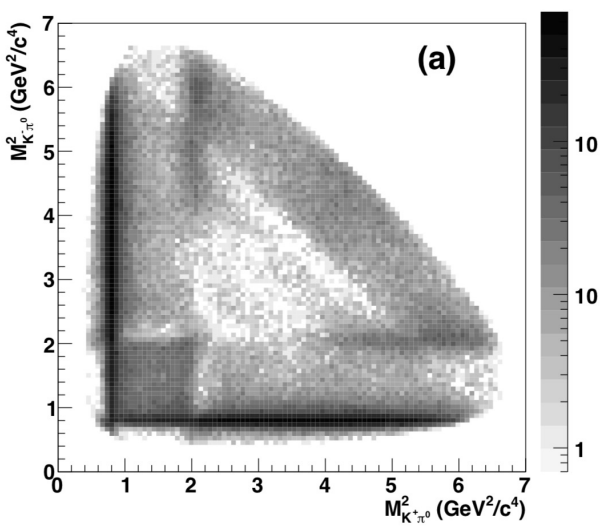
- ✓ $s\bar{s}g$ hybrid
- ✓ 2^3D_1 or 3^3S_1 $s\bar{s}$
- ✓ tetraquark
- ✓ molecular state $\Lambda\bar{\Lambda}$
- ✓ $\phi f_0(980)$ resonance with FSI
- ✓ Three body system ϕKK

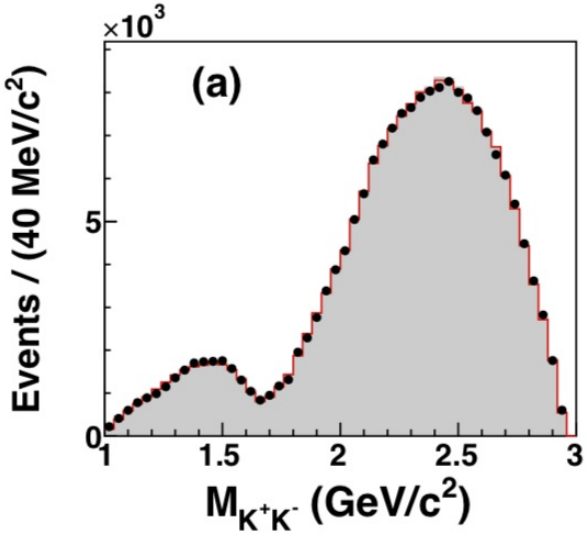
The nature of $\phi(2170)$ still not fully understand !

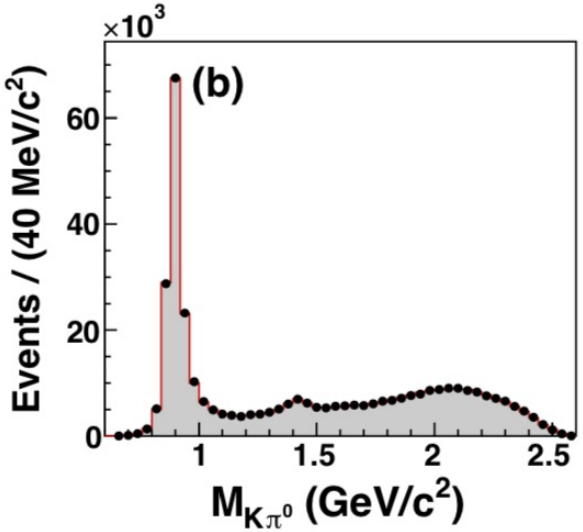
See Lei Xia's talk for details

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

Phys. Rev. D100,032004(2019)



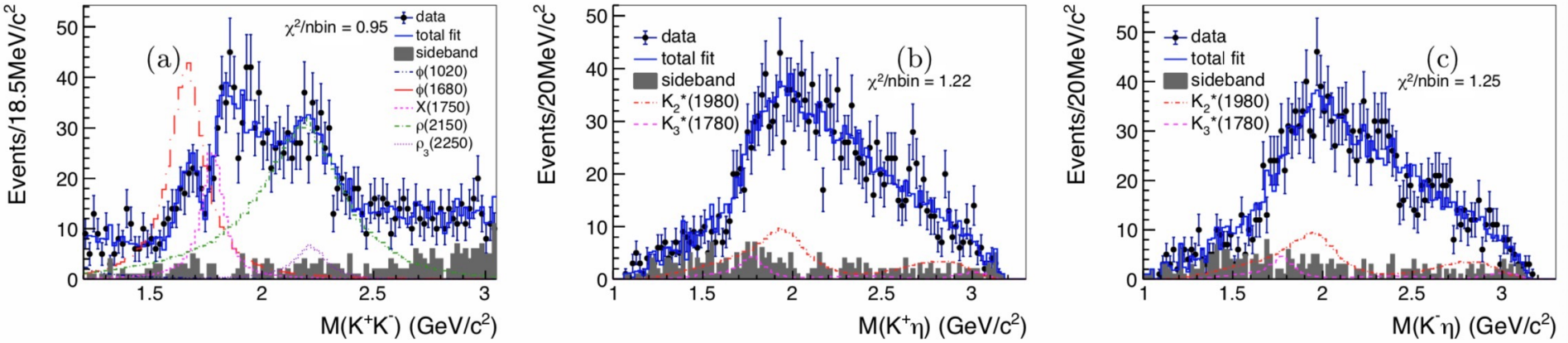




- The dominant contribution is from K*(892)
- First observation of $K^*_2(1980)$ and $K^*_4(2045)$ in J/ψ decays
- Two broad 1^{--} structures were observed in K^+K^- mass spectrum, Possibly contributed from $\omega(1650)$ and $\rho(2150)$

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

Phys. Rev. D101,032008(2020)



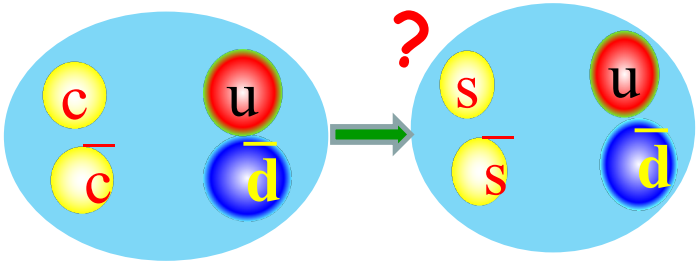
- Observation of both ϕ(1680) and X(1750) implies X(1750) is a new structure
- A broad structure around 2.2 GeV is observed, either ϕ(2170) or ρ(2150)?

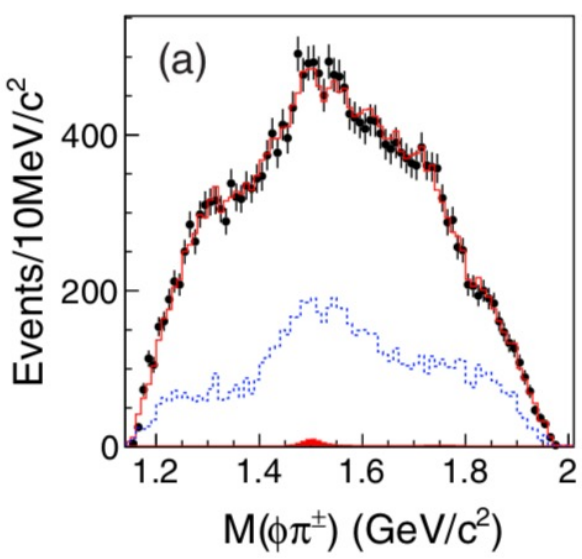
Search for Zs in e+e-⟶ ϕπ π

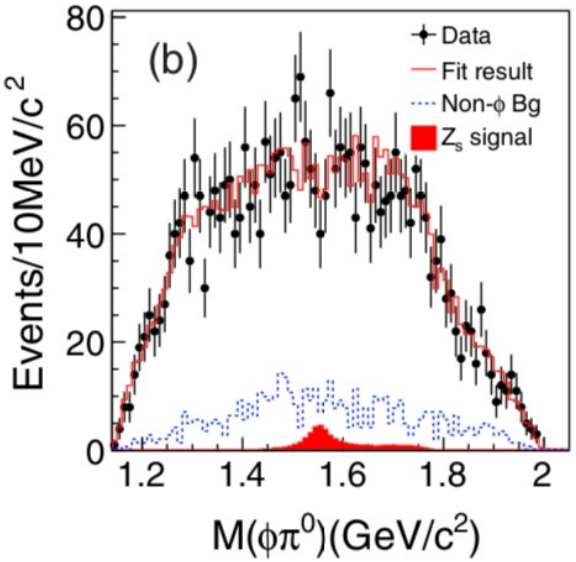
PRD99，011101(2018)

$Y(4260) \to J/\psi\pi^+\pi^-$ charm, ⇒ Z_c

$Y(2175) \to \phi(1020)\pi^+\pi^-$ strange ⇒ Z_s ?







No evident structure observed in ϕπ mass spectra

Summary& Prospects

- Rich physics in light hadrons
  - Light hadron spectroscopy → Quark model
  - Light hadron decays → QCD
  - ……
- 10 billion J/ψ events available at BESIII !
  - A unique opportunity to map the light hadron spectroscopy
- **More surprises at BESIII !**