Light Exotics at BESIII

Status and Highlights

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on behalf of the BESIII Collaboration

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Phi to Psi 2026

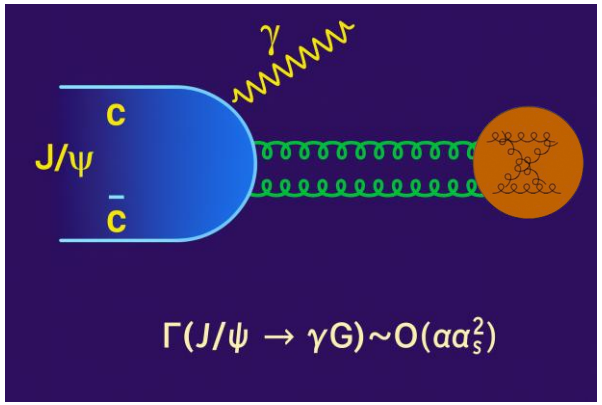
8 – 11 June 2026, Pisa

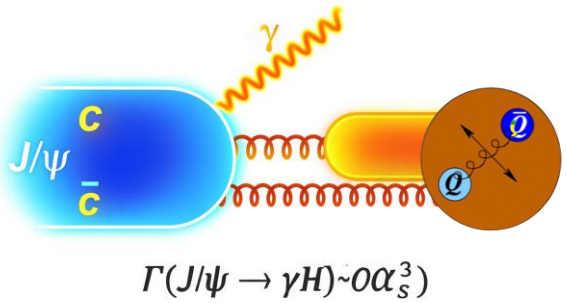
Istituto Nazionale di Fisica Nucleare

Università degli Studi di Ferrara

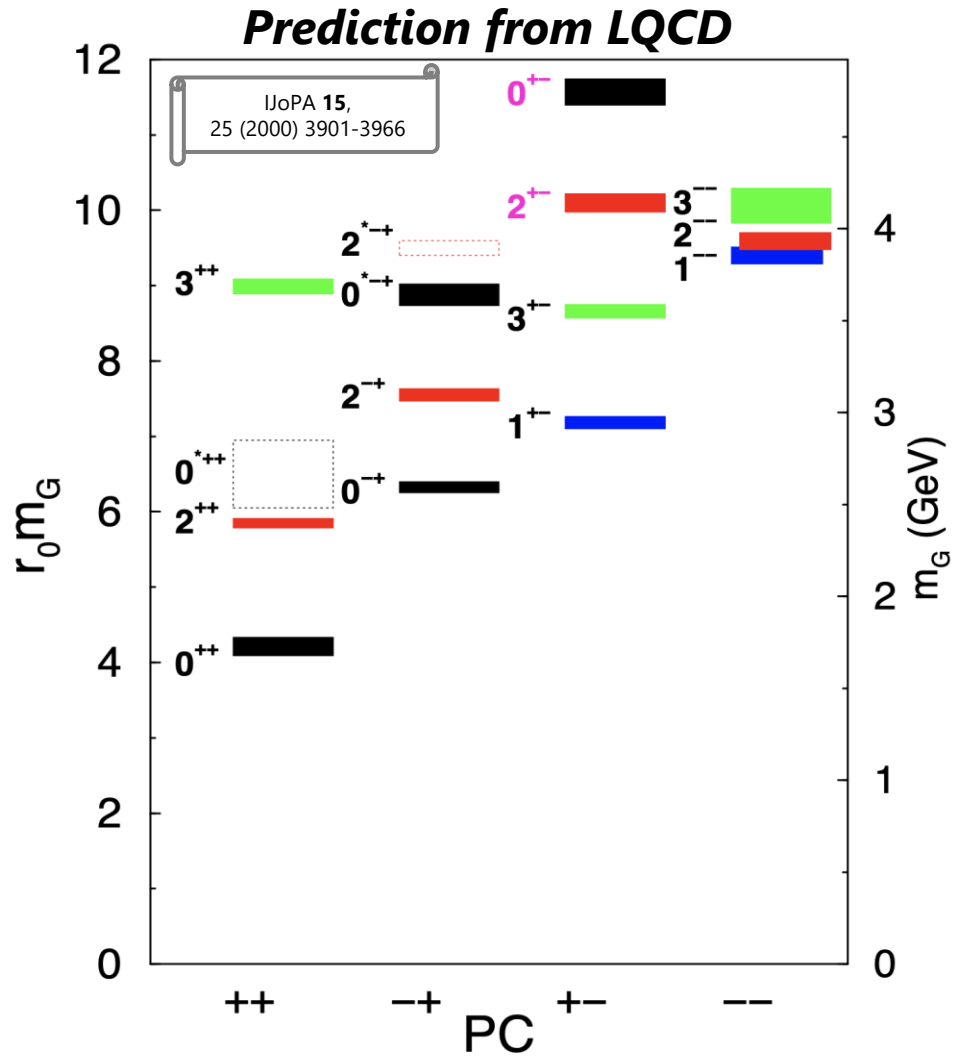
Glueballs (?) with Radiative J/ψ Decays

Charmonium radiative decays create an ideal environment for studying glueballs and hybrid hadrons:
→ low background, high statistics and gluon-rich process





According to pQCD, glueballs and hybrids are expected to present a larger production cross section compared to mesons



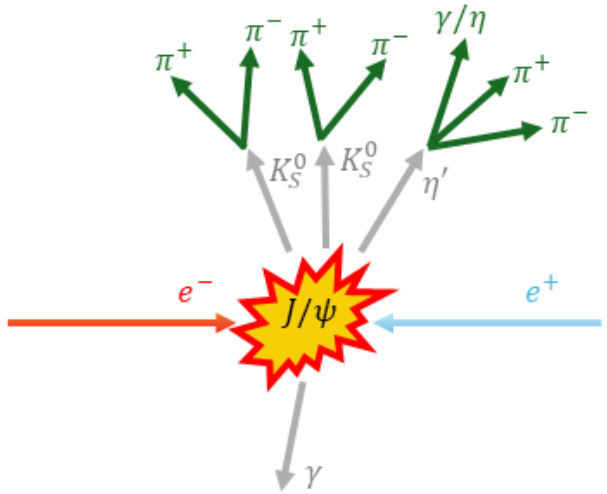
X(2370): Glueball-like particle (?)

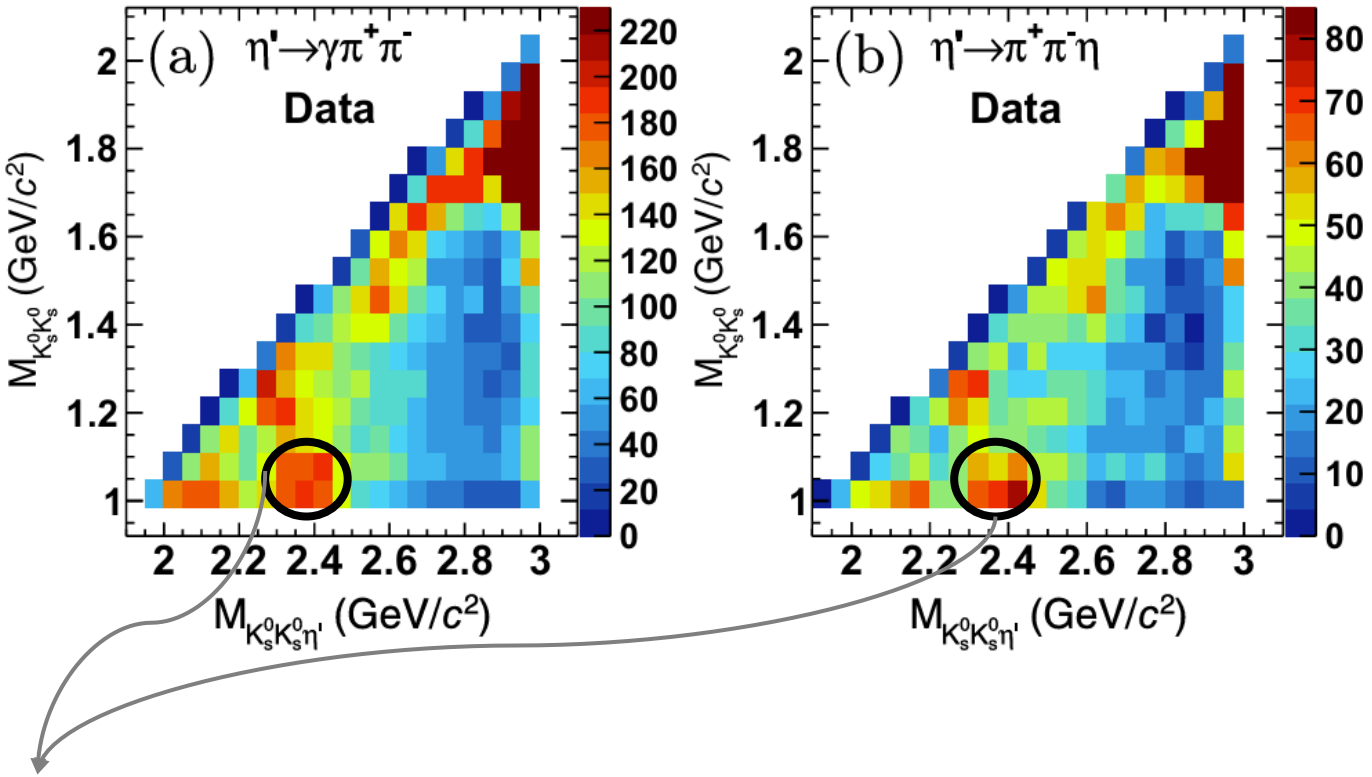
First observed in $J/\psi \to \gamma\pi^+\pi^-\eta'$

Confirmed in $J/\psi \to \gamma K^+K^-\eta'$ *and in* $J/\psi \to \gamma K_S^0 K_S^0 \eta'$

X(2370): Glueball-like particle

$$J/\psi \to \gamma K_S^0 K_S^0 \eta'$$



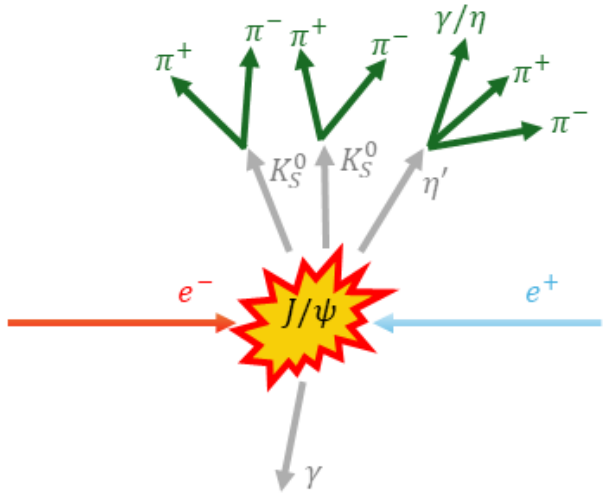


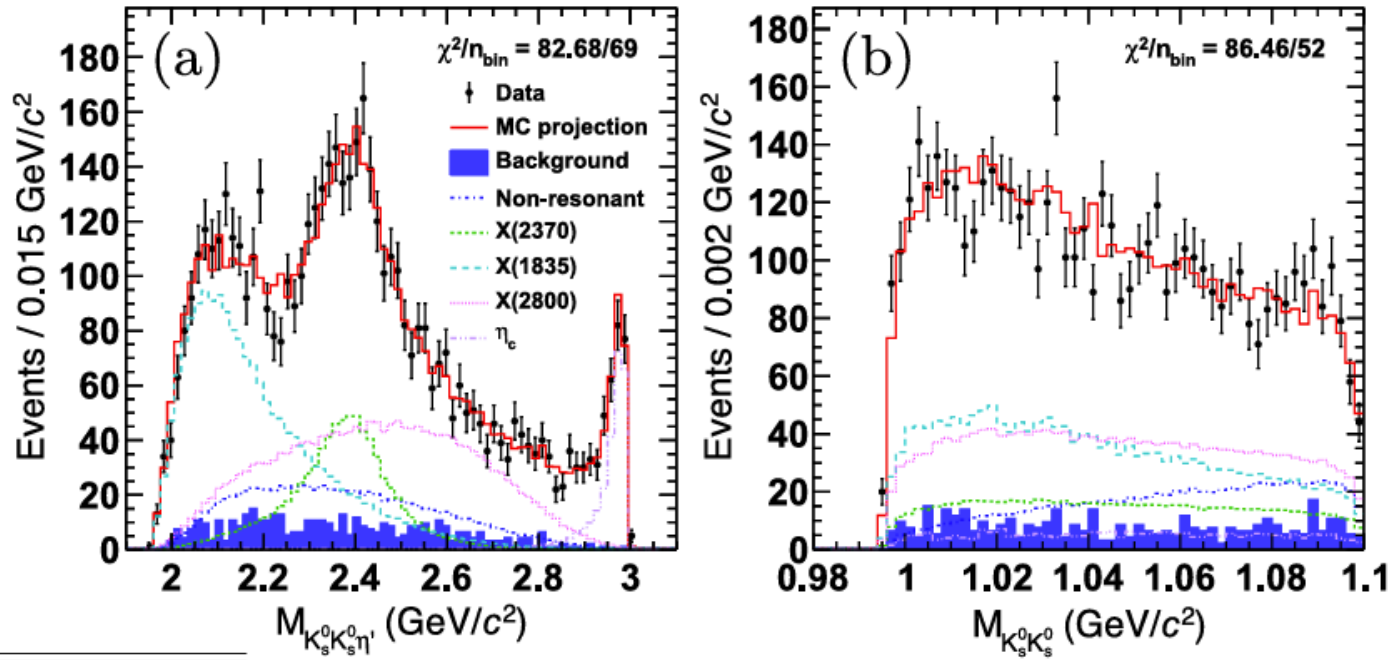
- Enhancement near the $K_S^0 K_S^0$ threshold in relation to the structure around 2.4 GeV
- Clear connection between the $f_0(980)$ and the structure around 2.4 GeV

Phys. Rev: Lett. ***132****, 181901 (2024)*

X(2370): Glueball-like particle

$$J/\psi \to \gamma K_S^0 K_S^0 \eta'$$



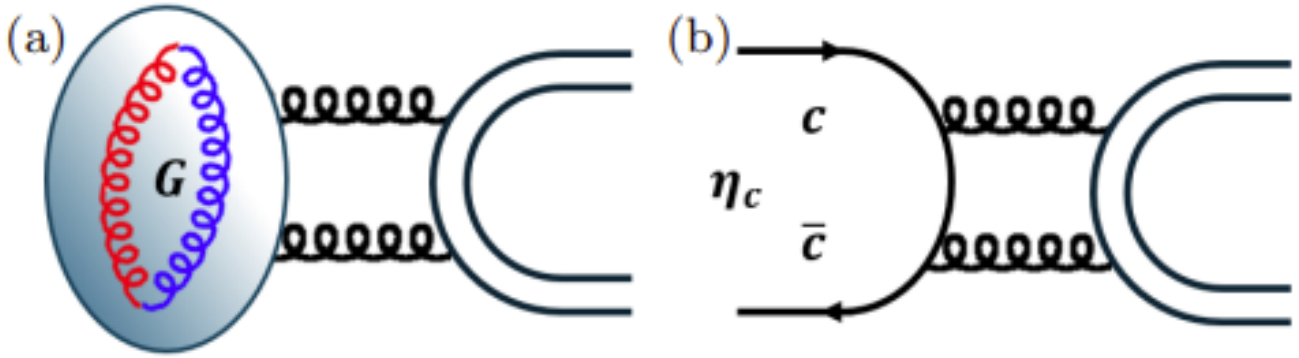


state	J^{PC}	Decay mode	Mass (MeV/c^2)	Width (MeV/c^2)	Significance
X(2370)	0^{-+}	$f_0(980)\eta'$	2395^{+11}_{-11}	188^{+18}_{-17}	14.9σ
X(1835)	0^{-+}	$f_0(980)\eta'$	1844	192	22.0σ
X(2800)	0^{-+}	$f_0(980)\eta'$	2799^{+52}_{-48}	660^{+180}_{-116}	16.4σ
η_c	0^{-+}	$f_0(980)\eta'$	2983.9	32.0	$> 20.0\sigma$
PHSP	0^{-+}	$\eta'(K_S^0K_S^0)_{S-wave}$	− − −	− − −	9.0σ
		$\eta'(K_S^0K_S^0)_{D-wave}$	− − −	− − −	16.3σ

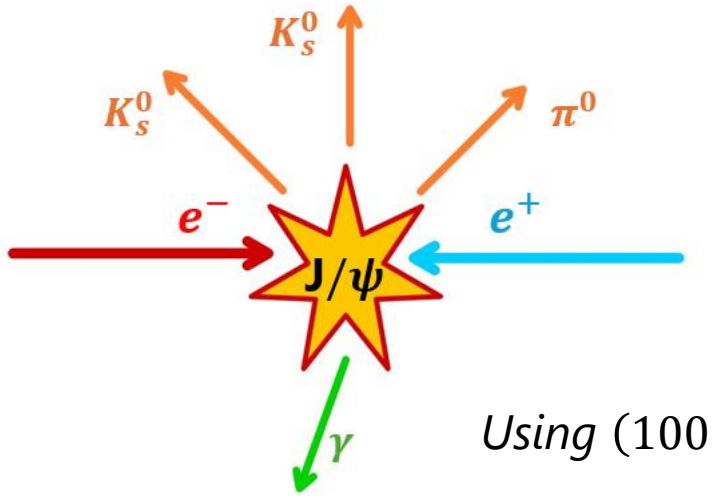
Spin parity of $X(2370)$ is determined to be $\mathbf{0^{-+}}$ for the first time with a significance greater than $\mathbf{10\sigma}$
The **mass** of the $X(2370)$ is in agreement with the LQCD mass prediction of the lightest pseudoscalar glueball, $\mathbf{2395 \pm 14\ MeV/c^2}$

Phys. Rev: Lett. ***132****, 181901 (2024)*

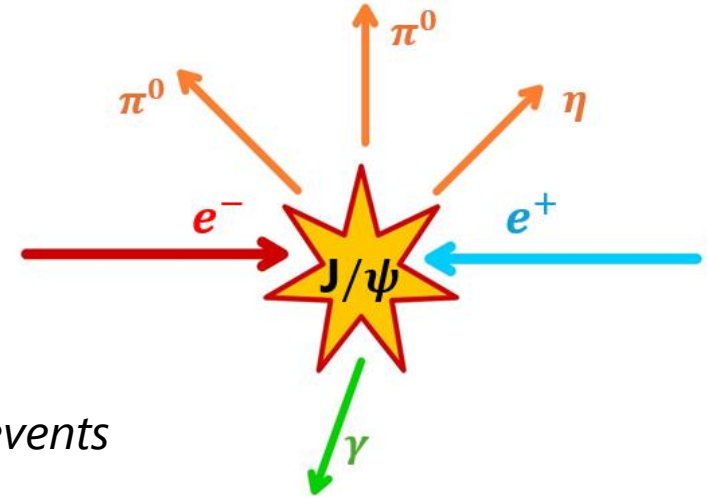
X(2370): Glueball-like particle



$J/\psi \to \gamma K_S^0 K_S^0 \pi^0$



$J/\psi \to \gamma \pi^0 \pi^0 \eta$

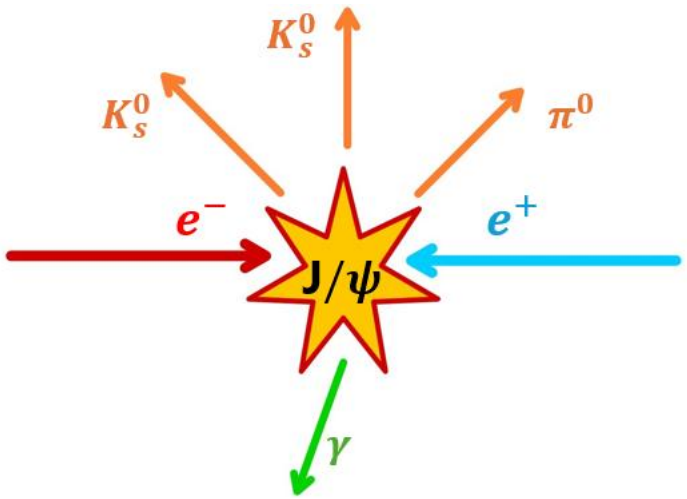


Using $(10087 \pm 44) \times 10^6$ J/ψ *events*

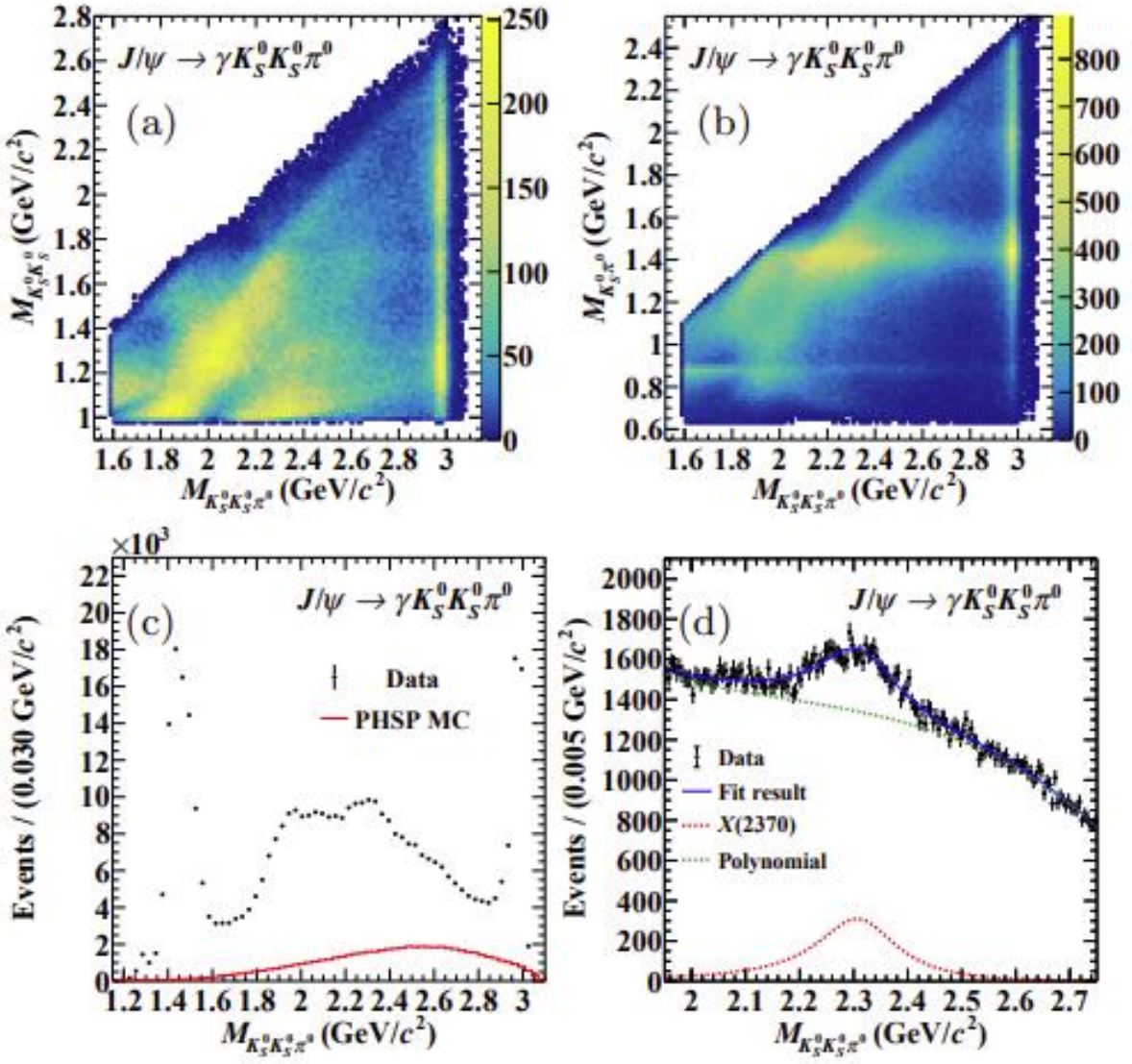
http://arxiv.org/abs/2605.26495

X(2370): Glueball-like particle

$$J/\psi \to \gamma K_S^0 K_S^0 \pi^0$$



The two-dimensional distributions indicate several possible intermediate processes
→ $a_0(980)^0\pi^0$ and $K_0^*(1430)K_S^0 \to K_S^0 K_S^0 \pi^0$



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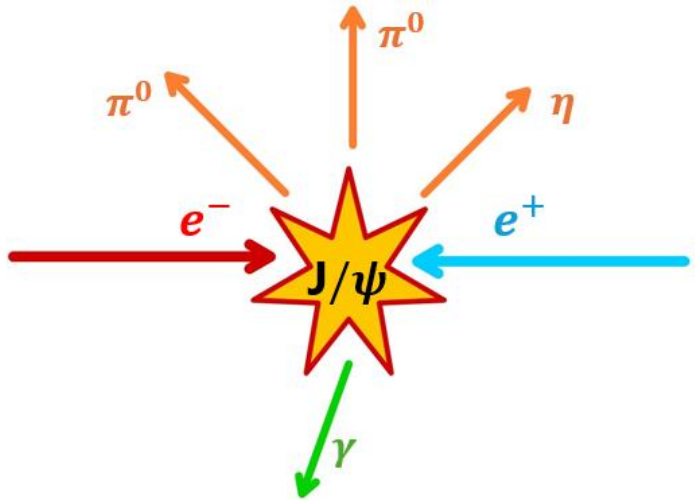
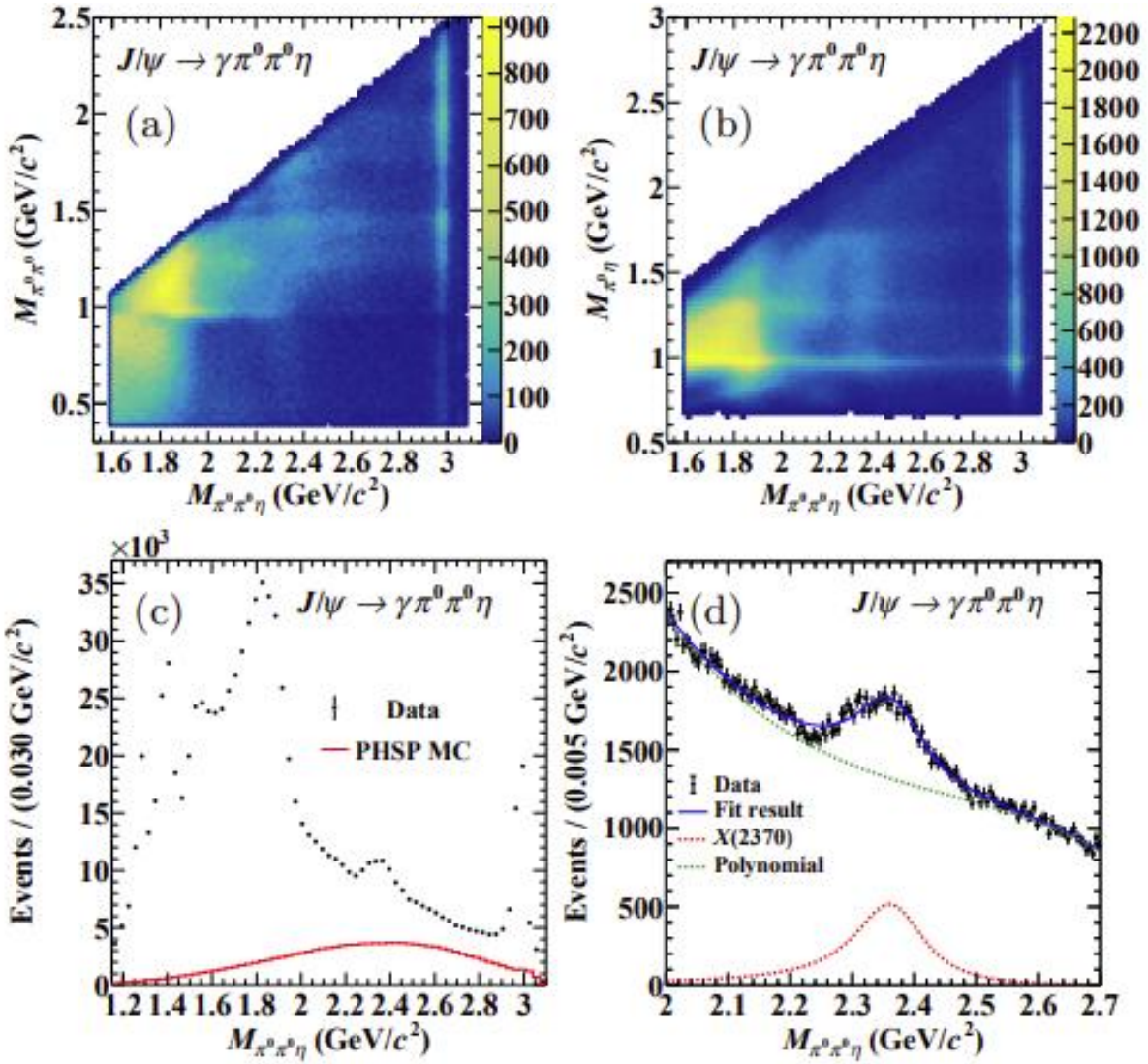
X(2370): Glueball-like particle

$$J/\psi \to \gamma\pi^0\pi^0\eta$$



The two-dimensional distributions indicate several possible intermediate processes
→ $a_0(980)^0\pi^0 \to \pi^0\pi^0\eta$ and $f_0(1500)\eta$



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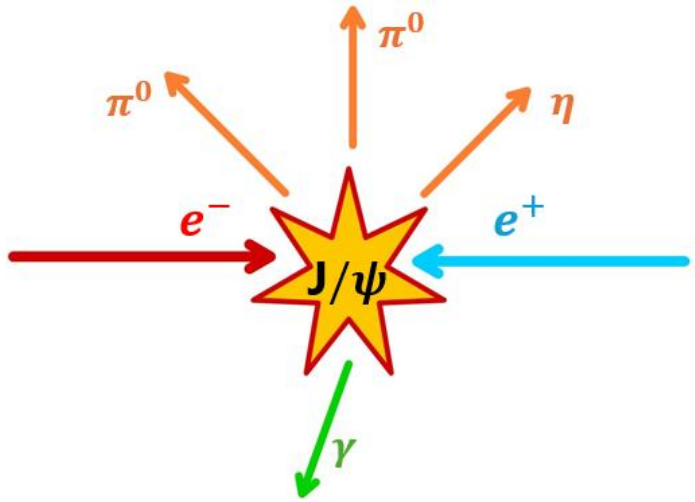
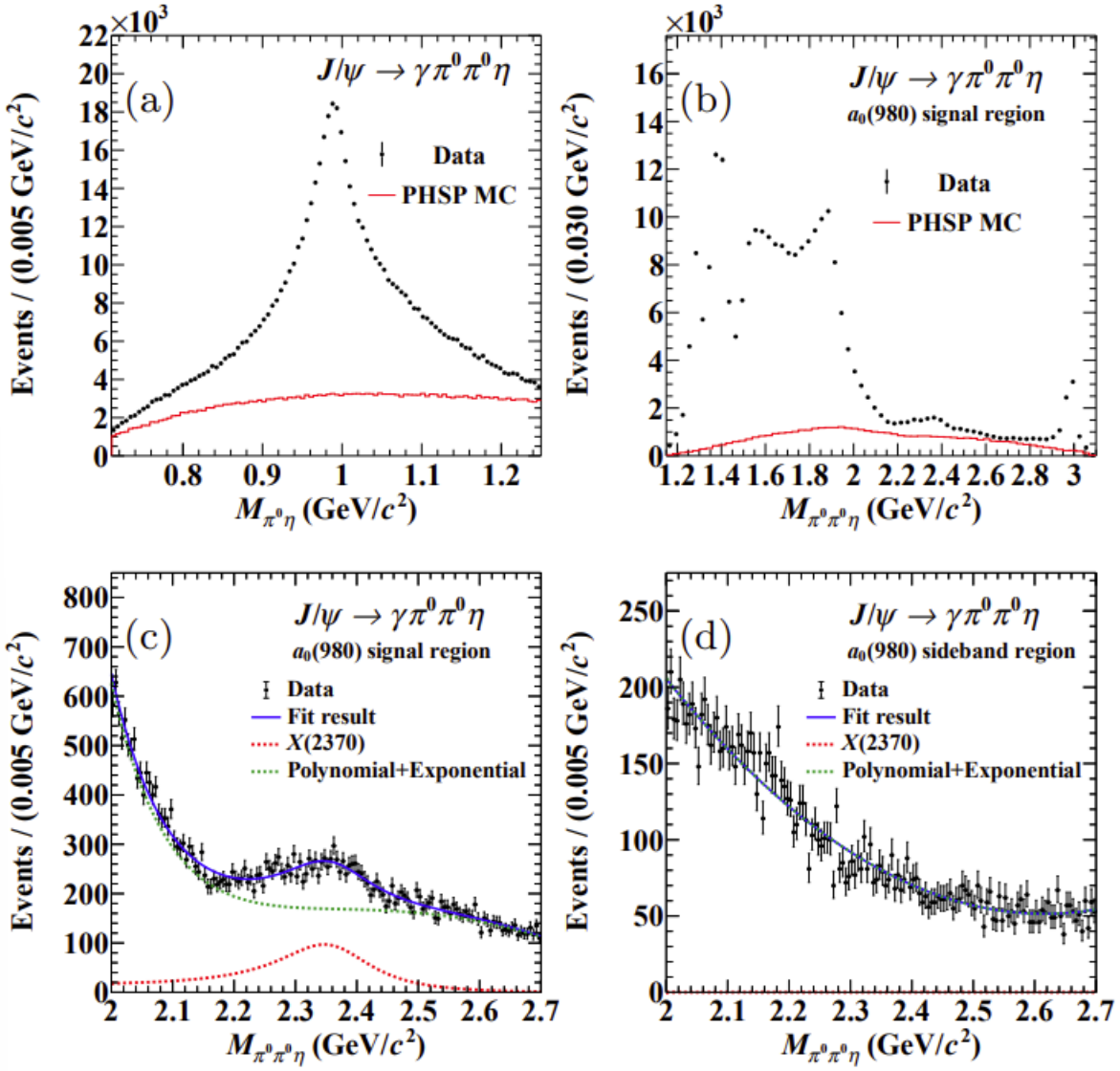
X(2370): Glueball-like particle

$$J/\psi \to \gamma\pi^0\pi^0\eta$$



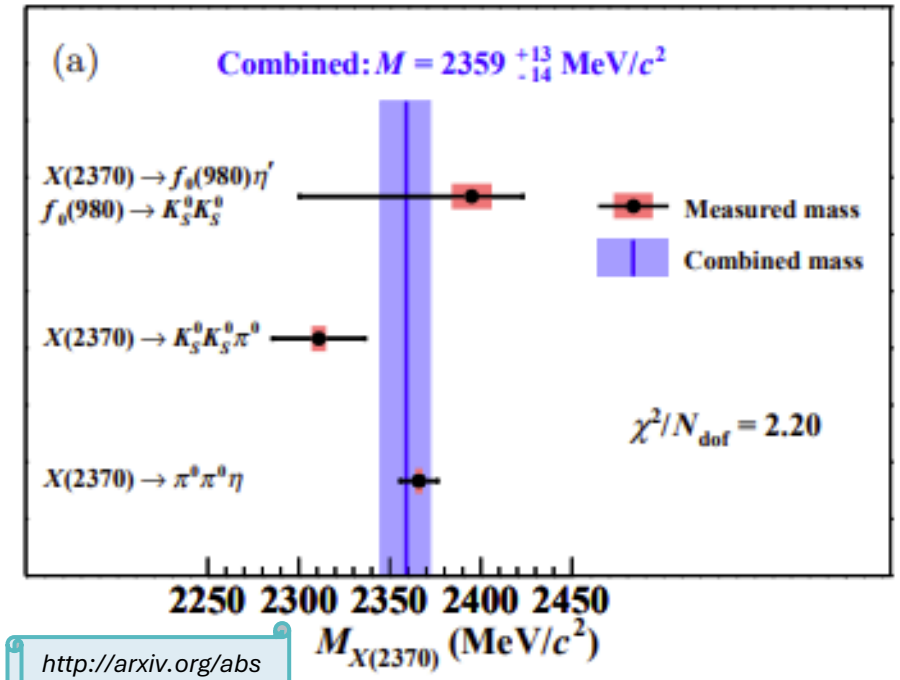
By selecting the $a_0(980)^0$ mass region
→ $X(2370) \to a_0(980)^0\pi^0$
with $a_0(980)^0 \to \pi^0\eta$
observed with significance $> 9\sigma$

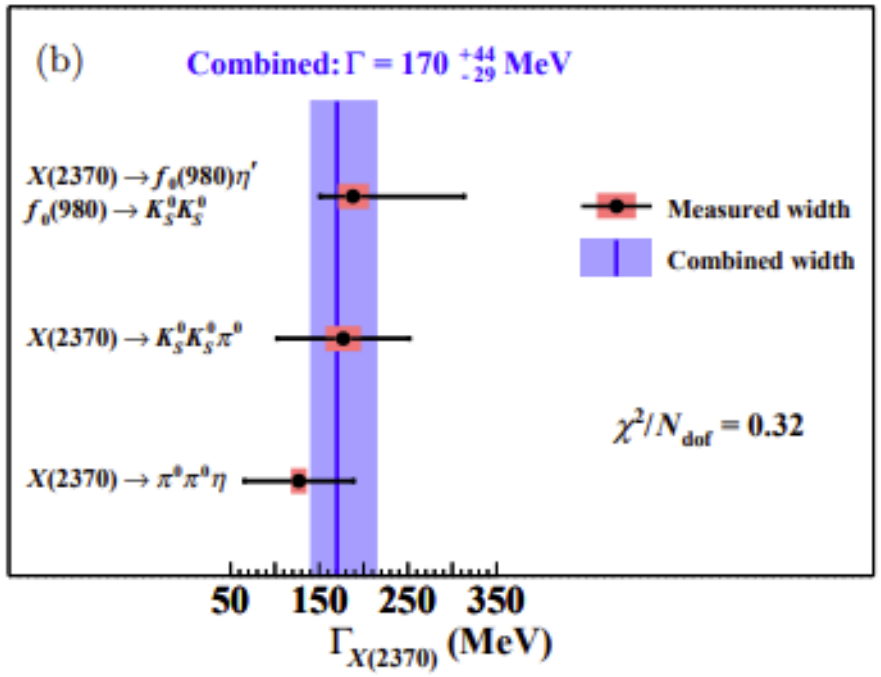


http://arxiv.org/abs/2605.26495

X(2370): Glueball-like particle

Decay	$M_{X(2370)}$	$\Gamma_{X(2370)}$
$X(2370) \to K_S^0 K_S^0 \pi^0$	$2311 \pm 4(stat) \pm 25\ (syst)\ \mathrm{MeV/c^2}$	$177 \pm 20(stat) \pm 72(syst)\ \mathrm{MeV}$
$X(2370) \to \pi^0 \pi^0 \eta$	$2366 \pm 2(stat) \pm 10(syst)\ \mathrm{MeV/c^2}$	$127 \pm 9(stat) \pm 61(syst)\ \mathrm{MeV}$
$X(2370) \to a_0(980)^0 \pi^0$	$2350 \pm 5(stat) \pm 9(syst)\ \mathrm{MeV/c^2}$	$180 \pm 20(stat) \pm 58(syst)\ \mathrm{MeV}$





http://arxiv.org/abs/2605.26495

$$M_{X(2370)} = 2359^{+13}_{-14}\ \mathrm{MeV/c^2}$$
$$\Gamma_{X(3270)} = 170^{+44}_{-29}\ \mathrm{MeV}$$

The similarities in decay mode between the $X(2370)$ and η_c are consistent with the expected features of a pseudoscalar glueball.

X(2370): Glueball-like particle

Decay	$M_{X(2370)}$	$\Gamma_{X(2370)}$
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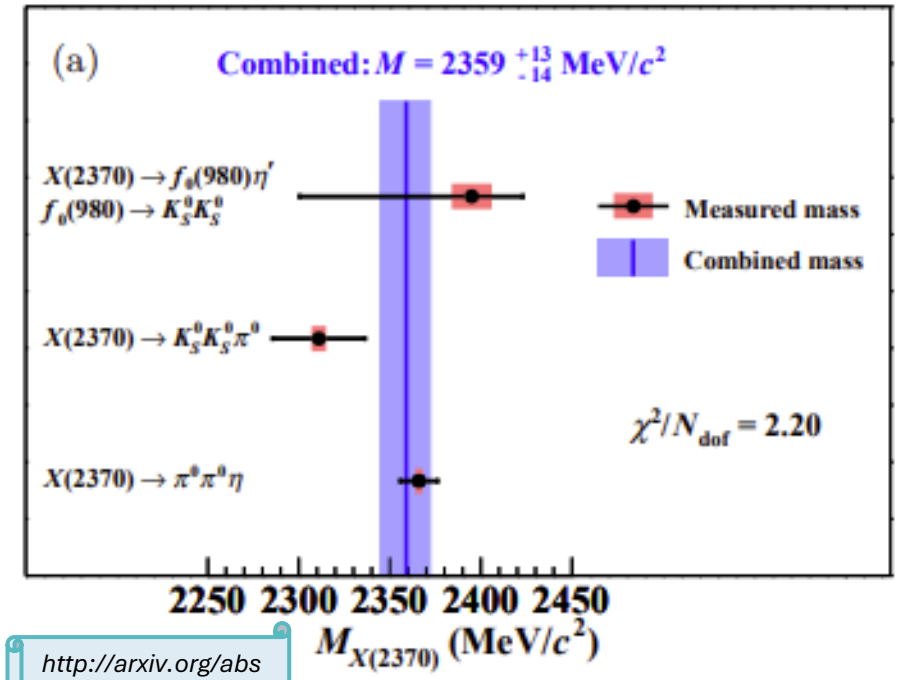

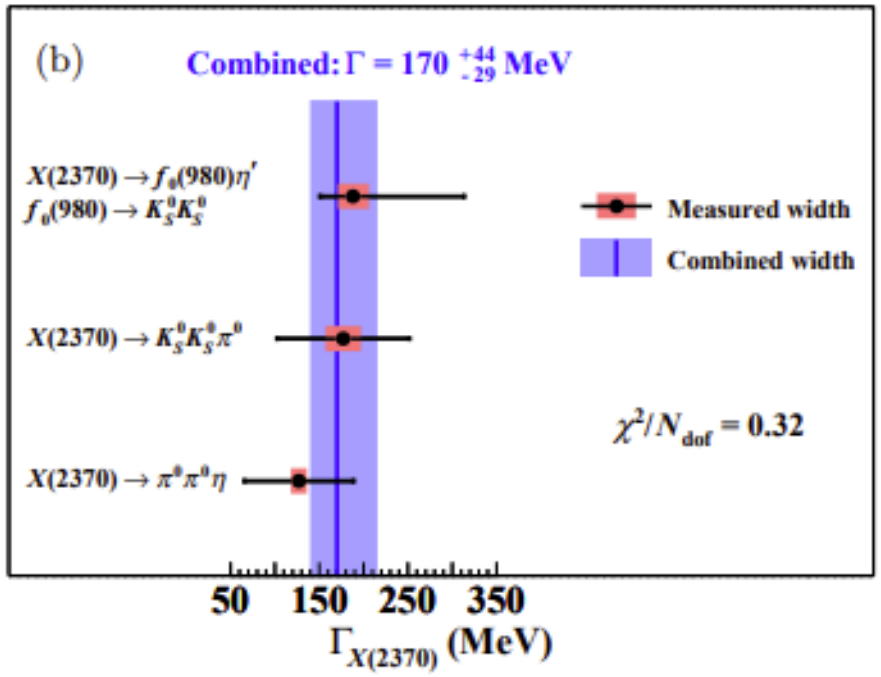

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$M_{X(2370)} = 2359^{+13}_{-14}\ \mathrm{MeV/c^2}$
$\Gamma_{X(3270)} = 170^{+44}_{-29}\ \mathrm{MeV}$

$BR(J/\psi \to \gamma X(2370))$ seems to be larger than one order of magnitude

→ More experimentally and theoretically studies needed!

J/ψ Radiative Decay

Acting as a **flavor filter**, the decays $\mathbf{J/\psi \to \gamma X}$**,** $\boldsymbol{X \to \gamma V}$ $(\boldsymbol{V = \rho, \omega, \phi})$, play a crucial role in probing the quark content of intermediate resonances

$X(1835)$ *and* $\eta(1405)$

The resonant state ***X(1835)*** was observed for the first time by BESIII in the decay $\mathbf{J/\psi \to \gamma \pi^+ \pi^- \eta'}$ with quantum numbers $\boldsymbol{J^{PC} = 0^{-+}}$

Many theoretical interpretations:

- Nucleon-antinucleon bound state $\mathrm{N}\bar{N}$
- Baryonium with gluonic content
- Second radial excitation of the η' meson
- Exotic state: $\eta_c - glueball$ or $pseudoscalar\ glueball$

Phys. Rev. Lett. 95, 262001 (2005)

In the region around **1.4 GeV**, the pseudoscalar spectrum presents a complex structure characterized by the overlapping of two resonances:

- $\boldsymbol{\eta(1475)}$, interpreted as the first radial excitation of the η' meson
- $\boldsymbol{\eta(1405)}$, pseudoscalar glueball candidate (?)

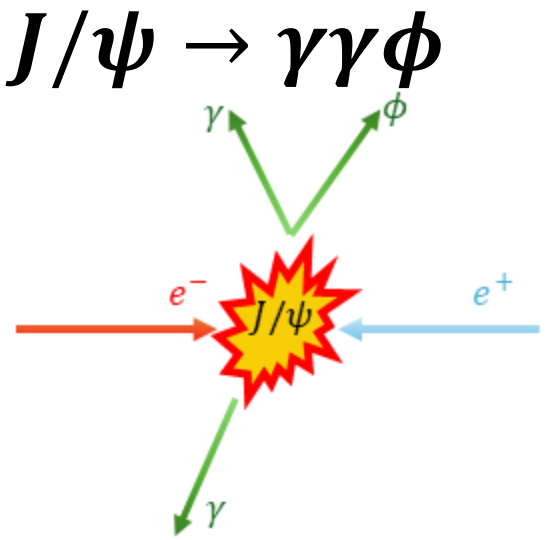
→ However, a significant discrepancy exists between the $\eta(1405)$ mass and **LQCD prediction** (*2.3-3.0* GeV)

- Are they truly two distinct resonances?

Phys. Rev. Lett. 108, 182001 (2012)

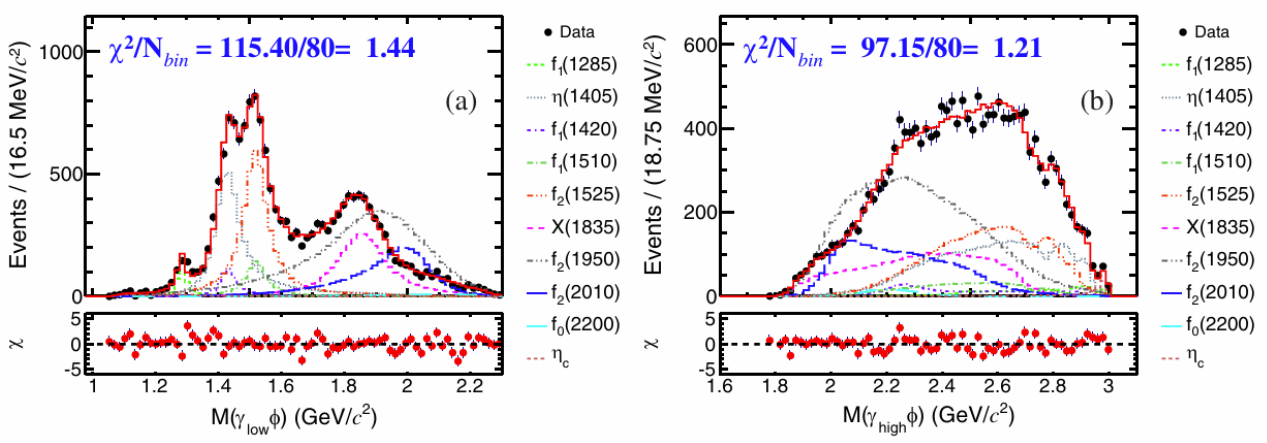
Phys. Rev: Lett. **111**, 052011 (2025)

$X(1835)$ and $\eta(1405)$ in $J/\psi \to \gamma\gamma\phi$



First time in $\gamma\phi$

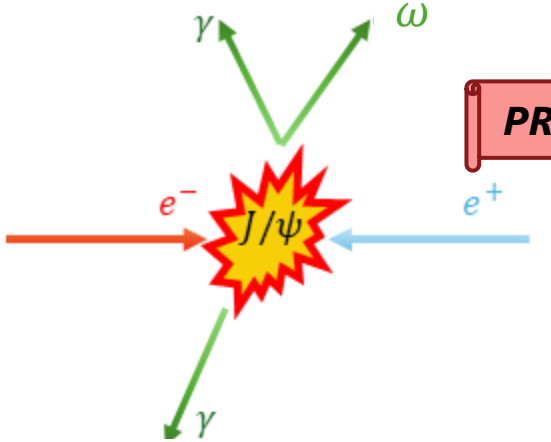
Resonance	M (MeV/c^2)	Γ (MeV)	$\mathcal{B}(\times 10^{-6})$	Significance
$f_1(1285)$	1281.9	22.7	$0.29 \pm 0.03^{+0.11}_{-0.09}$	17.3σ
$f_1(1420)$	1426.3	54.5	$0.55 \pm 0.07^{+0.18}_{-0.17}$	9.0σ
$\eta(1405)$	$1422.0 \pm 2.1^{+5.9}_{-7.8}$	$86.3 \pm 2.7^{+6.6}_{-17.4}$	$3.57 \pm 0.18^{+0.59}_{-0.61}$	18.9σ
$f_1(1510)$	1518.0	73.0	$0.78 \pm 0.09^{+0.34}_{-0.30}$	5.3σ
$f_2(1525)$	1517.4	86.0	$2.76 \pm 0.18^{+0.90}_{-0.61}$	16.4σ
$X(1835)$	$1849.3 \pm 3.0^{+7.6}_{-10.0}$	$179.6 \pm 8.7^{+22.5}_{-27.9}$	$3.37 \pm 0.19^{+0.78}_{-1.10}$	15.3σ
$f_2(1950)$	1936.0	464.0	$9.96 \pm 0.60^{+3.44}_{-2.13}$	13.1σ
$f_2(2010)$	2011.0	202.0	$4.63 \pm 0.43^{+1.42}_{-1.46}$	11.3σ
$f_0(2200)$	2187.0	207.0	$0.20 \pm 0.04^{+0.05}_{-0.07}$	6.3σ
η_c	2983.9	32.0	$0.21 \pm 0.03^{+0.05}_{-0.07}$	12.9σ



- $\eta_c \to \gamma\phi$ observed for the first time
- $\eta(1405)$ is unfavorable to be a glueball → excited state of η'
- $\eta(1475)$ and $\eta(1295)$ cannot be excluded
- $X(1835)$ is confirmed to be $J^{PC} = 0^{-+}$ with a sizable $s\bar{s}$ component → second radial excitation of the η'
- No signals for $\eta_1(1855)$ and $X(2370)$

Preliminary: $X(1835)$ *and* $\eta(1405)$ *in* $J/\psi \to \gamma\gamma\omega$

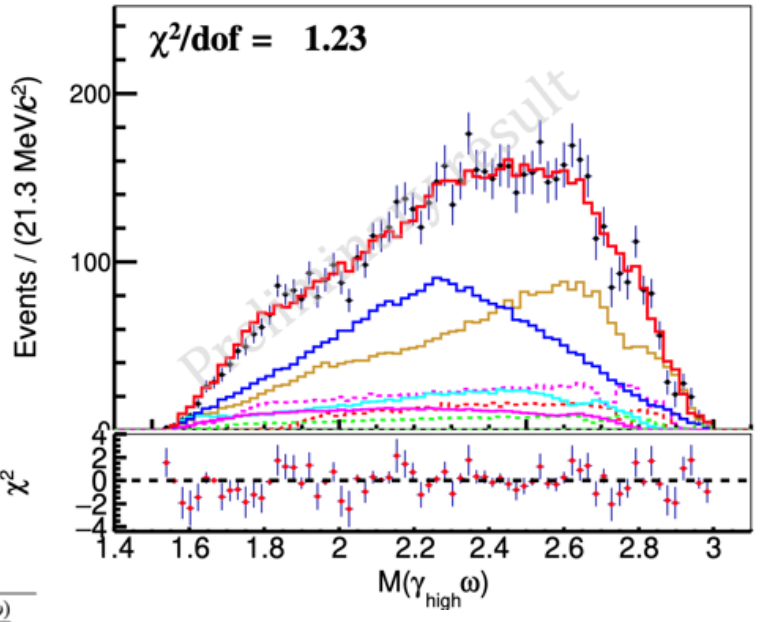
$J/\psi \to \gamma\gamma\omega$

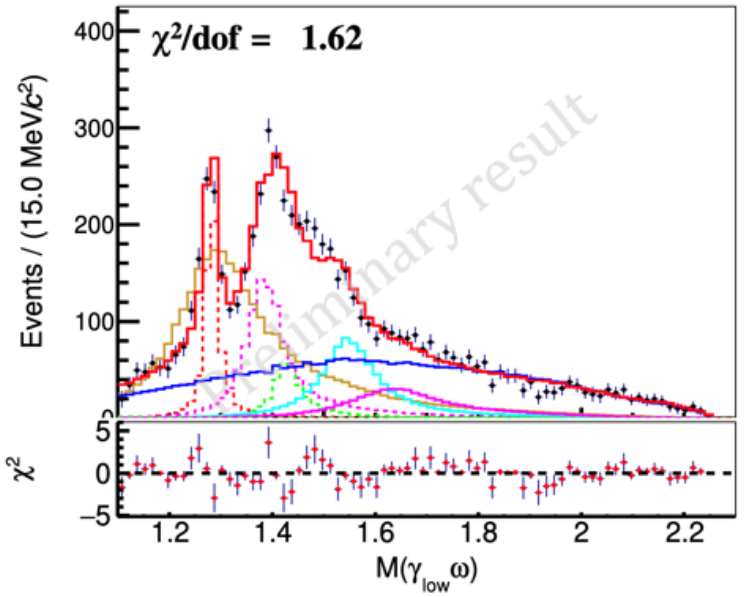


PRELIMINARY

[this analysis] [PRD 111, 052011 (2025)]

Resonance	$J/\psi \to \gamma R \to \gamma\gamma\omega(\times 10^{-6})$	$J/\psi \to \gamma R \to \gamma\gamma\phi(\times 10^{-6})$	$\frac{\Gamma(R\to\gamma\omega)}{\Gamma(R\to\gamma\phi)}$
$f_1(1285)$	$1.73 \pm 0.12^{+0.13}_{-0.18}$	$0.29 \pm 0.03^{+0.11}_{-0.09}$	3.5 ± 1.5
$f_1(1420)$	$0.88 \pm 0.10^{+0.20}_{-0.49}$	$0.55 \pm 0.07^{+0.18}_{-0.17}$	1.1 ± 0.7
$\eta(1405)$	$3.54 \pm 0.20^{+0.65}_{-0.24}$	$3.57 \pm 0.18^{+0.59}_{-0.61}$	0.3 ± 0.1
η_c	$0.20 \pm 0.06^{+0.03}_{-0.09}$	$0.21 \pm 0.03^{+0.05}_{-0.07}$	0.8 ± 0.5
$\eta(1295)$	< 0.35	< 0.84	
$\eta(1475)$	< 0.14	< 0.38	
$X(1835)$	< 0.11	$3.37 \pm 0.19^{+0.78}_{-1.10}$	
$X(2370)$	< 0.04	< 0.11	
$\eta_1(1855)$	< 0.33	< 4.74	





- Predominantly $\mathbf{2^{++}}$ componets
- $\boldsymbol{\eta(1405) \to \gamma\phi}$ with a partial width 3 times than for $\gamma\omega$
- $\boldsymbol{f_1(1285) \to \gamma\omega}$ with a partial width 3 times than for $\gamma\phi$
- $\boldsymbol{\eta(1405)}$ mass and width different from PDG values
- $\boldsymbol{X(1835)}$ not observed → second radial excitation of η' with $\bar{s}s$ components
- $\eta_1(1855)$ and X(2370) suppressed → gluonic components

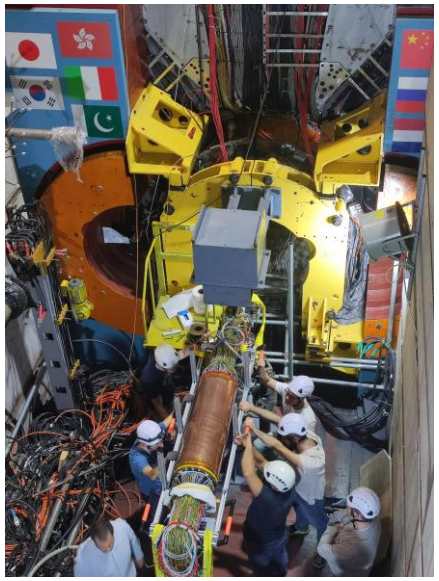
Summary

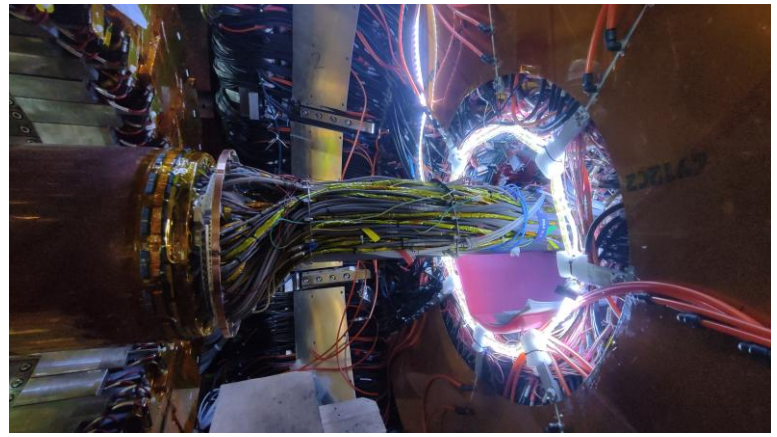
Since the beginning of data taking in 2008, BESIII has played an important role in the exploration of the charmonium spectrum and in the characterization of XYZ states.

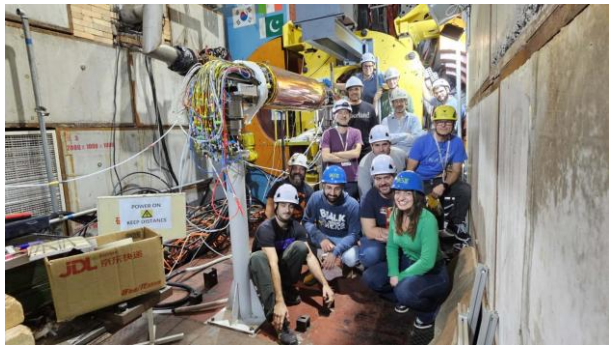
But the story of BESIII is far from over ...

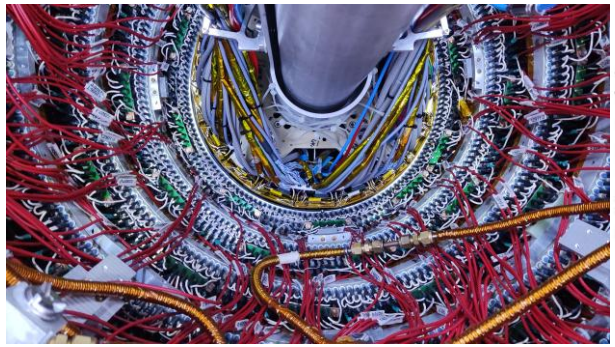
- Upgrade of the **CGEM-IT** inner tracker
- Accelerator upgrade

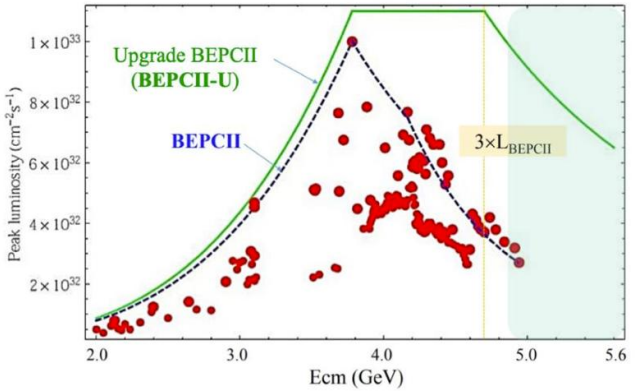
New high-statistics and high-energy datasets will open new horizons for the search for XYZ states and for the detailed study of charmed baryons











Grazie per l'attenzione!

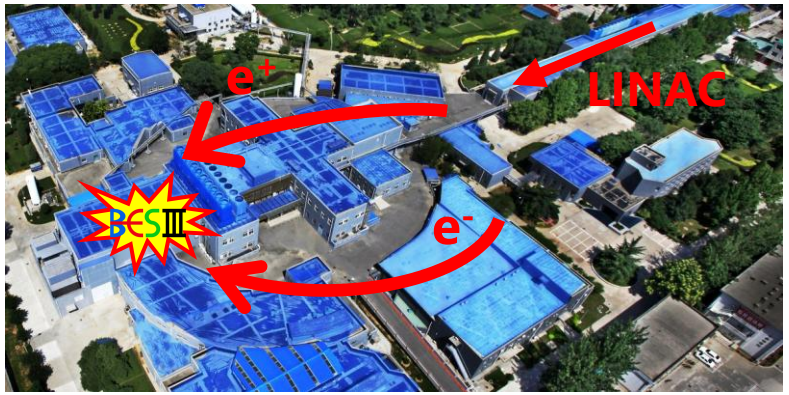
Backup

Outline

- The BESIII Experiment
- Glueballs with Radiative J/ψ Decays @BESIII
- $X(2370)$: glueball-like particle
- Radiative J/ψ Decays
- Summary

BESIII Experiment

BESIII (Beijing Spectrometer III) is an experiment located at the BEPCII (Beijing Electron Positron Collider II) at IHEP (Institute of High Energy Physics)



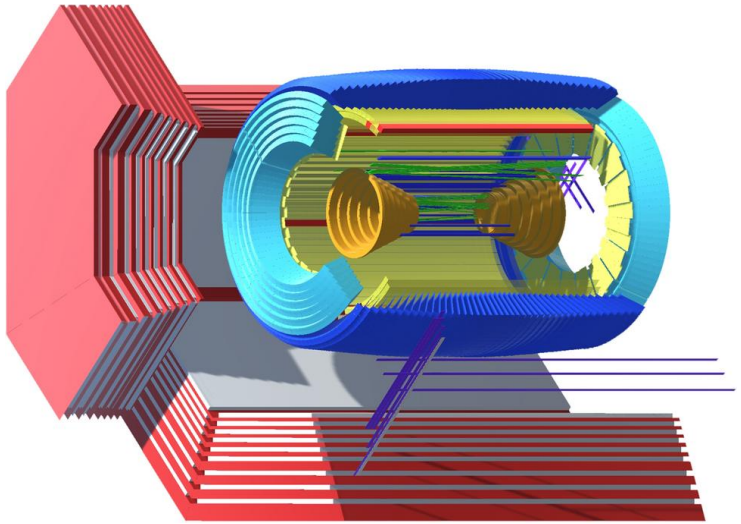
Multi-layer Drift Chamber

Time of Flight Detector

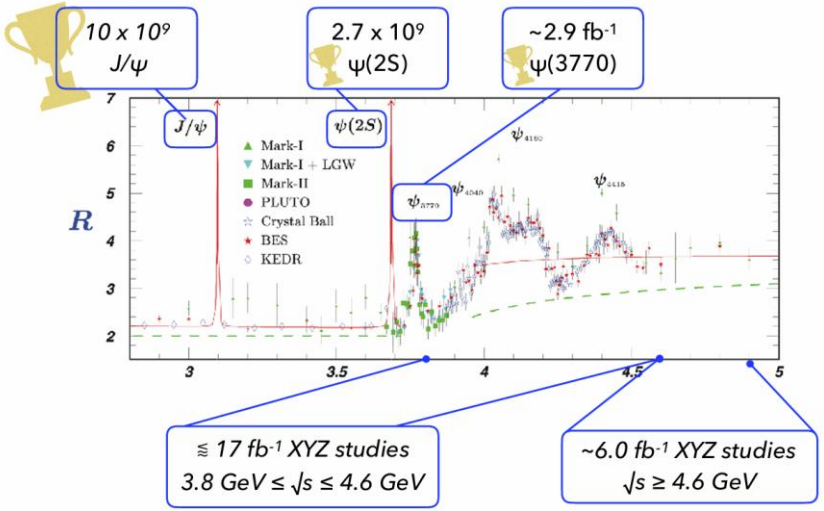
EM Calorimeter

1T Solenoidal Magnet

Muon Detector



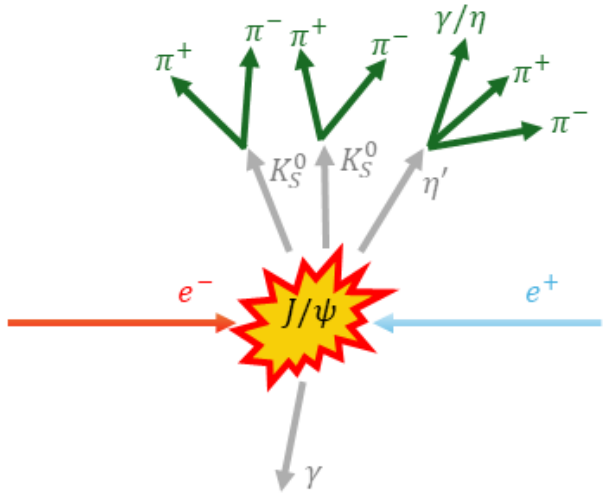
BESIII has collected the world's largest sample of ***J/ψ*** and of ***ψ(nS)***



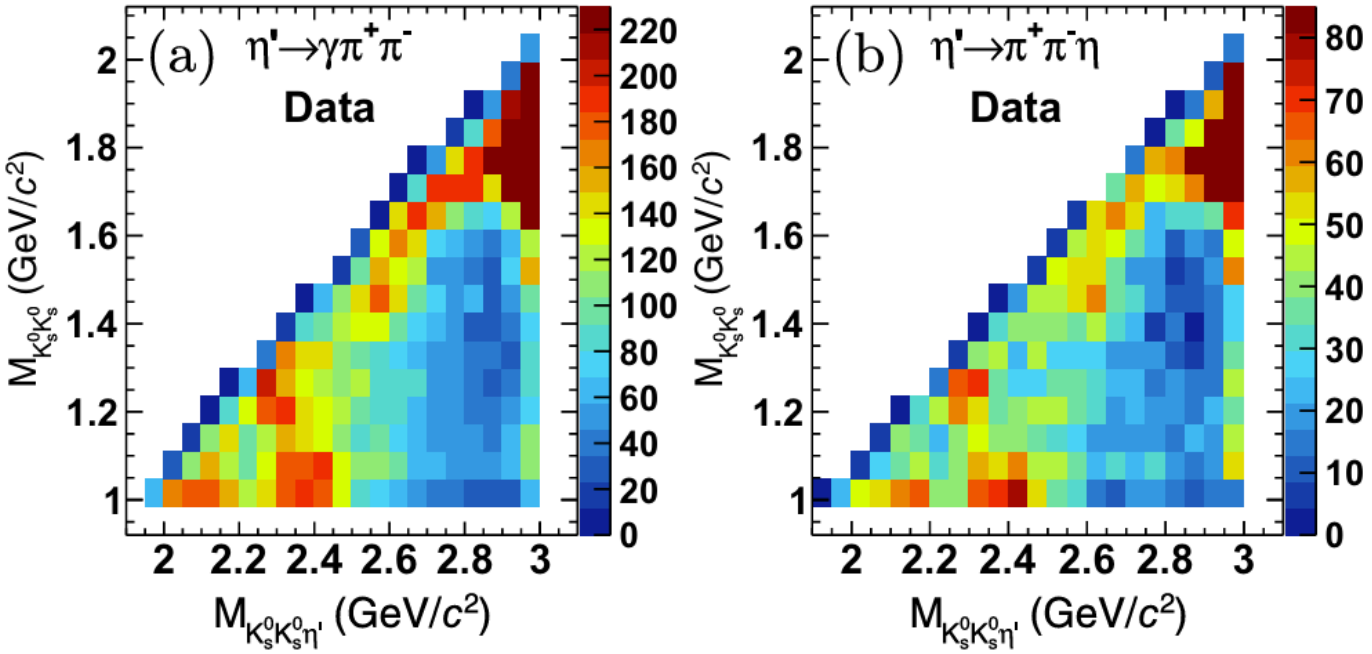
τ-charm factory 2.0 GeV ≤ √s ≤ 4.95 GeV with an instantaneous luminosity of 10^{33} cm^{-2} s^{-1} @ √s=3.77 GeV

X(2370): Glueball-like particle in $J/\psi \to \gamma K_S^0 K_S^0 \eta'$

$$J/\psi \to \gamma K_S^0 K_S^0 \eta'$$



Using 10 bilion J/ψ events

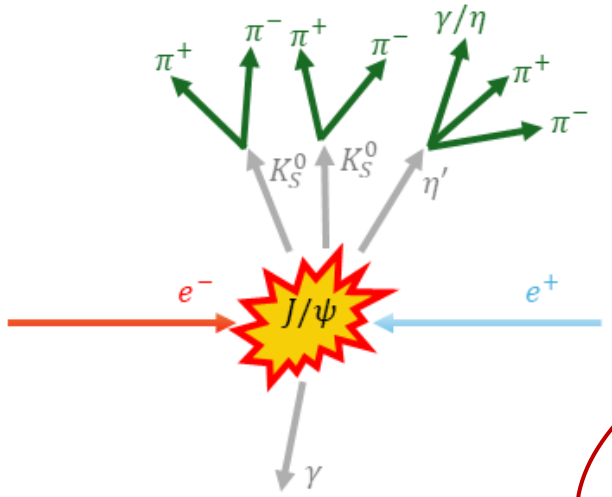


Main background ($J/\psi \to \pi^0 K_S^0\ K_S^0\eta'$ and $J/\psi \to K_S^0 K_S^0 \eta'$) are forbidden by exchange symmetry and CP conservation

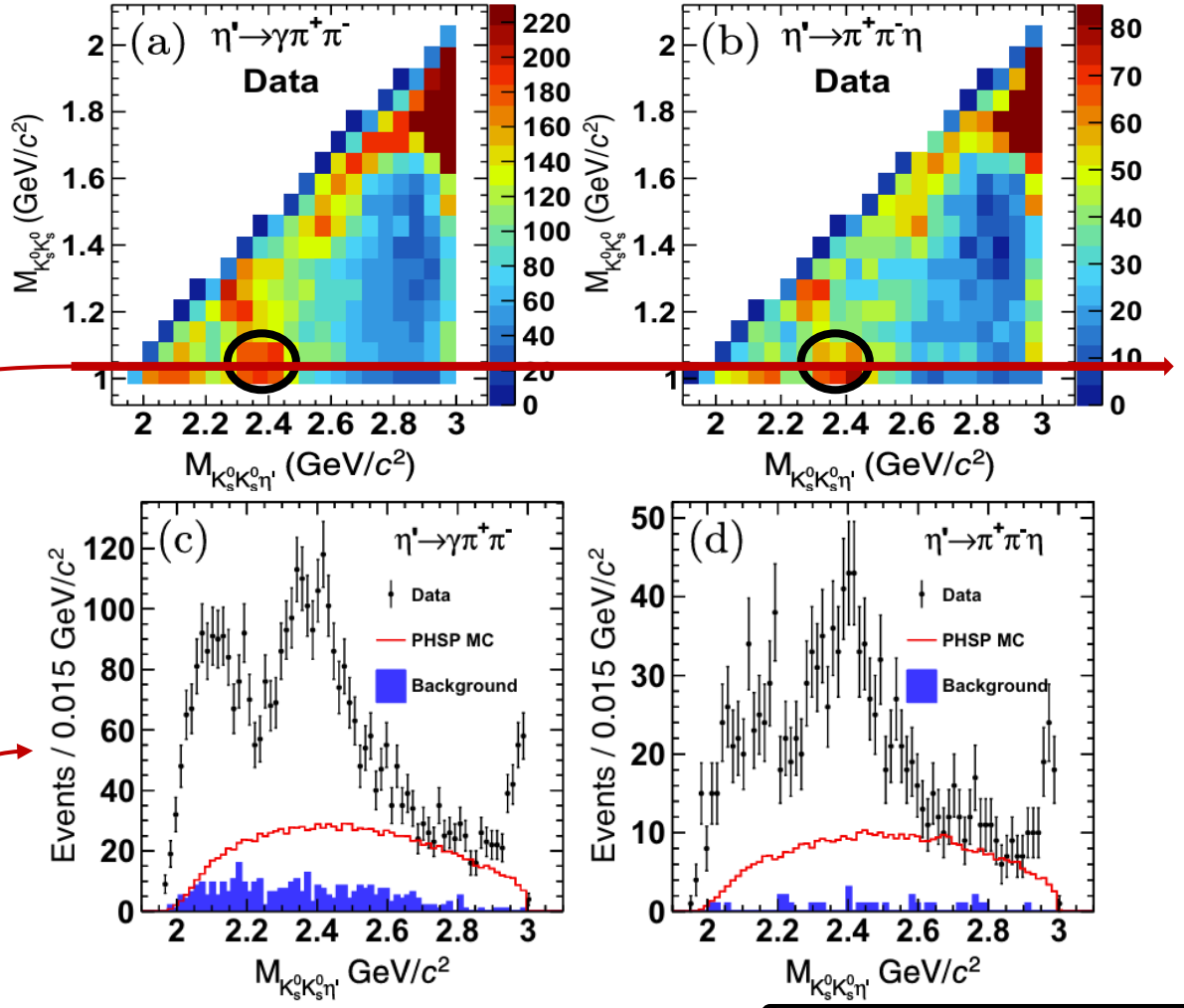
Phys. Rev: Lett. ***132****, 181901 (2024)*

X(2370): Glueball-like particle

$$J/\psi \to \gamma K_S^0 K_S^0 \eta'$$



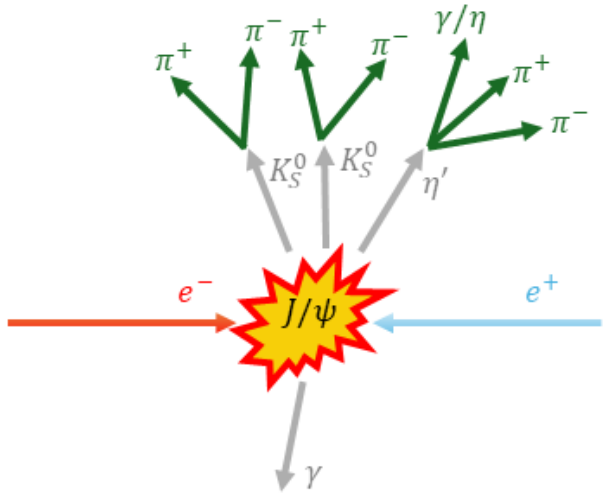
To select $f_0(980)$
$\rightarrow M(K_S^0 K_S^0) < 1.1\ GeV$

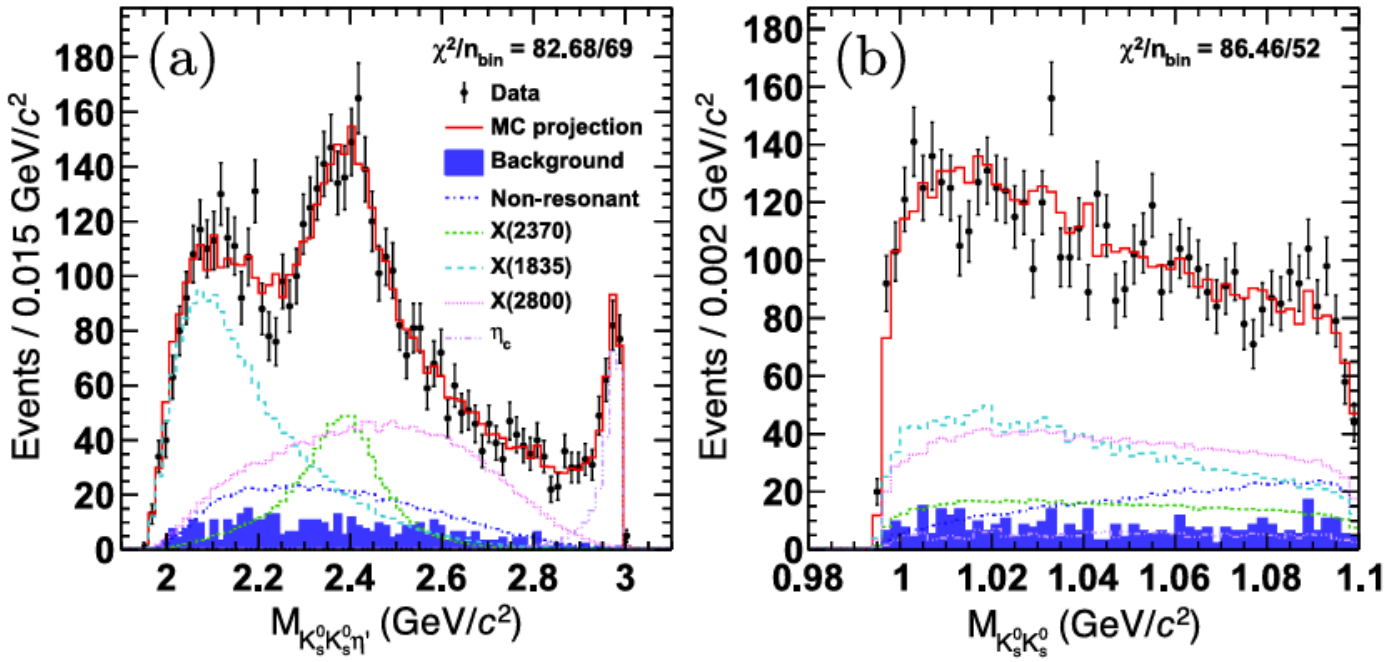


Phys. Rev: Lett. ***132****, 181901 (2024)*

X(2370): Glueball-like particle

$$J/\psi \to \gamma K_S^0 K_S^0 \eta'$$





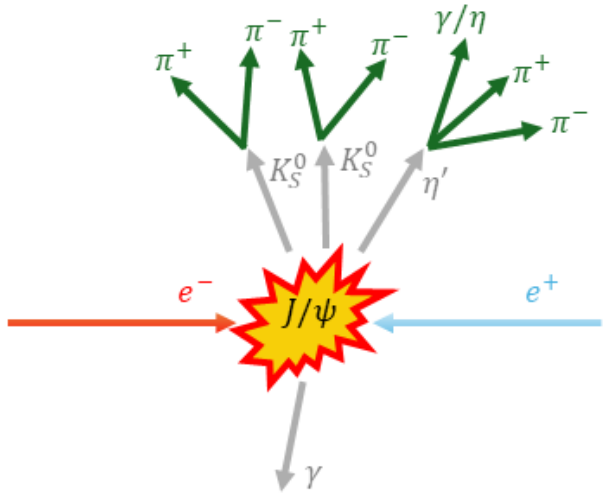
The parametrisation for the **PWA:**

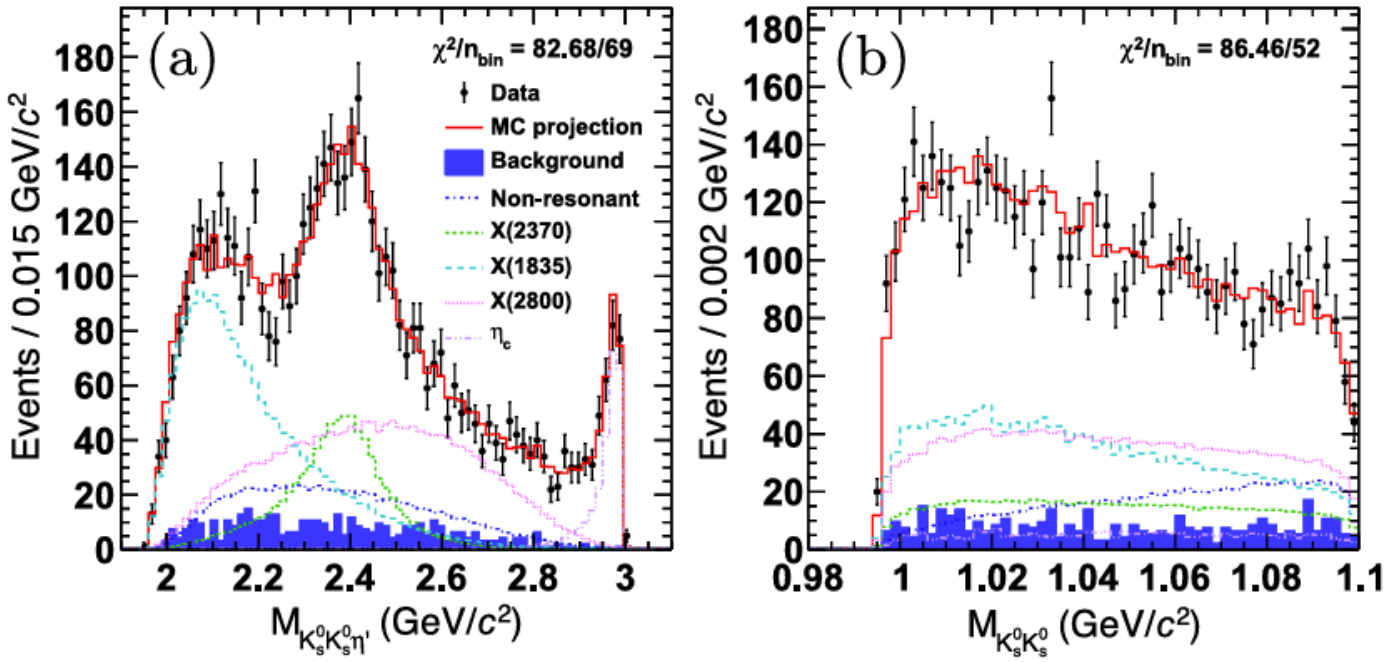
- The $\boldsymbol{f_0(980)\eta'}$, with $f_0(980) \to K_S^0 K_S^0$, is described via the $\boldsymbol{X(1835)}$, $\boldsymbol{X(2370)}$ and $\boldsymbol{\eta_c}$ resonances, and a **broad** $\boldsymbol{X(2800)}$ $\left(\boldsymbol{J^{PC} = 0^{-+}}\right)$ structure, and a **non-resonant** $(\boldsymbol{K_S^0 K_S^0})_{\boldsymbol{S/D-wave}}$ component
- The $X(1835)$, $X(2370)$ and the $X(2800)$ are described by **Breit-Wigner** distributions, while the $f_0(980)$ by a **Flattè**

Phys. Rev: Lett. ***132****, 181901 (2024)*

X(2370): Glueball-like particle in $J/\psi \to \gamma K_S^0 K_S^0 \eta'$

$J/\psi \to \gamma K_S^0 K_S^0 \eta'$





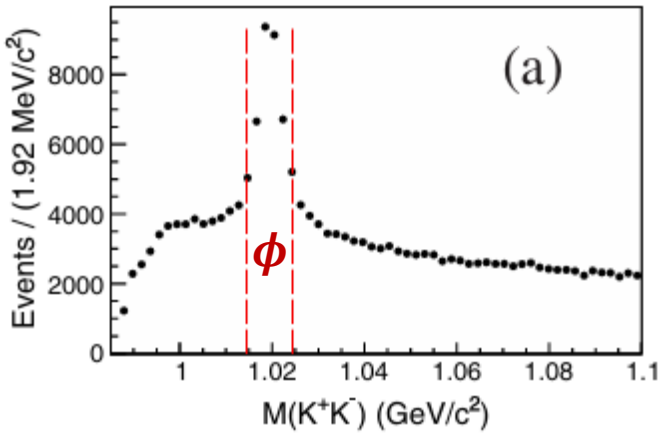
The parametrisation for the **PWA:**

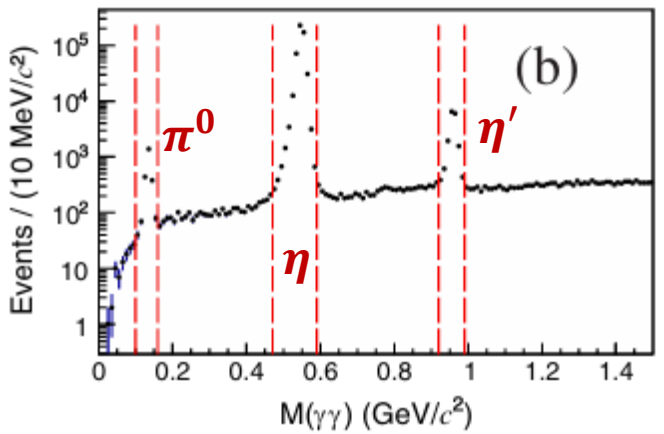
- The $X(2800)$ is included to effectively describe the $X(2600)$, (observed at $4.2\ \sigma$), and the tail of the η_c
- The $X(2800)$ was fitted using differnt PWA models, on which its significance strictly depends

Phys. Rev: Lett. ***132****, 181901 (2024)*

$X(1835)$ *e* $\eta(1405)$: *Recent Results*

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



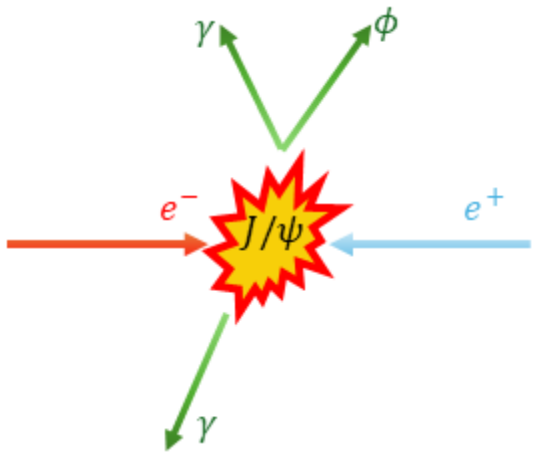


Acting as a **flavor filter**, the decays $\mathbf{J/\psi \to \gamma X}$, $\boldsymbol{X \to \gamma V}$ $(\boldsymbol{V = \rho, \omega, \phi})$, provide a clean tool to disentagle the quark content of intermediate resonances

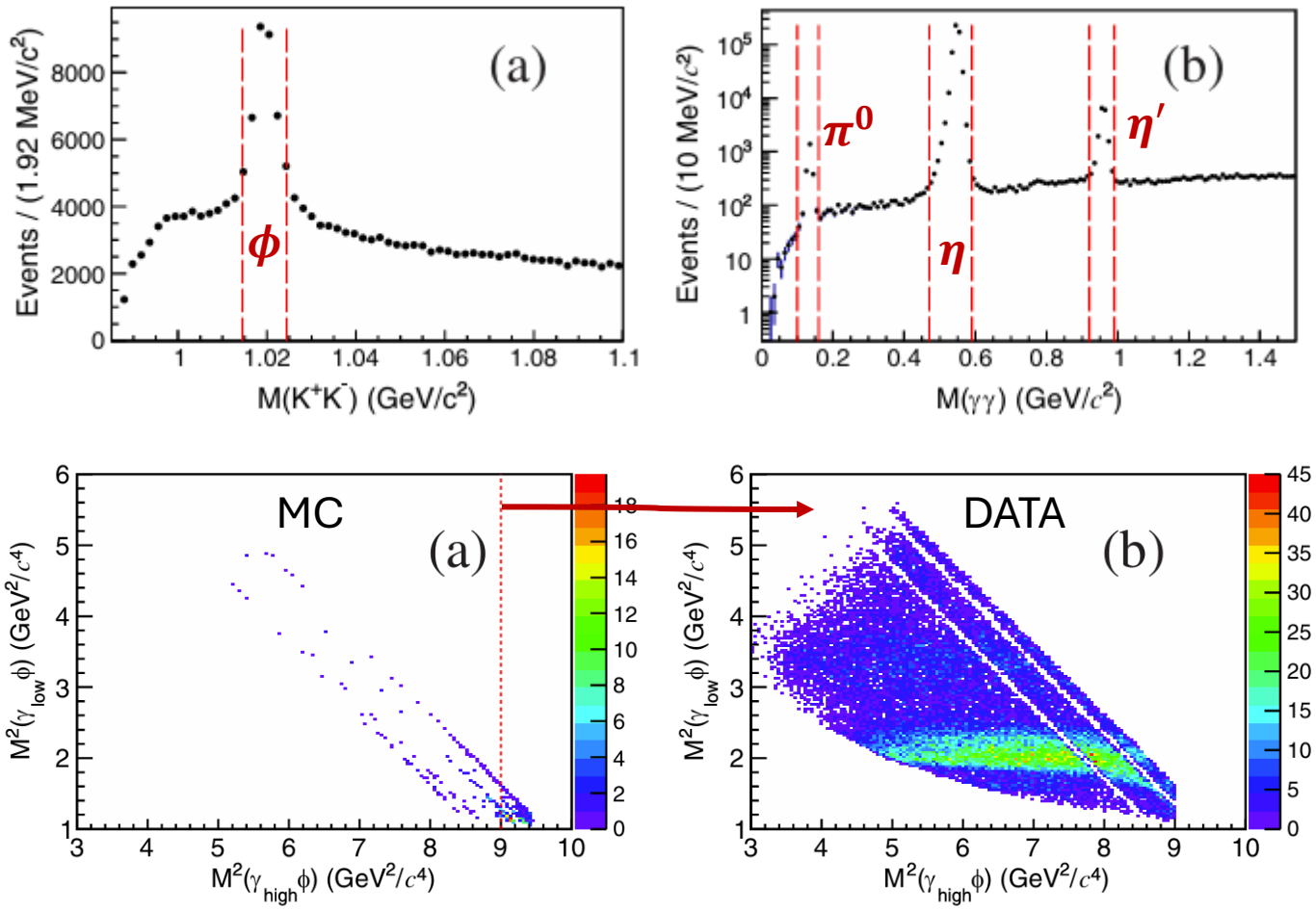
Phys. Rev: Lett. ***111****, 052011 (2025)*

$X(1835)$ e $\eta(1405)$: Recent Results

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



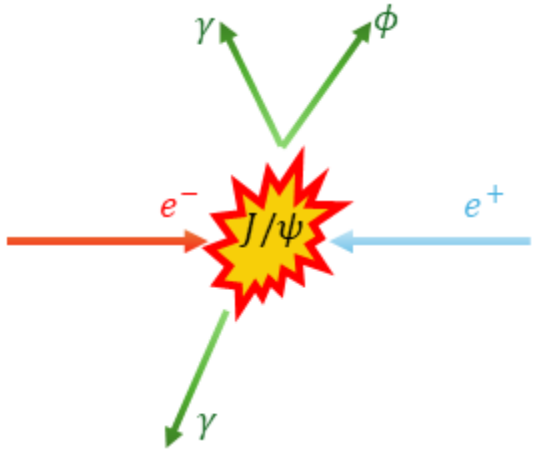
GPUPWA framework used to disentagle the structures in the Dalitz plot



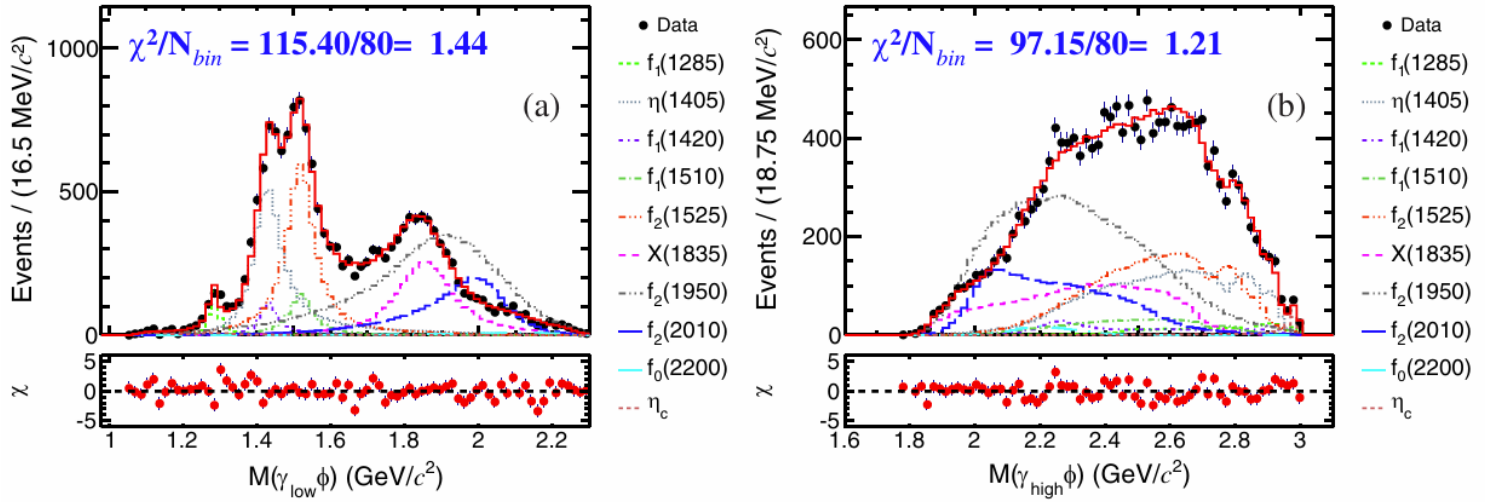
Phys. Rev: Lett. ***111****, 052011 (2025)*

$X(1835)$ e $\eta(1405)$: Recent Results

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



Resonance	M (MeV/c^2)	Γ (MeV)	$\mathcal{B}(\times 10^{-6})$	Significance
$f_1(1285)$	1281.9	22.7	$0.29 \pm 0.03^{+0.11}_{-0.09}$	17.3σ
$f_1(1420)$	1426.3	54.5	$0.55 \pm 0.07^{+0.18}_{-0.17}$	9.0σ
$\eta(1405)$	$1422.0 \pm 2.1^{+5.9}_{-7.8}$	$86.3 \pm 2.7^{+6.6}_{-17.4}$	$3.57 \pm 0.18^{+0.59}_{-0.61}$	18.9σ
$f_1(1510)$	1518.0	73.0	$0.78 \pm 0.09^{+0.34}_{-0.30}$	5.3σ
$f_2(1525)$	1517.4	86.0	$2.76 \pm 0.18^{+0.90}_{-0.61}$	16.4σ
$X(1835)$	$1849.3 \pm 3.0^{+7.6}_{-10.0}$	$179.6 \pm 8.7^{+22.5}_{-27.9}$	$3.37 \pm 0.19^{+0.78}_{-1.10}$	15.3σ
$f_2(1950)$	1936.0	464.0	$9.96 \pm 0.60^{+3.44}_{-2.13}$	13.1σ
$f_2(2010)$	2011.0	202.0	$4.63 \pm 0.43^{+1.42}_{-1.46}$	11.3σ
$f_0(2200)$	2187.0	207.0	$0.20 \pm 0.04^{+0.05}_{-0.07}$	6.3σ
η_c	2983.9	32.0	$0.21 \pm 0.03^{+0.05}_{-0.07}$	12.9σ



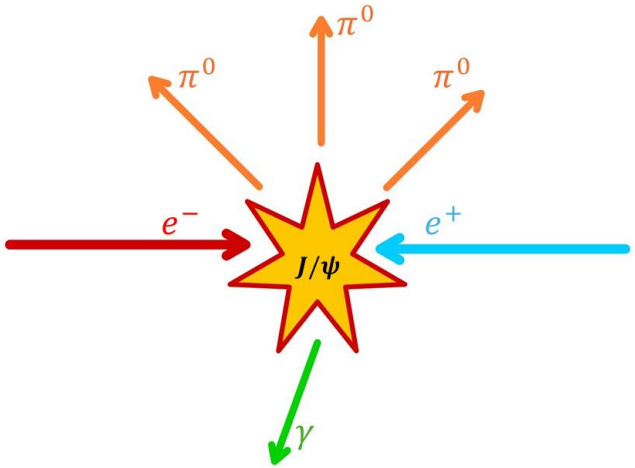
$\eta(1405)$ and $f_1(1420)$ are needed to describe the structure with mass around 1.4 GeV

Phys. Rev: Lett. ***111****, 052011 (2025)*

$f_1(1420)$ and $\eta(1405)$

$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$



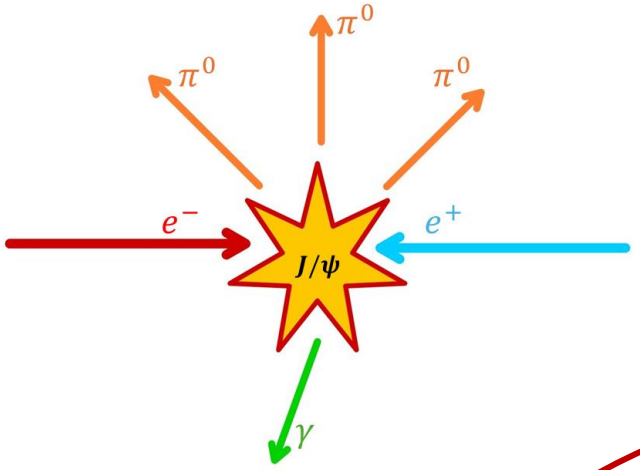
- To clarify the nature of states like $\eta(1405)$ and $\eta(1475)$ and investigate the properties of pseudoscalar and axial-vector mesons around 1.3 and 1.4 GeV

- Investigate anomalous isospin-breaking effects in the decay $\eta(1405) \to f_0(980)\pi^0$, potentially driven by the "triangle singularity" mechanics

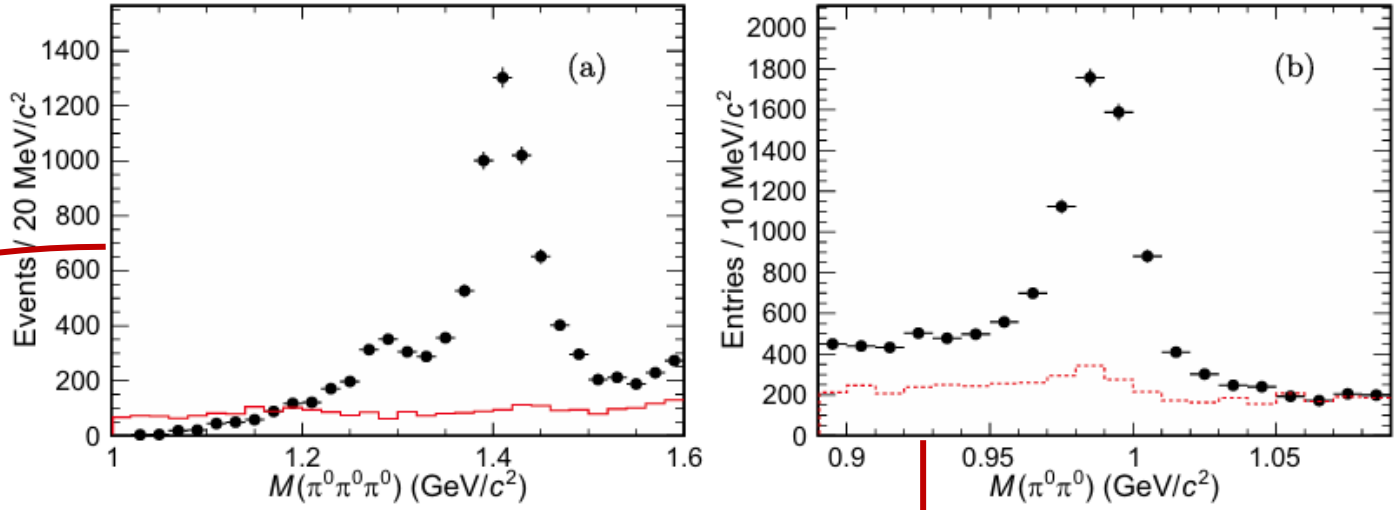
Phys. Rev: Lett. ***D 112****, 032007 (2025)*

$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$



To clarify the nature of states like $\eta(1405)$ and $\eta(1475)$ and investigate the properties of pseudoscalar and axial-vector mesons around 1.3 and 1.4 GeV



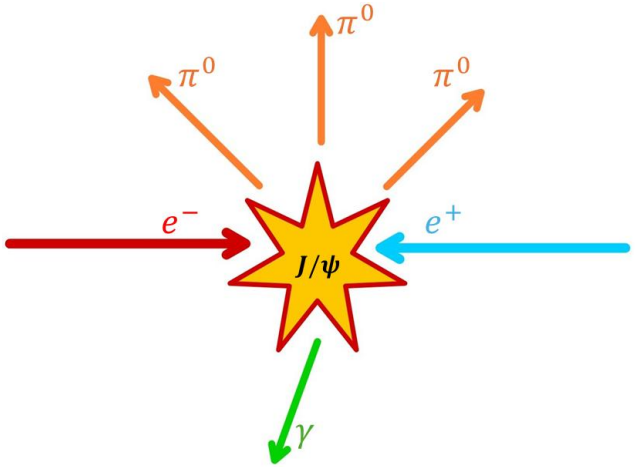
The $\pi^0\pi^0\pi^0$ invariant mass distribution shows distinct enhancements around 1.3 GeV and 1.4 GeV

Strikingly narrow and prominent peak correspondig to the $f_0(980)$ in the $\pi^0\pi^0$ spectrum

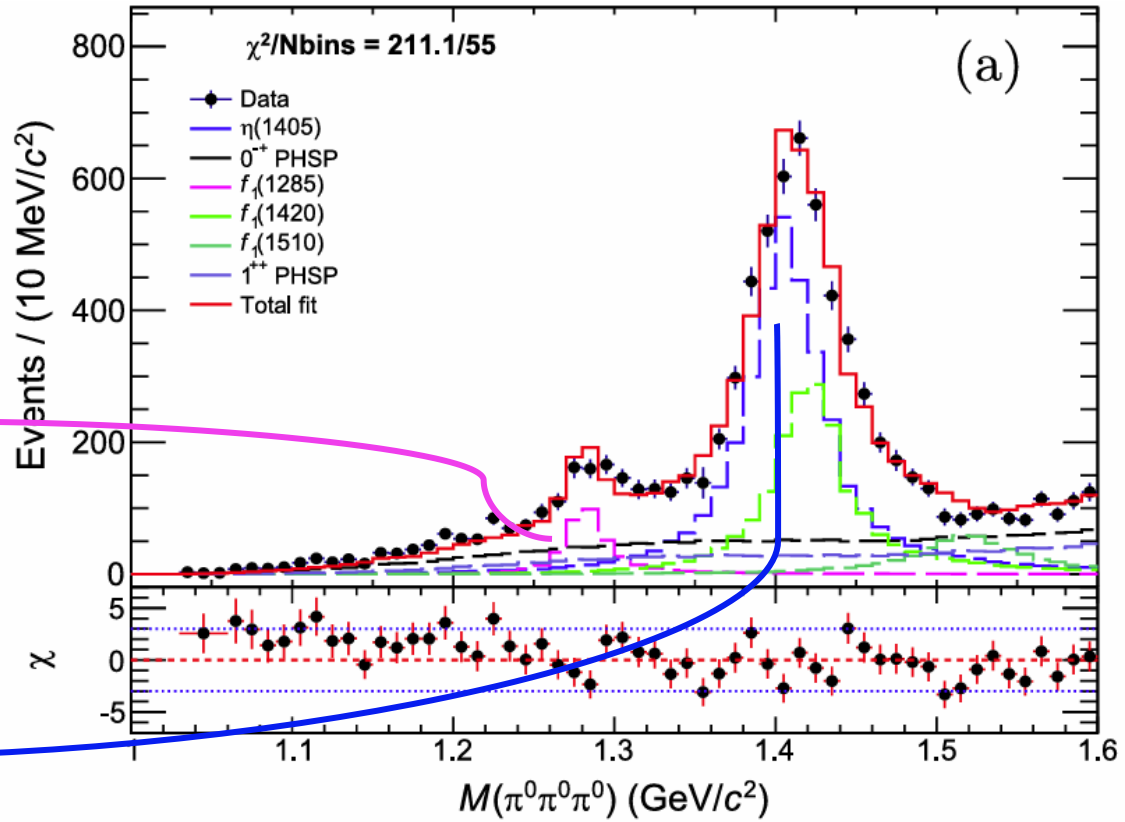
Phys. Rev: Lett. ***D 112****, 032007 (2025)*

$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$



Mass Dependent (MD) PWA was performed for $M(\pi^0\pi^0\pi^0) < 1.6$ **GeV** to decompose the overlapping states



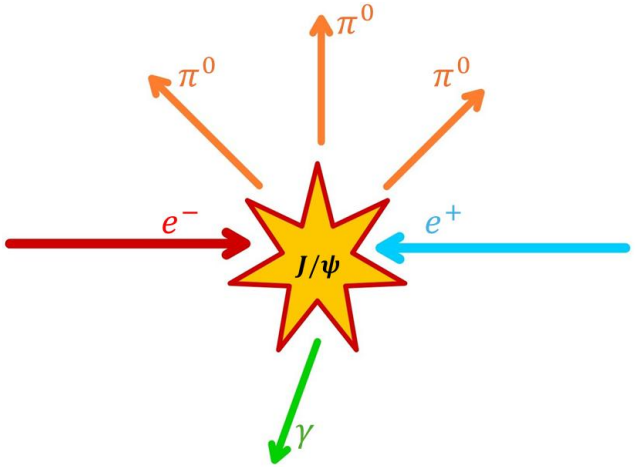
The structure around 1.3 GeV is dominated mostly by $f_1(1285)$

The peak at 1.4 GeV is a coherent mixture of the $\eta(1405)$ and the $f_1(1420)$

Phys. Rev: Lett. ***D 112****, 032007 (2025)*

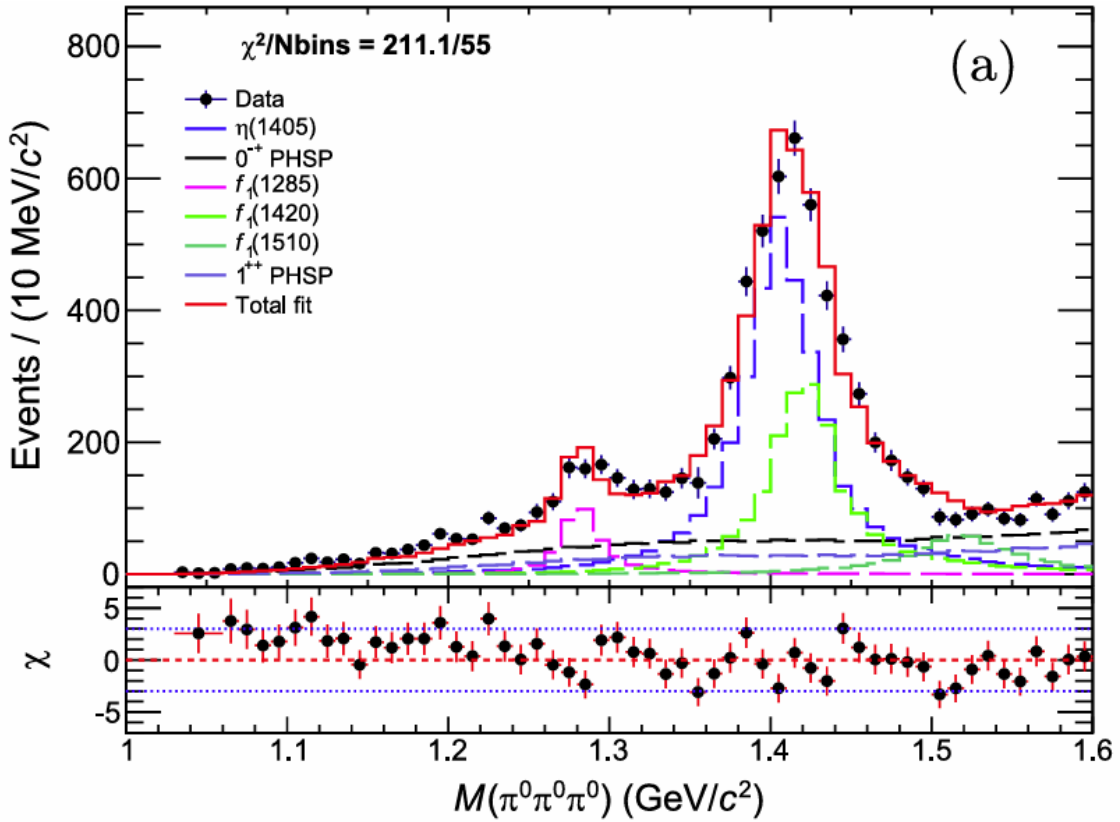
$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$



For the first time, three axial vectors - $f_1(1285)$, $f_1(1420)$, $f_1(1510)$- are observed decaying into $\pi^0\pi^0\pi^0$

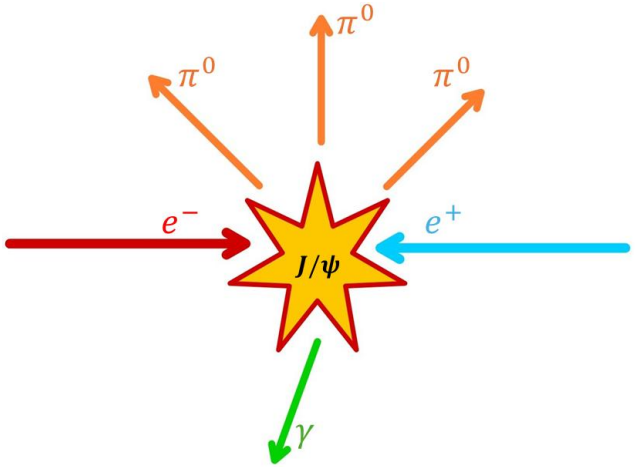
Mass-Dependent (MD) PWA was performed for $M(\pi^0\pi^0\pi^0) < 1.6$ **GeV** to decompose the overlapping states



Phys. Rev: Lett. ***D 112****, 032007 (2025)*

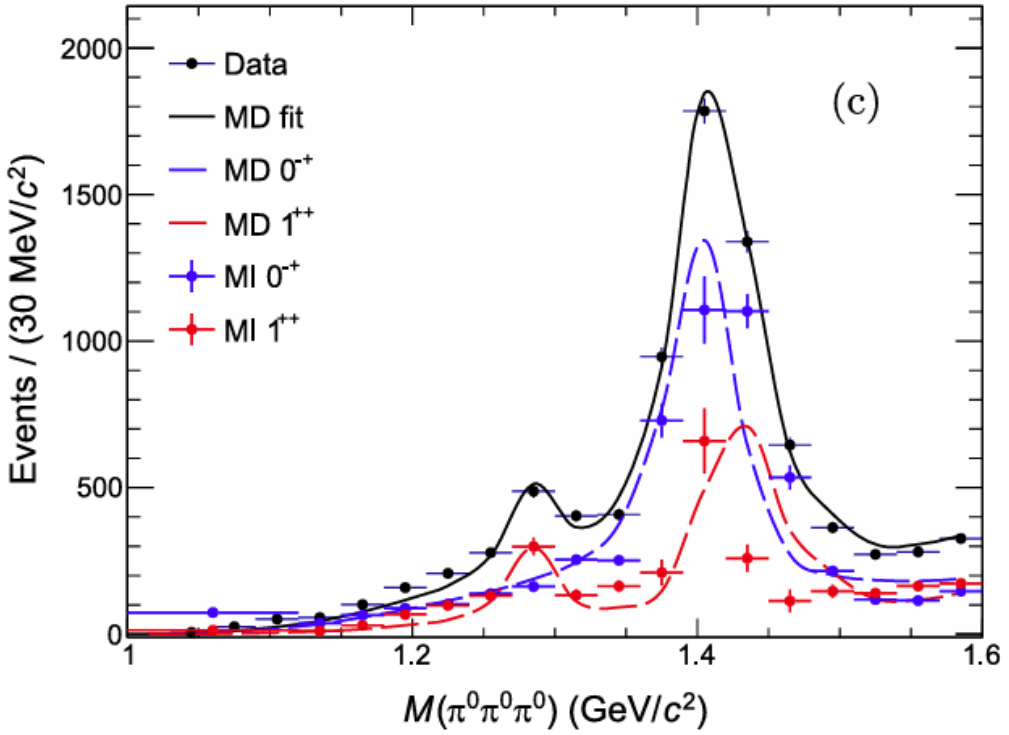
$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$



A Mass-Independent (MI) PWA was performed bin-by-bin to check and validate the MD baseline model

Qualitative agreement between MI and MD PWA, where the structure around 1.3 GeV is dominated by a 1^{++} contribution and the one arount 1.4 GeV aries from 0^{-+} and 1^{++} resonances

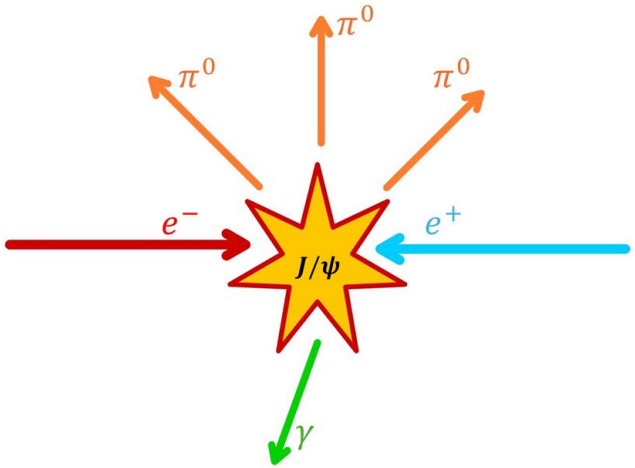


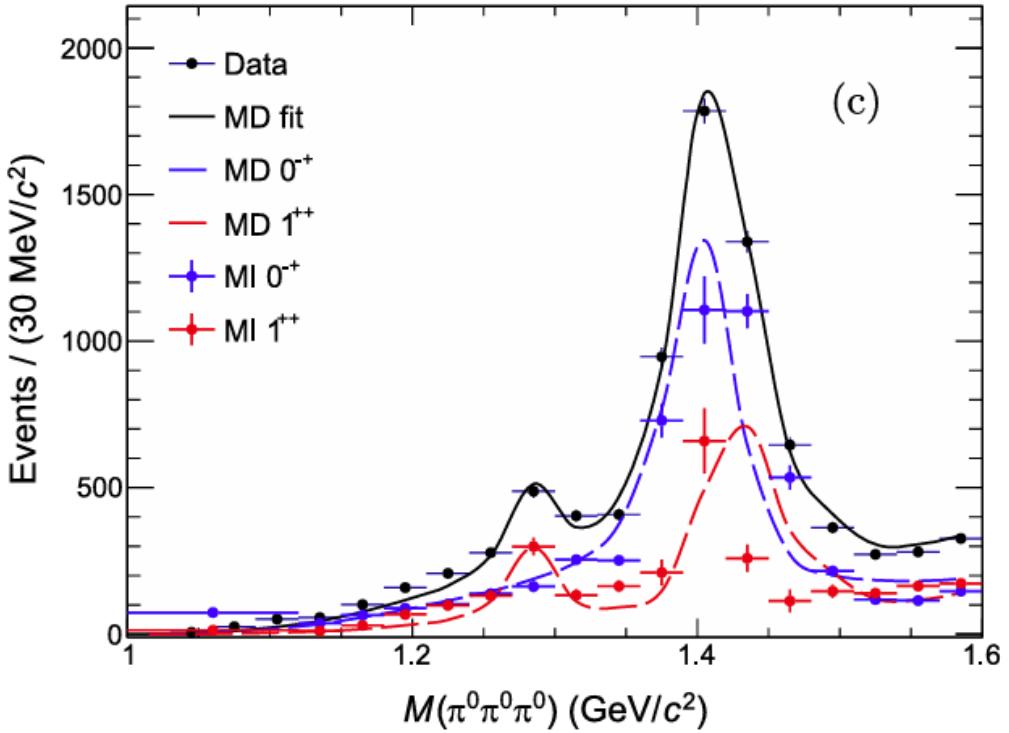
Comparison MD and MI PWA fits on $M(\pi^0\pi^0\pi^0)$ for contributions with subdecays of $f_0(980)\pi^0$ and 0^{++} $PHSP$ π^0 combined

Phys. Rev: Lett. ***D 112****, 032007 (2025)*

$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$





A Mass-Independent (MI) PWA was performed bin-by-bin to check and validate the MD baseline model

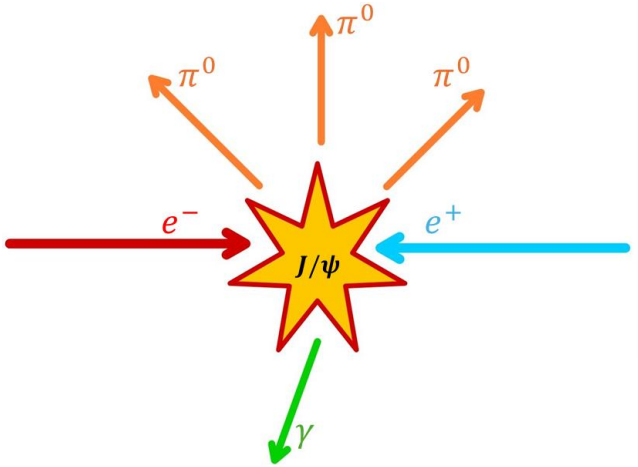
Qualitative agreement between MI and MD PWA, where the structure around 1.3 GeV is dominated by a 1^{++} contribution and the one arount 1.4 GeV aries from 0^{-+} and 1^{++} resonances

More sophisticated model incorporating the coupled-channel effect near the K*K threshold is required to describe the data

Phys. Rev: Lett. ***D 112****, 032007 (2025)*

$f_1(1420)$ and $\eta(1405)$ in $J/\psi \to \gamma\pi^0\pi^0\pi^0$

$J/\psi \to \gamma\pi^0\pi^0\pi^0$



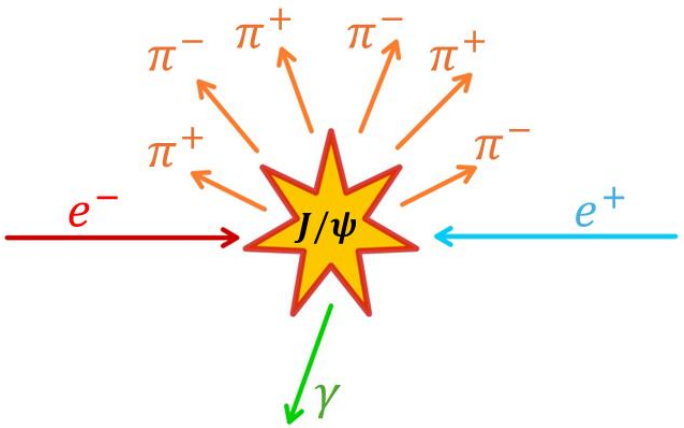
Resonance	M (MeV/c^2)	Γ (MeV)	$\mathcal{B}$	Significance (σ)
$\eta(1405)$	$1404^{+0.8\ +2.0}_{-1.5\ -8.1}$	$46^{+1.8\ +4.2}_{-2.0\ -0.0}$	$(4.62 \pm 0.15^{+5.08}_{-0.18}) \times 10^{-6}$	19.1
0^{-+} PHSP	...	...	$(3.24 \pm 0.08^{+0.41}_{-1.54}) \times 10^{-5}$	24.8
first obs. in the decay of $3\pi^0$: $f_1(1285)$	1281.9	22.7	$(5.64 \pm 0.45^{+0.74}_{-3.05}) \times 10^{-7}$	13.3
first obs. in the decay of $3\pi^0$: $f_1(1420)$	$1418^{+1.7\ +2.0}_{-2.1\ -2.2}$	$46^{+3.4\ +6.1}_{-2.3\ -11.0}$	$(2.23 \pm 0.16^{+0.20}_{-1.20}) \times 10^{-6}$	13.7
first obs. in the decay of $3\pi^0$: $f_1(1510)$	1518	73	$(7.91 \pm 1.20^{+0.74}_{-3.83}) \times 10^{-7}$	8.8
1^{++} PHSP	...	...	$(2.60 \pm 0.08^{+1.48}_{-1.66}) \times 10^{-5}$	13.3

- Disentangled the $J^{PC} = 0^{-+}$ *and* 1^{++}contributions below the 1.6 GeV
- Confirmed significant isospin-violating decays of both $\eta(1405)$ and $f_1(1420)$ into $f_0(980)\pi^0$
- Provided crucial new inputs (branching fractions) for understanding the 1^{++}meson nonet near the $K^*\bar{K}$threshold
- Fully resolving the $\eta(1405)/\eta(1475)$ puzzle and the triangle singularity will require a comprehensive, coupled-channel analysis including the $K_S^0 K_S^0 \pi^0$final state

Phys. Rev: Lett. ***D 112****, 032007 (2025)*

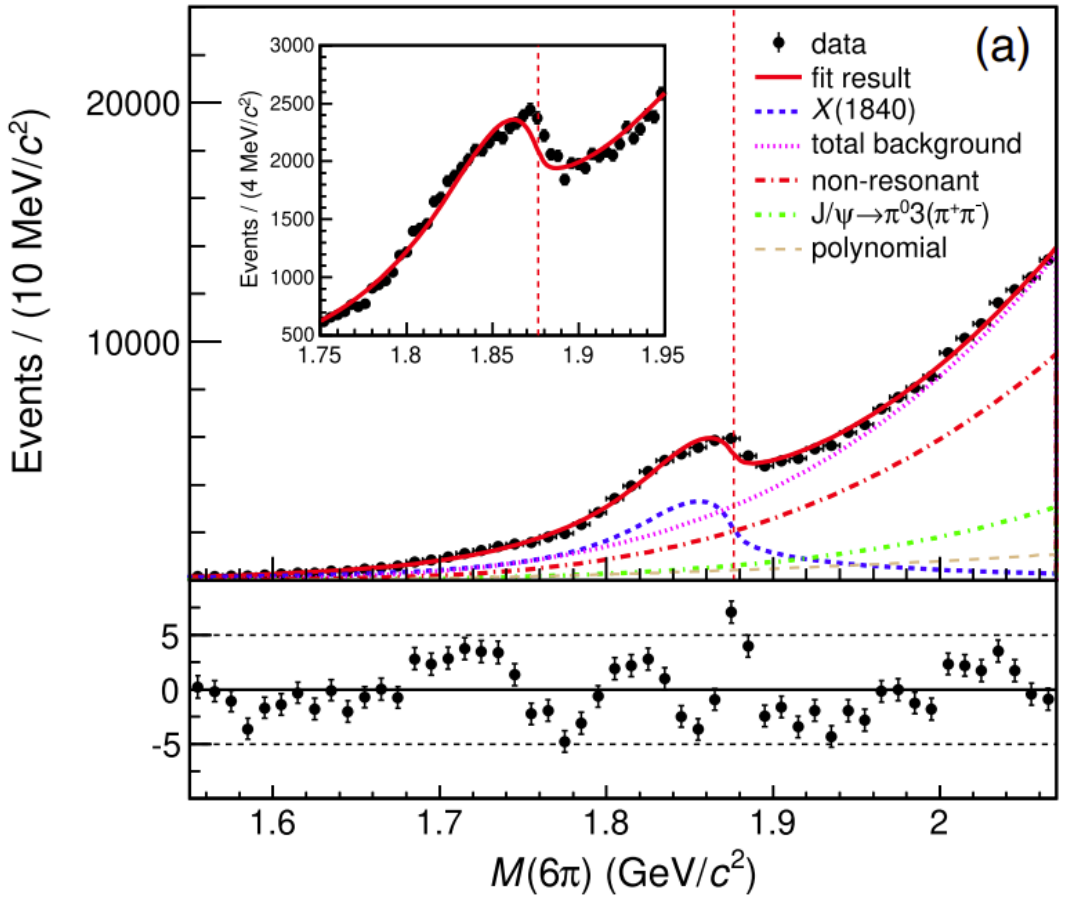
$X(1840)$ *and* $X(1880)$ *in* $J/\psi \to \gamma 3(\pi^+\pi^-)$

$J/\psi \to \gamma 3(\pi^+\pi^-)$



MODE a) → threshold effect

Incorporating the Flattè formula for the opening of **the** $X(1840) \to \bar{p}p$ decay

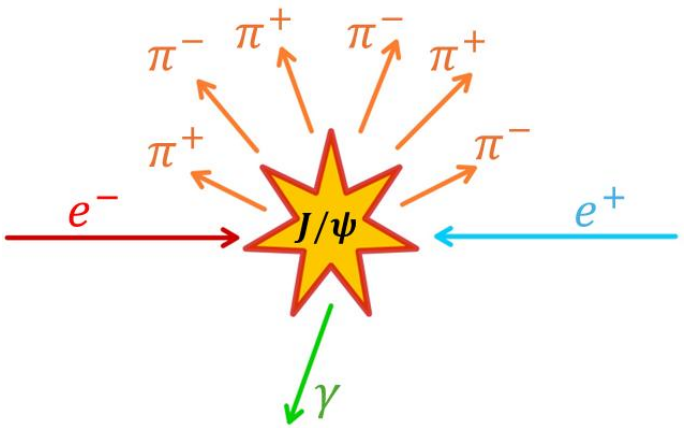


Phys. Rev: Lett. ***132****, 151901 (2024)*

$X(1840)$ *and* $X(1880)$

$X(1840)$ *and* $X(1880)$ *in* $J/\psi \to \gamma 3(\pi^+\pi^-)$

$J/\psi \to \gamma 3(\pi^+\pi^-)$



- The X(1840): later observed in $\gamma 3(\pi^+\pi^-)$ mass spectrum, this state was thought to be a decay mode of X(1835), despite having a substantially narrower width

- This study analyses the X(1840) line shape to investigate a potential slope-changing near the $p\bar{p}$ mass threshold in the $M(6\pi)$ spectrum

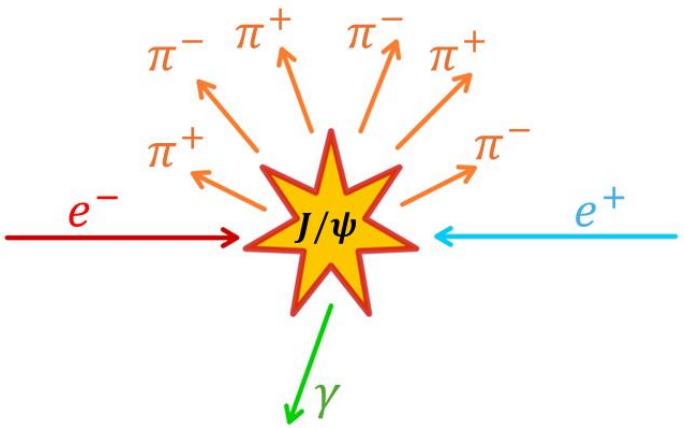
- Study of the $J/\psi \to \gamma 3(\pi^+\pi^-)$, with a dataset 45 times larger than the sample previously analyzed

Phys. Rev: Lett. ***88,*** *091502 (2013)*

Phys. Rev: Lett. ***132,*** *151901 (2024)*

$X(1840)$ *and* $X(1880)$ *in* $J/\psi \to \gamma 3(\pi^+\pi^-)$

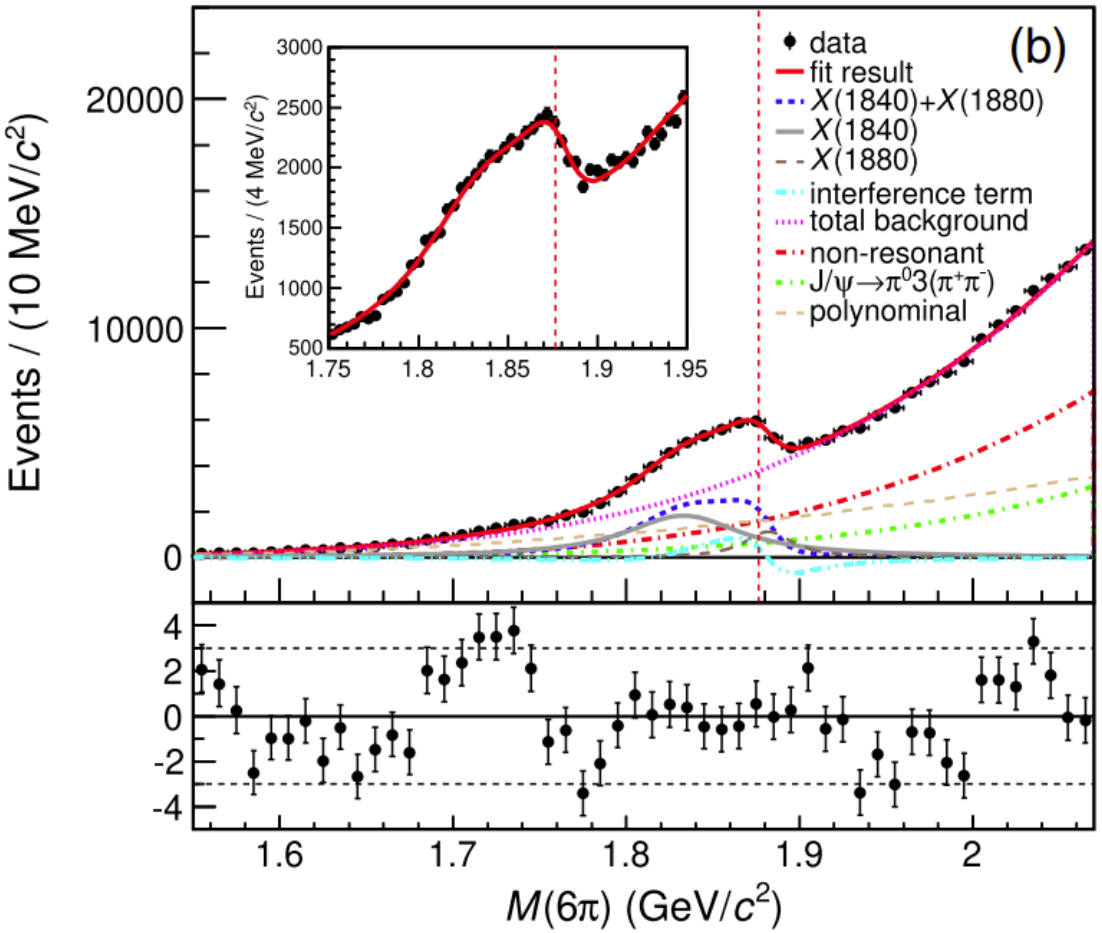
$J/\psi \to \gamma 3(\pi^+\pi^-)$



A significant structure is observed for the first time at 1.84 GeV, near the $\bar{p}p$ threshold

Coherent sum of two structures

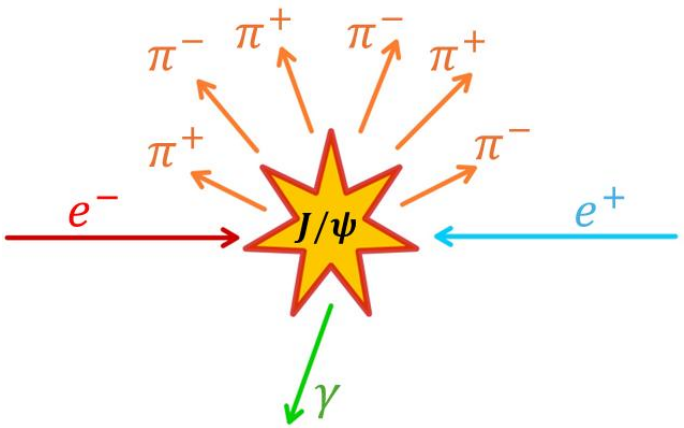
Interference between two resonances: a coherent sum allowing quantum interference between two distinct resonant structures $X(1840)$ *and* $X(1880)$

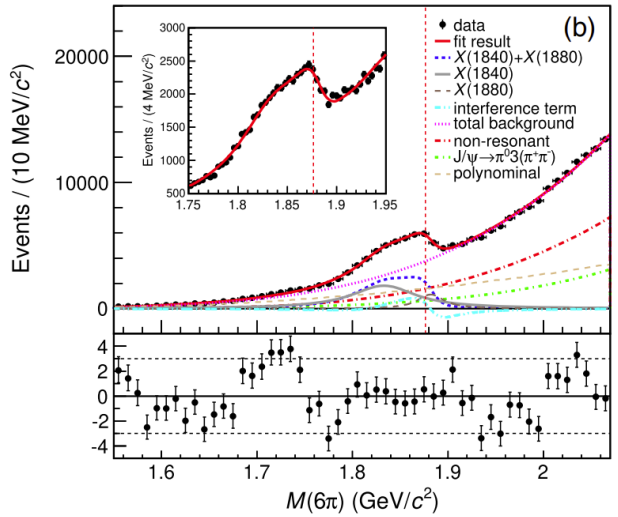


Phys. Rev: Lett. ***132****, 151901 (2024)*

$X(1840)$ *and* $X(1880)$ *in* $J/\psi \to \gamma 3(\pi^+\pi^-)$

$J/\psi \to \gamma 3(\pi^+\pi^-)$





Parameters	Solution I	Solution II
$M_{X(1840)}$ (MeV/c^2)	$1832.5 \pm 3.1 \pm 2.5$	
$\Gamma_{X(1840)}$ (MeV)	$80.7 \pm 5.2 \pm 7.7$	
$\mathcal{B}_{X(1840)}(\times 10^{-5})$	$1.19 \pm 0.30 \pm 0.15$	$2.07 \pm 0.50 \pm 0.36$
$M_{X(1880)}$ (MeV/c^2)	$1882.1 \pm 1.7 \pm 0.7$	
$\Gamma_{X(1880)}$ (MeV)	$30.7 \pm 5.5 \pm 2.4$	
$\mathcal{B}_{X(1880)}(\times 10^{-5})$	$0.29 \pm 0.20 \pm 0.09$	$1.19 \pm 0.31 \pm 0.18$

Observation of X(1880) with a statistical significance larger than 10σ

The discovery of two overlapping structures near the 1.84 GeV provides strong experimental evidence suggesting a $p\bar{p}$ resonance

Phys. Rev: Lett. ***132****, 151901 (2024)*