高激发态轻强子性质的研究

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2025.4.13

第十届XYZ研讨会

C.X.Liu, L.M.Wang, T.Y.Li and X.Liu, Phys. Rev. D 110, no.11, 114049 (2024)
L.M.Wang, W.X.Tian, T.Y.Li, C.X.Liu and X.Liu, Phys. Rev. D 110, no.7, 074021 (2024)

Outline

1. Background

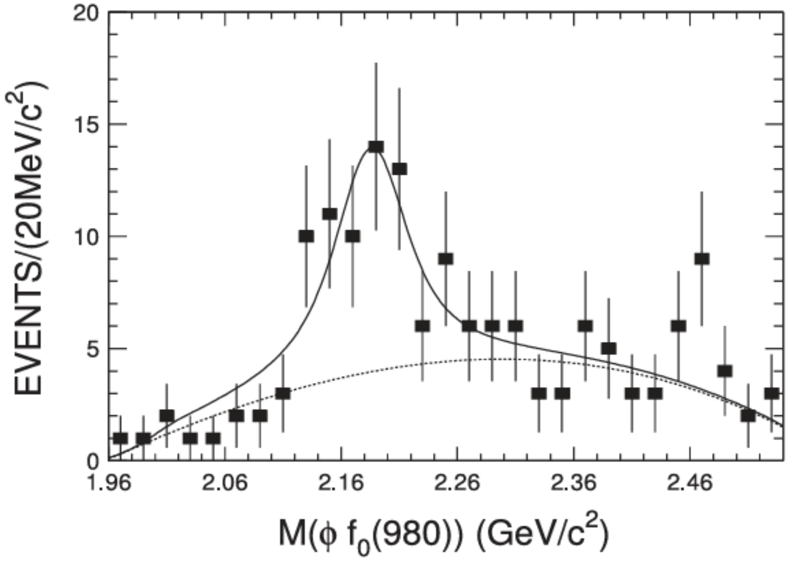
2. Mass spectrum

3. Decay behaviors

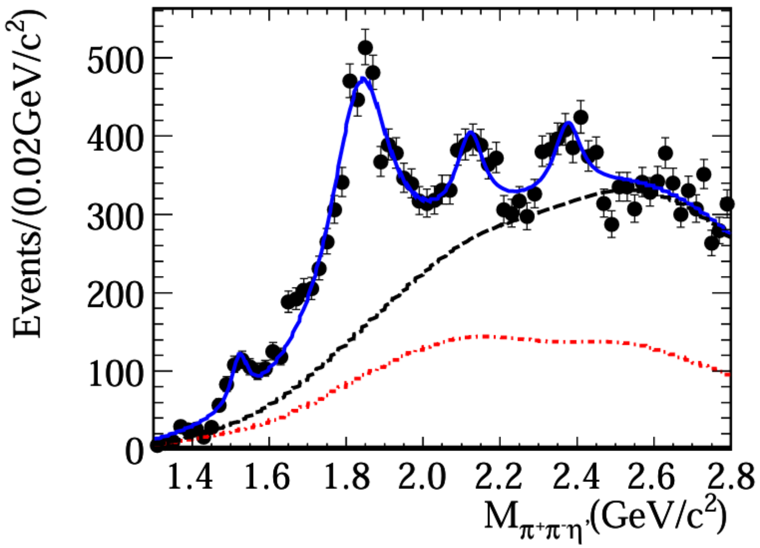
4. Summary

Background

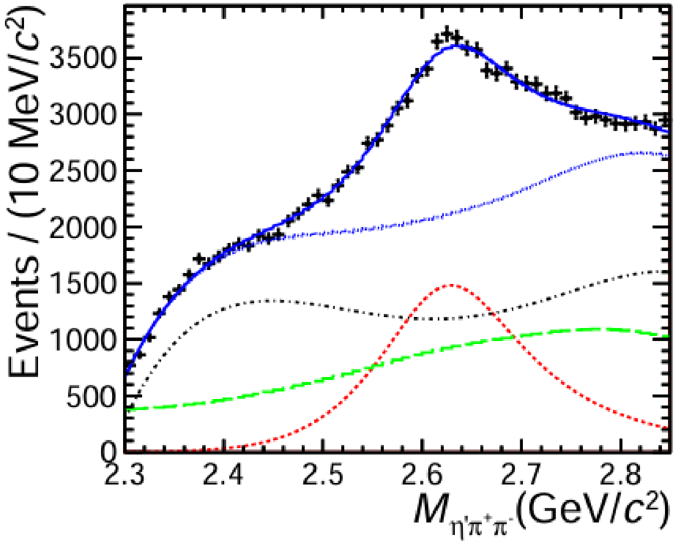
New observed high-lying states



Observation of $Y(2175)$
Phys. Rev. Lett. 106, 072002 (2011)



Observation of $X(2370)$
Phys. Rev. Lett. 100, 102003 (2008)

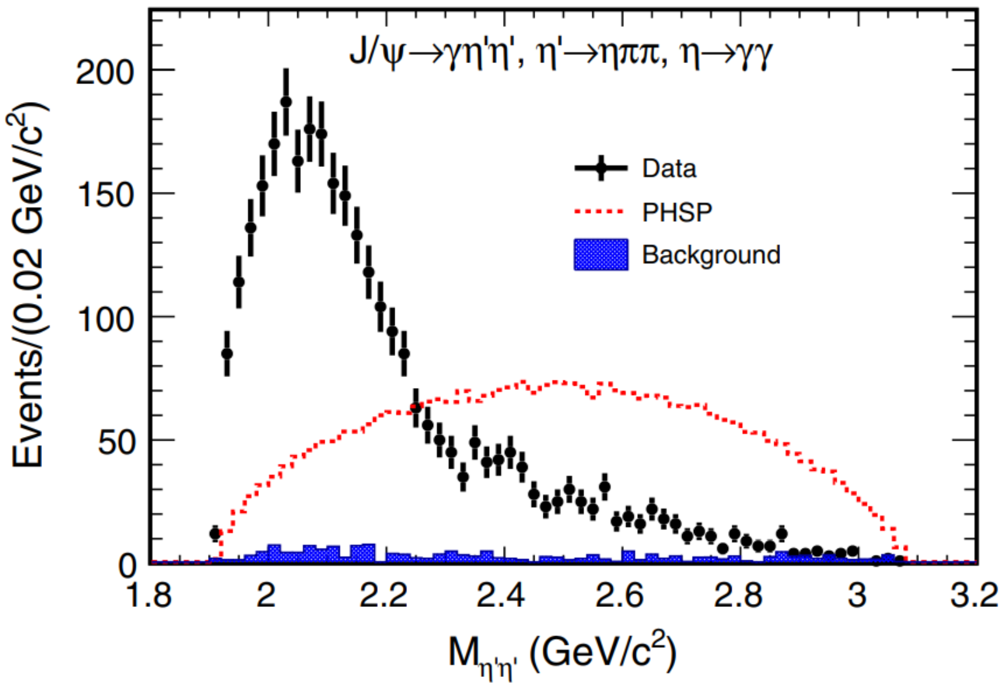


Observation of $X(2600)$
Phys. Rev. Lett. 129, 042001 (2022)

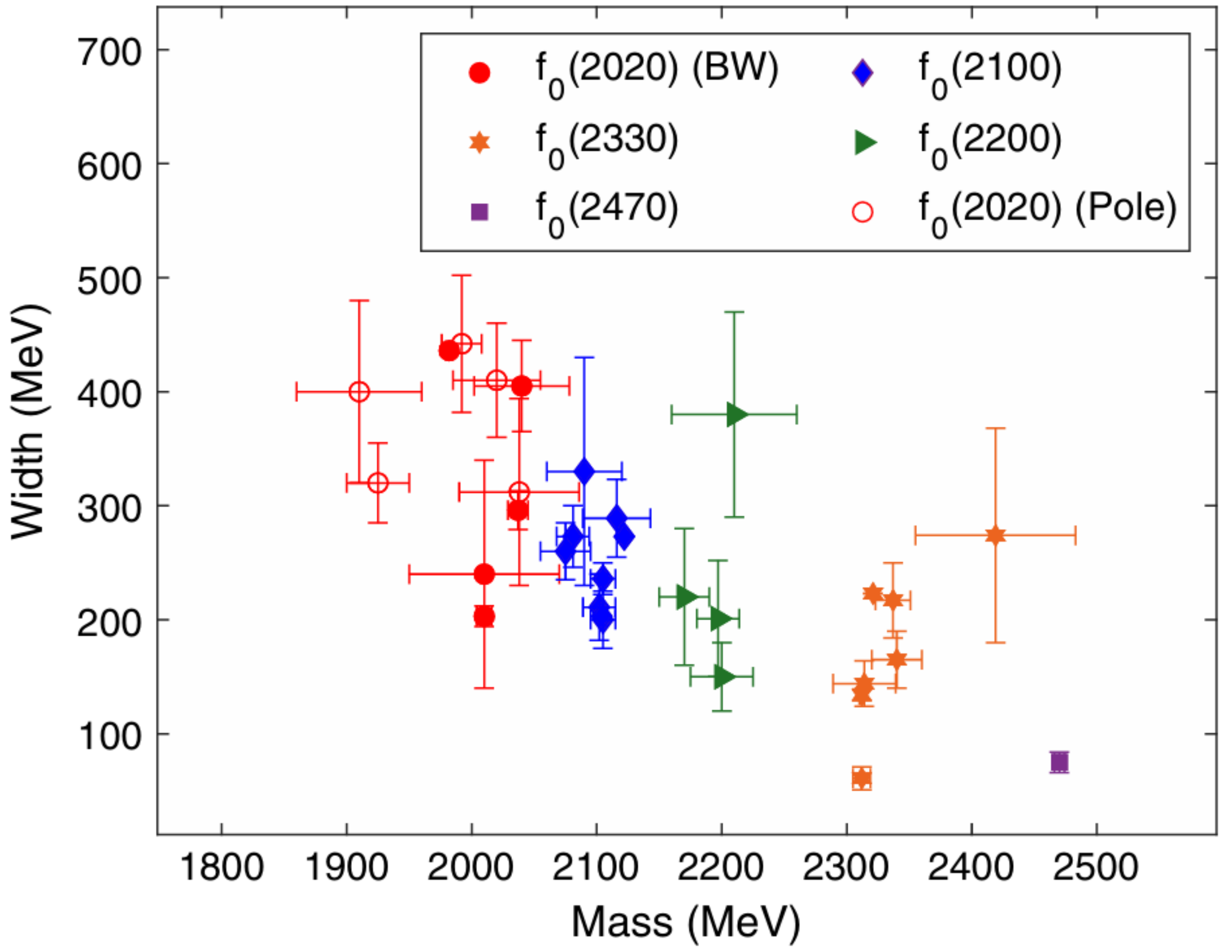
We propose that it is an appropriate time to establish high-lying mesons

High-lying scalar states

High-lying scalar states $f_0(2020)$, $f_0(2330)$and $f_0(2470)$



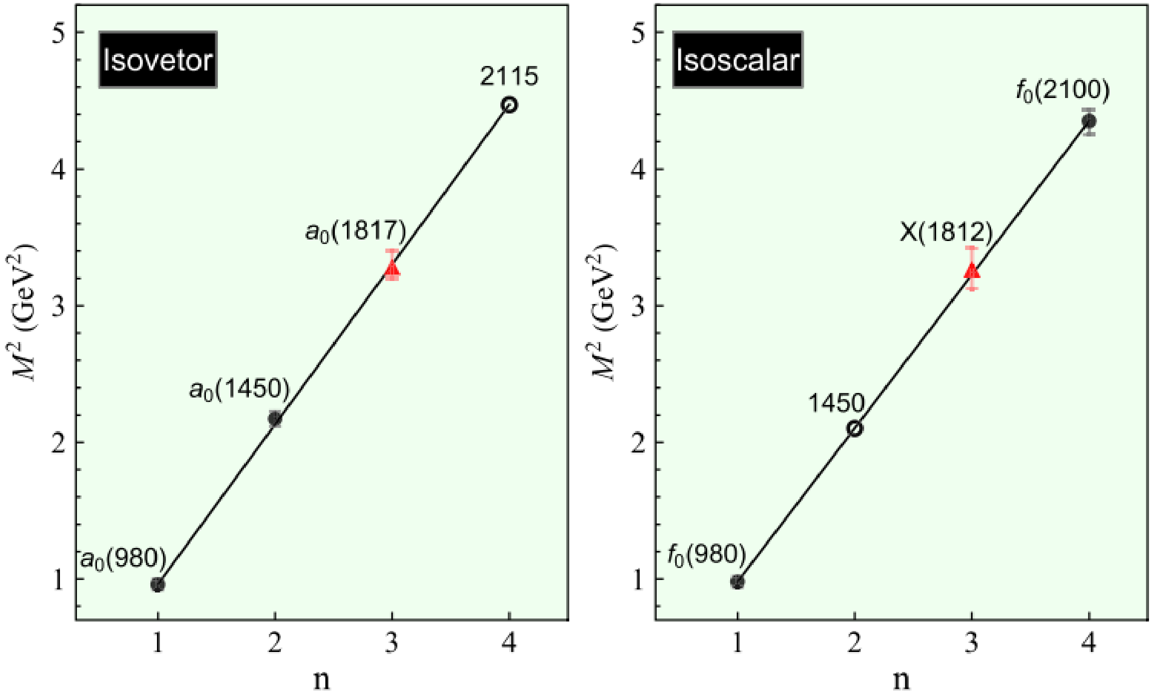
Phys. Rev. D 105, 072002 (2022)



This mess situation should be clarified by further studies

Our previous work of scalar mesons

Low-lying scalar mesons family including new observed $a_0(1817)$



Phys. Rev. D 105, 114014 (2022)

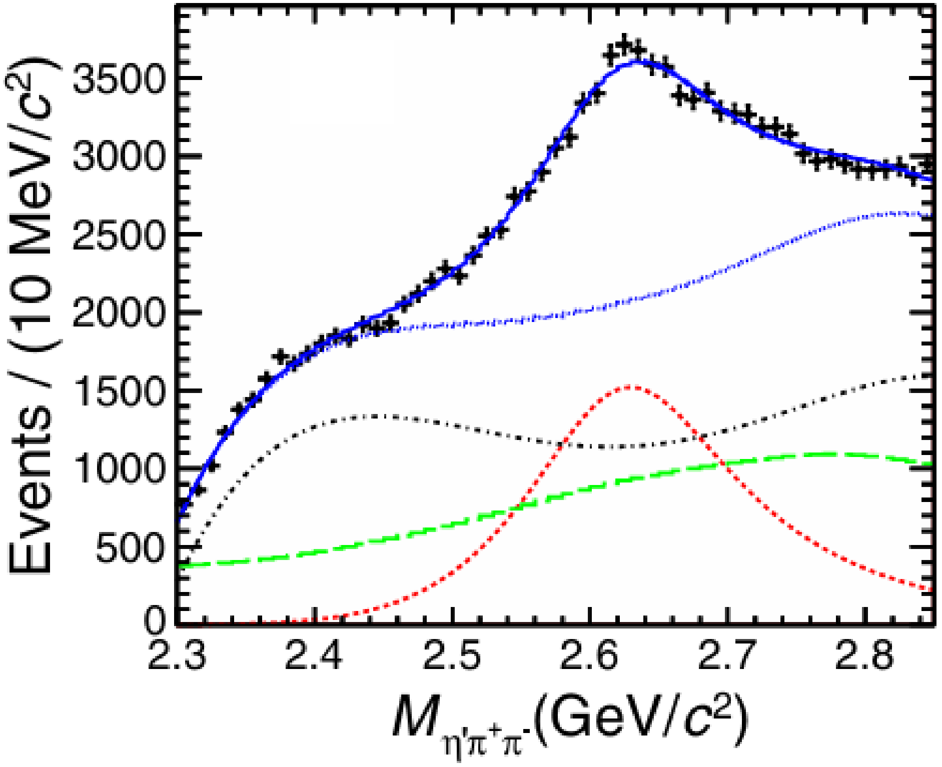
← Our prior research focused on selected low-mass scalar meson states

These high-lying states also have not been established in our work →

•	$f_0(2020)$	$0^+(0^{++})$
•	$f_4(2050)$	$0^+(4^{++})$
	$\pi_2(2100)$	$1^-(2^{-+})$
	$f_0(2100)$	$0^+(0^{++})$
	$f_2(2150)$	$0^+(2^{++})$
	$\rho(2150)$	$1^+(1^{--})$
•	$\phi(2170)$	$0^-(1^{--})$
	$f_0(2200)$	$0^+(0^{++})$
	$f_J(2220)$	$0^+(2^{++}$ or $4^{++})$
	$\omega(2220)$	$0^-(1^{--})$
	$\eta(2225)$	$0^+(0^{-+})$
	$\rho_3(2250)$	$1^+(3^{--})$
•	$f_2(2300)$	$0^+(2^{++})$
	$f_4(2300)$	$0^+(4^{++})$
	$f_0(2330)$	$0^+(0^{++})$
•	$f_2(2340)$	$0^+(2^{++})$
	$\rho_5(2350)$	$1^+(5^{--})$
	$X(2370)$	$?^?(?^{??})$
	$f_0(2470)$	$0^+(0^{++})$

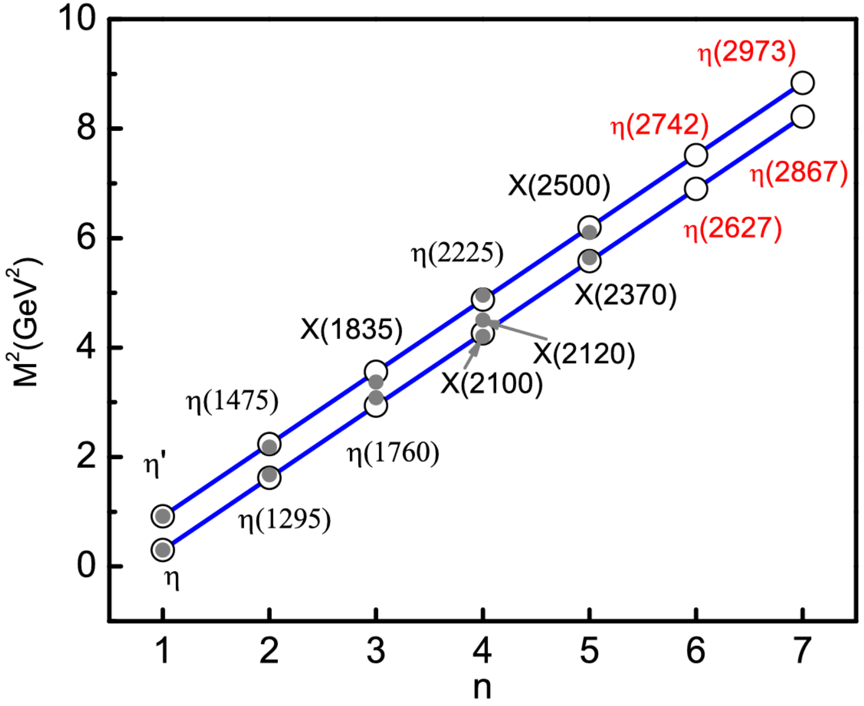
New observed $X(2600)$

The $X(2600)$ state



Phys. Rev. Lett. 129, 042001 (2022)

The quantum numbers J^{PC} of the $X(2600)$ could be either 0^{-+} or 2^{-+}. In our previous work, it is proposed as an $\eta(6S)$ state



Phys. Rev. D 102, 114034 (2020)

The possibility of the $X(2600)$ being a pseudotensor meson with $J^{PC} = 2^{-+}$ still needs to be examined

The η_2 family

The summary table in the PDG includes the $\eta_2(1645)$ and $\eta_2(1870)$ states

The $\eta_2(2030)$ and $\eta_2(2250)$ are listed as further states

Including the previously discussed $X(2600)$, there are five isoscalar pseudotensor states awaiting classification

$\eta_2(1645)$ $I^G(J^{PC}) = 0^+(2^{-+})$

$\eta_2(1645)$ MASS	1617 ± 5 MeV
$\eta_2(1645)$ WIDTH	181 ± 11 MeV

$\eta_2(1870)$ $I^G(J^{PC}) = 0^+(2^{-+})$

$\eta_2(1870)$ MASS	1842 ± 8 MeV
$\eta_2(1870)$ WIDTH	225 ± 14 MeV

J^{PC}	Mass M (MeV)	Width Γ (MeV)
2^{-+}	2267±14	290±50
2^{-+}	(2030)	(205)
2^{-+}	(1860)	(250)

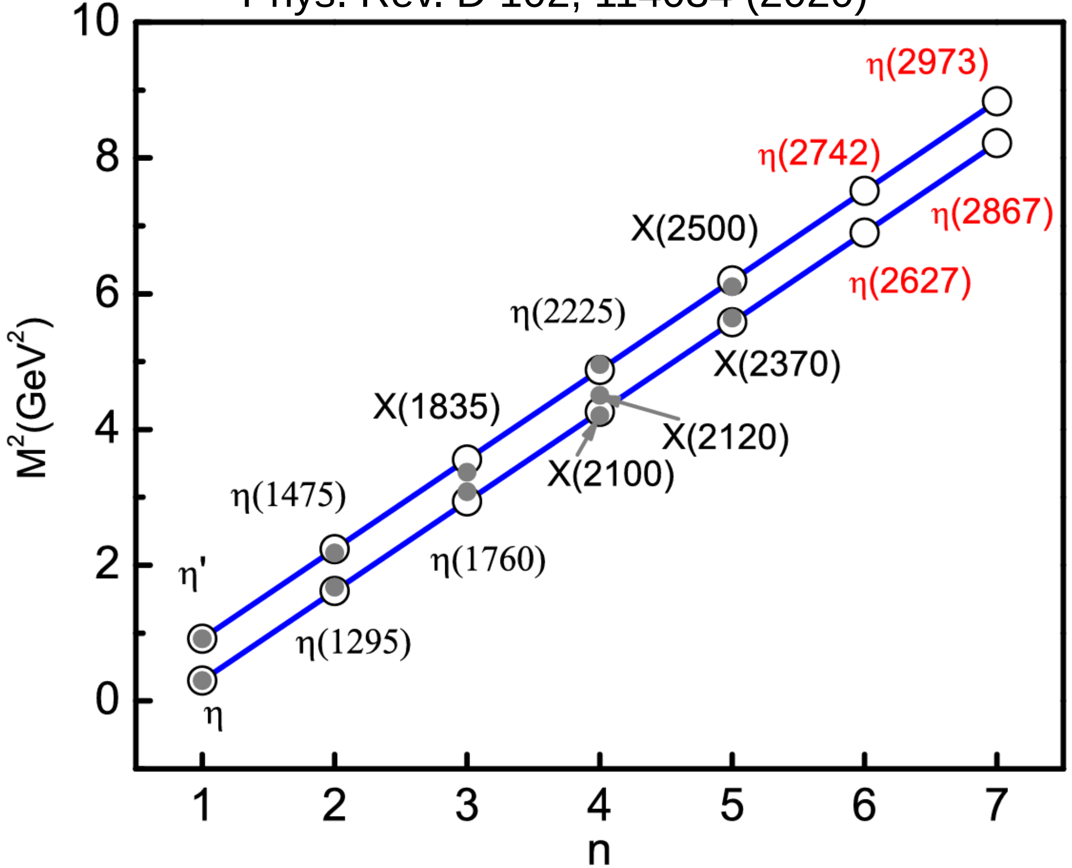
Phys. Lett. B 491, 47 (2000)

Mass spectrum

The Regge trajectories

In our previous work, we studied low-lying scalar mesons and pseudoscalar mesons using the Regge trajectory

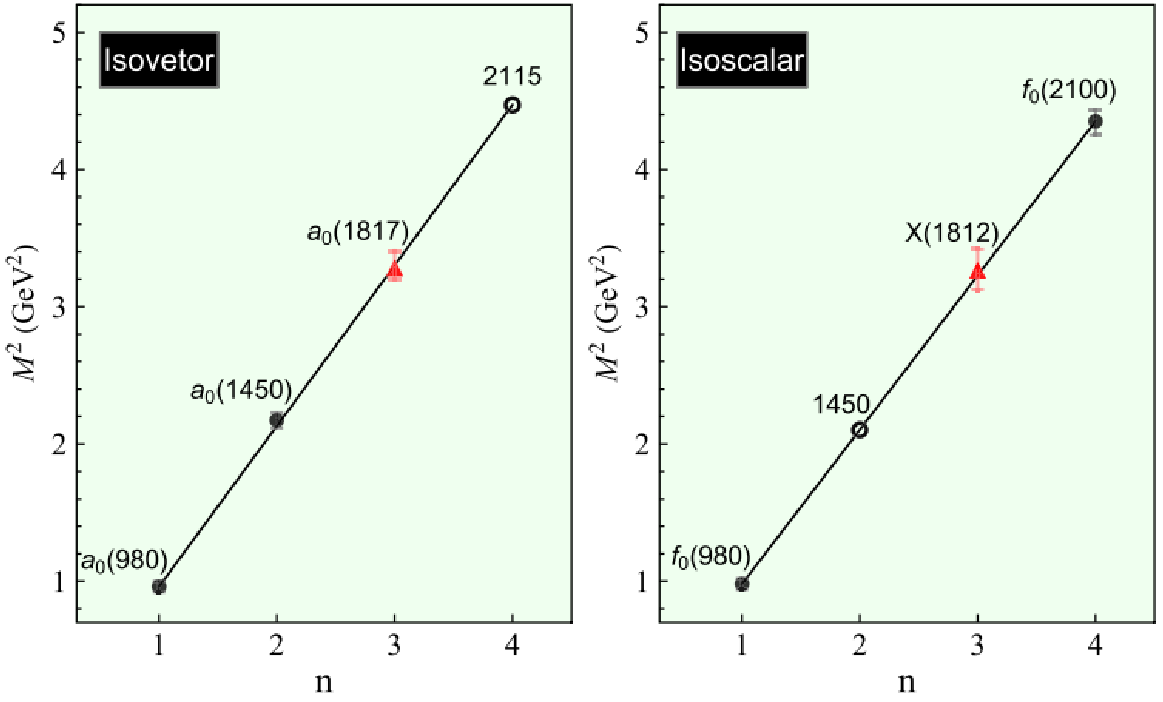
Phys. Rev. D 102, 114034 (2020)



The Regge trajectory shows that the masses of hadrons follow a pattern that can be written as

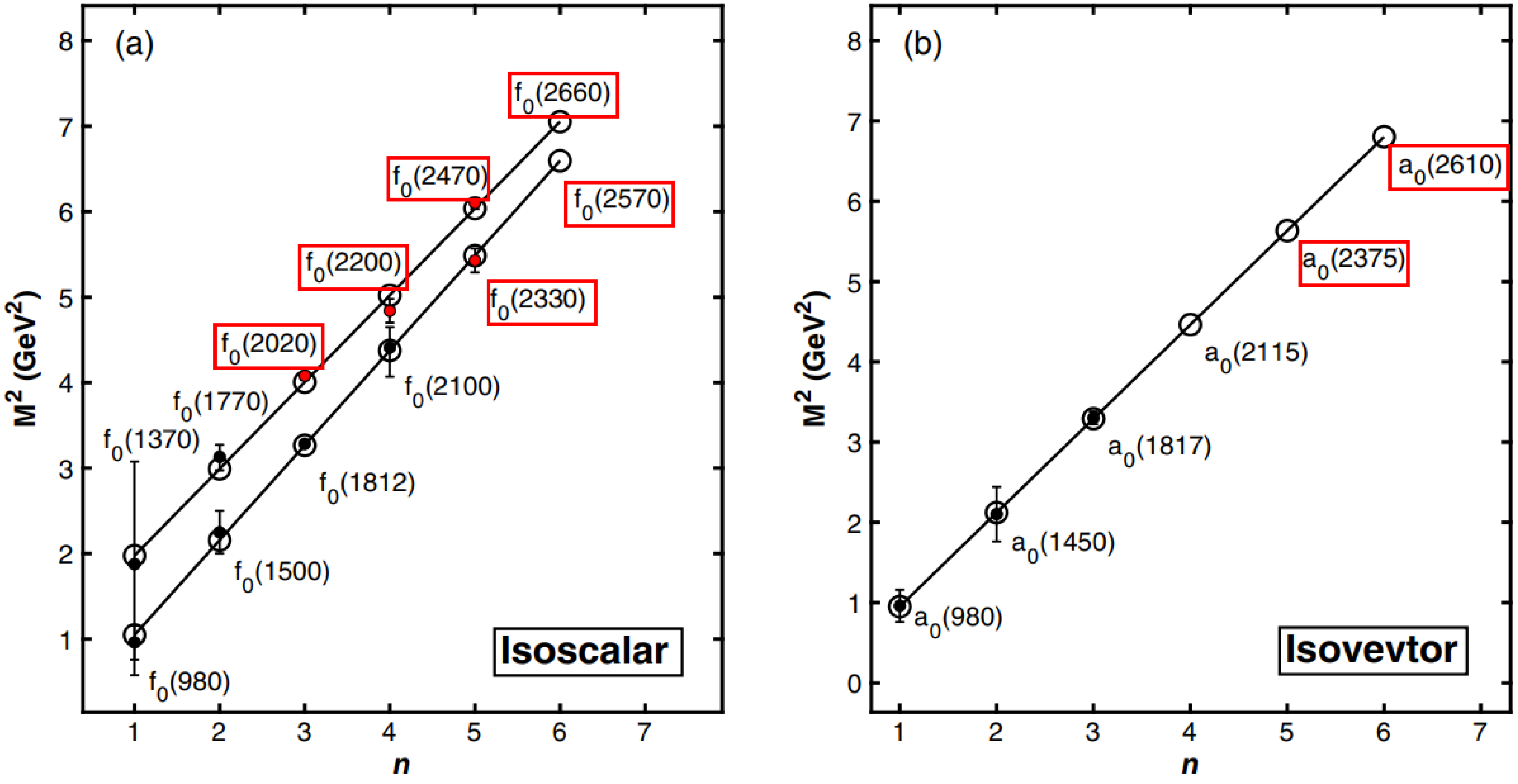
$$M^2 = M_0^2 + (\mathrm{n}-1)\mu^2$$

Phys. Rev. D 105, 114014 (2022)



The Regge trajectories of scalar mesons

Three Regge trajectories of the scalar mesons family: f_0 states (a) and a_0 states (b), while f_0 states can be categorized into $n\bar{n}$ states ($f_0(980)$) and $s\bar{s}$ states ($f_0(1370)$)



← The states are studied in our work

Not included $f_0(500)$ and $f_0(1710)$

$n\bar{n}$: u and d quarks

$s\bar{s}$: s quarks

The Godfrey-Isgur (GI) model

In the nonrelativistic limit, the effective potential：

$$\tilde{H} = \sqrt{m_1^2 + \mathbf{p}^2} + \sqrt{m_2^2 + \mathbf{p}^2} + \tilde{V}_{\text{eff}}(\mathbf{p}, \mathbf{r}),$$

$$V_{\text{eff}}(r) = H^{\text{conf}} + H^{\text{hyp}} + H^{\text{so}},$$

$$H^{\text{conf}} = \left[-\frac{3}{4}(c + br) + \frac{\alpha_s(r)}{r}\right](\boldsymbol{F}_1 \cdot \boldsymbol{F}_2)$$

$$= S(r) + G(r),$$

↑ Cornell potential

$$H^{\text{hyp}} = -\frac{\alpha_s(r)}{m_1 m_2}\left[\frac{8\pi}{3}\boldsymbol{S}_1 \cdot \boldsymbol{S}_2 \delta^3(\boldsymbol{r}) + \frac{1}{r^3}\left(\frac{3\boldsymbol{S}_1 \cdot \boldsymbol{r} \boldsymbol{S}_2 \cdot \boldsymbol{r}}{r^2} - \boldsymbol{S}_1 \cdot \boldsymbol{S}_2\right)\right] \times (\boldsymbol{F}_1 \cdot \boldsymbol{F}_2),$$

$$H^{\text{so}} = H^{\text{so(cm)}} + H^{\text{so(tp)}},$$

$$H^{\text{so(cm)}} = \frac{-\alpha_s(r)}{r^3}\left(\frac{1}{m_1} + \frac{1}{m_2}\right)\left(\frac{\boldsymbol{S}_1}{m_1} + \frac{\boldsymbol{S}_2}{m_2}\right) \cdot \boldsymbol{L}(\boldsymbol{F}_1 \cdot \boldsymbol{F}_2),$$

$$H^{\text{so(tp)}} = -\frac{1}{2r}\frac{\partial H^{\text{conf}}}{\partial r}\left(\frac{\boldsymbol{S}_1}{m_1^2} + \frac{\boldsymbol{S}_2}{m_2^2}\right) \cdot \boldsymbol{L}$$

To account for relativistic effects, two modifications are introduced, a smearing function and momentum-dependent factorsare

$$\tilde{f}(r) = \int d^3 r' \rho(\mathbf{r} - \mathbf{r}') f(r'), \quad \rho(\mathbf{r} - \mathbf{r}') = \frac{\sigma^3}{\pi^{3/2}} e^{-\sigma^2(\mathbf{r}-\mathbf{r}')^2},$$

$$\tilde{G}(r) \to \left(1 + \frac{p^2}{E_1 E_2}\right)^{1/2} \tilde{G}(r) \left(1 + \frac{p^2}{E_1 E_2}\right)^{1/2}$$

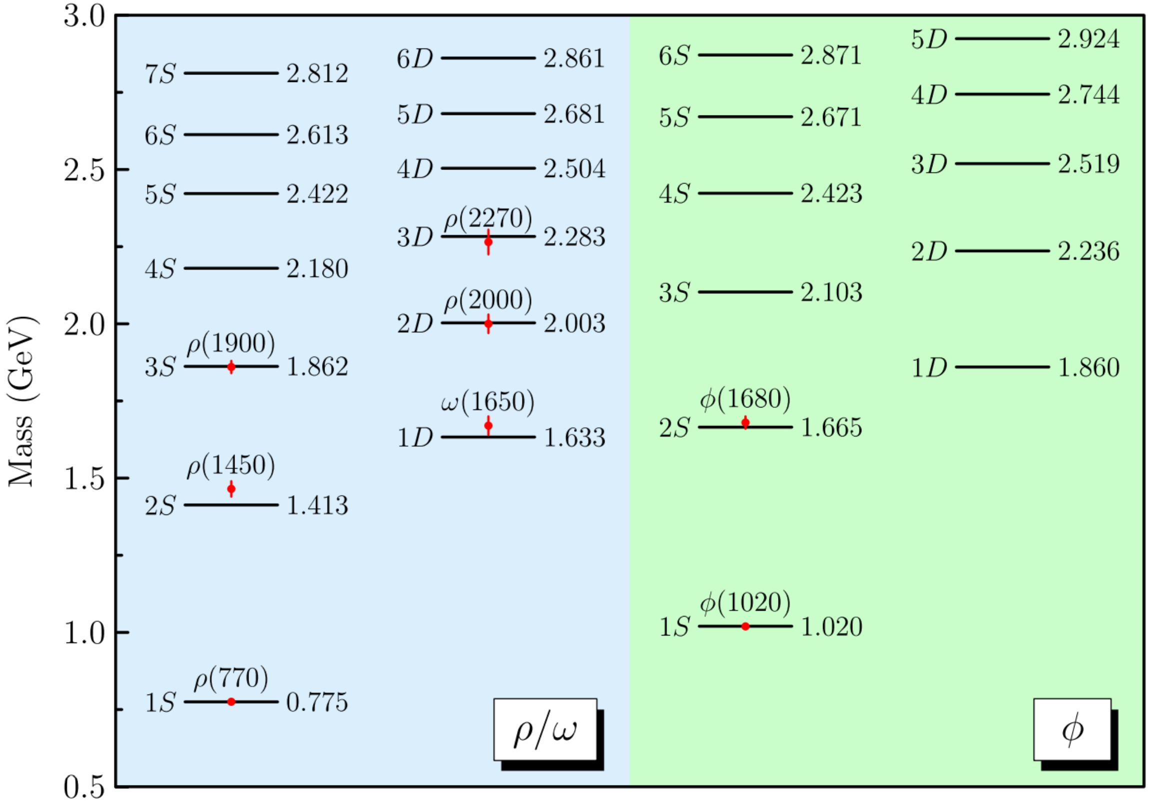
$$\frac{\tilde{V}_i(r)}{m_1 m_2} \to \left(\frac{m_1 m_2}{E_1 E_2}\right)^{1/2+\epsilon_i} \frac{\tilde{V}_i(r)}{m_1 m_2} \left(\frac{m_1 m_2}{E_1 E_2}\right)^{1/2+\epsilon_i},$$

The screening effect replaces the line potential to account for the unquenched effect

$$br \to \frac{b(1 - e^{-\mu r})}{\mu}, \quad H^{\text{scr}} = \frac{b(1 - e^{-\mu r})}{\mu} - \frac{4\alpha_s(r)}{3r} + c.$$

The mass spectrum of η_2 family

The mass spectrum of $\rho, \ \omega, \ \phi$



Phys. Rev. D 105, 034011 (2022)

The parameters involved in the GI model from our previous work

Parameter	Value	Parameter	Value
m_u (GeV)	0.22	m_d (GeV)	0.22
m_s (GeV)	0.424	b (GeV^2)	0.229
ϵ_c	−0.164	ϵ_{sos}	0.9728
σ_0 (GeV)	1.8	s (GeV)	3.88
μ (GeV)	0.081	c (GeV)	−0.30
ϵ_{sov}	0.262	ϵ_t	1.993

Comparison of the calculated results and the experimental data

States	This work	Experimental values
$\eta_2(1D)$	1650	$1645 \pm 14 \pm 15$ [22]
$\eta_2(2D)$	2003	$2030 \pm 10 \pm 15$ [23]
$\eta_2(3D)$	2279	2267 ± 14 [24]
$\eta_2(4D)$	2498	...
$\eta_2'(1D)$	1882	$1881 \pm 32 \pm 40$ [25]
$\eta_2'(2D)$	2238	...
$\eta_2'(3D)$	2520	...
$\eta_2'(4D)$	2764	...

Decay behaviors

The Quark-Pair-Creation model

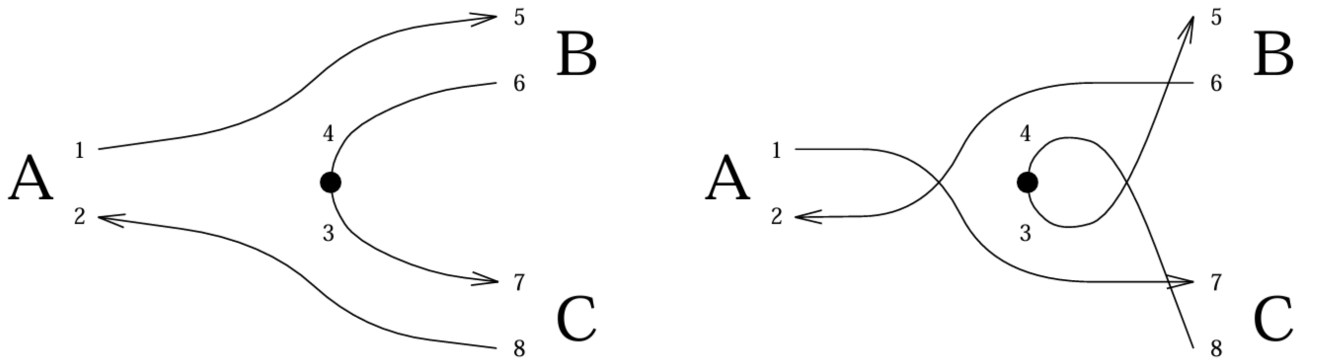
$$\langle BC|\mathcal{T}|A\rangle = \delta^3(\mathbf{P}_B + \mathbf{P}_C)\mathcal{M}^{M_{J_A}M_{J_B}M_{J_C}}$$

$$\mathcal{T} = -3\gamma\sum_m \langle 1m; 1-m|00\rangle \int d\mathbf{p}_3 d\mathbf{p}_4 \delta^3(\mathbf{p}_3 + \mathbf{p}_4) \times \mathcal{Y}_{1m}\left(\frac{\mathbf{p}_3 - \mathbf{p}_4}{2}\right)\chi^{34}_{1,-m}\phi^{34}_0(\omega^{34}_0)_{ij} b^\dagger_{3i}(\mathbf{p}_3) d^\dagger_{4j}(\mathbf{p}_4).$$

$$|A(n_A{}^{2S_A+1}L_{A\,J_A M_{J_A}})(\vec{P}_A)\rangle \equiv \sqrt{2E_A}\sum_{M_{L_A},M_{S_A}} \langle L_A M_{L_A} S_A M_{S_A}|J_A M_{J_A}\rangle \times \int \mathrm{d}^3\vec{p}_A\, \psi_{n_A L_A M_{L_A}}(\vec{p}_A)\, \chi^{12}_{S_A M_{S_A}}\, \phi^{12}_A\, \omega^{12}_A \times |q_1(\tfrac{m_1}{m_1+m_2}\vec{P}_A + \vec{p}_A)\, \bar{q}_2(\tfrac{m_2}{m_1+m_2}\vec{P}_A - \vec{p}_A)\rangle.$$

$$\mathcal{M}^{JL}(\boldsymbol{P}) = \frac{\sqrt{4\pi(2L+1)}}{2J_A+1}\sum_{M_{J_B}M_{J_C}} \langle L0; JM_{J_A}|J_A M_{J_A}\rangle \times \langle J_B M_{J_B}; J_C M_{J_C}|J_A M_{J_A}\rangle \mathcal{M}^{M_{J_A}M_{J_B}M_{J_C}}.$$

$$\Gamma = \frac{\pi}{4}\frac{|P_E|}{m_A^2}\sum_{J,L}|\mathcal{M}^{JL}(\boldsymbol{P})|^2$$



$\gamma = 7.1$ for the scalar mesons, $\gamma = 6.57$ for the η_2 family

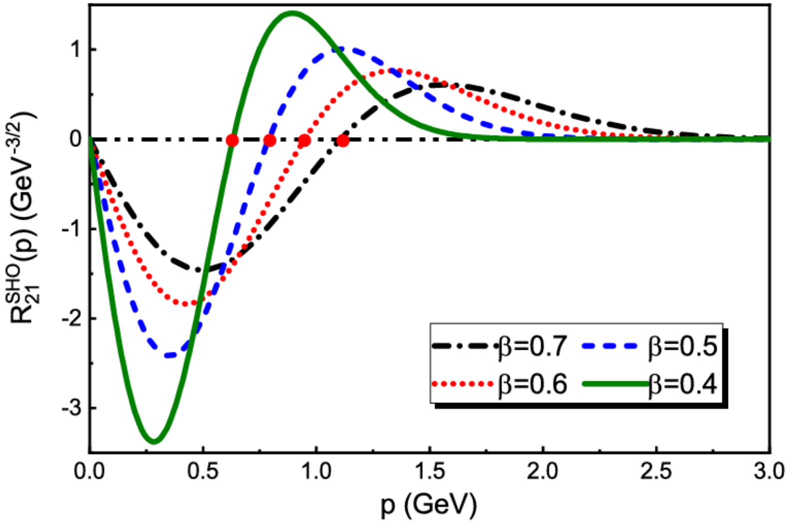
The simple harmonic oscillator (SHO) wave function

$$\phi^p_{\mathrm{nlm}}(R,p) = R^p_{nl}(R,p)Y_{lm}(\hat{P}),$$

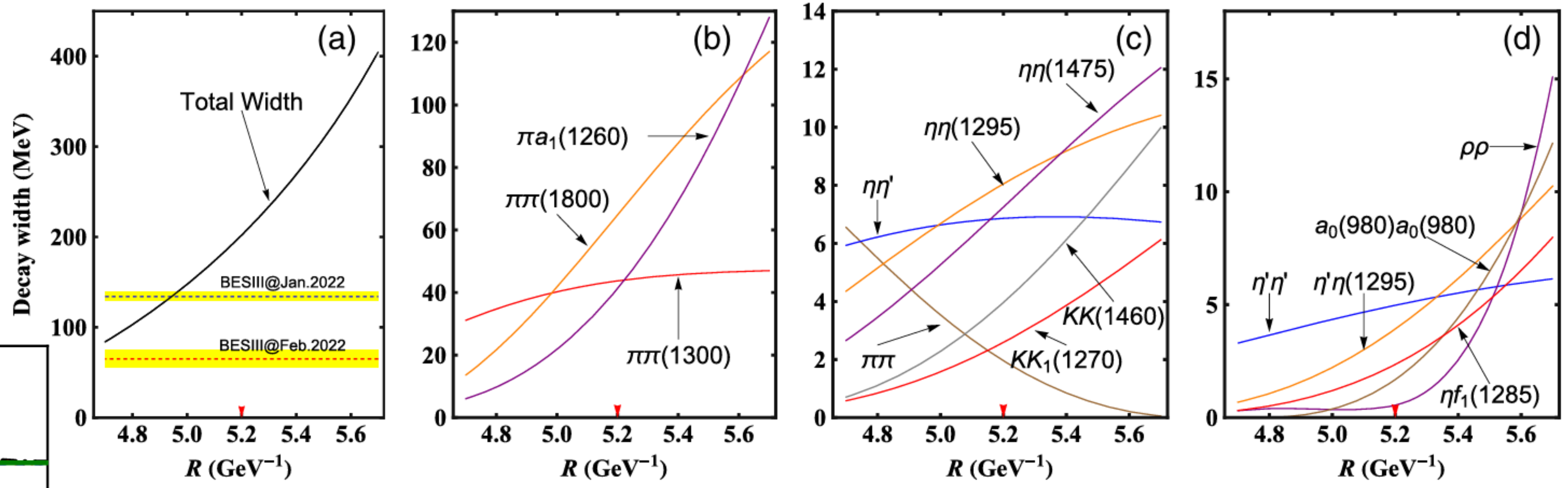
$$R^p_{nl}(R,p) = (-1)^n(-i)^l R^{\frac{3}{2}+l}\sqrt{\frac{2n!}{\Gamma(n+l+\frac{3}{2})}}\, L_n^{l+\frac{1}{2}}(R^2p^2)e^{\frac{-R^2p^2}{2}}p^l$$

Decay behaviors of f_0 (2330)

Node effect →



Phys. Rev. D 101, 054029 (2020)



↑

Center R value ± 0.5

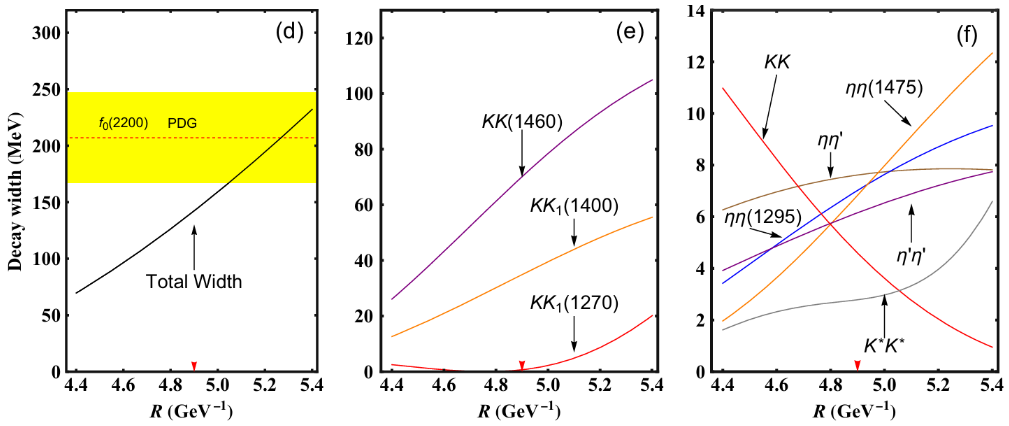
R value:

Phys. Rev. D 72, 094004 (2005)
Phys. Rev. D 55, 4157 (1997)

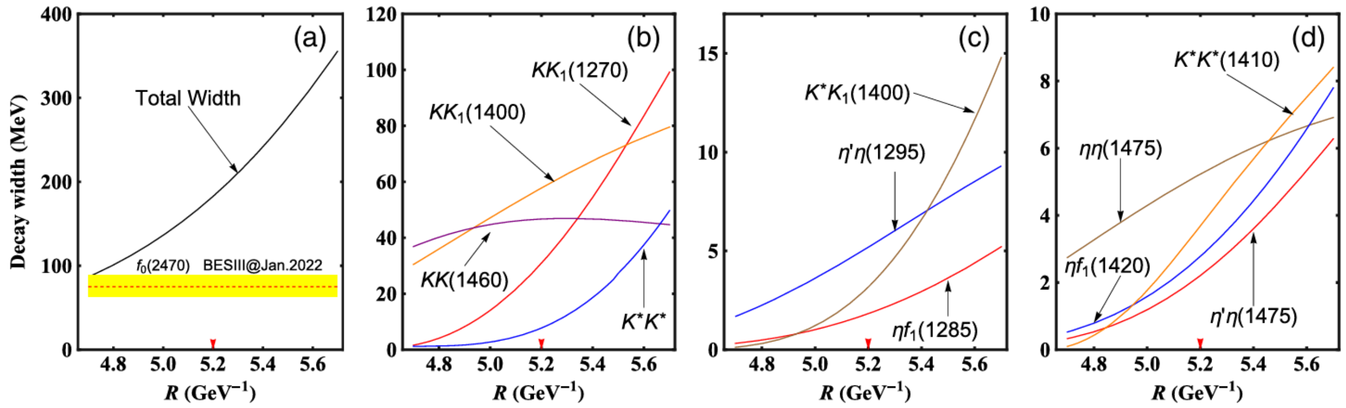
Consist with the result of BESIII Collaboration

Major decay channels: $\pi a_1(1260)$ $\pi\pi(1800)$ and $\pi\pi(1300)$

Decay behaviors of other scalar states



Consist with PDG data at R = 5.0 to 5.4



Consist with PDG data at R = 4.7

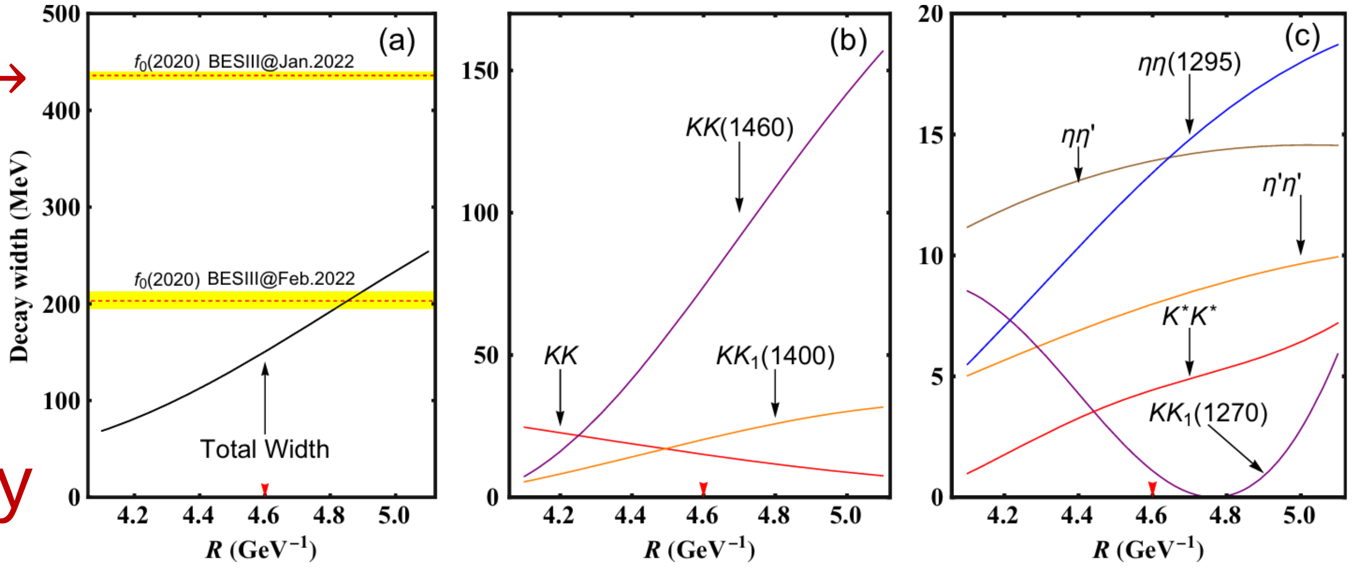
$J/\psi \to \gamma\eta'\eta'$ result →

Phys. Rev. D 105, 072002 (2022)

$J/\psi \to \gamma\eta\eta'$ result →

Phys. Rev. D 106, 072012 (2022)

$f_0(2020)$ requires further study



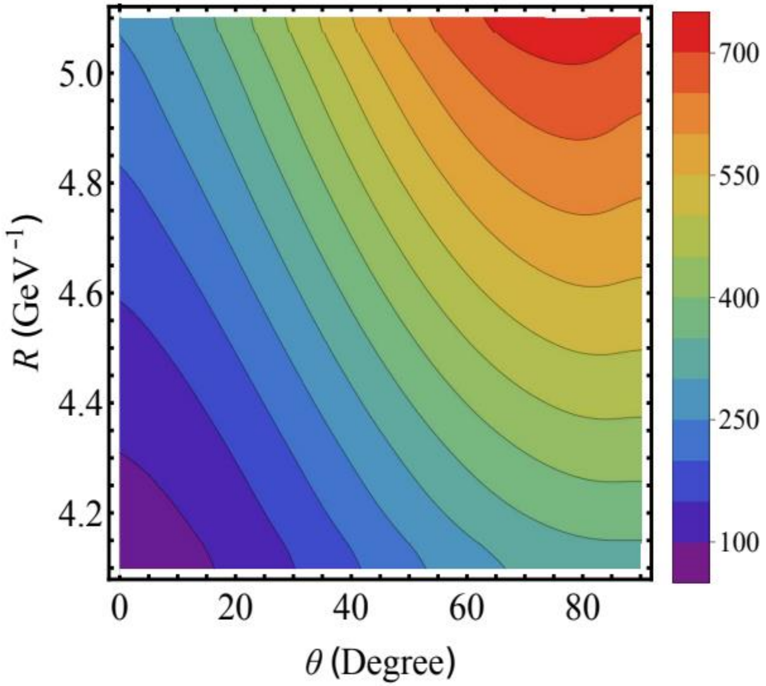
The mixing of f_0 (2020)

The mixing scheme of $f_0(2020)$

$$\begin{pmatrix} |f_0(2020)\rangle \\ |f_0(1812)\rangle \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} |s\bar{s}\rangle \\ |n\bar{n}\rangle \end{pmatrix}$$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
$436 \pm 4 ^{+46}_{-49}$		[1] ABLIKIM	2022C	BES3	$J/\psi \to \gamma\eta'\eta' \to 4\gamma 2(\pi^+\pi^-)$
$203 \pm 9 ^{+13}_{-11}$		[2] ABLIKIM	2022AS	BES3	$J/\psi(1S) \to \gamma\eta\eta'$

The total decay widths of the $f_0(2020)$

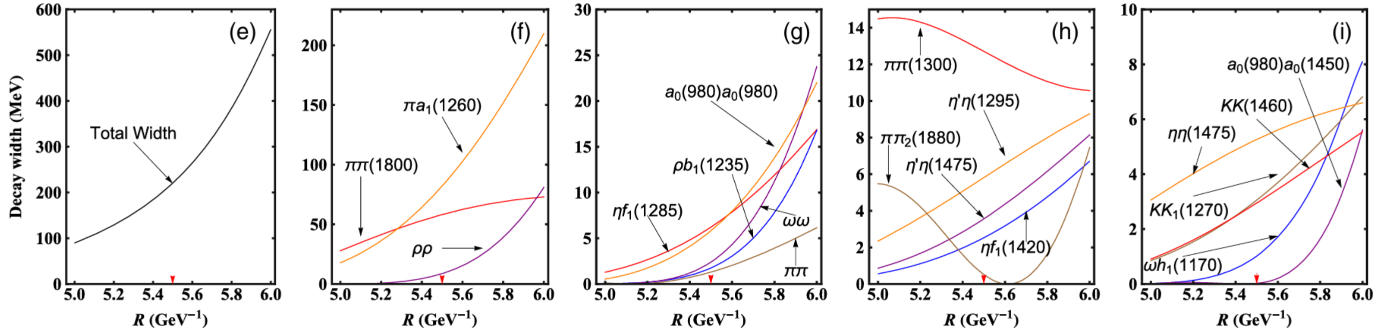


The partial decay widths of $f_0(2020)$ when taking center R value at 4.6 GeV

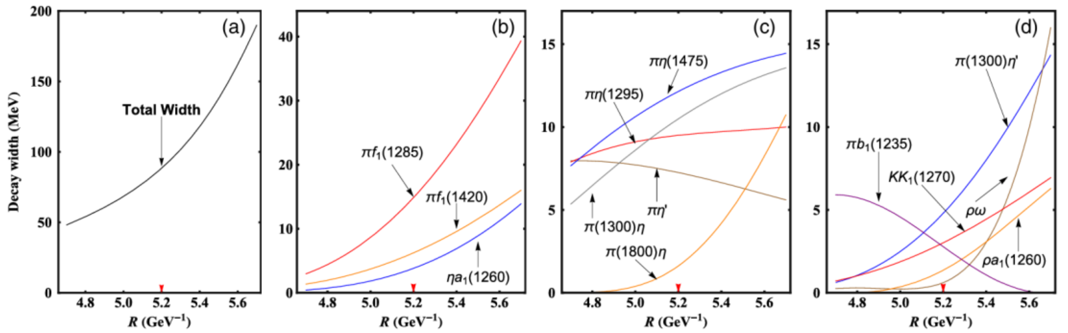
Channels	$\theta = 15^\circ$	$\theta = 50^\circ$
$\pi\pi$	1.44	12.58
$\pi\pi(1300)$	10.51	92.09
$\pi\pi(1800)$	14.41	126.25
$\pi a_1(1260)$	3.01	26.40
$\eta\eta$	5.79	9.56
$\eta\eta'$	5.86	1.21
$\eta\eta(1295)$	23.50	38.79
$\eta'\eta'$	12.43	17.41
KK	20.38	22.34
$KK_1(1400)$	17.50	6.74
$KK_1(1460)$	82.75	62.64
Total width	203.92	429.40

Assuming $R = 4.6\ \mathrm{GeV}^{-1}$ and considering $\theta = 15^\circ$ or 50°, we derive different decay widths as reported by BESIII collaboration

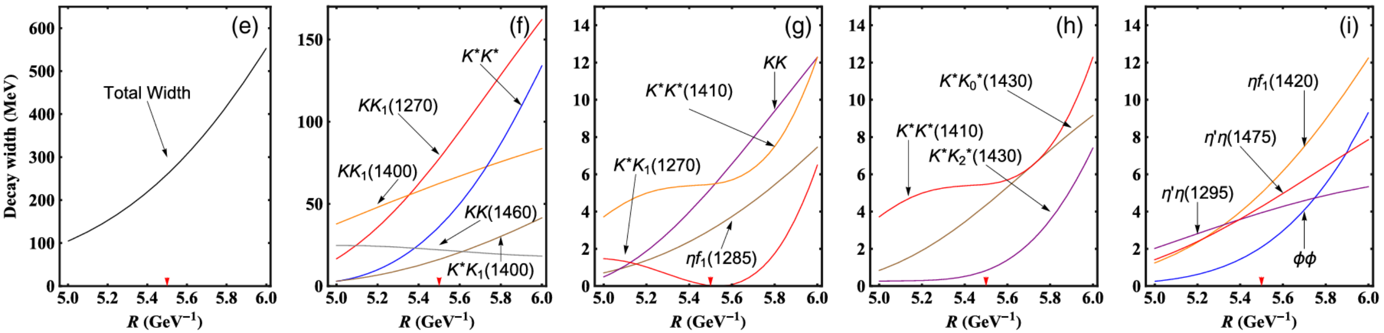
The predicted scalar mesons



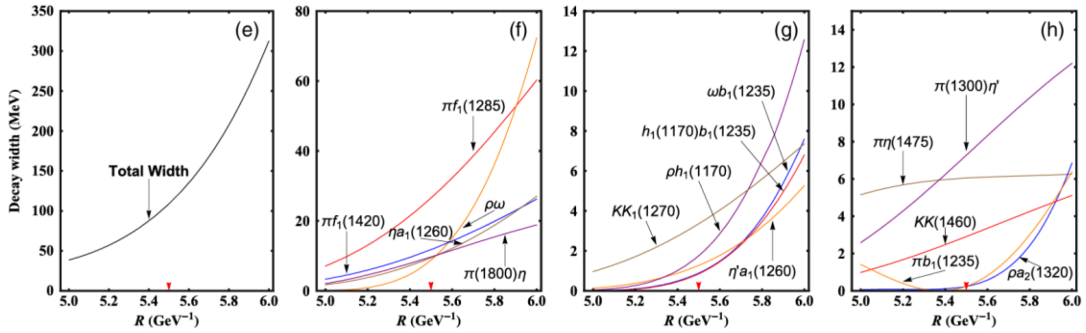
$f_0(2570)$, decay width is about 200 MeV at center R value



$a_0(2375)$, decay width is about 80 MeV at center R value



$f_0(2660)$, decay width is about 300 MeV at center R value



$a_0(2610)$, decay width is about 100 MeV at center R value

The decay behaviors of η_2 family

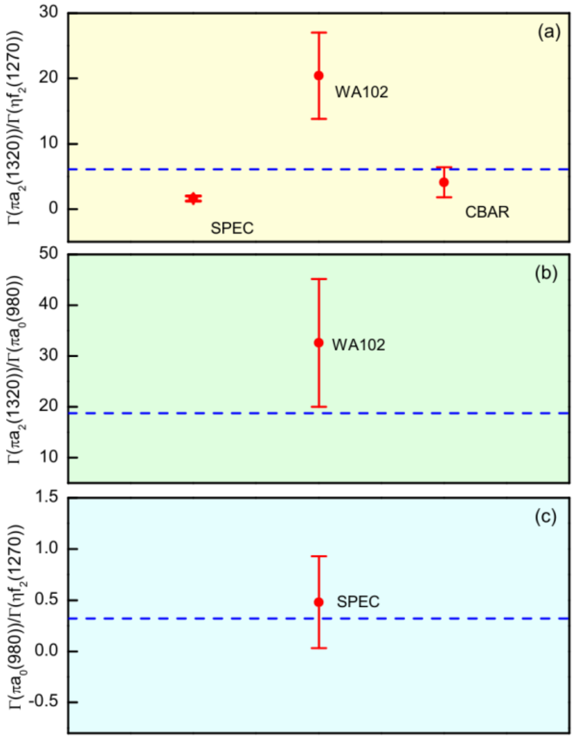
States	This work	Experimental values
$\eta_2(1D)$	1650	$1645 \pm 14 \pm 15$
$\eta_2(2D)$	2003	$2030 \pm 10 \pm 15$
$\eta_2(3D)$	2279	2267 ± 14
$\eta_2(4D)$	2498	...
$\eta_2'(1D)$	1882	$1881 \pm 32 \pm 40$
$\eta_2'(2D)$	2238	...
$\eta_2'(3D)$	2520	...
$\eta_2'(4D)$	2764	...

The mixing within the η_2 family

$$\begin{pmatrix} |\eta_2(nD)\rangle \\ |\eta_2'(nD)\rangle \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} |n\bar{n}\rangle \\ |s\bar{s}\rangle \end{pmatrix}$$

State	$\eta_2(1D)$			$\eta_2'(1D)$		
Decay channel	$\theta = 0°$	$\theta = 15°$	$\theta = 30°$	$\theta = 0°$	$\theta = 15°$	$\theta = 30°$
$a_2(1320)\pi$	173.3	161.8	130.0	...	15.3	57.2
$\rho\rho$	28.5	26.6	21.4	...	8.3	31.0
$\omega\omega$	7.7	7.2	5.8	...	2.7	10.0
$a_0(980)\pi$	7.0	6.5	5.2	...	0.8	3.1
$a_1(1260)\pi$	4.2	3.9	3.2	...	2.4	8.9
KK^*	2.6	10.1	20.7	79.8	60.4	39.7
K^*K^*	...	...	...	29.5	32.8	30.0
$\eta f_2(1270)$	...	...	...	0.2	1.8	9.4
Total width	223.3	216.1	186.3	109.5	123.5	189.3
Exp	$180^{+40}_{-21} \pm 25$			$221 \pm 82 \pm 44$		

The mixing angles θ for all η_2 meson states are constrained to $\theta < 30°$



The branching ratio of $\eta_2(1870)$

The η_2 mesons

The $\eta_2(2030)$ and $\eta_2(2250)$ are currently listed as tentative state in the PDG

State	$\eta_2(2D)$			$\eta_2'(2D)$		
Decay channel	$\theta=0°$	$\theta=15°$	$\theta=30°$	$\theta=0°$	$\theta=15°$	$\theta=30°$
$\pi a_2(1700)$	91.7	85.5	68.7	\	7.1	26.4
$\pi a_2(1320)$	51.7	48.3	38.8	\	6.3	23.6
$\rho b_1(1235)$	20.6	19.2	15.4	\	4.9	18.4
$\rho\rho$	19.2	17.9	14.4	\	3.0	10.1
$\omega h_1(1170)$	6.3	5.9	4.8	\	2.3	8.5
$\omega\omega$	6.0	5.6	4.5	\	1.0	3.6
$\pi a_0(1450)$	4.9	4.6	3.7	\	0.5	1.9
$a_0(980)\pi$	3.3	3.1	2.5	\	9×10^{-4}	3×10^{-3}
$\eta f_2(1270)$	3.1	3.0	2.5	2×10^{-2}	0.1	2.9
$a_1(1260)\pi$	2.2	2.1	1.6	\	3×10^{-2}	0.1
$KK^*(1410)$	1.3	4.8	9.6	44.0	27.3	17.2
KK^*	0.4	2.7	6.7	23.4	24.1	17.7
K^*K^*	0.2	0.3	0.8	17.9	18.0	15.3
$KK_2^*(1430)$	0.1	0.3	0.8	35.7	39.8	35.9
$KK_0^*(1430)$	4×10^{-2}	6×10^{-3}	0.1	7.0	6.0	5.7
K_1K^*	\	\	\	8.9	7.2	6.4
$\omega\omega(1420)$	\	\	\	\	0.6	2.2
Total width	211.0	203.3	174.9	136.9	148.2	195.9
Exp	205 ± 10 ± 15 [23]			\		

State	$\eta_2(3D)$			$\eta_2'(3D)$		
Decay channel	$\theta=0°$	$\theta=15°$	$\theta=30°$	$\theta=0°$	$\theta=15°$	$\theta=30°$
$\pi a_2(1700)$	29.5	27.6	22.2	⋯	3.7	13.9
$\pi a_2(1320)$	18.4	17.1	13.8	⋯	3.7	13.8
$\rho\rho$	10.7	10.0	8.0	⋯	2.9	10.9
$\pi a_0(980)$	6.1	5.7	4.6	⋯	0.1	0.5
$\rho b_1(1235)$	6.1	5.7	4.6	⋯	3.1	11.7
$\pi a_1(1260)$	3.8	3.5	2.8	⋯	0.4	1.6
$\omega\omega$	3.3	3.1	2.5	⋯	1.0	3.5
$\rho\rho(1450)$	2.5	2.3	1.9	⋯	1.9	7.2
$\omega h_1(1170)$	2.4	2.2	1.8	⋯	1.4	5.1
$\omega\omega(1420)$	1.6	1.5	1.2	⋯	0.7	2.7
$\eta f_0(1500)$	1.6	1.5	1.2	⋯	1×10^{-2}	4×10^{-2}
$\eta f_2(1270)$	1.3	1.2	1.1	3×10^{-2}	0.3	1.6
$\pi a_0(1450)$	1.3	1.2	0.9	⋯	0.4	1.4
K^*K_1	0.7	0.4	0.2	5.6	12.2	10.2
$KK^*(1410)$	0.2	1.6	3.9	13.5	19.7	15.0
KK^*	0.1	1.1	3.1	16.0	14.1	10.6
$KK_2^*(1430)$	0.1	0.4	1.2	20.3	26.5	22.7
$KK_0^*(1430)$	1×10^{-2}	3×10^{-2}	0.2	3.5	4.6	4.2
$KK_1(1650)$	1×10^{-2}	7×10^{-3}	4×10^{-3}	0.2	1.1	0.8
$K^*K^*(1410)$	⋯	⋯	⋯	18.9	16.8	13.9
K^*K_1'	⋯	⋯	⋯	5.5	5.0	4.0
$K^*K(1460)$	⋯	⋯	⋯	4.0	5.6	4.3
$\pi(1300)a_0(980)$	⋯	⋯	⋯	⋯	0.5	1.9
$a_1(1260)a_1(1260)$	⋯	⋯	⋯	⋯	0.5	2.0
Total width	89.9	84.9	76.0	101.8	142.9	177.6
Exp	290 ± 50 [24]			⋯		

The $\eta_2(4D)$ and $X(2600)$

Case	$f_0(1500)$	$X(2600)$
Mass (MeV/c^2)	$1498.0 \pm 4.5^{+4.0}_{-15.2}$	$2617.8 \pm 2.1^{+18.2}_{-1.9}$
Width (MeV)	$166 \pm 10^{+13}_{-26}$	$200 \pm 8^{+20}_{-17}$

Calculated decay width is significantly lower than $X(2600)$

This discrepancy rules out the possibility of identifying the $X(2600)$, as a $\eta'_2(4D)$ state

Proved our earlier result
Still need further exploration

State	$\eta_2(4D)$			$\eta_2'(4D)$		
Decay channel	$\theta = 0°$	$\theta = 15°$	$\theta = 30°$	$\theta = 0°$	$\theta = 15°$	$\theta = 30°$
$\pi a_2(1700)$	18.0	16.8	13.5	...	2.8	10.3
$\pi a_2(1320)$	9.9	9.2	7.4	...	2.6	9.5
$\rho\rho(1450)$	5.2	4.8	3.9	...	2.8	10.4
$\pi a_0(980)$	4.7	4.4	3.5	...	0.3	1.1
$\rho\rho$	4.1	3.9	3.1	...	1.8	6.6
$\rho b_1(1235)$	3.9	3.7	2.9	...	2.3	8.5
$\pi a_1(1260)$	2.4	2.2	1.8	...	0.4	1.6
$\omega\omega(1420)$	2.1	2.0	1.6	...	1.0	3.8
$\omega h_1(1170)$	1.7	1.6	1.3	...	1.0	3.7
$\pi(1300)a_0(980)$	1.3	1.2	1.0	...	0.2	0.8
$\omega\omega$	1.3	1.2	1.0	...	0.6	2.1
$\eta f_0(1500)$	1.1	1.1	0.8	...	1×10^{-2}	5×10^{-2}
$\eta f_2(1270)$	0.8	0.8	0.6	1×10^{-2}	0.2	1.1
$K_1 K^*$	0.3	0.3	0.3	4.8	9.8	7.9
$a_1(1260)a_0(980)$	0.3	0.2	0.2	...	0.3	1.3
$KK^*(1410)$	0.2	0.8	2.1	6.2	11.7	9.9
$K^*K^*(1410)$	0.2	0.1	0.3	20.7	13.7	11.6
$KK_2^*(1430)$	0.1	0.4	1.4	15.4	19.4	16.0
$K^*K_2^*(1430)$	0.1	0.6	1.3	6.1	11.5	9.5
K^*K^*	7×10^{-2}	0.3	1.0	11.0	15.6	12.8
KK^*	3×10^{-2}	0.7	2.1	12.9	11.6	9.0
$K_1'K^*$	2×10^{-2}	0.2	0.6	5.1	10.6	8.6
$K^*K(1460)$	2×10^{-2}	6×10^{-2}	0.1	6.1	5.7	4.4
$KK_0^*(1430)$	3×10^{-4}	4×10^{-2}	0.2	1.9	2.8	2.4
$K^*K_1(1650)$	...	...	...	7.1	15.8	12.7
$K_1K^*(1410)$	...	...	...	2.4	0.9	1.2
$K_1K_2^*(1430)$	...	...	...	1.2	1.3	0.9
$a_1(1260)a_2(1320)$	...	...	...	...	0.5	1.7
$\rho(1450)b_1(1235)$	...	...	...	...	0.4	1.6
Total width	57.9	55.9	52.0	98.5	147.6	171.0

Summary

1. We conduct a systematic investigation of high-lying scalar and η_2 mesons.

2. The mass spectrums are constructed for scalar mesons and η_2 states through Regge trajectory and GI model.

3. Strong decay behaviors are analyzed via the QPC model, calculating partial widths and branching ratios.

4. The study of high-lying states may be a new task for experimental study.

THANKS!