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The $\Omega(2012)$ as a $\bar{K}\Xi^*(1530)$ hadronic molecule

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Outline

Motivation

$\bar{K}\Xi^*(1530)$ *and* $\eta\Omega$ *interactions in s wave and* $\bar{K}\Xi$ *in d wave*

Searching $\Omega(2012)$ *in the* $\Omega_c^0 \to \pi^+\Omega^-(2012) \to \pi^+(\bar{K}\Xi)^-$ *decay*

Summary

Observation of an Excited Ω^- Baryon

PHYSICAL REVIEW LETTERS 121, 052003 (2018)

(The Belle Collaboration)

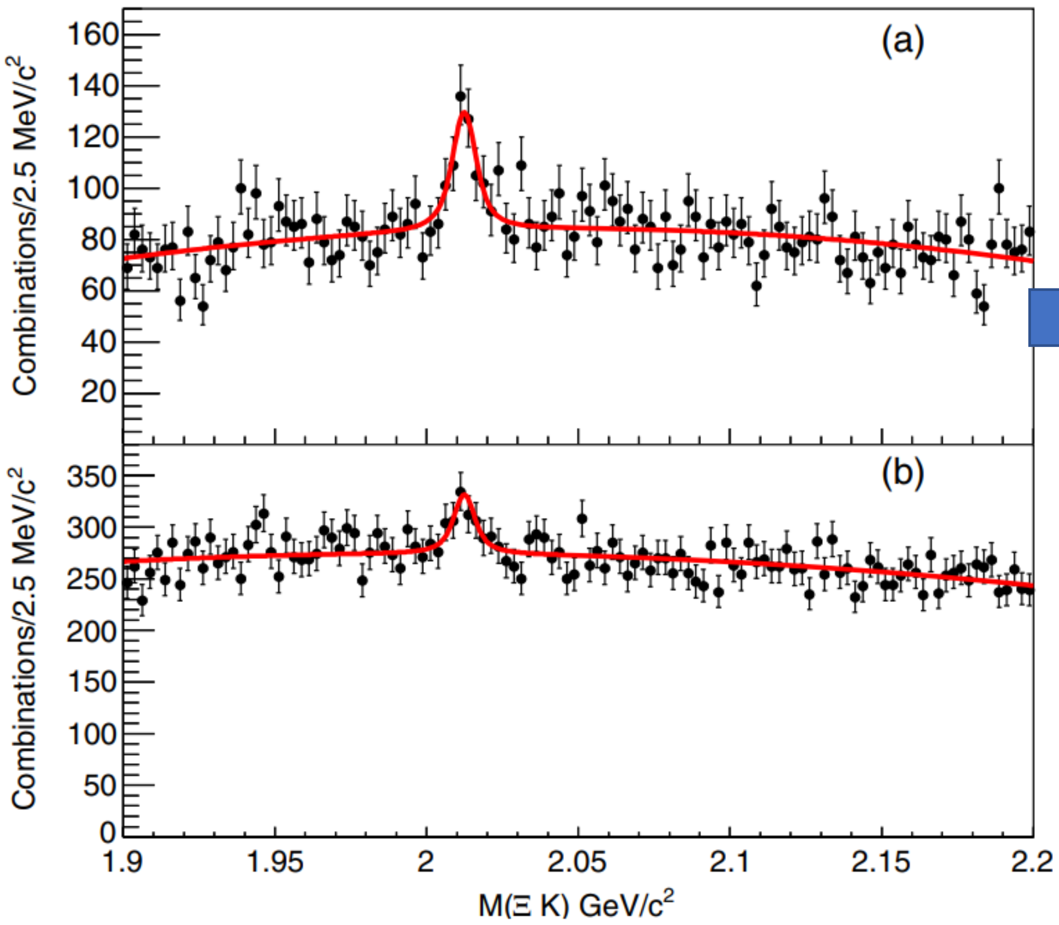


FIG. 2. The (a) $\Xi^0 K^-$ and (b) $\Xi^- K_S^0$ invariant mass distributions in data taken at the $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ resonance energies. The curves show a simultaneous fit to the two distributions with a common mass and width.

$$M = 2012.4 \pm 0.7 \pm 0.6 \text{ MeV}$$

$$\Gamma = 6.4^{+2.5}_{-2.0} \pm 1.6 \text{ MeV}$$

Narrow width

$$\rightarrow \bar{K}\Xi \ in \ d - wave$$

$$preferred \ J^P = \frac{3}{2}^-$$

$$and \ I = 0$$

XI Baryons (S = -2, I = 1/2)

Note on Xi Resonances	Xi(1950)
Xi0	Xi(2030)
Xi-	Xi(2120)
Xi(1530)	Xi(2250)
Xi(1620)	Xi(2370)
Xi(1690)	Xi(2500)
Xi(1820)	

Collapse Xi Baryons table

Omega Baryons (S = -3, I = 0)

- Omega-
- Omega(2012)-
- Omega(2250)-
- Omega(2380)-
- Omega(2470)-

Collapse Omega Baryons table

SSS

Citation: S. Navas *et al.* (Particle Data Group), Phys. Rev. D **110**, 030001 (2024)

$\Omega(2012)^-$

$I(J^P) = 0(?^-)$ Status: ∗∗∗

Seen in $\Xi^0 K^-$ and $\Xi^- K^0_S$ decays with a combined significance of 8.3 standard deviations.

$\Omega(2012)^-$ MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2012.4±0.7±0.6	520	YELTON	18A	BELL	In $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$

$\Omega(2012)^-$ WIDTH

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{6.4^{+2.5}_{-2.0}\pm1.6}$	520	YELTON	18A	BELL	In $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$

$\Omega(2012)^-$ DECAY MODES

Branching fractions are given relative to the one **DEFINED AS 1**.

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	ΞK		
Γ_2	$(\Xi\pi)K$		
Γ_3	$\Xi^0 K^-$	**DEFINED AS 1**	
Γ_4	$\Xi^- \overline{K}^0$	0.83±0.21	
Γ_5	$\Xi^0 \pi^0 K^-$	<0.30	90%
Γ_6	$\Xi^0 \pi^- \overline{K}^0$	<0.21	90%
Γ_7	$\Xi^- \pi^0 \overline{K}^0$	<0.7	90%
Γ_8	$\Xi^- \pi^+ K^-$	<0.08	90%

Before "the observation"

Chiral quark Model Predictions

W.L. Wang, F. Huang, Z.Y. Zhang, Y.W. Yu and F. Liu, $\Omega\omega$ states in a chiral quark model, Commun. Theor. Phys. 48, 695 (2007).

W.L. Wang, F. Huang, Z.Y. Zhang, Y.W. Yu and F. Liu, A Possible Omega pi molecular state, Eur. Phys. J. A32, 293 (2007).

W.L. Wang, F. Huang, Z.Y. Zhang and F. Liu, Xi anti-K interaction in a chiral model, J. Phys. G35, 085003 (2008).

W.L. Wang, F. Huang, Z.Y. Zhang and F. Liu, omega phi states in chiral quark model, Mod. Phys. Lett. A25, 1325 (2010).

Five-quark picture Predictions

C.S. An, B.C. Metsch and B.S. Zou, Mixing of the low-lying three- and five-quark Ω states with negative parity, Phys. Rev. C87, 065207 (2013).

C.S. An and B.S. Zou, Low-lying Ω states with negative parity in an extended quark model with Nambu-Jona-Lasinio interaction, Phys. Rev. C89, 055209 (2014).

S.G. Yuan, C.S. An, K.W. Wei, B.S. Zou and H.S. Xu, Spectrum of low-lying sssqqbar configurations with negative parity, Phys. Rev. C87, 025205 (2013).

Quark Model Predictions

$$Strangenss\ \ -2\ and\ \ -3\ baryons\ in\ a\ quark\ model\ with\ chromodymics$$

$$\mathbf{Kuang\ Ta\ Chao}, Nathan\ Isgur, and\ Gabriel\ Karl,\ \mathbf{PRD23, 155\ (1981)}.$$

$$M_{\Omega^*} = 2020\ \text{MeV}\ with\ J^P = \frac{3}{2}^-$$

Chiral Unitary Approach Prediction

Baryonic resonances from baryon decuplet-meson octet interaction

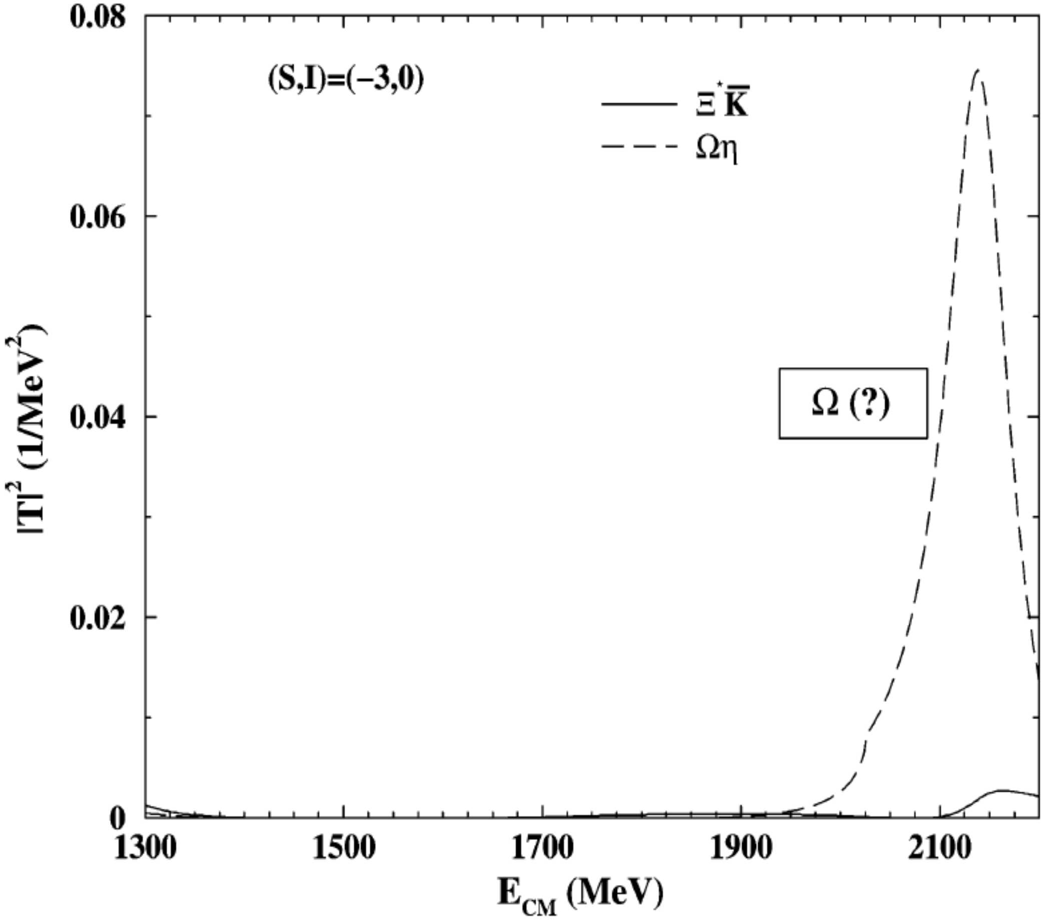
Sourav Sarkar *, E. Oset, M.J. Vicente Vacas

Nuclear Physics A 750 (2005) 294–323

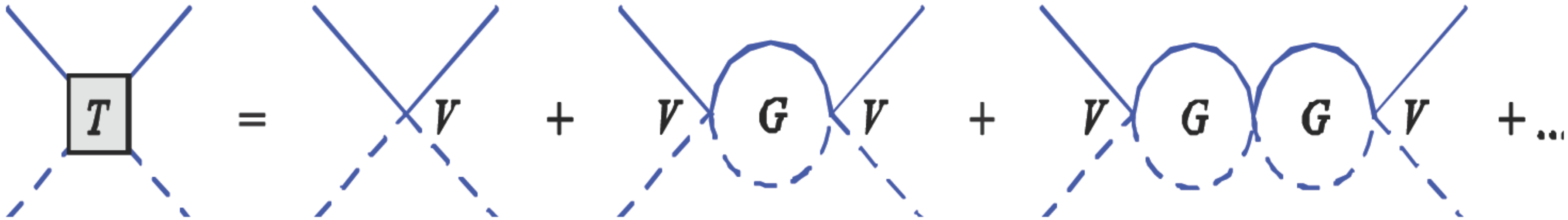
Couplings of the resonance with $S=-3$ and $I=0$ to various channels

z_R	$2141 - i38$	
	g_i	$\lvert g_i \rvert$
$\Xi^* \bar{K}$	$1.1 - i0.8$	1.4
$\Omega\eta$	$3.3 + i0.4$	3.4

Two channels are in s-wave.



Effective filed theory: chiral unitary approach

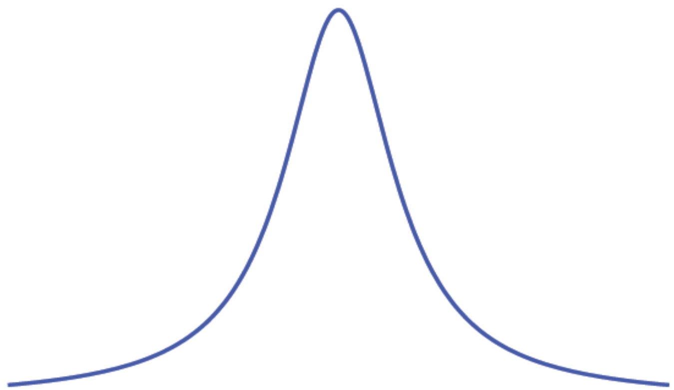


Summing All order contributions:

$$V + VGV + VGVGV + \cdots = \frac{V}{1 - GV}$$

1-GV=0

s=s$_0$



Mass pole corresponds to a resonance structure

The $\Xi^* \bar{K}$ and $\Omega\eta$ Interaction Within a Chiral Unitary Approach*

Si-Qi Xu (徐思琦),[1,2] Ju-Jun Xie (谢聚军),[2,3,†] Xu-Rong Chen (陈旭荣),[2] and Duo-Jie Jia (贾多杰)[1]

Commun. Theor. Phys. **65** (2016) 53–56

$M = 2012.7$ MeV, *below the threshold of* $\bar{K}\Xi^*(1530)$

with $a_\mu = -2.5$ *and* $\mu = 700$ MeV

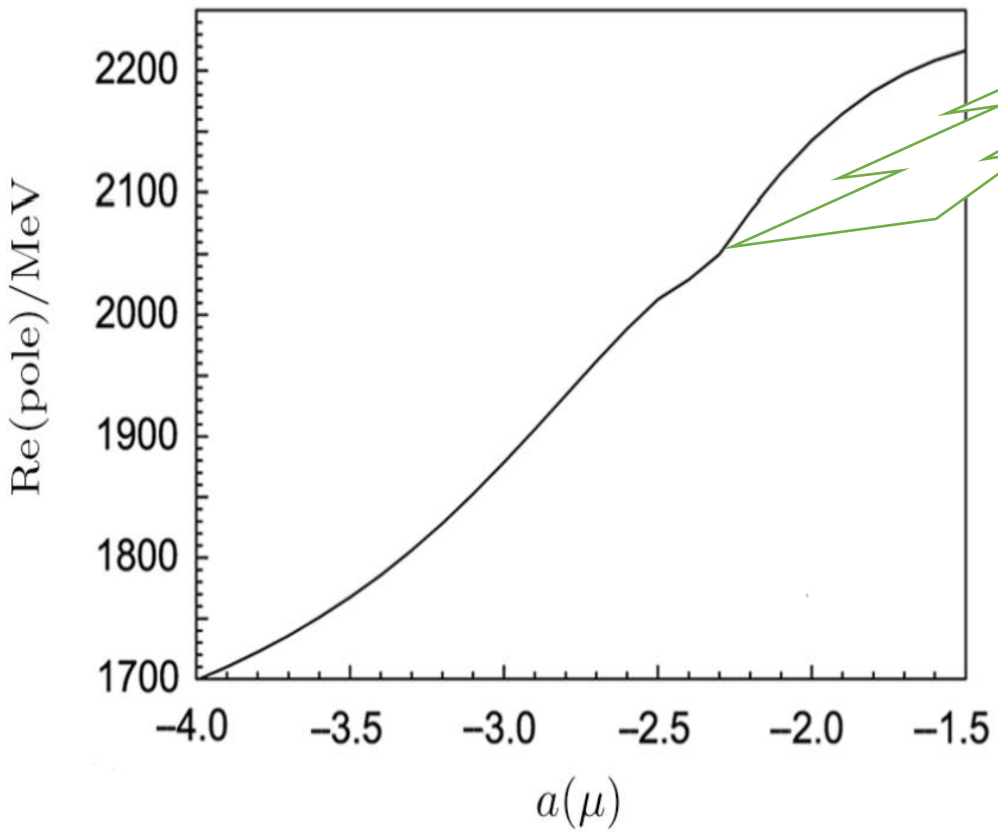


Fig. 3 Results of varying $a(\mu)$ over the $3/2^-$ Ω resonance mass.

$$V_{ij} = -C_{ij}\frac{1}{4f^2}(k^0 + k'^0)\,,$$

$$C_{11} = 0\,,\ C_{12} = C_{21} = 3\,,\ C_{22} = 0\,.$$

$$T = [1 - VG]^{-1}V$$

$$\begin{aligned} G_l = \frac{2M_l}{16\pi^2}\Big\{ & a_l(\mu) + \ln\frac{M_l^2}{\mu^2} + \frac{m_l^2 - M_l^2 + s}{2s}\ln\frac{m_l^2}{M_l^2} \\ & + \frac{q_l}{\sqrt{s}}[\ln(s - (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \\ & + \ln(s + (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \\ & - \ln(-s + (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \\ & - \ln(-s - (M_l^2 - m_l^2) + 2q_l\sqrt{s})]\Big\}\,, \end{aligned}$$

After "the observation"

Quark Model

J^P *could be* $3/2^-$, *but,*

$1/2^-$ *cannot be completely excluded.*

L.Y. Xiao and X.H. Zhong, Phys. Rev. D 98, 034004 (2018).

Z.Y. Wang, L.C. Gui, Q.F. Lü, L.Y. Xiao and X.H. Zhong, Phys. Rev. D98,114023 (2018).

M.S. Liu, K.L. Wang, Q.F. Lü and X.H. Zhong, Phys. Rev. D101, 016002 (2020) .

Hadronic molecule

T.M. Aliev, K. Azizi, Y. Sarac and H. Sundu, Phys. Rev. D98, 014031 (2018); arXiv:1806.01626.

M.V. Polyakov, H.D. Son, B.D. Sun and A. Tandogan, Phys. Lett. B792, 315 (2019); arXiv:1806.04427.

M.P. Valderrama, Phys. Rev. D98, 054009 (2018); arXiv:1807.00718.

Y.H. Lin and B.S. Zou, Phys. Rev. D98, 056013 (2018); arXiv:1807.00997.

T.M. Aliev, K. Azizi, Y. Sarac and H. Sundu, Eur. Phys. J. C78, 894 (2018); arXiv:1807.02145.

R. Pavao and E. Oset, Eur. Phys. J. C78, 857 (2018); arXiv:1808.01950.

Y. Huang, M.Z. Liu, J.X. Lu, J.J. Xie and L.S. Geng, Phys. Rev. D98, 076012 (2018); arXiv:1807.06485.

J^P *should be* $3/2^-$, *and large decay width to* $\bar{K}\pi\Xi$.

Coupled channels dynamics in the generation of the $\Omega(2012)$ resonance

Eur. Phys. J. C (2018) 78:857

R. Pavao[a], E. Oset

$$F = -\frac{1}{4f^2}(k^0 + k'^0)$$

$$V = \begin{array}{cc} \begin{array}{ccc} \bar{K}\Xi^* & \eta\Omega & \bar{K}\Xi \end{array} & \\ \begin{pmatrix} 0 & 3F & \alpha q^2 \\ 3F & 0 & \beta q^2 \\ \alpha q^2 & \beta q^2 & 0 \end{pmatrix} & \begin{array}{c} \bar{K}\Xi^* \\ \eta\Omega \\ \bar{K}\Xi \end{array} \end{array}$$

$$G_{\bar{K}\Xi}(\sqrt{s}) = \int_{|\vec{q}|<q'_{\max}} \frac{d^3q}{(2\pi)^3} \frac{(q/q_{on})^4}{2\omega_{\bar{K}}(\vec{q})} \frac{M_\Xi}{E_\Xi(\vec{q})} \frac{1}{\sqrt{s} - \omega_{\bar{K}}(\vec{q}) - E_\Xi(\vec{q}) + i\epsilon},$$

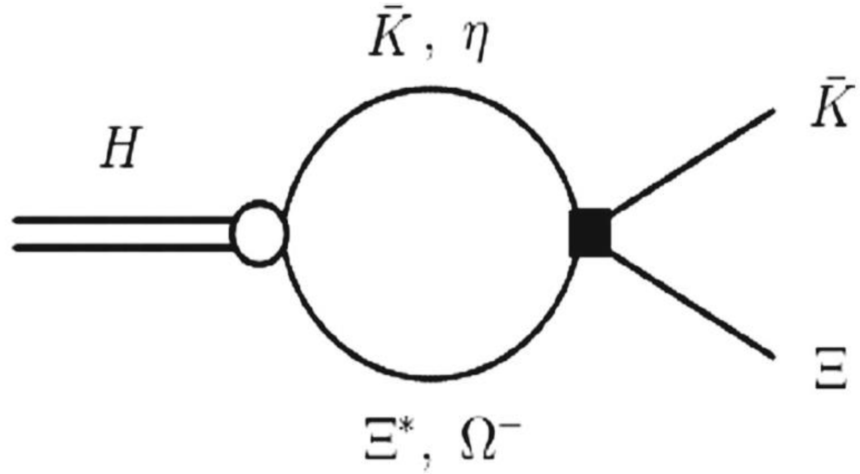


Fig. 2 Decay of $H \to \bar{K}\Xi$ through the creation and re-scattering of the $\bar{K}\Xi^*$ and $\eta\Omega$ pairs

α (10^{-8} MeV^{-3})	β (10^{-8} MeV^{-3})	$q_{\max}$ (MeV)	$(m_{\Omega^*}, \Gamma_{\Omega^*})$ (MeV)	$\Gamma(\bar{K}\Xi)$ (MeV)	$\Gamma(\pi\bar{K}\Xi)$ (MeV)
5.0	0.1	735	(2012.19, 6.36)	3.35	3.01
4.0	1.5	735	(2012.4, 6.2)	3.22	2.98
3.0	3.0	735	(2012.36, 6.19)	3.25	2.94
2.0	4.5	735	(2012.26, 6.23)	3.34	2.89

Search for $\Omega(2012) \to K\Xi(1530) \to K\pi\Xi$ at Belle

PHYSICAL REVIEW D **100,** 032006 (2019)

Using data samples of e^+e^- collisions collected at the $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ resonances with the Belle detector, we search for the three-body decay of the $\Omega(2012)$ baryon to $K\pi\Xi$. This decay is predicted to dominate for models describing the $\Omega(2012)$ as a $K\Xi(1530)$ molecule. No significant $\Omega(2012)$ signals are observed in the studied channels, and 90% credibility level upper limits on the ratios of the branching fractions relative to $K\Xi$ decay modes are obtained.

$$\mathcal{R}^{\Xi\pi K}_{\Xi K} = \frac{\mathcal{B}(\Omega(2012) \to \Xi(1530)(\to \Xi\pi)K)}{\mathcal{B}(\Omega(2012) \to \Xi K)} < 11.9\%$$

at 90% C.L.

$\mathcal{R}^{\Xi^0\pi^0K^-}_{\Xi^0K^-}$, $\mathcal{R}^{\Xi^-\pi^+K^-}_{\Xi^0K^-}$, $\mathcal{R}^{\Xi^0\pi^-\bar{K}^0}_{\Xi^-\bar{K}^0}$, and $\mathcal{R}^{\Xi\pi K}_{\Xi K}$ to be 9.3%, 81.1%, 21.3%, 30.4%, 7.8%, 25.6%, and 11.9%, respectively. Our result strongly disfavors the molecular interpretation

What should we do next?

Reanalysis of the newly observed Ω^* state in hadronic molecule model

Yong-Hui Lin,[1,2,*] Fei Wang,[2,†] and Bing-Song Zou[1,2,3,‡]

arXiv:1910.13919

parity). It is found that the latest experimental measurements are compatible with the $1/2^+$ and $3/2^+$ $\bar{K}\Xi(1530)$ molecular pictures, while the $5/2^+$ $\bar{K}\Xi(1530)$ molecule shows the larger $\bar{K}\pi\Xi$ three-body decay compared with the $\bar{K}\Xi$ decay as the case of S-wave molecule. Thus, the newly observed $\Omega(2012)$ can be interpreted as the $1/2^+$ or $3/2^+$ $\bar{K}\Xi(1530)$ molecule state according to current experiment data.

The molecular picture for the $\Omega(2012)$ revisited

Natsumi Ikeno,[1,2,*] Genaro Toledo,[2,3,†] and Eulogio Oset[2,‡]

arXiv:2003.07580

channels is obtained from chiral Lagrangians. The transition potential between $\bar{K}\Xi^*$, $\eta\Omega$ and $\bar{K}\Xi$ is taken in terms of free parameters, which together with a cut off to regularize the meson-baryon loops are fitted to the $\Omega(2012)$ data. We find that all data including the recent Belle experiment on $\Gamma_{\Omega^*\to\pi\bar{K}\Xi}/\Gamma_{\Omega^*\to\bar{K}\Xi}$, are compatible with the molecular picture stemming from meson baryon interaction of these channels.

Revisiting the $\Omega(2012)$ as a hadronic molecule and its strong decays

Jun-Xu Lu,[1] Chun-Hua Zeng,[2,3] En Wang,[4] Ju-Jun Xie,[2,3,4,*] and Li-Sheng Geng[1,4,†]

arXiv:2003.07588

mode of $\Omega(2012)\to\bar{K}\Xi$. In this work, we revisit the newly observed $\Omega(2012)$ from the molecular perspective where this resonance appears to be a dynamically generated state with spin-parity $3/2^-$ from the coupled channels interactions of the $\bar{K}\Xi^*(1530)$ and $\eta\Omega$ in s-wave and $\bar{K}\Xi$ in d-wave. With the model parameters for the d-wave interaction, we show that the ratio of these decay fractions reported recently by the Belle collaboration can be easily accommodated.

$\bar{K}\Xi^*$, $\eta\Omega$ *and* $\bar{K}\Xi$ *coupled channel interactions in s wave*

$$
\begin{aligned}
V_{11} &= V_{22} = V_{33} = 0, \\
V_{12} &= V_{21} = -\frac{3}{4f_\pi^2}(k_1^0 + k_2^0), \\
V_{13} &= V_{31} = \alpha q_3^2, \\
V_{23} &= V_{32} = \beta q_3^2,
\end{aligned}
$$

$$
\begin{aligned}
k_1^0 &= \frac{s + m_{\bar{K}}^2 - M_{\Xi^*}^2}{2\sqrt{s}}, \\
k_2^0 &= \frac{s + m_\eta^2 - M_\Omega^2}{2\sqrt{s}},
\end{aligned}
$$

$$G_{11} = \int_0^{\Lambda_1} \frac{d^3q}{(2\pi)^3} \frac{1}{2\omega_1} \frac{M_{\Xi^*}}{E_1} \frac{1}{\sqrt{s} - \omega_1 - E_1 + i\epsilon}$$

$$G_{22} = \int_0^{\Lambda_2} \frac{d^3q}{(2\pi)^3} \frac{1}{2\omega_2} \frac{M_\Omega}{E_2} \frac{1}{\sqrt{s} - \omega_2 - E_2 + i\epsilon}$$

$$G_{33} = \int_0^{\Lambda_3} \frac{d^3q}{(2\pi)^3} \frac{(q/q_3)^4}{2\omega_3} \frac{M_\Xi}{E_3} \frac{1}{\sqrt{s} - \omega_3 - E_3 + i\epsilon}$$

$$q_3 = \frac{\sqrt{[s - (m_{\bar{K}} + M_\Xi)^2][s - (m_{\bar{K}} - M_\Xi)^2]}}{2\sqrt{s}}$$

$$T = V + VGT = [1 - VG]^{-1} V$$

Jun-Xu Lu, Chun-Hua Zeng, En Wang, Ju-Jun Xie, and Li-Sheng Geng, arXiv:2003.07588

Pole of scattering amplitude T

$$T_{ij} = \frac{g_{ii} g_{jj}}{\sqrt{s} - z_R}, \qquad Z_R = M_R - i\frac{\Gamma_R}{2}$$

g_{kk} is the coupling of the resonance to the kth channel.

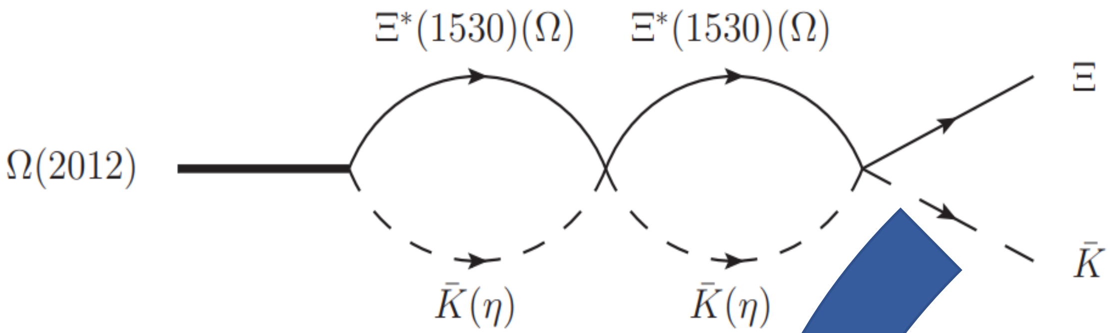
Assumption $\Lambda_1 = \Lambda_2 = \Lambda_3 = q_{\mathrm{max}}$

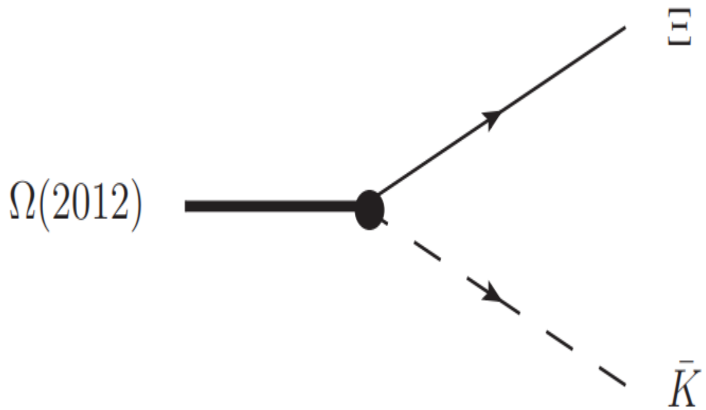
$M = 2012.4 \pm 0.9$ MeV $\quad \Gamma = 6.4 \pm 3.0$ MeV $\quad R^{\bar{K}\pi\Xi}_{\bar{K}\Xi} < 11.9\%$

$\alpha < -5 \times 10^{-8}\mathrm{MeV}^{-3}$, $\beta > 15 \times 10^{-8}\mathrm{MeV}^{-3}$

$q_{\mathrm{max}} > 720$ MeV.

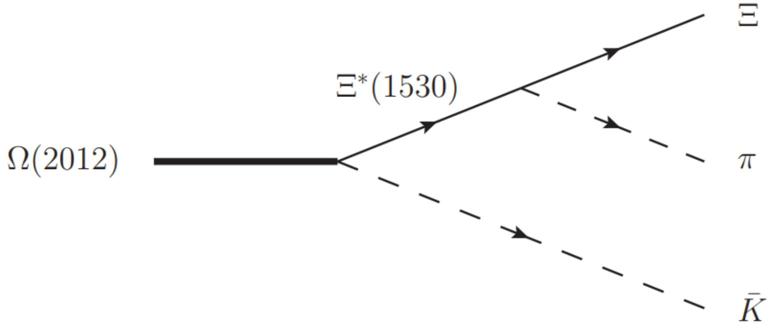
Two body decay





$$\Gamma_{\Omega(2012)\to\bar{K}\Xi} = \frac{|g_{\Omega^*\bar{K}\Xi}|^2}{2\pi}\frac{M_\Xi}{M}q_{\bar{K}}$$

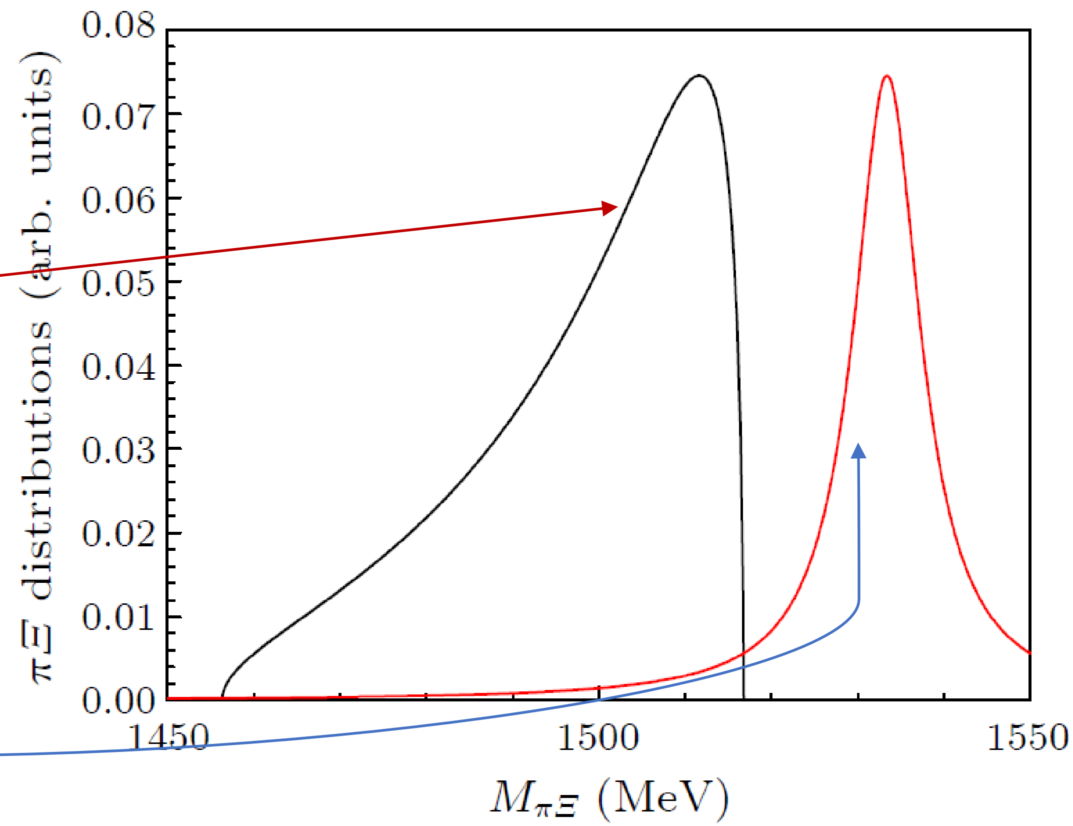
Three body decay



$$\Gamma_{\Omega(2012)\to\bar{K}\pi\Xi} = \int_{m_\pi + M_\Xi}^{M - m_{\bar{K}}} \frac{d\Gamma}{dM_{\pi\Xi}}$$

$$\frac{d\Gamma_{\Omega(2012)\to\bar{K}\pi\Xi}}{dM_{\pi\Xi}} = \frac{M_{\pi\Xi}}{\pi^2 M} \frac{|g_{\Omega^*\bar{K}\Xi^*}|^2 p_{\bar{K}} \tilde{\Gamma}_{\Xi^*}}{4(M_{\pi\Xi} - M_{\Xi^*})^2 + \tilde{\Gamma}^2_{\Xi^*}},$$

$$\frac{d|T|^2_{\pi\Xi\to\Xi(1530)\to\pi\Xi}}{dM_{\pi\Xi}} \propto \frac{M_{\Xi^*}\Gamma_{\Xi^*}}{(M_{\pi\Xi} - M_{\Xi^*})^2 + \Gamma^2_{\Xi^*}/4},$$



Very small phase space!!!

Pseudo-"fitting"

$$Fix\ q_{\max} \qquad \chi^2 = \left(\frac{M^{\text{th}} - M^{\text{exp}}}{\Delta M^{\text{exp}}}\right)^2 + \left(\frac{\Gamma^{\text{th}} - \Gamma^{\text{exp}}}{\Delta \Gamma^{\text{exp}}}\right)^2$$

(α, β)	χ^2	χ^2_{min}
(α_1, β_1)	$\chi^{2(1)}_{best}$	
$\vdots$	$\vdots$	
(α_i, β_i)	$\chi^{2(i)}_{best}$	$\Longrightarrow \chi^2_{min} = \chi^{2(k)}_{best}$
$\vdots$	$\vdots$	
(α_N, β_N)	$\chi^{2(N)}_{best}$	

$$\chi^2_{\text{best}} < \chi^2_{\text{min}} + 1$$

$$\Downarrow$$

$$\alpha = \alpha_0 \pm \Delta\alpha$$

$$\beta = \beta_0 \pm \Delta\beta$$

$$(\alpha_0, \beta_0) = (\alpha_k, \beta_k)$$

Results

$q_{\max}$ (MeV)	α (10^{-8} MeV^{-3})	β (10^{-8} MeV^{-3})	(M_R, Γ_R) (MeV)	$\lvert g_{\Omega^* \bar{K}\Xi^*}\rvert$	$\lvert g_{\Omega^* \eta\Omega}\rvert$	$\lvert g_{\Omega^* \bar{K}\Xi}\rvert$
735	-6.6 ± 0.8	16.5 ± 0.8	$(2012.3 \pm 0.4, 8.3 \pm 0.6)$	1.83 ± 0.02	3.35 ± 0.06	0.42 ± 0.02
750	-9.9 ± 0.5	18.5 ± 0.5	$(2012.2 \pm 0.4, 7.8 \pm 0.8)$	1.80 ± 0.01	3.46 ± 0.06	0.41 ± 0.03
800	-17.5 ± 0.6	20.6 ± 0.5	$(2012.4 \pm 0.5, 6.4 \pm 1.3)$	1.58 ± 0.02	3.60 ± 0.04	0.37 ± 0.04
850	-20.2 ± 1.0	19.6 ± 0.8	$(2012.4 \pm 0.5, 6.4 \pm 1.1)$	1.39 ± 0.03	3.78 ± 0.04	0.37 ± 0.03
900	-20.8 ± 1.7	17.5 ± 1.1	$(2012.4 \pm 0.5, 6.4 \pm 1.3)$	1.25 ± 0.04	3.85 ± 0.04	0.37 ± 0.04

$\Gamma_{\Omega(2012)\to\bar{K}\pi\Xi}$ (MeV)	$\Gamma_{\Omega(2012)\to\bar{K}\Xi}$ (MeV)	$\mathrm{Br}[\Omega(2012) \to \bar{K}\pi\Xi]$	$\mathrm{Br}[\Omega(2012) \to \bar{K}\Xi]$	R
0.87 ± 0.03	7.32 ± 0.64	$(10.5^{+0.5}_{-0.8})\%$	$(88.4^{+0.5}_{-1.5})\%$	11.88%
0.84 ± 0.04	6.96 ± 0.63	$(9.5^{+0}_{-1.0})\%$	$(90.5^{+0}_{-2.6})\%$	10.50%
0.66 ± 0.02	5.57 ± 1.37	$(10.3^{+1.6}_{-1.7})\%$	$(86.5^{+1.6}_{-2.9})\%$	11.90%
0.51 ± 0.03	5.66 ± 1.07	$(7.9^{+1.9}_{-1.5})\%$	$(88.2^{+1.9}_{-1.6})\%$	9.00%
0.41 ± 0.03	5.73 ± 1.25	$(6.5^{+1.7}_{-1.9})\%$	$(90.0^{+1.7}_{-2.2})\%$	7.22%

Three body decay width is small !!!

1, Small phase space
2, Narrow width of $\Xi^*(1530)$

Until now

(i) *The* $\Omega(2012)$ *state was only observed by the Belle collaboration;*

(ii) *Most of its properties, such as decay fractions and spin, are not determined yet.*

$\boxed{\Omega(2012)^-}$ $I(J^P) = 0(?^-)$ Status: $***$

Seen in $\Xi^0 K^-$ and $\Xi^- K^0_S$ decays with a combined significance of 8.3 standard deviations.

It is also generally accepted that $\Omega(2012)$ is a $1P$ orbital excitation of the ground Ω baryon with three strange quarks, whose quantum numbers are $J^P = 3/2^-$.

Searching for new production mode is very important!

The $\Omega(2012)$ in the $\Omega_c^0 \to \pi^+\Omega^-(2012) \to \pi^+(\bar{K}\Xi)^-$ and $\pi^+(\bar{K}\Xi\pi)^-$ decays

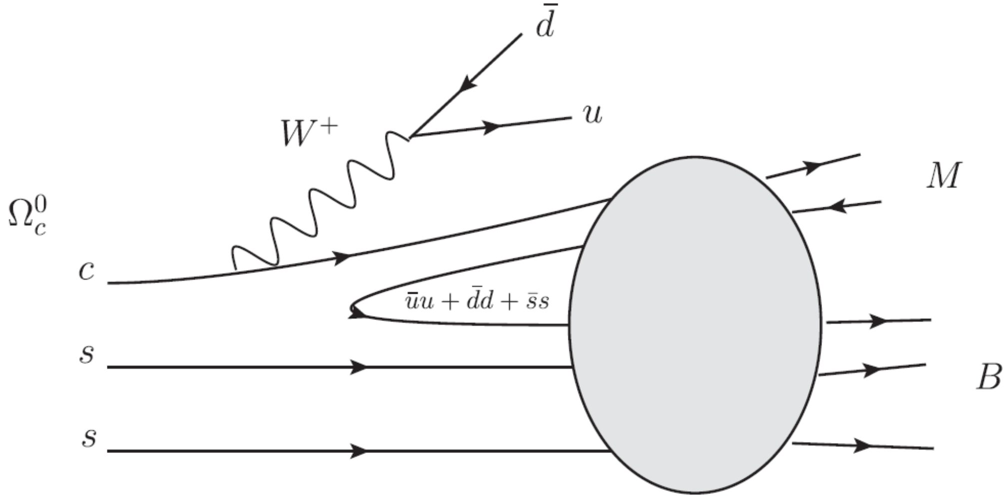


FIG. 1. Dominant quark-line schematic diagram for $\Omega_c^0 - \pi^+$MB decay.

$$|\Xi^{*0}\rangle = \frac{1}{\sqrt{3}}|uss + sus + ssu\rangle,$$

$$|\Xi^{*-}\rangle = \frac{1}{\sqrt{3}}|dss + sds + ssd\rangle,$$

$$|\Omega\rangle = |sss\rangle,$$

$$|\eta\rangle = \frac{1}{\sqrt{3}}|\bar{u}u + \bar{d}d - \bar{s}s\rangle.$$

$$\begin{aligned}|\mathrm{MB}\rangle &= |s(\bar{u}u + \bar{d}d + \bar{s}s)ss\rangle \\ &= \frac{1}{\sqrt{3}}(|K^-\Xi^{*0}\rangle + |\bar{K}^0\Xi^{*-}\rangle) - \frac{1}{\sqrt{3}}|\eta\Omega\rangle, \\ &= \sqrt{\frac{2}{3}}|\bar{K}\Xi^*\rangle_{I=0} - \frac{1}{\sqrt{3}}|\eta\Omega\rangle,\end{aligned}$$

Hadron level

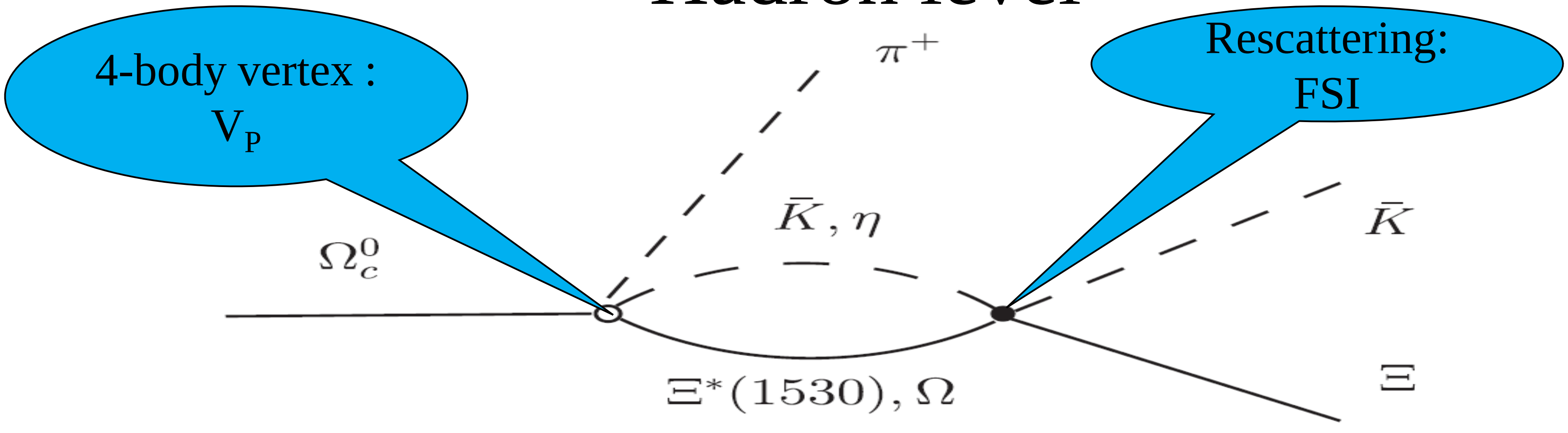


FIG. 2. Diagram for the meson-baryon final-state interaction for the $\Omega_c^0 \to \pi^+\Omega(2012)^- \to \pi^+(\bar{K}\Xi)^-$ decay.

$$\mathcal{M}_{\Omega_c^0\to\pi\bar{K}\Xi} = V_p\left(\sqrt{\frac{2}{3}}G_{\bar{K}\Xi^*}(M_{\rm inv})t_{\bar{K}\Xi^*\to\bar{K}\Xi}(M_{\rm inv}) - \sqrt{\frac{1}{3}}G_{\eta\Omega}(M_{\rm inv})t_{\eta\Omega\to\bar{K}\Xi}(M_{\rm inv})\right)$$

$$t_{\bar{K}\Xi^*\to\bar{K}\Xi} = \frac{g_{\Omega^*\bar{K}\Xi^*}g_{\Omega^*\bar{K}\Xi}}{M_{\rm inv} - M_{\Omega^*} + i\Gamma_{\Omega^*}/2}, \qquad t_{\eta\Omega\to\bar{K}\Xi} = \frac{g_{\Omega^*\eta\Omega}g_{\Omega^*\bar{K}\Xi}}{M_{\rm inv} - M_{\Omega^*} + i\Gamma_{\Omega^*}/2},$$

$$\frac{d\Gamma_{\Omega_c^0\to\pi^+\bar{K}\Xi}}{dM_{\bar{K}\Xi}} = \frac{1}{16\pi^3}\frac{M_\Xi}{M_{\Omega_c^0}}p_\pi^3 p_{\bar{K}}\sum|\mathcal{M}_{\Omega_c^0\to\pi^+\bar{K}\Xi}|^2$$

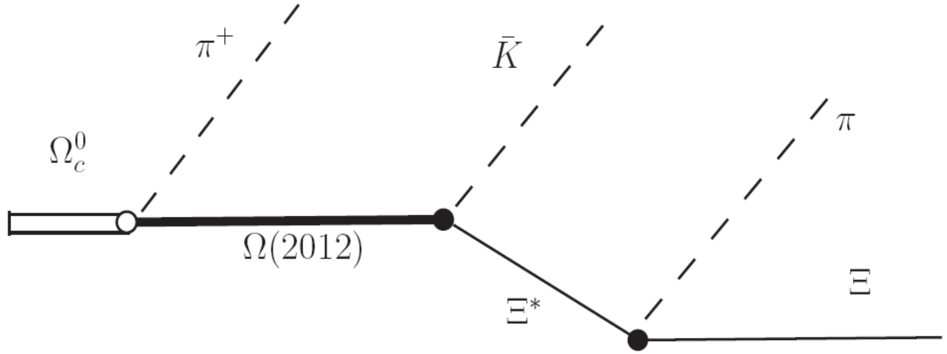


FIG. 3: Schematic diagram for the decay of $\Omega_c^0 \to \pi^+\Omega(2012)^- \to \pi^+[\bar{K}\Xi^*(1530)]^- \to \pi^+(\bar{K}\Xi\pi)^-$.

$$\mathcal{M}_{\Omega_c^0\to\pi^+\bar{K}\Xi\pi} = \frac{g_{\Xi^*\Xi\pi}\bar{p}_\pi \mathcal{M}_{\Omega_c^0\to\pi^+\bar{K}\Xi^*}}{M_{\Xi\pi} - M_{\Xi^*} + i\Gamma_{\Xi^*}/2}$$

$$\mathcal{M}_{\Omega_c^0\to\pi\bar{K}\Xi^*} = V_p\left(\sqrt{\frac{2}{3}}[1 + G_{\bar{K}\Xi^*}(M_{\text{inv}})t_{\bar{K}\Xi^*\to\bar{K}\Xi^*}(M_{\text{inv}})] - \sqrt{\frac{1}{3}}G_{\eta\Omega}(M_{\text{inv}})t_{\eta\Omega\to\bar{K}\Xi^*}(M_{\text{inv}})\right)$$

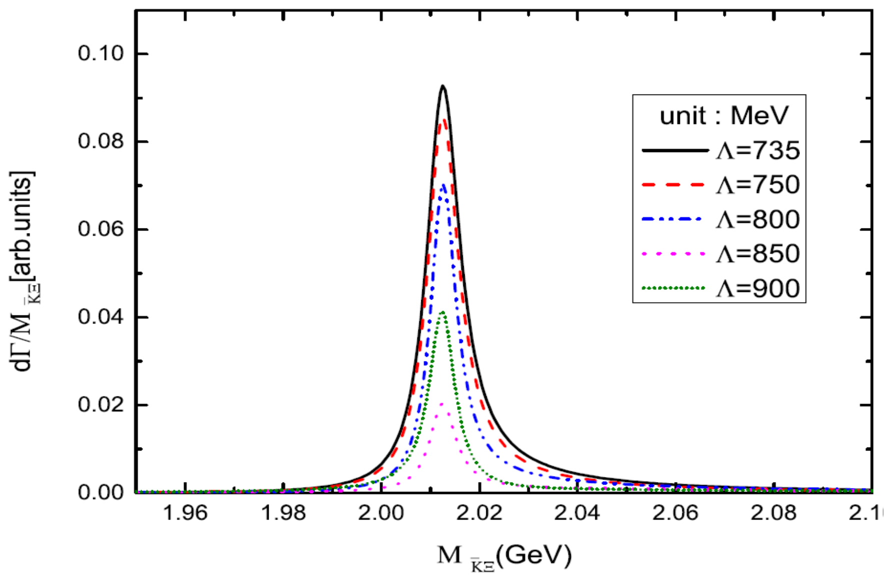
$$t_{\bar{K}\Xi^*\to\bar{K}\Xi^*} = \frac{g_{\Omega^*\bar{K}\Xi^*}g_{\Omega^*\bar{K}\Xi^*}}{M_{\text{inv}} - M_{\Omega^*} + i\Gamma_{\Omega^*}/2}, \qquad t_{\eta\Omega\to\bar{K}\Xi^*} = \frac{g_{\Omega^*\eta\Omega}g_{\Omega^*\bar{K}\Xi^*}}{M_{\text{inv}} - M_{\Omega^*} + i\Gamma_{\Omega^*}/2},$$

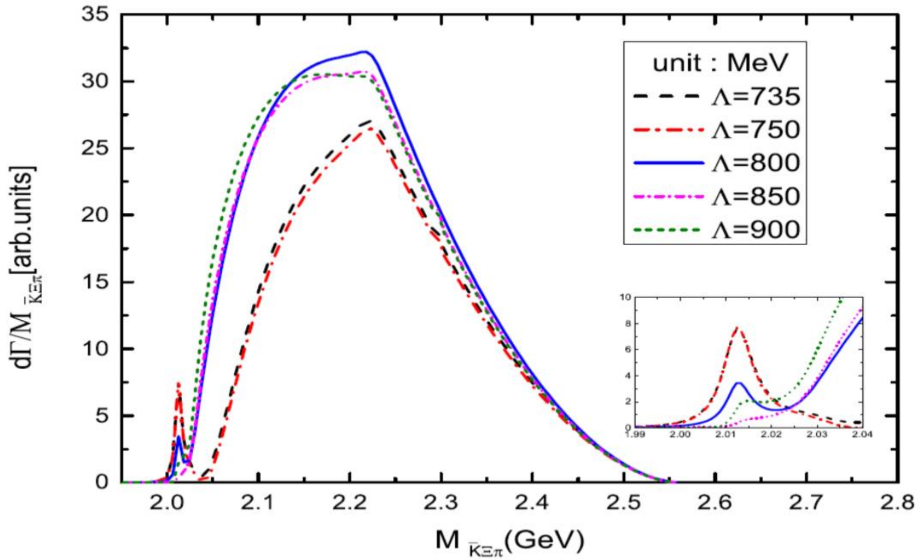
$$\frac{d\Gamma_{\Omega_c^0\to\pi\bar{K}\Xi\pi}}{dM_{\bar{K}\Xi\pi}dM_{\Xi\pi}} = \frac{M_\Xi p'_\pi \tilde{p}_K \bar{p}_\pi}{64\pi^5 M_{\Omega_c^0}} \sum |\mathcal{M}_{\Omega_c^0\to\pi^+\bar{K}\Xi\pi}|^2$$

$$\frac{d\Gamma_{\Omega_c^0\to\pi\bar{K}\Xi\pi}}{dM_{\bar{K}\Xi\pi}} = \int_{M_\Xi+m_\pi}^{M_{\bar{K}\Xi\pi}-m_{\bar{K}}} \frac{d\Gamma_{\Omega_c^0\to\pi\bar{K}\Xi\pi}}{dM_{\Xi\pi}dM_{\bar{K}\Xi\pi}} dM_{\Xi\pi}$$

Invariant mass distributions

Model	$\Lambda = q_{\max}$ (MeV)	M_{Ω^*} (MeV)	Γ_{Ω^*} (MeV)	$g_{\Omega^* \bar{K}\Xi^*}$	$g_{\Omega^* \eta\Omega}$	$g_{\Omega^* \bar{K}\Xi}$
I	735	2012.3	8.3	$(1.826, -0.064)$	$(3.350, 0.159)$	$(-0.419, -0.040)$
II	750	2012.2	7.8	$(1.796, -0.128)$	$(3.448, 0.298)$	$(-0.399, -0.109)$
III	800	2012.4	6.4	$(1.574, 0.188)$	$(3.590, -0.313)$	$(-0.307, 0.201)$
IV	850	2012.4	6.4	$(1.386, 0.090)$	$(3.777, -0.151)$	$(-0.353, 0.109)$
V	900	2012.4	6.4	$(1.251, 0.063)$	$(3.853, -0.111)$	$(-0.363, 0.082)$





Theoretical study of the $\Omega(2012)$ state in the $\Omega_c^0 \to \pi^+\Omega(2012)^- \to \pi^+(\bar{K}\Xi)^-$ and $\pi^+(\bar{K}\Xi\pi)^-$ decays

Chun-Hua Zeng, Jun-Xu Lu, En Wang, Ju-Jun Xie, and Li-Sheng Geng
Phys. Rev. D **102**, 076009 – Published 19 October 2020

New experimental results

Evidence for the decay $\Omega_c^0 \to \pi^+\Omega(2012)^- \to \pi^+(\bar{K}\Xi)^-$

Belle Collaboration • Y. Li (Fudan U.) et al. (Jun 1, 2021)

Published in: *Phys.Rev.D* 104 (2021) 5, 052005 • e-Print: 2106.00892 [hep-ex]

Observation of $\Omega(2012)^- \to \Xi(1530)\bar{K}$ and measurement of the effective couplings of $\Omega(2012)^-$ to $\Xi(1530)\bar{K}$ and $\Xi\bar{K}$

Belle Collaboration (Jul 7, 2022)

e-Print: 2207.03090 [hep-ex]

$$\mathcal{R}_{\Xi\bar{K}}^{\Xi\pi\bar{K}} = 0.97 \pm 0.24 \pm 0.07,$$

In 2019

$$\mathcal{R}_{\Xi K}^{\Xi\pi K} = \frac{\mathcal{B}(\Omega(2012) \to \Xi(1530)(\to \Xi\pi)K)}{\mathcal{B}(\Omega(2012) \to \Xi K)} < 11.9\%$$

at 90% C.L.

below the $\bar{K}\Xi(1530)$ mass threshold. In this new analysis, $M_{\pi\Xi} < 1.517\,\mathrm{GeV}$ is required and the signal shape of $\Omega(2012)$ was parameterized with a Flatté-like function to account for the allowed phase space. Such selection criteria were not included in the previous analysis in Ref. [20], and they improve the signal-background separation and hence increase the signal yield. The new result of the ratio $\mathcal{R}_{\bar{K}\Xi}^{\bar{K}\pi\Xi}$ is $0.97 \pm 0.24 \pm 0.07$. This is consistent with the

Summary

We conclude that

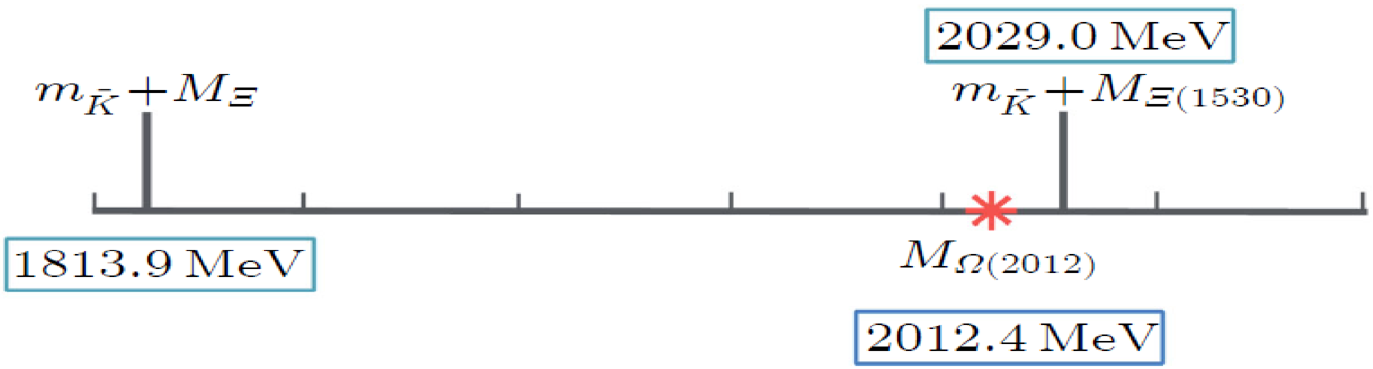
Chinese Physics Letters **41**, 081402 (2024)

The $\Omega(2012)$ as a Hadronic Molecule

Ju-Jun Xie(谢聚军)[1,2,3*] and Li-Sheng Geng(耿立升)[4,5,6,3*]

Review

The $\Omega(2012)$ is a hadronic molecular state, dynamically generated from coupled channel interactions of $\bar{K}\Xi^*(1530)$ and $\eta\Omega$ in s wave and $\bar{K}\Xi$ in d wave.



Thank you very much for your attention!