



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

谢聚军
(Ju-Jun Xie)

中国科学院近代物理研究所
(Institute of Modern Physics, CAS)

July 26, 2021 @ Hadron2021, Mexico City (on line)

Outline

Motivation

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

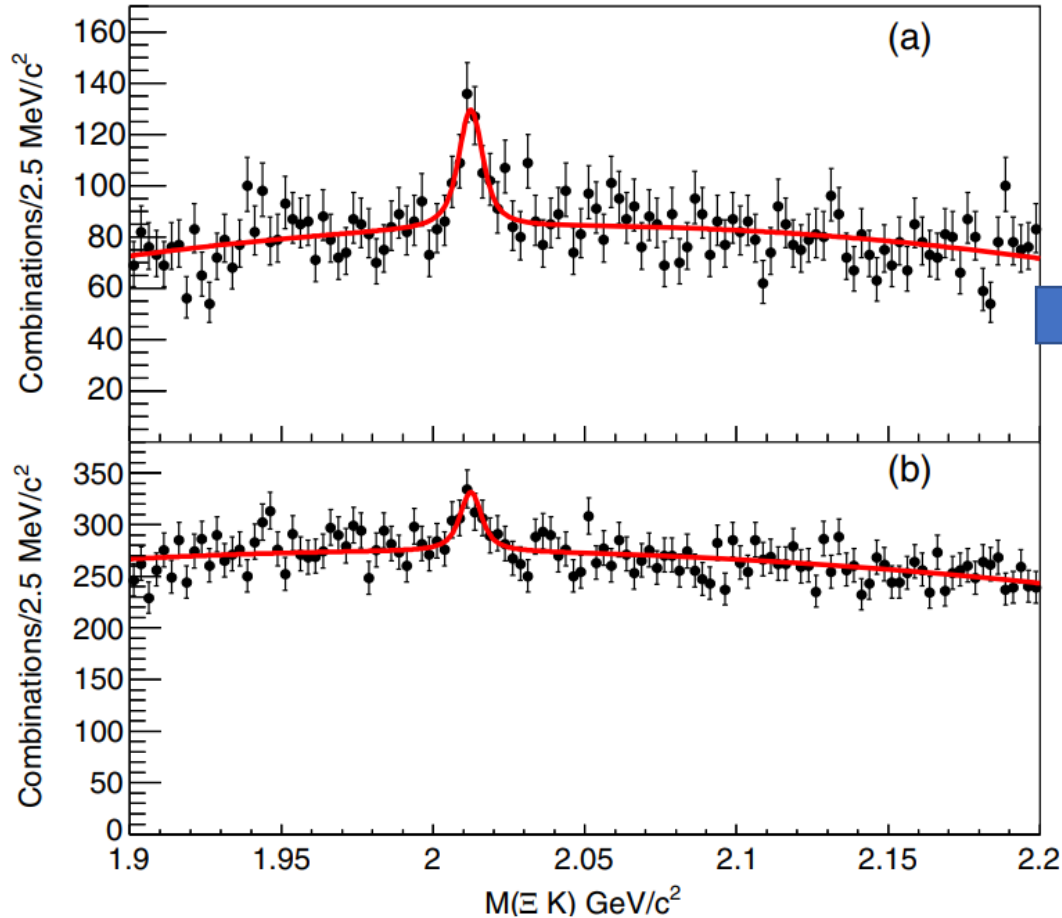
Searching $\Omega(2012)$ in the $\Omega_c^0 \rightarrow \pi^+\Omega^-(2012) \rightarrow \pi^+(\bar{K}\Xi)^-$ decay

Summary

Observation of an Excited Ω^- Baryon

PHYSICAL REVIEW LETTERS 121, 052003 (2018)

(The Belle Collaboration)



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

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

Narrow width

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



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

$$\text{and } I = 0$$

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.

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

Strangeness - 2 and - 3 baryons in a quark model with chromodynamics

Kuang Ta Chao, Nathan Isgur, and Gabriel Karl, 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

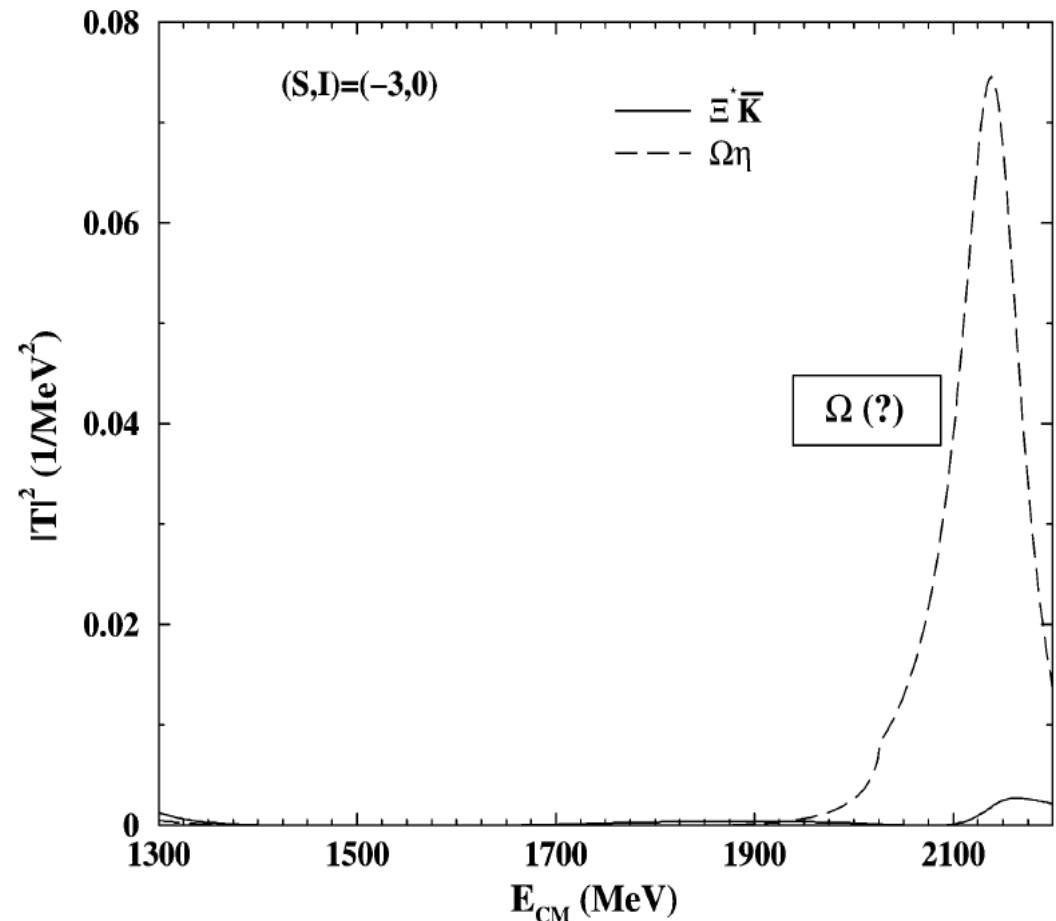
Sourav Sarkar*, E. Oset, M.J. Vicente Vacas

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

Two channels are in s-wave.



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

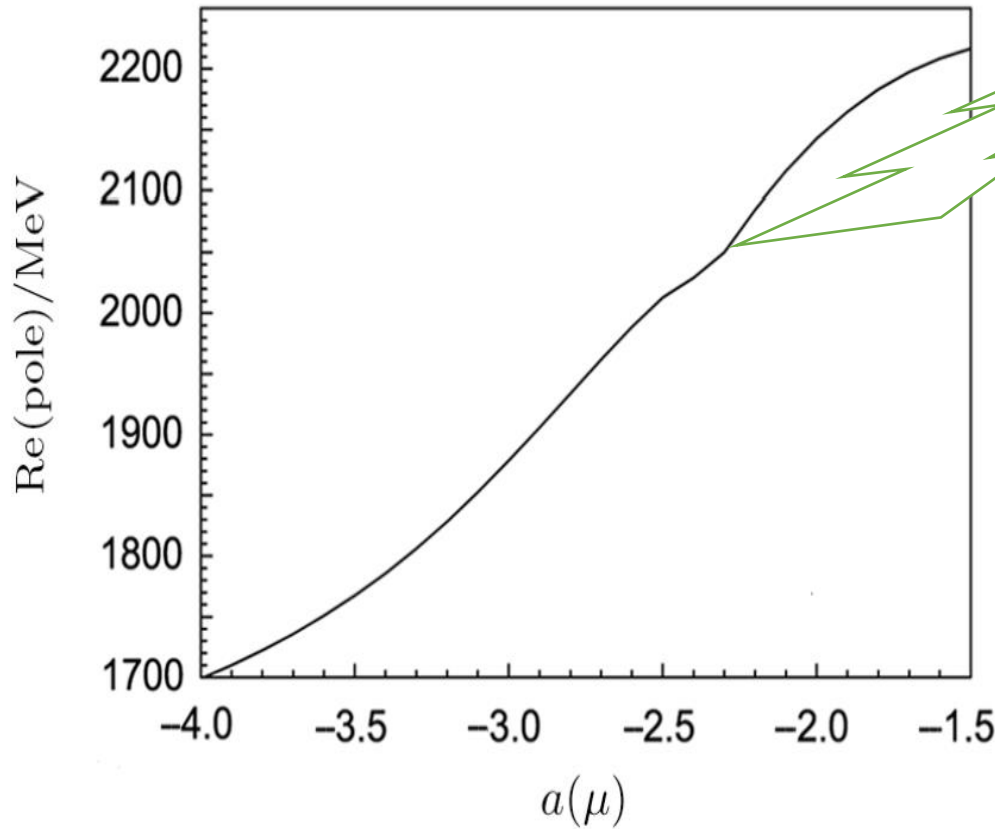


Fig. 3 Results of varying $a(\mu)$ over the $3/2^-$ Ω resonance mass.

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

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

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

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

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

$$G_l = \frac{2M_l}{16\pi^2} \left\{ a_l(\mu) + \ln \frac{M_l^2}{\mu^2} + \frac{m_l^2 - M_l^2 + s}{2s} \ln \frac{m_l^2}{M_l^2} \right. \\ \left. + \frac{q_l}{\sqrt{s}} [\ln(s - (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \right. \\ \left. + \ln(s + (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \right. \\ \left. - \ln(-s + (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \right. \\ \left. - \ln(-s - (M_l^2 - m_l^2) + 2q_l\sqrt{s}) \right\},$$

After “the observation”

Quark Model

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) .

*J^P could be $3/2^-$, but,
 $1/2^-$ cannot be completely excluded.*

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.

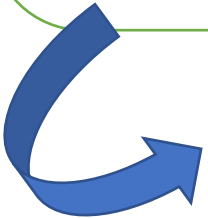
M.P. Valderrama, Phys. Rev. D98, 054009 (2018); arXiv:1807.00718.

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.

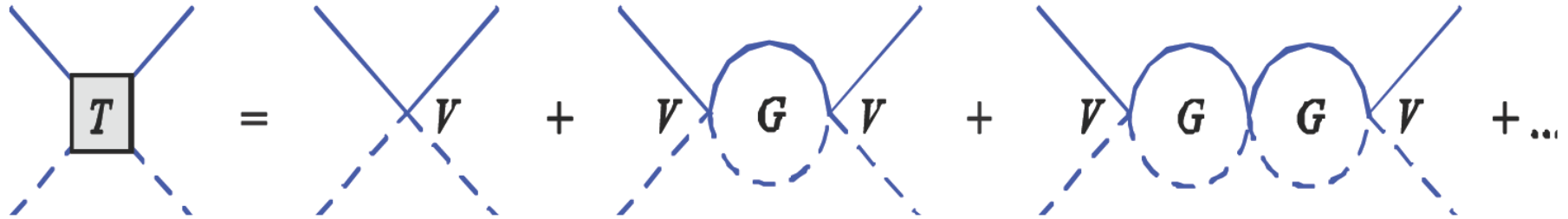
R. Pavao and E. Oset, Eur. Phys. J. C78, 857 (2018); arXiv:1808.01950.

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 $\bar{K}\pi\Xi$.

Effective field theory: chiral unitary approach



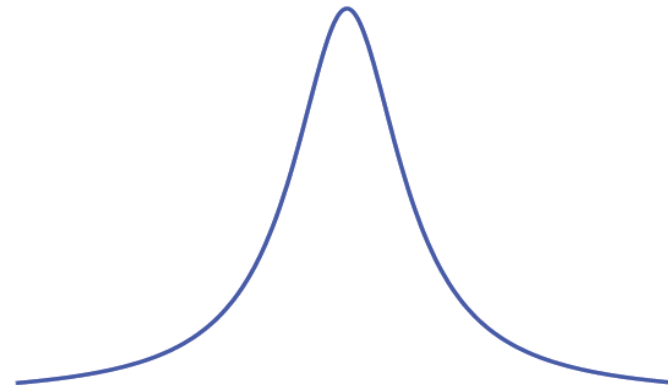
Summing All order contributions:

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

$$1 - GV = 0$$



$$S = S_0$$



Mass pole corresponds to a resonance structure

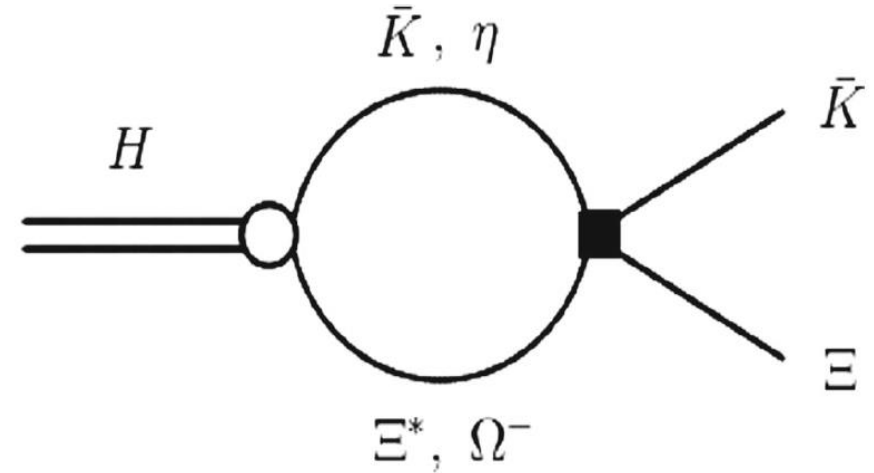
Coupled channels dynamics in the generation of the Ω (2012) resonance

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

R. Pavao^a, E. Oset

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

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



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

Fig. 2 Decay of $H \rightarrow \bar{K} \Xi$ 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 $\Omega(2012) \rightarrow K\Xi(1530) \rightarrow K\pi\Xi$ 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.**

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

at 90% C.L.



$\mathcal{R}_{\Xi^0 K^-}^{\Xi^0 \pi^0 K^-}$, $\mathcal{R}_{\Xi^0 K^-}^{\Xi^- \pi^+ K^-}$, $\mathcal{R}_{\Xi^- \bar{K}^0}^{\Xi^0 \pi^- \bar{K}^0}$, and $\mathcal{R}_{\Xi K}^{\Xi\pi K}$ 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**



图片来源: Veer图库 www.veer.com

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 $\Gamma_{\Omega^* \rightarrow \pi \bar{K}\Xi} / \Gamma_{\Omega^* \rightarrow \bar{K}\Xi}$, 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 $\Omega(2012) \rightarrow \bar{K}\Xi$. 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

$$V_{11} = V_{22} = V_{33} = 0,$$

$$V_{12} = V_{21} = -\frac{3}{4f_\pi^2}(k_1^0 + k_2^0),$$

$$V_{13} = V_{31} = \alpha q_3^2,$$

$$V_{23} = V_{32} = \beta q_3^2,$$

$$k_1^0 = \frac{s + m_{\bar{K}}^2 - M_{\Xi^*}^2}{2\sqrt{s}},$$

$$k_2^0 = \frac{s + m_\eta^2 - M_\Omega^2}{2\sqrt{s}},$$

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

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

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

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



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

Pole of scattering amplitude T

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

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

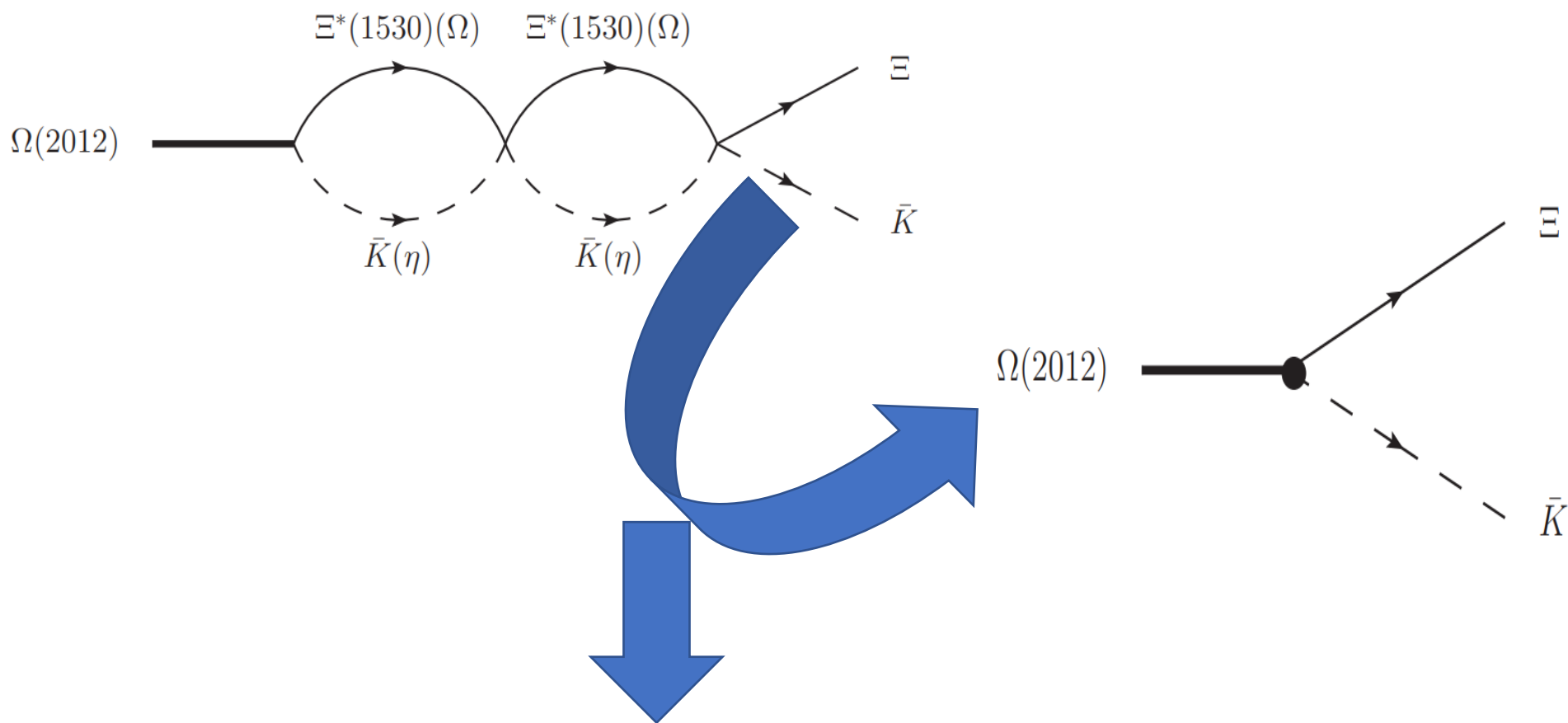
Assumption $\Lambda_1 = \Lambda_2 = \Lambda_3 = q_{\max}$

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



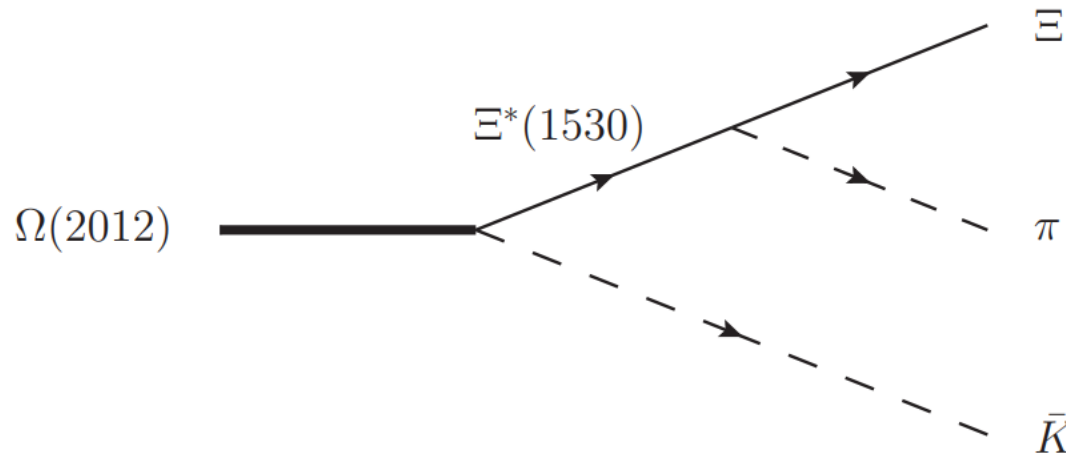
$$\alpha < -5 \times 10^{-8} \text{ MeV}^{-3}, \quad \beta > 15 \times 10^{-8} \text{ MeV}^{-3}$$
$$q_{\max} > 720 \text{ MeV}.$$

Two body decay



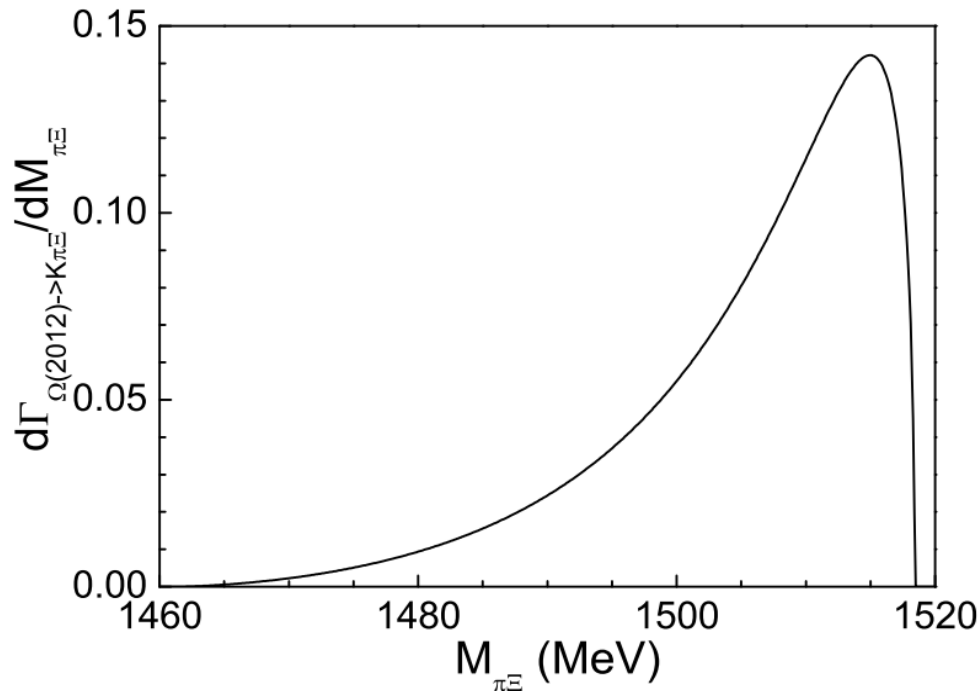
$$\Gamma_{\Omega(2012) \rightarrow \bar{K}\Xi} = \frac{|g_{\Omega^* \bar{K}\Xi}|^2}{2\pi} \frac{M_\Xi}{M} q_{\bar{K}}$$

Three body decay



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

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



Very small phase space!!!

Pseudo-“fitting”

Fix q_{\max}

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

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

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



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

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

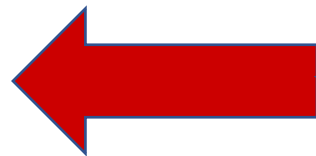
$$(\alpha_0, \beta_0) = (\alpha_k, \beta_k)$$

Results

q_{\max} (MeV)	α (10^{-8} MeV $^{-3}$)	β (10^{-8} MeV $^{-3}$)	(M_R, Γ_R) (MeV)	$ g_{\Omega^* \bar{K} \Xi^*} $	$ g_{\Omega^* \eta \Omega} $	$ g_{\Omega^* \bar{K} \Xi} $
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

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

Three body
decay width is
small !!!



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

- (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.*

$\Omega(2012)^-$

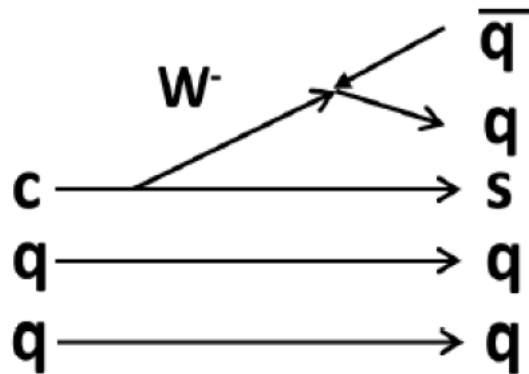
$I(J^P) = 0(?^-)$ Status: ***

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

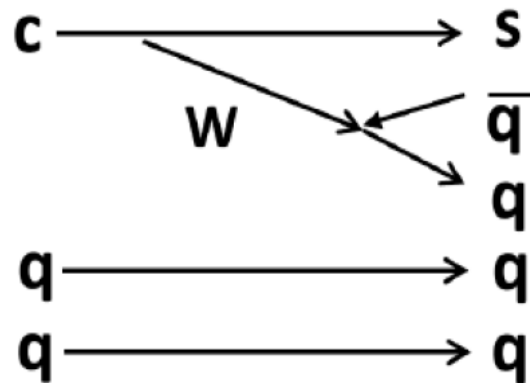
It is also generally accepted that $\Omega(2012)$ is a $1P$ orbital excitation of the ground Ω baryon with three strange quarks, whose quantum numbers are $J^P = 3/2^-$.

Searching for new production mode is very important!

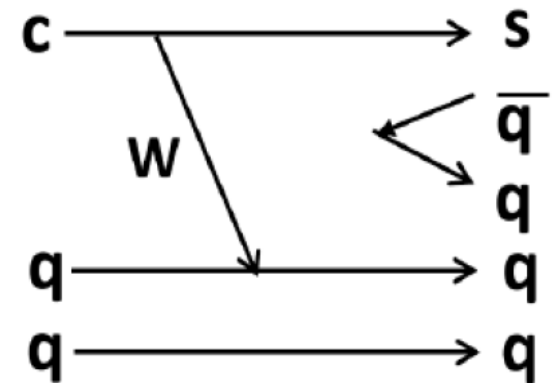
The charmed baryon decays



Spectator



Internal W



W-exchange

- The weak decay of charmed baryon is a good laboratory for studying strange baryons as decay proceed via $c \rightarrow s$ transition, but it has not been well understood well.
- Three diagrams contribute in the tree level, but their strengths are not known.

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

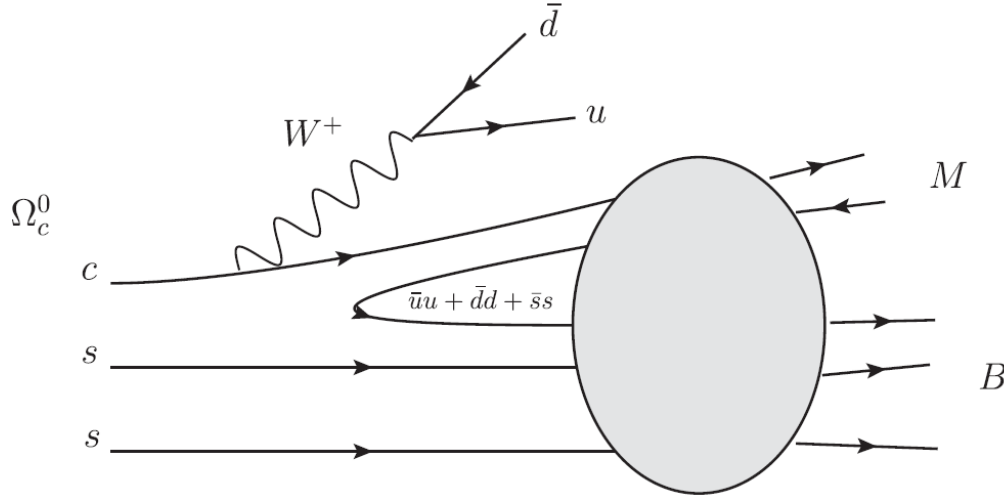


FIG. 1. Dominant quark-line schematic diagram for $\Omega_c^0 - \pi^+ \text{MB}$ decay.

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

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

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

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

$$|\text{MB}\rangle = |s(\bar{u}u + \bar{d}d + \bar{s}s)ss\rangle$$

$$= \frac{1}{\sqrt{3}} (|K^- \Xi^{*0}\rangle + |\bar{K}^0 \Xi^{*-}\rangle) - \frac{1}{\sqrt{3}} |\eta \Omega\rangle,$$

$$= \sqrt{\frac{2}{3}} |\bar{K} \Xi^*\rangle_{I=0} - \frac{1}{\sqrt{3}} |\eta \Omega\rangle,$$



Hadron level

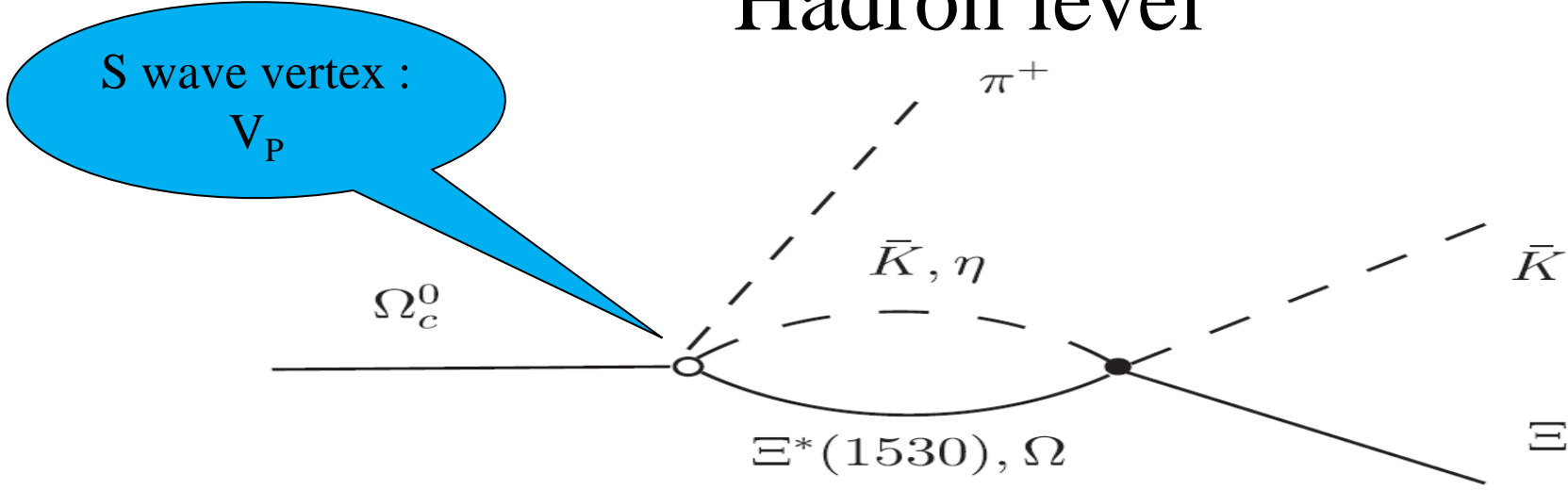
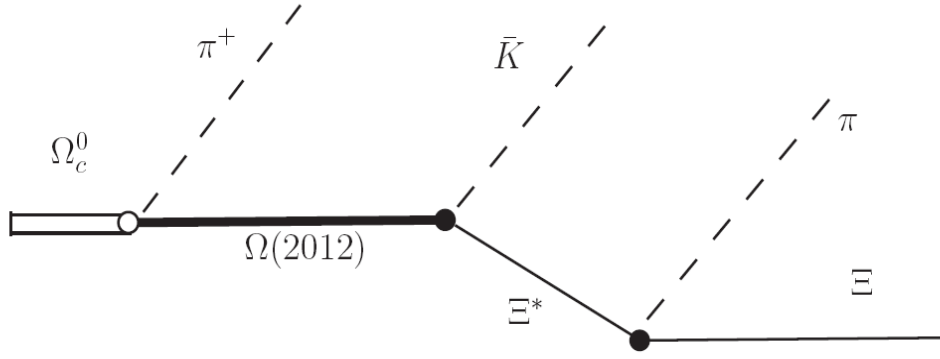


FIG. 2. Diagram for the meson-baryon final-state interaction for the $\Omega_c^0 \rightarrow \pi^+ \Omega(2012)^- \rightarrow \pi^+ (\bar{K}\Xi)^-$ decay.

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

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

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



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

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

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

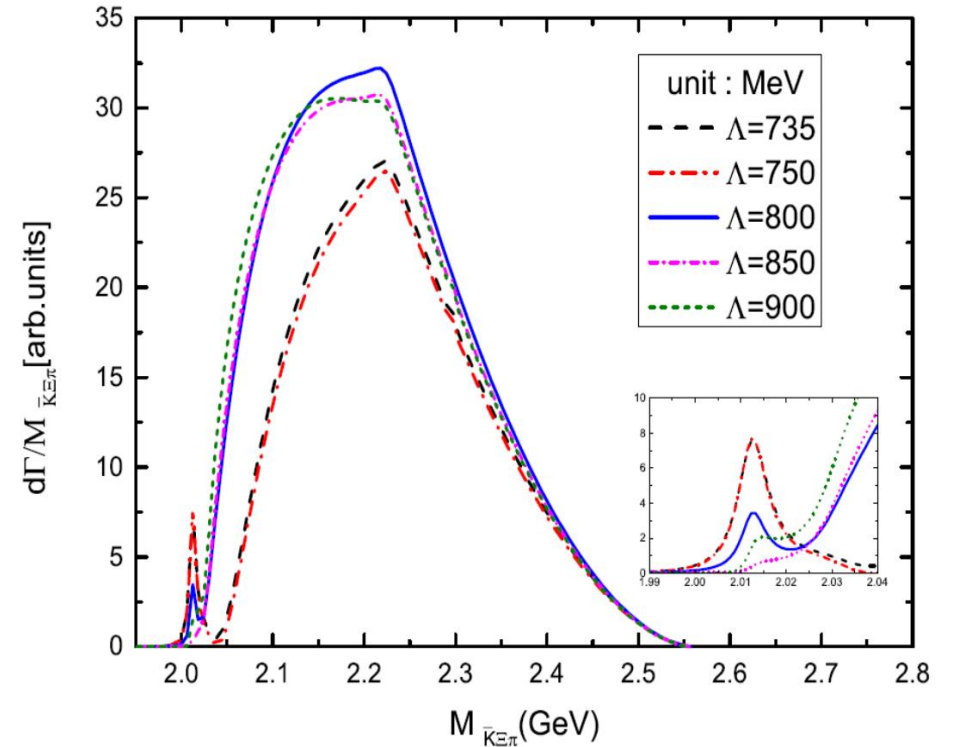
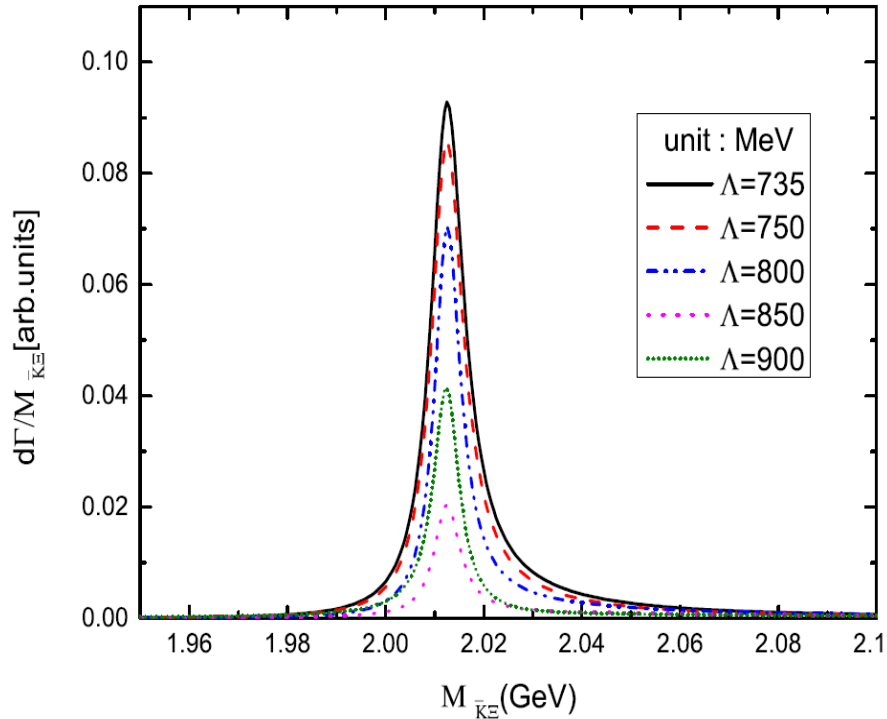
$$t_{\bar{K} \Xi^* \rightarrow \bar{K} \Xi^*} = \frac{g_{\Omega^* \bar{K} \Xi^*} g_{\Omega^* \bar{K} \Xi^*}}{M_{\text{inv}} - M_{\Omega^*} + i\Gamma_{\Omega^*}/2}, \quad t_{\eta \Omega \rightarrow \bar{K} \Xi^*} = \frac{g_{\Omega^* \eta \Omega} g_{\Omega^* \bar{K} \Xi^*}}{M_{\text{inv}} - M_{\Omega^*}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

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

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

Invariant mass distributions

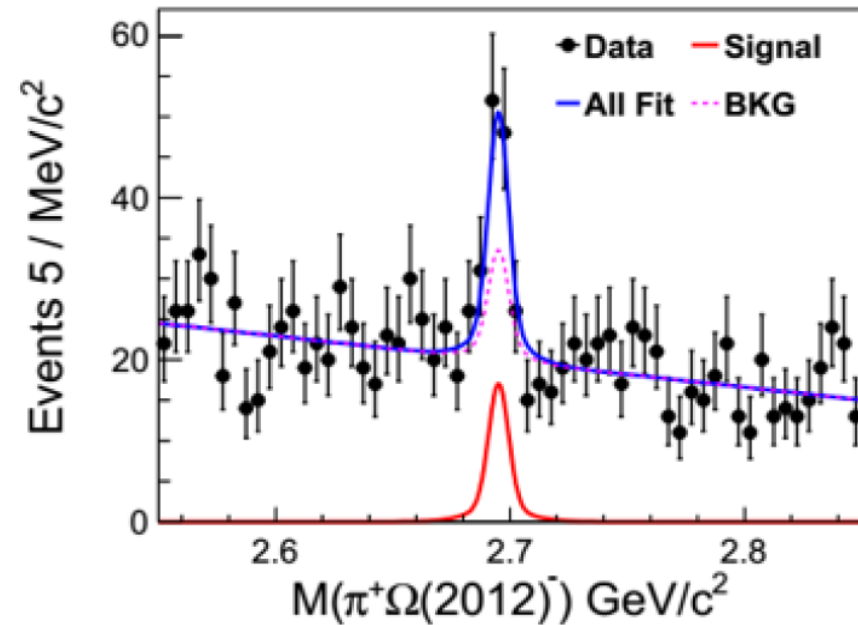
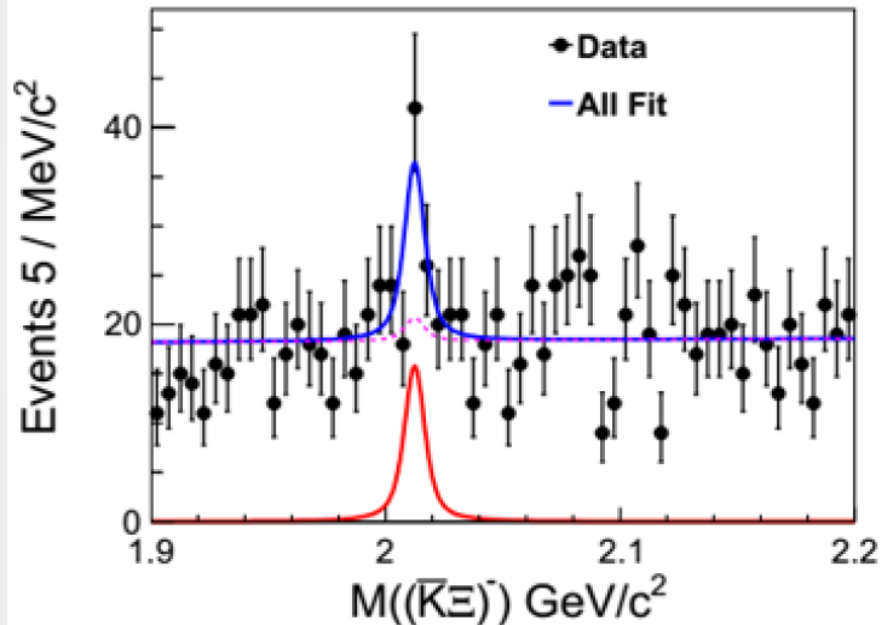
Model	$\Lambda = q_{\max}$ (MeV)	M_{Ω^*} (MeV)	Γ_{Ω^*} (MeV)	$g_{\Omega^* \bar{K} \Xi^*}$	$g_{\Omega^* \eta \Omega}$	$g_{\Omega^* \bar{K} \Xi}$
I	735	2012.3	8.3	(1.826, -0.064)	(3.350, 0.159)	(-0.419, -0.040)
II	750	2012.2	7.8	(1.796, -0.128)	(3.448, 0.298)	(-0.399, -0.109)
III	800	2012.4	6.4	(1.574, 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)



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

arXiv:2106.00892

- A 2D un-binned maximum-likelihood simultaneous fit is performed to $M((\bar{K}\Xi)^-)$ and $M(\pi^+ \Omega(2012)^-)$ distributions.



$$N_{\text{fit}} = 46.6 \pm 12.3$$

$$\frac{\text{Br}(\Omega_c^0 \rightarrow \pi^+ \Omega(2012)^-) \times \text{Br}(\Omega(2012)^- \rightarrow (\bar{K}\Xi)^-)}{\text{Br}(\Omega_c^0 \rightarrow \pi^+ (\bar{K}\Xi)^-)}$$

Signal significance: 4.2σ

(including systematic uncertainties) = $(6.50 \pm 1.22(\text{stat.}) \pm 0.94(\text{syst.}))\%$

Summary

We conclude that

*The $\Omega(2012)$ is a molecular hadronic 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.*

However

We need more efforts, both on theoretical and experimental sides.

Thank you very much for your attention!