The Ω(2012) as a dynamically generated state from coupled channels

21 August 2019

HADRON2019

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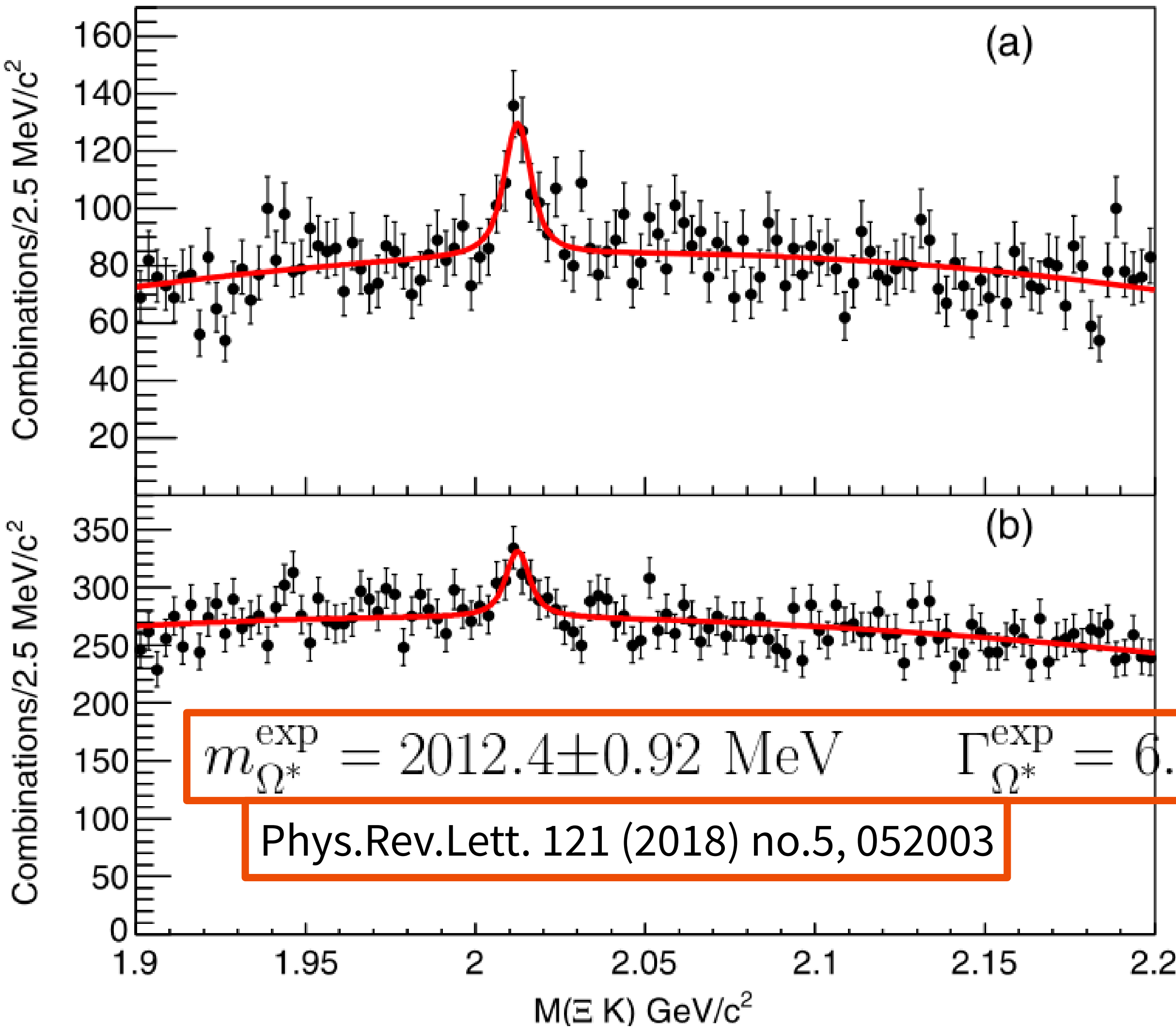
Motivation



$$m^{\mathrm{exp}}_{\Omega^*} = 2012.4 \pm 0.92 \ \mathrm{MeV} \qquad \Gamma^{\mathrm{exp}}_{\Omega^*} = 6.4^{+3.0}_{-2.6} \ \mathrm{MeV}$$

Phys.Rev.Lett. 121 (2018) no.5, 052003

Motivation

Studied and predicted by many quark models, lattice simulations, etc

As a molecular state

M.V. Polyakov, *et al.*, **arXiv:1806.04427** (2018)
M.P. Valderrama, **Phys. Rev. D98(5), 054009** (2018)
Y.H. Lin, B.S. Zou, **Phys. Rev. D98(5), 056013** (2018)
Y. Huang, *et al.*, **Phys. Rev. D98,076012** (2018)

Motivation

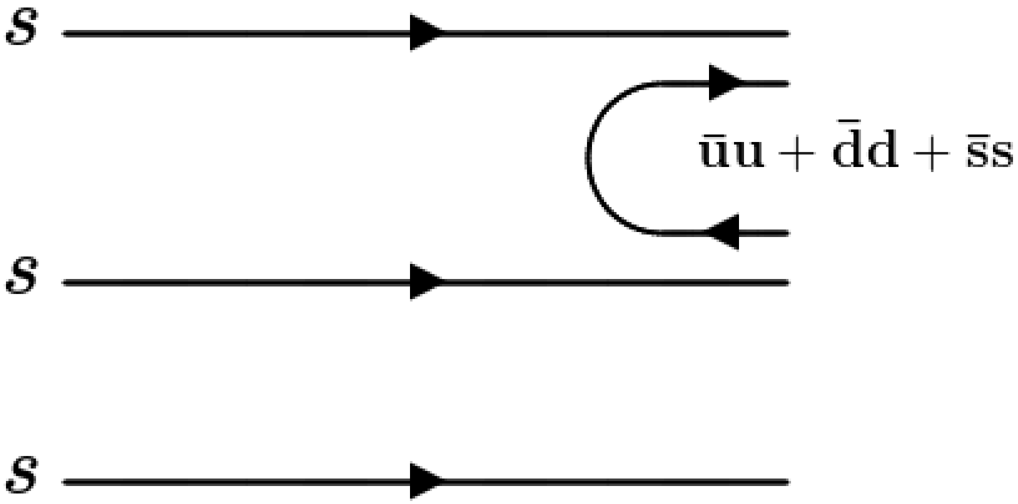
S. Sarkar, E. Oset, M.J. Vicente Vacas, **Nucl. Phys. A750, 294**(2005)

$$
\begin{array}{cc}
 & \bar{K}\Xi^* \;\; \eta\Omega \\
V = & \begin{pmatrix} 0 & 3 \\ 3 & 0 \end{pmatrix} \times \dfrac{-1}{4f^2}(k^0 + k'^0)
\end{array}
$$

$$a \simeq -2 \Rightarrow M_\Omega = 2142 \text{ MeV}$$

$$a \simeq -3.4 \Rightarrow M_\Omega = 1785 \text{ MeV}$$

Formalism



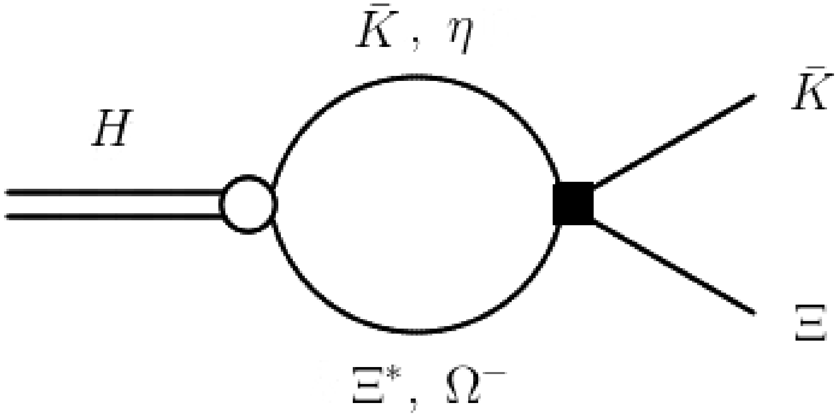
$$sss \to \sum_{i=1}^{3} s\bar{q}_i q_i ss \equiv H$$

Formalism

$$H = \frac{1}{\sqrt{3}} K^{-} \Xi^{*0} + \frac{1}{\sqrt{3}} K^{0} \Xi^{*-} - \frac{\eta}{\sqrt{3}} \Omega^{-}$$

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

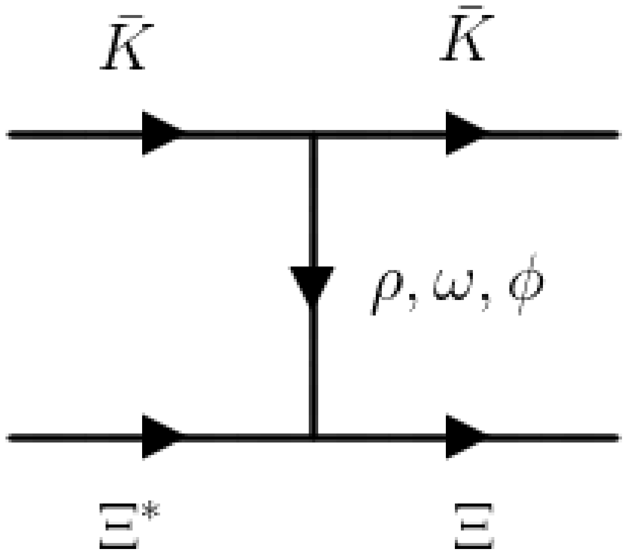
Formalism

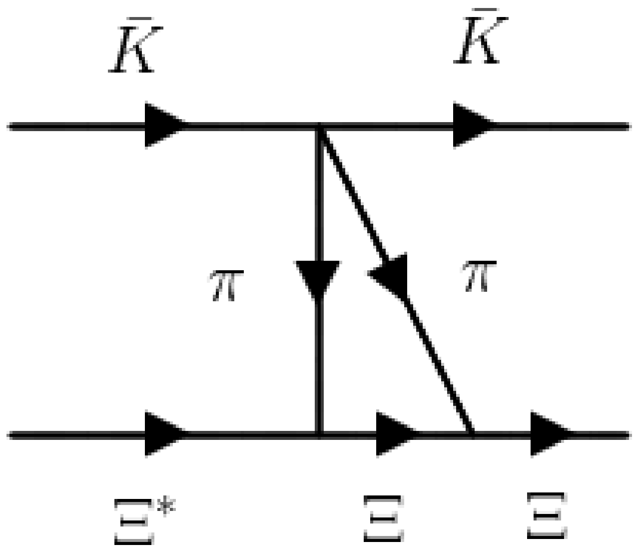


$$A(M_{\rm inv}[\bar{K}\Xi]) = \sqrt{\frac{2}{3}}\, G_{\bar{K}\Xi^*}\, t_{\bar{K}\Xi^*,\bar{K}\Xi} - \frac{1}{\sqrt{3}}\, G_{\eta\Omega}\, t_{\eta\Omega,\bar{K}\Xi}$$

Formalism

One needs to take into account $\bar{K}\Xi^*, \eta\Omega \to \bar{K}\Xi$





Formalism

One needs to take into account $\bar{K}\Xi^*, \eta\Omega \to \bar{K}\Xi$

$$\begin{array}{cc} & \begin{array}{ccc} \bar{K}\Xi^* & \eta\Omega & \bar{K}\Xi \end{array} \\ V = & \begin{pmatrix} 0 & 3F & \boxed{\alpha q^2} \\ 3F & 0 & \boxed{\beta q^2} \\ \alpha q^2 & \beta q^2 & 0 \end{pmatrix} \end{array} \begin{array}{c} \bar{K}\Xi^* \\ \eta\Omega \\ \bar{K}\Xi \end{array} \qquad F = -\frac{1}{4f^2}(k^0 + k'^0)$$

$$G(\sqrt{s}) = \int_{|\vec{q}|<q'_{\max}} \frac{d^3q}{(2\pi)^3} \frac{M}{2\omega(\vec{q})E(\vec{q})} \frac{1}{\sqrt{s} - \omega(\vec{q}) - E(\vec{q}) + i\epsilon}$$

Formalism

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

$$T = V + VGV + VGVGV + \cdots$$

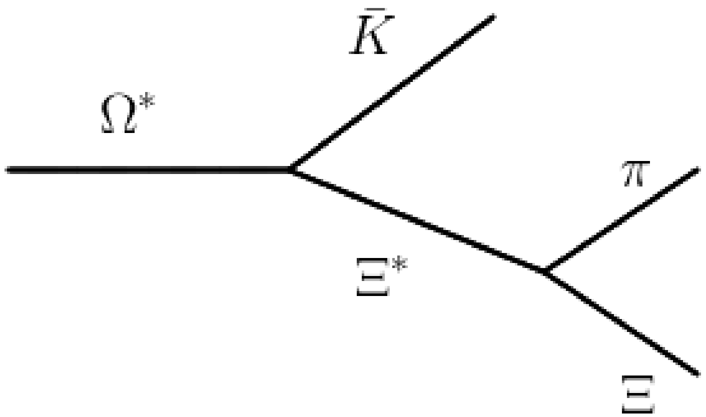
$$G_{\bar{K}\Xi}(\sqrt{s}) = \int_{|\vec{q}|<q'_{\max}} \frac{d^3q}{(2\pi)^3} \frac{(q/q_{on})^4}{2\omega_{\bar{K}}(\vec{q})} \frac{M_\Xi}{E_\Xi(\vec{q})} \frac{1}{\sqrt{s} - \omega_{\bar{K}}(\vec{q}) - E_\Xi(\vec{q}) + i\epsilon}$$

$$q_{on} = \frac{\lambda^{1/2}\left(s, m_{\bar{K}}^2, m_\Xi^2,\right)}{2\sqrt{s}}$$

Formalism

* Large portion of the width comes from $\Omega^* \to \bar{K}\pi\Xi$

- S-Q Xu *et al.*, **Commun. Theor. Phys. 65 (2016) 53-56**
- Y-H Lin and B-S Zou, **Phys. Rev. D 98 (2018) 056013**
- Yin Huang *et al.*, **Phys. Rev. D 98 (2018) 076012**



$$\tilde{G}_{\bar{K}\Xi^*}(\sqrt{s}) = \frac{1}{N}\int_{M_{\Xi^*}-\Delta M_{\Xi^*}}^{M_{\Xi^*}+\Delta M_{\Xi^*}} d\tilde{M}\left(-\frac{1}{\pi}\right)\mathrm{Im}\left(\frac{1}{\tilde{M}-M_{\Xi^*}+i\frac{\Gamma_{\Xi^*}}{2}}\right) G_{\bar{K}\Xi^*}(\sqrt{s}, m_{\bar{K}}, \tilde{M})$$

***MORE ABOUT THIS AT THE END**

Results

Fitting parameters: $\alpha, \quad \beta, \quad q_{\rm max}, \quad q'_{\rm max}$

- L. Roca *et al.*, **Phys. Rev. C 73 (2006) 045208**

$$\Lambda \sim 700 \text{ MeV} \qquad \alpha, \beta \sim 10^{-7} \text{ MeV}^{-3} \qquad a \simeq -8$$

$$d - \text{wave}$$

- Yin Huang *et al.*, **Phys. Rev. D 98 (2018) 076012**

$$a = -2.5 \Rightarrow \Lambda \simeq 730 \text{ MeV}$$

Results

Fitting parameters: $\alpha, \quad \beta, \quad q_{\rm max}, \quad q'_{\rm max}$

- M. Pavon Valderrama, **Phys. Rev. D 98 (2018) 054009**

$$\langle \bar{K}\Xi^* |\, \hat{V} \,| \bar{K}\Xi \rangle = C_D \, \vec{\sigma}\cdot\vec{q} \;\; \vec{S}\cdot\vec{q} \qquad\qquad C_D \sim \frac{1}{f^2\Lambda_\chi}$$

$$f = f_\pi = 93 \text{ MeV} (f_K = 160 \text{ MeV})$$

$$C_D = 1.2\times10^{-7} \text{ MeV}^{-3} (3.9\times10^{-8} \text{ MeV}^{-3})$$

$$\boxed{\alpha = 4.7\times10^{-8} \text{ MeV}^{-3} (1.6\times10^{-8} \text{ MeV}^{-3})}$$

Results

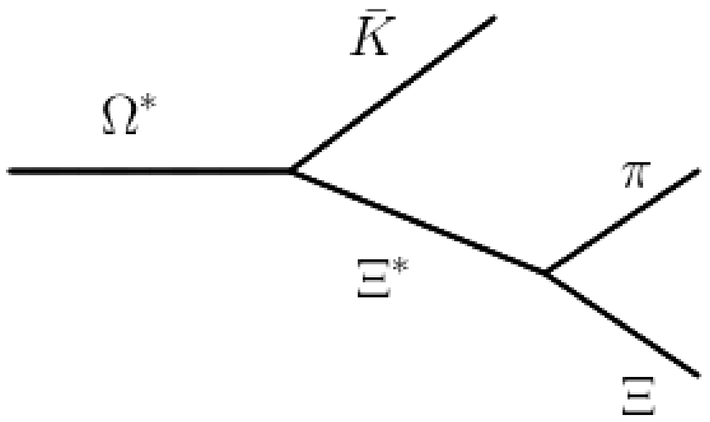
Fitting parameters: $\alpha, \quad \beta, \quad q_{\max}, \quad q'_{\max}$

α (MeV^{-3})	β (MeV^{-3})	$q_{\max} = q'_{\max}$ (MeV)
4.0×10^{-8}	1.5×10^{-8}	735

$$m_{\Omega^*} = 2012.37 \text{ MeV}, \qquad \Gamma_{\Omega^*} = 6.24 \text{ MeV}.$$

$$m_{\Omega^*}^{\text{exp}} = 2012.4 \pm 0.92 \text{ MeV} \qquad \Gamma_{\Omega^*}^{\text{exp}} = 6.4^{+3.0}_{-2.6} \text{ MeV}$$

Results



$$m_{\Omega^*}^{(\text{no conv.})} = 2013.5 \text{ MeV} \qquad \Gamma_{\Omega^*}^{(\text{no conv.})} = 3.2 \text{ MeV}$$

$$\Gamma_{\Omega^* \to \bar{K}\pi\Xi} = \Gamma_{\Omega^*} - \Gamma_{\Omega^*}^{(\text{no conv.})} \simeq 3$$

- Y-H Lin and B-S Zou, **Phys. Rev. D 98 (2018) 056013**

$$\Gamma_{\Omega^* \to \bar{K}\pi\Xi} = 2.4 \text{ MeV}$$

- Yin Huang *et al.*, **Phys. Rev. D 98 (2018) 076012**

$$\Gamma_{\Omega^* \to \bar{K}\pi\Xi} \sim 3 \text{ MeV}$$

Results

$g_{\bar{K}\Xi^*}$	$g_{\eta\Omega}$	$g_{\bar{K}\Xi}$
$2.01 + i0.02$	$2.84 - i0.01$	$-0.29 + i0.04$

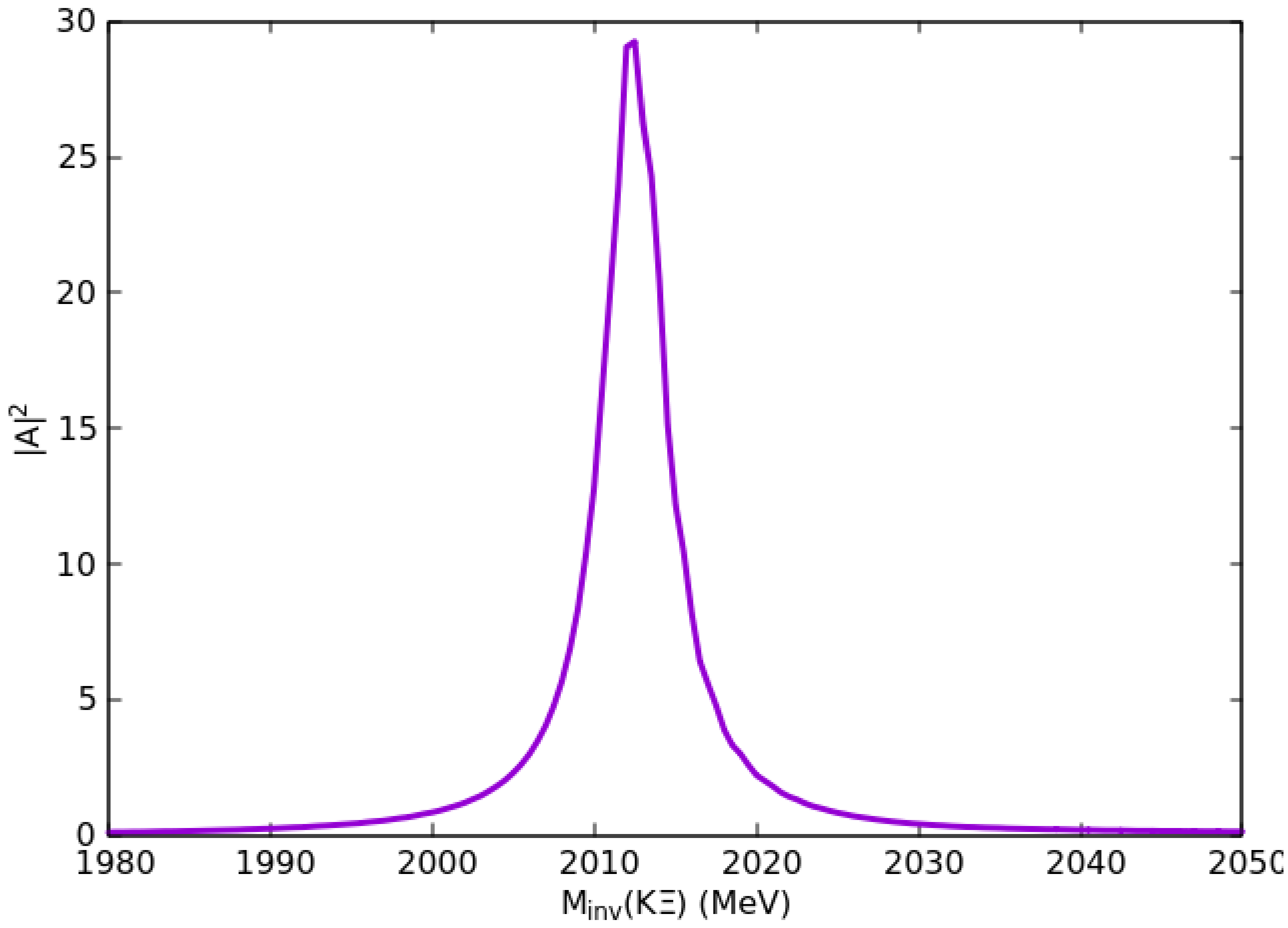
- Yin Huang *et al.*, **Phys. Rev. D 98 (2018) 076012**

$$g_{\bar{K}\Xi^*} = 1.65 \qquad g_{\eta\Omega} = 2.8$$

$\left(-g^2 \frac{\partial G(\sqrt{s})}{\partial\sqrt{s}}\right)_{\bar{K}\Xi^*}$	$\left(-g^2 \frac{\partial G(\sqrt{s})}{\partial\sqrt{s}}\right)_{\eta\Omega}$
$0.636 - i0.068$	$0.164 - i0.002$

Results

$$A(M_{\rm inv}[\bar{K}\Xi]) = \sqrt{\frac{2}{3}}\, G_{\bar{K}\Xi^*}\, t_{\bar{K}\Xi^*,\bar{K}\Xi} - \frac{1}{\sqrt{3}}\, G_{\eta\Omega}\, t_{\eta\Omega,\bar{K}\Xi}$$



Results

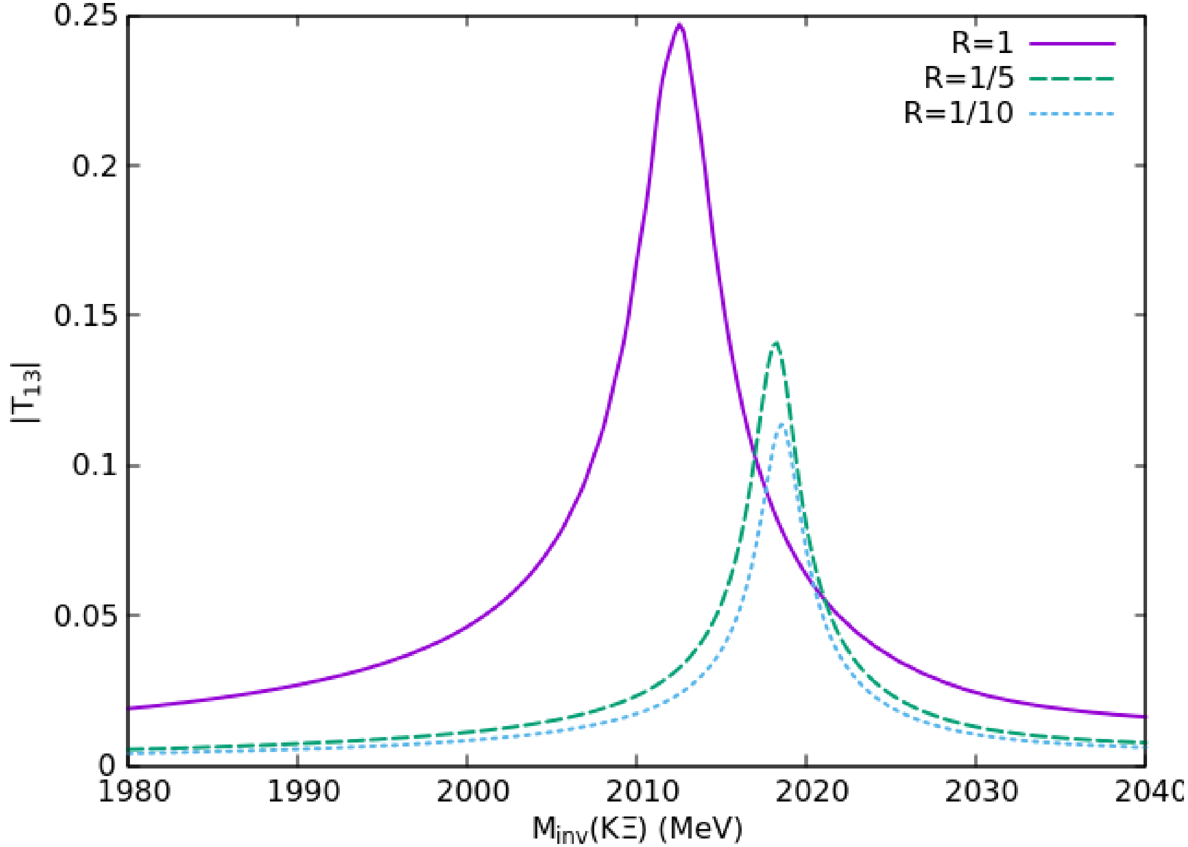
How dependent are the results on the parameters?

$$\Lambda \to 835 \ \text{MeV}$$

$$m_{\Omega^*} = 1982.23 \ \text{MeV}, \qquad \Gamma_{\Omega^*} = 3.13 \ \text{MeV}$$

Results

How dependent are the results on the parameters?



$$\alpha \to R\alpha$$

Results

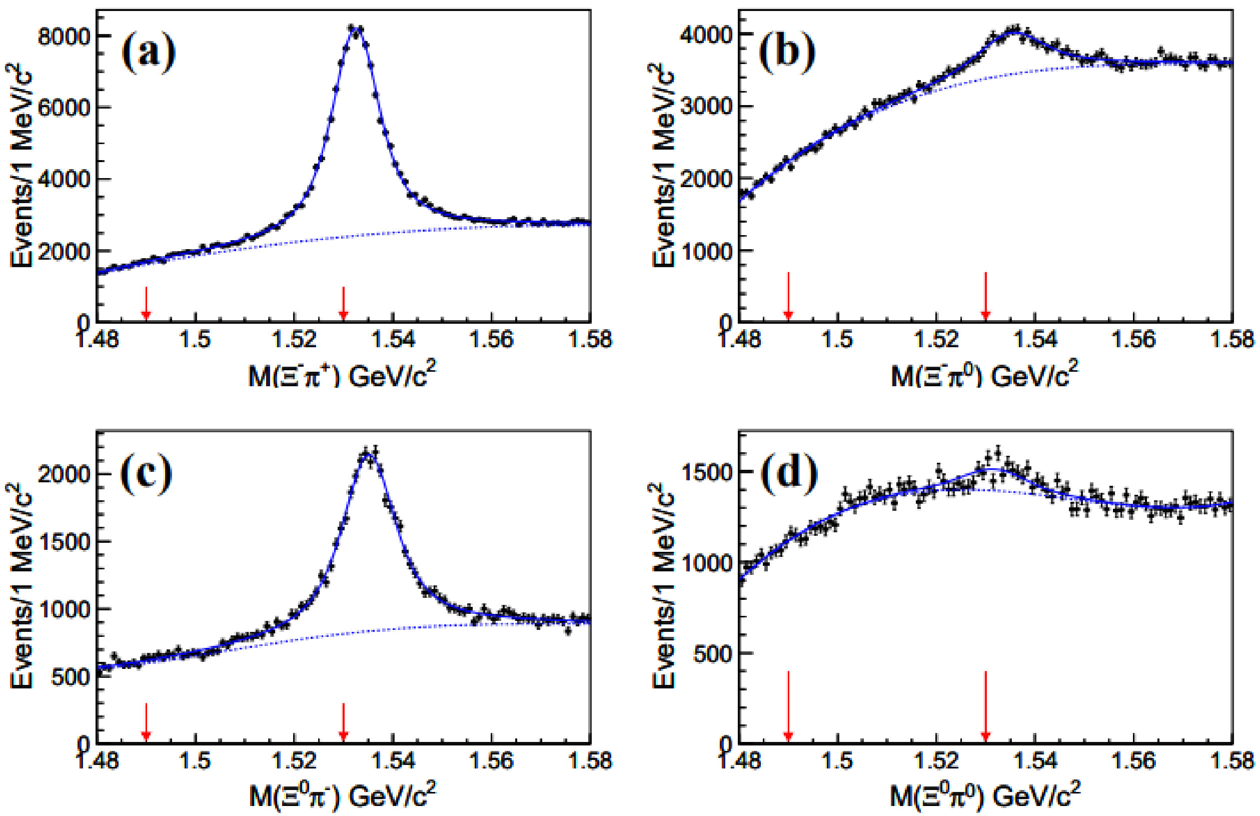
How dependent are the results on the parameters?

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

Update

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

S. Jia *et al.* (Belle Collab.) **Phys.Rev. D100 (2019) 032006**



Conclusions

(s-wave) (d-wave)

- Coupled channels with $\bar{K}\Xi^*$ $\eta\Omega$ $\bar{K}\Xi$
- Take into account $\Omega^* \to \bar{K}\pi\Xi$ with convolution
- $\bar{K}\Xi^*$ the most important channel but $\eta\Omega$ is also important
- Very stable $\Gamma_{\Omega^* \to \bar{K}\pi\Xi}$