粲重子衰变过程中研究奇特强子态

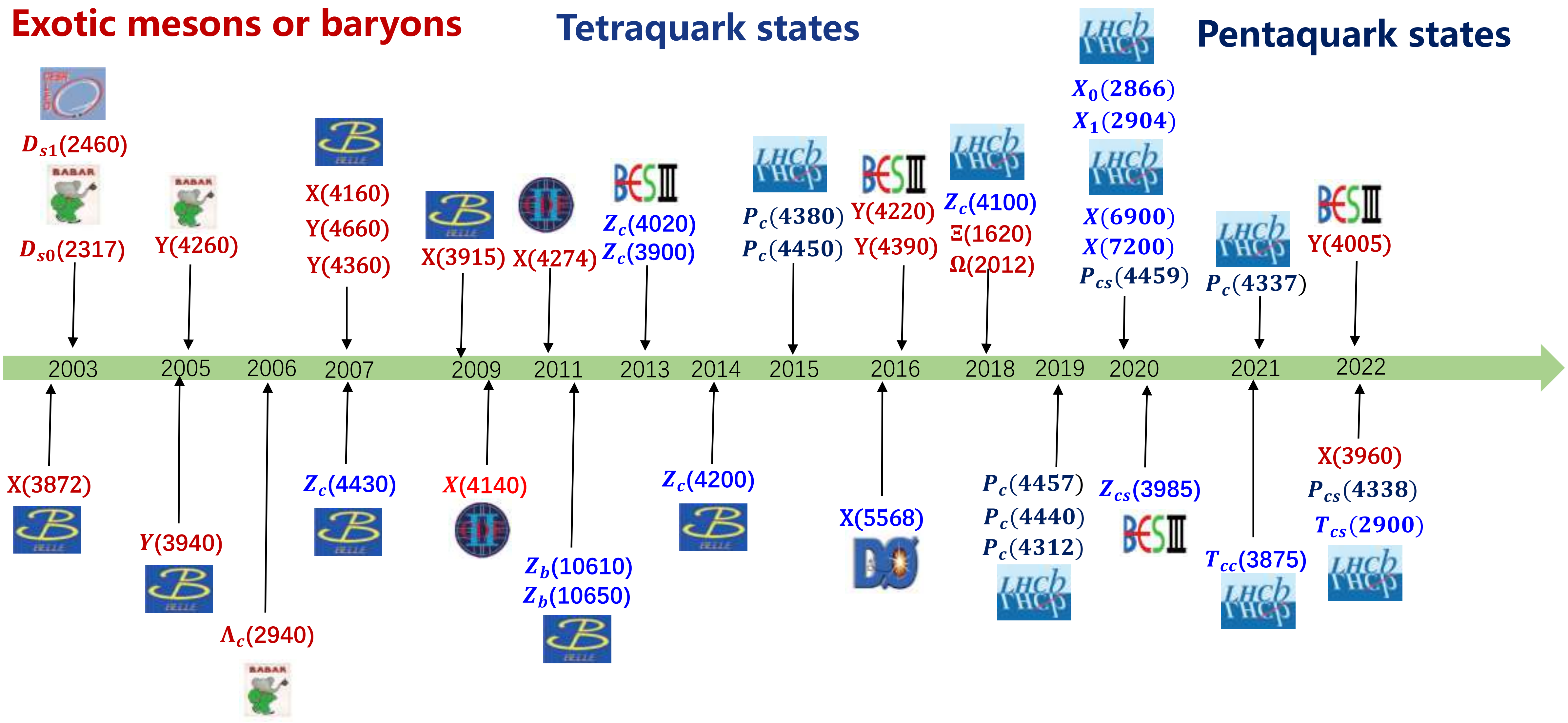
王 恩 郑州大学

第三届强子与重味物理理论与实验联合研讨会

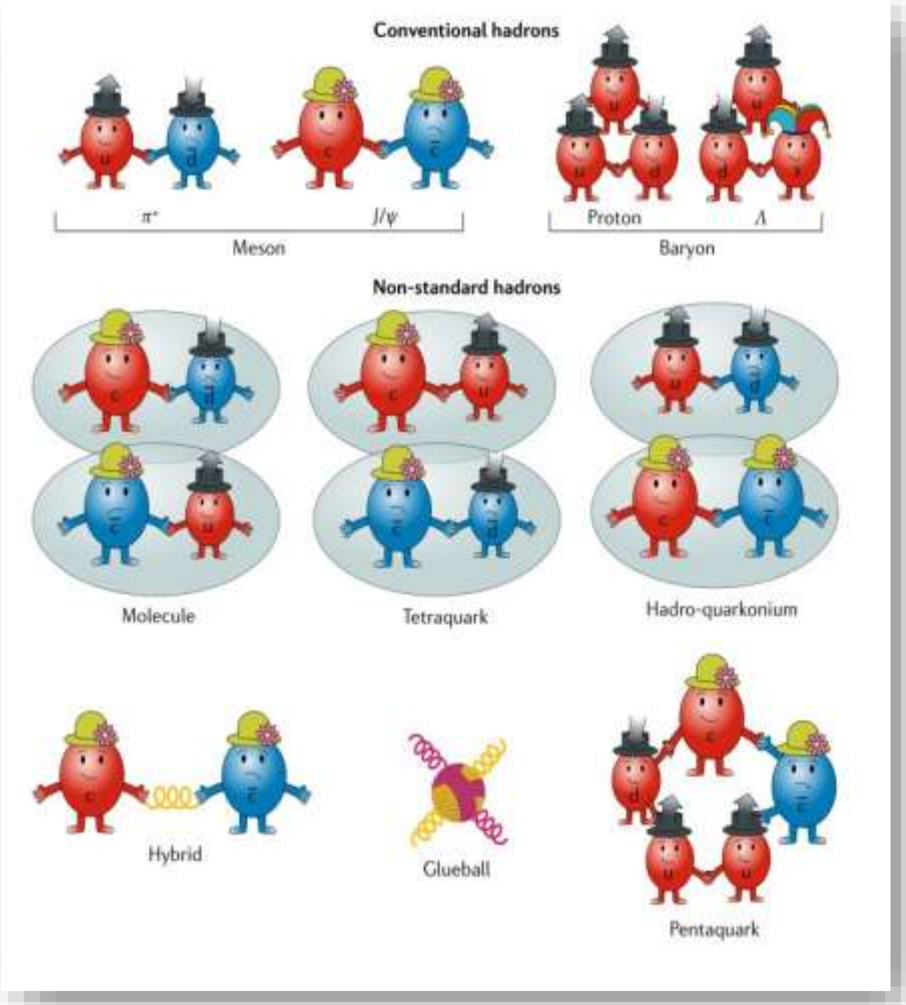
2024年4月5日-8日

Exotic states

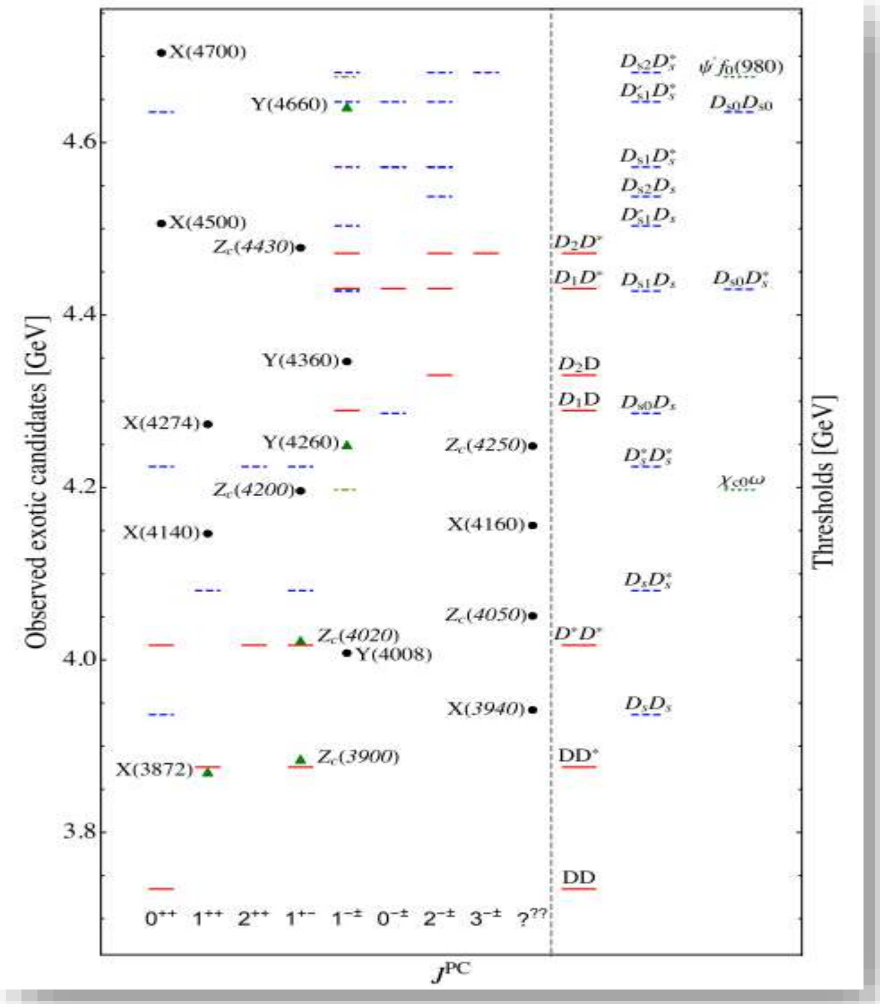
耿立升老师报告



Hadrons



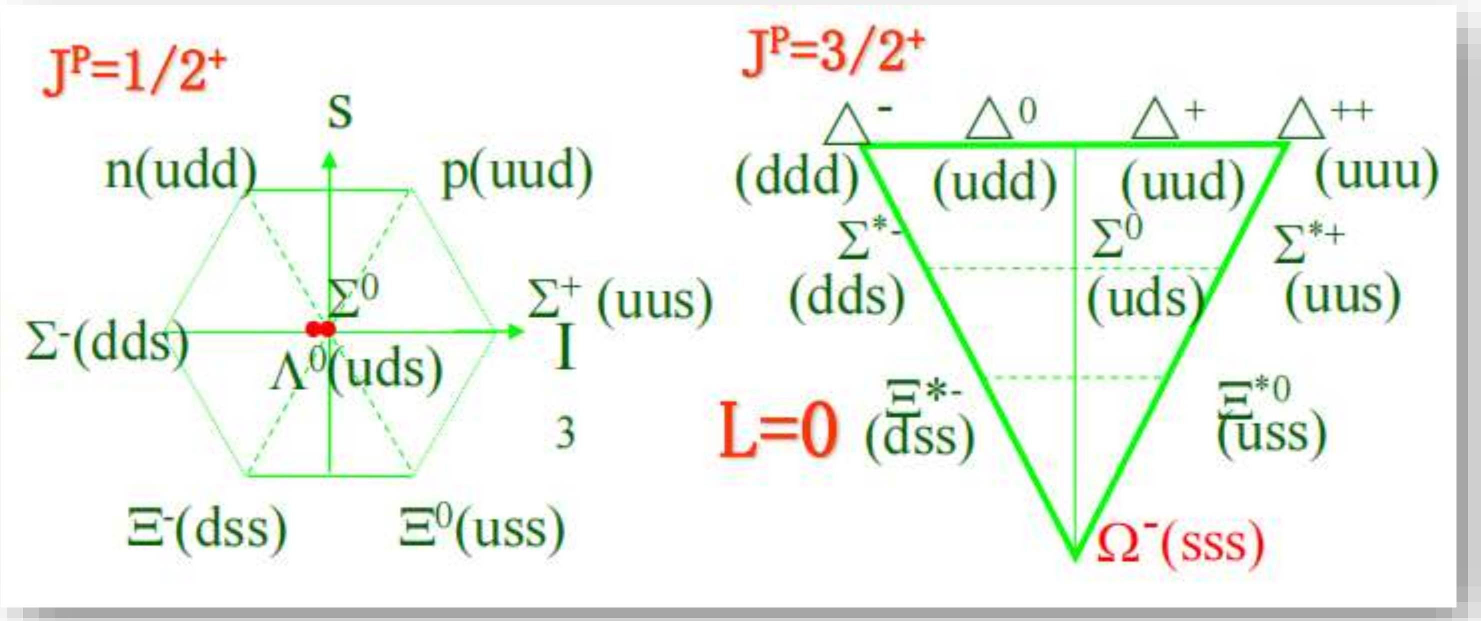
C.Z.Yuan, Nature Rev. Phys. 1 (2019) 480



FKGuo, et.al, Mod. Phys. 90 (2018) 015004

Ground light baryons

- SU(3) flavor multiplets of ground baryons



盖尔曼-大久保质量: $M = a + bY + c\left[I(I+1) - \frac{1}{4}Y^2\right]$

质量公式预言 m_Ω**=1670 MeV**
实验: m_Ω**=1672.45±0.29 MeV**

Low-lying baryons with $J^P=1/2^-$

$1/2^-$ baryon nonet with strangeness

Zou, EPJA 35 (2008) 325

- Mass pattern : quenched or unquenched ?

  uds (L=1) $1/2^-$ ~ $\Lambda^*(1670)$ ~ $[us][ds]\bar{s}$
  uud (L=1) $1/2^-$ ~ $N^*(1535)$ ~ $[ud][us]\bar{s}$
  uds (L=1) $1/2^-$ ~ $\Lambda^*(1405)$ ~ $[ud][su]\bar{u}$
  uus (L=1) $1/2^-$ ~ $\Sigma^*(1390)$ ~ $[us][ud]\bar{d}$

  Zou et al, NPA835 (2010) 199 ; CLAS, PRC87(2013)035206

- Strange decays of N*(1535) and Λ*(1670) :

  N*(1535) large couplings $g_{N^*N\eta}$, $g_{N^*K\Lambda}$, $g_{N^*N\eta'}$, $g_{N^*N\phi}$
  Λ*(1670) large coupling $g_{\Lambda^*\Lambda\eta}$

邹冰松老师报告

Citation: R.L. Workman *et al.* (Particle Data Group), Prog.Theor.Exp.Phys. **2022**, 083C01 (2022)

$\Sigma(1620)\ 1/2^-$ $\quad I(J^P) = 1(\frac{1}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018) and 2019 updat

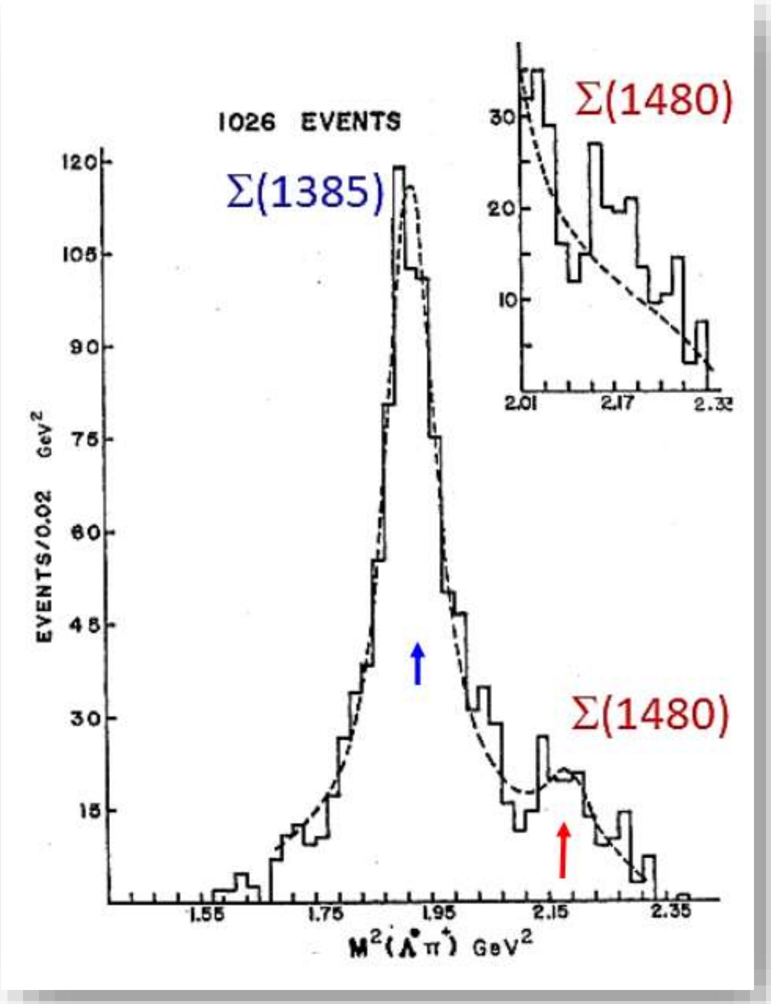
$\Sigma(1480)$ Bumps $\quad I(J^P) = 1(?^?)$ Status: *

OMITTED FROM SUMMARY TABLE

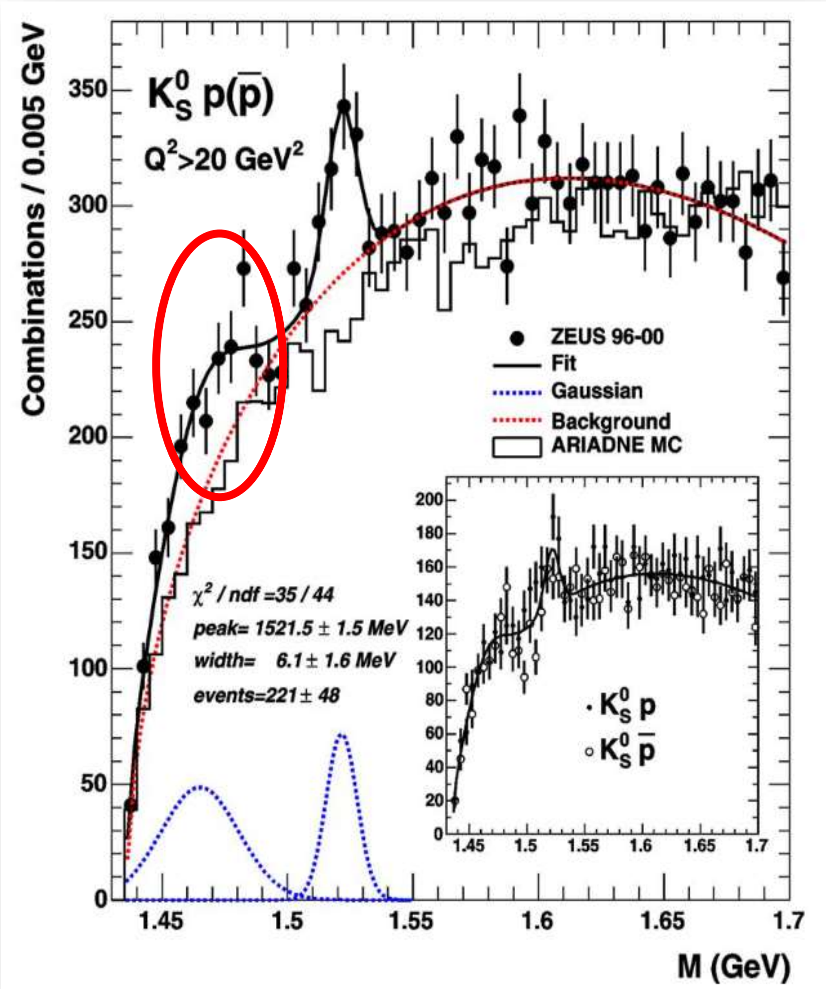
These are peaks seen in $\Lambda\pi$ and $\Sigma\pi$ spectra in the reaction $\pi^+ p \to (Y\pi)K^+$ at 1.7 GeV/c. Also, the Y polarization oscillates in the same region.

Exp. signals of $\Sigma(1480)$

$\pi^+ p \rightarrow \pi^+ K^+ \Lambda$
Yu-Li Pan *et al*, PRD 2, 449 (1970)

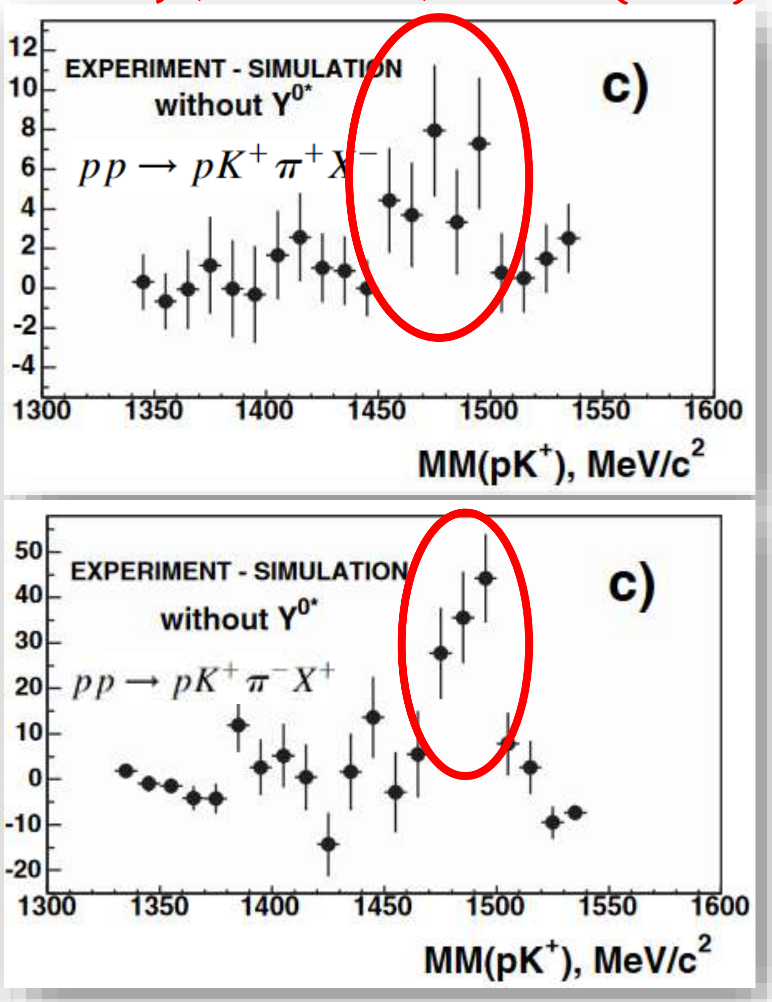


$e^+ p \rightarrow e^+ K^0 \mathrm{pX}$
ZEUS PLB591 (2004) 7–22



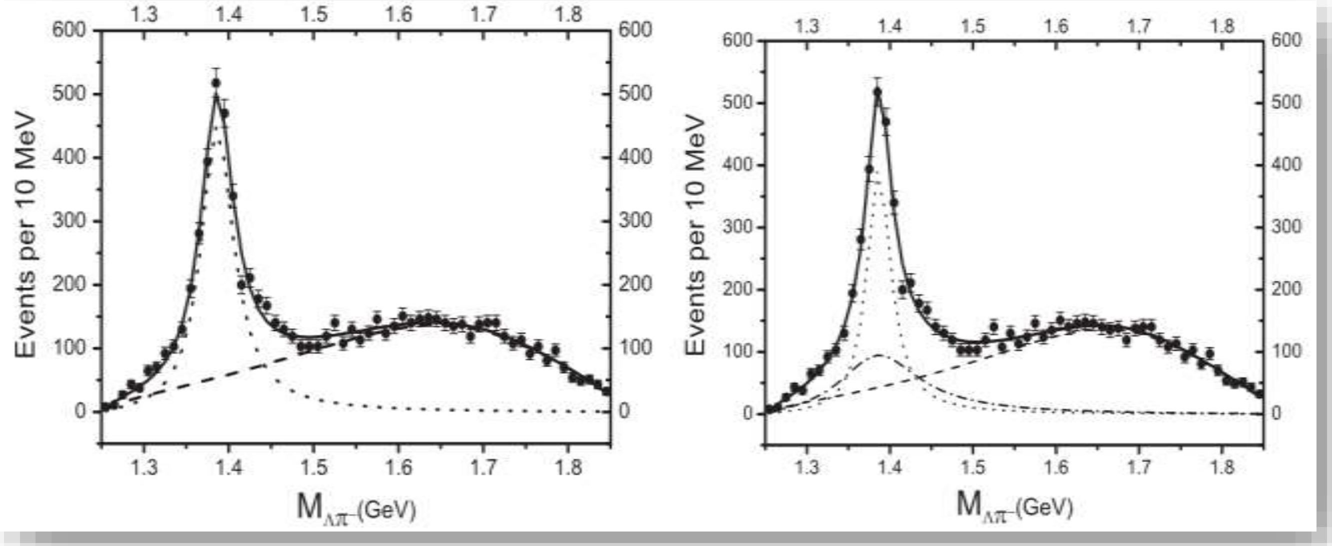
$pp \rightarrow pK^+ Y^{0*}$

COSY-Ju;ich PRL 96, 012002 (2006)



Evidence of $\Sigma(1/2^-)$

- $K^- p \to \Lambda\pi^+\pi^-$, Wu-Dulat-Zou, PRD80(2009)017503



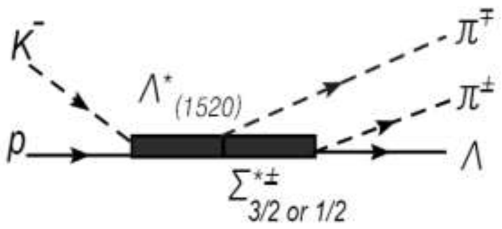
$$\frac{dN}{dm_{\Lambda\pi^-}} \propto p_1 \times p_2 \times \sum_{i=1}^{3} \frac{|a_i|}{(m_{\Lambda\pi^-}^2 - m_i^2)^2 + m_i^2 \times \Gamma_i^2},$$

Here we reexamine some old data of the $K^- p \to \Lambda\pi^+\pi^-$ reaction and find that besides the well-established $\Sigma^*(1385)$ with $J^P = 3/2^+$, there is indeed some evidence for the possible existence of a new Σ^* resonance with $J^P = 1/2^-$ around the same mass but with broader decay width. There are also indications for such a possibility in the $J/\psi \to \bar{\Sigma}\Lambda\pi$ and $\gamma n \to K^+\Sigma^{*-}$ reactions. At present, the evidence is not strong. Therefore, high statistics studies

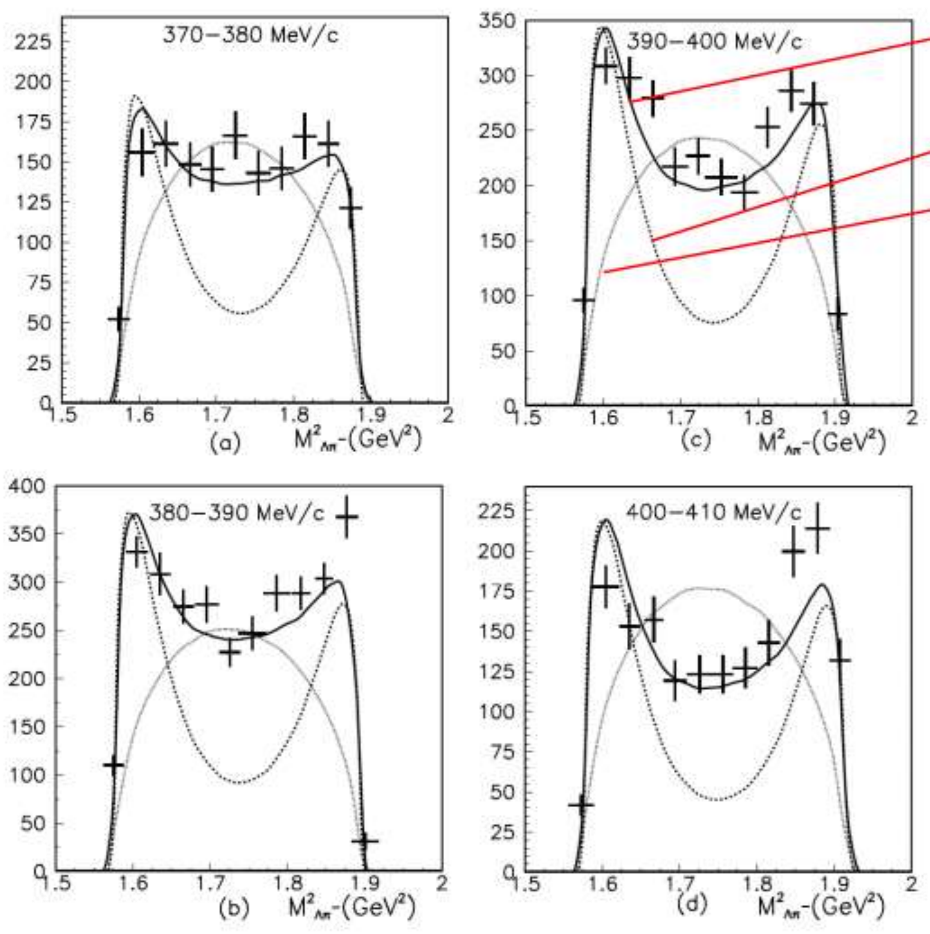
	$M_{\Sigma^*(3/2)}$	$\Gamma_{\Sigma^*(3/2)}$	$M_{\Sigma^*(1/2)}$	$\Gamma_{\Sigma^*(1/2)}$	χ^2/ndf (Fig. 1)	χ^2/ndf (Fig. 2)
Fit1	1385.3 ± 0.7	46.9 ± 2.5			68.5/54	10.1/9
Fit2	$1386.1^{+1.1}_{-0.9}$	$34.9^{+5.1}_{-4.9}$	$1381.3^{+4.9}_{-8.3}$	$118.6^{+55.2}_{-35.1}$	58.0/51	3.2/9

J.J.Wu’s slide

$K^- p \rightarrow \Lambda \pi^+ \pi^-$



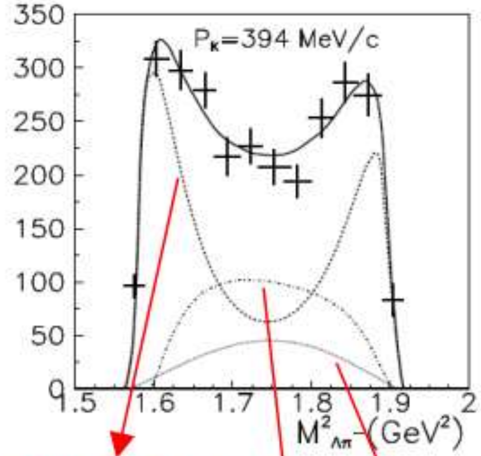
P_K=0.3-0.6 GeV   **J. J. Wu, S. Dulat and B. S. Zou PRC 81,045210**



59% Σ*(3/2⁺)+ 41% Σ*(1/2⁻)

100% Σ*(3/2⁺)

Phase space

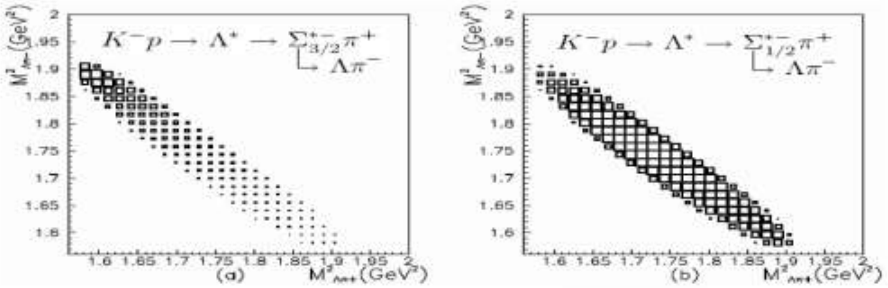


59% Σ*(3/2⁺)

Interference

12. 5% Σ*(1/2⁻)

First reason: S-wave between the Σ*⁻(3/2⁺) and π⁺ ; but P-wave between the Σ*⁻(1/2⁻) and π⁺ .



Second reason: the width of Σ*⁻(3/2⁺) is 35.5MeV; but that of Σ*⁻(1/2⁻) is 118.6MeV from fit before.

Search for $\Sigma(1/2^-)$

- $\Lambda_c \to \Lambda\eta\pi$, Xie-Geng, PRD95(2017) 074024
- $\gamma n \to K\Sigma(1/2^-)$, Lyu-EW-Xie-Wei, CPC47 (2023) 053108
- $\chi_{c0} \to \bar{\Sigma}\Sigma\pi$, EW-Xie-Oset, PLB753(2016)526
- $\chi_{c0} \to \bar{\Lambda}\Sigma\pi$, EW-Xie-Oset, PRD98(2018)114017
- $\Lambda_c \to \Sigma^+\pi^+\pi^0\pi^-$, Xie-Oset, Phys.Lett.B 792 (2019) 450
- $\gamma N \to \Sigma(1/2^-)N$, Kim-Nam-Hosaka, PRD(2021)114017

Low-lying baryons with $J^P=1/2^-$

- **Chiral Lagrangian**

$$\nabla_\mu B = \partial_\mu B + [\Gamma_\mu, B],$$
$$\Gamma_\mu = \tfrac{1}{2}(u^+\partial_\mu u + u\partial_\mu u^+),$$
$$U = u^2 = \exp(i\sqrt{2}\Phi/f),$$
$$u_\mu = iu^+\partial_\mu U u^+.$$

Oset Ramos, NPA635(1998)99

$$L_1^{(B)} = \langle \bar{B} i\gamma^\mu \nabla_\mu B\rangle - M_B\langle \bar{B}B\rangle + \tfrac{1}{2}D\langle \bar{B}\gamma^\mu\gamma_5\{u_\mu, B\}\rangle + \tfrac{1}{2}F\langle \bar{B}\gamma^\mu\gamma_5[u_\mu, B]\rangle$$

$$\Phi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta \end{pmatrix}, \quad B = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda \end{pmatrix}$$

At lowest order in momentum

$$L_1^{(B)} = \langle \bar{B} i\gamma^\mu \frac{1}{4f^2}[(\Phi\partial_\mu\Phi - \partial_\mu\Phi\Phi)B - B(\Phi\partial_\mu\Phi - \partial_\mu\Phi\Phi)]\rangle,$$

$$V_{ij} = -C_{ij}\frac{1}{4f^2}\bar{u}(p')\gamma^\mu u(p)(k_\mu + k'_\mu)$$

⬇ Neglect the spatial components at low energies

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

Low-lying baryons with $J^P=1/2^-$

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

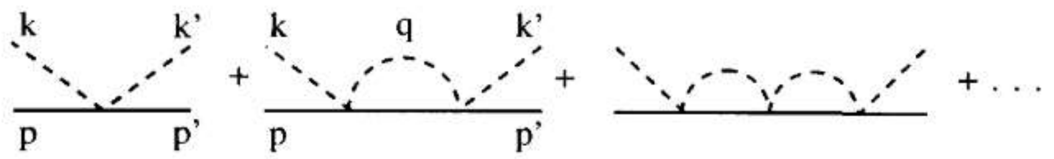
I=0	$\bar{K}N$	$\pi\Sigma$	$\eta\Lambda$	$K\Xi$
$\bar{K}N$	3	$-\sqrt{\frac{3}{2}}$	$\frac{3}{\sqrt{2}}$	0
$\pi\Sigma$		4	0	$\sqrt{\frac{3}{2}}$
$\eta\Lambda$			0	$-\frac{3}{\sqrt{2}}$
$K\Xi$				3

I=1	$\bar{K}N$	$\pi\Sigma$	$\pi\Lambda$	$\eta\Sigma$	$K\Xi$
$\bar{K}N$	1	-1	$-\sqrt{\frac{3}{2}}$	$-\sqrt{\frac{3}{2}}$	0
$\pi\Sigma$		2	0	0	1
$\pi\Lambda$			0	0	$-\sqrt{\frac{3}{2}}$
$\eta\Sigma$				0	$-\sqrt{\frac{3}{2}}$
$K\Xi$					1

Lippmann-Schwinger equations

$$t_{ij} = V_{ij} + V_{il}G_lT_{lj}\,,$$

$$V_{il}G_lT_{lj} = i\int\frac{d^4q}{(2\pi)^4}\frac{M_l}{E_l(\boldsymbol{q})}\frac{V_{il}(k,q)T_{lj}(q,k')}{k^0+p^0-q^0-E_l(\boldsymbol{q})+i\epsilon}\frac{1}{q^2-m_l^2+i\epsilon}\,.$$



On-shell approximations

$$2iV_{on}\int\frac{d^3q}{(2\pi)^3}\int\frac{dq^0}{2\pi}\frac{M}{E(q)}\frac{q^0-k^0}{k^0-q^0}\frac{1}{q^{02}-\omega(q)^2+i\epsilon}$$

Low-lying baryons with $J^P=1/2^-$

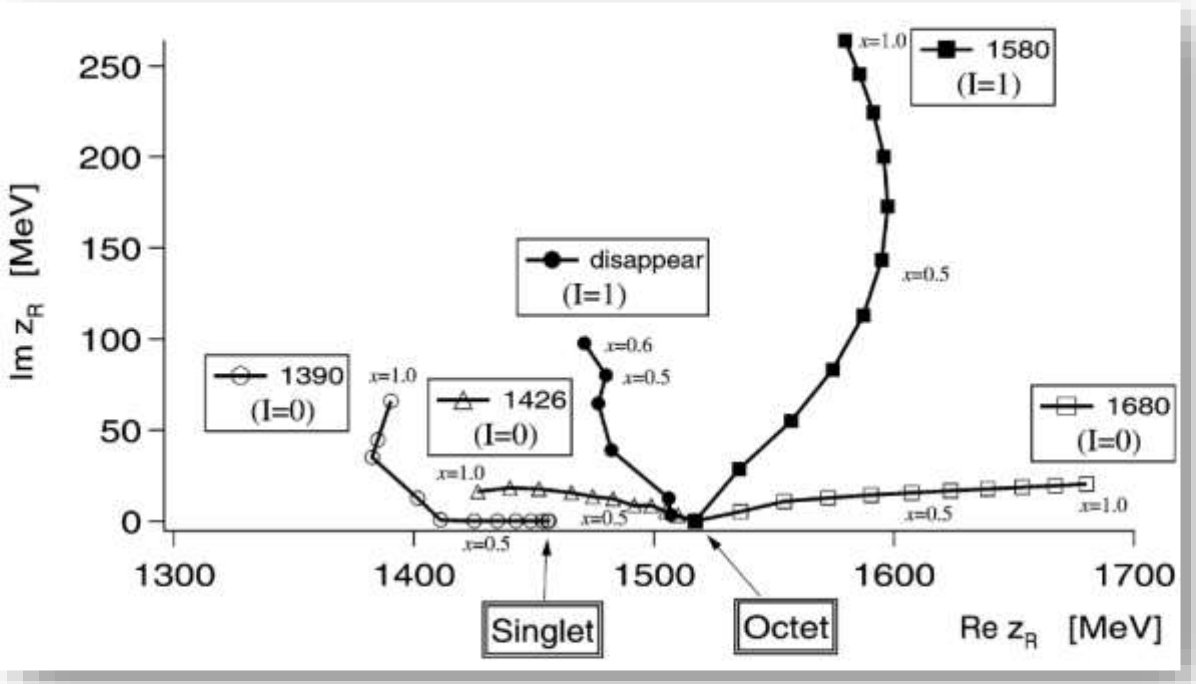
- **Bethe-Salpter Equation**

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

$$G_l = i\int \frac{d^4q}{(2\pi)^4}\frac{M_l}{E_l(\boldsymbol{q})}\frac{1}{k^0+p^0-q^0-E_l(\boldsymbol{q})+i\epsilon}\frac{1}{q^2-m_l^2+i\epsilon}$$
$$= \int \frac{d^3q}{(2\pi)^3}\frac{1}{2\omega_l(q)}\frac{M_l}{E_l(\boldsymbol{q})}\frac{1}{p^0+k^0-\omega_l(\boldsymbol{q})-E_l(\boldsymbol{q})+i\epsilon},$$

$$G_l = i2M_l\int\frac{d^4q}{(2\pi)^4}\frac{1}{(P-q)^2-M_l^2+i\epsilon}\frac{1}{q^2-m_l^2+i\epsilon}$$
$$= \frac{2M_l}{16\pi^2}\Big\{a_l(\mu)+\ln\frac{M_l^2}{\mu^2}+\frac{m_l^2-M_l^2+s}{2s}\ln\frac{m_l^2}{M_l^2}$$
$$+\frac{q_l}{\sqrt{s}}[\ln(s-(M_l^2-m_l^2)+2q_l\sqrt{s})+\ln(s+(M_l^2-m_l^2)+2q_l\sqrt{s})$$
$$-\ln(-s+(M_l^2-m_l^2)+2q_l\sqrt{s})-\ln(-s-(M_l^2-m_l^2)+2q_l\sqrt{s})]\Big\}$$

Jido Oller Oset Ramos Meissner, NPA725 (2003) 181

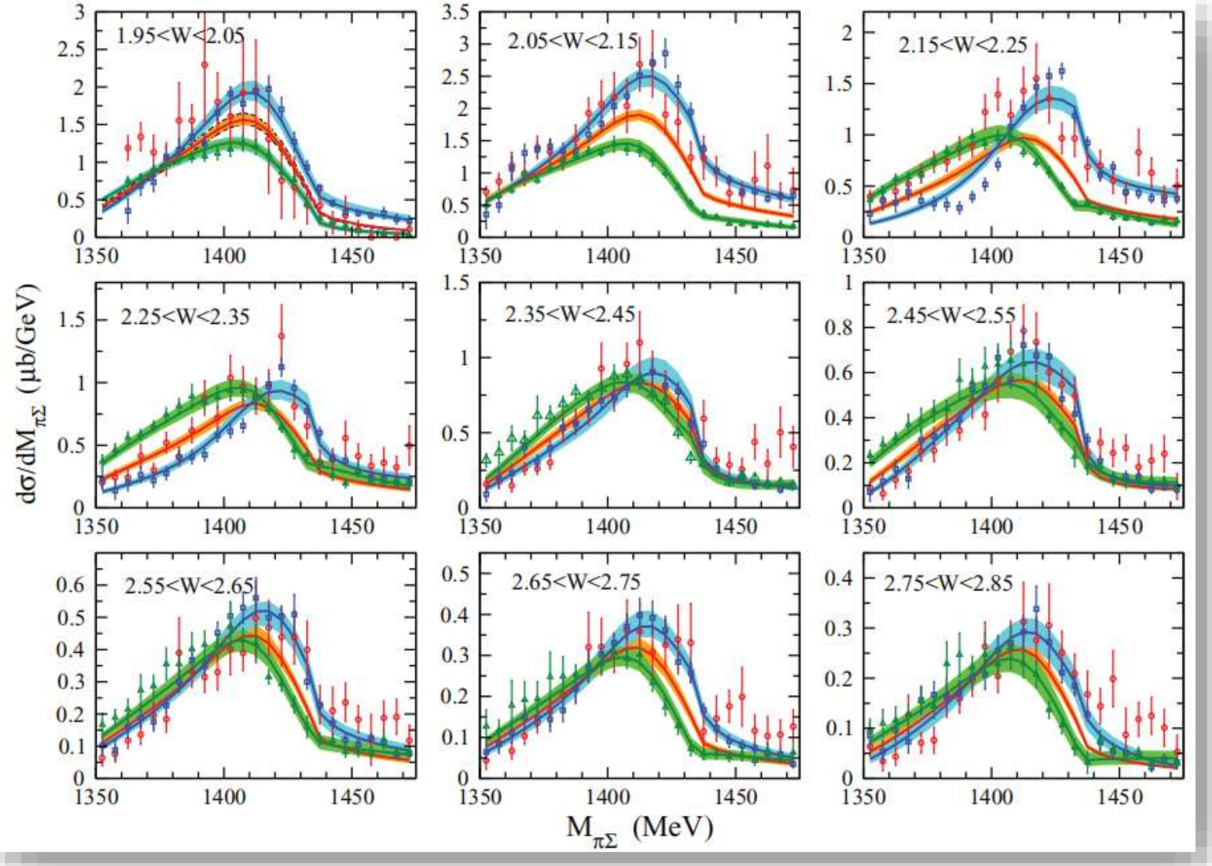


pole positions and couplings

$$T_{ij} = \frac{g_i g_j}{z - z_R}.$$

Σ(1/2⁻)

- **$\pi\Sigma$ photoproduction,** Roca-Oset, PRC 88, 055206 (2013)



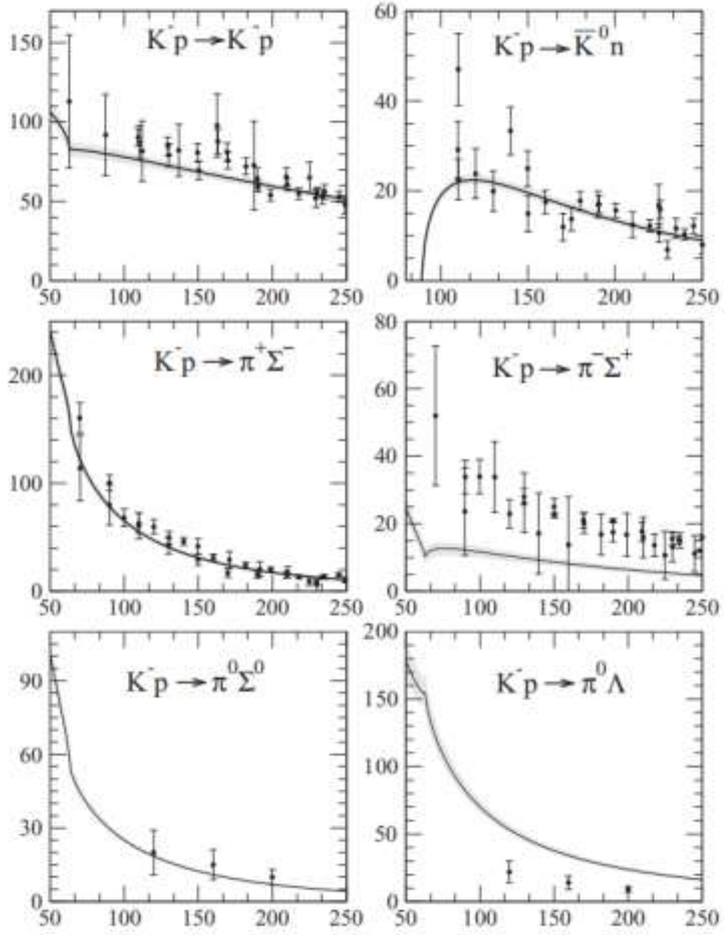
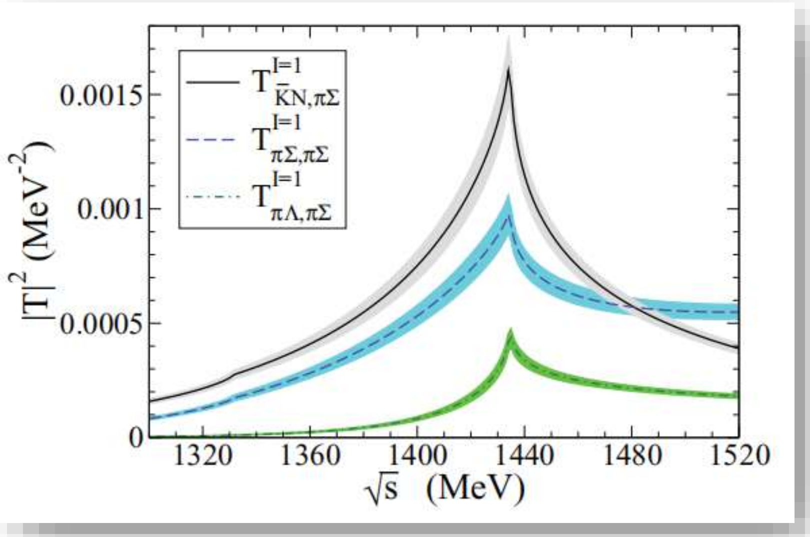


FIG. 6. Predicted K^-p cross sections (in millibarns). Experimental data are from Ref. [46].

Σ(1430)

- **$\pi\Sigma$ photoproduction,** Roca-Oset, PRC 88, 055206 (2013)



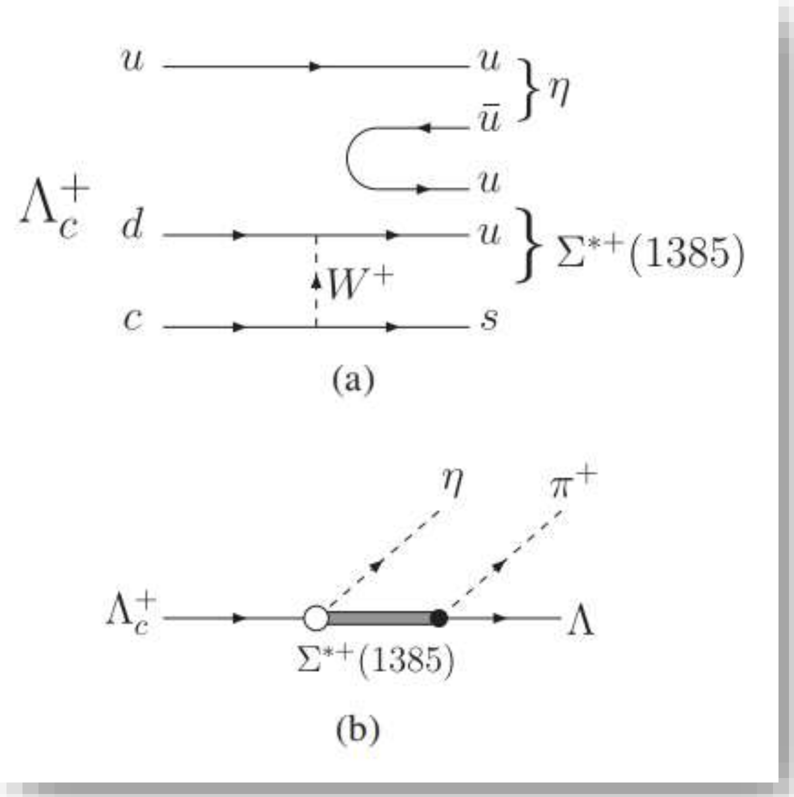
$$V_{ij} = -C_{ij}\frac{1}{4f^2}(k^0 + k'^0) \qquad C^1_{ij} = \begin{pmatrix} \alpha^1_{11} & -\alpha^1_{12} & -\sqrt{\frac{3}{2}}\alpha^1_{13} \\ -\alpha^1_{12} & 2\alpha^1_{22} & 0 \\ -\sqrt{\frac{3}{2}}\alpha^1_{13} & 0 & 0 \end{pmatrix}$$

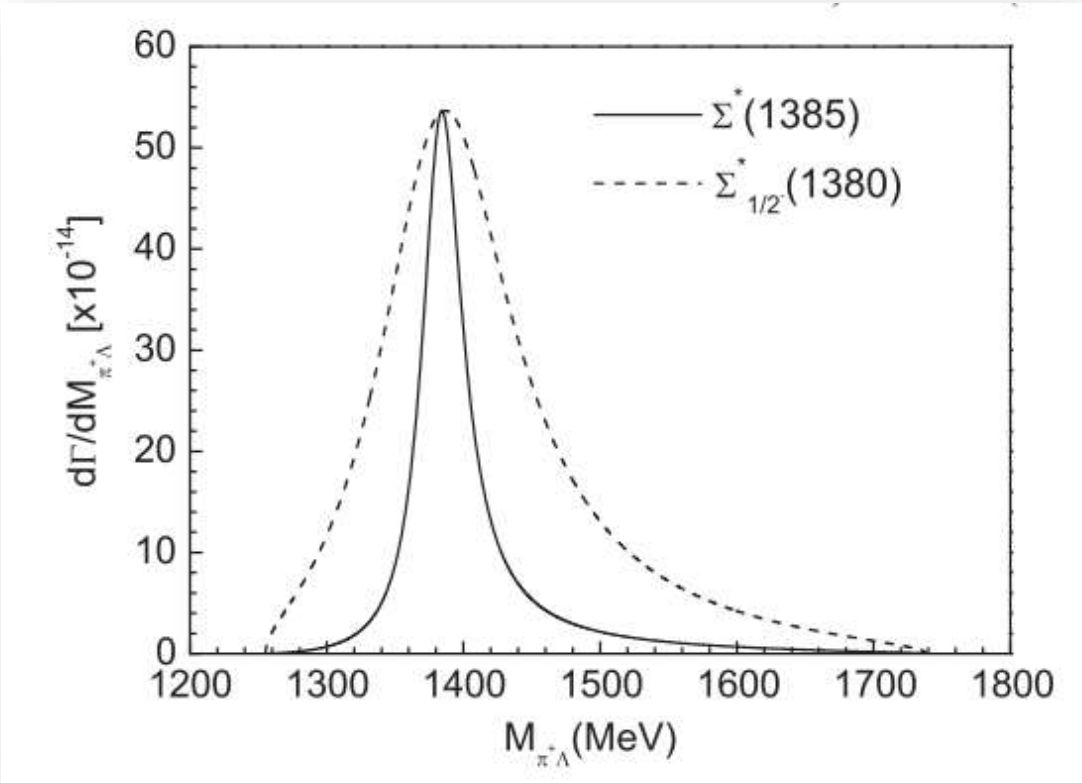
α^0_{11}	α^0_{12}	α^0_{22}	α^1_{11}	α^1_{12}	α^1_{13}	α^1_{22}
1.037	1.466	1.668	0.85	0.93	1.056	0.77

- **Oset-Ramos, NPA635 (1998) 99 [nucl-th/9711022].**
- **PB,VB, Hosaka, PRD 85, 114020 (2012)**
- **Oller-Meißner, Phys. Lett. B 500 (2001) 263 [hep-ph/0011146]**

$\Sigma(1/2^-)$ in $\Lambda_c \to \Lambda\eta\pi$

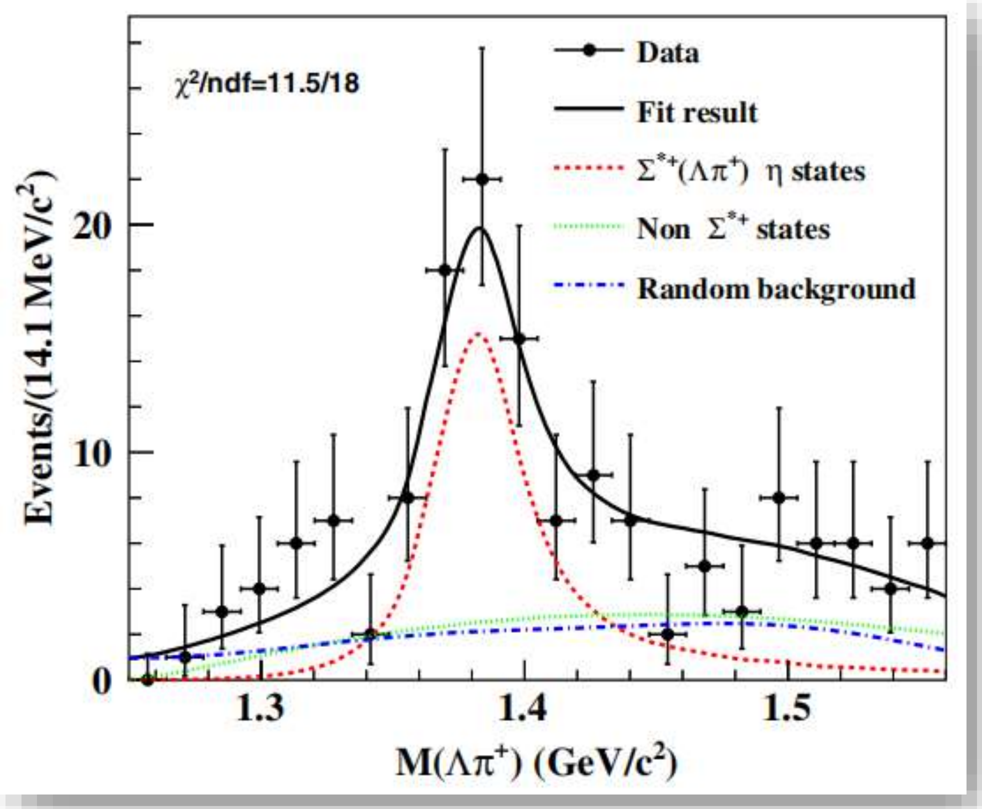
◻J.J.Xie, L.S.Geng, EPJC76(2016) 496, PRD95(2017) 074024



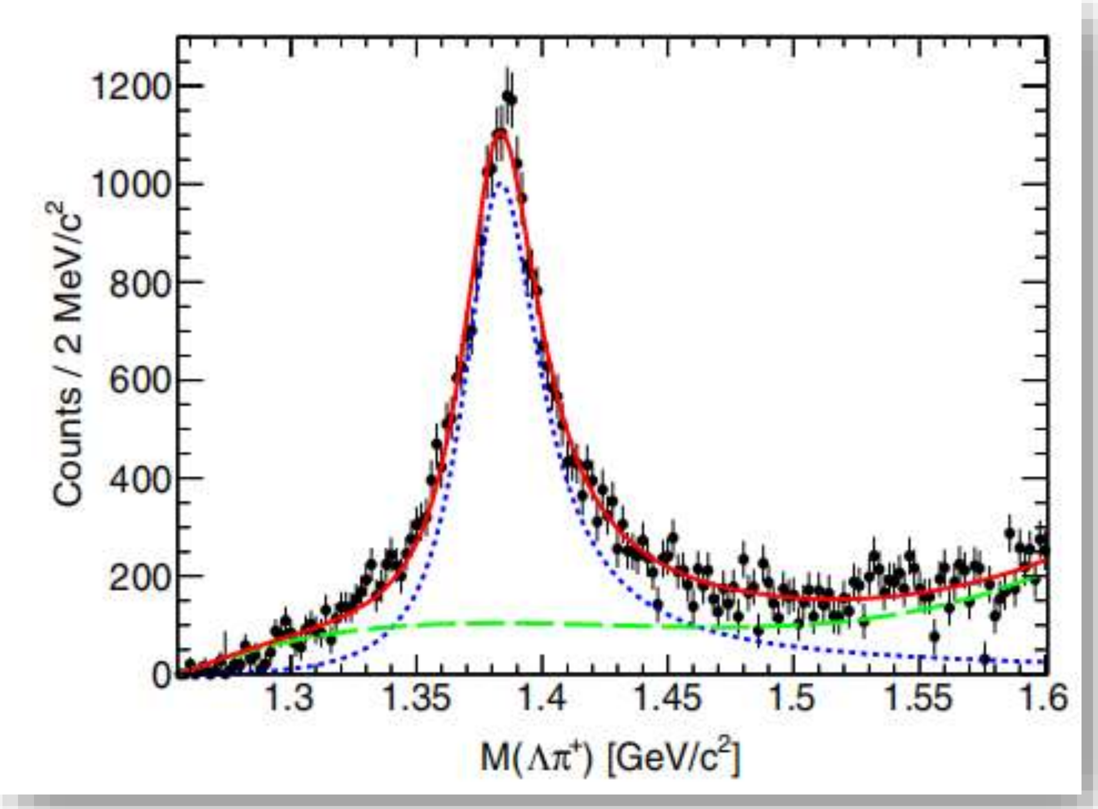


Belle and BESIII measurements

- $\Lambda_c \to \Lambda\eta\pi$

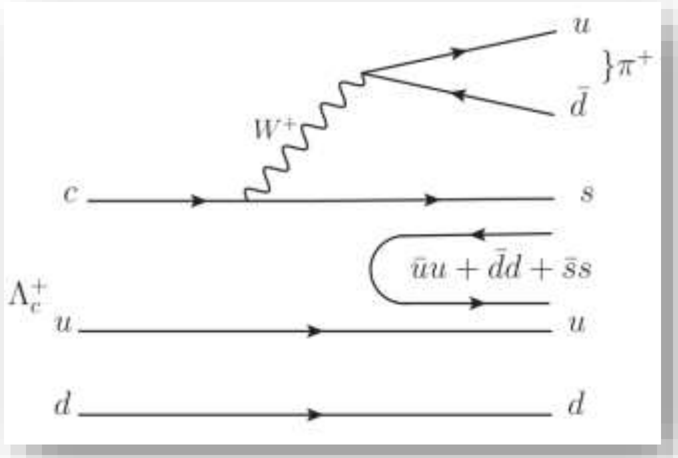


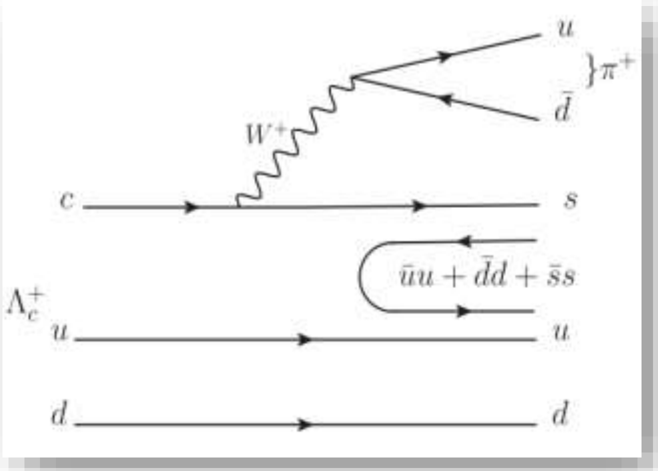
BESIII: PRD99, 032010 (2019)

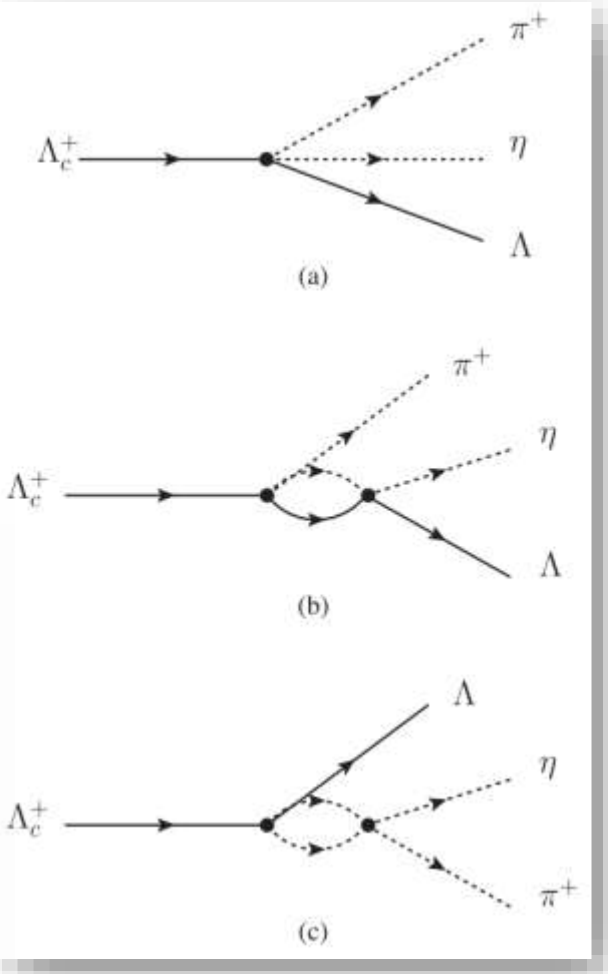


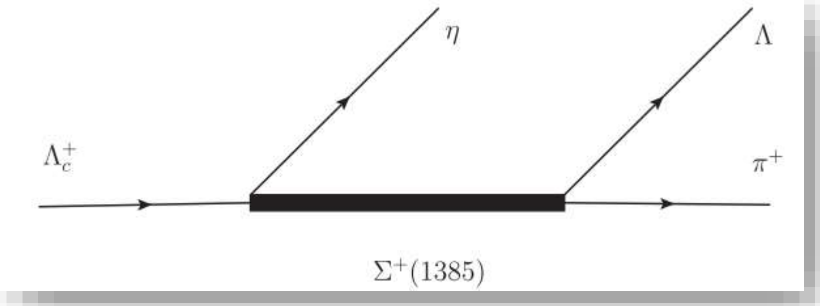
Belle: PRD103(2021)052005

Mechanism of $\Lambda_c \to \eta\Lambda\pi$









$$T^{\Sigma^*}(M_{\pi^+\Lambda}) = V_P'' \frac{|\vec{p}_\pi| \cdot |\vec{p}_\eta| \cdot \cos\theta}{M_{\pi^+\Lambda} - M_{\Sigma^*} + i\frac{\Gamma_{\Sigma^*}}{2}},$$

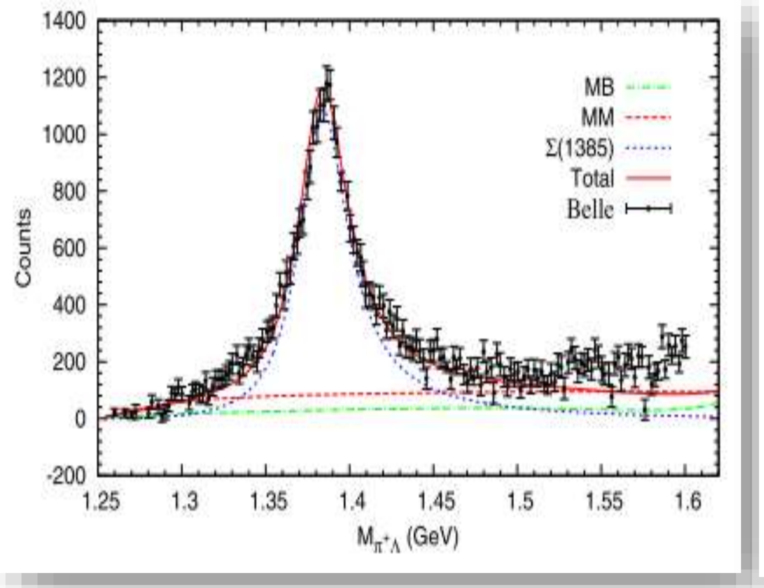
$$T^{\rm MB}(M_{\eta\Lambda}) = V_P\Big\{-\frac{\sqrt{2}}{3} + G_{K^-p}(M_{\eta\Lambda})t_{K^-p\to\eta\Lambda}(M_{\eta\Lambda}) + G_{\bar{K}^0n}(M_{\eta\Lambda})t_{\bar{K}^0n\to\eta\Lambda}(M_{\eta\Lambda}) - \frac{\sqrt{2}}{3}G_{\eta\Lambda}(M_{\eta\Lambda})t_{\eta\Lambda\to\eta\Lambda}(M_{\eta\Lambda})\Big\},$$

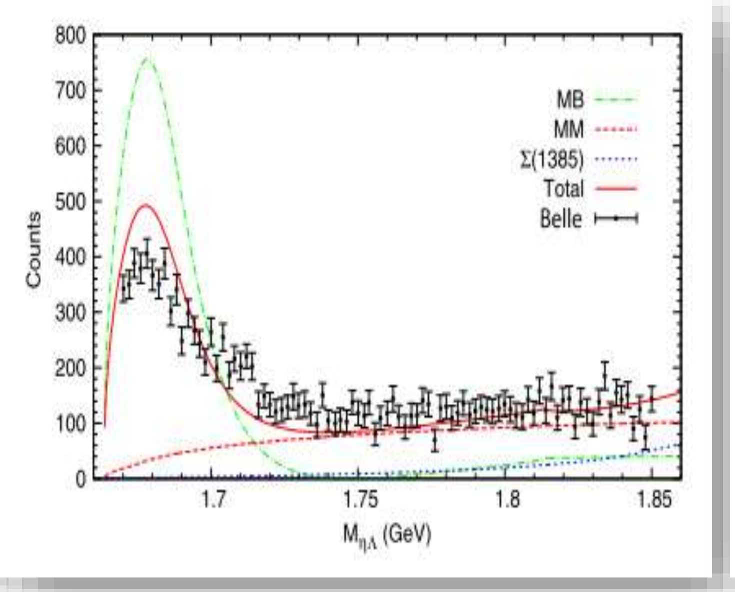
$$T^{\rm MM}(M_{\pi^+\eta}) = V_P'\frac{2\sqrt{2}}{3}\Big\{1 + G_{\pi^+\eta}(M_{\pi^+\eta})t_{\pi^+\eta\to\pi^+\eta}(M_{\pi^+\eta}) + \frac{\sqrt{3}}{2}G_{K^+\bar{K}^0}(M_{\pi^+\eta})t_{K^+\bar{K}^0\to\pi^+\eta}(M_{\pi^+\eta})\Big\}, \quad ($$

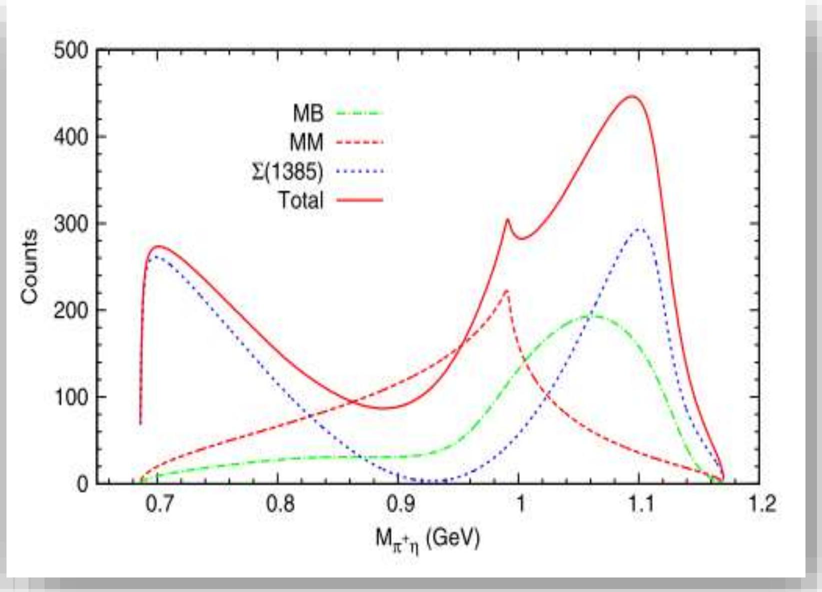
GYW-EW-Xie-Geng-Wei, PRD 106, 056001 (2022)

Analysis the Belle data

- $\Lambda_c \to \Lambda\eta\pi$, GYW-EW-Xie-Geng-Wei, PRD 106, 056001 (2022)

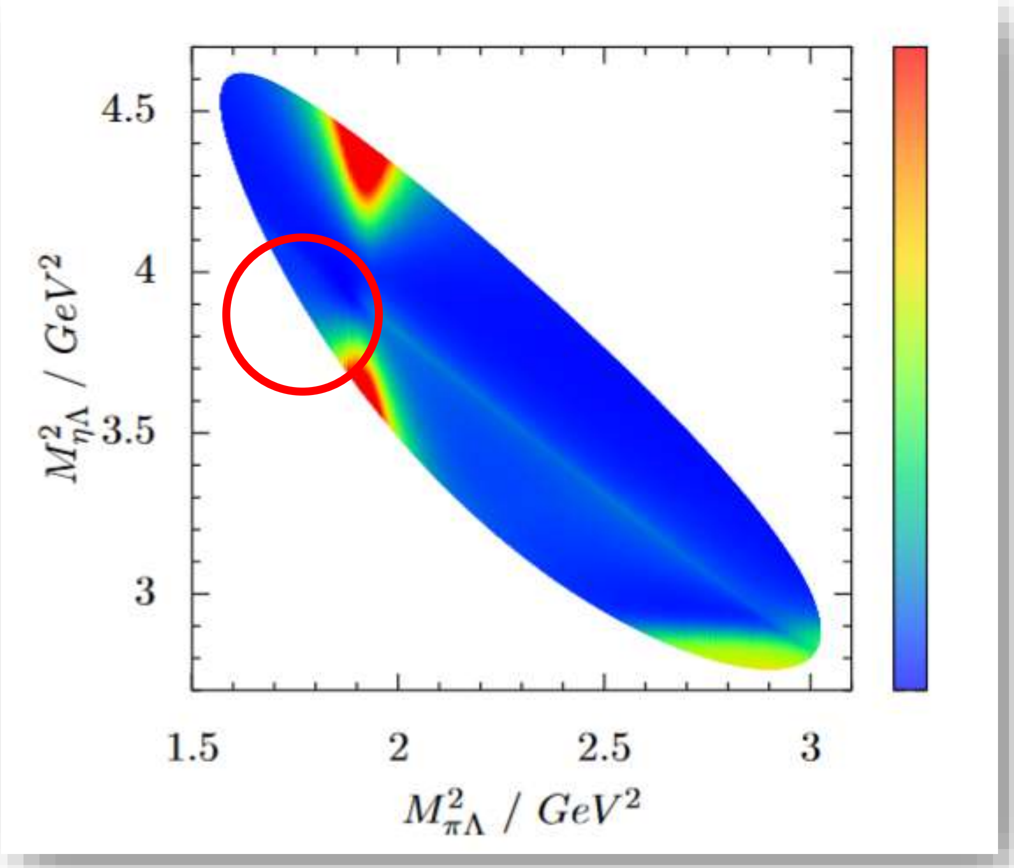


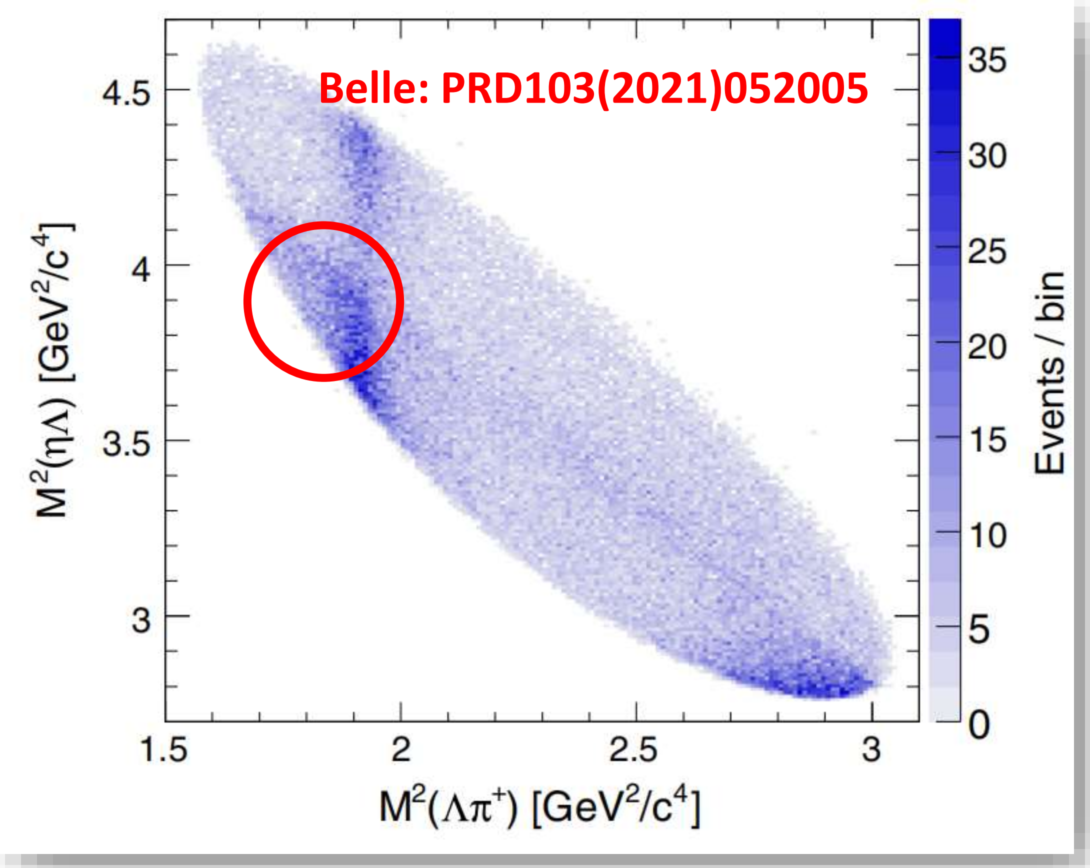




By regarding the $\Lambda(1670)$ as the molecule, we could well reproduce the Belle data of the mass distributions.

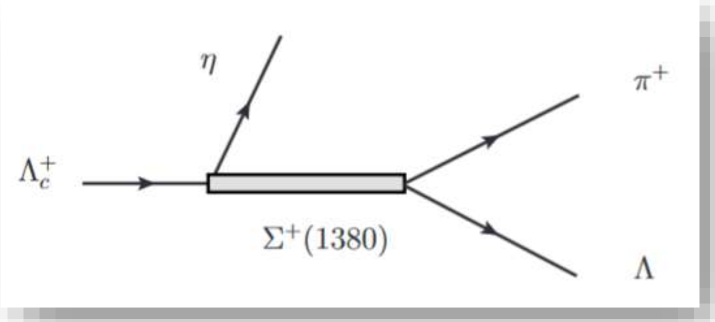
Dalitz plot of $\Lambda_c \to \eta\Lambda\pi$





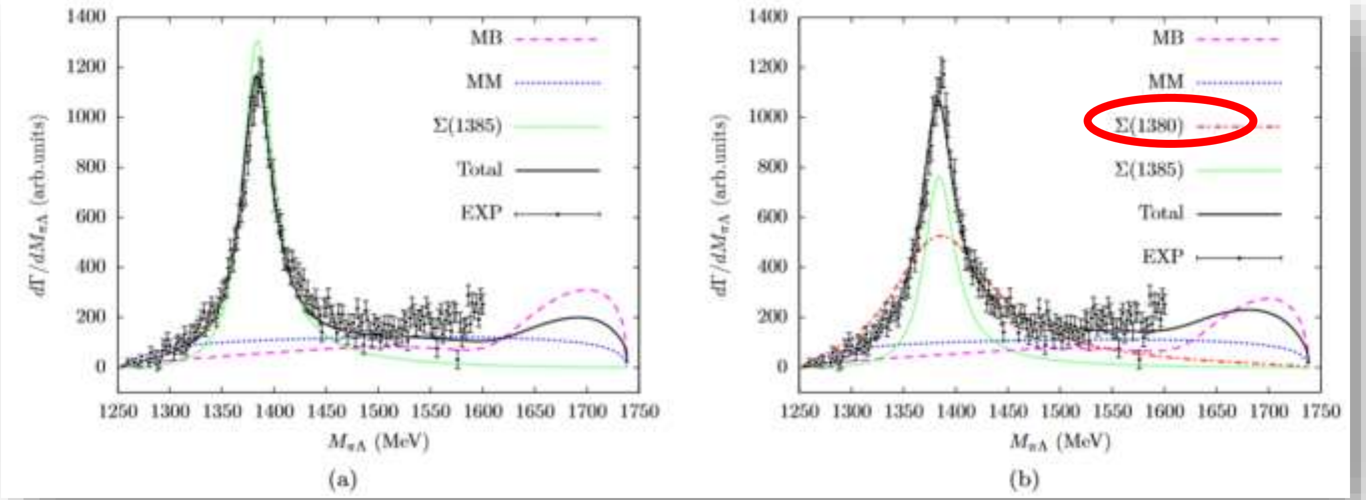
$\Sigma(1380)$ in $\Lambda_c \to \eta\Lambda\pi$

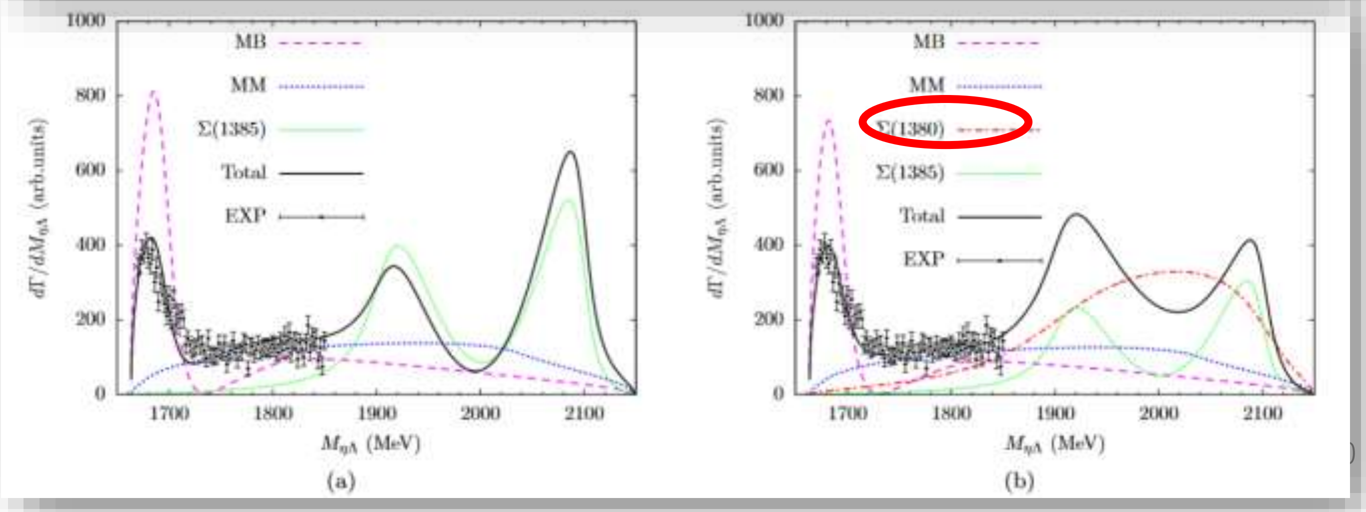
- **Intermediate of $\Sigma(1380)$**



$$\mathcal{T}^{\Sigma(1380)} = \frac{V_P''' M_{\Sigma(1380)}}{M_{\pi^+\Lambda} - M_{\Sigma(1380)} + i\frac{\Gamma_{\Sigma(1380)}}{2}},$$

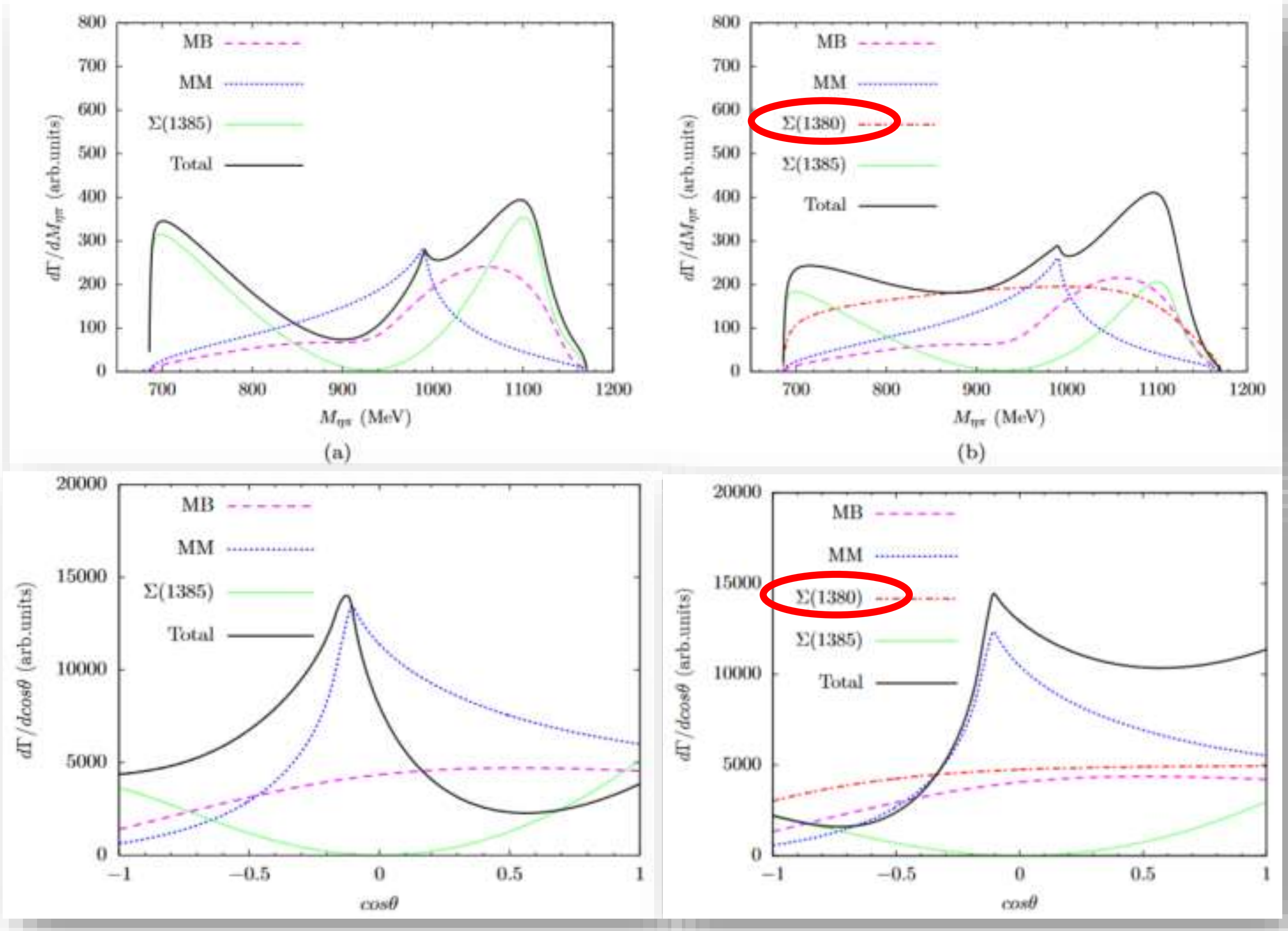
'''



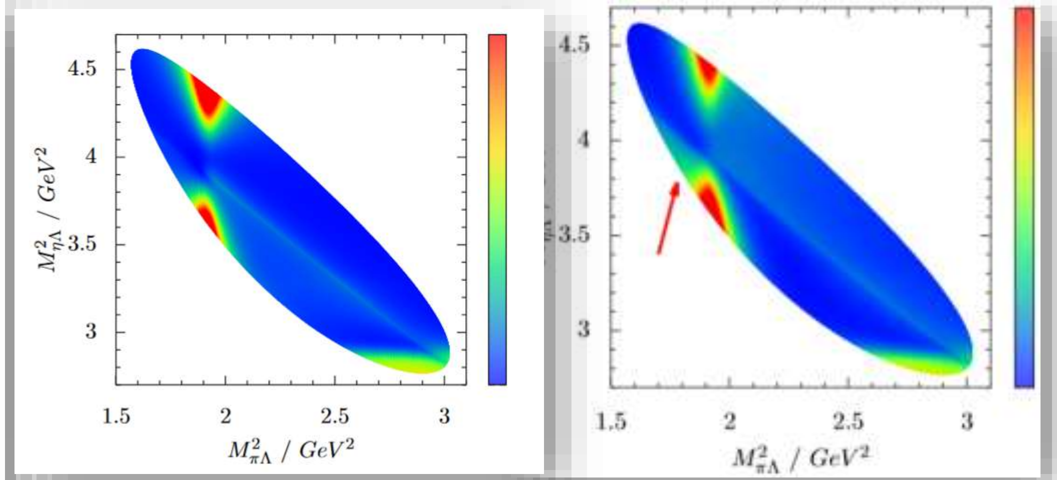


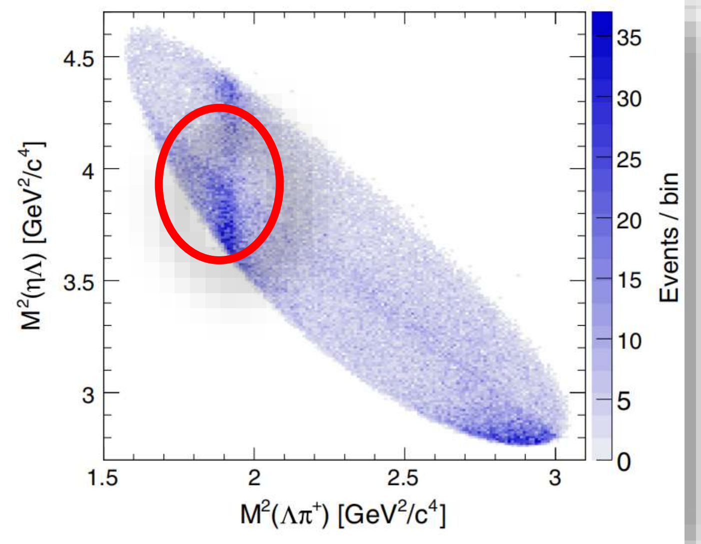
EW, JJWu, to be prepared

The results with/without Σ(1380)



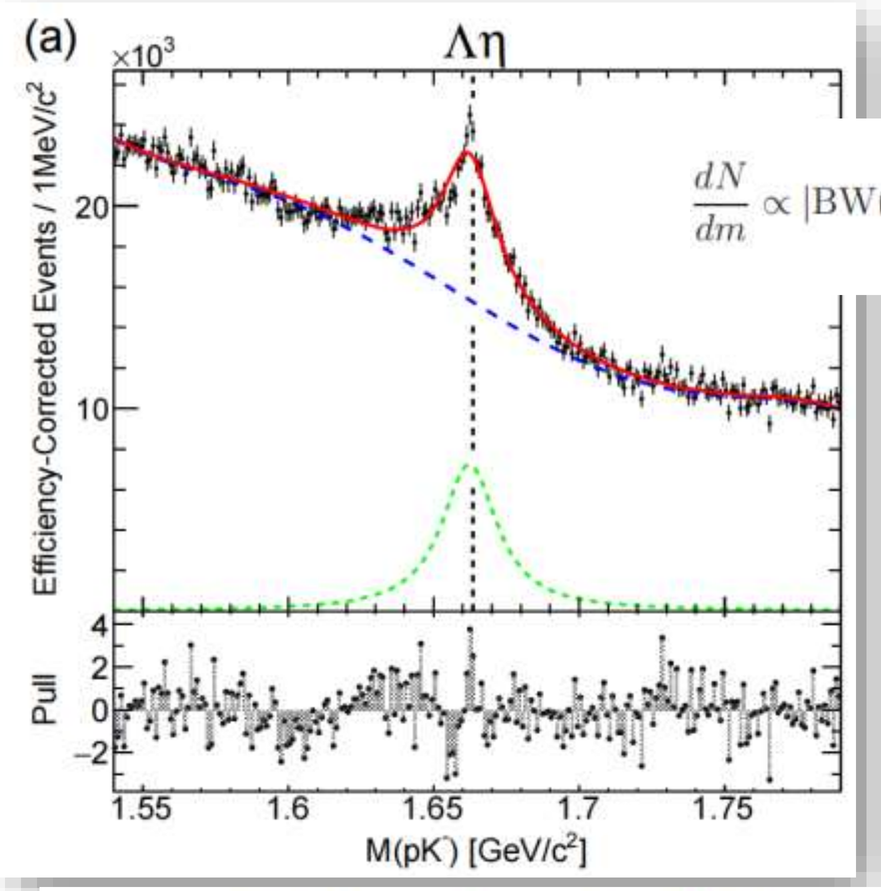
$M_{\pi\Lambda} \geq 1450$ MeV and $M_{\eta\Lambda} \geq 1760$ MeV.





EW, JJWu, to be prepared

The cusp in the $\Lambda_c \to pK\pi$

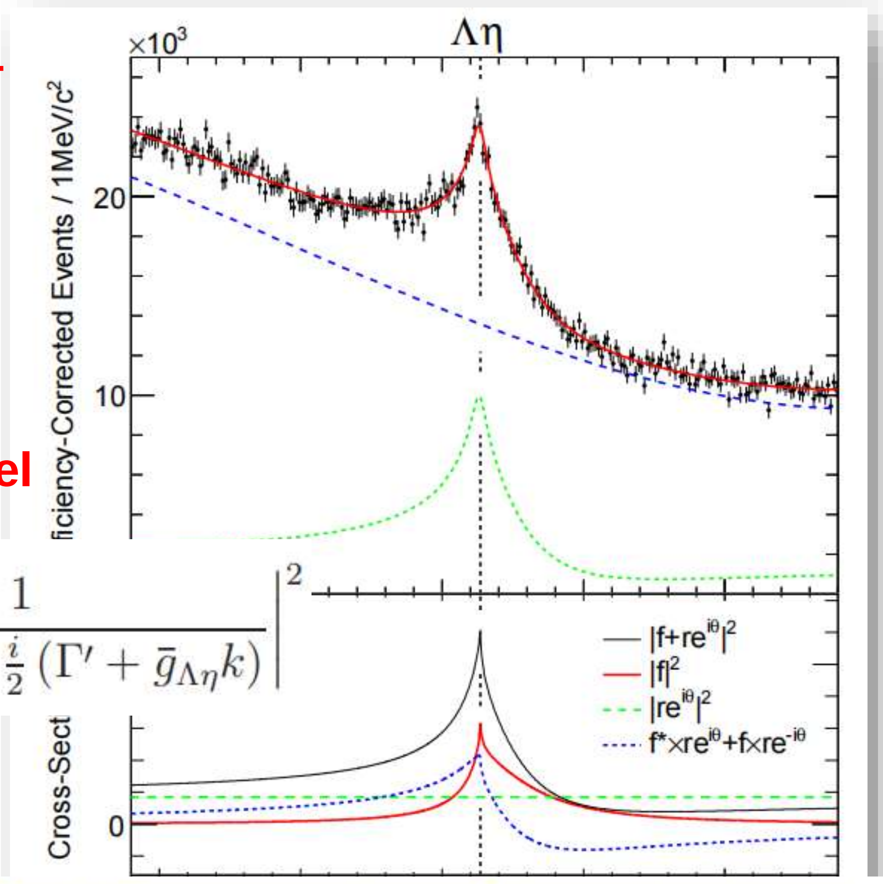


Belle: PRD108(2023)L031104

$$\frac{dN}{dm} \propto |\mathrm{BW}(m)|^2 = \left|\frac{1}{(m-m_0)+i\frac{\Gamma_0}{2}}\right|^2$$

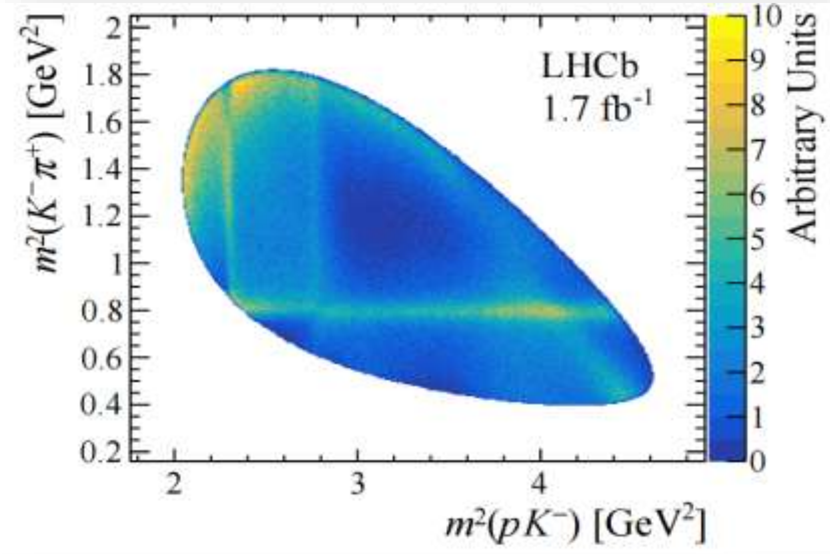
Flatte model

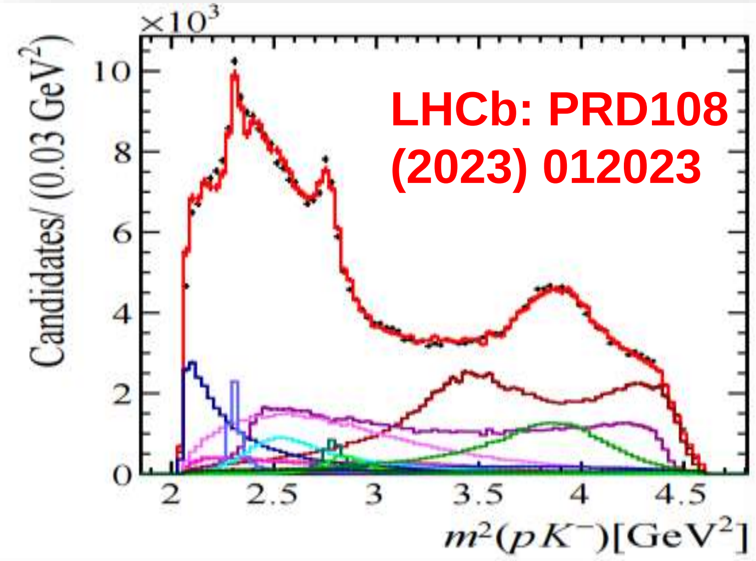
$$\frac{dN}{dm} \propto |f(m)|^2 = \left|\frac{1}{m-m_f+\frac{i}{2}(\Gamma'+\bar{g}_{\Lambda\eta}k)}\right|^2$$



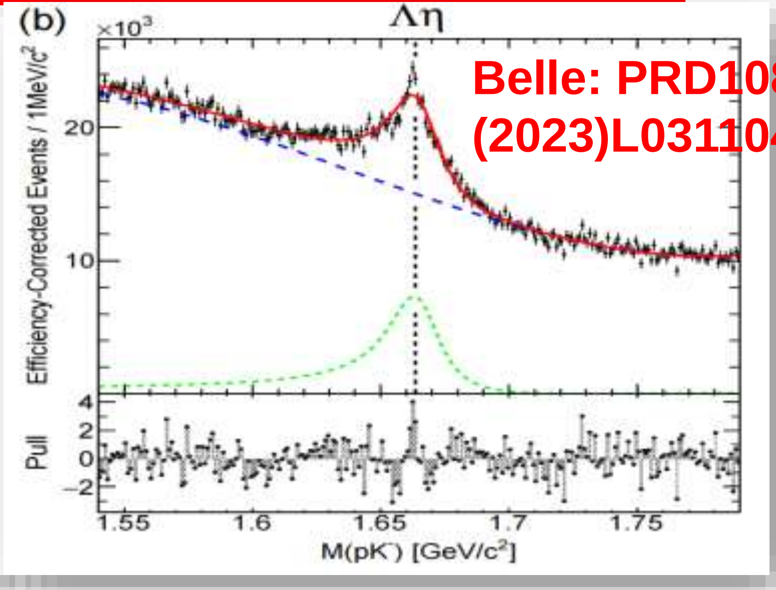
point better than the BW function. These results show that the present peaking structure is explained better by a threshold cusp than to a new hadron resonance by more than 7σ.

$\Lambda(1670)$ in $\Lambda_c \to pK^-\pi^+$

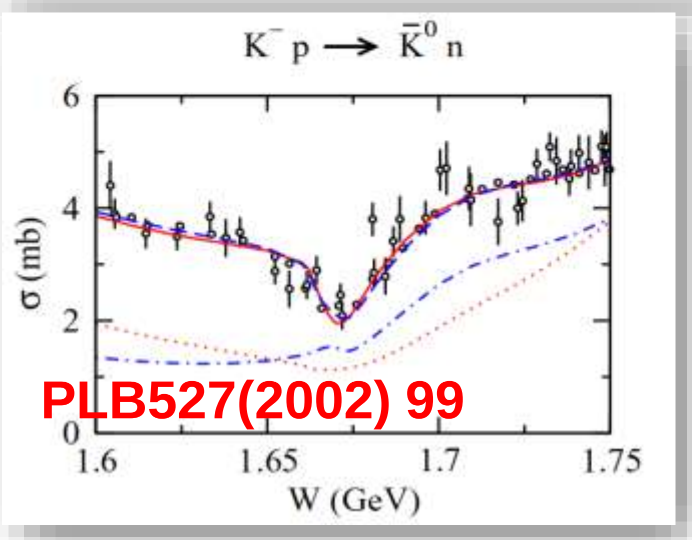




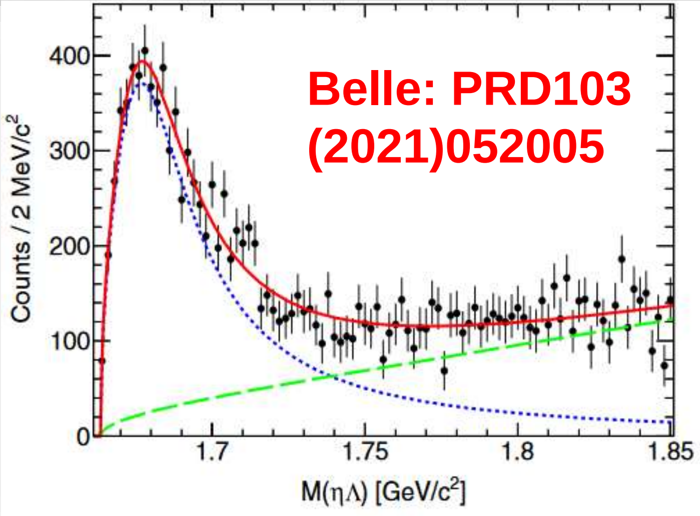
LHCb: PRD108 (2023) 012023



Belle: PRD108 (2023)L031104



PLB527(2002) 99

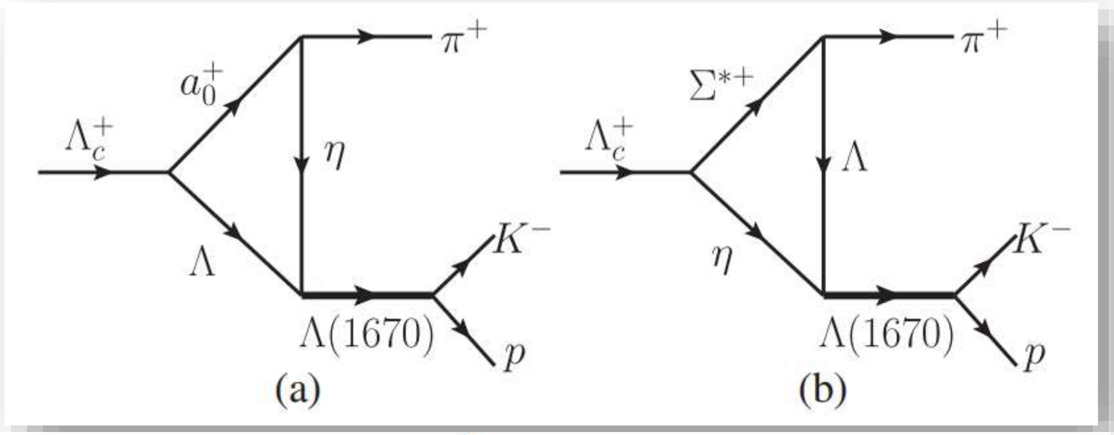


Belle: PRD103 (2021)052005

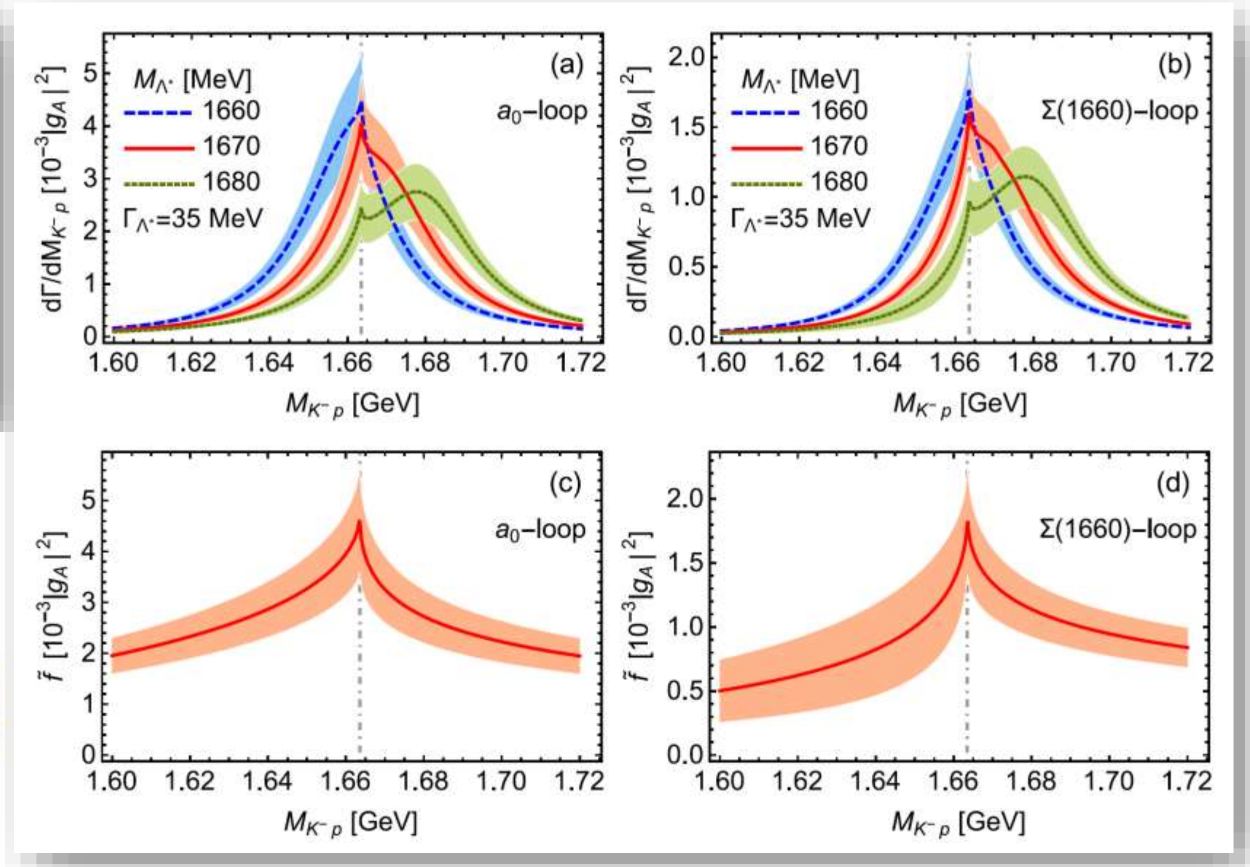
Resonances	Mass $[\mathrm{MeV}/c^2]$	Width [MeV]
$\Lambda(1670)$	$1674.3 \pm 0.8 \pm 4.9$	$36.1 \pm 2.4 \pm 4.8$
$\Sigma(1385)^+$	$1384.8 \pm 0.3 \pm 1.4$	$38.1 \pm 1.5 \pm 2.1$

$\Lambda(1670)$: cusp? Dip? peak?

TS in $\Lambda_c \to pK\pi$

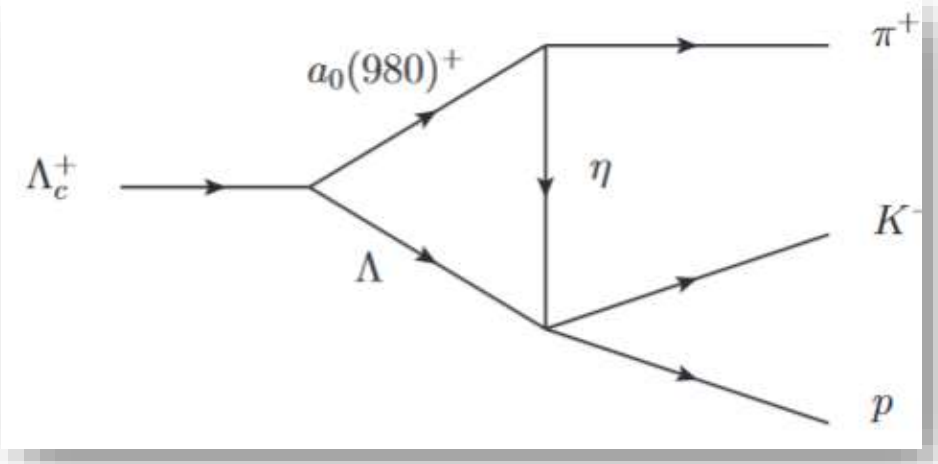


$$\mathcal{T} = \frac{1}{s - M^2_{\Lambda(1670)} + iM_{\Lambda(1670)}\Gamma_{\Lambda(1670)}} \times \int \frac{d^4 q_1}{(2\pi)^4} \frac{\mathcal{A}}{(q_1^2 - m_1^2)(q_2^2 - m_2^2)(q_3^2 - m_3^2)},$$



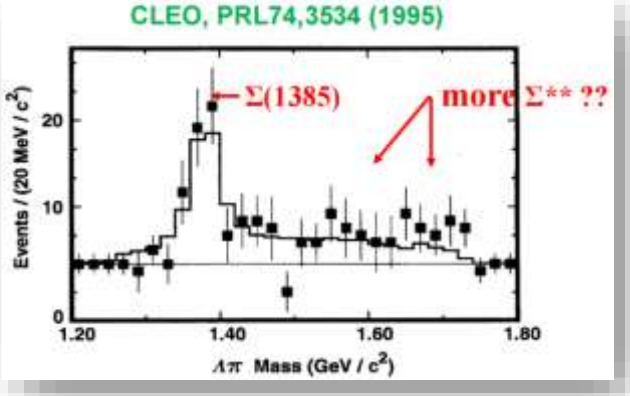
XHLiu, GLi, JJXie, and QZhao, PRD100(2019)054006

TS+ Coupled-channel effects

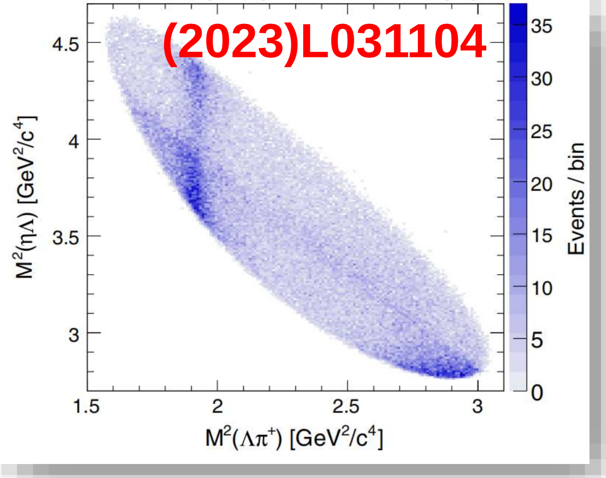


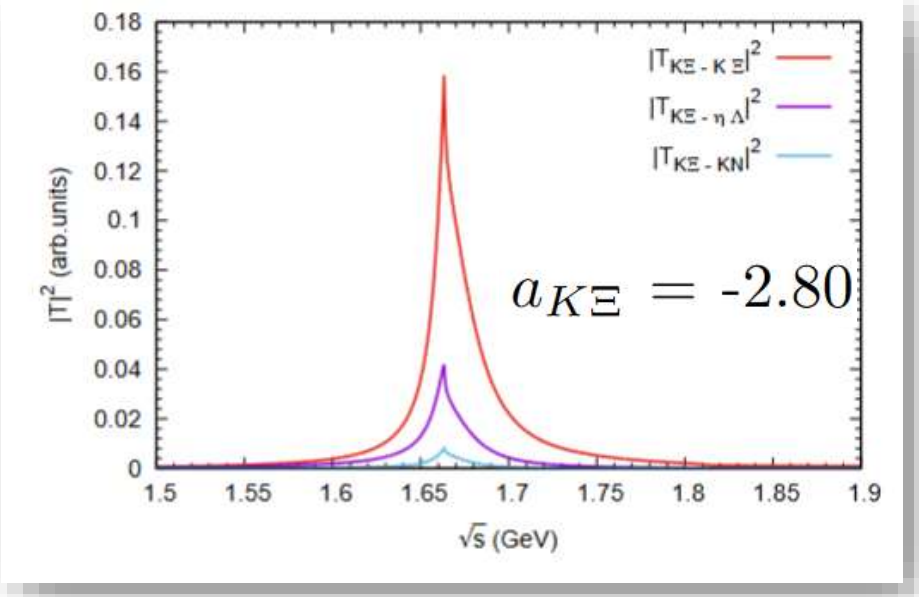
$$\mathcal{T}^{\rm TS} = \mathcal{Q} t^{TS} \times t_{\Lambda\eta\to K^- p},$$

$$t^{TS} = i\int \frac{d^4q}{(2\pi)^4}\frac{2m_1}{q^2 - m_1^2 + i\varepsilon}\frac{1}{(P-q)^2 - m_2 + i m_2\Gamma_2} \times \frac{1}{(P-q-k)^2 - m_3^2 + i\varepsilon}, \quad (10)$$



Belle: PRD108 (2023)L031104

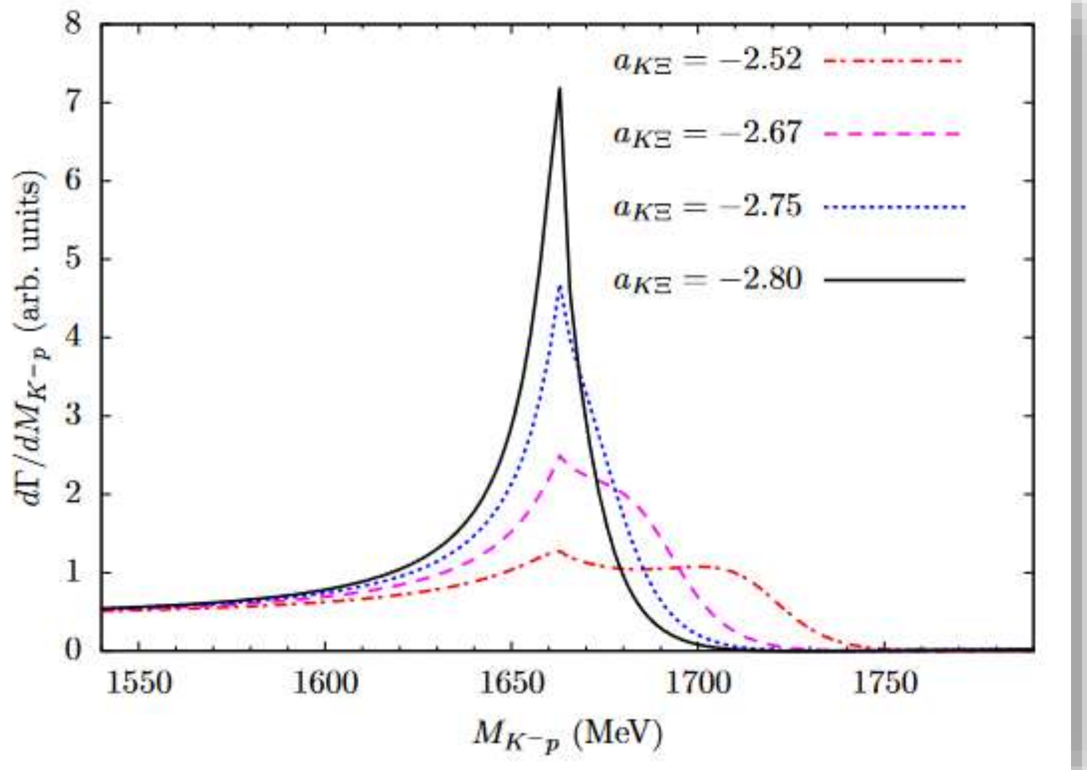


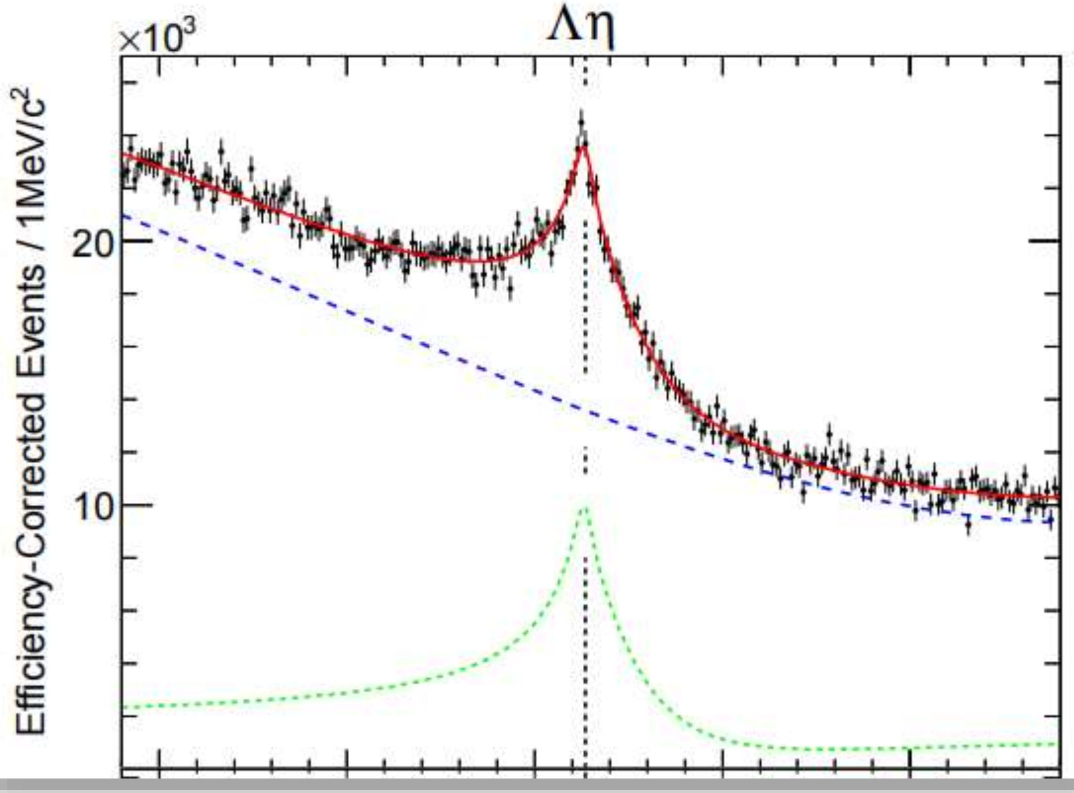


No signal of $\Sigma(1660)$

Results of the mass distribution

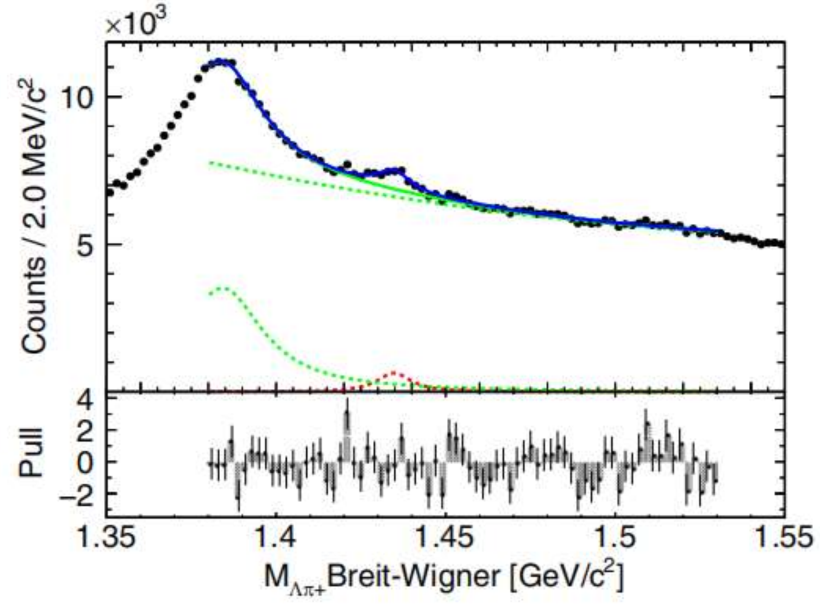
- **EW-GYWang, to be prepared**



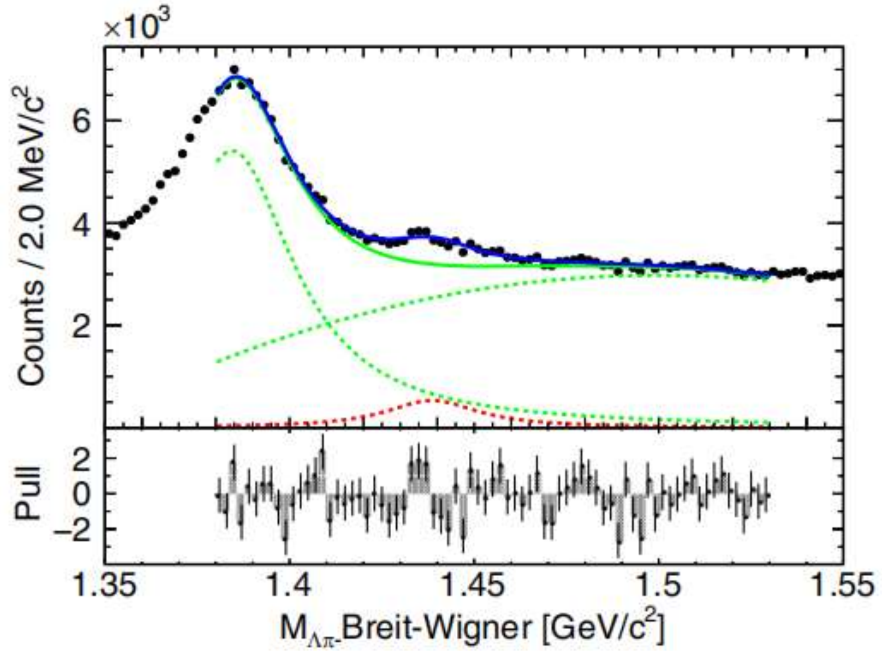


Belle measurements

- $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$, Belle, PRL130, 151903 (2023)



(a)

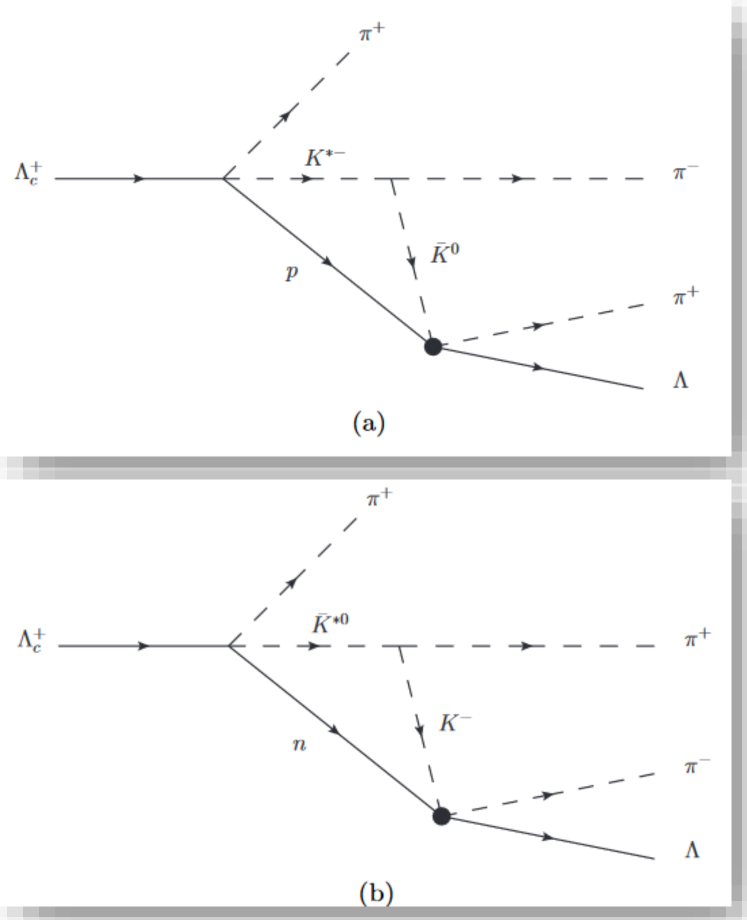


Mode	E_{BW} (MeV/c^2)	Γ (MeV/c^2)	χ^2/NDF
$\Lambda\pi^+$	1434.3 ± 0.6	11.5 ± 2.8	74.4/68
$\Lambda\pi^-$	1438.5 ± 0.9	33.0 ± 7.5	92.3/68

Evidence of $\Sigma(1430)$

- $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$, **TS**

Dai-Pavao-Sakai-Oset, PRD 97, 116004 (2018)
Xie-Oset, PLB 792, 450-453 (2019)



$$t_{\Lambda_c^+\to\pi^+K^{*-}p} = A\vec{\sigma}\cdot\vec{\epsilon},$$

$$\frac{d\Gamma_{\Lambda_c^+\to\pi^+K^{*-}p}}{dM_{\rm inv}(K^{*-}p)} = \frac{1}{(2\pi)^3}\frac{2M_{\Lambda_c^+}2M_p}{4M^2_{\Lambda_c^+}}p_{\pi^+}\tilde{p}_{K^{*-}} \times \bar{\sum}\sum|t_{\Lambda_c^+\to\pi^+K^{*-}p}|^2,$$

$$\mathcal{B}(\Lambda_c^+ \to \pi^+K^{*-}p) = (1.4\pm0.5)\times10^{-2}$$

$$|A|^2 = (3.9 \pm 1.4) \times 10^{-16}\ \mathrm{MeV}^{-2}$$

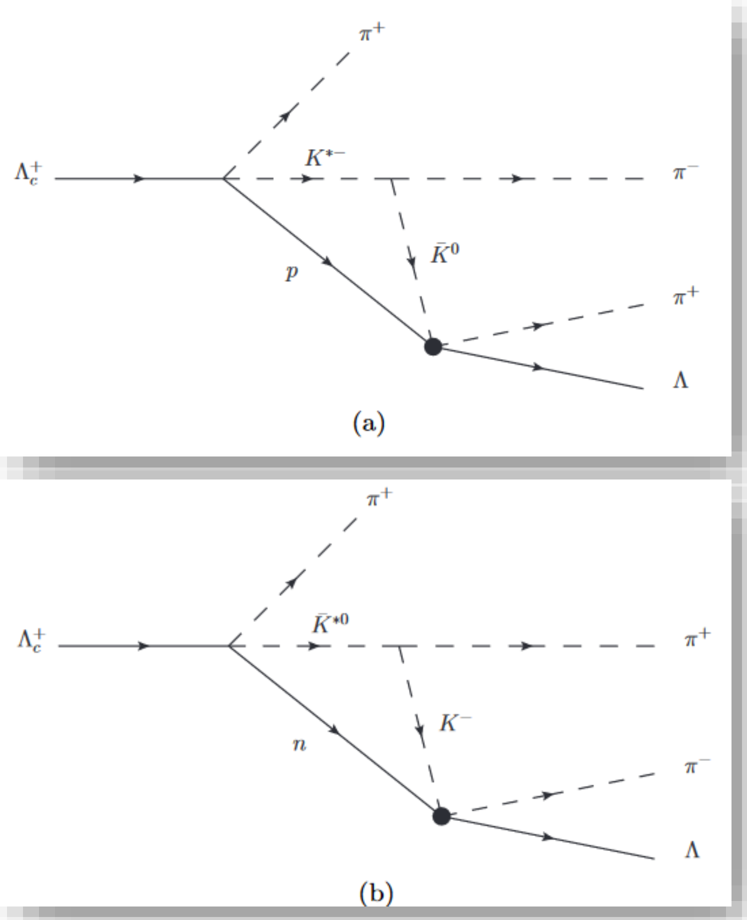
$$\mathcal{L}_{VPP} = -ig < V^\mu[P,\partial P] >$$

$$\mathcal{L}_{\bar{K}^*\to\pi\bar{K}} = -ig\left(K^{*-}\right)^\mu\left(\pi^-\partial_\mu\bar{K}^0 - \partial_\mu\pi^-\bar{K}^0\right).$$

Evidence of $\Sigma(1430)$

- $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$, **TS**

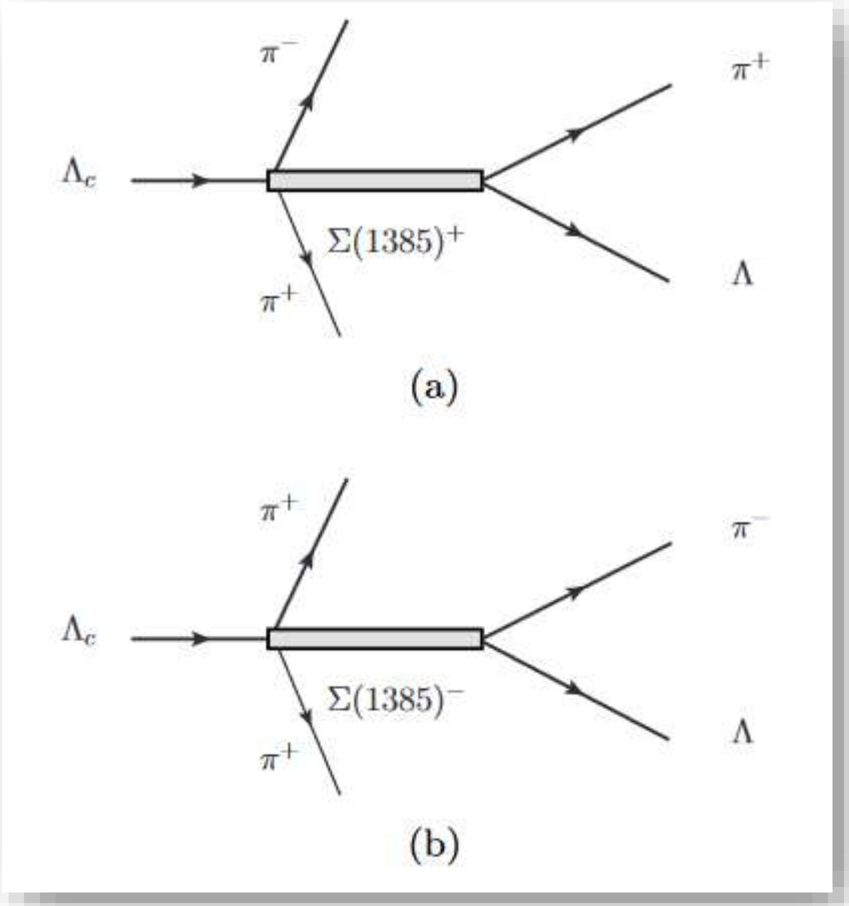
Dai-Pavao-Sakai-Oset, PRD 97, 116004 (2018)
Xie-Oset, PLB 792, 450-453 (2019)



$$t_T^a = \int \frac{d^3q}{(2\pi)^3} \frac{2M_p}{8\omega_p\omega_{K^{*-}}\omega_{\bar{K}^0}} \frac{1}{k_a^0 - \omega_{K^{*-}} - \omega_{\bar{K}^0} + i\frac{\Gamma_{K^{*-}}}{2}}$$
$$\times \frac{1}{P^0 + \omega_p + \omega_{\bar{K}^0} - k_a^0}\left(2 + \frac{\vec{q}\cdot\vec{k}}{|\vec{k}|^2}\right)$$
$$\times \frac{2P^0\omega_p + 2k_a^0\omega_{\bar{K}^0} - 2(\omega_p + \omega_{\bar{K}^0})(\omega_p + \omega_{\bar{K}^0} + \omega_{K^{*-}})}{P^0 - \omega_{K^{*-}} - \omega_p + i\frac{\Gamma_{K^{*-}}}{2}}$$
$$\times \frac{1}{P^0 - \omega_p - \omega_{\bar{K}^0} - k_a^0 + i\varepsilon}, \qquad (19)$$

Evidence of Σ(1430)

- $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$, TS



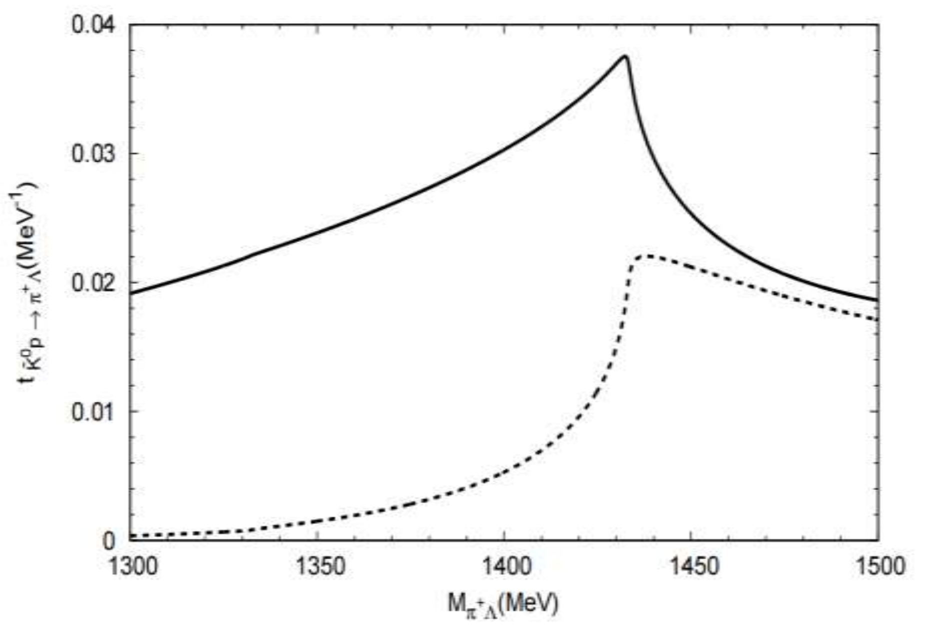
$$T^{\Sigma^{*+}(1385)} = \frac{V_p|p_{\pi^+}|}{M_{\pi^+\Lambda} - M_{\Sigma^{*+}} + i\frac{\Gamma_{\Sigma^{*+}}}{2}},$$

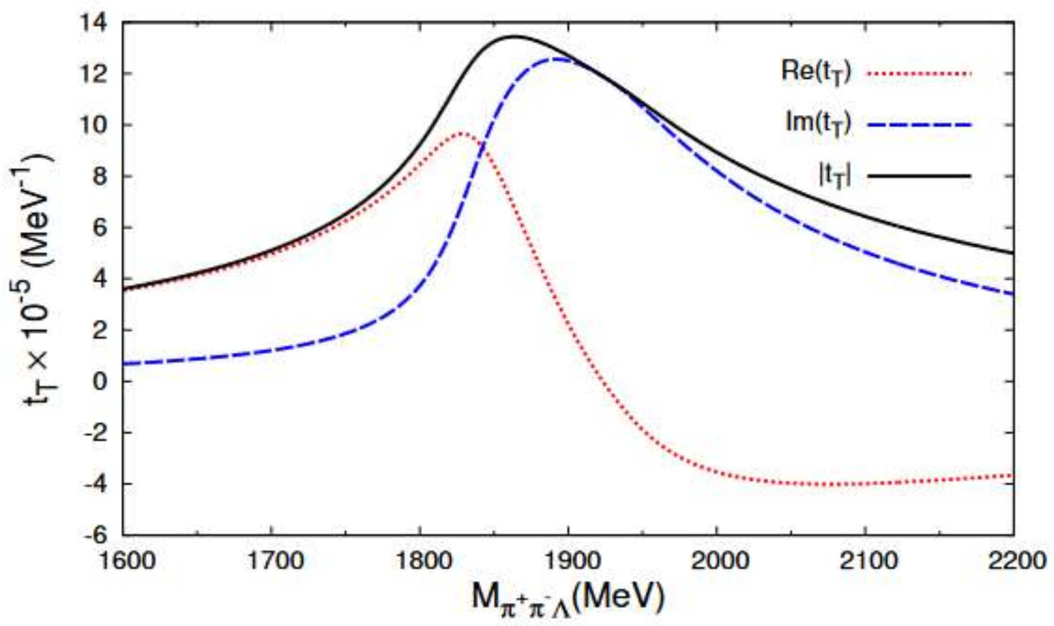
$$T^{\Sigma^{*-}(1385)} = \frac{V_p|p_{\pi^-}|}{M_{\pi^-\Lambda} - M_{\Sigma^{*-}} + i\frac{\Gamma_{\Sigma^{*-}}}{2}},$$

$$\frac{d^3\Gamma}{dM_{\pi^+\pi^-\Lambda}dM_{\pi^+\Lambda}dM_{\pi^-\Lambda}} = \frac{g^2|A|^2}{64\pi^5}\frac{M_\Lambda}{M_{\Lambda_c^+}}\tilde{p}_{\pi^+}\frac{M_{\pi^+\Lambda}M_{\pi^-\Lambda}}{M_{\pi^+\pi^-\Lambda}}$$
$$\Big\{|\vec{k}_a|^2|t_T^a\mathcal{M}^a|^2 + |\vec{k}_b|^2|t_T^b\mathcal{M}^b|^2 + 2\mathrm{Re}[t_T^a\mathcal{M}^a(t_T^b\mathcal{M}^b)^*]$$
$$\times\vec{k}_a\cdot\vec{k}_b + |T^{\Sigma^{*+}(1385)}|^2 + |T^{\Sigma^{*-}(1385)}|^2\Big\}, \qquad (29)$$

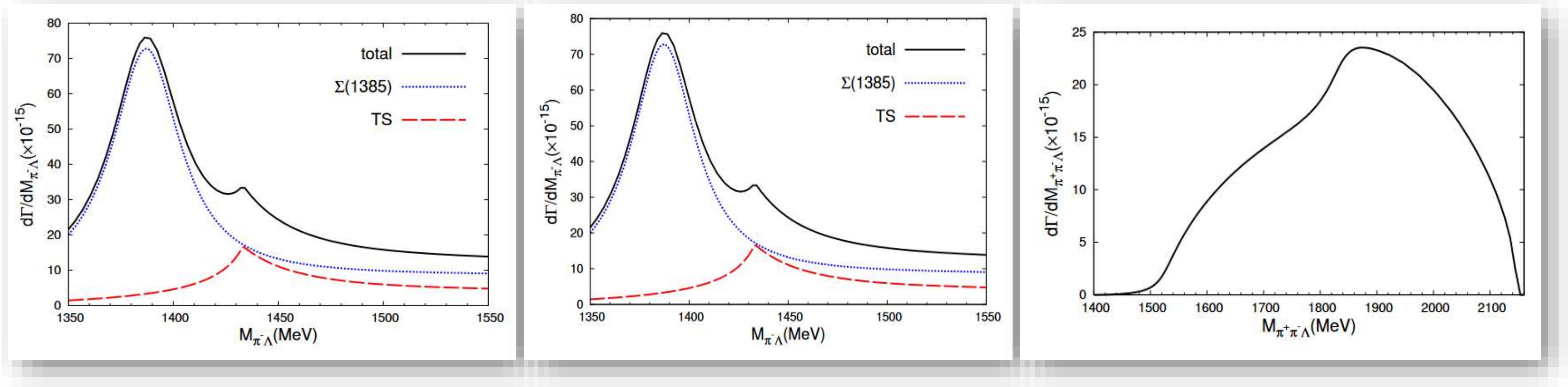
Evidence of $\Sigma(1430)$

- $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$, Lyu-GYW-EW-Xie-Geng, to prepare





Results of $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$



Cusp signal of $\Sigma(1/2^-)$ around $\bar{K}N$ threshold!

Summary

- Belle measurements of $\Lambda_c \to \eta\Lambda\pi$ show some hints of the $\Sigma(1/2^-)$, and the more precise measurements could be used to test the existence of $\Sigma(1/2^-)$.
- The cusp observe in the pK^- mass distribution of $\Lambda_c \to pK^-\pi^+$ should be due to the TS and $\Lambda(1670)$, and the line-shape could be used to constrain the theoretical parameter.
- The cusp structure around 1430 MeV in $\Lambda_c \to \Lambda\pi\pi\pi$ could be associated with the $\Sigma(1430)$.

Thank you very much!