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

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第九届手征有效场论研讨会

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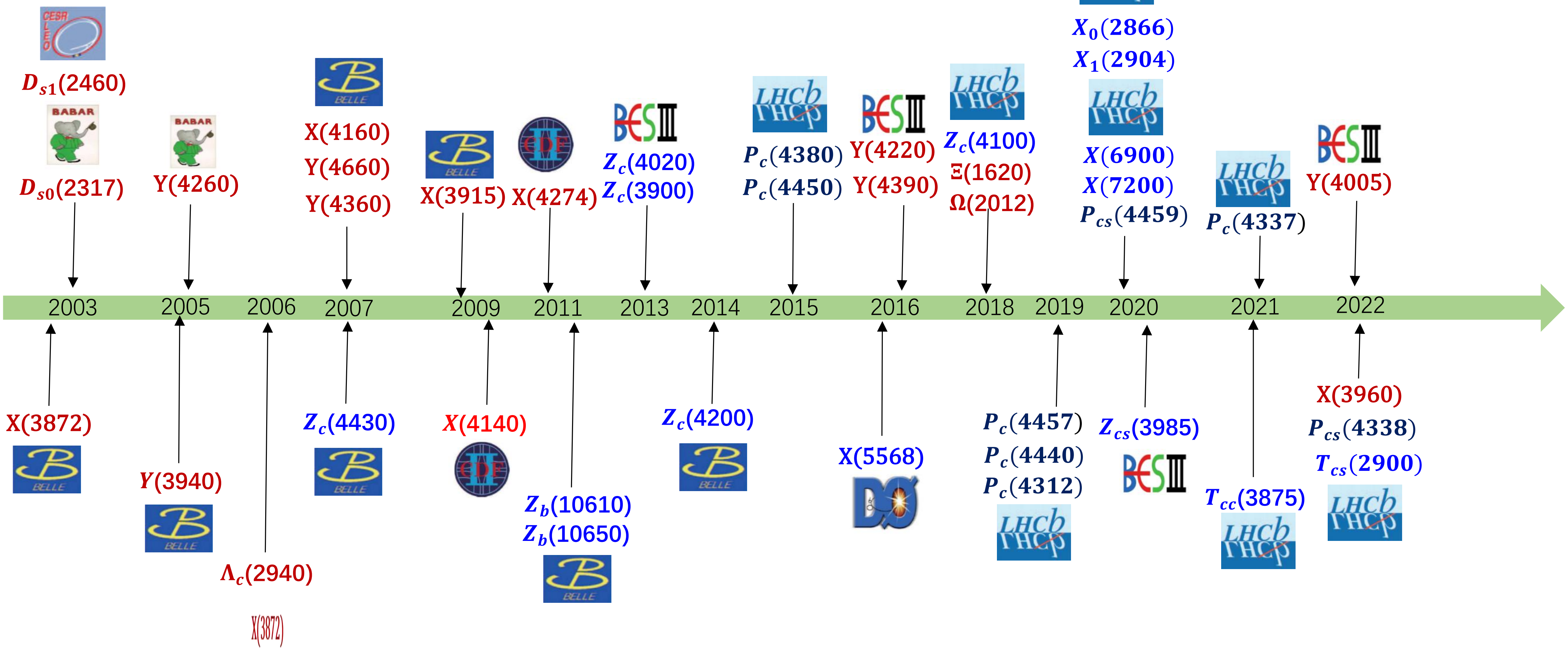
EW, LSGeng, JJWu, JJXie, and BSZou, Chin. Phys. Lett. 41, 101401 [arXiv:2406.07839]

Exotic states

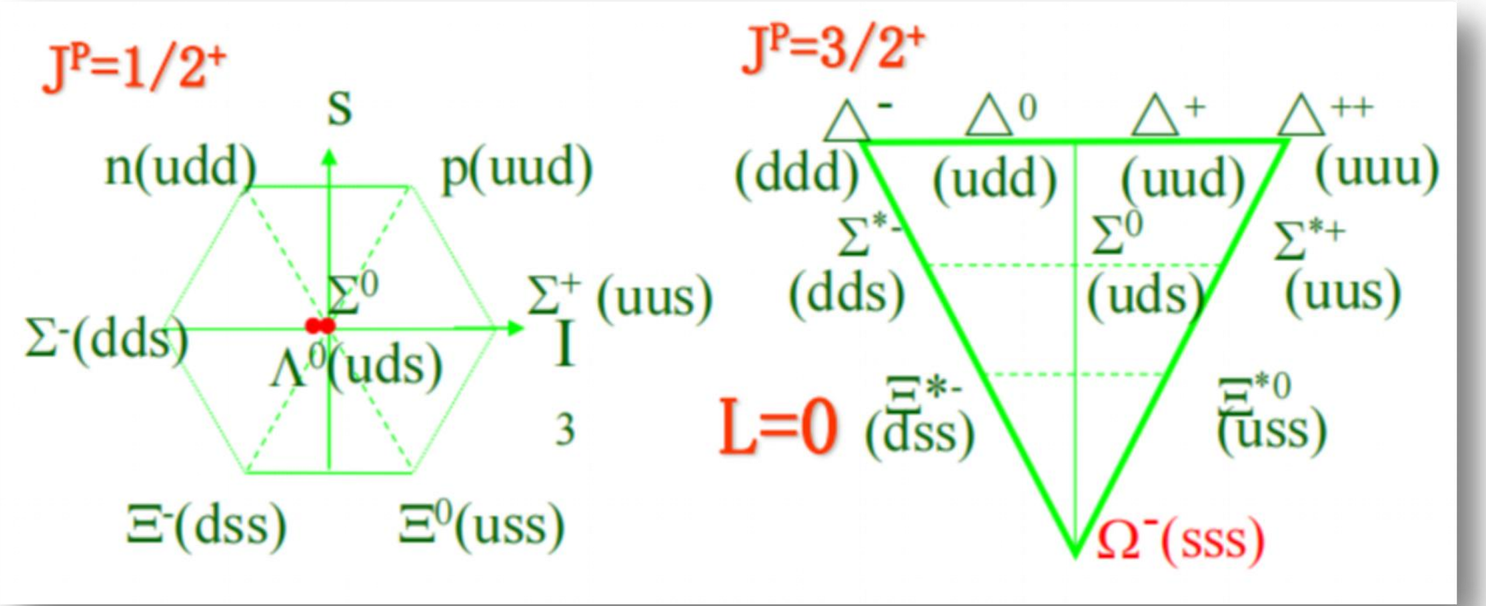
耿立升老师报告

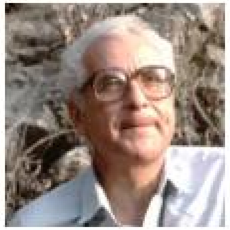
Exotic mesons or baryons **Tetraquark states** **Pentaquark states**



Ground light baryons

□ground baryons





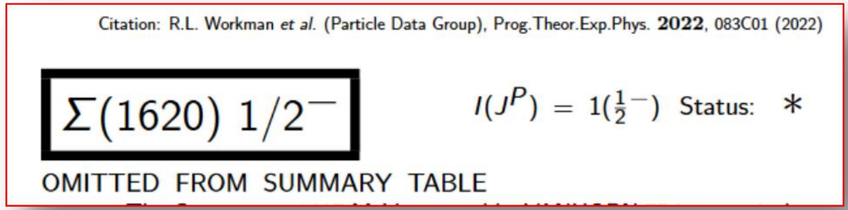

盖尔曼-大久保质量: $M = a + bY + c\left[I(I+1) - \frac{1}{4}Y^2\right]$

质量公式预言 m_Ω=1670 MeV

实验: m_Ω=1672.45±0.29 MeV

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

- Two poles of $\Lambda(1405)$
- mass reverse problem
- Large couplings of N(1535) to $N\eta$, $K\Lambda$
- Different lineshapes of $\Lambda(1670)$
- Missing $\Sigma(1/2^-)$



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

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

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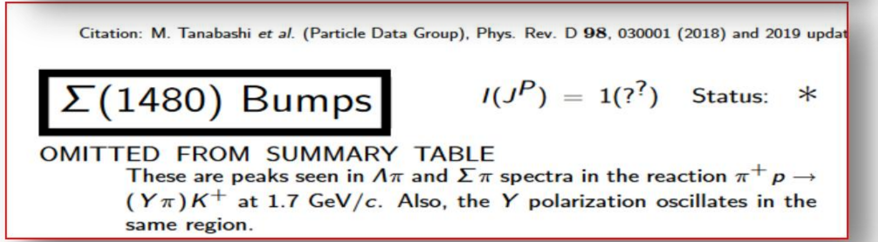
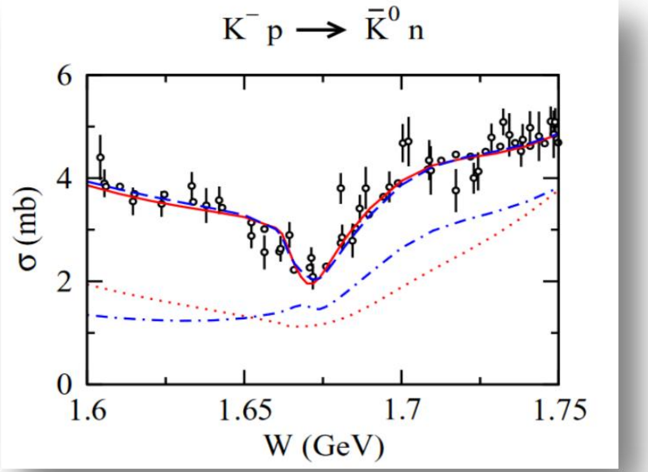


Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018) and 2019 updat

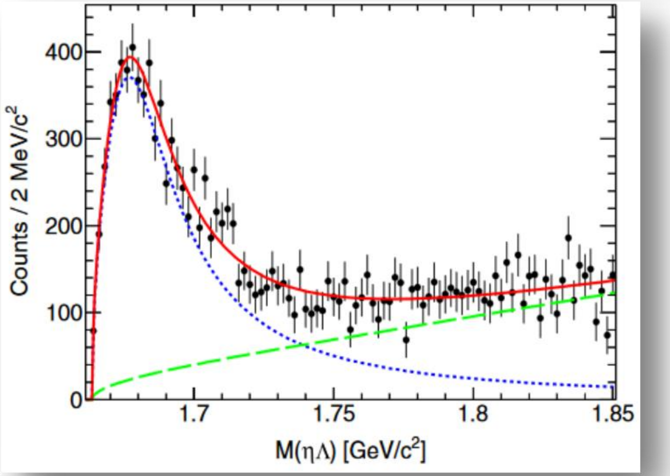
$\Sigma(1480)$ Bumps $I(J^P) = 1(?^?)$ Status: $*$

OMITTED FROM SUMMARY TABLE

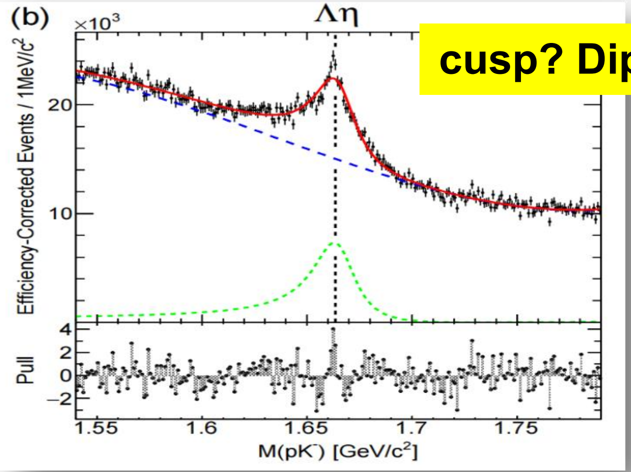
These are peaks seen in $\Lambda\pi$ and $\Sigma\pi$ spectra in the reaction $\pi^+ p \to (Y\pi)K^+$ at 1.7 GeV/c. Also, the Y polarization oscillates in the same region.



PLB527(2002) 99



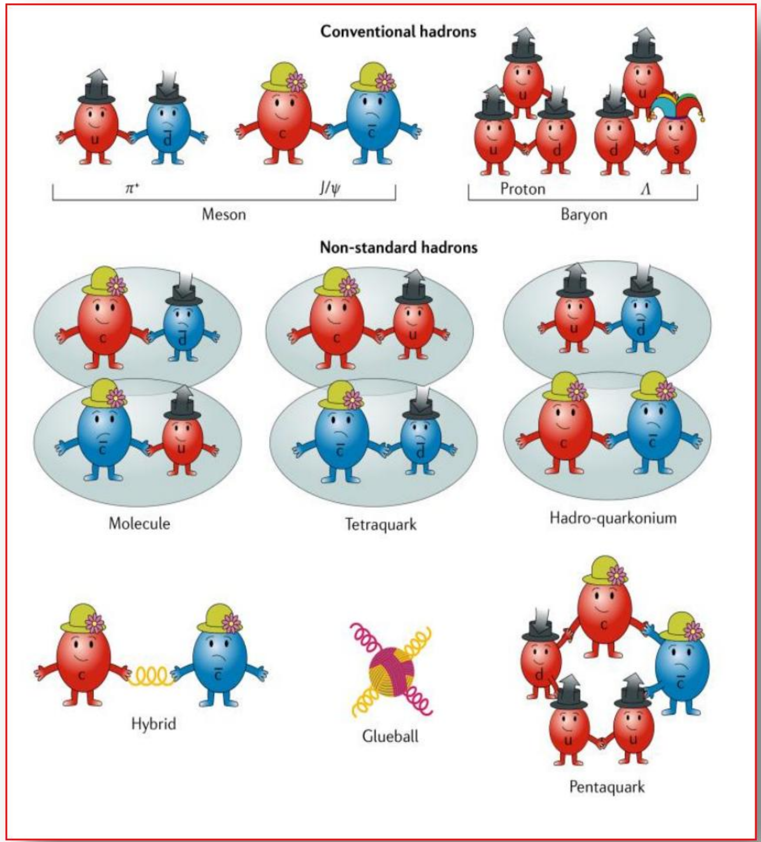
Belle, PRD103(2021)052005

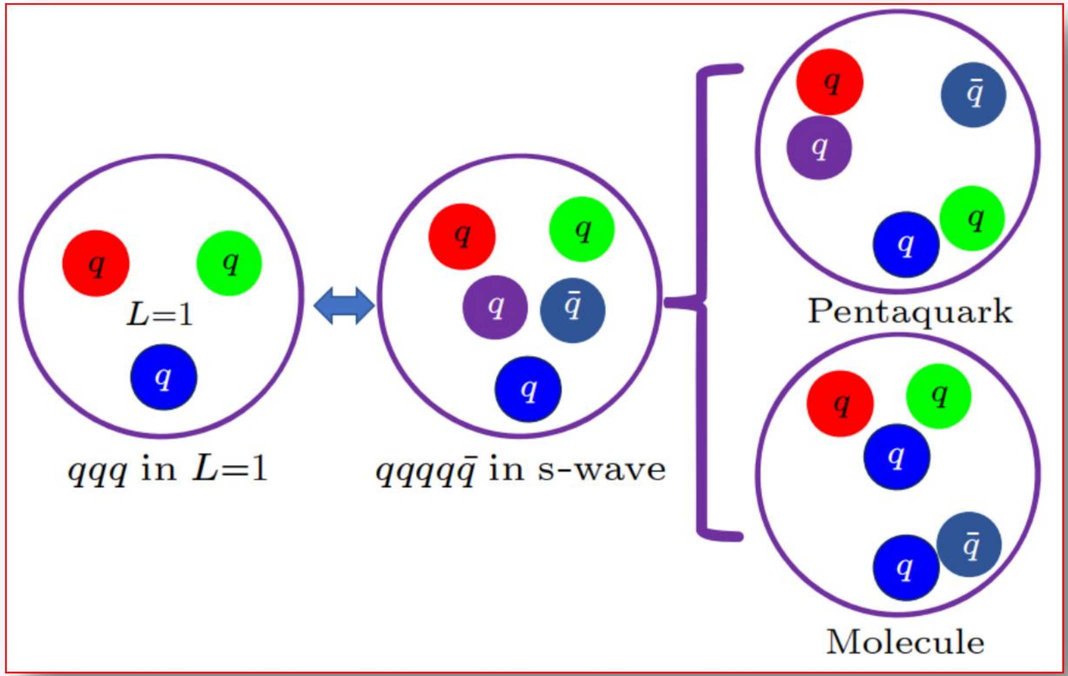


cusp? Dip? peak?

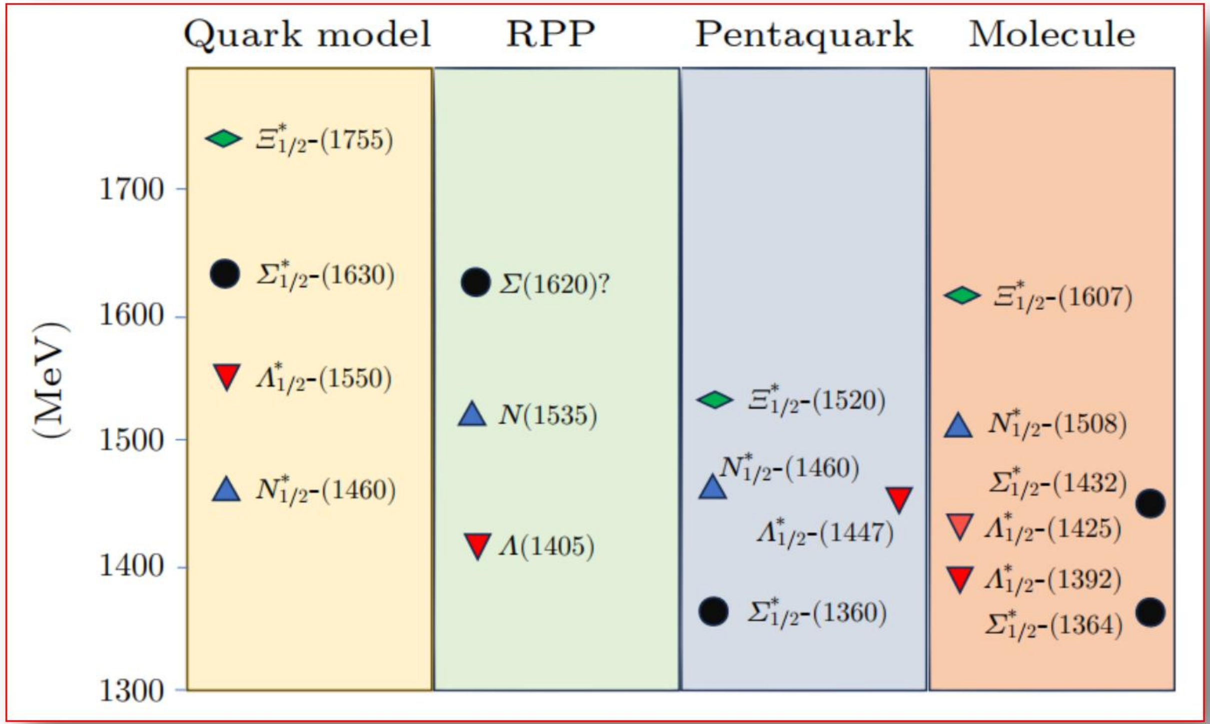
Belle: PRD108 (2023) L031104

Exotic structures of Hadrons

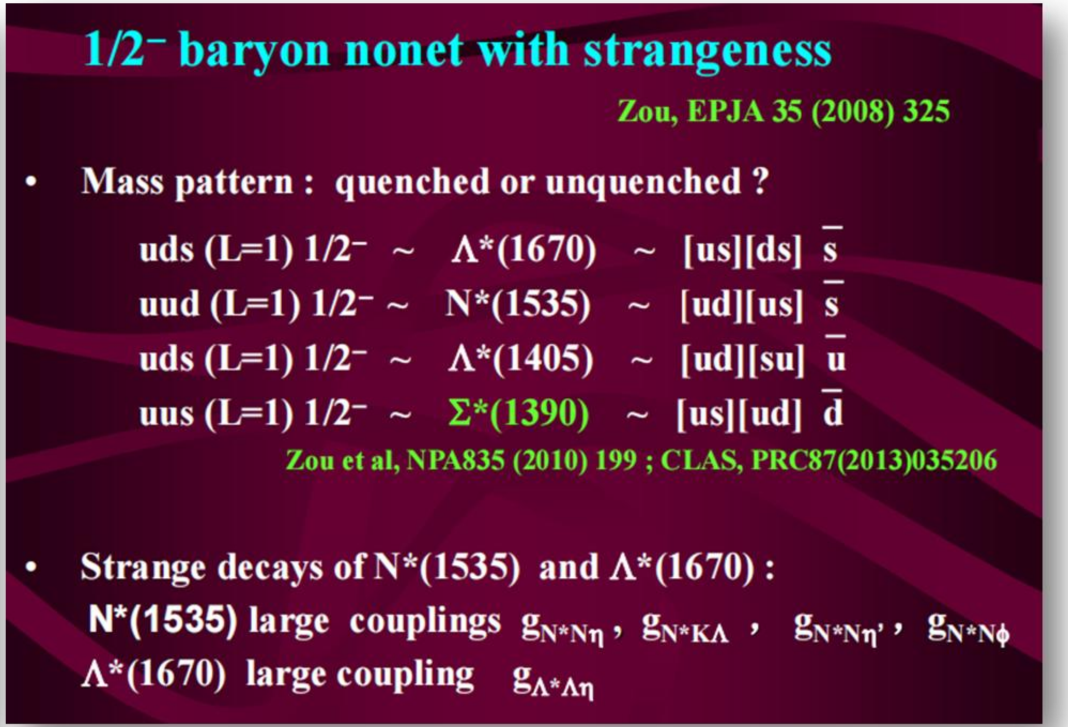




C.Z.Yuan, Nature Rev. Phys. 1 (2019) 480



Quark model
RPP
Pentaquark
Molecule
(MeV)
1700
1600
1500
1400
1300
$\Xi^*_{1/2^-}$(1755)
$\Sigma^*_{1/2^-}$(1630)
$\Lambda^*_{1/2^-}$(1550)
$N^*_{1/2^-}$(1460)
Σ(1620)?
N(1535)
Λ(1405)
$\Xi^*_{1/2^-}$(1520)
$N^*_{1/2^-}$(1460)
$\Lambda^*_{1/2^-}$(1447)
$\Sigma^*_{1/2^-}$(1360)
$\Xi^*_{1/2^-}$(1607)
$N^*_{1/2^-}$(1508)
$\Sigma^*_{1/2^-}$(1432)
$\Lambda^*_{1/2^-}$(1425)
$\Lambda^*_{1/2^-}$(1392)
$\Sigma^*_{1/2^-}$(1364)



1/2⁻ baryon nonet with strangeness
Zou, EPJA 35 (2008) 325
• Mass pattern : quenched or unquenched ?
uds (L=1) 1/2⁻ ~ Λ*(1670) ~ [us][ds] $\bar{s}$
uud (L=1) 1/2⁻ ~ N*(1535) ~ [ud][us] $\bar{s}$
uds (L=1) 1/2⁻ ~ Λ*(1405) ~ [ud][su] $\bar{u}$
uus (L=1) 1/2⁻ ~ Σ*(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 $g_{\Lambda^*\Lambda\eta}$

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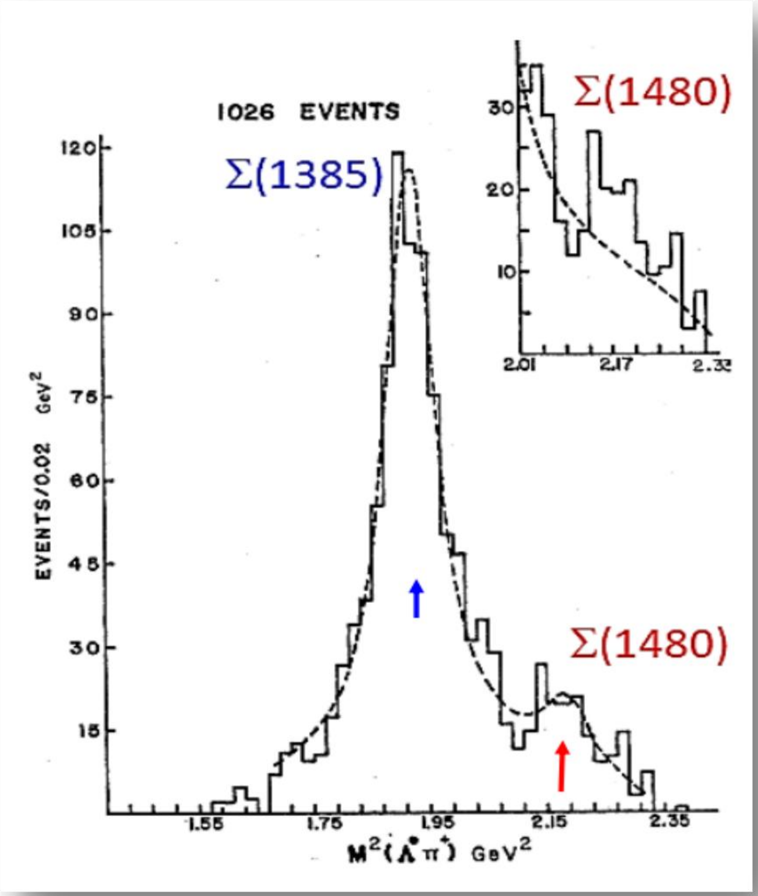
Exp. signals of Σ(1480)

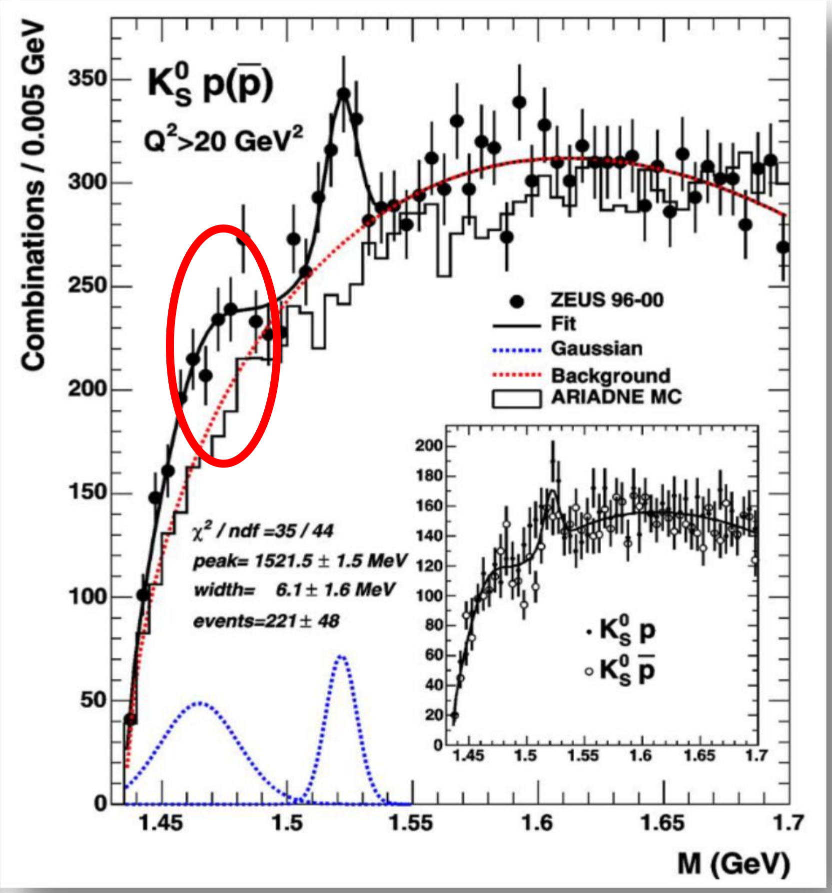
$\pi^+ p \to \pi^+ K^+ \Lambda$

Yu-Li Pan et al, PRD2, 449 (1970)



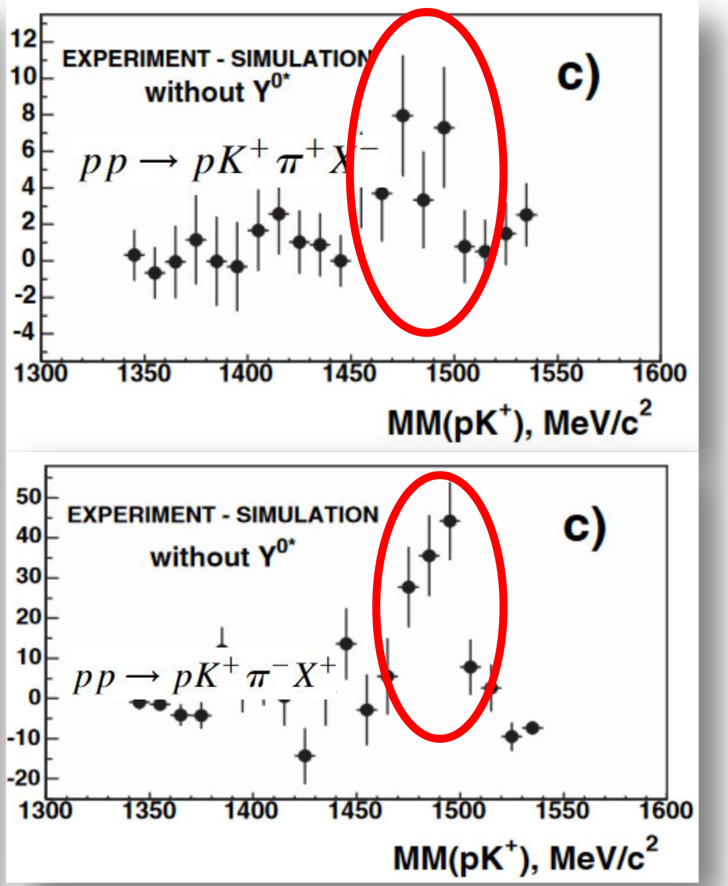
$e^+ p \to e^+ K^0 \mathrm{pX}$

ZEUS PLB591 (2004) 7–22



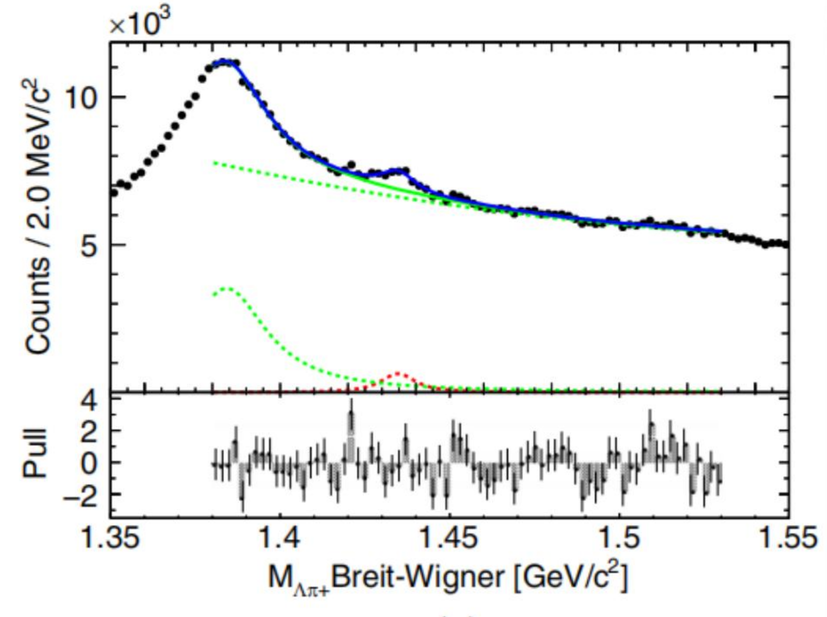
$pp \to pK^+ Y^{0*}$

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

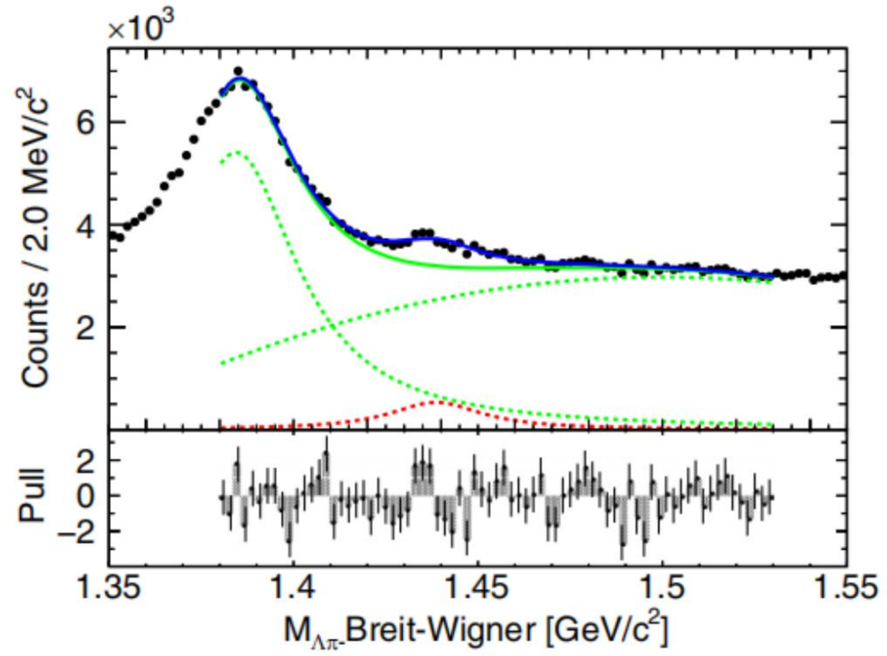


$\Sigma(1/2^-)$-like structure

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



(a)



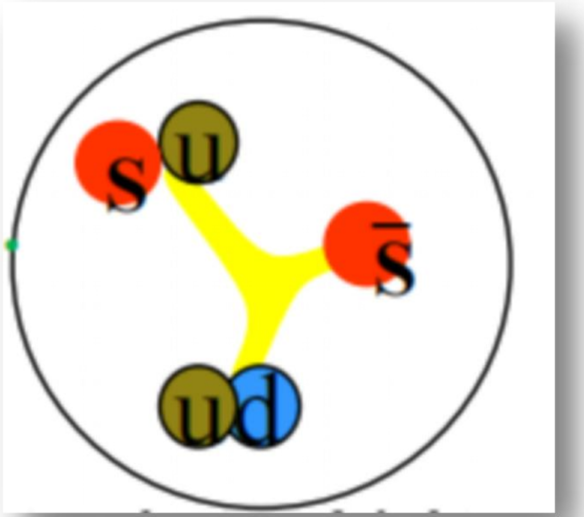
Mode	E_{BW} (MeV/c^2)	Γ (MeV/c^2)	χ^2/NDF
$\Lambda\pi^+$	1434.3 ± 0.6	11.5 ± 2.8	74.4/68
$\Lambda\pi^-$	1438.5 ± 0.9	33.0 ± 7.5	92.3/68

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

- **Pentaquark**, S. L. Zhu, etc. High Energy Phys. Nucl. Phys. 29, 250(2005).

Table 2. Flavor wave functions and masses of the $\frac{1}{2}^-$ pentaquark octet and singlet.

	(Y,I)	I_3	flavor wave functions	masses (MeV)
p_8	$(1,\frac{1}{2})$	$\frac{1}{2}$	$[su][ud]\bar{s}$	1460
n_8		$-\frac{1}{2}$	$[ds][ud]\bar{s}$	1460
Σ_8^+	$(0,1)$	1	$[su][ud]\bar{d}$	1360
Σ_8^0		0	$\frac{1}{\sqrt{2}}([su][ud]\bar{u}+[ds][ud]\bar{d})$	1360
Σ_8^-		-1	$[ds][ud]\bar{u}$	1360
Λ_8	$(0,0)$	0	$\frac{[ud][su]\bar{u}+[ds][ud]\bar{d}-2[su][ds]\bar{s}}{\sqrt{6}}$	1533
Ξ_8^0	$(-1,\frac{1}{2})$	$\frac{1}{2}$	$[ds][su]\bar{d}$	1520
Ξ_8^-		$-\frac{1}{2}$	$[ds][su]\bar{u}$	1520
Λ_1	$(0,0)$	0	$\frac{[ud][su]\bar{u}+[ds][ud]d+[su][ds]\bar{s}}{\sqrt{3}}$	1447



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

- **Pentaquark,** C. Helminen and D. O. Riska, NPA699, 624(2002).

$[4]_X[1111]_{CFS}[211]_C$ $[f]_{FS}[f]_F[f]_S$	Energy (MeV)	J^P	Λ (emp.)	Σ (emp.)
$[31]_{FS}[211]_F[22]_S$	1509	$\frac{1}{2}^-$	$\Lambda(1405)$	$\Sigma(1560)(**)$
$[31]_{FS}[211]_F[31]_S$	1565	$\frac{1}{2}^-$		$\Sigma(1560)(**)$, $\Sigma(1620)(**)$
		$\frac{3}{2}^-$	$\Lambda(1520)$	$\Sigma(1580)(**)$

unknown. If indeed the $\Lambda(1405)$ is partly a 5-quark state, it would be natural to expect the $\Sigma(1560)$ to be the analog of the $\Lambda(1405)$, and thus that it has $J^P=\frac{1}{2}^-$. This is indeed what the structure of the $qqqq\bar{q}$ spectrum shown in Table 7 indicates. This would also explain why the usual quark-model description of the baryons as 3-quark states cannot predict sufficiently low energies for the $\Lambda(1405)$ and $\Sigma(1560)$ [4]. The $\Sigma(1480)(*)$

PDG2001

$\Sigma(1560)$ Bumps $I(J^P) = 1(?^?)$ Status: $**$

OMITTED FROM SUMMARY TABLE

This entry lists peaks reported in mass spectra around 1560 MeV without implying that they are necessarily related.

VALUE (MeV)	*EVTS*
≈ 1560 OUR ESTIMATE	
1553±7	121
1572±4	40

VALUE (MeV)
79±30
15± 6

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

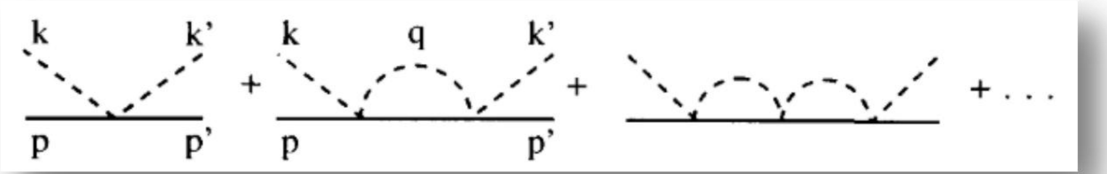
□Chiral Lagrangian

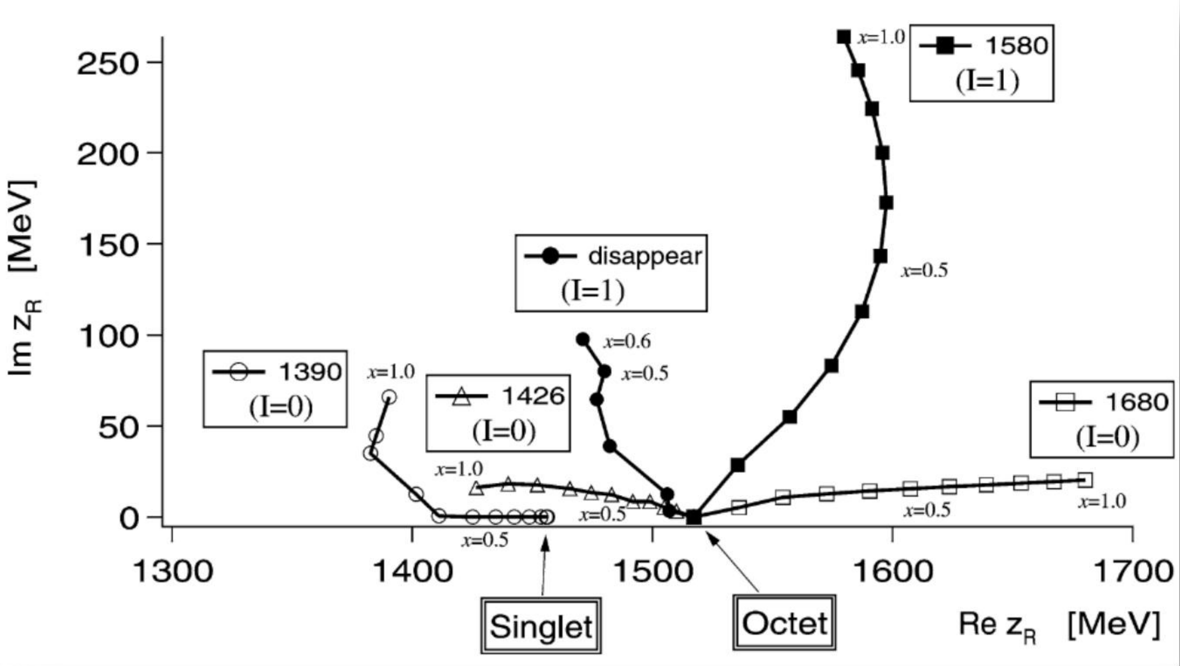
$$L_1^{(B)} = \langle \bar{B} i\gamma^\mu \nabla_\mu B\rangle - M_B \langle \bar{B} B\rangle + \tfrac{1}{2} D \langle \bar{B}\gamma^\mu \gamma_5 \{u_\mu, B\}\rangle + \tfrac{1}{2} F \langle \bar{B}\gamma^\mu \gamma_5 [u_\mu, B]\rangle$$

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

$$T = [1 - VG]^{-1} V \qquad T_{ij} = \frac{g_i g_j}{z - z_R}$$

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





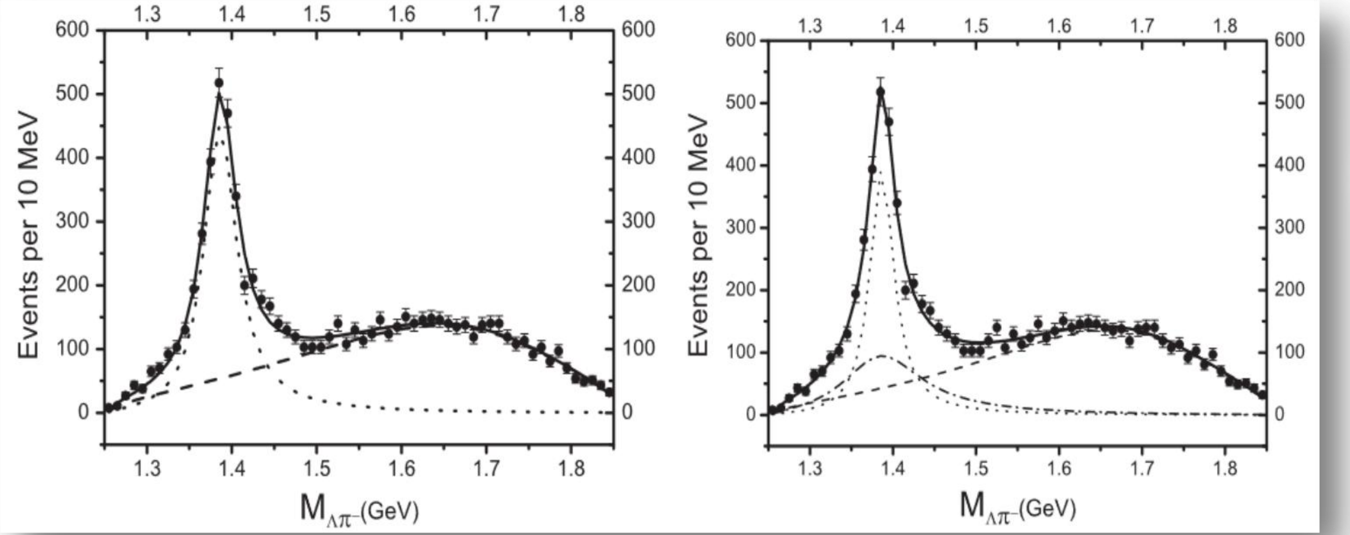
Jido Oller Oset Ramos Meissner NPA725 (2003) 181

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

- hadron-hadron scattering, Kp, Λp
- γ-production, ν-production
- charmed baryon decays
- charmonium decays

Hadron-hadron scattering

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



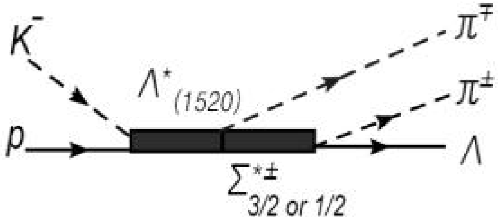
$$\frac{dN}{dm_{\Lambda\pi^-}} \propto p_1 \times p_2 \times \sum_{i=1}^{3} \frac{|a_i|}{(m^2_{\Lambda\pi^-} - m_i^2)^2 + m_i^2 \times \Gamma_i^2},$$

Here we reexamine some old data of the $K^- p \rightarrow \Lambda\pi^+\pi^-$ 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 $J/\psi \rightarrow \bar{\Sigma}\Lambda\pi$ and $\gamma n \rightarrow K^+\Sigma^{*-}$ reactions. At present, the evidence is not strong. Therefore, high statistics studies

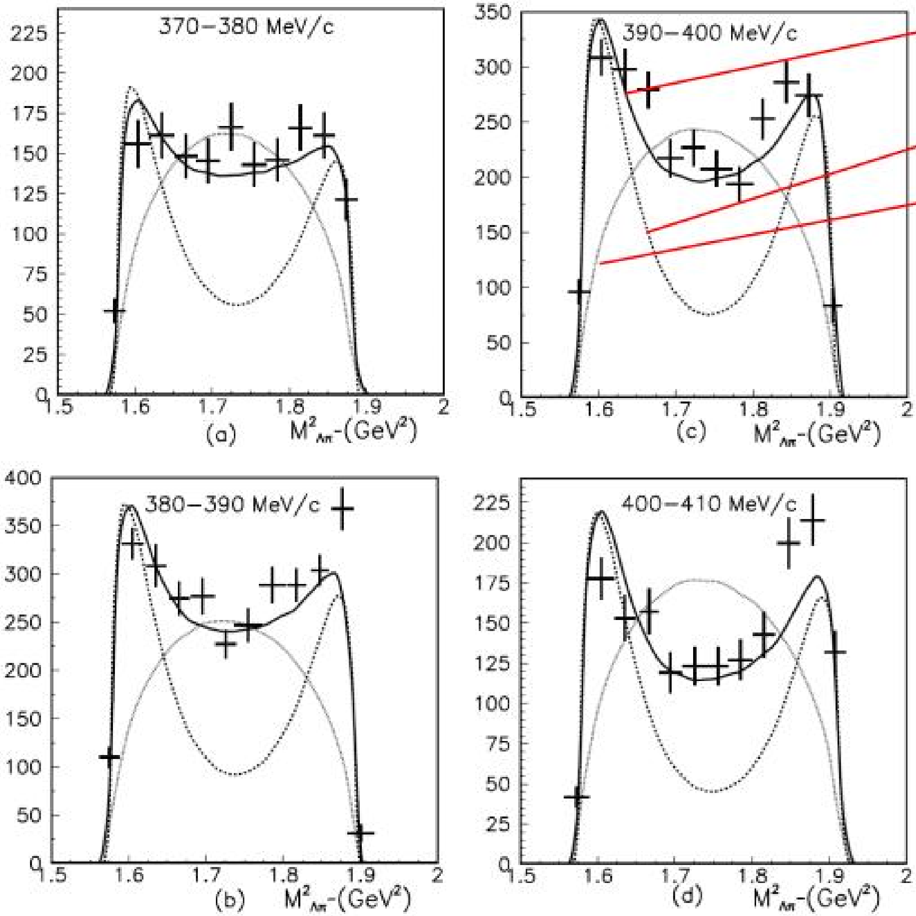
	$M_{\Sigma^*(3/2)}$	$\Gamma_{\Sigma^*(3/2)}$	$M_{\Sigma^*(1/2)}$	$\Gamma_{\Sigma^*(1/2)}$	χ^2/ndf (Fig. 1)	χ^2/ndf (Fig. 2)
Fit1	1385.3 ± 0.7	46.9 ± 2.5			68.5/54	10.1/9
Fit2	$1386.1^{+1.1}_{-0.9}$	$34.9^{+5.1}_{-4.9}$	$1381.3^{+4.9}_{-8.3}$	$118.6^{+55.2}_{-35.1}$	58.0/51	3.2/9

J.J.Wu's slide

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



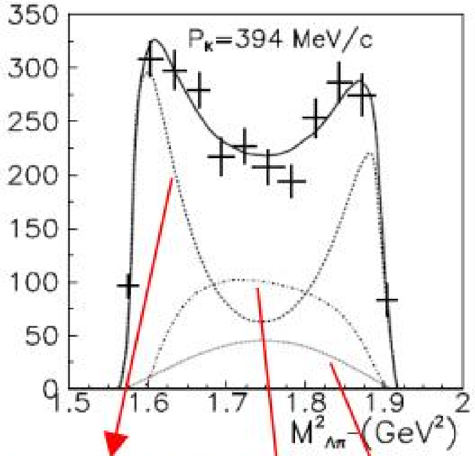
P_K=0.3-0.6 GeV J. J. Wu, S. Dulat and B. S. Zou PRC 81,045210



59% $\Sigma^*(3/2^+)$+ 41% $\Sigma^*(1/2^-)$

100% $\Sigma^*(3/2^+)$

Phase space

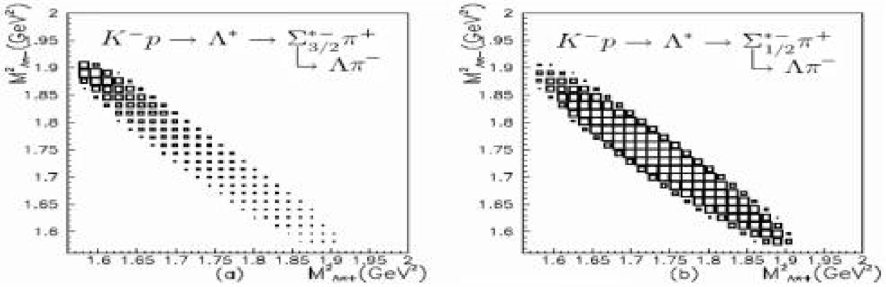


59% $\Sigma^*(3/2^+)$

Interference

12. 5% $\Sigma^*(1/2^-)$

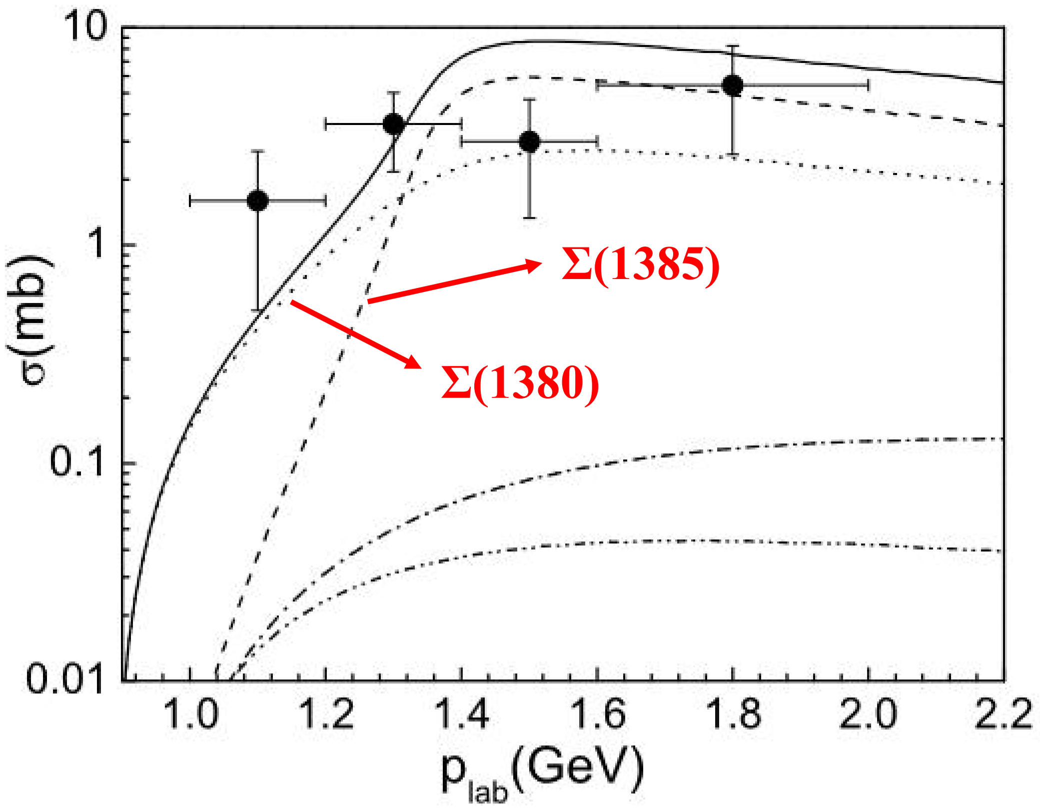
First reason: S-wave between the $\Sigma^{*-}(3/2^+)$ and π^+; but P-wave between the $\Sigma^{*-}(1/2^-)$ and π^+ .



Second reason: the width of $\Sigma^{*-}(3/2^+)$ is 35.5MeV; but that of $\Sigma^{*-}(1/2^-)$ is 118.6MeV from fit before.

Hadron-hadron scattering

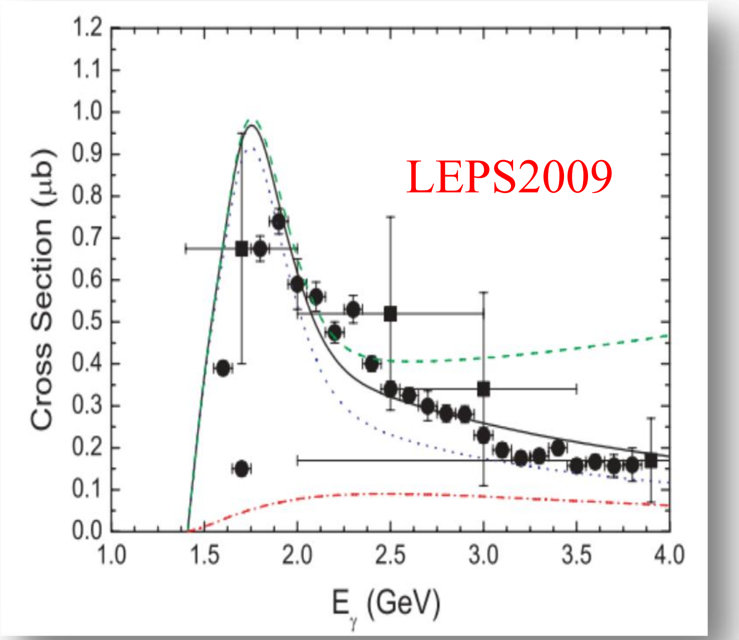
- $\Lambda p \to \Lambda p \pi^0$, JJXie, JJWu, and BSZou, PRC90(2014)055204

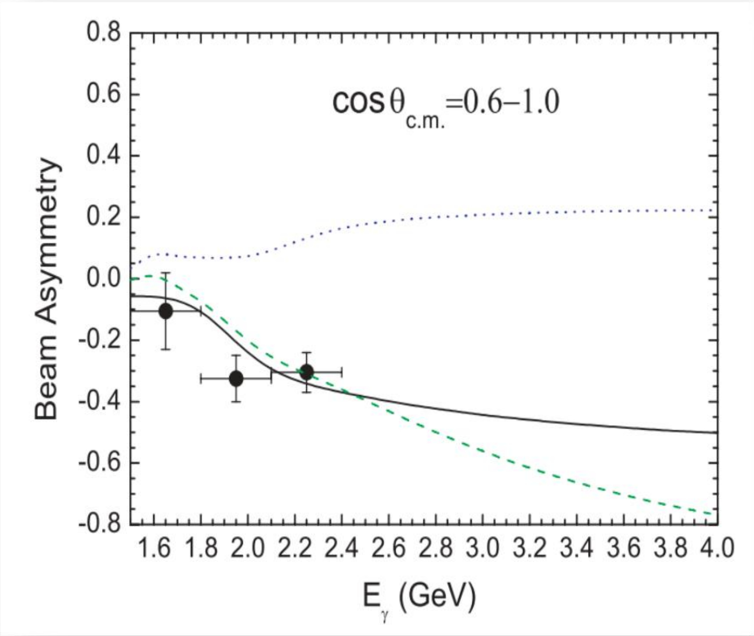


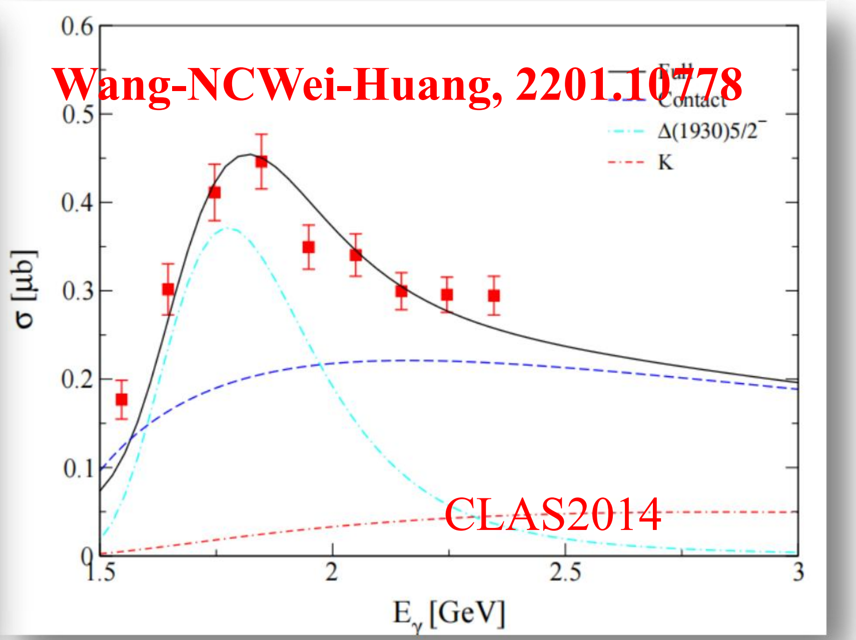
The $\Sigma^*(1385)$ resonance can not reproduce the near threshold enhancement for the $\Lambda p \to \Lambda p \pi^0$ reaction because it decays to $\pi\Lambda$ in relative P-wave and is suppressed at low energies. On the contrary, the newly $\Sigma^*(1380)$ state decays to $\pi\Lambda$ in relative S-wave, and can describe the near threshold enhancement fairly well, which indicate that the $\Lambda p \to \Lambda p \pi^0$ data support the existence of this $\Sigma^*(1380)$ state, and more accurate data for this

γ/ν-production

- $\gamma N \to K\Sigma(1385)$, Gao-Wu-Zou, PRC 81(2010) 055203





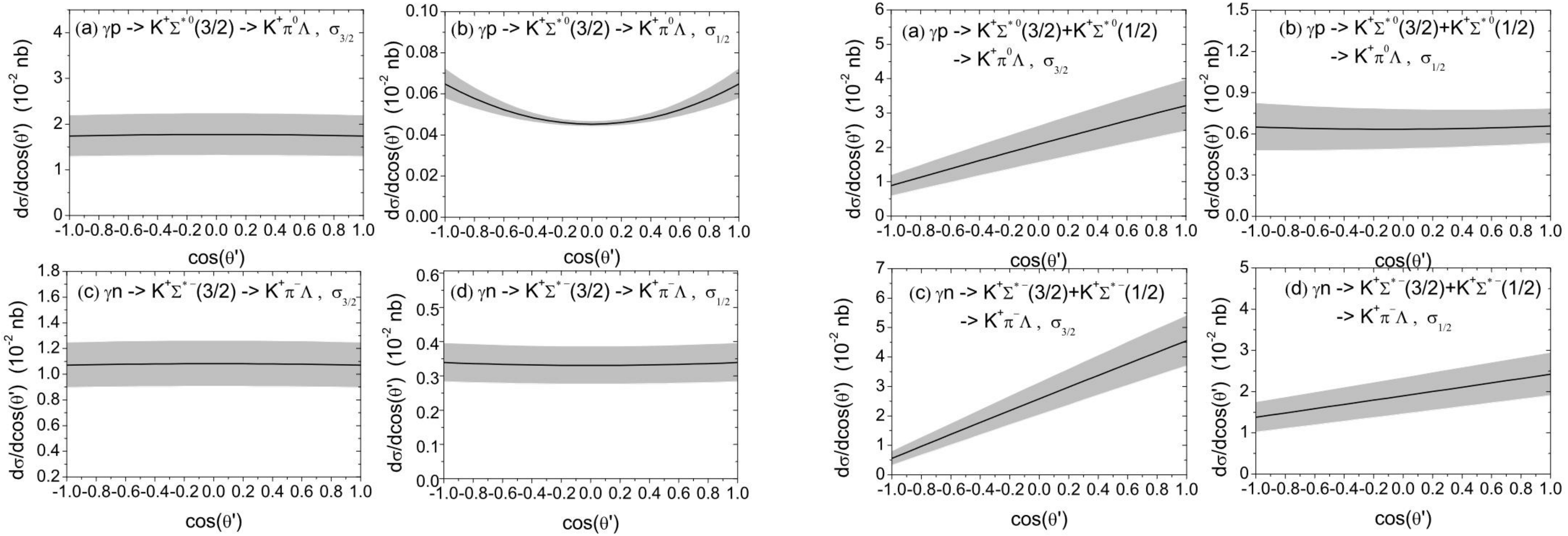


the case that the $\Sigma(\frac{1}{2}^-)$ may contribute to the observables of the $K\Sigma^*(1385)$ photoproduction in our experiments. Our results show that the $\Sigma(\frac{1}{2}^-)$ production can provide a large negative contribution to beam asymmetry, which helps to explain the large negative linear beam asymmetry observed by the LEPS experiment. With a portion of the $\Sigma(\frac{1}{2}^-)$, the same set of parameters can reproduce both the data for $\gamma n \to K^+\Sigma^{*-}$

and, in particular, to figure out which one of the $N(1895)1/2^-$, $\Delta(1900)1/2^-$, and $\Delta(1930)5/2^-$ resonances is really capable for a simultaneous description of the data for both $K^+\Sigma^0(1385)$ and $K^+\Sigma^-(1385)$ photoproduction reactions. The results show that the available data on differential and total cross sections and photo-beam asymmetries for $\gamma n \to K^+\Sigma^-(1385)$ can be reproduced only with the inclusion of the $\Delta(1930)5/2^-$ resonance rather than the other two. The generalized contact term and the t-channel K exchange are found to dominate the background contributions

γ/ν-production

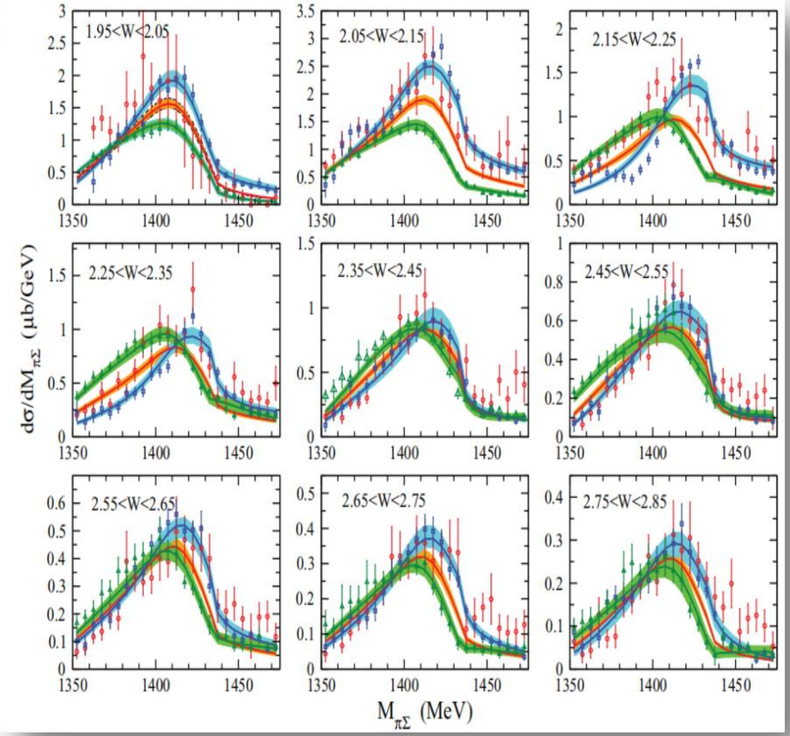
□ $\gamma p \to K^+\pi\Lambda$, YHChen, BSZou, PRC 88, 024304(2013)



The angular distribution of the π are distinctly different assuming that the Σ(1/2⁻) exists or not.

γ/ν-production

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



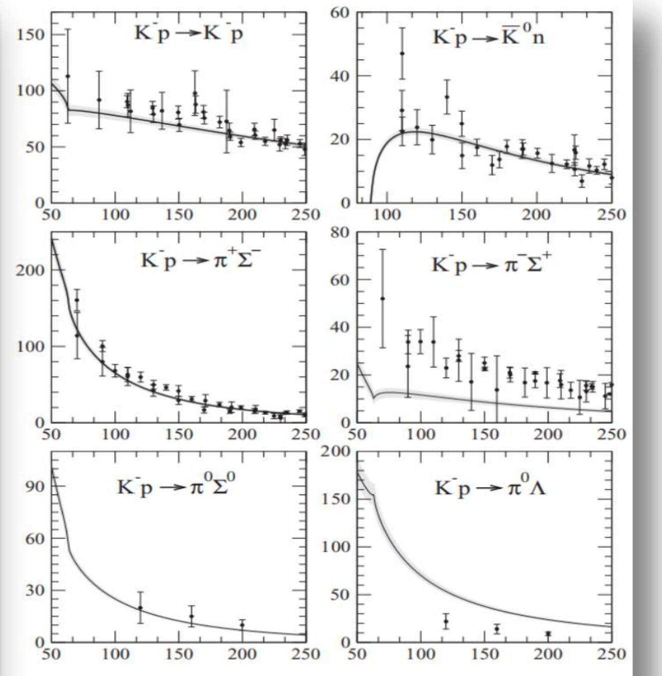
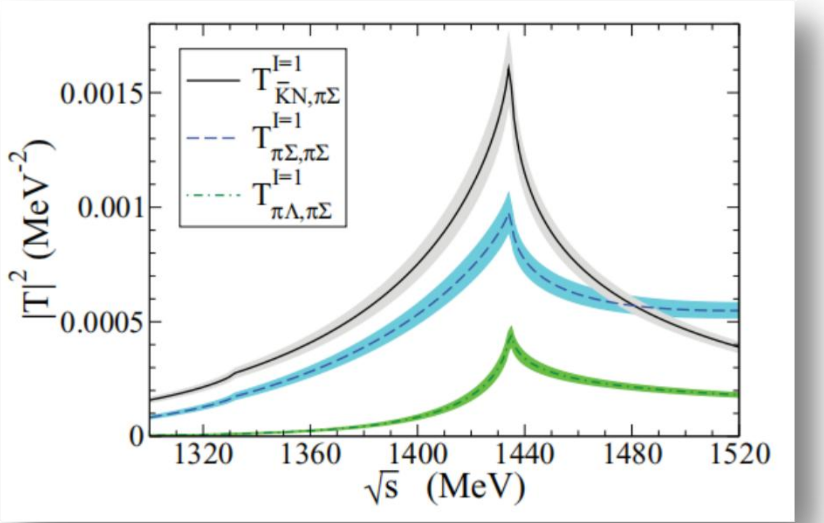


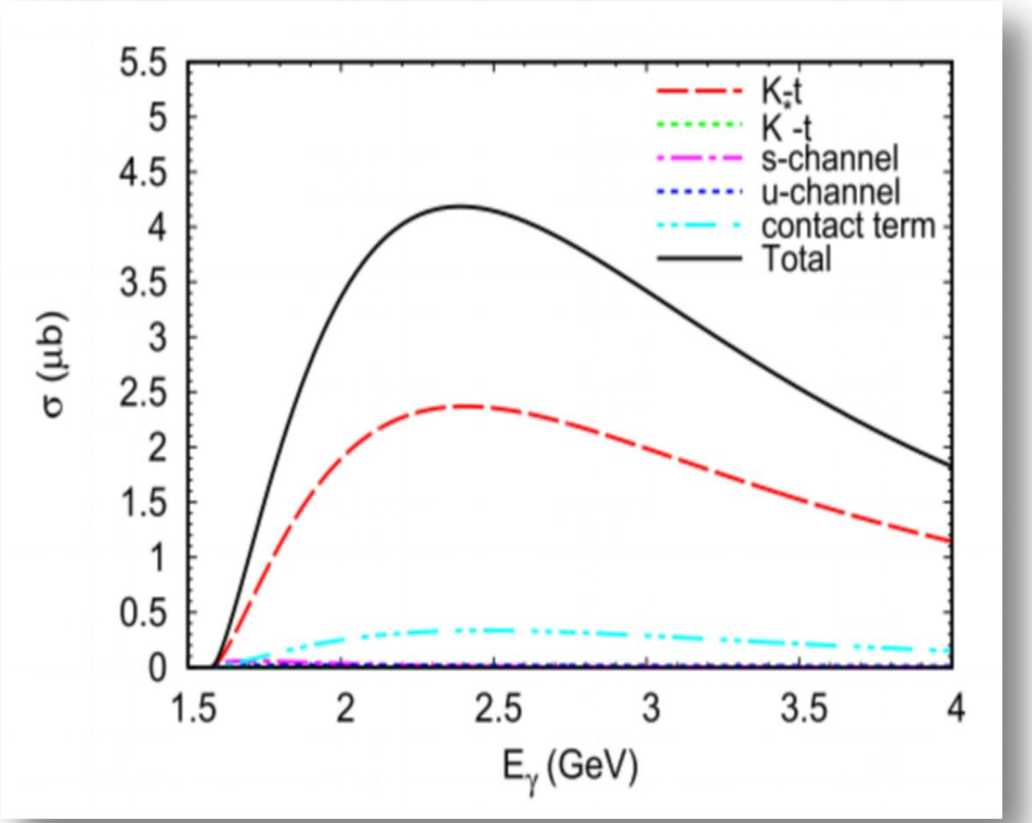
FIG. 6. Predicted K^-p cross sections (in millibarns). Experimental data are from Ref. [46].

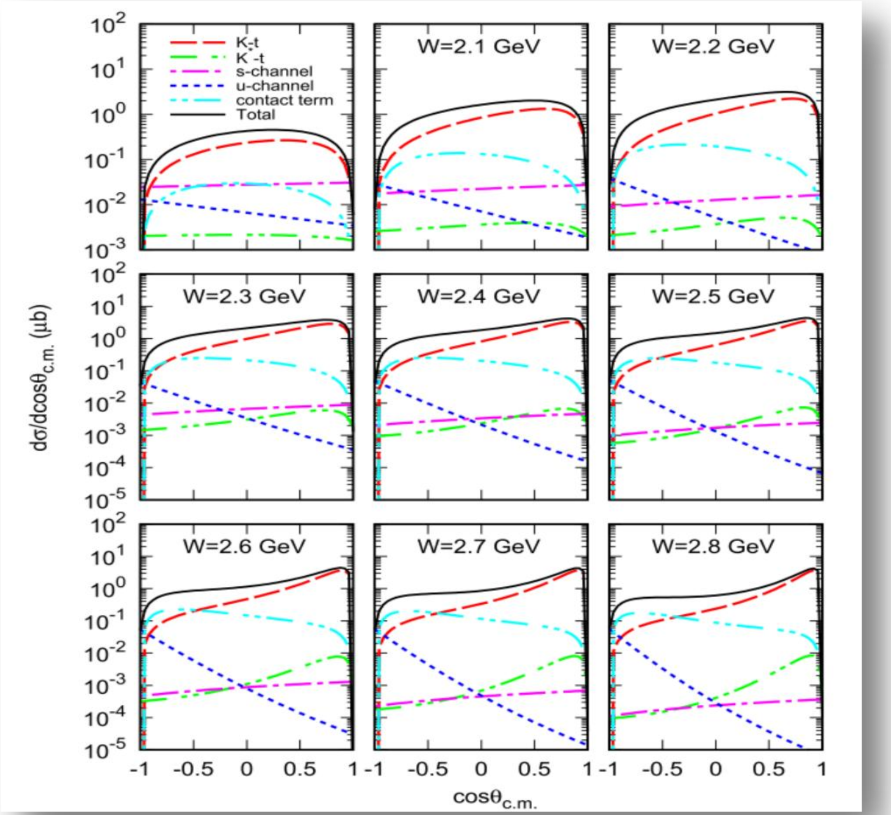


Oset-Ramos, NPA635 (1998)
PB,VB, Hosaka, PRD 85, 114020 (2012)
Oller-Meißner, Phys. Lett. B 500 (2001) 263

γ/ν-production

- $\gamma N \rightarrow K\Sigma(1/2^-)$), Lyu−EW−Xie−Wei, CPC47 (2023) 053108

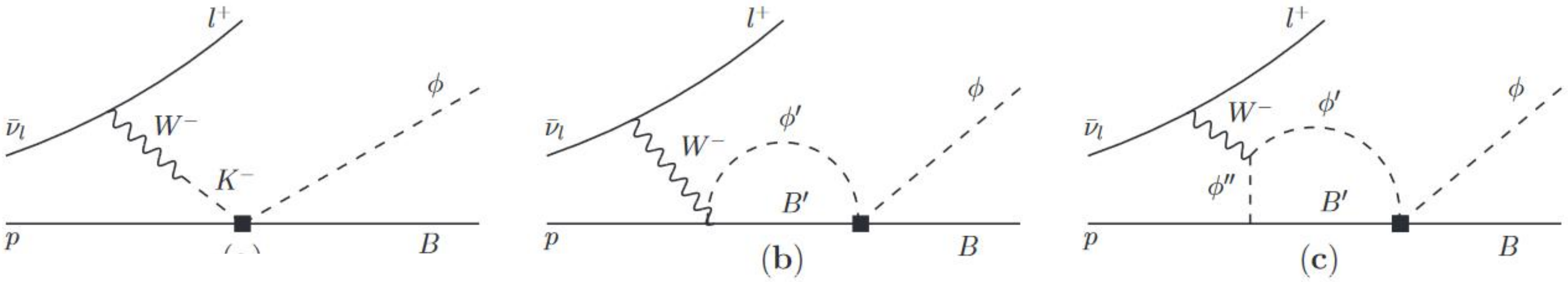


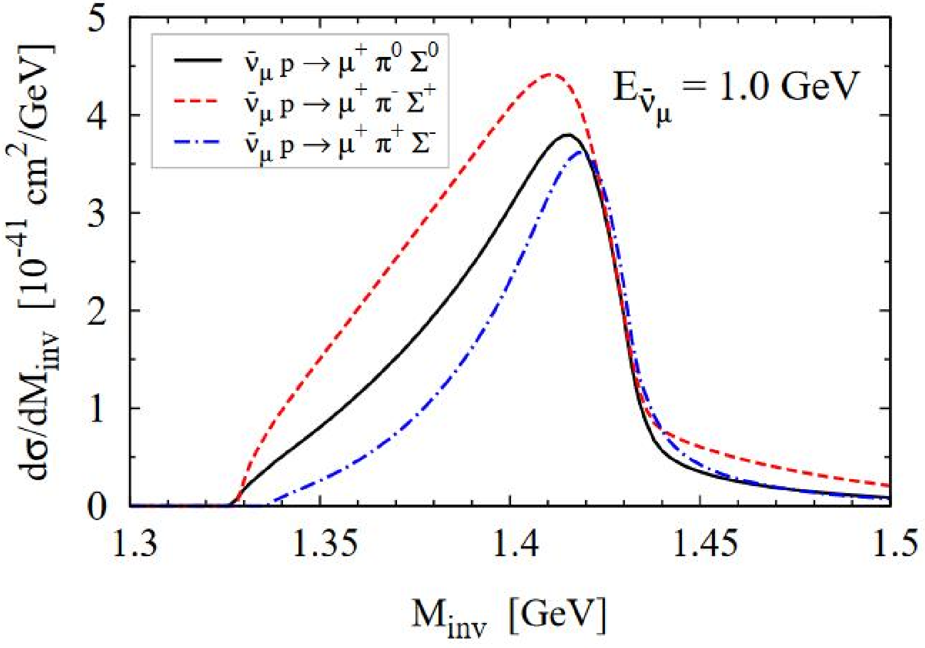


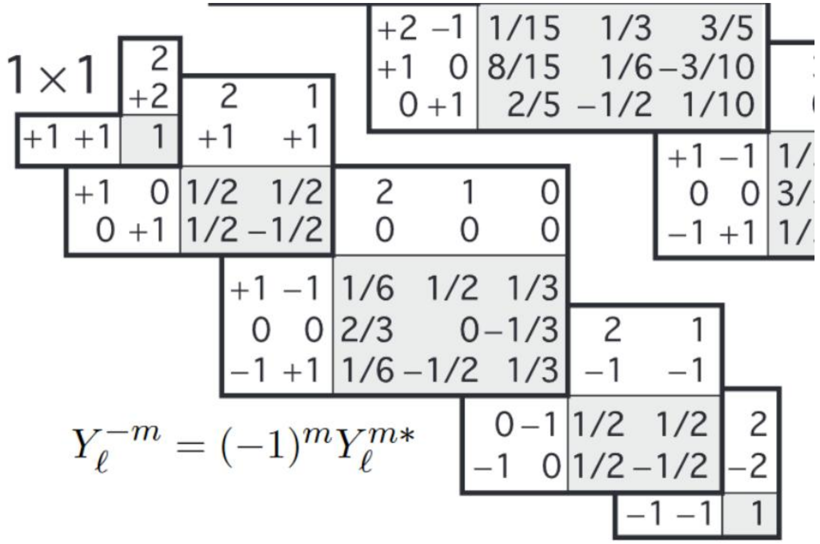
γ/ν-production

•JJWu and BSZou, Few Body Syst. 56 (2015) 4-5, 165
•XLRen, Oset, Nieves, PRC91 (2015) 045201

- $\nu N \to \mu\pi\Sigma$



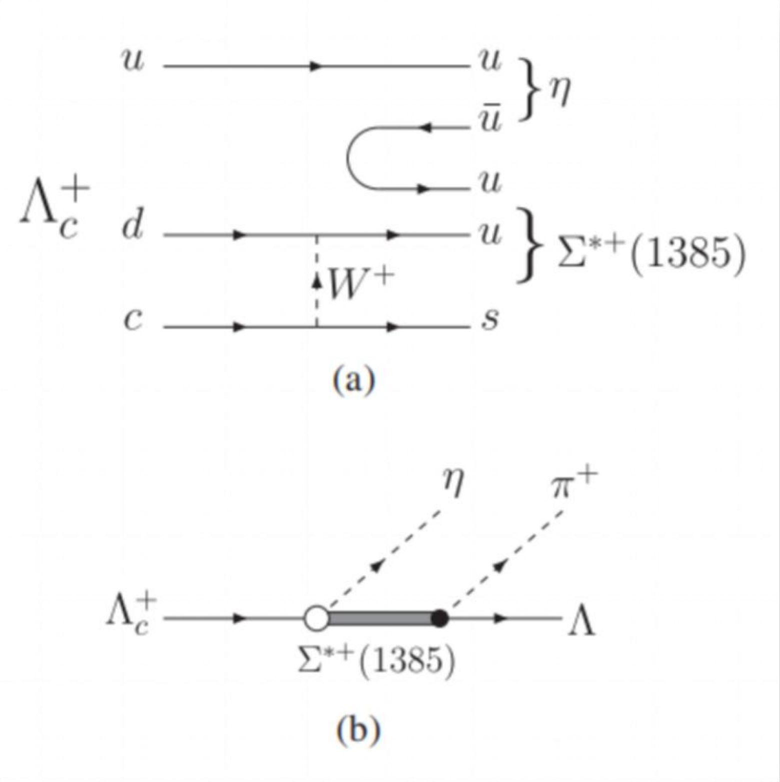


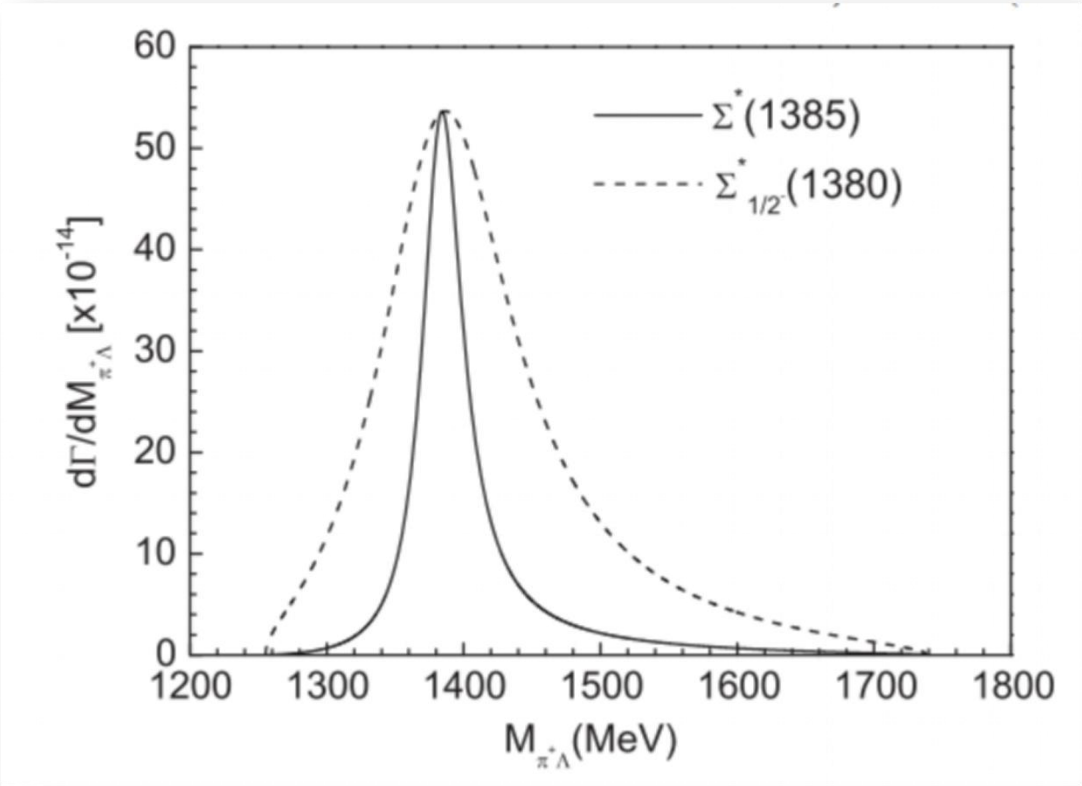


$$Y_\ell^{-m} = (-1)^m Y_\ell^{m*}$$

Charmed baryon decays

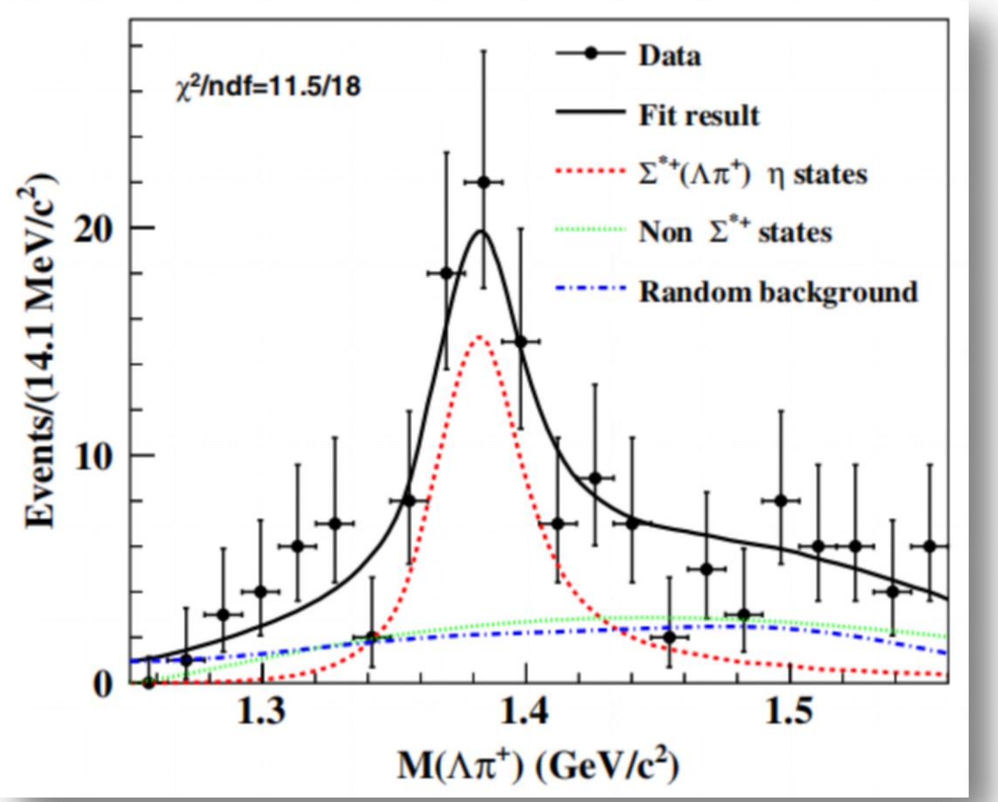
- $\Lambda_c \to \Lambda\eta\pi$, J.J.Xie, L.S.Geng, EPJC76(2016) 496, PRD95(2017) 074024

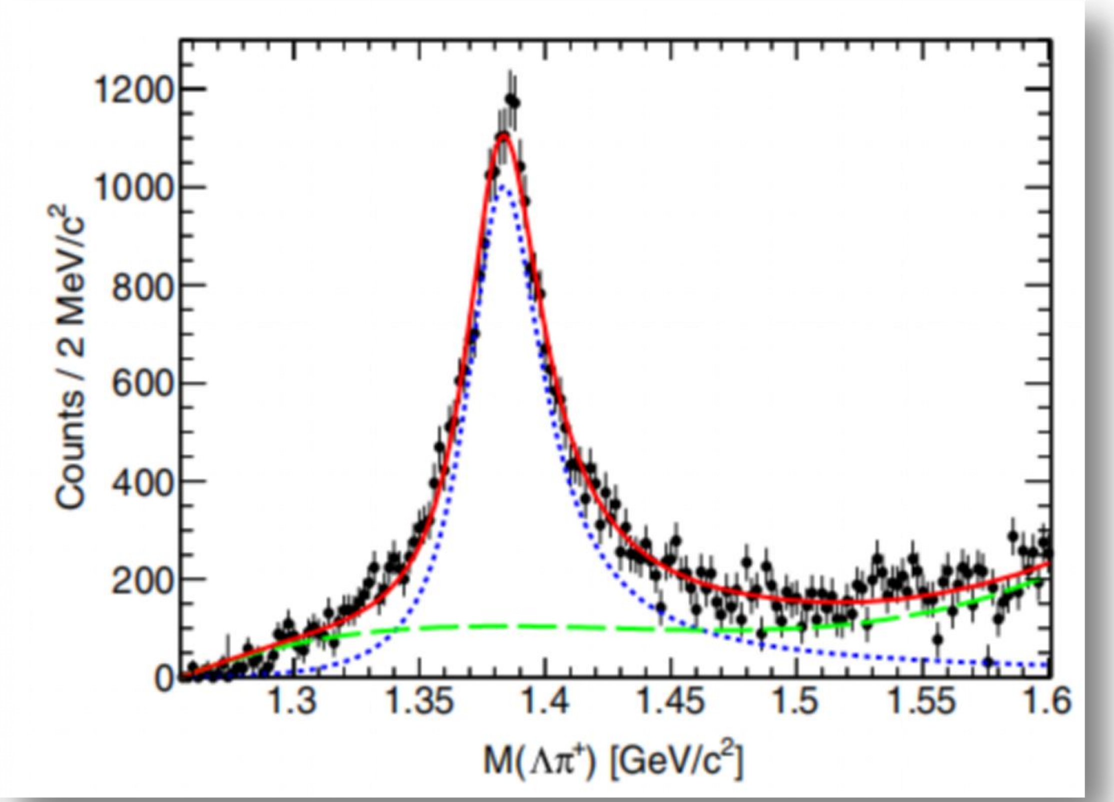




Belle and BESIII measurements

□ $\Lambda_c \to \Lambda\eta\pi$

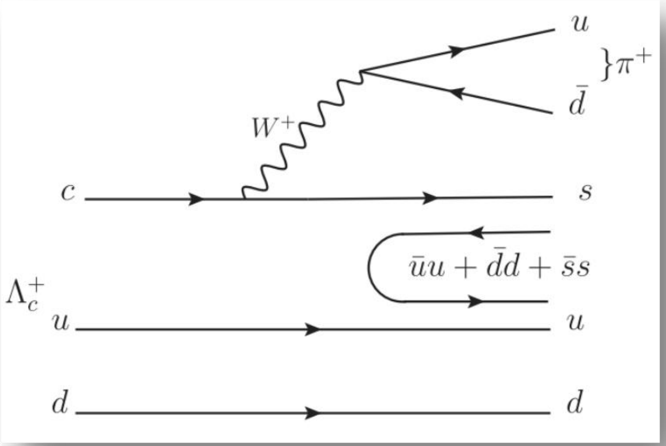


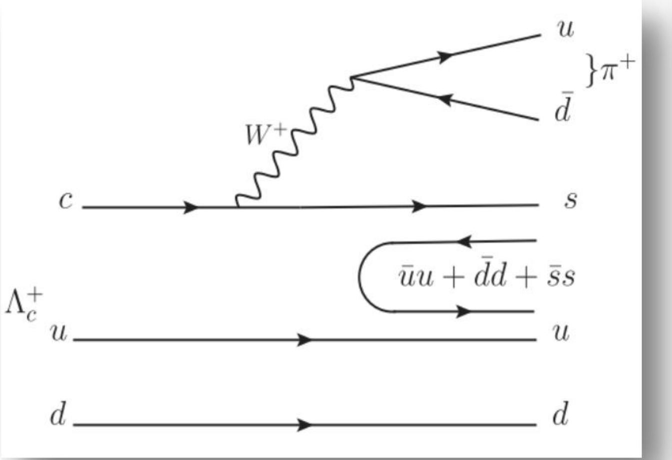


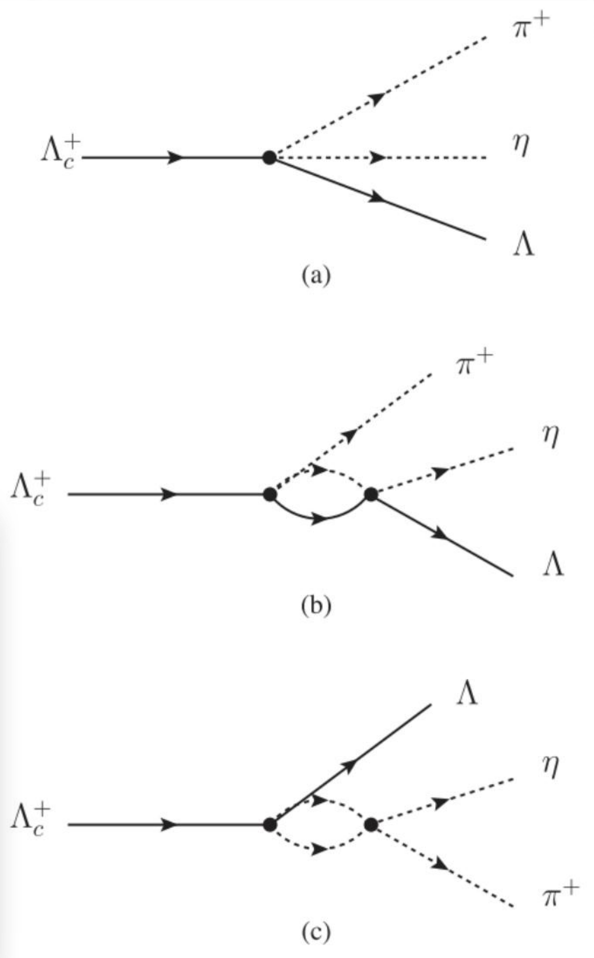
BESIII: PRD99, 032010 (2019)

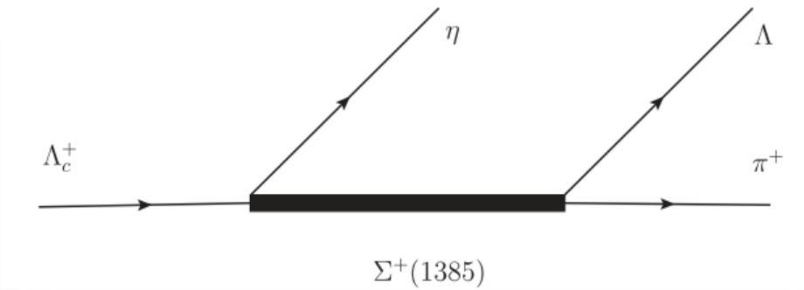
Belle: PRD103(2021)052005

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









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

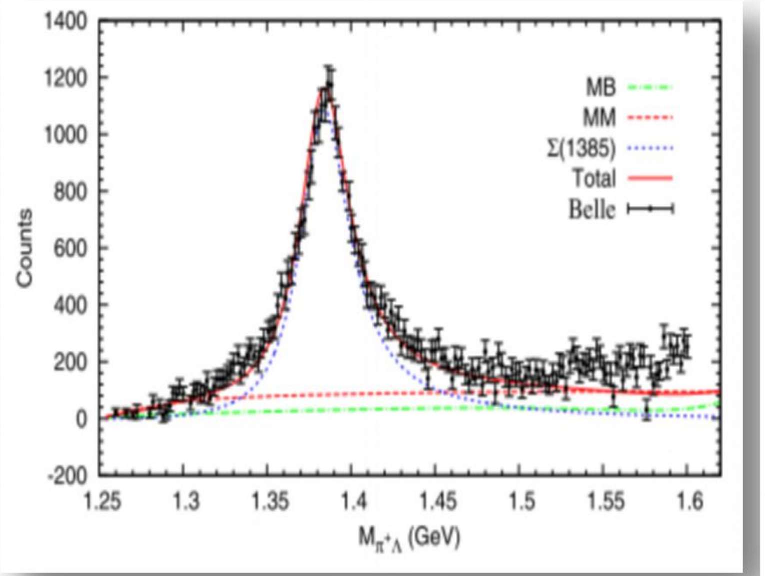
$$\begin{aligned} T^{\mathrm{MB}}(M_{\eta\Lambda}) = V_P\Big\{ & -\frac{\sqrt{2}}{3} + G_{K^-p}(M_{\eta\Lambda})t_{K^-p\to\eta\Lambda}(M_{\eta\Lambda}) \\ & + G_{\bar{K}^0 n}(M_{\eta\Lambda})t_{\bar{K}^0 n\to\eta\Lambda}(M_{\eta\Lambda}) \\ & -\frac{\sqrt{2}}{3}G_{\eta\Lambda}(M_{\eta\Lambda})t_{\eta\Lambda\to\eta\Lambda}(M_{\eta\Lambda})\Big\},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

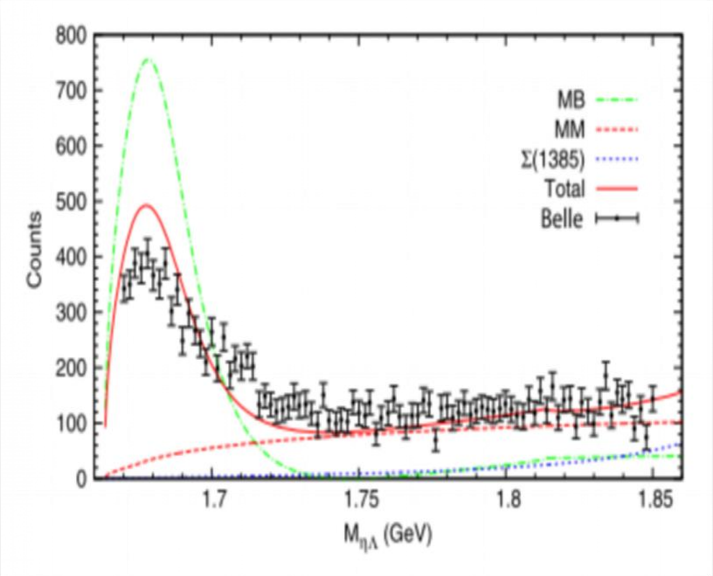
$$\begin{aligned} T^{\mathrm{MM}}(M_{\pi^+\eta}) = V_P' \frac{2\sqrt{2}}{3}\Big\{ & 1 + G_{\pi^+\eta}(M_{\pi^+\eta})t_{\pi^+\eta\to\pi^+\eta}(M_{\pi^+\eta}) \\ & + \frac{\sqrt{3}}{2}G_{K^+\bar{K}^0}(M_{\pi^+\eta})t_{K^+\bar{K}^0\to\pi^+\eta}(M_{\pi^+\eta})\Big\}, \end{aligned}$$

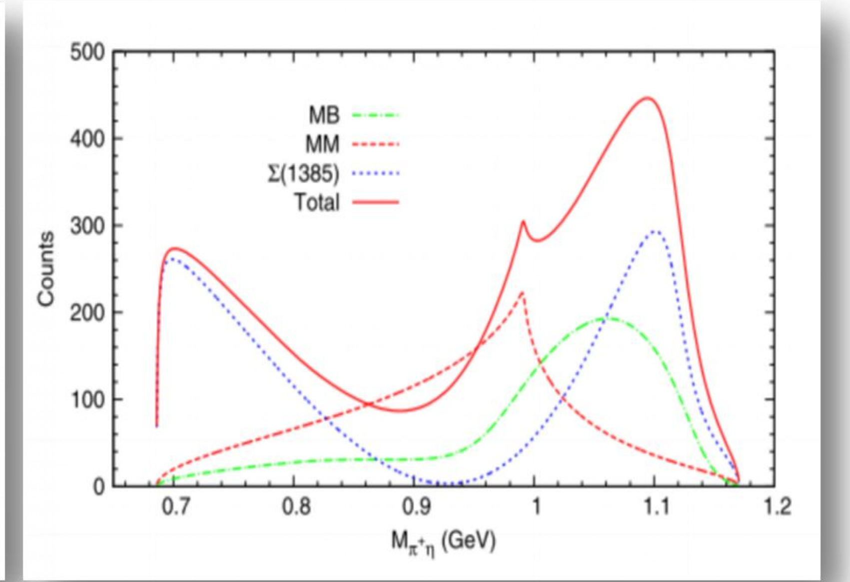
GYW-EW-Xie-Geng-Wei, PRD 106, 056001 (2022)

Analysis the Belle data

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

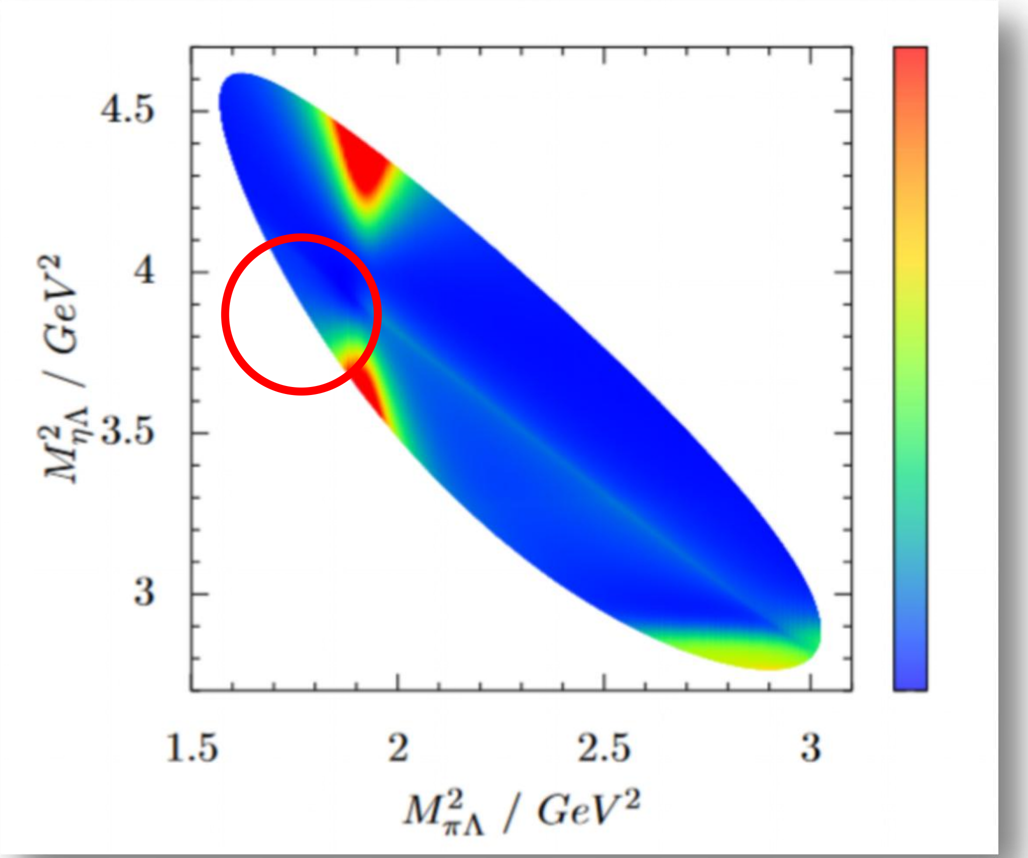


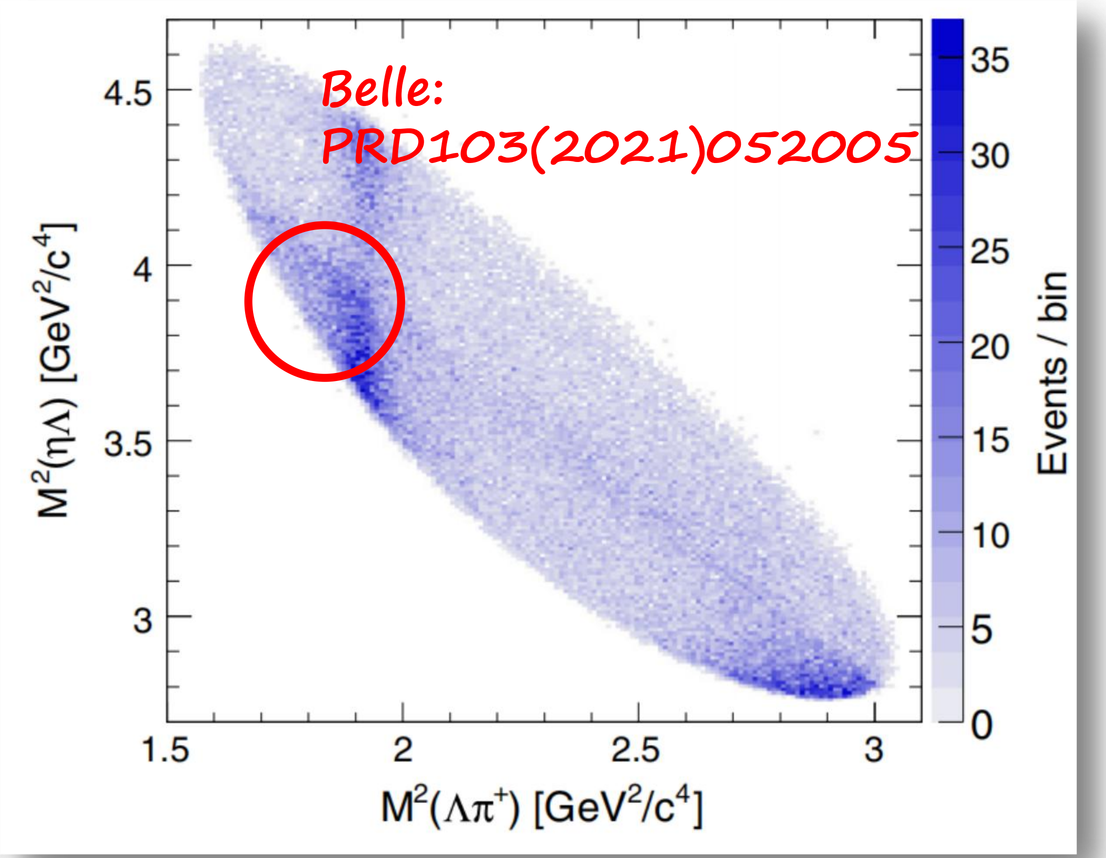




By regarding the $\Lambda(1670)$ as the molecule, we could well reproduce the Belle data of the mass distributions.

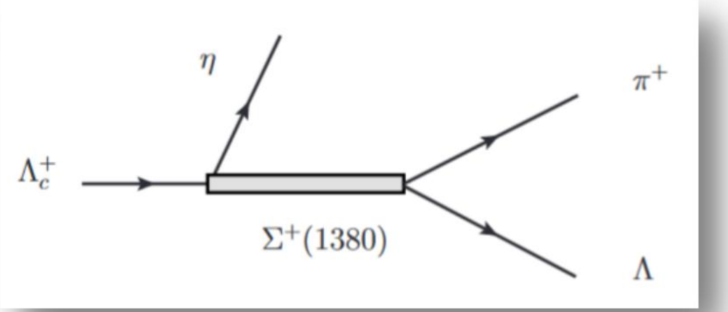
Dalitz plot of $\Lambda_c \to \eta\Lambda\pi$



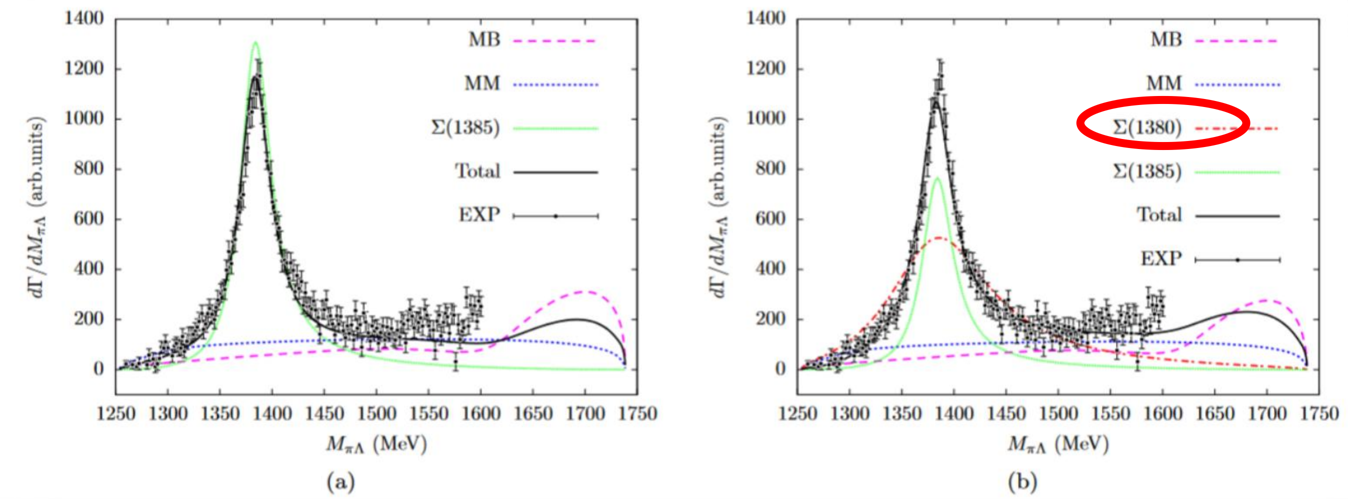


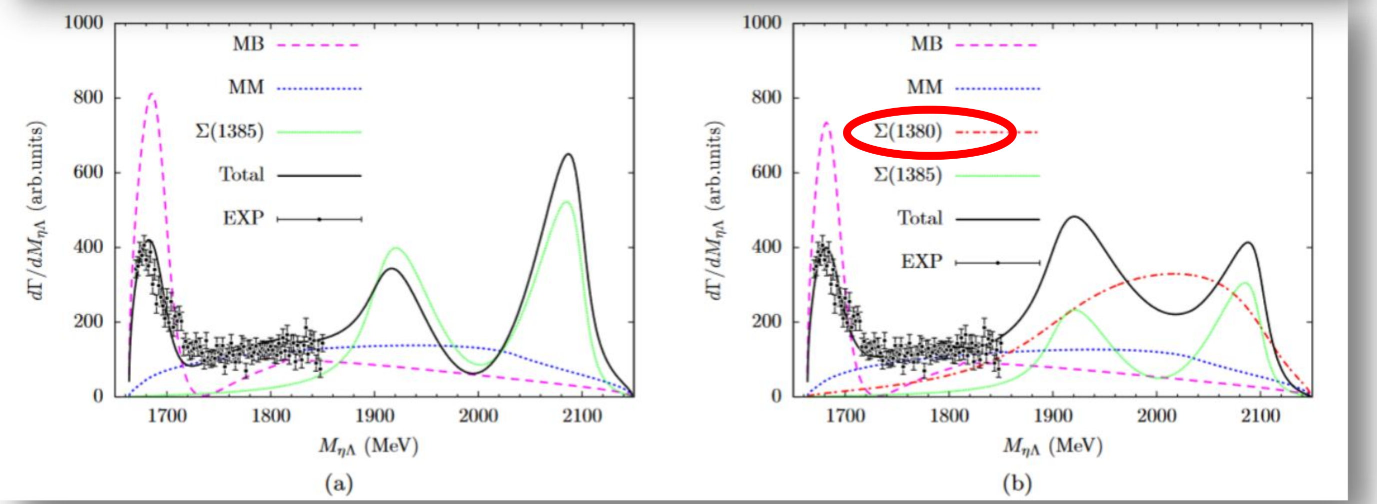
$\Sigma(1/2^-)$ in $\Lambda_c \to \eta\Lambda\pi$

□Intermediate of $\Sigma(1/2^-)$



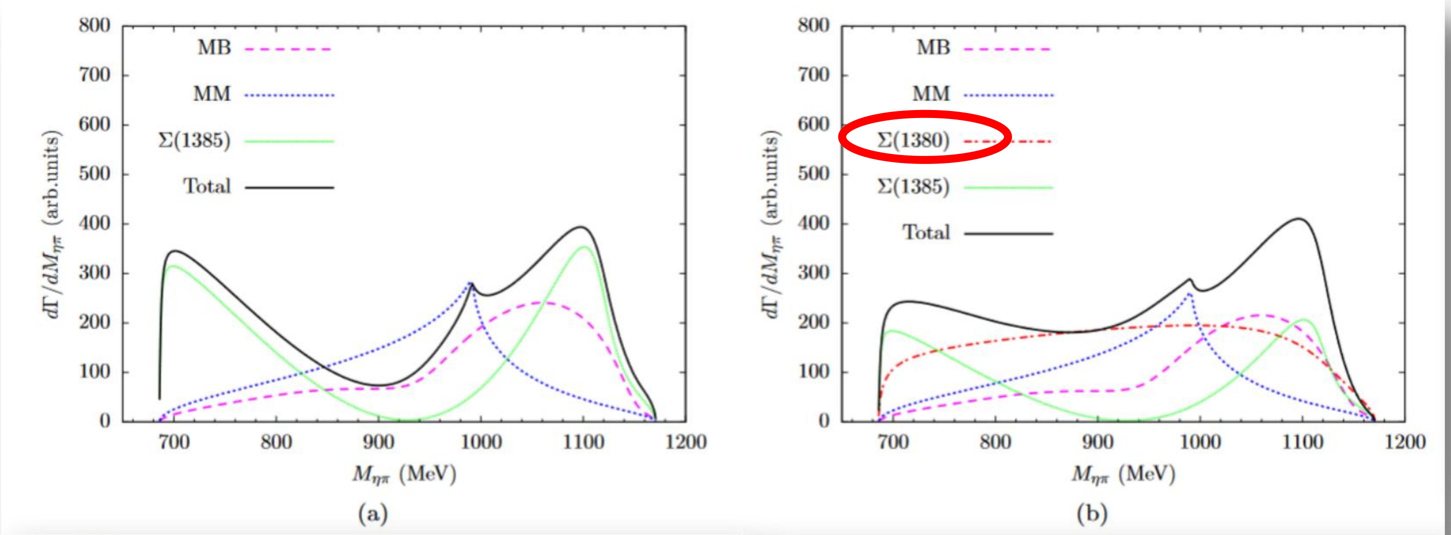
$$\mathcal{T}^{\Sigma(1/2^-)} = \frac{V^{\Sigma(1/2^-)} M_{\Sigma(1/2-)} \Gamma_{\Sigma(1/2-)}}{M^2_{\pi^+\Lambda} - M^2_{\Sigma(1/2-)} + i M_{\Sigma(1/2-)} \Gamma_{\Sigma(1/2-)}},$$

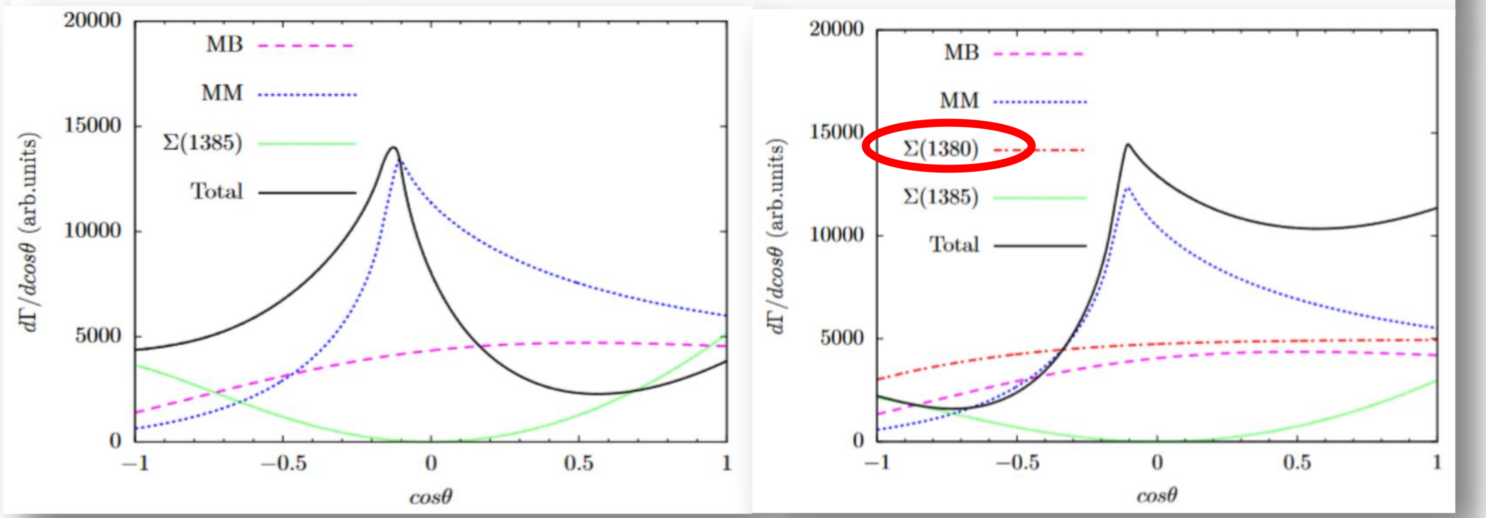


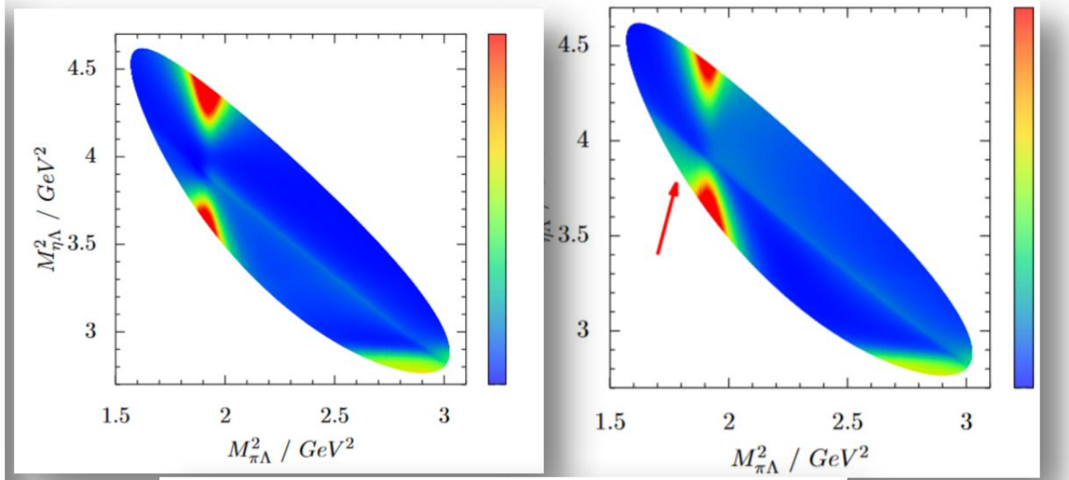


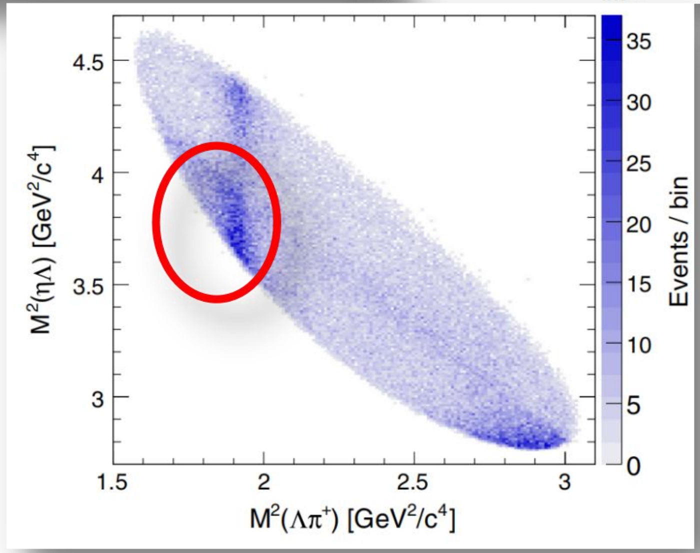
EW, JJWu, to be prepared

The results with/without Σ(1380)







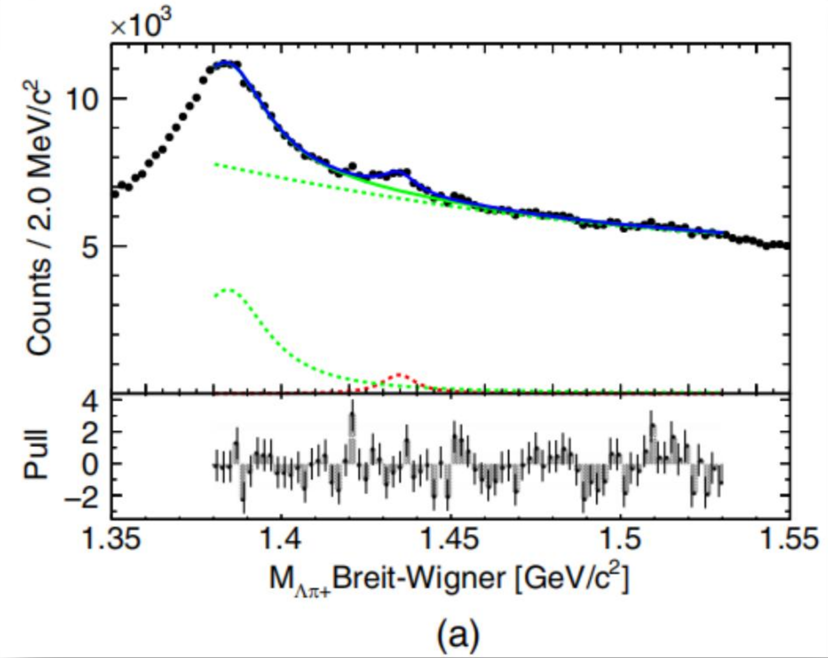


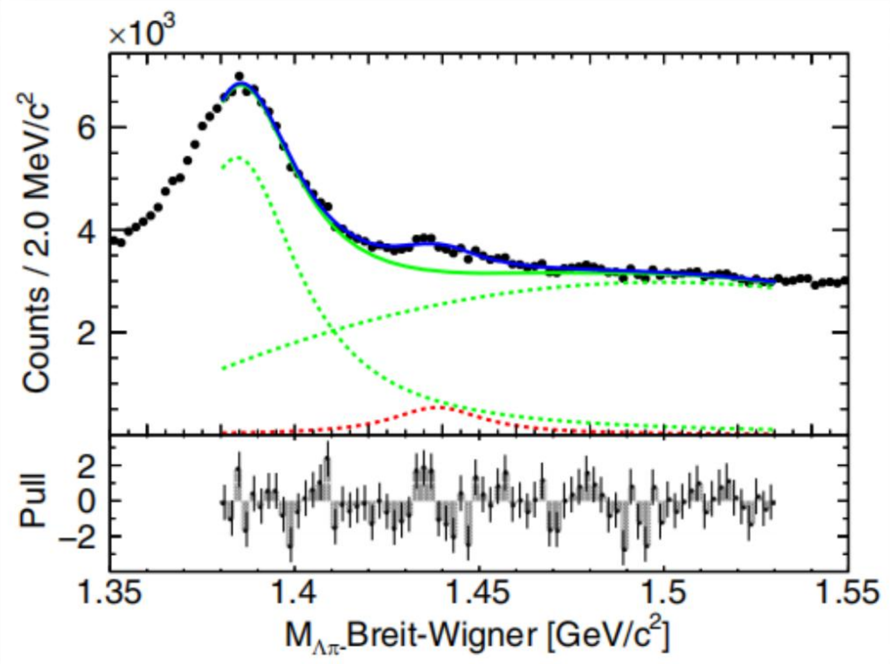
$M_{\pi\Lambda} \geq 1450$ MeV and $M_{\eta\Lambda} \geq 1760$ MeV.

EW, JJWu, to be prepared

Belle measurements

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



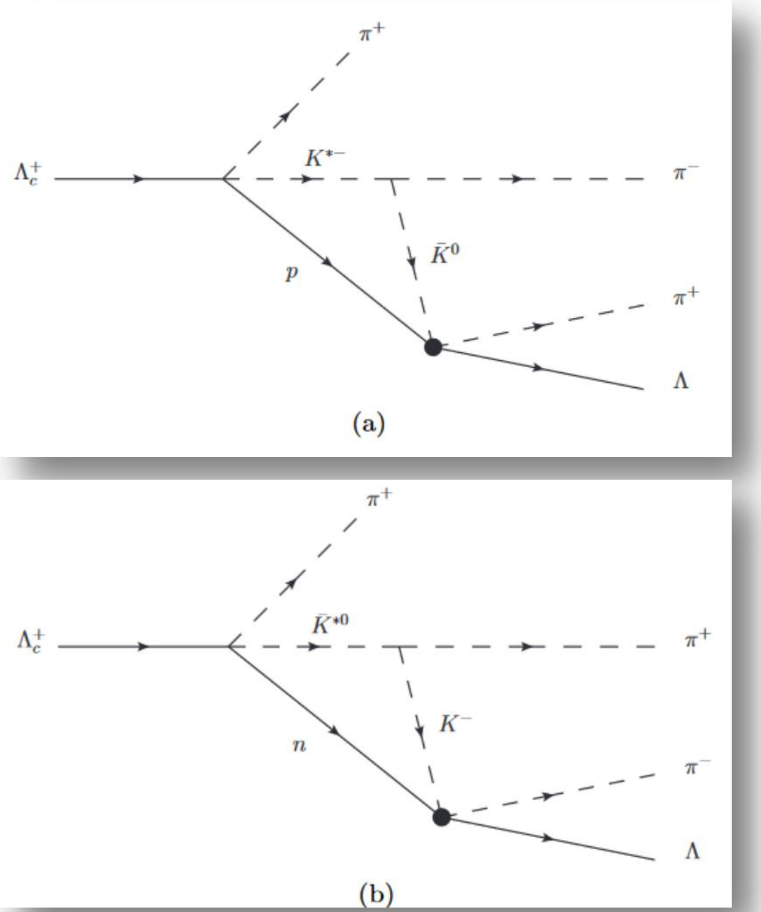


Mode	E_{BW} (MeV/c^2)	Γ (MeV/c^2)	χ^2/NDF
$\Lambda\pi^+$	1434.3 ± 0.6	11.5 ± 2.8	74.4/68
$\Lambda\pi^-$	1438.5 ± 0.9	33.0 ± 7.5	92.3/68

Evidence of $\Sigma(1430)$

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

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



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

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

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

$$|A|^2 = (3.9\pm1.4)\times10^{-16}\ \mathrm{MeV}^{-2}$$

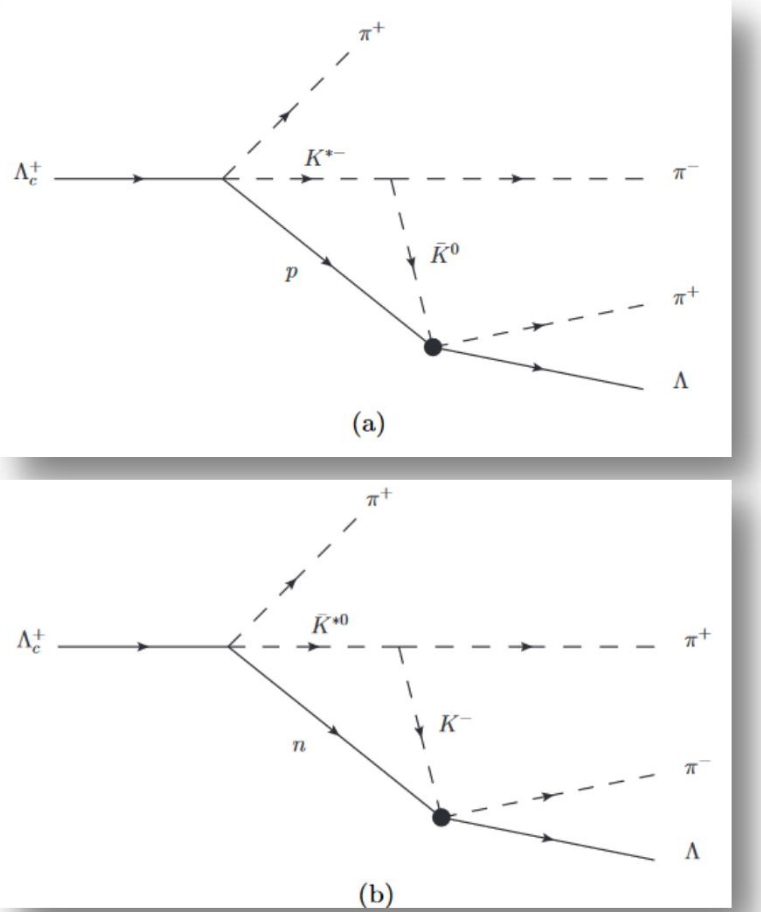
$$\mathcal{L}_{VPP} = -ig < V^\mu[P,\partial P] >$$

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

Evidence of $\Sigma(1430)$

□ $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$

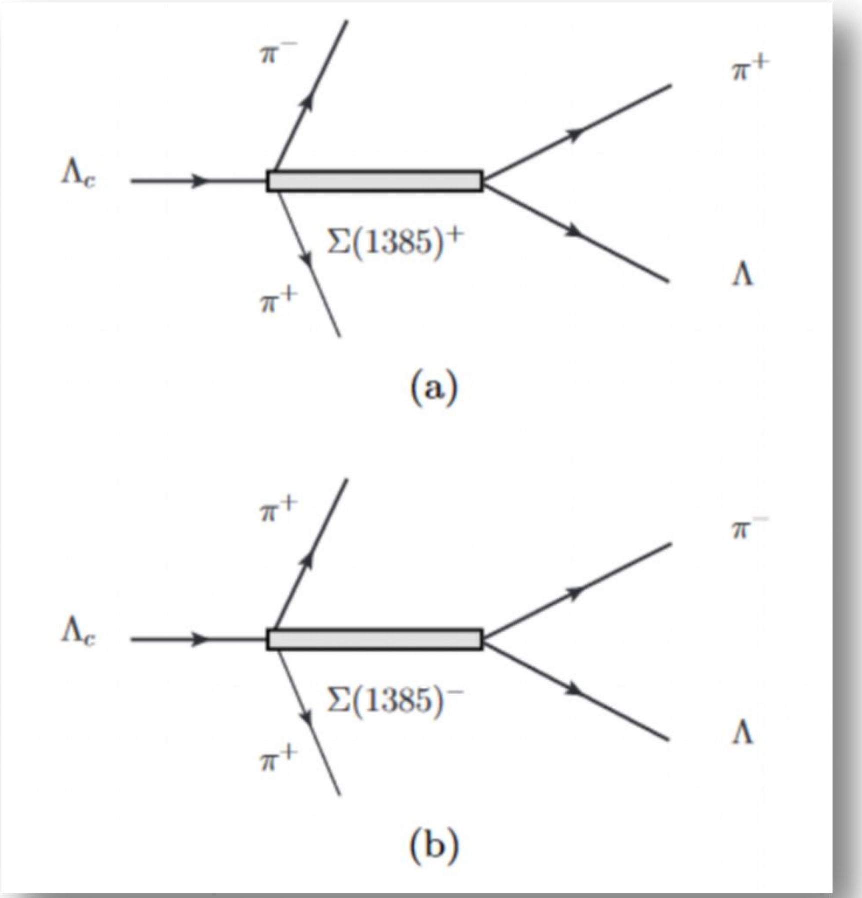
Dai-Pavao-Sakai-Oset, PRD 97, 116004 (2018)
Xie-Oset, PLB 792, 450-453 (2019)



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

Evidence of $\Sigma(1430)$

- $\Lambda_c \rightarrow \Lambda\pi^+\pi^+\pi^-$



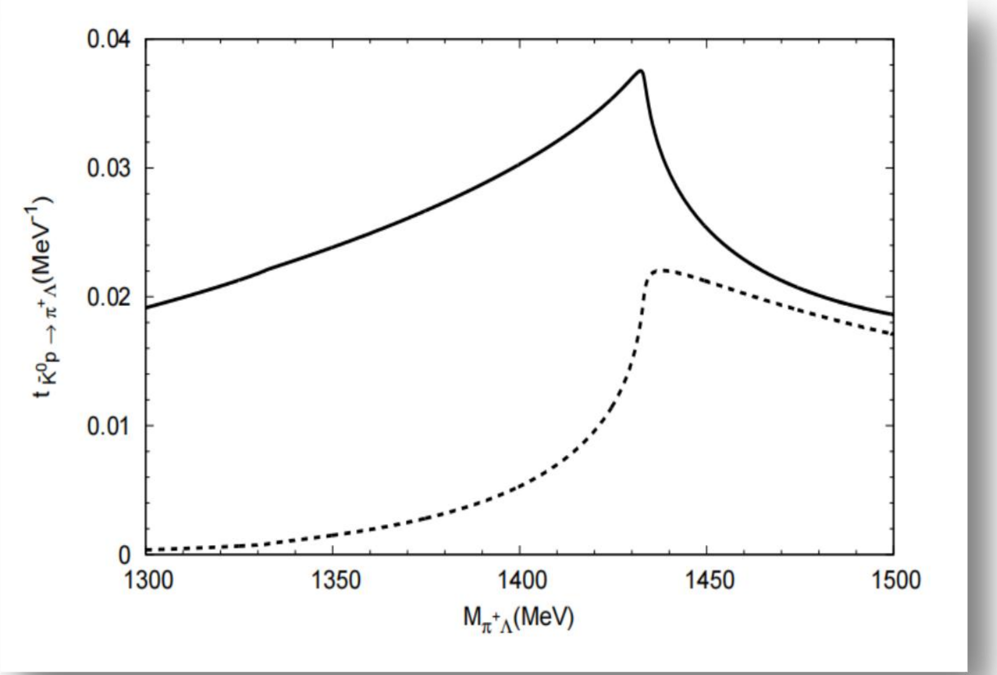
$$T^{\Sigma^{*+}(1385)} = \frac{V_p |p_{\pi^+}|}{M_{\pi^+\Lambda} - M_{\Sigma^{*+}} + i\frac{\Gamma_{\Sigma^{*+}}}{2}},$$

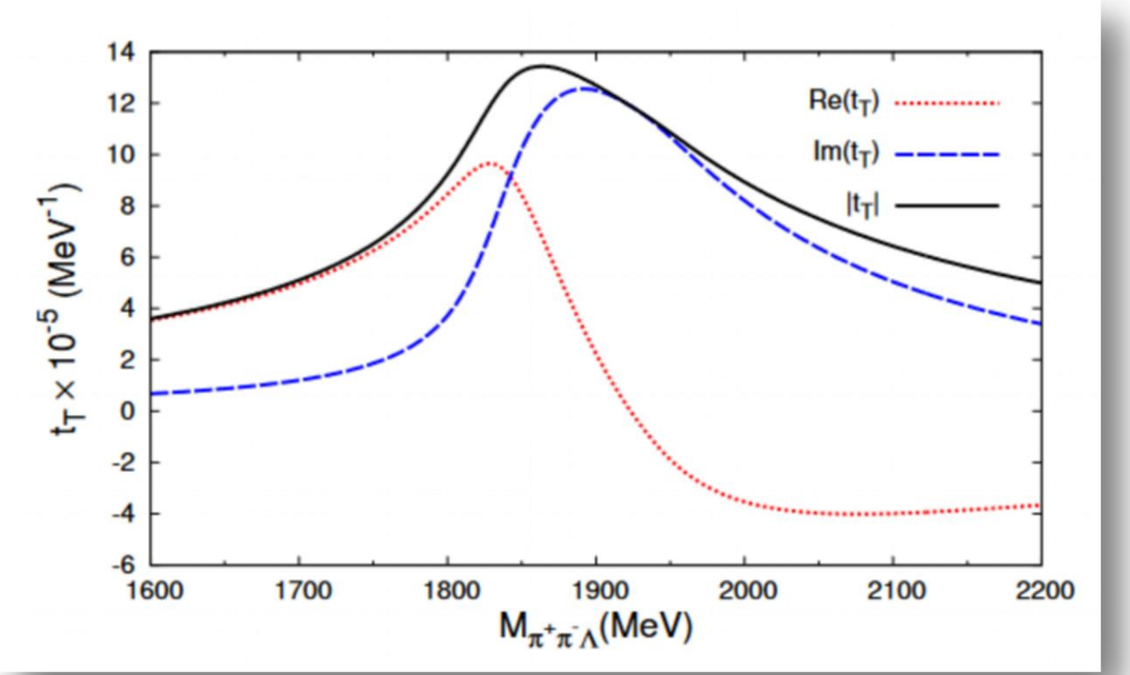
$$T^{\Sigma^{*-}(1385)} = \frac{V_p |p_{\pi^-}|}{M_{\pi^-\Lambda} - M_{\Sigma^{*-}} + i\frac{\Gamma_{\Sigma^{*-}}}{2}},$$

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

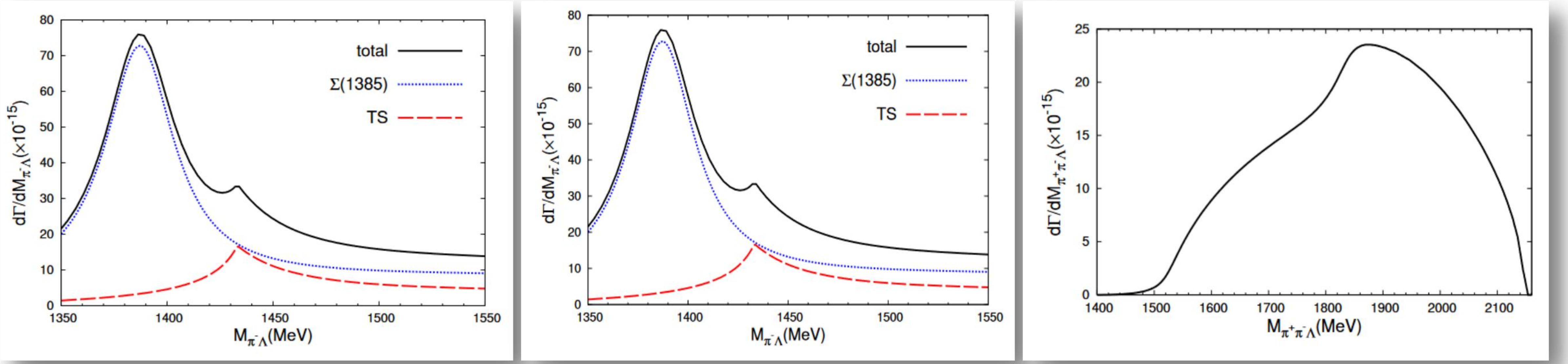
Evidence of $\Sigma(1430)$

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





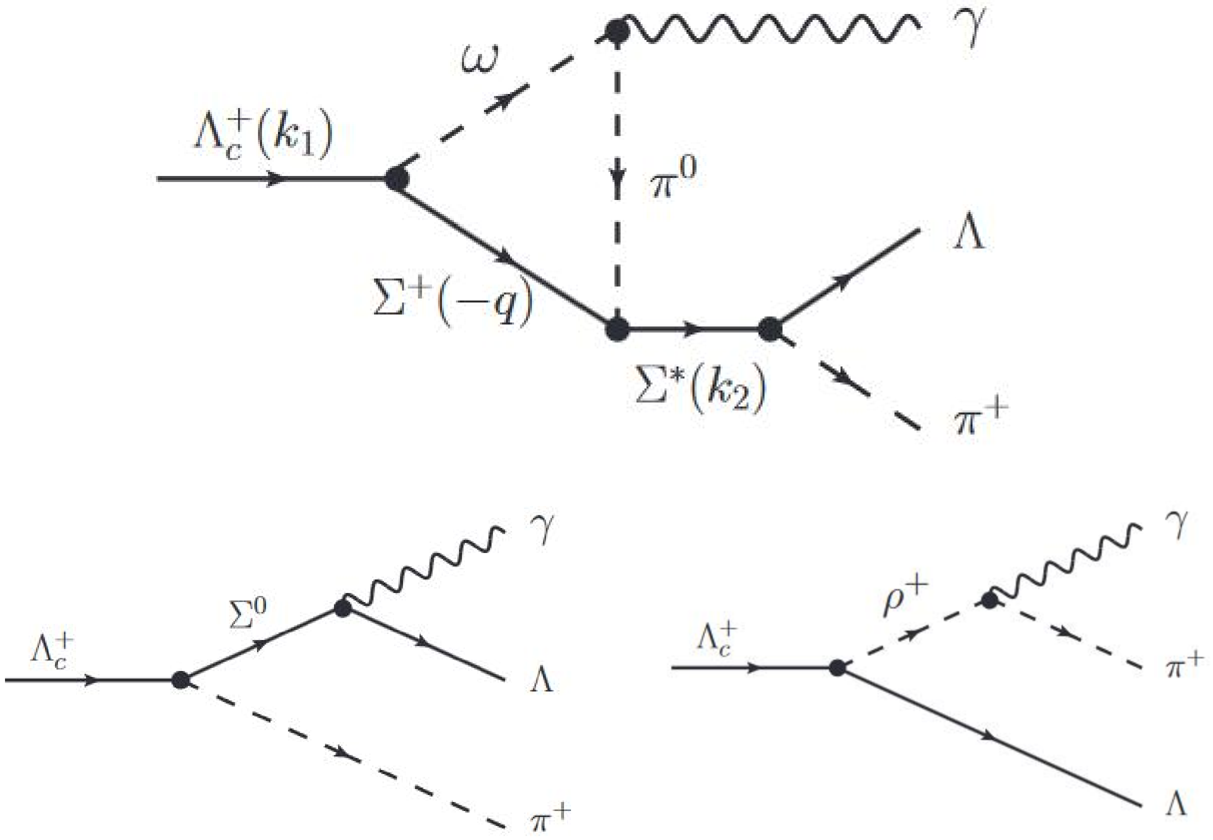
Results of $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$

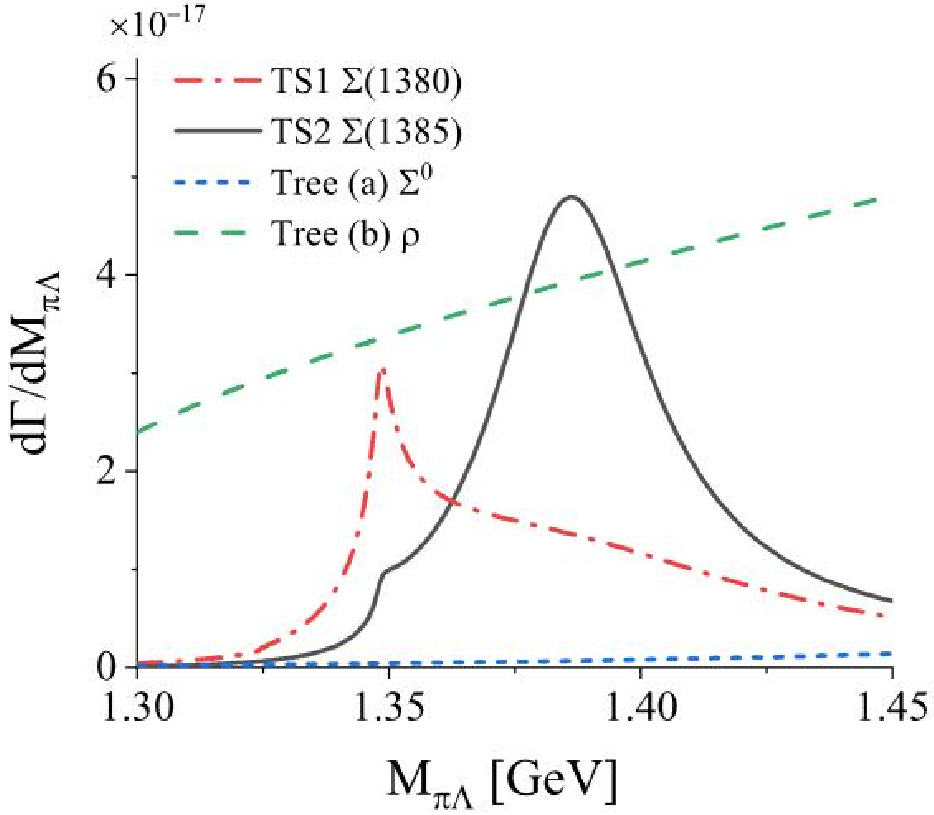


Cusp signal of $\Sigma(1/2^-)$ around $\bar{K}N$ threshold!

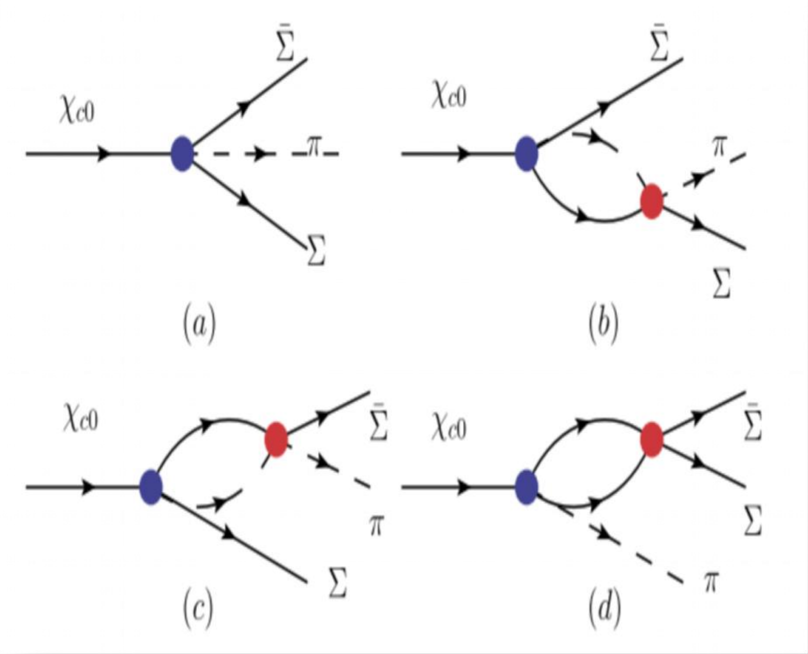
Charmed baryon decay

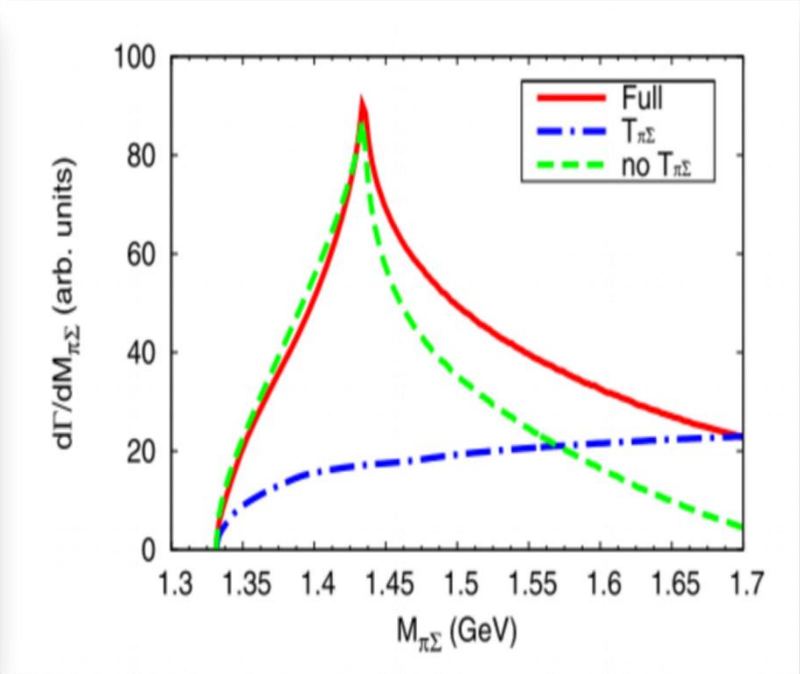
- $\Lambda_c^+ \to \gamma\Lambda\pi$, KWang,YFWang, BCLiu, and Fhuang, 2408.12965

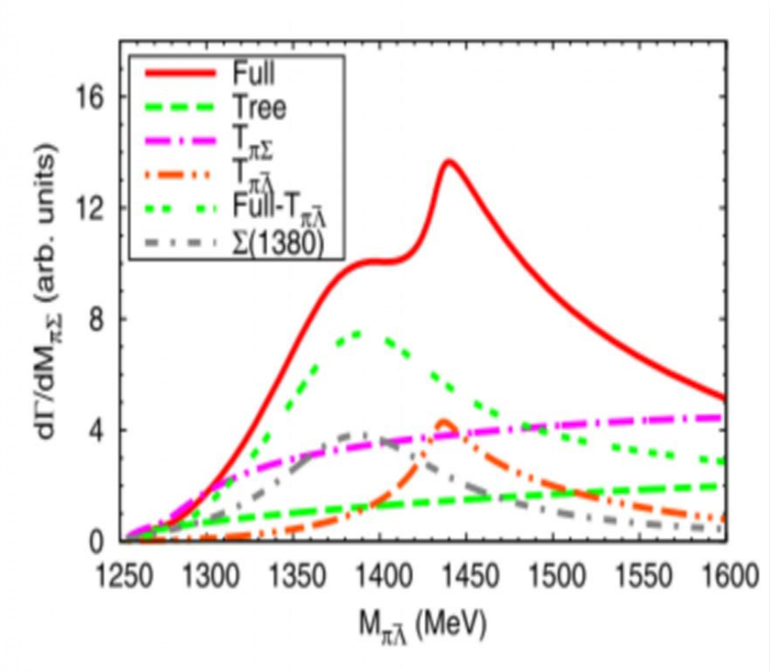




Charmonium decays







$\chi_{c0} \to \bar{\Sigma}\Sigma\pi$

PLB753(2016)526

$\chi_{c0} \to \bar{\Lambda}\Sigma\pi$

PRD98(2018)114017

Two poles of $\Sigma(1/2^-)$

PHYSICAL REVIEW LETTERS **130,** 071902 (2023)

Cross-Channel Constraints on Resonant Antikaon-Nucleon Scattering

Jun-Xu Lu,[1,2] Li-Sheng Geng,[3,2,4,5,*] Michael Doering,[6,7] and Maxim Mai[8,6]
[1]*School of Space and Environment, Beijing 102206, China*
[2]*School of Physics, Beihang University, Beijing 102206, China*

It is interesting to note that in our NNLO fit there exist two $I = 1$ states around the $\bar{K}N$ threshold located at $(1435, -39)$ MeV and $(1440, -135)$ MeV on the $(--++++)$ sheet, the order of which corresponds to $\pi\Lambda, \pi\Sigma, \bar{K}N, \eta\Lambda, \eta\Sigma, K\Xi$ respectively. Both states are well above the K^-p threshold and appear as cusps on the real axis. In the Fit "NNLO*" in which the constraints from baryon masses are omitted, the two $I = 1$ states are located at $(1364, -110)$ MeV and $(1432, -18)$ MeV also on the $(--++++)$ sheet. In this case, the narrower state still shows up as a cusp but the broader one becomes a broad enhancement on the $I = 1$ amplitude on the real axis. We note that the existence of a $\Sigma^*(\frac{1}{2}^-)$ state has been predicted in a number of UChPT

Are there two poles of $\Sigma(1/2^-)$?

Summary

- The missing $\Sigma(1/2^-)$ is important for understanding the baryon spectrum.
- Internal structure: compact pentaquark & molecule
- Searching for $\Sigma(1/2^-)$ in
  - Hadron-hadron scattering
  - γ/ν-production
  - Charmed baryon decays
  - Charmonium decays

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Thank you very much!