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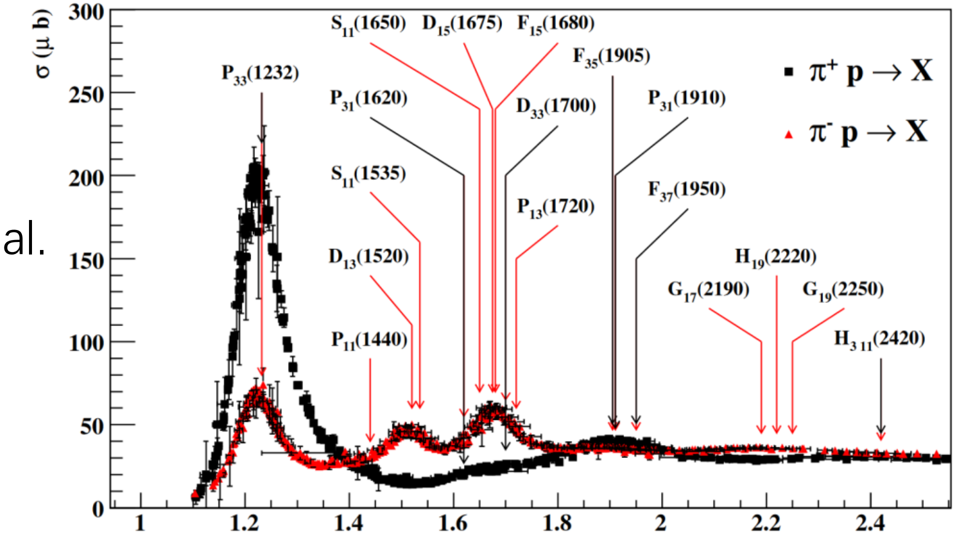
Analysis of Σ^* via isospin-selective $K_L p$ scattering

郭丹 On behalf of KLF

燕山大学

Dan Guo, Jun Shi (South-China Normal U.), Igor Strakovsky (Goerge-Washington U.) and Bing-Song Zou (Tsinghua U.), Analysis of Σ^* via isospin selective reaction $K_L p \to \pi^+ \Sigma^0$, Phys. Rev. D 112, 034006 (2025).

πN **scattering**: ~10^5 datasets
most clear in particle & nuclear physics.
All four-star N^*, Δ^*. Basic couplings $g_{\pi NN}$ et al.
PWA: SAID, MAID.



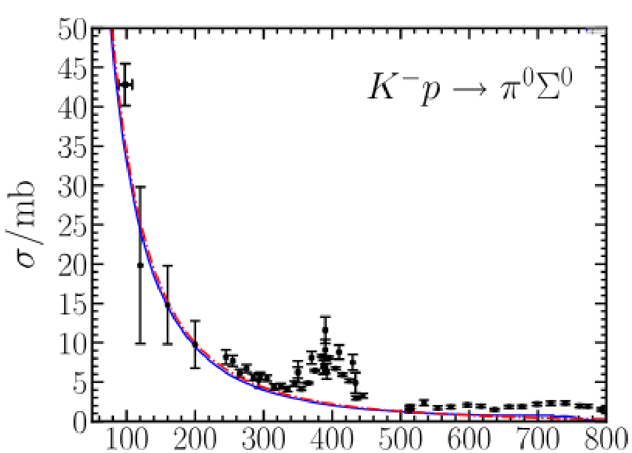
Thesis: Williams:2007zzg

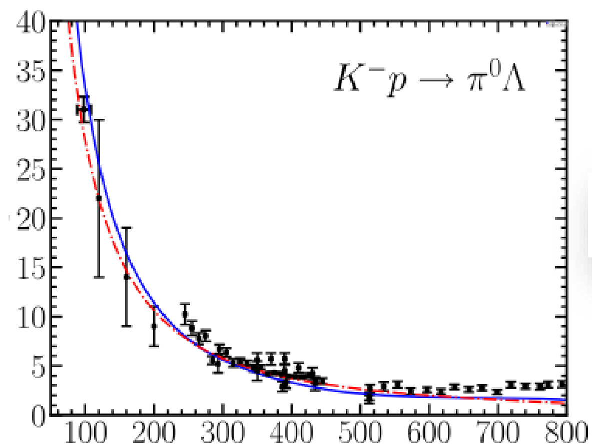
For **hyperon**: Λ^*, Σ^*, Ξ^*, Ω^*. $\bar{K}N$ scattering is most favored.

$Q > 0$ reaction,
kinematically allowed @ $P_{lab} = 0\ MeV$

$$Q = \sum_i m_i - \sum_f m_f$$

Near $\bar{K}N$ threshold with large phase space, strong coupling





~10 mb

$$\frac{d\sigma_{\pi^0\Lambda}}{d\Omega} = \frac{d\sigma_{\pi^0\Lambda}}{2\pi\, d\cos\theta} = \frac{1}{64\pi^2 s}\frac{|\mathbf{q}|}{|\mathbf{k}|}\overline{|\mathcal{M}|^2}$$

However, **hyperon** spectrum is very **ambiguous**

Mainly due to: old scattering data (1980s), scarcity of polarizations, **isospin-mixing**

$$
\begin{aligned}
T(K^-p \to \pi^-\Sigma^+) &= -\frac{1}{2}T^1(\overline{K}N \to \pi\Sigma) - \frac{1}{\sqrt{6}}T^0(\overline{K}N \to \pi\Sigma), \\
T(K^-p \to \pi^+\Sigma^-) &= \frac{1}{2}T^1(\overline{K}N \to \pi\Sigma) - \frac{1}{\sqrt{6}}T^0(\overline{K}N \to \pi\Sigma), \\
T(K^-p \to \pi^0\Sigma^0) &= \frac{1}{\sqrt{6}}T^0(\overline{K}N \to \pi\Sigma),
\end{aligned}
$$

E. Wang, L. S. Geng, J. J. Wu, J. J. Xie, and B. S. Zou, Review of the low-lying excited baryons $\Sigma^*(1/2^-)$, Chin. Phys. Lett. 41, 101401 (2024).

Difficulties of amplitude reversion: **phase ambiguity**, parameter degeneracy, incomplete exp. obser. set→ Multi-solution problem (nonlinear)

$$Observables \propto |\mathcal{M}|^2 = \mathcal{M} * \mathcal{M}^\dagger$$

allow an arbitrary phase $e^{i\phi}$

$$Observables \propto |\mathcal{M}|^2 = (e^{i\phi} * \mathcal{M}) * \left(e^{i\phi} * \mathcal{M}\right)^\dagger$$

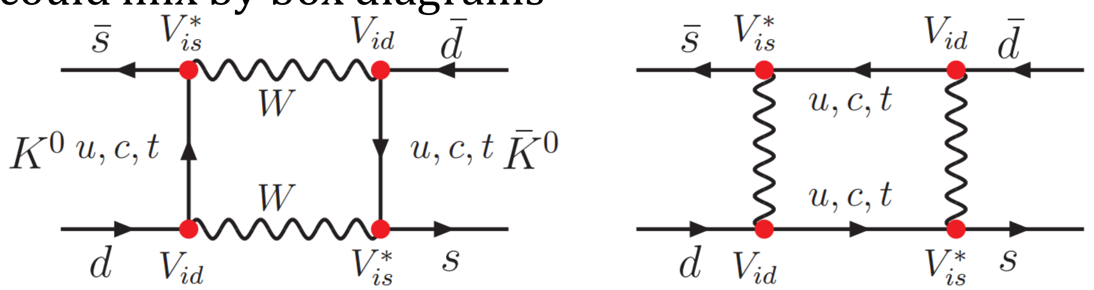
For multi-resonance reaction, relative phase must introduced.

At least, ± 1, $\pm i$ phase.

isospin selective $K_L p \to \pi^+ \Sigma^0$ process

$K^0\ \bar{K}^0$ as flavor eigenstates, could mix by box diagrams

$K^0 - \bar{K}^0$ mixing



Ignore CP-violation term ($< 10^{-3}$), define CP eigenstates:

$$K_S^0 = \frac{1}{\sqrt{2}}(K^0 + \bar{K}^0),\ K_L^0 = \frac{1}{\sqrt{2}}(K^0 - \bar{K}^0)$$

mean life K_L: $5.116 \times 10^{-8}\ s$ ($c\tau = 15.3$ m)
K_S: $0.895 \times 10^{-10}\ s$ ($c\tau = 2.68$ cm)

K_L suitable as a beam to collide on the proton target.
Most of $\bar{K}N$ scattering data from $K^- p$ reaction, contain both isoscalar and isovector

$$\begin{aligned}
T(K^-p \to \pi^-\Sigma^+) &= -\frac{1}{2}T^1(\bar{K}N \to \pi\Sigma) - \frac{1}{\sqrt{6}}T^0(\bar{K}N \to \pi\Sigma), \\
T(K^-p \to \pi^+\Sigma^-) &= \frac{1}{2}T^1(\bar{K}N \to \pi\Sigma) - \frac{1}{\sqrt{6}}T^0(\bar{K}N \to \pi\Sigma), \\
T(K^-p \to \pi^0\Sigma^0) &= \frac{1}{\sqrt{6}}T^0(\bar{K}N \to \pi\Sigma),
\end{aligned}$$

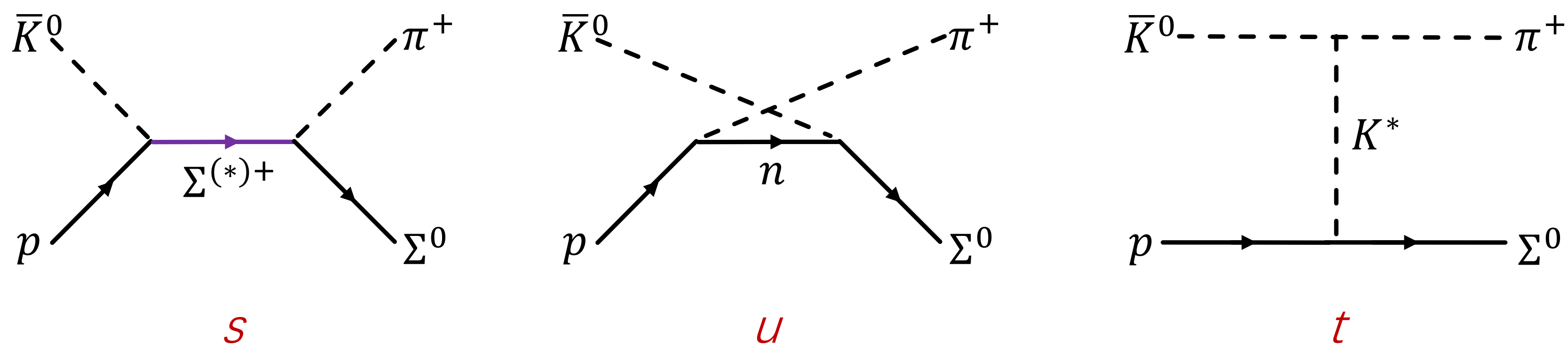
$$T(K_L p \to \pi^+\Sigma^0) = -\frac{1}{2}T^1(\bar{K}N \to \pi\Sigma),$$

$$T(K_L p \to \pi^0\Sigma^+) = \frac{1}{2}T^1(\bar{K}N \to \pi\Sigma),$$

$K^- p$ include $I = 0, 1$ amplitudes

$K_L p$ only $I = 1$ amplitudes

For $K_L p \to \pi^+\Sigma^0$, only $\bar{K}^0$ contributes, tree-level Feynman diagrams:



In the energy range up to 1.7 GeV, Σ^* resonances(up to D-wave): $J^P = 1/2^\pm, 3/2^\pm, 5/2^-$

$1/2^+$:

$$\mathcal{L}_{KN\Sigma} = \frac{g_{KN\Sigma}}{M_N + M_\Sigma}\partial_\mu \bar{K}\,\bar{\Sigma}\cdot\tau\gamma^\mu\gamma_5 N + \text{H.c.},$$

$$\mathcal{L}_{\pi\Sigma\Sigma} = i\frac{f_{\pi\Sigma\Sigma}}{m_\pi}\bar{\Sigma}\gamma^\mu\gamma_5 \times \Sigma\cdot\partial_\mu\pi + \text{H.c.},$$

$1/2^-$:

$$\mathcal{L}_{KN\Sigma(1/2^-)} = -ig_{KN\Sigma(1/2^-)}\bar{K}\,\bar{\Sigma}(1/2^-)\cdot\tau N + \text{H.c.},$$

$$\mathcal{L}_{\pi\Sigma\Sigma(1/2^-)} = g_{\pi\Sigma\Sigma(1/2^-)}\bar{\Sigma}(1/2^-)\times\Sigma\cdot\pi + \text{H.c.}.$$

$3/2^+$:

$$\mathcal{L}_{KN\Sigma^*} = \frac{f_{KN\Sigma^*}}{m_K}\partial_\mu\bar{K}\bar{\Sigma}^{*\mu}\cdot\tau N + \text{H.c.},$$

$$\mathcal{L}_{\pi\Sigma\Sigma^*} = i\frac{f_{\pi\Sigma\Sigma^*}}{m_\pi}\partial_\mu\pi\cdot\bar{\Sigma}^{*\mu}\times\Sigma + \text{H.c.}.$$

$3/2^-$:

$$\mathcal{L}_{KN\Sigma(3/2^-)} = \frac{f_{KN\Sigma(3/2^-)}}{m_K}\partial_\mu\bar{K}\bar{\Sigma}^\mu(3/2^-)\cdot\tau\gamma_5 N + \text{H.c.},$$

$$\mathcal{L}_{\pi\Sigma\Sigma(3/2^-)} = i\frac{f_{\pi\Sigma\Sigma(3/2^-)}}{m_\pi}\partial_\mu\pi\cdot\bar{\Sigma}^\mu(3/2^-)\times\gamma_5\Sigma + \text{H.c.}.$$

$5/2^-$:

$$\mathcal{L}_{KN\Sigma(5/2^-)} = g_{KN\Sigma(5/2^-)}\partial_\mu\partial_\nu\bar{K}\bar{\Sigma}^{\mu\nu}(5/2^-)\cdot\tau N + \text{H.c.},$$

$$\mathcal{L}_{\pi\Sigma\Sigma(5/2^-)} = ig_{\pi\Sigma\Sigma(5/2^-)}\partial_\mu\partial_\nu\pi\cdot\bar{\Sigma}^{\mu\nu}(5/2^-)\times\Sigma + \text{H.c.}.$$

u-channel:

$$\mathcal{L}_{\pi NN} = \frac{g_{\pi NN}}{2M_N}\bar{N}\gamma^\mu\gamma_5\partial_\mu\pi\cdot\tau N,$$

t-channel:

$$\mathcal{L}_{K^*K\pi} = ig_{K^*K\pi}\bar{K}^*_\mu(\pi\cdot\tau\partial^\mu K - \partial^\mu\pi\cdot\tau K),$$

$$\mathcal{L}_{K^*N\Sigma} = -g_{K^*N\Sigma}\bar{\Sigma}\cdot\tau\left(\gamma_\mu\bar{K}^{*\mu} - \frac{\kappa_{K^*N\Sigma}}{2M_N}\sigma_{\mu\nu}\partial^\nu\bar{K}^{*\mu}\right)N + \text{H.c.}.$$

Form factors account for off-shell effects:

$$F_B(q_{ex}^2, M_{ex}) = \frac{\Lambda^4}{\Lambda^4 + (q_{ex}^2 - M_{ex}^2)^2}$$

Total amp.:

$$\mathcal{M}^{r_2,r_1}_{\bar{K}^0 p\to\pi^+\Sigma^0} = \bar{u}_{r_2}(p_2)\mathcal{A}u_{r_1}(p_1) = \bar{u}_{r_2}(p_2)\left(\sum_i \mathcal{A}_i\right)u_{r_1}(p_1)$$

Differential cross section:

$$\frac{d\sigma_{K_L p\to\pi^+\Sigma^0}}{d\Omega} = \frac{d\sigma_{K_L p\to\pi^+\Sigma^0}}{2\pi d\cos(\theta)} = \frac{1}{2}\frac{1}{64\pi^2 s}\frac{|\vec{k}_2|}{|\vec{k}_1|}\overline{|\mathcal{M}_{\bar{K}^0 p\to\pi^+\Sigma^0}|}^2$$

Initial couplings estimated from SU(3) relations or partial decay widths.
A tunable scaling factor $\in [1/2, 2]$ is introduced account for SU(3) breaking.

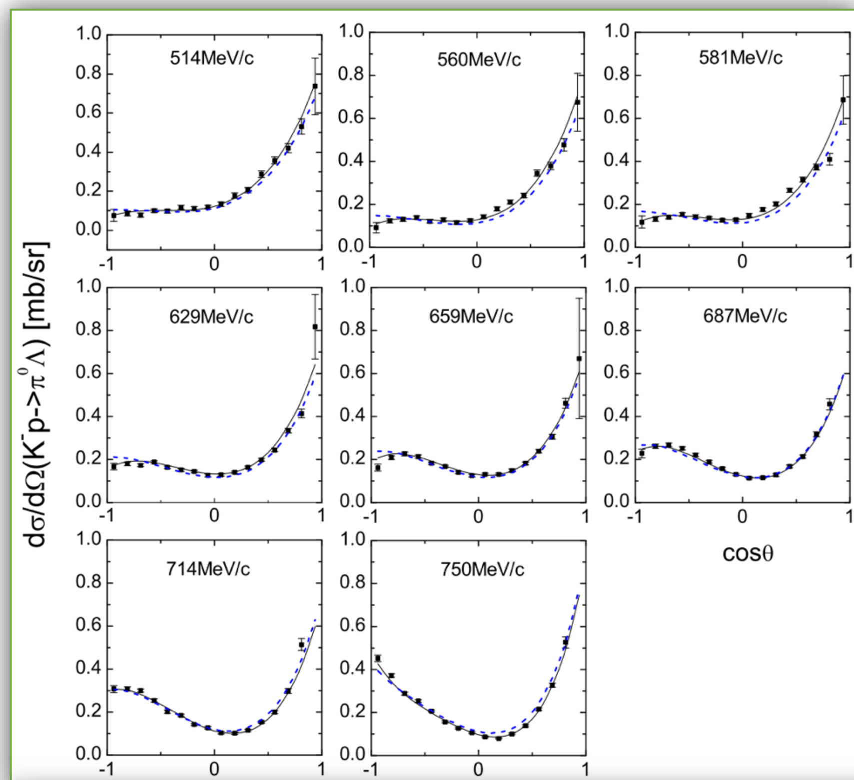
	Mass (MeV) (PDG estimate)	Γ_{tot} (MeV) (PDG estimate)	$(\Gamma_{\pi\Lambda}\Gamma_{KN})^{\frac{1}{2}}/\Gamma_{tot}$ (PDG range)
$\Sigma(1670)\frac{3}{2}^-$	$1673.1^{+1.4}_{-1.6}$ (1665, 1685)	$53^{+7}_{-5.5}$ (40, 80)	$+0.08^{+0.022}_{-0.018}$ (0.02, 0.17)
$\Sigma(1635)$ or $\Sigma(1660)\frac{1}{2}^+$	$1634.8^{+2.7}_{-4.5}$ (1630, 1690)	120 ± 12 (40, 200)	$-0.065^{+0.015}_{-0.017}$ (0,0.24)

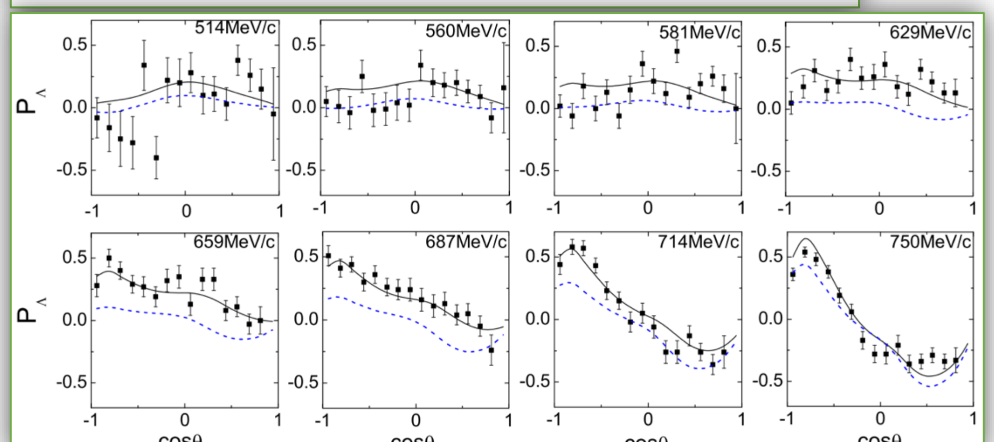
Our previous work:

P. Gao, B.S. Zou, A. Sibirtsev/ Nuclear Physics A 867 41 (2011)

$K^- p \to \pi^0 \Lambda$: dcs and recoil polarization

Cited by PDG





Σ(1660) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1640 to 1680 (≈ 1660) OUR ESTIMATE				
1665 ±20	SARANTSEV	19	DPWA	$\overline{K}N$ multichannel
1633 ± 3	GAO	12	DPWA	$\overline{K}N \to \Lambda\pi$
1665.1±11.2	KOISO [1]	85	DPWA	$K^- p \to \Sigma\pi$
1670 ±10	GOPAL	80	DPWA	$\overline{K}N \to \overline{K}N$
1679 ±10	ALSTON-...	78	DPWA	$\overline{K}N \to \overline{K}N$
1668 ±25	VANHORN	75	DPWA	$K^- p \to \Lambda\pi^0$
1670 ±20	KANE	74	DPWA	$K^- p \to \Sigma\pi$

Σ(1660) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 300 (≈ 200) OUR ESTIMATE				
300^{+140}_{-40}	SARANTSEV	19	DPWA	$\overline{K}N$ multichannel
121^{+4}_{-7}	GAO	12	DPWA	$\overline{K}N \to \Lambda\pi$
81.5± 22.2	KOISO [1]	85	DPWA	$K^- p \to \Sigma\pi$
152 ± 20	GOPAL	80	DPWA	$\overline{K}N \to \overline{K}N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\overline{K} \to \Sigma(1660) \to \Lambda\pi$ **$(\Gamma_1\Gamma_2)^{1/2}/\Gamma$**

VALUE	DOCUMENT ID		TECN	COMMENT
$-0.064^{+0.005}_{-0.003}$	GAO	12	DPWA	$\overline{K}N \to \Lambda\pi$
< 0.04	GOPAL	77	DPWA	$\overline{K}N$ multichannel
$0.12^{+0.12}_{-0.04}$	VANHORN	75	DPWA	$K^- p \to \Lambda\pi^0$

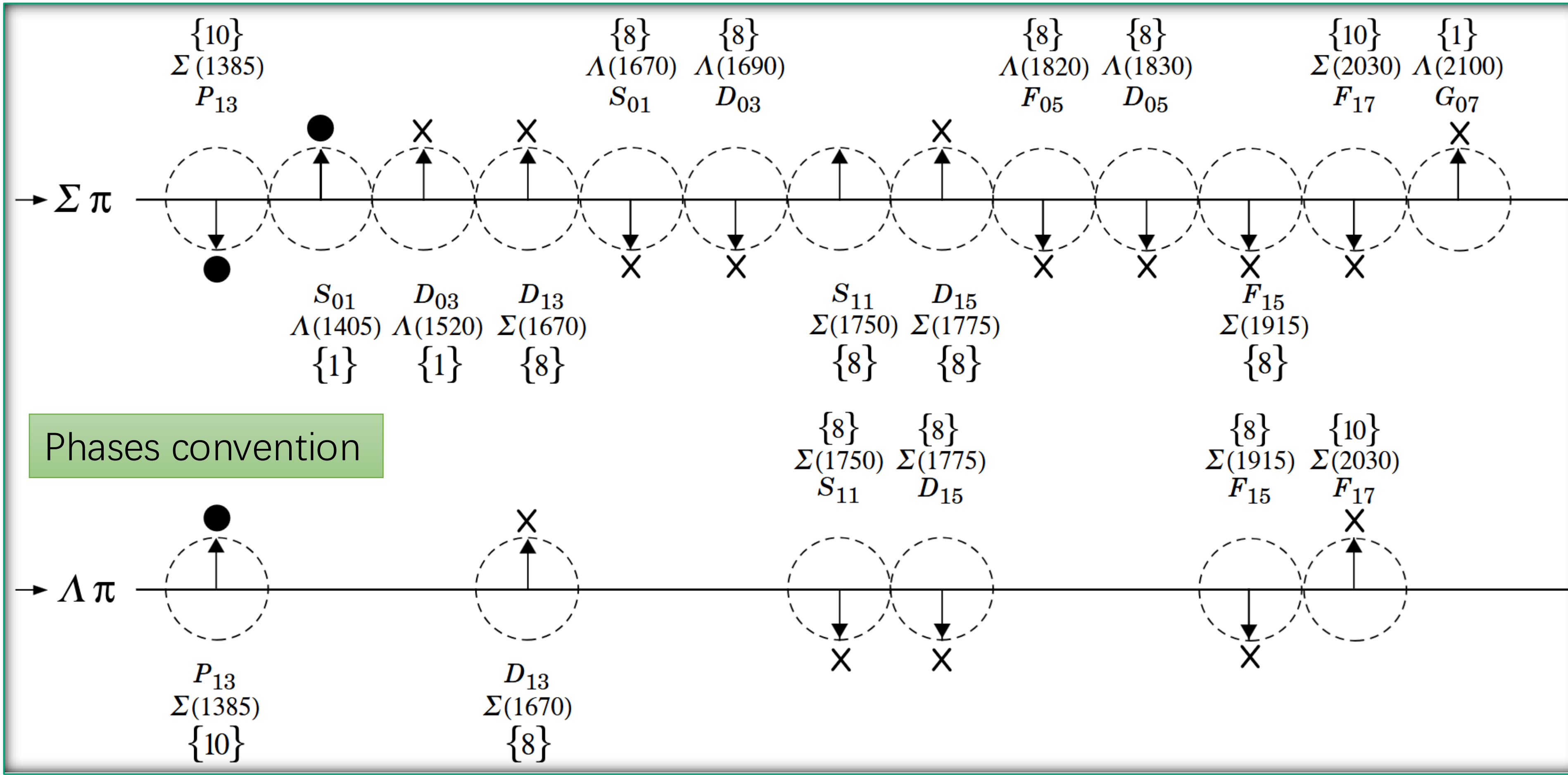
The sign denotes amp. phase

PDG review:

82. Λ and Σ Resonances

Revised August 2021 by V.D. Burkert (Jefferson Lab), V. Crede (Florida State U.), E. Klempt (Bonn U.), U. Thoma (Bonn U.), L. Tiator (KPH, JGU Mainz) and R.L. Workman (George Washington U.).

$\Sigma\pi$ final state: Σ^* Λ^* signs, $\Lambda\pi$: Σ^* signs.



● set by convention, ⇂↿ by SU(3) assignments, × experiment determined

Include four-star $\Sigma^{(*)}$: $\Sigma(1189)1/2^+$, $\Sigma(1385)3/2^+$, $\Sigma(1670)3/2^-$, $\Sigma(1775)5/2^-$
unestablished states: $\Sigma(1580)3/2^-$, $\Sigma(1620)1/2^-$, $\Sigma(1660)1/2^+$, $\Sigma(1750)1/2^-$

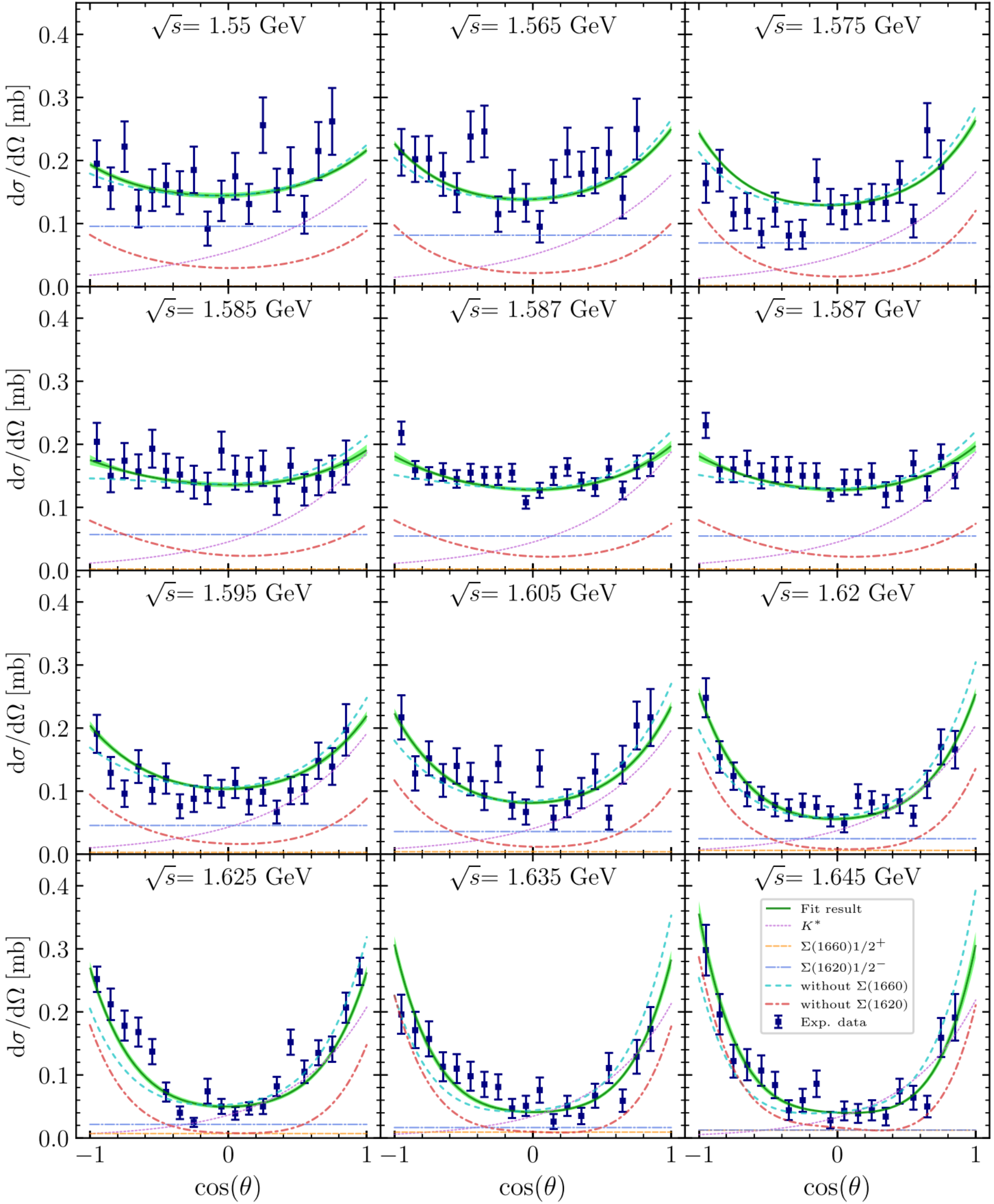
Fitted results

Origin: only **** states: $\chi^2/dof = 2.8$

keeping strict phase conventions

	m (MeV)	Γ (MeV)	Signs
$\Sigma(1189)1/2^+$	1192	0	...
$\Sigma(1385)3/2^+$	1384	36	↓
$\Sigma(1670)3/2^-$	1675	70	↑
$\Sigma(1775)5/2^-$	1775	120	↑

Resonances	Parameters	Optimal fit	Fit I	Fit II	Fit III	Estimates
K^*	$g_{K^*N\Sigma}$	-7.0 ± 0.5	-7.0	-2.7	-7.0 ± 1.2	$[-7.0, -1.2]$
	$\kappa_{K^*N\Sigma}$	-1.6 ± 0.2	-2.3	-2.3	-1.6 ± 0.8	$[-2.3, -0.2]$
	Λ	0.97 ± 0.01	1.01	2.0	0.97 ± 0.09	$[0.5, 2.0]$
N	Λ	1.42 ± 0.04	1.93	1.47	1.4 ± 0.4	$[0.5, 2.0]$
$\Sigma(1189)1/2^+$	$g_{KN\Sigma}f_{\pi\Sigma\Sigma}$	-1.50 ± 3.0	-3.39	-1.35	-1.50 ± 3.0	$[-5.4, -1.3]$
	Λ	0.5 ± 1.1	0.6	0.5	0.5 ± 1.3	$[0.5, 2.0]$
$\Sigma(1385)3/2^+$	$f_{KN\Sigma^*}f_{\pi\Sigma\Sigma^*}$	-1.34 ± 4.0	-4.49	-5.7	-1.34 ± 4.0	$[-5.7, -1.1]$
	Λ	0.50 ± 0.18	0.5	0.6	0.5 ± 1.3	$[0.5, 2.0]$
$\Sigma(1670)3/2^-$	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{\rm tot}$	$+0.26 \pm 0.04$	$+0.27$	$+0.29$	$+0.24 \pm 0.06$	$[0.09, 0.38]$
	Λ	0.72 ± 0.07	0.61	0.62	0.76 ± 0.17	$[0.5, 2.0]$
$\Sigma(1775)5/2^-$	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{\rm tot}$	$+0.24 \pm 0.04$	$+0.24$	$+0.24$	$+0.24 \pm 0.12$	$[0.06, 0.24]$
	Λ	2.0 ± 1.4	2.0	1.1	2.0 ± 1.5	$[0.5, 2.0]$
$\Sigma(1580)3/2^-$	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{\rm tot}$	$+0.032 \pm 0.005$	$+0.034$	...	$+0.031 \pm 0.005$	$[-0.4, 0.4]$
	Λ	0.50 ± 0.09	0.5	...	0.50 ± 0.11	$[0.5, 2.0]$
$\Sigma(1660)1/2^+$	M (GeV)	1.696 ± 0.010	1.75	...	1.673 ± 0.027	$[1.40, 1.75]$
	Γ (GeV)	0.108 ± 0.021	0.073	...	0.10 ± 0.04	$[0.01, 0.40]$
	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{\rm tot}$	-0.112 ± 0.006	-0.121	...	-0.086 ± 0.048	$[-0.48, 0.48]$
	Λ	2.0 ± 0.8	2.0	...	2.0 ± 1.2	$[0.5, 2.0]$
$\Sigma(1620)1/2^-$	M (GeV)	1.541 ± 0.003	1.4(Fixed)	1.545	1.542 ± 0.007	$[1.35, 1.65]$
	Γ (GeV)	0.129 ± 0.002	0.4	0.10	0.16 ± 0.05	$[0.01, 0.40]$
	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{\rm tot}$	-0.633 ± 0.009	-2.32	-0.45	-0.779 ± 0.259	$[-3.2, 3.2]$
	Λ	0.89 ± 0.04	1.07	0.59	0.72 ± 0.19	$[0.5, 2.0]$
$\Sigma(1750)1/2^-$	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{\rm tot}$	...	...	...	$+0.093 \pm 0.187$	$[-1.2, 1.2]$
	Λ	...	...	...	1.9 ± 0.8	$[0.5, 2.0]$
	d.o.f.	223	224	229	221	
	χ^2/d.o.f.	1.606	1.707	1.774	1.619	



Narrow 1-σ errorband,
robust para constraint
χ^2/DoF=1.606

t-channel dominates the forward-angle.
s-channel no angle dependence.

$\Sigma(1660)1/2^+$	M (GeV)	1.696 ± 0.010
	Γ (GeV)	0.108 ± 0.021
	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{tot}$	-0.112 ± 0.006
	Λ	2.0 ± 0.8
$\Sigma(1620)1/2^-$	M (GeV)	1.541 ± 0.003
	Γ (GeV)	0.129 ± 0.002
	$\sqrt{\Gamma_{\bar{K}N}\Gamma_{\pi\Sigma}}/\Gamma_{tot}$	-0.633 ± 0.009
	Λ	0.89 ± 0.04

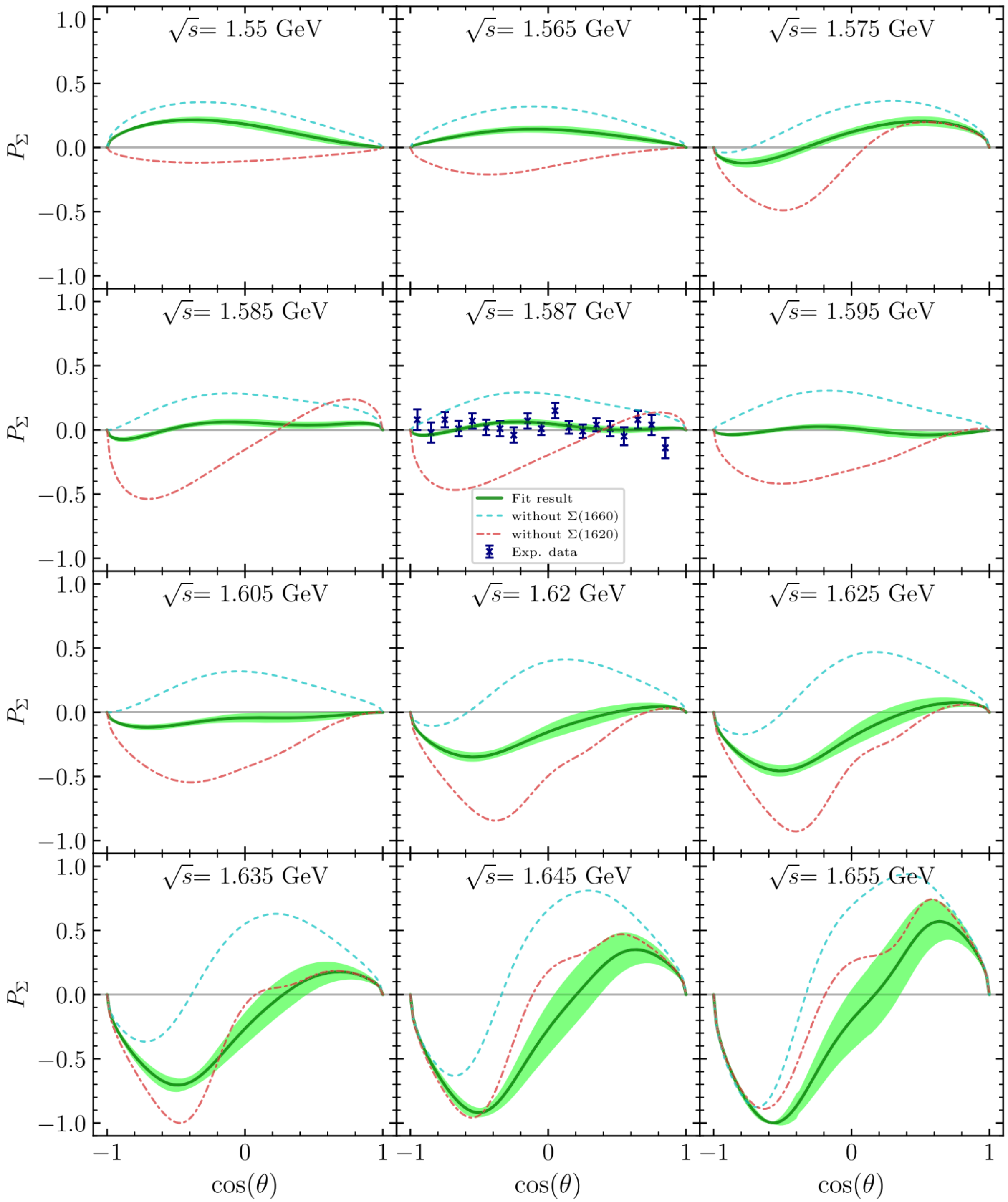
$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\bar{K} \to \Sigma(1660) \to \Sigma\pi$

VALUE	DOCUMENT ID	
-0.13 ± 0.04	[1] KOISO	85
-0.16 ± 0.03	GOPAL	77
-0.11 ± 0.01	KANE	74

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\bar{K} \to \Sigma(1620) \to \Sigma\pi$

VALUE	DOCUMENT ID	
$+0.32\pm0.03$	ZHANG	13A
not seen	HEPP	76B
$+0.40\pm0.06$	LANGBEIN	72
$+0.08$	KIM	71

Fitted M Γ of $\Sigma(1/2^-)$ compatible with
Phys. Rev. C 88, 035205 (2013).
Phys. Rev. C 92, 025205 (2015) .



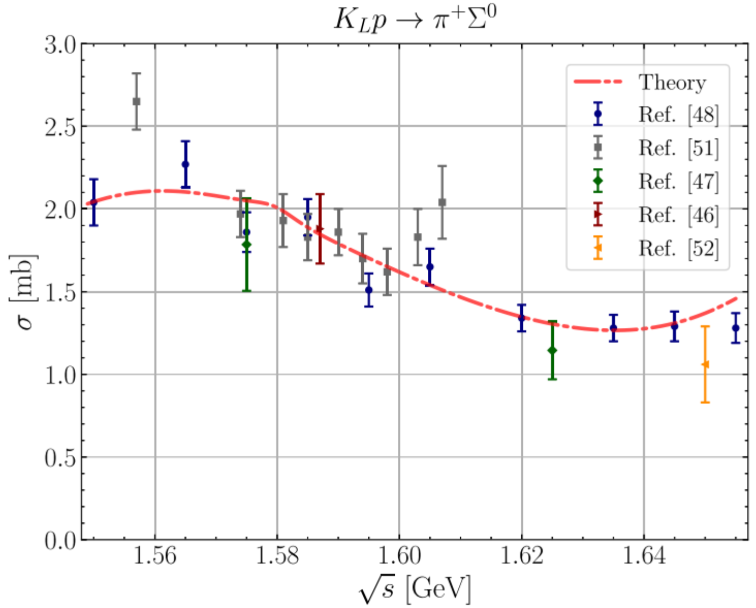
Recoil polarization

$$P_\Sigma = -\frac{2\,\mathrm{Im}\left(\mathcal{M}^{1/2,1/2}_{\bar{K}^0 p\to\pi^+\Sigma^0}\mathcal{M}^{*-1/2,1/2}_{\bar{K}^0 p\to\pi^+\Sigma^0}\right)}{\overline{\left|\mathcal{M}_{\bar{K}^0 p\to\pi^+\Sigma^0}\right|^2}}$$

Polarization arises from interference. Single diagram produce zero polarization.

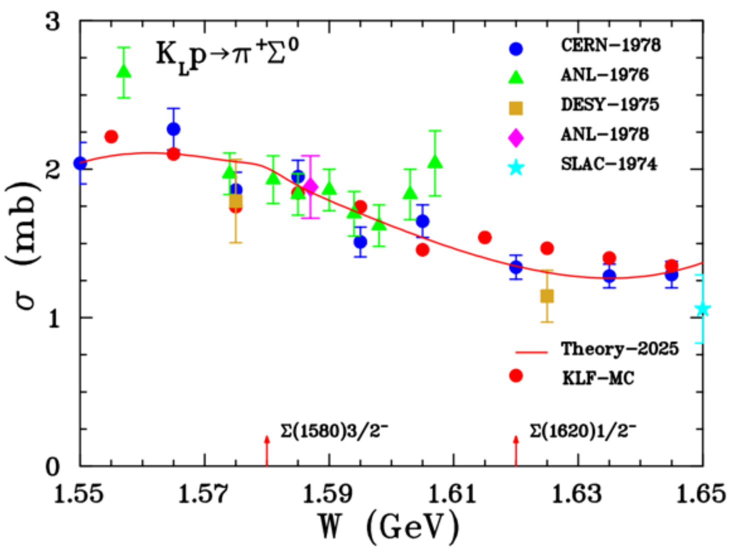
Measuring the asymmetry in the spin distribution of the recoiling Σ^0 along the direction normal to the reaction plane.

In fit procedure, not include total c-s data.
Comparison of theoretical and experimental



Agree well with MC result, talk by Moskov Amaryan, KLF Collaboration

Isospin-Selective Reaction $K_L p \to \pi^+ \Sigma^0$ Provides Clean Probe for Investigating $I = 1$ Σ^* Resonances



Analysis of this reaction using effective *Lagrangian* approach for first time, incorporating well-established (4*): $\Sigma(1189)1/2^+$, $\Sigma(1385)3/2^+$, $\Sigma(1670)3/2^-$, & $\Sigma(1775)5/2^-$ states, while also exploring contributions from other unestablished states.

Dan Guo, Jun Shi, Igor Strakovsky, & Bing-Song Zou, arXiv:2504.21342 [hep-ph]

It was found that besides established resonances, contributions from $\Sigma(1660)1/2^+$ (3*), $\Sigma(1580)3/2^-$ (1*), & $\Sigma(1620)1/2^-$ (1*) improve description.

Further, include $K_L p \to \pi^+ \Lambda$, joint fitting

Migrad				
FCN = 855 (chi2/ndof = 1.6) EDM = 0.000158 (Goal: 0.0002)		Nfcn = 6534 time = 125.1 sec		
Valid Minimum		SOME Parameters at limit		
Below EDM threshold (goal x 10)		Below call limit		
Covariance	Hesse ok	Accurate	Pos. def.	Not forced

	Name	Value	Hesse Err	Minos Err-	Minos Err+	Limit-	Limit+	Fixed
0	c1a	1.10	0.04			0.5	2	
1	c2a	0.971	0.020			0.5	2	
2	c3a	1.143	0.035			0.5	2	
3	c4a	0.615	0.013			0.5	2	
4	c5a	2.0	1.4			0.5	2	
5	c6a	0.97	0.21			0.5	2	
6	c7a	2.0	0.2			0.5	2	
7	p1a	-2.70	0.06			-10.84	-2.7	
8	p2a	-1.230	0.022			-7	-1.23	
9	p3a	-2.28	0.08			-2.28	-0.24	
10	p4a	2.50	0.19			2.5	12.8	
11	p5a	-0.54	0.08			-5	5	
12	p6a	16.9	0.8			7.8	31.3	
13	p7a	4.86	0.04			1.2	4.86	
14	m5	1.637	0.004			1.62	1.69	
15	w5	0.129	0.015			0.01	0.4	
16	m5m	1.5566	0.0019			1.35	1.65	
17	w5m	0.117	0.011			0.01	0.4	
18	p8a	-1.14	0.12			-10	10	
19	c8a	0.622	0.028			0.5	2	
20	p9a	1.93	0.10			-5	5	
21	c9a	2	1			0.5	2	
22	p10a	0.55	0.27			-20	20	
23	c10a	0.50	0.11			0.5	2	
24	p1b	8.43	0.24			2.1084	8.4336	
25	p2b	-9.8	0.6			-12.22	-2.13	
26	p3b	1.22	0.04			1.215	5.32	
27	p4b	19.2	1.2			4.55	19.2	
28	p5b	0.93	0.13			-5	5	
29	p6b	-11.7	1.0			-14.854	-3.7135	
30	p7b	2.5	0.6			2.1435	8.5738	
31	p8b	0.30	0.04			-5	5	
32	p9b	-0.81	0.33			-5	5	
33	p10b	0.64	0.09			-20	20	

Common cutoffs and Consistent phase for two channels.

χ^2= 855.029,

χ^2/dof= 1.6041

dof=283+284−34=533

NE=14, Ecm=1.55--1.672 $\Sigma\pi, \Lambda\pi$

283=264+19, 284=265+19 dcs+polar

$\Sigma(1660)1/2^+$:

$m = 1.637$ GeV,

$\Gamma = 0.129$ GeV

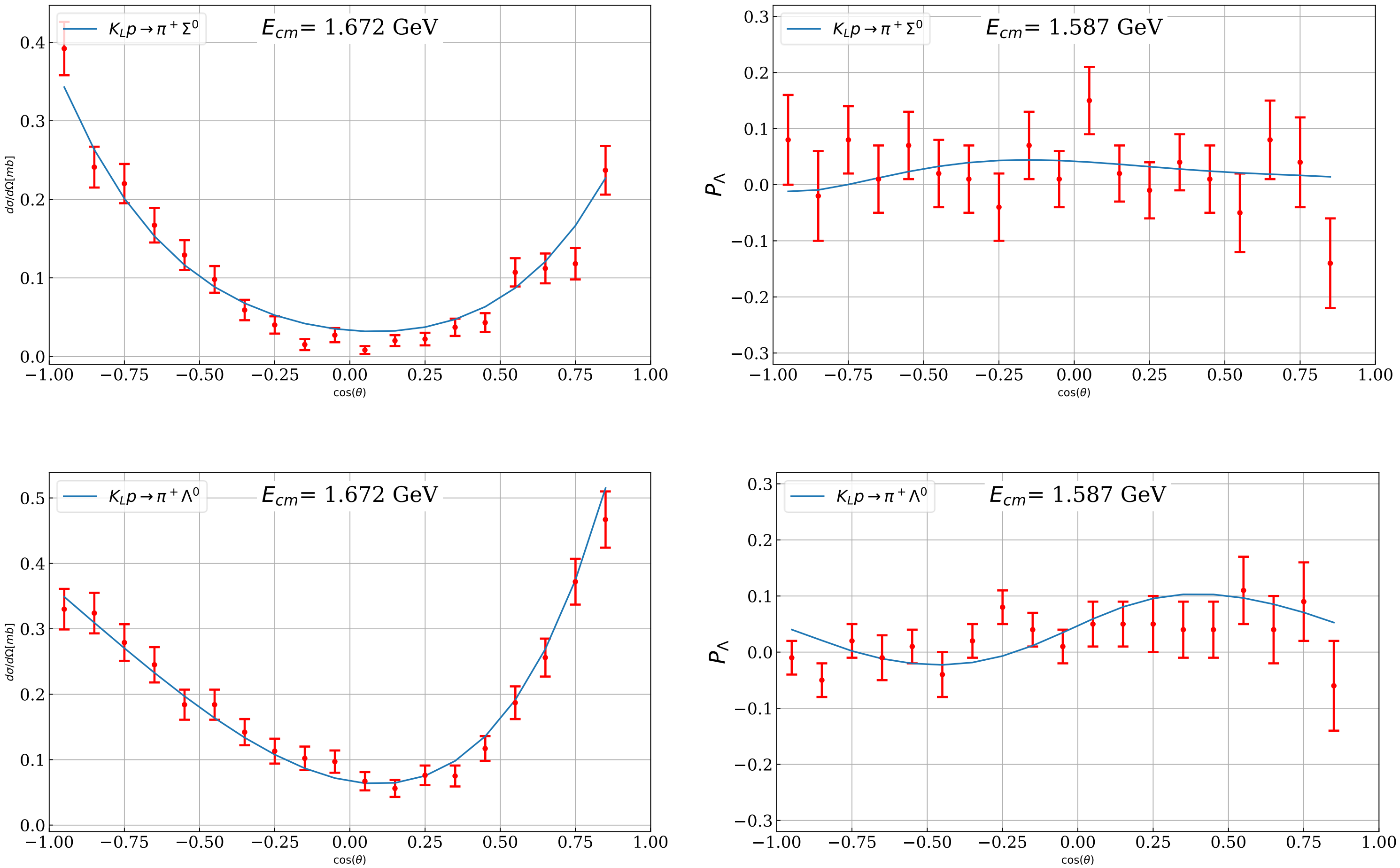
$\Sigma(1620)1/2^-$:

$m = 1.557$ GeV,

$\Gamma = 0.117$ GeV

Coming soon!

Example



Coming soon!

Conclusion

(1) The first theoretical analysis of $K_L p \to \pi^+ \Sigma^0$ and $\pi^+ \Lambda$ using effective Lagrangian method, with strict phase convention and isospin-selection.

(2) Further confirm the existence of $\Sigma(1660)1/2^+$.

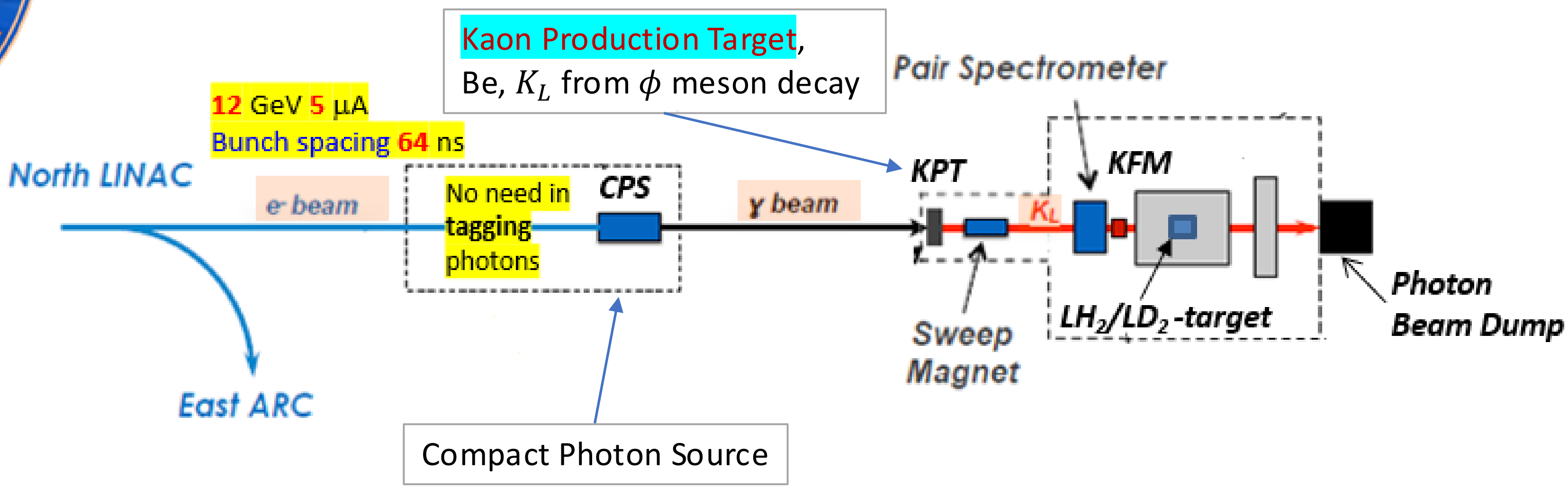
(3) Due to the limited quality of historical data earlier than 1980, in present, the mass of $\Sigma(1620)1/2^-$ is fitted around 1.55 GeV.

Expecting more precise measurements of $K_L p$ scattering in wider energy range by **KLF** based on GlueX experiment.

Outlook

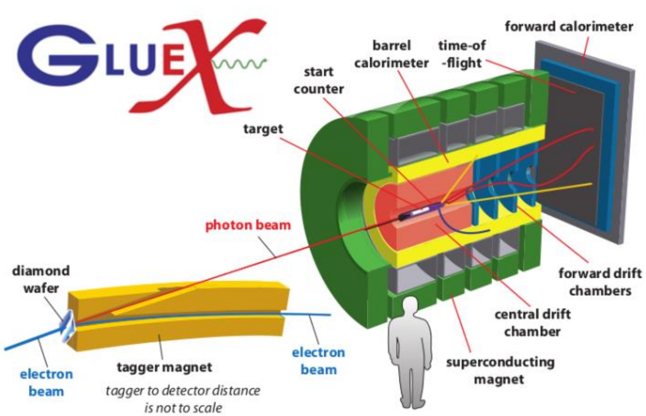
After confirmation of $\Sigma(1660)1/2^+$ and $\Sigma(1620)1/2^-$ on tree-level, perform coupled-channel analysis considering unitarity and analyticity. Similar procedure for Λ^*, or isolate the Λ^* contribution in $K^- p$ scattering.

KLF exp. introduction



Production chain:

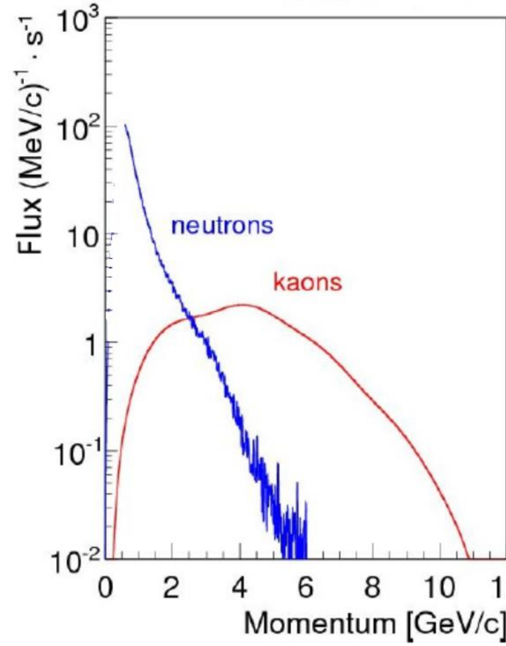
$$e^-(12\text{GeV } 3.1\times10^{13}/sec) \to \gamma(1.5\text{GeV } 4.7\times10^{12}/sec)$$
$$\to K_L(1\times10^4 K_L/sec)$$



W = 1490 MeV to 2500 MeV

Unprecedented!!

Property	Value
Electron beam current (μA)	5
Electron flux at CPS (s^{-1})	3.1×10^{13}
Photon flux at Be-target $E_\gamma > 1500$ MeV (s^{-1})	4.7×10^{12}
K_L beam flux at cryogenic target (s^{-1})	1×10^{4}
K_L beam σ_p/p @ 1 GeV/c (%)	$\sim$1.5
K_L beam σ_p/p @ 2 GeV/c (%)	$\sim$5
K_L beam nonuniformity (%)	< 2
K_L beam divergence (°)	< 0.15
$K^0/\overline{K^0}$ ratio at Be-target	2:1
Background neutron flux at cryogenic target (s^{-1})	6.6×10^{5}
Background γ flux at cryogenic target (s^{-1}), $E_\gamma > 100$ MeV	6.5×10^{5}



Neutral flux identification

Except for $\pi\Sigma$, $\pi\Lambda$, also for KN, $\overline{K}N$, $K\Xi$ and $K\pi$

$$T(K^-p\to K^-p) = \frac{1}{2}T^1(\overline{K}N\to\overline{K}N)+\frac{1}{2}T^0(\overline{K}N\to\overline{K}N),$$
$$T(K^-p\to\overline{K^0}n) = \frac{1}{2}T^1(\overline{K}N\to\overline{K}N)-\frac{1}{2}T^0(\overline{K}N\to\overline{K}N),$$
$$T(K^+p\to K^+p) = T^1(KN\to KN),$$
$$T(K^+n\to K^+n) = \frac{1}{2}T^1(KN\to KN)+\frac{1}{2}T^0(KN\to KN),$$

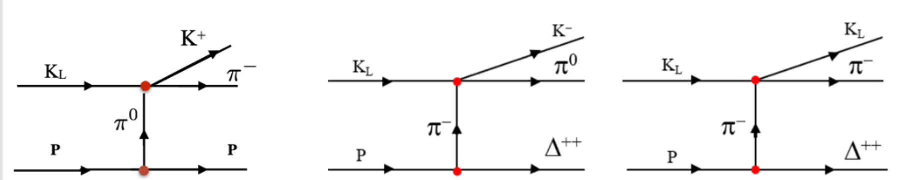
$$T(K_Lp\to K_Sp)=\frac{1}{2}\left(\frac{1}{2}T^1(KN\to KN)+\frac{1}{2}T^0(KN\to KN)\right)-\frac{1}{2}T^1(\overline{K}N\to\overline{K}N),$$

$$T(K_Lp\to K_Lp)=\frac{1}{2}\left(\frac{1}{2}T^1(KN\to KN)+\frac{1}{2}T^0(KN\to KN)\right)+\frac{1}{2}T^1(\overline{K}N\to\overline{K}N),$$

$$T(K_Lp\to K^+n)=\frac{1}{\sqrt{2}}\left(\frac{1}{2}T^1(KN\to KN)-\frac{1}{2}T^0(KN\to KN)\right).$$

$$T(K^-p\to K^0\Xi^0) = \frac{1}{2}T^1(\overline{K}N\to K\Xi)+\frac{1}{2}T^0(\overline{K}N\to K\Xi),$$
$$T(K^-p\to K^+\Xi^-) = \frac{1}{2}T^1(\overline{K}N\to K\Xi)-\frac{1}{2}T^0(\overline{K}N\to K\Xi),$$
$$T(K_Lp\to K^+\Xi^0) = -\frac{1}{\sqrt{2}}T^1(\overline{K}N\to K\Xi).$$

$K\pi$ Scattering



$$\frac{1}{3}(T^{1/2}-T^{3/2}) \qquad \frac{1}{3}(T^{1/2}-T^{3/2}) \qquad \frac{1}{3}(T^{1/2}+T^{3/2})$$

The 8th KLF Collaboration Meeting, 2026年5月6日 US/Eastern 时区

https://indico.jlab.org/event/1010/timetable/#20260506

8th KLF Collaboration Meeting

8TH KLF Collaboration

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Time: May 6, 2026 08:00 AM Eastern Time (US and Canada)
Zoom: https://jlab-org.zoomgov.com/j/1619255039?pwd=krmtubnYuAkbjssPjelzNtk6Qh3dSD.1

Meeting ID: 161 925 5039
Passcode: 468604

开始 2026年5月6日 07:20
结束 2026年5月6日 17:20
US/Eastern

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Igor Strakovsky

KLF Collaboration

Page | Discussion

Peking University

- *Dan Guo*, Peking University

This page was last edited on 1 May 2025, at 17:24.

https://wiki.jlab.org/klproject/index.php/Peking_University

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h-index	72	72
Citations/paper (avg)	48.6	56.8

Thank you for your attention!

燕山大學
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Back up

Error propagation

$\vec{x} = (x_1, \ldots, x_i)$ input data vector, $\vec{p} = (p_1, \ldots, p_n)$ parameter vector

Model output: $\vec{y} = f(\vec{x}; \vec{p}) = (y_1, \ldots, y_m)$

a fit by Minuit, given the covariance matrix C of para, $n \times n$

Numerically calculate the Jacobi matrix J of first derivatives, $m \times n$:

$$J_{ab} = \frac{\partial y_a}{\partial p_b}$$

then obtain the covariance matrix C' of output, $m \times m$

$$C' = JCJ^T$$

Square roots of diagonal elements giving the errors.