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Baryon resonances in strangeness production

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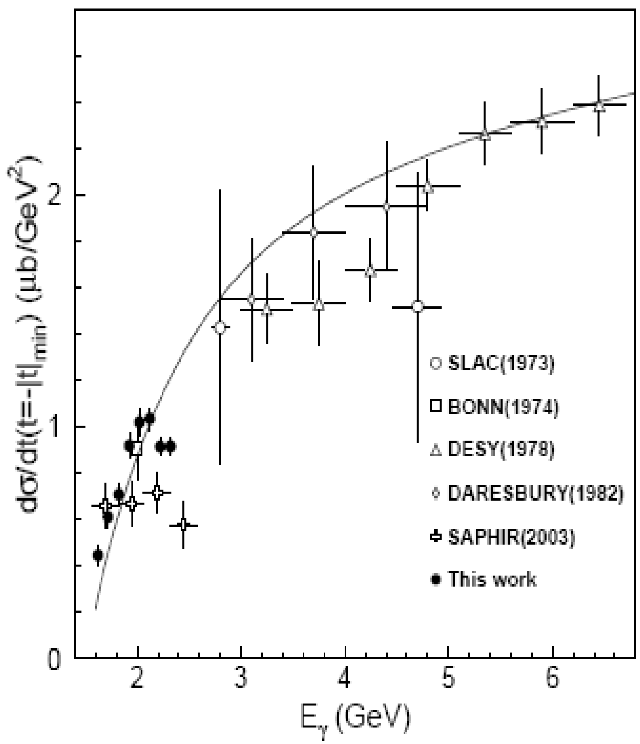
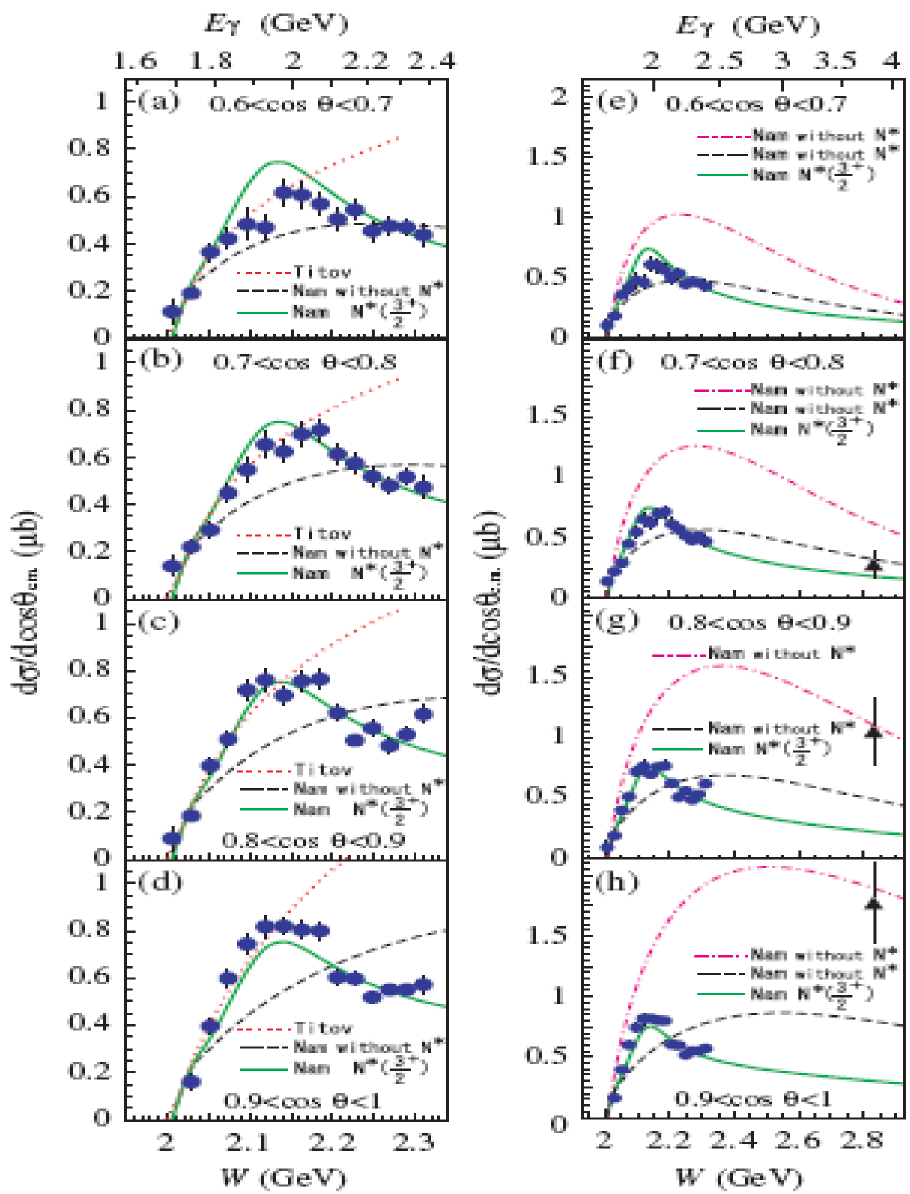
Outline

- N(2120) in $\gamma p \rightarrow p\phi$ and $\gamma p \rightarrow K^+\Lambda(1520)$ reactions
- $\Delta(1940)$ in $\pi^+ p \rightarrow K^+\Sigma^+(1385)$ and $pp \rightarrow nK^+\Sigma^+(1385)$ reactions
- A possible $\Sigma(1380)$ state in $\Lambda p \rightarrow \Lambda p \pi^0$ reaction
- Summary

Study “N(2080)” in γp->pϕ and γp-> K$^+$Λ(1520) reactions





PRL, 95, 182001 (2005); PRL, 104, 172001 (2010), LEPS Collaboration.

Why N(2080)

1,The threshold of pϕ and KΛ(1520) is about 2.0 GeV;
2, The isospion of pϕ and KΛ(1520) is ½; No contributions from Δ resonances.

1), $N^*(2080)$, $J^P = 3/2^-$, status: **;
2), $N^*(2090)$, $J^P = 1/2^-$, status: *;
3), $N^*(2100)$, $J^P = 1/2^+$, status: *.

PDG 2010

Quark Model prediction:

N(2080) has significant contributions to the γ p->$K^+\Lambda(1520)$ reaction

Capstick, PRD 46, 2864 (1992); 58, 074011 (1998).

Our model

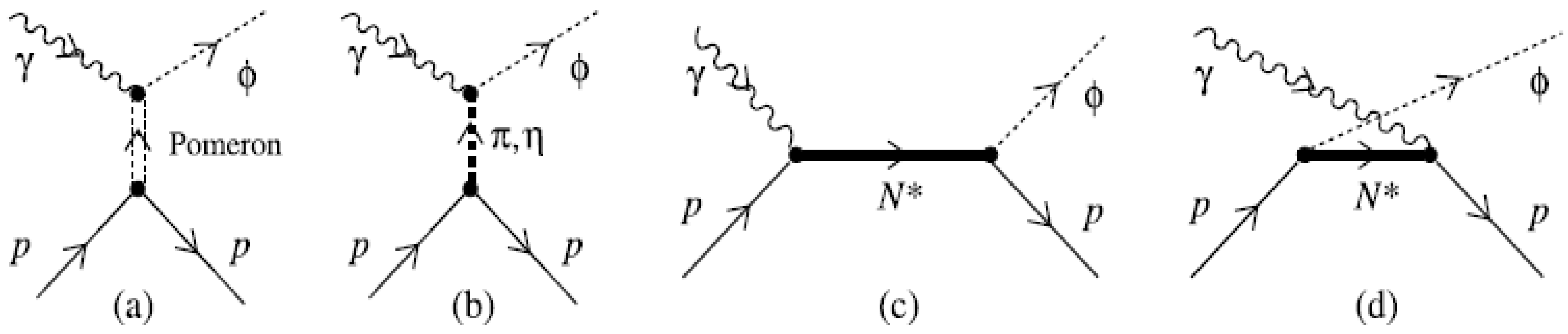
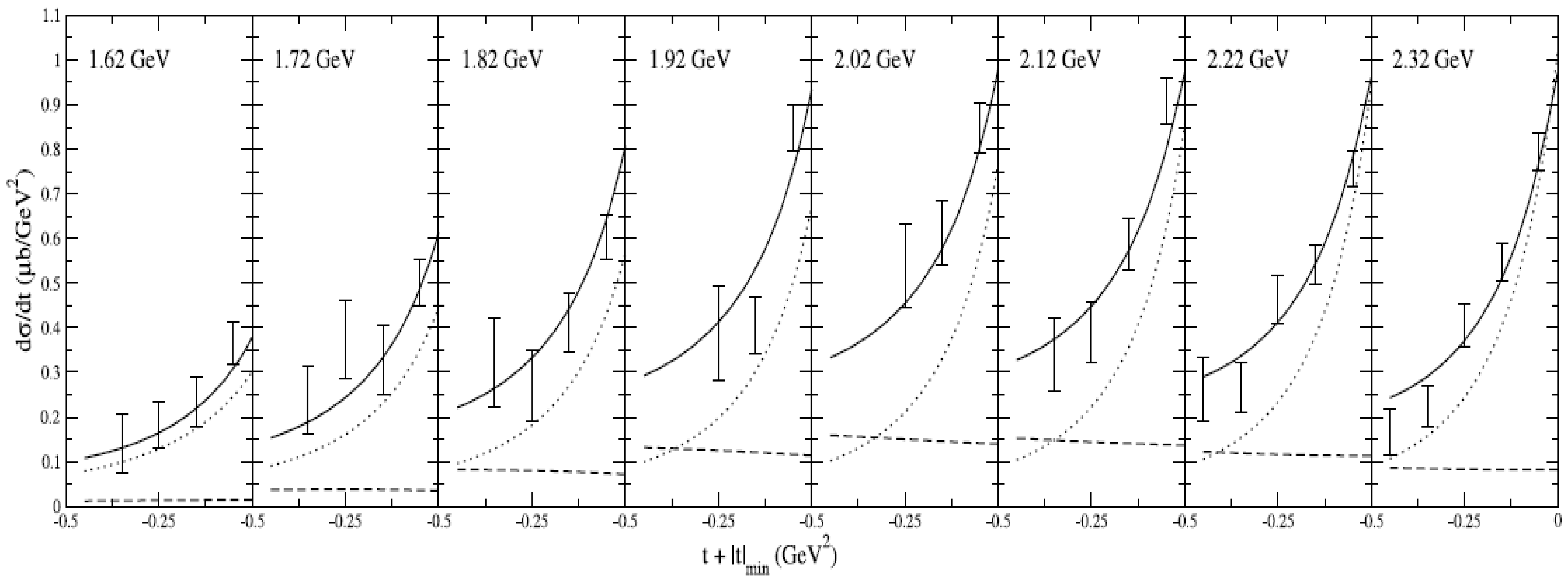


Fig. 1. (a) Pomeron-exchange, (b) (π, η)-exchange, and (c,d) s- and u-channel N^*-exchange diagrams for $\gamma p \to \phi p$ reaction.



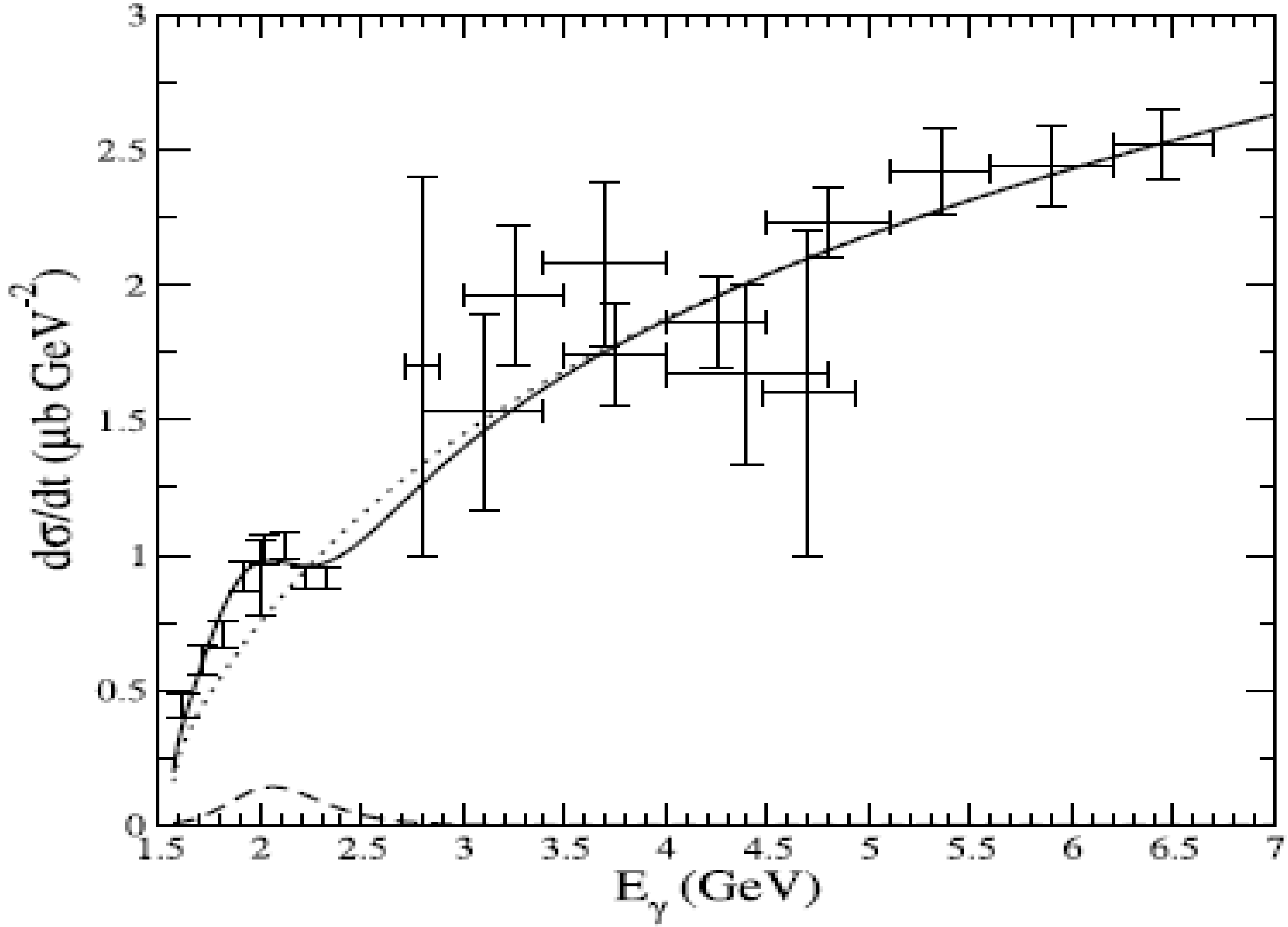


Fig. 2. Differential cross section of $\gamma p \to \phi p$ at forward direction as a function of photon energy E_γ. The dotted, dashed, and solid lines denote contributions from nonresonant, resonance with $J^P = 3/2^-$, and their sum, respectively. Data are from Refs. [10,17].

Alvin Kiswandhi, Ju-Jun Xie, Shin Nan Yang, PLB, 691, 214 (2010).

Is it N(2080) in the PDG2010 ?

Table 1
The results for N^* parameters with $J^P = 3/2^-$.

M_{N^*} (GeV)	2.10 ± 0.03
Γ_{N^*} (GeV)	0.465 ± 0.141
$eg^{(1)}_{\gamma NN^*} g^{(1)}_{\phi NN^*}$	-0.186 ± 0.079
$eg^{(1)}_{\gamma NN^*} g^{(2)}_{\phi NN^*}$	-0.015 ± 0.030
$eg^{(1)}_{\gamma NN^*} g^{(3)}_{\phi NN^*}$	-0.02 ± 0.032
$eg^{(2)}_{\gamma NN^*} g^{(1)}_{\phi NN^*}$	-0.212 ± 0.076
$eg^{(2)}_{\gamma NN^*} g^{(2)}_{\phi NN^*}$	-0.017 ± 0.035
$eg^{(2)}_{\gamma NN^*} g^{(3)}_{\phi NN^*}$	-0.025 ± 0.037

One might be tempted to identify the $3/2^-$ as the $D_{13}(2080)$ as listed in PDG [12]. The coupling constants given Table 1 can be used to calculate the ratio of the helicity amplitudes $A_{1/2}$ and $A_{3/2}$, though not their magnitudes since only the product of the coupling constants for γNN^* and ϕNN^* are determined. We obtain a value of $A_{\frac{1}{2}}/A_{\frac{3}{2}} = 1.16$, while it is -1.18 for $D_{13}(2080)$.

Maybe
No!

Alvin Kiswandhi,
Ju-Jun Xie,
Shin Nan Yang,
PLB, 691, 214 (2010).

N(2080) in PDG 2012 and 2014

Citation: K.A. Olive *et al.* (Particle Data Group), Chin. Phys. C38, 090001 (2014) (URL: http://pdg.lbl.gov)

$N(2120)\ 3/2^-$

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ Status: ∗∗

OMITTED FROM SUMMARY TABLE

Before the 2012 *Review*, all the evidence for a $J^P = 3/2^-$ state with a mass above 1800 MeV was filed under a two-star $N(2080)$. There is now evidence from ANISOVICH 12A for two $3/2^-$ states in this region, so we have split the older data (according to mass) between a three-star $N(1875)$ and a two-star $N(2120)$.

$N(2120)$ BREIT-WIGNER MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
2120 OUR ESTIMATE				
2150 ± 60	ANISOVICH	12A	DPWA	Multichannel
2060 ± 80	[1] CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2081 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

$N(2120)$ BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
330 ± 45	ANISOVICH	12A	DPWA	Multichannel
300 ± 100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$ (higher m)
265 ± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

$N(2120)$ PHOTON DECAY AMPLITUDES

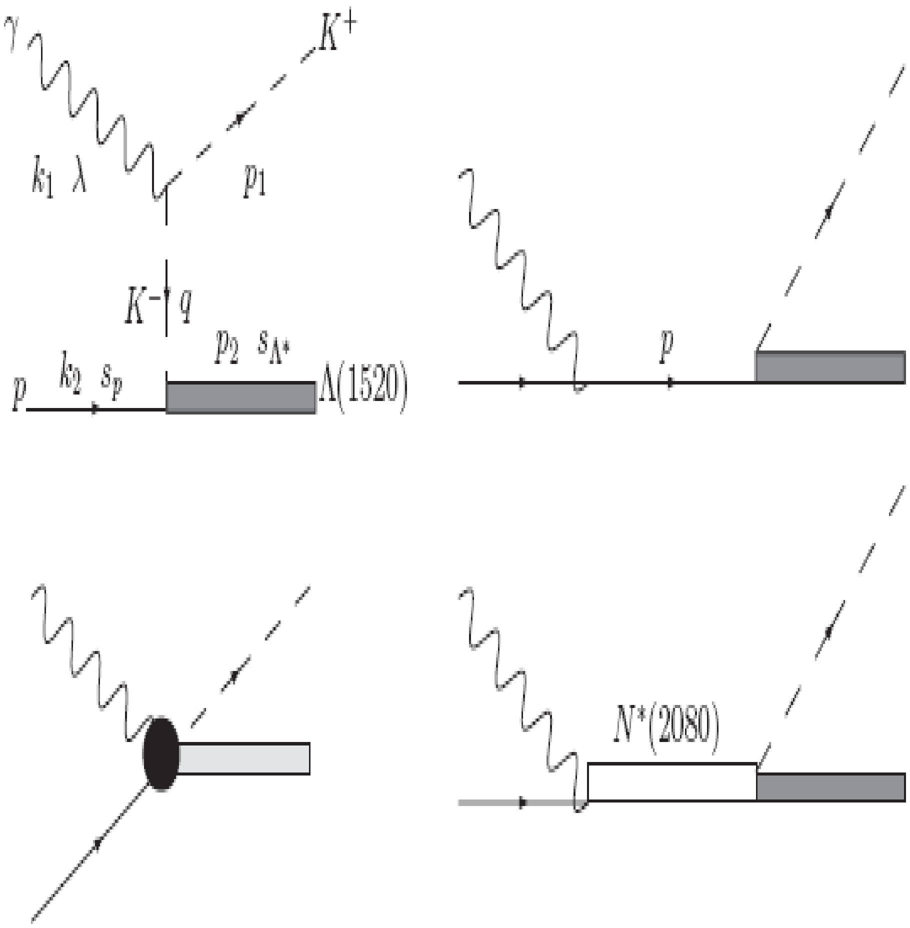
$N(2120) \rightarrow p\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.125 ± 0.045	[2] ANISOVICH	12A	DPWA	Phase $= (-55 \pm 20)^\circ$

$N(2120) \rightarrow p\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.150 ± 0.060	[2] ANISOVICH	12A	DPWA	Phase $= (-35 \pm 15)^\circ$

The ɣ p->K⁺Λ(1520) reaction



$$\mathcal{L}_{\gamma KK} = -ie(K^-\partial^\mu K^+ - K^+\partial^\mu K^-)A_\mu, \quad (1)$$

$$\mathcal{L}_{Kp\Lambda^*} = \frac{g_{KN\Lambda^*}}{m_K}\bar{\Lambda}^{*\mu}(\partial_\mu K^-)\gamma_5 p + \mathrm{H.c.}, \quad (2)$$

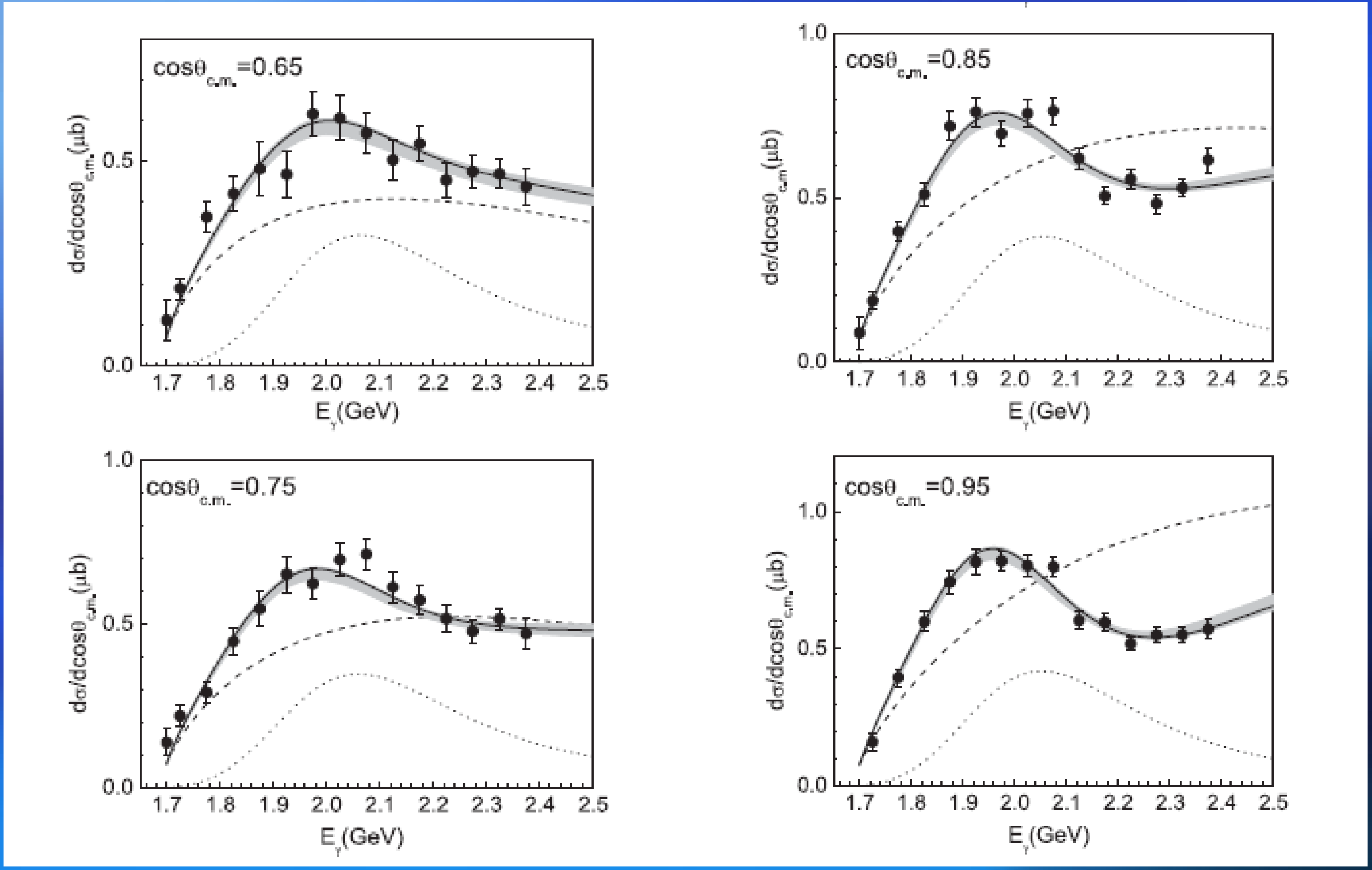
$$\mathcal{L}_{\gamma pp} = -e\bar{p}\left(\not{A} - \frac{\kappa_p}{2M_N}\sigma_{\mu\nu}(\partial^\nu A^\mu)\right)p + \mathrm{H.c.}, \quad (3)$$

$$\mathcal{L}_{\gamma Kp\Lambda^*} = -ie\frac{g_{KN\Lambda^*}}{m_K}\bar{\Lambda}^{*\mu}A_\mu K^-\gamma_5 p + \mathrm{H.c.}, \quad (4)$$

$$\mathcal{L}_{\gamma NN^*} = \frac{ief_1}{2m_N}\bar{N}^*_\mu\gamma_\nu F^{\mu\nu}N - \frac{ef_2}{(2m_N)^2}\bar{N}^*_\mu F^{\mu\nu}\partial_\nu N + \mathrm{H.c.}, \quad (5)$$

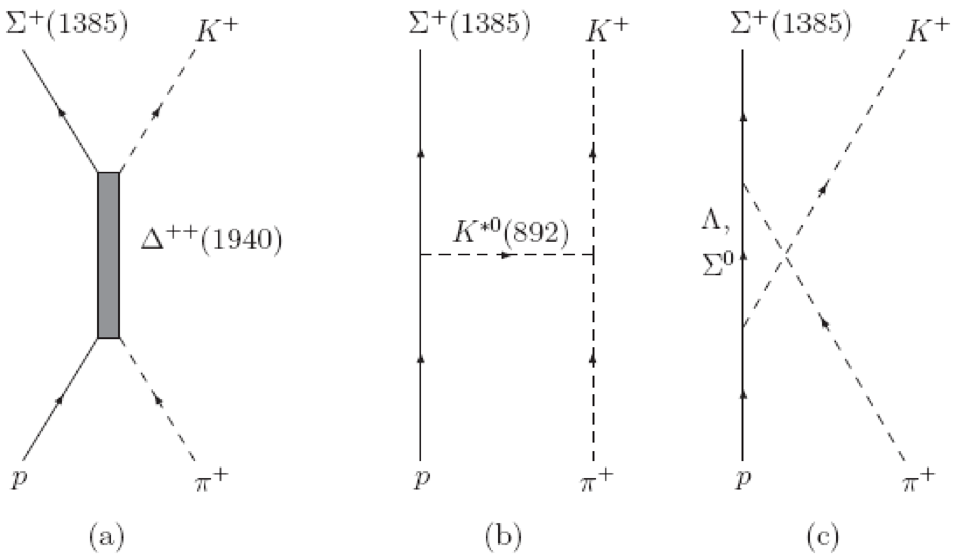
$$\mathcal{L}_{K\Lambda^*N^*} = \frac{g_1}{m_K}\bar{\Lambda}^*_\mu\gamma_5\gamma_\alpha(\partial^\alpha K)N^{*\mu} + \frac{ig_2}{m_K^2}\bar{\Lambda}^*_\mu\gamma_5(\partial^\mu\partial_\nu K)N^{*\nu} + \mathrm{H.c.}, \quad (6)$$

Fitted results



Ju-Jun Xie, and Juan Nieves, Phys. Rev. C 82, 045205 (2010)

Δ(1940) in π⁺p-> K⁺Σ⁺(1385) and pp->nK⁺Σ⁺(1385) reactions

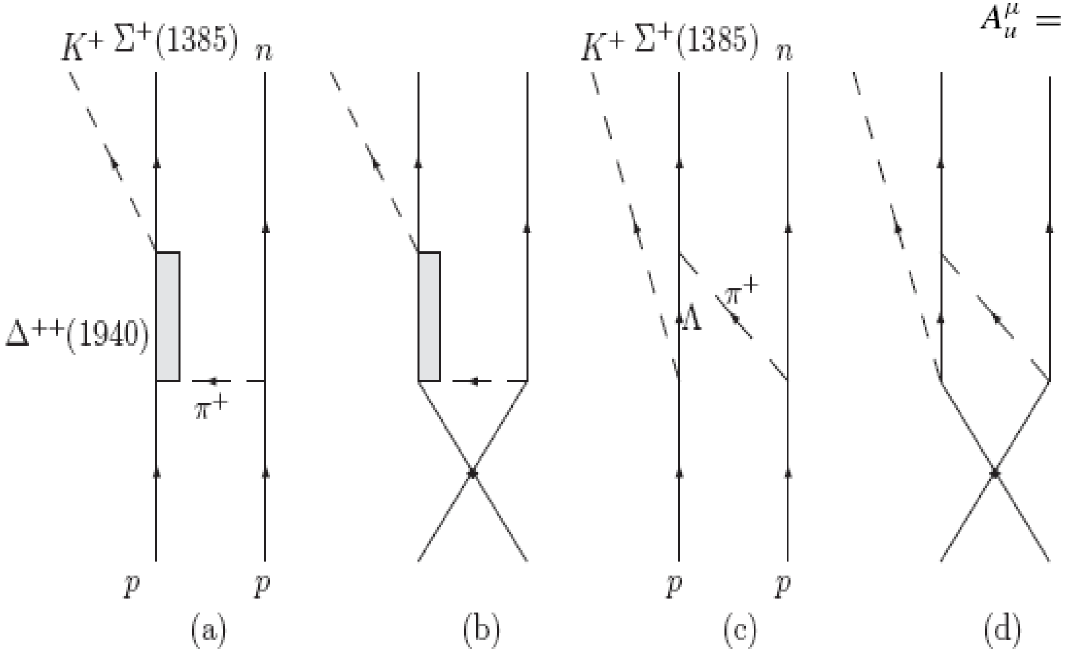


$$A_s^{\mu} = i\frac{g_{\pi N\Delta^*}}{m_\pi D}\left\{\frac{g_1}{m_K}\not{p}_3(\not{q}_s + M_{\Delta^*})\left[p_1^{\mu} - \frac{1}{3}\gamma^{\mu}\not{p}_1 - \frac{1}{3M_{\Delta^*}}(\gamma^{\mu} q_s p_1 - q_s^{\mu}\not{p}_1) - \frac{2}{3M_{\Delta^*}^2} q_s^{\mu} q_s p_1\right] - \frac{g_2}{m_K^2}(\not{q}_s + M_{\Delta^*})p_3^{\mu}\left[p_1 p_3 - \frac{1}{3}\not{p}_3\not{p}_1 - \frac{1}{3M_{\Delta^*}}(\not{p}_3 q_s p_1 - q_s p_3 \not{p}_1) - \frac{2}{3M_{\Delta^*}^2} q_s p_3 q_s p_1\right]\right\} f_s, \quad (19)$$

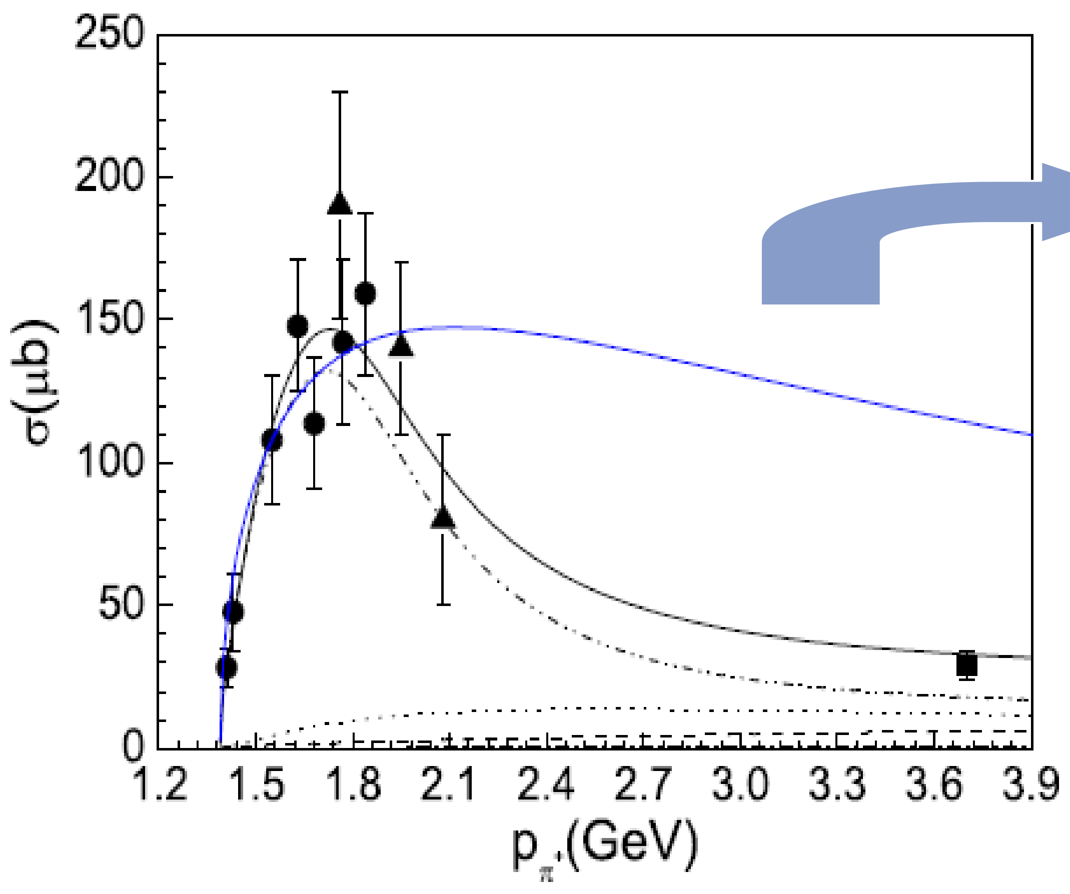
$$A_t^{\mu} = \frac{\sqrt{2} g_{K^* K\pi} g_{K^* N\Sigma^*}}{m_N (t - m_{K^*}^2)}(\not{p}_3 p_1^{\mu} - \not{p}_1 p_3^{\mu}) f_t, \quad (20)$$

$$A_u^{\mu} = i\frac{g_{\Sigma^*\pi\Sigma/\Lambda} g_{KN\Sigma/\Lambda}}{m_\pi (u - m_{\Sigma/\Lambda}^2)}(\not{q}_u + m_{\Sigma/\Lambda})\gamma_5 p_1^{\mu} f_u, \quad (21)$$

$$-iT_i = \bar{u}_{\mu}(p_4, s_{\Sigma^*}) A_i^{\mu} u(p_2, s_p),$$



Fitted results for $\pi^+ p \to K^+ \Sigma^+(1385)$ reaction

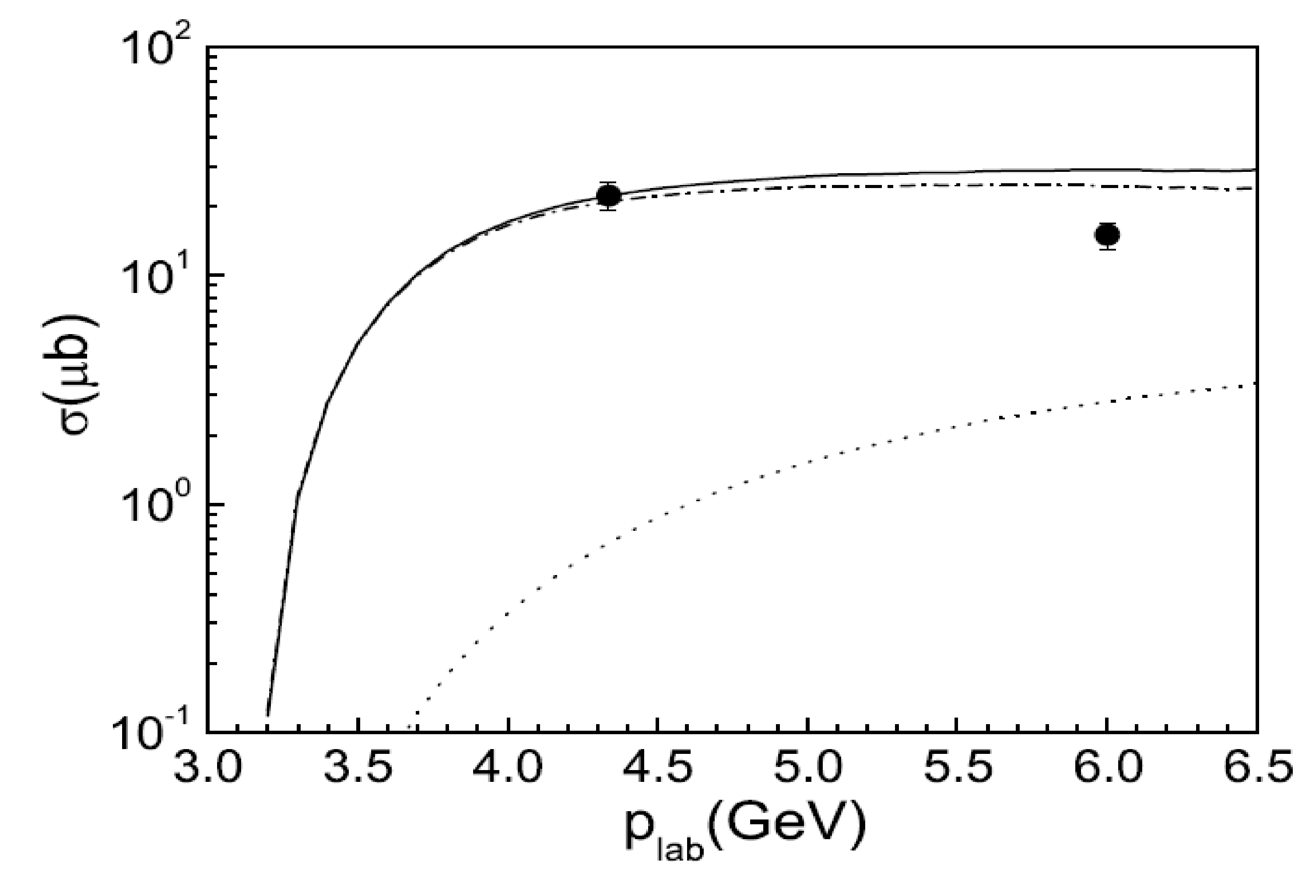


$$\frac{d\sigma}{d\cos\theta} \propto \frac{1-\cos^2\theta}{(t-M_{K^*}^2)^2},$$

$M_{\Delta^*} = 1940 \pm 24$ MeV, $\Gamma_{\Delta^*} = 172 \pm 94$ MeV,

Ju-Jun Xie, En Wang, and Bing-Song Zou, PRC 90, 025207 (2014).

Total cross sections for pp->nK$^+\Sigma^+$(1385) reaction



Angle distributions

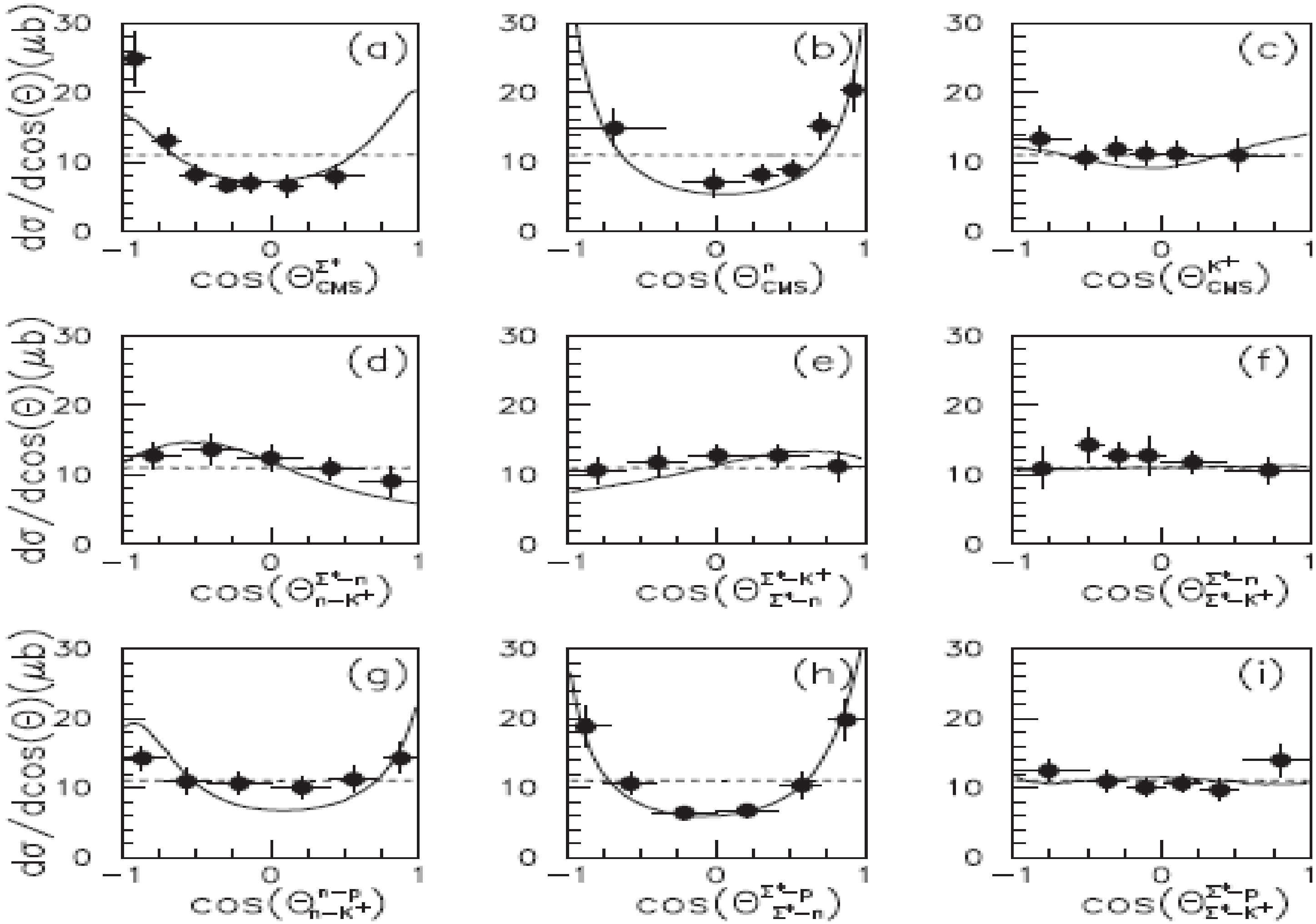


FIG. 6. Angular differential cross sections for the $pp \to nK^+\Sigma^+(1385)$ reaction in CMS [(a) $\Theta^{\Sigma^+}_{\rm CMS}$, (b) $\Theta^{n}_{\rm CMS}$, (c) $\Theta^{K^+}_{\rm CMS}$], helicity [(d) $\Theta^{\Sigma^+-n}_{n-K^+}$, (e) $\Theta^{\Sigma^+-K^+}_{\Sigma^+-n}$, (f) $\Theta^{\Sigma^+-n}_{\Sigma^+-K^+}$], and Gottfried-Jackson [(g) $\Theta^{n-p}_{n-K^+}$, (h) $\Theta^{\Sigma^+-p}_{\Sigma^+-n}$, (i) $\Theta^{\Sigma^+-p}_{\Sigma^+-K^+}$] reference frames. The dashed lines are pure phase-space distributions, while the solid lines are full results from our model. The experimental data are taken from Ref. [14].

A possible Σ(1380) state with spin parity 1/2⁻

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

	(Y, I)	I_3	flavor wave functions	masses (MeV)
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

Ao Zhang, Y. R. Liu, P.Z. Huang, W.Z. Deng, X.L. chen and S.L. Zhu, High Energy Phys. Nucl. Phys. 29, 250 (2005).

PHYSICAL REVIEW D **80**, 017503 (2009)

Evidence for a new Σ^* resonance with $J^P = 1/2^-$ in the old data of the $K^- p \to \Lambda\pi^+\pi^-$ reaction

Jia-Jun Wu,[1] S. Dulat,[2,3] and B. S. Zou[1,3]

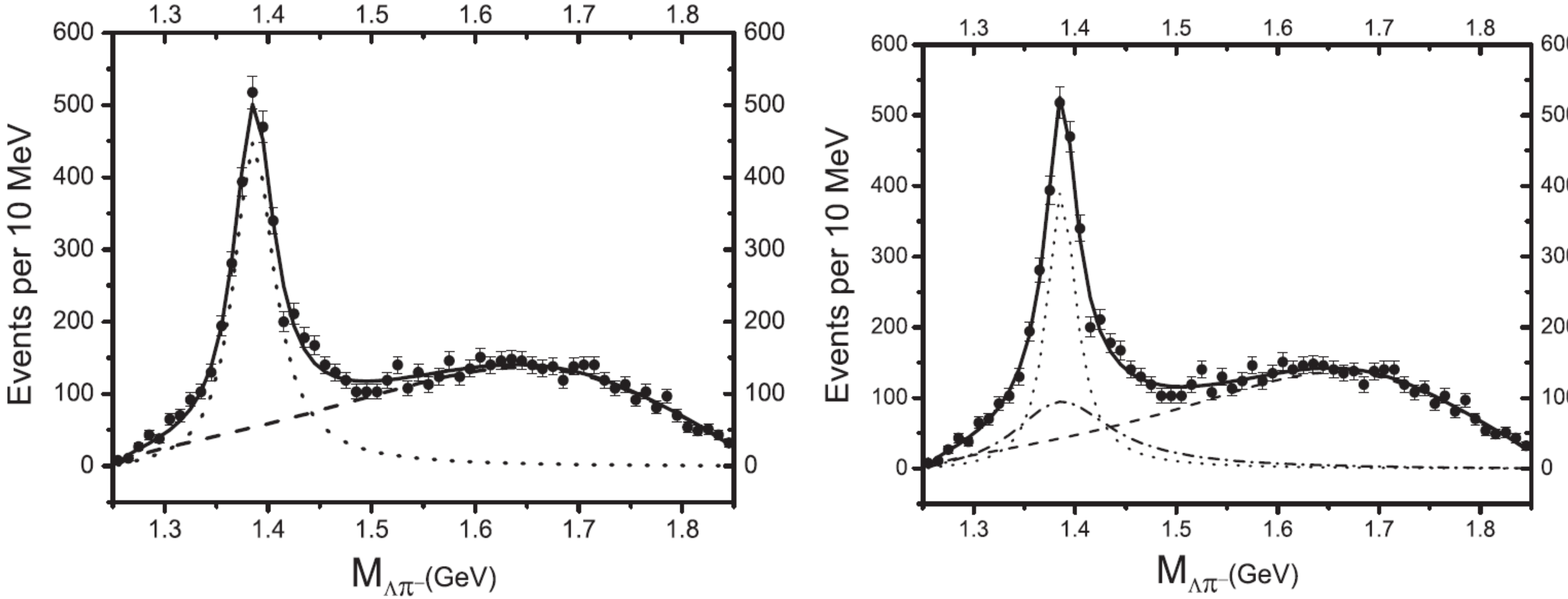


FIG. 1. Fits to the $\Lambda\pi^-$ mass spectrum with a single Σ^* (left panel) and two Σ^* resonances (right panel) around 1385 MeV with fitting parameters listed in Table I. The experiment data are from Ref. [14].

TABLE I. Fitted parameters with statistical errors and χ^2 over the number of degrees of freedom (ndf) for the fits with a single (Fit1) and two Σ^* resonances (Fit2) around 1385 MeV.

	$M_{\Sigma^*(3/2)}$	$\Gamma_{\Sigma^*(3/2)}$	$M_{\Sigma^*(1/2)}$	$\Gamma_{\Sigma^*(1/2)}$	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

Study possible Σ(1380) state in $\Lambda p \to \Lambda p \pi^0$ reaction

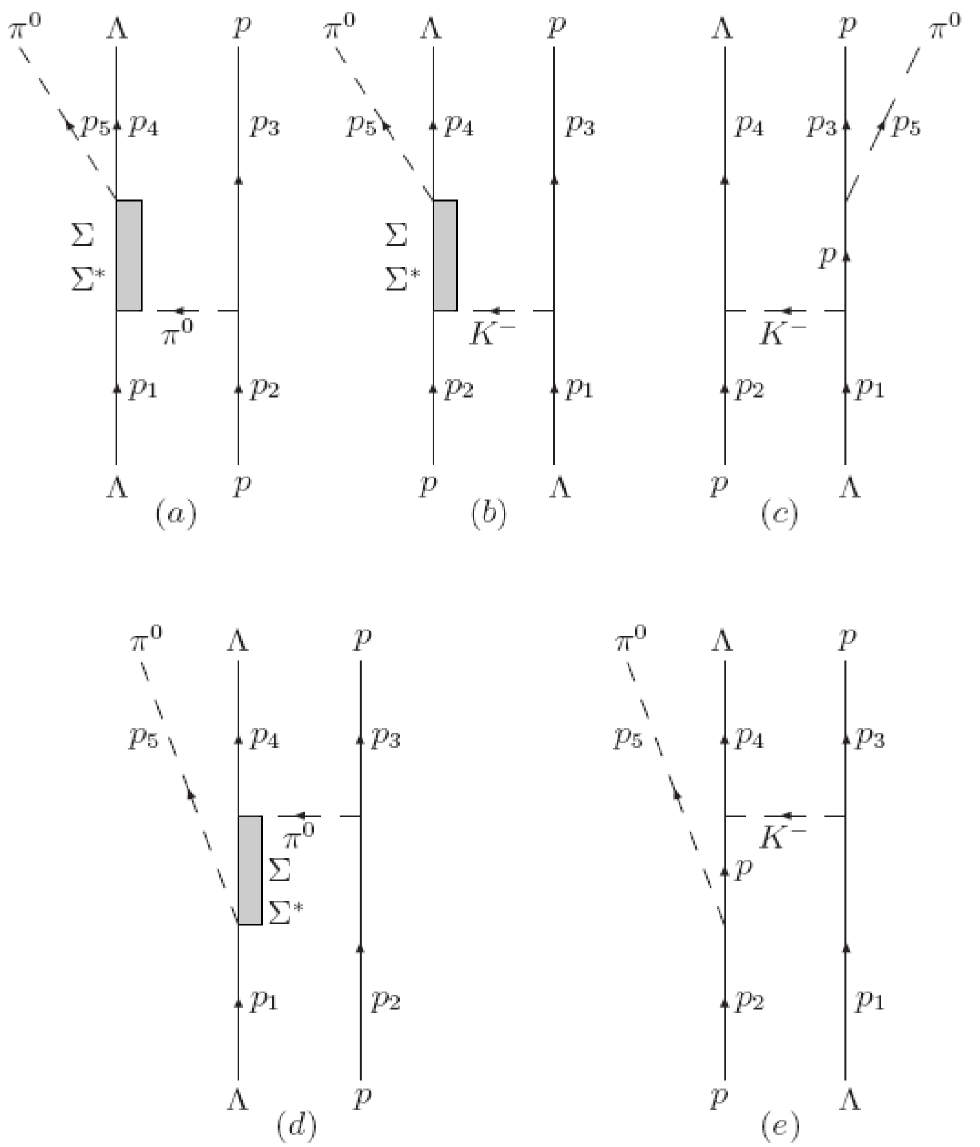


FIG. 1: Feynman diagrams for $\Lambda p \to \Lambda p \pi^0$ reaction.

$$\mathcal{L}_{\pi NN} = -\frac{g_{\pi NN}}{2m_N}\bar{N}\gamma_5\gamma_\mu\vec{\tau}\cdot\partial^\mu\vec{\pi}N, \tag{1}$$

$$\mathcal{L}_{KN\Lambda} = -\frac{g_{KN\Lambda}}{m_N+m_\Lambda}\bar{\Lambda}\gamma_5\gamma_\mu\partial^\mu K N + \mathrm{h.c.}, \tag{2}$$

$$\mathcal{L}_{\pi\Lambda\Sigma} = -\frac{g_{\pi\Lambda\Sigma}}{m_\Lambda+m_\Sigma}\bar{\Lambda}\gamma_5\gamma_\mu\partial^\mu\vec{\pi}\cdot\vec{\Sigma} + \mathrm{h.c.}, \tag{3}$$

$$\mathcal{L}_{KN\Sigma} = -\frac{g_{KN\Sigma}}{m_N+m_\Sigma}\bar{N}\gamma_5\gamma_\mu\partial^\mu K\vec{\tau}\cdot\vec{\Sigma} + \mathrm{h.c.}, \tag{4}$$

$$\mathcal{L}_{\pi\Lambda\Sigma_1^*} = \frac{g_{\pi\Lambda\Sigma_1^*}}{m_\pi}\bar{\Sigma}_1^{*\mu}(\vec{\tau}\cdot\partial_\mu\vec{\pi})\Lambda + \mathrm{h.c.}, \tag{5}$$

$$\mathcal{L}_{KN\Sigma_1^*} = \frac{g_{KN\Sigma_1^*}}{m_K}\bar{\Sigma}_1^{*\mu}(\partial_\mu K)N + \mathrm{h.c.}, \tag{6}$$

$$\mathcal{L}_{\pi\Lambda\Sigma_2^*} = g_{\pi\Lambda\Sigma_2^*}\bar{\Sigma}_2^*\vec{\tau}\cdot\vec{\pi}\Lambda + \mathrm{h.c.}, \tag{7}$$

$$\mathcal{L}_{KN\Sigma_2^*} = g_{KN\Sigma_2^*}\bar{\Sigma}_2^* K N + \mathrm{h.c.}, \tag{8}$$

Ju-Jun Xie, Jia-Jun Wu, and Bing-Song Zou, PRC **90**, 055204 (2014)

Numerical results

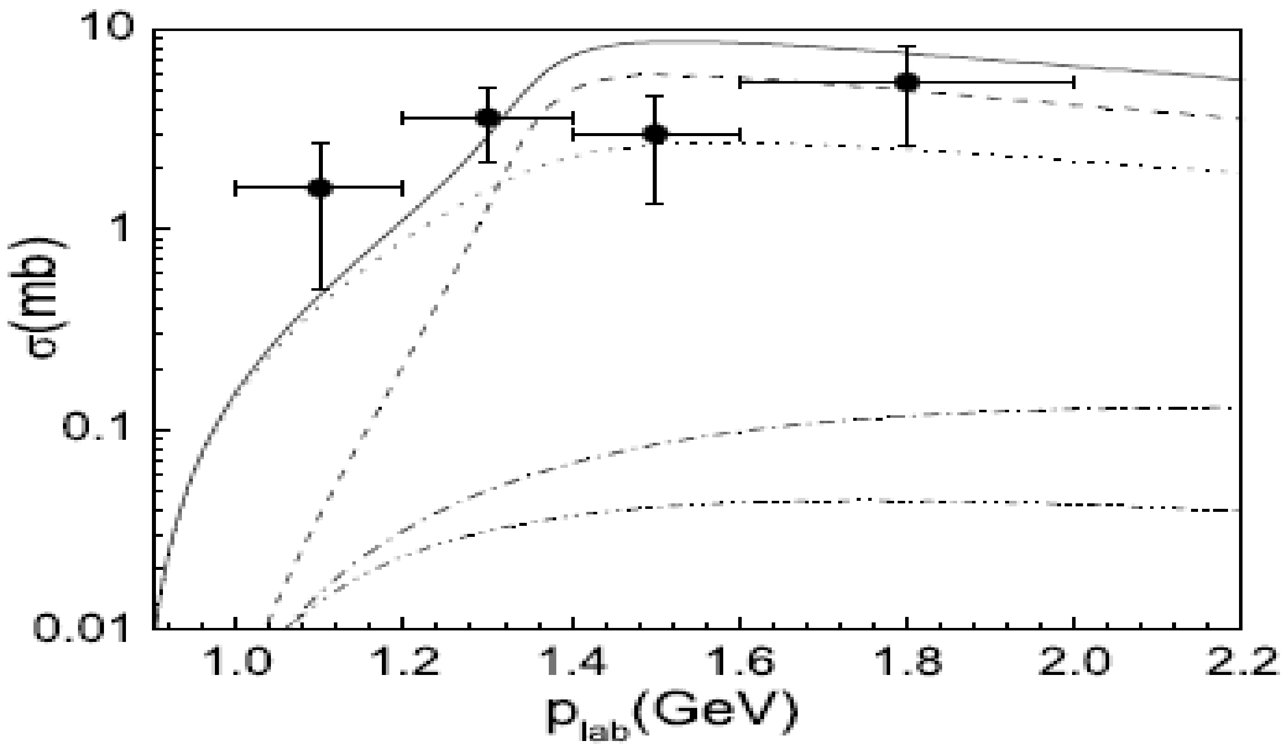


FIG. 3: Contributions of $\Sigma^*(1385)$ resonance (dashed line), $\Sigma^*(1380)$ state (dotted line), nucleon pole (dash-dotted line) and $\Sigma(1193)$ pole (dash-dot-dotted line) to the total cross sections vs the beam momentum p_{lab} for the $\Lambda p \to \Lambda p \pi^0$ reaction. Their total contribution is shown by solid line. The experimental data are taken from Ref. [15].

$\Sigma(1385)$: $3/2^+$, decaying to $\pi\Lambda$ in p-wave $\Sigma(1380)$: $1/2^-$, decaying to $\pi\Lambda$ in s-wave

Predictions

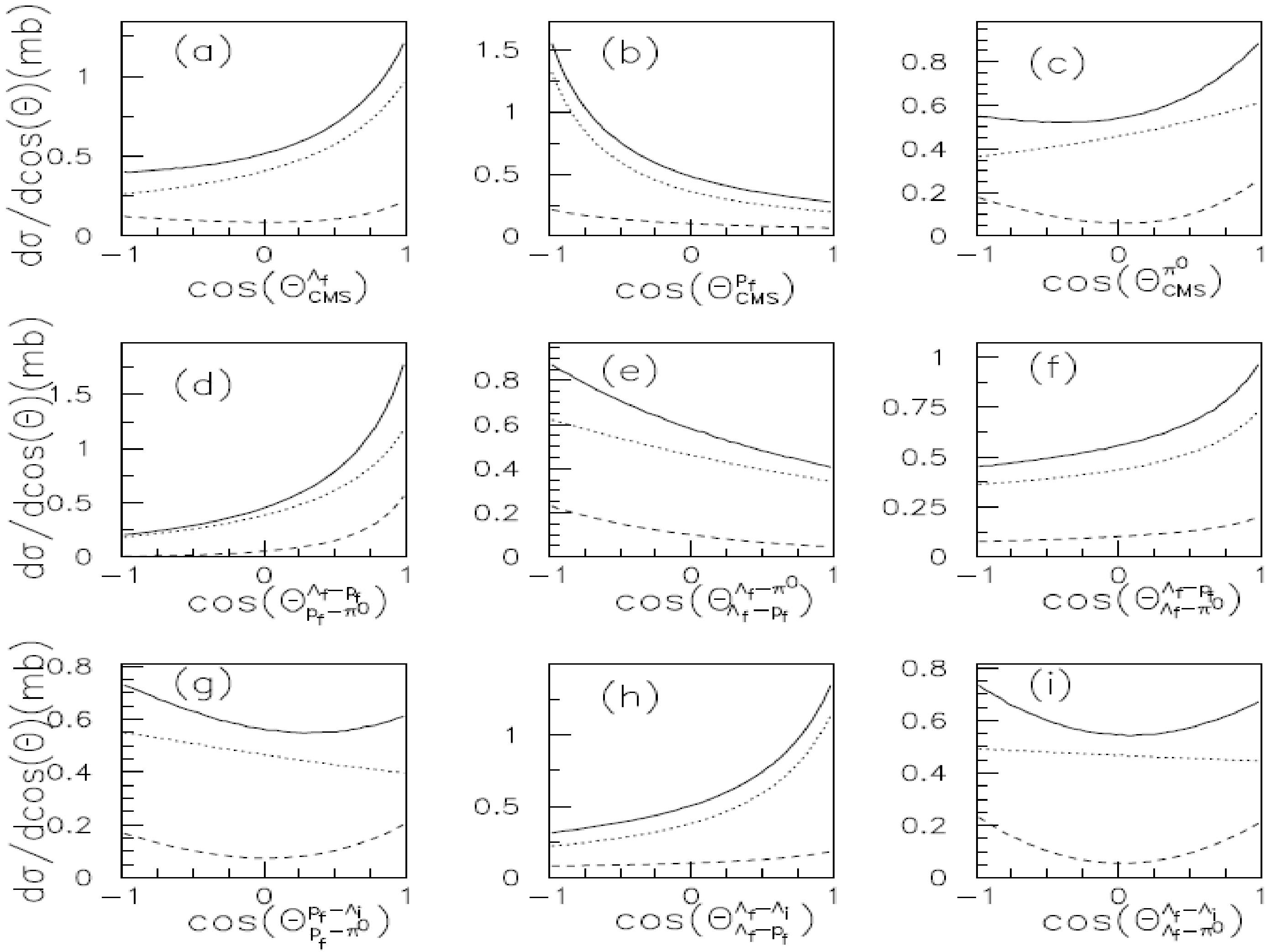


FIG. 4: Angular differential cross sections for the $\Lambda p \to \Lambda p \pi^0$ reaction in CMS [(a): $\Theta^{\Lambda_f}_{\mathrm{CMS}}$, (b): $\Theta^{p_f}_{\mathrm{CMS}}$, (c): $\Theta^{\pi^0}_{\mathrm{CMS}}$], helicity [(d): $\Theta^{\Lambda_f - p_f}_{p_f - \pi^0}$, (e): $\Theta^{\Lambda_f - \pi^0}_{\Lambda_f - p_f}$, (f): $\Theta^{\Lambda_f - p_f}_{\Lambda_f - \pi^0}$], and Gottfried-Jackson [(g): $\Theta^{p_f - \Lambda_i}_{p_f - \pi^0}$, (h): $\Theta^{\Lambda_f - \Lambda_i}_{\Lambda_f - p_f}$, (i): $\Theta^{\Lambda_f - \Lambda_i}_{\Lambda_f - \pi^0}$] reference frames. The dashed and solid curves stand the contributions of the $\Sigma^*(1385)$ and $\Sigma^*(1380)$, respectively. The results are obtained at $p_{\mathrm{lab}} = 1.2$ GeV.

Summary

1, The N(2120) has significant coupling to $K\Lambda(1520)$ channel and gives important contribution to the $K\Lambda(1520)$ production;

2, The γ p->pϕ and γ p-> $K^+\Lambda(1520)$ reactions should be studied together

γ p-> K^+

K^-

p

ϕ

$\Lambda(1520)$

3, The pp->$nK^+\Sigma^+(1385)$ reaction is a good isospin 3/2 filter for studying Δ resonances;

4, The $\Lambda p \to \Lambda p \pi^0$ reaction can be used to study the possible $\Sigma(1380)$ state.

Thank you very much for your attention!