Amplitude analysis of $\gamma N \rightarrow K\pi\Lambda$ & $Kp \rightarrow \pi\Lambda$

Bing-Song Zou
Institute of High Energy Physics, CAS, Beijing
Theoretical Physics Center for Science Facilities, CAS

Puze Gao, J. J. Wu, B. S. Zou, PRC81(2010) 055203
Puze Gao, B. S. Zou, A. Sibirtsev, arXiv:1011.2387 [nucl-th]

Outline：

- Motivation
- Analysis of $\gamma N \rightarrow K\pi\Lambda$
- Analysis of $Kp \rightarrow \pi\Lambda$
- Summary

1. Motivation

Distinguishable model predictions for Σ^* of $1/2^-$ SU(3) octet

Quenched & unquenched quark models

L=1 qqq excitation	**L=0 $\bar{q}qqqq$ excitation**
udq ~ N*(1535)	**udus $\bar{s}$ ~ N*(1535)**
uds $\Lambda^*(1670)$, $\Sigma^*(\sim1630)$	**udsq $\bar{q}$ $\Lambda^*(1405)$, $\Sigma^*(\sim1380)$**

Σ* in PDG

****
Σ (1189)$1/2^+$ Σ*(1385)$3/2^+$ Σ*(1670)$3/2^-$
Σ*(1775)$5/2^-$ Σ*(1915)$5/2^+$ Σ*(2030)$7/2^+$

***
Σ*(1660)$1/2^+$ Σ*(1750)$1/2^-$ Σ*(1940)$3/2^-$
Σ*(2250)??

**
Σ*(1620)$1/2^-$ Σ*(1690)?? Σ*(1880)$1/2^+$
Σ*(2080)$3/2^+$ Σ*(2455)?? Σ*(2620)??

*
Σ*(1480)?? Σ*(1560)?? Σ*(1580)$3/2^-$
Σ*(1770)$1/2^+$ Σ*(1840)$3/2^+$ Σ*(2000)$3/2^-$
Σ*(2070)$5/2^+$ Σ*(2100)$7/2^-$ Σ*(3000)??
Σ*(3170)??

All from old experiments of 1970-1985 !!

No Σ*(1/2⁻) around 1380 MeV ?

Re-analysis of old data on $K^- p \to \Lambda\pi^+\pi^-$

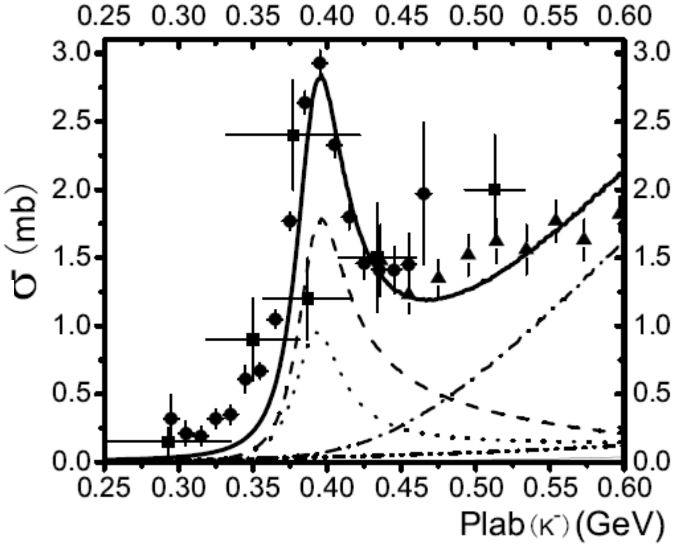
Wu, Dulat, Zou, PRD80 (2009) 017503; PRC81 (2010) 045210

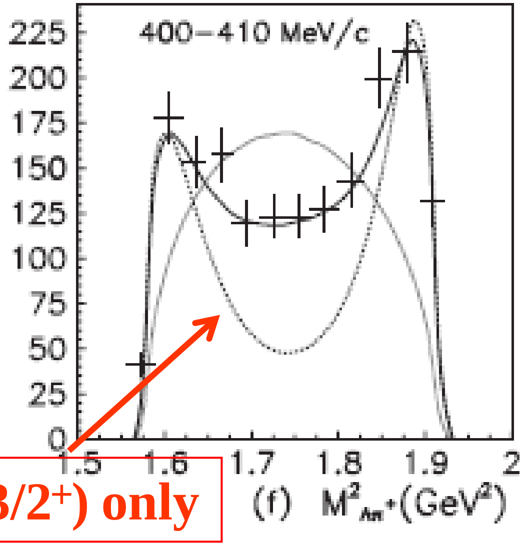
→ Possibly hidden Σ*(1/2⁻) under Σ*(1385)3/2⁺ peak

$$K^-p \to \Lambda^* \to \Sigma^{*-}_{3/2}\pi^+ \to \Lambda\pi^+\pi^-$$

$$K^-p \to \Lambda^* \to \Sigma^{*-}_{1/2}\pi^+ \to \Lambda\pi^+\pi^-$$

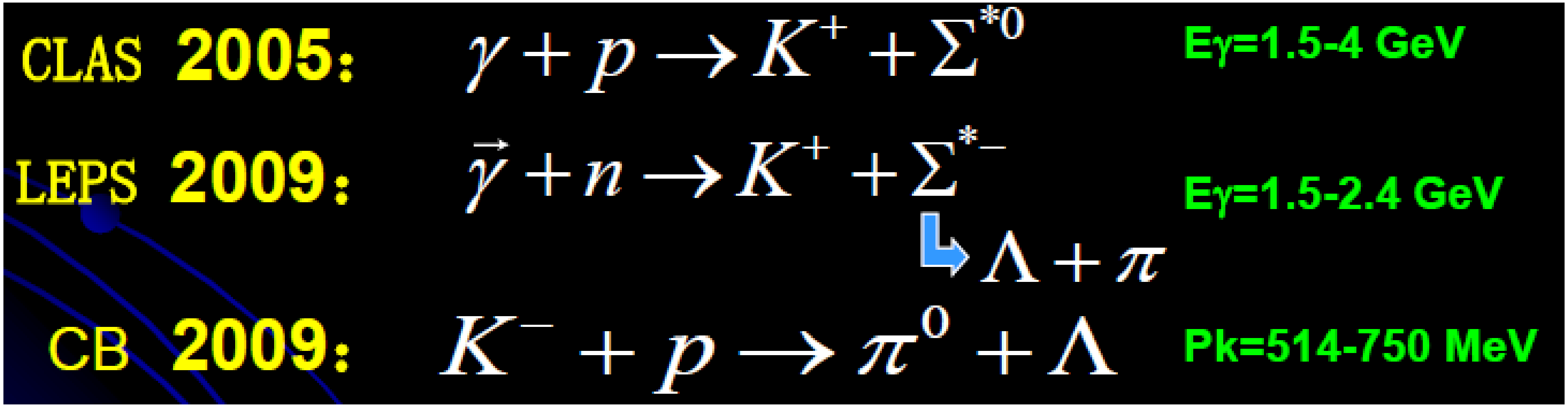
$P_K \approx 0.4$ GeV





Σ*(3/2⁺) only

New generation experiments on Σ* at CLAS, LEPS, CB



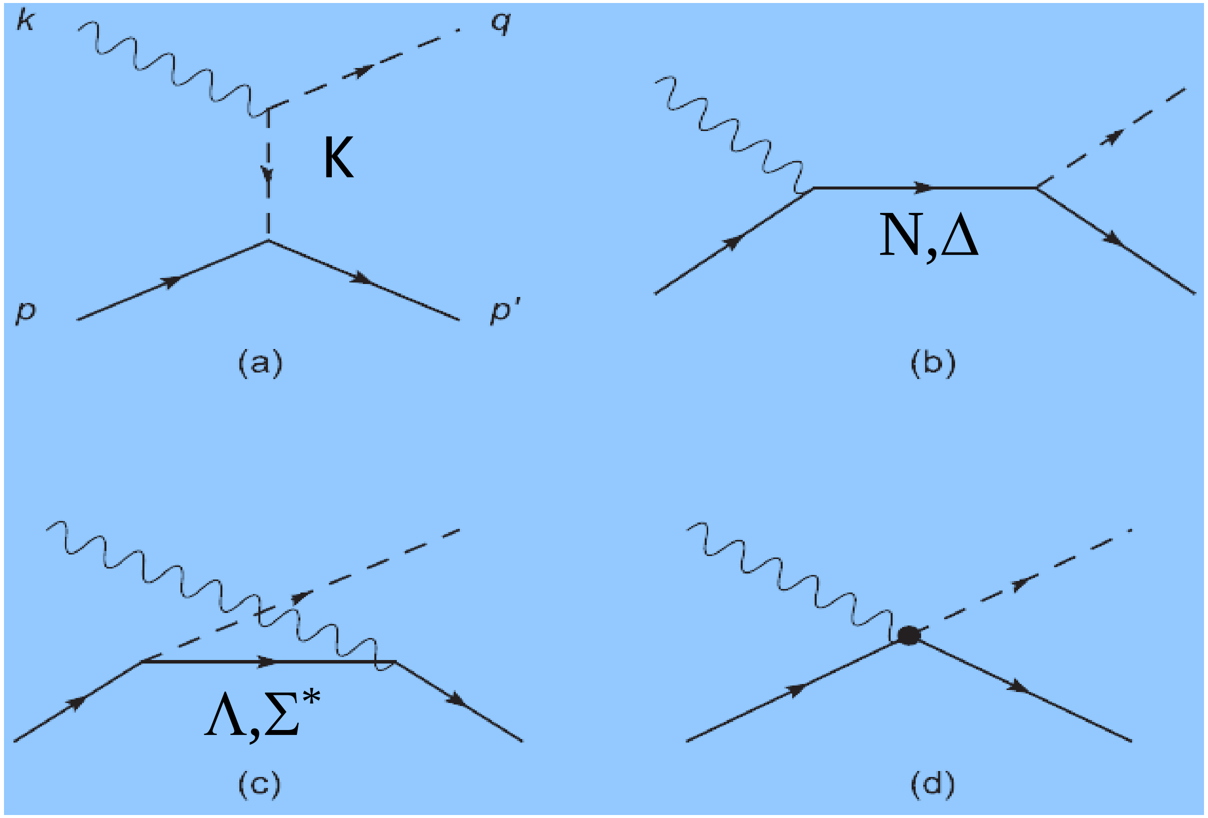
CLAS 2005:	$\gamma + p \rightarrow K^+ + \Sigma^{*0}$	Eγ=1.5-4 GeV
LEPS 2009:	$\vec{\gamma} + n \rightarrow K^+ + \Sigma^{*-}$ ↳ $\Lambda + \pi$	Eγ=1.5-2.4 GeV
CB 2009:	$K^- + p \rightarrow \pi^0 + \Lambda$	Pk=514-750 MeV

Anything new on Σ* ?

2. Analysis of γN→KπΛ

First studied with Effective Lagrangian approach

by Oh, Ko, Nakayama, **PRC**77,045204(2008)



Feynman diagrams for γN → KΣ*(3/2⁺)

•Form factors and contact current:

t-channel K exc.

$$F_M = \frac{\Lambda_M^2 - m_K^2}{\Lambda_M^2 - q_t^2},$$

Other channels

$$F_B(q_{\rm ex}^2, M_{\rm ex}) = \left[\frac{n\Lambda_B^4}{n\Lambda_B^4 + \left(q_{\rm ex}^2 - M_{\rm ex}^2\right)^2}\right]^n$$

The contact current for $\gamma p \to K^+ \Sigma^{*0}$ is

- Haberzettl et. al, **PRC**74,045202(2006)

$$M_c^{\mu\nu} = ie\frac{f_{KN\Sigma^*}}{m_K}\left(g^{\mu\nu} f_t - q^\mu C^\nu\right),$$

where

$$\begin{aligned} C^\nu = {} & -(2q-k)^\nu \frac{f_t - 1}{t - m_K^2}[1 - h(1 - f_s)] \\ & -(2p+k)^\nu \frac{f_s - 1}{s - M_N^2}[1 - h(1 - f_t)] \end{aligned}$$

The contact current for $\gamma n \rightarrow K^{+}\Sigma^{*-}$ is

$$M_c^{\mu\nu} = ie\sqrt{2}\frac{f_{KN\Sigma^*}}{m_K}(g^{\mu\nu} f_t - q^{\mu} C^{\nu}),$$

where

$$C^{\nu} = -(2q-k)^{\nu}\frac{f_t - 1}{t - m_K^2}[1 - h(1 - f_u)] + (2p' - k)^{\nu}\frac{f_u - 1}{u - M_{\Sigma^*}^2}[1 - h(1 - f_t)]$$

where

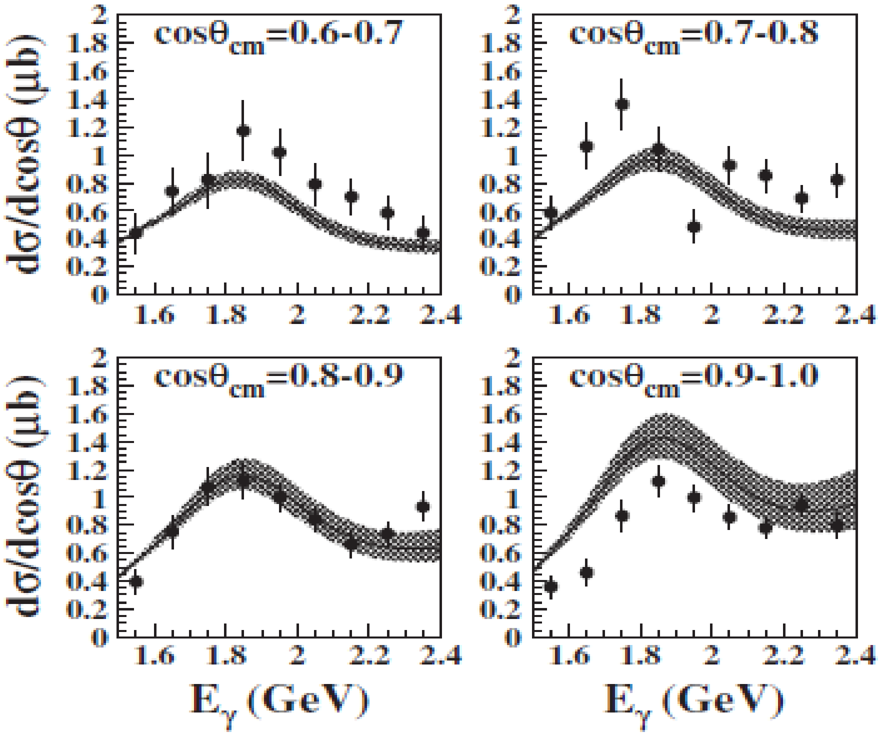
$$f_t = F_M^2 \text{ and } f_s = F_B^2(s, M_N)$$

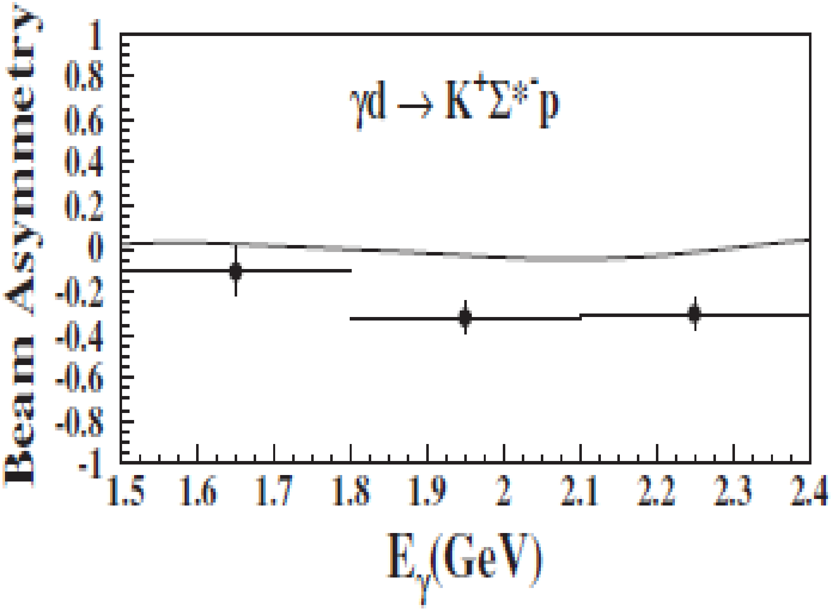
$$f_u = F_B^2(u, M_{\Sigma}^*)$$

h is a free parameter to fit experiments.

Prediction vs data

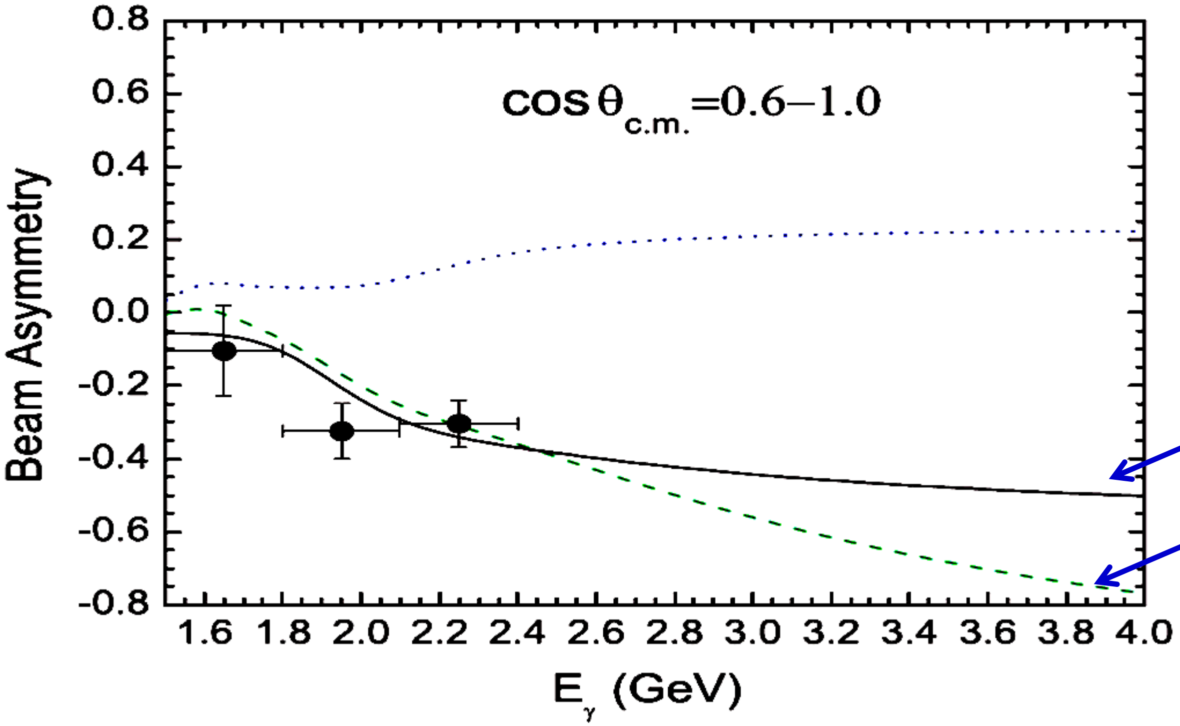
- Total cross section $\gamma p \rightarrow K^+\Sigma^{*0}$ of CLAS well described.
- differential cross section $\vec{\gamma} n \rightarrow K^+\Sigma^{*-}$ of LEPS data also be described, **but not for the Beam asymmetry A_{beam}** .





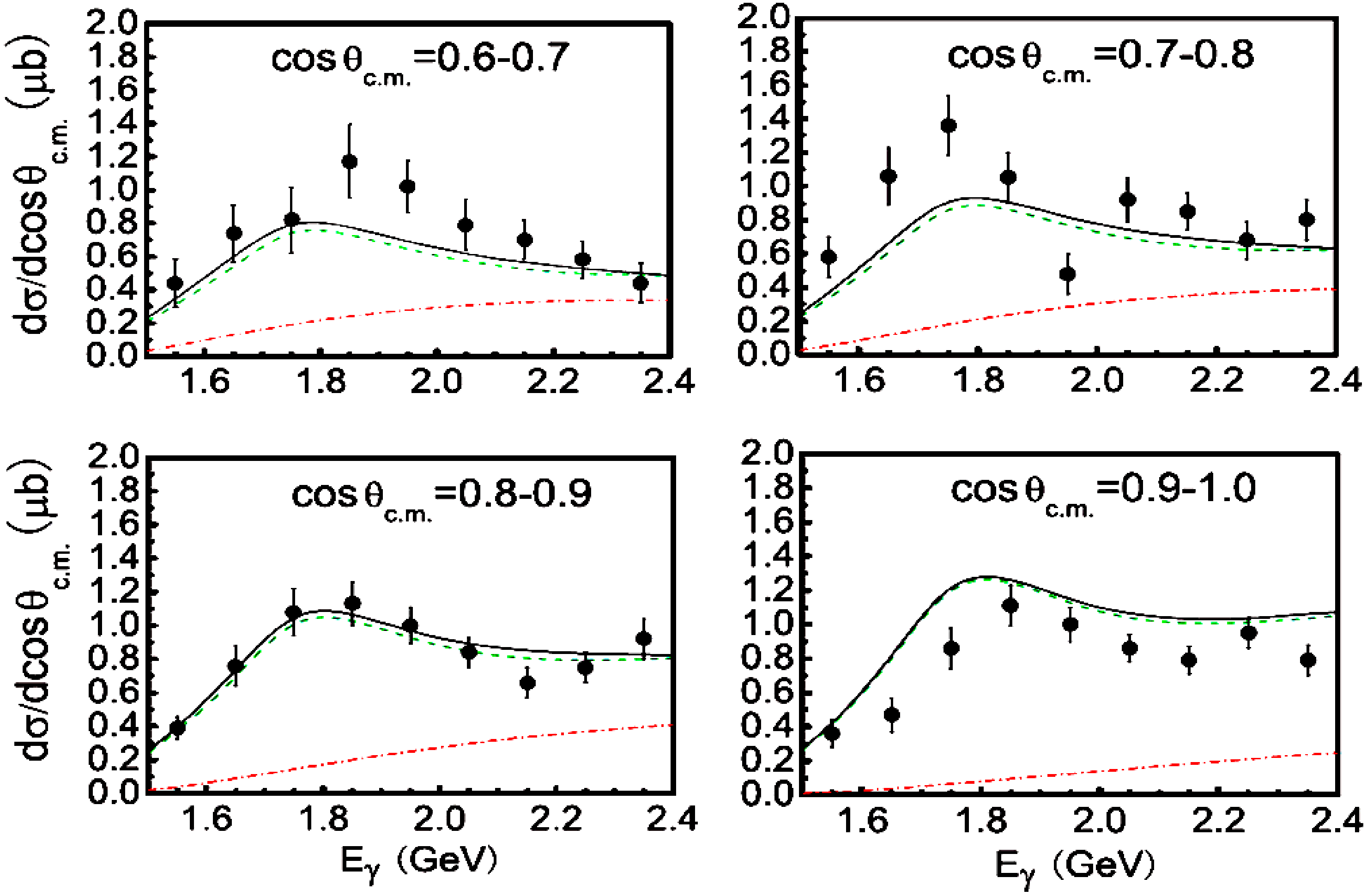
•Hicks, et.al. (LEPS), **PRL**102,012501(2009)

Two possible solutions for the problem:



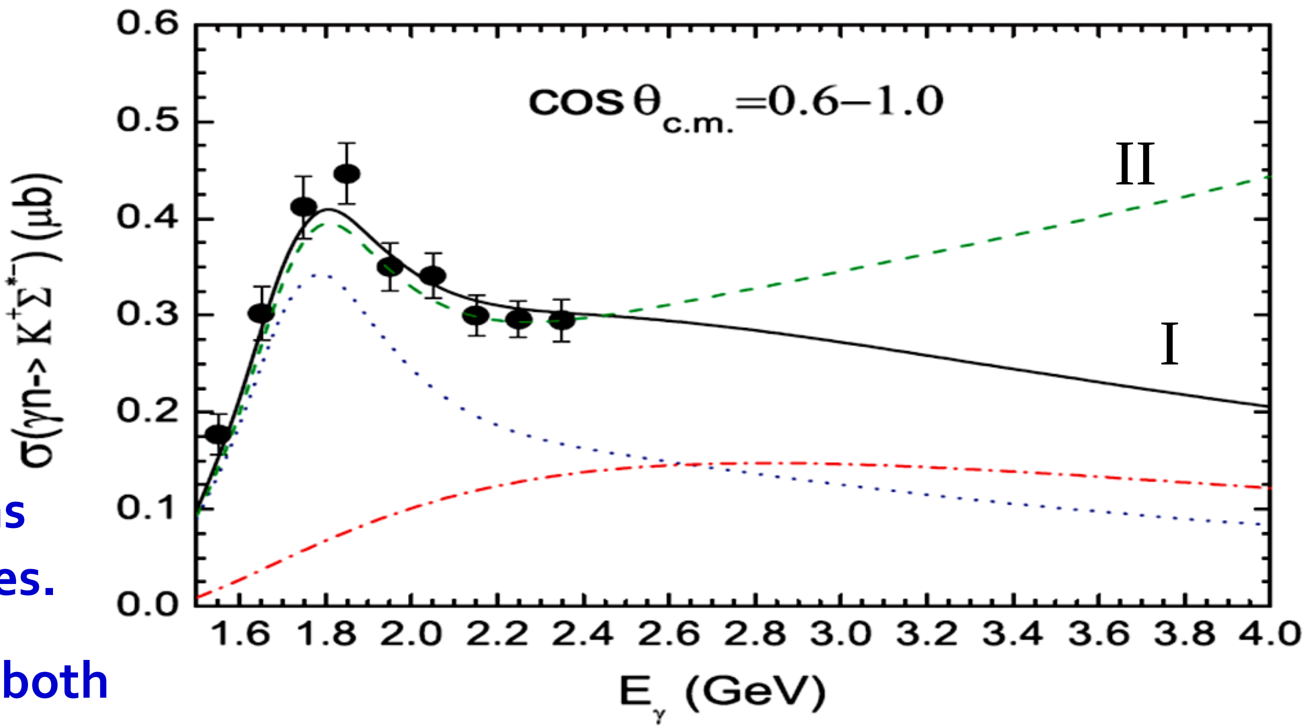
Include **Σ(1380)1/2^{-}**

Tune parameter h=1.11



ds/dcos$\theta_{c.m.}$ for $\gamma n \rightarrow K\Sigma^*$ compared with LEPS data

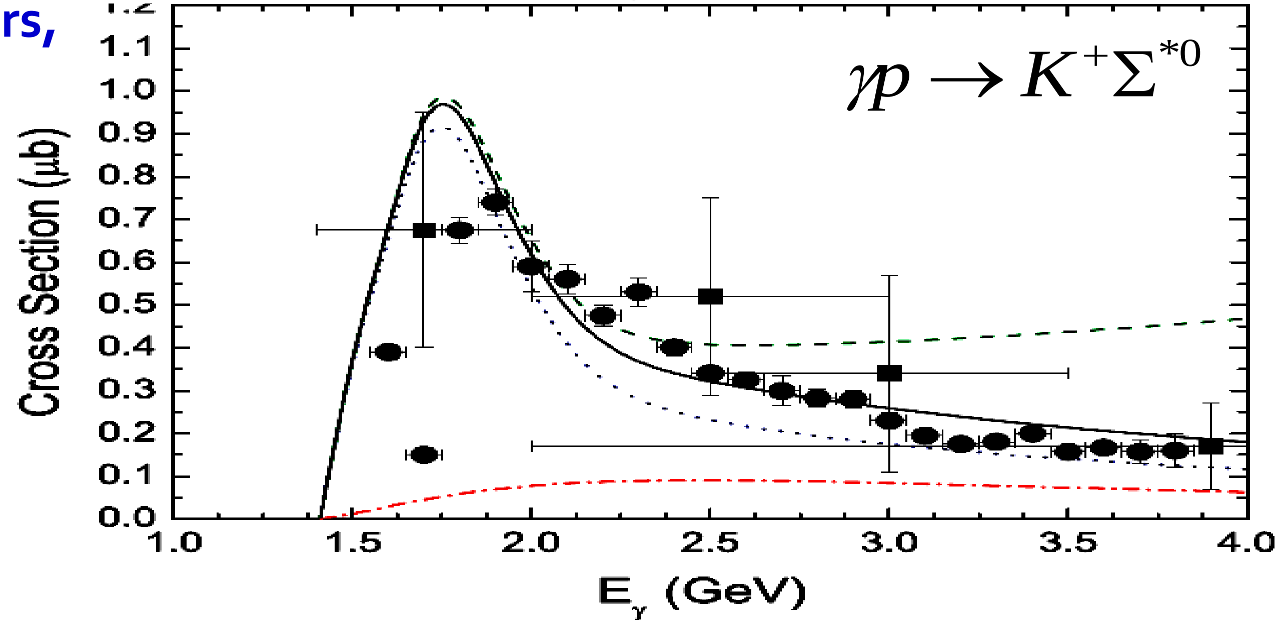
Integrated cross section for $\gamma n \rightarrow K\Sigma^*$ vs. LEPS data



different predictions for the two schemes.

Scheme I describes both with same parameters, Scheme II shoud use different h .

Integrated cross section for $\gamma p \rightarrow K\Sigma^*$ vs. CLAS data



3. Analysis of Kp → π Λ

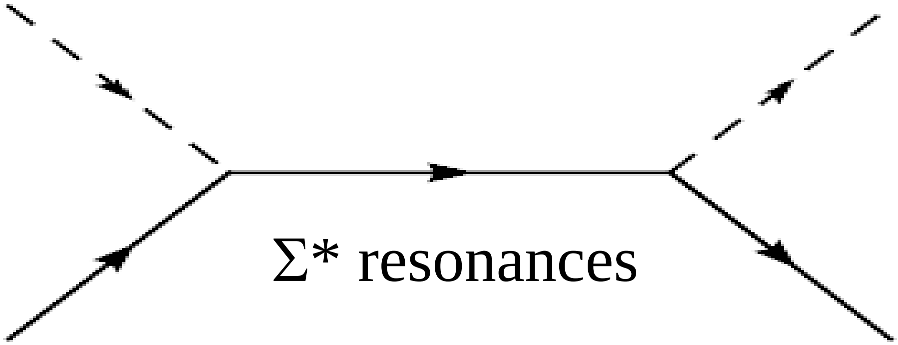
Crystal Ball 2009: $K^- + p \to \pi^0 + \Lambda$

Prakhov et al.,
PRC 80,025204

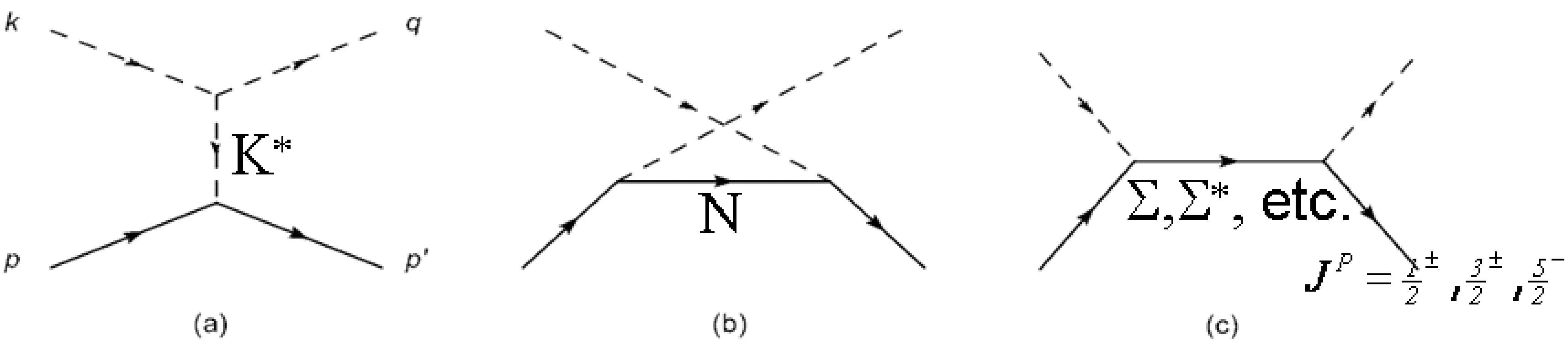
p_K=514-750 MeV

$$\sqrt{s} = 1569 - 1676 \text{ MeV}$$

The high precision new data can give valuable information for Σ* resonances.


Σ* resonances

Basic ingredients : $K^- + p \rightarrow \pi^0 + \Lambda$ $\sqrt{s} = 1569 - 1676 \text{ MeV}$



$J^P = \frac{1}{2}^{\pm}, \frac{3}{2}^{\pm}, \frac{5}{2}^{-}$

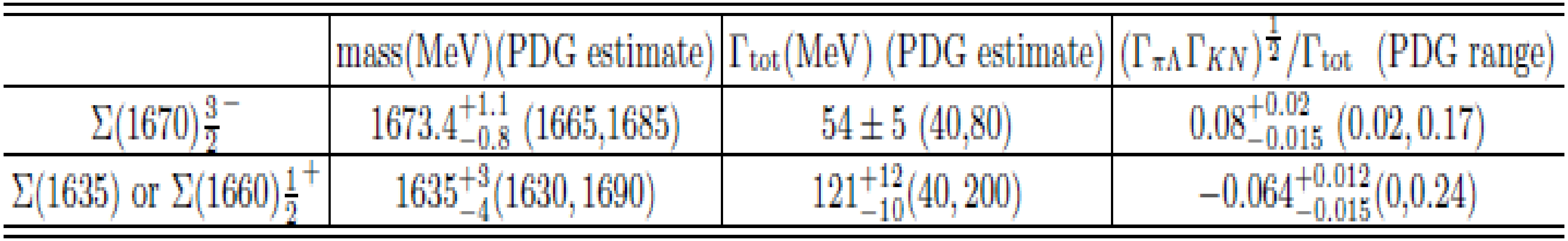
******** $\Sigma(1189)\frac{1}{2}^{+},\ \Sigma^*(1385)\frac{3}{2}^{+},\ \Sigma(1670)\frac{3}{2}^{-}$ and $\Sigma(1775)\frac{5}{2}^{-}$

With these basic ingredients of 14 tunable parameters , the best fit gives χ^2 =763 for the 248 data points, including

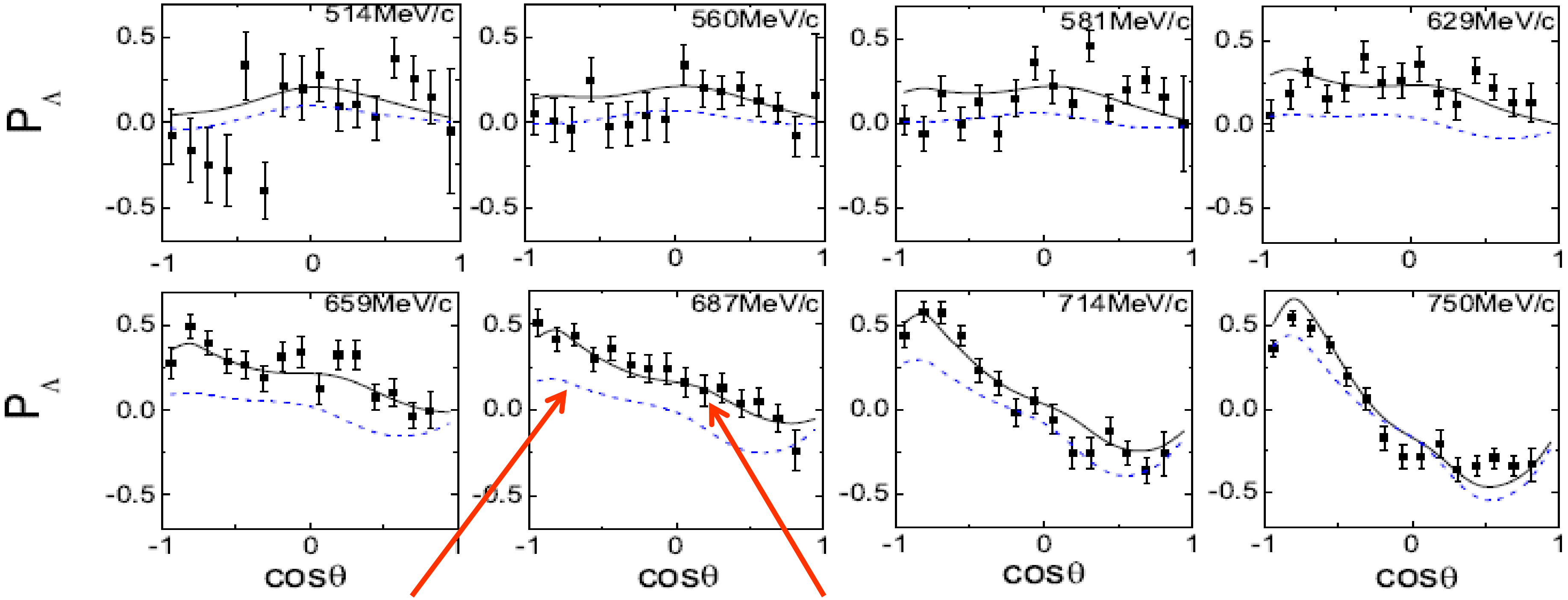
Differential cross sections: $$\frac{d\sigma_{\pi^0\Lambda}}{d\Omega} = \frac{d\sigma_{\pi^0\Lambda}}{2\pi d\cos\theta} = \frac{1}{64\pi^2 s}\frac{|\mathbf{q}|}{|\mathbf{k}|}|\bar{\mathcal{M}}|^2$$

Λ Polarization : $$P_\Lambda = \frac{3}{\alpha_\Lambda}\left(\int \cos\theta' \frac{d\sigma_{K^-p\to\pi^0\Lambda\to\pi^0\pi N}}{d\Omega d\Omega'} d\Omega'\right) \Big/ \frac{d\sigma_{\pi^0\Lambda}}{d\Omega}$$

Adding *** Σ(1660)1/2$^+$, χ^2 =223 for 248 data points with 18 tunable parameters.

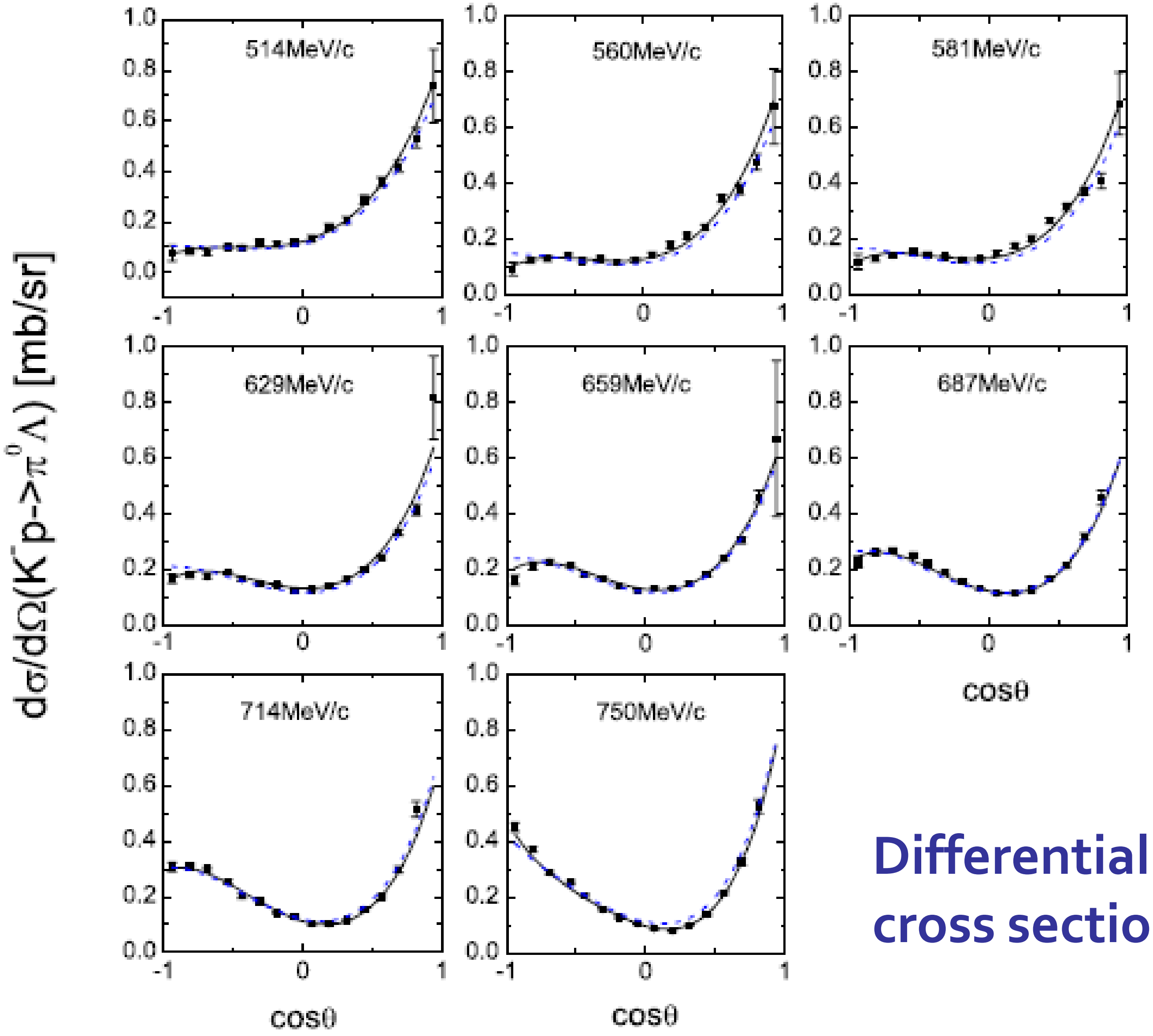


	mass(MeV)(PDG estimate)	Γ_{tot}(MeV) (PDG estimate)	$(\Gamma_{\pi\Lambda}\Gamma_{KN})^{\frac{1}{2}}/\Gamma_{tot}$ (PDG range)
$\Sigma(1670)\frac{3}{2}^-$	$1673.4^{+1.1}_{-0.8}$ (1665,1685)	54 ± 5 (40,80)	$0.08^{+0.02}_{-0.015}$ (0.02, 0.17)
$\Sigma(1635)$ or $\Sigma(1660)\frac{1}{2}^+$	1635^{+3}_{-4}(1630, 1690)	121^{+12}_{-10}(40, 200)	$-0.064^{+0.012}_{-0.015}$(0,0.24)



with basic ingredients

adding Σ(1635) 1/2$^+$



Differential cross sections

$$K^- + p \rightarrow \pi^0 + \Lambda \qquad \sqrt{s} = 1569 - 1676\ \mathrm{MeV}$$

Replacing $\Sigma(1635)\ 1/2^+$ by a $\Sigma(1/2^-)$, χ^2 increases by more than 160 with mass goes down to be below 1400 MeV.

$\Sigma(1380)1/2^-$ is not needed, but cannot be excluded.

CB Λ Polarization data is crucial for discriminating $\Sigma^*(1620)1/2^-$ from $\Sigma(1635)\ 1/2^+$.

Summary

With the analysis of three reactions:

$K p \to \pi\pi\Lambda$

$\gamma n \to K\Sigma^*$

The evidence of $\Sigma^*(1/2-)$ predicted by the pentaquark models.

$K p \to \pi\Lambda$

Existence of $\Sigma(1660)1/2 +$(***), with mass near 1635MeV, width 121MeV.

Need More experiment data to confirm them!!