K* vector meson coupling to the Λ(1520) resonance

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2006, Mar. 27th

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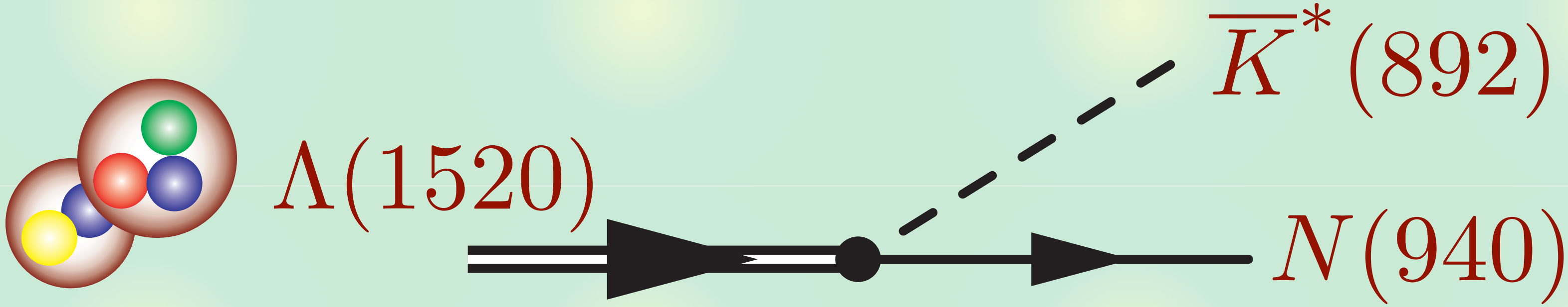


- ☆ Introduction to Λ(1520)
- ☆ Chiral unitary model
- ☆ Description of Λ(1520)
- ☆ Formulation
- ☆ Results and discussion
- ☆ Summary

Introduction : Λ(1520)

$\Lambda(1520) : J^P = 3/2^-, I = 0$

Mass : 1519.5 ± 1.0 MeV

Width : 15.6 ± 1.0 MeV

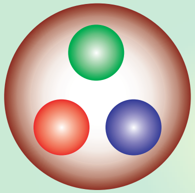
Decay modes :

$$\Lambda(1520) \to N\bar{K} \quad 45\%$$
$$\Lambda(1520) \to \Sigma\pi \quad 42\%$$
$$\Lambda(1520) \to \Lambda\pi\pi \quad 10\%$$

(Naive) Quark model : SU(3) singlet

★ large LS splitting with Λ(1405)?

★ decay branching ratio?



$\Lambda(1520)$: recent interest

Photo-production experiments

Large p/n asymmetry?

LEPS @ SPring-8, CLAS @ J-lab.

S.I. Nam *et al.*, Phys. Rev. D 71, 114012 (2005)

Importance of the K* exchange?

D. P. Barber *et al.*, Z. Phys. C 7, 17 (1980)

A. Sibirtsev *et al.*, hep-ph/0509145

Θ^+ Λ^* coherent production on deuteron

LEPS @ SPring-8

A.I. Titov *et al.*, Phys. Rev. C 72, 035206 (2005)

-> to understand the reaction dynamics

Chiral unitary model

Chiral symmetry

Low energy behavior

+

Unitarity of S-matrix

Non-perturbative resummation

Scattering of 8 meson(0^-) and 8 baryon($1/2^+$)

Dynamical generation

$$J^P = 1/2^- \text{ resonances}$$

$$\Lambda(1405), \Lambda(1670),$$
$$\Sigma(1620), \Xi(1620),$$
$$N(1535)$$

Chiral unitary model

Chiral symmetry

Low energy behavior

+

Unitarity of S-matrix

Non-perturbative resummation

Scattering of 8 meson(0^-) and 10 baryon($3/2^+$)

Dynamical generation

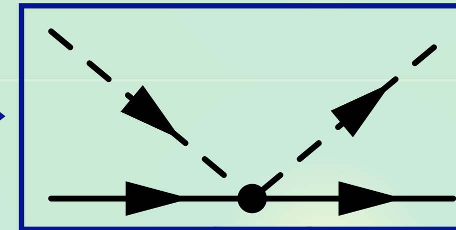
$J^P = 3/2^-$ resonances

$\Lambda(1520), \Sigma(1670),$
$\Xi(1820), \ldots$

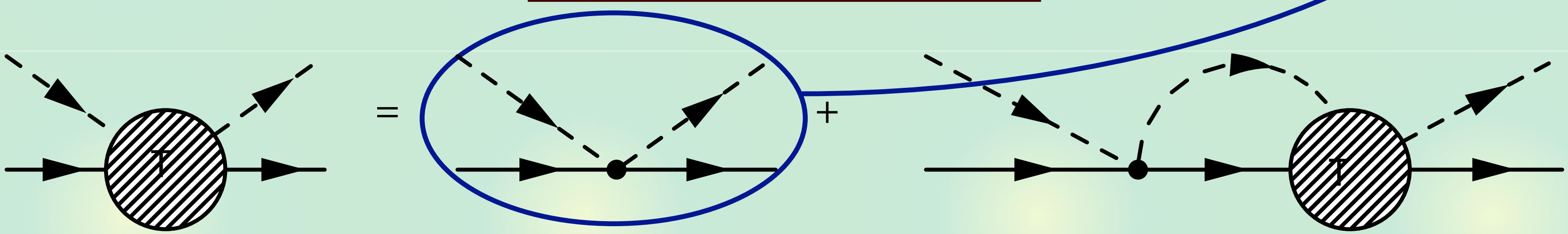
Framework of the chiral unitary model

Chiral perturbation theory

$$\mathcal{L}_{WT} = \frac{1}{4f^2}\mathrm{Tr}(\bar{B} i \gamma^{\mu}[(\Phi\partial_{\mu}\Phi - \partial_{\mu}\Phi\Phi), B])$$

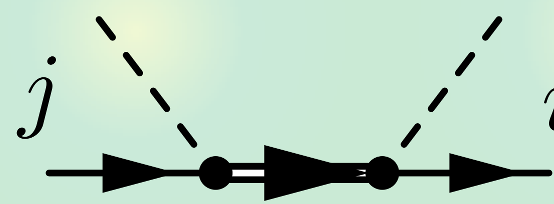


Unitarization



$$T_{ij}(\sqrt{s}) \sim \frac{g_i g_j}{\sqrt{s} - M_R + i\Gamma_R/2} + T_{ij}^{BG}$$

$\sim$



Decuplet-Octet scattering

Interaction of 8 meson and 10 baryon is derived from chiral perturbation theory

E. Kolomeitsev *et al.*, PLB 585, 243 (2004)
S. Sarkar *et al.*, NPA 750, 294 (2005)

non-relativistic reduction + s-wave

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

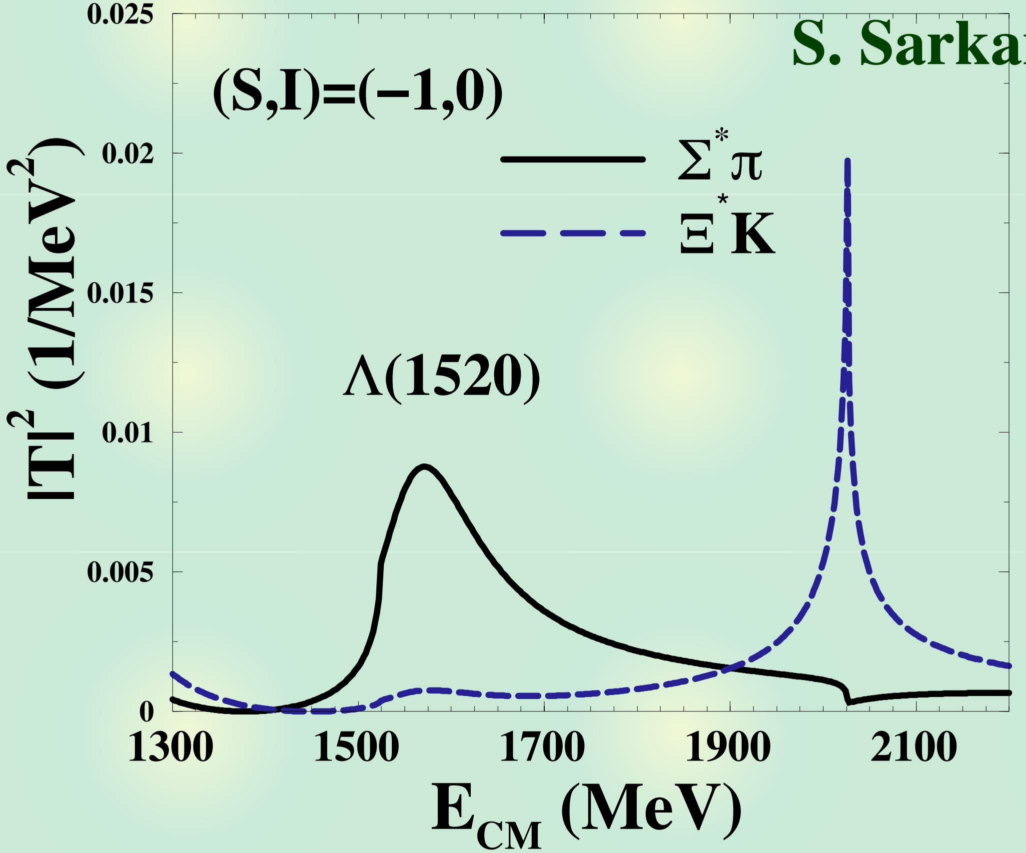
-> same structure as 8–8 scattering

SU(3) decomposition

8 × 10 = 8 + 10 + 27 + 35 repulsive

attractive (8 + 10)   weakly attractive (27)

Result for Λ(1520)



S. Sarkar *et al.*, NPA 750, 294 (2005)

Pole is searched for
-> to check whether
resonance or not

Caveats :

★ Decuplet baryons do not decay

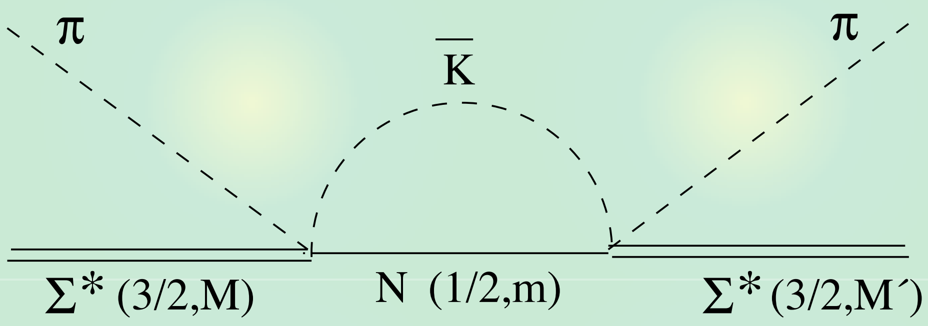
★ No coupling to other MB channels

-> Results should be regarded as qualitative

Quantitative description of Λ(1520)

More quantitative description

-> include d-wave channels : $\bar{K}N$, $\pi\Sigma$

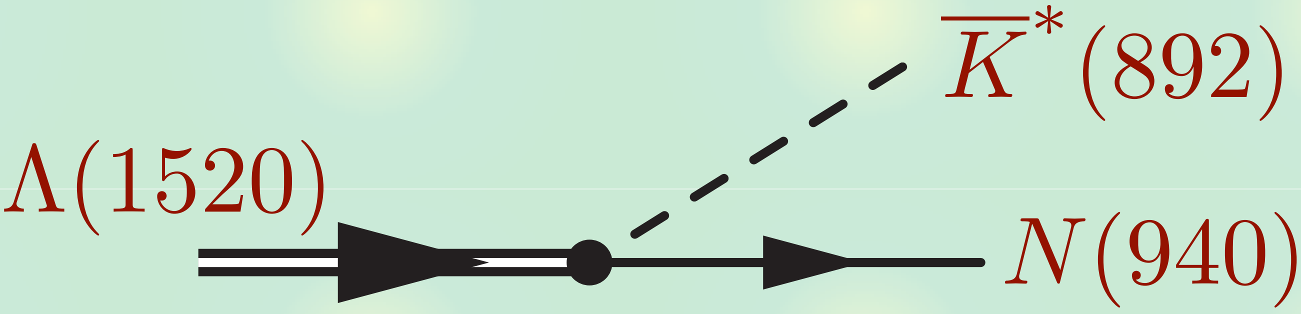


Decay width, branching ratio are reproduced

<- Additional coupling constants

S. Sarkar *et al.*, PRC 72, 015206 (2005) **-> K induced reaction**
L. Roca *et al.*, nucl-th/0602016 **-> pp collision**
M. Döring *et al.*, nucl-th/0601027 **-> radiative decay**

Formulation



Effective interaction Lagrangian

$$\mathcal{L}_{\Lambda^*\bar{K}^*N} = \frac{g_{\Lambda^*\bar{K}^*N}}{M_{K^*}} \bar{\Lambda}^*_\mu \gamma_\nu (\partial^\mu K^{*\nu} - \partial^\nu K^{*\mu}) N + h.c.$$

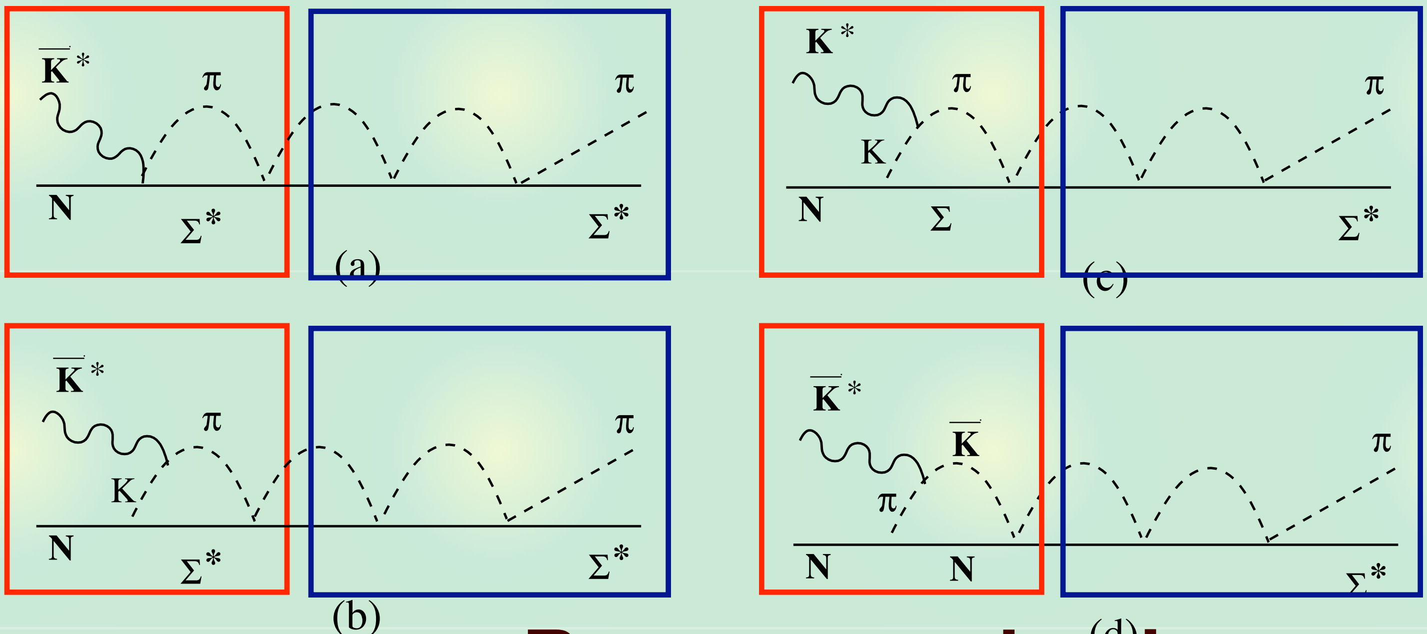
Non-relativistic reduction (s-wave)

$$-it_{\Lambda^*\bar{K}^*N} = g_{\Lambda^*\bar{K}^*N} \boldsymbol{S} \cdot \boldsymbol{\epsilon}$$

Formulation

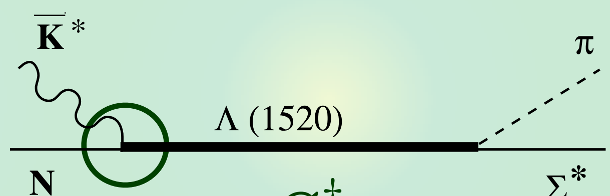
Amplitude for $\bar{K}^* N \to \pi \Sigma^*$

Microscopic couplings **Chiral unitary model**



Resonance dominance

$$P_0 \sim M_{\Lambda^*}$$



$$g_{\Lambda^* \bar{K}^* N} \boldsymbol{S}^\dagger \cdot \boldsymbol{\epsilon}$$

Formulation

Nucleon : on-shell

$$k_0 = P_0 - E_N(k) = P_0 - \sqrt{M_N^2 - k^2}$$

Calculated by evaluating diagrams

$$\boxed{g_{\Lambda^* \bar{K}^* N}(P_0, k)} = \underline{g_{\Lambda^* \pi \Sigma^*}} \left[\underline{G_{\pi \Sigma^*}(P_0) + \frac{2}{3} \tilde{G}_{\pi \Sigma^* K}(P_0, k)} \right] \underline{g_{\pi \Sigma^* \bar{K}^* N}}$$

$$+ \underline{g_{\Lambda^* \pi \Sigma}} \, \underline{\tilde{G}_{\pi \Sigma K}(P_0, k) g_{\pi \Sigma \bar{K}^* N}} + \underline{g_{\Lambda^* \bar{K} N}} \, \underline{\tilde{G}_{\bar{K} N \pi}(P_0, k) g_{\bar{K} N \bar{K}^* N}}$$

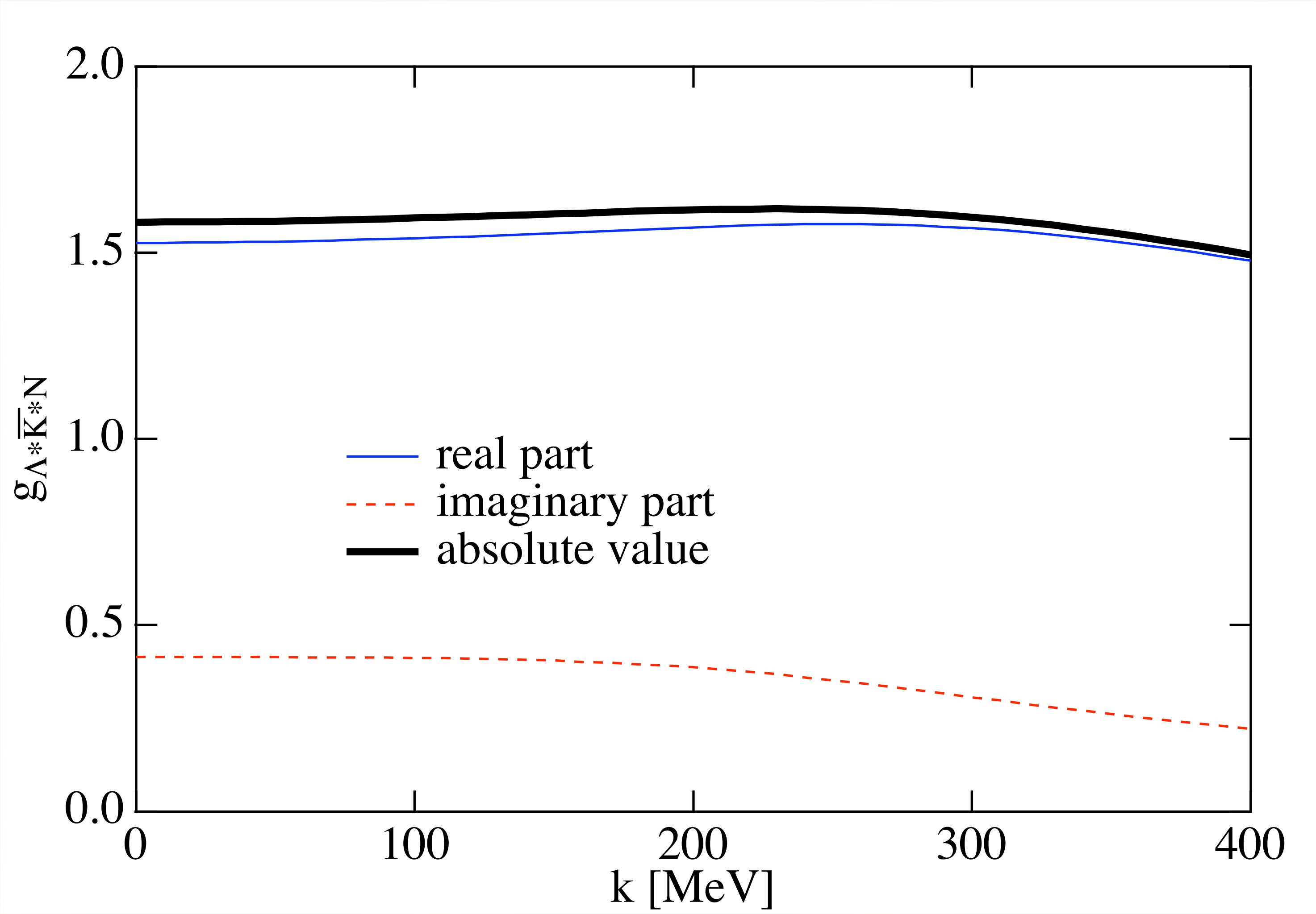
Residue of the pole in chiral unitary model

Evaluate this at

$P_0 = 1520 \text{ MeV}$ **(resonance dominance)**

$k \sim 0 \text{ MeV}$ **(s-wave dominance)**

Numerical result



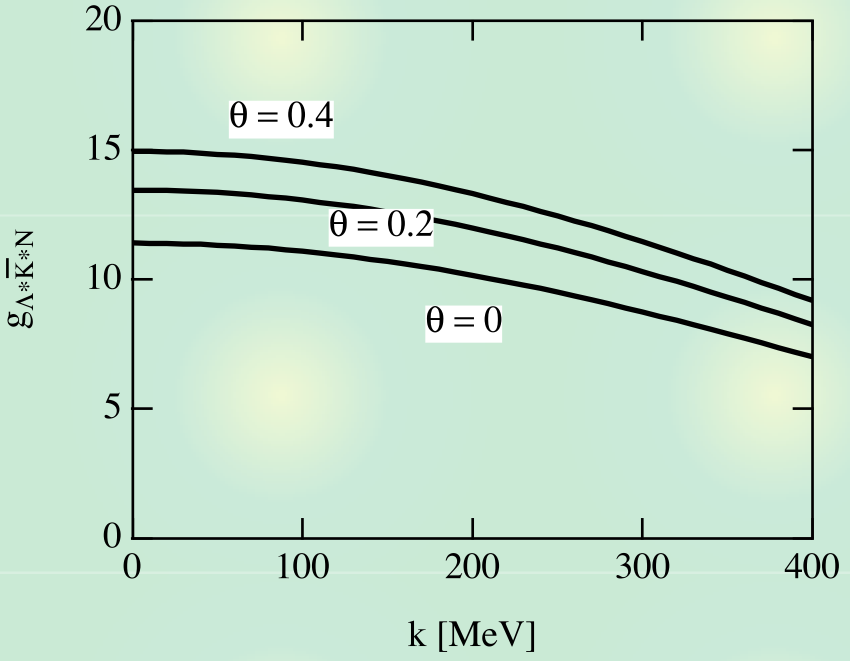
Small number : |g| ~ O(1)

Comparison with other estimations

Chrial unitary model : |g| ~ O(1)

Quark model : g ~ O(10)

θ : 8–1 mixing angle



Chrial unitary model gives a small number.

Summary 1

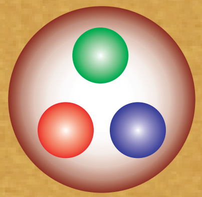
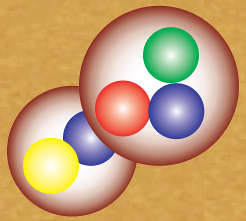
We calculate the $\bar{K}^*N$ coupling to the $\Lambda(1520)$ in the chiral unitary model.

- **The $\Lambda(1520)$ is generated dynamically in the 8meson-10baryon scattering with phenomenological couplings to the d-wave 8meson-8baryon channels.**
- **The obtained coupling constant g~1 is small compared with the quark model result.**

T. Hyodo, S. Sarkar, A. Hosaka, E. Oset, Phys. Rev. C73, 035209 (2006).

Summary 2

Difference between two models

	quark model	ChU model
quark structure		
SU(3) rep.	1 + 8	8 + 27 (+1)
angular momentum	p-wave	s-wave (+ d-wave)
$g_{\Lambda^* \bar{K}^* N}$	~10	~1

Experimental determination of |g| will shed light on the structure of the Λ(1520)

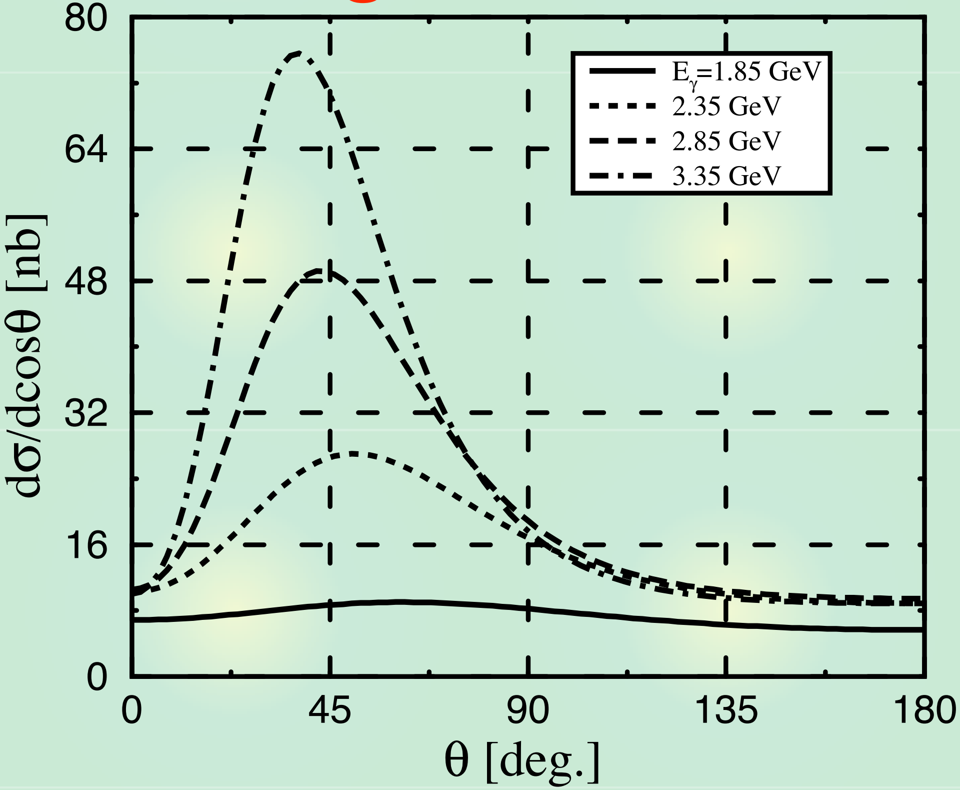
Experiments?

Angular dependence of γn —> KΛ(1520)

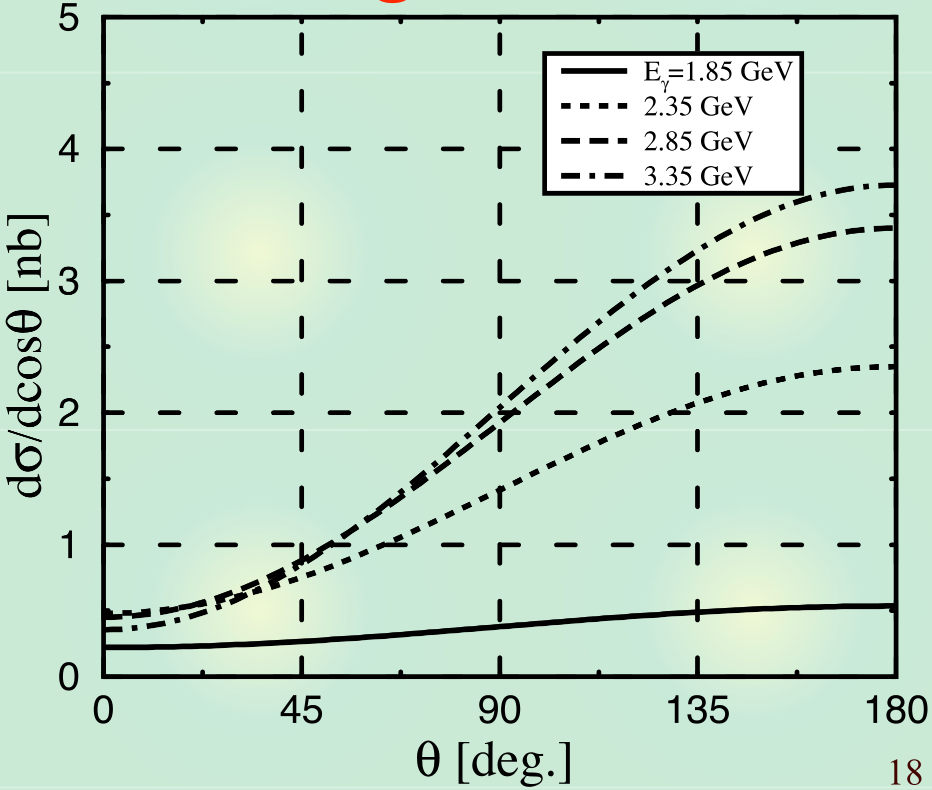
Effective Lagrangian + Born approximation

S. I. Nam, *et al.*, PRC71, 114012 (2005)

g = +11

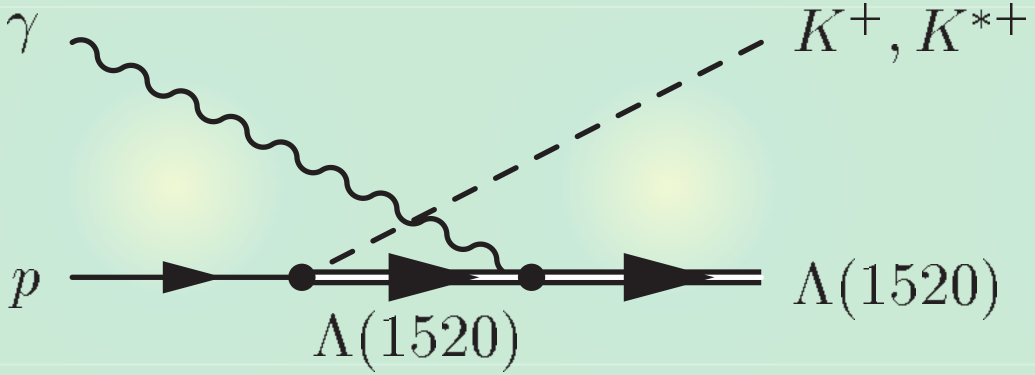


g = 0



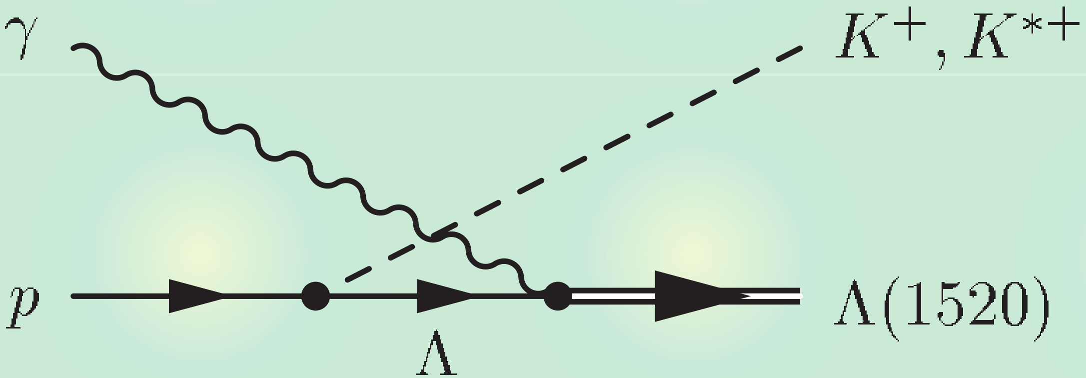
Experiments?

u-channel photoproduction : Λ(1520) at forward



Measure the ratio of K and K* couplings

background : ground state Λ exchange



Comparison with other estimations

Chrial unitary model : |g| ~ O(1)

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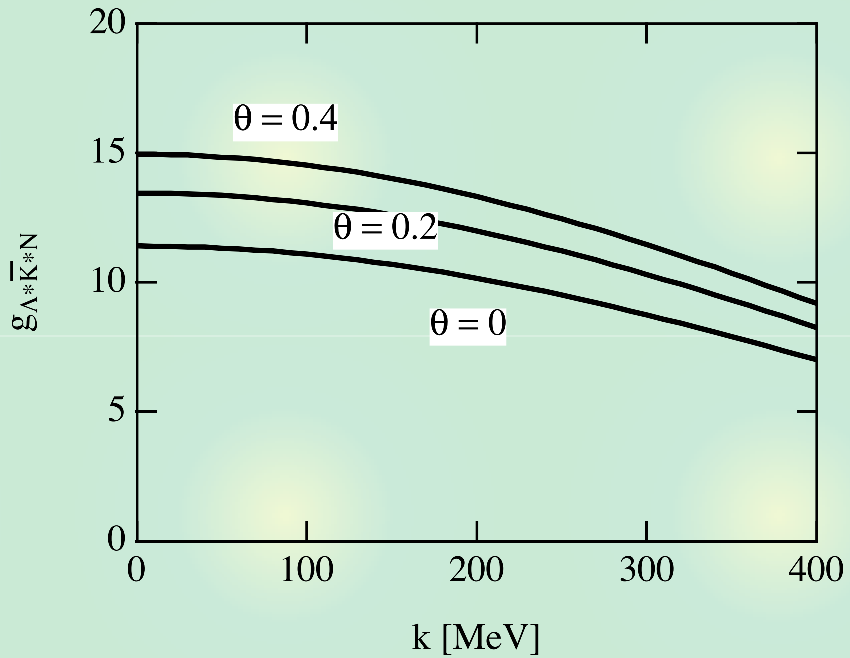


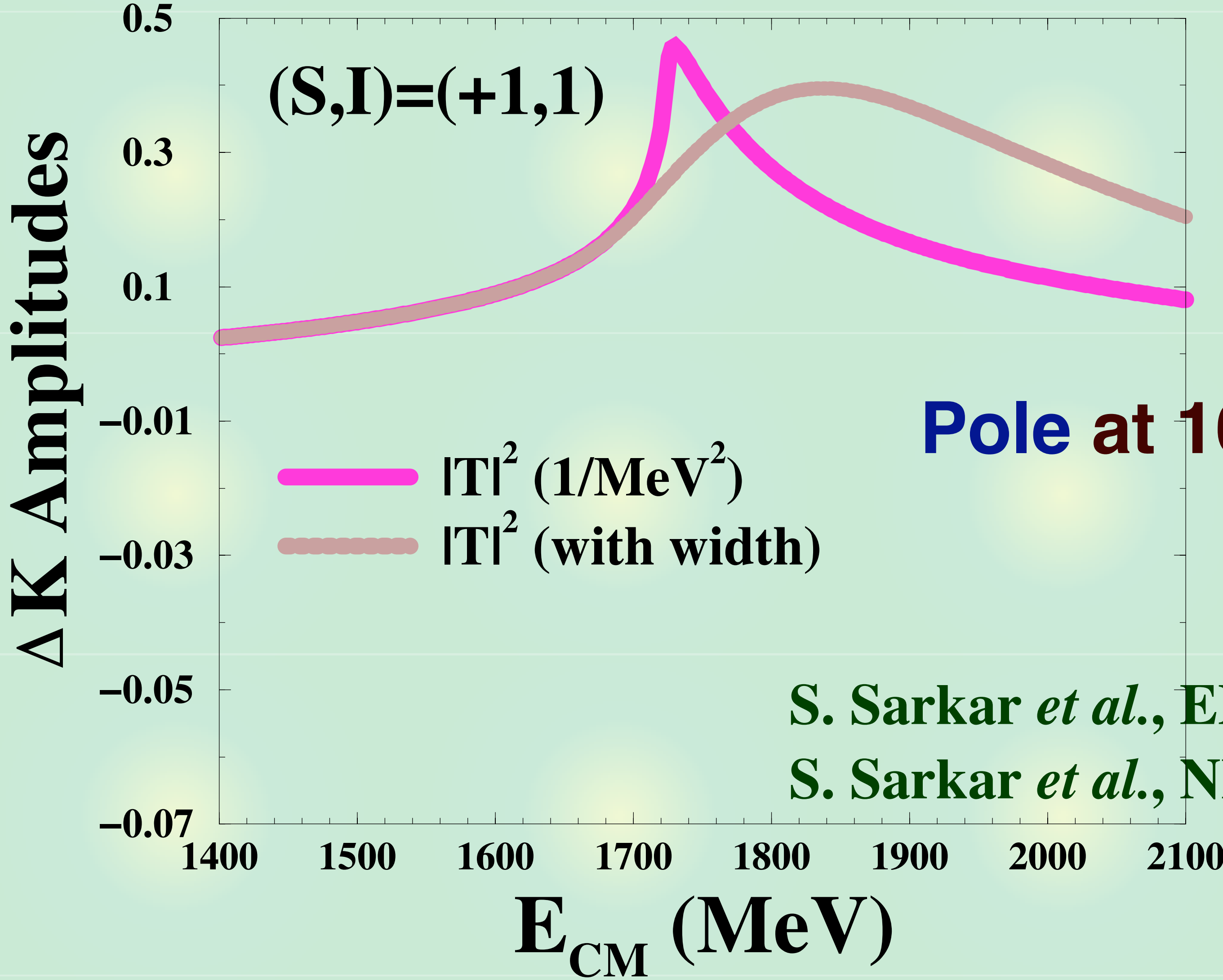
Fitting by Regge model to experiment

g = +7.1 or -12.6 A. I. Titov, *et al.*, PRC72, 035206 (2005)

Chrial unitary model gives a small number.

Results for the exotic state?

8 × 10 = 8 + 10 + 27 + 35 weakly attractive



Pole at 1635 MeV

S. Sarkar *et al.*, EPJ A24, 287 (2005)

S. Sarkar *et al.*, NPA 750, 294 (2005)