Λ(1405) production in K^- d → n π Σ at DAFNE

E. Oset, D. Jido, T. Sekihara, M. Bayar and J. Yamagata

Kbar N interaction and the two Λ(1405) states
K^- d → n π Σ with finite K^- momentum
K^- d → n π Σ at DAFNE
A possible Kbar NN strongly bound state with S=1 for NN

The Kbar N interaction is studied using chiral lagrangians and unitary techniques in coupled channels: Chiral Unitary Approach.

Several resonances are dynamically generated, including two Λ(1405) states, from the interaction of the octet of pseudoscalar mesons and the octet of baryons: Kbar N, π Σ, π Λ, η Σ, η Λ, K Ξ

Kbar N, π Σ are the most important channels for the Λ(1405) .

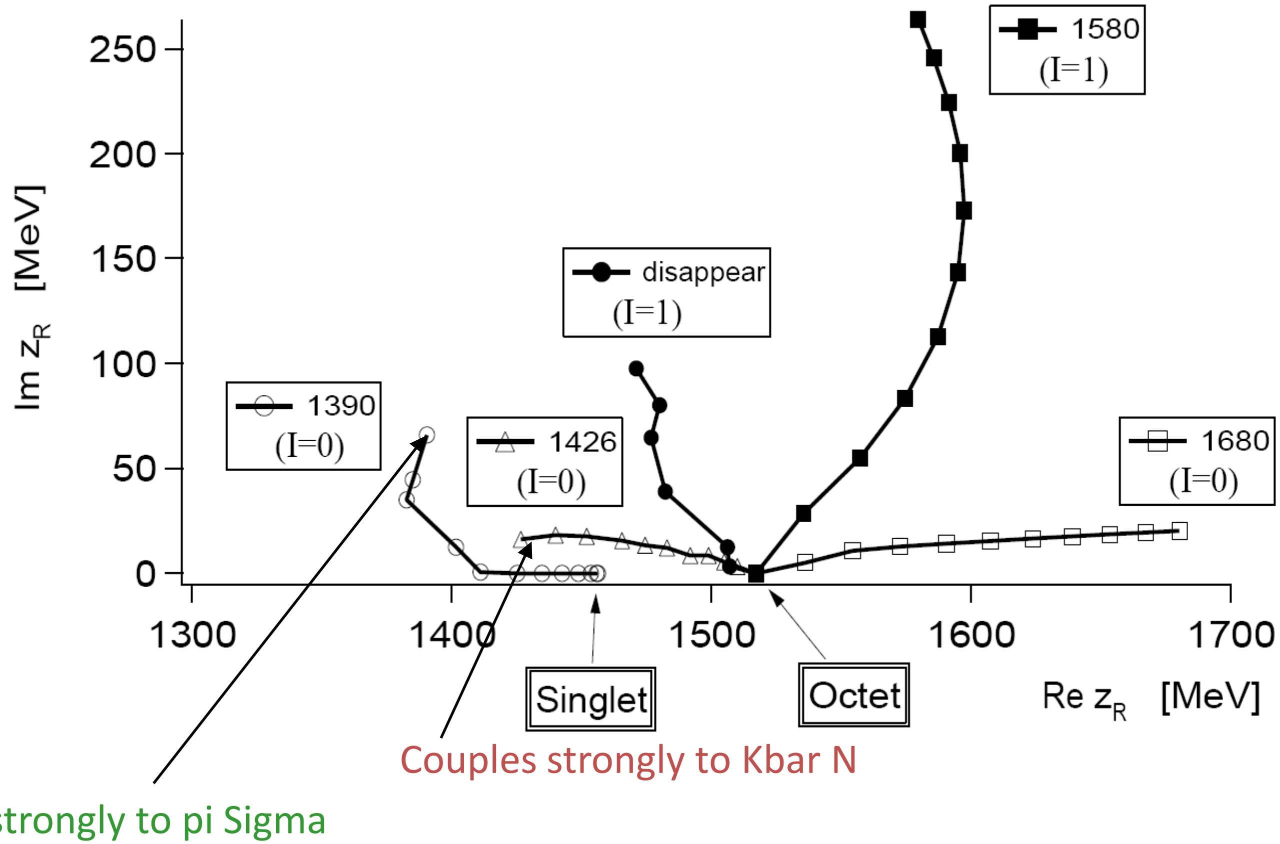
Poles of S=-1 J^P=1/2 $^-$ Resonances

Jido, Oller, Oset, Ramos, Meissner NPA03

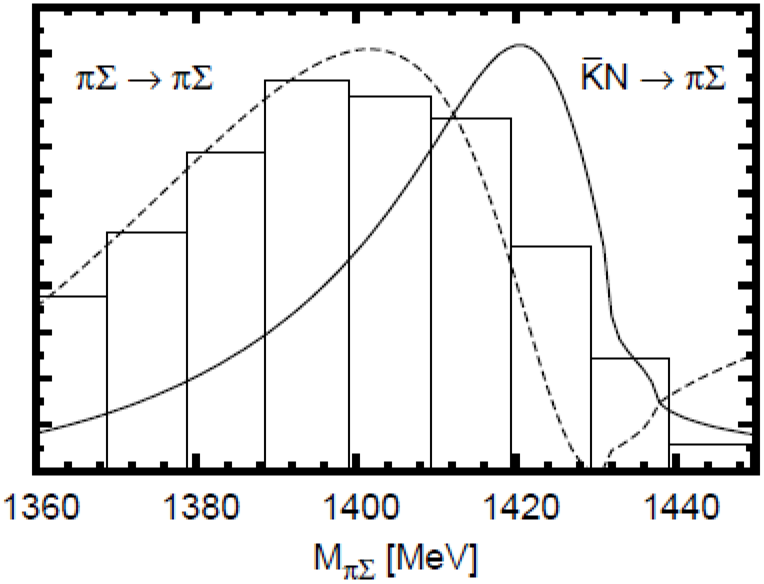
$$8 \otimes 8 = 1 \oplus 8_s \oplus 8_a \oplus 10 \oplus \overline{10} \oplus 27$$

$$M_i(x) = M_0 + x(M_i - M_0),$$
$$m_i^2(x) = m_0^2 + x(m_i^2 - m_0^2),$$
$$a_i(x) = a_0 + x(a_i - a_0),$$

X ∈ [0,1]



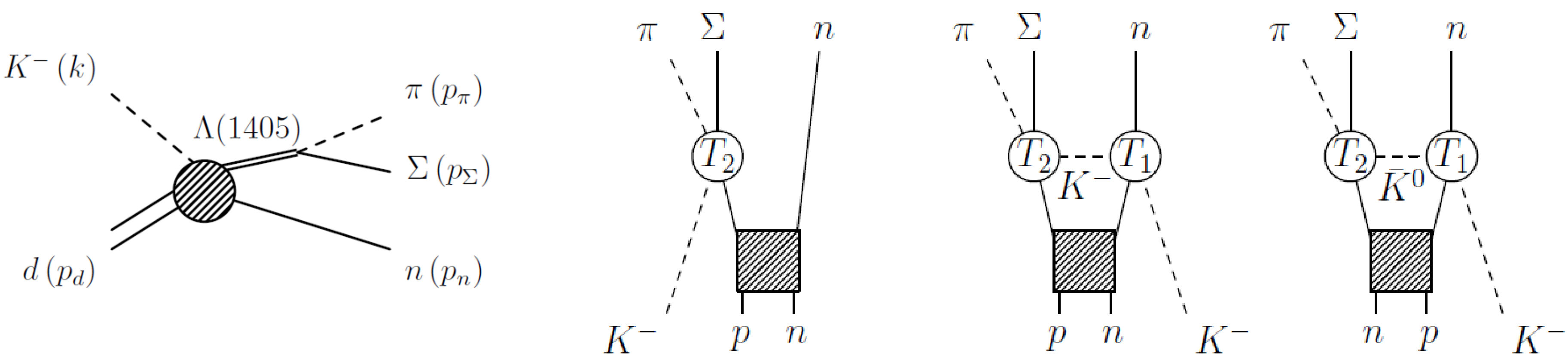
Effect of coupling to the different states in different amplitudes



The nominal Λ(1405) has this mass, the theory says that if we excite the resonance induced by Kbar N we should mostly excite the narrow state around 1520 MeV…… Example of K^- p → $\pi^0 \pi^0 \Sigma^0$, Prakhov …..

A new reaction to test it : K^- d → n π Σ,

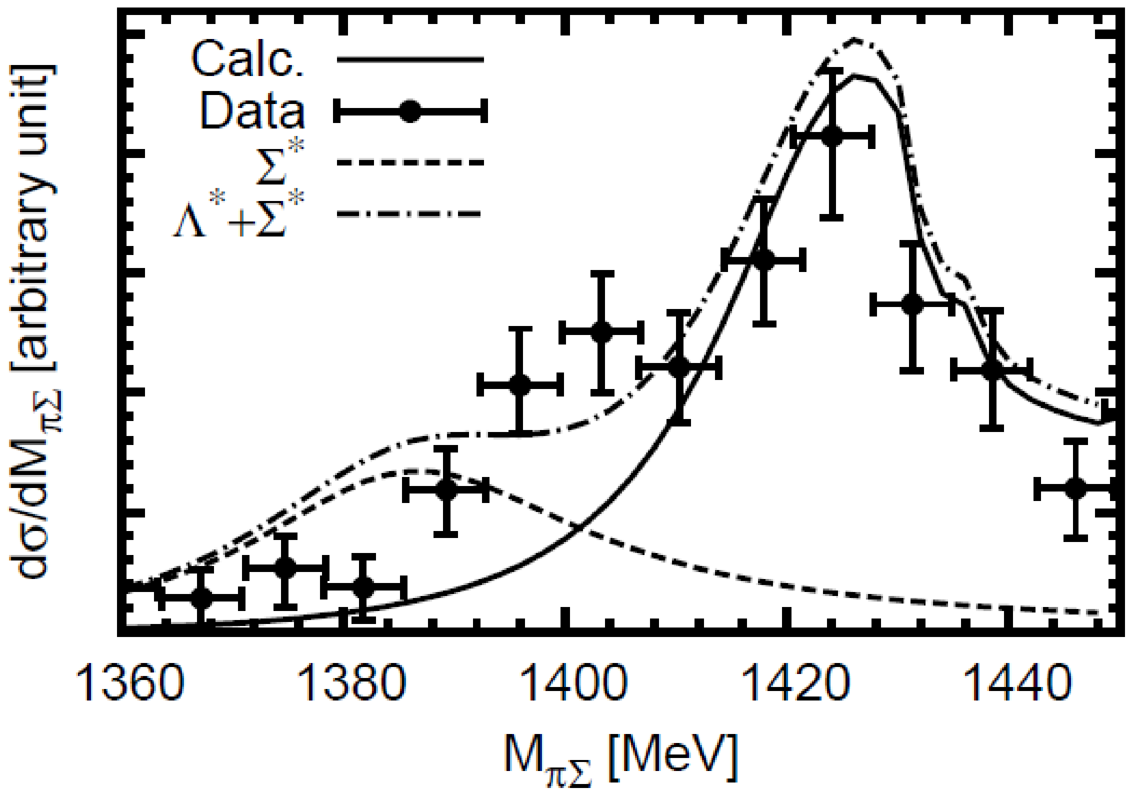
Λ(1405) is below Kbar N threshold ???????



$$T_1 = T_{K^-p\to\pi\Sigma}(M_{\pi\Sigma})\,\varphi(\boldsymbol{p}_n - \frac{\boldsymbol{p}_d}{2})$$

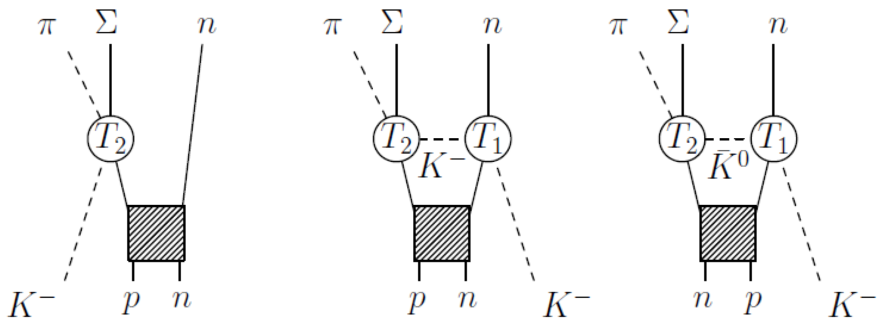
$$T_2 = T_{K^-p\to\pi\Sigma}(M_{\pi\Sigma}) \int \frac{d^3q}{(2\pi)^3} \frac{\tilde{\varphi}(\boldsymbol{q} + \boldsymbol{p}_n - \boldsymbol{k} - \frac{\boldsymbol{p}_d}{2})}{q^2 - m_K^2 + i\epsilon} \times T_{K^-n\to K^-n}(W_1)\,. \quad ($$

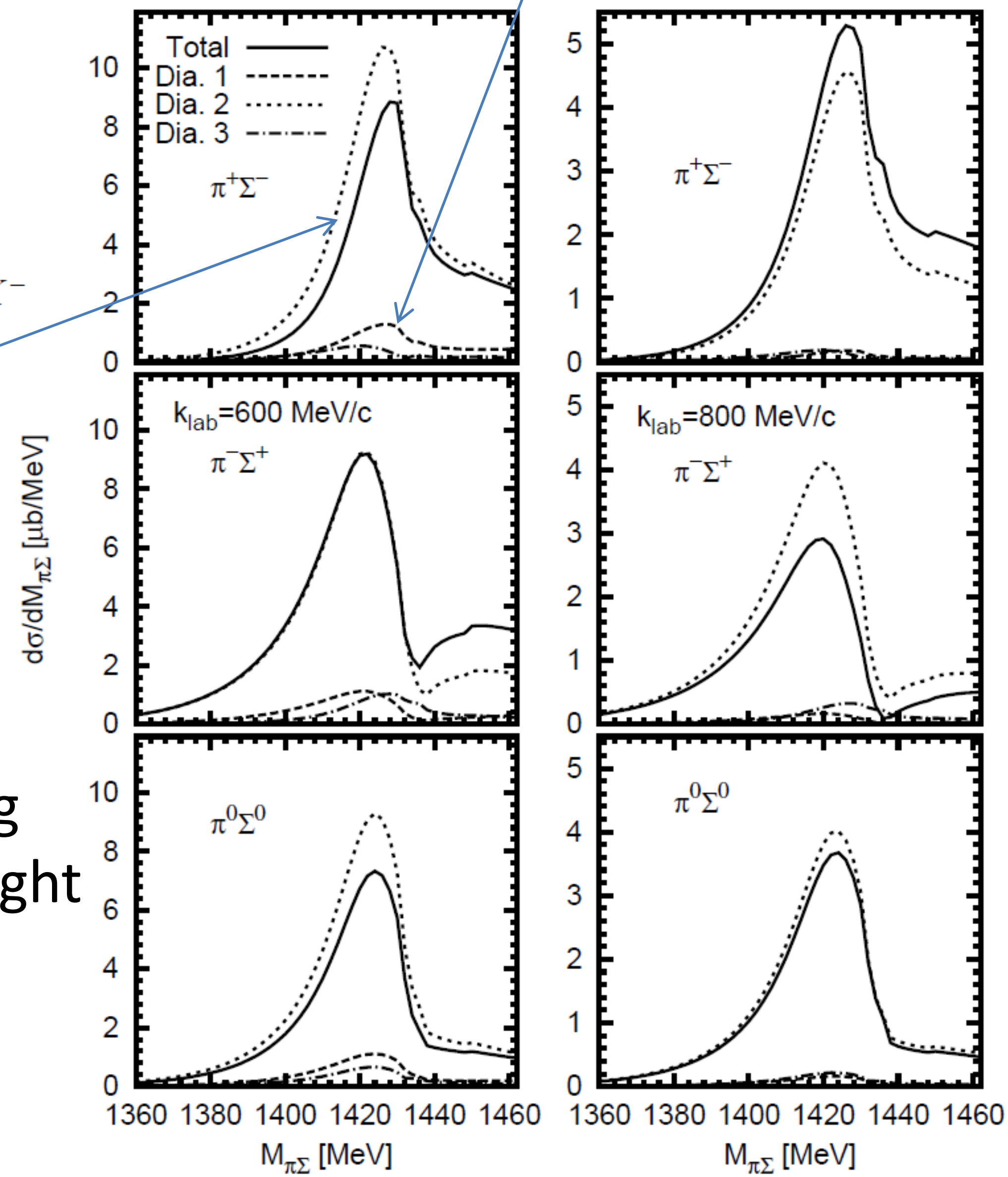
O. Braun *et al.*, Nucl. Phys. B **129**, 1 (1977)



Theory: Jido, Sekihara, E. O. Eur Phys J A 2009

Single scattering



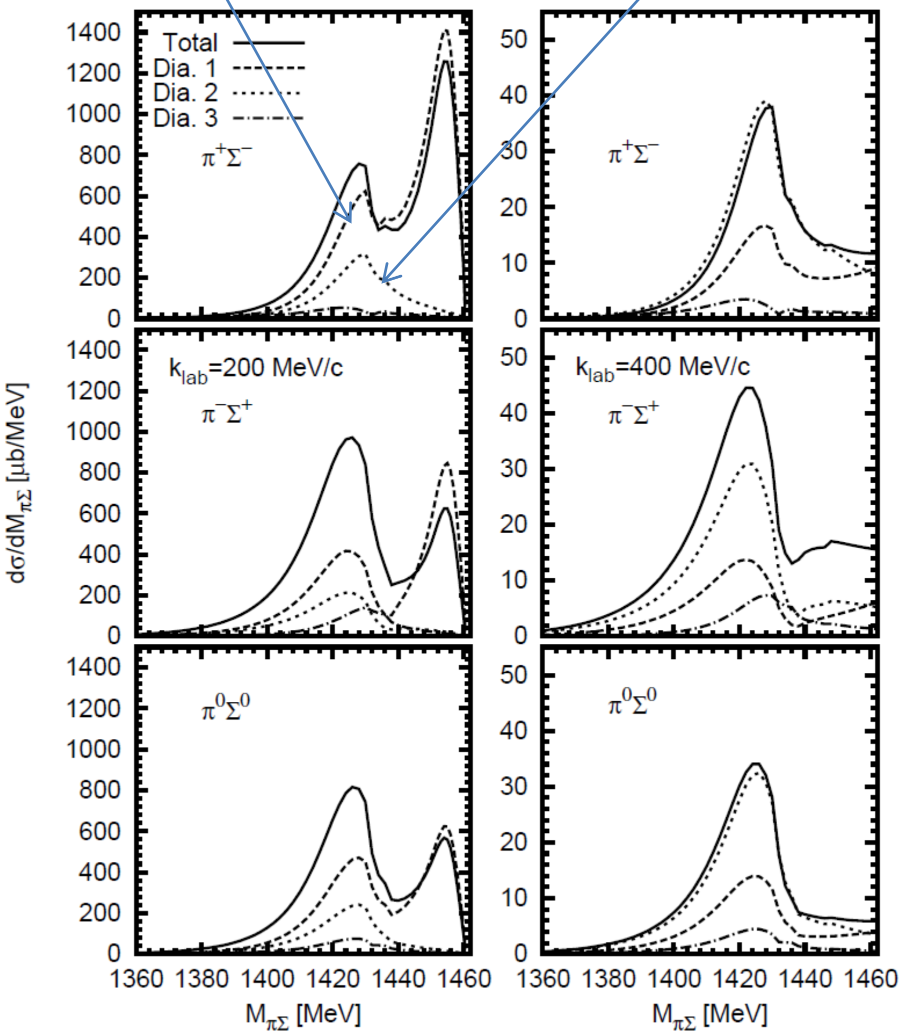


Double scattering

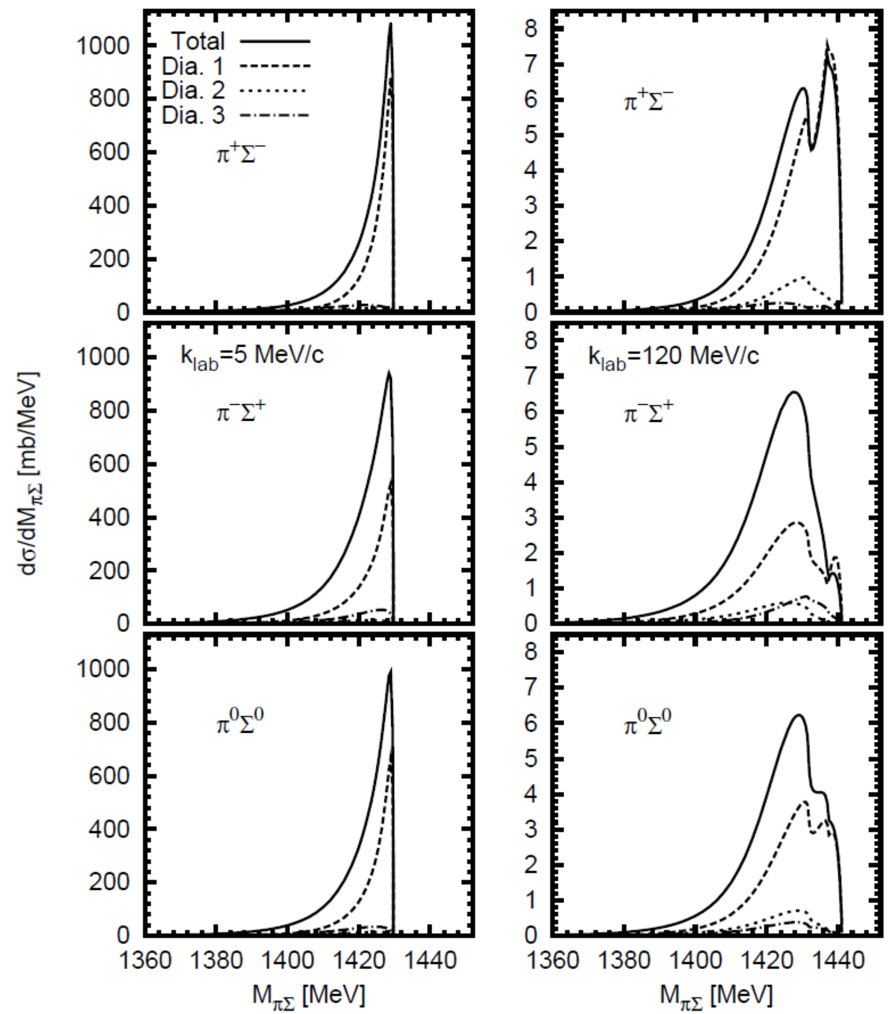
The single scattering contributes mostly at large M_{inv} corresponding to free K^- p scattering with K^- in flight

What happens if we decrease the K- momentum?

Single scattering   Double scattering



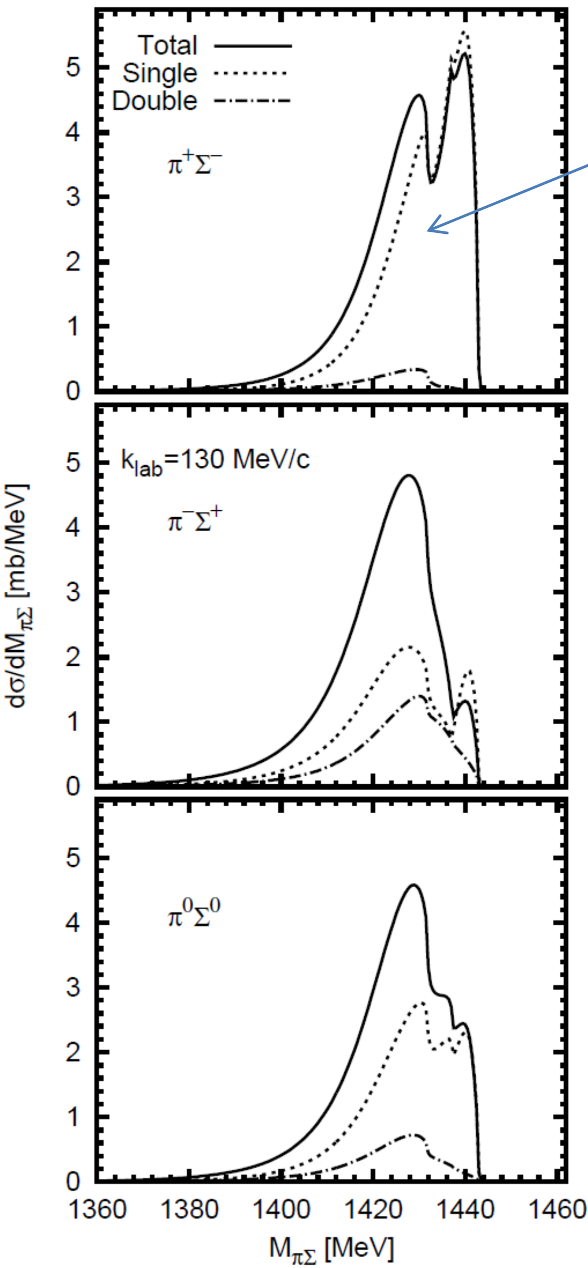
Single scattering catches up and distorts the signal

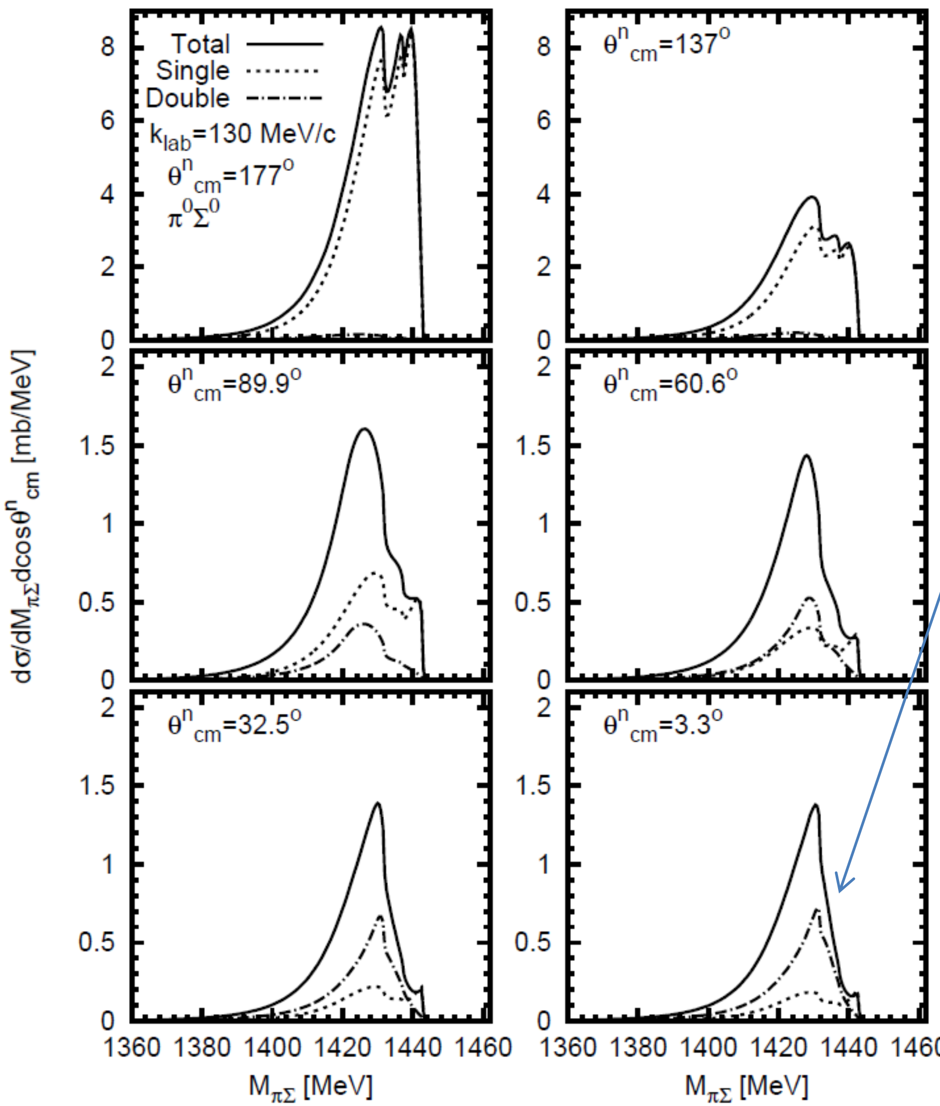


DAFNE conditions: K coming from ϕ decay:

Hope restored: measure n in coincidence forward in CM (n from single scattering go backwards)

Hopeless





The signal of the Λ(1405) is predicted clearly around 1420-1425 MeV, like in Braun experiment.

The cross sections obtained are measurable in a few months run, while data are collected for other purposes.

Nevio Grion is planning the experiment.

Byproduct: can there be a strongly bound (not kaonic state) of $K^{-}d$?

The Kbar NN system has been thouroghly studied theoretically: Consensus that there is bound state. Differences in mass and width. B=10-70 MeV, Γ=50-110 MeV

Experimentally: several claims, which have been disproved. No evidence, Γ too big???

Y. Ikeda and T. Sato, Phys. Rev. C **76**, 035203 (2007).

N. V. Shevchenko, A. Gal and J. Mares, Phys. Rev. Lett. **98**, 082301 (2007).

N. V. Shevchenko, A. Gal, J. Mares and J. Revai, Phys. Rev. C **76**, 044004 (2007)

A. Dote, T. Hyodo and W. Weise, Nucl. Phys. A **804**, 197 (2008).

A. Dote, T. Hyodo and W. Weise, Phys. Rev. C **79**, 014003 (2009).

Y. Ikeda and T. Sato, Phys. Rev. C **79**, 035201 (2009).

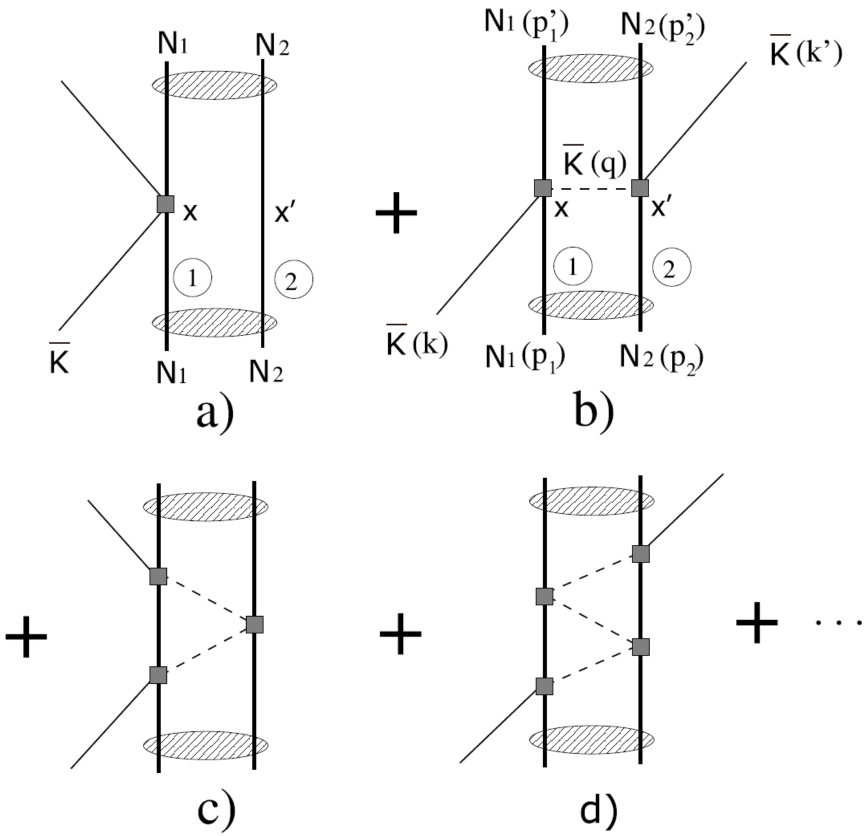
T. Yamazaki and Y. Akaishi, Phys. Lett. B **535** (2002) 70

Y. Ikeda, H. Kamano and T. Sato, Prog. Theor. Phys. **124**, 533 (2010)

All them search and find a state with S_{NN}=0 which is the most bound.
No one looked for S_{NN}=1 , like K^{-} d state.

Kbar NN scattering Fixed Center approximation to Faddeev equations

M. Bayar, J. Yamagata, E. O.



$$T = T_1 + T_2$$

$$T_1 = t_1 + t_1 G_0 T_2$$

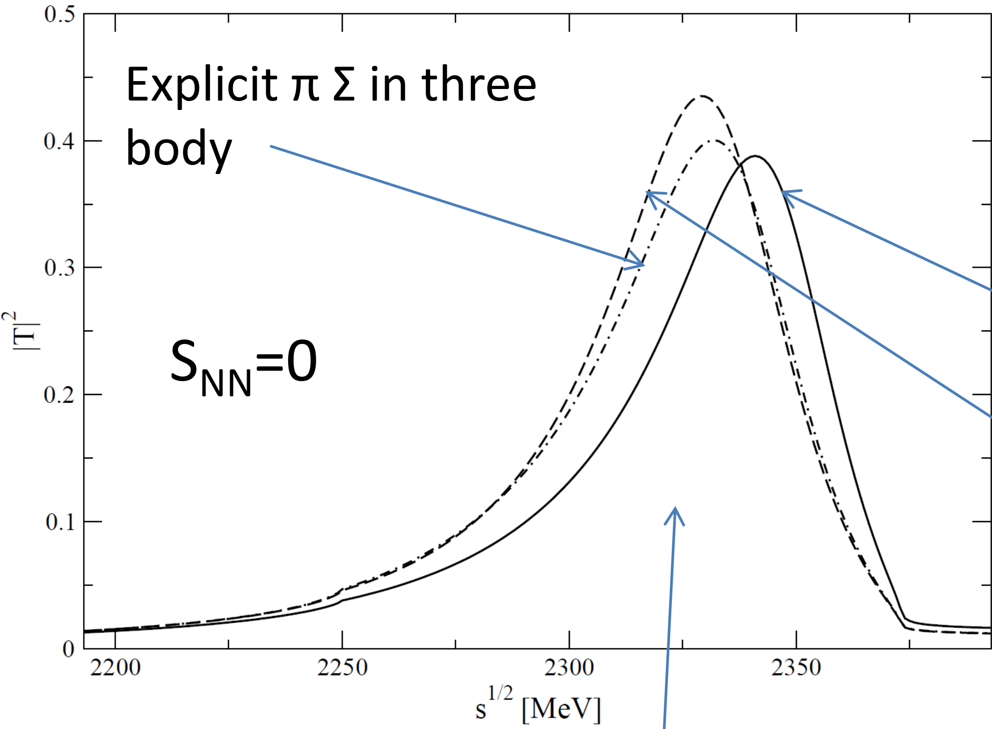
$$T_2 = t_2 + t_2 G_0 T_1$$

$$t_1 = t_2$$

$$G_0 = \int \frac{d^3q}{(2\pi)^3} F_{NN}(q) \frac{1}{q^{0\,2} - \vec{q}^{\,2} - m_{\bar K}^2 + i\epsilon}$$

NN form factor

$$T = \frac{2t_1}{1 - t_1 G_0}$$

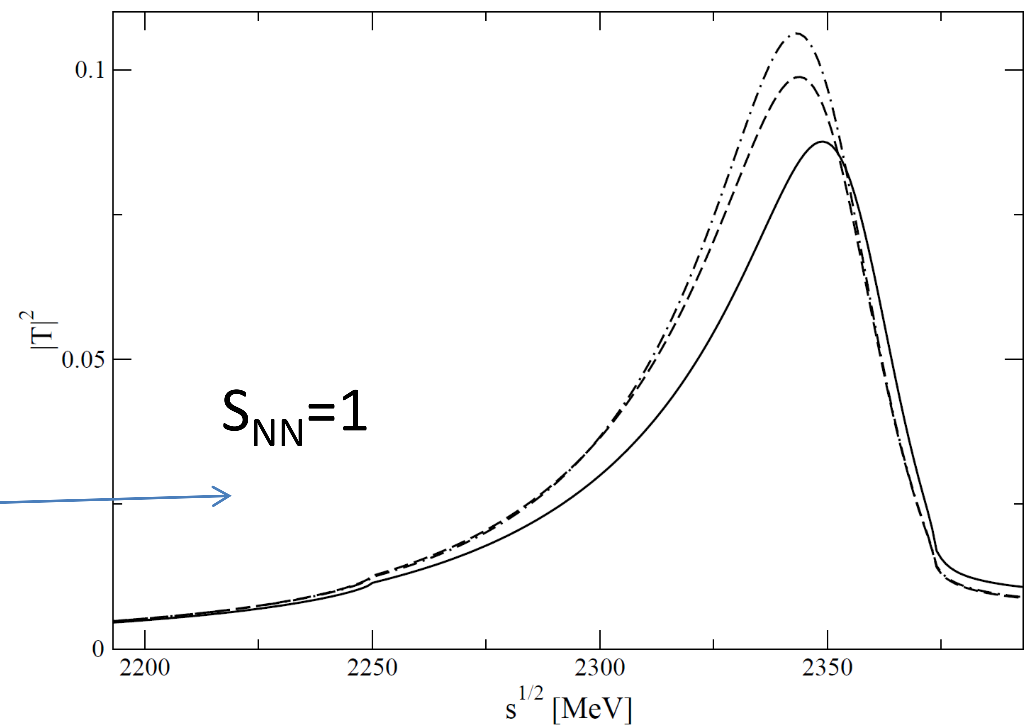


Kbar NN threhold: 2372 MeV

NN size of deuteron

NN decreased size to about half radius from Hyodo et al.

State bound by 45-50 MeV
Γ around 50 MeV



State bound by 30 MeV
Γ around 50 MeV

Extra widh from Kbar absorption

For S_{NN}=0 the FCA provides results similar to those of Hyodo, Dote, Weise , since same input is used.

Novel prediction for S_{NN}=1, K^- d strongly bound state. Not fund before because people used variational calculations to get minimum energy, or those who used Faddeev preassumed S_{NN}=0.

Experiments continue: the existence of new S_{NN}=1 state might make the observation more difficult because overlap of two states.

Theoretical confirmation with other methods welcome!!

Conclusions

Mounting evidence that there are two Λ(1405) states

The $K^- d \rightarrow n \pi \Sigma$ reaction with K^- in flight gives evidence of the high energy, narrow Λ(1405) state

DAFNE low energy Kaons still good, but neutrons forward must be measured in coincidence. Proposal planned.

There is a strongly bound Kbar NN system, with $S_{NN}=1$ like in d

This is a novel theoretical finding since only $S_{NN}=0$ has been investigated so far. Caveat with the width for experimental identification.