New insights in $\bar{K}N$ scattering and the Λ(1405)

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1. **Introduction. Interest.**
2. **Two-pole nature of the Λ(1405)**
3. **Uncertainties in the lighter pole and subthreshold extrapolation of K^-p scattering**
4. **Reproduction of πΣ production experimental data**
5. **I=1 resonances around the $\bar{K}N$ threshold**
6. **Dynamically generated I=0 , 1 resonances**
7. **S-wave S=-1 meson-baryon scattering at NLO in UChPT**
8. **Conclusions**

1. INTRODUCTION. INTEREST.

$\bar{K}N$ **scattering:**

Goldstone boson dynamics:

π , K , η : We have at our disposal chiral Effective Field Theory and its results

At the same time one has large masses involved:

-baryon masses

-kaon and eta masses

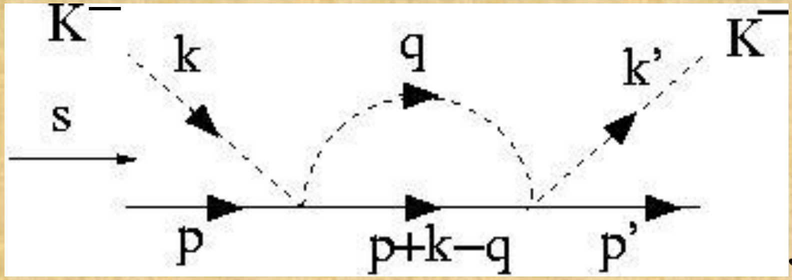
Non-perturbative dynamics originates:

NN scattering: Deuteron

$K\bar{K}$ scattering: $f_0(980)$

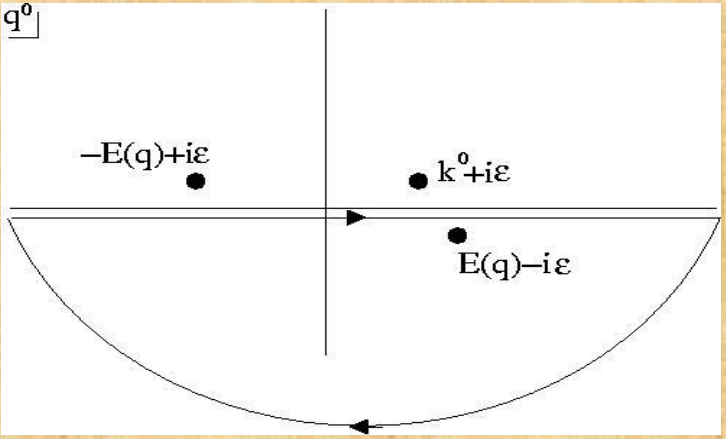
Let us keep track of the kaon mass, $M_K \approx 500\,MeV$

We follow S.Weinberg in NPB363,3 (´91) for NN scattering (N mass)



Unitarity Diagram

$$\int \frac{dq^0}{(k^0 - q^0 + i\epsilon)(q^0 + E(q) - i\epsilon)(q^0 - E(q) + i\epsilon)}$$

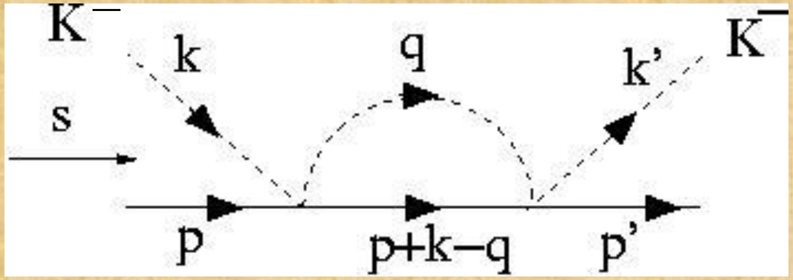


$$\frac{1}{k^0 - E(q)}\frac{1}{2E(q)} \simeq \frac{2M_K}{k^2 - q^2}\frac{1}{2M_K}$$

Unitarity enhancement for low three-momenta: $\frac{2M_K}{q}$

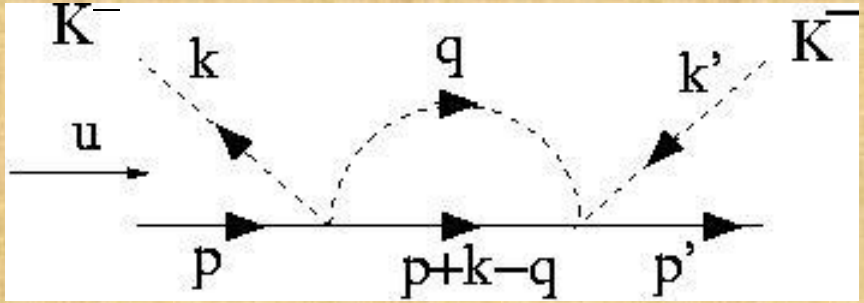
Around one order of magnitude in the region of the Λ(1405) region,
$|q| \simeq 100\ MeV$

$$M_K \approx 500$$



Unitarity Diagram

$$\frac{1}{k^0 - E(q)}\frac{1}{2E(q)} \simeq \frac{2M_K}{k^2-q^2}\frac{1}{2M_K}$$



Let us take now the crossed diagram

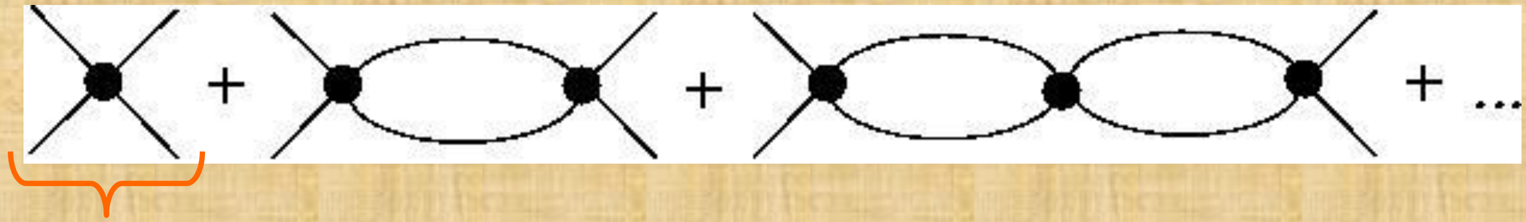
$$k \to -k$$

$$\frac{1}{k^0 + E(q)}\frac{1}{2E(q)} \simeq \frac{1}{4M_K^2}$$

Unitarity&Crossed loop diagram: $\frac{4M_K^2}{k^2-q^2}$

Unitarity enhancement for low three-momenta: $\frac{2M_K}{q}$

- **Enhancement of the unitarity cut that makes definitively smaller the overall scale Λ_{CHPT} in meson-baryon scattering with strangeness:**



Arbitrary Meson-Baryon Vertex

Having large masses (Baryon+Kaon masses) compared with typical low three-momenta drives the appearance of the Λ(1405) close to threshold in $\bar{K}N$ scattering.

$\bar{K}N$ + coupled channels $(\pi\Sigma, \ldots)$ is essential to study:

Review:

Hyodo, Jido, Prog. Part. Nucl. Phys. **67**, 55 (2012)

- Confront precise measurements for kaonic hydrogen
- Recent and planned experiments: photoproduction (LEPS,CLAS), pp colision (COSY, GSI),K^- N with free N or in Deuteron (J-PARC,DAFNE)
- Two-pole nature of the $\Lambda(1405)$
- $\bar{K}NN$ few-body states
- Strongly bound $\bar{K}$ in nuclei
- Kaons in nuclear matter. Kaon condensation
- Kaonic atoms

2. Two-Pole nature for the Λ(1405)

- Λ(1405) was predicted theoretically by Dalitz and Tuan (vector-exchange models), Phys.Rev.Lett.2,425(1959), Ann.Phys.10,307(1960)
- Experimentally discovered by Alston et al., Phys.Rev.Lett.6,698(1961)
- Cloudy Bag Model: Veit, Jennings, Thomas, Barret, Phys.Lett. B137,415(1984); Phys.Rev.D31,1033(1985)
- Fink, He, R.H.Landau,Schnick, Phys.Rev.C41,2720(1990) obtained that the Λ(1405) in the Cloudy Bag Model corresponds to two poles in the complex plane.

- Independently rediscovered in: Unitarized ChPT (Chiral Unitary Approach) by Meissner,J.A.O., Phys.Lett.B500, 263(2001): the analysis of poles in the complex plane revealed two poles for the Λ(1405)

This issue was studied in more detail by Jido, Oset, Ramos, Meissner,J.A.O., Nucl.Phys.A725,181(2003)

- Jülich model of meson exchanges: Mueller-Groeling, Holinde, Speth, Nucl.Phys.A513,557(1990)
- Haidenbauer,Krein,Meissner and Tolos, Eur.Phys.J.A47,18(2011) established that in the Jülich model the Λ(1405) also corresponds to two poles

Jido, Oset, Ramos, Meissner,J.A.O., Nucl.Phys.A725,181(2003)

$$T_{ij}(s) = \frac{g_i g_j}{s_R - s} + \dots$$

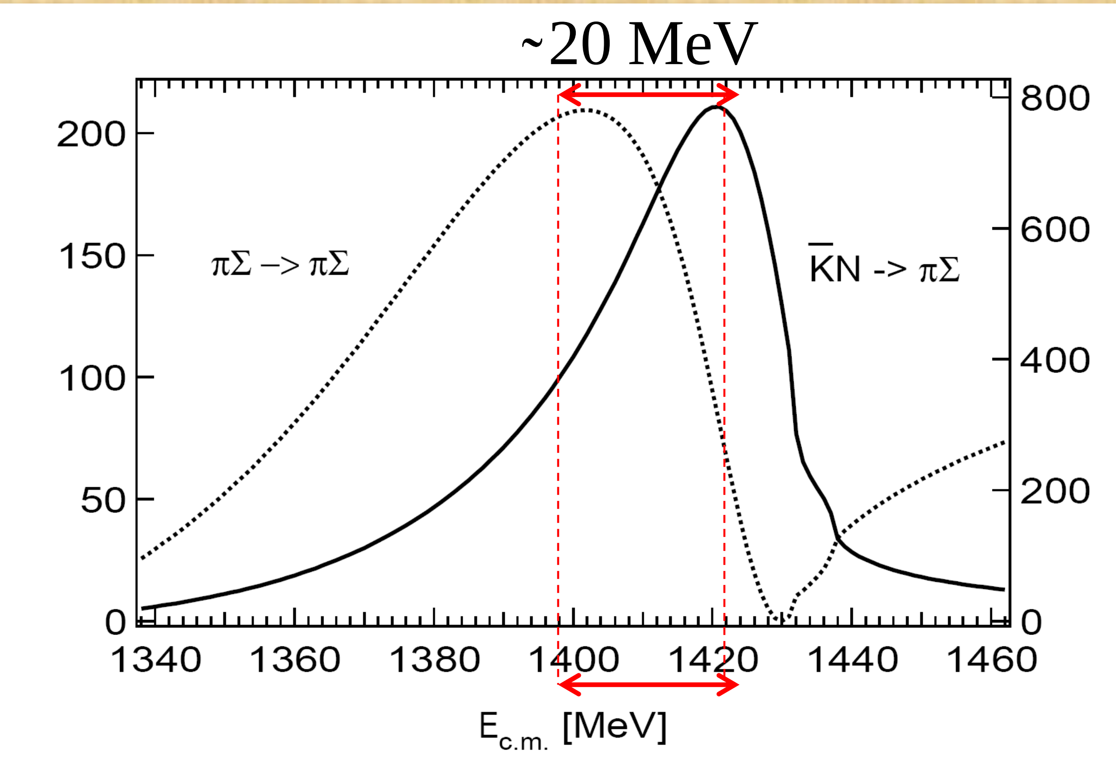
Bennhold,Oset,Ramos, Phys.Lett.B527,90(2002)

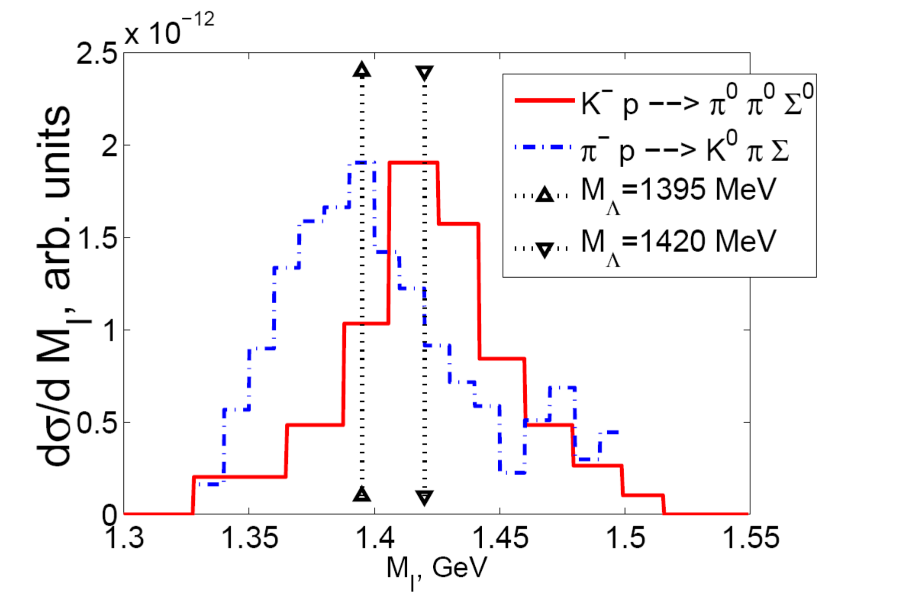
Oset,Ramos, Nucl.Phys.A635, 99(1998)

$I=0$	$1390 - i\,66$	$1426 - i\,16$
	$\lvert g_i \rvert$	$\lvert g_i \rvert$
$\pi\Sigma$	2.9	1.5
$\bar{K}N$	2.1	2.7
$\eta\Lambda$	0.77	1.4
$K\Xi$	0.61	0.35

Meissner, J.A.O., Phys.Lett.B500,263(2001)

$I=0$	$1379 - i\,27$	$1434 - i\,11$
	$\lvert g_i \rvert$	$\lvert g_i \rvert$
$\pi\Sigma$	1.87	1.6
$\bar{K}N$	1.11	1.85
$\eta\Lambda$	0.38	1.23
$K\Xi$	0.61	0.36





Two experimental shapes of $\Lambda(1405)$ resonance

From Magas et al., PRL95,052301(2005)

3. The broader pole is not well determined from scattering data

- Before the recent and most precise measurement of the energy shift and width of kaonic hydrogen by the SIDDHARTA Coll:

Taking calculationss with the interacting kernal up to $O(p^2)$

J.A.O., Eur.Phys.J.A28,63(2006)

(1300~1380)-i (13~60) MeV ; (1414~1429)-i (18~23) MeV

Borasoy,Meissner,Nissler, Phys.Rev.C74,055201(2006)

$$1348^{+293}_{-86} - i\,62^{+200}_{-60}\ \text{MeV}\ ;\ 1418^{+60}_{-38} - i\,31^{+34}_{-24}\ \text{MeV}$$

- After the measurement by the SIDDHARTA Coll. Bazzi *et al.*, Phys.Lett.B704,113(2011)

Z.-H.Guo,J.A.O., Phys.Rev.C87,035202(2013)

$$(1380 \sim 1450) - i\,(90 \sim 150)\ \text{MeV}$$
$$(1413 \sim 1424) - i\,(31 \sim 14)\ \text{MeV}$$

Ikeda, Hyodo, Weise, Nucl.Phys.A881,98(2012)

$$1381^{+18}_{-6} - i\,81^{+19}_{-8}\ \text{MeV}$$
$$1424^{+7}_{-23} - i\,26^{+3}_{-14}\ \text{MeV}$$

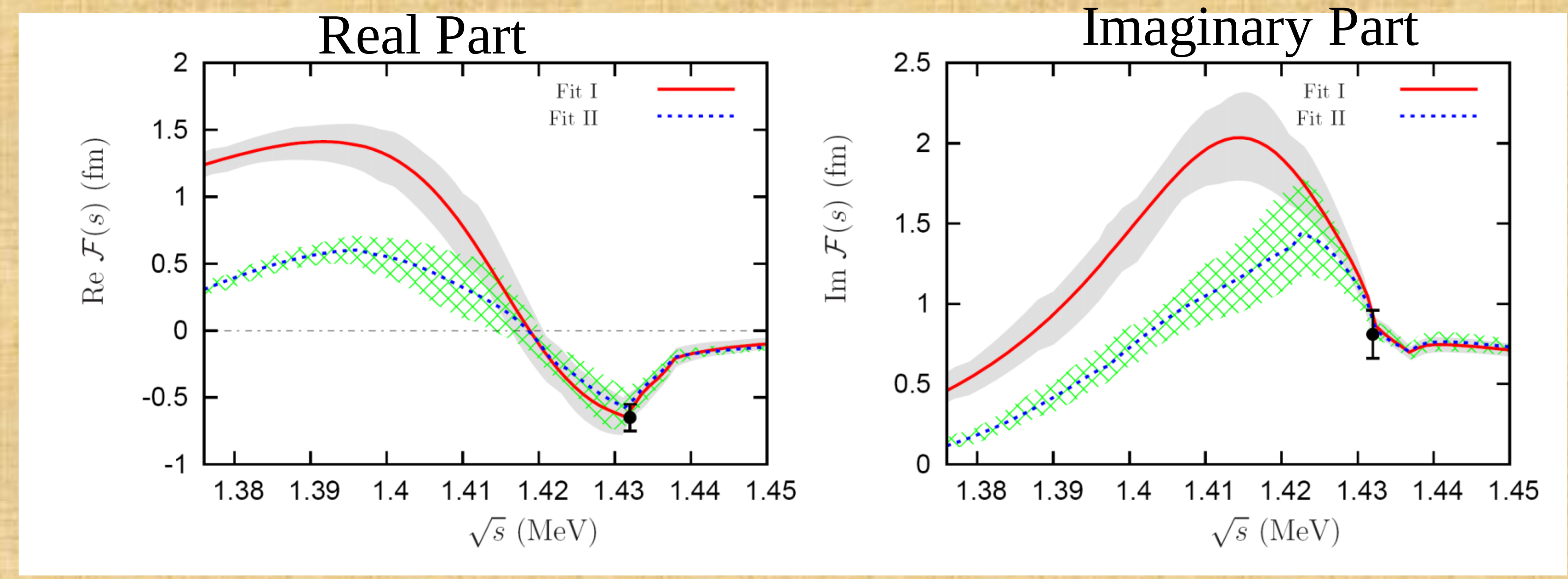
Two-pole nature for the $\Lambda(1405)$ is always confirmed

Obtained also in Mai,Meissner Nucl.Phys.A900, 51(2013)

The narrower pole is better known than the wider one

Strong influence in the subthreshold continuation of $\bar{K}N$ scattering amplitude

$K^- p \to K^- p$: Guo,J.A.O.,Phys.Rev.C87,035202(2013)



Experimental information on πΣ threshold scattering data will allow to pin down much more precisely the wider pole and overcome this uncertainty: FSI, LQCD,…

Ikeda,Hyodo,Jido,Kamano,Sato,Yazaki, Prog.Theor.Phys.125,1205(2011)

Increase your data and reproduce them…

4. To make use of experimental data from πΣ production experiments

- The only theoretical approach to take advantage of all these data corresponds to Oset et al. within the chiral unitary appraoch
- Remarkably compatibility with data. Main facts in the **isoscalar** S-wave S=-1 scattering are accounted for.

Photoproduction data

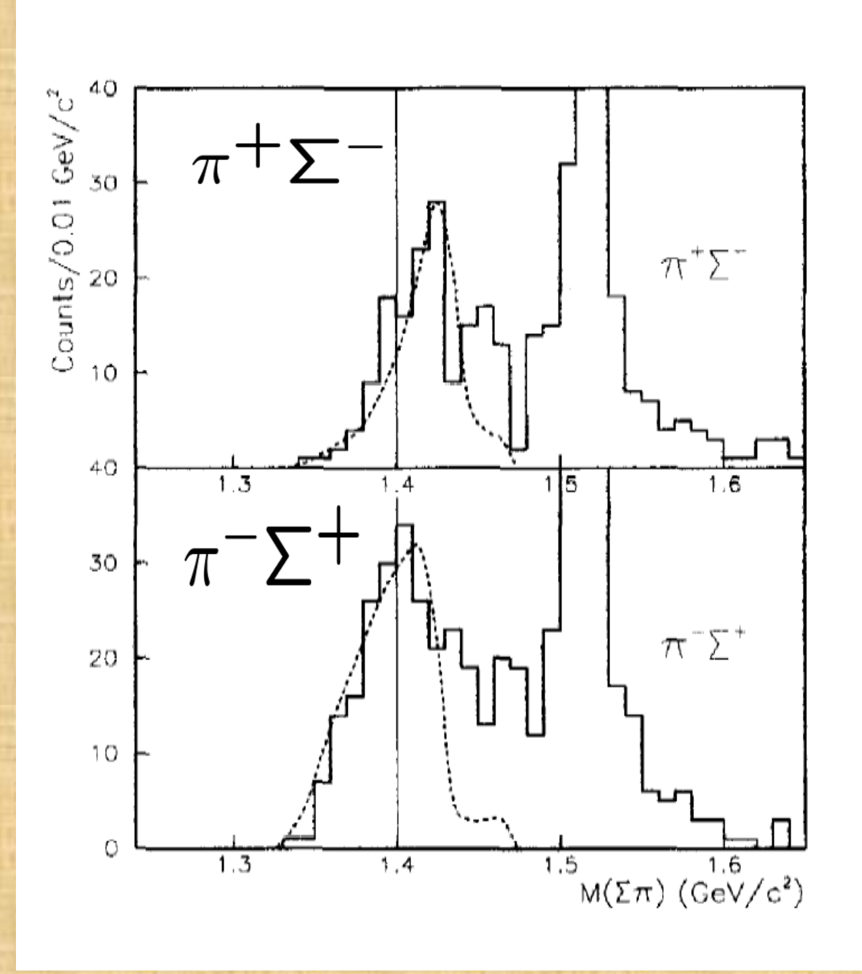
$$\gamma p \rightarrow K^+\Lambda(1405) \rightarrow K^+\pi^+\Sigma^-, K^+\pi^-\Sigma^+$$

Prediction Nacher, Oset, Toki, Ramos, Phys.Lett. B455,55(1999)

Confirmed at LEPS: Ahn, Nucl.Phys.A721, 715(2003); Niiyama *et al.*, Phys.Rev.C78,035202(2008)

J.K. Ahn, NP A721 ('03) 715

Line: Nacher et al. Theory.



CLAS data, Moriya et al., Phys.Rev.C87,035206(2012)

K. Moriya's talk

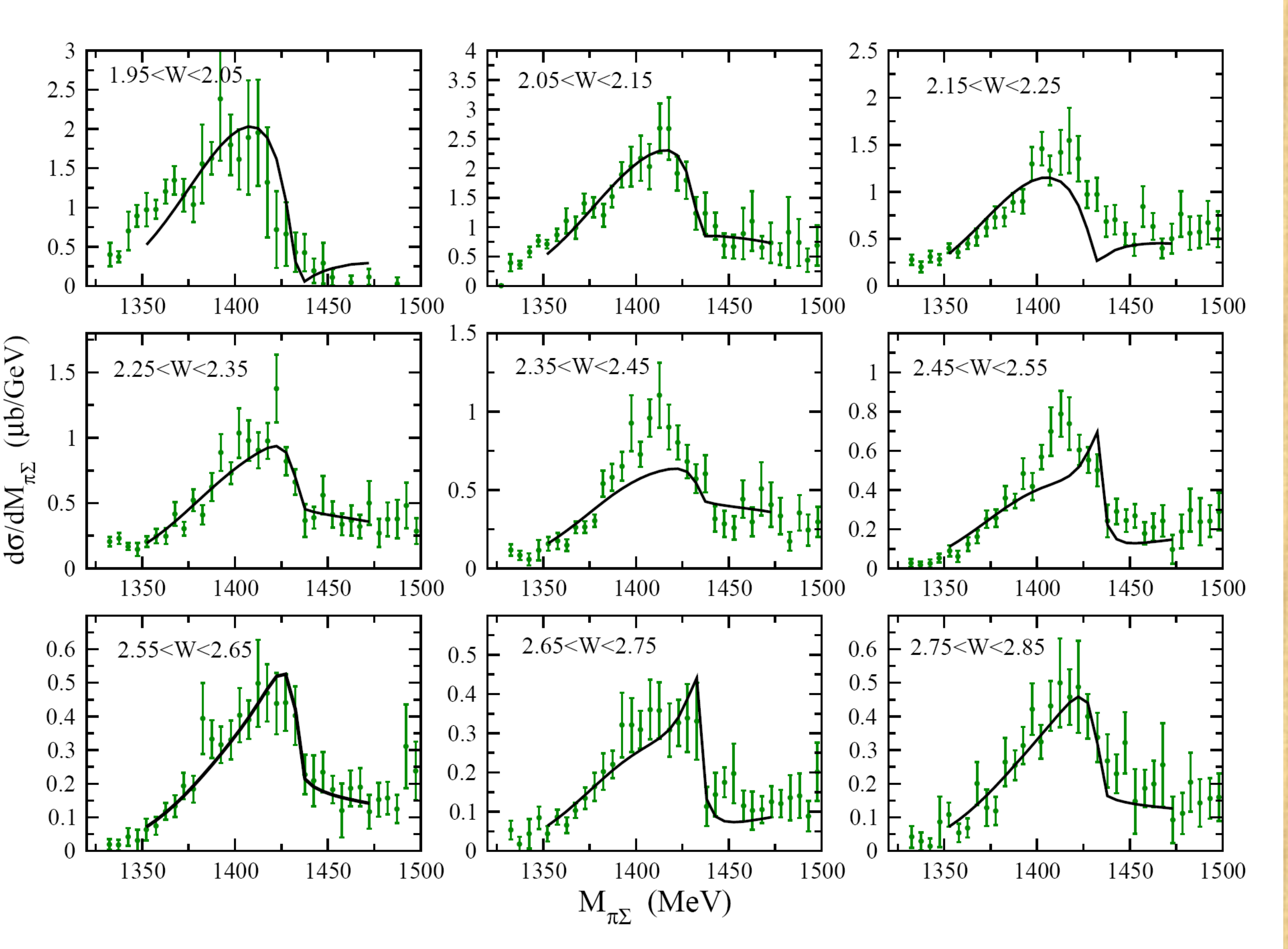
Isoscalar part fitted by Roca, Oset,Phys.Rev.C87,055201(2013)

The same strong amplitudes

The production process is parametrized in terms of 27 parameters. Still it is not a trivial matter.

L.Roca's talk

$\gamma p \rightarrow K^+ \pi^0 \Sigma^0$



CLAS data (points); Roca, Oset: line (3 free parameters/panel)

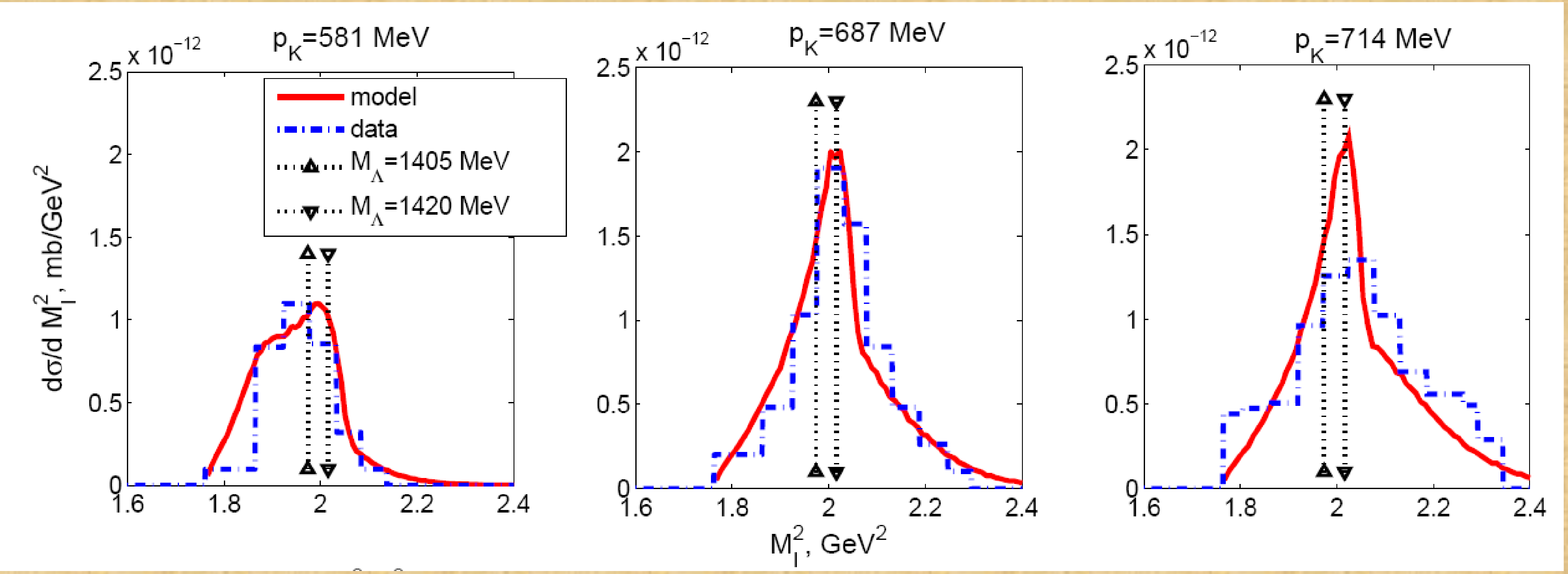
$K^- p \to \pi^0 \pi^0 \Sigma^0$

Prakhov *et al.* [Crystal Ball Coll.], Phys.Rev.C70,034605(2004)

Theory: Magas, Oset, Ramos, Phys.Rev.Lett.95,052301(2005)

J.A.O.,Eur.Phys.JA28,63(2006); Z.-H.Guo,J.A.O.,Phys.Rev.C87, 035202(2013)

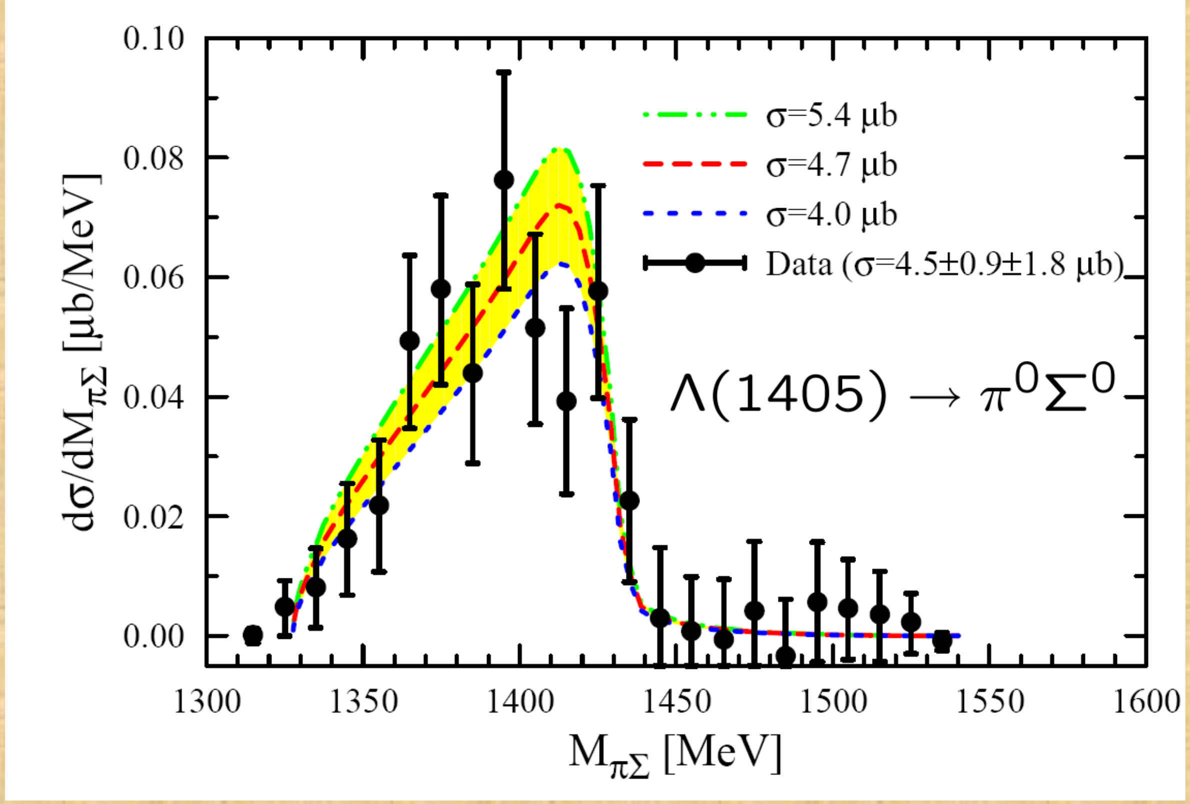
NO Fit



$pp \rightarrow pK^+Y^0$

Zychor *et al.*, Phys.Lett.B660,167(2008)
COSY-Jülich

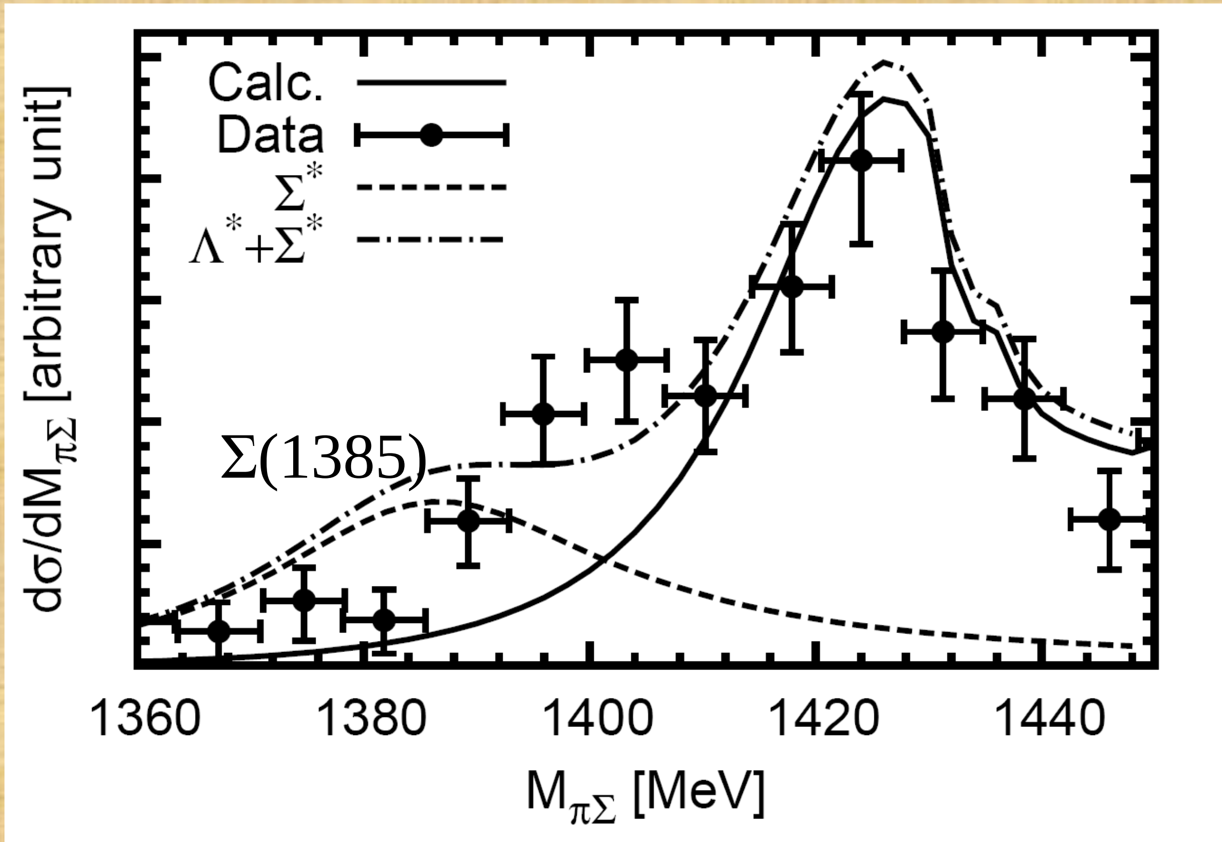
Theory: Geng, Oset, Eur.Phys.JA34, 405(2007)



HADES Coll. Phys.Rev.C87, 025201(2013) L.Fabbietti's talk

$K^- d \to n\pi\Sigma$ Braun *et al.*, Nucl.Phys.B129, 1(1977)

Theory: Jido,Oset,Sekihara, Eur.Phys.J.A42, 257(2009)



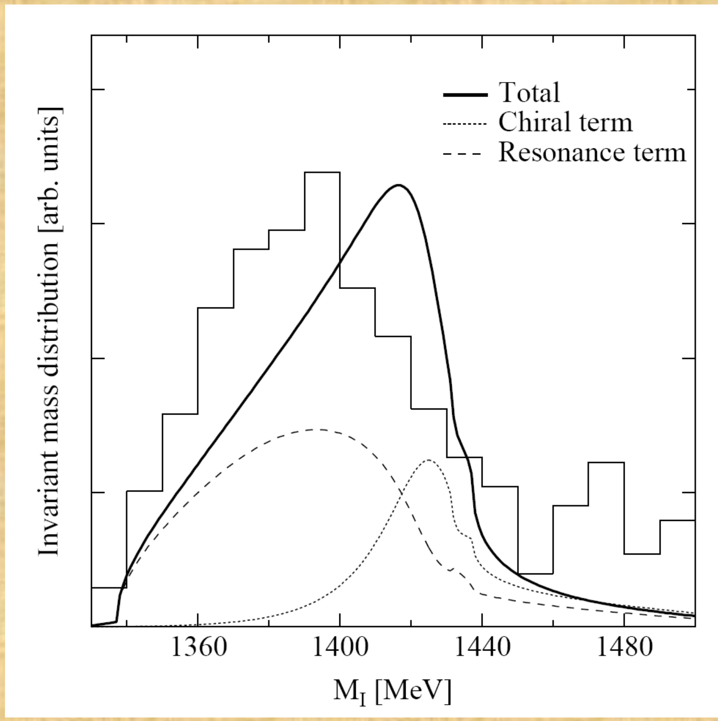
J-PARC proposal E31

IKON/KLOE DAFNE, Curceanu, Zmeskal, arXiv:1104.1926[nucl-ex]

$\pi^- p \to K^0 \pi \Sigma$

Thomas *et al.*, Nucl.Phys.B56, 15(1973)

Theory: Hyodo,Hosaka,Oset,Ramos,
Vicente-Vacas, Phys.Rev.C68, 065203(2003)

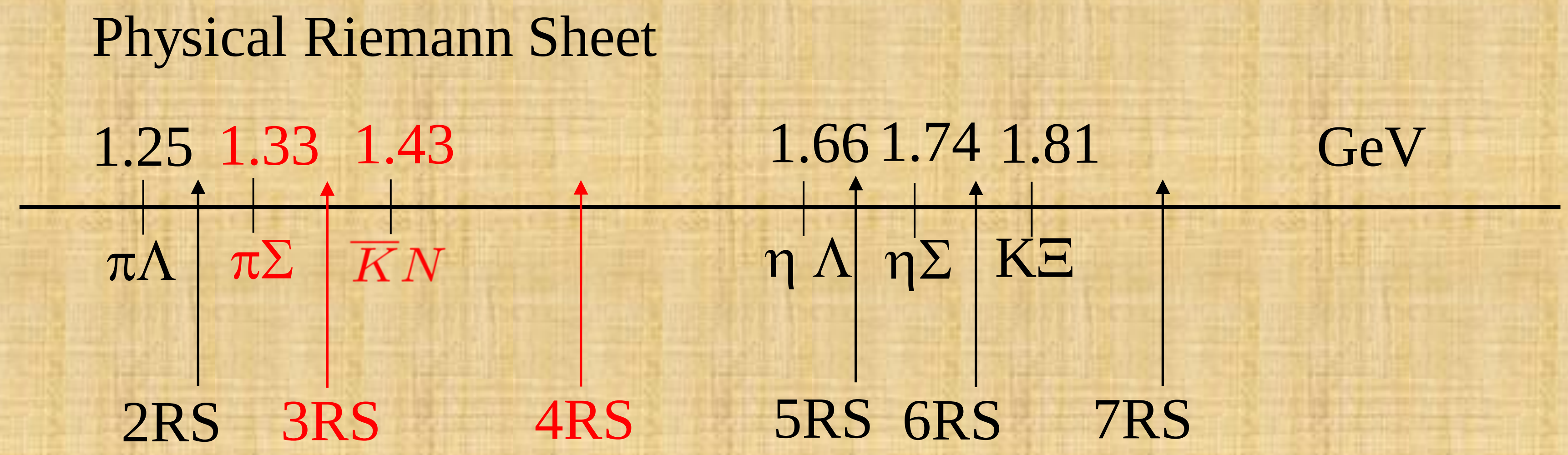


An overall fait description of $\bar{K}N$ scattering is achieved

Intresting project: All these data + NLO ChPT kernels → More precission

5. I=1 Resonances around the $\bar{K}N$ threshold

Predicted in a series of studies in which I was involved:



- Meissner, J.A.O., Phys.Lett.B500,263(2001):

3rd: 1440-i 70 ; 4th: 1420-i 42 MeV

- *I=1 poles around the $\bar{K}N$ threshold were also reported in Prades, Verbeni, JAO Phys.Rev.Lett.95,172502(2005); JAO Eur.Phys.J.A28,63(2006)*

- Z.-H.Guo, J.A.O., Phys.Rev.C87, 035202(2013)

3rd: 1376-i 33 ; 1414-i 12 MeV (Fit II) No poles in Fit I

I=0 signal is larger than the I=1 but the latter is visible through interference effects: $\pi^+ \Sigma^-$ & $\pi^- \Sigma^+$

$$\frac{d\sigma(\pi^+\Sigma^-)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 + \frac{2}{\sqrt{6}}Re(T^{(0)}T^{(1)*})$$

$$\frac{d\sigma(\pi^-\Sigma^+)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 - \frac{2}{\sqrt{6}}Re(T^{(0)}T^{(1)*})$$

$$\frac{d\sigma(\pi^0\Sigma^0)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2$$

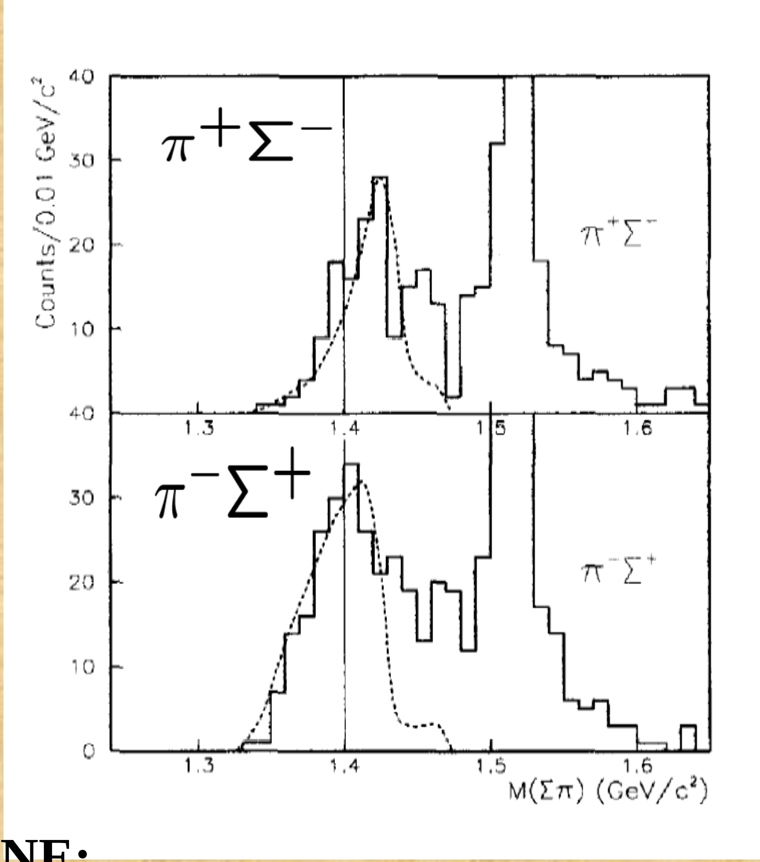
INFLUENCE OF THE I=1 STRENGTH IN πΣ EVENT DISTRIBUTION

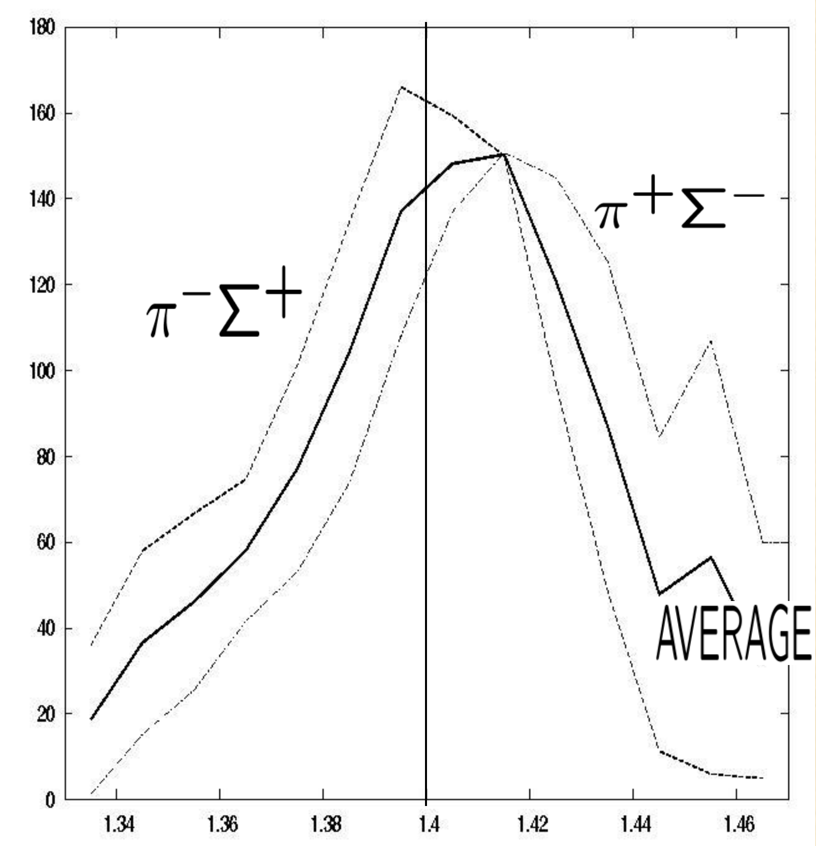
$$\gamma p \rightarrow K^+\Lambda(1405)$$
$$\rightarrow K^+\pi^+\Sigma^-,\ K^+\pi^-\Sigma^+$$

$$K^-p \rightarrow \Sigma^\pm\pi^\mp\pi^-\pi^+$$

J.K. Ahn, NP A721 ('03) 715c

Hemingway,NPB253,742('85)



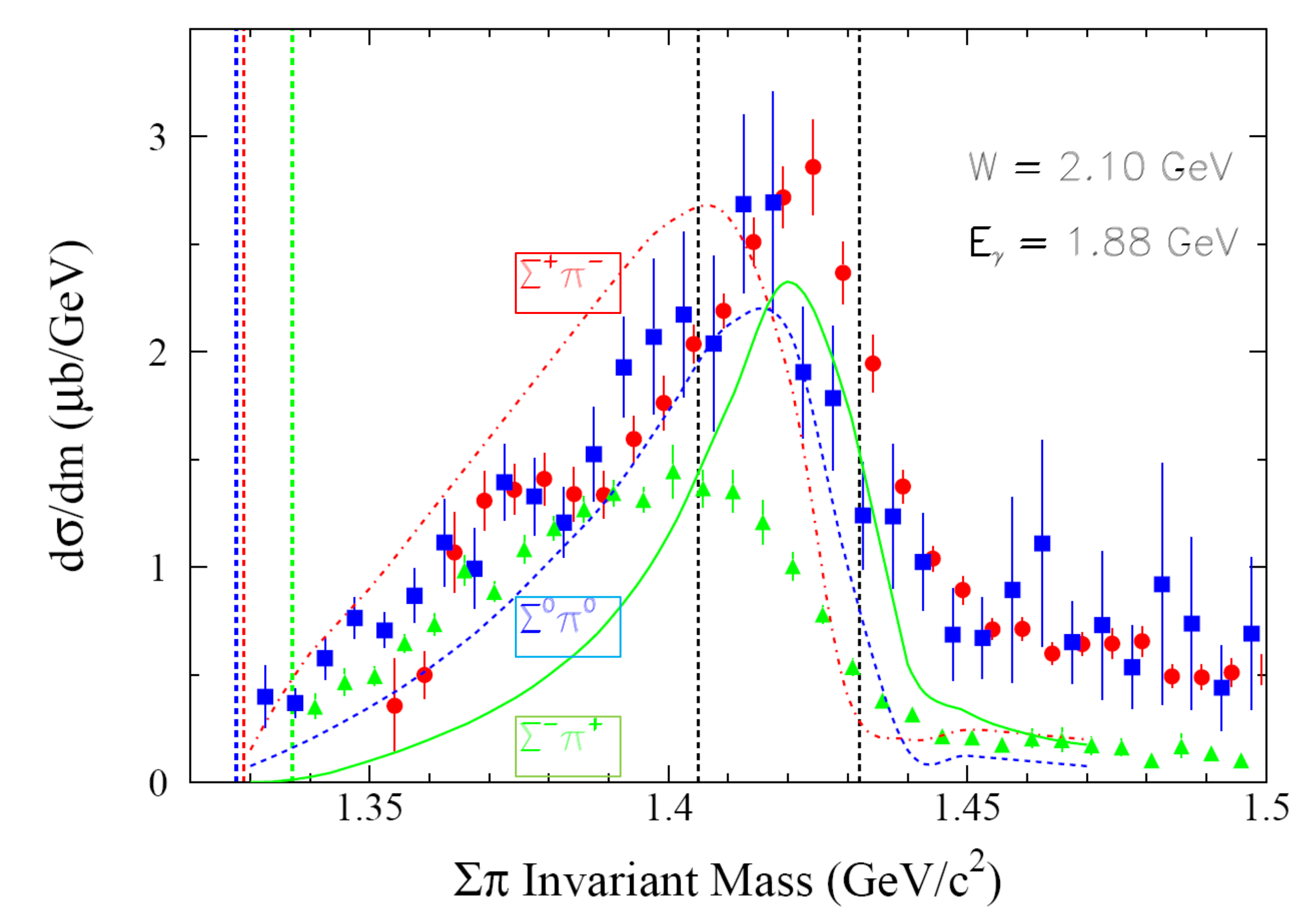


LINE:

Nacher,Oset,Toki,Ramos PL B455 ('99)55

Large I=1 effects have been detected in the photoproduction experiment at CLAS, Moriya *et al.*, *Phys.Rev.C87,035206 (2013)*

$$\gamma p \longrightarrow K^+ \pi \Sigma$$



Line Curves, Nacher et al. Better reproduction for $\pi^0\Sigma^0$ But not for the charged modes with I=1

Also in Niiyama *et al. [LEPS Coll.]*, Phys.Rev.C78,035202(2008)

Moriya *et al.* [CLAS Coll.] Phys.Rev.C87,035206(2013)

Include two I=1 resonances at:

M_1=1413±10 Γ_1=52±10 MeV

M_2=1394±20 Γ_2=149±40 MeV

Z.-H.Guo, J.A.O., Phys.Rev.C87, 035202(2013)

3rd: 1376-i 33 ; 1414-i 12 MeV (Fit II)

Ours are narrower but the masses are quite similar

A detailed theoretical analysis of CLAS data on photoproduction could finally confirm the existence of light I=1 strangeness=-1 ½- resonances

Born terms play an important role in the origin of such I=1 poles, they are neglected by Oset et al.

There is extra strength due to branch cuts around the

$\bar{K}N$ threshold from u-channel exchange of

$$I=1 \quad \begin{cases} \eta\Sigma \to \eta\Sigma \\ \eta\Sigma \to K\Xi \end{cases}$$

COUPLED CHANNEL DYNAMICS IN I=1 IS ESSENTIAL

- Other eviences reported in: Wu, Dulat, Zou Phys.Rev.D80, 017503(2009); Zou, Int.J.Mod.Phys.A21, 5552 (2006) motivated by unquenched quark model.

Born terms play an important role in the origin of such I=1 poles, they are neglected by Oset et al.

There is extra strength due to branch cuts around the $\bar{K}N$ threshold from u-channel exchange of

$$I=1 \quad \begin{cases} \eta\Sigma \rightarrow \eta\Sigma \\ \eta\Sigma \rightarrow K\Xi \end{cases}$$

COUPLED CHANNEL DYNAMICS IN I=1 IS ESSENTIAL

Main Features:
Full LO

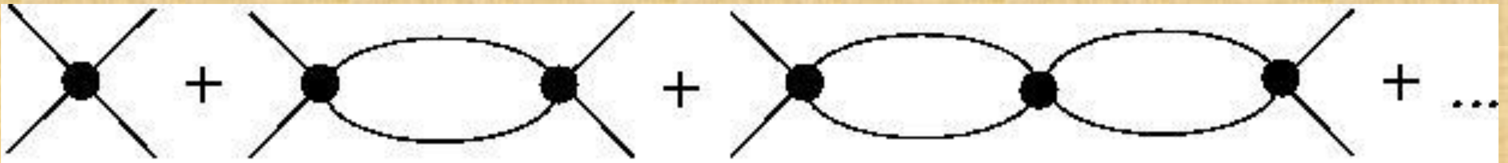
WT+Born terms

⟺

NLO: Reach more precision and accurateness. More data should be fitted

6. I=0,1 Resonances around the $\bar{K}N$ threshold: Dynamically generated resonances

1. The dyamics requires naturalness for the iteration of reducible diagrams (unitarity loops. No bare poles)



This can be done in terms of a subtraction constant

$$a(\mu) \simeq -2\log\left(1+\sqrt{1+\frac{m^2}{\mu^2}}\right) \simeq -2 \qquad \text{for } \mu \simeq 1 \text{ GeV}$$

Meissner,J.A.O., Phys.Lett.B500, 263 (2001)

Hyodo,Jido,Hosaka,Phys.Rev.C78,025023(2008) refer to:
Natural Renormalization Condition

• Strong sensitivity of the pole positions with the unphysical Riemann sheets:

The pole position is the same independently of the unphysical Riemann sheet for resonances with a dominant bare component

Au,Morgan,Pennington, Phys.Rev.D35,1633(1975)

3rd: I=0 (1379.2-i 27.6) ; (1433.7-i 11.0) MeV

4th: I=0 (1346.2-i 3.0) ; (1411.9-i 48.8) MeV

3rd: I=1 (1444.0-i 69.4) ; 4th: (1411.9-i 41.7) MeV

Meissner,J.A.O. PLB500(2001)

In Z.-H.Guo, J.A.O. Phys.Rev.C87,035202(2013) all the I=0 and 1 poles are reported in the 3RS

- Electromagnetic radii/form factors for the $\Lambda(1405)$

Sekihara,Hyodo,Jido, Phys.Lett.B669, 133(2008);
Phys.Rev.C83, 055202(2012)

$$\langle r^2\rangle_M = 1.138 - i\,0.343 \longrightarrow |\langle r^2\rangle_M| \sim 1.2 \text{ fm}^2$$

Which is much larger than the one for the neutron $\langle r^2\rangle \sim 0.66 \text{ fm}^2$

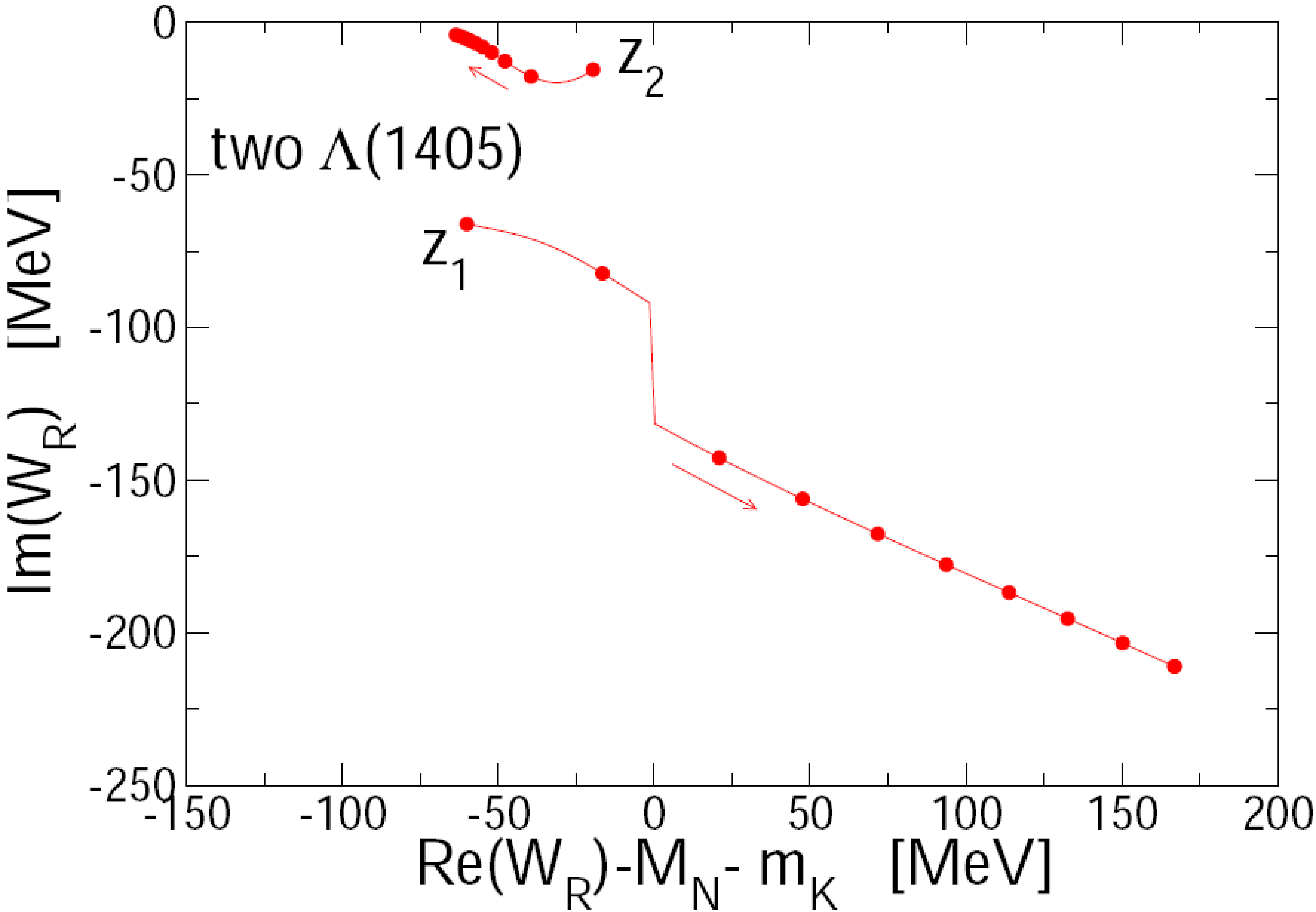
- Scaling behaviour with the Number of Colours of QCD, **Nc**

Hyodo, Jido, Roca, Phys.Rev.D77,056010 (2008);

Roca,Hyodo,Jido, Nucl.Phys.A809,65(2008)

Standard qqq baryons: $M \sim \mathcal{O}(N_c)$ $\Gamma \sim \mathcal{O}(1)$

Goity, Phys.Atom.Nucl.68,624(2005)



z2
z1
two Λ(1405)
Im(W_R) [MeV]
Re(W_R)-M_N- m_K [MeV]
0
-50
-100
-150
-200
-250
-150
-100
-50
0
50
100
150
200

7. S-WAVE, S=-1 MESON-BARYON SCATTERING

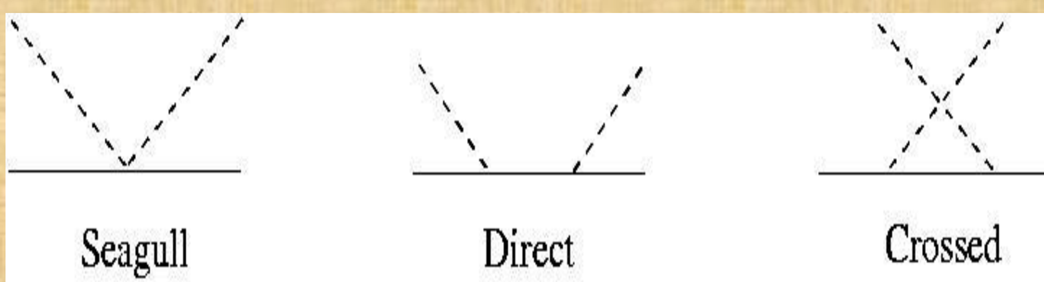
by Z.-H. Guo, J.A.O., Phys.Rev.C87,035202(2013)

$$T = \left[R^{-1} + g(s)\right]^{-1} = \left[I + R \cdot g(s)\right]^{-1} \cdot R(s)$$

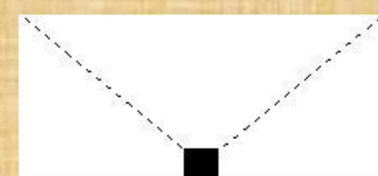
$R = R_1 = T_1$ LEADING ORDER, $\mathcal{O}(p)$

$R = R_1 + R_2 = T_1 + T_2$, NLO, $\mathcal{O}(p^2)$

for $O(p^3)$ and higher $R_n \neq T_n$



$\mathcal{O}(p)$ from $\mathcal{L}_1$



$\mathcal{O}(p^2)$ from $\mathcal{L}_2$

Ten two-body coupled chanenls:

$\pi^0\Lambda(1.25)$ $\pi^0\Sigma^0$ $\pi^-\Sigma^+$ $\pi^+\Sigma^-(1.33)$ K^-p $\bar{K}^0p(1.43)$
$\eta\Lambda(1.66)$ $\eta\Sigma^0(1.74)$ $K^0\Xi^0$ $K^-\Xi^+(1.81)$

S-wave projection of ChPT amplitudes

$$R_{ij} = \frac{1}{4\pi}\int d\Omega\, V_{ij}(W, \Omega, \sigma_i, \sigma_i)$$

Cross sections

$$\sigma(M_iB_i \to M_jB_j) = \frac{1}{16\pi s}\frac{|\vec{p}_j|}{|\vec{p}_i|}|T_{M_iB_i\to M_jB_i}|^2$$

I) DATA INCLUDED IN THE FITS

1) CROSS SECTIONS:

$$K^- p \to K^- p \, , \bar{K}^0 n \, , \pi^+ \Sigma^- \, , \pi^- \Sigma^+ \, , \pi^0 \Sigma^0 \, , \pi^0 \Lambda$$

In the fit we include data from threshold up to $p_{lab} = 0.3$ GeV.

2) Precisely Measured Ratios 5%

$$\gamma = \frac{\sigma(K^- p \to \pi^+ \Sigma^-)}{\sigma(K^- p \to \pi^- \Sigma^+)} = 2.36 \pm 0.12 \, ,$$

$$R_c = \frac{\sigma(K^- p \to \text{charged particles})}{\sigma(K^- p \to \text{all})} = 0.664 \pm 0.033 \, ,$$

$$R_n = \frac{\sigma(K^- p \to \pi^0 \Lambda)}{\sigma(K^- p \to \text{all neutral states})} = 0.189 \pm 0.015 ,$$

3) $\pi\Sigma$ EVENT DISTRIBUTION AROUND THE $\Lambda(1405)$ RESONANCE

4) SIDDHARTA STRONG SHIFT AND WIDTH OF KAONIC HYDROGEN

5) WE ALSO CONSTRAINT OUR FITS BY CALCULATING AT O(p^2) IN PURE BARYON CHPT SEVERAL PION-NUCLEON OBSERVABLES, WHERE CHPT EXPANSION IS MORE RELIABLE:

$$\sigma_{\pi N} = -2m_\pi^2(2b_0 + b_F + b_D) ,$$

$$a_{0+}^{+} = \frac{m_\pi^2}{2\pi f^2}\left(-2b_1 + b_2 + b_3 - \frac{g_A^2}{8m}\right)$$

b_i from the fits

$\sigma_{\pi N}$= 30±20 MeV (*45±8 MeV* from *Gasser,Leutwyler,Sainio PLB253,252 ('91),*

59 ±7 MeV Alarcón,Martin-Camalich,JAO PRD85,051503(R)('12) ; higher order

corrections ±10 MeV ***Gasser, AP254,192('97))***

a_{0+}^{+}=(0 ± 1) $m_\pi^{-1}10^{-2}$ ***Baru et al.,PLB694,473('11)*** (*7.6 ± 3.1) $m_\pi^{-1}10^{-3}$ and expected higher order corrections +$m_\pi\, 10^{-2}$ from unitarity* ***Bernard et al. PLB309,421('93).***

We also include in the fit the baryon masses calculated

at $\mathcal{O}(p^2)$ in ChPT: m_N, m_Λ, m_Σ, m_Ξ 30% error

I) RECENT FURTHER DATA INCLUDED IN THE EXTENDED ANALYSIS *JAO EPJA28,63(2006), not in the most recent studies of Ikeda, Hyodo, Weise nor of Mai, Meissner*

6) $\sigma(K^- p \to \eta\Lambda)$ cross-section

On top of the $\Lambda(1670)$ resonance.

7) $\sigma(K^- p \to \Sigma^0\pi^0\pi^0)$

total cross-section and event distribution.

6) and 7) measured by the Crystall-Ball Collaboration , 2001 and 2004, respectively. Precise experimental data.

8) $\Lambda\pi$ P- and S-wave phase shift difference at Ξ^- mass $\delta_P - \delta_S = (3.2 \pm 5.3)^o$.

E756 Coll. PRL91,031601 ('03)

Two sources of uncerainty, overlooked in other studies, are discussed

1.- Use of a FIT I: common f (pseudoscalar weak decay constant) or FIT II: distinguishing between f_π, f_K, f_η

It gives rise to a rather large uncertainty in the subthreshold extrapolation of the K^-p scattering amplitude

2.- Two χ^2 definitions used in the literature:

Weighted χ^2 per observable:

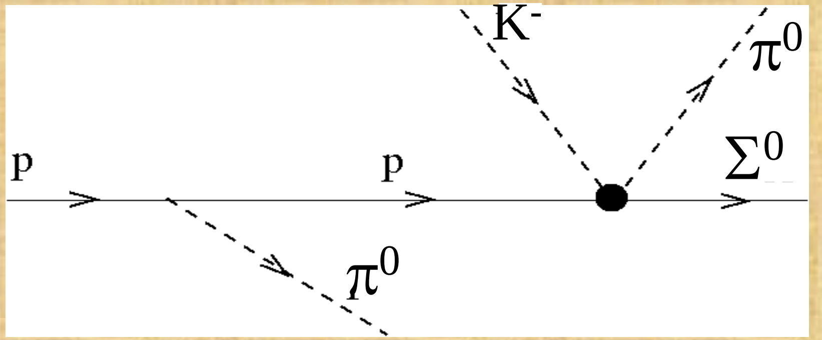
$$\chi^2_{d.o.f} = \frac{\sum_k n_k}{K(\sum_k n_k - n_p)} \sum_{k=1}^{K} \frac{\chi^2_k}{n_k}$$

Common χ^2 definition:

$$\chi^2_{d.o.f} = \frac{1}{\sum_k n_k - n_p} \sum_{k=1}^{K} \chi^2_k$$

Our fits are quite stable under the change of the χ^2 definition

For the calculation of the process $K^- p \rightarrow \pi^0 \pi^0 \Sigma^0$ we take as the production vertex the mechanism:



Magas, Oset, Ramos PRL95,052301('05).

JAO EPJA28,63(2006).

Which dominates due to the almost on-shell character of the intermediate proton.

The solid point means full $K^- p \rightarrow \pi^0 \Sigma^0$ S-wave

Parameters	Fit I $\chi^2/d.o.f = 0.85$	Fit II $\chi^2_{d.o.f} = 0.96$	$\mathcal{O}(p)$ $\chi^2_{d.o.f} = 1.87$
f (MeV)	$124.60^{+1.61}_{-1.04}$	Fixed	$116.05^{+1.89}_{-1.57}$
b_0 (GeV^{-1})	$-0.230^{+0.025}_{-0.022}$	$-0.292^{+0.008}_{-0.007}$	0
b_D (GeV^{-1})	$-0.027^{+0.019}_{-0.020}$	$0.101^{+0.008}_{-0.007}$	0
b_F (GeV^{-1})	$-0.183^{+0.075}_{-0.077}$	$-0.200^{+0.009}_{-0.010}$	0
b_1 (GeV^{-1})	$0.714^{+0.011}_{-0.014}$	$0.522^{+0.005}_{-0.005}$	0
b_2 (GeV^{-1})	$1.331^{+0.036}_{-0.038}$	$1.015^{+0.023}_{-0.023}$	0
b_3 (GeV^{-1})	$-0.696^{+0.050}_{-0.043}$	$-0.306^{+0.015}_{-0.013}$	0
b_4 (GeV^{-1})	$-0.889^{+0.024}_{-0.034}$	$-0.899^{+0.008}_{-0.010}$	0
a_1	$2.587^{+0.962}_{-0.881}$	$4.761^{+0.424}_{-0.331}$	$-6.377^{+1.199}_{-1.050}$
a_2	$-0.830^{+0.090}_{-0.118}$	$-0.447^{+0.144}_{-0.134}$	$-1.772^{+0.193}_{-0.108}$
a_5	$-1.073^{+0.034}_{-0.029}$	$-1.685^{+0.042}_{-0.034}$	$-1.668^{+0.032}_{-0.042}$
a_7	$1.164^{+0.368}_{-0.342}$	$1.401^{+0.178}_{-0.146}$	$-2.215^{+0.170}_{-0.123}$
a_8	$-1.938^{+0.622}_{-1.250}$	$-0.168^{+0.063}_{-0.047}$	$-0.170^{+0.215}_{-0.211}$
a_9	$-2.161^{+0.021}_{-0.021}$	$-2.406^{+0.034}_{-0.022}$	$-2.223^{+0.088}_{-0.040}$
r (GeV^{-1})	$24.28^{+3.80}_{-3.49}$	$18.27^{+2.52}_{-3.44}$	$11.20^{+3.21}_{-13.82}$
r' (GeV^{-1})	$10.85^{+6.59}_{-5.67}$	$17.65^{+8.47}_{-14.06}$	$5.40^{+6.16}_{-18.46}$

All the subtraction constants a_i have natural size O(1)

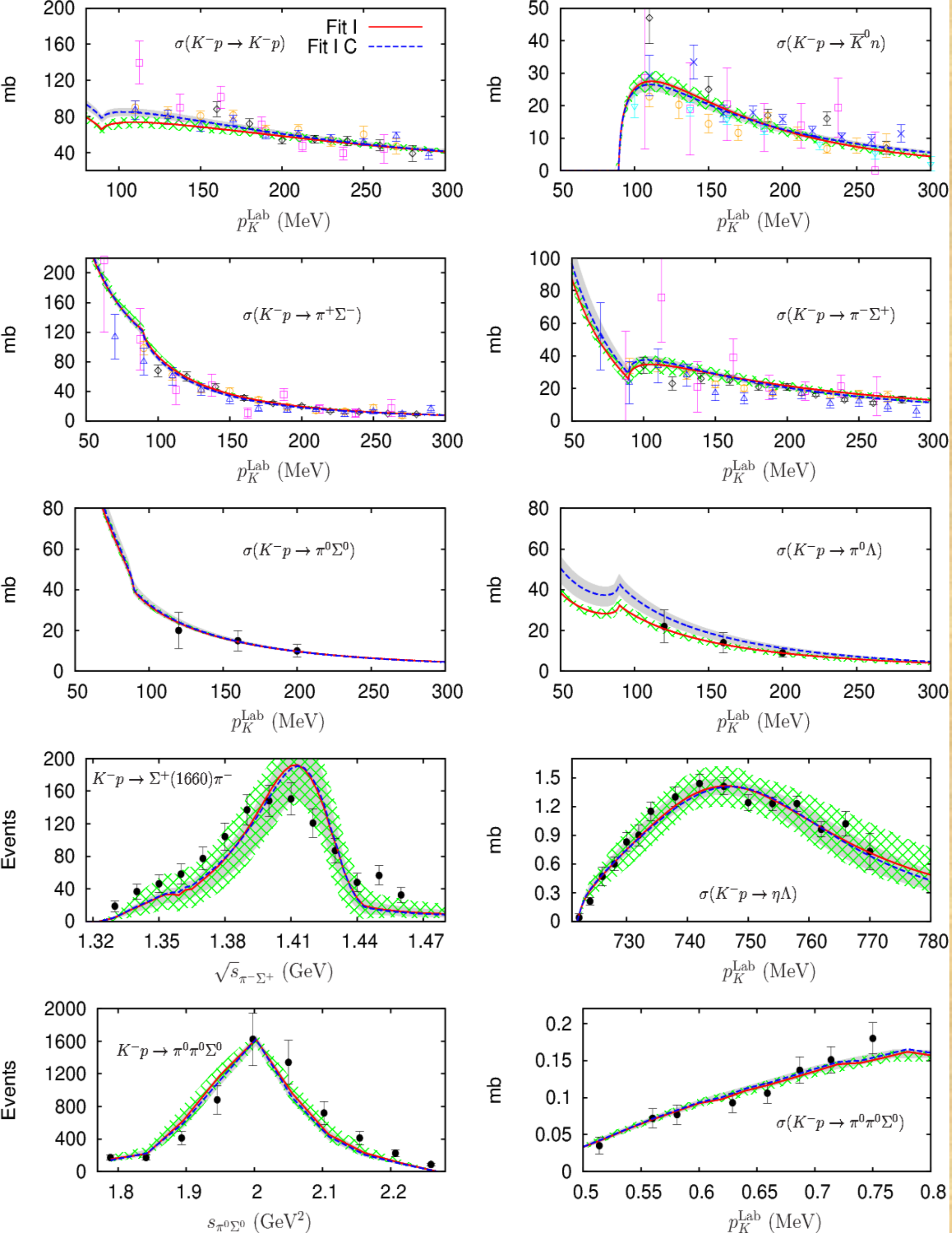
The same applies to the b_i

Fits I and II: Good reproduction of data with $\chi^2_{d.o.f}$ smaller than 1

$\mathcal{O}(p)$ Fit: It also gives rise to quite a good fit.

It fais to reproduce $\sigma(K^- p \to \eta\Lambda)$.

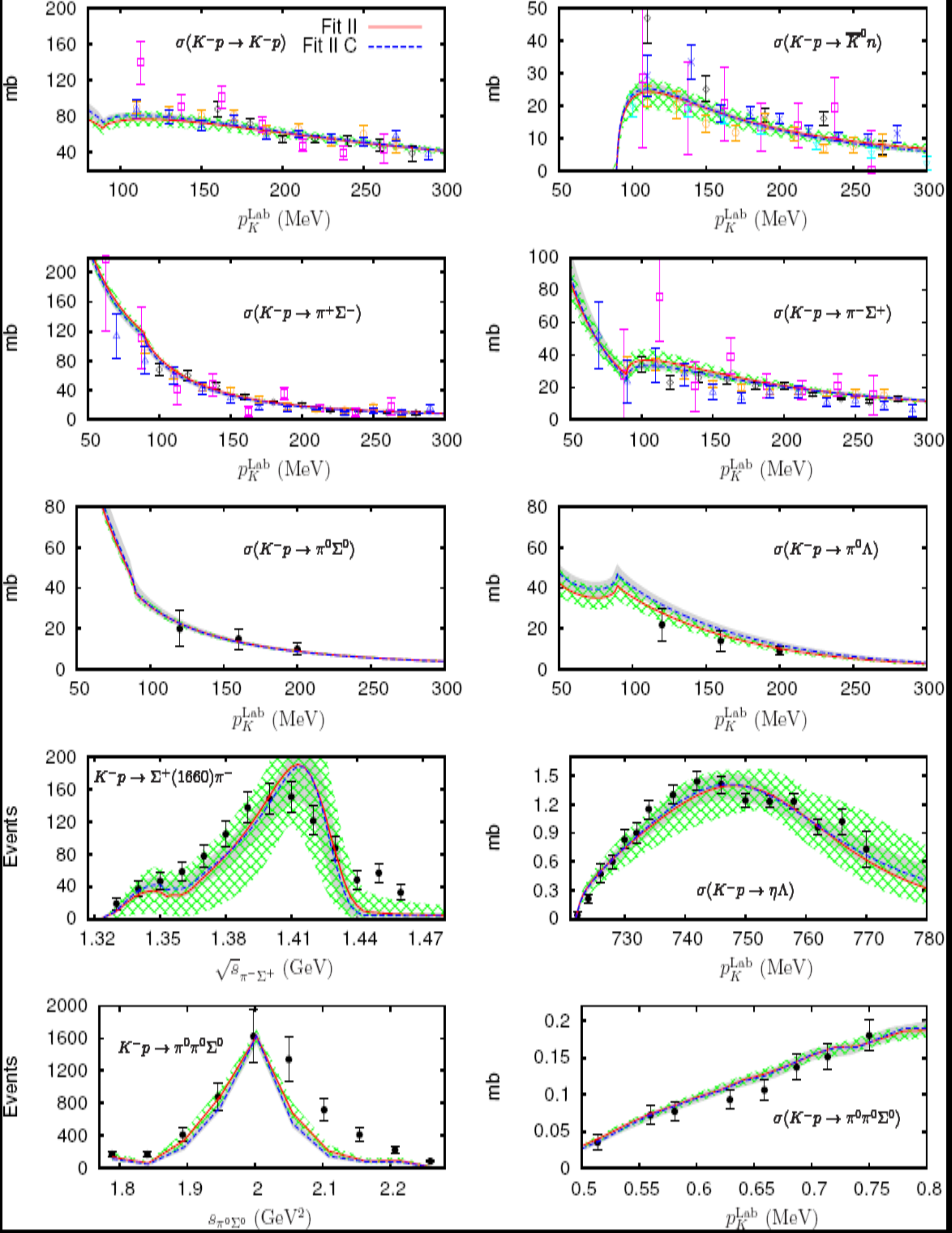
Removing these data $\chi^2_{d.o.f} \simeq 1.23$



FIT I

Solid: χ^2 weighted per observable

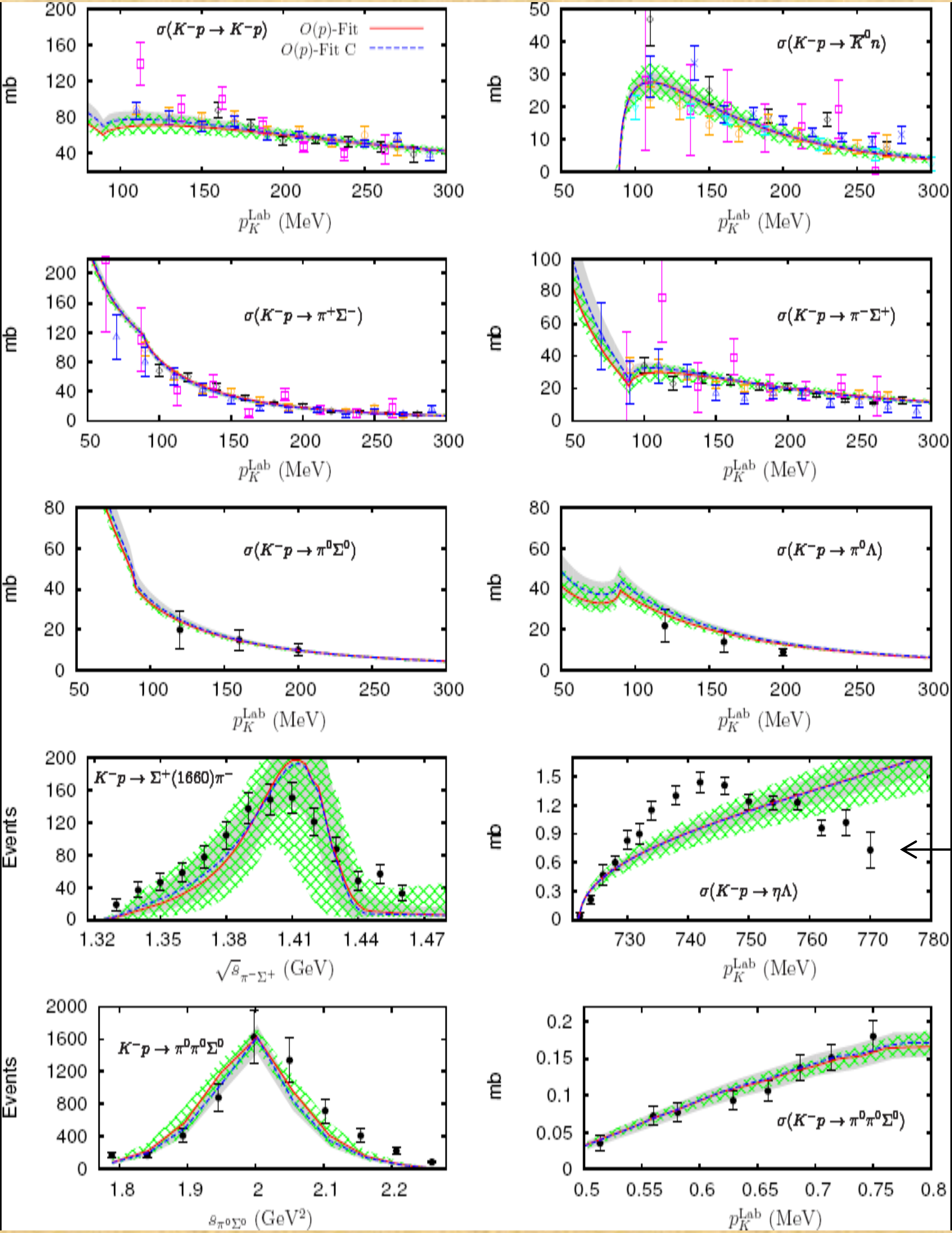
Dashed: χ^2 common definition



FIT II

Solid: χ^2 weighted per observable

Dashed: χ^2 common definition

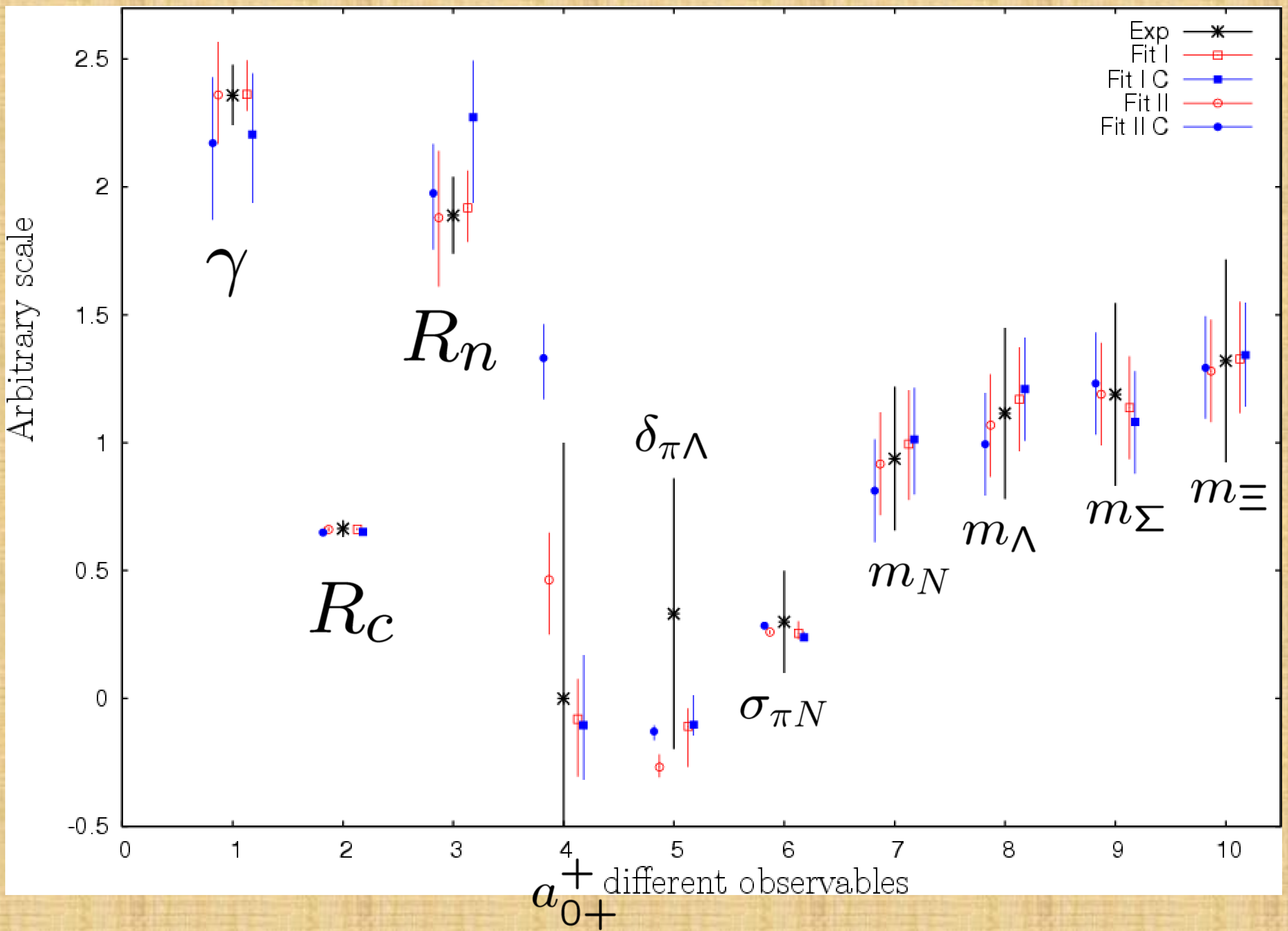


$\mathcal{O}(p)$**-Fit**

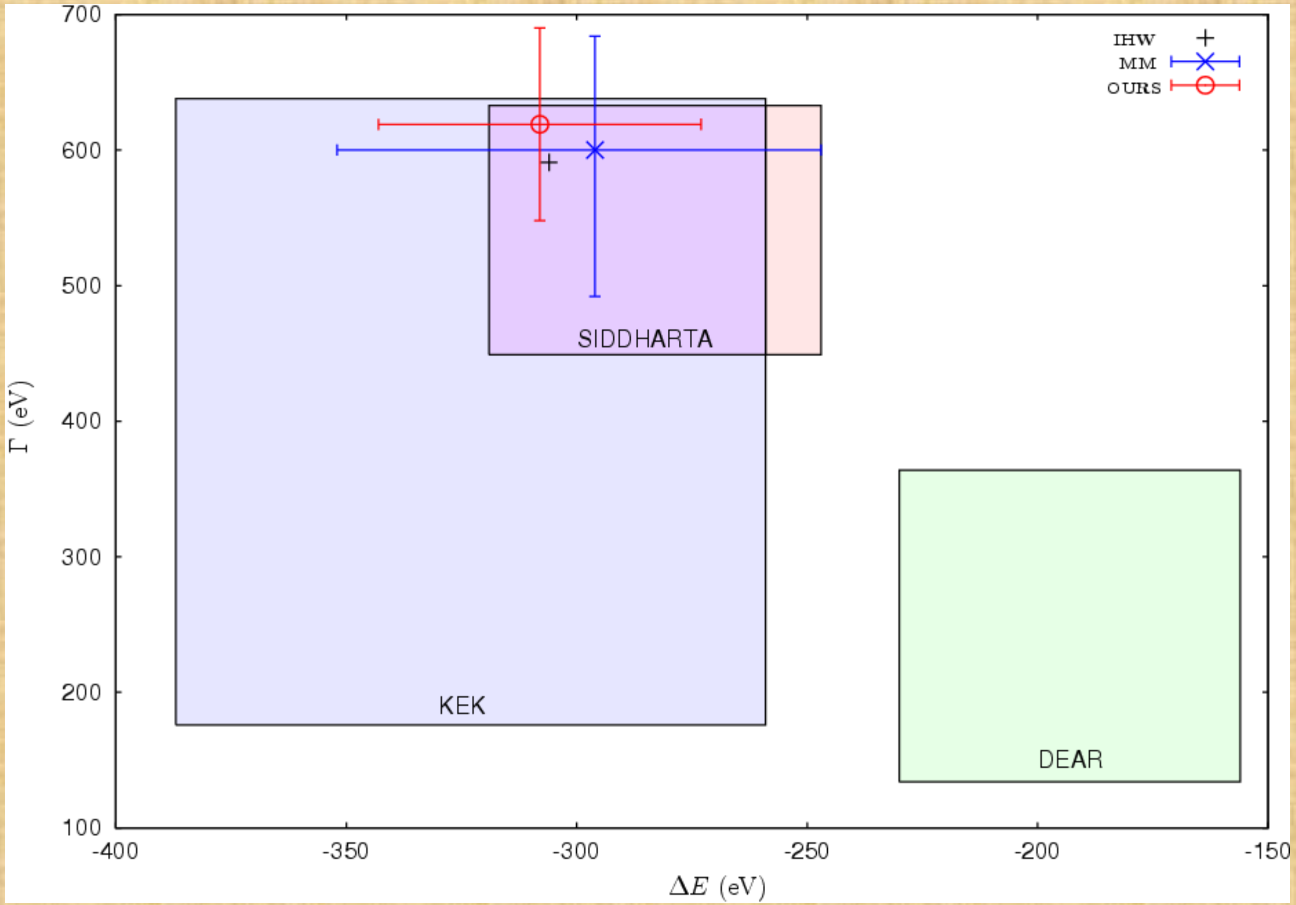
Solid: χ^2 weighted per observable

Dashed: χ^2 common definition

← ***Problem***



Exp
Fit I
Fit I C
Fit II
Fit II C
γ
R_n
R_c
$\delta_{\pi\Lambda}$
$\sigma_{\pi N}$
m_N
m_Λ
m_Σ
m_Ξ
a_{0+}^{+}
Arbitrary scale
different observables



IHW:
Ikeda, Hyodo, Weise (2012)

MM: Mai,Meissner (2013)

Interpret:

Systematic uncertainty: Treatment of f's, definition for χ^2, higher orders,. . .

Spread of central values for fits I and II

We calculate the mean and variance

Statistical uncertainty: largest error bars from common χ^2 def.

K^- p scattering length:

Martin, NPB179,33('81): …………………………………………………… $a_{K^-p} = -0.67 + i\,0.64$ fm

Kaiser,Siegel,Weise, NPA594,325('95): ……………………………… $a_{K^-p} = -0.97 + i\,1.1$ fm

Oset,Ramos, NPA635,99('98): ……………………………………………$a_{K^-p} = -0.99 + i\,0.97$ fm

Meissner,JAO PLB500,263('01): …………………………………………$a_{K^-p} = -0.75 + i\,1.2$ fm

Borasoy,Nissler,Weise,PRL94,213401('05), EPJA25,79('05):………$a_{K^-p} = -0.51 + i\,0.82$ fm

Prades,Verbeni,JAO PRL95,172502('05): ……………………………A_4^+: $a_{K^-p} = -0.51 + i\,0.42$ fm

B_4^+: $-1.01 + i\,0.80$ fm

JAO, EPJA28,63('06) :……………………………………………………A-fit: $a_{K^-p} = -0.5 + i\,0.41$ fm

B-fit: $a_{K^-p} = -1.0 + i\,1.0$ fm

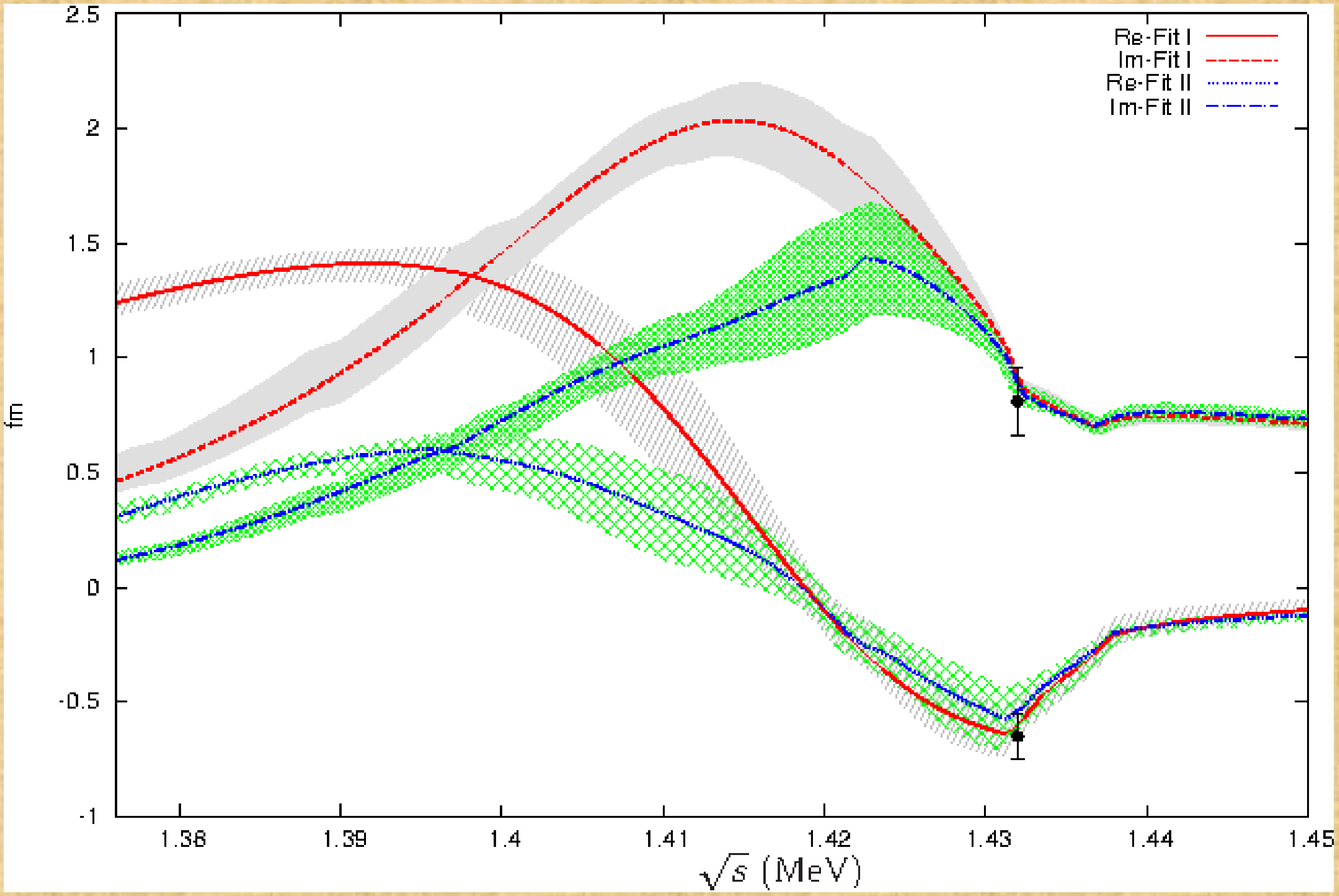
Ikeda, Hyodo, Weise NPA881,98(2012)……………………………………… $a_{K^-p} = -0.70 + i\,0.89$ fm

$$a_{K^-n} = 0.57^{+0.04}_{-0.21} + i\,0.72^{+0.26}_{-0.41} \quad \text{fm}$$

This work:

$$a_{K^-p} = (-0.74 \pm 0.08) + i\,(0.93 \pm 0.09) \quad \text{fm}$$
$$a_{K^-n} = (+0.31 \pm 0.06) + i\,(0.50 \pm 0.05) \quad \text{fm}$$

$K^- p$ Subthreshold Extrapolation:



The uncertainty due to the change of fit is much larger than the statistical error band. An $O(p^3)$ calculation is called for.

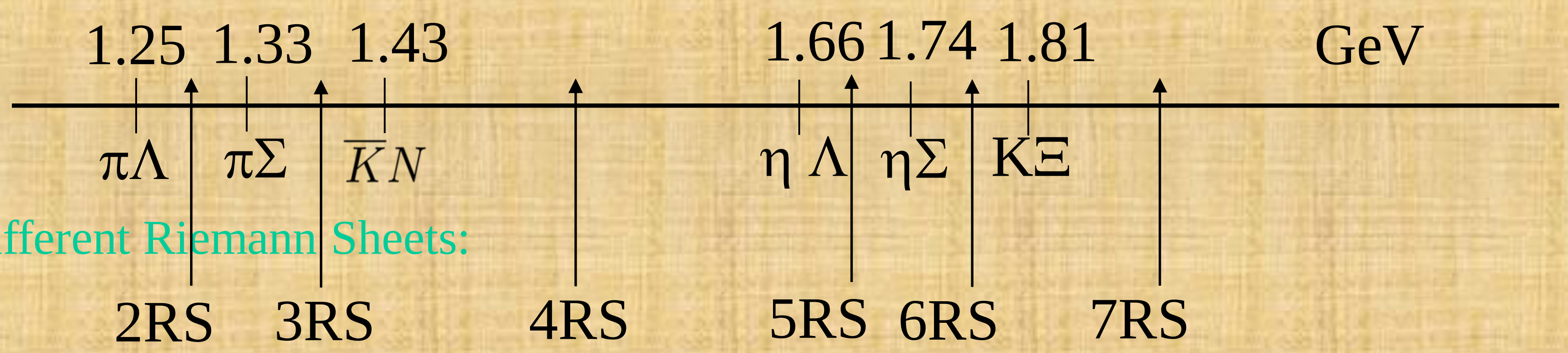
POLE CONTENT

$$T_{ij} = -\lim_{s \to s_R} \frac{\boxed{\gamma_i \gamma_j}}{s - \boxed{s_R}}$$

Residues

Pole Position $\simeq (M_R - i\,\Gamma_R/2)^2$

Physical Riemann Shet



Pole	$\|\beta_{\pi\Lambda}\|$	$\|\beta_{\pi\Sigma}\|_0$	$\|\beta_{\pi\Sigma}\|_1$	$\|\beta_{\pi\Sigma}\|_2$	$\|\beta_{\bar{K}N}\|_0$	$\|\beta_{\bar{K}N}\|_1$	$\|\beta_{\eta\Lambda}\|$	$\|\beta_{\eta\Sigma}\|$	$\|\beta_{K\Xi}\|_0$	$\|\beta_{K\Xi}\|_1$
$\Lambda(1405)$										
$1388^{+9}_{-9} - i\,114^{+24}_{-25}$ (3RS)	$0.0^{+0.0}_{-0.0}$	$8.2^{+0.8}_{-0.5}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$6.1^{+1.1}_{-0.6}$	$0.1^{+0.0}_{-0.0}$	$2.2^{+0.6}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$1.9^{+0.2}_{-0.1}$	$0.1^{+0.0}_{-0.0}$
$1421^{+3}_{-2} - i\,19^{+8}_{-5}$ (3RS)	$0.2^{+0.1}_{-0.1}$	$4.2^{+1.5}_{-0.9}$	$0.2^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$6.2^{+1.2}_{-0.5}$	$0.3^{+0.1}_{-0.1}$	$2.8^{+0.5}_{-0.3}$	$0.4^{+0.2}_{-0.1}$	$0.7^{+0.4}_{-0.3}$	$0.4^{+0.1}_{-0.1}$
$\Lambda(1670)$										
$1676^{+5}_{-3} - i\,7^{+5}_{-3}$ (4RS)	$0.0^{+0.0}_{-0.0}$	$0.9^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.5^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.6^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.0^{+0.1}_{-0.1}$	$0.1^{+0.0}_{-0.0}$
$1677^{+5}_{-3} - i\,11^{+5}_{-3}$ (5RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.1}_{-0.1}$	$0.1^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.5^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$
$1677^{+5}_{-3} - i\,11^{+5}_{-3}$ (6RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.4}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$1.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$
$\Sigma\ I = 1$										
$1376^{+3}_{-3} - i\,33^{+5}_{-5}$ (3RS)	$2.0^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.1^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.1^{+0.0}_{-0.0}$	$2.1^{+0.5}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$4.0^{+0.5}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$6.3^{+0.2}_{-0.2}$
$1414^{+2}_{-3} - i\,12^{+1}_{-2}$ (3RS)	$1.9^{+0.1}_{-0.1}$	$0.3^{+0.1}_{-0.1}$	$1.0^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.4^{+0.2}_{-0.1}$	$2.5^{+0.3}_{-0.4}$	$0.2^{+0.1}_{-0.1}$	$3.3^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$3.3^{+0.3}_{-0.3}$
$1686^{+18}_{-18} - i\,101^{+9}_{-8}$ (5RS)	$0.2^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$3.5^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.9^{+0.3}_{-0.3}$	$0.1^{+0.0}_{-0.0}$	$10.9^{+0.2}_{-0.2}$
$1741^{+12}_{-13} - i\,94^{+3}_{-3}$ (6RS)	$1.1^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$2.3^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$2.8^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.7^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$7.9^{+0.3}_{-0.2}$

1. *Two pole structure of Λ(1405)*

Fit II

Pole	$\lvert\beta_{\pi\Lambda}\rvert$	$\lvert\beta_{\pi\Sigma}\rvert_0$	$\lvert\beta_{\pi\Sigma}\rvert_1$	$\lvert\beta_{\pi\Sigma}\rvert_2$	$\lvert\beta_{\bar{K}N}\rvert_0$	$\lvert\beta_{\bar{K}N}\rvert_1$	$\lvert\beta_{\eta\Lambda}\rvert$	$\lvert\beta_{\eta\Sigma}\rvert$	$\lvert\beta_{K\Xi}\rvert_0$	$\lvert\beta_{K\Xi}\rvert_1$
$\Lambda(1405)$										
$1388^{+9}_{-9} - i\,114^{+24}_{-25}$ (3RS)	$0.0^{+0.0}_{-0.0}$	$8.2^{+0.8}_{-0.5}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$6.1^{+1.1}_{-0.6}$	$0.1^{+0.0}_{-0.0}$	$2.2^{+0.6}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$1.9^{+0.2}_{-0.1}$	$0.1^{+0.0}_{-0.0}$
$1421^{+3}_{-2} - i\,19^{+8}_{-5}$ (3RS)	$0.2^{+0.1}_{-0.1}$	$4.2^{+1.5}_{-0.9}$	$0.2^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$6.2^{+1.2}_{-0.5}$	$0.3^{+0.1}_{-0.1}$	$2.8^{+0.5}_{-0.3}$	$0.4^{+0.2}_{-0.1}$	$0.7^{+0.4}_{-0.3}$	$0.4^{+0.1}_{-0.1}$
$\Lambda(1670)$										
$1676^{+5}_{-3} - i\,7^{+5}_{-3}$ (4RS)	$0.0^{+0.0}_{-0.0}$	$0.9^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.5^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.6^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.0^{+0.1}_{-0.1}$	$0.1^{+0.0}_{-0.0}$
$1677^{+5}_{-3} - i\,11^{+5}_{-3}$ (5RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.1}_{-0.1}$	$0.1^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.5^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$
$1677^{+5}_{-3} - i\,11^{+5}_{-3}$ (6RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.4}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$1.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$
$\Sigma\ I = 1$										
$1376^{+3}_{-3} - i\,33^{+5}_{-5}$ (3RS)	$2.0^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.1^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.1^{+0.0}_{-0.0}$	$2.1^{+0.5}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$4.0^{+0.5}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$6.3^{+0.2}_{-0.2}$
$1414^{+2}_{-3} - i\,12^{+1}_{-2}$ (3RS)	$1.9^{+0.1}_{-0.1}$	$0.3^{+0.1}_{-0.1}$	$1.0^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.4^{+0.2}_{-0.1}$	$2.5^{+0.3}_{-0.4}$	$0.2^{+0.1}_{-0.1}$	$3.3^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$3.3^{+0.3}_{-0.3}$
$1686^{+18}_{-18} - i\,101^{+9}_{-8}$ (5RS)	$0.2^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$3.5^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.9^{+0.3}_{-0.3}$	$0.1^{+0.0}_{-0.0}$	$10.9^{+0.2}_{-0.2}$
$1741^{+12}_{-13} - i\,94^{+3}_{-3}$ (6RS)	$1.1^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$2.3^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$2.8^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.7^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$7.9^{+0.3}_{-0.2}$

1. *Two pole structure of Λ(1405)*
2. *We also obtain the Λ(1670) in good agreement with properties in PDG*

Pole	$\lvert\beta_{\pi\Lambda}\rvert$	$\lvert\beta_{\pi\Sigma}\rvert_0$	$\lvert\beta_{\pi\Sigma}\rvert_1$	$\lvert\beta_{\pi\Sigma}\rvert_2$	$\lvert\beta_{\bar{K}N}\rvert_0$	$\lvert\beta_{\bar{K}N}\rvert_1$	$\lvert\beta_{\eta\Lambda}\rvert$	$\lvert\beta_{\eta\Sigma}\rvert$	$\lvert\beta_{K\Xi}\rvert_0$	$\lvert\beta_{K\Xi}\rvert_1$
$\Lambda(1405)$										
$1388^{+9}_{-9} - i\,114^{+24}_{-25}$ (3RS)	$0.0^{+0.0}_{-0.0}$	$8.2^{+0.8}_{-0.5}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$6.1^{+1.1}_{-0.6}$	$0.1^{+0.0}_{-0.0}$	$2.2^{+0.6}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$1.9^{+0.2}_{-0.1}$	$0.1^{+0.0}_{-0.0}$
$1421^{+3}_{-2} - i\,19^{+8}_{-5}$ (3RS)	$0.2^{+0.1}_{-0.1}$	$4.2^{+1.5}_{-0.9}$	$0.2^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$6.2^{+1.2}_{-0.5}$	$0.3^{+0.1}_{-0.1}$	$2.8^{+0.5}_{-0.3}$	$0.4^{+0.2}_{-0.1}$	$0.7^{+0.4}_{-0.3}$	$0.4^{+0.1}_{-0.1}$
$\Lambda(1670)$										
$1676^{+5}_{-3} - i\,7^{+5}_{-3}$ (4RS)	$0.0^{+0.0}_{-0.0}$	$0.9^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.5^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.6^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.0^{+0.1}_{-0.1}$	$0.1^{+0.0}_{-0.0}$
$1677^{+5}_{-3} - i\,11^{+5}_{-3}$ (5RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.1}_{-0.1}$	$0.1^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.5^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$
$1677^{+5}_{-3} - i\,11^{+5}_{-3}$ (6RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.4}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$1.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$10.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$
$\Sigma\ I=1$										
$1376^{+3}_{-3} - i\,33^{+5}_{-5}$ (3RS)	$2.0^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.1^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.1^{+0.0}_{-0.0}$	$2.1^{+0.5}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$4.0^{+0.5}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$6.3^{+0.2}_{-0.2}$
$1414^{+2}_{-3} - i\,12^{+1}_{-2}$ (3RS)	$1.9^{+0.1}_{-0.1}$	$0.3^{+0.1}_{-0.1}$	$1.0^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.4^{+0.2}_{-0.1}$	$2.5^{+0.3}_{-0.4}$	$0.2^{+0.1}_{-0.1}$	$3.3^{+0.4}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$3.3^{+0.3}_{-0.3}$
$1686^{+18}_{-18} - i\,101^{+9}_{-8}$ (5RS)	$0.2^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$3.5^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.9^{+0.3}_{-0.3}$	$0.1^{+0.0}_{-0.0}$	$10.9^{+0.2}_{-0.2}$
$1741^{+12}_{-13} - i\,94^{+3}_{-3}$ (6RS)	$1.1^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$2.3^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$2.8^{+0.1}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$3.7^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$7.9^{+0.3}_{-0.2}$

1. *Two pole structure of Λ(1405)*
2. *We also obtain the Λ(1670) in good agreement with properties in PDG*
3. *I=1 Poles around the KN threshold. Strong coupling to $\bar{K}$N.*

   Σ(1620)

   Σ(1750)

FIT I

Pole	$\lvert\beta_{\pi\Lambda}\rvert$	$\lvert\beta_{\pi\Sigma}\rvert_0$	$\lvert\beta_{\pi\Sigma}\rvert_1$	$\lvert\beta_{\pi\Sigma}\rvert_2$	$\lvert\beta_{\bar{K}N}\rvert_0$	$\lvert\beta_{\bar{K}N}\rvert_1$	$\lvert\beta_{\eta\Lambda}\rvert$	$\lvert\beta_{\eta\Sigma}\rvert$	$\lvert\beta_{K\Xi}\rvert_0$	$\lvert\beta_{K\Xi}\rvert_1$
$\Lambda(1405)$										
$1436^{+11}_{-9} - i\,126^{+17}_{-23}$ (3RS)	$0.0^{+0.0}_{-0.0}$	$8.8^{+0.6}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$7.7^{+0.9}_{-0.7}$	$0.0^{+0.0}_{-0.0}$	$1.4^{+0.3}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$2.1^{+0.8}_{-0.3}$	$0.0^{+0.0}_{-0.0}$
$1417^{+2}_{-4} - i\,24^{+5}_{-3}$ (3RS)	$0.1^{+0.0}_{-0.0}$	$5.0^{+1.0}_{-0.6}$	$0.1^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$7.7^{+0.8}_{-0.4}$	$0.1^{+0.0}_{-0.0}$	$1.4^{+0.4}_{-0.2}$	$0.1^{+0.0}_{-0.0}$	$1.5^{+0.5}_{-0.4}$	$0.1^{+0.0}_{-0.0}$
$\Lambda(1670)$										
$1674^{+2}_{-2} - i\,8^{+2}_{-3}$ (4RS)	$0.0^{+0.0}_{-0.0}$	$0.8^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.5^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$1.5^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$10.8^{+0.2}_{-0.2}$	$0.1^{+0.0}_{-0.0}$
$1674^{+3}_{-2} - i\,11^{+4}_{-3}$ (5RS)	$0.0^{+0.0}_{-0.0}$	$0.9^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$1.7^{+0.3}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$11.1^{+0.3}_{-0.2}$	$0.1^{+0.0}_{-0.0}$
$1673^{+3}_{-2} - i\,11^{+4}_{-3}$ (6RS)	$0.0^{+0.0}_{-0.0}$	$0.9^{+0.2}_{-0.1}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$1.6^{+0.2}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$1.7^{+0.3}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$11.1^{+0.3}_{-0.2}$	$0.1^{+0.0}_{-0.0}$
$\Sigma\ I = 1$										
$1646^{+21}_{-55} - i\,160^{+58}_{-30}$ (4RS)	$3.1^{+1.3}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$3.0^{+0.1}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$2.9^{+0.3}_{-0.2}$	$0.0^{+0.0}_{-0.0}$	$7.9^{+0.6}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$6.4^{+0.9}_{-1.2}$
$1878^{+45}_{-59} - i\,169^{+21}_{-34}$ (6RS)	$1.0^{+0.2}_{-0.4}$	$0.0^{+0.0}_{-0.0}$	$5.8^{+0.9}_{-0.6}$	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$3.7^{+0.3}_{-0.3}$	$0.0^{+0.0}_{-0.0}$	$3.9^{+1.1}_{-1.0}$	$0.1^{+0.0}_{-0.0}$	$16.1^{+2.4}_{-1.6}$

No I=1 resonances around the $\bar{K}N$ threshold

The broader $\Lambda(1405)$ is above the $\bar{K}N$ threshold

8. CONCLUSIONS

1. Rich pole structure around the $\pi\Sigma$ and $\bar{K}N$ thresholds
2. Two-pole nature of the $\Lambda(1405)$
3. Uncertainty in the broader pole $\rightarrow$ uncertainties in the subthreshold extrapolation of $K^{-}p$ scattering
4. $\pi\Sigma$ scattering information around its threshold is mostly welcome to fix broader I=0 pole
5. Possible confirmation of I=1 resonances by CLAS photoproduction data
6. Thorough study of all $\pi^{+}\Sigma^{-}$, $\pi^{-}\Sigma^{+}$, $\pi^{0}\Sigma^{0}$ production data (Oset et al. $\rightarrow$ go beyond with more accurateness)
7. All these resonances are dynamically generated

Guo,J.A.O., Phys.Rev.C87,035202(20013) study:

1. A UCHPT study of meson-baryon dynamics with strangeness=-1 in S-wave up to NNLO or $O(p^2)$
2. We reproduce: scattering data, including results on kaonic hydrogen given by the SIDDHARTA Collaboration and from the Crystall Ball Collaboration.
3. Scattering data and kaonic hydrogen measurement by SIDDHARTA are consistent.
4. We study two sources of ambiguity:

   1) Use of a common pseudoscalar weak decay constant or distinguishing between f_π, f_K and f_η.

   2) Two definitions of χ^2

   1) increases significantly the uncertainty in the subthreshold extrapolation of the K^-p scattering amplitude

7) We confirm the two pole structure of the Λ(1405).

We also reproduce the Λ(1670)

In Fit II we also have poles around the KbarN threshold in I=1, also advocated in interpreting photoproduction data Moriya [CLAS Coll.]Phys.Rev.C87,035206(2013)

Σ(1620), Σ(1750)

8) Scattering lengths

$$a_{K^-p} = (-0.74 \pm 0.08) + i\,(0.93 \pm 0.09) \quad \text{fm}$$
$$a_{K^-n} = (+0.31 \pm 0.06) + i\,(0.50 \pm 0.05) \quad \text{fm}$$

9) To improve the knowledge of the subthreshold extrapolation of the $K^- p$ amplitude requires an $O(p^3)$ calculation.

Then the kernel will be sensitive to the change in the f’s