IKP, 22nd May 2003

Chiral Dynamics of the Two Λ(1405) States

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- **Introduction: The Chiral Unitary Approach**
- **Chiral Effective Field Theories**
- **Formalism**
- **Meson-Meson**
- **Meson-Baryon**

The Chiral Unitary Approach

1. A systematic scheme able to be applied when the interactions between the hadrons are not perturbative (even at low energies).
   - S-wave meson-meson scattering: I=0 (σ(500), f_0(980)), I=1 (a_0(980)), I=1/2 (κ(700)). Related by SU(3) symmetry.
   - S-wave Strangeness S=-1 meson-baryon interactions. I=0 Λ(1405) and other resonances.
   - 1S0, 3S1 S-wave Nucleon-Nucleon interactions.
2. Then one can study:
   - Strongly interacting coupled channels.
   - Large unitarity loops.
   - Resonances.
3. This allows as well to use the Chiral Lagrangians for higher energies.
4. The same scheme can be applied to productions mechanisms. Some examples:
   - Photoproduction: $\gamma\gamma \rightarrow \pi^0\pi^0, \pi^+\pi^-, \pi^0\eta, K^+K^-, K^0\overline{K}^0$
   - Decays: $J/\Psi \rightarrow \phi(\omega)\pi\pi, K\overline{K}$

     $\phi(1020) \rightarrow \gamma K^0\overline{K}^0, \gamma\pi^0\pi^0, \gamma\pi^0\eta$

5. Connection with perturbative QCD, $\alpha_S\,(4\ \text{GeV}^2)/\pi \approx 0.1$. (OPE). E.g. providing phenomenological spectral functions for QCD Sum Rules, Imposing high energy QCD constraints to restrict free parameters, etc...
6. It is based in performing a chiral expansion, not of the amplitude itself as in Chiral Perturbation Theory (CHPT), or alike EFT´s (HBCHPT, KSW, CHPT+Resonances), but of a kernel with a softer expansion.

Chiral Perturbation Theory

Weinberg, Physica A96,32 (79); Gasser, Leutwyler, Ann.Phys. (NY) 158,142 (84)

QCD Lagrangian		**Hilbert Space** **Physical States**
u, d, s massless quarks $\mathbf{SU(3)_L \otimes SU(3)_R}$	**Spontaneous Chiral Symmetry Breaking** $\longrightarrow$	 $\mathbf{SU(3)_V}$

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$SU(3)_L \otimes SU(3)_R$ ⟶ $SU(3)_V$

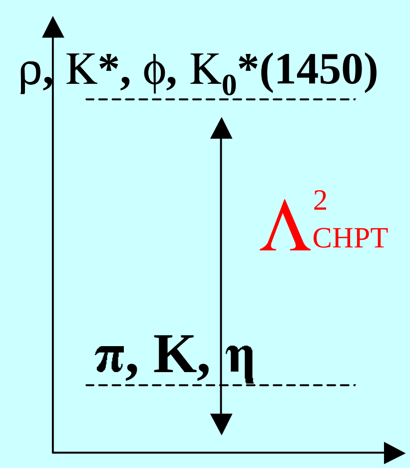
Spontaneous Chiral Symmetry Breaking

Goldstone Theorem

Octet of massles pseudoscalars

π, K, η

Energy gap



$m_q \neq 0$. Explicit breaking of Chiral Symmetry

Non-zero masses

$m_P^2 \propto m_q$

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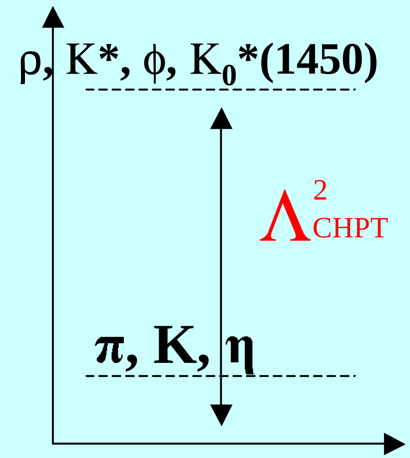


$m_q \neq 0$. Explicit breaking of Chiral Symmetry — **Non-zero masses $m_P^2 \propto m_q$**

Perturbative expansion in powers of the external four-momenta of the pseudo-Goldstone bosons over Λ^2_{CHPT}

$$L = L_2 + L_4 + \dots \qquad \frac{L_4}{L_2} = O\left(\frac{p^2}{\Lambda^2_{CHPT}}\right)$$

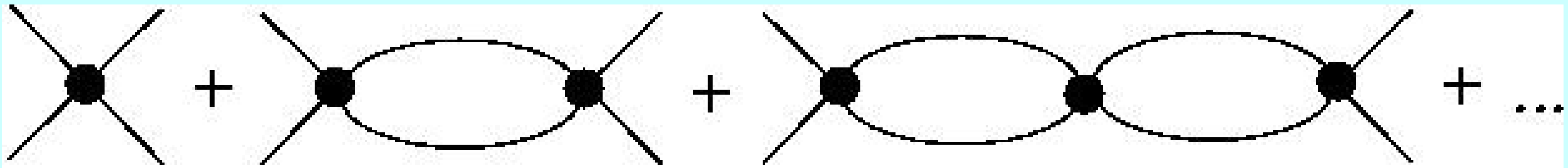
$$\Lambda_{CHPT} \approx 1 \text{ GeV} \approx M_\rho \approx 4\pi f_\pi \approx 1 \text{ GeV}$$

- When massive fields are present (Nucleons, Deltas, etc) the heavy masses (e.g. Nucleon mass) are removed and the expansion typically involves the quark masses and the small three-momenta involved at low kinetic energies.
- New scales or numerical enhancements can appear that makes definitively smaller the overall scale Λ, e.g:
  - Scalar Sector (S-waves) of meson-meson interactions with I=0,1,1/2 the unitarity loops are enhanced by numerical factors.

P-WAVE S-WAVE

$$\frac{s-4m_\pi^2}{6f^2} \rightarrow \frac{s-m_\pi^2}{f^2}$$

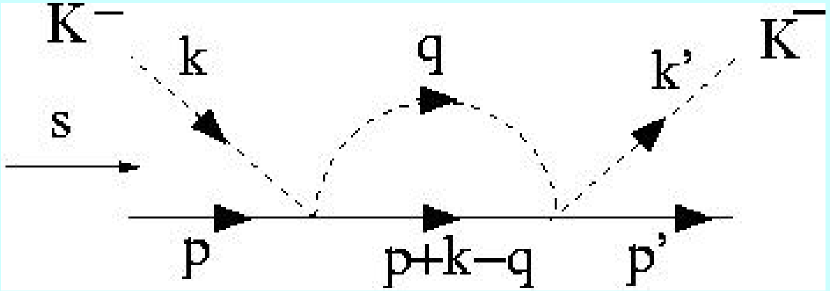
Enhancement by a factor 6^L



  - Presence of large masses compared with the typical momenta, e.g. Kaon masses in driving the appearance of the $\Lambda(1405)$ close to tresholed. This also occurs similarly in the S-waves of Nucleon-Nucleon scattering.

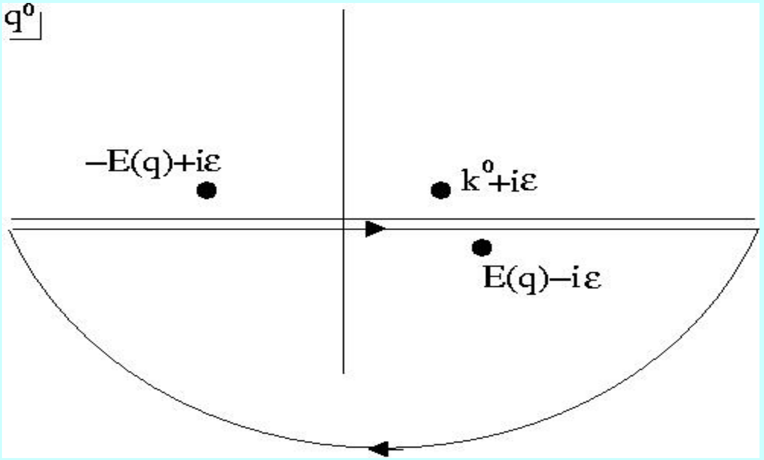
Let us keep track of the kaon mass, $M_K \approx 500$ MeV

We follow similar argumentos to those of S. Weinberg in NPB363,3 (´91) respect to NN scattering (nucleon mass).



Unitariy Diagram

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



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

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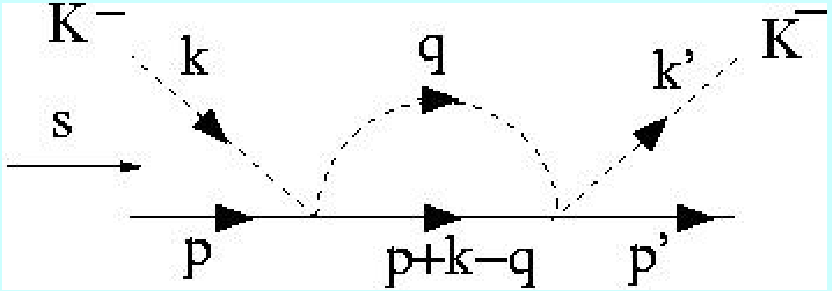
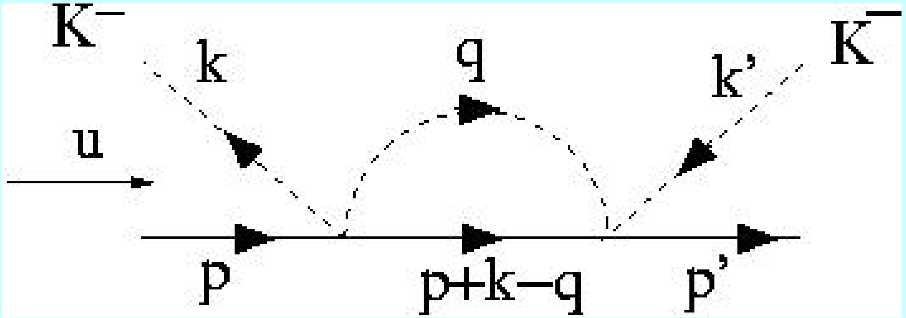


Unitariy Diagram

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



Let us take now the crossed diagram

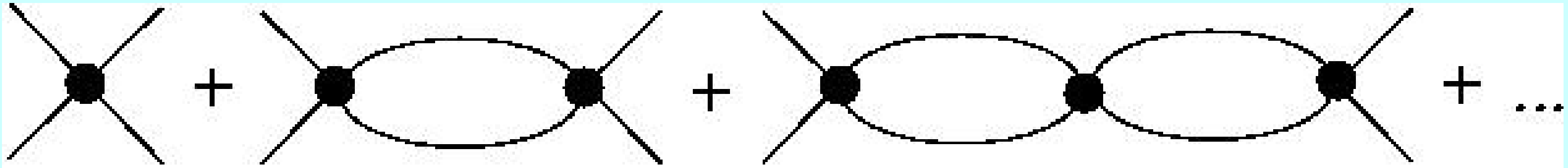
$k \to -k$

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

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

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

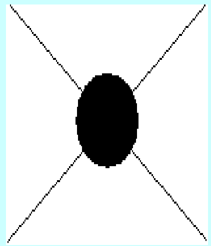
In all these examples the unitarity cut (sum over the unitarity bubbles) is enhanced.



We finally make an expansion of the „Interacting Kernel"

from the appropriate EFT and then the unitarity cut is fulfilled to

all orders (non-perturbatively)



– Other important non-perturbative effects arise because of the presence of nearby resonances of non-dynamical origin with a well known influence close to threshold, e.g. the ρ(770) in P-wave ππ scattering, the Δ(1232) in πN P-waves,...

  Unitarity only dresses these resonances but it is not responsible of its generation (typical q$\bar{q}$,qqq, ... states)

These resonances are included explicitly in the interacting kernel in a way consistent with chiral symmetry and then the right hand cut is fulfilled to all orders.

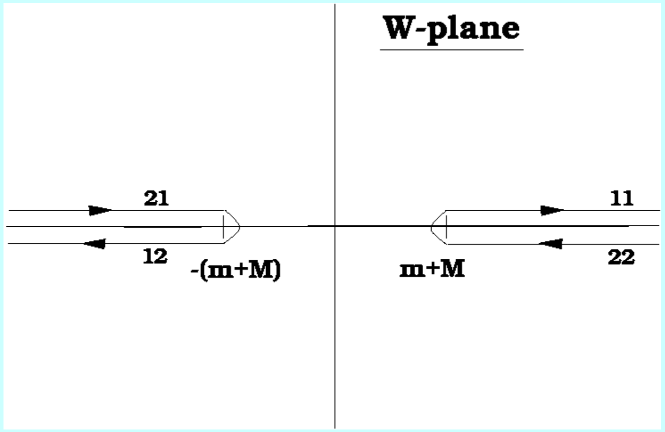
General Expression for a Partial Wave Amplitude

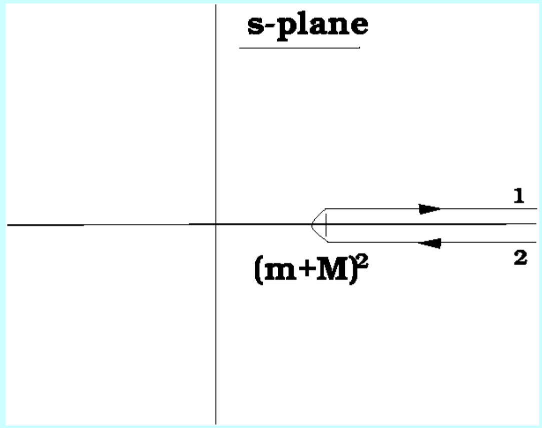
- Above threshold and on the real axis (physical region), a partial wave amplitude must fulfill because of unitarity:

$$Im T_{ij} = \sum_k T_{ik}\, \rho_k\, T^*_{kj} \quad \rightarrow \quad Im T^{-1}{}_{ij} = -\rho_i\, \delta_{ij}$$

Unitarity Cut

W=√s



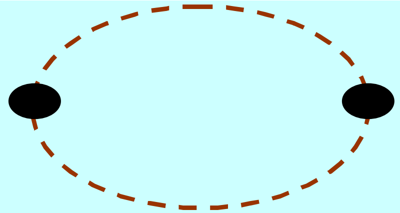


We perform a dispersion relation for the inverse of the partial wave (the unitarity cut is known)

$$T^{-1}_{ij} = R^{-1}_{ij} + \delta_{ij}\left(g(s_0)_i - \frac{s-s_0}{\pi}\int \frac{\rho(s')_i\, ds'}{(s'-s-i0^+)(s'-s_0)} \right)$$

The rest

g(s): Single unitarity bubble

g(s)= 

$$g(s)=\frac{1}{4\pi^2}\left(a_{SL}+\sigma(s)\log\left(\frac{\sigma(s)-1}{\sigma(s)+1}\right)\right)$$

$$\sigma(s)=\frac{2\,q}{\sqrt{s}}$$

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

T obeys a CHPT/alike expansion

R is fixed by matching algebraically with the CHPT/alike
CHPT/alike+Resonances
expressions of T

In doing that, one makes use of the CHPT/alike counting for g(s)

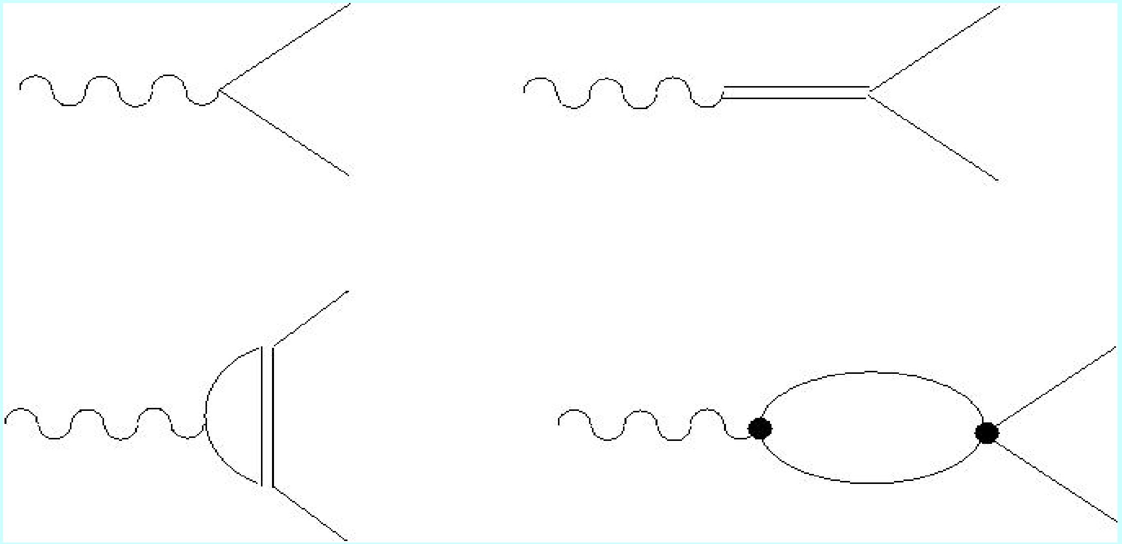
The counting/expressions of R(s) are consequences of the known ones of g(s) and T(s)

The CHPT/alike expansion is done to R(s). Crossed channel dynamics is included perturbatively.

The final expressions fulfill unitarity to all orders since R is real in the physical region (T from CHPT fulfills unitarity pertubatively as employed in the matching).

Production Processes

The re-scattering is due to the strong „final“ state interactions from some „weak“ production mechanism.



$$Im\, F_i = \sum_k F_k\, \rho_k\, T^*_{ki}$$

We first consider the case with only the right hand cut for the strong interacting amplitude, R^{-1} is then a sum of poles (CDD) and a constant. It can be easily shown then:

$$F = (I + R\, g(s))^{-1}\, \xi$$

Finally, ξ is also expanded pertubatively (in the same way as R) by the matching process with CHPT/alike expressions for F, order by order. The crossed dynamics, as well for the production mechanism, are then included pertubatively.

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LET US SEE SOME APPLICATIONS

Meson-Meson Scalar Sector

1) The mesonic scalar sector has the vacuum quantum numbers 0^{++}. Essencial for the study of Chiral Symmetry Breaking: Spontaneous and Explicit m_u, m_d, m_s .

2) In this sector the mesons really interact strongly.
   1) Large unitarity loops.
   2) Channels coupled very strongly, e.g. $\pi\pi$- $K\bar{K}$, $\pi\eta$- $K, \bar{K}$ ...
   3) Dynamically generated resonances, ~~Breit-Wigner formulae~~, ~~VMD~~, ...

3) OZI rule has large corrections.
   1) No ideal mixing multiplets.
   2) ~~Simple quark model.~~

Points 2) and 3) imply large deviations with respect to Large Nc QCD.

4) A precise knowledge of the scalar interactions of the lightest hadronic thresholds, $\pi\,\pi$ and so on, is often required.

- **Final State Interactions (FSI) in ε'/ε , Pich, Palante, Scimemi, Buras, Martinelli,...**
- **Quark Masses (Scalar sum rules, Cabbibo suppressed Tau decays.)**
- **Fluctuations in order parameters of SχSB.**

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- **Quark Masses (Scalar sum rules, Cabbibo suppressed Tau decays.)**
- **Fluctuations in order parameters of SχSB.**

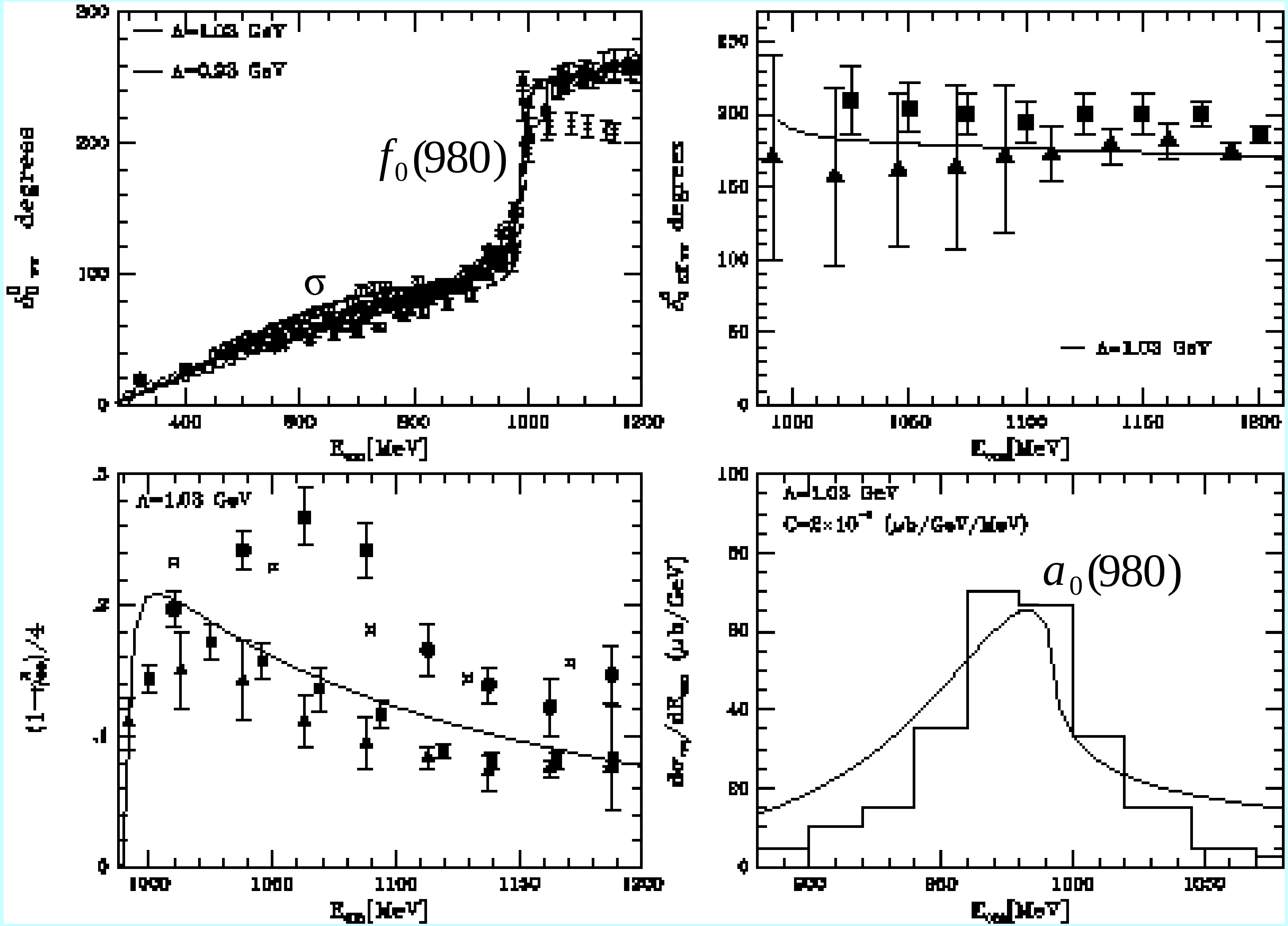
Let us apply the chiral unitary approach $T = \left(R^{-1} + g(s)\right)^{-1}$

- LEADING ORDER:

g is order 1 in CHPT $T = T_2 = R_2 - R_2 g R_2 + ..$ $R = R_2 = T_2$

Oset, Oller, NPA620,438(97)

$a_{SL} \cong -0.5$ only free parameter, equivalently a three-momentum cut-off $\Lambda \cong 0.9$ GeV



σ
$f_0(980)$
$a_0(980)$

Pole positions and couplings

$f_0(980)$ (GeV)	$a_0(980)$ (GeV)
$0.993 - i\, 0.012$	$1.009 - i\, 0.056$
$\lvert g^f_{\pi\pi} \rvert = 1.90$	$\lvert g^a_{\pi\eta} \rvert = 3.54$
$\lvert g^f_{KK} \rvert = 3.80$	$\lvert g^a_{KK} \rvert = 5.20$

$Br(f_0(980) \to \pi\pi)=0.70$ **$Br(a_0(980) \to \pi\eta)=0.63$**

All these resonances were dynamically generated from the lowest order CHPT amplitudes due to the enhancement of the unitarity loops.

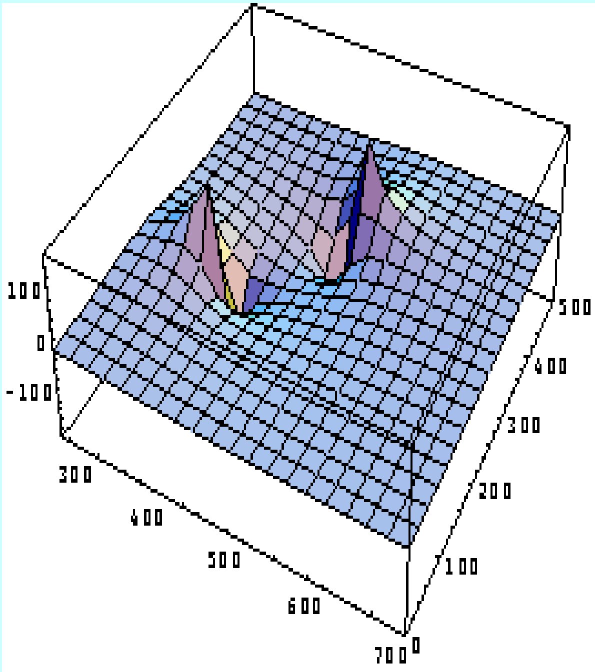
In Oset,Oller PRD60,074023(99) we studied the I=0,1,1/2 S-waves.

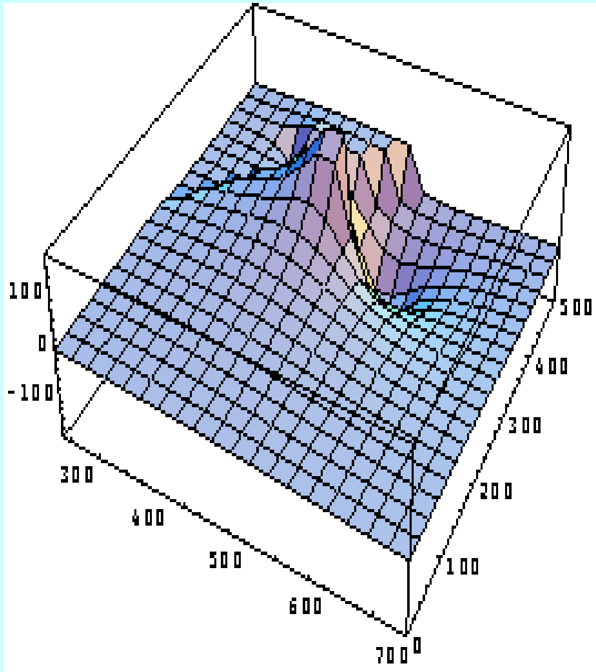
The input included next-to-leading order CHPT plus resonances:

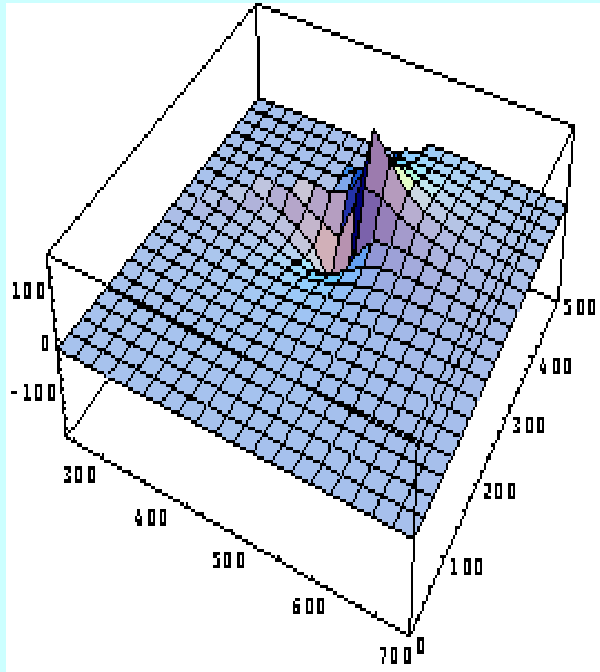
1. Cancellation between the crossed channel loops and crossed channel resonance exchanges. (Large Nc violation).

2. Dynamically generated renances. The tree level or preexisting resonances move higher in energy (octet around 1.4 GeV). Pole positions were very stable under the improvement of the kernel R (convergence).

3. In the SU(3) limit we have a degenerate octet plus a singlet of dynamically generated resonances σ, $f_0(980)$, $a_0(980)$, $\kappa(700)$



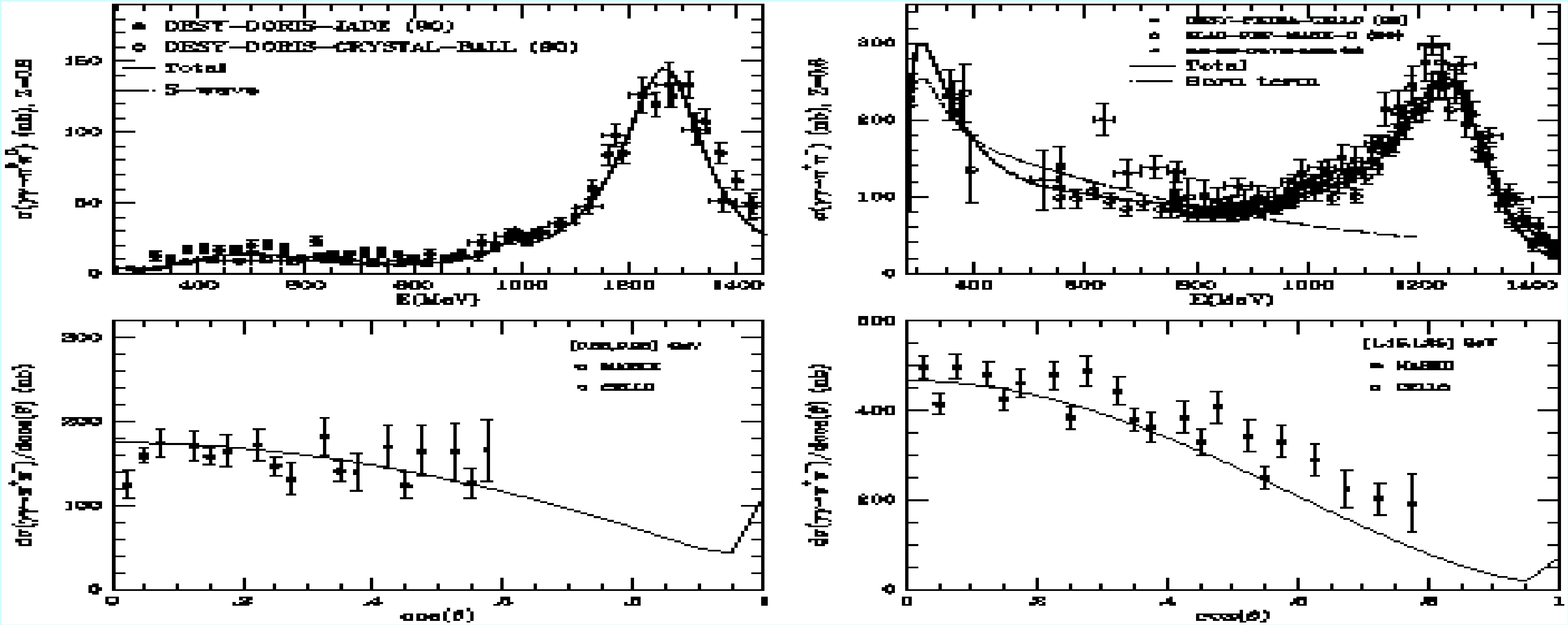




Using these T-matrices we also corrected by Final State Interactions the processes $\gamma\gamma \to \pi^+\pi^-, \pi^0\pi^0, \pi\eta, K^+K^-, K^0\bar{K}^0$

Where the input comes from CHPT at one loop, plus resonances. There were some couplings and counterterms but were taken from the literature. No fit parameters.

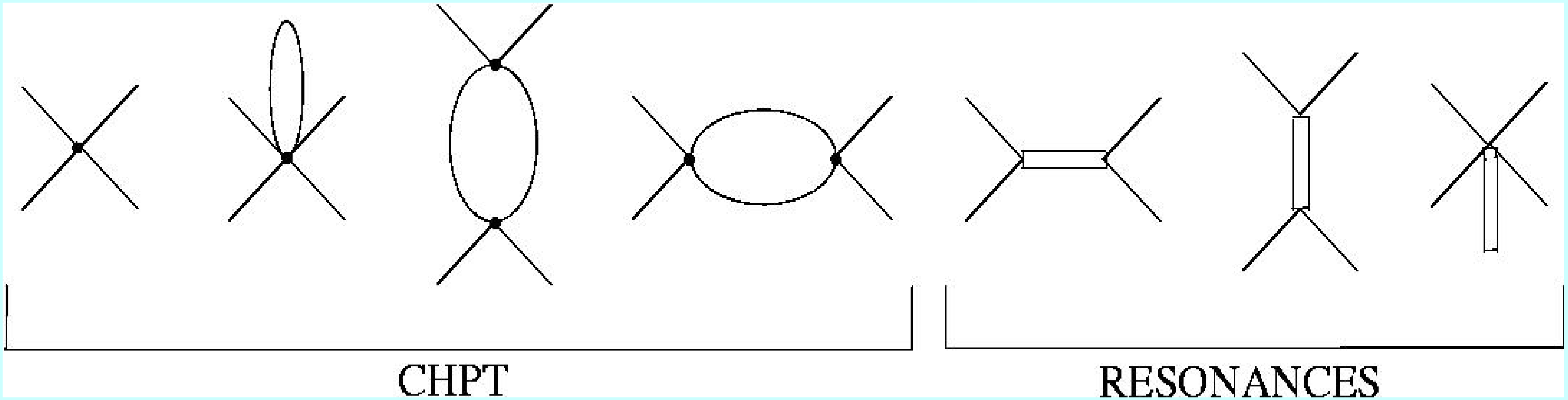
Oset, Oller NPA629,739(98).



CHPT+Resonances

Ecker, Gasser, Pich and de Rafael, NPB321, 311 (´98)
Resonances give rise to a resummation of the chiral series at the tree level (local counterterms beyond O(p^4).

$$\frac{1}{M^2-q^2}=\frac{1}{q^2}+\frac{q^2}{M^4}+\frac{q^4}{M^6}+\ldots \quad q^2<<M^2$$



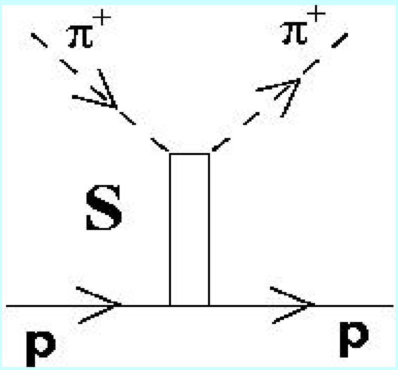
The counting used to perform the matching is a simultaneous one in the number of loops calculated at a given order in CHPT (that increases order by order). E.g:

- Meissner, J.A.O, NPA673,311 (´00) the πN scattering was studied up to one loop calculated at O(p^3) in HBCHPT+Resonances.

- Jamin, Pich, J.A.O, NPB587, 331 (´00), $K\pi, K\eta, K\eta'$ scattering.

- The inclusion of the resonances require the knowledge of their bare masses and couplings, that were fitted to experiment

A theoretical input for their values would be very welcome:
  - The CHUA would reduce its freedom and would increase its predictive power.
  - For the microscopic models, one can then include the so important final state interactions that appear in some channels, particularly in the scalar ones. Also it would be possible to identify the final physical poles originated by such bare resonances and to work simultaneously with those resonances dynamically generated.



$$L_{SNN} = -g_{sNN} \bar{\Psi} \Psi S$$

$$L_{S\pi\pi} = S\left(\bar{c}_m \mathrm{Tr}(X^+) + \bar{c}_d \mathrm{Tr}(u_\mu u^\mu) \right)$$

S-Wave, S=-1 Meson-Baryon Scattering

U.-G. Meißner, J.A.O, PLB500, 263 (´01), PRD64, 014006 (´01)

Jido, Oset, Ramos, Meißner, J.A.O, nucl-th/0303062

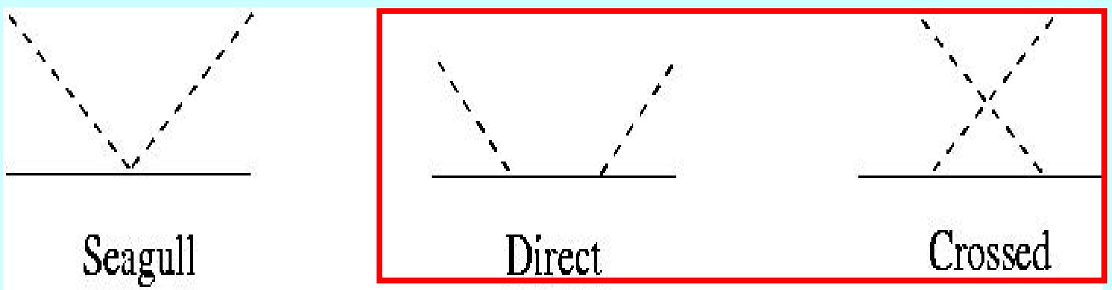
As in the scalar sector the unitarity cut is enhanced.

$$T = (R^{-1} + g(s))^{-1} = (I + R.g(s))^{-1} R(s)$$

– LEADING ORDER: g is order p in (HB)CHPT (meson-baryon)

$$T = T_1 = R_1$$

No bare resonances



Non-negligible for energies greater than 1.3 GeV

Many channels: $K^- p, \bar{K}^0 n, \pi^0\Sigma^0, p^+\Sigma^-, \pi^-\Sigma^+, \pi^0\Lambda, \eta\Lambda, \eta\Sigma^0, K^+\Xi^-, K^0\Xi^0$

Important isospin breaking effects due to cusp at thresholds, we work with the physical basis

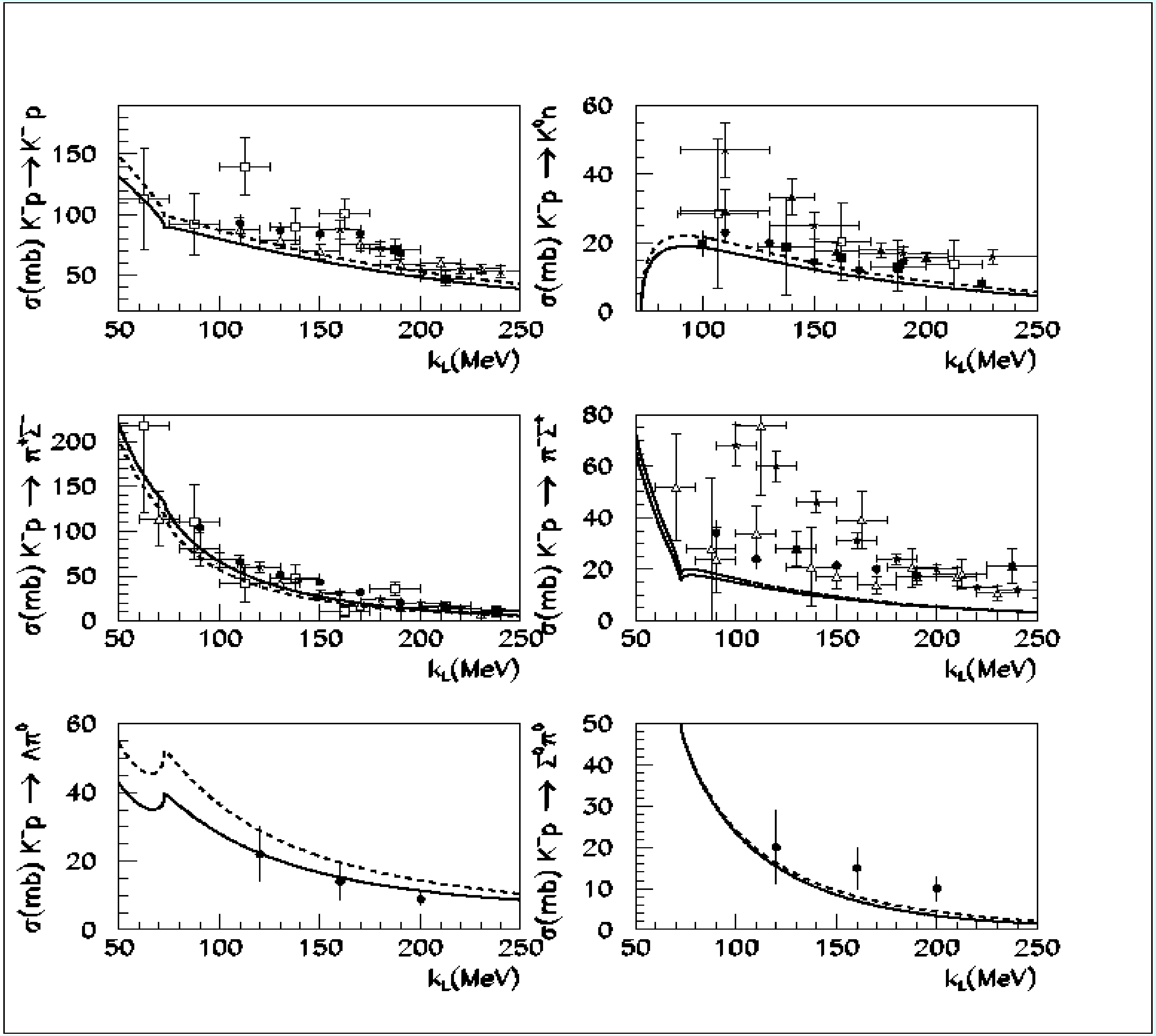
- Free Parameters:
  - a_{SL} subtraction constant.
  - M_0 Mass of the lightest baryon octet in the chiral limit.
  - f, weak pseudoscalar decay constant in the SU(3) chiral limit ($m_u = m_d = m_s = 0$)

  Natural Values (Set II):

  - M_0 =1.15 GeV, from the average of the masses in the baryon octet.
  - f=86.4 MeV, known value of f in the SU(2) chiral limit.
  - a=-2, the subtraction constant is fixed by comparing g(s) with that calculated with a cut-off around 700 MeV, Oset, Ramos, NPA635,99 (´98).

  Fitted Values (Set I):

  - M_0 =1.29 GeV
  - f=74 MeV
  - a=-2.23



σ(mb) K⁻p → K⁻p
σ(mb) K⁻p → K̄⁰n
σ(mb) K⁻p → π⁺Σ⁻
σ(mb) K⁻p → π⁻Σ⁺
σ(mb) K⁻p → Λπ⁰
σ(mb) K⁻p → Σ⁰π⁰
k_L(MeV)

$\pi\Sigma$ Mass Distribution

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

Typically one takes: $\frac{dN_{\pi^-\Sigma^+}}{dE} = C|T_{\pi\Sigma\rightarrow\pi\Sigma}|^2 p_{\pi\Sigma}$

As if the process were elastic

E.g: Dalitz, Deloff, JPG 17,289 (´91); Kaiser, Siegel, Weise NPB594,325 (´95); Oset, Ramos NPA635, 99 (´89)

But the $\bar{K}N$ threshold is only 100 MeV above the $\pi\Sigma$ one, comparable with the widths of the present resonances in this region and with the width of the shown invariant mass distribution. The presciption is ambiguous, why not?

$$\frac{dN_{\pi^-\Sigma^+}}{dE} = C|T_{\bar{K}N\rightarrow\pi\Sigma}|^2 p_{\pi\Sigma}$$

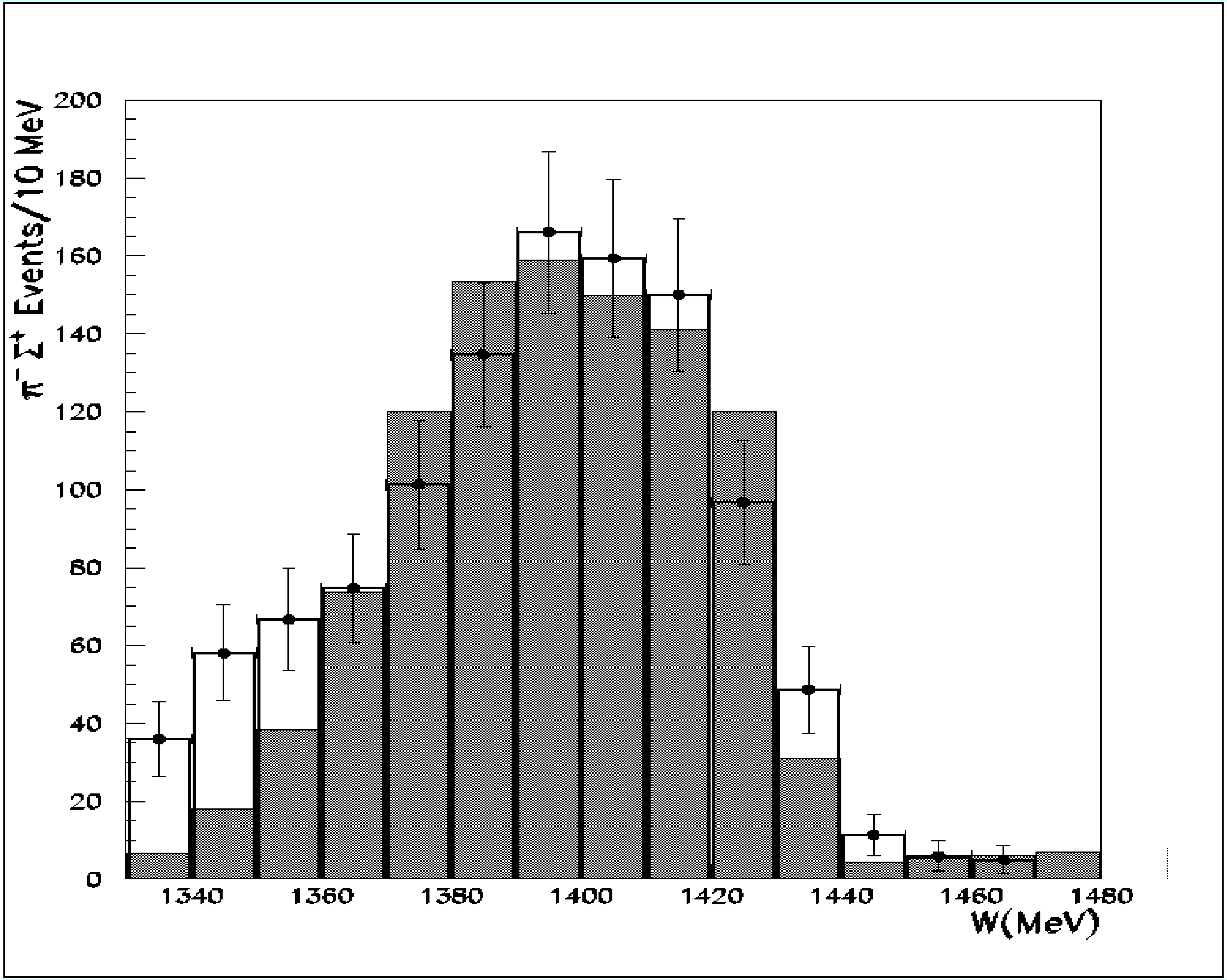
We follow the Production Process scheme previously shown:

$$F = (I + Rg)^{-1}\xi \qquad \xi^T = (r_1, r_1, r_2, r_2, r_2, 0,0,0,0,0)$$

I=0 Source

$$\frac{r_1}{r_2} = 1.42$$

r1=0 (common approach)



$\pi\Sigma$ Mass Distribution

	Our Results
$\gamma = \frac{\Gamma(K^- p \to \pi^+ \Sigma^-)}{\Gamma(K^- p \to \pi^- \Sigma^+)} = 2.36 \pm 0.04$	2.33
$R_c = \frac{\Gamma(K^- p \to Charged)}{\Gamma(K^- p \to All)} = 0.664 \pm 0.011$	0.645
$R_n = \frac{\Gamma(K^- p \to \pi^0 \Lambda)}{\Gamma(K^- p \to Neutral)} = 0.189 \pm 0.015$	0.227

- Scattering Lengths: $a_0 = -0.58 + i1.19 \quad fm$

  $a_0 = -0.53 + i0.95 \quad fm$ Isospin Limit

Data:

Kaonic Hydrogen: $a_0 = (-0.78 \pm 0.15 \pm 0.03) + i(0.49 \pm 0.25 \pm 0.12) fm$

Isospin Scattering Lengths: $a_0 = (-0.68 \pm 0.10) + i(0.64 \pm 0.10) fm$

In Meißner, J.A.O PLB500, 263 (´01), several poles were found.

1. All the poles were of dynamical origin, they disappear in Large Nc, because R.g(s) is order 1/Nc and is subleading with respect to the identity I.

$$T = (I + \mathrm{R.g}(s))^{-1}\mathrm{R}(s) \to \mathrm{R}(s)$$

The subtraction constant corresponds to evalute the unitarity loop with a cut-off Λ of natural size (scale) around the mass of the ρ.

$$a_{SL} = -2\,\mathrm{Log}\left(1 + \sqrt{1 + \frac{M_N}{\Lambda^2}}\right) \cong -2 \qquad M_N \to N_c$$

2. Two I=1 poles, one at 1.4 GeV and another one at around 1.5 GeV.

3. The presence of two resonances (poles) around the nominal mass of the Λ(1405).

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2. Two I=1 poles, one at 1.4 GeV and another one at around 1.5 GeV.

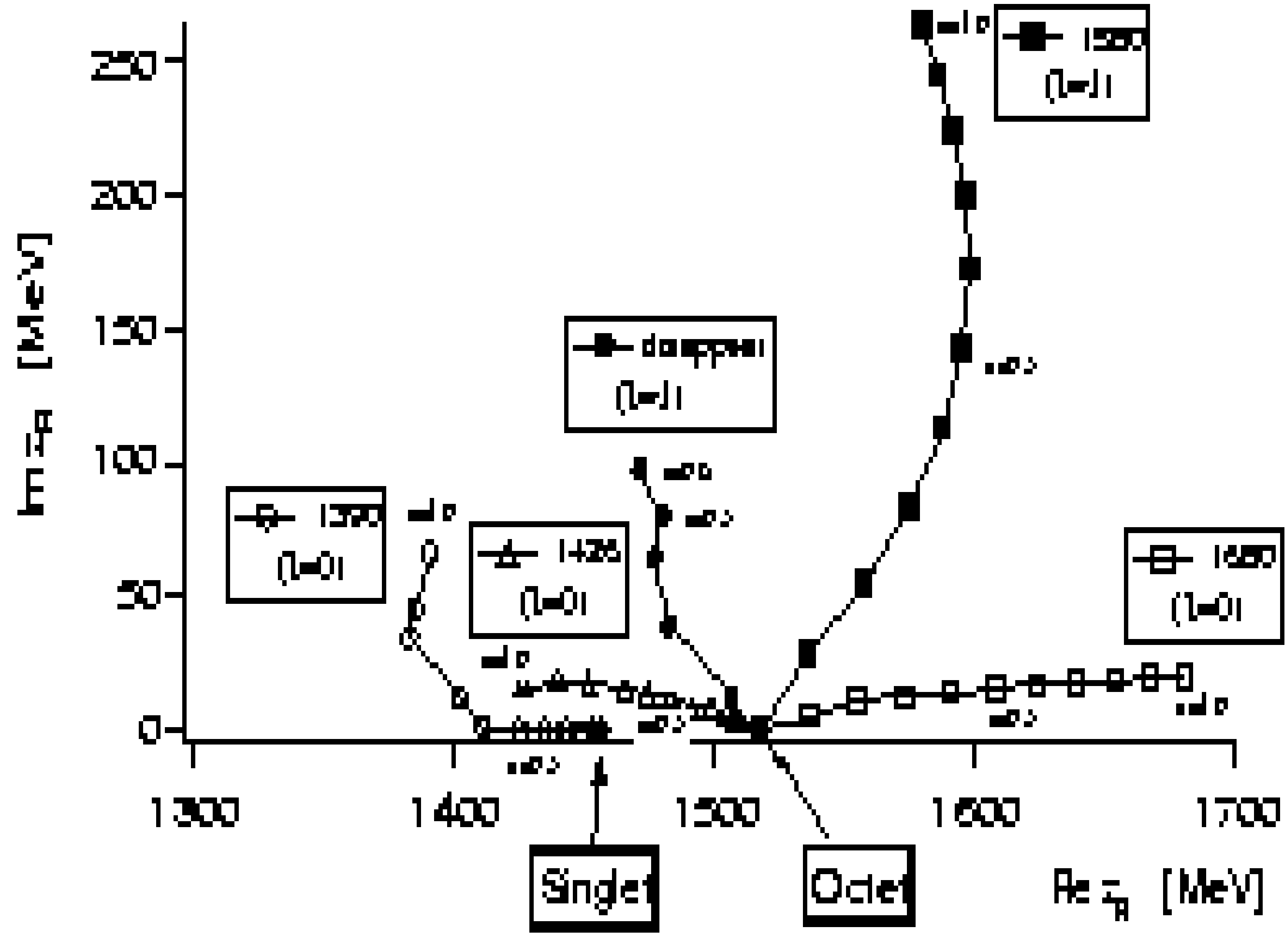
3. The presence of two resonances (poles) around the nominal mass of the Λ(1405).

These points were further studied in: Jido, Oset, Ramos, Meißner, J.A.O, nucl-th/0303062, taking into account as well another study of Oset,Ramos,Bennhold PLB527,99 (02).

SU(3) decomposition $\quad 8 \otimes 8 \rightarrow 1 \oplus 8_s \oplus 8_a \oplus 10 \oplus 27$

Isolating the different SU(3) invariant amplitudes one observes de presence of poles for the Singlet (1), Symmetric Octet (8_S), Antisymmetric Octet (8_A).

DEGENERATE



0
50
100
150
200
250
1300
1400
1500
1600
1700
Im z_R [MeV]
Re z_R [MeV]
1390 (I=0)
1426 (I=0)
disappear (I=1)
1580 (I=1)
1680 (I=0)
Singlet
Octet

Table 1: Pole positions and couplings to $I = 0$ physical states

z_R ($I = 0$)	$1379 + 27i$ g_i	$\|g_i\|$	$1434 + 11i$ g_i	$\|g_i\|$	$1692 + 14i$ g_i	$\|g_i\|$
$\pi\Sigma$	$-1.76 - 0.62i$	1.87	$-0.56 - 1.02i$	1.16	$-0.08 - 0.92i$	0.93
$\bar{K}N$	$0.86 + 0.70i$	1.11	$-1.74 + 0.69i$	1.85	$0.32 + 0.41i$	0.52
$\eta\Lambda$	$0.19 + 0.39i$	0.38	$-1.20 + 0.29i$	1.23	$-0.83 - 0.19i$	0.85
$K\Xi$	$-0.52 - 0.19i$	0.55	$-0.20 - 0.30i$	0.36	$3.87 + 0.05i$	3.87

a) b) — $\Lambda(1405)$ $\Lambda(1670)$

Table 2: Pole positions and couplings to $I = 1$ physical channels

z_R ($I = 1$)	$1401 + 40i$ g_i	$\|g_i\|$	$1488 + 114i$ g_i	$\|g_i\|$
$\pi\Lambda$	$0.60 + 0.47i$	0.76	$0.98 + 0.84i$	1.3
$\pi\Sigma$	$1.27 + 0.71i$	1.5	$-1.32 - 1.00i$	1.7
$\bar{K}N$	$-1.24 - 0.79i$	1.4	$-0.80 - 0.37i$	1.1
$\eta\Sigma$	$0.36 + 0.41i$	0.69	$0.58 + 0.29i$	0.65
$K\Xi$	$0.12 + 0.05i$	0.13	$-1.68 - 0.91i$	1.9

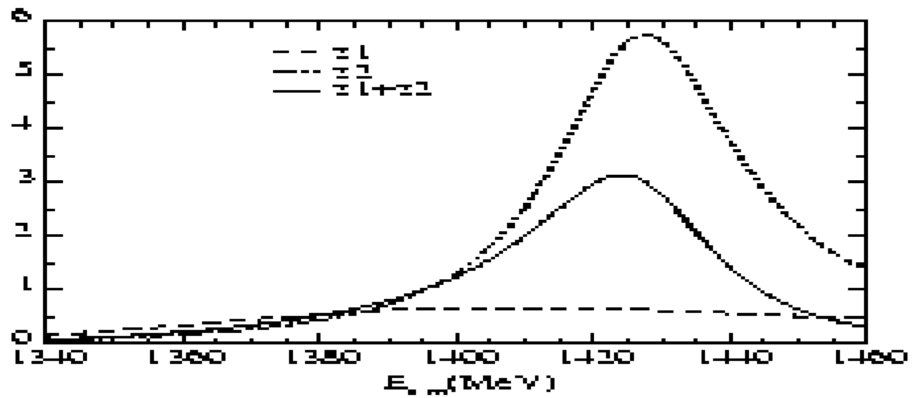
a) is more than twice wider than b) (Quite Different Shape)

b) Couples stronger to $\bar{K}N$ than to $\pi\Sigma$ contrarily to a)

It depends to which resonance the production mechanism couples stronger that the shape will move from one to the other resonance

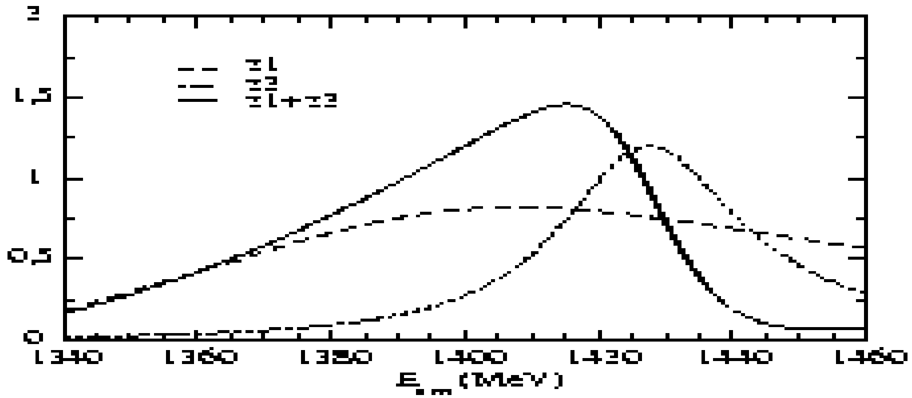
Simple parametrization of our own results with BW like expressions

$$g^{R_1}_{\bar{K}N}\frac{1}{W - M_{R_1} + i\Gamma_{R_1}/2}g^{R_1}_{\pi\Sigma} + g^{R_2}_{\bar{K}N}\frac{1}{W - M_{R_2} + i\Gamma_{R_2}/2}g^{R_2}_{\pi\Sigma},$$



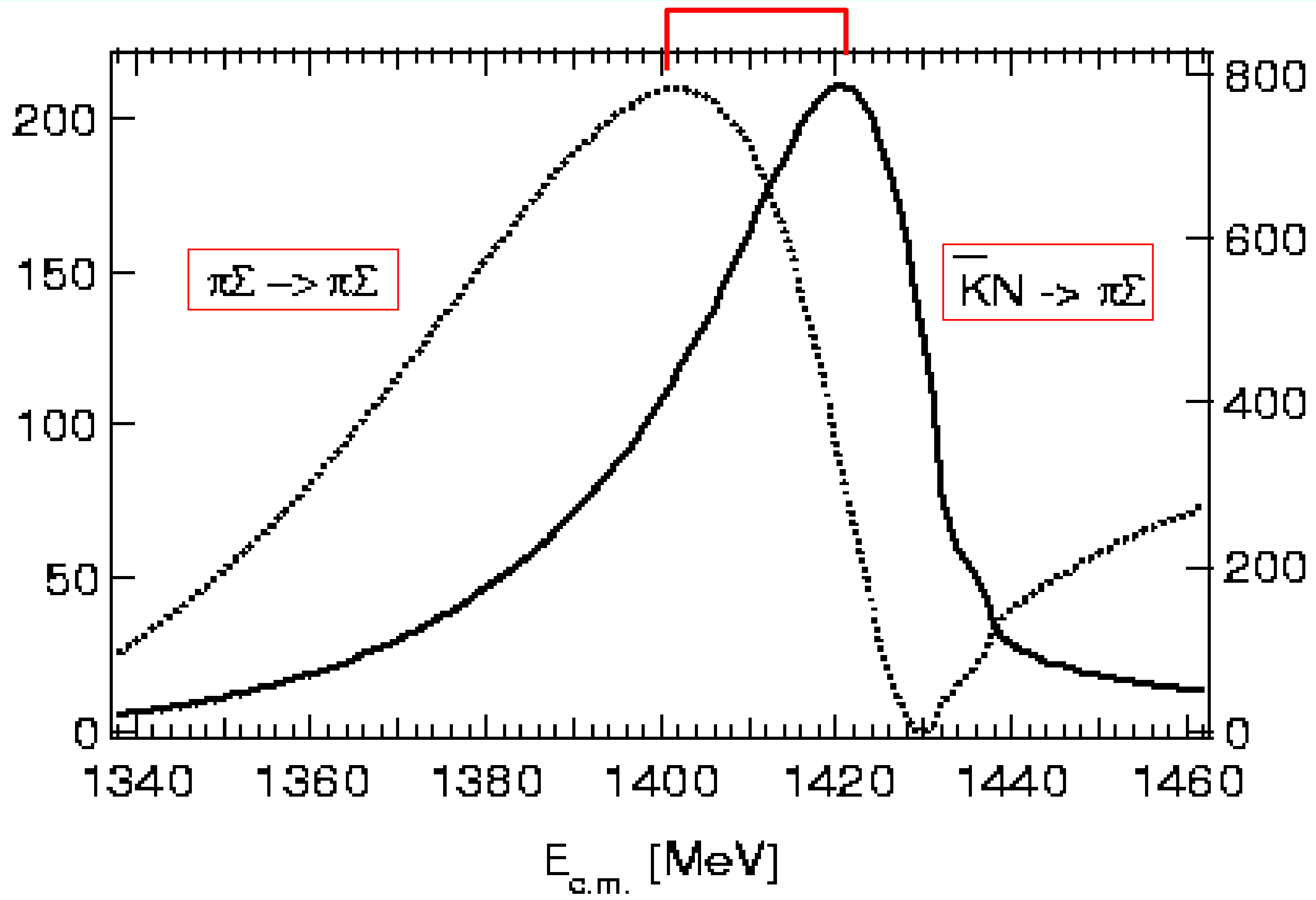
$\pi\Sigma \rightarrow \bar{K}N$

$$g^{R_1}_{\pi\Sigma}\frac{1}{W - M_{R_1} + i\Gamma_{R_1}/2}g^{R_1}_{\pi\Sigma} + g^{R_2}_{\pi\Sigma}\frac{1}{W - M_{R_2} + i\Gamma_{R_2}/2}g^{R_2}_{\pi\Sigma}.$$



$\pi\Sigma \rightarrow \pi\Sigma$

Full Results of our approach



1) The shift in the peaks of both shapes
2) The different widths

SU(3) Decomposition of the Physical Resonances

- $|A>$ is a physical pole; $|\mu'>$ is a SU(3) eigenstate; μ is 1,8s or 8a

$$|A> \; = \Sigma_\mu \, C^A_\mu \, |\mu'> \qquad \Sigma_\mu \, |C^A_\mu|^2 = 1$$

$$g(A \rightarrow \gamma) = \Sigma_\mu C^A_\mu \, g(\mu' \rightarrow \gamma)$$

Leading order in SU(3) breaking

$$g(A \rightarrow \gamma) = C^A_\gamma \, g(\gamma' \rightarrow \gamma)$$

$|\gamma>$ is a meson-baryon state with well defined SU(3) quantum numbers

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Leading order in SU(3) breaking

$$g(A \to \gamma) = C^A_\gamma \, g(\gamma' \to \gamma)$$

|γ> is a meson-baryon state with well defined SU(3) quantum numbers

We can calculate them → The coefficients $C_\gamma{}^A$ can then be determined

I=0

Pole (MeV)	C_1	C_{8_A}/C_1	C_{8_S}/C_1	$\|C_1\|^2$	$\|C_{8_A}\|^2$	$\|C_{8_s}\|^2$
1379+ i 27	0.96	0.15+ i 0.11	0.15- i 0.19	0.92	0.03	0.05
1434+ i 11	0.49	0.64+ i 0.77	0.71+ i 1.28	0.24	0.24	0.52
1692+ i 14	0.48	1.58+ i0.37	0.78+ i 0.16	0.23	0.63	0.14

I=1

Pole (MeV)	C_{8_A}	C_{8_S}/C_{8_A}	$\|C_{8_A}\|^2$	$\|C_{8_s}\|^2$
1401+ i 40	0.81	0.72+ i0.07	0.66	0.34
1488+ i 114	0.59	1.37- i 0.06	0.35	0.65

Conclusions and Outlook

- Chiral Unitary Approach:
  - Systematic and versatile scheme to treat self-strongly interacting channels (S-wave $\pi\pi$, S-wave S=-1 $\bar{K}N$, NN, through the chiral (appropriate EFT) expansion of an interaction kernel R.
  - Based on Analyticity and Unitarity.
  - The same scheme is amenable to correct from FSI Production Processes.
  - It treats both resonant (preexisting/dynamically generated) and background contributions.
  - It can also be extended to higher energies to fit data.

Conclusions and Outlook

- Scalar S=-1 meson-baryon sector:
  - Several I=0,I=1 poles appear corresponding in the SU(3) limit to a singlet, symmetric octet and antisymmetric octet multiplets.
  - The $\Lambda(1405)$ observed resonant shape in $\pi\Sigma$ is a combination of two rather different resonances (couplings and widhts).
  - That could be distinguish by taking different reactions and observing the different shapes, e.g. $K^- p \to \Lambda(1405)\,\gamma$
  - Undetected I=1 pole around 1.4 GeV and width around 80 MeV, that could be more easily observed in the $\pi\Sigma$ channel.
  - Future:
  - Perform a complete NLO/NNLO (one loop) calculation in R.
  - To include explicit resonances (as can be done in this scheme) (P-waves).
  - To study photoproduction of strangeness (K, η,η') taking into account the new data from ELSA, TJNAF.