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Strangeness –1 Meson-Baryon Scattering and its Spectroscopy from Unitary CHPT

José A. Oller

Departamento de Física, Univ. Murcia

In collaboration with Joaquim Prades and Michela Verbeni

(Univ. Granada)

1. **Introduction. Interest.**
2. **UCHPT**
3. **S-Wave, S=-1 Meson-Baryon Scattering**
4. **Scattering**
5. **Spectroscopy**
6. **Conclusions**

1. INTRODUCTION. INTEREST.

$\bar{K}N$ SCATTERING, TEN TWO BODY COUPLED CHANNELS:

$\pi^0\Lambda\ \pi^0\Sigma^0\ \pi^-\Sigma^+\ \pi^+\Sigma^-\ K^-p\ \bar{K}^0p\ \eta\Lambda\ \pi^0\Sigma^0\ K^0\Xi^0\ K^-\Xi^+$

$$8 \times 8 = 1 + 8_s + 8_a + 10 + \overline{10} + 27$$

The representations 1, 8_s, 8_a and 27(exotic) give rise to resonances.

- Potential Models, Quark Models, (Chiral) Bag Models, etc
- CHPT+Unitarization (UCHPT)

Kaiser,Siegel,Weise NPA594,325('95)

Oset, Ramos NPA635,99('98)

Meissner,JAO PLB500,263('01)

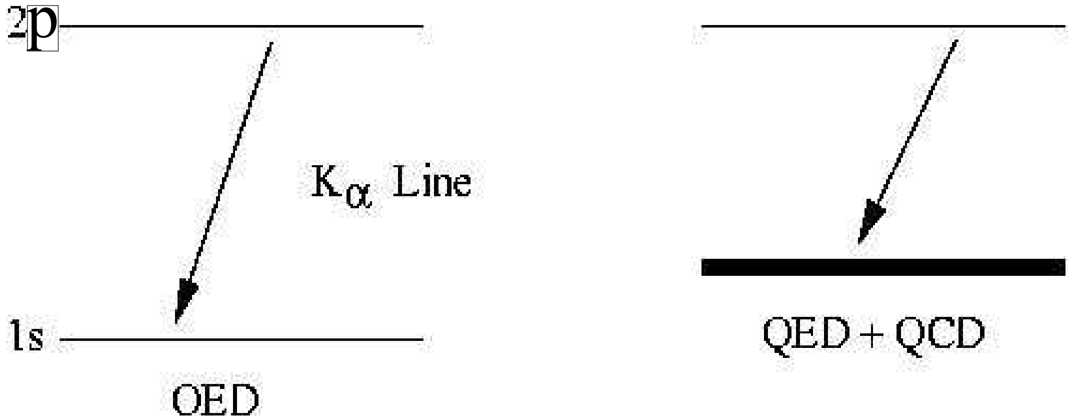
Lutz,Kolomeitsev NPA700,193('02) ;

Garcia-Recio, Lutz, Nieves, PLB582,49 ('04); García-Recio, Nieves, Ruiz Arriola, Vicente Vacas, Phys.Rev.D67:076009,2003

Borasoy, Nissler, Weise PRL94,213401 (05),EPJA25,79(´05),hep-ph/0606108, PRL96,199201(C)

Renewed interest with the precise measurement by DEAR Coll. of strong shift and width of kaonic hydrogen 1s energy level

G. Beer et al., PRL94,212302('05)



Upwards shift

Repulsive $K^- p \to K^- p$

$$K^- p \to \begin{cases} \pi^0 \Lambda\ ,\ \pi^\mp \Sigma^\pm \ \text{[strong]} \\ \Sigma\pi\gamma\ ,\ \Sigma\pi e^+ e^-\ ,\ \Sigma\gamma\ , \ldots < 1\% \end{cases}$$

Unstable

DEAR:

$$\Delta E = 193 \pm 37(stat.) \pm 6(syst.)\ \text{eV}$$
$$\Gamma = 249 \pm 111(stat.) \pm 39(syst.)\ \text{eV}$$

KEK:

$$\Delta E = 323 \pm 63 \pm 11\ \text{eV}$$
$$\Gamma = 407 \pm 208 \pm 100\ \text{eV}.$$

Meissner,Raha,Rusetsky EPJ C35,349('04); Borasoy,Nissler,Weise PRL94,213401(05), EPJA25,79(05) pointed out a possible inconsistency between DEAR and previous scattering data. SU(3) chiral dynamics results agree with KEK but disagrees with the factor 2 more precise DEAR measurement

$$E_{1s} = E_{1s}^{em} + \epsilon_{1s} \text{ , } \epsilon_{1s} \text{ is complex}$$

Deser Formula $\epsilon_{1s} = -2\alpha^3 \mu_C^2 T_{K-p}$

Precise knowledge   Precise determination

$\epsilon_{1s} \Longleftrightarrow T_{K-p}$ at threshold

Meissner,Raha,Rusetsky EPJ C35,349('04) include isospin breaking correction on the Deser formula up to an including $O(\alpha^4, \alpha^3(m_u - m_d)) \sim 9\%$

Cusp Effect: ~ 50% $O(\delta^{1/2})$

Coulomb Effects: ~ 10 – 15 %

Vacuum Polarization: ~ 1%

$$\Delta E_{1s} - \frac{i}{2}\Gamma_{1s} = -\frac{\alpha^3 \mu_C^3}{2\pi M_{K+}} T_{K-p} \left\{ 1 - \frac{\alpha \mu_C^2 s_1(\alpha)}{4\pi M_{K+}} T_{K-p} \right\}$$

$\delta \sim \alpha \sim m_u - m_d$

DEAR/SIDDHARTA Coll. Aims to finally measure it up to eV level, a few percent (nowadays the precission is 20%).

http://www.lnf.infn.it/esperimenti/dear/DEAR_RPR.pdf

Other interesting finding for which a precise knowledge of $\bar{K}N$ scattering is of foremost importance:

- Nature of Λ(1405), problems in lattice QCD. Dynamically generated resonance.

- Two poles making up the Λ(1405)

Meissner,JAO PLB500,263('01) ; Jido, Oset, Ramos, Meissner, J.A.O, NPA725(03)181

Magas, Oset, Ramos PRL95,052301('05); S. Prakhov et al. (Crystall Ball Coll.), PRC70,034605('04));

- Strangeness content of the proton and large pion-nucleon sigma terms,

$\langle p|\bar{s}s|p\rangle$ strange proton-scalar form factor
related by unitarity with $\bar{K}N$ amplitiudes.

- Kaonic Atoms. Kaons in nuclear matter, etc.

2. UNITARY CHPT (UCHPT).

1. A systematic scheme able to be applied when the interactions between the hadrons are not perturbative (even at low energies).
   - Meson-meson processes, both scattering and (photo)production, involving I=0,1,1/2 S-waves, $J^{PC}=0^{++}$ (vaccum quantum numbers)

     I=0 σ(500) - really low energies

     Not low energies - I=0 $f_0(980)$, I=1 $a_0(980)$, I=1/2 κ(700).

     Related by SU(3) symmetry.
   - Processes involving S=–1 (strangeness) S-waves meson-baryon interactions $J^P=1/2^-$. I=0 Λ(1405) , Λ(1670), I=1 Σ(1670), possible Σ(1400), etc...

     One also finds other resonances in S=-2, 0, +1, and even with I=2...
   - Processes involving scattering or production of, particularly, the lowest Nucleon-Nucleon partial waves like the $^1S_0$, $^3S_1$ or P-waves. Deuteron, Nuclear matter, Nuclei.
2. Then one can study:
   – Strongly interacting coupled channels.
   – Large unitarity loops.
   – Resonances.

4. This allows as well to use the Chiral Lagrangians for higher energies. (BONUS)

5. Since one can also use the chiral Lagrangians for higher energies it is possible to establish a connection with perturbative QCD, α_S (4 GeV^2)/$\pi\approx$0.1. (OPE). E.g. providing phenomenological spectral functions for QCD Sum Rules (going definitively beyond the sometimes insufficient hadronic scheme of narrow resonance+resonance dominance).

   Jamin,Pich, JAO
   V_{us}:JHEP 0402,047('04)
   $m_{u,d,s}$: EPJ C24, 237 ('02); hep-ph/0605095

6. The same scheme can be applied to productions mechanisms. Some examples: !

   - Photoproduction: $\gamma\gamma$! $\pi^0\pi^0$, $\pi^+\pi^-$, K^+K^-, K^0K^0, $\pi^0\eta$; D ! 3π, K 2π, ...
     γ p ! K^+ Λ(1405) ; **(γ, $\pi\pi$)** ; γ d ! d ; γ NN ! NN ; γ d ! γ d ; ...
   - Decays: ϕ ! γ $\pi^0\pi^0$, $\pi^0\eta$, K^0K^0 ; J/Ψ ! ϕ (ω) $\pi\pi$, KK ;
     f_0(980) ! $\gamma\gamma$; branching ratios ...

JAO PRD 71,054030 ('05) on D ! 3π, K 2π and D_s ! 3π , and references therein

Chiral Perturbation Theory

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

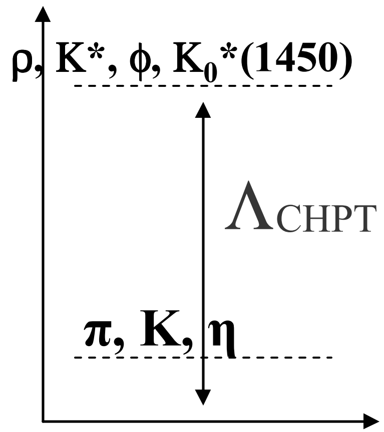
QCD Lagrangian

Hilbert Space
Physical States

u, d, s massless quarks $SU(3)_L \otimes SU(3)_R$ $\longrightarrow$ **Spontaneous Chiral Symmetry Breaking** $SU(3)_V$

Goldstone Theorem

Octet of massles pseudoscalars
π, K, η
Energy gap



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

Non-zero masses
$m_P^2 \propto m_q$

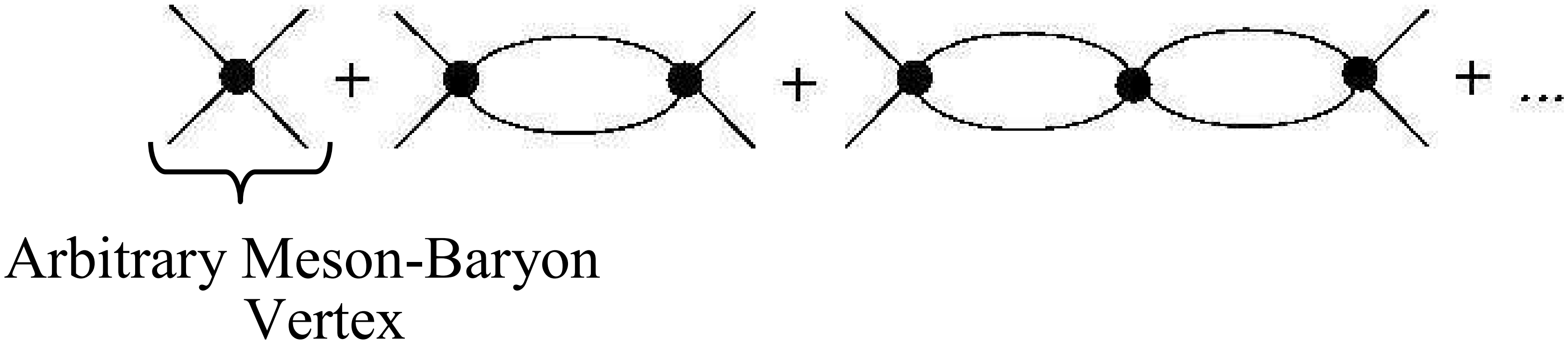
Perturbative expansion in powers of the external four-momenta of the pseudo-Goldstone bosons over Λ^2_{CHPT}

$$L = L_2 + L_4 + \ldots$$

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

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

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

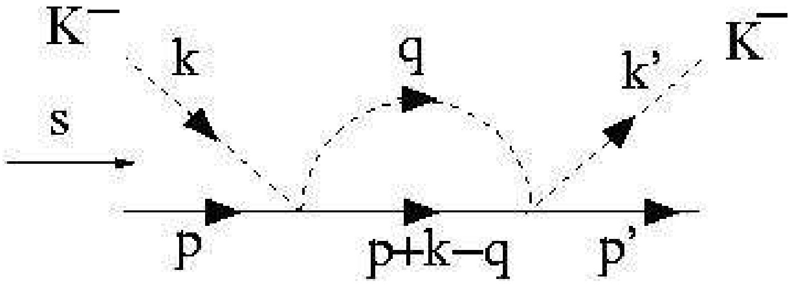


–Presence of large masses compared with the typical low three-momenta (Baryon+Kaon masses) drive the appearance of the Λ(1405) close to threshold in $\bar{K}N$ scattering.

This also occurs similarly in Nucleon-Nucleon scattering with the nucleon mass

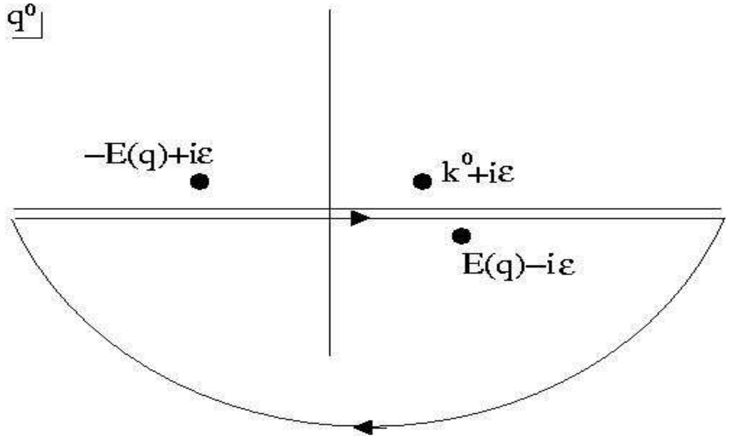
Let us keep track of the kaon mass, $M_K \approx 500$ MeV

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



Unitarity Diagram

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



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

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

Around one order of magnitude in the region of the $\Lambda(1405)$ region,

|q| ' 100 MeV

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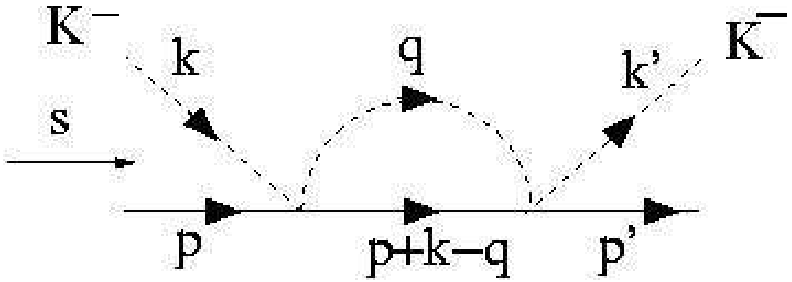

Unitarity Diagram

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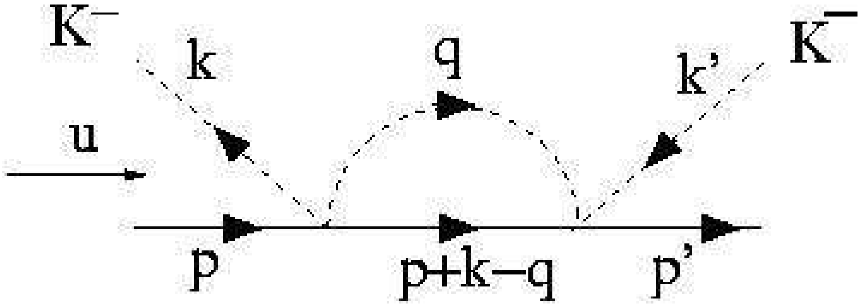


Let us take now the crossed diagram

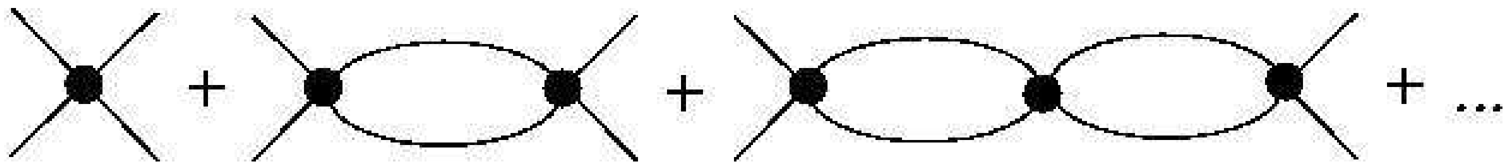
$$k \to -k$$

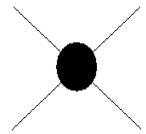
$$\frac{1}{k^0 + \mathrm{E}(q)} \frac{1}{2\mathrm{E}(q)} \cong \frac{1}{4M_K^2}$$

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.



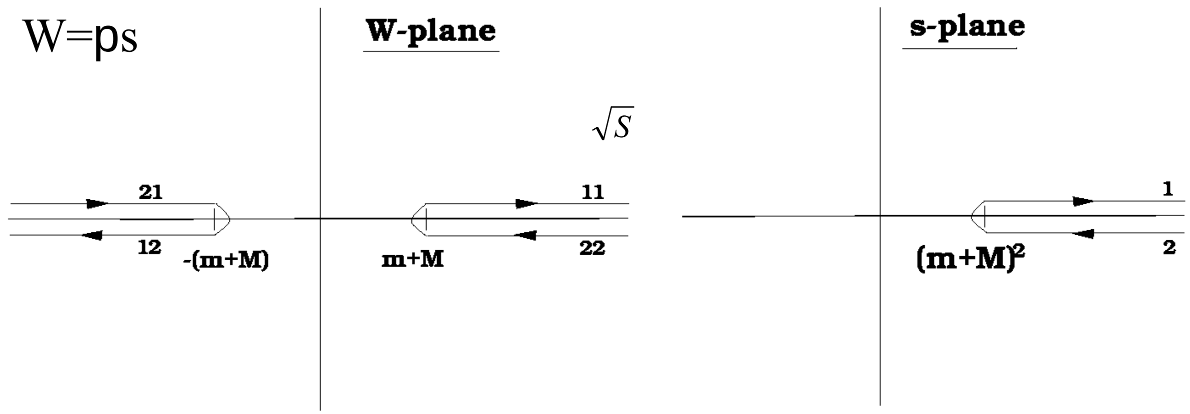
UCHPT makes an expansion of an ``Interacting Kernel´´ 

from the appropriate EFT and then the unitarity cut is fulfilled to all orders (non-perturbatively)

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:

$$\mathrm{Im}\, T_{ij} = \sum_k T_{ik}\rho_k T^*_{kj} \longrightarrow \mathrm{Im}\, T^{-1}_{ij} = -\rho_i\, \delta_{ij}$$ Unitarity Cut

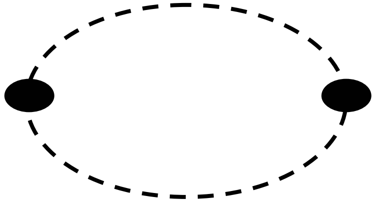


We perform a dispersion relation for the inverse of the partial wave (the discontinuity when crossing the unitarity cut is known)

$$T^{-1}_{ij} = R^{-1}_{ij} + \delta_{ij}\left(g(s_0)_i - \frac{s-s_0}{\pi}\int_{s_{th;i}}^{\infty} \frac{\rho(s')_i}{(s'-s-i0^+)(s'-s_0)} ds' \right)$$

The rest

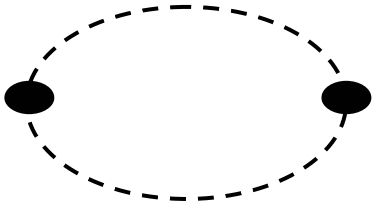
$g(s)_i$: Single unitarity bubble

g(s)= 

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

$$T = \left[R^{-1} + g(s)\right]^{-1} = [I + R \cdot g]^{-1} \cdot R \qquad \sigma(s) = \frac{2q}{\sqrt{s}}$$

1. T obeys a CHPT/alike expansion

g(s)= 

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

$$T \;=\; \left[R^{-1}+g(s)\right]^{-1} = [I + R\cdot g]^{-1}\cdot R \qquad \sigma(s)=\frac{2q}{\sqrt{s}}$$

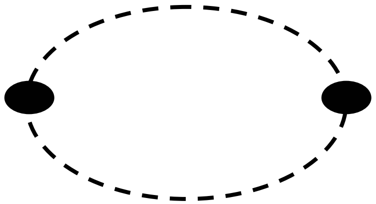
1. T obeys a CHPT/alike expansion $T = T_1 + T_2 + T_4 + \ldots$

2. R is fixed by matching algebraically with the CHPT/alike

CHPT/alike+Resonances

expressions of T, **R= $\mathbf{R_1}$+$\mathbf{R_2}$ $\mathbf{R_3}$+...**

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

The countingof R(s) is consequence of the known ones of g(s) and T(s) g(s)= 

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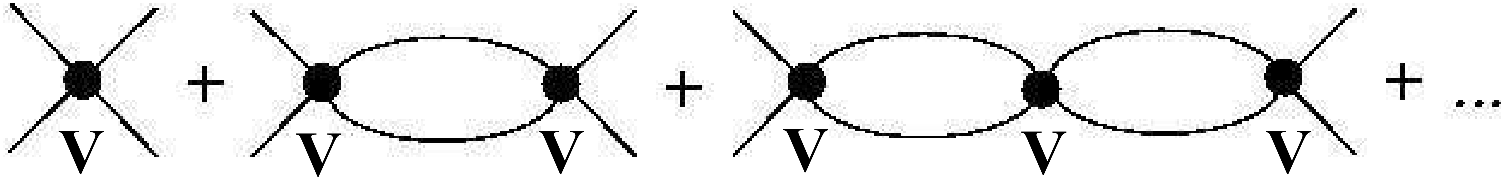
3. The CHPT/alike expansion is done to R(s). Crossed channel dynamics is included perturbatively.

Historically, the first approach to apply a Chiral expansion to an interacting KERNEL was:

S. Weinberg, PL B251(1990)288, NP B363(1991)3, PL B295 (1992)114 FOR THE NUCLEON-NUCLEON INTERACTIONS.

The Chiral expansion was applied to the set of two nucleon irreducible diagrams, THE POTENCIAL, which was then iterated through a Lippmann-Schwinger equation.



The solution to the LS equation is NUMERICAL

Further regularization is needed when solving the LS equation (cut-off dependence) so that the new divergences are not reabsorbed by the counterterms introduced in V

N. Kaiser, P.B. Siegel and W.Weise NP A594(1995)325 proceeded analogously in the S-wave strangeness= –1 meson-baryon sector

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

J.Prades, M. Verbeni, JAO PRL95,172502(05), PRL96,199202(06)(Reply)

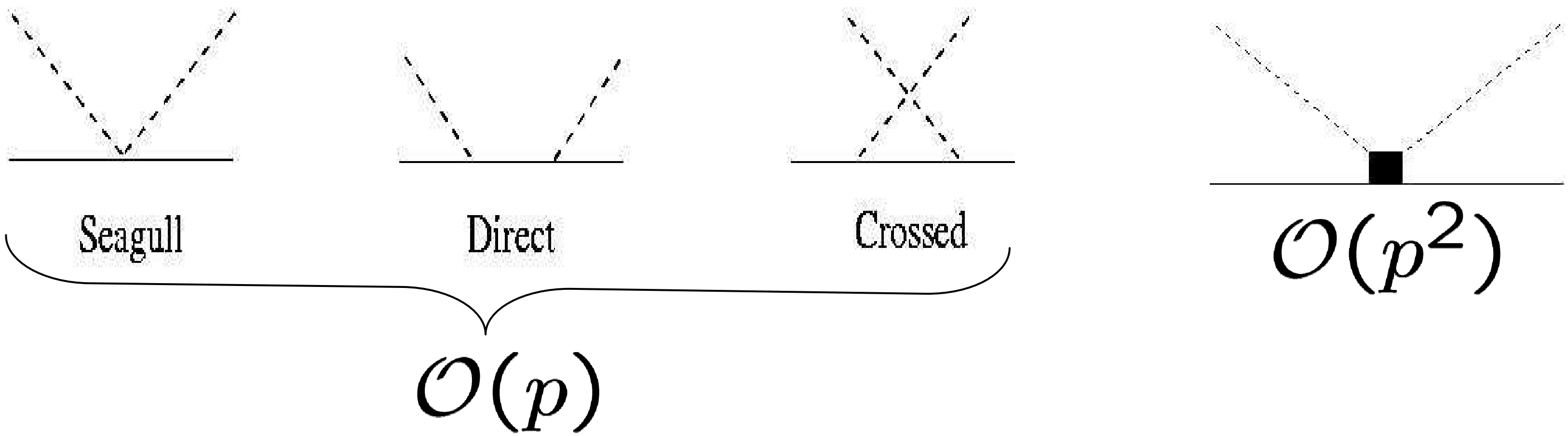
J.A. Oller, EPJA 28,63(2006)

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

$R = R_1 = T_1$ 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 $R_n \neq T_n$



$\mathcal{O}(p)$ and $\mathcal{O}(p^2)$ Chiral Lagrangians

$$\begin{aligned}\mathcal{L}_1 &= \langle i\bar{B}\gamma^\mu[D_\mu, B]\rangle - m_0\langle\bar{B}B\rangle \\ &+ \frac{D}{2}\langle\bar{B}\gamma^\mu\gamma_5\{u_\mu, B\}\rangle + \frac{F}{2}\langle\bar{B}\gamma^\mu\gamma_5[u_\mu, B]\rangle \ ,\end{aligned}$$

$D = 0.8, F = 0.46, m_0 =$proton mass in SU(3) chiral limit

$$\begin{aligned}\mathcal{L}_2 &= b_0\langle\bar{B}B\rangle\langle\chi_+\rangle + b_D\langle\bar{B}\{\chi_+, B\}\rangle + b_F\langle\bar{B}[\chi_+, B]\rangle \\ &+ b_1\langle\bar{B}[u_\mu,[u^\mu, B]]\rangle + b_2\langle\bar{B}\{u_\mu,\{u^\mu, B\}\}\rangle \\ &+ b_3\langle\bar{B}\{u_\mu,[u^\mu, B]\}\rangle + b_4\langle\bar{B}B\rangle\langle u_\mu u^\mu\rangle + \cdots \ .\end{aligned}$$

$U = e^{i\Phi/f}\ ,\ U = u^2\ ,\ u = e^{i\Phi/2f}\ ,\ u_\mu = iu^\dagger(\partial_\mu U)u^\dagger$

$\chi_+ = u^\dagger\chi u^\dagger + u\chi^\dagger u\ ,\ \chi = \begin{pmatrix} m_\pi^2 & 0 & 0 \\ 0 & m_\pi^2 & 0 \\ 0 & 0 & 2m_K^2 - m_\pi^2 \end{pmatrix}$

$$\Phi = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta \end{pmatrix} \quad B = \begin{pmatrix} \frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda}{\sqrt{6}} & \Sigma^+ & p \\ \Sigma^- & -\frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda}{\sqrt{6}} & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda \end{pmatrix}$$

EXPERIMENTAL DATA

S= – 1 meson-baryon sector is plenty of data

Good ground test for SU(3) chiral dynamics, where very strong SU(3) breaking effects due to the explicit presence of mesons/baryons with strangeness– Explicit breaking of chiral symmetry

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

I) DATA INCLUDED IN THE ANALYSIS

Prades,Verbeni,JAO PRL95,172502(05)

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 $p_{lab} = 0.2$ GeV.

2) Precisely Measured Ratios

$$\gamma = \frac{\sigma(K^- p \to \pi^+ \Sigma^-)}{\sigma(K^- p \to \pi^- \Sigma^+)} = 2.36 \pm 0.04 \; ,$$

$$R_c = \frac{\sigma(K^- p \to \text{charged particles})}{\sigma(K^- p \to \text{all})} = 0.664 \pm 0.011 \; ,$$

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

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

4) DEAR and KEK STRONG SHIFT AND WIDTH OF KAONIC HYDROGEN

5) WE ALSO CONSTRAINT OUR FITS CALCULATING AT O(p²) IN PURE BARYON CHPT SEVERAL PION-NUCLEON OBSERVABLES, WHERE CHPT EXPANSION IS 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

b_D, b_f and b_3 in terms of b_0, b_1 and b_2.

$$m_0 = m_p + 4m_K^2(b_0 + b_D - b_F) + 2m_\pi^2(b_0 + 2b_F) \; .$$

$\boldsymbol{\sigma_{\pi N}}$=20, 30, 40 MeV (45±8 from **Gasser,Leutwyler,Sainio PLB253,252 ('91),** higher order corrections §10 MeV **Gasser, AP254,192('97))**

$\mathbf{m_0}$=0.7 or 0.8 GeV

$\mathbf{a_{0+}^+}$=(-1± 1) m_π 10^{-2} Exp. –0.25± 0.49 **Schroder et al.,PLB469,25('99)** and expected higher order corrections $+m_\pi\,10^{-2}$ from unitarity **Bernard et al. PLB309,421('93).**

I) RECENT FURTHER DATA INCLUDED IN THE EXTENDED ANALYSIS ***JAO EPJA28,63(2006)***

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

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

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

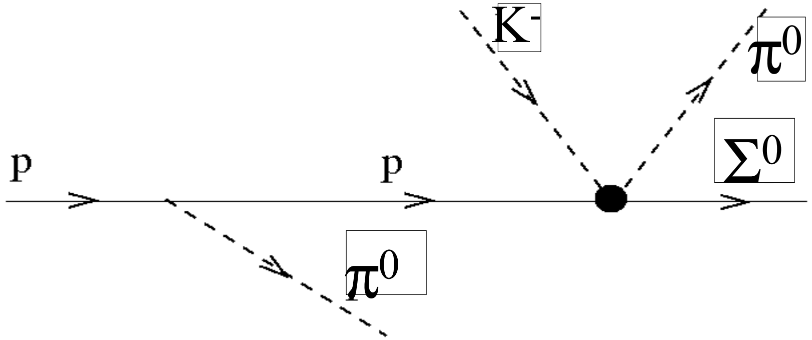
total cross-section and event distribution.

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 $\delta_P - \delta_S = (4.6 \pm 1.4)^\circ$.

HyperCP Collaboration

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



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

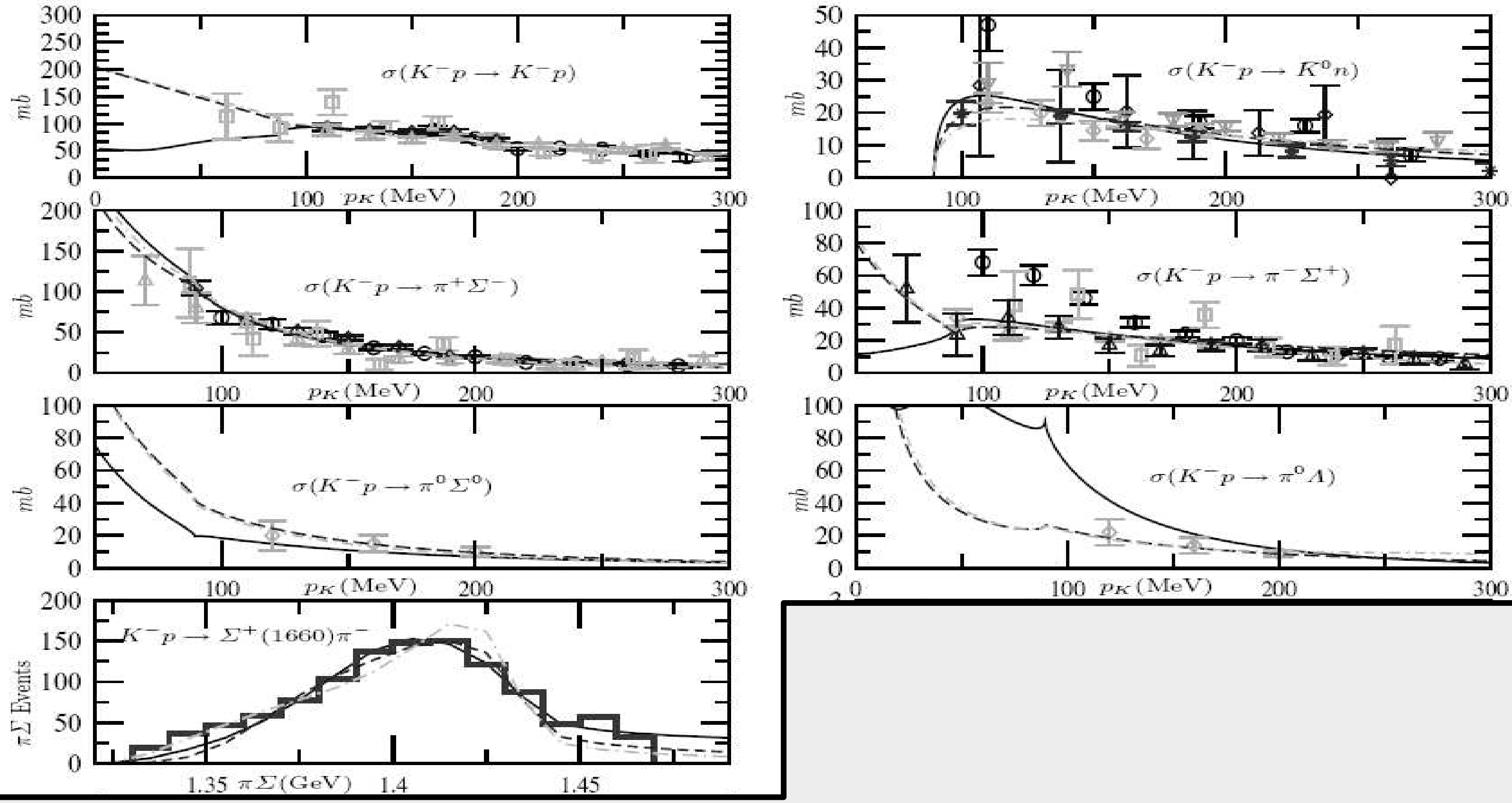
Which dominates due to the almost on-shell character of the intermediate proton.

The solid point means full K^- p ! π^0 Σ^0 S-wave

4. RESULTS

Two classes of fits A,B with 1s kaonic hydrogen ΔE and Γ :
A: Around DEAR (The fits are numerically more stable)
B: Away from DEAR.

Reproduction of the data by the fits of Prades,Verbeni,JAO PRL95('05), plus an O(p) fit.



Solid: Fit A. **Dashed**: Fit B. **Dash-Dotted**: O(p) Fit.

	A_4^+	B_4^+	$\mathcal{O}(p)$
γ	2.36	2.36	2.35
R_c	0.628	0.655	0.667
R_n	0.172	0.195	0.205
ΔE (eV)	201	403	390
Γ (eV)	338	477	525
ΔE_D (eV)	209	416	394
Γ_D (eV)	346	662	716
a_{K^-p} (fm)	$-0.51+i\,0.42$	$-1.01+i\,0.80$	$-0.96+i\,0.87$
a_0 (fm)	$-1.23+i\,0.45$	$-1.63+i\,0.81$	$-1.55+i\,0.87$
a_1 (fm)	$0.98+i\,0.35$	$-0.01+i\,0.54$	$-0.03+i\,0.65$
$\delta_{\pi\Lambda}(\Xi)$ (°)	2.5	0.2	−1.9
m_0 (GeV)	0.8*	0.8*	...
a_{0+}^+ $(10^{-2}\cdot M_\pi^{-1})$	−1.2	−1.7	...
$\sigma_{\pi N}$ (MeV)	40*	40*	...

Experiment

γ	2.36 ± 0.04
R_c	0.664 ± 0.011
R_n	0.189 ± 0.015
Δ_E	193 ± 38
Γ	249 ± 118
$\delta_{\pi\Lambda}$	4.6 ± 2

Units		A_4^+	B_4^+	$\mathcal{O}(p)$
MeV	f	79.8	89.2	88.0
GeV^{-1}	b_0	−0.855	−0.318	0*
GeV^{-1}	b_D	+0.715	−0.101	0*
GeV^{-1}	b_F	−0.036	−0.314	0*
GeV^{-1}	b_1	+0.605	−0.193	0*
GeV^{-1}	b_2	+1.075	−0.275	0*
GeV^{-1}	b_3	−0.189	−0.153	0*
GeV^{-1}	b_4	−1.249	−0.277	0*
	a_1	−1.155	−1.570	−0.472
	a_2	−0.383	−2.062	−1.572
	a_5	−1.304	−2.605	−1.266
	a_7	−1.519	−1.568	−1.853
	a_8	−1.212	−2.064	−1.210
	a_9	−0.145	−0.886	+3.337

Three b's are fixed in terms of the others from the $O(p^2)$ constraints

$\sigma_{\pi N} = 40$ MeV

$m_0 = 0.8$ GeV

$a_{0+}^+ = (-1 \pm 1) m_\pi^{-1} 10^{-2}$

$a_2 = a_3 = a_4$, $a_5 = a_6$, $a_9 = a_{10}$

	A_4^+	B_4^+	$\mathcal{O}(p)$
γ	2.36	2.36	2.35
R_c	0.628	0.655	0.667
R_n	0.172	0.195	0.205
ΔE (eV)	201	403	390
Γ (eV)	338	477	525
ΔE_D (eV)	209	416	394
Γ_D (eV)	346	662	716
a_{K^-p} (fm)	$-0.51 + i\,0.42$	$-1.01 + i\,0.80$	$-0.96 + i\,0.87$
a_0 (fm)	$-1.23 + i\,0.45$	$-1.63 + i\,0.81$	$-1.55 + i\,0.87$
a_1 (fm)	$0.98 + i\,0.35$	$-0.01 + i\,0.54$	$-0.03 + i\,0.65$
$\delta_{\pi\Lambda}(\Xi)$ (°)	2.5	0.2	−1.9
m_0 (GeV)	0.8*	0.8*	...
a_{0+}^+ ($10^{-2} \cdot M_\pi^{-1}$)	−1.2	−1.7	...
$\sigma_{\pi N}$ (MeV)	40*	40*	...

Experiment

γ	2.36 ± 0.04
R_c	0.664 ± 0.011
R_n	0.189 ± 0.015
Δ_E	193 ± 38
Γ	249 ± 118
$\delta_{\pi\Lambda}$	4.6 ± 2

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MeV	f	79.8	89.2	88.0
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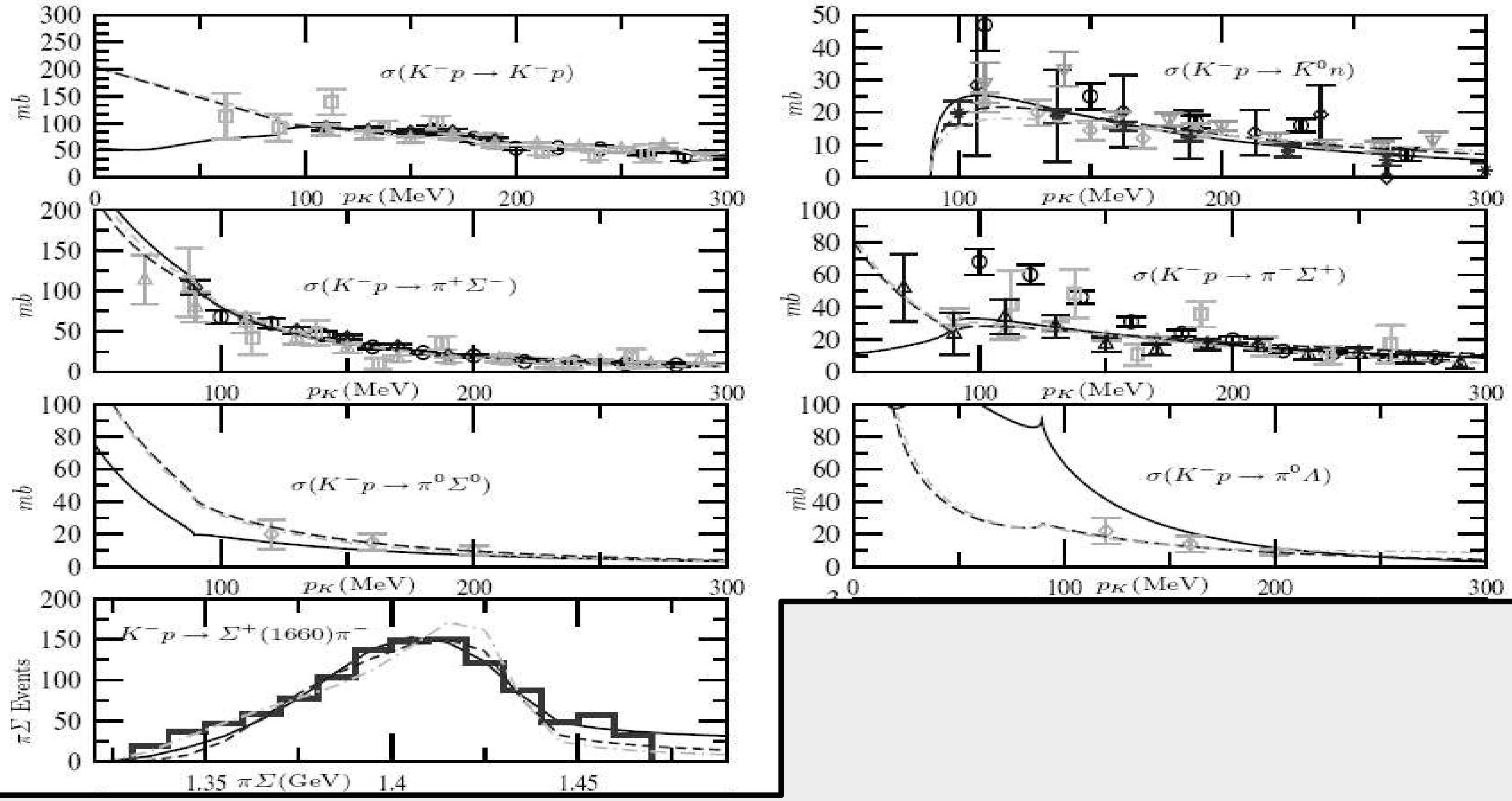
GeV^{-1}	b_F	−0.036	−0.314	0*
GeV^{-1}	b_1	+0.605	−0.193	0*
GeV^{-1}	b_2	+1.075	−0.275	0*
GeV^{-1}	b_3	−0.189	−0.153	0*
GeV^{-1}	b_4	−1.249	−0.277	0*
	a_1	−1.155	−1.570	−0.472
	a_2	−0.383	−2.062	−1.572
	a_5	−1.304	−2.605	−1.266
	a_7	−1.519	−1.568	−1.853
	a_8	−1.212	−2.064	−1.210
	a_9	−0.145	−0.886	+3.337

Fit A reproduces simultaneously scattering data plus DEAR measurement

It was the first chiral fit to accomplish this

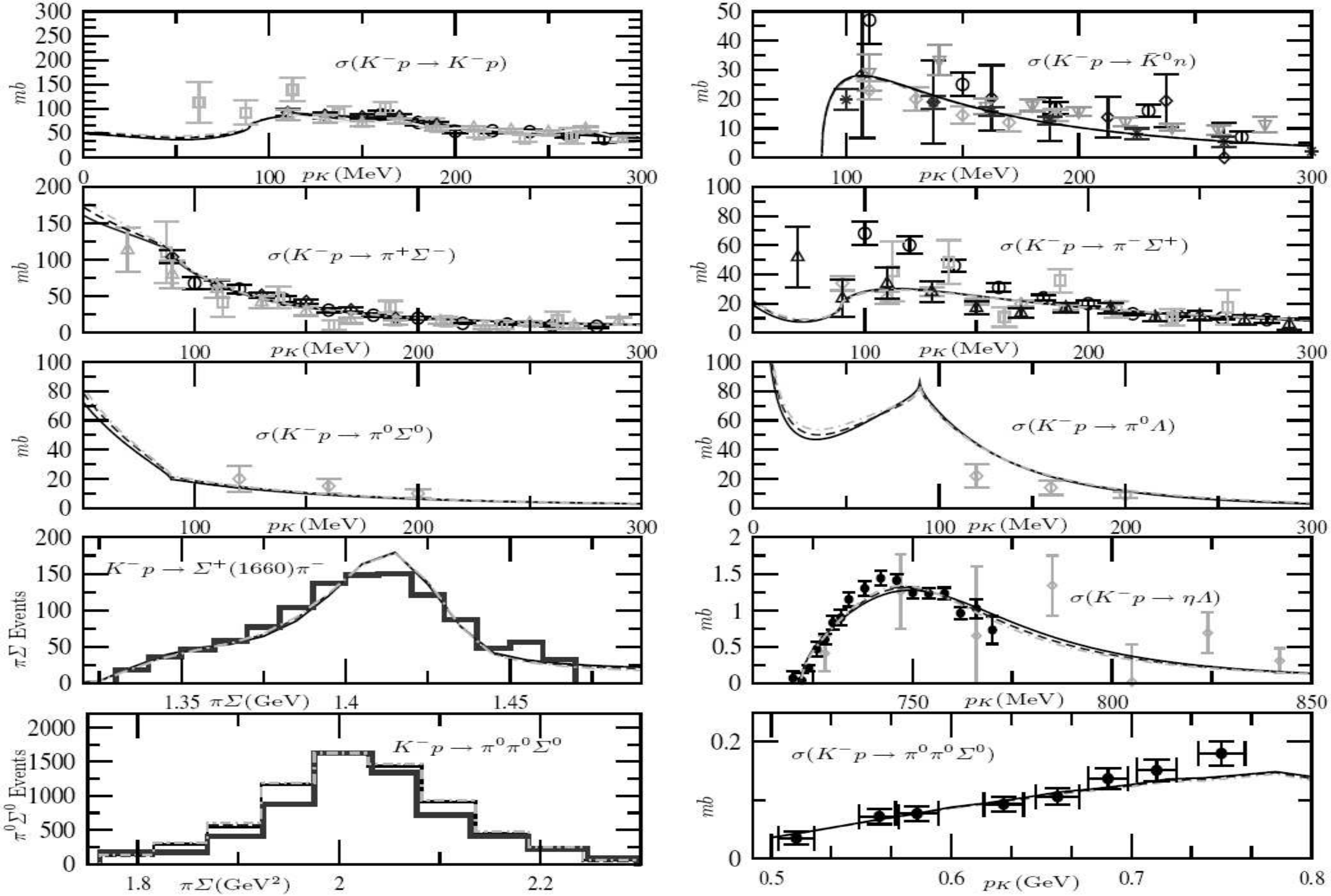
However, it fails to reproduce the Crystall Ball data.

Reproduction of the data by the fits of Prades,Verbeni,JAO PRL95('05), plus an O(p) fit.



Solid: Fit A. **Dashed**: Fit B. **Dash-Dotted**: O(p) Fit.

Reproduction of the data by the new A-type fits (agreement with DEAR) of **JAO, EPJA28,63('06)**



$\sigma_{\pi N}$	20*	30*	40*
γ	2.36	2.36	2.37
R_c	0.629	0.628	0.628
R_n	0.168	0.171	0.173
ΔE (eV)	194	192	192
Γ (eV)	324	302	270
ΔE_D (eV)	204	204	207
Γ_D (eV)	361	338	305
a_{K^-p} (fm)	$-0.49+i\,0.44$	$-0.49+i\,0.41$	$-0.50+i\,0.37$
a_0 (fm)	$-1.07+i\,0.53$	$-1.04+i\,0.50$	$-1.02+i\,0.45$
a_1 (fm)	$0.44+i\,0.15$	$0.40+i\,0.15$	$0.33+i\,0.14$
$\delta_{\pi\Lambda}(\Xi)$ (°)	3.4	4.5	5.7
m_0 (GeV)	1.2	1.1	1.0
a_{0+}^{+} ($10^{-2} \cdot M_\pi^{-1}$)	−2.0	−2.2	−2.2

Experiment

γ	2.36 ± 0.04
R_c	0.664 ± 0.011
R_n	0.189 ± 0.015
Δ_E	193 ± 38
Γ	249 ± 118
$\delta_{\pi\Lambda}$	4.6 ± 2

Units	$\sigma_{\pi N}$ MeV	20*	30*	40*
MeV	f	75.2	71.8	67.8
GeV^{-1}	b_0	−0.615	−0.750	−0.884
GeV^{-1}	b_D	+0.818	+0.848	+0.873
GeV^{-1}	b_F	−0.114	−0.130	−0.138
GeV^{-1}	b_1	+0.660	+0.670	+0.676
GeV^{-1}	b_2	+1.144	+1.169	+1.189
GeV^{-1}	b_3	−0.297	−0.316	−0.315
GeV^{-1}	b_4	−1.048	−1.181	−1.307
	a_1	−1.786	−1.591	−1.413
	a_2	−0.519	−0.454	−0.386
	a_5	−1.185	−1.170	−1.156
	a_7	−5.251	−5.209	−5.123
	a_8	−1.316	−1.310	−1.308
	a_9	−1.186	−1.132	−1.050

Units		A_4^+	B_4^+	$\mathcal{O}(p)$
MeV	f	79.8	89.2	88.0
GeV^{-1}	b_0	−0.855	−0.318	0*
GeV^{-1}	b_D	+0.715	−0.101	0*
GeV^{-1}	b_F	−0.036	−0.314	0*
GeV^{-1}	b_1	+0.605	−0.193	0*
GeV^{-1}	b_2	+1.075	−0.275	0*
GeV^{-1}	b_3	−0.189	−0.153	0*
GeV^{-1}	b_4	−1.249	−0.277	0*
	a_1	−1.155	−1.570	−0.472
	a_2	−0.383	−2.062	−1.572
	a_5	−1.304	−2.605	−1.266
	a_7	−1.519	−1.568	−1.853
	a_8	−1.212	−2.064	−1.210
	a_9	−0.145	−0.886	+3.337

Three b's are fixed in terms of the others from the $O(p^2)$ constraints

$\sigma_{\pi N}$	20*	30*	40*
γ	2.36	2.36	2.37
R_c	0.629	0.628	0.628
R_n	0.168	0.171	0.173
ΔE (eV)	194	192	192
Γ (eV)	324	302	270
ΔE_D (eV)	204	204	207
Γ_D (eV)	361	338	305
a_{K^-p} (fm)	$-0.49 + i\,0.44$	$-0.49 + i\,0.41$	$-0.50 + i\,0.37$
a_0 (fm)	$-1.07 + i\,0.53$	$-1.04 + i\,0.50$	$-1.02 + i\,0.45$
a_1 (fm)	$0.44 + i\,0.15$	$0.40 + i\,0.15$	$0.33 + i\,0.14$
$\delta_{\pi\Lambda}(\Xi)$ (°)	3.4	4.5	5.7
m_0 (GeV)	1.2	1.1	1.0
a^+_{0+} $(10^{-2} \cdot M_\pi^{-1})$	−2.0	−2.2	−2.2

Experiment

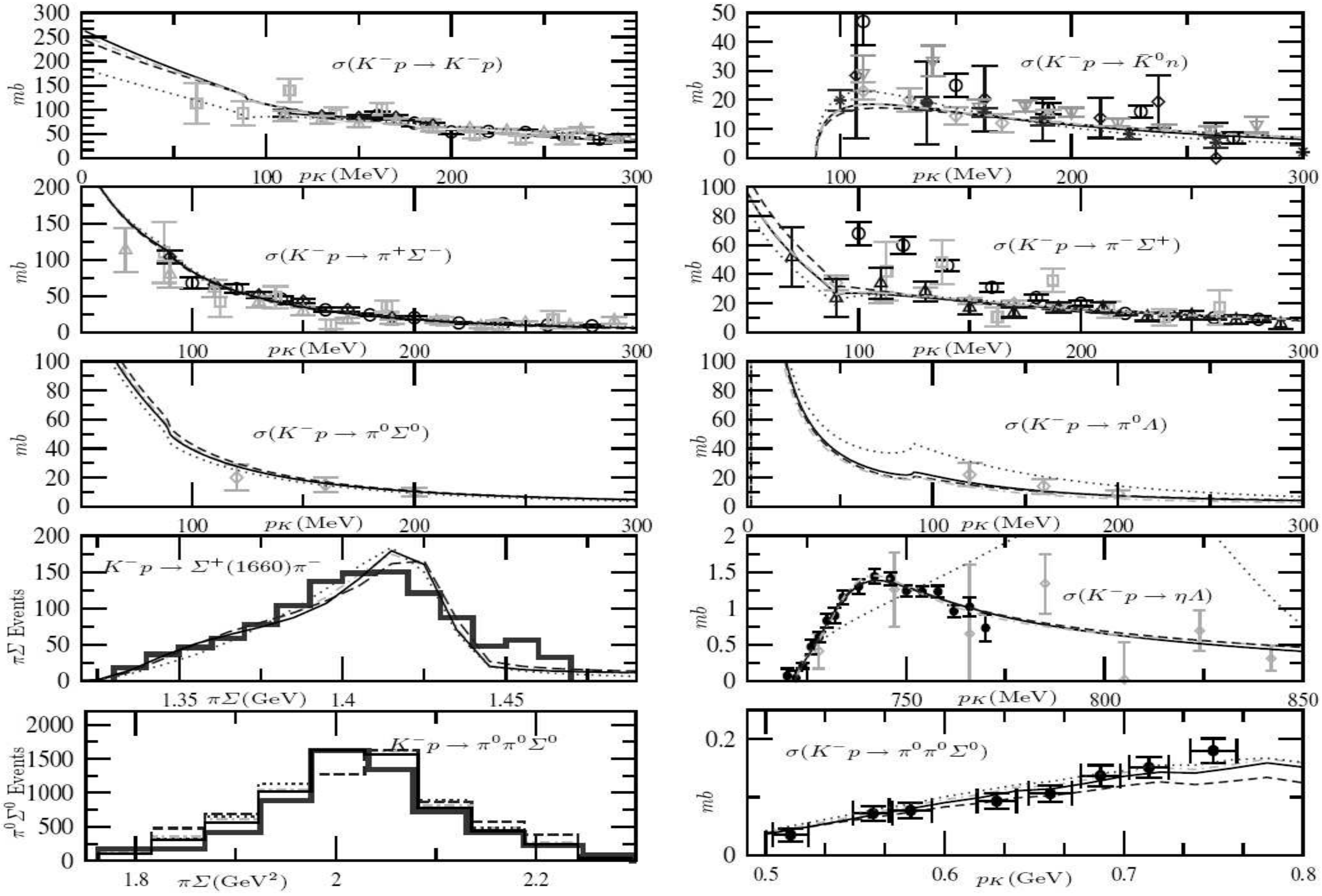
γ	2.36 ± 0.04
R_c	0.664 ± 0.011
R_n	0.189 ± 0.015
Δ_E	193 ± 38
Γ	249 ± 118
$\delta_{\pi\Lambda}$	4.6 ± 2

Units	$\sigma_{\pi N}$ MeV	20*	30*	40*
MeV	f	75.2	71.8	67.8
GeV^{-1}	b_0	−0.615	−0.750	−0.884
GeV^{-1}	b_D	+0.818	+0.848	+0.873
GeV^{-1}	b_F	−0.114	−0.130	−0.138
GeV^{-1}	b_1	+0.660	+0.670	+0.676
GeV^{-1}	b_2	+1.144	+1.169	+1.189
GeV^{-1}	b_3	−0.297	−0.316	−0.315
GeV^{-1}	b_4	−1.048	−1.181	−1.307
	a_1	−1.786	−1.591	−1.413
	a_2	−0.519	−0.454	−0.386
	a_5	−1.185	−1.170	−1.156
	a_7	−5.251	−5.209	−5.123
	a_8	−1.316	−1.310	−1.308
	a_9	−1.186	−1.132	−1.050

These fits agree with all the experimental dada, both scattering and atomic, including the most recent ones.

Three b's are fixed in terms of the others from the O(p^2) constraints

Reproduction of the data by the new B-type fits (do not agree with DEAR) of **JAO, EPJA28,63('06)**



Experiment

γ	2.36 ± 0.04
R_c	0.664 ± 0.011
R_n	0.189 ± 0.015
Δ_E	193 ± 38
Γ	249 ± 118
$\delta_{\pi\Lambda}$	4.6 ± 2

Units	$\sigma_{\pi N}$ MeV	20*	30*	40*	$\mathcal{O}(p)$
MeV	f	95.8	113.2	100.0	93.9
GeV^{-1}	b_0	−0.201	−0.159	−0.487	0*
GeV^{-1}	b_D	−0.005	−0.297	0.127	0*
GeV^{-1}	b_F	−0.133	−0.157	−0.188	0*
GeV^{-1}	b_1	+0.122	+0.016	+0.135	0*
GeV^{-1}	b_2	−0.080	−0.151	−0.037	0*
GeV^{-1}	b_3	−0.533	−0.281	−0.494	0*
GeV^{-1}	b_4	+0.028	−0.291	−0.173	0*
	a_1	+4.037	+4.188	+2.930	−2.958
	a_2	−2.063	−3.129	−2.400	−1.479
	a_5	−1.131	−1.214	−1.225	−1.330
	a_7	−3.488	−3.000	−2.795	−1.805
	a_8	−0.347	+0.642	+2.906	−0.655
	a_9	−1.767	−2.109	−1.913	−1.918

These fits disagree with DEAR but agree with KEK

The scattering length a_{K^-p} is much larger than in the A-type fits.

Numerically it is simpler to obtain A-type fits

Three b's are fixed in terms of the others from the $O(p^2)$ constraints

K^-p Scattering Length:

Martin, NPB179,33('81): a_{K^-p}= –0.67+i0.64 fm

Kaiser,Siegel,Weise, NPA594,325('95): a_{K^-p}= –0.97+i1.1 fm

Oset,Ramos, NPA635,99('98): a_{K^-p}= –0.99+i0.97 fm_

Meissner,JAO PLB500,263('01): a_{K^-p}= –0.75+i1.2 fm

Borasoy,Nissler,Weise,PRL94,213401('05), EPJA25,79('05):

a_{K^-p}= –0.51+i0.82 fm They Cannot reproduce the elastic K^-p ! K^-p cross sections nor the DEAR measurement (compromise)

hep-ph/0606108 a_{K^-p}= –1.05+i0.75 fm

Our works A_4^+: a_{K^-p}= –0.51+i 0.42 fm ; B_4^+: -1.01+i 0.80 fm

New A-type:

$\sigma_{\pi N}$	20*	30*	40*
a_{K^-p} (fm)	$-0.49+i\,0.44$	$-0.49+i\,0.41$	$-0.50+i\,0.37$
a_0 (fm)	$-1.07+i\,0.53$	$-1.04+i\,0.50$	$-1.02+i\,0.45$
a_1 (fm)	$0.44+i\,0.15$	$0.40+i\,0.15$	$0.33+i\,0.14$

New B-type:

$\sigma_{\pi N}$	20*	30*	40*	$\mathcal{O}(p)$
a_{K^-p} (fm)	$-1.01+i\,1.03$	$-0.93+i\,1.07$	$-1.06+i\,1.02$	$-0.79+i\,0.94$
a_0 (fm)	$-1.75+i\,1.15$	$-1.65+i\,1.30$	$-1.79+i\,1.10$	$-1.50+i\,1.00$
a_1 (fm)	$-0.13+i\,0.39$	$-0.14+i\,0.36$	$-0.12+i\,0.46$	$0.32+i\,0.46$

$$\Delta E - \frac{i}{2}\Gamma = -2\alpha^3\mu_c a_{K^-p}\left(1 - 2\alpha(\log\alpha - 1)\mu_c a_{K^-p}\right)$$
$$= -2\alpha^3\mu_c^2 a_{K^-p}\left(1 - \frac{a_{K^-p}}{a_{\text{Coulomb}}}\right)$$

$$a_{\text{Coulomb}} = \frac{1/\mu_c\alpha}{2(\log\alpha - 1)} = \frac{83.57}{-11.84} = -7.06 \text{ fm}$$

a_{K^-p}=-0.5+i 0.4 fm (A)

a_{K^-p}=-1+i 1 fm (B)

Similarly for a_{K^-p}=-1+i 0.8 fm (Borasoy et al hep-ph/0606108)

$$\left|\frac{a_{K^-p}}{a_{\text{Coulomb}}}\right| =$$

	(A)	(B)
	8%	**20%**
	$O(\delta^{3/2})$' **4%**	$O(\delta^{3/2})$'**14%**

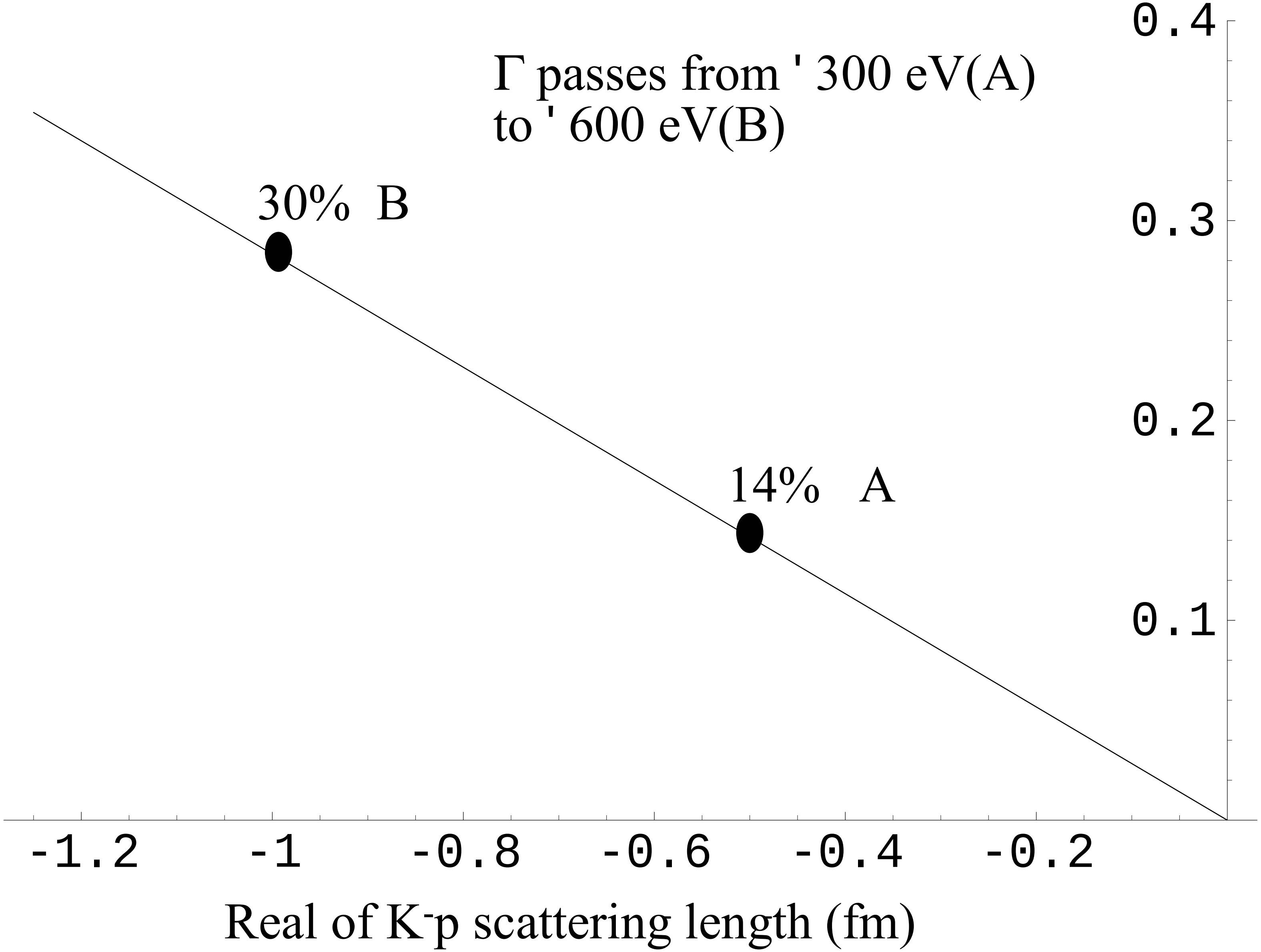
ΔE passes from ' 190 eV(A) to ' 450 eV(B)

One is talking about a factor 2 of difference

Which is the energy range of applicability of the formalism ofMeissner&Rusetsky&Raha? What happens if one studies isospin breaking effects in scattering at another energy close to threshold? The Λ(1405) resonance is very close (1414-i 23) MeV. Strong energy dependence.

K^-p threshold: 1432 MeV ; $\overline{K}^0n$ threshold: 1437.2 MeV

Im(MRR-Desser)/Im(Deser), only depends on the real part of the $K^{-}p$ scattering length. Isospin Breaking Corrections.



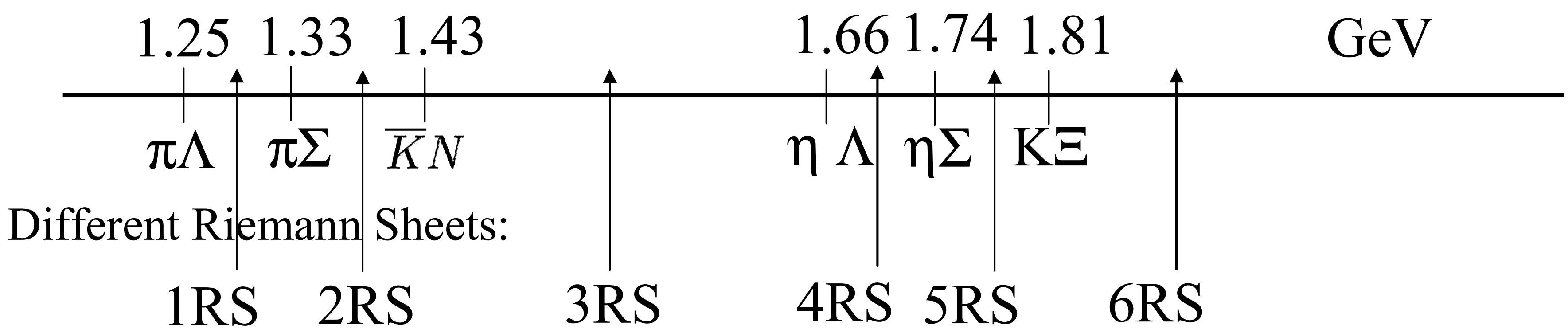
5. SPECTROSCOPY

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

Residues

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

Physical Riemann Shet



Fit I: New A-type fit with $\sigma_{\pi N}$=40 MeV

I=0 Poles (MeV)

Λ(1310)

Λ(1405)

PDG:M=1405.5§ 4

Γ=50§ 2

Λ(1670)

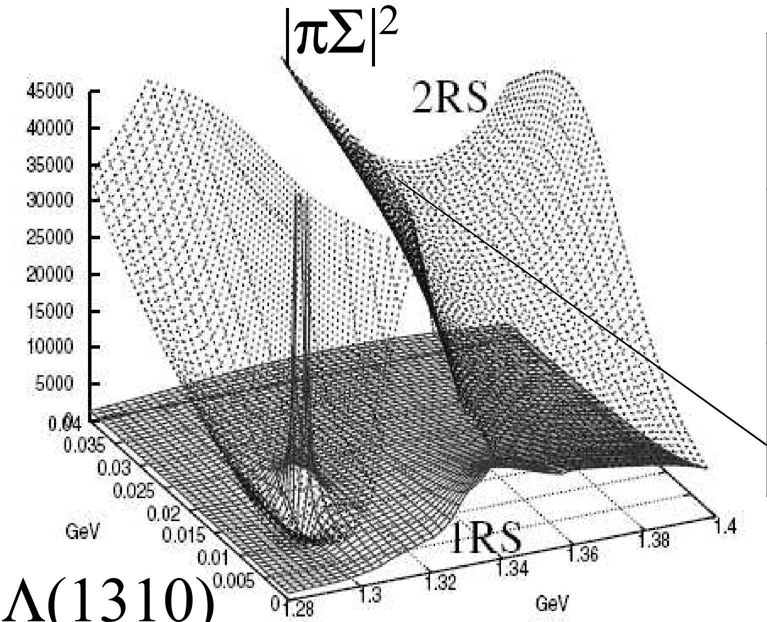
PDG:M=1670§ 10

Γ=35§ 15

Λ(1800)

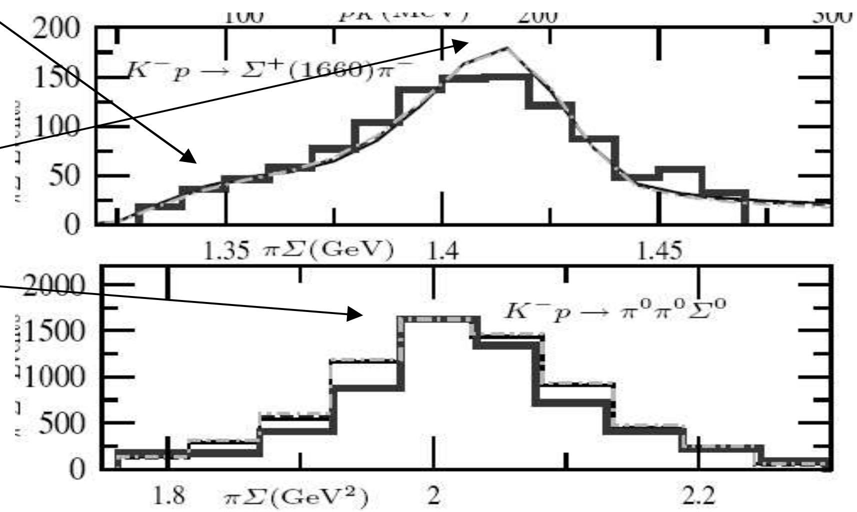
PDG:M=1700-1900

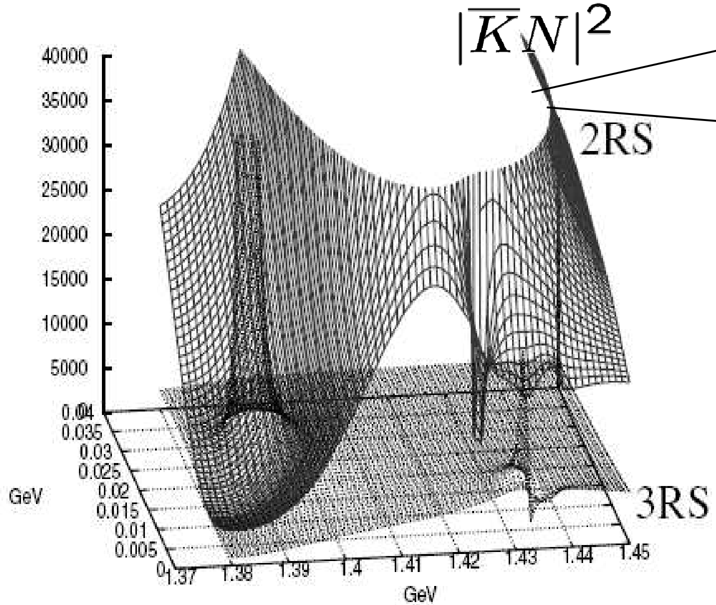
Γ=65 - 600



Λ(1310)

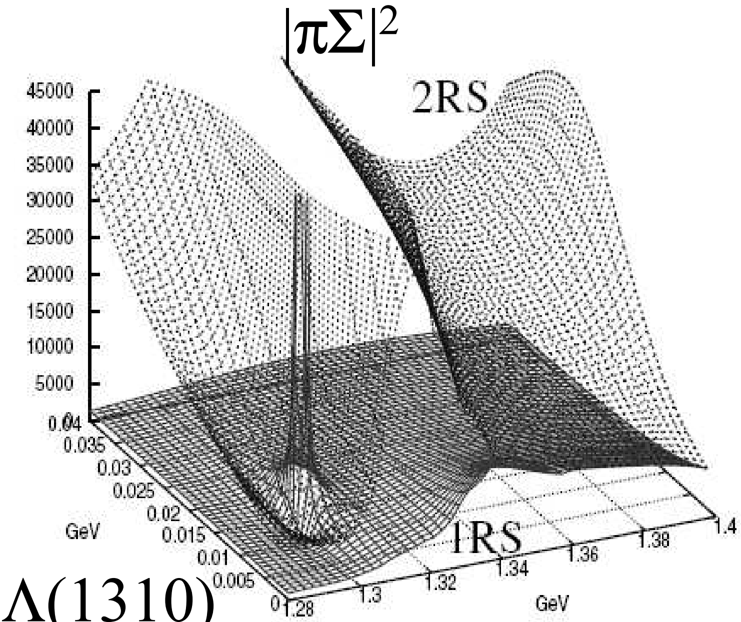
Re(Pole)	-Im(Pole)	Sheet							
$\|\gamma_{\pi\Lambda}\|$	$\|\gamma_{\pi\Sigma}\|_0$	$\|\gamma_{\pi\Sigma}\|_1$	$\|\gamma_{\pi\Sigma}\|_2$	$\|\gamma_{\bar{K}N}\|_0$	$\|\gamma_{\bar{K}N}\|_1$	$\|\gamma_{\eta\Lambda}\|$	$\|\gamma_{\eta\Sigma}\|$	$\|\gamma_{K\Xi}\|_0$	$\|\gamma_{K\Xi}\|_1$
1301	13	1RS							
0.03	1.12	0.02	0.01	5.83	0.05	0.41	0.04	2.11	0.03
1309	13	2RS							
0.02	3.66	0.02	0.02	4.46	0.04	0.21	0.04	3.05	0.03





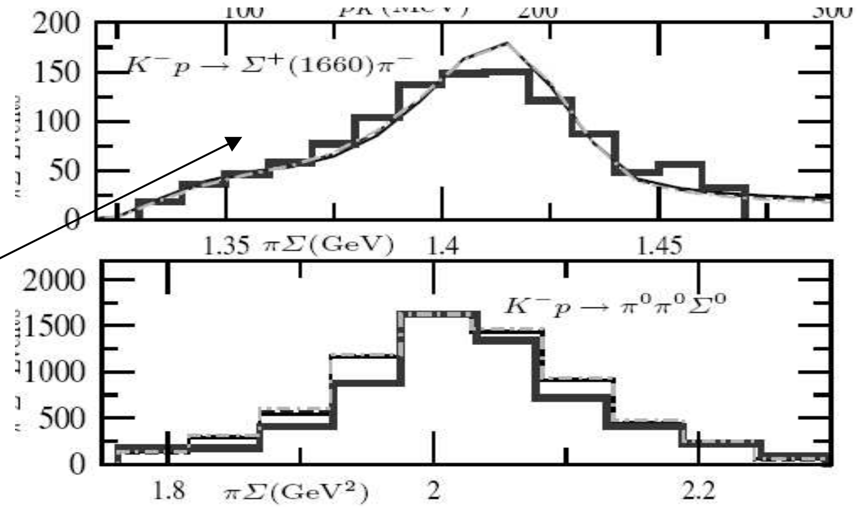
Λ(1405)

Re(Pole)	-Im(Pole)	Sheet							
$\|\gamma_{\pi\Lambda}\|$	$\|\gamma_{\pi\Sigma}\|_0$	$\|\gamma_{\pi\Sigma}\|_1$	$\|\gamma_{\pi\Sigma}\|_2$	$\|\gamma_{\bar{K}N}\|_0$	$\|\gamma_{\bar{K}N}\|_1$	$\|\gamma_{\eta\Lambda}\|$	$\|\gamma_{\eta\Sigma}\|$	$\|\gamma_{K\Xi}\|_0$	$\|\gamma_{K\Xi}\|_1$
1414	23	2RS							
0.14	4.24	0.13	0.01	4.87	0.39	0.85	0.20	9.35	0.11
1388	17	3RS							
0.02	3.81	0.02	0.02	1.33	0.04	0.42	0.04	9.55	0.04



$\Lambda(1310)$

Re(Pole)	-Im(Pole)	Sheet							
$\lvert\gamma_{\pi\Lambda}\rvert$	$\lvert\gamma_{\pi\Sigma}\rvert_0$	$\lvert\gamma_{\pi\Sigma}\rvert_1$	$\lvert\gamma_{\pi\Sigma}\rvert_2$	$\lvert\gamma_{\bar{K}N}\rvert_0$	$\lvert\gamma_{\bar{K}N}\rvert_1$	$\lvert\gamma_{\eta\Lambda}\rvert$	$\lvert\gamma_{\eta\Sigma}\rvert$	$\lvert\gamma_{K\Xi}\rvert_0$	$\lvert\gamma_{K\Xi}\rvert_1$
1301	13	1RS							
0.03	1.12	0.02	0.01	5.83	0.05	0.41	0.04	2.11	0.03
1309	13	2RS							
0.02	3.66	0.02	0.02	4.46	0.04	0.21	0.04	3.05	0.03



The second $\Lambda(1405)$ washed out. Moves to even lower energies and it reduces on the real axis to strong $\pi\Sigma$ cusp effect

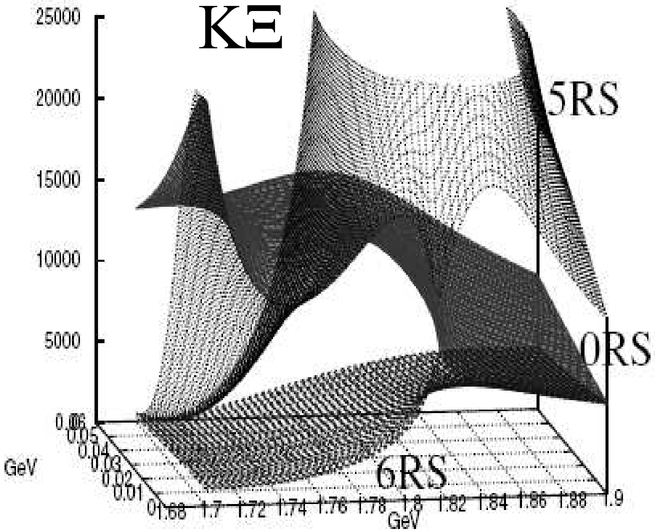
This pole depends strongly on the approach employed and value of the parameters

Λ(1670)

Re(Pole)	-Im(Pole)	Sheet							
$\|\gamma_{\pi\Lambda}\|$	$\|\gamma_{\pi\Sigma}\|_0$	$\|\gamma_{\pi\Sigma}\|_1$	$\|\gamma_{\pi\Sigma}\|_2$	$\|\gamma_{\bar{K}N}\|_0$	$\|\gamma_{\bar{K}N}\|_1$	$\|\gamma_{\eta\Lambda}\|$	$\|\gamma_{\eta\Sigma}\|$	$\|\gamma_{K\Xi}\|_0$	$\|\gamma_{K\Xi}\|_1$
1676	10	3RS							
0.01	1.28	0.03	0.00	1.67	0.01	2.19	0.07	5.29	0.07
1673	18	4RS							
0.01	1.26	0.02	0.00	1.82	0.01	2.13	0.06	5.32	0.06

Assymetry in the width, before the ηΛ threshold Γ=20 MeV and above Γ=36 MeV

Λ(1800)



Re(Pole)	-Im(Pole)	Sheet							
$\|\gamma_{\pi\Lambda}\|$	$\|\gamma_{\pi\Sigma}\|_0$	$\|\gamma_{\pi\Sigma}\|_1$	$\|\gamma_{\pi\Sigma}\|_2$	$\|\gamma_{\bar{K}N}\|_0$	$\|\gamma_{\bar{K}N}\|_1$	$\|\gamma_{\eta\Lambda}\|$	$\|\gamma_{\eta\Sigma}\|$	$\|\gamma_{K\Xi}\|_0$	$\|\gamma_{K\Xi}\|_1$
1825	49	5RS							
0.02	2.29	0.02	0.00	2.10	0.02	0.89	0.03	7.43	0.09

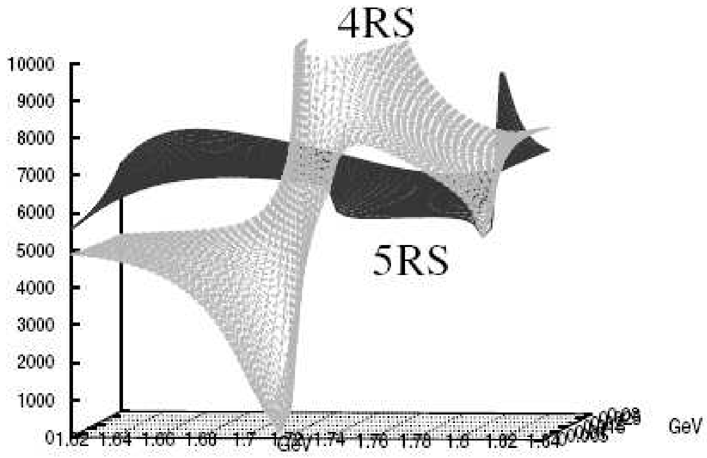
I=1 Poles (MeV)

Σ(1750)

PDG:M=1730-1800

Γ=50 - 160

Σ(1750)

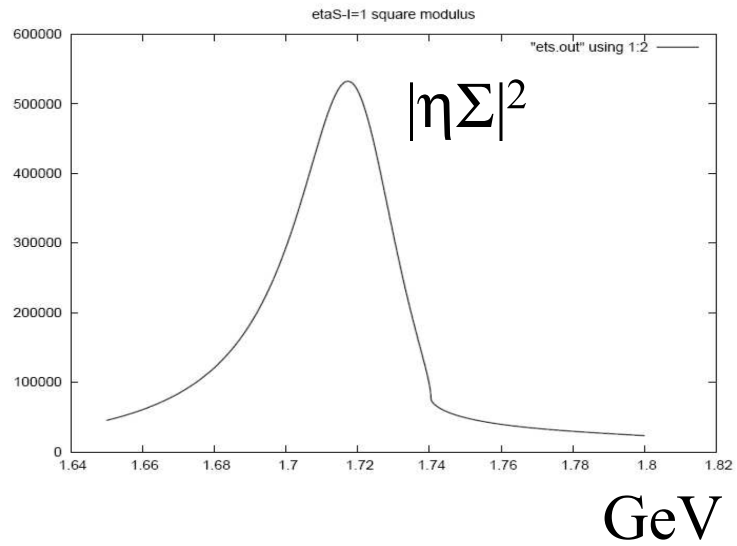


Re(Pole)	-Im(Pole)	Sheet							
$\lvert\gamma_{\pi\Lambda}\rvert$	$\lvert\gamma_{\pi\Sigma}\rvert_0$	$\lvert\gamma_{\pi\Sigma}\rvert_1$	$\lvert\gamma_{\pi\Sigma}\rvert_2$	$\lvert\gamma_{\bar{K}N}\rvert_0$	$\lvert\gamma_{\bar{K}N}\rvert_1$	$\lvert\gamma_{\eta\Lambda}\rvert$	$\lvert\gamma_{\eta\Sigma}\rvert$	$\lvert\gamma_{K\Xi}\rvert_0$	$\lvert\gamma_{K\Xi}\rvert_1$
1720	18	4RS							
1.82	0.02	1.21	0.00	0.02	0.95	0.02	6.78	0.05	5.31

For the open channels πΛ, πΣ , $\overline{K}N$ it is a distorted bump

For the closed channels ηΣ and KΞ it is a clear resonance shape. Much larger coupling constants.

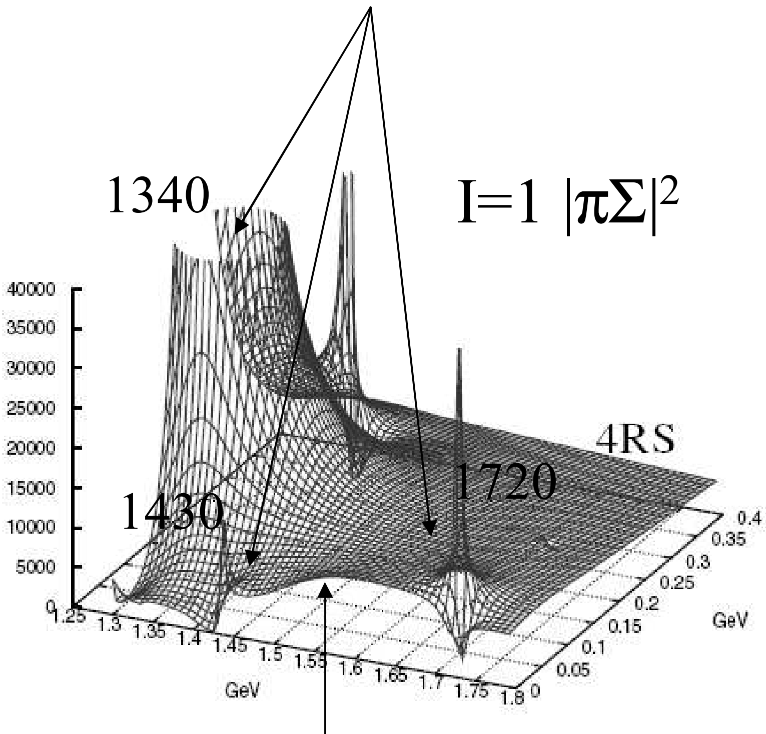
Physical Axis



Σ(1620)

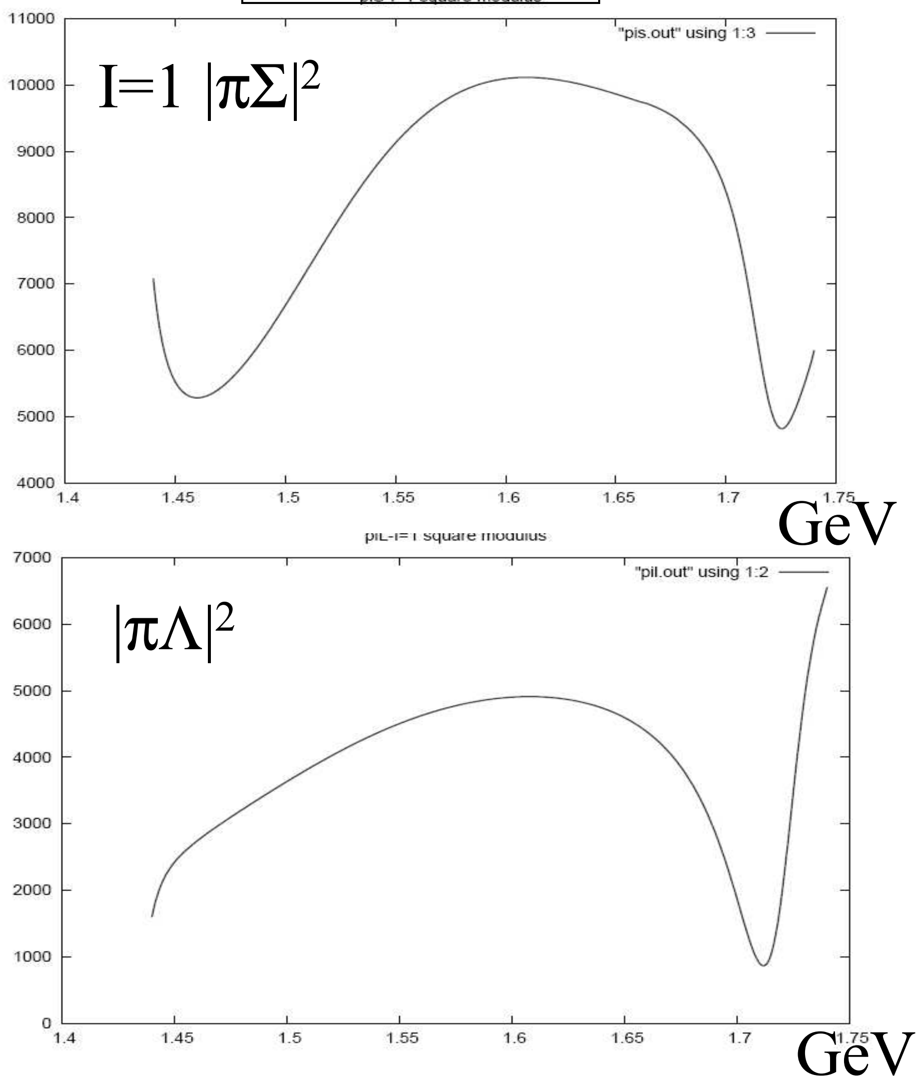
The amplitudes show a broad bumpt after the $\overline{K}N$ threshold and before that of the ηΣ

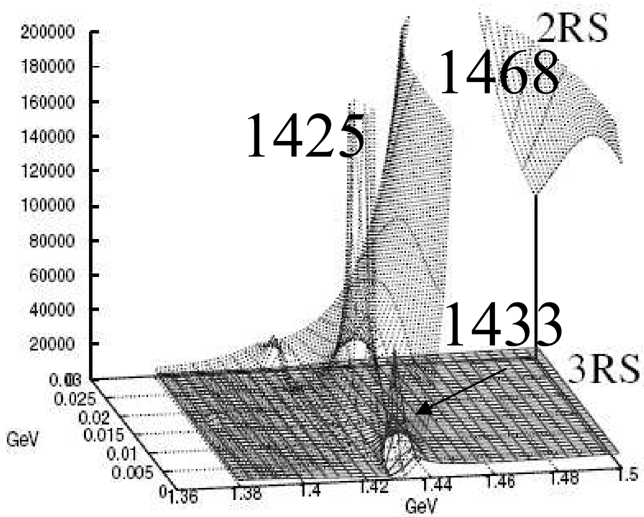
Multipole interference effect



Σ(1620) Bump

Physical Axis

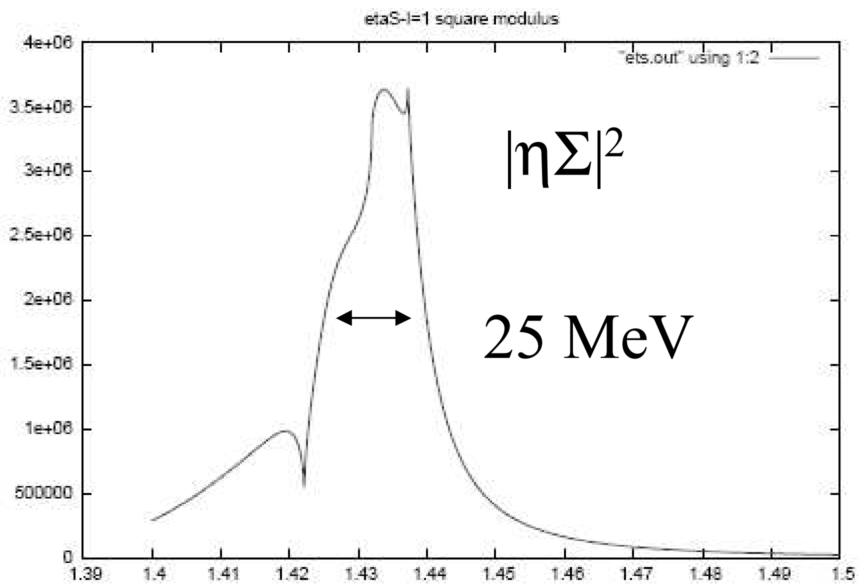


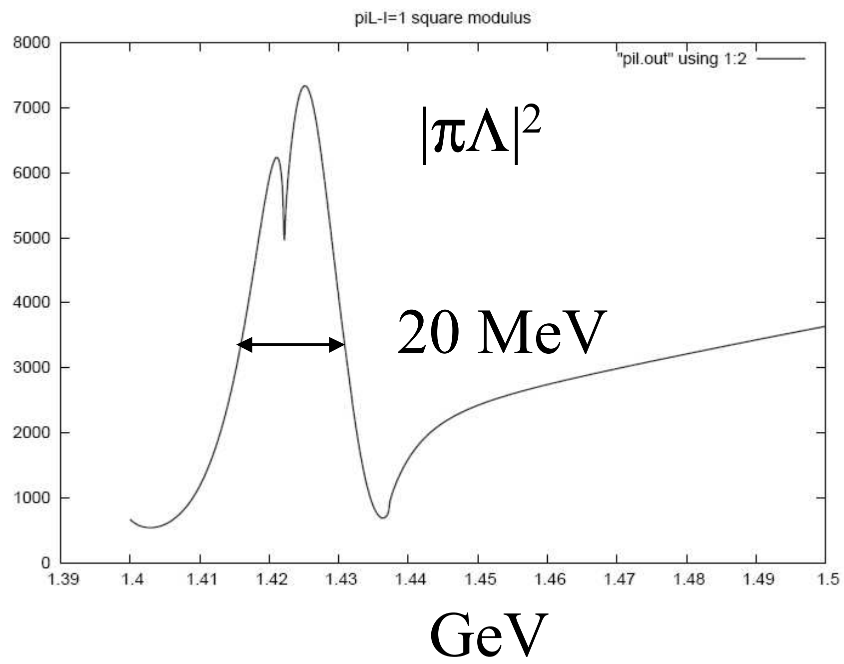


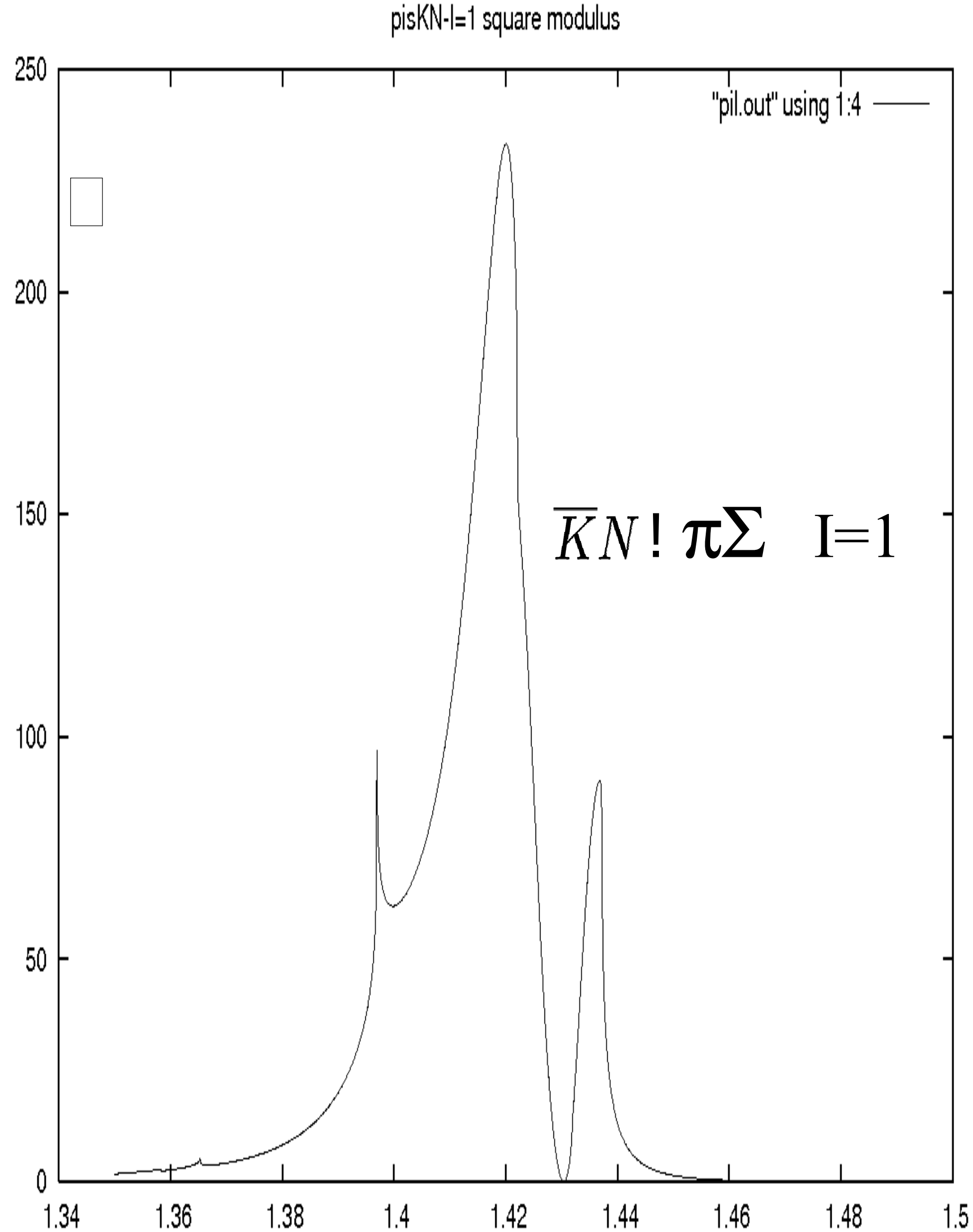
Re(Pole)	-Im(Pole)	Sheet							
$\lvert\gamma_{\pi\Lambda}\rvert$	$\lvert\gamma_{\pi\Sigma}\rvert_0$	$\lvert\gamma_{\pi\Sigma}\rvert_1$	$\lvert\gamma_{\pi\Sigma}\rvert_2$	$\lvert\gamma_{\bar{K}N}\rvert_0$	$\lvert\gamma_{\bar{K}N}\rvert_1$	$\lvert\gamma_{\eta\Lambda}\rvert$	$\lvert\gamma_{\eta\Sigma}\rvert$	$\lvert\gamma_{K\Xi}\rvert_0$	$\lvert\gamma_{K\Xi}\rvert_1$
1425	6.5	2RS							
1.35	0.24	1.66	0.01	0.35	3.92	0.05	4.23	0.49	2.98
1468	13	2RS							
2.80	0.16	5.96	0.02	0.23	8.74	0.04	10.66	0.19	2.48
1433	3.7	3RS							
0.65	0.08	0.80	0.00	0.12	1.58	0.02	5.82	0.20	2.14

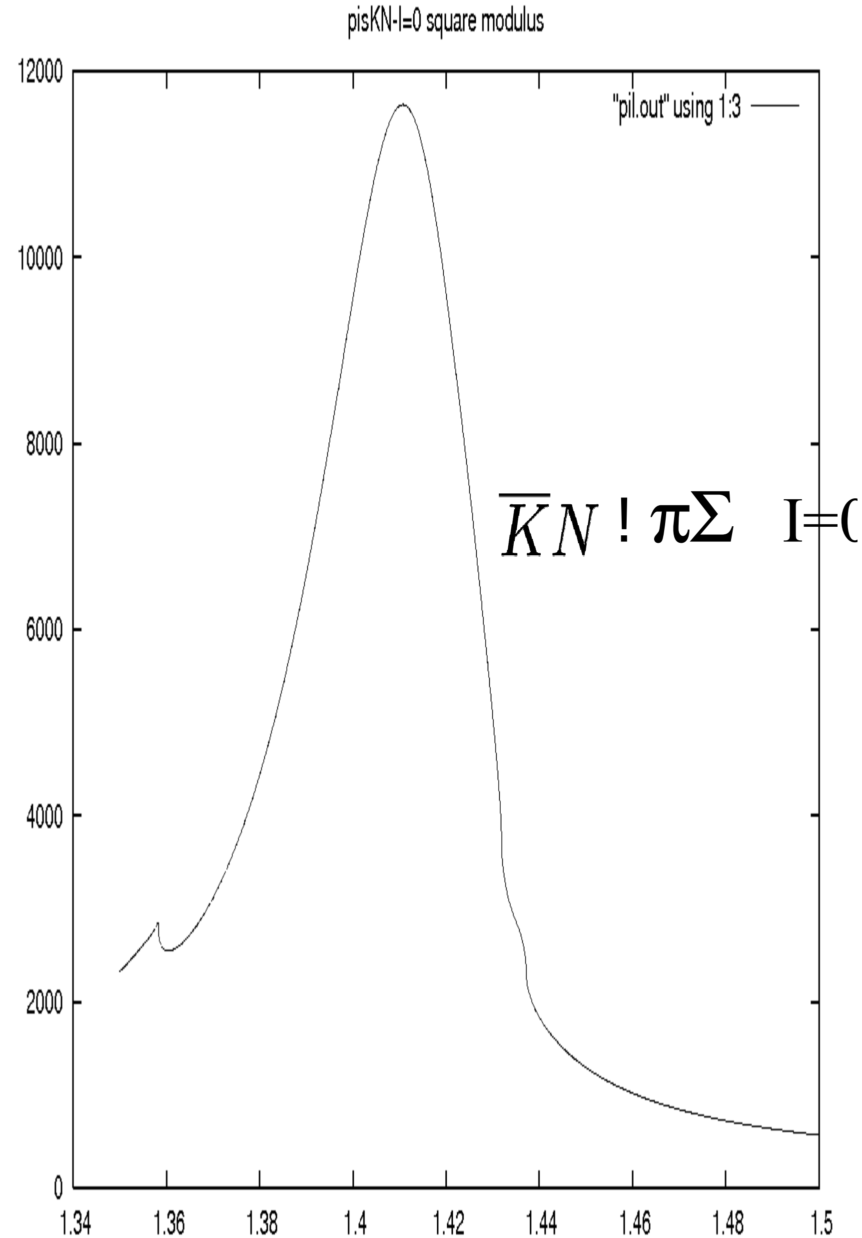
Σ(1480) Bumps * in PDG. Observation by COSY PRL96,012002('06)

On the physical axis between 1.4 and 1.5 GeV





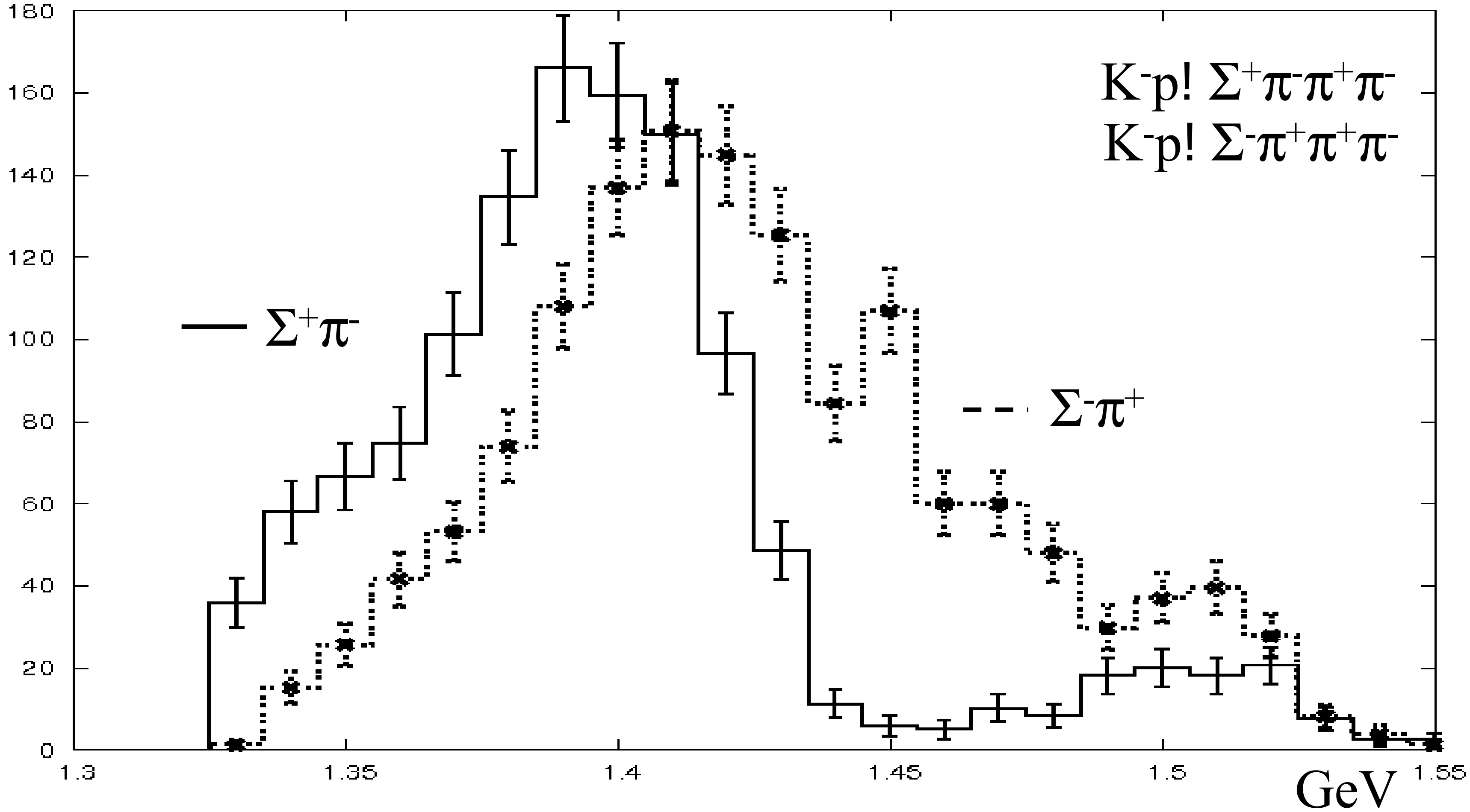

pisKN-I=1 square modulus
"pil.out" using 1:4
$\overline{K}N \,!\, \pi\Sigma$ I=1
250
200
150
100
50
0
1.34
1.36
1.38
1.4
1.42
1.44
1.46
1.48
1.5


pisKN-I=0 square modulus
"pil.out" using 1:3
$\overline{K}N \,!\, \pi\Sigma$ I=(
12000
10000
8000
6000
4000
2000
0
1.34
1.36
1.38
1.4
1.42
1.44
1.46
1.48
1.5

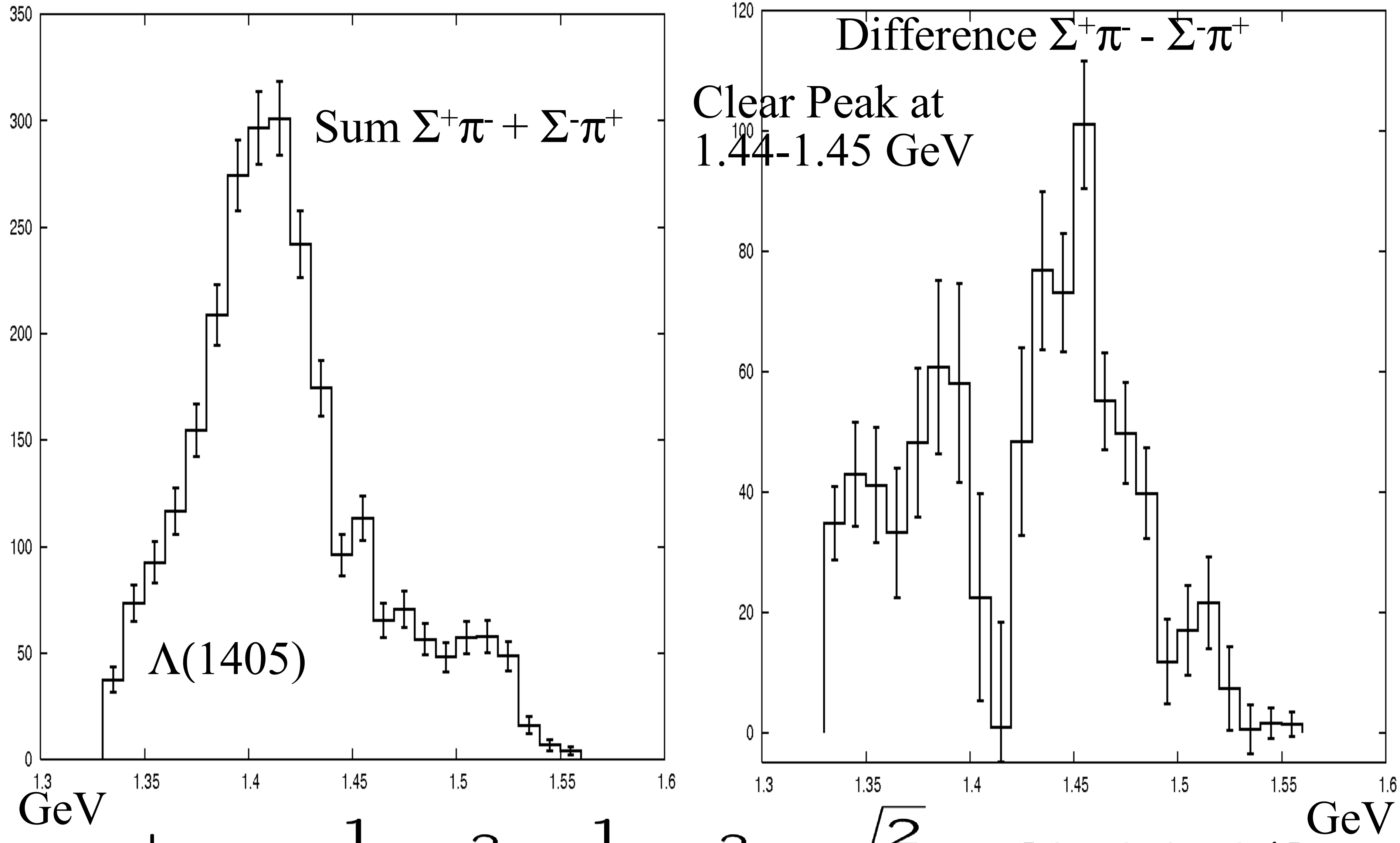
Borasoy et al in hep-ph/0606108 do not considering those fits producing I=1 resonances with Im(W)>-50 MeV

Evidence about the fact that I=1 is not so flat....

From experiment: R.J. Hemingway, NPB253,742(´85)



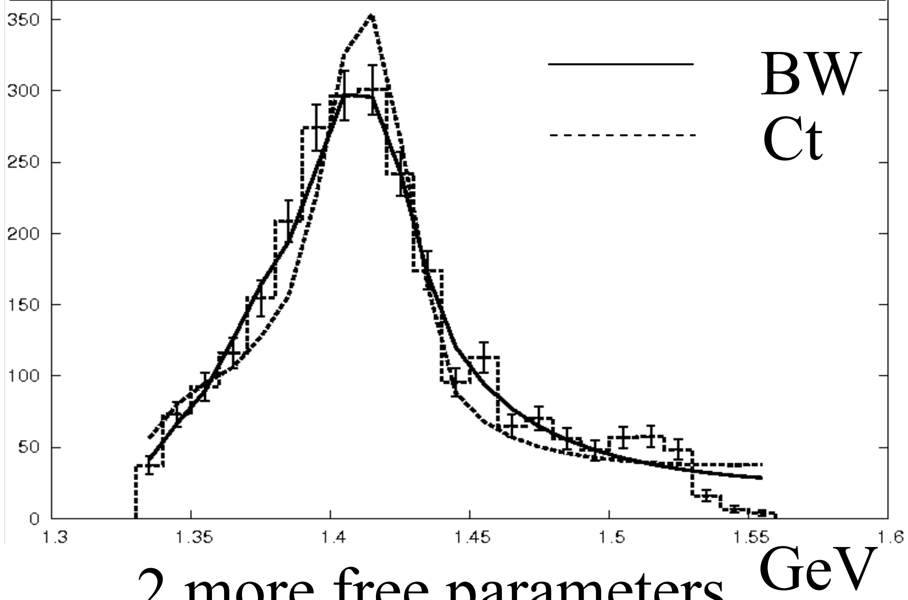
The spectrum is not the same, although I=0 component is the same in $\Sigma^+\pi^-$ and $\Sigma^-\pi^+$ The position of the peak is shifted



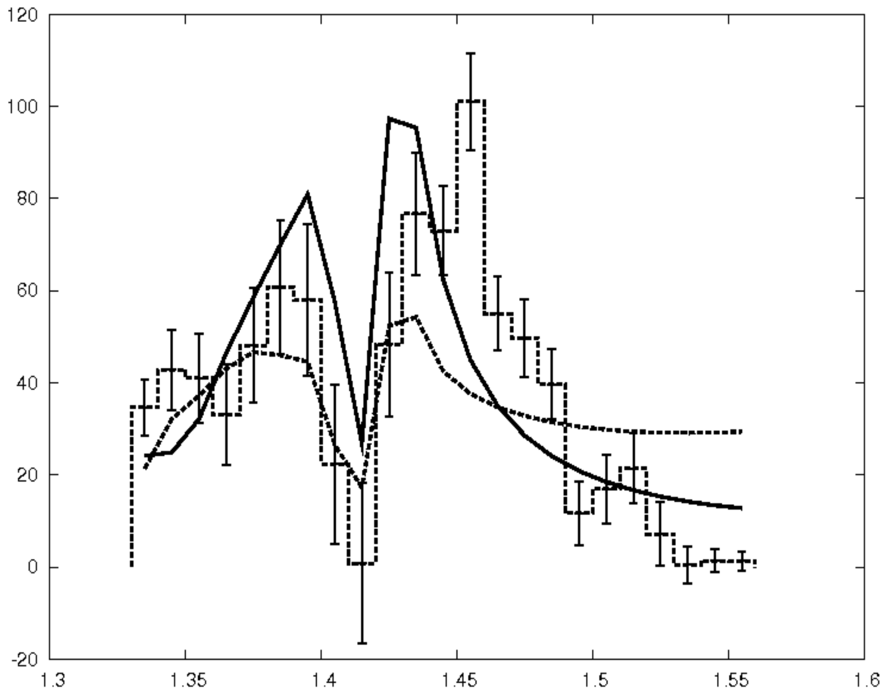
$$\Sigma^+\pi^- \propto \frac{1}{2}|I_0|^2 + \frac{1}{3}|I_1|^2 + \sqrt{\frac{2}{6}}\mathrm{Re}\left[(I_0)(I_1)^*\right]$$

$$\Sigma^-\pi^+ \propto \frac{1}{2}|I_0|^2 + \frac{1}{3}|I_1|^2 - \sqrt{\frac{2}{6}}\mathrm{Re}\left[(I_0)(I_1)^*\right]$$

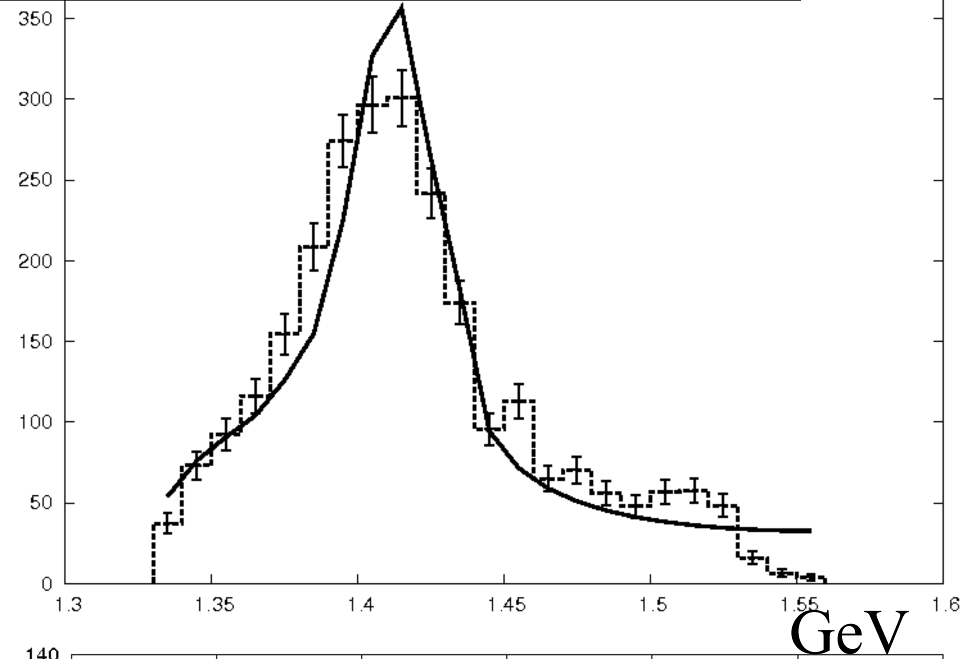
I=1 with a BW&Ct Term

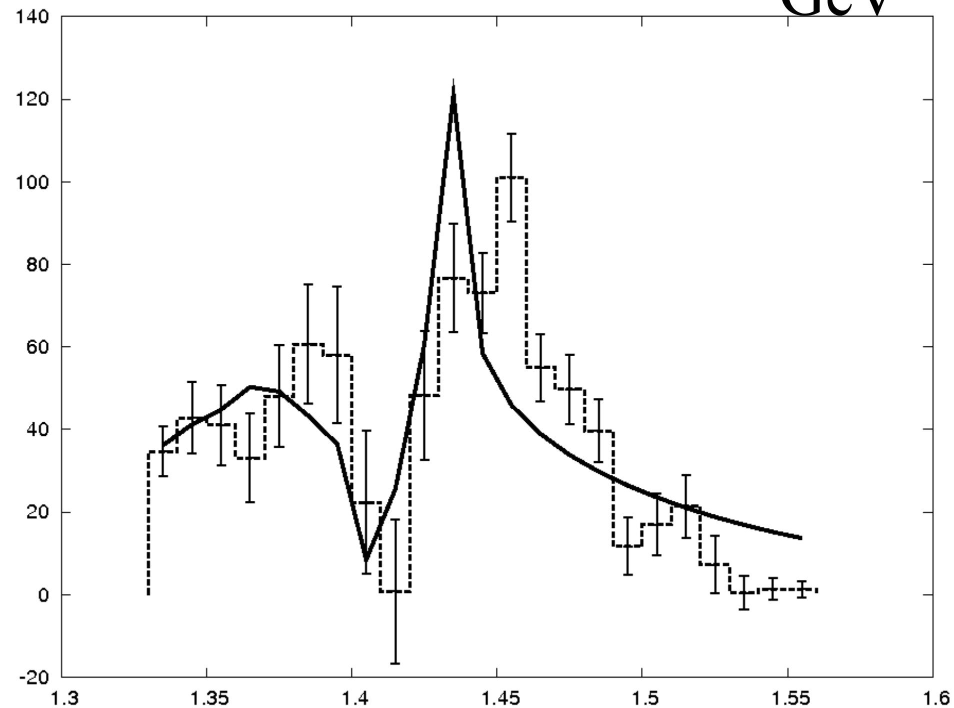


2 more free parameters



I=1 from our amplitudes

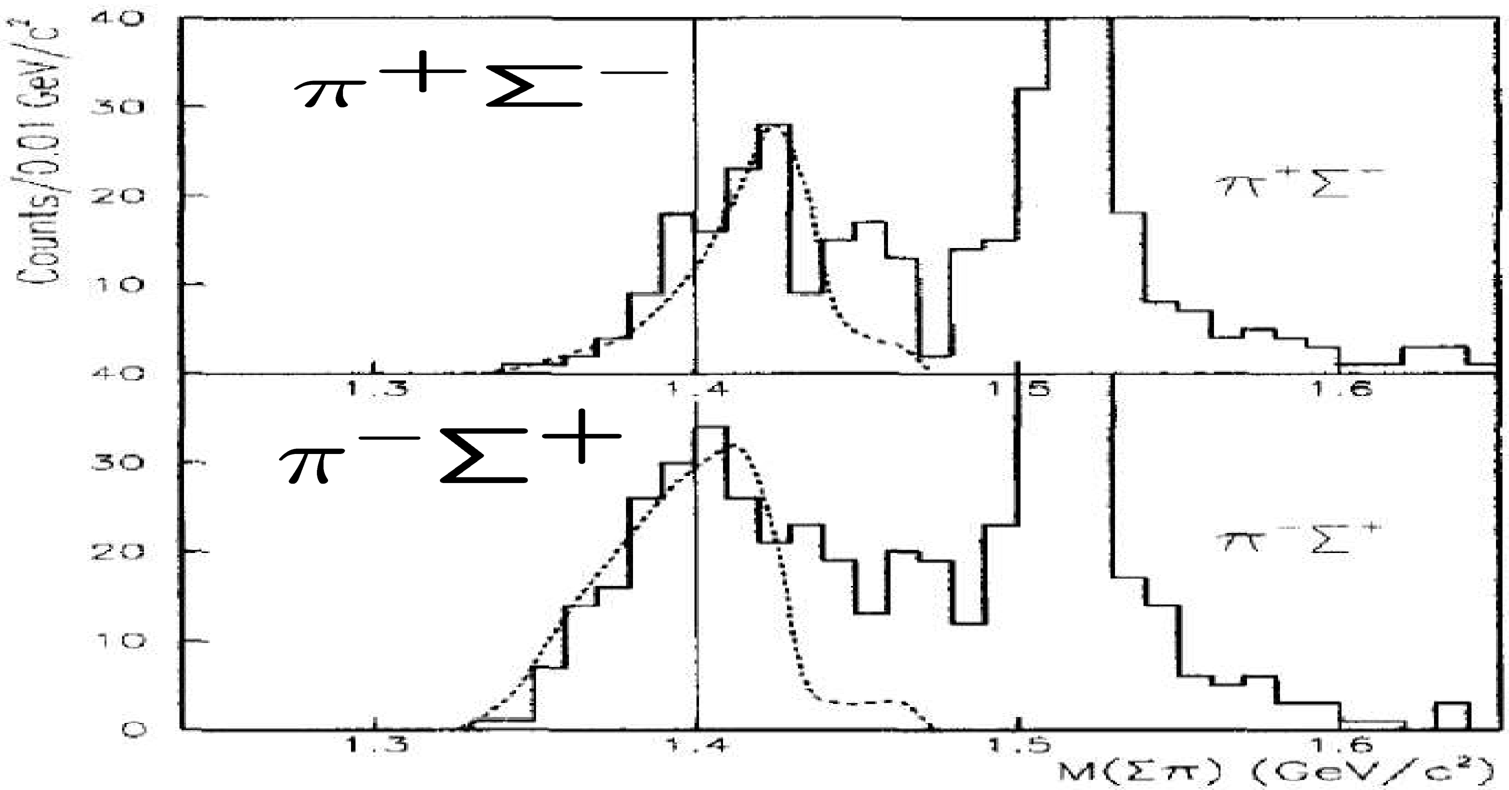




ONE MORE REACTION

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

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

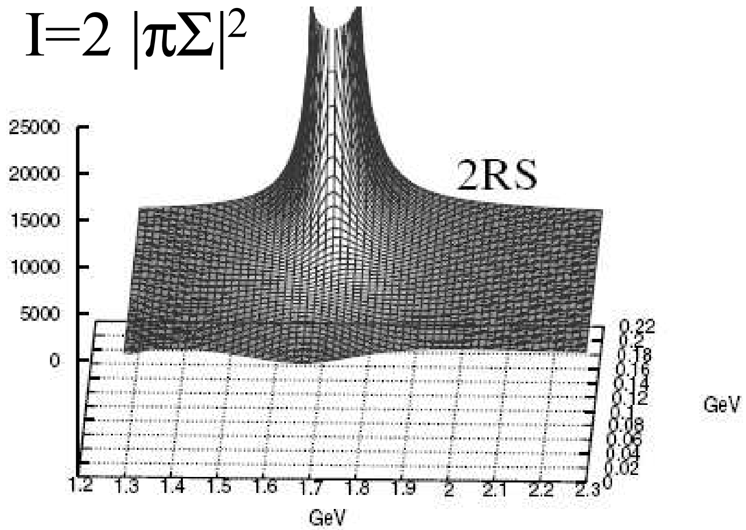


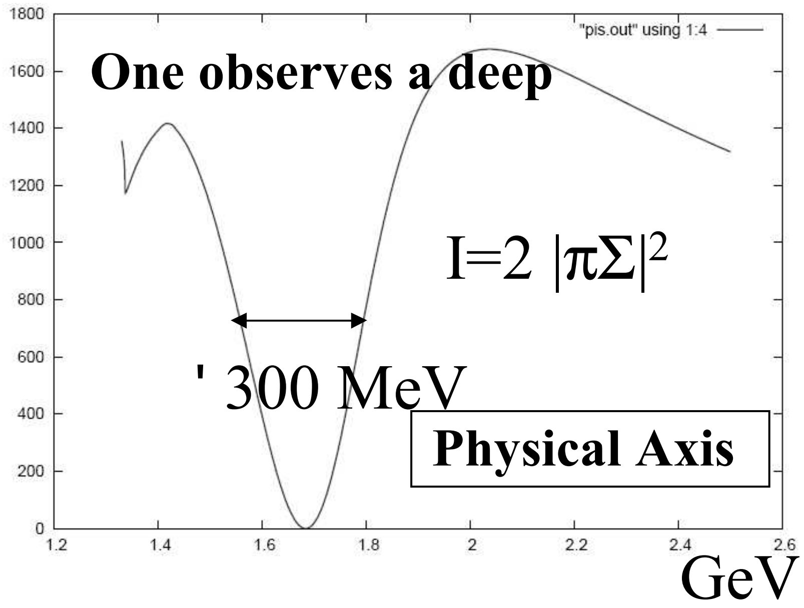
LINE: theory

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

I=2 Pole (MeV) at 1722-i 181 MeV

Exotic state





The only resonance in I=2

Non uniform shape for $\pi\Sigma$. I=2 is of size not negligibly small compared with the other $\pi\Sigma$ isospin channels.

Fit I: New A-type fit with $\sigma_{\pi N}$=40 MeV

I=0: Λ(1310), Λ(1405), Λ(1670), Λ(1800)

I=1: Σ(1480), Σ(1620), Σ(1750)

Fit II: New B-type fit with $\sigma_{\pi N}$=40 MeV

I=0: Λ(1350), Λ(1405), Λ(1670) , ~~Λ(1800)~~

I=1: Σ(1480), ~~Σ(1620)~~, ~~Σ(1750)~~

Only in $\overline{K}N$

8- 8=1©8_s©8_a©10©10 ©27

Fit I: has attractive SU(3) kernels for 1, 8_s, 8_a, 27. This can accomodate 4 I=0 and 3 I=1 resonances.

Fit II: has attractive SU(3) kernels for 1, 8_s, 8_a, 10. This can accomodate 3 I=0 and 3 I=1 resonances.

4. CONCLUSIONS

1. A UCHPT study of meson-baryon dynamics with strangeness=-1 in S-wave up to NNLO or $O(p^2)$
2. We reproduce simultaneously scattering data, including the recent and precise results from the Crystall Ball Collaboration, and atomic data on kaonic hydrogen given by the DEAR Collaboration with the A-type fits.
3. We also find other fits, B-type, that do not reproduce DEAR, but agree with KEK and with scattering data.
4. The A-type fits are also able to generate the four Λ's: Λ(1310), Λ(1405), Λ(1670), Λ(1800). All the ones quoted in PDG with $1/2^-$ in this energy range.
5. These fits also generate the I=1 resonances quoted in the PDG: Σ(1440), Σ(1620) and Σ(1750). **5+6** is a UNIQUE feature in the literature.
6. The B-type fits are not able to generate a comparable set of resonances. The Λ(1800) and the Σ(1750) are missing.

7. We have also shown some evidence about the presence of I=1 resonances close to the $\bar{K}N$ threshold.
8. Fits A are preferred over Fits B with present information.
9. ***$a_{K^- p} = -0.5 + i\, 0.4$ fm***

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Maigmó, Alicante

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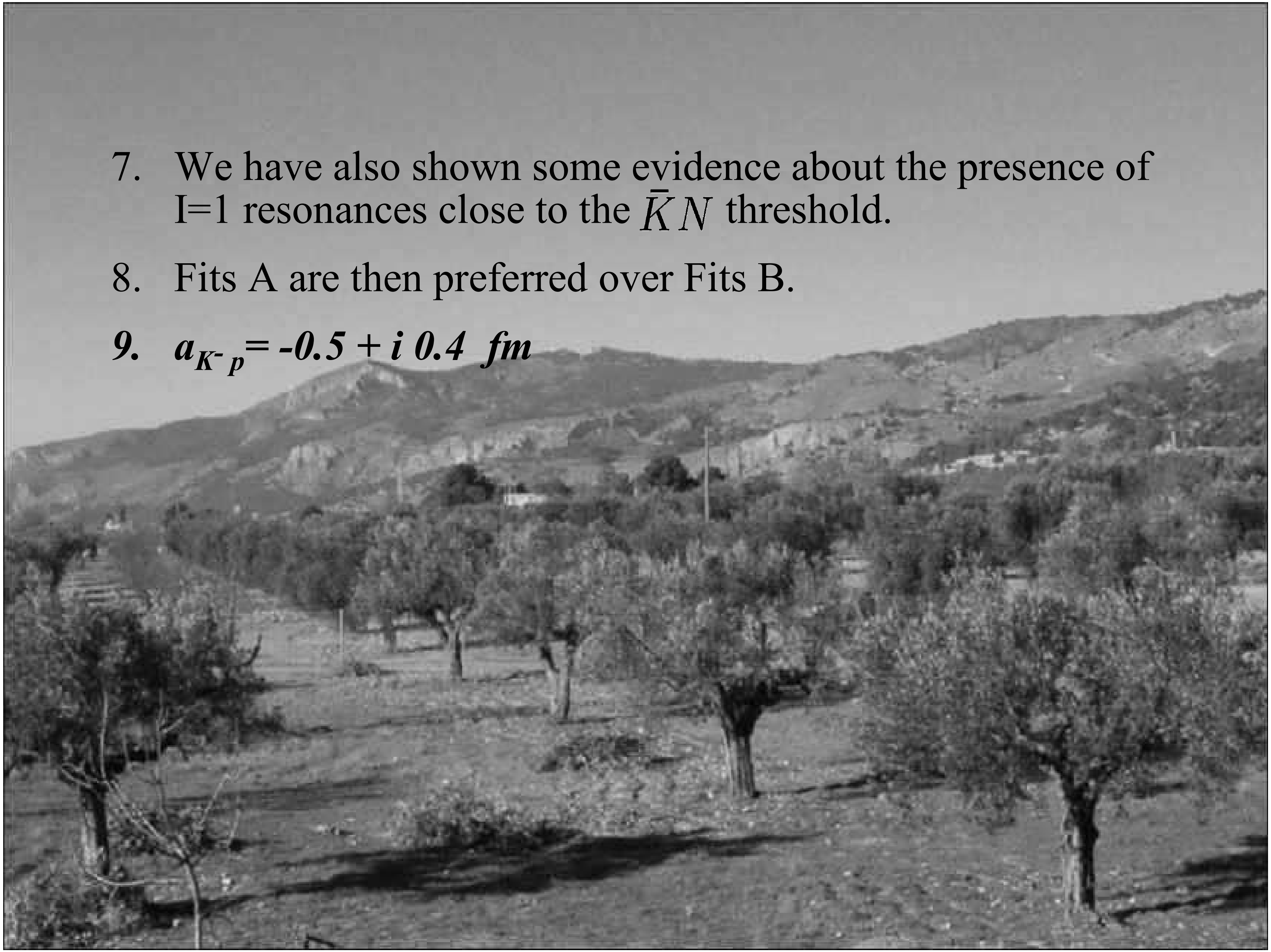

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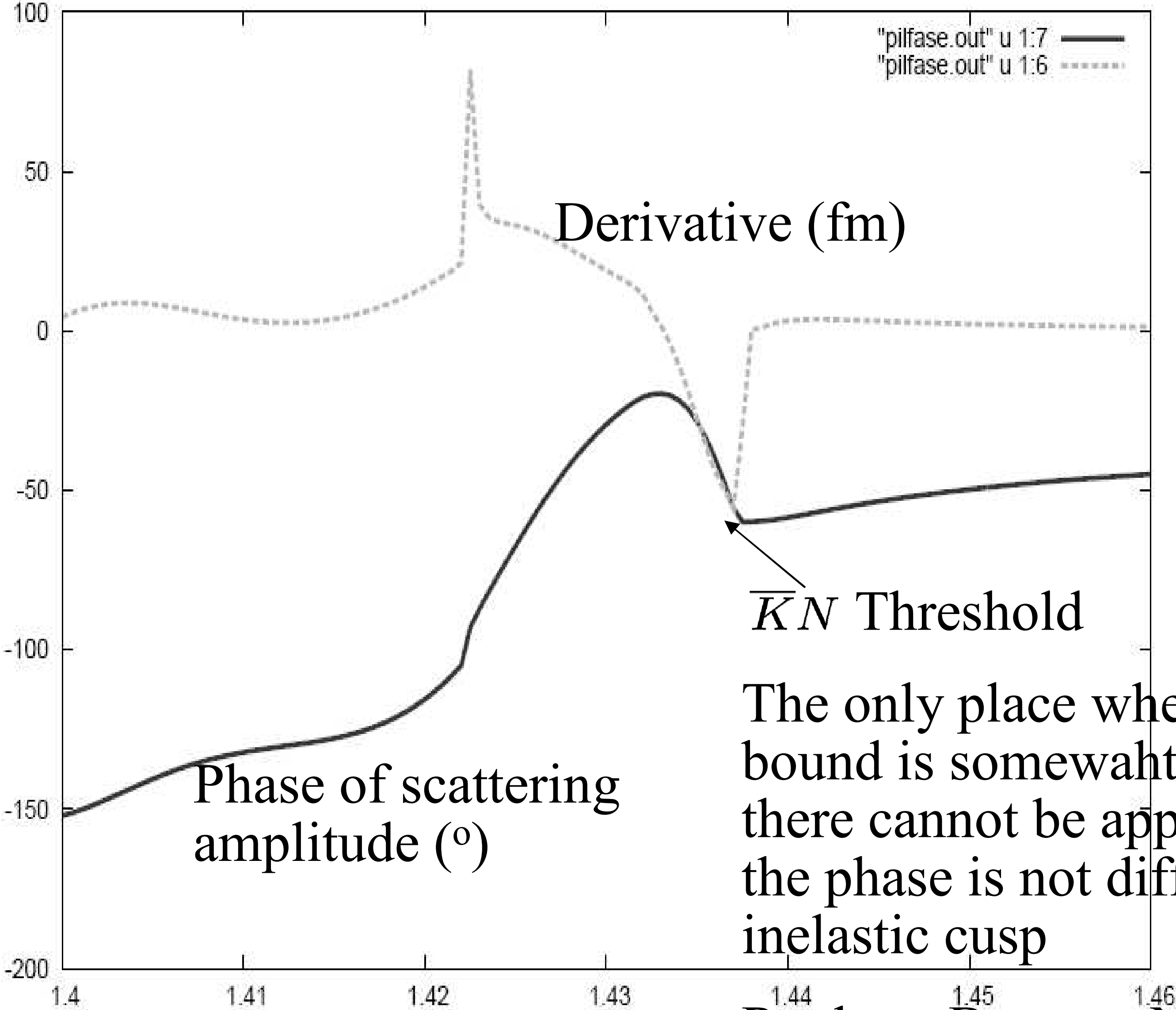

The only place where Wigner bound is somewaht violated but there cannot be applied because the phase is not differetiable – inelastic cusp

Reply to Borasoy,Nissler,Weise Comment PRL96,199201('06)