$\bar{K}N$ chiral interaction beyond s-wave

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with:

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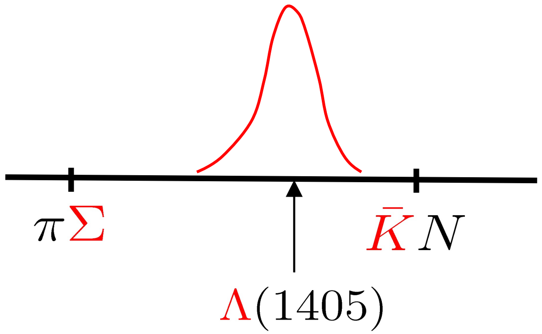
Outline

- $\bar{K}N$ interaction and the s-wave $\Lambda(1405)$ resonance (brief history and some breakthroughs)
- Our chiral model (evolution over the years)
- New step forward: terms beyond s-wave
- Formalism
- Results in the $\bar{K}N$ sector
- Conclusions

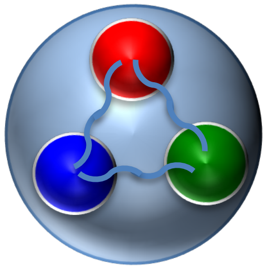
The Λ(1405)

- The $\bar{K}N$ interaction in the isospin I=0 channel is able develop a **quasi-bound state**, the Λ(1405), located only 27 MeV below the $\bar{K}N$ threshold

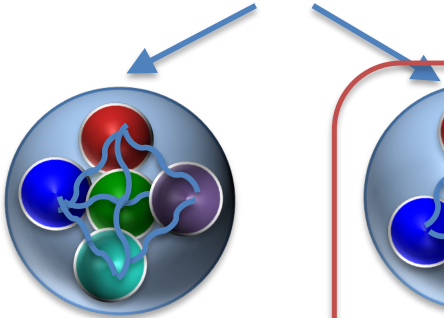


- It may be considered the first "pentaquark" ever observed

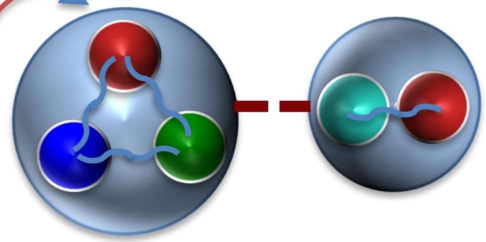
in **conventional quark models:**
baryons are qqq states



exotic baryons:
pentaquarks (5q states)



compact



baryon-meson bound state (or *molecule*)

Late fifties/sixties (first stellar period)

- Intense activity in bubble-chamber experiments (BNL, CERN, Rutherford) established the presence of a resonance with strangeness -1 around 1405 MeV. (The $\Lambda(1405)$ becomes a PDG baryon in 1963)

- The idea of the $\Lambda(1405)$ being a meson-baryon molecule was originally proposed by Dalitz and Tuan in the late 1950's (a quasibound state was found from solving a coupled-channel Schrödinger equation involving $\bar{K}N$ and $\pi\Sigma$)

R. H. Dalitz and S. F. Tuan, Annals of Phys. 10 (1960) 307

seventies/eighties

- Continuous experimental activity in bubble-chambers and in emulsions (cross section measurements, threshold branching ratios, …)

- The $\Lambda(1405)$ cannot be accommodated in quark models, which systematically predicted for it a too high mass.

1990 – 2005 (around the turn of the century)

- Conflicting measurements of the kaonic hydrogen shift and width of the 1s state: KEK-PS E228 (1998) and DEAR (2005)

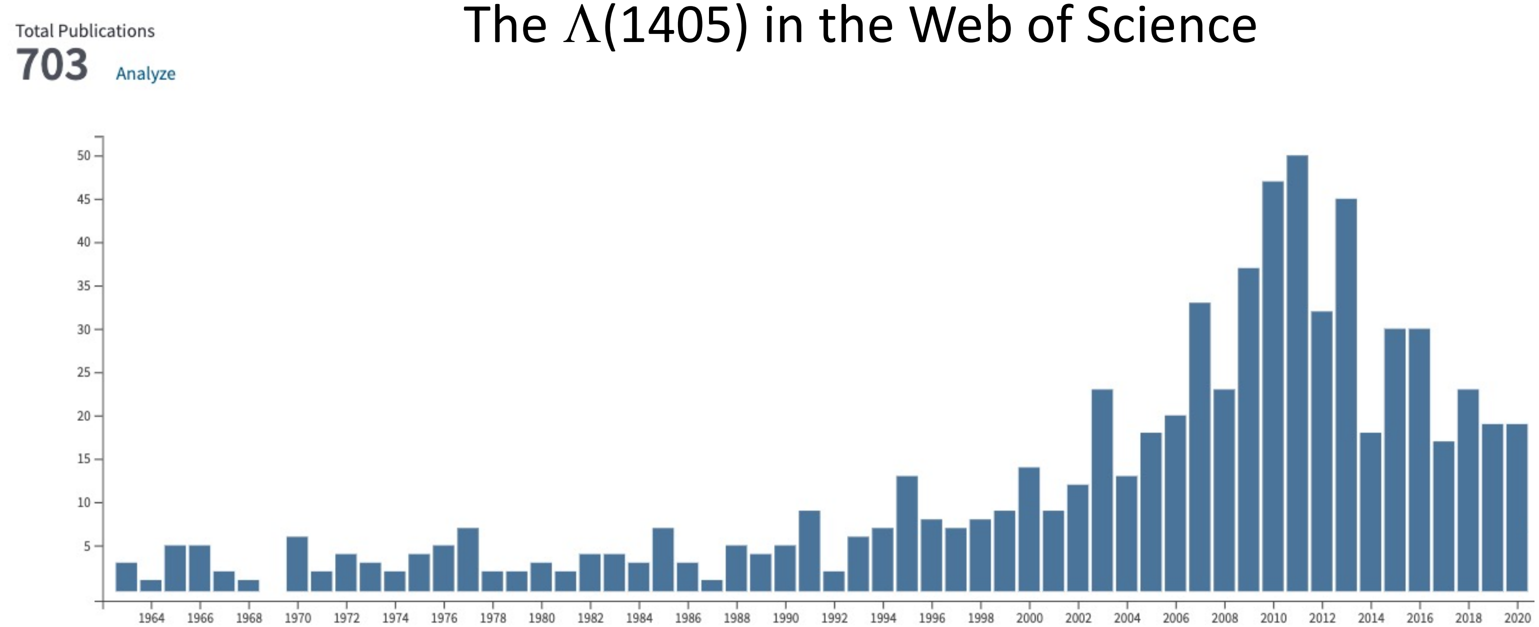
- The Dalitz/Tuan idea of a quasi-bound meson-baryon interpretation of the $\Lambda(1405)$ is reformulated in terms of an effective chiral unitary theory in coupled channels (in s-wave)

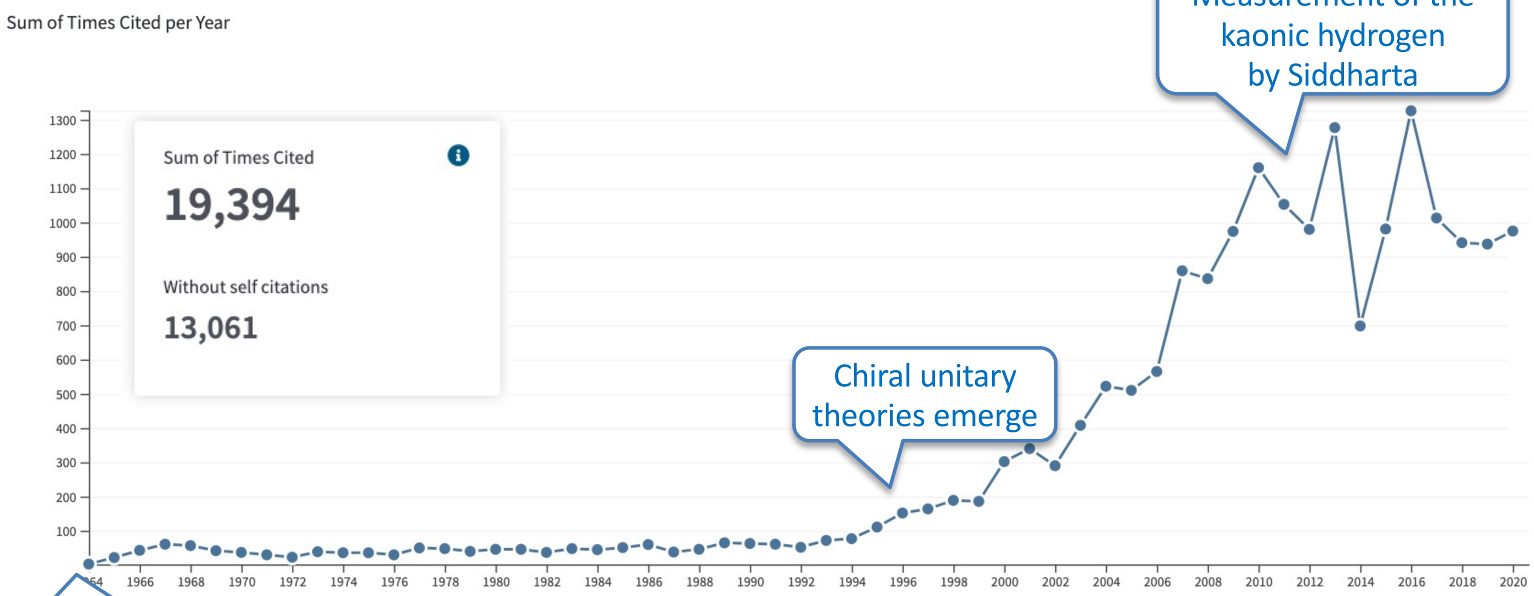
  N. Kaiser, P. B. Siegel, and W. Weise, Nucl. Phys. A594 (1995) 325
  E. Oset and A. Ramos, Nucl. Phys. A635 (1998) 99

- For the next ten years, intense theoretical work (NLO Lagrangian, s-channel and u-channel Born terms…) finding similar features:
  - ✓ $\bar{K}N$ scattering data reproduced very satisfactorily
  - ✓ Two-pole structure of $\Lambda(1405)$

J. A. Oller, U. -G. Meissner, Phys. Lett. B 500, 263 (2001).
M. F. M. Lutz, E. Kolomeitsev, Nucl. Phys. A 700, 193 (2002).
B. Borasoy, E. Marco, S. Wetzel, Phys. Rev. C 66, 055208 (2002).
C. Garcia-Recio, J. Nieves, E. Ruiz Arriola and M. J. Vicente Vacas, Phys. Rev. D 67, 076009 (2003).
D. Jido, J. A. Oller, E. Oset, A. Ramos and U. G. Meissner, Nucl. Phys. A 725, 181 (2003).
B. Borasoy, R. Nissler, W. Wiese, Eur. Phys. J. A 25, 79 (2005).
V.K. Magas, E. Oset, A. Ramos, Phys. Rev. Lett. 95, 052301 (2005).
B. Borasoy, U. -G. Meissner and R. Nissler, Phys. Rev. C 74, 055201 (2006)

The Λ(1405) in the Web of Science





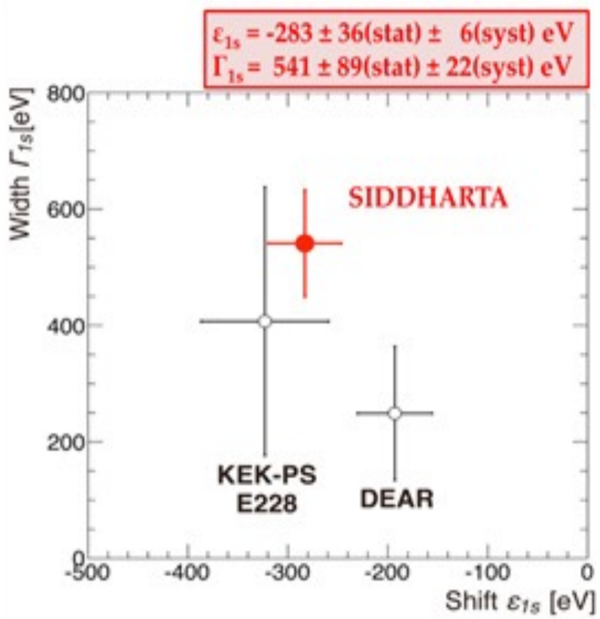
Measurement of the kaonic hydrogen by Siddharta

Chiral unitary theories emerge

The Λ(1405) appears in the PDG (1963)

After 2005

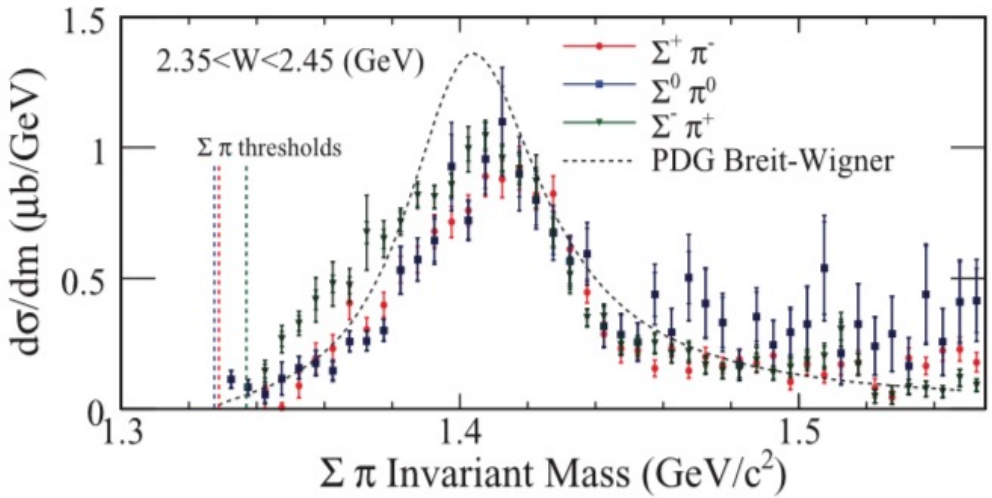
- The energy shift and width of the 1s state in kaonic hydrogen measured by SIDDHARTA@DAΦNE fixes the $K^{-}p$ scattering length with a 20% precision.



M. Bazzi et al., Phys. Lett. B 704, 113 (2011)

- Various important experiments to understand the Λ(1405) line shape and its two pole structure:

→ photo- & electro-production reactions at LEPS (Niiyama et al. 2008) and CLAS (Moriya et al., 2013, 2014, Lu et al., 2013)



K. Moriya *et al.*, Phys. Rev. C87, 035206(2013).

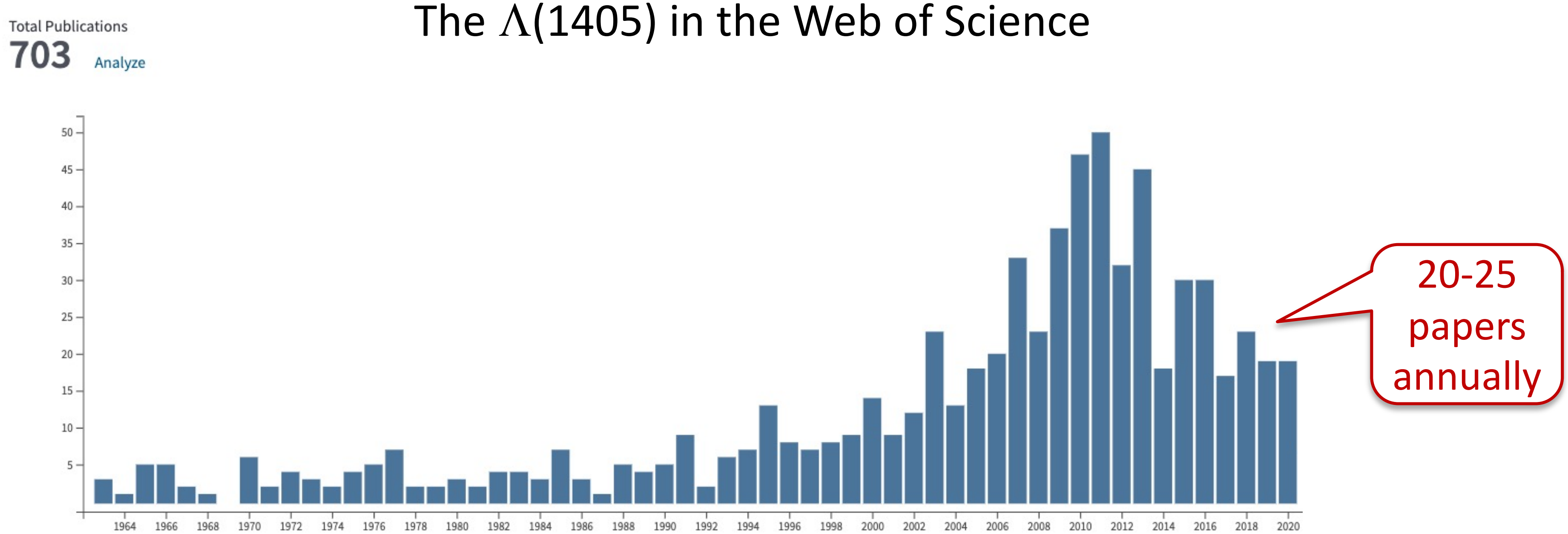
→ pp reactions at COSY (Zychor et al., 2008) and HADES (Agakishiev et al., 2013)

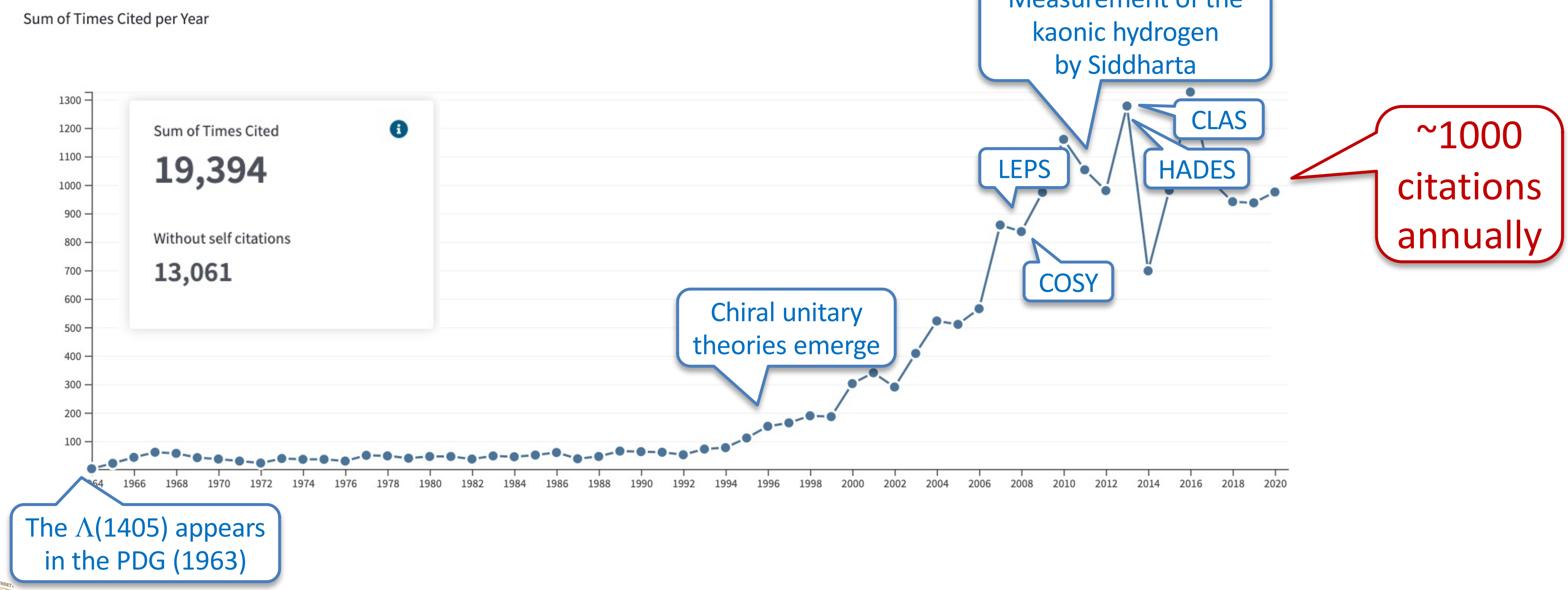
After 2005

- The new and improved data helped to constrain the theoretical models better!
  (explaining the proliferation of works, and
  maintaining the interest on this problem alive)

Y. Ikeda, T. Hyodo, W. Wiese, Nucl. Phys. A 881, 98 (2012).
A. Cieply and J. Smejkal, Nucl. Phys. A 881, 115 (2012).
Zhi-Hui Guo, J. A. Oller, Phys. Rev. C 87, 035202 (2013).
T. Mizutani, C. Fayard, B. Saghai and K. Tsushima, Phys. Rev. C 87, 035201 (2013).
L. Roca and E. Oset: Phys. Rev. C 87, 055201 (2013), Phys. Rev. C 88, 055206 (2013).
M. Mai and U. G. Meißner, Eur. Phys. J. A 51, 30 (2015).
A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 92, 015206 (2015).
A. Ramos, A. Feijoo, V. Magas, Nucl. Phys. A 954, 58 (2016).
A. Cieplý, M. Mai, U-G. Meißner, J. Smejkal, Nucl.Phys.A 954, 17 (2016).
A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 99, 035211 (2019)
…

The Λ(1405) in the Web of Science





Our chiral model (evolution over the years)

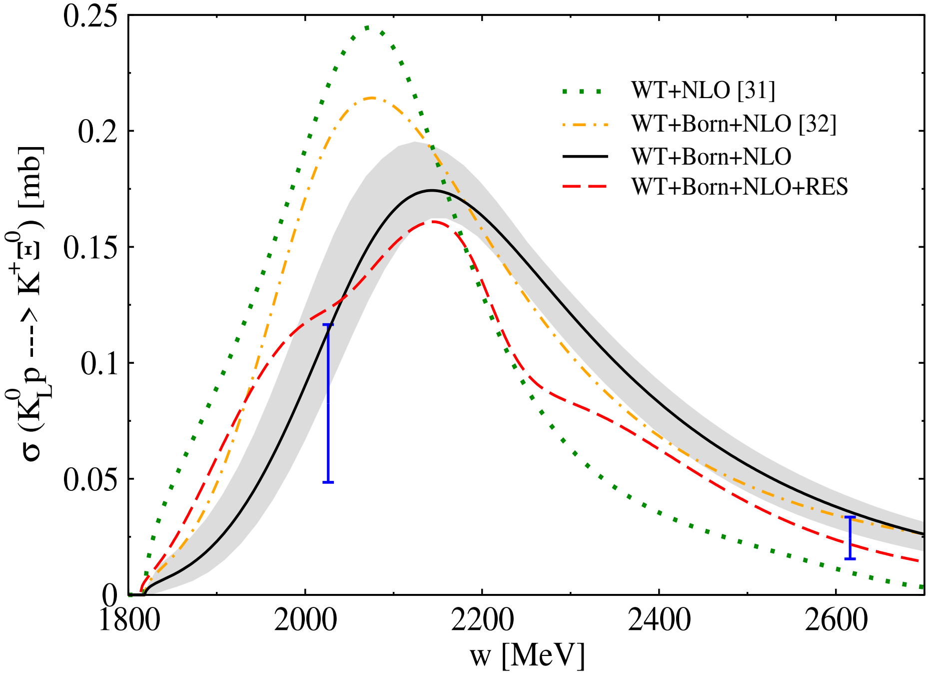
The Barcelona group has contributed to this process of model improvement (with the focus on constraining the NLO pieces of the Lagrangian better)

1. studying reactions that are especially sensitive to NLO (as the LO contributions vanish), e.g $K^-p \rightarrow K^0\Xi^0$, $K^+\Xi^-$ **A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 92, 015206 (2015)**

2. analyzing the interplay between the Born terms and NLO contributions **A. Ramos, A. Feijoo, V. Magas, Nucl. Phys. A 954, 58 (2016)**

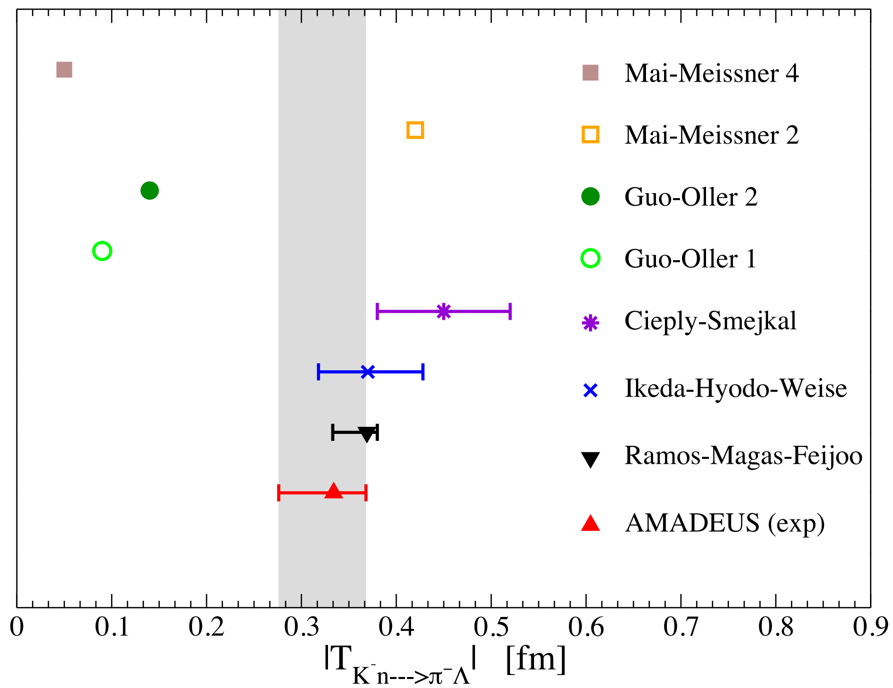
3. studying isospin filtering reactions especially sensitive to NLO **A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 99, 035211 (2019)**

Predictions (reproduction of Isospin filtering observables)



$K_L^0 p \longrightarrow K^+ \Xi^0$ reaction (pure $I = 1$ process)

Could be measured at J-Lab
(proposal for a secondary K_L beam
by the KLF collaboration)



$K^- n \longrightarrow \pi^- \Lambda$ amplitude (pure $I = 1$)

K. Piscicchia et al.., Phys.Lett. B782 (2018) 339-345
AMADEUS collaboration

New step forward: terms beyond s-wave

All our previously developed $\bar{K}N$ interaction models are in s-wave!

However, the different terms of the chiral lagrangian contain higher partial waves

I will report on new fits that take these terms into consideration (up to p-wave)

Why p- and higher partial waves?

➔ to extend the description of the theory to higher energies above the meson-baryon thresholds

➔ to investigate if dynamical resonances may appear

➔ to extend the $\bar{K}N$ interaction to higher momentum, as that acquired by antikaons penetrating in a nuclear medium.

Previous works including the p-waves of the chiral lagrangian:

➔ strangeness S=0 sector

J. Caro Ramon, N. Kaiser, S. Wetzel and W. Weise, Nucl. Phys. A 672, 249 (2000).

➔ strangeness S=+1 sector

K. Aoki, D. Jido, PTEP 2019, no.1, 013D01 (2019)

➔ strangeness S=-1 sector

D. Jido, E. Oset, A. Ramos, Phys. Rev. C 66, 055203 (2002).

(LO Lagrangian, not too much effect of p-wave (only low energy data is considered), but very useful for the theoretical developments)

D. Sadasivan, M.Mai, M.Döring, Phys. Lett. B 789, 329 (2019)

(LO+NLO Lagrangians. A dynamical p-wave pole is found! ($J^P=1/2^+$) mimicking their lack of $\Sigma^*(1385)$ in $J^P=3/2^+$. Neglects certain NLO terms.

A few strokes of the formalism:

We derive an *interaction kernel* (that consists of 4 diagrams):

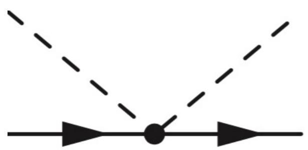
from the Chiral Lagrangian up to NLO:

$$\mathcal{L}^{eff}(B,U) = \mathcal{L}^{(1)}_{MB}(B,U) + \mathcal{L}^{(2)}_{MB}(B,U)$$

The leading order (LO) generates:

$$\mathcal{L}^{(1)}_{MB} = \langle \bar{B}(i\gamma_\mu D^\mu - M_0)B \rangle + \frac{1}{2} D \langle \bar{B}\gamma_\mu\gamma_5\{u^\mu, B\}\rangle + \frac{1}{2} F \langle \bar{B}\gamma_\mu\gamma_5[u^\mu, B]\rangle$$

Weinberg-Tomozawa (WT)

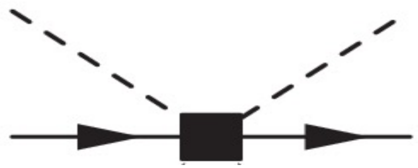


Direct and Crossed Born terms

The next lo leading order (NLO), just considering the contact term, is:

$$\mathcal{L}_{\phi B}^{(2)} = b_D\langle\bar{B}\{\chi_+,B\}\rangle + b_F\langle\bar{B}[\chi_+,B]\rangle + b_0\langle\bar{B}B\rangle\langle\chi_+\rangle + d_1\langle\bar{B}\{u_\mu,[u^\mu,B]\}\rangle$$
$$+d_2\langle\bar{B}[u_\mu,[u^\mu,B]]\rangle + d_3\langle\bar{B}u_\mu\rangle\langle u^\mu B\rangle + d_4\langle\bar{B}B\rangle\langle u^\mu u_\mu\rangle$$
$$-\frac{g_1}{8M_N^2}\langle\bar{B}\{u_\mu,[u_\nu,\{D^\mu,D^\nu\}B]\}\rangle - \frac{g_2}{8M_N^2}\langle\bar{B}[u_\mu,[u_\nu,\{D^\mu,D^\nu\}B]]\rangle$$
$$-\frac{g_3}{8M_N^2}\langle\bar{B}u_\mu\rangle\langle[u_\nu,\{D^\mu,D^\nu\}B]\rangle - \frac{g_4}{8M_N^2}\langle\bar{B}\{D^\mu,D^\nu\}B\rangle\langle u_\mu u_\nu\rangle$$
$$-\frac{h_1}{4}\langle\bar{B}[\gamma^\mu,\gamma^\nu]Bu_\mu u_\nu\rangle - \frac{h_2}{4}\langle\bar{B}[\gamma^\mu,\gamma^\nu]u_\mu[u_\nu,B]\rangle - \frac{h_3}{4}\langle\bar{B}[\gamma^\mu,\gamma^\nu]u_\mu\{u_\nu,B\}\rangle$$
$$-\frac{h_4}{4}\langle\bar{B}[\gamma^\mu,\gamma^\nu]u_\mu\rangle\langle u_\nu,B\rangle + h.c.$$

New terms taken into account



NLO term

- Contributions with g_3 get cancelled
- $b_0, b_D, b_F, d_1, d_2, d_3, d_4, g_1, g_2, g_4, h_1, h_2, h_3, h_4$ are treated as parameters of the model

Interaction kernels:

(indices *i* and *j* denote any of the S=-1 coupled MB channels)

$$V_{ij}^{WT} = -\frac{N_i N_j}{4f^2} C_{ij} \left\{ (2\sqrt{s} - M_i - M_j) \chi_f^{\dagger s'} \chi_0^s + \frac{2\sqrt{s}+M_i+M_j}{(E_i+M_i)(E_j+M_j)} \chi_f^{\dagger s'} \left[\vec{q}_j \cdot \vec{q}_i + i(\vec{q}_j \times \vec{q}_i) \cdot \vec{\sigma} \right] \chi_0^s \right\}$$

➔ s, p wave

$$V_{ij}^{D} = \frac{N_i N_j}{12 f^2} \sum_k \frac{C_{\bar{i}i,k}^{(\mathrm{Born})} C_{\bar{j}j,k}^{(\mathrm{Born})}}{s - M_k^2} \left\{ (\sqrt{s} - M_k)(s + M_i M_j - \sqrt{s}(M_i + M_j)) \chi_j^{\dagger s'} \chi_i^s + \frac{(s + \sqrt{s}(M_i + M_j) + M_i M_j)(\sqrt{s} + M_k)}{(E_i + M_i)(E_j + M_j)} \chi_j^{\dagger s'} \left[\vec{q}_j \cdot \vec{q}_i + i(\vec{q}_j \times \vec{q}_i) \cdot \vec{\sigma} \right] \chi_i^s \right\}$$

➔ s, p waves

$$V_{ij}^{C} = -\frac{N_i N_j}{12 f^2} \sum_k \frac{C_{\bar{j}k,i}^{(\mathrm{Born})} C_{\bar{i}k,j}^{(\mathrm{Born})}}{u - M_k^2} \left\{ \left[u(\sqrt{s} + M_k) + \sqrt{s}(M_j(M_i + M_k) + M_i M_k) - M_j(M_i + M_k)(M_i + M_j) - M_i^2 M_k \right] \chi_j^{\dagger s'} \chi_i^s + \left[u(\sqrt{s} - M_k) + \sqrt{s}(M_j(M_i + M_k) + M_i M_k) + M_j(M_i + M_k)(M_i + M_j) + M_i^2 M_k \right] \chi_j^{\dagger s'} \frac{\vec{q}_j \cdot \vec{q}_i + i(\vec{q}_j \times \vec{q}_i) \cdot \vec{\sigma}}{(E_i + M_i)(E_j + M_j)} \chi_i^s \right\}$$

➔ s, p, d, waves

$$
\begin{aligned}
V_{ij}^{NLO} \quad = \quad & \frac{N_i N_j}{f^2}\left[D_{ij} - 2L_{ij}{q_j}^{\mu}{q_i}_{\mu} + \frac{1}{2M_N^2} g_{ij}({p_i}^{\mu}{q_j}_{\mu}{p_i}^{\nu}{q_i}_{\nu} + {p_j}^{\mu}{q_j}_{\mu}{p_j}^{\nu}{q_i}_{\nu})\right]\left(\chi_j^{\dagger s'}\chi_i^s\right. \\
& \left. -\chi_j^{\dagger s'}\frac{\vec{q}_j\cdot\vec{q}_i + i(\vec{q}_j\times\vec{q}_i)\cdot\vec{\sigma}}{(E_i+M_i)(E_j+M_j)}\chi_i^s\right) + \frac{N_i N_j}{f^2}h_{ij}\left[-\left(\frac{{q_j}_0{q_i}^2}{E_i+M_i} + \frac{{q_i}_0{q_j}^2}{E_j+M_j}\right.\right. \\
& \left. + \frac{{q_j}^2{q_i}^2}{(E_i+M_i)(E_j+M_j)} + \frac{(\vec{q}_j\cdot\vec{q}_i)^2}{(E_i+M_i)(E_j+M_j)}\right)\chi_j^{\dagger s'}\chi_i^s \\
& + \left(\frac{{q_i}_0}{E_i+M_i} + \frac{{q_j}_0}{E_j+M_j}\right)\chi_j^{\dagger s'}\vec{q}_j\cdot\vec{q}_i\chi_i^s + \left(\frac{{q_i}_0}{E_i+M_i} + \frac{{q_j}_0}{E_j+M_j} + \right. \\
& \left.\left. \frac{\vec{q}_j\cdot\vec{q}_i}{(E_i+M_i)(E_j+M_j)} - 1\right) i\chi_j^{\dagger s'}(\vec{q}_j\times\vec{q}_i)\cdot\vec{\sigma}\chi_i^s\right]
\end{aligned}
$$

➔ s, p, d waves

Unitarization (I):

The former tree-level amplitudes

$$T_{ij} = \chi_j^{\dagger s'} [f(\sqrt{s},\theta) - i(\vec{\sigma}\cdot\hat{n}) g(\sqrt{s},\theta)]\chi_i^s \qquad \hat{n} = \frac{\vec{q}_j \times \vec{q}_i}{|\vec{q}_j \times \vec{q}_i|}$$

are partial-wave decomposed:

$$\begin{aligned} f(\sqrt{s},\theta) &= \sum_{l=0}^{\infty} f_l(\sqrt{s})\, P_l(cos\theta) \\ g(\sqrt{s},\theta) &= \sum_{l=1}^{\infty} g_l(\sqrt{s})\, sin\theta\, \frac{dP_l(cos\theta)}{d(cos\theta)} \end{aligned}$$

and then recoupled into well defined total angular momentum j (conserved)

$$f_{l+}^{tree}(\sqrt{s}) = \frac{1}{2l+1}\left(f_l(\sqrt{s}) + l\, g_l(\sqrt{s})\right), \quad j = l + \tfrac{1}{2}$$

$$f_{l-}^{tree}(\sqrt{s}) = \frac{1}{2l+1}\left(f_l(\sqrt{s}) - (l+1)\, g_l(\sqrt{s})\right), \quad j = l - \tfrac{1}{2}$$

Unitarization (II):

Finally, the unitarized amplitudes are obtained from the Bethe-Salpeter equation

$$f_{l\pm} = \left[1 - f_{l\pm}^{tree} G\right]^{-1} f_{l\pm}^{tree}$$

(on-shell factorization has been employed)

where *G* is the diagonal matrix of MB loops (dimensional regularization):

$$G_l = \frac{2M_l}{(4\pi)^2}\left\{ a_l(\mu) + \ln\frac{M_l^2}{\mu^2} + \frac{m_l^2 - M_l^2 + s}{2s}\ln\frac{m_l^2}{M_l^2} + \frac{q_{\rm cm}}{\sqrt{s}}\ln\left[\frac{(s+2\sqrt{s}q_{\rm cm})^2-(M_l^2-m_l^2)^2}{(s-2\sqrt{s}q_{\rm cm})^2-(M_l^2-m_l^2)^2}\right]\right\}$$

subtraction constants for the dimensional regularization scale $\mu = 1GeV$ in all channels

Cross sections:

$$\sigma_{ij} = \frac{M_i\, M_j\, q_j}{4\,\pi\, s\, q_i}\left[|f_0|^2 + 2|f_{1+}|^2 + |f_{1-}|^2 + 3|f_{2+}|^2 + 2|f_{2-}|^2\right]$$

- $|f_0|^2$: $J^P=1/2^-$ (s-wave)
- $|f_{1+}|^2$: $J^P=3/2^+$ (p-wave)
- $|f_{1-}|^2$: $J^P=1/2^+$ (p-wave)
- $|f_{2+}|^2$: $J^P=5/2^-$ (d-wave)
- $|f_{2-}|^2$: $J^P=3/2^-$ (d-wave)

Fitting procedure:

Parameters:

- Decay constant f (partially constrained: $\boldsymbol{f_\pi^{exp}} \leq \boldsymbol{f} \leq 1.3\boldsymbol{f_\pi^{exp}}$, $\boldsymbol{f_\pi^{exp}}$=93 MeV)
- Axial vector couplings *D, F* (we impose $g_A = D + F = 1.26$)
- 14 coefficients of NLO: $b_0, b_D, b_F, d_1, d_2, d_3, d_4, g_1, g_2, g_4, h_1, h_2, h_3, h_4$
- 6 subtracting constants (isospin symmetry employed):

$$a_{K^-p} = a_{\bar{K}^0 n} = a_{\bar{K}N}$$

$$a_{\pi\Lambda}$$

$$a_{\pi^+\Sigma^-} = a_{\pi^-\Sigma^+} = a_{\pi^0\Sigma^0} = a_{\pi\Sigma}$$

$$a_{\eta\Lambda}$$

$$a_{\eta\Sigma}$$

$$a_{K^+\Xi^-} = a_{K^0\Xi^0} = a_{K\Xi}$$

Fitted to cross-section data, threshold branching-ratios, kaonic hidrogen…

Conservative approach: we fit to the same data employed in our last s-wave work!

Observable	Points	Observable	Points
$\sigma_{K^-p\to K^-p}$	245	$\sigma_{K^-p\to \bar{K}^0 n}$	317
$\sigma_{K^-p\to \pi^0\Lambda}$	225	$\sigma_{K^-p\to \pi^0\Sigma^0}$	125
$\sigma_{K^-p\to \pi^-\Sigma^+}$	198	$\sigma_{K^-p\to \pi^+\Sigma^-}$	213
$\sigma_{K^-p\to \eta\Sigma^0}$	9	$\sigma_{K^-p\to \eta\Lambda}$	106
$\sigma_{K^-p\to K^+\Xi^-}$	54	$\sigma_{K^-p\to K^0\Xi^0}$	30
γ	1	ΔE_{1s}	1
R_n	1	Γ_{1s}	1
R_c	1		

$$\gamma = \frac{\Gamma(K^-p\to\pi^+\Sigma^-)}{\Gamma(K^-p\to\pi^-\Sigma^+)}$$

$$R_n = \frac{\Gamma(K^-p\to\pi^0\Lambda)}{\Gamma(K^-p\to \mathrm{neutral\,states})}$$

$$R_c = \frac{\Gamma(K^-p\to\pi^+\Sigma^-,\pi^-\Sigma^+)}{\Gamma(K^-p\to \mathrm{inelastic\,channels})}$$

3 different models:

s-wave (old): our WT+Born+NLO **s-wave** fit in Phys. Rev. C 99, 035211 (2019).
Same data, but NLO lagrangian does not contain the “h” and “g” terms.

s-wave: a new WT+Born+NLO **s-wave fit** which incorporates the “h” and “g” terms.

s+p waves: same as the previous fit but incorporatind the **s- and p-wave** contributions of the WT+Born+NLO kernels

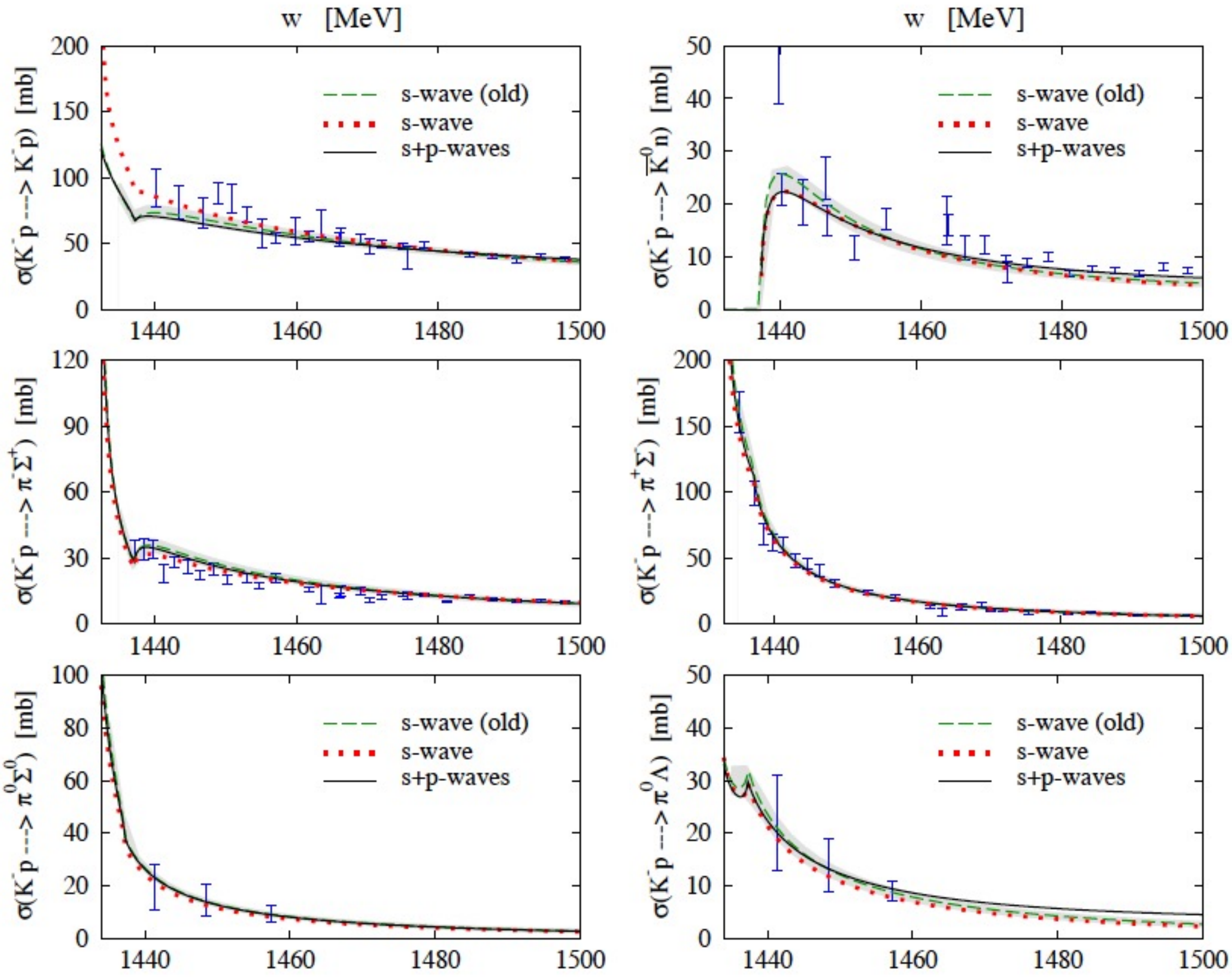
Results: threshold observables

	γ	R_n	R_c	$a_p(K^- p \to K^- p)$	ΔE_{1s}	Γ_{1s}
s+p-waves	2.36	0.188	0.662	$-0.70 + \mathrm{i}\,0.81$	297	532
s-wave	2.40	0.179	0.665	$-0.64 + \mathrm{i}\,0.83$	280	560
s-wave (old)	$2.36^{+0.03}_{-0.03}$	$0.188^{+0.010}_{-0.011}$	$0.659^{+0.005}_{-0.002}$	$-0.65^{+0.02}_{-0.08} + \mathrm{i}\,0.88^{+0.02}_{-0.05}$	288^{+23}_{-8}	588^{+9}_{-40}
Exp.	2.36 ± 0.04	0.189 ± 0.015	0.664 ± 0.011	$(-0.66 \pm 0.07) + \mathrm{i}\,(0.81 \pm 0.15)$	283 ± 36	541 ± 92

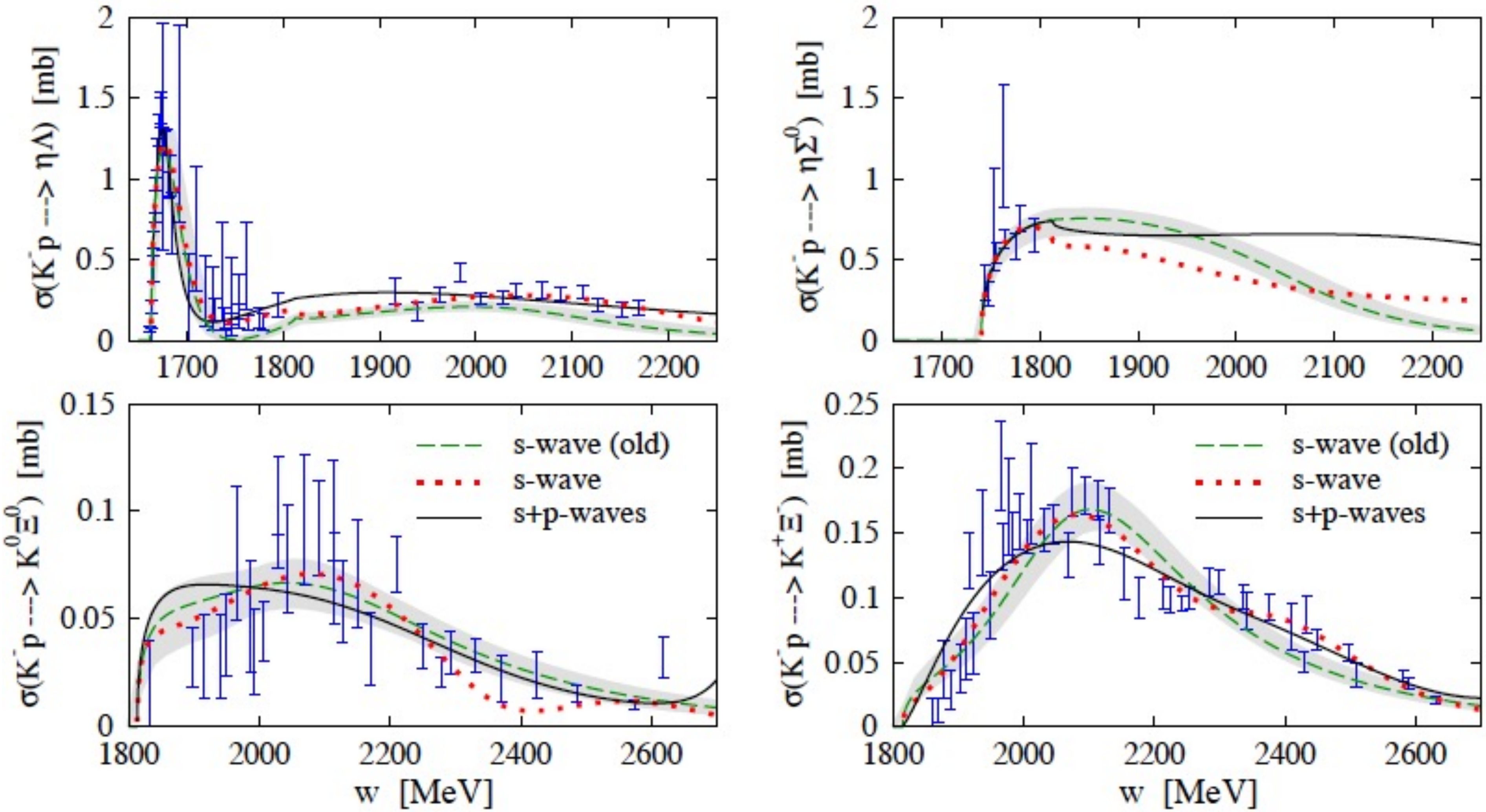
The three models do comparatively well at threshold

→ nothing is gained by incorporating the p-waves (obvious result)

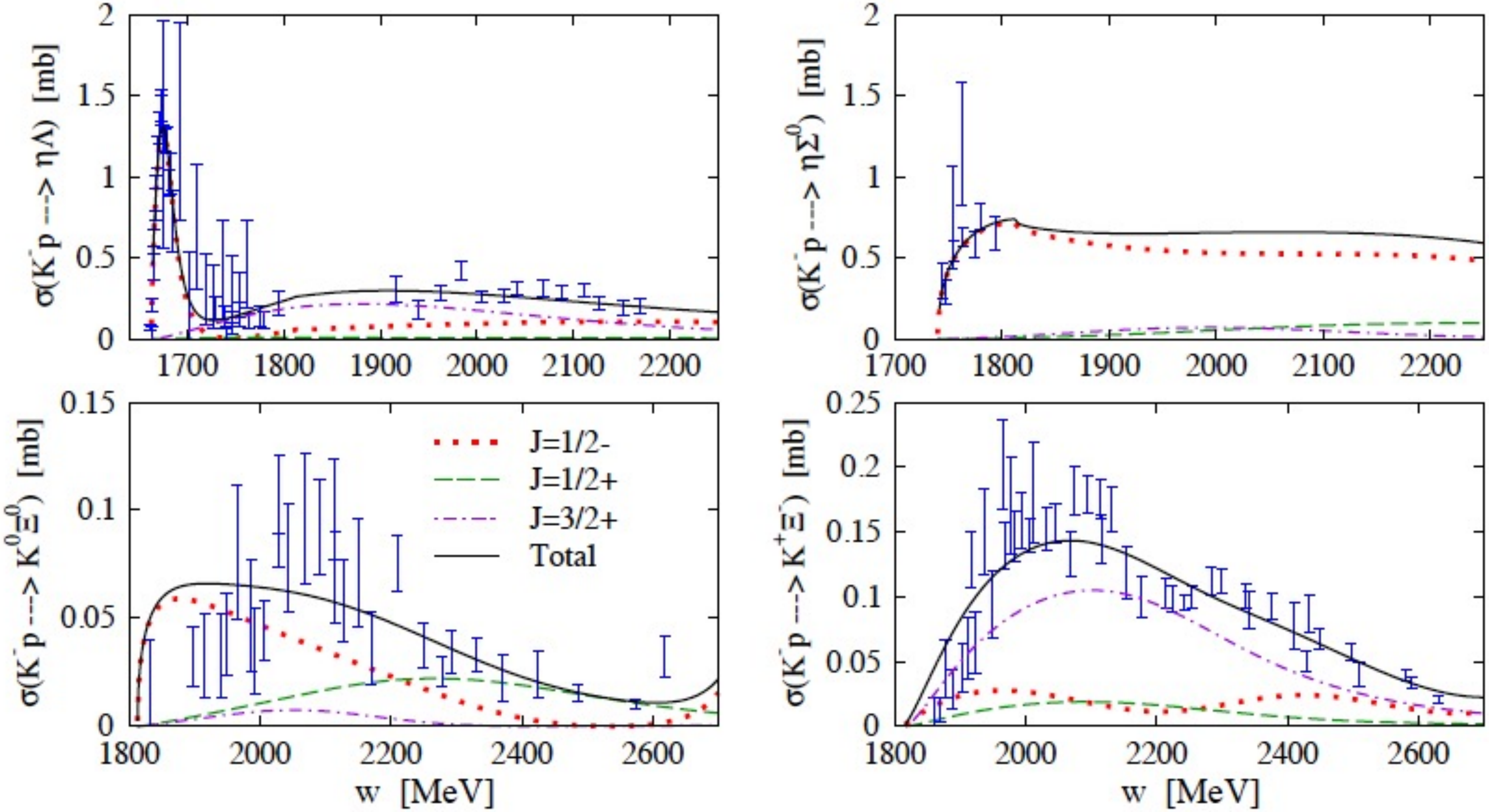
Results: cross sections (classical processes)



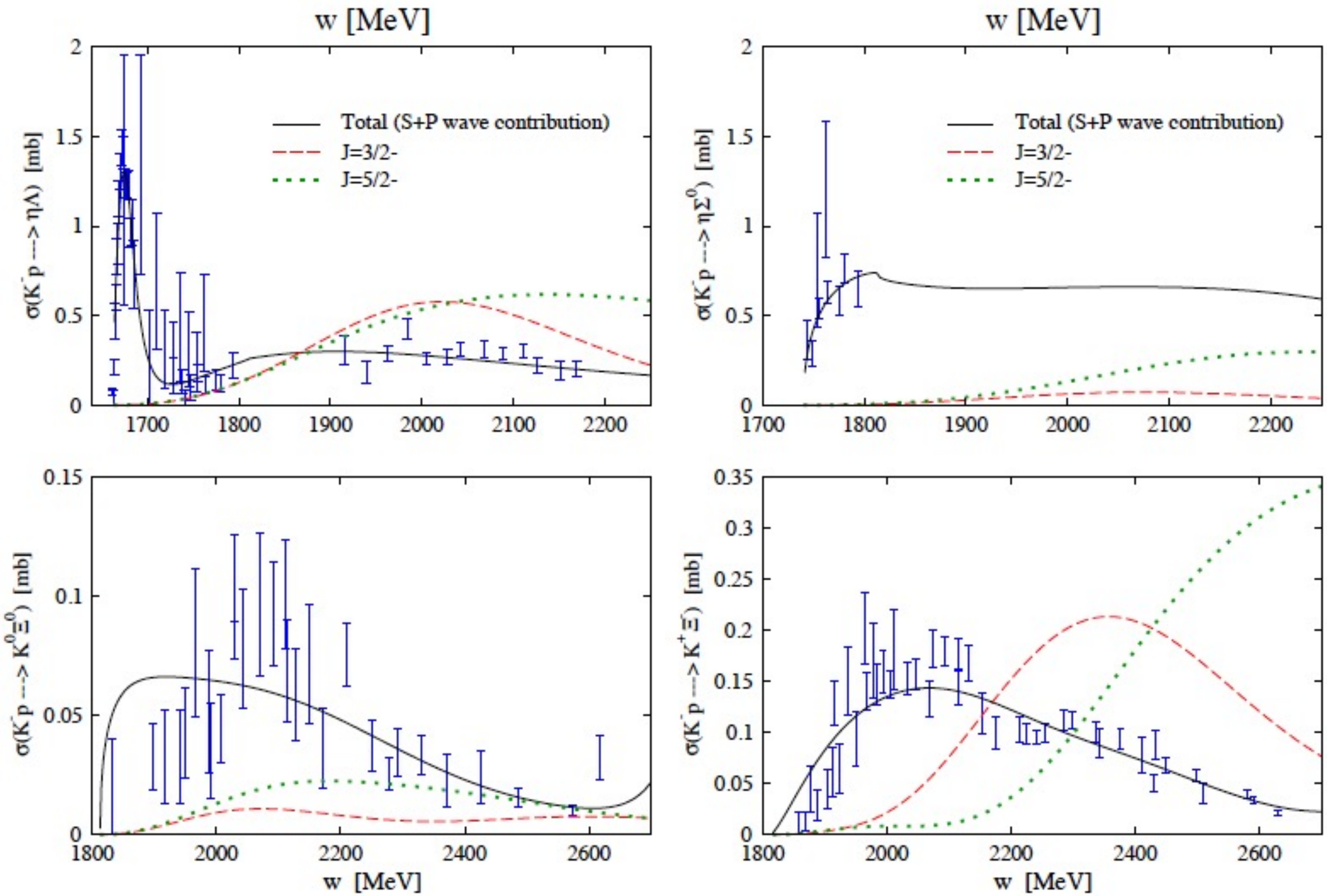
Results: cross sections (higher mass channels)



Separating the individual partial waves from the **s+p-waves** fit



Having fixed all the parameters in the **s+p waves** fit, we can see the influence of the d-waves:



A fit incorporating also the d-waves seems necessary. Work in progres...

s-wave poles ($J^P=1/2^-$)

s+p-wave model					
$0^- \oplus \frac{1}{2}^+$ interaction in $(I,S)=(0,-1)$ sector					
Pole		$\lvert g_{\pi\Sigma}\rvert$	$\lvert g_{\bar{K}N}\rvert$	$\lvert g_{\eta\Lambda}\rvert$	$\lvert g_{K\Xi}\rvert$
$\Lambda(1405)$					
$1399.72 - i\,59.26$		2.66	2.46	0.51	0.56
$1423.05 - i\,29.01$		3.49	2.42	0.80	0.49
$\Lambda(1670)$					
$1674.05 - i\,15.54$		0.39	0.36	1.29	3.56
$0^- \oplus \frac{1}{2}^+$ interaction in $(I,S)=(1,-1)$ sector					
Pole	$\lvert g_{\pi\Lambda}\rvert$	$\lvert g_{\pi\Sigma}\rvert$	$\lvert g_{\bar{K}N}\rvert$	$\lvert g_{\eta\Sigma}\rvert$	$\lvert g_{K\Xi}\rvert$
Σ^*					
$1590.47 - i\,240.70$	1.95	1.48	1.35	0.41	0.63

s-wave (old)					
$0^- \oplus \frac{1}{2}^+$ interaction in $(I,S)=(0,-1)$ sector					
Pole		$\lvert g_{\pi\Sigma}\rvert$	$\lvert g_{\bar{K}N}\rvert$	$\lvert g_{\eta\Lambda}\rvert$	$\lvert g_{K\Xi}\rvert$
$\Lambda(1405)$					
$1419^{+16}_{-22} - i\,71^{+24}_{-31}$		3.40	2.98	1.10	0.65
$1420^{+15}_{-21} - i\,27^{+18}_{-11}$		2.31	3.51	1.26	0.36
$\Lambda(1670)$					
$1675^{+10}_{-11} - i\,31^{+4}_{-7}$		0.47	0.59	1.74	3.71
$0^- \oplus \frac{1}{2}^+$ interaction in $(I,S)=(1,-1)$ sector					
Pole	$\lvert g_{\pi\Lambda}\rvert$	$\lvert g_{\pi\Sigma}\rvert$	$\lvert g_{\bar{K}N}\rvert$	$\lvert g_{\eta\Sigma}\rvert$	$\lvert g_{K\Xi}\rvert$
Σ^*					
$1701^{+16}_{-1} - i\,170^{+2}_{-7}$	1.96	0.47	1.21	0.36	0.98

Our model does not generate poles in p-wave ($J^P=1/2^+$ or $3/2^+$) !

Conclusions

The p-waves of the chiral lagrangian influence substantially the cross sections of the $K^- p \rightarrow K^+\Xi^-$, $K^0\Xi^0$, $\eta\Lambda$, $\eta\Sigma^0$ reactions.

The strength of the different partial waves might be considerably different than what is found, for instance, in more phenomenological approches like the BnGa fits.

It is clear that the interrelated d-waves (that do not depend on additional parameters) need to be incorporated in the fits. This requires to consider many more data points (higher energies, differential cross sections, ect..).

We are now in the process of tackling this ingent task, which can be done after the present work has shown that the incorporation of p-waves does not spoil (rather, it improves) the description of data with s-wave contributions only.

Thank you for your attention