The NLO Chiral Lagrangian from the meson-baryon interaction in S=-1 sector.

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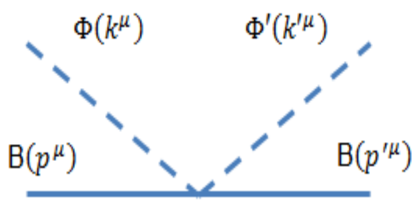
INTRODUCTION

Problem:
Study of the **meson-baryon interaction** in the **S=-1** sector.
10 channels involved in this sector:
$K^-p, \bar{K}^0 n, \pi^0\Lambda, \pi^0\Sigma^0, \pi^+\Sigma^-, \pi^-\Sigma^+, \eta\Lambda, \eta\Sigma^0, K^+\Xi^-, K^0\Xi^0$



Framework:
QCD (with quarks and gluons as degrees of freedom), **but**…

1. **Low energy regime** requires an **Effective Lagrangian**, with hadrons as degrees of freedom, which respects the symmetries of QCD. (**Chiral Perturbation Theory, ChPT**)
2. **Presence of resonances** (e.g., $\Lambda(1405)$) makes the use of **nonperturbative scheme** mandatory. (**Unitarized Chiral Perturbation Theory, UChPT)**

Goal:

1. **Find** a reliable set of **parameters** of he **Chiral Effective Lagrangian**, paying special attention to the **NLO coefficients**, by **fitting** to the existing **data**.
2. **Give predictions** for new/not measured observables from the different obtained parametrizations.

CHIRAL EFFECTIVE LAGRANGIAN (Meson-Baryon interaction)

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

- **Leading order (LO)**

$$\mathcal{L}_{MB}^{(1)}(B,U) = \langle \bar{B} i\gamma^\mu \nabla_\mu B \rangle - M_B \langle \bar{B} B \rangle + \frac{1}{2} D \langle \bar{B} \gamma^\mu \gamma_5 \{u_\mu, B\} \rangle + \frac{1}{2} F \langle \bar{B} \gamma^\mu \gamma_5 [u_\mu, B] \rangle$$

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- **Weinberg-Tomozawa term (WT)**

$$V_{ij}^{WT} = -C_{ij}\frac{1}{4f^2}\left(\sqrt{s} - M_i - M_j\right) N_i\, N_j$$

1. Dominant contribution.
2. Interaction mediated, basically, by the constant f of the leptonic decay of the meson, $1.15 f_{\pi}^{exp} \leq f \leq 1.22\, f_{\pi}^{exp}$, f_{π}^{exp}=93 *MeV*.
3. ***Key point:*** Special attention is paid to $K^{-}p \rightarrow K\,\Xi$ reactions
   There is no direct contribution from these reactions : $C_{K^-p\rightarrow K^0\Xi^0} = C_{K^-p\rightarrow K^+\Xi^-} = 0$
4. **Next terms in hierarchy could play a relevant role in these channels!!!**

CHIRAL EFFECTIVE LAGRANGIAN (Meson-Baryon interaction)

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$$\mathcal{L}_{MB}^{(1)}(B,U) = \langle \bar{B} i\gamma^{\mu}\nabla_{\mu} B\rangle - M_B\langle \bar{B}B\rangle + \boxed{\frac{1}{2}D\langle \bar{B}\gamma^{\mu}\gamma_5\{u_{\mu},B\}\rangle + \frac{1}{2}F\langle \bar{B}\gamma^{\mu}\gamma_5[u_{\mu},B]\rangle}$$

- **Born terms**

1. **Direct diagram (s-channel Born term)**

$$V_{ij}^{D} = V_{ij}^{D}(D,F)$$

2. **Cross diagram (u-channel Born term)**

$$V_{ij}^{C} = V_{ij}^{C}(D,F)$$

D+F=1.26

CHIRAL EFFECTIVE LAGRANGIAN (Meson-Baryon interaction)

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

- **Leading order (LO)**

$$\mathcal{L}_{MB}^{(1)}(B,U) = \langle \bar{B} i\gamma^{\mu}\nabla_{\mu}B\rangle - M_B\langle \bar{B}B\rangle + \frac{1}{2}D\langle \bar{B}\gamma^{\mu}\gamma_5\{u_{\mu},B\}\rangle + \frac{1}{2}F\langle \bar{B}\gamma^{\mu}\gamma_5[u_{\mu},B]\rangle$$

- **Next to leading order (NLO)**, just considering the **contact term**

$$\mathcal{L}_{MB}^{(2)}(B,U) = \boxed{\begin{aligned} & b_D\langle \bar{B}\{\chi_+,B\}\rangle + b_F\langle \bar{B}[\chi_+,B]\rangle + b_0\langle \bar{B}B\rangle\langle\chi_+\rangle + d_1\langle \bar{B}\{u_{\mu},[u^{\mu},B]\}\rangle \\ & + d_2\langle \bar{B}\left[u_{\mu},[u^{\mu},B]\right]\rangle + d_3\langle \bar{B}u_{\mu}\rangle\langle u^{\mu}B\rangle + d_4\langle \bar{B}B\rangle\langle u^{\mu}u_{\mu}\rangle \end{aligned}}$$

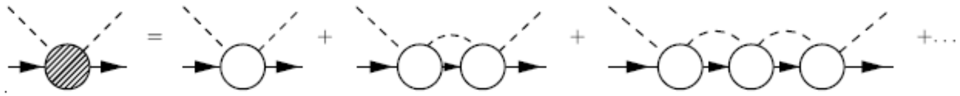
$$\Downarrow$$

$$V_{ij}^{NLO} = V_{ij}^{NLO}(b_0, b_D, b_F, d_1, d_2, d_3, d_4)$$

Not fixed low energy coefficients ⇨ **parameters of the model!**

UChPT as nonperturbative scheme to obtain scattering amplitude.

Unitarization via the Bethe-Salpeter equation:



$$T_{ij} = V_{ij} + V_{il}G_lV_{lj} + V_{il}G_lV_{lk}G_kV_{kj} + \cdots$$

$$T_{ij} = V_{ij} + V_{il}G_lT_{lj} \Longrightarrow \boxed{T = (1 - VG)^{-1}V}$$

$$G_k = \frac{M_k}{16\pi^2}\left(a_k(\mu) + ln\frac{M_k^2}{\mu^2} + \frac{m_k^2 - M_k^2 + s}{2s} ln\frac{m_k^2}{M_k^2} - 2i\pi\frac{q_k}{\sqrt{s}}\right) + \frac{M_k}{16\pi^2}\left\{\frac{q_k}{\sqrt{s}} ln\left(\frac{s^2 - \left((M_k^2 - m_k^2) + 2q_k\sqrt{s}\right)^2}{s^2 - \left((M_k^2 - m_k^2) - 2q_k\sqrt{s}\right)^2}\right)\right\}$$

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

With isospin symmetry

$$\begin{cases} a_{K^-p} = a_{\bar{K}^0n} = \boldsymbol{a_{\bar{K}N}} \\ a_{\pi^0\Lambda} = \boldsymbol{a_{\pi\Lambda}} \\ a_{\pi^0\Sigma^0} = a_{\pi^+\Sigma^-} = a_{\pi^-\Sigma^+} = \boldsymbol{a_{\pi\Sigma}} \\ \boldsymbol{a_{\eta\Lambda}} \\ a_{\eta\Sigma^0} = \boldsymbol{a_{\eta\Sigma}} \\ a_{K^+\Xi^-} = a_{K^0\Xi^0} = \boldsymbol{a_{K\Xi}} \end{cases}$$

6 PARAMETERS!

Finally:.

$$V_{ij} = V_{ij}^{WT} + V_{ij}^{D} + V_{ij}^{C} + V_{ij}^{NLO} \Rightarrow \boxed{T = (1 - VG)^{-1}V} \Rightarrow T_{ij}^{NLO}$$

Fitting parameters:

- Decay constant **f**
- Axial vector couplings **D, F**
- 7 coefficients of the NLO lagrangian terms $b_0, b_D, b_F, d_1, d_2, d_3, d_4$
- 6 subtracting constants $a_{\bar{K}N}, a_{\pi\Lambda}, a_{\pi\Sigma}, a_{\eta\Lambda}, a_{\eta\Sigma}, a_{K\Xi}$

$$V_{ij} = V_{ij}^{WT} + V_{ij}^{NLO} \Rightarrow \boxed{T = (1 - VG)^{-1}V} \Rightarrow T_{ij}^{NLO}$$

Some remarks on the results we got from this model:

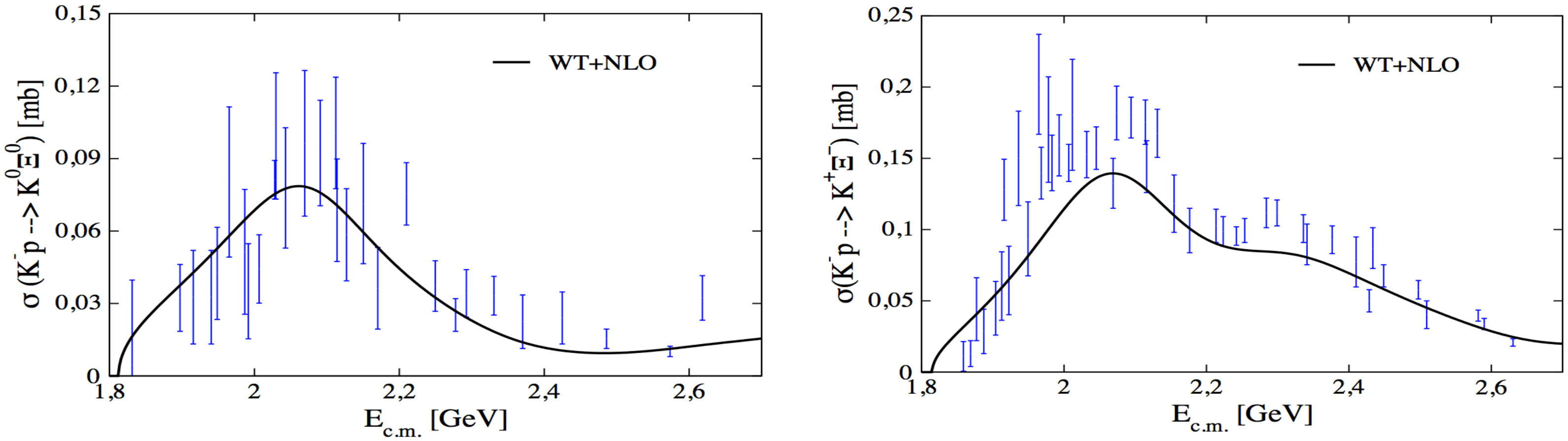
A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 92, 015206 (2015)

New scattering data should be taken into account:

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

- Channels traditionally employed
- Channels never employed before

- **The model reproduced successfully the scattering data.**



- **The obtained values for NLO coefficients were more reliable.**

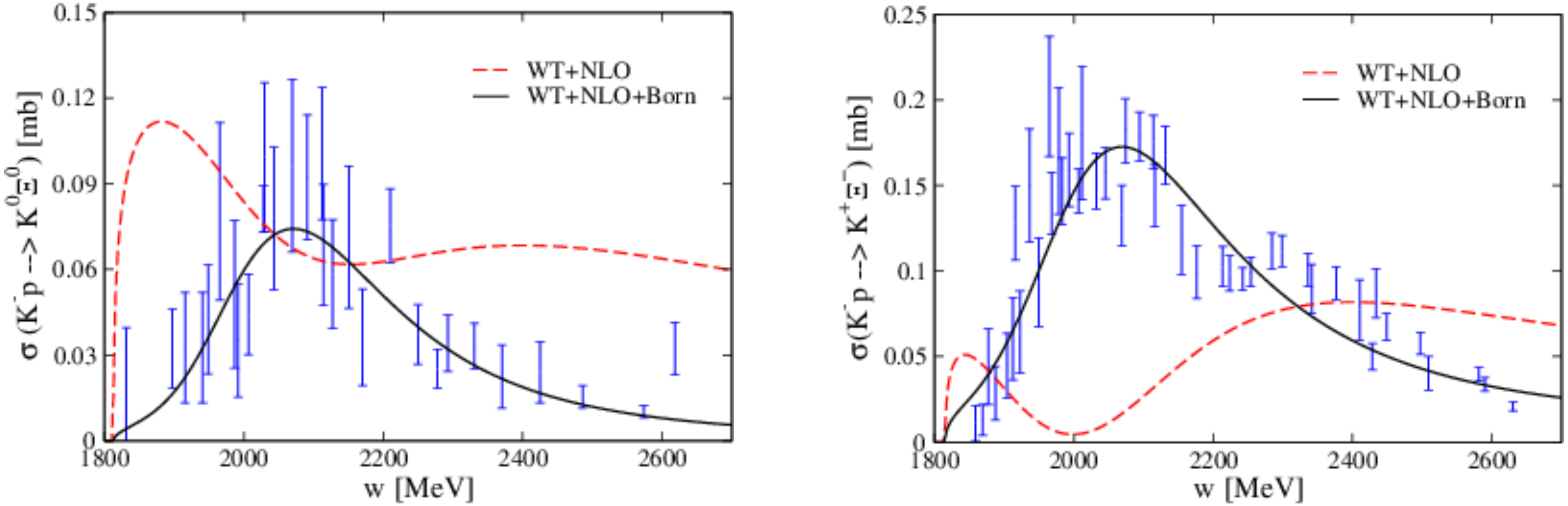
INCLUSION OF BORN TERMS

$$V_{ij} = V_{ij}^{WT} + V_{ij}^{D} + V_{ij}^{C} + V_{ij}^{NLO} \Rightarrow \boxed{T = (1 - VG)^{-1}V} \Rightarrow T_{ij}^{NLO}$$

A new fit which includes the Born contributions was performed.
A. Ramos, A. Feijoo, V. Magas, Nucl. Phys. A 954, 58 (2016)

New parametrization was obtained for :
f, b_0, b_D, b_F, d_1, d_2, d_3, d_4, $a_{\bar{K}N}$, $a_{\pi\Lambda}$, $a_{\pi\Sigma}$, $a_{\eta\Lambda}$, $a_{\eta\Sigma}$, $a_{K\Xi}$, D, F

We reach a very good agreement with all the experimental data



Interesting finding when checking the relevance of each term employing this new parametrization:
The contribution of Born terms is at the same order as the NLO one!!!

RESULTS I
Comparison between models

	WT+NLO	WT+NLO+Born
$a_{\bar{K}N}$ (10^{-3})	6.55 ± 0.63	1.77 ± 2.38
$a_{\pi\Lambda}$ (10^{-3})	54.8 ± 7.5	55.2 ± 13.5
$a_{\pi\Sigma}$ (10^{-3})	-2.29 ± 1.89	2.33 ± 3.17
$a_{\eta\Lambda}$ (10^{-3})	-14.2 ± 12.7	8.00 ± 5.04
$a_{\eta\Sigma}$ (10^{-3})	-5.17 ± 0.07	6.5 ± 20.6
$a_{K\Xi}$ (10^{-3})	27.0 ± 7.8	-9.04 ± 3.63
f/f_π	1.20 ± 0.01	1.21 ± 0.03
b_0 (GeV^{-1})	-1.21 ± 0.01	-0.70 ± 0.23
b_D (GeV^{-1})	0.05 ± 0.04	0.31 ± 0.20
b_F (GeV^{-1})	0.26 ± 0.15	0.65 ± 0.41
d_1 (GeV^{-1})	-0.11 ± 0.06	0.17 ± 0.26
d_2 (GeV^{-1})	0.65 ± 0.02	0.17 ± 0.11
d_3 (GeV^{-1})	2.85 ± 0.04	0.37 ± 0.16
d_4 (GeV^{-1})	-2.10 ± 0.02	0.01 ± 0.09
D	-	0.90 ± 0.10
F	-	0.40 ± 0.08
$\chi^2_{\mathrm{d.o.f.}}$	0.65	0.73

Very different sets of fitting parameters.

No accuracy gain of the fitting parameters.

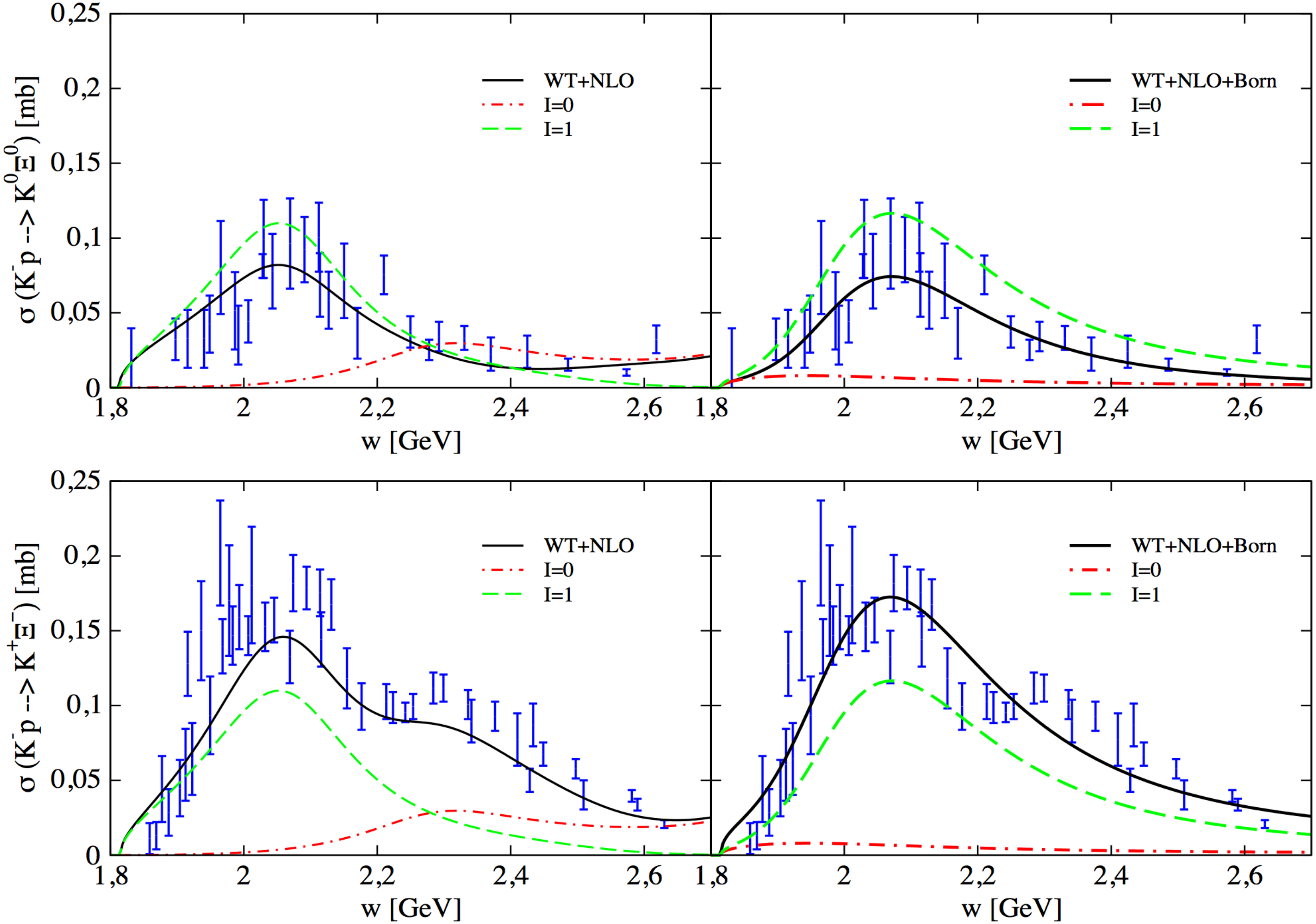
The subtraction constants related to WT+NLO+Born are more natural sized.

Which are the most realistic values for the NLO coefficients?

Where does the difference in the physical interpretation lie ???

The goodness of the fits is almost equal.

ISOSPIN BASIS DECOMPOSITION
Comparison between models



ISOSPIN FILTERING PROCESSES

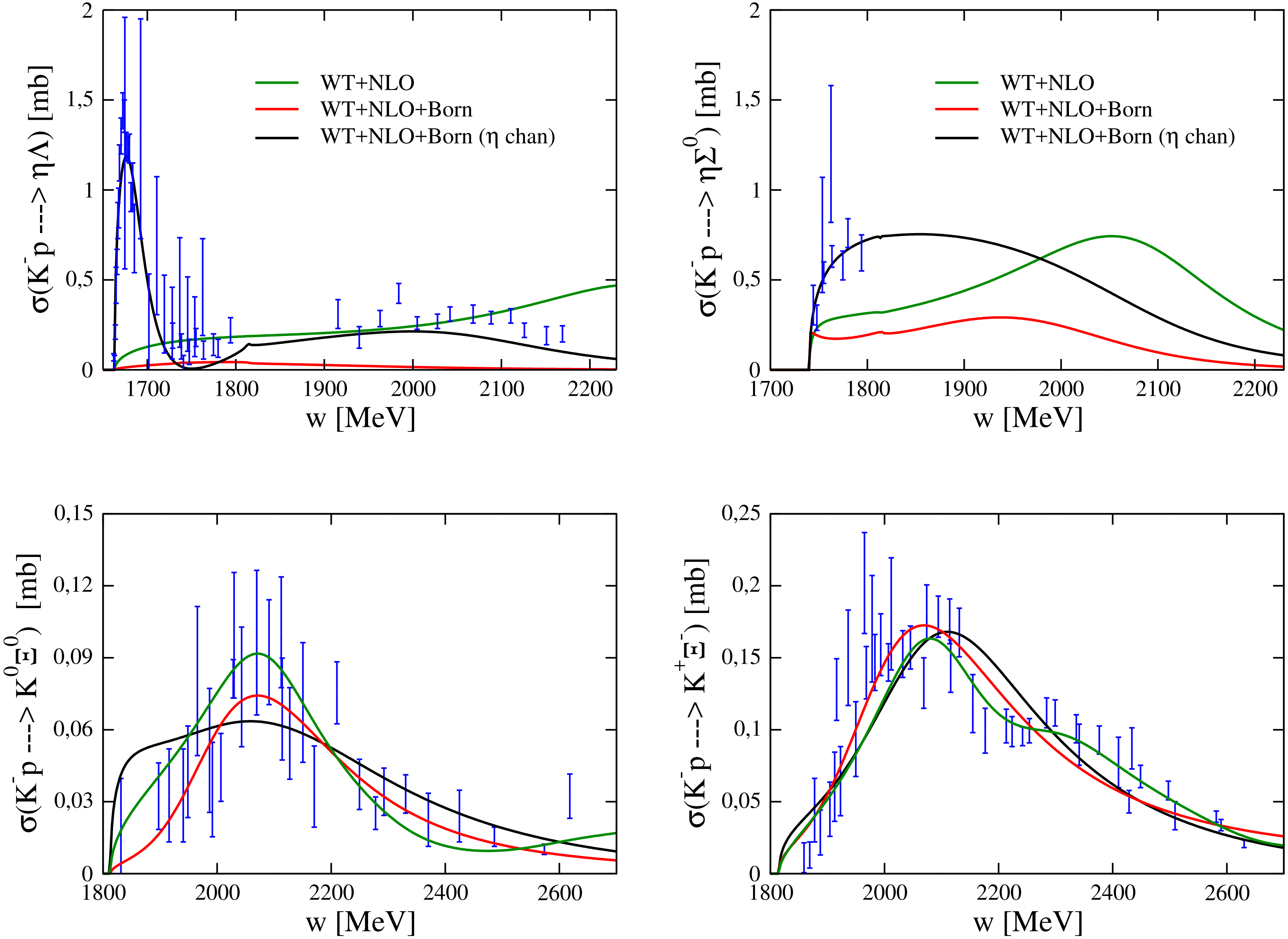
Scenarios consisting of processes which filter isospin could provide more constraints in order to get more reliable values of NLO coefficients.

- **Inclusion of the experimental data from $\eta\Lambda$, $\eta\Sigma^0$ channels in the fitting procedure, pure $I = 0$ and $I = 1$ processes respectively.**

  Until then the scattering data used in the fits come from:

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

WT+Born+NLO
Considering $K^- p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in the fit

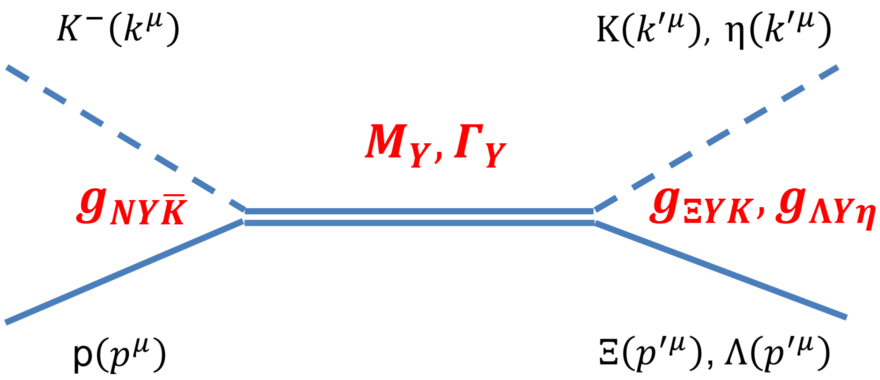


INCLUSION OF HYPERONIC RESONANCES

- Inclusion of high spin and high mass resonances allows us to study the accuracy and stability of the NLO parameters ($b_0, b_D, b_F, d_1, d_2, d_3, d_4$).

- It also simulates the contributions of higher angular momenta of the other channels via rescattering in the energy regime above $K\Xi$ threshold.

Resonance	$I\ (J^P)$	Mass (MeV)	Γ (MeV)	$\Gamma_{K\Xi}/\Gamma$
$\Lambda(1890)$	$0\ (\frac{3}{2}^+)$	1850 - 1910	60 - 200	
$\Lambda(2100)$	$0\ (\frac{7}{2}^-)$	2090 - 2110	100 - 250	$< 3\%$
$\Lambda(2110)$	$0\ (\frac{5}{2}^+)$	2090 - 2140	150 - 250	
$\Lambda(2350)$	$0\ (\frac{9}{2}^+)$	2340 - 2370	100 - 250	
$\Sigma(1915)$	$1\ (\frac{5}{2}^+)$	1900 - 1935	80 - 160	
$\Sigma(1940)$	$1\ (\frac{3}{2}^-)$	1900 - 1950	150 - 300	
$\Sigma(2030)$	$1\ (\frac{7}{2}^+)$	2025 - 2040	150 - 200	$< 2\%$
$\Sigma(2250)$	$1\ (?^?)$	2210 - 2280	60 - 150	



Y= $\Lambda(1890), \Sigma(2030), \Sigma(2250)$

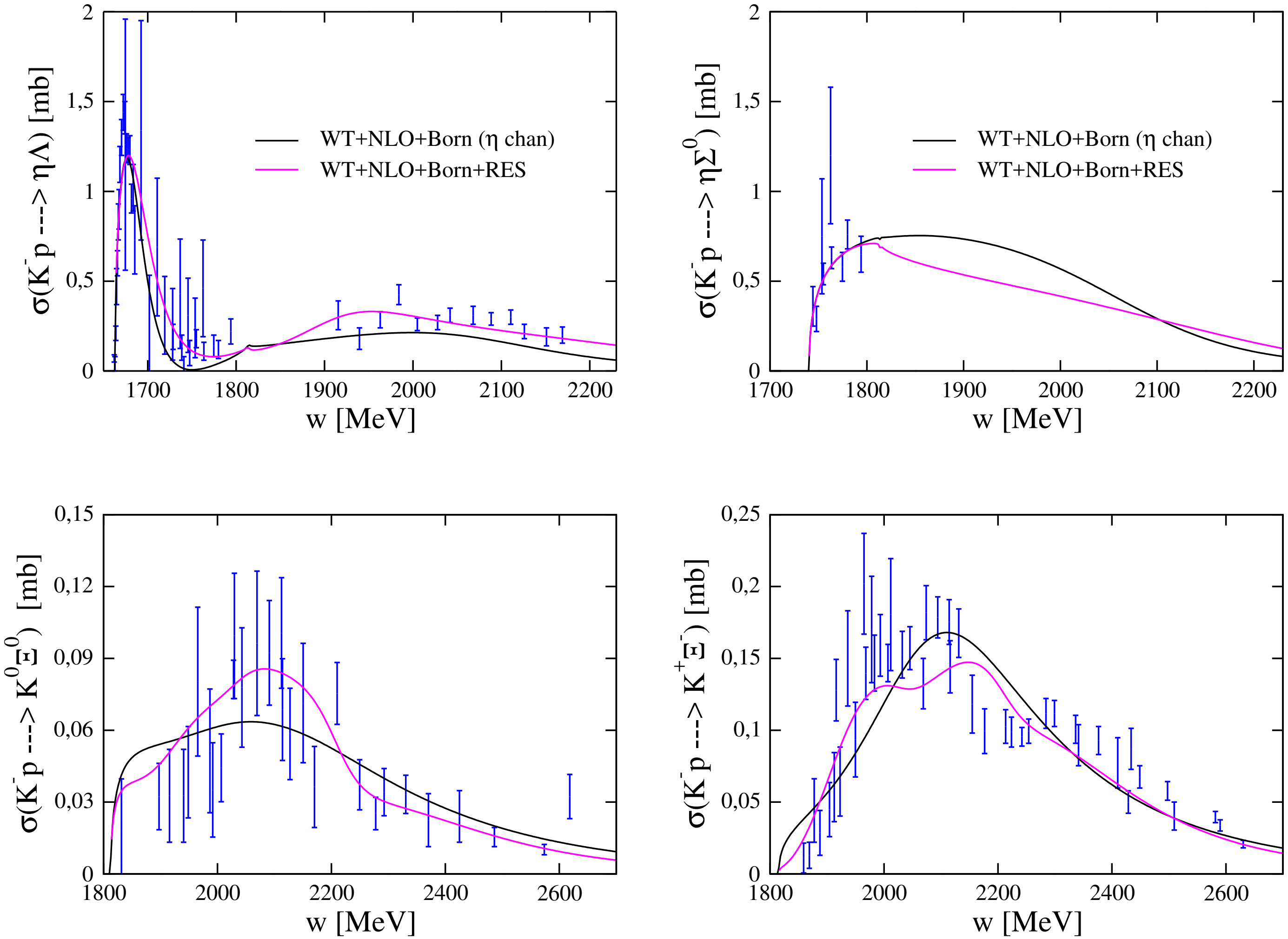
Only for the $\bar{K}N \longrightarrow K\Xi$ reactions:

$$T^{tot}_{ij,s,s'} = T^{NLO}_{ij,s,s'} + T^{5/2^-}_{s,s'} + T^{7/2^+}_{s,s'} + T^{3/2^+}_{s,s'}$$

Only for the $\bar{K}N \longrightarrow \eta\Lambda$ reactions:

$$T^{tot}_{ij,s,s'} = T^{NLO}_{ij,s,s'} + T^{3/2^+}_{s,s'}$$

RESULTS II: WT+Born+NLO vs. WT+Born+NLO+RES
Considering $K^- p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in the fit



	γ	R_n	R_c	$a_p(K^-p \to K^-p)$	ΔE_{1s}	Γ_{1s}
WT+NLO+Born	2.36	0.188	0.659	$-0.65 + i\,0.88$	288	588
WT+NLO+Born+RES	2.36	0.189	0.661	$-0.64 + i\,0.87$	283	587
Exp.	2.36	0.189	0.664	$-0.66 + i\,0.81$	283	541
	± 0.04	± 0.015	± 0.011	$(\pm 0.07) + i\,(\pm 0.15)$	± 36	± 92

RESULTS II: WT+Born+NLO vs. WT+Born+NLO+RES
Considering $K^- p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in the fit

	WT+NLO+Born	WT+NLO+Born+RES
$a_{\bar{K}N}$ (10^{-3})	1.27 ± 0.12	1.52 ± 0.21
$a_{\pi\Lambda}$ (10^{-3})	-6.1 ± 12.9	-2.6 ± 13.9
$a_{\pi\Sigma}$ (10^{-3})	0.68 ± 1.43	2.1 ± 1.2
$a_{\eta\Lambda}$ (10^{-3})	-0.67 ± 1.06	0.76 ± 1.21
$a_{\eta\Sigma}$ (10^{-3})	8.00 ± 3.26	10.1 ± 3.7
$a_{K\Xi}$ (10^{-3})	-2.51 ± 0.99	-2.01 ± 0.74
f/f_π	1.20 ± 0.03	1.18 ± 0.03
b_0 (GeV^{-1})	0.13 ± 0.04	-0.07 ± 0.01
b_D (GeV^{-1})	0.12 ± 0.01	0.13 ± 0.01
b_F (GeV^{-1})	0.21 ± 0.02	0.27 ± 0.02
d_1 (GeV^{-1})	0.15 ± 0.03	0.14 ± 0.03
d_2 (GeV^{-1})	0.13 ± 0.03	0.13 ± 0.01
d_3 (GeV^{-1})	0.30 ± 0.02	0.40 ± 0.02
d_4 (GeV^{-1})	0.25 ± 0.03	0.02 ± 0.02
D	0.70 ± 0.16	0.70 ± 0.15
F	0.51 ± 0.11	0.40 ± 0.11
$g_{\Xi Y_{5/2} K} g_{N Y_{5/2} \bar{K}}$	-	-3.88 ± 9.58
$g_{\Xi Y_{7/2} K} g_{N Y_{7/2} \bar{K}}$	-	-14.3 ± 14.4
$\Lambda_{5/2}$	-	541.31 ± 290.0
$\Lambda_{7/2}$	-	500.0 ± 426.8
$M_{Y_{5/2}}$	-	2210.0 ± 39.1
$M_{Y_{7/2}}$	-	2040.0 ± 14.88
$\Gamma_{5/2}$	-	150.0 ± 52.4
$\Gamma_{7/2}$	-	150.0 ± 43.1
$g_{\Lambda Y_{3/2} \eta} g_{N Y_{3/2} \bar{K}}$	-	8.9 ± 11.8
$g_{\Xi Y_{3/2} K} g_{N Y_{3/2} \bar{K}}$	-	6.20 ± 8.21
$\Lambda_{3/2}$	-	839.7 ± 406.7
$M_{Y_{3/2}}$	-	1910.0 ± 44.70
$\Gamma_{3/2}$	-	200.0 ± 120.3
$\chi^2_{\mathrm{d.o.f.}}$	1.14	0.96

Natural sized values for all

Very homogeneous and accurate values

16% improvement on the goodness of the fit

ISOSPIN FILTERING PROCESSES

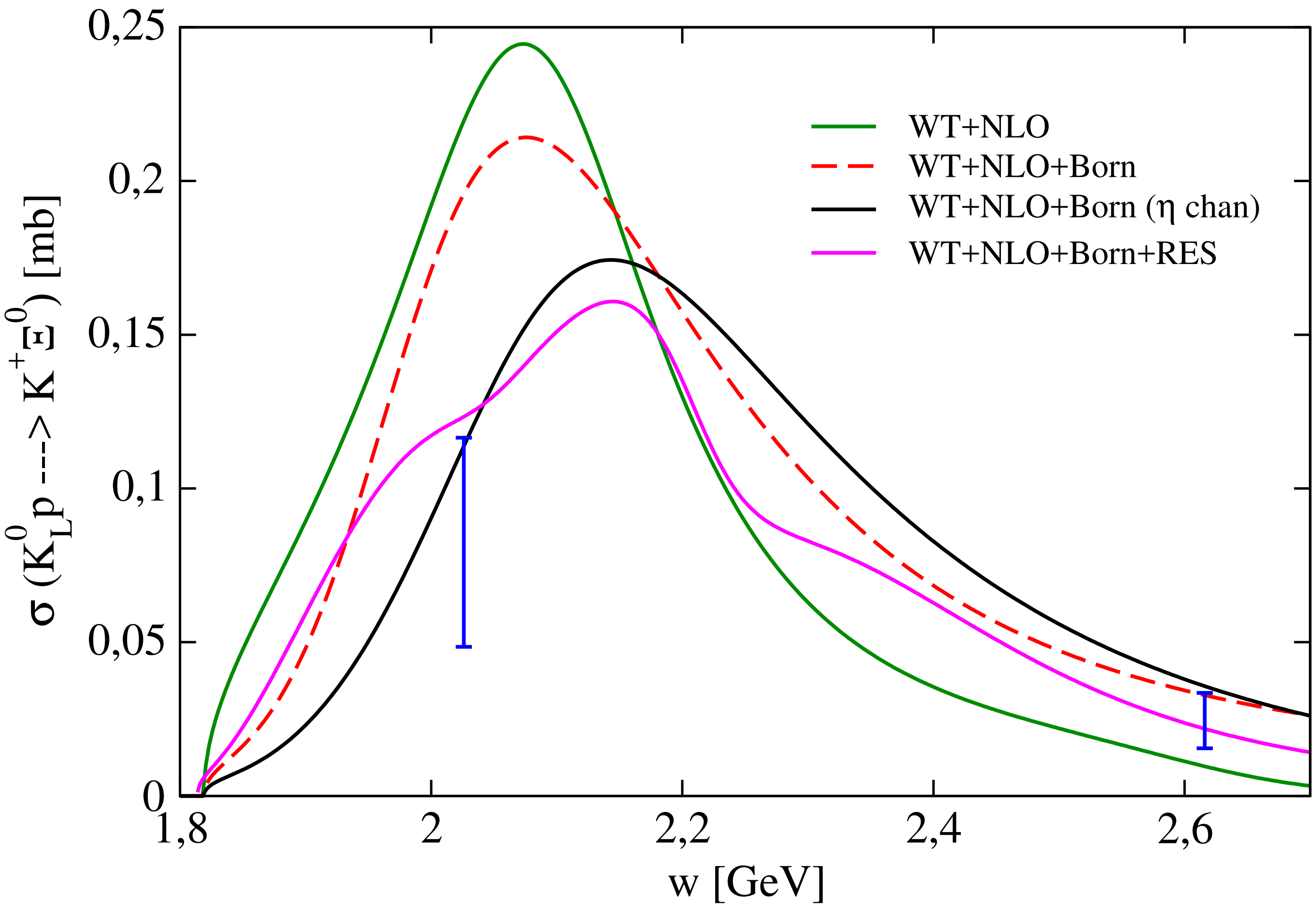
New scenarios consisting of processes which filter isospin could provide more constraints in order to get more reliable values of NLO coefficients.

- **Inclusion of the experimental data from $\eta\Lambda$, $\eta\Sigma^0$ channels in the fitting procedure, pure $I = 0$ and $I = 1$ processes respectively.**
  Until then the scattering data used in the fits come from:
  $K^- p \longrightarrow K^- p, \bar{K}^0 n, \pi^0 \Lambda, \pi^0 \Sigma^0, \pi^+ \Sigma^-, \pi^- \Sigma^+, K^+ \Xi^-, K^0 \Xi^0$

- **J-Lab proposal for the secondary K_L beam for the reaction $K^- n \longrightarrow K^0 \Xi^-$, pure $I = 1$ process.**
  A. Ramos, A. Feijoo, V. Magas, arXiv: 1604.02141 (Conference Proceedings).
  A. Ramos, A. Feijoo, V. Magas, Nucl. Phys. A 954, 58 (2016)..

Prediction for $K^{-}n \longrightarrow K^{0}\Xi^{-}$ reaction

(pure $I = 1$ process)



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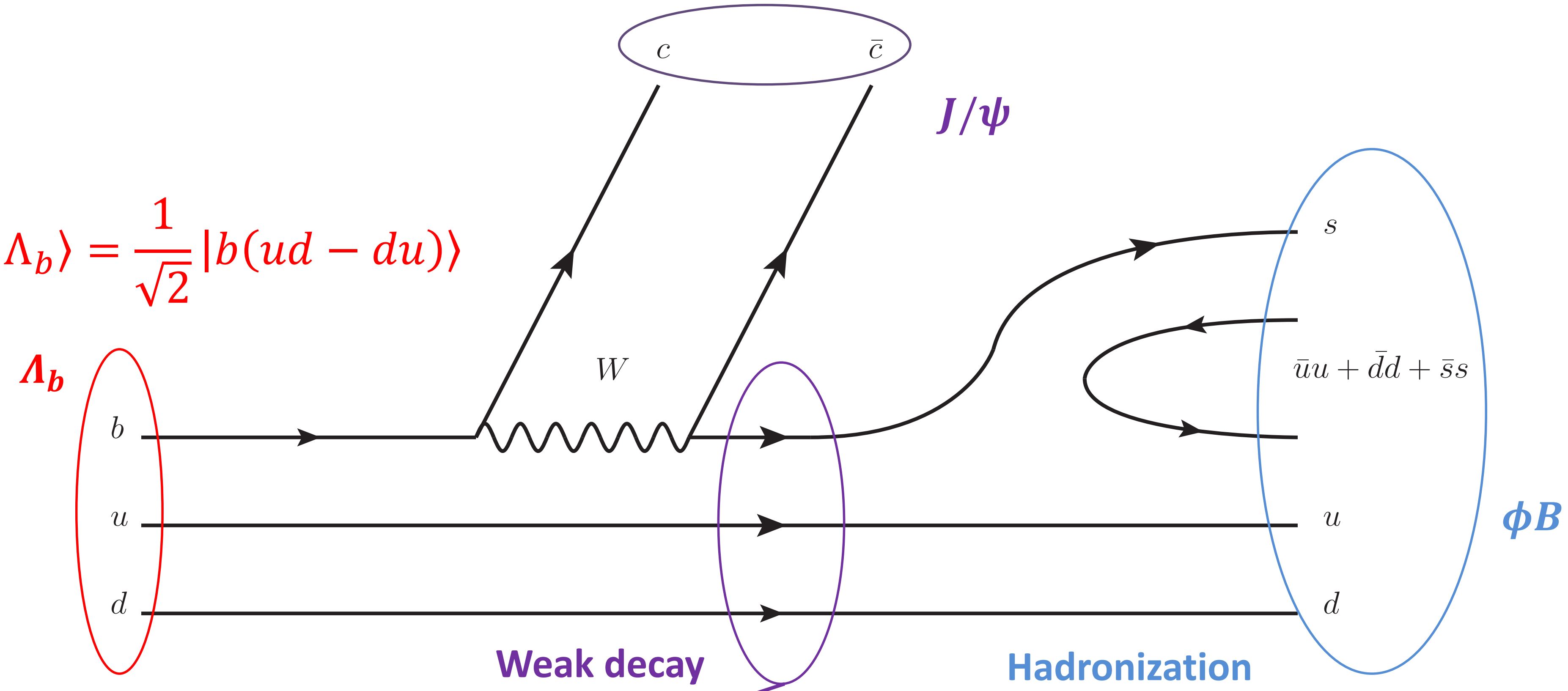
- **$\Lambda_b \longrightarrow J/\psi\, \eta\Lambda,\ J/\psi\, K\Xi$ decayment, pure $I=0$ process.**
  A. Feijoo, V. Magas, A. Ramos, E. Oset, Phys. Rev. D 92, 076015 (2015).

ISOSPIN FILTERING PROCESSES: $\Lambda_b \longrightarrow J/\psi\ \phi B$

$$|\Lambda_b\rangle = \frac{1}{\sqrt{2}}|b(ud-du)\rangle$$



$$\frac{1}{\sqrt{2}}|s(ud-du)\rangle$$

$$\frac{1}{\sqrt{2}}\left|s\left(u\bar{u}+d\bar{d}+s\bar{s}\right)(ud-du)\right\rangle =$$

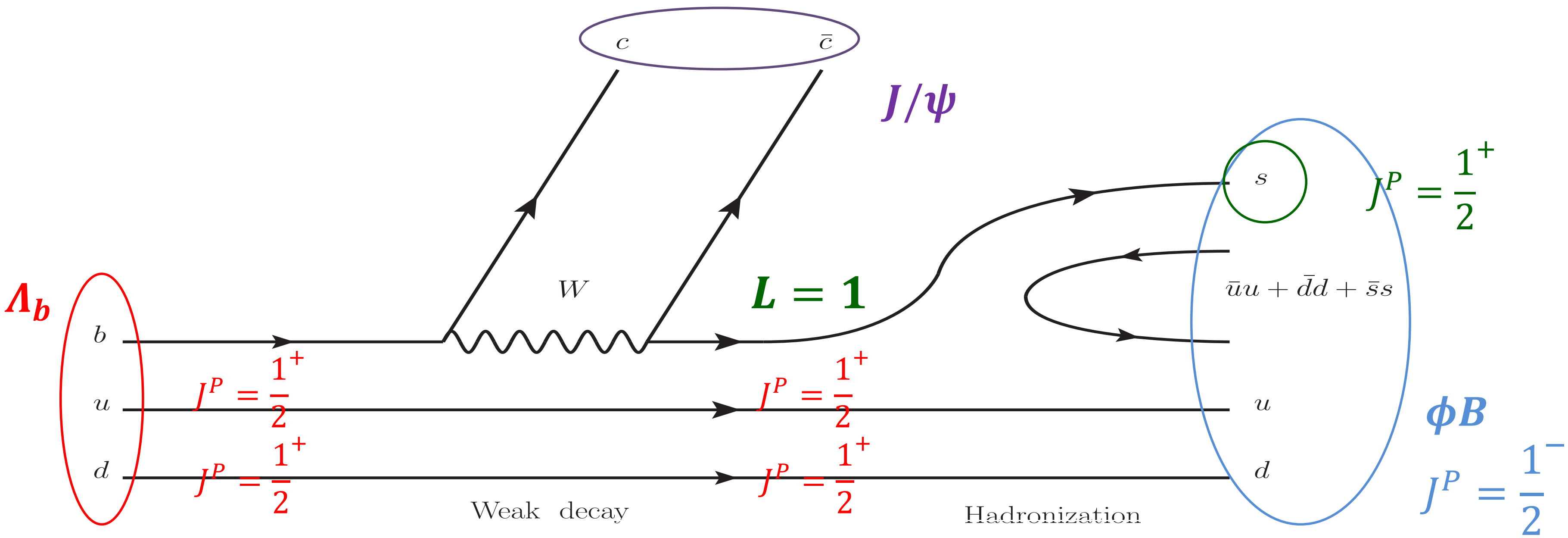
$$|K^-p\rangle + |\bar{K}^0 n\rangle + \frac{\sqrt{2}}{3}|\eta\Lambda\rangle$$

ISOSPIN FILTERING PROCESSES: $\Lambda_b \longrightarrow J/\psi\, \phi B$

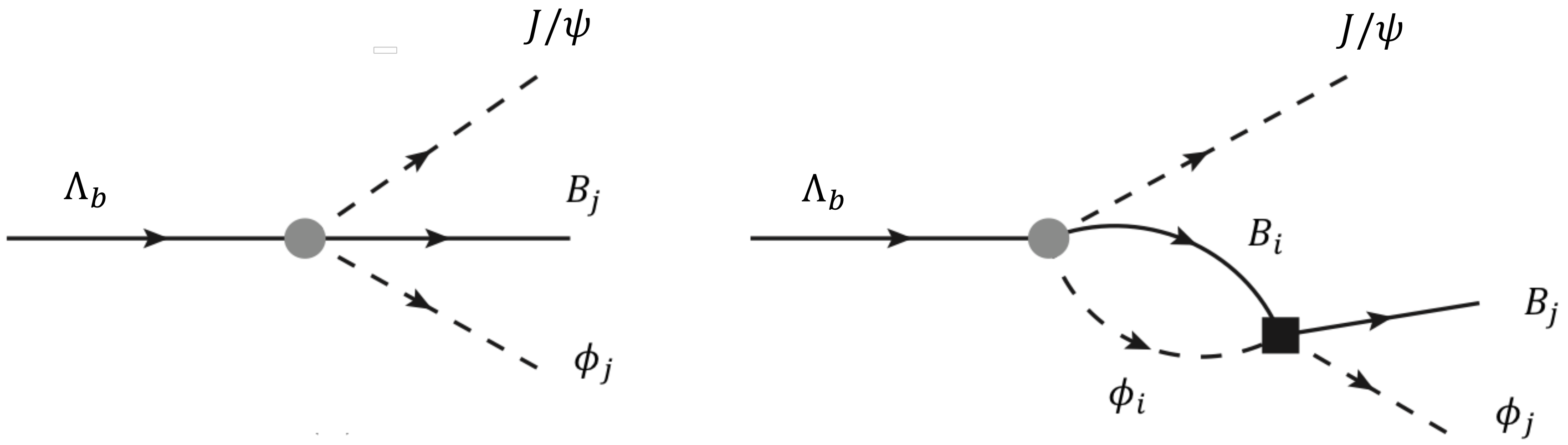
- Λ_b, b have I=0 $\longrightarrow$ ud quark pair has I=0
- We assume that u and d quarks act as spectators
- After the weak decay the combination of ud with s can only form Λ (I=0) states

  R. Aaij. et al. [LHCb Collaboration], Phys. Rev. Lett. 115 072001 (2015).

$$|\Lambda_b\rangle = \frac{1}{\sqrt{2}}|b\boxed{(ud-du)}\rangle \qquad \frac{1}{\sqrt{2}}|s\boxed{(ud-du)}\rangle$$



ISOSPIN FILTERING PROCESSES: $\Lambda_b \longrightarrow J/\psi\, \phi B$



$$\mathcal{M}(M_{\phi B}, M_{J/\psi B}) = V_P[h_{\phi B} + \sum_i h_i\, G_i(M_{\phi B}) t_{i,\phi B}(M_{\phi B})]$$

$$h_{\pi^0\Sigma^0} = h_{\pi^+\Sigma^-} = h_{\pi^-\Sigma^+} = h_{K^+\Xi^-} = h_{K^0\Xi^0} = 0,$$

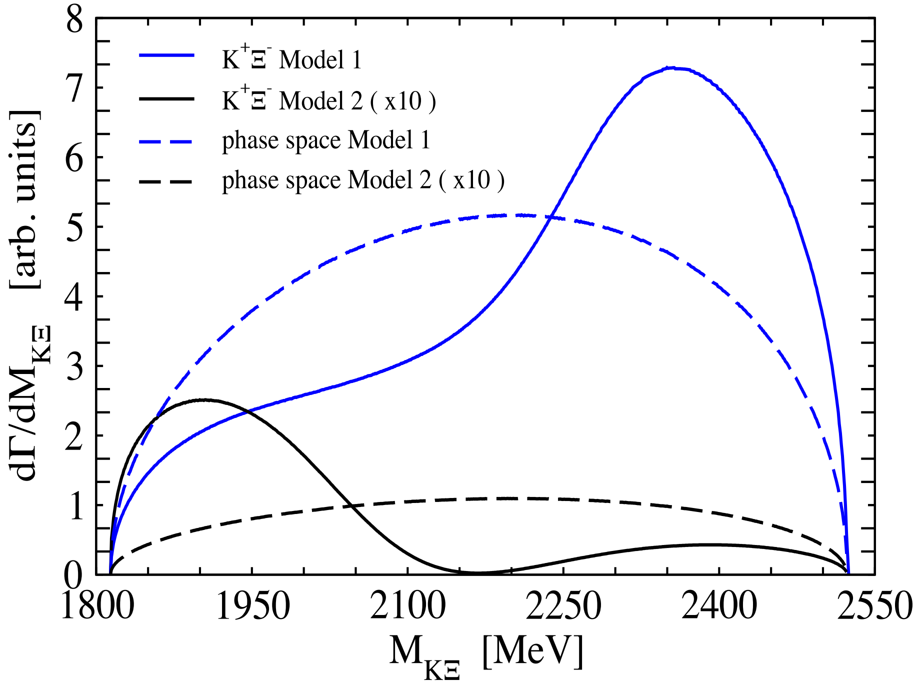
$$h_{K^-p} = h_{\bar{K}^0 n} = 1, \qquad h_{\eta\Lambda} = \frac{\sqrt{2}}{3}$$

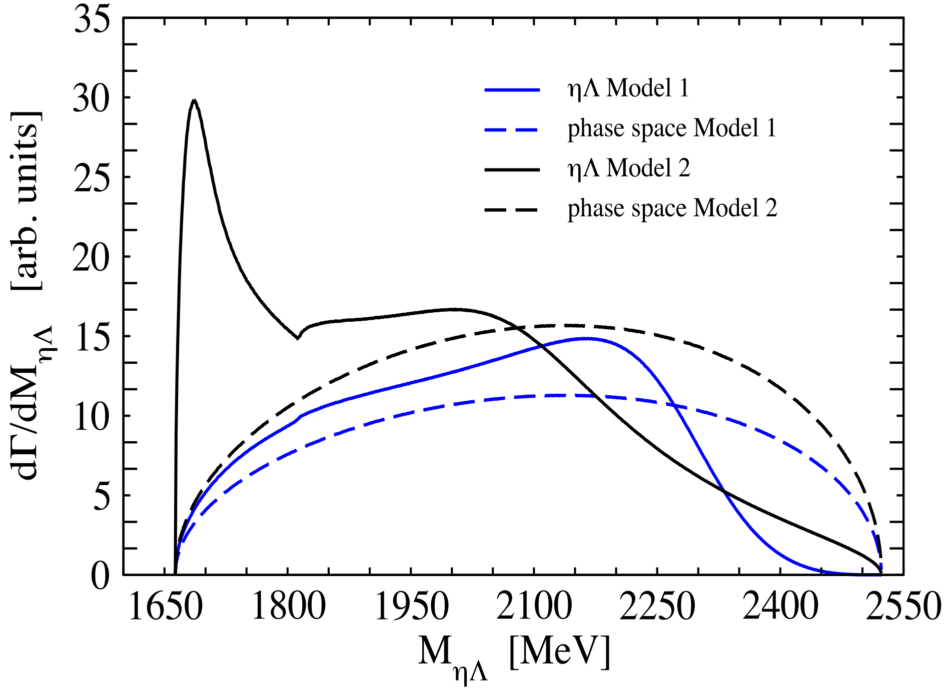
- Meson-Baryon loop function $\boldsymbol{G_i}$ $(i = K^-p, \bar{K}^0 n, \eta\Lambda)$
- Scattering amplitude $\boldsymbol{t_{i,\phi B}}$
  employing **Model 1 (*WT+NLO*)** and **Model 2 (*WT+NLO+Born+η chan*)**
- The $\boldsymbol{V_P}$ factor absorbs the CKM matrix elements and the kinematic prefactors
- We study the particular cases $\boldsymbol{\phi B}$ **=** $\boldsymbol{K^+\Xi^-, \eta\Lambda}$

ISOSPIN FILTERING PROCESSES: $\Lambda_b \longrightarrow J/\psi\ \phi B$

$\Lambda_b \longrightarrow J/\psi\ \eta\Lambda, J/\psi\ K\Xi$

(pure $I = 0$ processes)





Promising data from LHCb would be very useful to constrain our models!

CONCLUSIONS

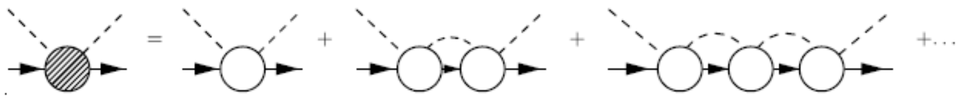
- Chiral Perturbation Theory with unitarization in coupled channels is a very powerful technique to describe low energy hadron dynamics.
- The $\bar{K}N \longrightarrow K\Xi$ channels are very sensitive to the NLO terms of the lagrangian as well as to the Born terms, so they provide more reliable values of the NLO parameters.
- Experimental data from processes which filter isospin have been shown to be very helpful to reproduce properly the whole meson-baryon channels of the S=-1 sector and to constrain the fitting parameters.
- Addition of resonant terms in the scattering amplitude could play a significant role in the $\bar{K}N \longrightarrow K\Xi, \eta\Lambda$ reactions giving a significantly better agreement with experimental data.

THANK YOU

for your attention!!!

INTRODUCTION
UChPT as nonperturbative scheme to obtain scattering amplitude.

Bethe-Salpeter equation:



$$T_{ij} = V_{ij} + V_{il}G_l V_{lj} + V_{il}G_l V_{lk}G_k V_{kj} + \cdots$$

$$T_{ij} = V_{ij} + V_{il}G_l T_{lj} \Longrightarrow \boxed{T = (1 - VG)^{-1}V}$$

$$G_k = \frac{M_k}{16\pi^2}\left(a_k(\mu) + ln\frac{M_k^2}{\mu^2} + \frac{m_k^2 - M_k^2 + s}{2s} ln\frac{m_k^2}{M_k^2} - 2i\pi\frac{q_k}{\sqrt{s}}\right) + \frac{M_k}{16\pi^2}\left\{\frac{q_k}{\sqrt{s}} ln\left(\frac{s^2 - \left(\left(M_k^2 - m_k^2\right) + 2q_k\sqrt{s}\right)^2}{s^2 - \left(\left(M_k^2 - m_k^2\right) - 2q_k\sqrt{s}\right)^2}\right)\right\}$$

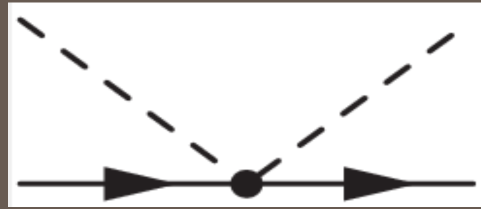
subtraction constants for the dimensional regularization scale $\mu = 1GeV$ in all the k channels.

With isospin symmetry

$$\left\{\begin{array}{c} a_{K^-p} = a_{\bar{K}^0 n} = a_{\bar{K}N} \\ a_{\pi^0\Lambda} = a_{\pi\Lambda} \\ a_{\pi^0\Sigma^0} = a_{\pi^+\Sigma^-} = a_{\pi^-\Sigma^+} = a_{\pi\Sigma} \\ a_{\eta\Lambda} \\ a_{\eta\Sigma^0} = a_{\eta\Sigma} \\ a_{K^+\Xi^-} = a_{K^0\Xi^0} = a_{K\Xi} \end{array}\right.$$

6 PARAMETERS!

FORMALISM
Effective lagrangian up to LO
Weinberg-Tomozawa Term, WT



WT, *lowest order term*

$$\mathcal{L}_{MB}^{(1)}(B,U) = \langle \bar{B} i\gamma^{\mu} \nabla_{\mu} B \rangle - M_B \langle \bar{B}B \rangle + \frac{1}{2} D \langle \bar{B}\gamma^{\mu}\gamma_5 \{u_{\mu}, B\} \rangle + \frac{1}{2} F \langle \bar{B}\gamma^{\mu}\gamma_5 [u_{\mu}, B] \rangle$$

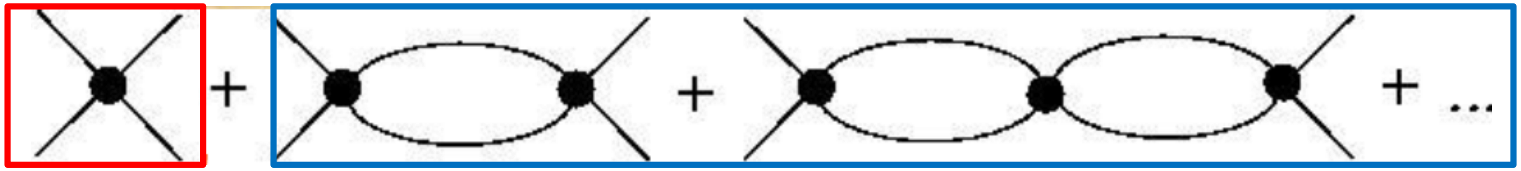
$$V_{ij}^{WT} = -C_{ij} \frac{1}{4f^2} \mathcal{N}_i \mathcal{N}_j \left(\sqrt{s} - M_i - M_j\right)$$

Special attention is paid to $K^- p \rightarrow K\,\Xi$ reactions:

- **There is no direct contribution from these reactions at lowest order**

$$C_{K^- p \rightarrow K^0 \Xi^0} = C_{K^- p \rightarrow K^+ \Xi^-} = 0$$

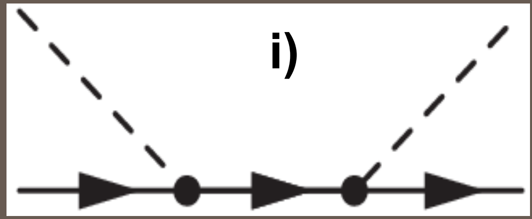
- **The rescattering terms due to the coupled channels are the only contribution to the scattering amplitude.**

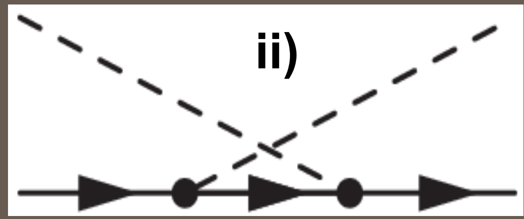


Next terms in hierarchy could play a relevant role in these channels!!!

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

FORMALISM
Effective lagrangian up to LO
Born Terms





$$\mathcal{L}_{MB}^{(1)}(B,U) = \langle \bar{B} i \gamma^{\mu} \nabla_{\mu} B \rangle - M_B \langle \bar{B} B \rangle + \frac{1}{2} D \langle \bar{B} \gamma^{\mu} \gamma_5 \{u_{\mu}, B\} \rangle + \frac{1}{2} F \langle \bar{B} \gamma^{\mu} \gamma_5 [u_{\mu}, B] \rangle$$

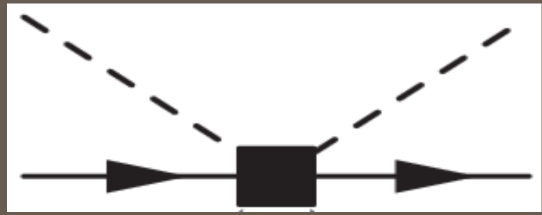
Born *terms*

i) $$V_{ij}^{D} = -\sum_{k=1}^{8} \frac{C_{\bar{i}i,k}^{(\mathrm{Born})} C_{\bar{j}j,k}^{(\mathrm{Born})}}{12 f^2} \mathcal{N}_i \mathcal{N}_j \frac{(\sqrt{s} - M_i)(\sqrt{s} - M_k)(\sqrt{s} - M_j)}{s - M_k^2}$$

ii) $$\begin{aligned} V_{ij}^{C} = &\sum_{k=1}^{8} \frac{C_{\bar{j}k,i}^{(\mathrm{Born})} C_{\bar{i}k,j}^{(\mathrm{Born})}}{12 f^2} \mathcal{N}_i \mathcal{N}_j \\ &\times \Bigg[\sqrt{s} + M_k - \frac{(M_i + M_k)(M_j + M_k)}{2\,(M_i + E_i)\,(M_j + E_j)} (\sqrt{s} - M_k + M_i + M_j) \\ &+ \frac{(M_i + M_k)(M_j + M_k)}{4 q_i q_j} \Big\{ \sqrt{s} + M_k - M_i - M_j \\ &- \frac{s + M_k^2 - m_i^2 - m_j^2 - 2 E_i E_j}{2\,(M_i + E_i)\,(M_j + E_j)} (\sqrt{s} - M_k + M_i + M_j) \Big\} \\ &\times \ln \frac{s + M_k^2 - m_i^2 - m_j^2 - 2 E_i E_j - 2 q_i q_j}{s + M_k^2 - m_i^2 - m_j^2 - 2 E_i E_j + 2 q_i q_j} \Bigg] \end{aligned}$$

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

FORMALISM
Effective lagrangian up to NLO



$$\mathcal{L}_{MB}^{(2)}(B,U) = b_D\langle \bar{B}\{\chi_+, B\}\rangle + b_F\langle \bar{B}[\chi_+, B]\rangle + b_0\langle \bar{B}B\rangle\langle\chi_+\rangle + d_1\langle \bar{B}\{u_\mu, [u^\mu, B]\}\rangle$$
$$+ d_2\langle \bar{B}\left[u_\mu, [u^\mu, B]\right]\rangle + d_3\langle \bar{B}u_\mu\rangle\langle u^\mu B\rangle + d_4\langle \bar{B}B\rangle\langle u^\mu u_\mu\rangle$$

Not fixed low energy coefficients ⟹ parameters of the model!

$$V_{ij}^{NLO} = \frac{1}{f^2}\mathcal{N}_i\mathcal{N}_j\left[D_{ij} - 2\left(\omega_i\omega_j + \frac{q_i^2 q_j^2}{3\,(M_i+E_i)\,(M_j+E_j)}\right)L_{ij}\right]$$

$$L_{K^-p\longrightarrow K^0\Xi^0} \neq 0 \qquad\qquad L_{K^-p\longrightarrow K^+\Xi^-} \neq 0$$

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

Assumption: **the contribution of the Born diagrams would be very moderate.**

This idea was reinforced by other works:
B. Borasoy, R. Nissler, W. Wiese, Eur. Phys. J. A 25, 79 (2005)
Y. Ikeda, T. Hyodo, W. Wiese, Nucl. Phys. A 881, 98 (2012)
T. Mizutani, C. Fayard, B. Saghai, K. Tsushima, Phys. Rev. C 87, 035201 (2013)

$$V_{ij} = V_{ij}^{WT} + \cancel{V_{ij}^{D}} + \cancel{V_{ij}^{C}} + V_{ij}^{NLO} \Rightarrow \boxed{T = (1 - VG)^{-1}V} \Rightarrow T_{ij}^{NLO}$$

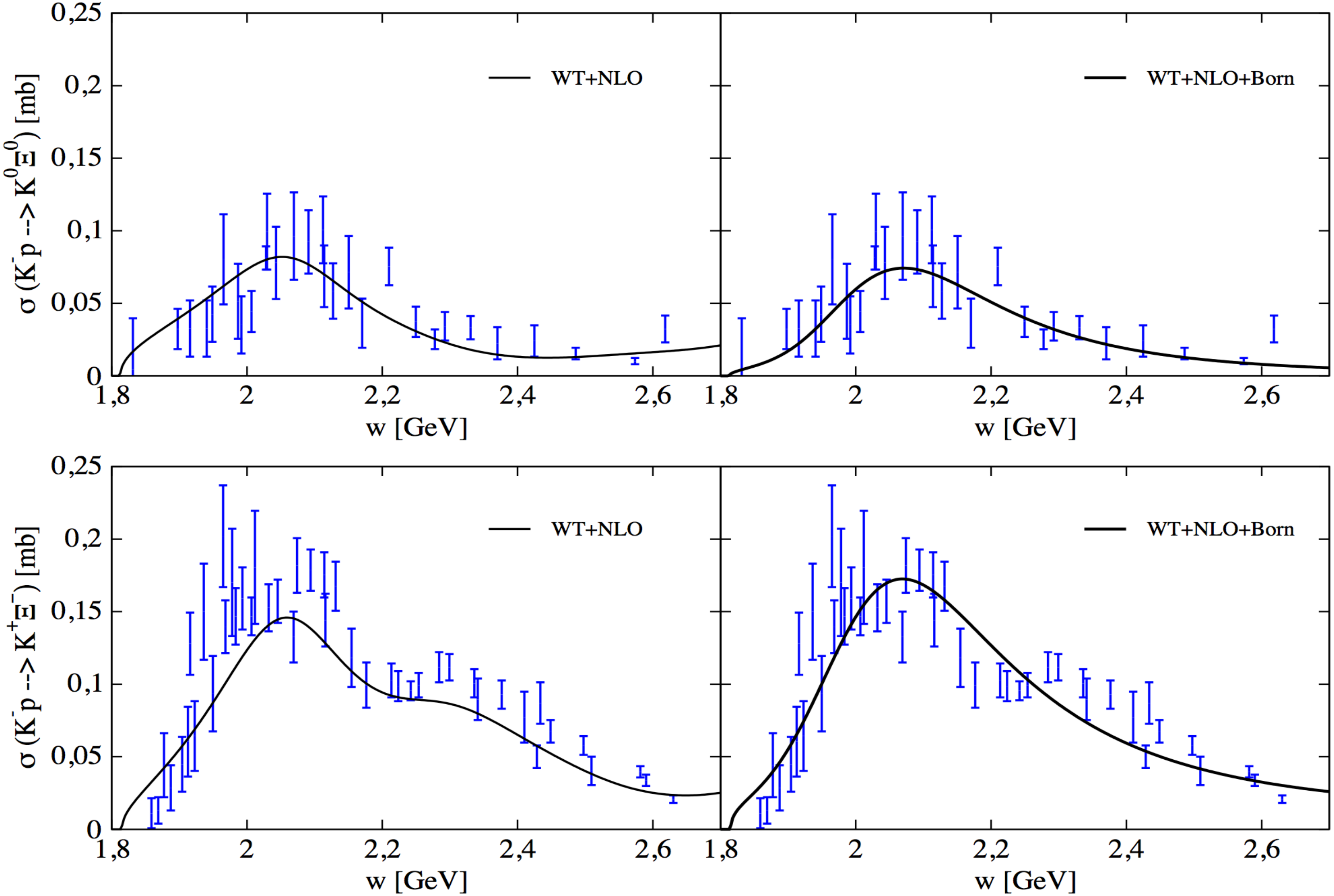
$K^- p \rightarrow K\,\Xi$ reactions could be very sensitive to the NLO corrections!!!

New scattering data should be taken into account:

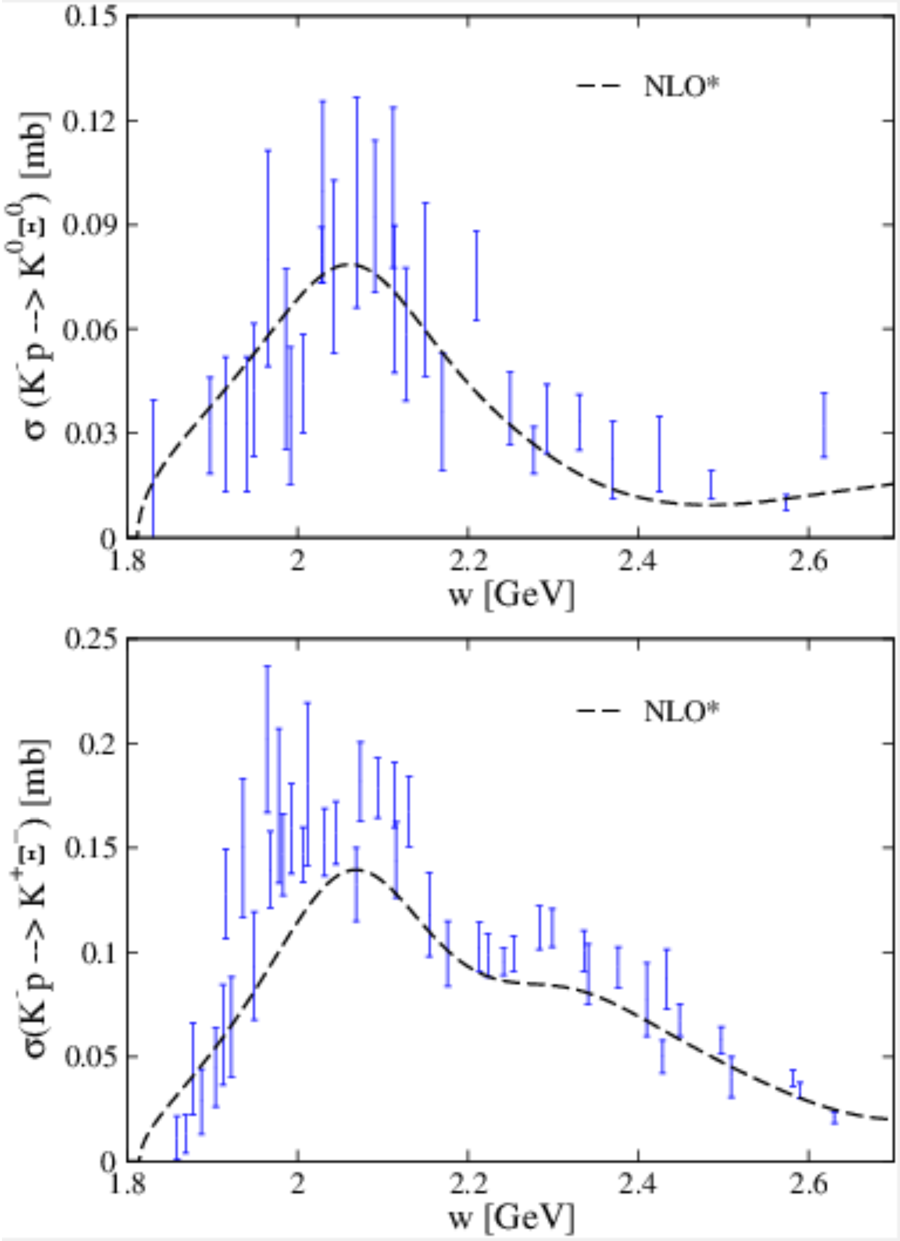
$$K^- p \Rightarrow \boxed{K^- p, \bar{K}^0 n, \pi^0 \Lambda, \pi^0 \Sigma^0, \pi^+ \Sigma^-, \pi^- \Sigma^+} \boxed{K^+ \Xi^-, K^0 \Xi^0}$$

- Channels traditionally employed
- Channels never employed before

INCLUSION OF BORN TERMS
Results I

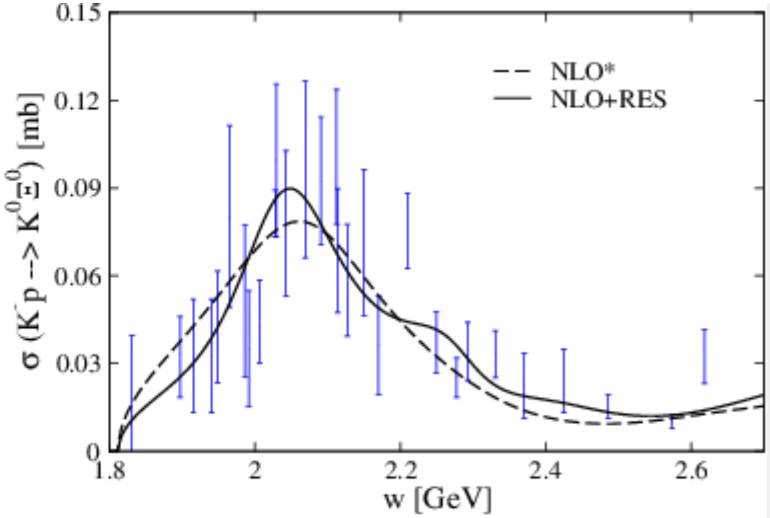


RESULTS I
Results for $\bar{K}N \longrightarrow K\Xi$

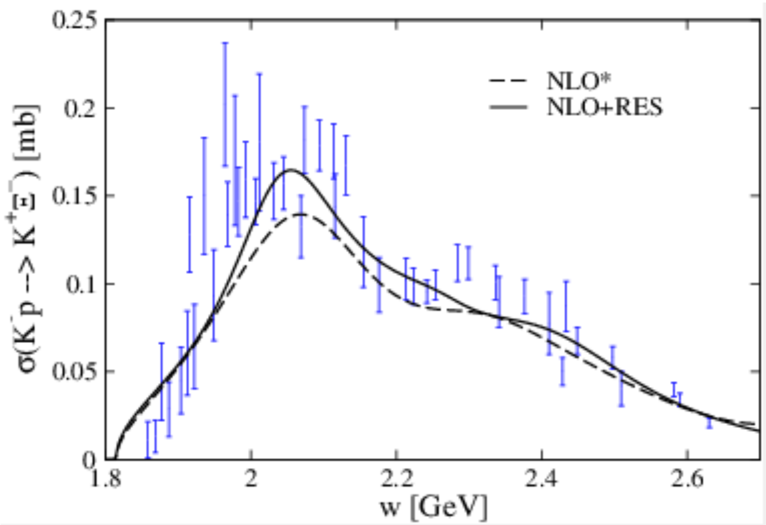


RESULTS I

Results for $\bar{K}N \longrightarrow K\Xi$ including $\Sigma(2030)$, $\Sigma(2250)$ resonances



	γ	R_n	R_c	$a_p(K^-p \rightarrow K^-p)$	ΔE_{1s}	Γ_{1s}
NLO*	2.37	0.189	0.664	$-0.69 + \mathrm{i}\,0.86$	300	570
NLO+RES	2.39	0.187	0.668	$-0.66 + \mathrm{i}\,0.84$	286	562
Exp.	2.36 ± 0.04	0.189 ± 0.015	0.664 ± 0.011	$-0.66 + \mathrm{i}\,0.81$ $(\pm 0.07) + \mathrm{i}\,(\pm 0.15)$	283 ± 36	541 ± 92



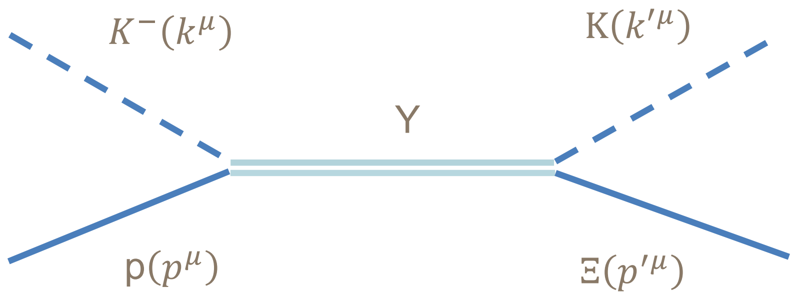
	NLO*	NLO+RES
b_0 (GeV^{-1})	-1.158 ± 0.021	-0.907 ± 0.004
b_D (GeV^{-1})	0.082 ± 0.050	-0.151 ± 0.008
b_F (GeV^{-1})	0.294 ± 0.149	0.535 ± 0.047
d_1 (GeV^{-1})	-0.071 ± 0.069	-0.055 ± 0.055
d_2 (GeV^{-1})	0.634 ± 0.023	0.383 ± 0.014
d_3 (GeV^{-1})	2.819 ± 0.058	2.180 ± 0.011
d_4 (GeV^{-1})	-2.036 ± 0.035	-1.429 ± 0.006

A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 92, 015206 (2015)

INCLUSION OF HYPERONIC RESONANCES

$\bar{K}N \longrightarrow Y \longrightarrow K\Xi$

Y= $\Sigma(2030)$, $\Sigma(2250)$



K. Nakayama, Y. Oh, H. Habertzettl, Phys. Rev. C74, 035205 (2006)
K. Shing Man, Y. Oh, K. Nakayama,, Phys. Rev. C83, 055201 (2011)

$$\Sigma(2030),\ J^P = \frac{7}{2}^+,\ T^{7/2^+}$$

$$\mathscr{L}^{7/2^\pm}_{BYK}(q) = -\frac{g_{BY_{7/2}K}}{m_K^3}\bar{B}\Gamma^{(\mp)}Y^{\mu\nu\alpha}_{7/2}\partial_\mu\partial_\nu\partial_\alpha K + H.c.$$

$$\Sigma(2250),\ J^P = \frac{5}{2}^-,\ T^{5/2^-}$$

$$\mathscr{L}^{5/2^\pm}_{BYK}(q) = i\frac{g_{BY_{5/2}K}}{m_K^2}\bar{B}\Gamma^{(\pm)}Y^{\mu\nu}_{5/2}\partial_\mu\partial_\nu K + H.c.$$

Finally, the scattering amplitudes related to the resonances can be obtained in the following way :

$$T^{5/2^-}(s',s) = \frac{g_{\Xi Y_{5/2}K}\,g_{NY_{5/2}\bar{K}}}{m_K^4}\bar{u}^{s'}_{\Xi}(p')\frac{k'_{\beta_1}k'_{\beta_2}\Delta^{\beta_1\beta_2}_{\alpha_1\alpha_2}k^{\alpha_1}k^{\alpha_2}}{\not{q} - M_{Y_{5/2}} + i\Gamma_{5/2}/2}u^s_N(p)\boxed{\exp\left(-\vec{k}^2/\Lambda^2_{5/2}\right)}\boxed{\exp\left(-\vec{k}'^2/\Lambda^2_{5/2}\right)}$$

$$T^{7/2^+}(s',s) = \frac{g_{\Xi Y_{7/2}K}\,g_{NY_{7/2}\bar{K}}}{m_K^6}\bar{u}^{s'}_{\Xi}(p')\frac{k'_{\beta_1}k'_{\beta_2}k'_{\beta_2}\Delta^{\beta_1\beta_2\beta_3}_{\alpha_1\alpha_2\alpha_3}k^{\alpha_1}k^{\alpha_2}k^{\alpha_3}}{\not{q} - M_{Y_{7/2}} + i\Gamma_{7/2}/2}u^s_N(p)\boxed{\exp\left(-\vec{k}^2/\Lambda^2_{7/2}\right)}\boxed{\exp\left(-\vec{k}'^2/\Lambda^2_{7/2}\right)}$$

INCLUSION OF HYPERONIC RESONANCES
$\bar{K}N \longrightarrow Y \longrightarrow K\Xi$

Y= $\Sigma(2030), \Sigma(2250)$

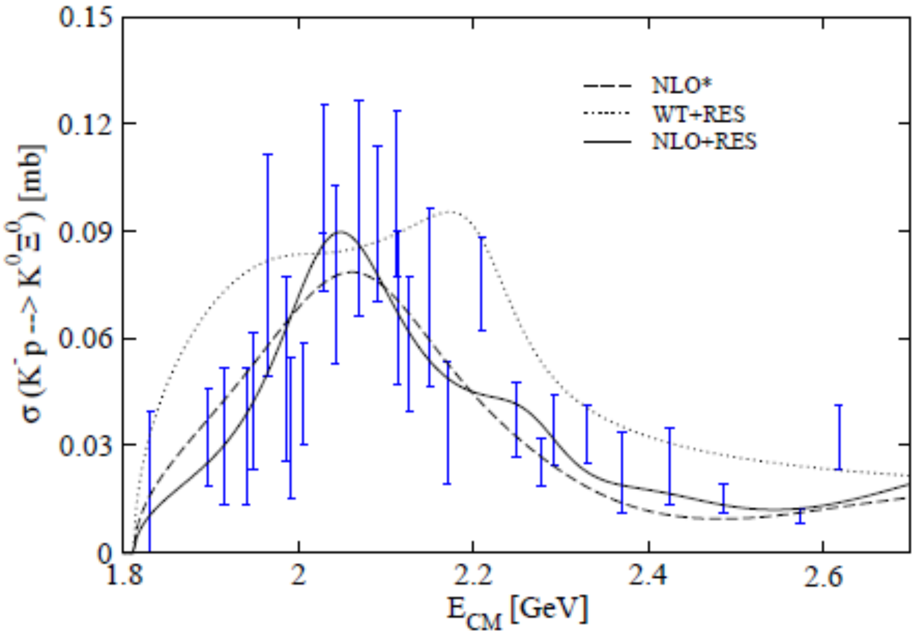
The total scattering amplitude for the $\bar{K}N \longrightarrow K\Xi$ reaction taking into account the unitarized chiral contributions up to NLO plus the phenomenological contributions from the resonances reads:

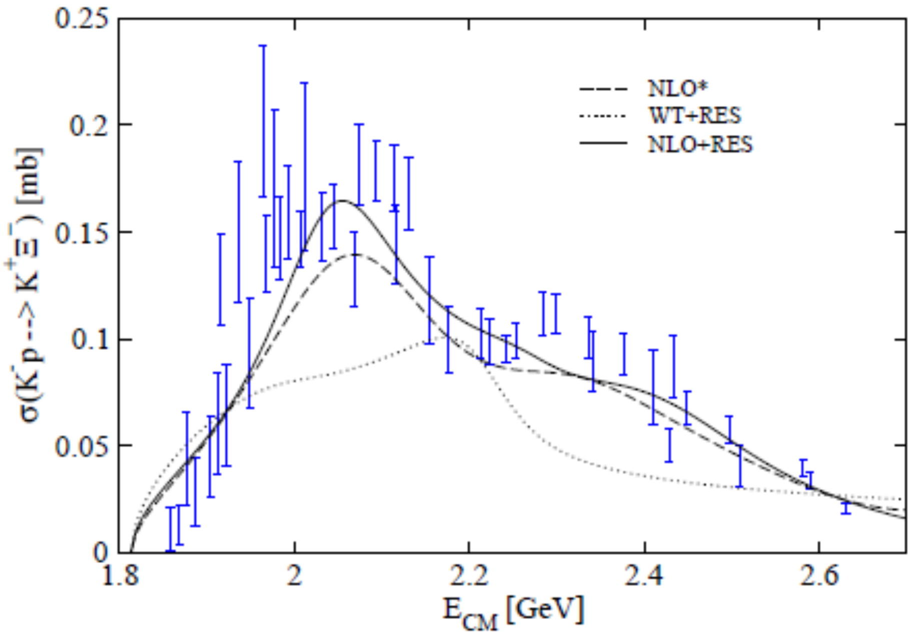
$$T^{tot}_{ij,s,s'} = T^{NLO}_{ij,s,s'} + T^{5/2^-}_{s,s'} + T^{7/2^+}_{s,s'}$$

Fitting parameters.

- Decay constant f
- Subtracting constants $a_{\bar{K}N}$, $a_{\pi\Lambda}$, $a_{\pi\Sigma}$, $a_{\eta\Lambda}$, $a_{\eta\Sigma}$, $a_{K\Xi}$
- Coefficients of the NLO lagrangian terms $b_0, b_D, b_F, d_1, d_2, d_3, d_4$
- Masses and width of the resonances $M_{Y_{5/2}}, M_{Y_{7/2}}, \Gamma_{5/2}, \Gamma_{7/2}$
  Not free at all, their values are constrained according to PDG summary
- Cutoff parameters from the form factor $\Lambda_{5/2}, \Lambda_{7/2}$
- Product of the coupling constants (one for each vertex) for both resonances
  $g_{\Xi Y_{5/2}K} \cdot g_{NY_{5/2}\bar{K}}$, $g_{\Xi Y_{7/2}K} \cdot g_{NY_{7/2}\bar{K}}$

RESULTS I
Results for $\bar{K}N \longrightarrow K\Xi$ including $\Sigma(2030), \Sigma(2250)$ resonances

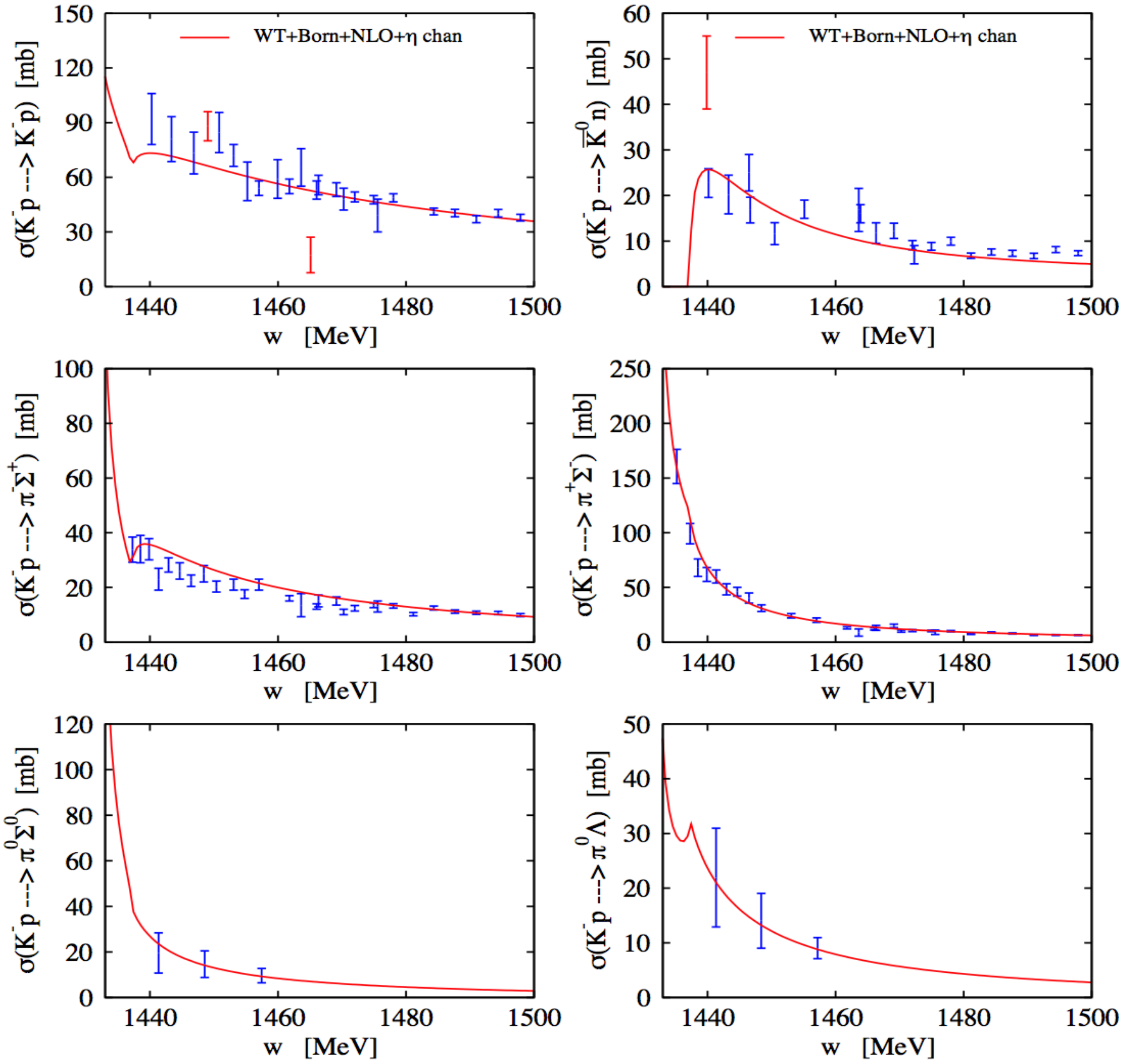




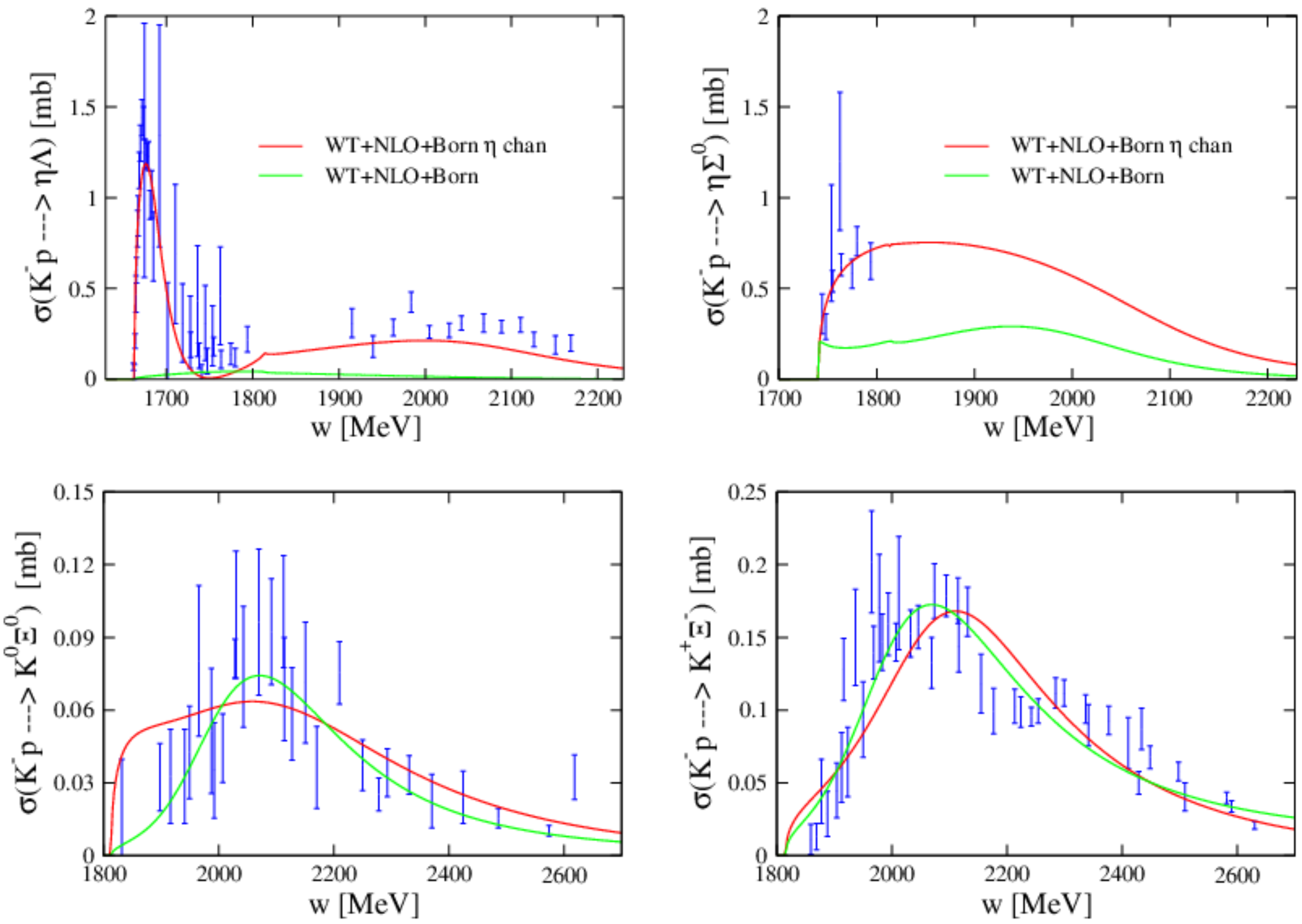
	γ	R_n	R_c	$a_p(K^-p \to K^-p)$	ΔE_{1s}	Γ_{1s}
NLO*	2.37	0.189	0.664	$-0.69 + \mathrm{i}\,0.86$	300	570
WT+RES	2.37	0.193	0.667	$-0.73 + \mathrm{i}\,0.81$	307	528
NLO+RES	2.39	0.187	0.668	$-0.66 + \mathrm{i}\,0.84$	286	562
Exp.	2.36	0.189	0.664	$-0.66 + \mathrm{i}\,0.81$	283	541
	± 0.04	± 0.015	± 0.011	$(\pm 0.07) + \mathrm{i}\,(\pm 0.15)$	± 36	± 92

A. Feijoo, V. Magas, A. Ramos, Phys. Rev. C 92, 015206 (2015)

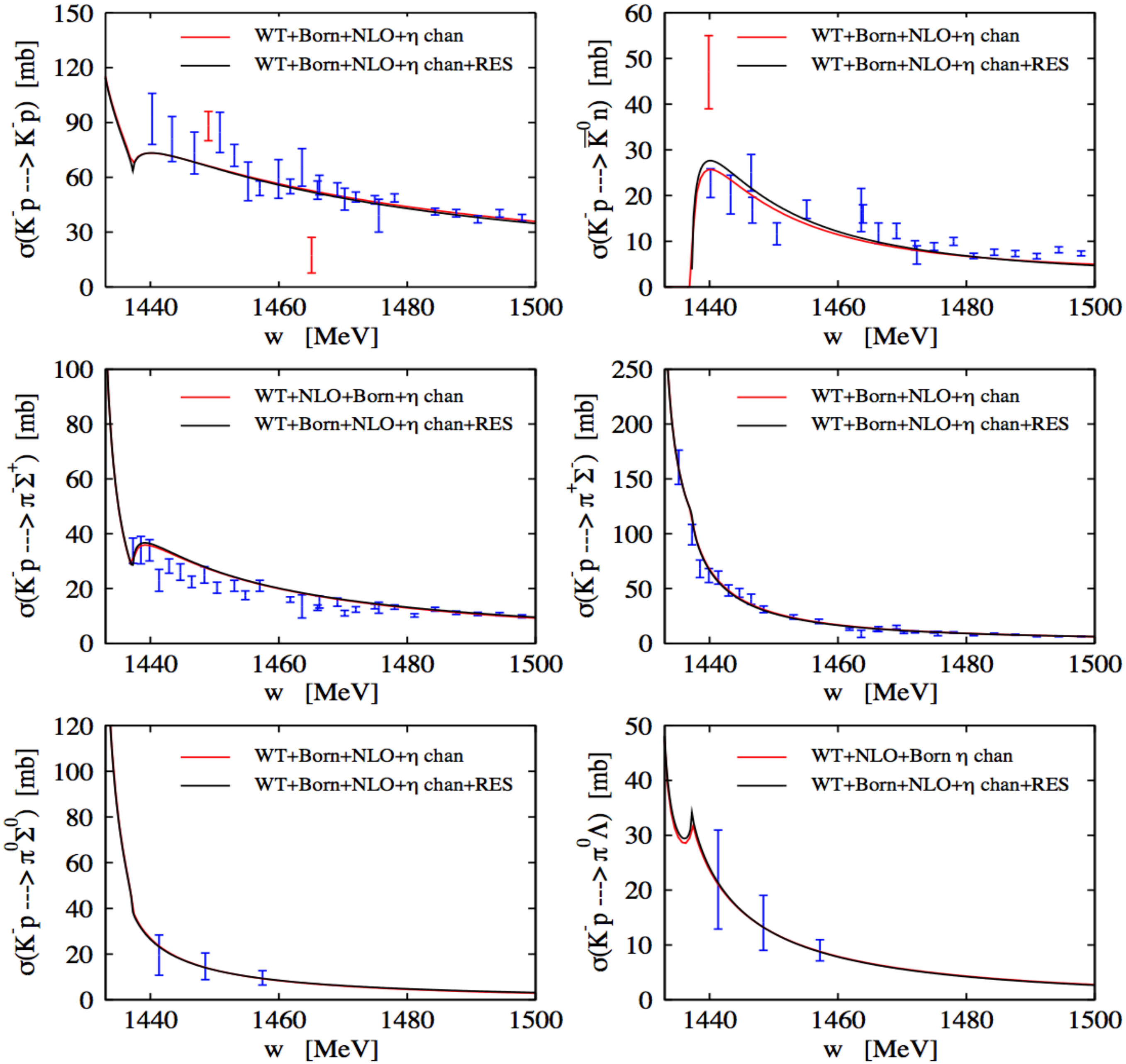
WT+Born+NLO
Considering $K^{-}p \longrightarrow \eta\Lambda, \eta\Sigma^{0}$ scattering data in the fit



INCLUSION OF BORN TERMS (work in progress)
Considering $K^{-}p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in addition in the fit



WT+Born+NLO vs. WT+Born+NLO+RES
Considering $K^- p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in the fit



INCLUSION OF BORN TERMS (work in progress)
Considering $K^- p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in addition in the fit

	WT+NLO+Born	WT+NLO+Born (η chan)
$a_{\bar{K}N}$ (10^{-3})	1.77 ± 2.38	1.27 ± 0.12
$a_{\pi\Lambda}$ (10^{-3})	55.2 ± 13.5	-6.1 ± 12.9
$a_{\pi\Sigma}$ (10^{-3})	2.33 ± 3.17	0.68 ± 1.43
$a_{\eta\Lambda}$ (10^{-3})	8.00 ± 5.04	-0.67 ± 1.06
$a_{\eta\Sigma}$ (10^{-3})	6.5 ± 20.6	8.00 ± 3.26
$a_{K\Xi}$ (10^{-3})	-9.04 ± 3.63	-2.51 ± 0.99
f/f_π	1.21 ± 0.03	1.20 ± 0.03
b_0 (GeV^{-1})	-0.70 ± 0.23	0.13 ± 0.04
b_D (GeV^{-1})	0.31 ± 0.20	0.12 ± 0.01
b_F (GeV^{-1})	0.65 ± 0.41	0.21 ± 0.02
d_1 (GeV^{-1})	0.17 ± 0.26	0.15 ± 0.03
d_2 (GeV^{-1})	0.17 ± 0.11	0.13 ± 0.03
d_3 (GeV^{-1})	0.37 ± 0.16	0.30 ± 0.02
d_4 (GeV^{-1})	0.01 ± 0.09	0.25 ± 0.03
D	0.90 ± 0.10	0.70 ± 0.16
F	0.40 ± 0.08	0.51 ± 0.11
$\chi^2_{\rm d.o.f.}$	0.73	1.14

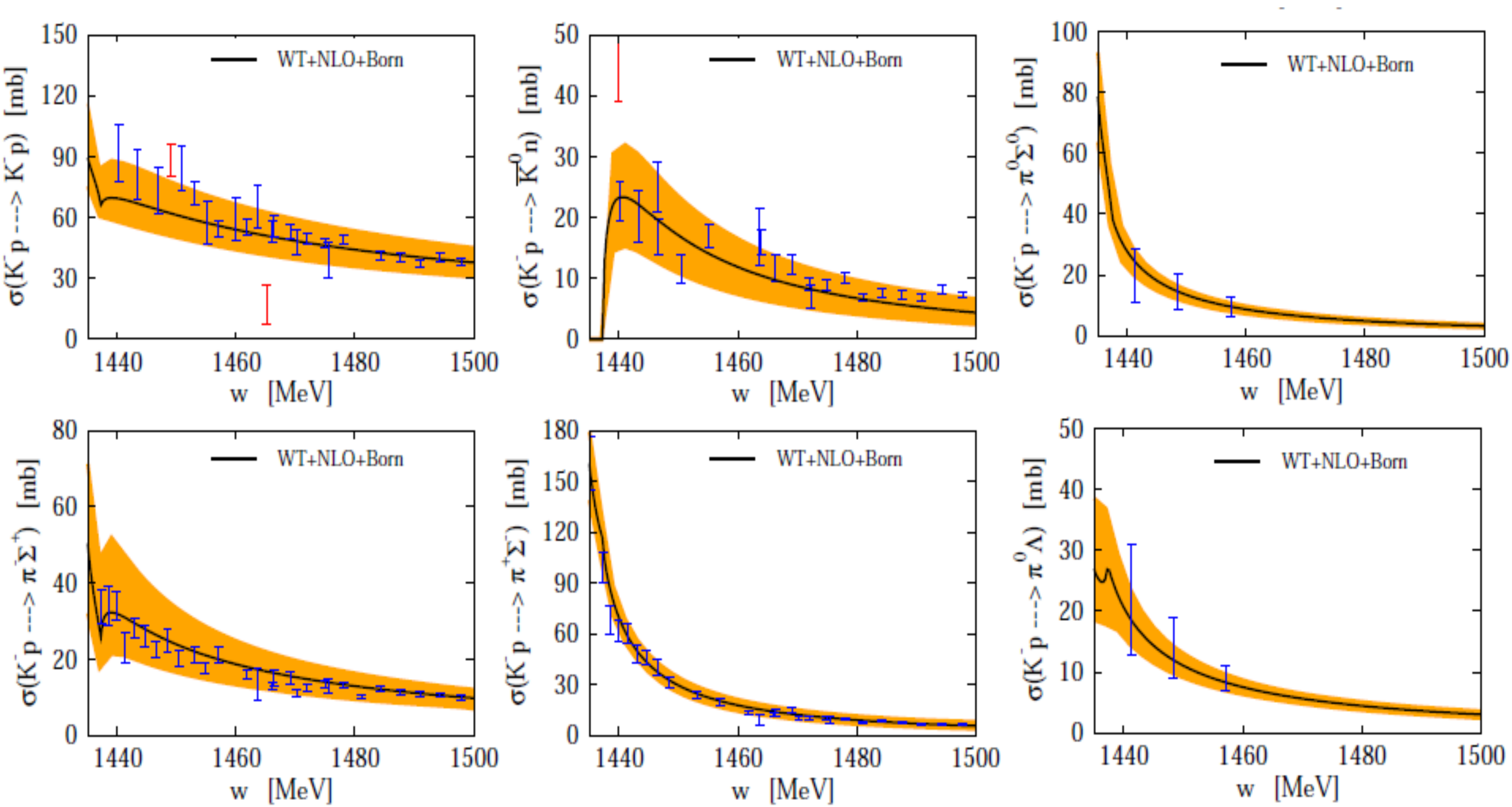
Natural sized values for all!

Very homogeneous and accurate values!!!

RESULTS I
Fitting parameters

	NLO*	WT+RES	NLO+RES
$a_{\bar{K}N}$ (10^{-3})	6.799 ± 0.701	-1.965 ± 2.219	6.157 ± 0.090
$a_{\pi\Lambda}$ (10^{-3})	50.93 ± 9.18	-188.2 ± 131.7	59.10 ± 3.01
$a_{\pi\Sigma}$ (10^{-3})	-3.167 ± 1.978	0.228 ± 2.949	-1.172 ± 0.296
$a_{\eta\Lambda}$ (10^{-3})	-15.16 ± 12.32	1.608 ± 2.603	-6.987 ± 0.381
$a_{\eta\Sigma}$ (10^{-3})	-5.325 ± 0.111	208.9 ± 151.1	-5.791 ± 0.034
$a_{K\Xi}$ (10^{-3})	31.00 ± 9.441	43.04 ± 25.84	32.60 ± 11.65
f/f_π	1.197 ± 0.011	1.203 ± 0.023	1.193 ± 0.003
b_0 (GeV^{-1})	-1.158 ± 0.021	-	-0.907 ± 0.004
b_D (GeV^{-1})	0.082 ± 0.050	-	-0.151 ± 0.008
b_F (GeV^{-1})	0.294 ± 0.149	-	0.535 ± 0.047
d_1 (GeV^{-1})	-0.071 ± 0.069	-	-0.055 ± 0.055
d_2 (GeV^{-1})	0.634 ± 0.023	-	0.383 ± 0.014
d_3 (GeV^{-1})	2.819 ± 0.058	-	2.180 ± 0.011
d_4 (GeV^{-1})	-2.036 ± 0.035	-	-1.429 ± 0.006
$g_{\Xi Y_{5/2} K} \cdot g_{N Y_{5/2} \bar{K}}$	-	-5.42 ± 15.96	8.82 ± 5.72
$g_{\Xi Y_{7/2} K} \cdot g_{N Y_{7/2} \bar{K}}$	-	-0.61 ± 14.12	0.06 ± 0.20
$\Lambda_{5/2}$ (MeV)	-	576.7 ± 275.2	522.7 ± 43.8
$\Lambda_{7/2}$ (MeV)	-	623.7 ± 287.5	999.0 ± 288.0
$M_{Y_{5/2}}$ (MeV)	-	2210.0 ± 39.8	2278.8 ± 67.4
$M_{Y_{7/2}}$ (MeV)	-	2025.0 ± 9.4	2040.0 ± 9.4
$\Gamma_{5/2}$ (MeV)	-	150.0 ± 71.3	150.0 ± 54.4
$\Gamma_{7/2}$ (MeV)	-	200.0 ± 44.6	200.0 ± 32.3
$\chi^2_{\mathrm{d.o.f.}}$	1.48	2.26	1.05

INCLUSION OF BORN TERMS
Results II



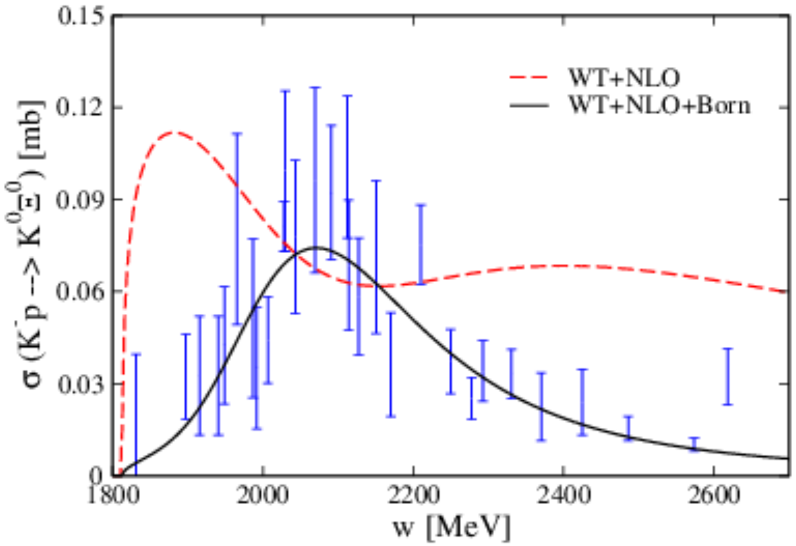
A. Ramos, A. Feijoo, V. Magas, Nucl. Phys. A 954, 58 (2016)

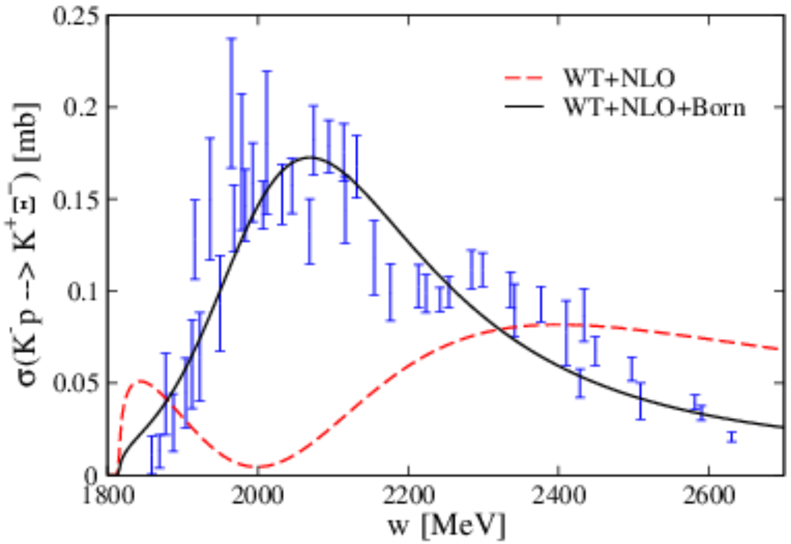
INCLUSION OF BORN TERMS

$$V_{ij} = V_{ij}^{WT} + V_{ij}^{D} + V_{ij}^{C} + V_{ij}^{NLO} \rightarrow \boxed{T = (1 - VG)^{-1}V} \rightarrow T_{ij}^{NLO}$$

What if we include Born diagrams???

A new fit which includes the Born contributions was performed.
New parametrization was obtained for :
f, b_0, b_D, b_F, d_1, d_2, d_3, d_4, $a_{\bar{K}N}$, $a_{\pi\Lambda}$, $a_{\pi\Sigma}$, $a_{\eta\Lambda}$, $a_{\eta\Sigma}$, $a_{K\Xi}$, D, F

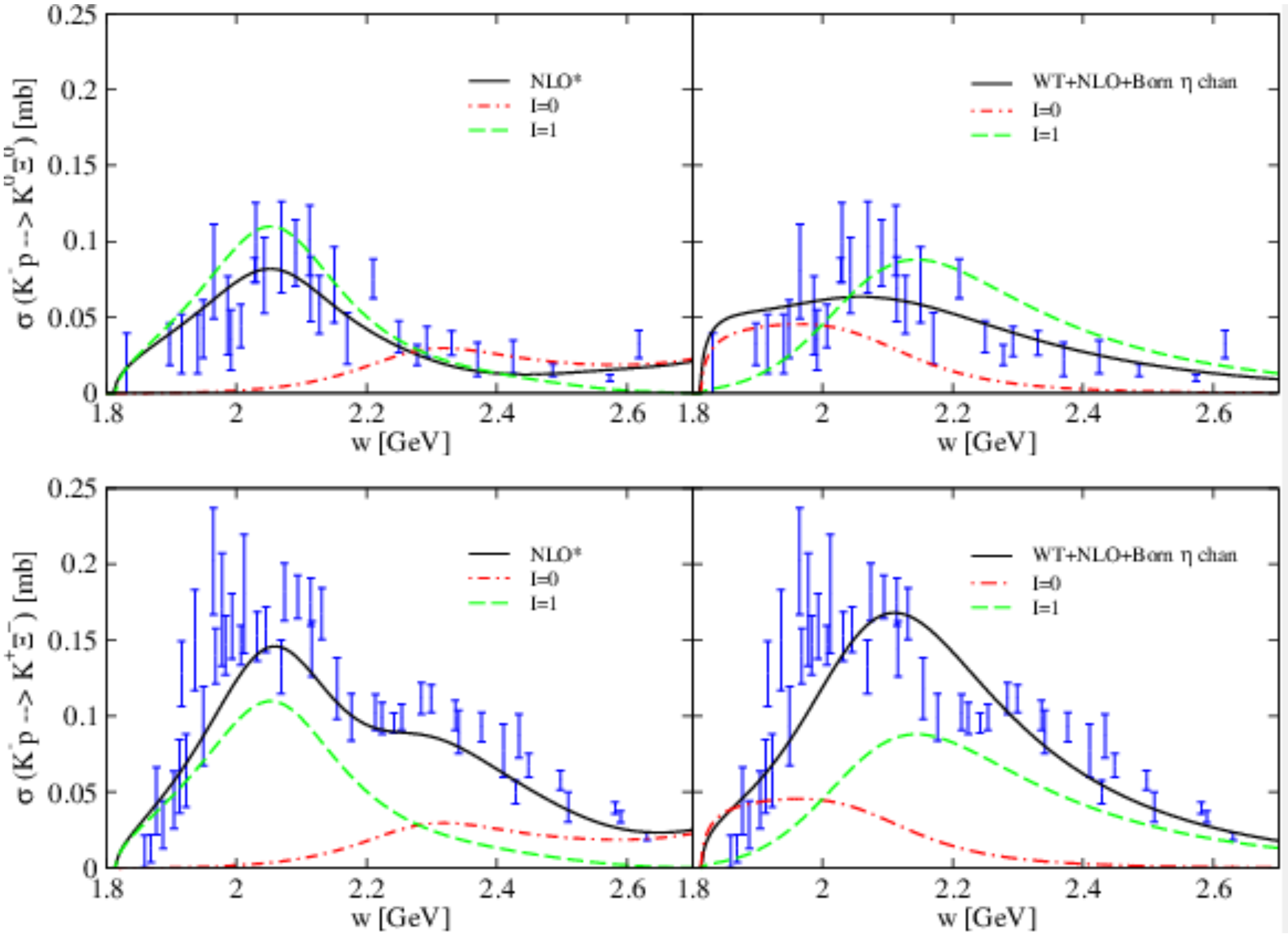




The contribution of Born terms is at the same order as the NLO one!!!

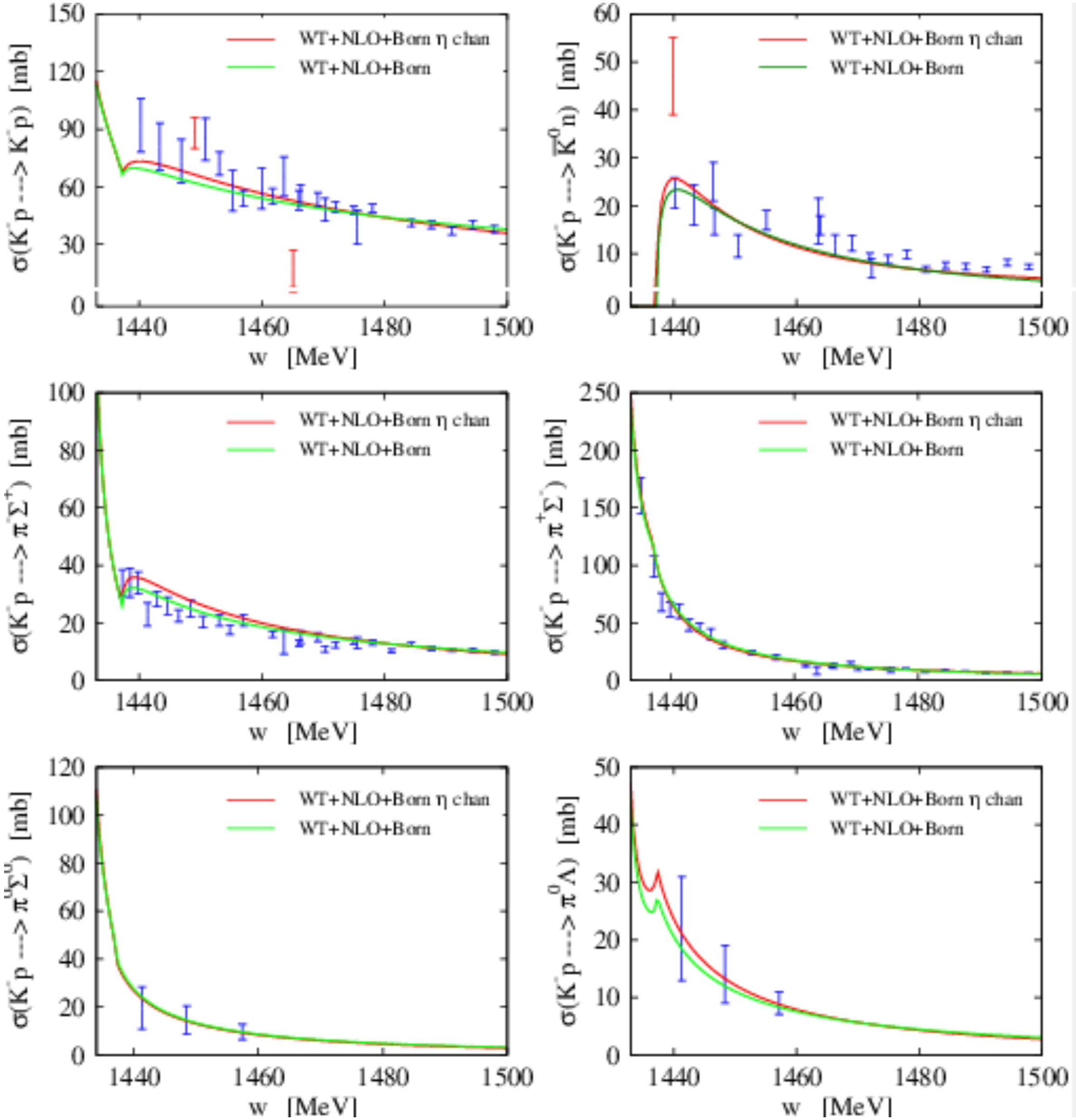
INCLUSION OF BORN TERMS (work in progress)
Considering $K^{-}p \longrightarrow \eta\Lambda, \eta\Sigma^{0}$ scattering data in addition in the fit

Comparison between Models in isospin basis decomposition



INCLUSION OF BORN TERMS (work in progress)

Considering $K^- p \longrightarrow \eta\Lambda, \eta\Sigma^0$ scattering data in addition in the fit



FORMALISM
Effective lagrangian up to NLO

D_{ij}

	K^-p	$\bar{K}^0n$	$\pi^0\Lambda$	$\pi^0\Sigma^0$	$\eta\Lambda$	$\eta\Sigma^0$	$\pi^+\Sigma^-$	$\pi^-\Sigma^+$	$K^+\Xi^-$	$K^0\Xi^0$
K^-p	$4(b_0+b_D)m_K^2$	$2(b_D+b_F)m_K^2$	$\frac{-(b_D+3b_F)\mu_1^2}{2\sqrt{3}}$	$\frac{(b_D-b_F)\mu_1^2}{2}$	$\frac{(b_D+3b_F)\mu_2^2}{6}$	$\frac{-(b_D-b_F)\mu_2^2}{2\sqrt{3}}$	0	$(b_D-b_F)\mu_1^2$	0	0
$\bar{K}^0n$		$4(b_0+b_D)m_K^2$	$\frac{(b_D+3b_F)\mu_1^2}{2\sqrt{3}}$	$\frac{(b_D-b_F)\mu_1^2}{2}$	$\frac{(b_D+3b_F)\mu_2^2}{6}$	$\frac{(b_D-b_F)\mu_2^2}{2\sqrt{3}}$	$(b_D-b_F)\mu_1^2$	0	0	0
$\pi^0\Lambda$			$\frac{4(3b_0+b_D)m_\pi^2}{3}$	0	0	$\frac{4b_Dm_\pi^2}{3}$	0	0	$\frac{-(b_D-3b_F)\mu_1^2}{2\sqrt{3}}$	$\frac{(b_D-3b_F)\mu_1^2}{2\sqrt{3}}$
$\pi^0\Sigma^0$				$4(b_0+b_D)m_\pi^2$	$\frac{4b_Dm_\pi^2}{3}$	0	0	0	$\frac{(b_D+b_F)\mu_1^2}{2}$	$\frac{(b_D+b_F)\mu_1^2}{2}$
$\eta\Lambda$					$\frac{4(3b_0\mu_3^2+b_D\mu_4^2)}{9}$	0	$\frac{4b_Dm_\pi^2}{3}$	$\frac{4b_Dm_\pi^2}{3}$	$\frac{(b_D-3b_F)\mu_2^2}{6}$	$\frac{(b_D-3b_F)\mu_2^2}{6}$
$\eta\Sigma^0$						$\frac{4(b_0\mu_3^2+b_Dm_\pi^2)}{3}$	$\frac{4b_Fm_\pi^2}{\sqrt{3}}$	$\frac{-4b_Fm_\pi^2}{\sqrt{3}}$	$\frac{-(b_D+b_F)\mu_2^2}{2\sqrt{3}}$	$\frac{(b_D+b_F)\mu_2^2}{2\sqrt{3}}$
$\pi^+\Sigma^-$							$4(b_0+b_D)m_\pi^2$	0	$(b_D+b_F)\mu_1^2$	0
$\pi^-\Sigma^+$								$4(b_0+b_D)m_\pi^2$	0	$(b_D+b_F)\mu_1^2$
$K^+\Xi^-$									$4(b_0+b_D)m_K^2$	$2(b_D-b_F)m_K^2$
$K^0\Xi^0$										$4(b_0+b_D)m_K^2$

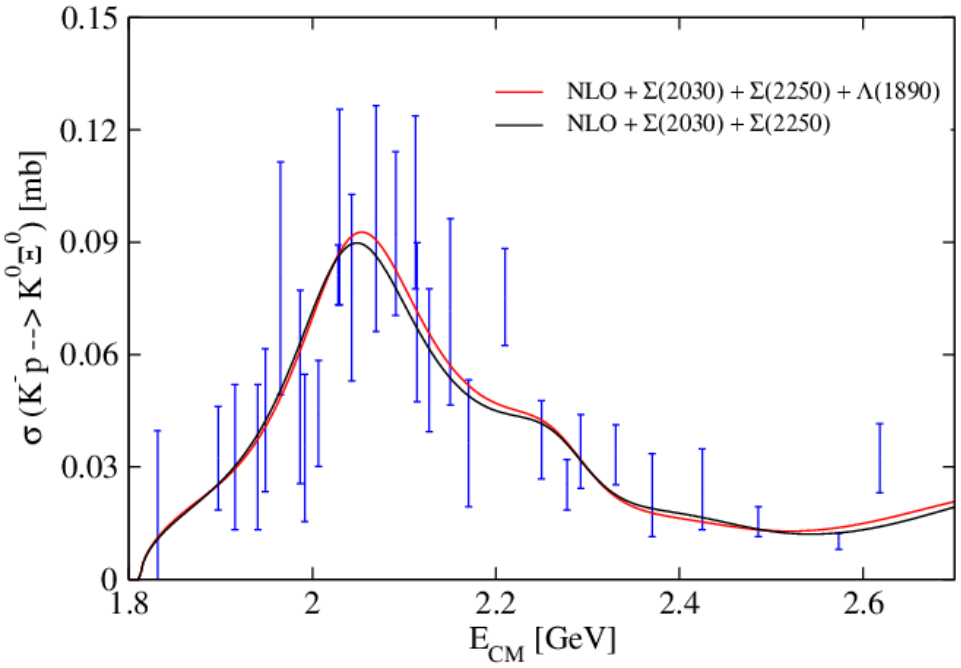
L_{ij}

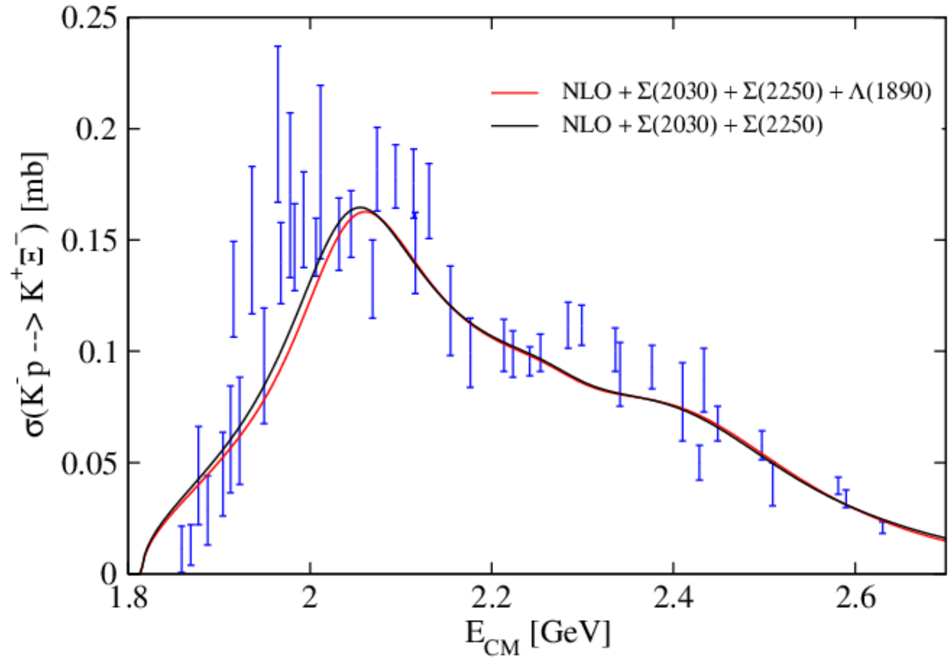
	K^-p	$\bar{K}^0n$	$\pi^0\Lambda$	$\pi^0\Sigma^0$	$\eta\Lambda$	$\eta\Sigma^0$	$\pi^+\Sigma^-$	$\pi^-\Sigma^+$	$K^+\Xi^-$	$K^0\Xi^0$
K^-p	$2d_2+d_3+2d_4$	$d_1+d_2+d_3$	$\frac{-\sqrt{3}(d_1+d_2)}{2}$	$\frac{-d_1-d_2+2d_3}{2}$	$\frac{d_1-3d_2+2d_3}{2}$	$\frac{d_1-3d_2}{2\sqrt{3}}$	$-2d_2+d_3$	$-d_1+d_2+d_3$	$-4d_2+2d_3$	$-2d_2+d_3$
$\bar{K}^0n$		$2d_2+d_3+2d_4$	$\frac{\sqrt{3}(d_1+d_2)}{2}$	$\frac{-d_1-d_2+2d_3}{2}$	$\frac{d_1-3d_2+2d_3}{2}$	$\frac{-(d_1-3d_2)}{2\sqrt{3}}$	$-d_1+d_2+d_3$	$-2d_2+d_3$	$-2d_2+d_3$	$-4d_2+2d_3$
$\pi^0\Lambda$			$2d_4$	0	0	d_3	0	0	$\frac{\sqrt{3}(d_1-d_2)}{2}$	$\frac{-\sqrt{3}(d_1-d_2)}{2}$
$\pi^0\Sigma^0$				$2(d_3+d_4)$	d_3	0	$-2d_2+d_3$	$-2d_2+d_3$	$\frac{d_1-d_2+2d_3}{2}$	$\frac{d_1-d_2+2d_3}{2}$
$\eta\Lambda$					$2(d_3+d_4)$	0	d_3	d_3	$\frac{-d_1-3d_2+2d_3}{2}$	$\frac{-d_1-3d_2+2d_3}{2}$
$\eta\Sigma^0$						$2d_4$	$\frac{2d_1}{\sqrt{3}}$	$\frac{-2d_1}{\sqrt{3}}$	$\frac{-(d_1+3d_2)}{2\sqrt{3}}$	$\frac{d_1+3d_2}{2\sqrt{3}}$
$\pi^+\Sigma^-$							$2d_2+d_3+2d_4$	$-4d_2+2d_3$	$d_1+d_2+d_3$	$-2d_2+d_3$
$\pi^-\Sigma^+$								$2d_2+d_3+2d_4$	$-2d_2+d_3$	$d_1+d_2+d_3$
$K^+\Xi^-$									$2d_2+d_3+2d_4$	$-d_1+d_2+d_3$
$K^0\Xi^0$										$2d_2+d_3+2d_4$

RESULTS II

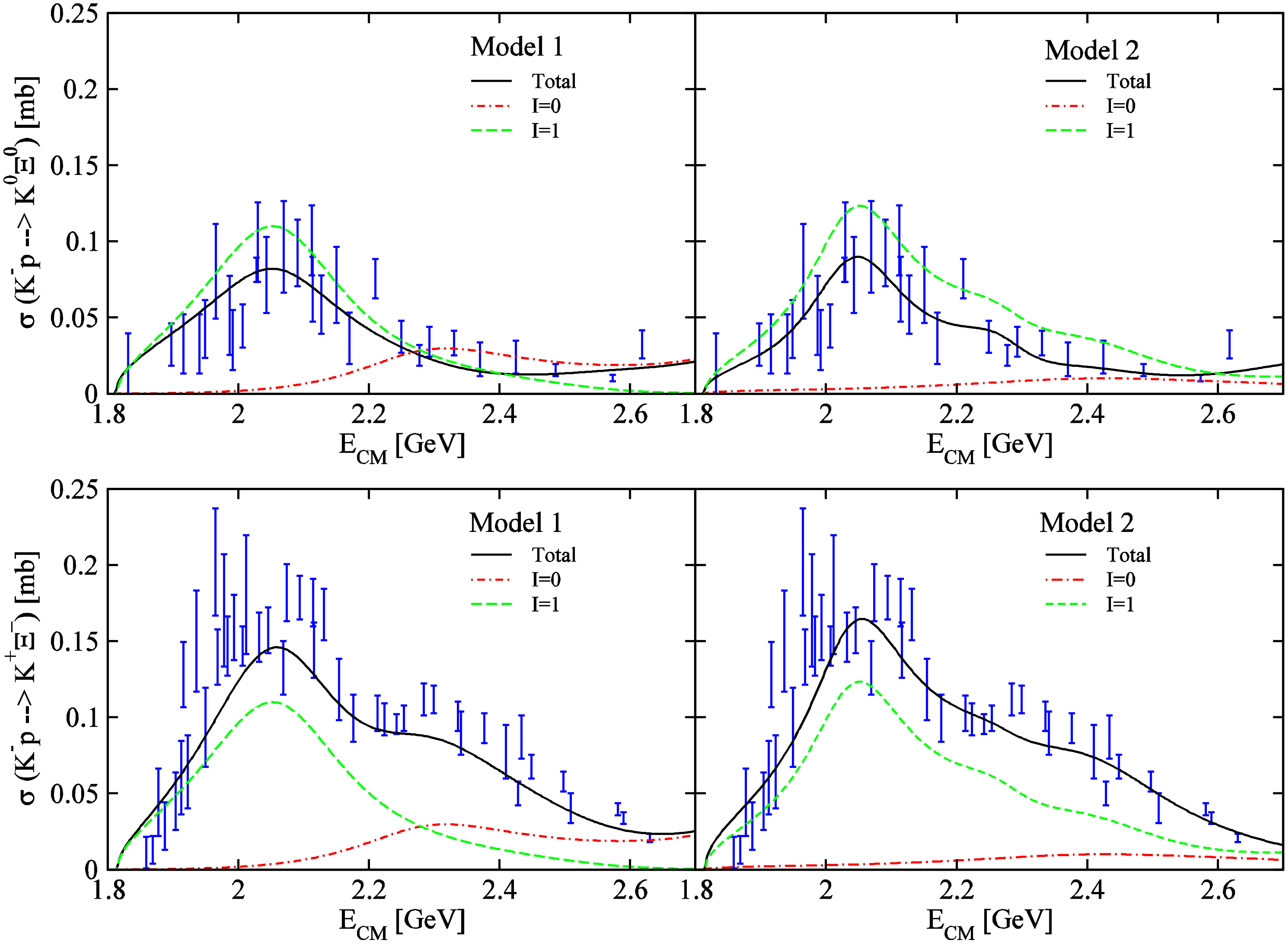
What happens if a third resonance is added?

For instance **Λ(1890),** as it was done in B. C. Jackson, Y. Oh, H. Haberzettl and K. Nakayama, arXiv: 1503.00845 [nucl-th].



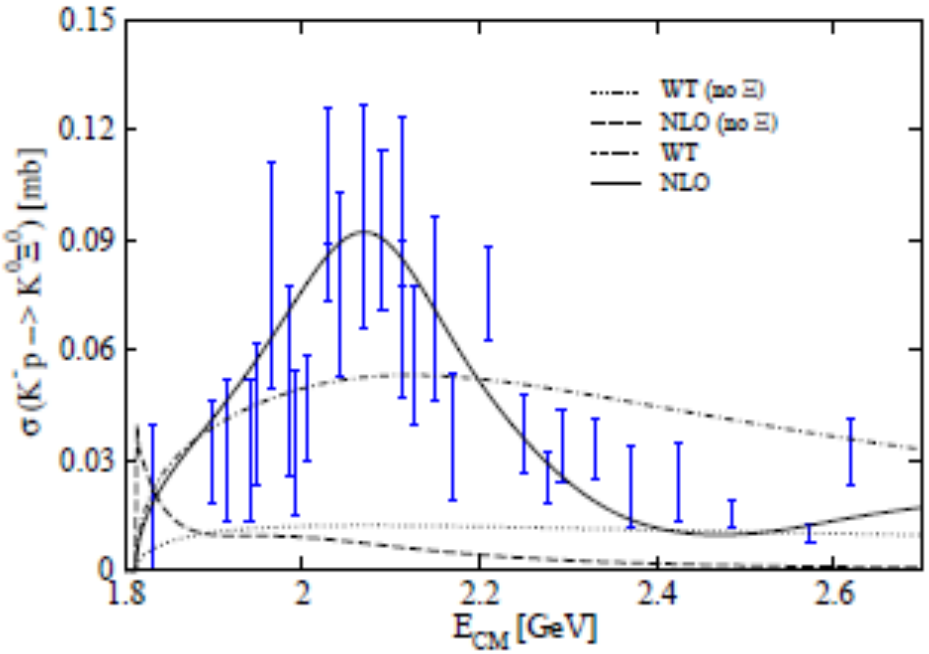


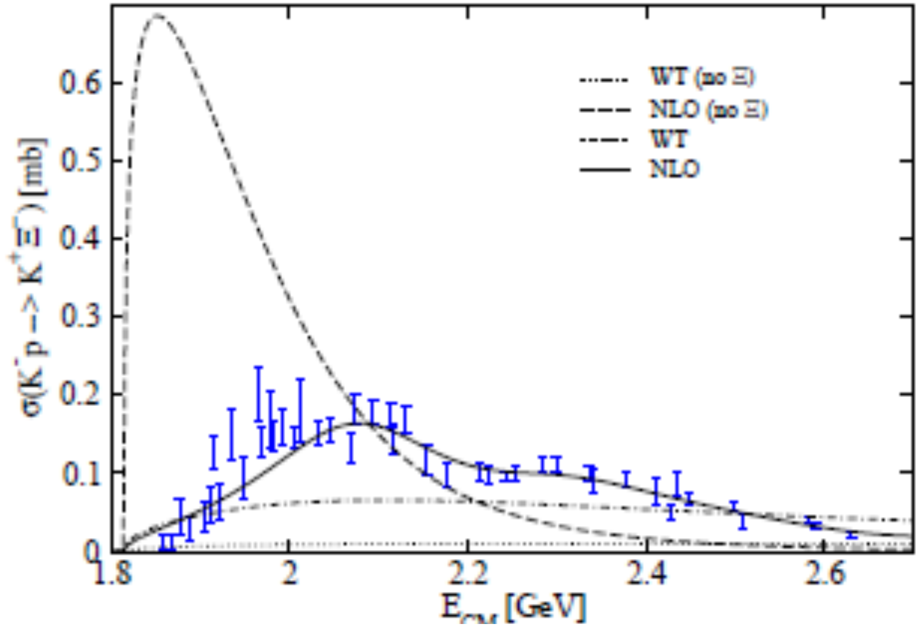
RESULTS II



Model 1
Total
I=0
I=1
Model 2
Total
I=0
I=1
σ (K⁻p --> K⁰Ξ⁰) [mb]
σ (K⁻p --> K⁺Ξ⁻) [mb]
E_CM [GeV]
0
0.05
0.1
0.15
0.2
0.25
1.8
2
2.2
2.4
2.6

Results for $\bar{K}N \longrightarrow K\Xi$

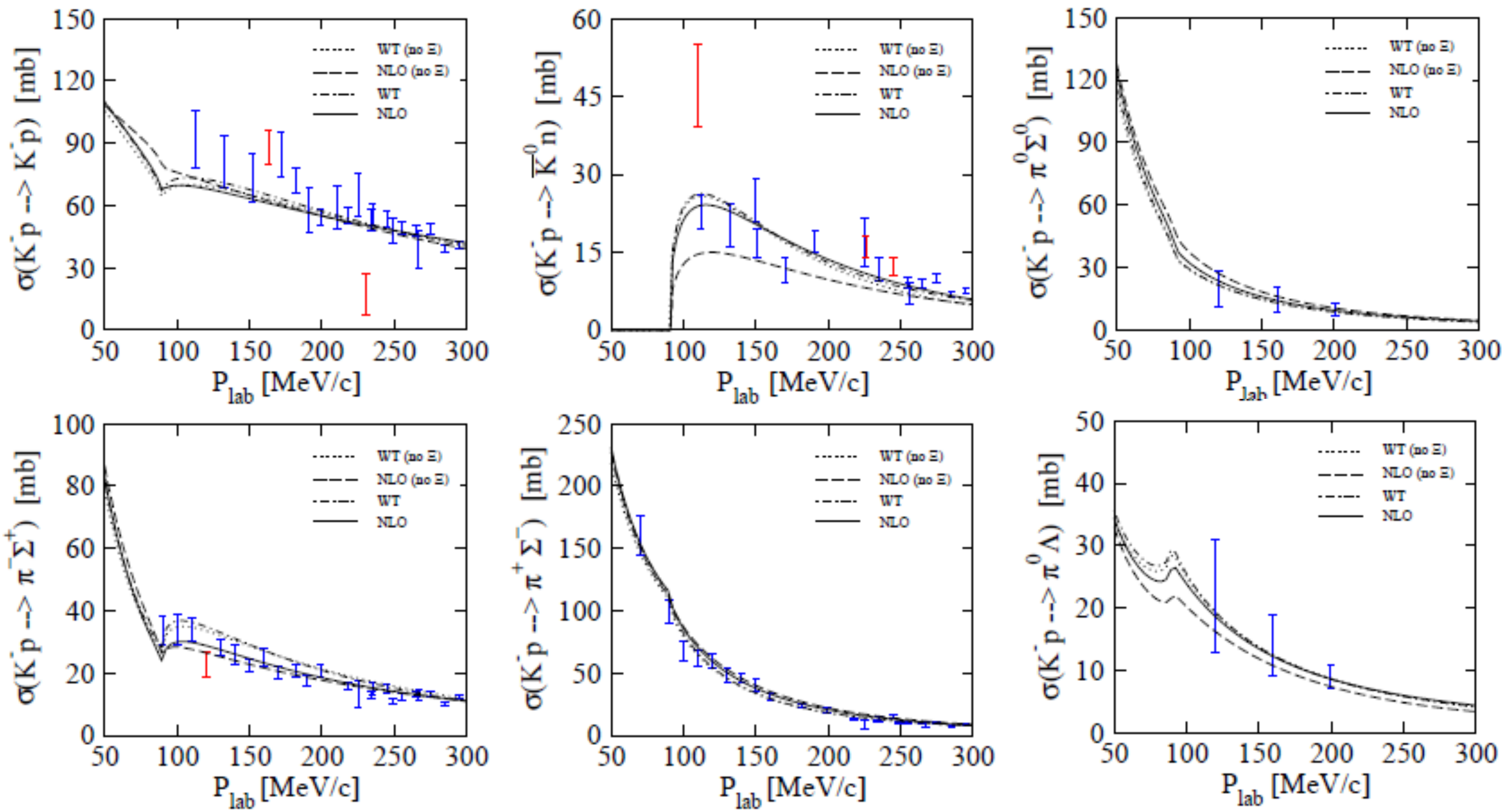




	γ	R_n	R_c	$a_p(K^-p \to K^-p)$	ΔE_{1s}	Γ_{1s}
WT (no $K\Xi$)	2.37	0.191	0.665	$-0.76 + i\,0.79$	316	511
NLO (no $K\Xi$)	2.36	0.188	0.662	$-0.67 + i\,0.84$	290	559
WT	2.36	0.192	0.667	$-0.76 + i\,0.84$	318	543
NLO	2.36	0.189	0.664	$-0.73 + i\,0.85$	310	557
Exp.	2.36 ± 0.04	0.189 ± 0.015	0.664 ± 0.011	$-0.66 + i\,0.81$ $(\pm 0.07) + i(\pm 0.15)$	283 ± 36	541 ± 92

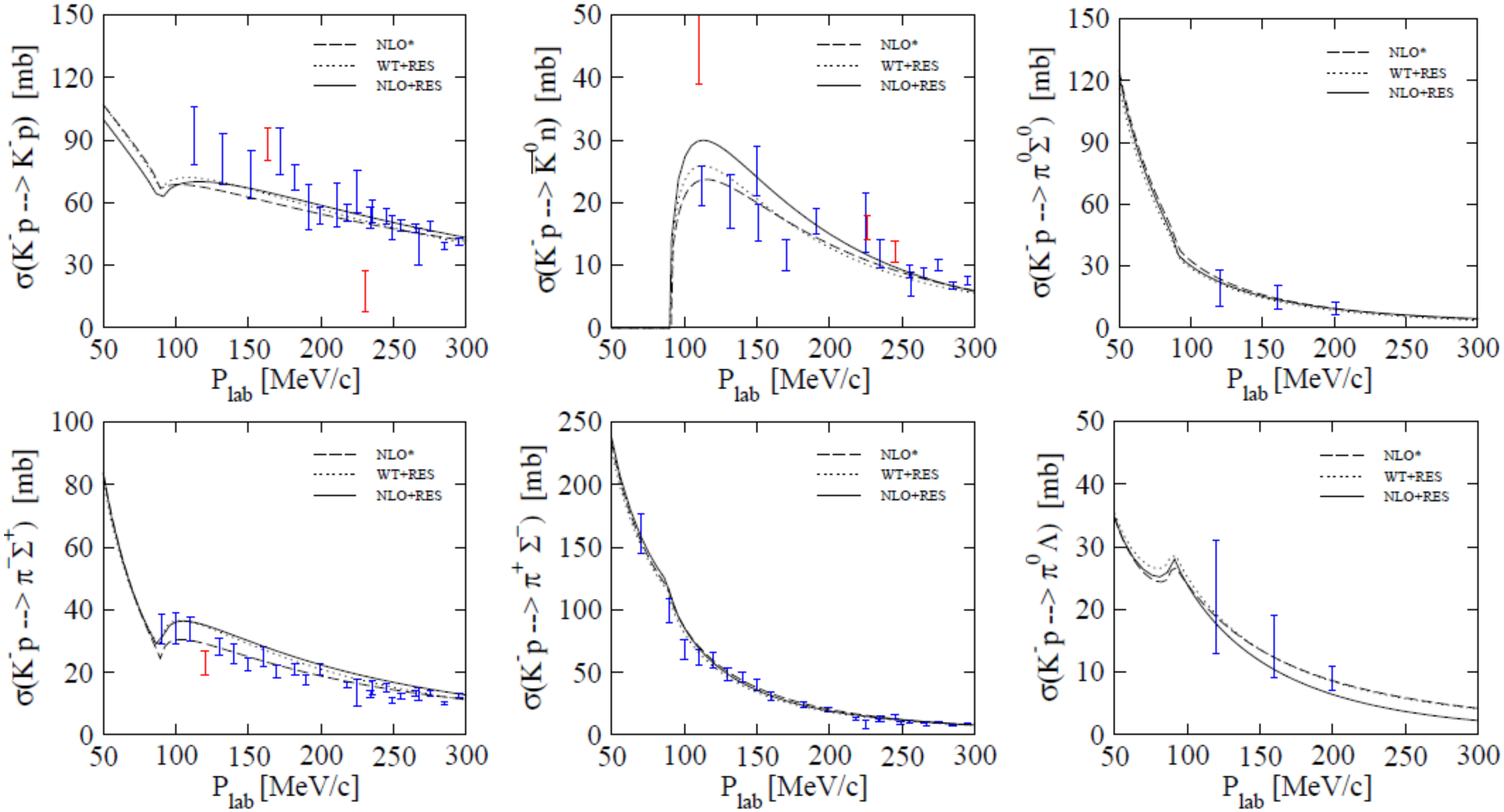
	WT (no $K\Xi$)	NLO (no $K\Xi$)	WT	NLO
$a_{\bar{K}N}$ (10^{-3})	-1.681 ± 0.738	5.151 ± 0.736	-1.986 ± 2.153	6.550 ± 0.625
$a_{\pi\Lambda}$ (10^{-3})	33.63 ± 11.11	21.61 ± 10.00	-248.6 ± 122.0	54.84 ± 7.51
$a_{\pi\Sigma}$ (10^{-3})	0.048 ± 1.925	3.078 ± 2.101	0.382 ± 2.711	-2.291 ± 1.894
$a_{\eta\Lambda}$ (10^{-3})	1.589 ± 1.160	-10.460 ± 0.432	1.696 ± 2.451	-14.16 ± 12.69
$a_{\eta\Sigma}$ (10^{-3})	-45.87 ± 14.06	-8.577 ± 0.353	277.8 ± 139.1	-5.166 ± 0.068
$a_{K\Xi}$ (10^{-3})	-78.49 ± 47.92	4.10 ± 12.67	30.85 ± 10.58	27.03 ± 7.83
f/f_π	1.202 ± 0.053	1.186 ± 0.012	1.202 ± 0.119	1.197 ± 0.008
b_0 (GeV^{-1})	-	-0.861 ± 0.014	-	-1.214 ± 0.014
b_D (GeV^{-1})	-	0.202 ± 0.011	-	0.052 ± 0.040
b_F (GeV^{-1})	-	0.020 ± 0.057	-	0.264 ± 0.146
d_1 (GeV^{-1})	-	0.089 ± 0.096	-	-0.105 ± 0.056
d_2 (GeV^{-1})	-	0.598 ± 0.062	-	0.647 ± 0.019
d_3 (GeV^{-1})	-	0.473 ± 0.026	-	2.847 ± 0.042
d_4 (GeV^{-1})	-	-0.913 ± 0.031	-	-2.096 ± 0.024
$\chi^2_{\rm d.o.f.}$	0.62	0.39	2.57	0.65

Results for $\bar{K}N \longrightarrow K\Xi$



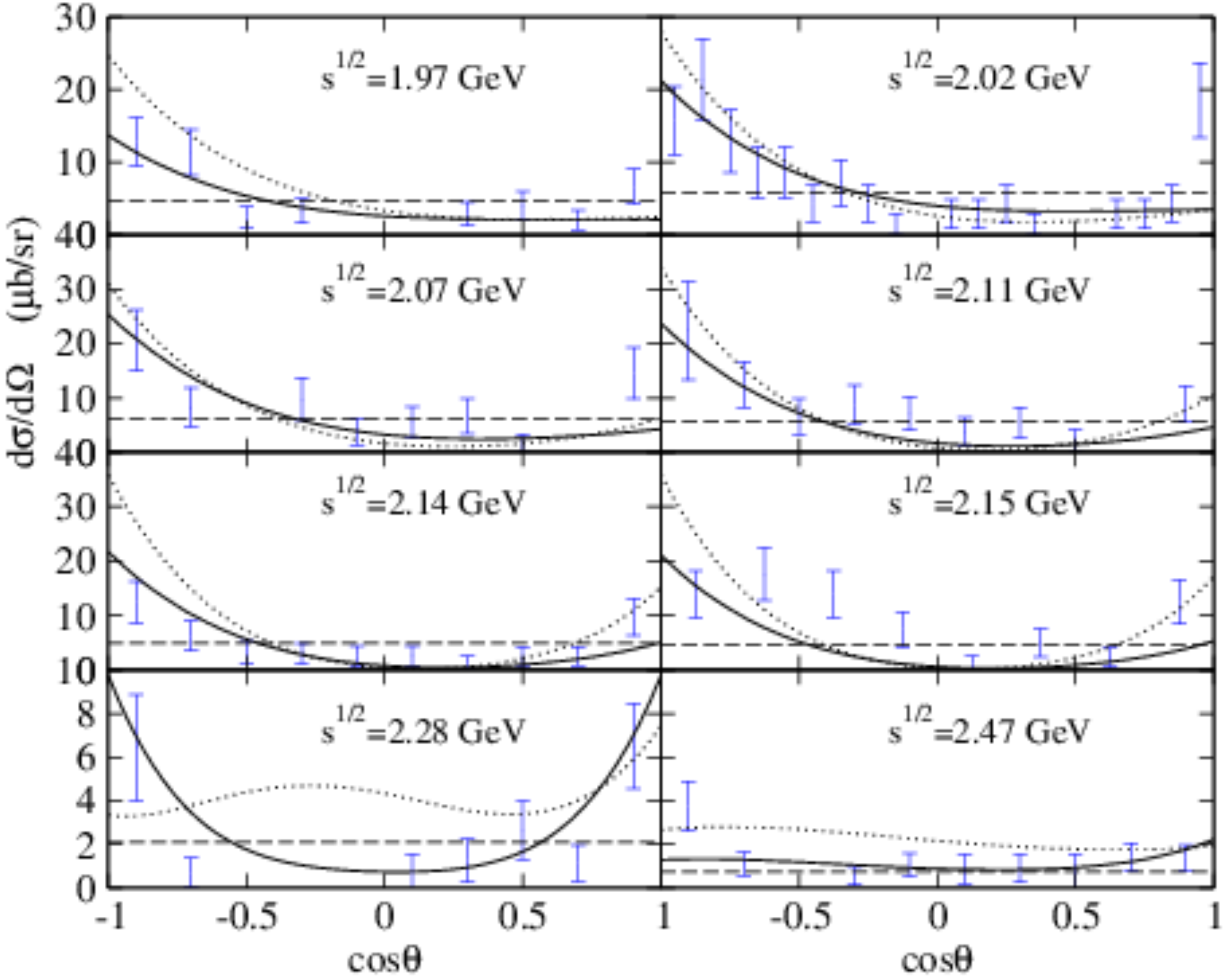
Results for $\bar{K}N \rightarrow K\Xi$

Results for $\bar{K}N \longrightarrow K\Xi$ including $\Sigma(2030)$, $\Sigma(2250)$ resonances

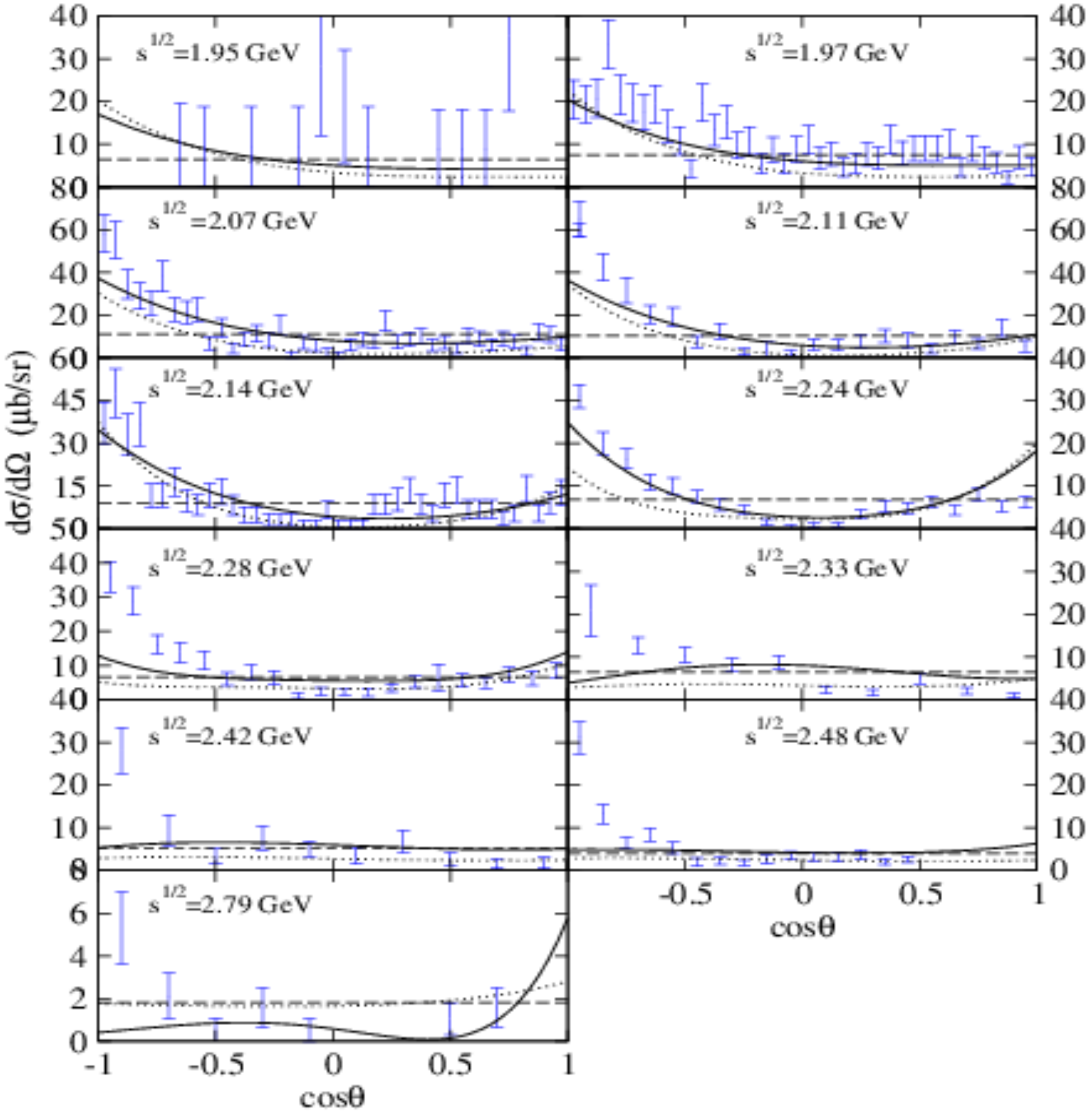


	γ	R_n	R_c	$a_p(K^-p \to K^-p)$	ΔE_{1s}	Γ_{1s}
NLO*	2.37	0.189	0.664	$-0.69 + \mathrm{i}\,0.86$	300	570
WT+RES	2.37	0.193	0.667	$-0.73 + \mathrm{i}\,0.81$	307	528
NLO+RES	2.39	0.187	0.668	$-0.66 + \mathrm{i}\,0.84$	286	562
Exp.	2.36	0.189	0.664	$-0.66 + \mathrm{i}\,0.81$	283	541
	± 0.04	± 0.015	± 0.011	$(\pm 0.07) + \mathrm{i}\,(\pm 0.15)$	± 36	± 92

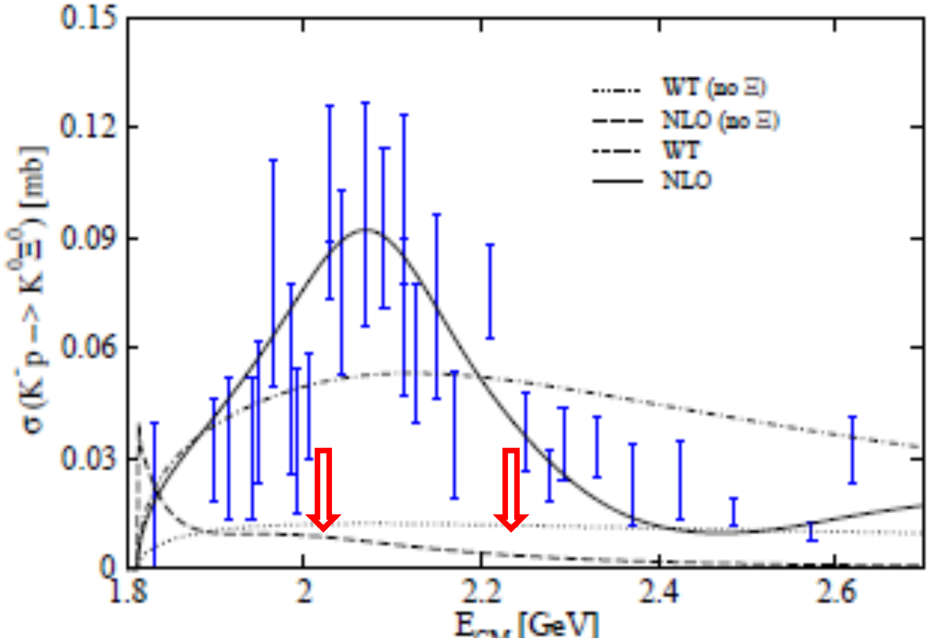
Differential cross section of the $\bar{K}N \longrightarrow K^0\Xi^0$



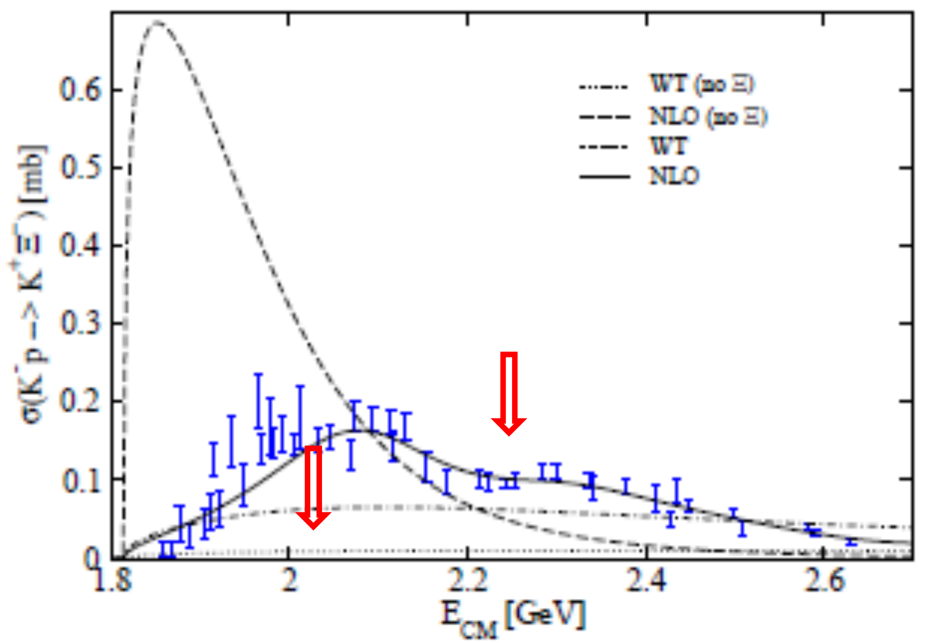
Differential cross section of the $\bar{K}N \longrightarrow K^+\Xi^-$



RESULTS I



Resonance	I (J^P)	Mass (MeV)	Γ (MeV)	$\Gamma_{K\Xi}/\Gamma$
$\Lambda(1890)$	0 $\left(\frac{3}{2}^+\right)$	1850 - 1910	60 - 200	
$\Lambda(2100)$	0 $\left(\frac{7}{2}^-\right)$	2090 - 2110	100 - 250	$< 3\%$
$\Lambda(2110)$	0 $\left(\frac{5}{2}^+\right)$	2090 - 2140	150 - 250	
$\Lambda(2350)$	0 $\left(\frac{9}{2}^+\right)$	2340 - 2370	100 - 250	
$\Sigma(1915)$	1 $\left(\frac{5}{2}^+\right)$	1900 - 1935	80 - 160	
$\Sigma(1940)$	1 $\left(\frac{3}{2}^-\right)$	1900 - 1950	150 - 300	
$\Sigma(2030)$	1 $\left(\frac{7}{2}^+\right)$	2025 - 2040	150 - 200	$< 2\%$
$\Sigma(2250)$	1 $(?^?)$	2210 - 2280	60 - 150	



Experimental data VS. the NLO model.

contribution of $\bar{K}N \longrightarrow Y \longrightarrow K\Xi$ reactions to the scattering amplitude.

In **Sharov, Korotkikh, Lanskoy, EPJA 47 (2011) 109,**
a phenomenological model was suggested in which
several combinations of resonances were tested

INCLUSION OF HYPERONIC RESONANCIES IN $\bar{K}N \longrightarrow K\Xi$

$$\Delta^{\beta_1\beta_2}_{\alpha_1\alpha_2}\left(\frac{5}{2}\right)=\frac{1}{2}\left(\theta^{\beta_1}_{\alpha_1}\theta^{\beta_2}_{\alpha_2}+\theta^{\beta_2}_{\alpha_1}\theta^{\beta_1}_{\alpha_2}\right)-\frac{1}{2}\theta_{\alpha_1\alpha_2}\theta^{\beta_1\beta_2}-\frac{1}{10}\left(\bar{\gamma}_{\alpha_1}\bar{\gamma}^{\beta_1}\theta^{\beta_2}_{\alpha_2}+\bar{\gamma}_{\alpha_1}\bar{\gamma}^{\beta_2}\theta^{\beta_1}_{\alpha_2}+\bar{\gamma}_{\alpha_2}\bar{\gamma}^{\beta_1}\theta^{\beta_2}_{\alpha_1}+\bar{\gamma}_{\alpha_2}\bar{\gamma}^{\beta_2}\theta^{\beta_1}_{\alpha_1}\right)$$

$$\theta^{\nu}_{\mu}=g^{\nu}_{\mu}-\frac{q_\mu q^\nu}{M_Y^2}$$

$$\bar{\gamma}_\mu=\gamma_\mu-\frac{q_\mu \not{q}}{M_Y^2}$$

$$\Delta^{\beta_1\beta_2\beta_3}_{\alpha_1\alpha_2\alpha_3}\left(\frac{7}{2}\right)=\frac{1}{36}\sum_{P(\alpha)P(\beta)}\left(\theta^{\beta_1}_{\alpha_1}\theta^{\beta_2}_{\alpha_2}\theta^{\beta_3}_{\alpha_3}-\frac{3}{7}\theta^{\beta_1}_{\alpha_1}\theta_{\alpha_2\alpha_3}\theta^{\beta_2\beta_3}-\frac{3}{7}\bar{\gamma}_{\alpha_1}\bar{\gamma}^{\beta_1}\theta^{\beta_2}_{\alpha_2}\theta^{\beta_3}_{\alpha_3}+\frac{3}{35}\bar{\gamma}_{\alpha_1}\bar{\gamma}^{\beta_1}\theta_{\alpha_2\alpha_3}\theta^{\beta_2\beta_3}\right)$$

INCLUSION OF HYPERONIC RESONANCES IN $\bar{K}N \longrightarrow K\Xi$

Taking into account the scattering amplitude given by LS equations for a NLO Chiral Lagrangian and the phenomenological contributions from the resonances, the total scattering amplitude for the $\bar{K}N \longrightarrow K\Xi$ reaction should be written as:

$$T^{tot}_{ij,s,s'} = T^{LS}_{ij,s,s'} + T^{5/2^-}_{s,s'} + T^{7/2^+}_{s,s'}$$

Being aware of isospin symmetry, the coupling constants for each channel have to integrate this fact in its value.

$\Sigma(2030)$, $\Sigma(2250)$ both have I=1 $\Rightarrow$

$$|K^+\Xi^-\rangle = -\frac{1}{\sqrt{2}}\left(|K\Xi\rangle_{I=1} + |K\Xi\rangle_{I=0}\right)$$

$$|K^0\Xi^0\rangle = \frac{1}{\sqrt{2}}\left(|K\Xi\rangle_{I=1} - |K\Xi\rangle_{I=0}\right)$$

Or in a equivalent manner:

- $K^-p \longrightarrow K^+\Xi^-$ $\Rightarrow$ $T^{tot}_{s,s'} = T^{LS}_{s,s'} - T^{5/2^-}_{s,s'} - T^{7/2^+}_{s,s'}$
- $K^-p \longrightarrow K^0\Xi^0$ $\Rightarrow$ $T^{tot}_{s,s'} = T^{LS}_{s,s'} + T^{5/2^-}_{s,s'} + T^{7/2^+}_{s,s'}$

On going work …

In order to improve results, the model could be developed taking into account:

- **Born (direct and cross) diagrams (fine tunning)**

$$\mathcal{L}_{MB}^{(YUKAWA)}(B,U) = \frac{1}{2} D\langle \bar{B}\gamma^{\mu}\gamma_5\{u_\mu, B\}\rangle + \frac{1}{2} F\langle \bar{B}\gamma^{\mu}\gamma_5[u_\mu, B]\rangle$$