Grupo Física Nuclear y Hadrónica

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Física nuclear y hadrónica a energías intermedias

FIS2014-51948 & PROMETEOII/2014/0068

Topics:

- ✓ Resonances in QCD
- ✓ Weak decays of heavy hadrons into dynamically generated resonances
- ✓ Finite volume treatment of scattering of hadrons
- ✓ Hadron properties (spectroscopy, magnetic moments, form factors) in the free space and in nuclei
- ✓ Neutrino-nucleon and neutrino-nucleus reactions
- ✓ Chiral perturbation theory with Δ states
- ✓ Heavy quark spin and flavor symmetries: XYZ states
- ✓ Pentaquarks and baryon molecular states and reactions to produce them
- ✓ Triangular singularities in hadron spectra and reactions
- ✓ Three body systems with hadrons
- ✓ Nuclear matter response functions & effective interactions

Collaborations:

Granada, Murcia, Salamanca, Barcelona, Córdoba, Madrid, Beijing, Lanzhou, Guilin, Dalian, Tübingen, Jülich, Osaka, Nara, Kyoto, Bonn, Minesota, Fermilab, CNRS-Orsay, Sao Paulo …

Periodo 2012-2016:

7 Tesis Doctorales (y una en Febrero 2017)
35-40 trabajos publicados /año
Numero similar de Talks en Conferencias
Unas 1900 citas/año en el Science Citation Index

Hadronic interactions and hadronic molecular “exotic” states

We use different sources of interaction: Chiral Lagrangians, Local hidden gauge approach, heavy quark symmetries.
Consider possible channels for certain quantum numbers,
Solve the Bethe Salpeter equation in coupled channels to implement unitarity.

The approach generates many hadronic states as a consequence of the hadron-hadron interaction: $f_0(500)$, $f_0(980)$, $a_0(980)$, $f_2(1270)$, axial vector mesons …
X(3872), $D_{s0}(2317)$, $B_1(5721)$, $B_2(5747)$ ….
Two Λ(1405) states, N*(1535), …..

Predictions or new states are made and some are being found.
$D_0(2600)$ was predicted in Molina, Nagahiro, Hosaka, Oset, PRD 80, 2009
It was found in P. del Amo (Babar) PRD 82, 2010

Baryon molecular states of hidden charm were predicted in 2010
Wu, Molina, Oset, Zou, PRL 2010, Supported later by different theoretical works:
Yan, Sun, He,Liu,Zhu, Chin. Phys. C, 2012
Garcia Recio,Nieves,Romanets,Salcedo, Tolos, PRD, 2013
Xiao,Nieves,Oset, PRD, 2013
Uchino, Liang, Oset, EPJA , 2016

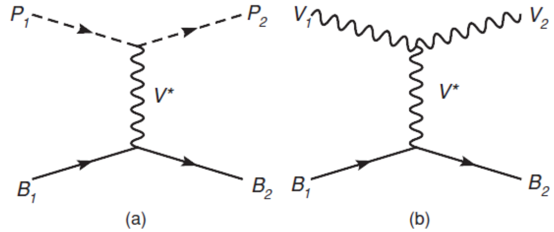
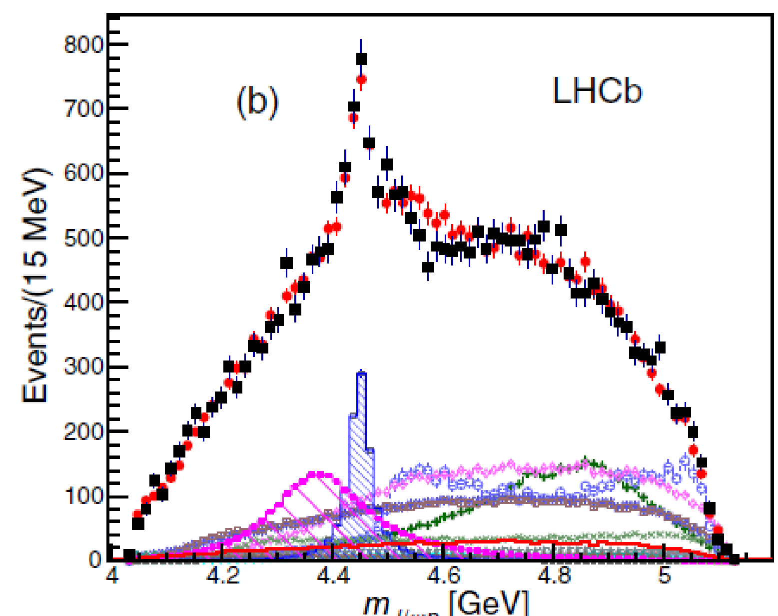


TABLE IX. Pole position z_R and coupling constants g_a to various channels for the states from $PB \to PB$ including the $J/\psi N$ and $J/\psi \Lambda$ channels.

(I, S)	z_R		g_a		
$(1/2, 0)$		$\bar{D}^*\Sigma_c$	$\bar{D}^*\Lambda_c^+$	$J/\psi N$	
	$4415 - 9.5i$	$2.83 - 0.19i$	$-0.07 + 0.05i$	$-0.85 + 0.02i$	
		2.83	0.08	0.85	
$(0, -1)$		$\bar{D}_s^*\Lambda_c^+$	$\bar{D}^*\Xi_c$	$\bar{D}^*\Xi_c'$	$J/\psi\Lambda$
	$4368 - 2.8i$	$1.27 - 0.04i$	$3.16 - 0.02i$	$-0.10 + 0.13i$	$0.47 + 0.04i$
		1.27	3.16	0.16	0.47
	$4547 - 6.4i$	$0.01 + 0.004i$	$0.05 - 0.02i$	$2.61 - 0.13i$	$-0.61 - 0.06i$
		0.01	0.05	2.61	0.61

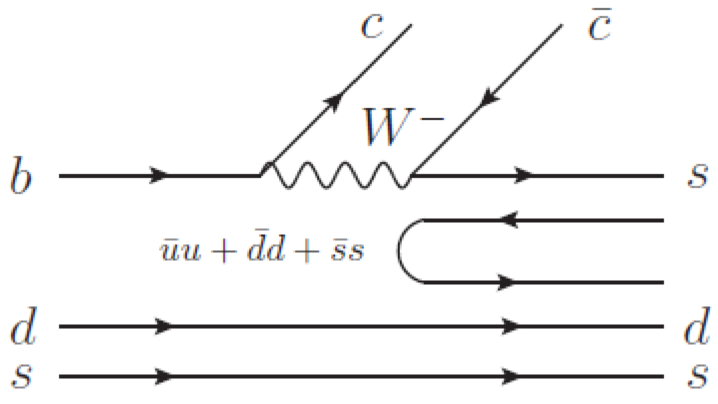
Phys.Rev.Lett. 115 (2015) 072001, LHCb collaboration In the reaction: $\Lambda_b \to J/\Psi\ p\ K^-$

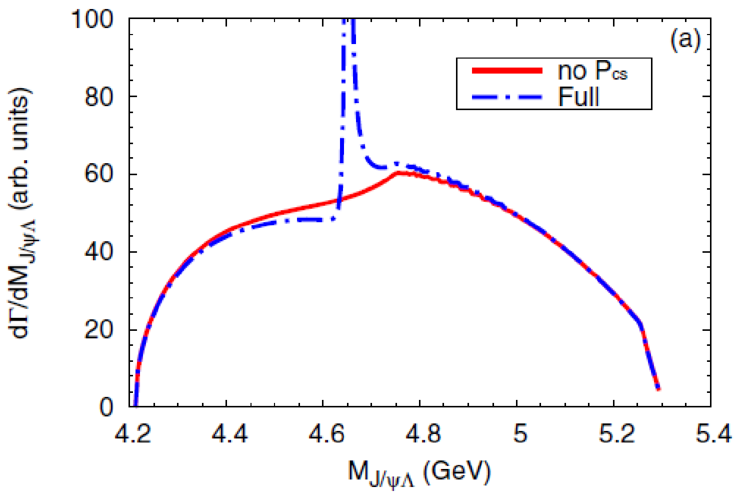
Note that there are also predictions for hidden charm states but with strangeness. LHCb is currently searching for them.



Looking for a hidden-charm pentaquark state with strangeness $S = -1$ from Ξ_b^- decay into $J/\psi K^- \Lambda$

Chen, Geng Liang, Oset, Wang, Xie, PRD 2016





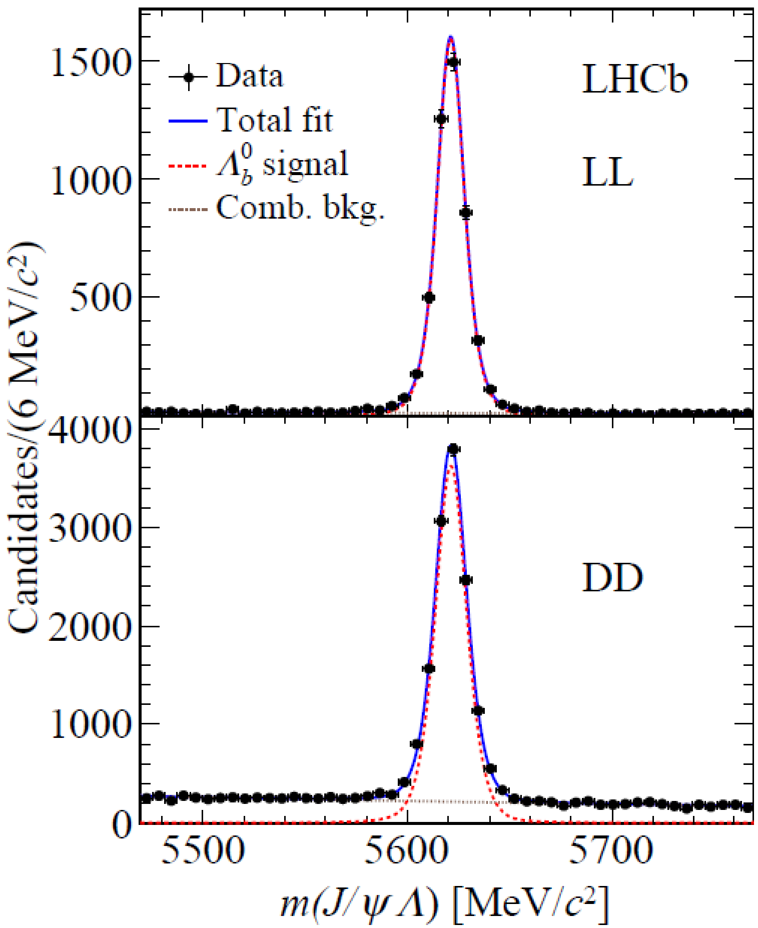
Uncertainties in the model are evaluated and the peak shows up at different energies and with different weight, but it always shows up.

LHCb is presently looking into this channel.

Observation of the $\Xi_b^- \to J/\psi\, \Lambda K^-$ decay

The LHCb collaboration†

1701.05274

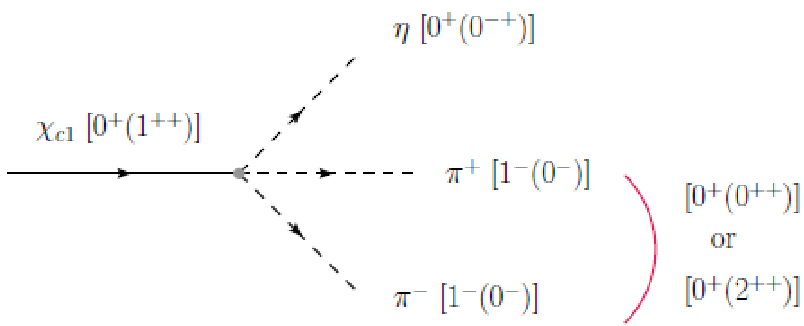


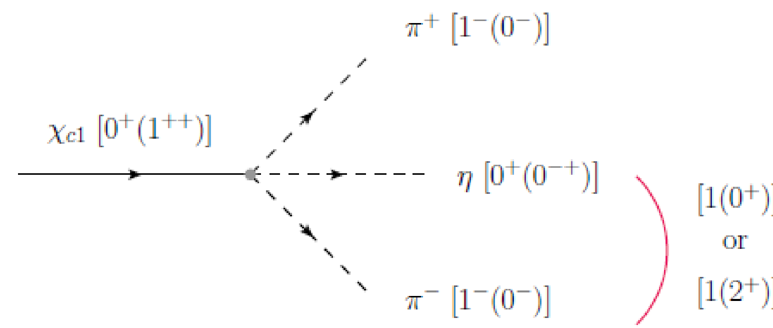
Today in the web

With the full data sample accumulated before the long shutdown of the LHC in 2018, it should be possible to apply a full amplitude analysis to the $\Xi_b^- \to J/\psi\, \Lambda K^-$ decay to search for hidden-charm pentaquarks with open strangeness.

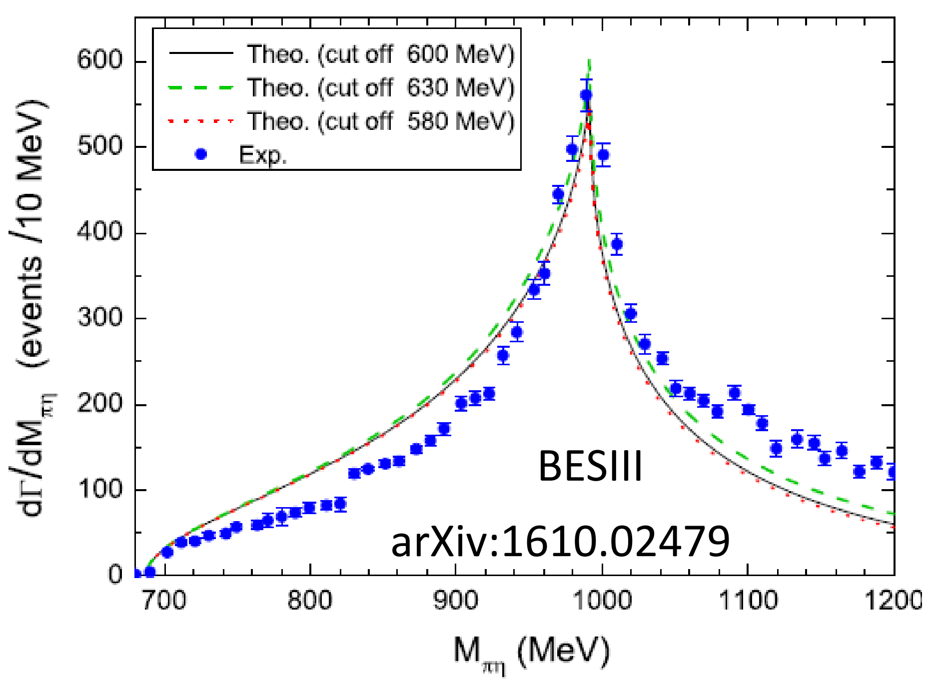
$f_0(500)$, $f_0(980)$, and $a_0(980)$ production in the $\chi_{c1} \to \eta\pi^+\pi^-$ reaction

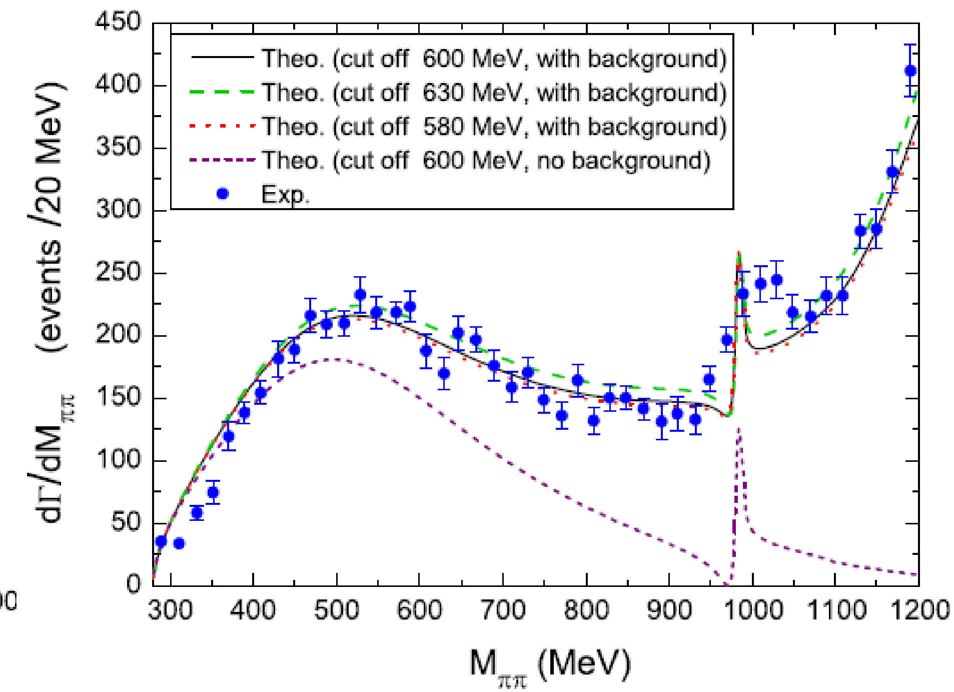
Liang, Xie, Oset, EPJ C 2016





Basic starting point: the χ_{c1} is an SU(3) singlet in u,d,s quarks. Interaction of meson pairs from the chiral unitary approach.





Ds(2317) and DK scattering in B decays from BaBar and LHCb data

M. Albaladejo, D. Jido, J. Nieves, E. Oset, EPJC (2016) 76:300

Table 1 Mass and DK probability of the $D^*_{s0}(2317)$ state, the $0(0^+)$ DK scattering length and the fitted parameter $a(\mu)$, together with the reduced χ^2, for each of the fits performed in this work

Fit	$M_{D^*_{s0}}$ (MeV)	P_{DK} (%)	a_0 (fm)	$a(\mu)$	χ^2/d.o.f.
LHCb	$2326^{+16}_{-16}{}^{+1}_{-5}$	$74^{+7}_{-6}{}^{+9}_{-1}$	$-1.10^{+0.19}_{-0.39}{}^{+0.01}_{-0.02}$	$-1.09^{+0.12}_{-0.10}{}^{+0.01}_{-0.04}$	1.43
BaBar	$2306^{+14}_{-23}{}^{+16}_{-9}$	$67^{+5}_{-7}{}^{+6}_{-10}$	$-0.87^{+0.15}_{-0.15}{}^{+0.11}_{-0.18}$	$-1.21^{+0.09}_{-0.13}{}^{+0.10}_{-0.06}$	1.32
Combined	$2315^{+12}_{-17}{}^{+10}_{-5}$	$70^{+4}_{-6}{}^{+4}_{-8}$	$-0.95^{+0.15}_{-0.15}{}^{+0.08}_{-0.13}$	$-1.16^{+0.08}_{-0.10}{}^{+0.06}_{-0.03}$	1.37

The first error is statistical, whereas the second one is systematic

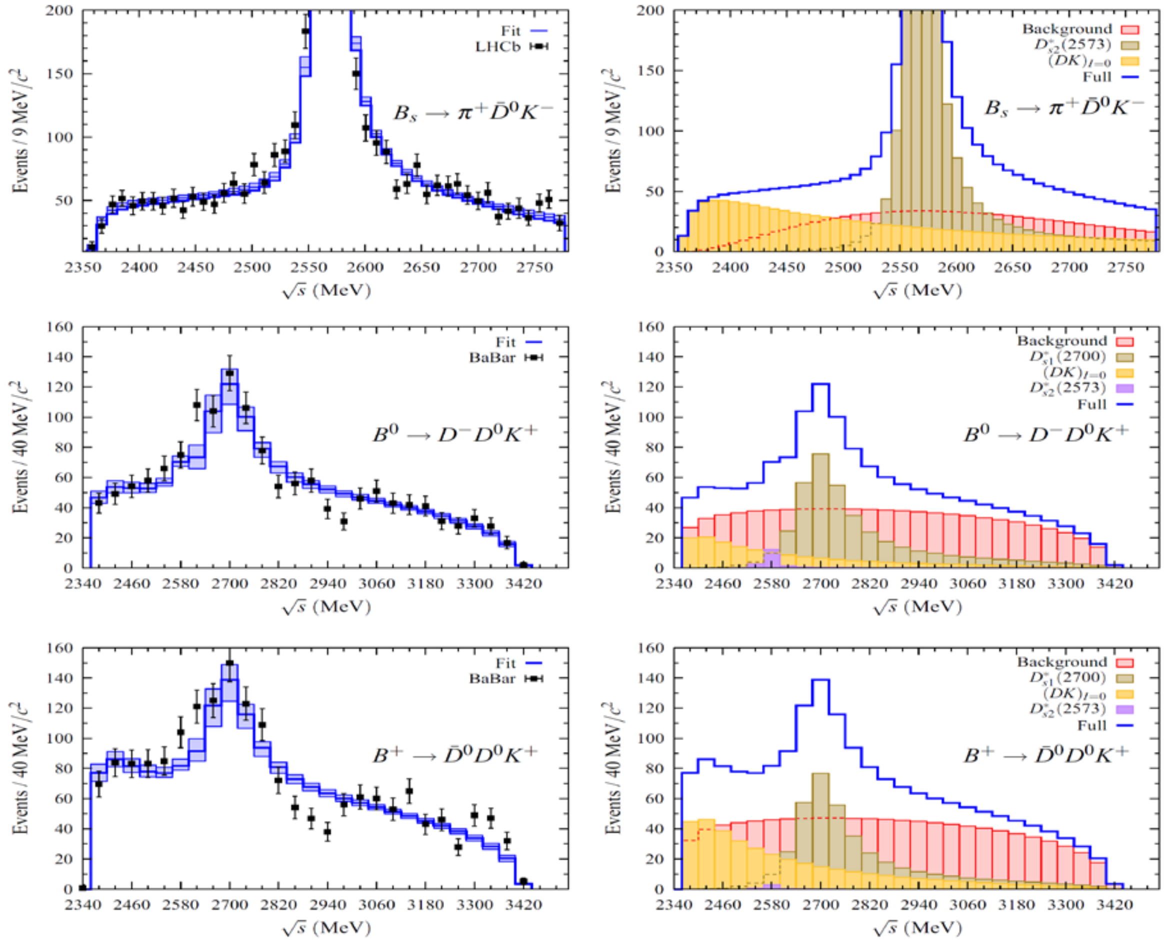
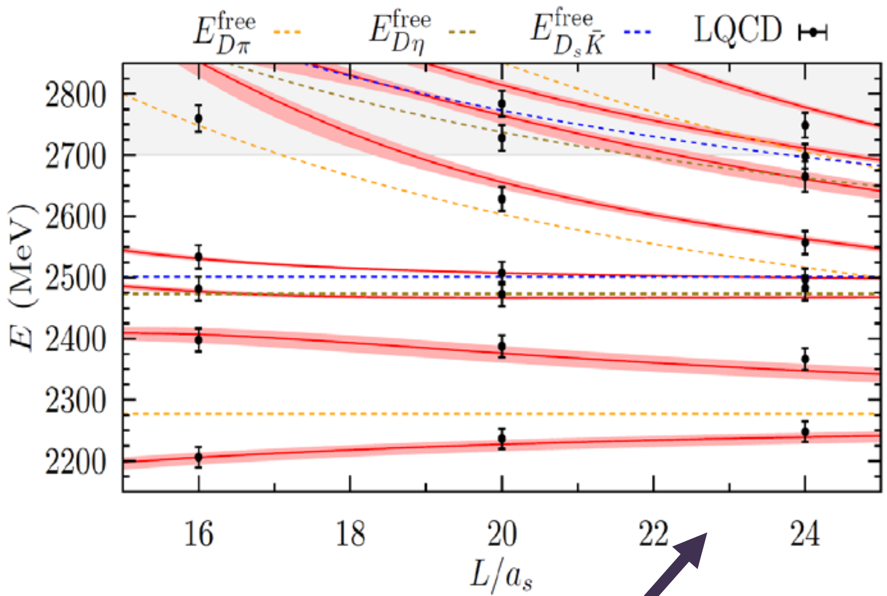


Fig. 4 The D^0K^+ invariant mass distributions for the reactions $B_s \to \pi^+\bar{D}^0K^-$ (*top panels*), $B^0 \to D^-D^0K^+$ (*middle panels*) and $B^+ \to \bar{D}^0D^0K^+$ (*lower panels*). In the *left panels*, our fitted theoretical distributions (*blue lines*) together with their error (*blue bands*), and confronted with the experimental distributions (data taken from the LHCb [52] and the BaBar [51] collaborations). In the *right panels* we show the different contributions to each decay. The fit shown here is the one called "combined" in Table 1



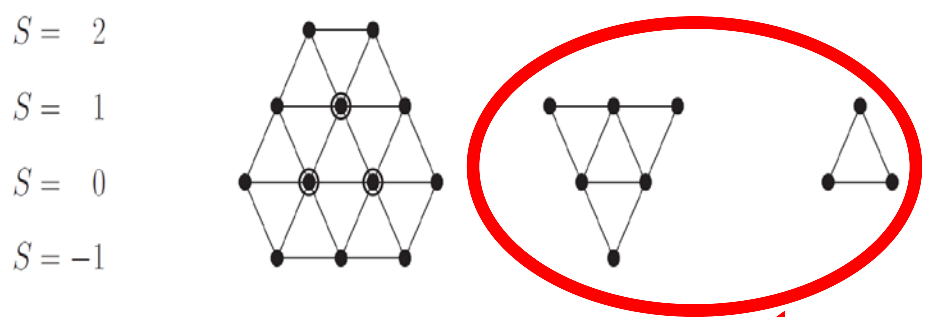
Two-pole structure of the D*(2400)

M. Albaladejo, P. Fernández-Soler, F.-K. Guo, J.Nieves, arXiv:1610.06727

$D\pi, D\eta, D_s\bar{K}$ coupled channels: NLO in HMChPT

- We find two poles $(J^P = 0^+)$ for the PDG **D*(2400)**
- Light flavor and heavy flavor+spin symmetries allow to describe/**predict** a

Finite volumen LQCD energy levels (Lüscher)



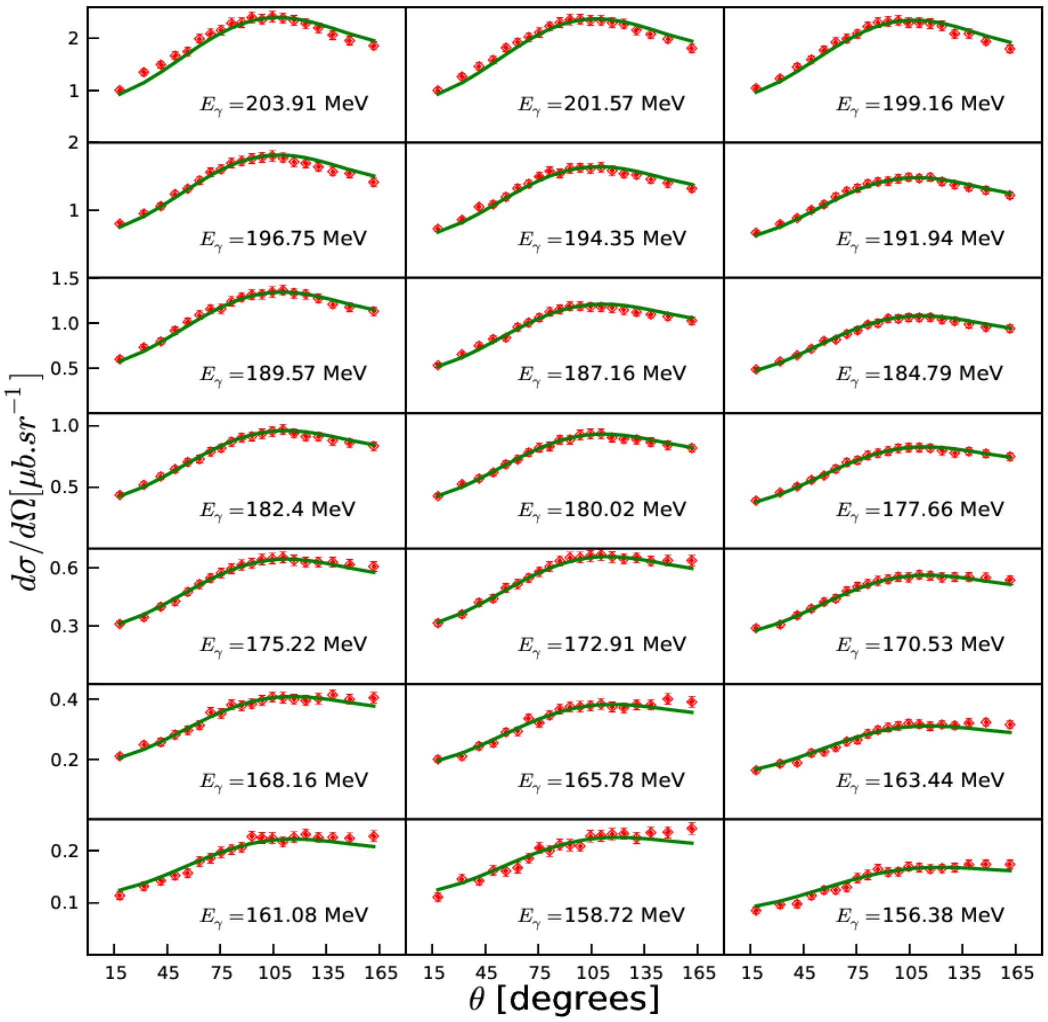
For intance, $D^*_{s0}(2317), D_{s1}(2460)$, partners in the bottom sectors, **near-threshold bound or virtual states in the BK channel (exotic state with quark content $bs\bar{d}\bar{u}$) that if bound they could only decay through weak and/or electromagnetic interactions.**

Attractive interaction

Precision tests of ChPT

- New, high precision, data of low energy processes allow to test and constrain the low energy effective theory of QCD: ChPT.
- ChPT with baryons has some long standing problems for an effective field theory:
  - A proper power counting
  - Slow convergence, more so for SU(3).
- The Extended On Mass Shell approach deals effectively with both problems
- We have studied the neutral pion photoproduction on the proton *(A.N. Hiller Blin)* at O(p3) and including the $\Delta(1232)$ explicitly
  - Find a much better agreement (Cross sect., polarization obs.) than the Infrared and Heavy Baryon approaches *(even at higher order calculations –with many free parameters-)*
  - $\Delta(1232)$ is essential for the convergence

Precision tests of ChPt



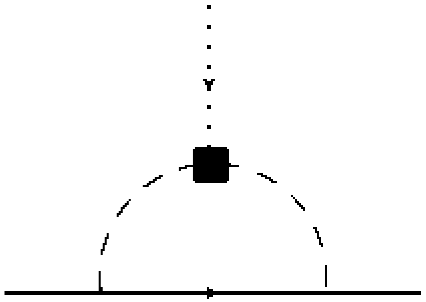
$$\gamma p \to \pi^0 p$$

Data from the A2 *and* CB-TAPS *coll. (Mainz)* 2013 vs ChPT at O(p3)

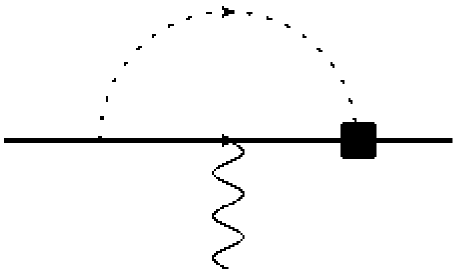
CP violating η decays vs nucleon EDM

- η decay into $\pi\pi$ violates CP and
  - induces a CP violating coupling η–nucleon

  This can be estimated using the same framework (ChPT + EOMS *with light mesons+nucleons+baryons decuplet as degrees of freedom*)



- The CP viol. η nucleon coupling induces a γ N coupling that leads to EDM



CP violating η decays vs. nucleon EDM

- The current limit on the neutron EDM

$$d_n \leq 2.9 \times 10^{-26}\ e\ cm$$

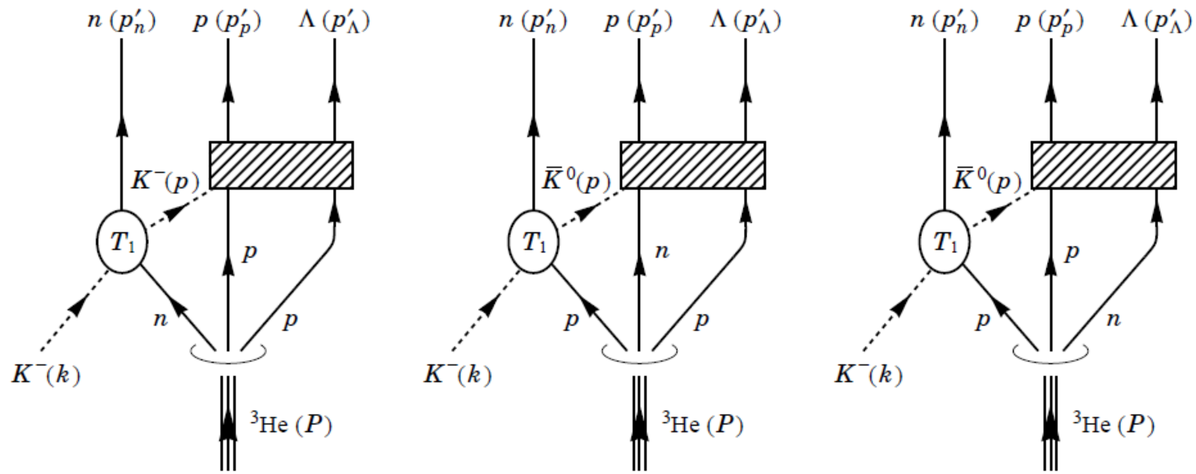
leads to $\eta \to \pi\pi$ branching ratios at least 8 orders of magnitude smaller than the current experimental limits measured by the LHCb coll.

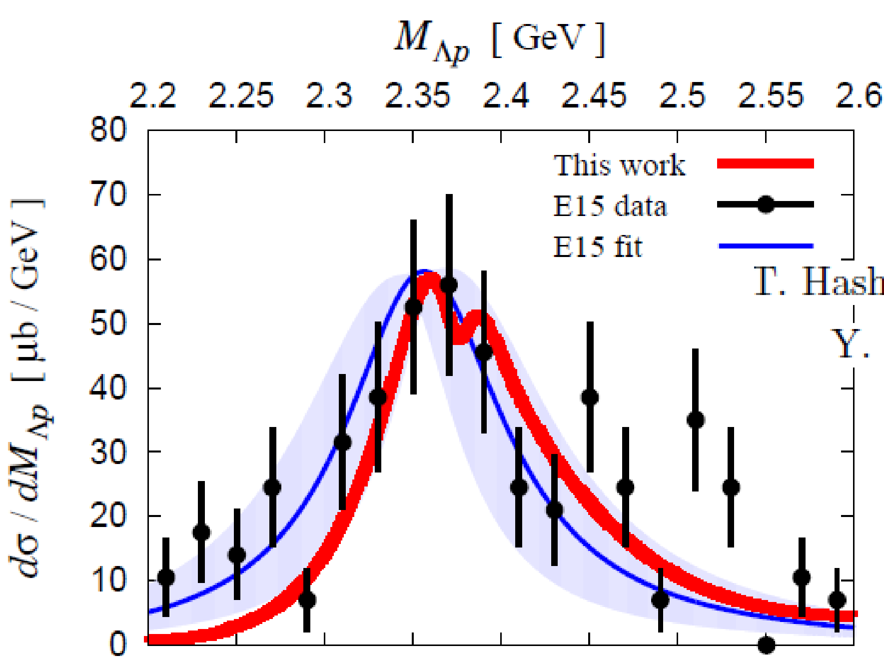
$$\text{B.R.}(\eta \to \pi^0\pi^0) < 3.5 \times 10^{-4}$$

On the structure observed in the in-flight ^{3}He(K^-, Λp)n reaction at J-PARC

Takayasu Sekihara[1,*] Eulogio Oset[2], and Angels Ramos[3]

PTEP 2016





T. Hashimoto *et al.* [J-PARC E15 Collaboration], PTEP **2015**

Y. Sada *et al.* [J-PARC E15 Collaboration], PTEP **2016**

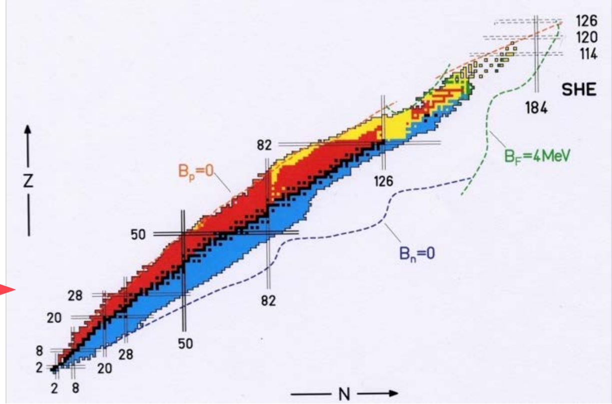
Our study confirms that the long searched for K- pp bound state corresponds to the left peak in the figure.

V(2B-3B)

MICROSCOPIC METHODS
Brueckner-Bethe-Goldstone
Chiral Effective Field Theory
Many-Body Perturbation Theory

Partial Wave Decomposition V(LSJT)

Veffective
Hartree-Fock-Bogoliubov



Finite range
D1, M3Y

Fixing tensor and spin-orbit
Zero-range limit
D. Davesne, P. Becker, A. Pastore, J. Navarro
Physical Review C 93 (2016) 064001
Annals of Physics 375 (2016) 288

Zero-range
N3LO Skyrme

EoS asymmetric nuclear matter
Neutron stars: mass-radius
D. Davesne, A. Pastore, J. Navarro
Astronomy & Astrophysics 585 (2016) A83

Neutrino Interactions

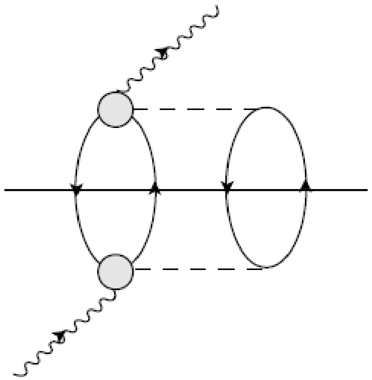
- Neutrino interactions with matter are at the heart all experiments seeking to unravel its nature.
- Oscillation experiments (with accelerator ν in the few-GeV region):
  T2K, NOvA, MicroBooNE, Hyper-K, DUNE/LBNF
  - Goals: ν mass hierarchy, CP violation
  - Good understanding of neutrino cross sections is important for:
    - ν detection, flavor ID
    - reduction of systematic errors
      - E_ν reconstruction, ν flux calibration
      - determination of (irreducible) backgrounds
  - Precision of 1-5% in ν cross sections might be required

Neutrino Interactions

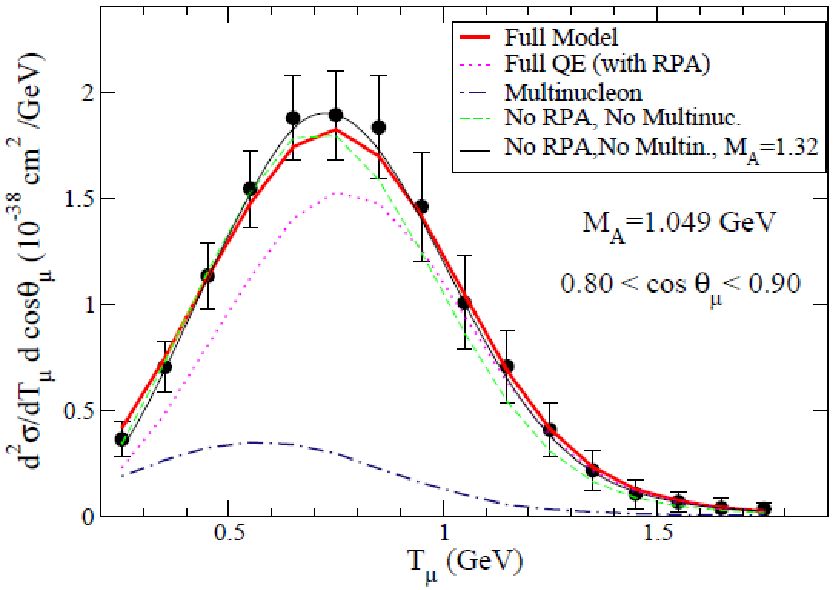
- The group has been making relevant contributions in the realistic theoretical modeling of neutrino interactions with nucleons and nuclei
  - quasielastic νA scattering
  - multinucleon contributions to νA inclusive cross sections
  - pion production on nucleons
  - heavier meson [K, η] and hyperon [Λ, Σ, Λ(1405)] production
  - pion final state interactions in nuclei
  - photon emission in neutral-current interactions
  - coherent particle (π, K, γ) production
  - nuclear effects in the DIS region
- These processes are relevant for current and future ν experiments e.g.
  - quasielastic scattering is used for kinematic E_ν reconstruction
  - π^0, γ emission in NC are backgrounds to $\nu_\mu \longrightarrow \nu_e$ searches

Neutrino Interactions

Two-nucleon (2p2h) contributions to the weak current



found to be very important to describe MiniBooNE CC $\nu_\mu{}^{12}C$ 0π data



Nieves et al., PLB 707 (2012)

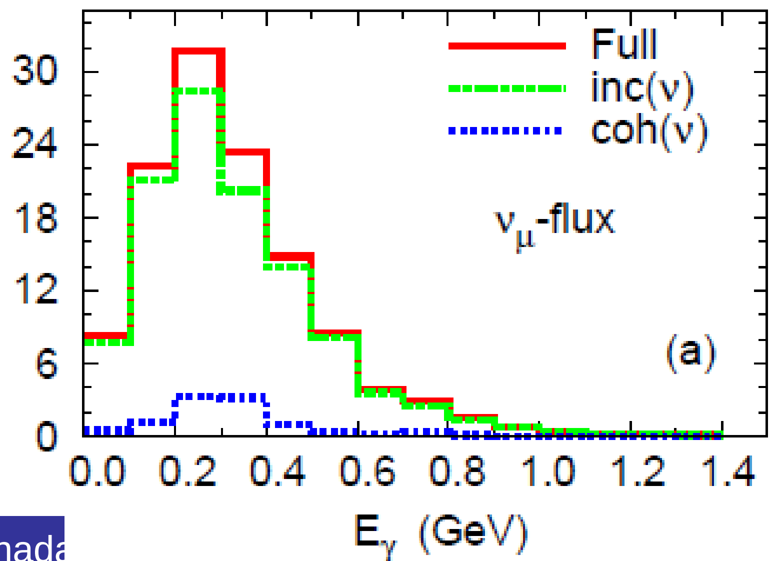
- 2p2h: E_ν misreconstruction, which has impact on oscillation analyses

Neutrino Interactions

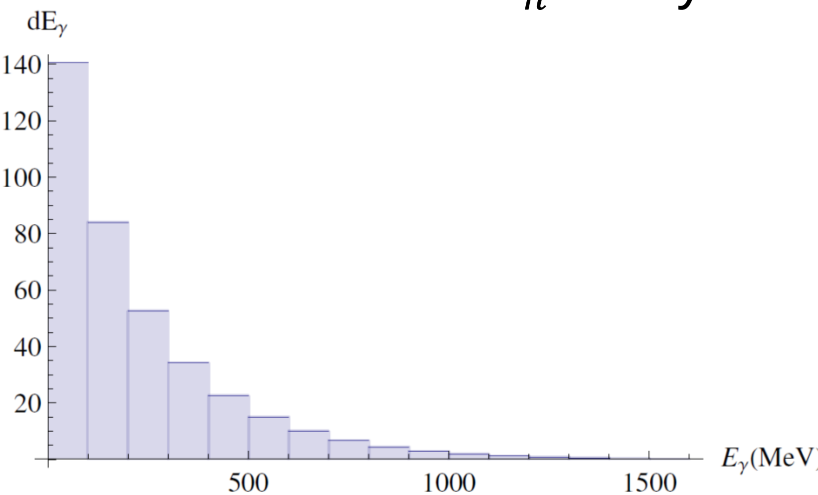
- New physics can manifest itself in neutrino interactions with matter
- For example: it has been suggested that weak/EM production of heavy neutrinos ($m_h \approx 50$ MeV) followed by $\nu_h \longrightarrow \nu\gamma$ can explain MiniBooNE anomaly (excess of low E_ν events in $\nu_\mu \longrightarrow \nu_e$ signal)
- Proper modeling of this scenario should be based on present understanding of electroweak interactions with nucleons and nuclei
- Can be tested at the Short Baseline Program @ Fermilab

(SBND + MicroBooNE + Icarus detectors). At MicroBooNE:

Standard



Radiative ν_h decay



L. Alvarez-Ruso, E. Saul, E. Wang