Hypernuclei in Gamow Shell Model

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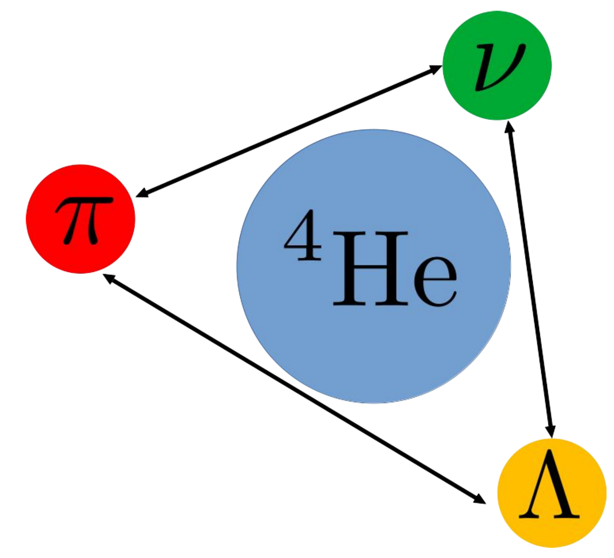
Introduction

Hypernuclei are exotic nuclear systems formed by introducing one or more hyperons into an atomic nucleus. The Λ hyperon is not Pauli blocked, so it can occupy any single-particle state, providing a distinguishable probe of the nuclear interior. Therefore, new nuclear structures or unknown properties of the baryonic interaction may manifest themselves in hypernuclei.

The description of an hyperon in the nuclear medium is a many-body problem, and therefore, hypernuclei have to be treated using microscopic nuclear theory models. An extension of the Gamow shell model formalism [1] has been done to the study of hypernuclei (GSM-H) [2] with applications for the structure of single-strangeness hypernuclei, where the gaussian hyperon(Y)-nucleon(N) interaction was introduced explicitly following the Hiyama's expression for the central (CTR), symmetric (SLS) and antisymmetric (ALS) spin-orbit parts [3] :

$$V_{\Lambda N}^{(\mathrm{CTR})}(r) = \sum_{\eta} \sum_{i=1}^{3} v_i^{(\eta)} \Pi^{(\eta)} e^{-(r/\beta_i)^2} \qquad \eta = \{\mathrm{se}, \mathrm{te}, \mathrm{so}, \mathrm{to}\}$$

$$V_{\Lambda N}^{\substack{\mathrm{SLS} \\ \mathrm{ALS}}}(r) = \sum_{i=1}^{2} v_i^{\substack{\mathrm{SLS} \\ \mathrm{ALS}}} \left(\Pi^{(\mathrm{te})} + \Pi^{(\mathrm{to})}\right) e^{-(r/\beta_i)^2} \left[L \cdot (s_\Lambda \pm s_N)\right]$$

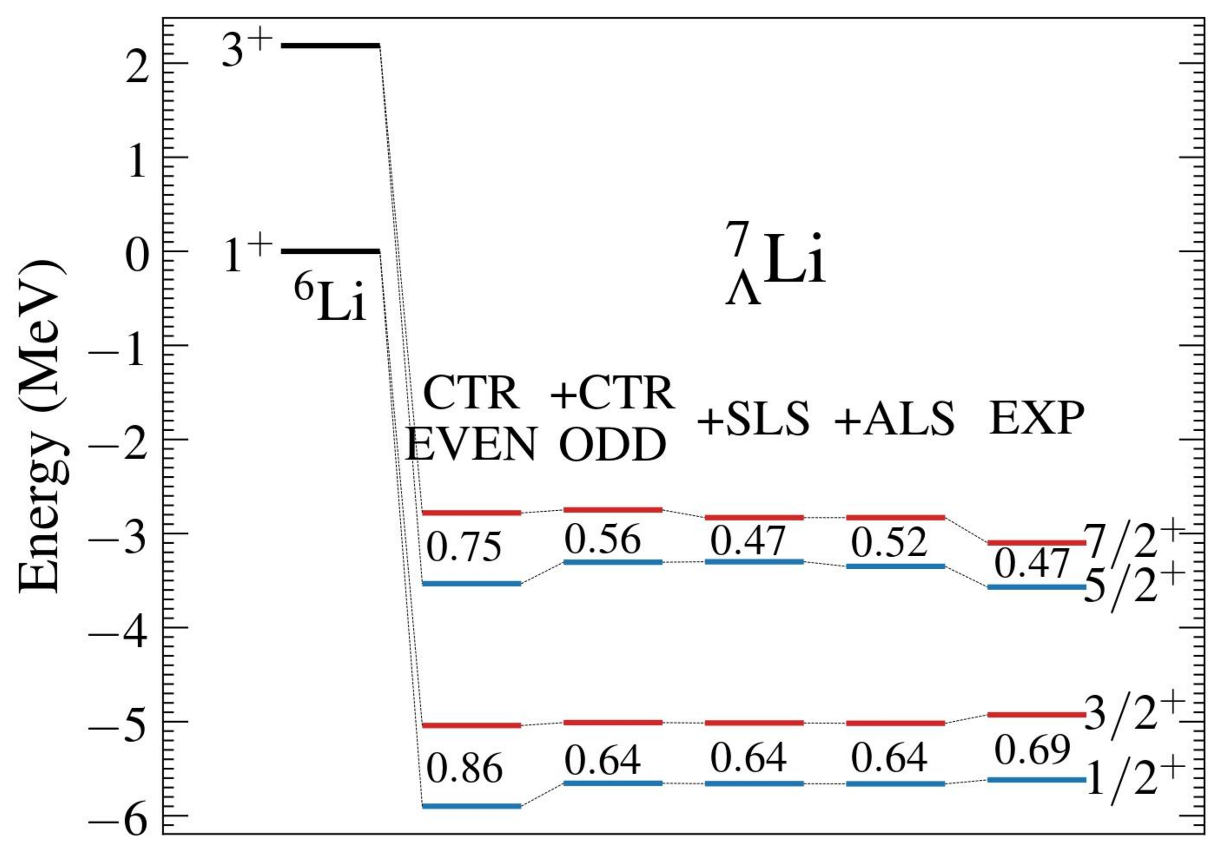


The goal of this project is to obtain information on baryon-baryon interaction in a unified way. Especially, it becomes an important issue to obtain information on YN interaction, following the hyperon-nucleon scattering experiments that are planned at JLab and J-PARC facilities in $^{40}_{\Lambda}\mathrm{Ca}$ and $^{40}_{\Lambda}\mathrm{K}$ [4].

The simplest case : $^{7}_{\Lambda}\mathrm{Li}$

At the beginning of the century, experimental data for $^{7}_{\Lambda}\mathrm{Li}$ have been gained systematically. The low-lying state energies, (1/2+, 3/2+) and (5/2+, 7/2+) became known with high resolution from γ-ray measurements [5]. Then, this hypernuclei was used to evaluate the GSM-H implementation, escentially the central YN part.

Our results for the central YN interaction is in agreement with the cluster-model [3] and shell-model [6] results, whit an overestimation of the (7/2+,5/2+) splitting.

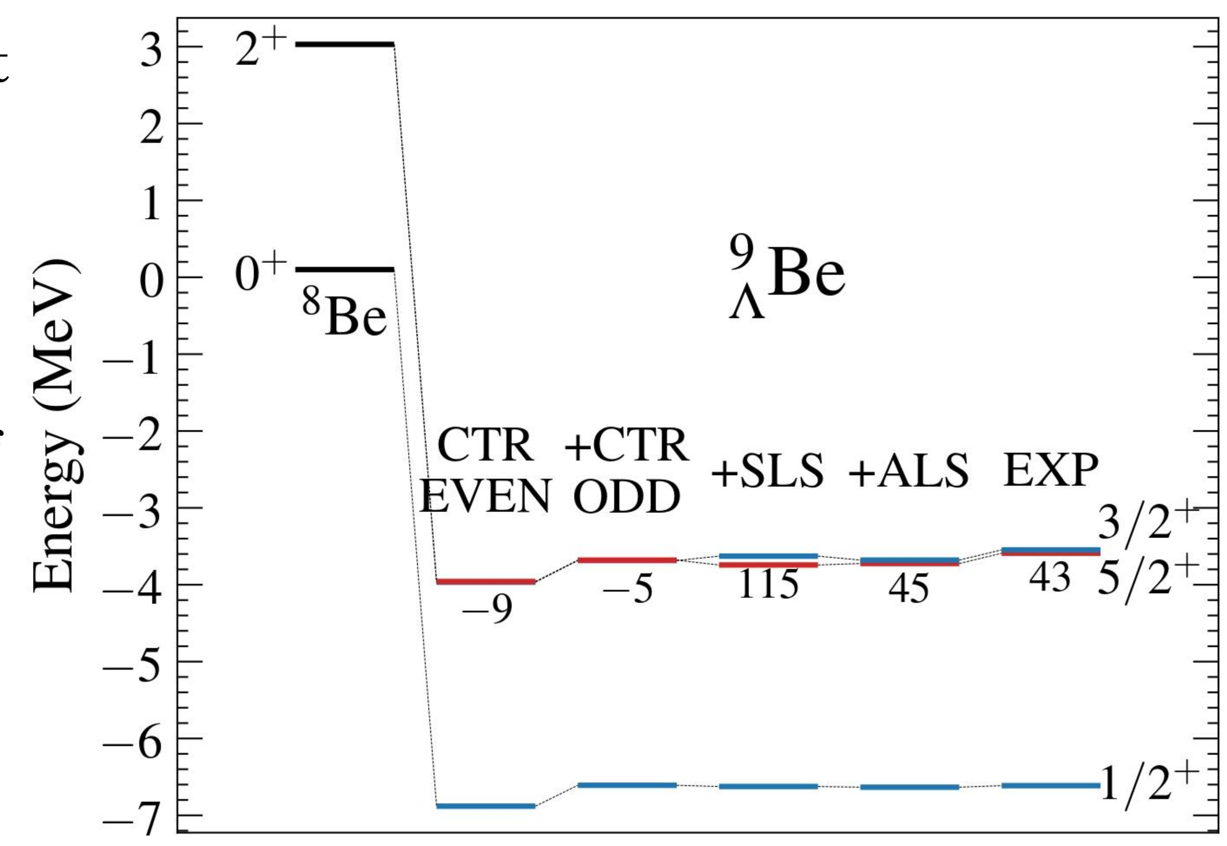


The A=9 system : $^{9}_{\Lambda}\mathrm{Be}$

We investigate structure of $^{9}_{\Lambda}\mathrm{Be}$ and properties of the underlying ΛN interaction, specially the spin-orbit part. The experimental splitting between the states (5/2+,3/2+) is coming from a reanalysis of the BNL E930 data [7].

Our calculation for this hypernuclei is again in agreement with the cluster-model [3] and shell-model [6].

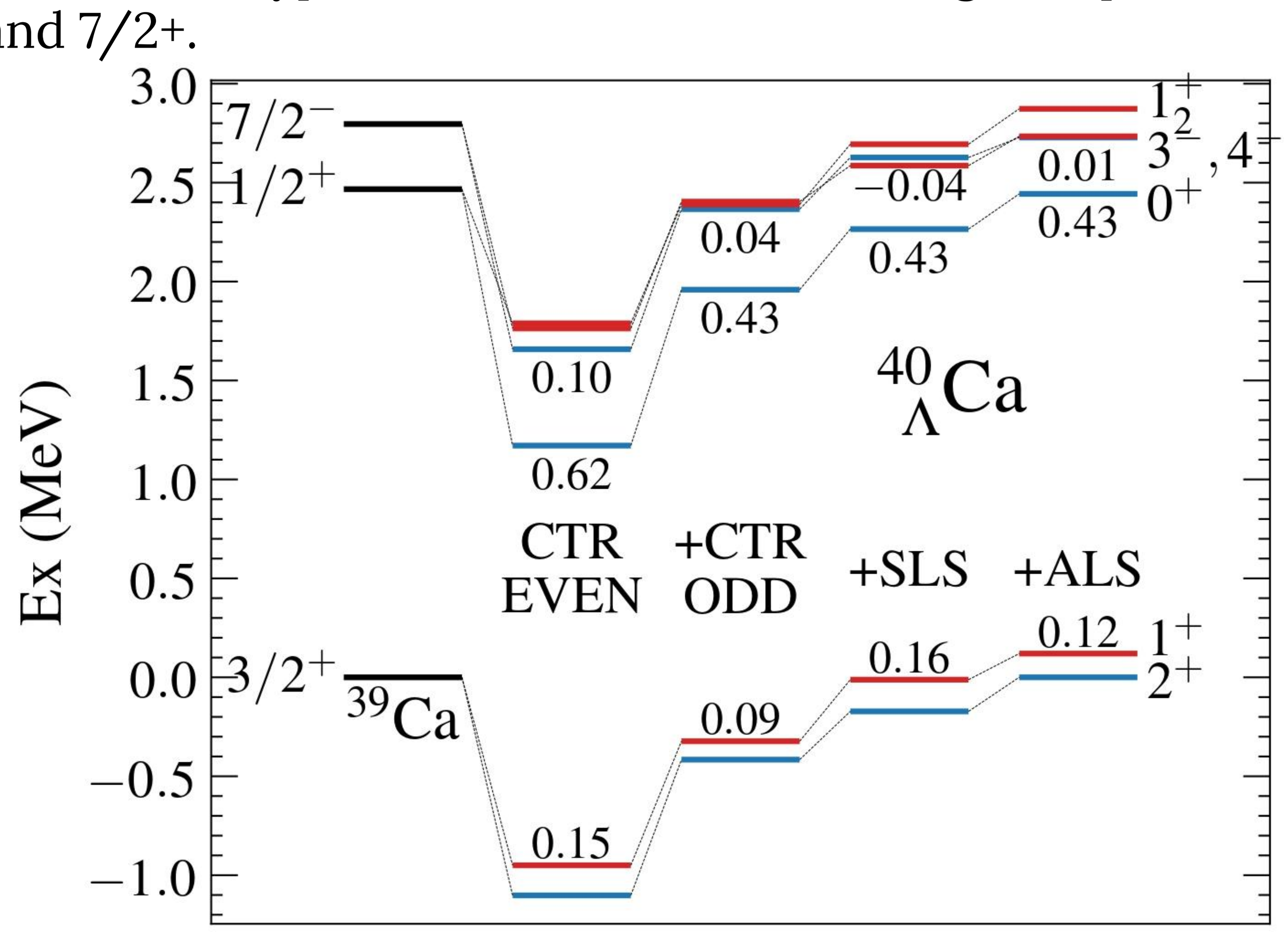
It can be seen that the inversion of the (5/2+,3/2+) is coming from the LS interaction. Furthermore, the overall splitting of 45 keV is also produced by the LS interaction.

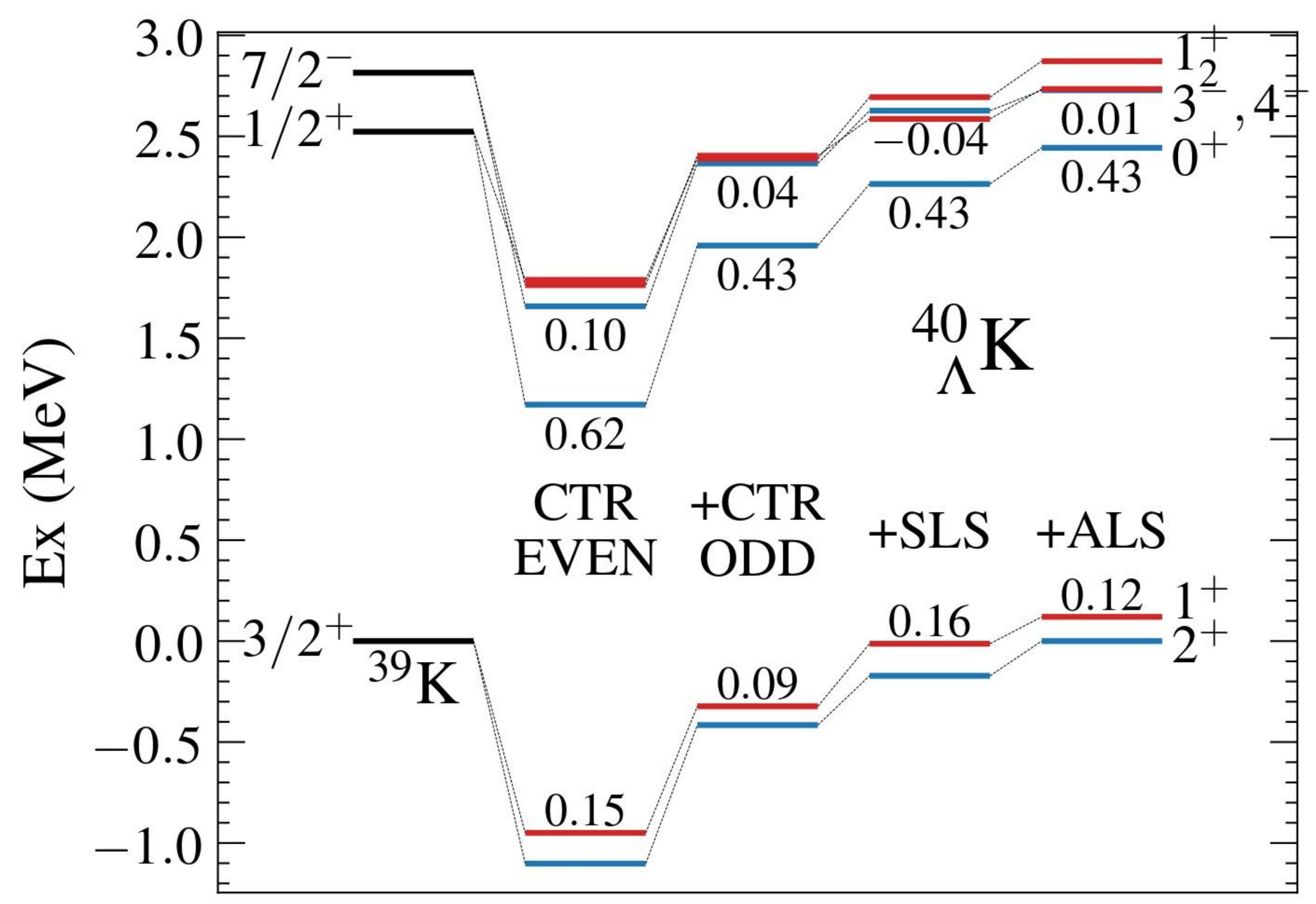


The future experiments : $^{40}_{\Lambda}\mathrm{Ca}$ and $^{40}_{\Lambda}\mathrm{K}$

The mirror systems $^{40}_{\Lambda}\mathrm{Ca}$ and $^{40}_{\Lambda}\mathrm{K}$ are modelized as the $^{28}\mathrm{Si}$ plus 12 valence baryons. The YN interaction used here is the same as in the A=7 and A=9, with an optimization of the NN interaction in order to reproduce the low-lying spectrum of $^{39}\mathrm{Ca}$ and $^{39}\mathrm{K}$.

The Λ binding energy is predicted to be 18.8 MeV and 12.3 MeV in $^{40}_{\Lambda}\mathrm{Ca}$ and $^{40}_{\Lambda}\mathrm{K}$ respectively. The lower doublet (2+,1+) has a separation of 120 keV in both hypernuclei, meanwhile the higher spectra has a mixture between the states (0+,1+) and (3-,4-) coupled to the core's states 1/2+ and 7/2+.





References

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Conclusion and perspectives

- Our model was able to reproduce the Λ spectra of the systems A=7 and A=9
- The inversion of the doublet (5/2+,3/2+) in $^{9}_{\Lambda}\mathrm{Be}$ is caused by the LS interaction
- The low-lying doublet of $^{40}_{\Lambda}\mathrm{Ca}$ and $^{40}_{\Lambda}\mathrm{K}$ was predicted to be the (2+,1+) with a separation energy of 120 keV.

The same model will be applied to the $^{48}_{\Lambda}\mathrm{Ca}$ and $^{48}_{\Lambda}\mathrm{K}$ systems that are expected to be measure in future experiments [4].
Calculation of electromagnetic transitions strengths are planned as well.