Isospin Symmetry Breaking in Mirror Nuclei

$^{23}$Mg – $^{23}$Na

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**Physics Case**

Isospin Symmetry implies identical level schemes for mirror nuclei. Differences in excitation energies in mirror nuclei are therefore an evidence of Isospin Symmetry Breaking (ISB)

The Mirror Energy Differences (MED) are defined as:

$$\text{MED}_{J,T} = E_{J,T,T=+1} - E_{J,T,T=-1}$$

and gives information on nuclear structure.

- The main contribution to MED comes from the Coulomb interaction.
- The way the nucleus aligns its protons
- The nuclear radius variation with J
- Single particle energies of different orbitals

In the f$_{7/2}$ shell an additional ISB term of nuclear origin must be added to reproduce the experimental MEDs

J=2 Anomaly

Is it needed also in other mass regions?

**The experiment**

- Aim: Study mirror nuclei $^{23}$Mg – $^{23}$Na up to high spin
- Reaction: $^{16}$O + $^{12}$C at 60-70 MeV.
- $^{23}$Mg – $^{23}$Na populated in α-α channels respectively
- Experimental setup
  - EXOGAM: 11 HPGe Clover for γ-ray detection
  - DIAMANT: 80 CsI scintillators for charged particles detection
  - NEUTRON WALL: 50 liquid scintillators for neutron detection

**Results: γ-ray spectra and level schemes**

![γ-ray spectra and level schemes](Image)

**Discussion: “Standard” shell model approach**

- USD interaction
- Coulomb term $V_{CM}$ calculated in harmonic oscillator basis
- Radial term $V_{R}$ obtained from the occupation numbers of the $s_{1/2}$ shell
- Correction applied to single particle energies
- “Nuclear” ISB term $V_{B}$ parameterized from A=42 mirror nuclei

- The Coulomb term reproduces the trend of the MED
- The $V_{CM}$ term is needed: this confirms the importance of the $s_{1/2}$ shell
- “Nuclear” ISB term $V_{B}$ makes the things worse: J=2 Anomaly?

**Discussion: Alternative Approach**

- Realistic NN N3LO interaction which naturally includes Coulomb term, single particle energy corrections and nuclear ISB term

- Different potential wells for π and ν:

  - $\hbar \omega_{π,ν}$ is strictly related to the radii $r_{π,ν}$
  - $r_{π}$ is fitted to the experiment.
  - $r_{ν}$ is obtained from the binding energies.

- Different $\hbar \omega_{π,ν}$ for each nucleus

- Radial term $V_{CM}$ obtained from the occupation numbers of the $s_{1/2}$ shell

- N3LO interaction reproduces the trend of the MED
- Nuclear ISB term naturally taken into account
- The $V_{CM}$ term is still needed: importance of the $s_{1/2}$ shell confirmed

**Perspectives**

- Include the radial term $V_{CM}$ in the interaction
  - Different $\hbar \omega_{π,ν}$ for each J

- Idea: exploit the relation between $\Delta \omega = \hbar \omega_{π} - \hbar \omega_{ν}$, and the difference in occupation numbers of π and ν in the $s_{1/2}$ shell (related to neutron skin)

- Application of the same approach to the other nuclei in the sd shell
- Application of the same approach to the f$_{7/2}$ shell: J=2 Anomaly?

**References**

- J. Bonnard et al., PRL 116, 212501 (2016)