Isospin Symmetry Breaking in Mirror Nuclei ^{23}Mg $-^{23}$ Na

A. Boso[1,2*], S. M. Lenzi[1,2], F. Recchia[1,2], S. Aydin[3], M. A. Bentley[4], B. Cederwall[5], E. Clement[6], G. de France[6], A. Di Nitto[7], A. Dijon[6], M. Doncel[5], F.Ghazi-Moradi[5], A. Gottardo[8], T. Henry[4], T. Hüyük[9], G. Jaworski[10], P.R. John[1,2], K. Juhsz[11], I. Kuti[12], B. Melon[13], D. Mengoni[1,2], C. Michelagnoli[1,2], V. Modamio[8], D.R. Napoli[8], B.M. Nyakó[12], J. Nyberg[14], M. Palacz[10], J.J. Valiente-Dobón[8]

[1] Dipartimento di Fisica e Astronomia Università di Padova, Padova, Italy. [2] INFN, Sezione di Padova, Padova, Italy. [3] Aksaray Universitesi, Department of Physics, Aksaray, Turkey [4] University of York, York, United Kingdom. [5] Royal Institute of Technology, Stockholm, Sweden [6] GANIL, Caen, France. [7] Dipartimento di Scienze Fisiche and INFN, Sezione di Napoli, Napoli, Italy [8] INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova) Italy. [9] IFIC-CSIC, Valencia, Spain. [10] Heavy Ion Laboratory, Warsaw University, Warszawa, Poland [11] University of Debrecen, H-4032 Debrecen, Hungary [12] MTA Atomki, H-4001 Debrecen, Hungary [13] Dipartimento di Fisica e INFN, Sezione di Firenze, Firenze, Italy [14] Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

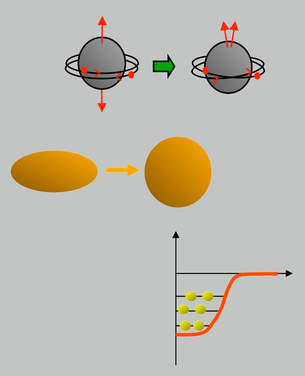
Physics Case

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:

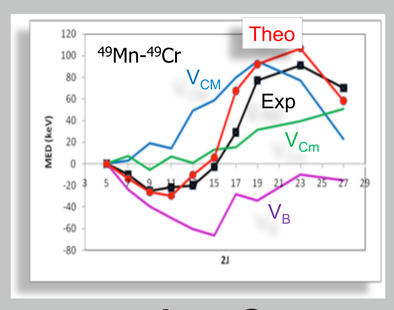
$$\mathbf{MED_{J,T} = E^*_{J,T,T_z=-T} - E^*_{J,T,T_z=T}}$$

and give information on nuclear structure.

- The main contribution to MED comes from the **Coulomb interaction** This gives information on:
  - ▷ The way the nucleus **aligns** its protons
  - ▷ The nuclear **radius variation** with **J**
  - ▷ **Single particle energies** of different orbitals



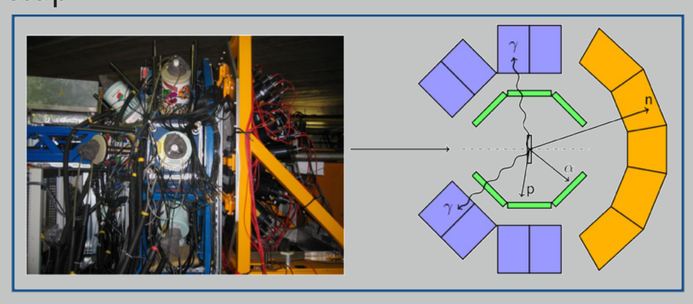
- In the $\mathbf{f_{7/2}}$ shell an additional ISB term of **nuclear** origin must be added to reproduce the experimental MEDs
  J=2 Anomaly



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 αn-αp 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

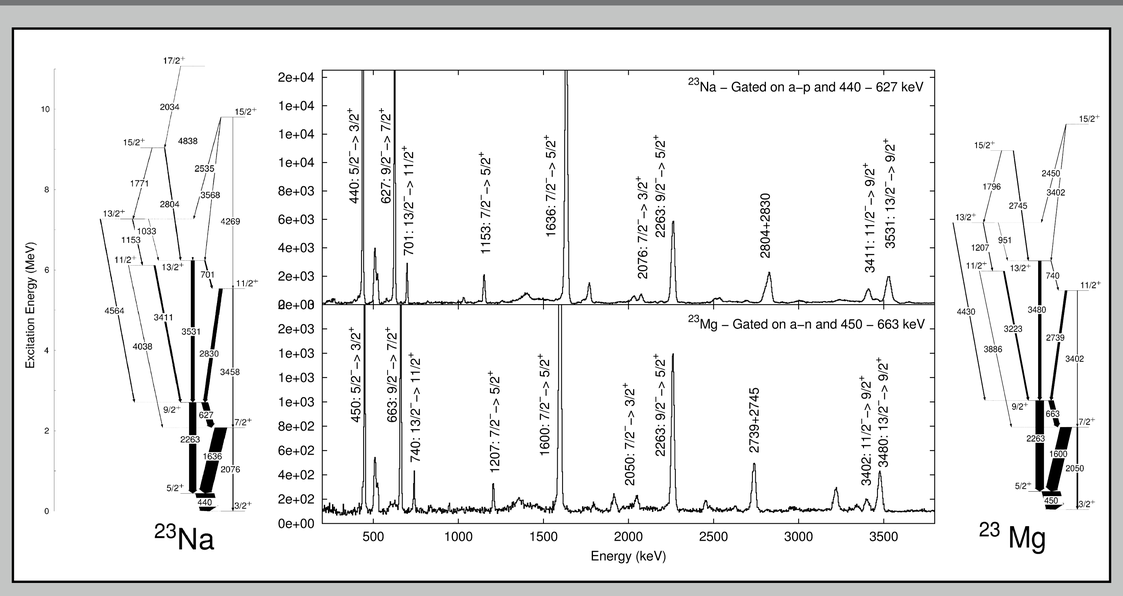
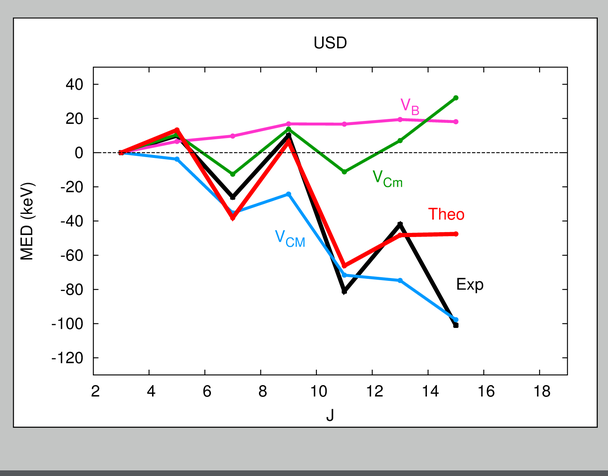


Figure 1: γ-ray spectra and level schemes of mirror nuclei ^{23}Mg $-^{23}$ Na

Discussion: "Standard" shell model approach

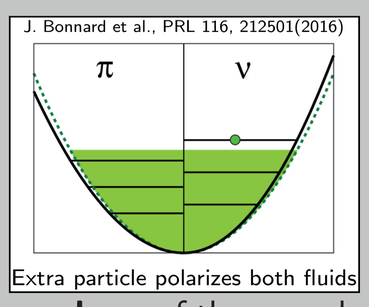
- **USD** interaction
- Coulomb term $\mathbf{V_{CM}}$ calculated in harmonic oscillator basis
- Radial term $\mathbf{V_{Cm}}$ obtained from the **occupation numbers** of the $\mathbf{s_{1/2}}$ shell
- Correction applied to single particle energies
- **"Nuclear"** ISB term $\mathbf{V_B}$ parameterized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



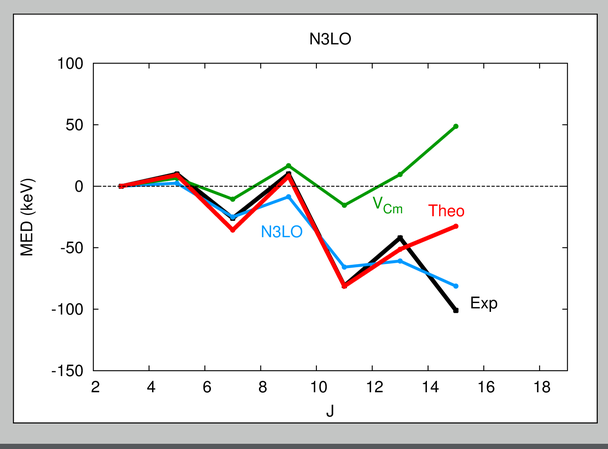
- The **Coulomb** term **reproduces the trend** of the MED
- The $\mathbf{V_{Cm}}$ term is needed: this confirms the **importance** of the $\mathbf{s_{1/2}}$ **shell**
- "Nuclear" ISB term $\mathbf{V_B}$ makes the things **worse**: **J=2 Anomaly??**

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:
    $\hbar\omega_{\pi,\nu}$ is strictly related to the radii $\mathbf{r_{\pi,\nu}}$.
    $\mathbf{r_\pi}$ is fitted to the experiment.
    $\mathbf{r_\nu}$ is obtained from the binding energies.
    Different $\hbar\omega_{\pi,\nu}$ for **each nucleus**



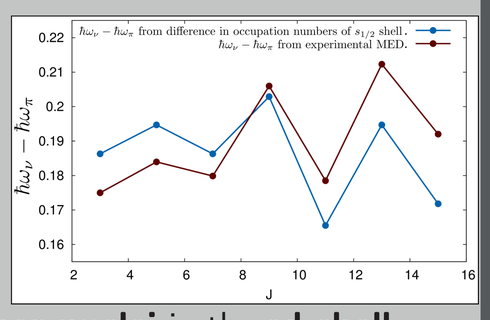
- Radial term $\mathbf{V_{Cm}}$ obtained from the **occupation numbers** of the $\mathbf{s_{1/2}}$ shell



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

Perspectives

- Include the **radial term** $\mathbf{V_{Cm}}$ in the interaction
  $\rightarrow$ **Different** $\hbar\omega_{\pi,\nu}$ for each J



- Idea: exploit the **relation** between $\mathbf{\Delta\hbar\omega = \hbar\omega_\pi - \hbar\omega_\nu}$ and the **difference in occupation numbers** of π and ν in the $\mathbf{s_{1/2}}$ 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 $\mathbf{f_{7/2}}$ **shell: J=2 Anomaly?**

References

- A. P. Zuker et al., PRL 89, 142502 (2002)
- M.A. Bentley and S.M. Lenzi, Prog. Part. Nucl. Phys. 59 497 (2007)
- J. Bonnard et al., PRL 116, 212501 (2016)

*alberto.boso@pd.infn.it