7th International Conference on Collective Motion in Nuclei under Extreme Conditions (COMEX7)

Mirror energy differences as a probe for cross-shell excitations in ^{43}Sc-^{43}Ti mirror pair

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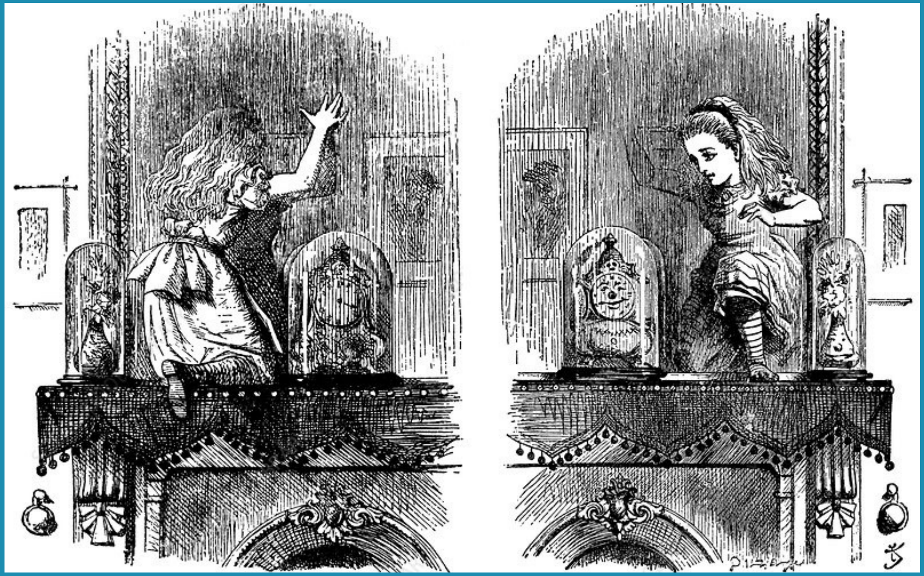

11–16 Jun 2023
Catania, Italy

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Introduction : proton-neutron symmetry

- **Exchange symmetry** between π and ν → isospin **T**

$$V_{pp} = V_{nn}$$

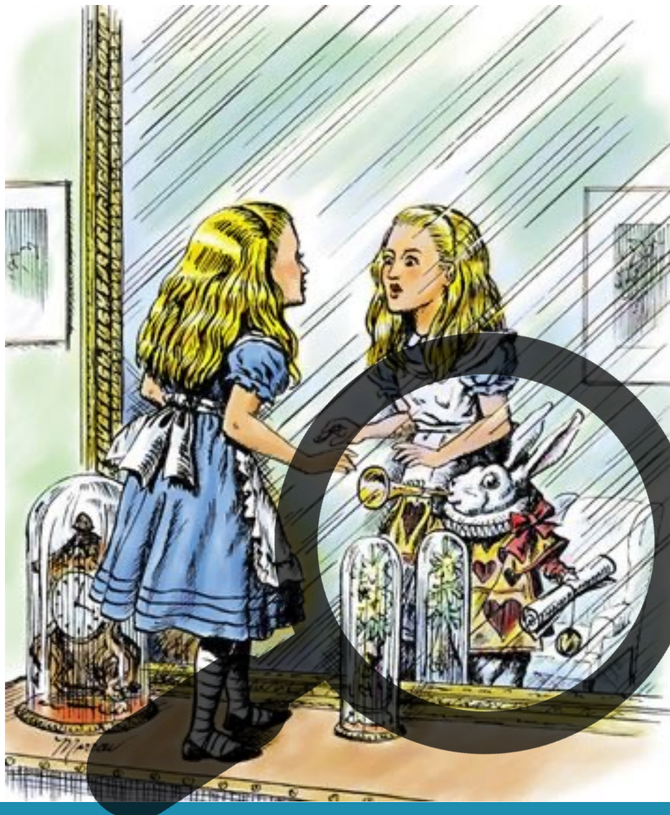
$$V_{np} = \frac{(V_{pp} + V_{nn})}{2}$$

- States with the same **T** in N=Z **mirror nuclei** → Isobaric Analogue States (**IAS**)

- ΔE_x between same-T states in isobaric doublets → **Mirror Energy Differences (MED)**

$$\mathrm{MED}_{J,T} = E^*_{J,T,T_z=-T} - E^*_{J,T,T_z=T}$$

- Differences between IAS magnifies **isospin non-conserving effects**

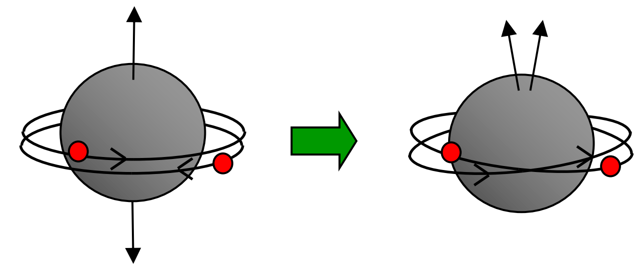


Shell model interpretation of MED

Coulomb effects:

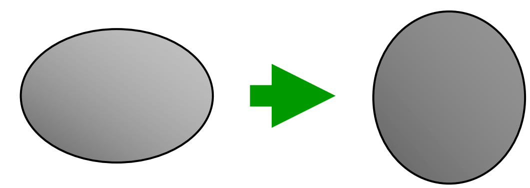
- **Multipole Coulomb term V_{CM}:**

  allignement of the valent protons



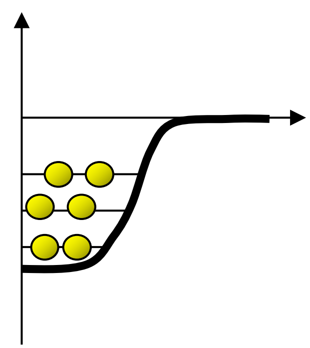
- **Monopole term V_{Cm}:**

  1. radius changes with J



  2. ℓ·ℓ term to account for shell effects

  3. ℓ·s **electromagnetic spin-orbit term (EMSO)**
  changes in single-particle energies
  different on π and ν, and when ℓ and s are parallel or aligned
  → Important in cross-shell excitations

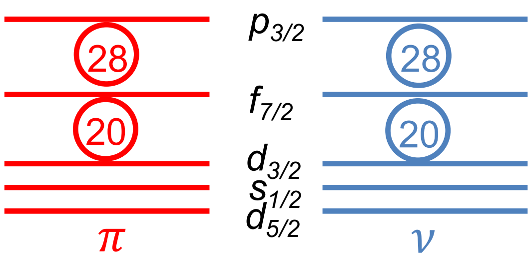


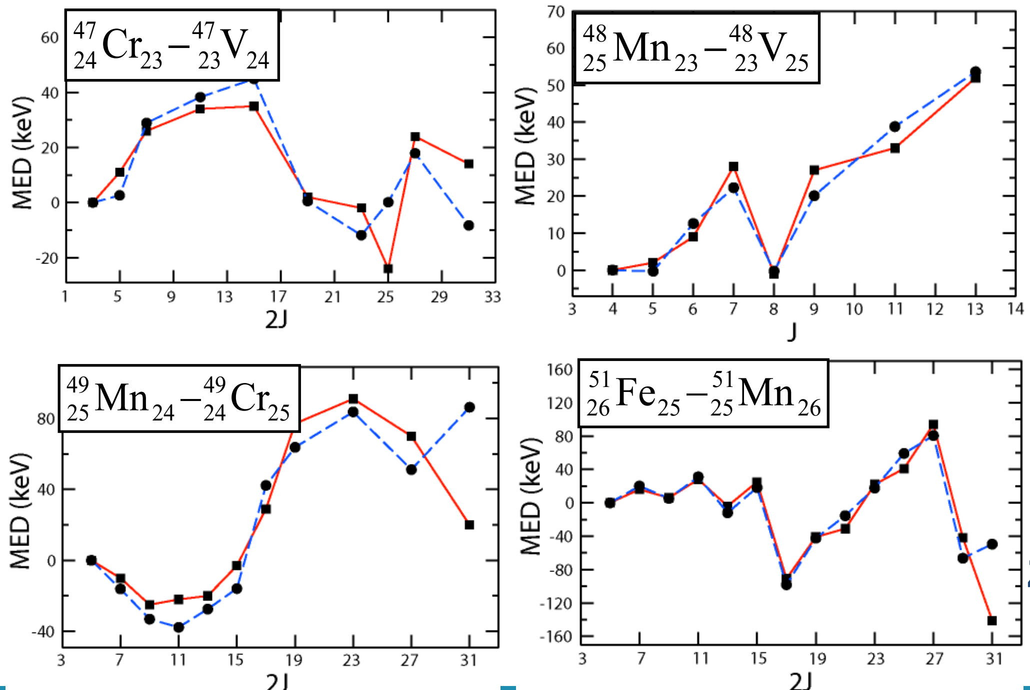
Isospin non-conserving term V_B : charge symmetry breaking

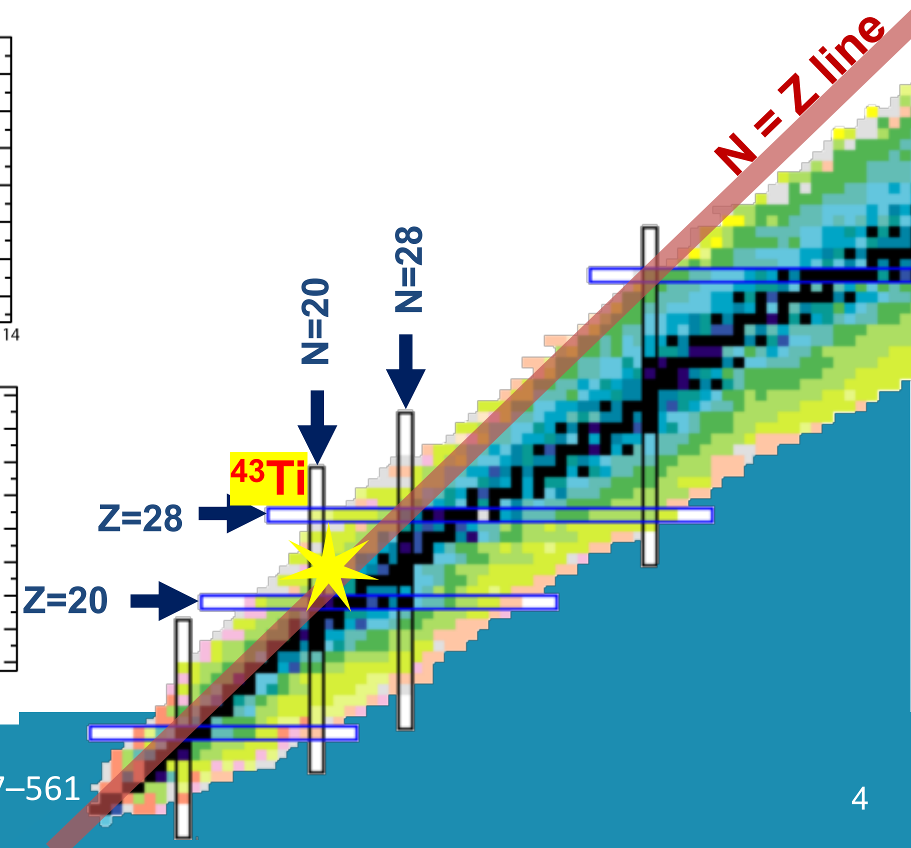
$$MED = V_{CM} + V_{Cm} + V_B$$

Mirror symmetry in the $f_{7/2}$ shell

- **between ^{40}Ca and ^{56}Ni: classic "playground" for isospin symmetry studies**:
  - more available experimentally
  - calculations can be limited to few shells (*sd* and *fp*)
  - nice way to study the interplay of the ISB effects

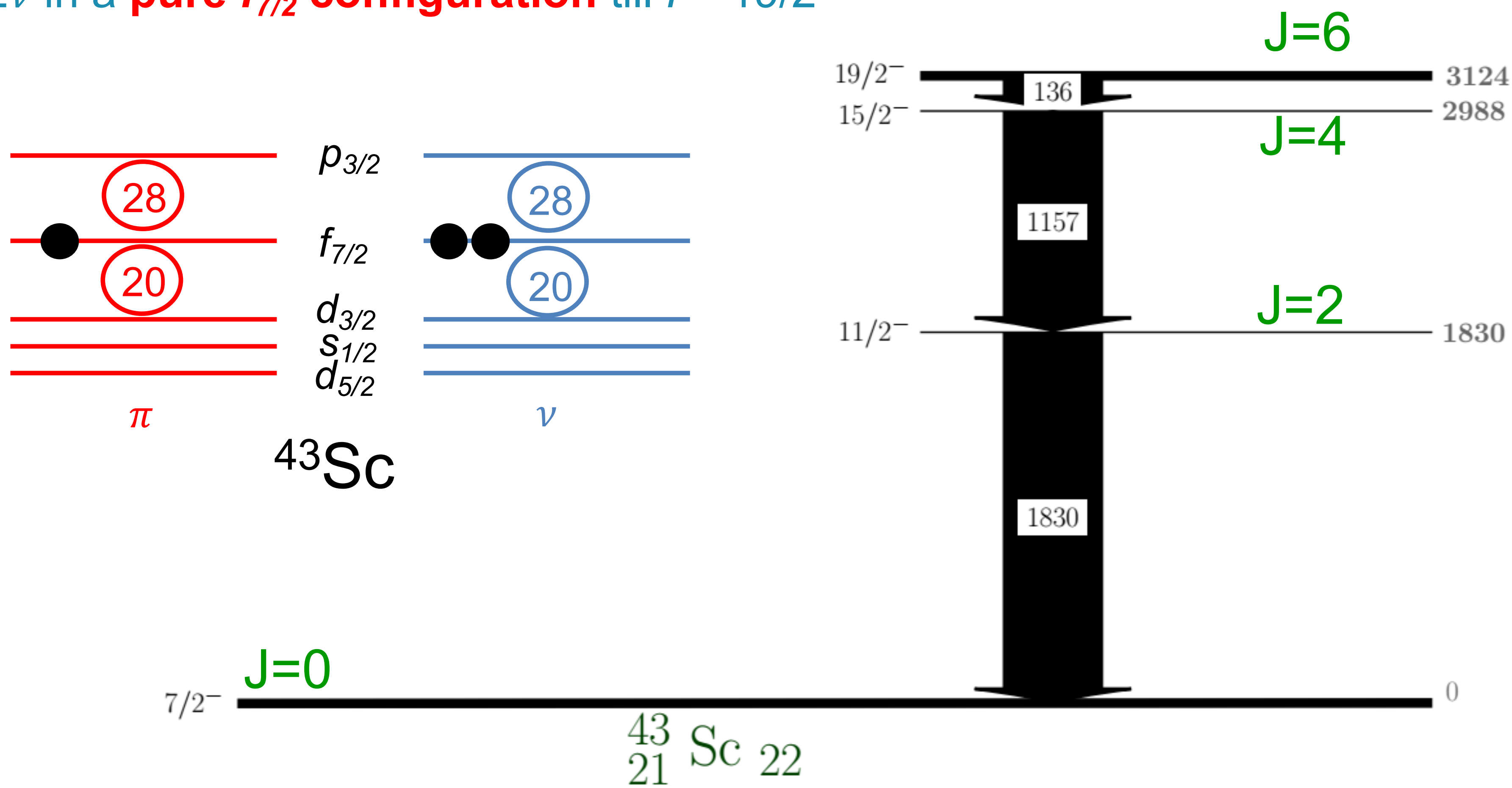




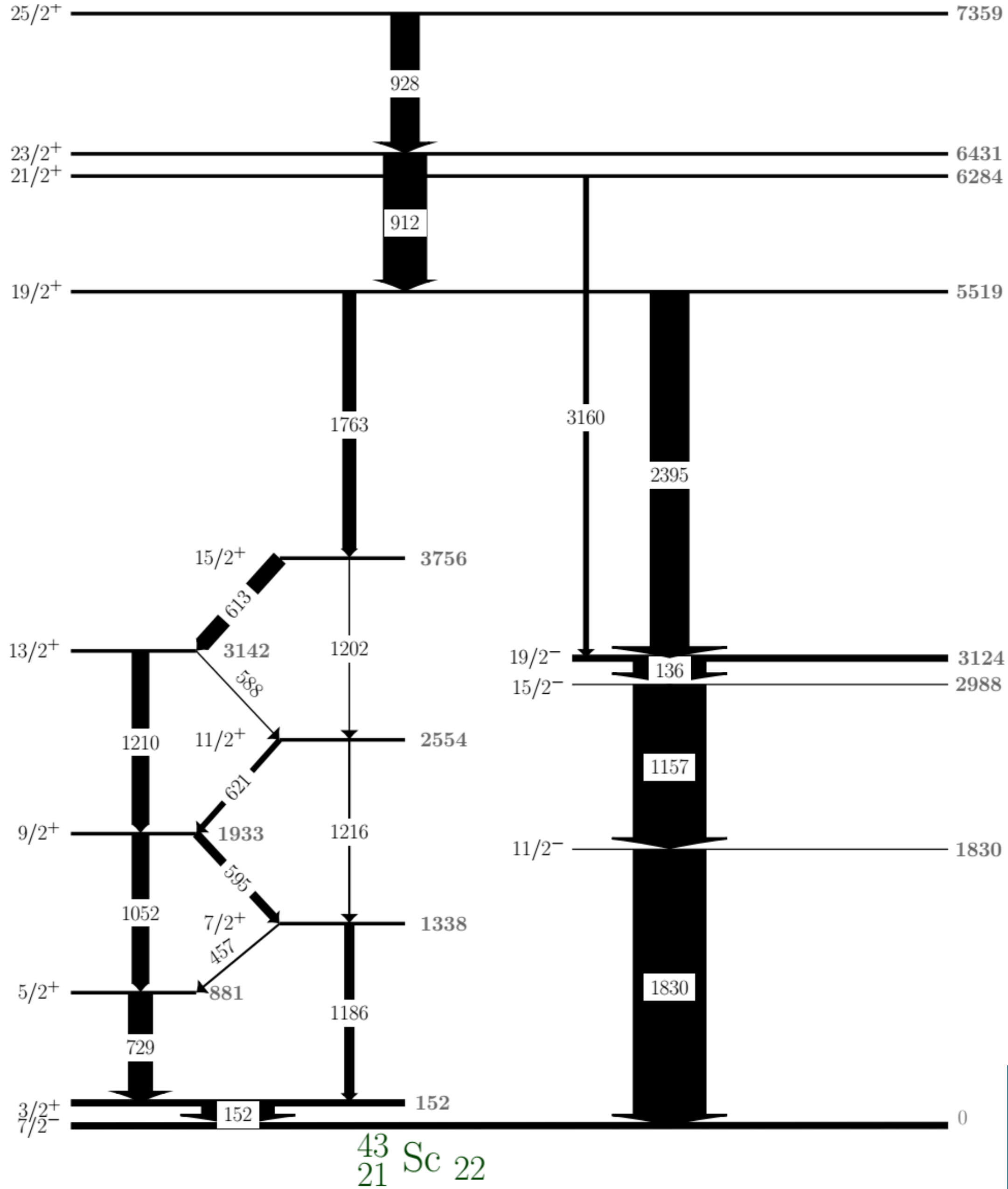


^{43}Sc : negative-parity states

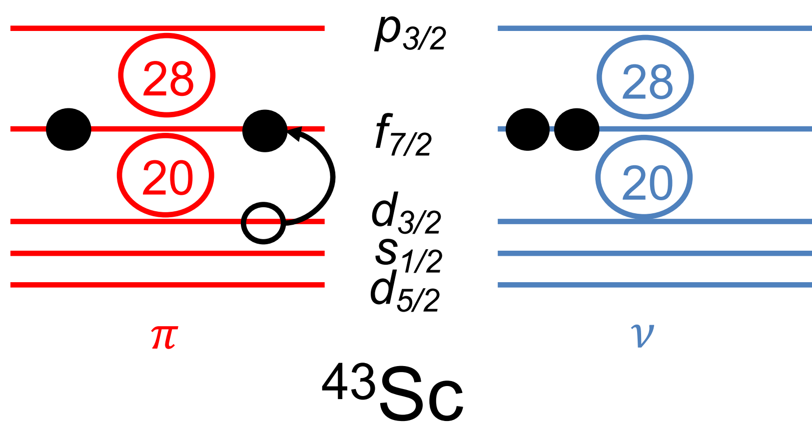
yrast structure, based on the $7/2^-$ g.s., is non-collective
terminates at the maximum spin that can be generated with one π and 2ν in a **pure $f_{7/2}$ configuration** till $I = 19/2^-$



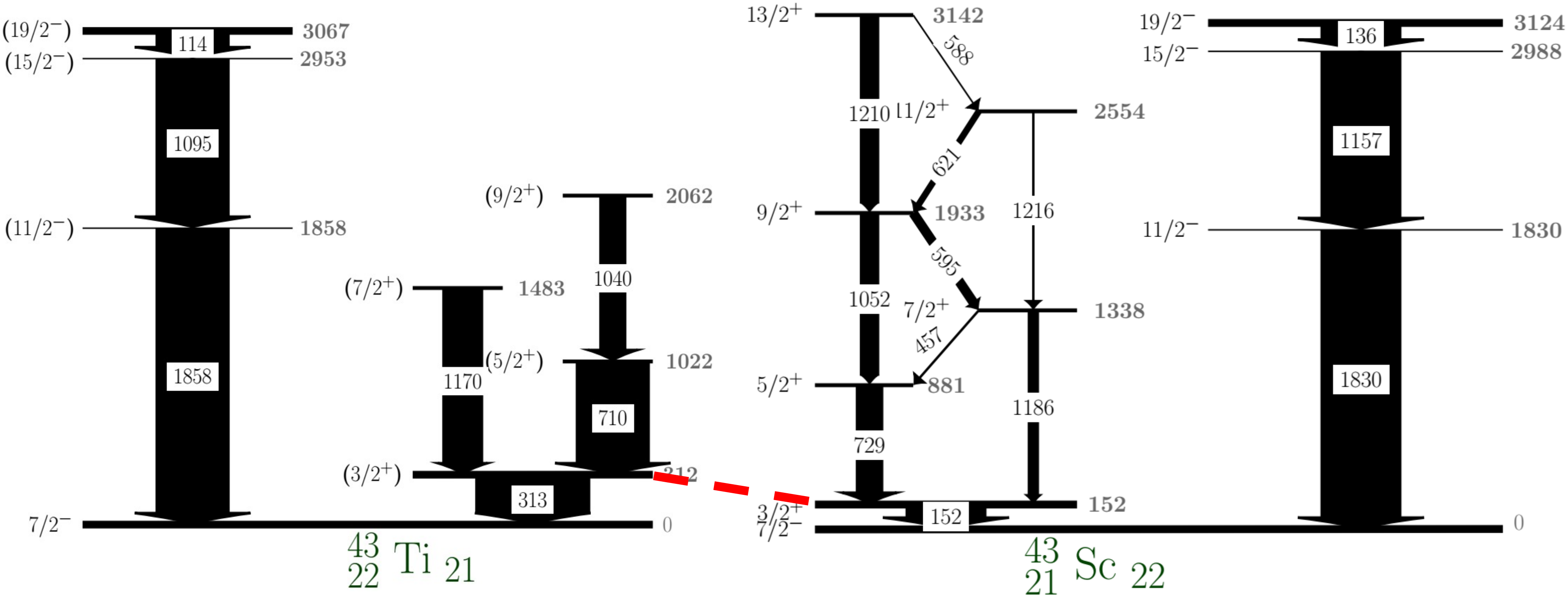
^{43}Sc : positive-parity states



- Rotational band built on the 3/2+ IS : **particle-hole cross-shell excitation from the *d*$_{3/2}$ orbit to the *fp* shell**
- With increasing spin, the alignment drives the nucleus towards a band termination at ***I* = 27/2+**

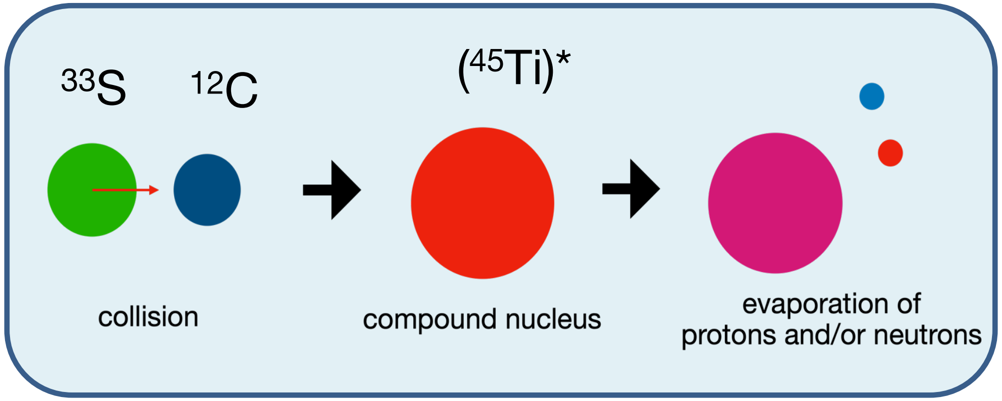


A=43 mirror pair



- Scheme of yrast states in ^{43}Ti known before this work
- The **3/2⁺** appears at **312 keV** instead of **152 keV**
  because N,Z = 20 gap size is different for π and ν
- **EMSO has a strong effect on MED** → study evolution of wavefunction as a function of the angular momentum

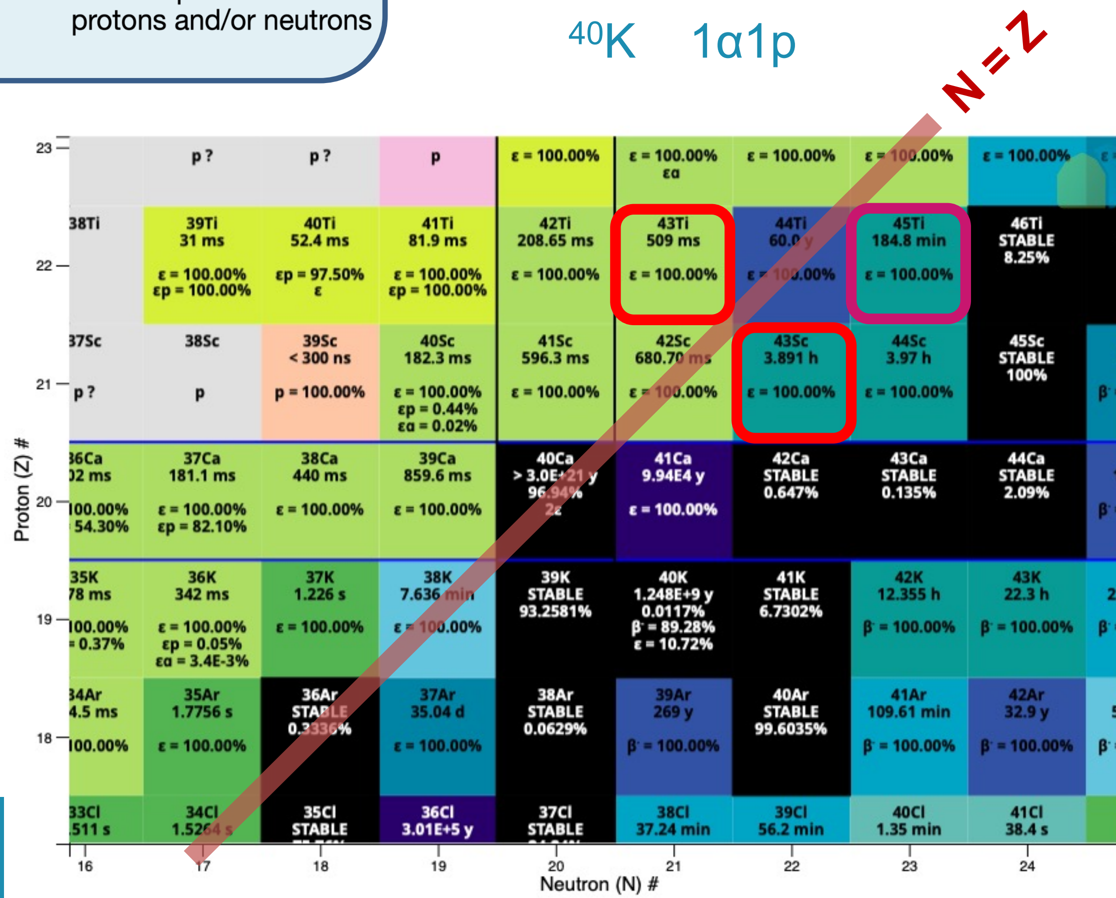
Experiment: spectroscopy of ^{43}Ti



^{43}Ti – 2n evaporation

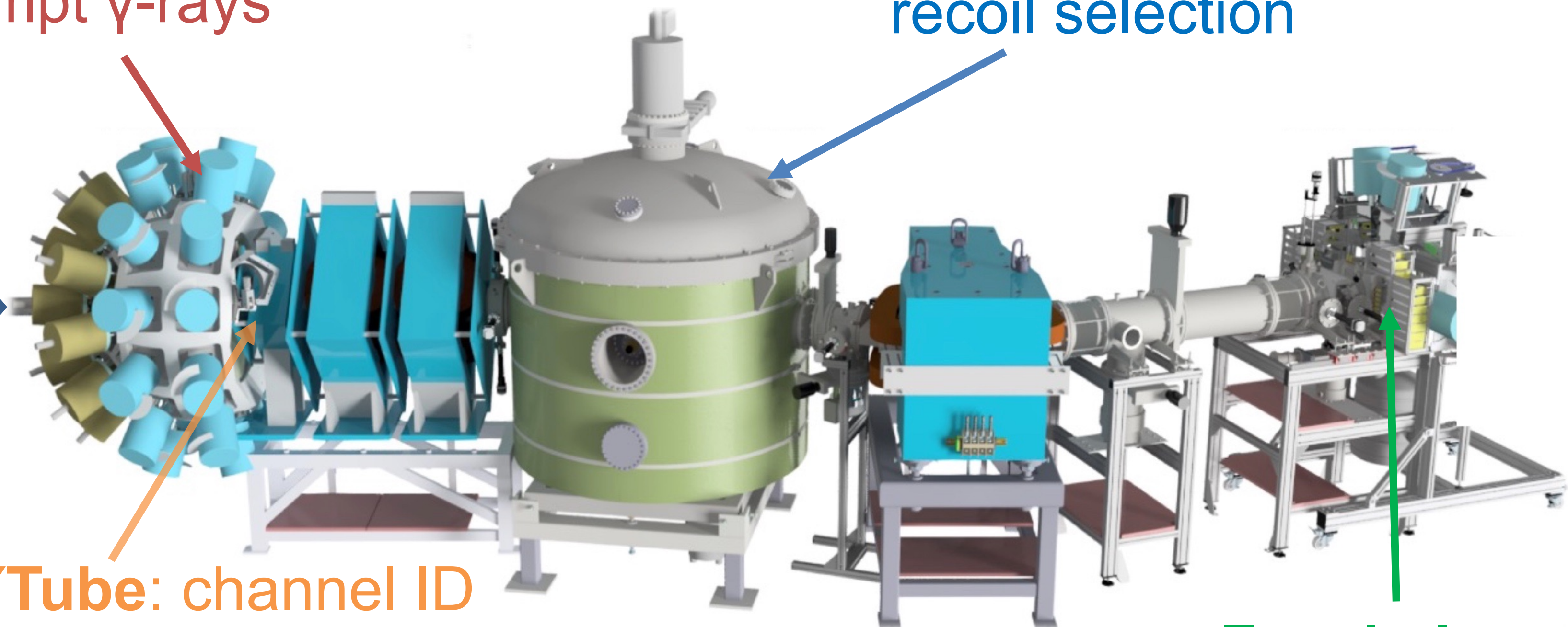
Stronger channels:

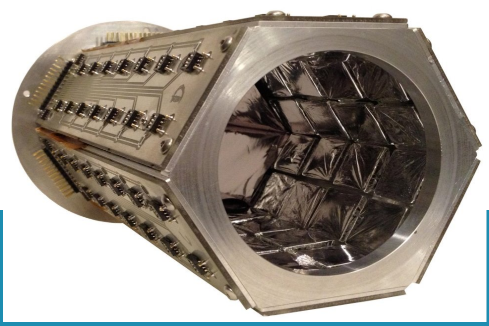
^{43}Sc 1p1n
^{43}Ca 2p
^{40}Ca 1α1n
^{40}K 1α1p



JYFL experiment JM11

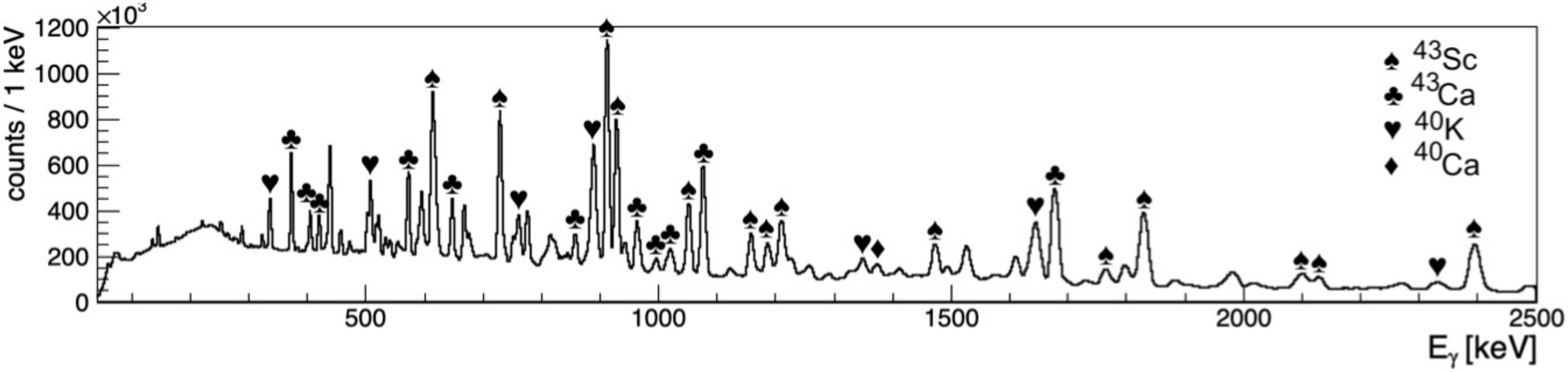
Reaction: **$^{33}S + ^{12}C \rightarrow ^{43}Ti + 2n$** @ 100 MeV beam energy





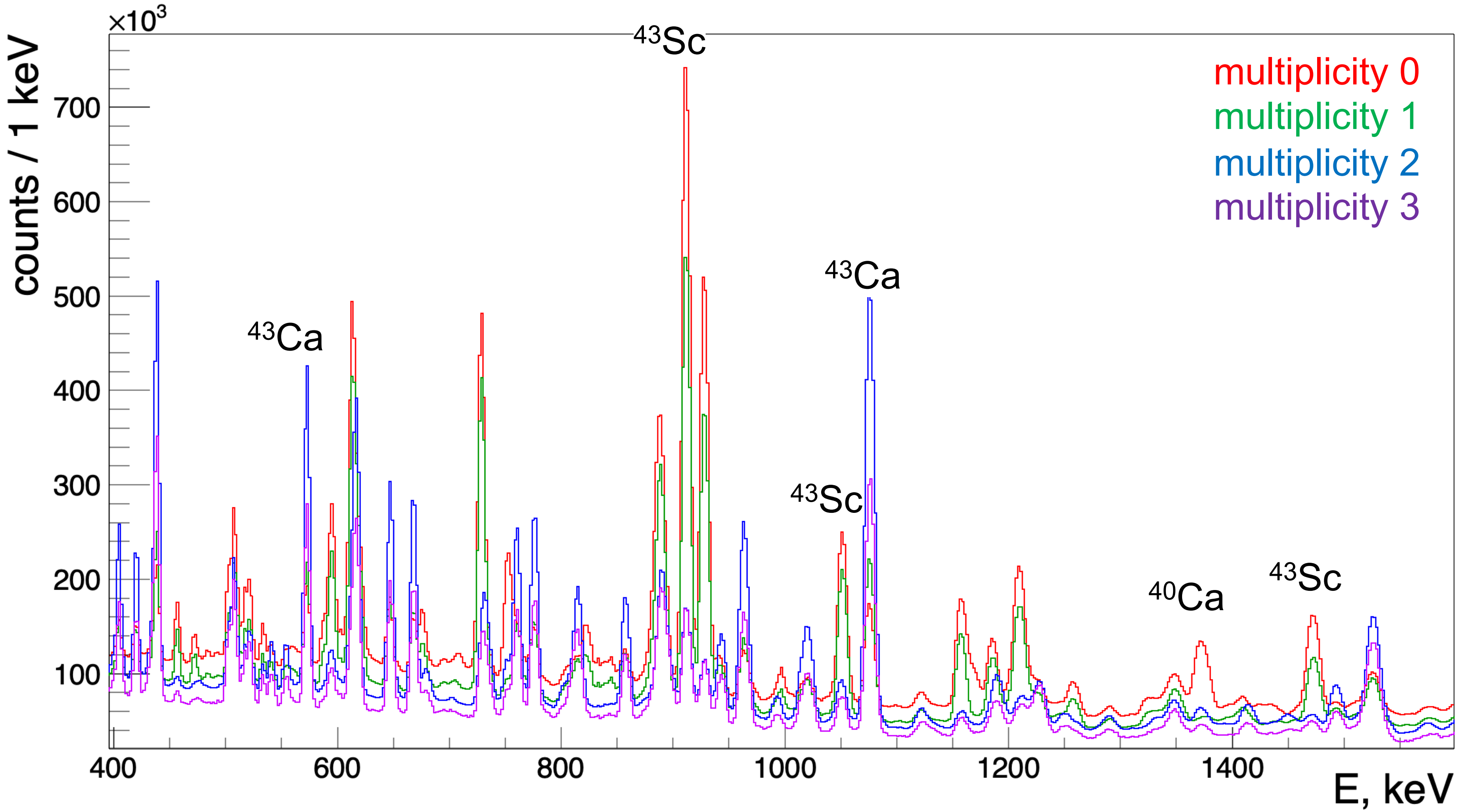
Prompt JUROGAM 3 spectrum

After selection with MARA, still many A/Q “twins” get transported to the focal plane



Additional constraints are needed!

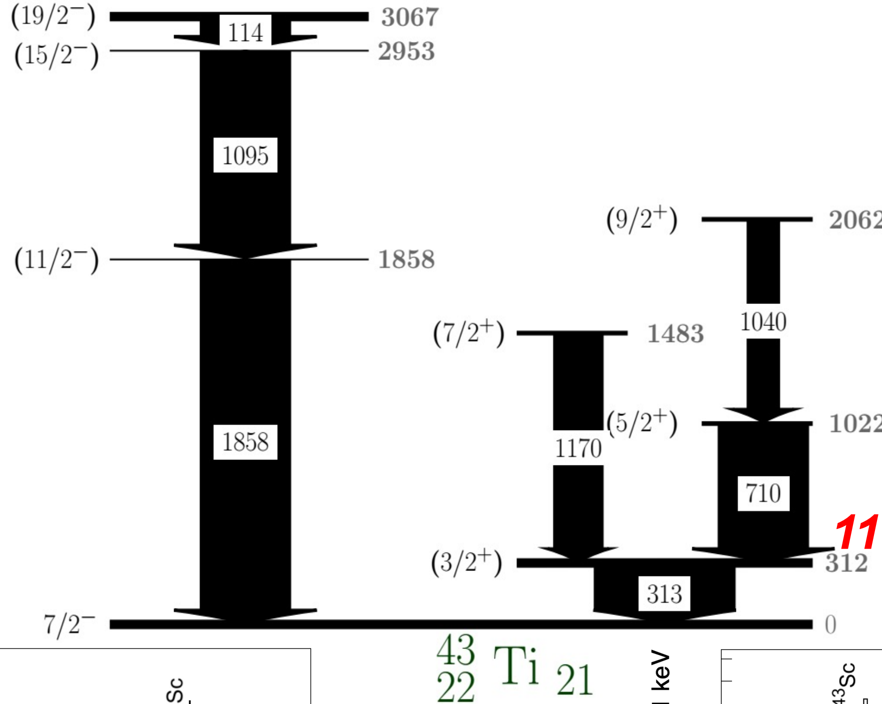
JYTube: charged particle tagging



Tagging on isomers in ^{43}Ti

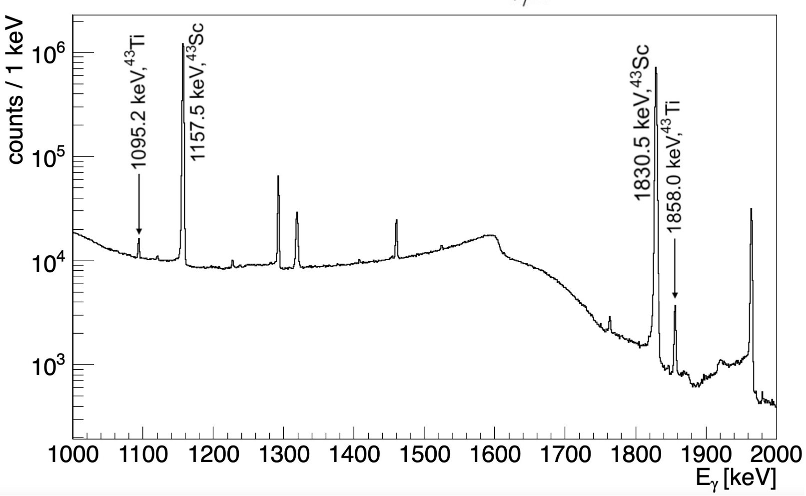
551 ns

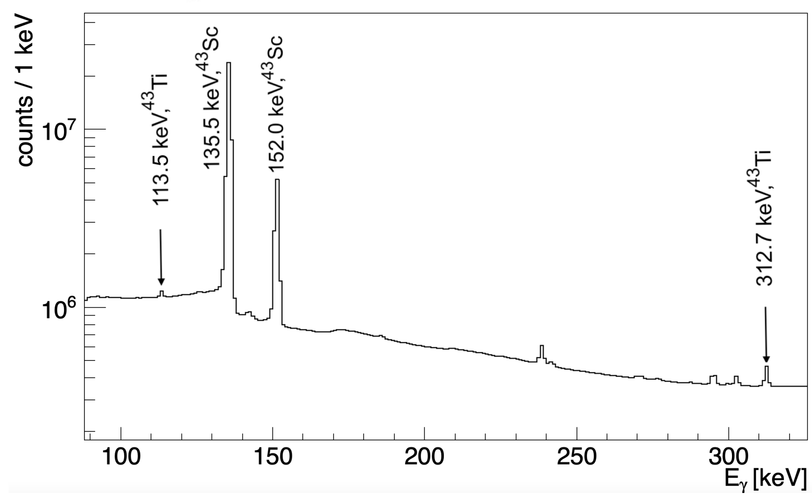
gate the on fast IS
→ negative-parity states



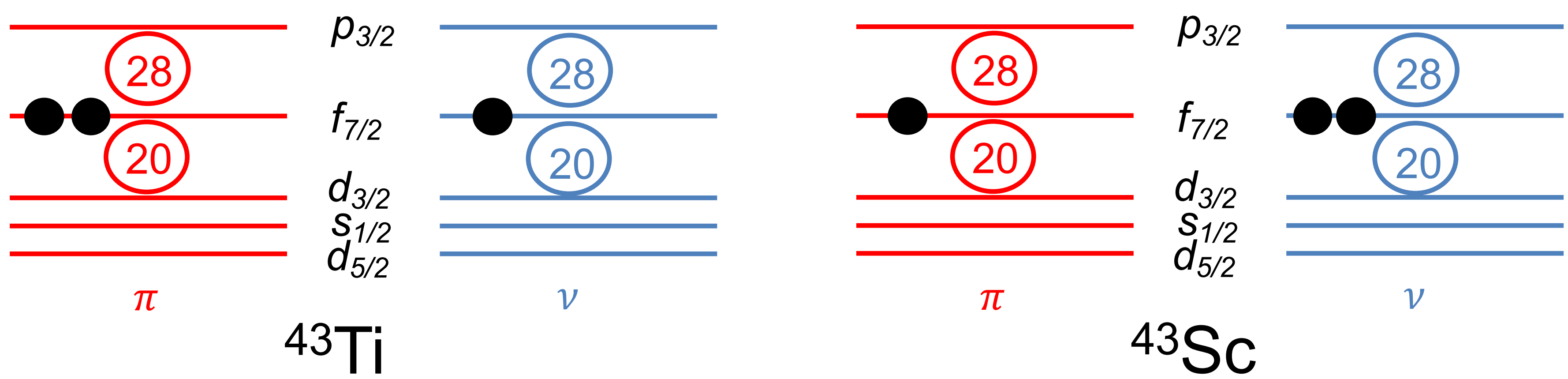
11.7 us

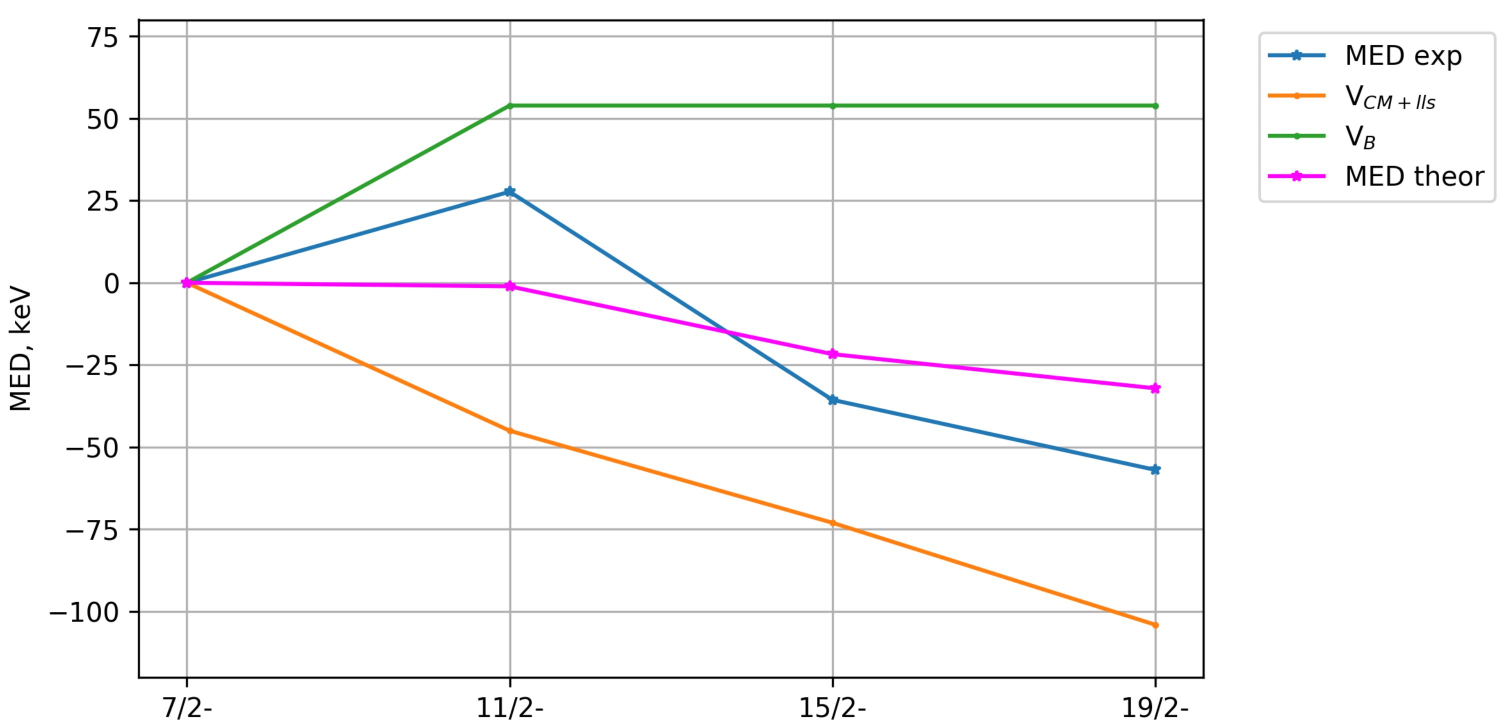
gate on the slow IS
→ positive-parity states



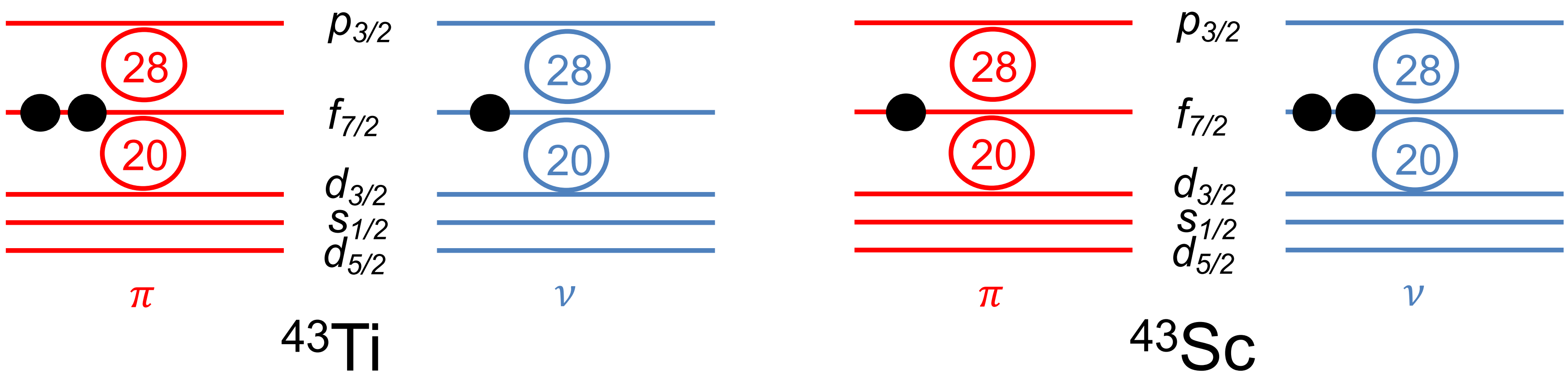


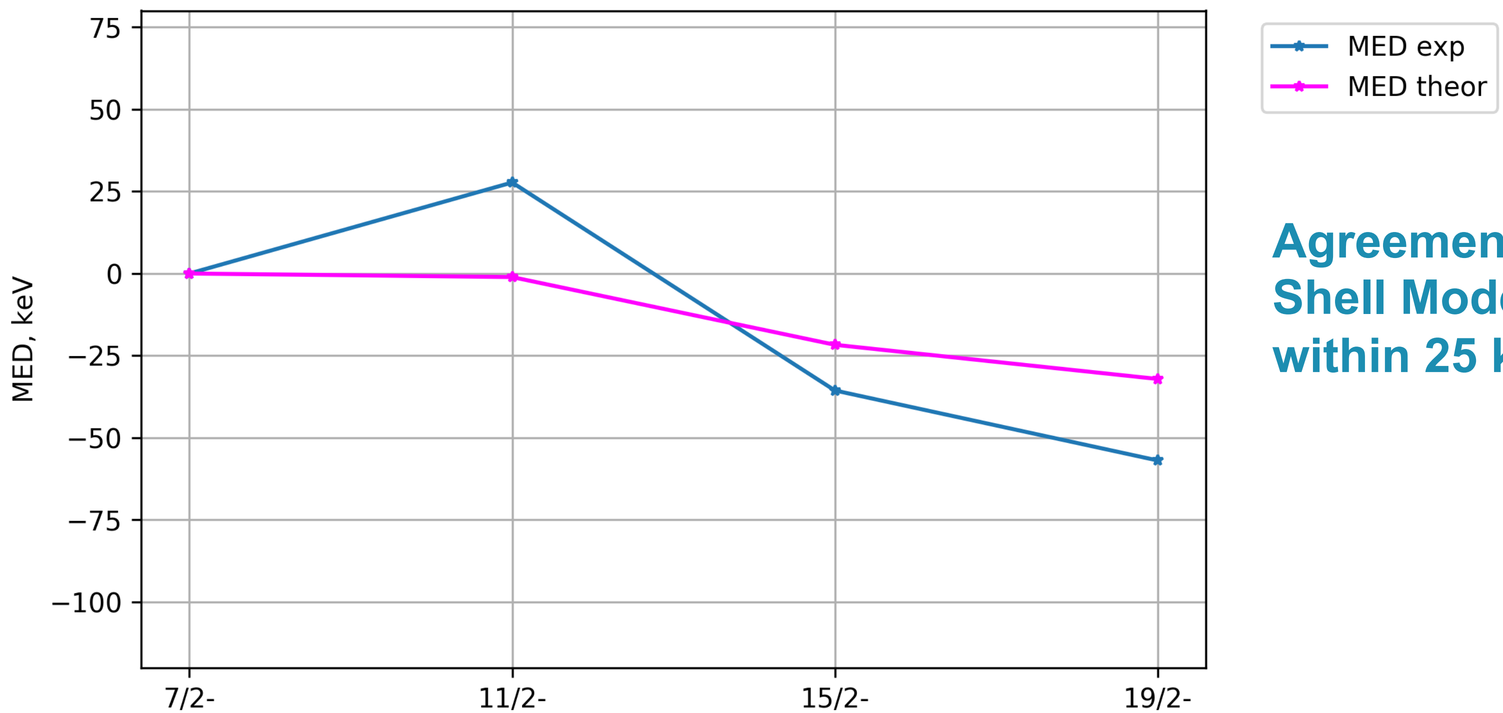
MED: Negative-partiy states





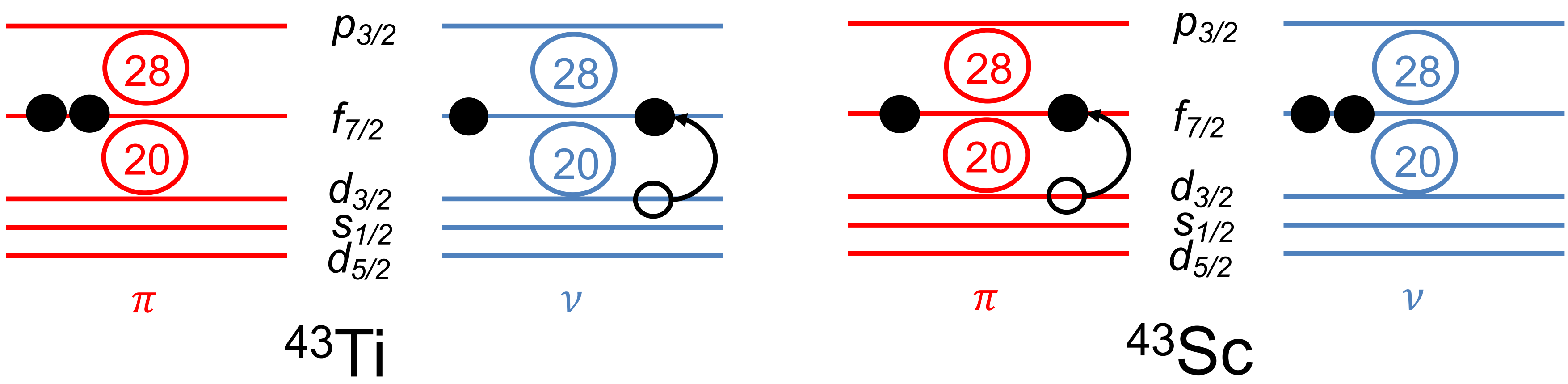
MED: Negative-partiy states

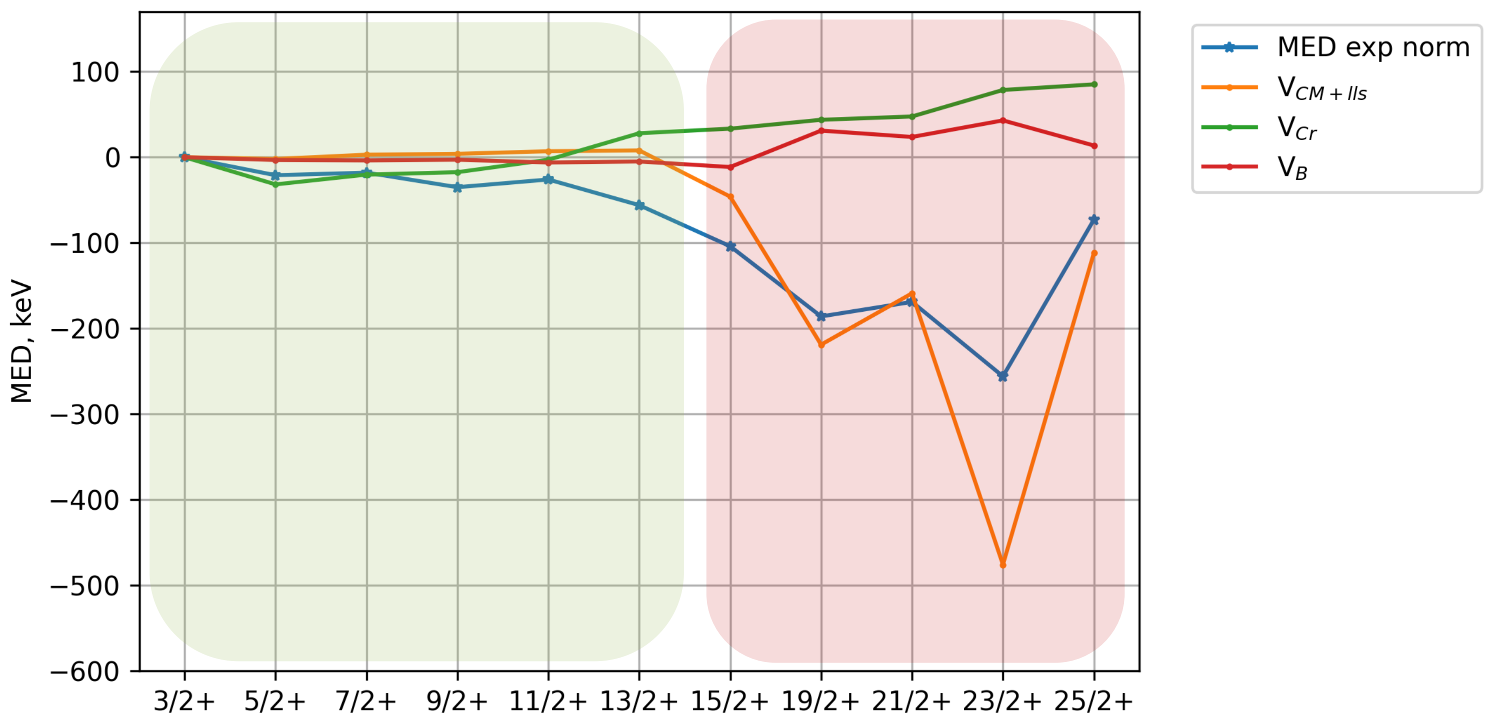




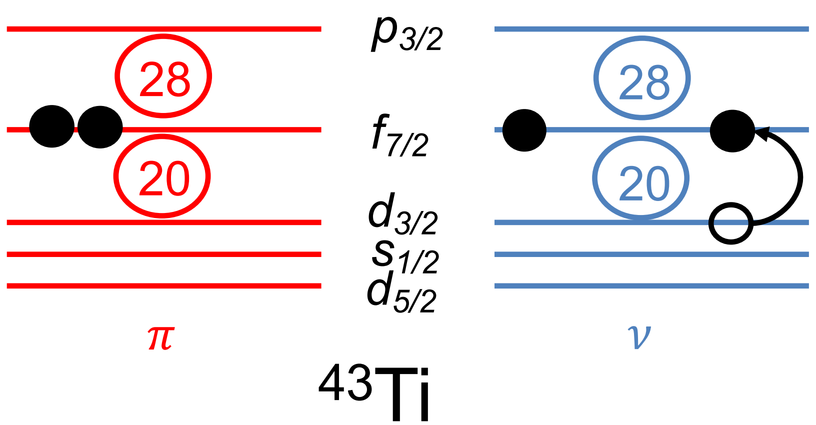
Agreement with Shell Model within 25 keV

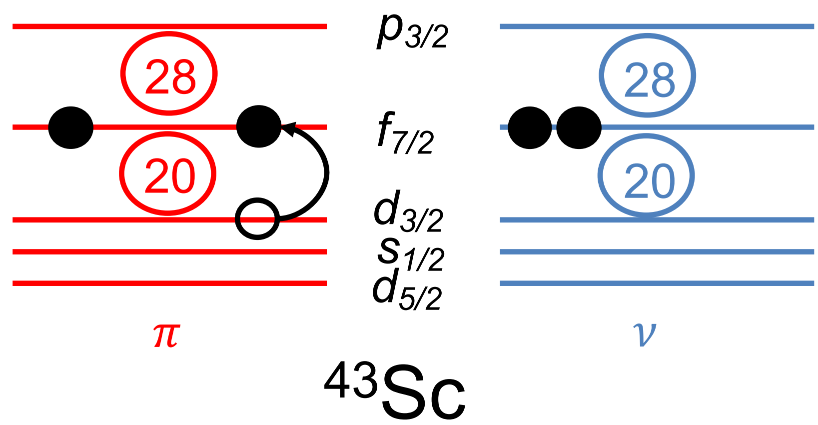
MED: Positive-partiy states

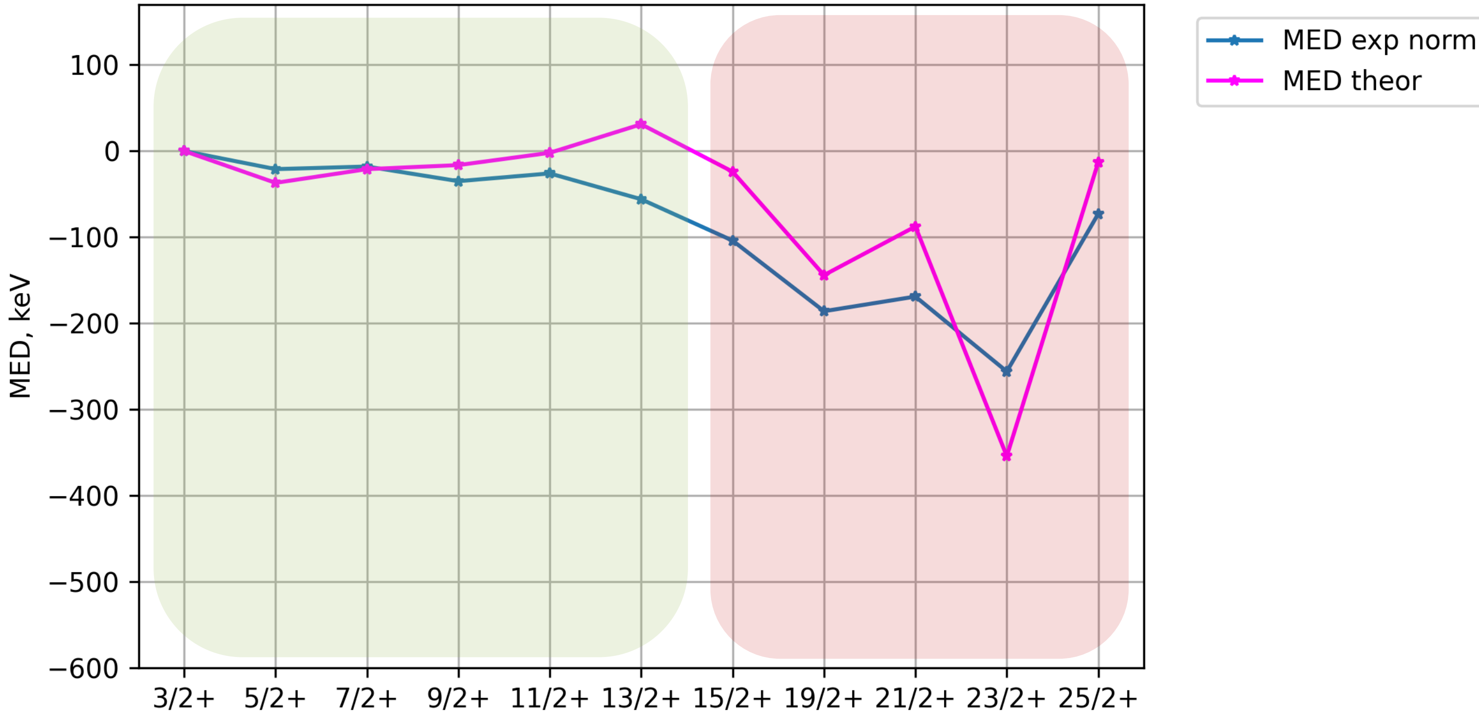




MED: Positive-partiy states

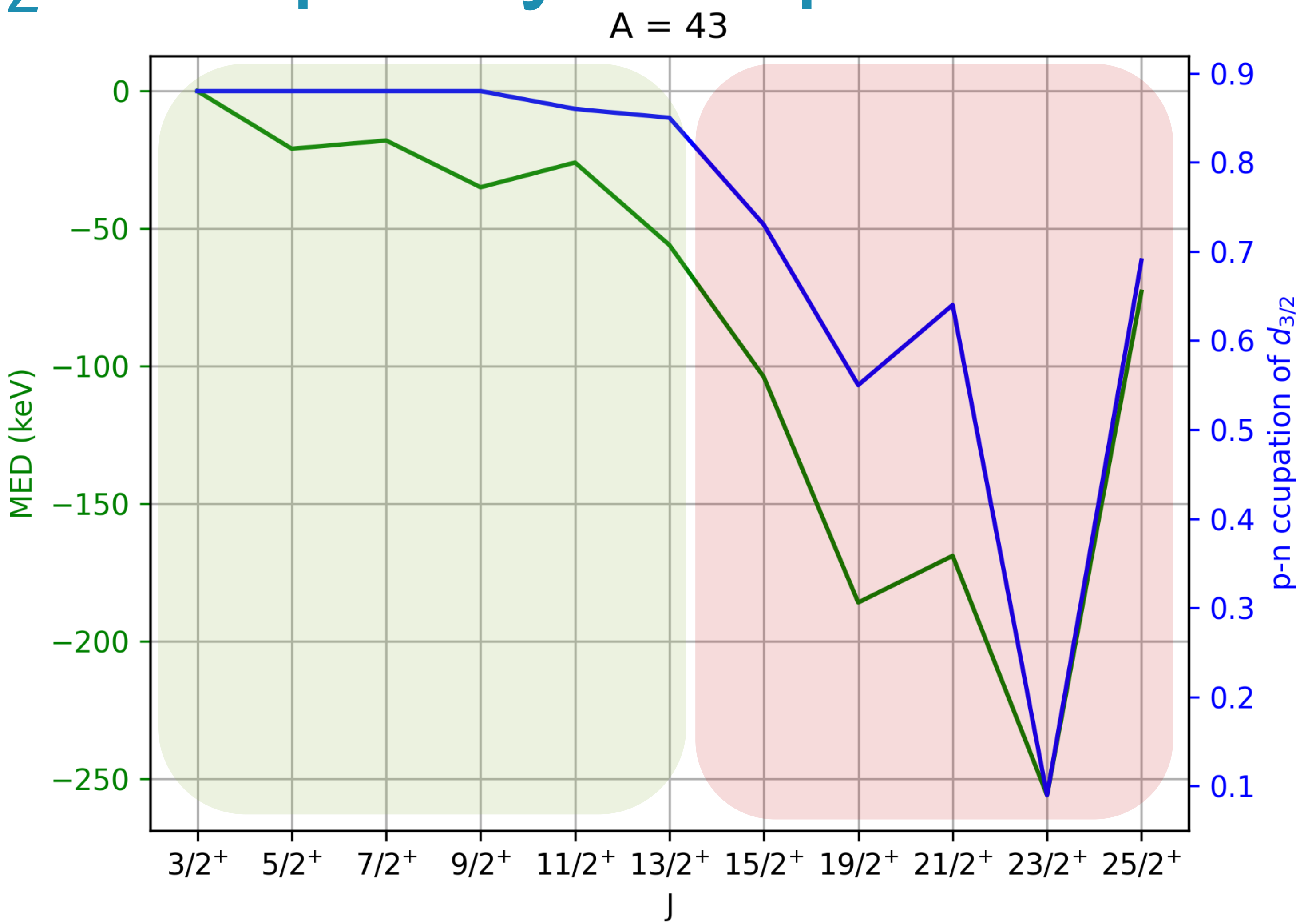






$d_{3/2}$ occupancy compared to MED

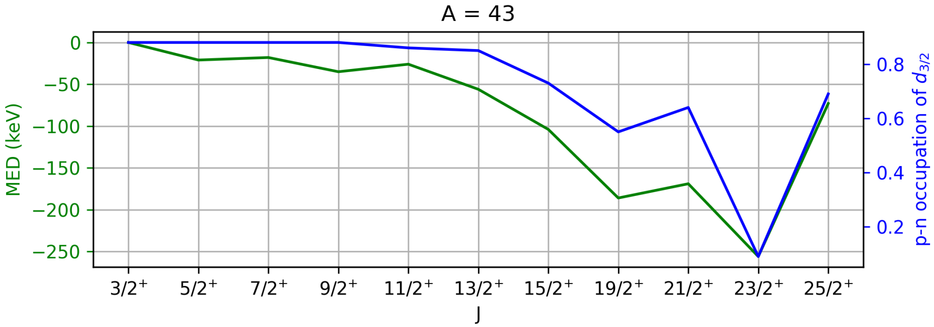
^{43}Ti

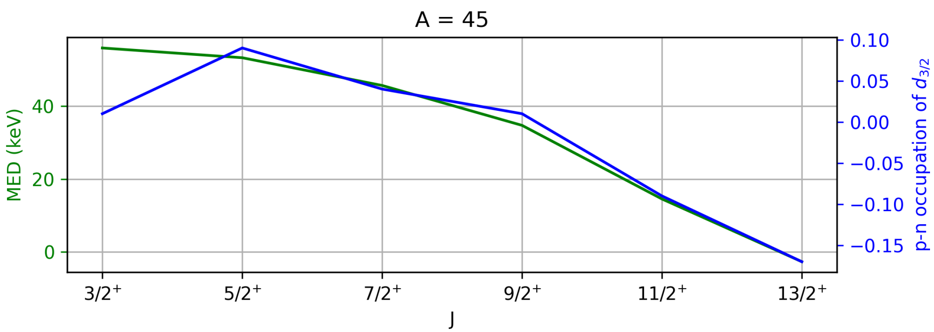


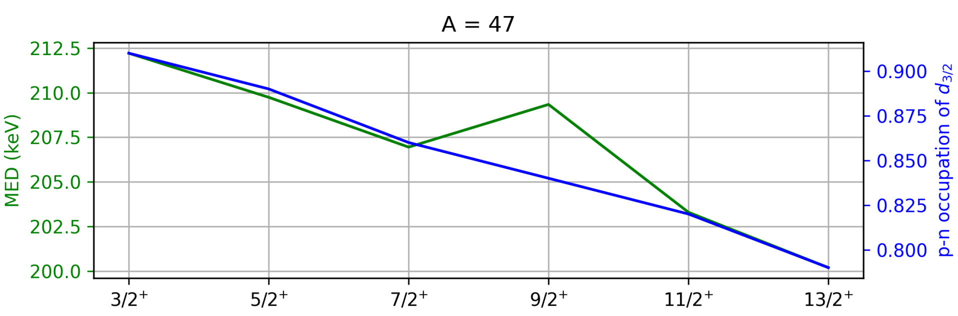
promoting a neutron

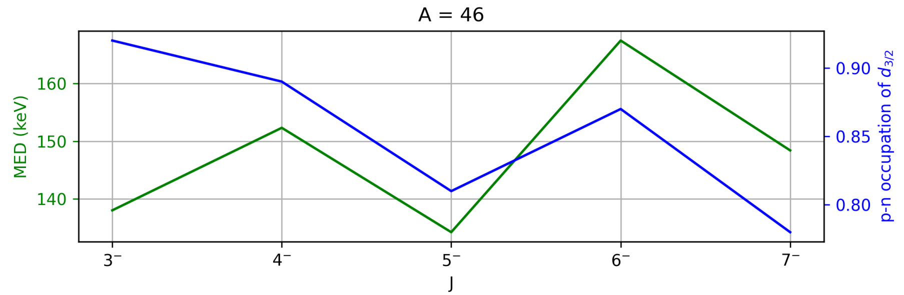
sometimes promoting a proton

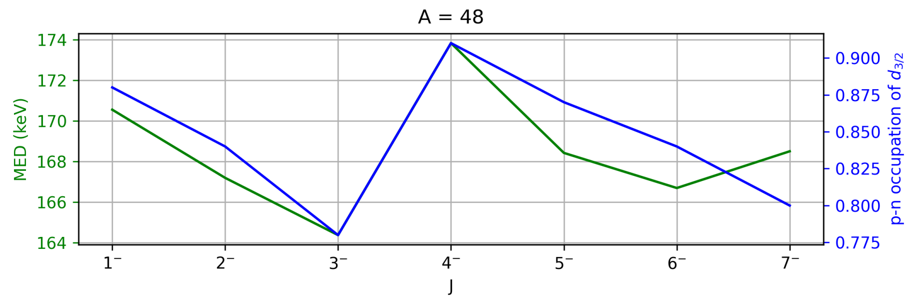
$d_{3/2}$ occupancy compared to MED











Conclusions

- Extended the level scheme of ^{43}Ti up to $25/2^+$
- For the negative-parity states, good agreement of MED between experiment and Shell Model
- The MED in A=43 increase after $15/2^+$ *because the excited nucleon is not always the same*
- This is put in evidence in the EMSO term (difference in the gap π and ν)
- As the calculations are in good agreement with the experiment, we can say that *the experimental MED allow us to probe the wavefunction*

JM11 collaboration

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