InTraNS 2024 Workshop

Mirror energy differences between ^{43}Ti and ^{43}Sc: a direct insight into the wave-functions

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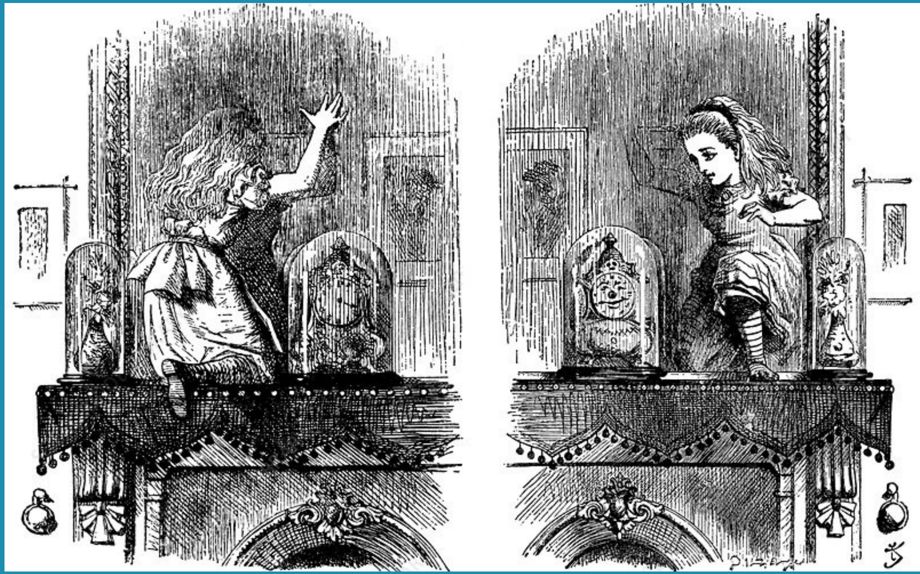

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Orsay, France

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Introduction : proton-neutron symmetry

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

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

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

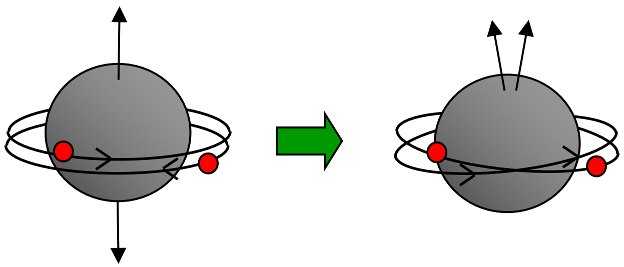
- States with the same **T** in N=Z **mirror nuclei** → Isobaric Analogue States (**IAS**)

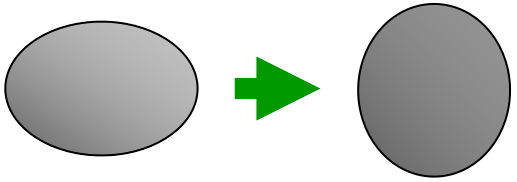
- ΔE_x between same-T states in isobaric doublets → **Mirror Energy Differences (MED)**

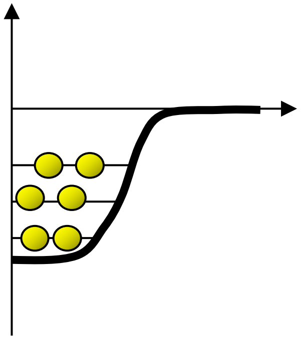
$$\mathrm{MED}_{J,T} = E^*_{J,T,T_z=-T} - E^*_{J,T,T_z=T}$$

- 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. $\ell \cdot \ell$ term to account for shell effects

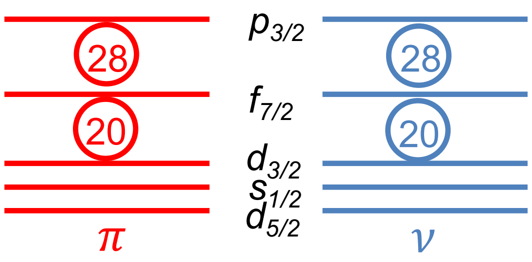
  3. $\ell \cdot s$ **electromagnetic spin-orbit term (EMSO)**
  changes in single-particle energies
  different on π and ν, and when ℓ and s are parallel or aligned
  → Important in cross-shell excitations

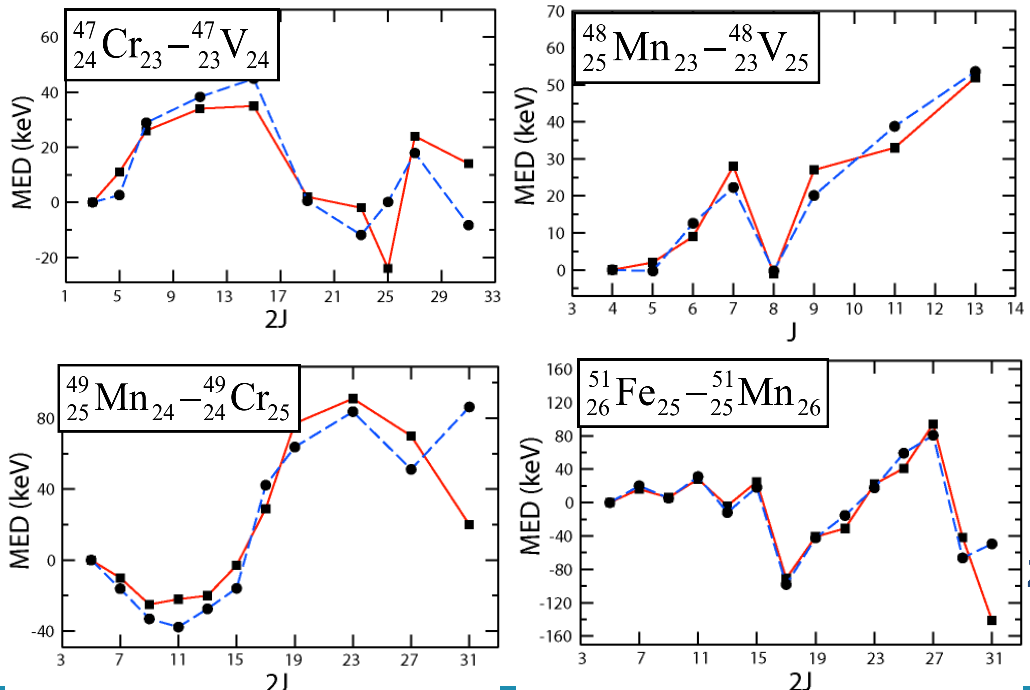
Isospin non-conserving term V_B : charge symmetry breaking

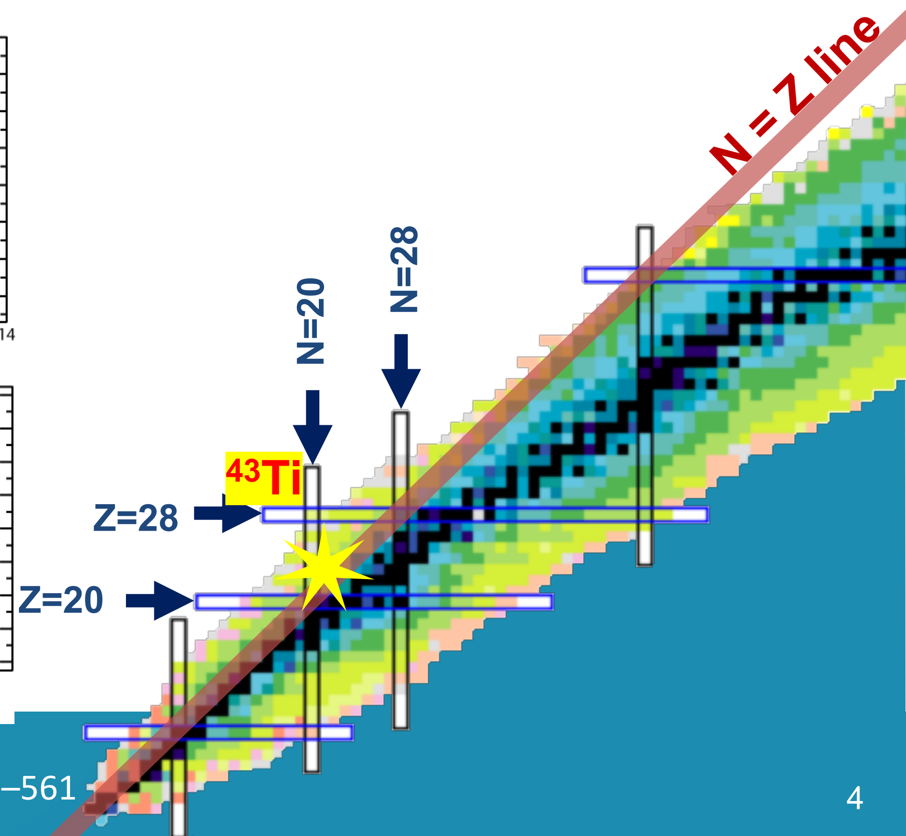
$$MED = V_{CM} + V_{Cm} + V_B$$

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



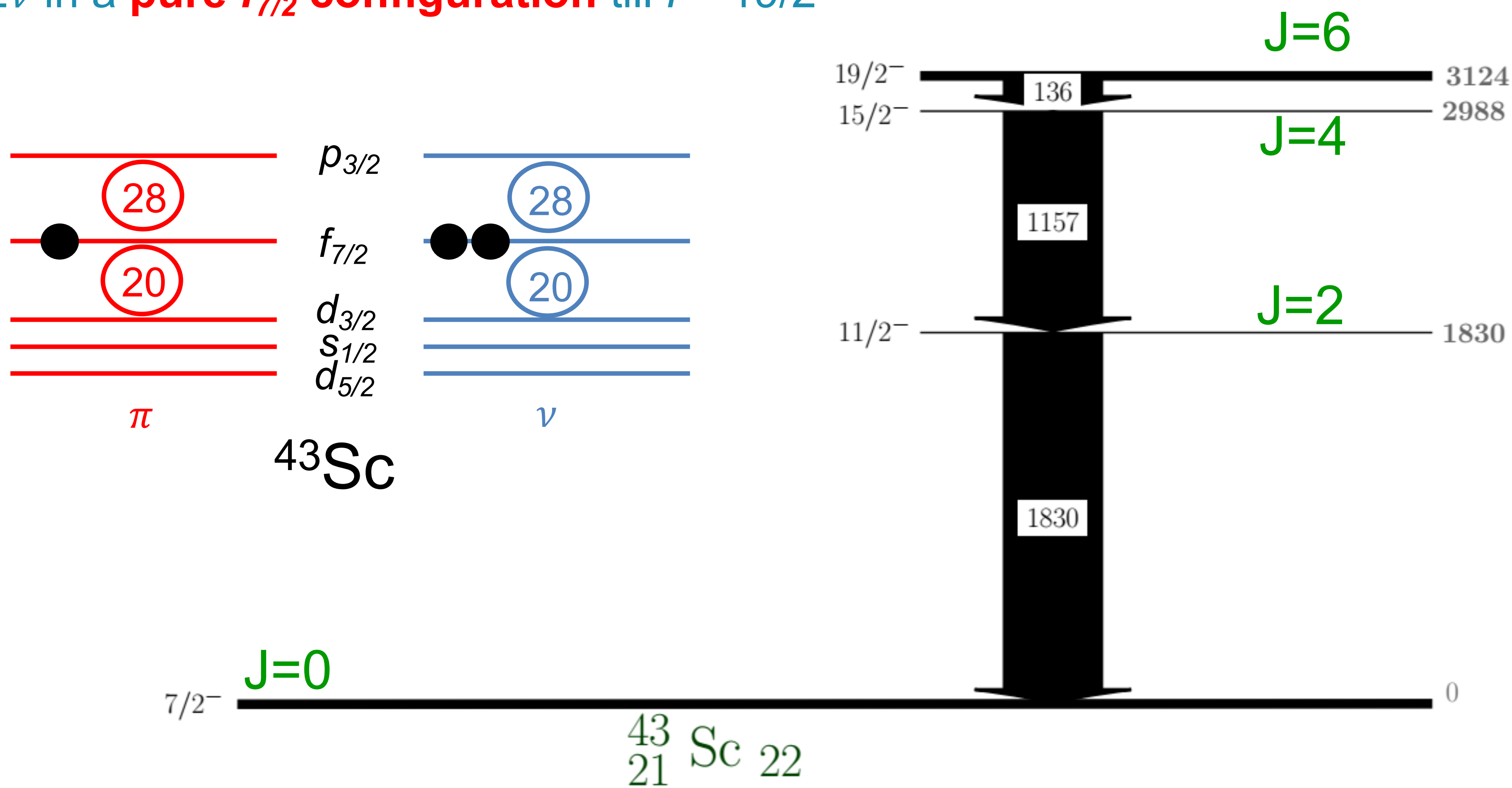




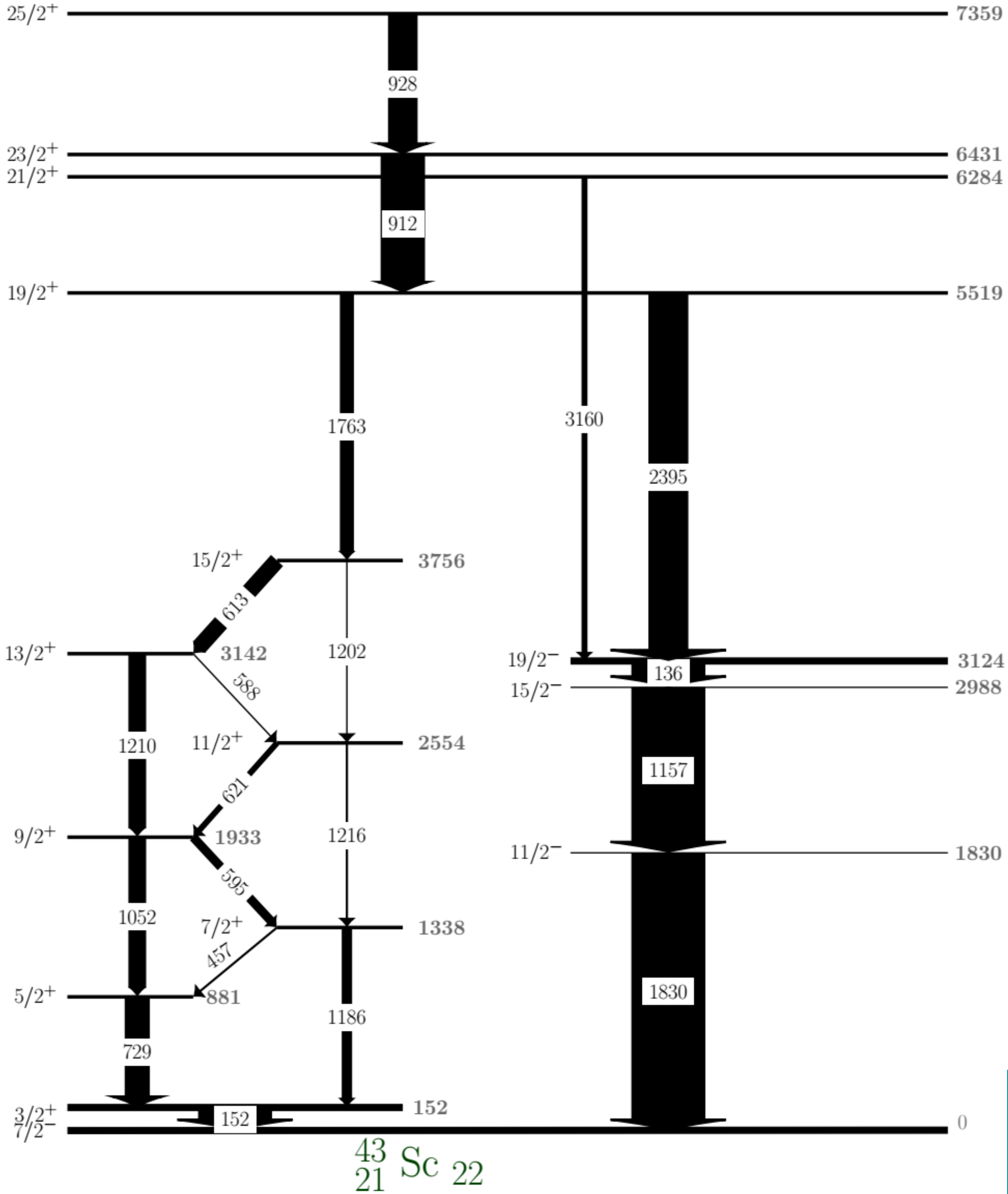
M.A. Bentley, S.M. Lenzi, Prog. Part. and Nuc. Phys. 59 (2007) 497–561

^{43}Sc : negative-parity states

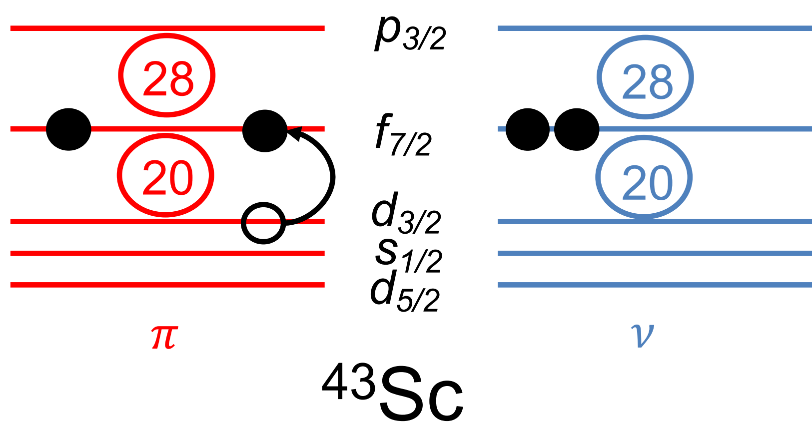
yrast structure, based on the 7/2$^-$ g.s., is non-collective
terminates at the maximum spin that can be generated with one π and 2ν in a **pure $f_{7/2}$ configuration** till *I* = 19/2$^-$



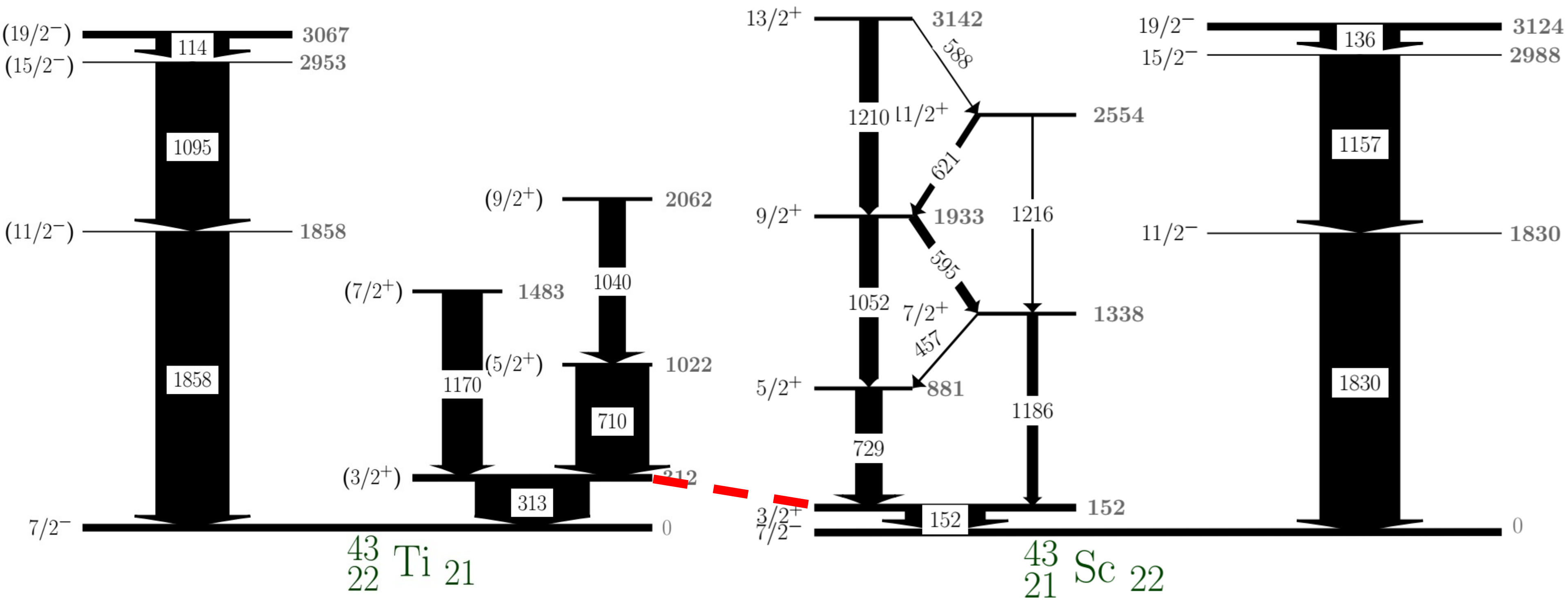
^{43}Sc : positive-parity states



- 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+**

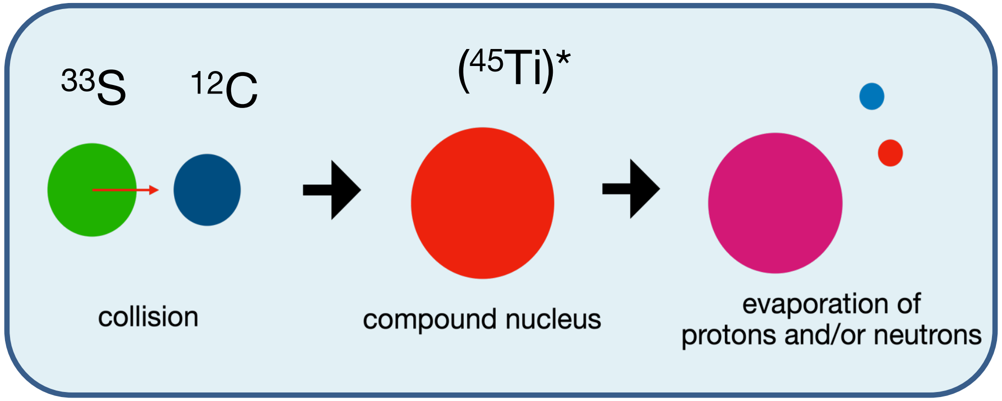


A=43 mirror pair



- 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

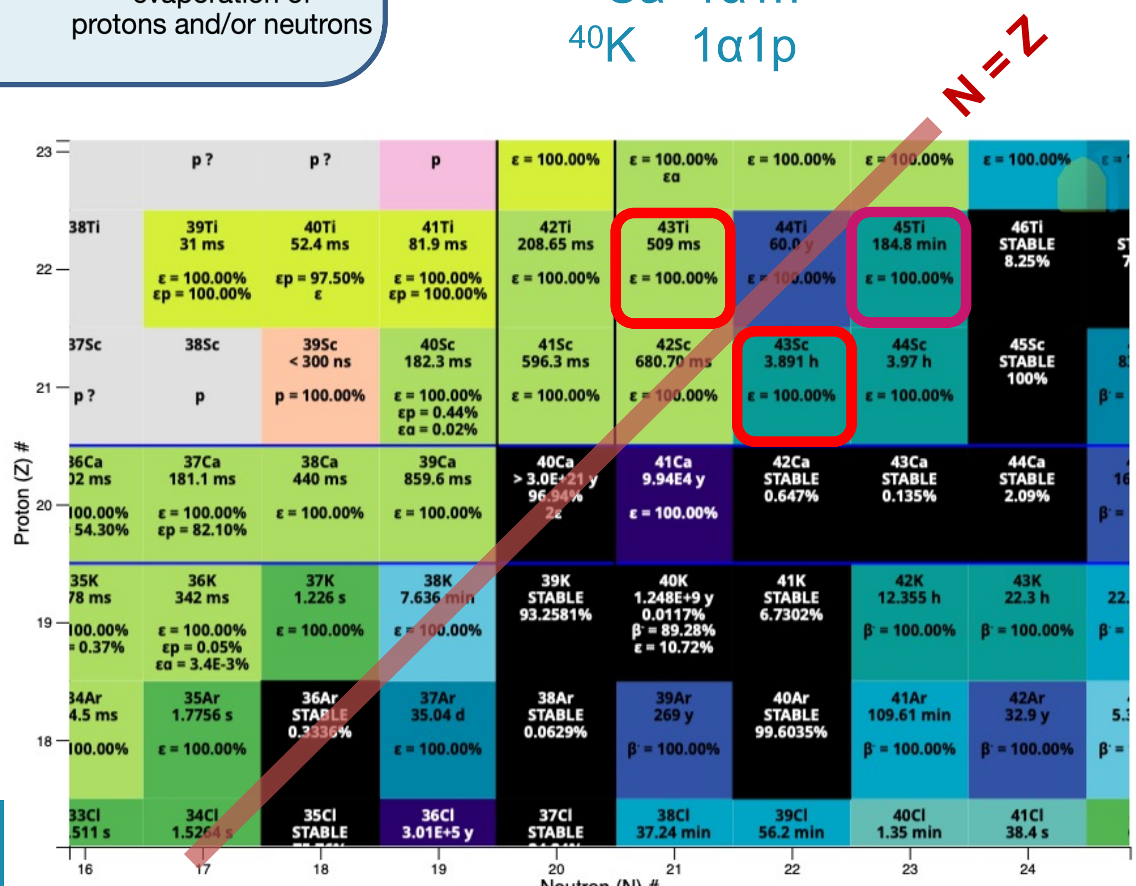
Experiment: spectroscopy of ^{43}Ti



^{43}Ti – 2n evaporation

Stronger channels:

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



JYFL experiment JM11

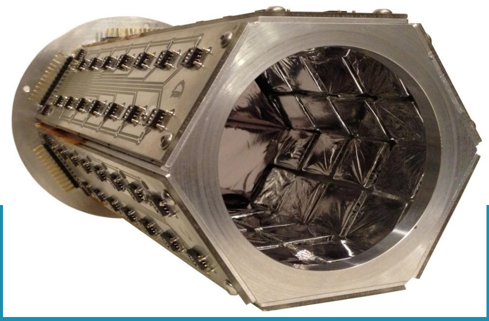
Reaction: $^{33}\mathbf{S} + {}^{12}\mathbf{C} \rightarrow {}^{43}\mathbf{Ti} + 2\mathbf{n}$ @ 100 MeV beam energy

JUROGAM 3
prompt γ-rays

MARA
recoil selection

beam

JYTube: channel ID

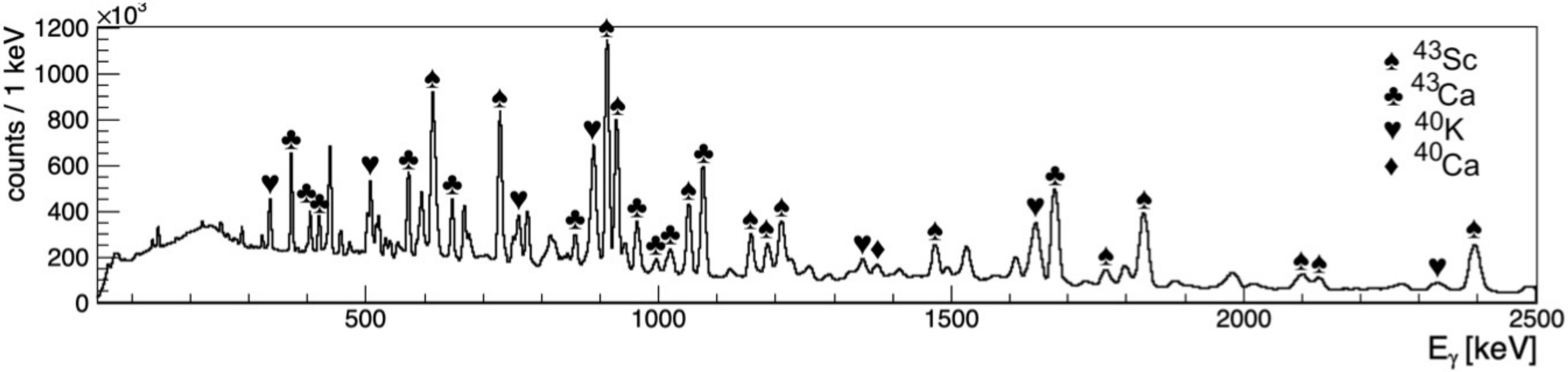


Focal plane:
DSSD, FPGe
isomer tagging

(talk by J. Pakarinen)

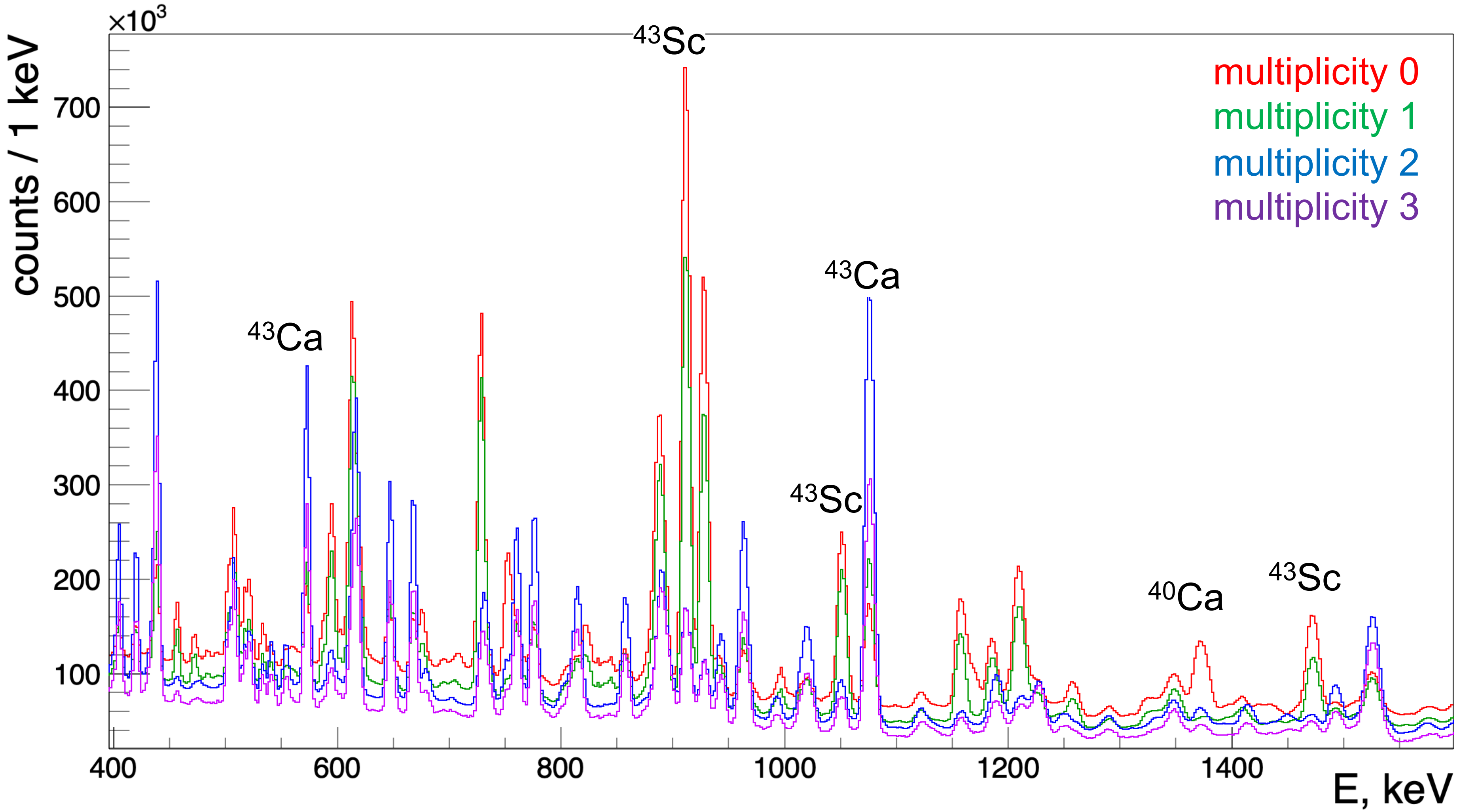
Prompt JUROGAM 3 spectrum

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



Additional constraints are needed!

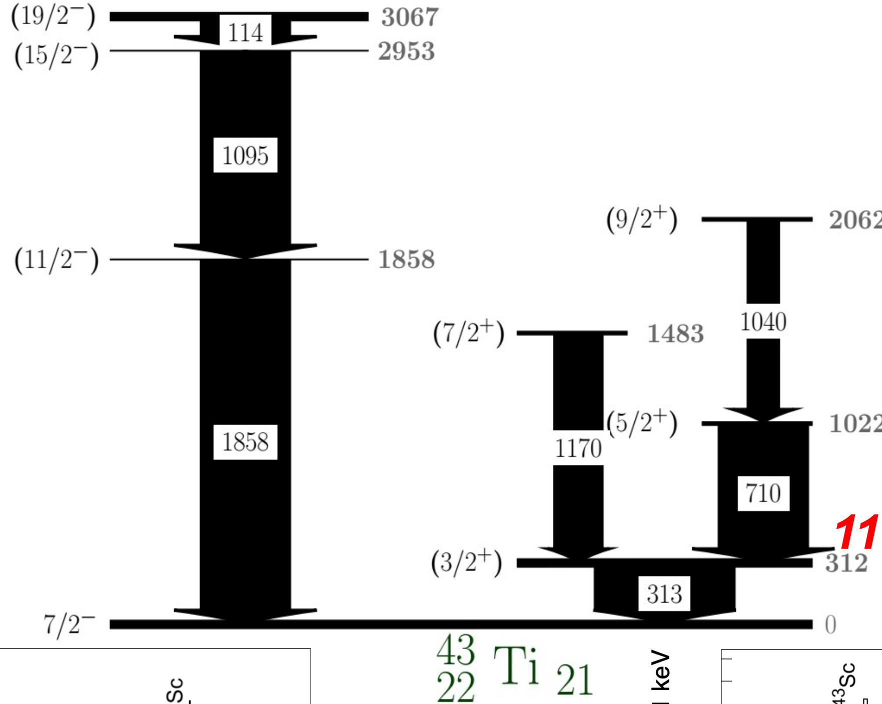
JYTube: charged particle tagging



Tagging on isomers in ^{43}Ti

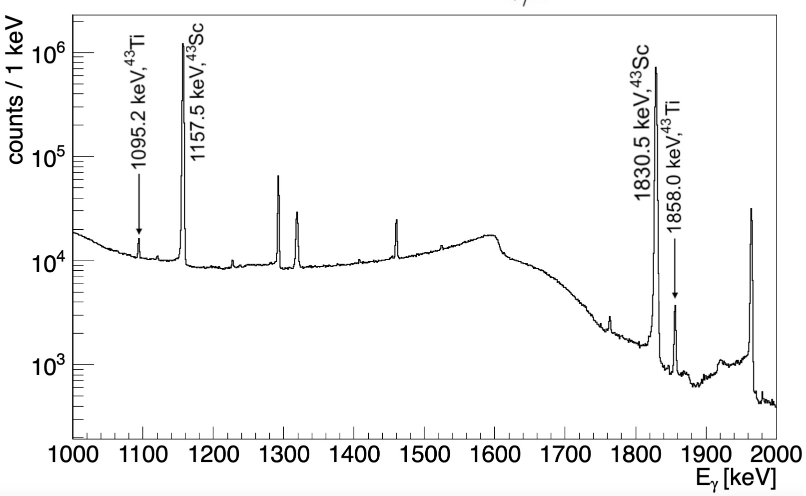
gate the on fast IS
→ negative-parity states

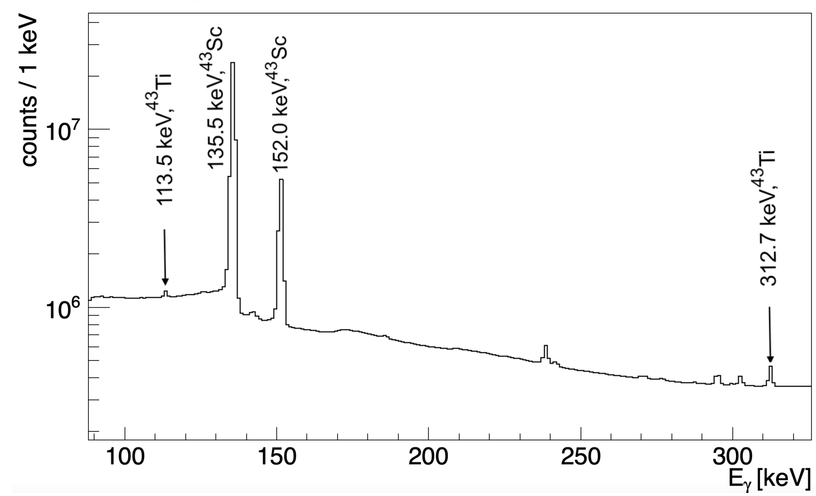
551 ns



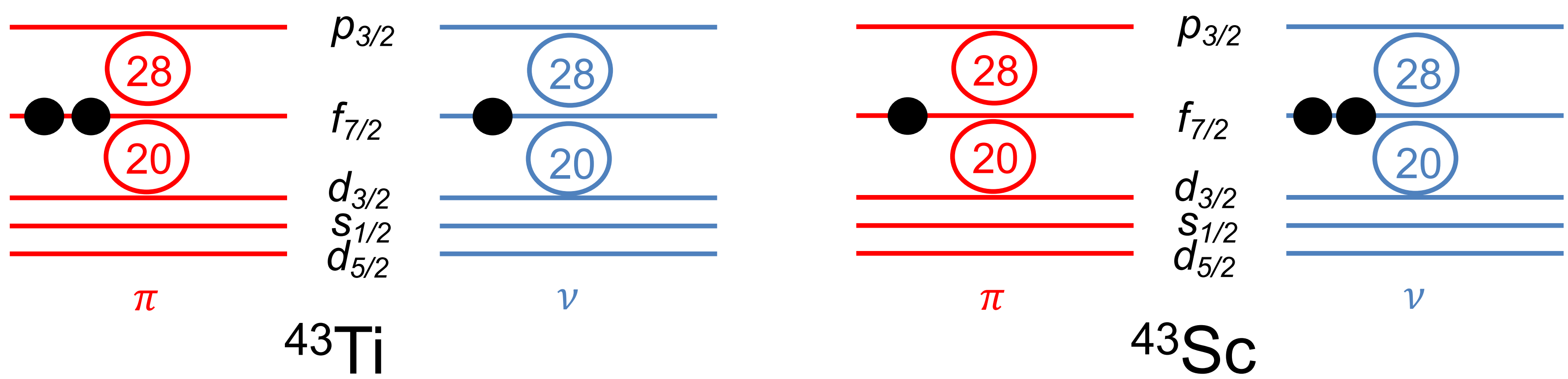
11.7 us

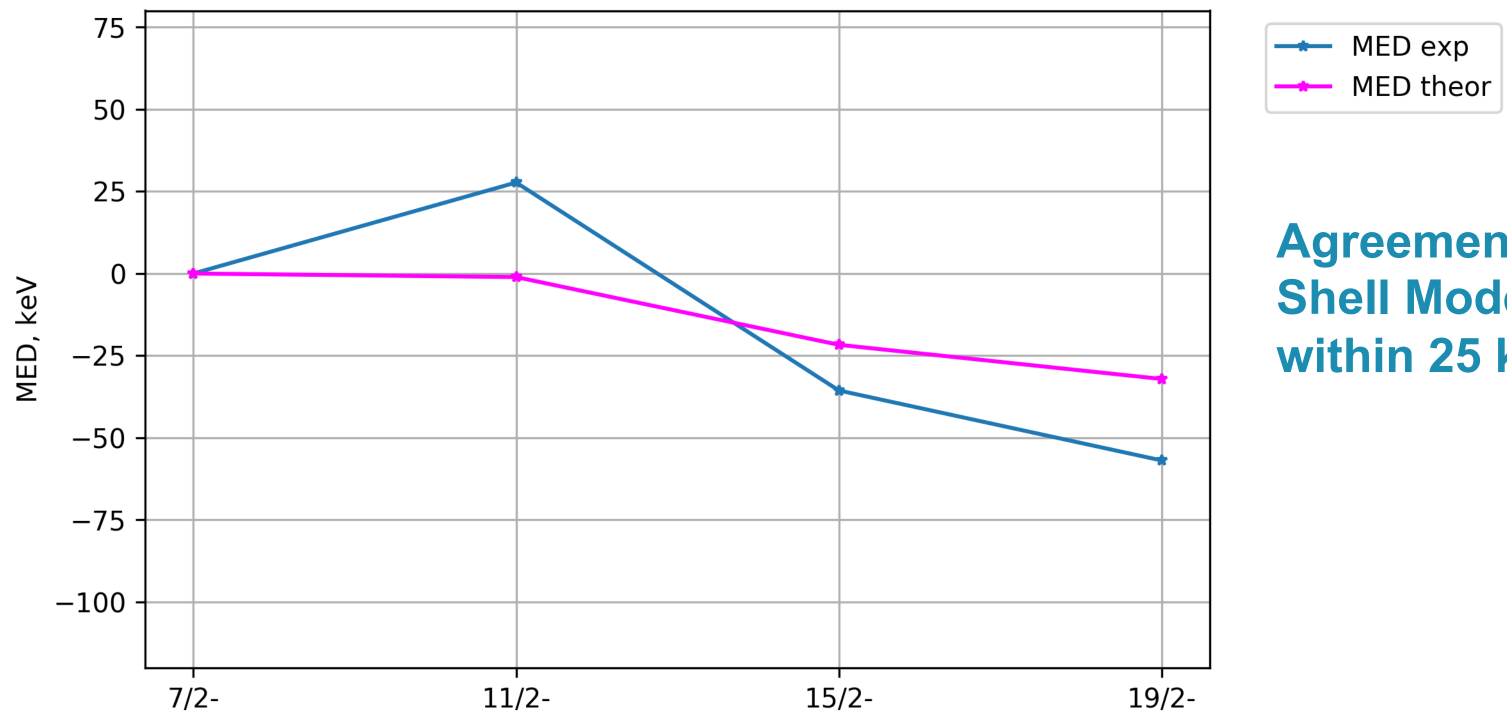
gate on the slow IS
→ positive-parity states





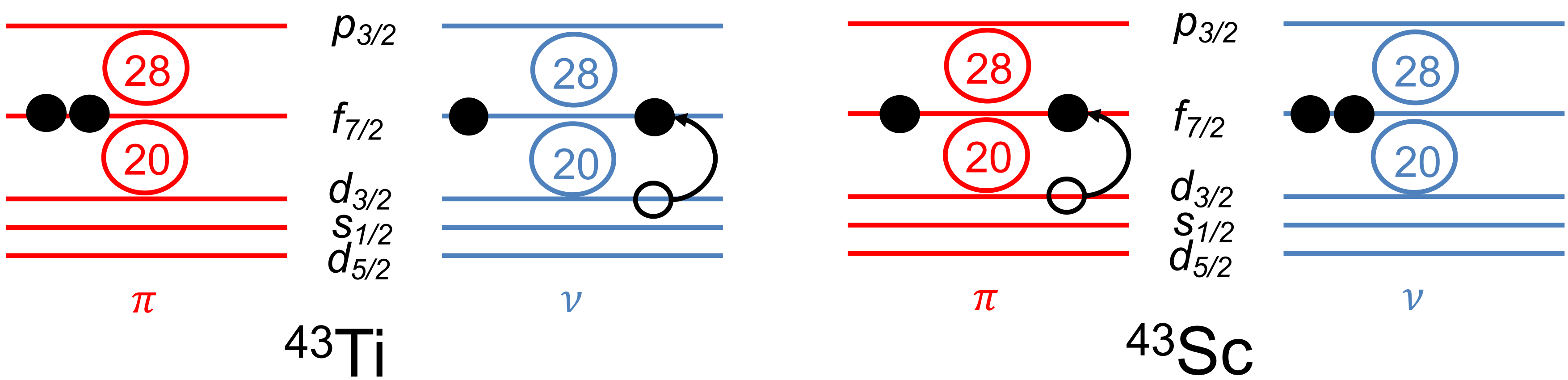
MED: Negative-partiy states

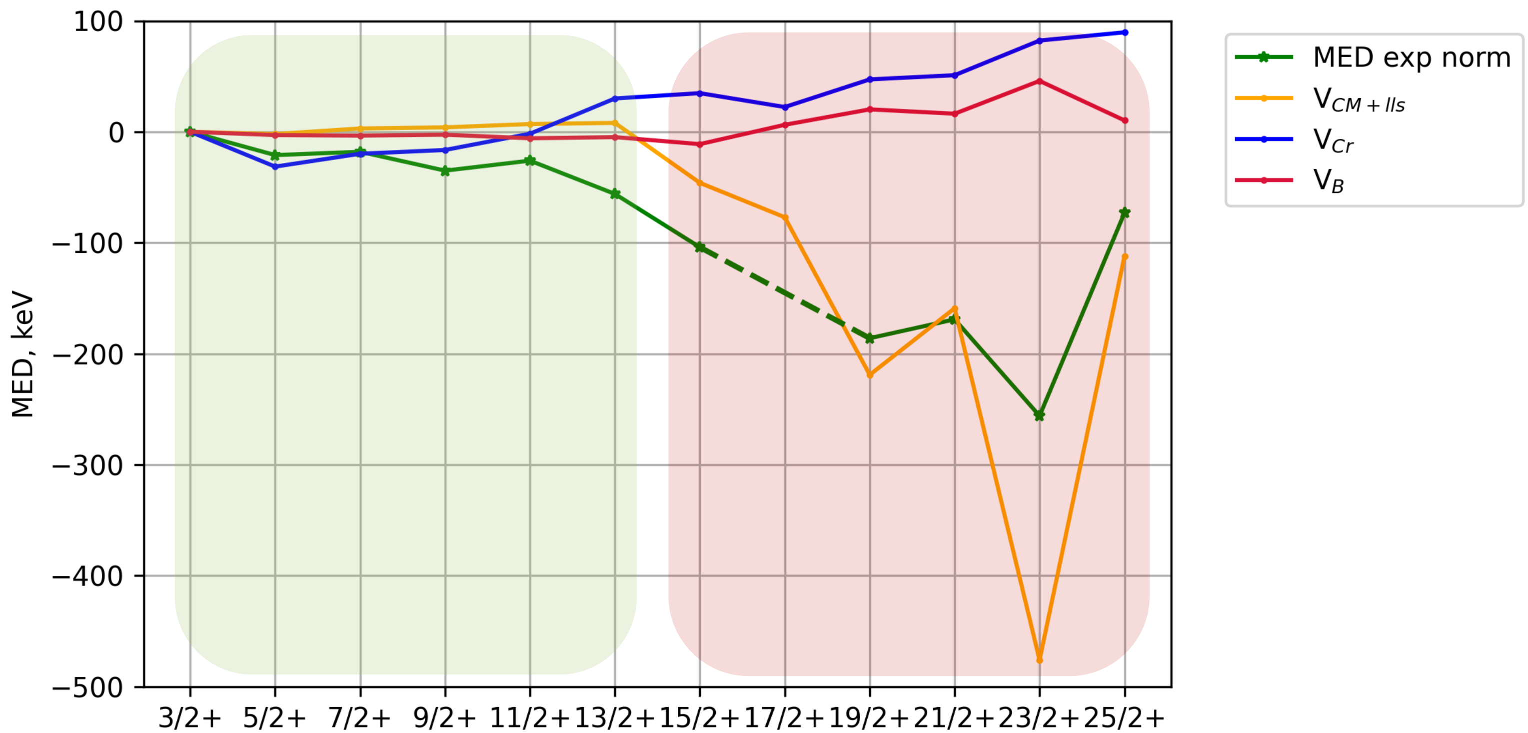




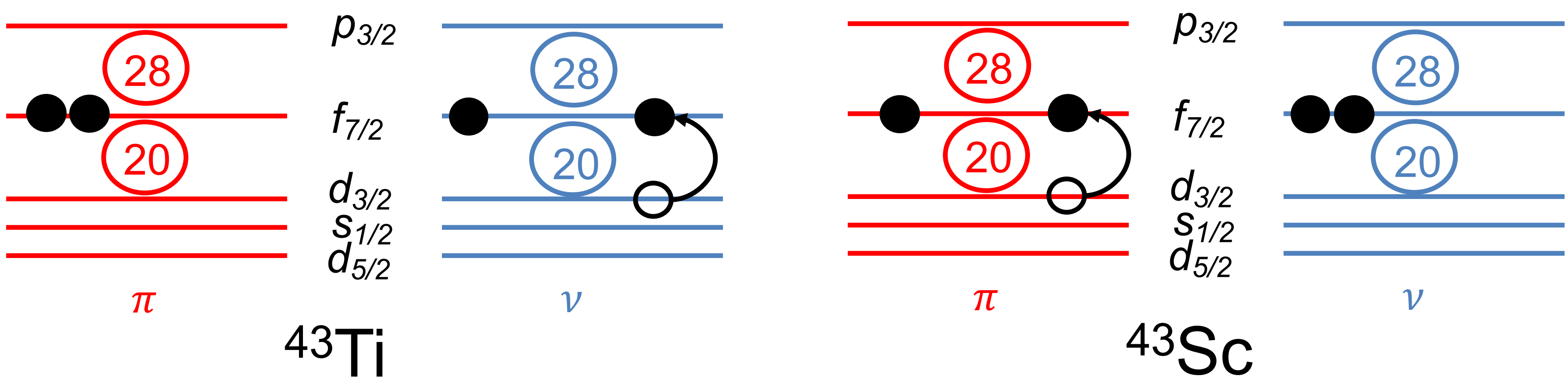
Agreement with Shell Model within 25 keV

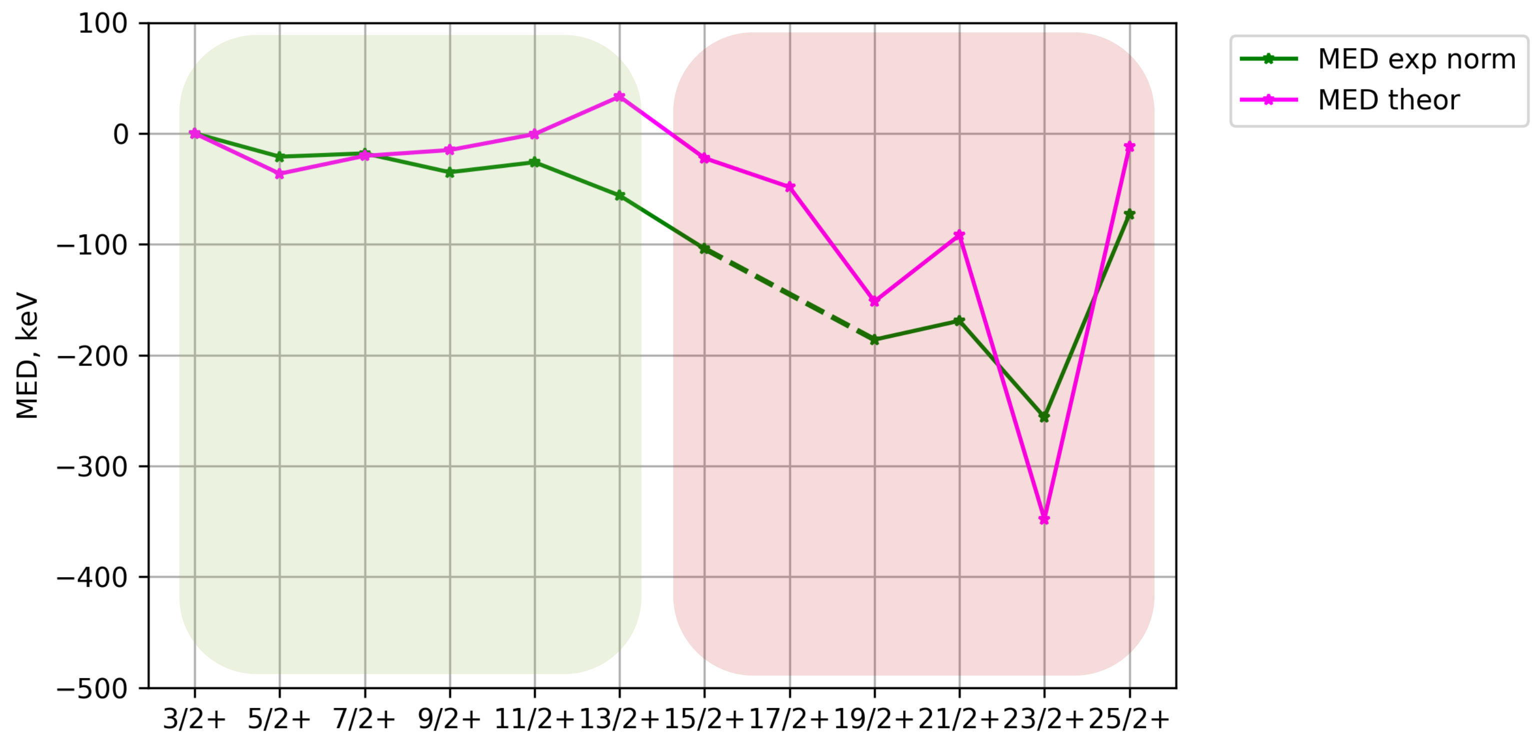
MED: Positive-partiy states





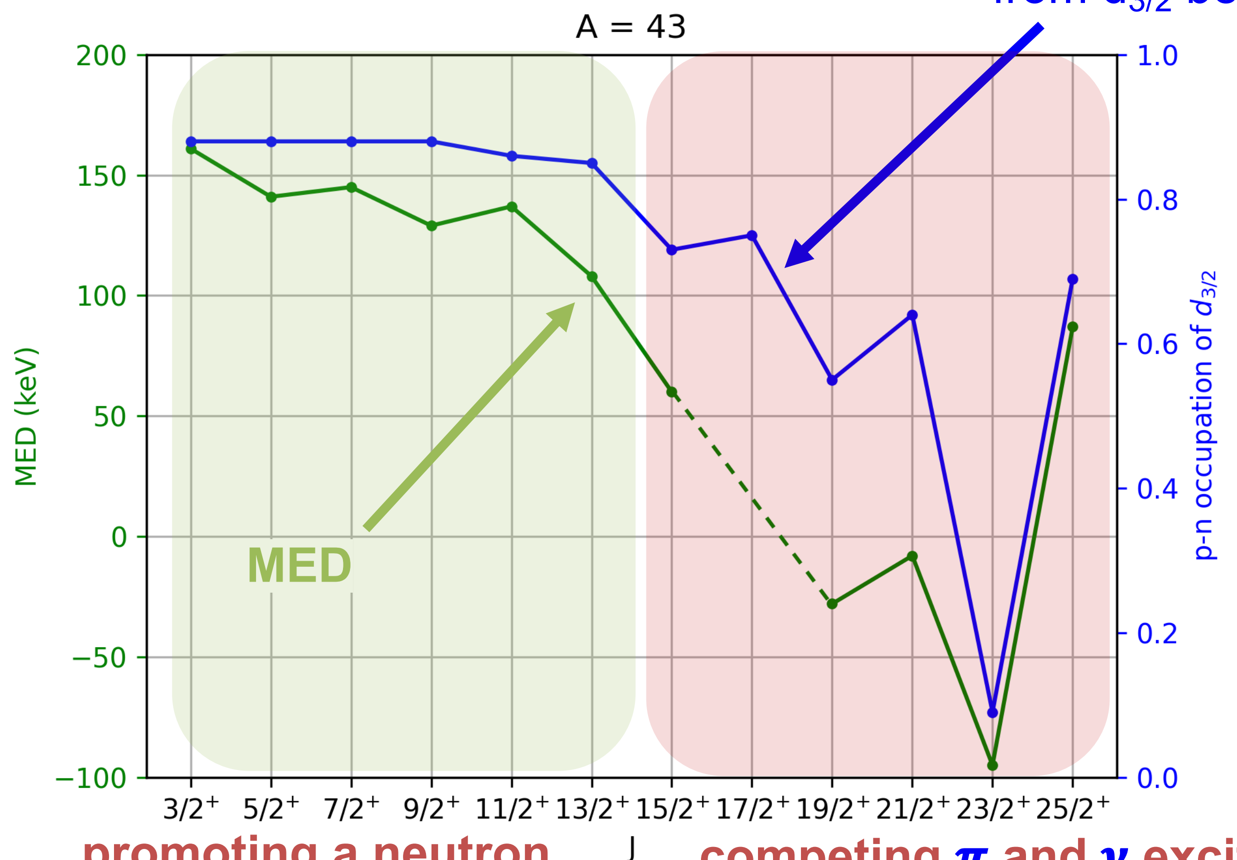
MED: Positive-partiy states





Correlation between MED and excitations across the N,Z=20 gap

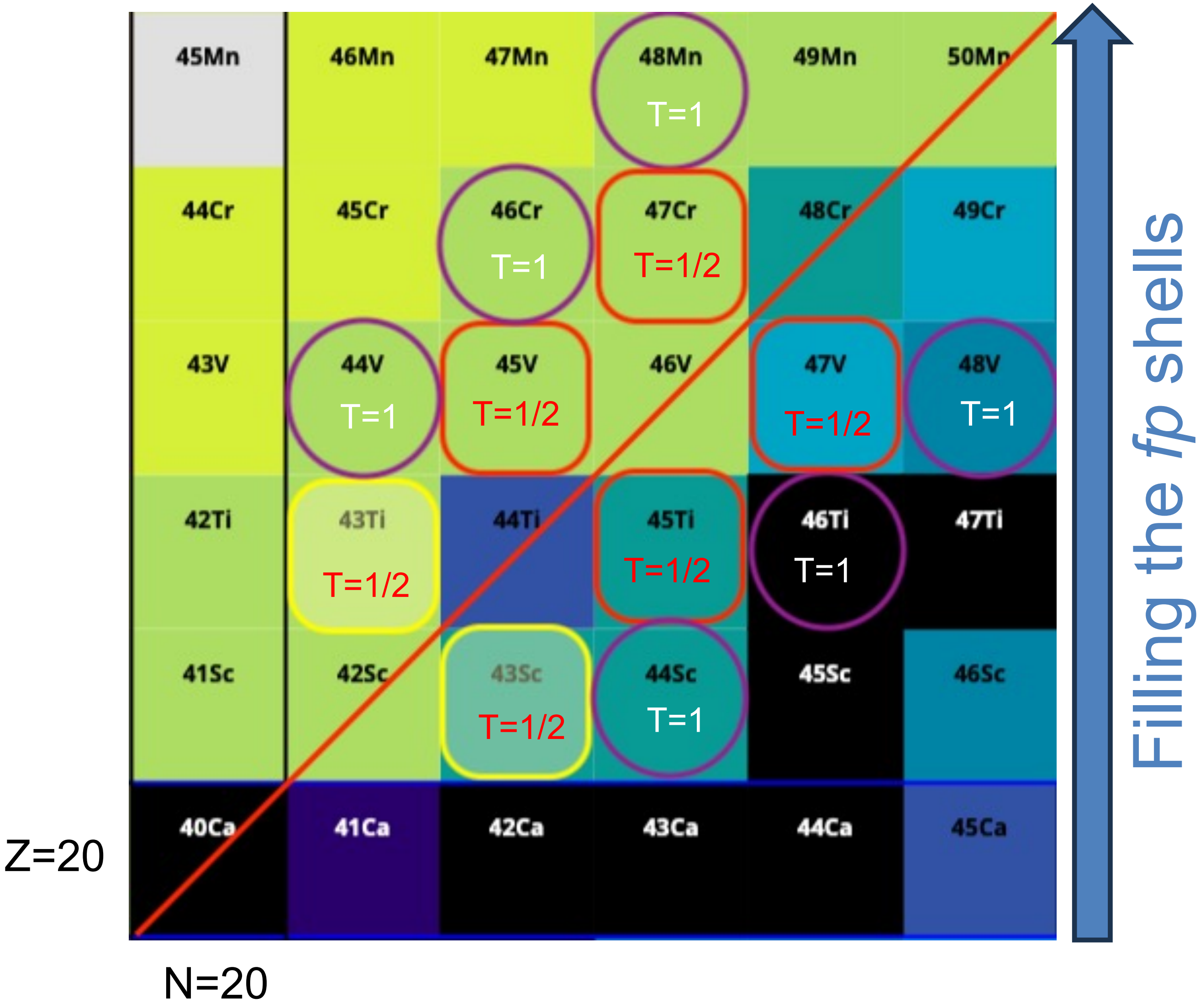
difference in excitation probability from $d_{3/2}$ between ν and π in ^{43}Ti



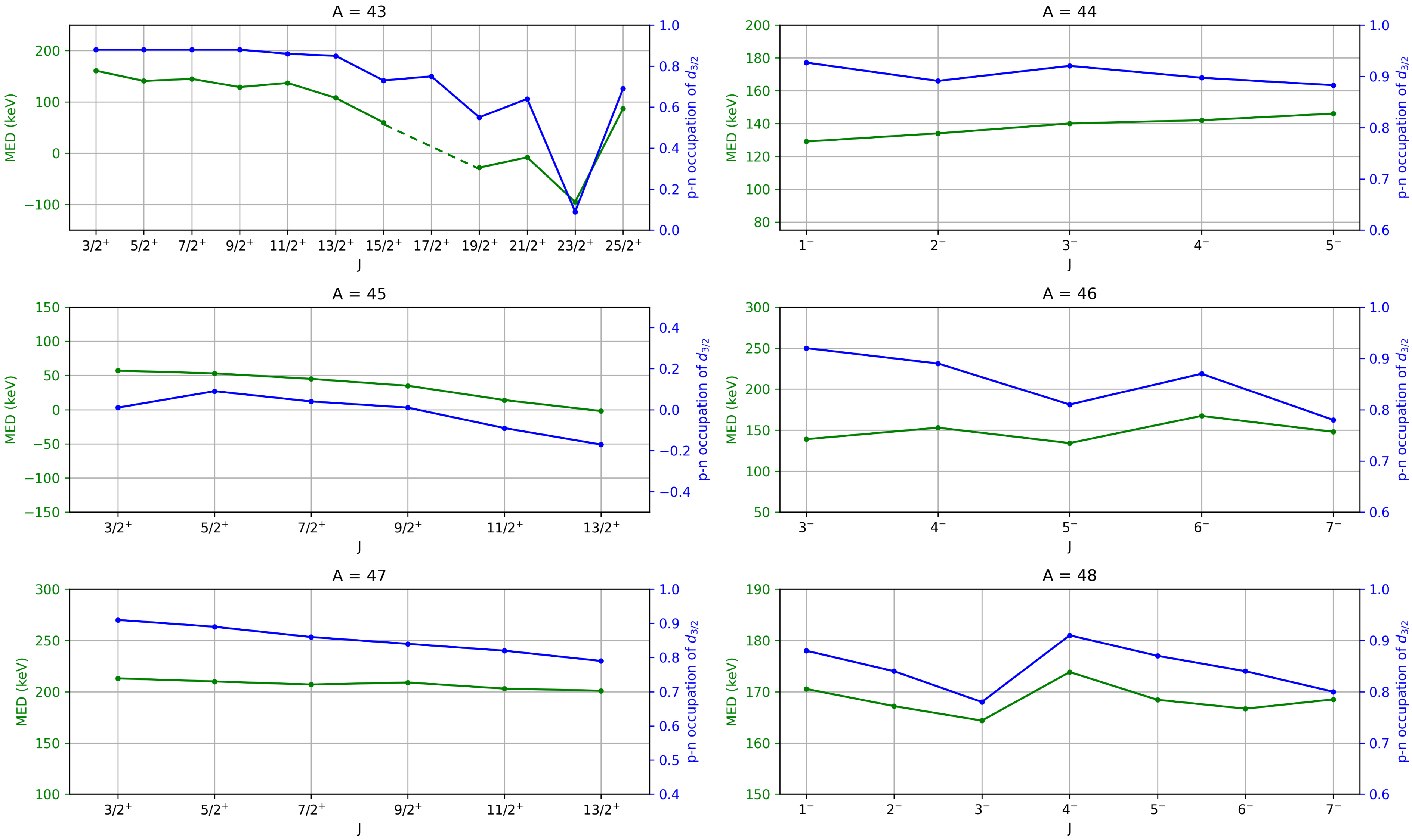
promoting a neutron

competing π and ν excitations

Systematic study of the $d_{3/2}$ occupancy



$d_{3/2}$ 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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