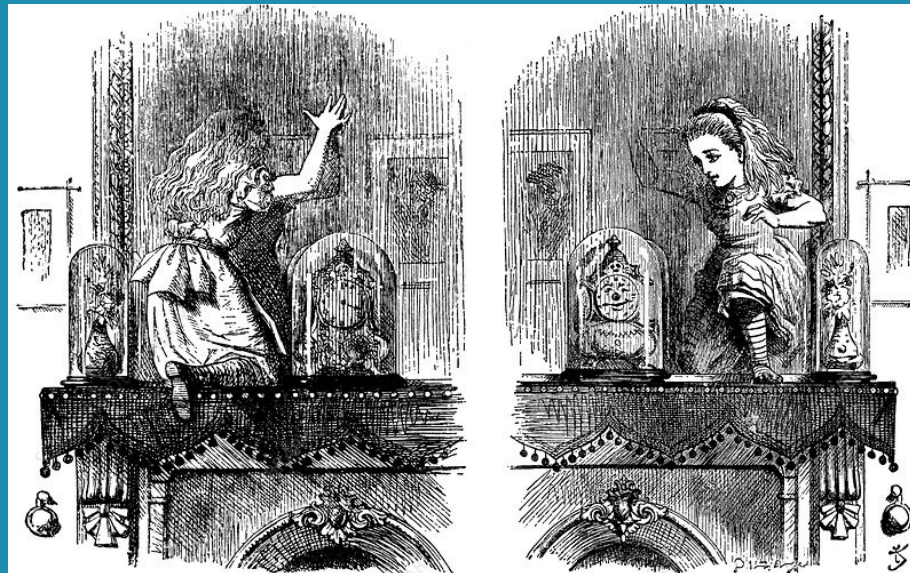


7th International Conference on Collective Motion in Nuclei under Extreme Conditions (COMEX7)

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

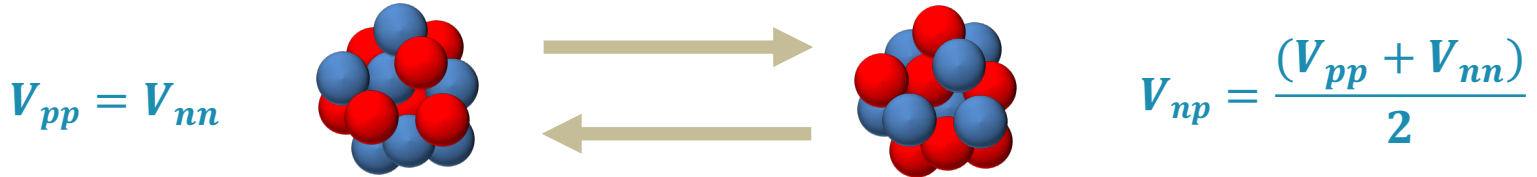
Kseniia Rezyunkina

INFN, Sezione di Padova



Introduction : proton-neutron symmetry

- Exchange symmetry between π and $\nu \rightarrow$ isospin T

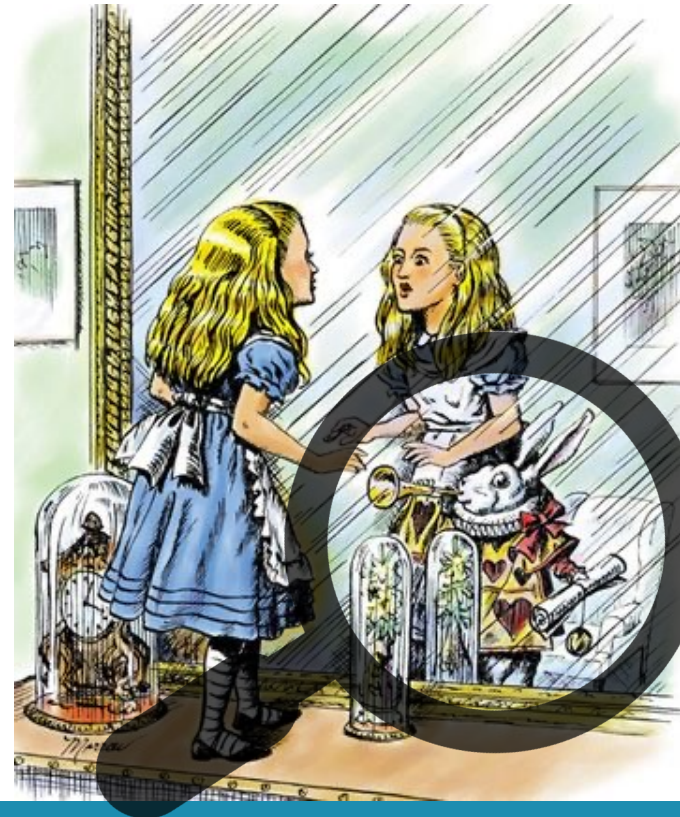


- States with the same T in $N=Z$ **mirror nuclei** \rightarrow Isobaric Analogue States (IAS)

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

$$\text{MED}_{J,T} = E_{J,T,T_z=-T}^* - E_{J,T,T_z=T}^*$$

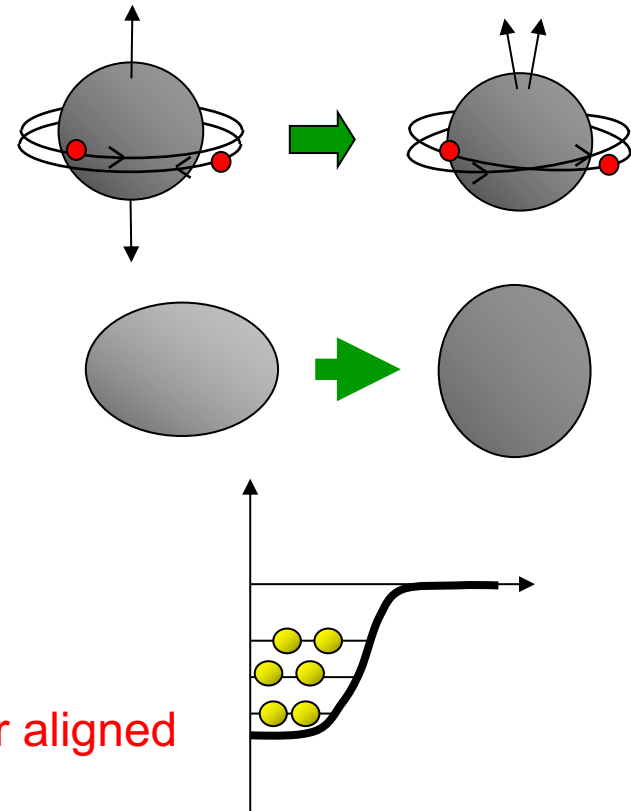
- Differences between IAS magnifies **isospin non-conserving effects**



Shell model interpretation of MED

Coulomb effects:

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

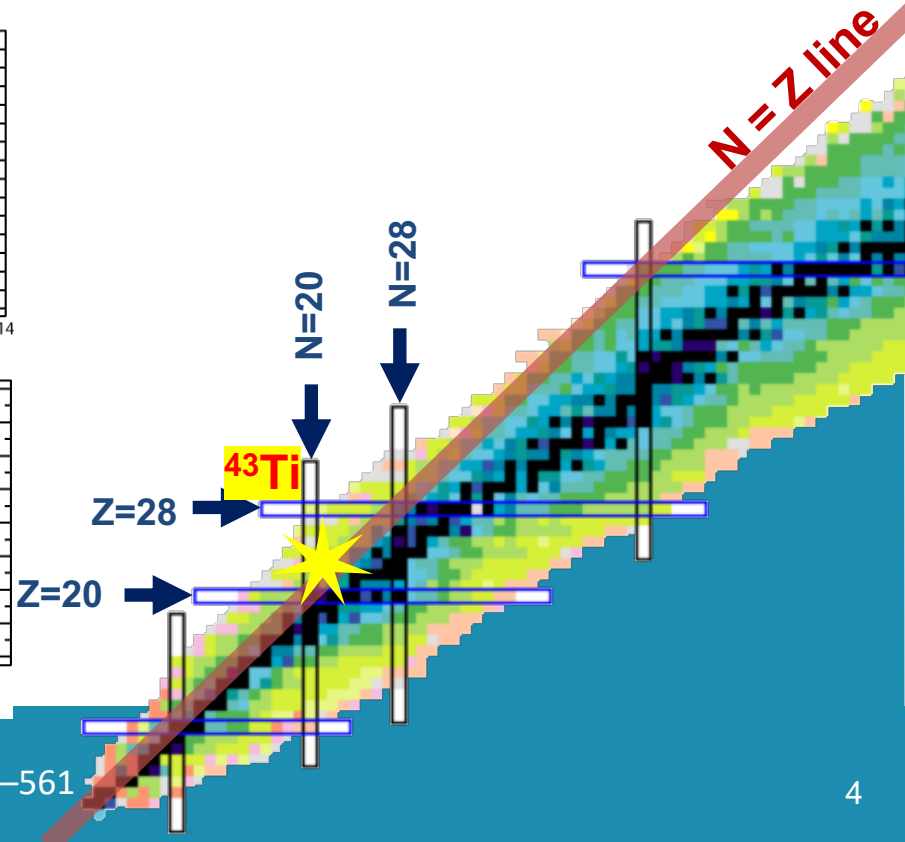
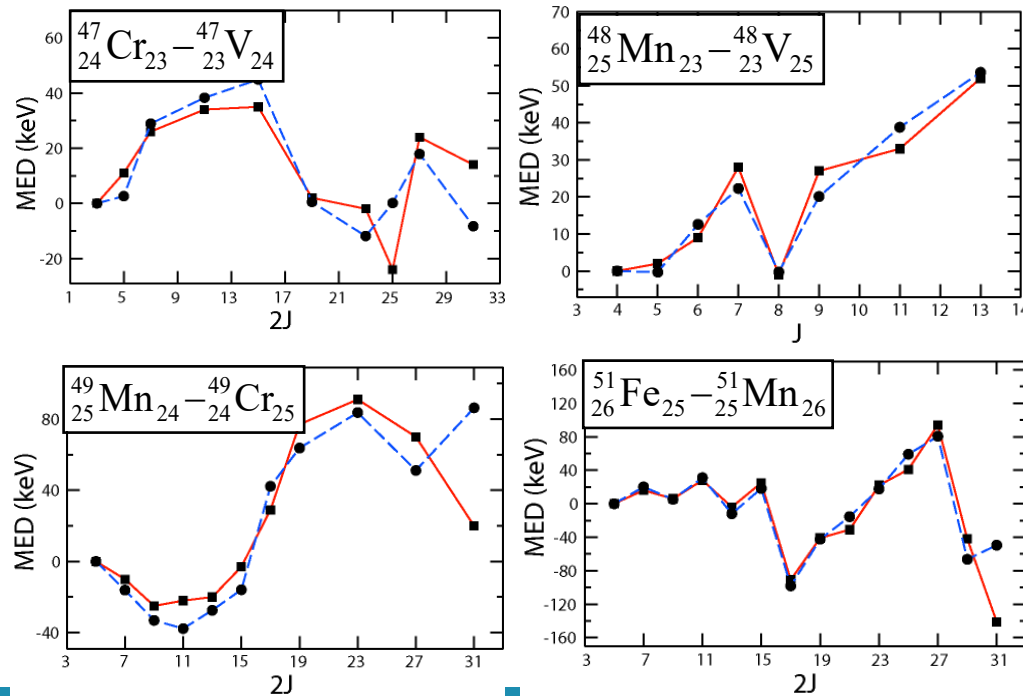
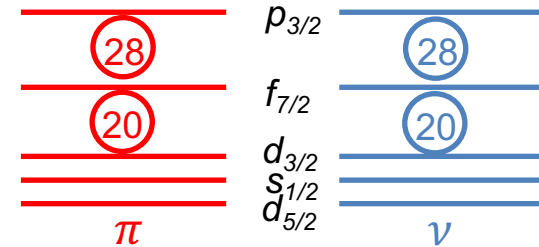


Isospin non-conserving term V_B : charge symmetry breaking

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

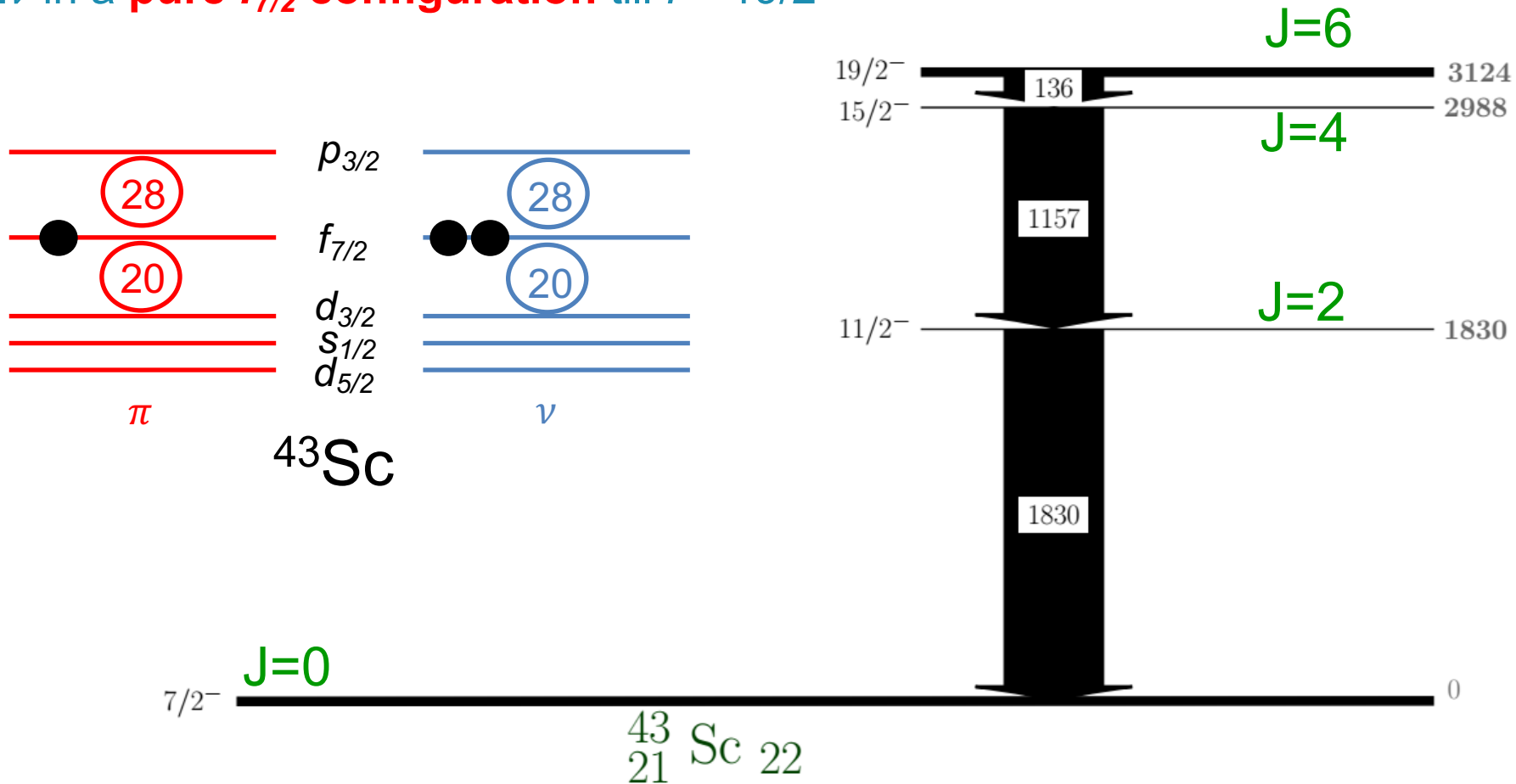
Mirror symmetry in the $f_{7/2}$ shell

- 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

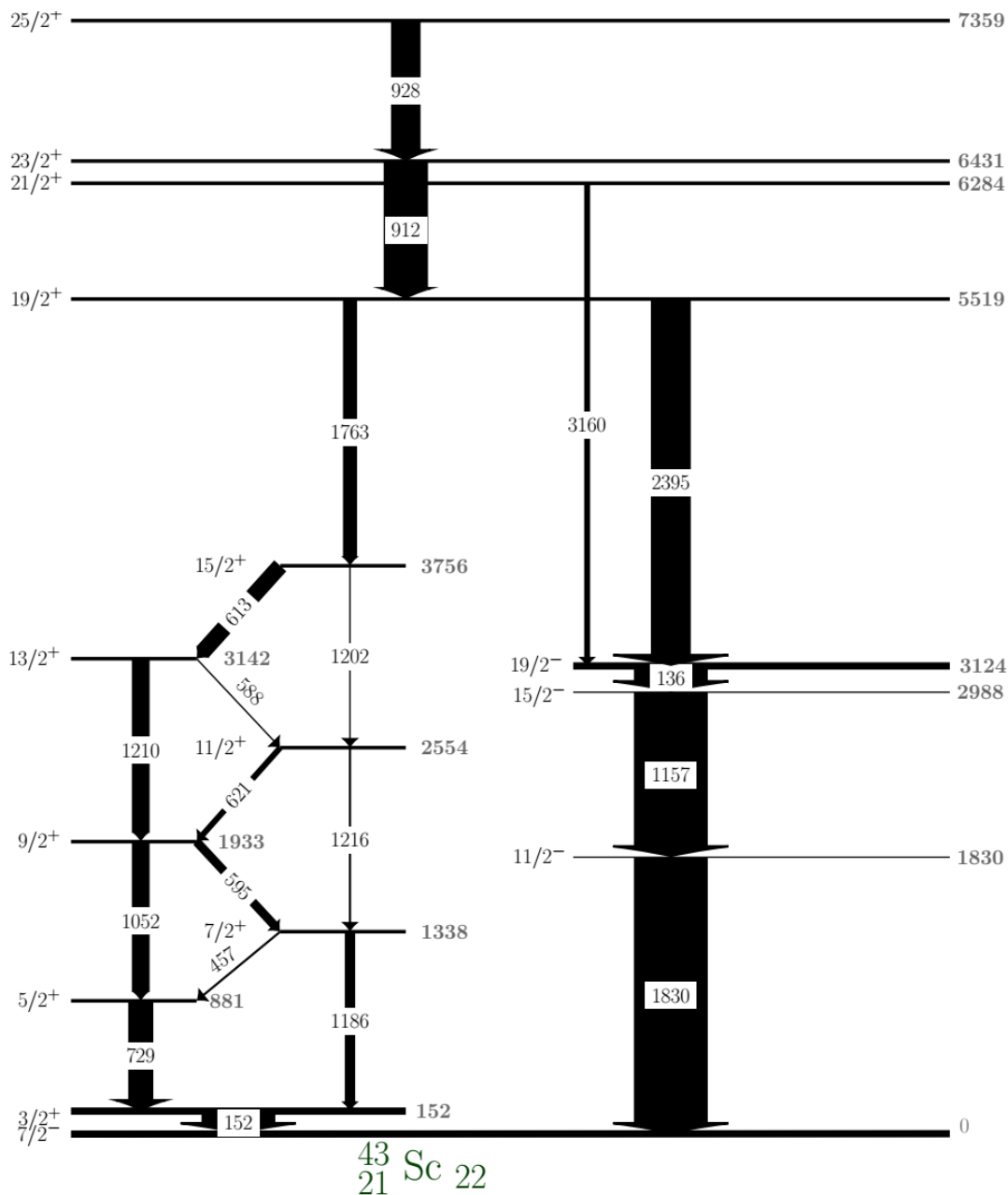


^{43}Sc : negative-parity states

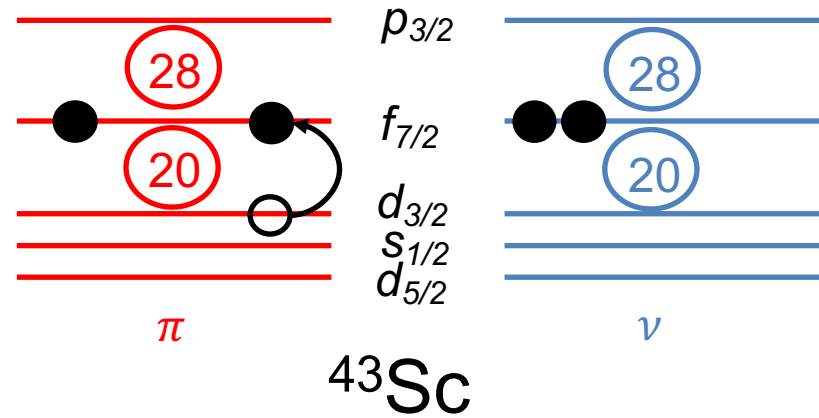
yrast structure, based on the $7/2^-$ g.s., is non-collective
 terminates at the maximum spin that can be generated with one π and
 2ν in a **pure $f_{7/2}$ configuration** till $I = 19/2^-$



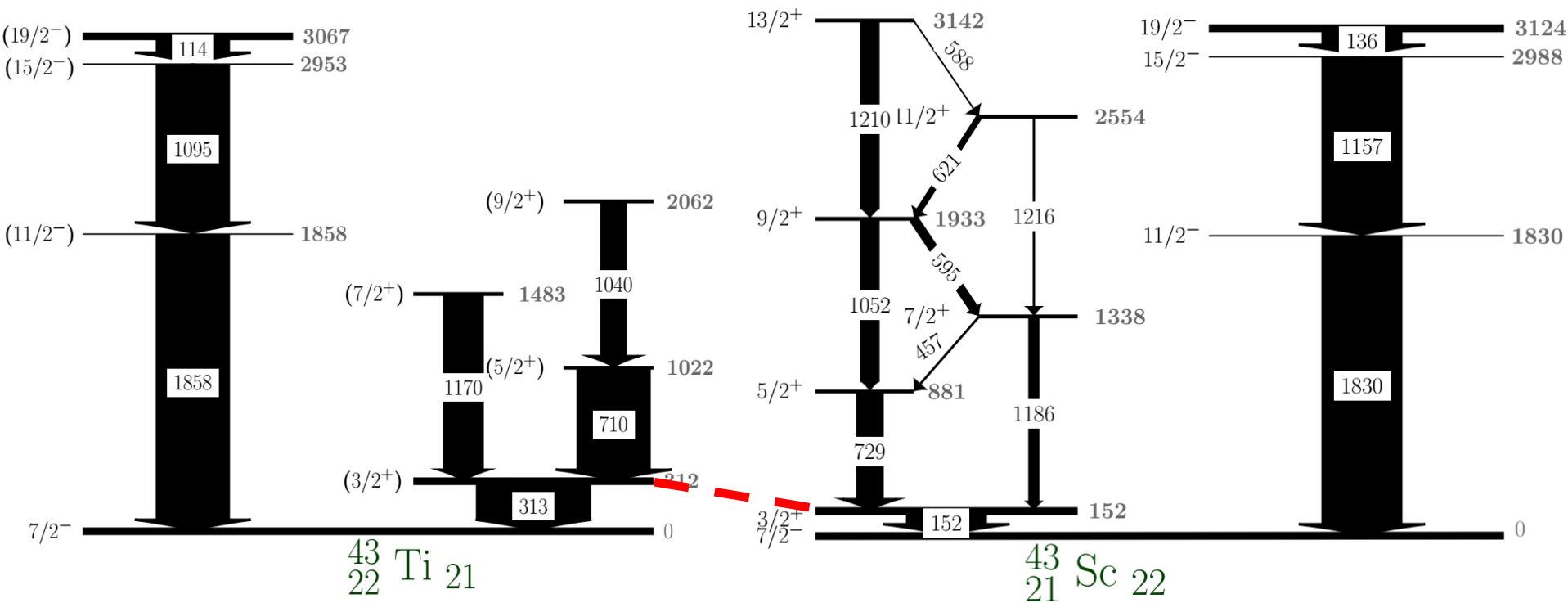
^{43}Sc : positive-parity states



- 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 $I = 27/2^+$

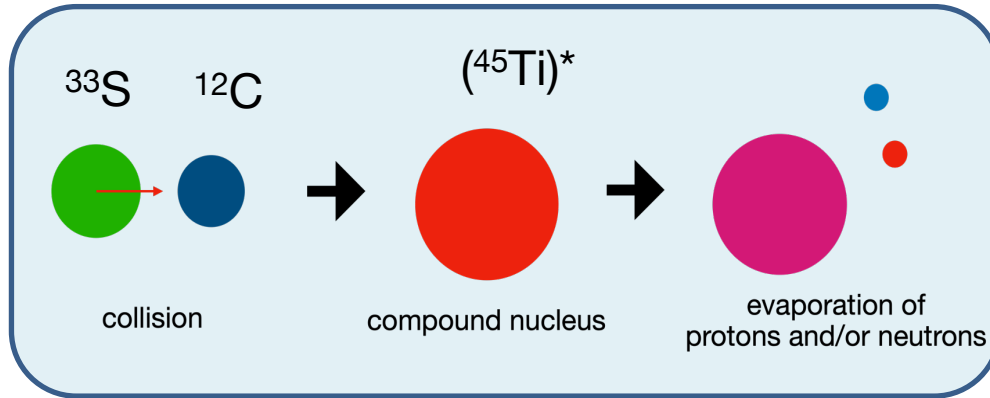


A=43 mirror pair



- 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 1 α 1n

^{40}K 1 α 1p



	p?	p?	p	$\epsilon = 100.00\%$	$\epsilon = 100.00\%$ $\epsilon\alpha$	$\epsilon = 100.00\%$	$\epsilon = 100.00\%$	$\epsilon = 100.00\%$	$\epsilon = 100.00\%$
23									
38Ti	39Ti 31 ms $\epsilon = 100.00\%$ $\epsilon p = 100.00\%$	40Ti 52.4 ms $\epsilon p = 97.50\%$ ϵ	41Ti 81.9 ms $\epsilon = 100.00\%$ $\epsilon p = 100.00\%$	42Ti 208.65 ms $\epsilon = 100.00\%$	43Ti 509 ms $\epsilon = 100.00\%$	44Ti 60.0 y $\epsilon = 100.00\%$	45Ti 184.8 min $\epsilon = 100.00\%$	46Ti STABLE 8.25%	47Ti STABLE 7.7%
22									
37Sc	38Sc	39Sc < 300 ns $p = 100.00\%$	40Sc 182.3 ms $\epsilon = 100.00\%$ $\epsilon p = 0.44\%$ $\epsilon\alpha = 0.02\%$	41Sc 596.3 ms $\epsilon = 100.00\%$	42Sc 680.70 ms $\epsilon = 100.00\%$	43Sc 3.891 h $\epsilon = 100.00\%$	44Sc 3.97 h $\epsilon = 100.00\%$	45Sc STABLE 100%	46Sc STABLE 8.2%
21	p?	p							$\beta =$
36Ca	37Ca 181.1 ms $\epsilon = 100.00\%$ $\epsilon p = 82.10\%$	38Ca 440 ms $\epsilon = 100.00\%$	39Ca 859.6 ms $\epsilon = 100.00\%$	40Ca > $3.0E+21$ y 96.94% 2 ϵ	41Ca 9.94E4 y $\epsilon = 100.00\%$	42Ca STABLE 0.647%	43Ca STABLE 0.135%	44Ca STABLE 2.09%	$\beta =$
20									
35K	36K 342 ms $\epsilon = 100.00\%$ $\epsilon p = 0.05\%$ $\epsilon\alpha = 3.4E-3\%$	37K 1.226 s $\epsilon = 100.00\%$	38K 7.636 min $\epsilon = 100.00\%$	39K STABLE 93.2581%	40K 1.248E+9 y 0.0117% $\beta = 89.28\%$ $\epsilon = 10.72\%$	41K STABLE 6.7302%	42K 12.355 h $\beta = 100.00\%$	43K 22.3 h $\beta = 100.00\%$	$\beta =$
19									
34Ar	35Ar 1.7756 s $\epsilon = 100.00\%$	36Ar STABLE 0.3336%	37Ar 35.04 d $\epsilon = 100.00\%$	38Ar STABLE 0.0629%	39Ar 269 y $\beta = 100.00\%$	40Ar STABLE 99.6035%	41Ar 109.61 min $\beta = 100.00\%$	42Ar 32.9 y $\beta = 100.00\%$	$\beta =$
18									
33Cl	34Cl 1.5264 s $\epsilon = 100.00\%$	35Cl STABLE 75.77%	36Cl 3.01E+5 y $\epsilon = 100.00\%$	37Cl STABLE 24.23%	38Cl 37.24 min $\beta = 100.00\%$	39Cl 56.2 min $\beta = 100.00\%$	40Cl 1.35 min $\beta = 100.00\%$	41Cl 38.4 s $\beta = 100.00\%$	$\beta =$
	16	17	18	19	20	21	22	23	24
	Neutron (N) #								

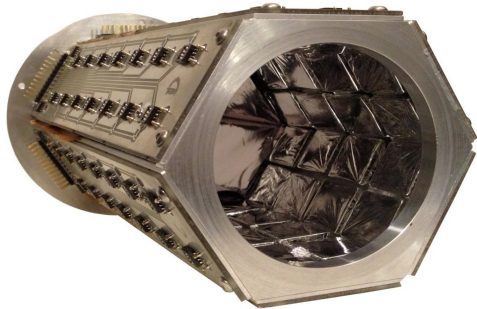
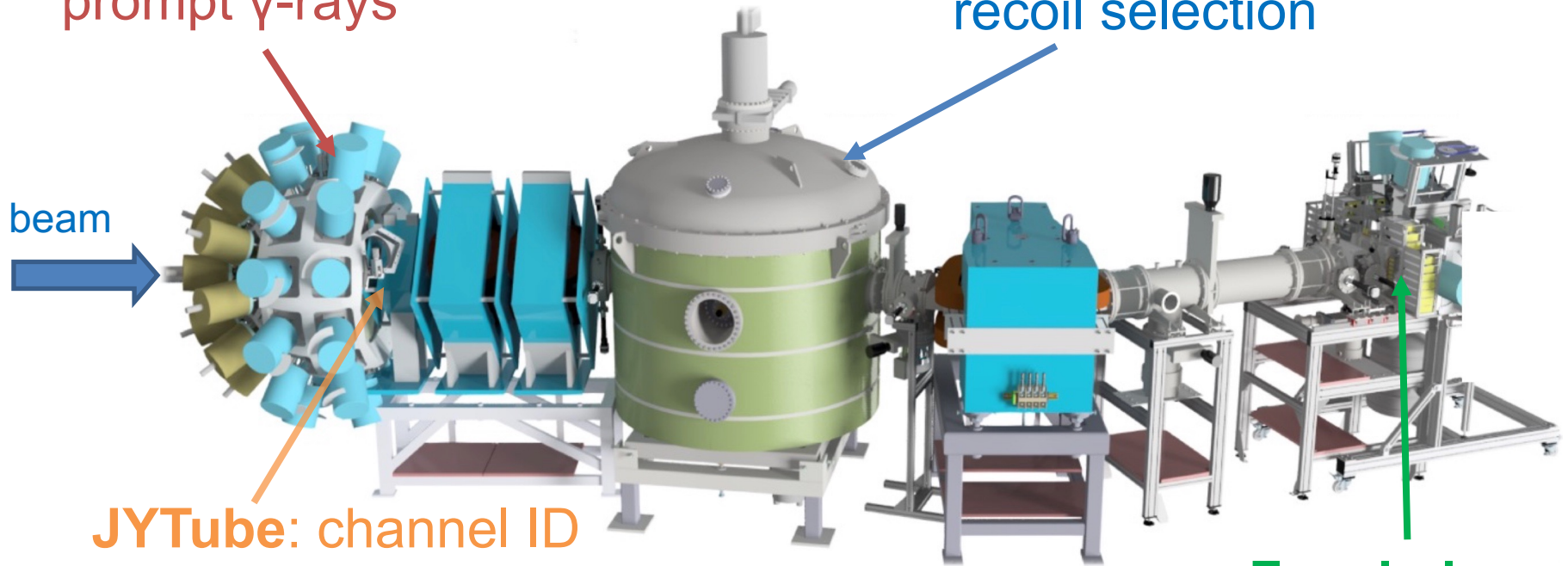
$N=Z$

JYFL experiment JM11

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

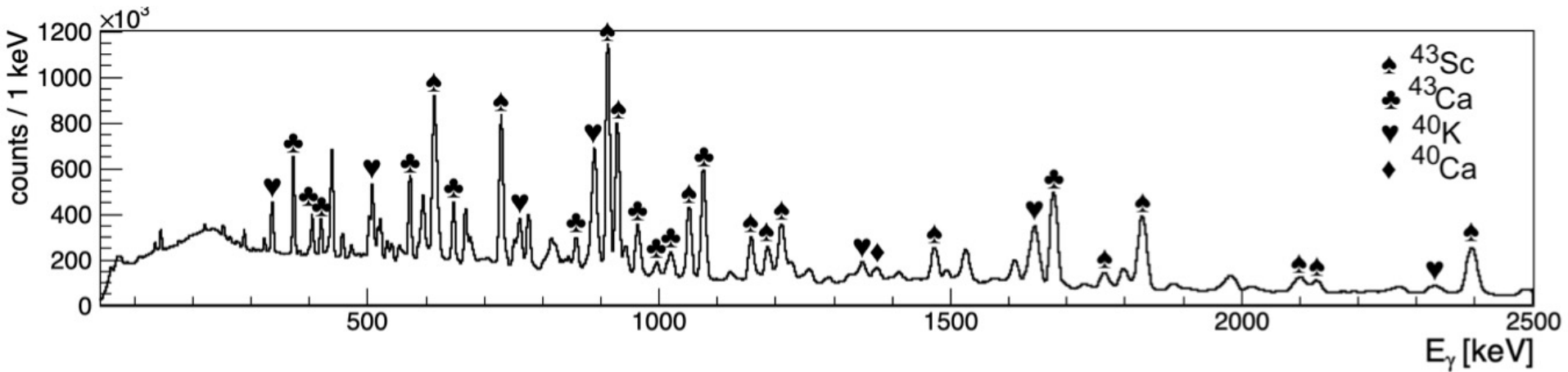
JUROGAM 3
prompt γ -rays

MARA
recoil selection



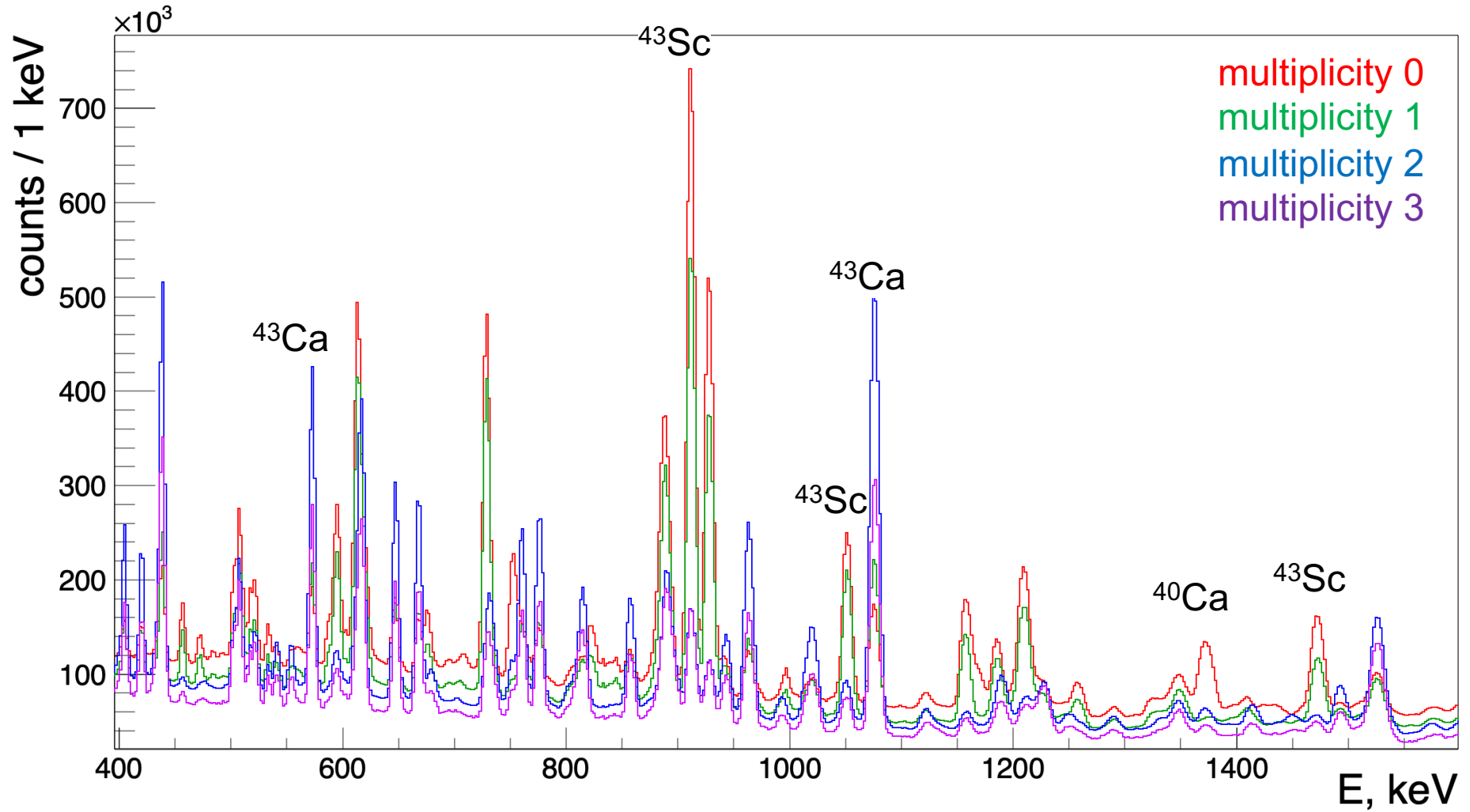
Prompt JUROGAM 3 spectrum

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



Additional constraints are needed!

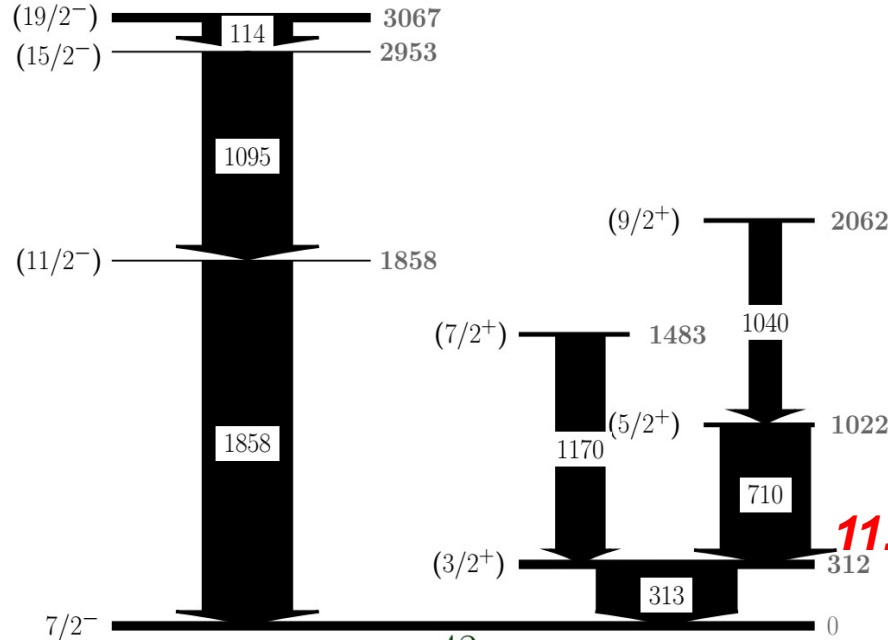
JYTube: charged particle tagging



Tagging on isomers in ^{43}Ti

gate the on fast IS
 → negative-parity
 states

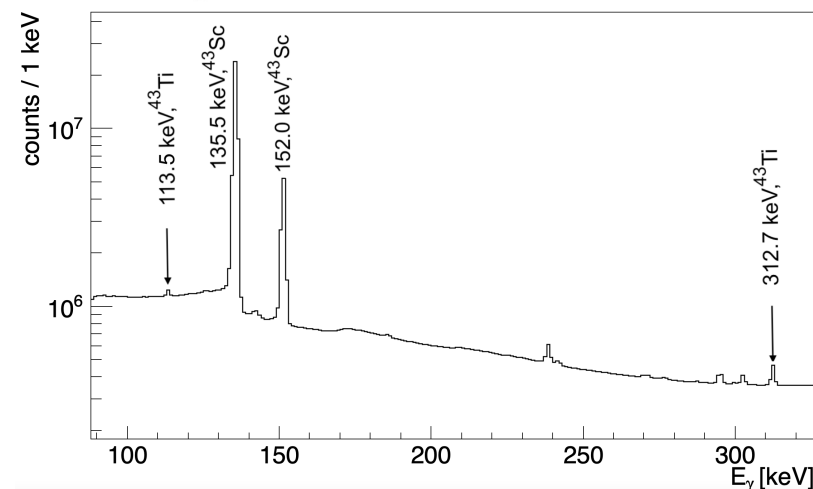
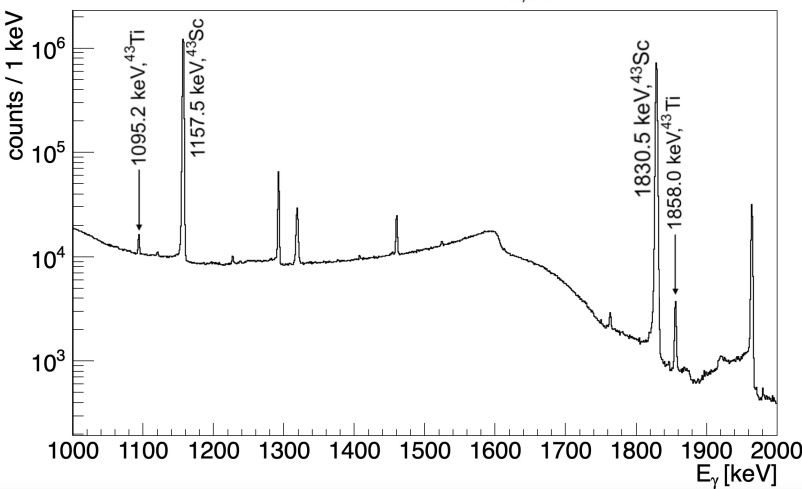
551 ns



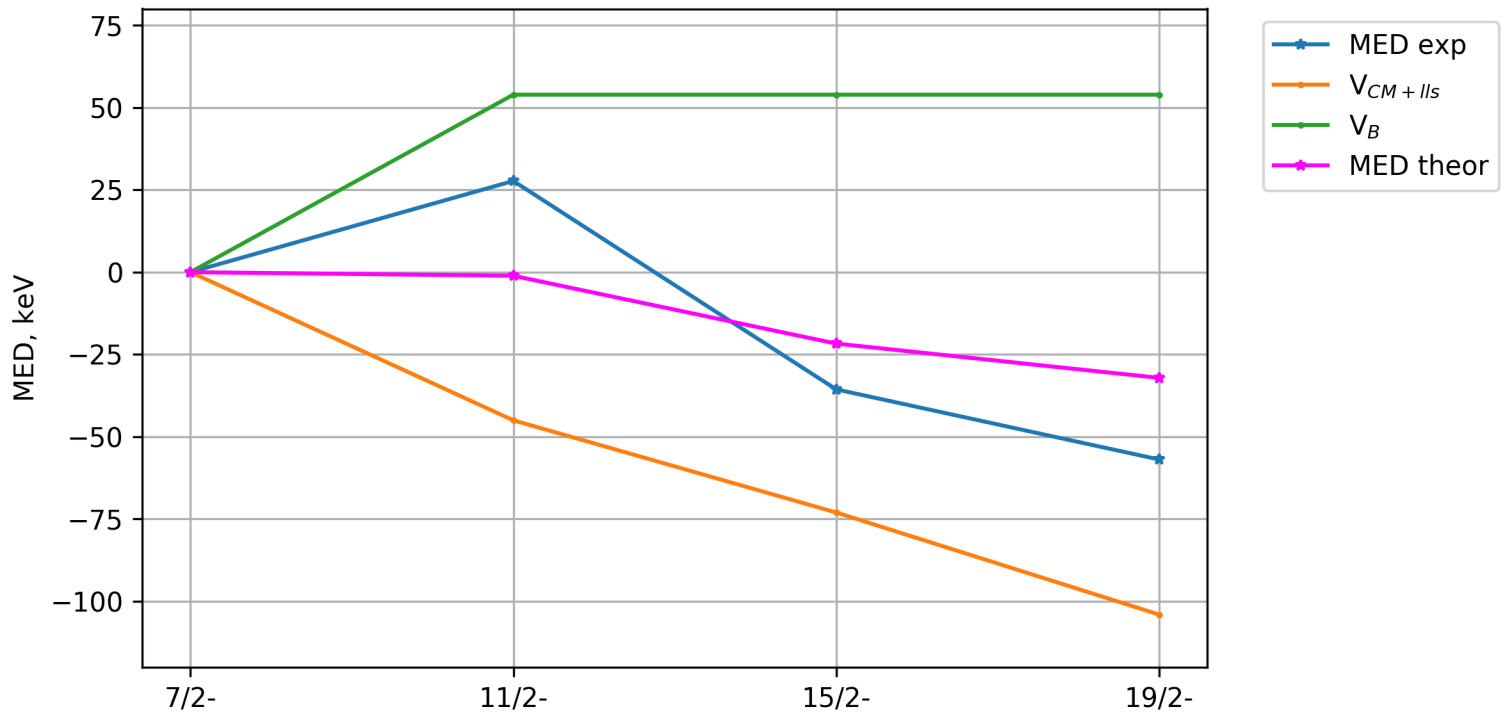
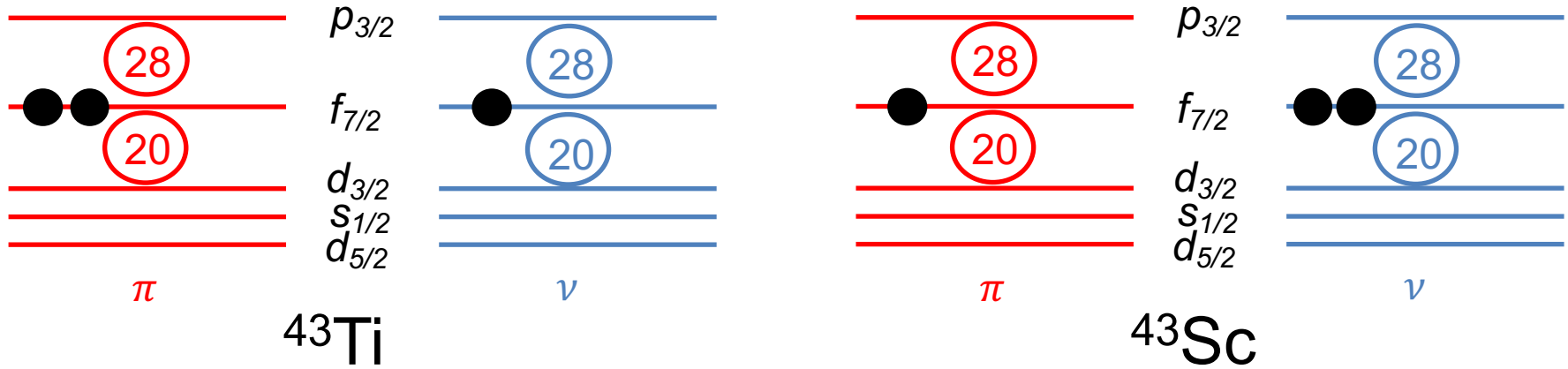
gate on the slow IS
 → positive-parity
 states

11.7 us

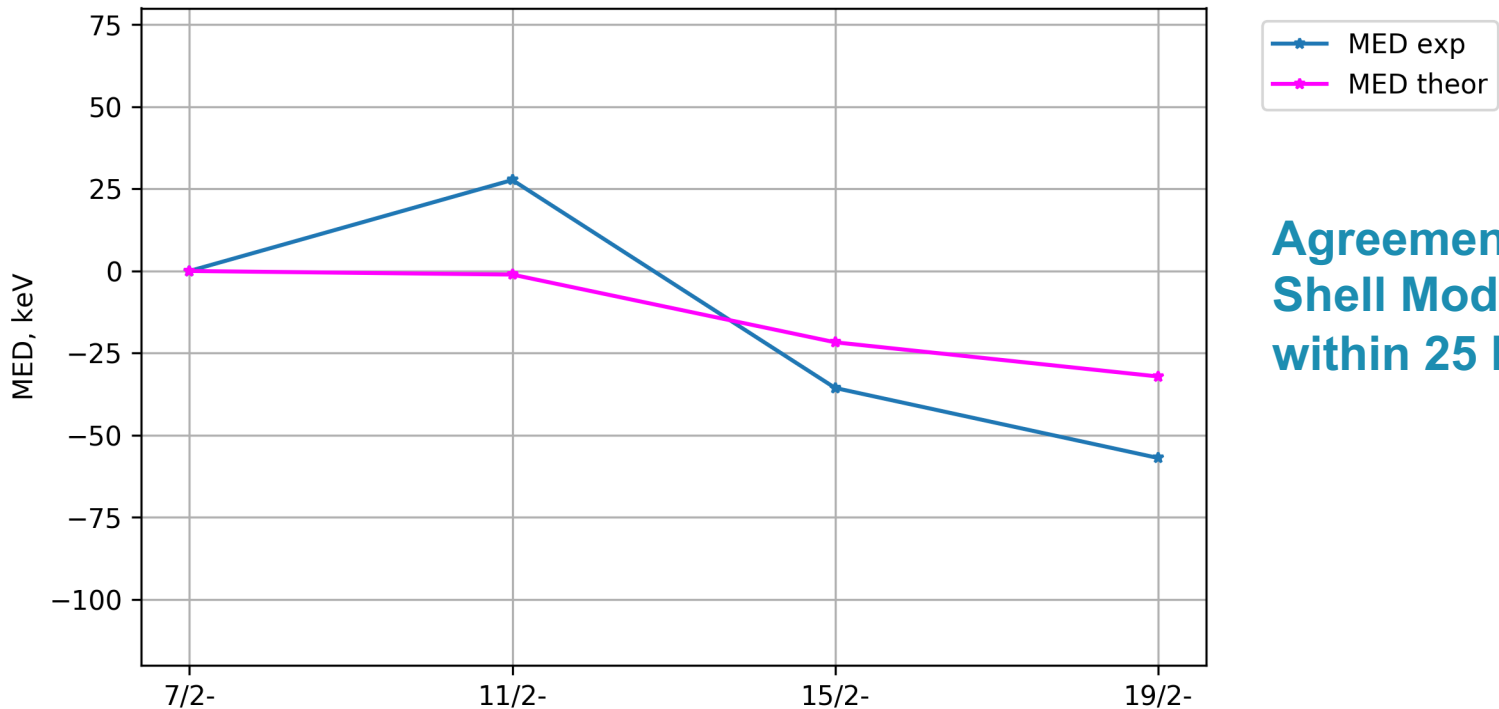
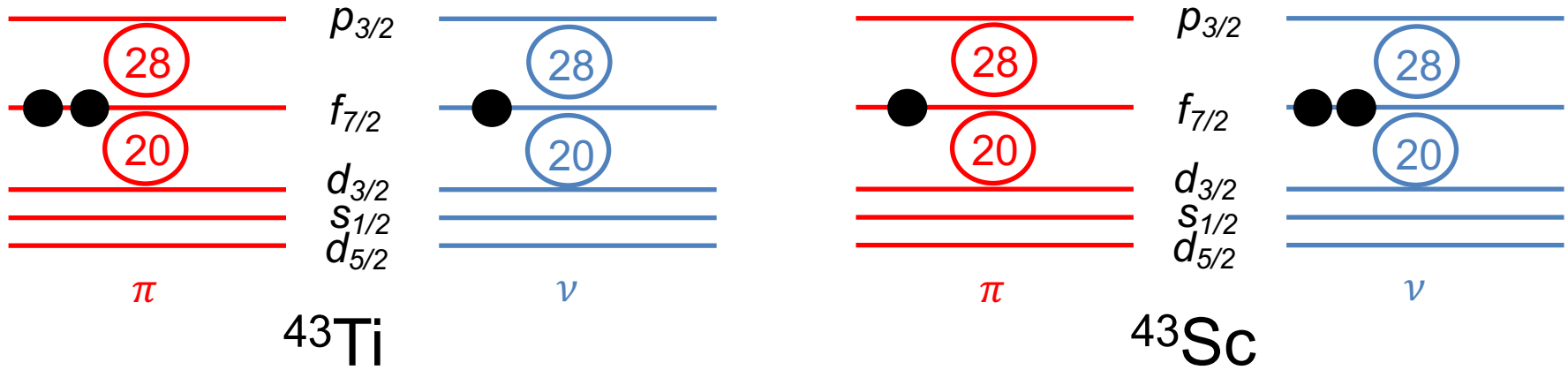
$^{43}_{22}\text{Ti}$ $^{21}_{21}$



MED: Negative-parity states

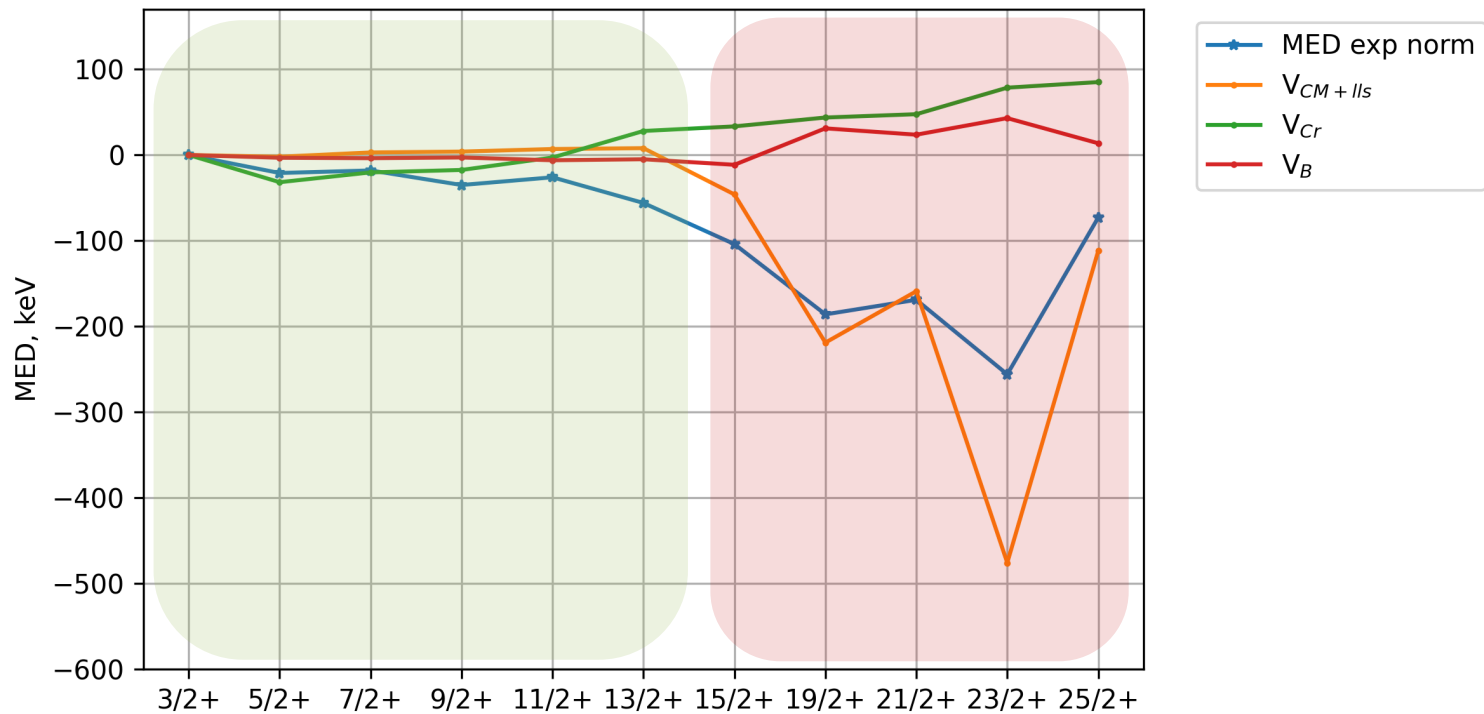
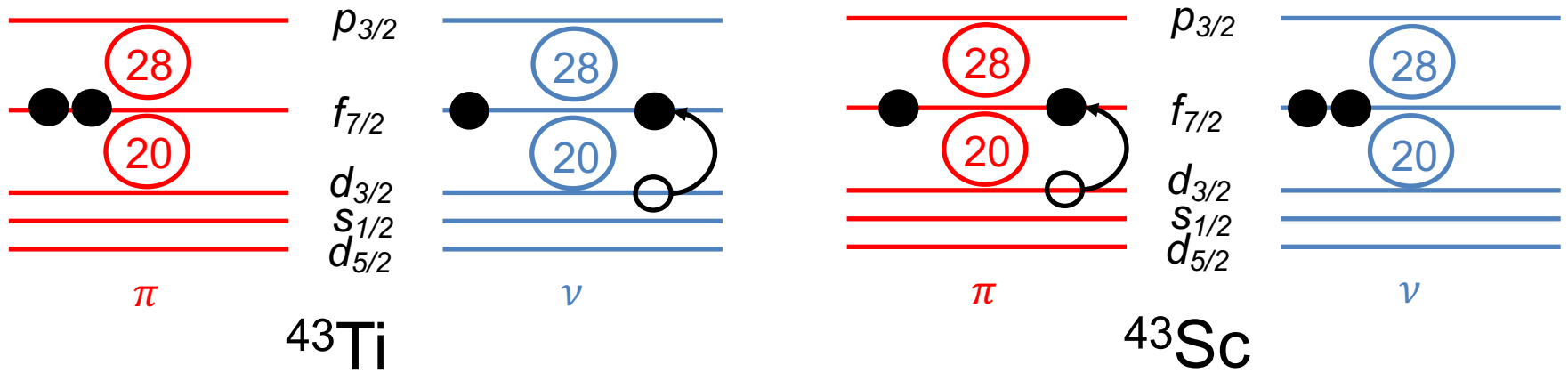


MED: Negative-parity states

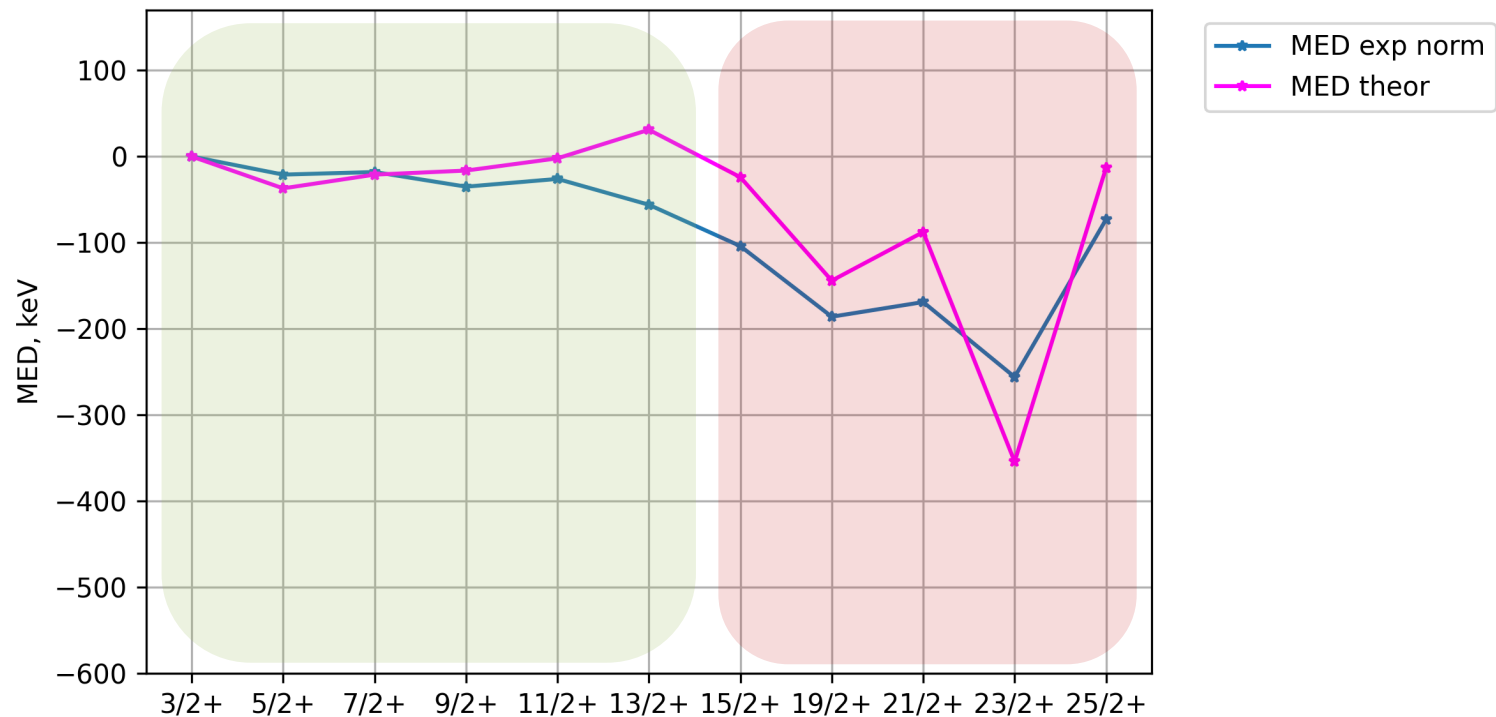
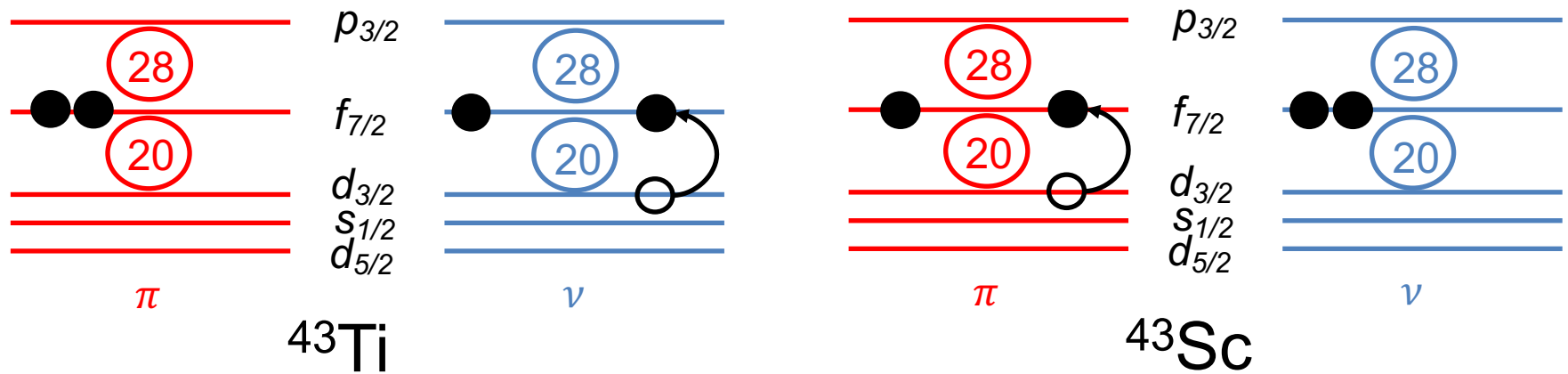


Agreement with Shell Model within 25 keV

MED: Positive-parity states



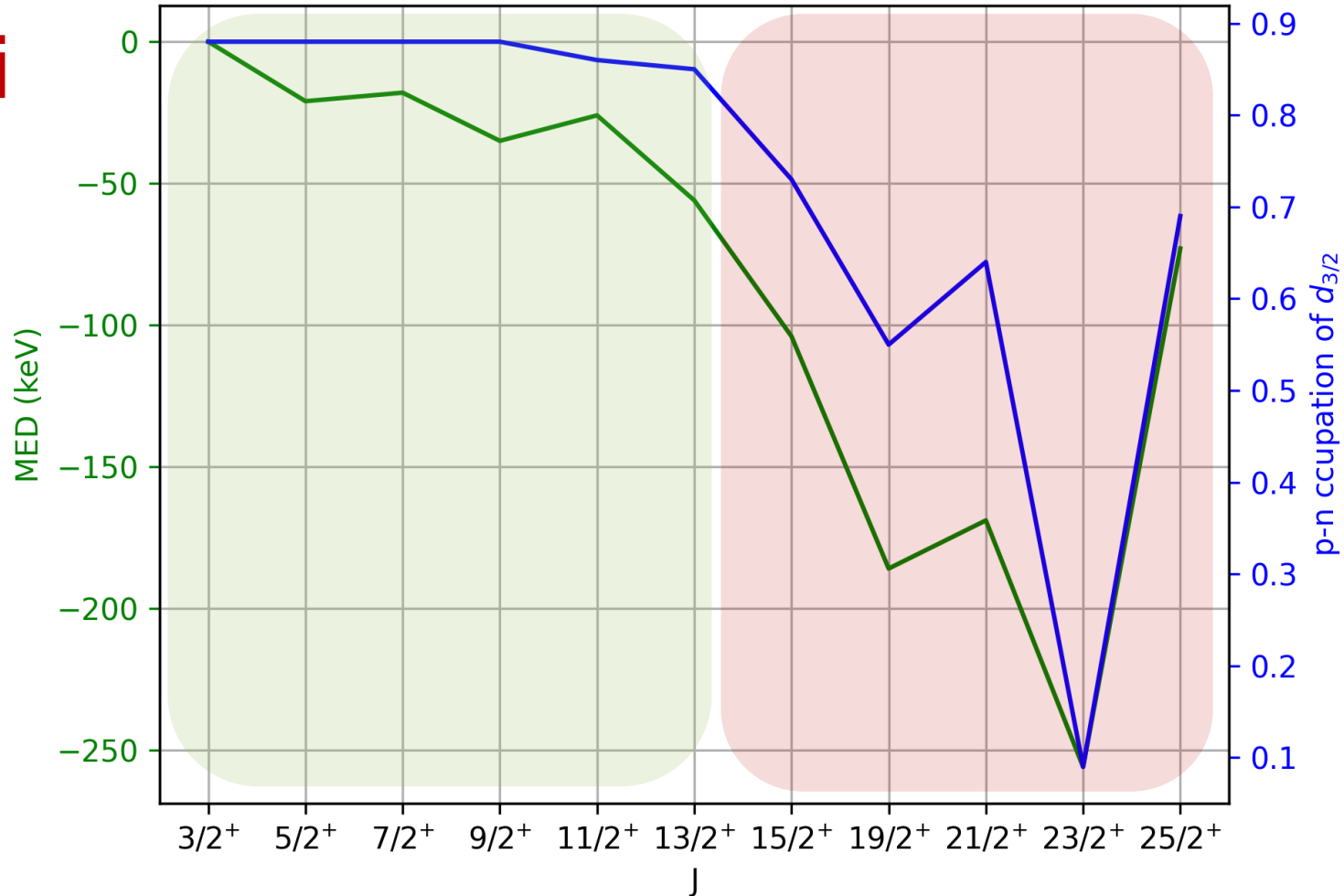
MED: Positive-parity states



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

A = 43

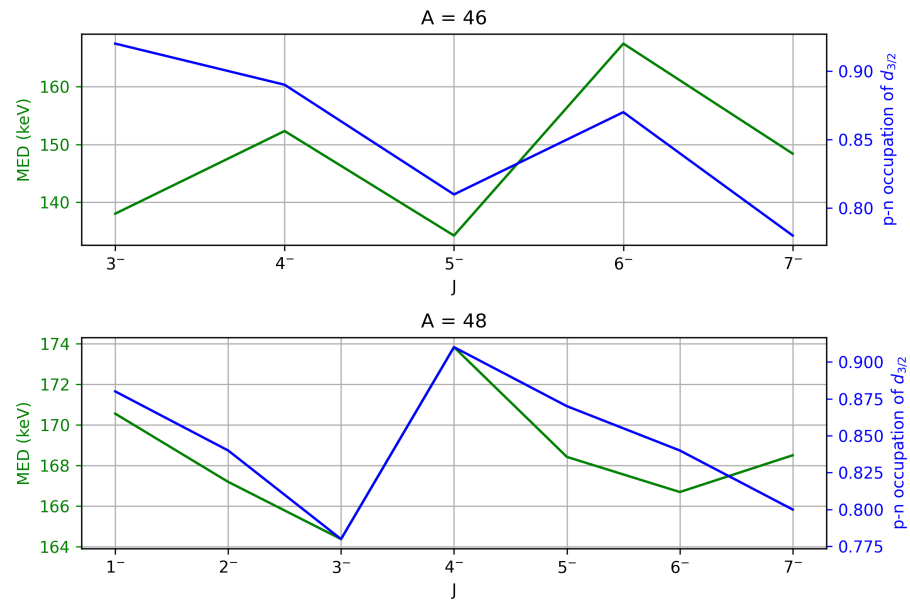
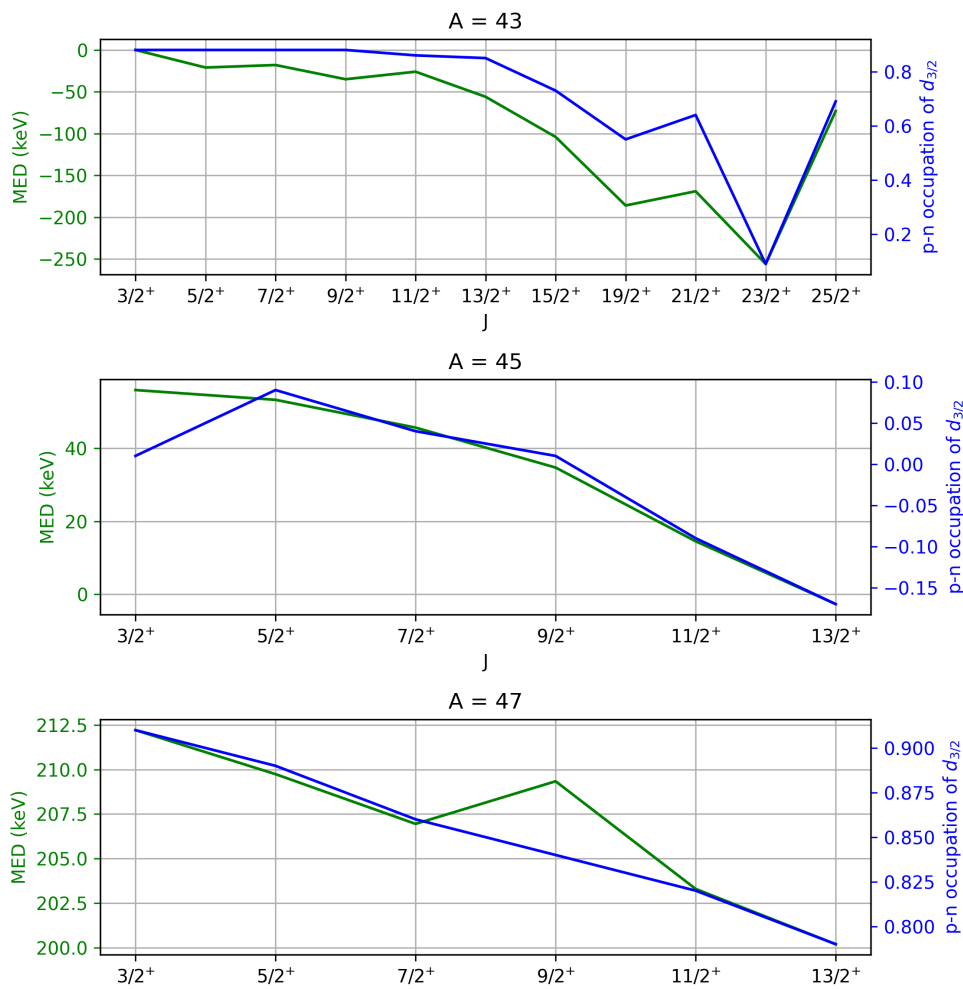
^{43}Ti



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

K. Rezynkina, S.M. Lenzi, F. Recchia, P. Aguilera,
J. Benito, S. Carollo, R. Escudeiro, J. Ha,
S. Pigliapoco et al.

INFN Sezione di Padova and University of Padova

M.L. Cortes, D. Napoli

INFN Legnaro National Laboratories

K. Auranen, T. Grahm, P. Greenlees, A. Illana, R. Julin,
H. Joukainen, H. Jutila, M. Leino, J. Louko, M. Luoma,
J. Ojala, **J. Pakarinen,** P. Rahkila, P. Ruotsalainen,
M. Sandzelius, J. Sarén, A. Tolosa Delgado, J. Uusitalo,
G.L. Zimba

University of Jyväskylä