UNIVERSITÀ DEGLI STUDI DI MILANO

INFN Istituto Nazionale di Fisica Nucleare

VIIth Topical Workshop on Modern Aspects in Nuclear Structure

The Many Facets of Nuclear Structure

BORMIO 3-8 February 2025

Re-investigating ^{107}Te

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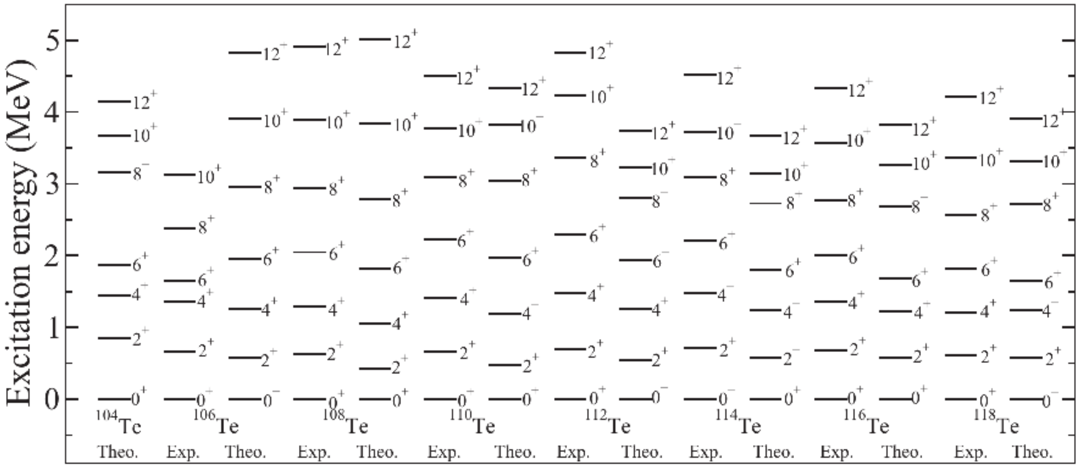
CSIC INFN JYFL

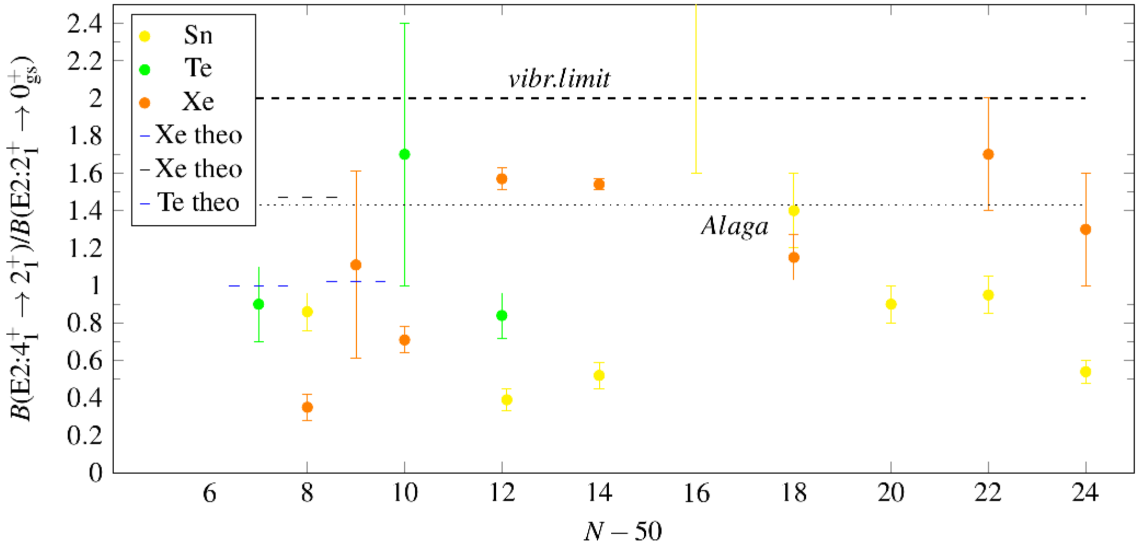
Modern Aspects in Nuclear Structure 2025 – Bormio, Italy

Overview

- Introduction
- Experimental setup
- Identification of ^{107}Te via Recoil Decay tagging
- Results and discussion - ^{107}Te
- Conclusions and perspectives

Introduction – Collectivity vs SP dof



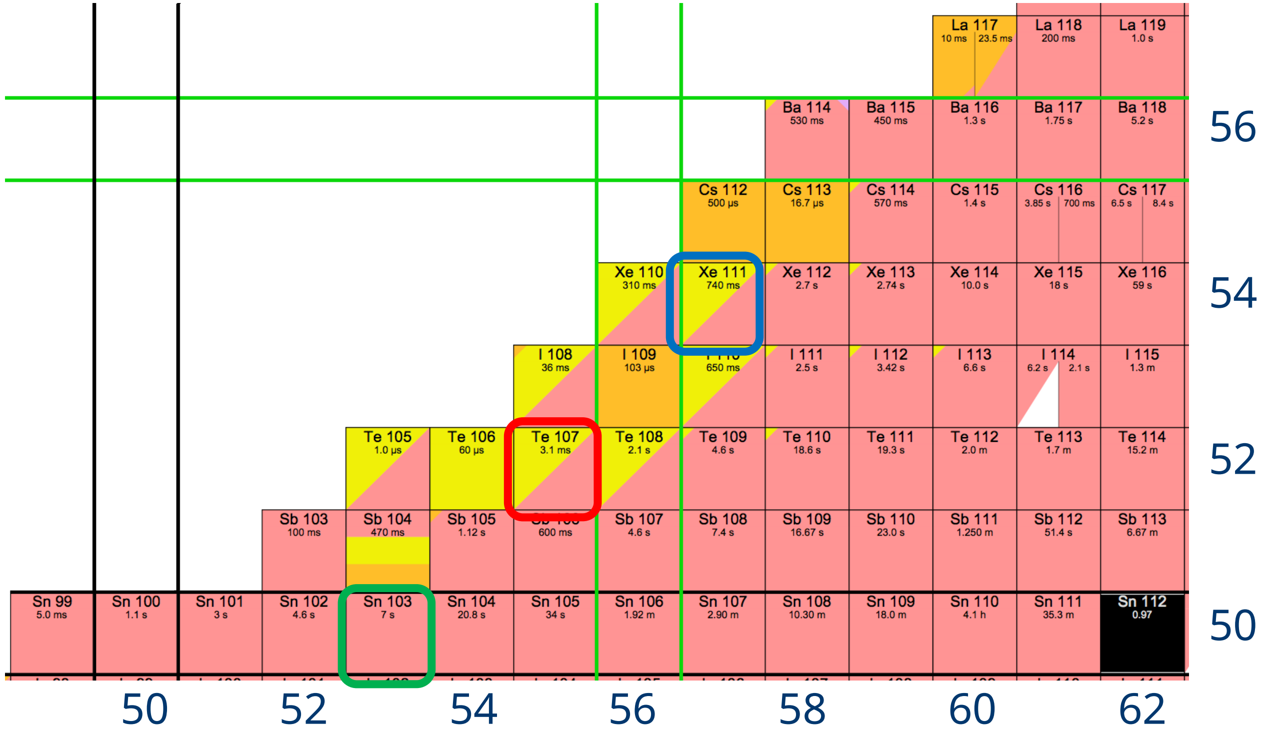


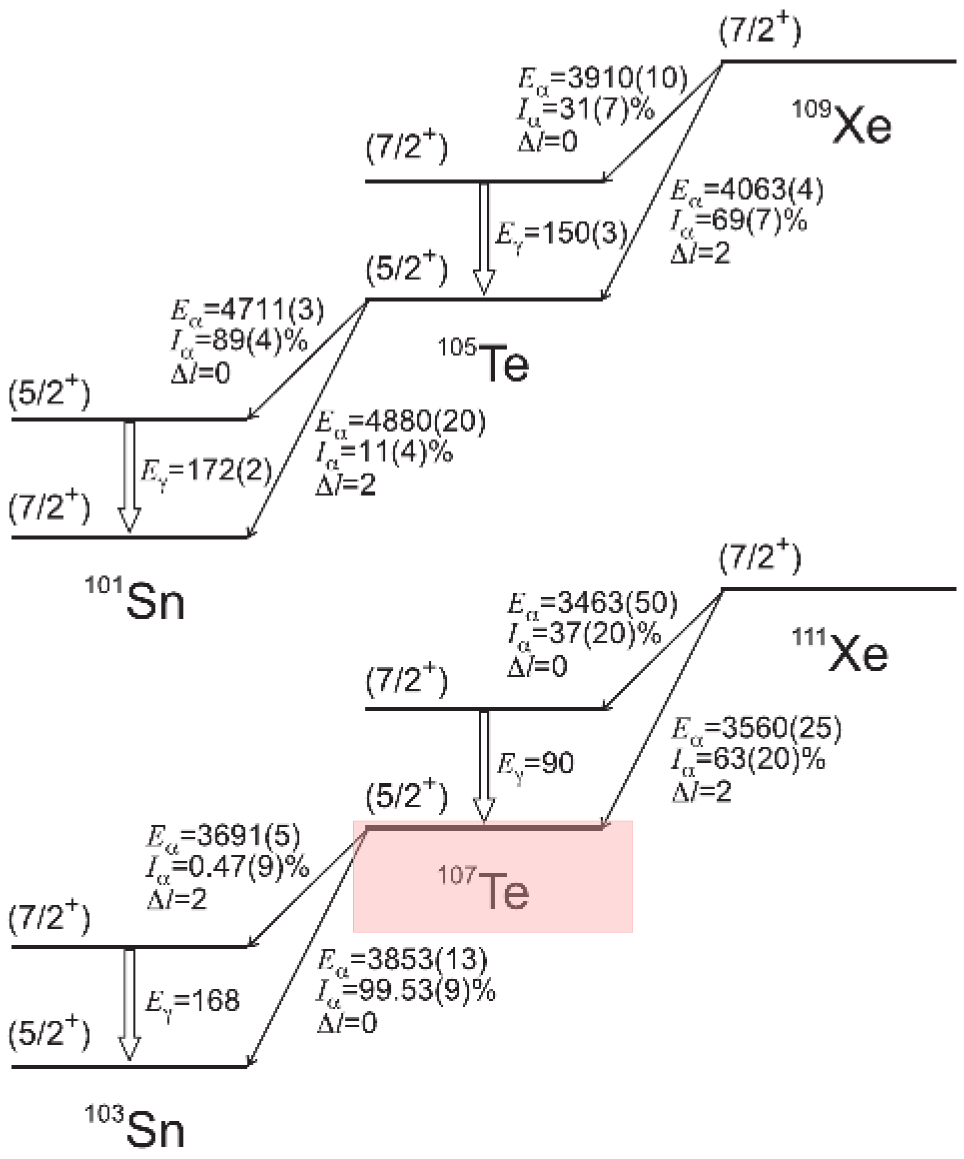
- Octupole deformation : Te, Xe, Ba
- Quadrupole vibrations
- Seniority
- πν interactions
- ..

B. Hadinia et al., *PRC* **72** (2005) 041303 (R)
D.S.Delion, et al., PRC 82 (2010) 024307
A.Illian Sison et al., PLB 848 (2024) 138371

Introduction – SPE ^{100}Sn

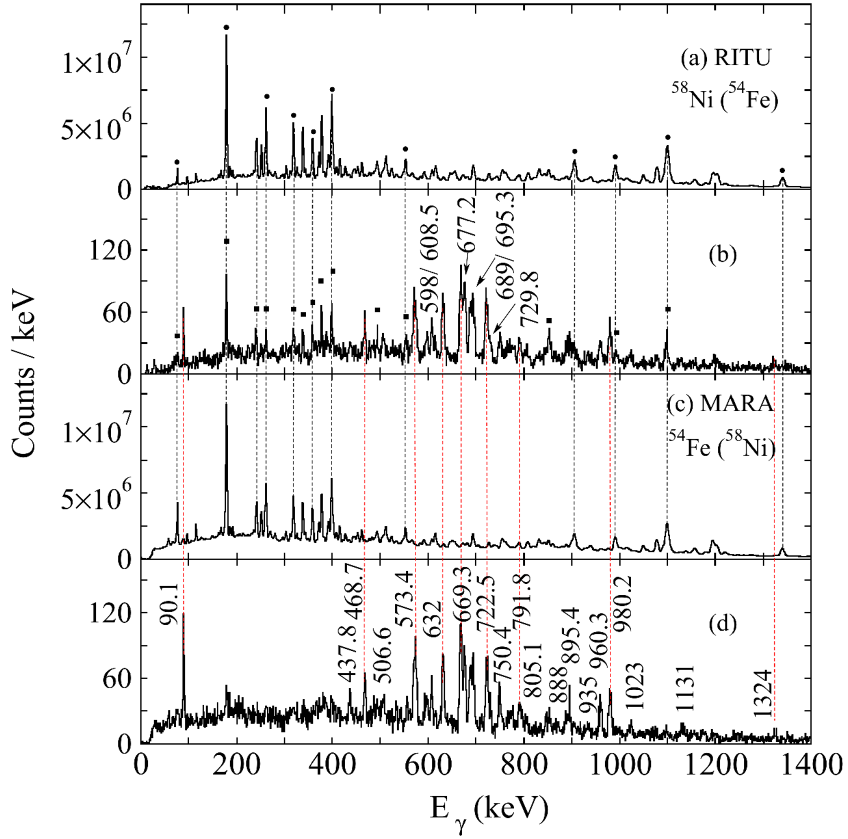
- SPE $d_{5/2}$, $g_{7/2}$:
- Alpha decay chain: ^{111}Xe → ^{107}Te → ^{103}Sn.

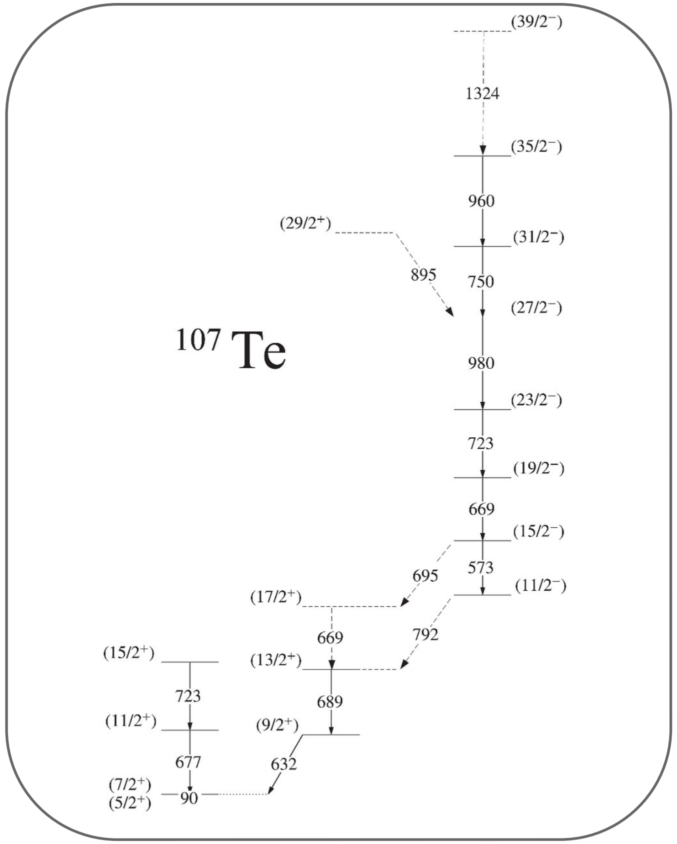


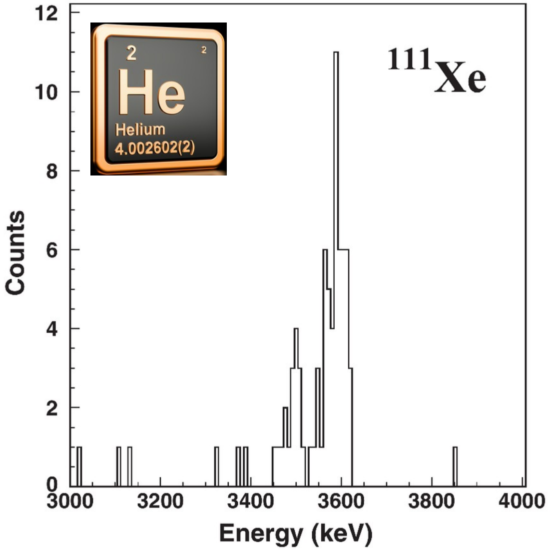


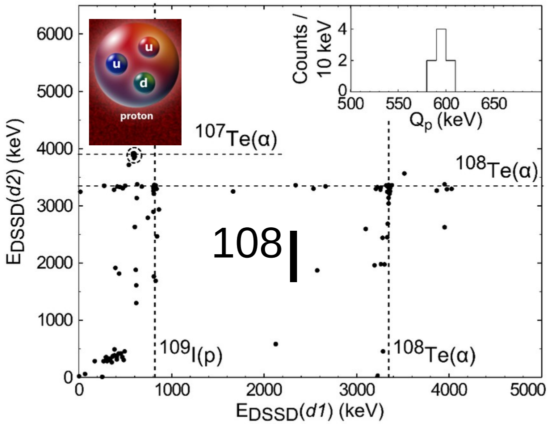
I.Darby et al., PRL 105, 162502 (2010)

Introduction – existing data









In-beam data (FE):
W.Zhang, et al., *PRC104* (2021)
B.Hadinia et al., *PRC 70* (2010)

Decay data:
D.Shardt et al., NPA 326 (1979)
D.Shardt et al., NPA 368 (1981),
R.Cartegni et al., PRC 85 (2012)
L.Capponi et al., PRC 101 (2020)

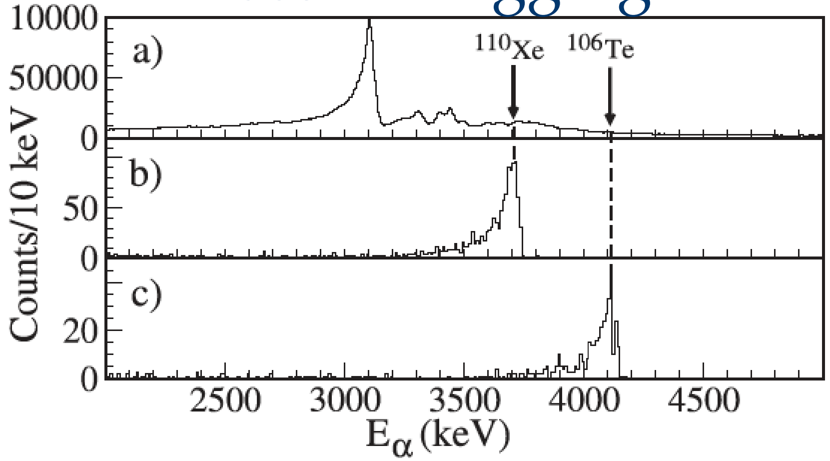
Experimental Setup

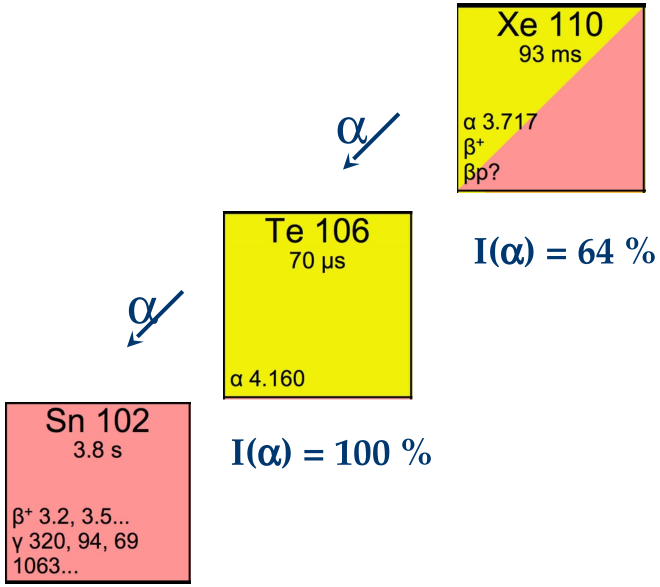
The experiment @ JYFL

Jurogam3 + MARA + MARA focal plane

- $^{54}Fe(^{58}Ni,2n)^{110}Xe$ @ 255 MeV
- I = 3.8 pnA
- 12 days of beamtime
- ^{112}Xe compound → 2n evaporation
- Recoil decay tagging (RDT)

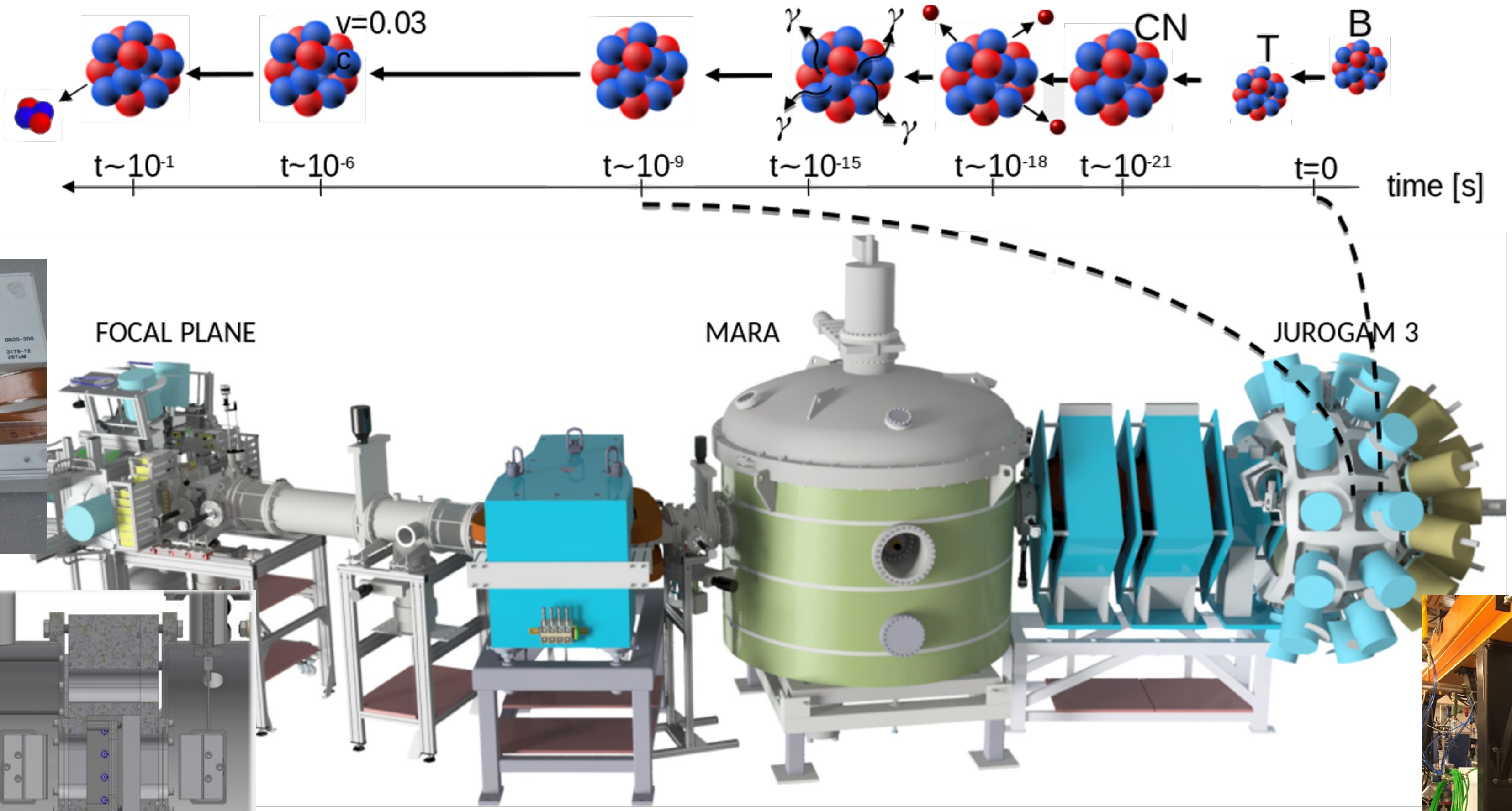
Recoil-α tagging

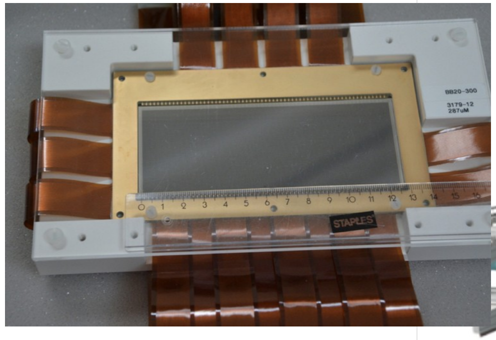


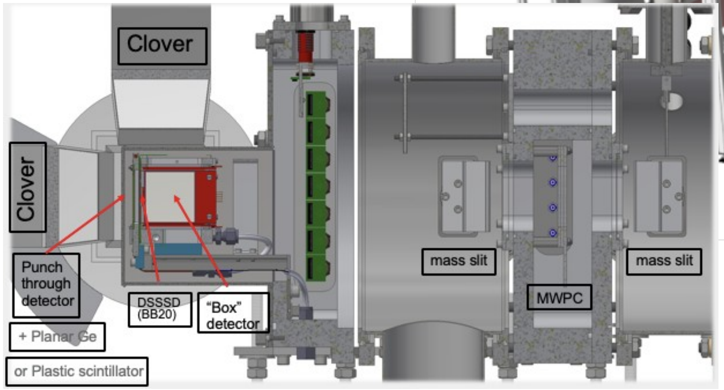


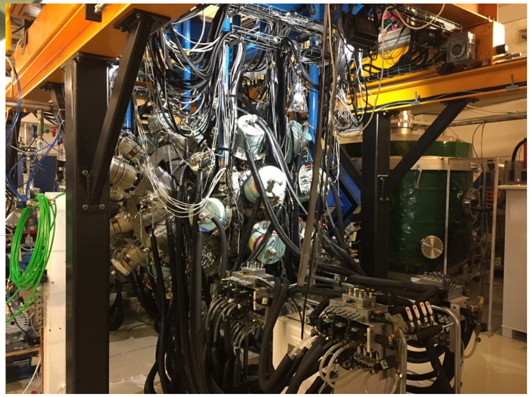
RDT: *detection of prompt γ ray at the reaction site followed by detection of evaporation residue implantation and decay at the focal plane of the recoil separator*

The experimental setup @ JYFL





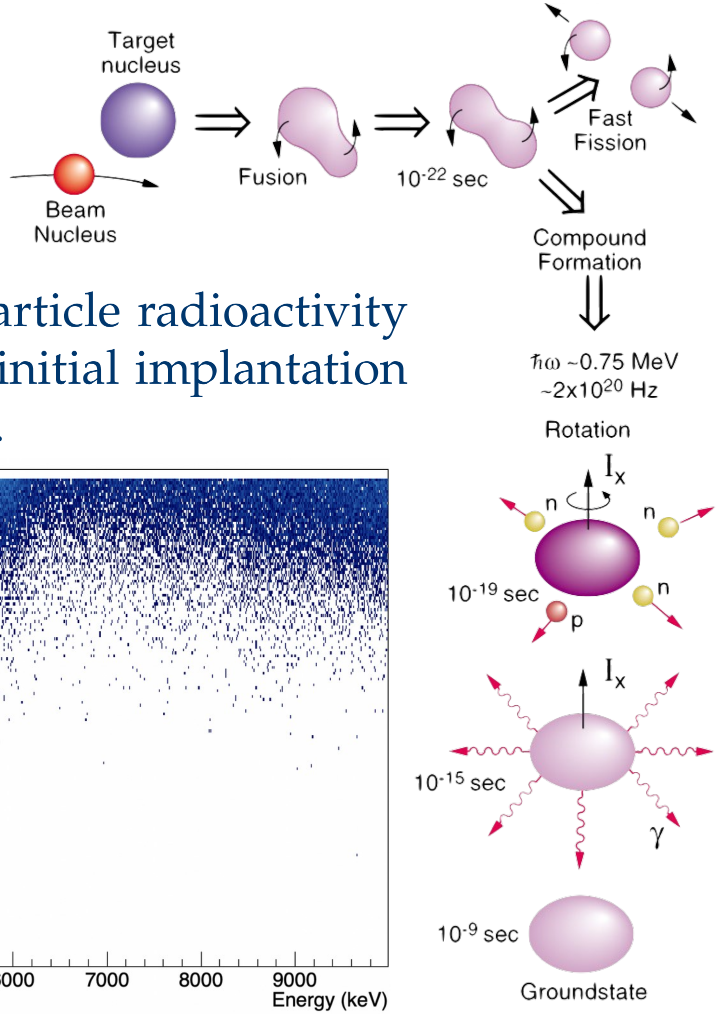


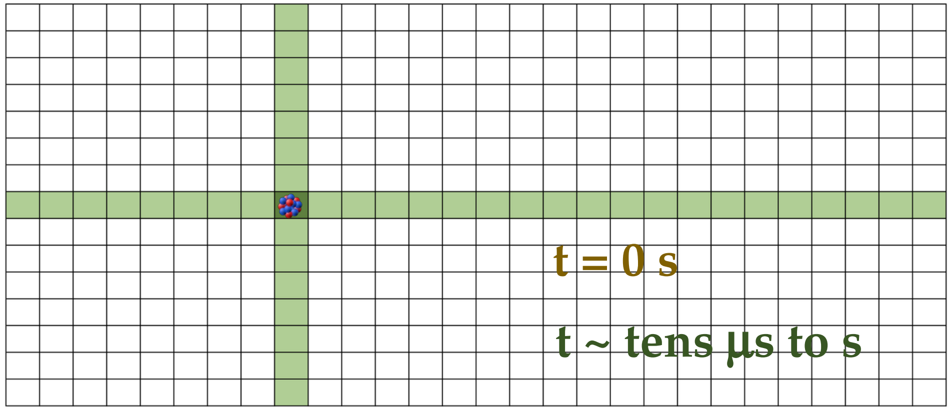


J. Sarén et al., NIMB 266 (2008)

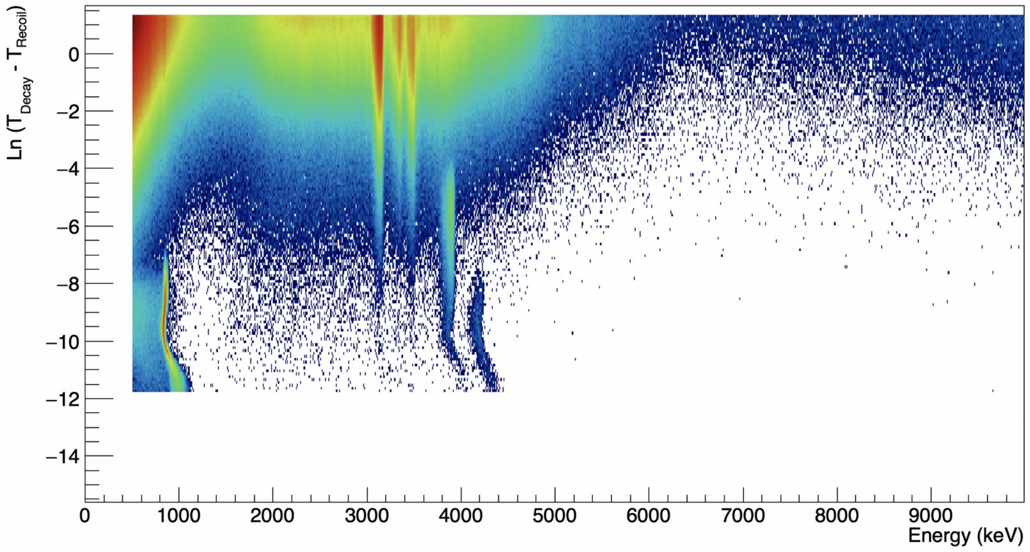
J. Pakarinen et al., EPJA 56 (2020)

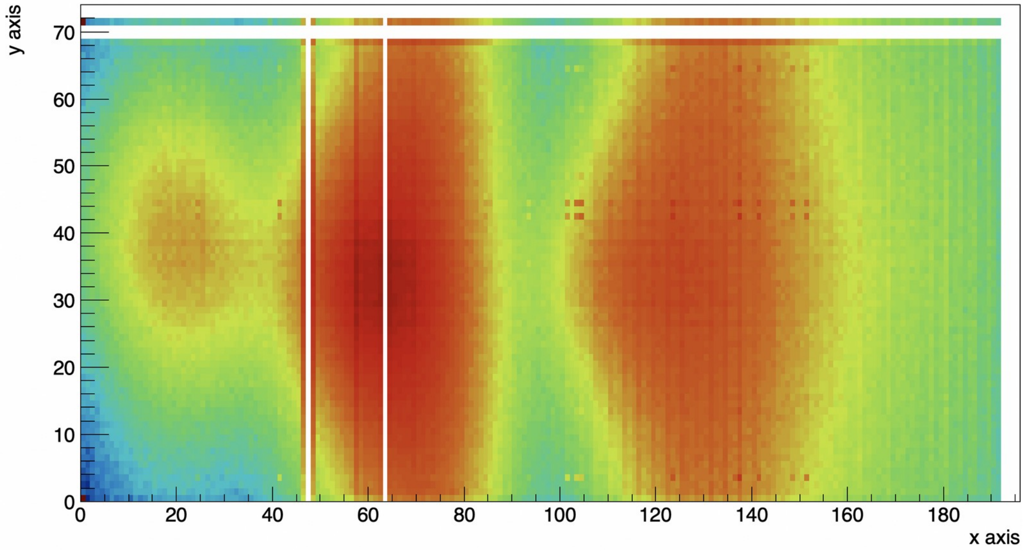
The Recoil-Decay Tagging (RDT) technique





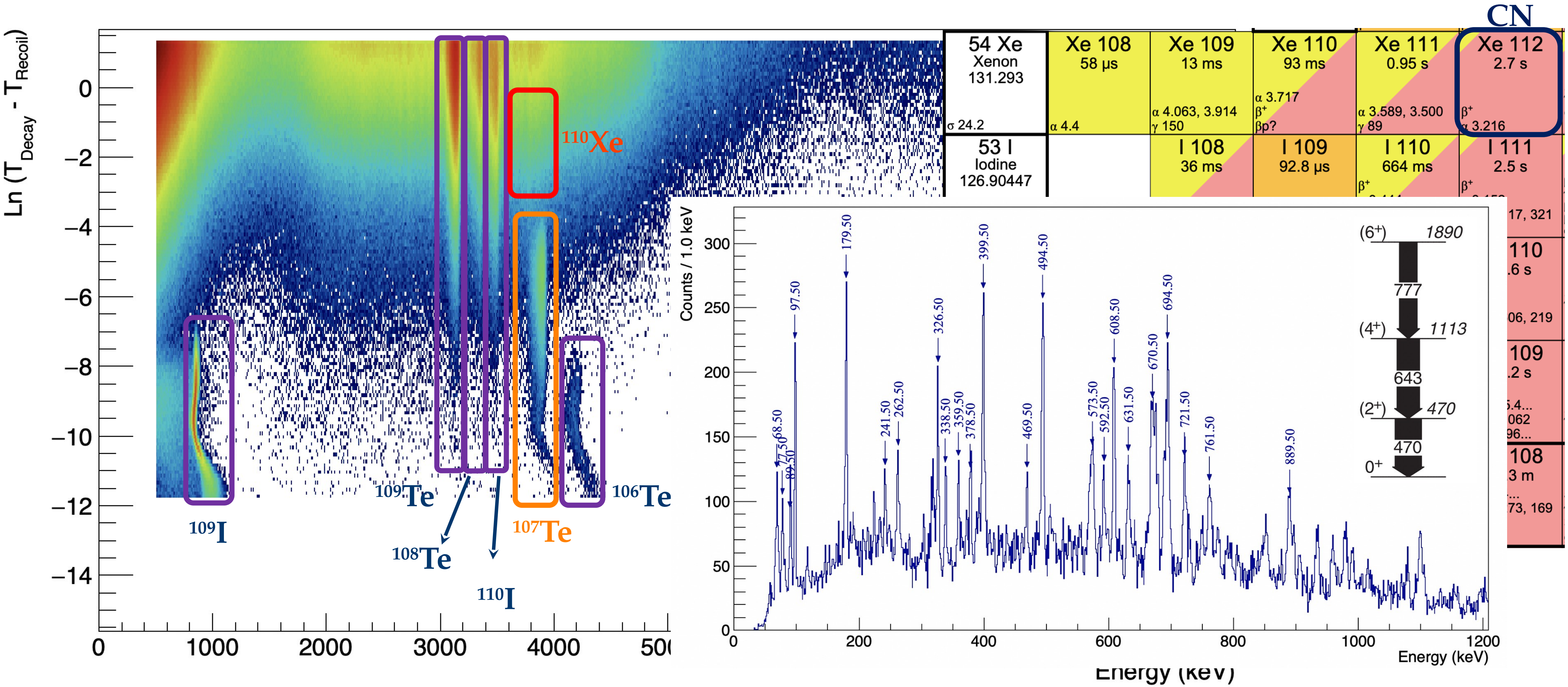
The subsequent charged-particle radioactivity can be correlated with the initial implantation within the same pixel (x, y).





E. Paul et al., *Phys. Rev. C* **51** 78-87(1995).

Identification of ^{110}Xe via RDT



Published Results – ^{110}Xe

Phys. Lett. B 848 (2024) 138371

Contents lists available at ScienceDirect

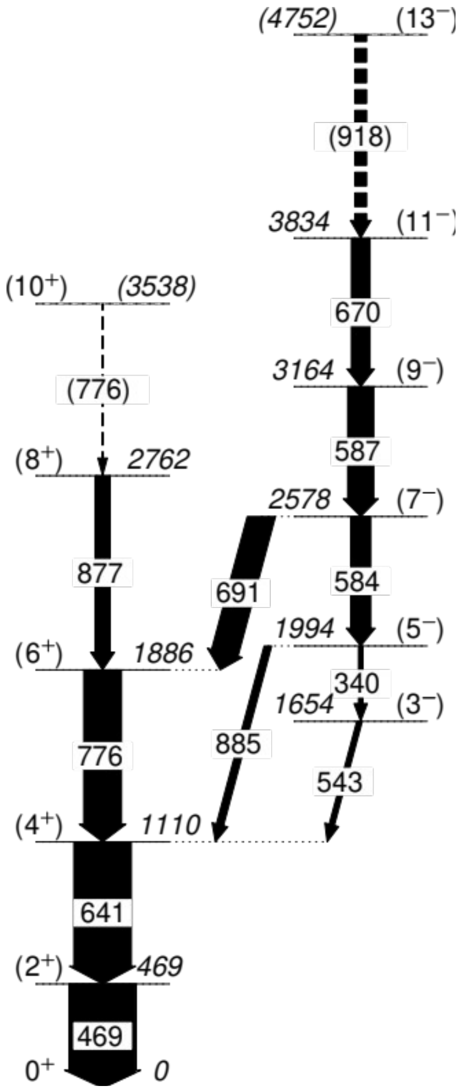
Physics Letters B

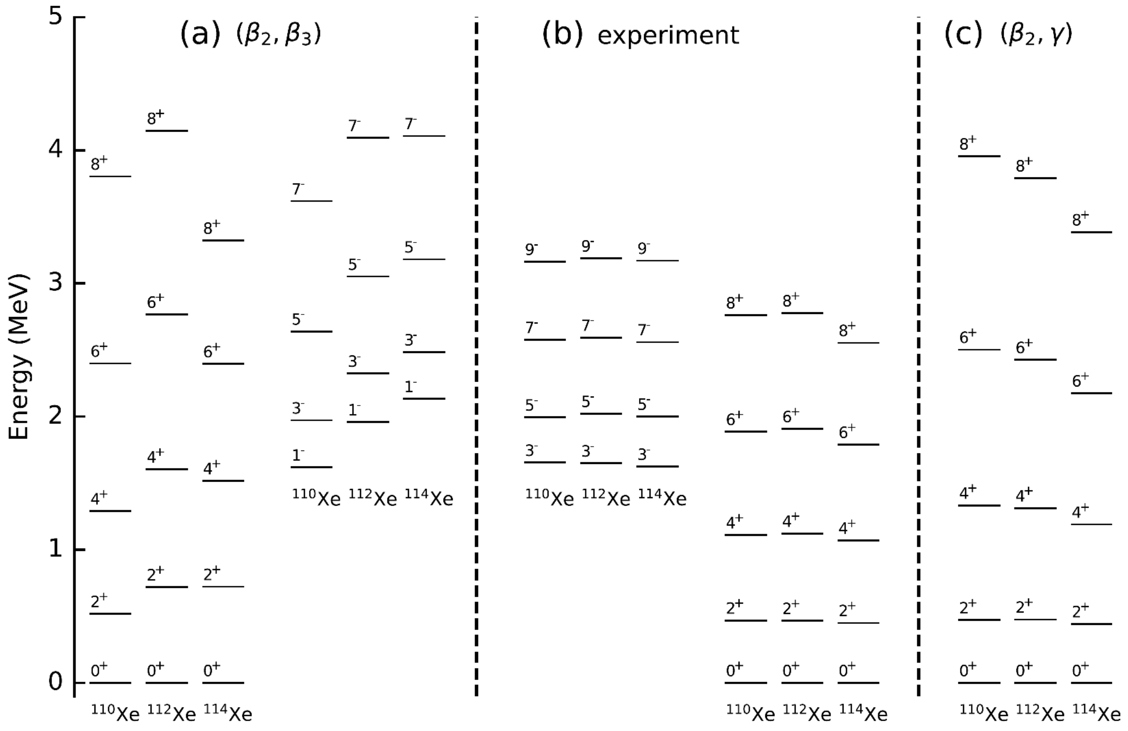
journal homepage: www.elsevier.com/locate/physletb

Letter

Octupole correlations in the N = Z + 2 = 56 ^{110}Xe nucleus

A. Illana [a,b,*], R.M. Pérez-Vidal [c,d,*], D. Stramaccioni [c,e], J.J. Valiente-Dobón [c],

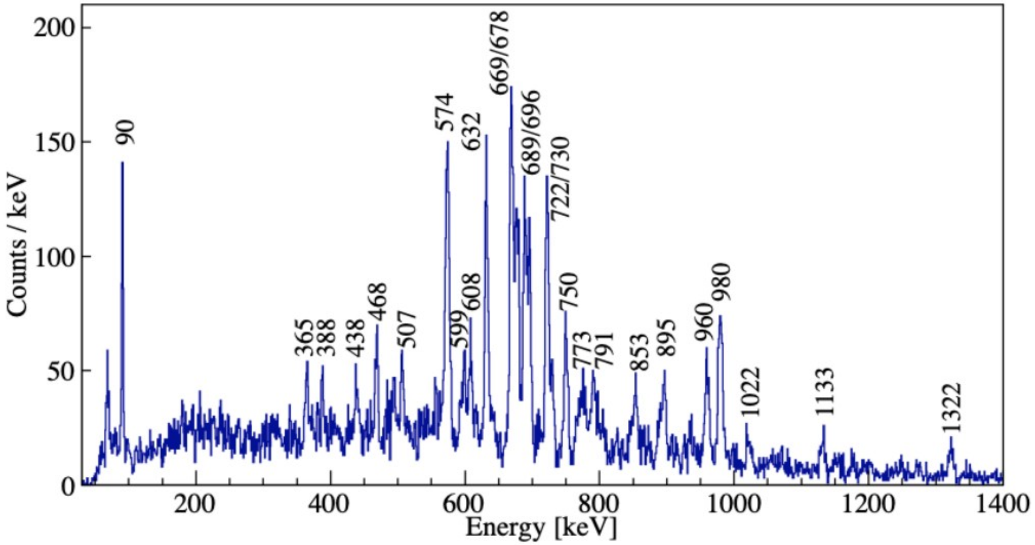


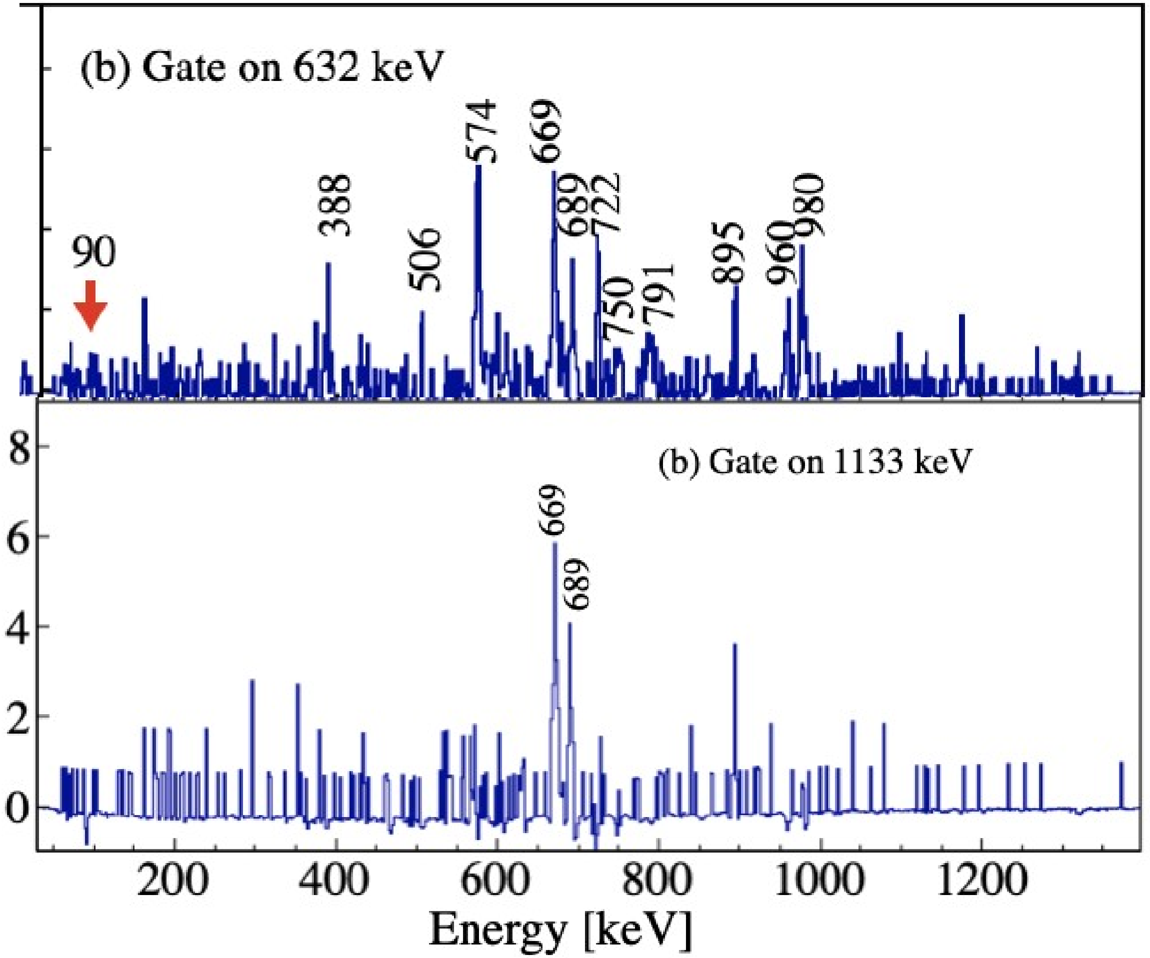


- Theroy: BE3 31 W.u and BE2 56 W.u..
- Theoretical energy levels are stretched wrt theory
- Some correlations still missing

Results

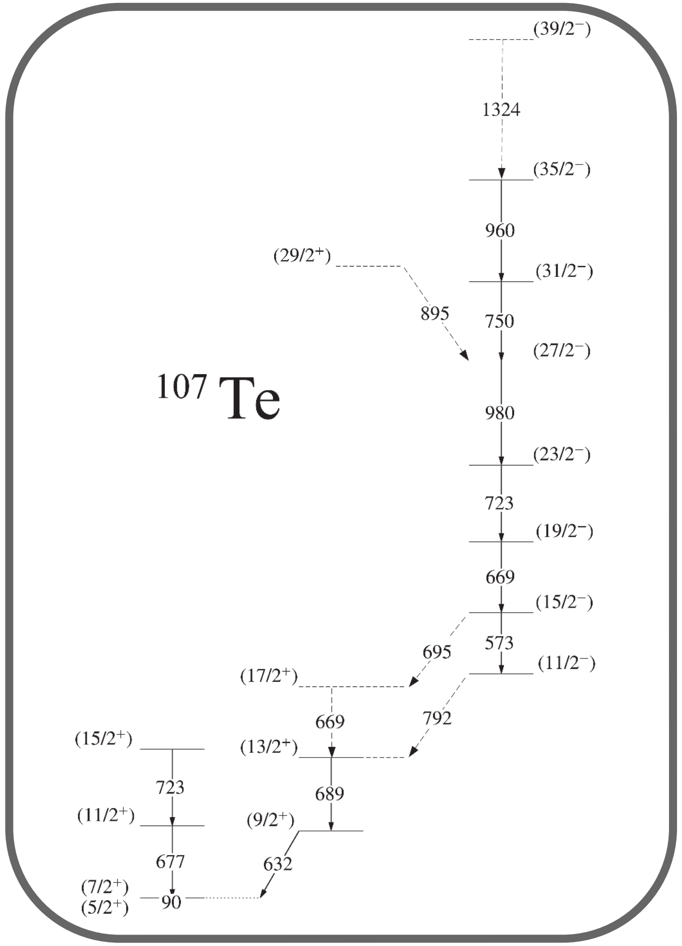
Results – ^{107}Te





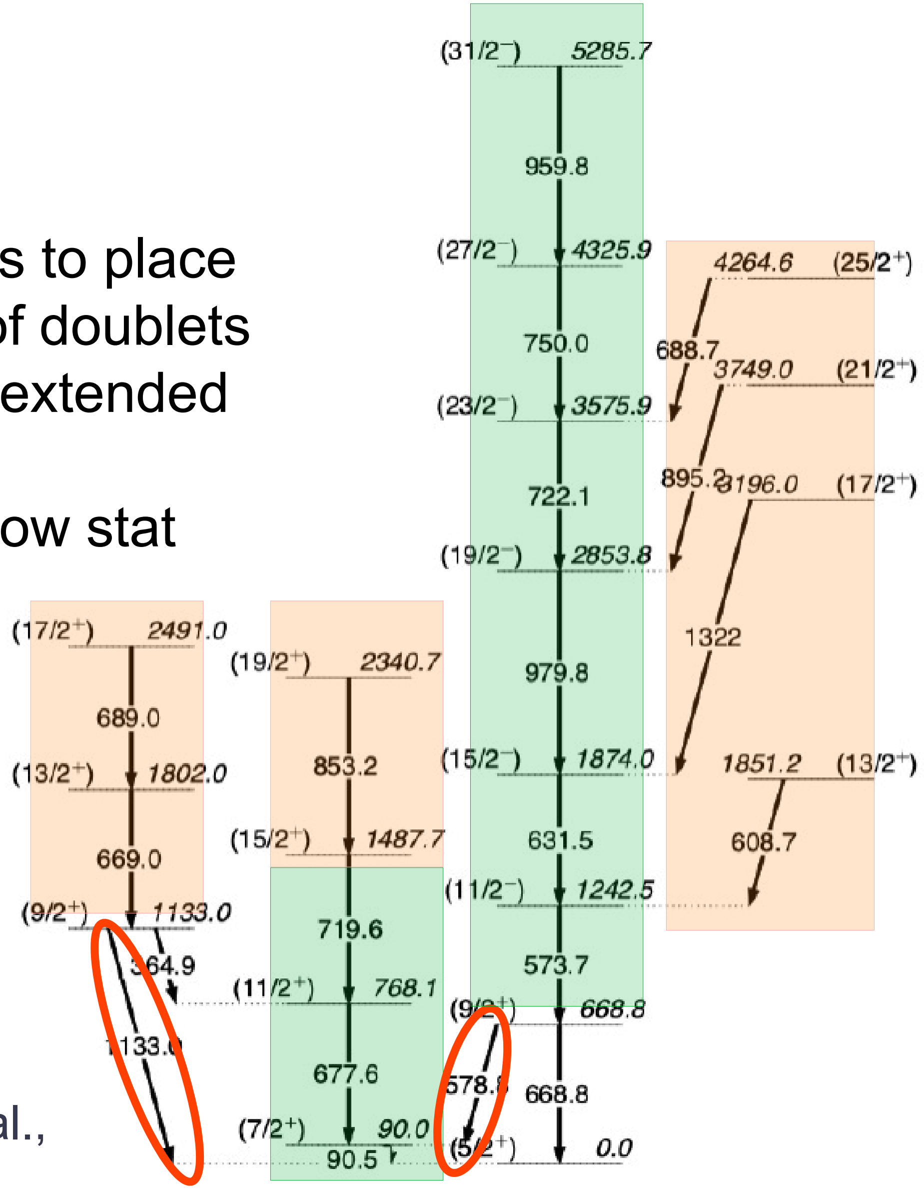
- Jurogam-MARA FP: delayed time coinc
- Residues vs α-decay tag (15 ms > 3τ)
- $\gamma\gamma$ time coincidence (~us)
- Coincidence spectra gated on “strong” transitions were possible.

Results – ^{107}Te level scheme



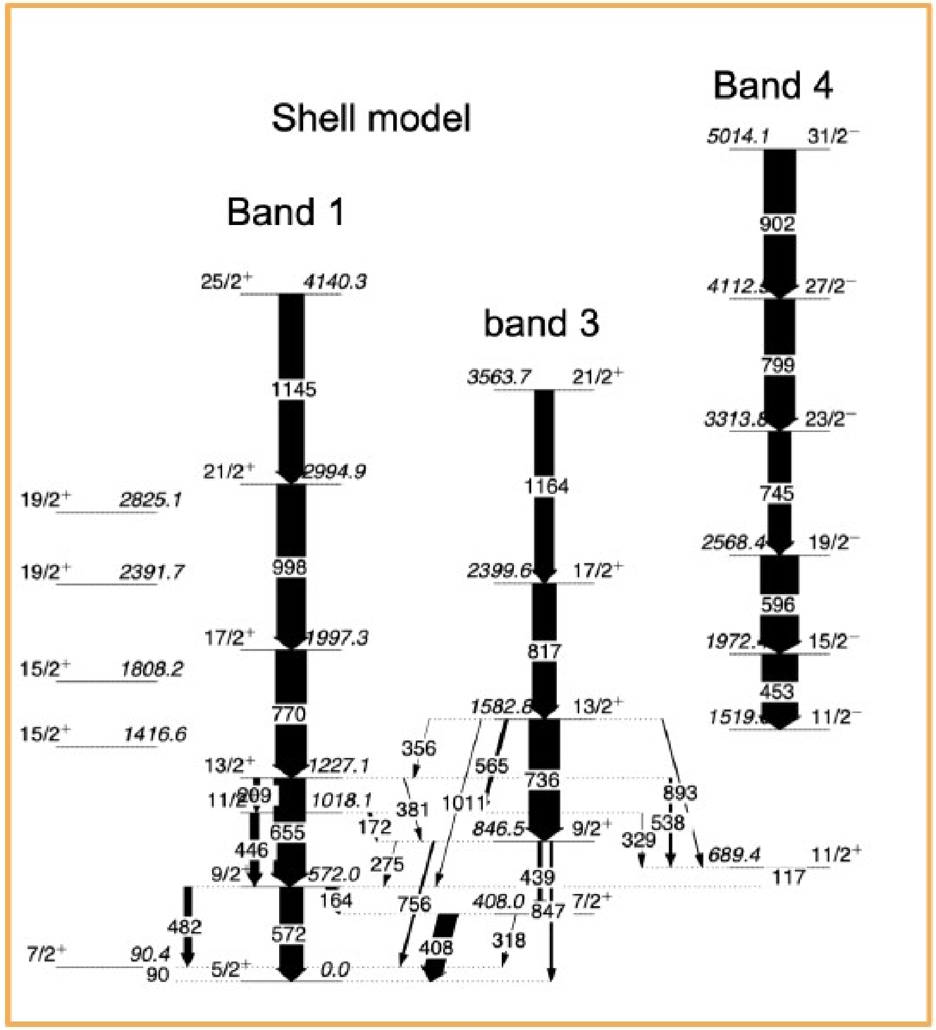
W.Zhang et al., *PRC104* (2021)

- Higher stat, yet some difficulties to place the levels given the presence of doublets
- GS quad. band confirmed and extended
- $h_{11/2}$ band confirmed
- New bands established, DCO low stat
- Sign of an octupole band?



G. Zhang, et al., in preparation

Discussion – ^{107}Te: comparison with theory



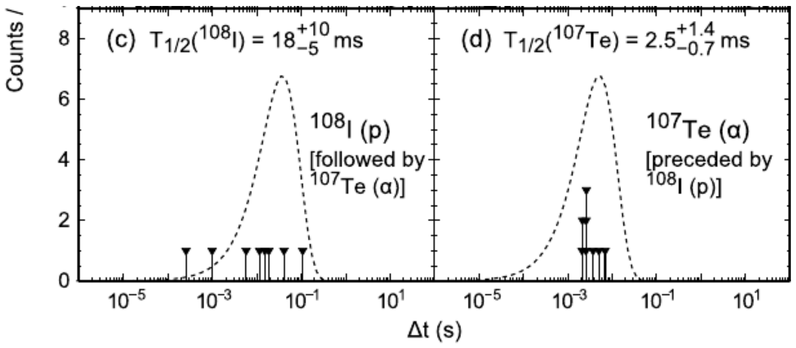
- SM: GCN50:82, valence *gds*+$h_{11/2}$
- ..Not so bad agreement with exp
- Indications of collectivity (BE2 strength in black arrows)
- ($5/2^+$) proposed for the gs band.

- *[..] 5/2+ level contains ~30% neutron d5 coupled to 0+ proton, same for the 7/2+ but with a neutron in g7 (~30%). Overall occupation is 4 particles and the odd neutron occupies the higher/lower orbital*
- *... $d_{5/2}$ and $g_{7/2}$ orbitals are closely spaced (but position very much dependent on the shell model, ie PM. Jodidar PRC111,2025)*

Discussion – decay to ^{107}Te

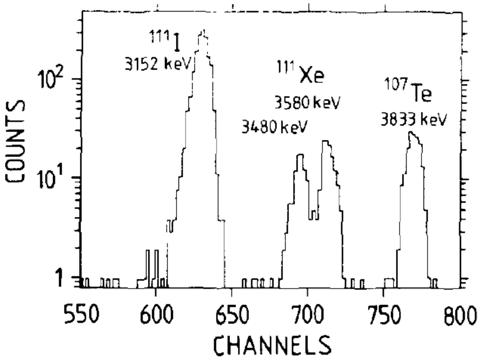
^{108}I proton decay → 107te

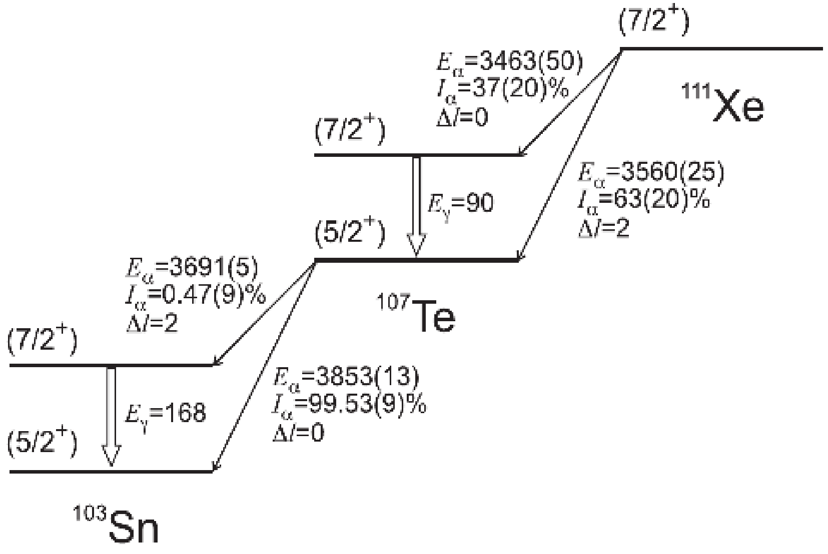
K.Auranen et al., PLB 792 (2019)

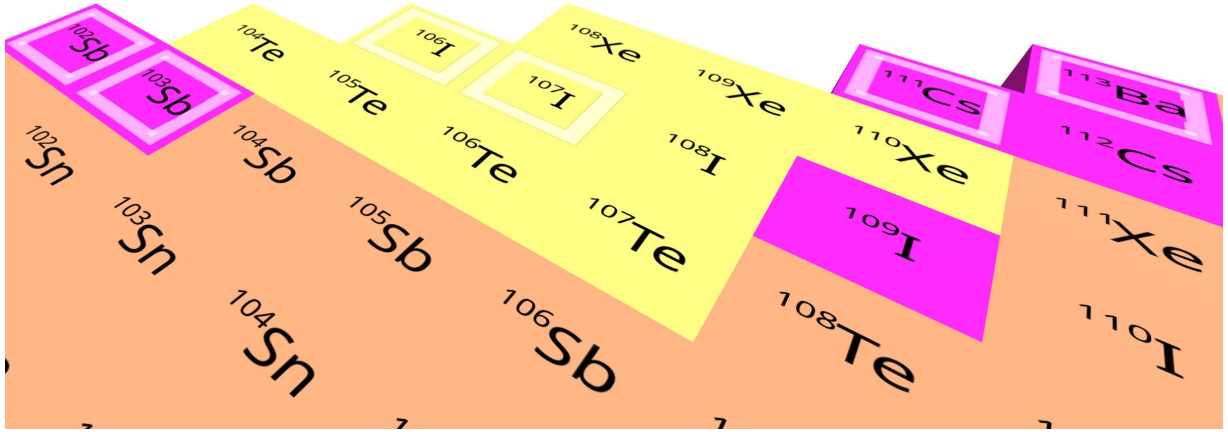


^{111}Xe α decay → ^{107}Te

D.Shardt et al., NPA 326 (1979)





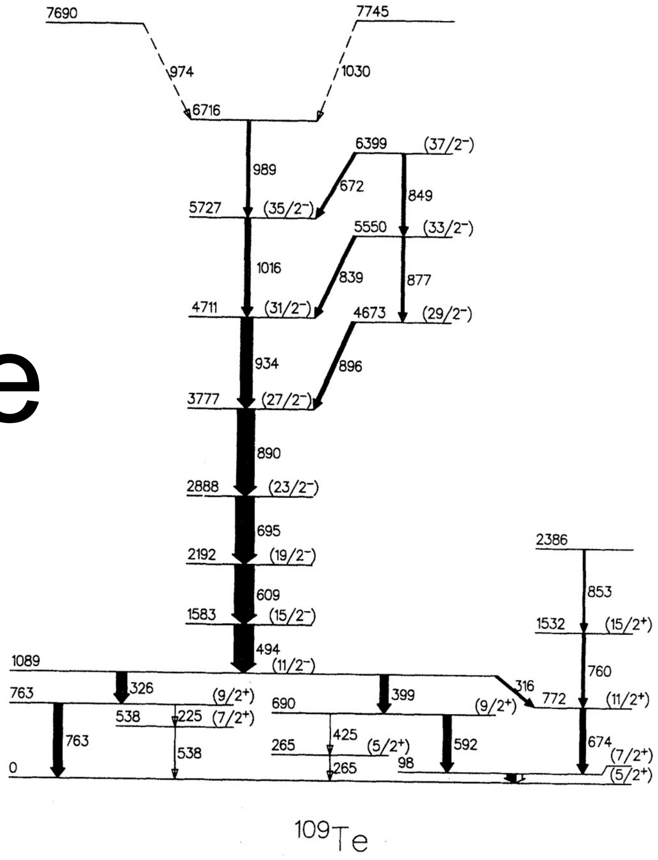


- Abundant α-decay data: b_α and δ^2 relying on the assumed J^π_{gs} in ^{111}Xe
- Proton decay: [..]strong admixture of $g_{7/2}$ and $d_{5/2}$

the first excited states in ^{107}Te, (5/2$^+$) and (7/2$^+$), are "proposed" based on systematics and theory

Discussion – $^{109\text{-}111}$Te systematics: $5/2^{+}$ and $7/2^{+}$

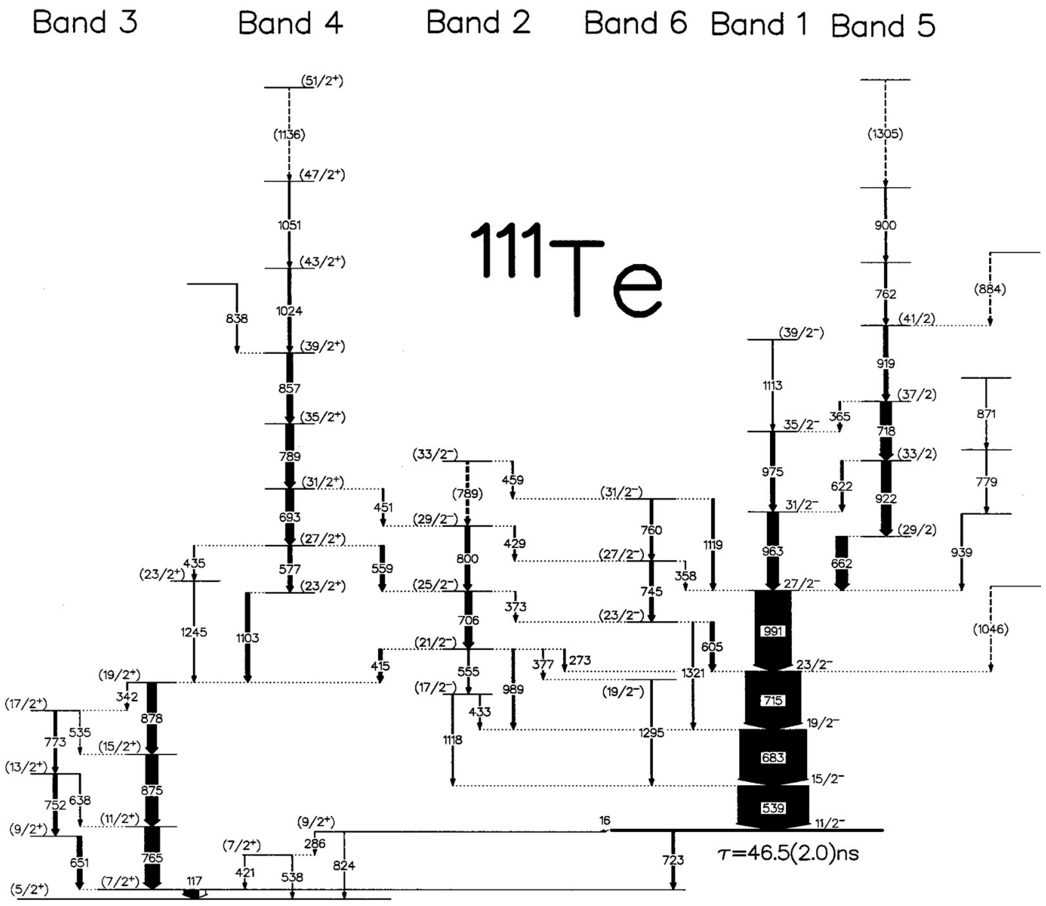
^{109}Te



- Tentative J^{π} assigned given DCO ratio, (ΔI difference based on a normalized ratio of γ-ray angular intensity)
- In ^{109}Te (5/2+) proposed base on theory and systematics
- Ambiguity in Dombrádi et al., 98 keV DCO compatible with mixed M1/E2 or stretched E2, unclear the choice in the paper. No plots shown.
- While in G.de Angelis et al., the lowest lying transition given of E2 character. But no isomer?

Zs. Dombrádi et al., PRC 51 (1995)
G.De Angelis et al, PLB 437 (1998)

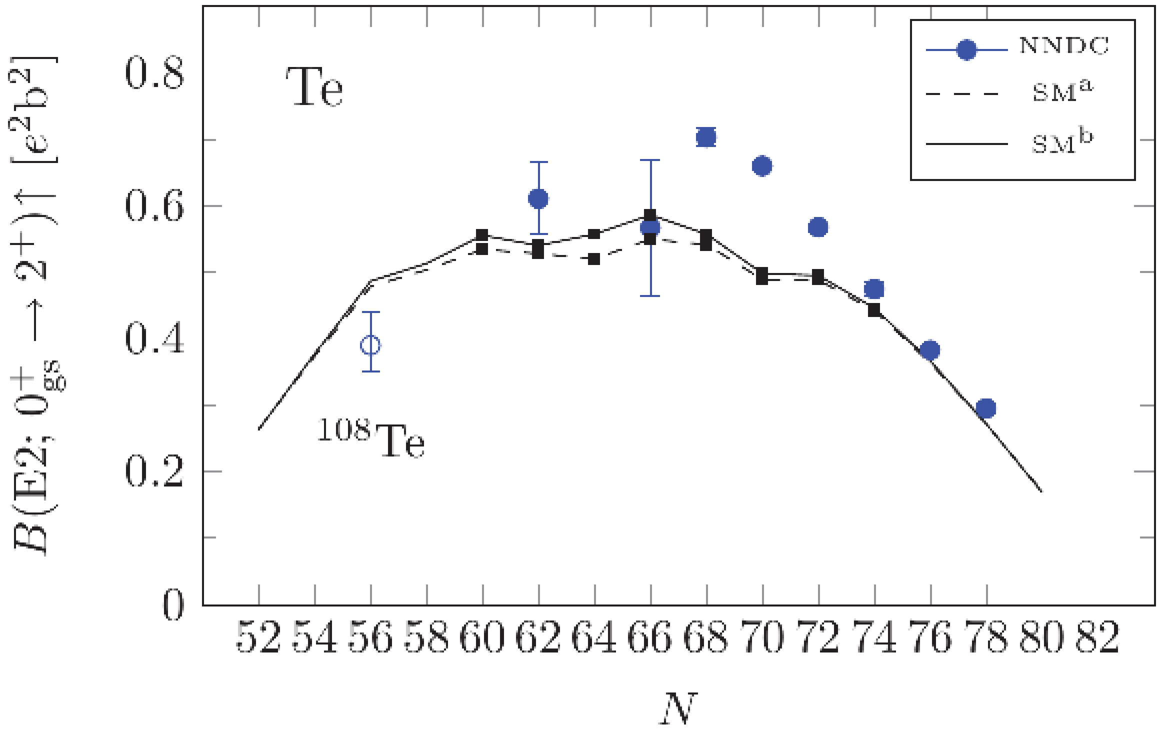
Discussion – $^{109\text{-}111}$Te systematics: $5/2^{+}$ and $7/2^{+}$



K. Starosta et al., Phys. Rev. C 61, 034308 (2000).
G. J. Lane et al., Phys. Rev. C 55, 1559 (1997).

- The 117-keV DCO is consistent with $\Delta I \leq 1$ and no plots shown.
- In ^{111}Te: (5/2+) is proposed
- A stronger argument the for spin assignment in ^{111}Te seems the $h_{11/2}$ ~50 ns isomer decay towards the gs band
- ... however such $h_{11/2}$ isomer in not present in ^{107}Te
- $^{113\text{-}115}$Te, gs is a well established $7/2^{+}$

Discussion – ^{108}Te lifetime



T. Bäck et al., Phys. Rev. C 84, 041306(R) (2011).

- Calculations performed with two sets of single particle energies, ε_{sp} . In the first set, the values for ε_{sp} were taken from Banu et al.. In the second set, the new result in Darby et al. was taken into account by setting ε_{sp} (g7/2) = 0 and ε_{sp} (d5/2) = 172 keV.
- [..] the inversion of the d5/2, g7/2 orbitals in the Te calculation, does not create any substantial effect.

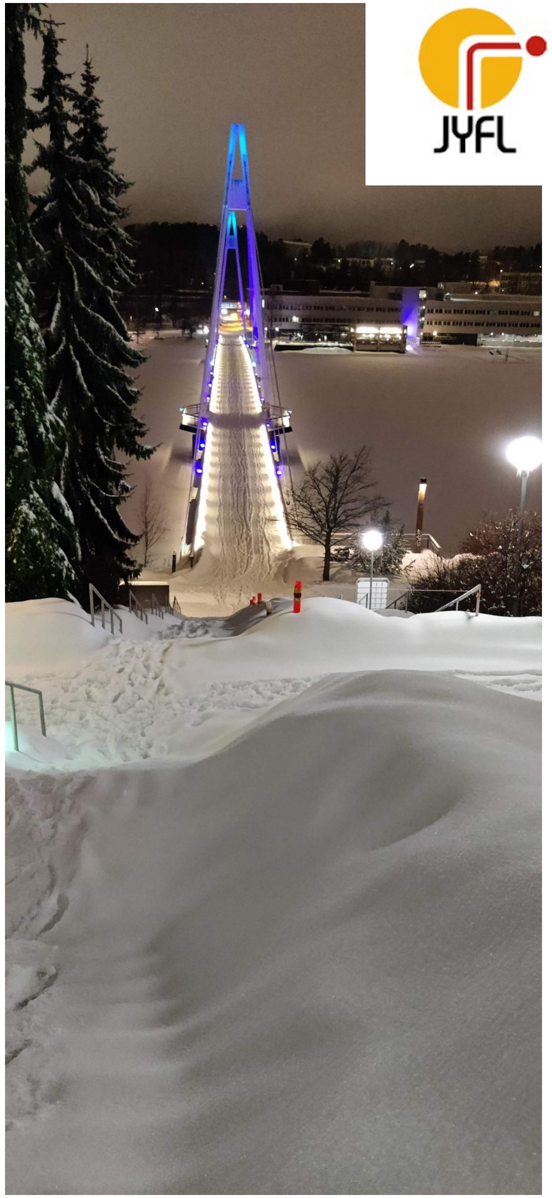
A. Banu et al., Phys. Rev. C 72, 061305(R) (2005).

I. Darby et al., Phys. Rev. Lett. 105, 162502 (2010).

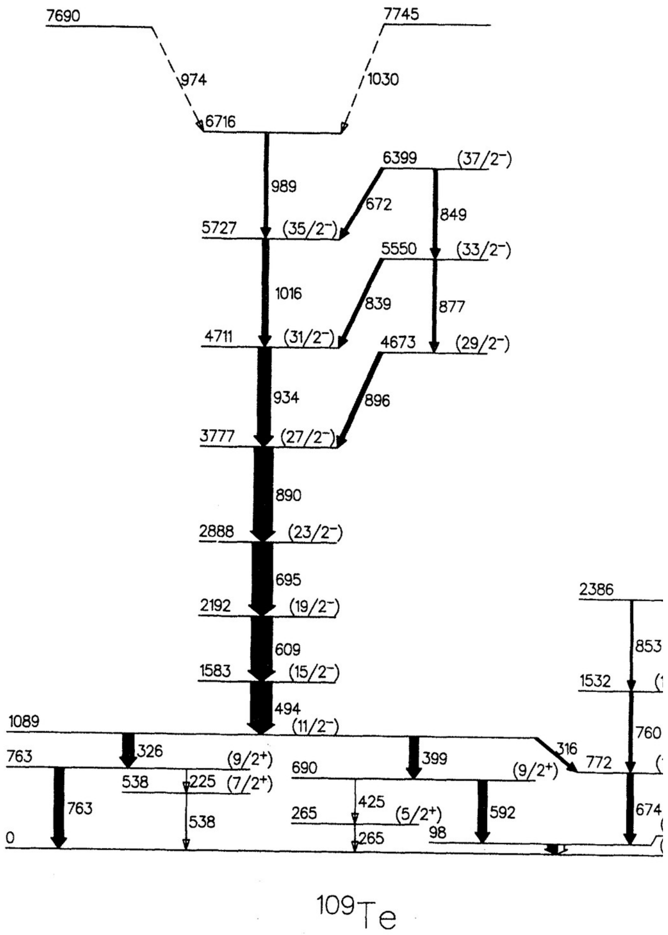
Conclusions and perspectives

- Results from JYFL exp populating (^{110}Xe and) ^{107}Te.
- Level scheme extended in ^{107}Te and SM calculations done, indication of collectivity and draft in preparation.
- First low-lying excited states relying on systematics, which seems to indicate a swap of $5/2^{+}$ and $7/2^{+}$ between ^{109}Te and ^{113}Te. Attempt to extract AD from our ^{107}Te data.
- Probably transfer/ko or lifetime/Coulex experiment in light o-e Te isotopes would contribute to establishing the J^{π}
- During spring this year a lifetime measurement is planned with AGATA@ LNL on the light Te-I-Xe

Thanks!



BACKUP



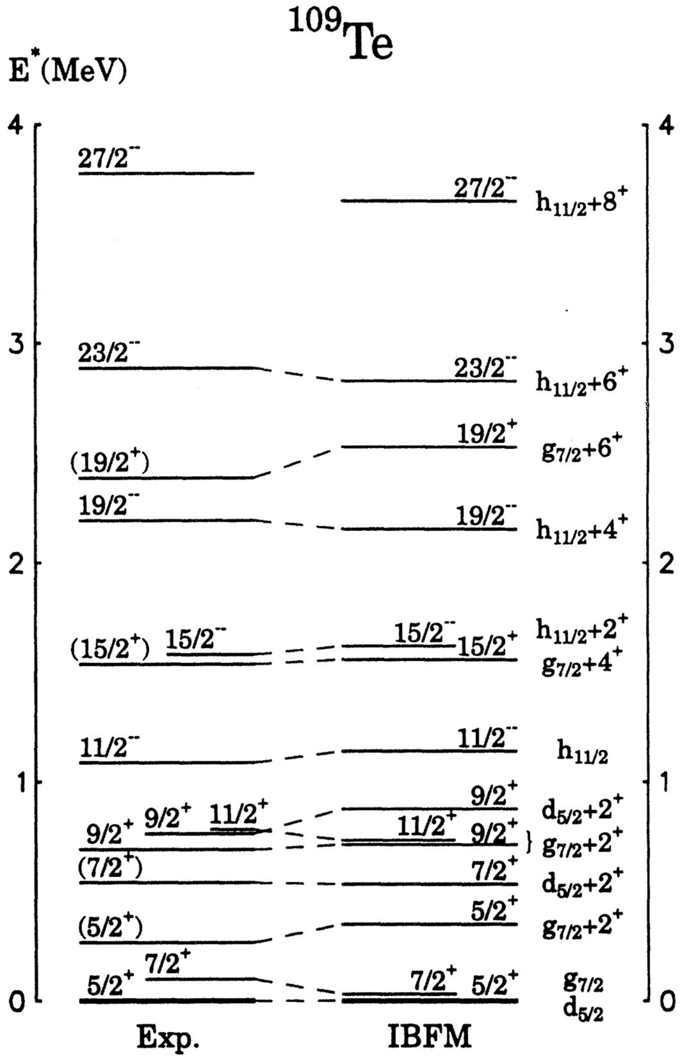


FIG. 4. Comparison of the experimental level scheme with the theoretical calculations based on the interacting boson-fermion model. On the right hand side of the figure the main components of the calculated wave functions are also given.

= $\frac{I_\gamma(143°)}{I_\gamma(79°)+I_\gamma(101°)}$ shown in Table I were used to deter-
ıe the angular momentum transferred by the γ rays.
;he case of weak transitions the ratios R had too large
ɔrs to draw definite conclusions. Even in the case of
ɔng transitions there remains some ambiguity, as the
ıe ratio can correspond to, e.g., a $\Delta I = 2$ stretched
or a $\Delta I = 0$ mixed $M1/E2$ transition with appropri-
mixing ratio, or similarly, the ratio can be the same
a pure $\Delta I = 0$ and a mixed $\Delta I = 1$ transition. In the
.lysis we always assumed $\Delta I > 0$. According to the-
tical estimates for stretched $E2$ transitions $R \approx 1.5$
l for stretched dipole transitions $R \approx 0.8$.

G. de Angelis et al.r Physics LettersB 437 (1998) 236–242

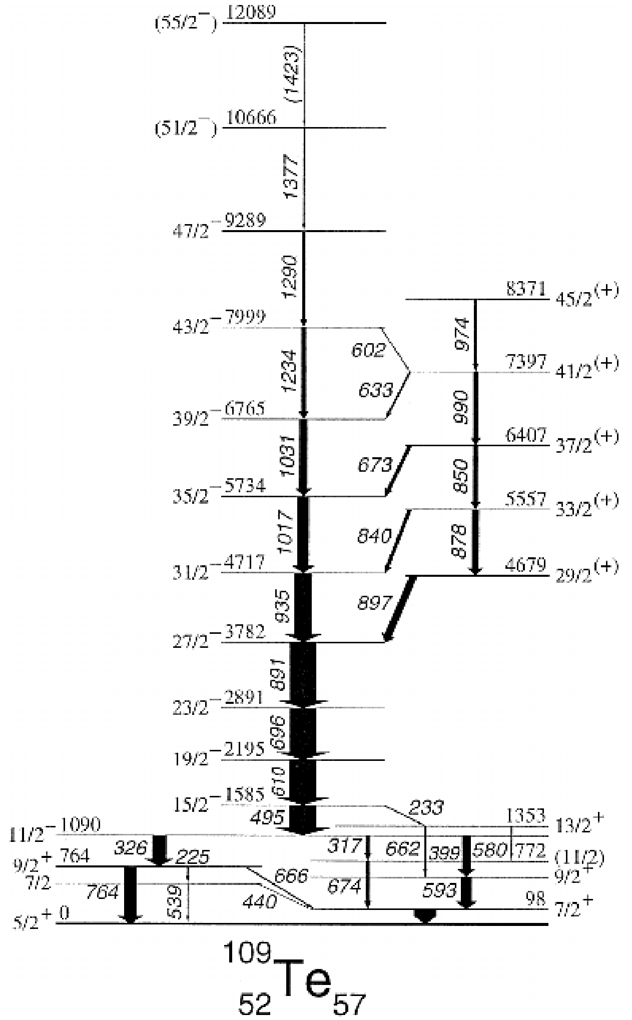
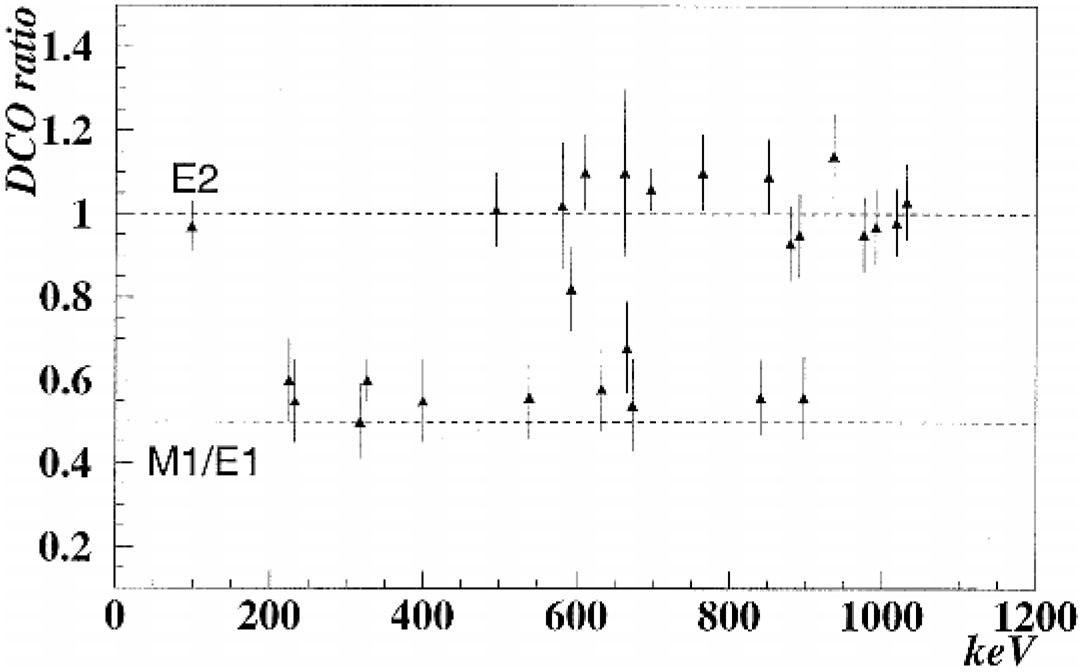
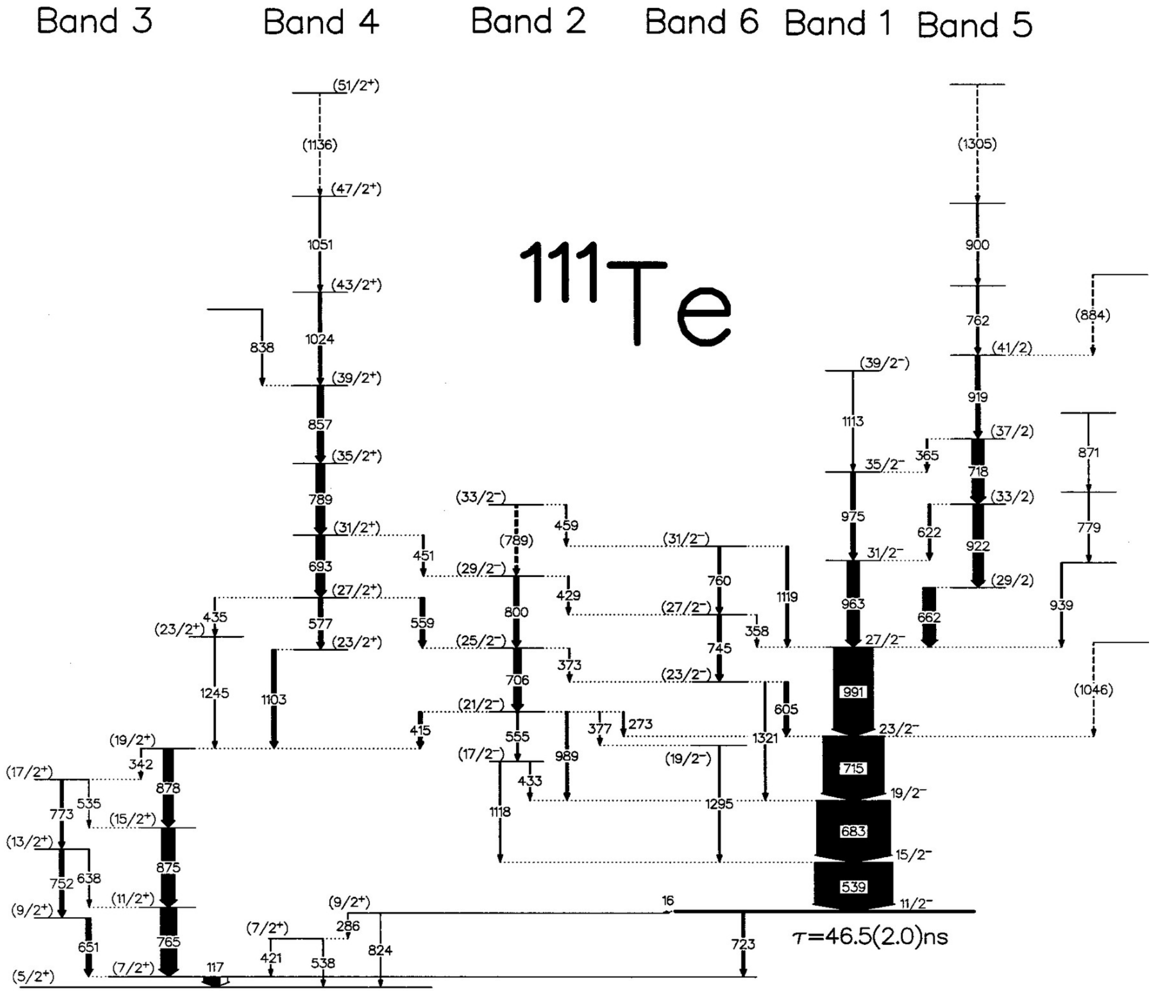


Fig. 2. Proposed level scheme of [109]Te. The energy labels are given in keV. The widths of the arrows are proportional to the relative intensities.



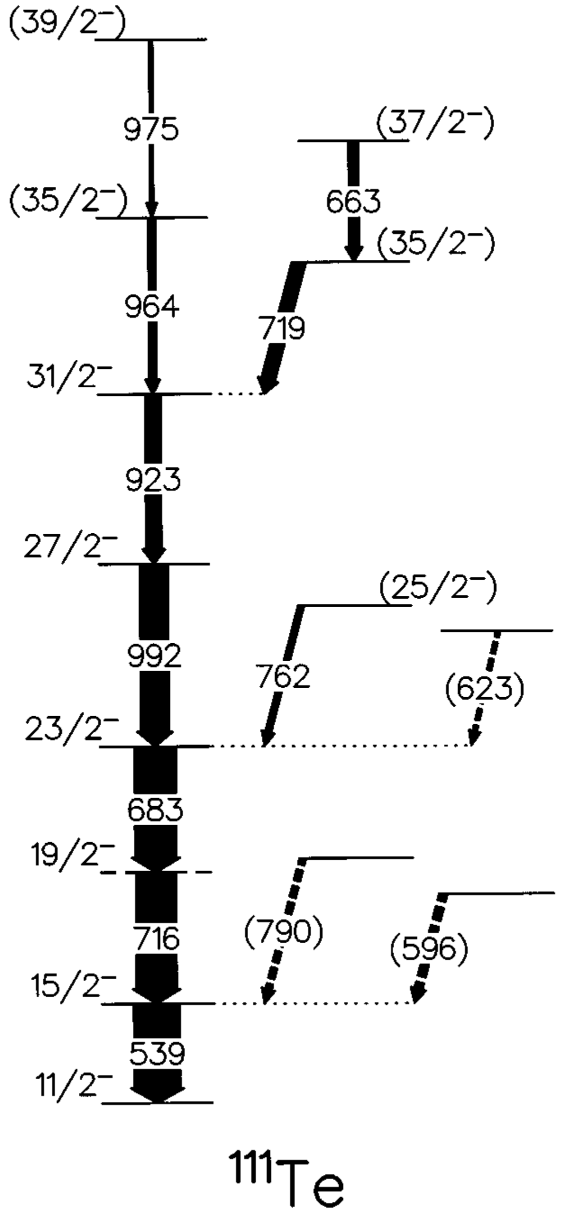


K. Starosta et al., Phys. Rev. C 61, 034308 (2000).

The absolute spin values for these states are pro-
posed on the basis of the multipolarity assignments for the
transitions connecting bands 3 and 4 to band 2.

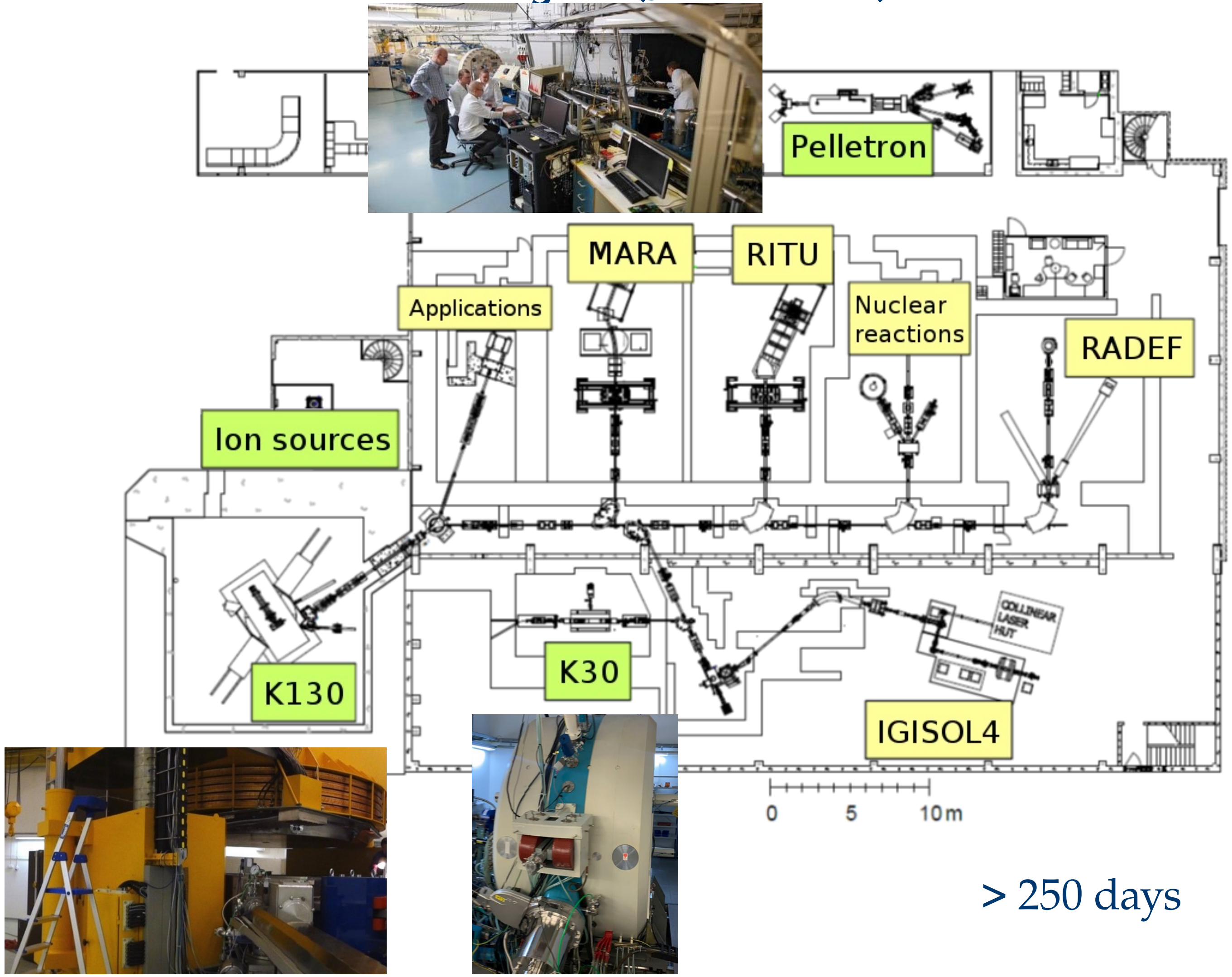
The 117 keV transition has a DCO ratio consistent with Al<1 which suggests a (5/2+) spin for the state with the lowest energy observed in this experiment. A ground state spin of (5/2+) in 111Te was suggested in Ref. [10] and adopted in Ref. [11]. The value is also consistent with the (5/2+) ground state spin of 109Te proposed in Refs. [7,8]. It should be noted, however, that (7/2+) was proposed as the ground state spin in 113Te [12].

G. J. Lane et al., Phys. Rev. C 55, 1559 (1997).



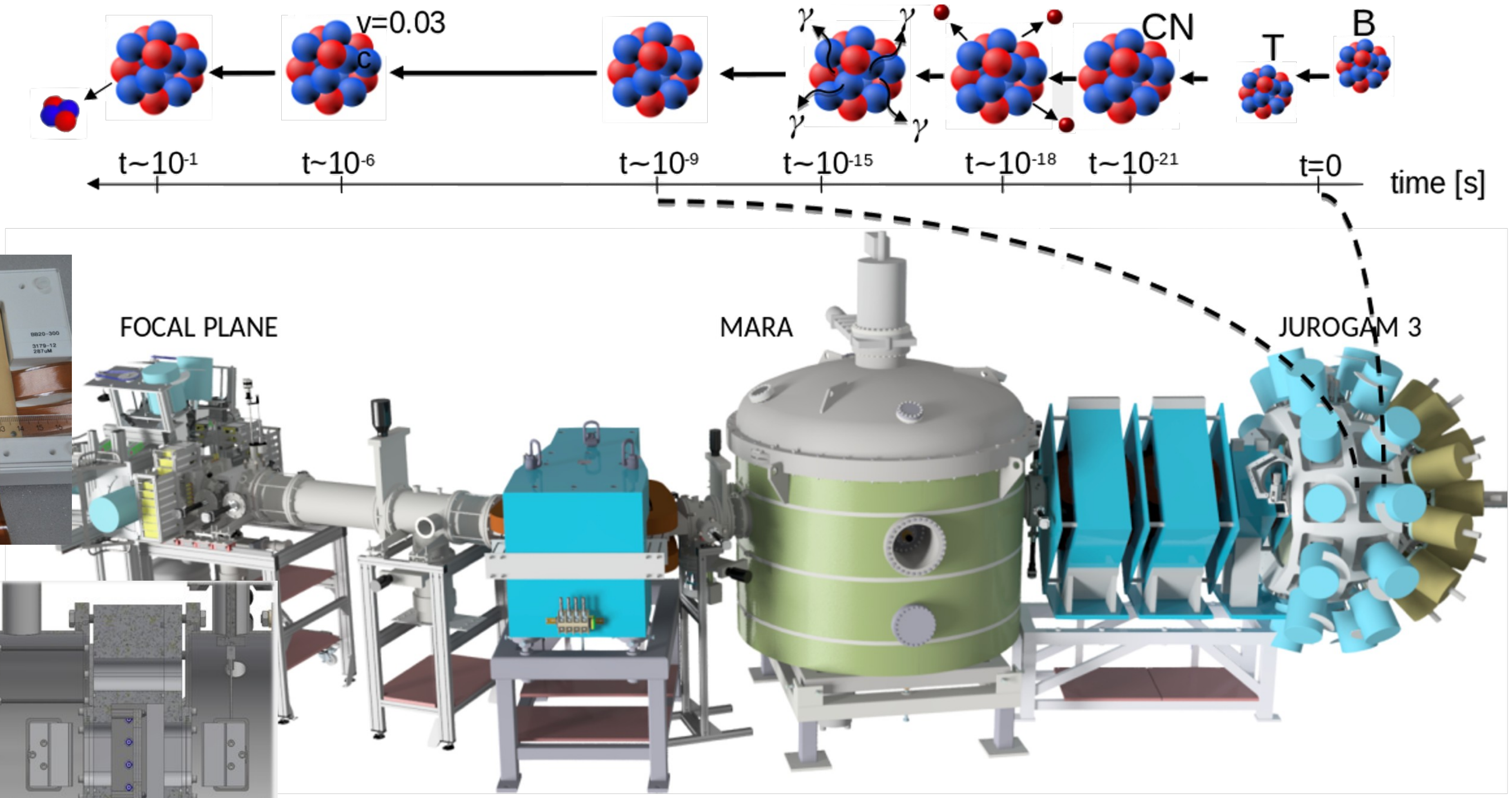
It is, however, possible that these g rays [116 keV] are due to vibrations built upon the **g7/2 quasineutron state**, as is observed in 109Te.

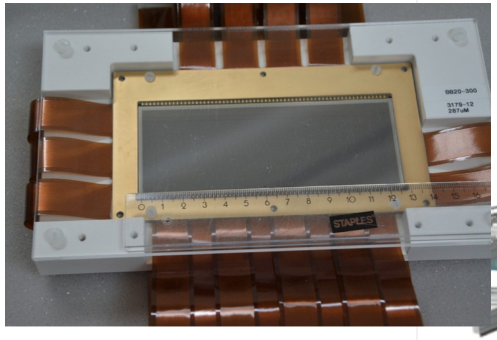
JYU Accelerator Laboratory (JYFL)

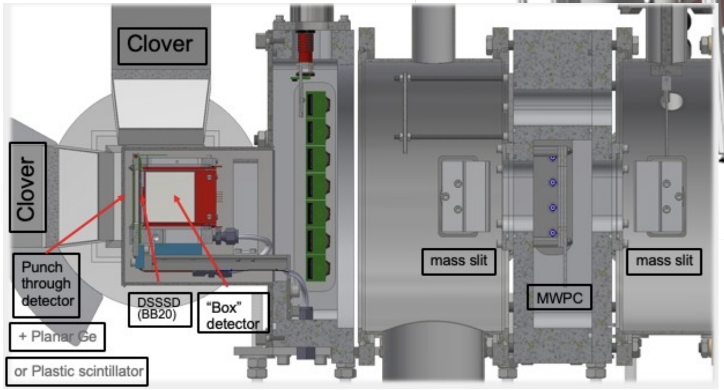


> 250 days

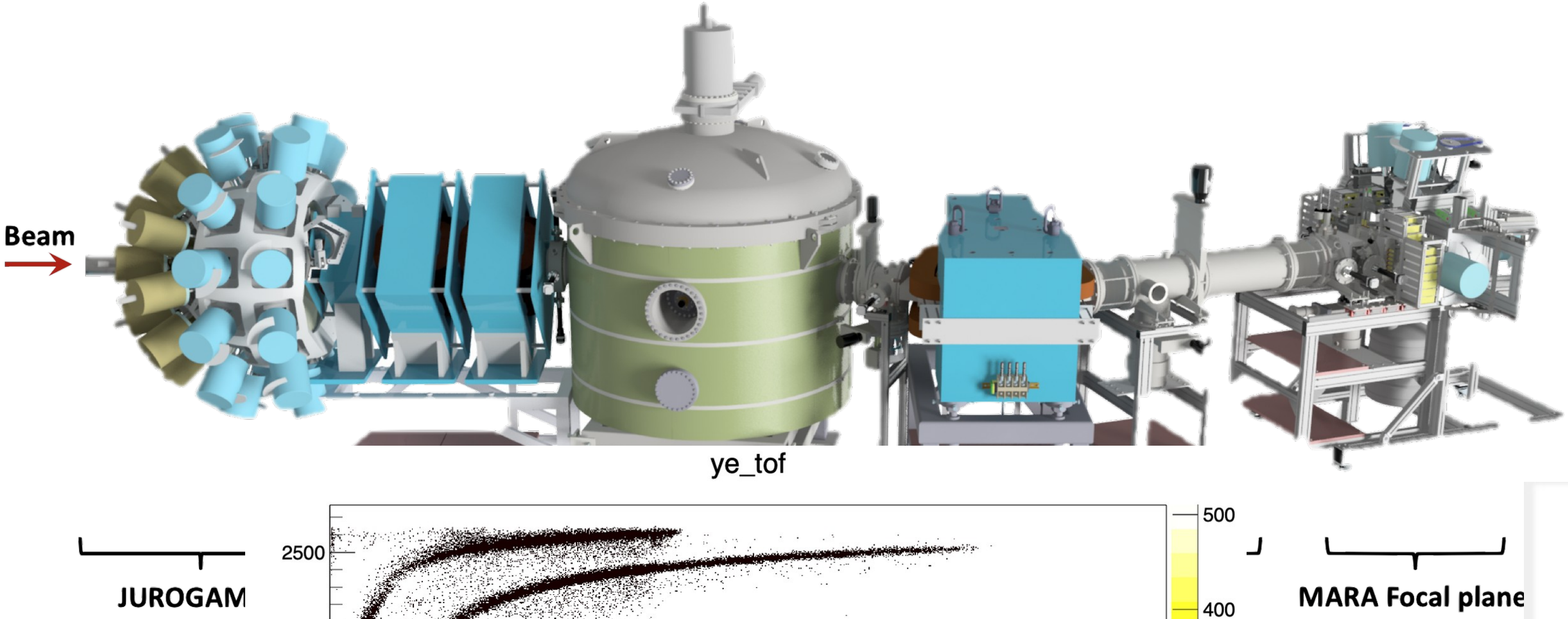
The MARA setup

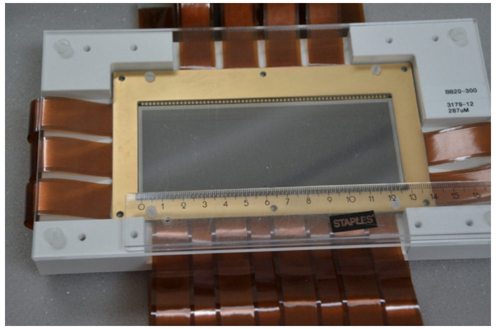


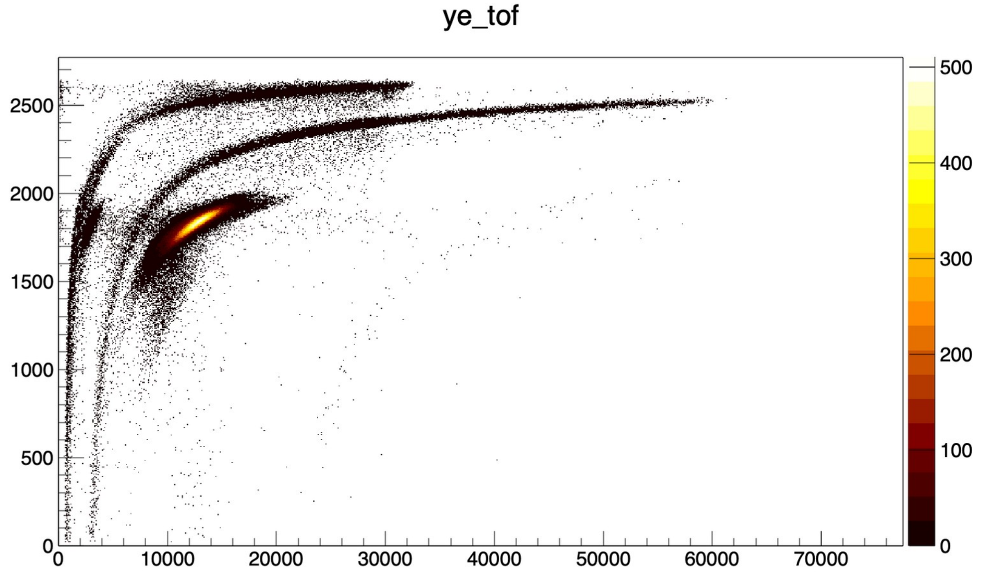


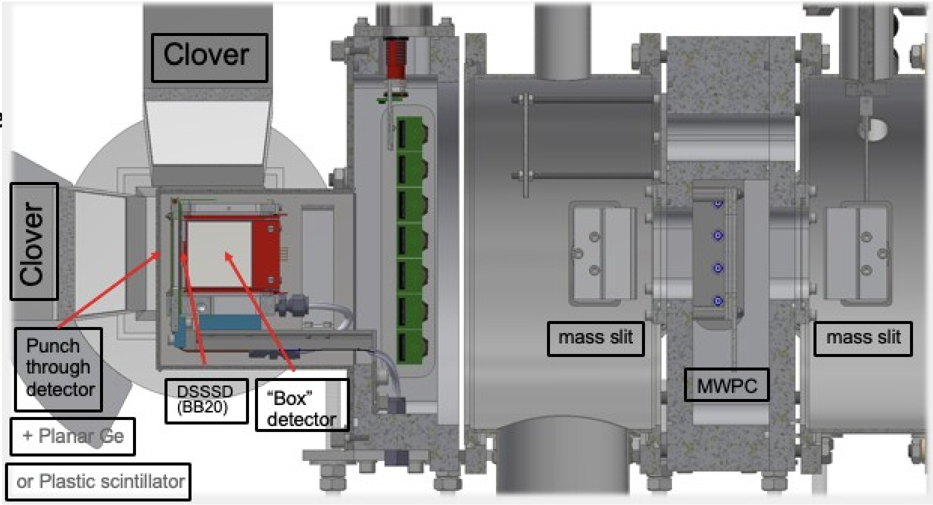


JUROGAM3 + MARA





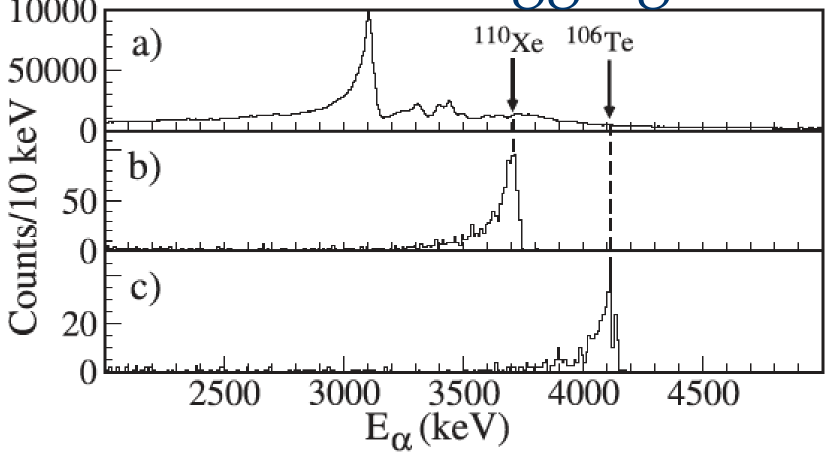


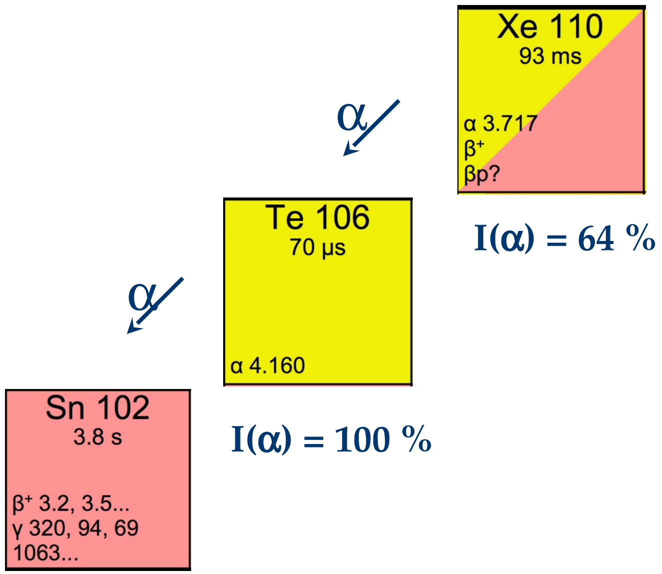


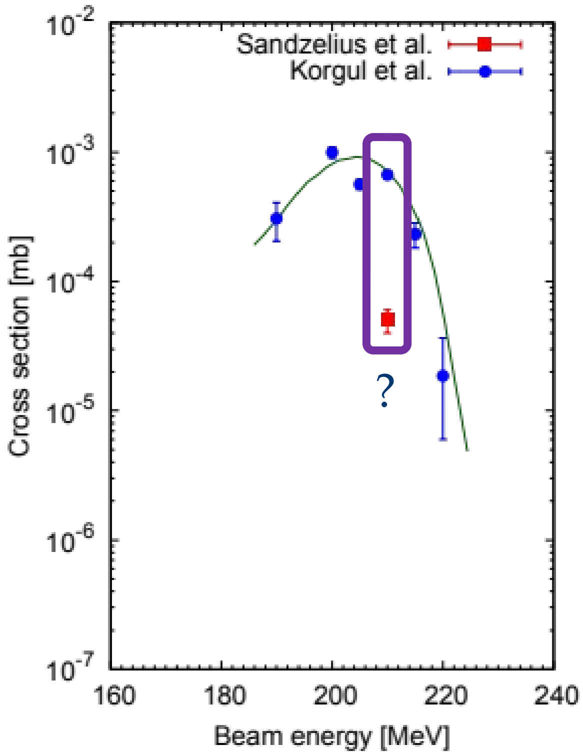
The experiment

$^{54}Fe(^{58}Ni,2n)^{110}Xe$ @ 215 MeV
I = 3.8 pnA
12 days of beamtime

Recoil-αα tagging

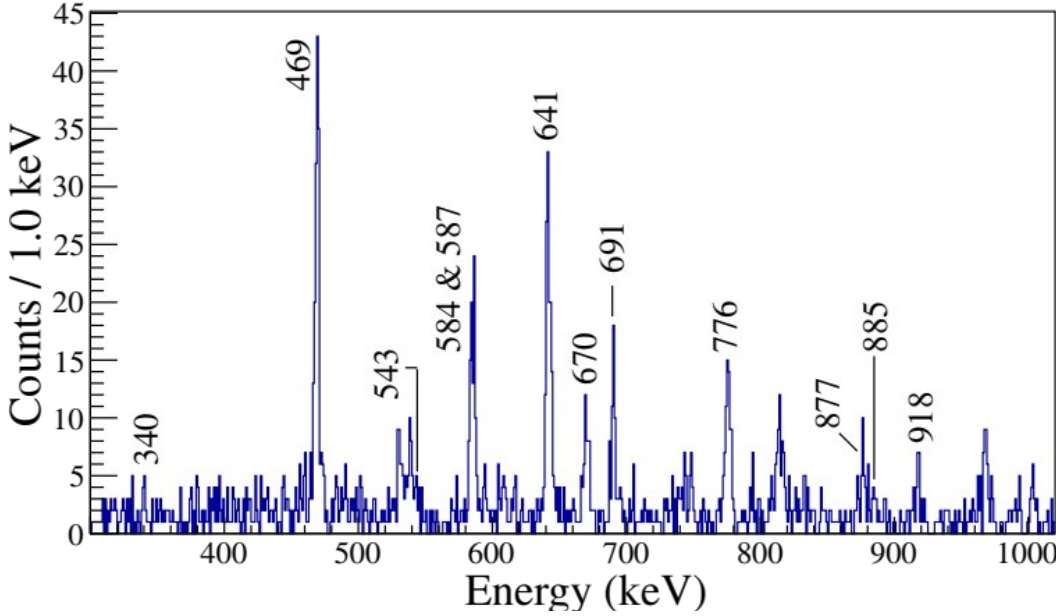


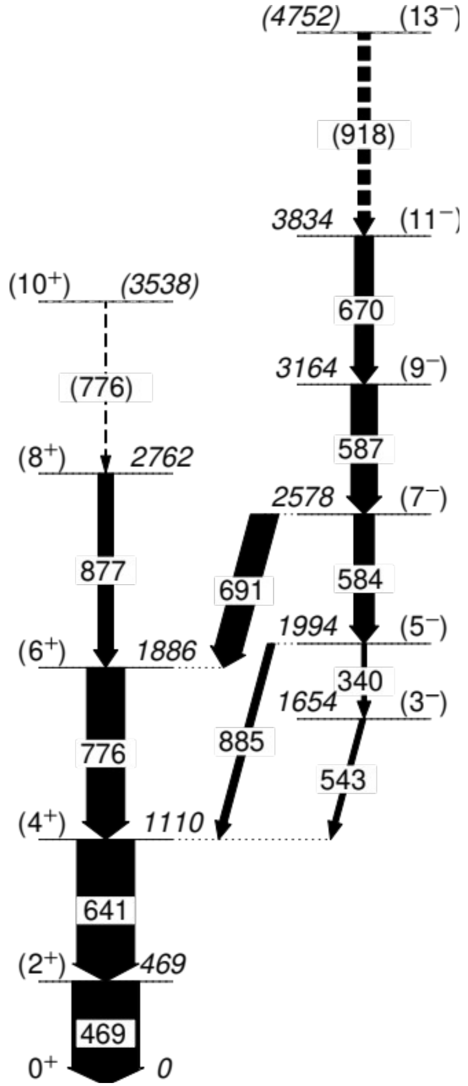


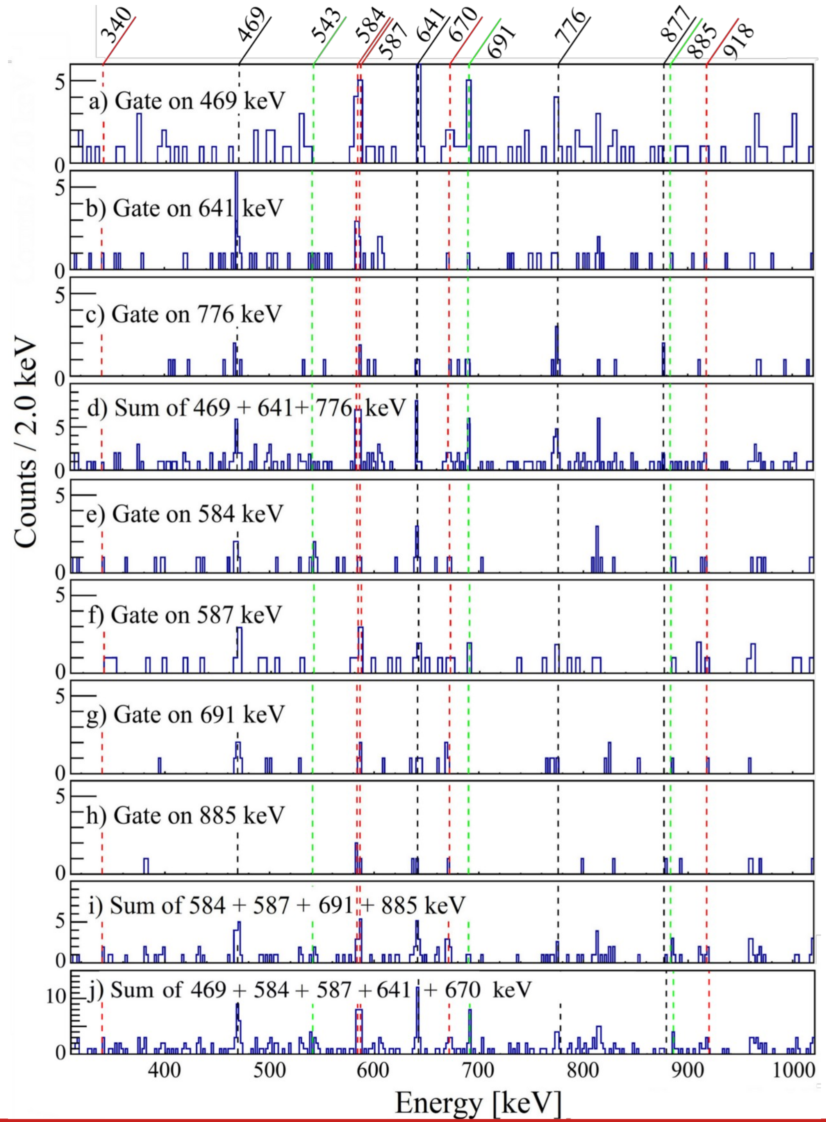


M. Sandzelius et al., *Phys. Rev. Lett.* **99** (2007) 022501
A. Korgul et al., *Phys. Rev. C* **77** (2008) 034301

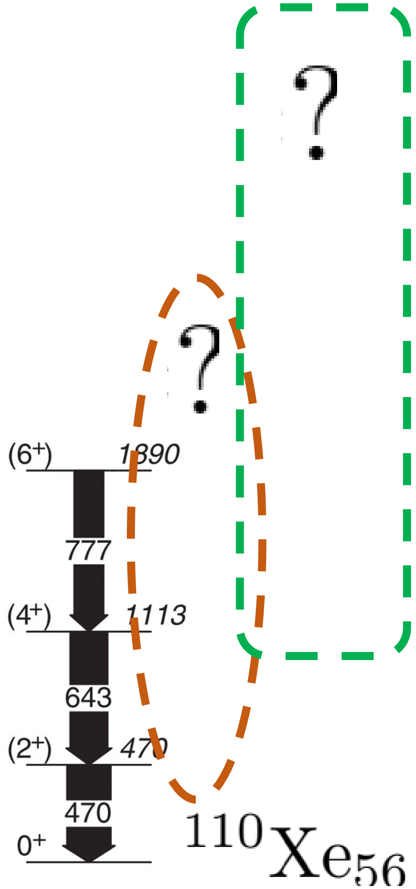
Results – ^{110}Xe

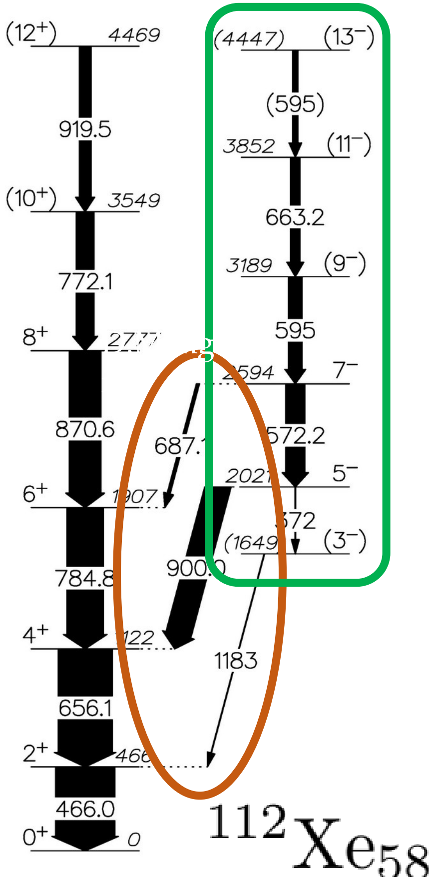


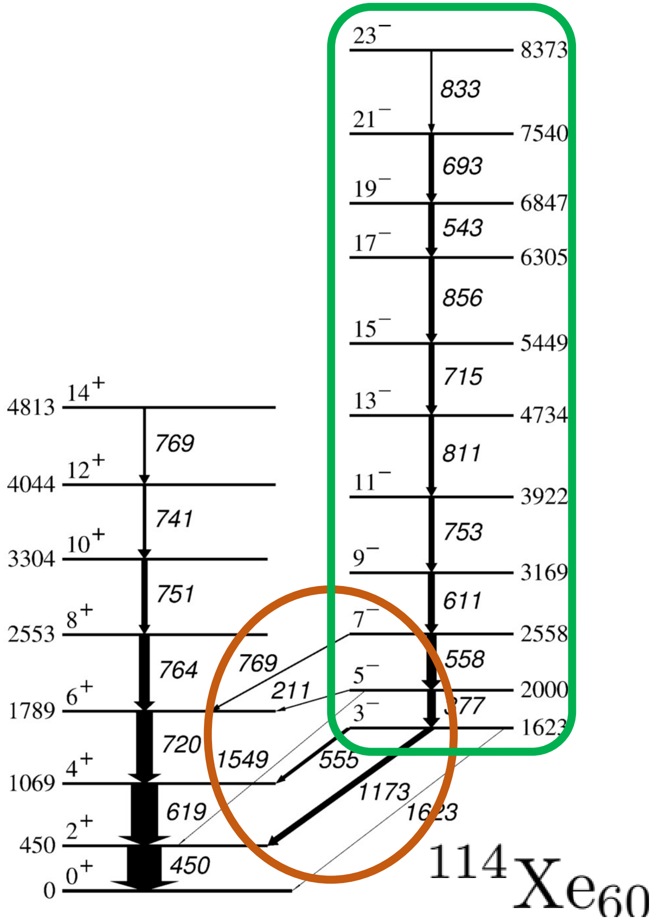




Introduction – existing data







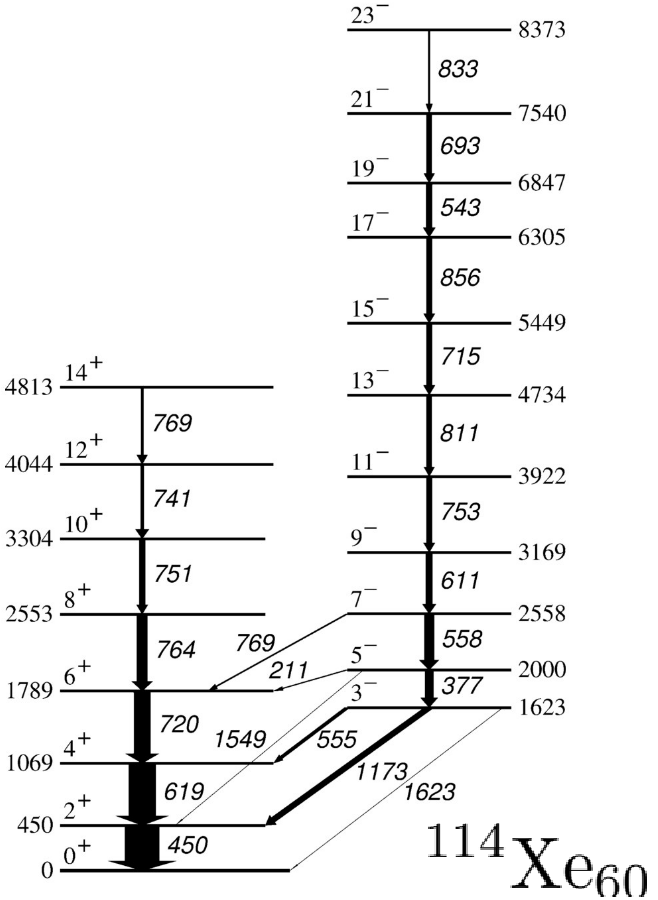
$$B(E3:3^- \rightarrow 0^+) = 77(27) W.u.$$

M. Sandzelius et al., *Phys. Rev. Lett.* **99** (2007) 022501

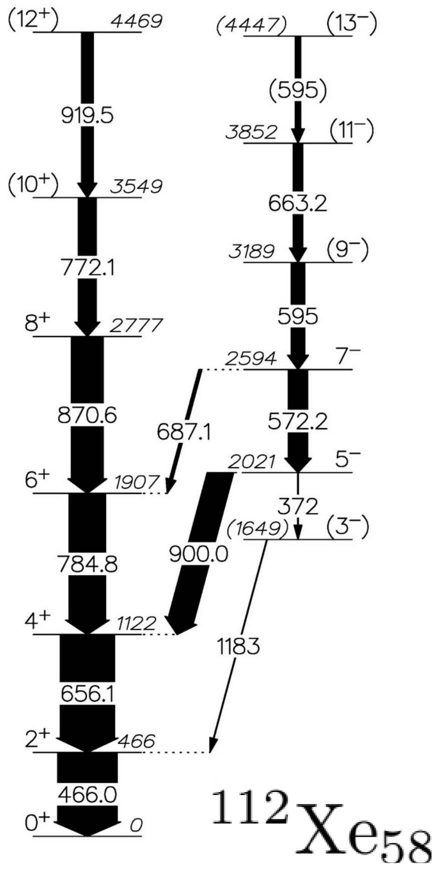
J.F. Smith et al., *Phys. Lett. B* **523** (2001) 13-21

G. de Angelis et al., *Phys. Lett. B* **535** (2002) 93-102

Results – ^{110}Xe



G. de Angelis et al., *Phys. Lett. B* **535** (2002) 93-102



J.F. Smith et al., *Phys. Lett. B* **523** (2001) 13-21

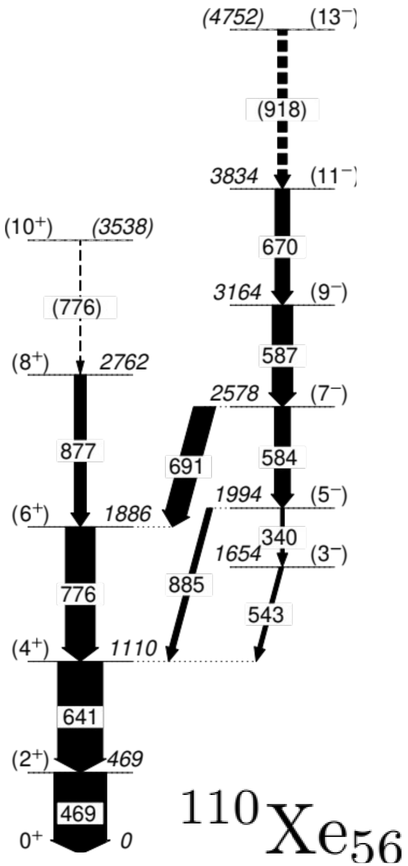


Table 2: Experimental B(E1)/B(E2) ratios and deduced B(E1) values for the $5^- \rightarrow 4^+$ and $7^- \rightarrow 6^+$ transitions in ^{110,112,114}Xe isotopes.

	$I_i^{\pi_i} \rightarrow I_f^{\pi_f}$	$B(E1)/B(E2)$ $[10^{-8}\ \mathrm{fm}^{-2}]$	$B(E1)$ $[10^{-4}$ W.u.$]$
^{110}Xe	$5^- \rightarrow 4^+$	0.8 (7)	0.3 (3)*
	$7^- \rightarrow 6^+$	22 (13)	9.6 (59)*
^{112}Xe	$5^- \rightarrow 4^+$	2.9 (9) [5]	1.0 (3) [5]
	$7^- \rightarrow 6^+$	1.7 (8) [5]	0.6 (2) [5]
^{114}Xe	$5^- \rightarrow 4^+$	< 0.02 [7]	< 0.003 [7]
		0.046 (13) [6]	0.006 (2) [6]
	$7^- \rightarrow 6^+$	1.5 (1) [7]	0.28 (2) [7]

* Assuming a quadrupole moment of 344 efm^2, taken from the theoretical calculations.

[5] J.F. Smith et al., *Phys. Lett. B* **523** (2001) 13-21
[6] S. Rugari et al., *Phys. Rev. C* **48** (1993) 2078
[7] E.S. Paul et al., *Nucl. Phys. A* **673** (2000) 31-44