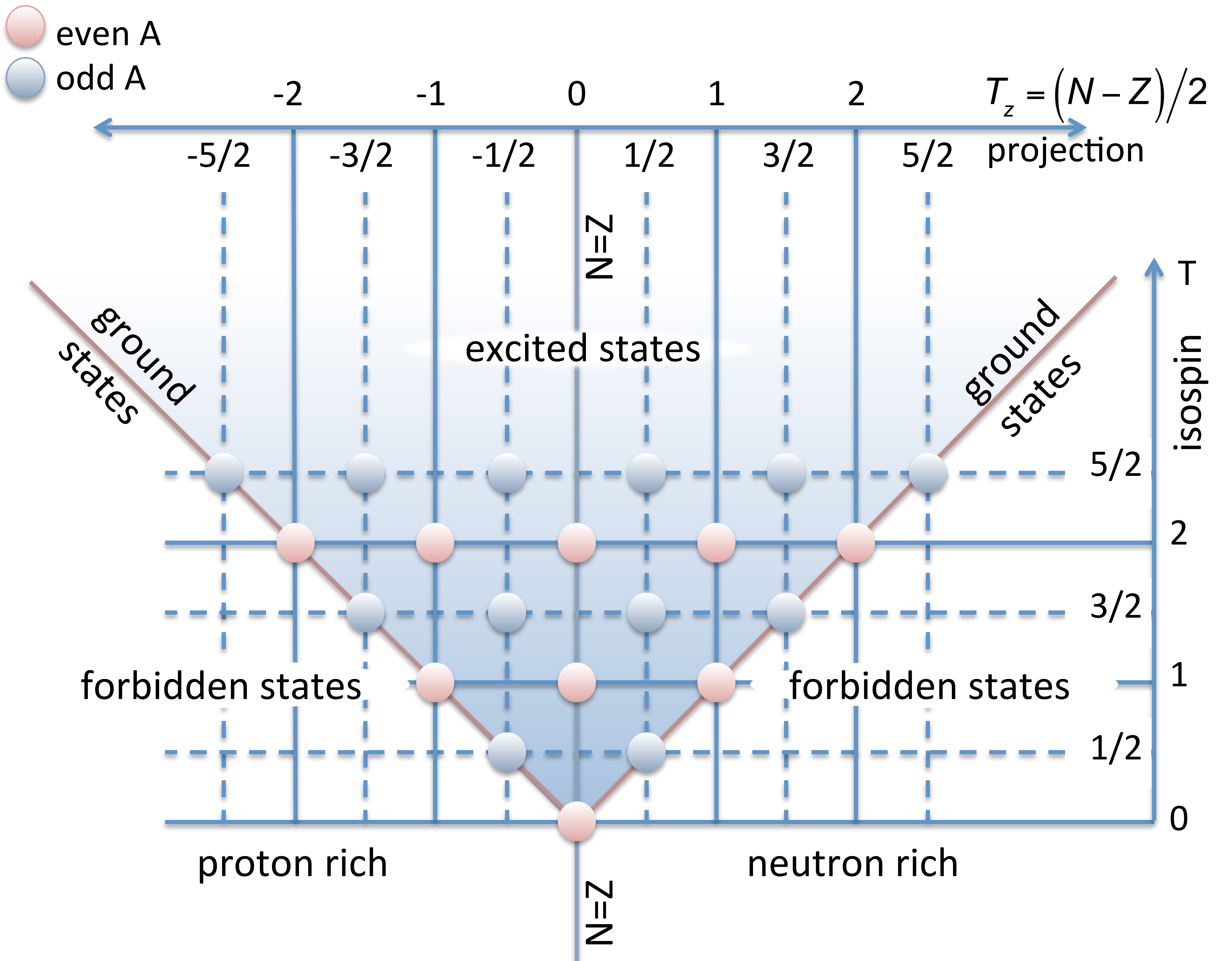
Isospin non-conserving interactions studied through triplet energy differences

David Jenkins

Isobaric Spin (Isospin)



For T=1 triplets:

$$\mathrm{MED}_J = E^*_{J,T_z=-1} - E^*_{J,T_z=+1}.$$

Mirror energy differences are isovector and sensitive to:
single-particle Coulomb shifts, electromagnetic spin-orbit interaction,
changes of shape/radius of nuclei

$$\mathrm{TED}_J = E^*_{J,T_z=-1} + E^*_{J,T_z=+1} - 2E^*_{J,T_z=0}.$$

Isotensor energy differences reflecting differences between nn, pp and pn force.
Not sensitive to one-body terms but only two-body
i.e. sensitive to Coulomb multipole and isospin-nonconserving forces

Shapes of N=Z nuclei

Very Prolate
Oblate
Triaxial

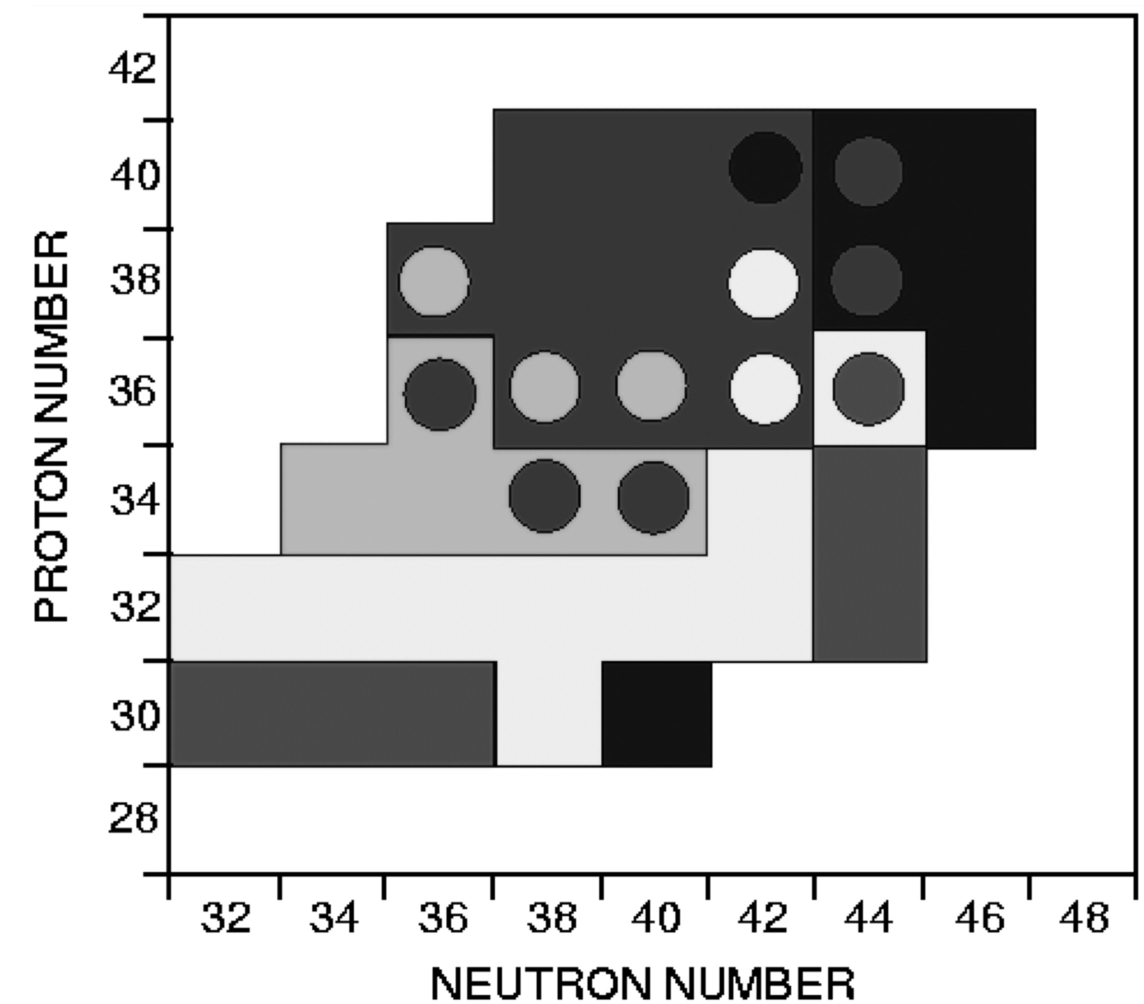
Very, very sensitive to underlying quantum structure…

The original phenomonological "M-M" theory, (Microscopic Macroscopic) was very sound.

P. Moller and J.R. Nix. At. Nuc. Data Tables, 26 (1981) 1965
S. Aberg. Phys Scr. 25 (1982) 23
W. Nazarewicz. Nucl. Phys A435 (1985) 397.
R. Bengtsson. Conf on the structure in the zirconium region, 1988

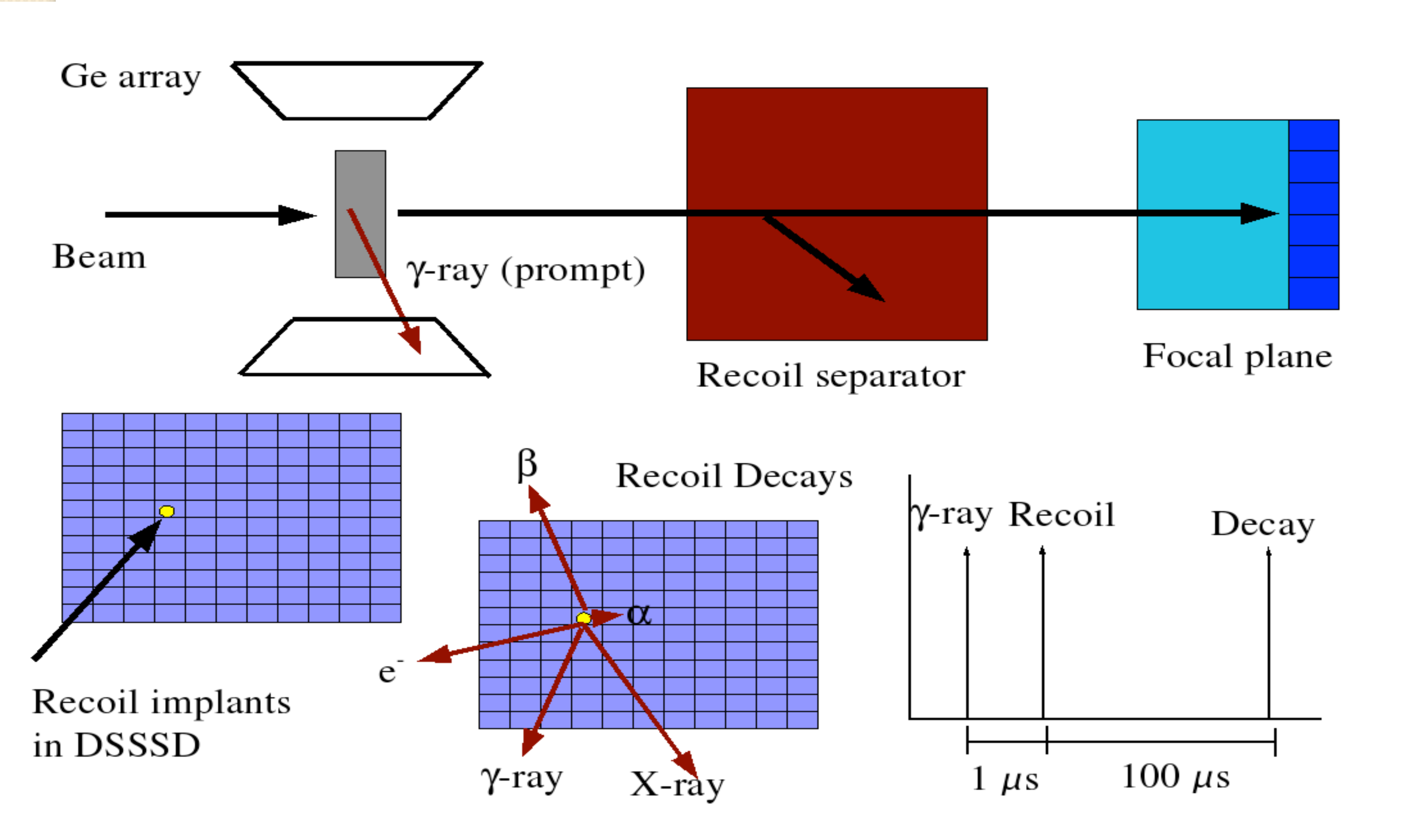
{Classic "Potential Energy Surface" calculations

…. BUT

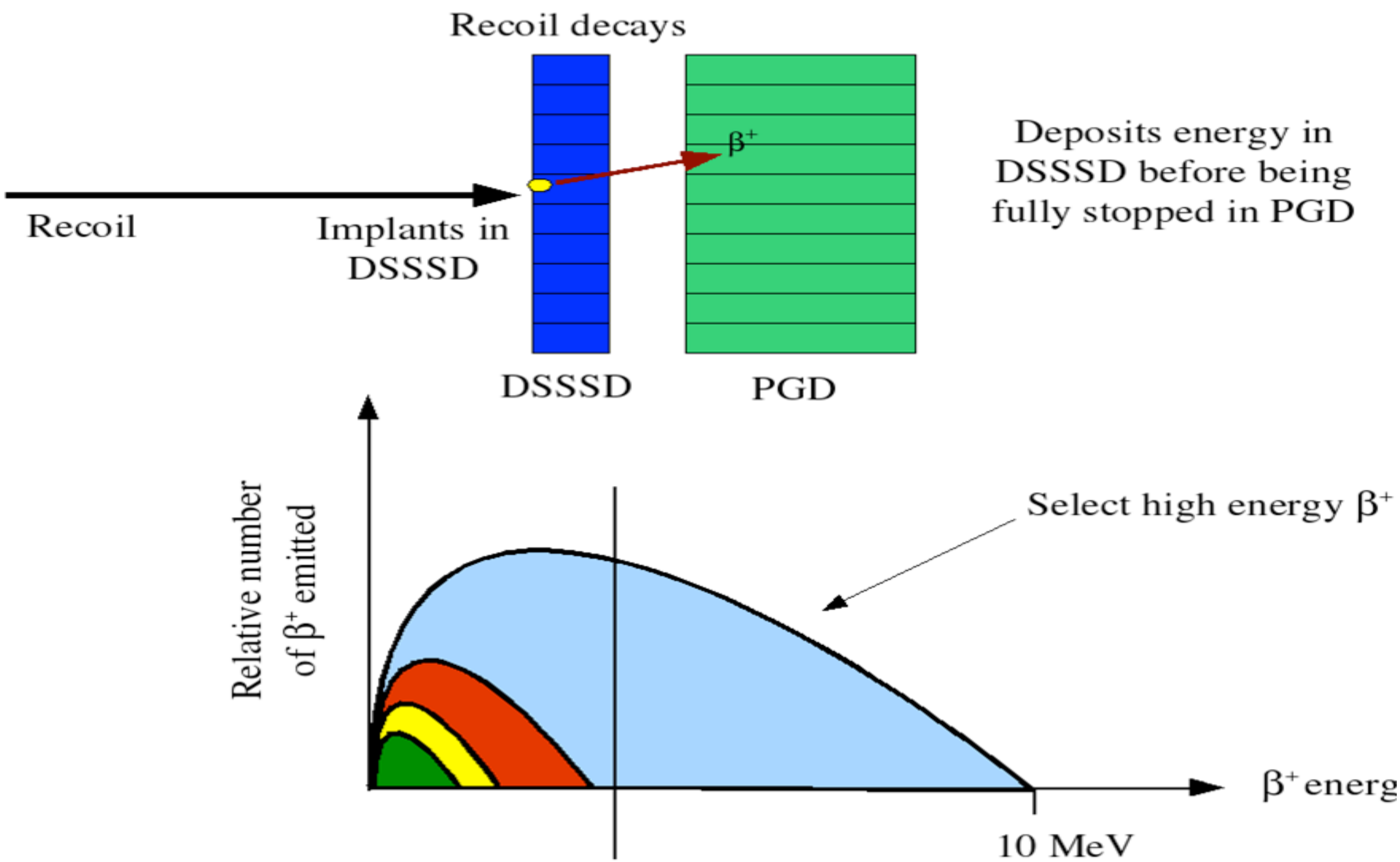


The whole concept of isolated "shapes" is naive: there are multiple shapes with lots of mixing, as the barriers between shapes are not high.

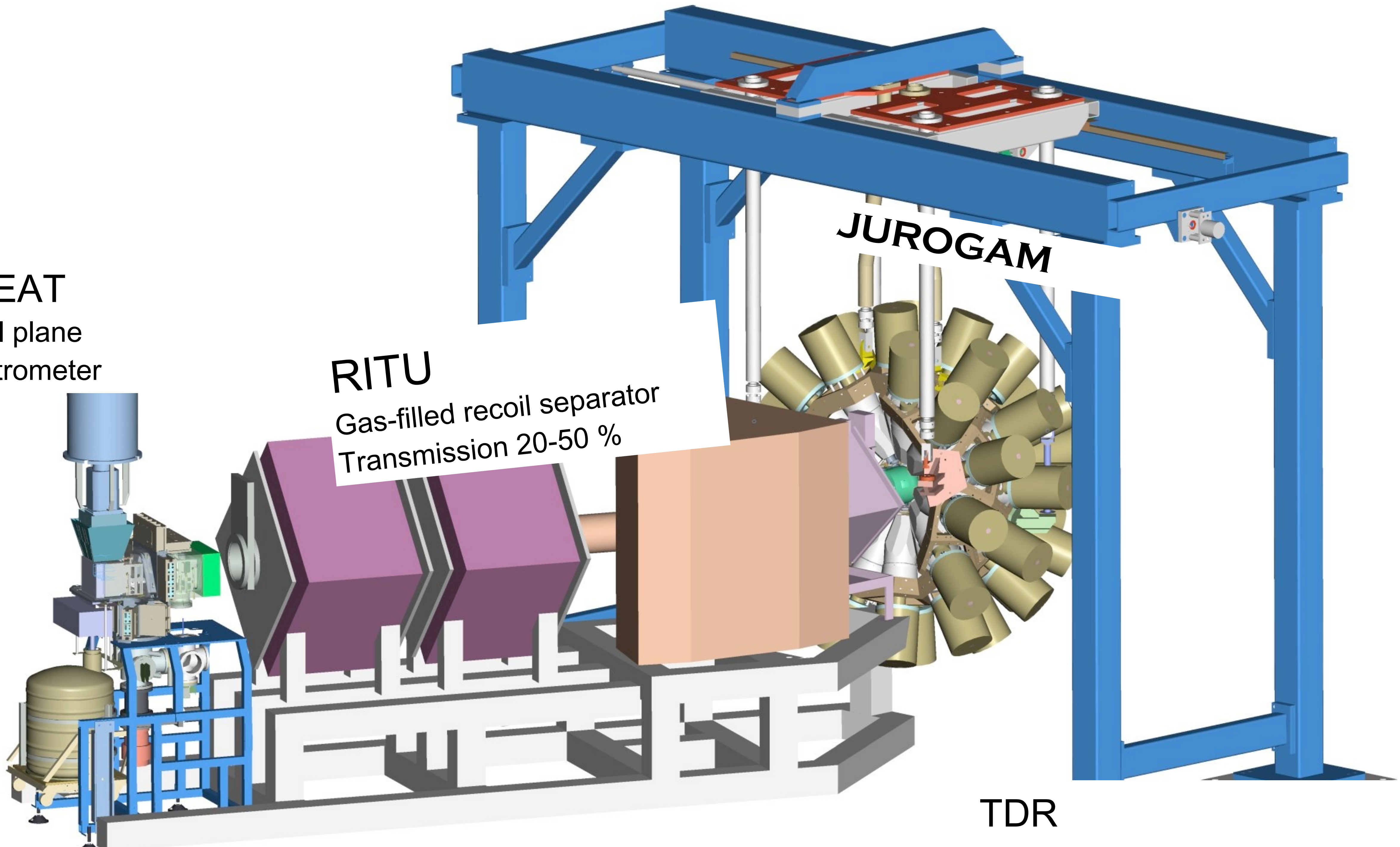
Recoil-decay tagging



Recoil-beta tagging



RDT Instrumentation at JYFL

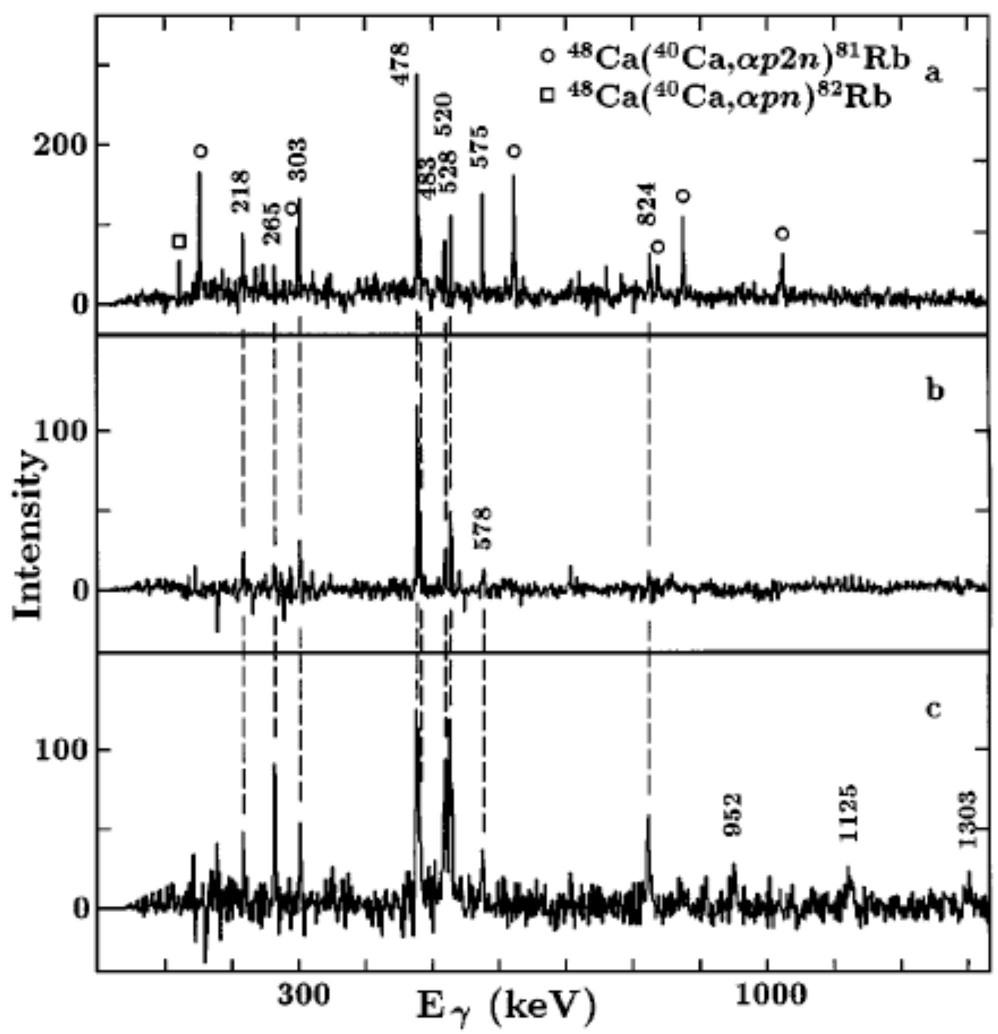


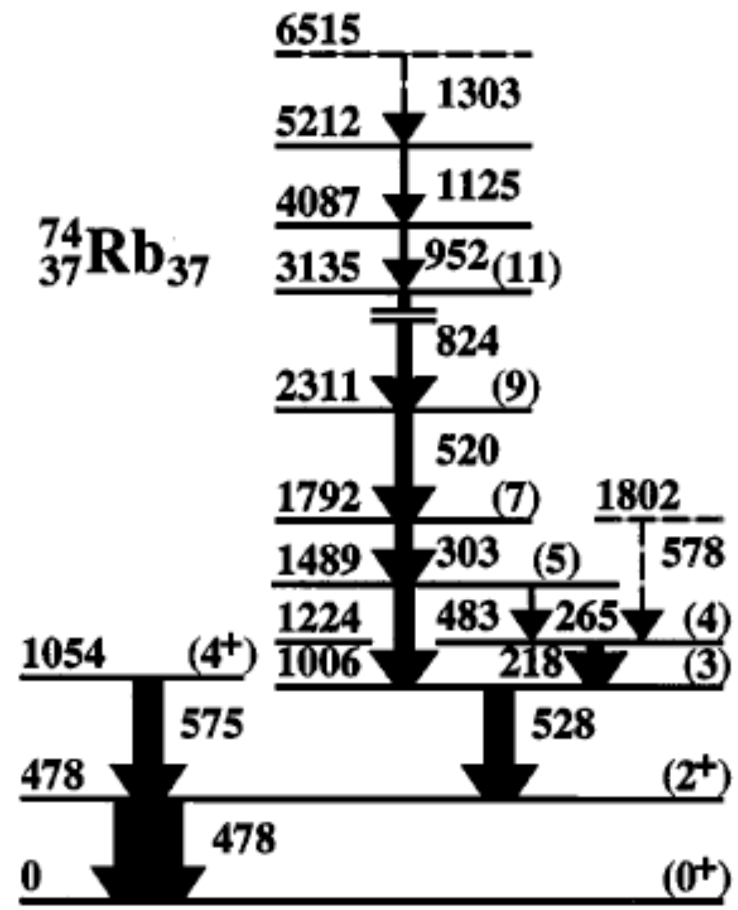
GREAT
Focal plane spectrometer

RITU
Gas-filled recoil separator
Transmission 20-50 %

TDR
Total Data Readout
Triggerless data acquisition system with 10 ns time stamping

Test case: ^{74}Rb





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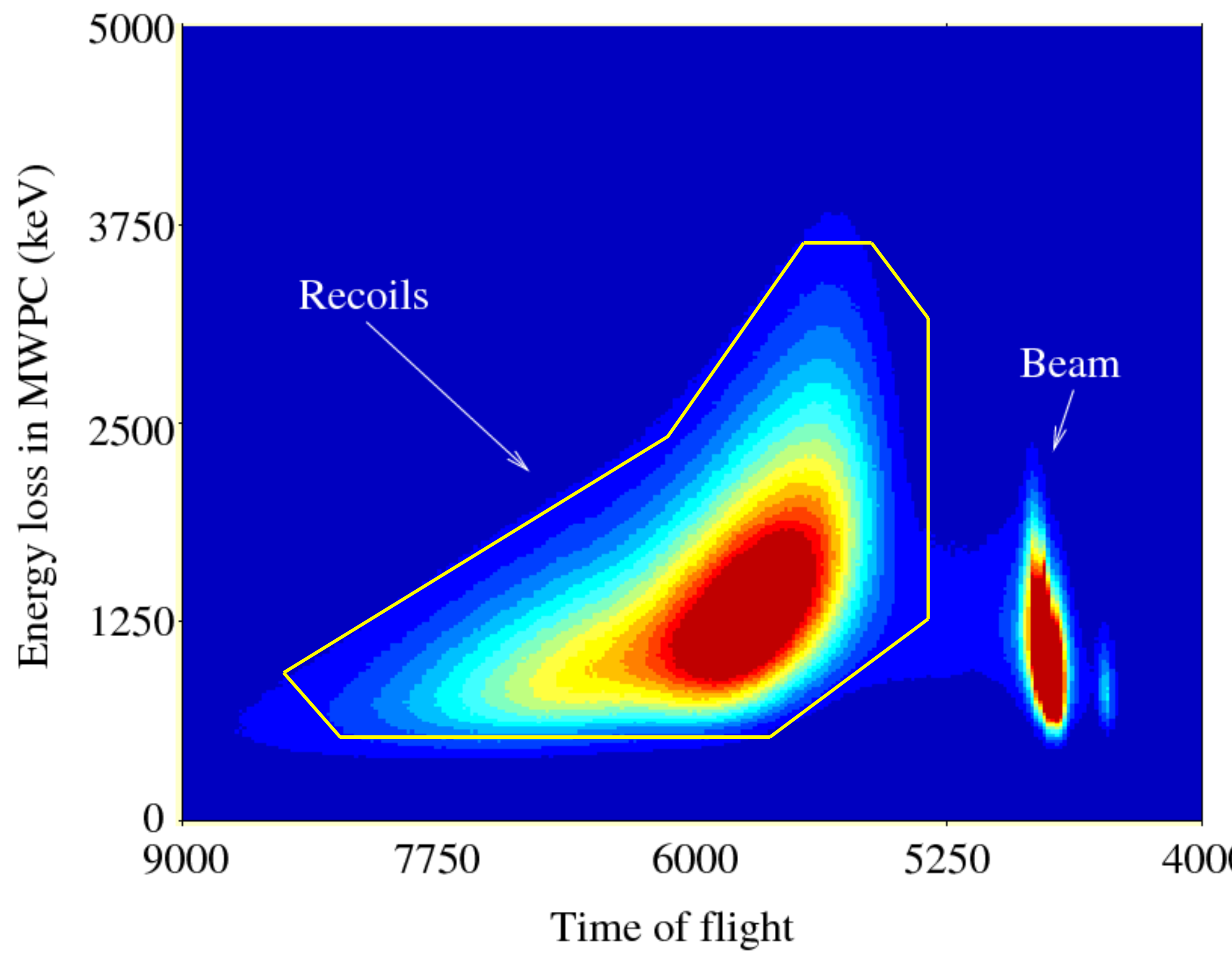
Identification of $T = 0$ and $T = 1$ Bands in the $N = Z = 37$ Nucleus ^{74}Rb

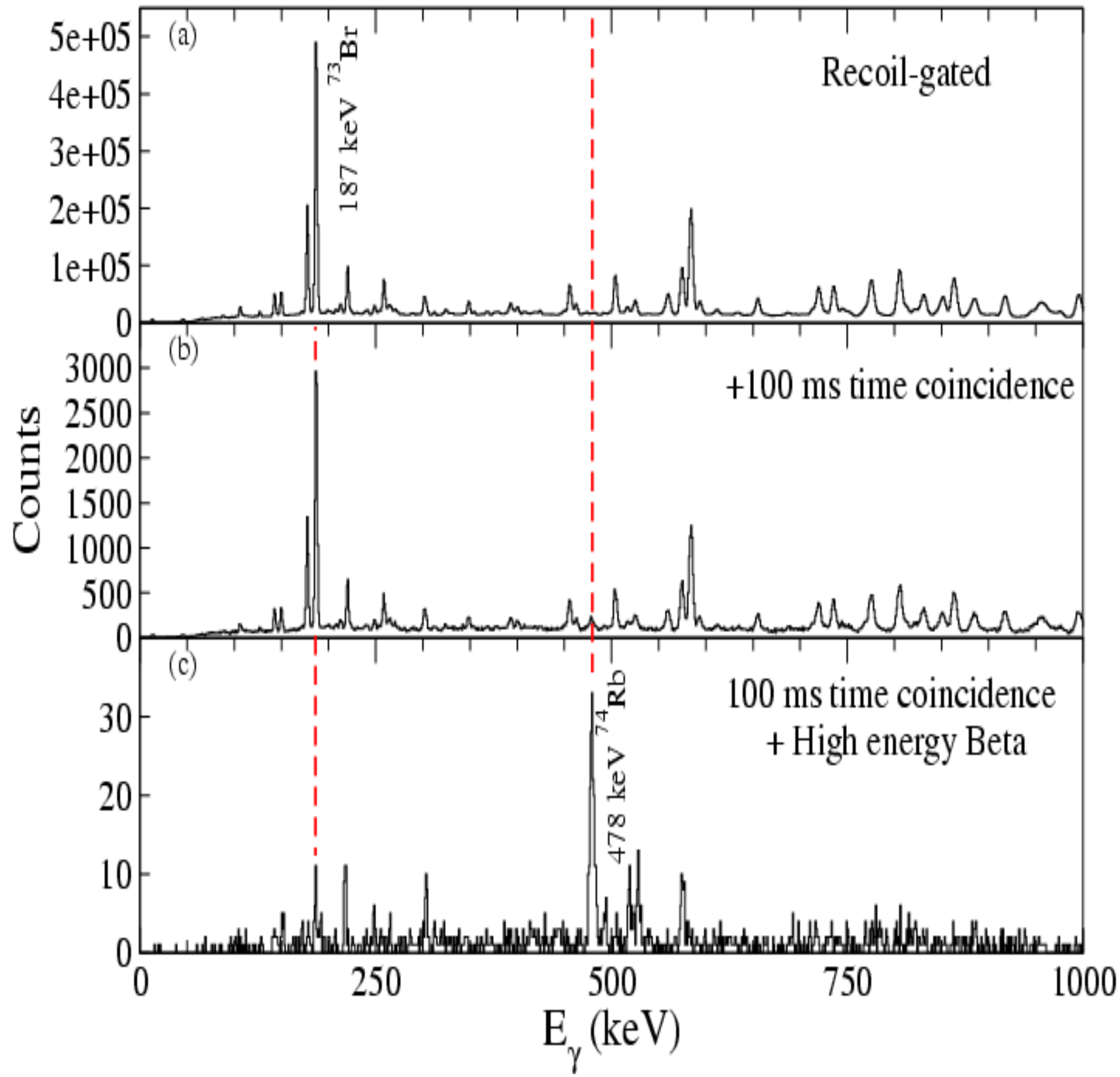
D. Rudolph,[1,*] C. J. Gross,[2,3] J. A. Sheikh,[4] D. D. Warner,[5] I. G. Bearden,[6] R. A. Cunningham,[5] D. Foltescu,[7] W. Gelletly,[8] F. Hannachi,[5,†] A. Harder,[1] T. D. Johnson,[1,‡] A. Jungclaus,[1] M. K. Kabadiyski,[1] D. Kast,[1] K. P. Lieb,[1] H. A. Roth,[7] T. Shizuma,[6] J. Simpson,[5] Ö. Skeppstedt,[7] B. J. Varley,[9] and M. Weiszflog[1]

Proof-of-principle

- ${}^{nat}Ca\,({}^{36}Ar, pn)\,{}^{74}Rb$
- E_{beam} = 103 MeV
- $\tau_{1/2}({}^{74}Rb)$ = 65 ms
- $\beta^{+}_{endpoint}$ ~ 10 MeV
- σ ~ 10 μb



^{74}Rb

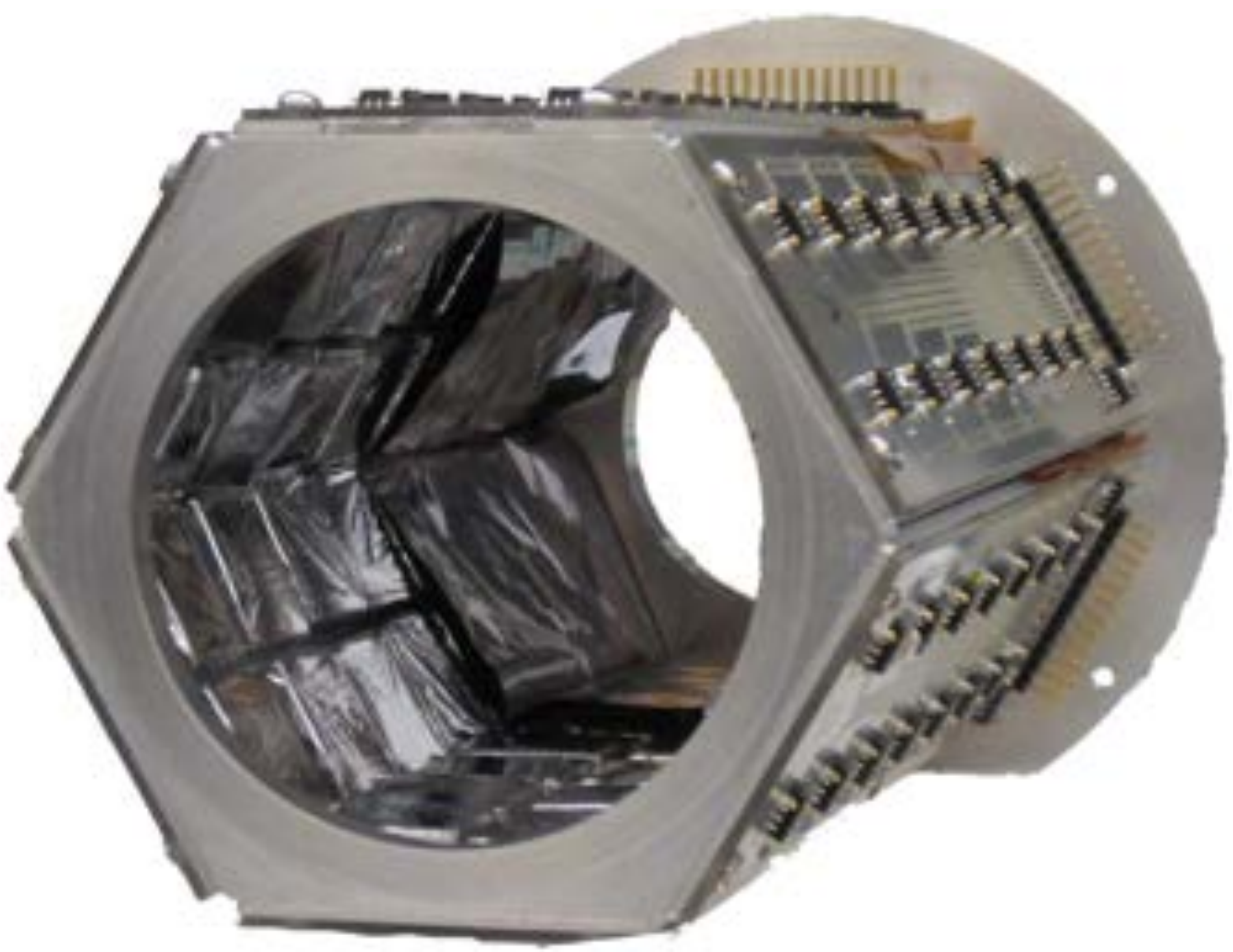


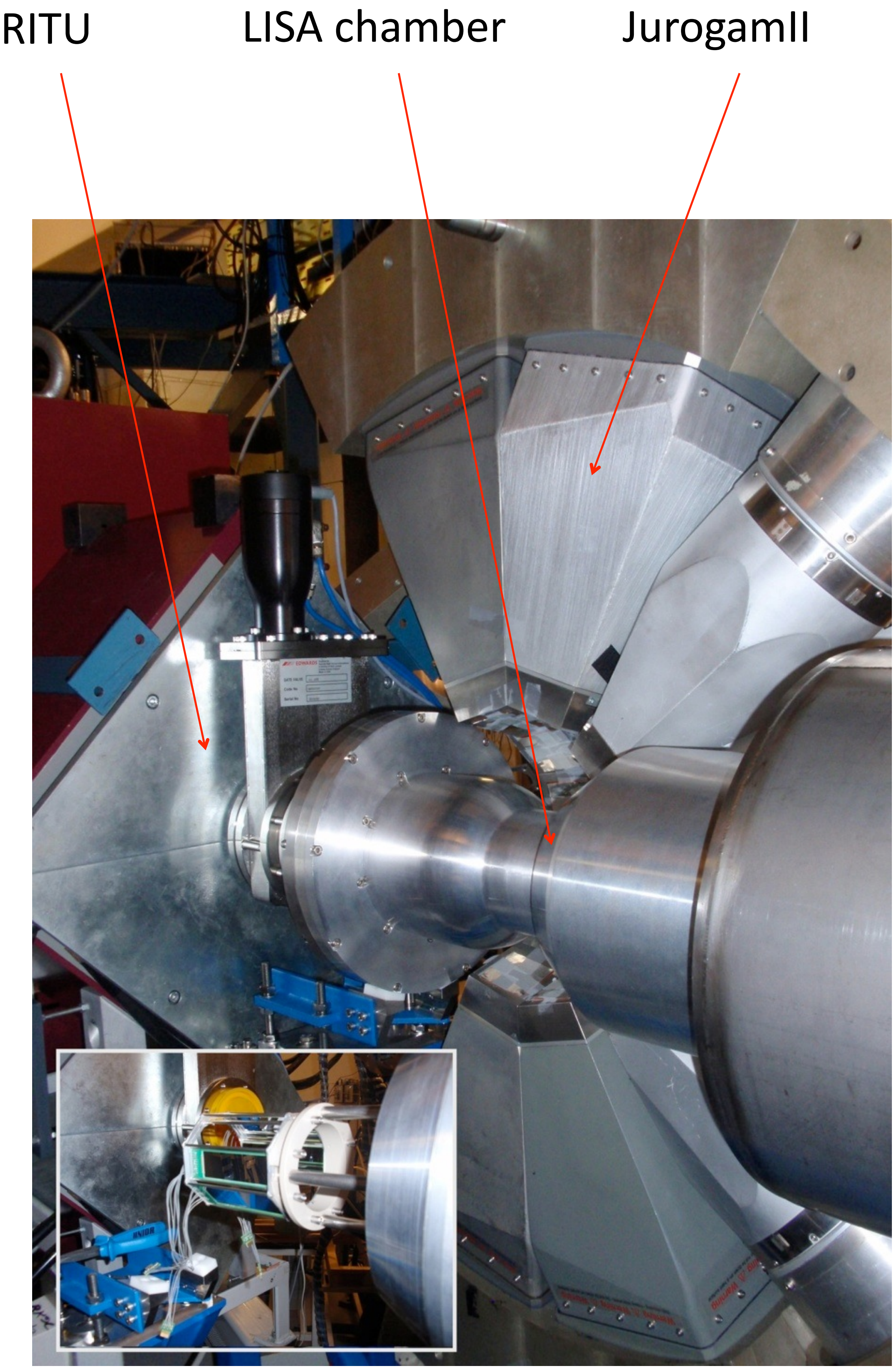
(a)
Recoil-gated
187 keV 73Br
(b)
+100 ms time coincidence
(c)
100 ms time coincidence
+ High energy Beta
478 keV 74Rb
Counts
Eγ (keV)
0
250
500
750
1000
5e+05
4e+05
3e+05
2e+05
1e+05
3000
2500
2000
1500
1000
500
30
20
10

Crossing the line of N=Z

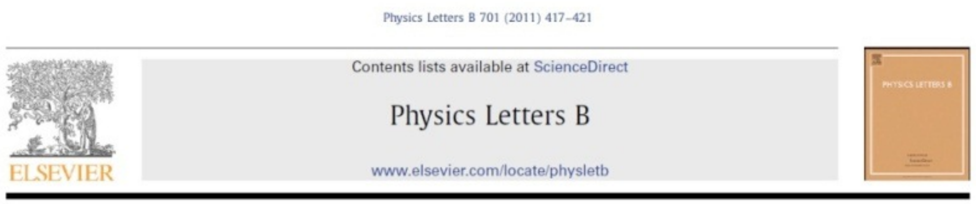
UoY Tube

- Designed to suppress events associated with cp evaporation channels.
- Consists of 96 20 x 20 mm CsI crystals (Hamamatsu) divided into 6 flanges (8 x 2 crystals in each flange).
- Signal chain: Mesytech preamplifiers -> ”GO-box” -> Lyrtech ADCs.
- Measured detection efficiency for 1 charged particle is 80-90 %.





^{66}Se


Physics Letters B 701 (2011) 417–421

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

First spectroscopy of ^{66}Se and ^{65}As: Investigating shape coexistence beyond the $N = Z$ line

A. Obertelli [a,*], T. Baugher [b], D. Bazin [b], S. Boissinot [a], J.-P. Delaroche [d], A. Dijon [e], F. Flavigny [a], A. Gade [b,c], M. Girod [d], T. Glasmacher [b,c], G.F. Grinyer [b], W. Korten [a], J. Ljungvall [a], S. McDaniel [b,c], A. Ratkiewicz [b,c], B. Sulignano [a], P. Van Isacker [e], D. Weisshaar [b]

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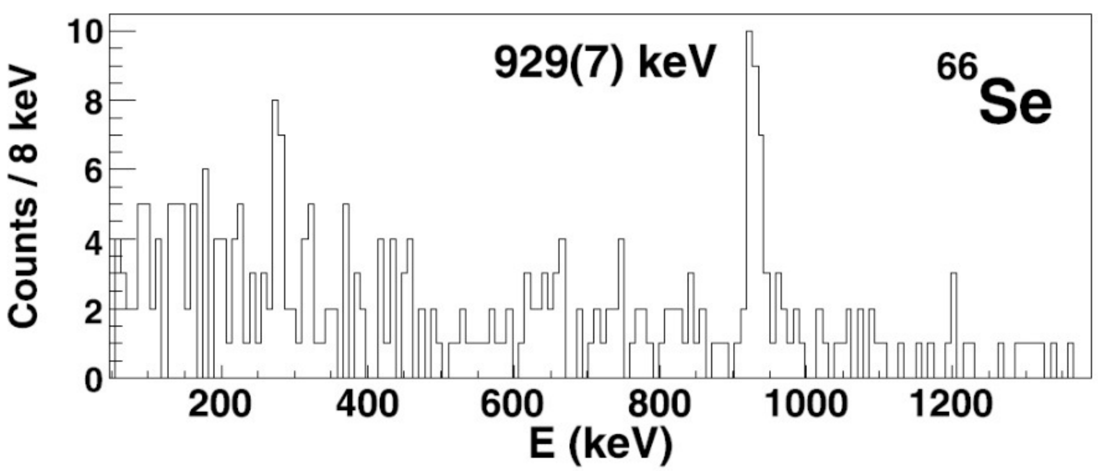
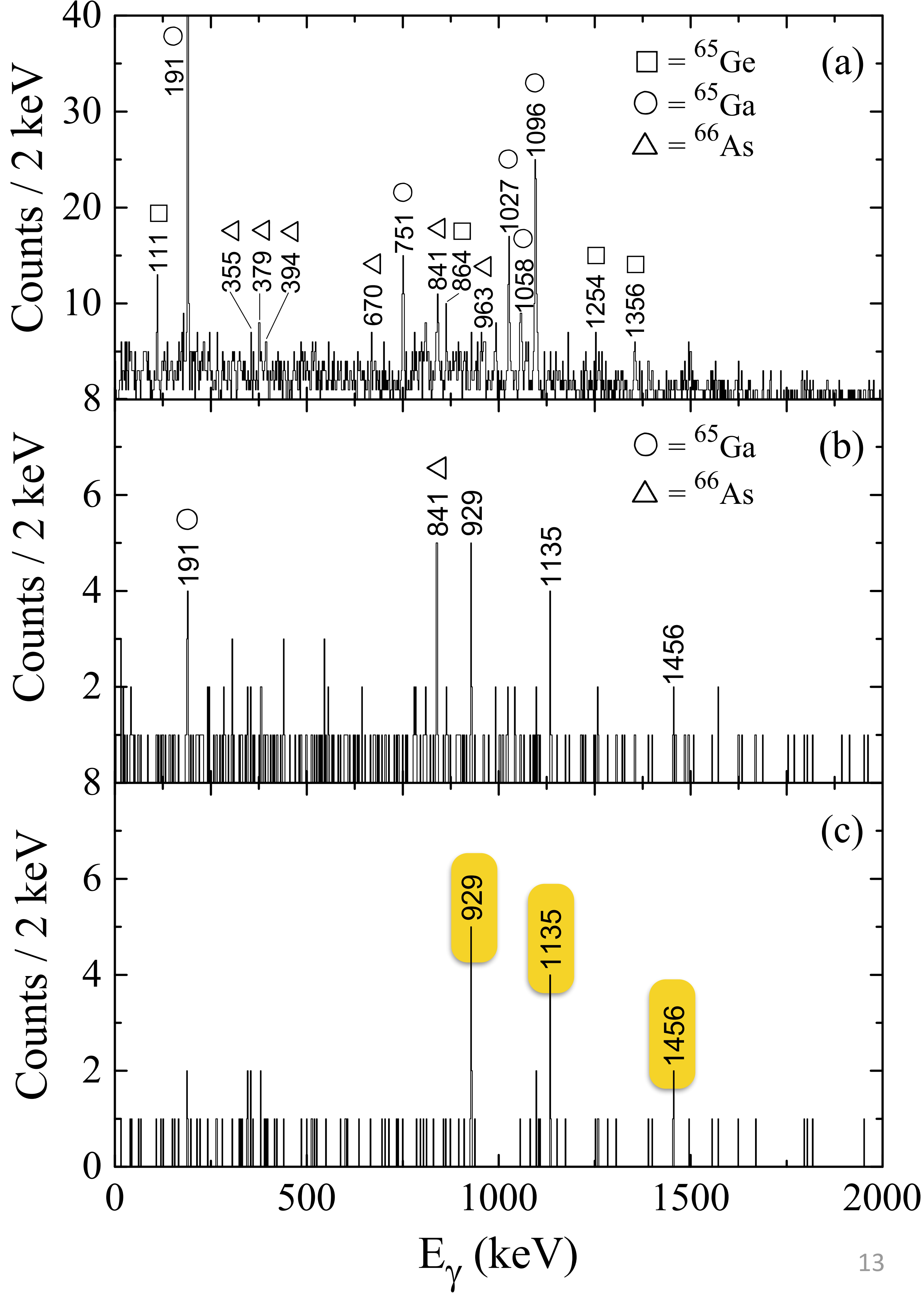
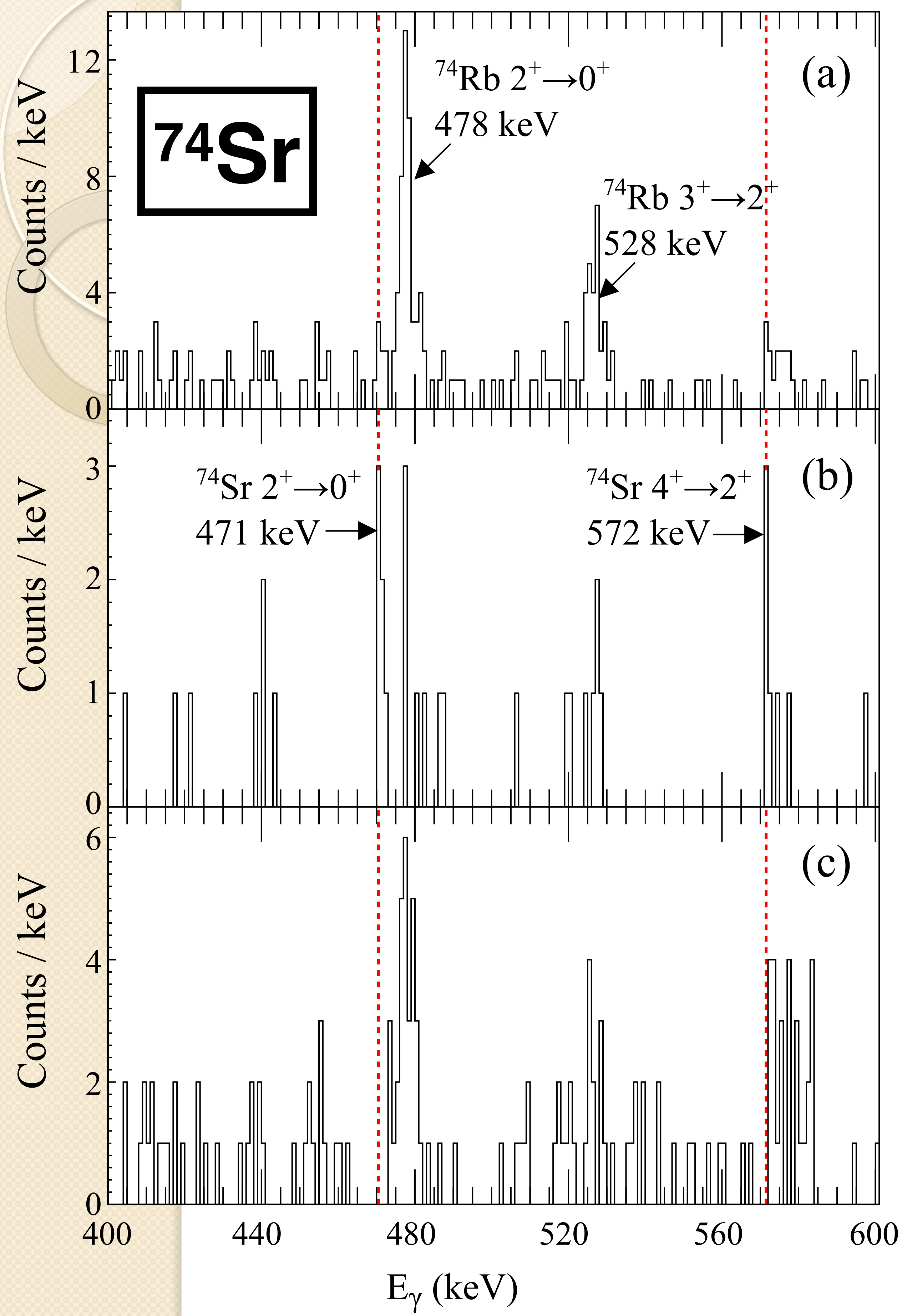
[e] Grand Accélérateur National d'Ions Lourds, CEA/DSM–CNRS/IN2P3, BP 55027, F-14076 Caen Cedex 5, France

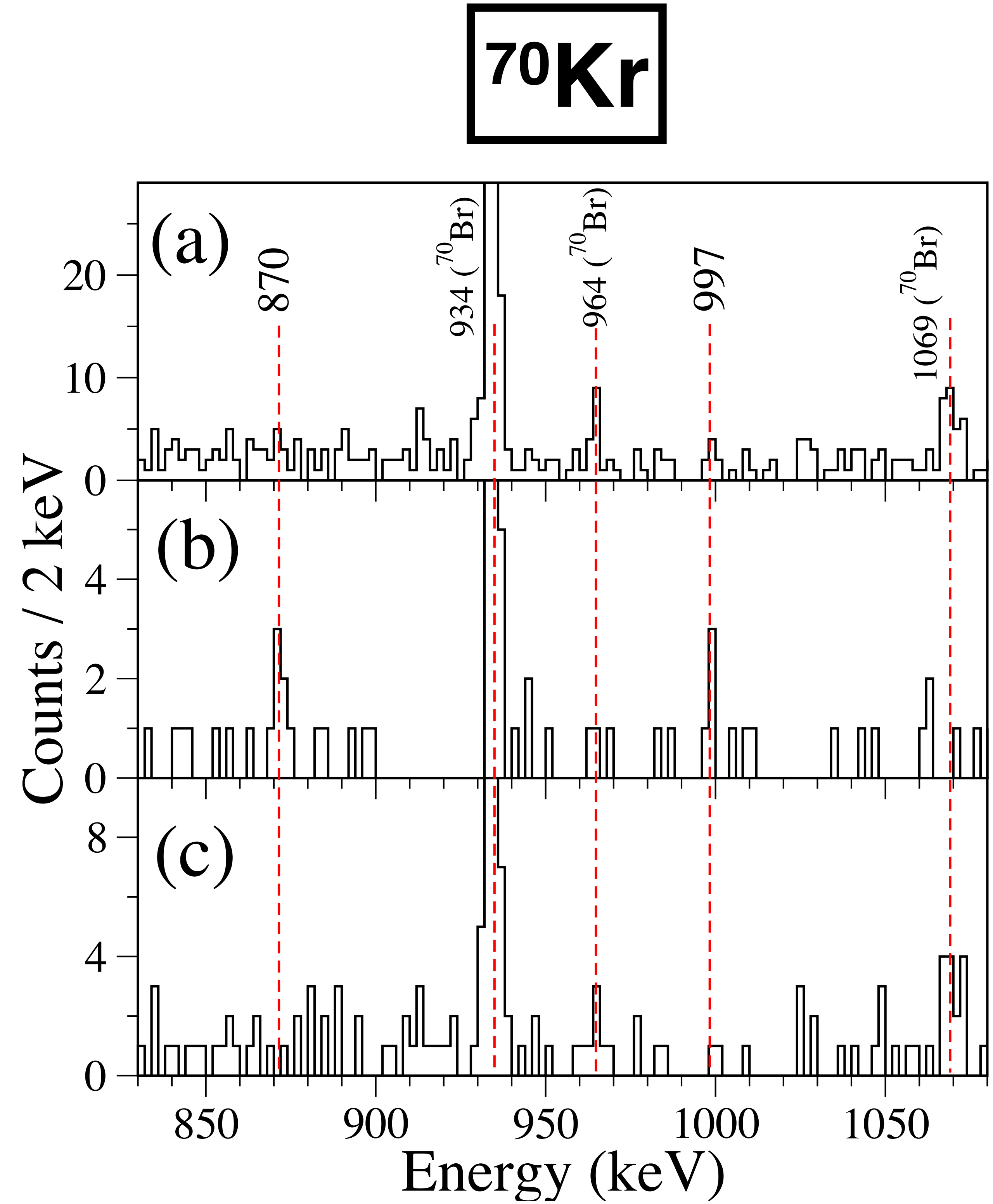




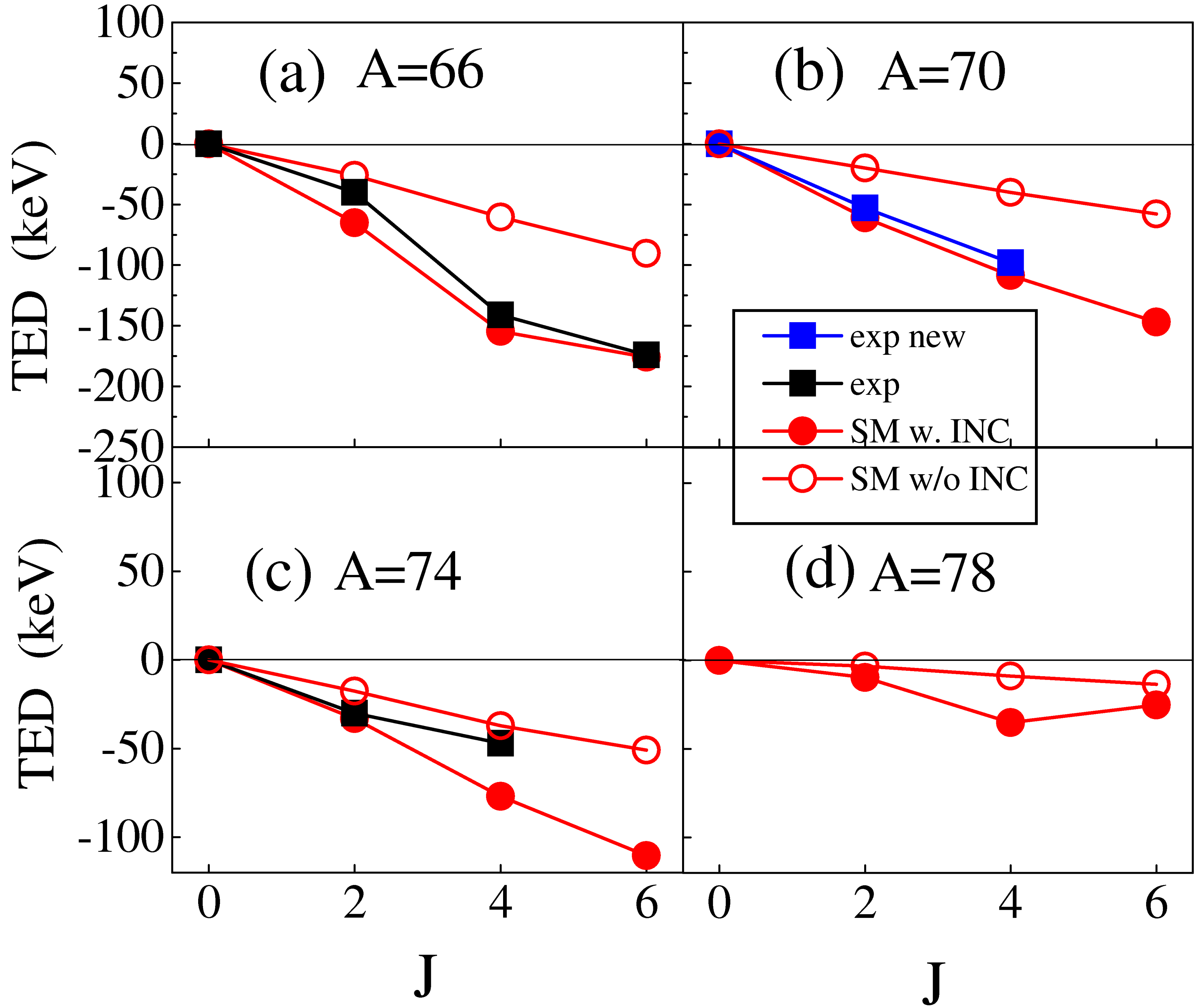
P. Ruotsalainen et al., Phys. Rev. C 83, 037303 (2013)



74Sr
(a)
74Rb 2+→0+
478 keV
74Rb 3+→2+
528 keV
(b)
74Sr 2+→0+
471 keV
74Sr 4+→2+
572 keV
(c)
Counts / keV
400
440
480
520
560
600
Eγ (keV)



70Kr
(a)
870
934 (70Br)
964 (70Br)
997
1069 (70Br)
(b)
(c)
Counts / 2 keV
850
900
950
1000
1050
Energy (keV)



(a) A=66
(b) A=70
(c) A=74
(d) A=78
TED (keV)
TED (keV)
J
J
exp new
exp
SM w. INC
SM w/o INC
100
50
0
-50
-100
-150
-200
-250
0
2
4
6

Conclusions

New techniques developed to study structure of nuclei beyond the line of N=Z:

- Beta-tagging
- Charged particle veto
- Highly-pixellated silicon detectors

Results obtained on excited states of N=Z-2 nuclei: ^{66}Se, ^{70}Kr and ^{74}Sr

TED extracted and compared with shell model calculations

TED appear to need additional isospin-nonconserving component to reproduce them as earlier shown in $f_{7/2}$ shell

TED can be reproduced using 100 keV INC term irrespective of orbitals involved e.g. fp for ^{66}Se and $g_{9/2}$ for ^{74}Rb

What is the origin of this INC component in terms of nuclear force?

Acknowledgements

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P. Ruotsalainen - ^{66}Se
D. Debenham - ^{70}Kr
J. Henderson - ^{74}Sr