Lessons from the RISING DECAY campaign

(and from isomeric separation at Jyväskylä)

Alison Bruce

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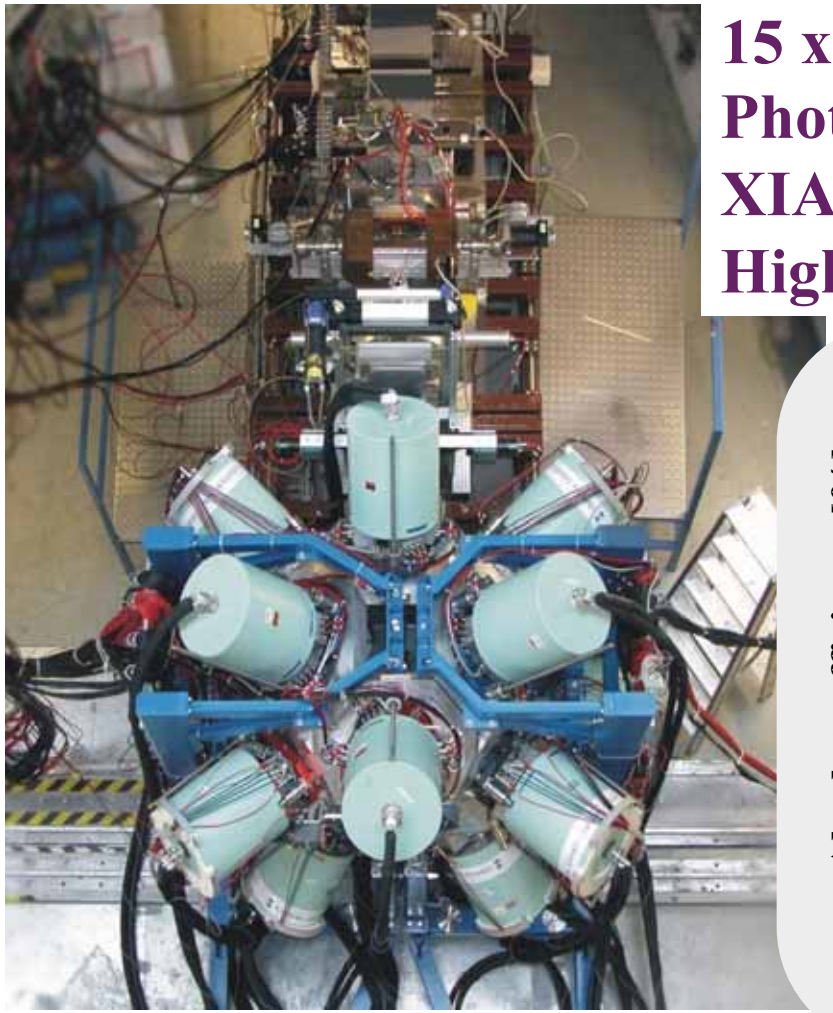
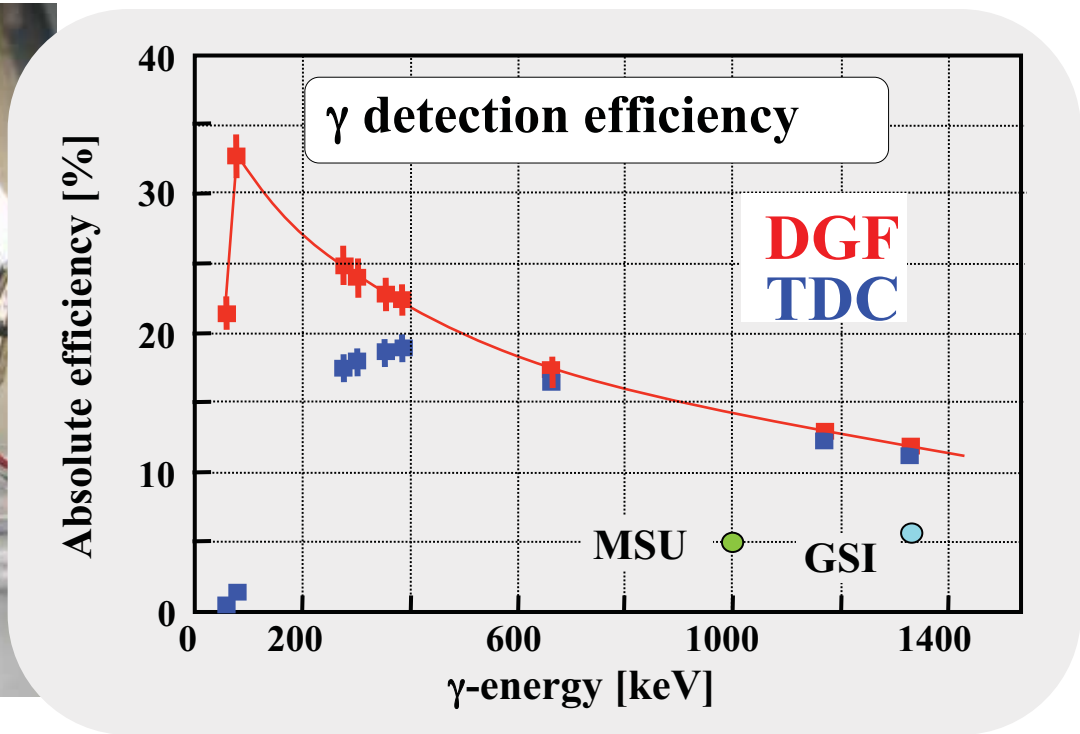
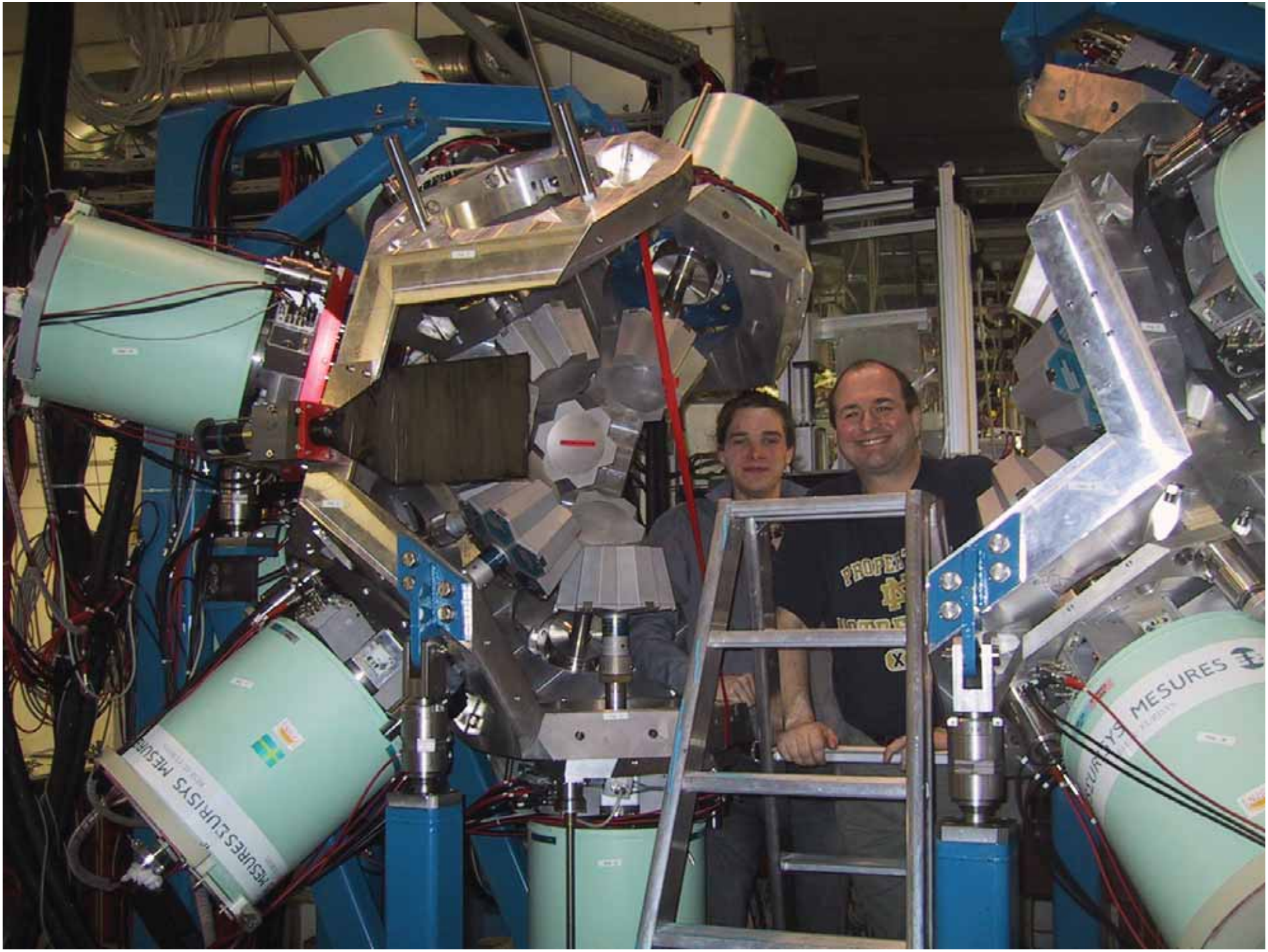
What is RISING?



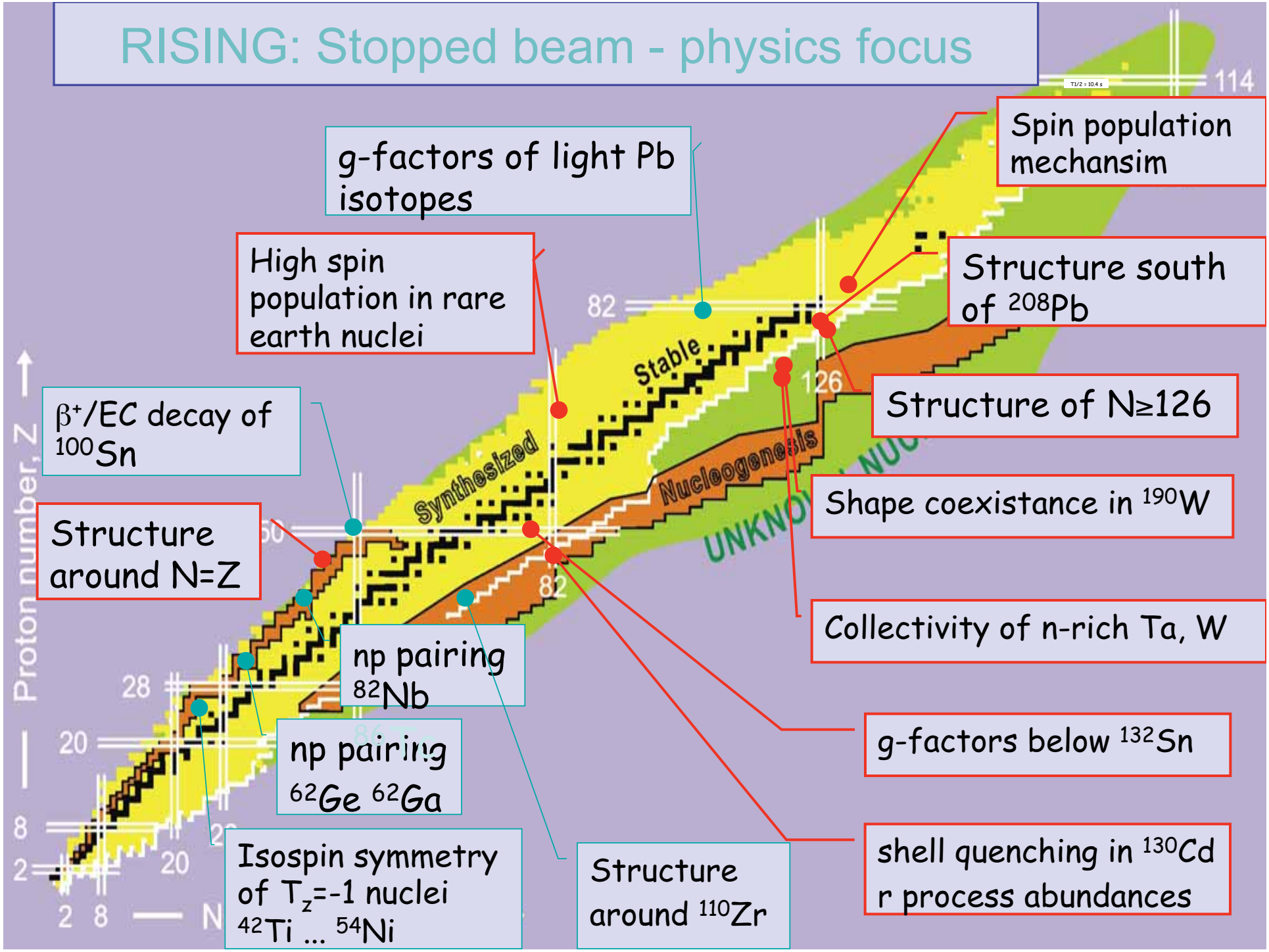
15 x 7 element Euroball CLUSTERs
Photopeak efficiency >10% at 1.3 MeV.
XIA-DGF electronics
High granularity (prompt flash problem)



S. Pietri et al., NIM B261 (2007) 1079


MESURES EURISYS MESURES

RISING: Stopped beam - physics focus



Accelerator facility at GSI-Darmstadt

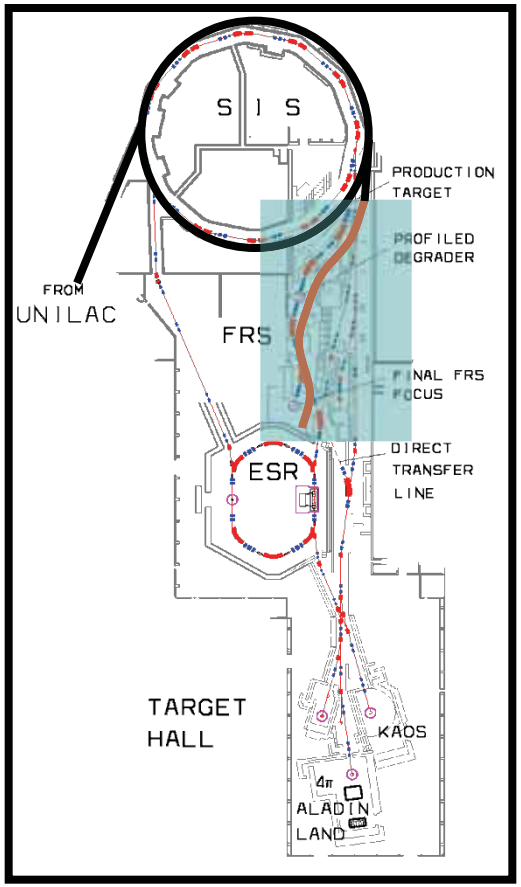
The Accelerators:

- **UNILAC** (injector) E=11.4 MeV/n
- **SIS 18Tm** corr. U 1 GeV/n

Beam Currents:

^{238}U - **10^8 pps**

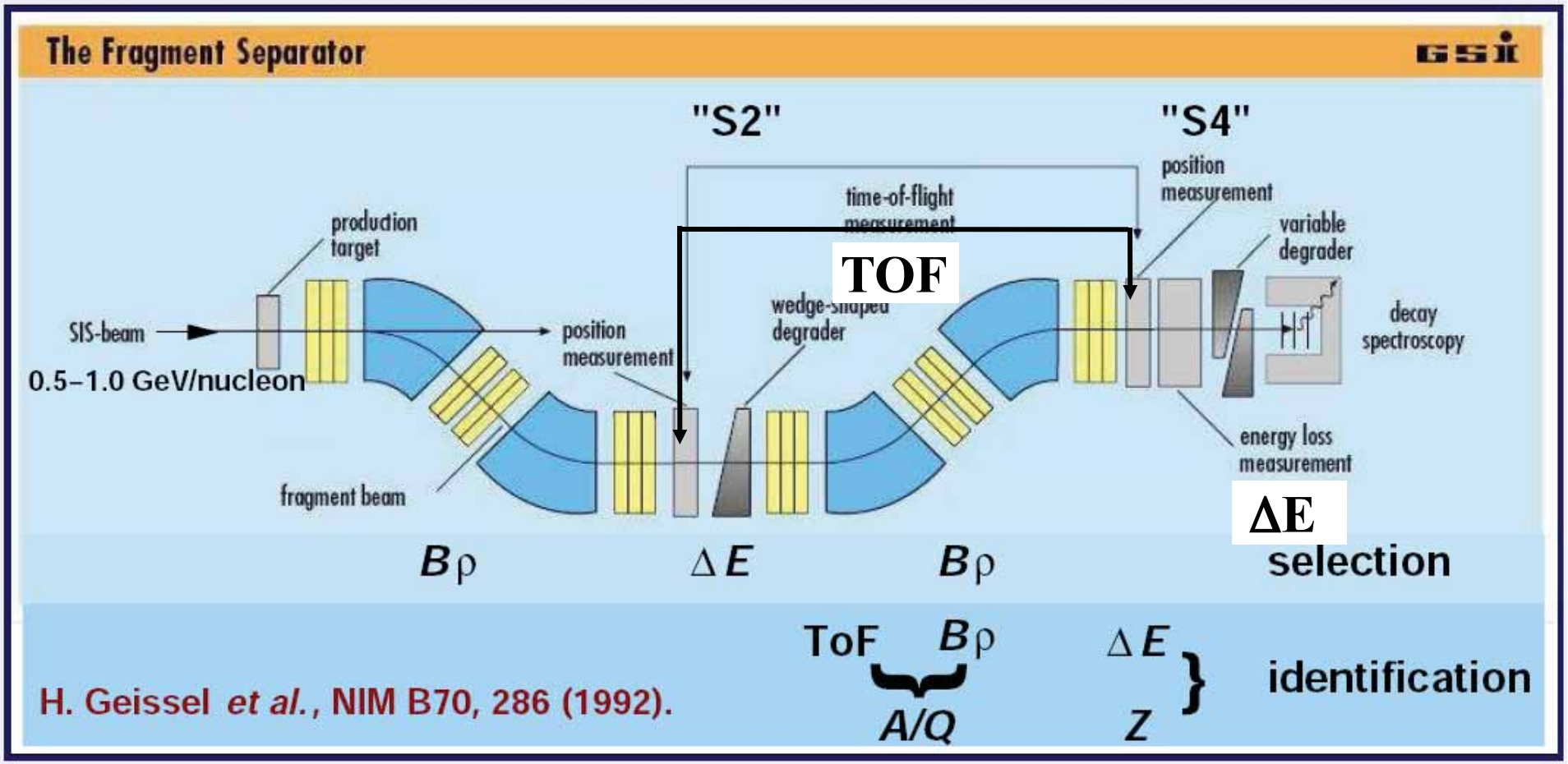
some medium mass nuclei- **10^9 pps**
(A~130)



FRS provides secondary radioactive ion beams:

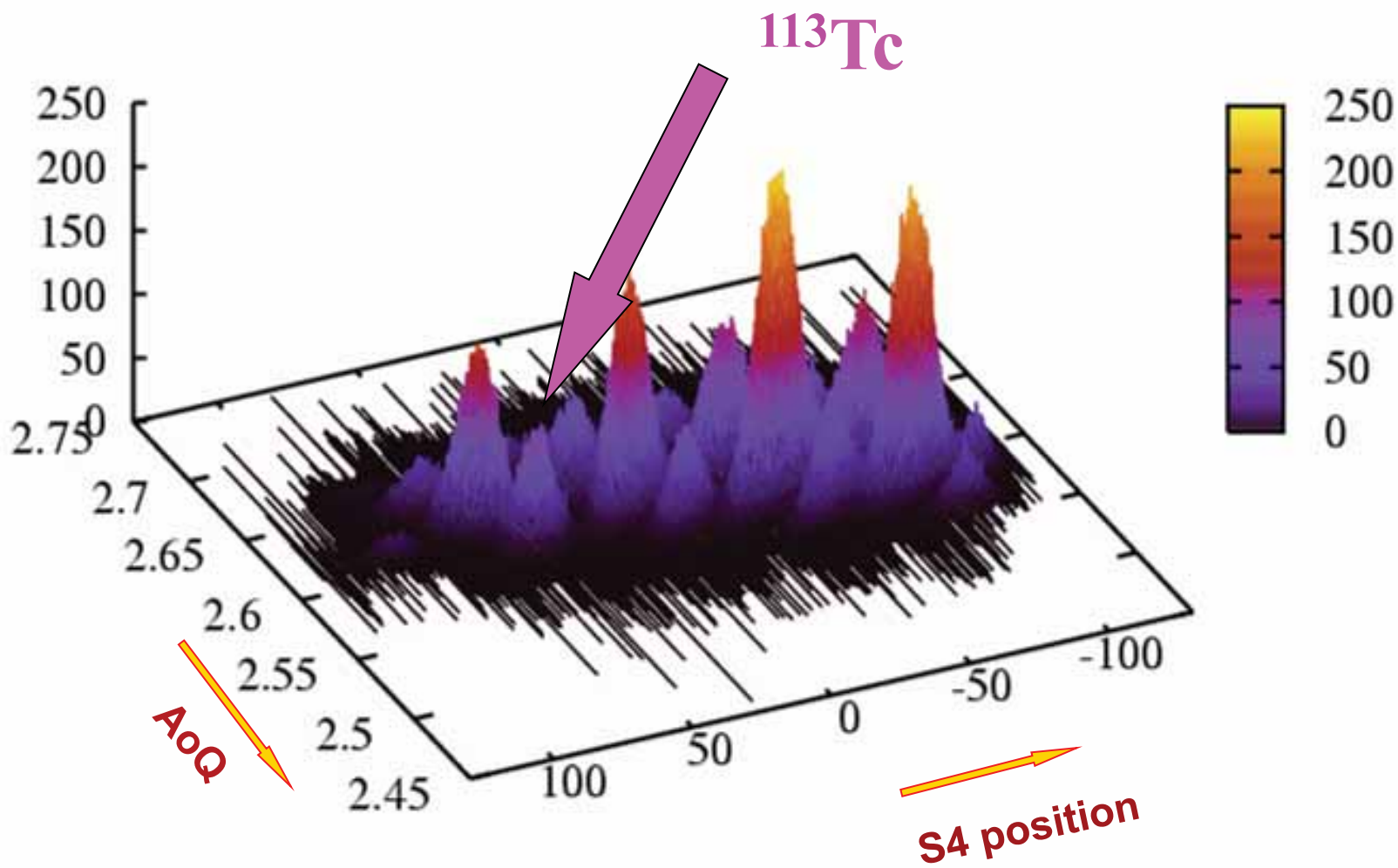
- fragmentation or fission of primary beams
- high secondary beam energies: 100 – 700 MeV/u
- fully stripped ions

Ion-by-ion identification with the FRS

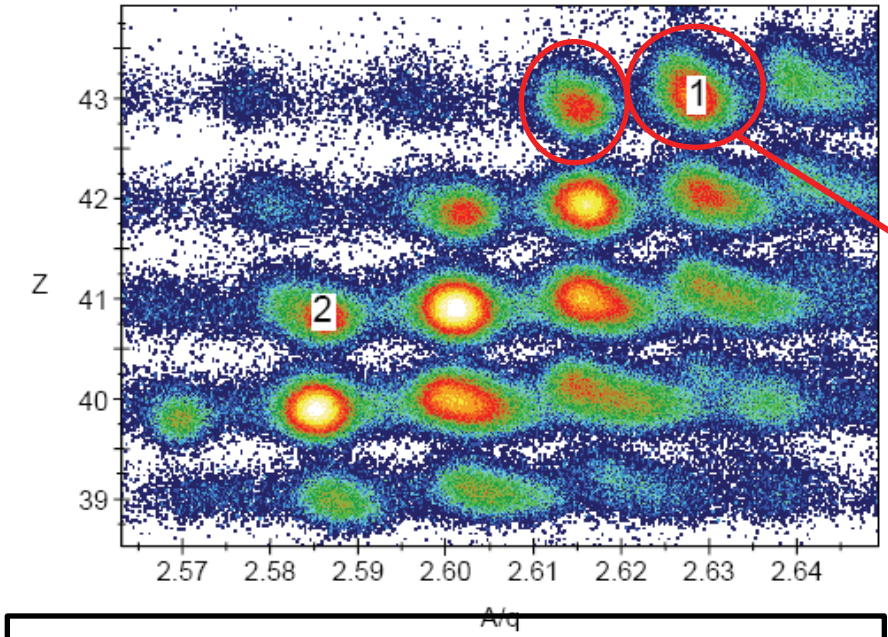


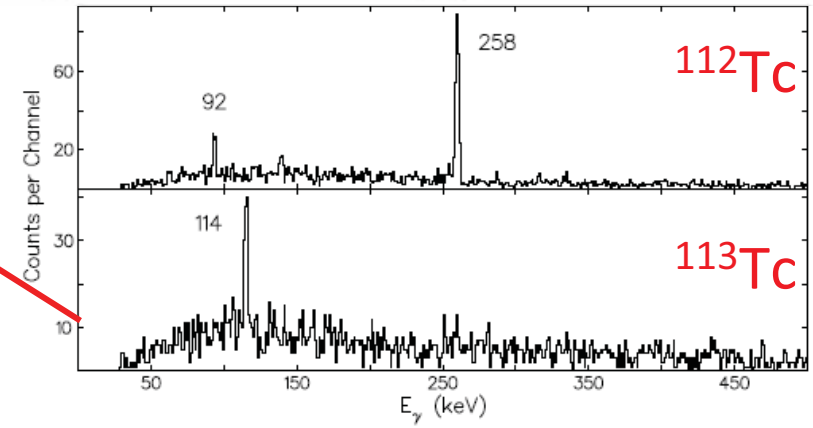
Cocktail of secondary, exotic fragments with ~ x00 MeV/u thru. FRS.
Separate and identify event-by-event. <u>Chemically independent</u>.

^{238}U fission on a ^{9}Be target
^{110}Nb setting:passive stopper

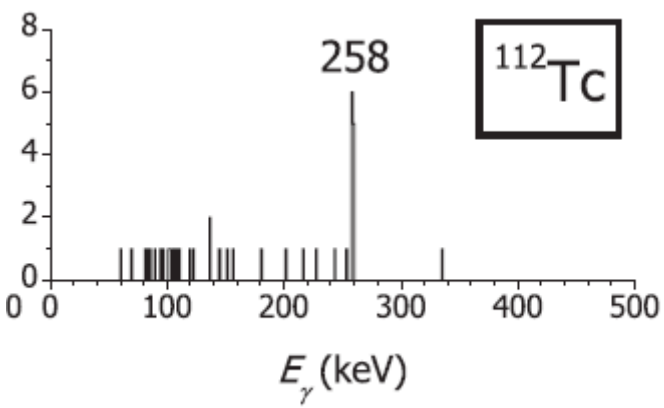


^{112,113}Tc spectroscopy at RISING

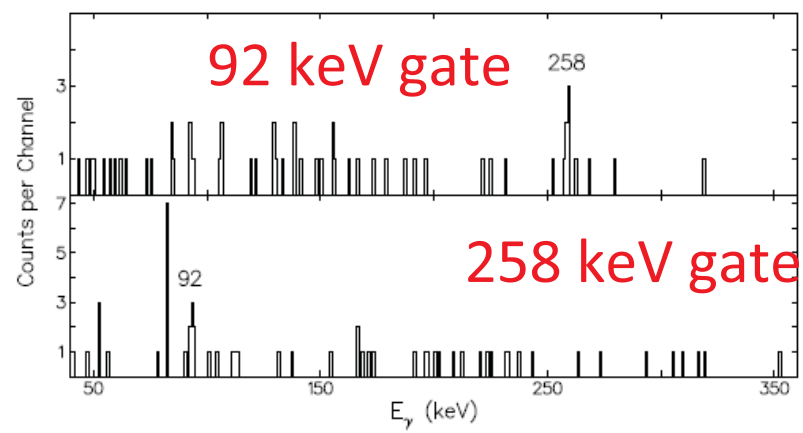




Coincidences are weak but clear:

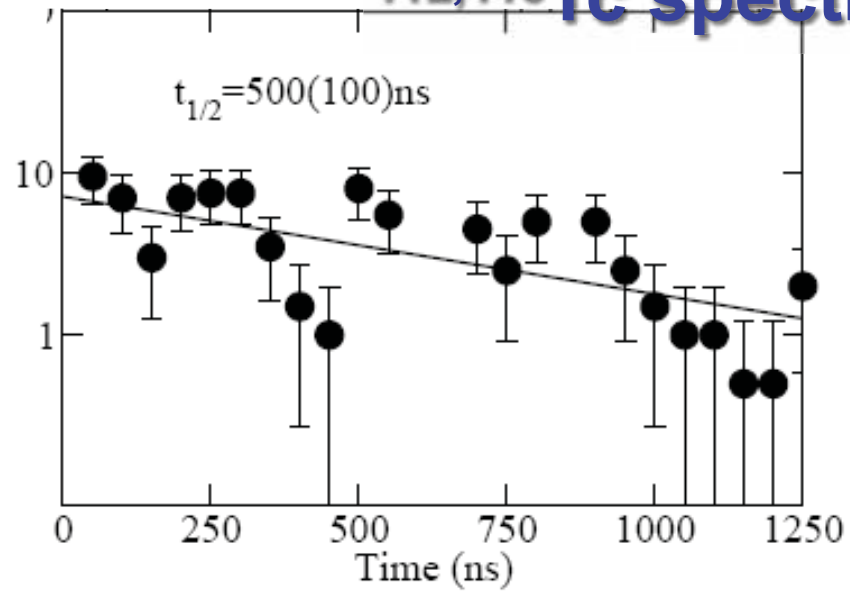


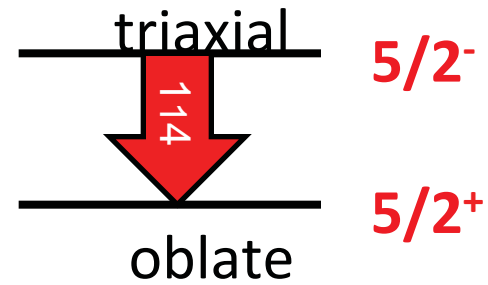
MSU: Folden et al; Phys Rev C79 (2009) 064318



^{112,113}Tc spectroscopy at RISING

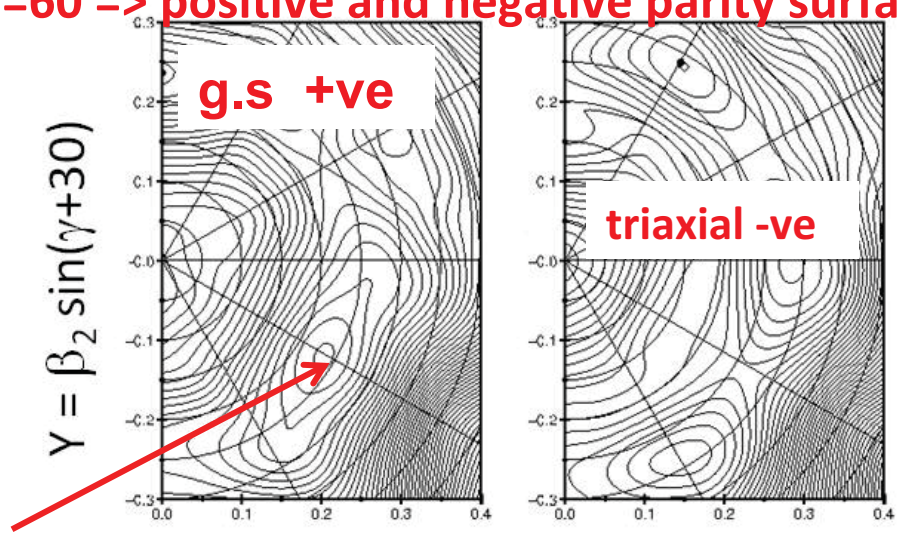
^{113}Tc





Measured hindrance for 114 keV E1 is 3 x 10^6 which is not unreasonable => **isomerism caused by shape change**

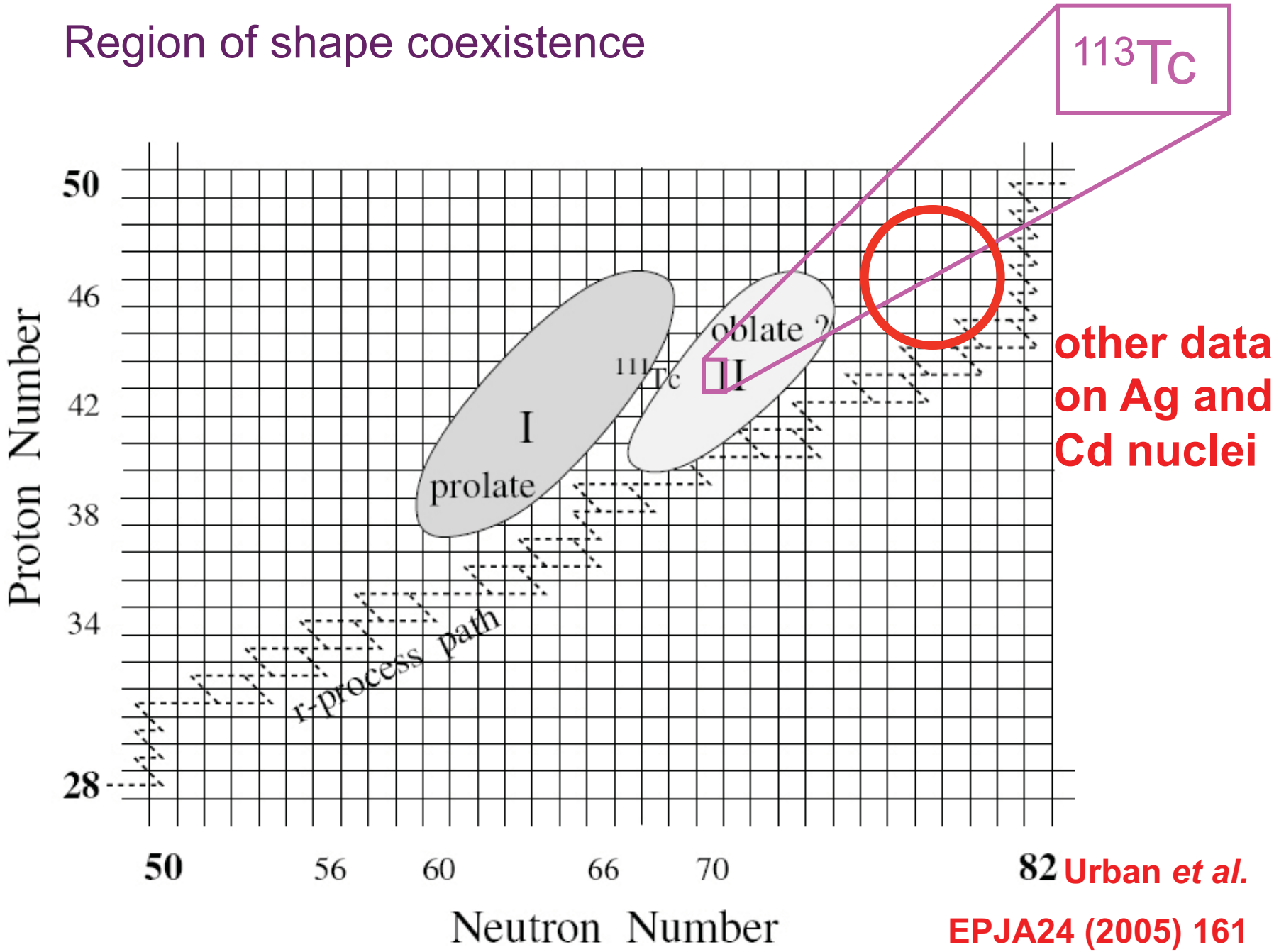
Z=43, N=60 => positive and negative parity surfaces



oblate, β_2~0.2
5/2[422]

Bruce, Lalkovski et al.
Phys Rev C82

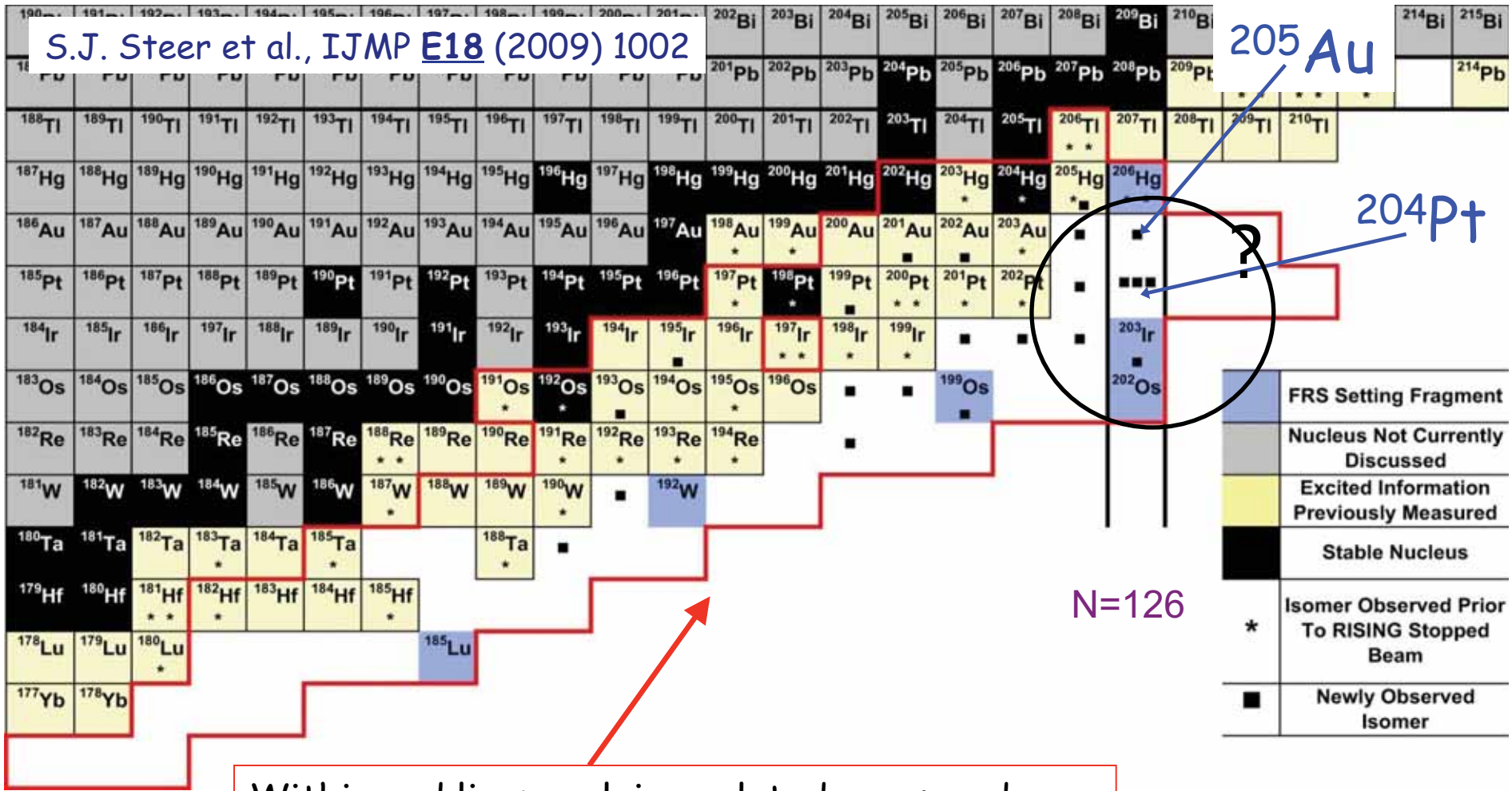
Region of shape coexistence



Urban *et al.*

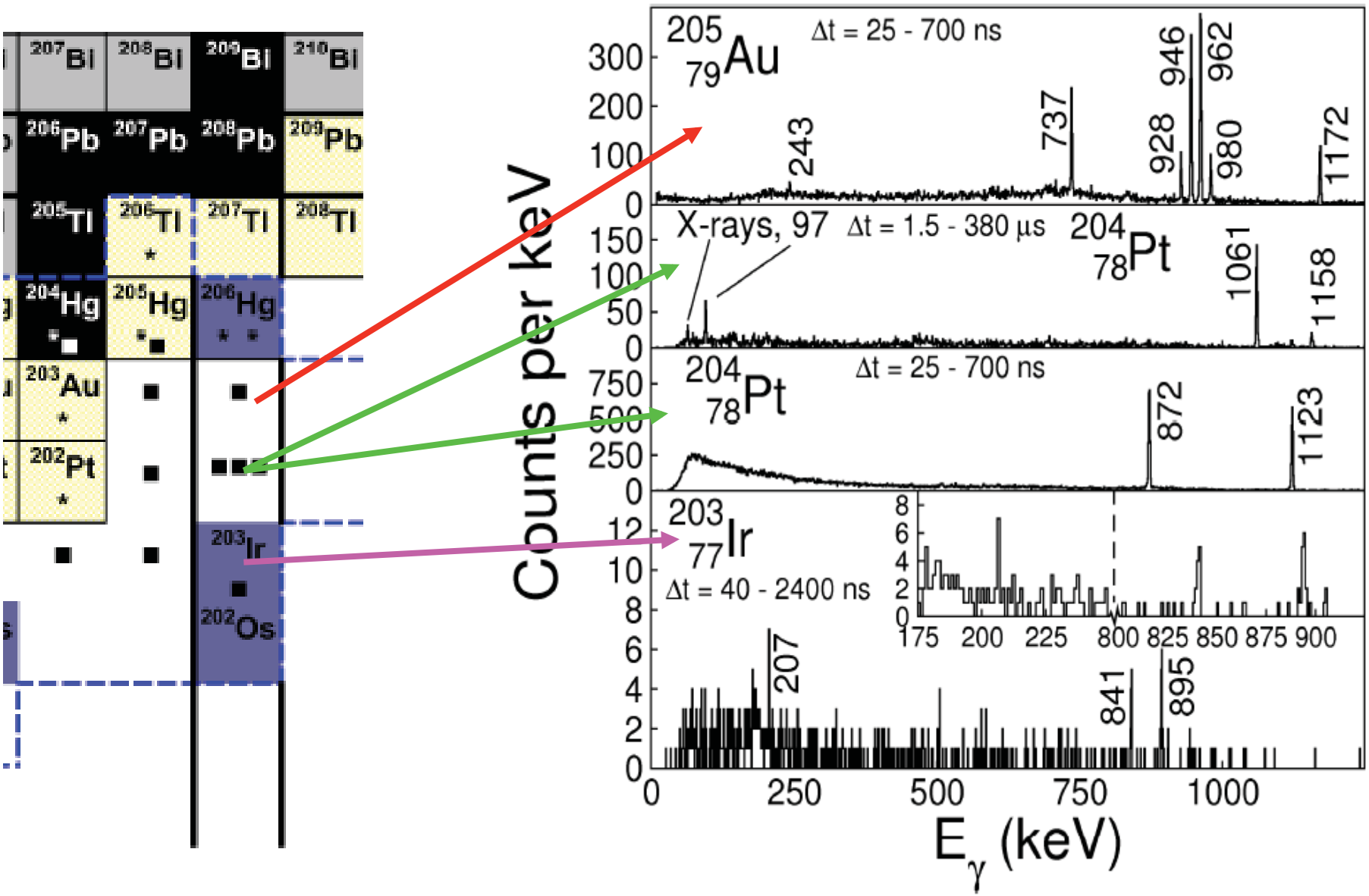
EPJA24 (2005) 161

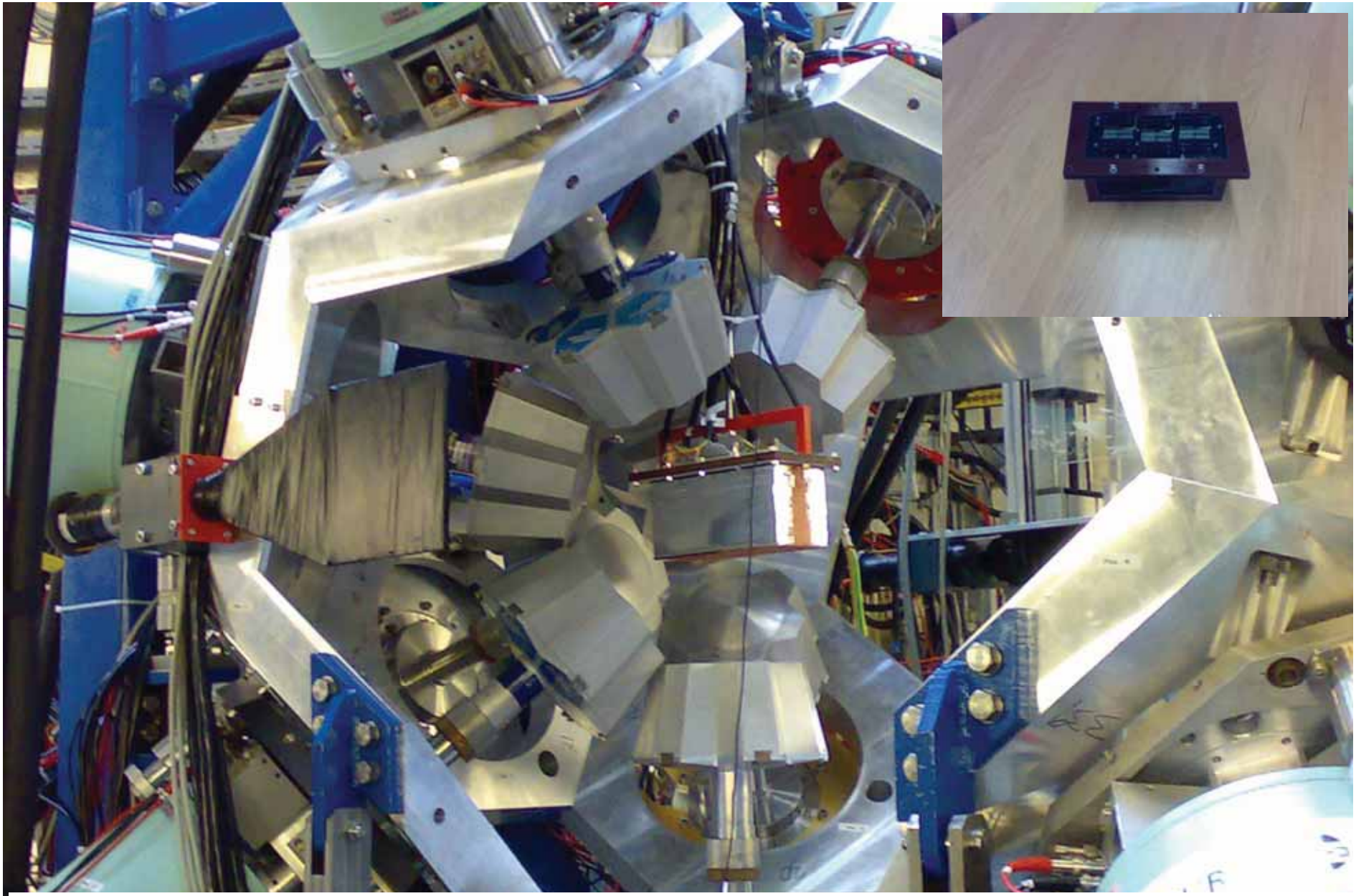
Information gathered from Passive Stopper RISING Stopped Beam (A~200)



Within red line: nuclei populated measured using FRS + RISING with 1 GeV/u ^{208}Pb beam.

S.J. Steer et al., Int. Jour. Mod. Phys. **E18** (2009) 1002
….isomer spectroscopy 'down' the N=126 line…first ID in such nuclei



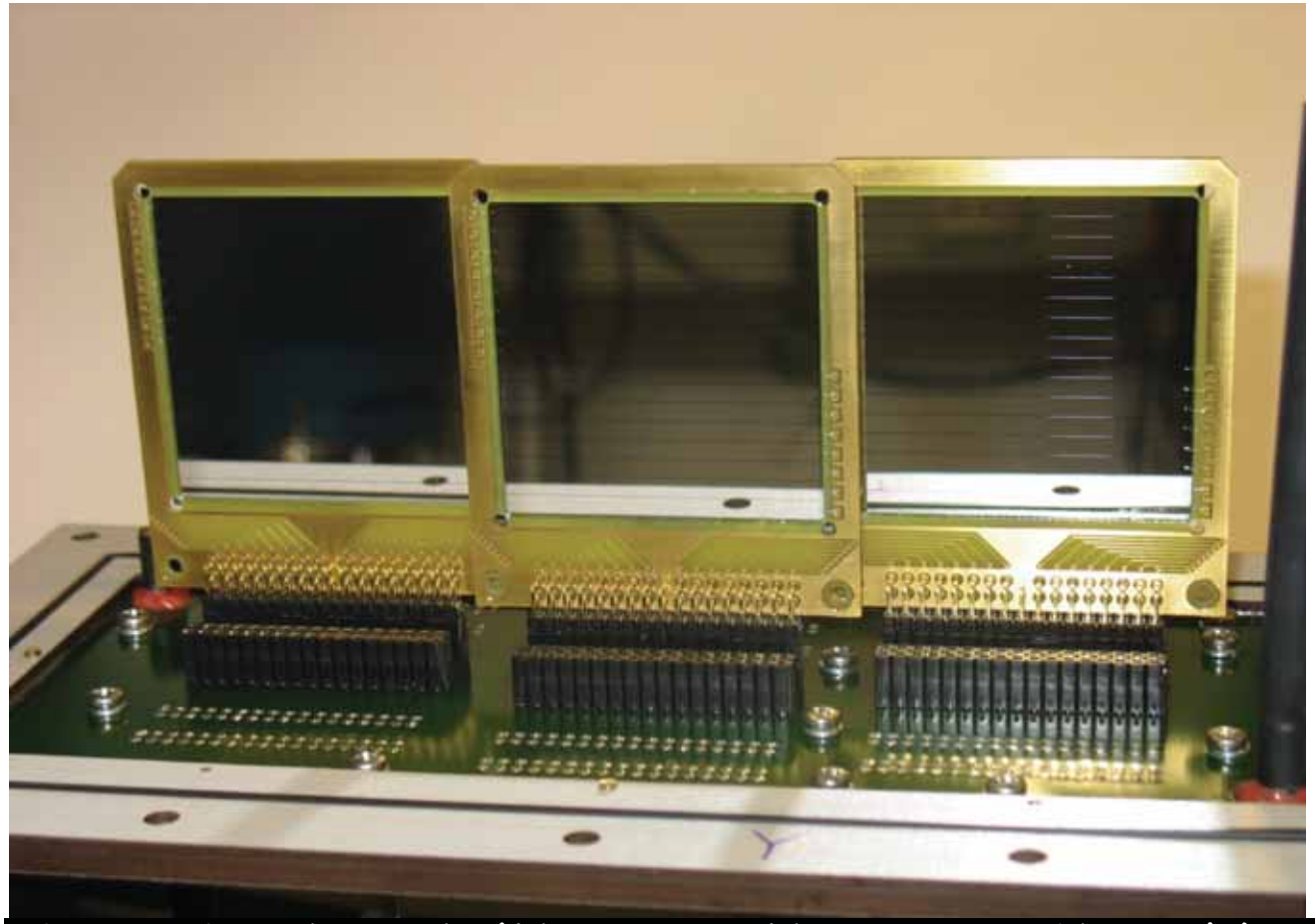


Passive Stopper measurements: γ-rays from isomer with $T_{1/2}$ for 10 ns → 1 ms.

Active Stopper measurements: β *–particles*, *i.e.* electrons, $T_{1/2}$ ms →mins

RISING Active Stopper Measurements

Passive Stopper: γ ray from isomer cascades with $T_{1/2}$ ~ 10 ns → 1 ms.



5 cm x 5 cm DSSSD (16 strips x 16 strips = 256 pixels) x 3 = 758 total pixels.

Active Stopper measurements: β– particles, internal conversion electrons.

$T_{1/2}$ up to ~ minutes; associated with delayed γ-rays.

See P.H. Regan et al., Int. Jour. Mod. Phys. **E17** (2008) 8 ;
R. Kumar NIM **A598** (2009) 754

Physics Letters B 672 (2009) 116–119

Contents lists available at ScienceDirect

Physics Letters B

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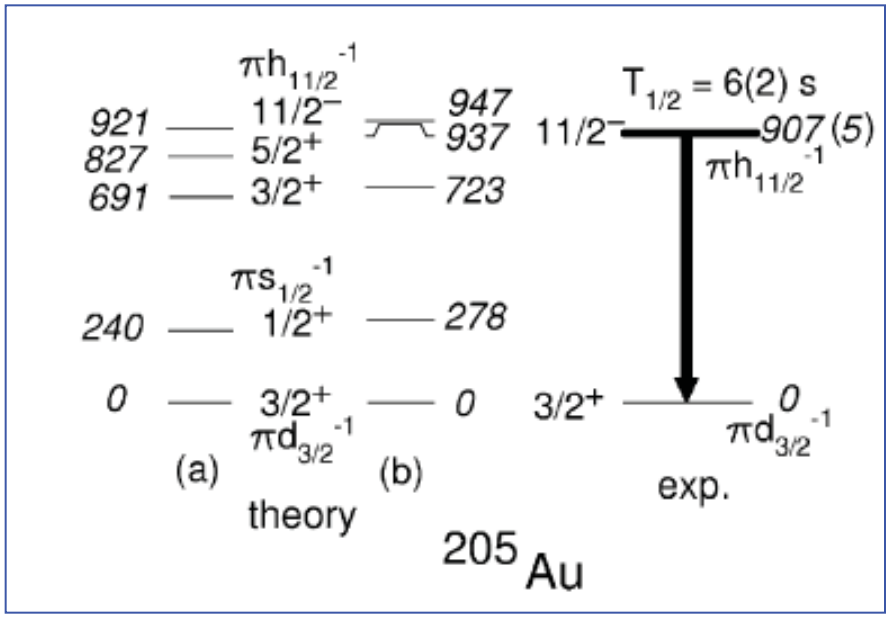
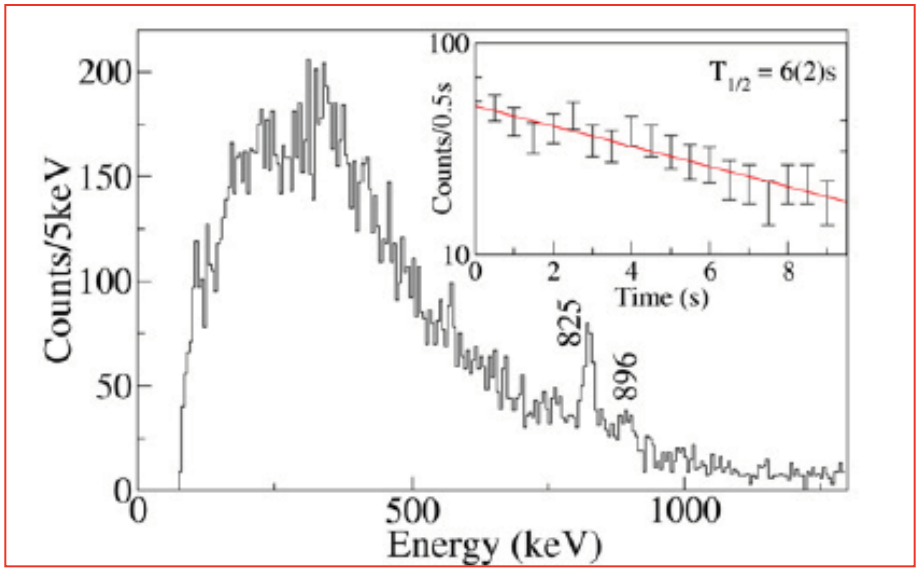
Proton–hole excitation in the closed shell nucleus ^{205}Au

Zs. Podolyák [a,*], G.F. Farrelly [a], P.H. Regan [a], A.B. Garnsworthy [a], S.J. Steer [a], M. Górska [b], J. Benlliure [c], E. Casarejos [c], S. Pietri [a], J. Gerl [b], H.J. Wollersheim [b], R. Kumar [d], F. Molina [e], A. Algora [e,f], N. Alkhomashi [a], G. Benzoni [g], A. Blazhev [h], P. Boutachkov [b], A.M. Bruce [i], L. Caceres [b,j], I.J. Cullen [a], A.M. Denis Bacelar [i], P. Doornenbal [b], M.E. Estevez [c], Y. Fujita [k], W. Gelletly [a], H. Geissel [b], H. Grawe [b], J. Grębosz [b,l], R. Hoischen [m,b], I. Kojouharov [b], S. Lalkovski [i], Z. Liu [a], K.H. Maier [n,l], C. Mihai [o], D. Mücher [h], B. Rubio [e], H. Schaffner [b], A. Tamii [k], S. Tashenov [b], J.J. Valiente-Dobón [p], P.M. Walker [a], P.J. Woods [q]

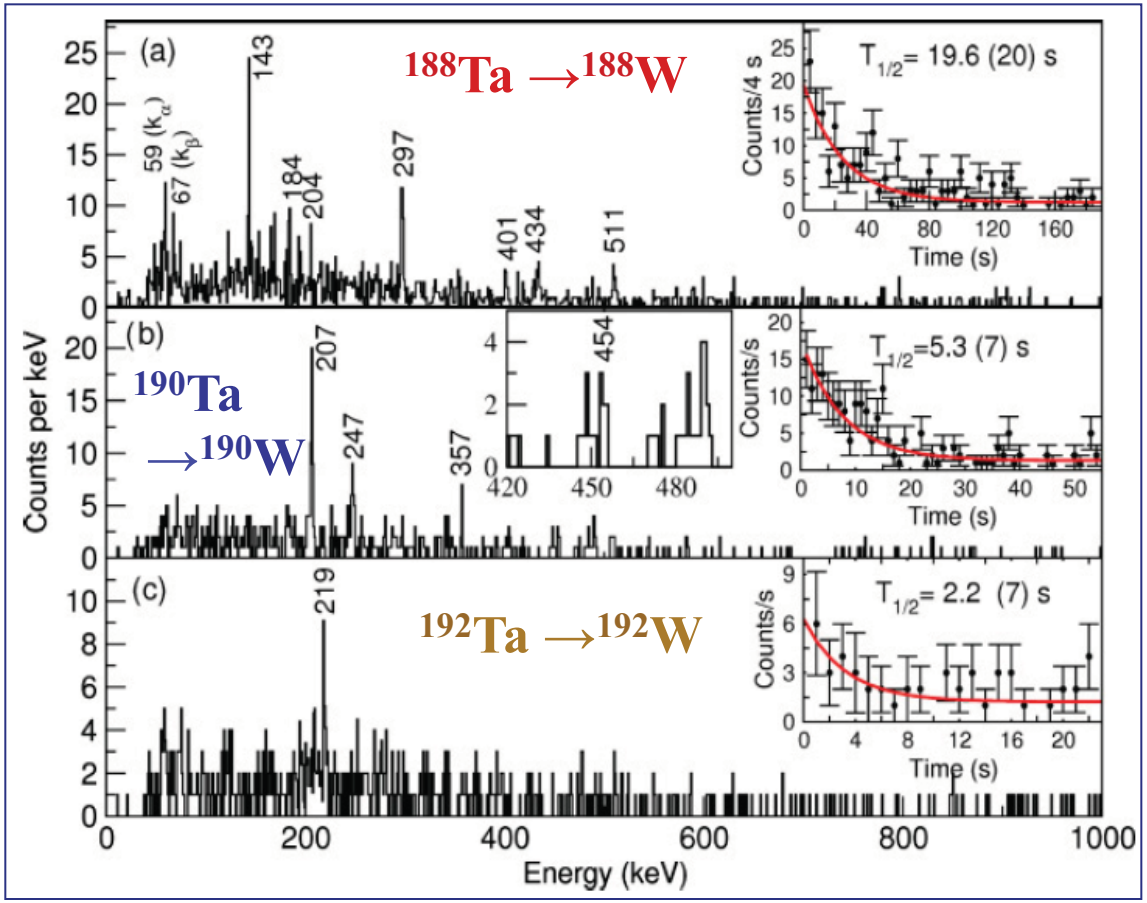


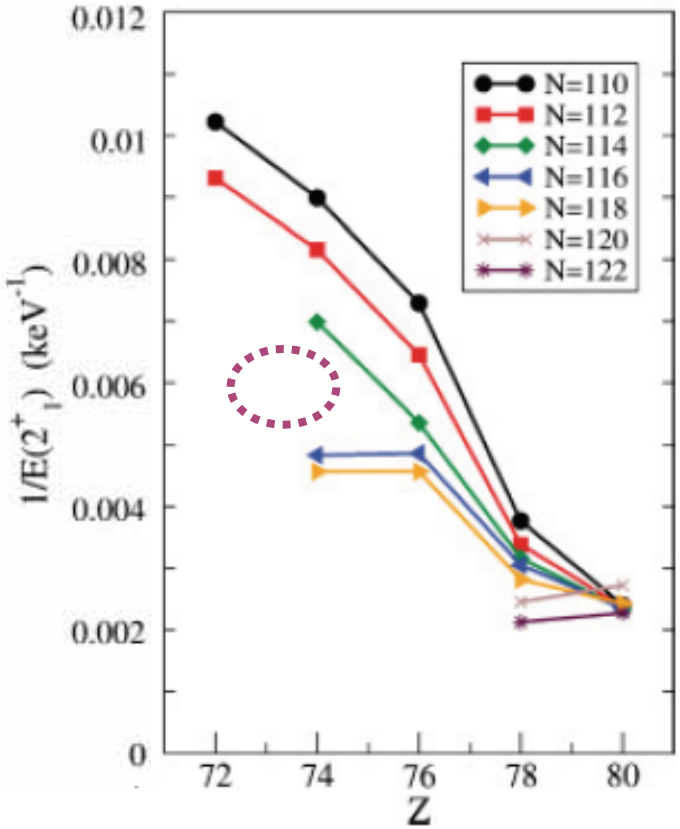


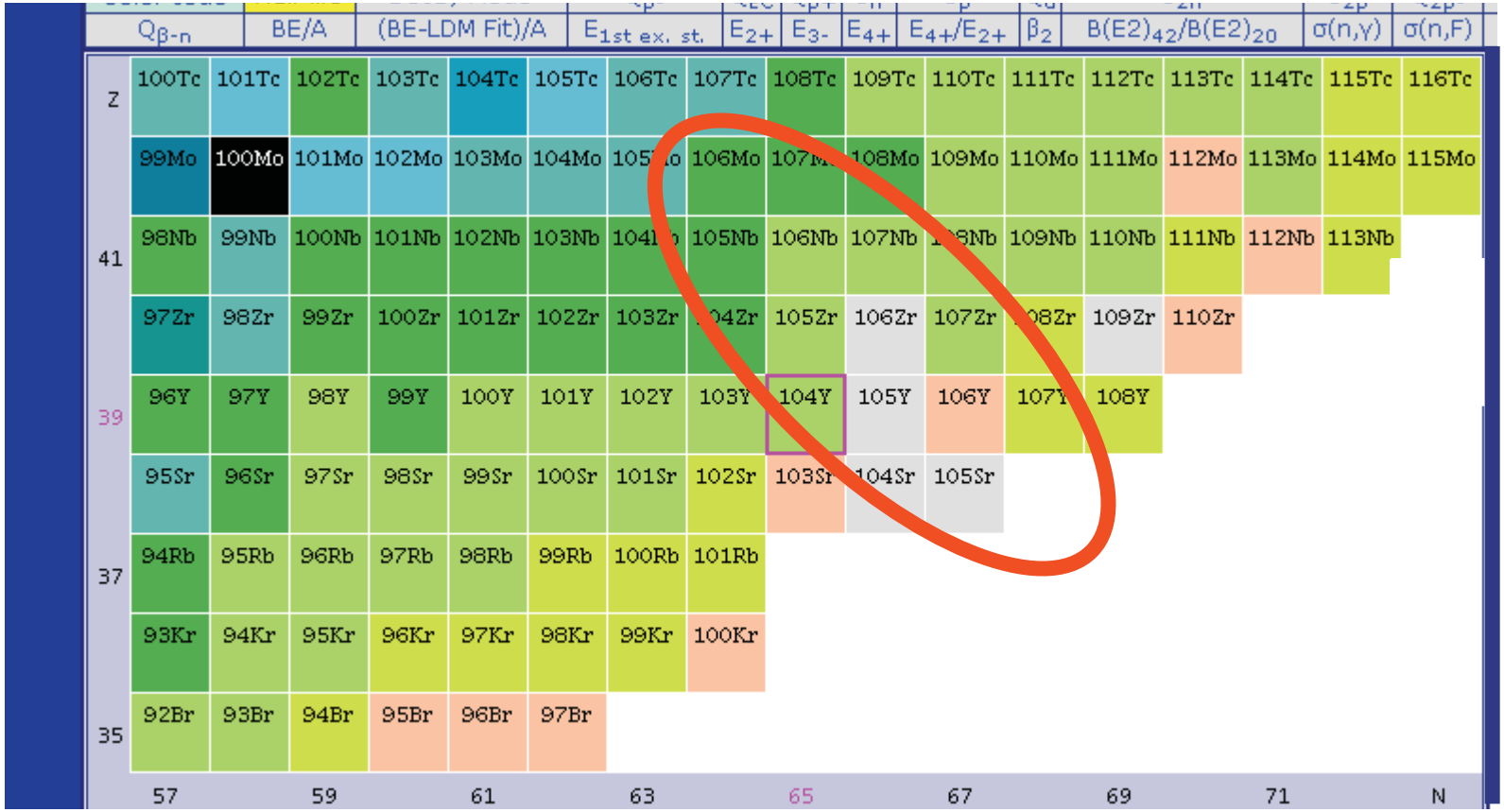
PHYSICAL REVIEW C **80**, 064308 (2009)

β^--delayed spectroscopy of neutron-rich tantalum nuclei: Shape evolution in neutron-rich tungsten isotopes

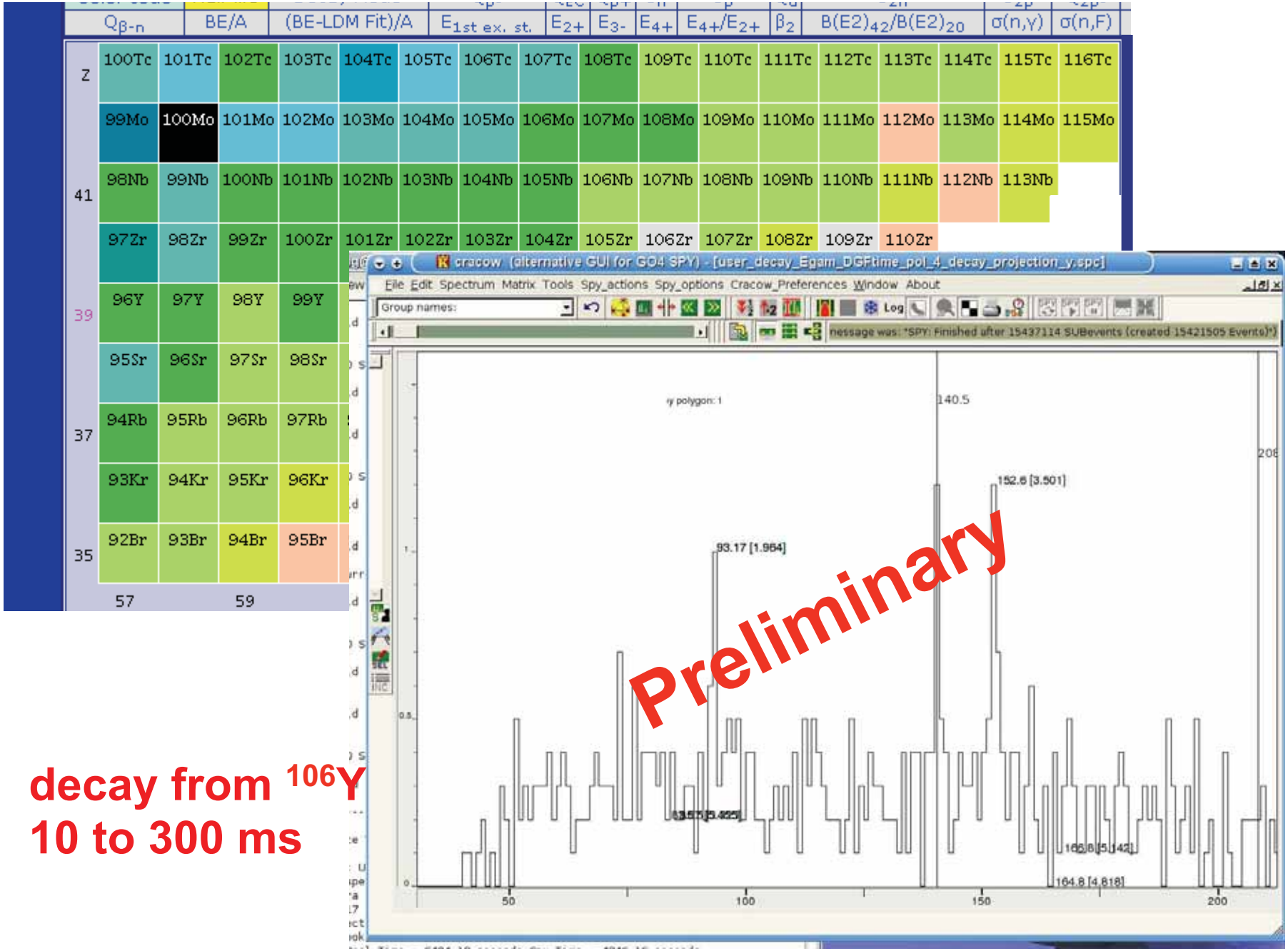
N. Alkhomashi,[1,*] P. H. Regan,[1] Zs. Podolyák,[1] S. Pietri,[1] A. B. Garnsworthy,[1] S. J. Steer,[1] J. Benlliure,[2] E. Caserejos,[2] R. F. Casten,[3] J. Gerl,[4] H. J. Wollersheim,[4] J. Grebosz,[5] G. Farrelly,[1] M. Górska,[4] I. Kojouharov,[4] H. Schaffner,[4] A. Algora,[6,7] G. Benzoni,[8] A. Blazhev,[9] P. Boutachkov,[4] A. M. Bruce,[10] A. M. Denis Bacelar,[10] I. J. Cullen,[1] L. Cáceres,[4] P. Doornenbal,[4] M. E. Estevez,[2] Y. Fujita,[11] W. Gelletly,[1] R. Hoischen,[4,12] R. Kumar,[13] N. Kurz,[4] S. Lalkovski,[10] Z. Liu,[14] C. Mihai,[15] F. Molina,[6] A. I. Morales,[2] D. Mücher,[9] W. Prokopowicz,[4] B. Rubio,[6] Y. Shi,[16] A. Tamii,[17] S. Tashenov,[4] J. J. Valiente-Dobón,[18] P. M. Walker,[1] P. J. Woods,[14] and F. R. Xu[16]







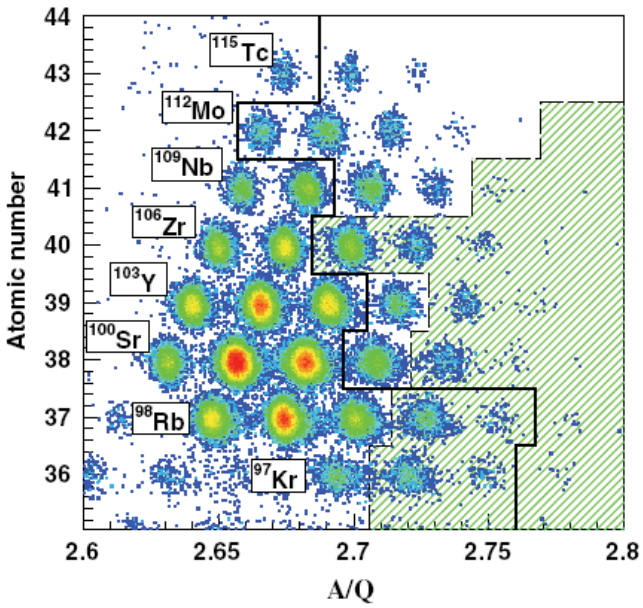
Another active stopper experiment focused on ^{106}Y



decay from ^{106}Y
10 to 300 ms

β-Decay Half-Lives of Very Neutron-Rich Kr to Tc Isotopes on the Boundary of the r-Process Path: An Indication of Fast r-Matter Flow

S. Nishimura,[1] Z. Li,[1] H. Watanabe,[1] K. Yoshinaga,[2,1] T. Sumikama,[2] T. Tachibana,[3] K. Yamaguchi,[4] M. Kurata-Nishimura,[1] G. Lorusso,[1,5] Y. Miyashita,[2] A. Odahara,[4] H. Baba,[1] J. S. Berryman,[6] N. Blasi,[7] A. Bracco,[7,8] F. Camera,[7,8] J. Chiba,[2] P. Doornenbal,[1] S. Go,[9] T. Hashimoto,[9] S. Hayakawa,[9] C. Hinke,[10] E. Ideguchi,[9] T. Isobe,[1] Y. Ito,[4] D. G. Jenkins,[11] Y. Kawada,[12] N. Kobayashi,[12] Y. Kondo,[12] R. Krücken,[10] S. Kubono,[9] T. Nakano,[2] H. J. Ong,[13] S. Ota,[9] Zs. Podolyák,[14] H. Sakurai,[1] H. Scheit,[1] K. Steiger,[10] D. Steppenbeck,[1] K. Sugimoto,[2] S. Takano,[2] A. Takashima,[4] K. Tajiri,[4] T. Teranishi,[15] Y. Wakabayashi,[16] P. M. Walker,[14] O. Wieland,[7] and H. Yamaguchi[9]



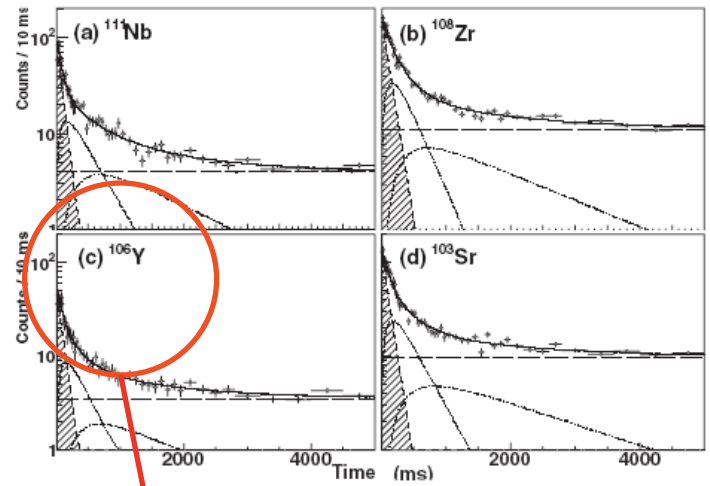


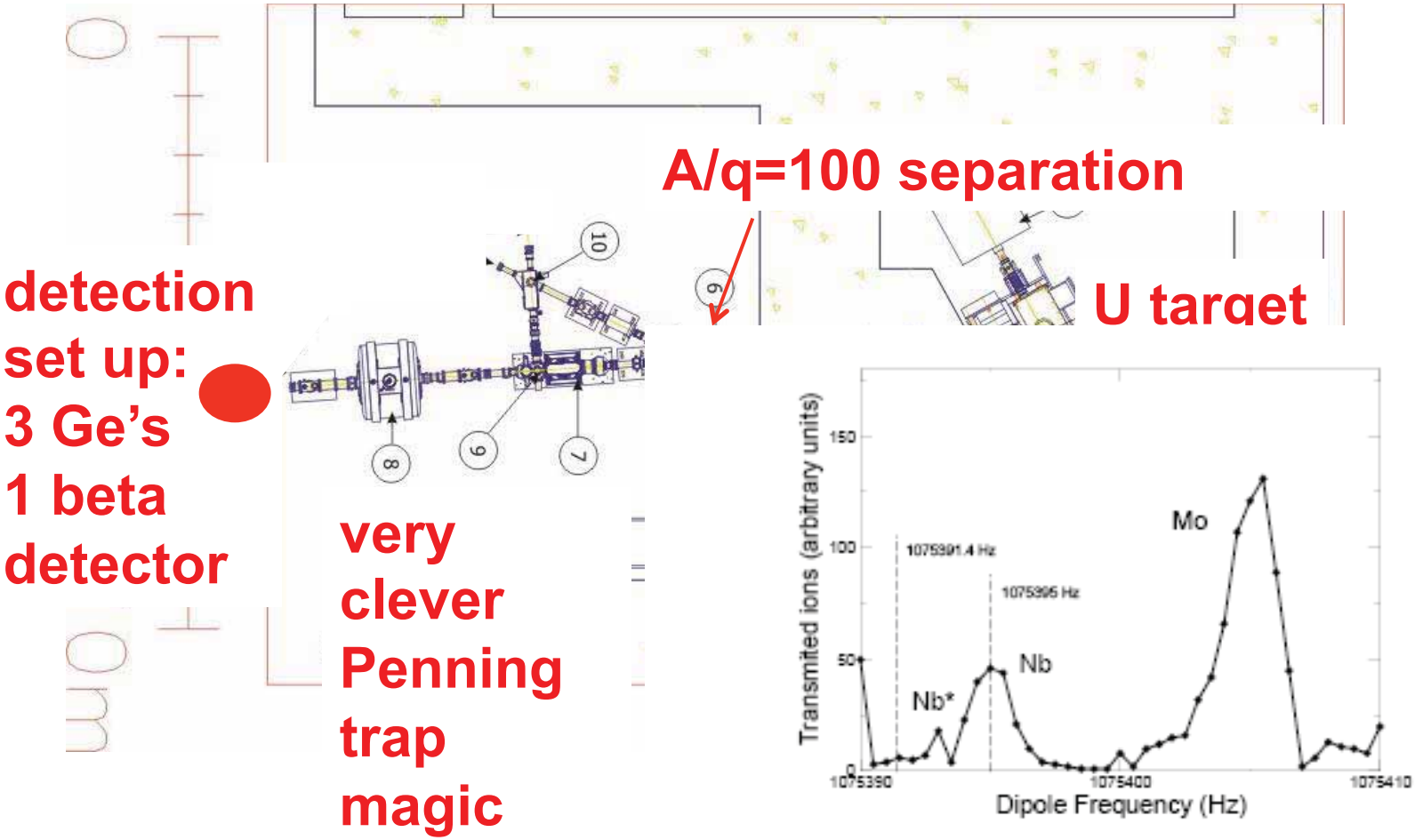
FIG. 2. Fitted decay curves for (a) ^{111}Nb, (b) ^{108}Zr, (c) ^{106}Y, and (d) ^{103}Sr. The data are presented with variable bin widths ranging from 10 to 5000 ms, with normalized counts per 10 ms.

^{106}Y 62 $^{+25}_{-14}$ ms

PRL **106,** 052502 (2011)

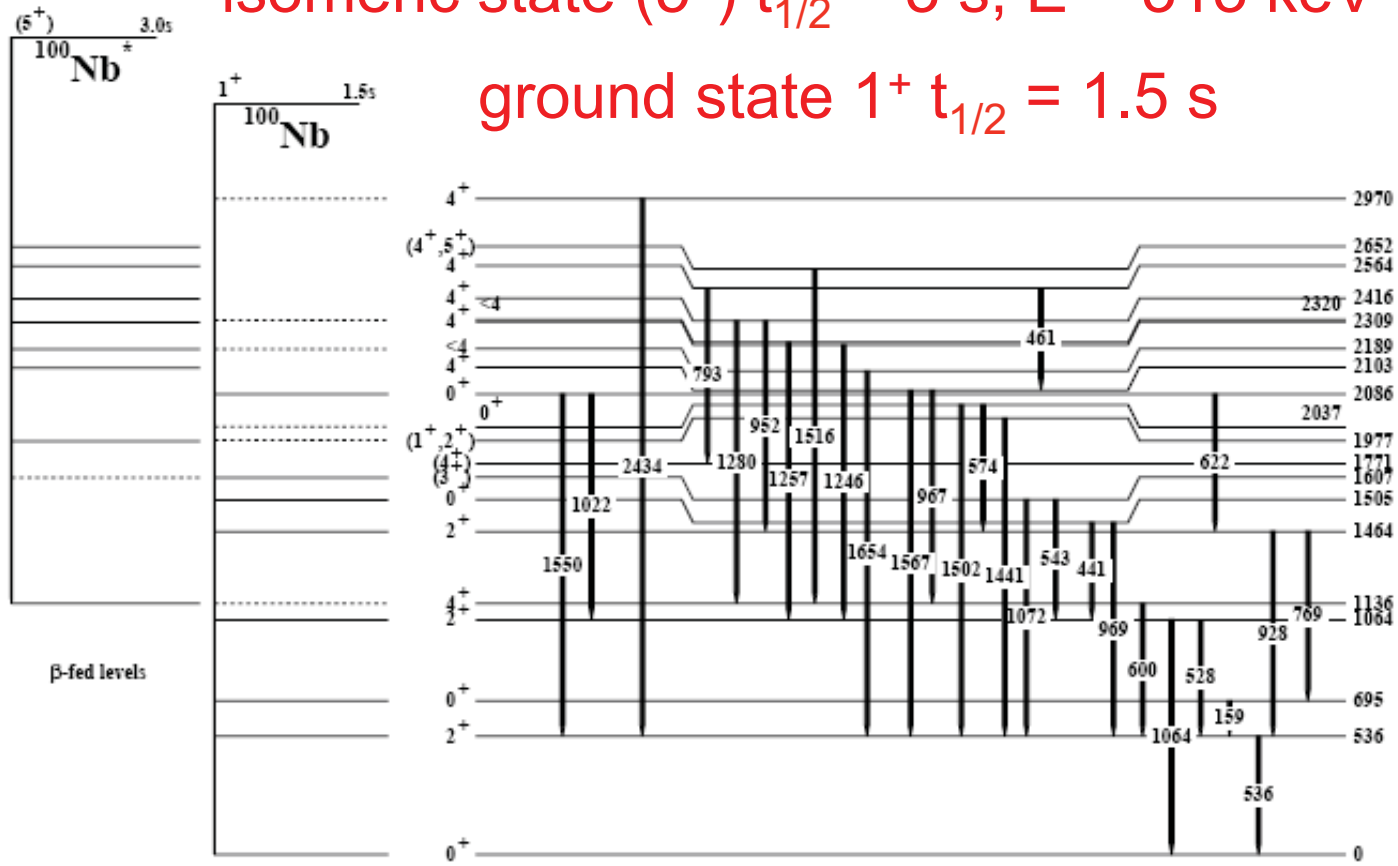
Isomer separation at Jyvaskyla:

Ion Guide Isotope Separator On Line



isomeric state (5^+) $t_{1/2}$ = 3 s, E = 313 keV

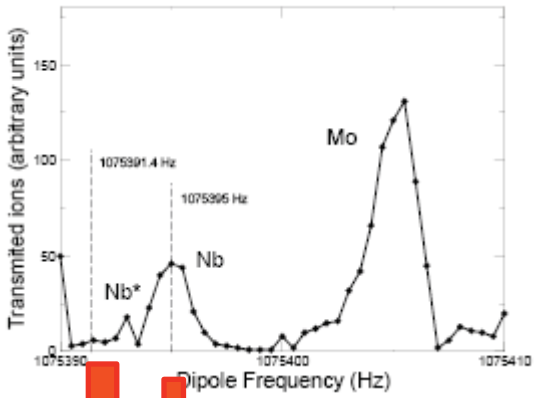
ground state 1^+ $t_{1/2}$ = 1.5 s

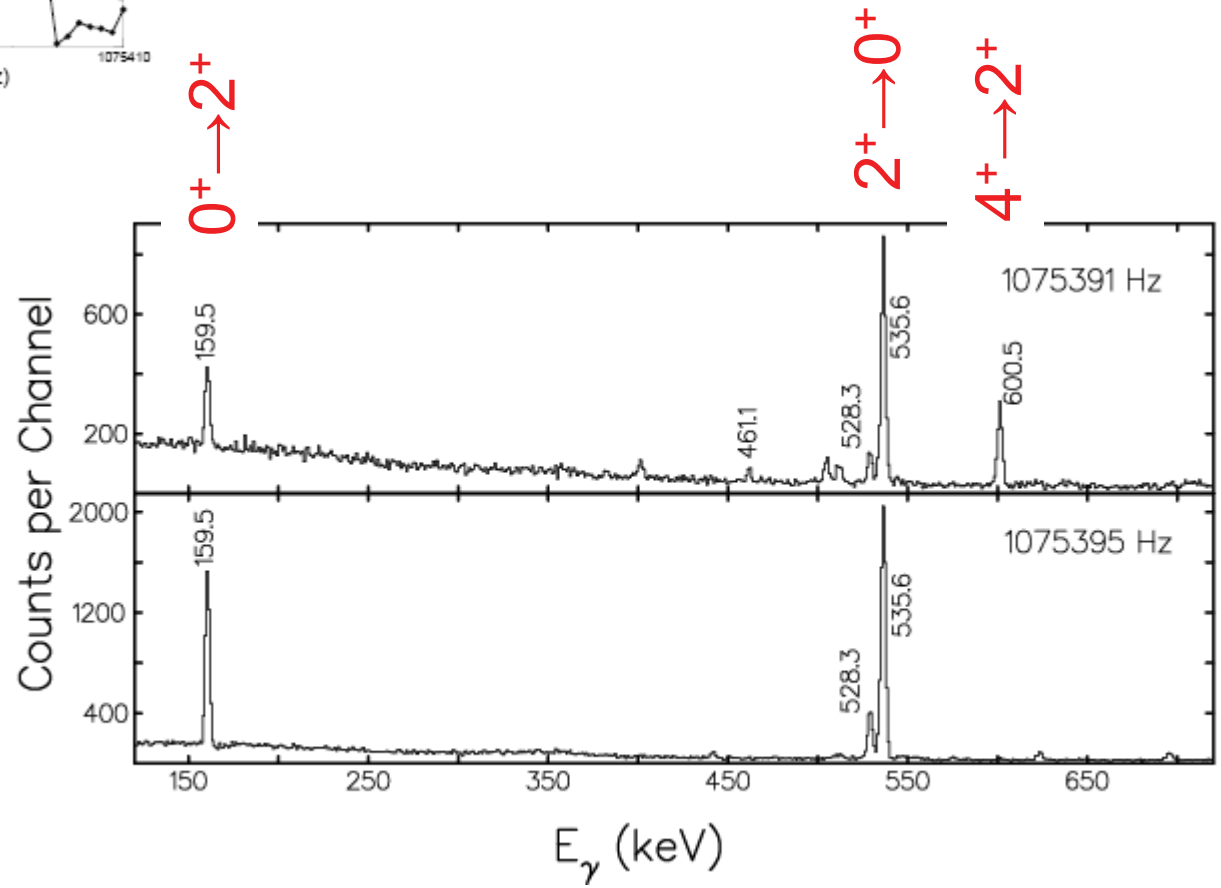


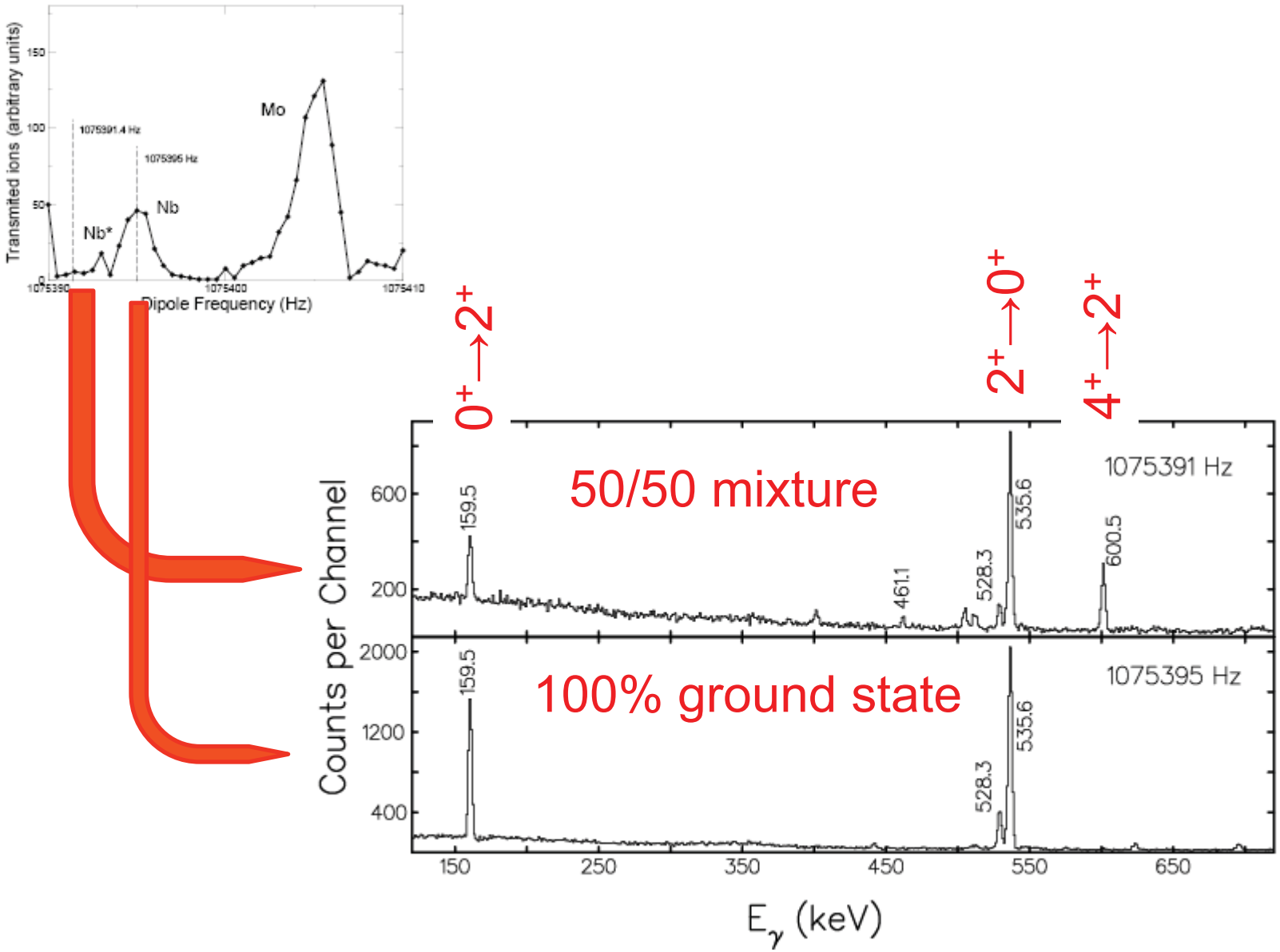
$^{100}_{42}Mo$

isomeric state (5^+) $t_{1/2}$ = 3 s

ground state 1^+ $t_{1/2}$ = 1.5 s






Transmited ions (arbitrary units)
Dipole Frequency (Hz)
Nb*
Nb
Mo
1075391.4 Hz
1075395 Hz
$0^+ \rightarrow 2^+$
$2^+ \rightarrow 0^+$
$4^+ \rightarrow 2^+$
50/50 mixture
100% ground state
1075391 Hz
1075395 Hz
159.5
461.1
528.3
535.6
600.5
Counts per Channel
E_γ (keV)