Lessons from the RISING DECAY campaign

(and from isomeric separation at Jyväskylä)

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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
RISING: Stopped beam - physics focus

- $T_1/2 = 10.4 \text{ s}$
- Rising: Stopped beam - physics focus
- $\beta^+/EC$ decay of $^{100}\text{Sn}$
- Isospin symmetry of $T_z=-1$ nuclei $^{42}\text{Ti} ... 54\text{Ni}$
- Structure around $N=Z$
- High spin population in rare earth nuclei
- Structure of $N \geq 126$
- Structure south of $^{208}\text{Pb}$
- Shape coexistence in $^{190}\text{W}$
- Collectivity of n-rich Ta, W
- Structure around $^{110}\text{Zr}$
- $g$-factors below $^{132}\text{Sn}$
- Shell quenching in $^{130}\text{Cd}$ r process abundances
- $g$-factors of light Pb isotopes
- Spin population mechanism
The Accelerators:
- **UNILAC** (injector) E=11.4 MeV/n
- **SIS 18Tm** corr. U 1 GeV/n

Beam Currents:

- $^{238}\text{U}$ - $10^8$ pps
- some medium mass nuclei - $10^9$ pps ($A\sim130$)

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. Chemically independent.
$^{238}\text{U}$ fission on a $^9\text{Be}$ target

$^{110}\text{Nb}$ setting: passive stopper

$^{113}\text{Tc}$

AoQ

S4 position
112,113Tc spectroscopy at RISING

Coincidences are weak but clear:

92 keV gate
258 keV gate

$^{113}\text{Tc}$ spectroscopy at RISING

$^{112,113}\text{Tc}$

$^{113}\text{Tc}$

$t_{1/2}=500(100)$ ns

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

$Y = \beta_2 \sin(\gamma+30)$

oblate, $\beta_2 \sim 0.2$

5/2[422]

$X = \beta_2 \cos(\gamma+30)$

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

Bruce, Lalkovski et al.
Phys Rev C82
Region of shape coexistence

Other data on Ag and Cd nuclei

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.
...isomer spectroscopy ‘down’ the N=126 line...first ID in such nuclei
Passive Stopper measurements: $\gamma$-rays from isomer with $T_{1/2}$ for 10 ns $\rightarrow$ 1 ms.
Active Stopper measurements: $\beta$ -particles, i.e. electrons, $T_{1/2}$ ms $\rightarrow$ mins
RISING Active Stopper Measurements

Passive Stopper: $\gamma$ ray from isomer cascades with $T_{1/2} \sim 10$ ns $\rightarrow$ 1 ms.

Active Stopper measurements: $\beta$-particles, internal conversion electrons.

$T_{1/2}$ up to $\sim$ minutes; associated with delayed $\gamma$-rays.

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

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

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\( ^{188}\text{Ta} \to ^{188}\text{W} \)

\( ^{190}\text{Ta} \to ^{190}\text{W} \)

\( ^{192}\text{Ta} \to ^{192}\text{W} \)
Another active stopper experiment focused on $^{106}Y$. 
Decay from $^{106}$Y
10 to 300 ms

Preliminary
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

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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 $62 \pm 25_{-14}^{+25}$ ms
Isomer separation at Jyvaskyla:

Ion Guide Isotope Separator On Line

A/q=100 separation

U target

Detection set up:
3 Ge’s
1 beta detector

very clever Penning trap magic
isomeric state \( (5^+) \) \( t_{1/2} = 3 \) s, \( E = 313 \) keV

ground state \( 1^+ \) \( t_{1/2} = 1.5 \) s
isomeric state (5+) $t_{1/2} = 3$ s

ground state 1$^+$ $t_{1/2} = 1.5$ s
$^{0+} \rightarrow 2^+$

$^{4+} \rightarrow 2^+$

$^{2+} \rightarrow 0^+$

100% ground state

50/50 mixture

Counts per Channel

$E_\gamma$ (keV)