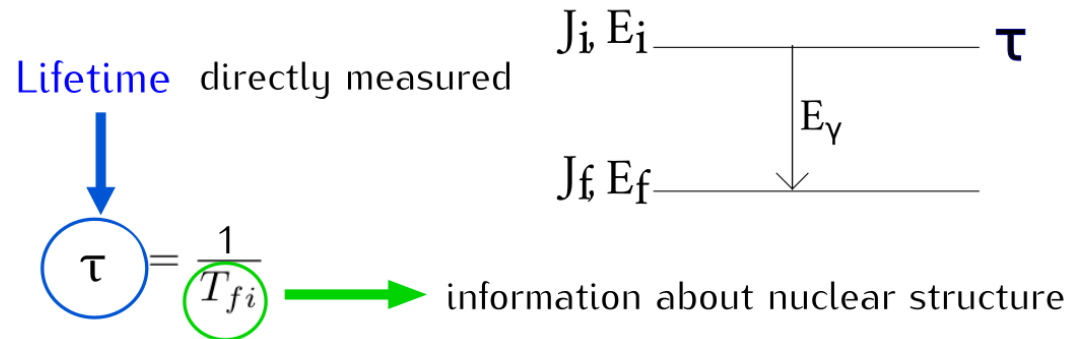


Fast timing beta-delayed gamma spectroscopy

Agnieszka Korgul
Faculty of Physics
University of Warsaw

Transition probabilities in gamma decay



Transition probability

$$T_{fi}^{(\sigma\lambda)} = \frac{2}{\epsilon_0 \hbar} \frac{\lambda + 1}{\lambda [(2\lambda + 1)!!]^2} \left(\frac{E_\gamma}{\hbar c} \right)^{2\lambda + 1} B(\sigma\lambda; \xi_i J_i \rightarrow \xi_f J_f)$$

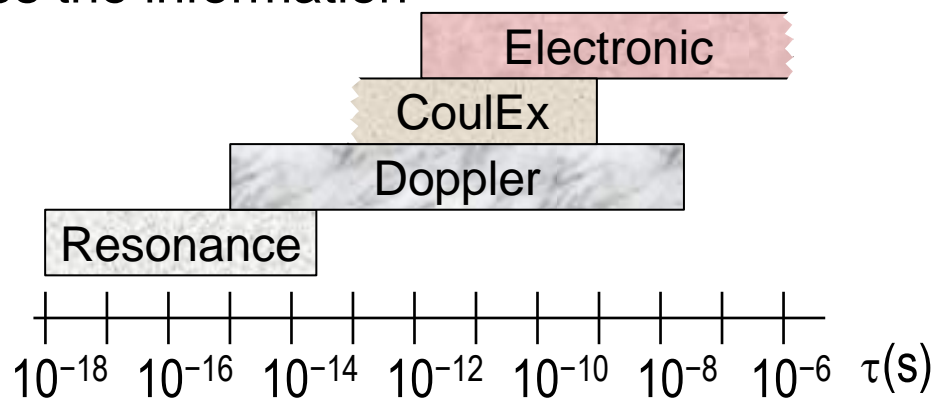
Reduced transition probability

$$B(\sigma\lambda; \xi_i J_i \rightarrow \xi_f J_f) \equiv \frac{1}{2J_i + 1} |(\xi_f J_f || \mathcal{M}_{\sigma\lambda} || \xi_i J_i)|^2$$

→ probes the structure of the wave functions

Transition probabilities in gamma decay

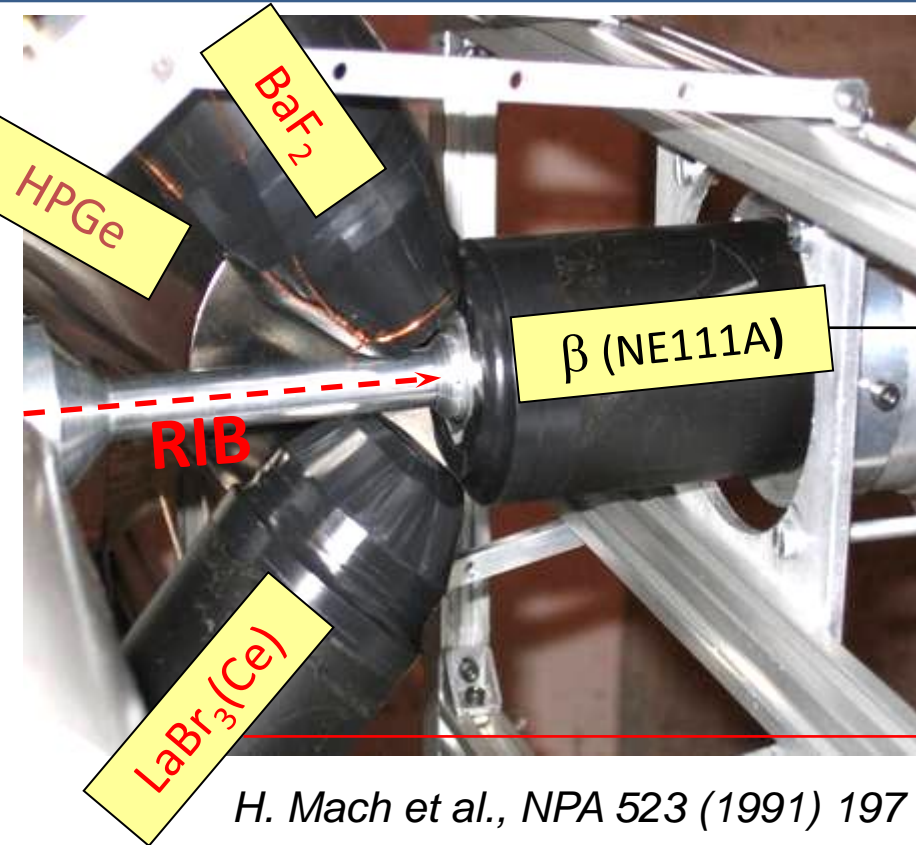
The measurement of the lifetime gives the information about nuclear matrix elements $B(XL)$



Access to nuclear properties

- Single particle estimates
 - Shell evolution
- $B(E2)$ values
 - deformation of even-even nuclei
 - collective modes (spin dependence), shape coexistence...
- Systematics

The Advanced Time Delayed $\beta\gamma\gamma(t)$ method



START:
Plastic β scintillator: **TIMING**
Fast response
Efficient start detector

start
stop



TAC

STOP:
LaBr₃(Ce)/BaF₂: TIMING
Fast response γ -detectors
Poor energy resolution

The Advanced Time Delayed $\beta\gamma\gamma(t)$ method

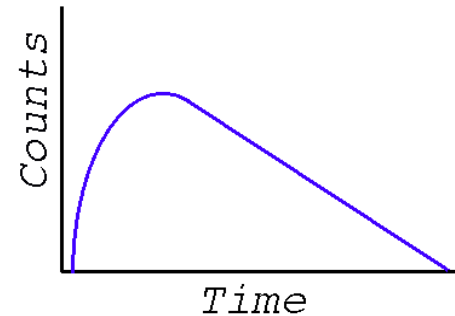
De-convolution of slope

- Slope = $T_{1/2}$
- Range: 30 ps to 30 ns (or longer)

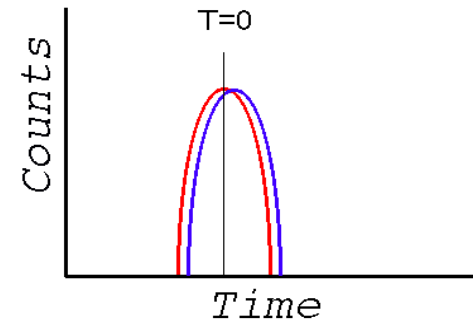
Centroid shift

- Shift in centroid position = τ
- Range: down to ~5-10 ps

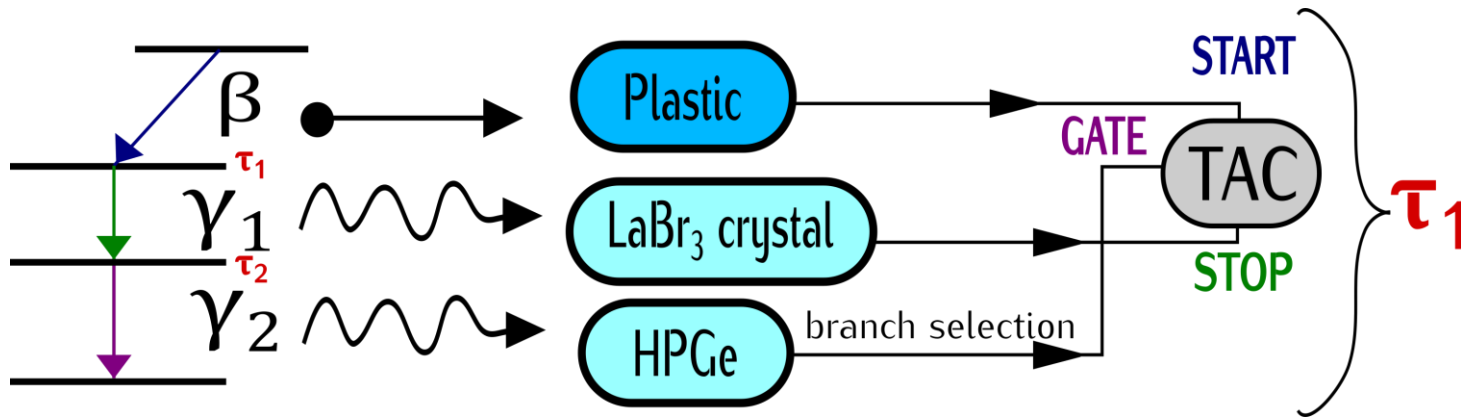
Time calibrations



TAC



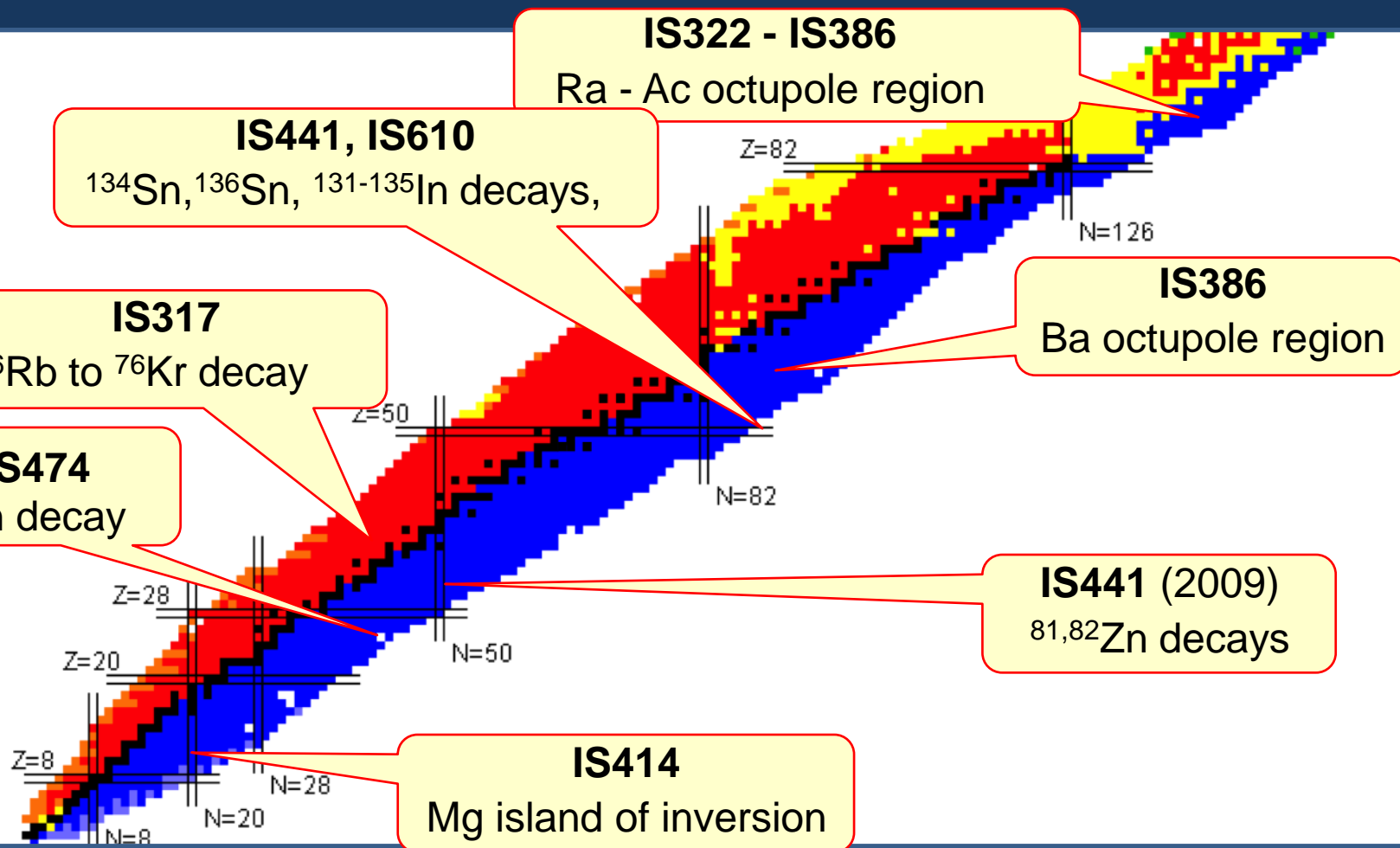
The Advanced Time Delayed $\beta\gamma\gamma(t)$ method



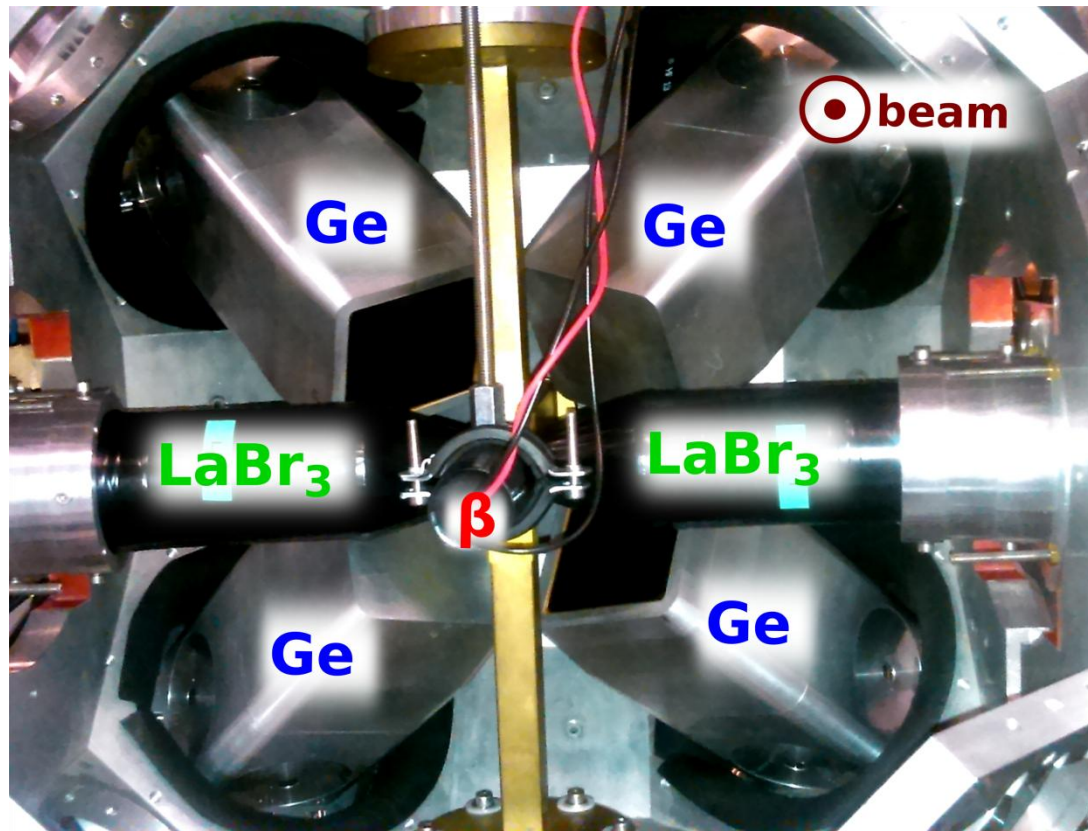
Crystal	External Delay (ns)	HV (V)	ORTEC MODE	FWHM ^{60}Co (ps)	FWHM ^{22}Na (ps)
A	1.6	1300	CFD	110±2	164±2
A	0.8	1300	LE	106±2	158±2
B	1.6	1300	CFD	98±2	148±2
C	1.6	1200	CFD	107±2	-

Crystal B:
8% Ce
PMT R9779

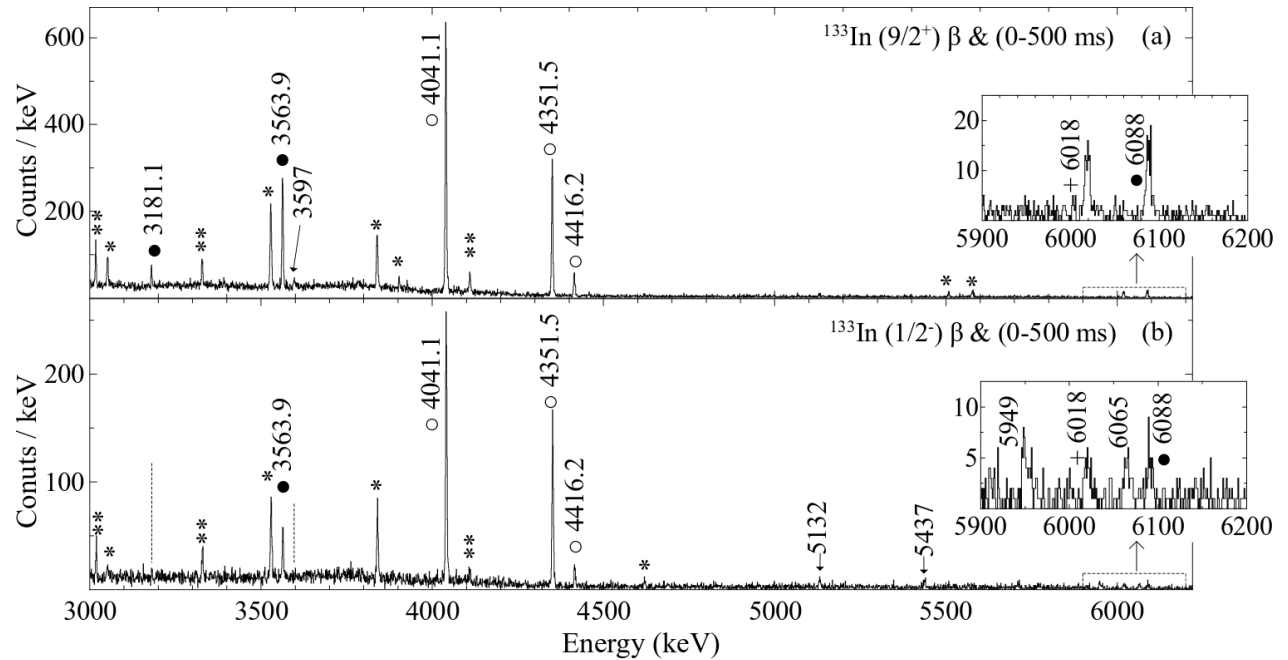
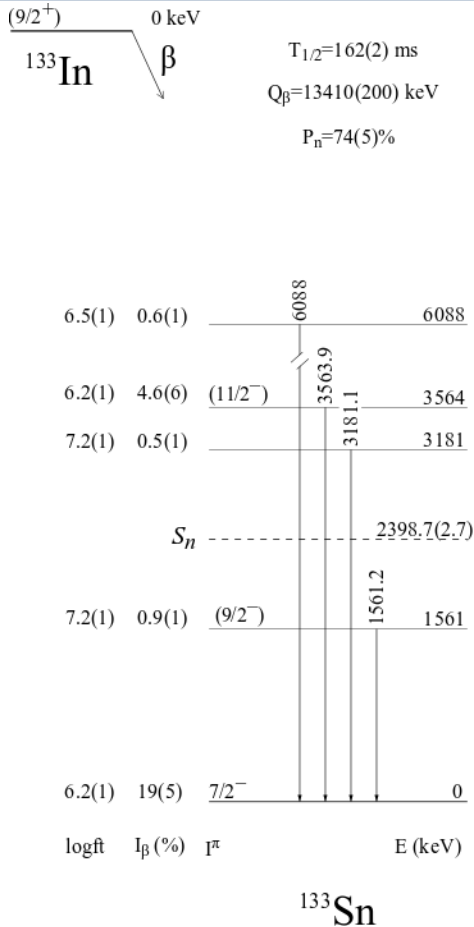
The Advanced Time Delayed $\beta\gamma\gamma(t)$ method at ISOLDE



Experimental setup (IS610, ISOLDE, Cern)



Problems



M. Piersa, A. Korgul et. al. PRC 2019

Experimental setup: PARIS



PARIS to be made of clusters:

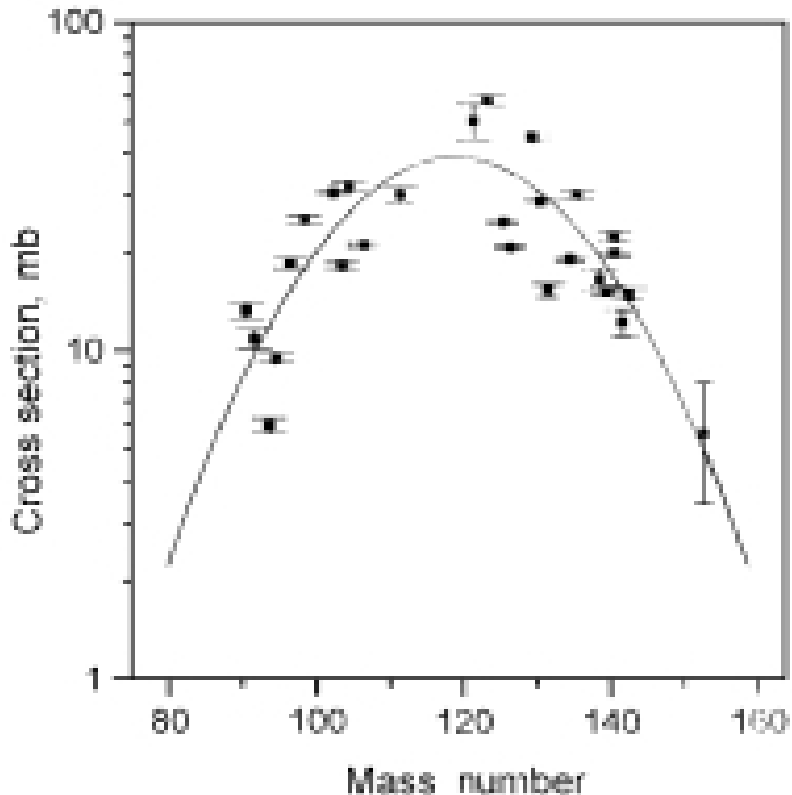
Cluster = 9 phoswiches

This allows, in its final phase, cubic or semi-spherical geometry with 24 clusters (216 phoswiches)

FWHM for (⁶⁰Co) - 600 ps
~9% for 2.5 MeV; 7% for 5 MeV
(8 clusters, 72 phoswiches)

M. Ciemala et. al

Mass distribution in ^{12}C induced fission of ^{232}Th



Experiment:

BARC-TIFR 14UD pelletron
accelerator,
Mumbai, India

$E_{\text{lab}}=72$ MeV

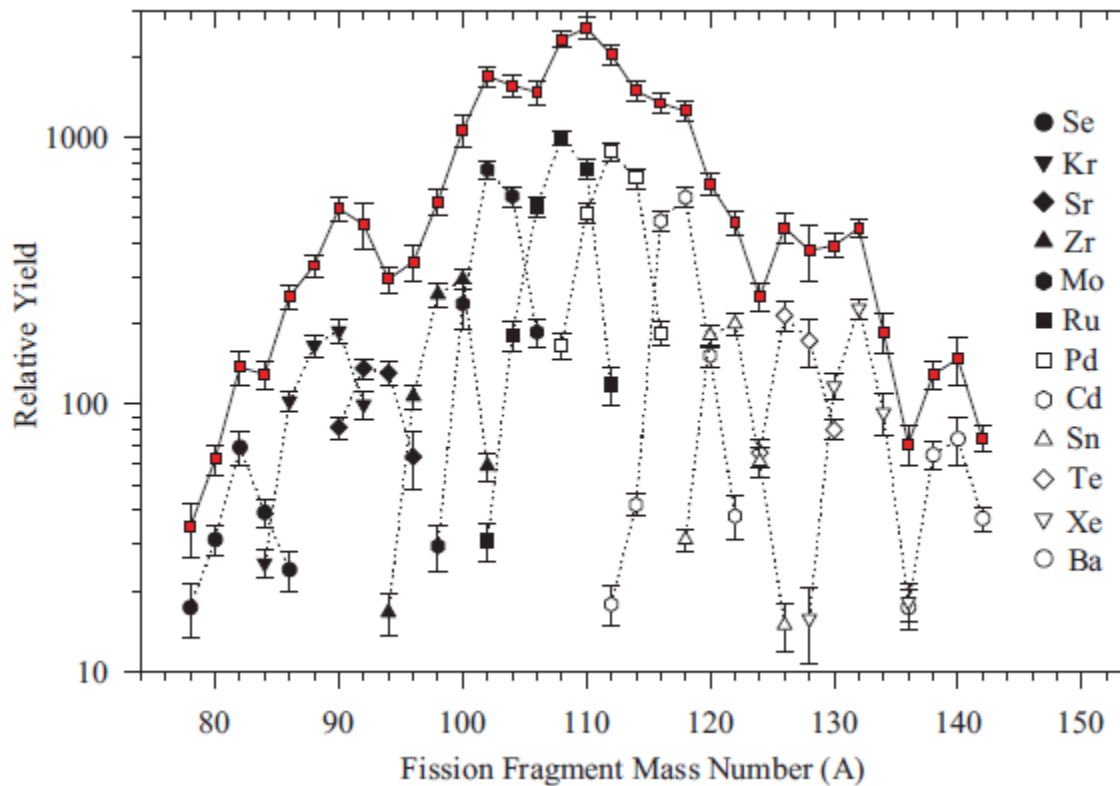
A. Ramaswami et al. Journal of Radioanalytical and Nuclear Chemistry 246, No. 1 (2000) 225-228

Mass distribution in ^{12}C induced fission of ^{232}Th

Table 2. Cumulative (C) and independent (I) formation cross sections of fission products in ^{12}C induced fission of ^{232}Th at $E_{lab} = 72 \text{ MeV}$

Sample No.	Nuclide	Type of fission	Cross section, mb	Charge distribution corrected values
1	^{91}Sr	C	13.12 ± 0.67	13.27 ± 0.68
2	^{92}Sr	C	10.47 ± 0.75	10.83 ± 0.77
3	^{94}Y	C	5.82 ± 0.30	5.94 ± 0.31
4	^{95}Zr	C	9.45 ± 0.27	9.48 ± 0.27
5	^{97}Zr	C	17.90 ± 0.60	18.54 ± 0.63
6	^{99}Mo	C	25.27 ± 0.59	25.29 ± 0.60
7	^{103}Ru	C	30.48 ± 0.65	30.49 ± 0.65
8	^{104}Te	C	17.88 ± 0.35	18.25 ± 0.35
9	^{105}Ru	C	31.67 ± 0.92	31.77 ± 0.92
10	^{107}Ru	C	21.05 ± 0.33	21.08 ± 0.32
11	^{112}Pd	C	28.04 ± 1.54	30.05 ± 1.61
12	^{122}Sb	I	3.42 ± 0.43	50.21 ± 6.17
13	^{124}Sb	I	14.06 ± 0.48	58.23 ± 1.98
14	^{126g}Sb	I	9.95 ± 0.17	24.73 ± 0.43
15	^{127}Sb	C	14.90 ± 0.26	20.69 ± 0.37
16	^{130}I	I	13.48 ± 0.34	44.72 ± 1.14
17	^{131}I	C	24.29 ± 0.36	28.51 ± 0.43
18	^{132}Te	C	4.18 ± 0.20	15.30 ± 0.77
19	^{135}Xe	C	12.00 ± 0.23	19.03 ± 0.36
20	^{136}Cs	I	12.13 ± 0.31	29.91 ± 0.75
21	^{139}Ba	C	12.99 ± 0.93	16.50 ± 1.19
	...			

Fission fragments produced in $^{208}\text{Pb}(^{18}\text{O},f)$



Experiment:

BARC-TIFR 14UD pelletron
accelerator,
Mumbai, India

$E_{\text{lab}}=90 \text{ MeV}$ (1.5 pA)

P. Banerjee et al.. Phys Rev C92, 024318 (2015)

Summary and outlook

possible experiments at SLCJ

- Fission fragments produced in $^{208}\text{Pb}(^{18}\text{O},f)$, $^{232}\text{Th}(^{12}\text{C},f)$,
- IGISOL facility (Ion Guide and Isotope Separator On-Line),
- EAGLE (central European Array for Gamma Levels Evaluations),
- LaBr₃, PARIS, HPGe....