NUCLEAR FISSION AT THE NORWEGIAN NUCLEAR RESEARCH CENTRE - SELECTED TOPICS

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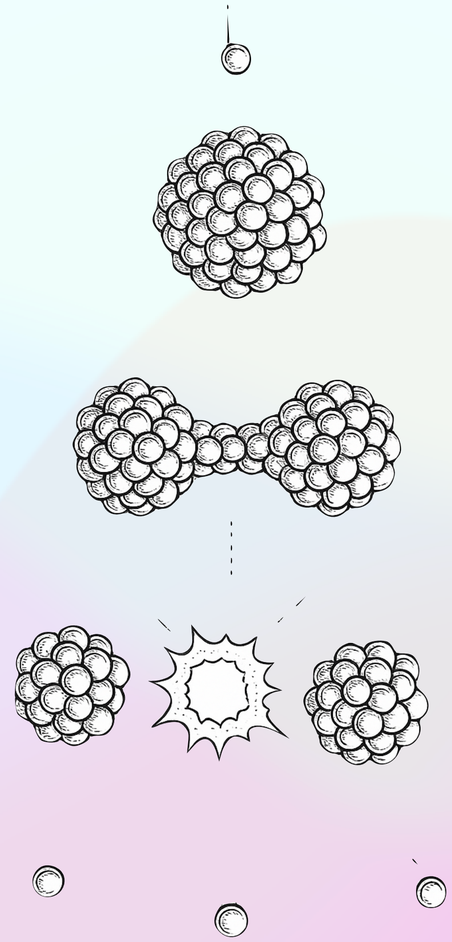
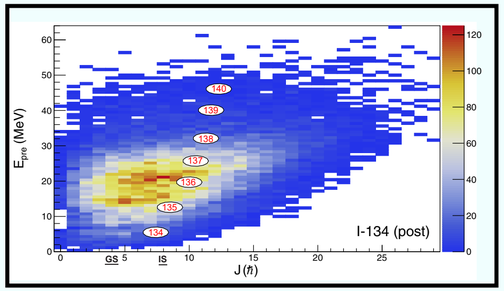
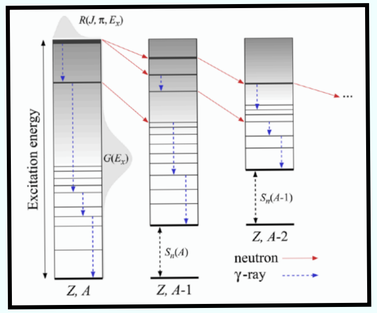
- *Department of Physics, University of Oslo, Norway*
- *Norwegian Nuclear Research Centre (NNRC), Norway*



NUCLEAR FISSION, LEVEL DENSITIES AND GAMMA STRENGTH





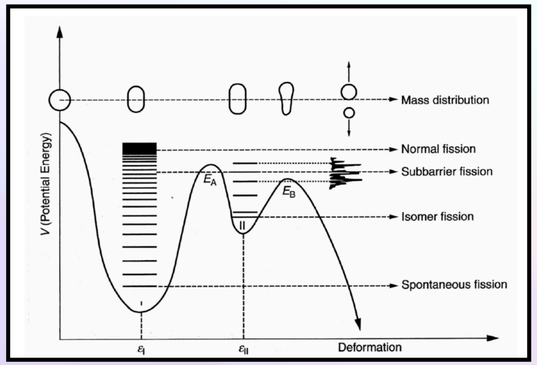
Neutron

Actinide

Excitation energy sharing

Angular momentum

kinetic energies



Prompt Neutron emission

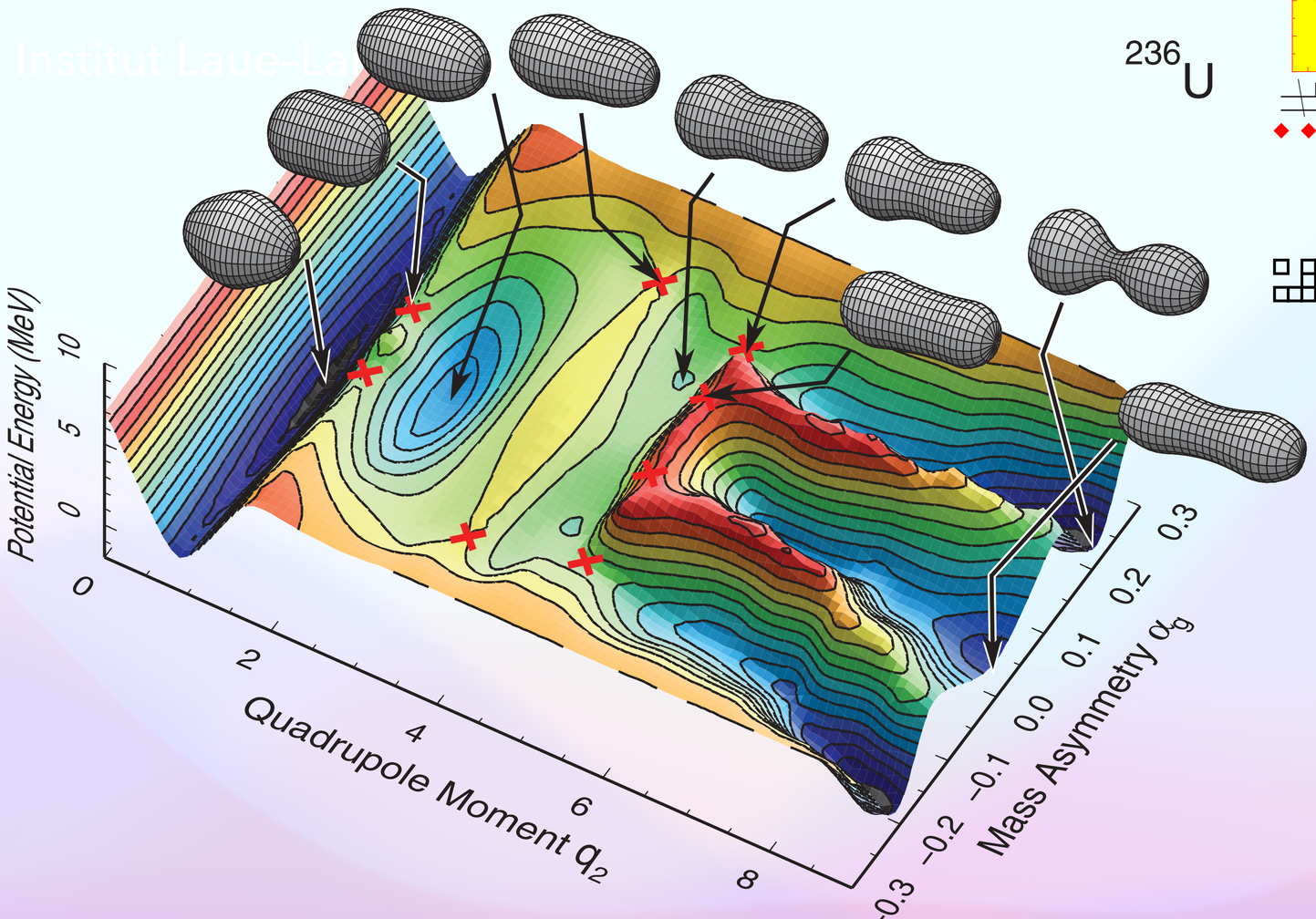
Prompt gamma emission

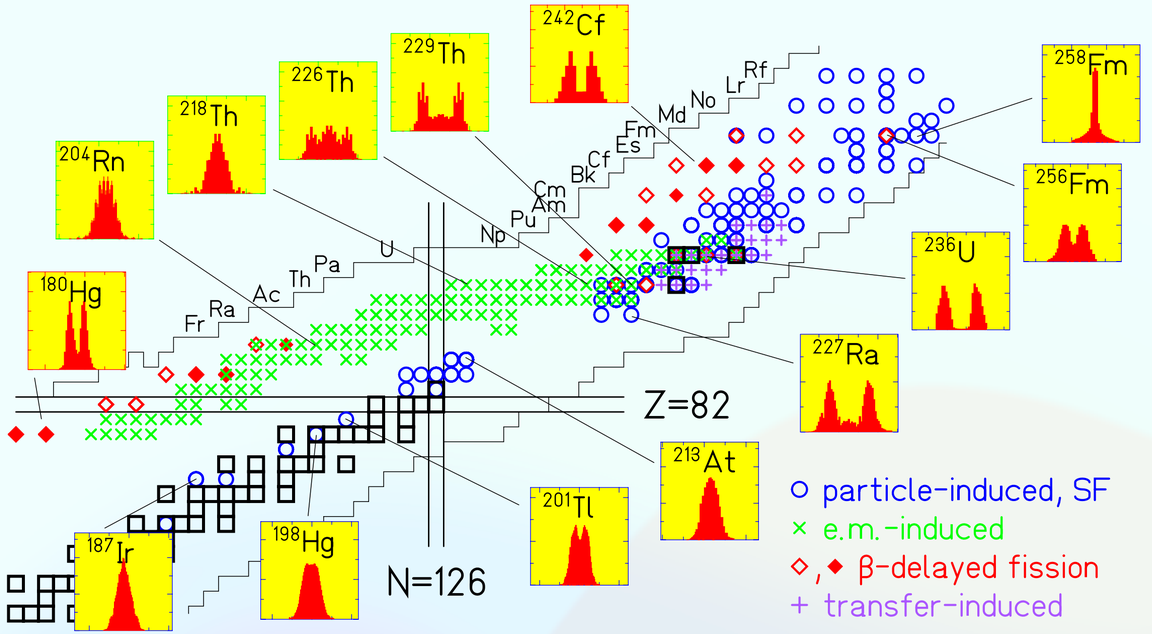
Delayed emission / Beta decay / isomers

β -

FISSION FRAGMENT MASS YIELDS

Takatoshi Ichikawa, Phys. Rev. C 86, 024610 (2012)

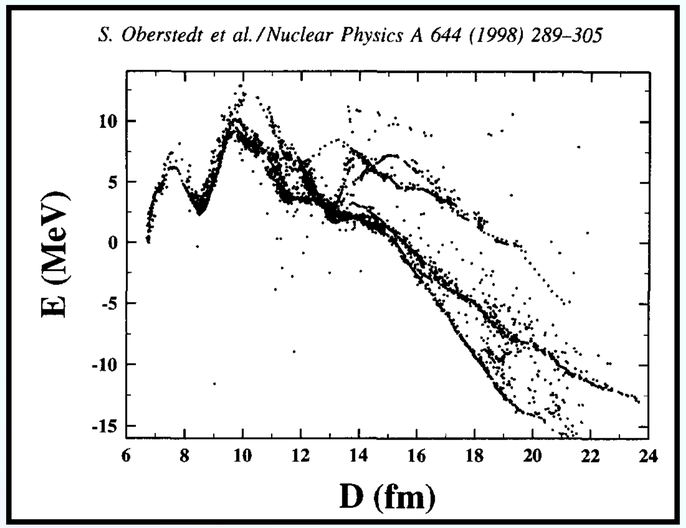


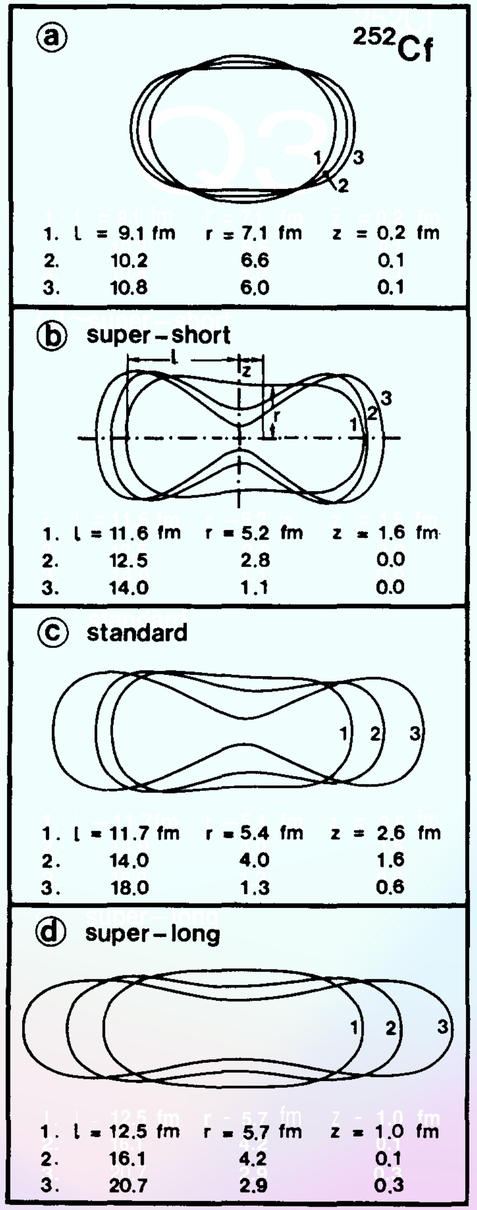


Schmidt and Jurado, Rep. Prog. Phys. 81 (2018) 106301

Potential energy landscapes of fissioning nuclei determine the mass split

BROSA FISSION MODES

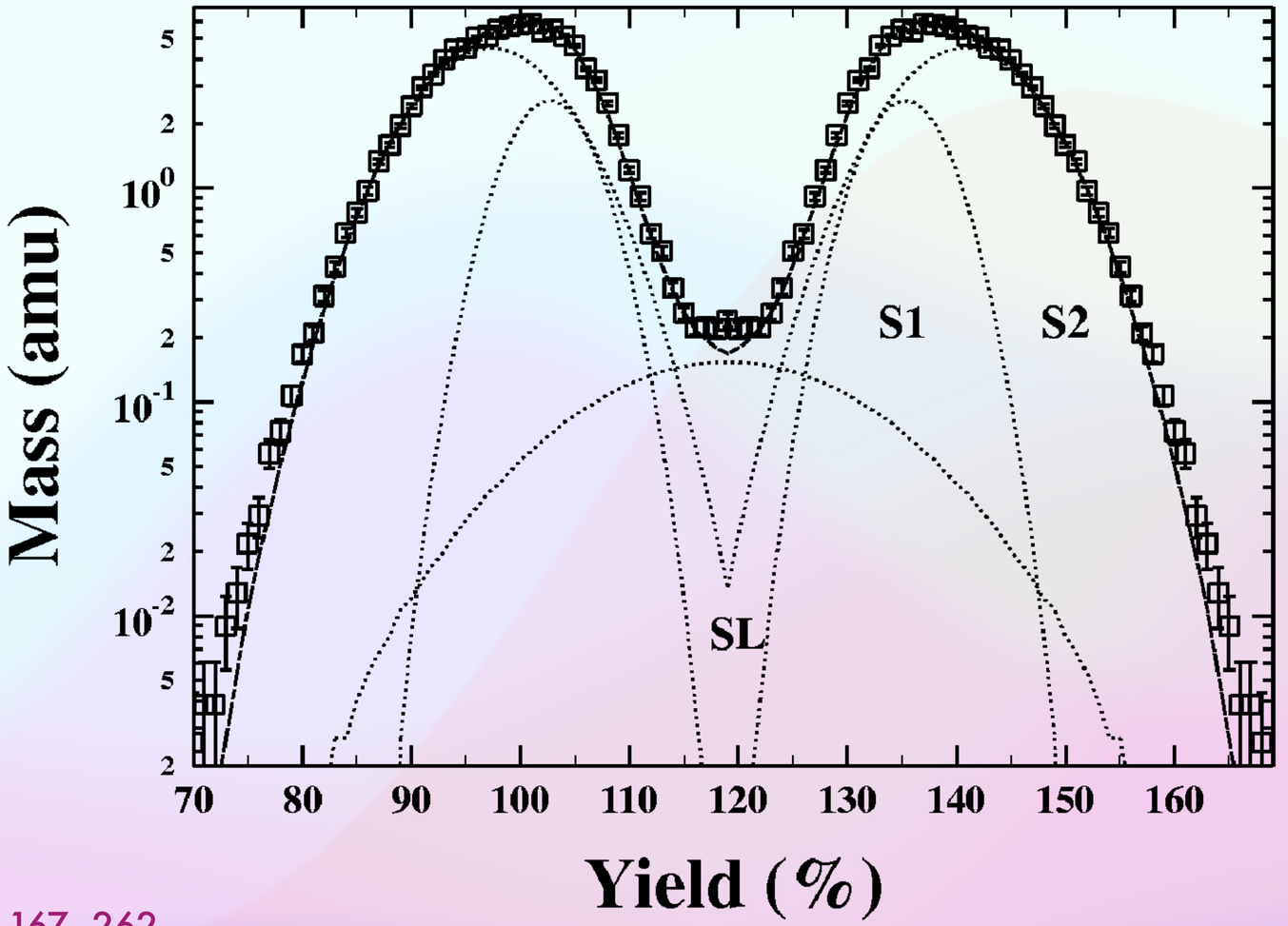




Brosa et al. PHYSICS REPORTS 97, (1990) 167–262.

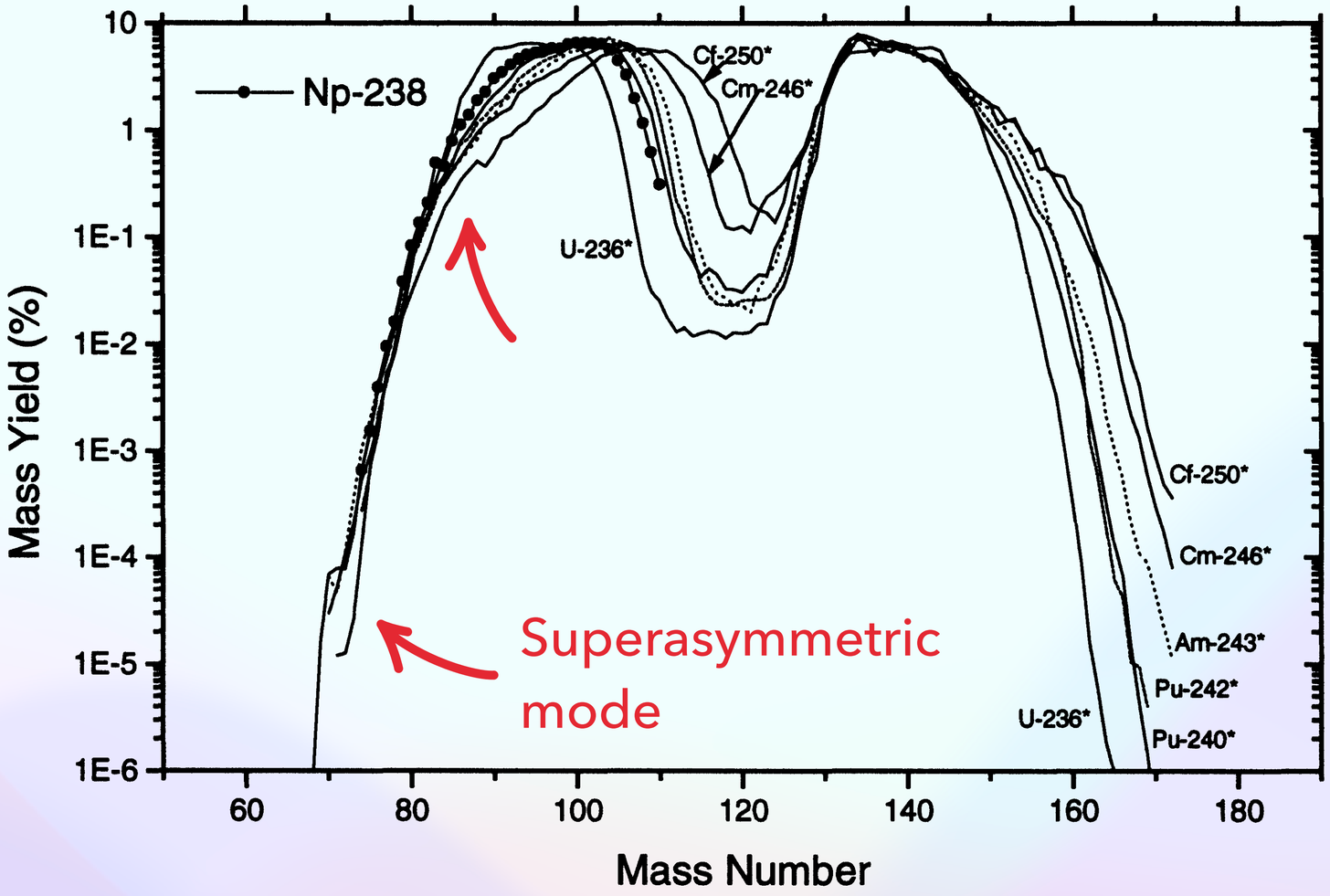
Fission mode signatures

F.-J. Hambsch et al. / Nuclear Physics A 679 (2000) 3–24

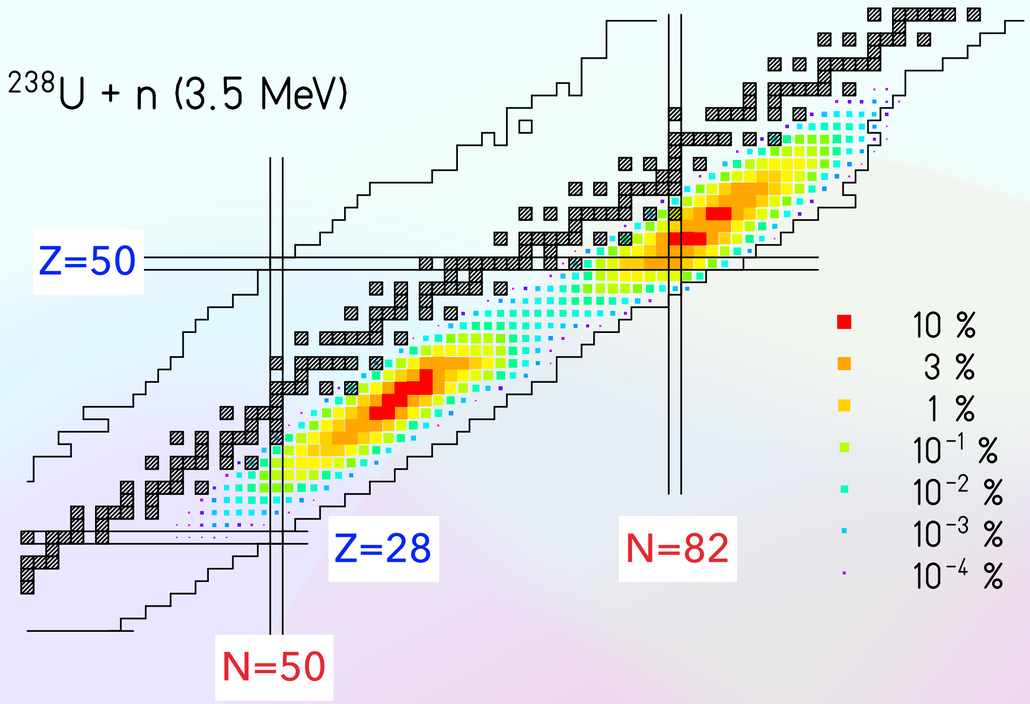


ROLE OF MAGIC SHELLS

Tsekhanovich et al., Nuclear Physics A 688 (2001) 633–658



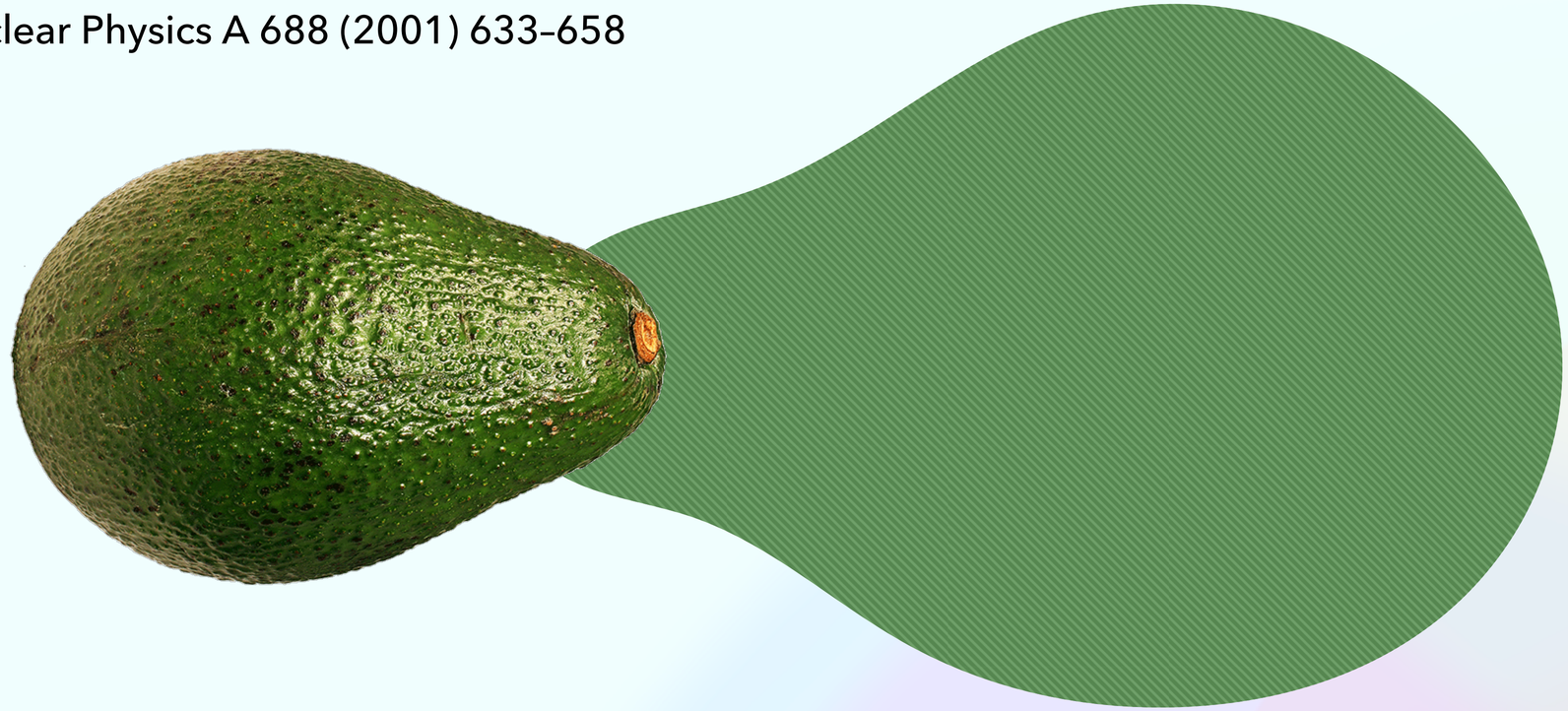
K.H. Schmidt et al. PHYS. REV. 10, 014701 (2007)



These fragments are extraordinary because they consist essentially only of nickel with the closed proton shell Z = 28!

SUPER-ASYMMETRIC FISSION MODE

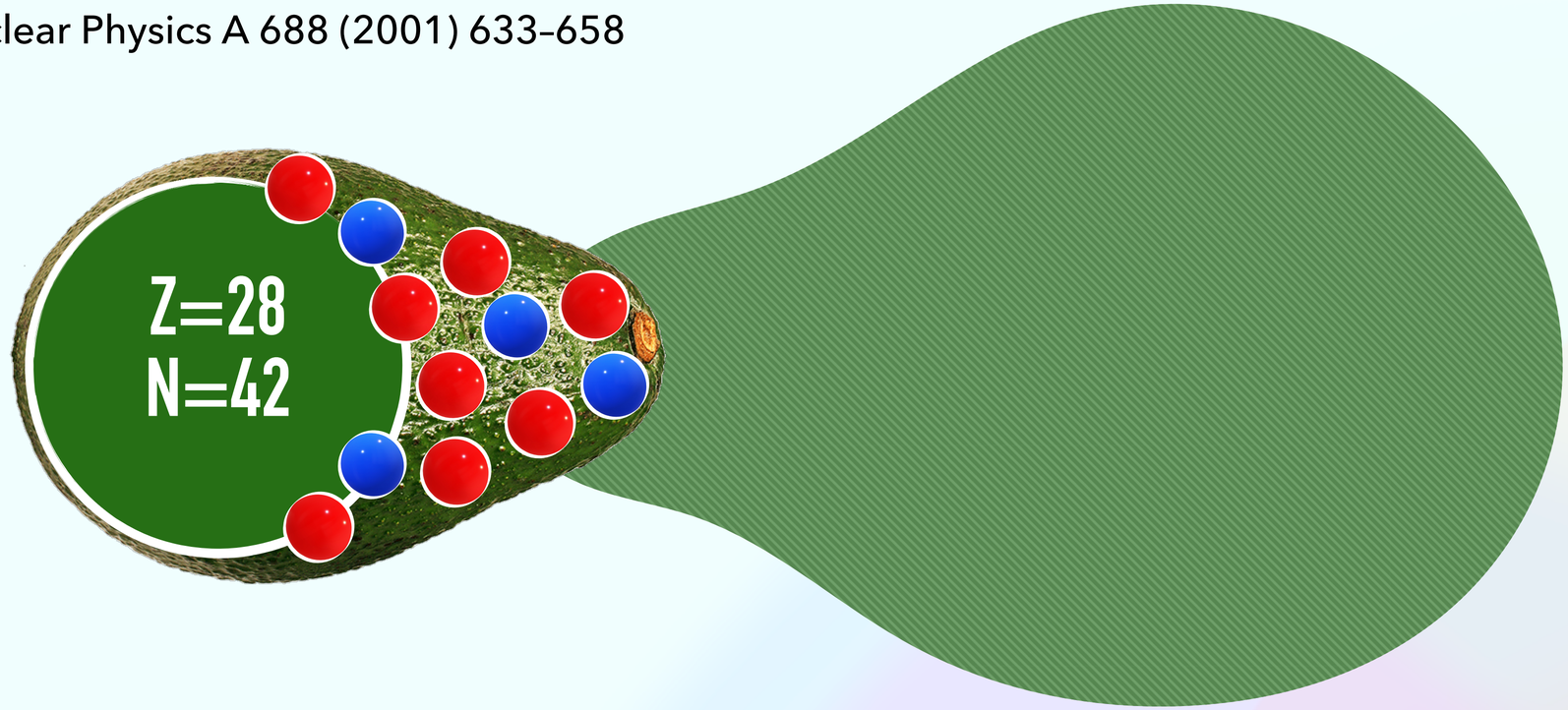
Tsekhanovich et al., Nuclear Physics A 688 (2001) 633–658



The light sphere visualised as a dumbbell has a mass
A ≈ 80 and is built somewhat like an **avocado**…

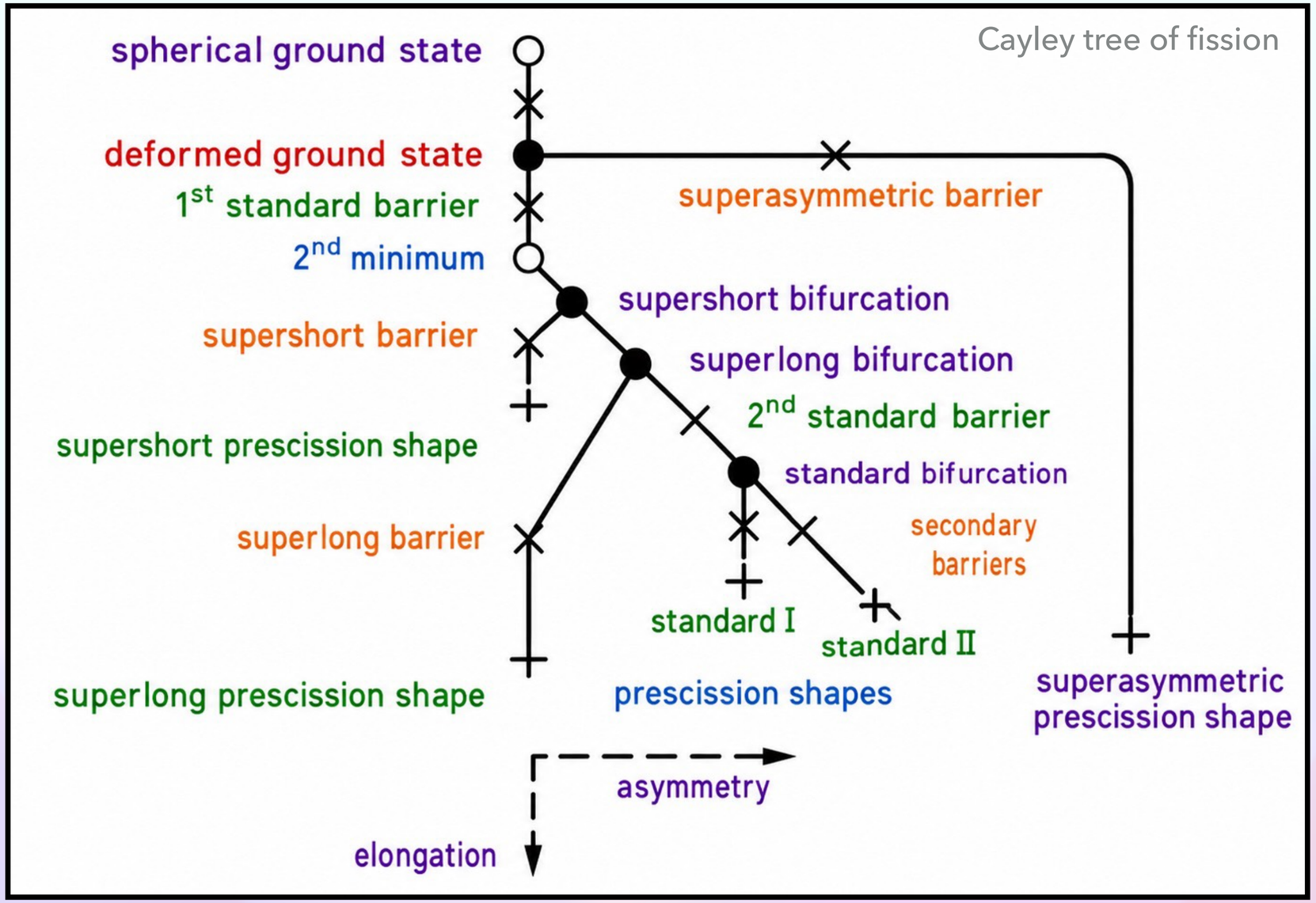
SUPER-ASYMMETRIC FISSION MODE

Tsekhanovich et al., Nuclear Physics A 688 (2001) 633–658



The light sphere visualised as a dumbbell has a mass
A ≈ 80 and is built somewhat like an avocado:
an inner cluster, Z = 28 and N = 42, surrounded by a layer of about 8 neutrons and 4 protons that make N ≈ 50.

SUPER-ASYMMETRIC FISSION MODE



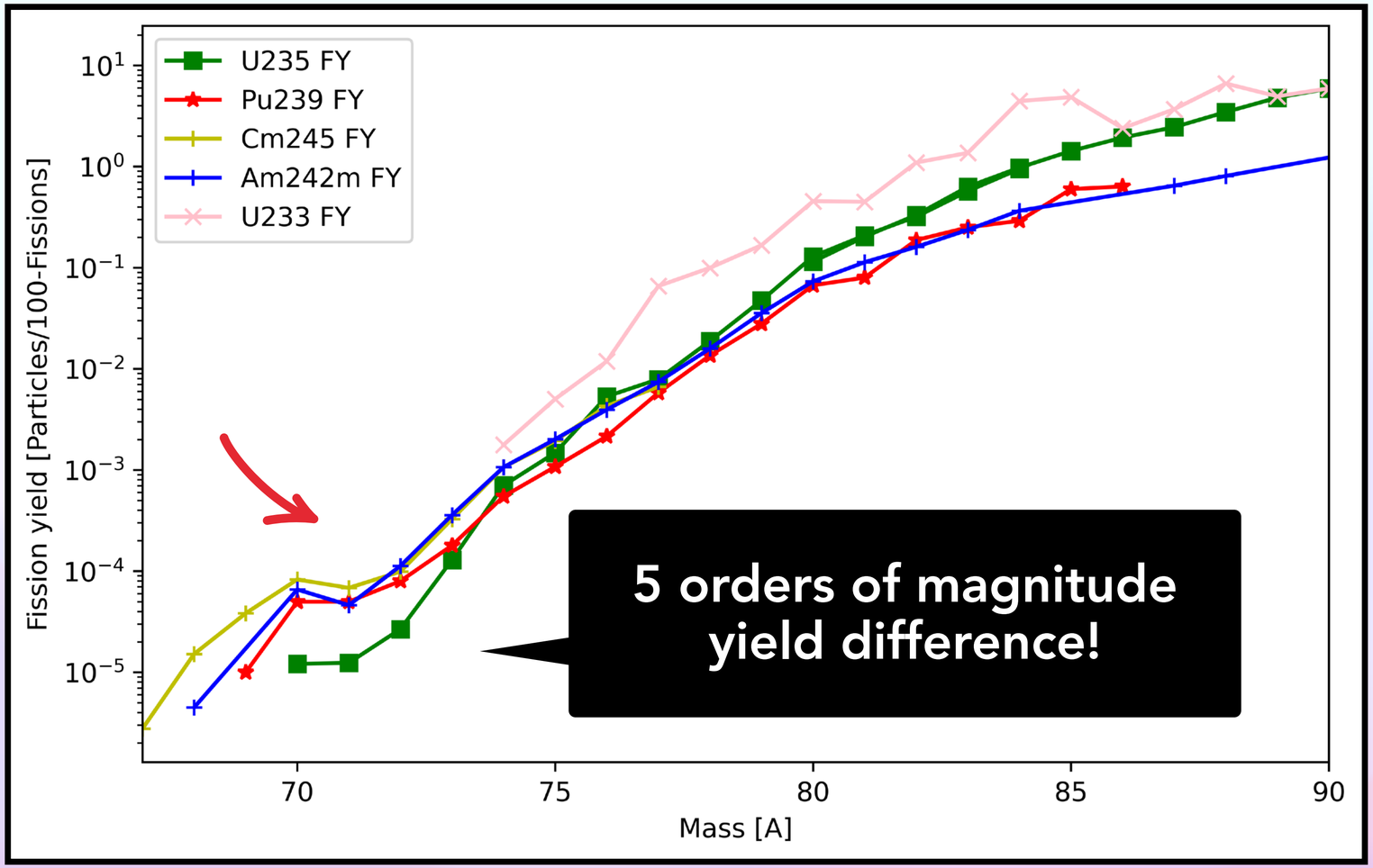
<u>According to Brosa:</u>

- Light systems do not experience superasymmetric mode
- The superasymmetric component seems to be special in every respect, for instance it shows almost a discontinuous behavior in energy (jumpy style).
  → ”Cluster emission”

EXPERIMENTS ON 233U(N,F) AT ILL

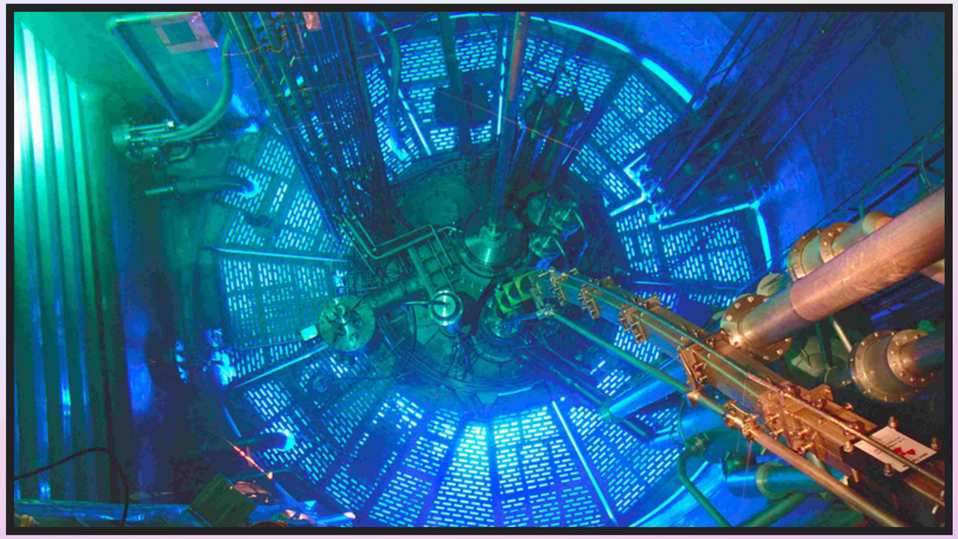
INSTITUT LAUE–LANGEVIN

^{233}U(n,f) lightest system to ever be measured!

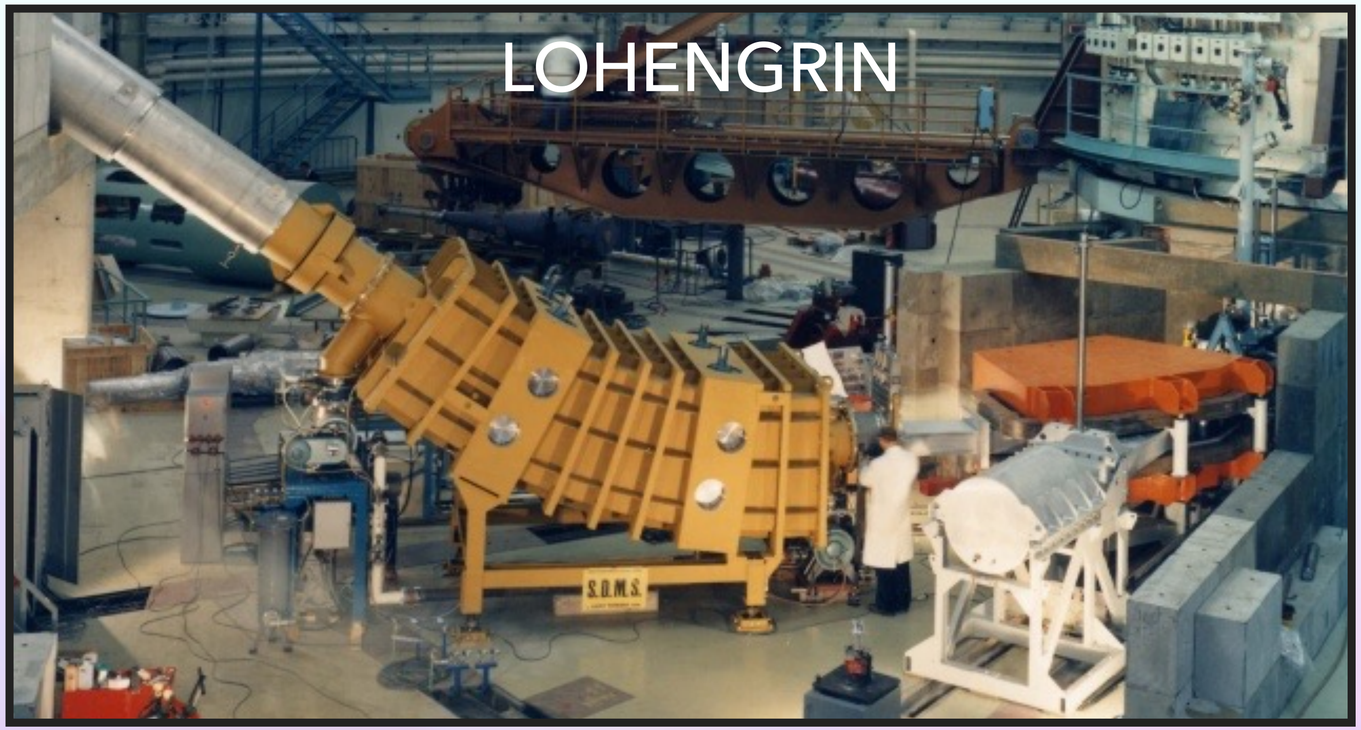


NEUTRONS FOR SOCIETY

1.5×10^{15} neutroner / s och cm^2



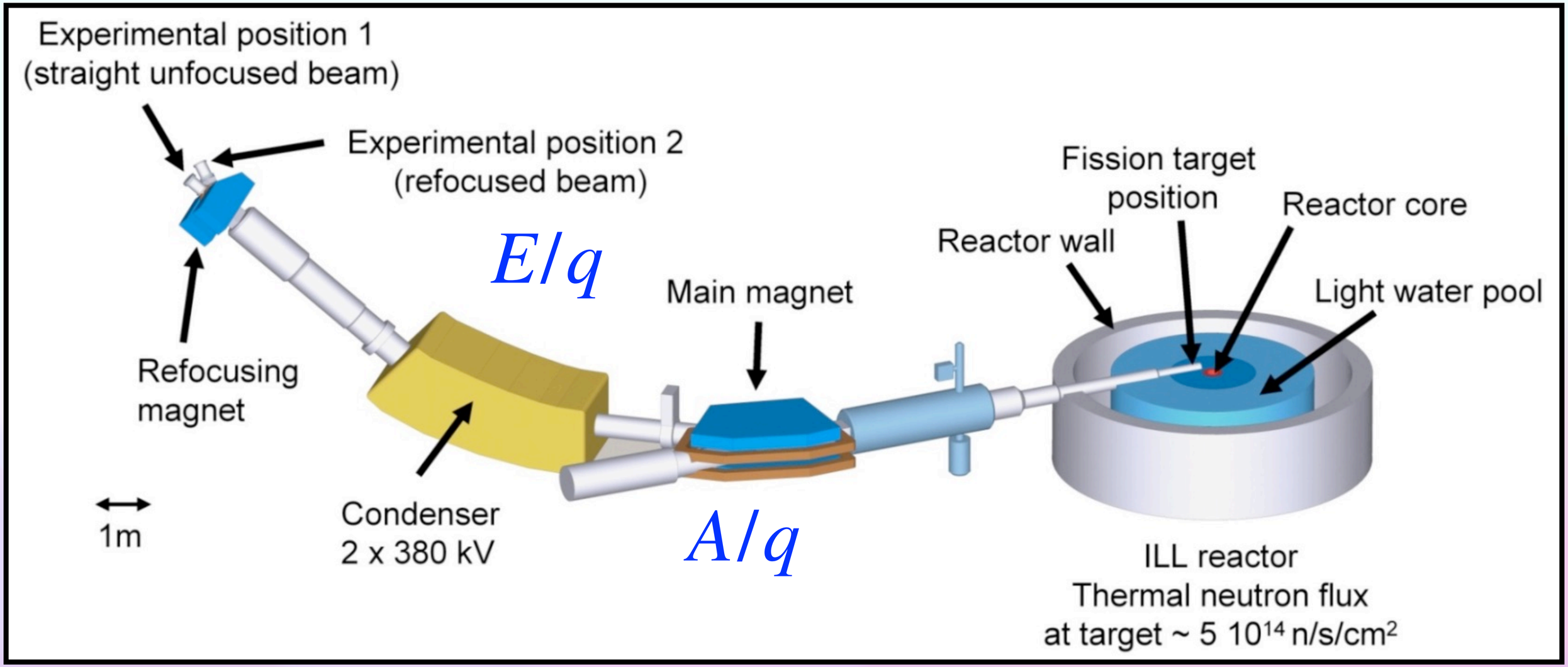
EXPERIMENTS ON 233U(N,F) AT ILL



3 campaigns:

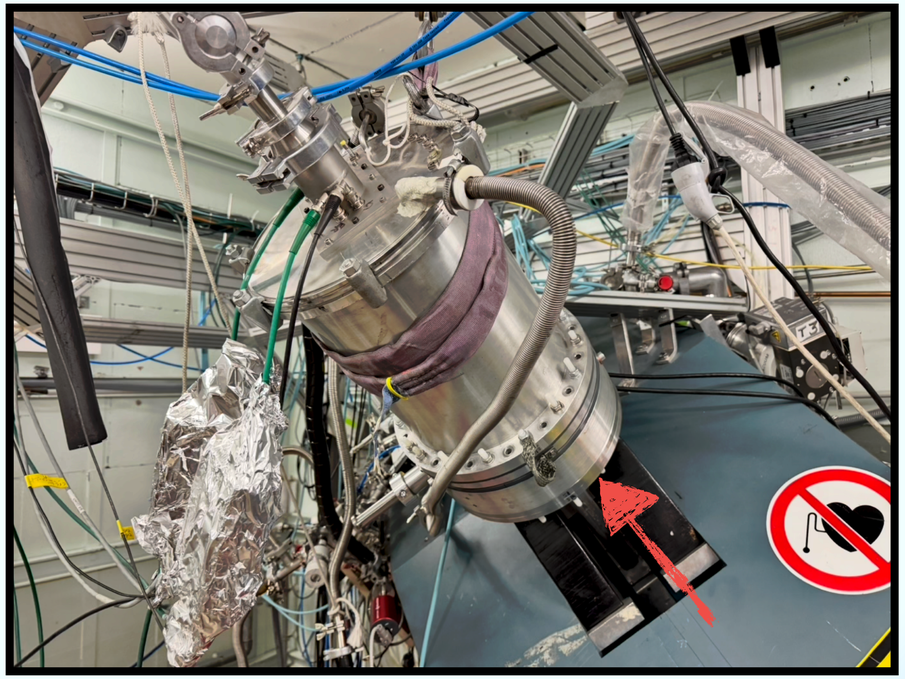
- June 2024
- June 2025
- April 2026

LOHENGRIN MASS RECOIL SPECTROMETER

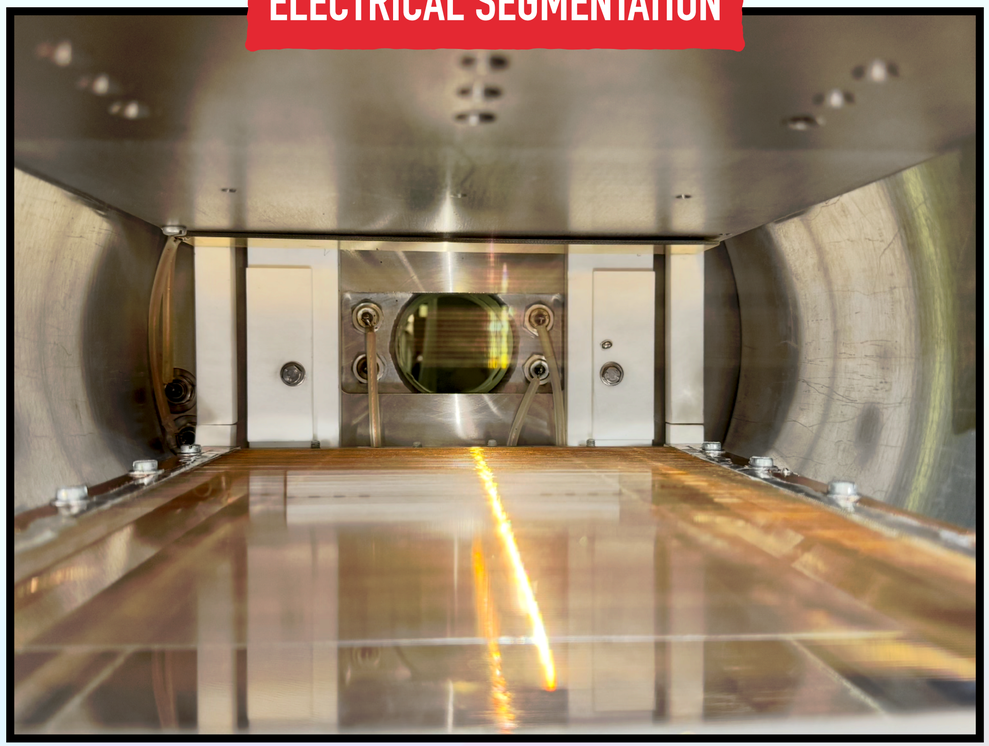


IONISATION CHAMBER

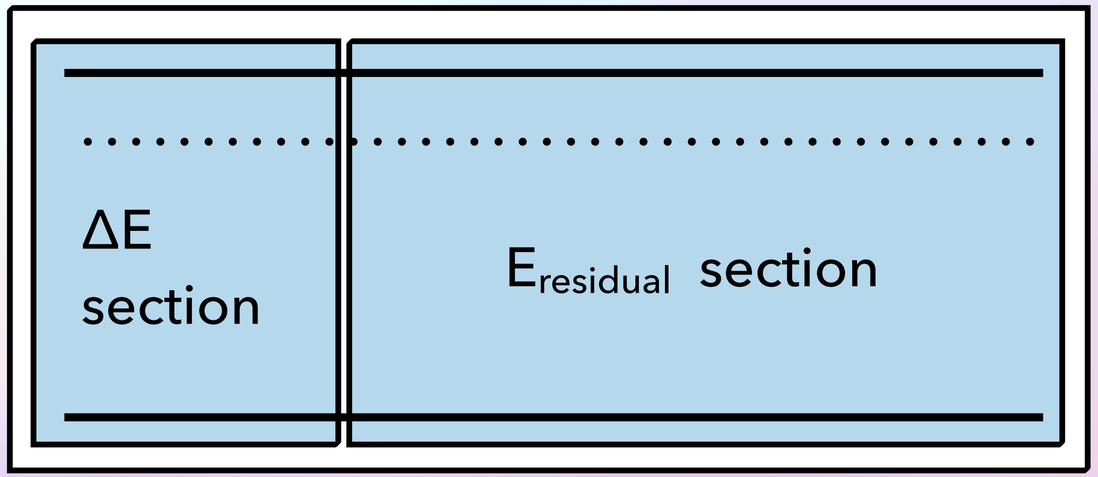
ΔE-E IONIZATION CHAMBER



ELECTRICAL SEGMENTATION

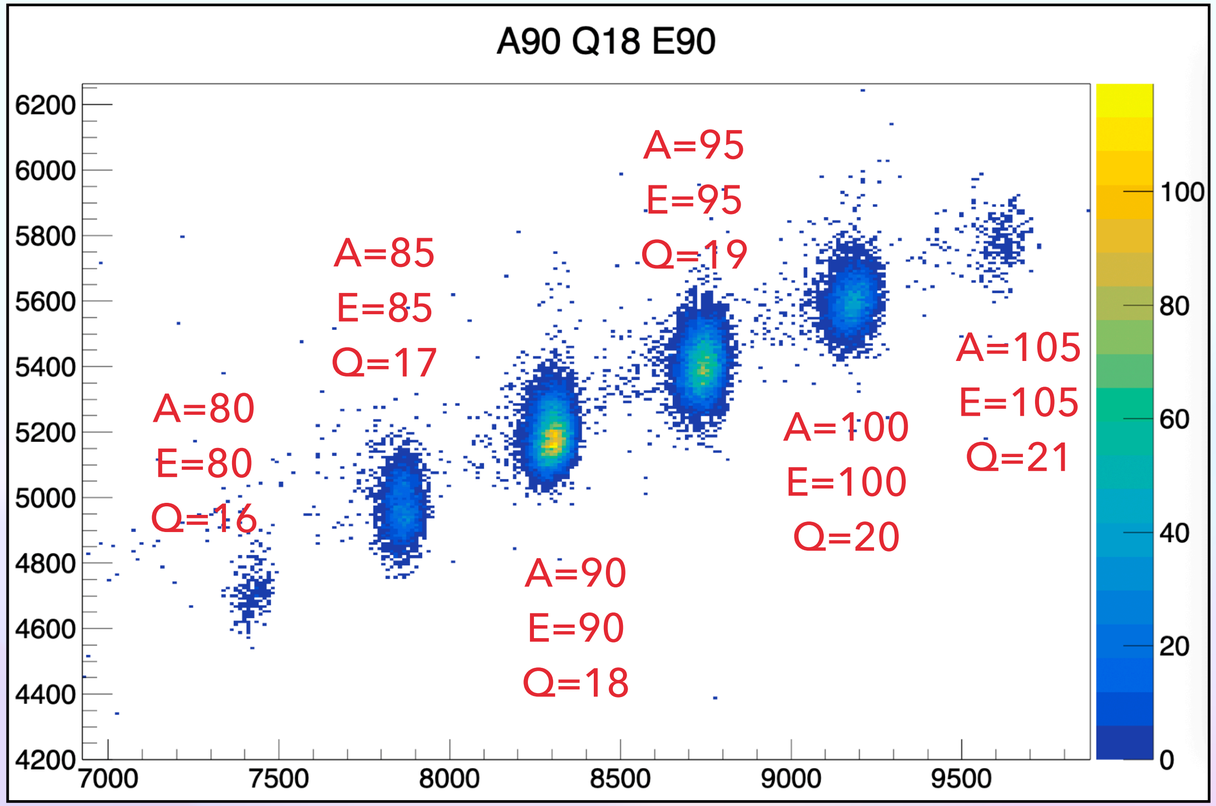


FISSION PRODUCT BEAM

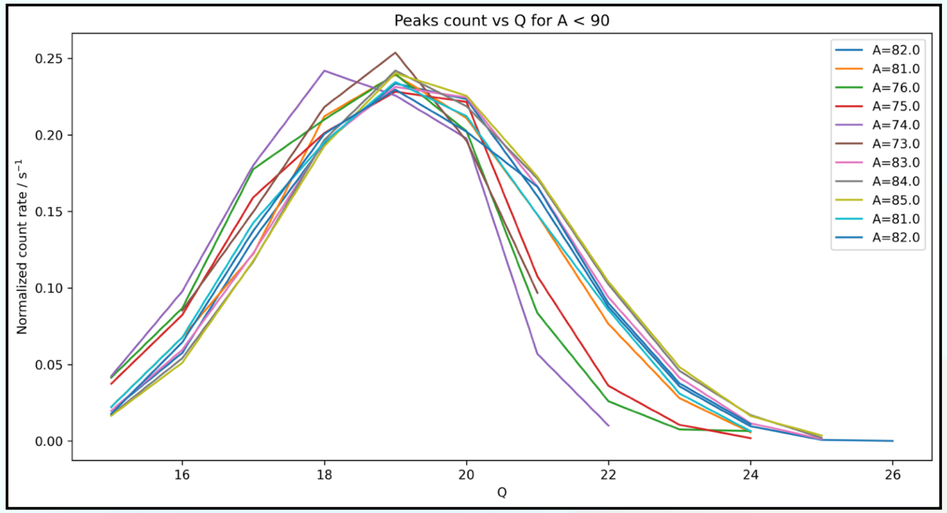


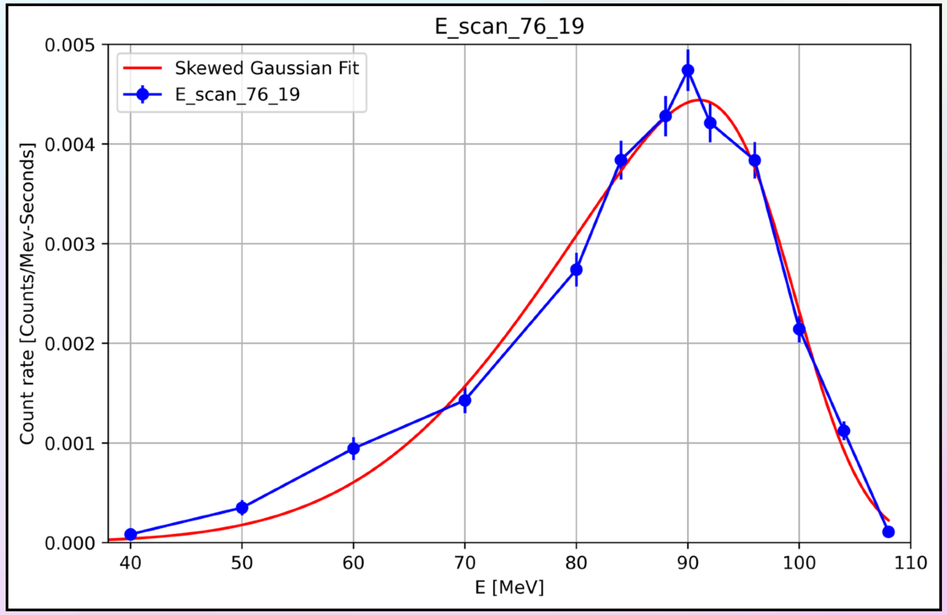
FISSION PRODUCT CHARGE AND ENERGY SCANS

$$\frac{A}{Q} = \frac{90}{18} = 5 \qquad \frac{E}{Q} = \frac{90}{18} = 5$$



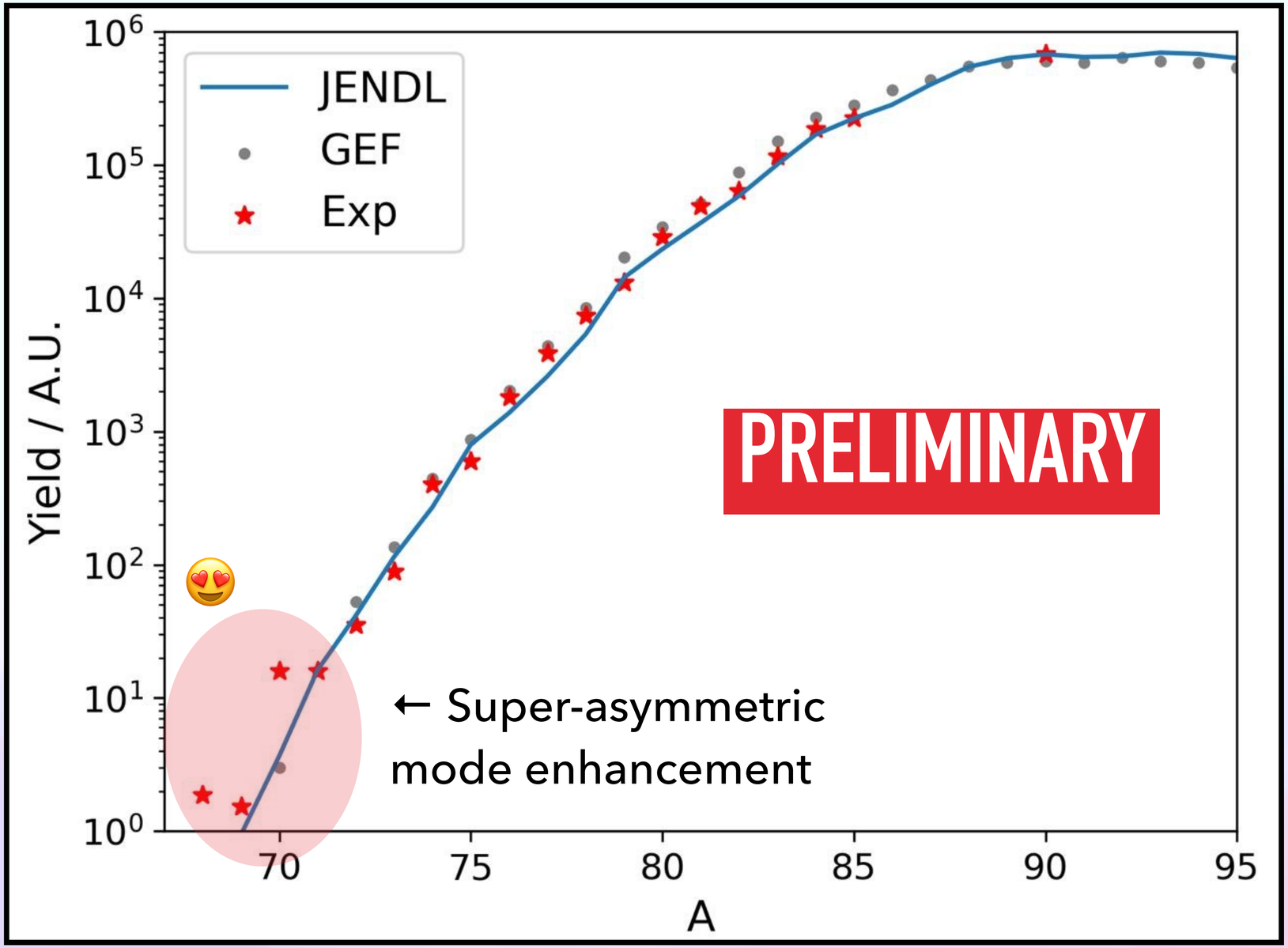
$$E_{tot} = \Delta E + E_r$$



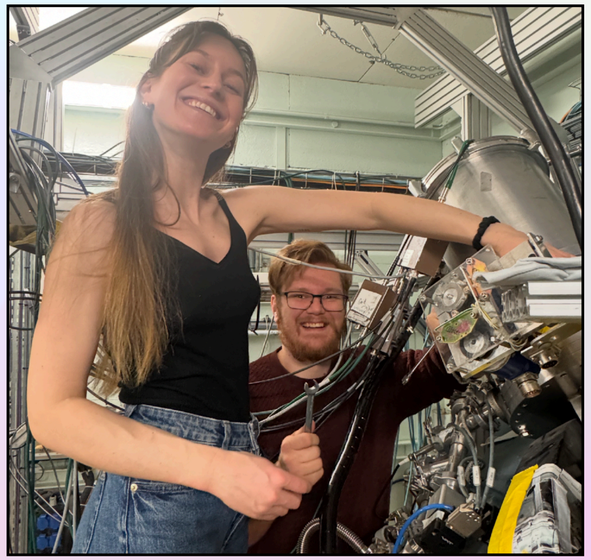


Energy and charge scans

PRELIMINARY RESULTS

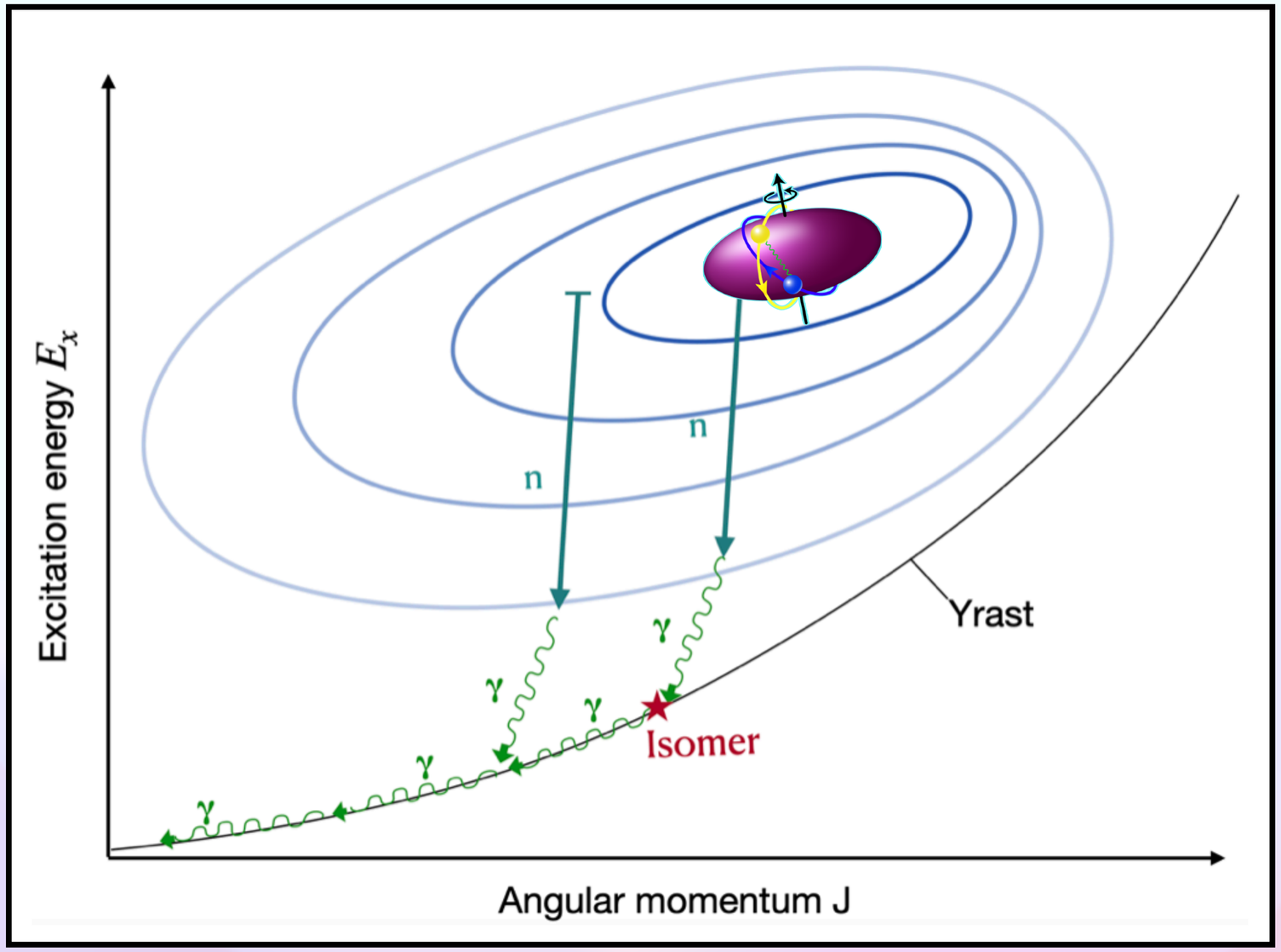


- Successfully measured down to A=67.
- Technical development: To use the chamber as time protection chamber



Ph.D. work of Marius Torsvoll and Maia Virgenes

ANGULAR MOMENTUM STUDIES

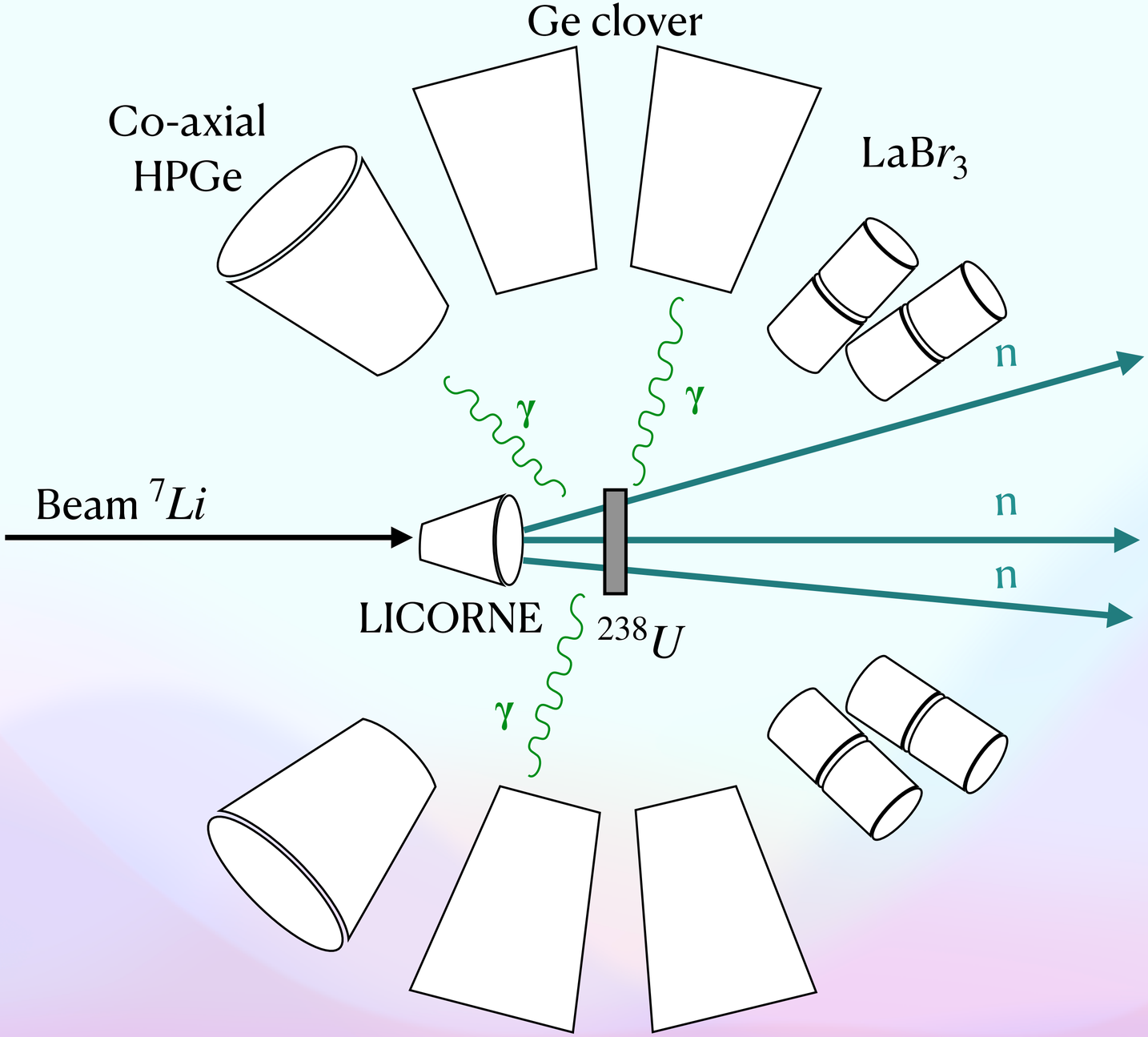


Isomeric yields ratios

De-excitation of FF by Hauser Feshbach in TALYS

Gamma ray correlations

ISOMERIC YIELD RATIOS



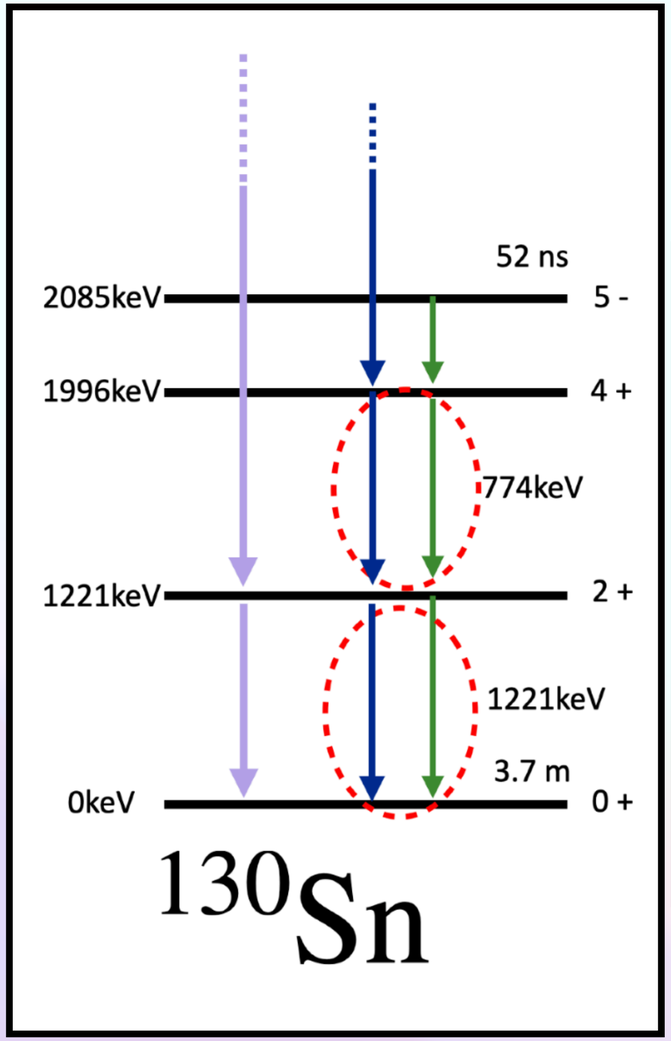
Ph.D. work of
Henrik Haug

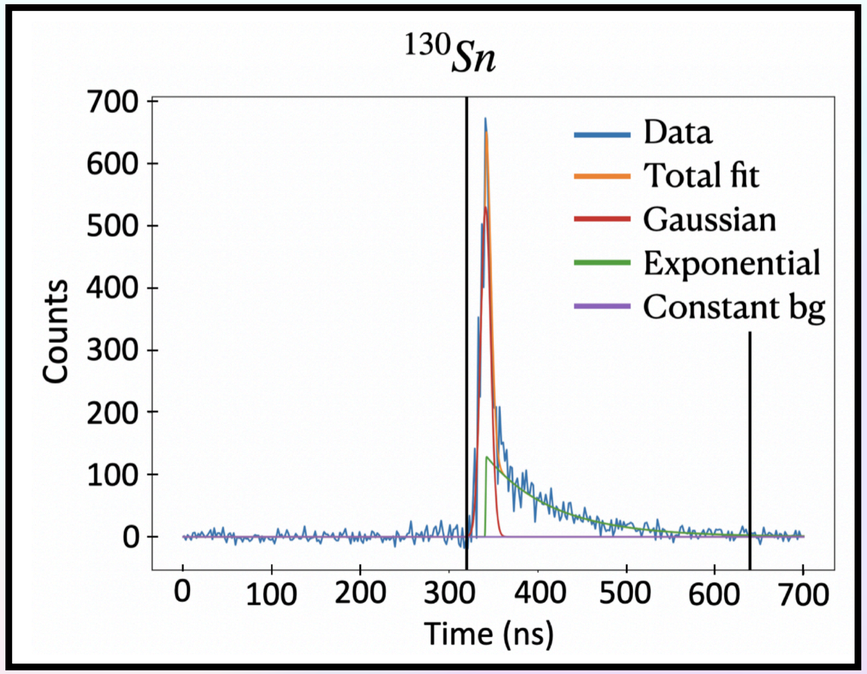
In collaboration
with Jon Wilson

- ν-ball fission campaign at ALTO facility at IJC Laboratory, Orsay
- 10 co-axial Compton-suppressed HPGe detectors , 24 Ge clover detectors
- ^{232}Th(n,f) with $E_n = 2.0 \pm 0.4$ MeV
- ^{238}U(n,f) with $E_n = 1.9 \pm 0.4$ MeV and $E_n = 3.4 \pm 0.3$ MeV

ISOMERIC YIELD RATIOS

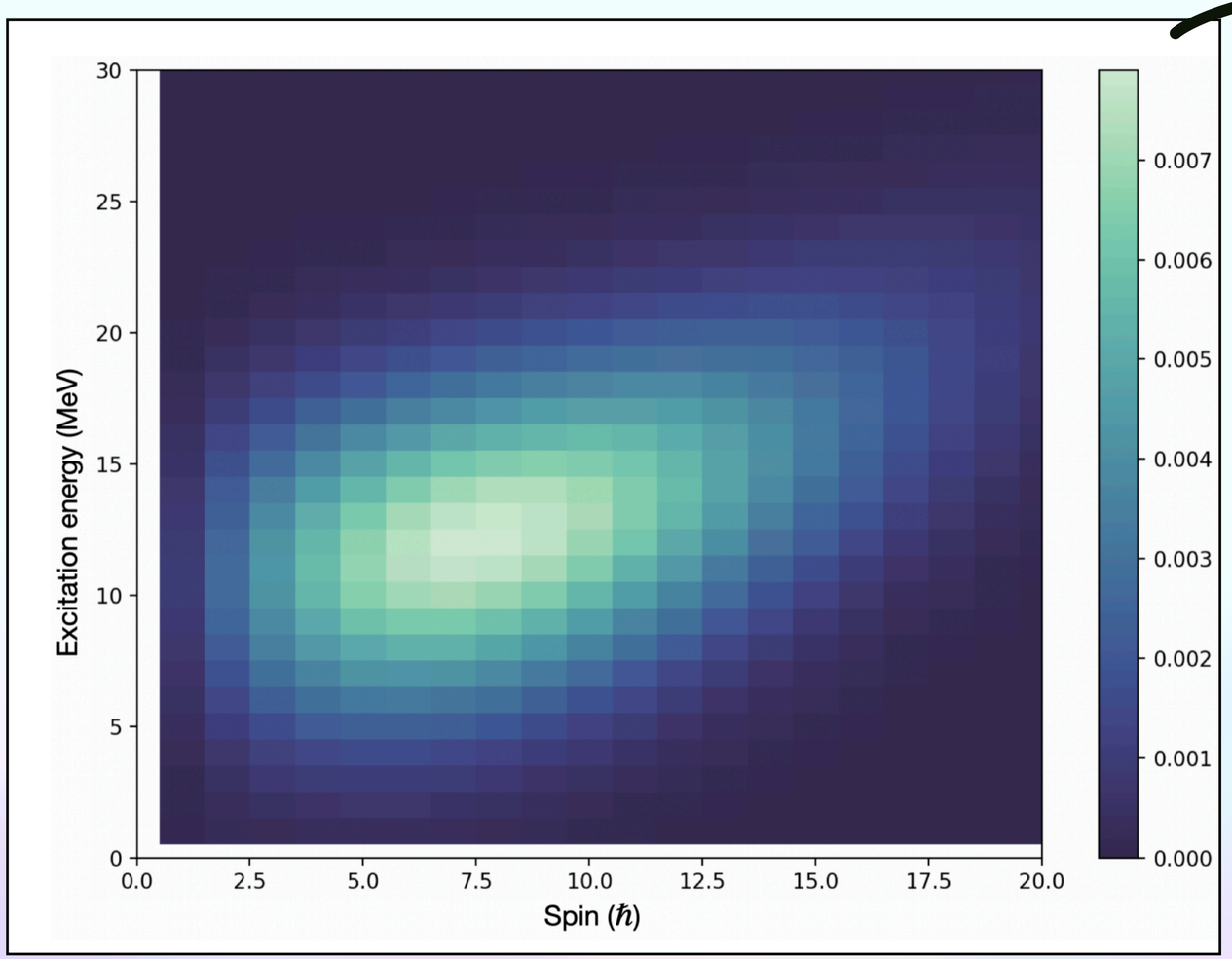
$$IYR = \frac{Isomer\ decay}{Total\ decay} = \frac{delayed}{prompt + delayed}$$





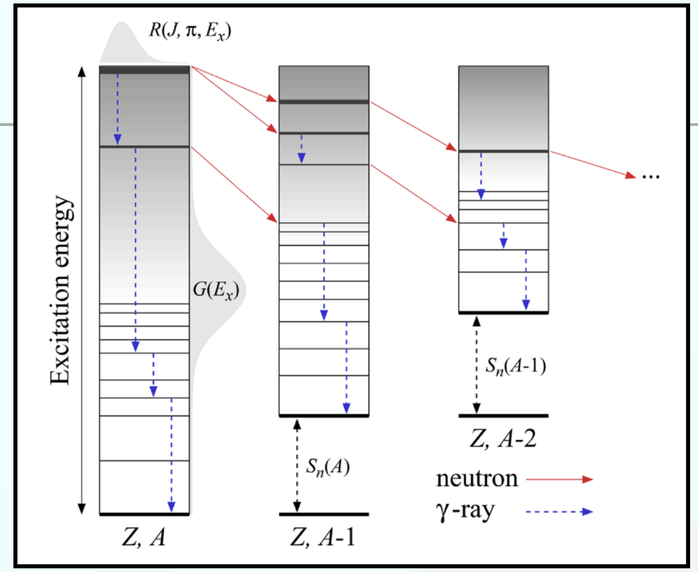
Nucleus	Reaction	E_n [MeV]	Isomer spin	Gated transitions
^{94}Rb	^{238}U(n,f)	1.9	10^-	6^+ & 4^+
^{130}Sn	^{238}U(n,f)	1.9	5^-	4^+ & 2^+
		3.4		
^{133}Te	^{238}U(n,f)	1.9	4n	$15/2^-$[^{133}Te]& $15/2^-$ & 4^+[^{102}Zr]
			4n	$15/2^-$[^{133}Te]& $15/2^-$ & 6^+[^{102}Zr]
^{135}Te	^{232}Th(n,f)	2.0		$15/2^-$ & $11/2^-$
			2n	$11/2^-$[^{135}Te]&2^+[^{96}Sr]
			3n	$11/2^-$[^{135}Te]&$3/2^+$[^{95}Sr]
			3n	$11/2^-$[^{135}Te]&$9/2^+$[^{95}Sr]
	^{238}U(n,f)	1.9	$19/2^-$	$15/2^-$ & $11/2^-$
			1n	$11/2^-$[^{135}Te]&$7/2^-$[^{103}Zr]
			2n	$11/2^-$[^{135}Te]&6^+[^{102}Zr]
			3n	$11/2^-$[^{135}Te]&$5/2^+$[^{101}Zr]
			4n	$11/2^-$[^{135}Te]&6^+[^{100}Zr]
		3.4		$15/2^-$ & $11/2^-$
			3n	$11/2^-$[^{135}Te]&$5/2^-$[^{101}Zr]

MODEL VALIDATION



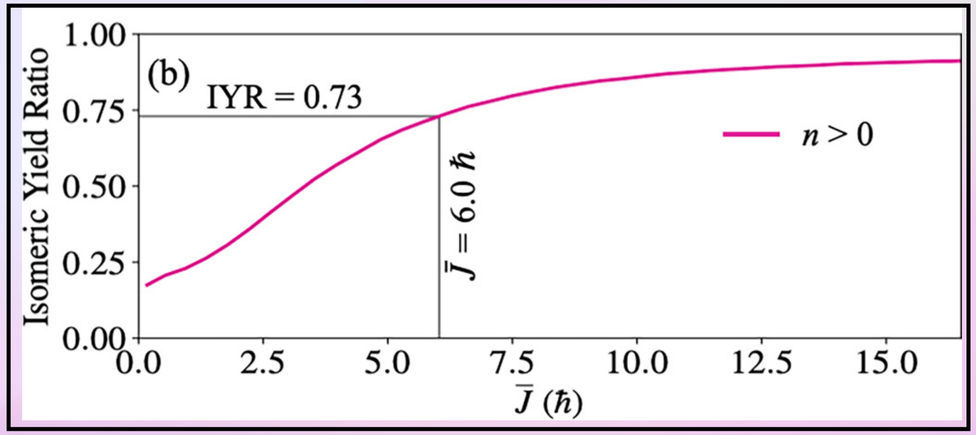
Surrogate model based one FREYA/GEF

TALYS



Input:

- Level densities and gamma strength functions
- Spin cut off parameter and energy dependence
- Nuclear deformation and Moment of inertia



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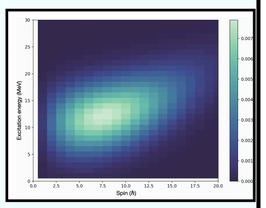
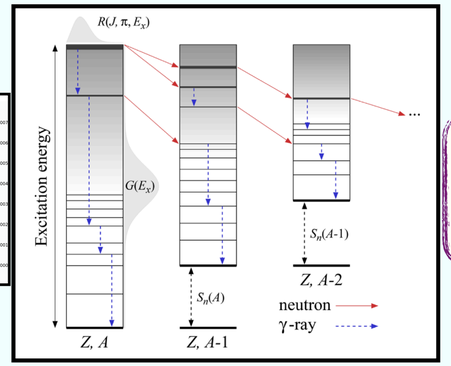
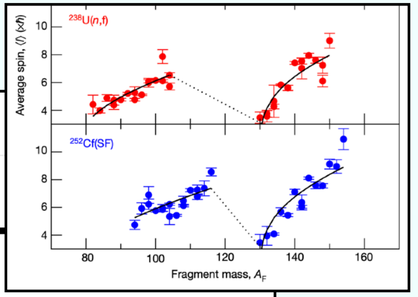




TALYS

Manchester spin method



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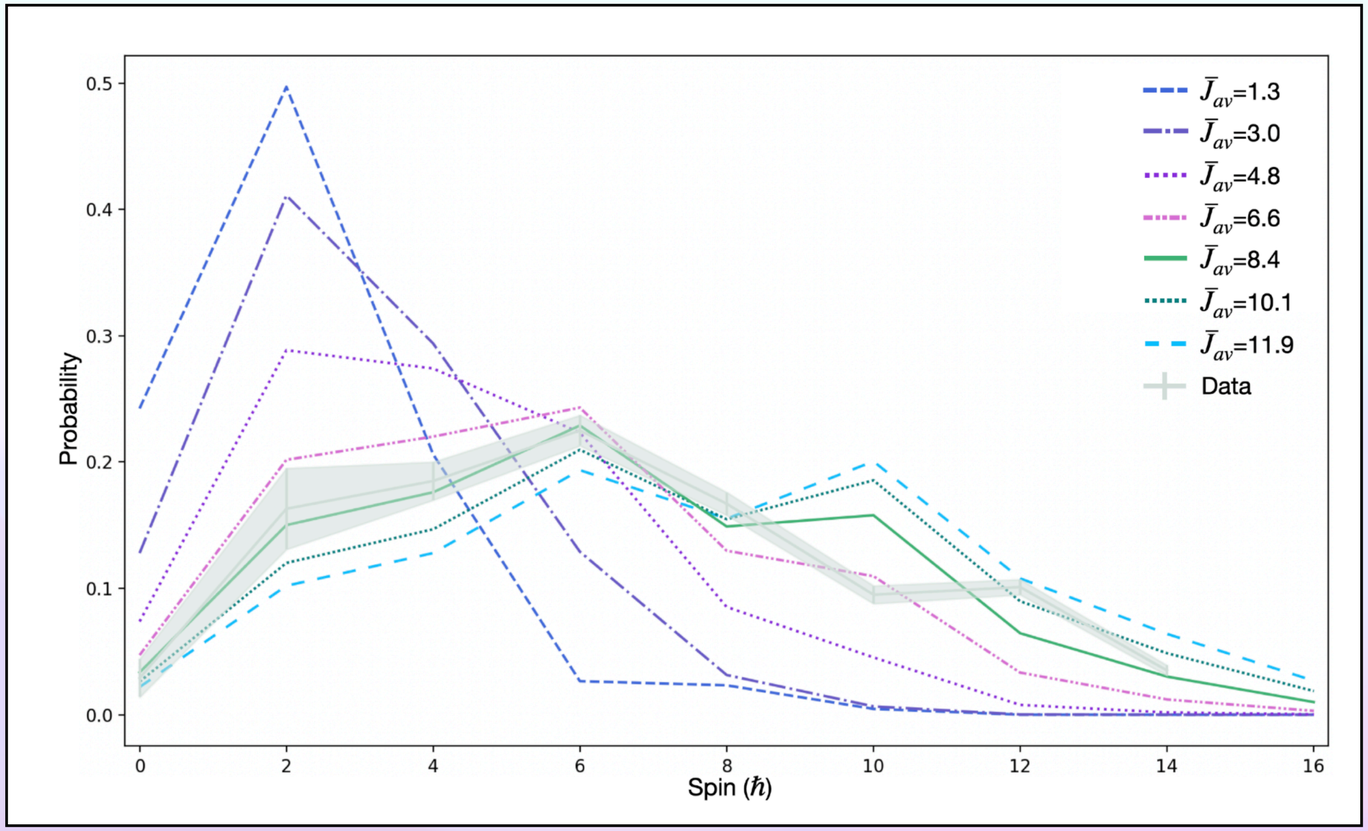
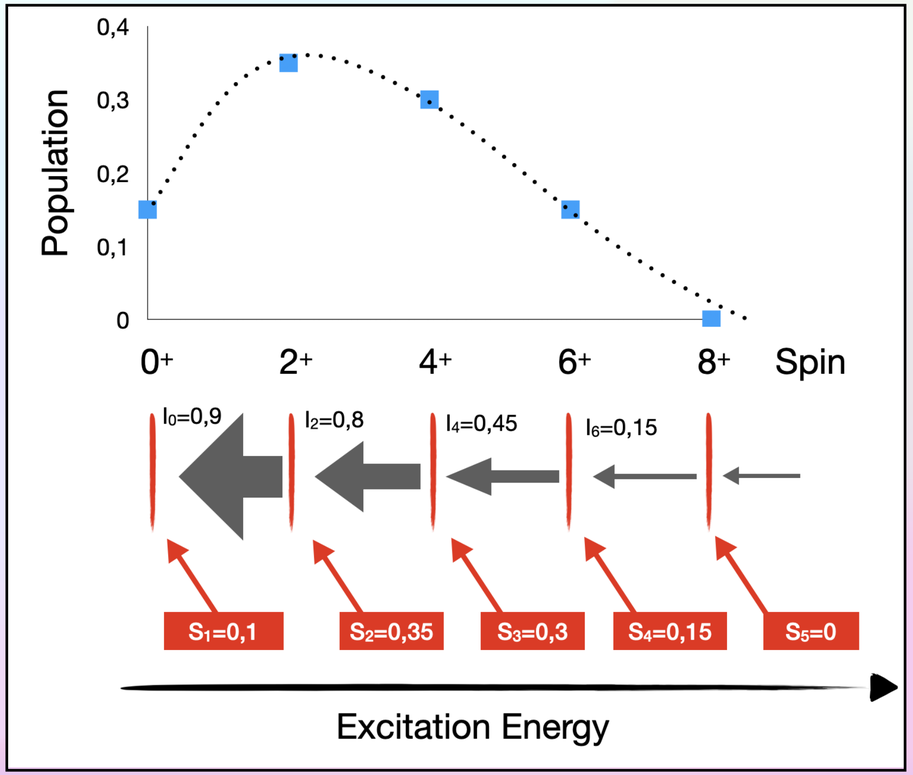
Article | Published: 24 February 2021

Angular momentum generation in nuclear fission

J. N. Wilson ✉, D. Thisse, M. Lebois, N. Jovančević, D. Gjestvang, R. Canavan, M. Rudigier, D. Étasse,





GAMMA-RAY ANGULAR DISTRIBUTIONS

$^{252}Cf(sf)$

Argonne National Laboratory

Ph.D. work of Henrik Haug

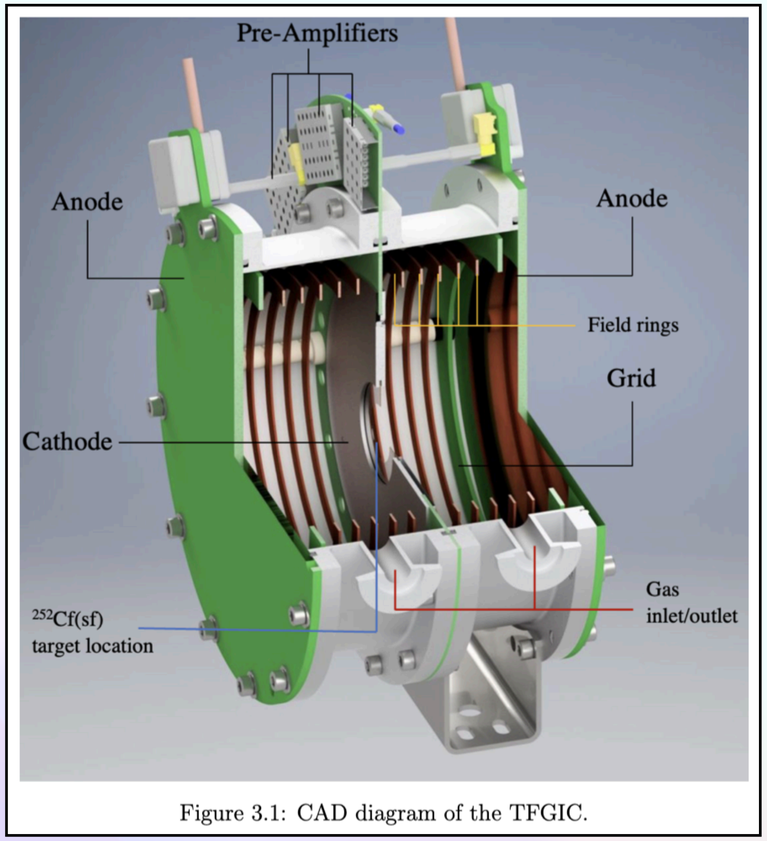


Figure 3.1: CAD diagram of the TFGIC.

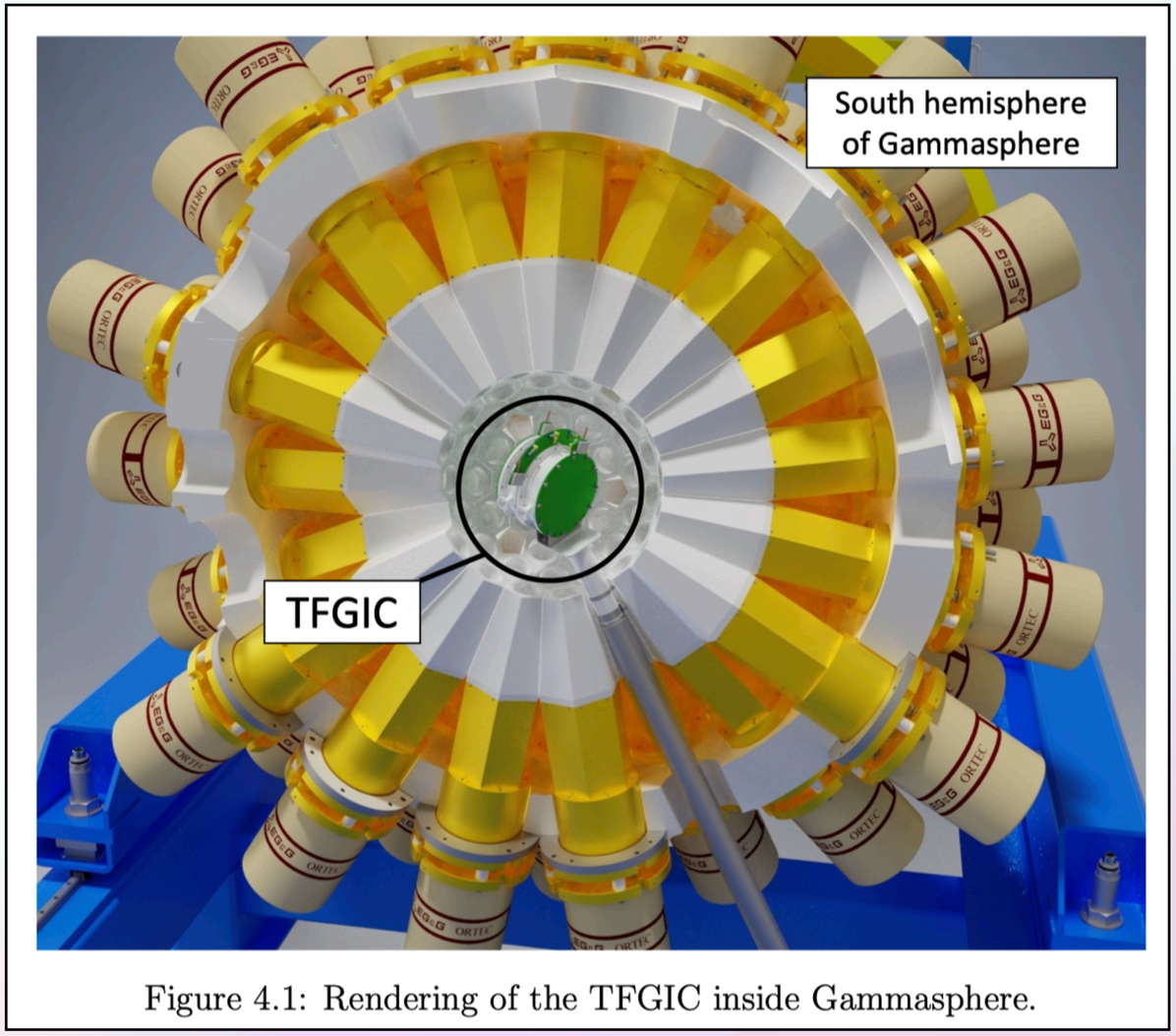
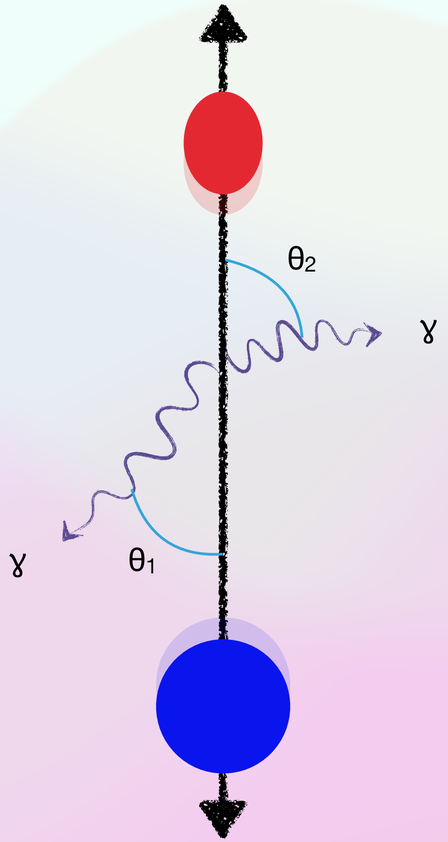


Figure 4.1: Rendering of the TFGIC inside Gammasphere.



PHD. THESIS NATHAN P. GIHA – UNIVERSITY OF MICHIGAN

NUCLEAR FISSION AT THE NORWEGIAN NUCLEAR RESEARCH CENTRE - SELECTED TOPICS

Ali Al-Adili

THANKS FOR YOU ATTENTION!

2026-05-22