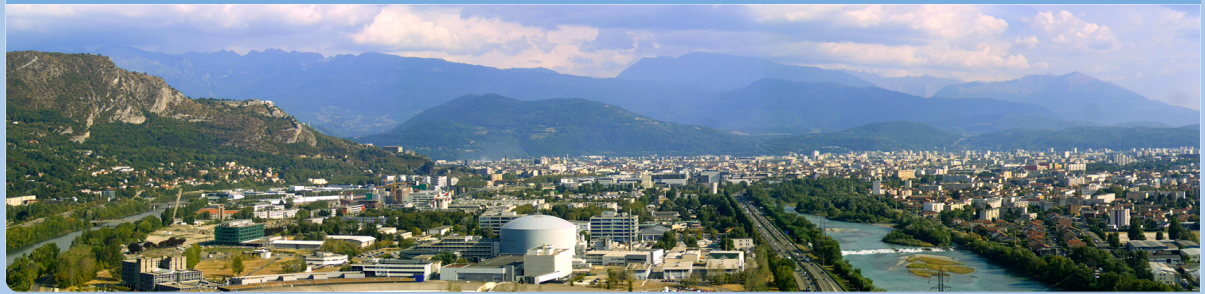
NEUTRONS FOR SOCIETY

Probing nuclear structure with thermal neutrons

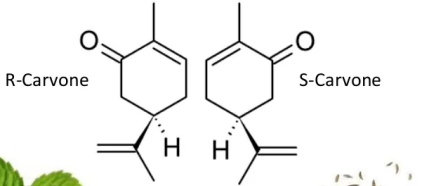
SSNET 2024 - International Conference on Shapes and Symmetries in Nuclei

Caterina Michelagnoli | 4 November 2024

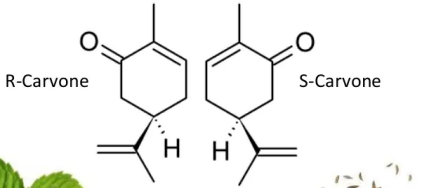
Institut Laue-Langevin and University of Grenoble-Alpes

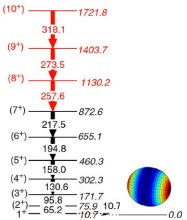


Shapes: molecules vs nuclei



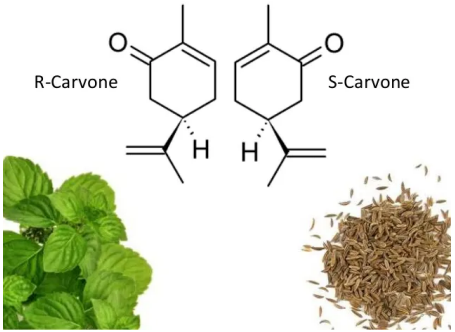
Shapes: molecules vs nuclei

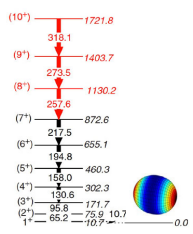




$^{100}Y_{61}$

Shapes: molecules vs nuclei





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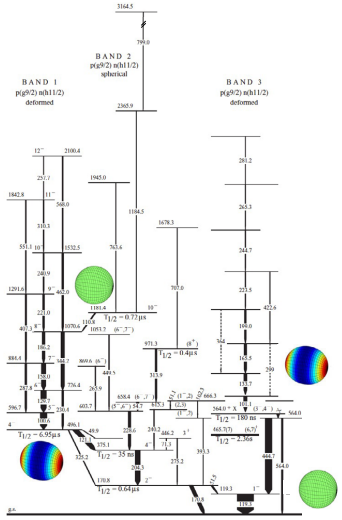
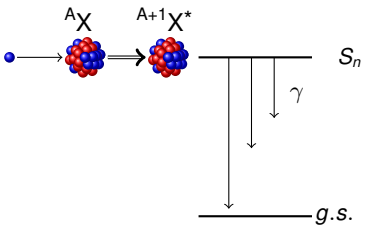


$^{98}Y_{59}$

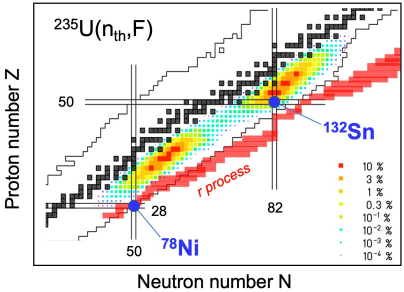
S. Leoni, C. Michelagnoli and J. Wilson, Riv. Nuovo Cim. 45 (2022) 461

Neutron-induced reactions



Thermal neutron capture reactions

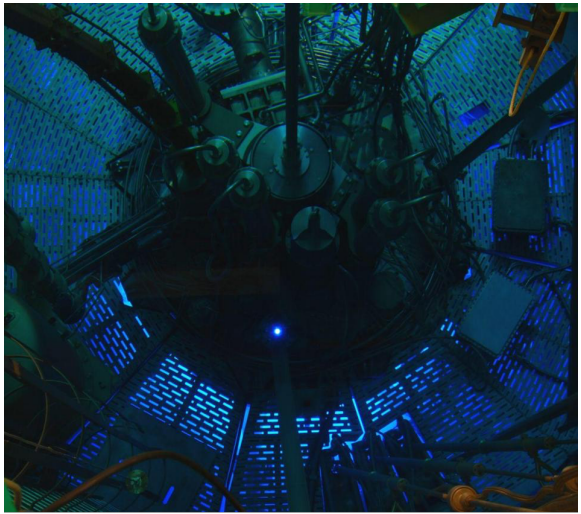
- Structure of nuclei close to stability
- Structure at low spin (below S_n)
- Cross-sections (applications)
- ^{27}Al(n,γ): σ=0.2 b; ^{157}Gd: 2.5 10^5b



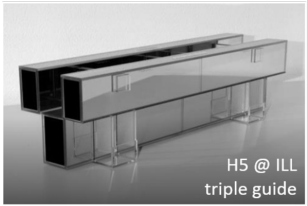
Neutron-induced fission

- Structure of n-rich nuclei (far from stability)
- Fission yields and dynamics
- ^{235}U: σ_f=585 b; ^{245}Cm: σ_f=2141 b

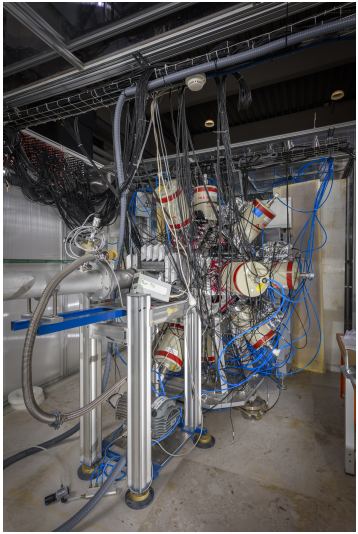
World's highest neutron flux for in-beam experiments



- ✓ up to 1.5 10^{15} n/s/cm^2
- ✓ in-pile irradiation of radioisotopes
- ✓ "slow" neutrons delivered to $\approx$ 40 instruments
- ✓ guided with little losses over hundreds of meters



High-resolution γ spectroscopy at a neutron beam



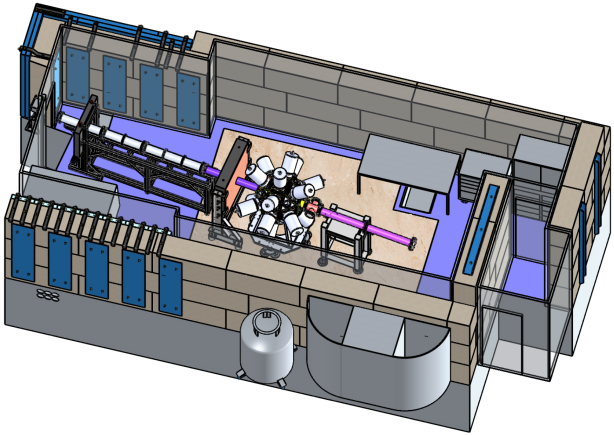
Fission Product Prompt γ-ray Spectrometer

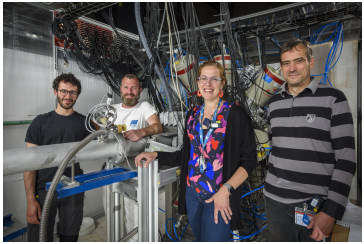
- ✓ 8HPGe clovers+Anti-Comptons (segmented)
- ✓ “pencil-like” thermal neutron beam (1.5cm diam., 5 10^7 n/s/cm^2)
- ✓ digital electronics
- ✓ list mode
- ✓ tight polycarbonate casemate (radioactive targets)
- ✓ possibility to add ancillary detectors: $LaBr_3$, additional clovers from IFIN-HH, ...

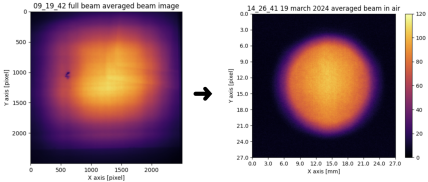
C. Michelagnoli et al., EPJ Web Conf., 193 (2018) 04009; many Master/PhD theses

G. Colombi et al., in preparation

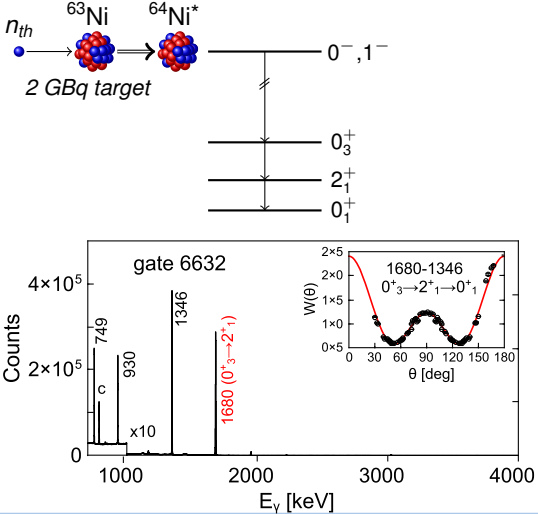
The FIPPS instrument at ILL

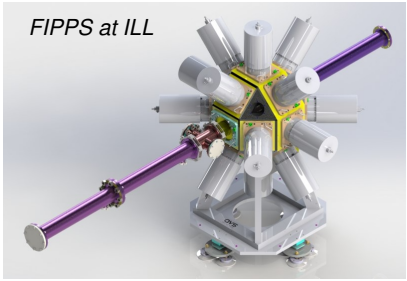


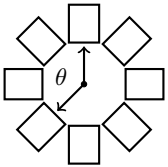




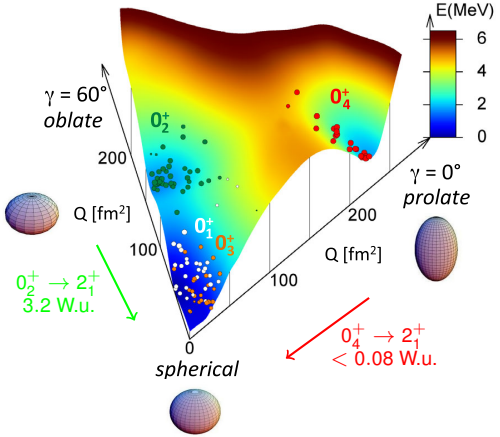
High-statistics coincidence measurements using radioactive targets

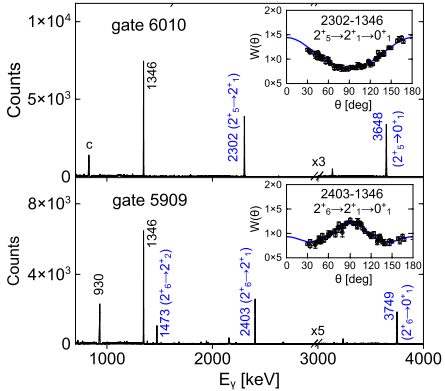






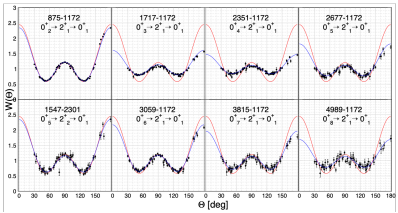
Shape coexistence in ^{64}Ni





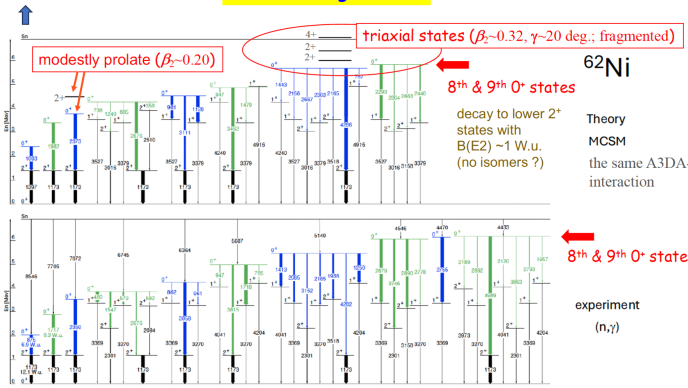
Adapted from N. Marginean at al., Phys. Rev. Lett. 118 (2017) 162502

Triaxiality in ^{62}Ni: MCSM calculations and (n,γ) data



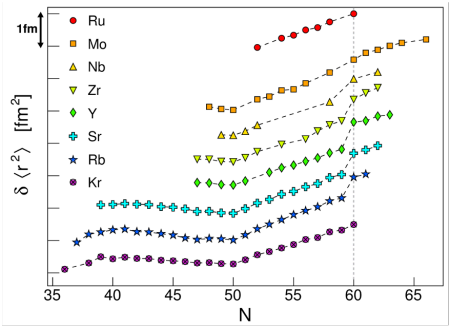
10 new 0^+ states identified via high-statistics angular correlations

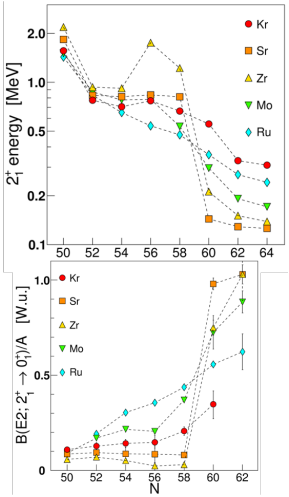
Current edge : ^{62}Ni



Courtesy of T. Otsuka

Shape coexistence in nuclei with A≈100

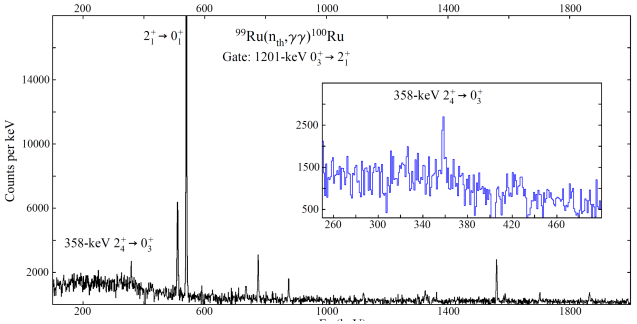


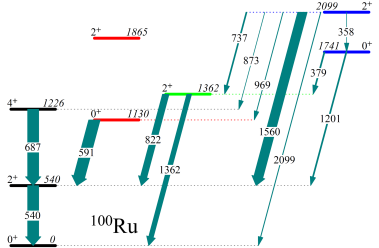


P. Garrett, M. Zielińska, E. Clément, PPNP 124, 103931 (2022)

Shape coexistence in Ru isotopes: structure of ^{100}Ru

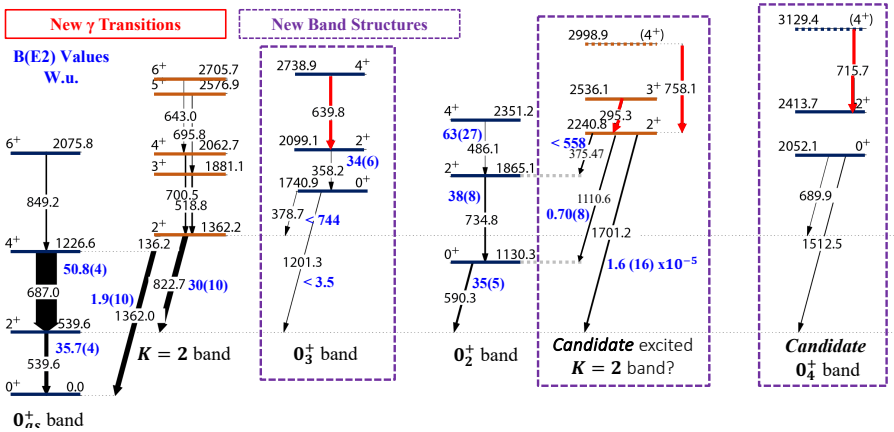
- Previous branching ratio for 358-keV γ ray, 3.1(4)%, leads to 270 W.u. $2_4^+ \rightarrow 0_3^+$ transition – obviously wrong, casting doubt on placement and band assignment
- New branching ratio 0.39(6)%, yielding 34(5) W.u. using half life of 390(70) fs from (n,$n'\gamma$) reaction – $B(E2)$ indicates similar collectivity to gsb that has 35.3(7) W.u.





Courtesy of P. Garret

Band structures in ^{100}Ru



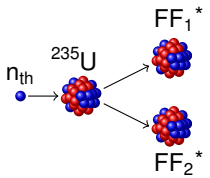
Analysis by S. Pannu (University of Guelph)

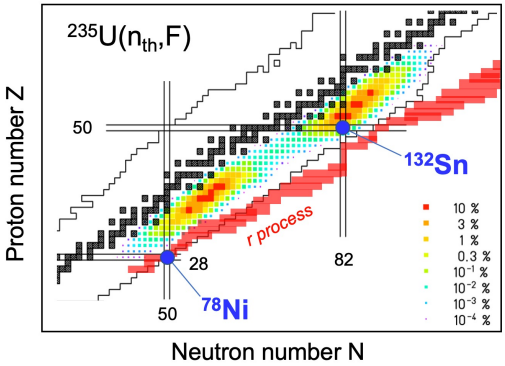
0^+ 1828

^{102}Ru(p,t)^{100}Ru Does not observe this state (S. Buck, M.Sc. Thesis, University of Guelph)
&
Current work sees no γ decay from this level

Courtesy of P. Garret

Neutron-rich nuclei produced in the fission process

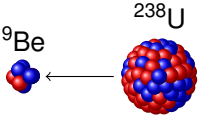


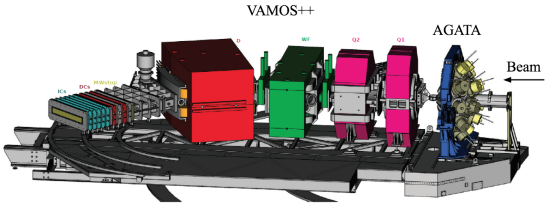


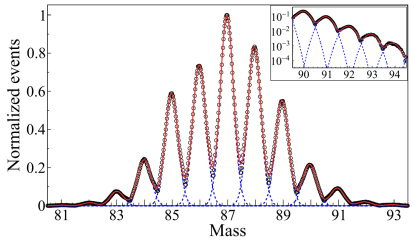
S. Leoni, C. Michelagnoli and J. Wilson, Riv. Nuovo Cim. 45 (2022) 461

High-resolution spectroscopy of neutron rich fission fragments

Beam-induced fission



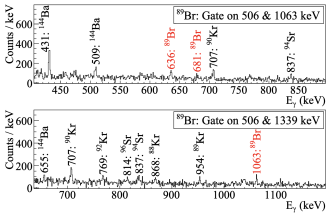


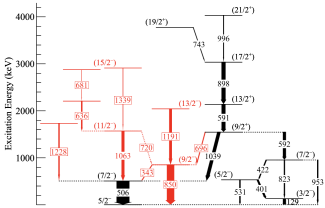


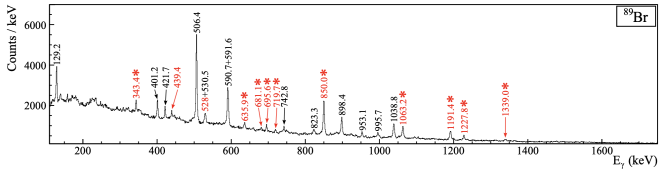
J. Dudouet et al., Phys. Rev. C 110 (2024) 034304

A. Navin, Phys. Lett. B 278 (2014) 136

Deformation of neutron-rich Br isotopes: two complementary data sets







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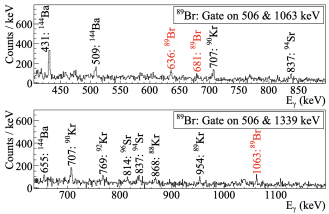
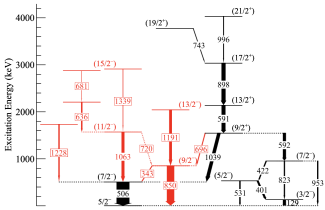
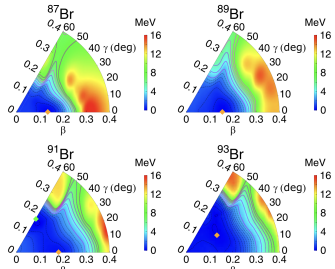
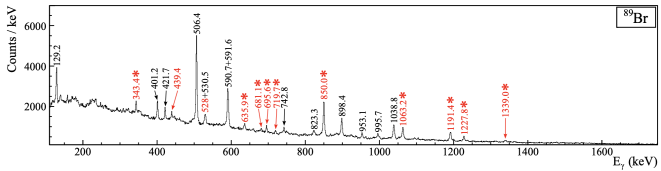




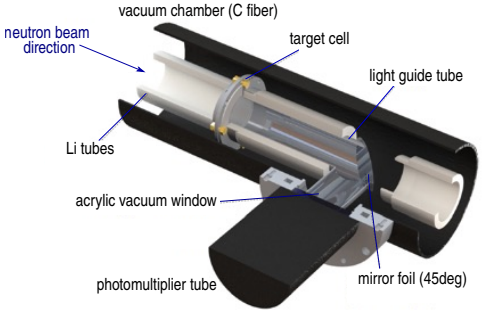
prolate to oblate shape transition

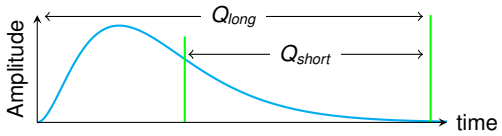


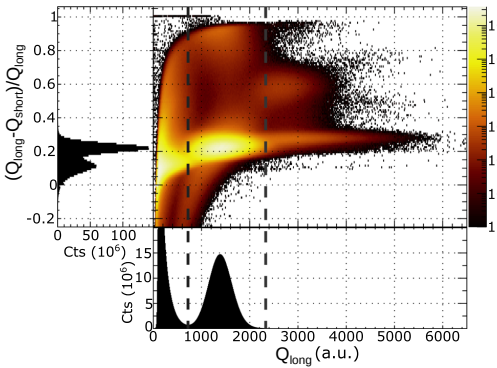


J. Dudouet et al., Phys. Rev. C 110 (2024) 034304

Selection of fission events using an active target







Adapted from F. Kandzia et al., Eur. Phys. J A 56 (2020) 207

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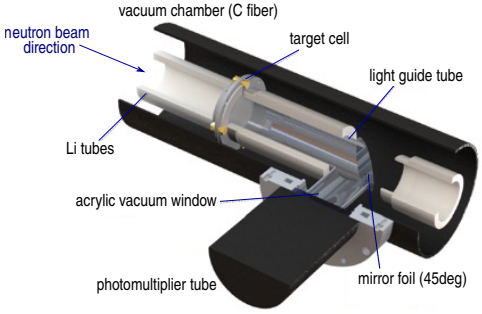

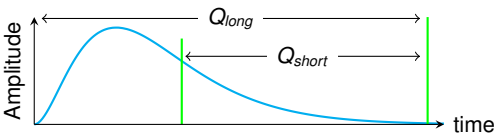

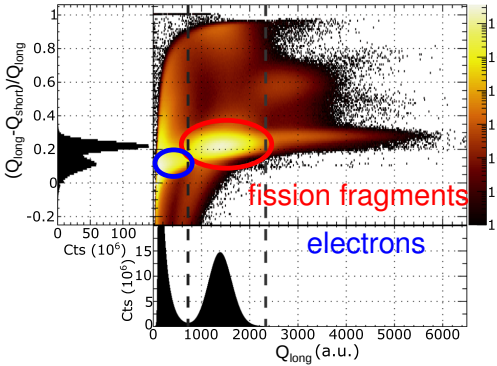

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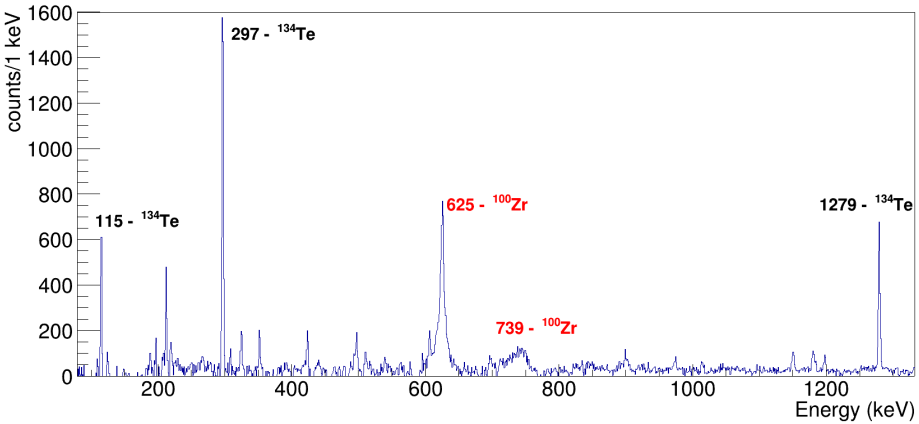
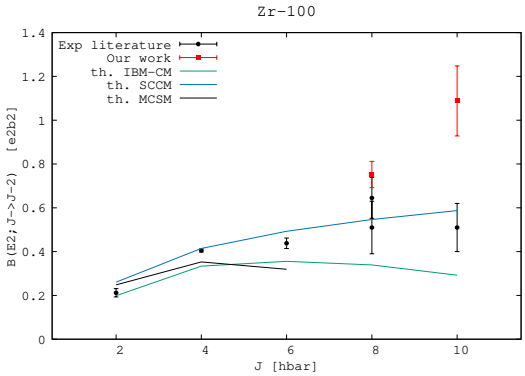
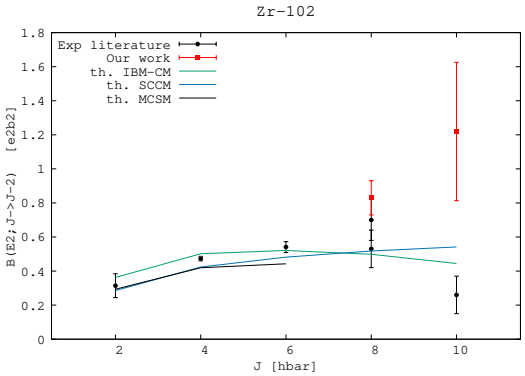
Lineshapes in multi-γ coincidence spectra



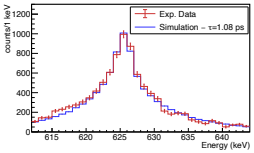
G. Colombi, PhD Thesis, Univ. Grenoble-Alpes, ILL and Univ. Milan, 2023

”Surprising” deformation in neutron-rich nuclei





$8^+ \rightarrow 6^+$ ^{102}Zr



G. Colombi, PhD Thesis, Univ. Grenoble-Alpes, ILL and Univ. Milan, 2023
G. Colombi et al., in preparation

Concluding remarks and future perspectives

- The slow neutrons produced by the ILL high flux reactor can be used for investigating nuclear deformation, shape coexistence and transition phenomena (complementary to other facilities)
  - nuclear structure close to stability (shape coexistence at zero spin - ^{62,64}Ni)
  - structure of neutron-rich fission fragments (shape coexistence, structure at large N/Z asymmetry, ...); lifetime measurements, deformation at medium-high spin in Zr isotopes

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- A fission fragment selection setup at a neutron beam will allow for high-sensitivity prompt spectroscopy of fission fragments (excellent performance expected, diamond technology)

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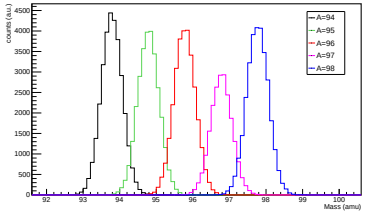
- Many projects/possibilities:
  - plunger setup for fission
  - ^{179}Ta radioactive target (^{180}Ta nucleosynthesis -ILL, nToF, LANSCE)
  - fission data open for LoI
  - diamond-based fission tag
  - ^{245}Cm(n,fission) campaign
  - other ideas ??



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