Nuclear structure after slow neutron reactions at ILL

Caterina Michelagnoli

Institut Laue-Langevin
Université Grenoble-Alpes

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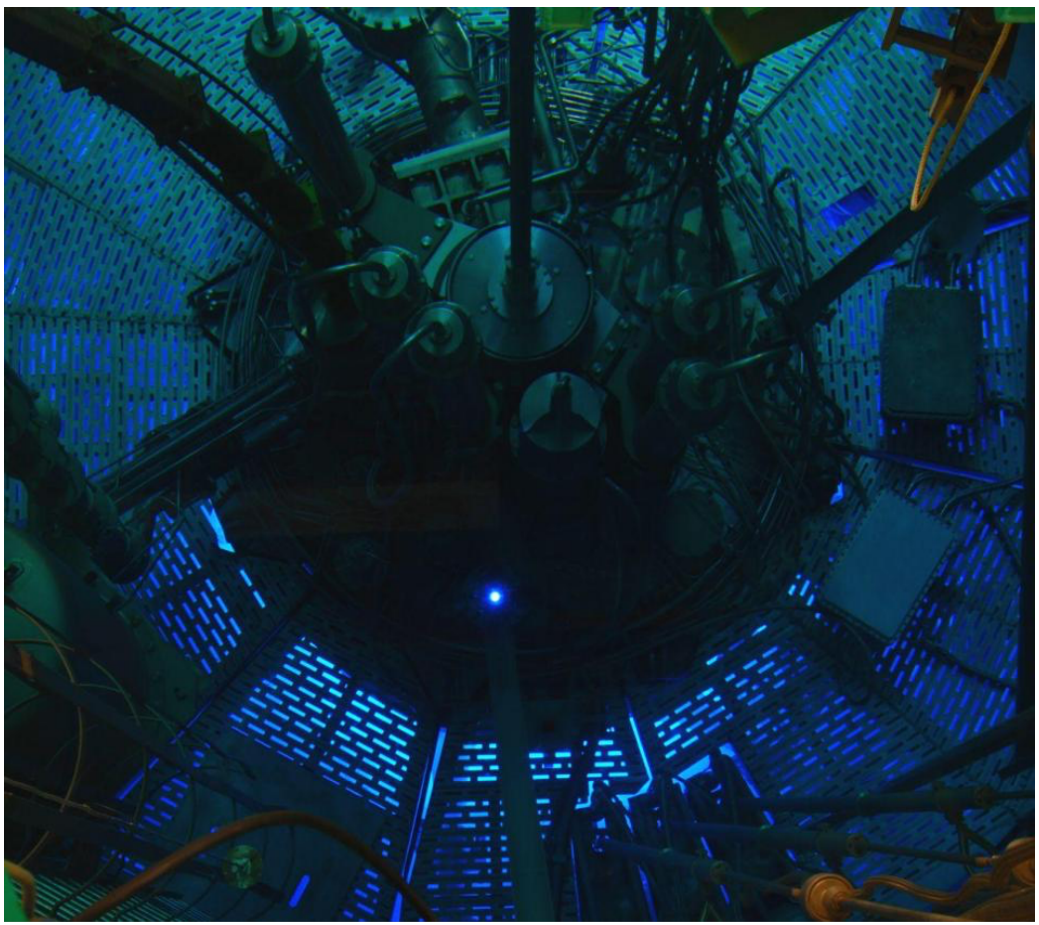
NEUTRONS FOR SOCIETY

UGA Université Grenoble Alpes

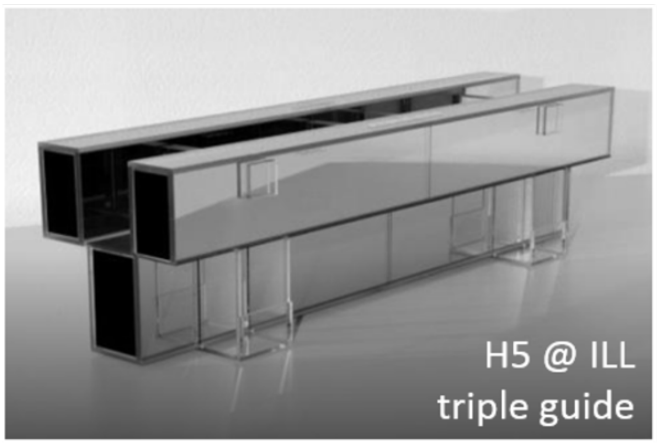
Contents

The ILL high-flux reactor

world's highest neutron flux for in-beam experiments

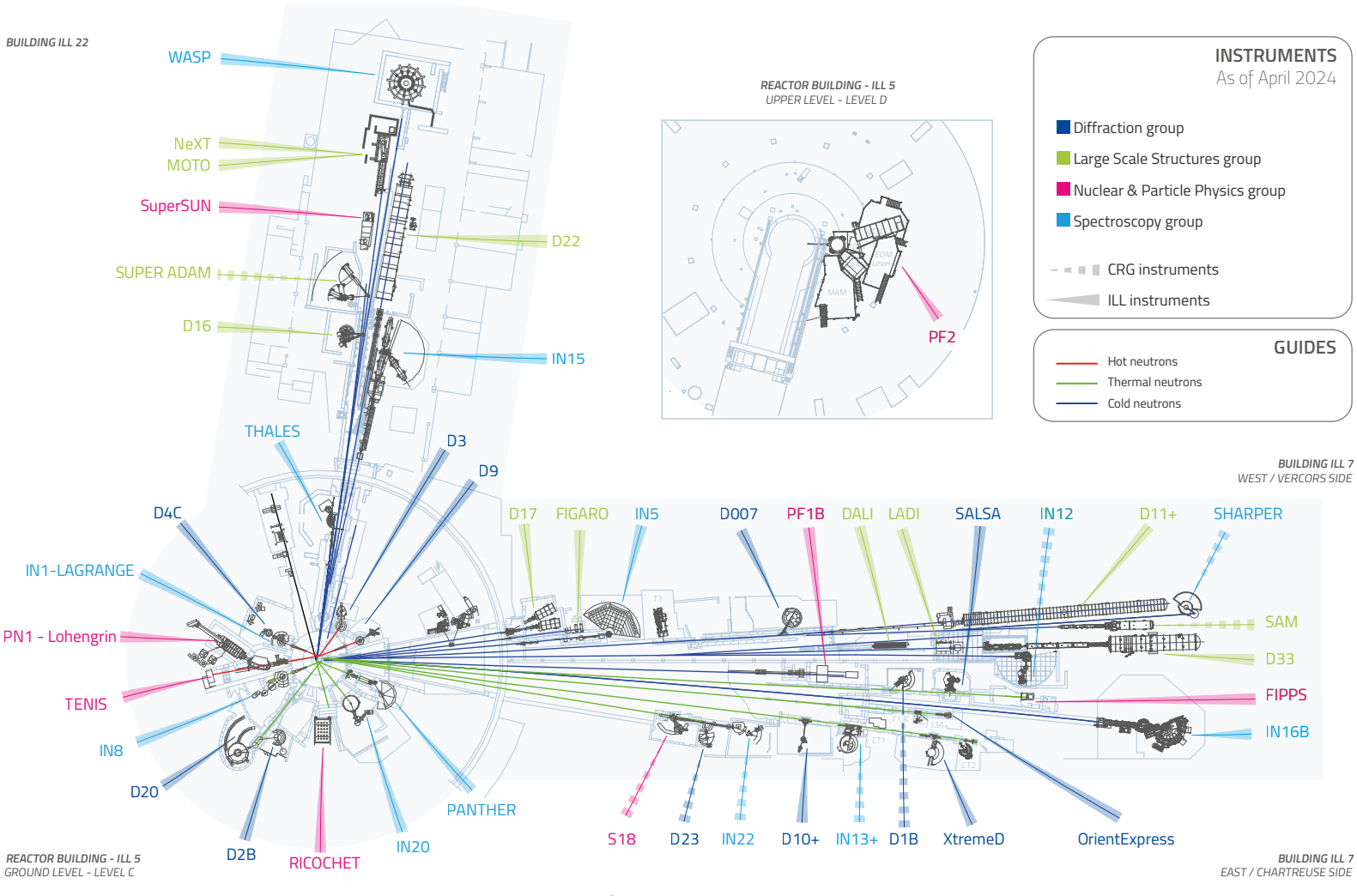


- up to 1.5 10^{15} n/s/cm^2
- in-pile irradiation of radioisotopes
- guided with little losses over hundreds of meters

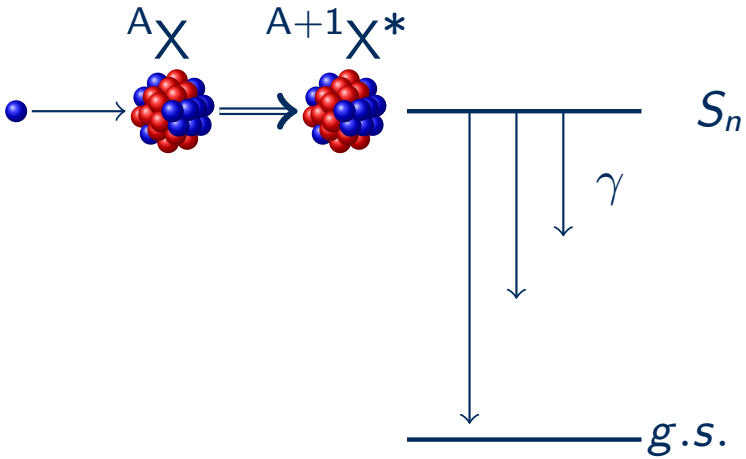


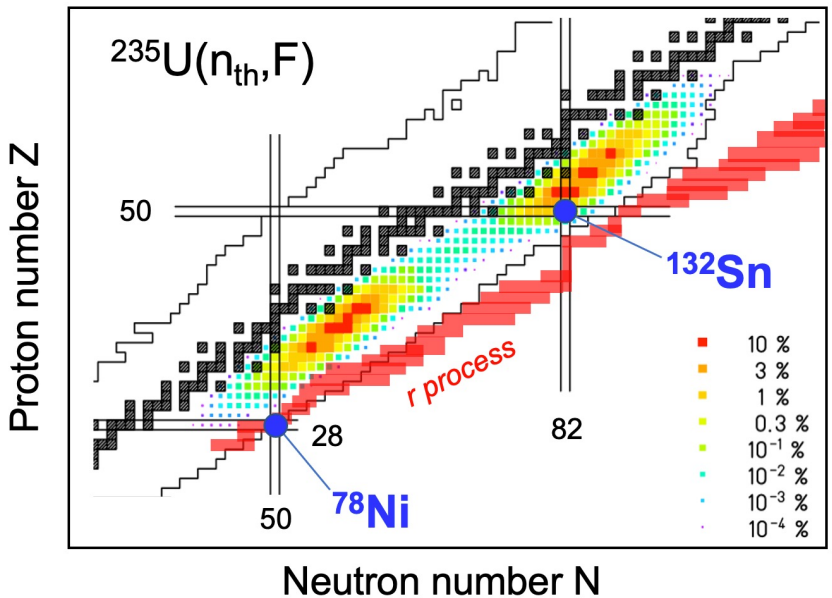
The ILL user facility

≈40 instruments, 10 scientific areas, ≈4000 users/year



Thermal neutron-induced reactions





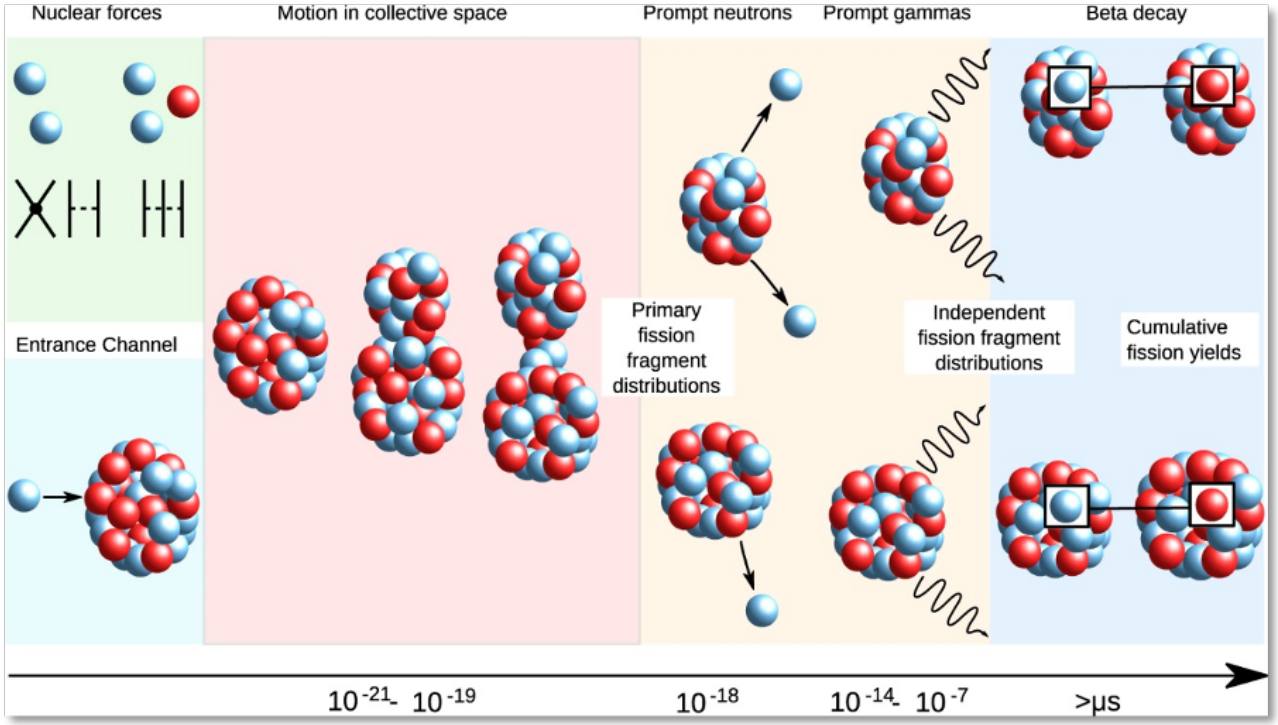
thermal-neutron capture reactions

- 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

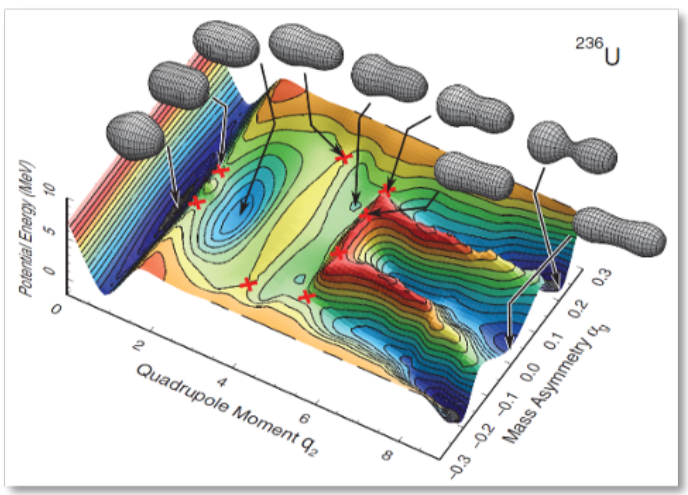
neutron-induced fission

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

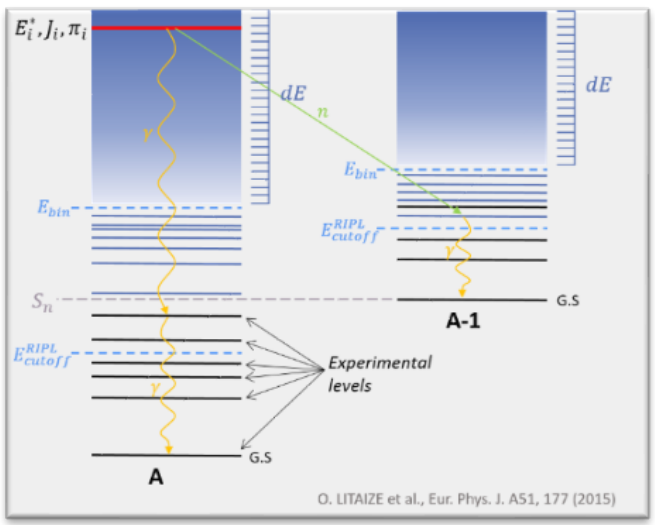
Nuclear Fission: how does it work?



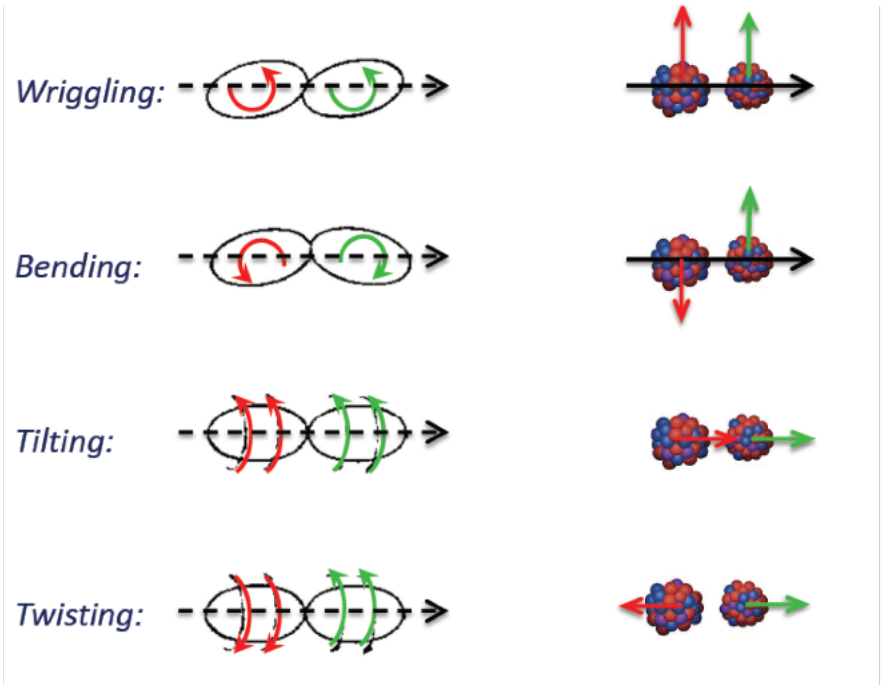
M. Bender et al., J. Phys. G 47 113002 (2020)



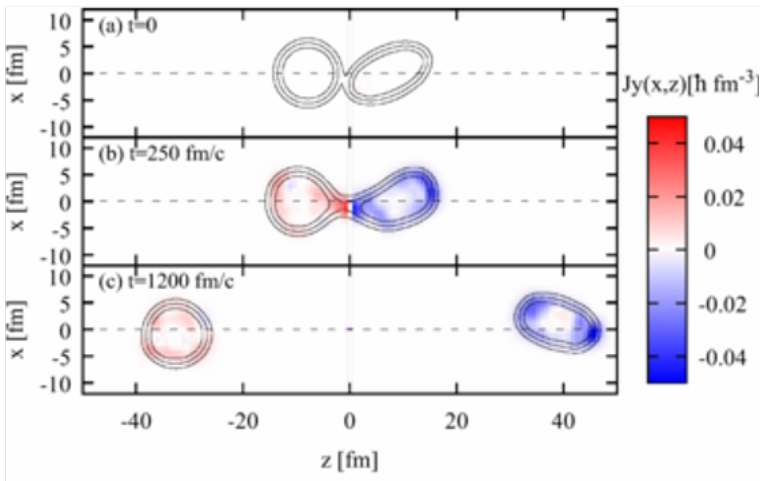
Ichikawa et al, Phys. Rev. C 40, 770 (1989)



Fission: generation of angular momentum

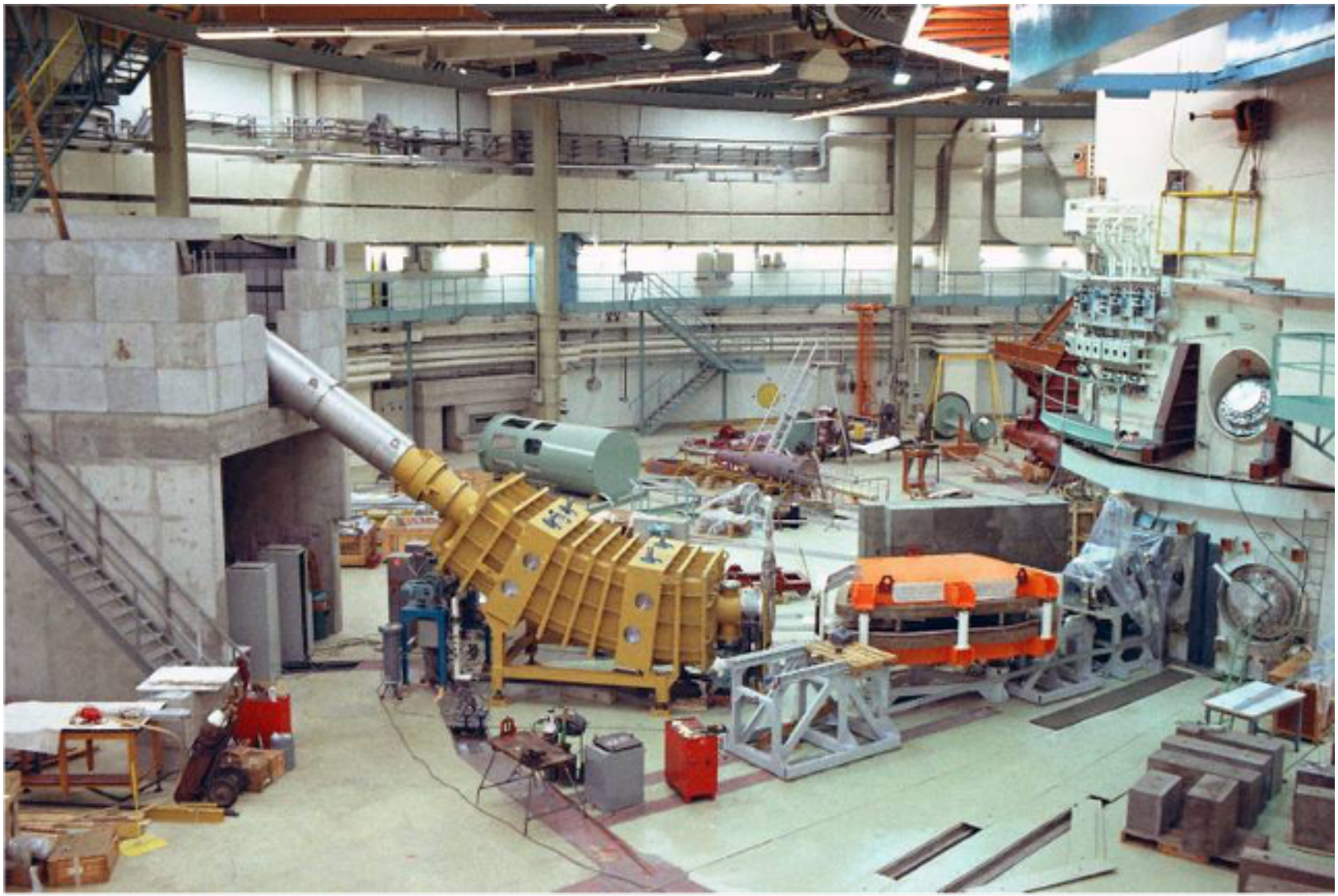


J. Randrup et al., EPJ WoC, 284,04004 (2023)

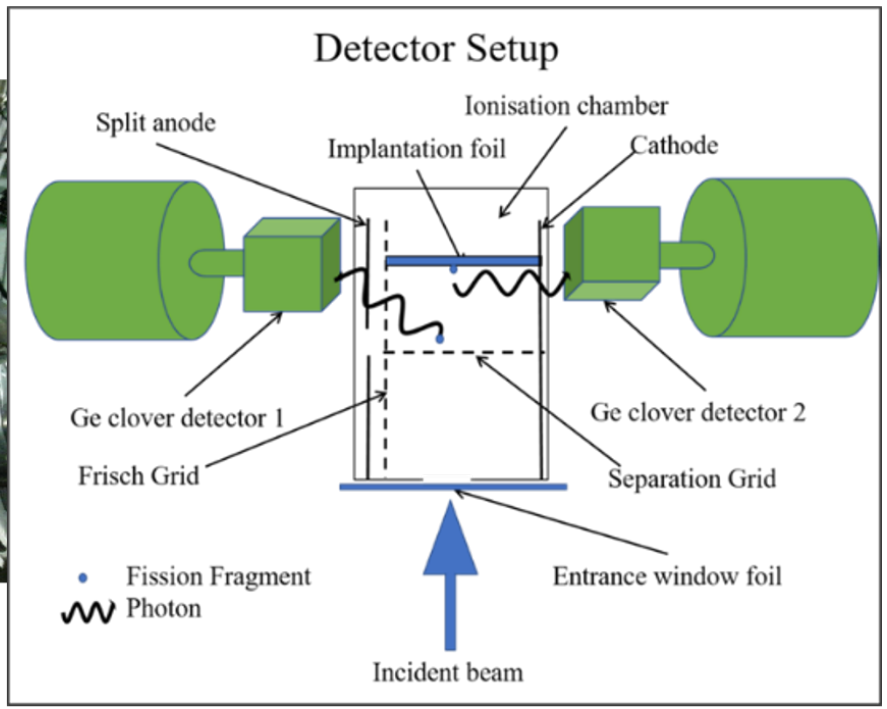


G. Scamps, Phys. Rev. C 106, 054614 (2022)

Measurement of isomeric fission yields: the Lohengrin fission fragment separator

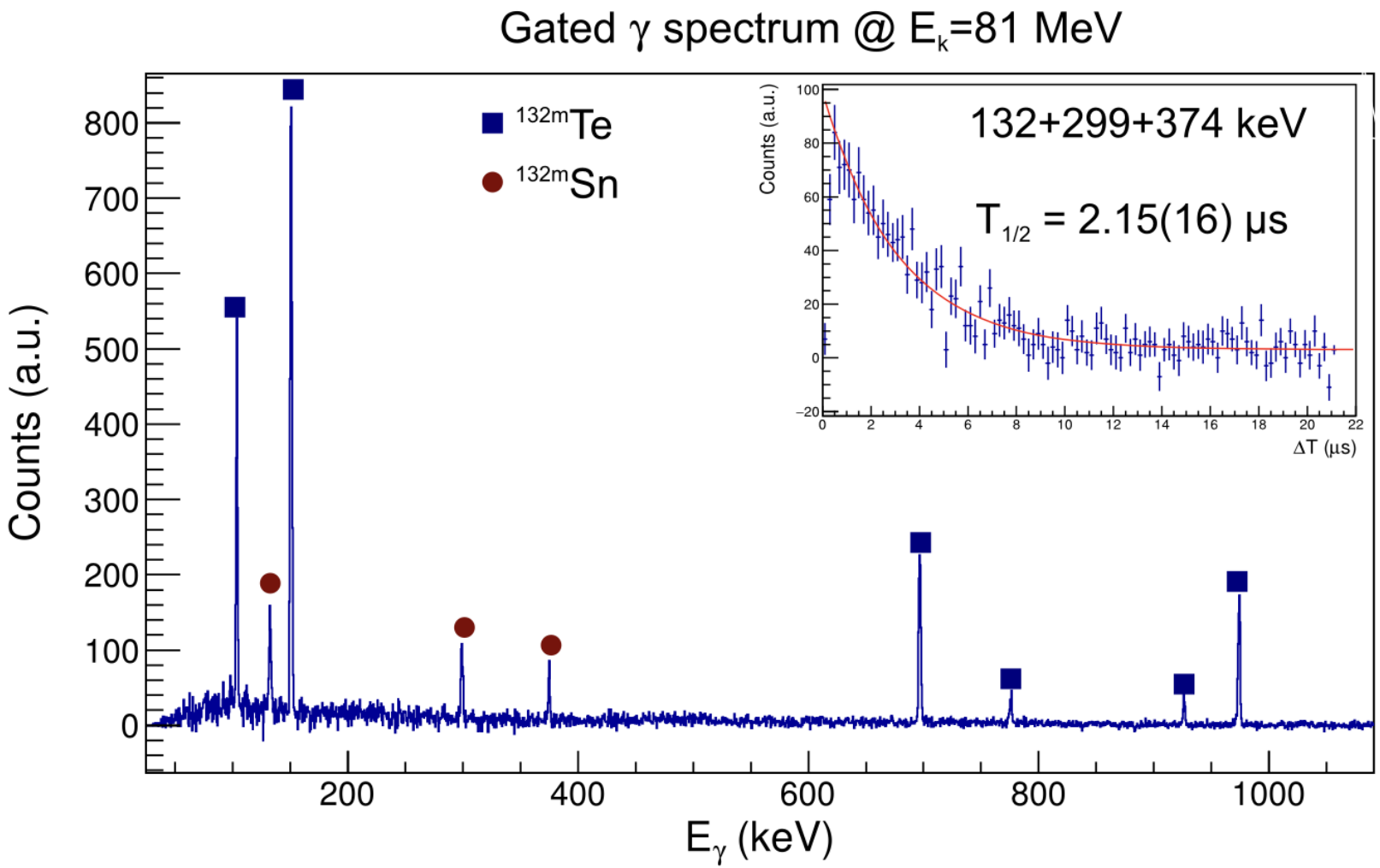


Measurement of isomeric fission yields: experimental setup



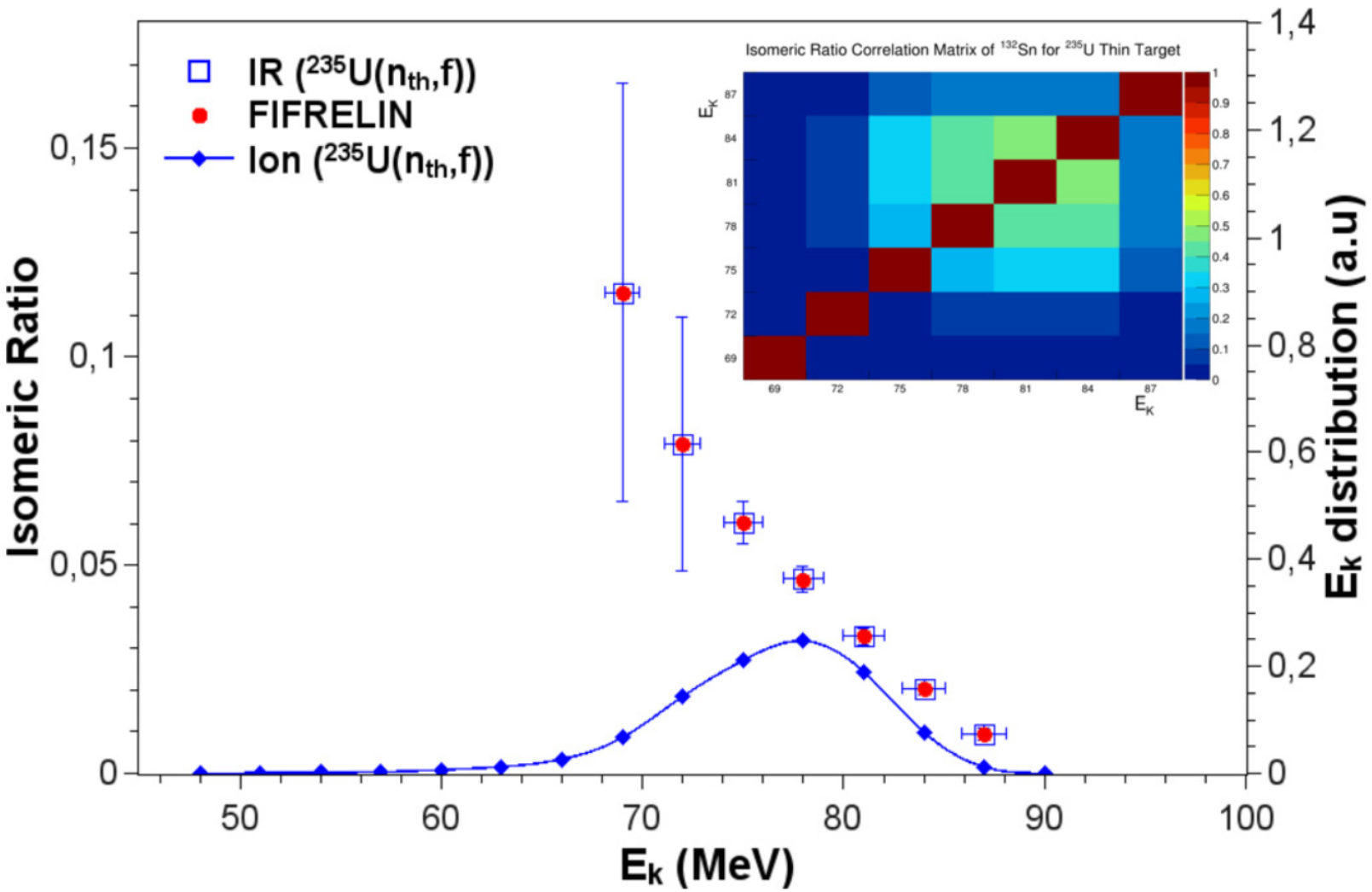
Courtesy of A. Chebboubi

Kinetic energy dependence of fission fragment isomeric ratios for spherical nuclei ^{132}Sn



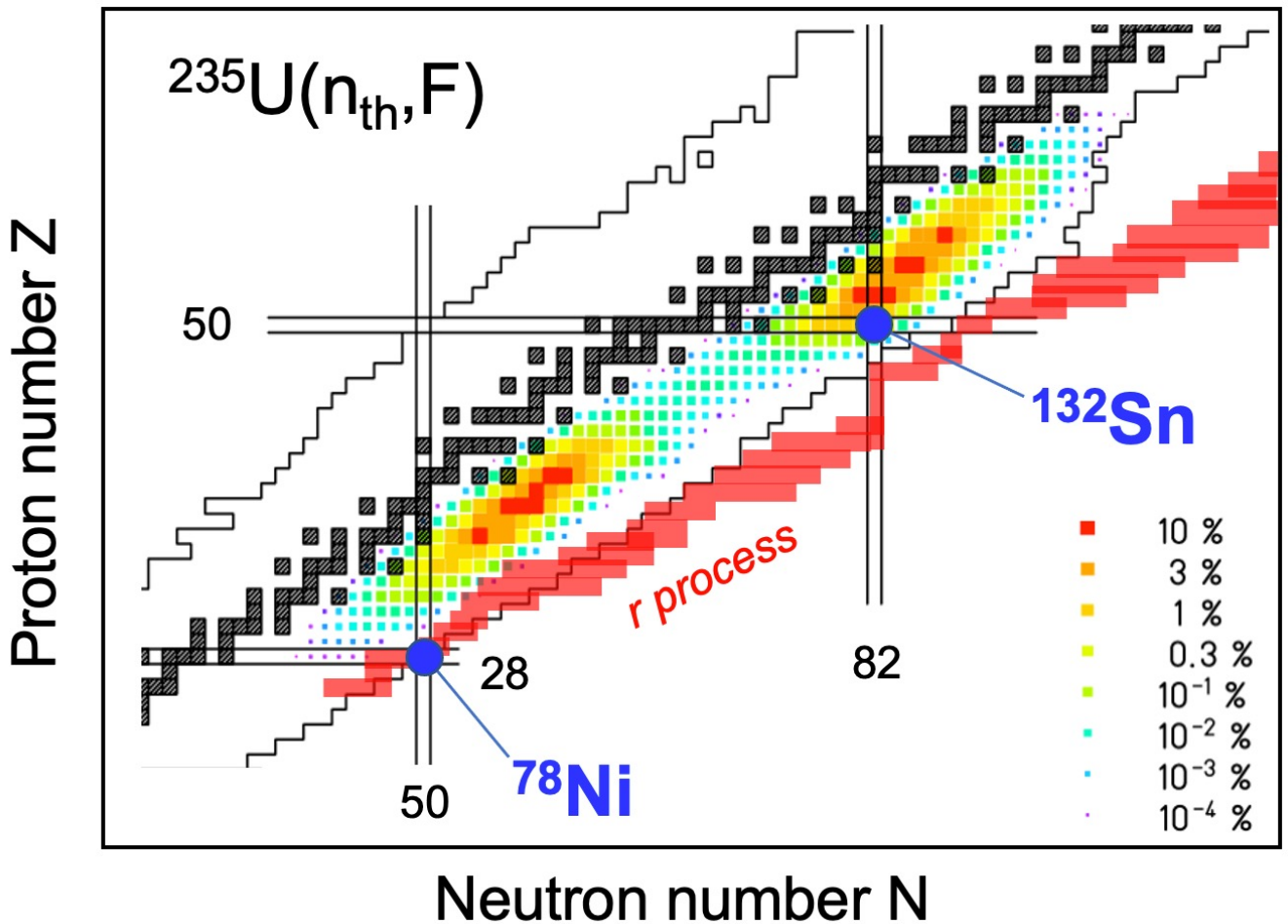
A. Chebboubi et al., Phys. Lett. B 775 (2017) 190

Kinetic energy dependence of fission fragment isomeric ratios for spherical nuclei ^{132}Sn



A. Chebboubi et al., Phys. Lett. B 775 (2017) 190

Neutron-rich nuclei produced in fission

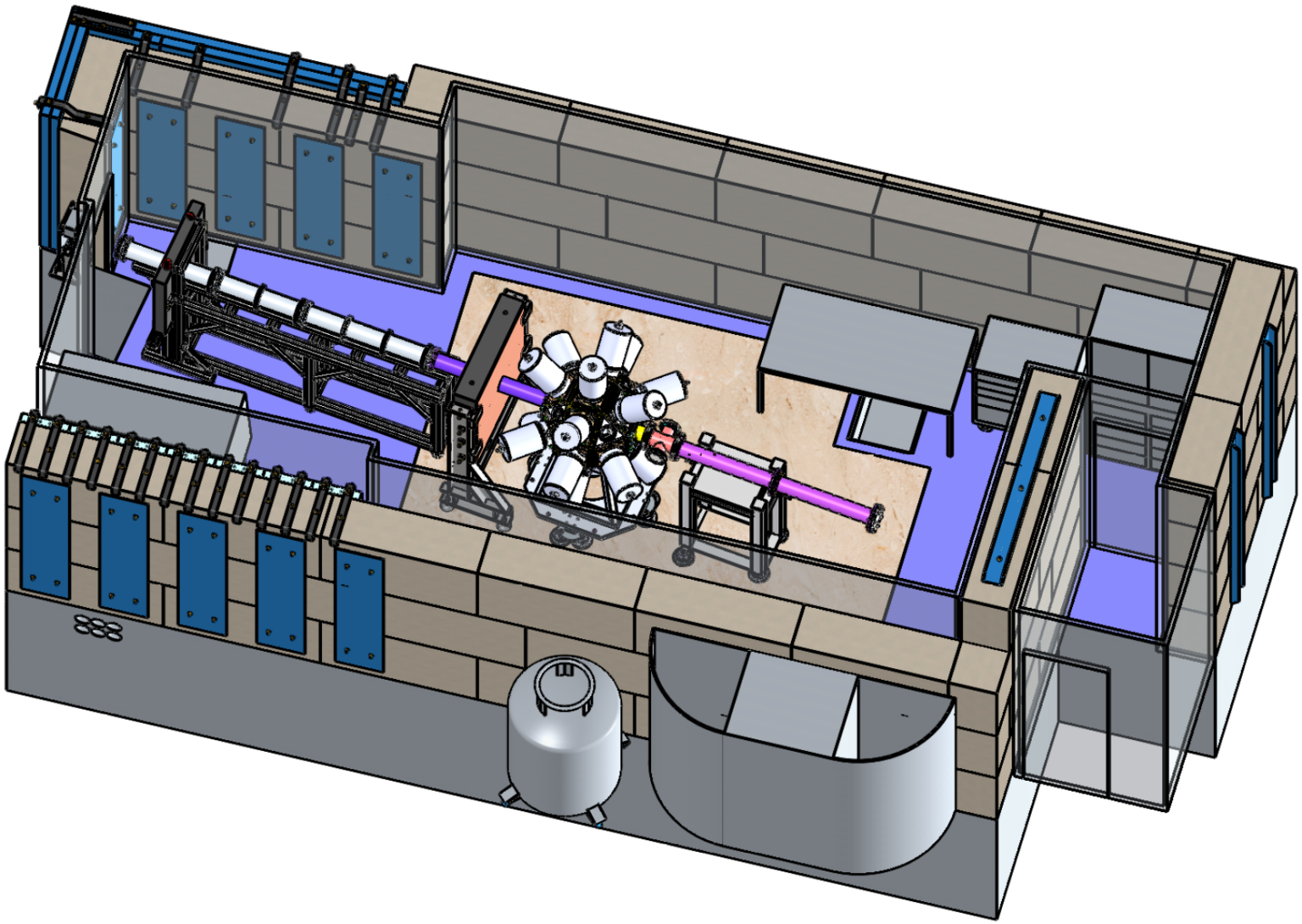


C. Freiburghaus et al., Astrophys. J. 516 (1999) 381

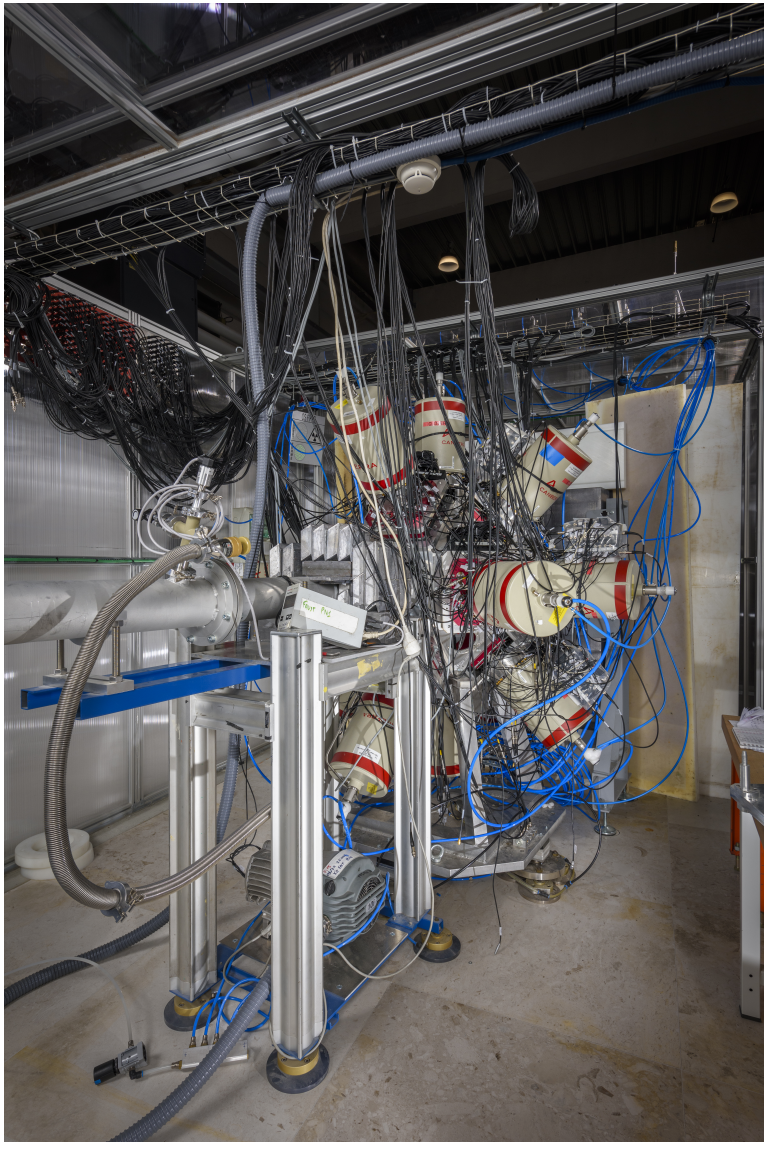
γ-ray spectroscopy is a challenge!

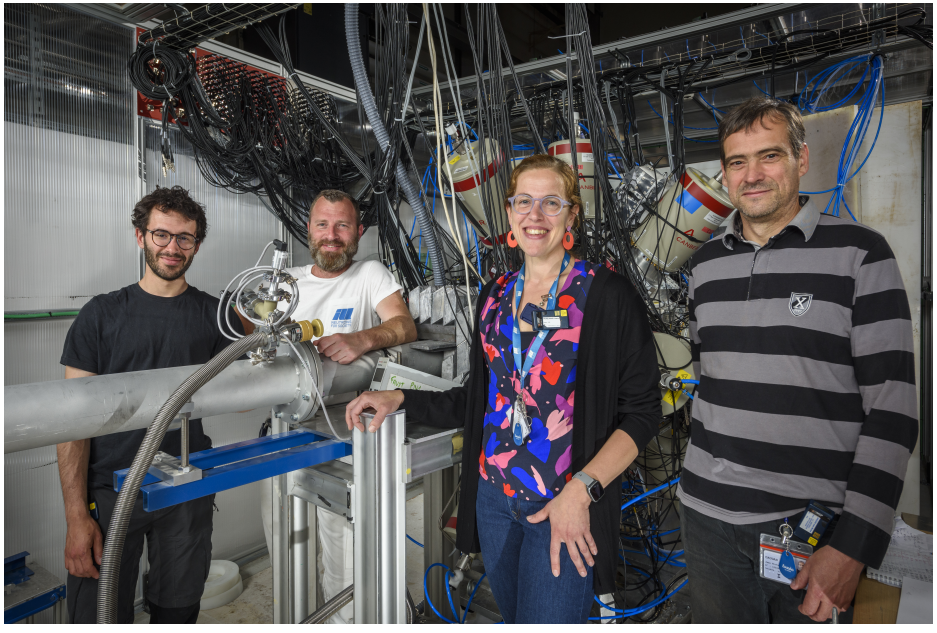
S. Leoni, C. Michelagnoli and J. Wilson, Riv. Nuovo Cim. 45 (2022) 461

In n-beam γ-ray spectroscopy at ILL: FIPPS

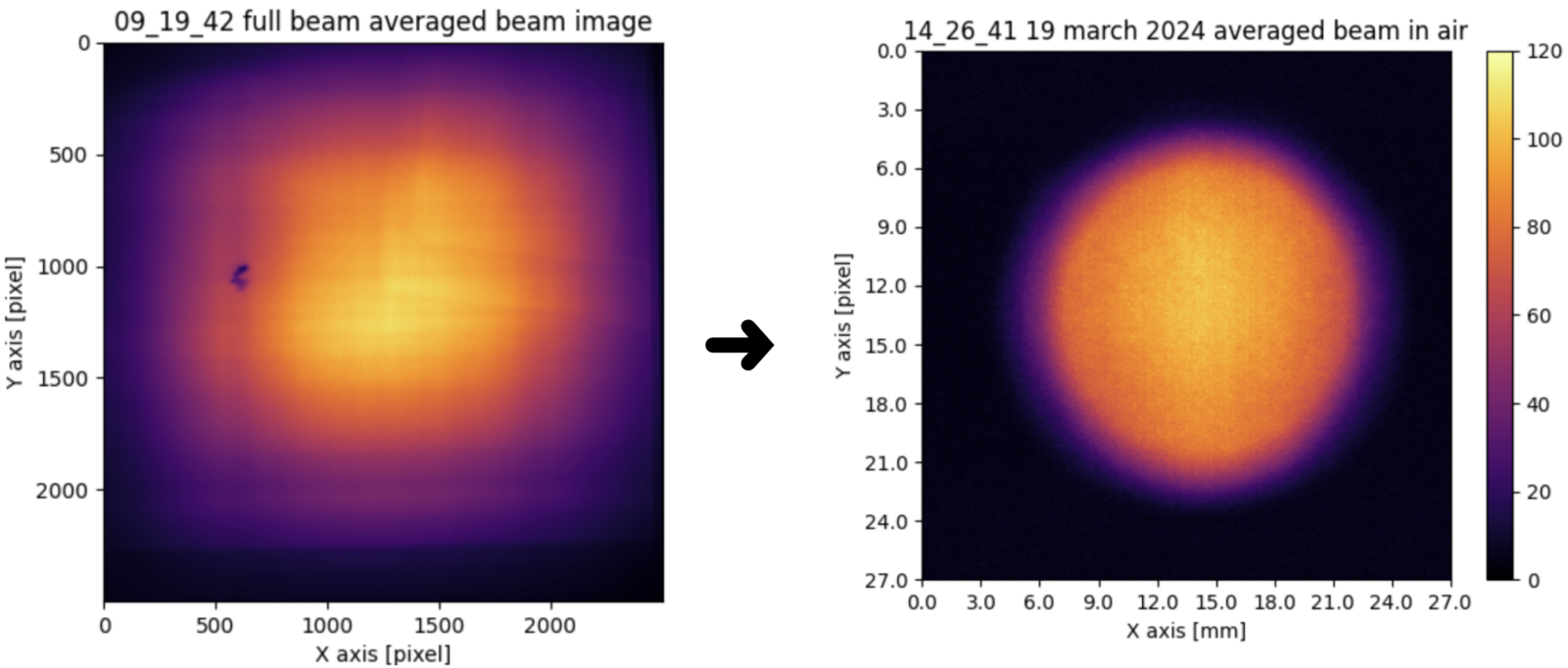


More beam and more space



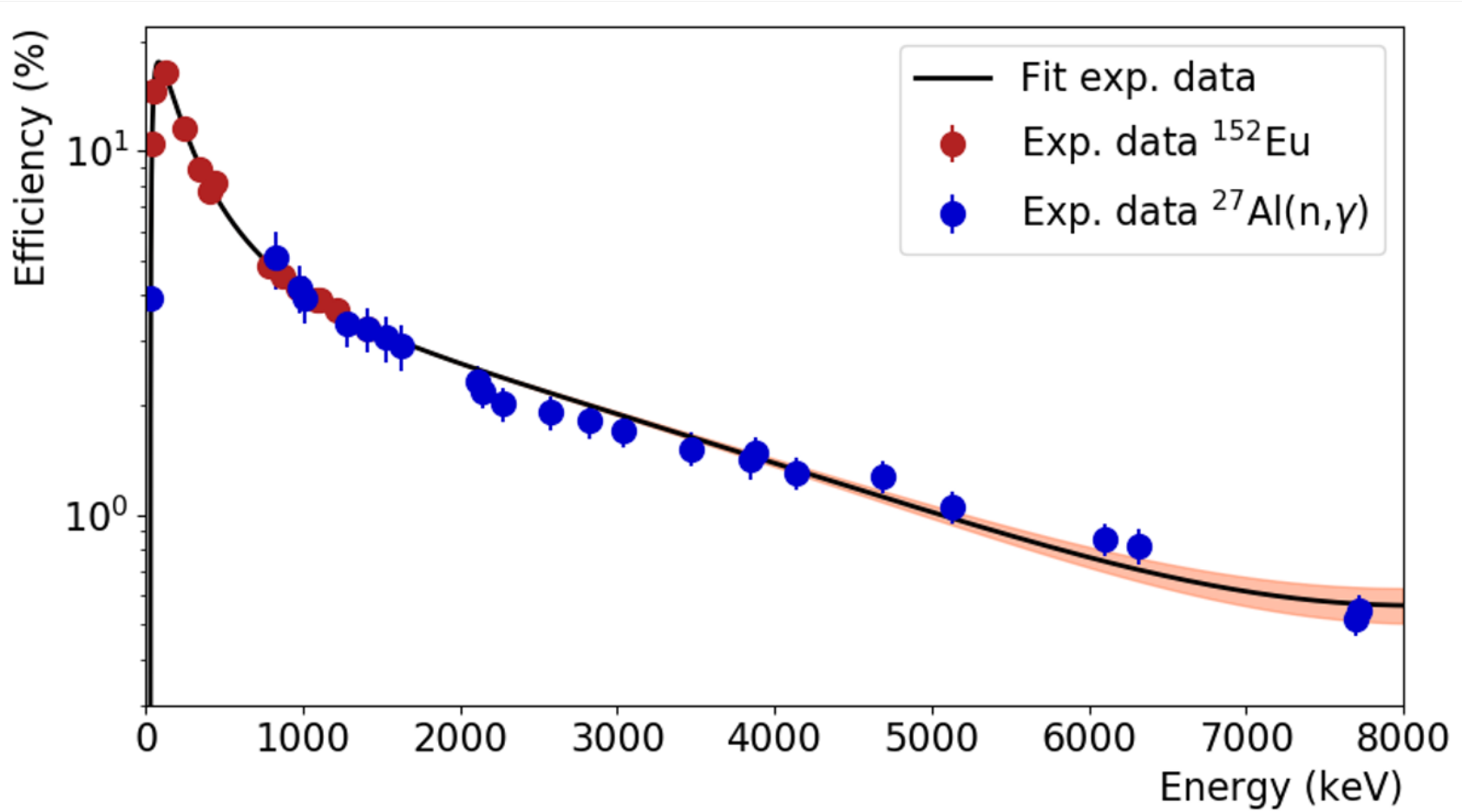


Neutron beam characterization



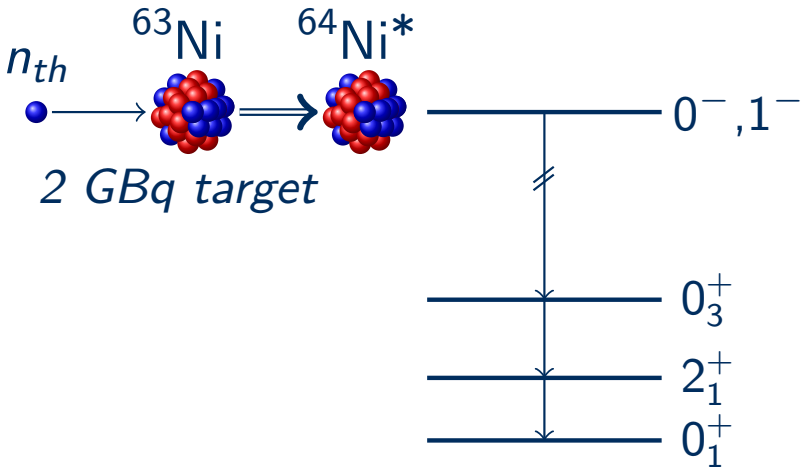
L. Domenichetti, ILL

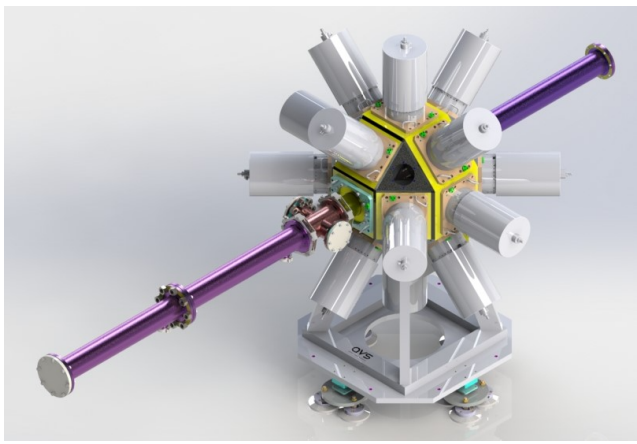
FIPPS HPGe array efficiency

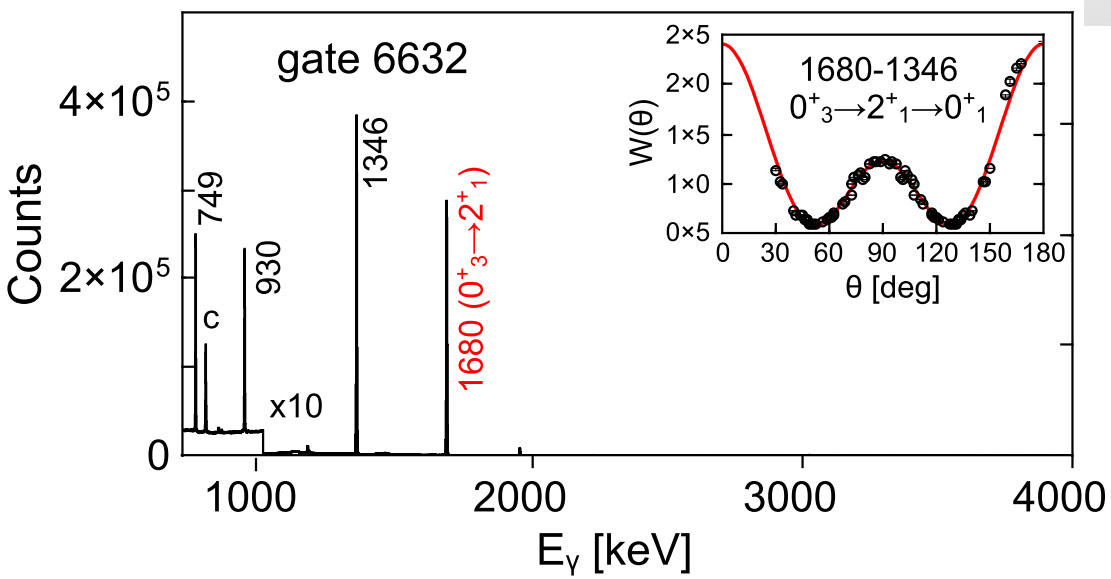


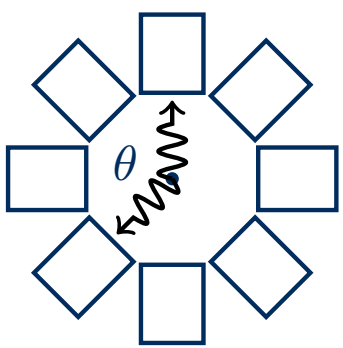
G. Colombi et al., in preparation

Angular correlation analysis+radioactive target

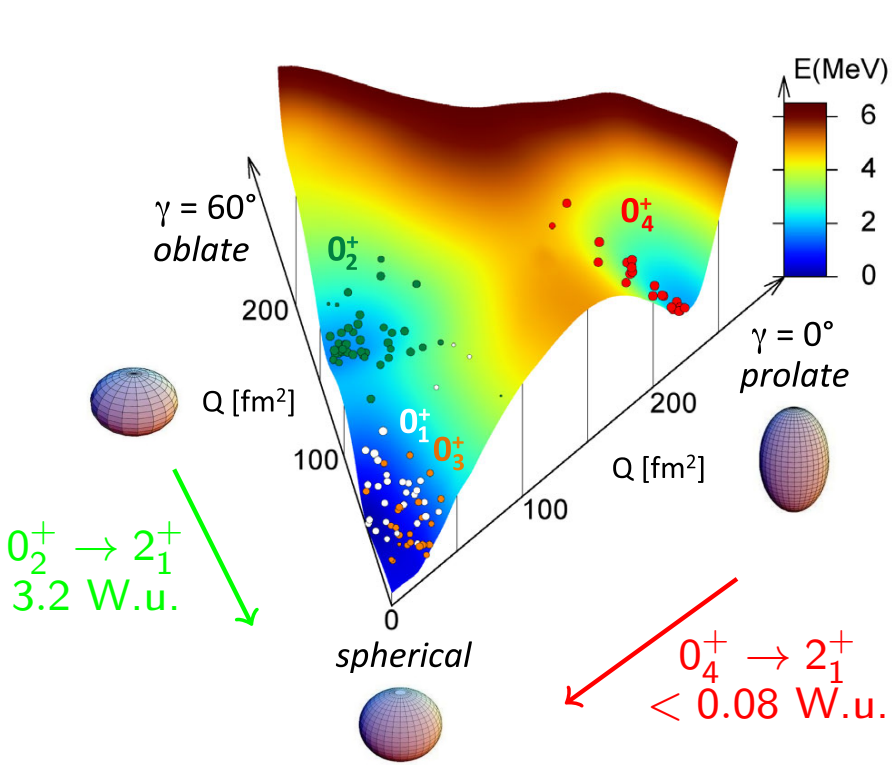


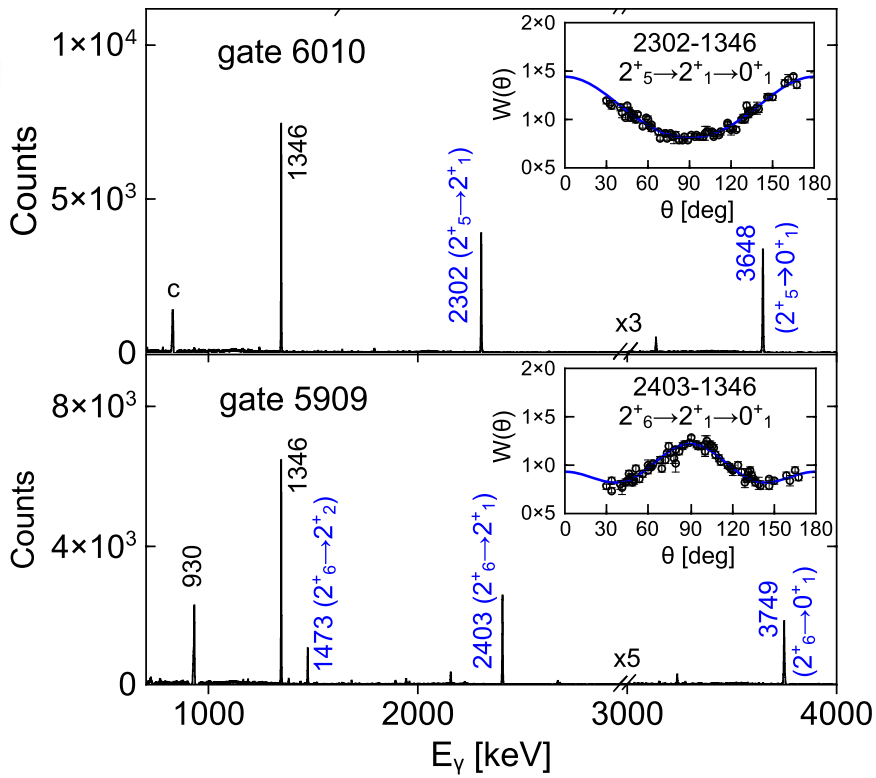






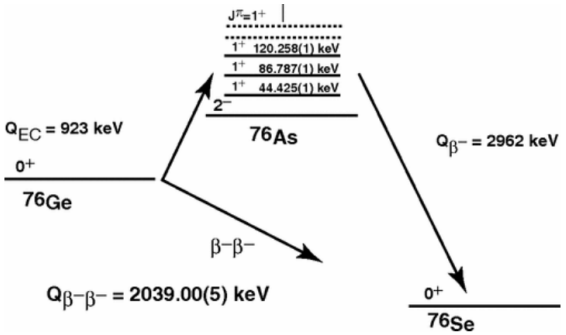
Shape coexistence at zero spin in Ni isotopes



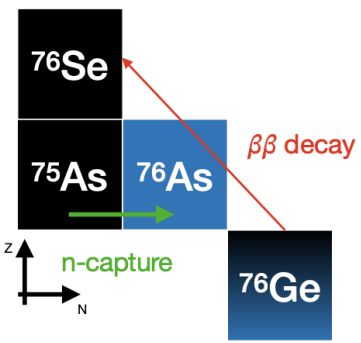


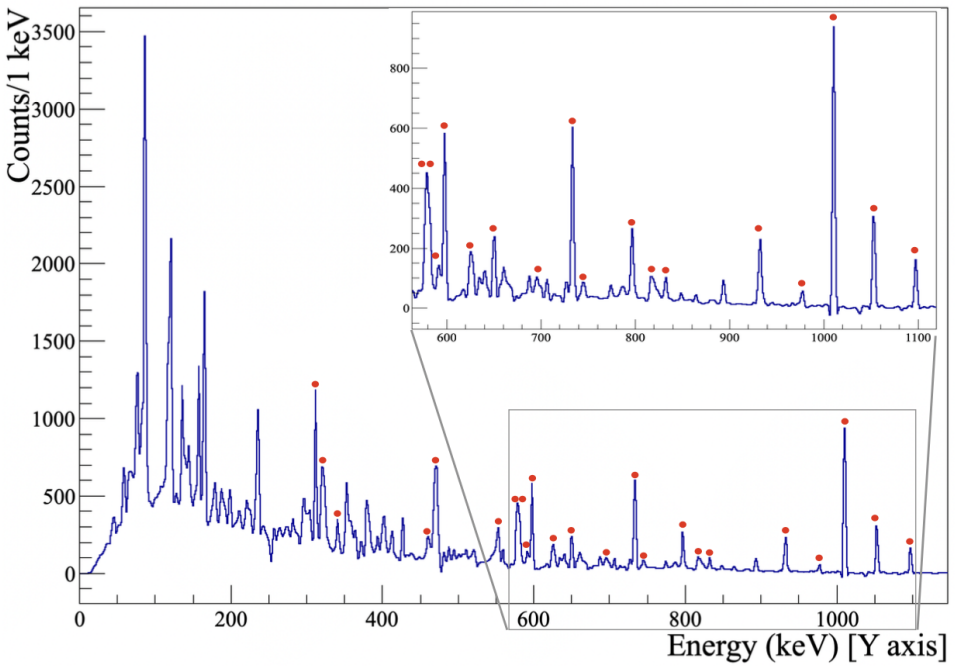
Adapted from N. Marginean at al., Phys. Rev. Lett. 118 (2017) 162502

Nuclear structure input for $\beta\beta$ studies



J. H. Thies et al., Phys. Rev. C 86, 014304 (2012)





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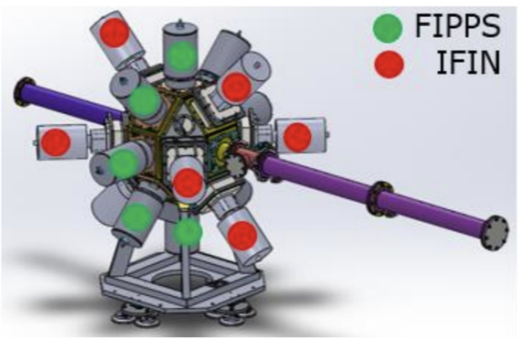
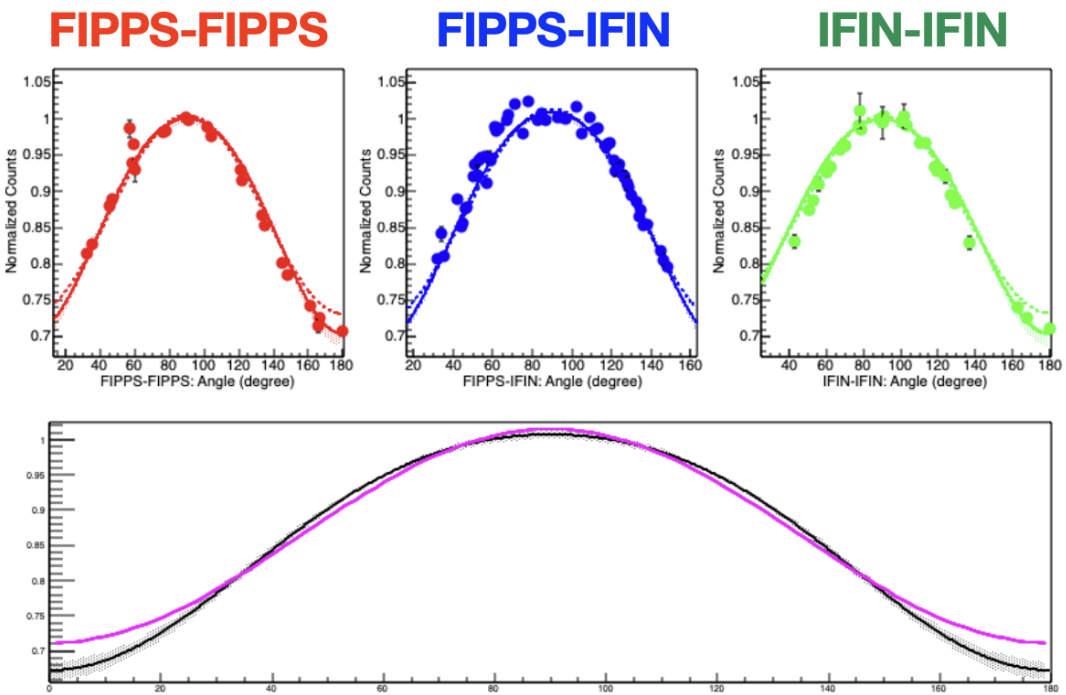
Nuclear structure input for $\beta\beta$ studies





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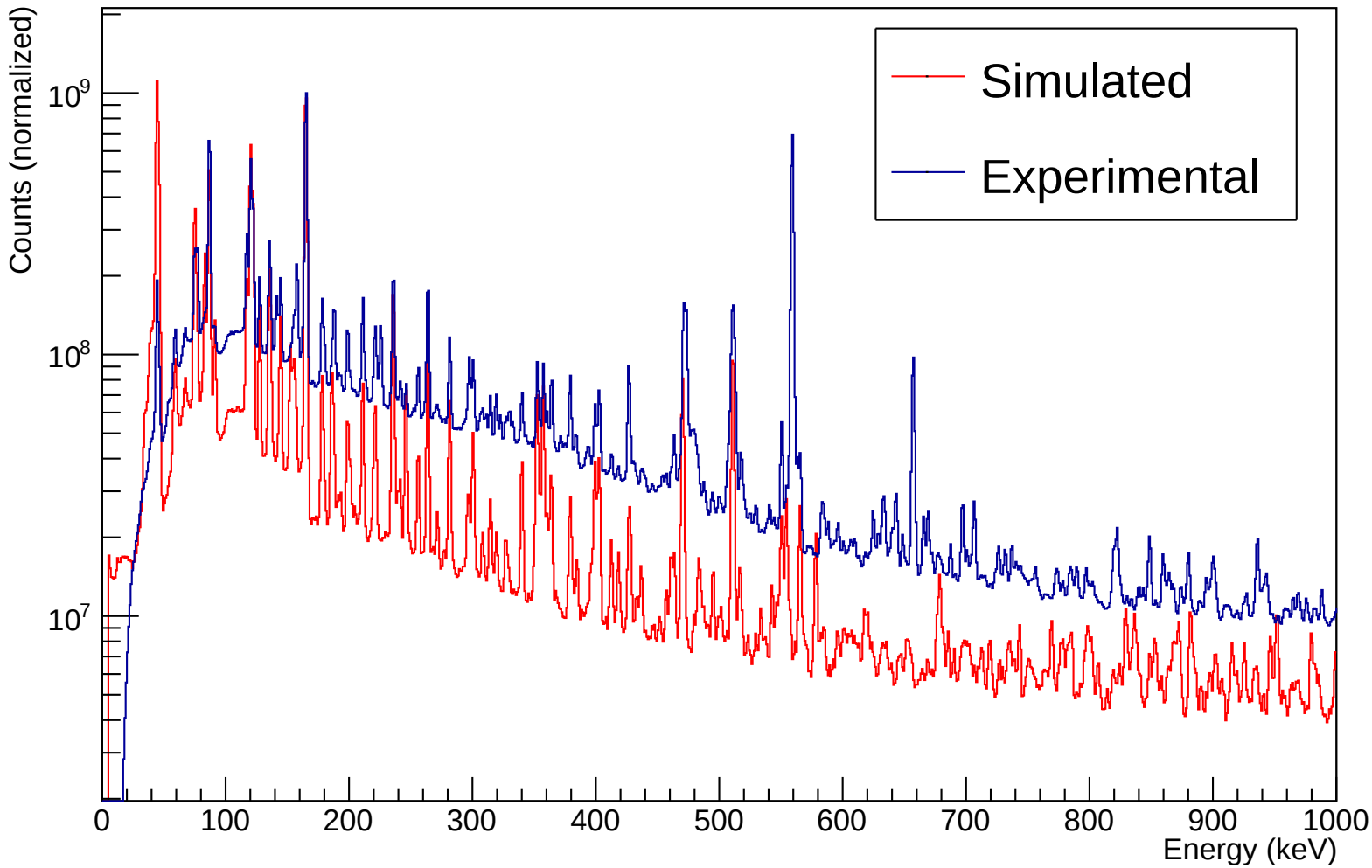
Statistical analysis of ^{75}As(n,γ)^{76}As data

Full Geant4 simulation including DICEBOX input



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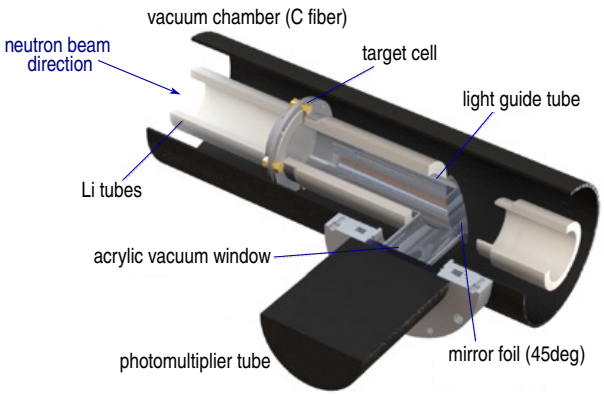
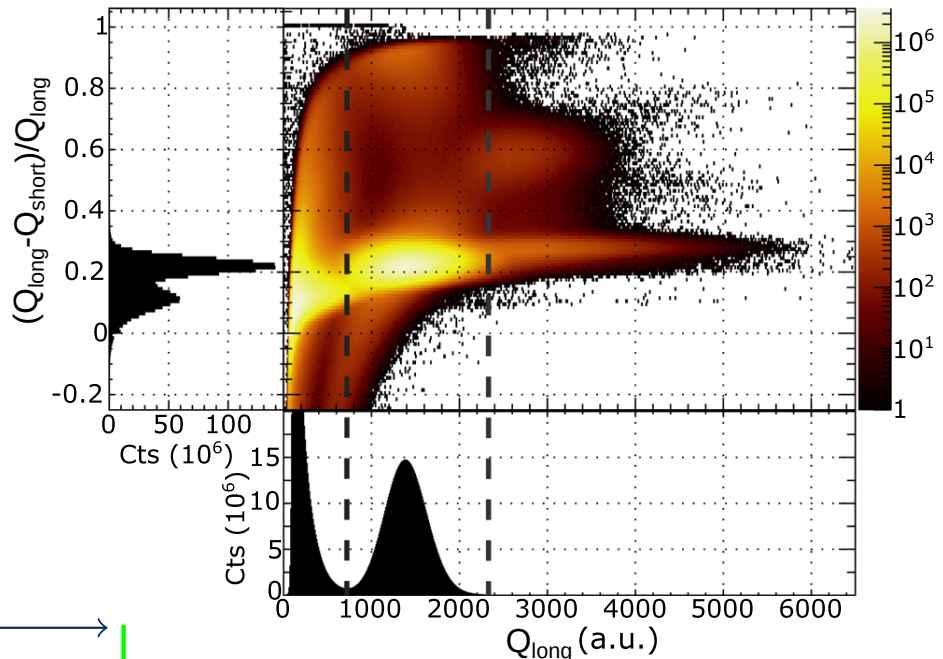
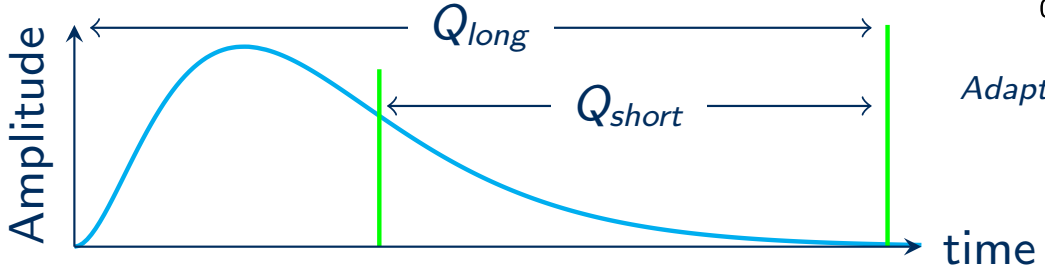
Selection of fission events using an active target

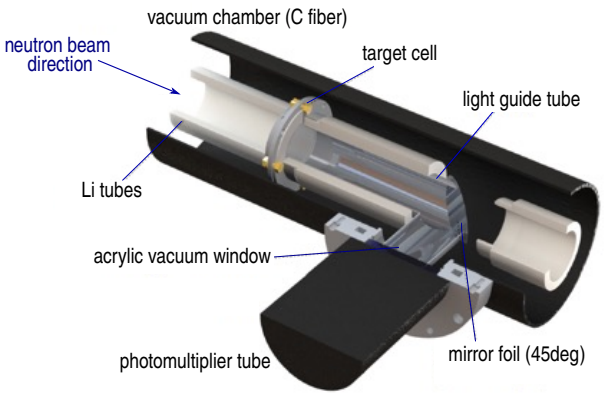


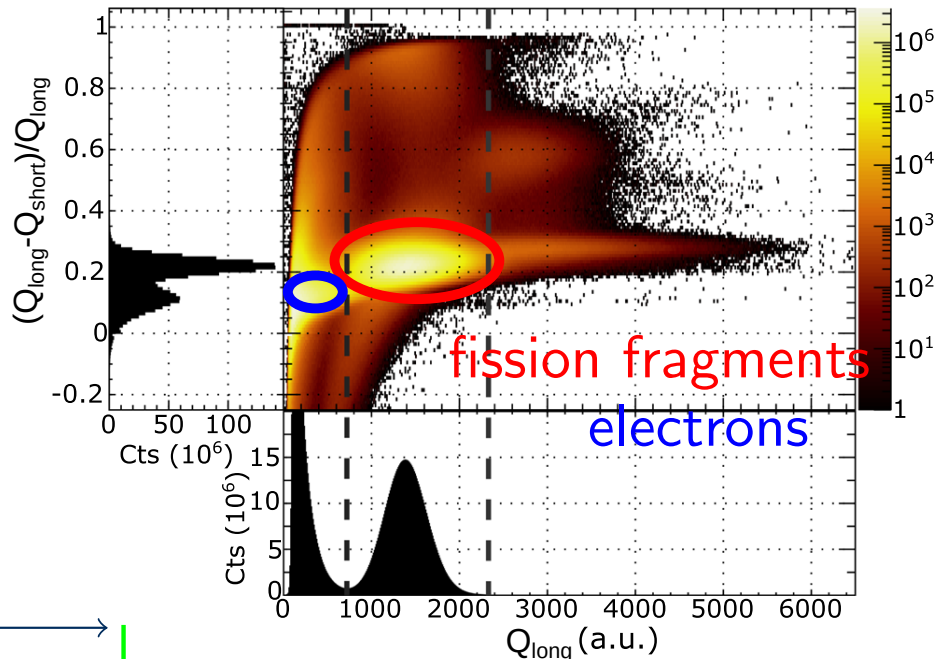




Adapted from F. Kandzia et al., EPJA56(2020)207

Selection of fission events using an active target





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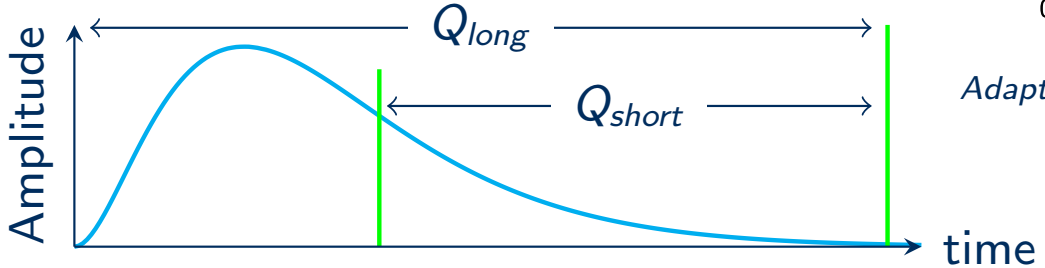
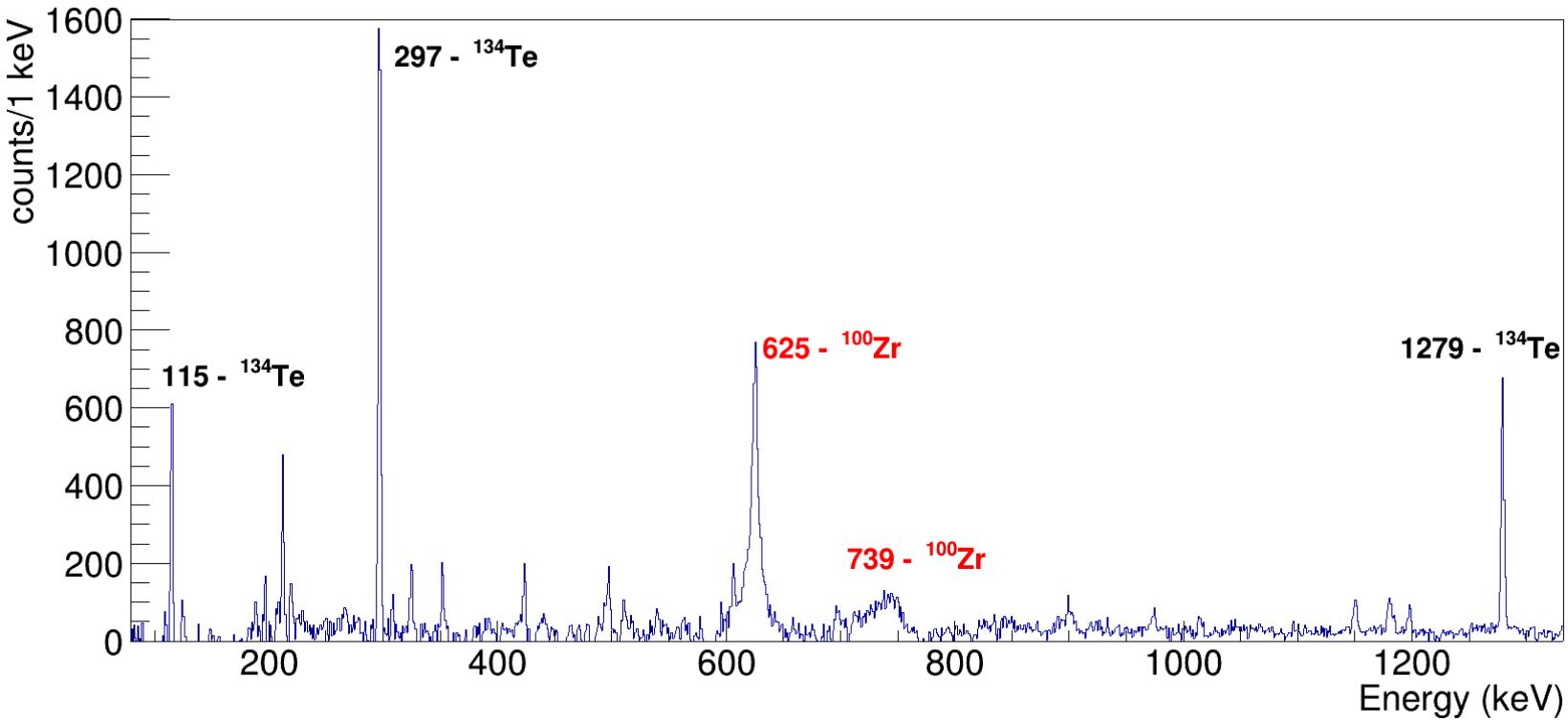
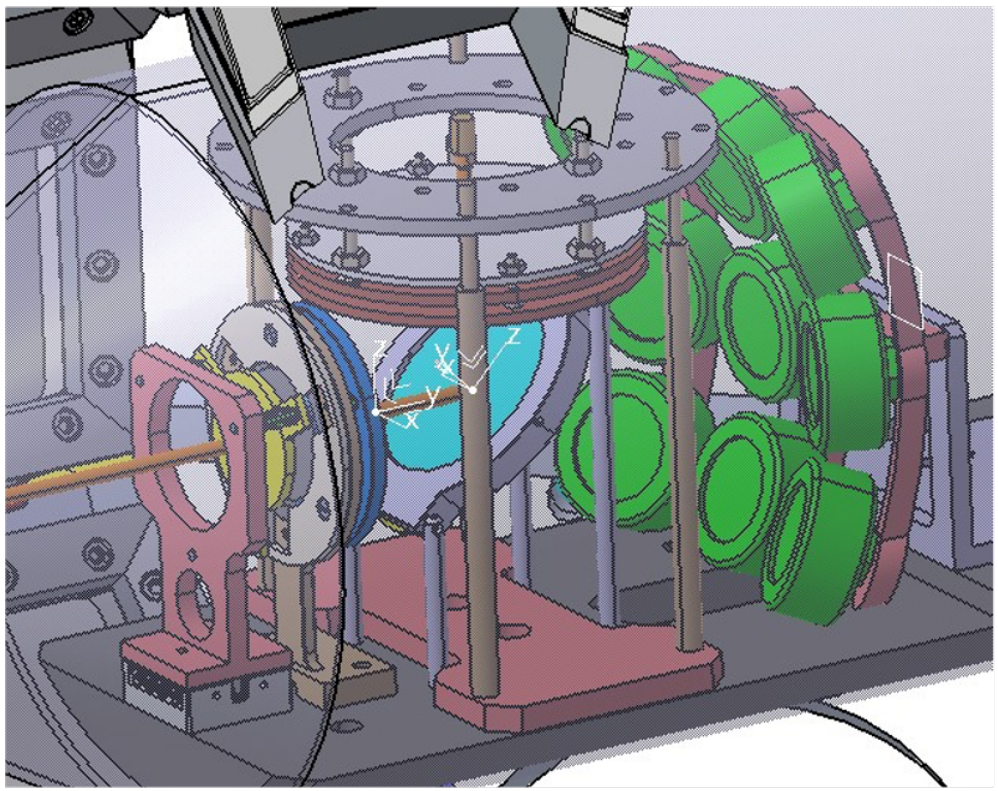


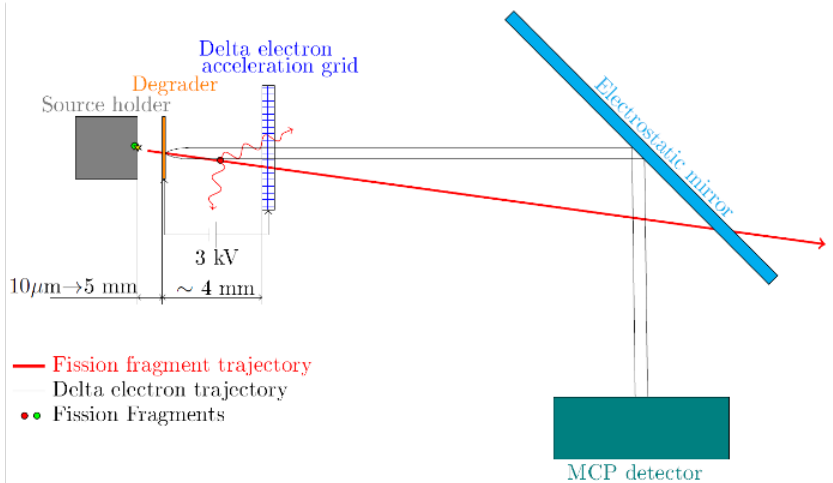
Lifetime determination via *lineshape* analysis

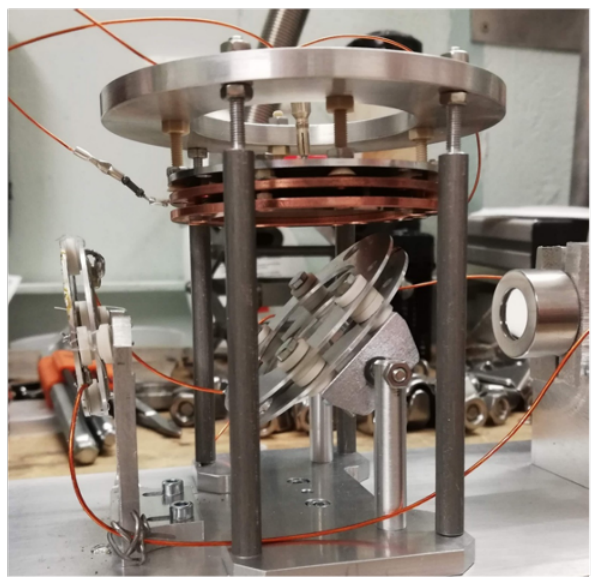


G. Colombi, PhD Thesis, Univ. Grenoble-Alpes, ILL and Univ. Milan, 2023

A *plunger* setup for a neutron beam

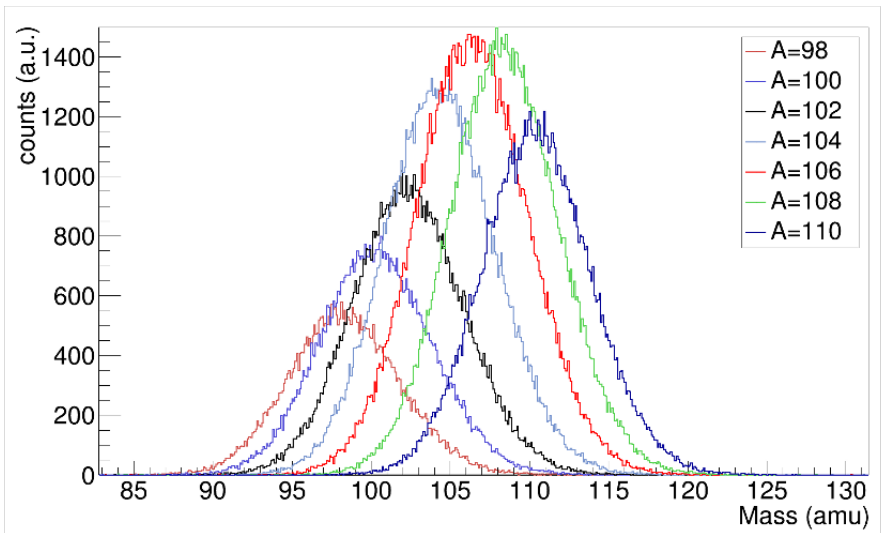


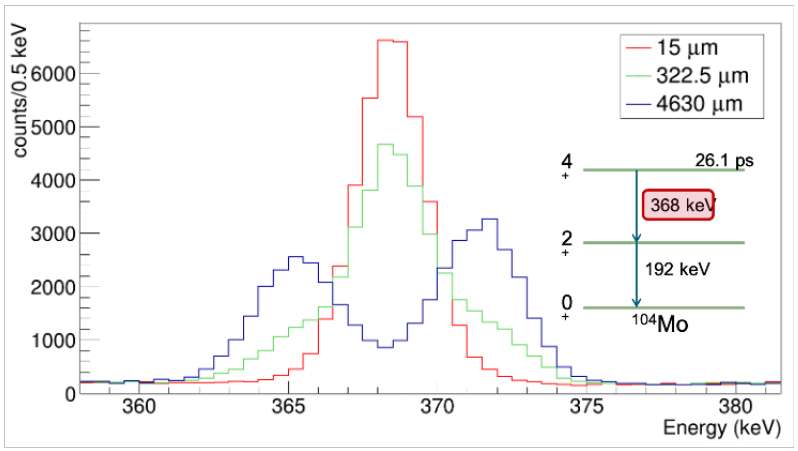




G. Colombi, PhD Thesis, Univ. Grenoble-Alpes, ILL and Univ. Milan, 2023

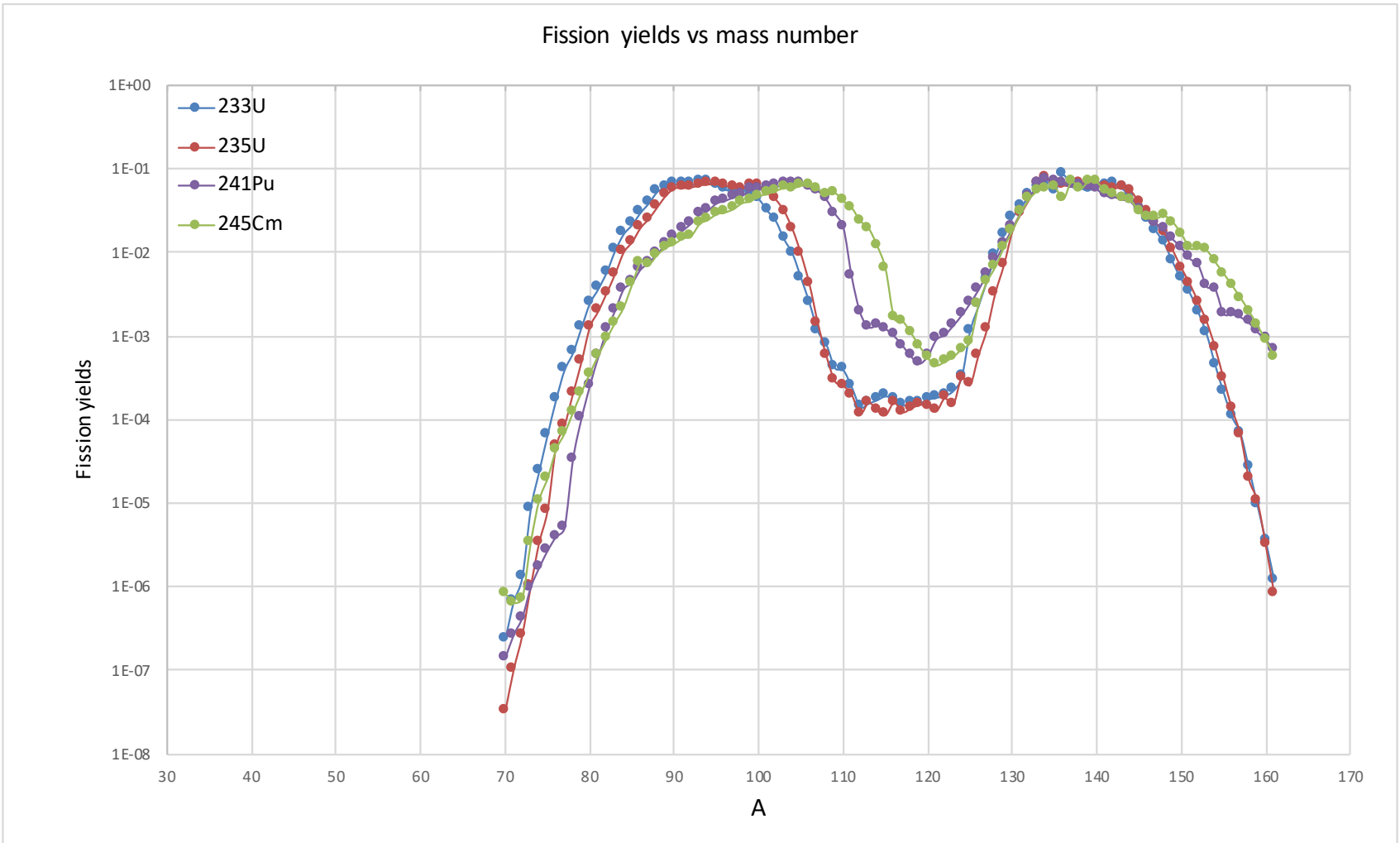
Simulations for the plunger setup at FIPPS



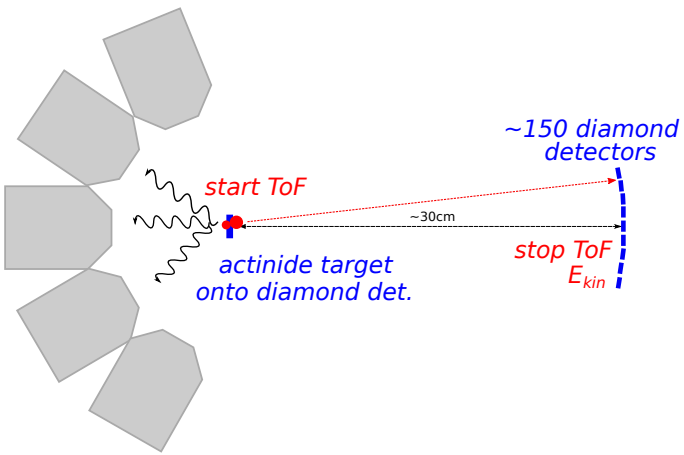


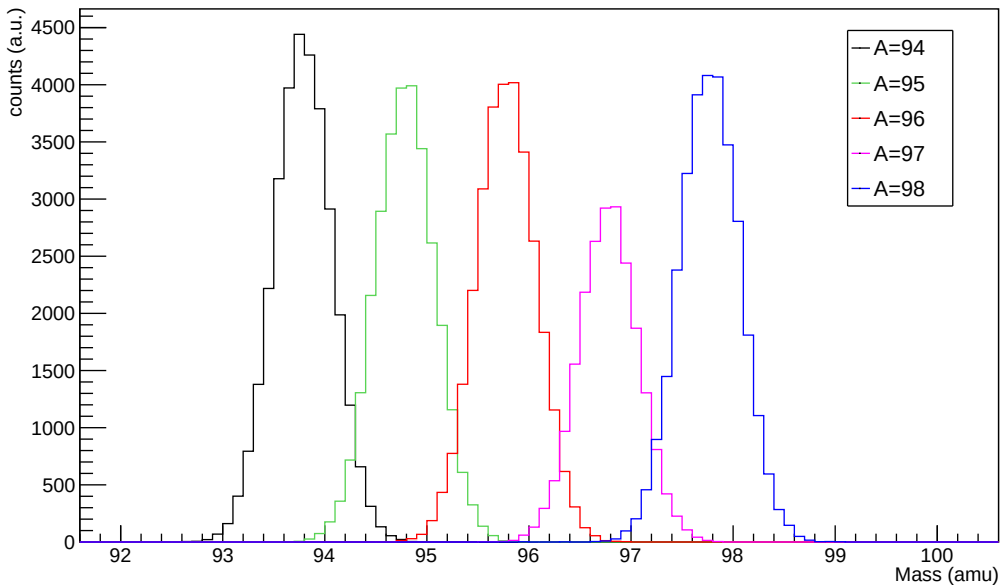
G. Colombi, PhD Thesis, Univ. Grenoble-Alpes, ILL and Univ. Milan, 2023

^{245}Cm fission campaign



Diamond-based FF identification setup





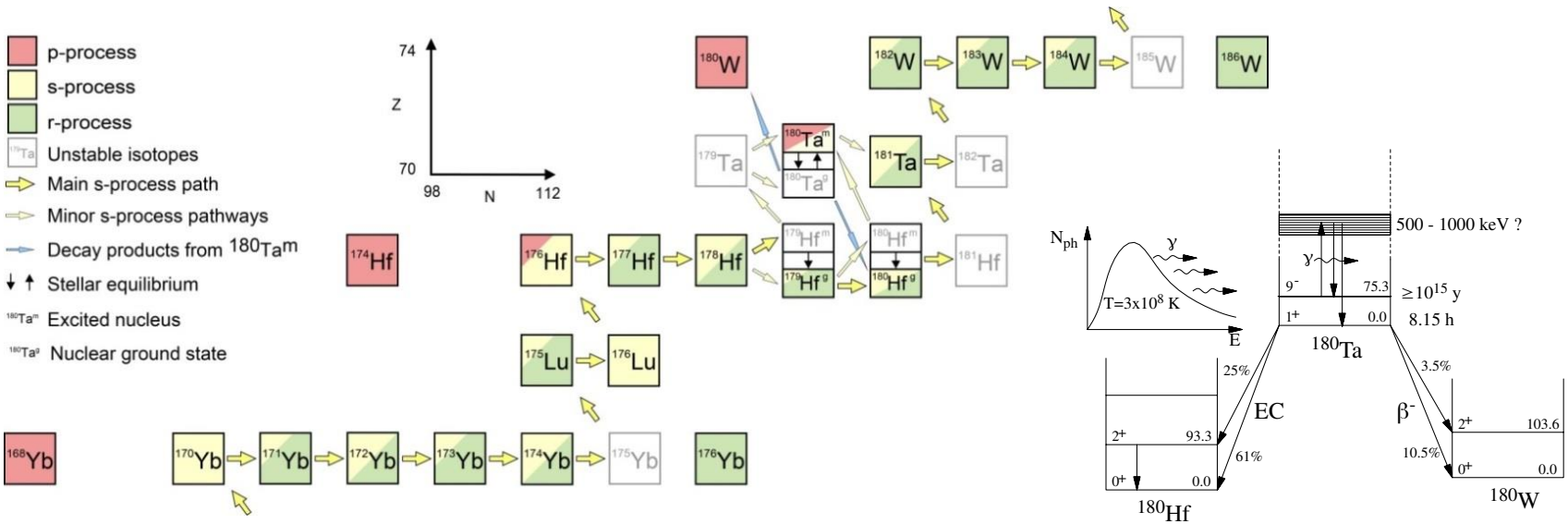
The puzzle of the astrophysical origin of ^{180}Ta

the rarest isotope found in the solar system

0.012% abundance; $J^\pi = 9^-$ isomeric state at 77 keV, $t_{1/2} = 10^{15}$y

Possible s-process scenario:

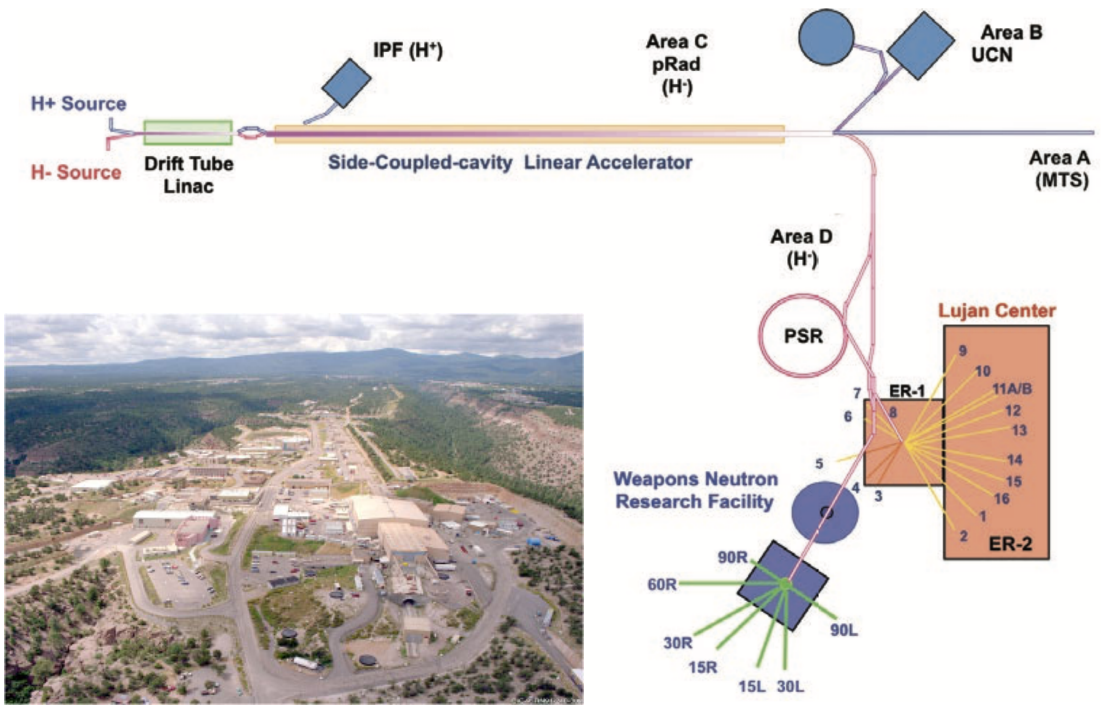
missing information on ^{180}Ta *intermediate states*

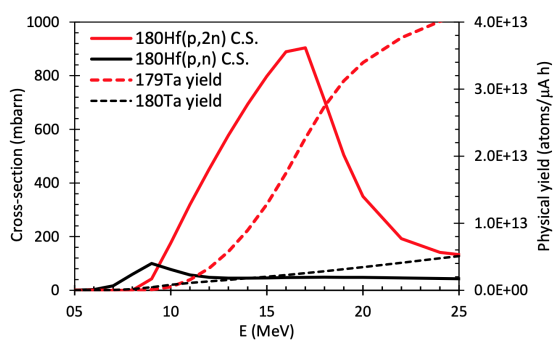


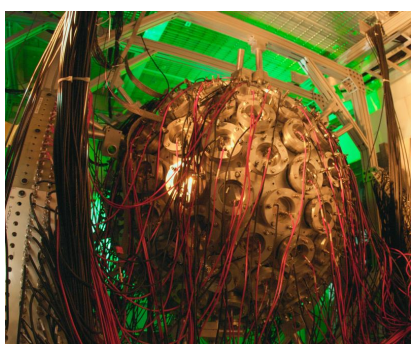
Phys. Rev. Lett. 83 (1999) 5242, Phys. Rev. C 75 (2007) 015804

A *multi-messenger* approach using a ^{179}Ta radioactive target

Production via the ^{180}Hf(p,2n)^{179}Ta reaction + radioch. Hf/Ta sep.
Thermal neutron capture reactions at FIPPS+fast neutron capture reactions at DANCE ⇒ intermediate states
new s-process cross-section measurements at nTOF







Project in collaboration with LANSCE and CERN

Conclusions

- Many activities and projects are going on at ILL to study fission and nuclear structure:
  - (n,γ) reactions (stable and radioactive targets)
  - data available from n-induced fission on ^{233,235}U
  - plunger setup, commissioning soon with Cf source
  - project for a diamond-based fission fragment separator
- Possibility to handle "all targets"
- Next ILL proposal deadline on September 15th

Acknowledgements

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J. Dudouet et al. IP2I Lyon

N. Marginean, C. Mihai, A. Turturica et al., IFIN-HH Bucharest

S. Leoni, S. Bottoni et al., University and INFN Milan

O. Serot, A. Chebboubi et al., CEA Cadarache

B. Fornal, N. Cieplicka et al., PAN Krakow

J.M. Regis, L. Knafla et al., IKP Cologne

H.Y. Lee, A.J. Couture, LANL

and many many other collaborators!!!

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