Results from particle-induced fission yield measurements at IGISOL-4

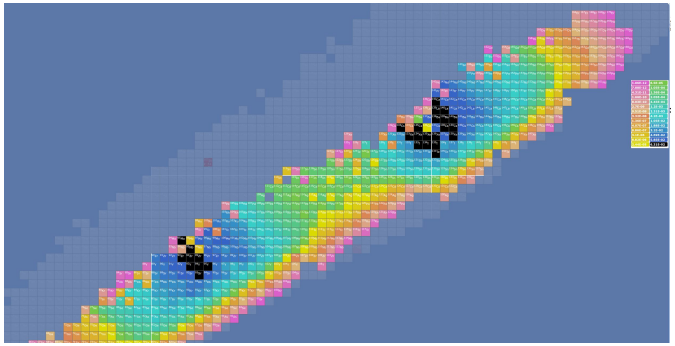
A. Mattera, V. Rakopoulos, S. Pomp,
M. Lantz, A. Solders, A. Al-Adili, K. Jansson
& the IGISOL group

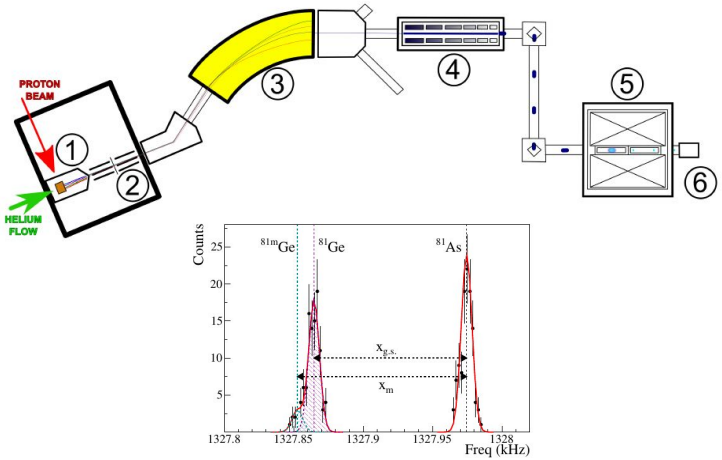
UPPSALA
UNIVERSITET

Outline

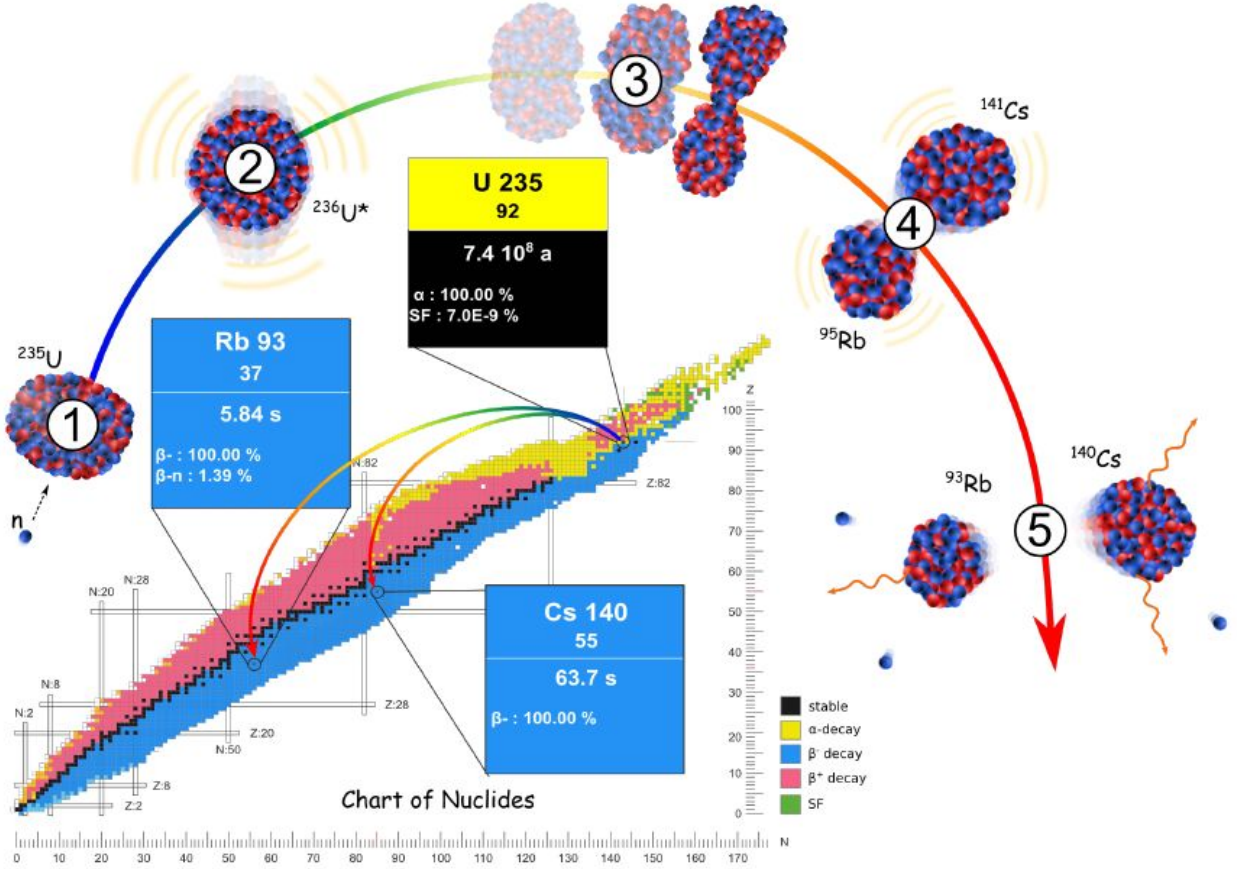
UPPSALA UNIVERSITET

- Motivation
- Fission studies at IGISOL-4
- p-induced isomeric yields
- n-induced isotopic yields
- Conclusions & Outlook





Fission Yields: what?



Fission Yields: probability of producing a certain nuclide in a fission event.

Independent (after fission) or **Cumulative** (after fission & decay).

FYs depend on the Compound Nucleus and the available energy.

Fission Yields: why?

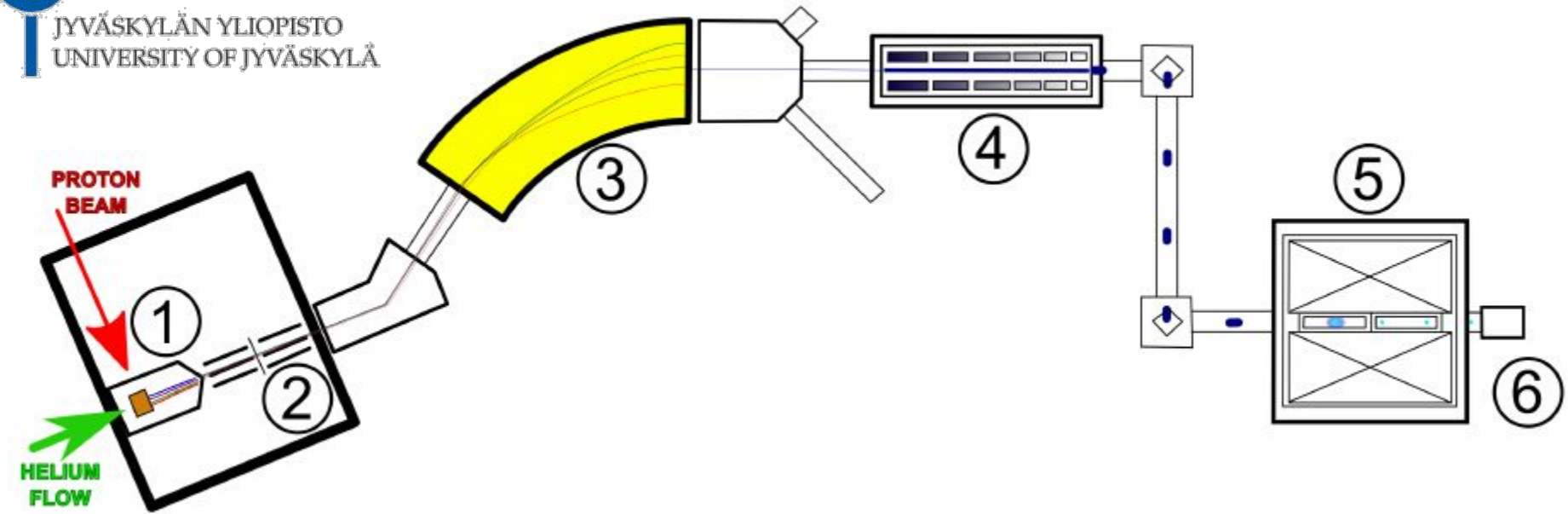
UPPSALA UNIVERSITET

- For **Light Water Reactors:** reduce uncertainty on current data
  - re-measure well-known fissioning systems to reduce uncertainties (especially in the low-yield regions)
- Towards **Gen-IV**
  - transmutation: measure FY from fission of minor actinides
  - fast reactors/ADS: measure FY at higher n-energies (energy dependence)
- **Fundamental Research**
  - nuclear astrophysics (nucleosynthesis)
  - provide benchmarks for model development
  - help understanding the fission process (energy dependence of FY, Isomeric Yield Ratios)

Fission studies at IGISOL-4

UPPSALA UNIVERSITET

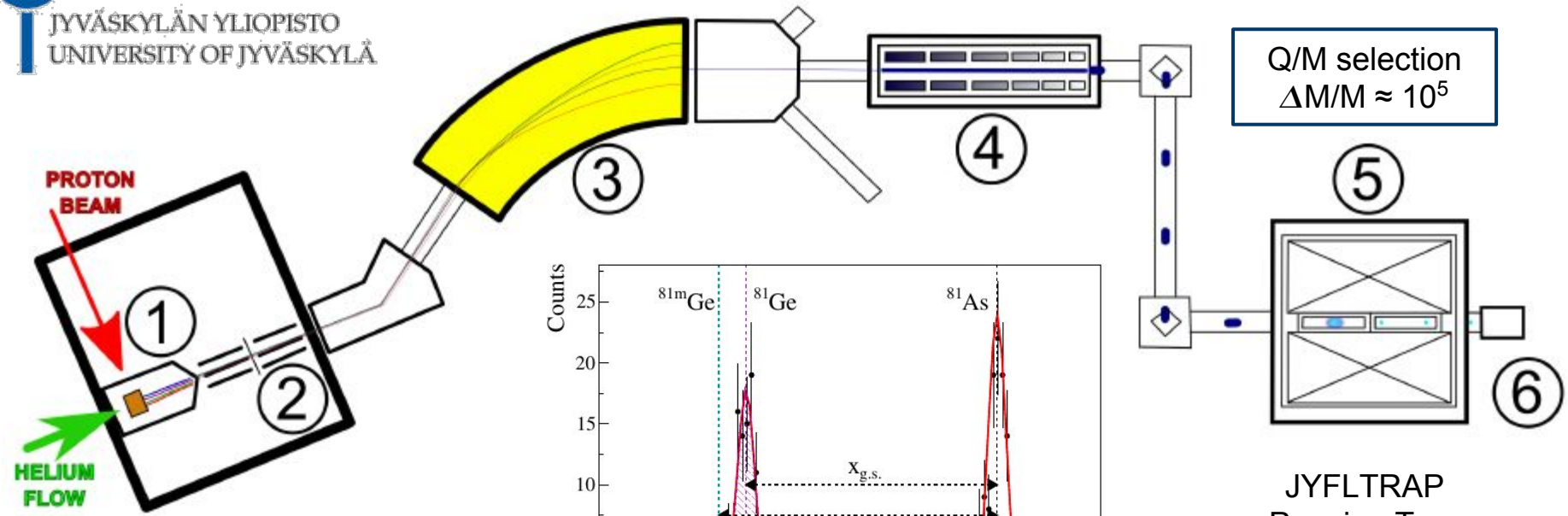
JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ



Fission studies at IGISOL-4

UPPSALA UNIVERSITET

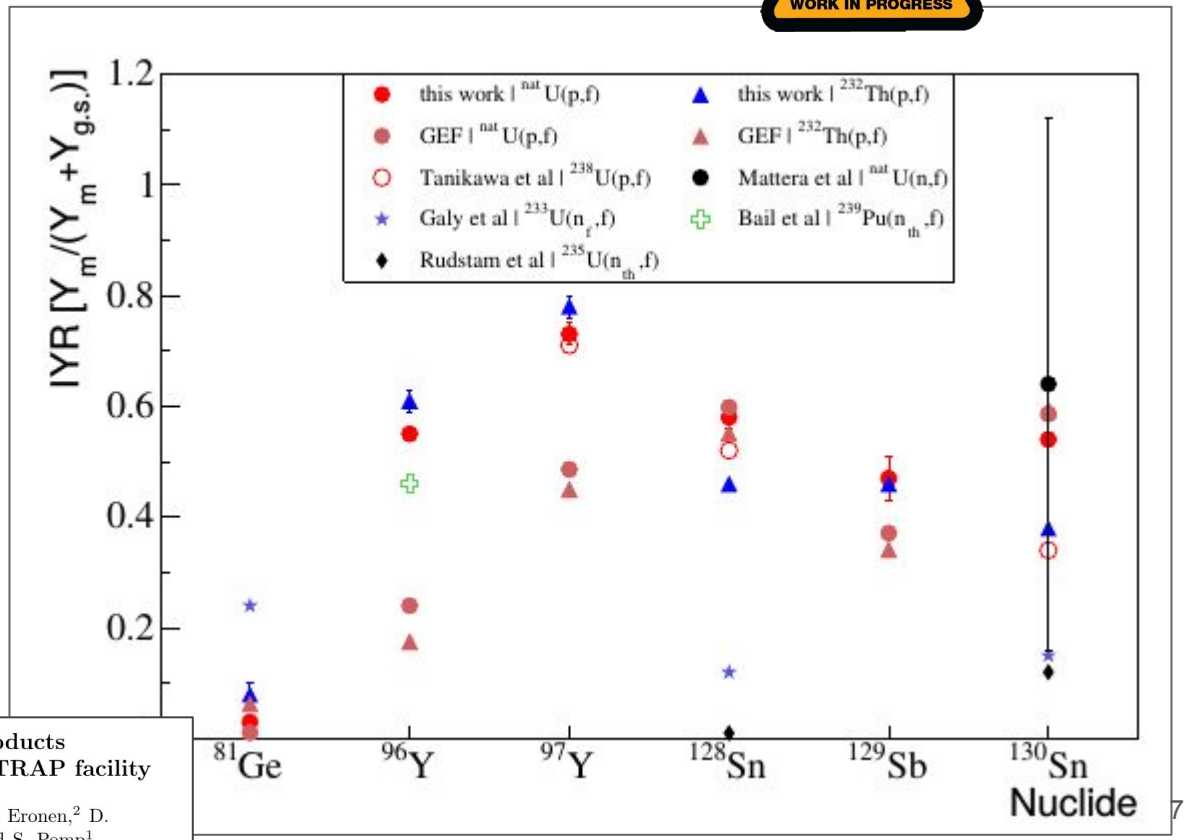
JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ



Isomeric yields: Results

UPPSALA UNIVERSITET

- Isomeric Yield Ratios extracted for 6 fission products and 2 fissioning systems (^{232}Th(p,f) and ^{nat}U(p,f)).
- There are some indications of **dependence of the IYR on the fissioning system**.
- Work in progress… Paper in preparation

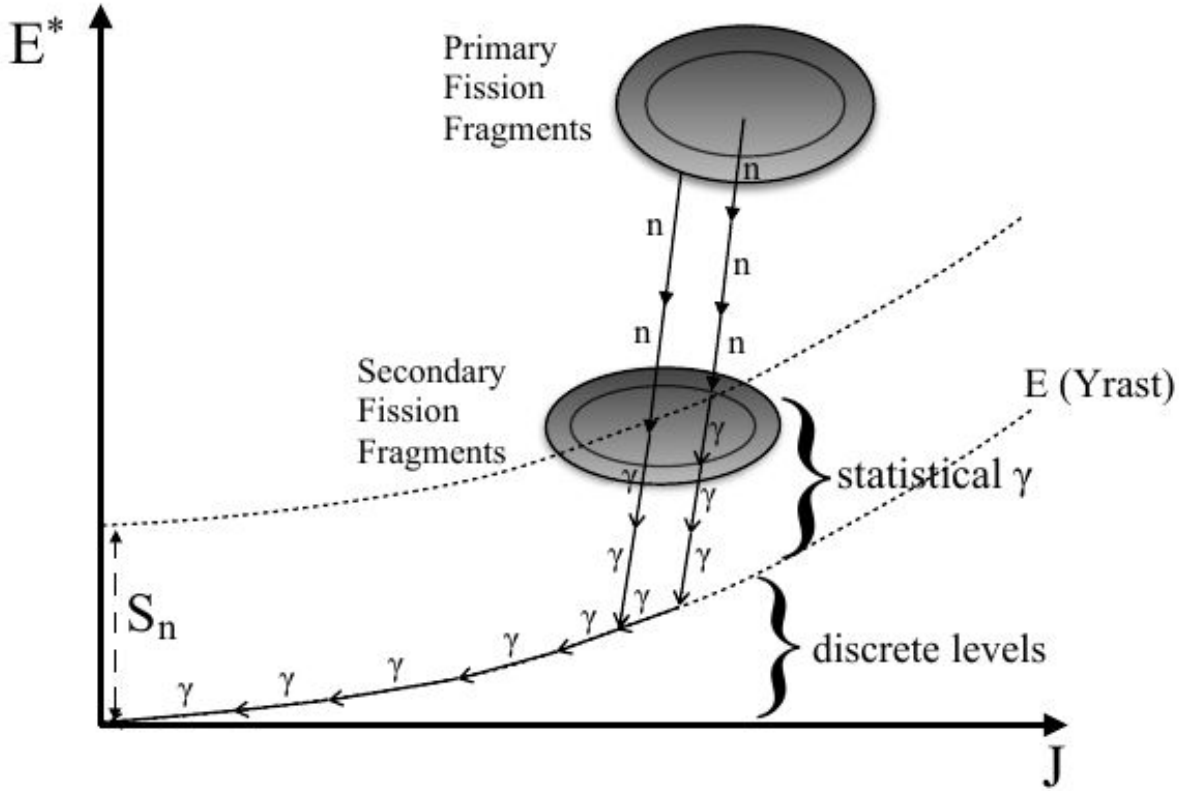


Determination of isomeric yield ratios of fission products from proton induced fission of ^{nat}U and ^{232}Th at the JYFLTRAP facility

V. Rakopoulos,[1] M. Lantz,[1,*] A. Al-Adili,[1] A. Mattera,[1] A. Solders,[1] T. Eronen,[2] D. Gorelov,[2] A. Jokinen,[2] I.D. Moore,[2] H. Penttilä,[2] S. Rinta-Antila,[2] and S. Pomp[1]

Extraction of J_{rms} of the Fragments from IYR

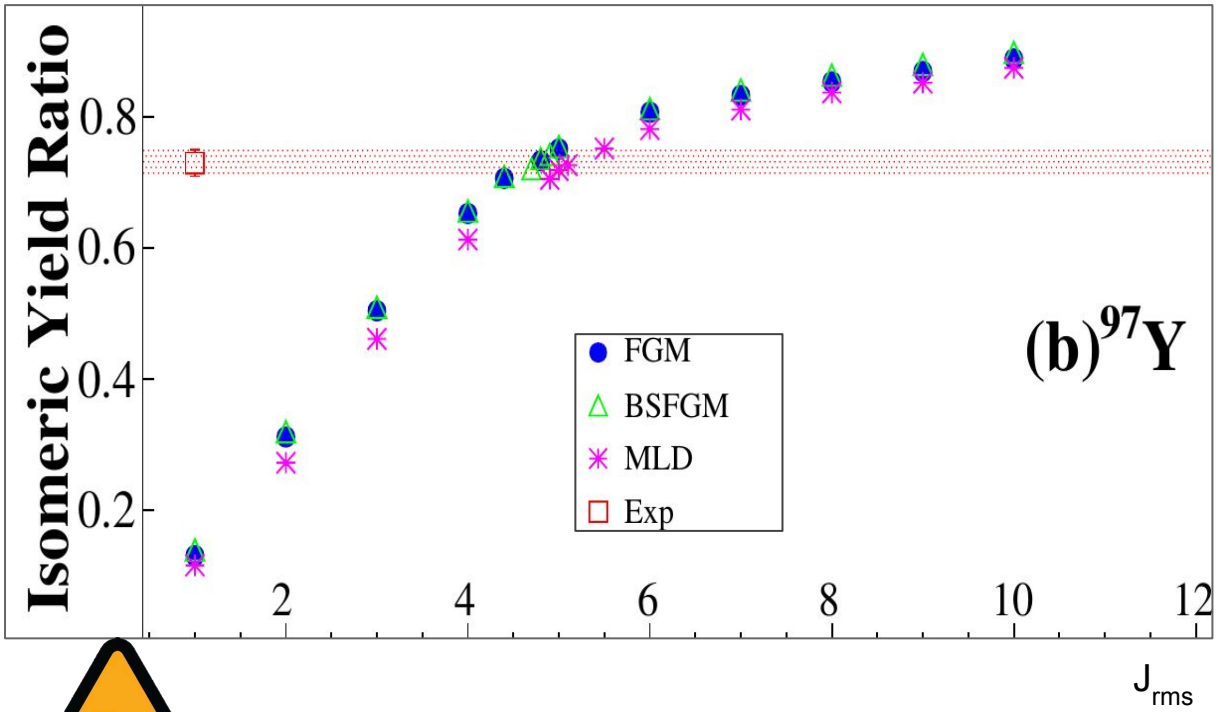
UPPSALA UNIVERSITET



- Isomeric Yield Ratios can be used to gain information on the angular momentum of the primary fragments
- Difficult to get spin distributions, but we can obtain information on the average spin
- Different methods and several approximations: in our work we try an approach based on the TALYS reaction

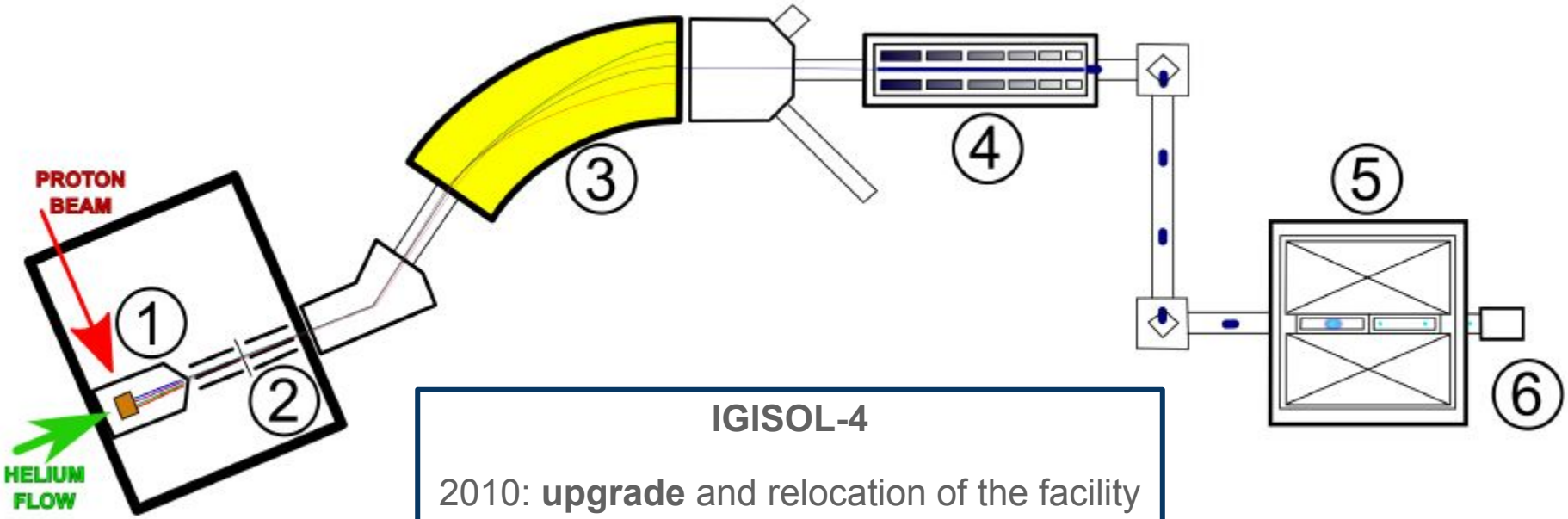
Extraction of J_{rms} of the Fragments from IYR

UPPSALA UNIVERSITET



- Perform TALYS calculations for different initial fragments, each with a different J_{rms}
- Extract IYR from TALYS and compare to experiments
- Some Isomers and FPs are produced in different paths (decay / neutron emission)

Fission studies at IGISOL-4



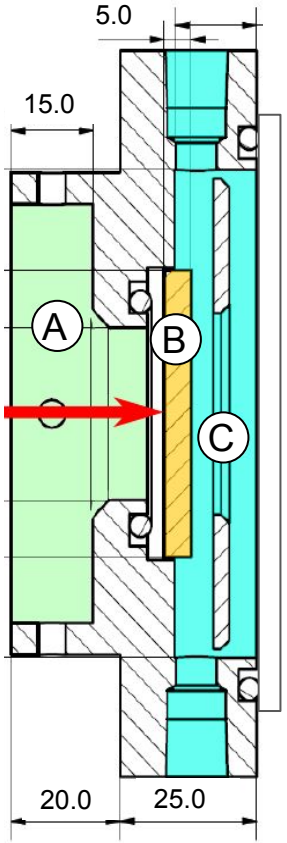
IGISOL-4

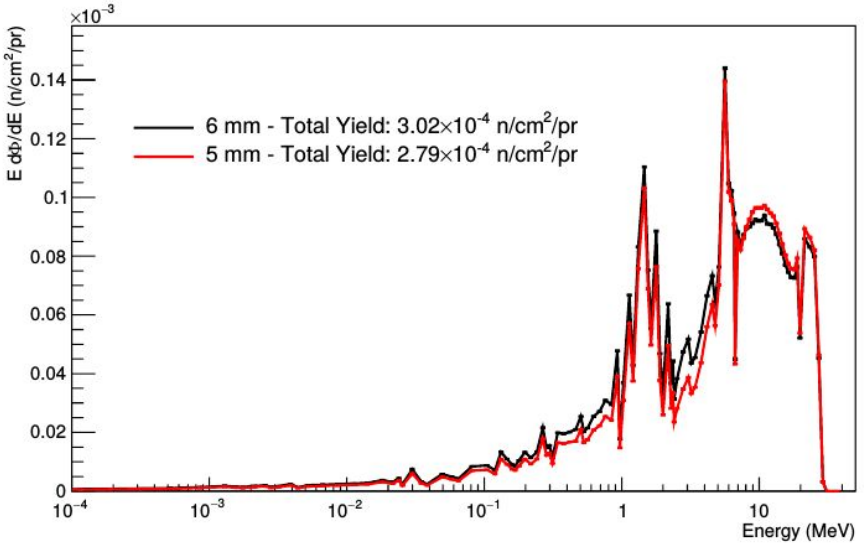
2010: **upgrade** and relocation of the facility & installation of a high-current MCC30/15 cyclotron → **proton-neutron conversion** and study of **n-induced fission**

Installation and characterisation of a n-source

UPPSALA UNIVERSITET

- A Vacuum to cyclotron
- B Be converter
- C Cooling Water

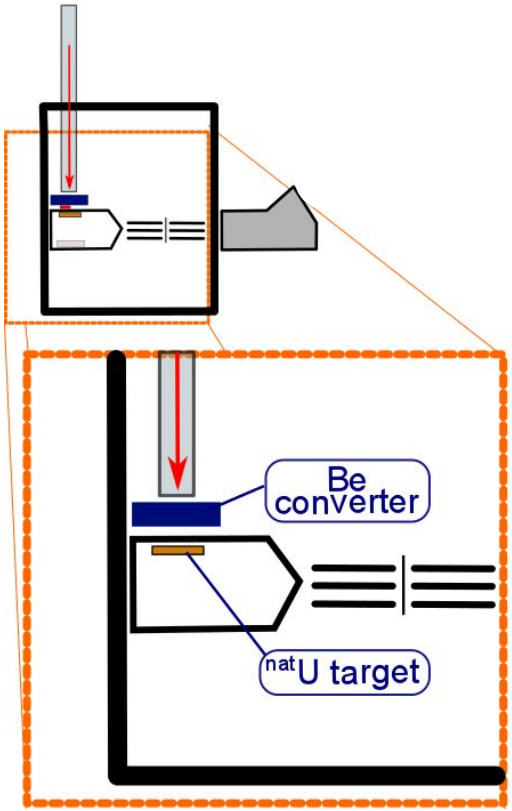




MCNPX is able to reproduce the energy shape in a satisfactory way

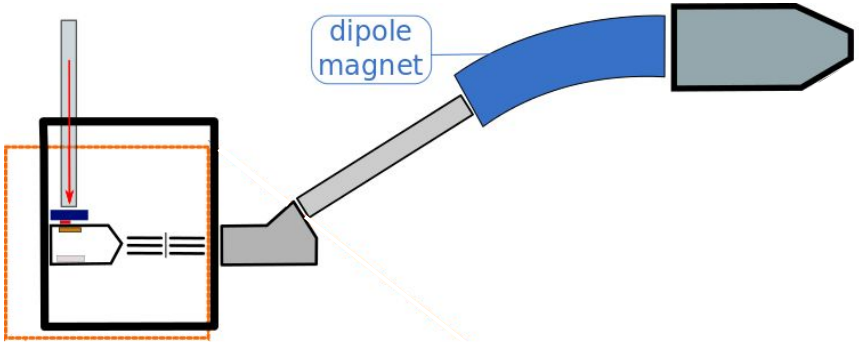
n-IGISOL 2016

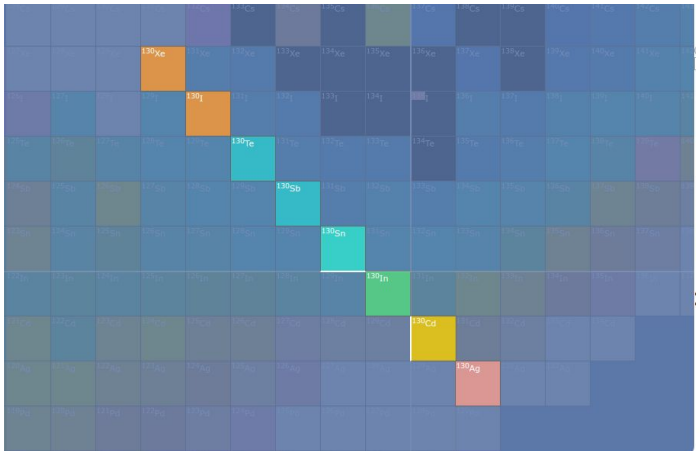
UPPSALA UNIVERSITET



n-IGISOL 2016

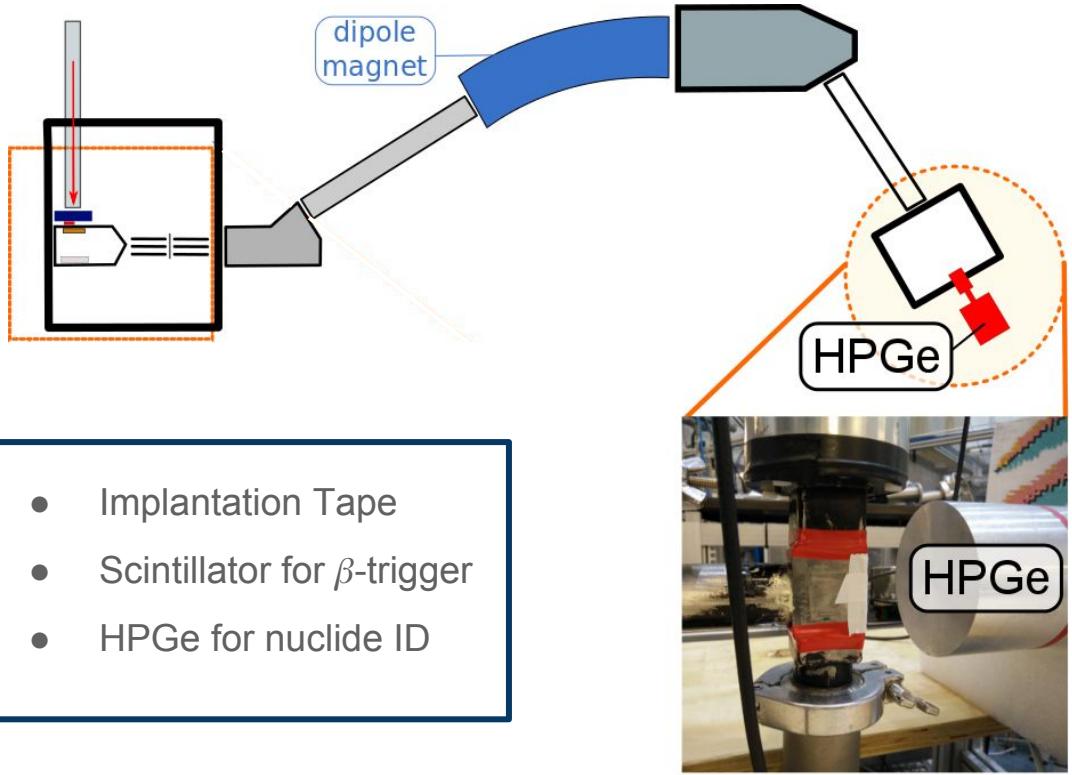
UPPSALA UNIVERSITET



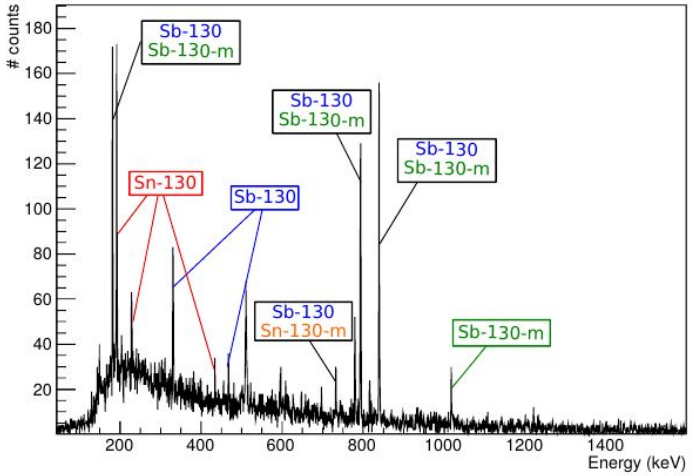


n-IGISOL 2016

UPPSALA UNIVERSITET



- Implantation Tape
- Scintillator for β-trigger
- HPGe for nuclide ID



- E_{avg}(neutrons) = 12.4 MeV
- First-chance fission amounts to 55%

First n-induced yields at IGISOL-4

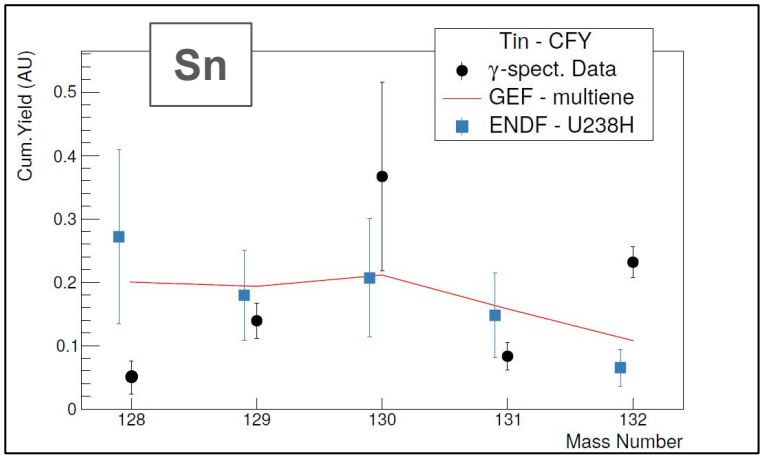
UPPSALA UNIVERSITET

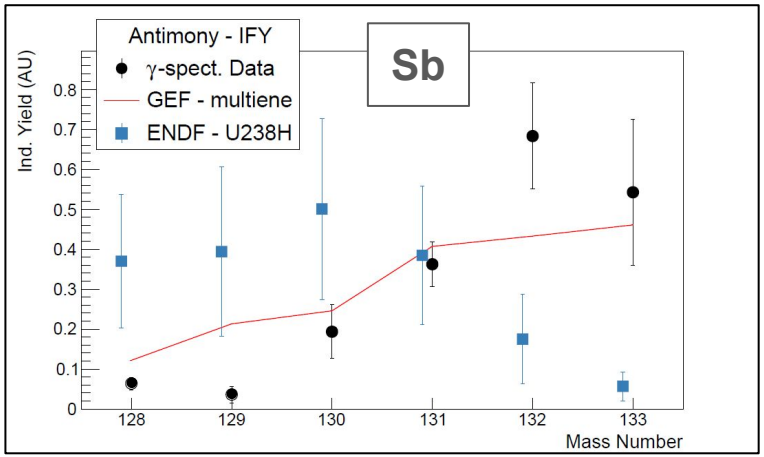
Cumulative Fission Yields

- Difference when compared with Evaluated Data (14 MeV n) and a GEF calculation with a realistic neutron spectrum

Independent Fission Yields

- Shifted mass-peak *vs* ENDF/B-VII.1
- GEF reproduces better the overall behaviour





Open Questions

UPPSALA UNIVERSITET

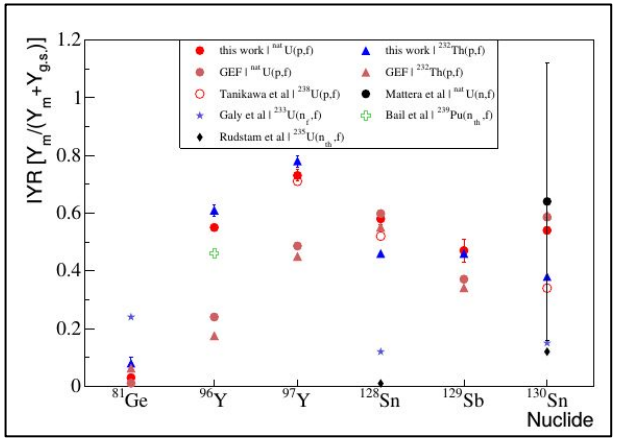
- Efficiency of IGISOL (!!!)
  - Z-dependent recombination effects in the ion guide
  - Extraction/Selection in SPIG+Dipole Magnet
  - simulations using GEF+GEANT4 to study mass/charge dependency
  - measurement with ^{252}Cf
- Analysis of Penning trap data:
  - check reproducibility
  - peaks fitting procedure (especially for overlapping peaks)
  - estimate uncertainties and background effects
- Neutron Source / Cyclotron

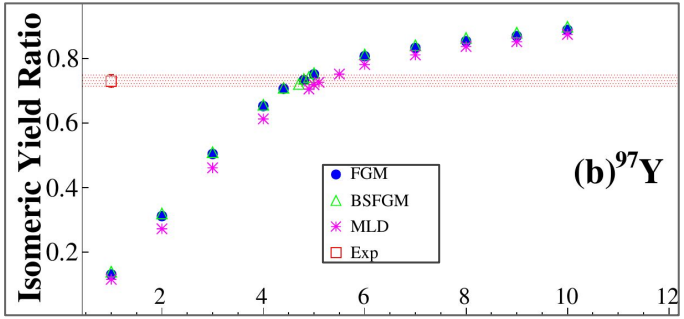
Conclusion & Outlook (1/3)

UPPSALA UNIVERSITET

Isomeric Yield Measurements with JYFLTRAP

- First **measurement for numerous isomeric yield pairs** (^{81}Ge, ^{96}Y, ^{129}Sb from ^{239}Np* and ^{233}Pa*)
- **Measurements with JYFLTRAP**, based on direct ion counting
- The $\mathbf{J_{rms}}$ was **extracted using** the **TALYS** reaction code based on the measured IYR
- New campaign planned for January 2018



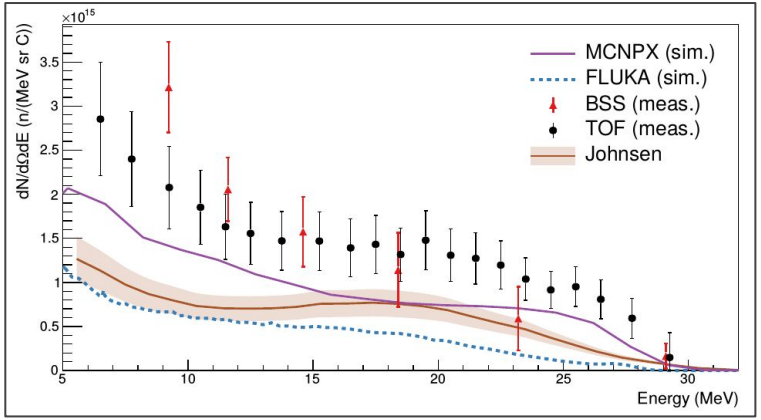


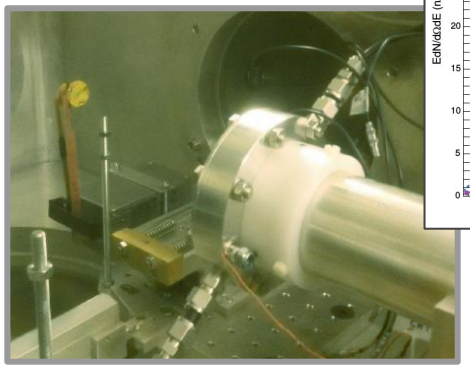
Conclusion & Outlook (2/3)

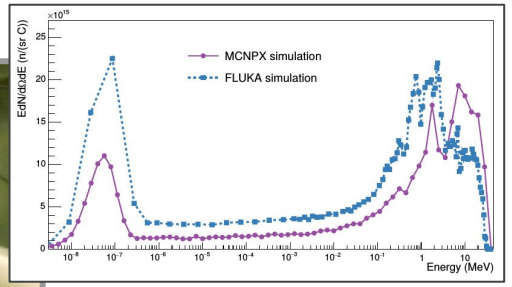
UPPSALA UNIVERSITET

A neutron source for IGISOL-JYFLTRAP

- Characterization measurements confirmed that **MCNPX describes the energy spectrum sufficiently well**
- The **total yield satisfies the requirements** for studies of fission at IGISOL
- More work is needed to **estimate the thermal component** and for a better **on-line beam monitoring** n-induced fission runs





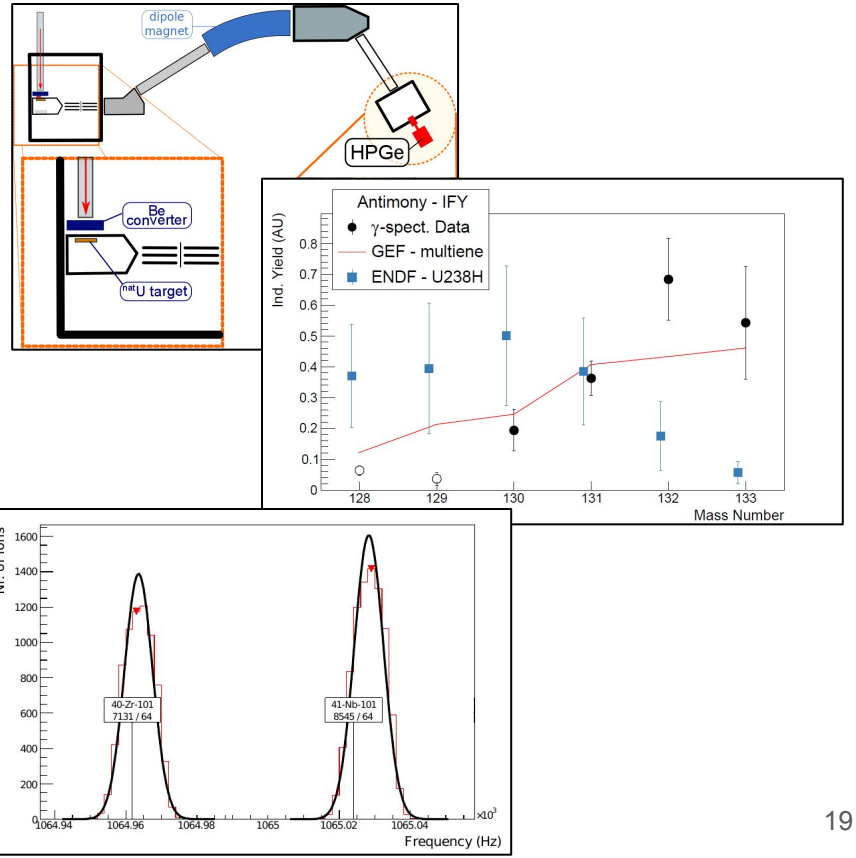


Conclusion & Outlook (3/3)

UPPSALA UNIVERSITET

Fission Yield measurements at IGISOL-4

- First successful **measurement of neutron-induced fission yields** at IGISOL-4
- Features observed for **CFY of Sn and IFY of Sb do not reproduce evaluated data** files for fission induced by fast neutrons.
- **Measurements with JYFLTRAP**, based on direct ion counting, will reduce both these uncertainties



Results from particle-induced fission yield measurements at IGISOL-4

Thank you!

UPPSALA
UNIVERSITET