Experimental insights into neutron - induced fission of ^{235}U and ^{237}Np using the FALSTAFF spectrometer at NFS

Overview :

- ➔ FALSTAFF: Detection principles, and experimental setup
- ➔ Experiments and analysis
- ➔ Falstaff@NFS : Results
- ➔ Future plans: Running the first two-arm experiment

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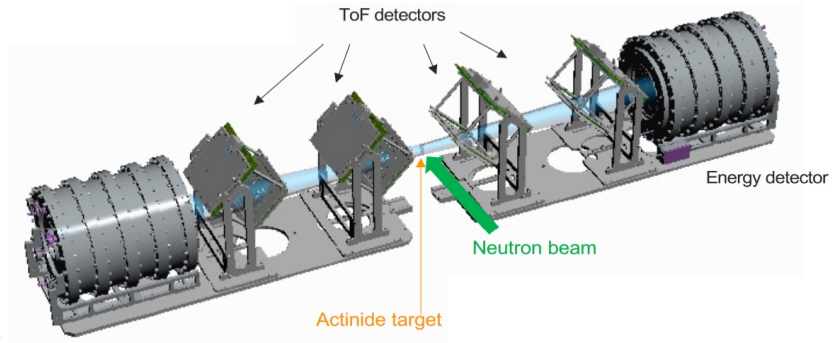
- Coincident detection of fission fragments as a function of incident neutron energy.



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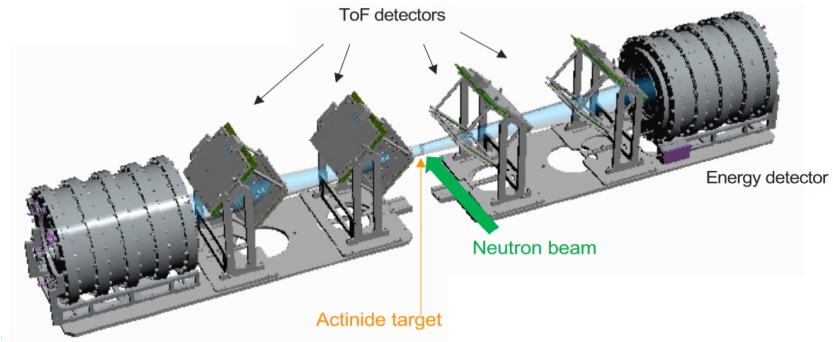
  ⇒ **2V method** to access velocity vectors of both FF ⇒ **M(pre)**



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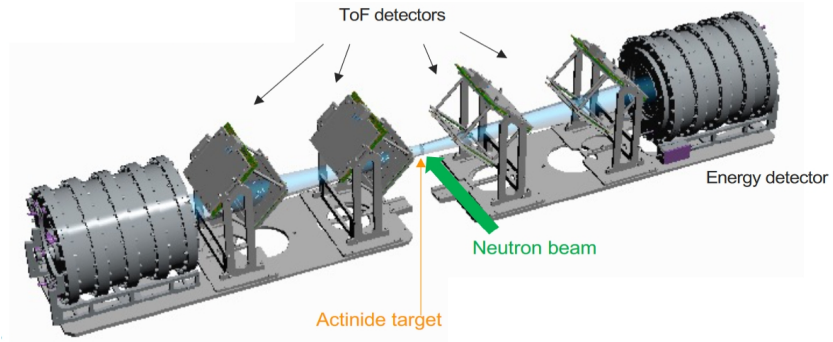

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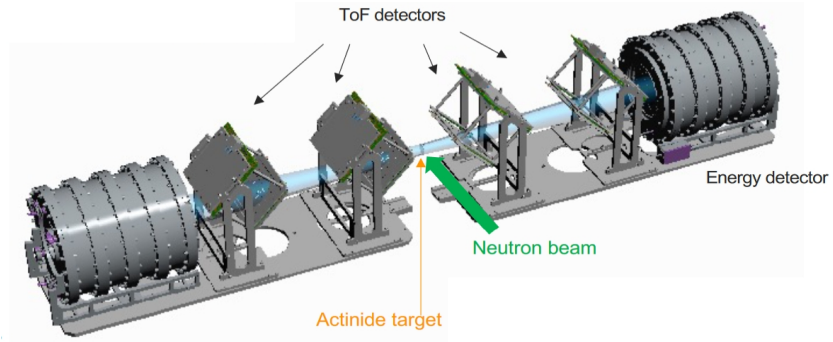

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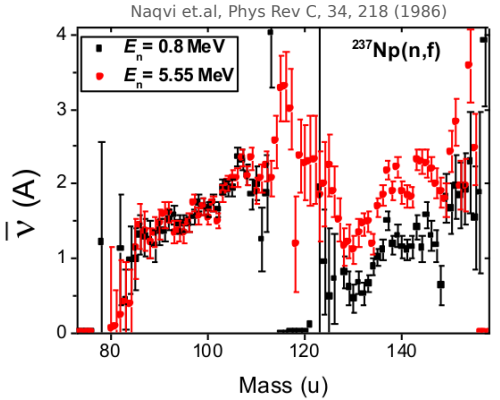

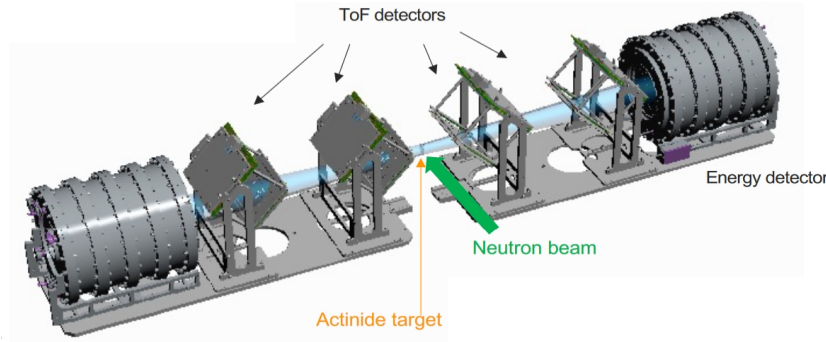

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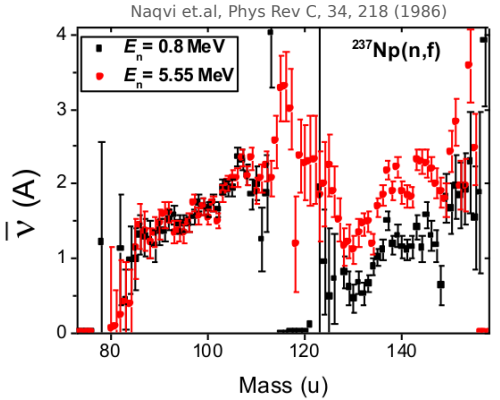
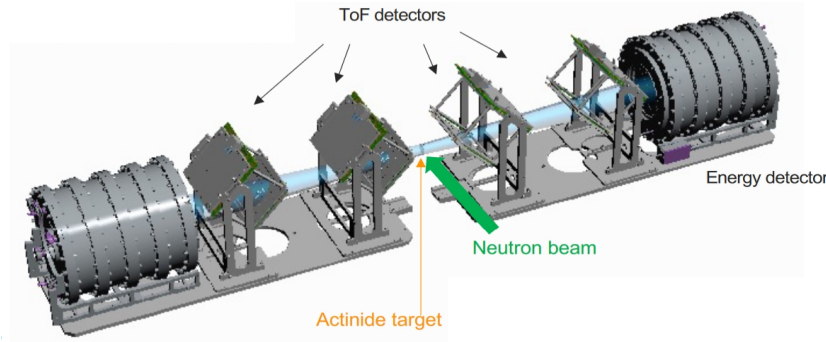
    ⇒ Using the energy loss profile and neural network.





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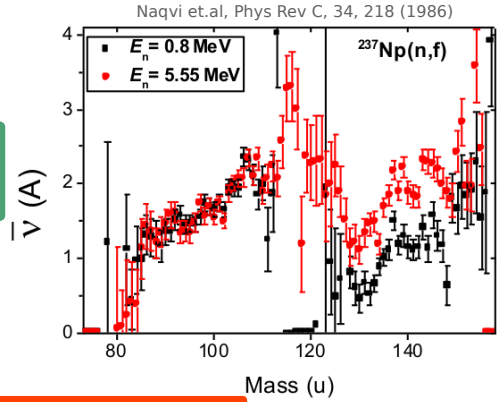


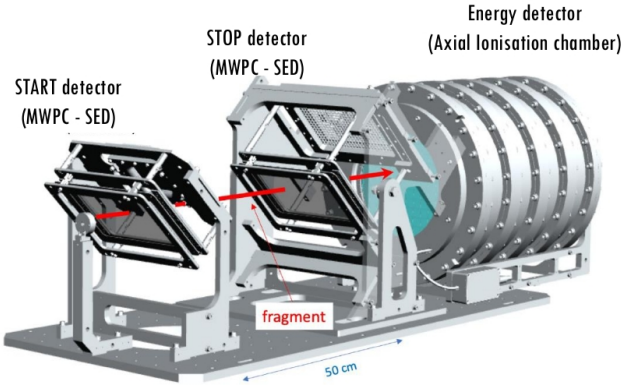
Challenges for the detection of the fission fragments in direct kinematics :

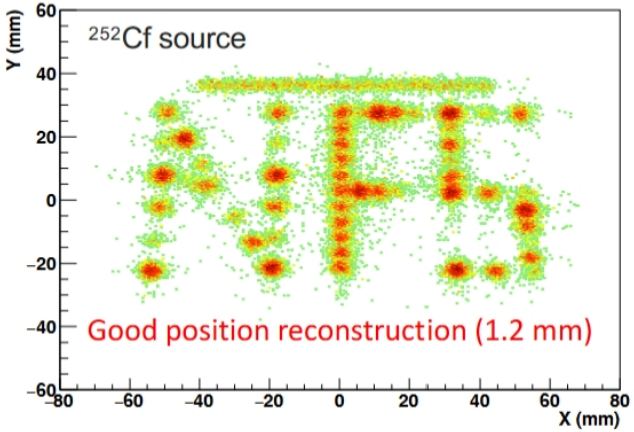
- Low energy fragments (energy loss corrections)
- Actinide-target production
  - Radius ≦ the radius of the NFS neutron beam
  - Massive enough for reasonable beam times but also thin to let the FF out
  - Two-sided to detect both FF → collaboration with JRC/Geel

Velocity and energy measurement

1. Secondary electron emission detector (Se-D)

- X,Y position detection of secondary electrons emitted when fission fragments pass through emissive foil.
- Length of flight ~ 50 cm, Position resolution : σ(X,Y) = 1.2 mm
- Optimised for high time resolution, σ(ToF) = 150 ps





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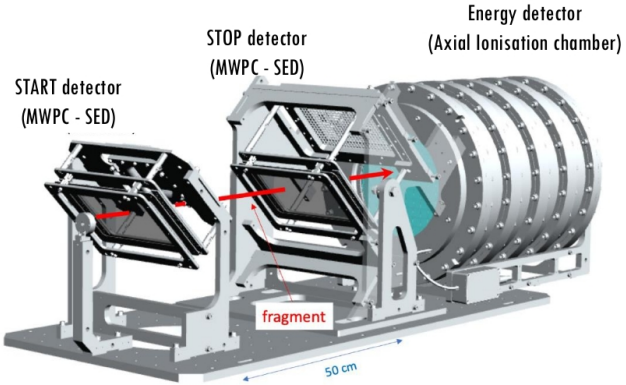
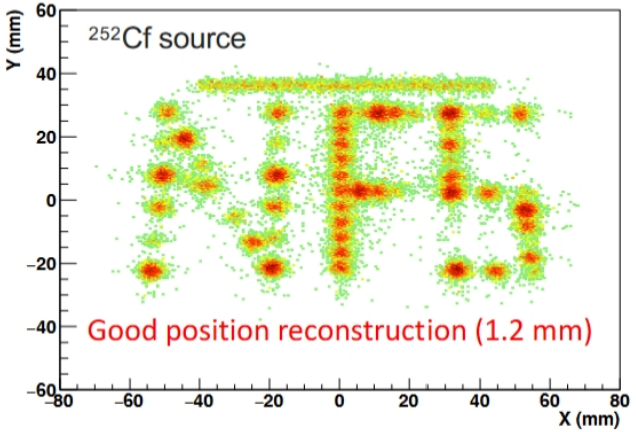
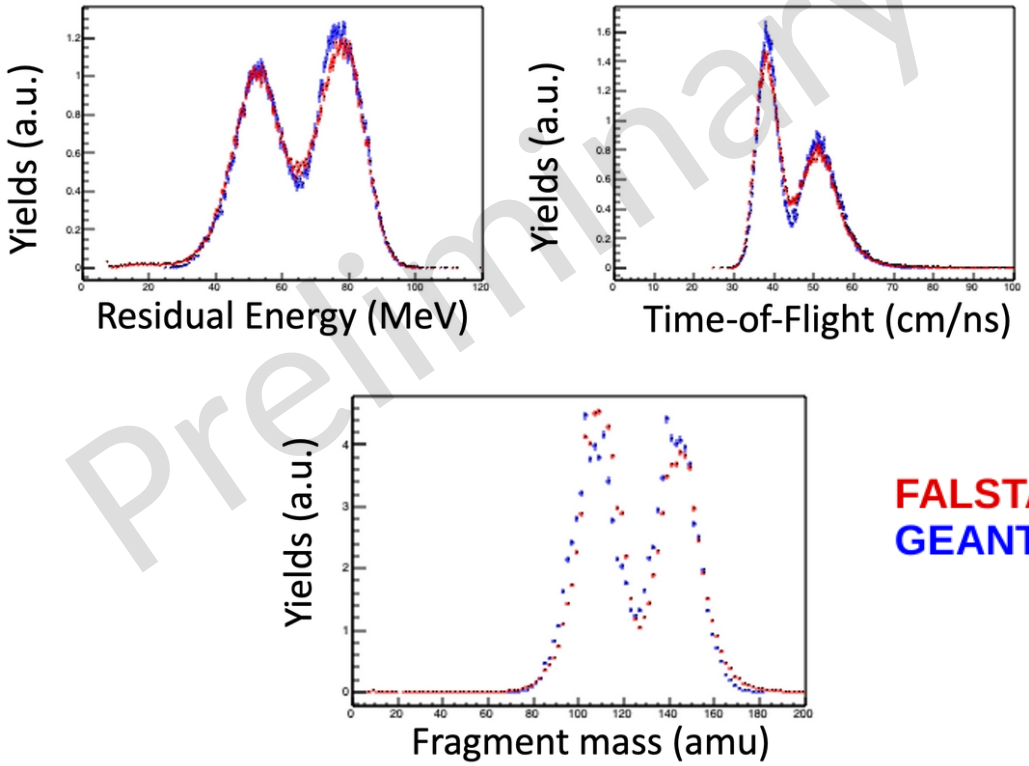


2. Axial ionisation-chamber (IC)

- FF stopped inside the gas of the IC.
- Calibration performed through dedicated ^{252}Cf measurement with different material budgets on the FF paths and compared with GEANT4 simulation.
- Resolution ⇒ Energy : σ(E)/E ~ 1%

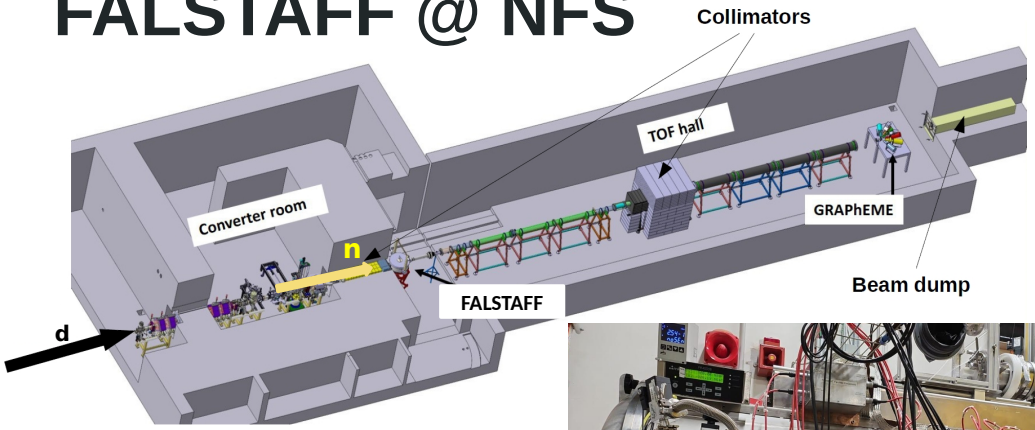


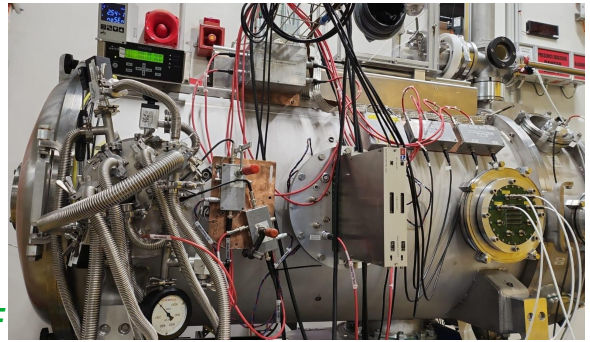
Measurement of ^{252}Cf (sf)



FALSTAFF data
GEANT4 simulation

FALSTAFF @ NFS





“One-arm” set-up of FALSTAFF

Neutron Beam @ NFS:

- Neutron beam production from d + ^{9}Be reaction
- Neutron energy measured from the **TOF technique**

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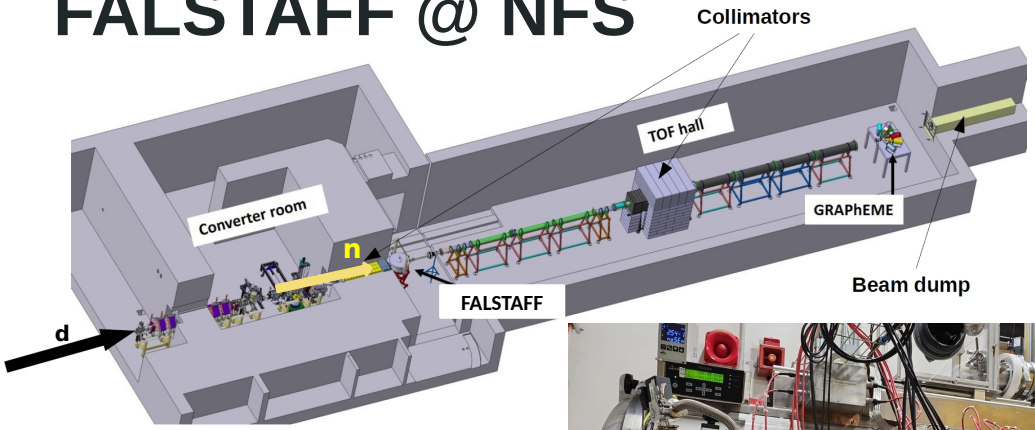

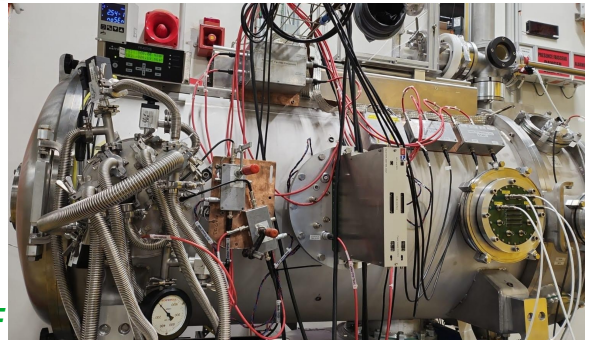

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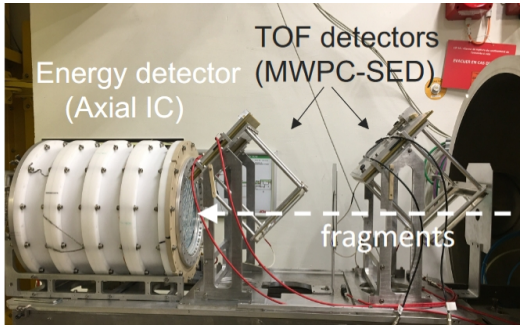

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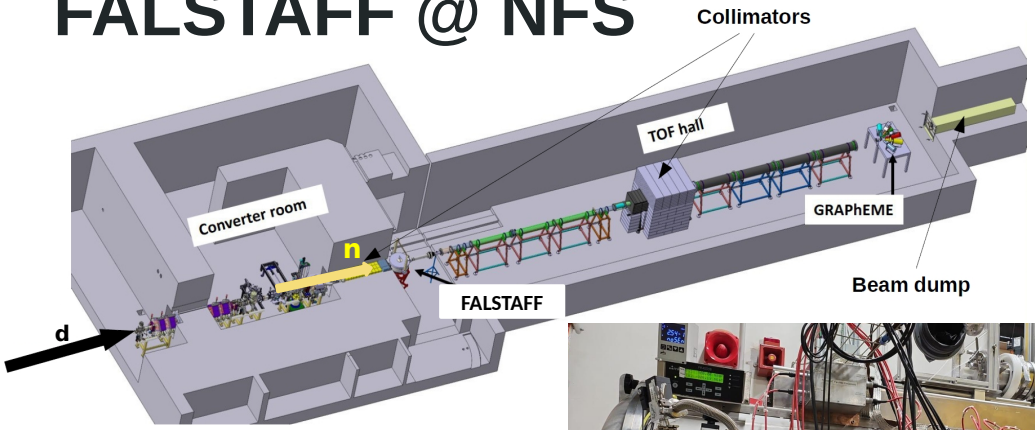

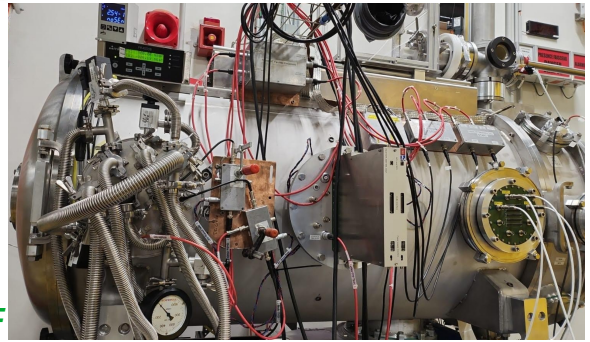

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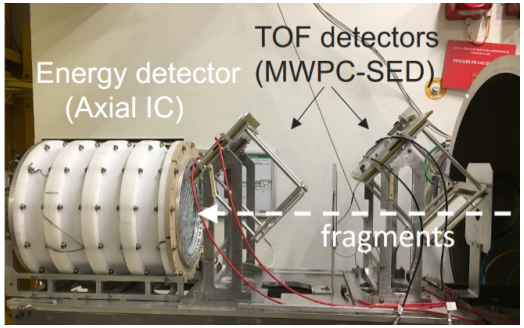

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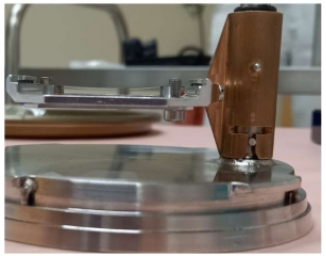

Targets from JRC/Geel (EU)
^{235}U & ^{237}Np chemical compounds :

- Areal density ~ 200 µg/cm^2
- ϕ(Target) = 30 mm
- ϕ(Beam) = 45 mm
- Al backing = 0.25 mm

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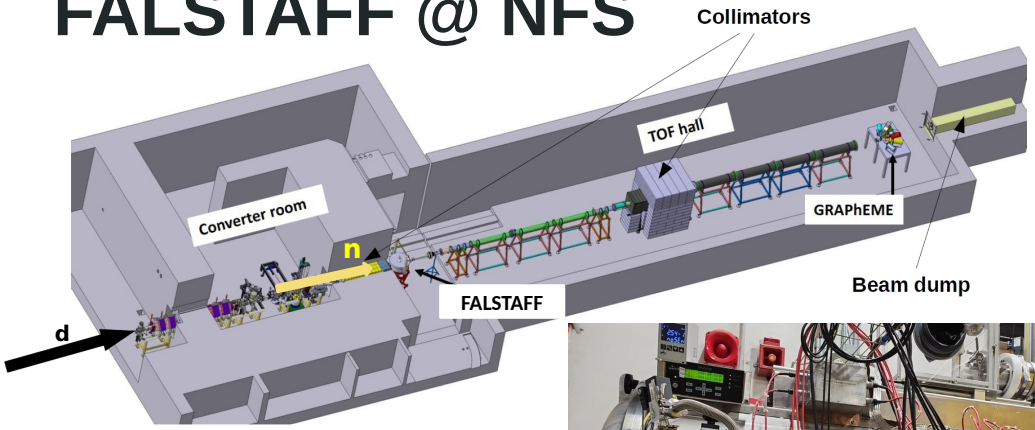

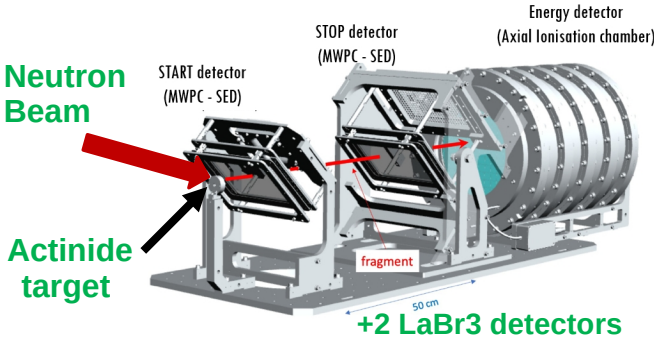

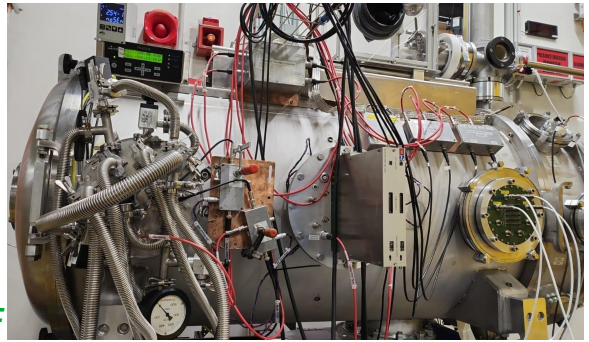

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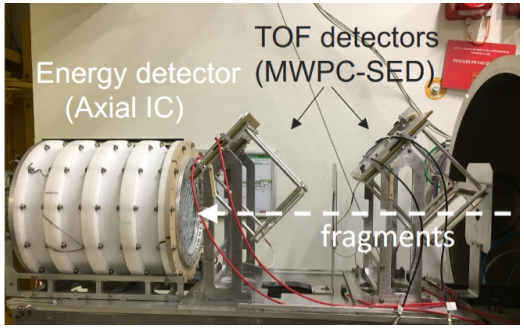

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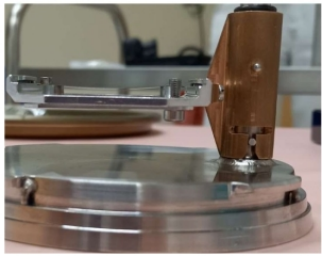

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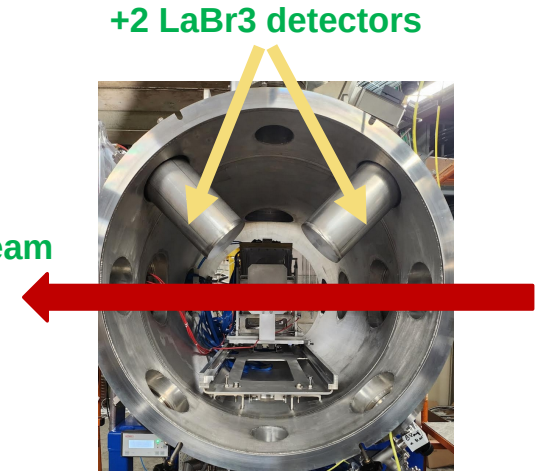
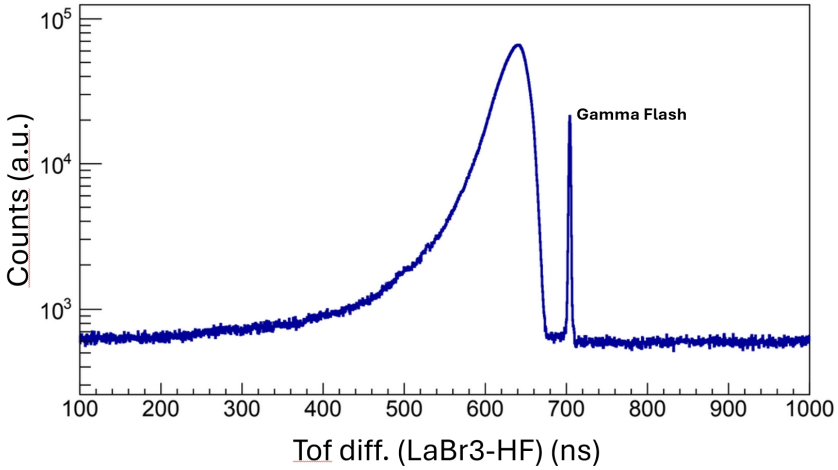
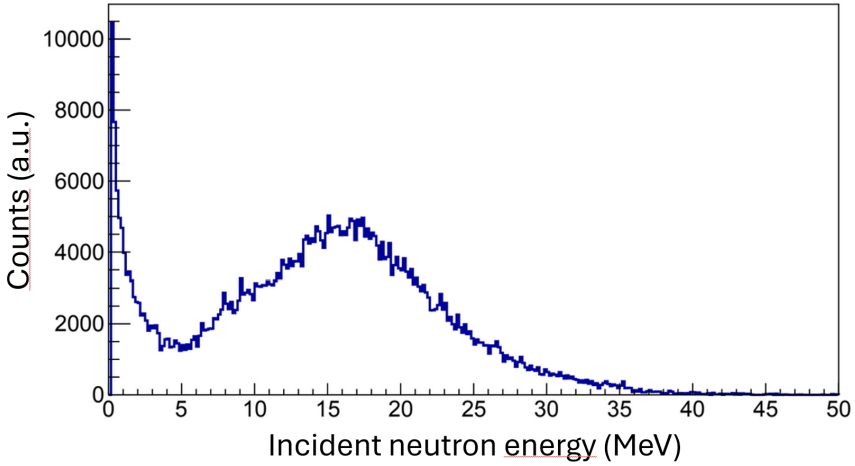
Incident neutron energy spectra

- Time reference : Low energy gamma flash from beam on converter.
- 2 LaBr3 detectors around target ⇒ (γ,γ') detection
- Neutron time of flight spectra (in coincidence with FALSTAFF)

  ➔ Different TOF diff. combinations between HF, FALSTAFF and LaBr3



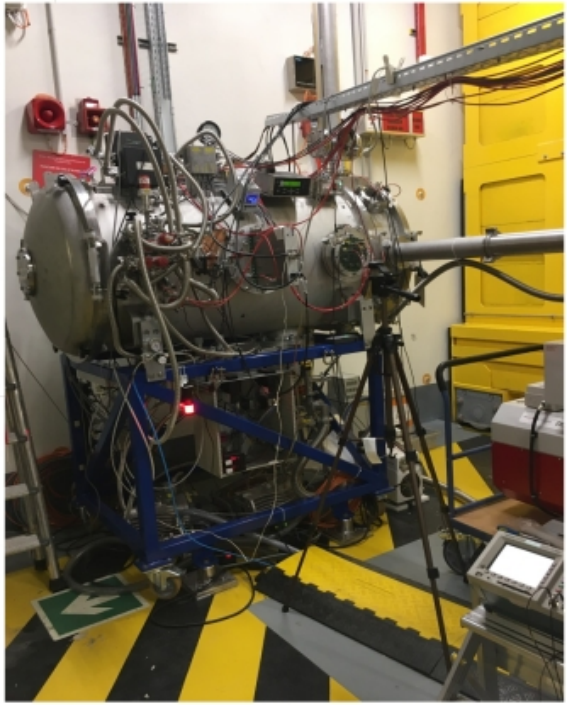




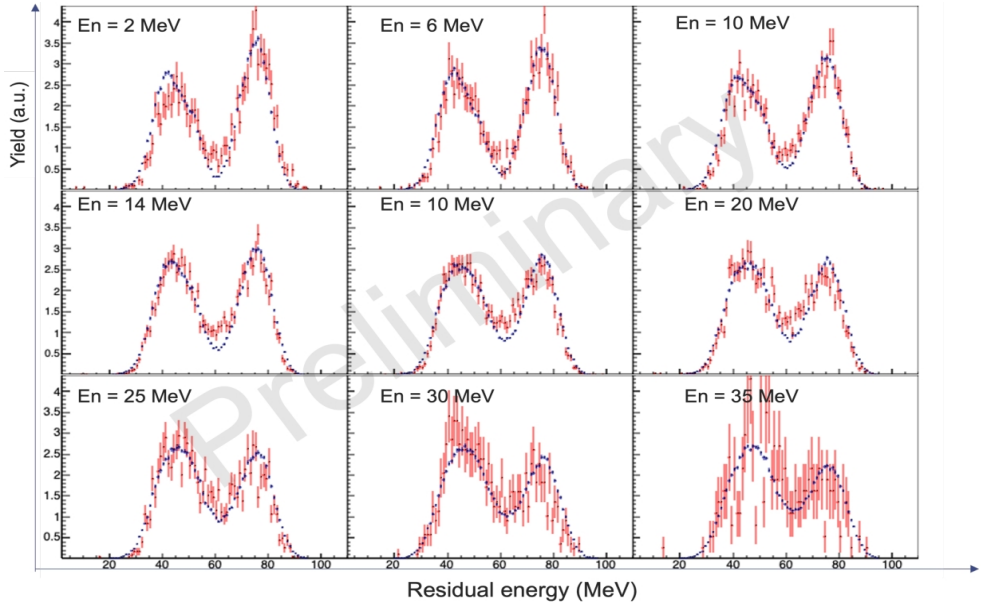
One-arm measurements with FALSTAFF

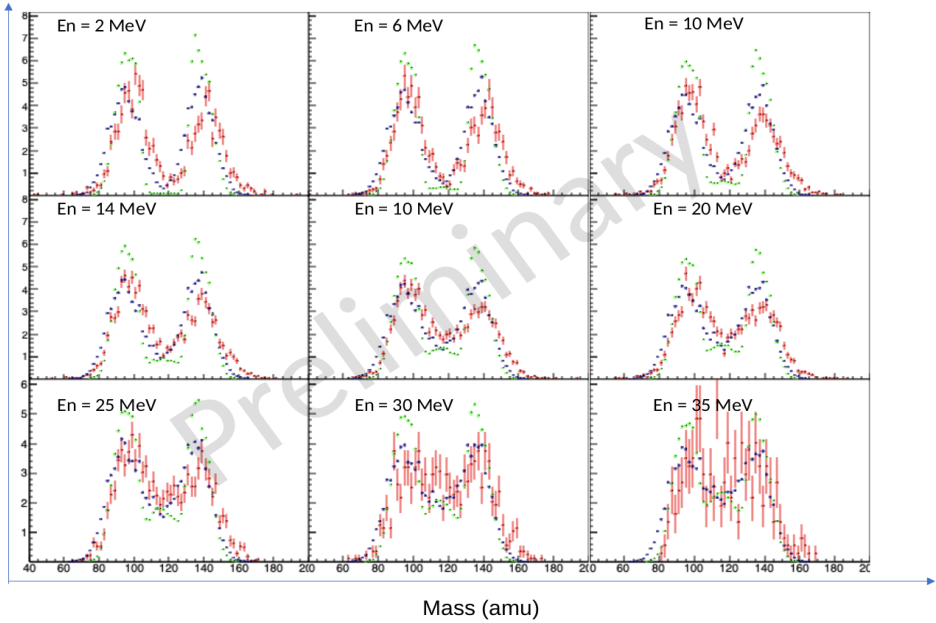
Two experiments performed so far with FALSTAFF one arm at the NFS facility in GANIL-SPIRAL2 :

- ^{235}U(n,f), Oct.-Nov. 2023
- ^{237}Np(n,f), Oct. 2024



Results : Energy and mass yields, ^{235}U(n,f)



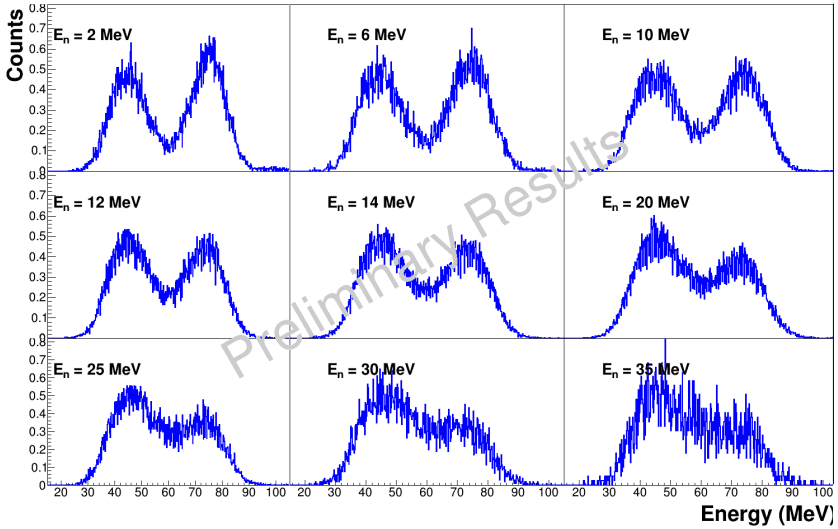


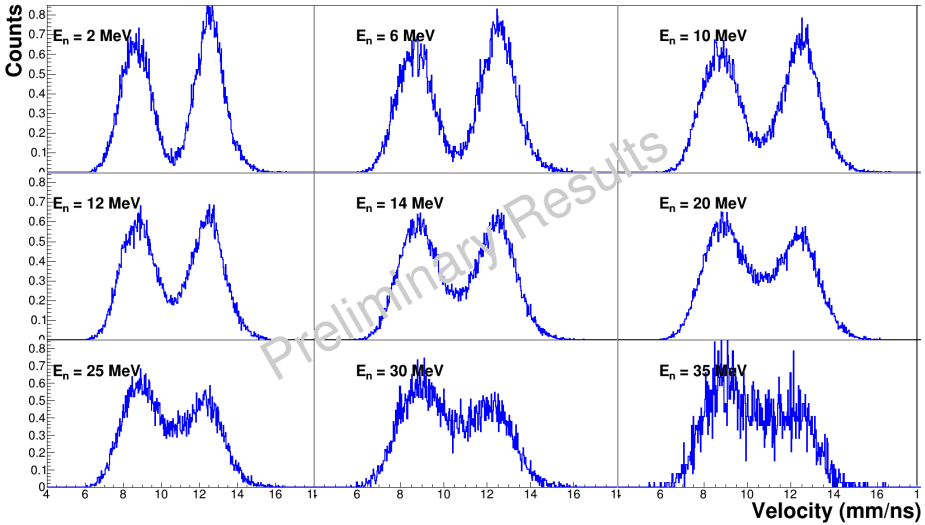
FALSTAFF data
GEANT4 simulation

GEF

D. Doré *et al.*, *to be published*

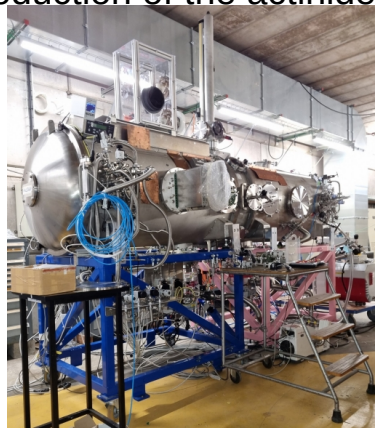
Results : Time of flight and velocity, ^{237}Np(n,f)





Conclusions

- ^{235}U(n,f) data analysed, low statistics, basic agreement on mass yields with simulation as f(En).
- Comparison with models through the detection filter still under investigation with some fine tuning of the GEANT4 model of FALSTAFF still going on.
- ^{237}Np(n,f) data being analysed, but with a good statistics, should be ready by end of fall 2025.
- Nuclear charge determination through neural-network learning under progress.
- FALSTAFF in its two-arm setup under completion at GANIL, for the detection of both fission fragments in coincidence. First experiment probably in spring 2026 on ^{235}U.
- Long-term science program at GANIL / SPIRAL2 / NFS, depending on the production of the actinide targets.



FALSTAFF two-arm under completion in GANIL (last week)

FALSTAFF Collaboration

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