235U fission fragment study with Falstaff at NFS

Outline

- FALSTAFF: goals, methods and experimental setup
- Preparatory phase : resolution meas., energy loss meas., charge id method
- Falstaff@NFS

FALSTAFF: goals, methods and experimental setup

Physics of the fission process

Excitation energy sharing
The deformation at scission
The role of structure effects
…

Observables

Coincident measurement of both fragments
Fragment mass, energy, charge
Gammas & neutrons multiplicities
Evolution with excitation energy
Evolution with fissionning nucleus
…

Observables

Few data available in the fast neutron energy domain

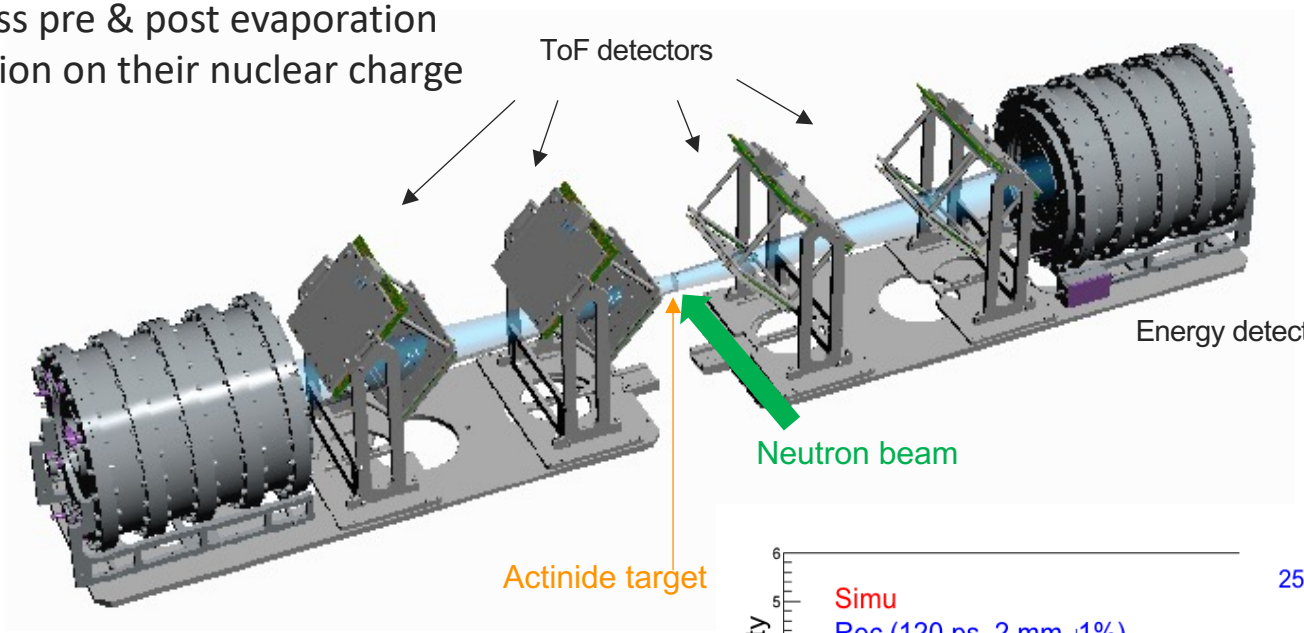
Nuclear application

Characterization of fission products of actinides

FALSTAFF: goals, methods and experimental setup

Study fission
- Direct kinematics (n-induced)
- Actinide targets

Experimental goals are to:
- detect both fragments in coincidence
- measure their kinetic energy
- identify their mass pre & post evaporation
- provide information on their nuclear charge



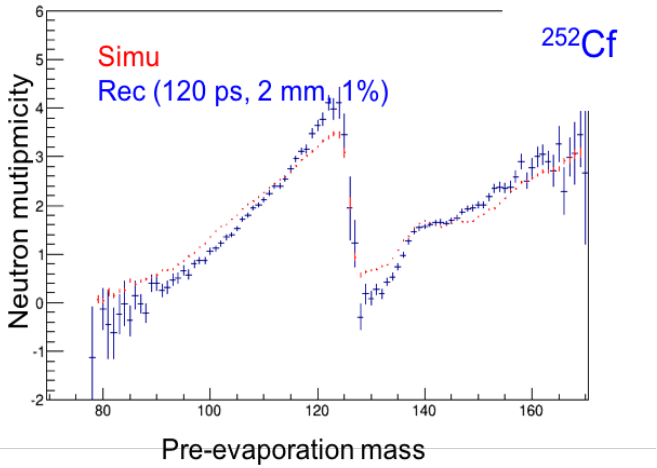
Geant4 simulations

TOF detectors : $\sigma(t)$ = 120 ps & σ (xy) = 2 mm

Axial IC: $\sigma(E)/E$ ~ 1 %

Pre-evap. fragment masses (2V): $\sigma(A)$ ~1 uma

Post-evap. fragment masses (EV): $\sigma(A)$ ~2 uma



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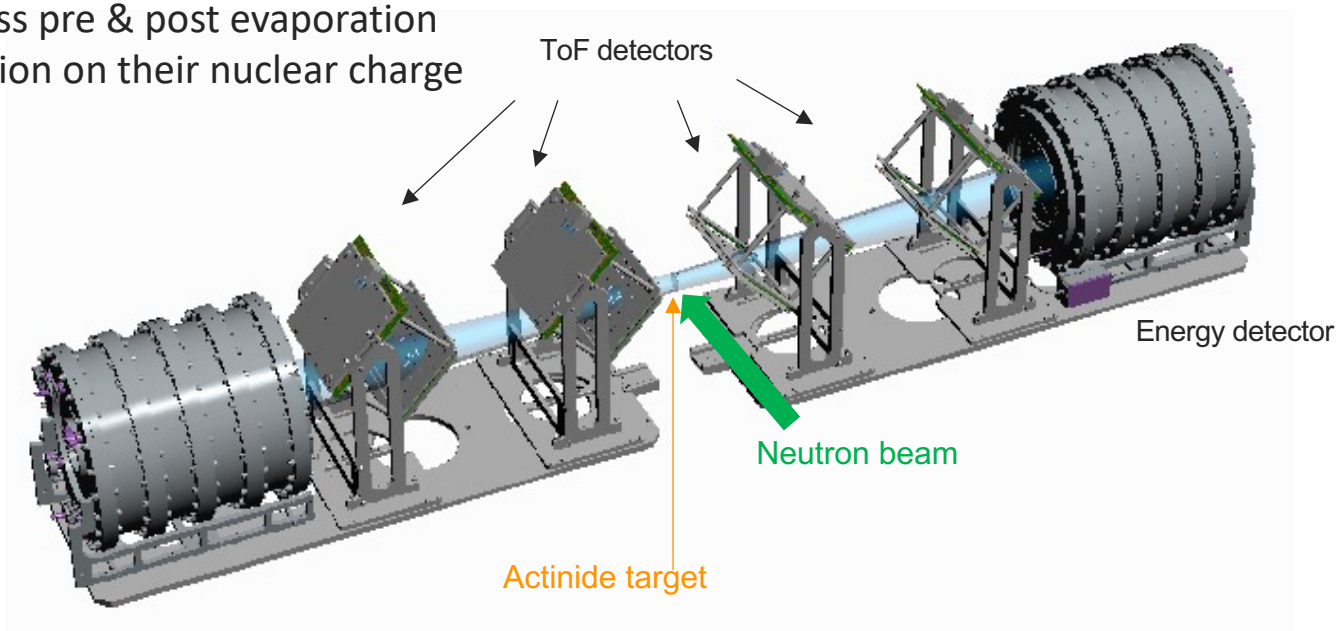

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Challenges

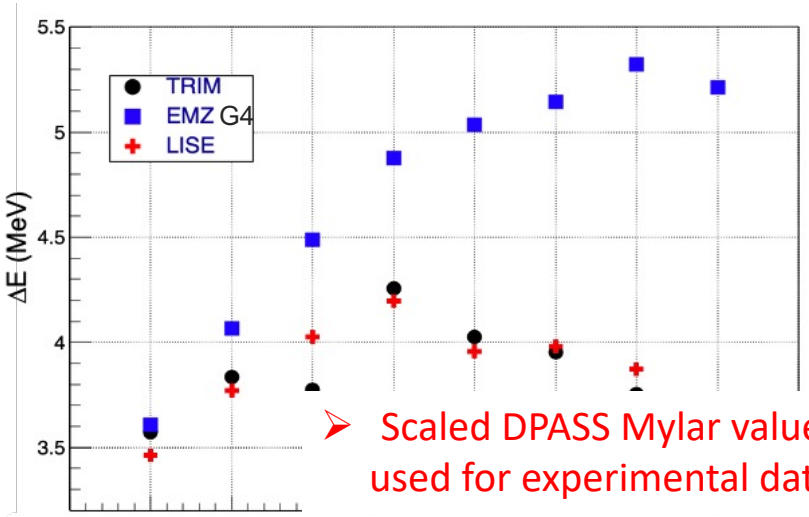
Experimental resolutions

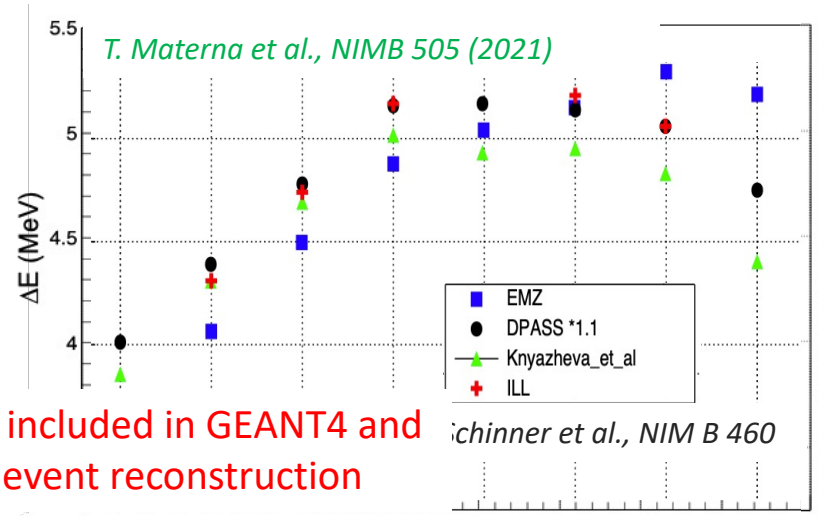
Direct kinematics :
- Charge identification
- low energy fragments
  -> energy loss corrections

Energy loss measurements

Projectile on 0.5 µm of Mylar

Experiment performed at Lohengrin (ILL) to measure **energy losses** in mylar foils





➢ Scaled DPASS Mylar values included in GEANT4 and used for experimental data event reconstruction

^{80}Ge 100 MeV ^{90}Kr 100 MeV ^{100}Zr 100 MeV ^{110}Ru 100 MeV ^{120}Cd 80 MeV ^{130}Sn 80 MeV ^{140}Cs 70 MeV ^{150}Ce 60 MeV

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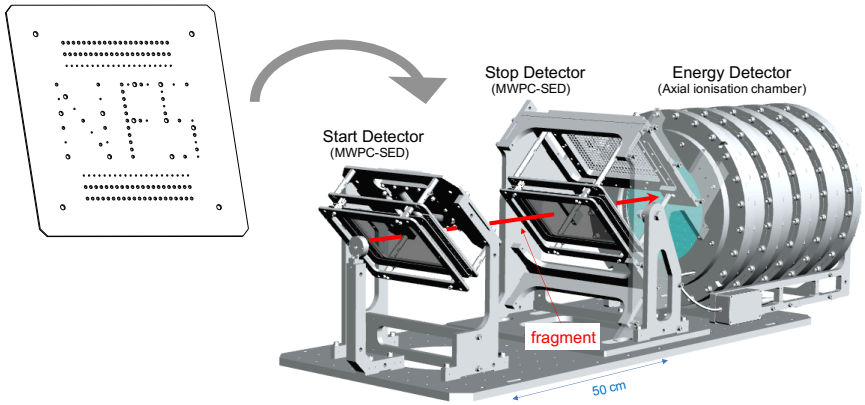
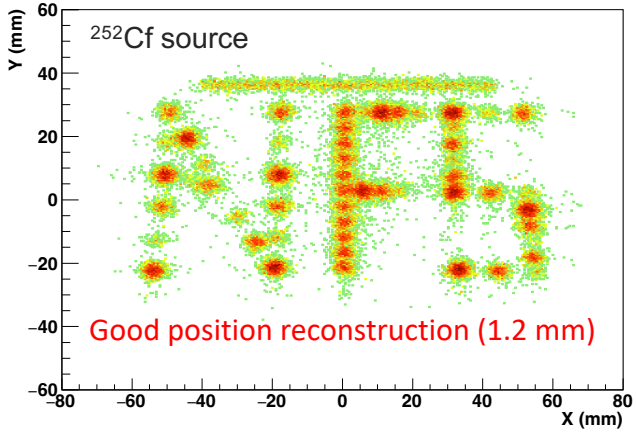
Position resolution



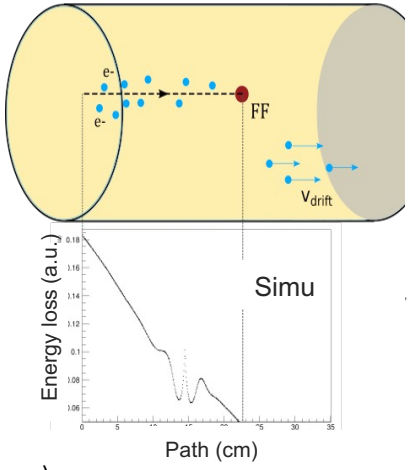


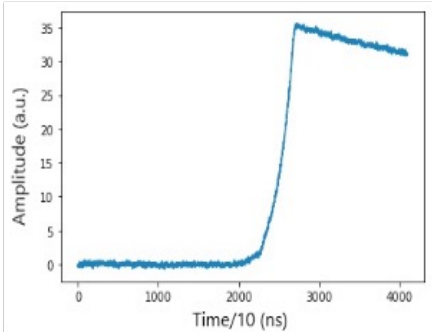
Charge identification through energy loss profile measurement

Possible to identify fragment nuclear charge using the energy loss profile and neural network

Need data with identified fragment to « settle » the neural network

→ *FALSTAFF@VAMOS experiment (D. Ramos)*

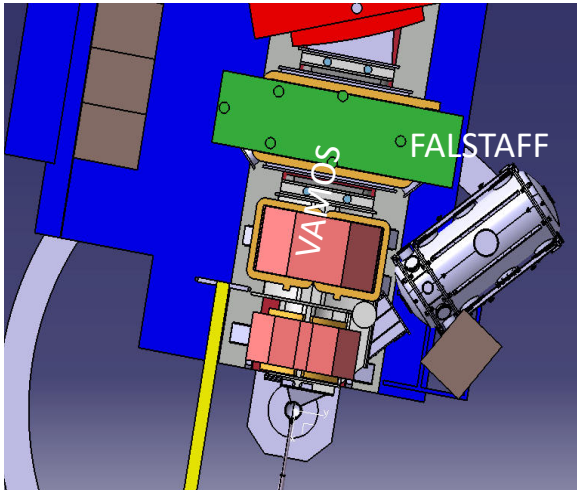




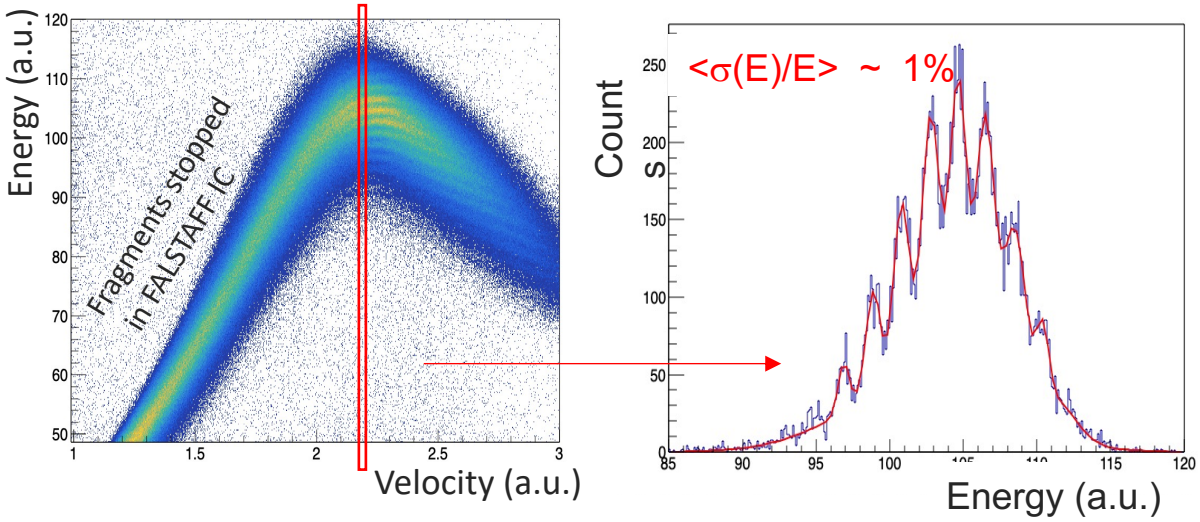
FALSTAFF @ VAMOS (test experiment, March 2022, PI D. Ramos)

^{238}U + C (Be) → fusion-fission main channel

- one fragment fully (Z,A,E) identified in VAMOS
- one fragment slowed down (small IC close to the target) and detected in FALSTAFF



Additional information

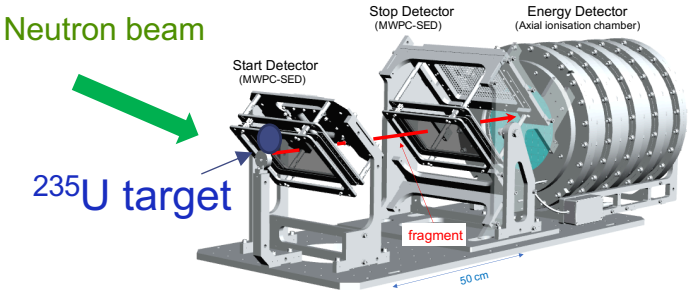


See Indu Jangid poster

Charge analysis still in progress, preliminary results are promising

E814 experiment: *^{235}U Fission fragment study with FALSTAFF at NFS*

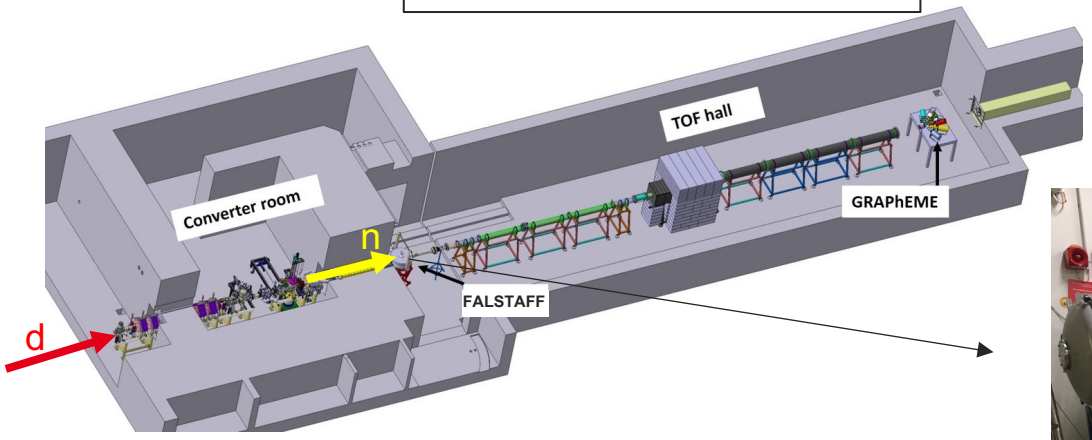
One arm experiment

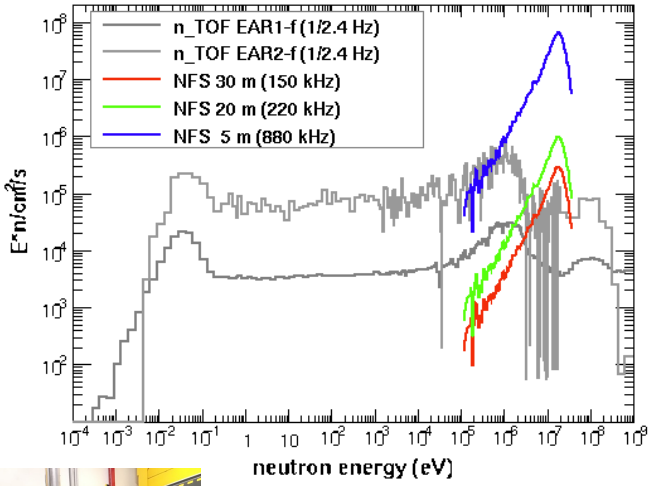


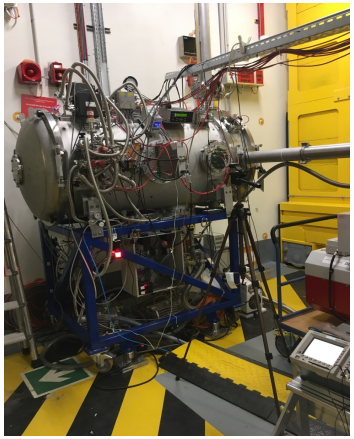
EV method
- Post-evaporation fragment mass

+2 LaBr3 detectors (Subatech, Nantes) close to the target

d+^{9}Be (thick)
I_{beam} = 8 μA (nominal 50 μA)
f = 1/200 * 88 MHz
~ 40 UTs

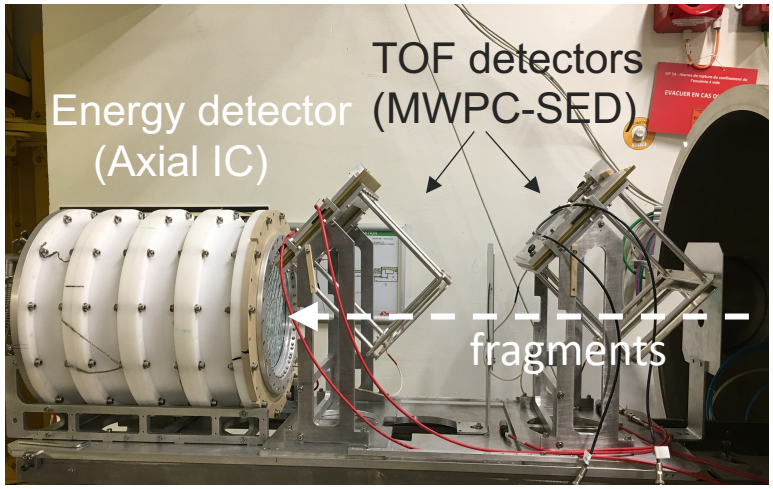


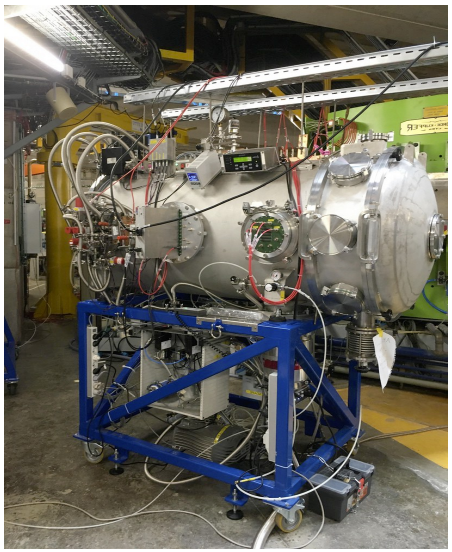




E814 pictures

E814 : Falstaff@NFS : ^{235}U

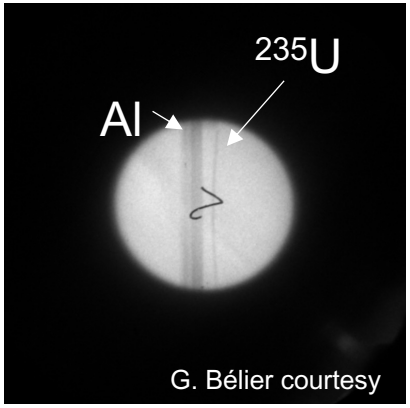




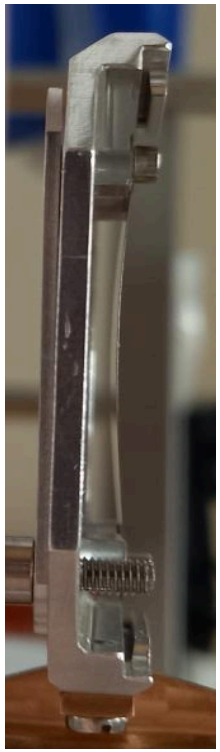
E814 target

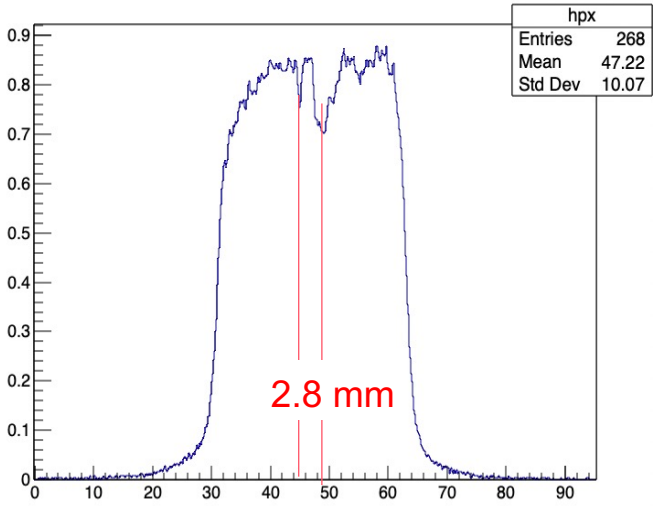
^{235}U target:

- JRC-Geel (99.94% ^{235}U)
- 195 μg/cm^2
- Φ 28 mm
- 1.2 mg
- Ta backing
- Al support



Photostimulable phosphor plate placed at the exit of the FALSTAFF chamber





Incident neutron energy spectrum

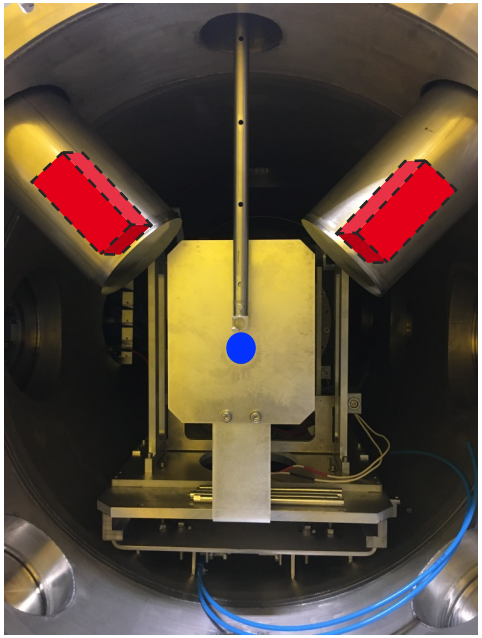
- Need of reference time

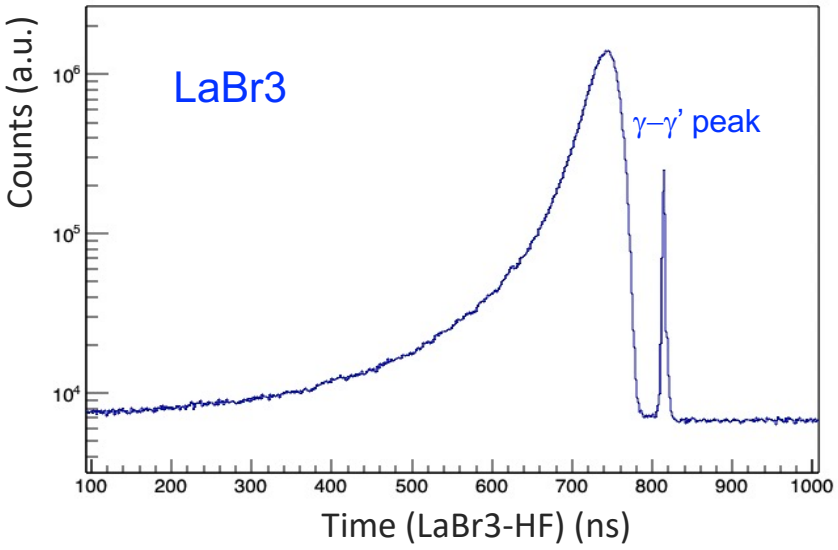
  Low energy gamma flash at NFS: no photo-fission

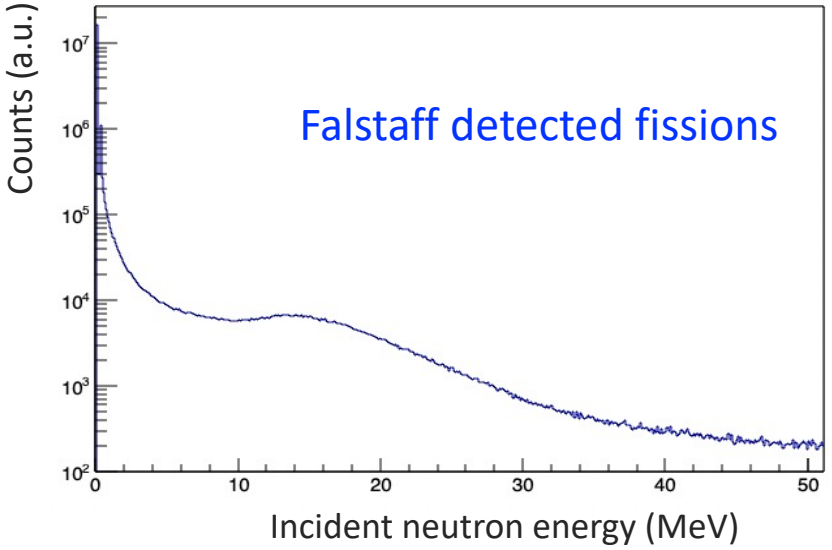
- 2 LaBr3 detectors from Subatech
  - 51x51x102 mm^3
  - 2 PM of 2''
  - 2% fwhm pour 1.33MeV
  - Internal bkg 730cps

- Neutron time spectra (producing detected fission in FALSTAFF) is obtained using:

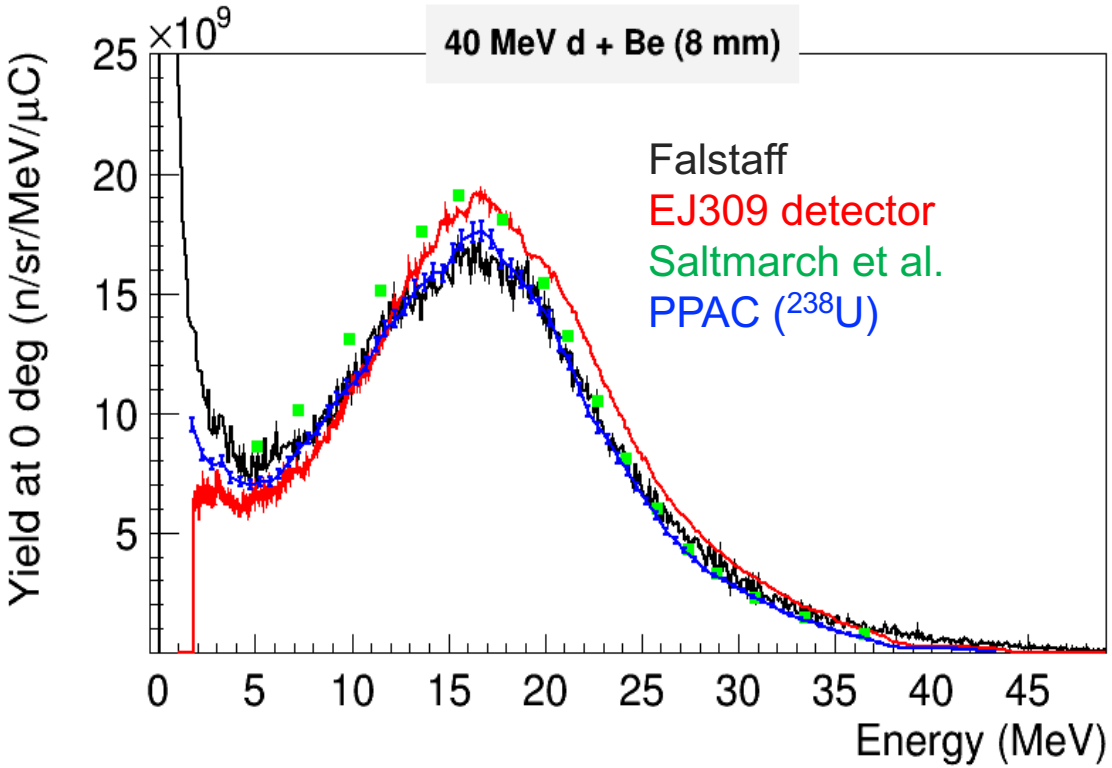
  Different dtime (HF, Falstaff, LaBr3)







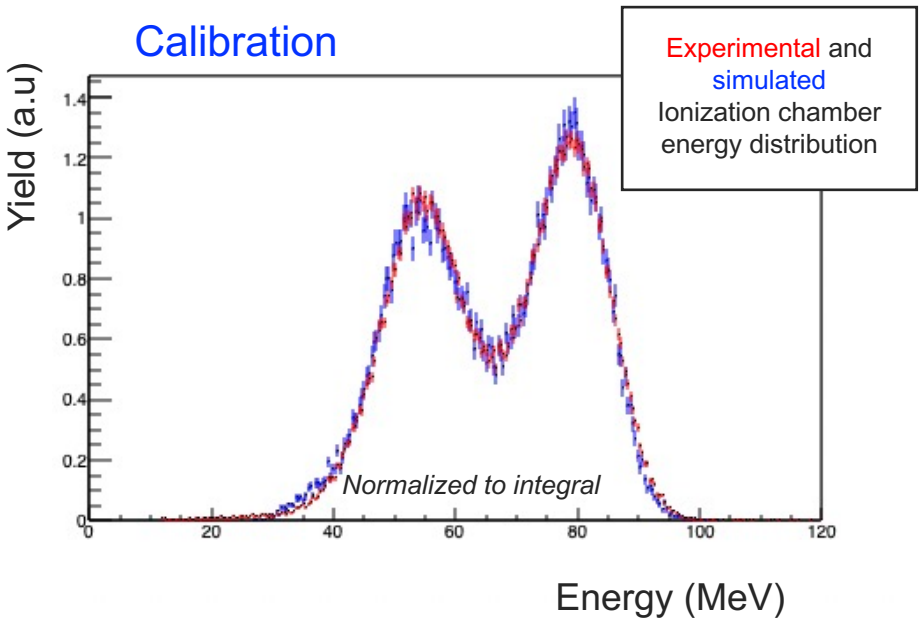
Neutron energy spectra & Statistics

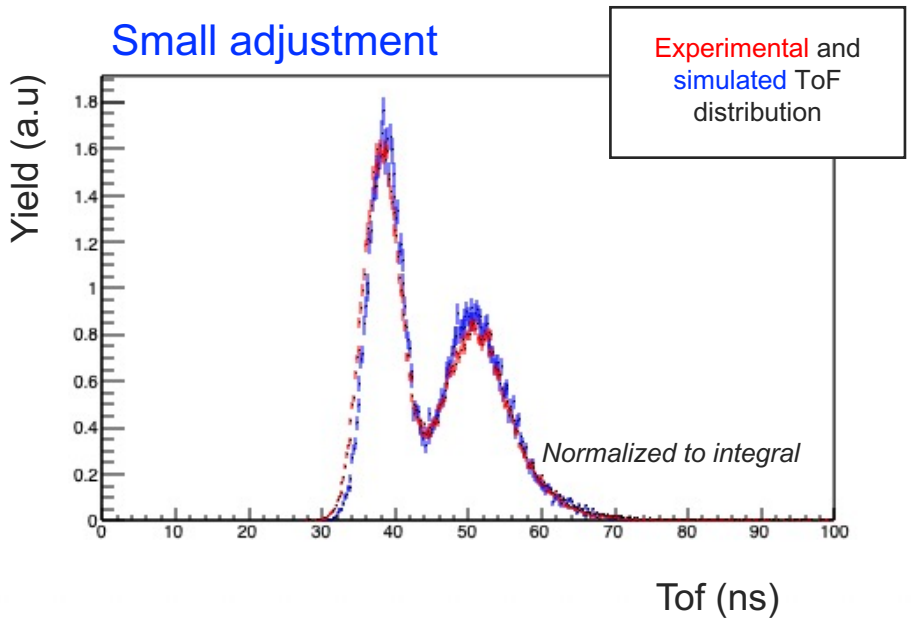


- Same trends
- Some discrepancies between measurements
  - not important for Falstaff since no absolute cross section measurement

Calibration

- Tricky point in this kind of experiment
- Based on simulations : ^{252}Cf





Simulations with GEF code :
- well known code in the nuclear data community
- parameters "adjusted" on available experimental data but …
few data in the fast energy domain

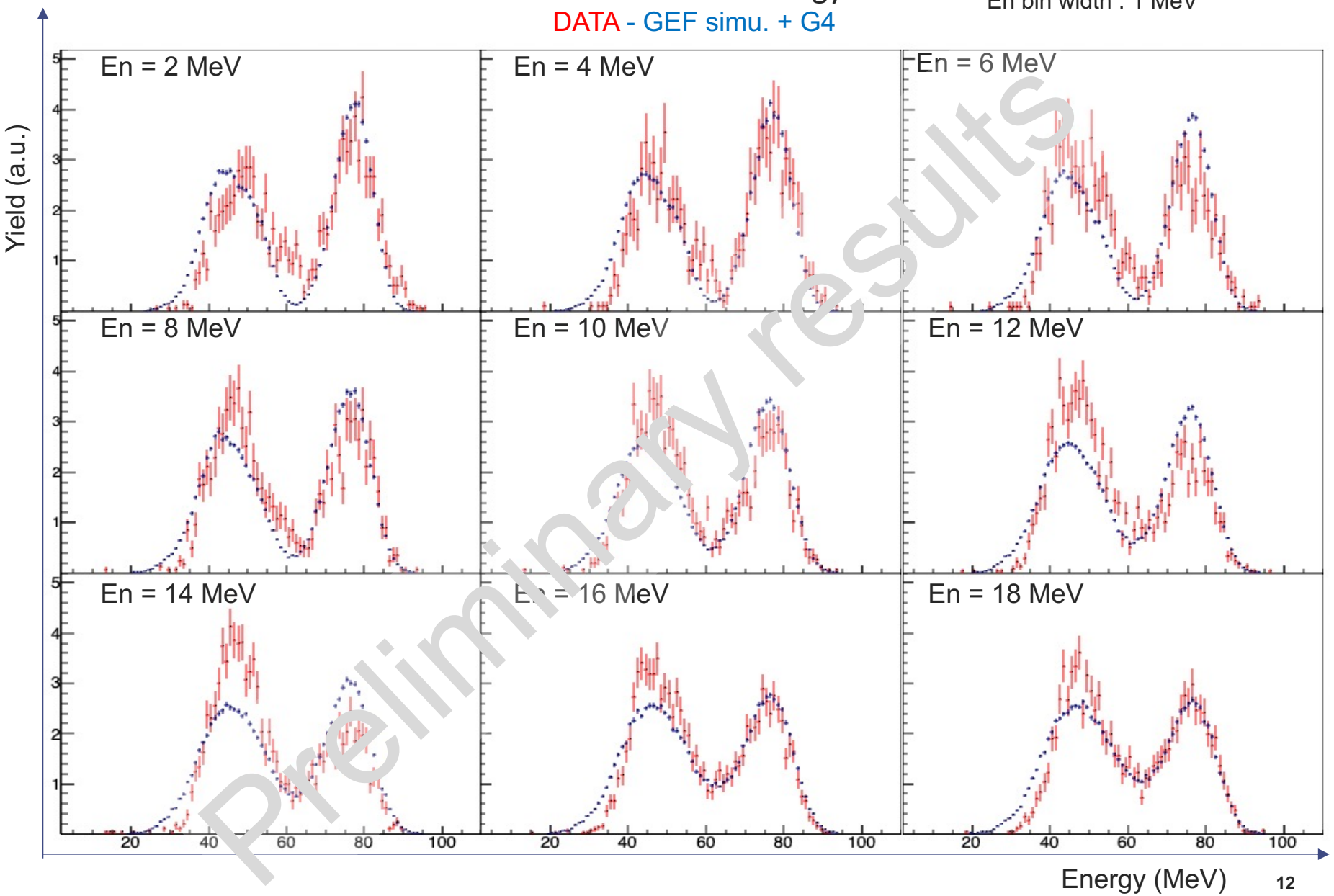
K.H. Schmidt et al., Technical report, JEFF Report 24, 2014.

Another well known code is **FIFRELIN** (DES/IRESNE).
Not used here because **FIFRELIN** results for U5
at different energies are not yet available (no pre-neutron data available)

O. Litaize et al., Phys. Rev. C, 82 (2010) 054616.

^{235}U preliminary results

Spectra normalized to integral
En bin width : 1 MeV

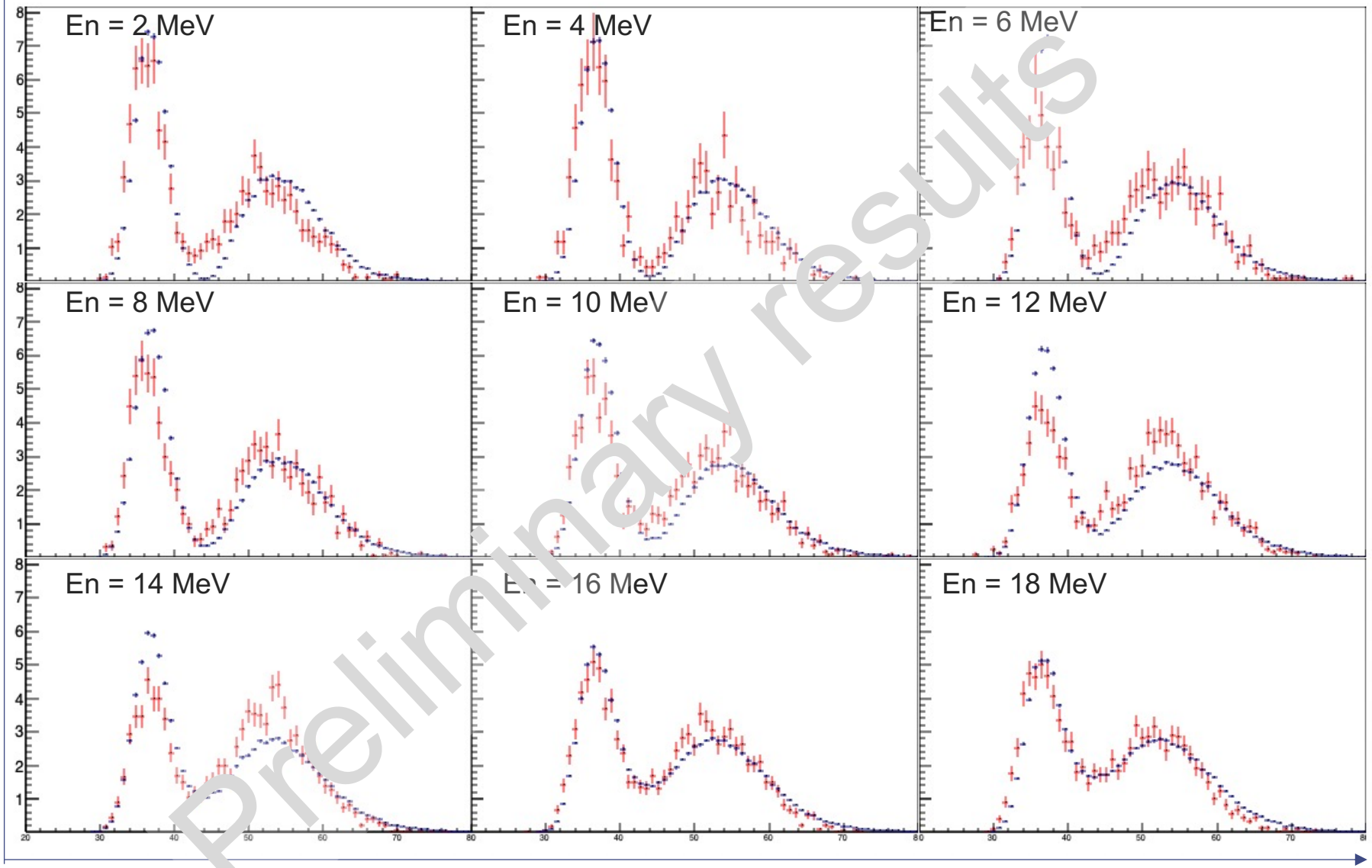


^{235}U preliminary results

Time-of-flight

DATA - GEF simu. + G4

Spectra normalized to integral
En bin width : 1 MeV



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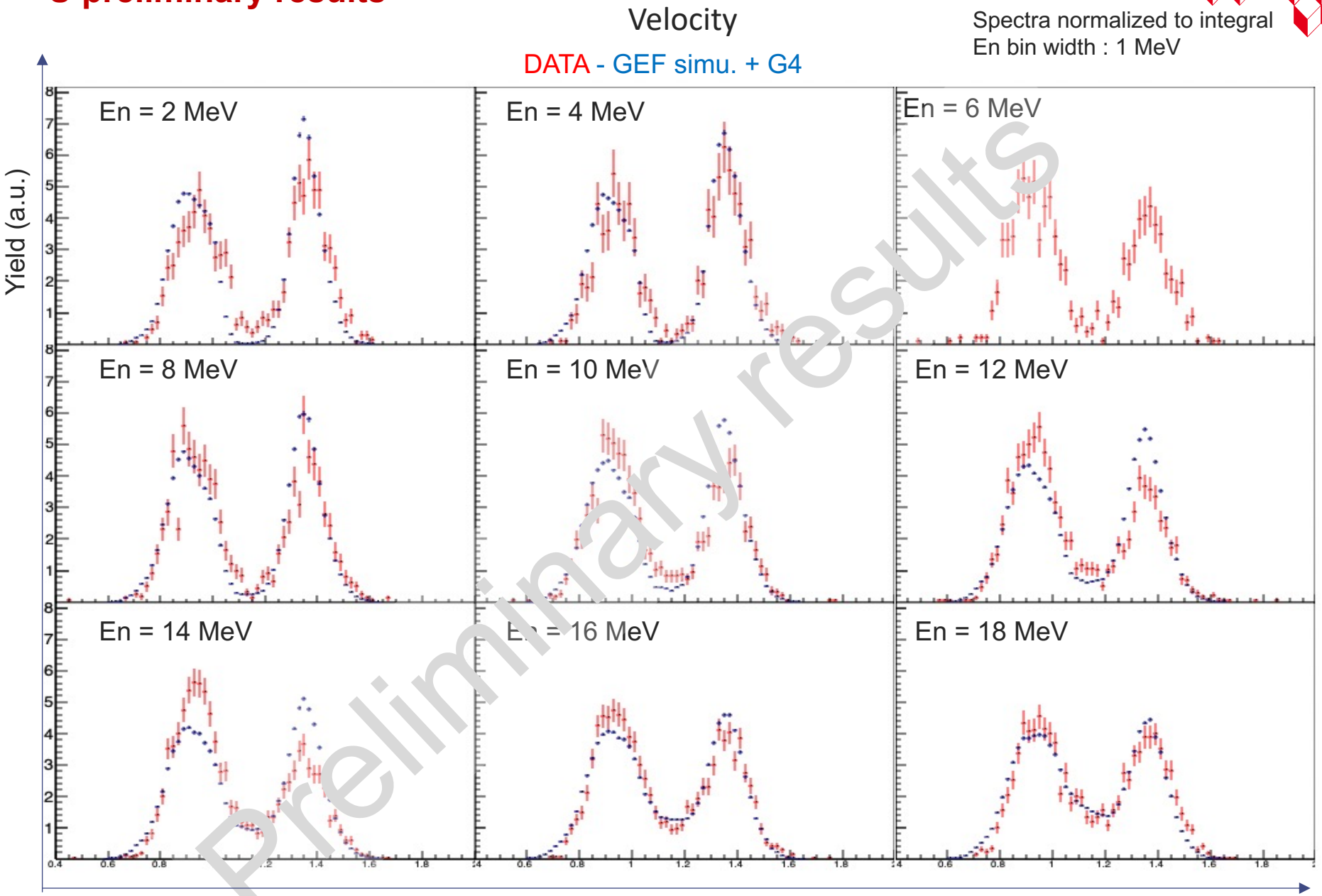
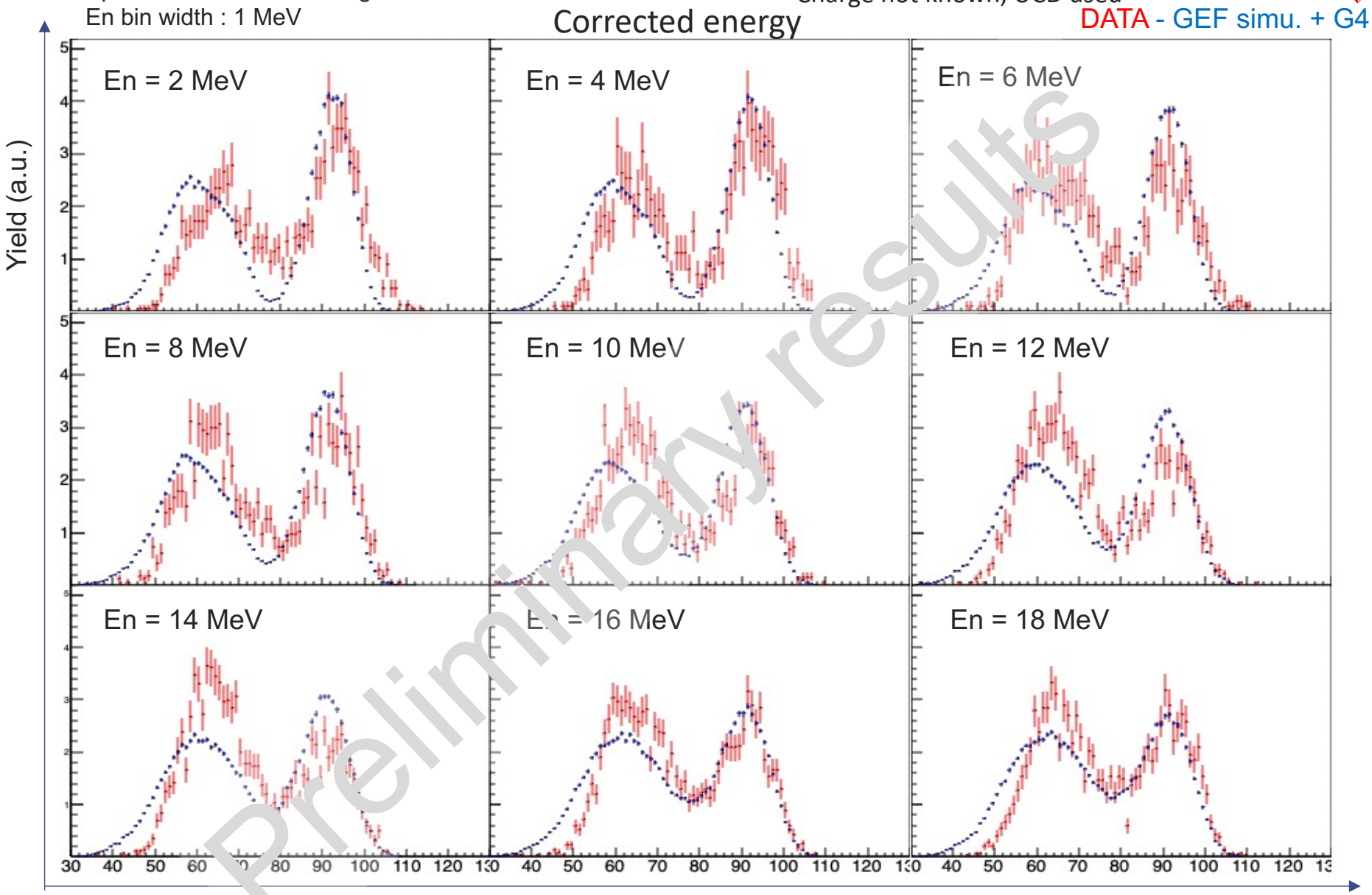


Corrected energy

Spectra normalized to integral
En bin width : 1 MeV

- Iterative process to correct the energy loss in the IC window and the Stop emissive foil
  - Charge not known, UCD used

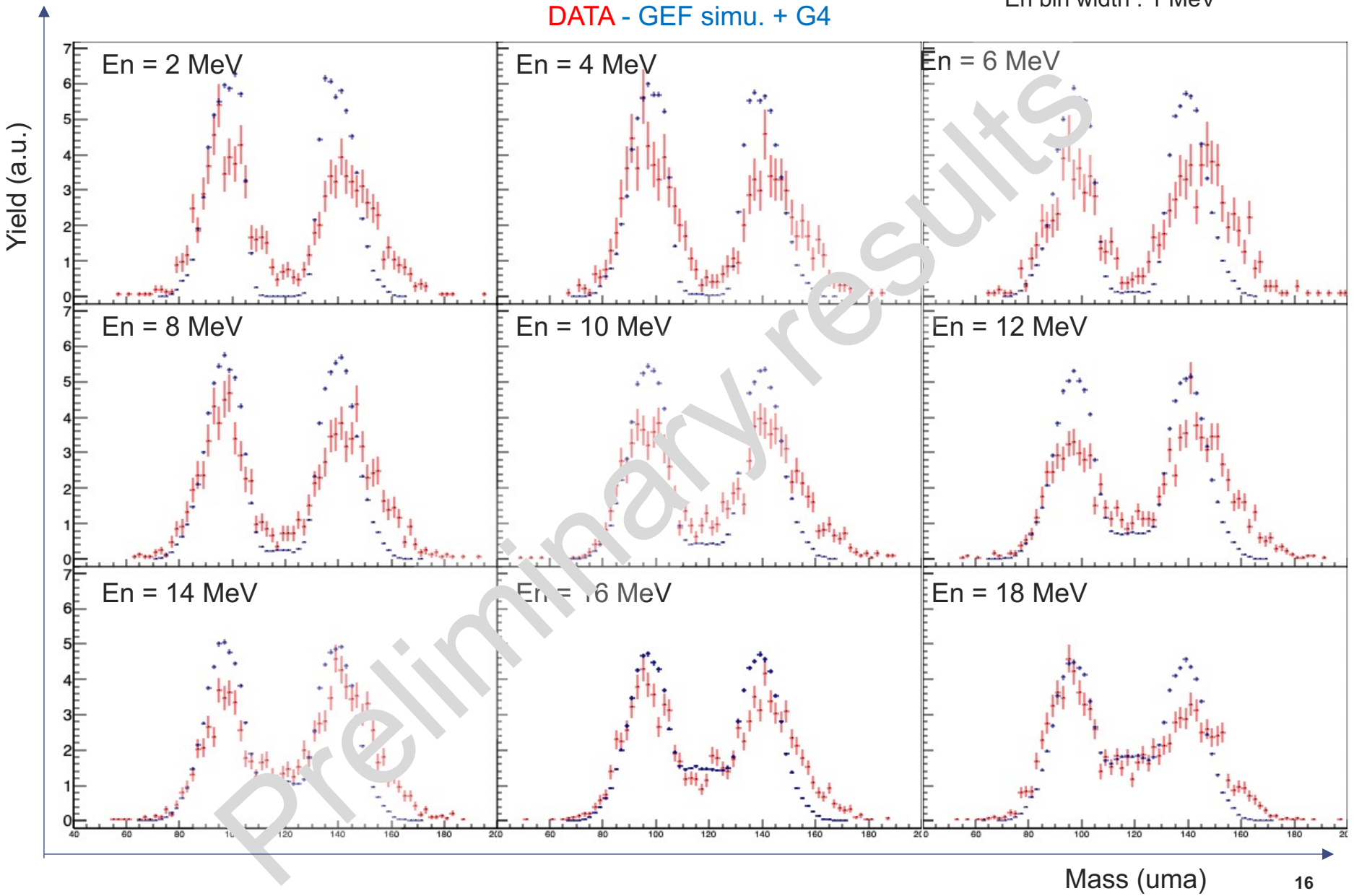


^{235}U preliminary results

Mass

DATA - GEF simu. + G4

Spectra normalized to integral
En bin width : 1 MeV

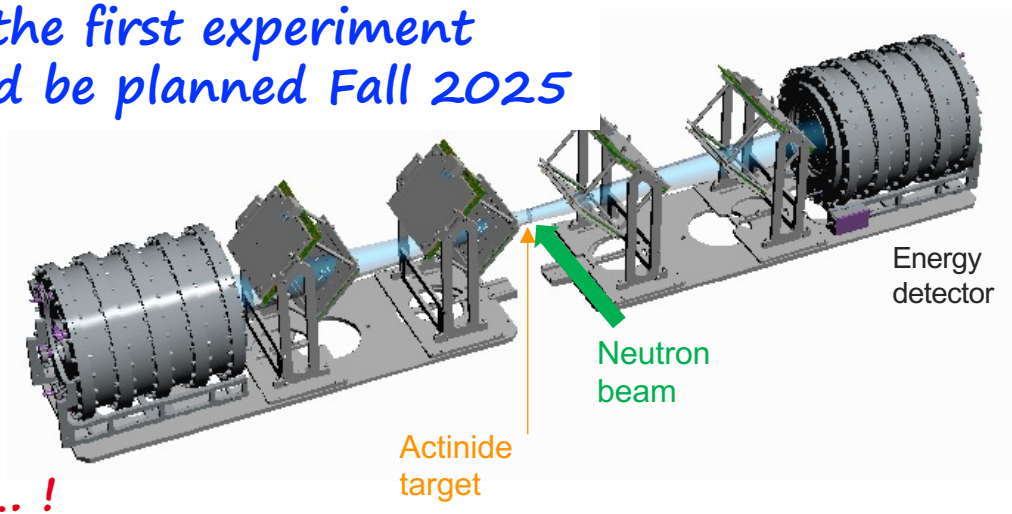


In summary

- Analysis of ^{235}U (n,f) exp. at NFS is still ongoing
  - Other calibrations for ionisation chamber needed
  - Cf meas. with HPGe in coincidence foreseen to check the mass reconstruction method
  - Analysis of FALSTAFF@ VAMOS exp. is in progress:
    - results are needed to extract nuclear charge information FALSTAFF

- ^{237}Np experiment (1-arm) to be submitted to PAC 2023 (J.E. Ducret)

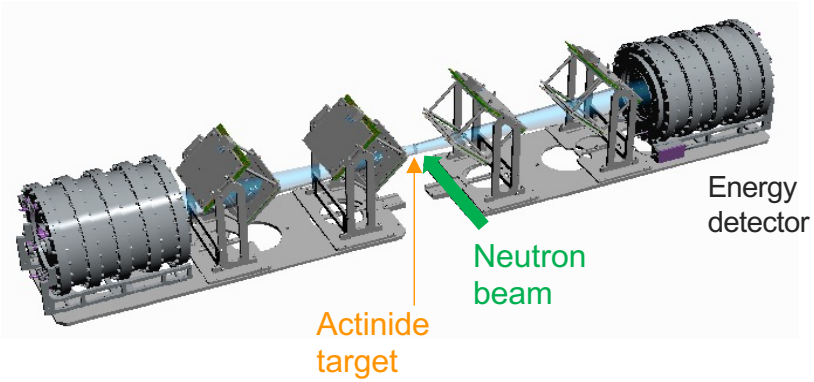
Finally, the second arm of FALSTAFF will be built and the first experiment with 2 arms could be planned Fall 2025



Thin actinide targets needed …. !

Support C. Stodel initiative and JRC-Geel target laboratory

Falstaff



Participants to the E814 experiment

DPhN: *Diane Doré, Eric Berthoumieux, Alain Letourneau, Thomas Materna, LoïcThulliez, Marine Vandebrouck, Mattéo Ballu, Pierre Herran, Gurpreet Kaur, Périne Miriot, Borana Mom*

GANIL: *Jean-Eric Ducret, Diego Ramos , Xavier Ledoux, Anne-Marie Frelin, Indu Jangid, Priya Sharma*

JRC/Geel: *Stephan Oberstedt*

Subatech: *Eric Bonnet, Magali Estienne, Muriel Fallot, Amanda Porta, Julien Pépin*

LP2I: *Paola Marini, Ludovic Matthieu, Teresa Kurtukian Nieto*

+ Technical staff at GANIL and Irfu/Saclay

+ support from CEA/DES/Iresne (Abdel Chebboubi, Olivier Litaize, Olivier Serot)

Merci