

DE LA RECHERCHE À L'INDUSTRIE



Other fundings



CEA/DEN, P2IO

www.cea.fr

Performance validation of the FALSTAFF first arm:

^{252}Cf and ^{235}U fission fragment characterisation

*D. Doré¹⁾, E. Berthoumieux¹⁾, Q. Deshayes¹⁾, L. Thulliez¹⁾,
M.O. Frégeau²⁾, X. Ledoux²⁾, J. Pancin²⁾, S. Oberstedt³⁾*

1) Irifu, CEA, Université Paris-Saclay, France

2) GANIL, Caen, France

3) European Commission, Joint Research Centre, Geel, Belgium

Outlook

- Goals and Motivations
- Detectors
- ^{252}Cf and ^{235}U results
- Perspectives and Summary

Goals and Motivations

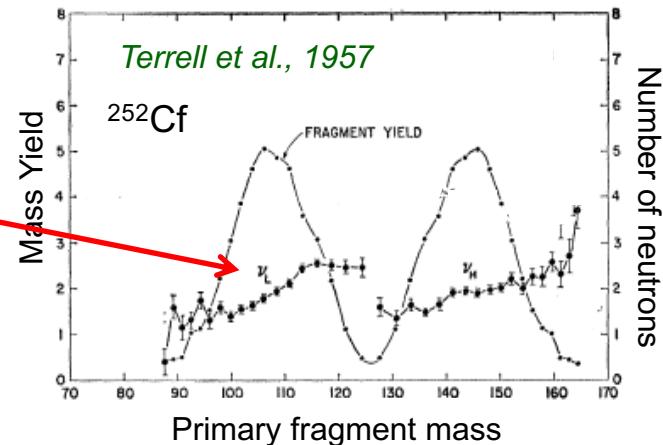
Study of actinide fission in the fast energy domain

Fragments in coincidence

- Kinetic energies
- Final masses (after n evaporation)
- Initial masses (before n evaporation)
- Charge

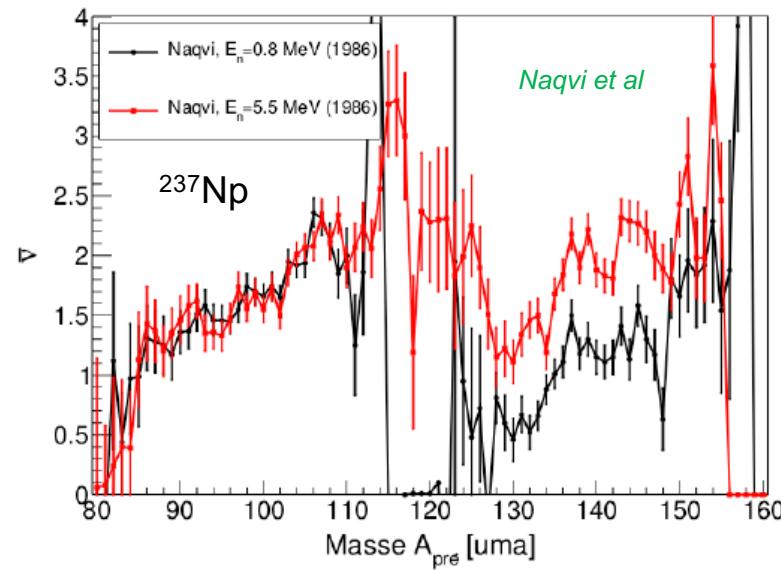
Actinides to study: $^{238,235}\text{U}$, ^{239}Pu , ^{237}Np , ^{232}Th , ^{233}U , ...
Experiment to be performed at NFS, ...

Neutron
mult.

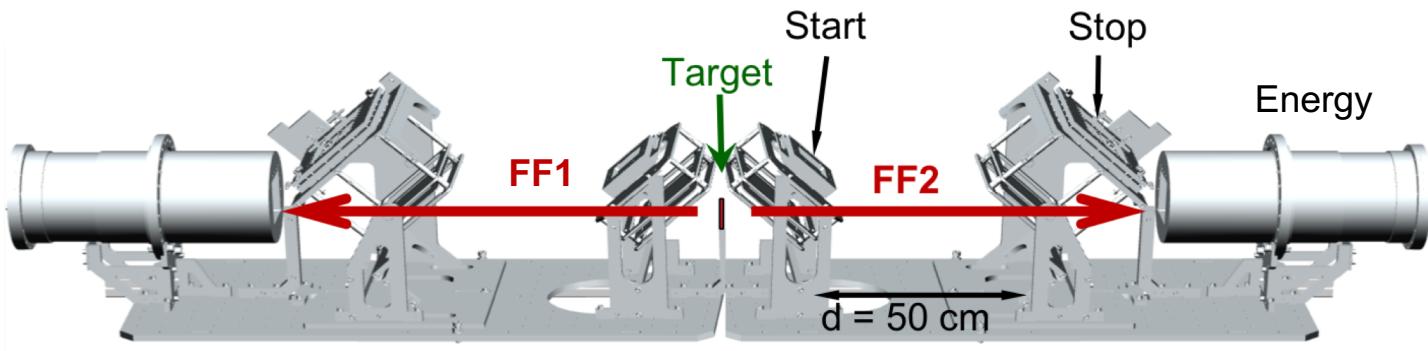


Data needed :

- ❖ Few data in the fast energy domain
 - Neutron multiplicity and fission yields important for ND libraries
 - Important for the understanding of the fission process : energy sharing, deformation, ...



Method



FF mass before evaporation (A_{pre}) → The 2V method

- Hyp: n evaporation does not modify velocity in average

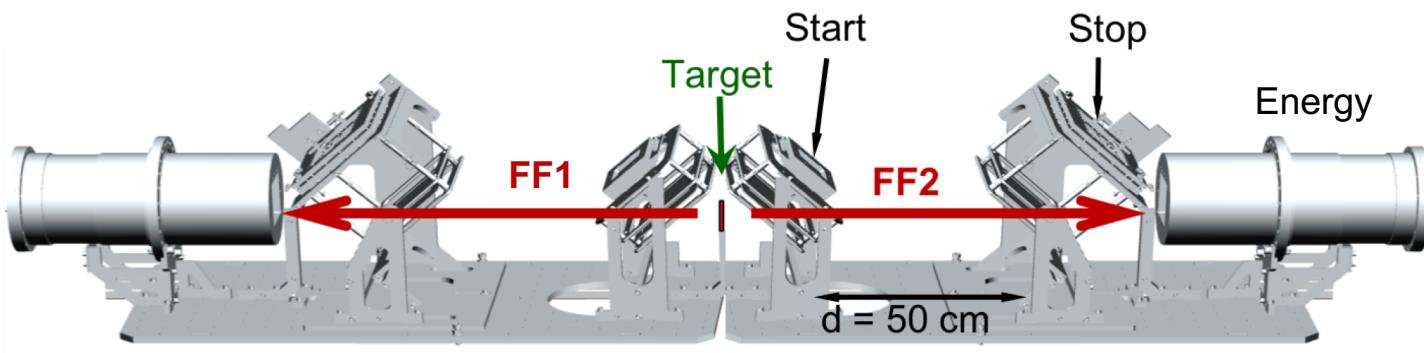
Measurement using time-of flight (TOF) method

- Timing resolution : $\sigma_t \sim 150 \text{ ps}$
- Spatial resolution : $\sigma_{x,y} \sim 2 \text{ mm}$



Emissive foils + MWPC

Method



FF mass before evaporation (A_{pre}) → The 2V method

- Hyp: n evaporation does not modify velocity in average

FF mass after evaporation (A_{post}) → The EV method

- Energy loss corrections

Measurement using time-of flight (TOF) method

- Timing resolution : $\sigma_t \sim 150 \text{ ps}$
- Spatial resolution : $\sigma_{x,y} \sim 2 \text{ mm}$

Measurement using an energy detector + TOF

- Timing & position resolution similar to 2V
- Energy resolution $\Delta E/E \sim 1 \%$
- Energy loss profile $\rightarrow \sim Z$

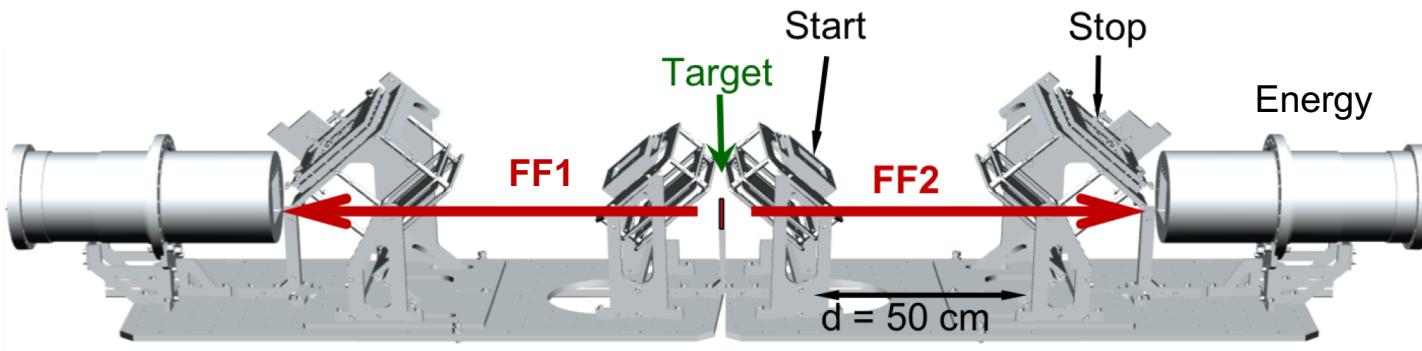
Emissive foils + MWPC

Fragment energy losses

- Thickness/homog. of materials
- Track reconstruction
- Good calc. of ΔE

Axial ionization chamber

Method



FF mass before evaporation (A_{pre}) → The 2V method

- Hyp: n evaporation does not modify velocity in average

FF mass after evaporation (A_{post}) → The EV method

- Energy loss corrections

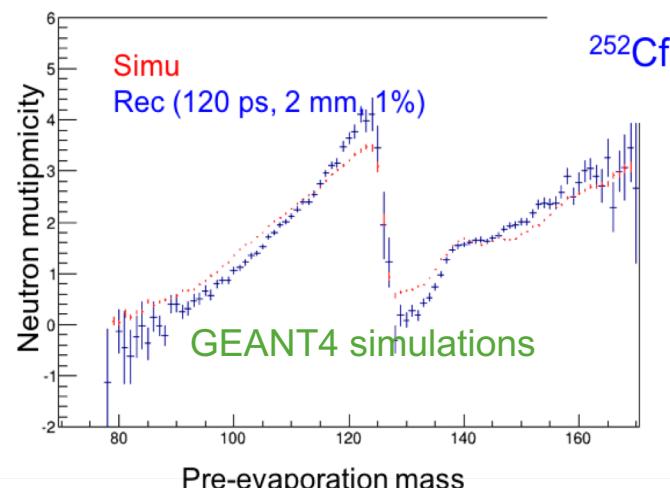
Measurement using time-of flight (TOF) method

- Timing resolution : $\sigma_t \sim 150 \text{ ps}$
- Spatial resolution : $\sigma_{x,y} \sim 2 \text{ mm}$

Measurement using an energy detector + TOF

- Timing & position resolution similar to 2V
- Energy resolution $\Delta E/E \sim 1 \%$
profile $\rightarrow \sim Z$

↓
Emissive foils + MWPC

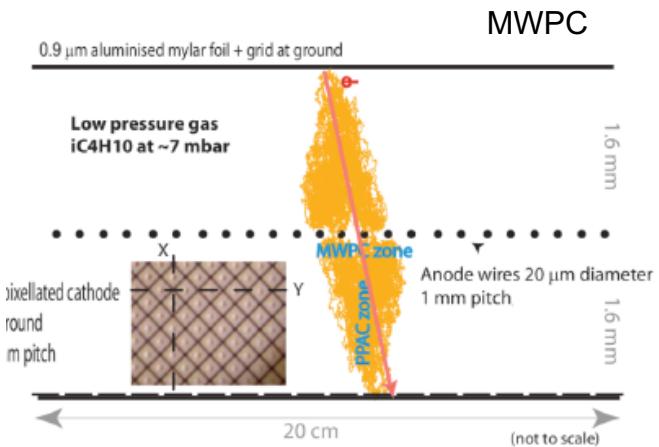


↓
Axial ionization chamber

ToF Detectors



Stop ($20 \times 14 \text{ cm}^2$)

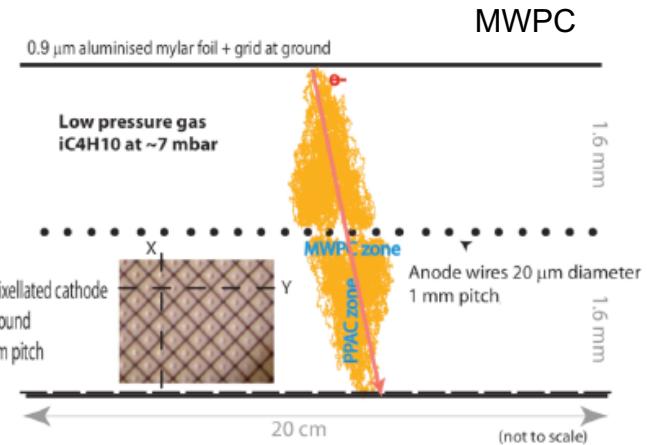


Analysis in progress

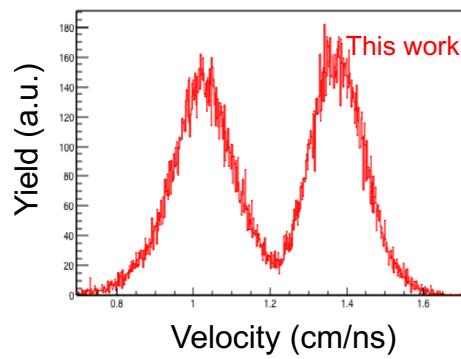
ToF Detectors



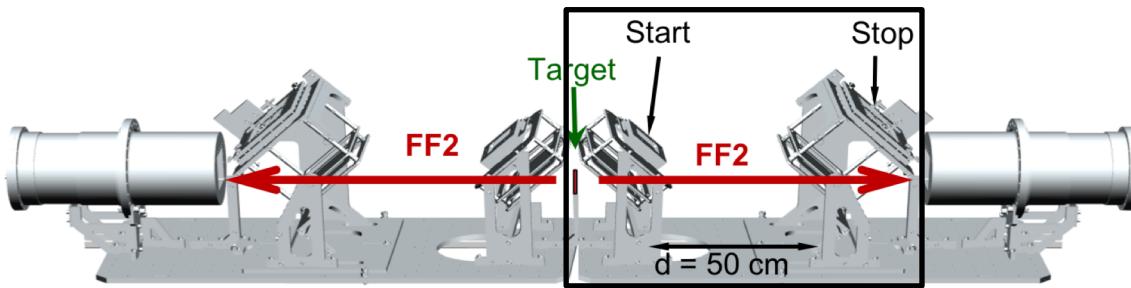
Stop ($20 \times 14 \text{ cm}^2$)



Analysis in progress



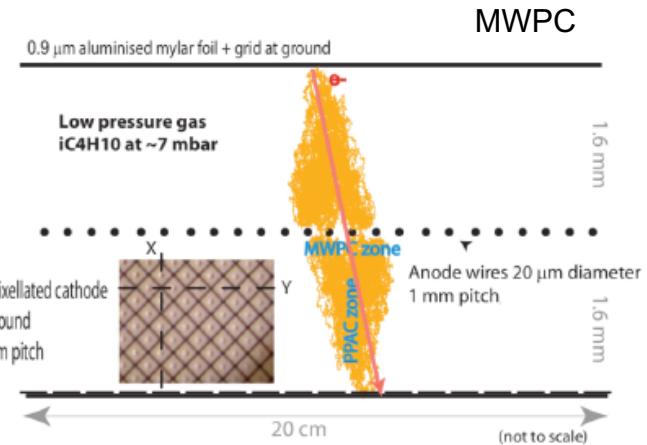
^{252}Cf source



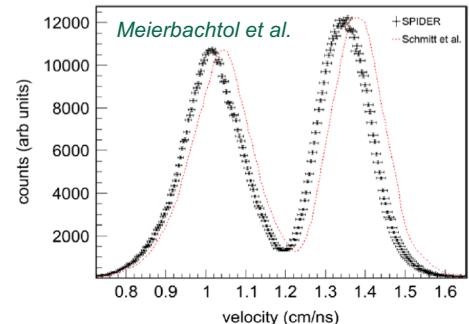
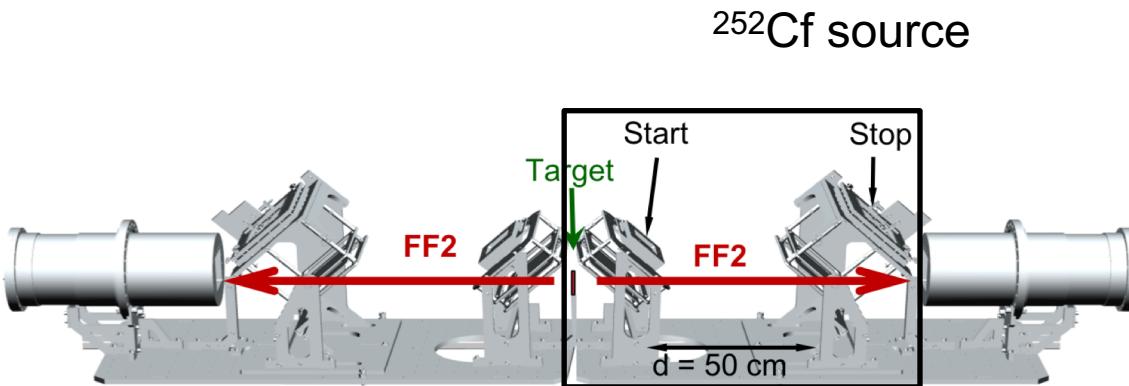
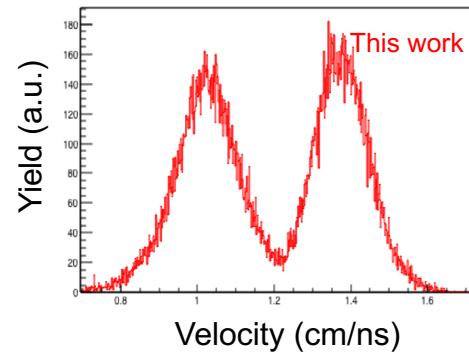
ToF Detectors



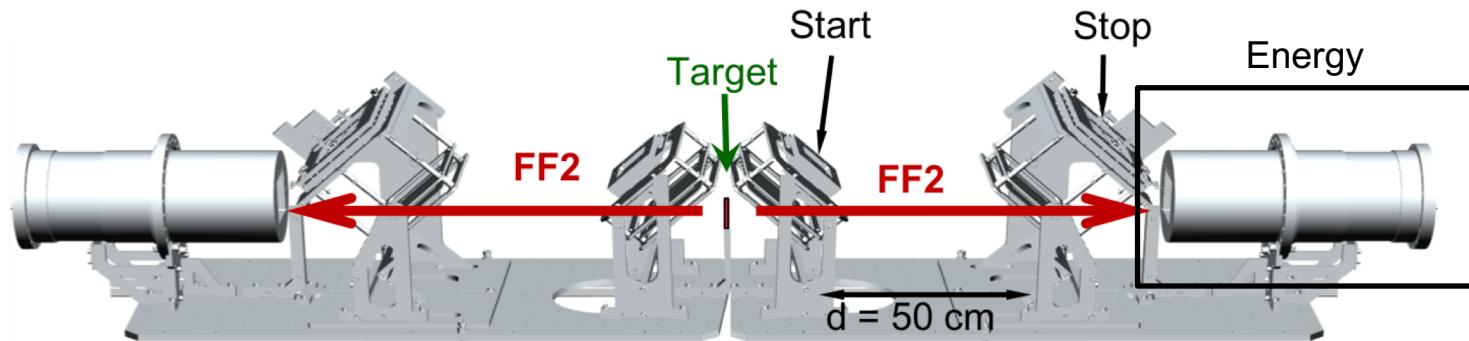
Stop ($20 \times 14 \text{ cm}^2$)



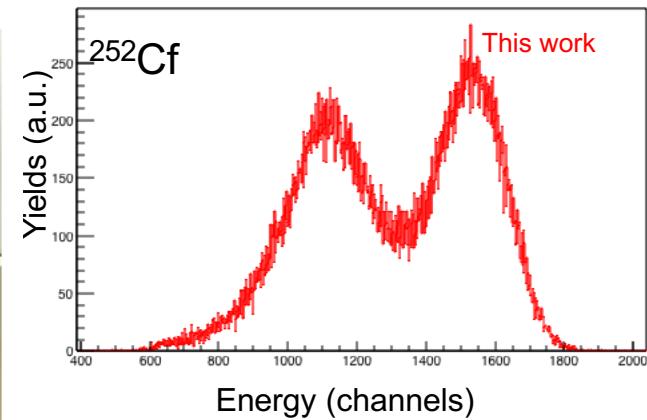
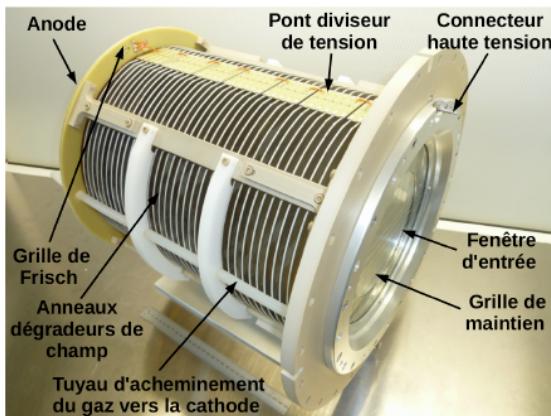
Analysis in progress



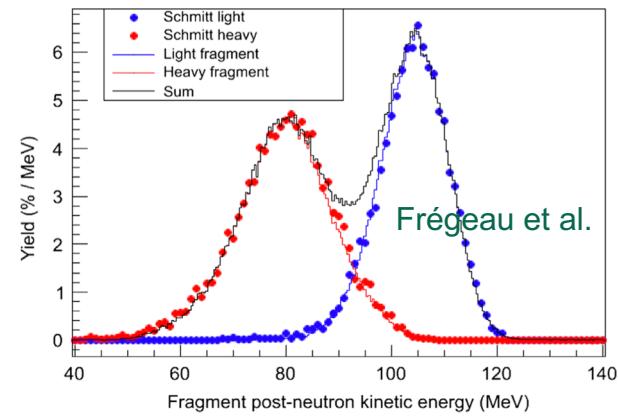
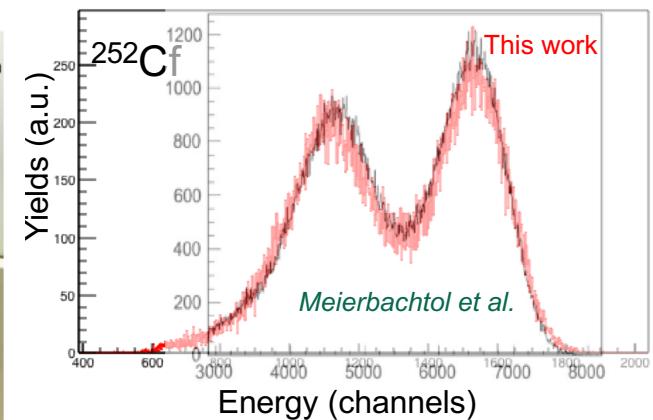
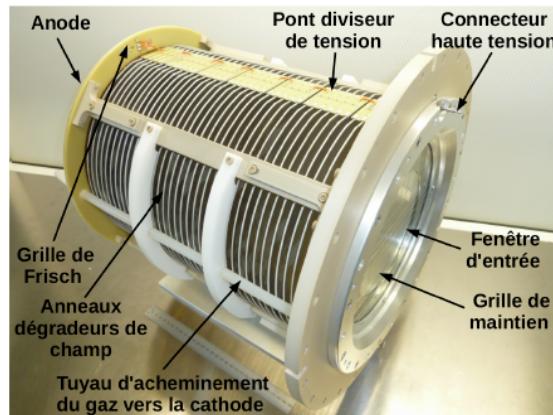
Energy Detector



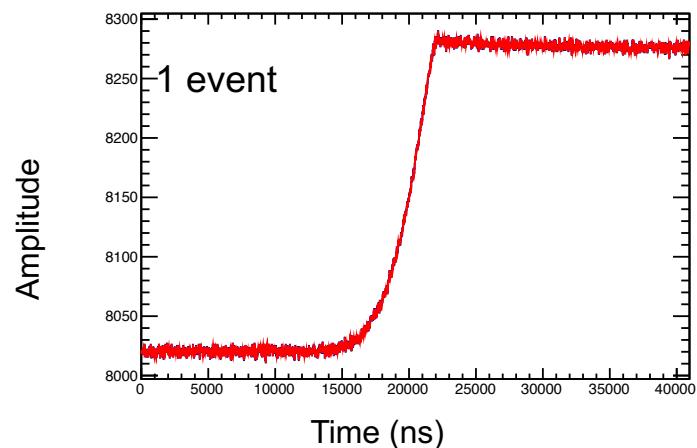
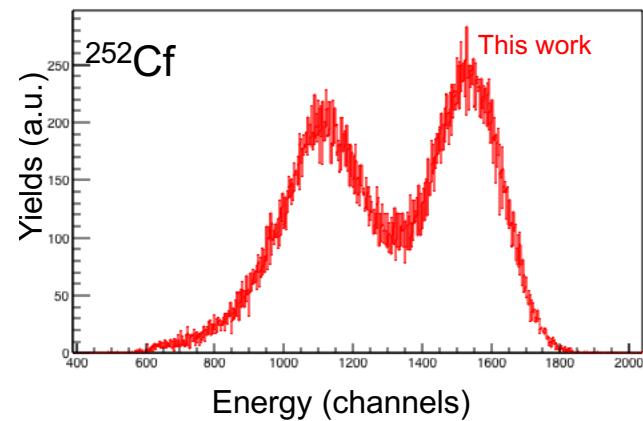
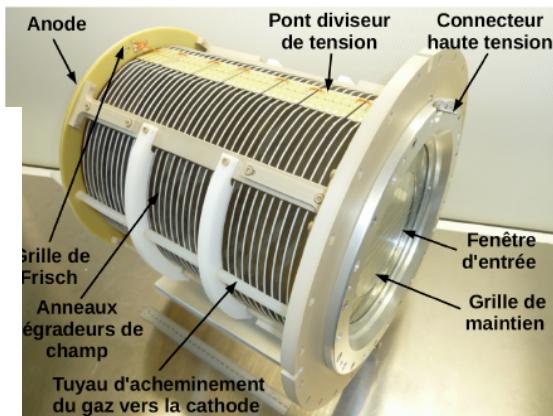
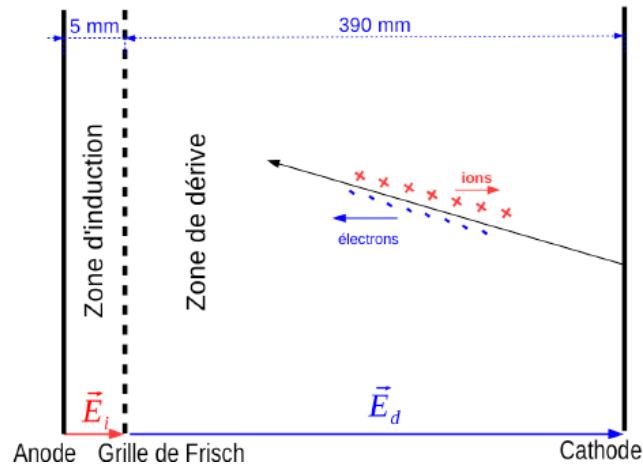
Energy Detector



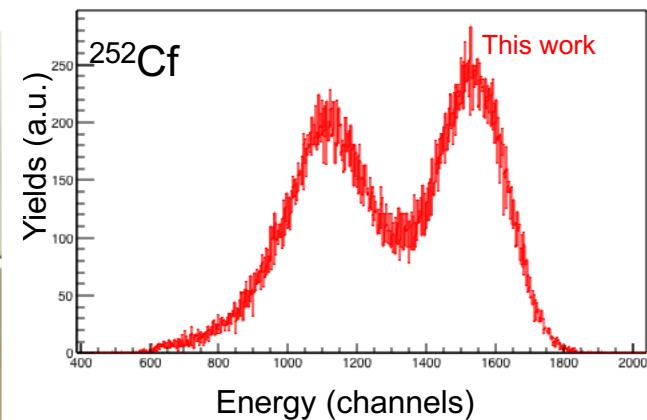
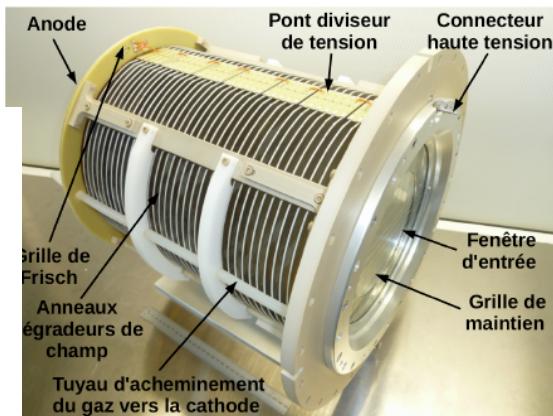
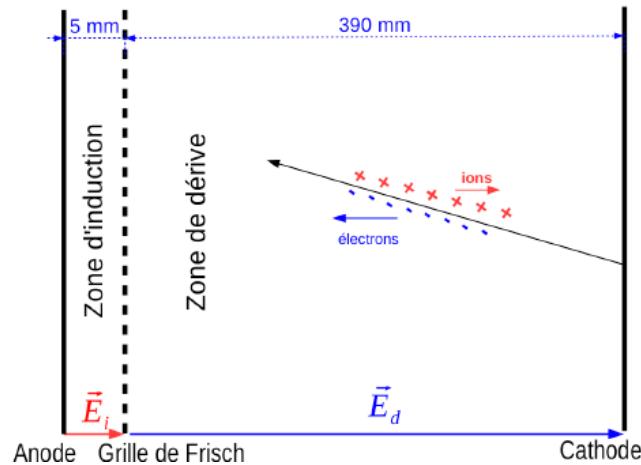
Energy Detector



Energy Detector



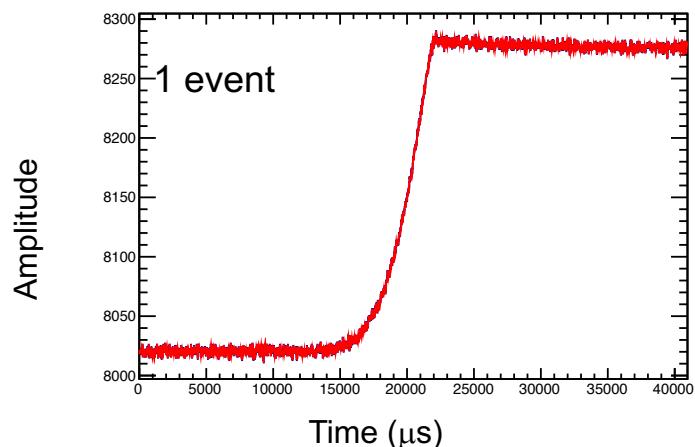
Energy Detector



- ❖ Calibration experiment at IPNO
- ❖ Energy and energy loss profile studies

- (Br, I) between 60-100 MeV
- Elastic scattering at 30°

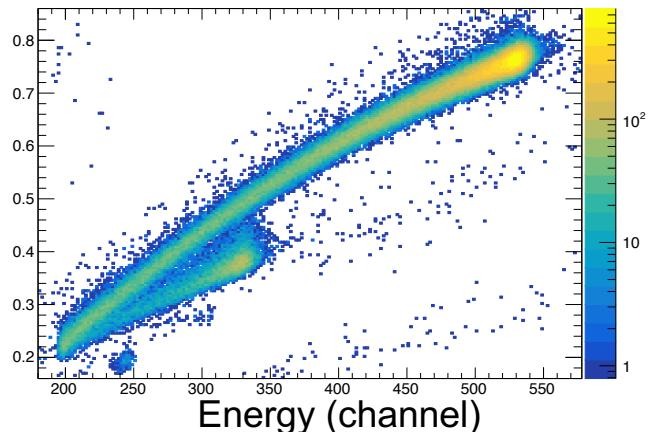
E. Berthoumieux & A. Zamel



D. Doré

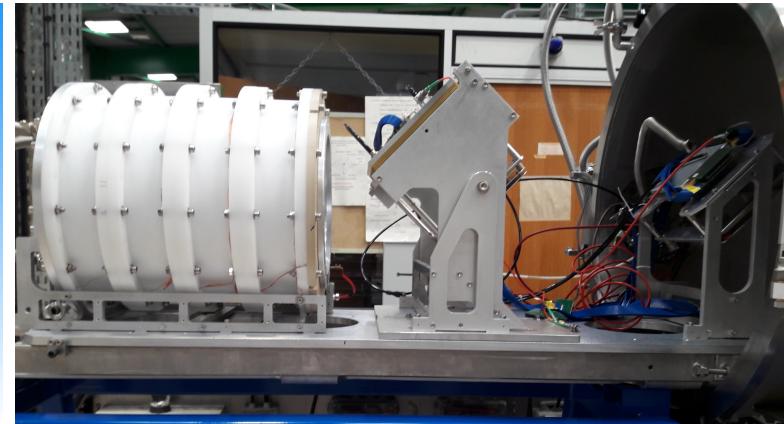
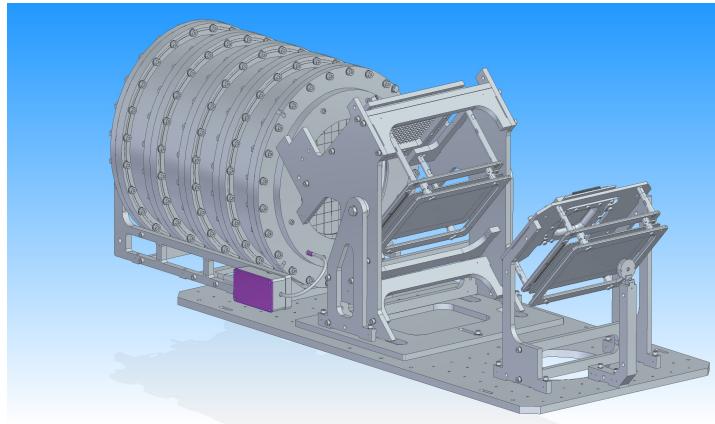
Wonder 2018

Max amplitude of derivative

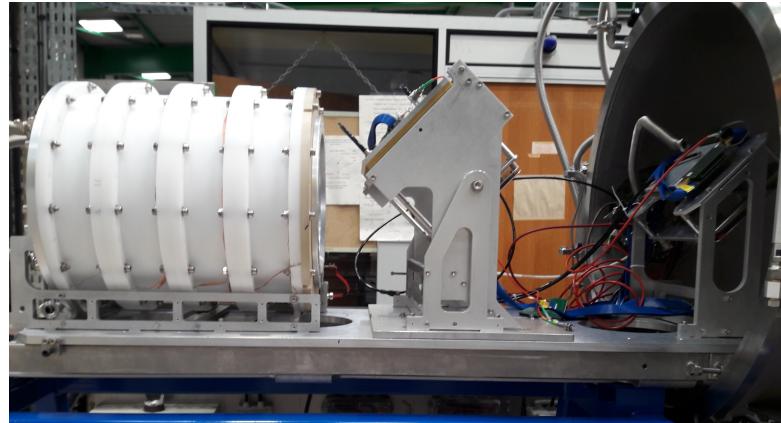
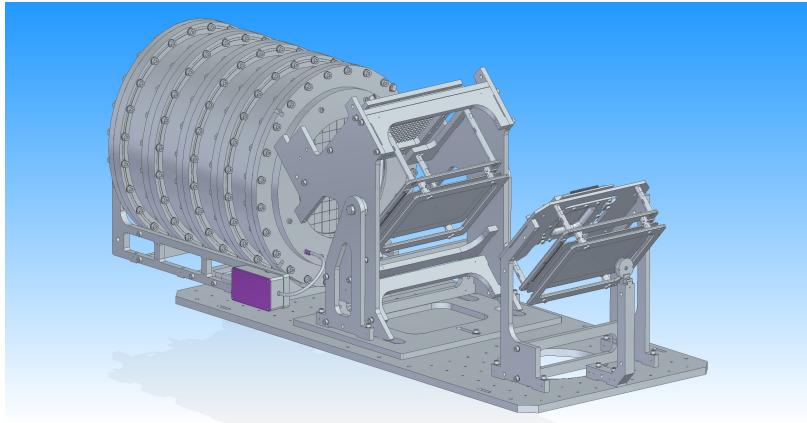


Page 13

First Arm of FALSTAFF

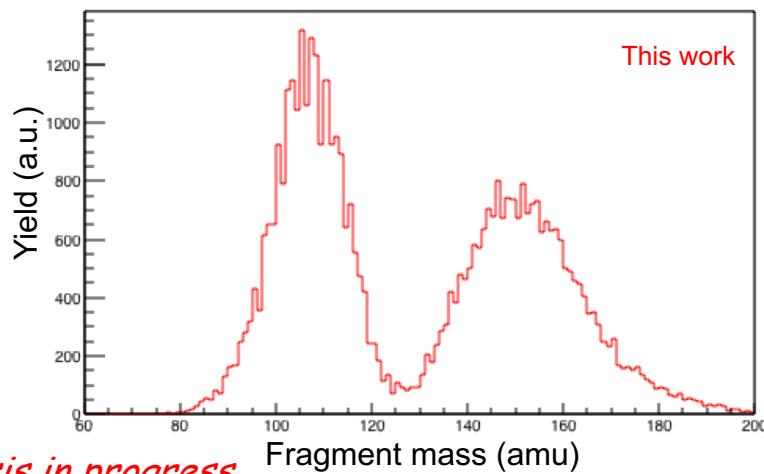


First Arm of FALSTAFF



With a ^{252}Cf source and using the EV method...

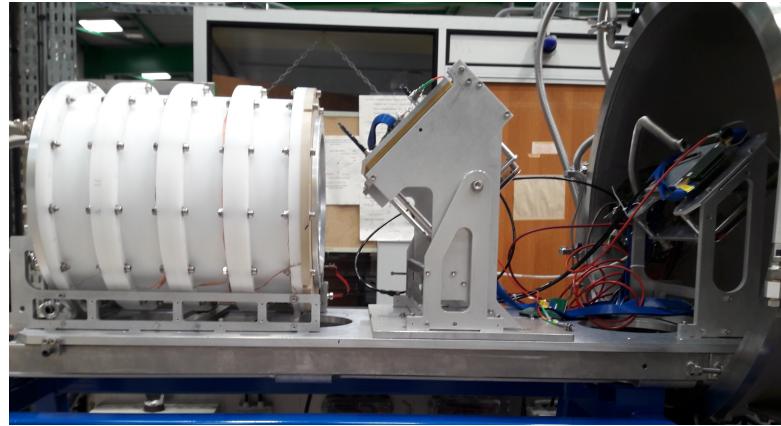
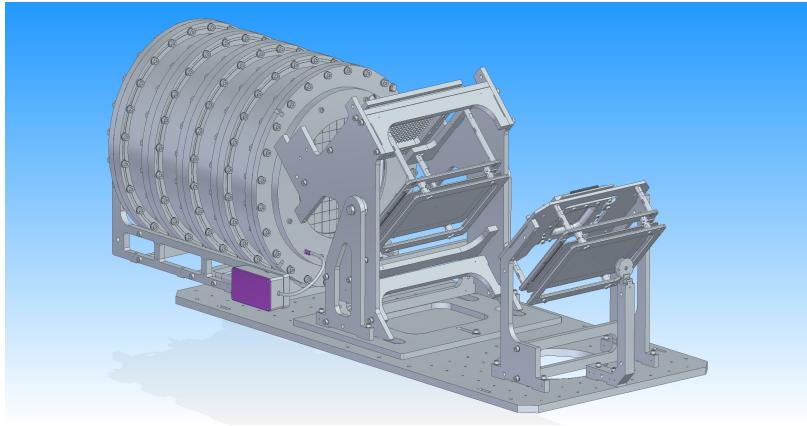
Iterative procedure
Energy loss corrections



Analysis in progress

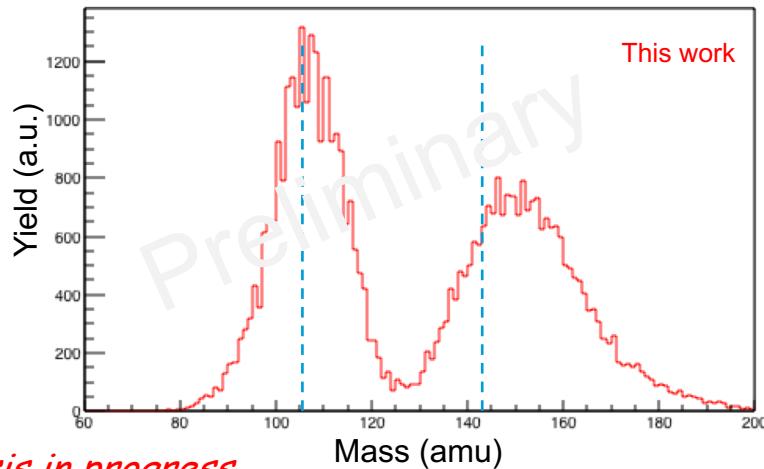
Loss of heavy fragments due to start detector problem

First Arm of FALSTAFF



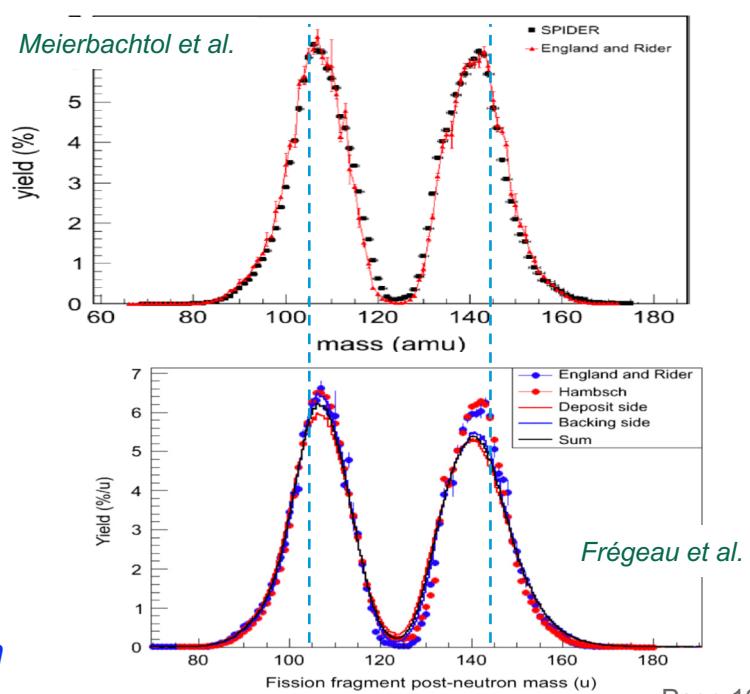
With a ^{252}Cf source and using the EV method...

Iterative procedure
Energy loss corrections



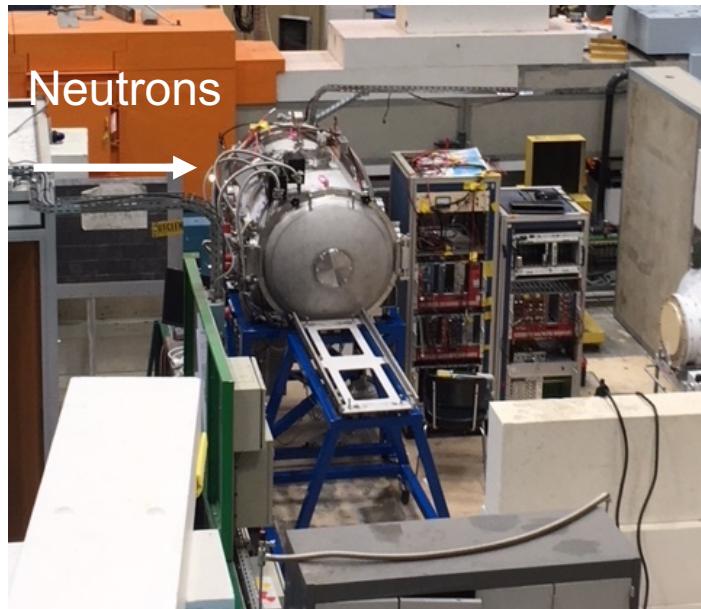
Analysis in progress

Loss of heavy fragments due to start detector problem
Distortion of the distribution



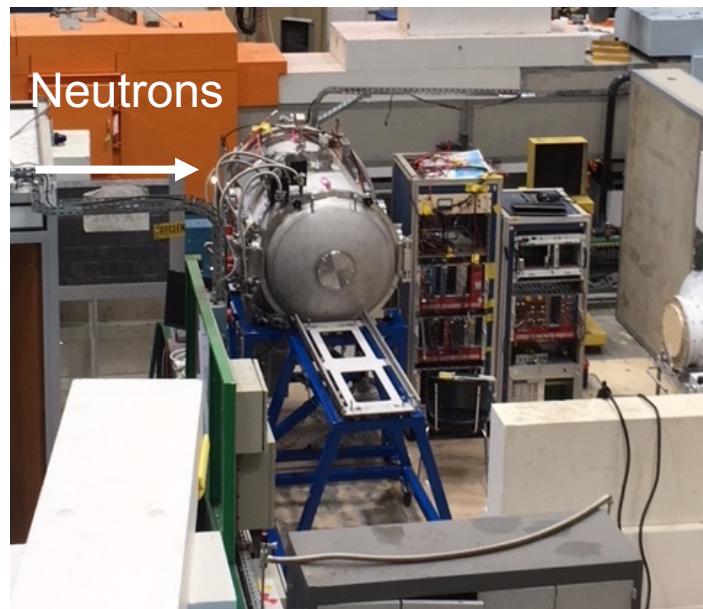
Experiment at the Orphée reactor (Saclay)

- ✓ Target : ^{235}U (8 & 20 μg , $\phi = 1 \text{ cm}$), CEA/DIF
- ✓ Thermal beam : $10^8 \text{ n/cm}^2/\text{s}$
- ✓ Two parts : June 2018, Sept-Oct 2018

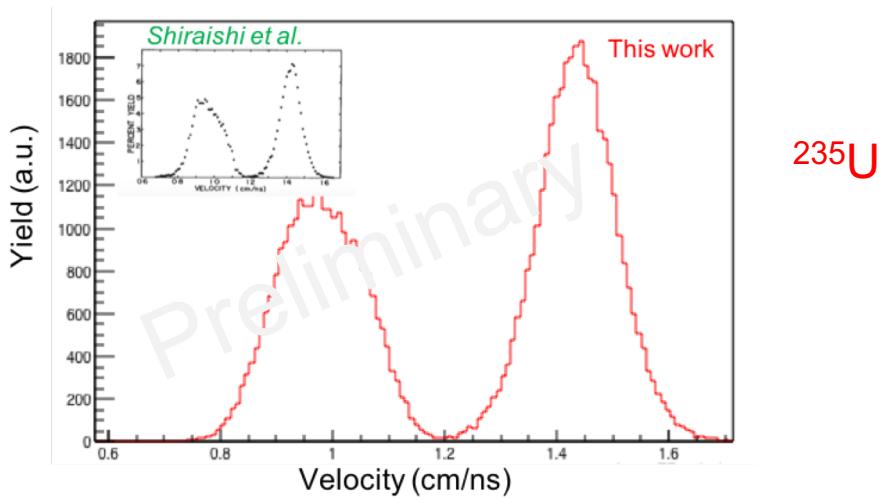


Experiment at the Orphée reactor (Saclay)

- ✓ Target : ^{235}U (8 & 20 μg , $\phi = 1 \text{ cm}$), CEA/DIF
- ✓ Thermal beam : $10^8 \text{ n/cm}^2/\text{s}$
- ✓ Two parts : June 2018, Sept-Oct 2018

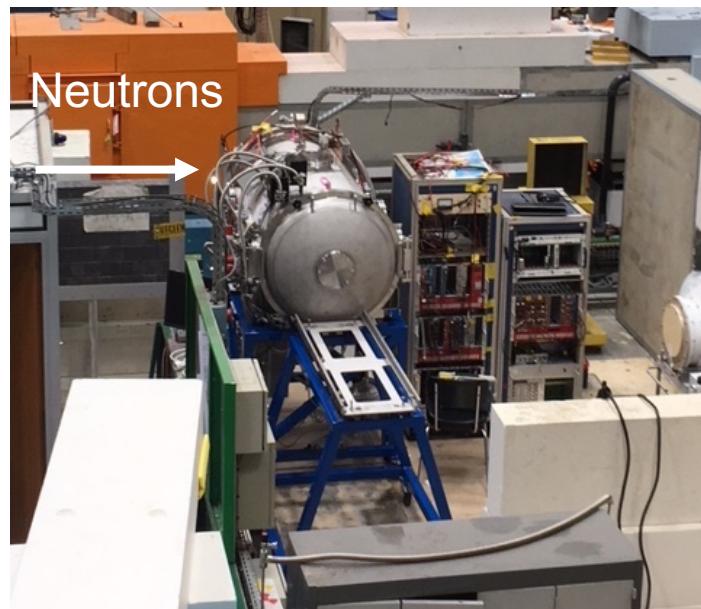


Analysis in progress

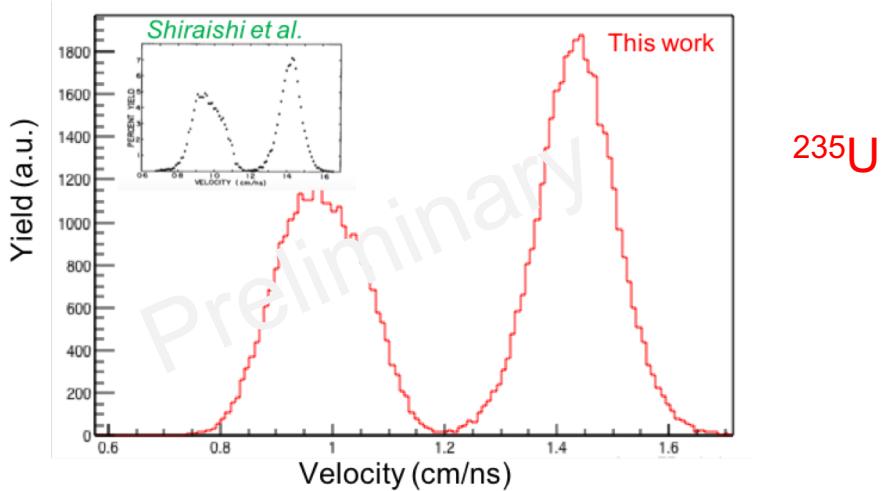


Experiment at the Orphée reactor (Saclay)

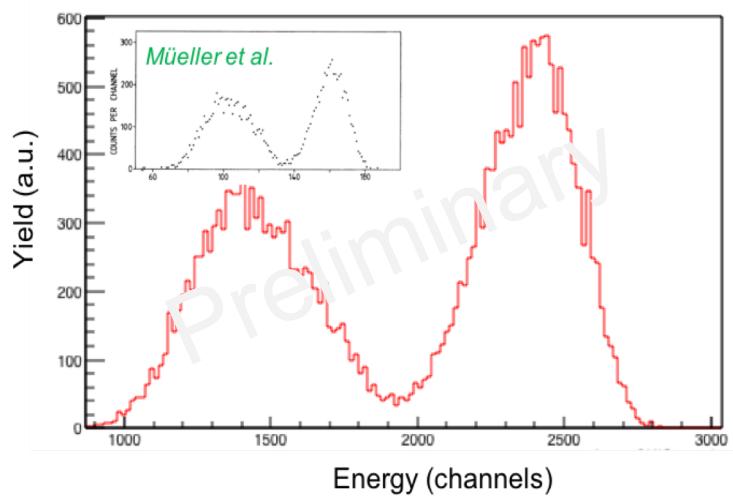
- ✓ Target : ^{235}U (8 & 20 μg , $\phi = 1 \text{ cm}$), CEA/DIF
- ✓ Thermal beam : $10^8 \text{ n/cm}^2/\text{s}$
- ✓ Two parts : June 2018, Sept-Oct 2018



Analysis in progress



^{235}U

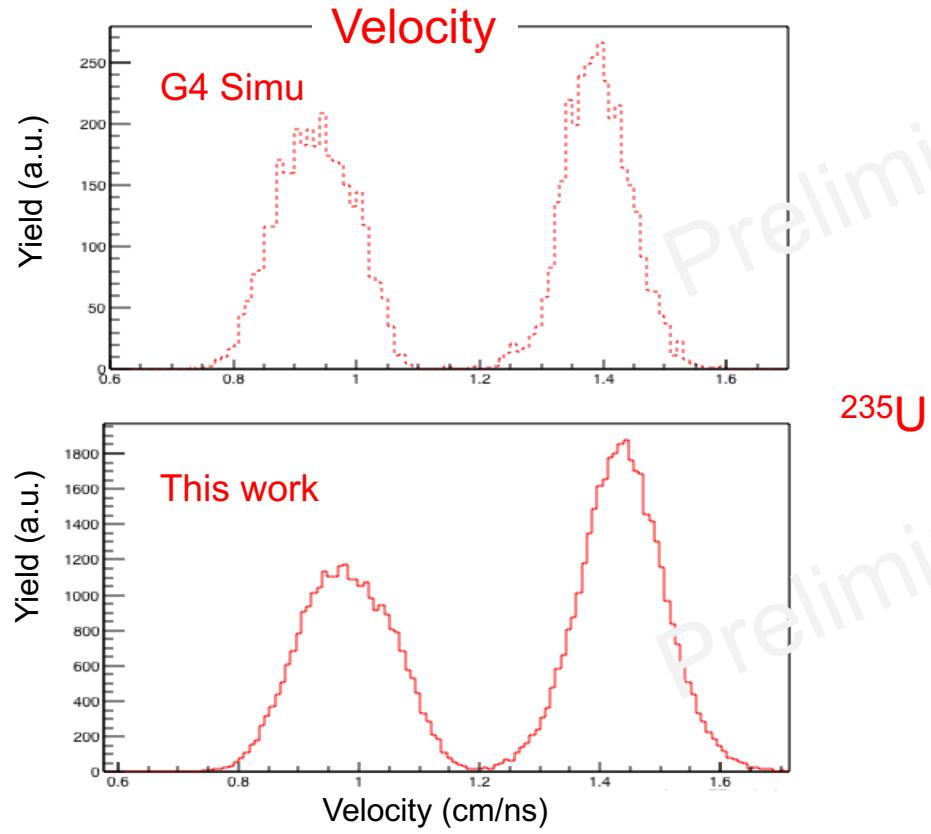


Comparisons Data & G4 Simulations

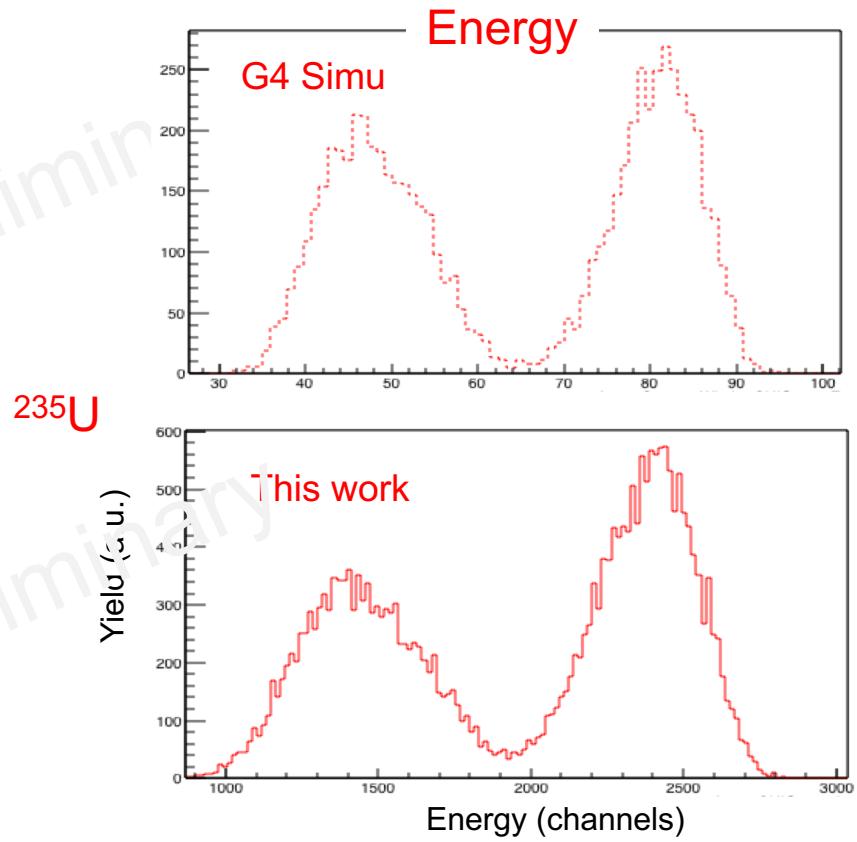
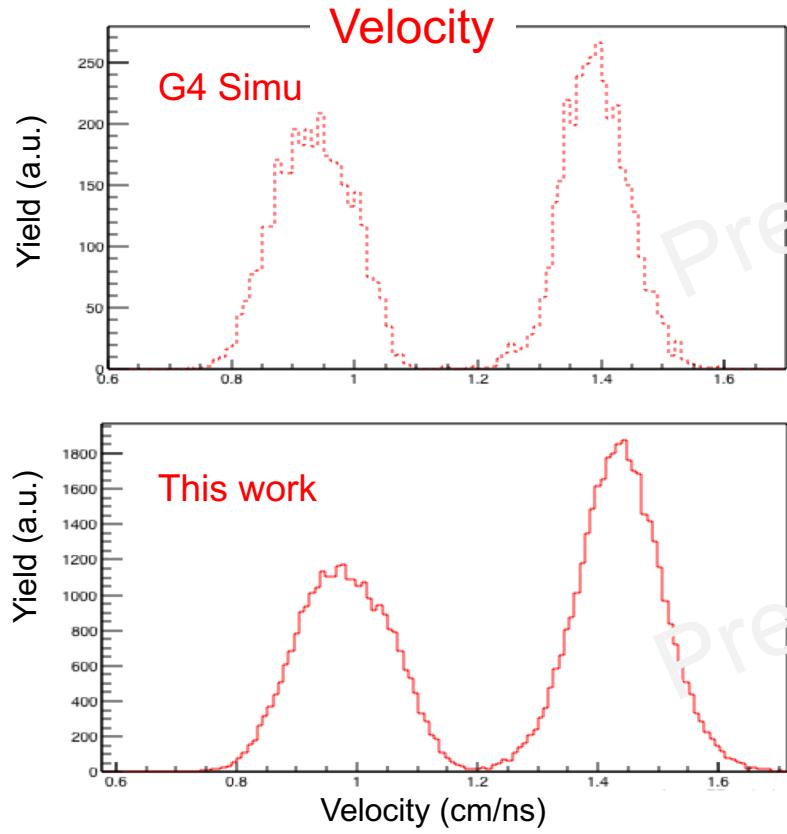
G4 simulations

- adjust simulated resolutions to reproduce 1-arm data
- perform 2-arm simulations and check if the results are good enough to study the correlation between neutron multiplicity and pre-fragment mass with 2 arms

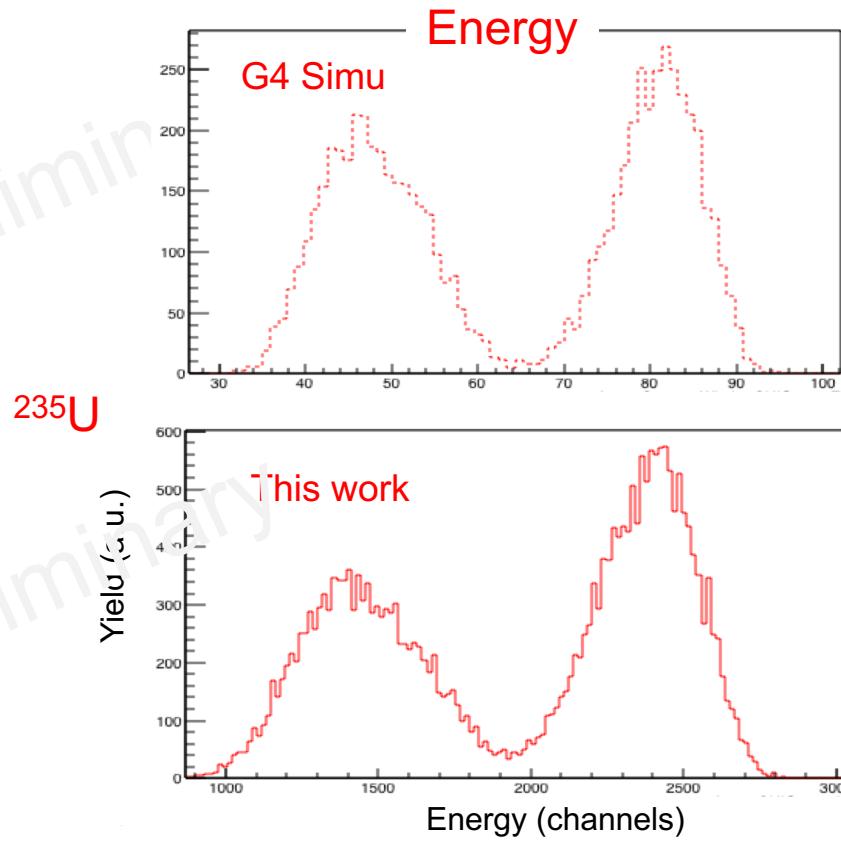
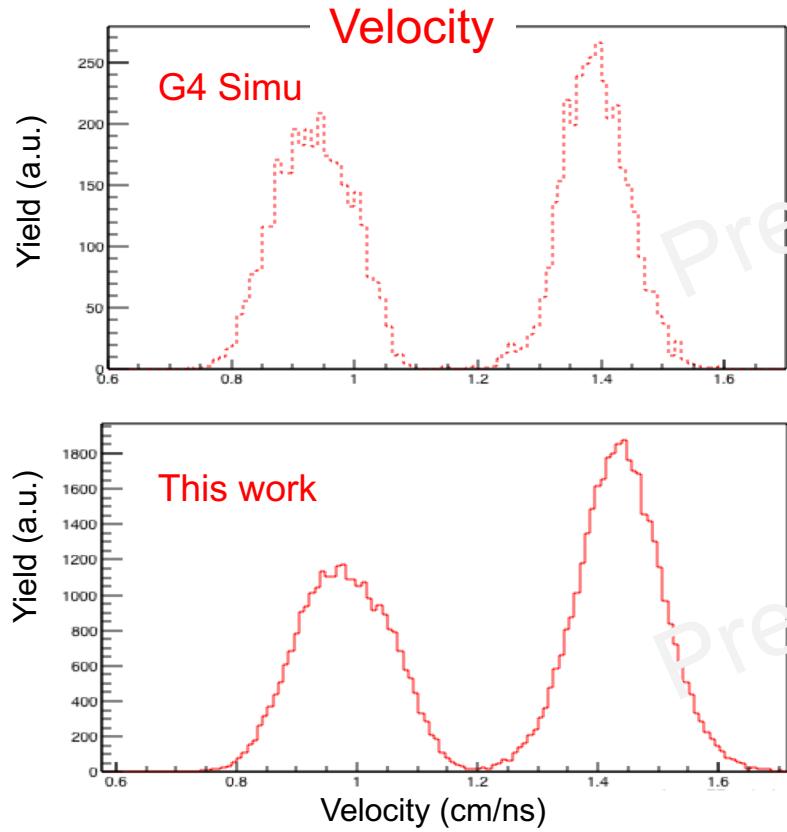
Comparisons Data & G4 Simulations



Comparisons Data & G4 Simulations

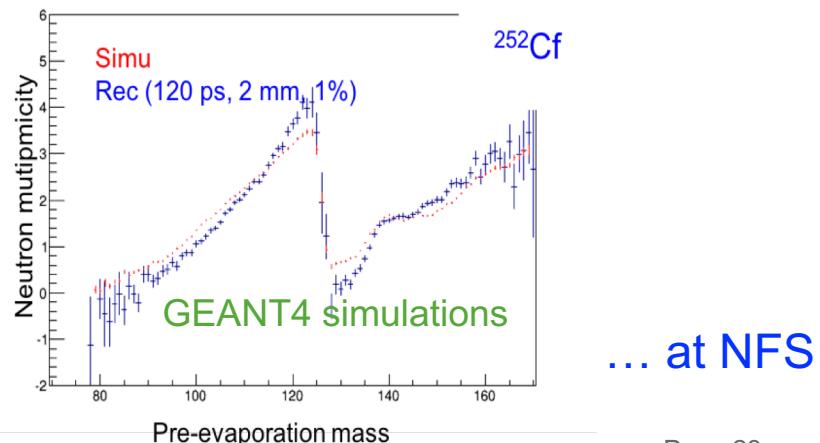


Comparisons Data & G4 Simulations

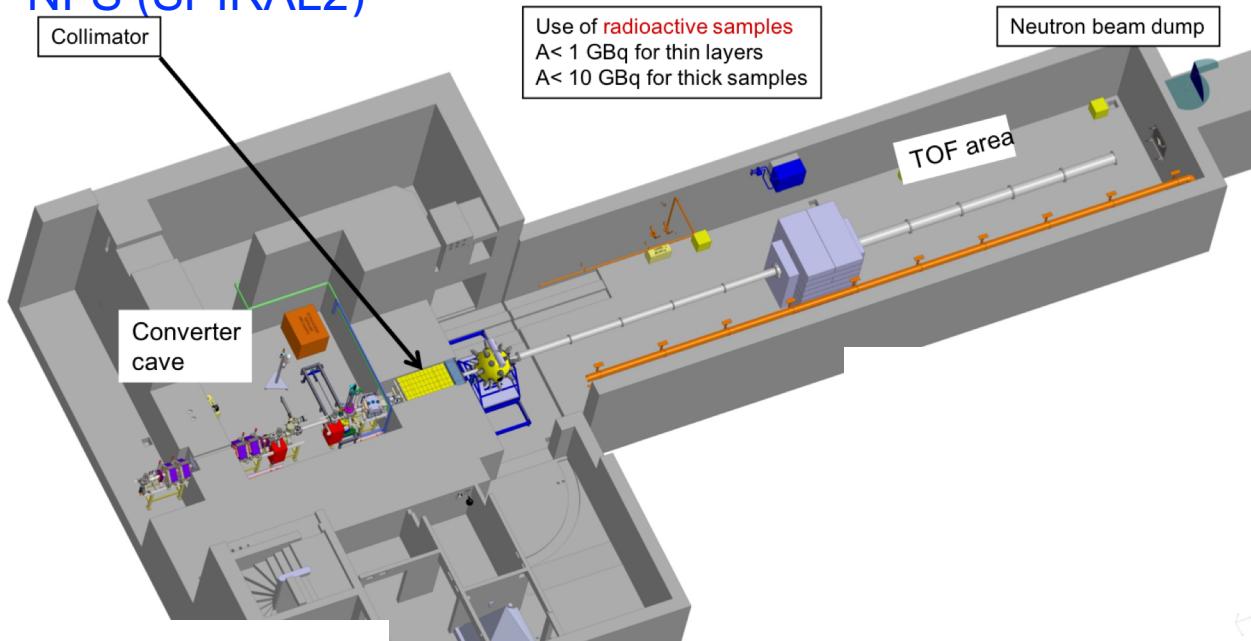


- Rather good agreement
- Inhomogeneities not taken into account
- Other variables to be compared

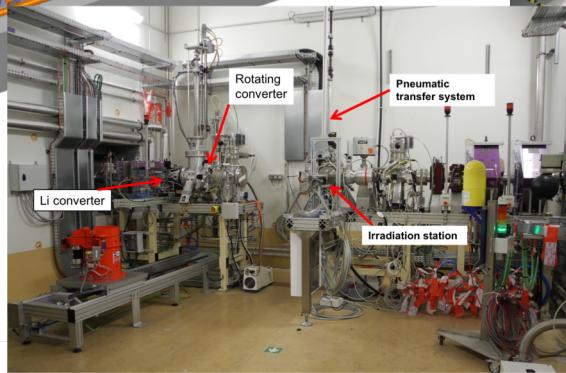
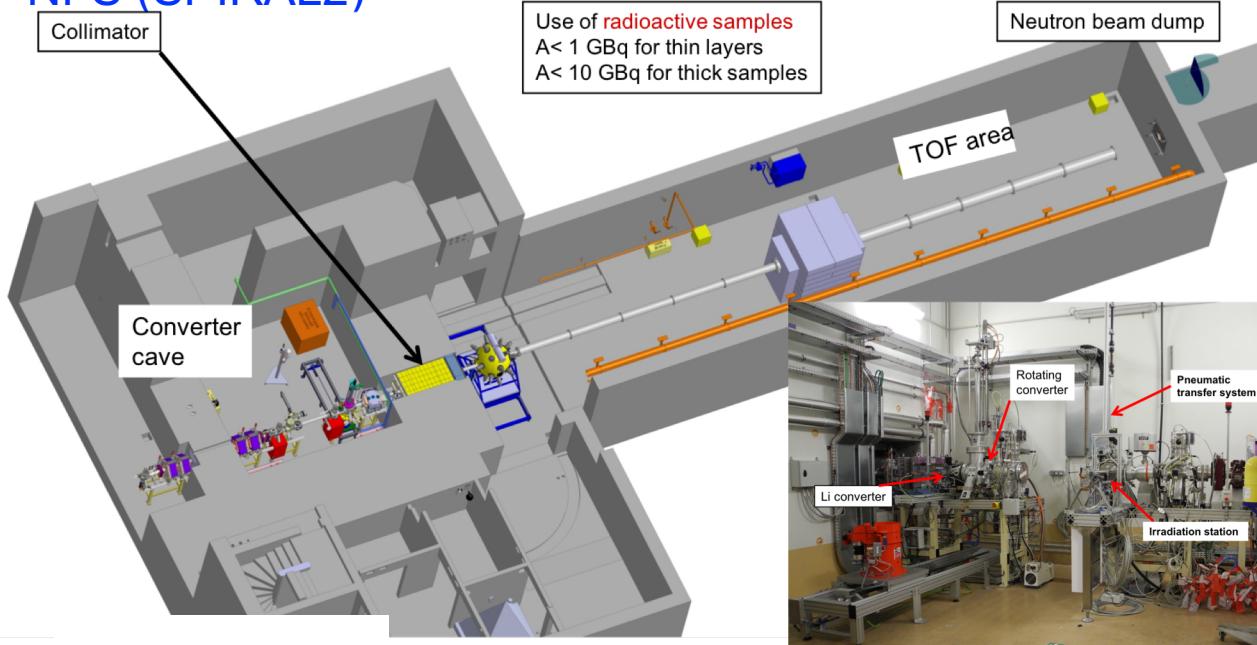
Exp. resolutions probably suitable
for 2-arm studies ...



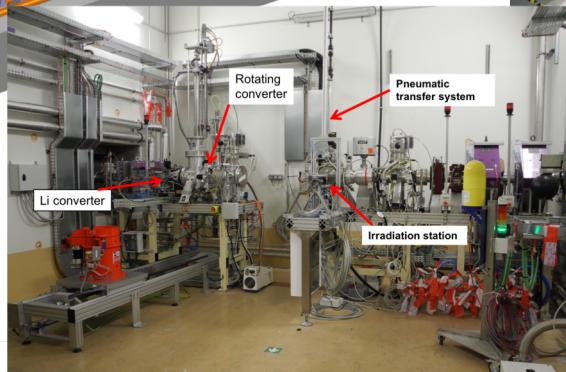
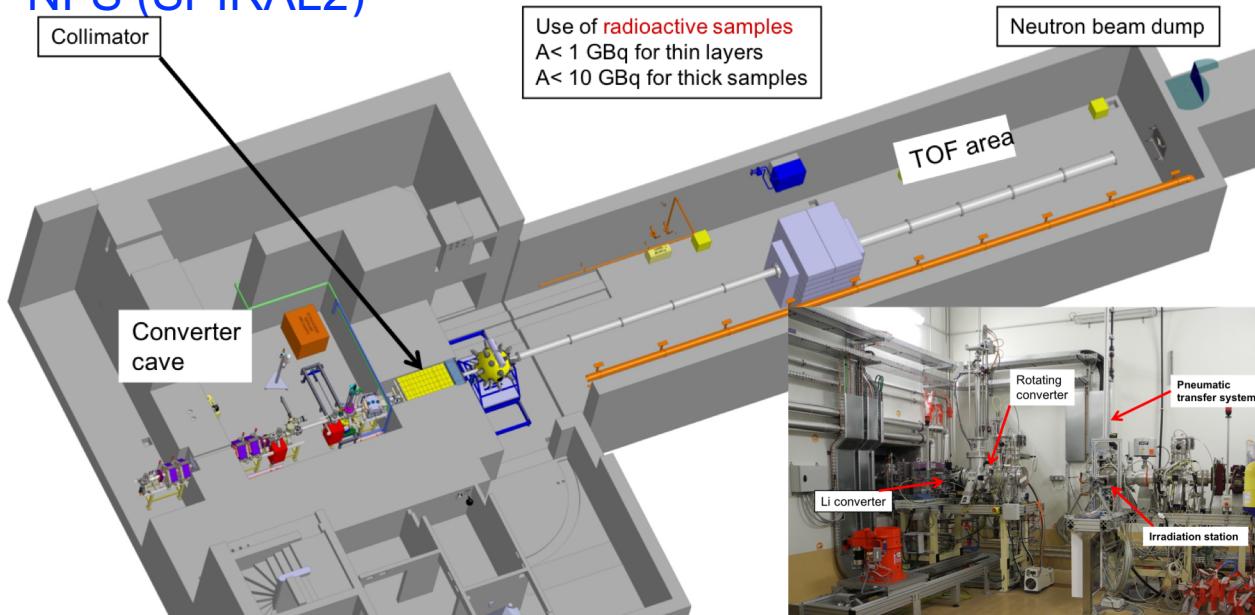
NFS (SPIRAL2)



NFS (SPIRAL2)



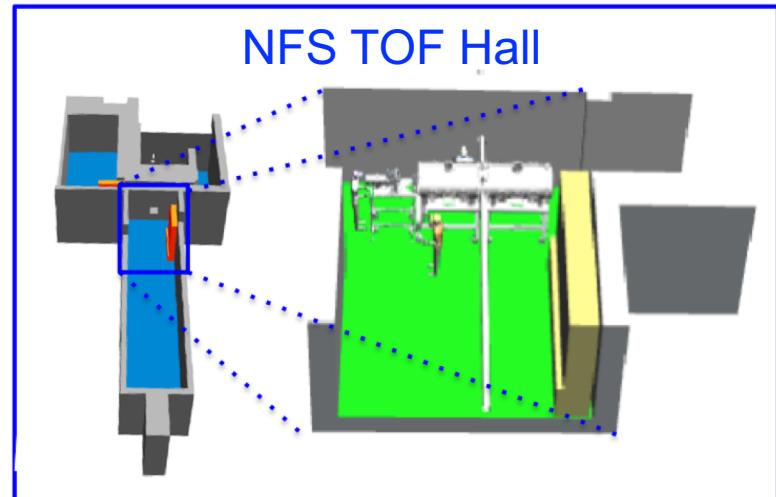
NFS (SPIRAL2)



≥ 2021 : FALSTAFF @ NFS

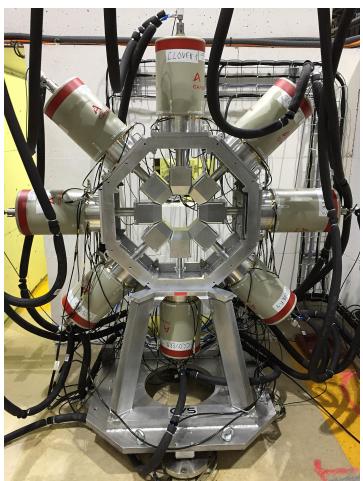
- 2nd arm to fund and build

- Mult neut vs fragment mass
- $^{238-235}\text{U}$, ^{239}Pu , ^{232}Th , ^{237}Np

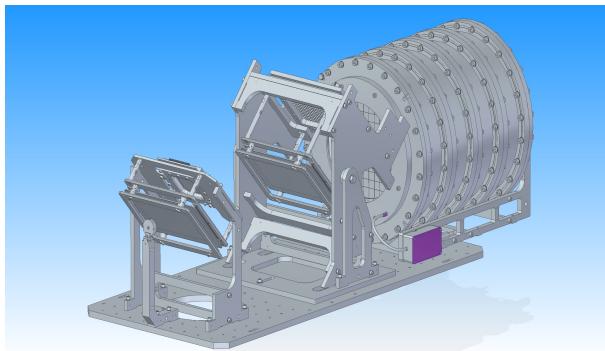


FALSTAFF @ FIPPS (gamma ray spectrometer of ILL)

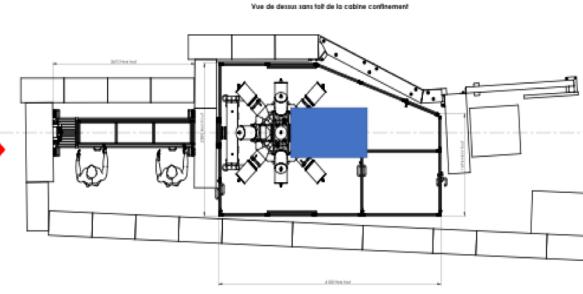
FIPPS



FALSTAFF

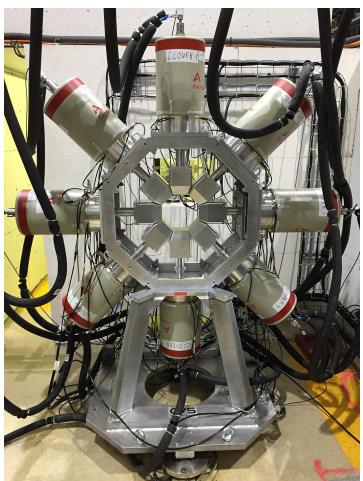


neutrons

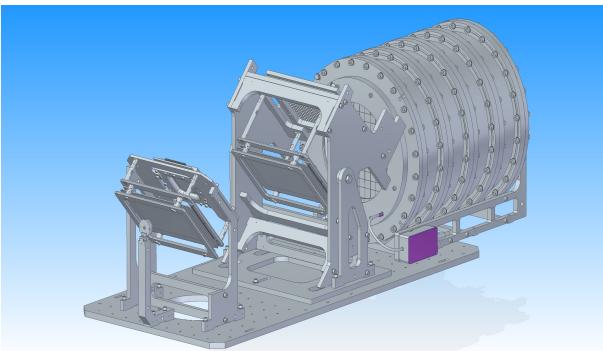


*T. Materna et al.
Project to be proposed to the next
ILL subcommittee*

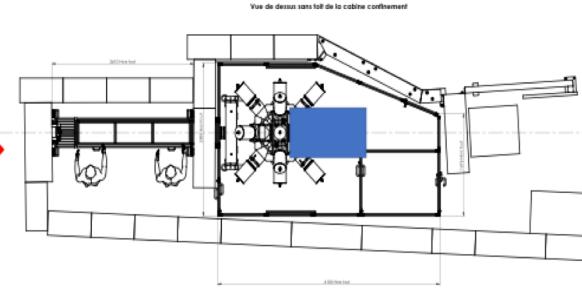
FIPPS



FALSTAFF



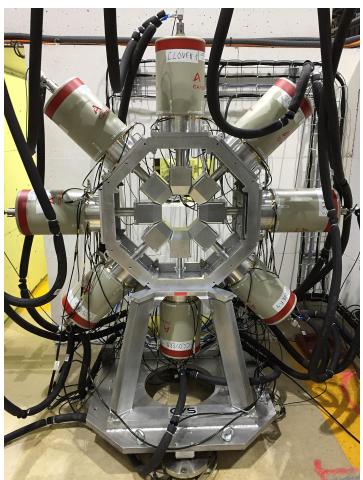
neutrons



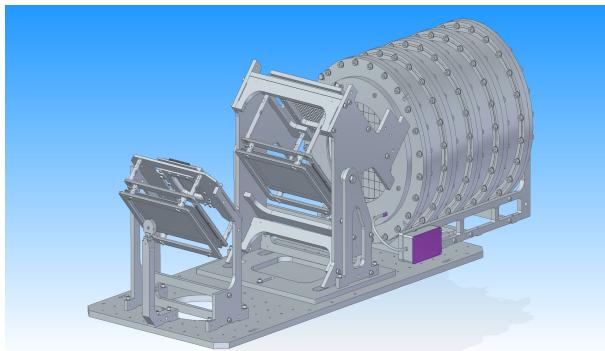
*T. Materna et al.
Project to be proposed to the next
ILL subcommittee*

- ❖ Calibrate Falstaff with well produced fully identified fission fragments

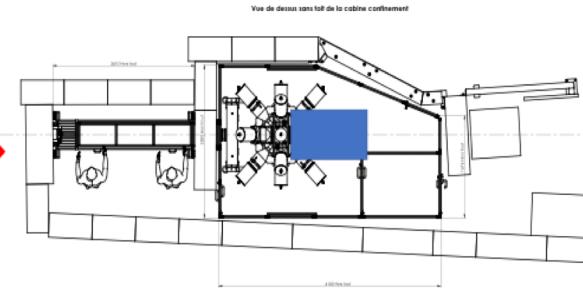
FIPPS



FALSTAFF



neutrons



*T. Materna et al.
Project to be proposed to the next
ILL subcommittee*

- ❖ Calibrate Falstaff with well produced fully identified fission fragments
- ❖ Nuclear data with (γ, γ, f) measurement in thermal fission with the best identification ever
 - Method :
 - FALSTAFF : E, V of one fragment \rightarrow filter events with A_1 with $\delta A_1 = 2$
 - FIPPS : - identification of one γ -ray transition to the second fragment $\rightarrow (A_2, Z_2)$
 - study of other γ -rays from the cascade in the second fragment
- ➔ Study of FF de-excitation and measurement of the fission yields

Summary

- First arm of FALSTAFF is running with source AND neutron beam
- Expected resolutions seem to be reached
 - ✓ Very promising results with the first arm of FALSTAFF
 - ✓ Room for improvement
- Expecting the funding of the second arm
- Preparation of the experiment at FIPPS

Open to new collaborations !

Performance validation of the FALSTAFF first arm: **^{252}Cf and ^{235}U fission fragment characterisation**

D. Doré¹⁾, E. Berthoumieux¹⁾, Q. Deshayes¹⁾, L. Thulliez¹⁾,
M.O. Frégeau²⁾, X. Ledoux²⁾, J. Pancin²⁾, S. Oberstedt³⁾

1) Irfu, CEA, Université Paris-Saclay, France

2) GANIL, Caen, France

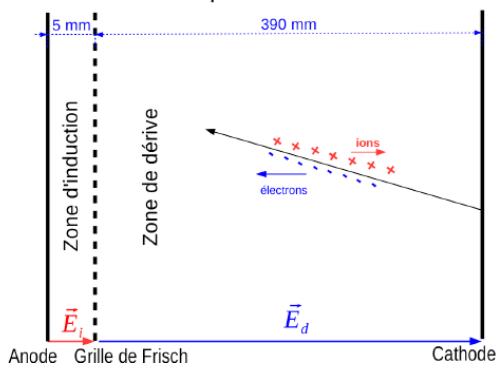
3) European Commission, Joint Research Centre, Geel, Belgium

Thanks to:

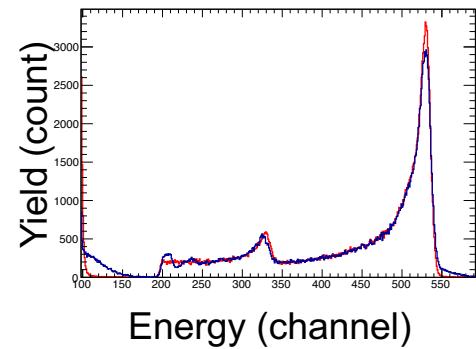
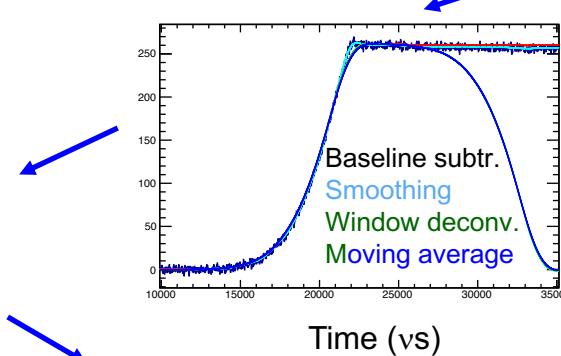
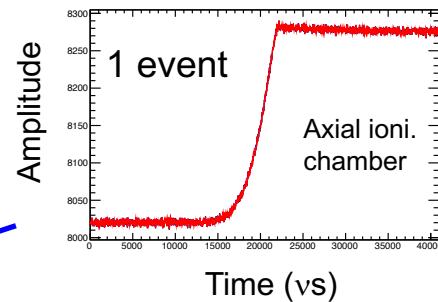
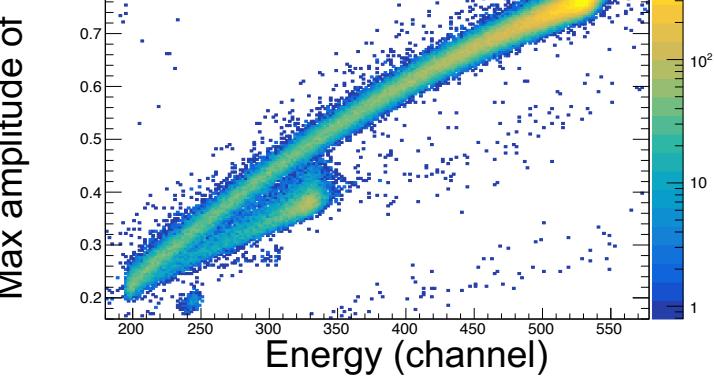
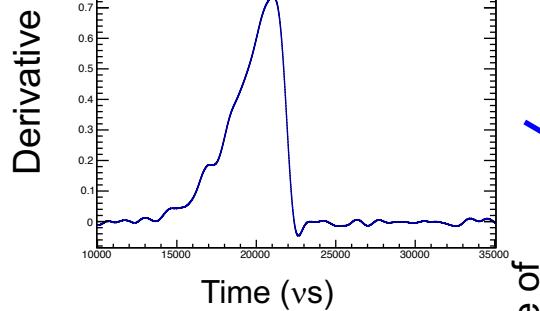
- DEDIP: P. Legou, M. Combet, M. Kebbiri, A. Marcel, J-P. Mols
- DPhN : P. Champion
- Irfu : E. Blanchard
- DPN/CEA-DIF : A. Chatillon, G. Bélier, V. Méot
- Orphée Team

Ionization chamber

- ❖ Calibration experiment at IPNO
 - ❖ Energy and energy loss profile studies



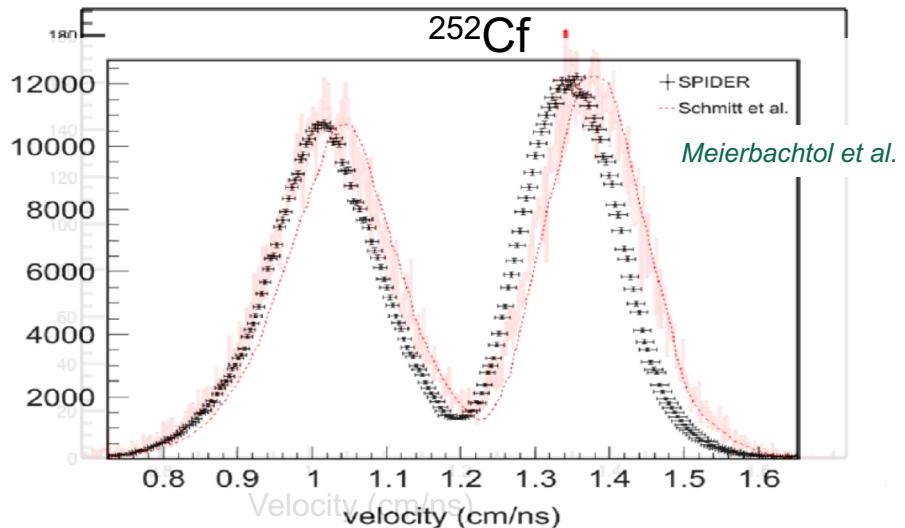
- (Br, I) between 60-100 MeV
- Elastic scattering at 30°



E. Berthoumieux & A. Zamel

ToF Detectors

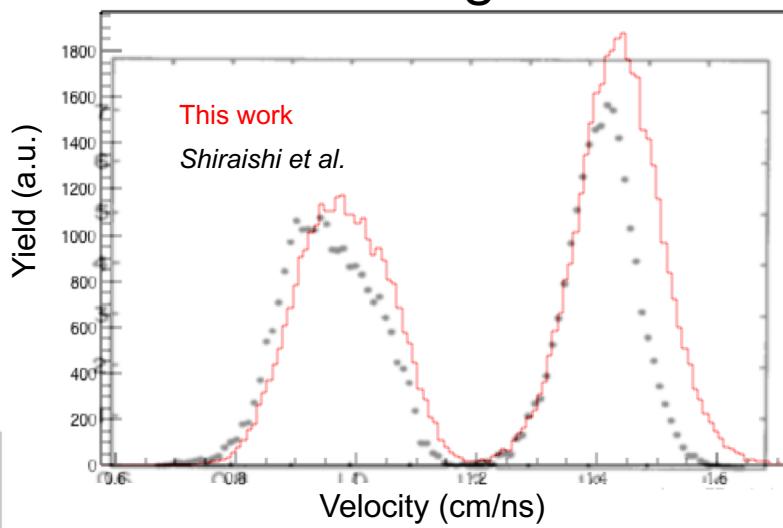
Yield (a.u.)



Velocity (cm/ns)

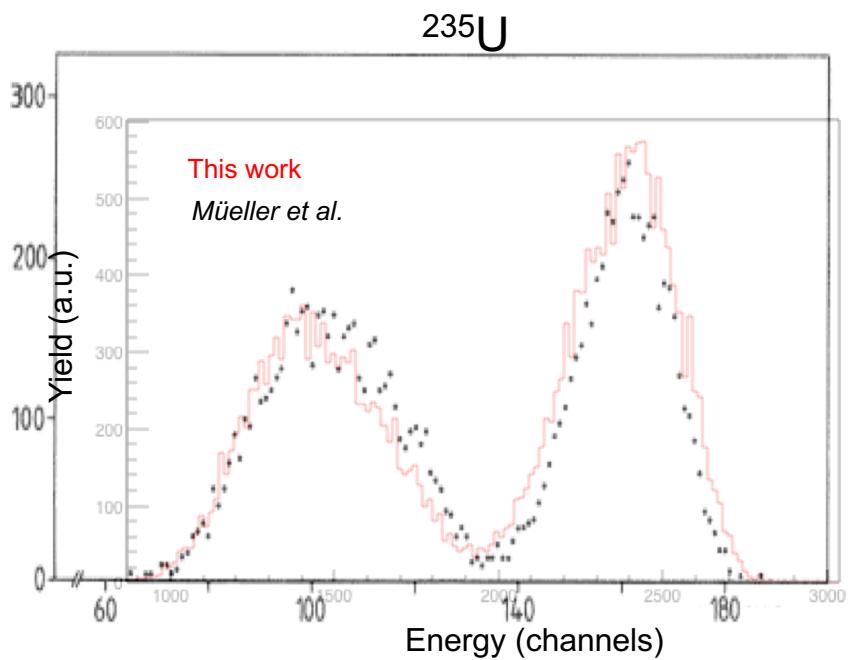
Meierbachtol et al.

^{235}U



This work

Shiraishi et al.



This work

Mueller et al.