DE LA RECHERCHE À L'INDUSTRIE

Développement du spectromètre FALSTAFF

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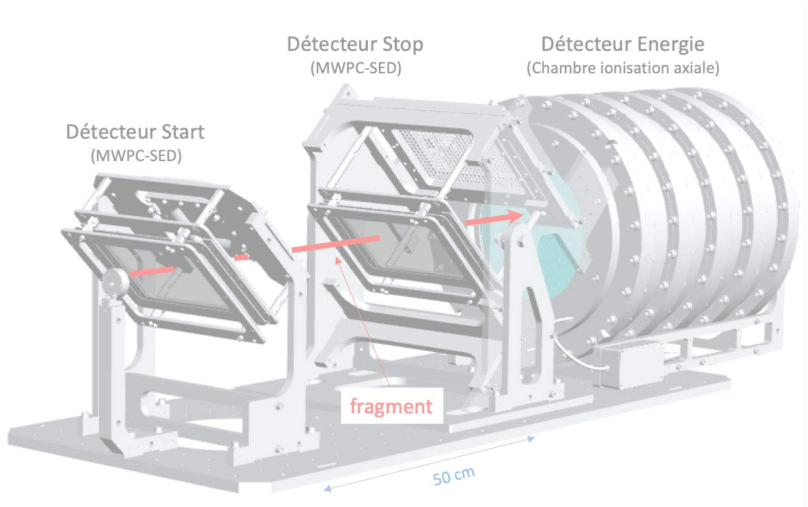


Other fundings

CEA/DEN, P2IO

www.cea.fr

FALSTAFF was developed to

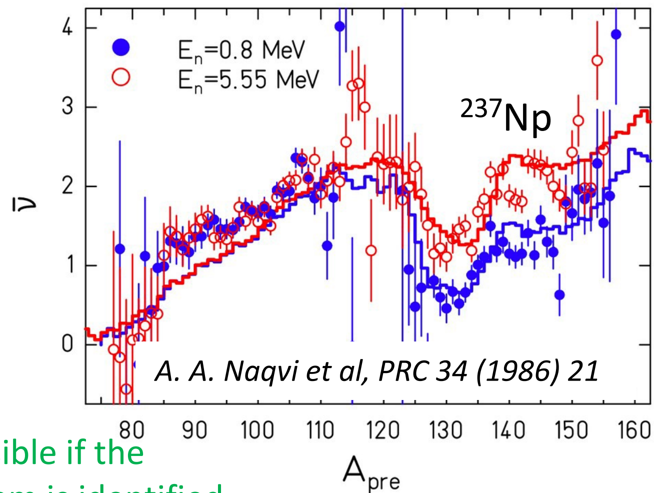
- Improve our fission process knowledge
  - *configurations at scission*
  - *excitation energy sharing*
  - *shell effects disappearance*
  - *…*
- Provide data for models and/or applications
  - *FIFRELIN (de-excitation model)*
  - *Waste management*
  - *Production of exotic nuclei*
  - *…*

With FALSTAFF we will study:

- fragments produced in fast neutron-induced domain (direct kinematics)
- the excitation energy sharing between fission fragments (neutron multiplicity)
- the fragment deformation (kinetic energy)
- the **evolution** of fragment masses and kinetic energies with the excitation energy over a large range

Available data
- mainly for thermal neutrons,
- ^{235}U,
- specific fragment isotopes and not for the whole fragment mass domain

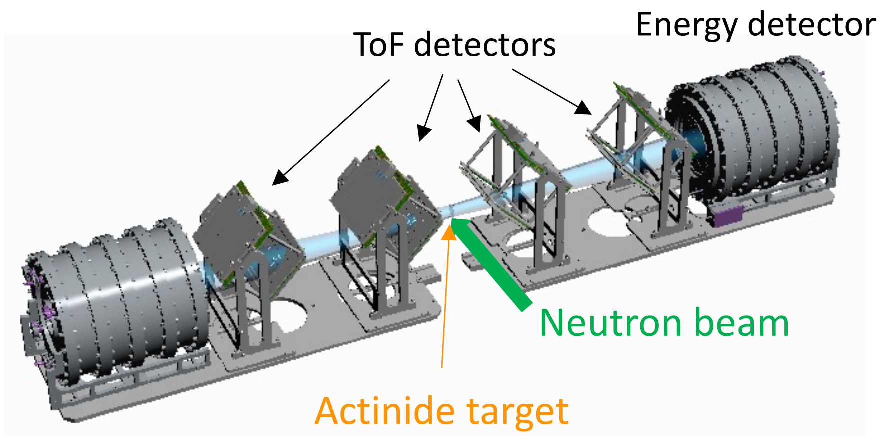
Very few data for fast neutrons:
- ^{235}U, ^{237}Np, …



Such study possible if the fissionning system is identified

Methods and detectors

FALSTAFF spectrometer



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 ?

Fragment energy losses in materials entail:

- Track reconstruction (positions required)
- Good energy loss calculation

2V Method

→ Pre-evaporation fragment masses ($\sigma(A)$ <1 uma)

→ ToF : 2 SED-MWPC detectors

→ $\sigma(t)$ = 120 ps & $\sigma(xy)$ = 2 mm

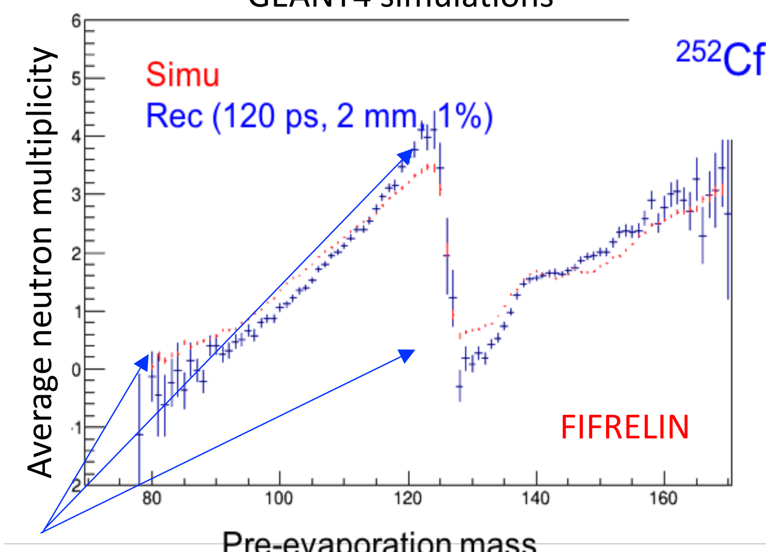
EV Method

→ Post-evaporation fragment mass ($\sigma(A)$ <2 uma)

→ ToF + axial ionisation chamber

→ $\sigma(E)/E$ ~1% + energy loss profile

GEANT4 simulations

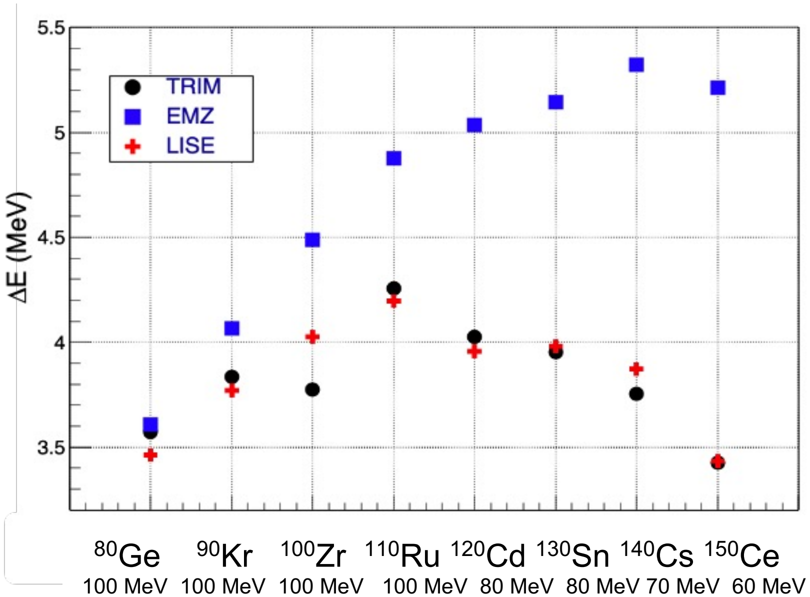


Effects due to assumption about constant velocity before and after evaporation

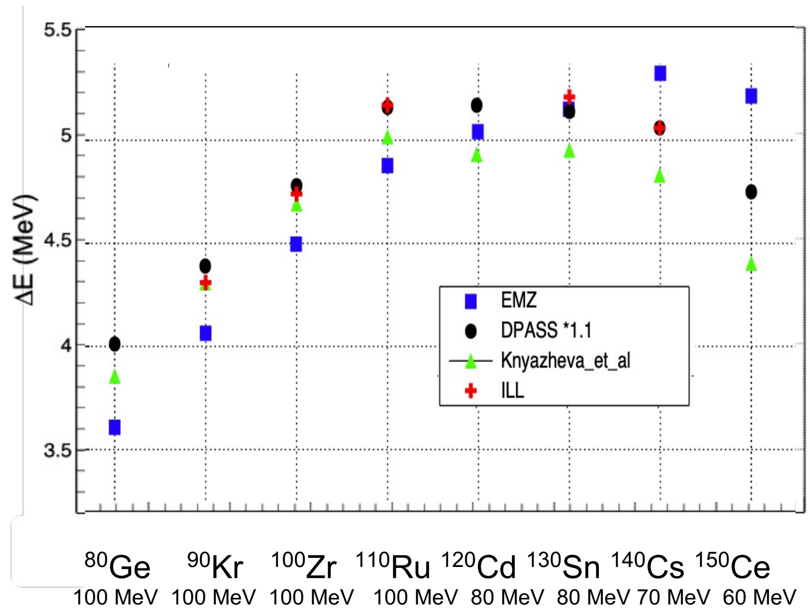
Correction determined (K. Janssen, thesis)

Fission fragment energy loss measurement @ Lohengrin (ILL)

T. Materna et al., NIMB 505 (2021)1-16



Projectile on 0.5 μm of Mylar



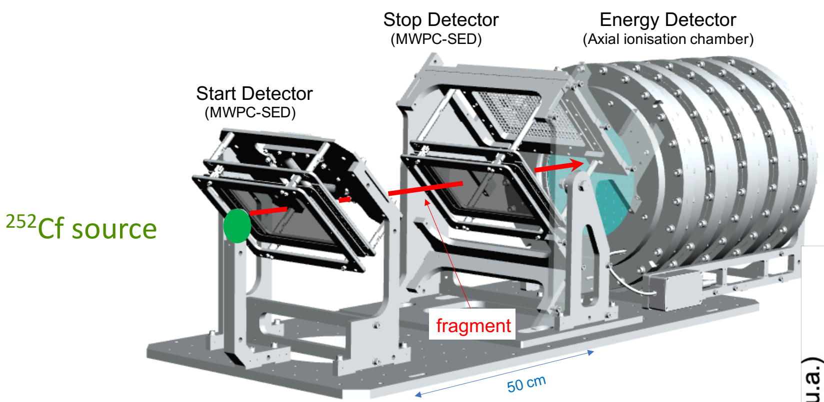
Projectile on 0.5 μm of Mylar

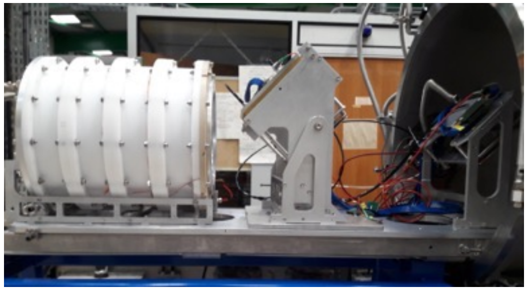
- Scaled DPASS Mylar values included in GEANT4 and used for experimental data event reconstruction

A. Schinner & P. Sigmund, NIM B 460 (2019) 19–26

TOF detector in test bench

- Time resolution ~100 ps
- Position resolution ~1.2 mm





In FALSTAFF

- Time resolution ~ 130-150 ps
- Position resolution ~2.3 mm

Close to expected values

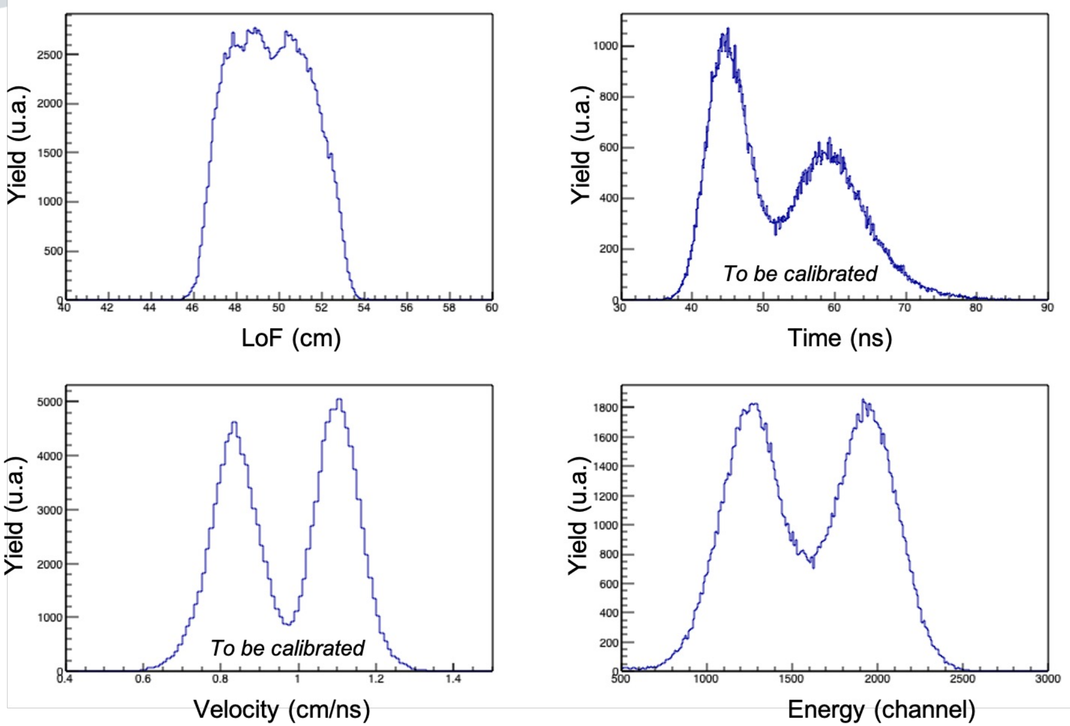
In 2021

→ DAQ modifications

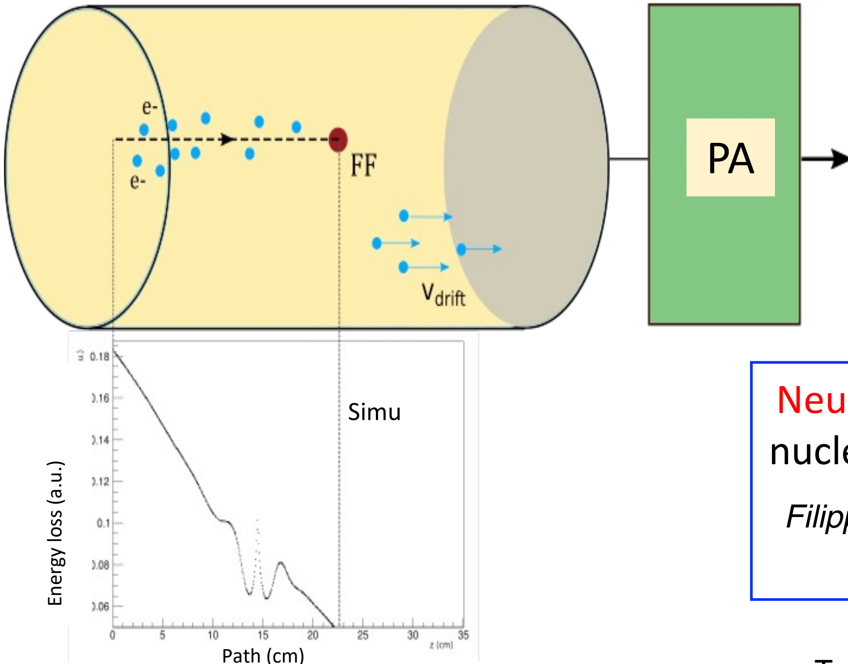
→ Moved to Ganil

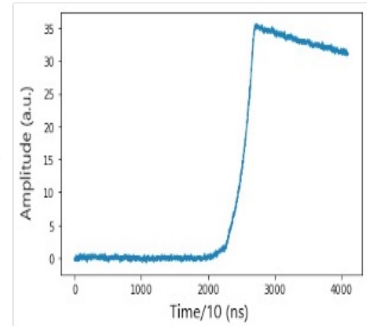
The absolute calibration has not been possible yet but the relative trends of the distributions seem OK

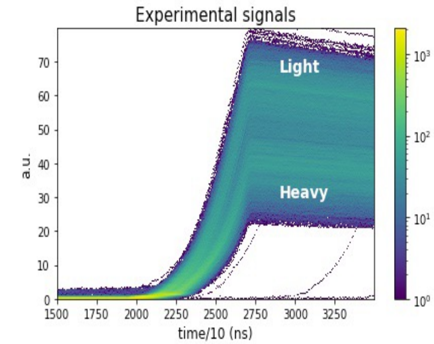
^{252}Cf source results



Energy loss profile in the axial ionization chamber



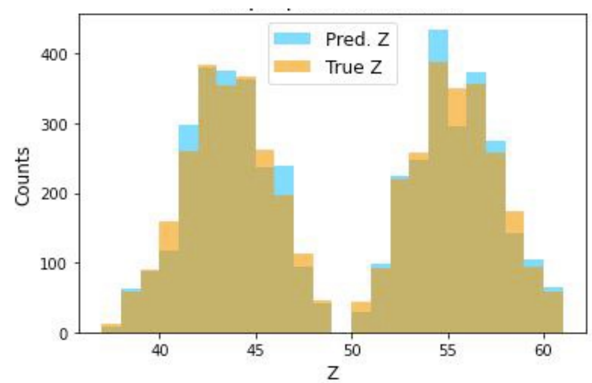




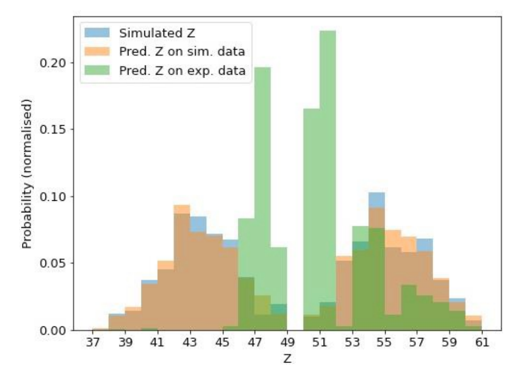
Neural networks used to identify fragment nuclear charge using the energy loss profile

Filippo Angelini & Lorenzo Domenichetti internship
*(**D. Ramos & J.-E. Ducret**, supervisors)*

Test with simulations



Test with data

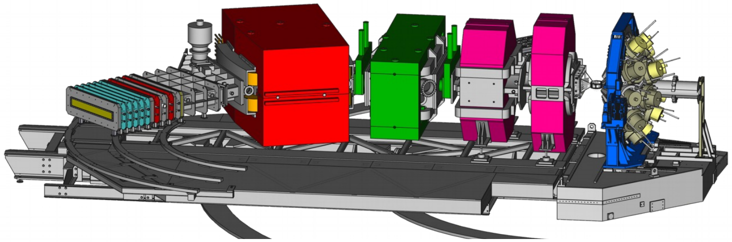


→ Need of identified fragment to « settle » the neural network
→ FALSTAFF@VAMOS experiment

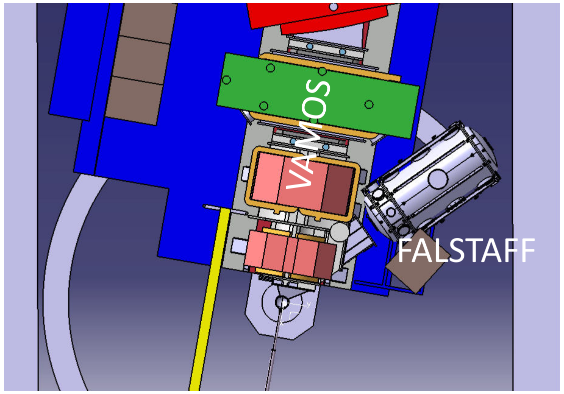
FALSTAFF @ VAMOS (test experiment, March 2022, PI D. Ramos)

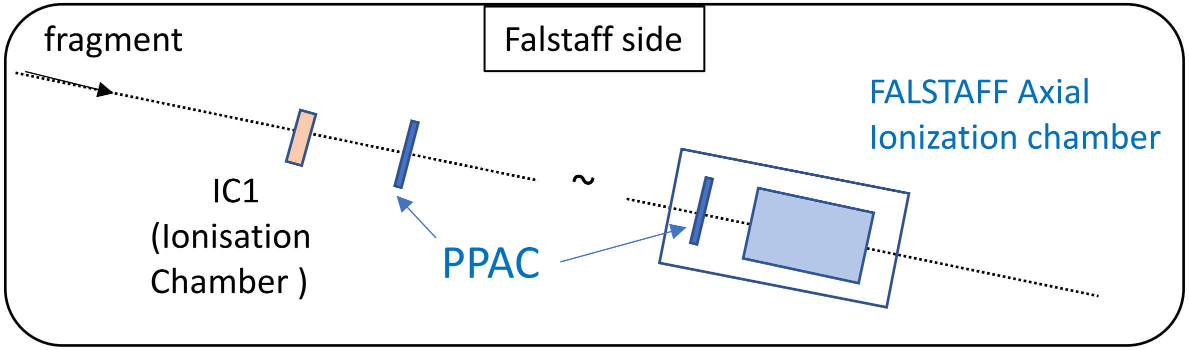
$^{238}U + C \rightarrow$ fusion-fission main channel

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



VAMOS SPECTROMETER





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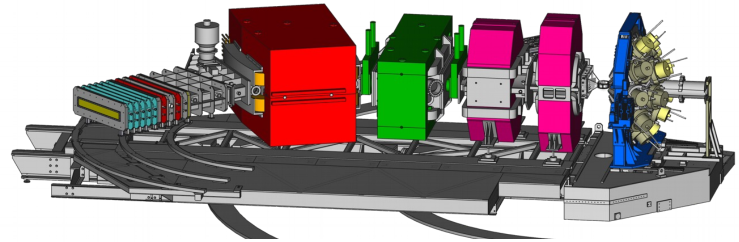

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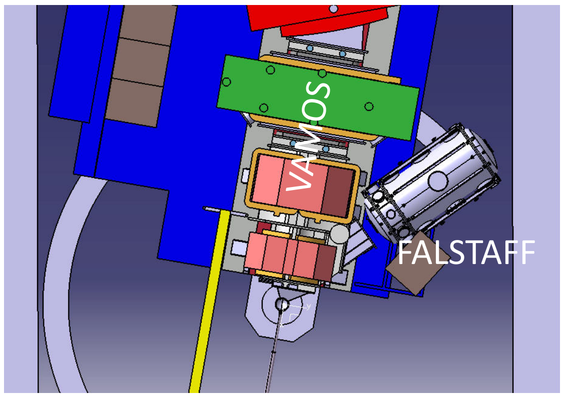
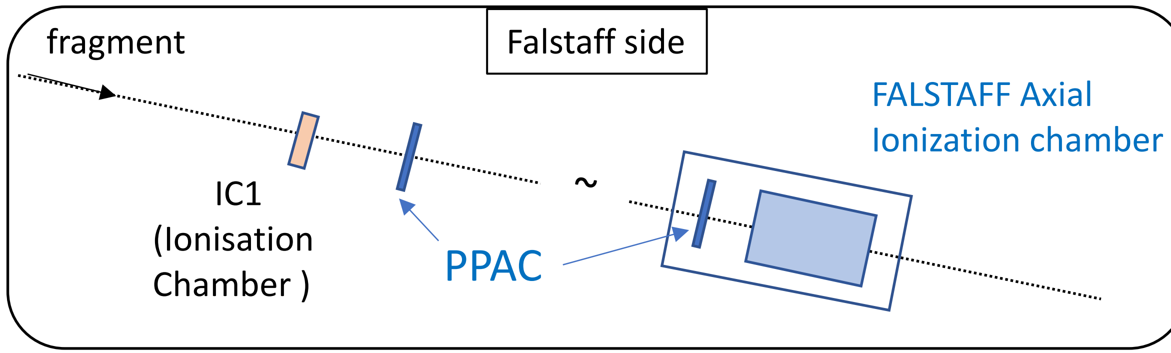
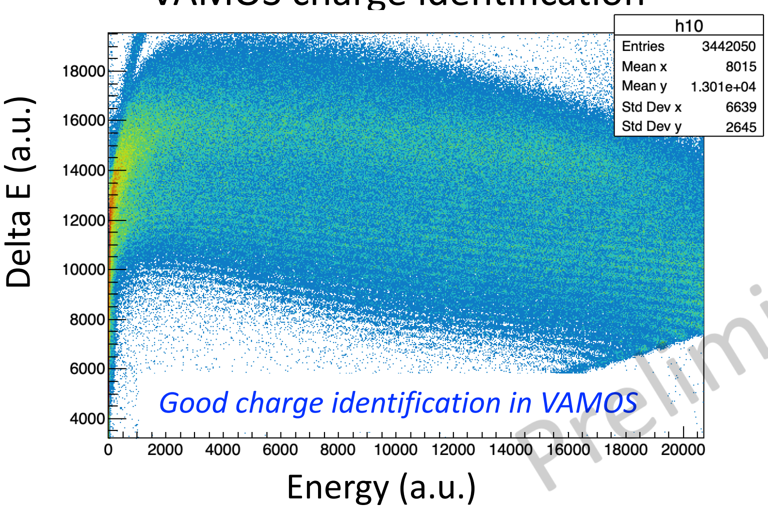




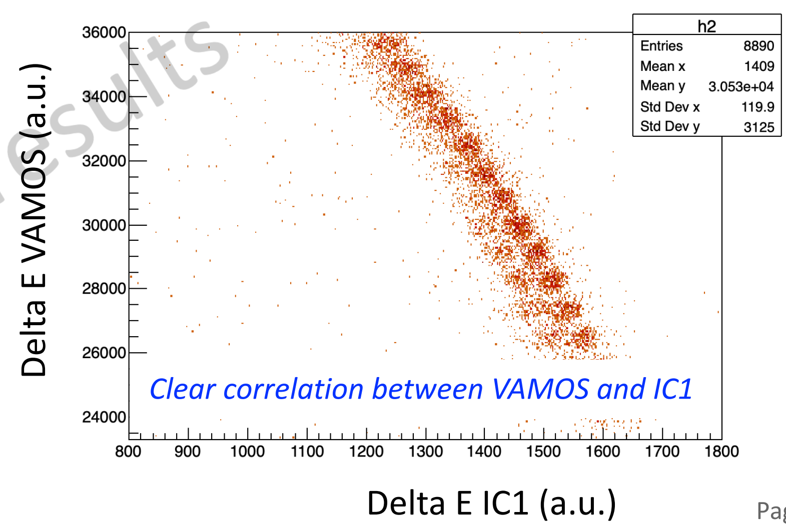
VAMOS charge identification



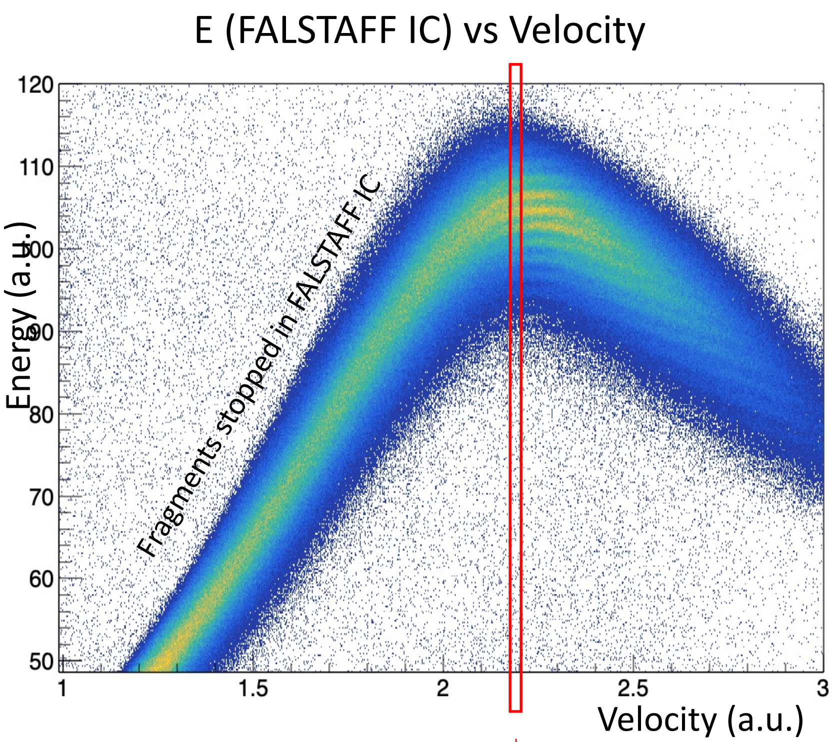
^{238}U + Be

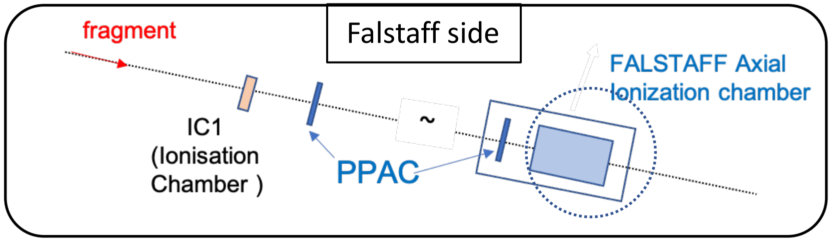
Preliminary results

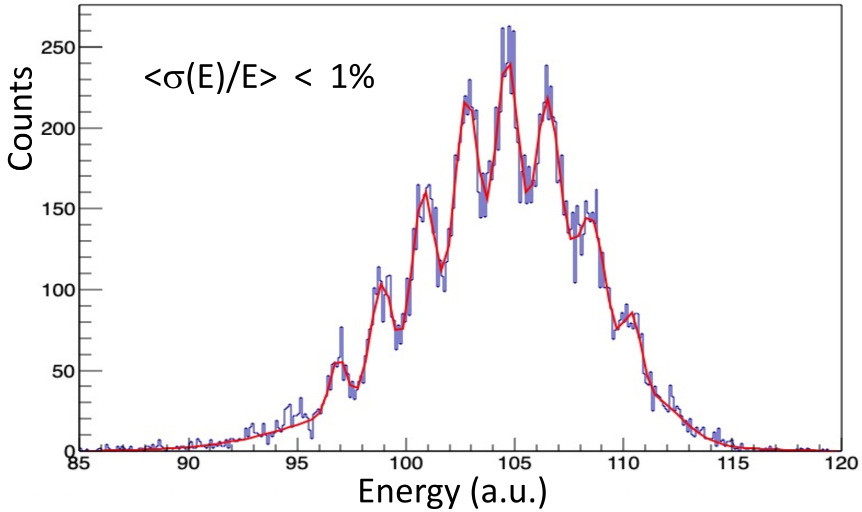
Correlations between VAMOS & IC1



FALSTAFF Ionization chamber energy resolution







Preliminary results

- Good energy resolution !
- Expected performance reached

Analysis of the energy loss profile vs Z & A to be performed

^{235}U Fission fragment study with FALSTAFF at NFS

E814 experiment

D. Doré[1], E. Berthoumieux[1], A. Letourneau[1], T. Materna[1], L. Thulliez[1], M. Vandebrouck[1], J-E. Ducret[2], X. Ledoux[2], J. Pancin[2], D. Ramos[2], S. Oberstedt[3], A. Cheboubbi[4], O. Litaize[4], O. Serot[4]

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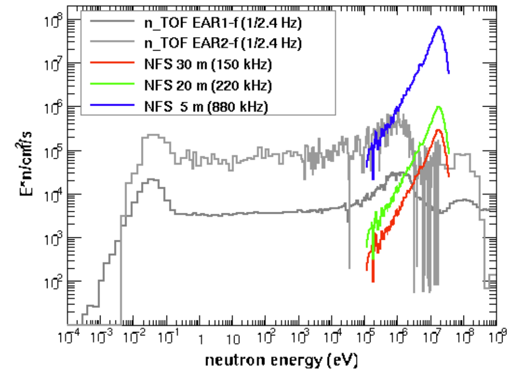
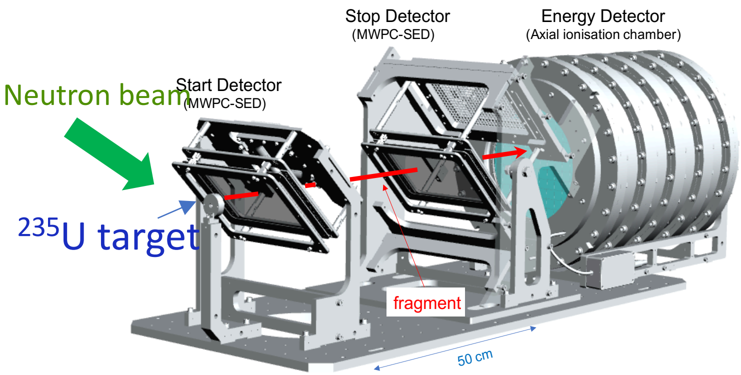
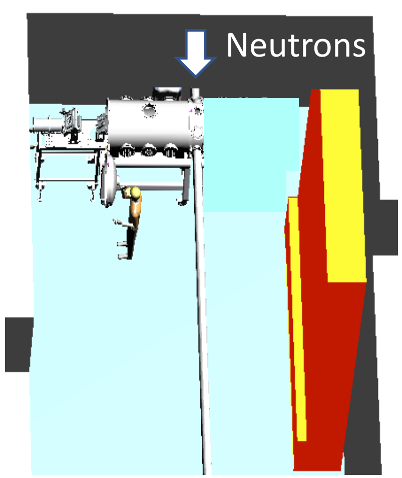
4) CEA, DEN, DER, SPRC, Cadarache





- Experiment with the 1st arm: M_{post} and E_k vs E_n



- 5 m from converter
  → Neutron flux ~1.E+06 n/cm²/s at 5 MeV for 1 MeV bin
- ^{235}U target to be provided by Geel (~195 μg/cm2, ϕ = 3 cm)
  → Purity 99.94 % : few pollution from other isotopes
- Background from thermal neutrons is negligible
  → 0.5 % of fission with T > 1 us

+ ε ~ 0.5 %
→ 10 fiss. det./s

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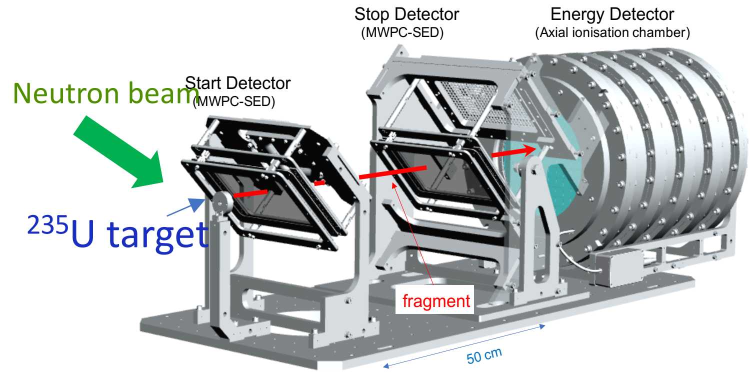
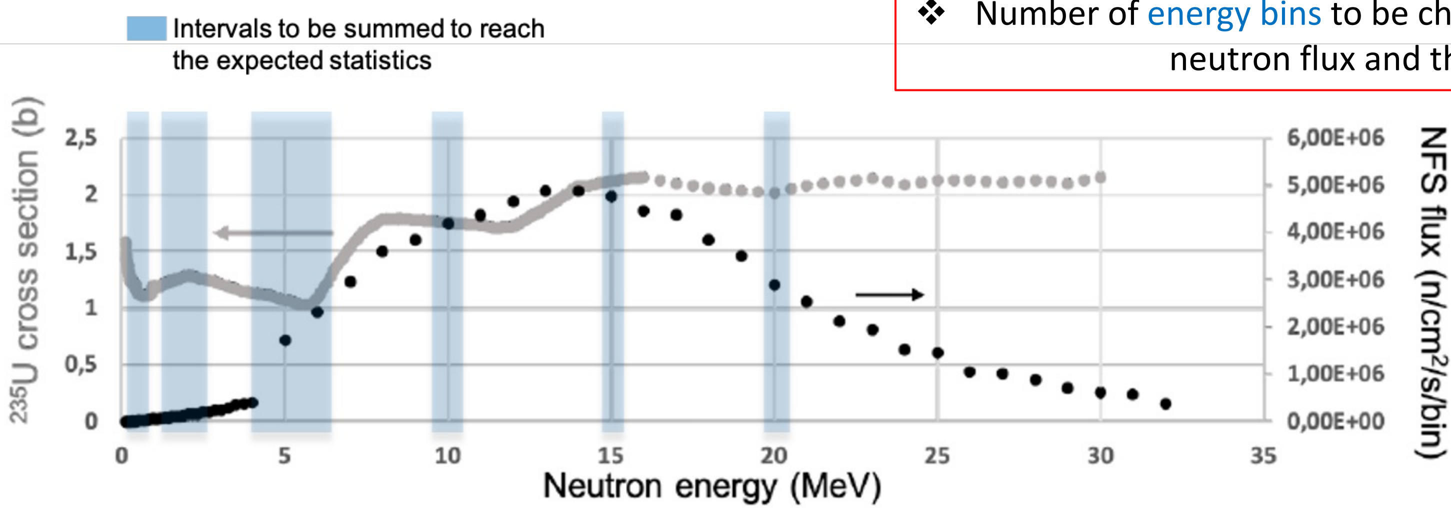


➢ Experiment with the 1st arm: M_{post} and E_k vs E_n

❖ ^{235}U target to be provided by Geel (~195 µg/cm2)
→ Purity 99.94 % : few pollution from other isotopes

❖ Background from thermal neutrons is negligible
→ 0.5 % of fission with T > 1 us

❖ Number of energy bins to be chosen according to the neutron flux and the available beamtime



2009 1st LOI SAC Ganil
2010-2014 : no manpower, detector resolution determination, 1st axial chamber design & building
2015: FALSTAFF is a Irfu project (manpower allocated), change of IC design
2016: design of the full setup, **final axial ionization delivered**, tests of detectors, Postdoc C. Golabek
2017: reaction chamber delivered, **test of IC at IPNO,** new simulations code, L. Thulliez Ph.D. defense, Postdoc A. Chietera
2018: **test of the full setup at Orphée**, Postdoc Q. Deshayes
2019: test of a new SED-MWPC detector, FALSTAFF-FIPPS experiment proposed in SANDA framework, **manip ΔE at ILL**
2020: **Ganil PAC proposal accepted**
2021: Collaboration enlarged, **Falstaff moved to GANIL**
2022: VAMOS-FALSTAFF test experiment, **NFS experiment**

FALSTAFF	Financement NACRE (k€)		
Labo	2020	2021	2022
DPhN/Irfu	10	11	5
GANIL/Irfu	5	6	6

Objectifs atteints

→ développement expérimental OK
→ taille de collaboration plus raisonnable
→ expérience acceptée

Objectifs non atteints

→ décision pour un second bras
→ pas encore de données …

Forces

→ Fort soutien à Ganil
→ Pas de retard p/r autres spectros
→

Faiblesses

→ thésards et postdocs difficiles à trouver
→ pas d’embauches prévues

Fission fragment studies with FALSTAFF at NFS

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- Construction du second bras (même techno?)(2023-24)
- Continuer à travailler sur la détermination de la charge Z (résultats préliminaires encourageants)
- ^{238}U, ^{232}Th, ^{239}Pu, ^{237}Np, ^{233}U à NFS
    - **Besoin de trouver des fournisseurs de cibles**
- Ajout de détecteurs ancillaires (neutrons, gammas)
- **Renforcer le lien avec les modélisateurs**
- **Rétablir le lien avec les théoriciens**