Prompt Fission Neutron Spectra measurement in the ^{235}U(n,f) reaction

Collaboration :

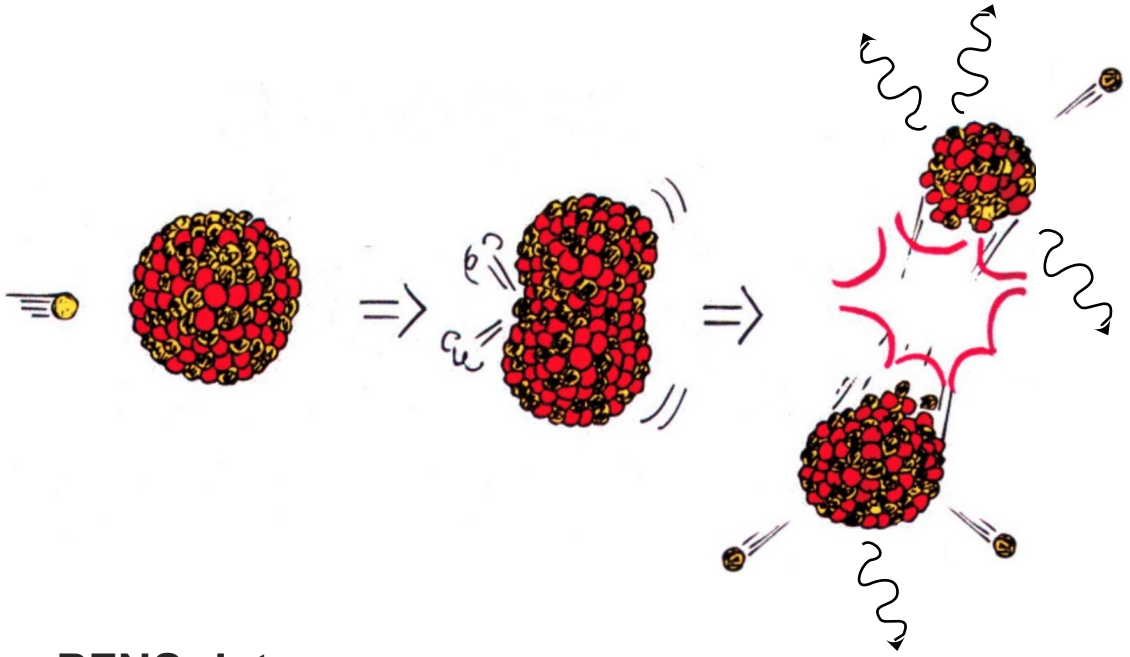
CEA: B. Mauss, J. Taïeb, B. Laurent, G. Bélier, A. Chatillon, P. Morfouace, O. Roig

LANSCE : M. Devlin, R.C. Haight, K.J. Kelly, J.M. O'Donnell

LPC Caen : D. Étasse

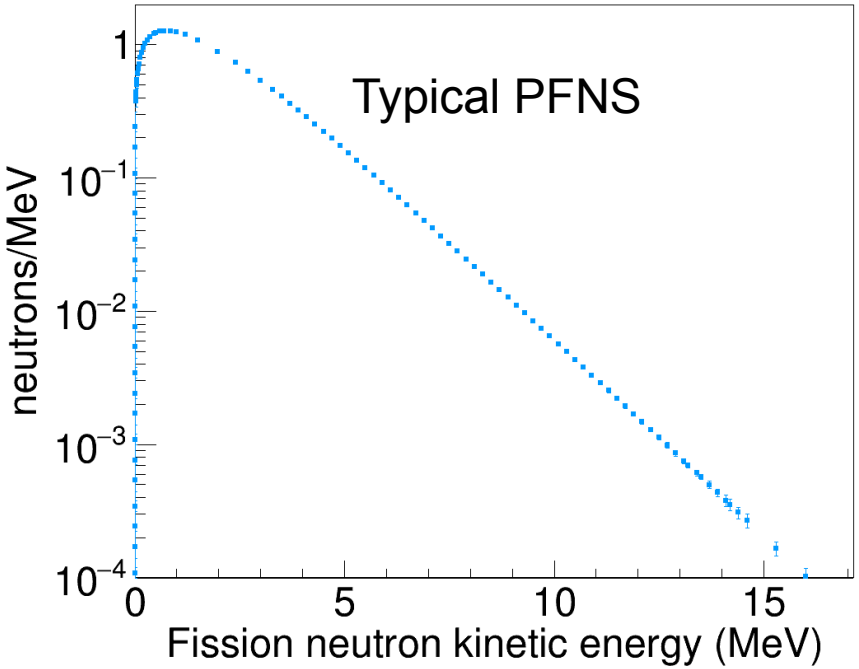
FIESTA 2024

Prompt fission neutron emission



Prompt Fission Neutron Spectra (PFNS)

- Emitted by the accelerated fragments
- Kinetic energy distribution
- Depends on the incident neutron energy and on the excited actinide

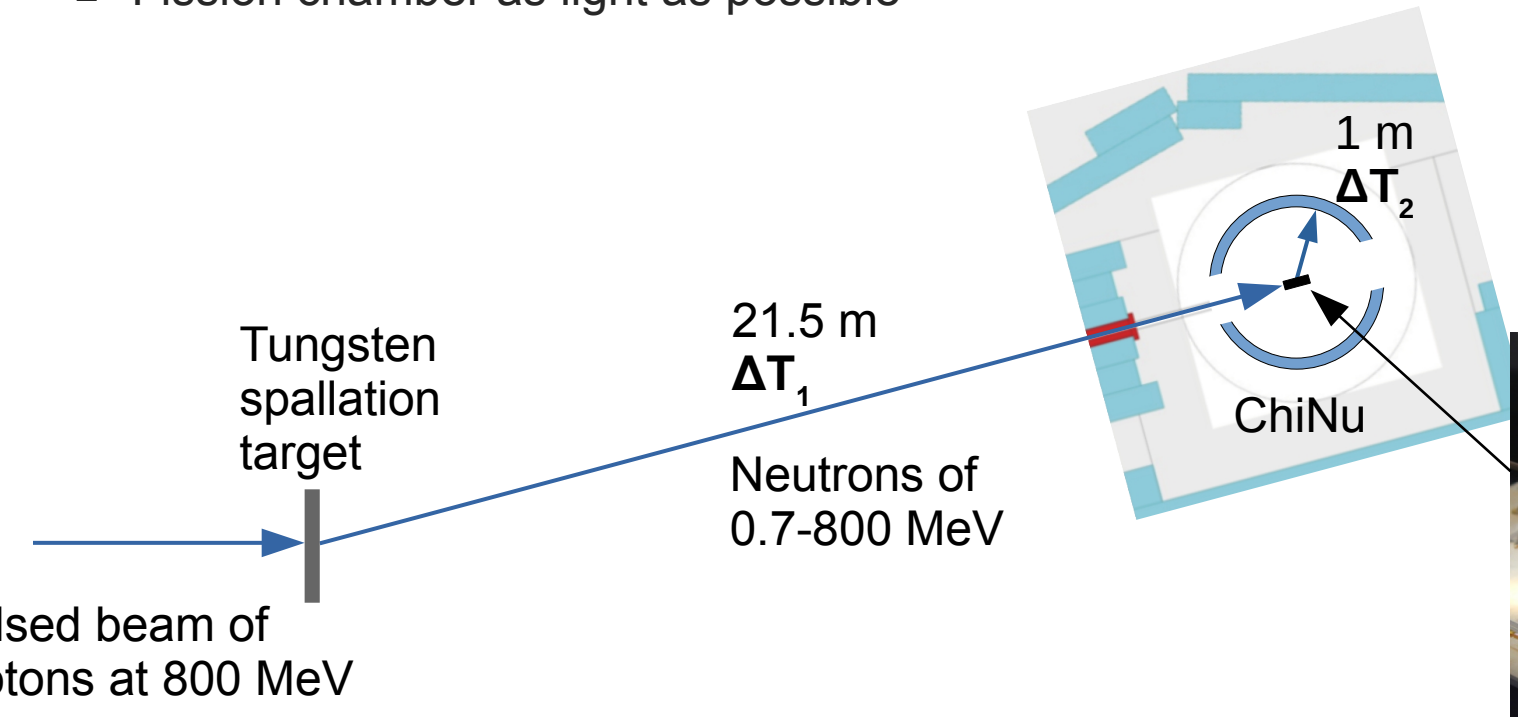


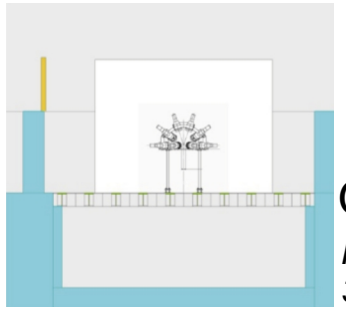
Need for PFNS data

- Crucial input for neutron transport codes
- Need for uncertainties on mean energy < 1%
- Need for uncertainties on neutron multiplicity < 0.5%
- Few data in ^{235}U above 1 MeV of incident neutron energies

Experimental setup at LANSCE

- Incident and fission neutron energies measured event by event by time of flight
- Limitation of neutron scattering:
  - Neutron get-lost pit: 3 m without concrete around the chamber
  - Fission chamber as light as possible

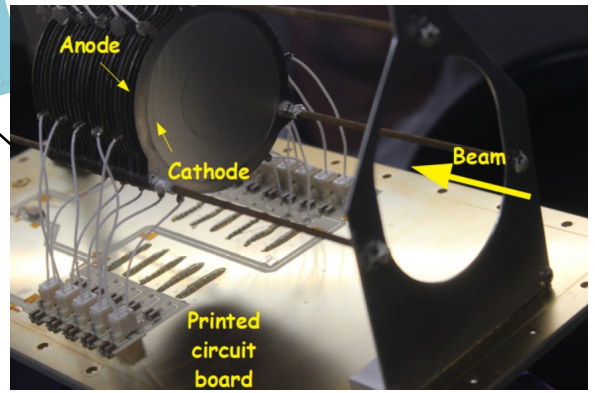




Get-lost pit

M. Devlin et al. NDS 148 322-337 (2018)

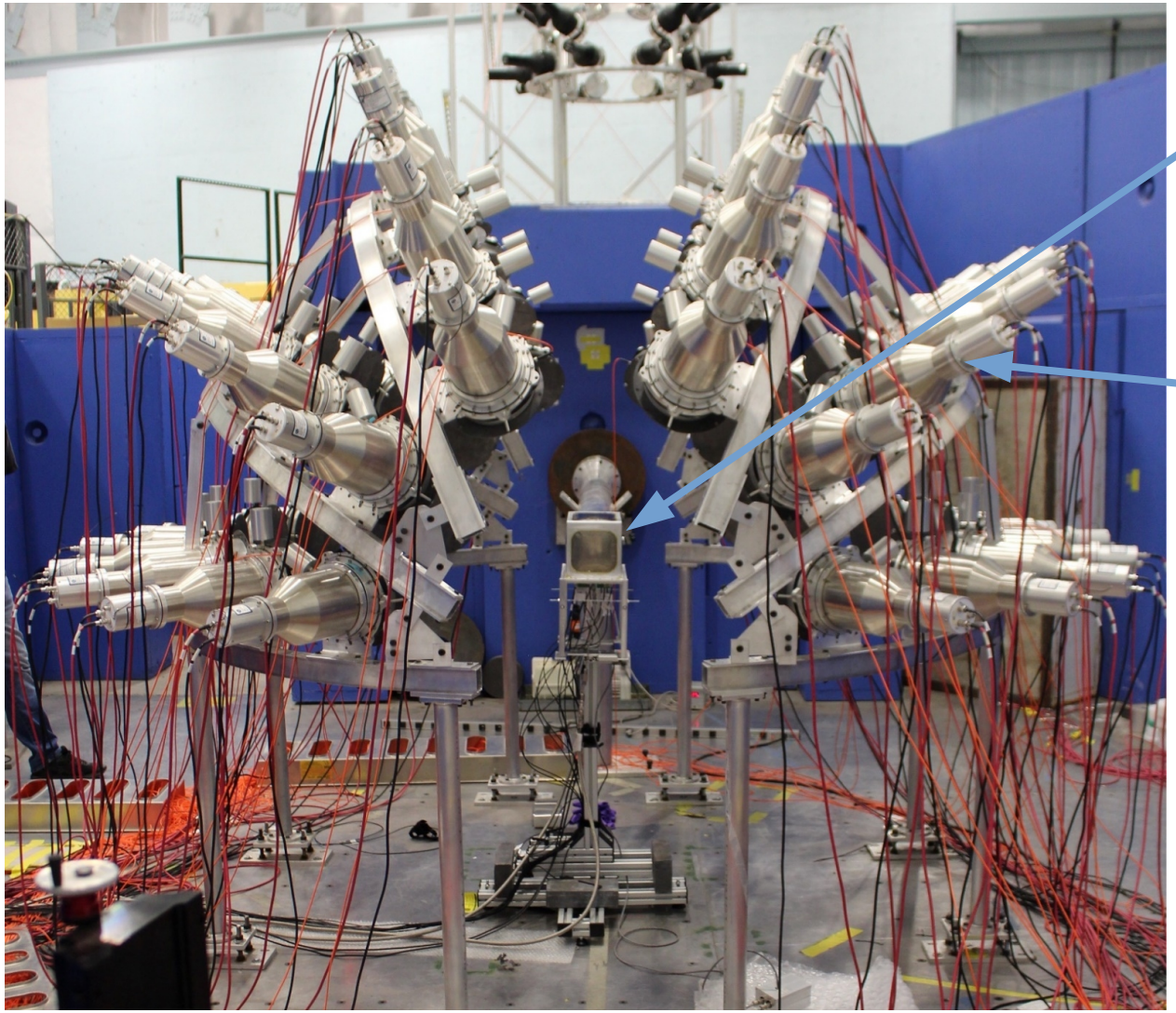
Fission chamber



P. Marini et al. PRC 101, 044614 (2020)

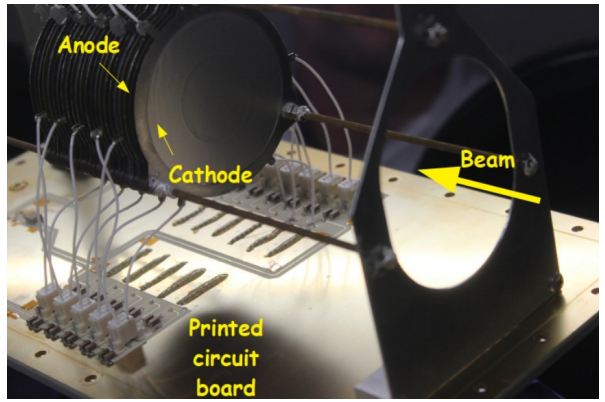
Targets provided by JRC-Geel

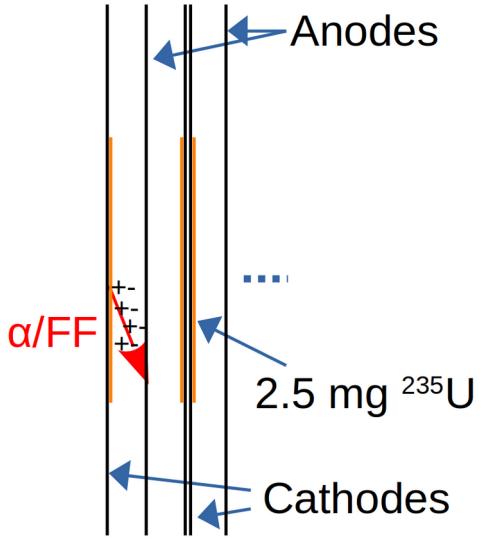
Setup on 15-L



- Fission chamber
  - Good α/fission separation
  - As light as possible
- 54 neutron detectors (ChiNu)
  - Liquid scintillators EJ-309
  - 9 polar angles from 30° to 150°
- Low neutron scattering
- Good fission tagging
- Good neutron/gamma separation
- Angular distributions

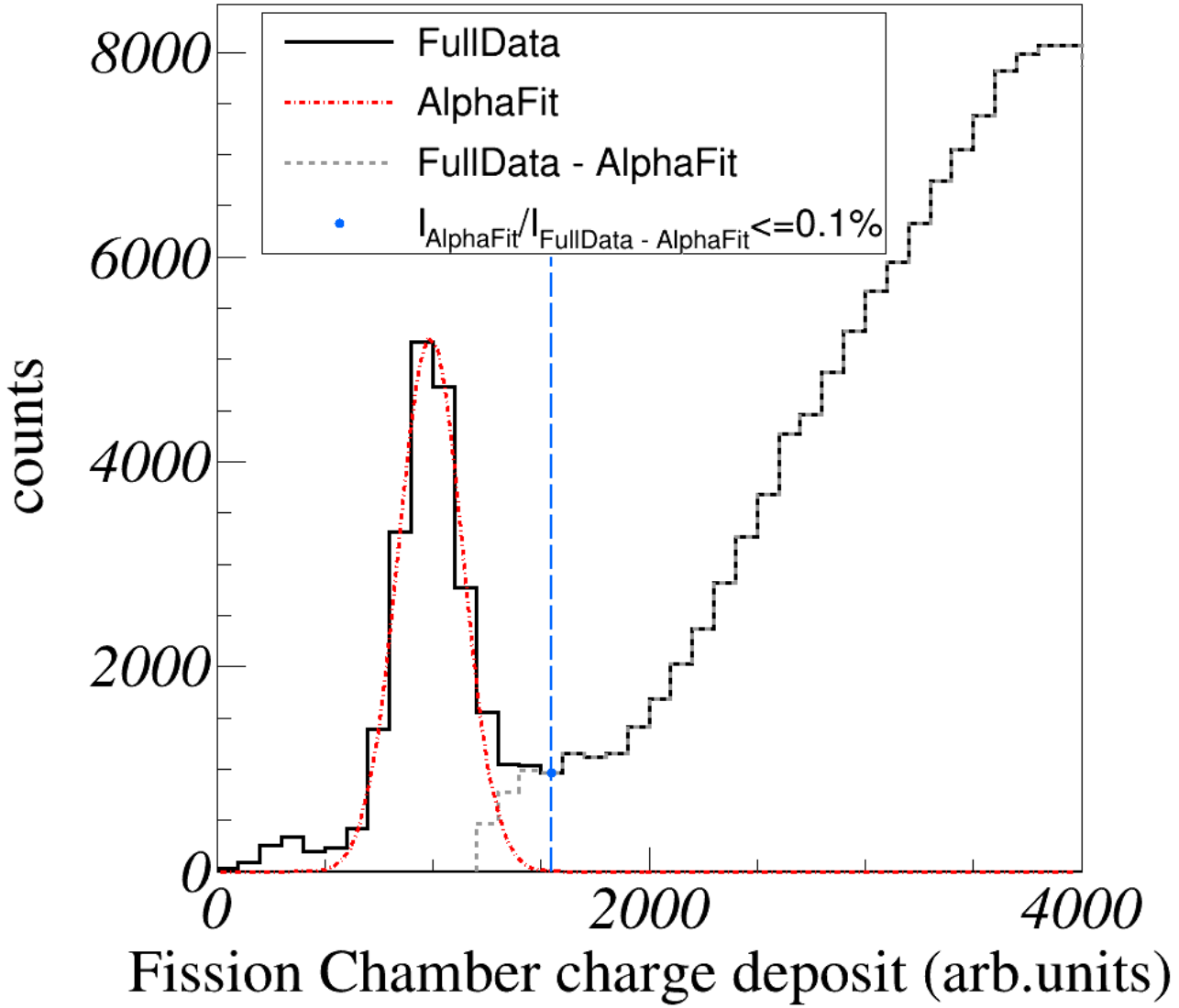
Fission chamber analysis





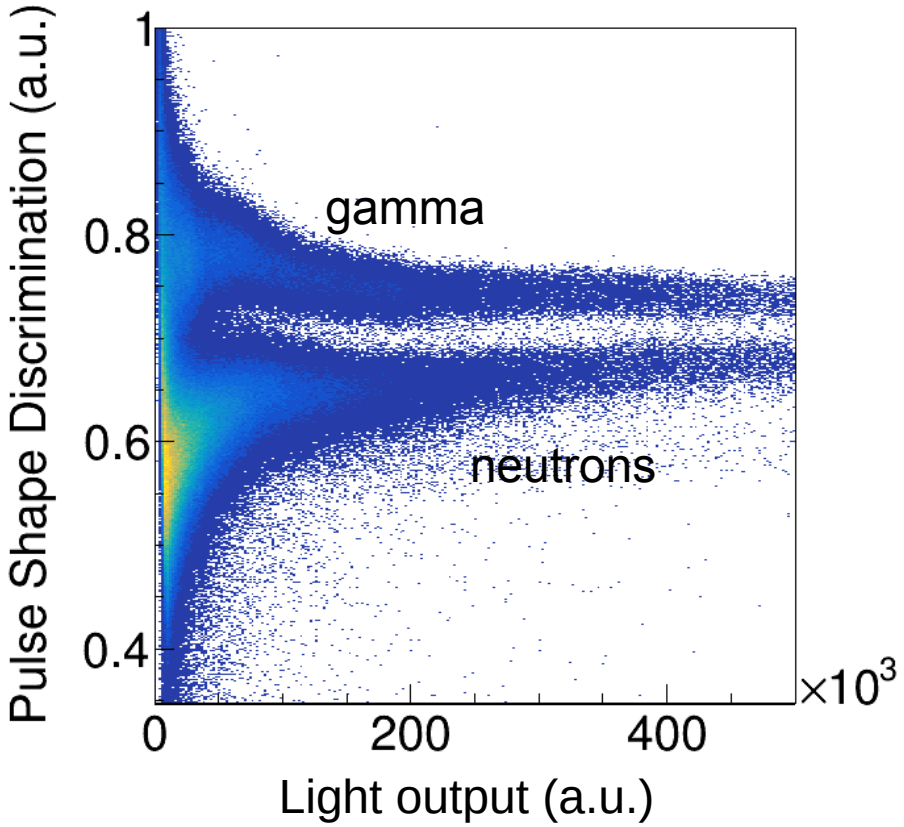
- Configuration:
  - 11 Cu anodes that are read
  - 22 Al cathodes: 55 mg ^{235}U (99.9% purity)

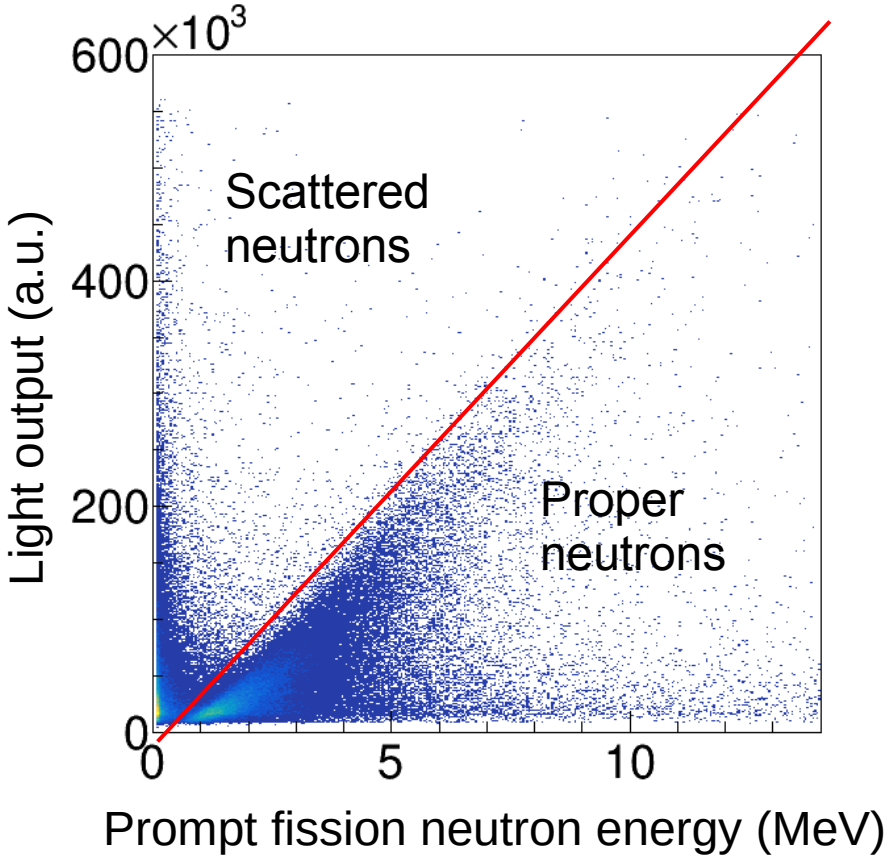
    → Produced at ec|JRC Geel, Belgium
- Fission events identification
  - Alpha peak selected and removed
  - Less than 0.1% alpha remain

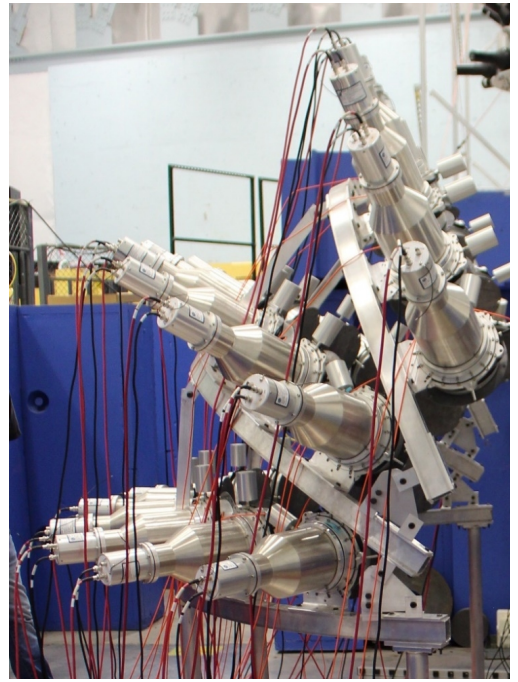


Chi-Nu analysis

- Neutron identification and scattered neutrons removal:
  - Detection of neutrons and gammas → different signal shapes
  - Correlation between the liquid scintillator light output and the neutron energy

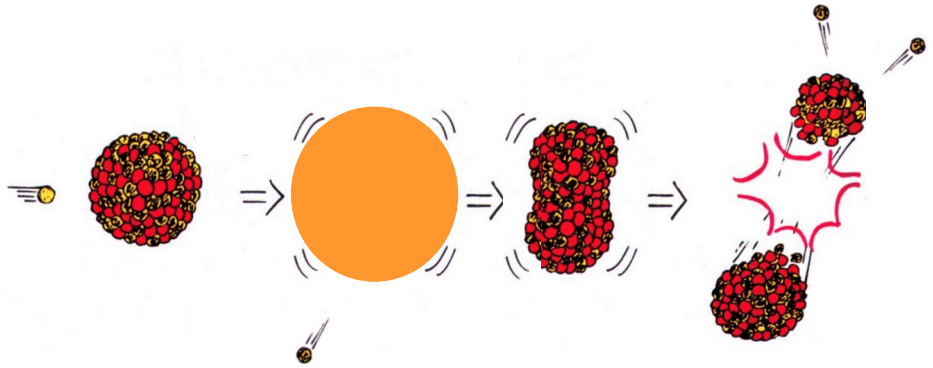


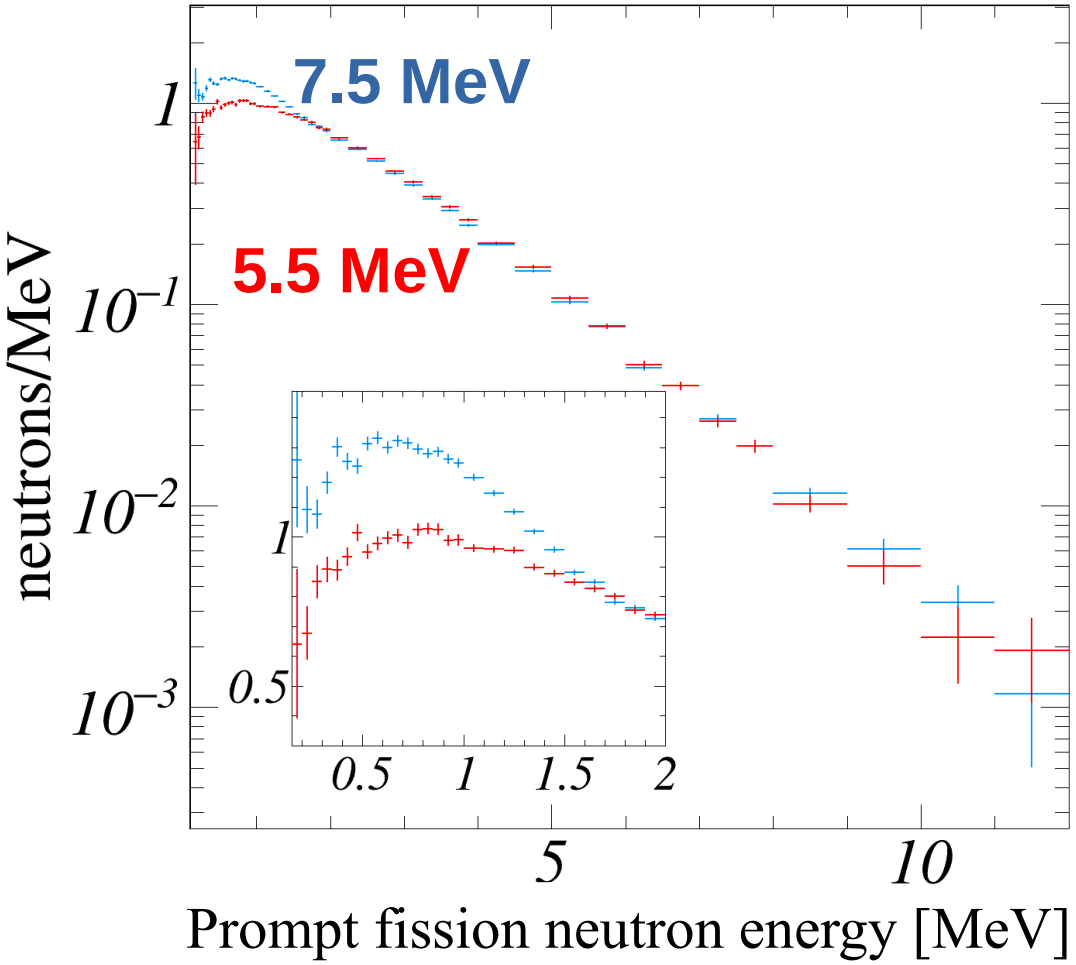




PFNS results for ^{235}U(n,f)

- Prompt fission neutron energy range: 0.18-11.5 MeV
- Spectra at 2 different energies are shown
- Observation of the opening of 2nd chance fission





PFNS obtained from 0.7 to 600 MeV of excitation energies

Comparison to evaluations

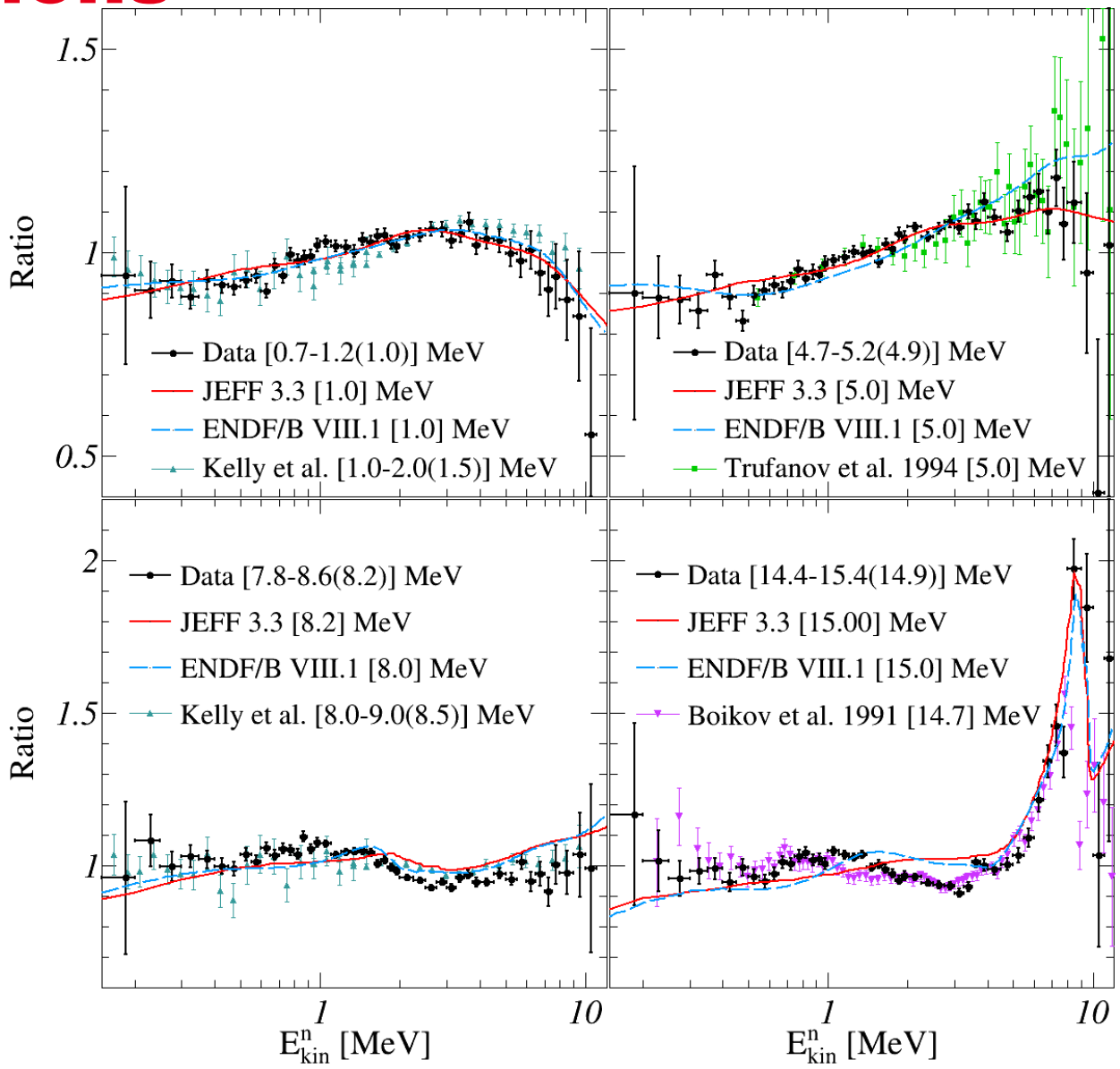
- Ratio to a 1.32 MeV Maxwell distribution
- Consistent with previous measurements
- Some discrepancies with evaluations

- Averaged values
  - Mean energy
  - Average neutron multiplicity
  - corrections applied:

    → Low energy extrapolation

    → Angular distribution extrapolation

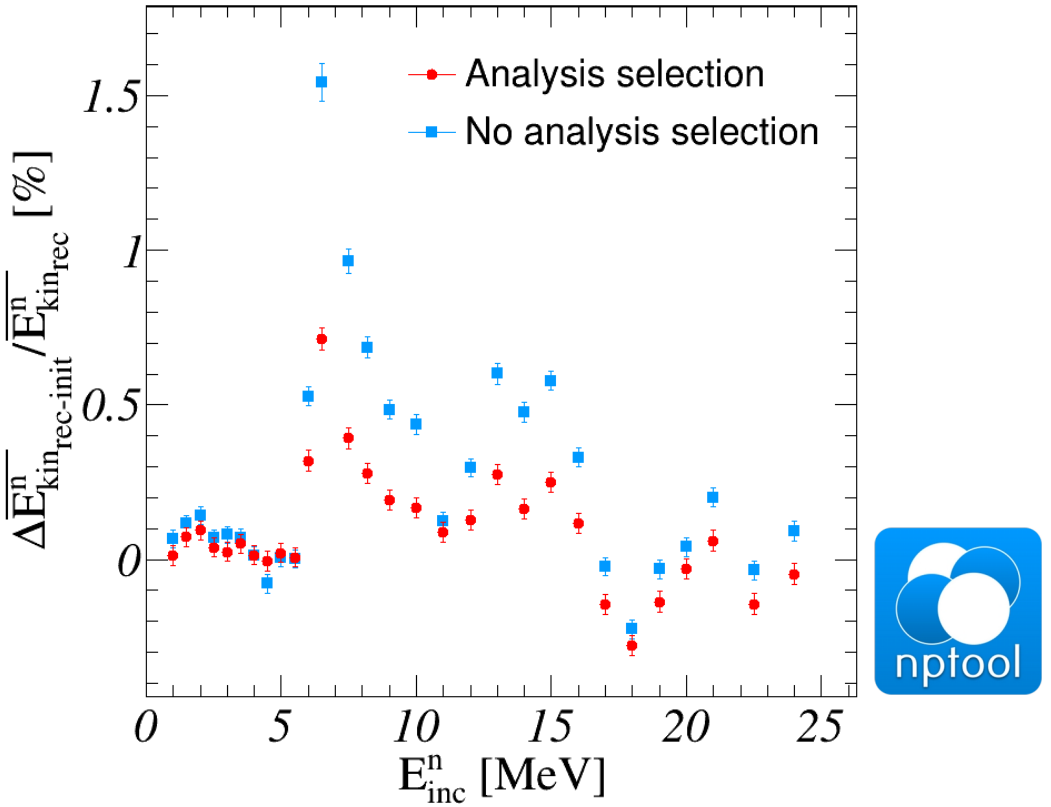
Article submitted



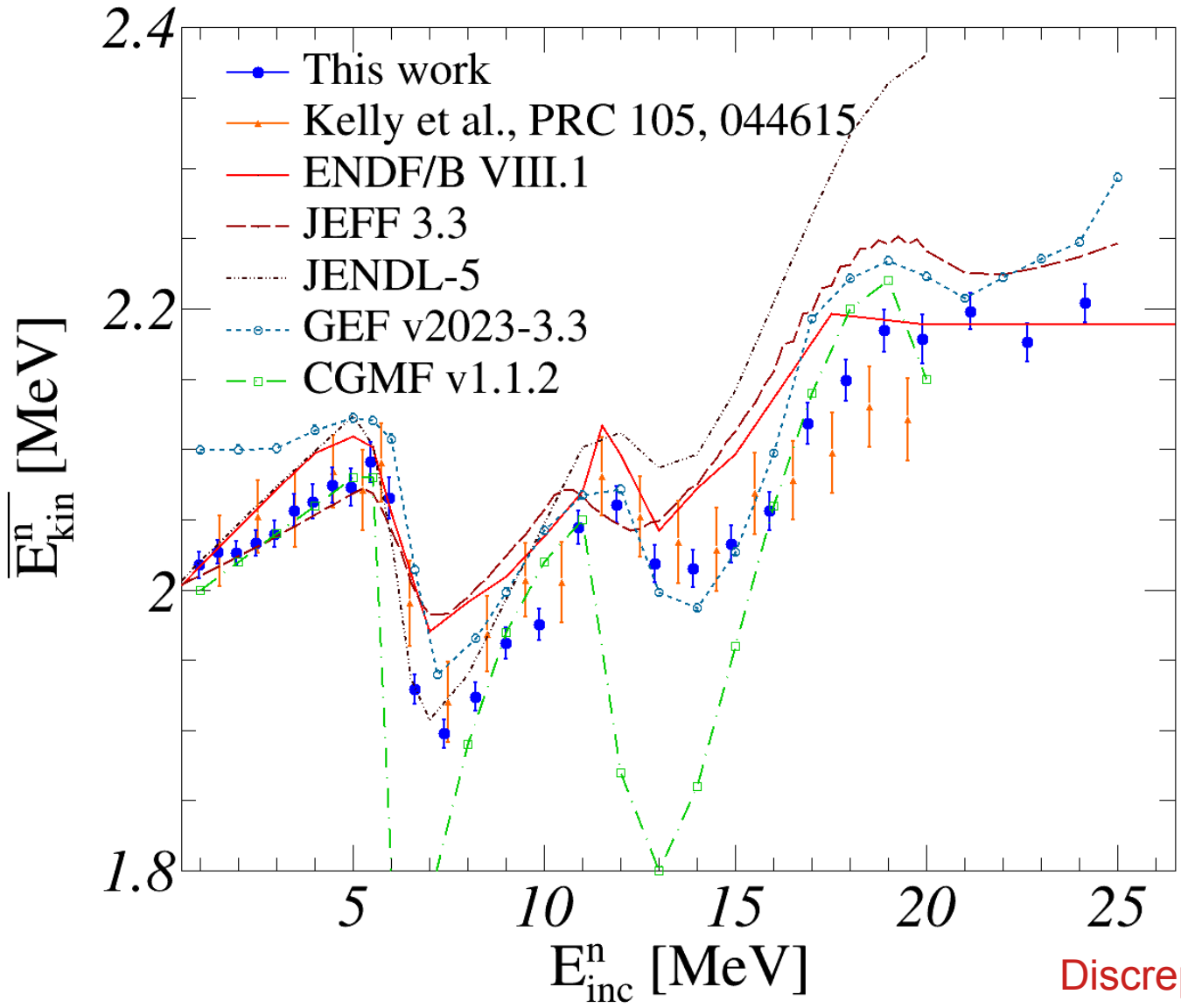
Additional corrections

- Corrections on the spectra and the mean energy:
  - Wraparound → pollution from $E_{incident}$<0.7 MeV
  - "Dark current" → pollution from high energy neutrons
  - Differences of spectra shapes
    → Efficiency calibration with ^{252}Cf(sf)
    → ^{235}U(n,f) measurement

- Example of the ^{252}Cf(sf) calibration effect
  - Simulation of the setup based on Geant4 (*nptool*)
  - Measured PFNS as input
  - Proper neutron selection: distortion effect ~ /2
    → Within uncertainties



Comparison of mean energies



- Each evaluation agrees with the data on different parts of the energy range
- Despite being too large at low energy, GEF well reproduces the 2nd, 3rd and 4th chance fission

Discrepancies to evaluations are outside error bars

Conclusion and perspectives

Conclusion

- A state-of-the-art experimental setup allows the measurement of PFNS at the LANSCE facility
- Incoming Neutrons and PFN are measured by double time-of-flight
- A measurement was performed on ^{235}U(n,f) and is submitted to PRC
  - Uncertainties on the mean energy are below 0.8%
- Comparison to evaluations show some significant discrepancies
  - Difficulties in reproducing n-chance fission

Perspectives

- Possibility to measure neutron multiplicities (see J. Taïeb's talk)
- Further measurements will come out
  - ^{238}U(n,f): finalization, first use of the VErsatile Neuntron DETection Array (see C. Lenain's talk)
  - ^{240}Pu(sf): ongoing, ^{240}Pu(n,f) planned in June 2025 (see O. Syrett's poster)

Thank you

Collaboration :

CEA-DAM : B. Mauss, J. Taïeb, B. Laurent, G. Bélier, A. Chatillon, P. Morfouace, O. Roig

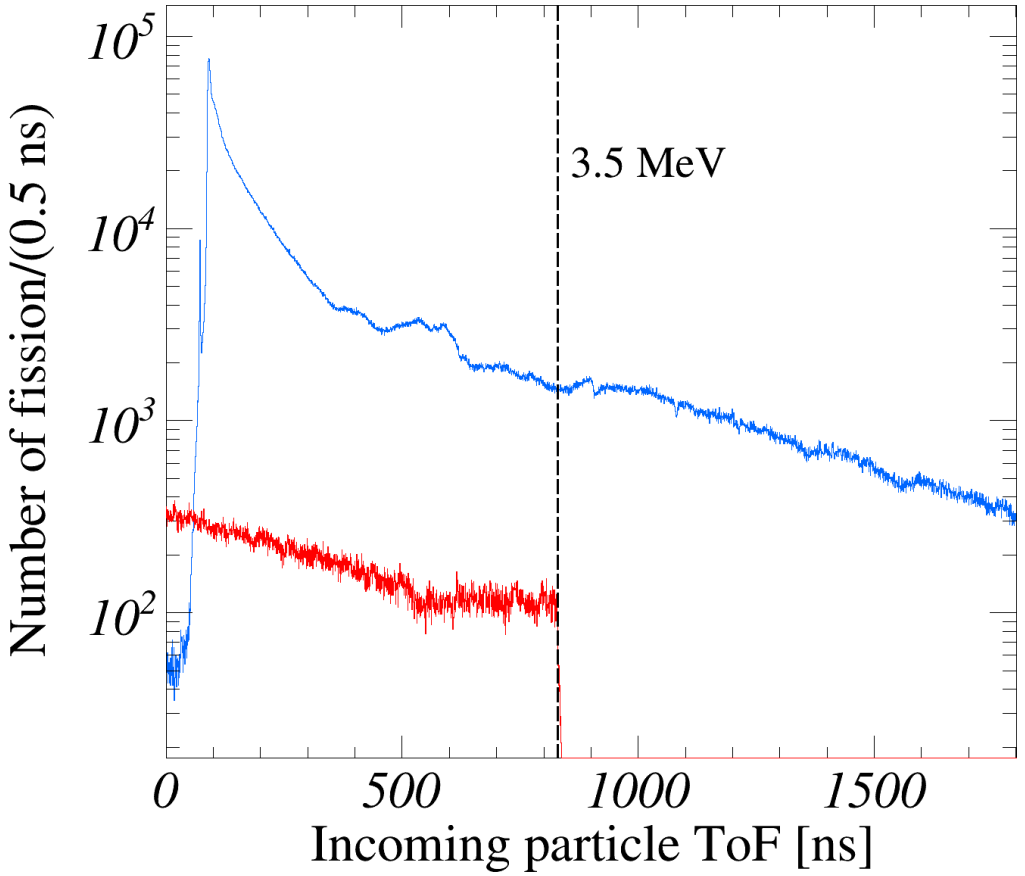
LPC Caen : D. Étasse

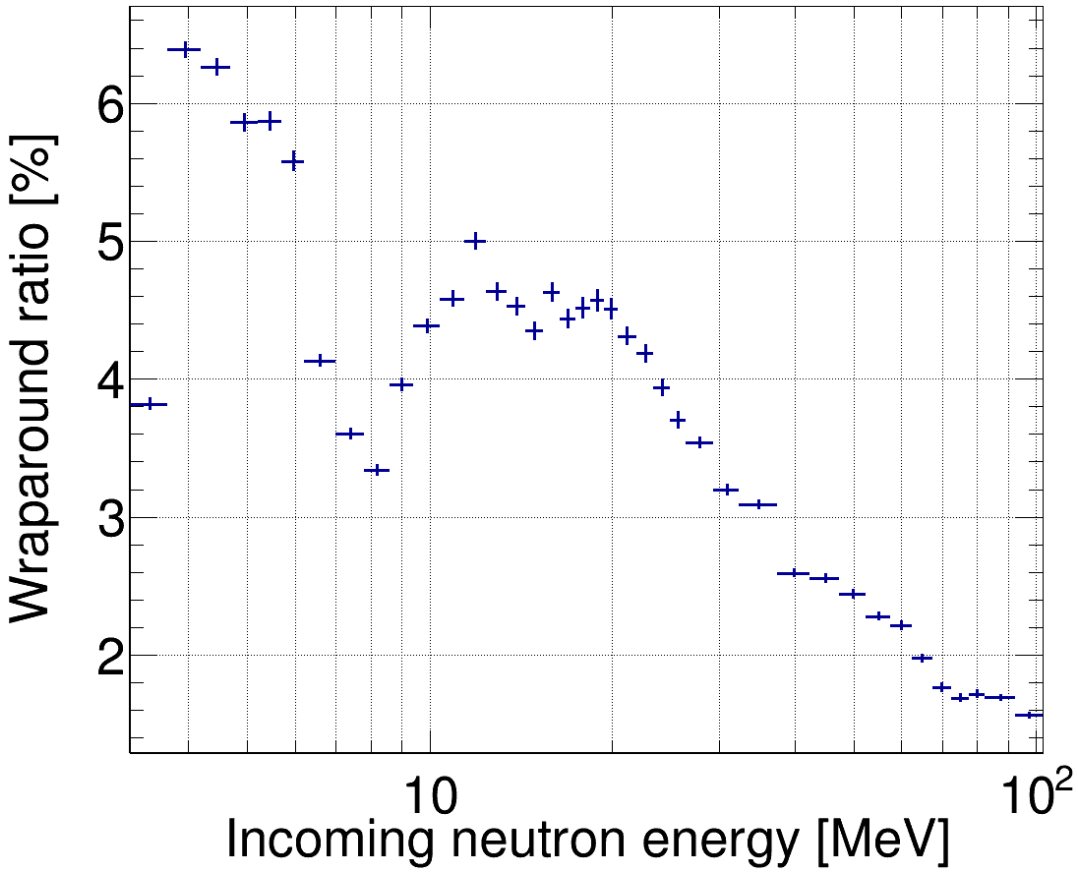
LANSCE : M. Devlin, R.C. Haight, K.J. Kelly, J.M. O'Donnell

CEA DAM Île de France
F-91297 Arpajon
France
benoit.mauss@cea.fr

Wraparound correction

Measurement with 3.6 µs-long pulse instead of 1.8 µs-long

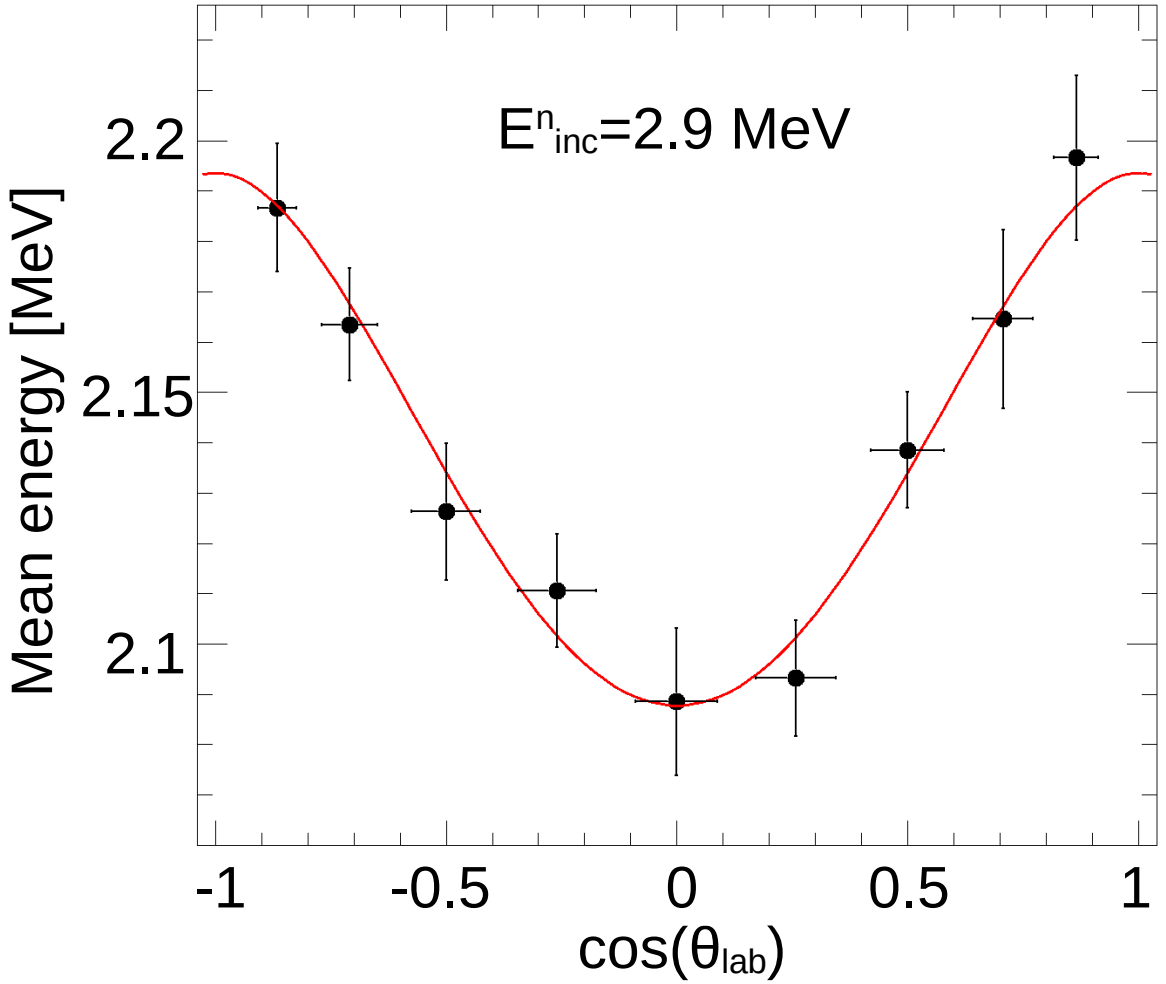


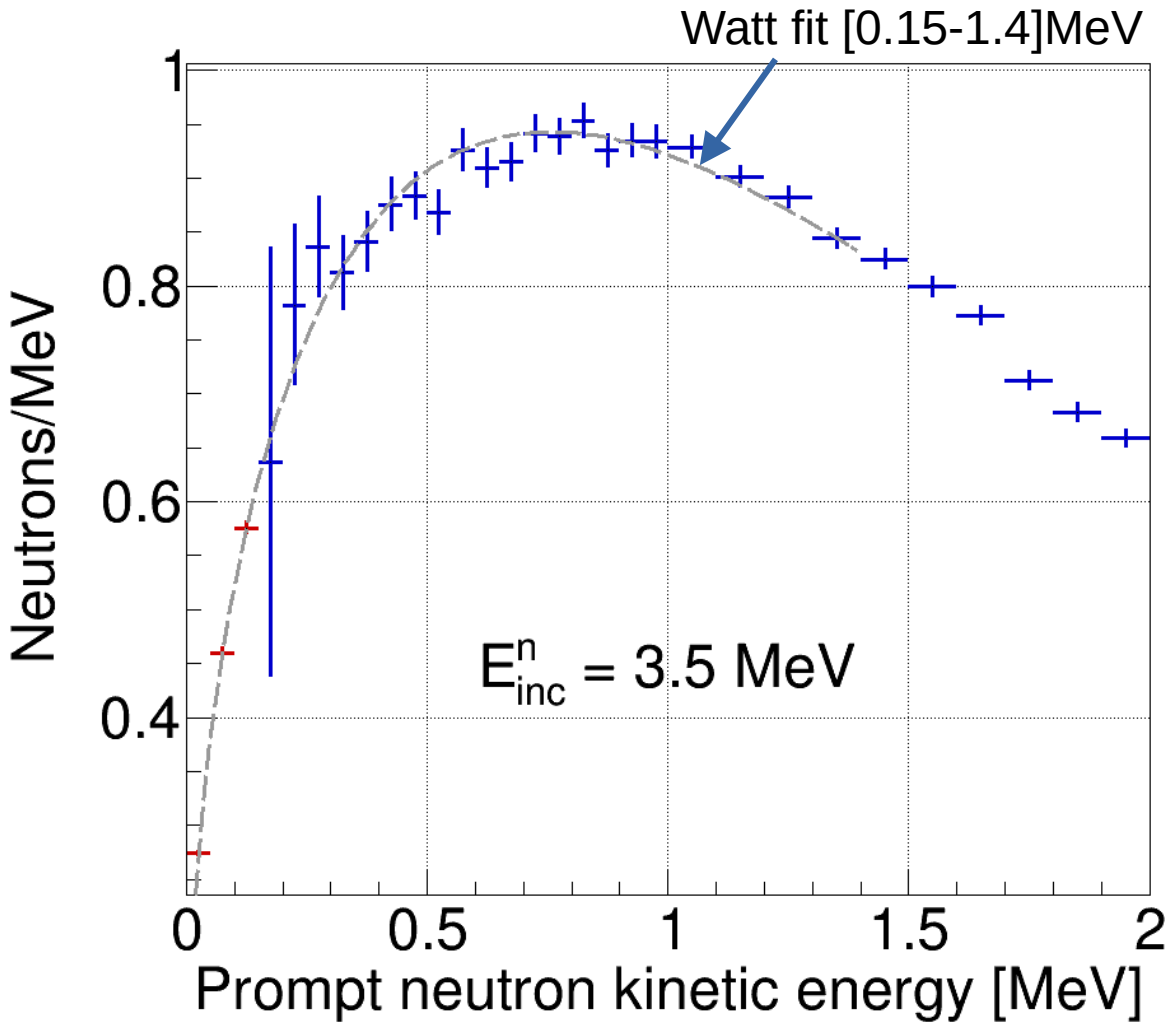


Pollution from a low incoming neutron energy PFNS

Extrapolations

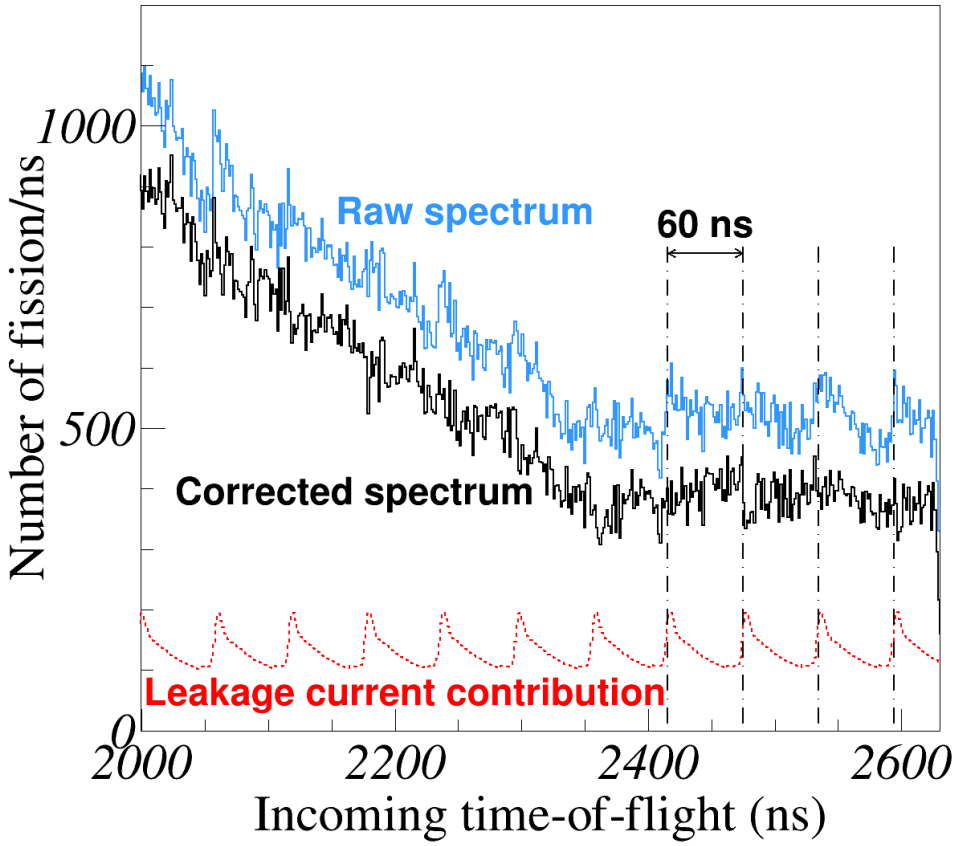
Angular and energy extrapolation

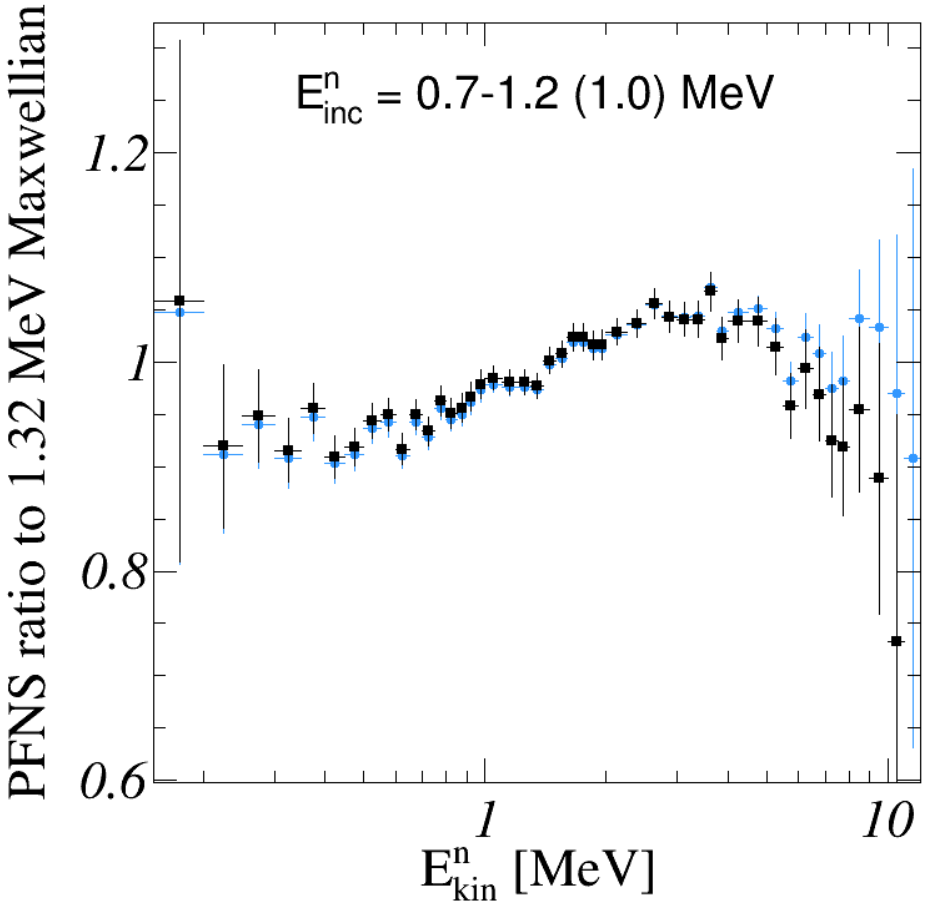




“Dark current” correction

Pollution from smaller pulse (0.5e-4 x main pulse) every 60 ns





Greatest effect on the E^n_{inc} first bin, negligible above E^n_{inc} = 2.2 MeV

Systematic error from ^{252}Cf(s.f.) calibration

Full simulation of the ChiNu setup for the ^{235}U(n,f) PFNS measurement