Neutron-induced fission cross-section of ^{237}Np obtained with two different detection systems

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Outline

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  - Present status of data
- Experimental setups
  - EAR-1 (PPACs)
  - EAR-2 (Micromegas)
- Beam request
- Summary

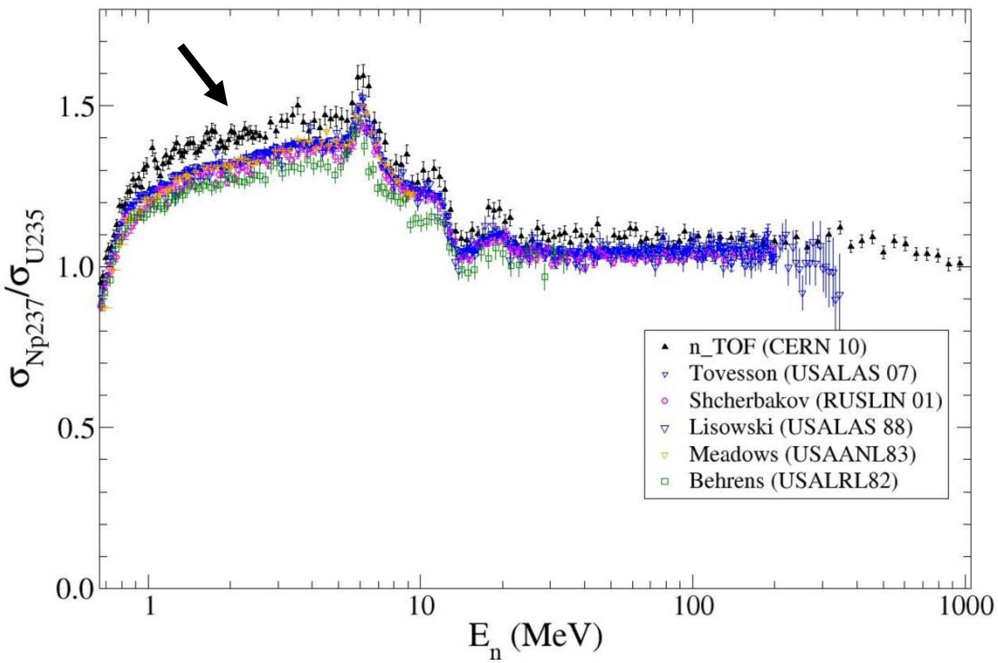
Introduction and motivation

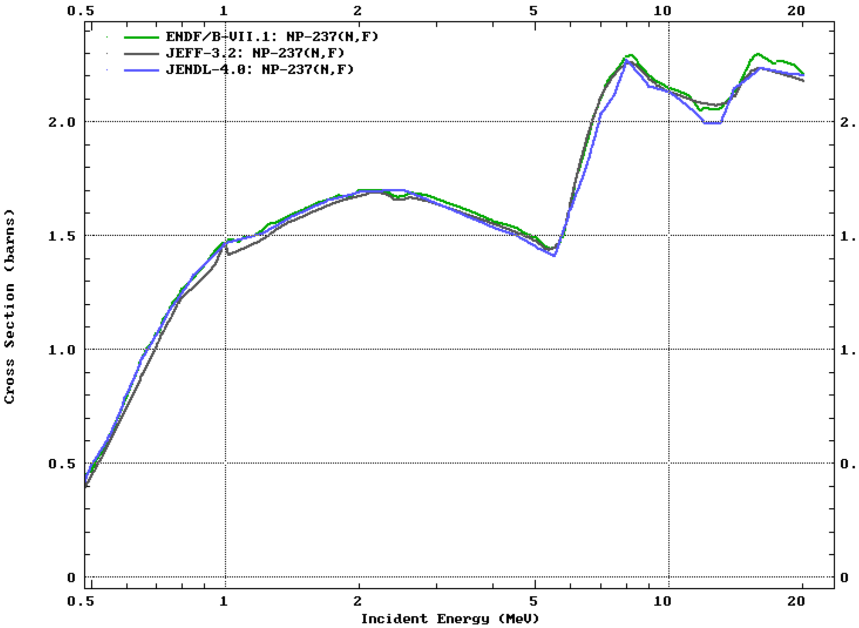
- ^{237}Np is a major component of spent nuclear fuel
- Accurate knowledge of cross-section essential for waste transmutation and advanced nuclear reactor studies (fast reactors etc.)

- *However…*
  - Significant discrepancies exist in data and in recent evaluations
  - Recent measurements have not clarified the situation

^{237}Np(n,f) cross-section: present status

- Significant discrepancies ~6-8% exist in data above the fission threshold
- Recent evaluations (ENDF/B.VII.1, JENDL-4.0) are also discrepant within a few percent in the same region
- n_TOF results obtained with PPACs (EAR-1) systematically higher than other measurements in fission plateau
- Other n_TOF dataset (with FIC detector) more in agreement with previous measurements
- Singularity of n_TOF PPAC results not conclusive…
  - …because apparent agreement between previous measurements is partly due to arbitrary normalisations
    - ENDF/B-VII adjusted to Tovesson
    - Tovesson normalised to ENDF/B-VI at 14 MeV due to unknown sample content
    - ENDF/B.VI adjusted to Lisowski
    - Lisowski normalised to Meadows above few MeV due to unknown sample content

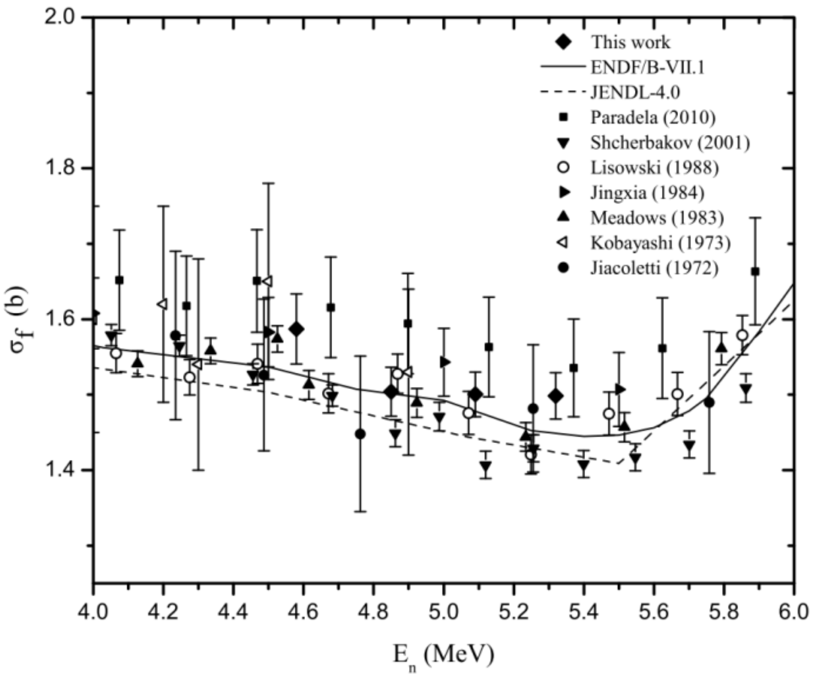




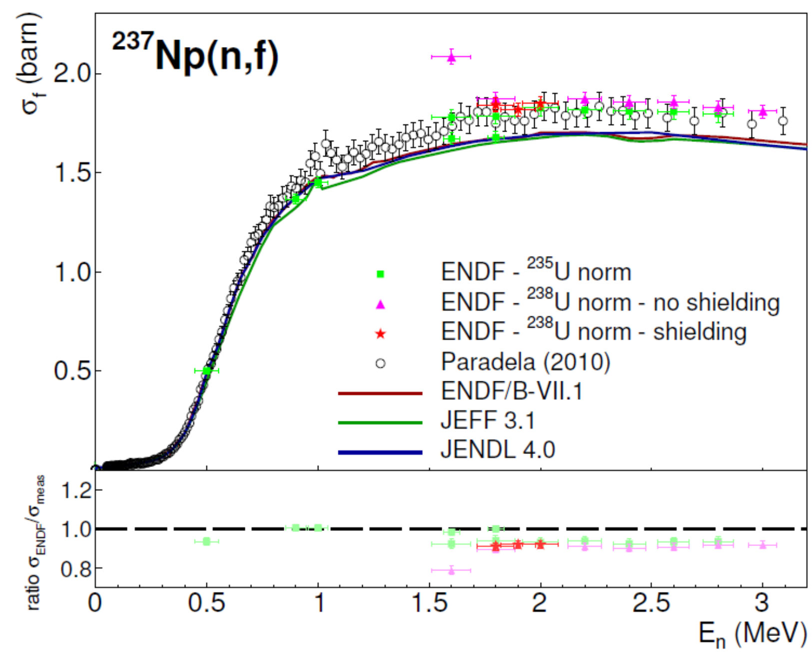
(Courtesy M. Diakaki, CEA)

^{237}Np(n,f) cross-section: present status

- Recent experiments with monoenergetic neutron beams have not resolved this discrepancy
  - Results with Micromegas detectors at 4.5-5.3 MeV (Athens, “Demokritos” van de Graaf) lie between evaluations and n_TOF data
  - Results obtained during the ^{240,242}Pu(n,f) measurement at IRMM van de Graaf show better agreement with n_TOF data (and better reproduction of Pu evaluations using these values) between 0.5-3 MeV



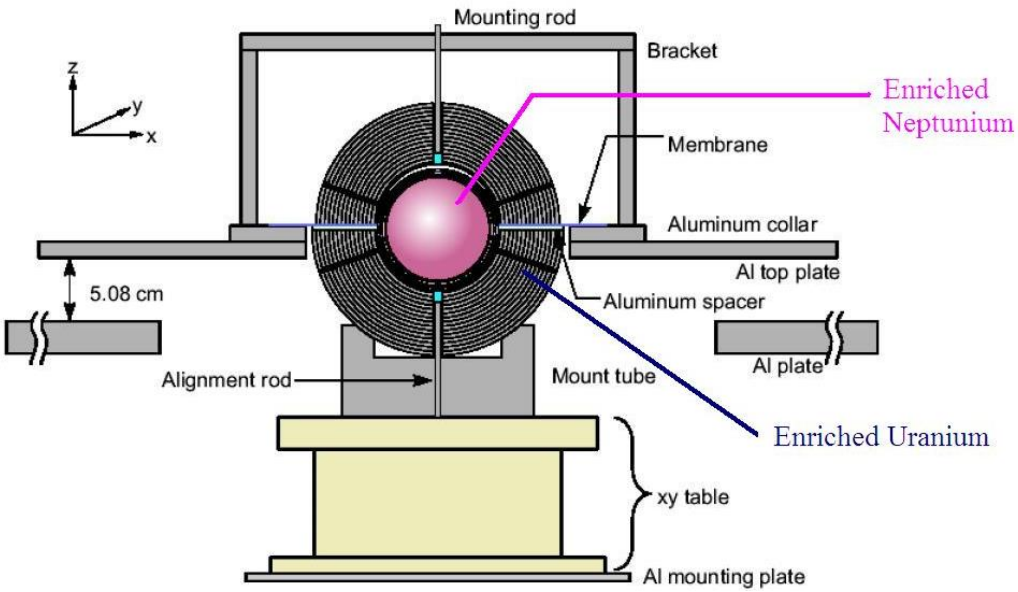
M. Diakaki et al.,
Eur. Phys. J. A (2013) 49: 62

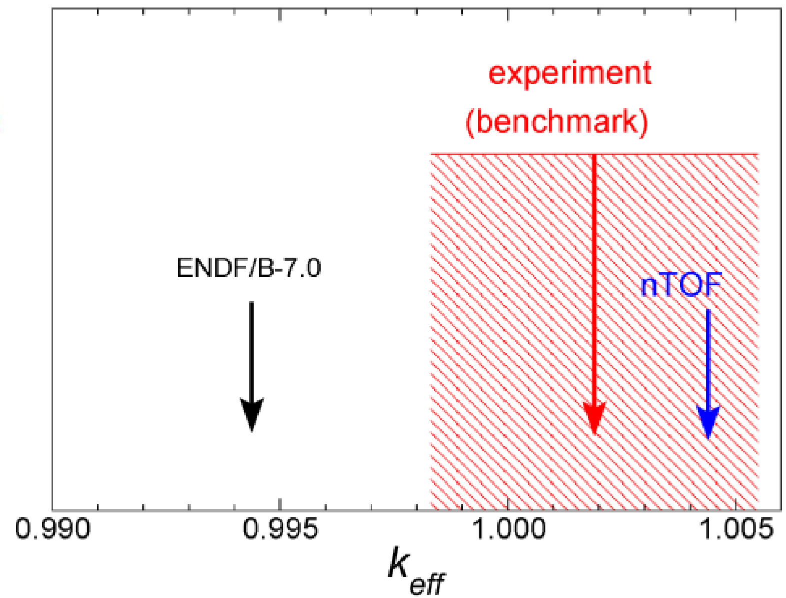


P. Salvador-Castineira,
PhD Thesis (2014)

Introduction and motivation

- Benchmark experiments lend additional support to n_TOF data
  - Enriched Np sphere inside enriched ^{235}U shells (LANL)

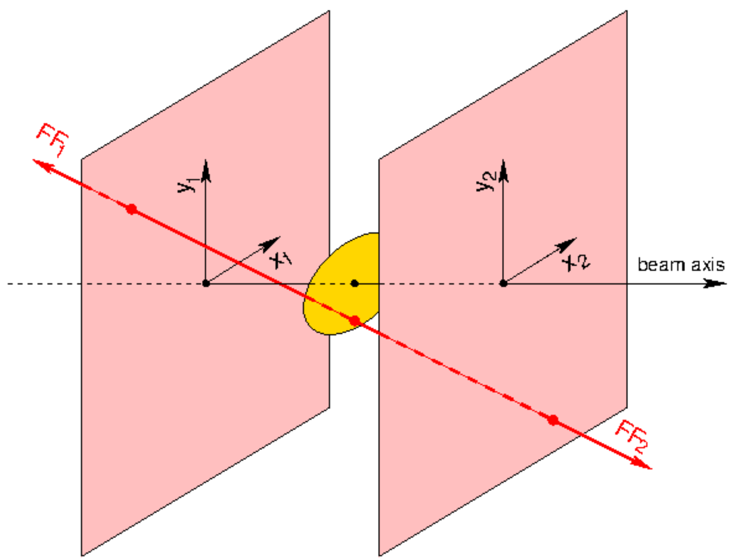


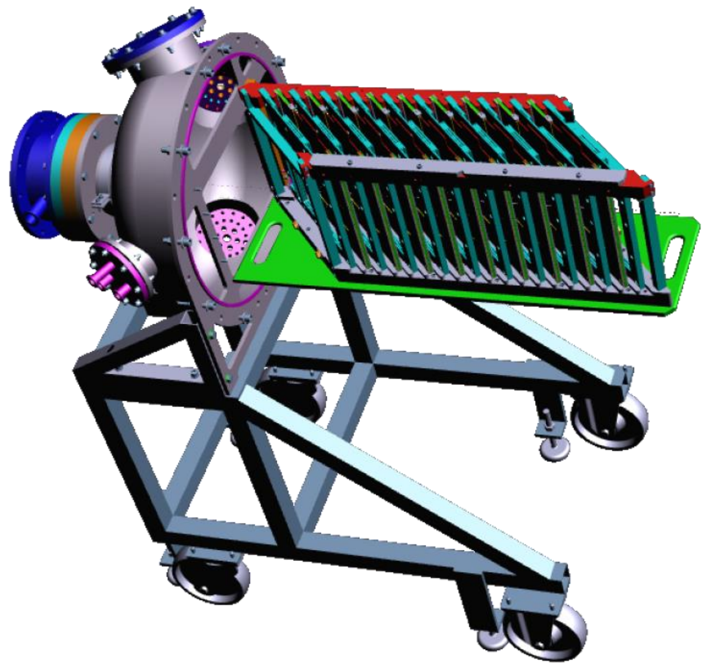


  - Benchmark experiment of Np fission rate under ^{252}Cf neutron field also favours n_TOF data
- Based on available data, a final conclusion cannot be drawn
  - An important open question in the field
- Measurements with different techniques (TOF, monoenergetic beams) and detectors are necessary to isolate systematic uncertainties and improve accuracy of evaluated cross-section
  - New measurements to be performed at IRMM and n_TOF (pending INTC approval)

Experimental setup (EAR-1)

- Based on PPAC detectors (Parallel Plate Avalanche Counters)
- Fission fragments detected in coincidence by the two PPACs surrounding each target
- Trajectories can be reconstructed to obtain the emission angle with respect to the beam
- Chamber can house up to 10 PPACs and 9 samples
- For the present proposal:
  - 50 mg of Np in 4 samples on thin Al backings
  - 2 x ^{235}U and 2 x ^{238}U samples as reference (approx. 10 mg per sample)

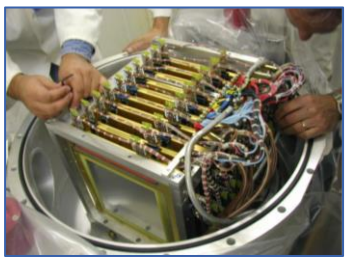


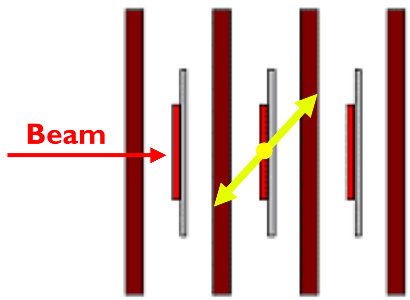


Experimental setup (EAR-1)

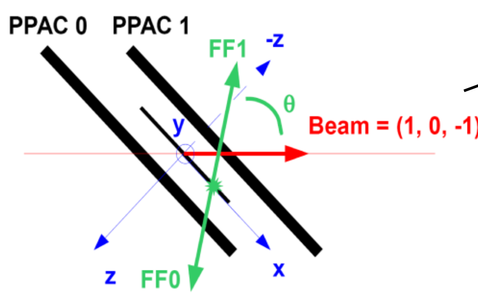
- Improved PPAC configuration compared to previous measurement
- In the past, detectors placed perpendicularly with respect to the beam
  - Angular acceptance was limited to 65°
- In new setup, detectors tilted by 45° with respect to the neutron beam
  - Efficiency is experimentally measured for each target

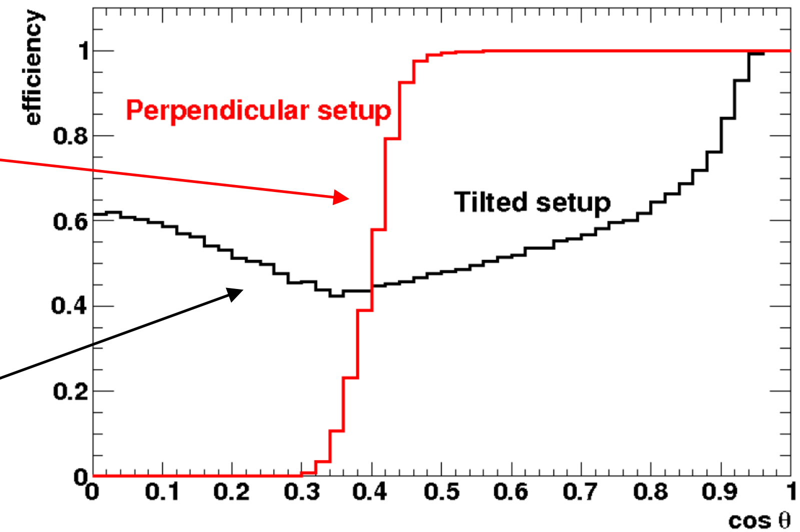
Old setup





New setup

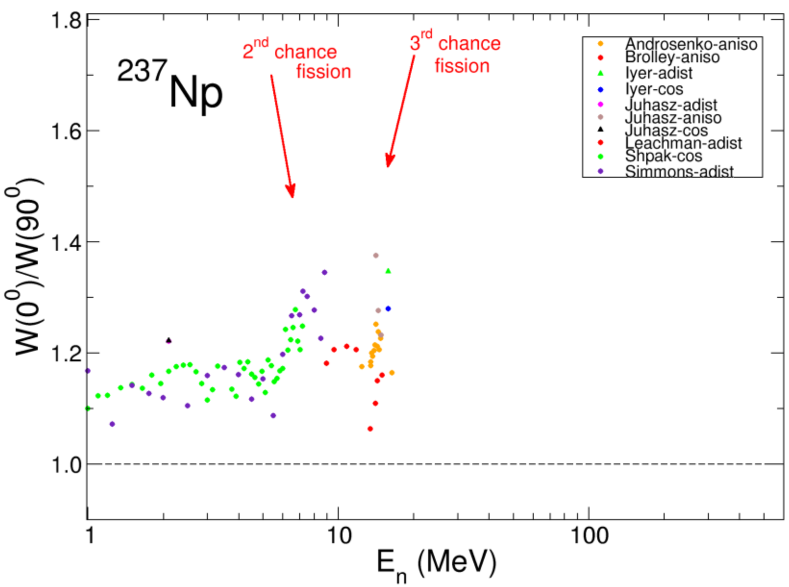


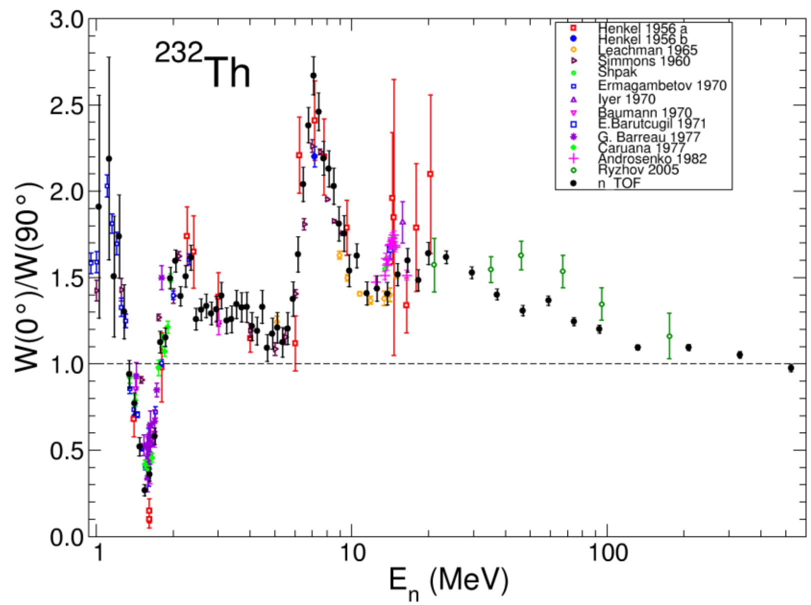


Fission fragment angular distributions

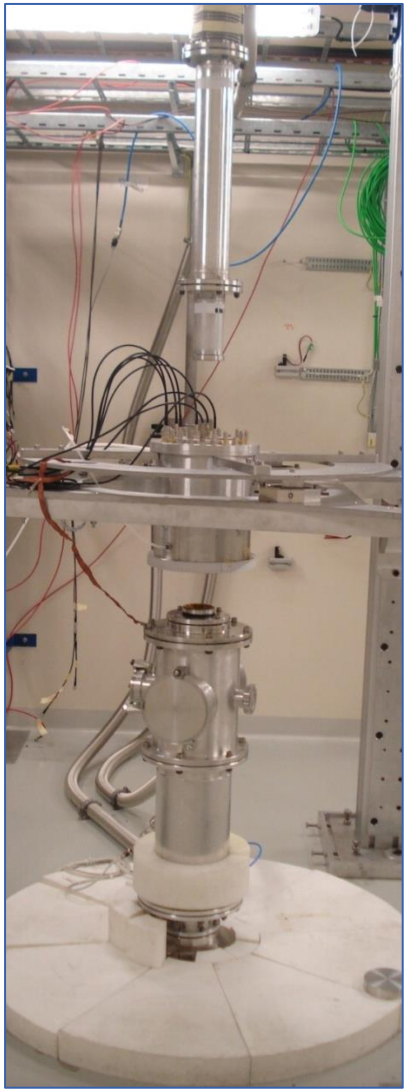
- The PPAC setup can also provide data on fission fragment angular distributions (FFAD)
- FFAD data important to:
  - Theoretical study of fission, BUT...
  - ...also for the more reliable determination of detection efficiency, improving accuracy of measured cross-sections
- The effect is important even for the PPAC configuration

- FFAD data for ^{237}Np is scarce above 10 MeV and very uncertain around 14 MeV
- As done previously with ^{232}Th, this measurement can extend the energy range and accuracy of experimental data

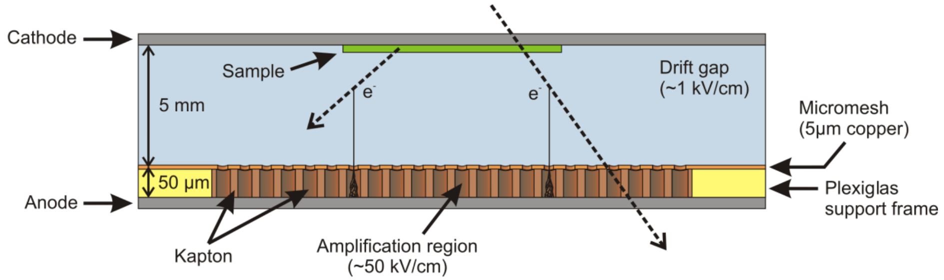




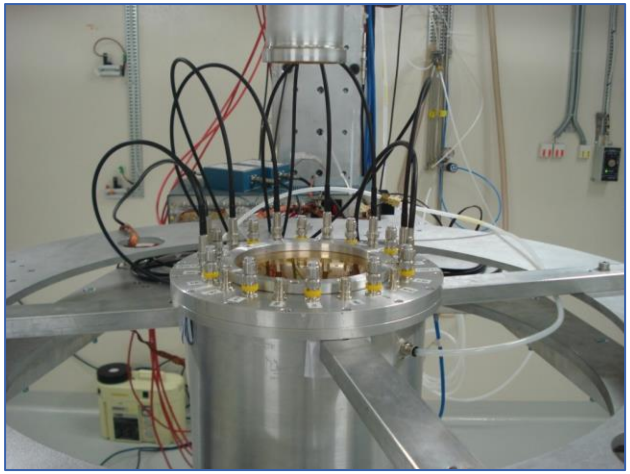
Experimental setup (EAR-2)



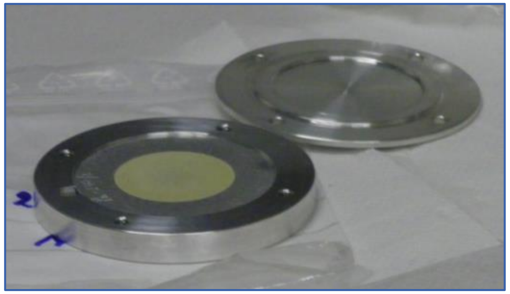
- Based on “microbulk” Micromegas (MICRO-MEsh GAseous Structure) detectors



- Already used in EAR-2 for ^{240}Pu(n,f) measurement (INTC-P-418)
- All hardware and software available
  - Chamber, chamber support, sample holders
  - Electronics
  - Analysis software, simulation tools

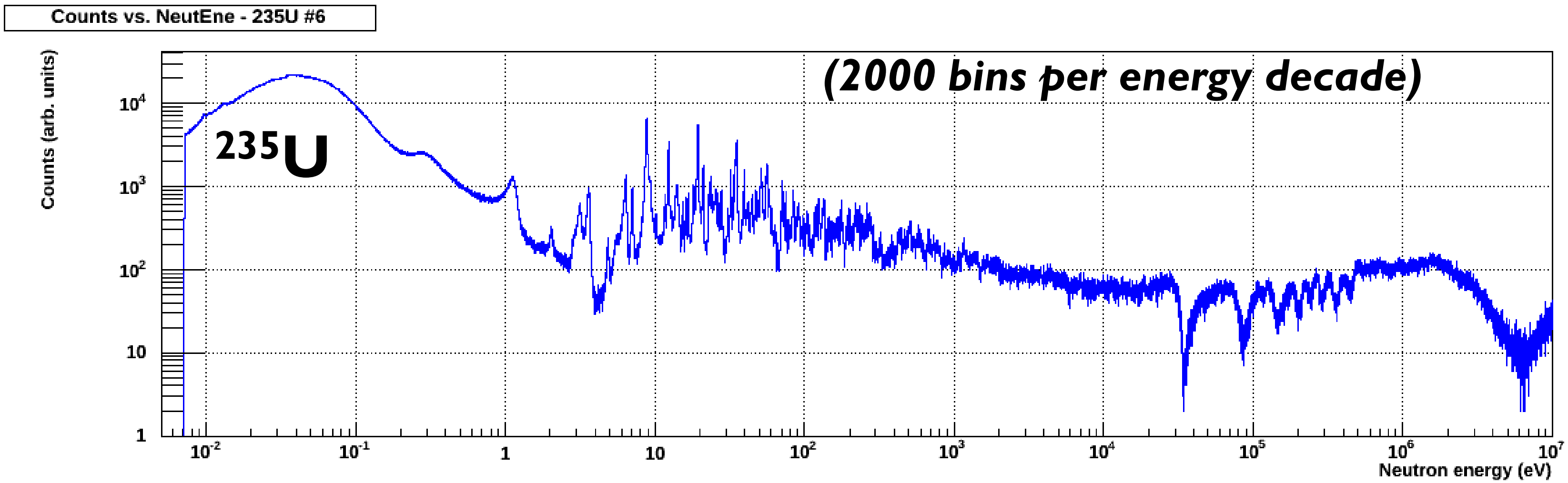


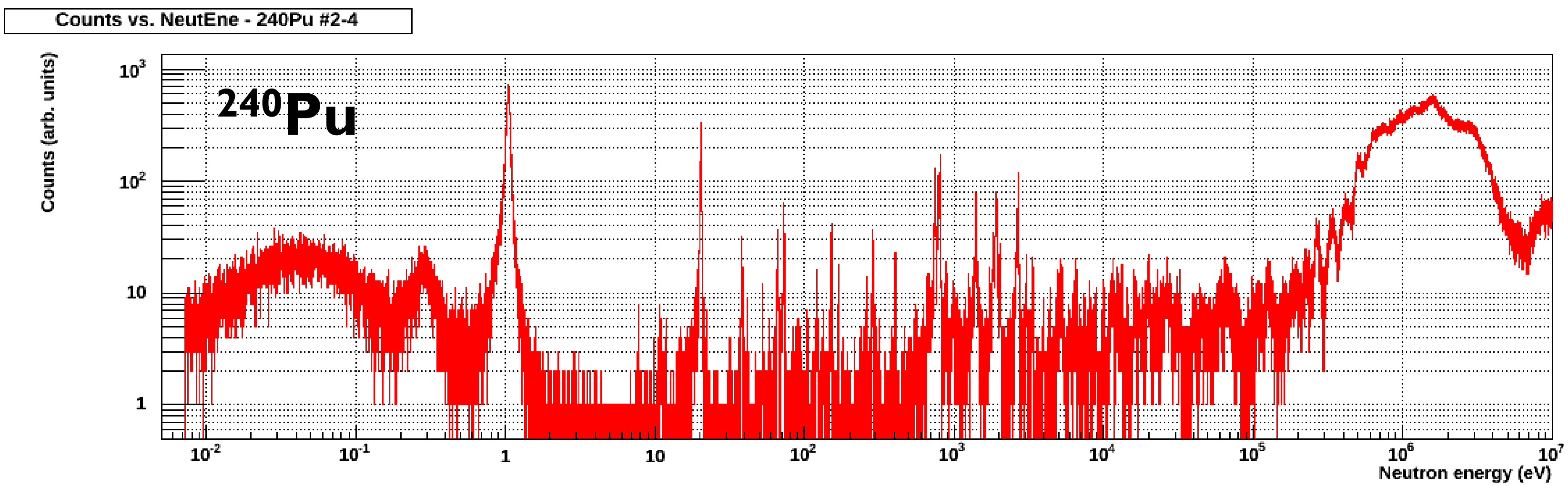
- 4 x ^{237}Np samples (~80µg/cm^2 per sample)
- 2 x ^{235}U and 2 x ^{238}U samples as reference
  - All samples 3 cm diameter



Experimental setup (EAR-2) – Previous results

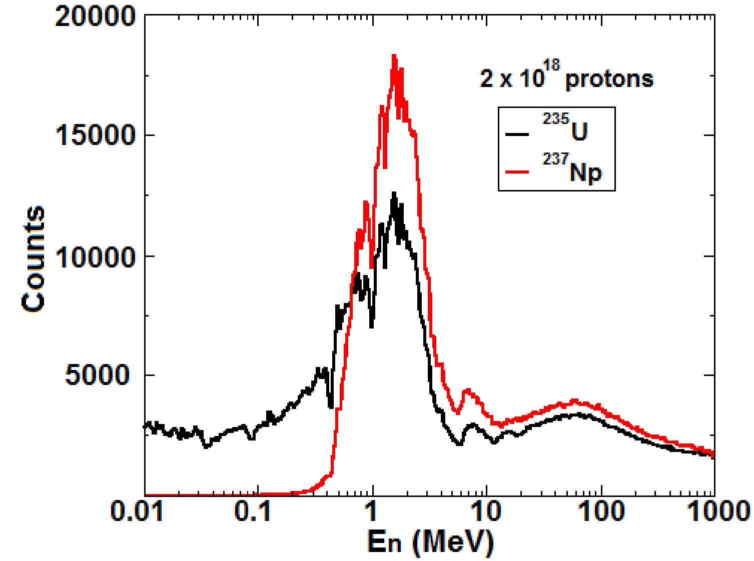
- Micromegas setup has been shown to work in high neutron rate environment of EAR-2



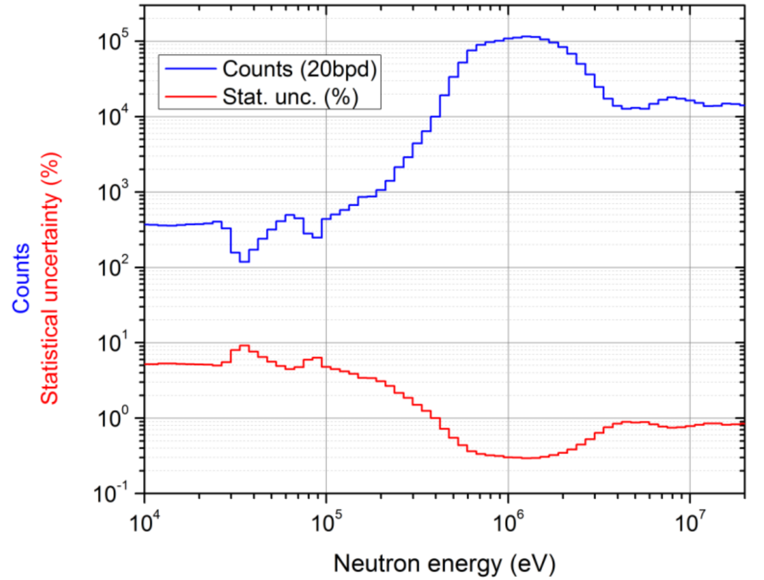


Beam request

- EAR-1
  - $2x10^{18}$ protons on target
  - "Fission" collimator (8 cm diameter)
  - Statistical uncertainty <1% for each sample above threshold
    - Dominated by reference samples above threshold, by Np samples below
    - Target-related systematic uncertainties will be revealed



- EAR-2
  - $2x10^{18}$ protons on target
  - Statistical uncertainty
    - <3% above 200keV
    - <1% above 400keV
  - Expected systematic uncertainties ~3%
    - Detector efficiency, amplitude threshold correction
  - Selected resonances will also be studied



- Duration ($2x10^{18}$ protons): 3-5 weeks, depending on beam delivery rate

Summary

- An important measurement of great interest to the nuclear data community
  - Significant discrepancies that need to be resolved
- Improved PPAC setup (EAR-1)
- Micromegas setup in EAR-2 already tested and used for ^{240}Pu(n,f) measurement
- Short experiments (3-5 weeks depending on beam delivery)
- Cross-check with different reference reactions
  - ^{235}U(n,f), ^{238}U(n,f)
- Timing of measurements dependent on sample preparation and internal n_TOF scheduling
- Analysis software already developed for both setups
  - Improvements, adjustments…
- $2x10^{18}$ protons requested for each measurement (EAR-1 & EAR-2)