Measurement of the ^{230}Th(n,f) reaction cross-section at EAR-1 and EAR-2 of the CERN n_TOF facility

R. Vlastou[1], M. Diakaki[1,2], A. Tsinganis[2], M. Kokkoris[1], A. Stamatopoulos[1], J. Andrzejewski[3], E. Berthoumieux[4], N. Colonna[5], E. Dupont[4], J. Heyse[6], N. Patronis[7], P. Schillebeeckx[6], L. Tassan-Got[2], E. Chiaveri[2]

and the n_TOF Collaboration

[1] *National Technical University of Athens (NTUA), Greece*
[2] *European Organisation for Nuclear Research (CERN), Geneva, Switzerland*
[3] *Uniwersytet Lódzki, Lodz, Poland*
[4] *CEA Saclay, Irfu, Gif-sur-Yvette, France*
[5] *Istituto Nazionale di Fisica Nucleare (INFN), Bari, Italy*
[6] *European Commission JRC, Institute for Reference Materials and Measurements, Geel, Belgium*
[7] *University of Ioannina, Greece*

Outline

- Motivation:

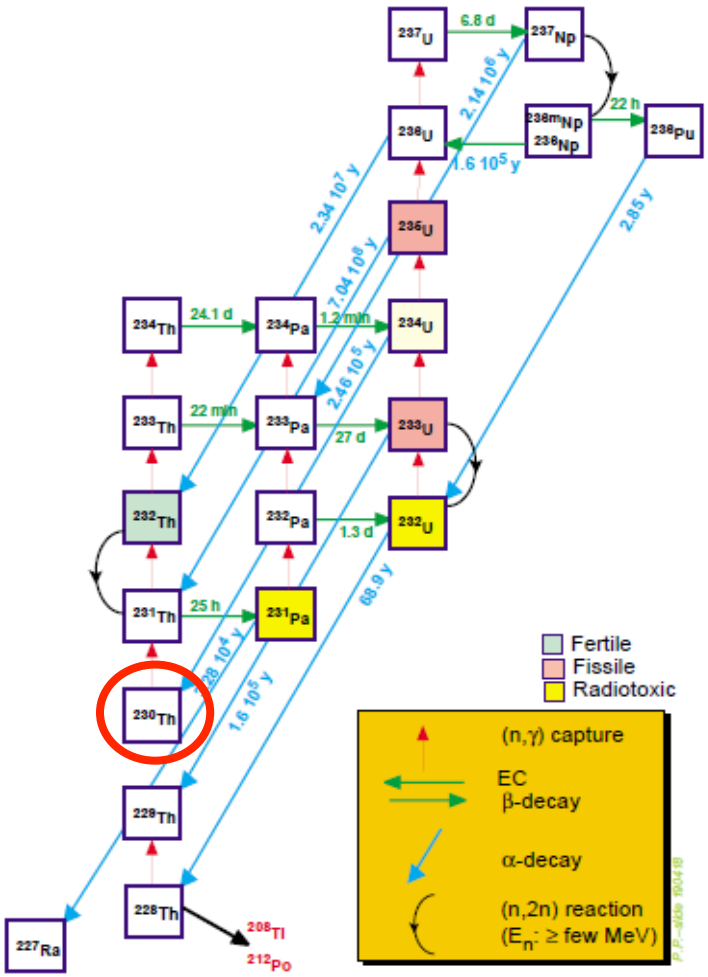
1. nuclear technology applications
2. fundamental research of the fission process

- Status of data

- Proposed experiment

- Summary

Motivation (I)



Nuclear technology applications:

- Important for the proposed **Th-U** fuel cycle

(advantages: radioactive waste management, non-proliferation).

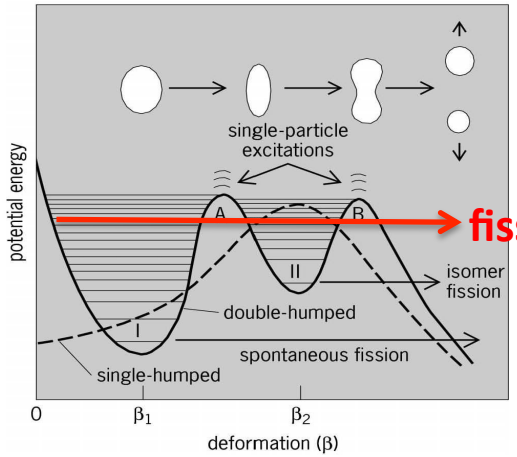
- All neutron induced reactions on Th isotopes

are needed with good accuracy

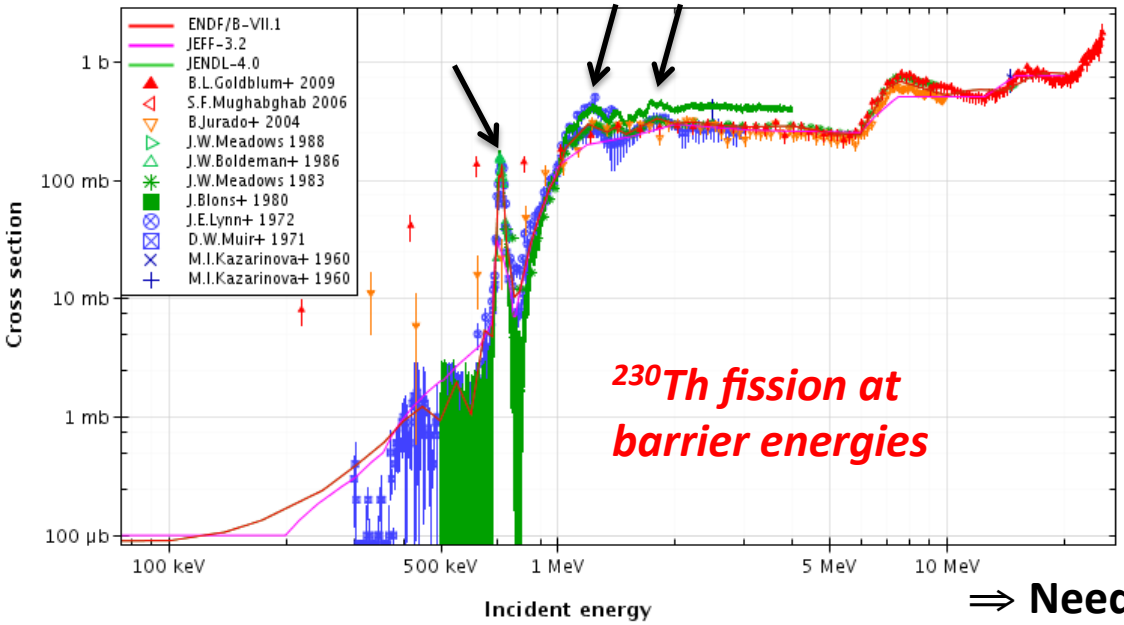
(For neutron energies: thermal to MeV)

Motivation (II)

- Study cross section close to fission barrier:
  structural behavior
  => **understanding of fission barrier structure**
  (barrier shape + states in wells)



- ***Th anomaly:***



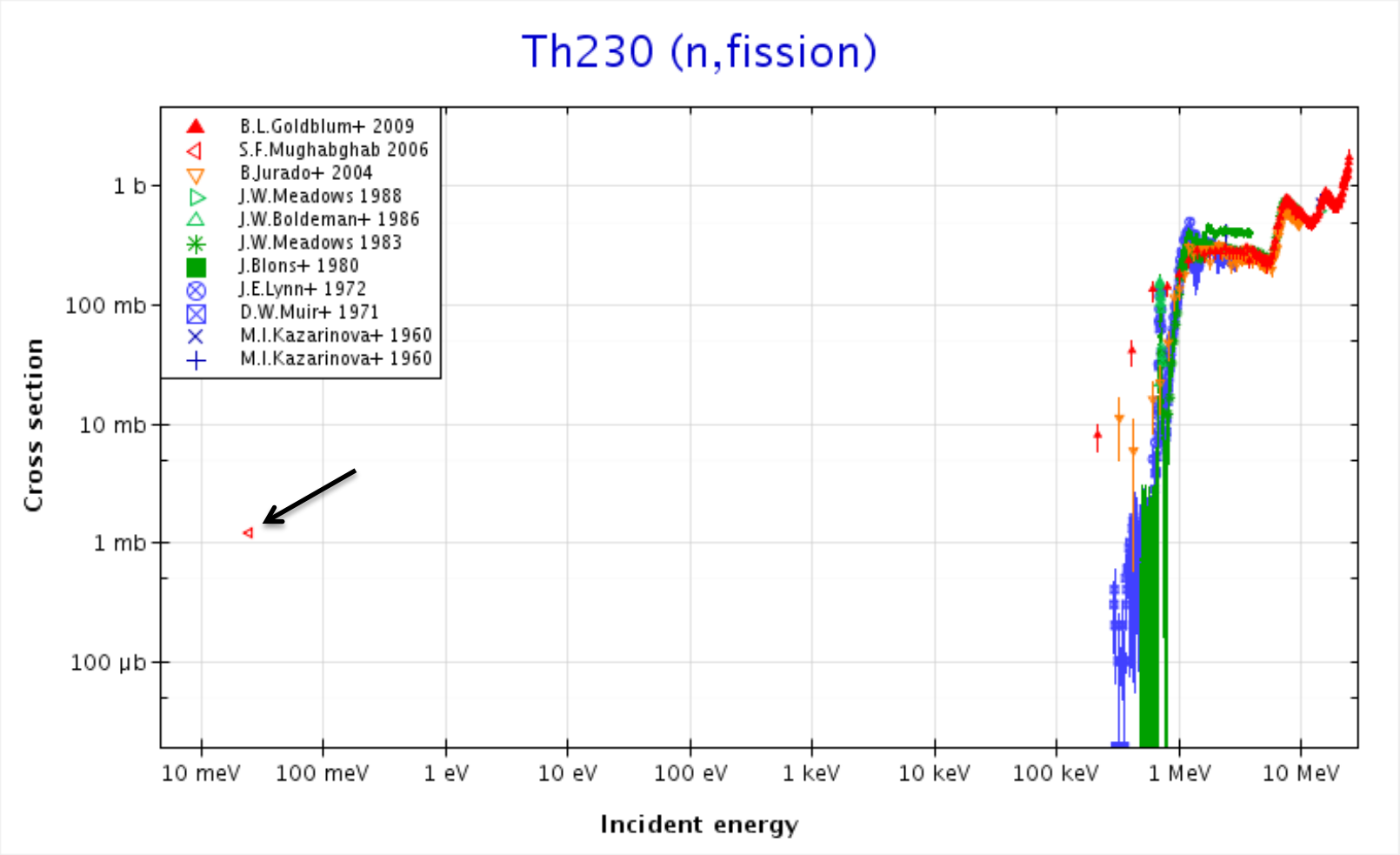
- Subject of extensive theoretical investigation:
  - Vibrational states (bandheads of rotational bands) in:
    - Second well (*James et al.*).
    - ***Third*** well (*Boldeman et al.*).
  - Phenomenological barriers from rearrangement of states during fission - Hybrid model (*Mirea et al*).

⇒ **Need for high accuracy + energy resolution data in order to test the models**

Status of data (I)

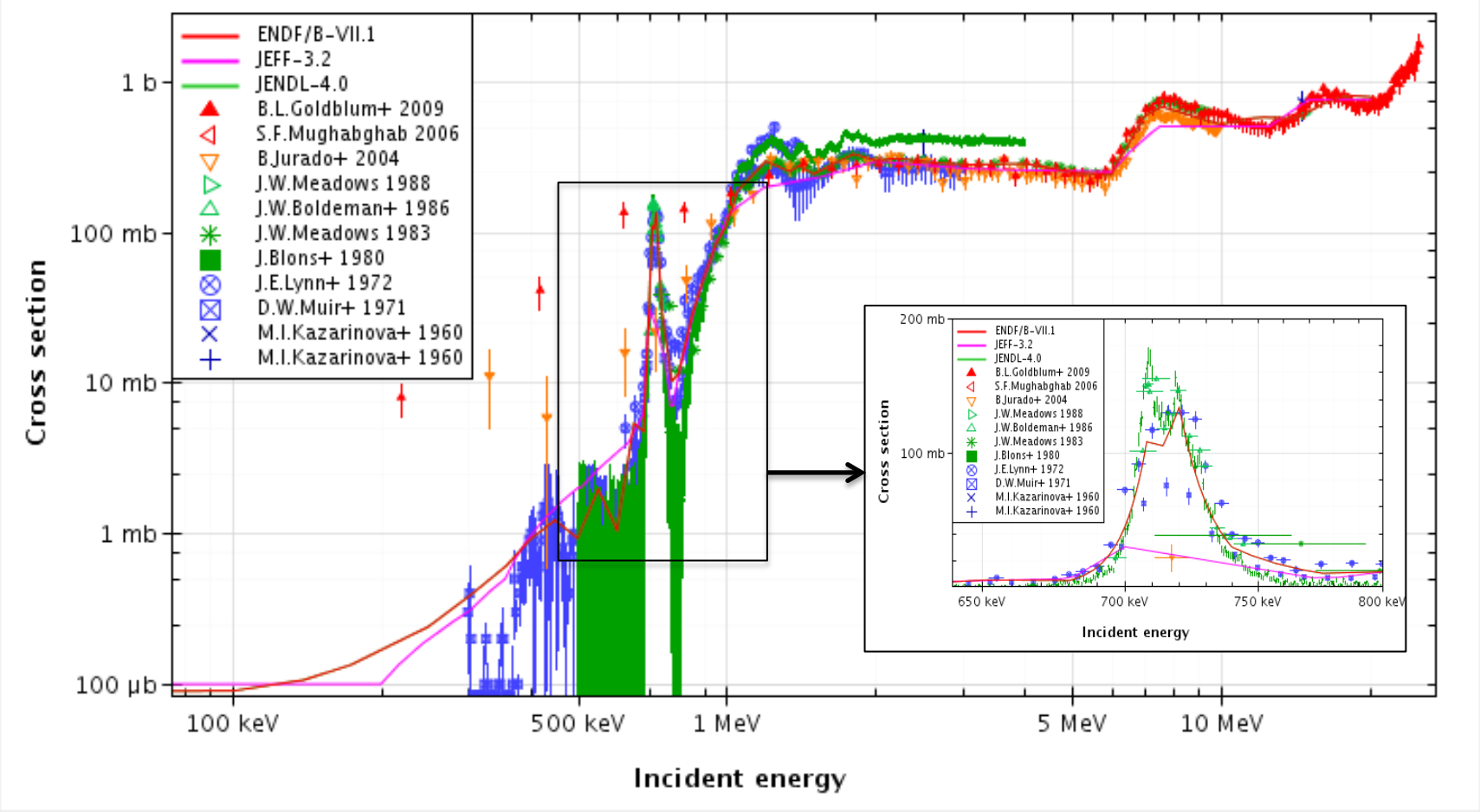
- Very scarce + discrepant data (*Very rare isotope, very low cross section)*

➢ No data below threshold (only one point at thermal)

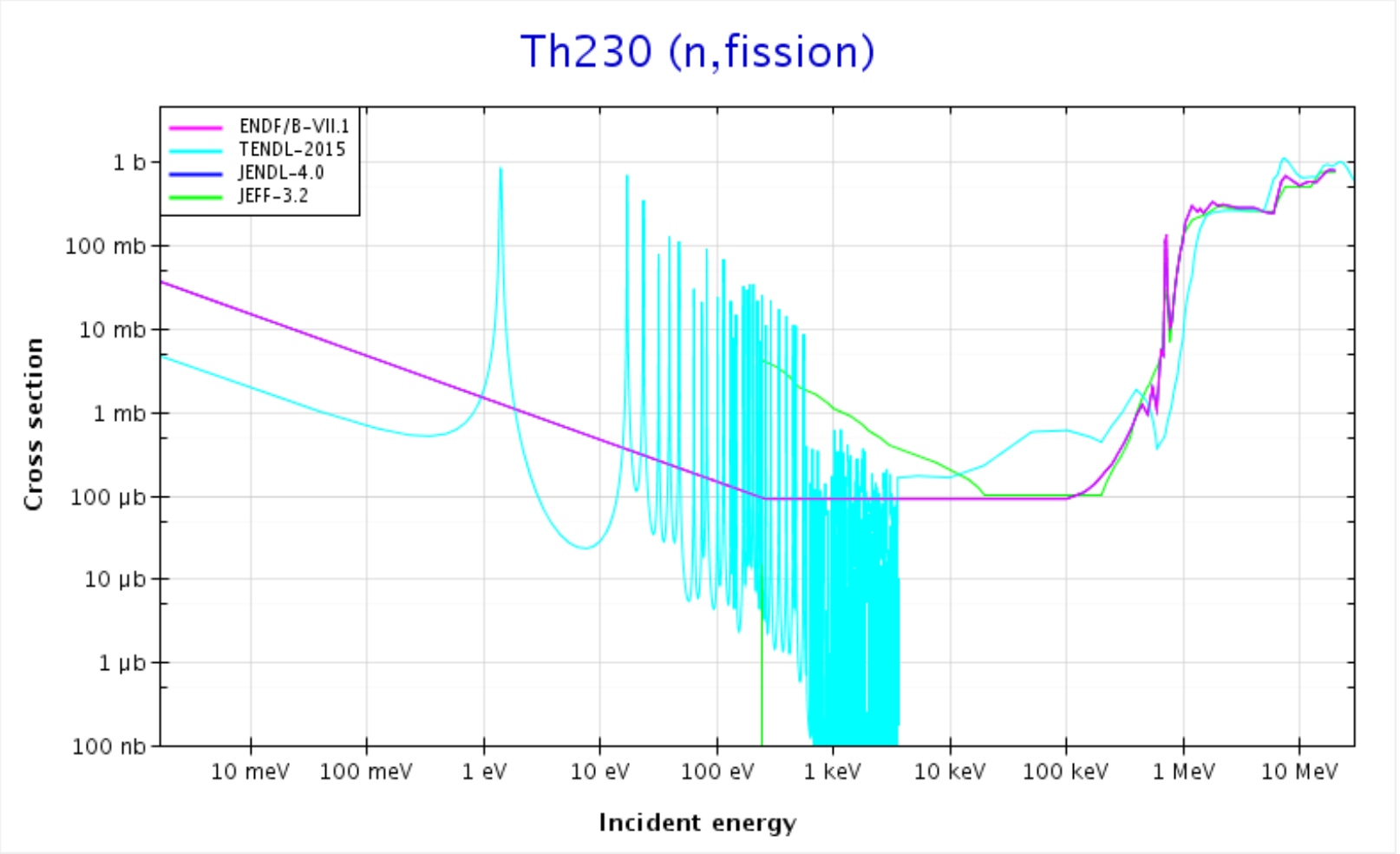


Status of data (II)

- Few datasets at and above the fission threshold up to 25 MeV (surrogate/indirect measurements, many discrepancies)



Status of evaluated data

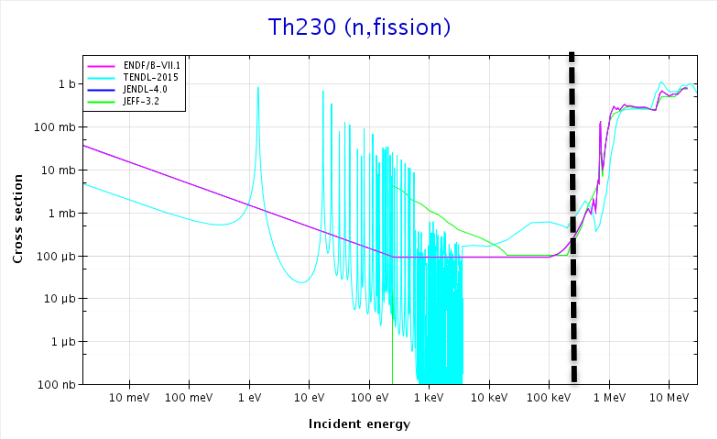


Proposed measurement

- Measurements are proposed to be performed at n_TOF:

1. **EAR-1:** high statistics data + excellent energy resolution mainly at and above the fission threshold.
2. **EAR-2** reasonable statistics + good resolution in the resonance and sub-threshold region.

- The **overlapping data from both areas** (mainly from the threshold region to higher energies): validation of the cross section results.
- Reference reactions: **^{235}U(n,f)**, **^{238}U(n,f)** and **^{10}B(n,α)**.



Difficulties:

1. **high alpha background (natural ^{230}Th radioactivity).**

⇒minimization of activity / target =>***minimum mass per target***

2. **low ^{230}Th(n,f) cross section**

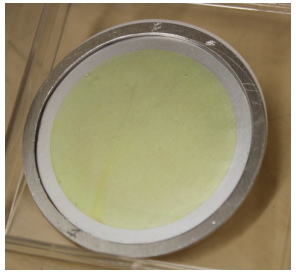
⇒maximization of instantaneous neutron fluence => ***big collimators***

⇒maximization of total mass => ***stack of many ^{230}Th targets***

Experimental setup (I)

Targets: Joint Research Centre – Geel, Belgium

preliminary agreement with IRMM already exists, to be made official upon approval of this proposal.



Courtesy: J. Heyse

- ***^{230}Th targets***:

➢ material available.

➢ Electrodeposition in the form of thorium dioxide (ThO_2) on 25 μm Al backing.

Isotope	Purity [%]	Thickness [μg/cm^2]	Diameter [cm]	Sample Mass [mg]	Sample Activity [MBq]	No. of samples	Total Mass [mg]	Total Activity [MBq]
^{230}Th	91.54	100	8.0	5.0	3.8	6	30.0	23

➢ Low mass/activity per sample, large surface

➢ Impurity: ^{232}Th (8.46%): contribution very small and easily subtracted (one hyperpure target for cross check).

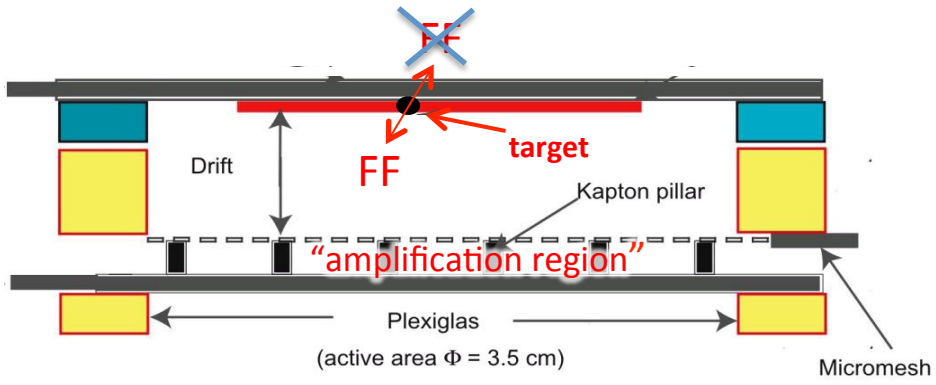
- ***Reference targets***: ^{235}U, ^{238}U, ^{10}B

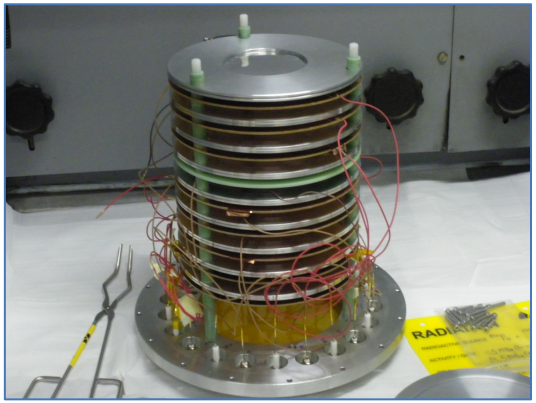
(same geometry + backing characteristics).

Experimental setup (II)

- **Detection system**: Micromegas microbulk detectors

(already successfully used at n_TOF for fission (^{237}Np,^{242}Pu, ^{240}Pu))





existing chamber up to 10 actinide targets measured simultaneously

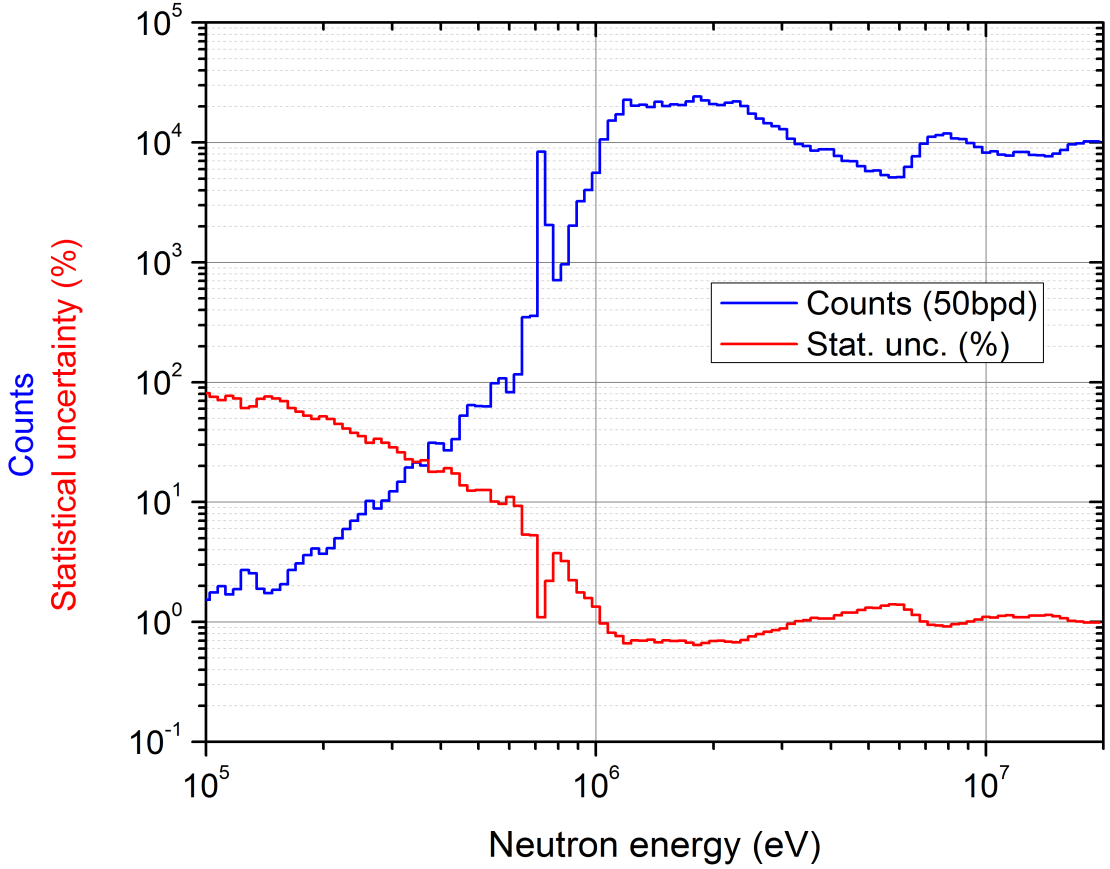
- **Electronics**: existing preamplifiers, some modifications envisaged based on previous experience.

- **Acquisition:** standard n_TOF Data Acquisition System based on flash-ADCs (12- or 14-bit). Analysis routines already developed.

Expected count rates – beam request

EAR-1:

- large (“fission”) collimator (8 cm diameter)
- $3x10^{18}$ protons on target

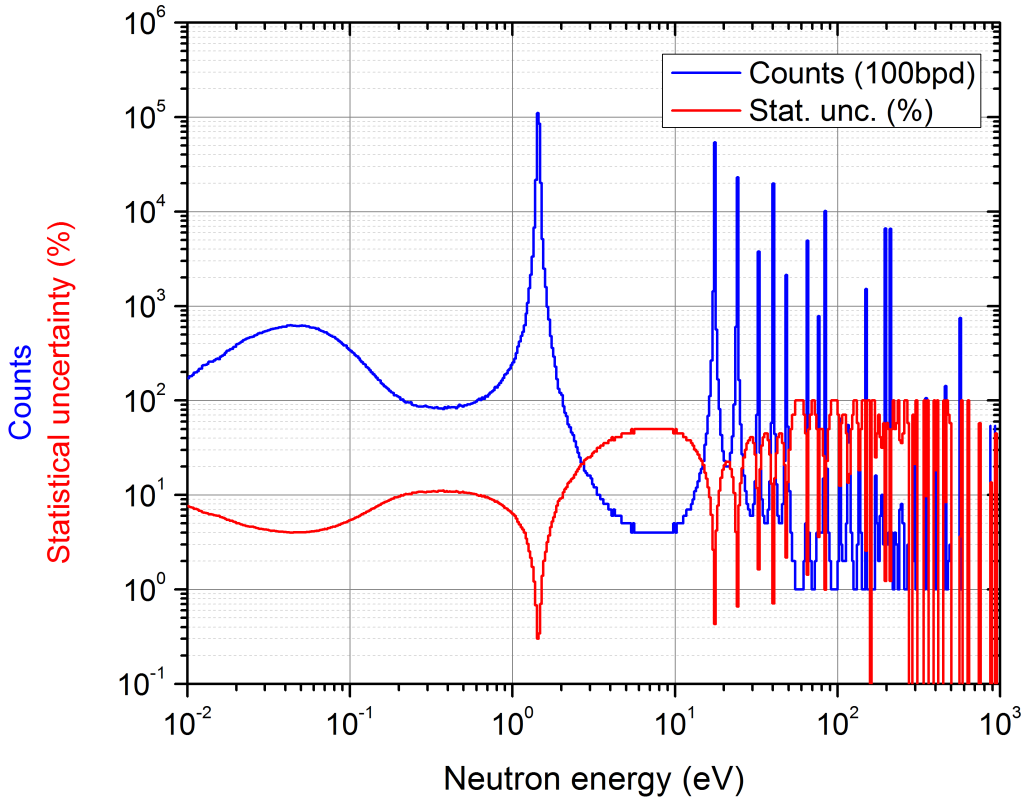


High statistics and resolution cross section data > 600 keV (investigation of resonant structure at threshold + data up to high energies)

Expected count rates – beam request

EAR-2:

- large (“fission”) collimator (6 cm diameter)
- calculations based on TENDL-2015
- 3×10^{18} protons on target



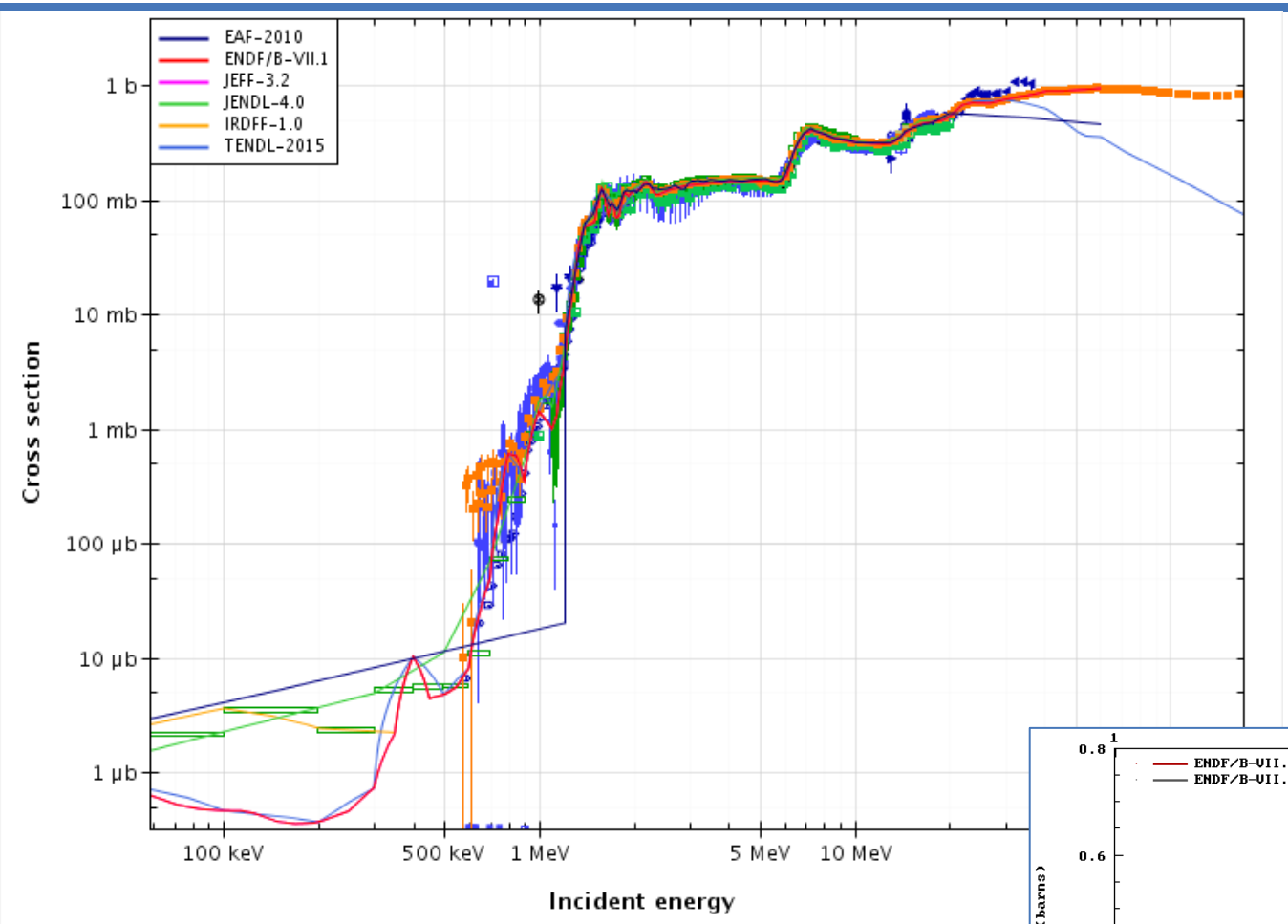
Reasonable statistics and resolution from thermal to subthreshold region (no data exist so far!)

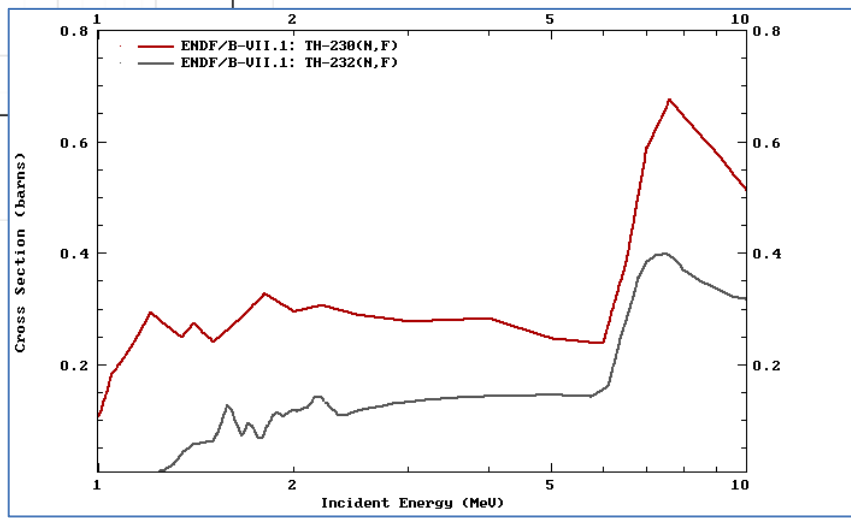
Summary

- **^{230}Th(n,f) cross section measurement**: Important for fundamental research on the fission process / nuclear reactor technology.
- The availability of the **very rare isotope ^{230}Th** at JRC-Geel, provides the opportunity to perform high-quality **direct measurement** at EAR-1 and EAR-2 exploiting their respective features: **The first complete high-accuracy dataset from thermal to tens of MeV.**

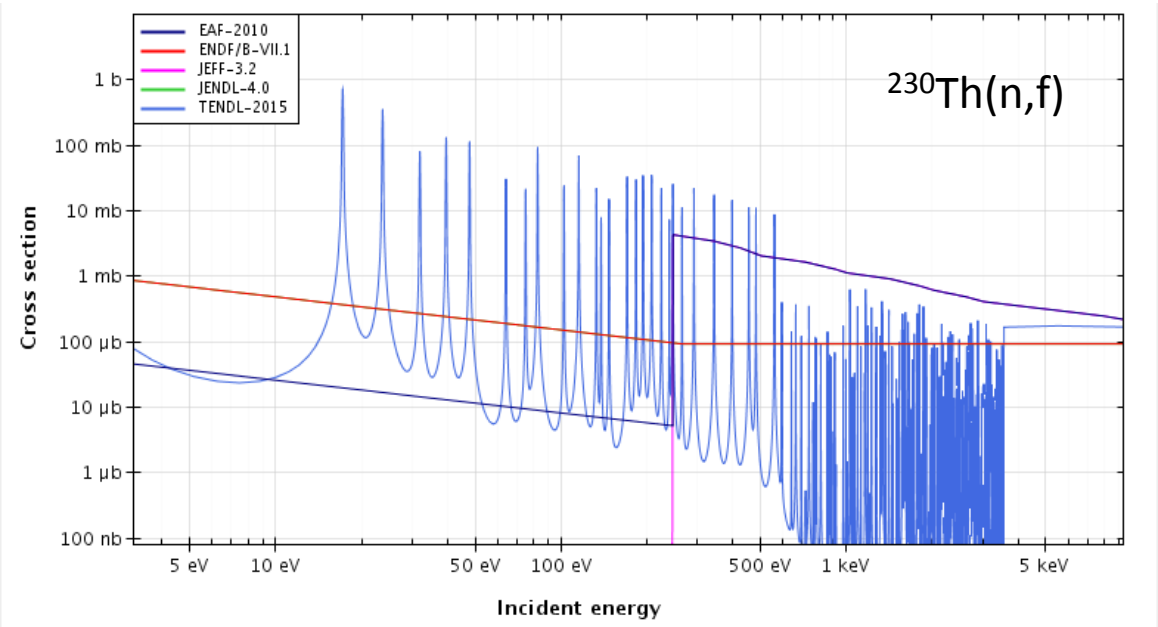
EXTRA SLIDES

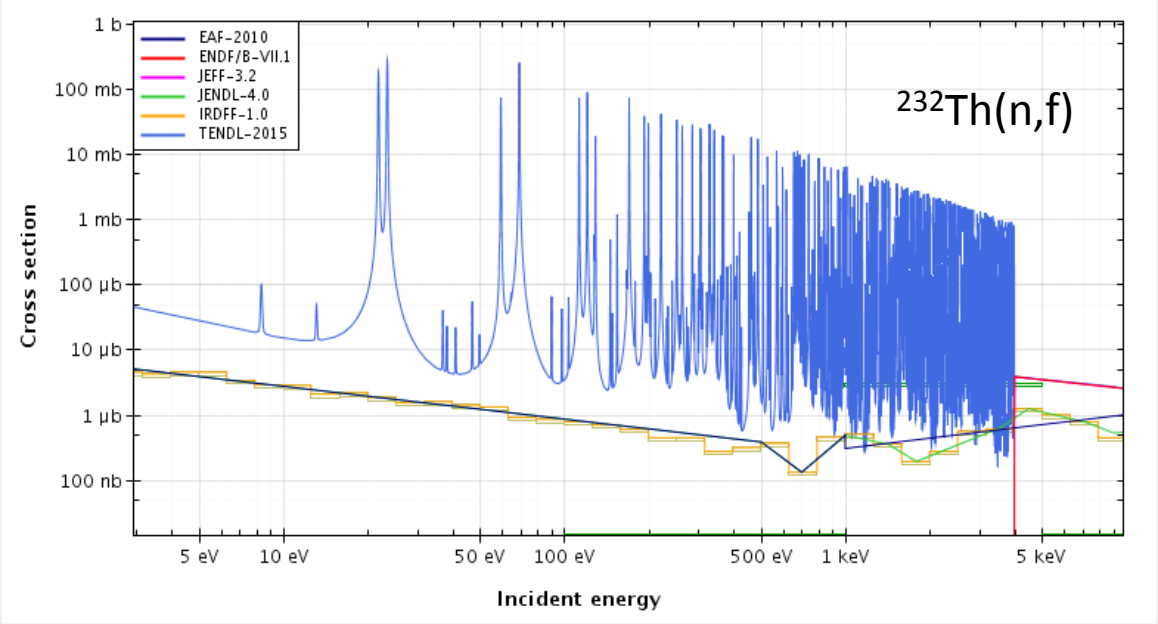
^{232}Th(n,f) cross section





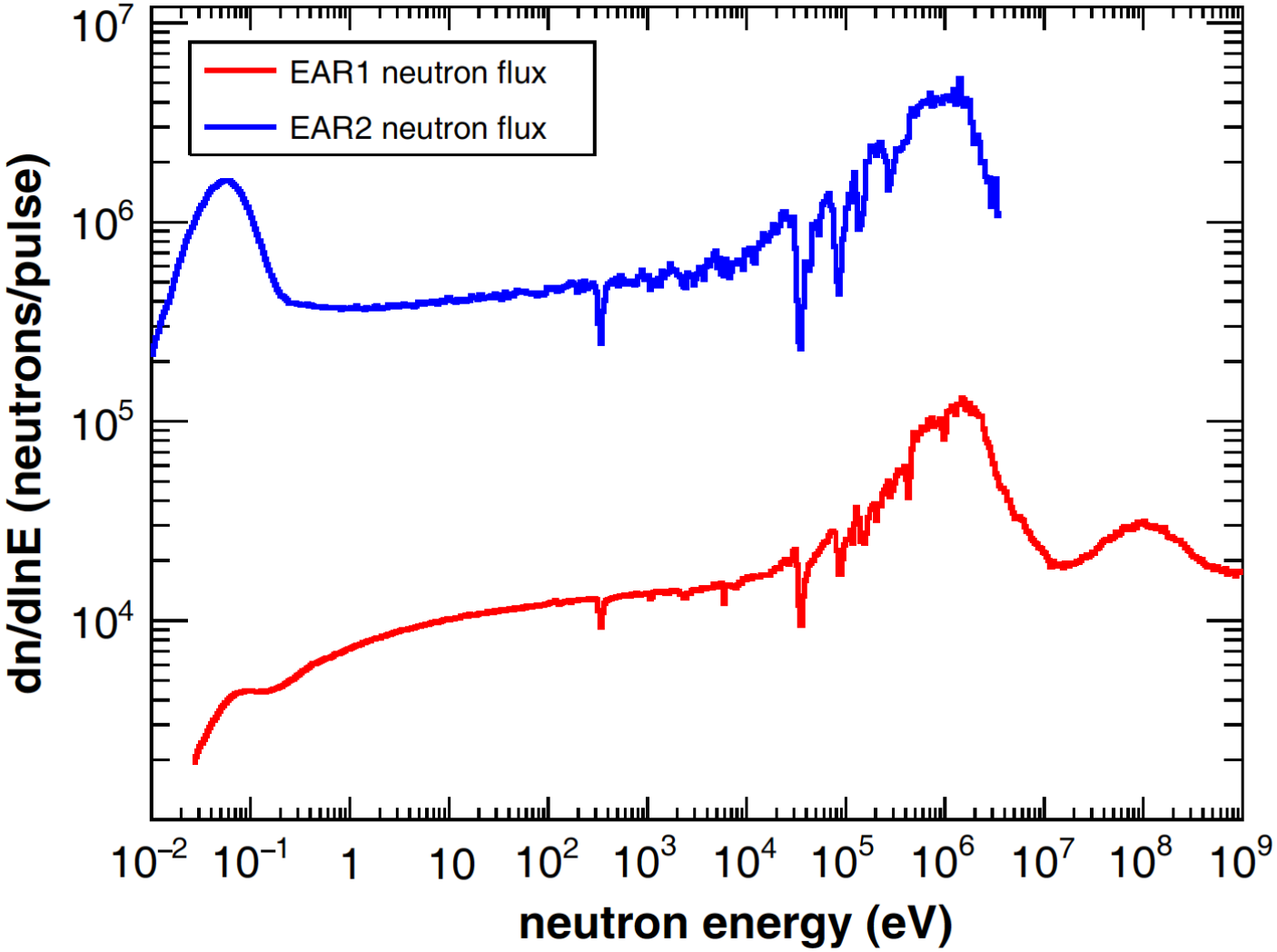
$^{230\text{-}232}$Th(n,f) cross section at resonances





T

n_TOF neutron flux



small collimators

- EAR1-185m, FWHM = 18mm
- EAR2-20m, FWHM = 21mm

Expected count rates – beam request

EAR-1:

- large (“fission”) collimator (8 cm diameter)
- 3×10^{18} protons on target