Measurement of the neutron capture cross section of ^{241}Am at n_TOF

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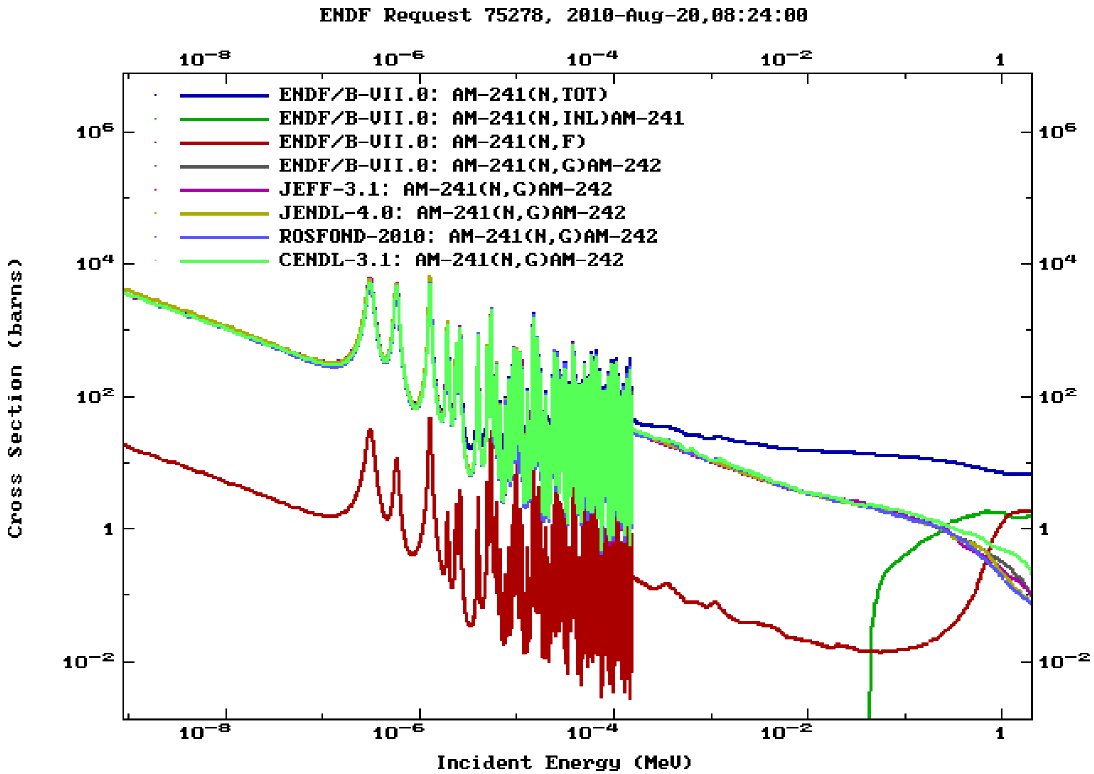
Final EFNUDAT Workshop 2010, Geneva (Switzerland)

The evaluated $^{241}Am(n,\gamma)$ cross sections



Relative differences:
10% @ thermal
8% @ 1 keV
3% @ 10 keV
7% @ 100 keV
12% @ 500 keV
40% @ 1MeV

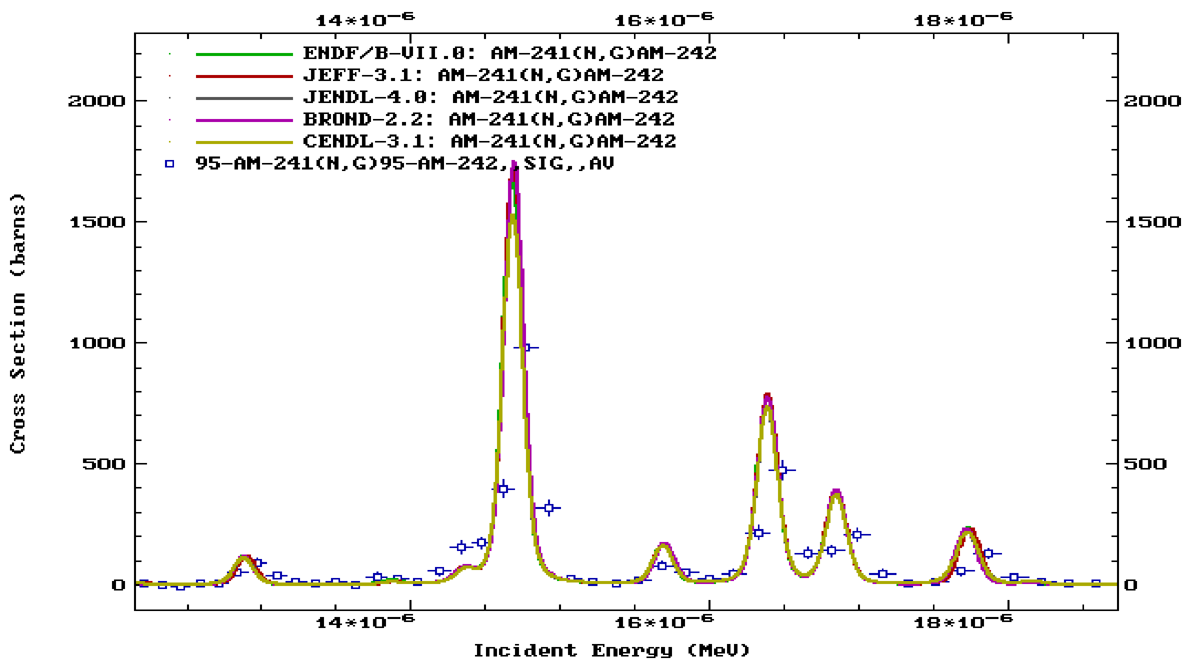
NEA WPEC-26 on ^{241}Am
GFR: 8% -> 3% between 200 eV and 2 keV
ADS: 8% -> 3% between 500 eV and 1.4 MeV

CANDIDE: Coordination Action on Nuclear Data for Industrial Development in Europe
$^{241}Am(n,\gamma)$ is within the 11 identified high priority (n,γ) measurements

^{241}Am differential s(n,g) measurements in the XXI century

Data from 1980s (RRR & URR) used samples of few grams

	LANSCE-DANCE *PRC 78 (2008) 034609*	**IRMM-GELINA** *Procc. ND2010*	**CERN-nTOF** *Ongoing (2010)*
Mass of ^{241}Am (mg)	0.22 mg	325 mg	32.2 mg
Flight Path (m)	22 m	12.5	185
Detection technique	Total Absorption (4π BaF_2)	Total Energy ($2xC_6D_6$)	Tot. Absorption & Tot. Energy (4π BaF_2 & $\underline{2xC_6D_6}$)
Energy range	Thermal to 320 keV	Thermal to 500 eV	Thermal to 1 MeV(?)

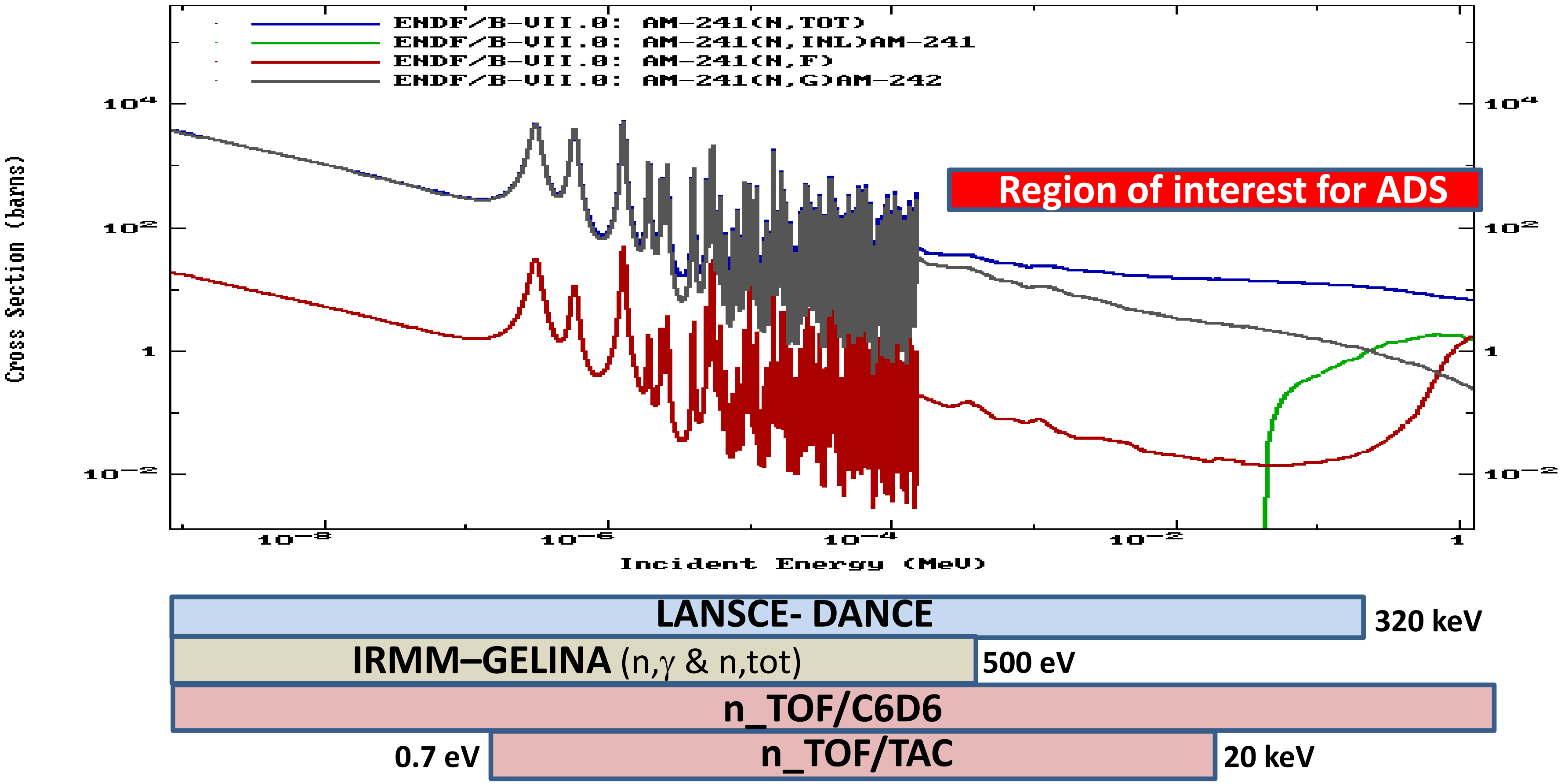


C. Guerrero et al. @ EFNUDAT 2010
"The ^{241}Am(n,γ) cross section measurement at n_TOF"

“Neutron capture cross section measurements of ^{238}U, ^{241}Am and ^{243}Am at n_TOF”, *CERN-INTC-2009-025/INTC-P-269*
Spokespersons: D. Cano-Ott (CIEMAT) and F. Gunsing (CEA), Technical Coordinator: V. Vlachoudis (CERN)

The measurements will be performed combining for the first time the TAC and 2xC6D6:

1. Reduction of systematic errors
2. Study of the complete range between thermal and 1 MeV (already achieved for ^{232}Th)
3. Extension of the RRR thanks to high statistics of the TAC



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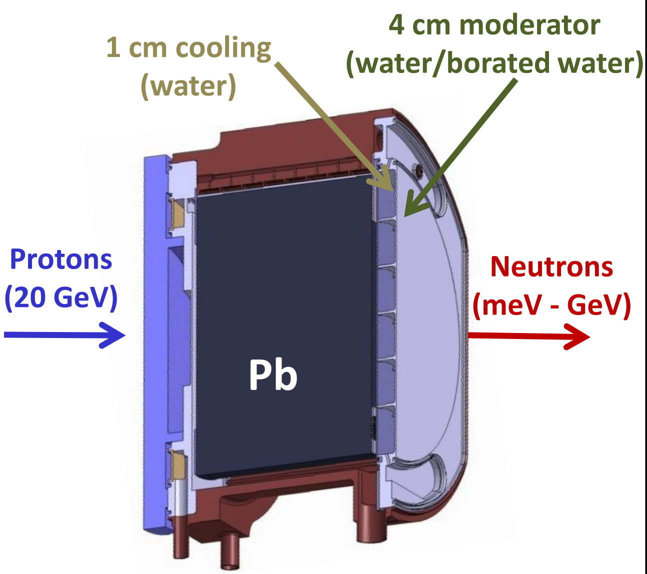
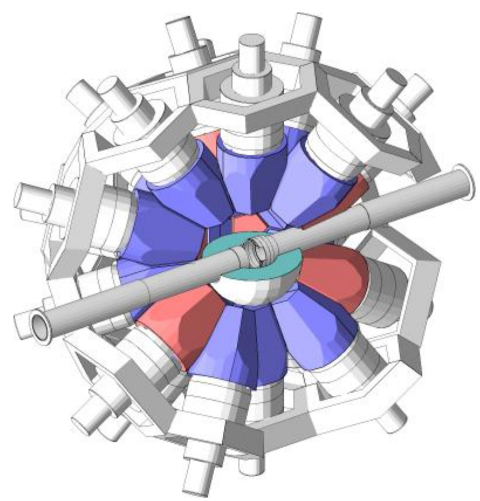
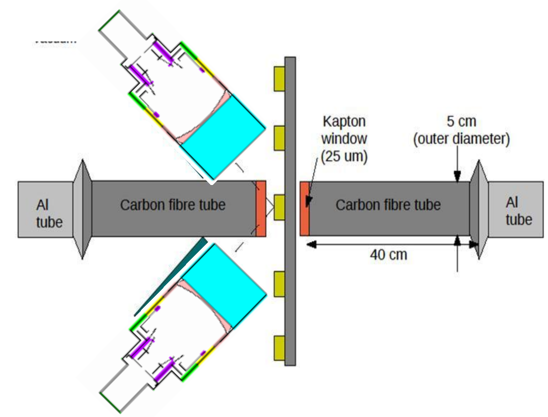
The n_TOF spallation target



The n_TOF Total Absorption Calorimeter



The n_TOF C_6D_6



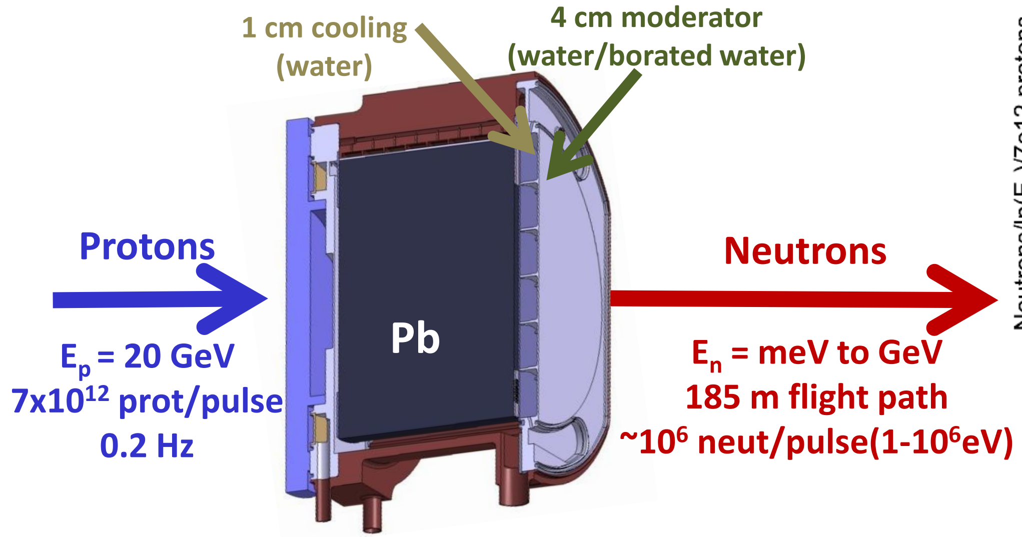
The n_TOF facility at CERN

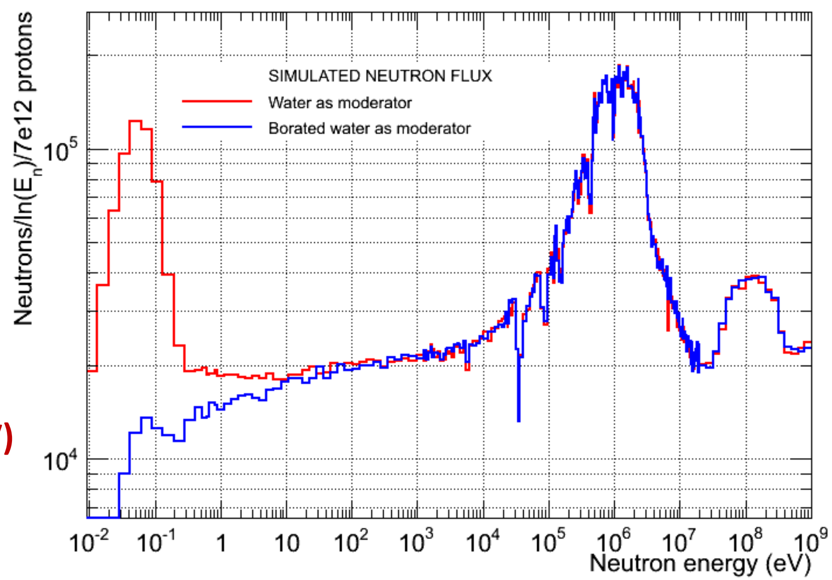
The n_TOF facility operates at CERN since 2001 aiming at the measurement of high accuracy neutron induced cross sections. The main advantages with respect to other facilities are:

- **Wide energy range in a single shot (thermal to GeV)**
- **Very high instantaneous intensity**
- **Large flight path (185 m).**

A new spallation source has been installed in 2009

The experimental area have been upgraded to a Work Sector Type-A (no limitation on sample activity)





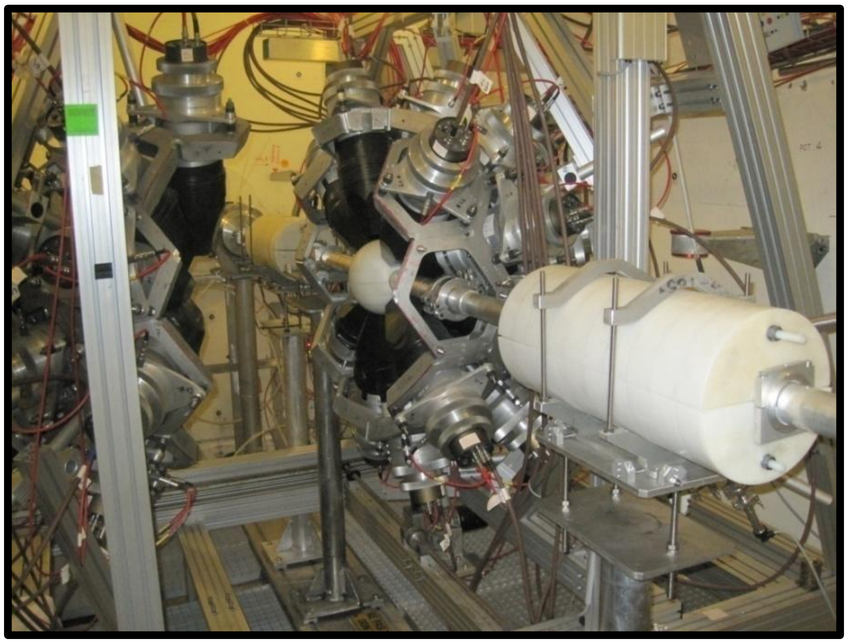
<u>Neutron Beam Monitoring:</u>

- MGAS detector with ^{10}B (thermal to 100 keV) and ^{235}U (thermal and 5 keV to 1 MeV) samples.
- Silicon Monitor looking at a ^{6}Li (thermal to 10 keV) sample.

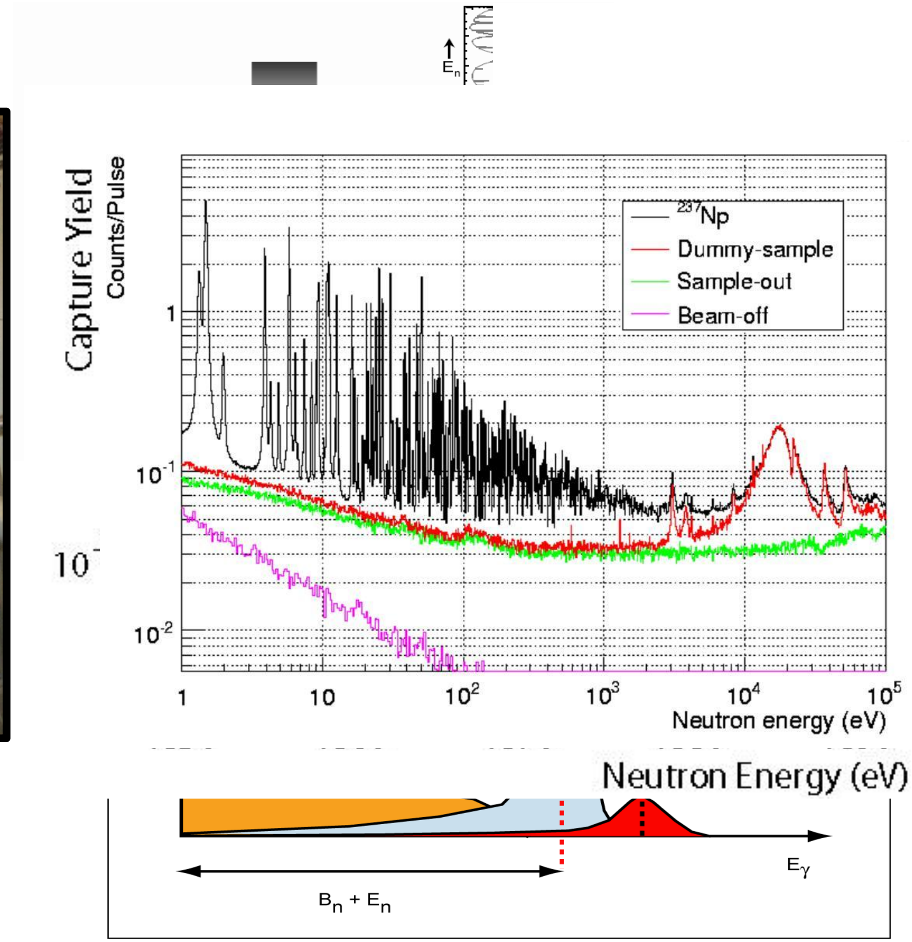
The n_TOF Total Absorption Calorimeter (TAC)

Detecting capture reactions means to detect the subsequent EM cascade.

It is very well suited for the detection of capture cascades in the measurement of low-mass/radioactive samples is the total absorption technique.



C. Guerrero et al., Nucl. Inst. And Meth. A **608** (2009) 424-433



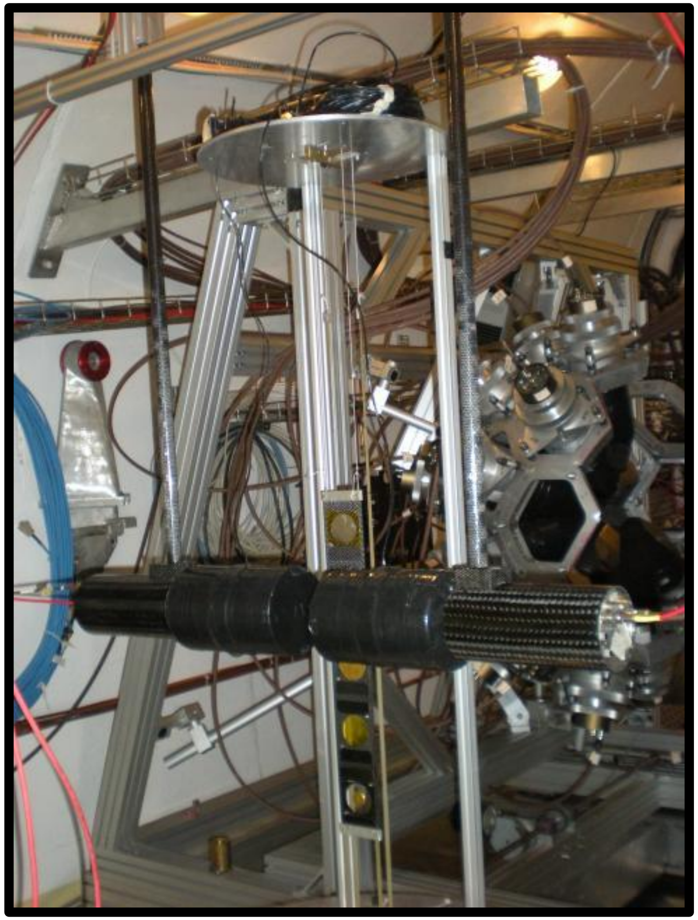
The n_TOF C6D6 Total Energy Detectors

The technique relies in two conditions:

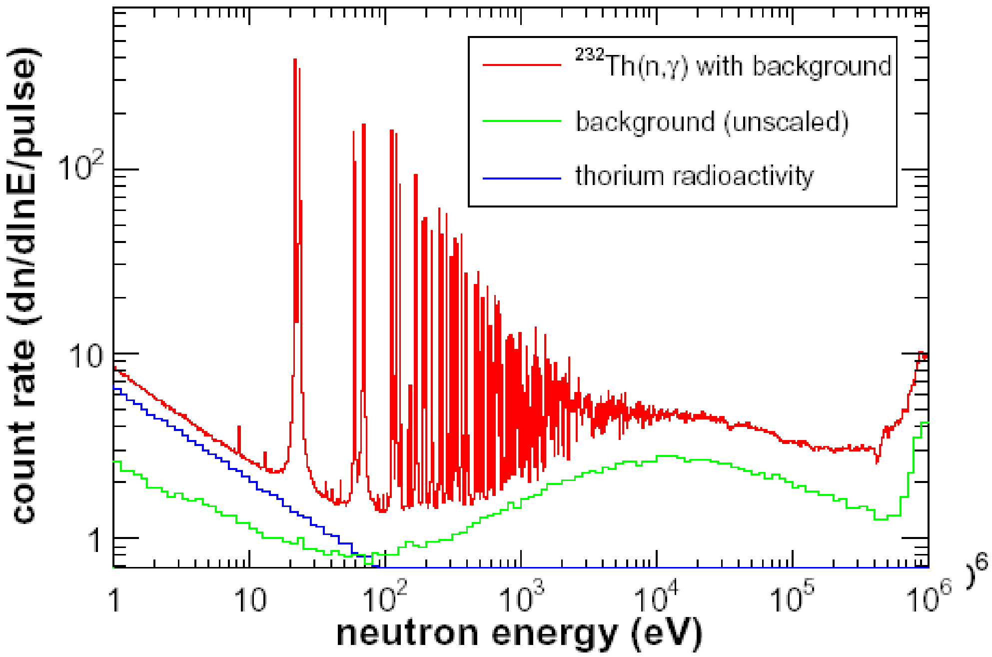
(i) $\varepsilon_\gamma << 1$ so that at most only one γ–ray per capture cascade is registered,

(ii) ε_γ is proportional to the energy of the registered γ-ray: $\varepsilon_\gamma \approx \alpha E_\gamma$.

In such case: $\varepsilon_c = 1 - \Pi_{j=1}^{m}(1-\varepsilon_{\gamma j}) \approx \sum_{j=1}^{m} \varepsilon_{\gamma j} \approx \alpha E_c$



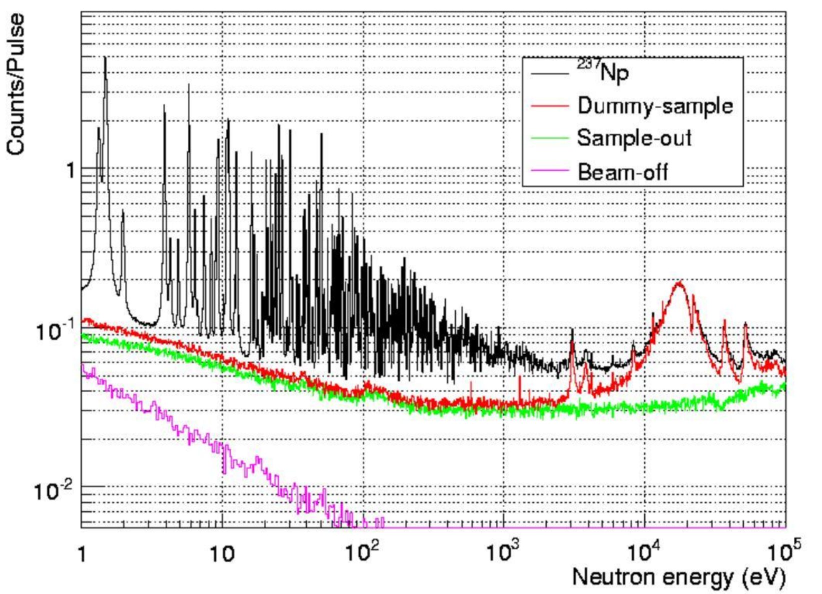
R. Plag et al., Nucl. Inst. And Meth. A ***496*** (2003) 425-436



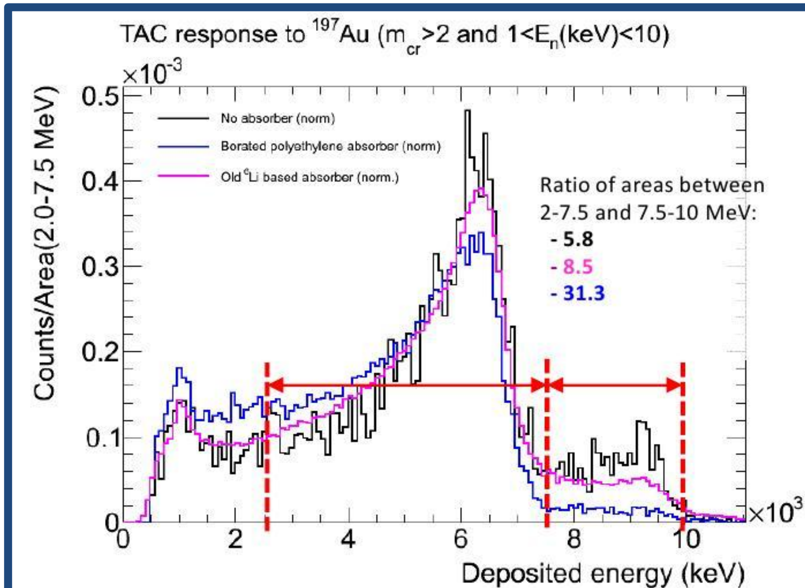
G. Aerts et al. Phys. Rev. C 73 (2006) 054610

Improvements from previous measurements: TAC

SITUATION IN 2004



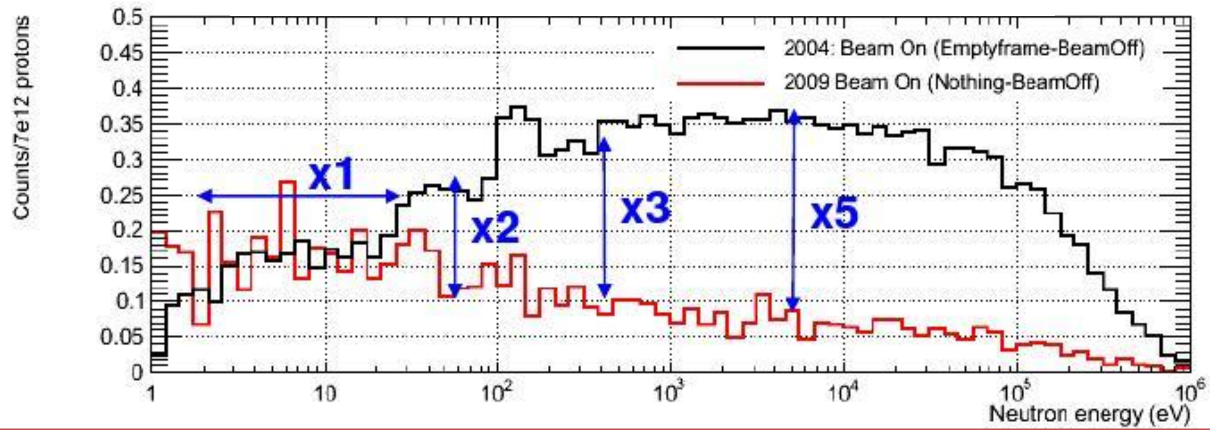
2. NEW NEUTRON ABSORBER



1. NO TI CAPSULES

We have eliminated the use of titanium capsules in our sample, thanks to the new Work Sector Type A.

3. NEW SHIELDING CONFIGURATION



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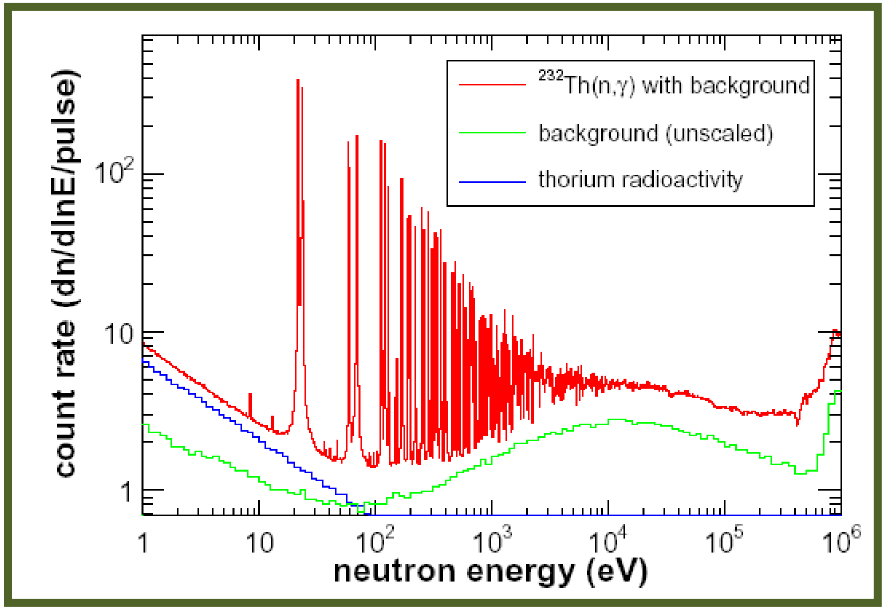
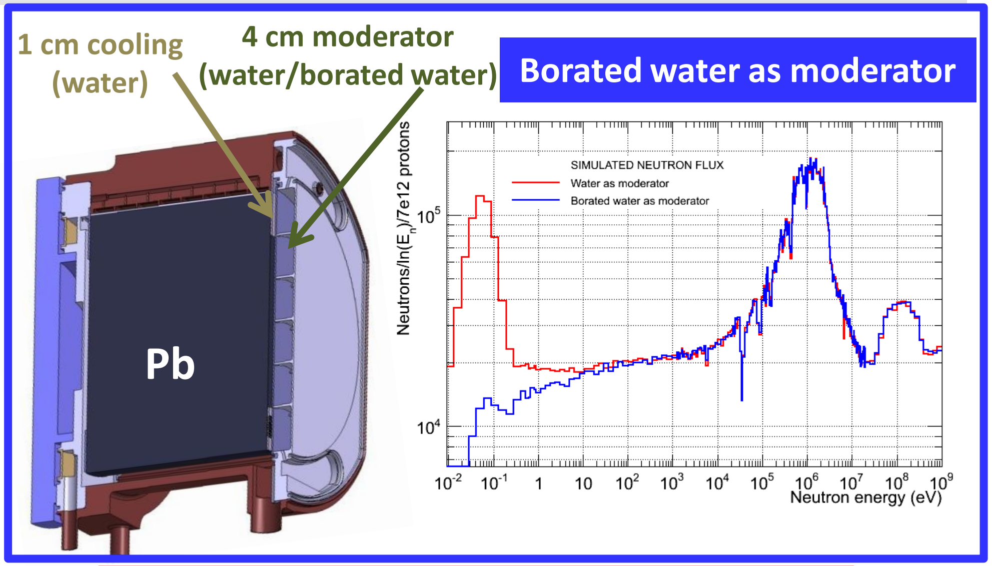
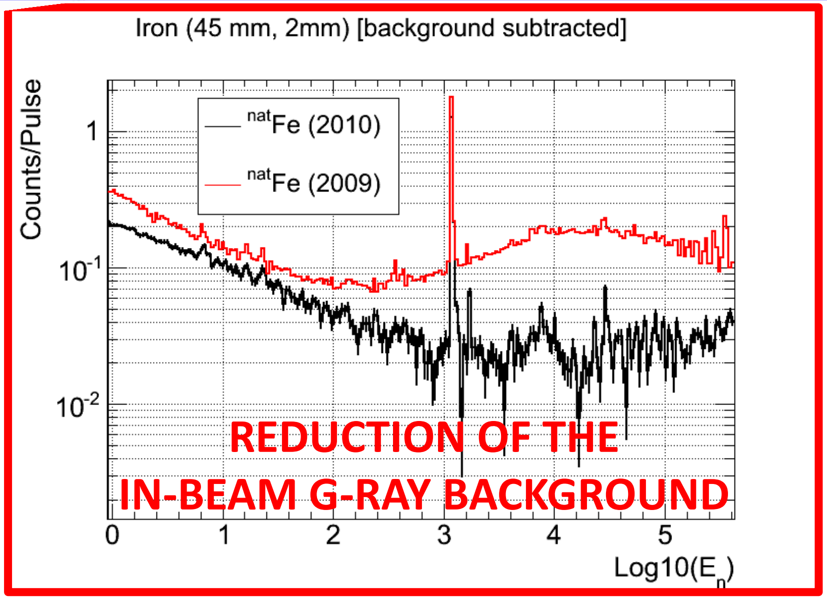






The ^{241}Am sample (3.8 GBq)

The sample (disk-shaped with 12.2 mm diameter) consists on 32.2 mg of ^{241}Am oxide embedded in a 305 mg Al_2O_3 matrix and encapsulated in a 0.5 mm thick aluminum canning. The sample is part of a set of samples prepared for IRMM at ITU from material given by CEA for (n,γ) and (n,2n) cross section measurements.

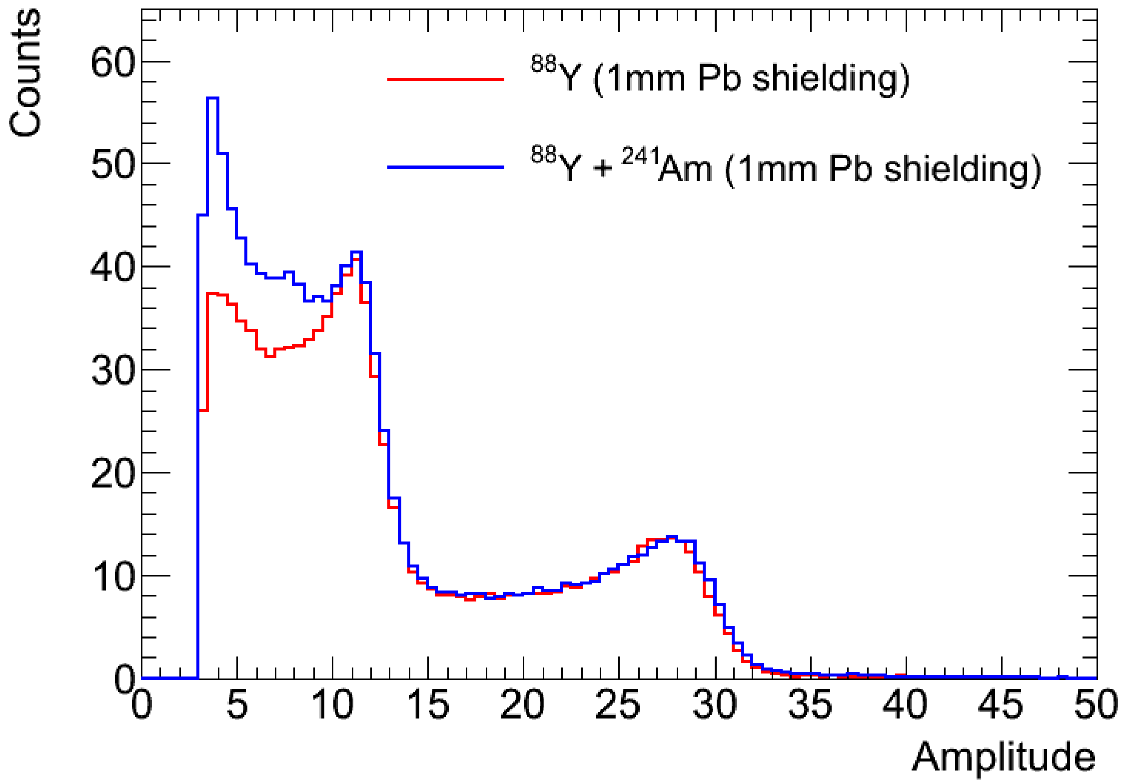
The main actinide impurities are:

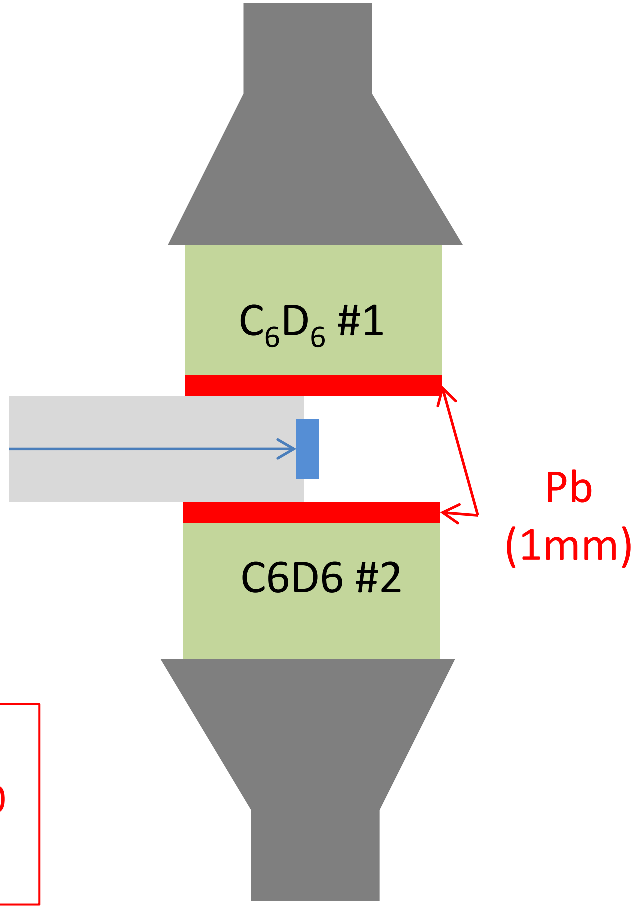
- ^{237}Np = 2.1%
- ^{233,236,238}U <0.01 %
- ^{239,240}Pu <0.2%

X-Ray imaging of the ^{241}Am sample

The experimental set-up with C_6D_6 detectors

The set-up consists of 2 modified Bicron C_6D_6 detectors, each with a volume of 0,61 l.
The front aluminum wall has been removed for reducing the neutron sensitivity.





Transmission of γ-rays through 1 mm of lead:

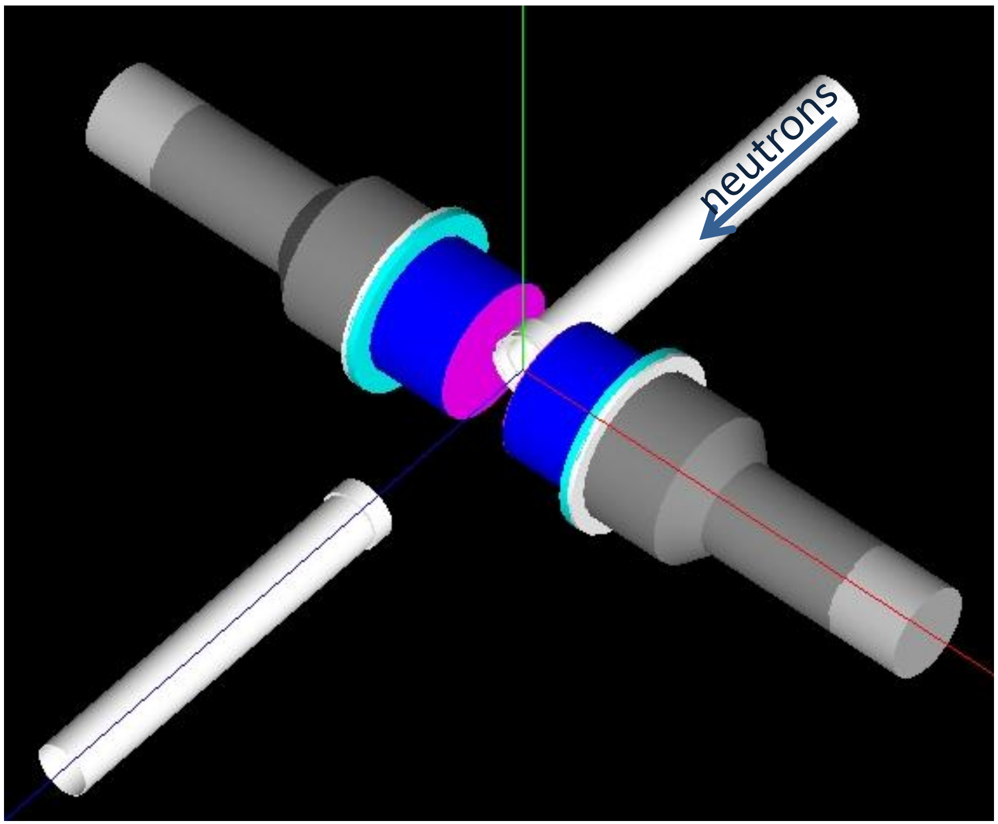
60 keV → 0.6%
1000 keV → 91%

Signal to background improved by a factor 150
(loosing only ~9% efficiency)

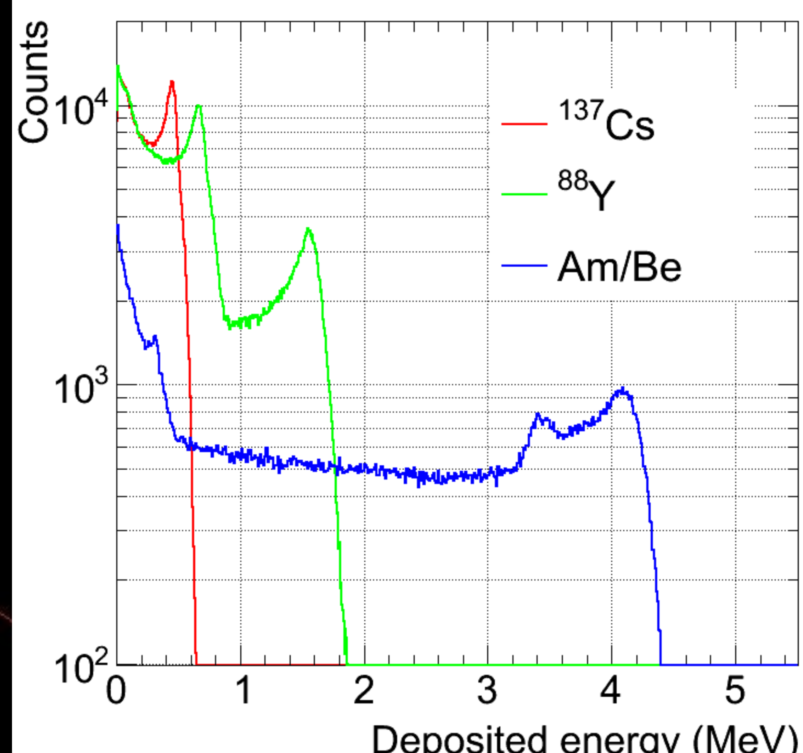
Calibrations and Monte Carlo simulations

Simulations with Geant4 including the detailed geometry of the set-up are used for:

- Amplitude/Energy calibration
- Calculation of the Pulse height Weighting Functions (ongoing)



MC simulation: Calibration sources on C_6D_6



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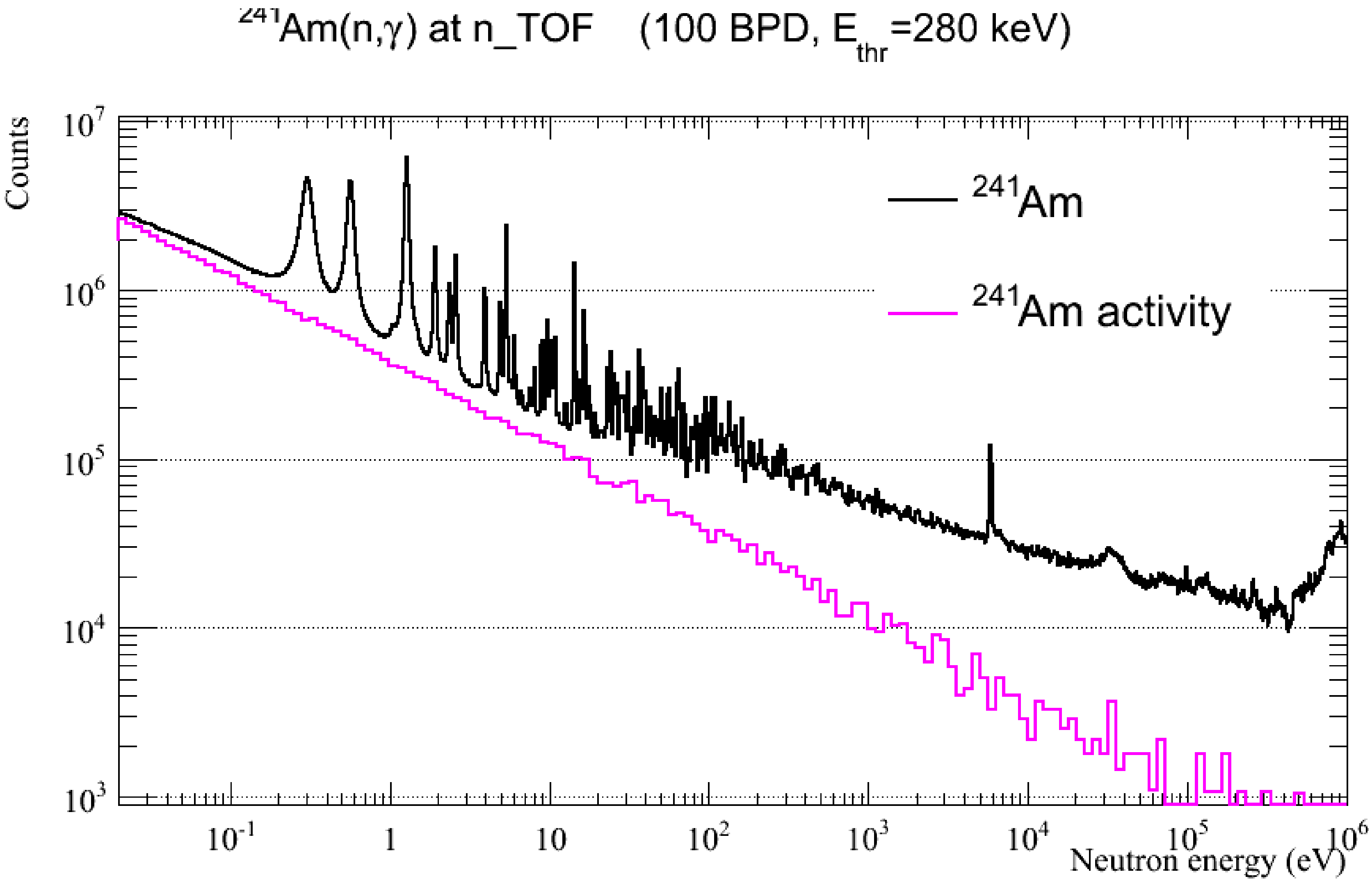
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
n_TOF

Preliminary Results: STATISTICS (30% of final data)



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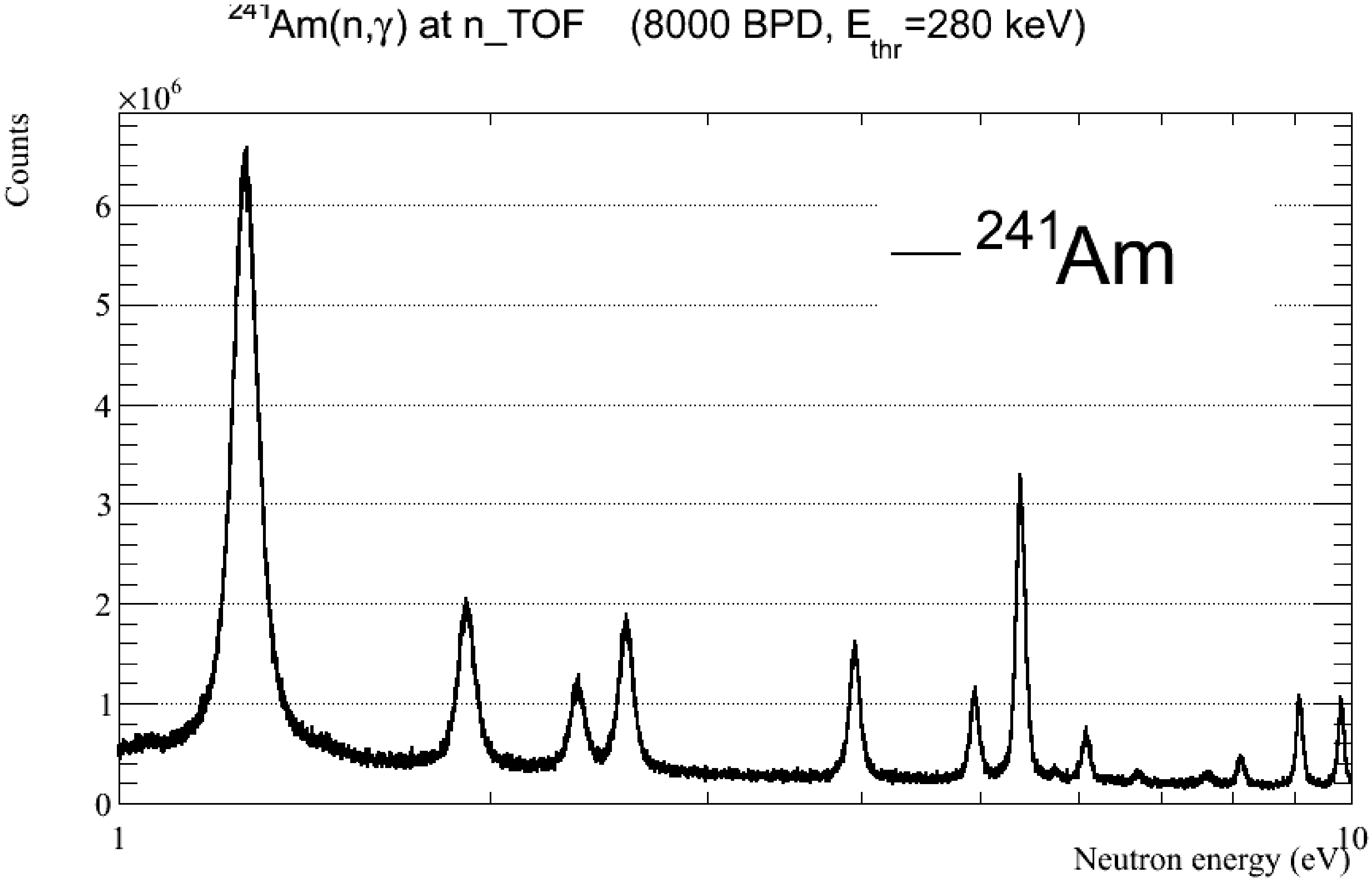

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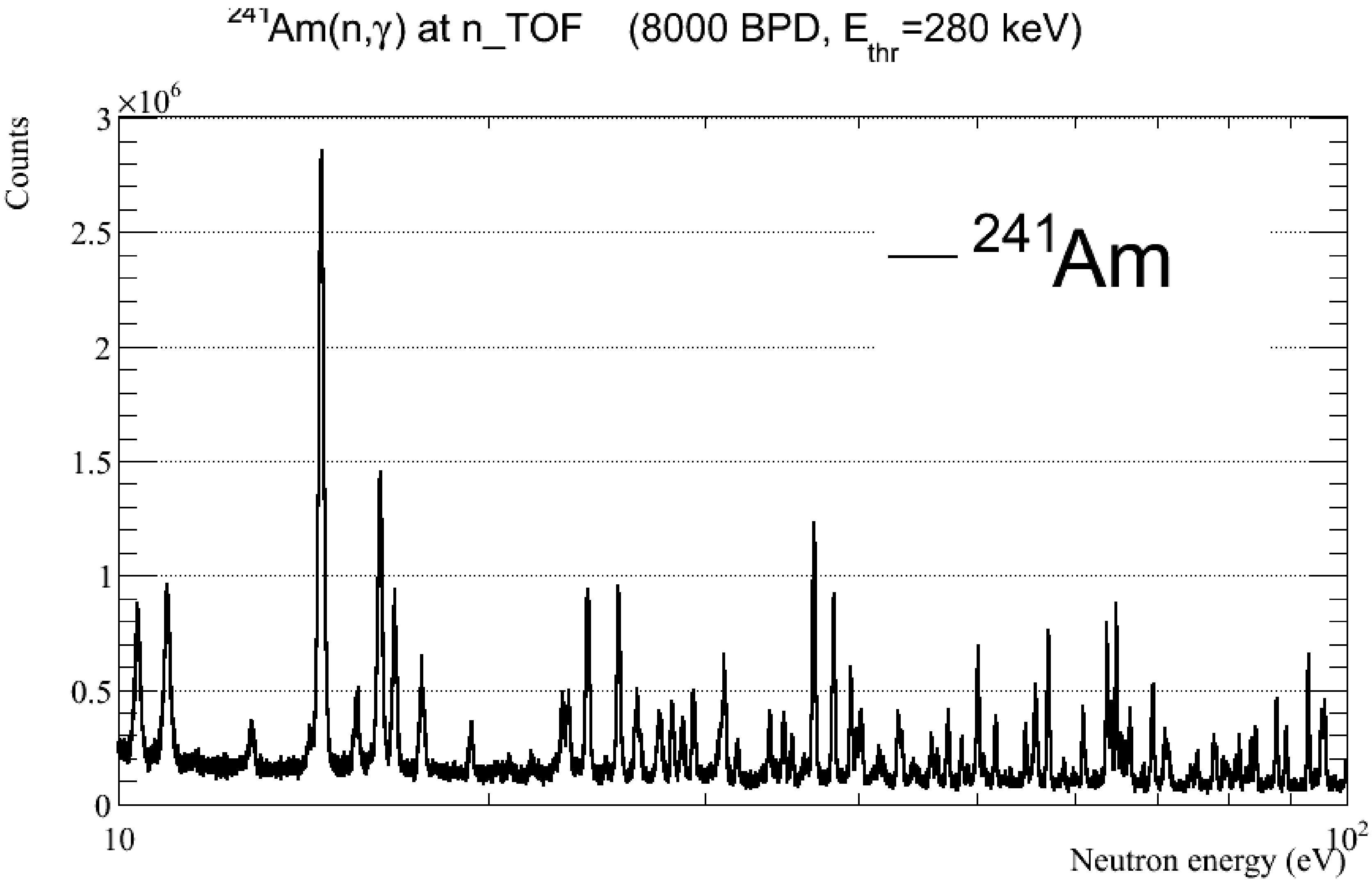

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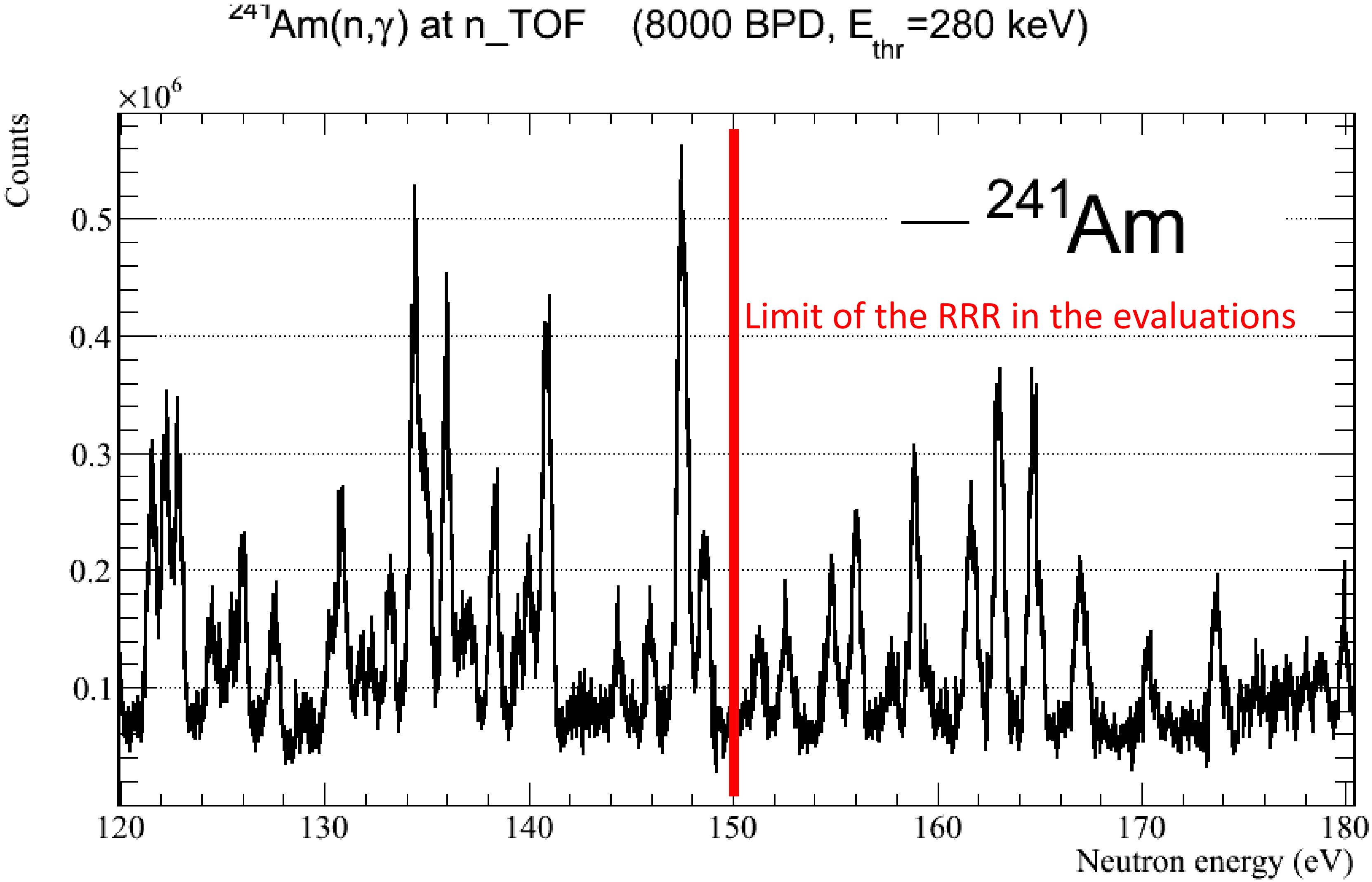
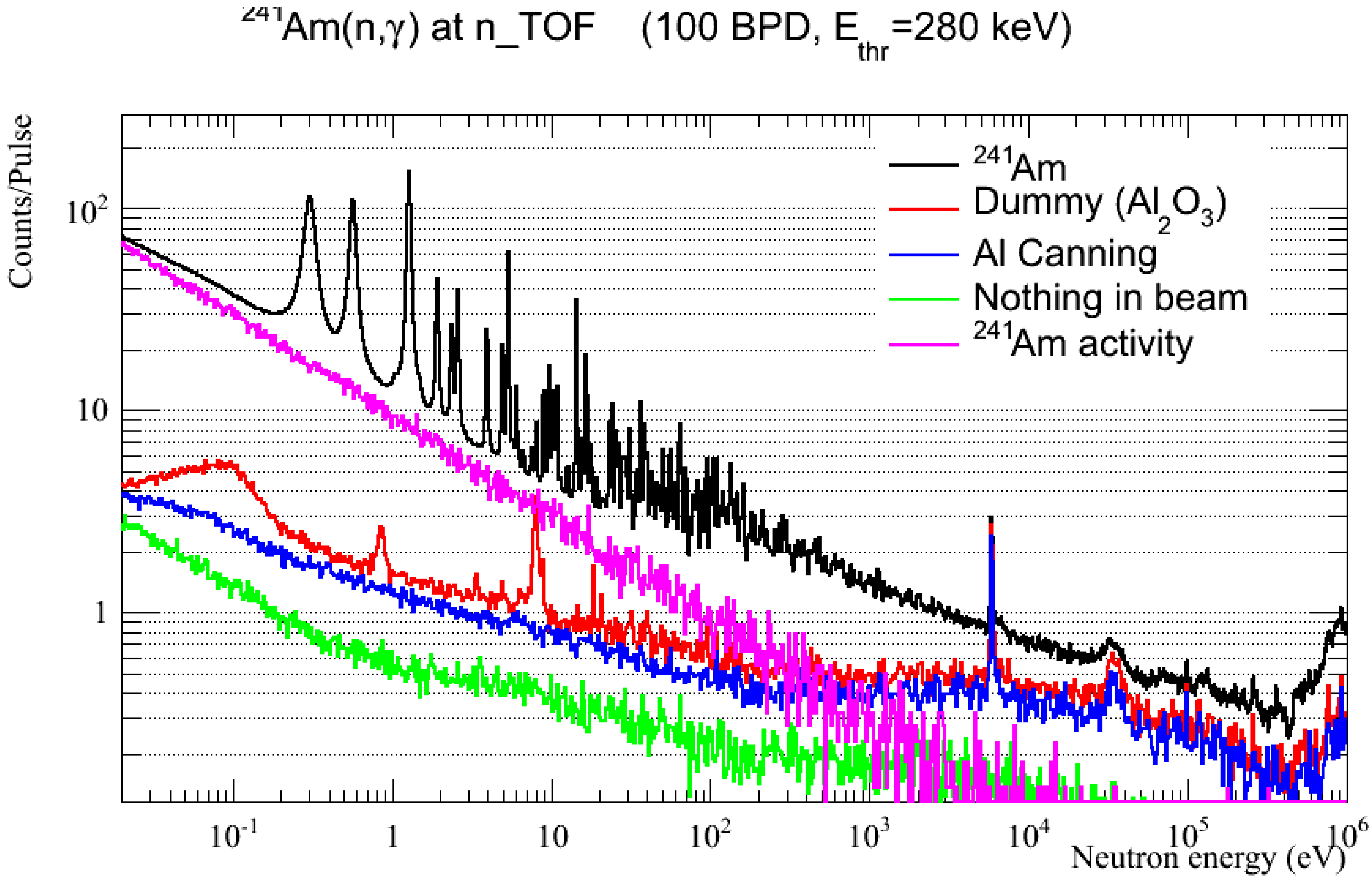
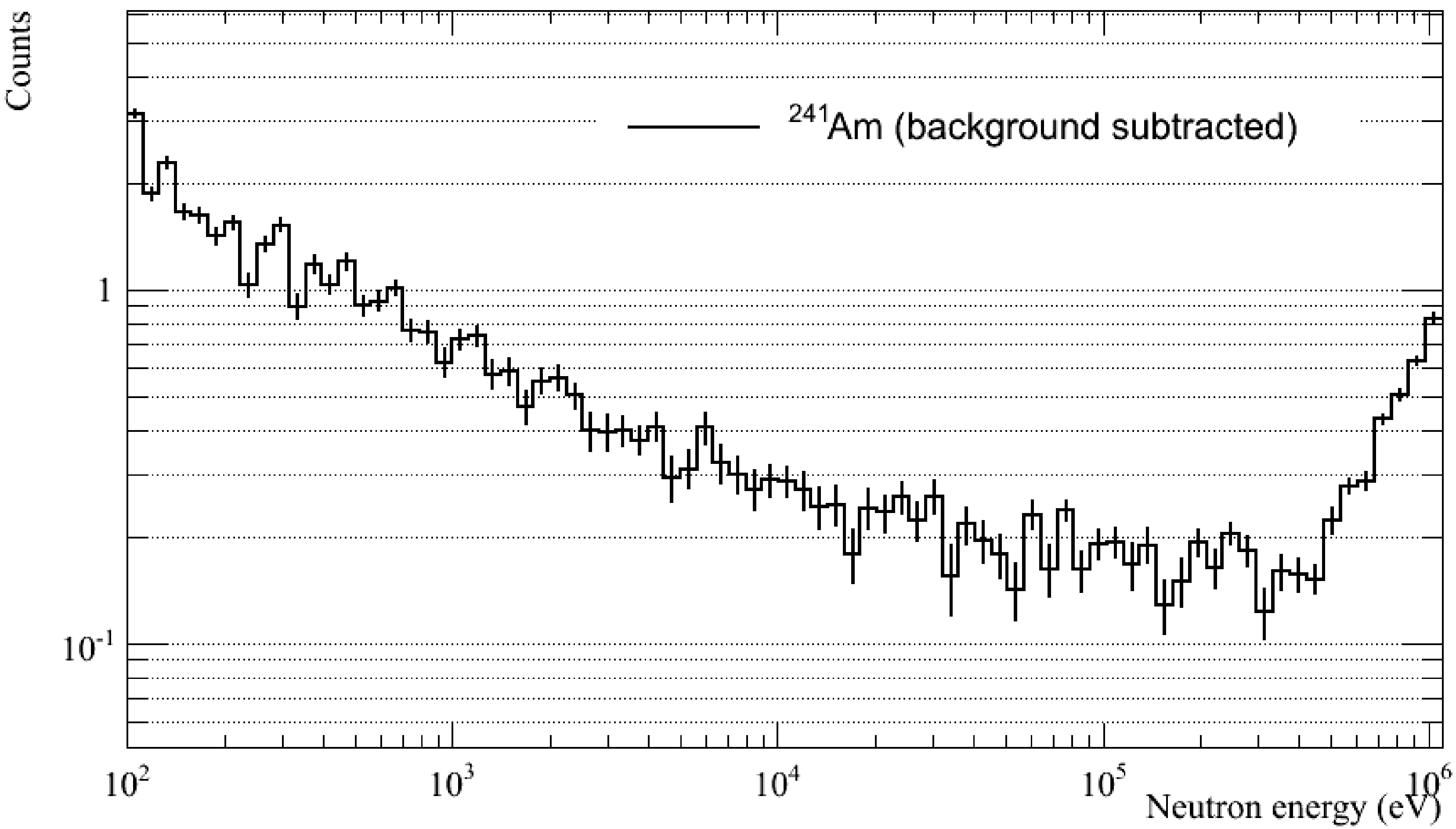


Preliminary Results: BACKGROUND



Preliminary Results: URR

^{241}Am(n,γ) at n_TOF in the URR (20 BPD, E_{thr}=280 keV)



Expected Results

CROSS SECTION AT THERMAL:

The results from C_6D_6 will provide data with statistical uncertainty better than 1%. Thus the uncertainty will be dominated by the knowledge of the **neutron flux at thermal (2-3%)** and the systematic uncertainties in the analysis (~2%). Overall accuracy expected ~**4%**.

RESOLVED RESONANCE REGION (RRR)

The **combination of the TAC and C_6D_6 data** will provide accurate resonance parameters with an overall accuracy dominated by the systematic uncertainties in the analysis: ~**3-**.

UNRESOLVED RESONANCE REGION (URR)

- BELOW 20 KEV

The **combination of the TAC and C_6D_6** data will provide data with statistical uncertainty better than 2%. The analysis by means of average resonance parameters will provide information about the reliability of the Res. Par. obtained in the RRR. Overall accuracy expected ~**3%**.

- BETWEEN 20 KEV AND 600 KEV

The measurement with C6D6 will provide data with statistical uncertainty better than 2%. The **background from the aluminum capsule and Al_2O_3** matrix will become comparable to the capture contribution. Overall accuracy expected **3-5%**.

- ABOVE 600 KEV

A higher threshold (~ 1MeV) will have to be used due to the **opening of the inelastic** channel. **Fission reactions** (threshold @ ~600 keV) will start to contribute to the recorded counting rate.
The overall accuracy expected is to be confirmed, but **5-10%** seems feasible.

Conclusions

The ^{241}Am(n,γ) cross section is being measured at the n_TOF facility:

- The C_6D_6 and TAC detectors will be combined for the first time
- Both detection set-ups will provide data even better than those obtained in the past thanks to several important upgrades.
- The measurement will cover the full range between thermal and 1 MeV

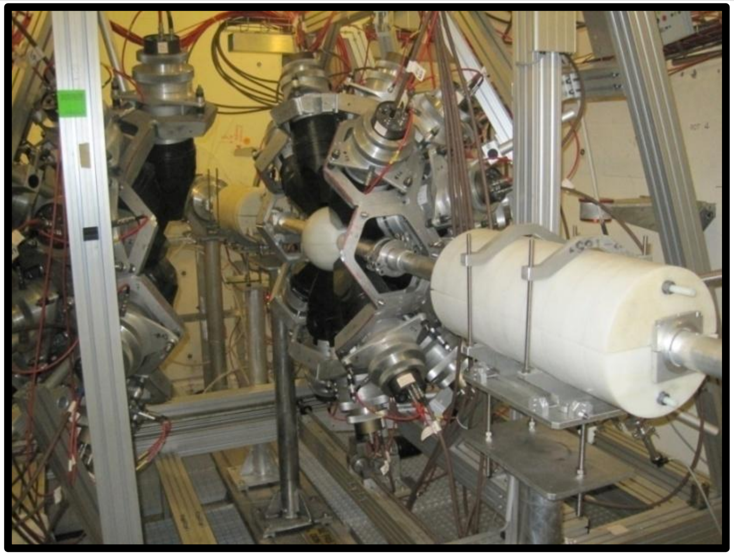
The preliminary data (30% statistics) with the C_6D_6 detectors show:

a) The activity of the sample is not a big issue for a threshold of 280 keV or higher
b) Resonances are well observed even above the actual limit of the RRR
c) The statistics will be sufficient for reaching the proposed accuracies in the thermal & URR
d) The fission background will be an issue above ~600 keV.

The expected accuracies are:

3% in the RRR.
3-5% in the thermal and URR up to 600 keV.
5-10% in the URR above 600 keV.

The measurement with the TAC set-up will start in mid September.



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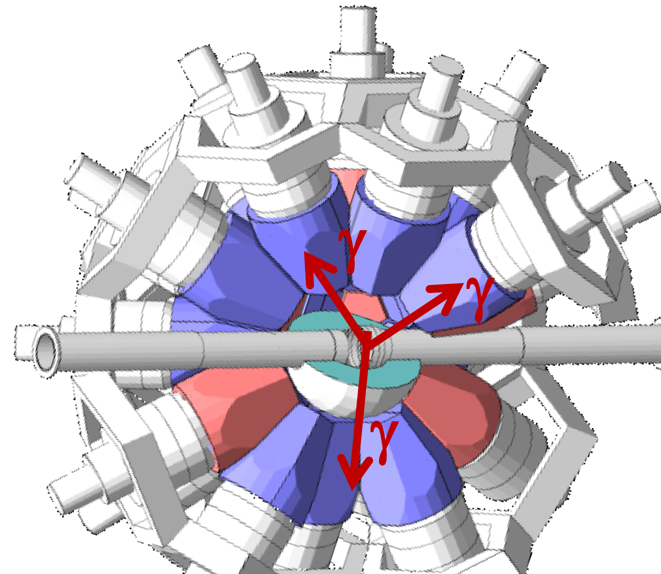
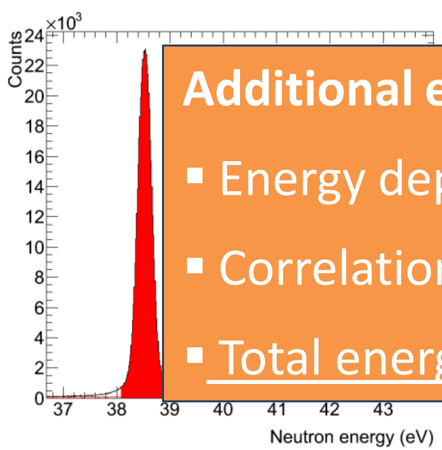
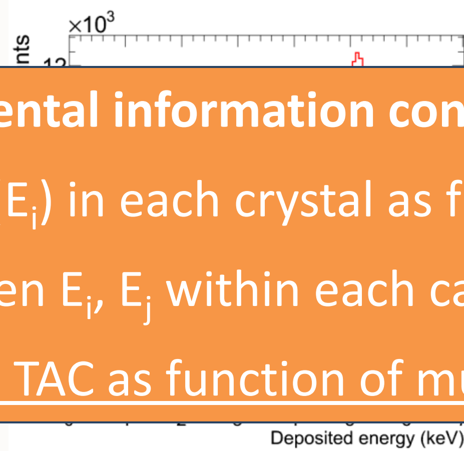


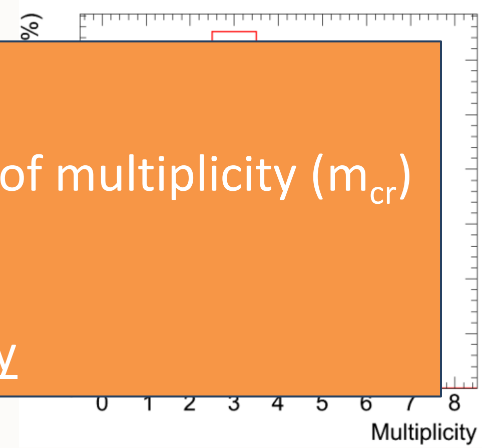
Neutron energy



Deposited energy



Multiplicity



Additional experimental information consists in:

- Energy deposited (E_i) in each crystal as function of multiplicity (m_{cr})
- Correlation between E_i, E_j within each cascade
- Total energy in the TAC as function of multiplicity