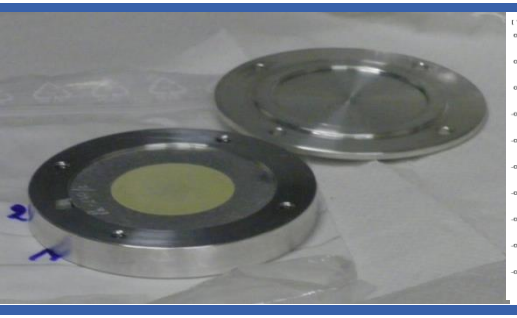
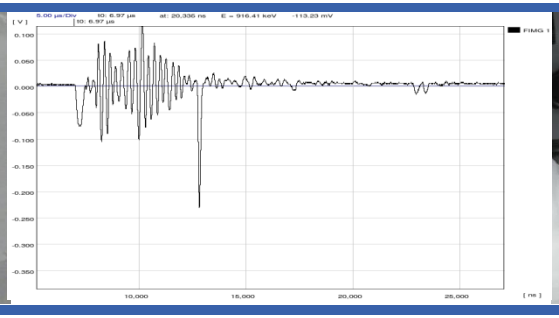
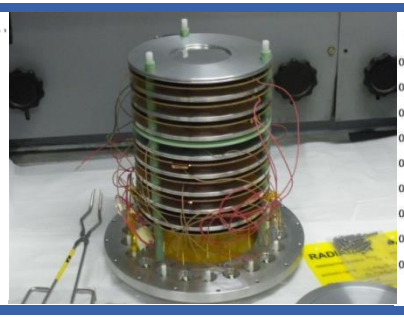
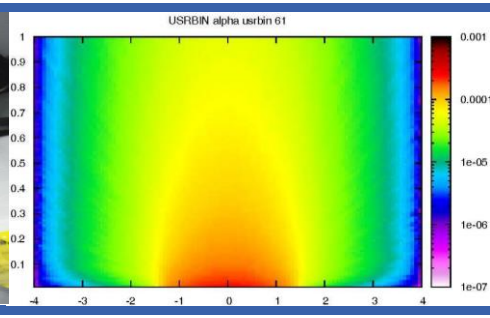






# $^{240,242}$Pu(n,f) measurement update

n_TOF Annual Collaboration Meeting
Bologna, November 27-29, 2013

# Outline

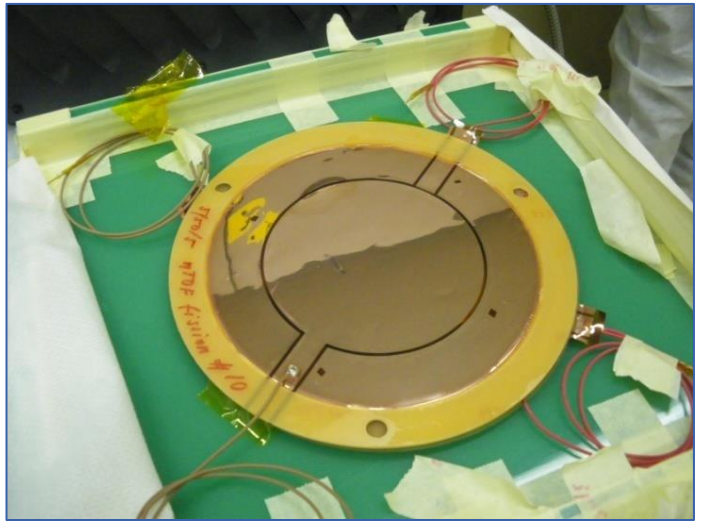
- Experimental
  - Main experimental issues
- Data analysis
- Results
  - Resonances
  - Fission threshold
- Simulations

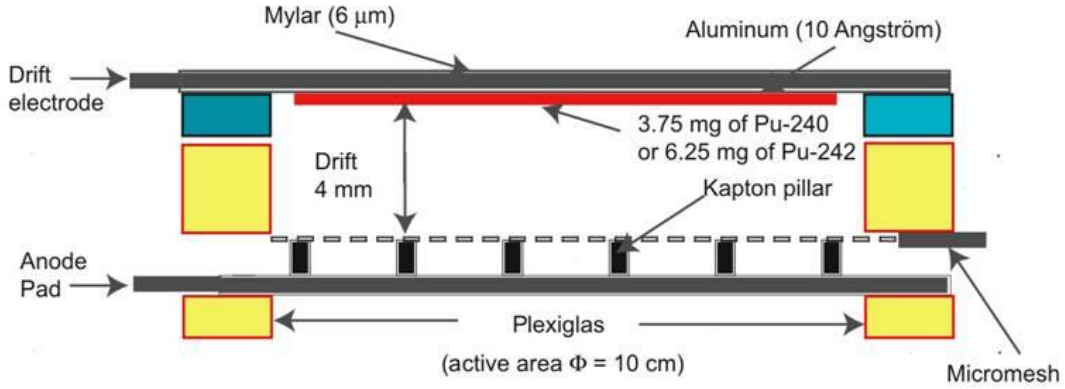
# 4 challenging experimental aspects

- Baseline oscillation after the γ-flash
  - …affects the high-energy region (> 1-2 MeV)
- High α-activity of the $^{240}$Pu samples (>6MBq/sample)
  - Long pile-up tail (>30% pile-up probability) worsens the α-FF separation
- Spontaneous fission background in $^{242}$Pu
- Gradual deterioration of detector performance due to high current / high α-activity
  - …critical for $^{240}$Pu
  - …but also relevant for $^{242}$Pu

# The Micromegas detector

- **MICRO**-**ME**sh **GA**seous **S**tructure
- Wireless gaseous detector
  - Drift electrode
  - Drift space (mm)
    - Primary ionisation and charge drift
  - Micromesh
  - Amplification region (25-50µm)
    - Charge multiplication
    - Readout
- Already used for beam monitoring at n_TOF
  - $^{10}B(n,\alpha)$ and $^{235}U(n,f)$



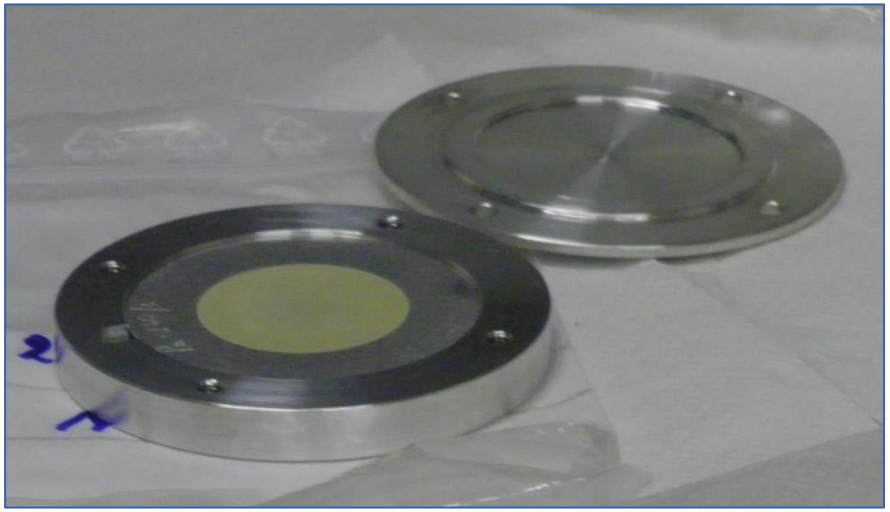



- Advantages
  - Low background (transparent detector)
  - Fast signal
  - *Robustness, radiation hardness*
  - *Stability for long runs*

# Samples

- Eight (8) samples (4 x $^{240}$Pu, 4 x $^{242}$Pu) received from IRMM (Geel) (*)
  - 3 cm diameter $PuO_2$ deposit
  - 0.25 mm aluminium backing (5cm diameter)

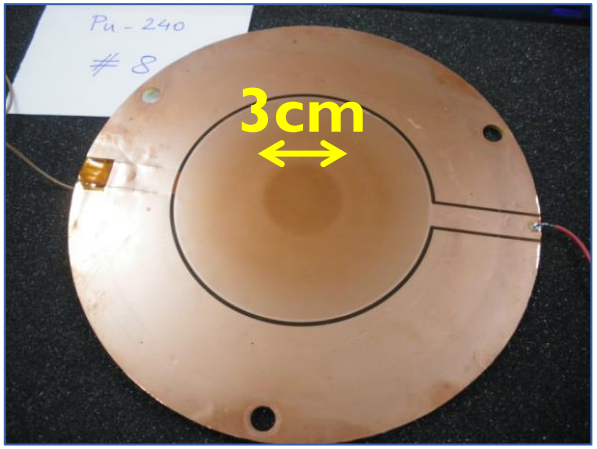
| $^{240}$Pu | | $^{242}$Pu | |
|---|---|---|---|
| $^{238}$Pu | 0.0733% | $^{238}$Pu | 0.002719% |
| $^{239}$Pu | 0.0144% | $^{239}$Pu | 0.00435% |
| **$^{240}$Pu** | **99.8915%** | $^{240}$Pu | 0.01924% |
| $^{241}$Pu | 0.00041% | $^{241}$Pu | 0.00814% |
| $^{242}$Pu | 0.02027% | **$^{242}$Pu** | **99.96518%** |
| $^{244}$Pu | 0.000046% | $^{244}$Pu | 0.00036% |
| | | | |
| **Mass** | 3.1mg | **Mass** | 3.6mg |
| **Activity** | 25.7MBq | **Activity** | 0.53MBq |
| | | | |
| **Surface density** | | **0.10 – 0.13 mg/cm²** | |

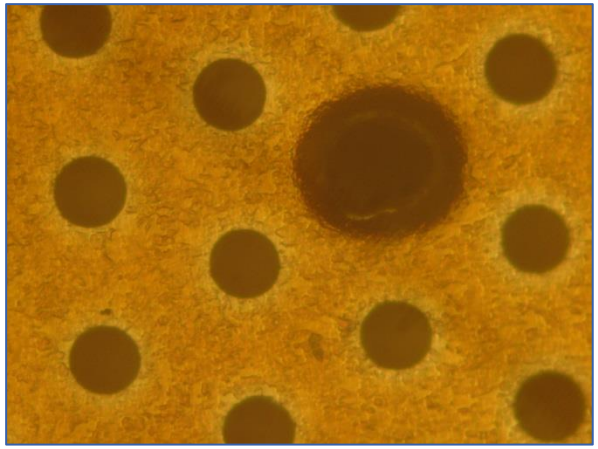
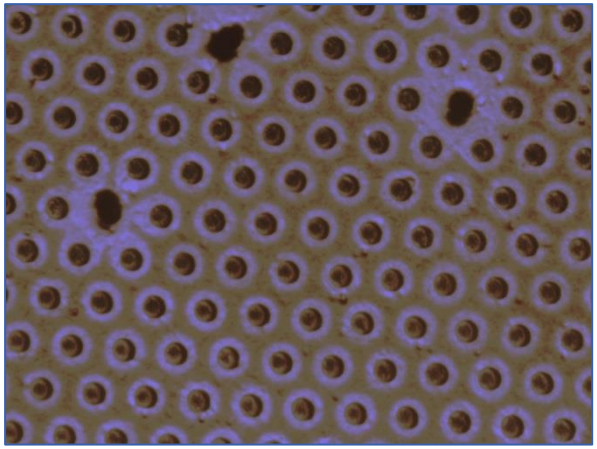


**(*) G. Sibbens et al.,** *Preparation of $^{240}$Pu and $^{242}$Pu targets to improve cross-section measurements for advanced reactors and fuel cycles*, Journal of Radioanalytical and Nuclear Chemistry (2013), http://dx.doi.org/10.1007/s10967-013-2668-7

# Detector deterioration: the case of $^{240}$Pu

- An unexpected alteration of some detectors was observed after removal from the chamber
  - A distinct discoloration of the micromesh is visible in the 4 detectors used with the $^{240}$Pu samples
  - Physical damage to the micromesh is visible under inspection with a microscope
  - This leads to a deterioration of the electrical field and a severe reduction of the gain
  - (Of interest to the MPGD community, a unique – if inadvertent – ageing test)



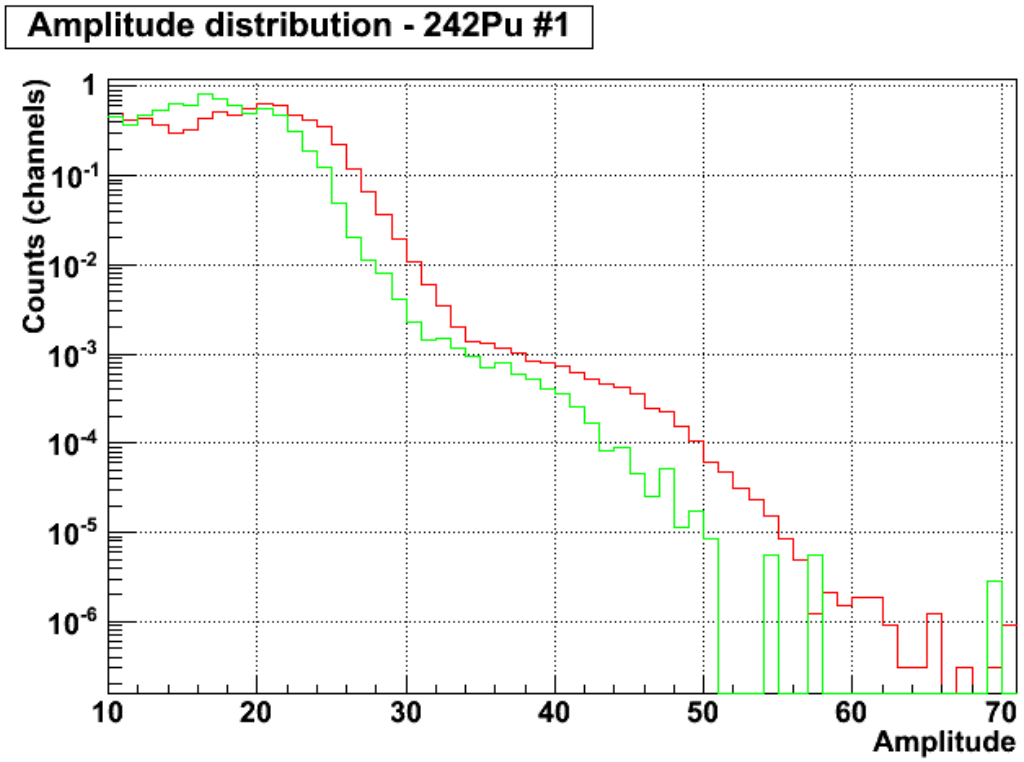



*Courtesy A. Teixeira (CERN)*

- A significant part of the data will have to be discarded
  - Only results for $^{242}$Pu in this talk

# Detector deterioration: the case of $^{242}$Pu

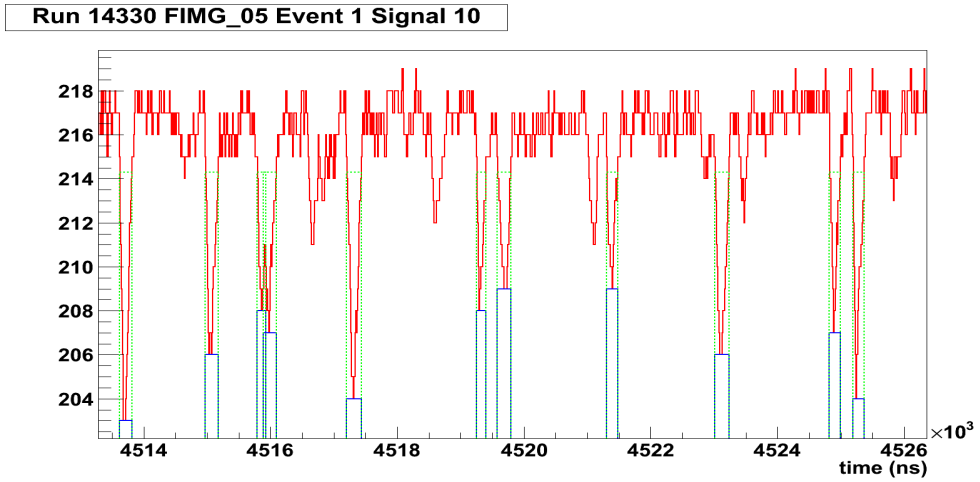
- The α-activity of the $^{242}$Pu samples is considerably lower (~0.13MBq/sample)
- A similar visible discoloration was NOT observed
  - …but the detectors have not been studied under a microscope
- A slow but non-negligible deterioration of the gain is observed!

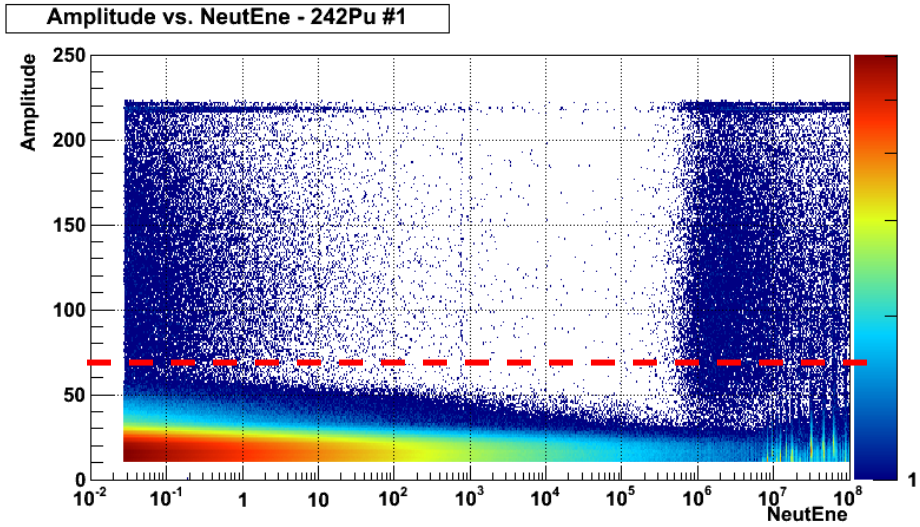



- Beam-off runs in det. #1 ($^{242}$Pu)
  - Evolution during 2012 run

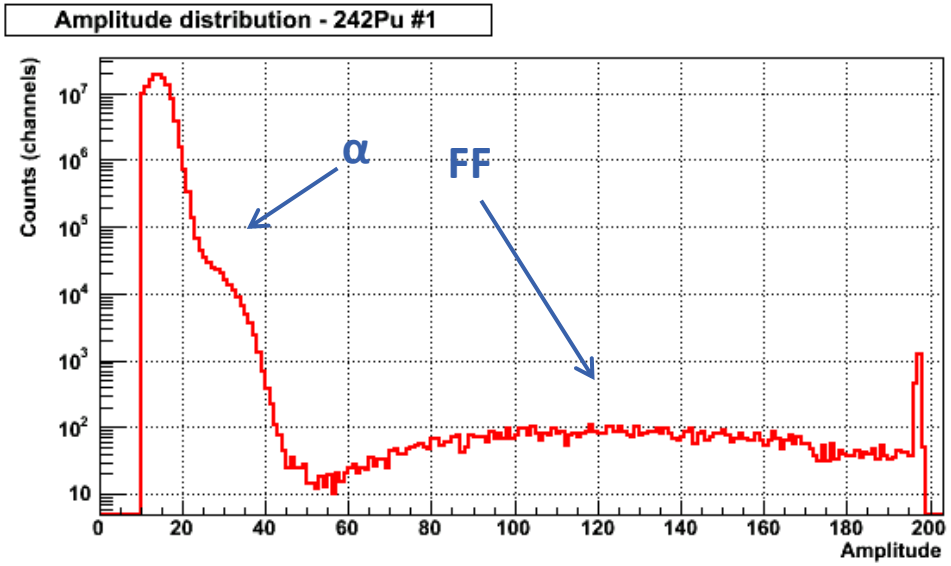
- *Additional gain fluctuations have been observed on the scale of a few hours, probably attributable to changes in the gas flow / pressure*

# Raw data analysis – Amplitude spectra ($^{242}$Pu)



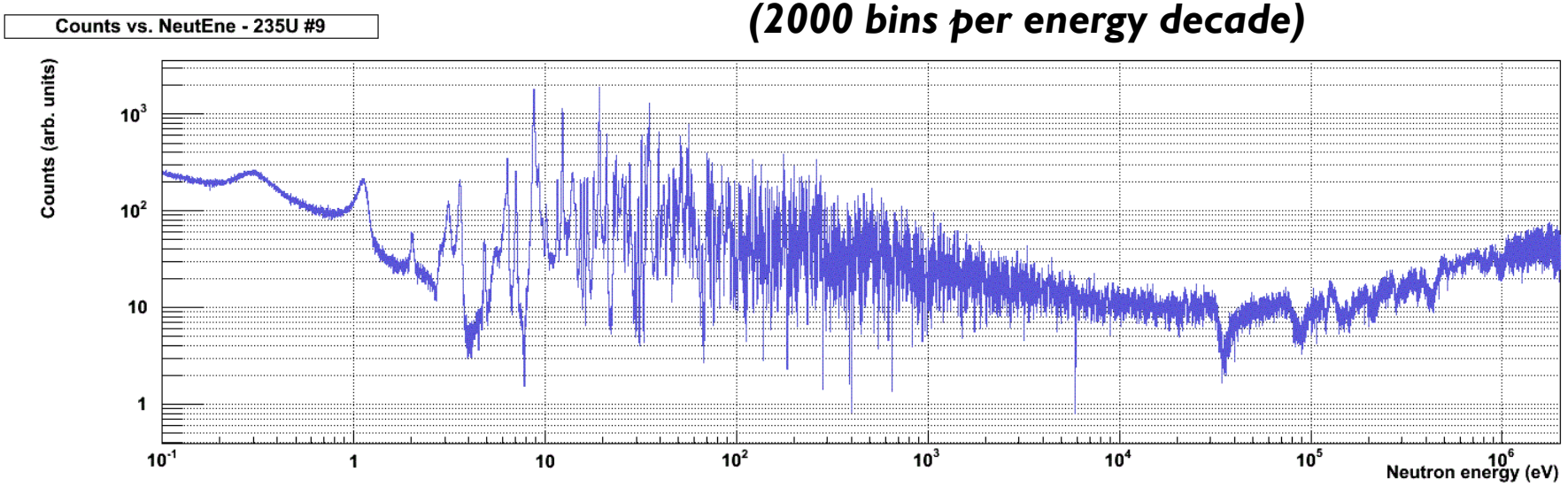



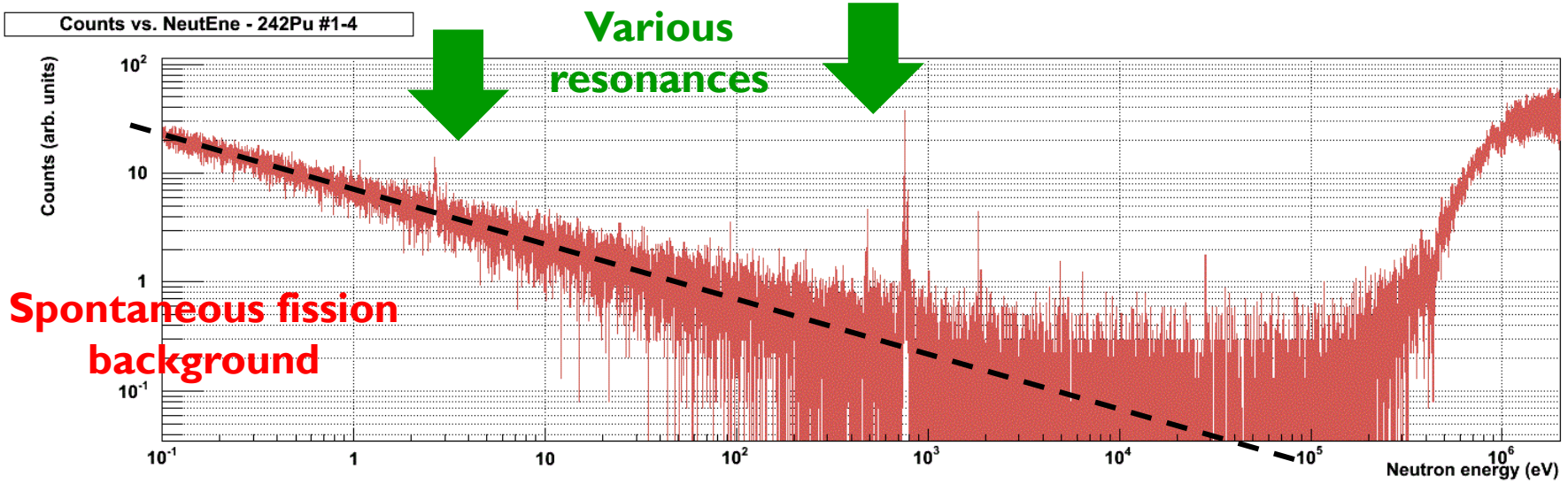

- Gain shift smears out the amplitude spectrum when pooling a lot of data together
  - Actually, the α/FF separation with the Micromegas is much better than we thought (looking at a shorter interval) →



# $^{235}U$ & $^{242}Pu$

*(2000 bins per energy decade)*

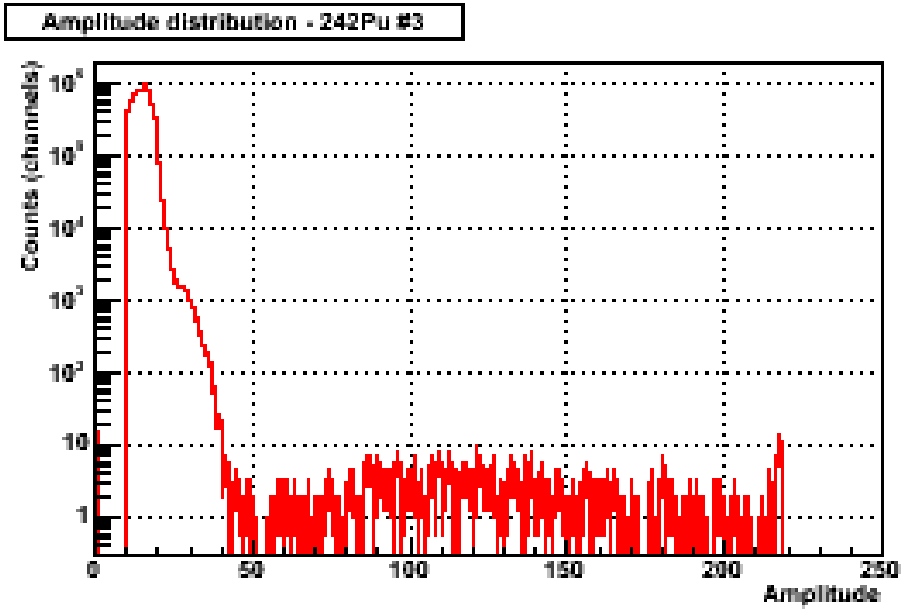


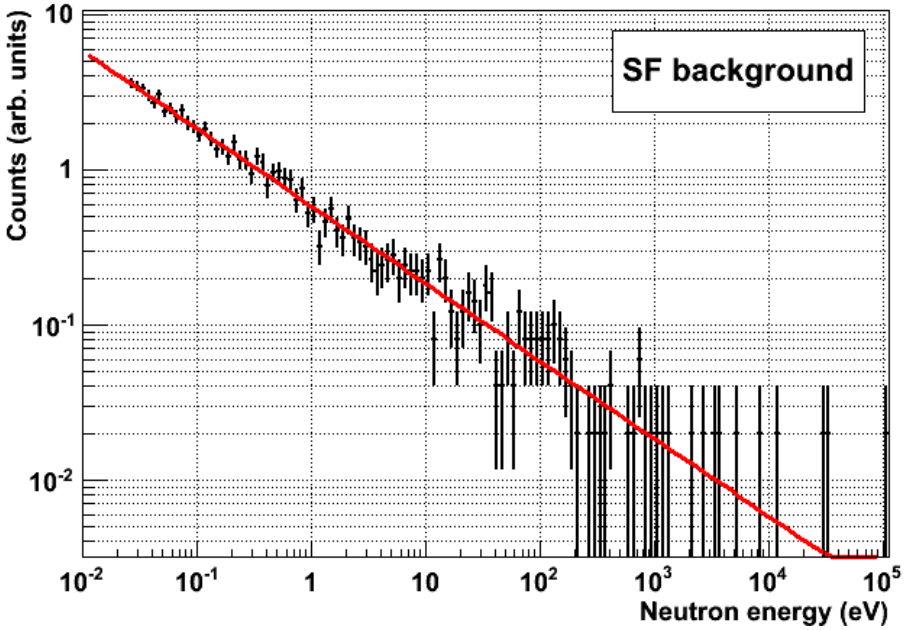



# $^{242}$Pu spontaneous fission background

- The spontaneous fission background dominates the low energy region and remains visible up to ~10 keV.
  - Still, several resonances can be observed above this background.
- Spontaneous fission branching ratio: 5.5 x $10^{-4}$ %
  - Fitted with an appropriate function
- As a check, the SF subtraction was made by fitting a more restricted region of the beam-on data → very small change, enforcing point that SF dominates

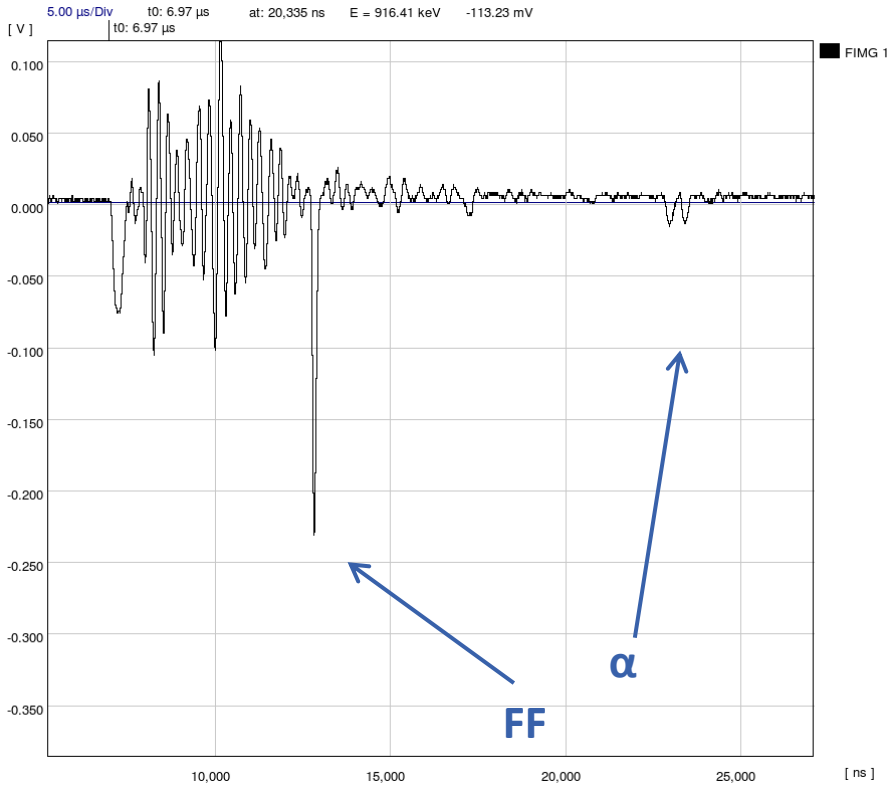
$$BGR = A \cdot e^{B \cdot log E_n} \quad , \quad B = 1.15129$$

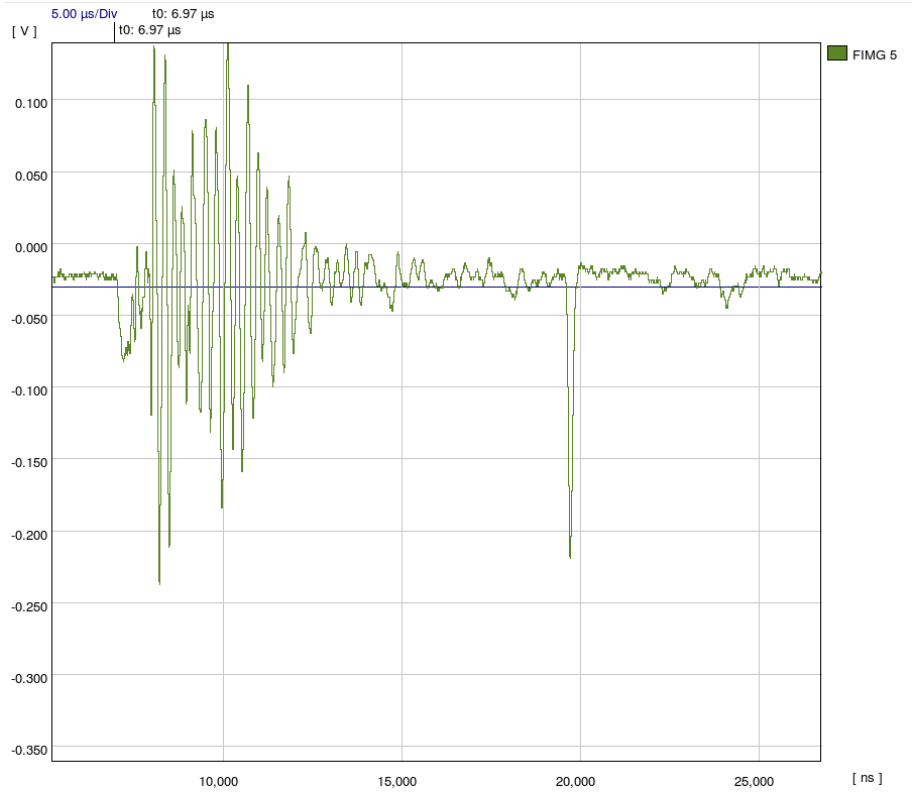


# Detector response to the γ-flash

- Baseline oscillations are dealt with off-line (next slide)

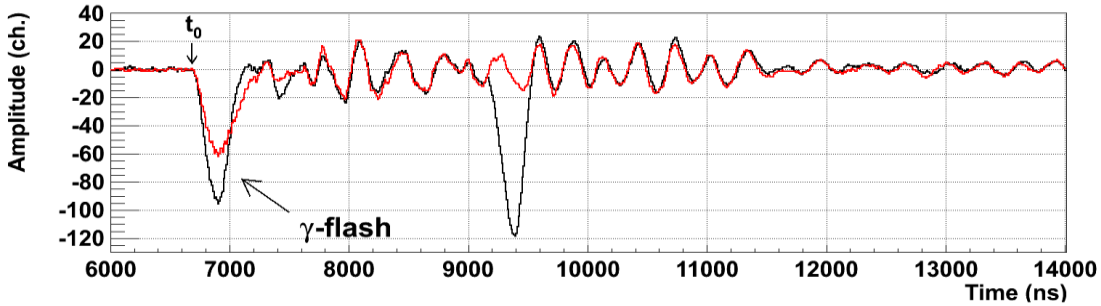


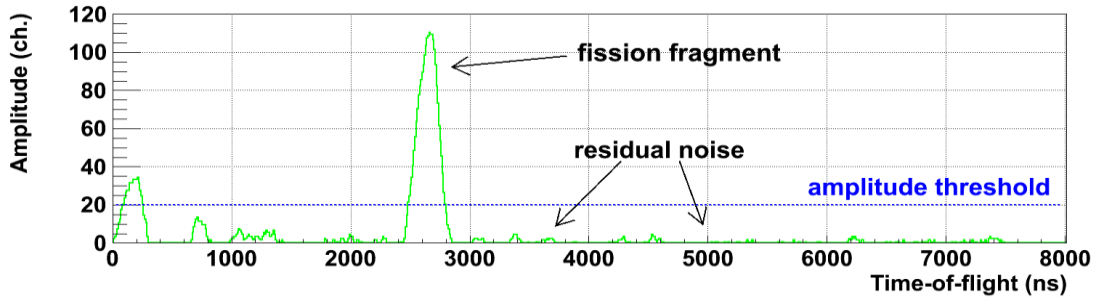



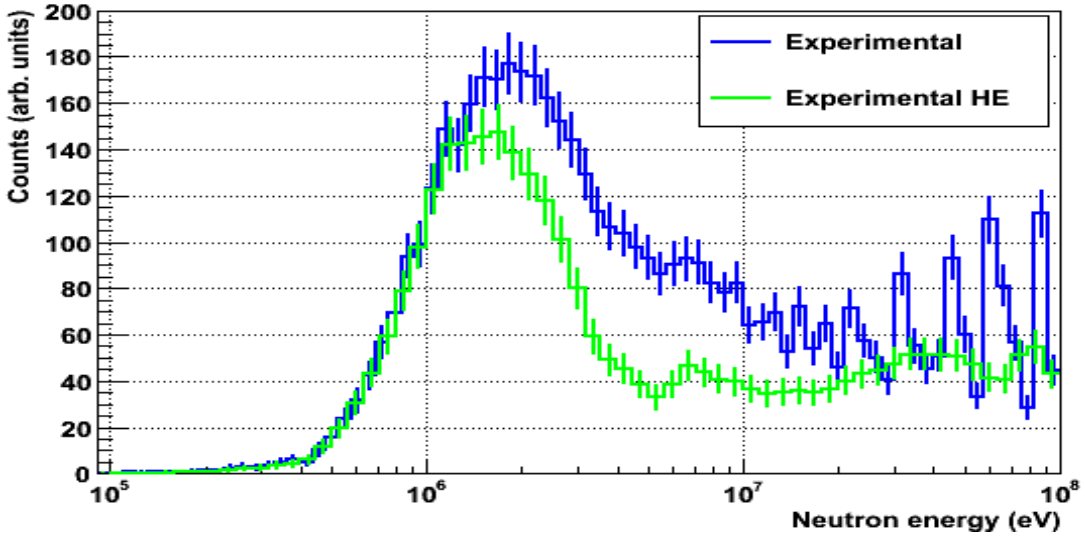

- Shielding of preamplifier mitigates problem

# The high-energy region

- Spallation process leads to significant production of prompt γ-rays and other relativistic particles
  - Initial γ-flash signal (hundreds of ns)
  - Baseline oscillation after the γ-flash lasts several μs and affects the high-energy data
- "Compensation method"
  - Oscillations recorded in adjacent detectors for the same proton bunch are almost identical
  - Baseline oscillation can be subtracted from adjacent detector
- One step added in the data-processing flow
  - Raw data are cleaned, the same peak-search routine is used to process the clean data

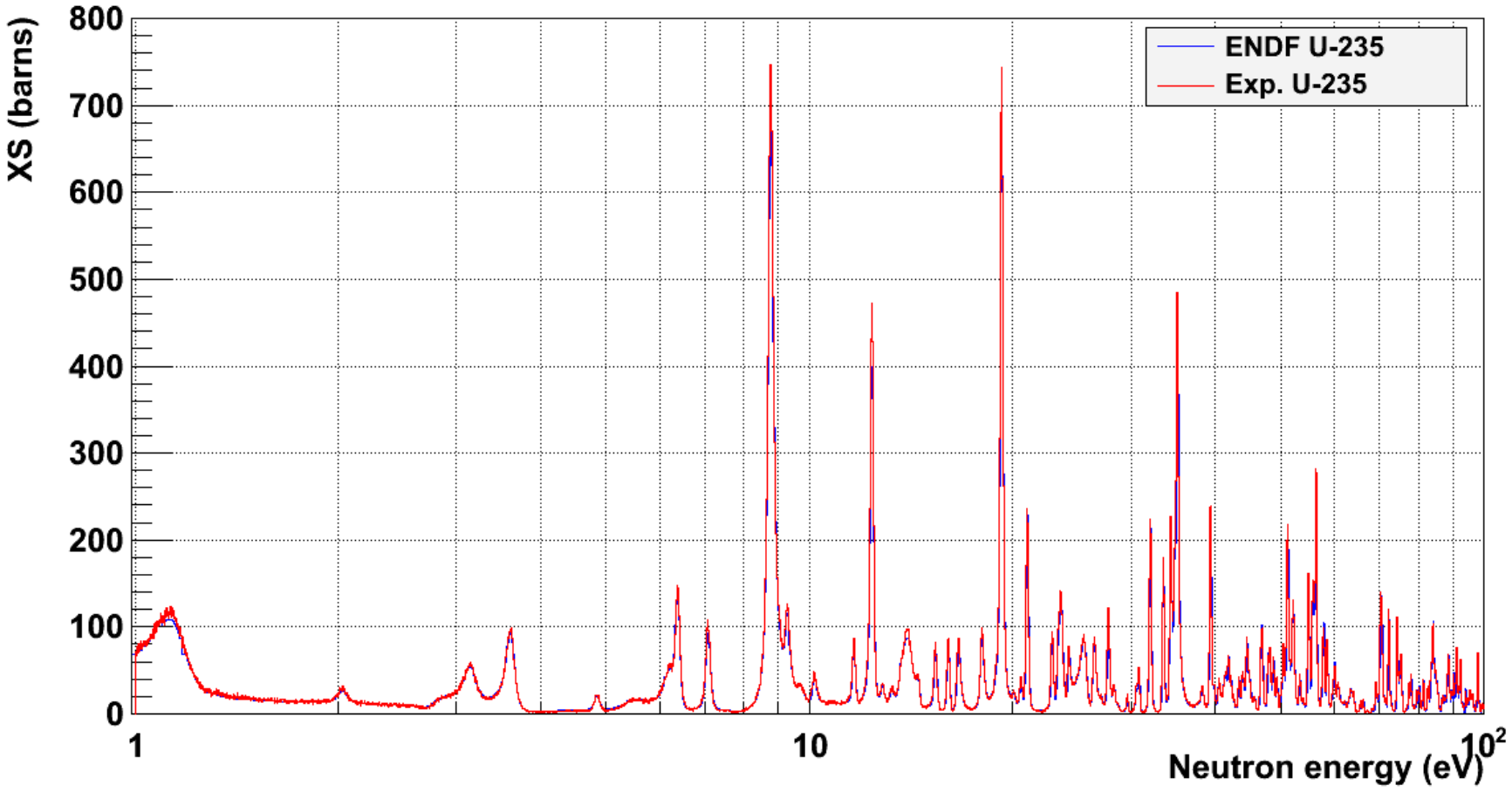


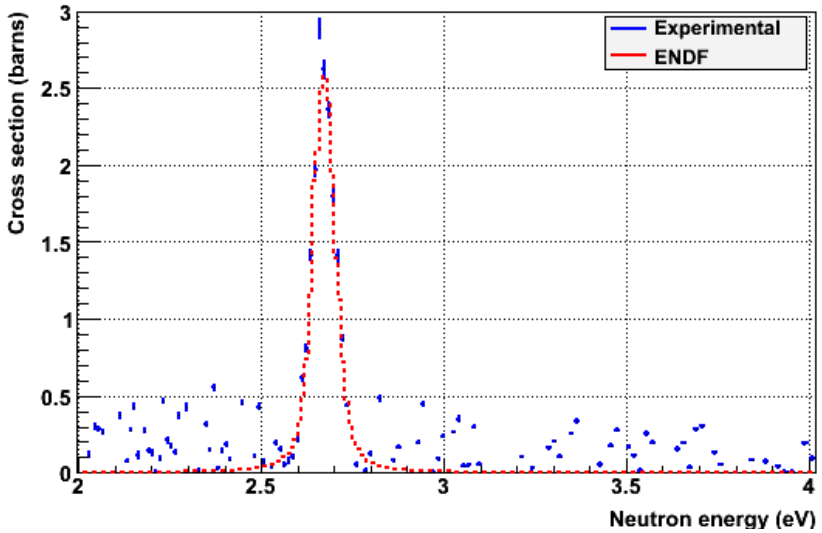



# $^{235}$U(n,f)

- Comparing with ENDF…

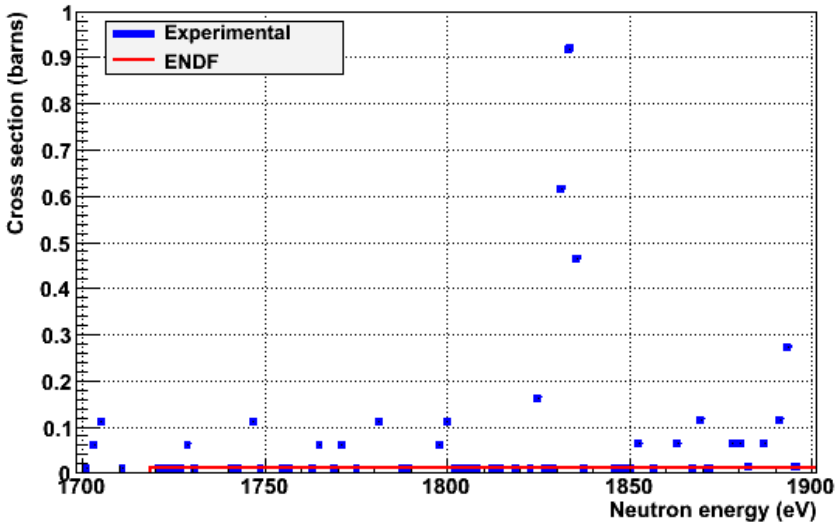


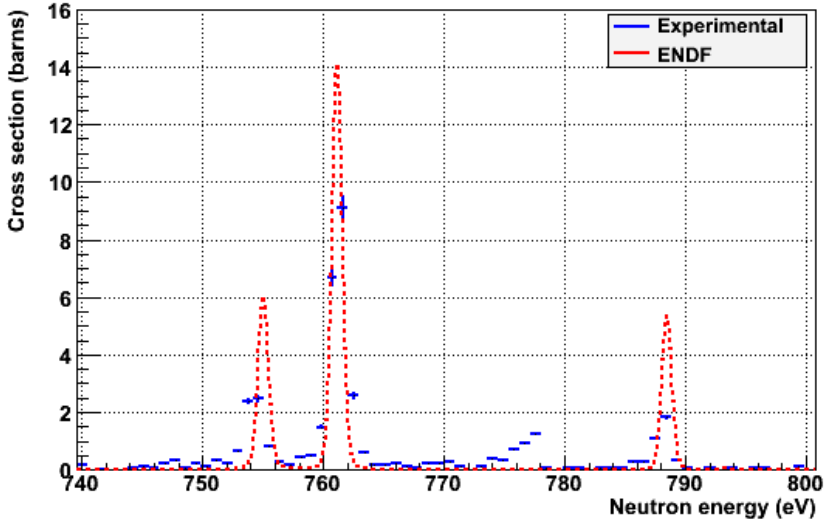
# Resolved resonances




1

3



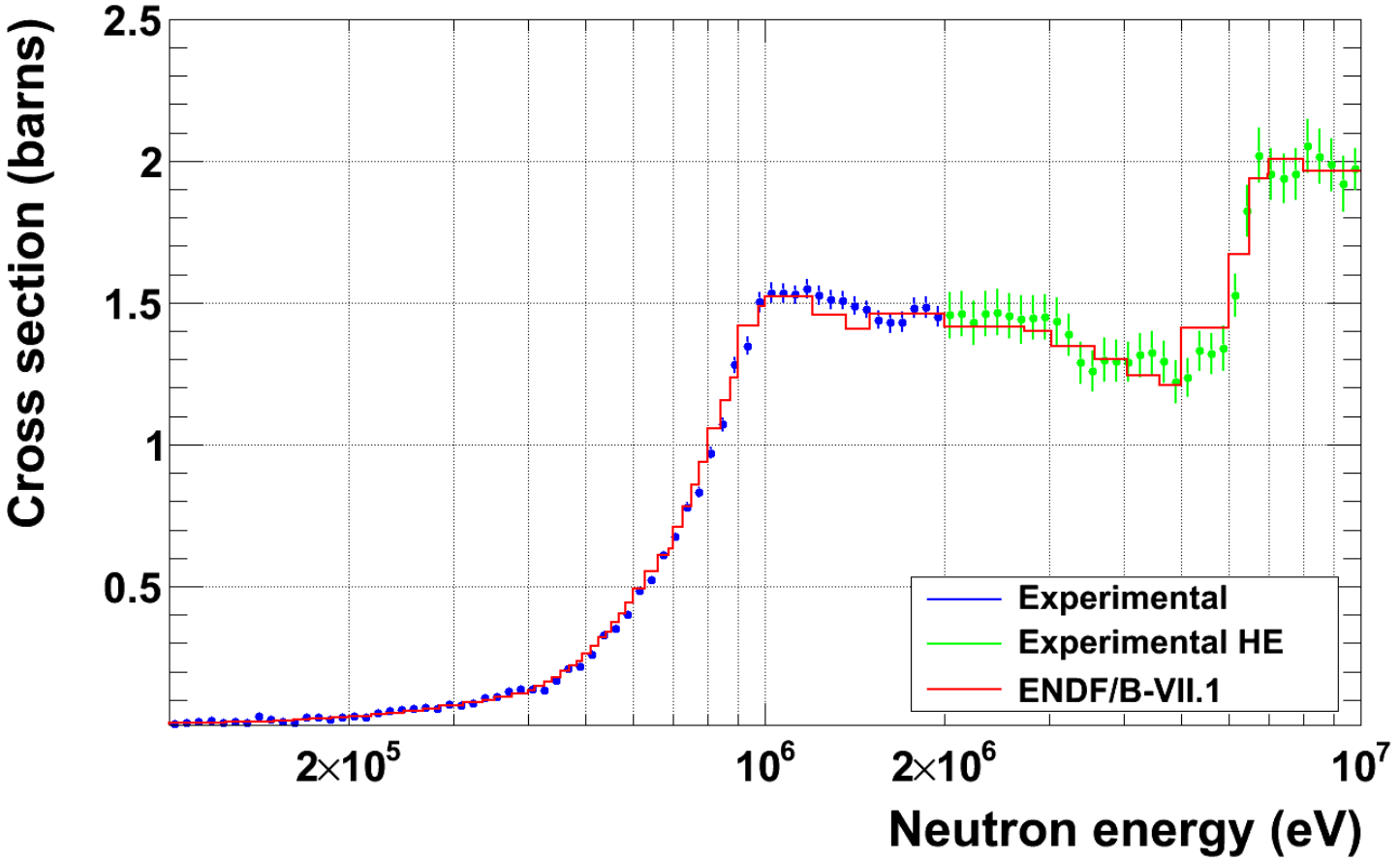




2

- 1) First resonance at ~2.7eV
  - Visible over spontaneous fission background
- 2) Resolved resonances around 700-800 eV
  - At ~780eV, a resonance not attributable to any of the stated sample impurities (at a preliminary analysis)
- 3) Resonance at 1833 eV, again not immediately attributable
- A few possible candidates at higher energy

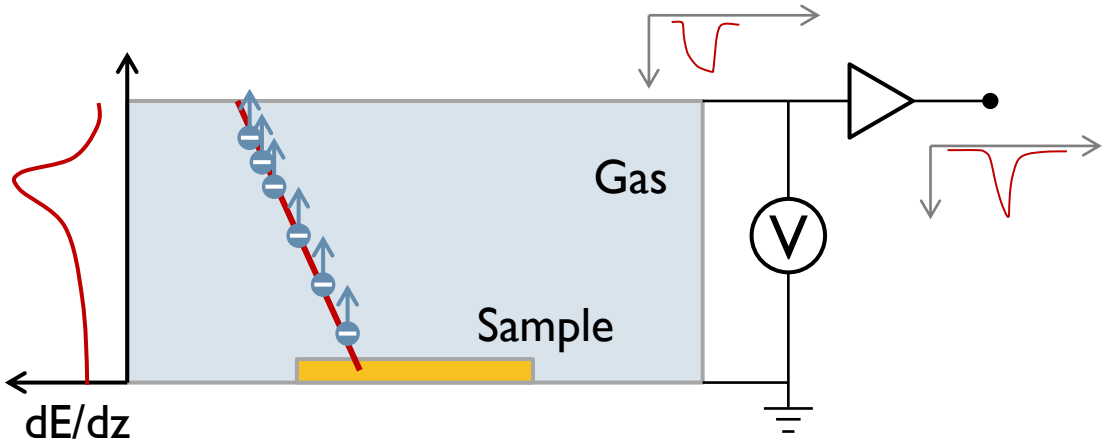
# Above the fission threshold

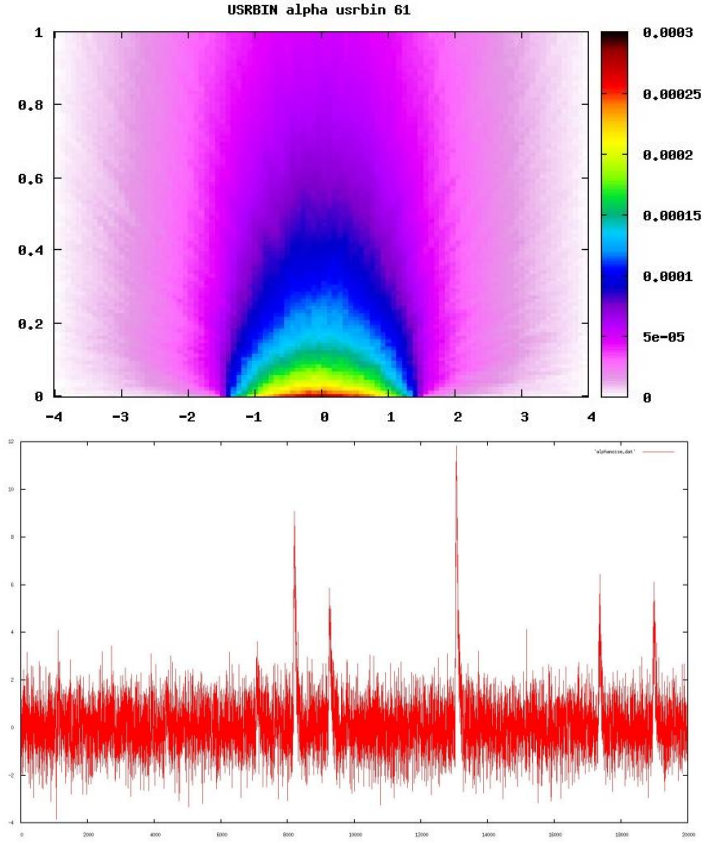
- Above the fission threshold
  - Max. energy limit will be pushed as high as possible



# Simulations

- Reproducing signals from α-particles and fission fragments
  - GEF code (A **GE**neral description of the **F**ission process) developed at CENBG (Bordeaux) can be used as a fission fragment event generator with a more realistic distribution, instead of the systematics used so far **NEW**
- Simplified geometry of samples and active detector volume created in FLUKA
- Energy deposition is scored event-by-event and transformed to charge
- Electron drift velocity calculated for given gas mixture and drift voltage (GARFIELD)
- We can thus calculate the current reaching the readout electrode and "pass" it through an appropriate circuit to reconstruct the signal

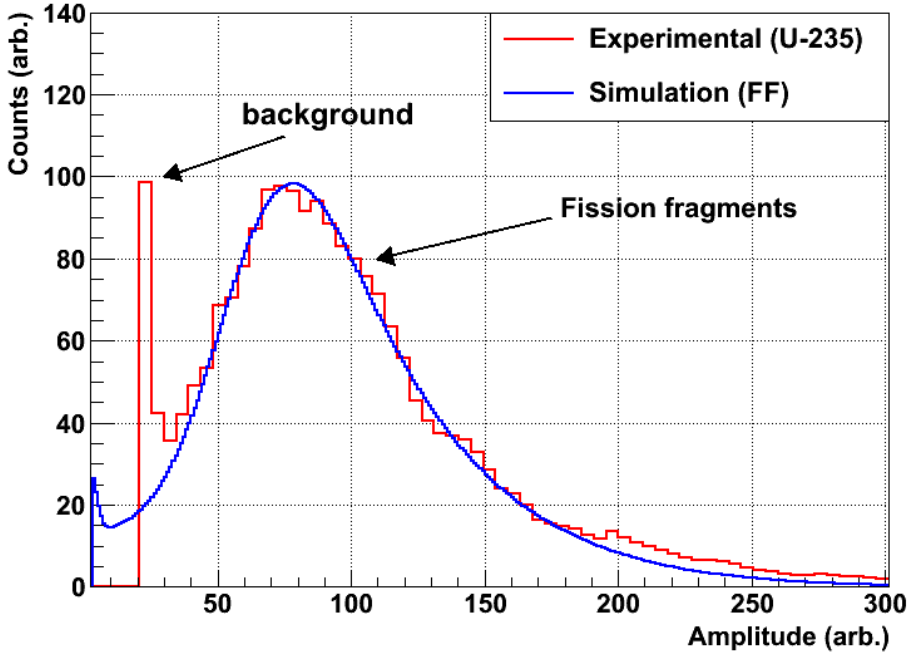


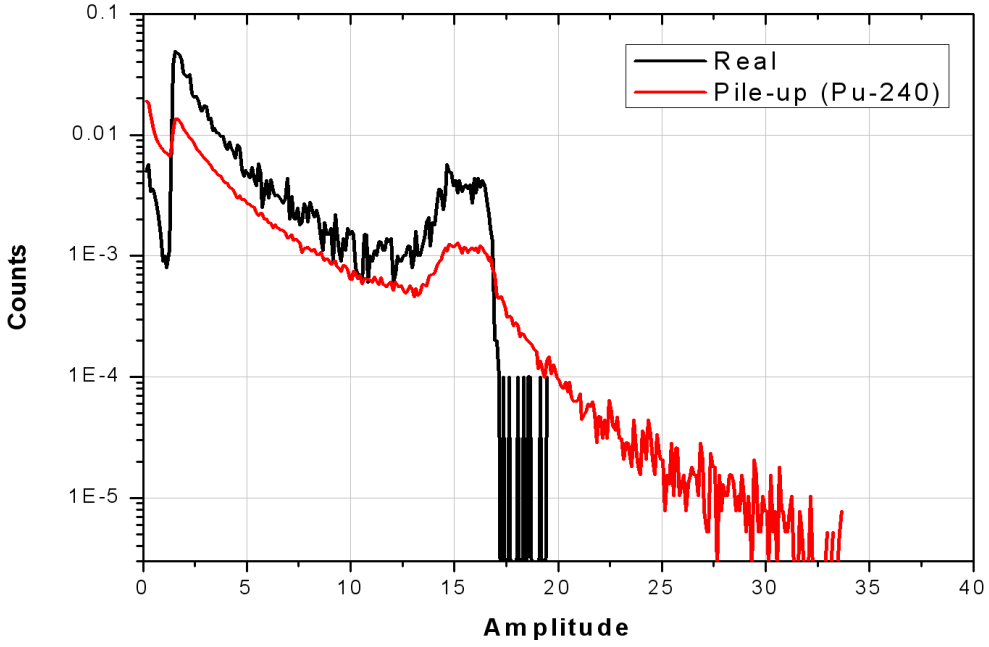




- A large time window is selected in which we randomly add:
  - white noise
  - α-particle and fission fragment pulses (at appropriate rates)

# Simulations

- Left: fission fragment pulse-height spectrum
  - Comparison of the real amplitude distribution of simulated fission fragments with the distribution extracted by the pulse analysis routine
- Right: how does α-pile-up (especially in $^{240}$Pu) affect the α-particle amplitude spectrum?
  - A long tail at higher amplitudes appears (just like in experimental data)



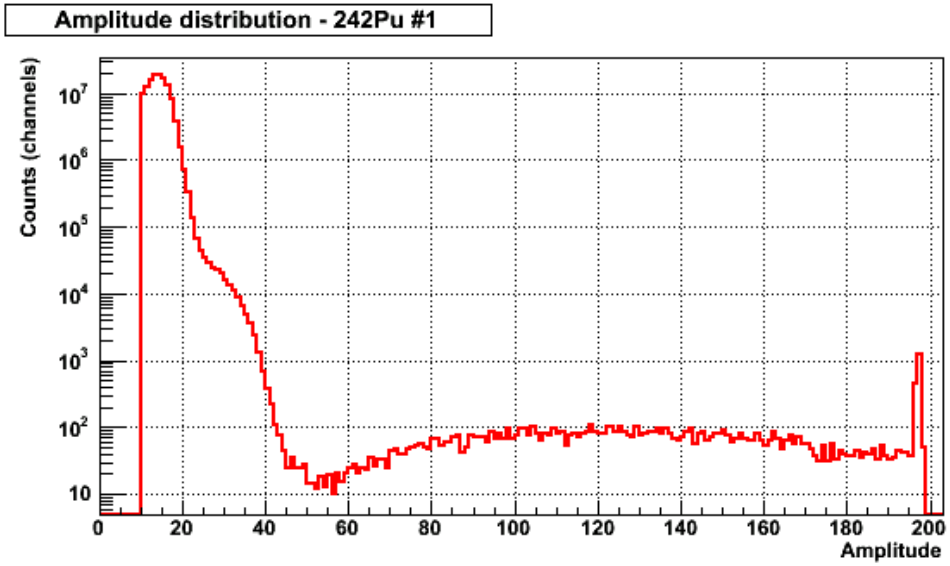
# Summary – Status report

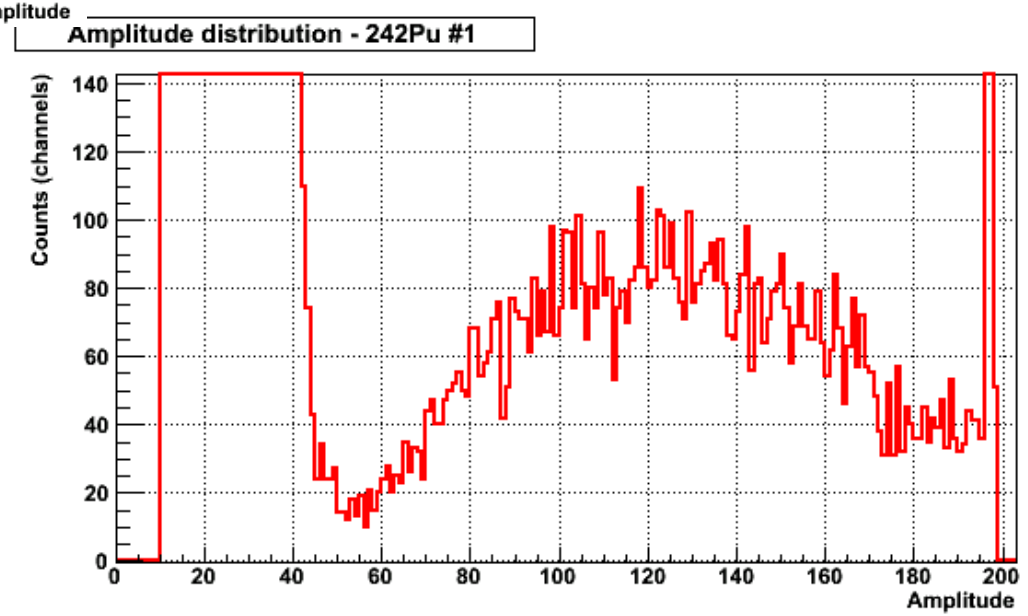
- Analysis of $^{242}$Pu data well under way
  - Main difficulty related to the gradual detector gain shift
  - Still to address:
    - Accurate determination of detector efficiency and amplitude cut correction (over time)
    - Accurate subtraction of spontaneous fission background
    - Final estimation of uncertainties
  - Analysis of high-energy data more CPU-intensive
  - >2Tb of reduced data (both isotopes)
- Large part of the $^{240}$Pu data needs to be discarded
  - A significant fraction of the data has been compromised due to the damage to the detectors
  - Besides this, analysis must be handled differently
    - Characterisation and subtraction of α-background, in order not to further reduce statistics by applying a very high amplitude threshold.
- Some new knowledge of the operation of the Micromegas has been acquired
  - …especially with respect to long-term measurements
  - To be kept in mind for the future, especially when measuring very radioactive samples

# The end


THAT CONCLUDES MY TWO-HOUR PRESENTATION. ANY QUESTIONS?
www.dilbert.com scottadams@aol.com
DID YOU INTEND THE PRESENTATION TO BE INCOMPREHENSIBLE, OR DO YOU HAVE SOME SORT OF RARE "POWERPOINT" DISABILITY?
8/9/03 © 2003 United Feature Syndicate, Inc.
ARE THERE ANY QUESTIONS ABOUT THE CONTENT?
THERE WAS CONTENT?

# Amplitude spectrum – $^{242}$Pu

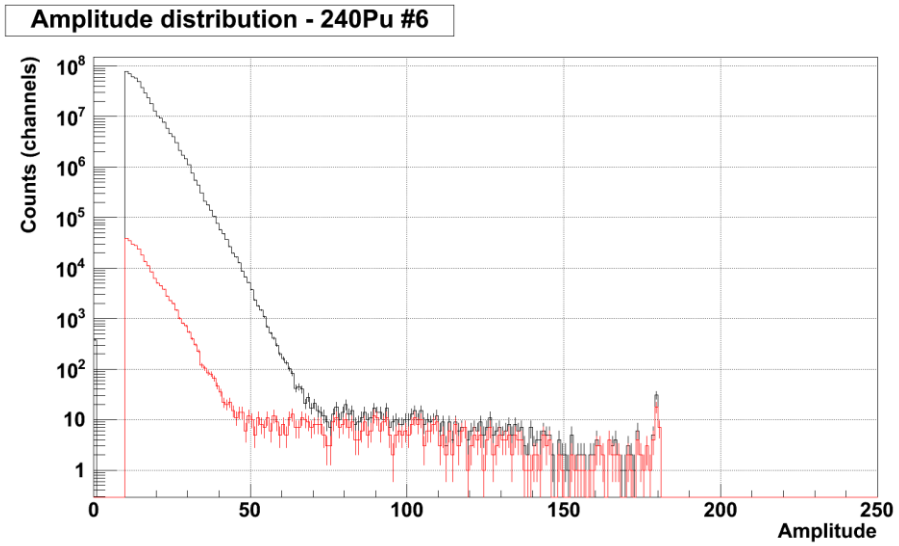


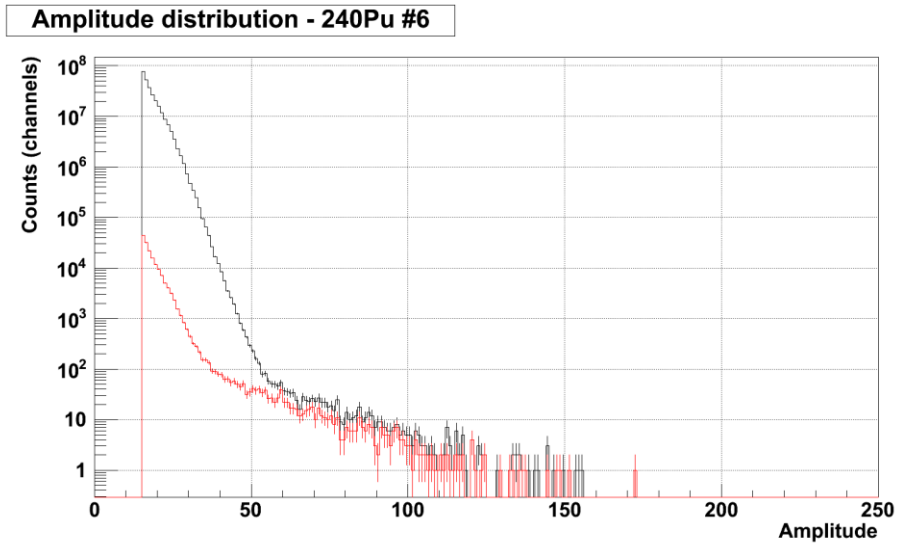
# Detector deterioration: the case of $^{240}$Pu

- Change in the amplitude spectra:

**Early in the run**



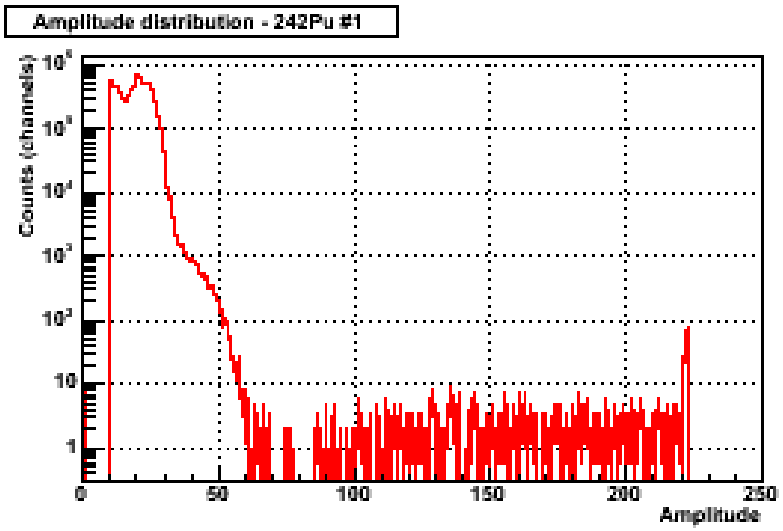

**Late in the run**

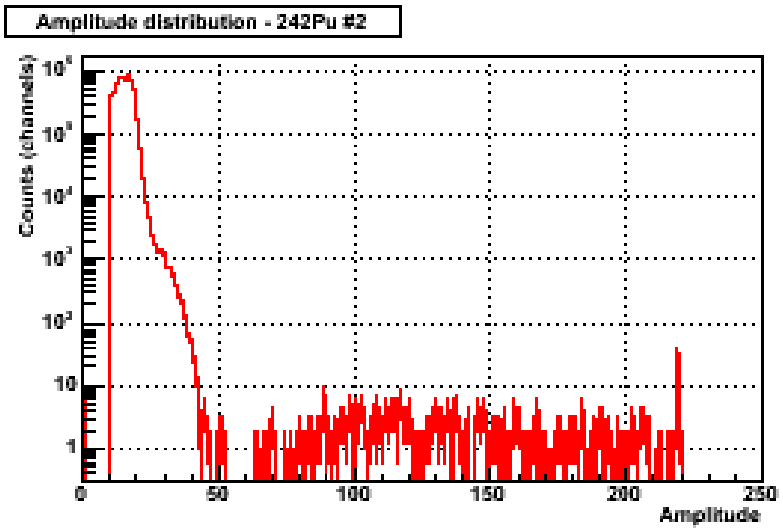


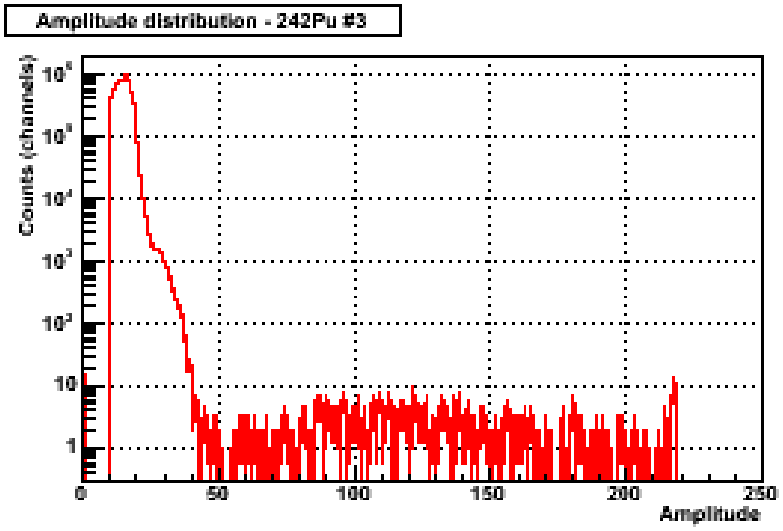

**En < 5MeV**

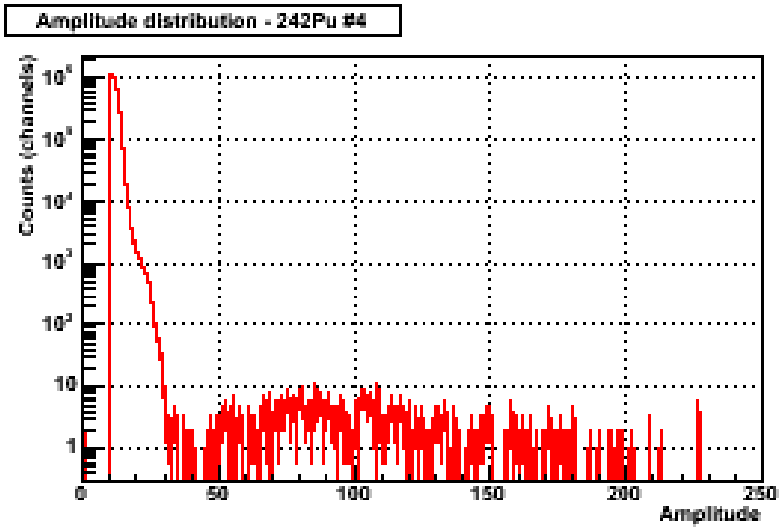
**0.1 MeV < En < 5 MeV**

# Detector deterioration: the case of $^{242}$Pu



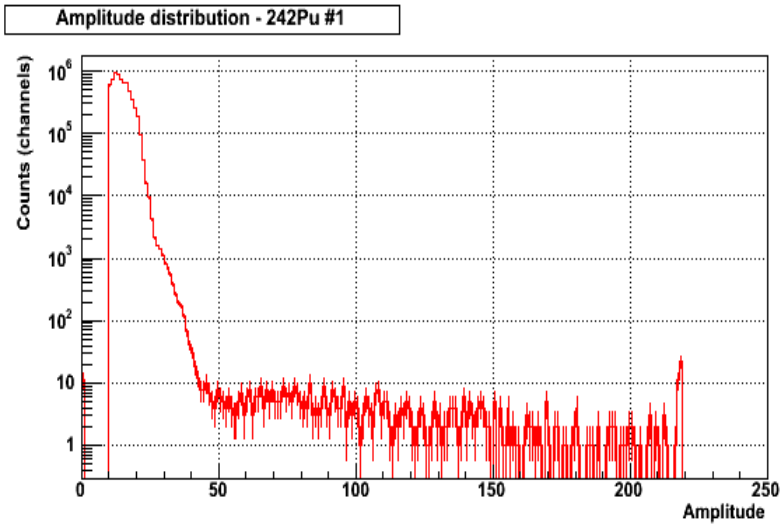



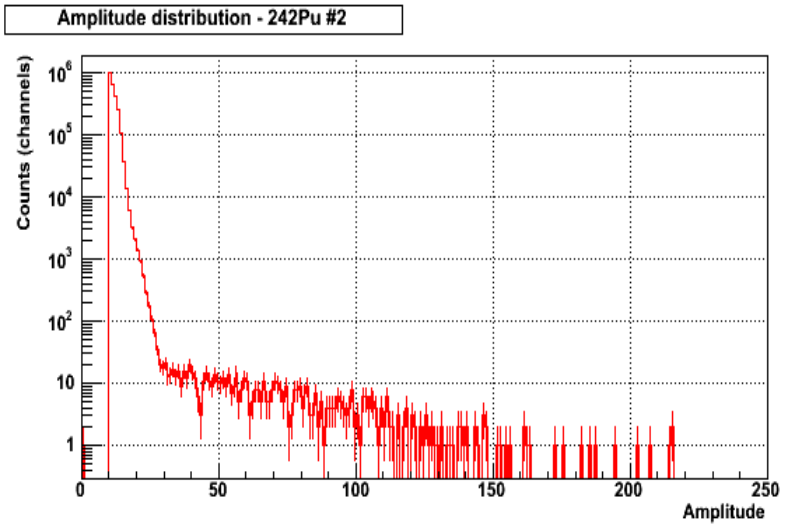



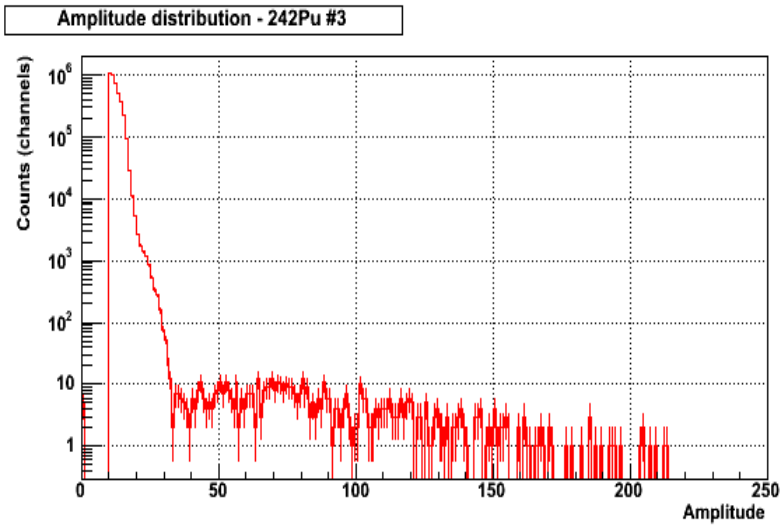



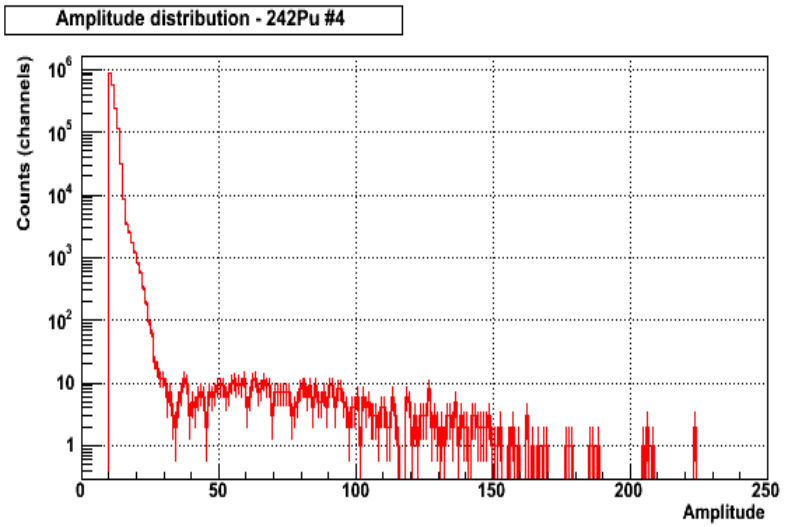

***Start of 2012 run***

# Detector deterioration: the case of $^{242}$Pu



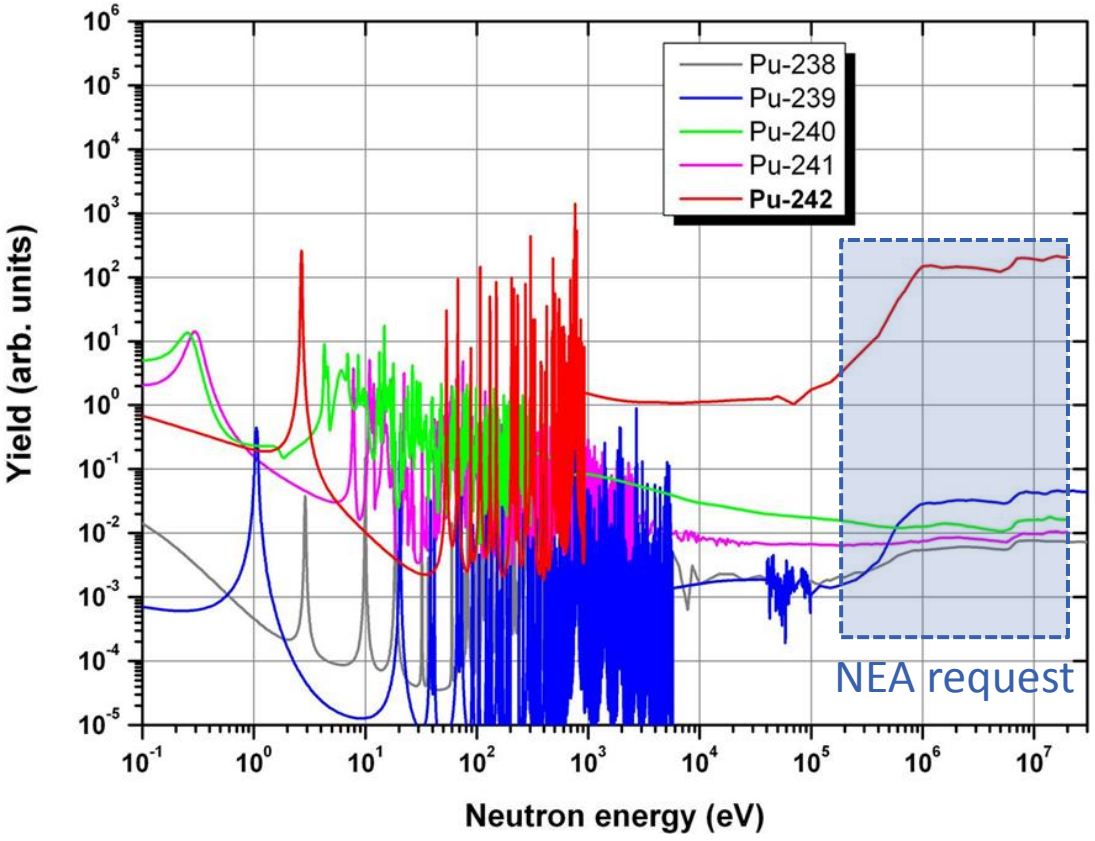




***End of 2012 run***

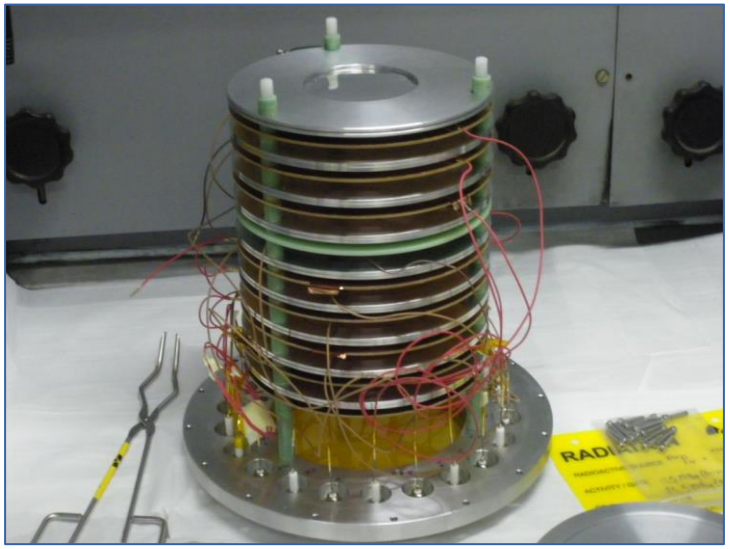
# The case of $^{242}$Pu

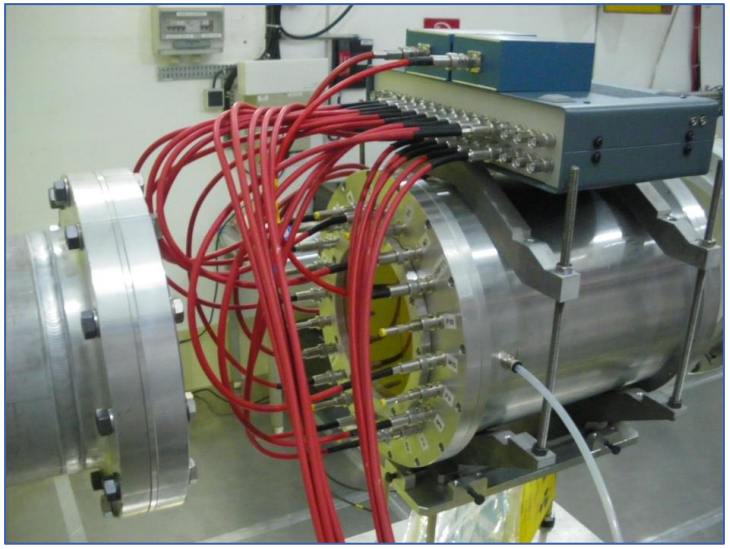



- Contribution of contaminants is very significant below few hundred eV
  - …up to 2 orders of magnitude greater than $^{242}$Pu yield
- However the contribution is negligible above a few keV

# The detector chamber & preamplifier module

- Designed to hold up to 10 samples and microbulk Micromegas detectors
  - BNC connections for signals and HV
  - Aluminium chamber
  - Kapton windows
- Gas mixture
  - 88% Ar : 10% $CF_4$ : 2% iso-$C_4H_{10}$
    p = 1 bar
- Preamplifier module
  - Electronic protection in place to prevent channel breakage
  - Shielding improved to reduce baseline oscillations





neutrons