Sino-German GDT Symposium
Ringberg, Tegernsee

Surface alpha events on segmented coaxial detectors

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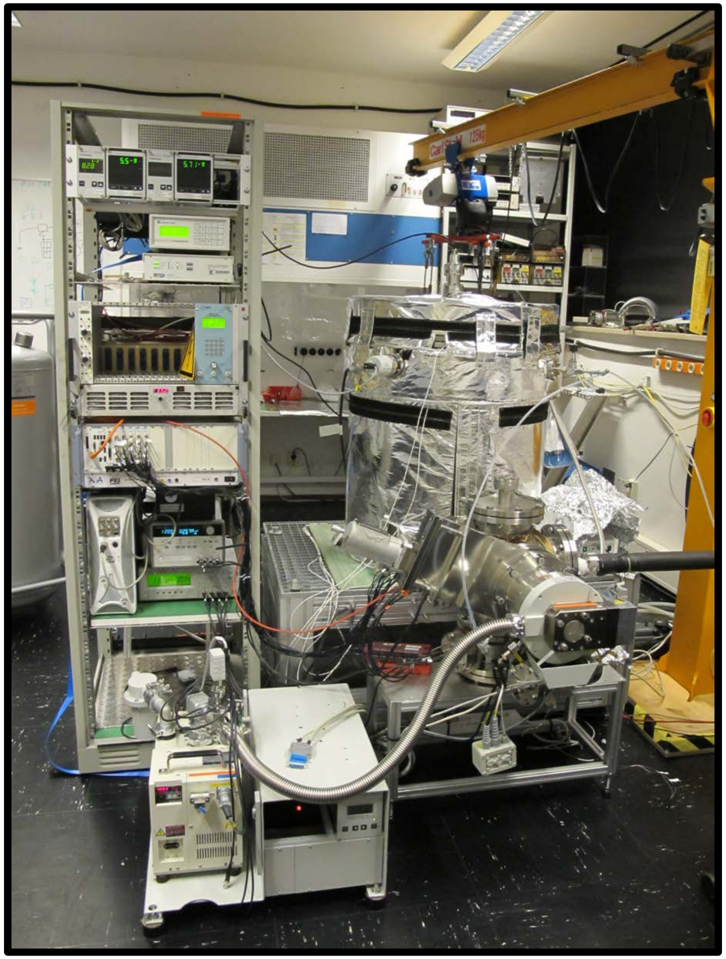
Outline

- **Introduction**
  - physics goal and motivation

- **Experimental set up**
  - the detector prototype: **SuperSiegfried**
  - the test facility: **GALATEA**

- **Top surface scanning**
  - alphas in Germanium Detectors
  - energy spectra and pulses
  - pulses characterization

- **Summary and Outlook**



Physics goal and motivations:

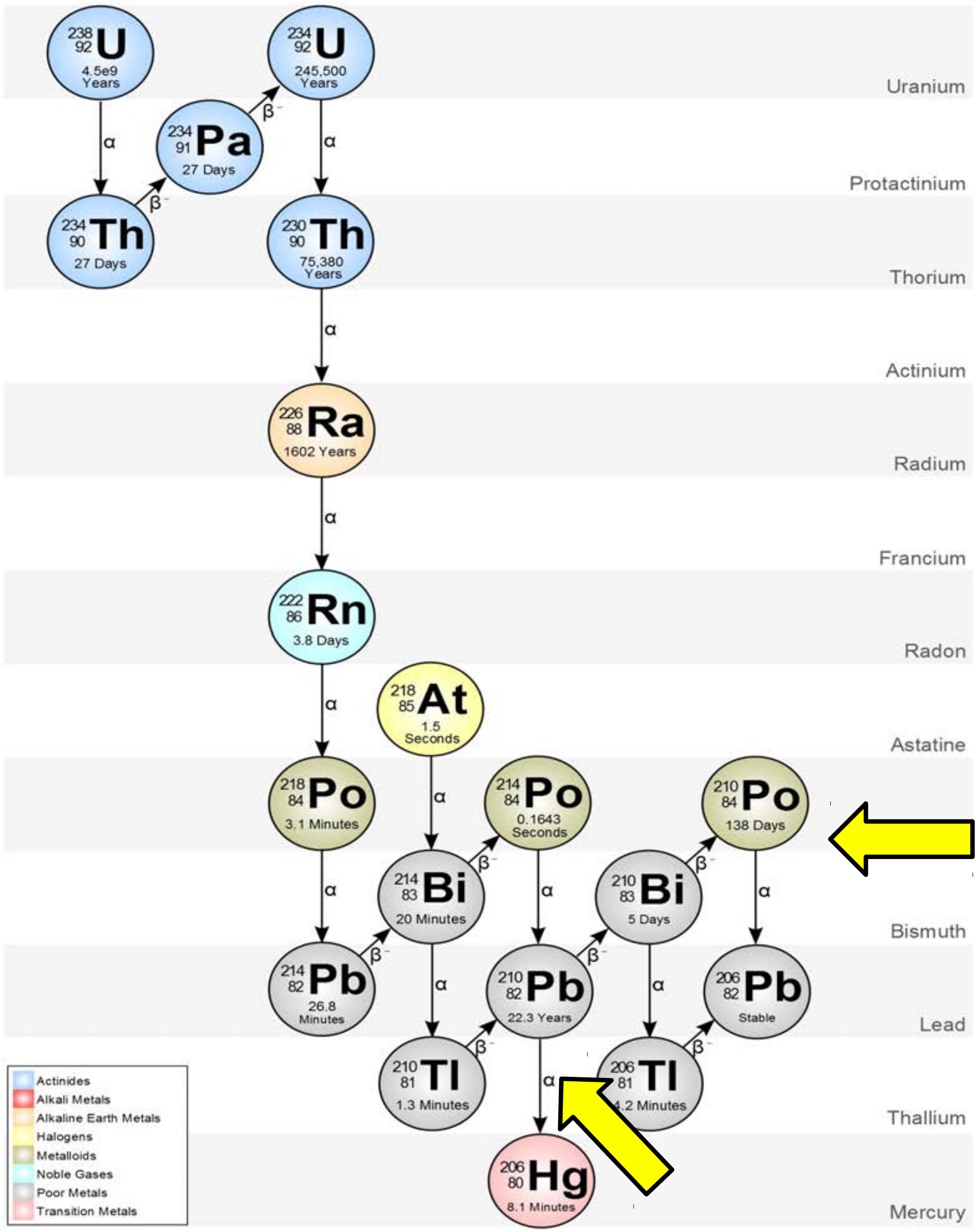
GOAL:

characterization of
detector response
for **alphas signal**

MOTIVATION:

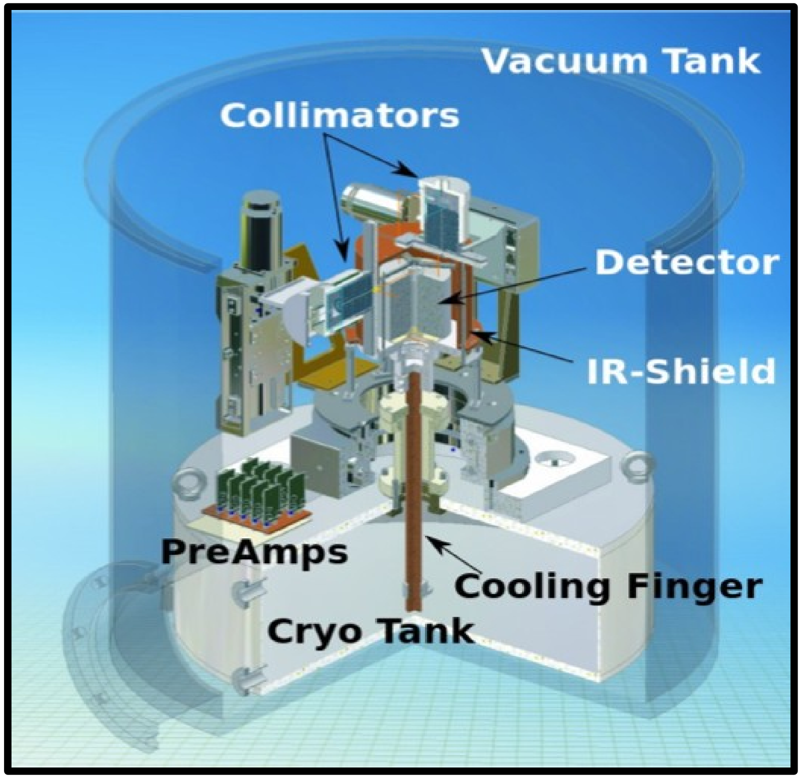
Alpha Background:
- Lead contamination on surfaces
- serious and often limiting
- $0\nu\beta\beta$, Dark Matter searches

Study alpha events in a controlled environment
- mirror pulses
- charge trapping



Experimental setup:

Shoot alphas from ^{241}Am on detector prototypes inside GALATEA

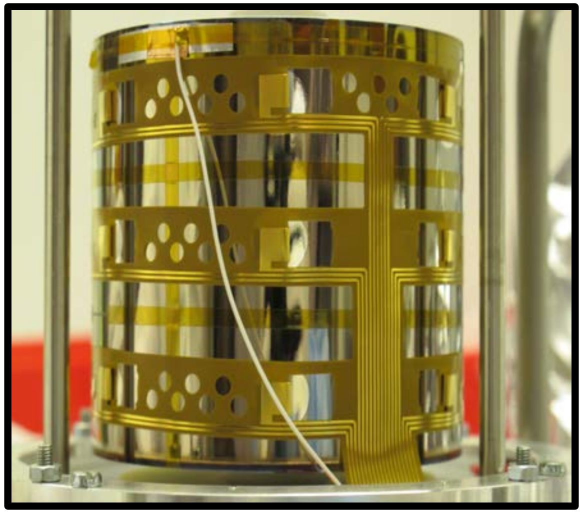


GALATEA:
I. Abt et al, Nucl. Instrum. Meth. A 782 (2015) 56-62

- vacuum chamber
    - low penetrating sources
- cryo tank to cool down the detector
- 3 motors to move 2 collimators in 3D:
    - collimated Am241 in the top collimator
        - scan along the radius
        - scan along the azimuthal angle
- electronics inside

Super Siegfried (SuSie):

- n-type true coaxial segmented detector
- segmentation scheme:
    - 3 in z X 6 in phi
    - 1 top segment not segmented in phi
- passivation layer on the top segment

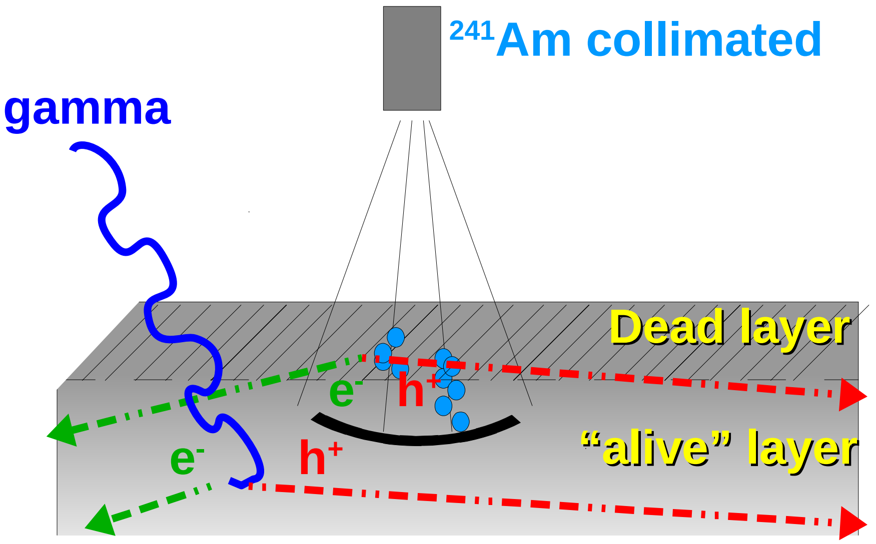


What do we expect in our detector?

Alphas = heavy charged particles

- **they lose energy by dE/dx**
- **short path inside the detector**
  - surface events
  - long pulses [low fields]

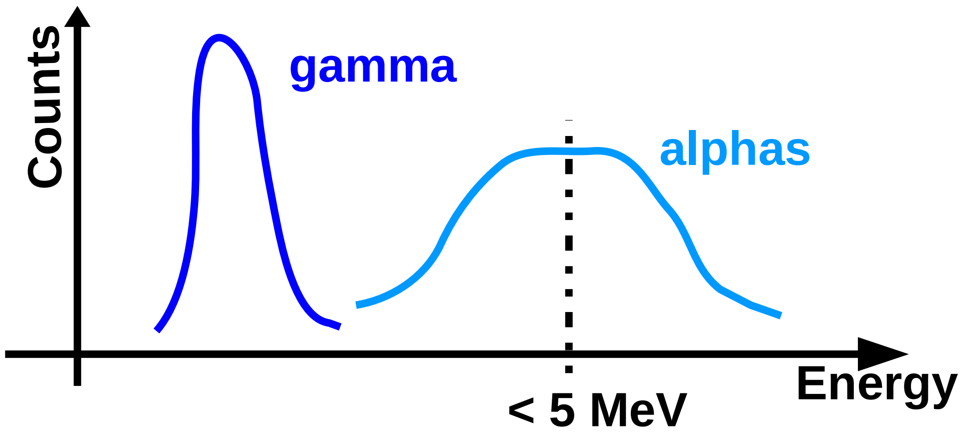
- **alphas from the ^{241}Am**
  - all with the same Energy ~ 5.6 MeV
  - all the same penetration depth



The final result depends on the combination of:

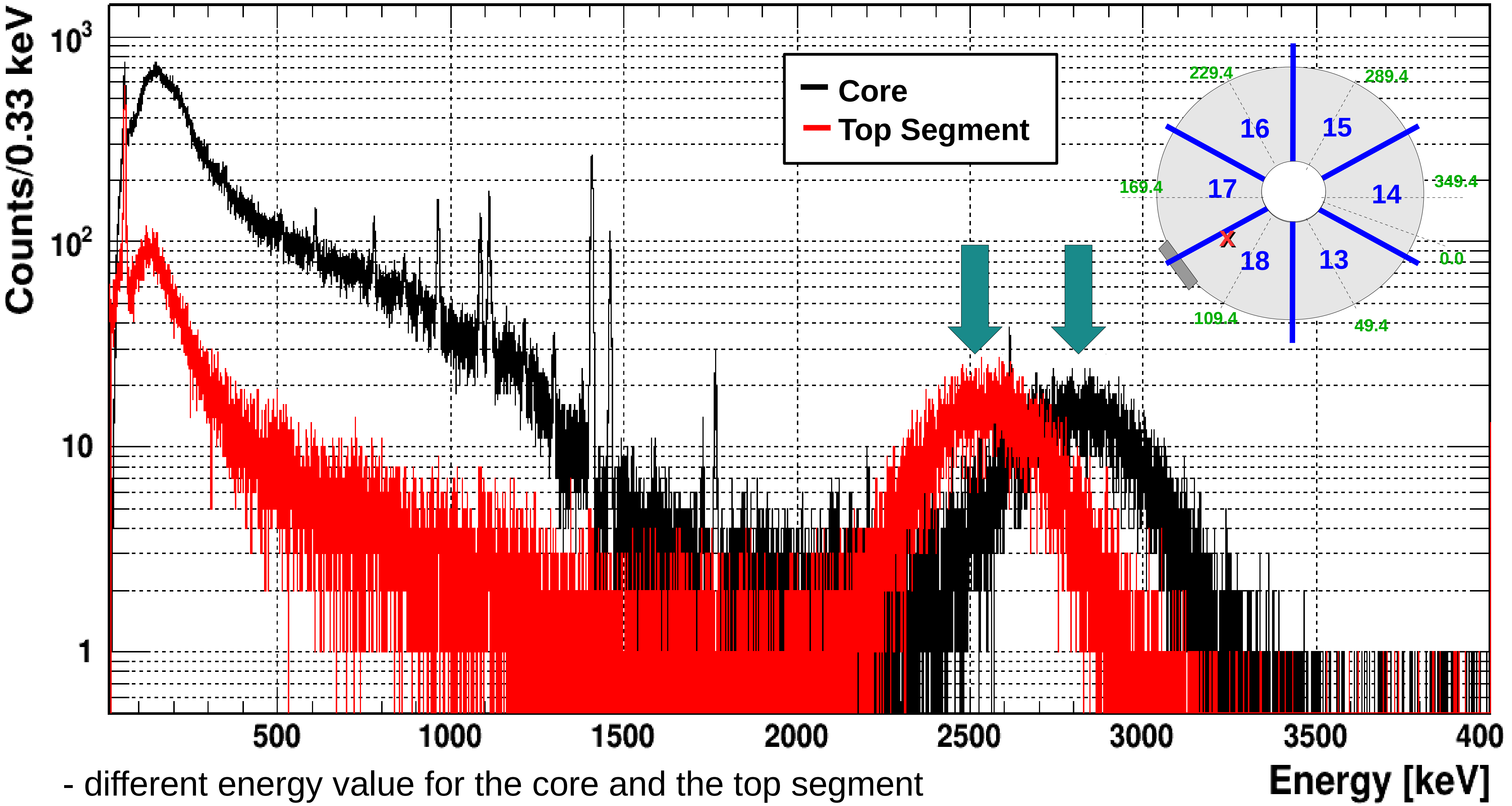
1) geometrical effect
- different incident angle
  - different path inside the dead layer
  - different energy deposited inside the detector

2) stochastic effect *(main one)*
- charge trapping



Alphas in the energy spectrum: r = 30 mm

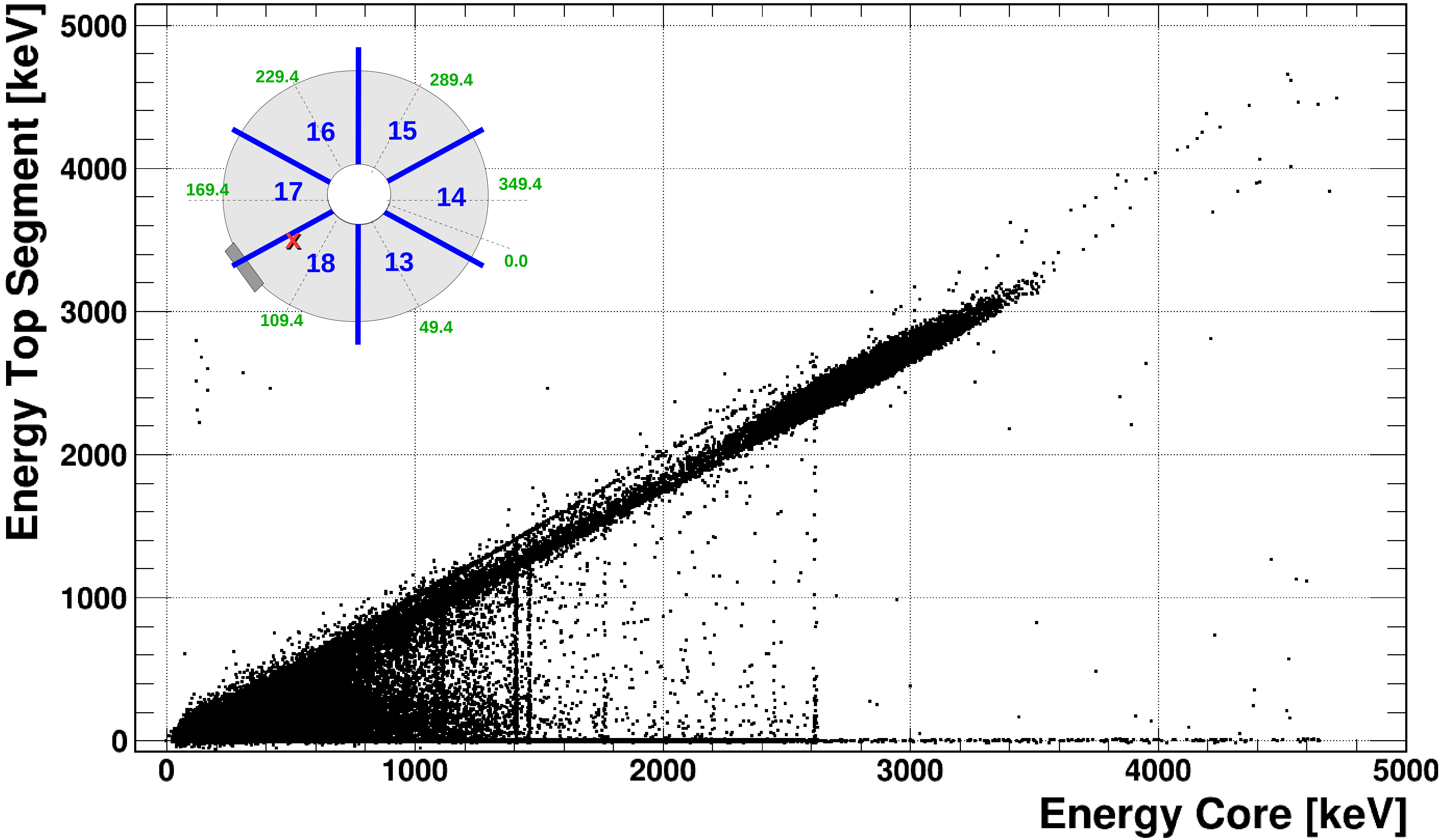
- **alpha bump** in the core and top segment energy spectrum
- visible also the **59 keV** gamma line from the ^{241}**Am**



- different energy value for the core and the top segment
    - evidence of **hole trapping**

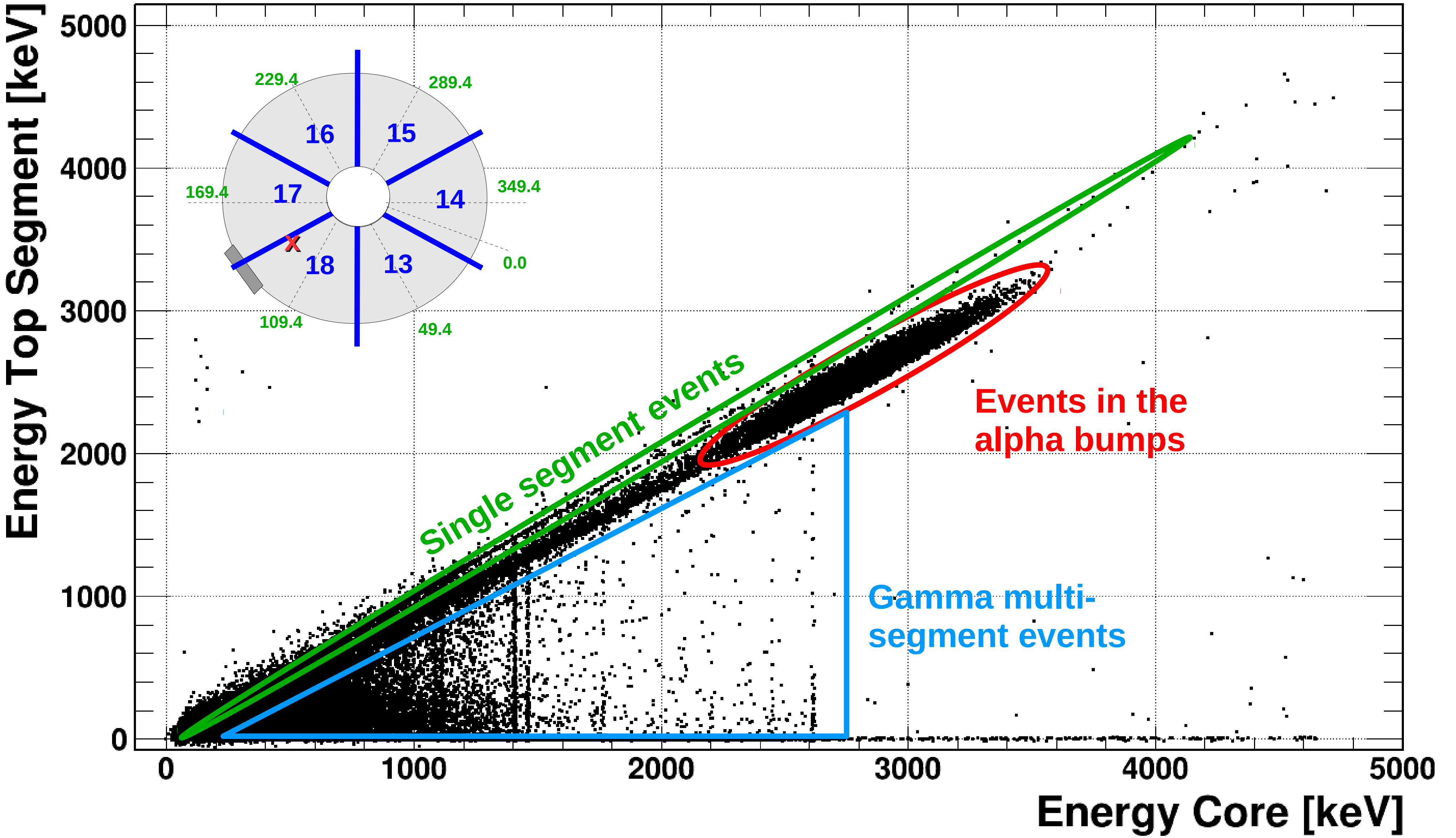
Energy correlation: top segment and core

evidence of **hole trapping:** the “blob” is out of the diagonal

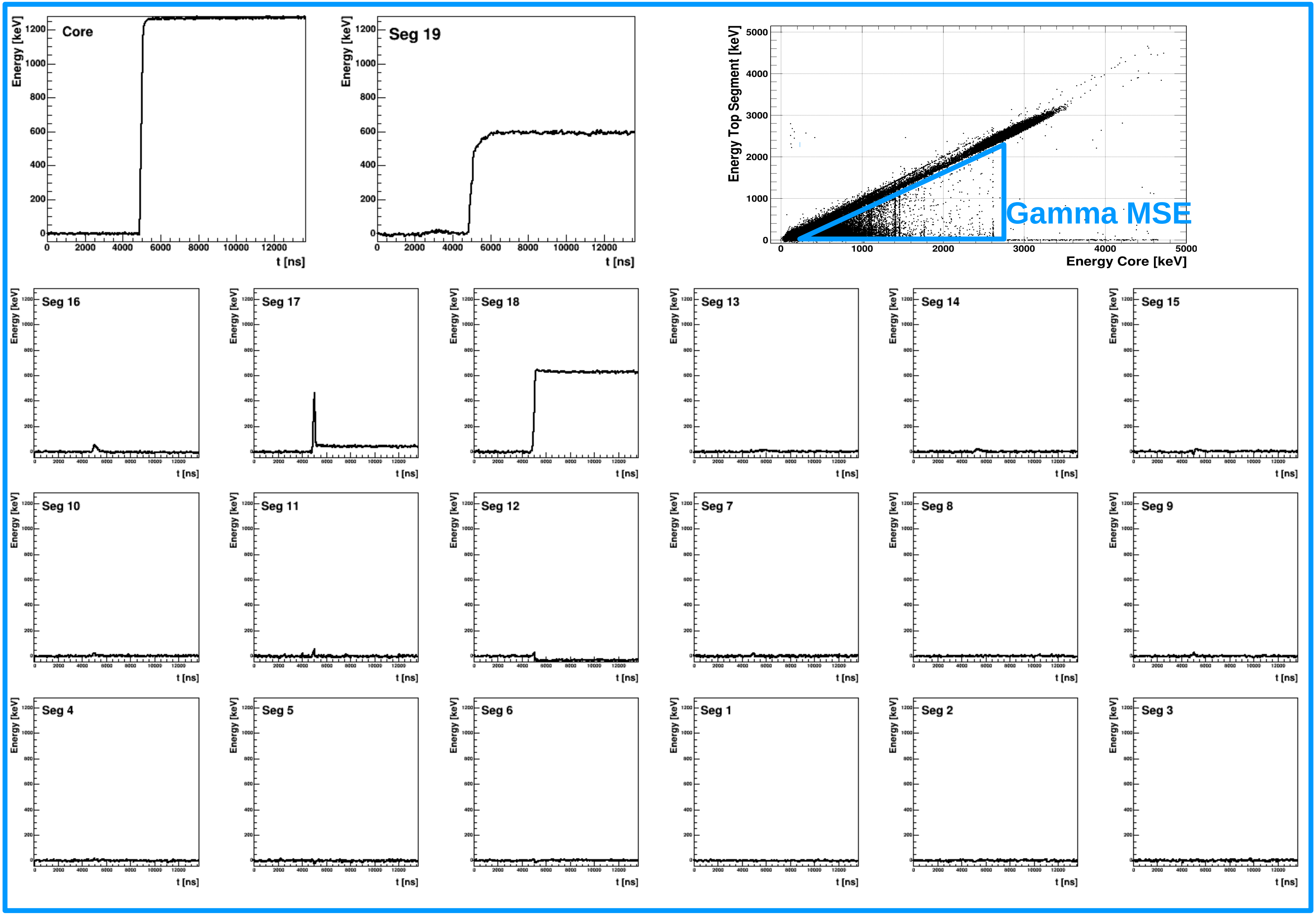


Energy correlation: top segment and core

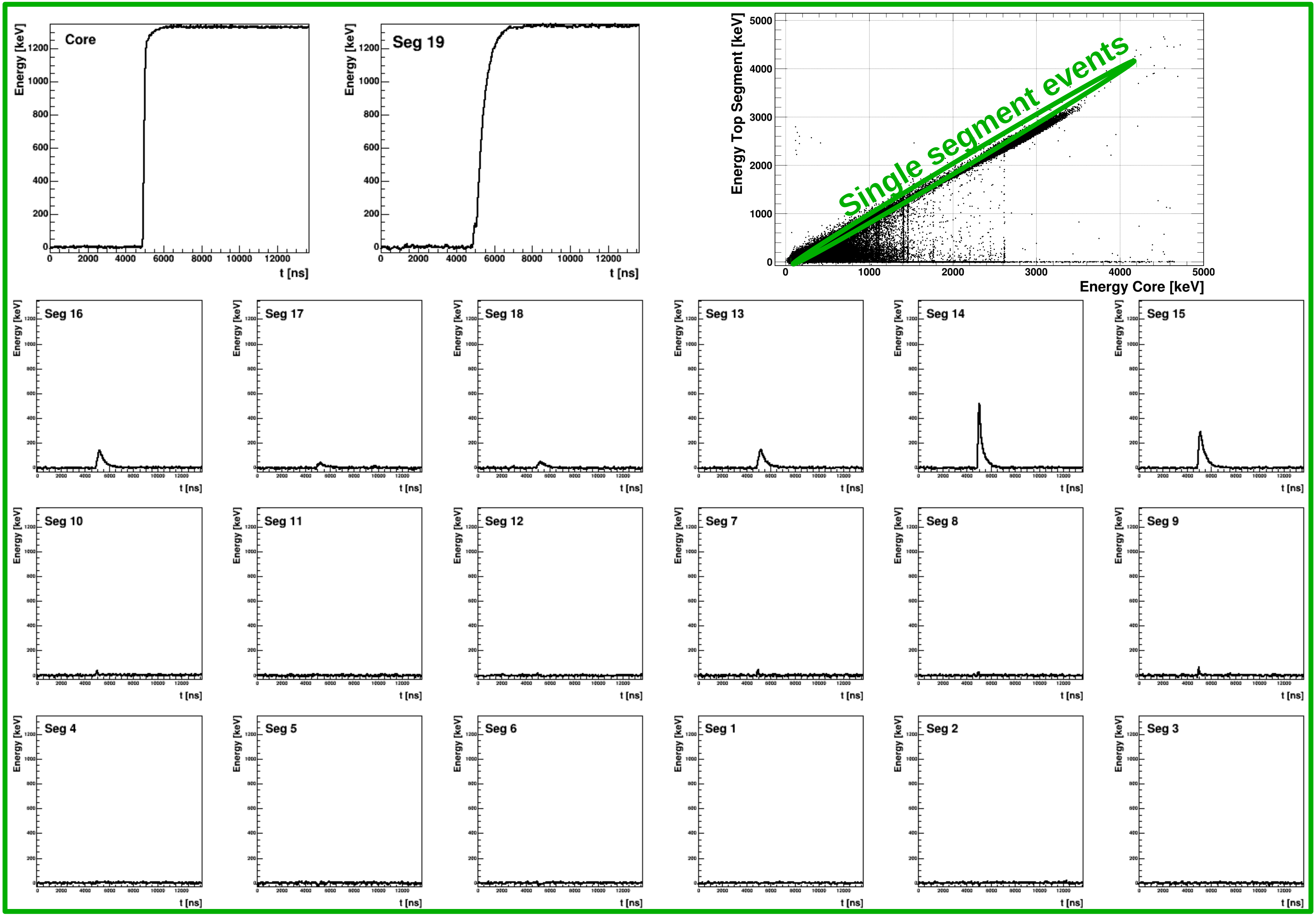
evidence of **hole trapping:** the “blob” is out of the diagonal



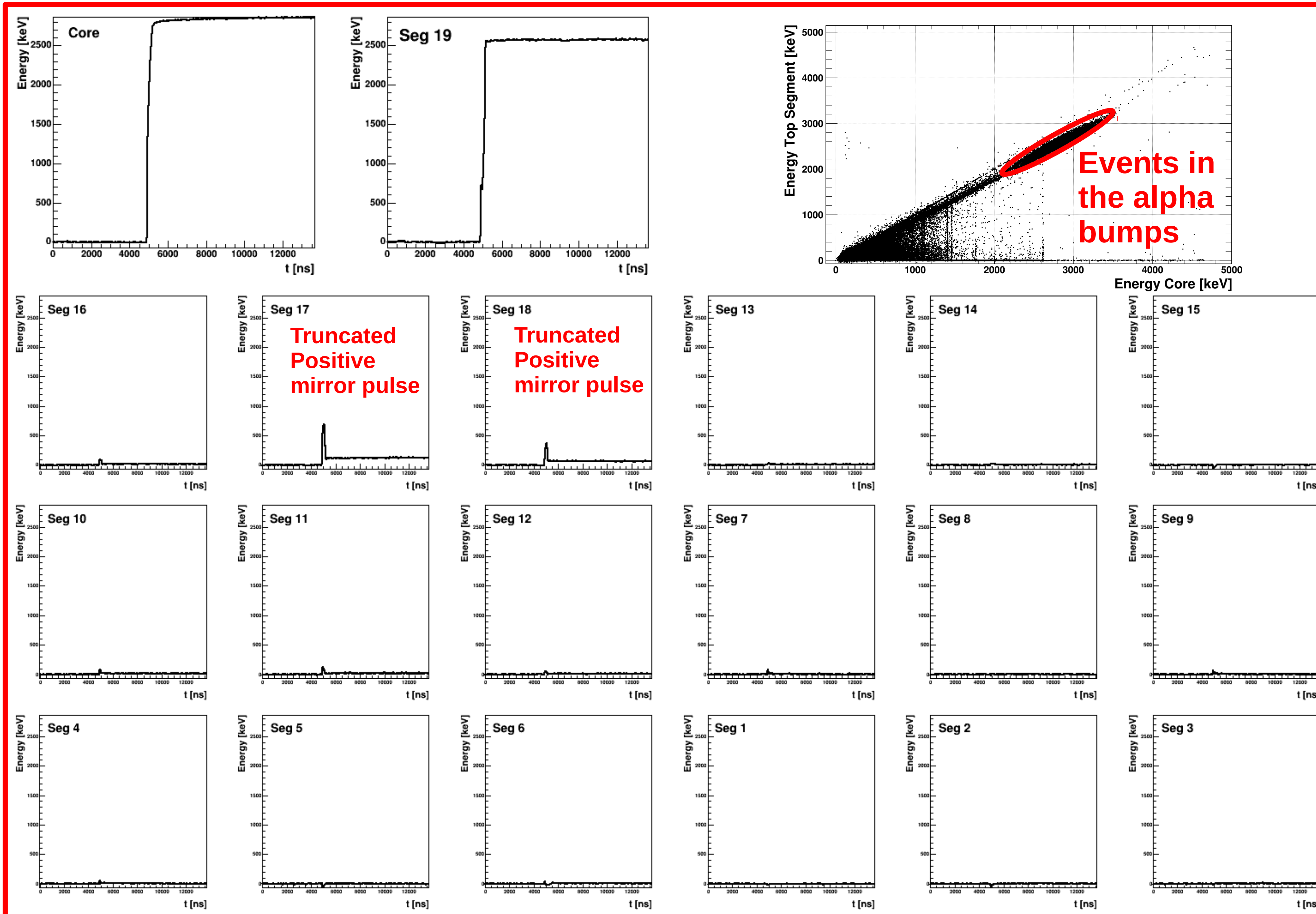
A typical multi segment event (MSE)



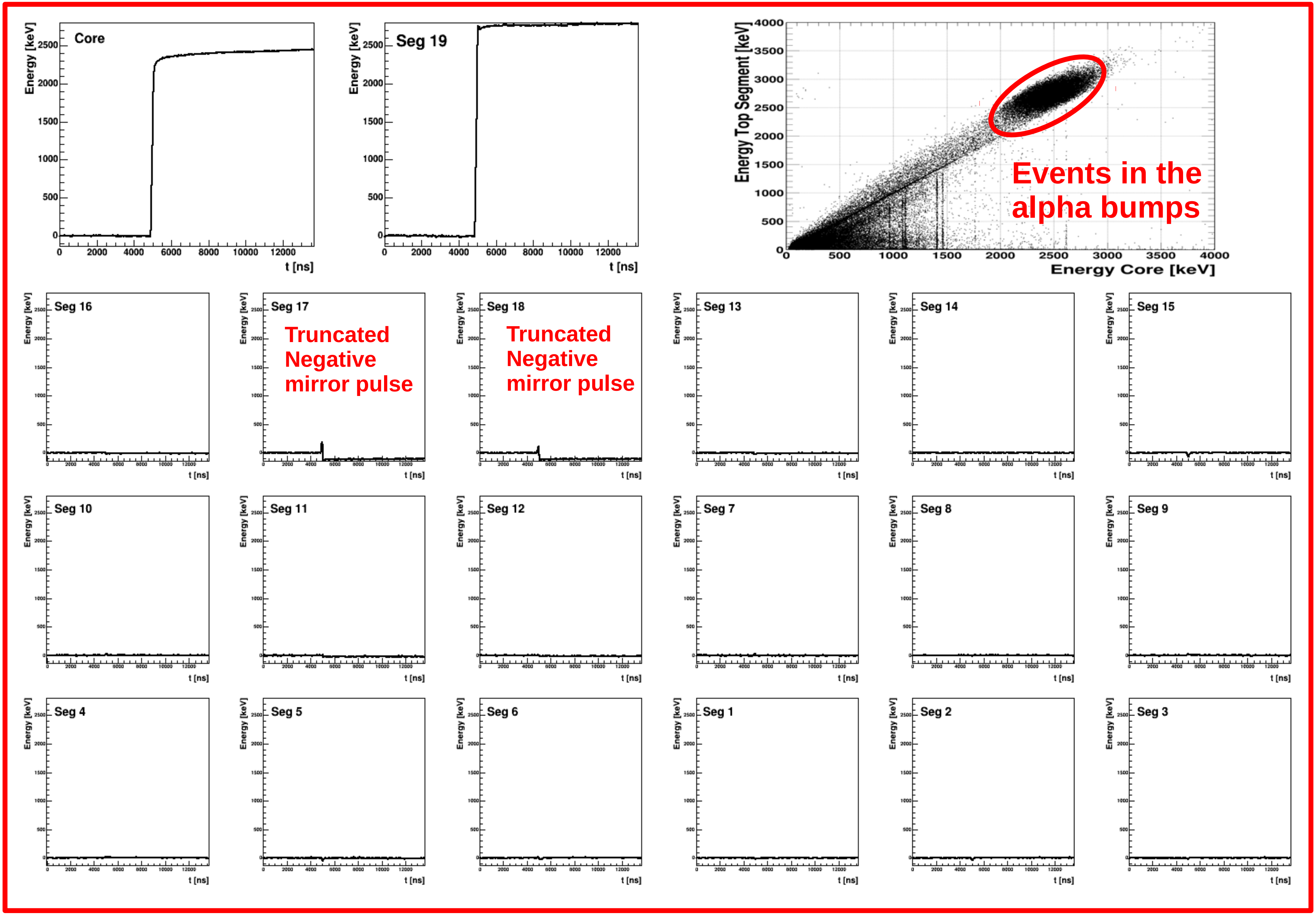
A typical Single Segment event (SSE)



A typical Event from the alpha “blob”

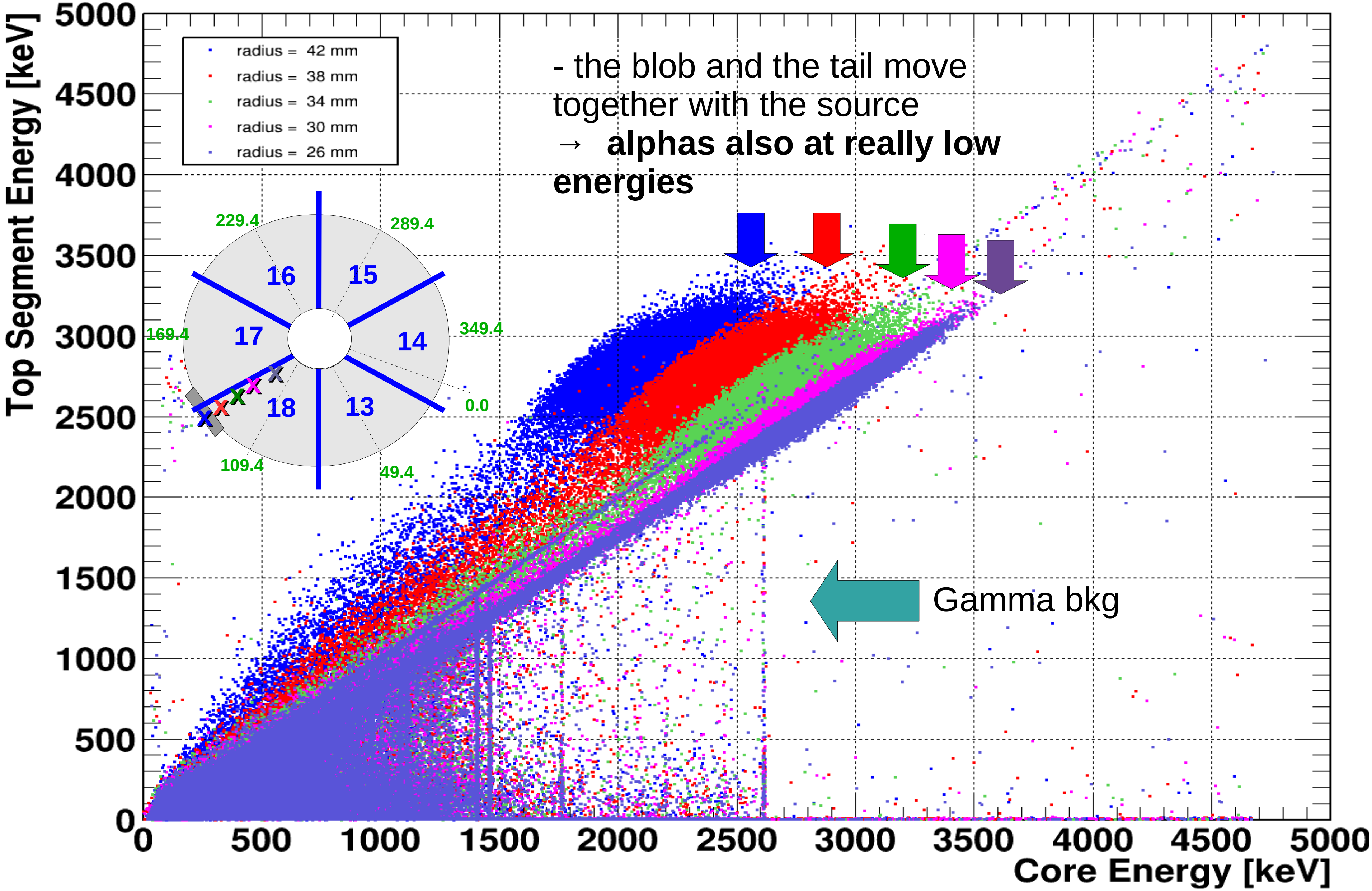


A typical Event from the alpha “blob” at higher radius



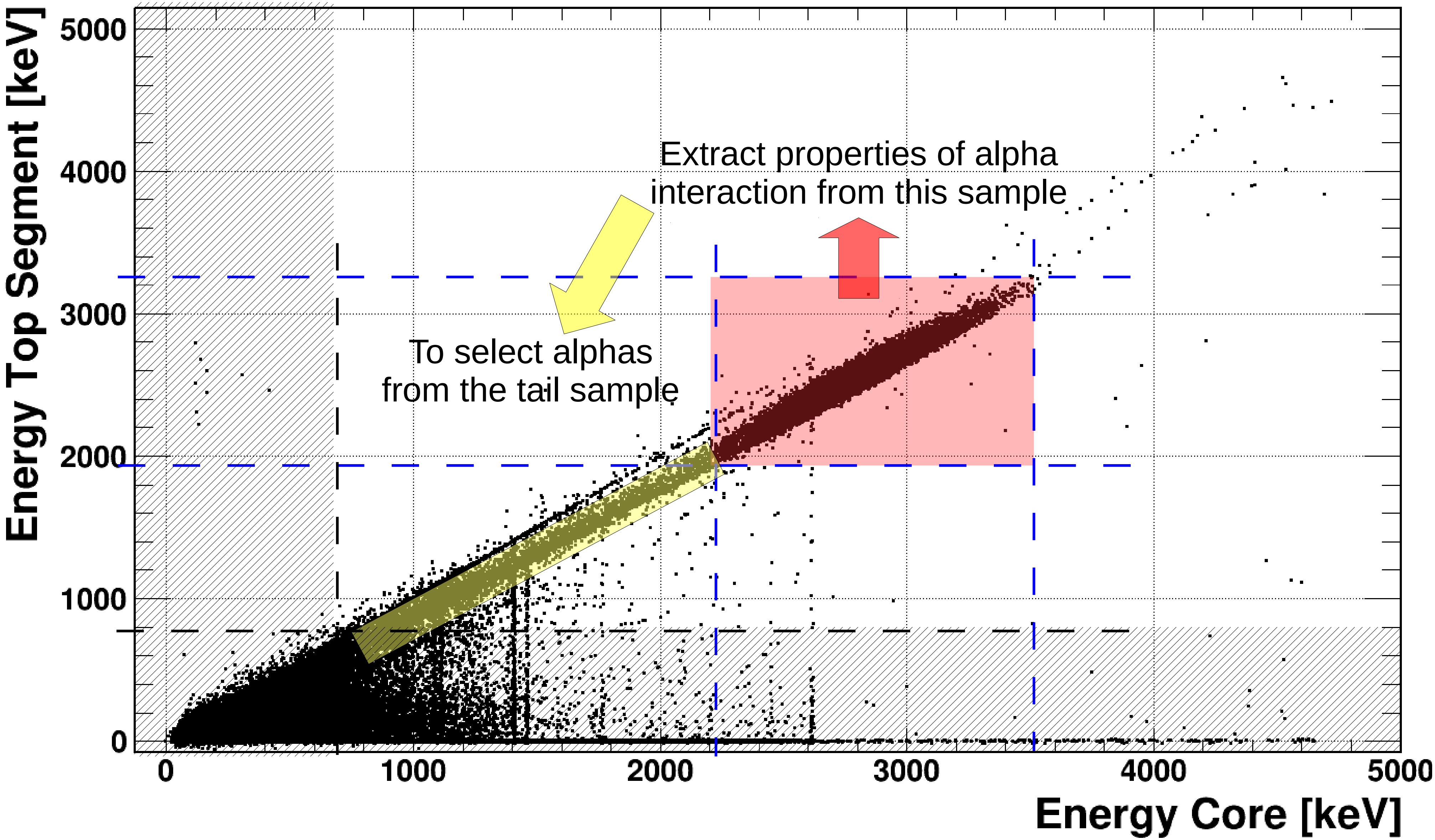
Energy Correlation for different scanning position

- **fixed phi scanning along the radius**

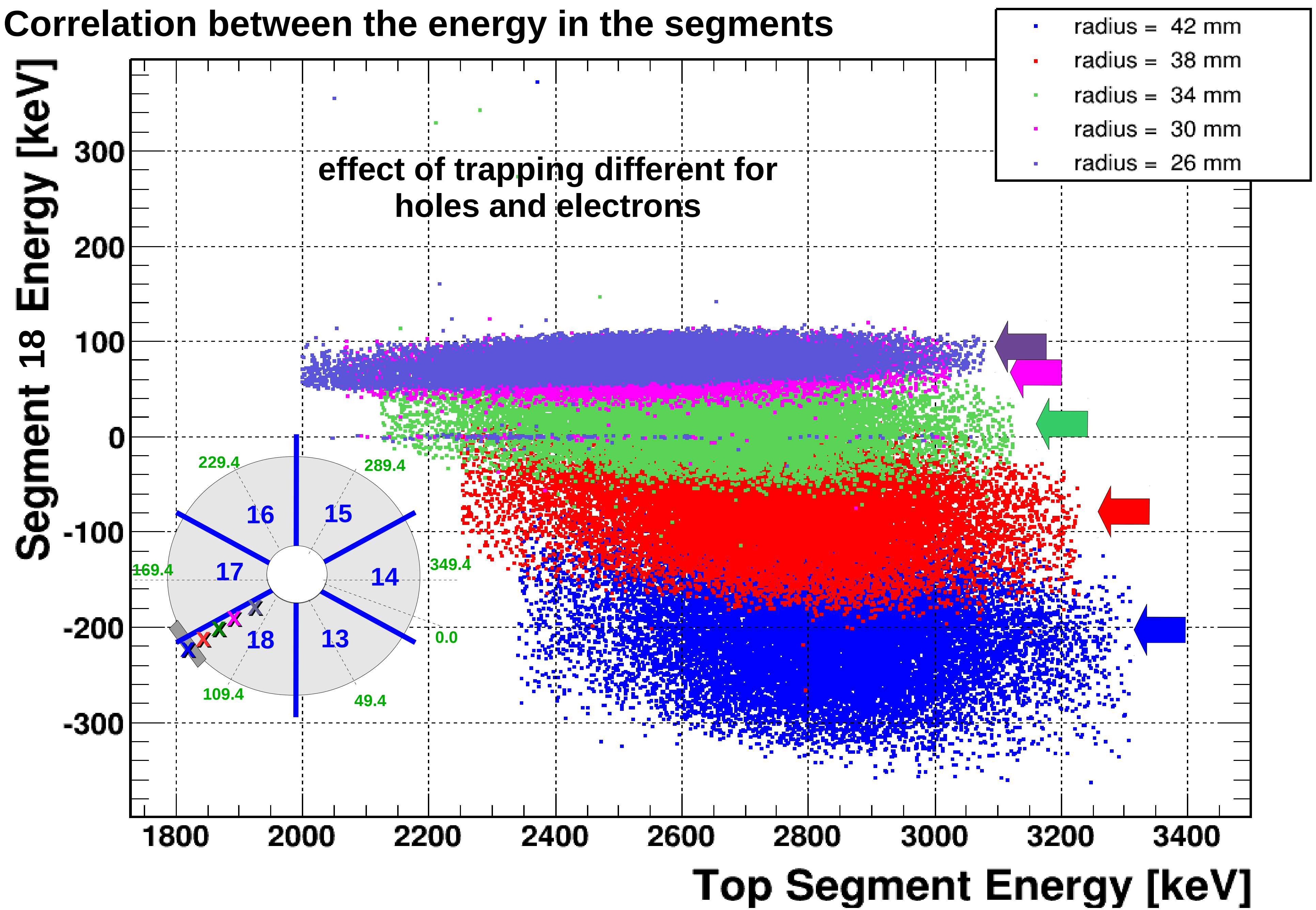


Alpha events selection strategy

- purest sample of Alphas = **BLOB**
    - **high energy gammas not contained in the 5 mm thick top segment**

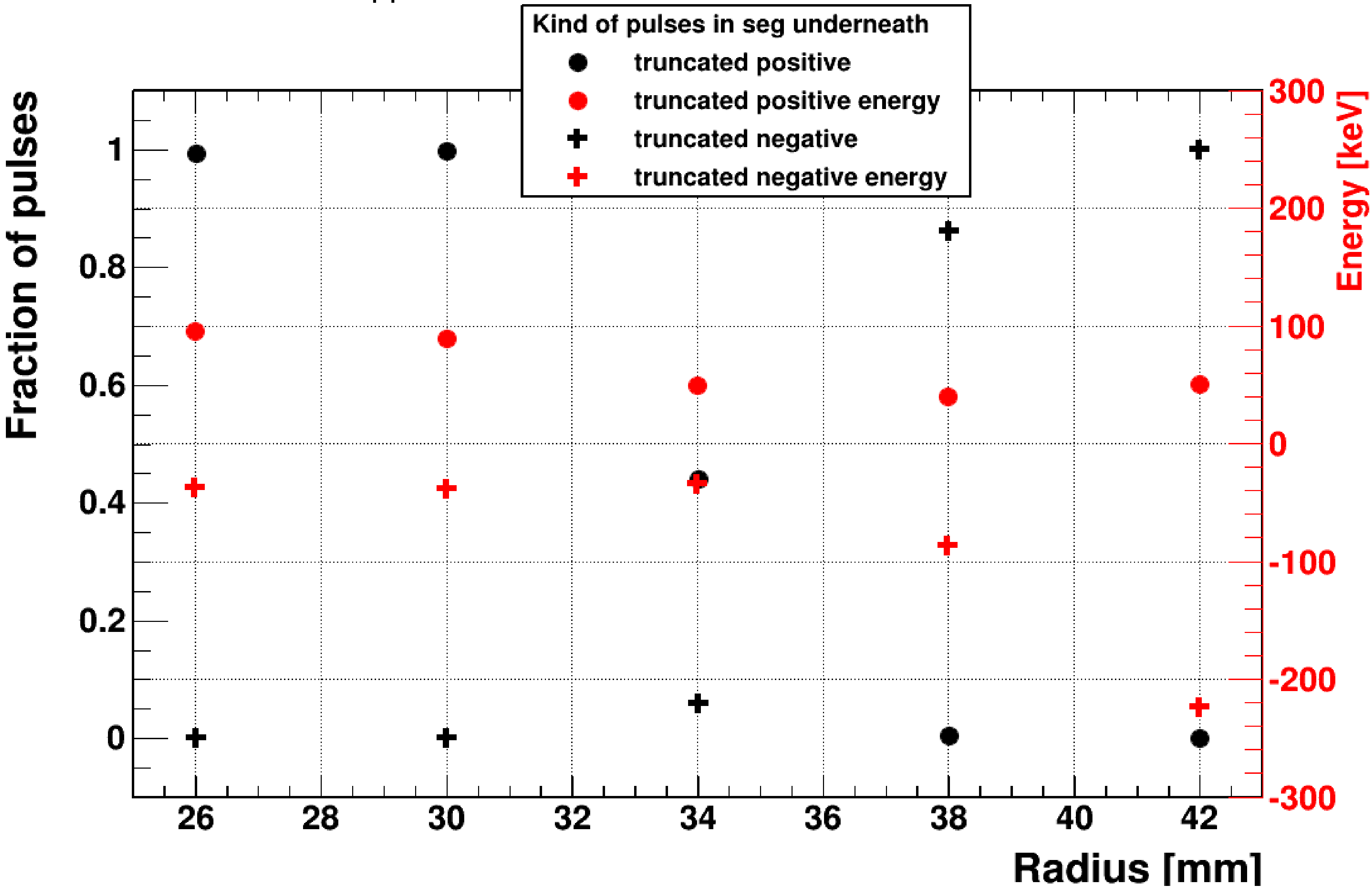


What does happen in the segments underneath?



What does happen in the segments underneath?

- fraction of truncated pulses in the two segments underneath
    - **correlation with the energy released**
- more electrons are trapped



Summary and Outlook:

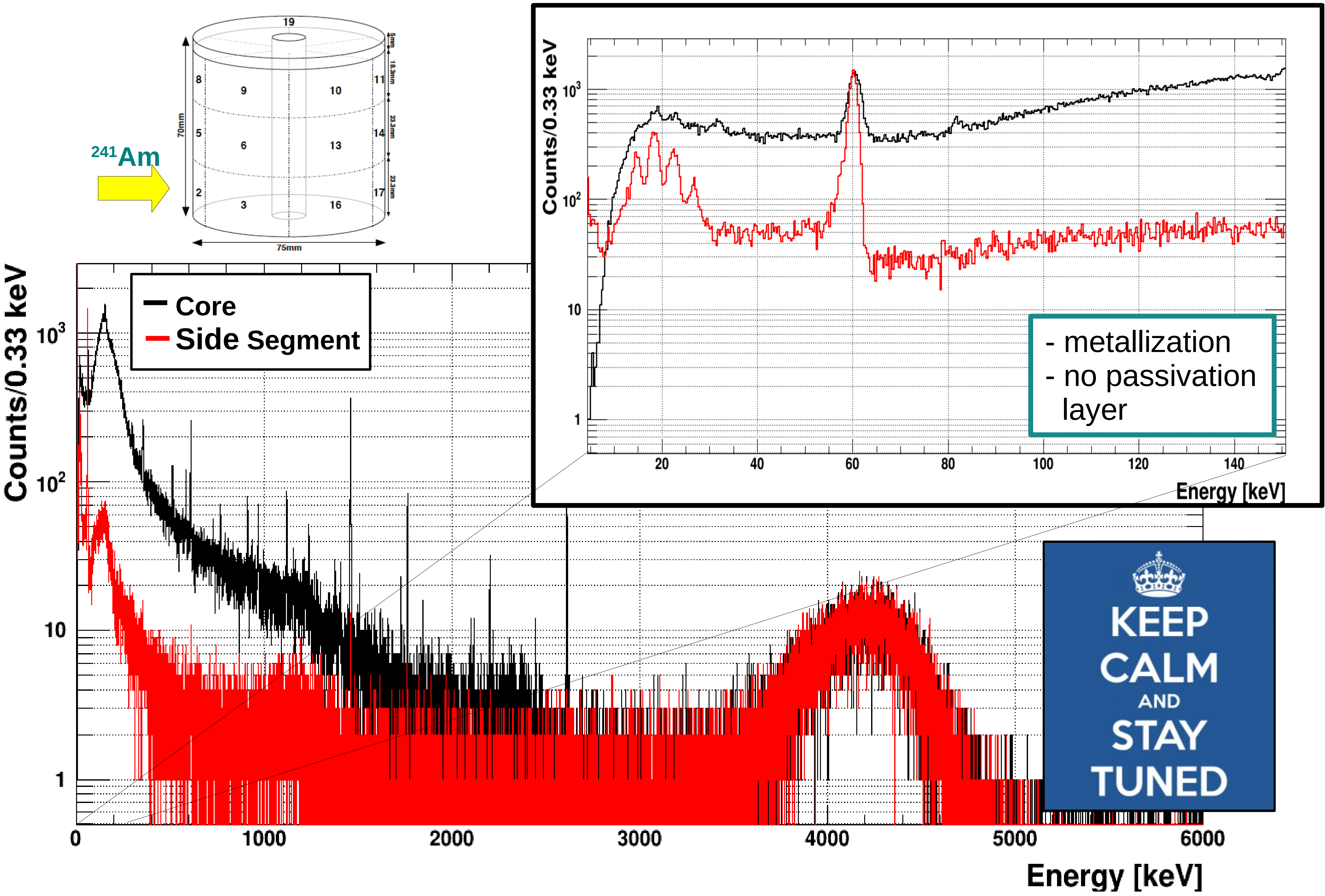
Conclusions:

- Scan of the **passivation layer** of a true coaxial n-type Ge detector done with ^{241}**Am**
- **pure samples** of surface events can be characterized
- **segmentation can help in the characterization**:
    - segments underneath show truncated pulses
- **electrons seem to be "more trapped" than holes**

What's next:

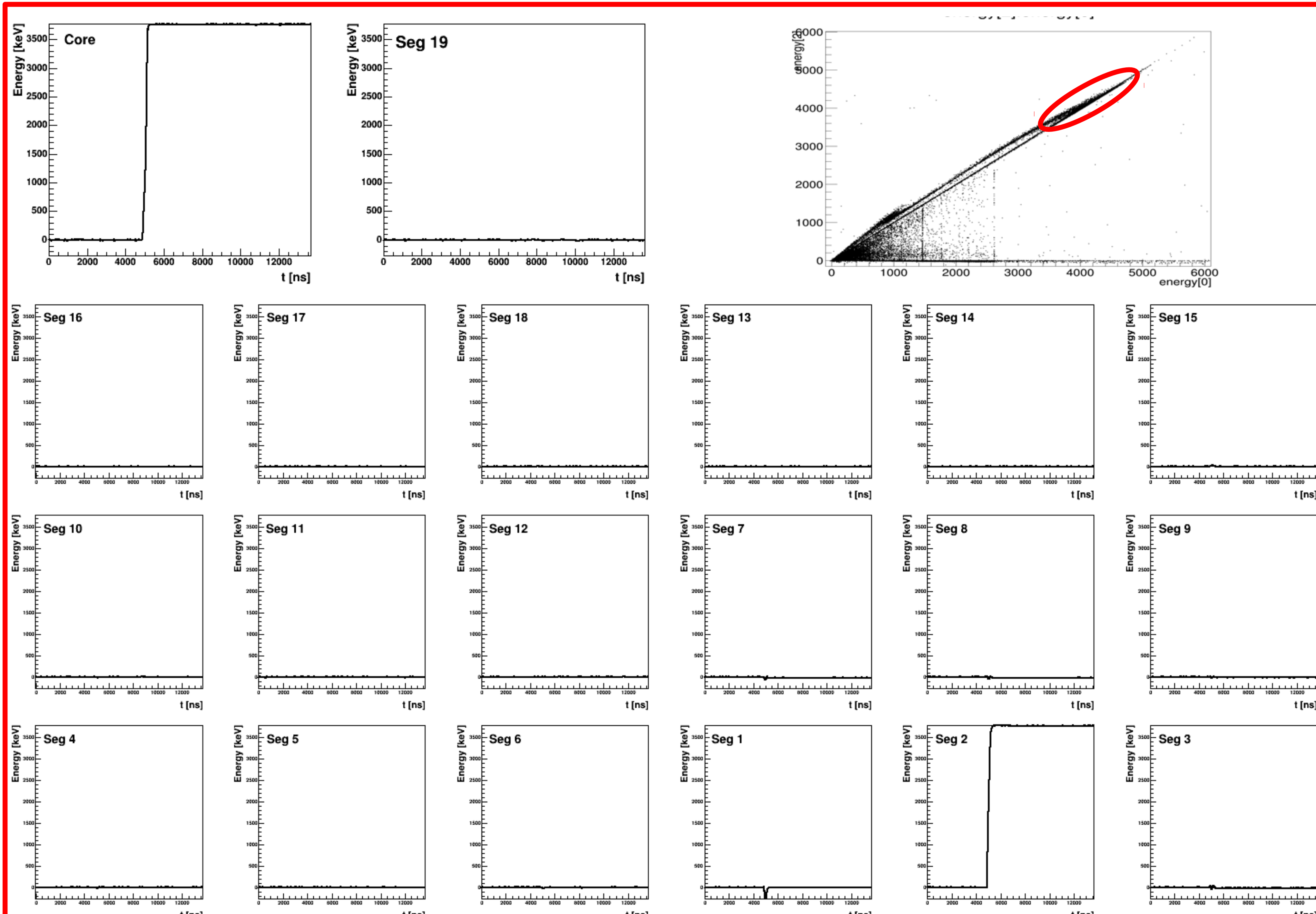
- **complete characterization** of the response to alpha particles:
    - timing information
    - closer look to the low energy alphas
- **side scan** of true coaxial n-type detector with ^{241}**Am**
    - no passivation layer
    - metallization
    - first results

Side Scan with ^{241}Am still on going (PRELIMINARY!!!)



Backup slides

A typical Event from the alpha “blob” from the side scan



Top surface scanning

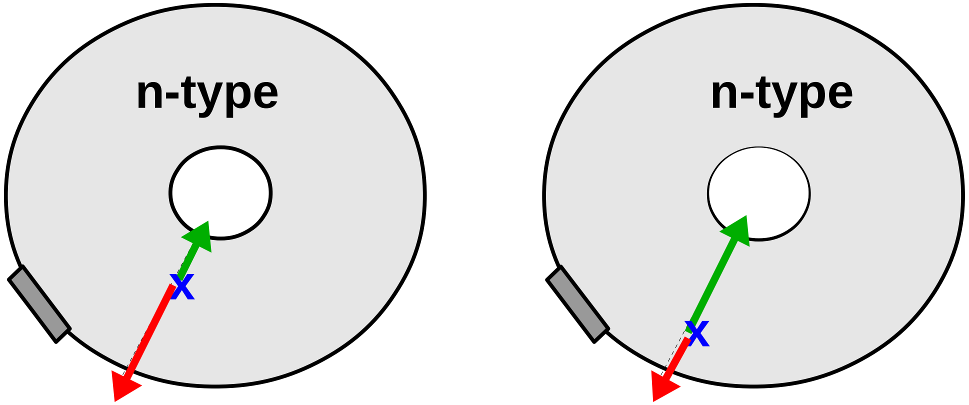
Scanning along the radius:

- fixed angle: varying the radius with steps of few mm
- check the different paths for the charge carriers
  - close to the surfaces

x point of interaction

→ electrons

→ holes



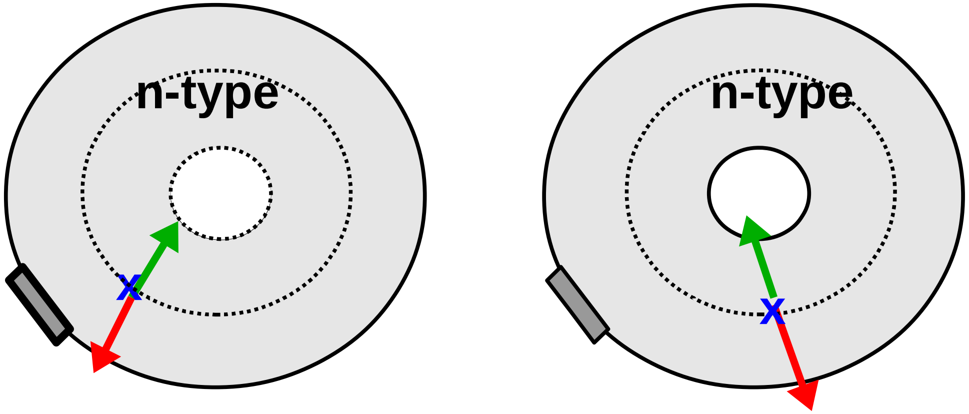
Scanning along the azimuthal angle:

- fixed radius: varying the angle with steps of few degrees
- check the effect of the Electric Field
  - change on the collection efficiency

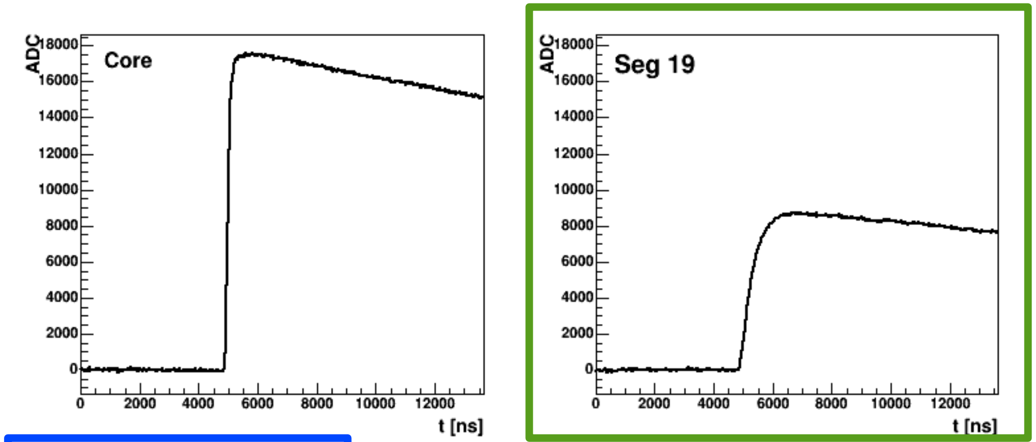
x point of interaction

→ electrons

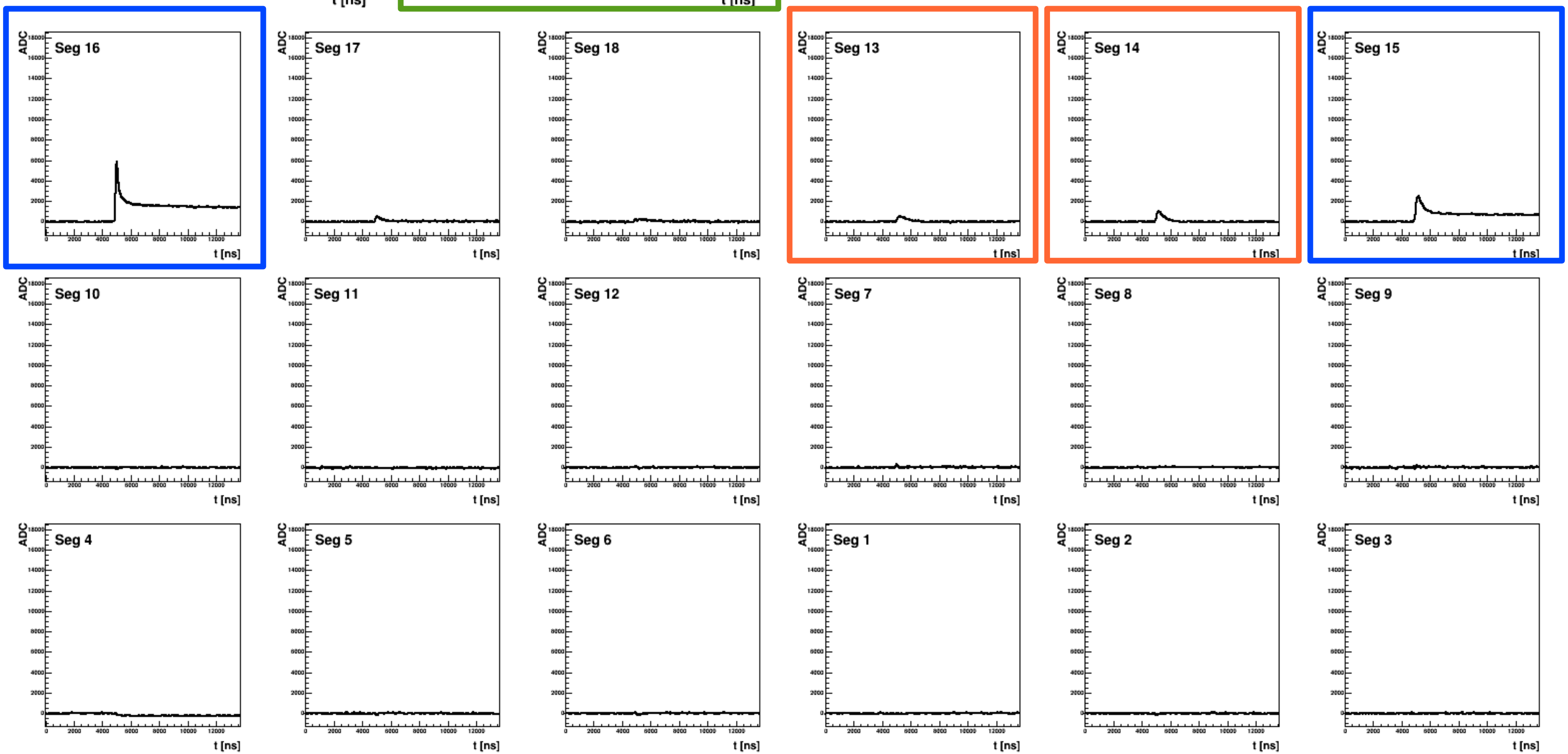
→ holes



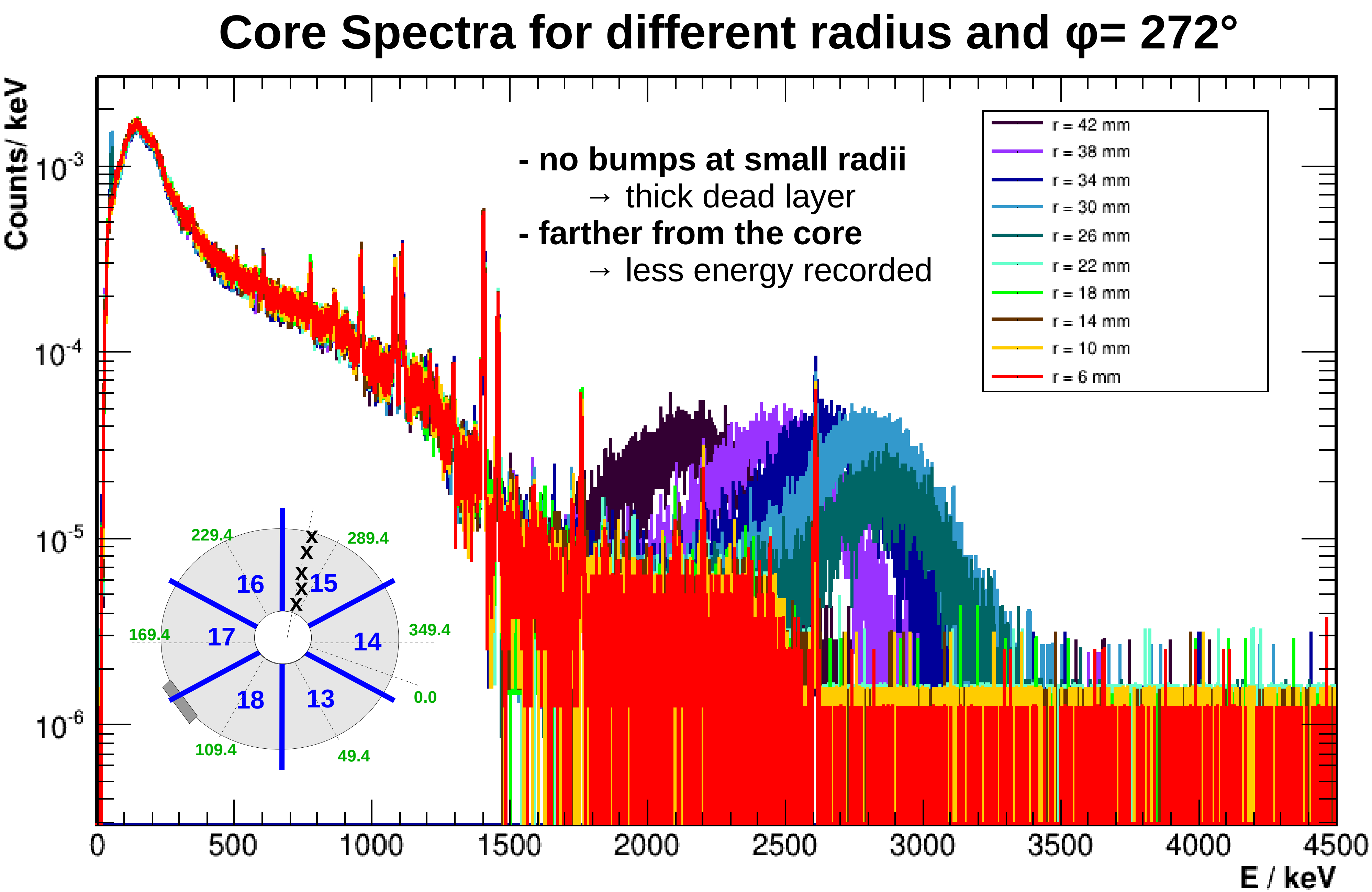
Alphas in the pulses



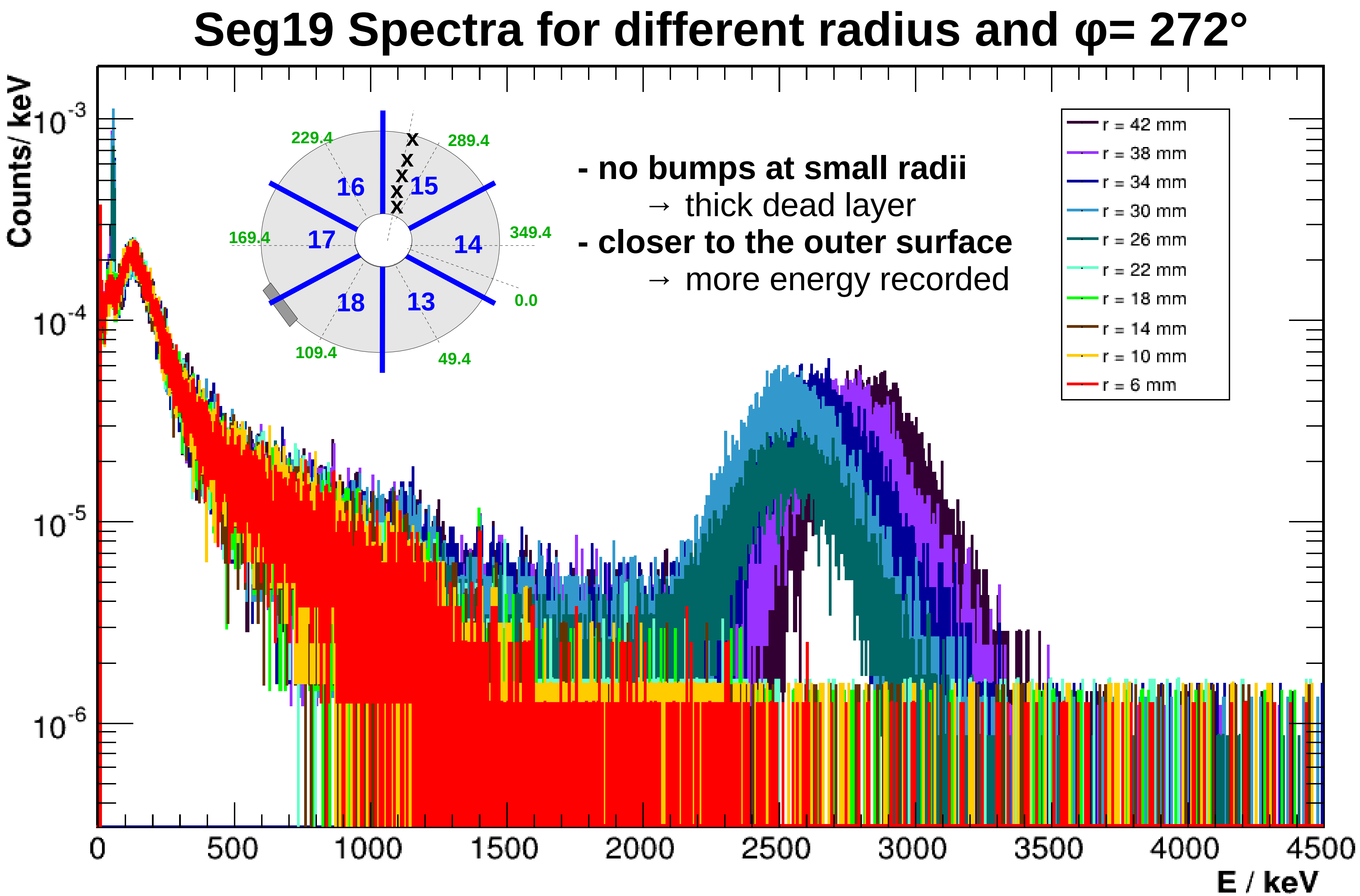
- long pulse in the 19th seg
- mirror pulses
- mirror pulses + charge trapping



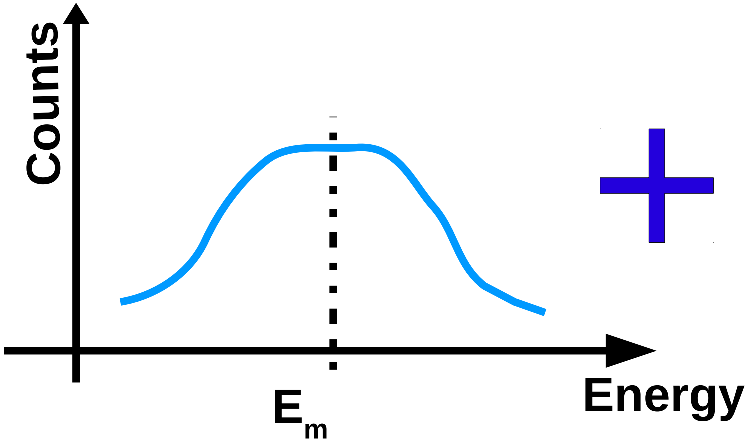
Scanning points along the radius: core comparison



Scanning point along the radius: Seg 19 comparison



From the energy spectra to the thickness value



$$E_\alpha - E_m = \frac{\partial E}{\partial x} \cdot d$$

?? µm

- E_α → initial energy of the alpha = **5.637 MeV**

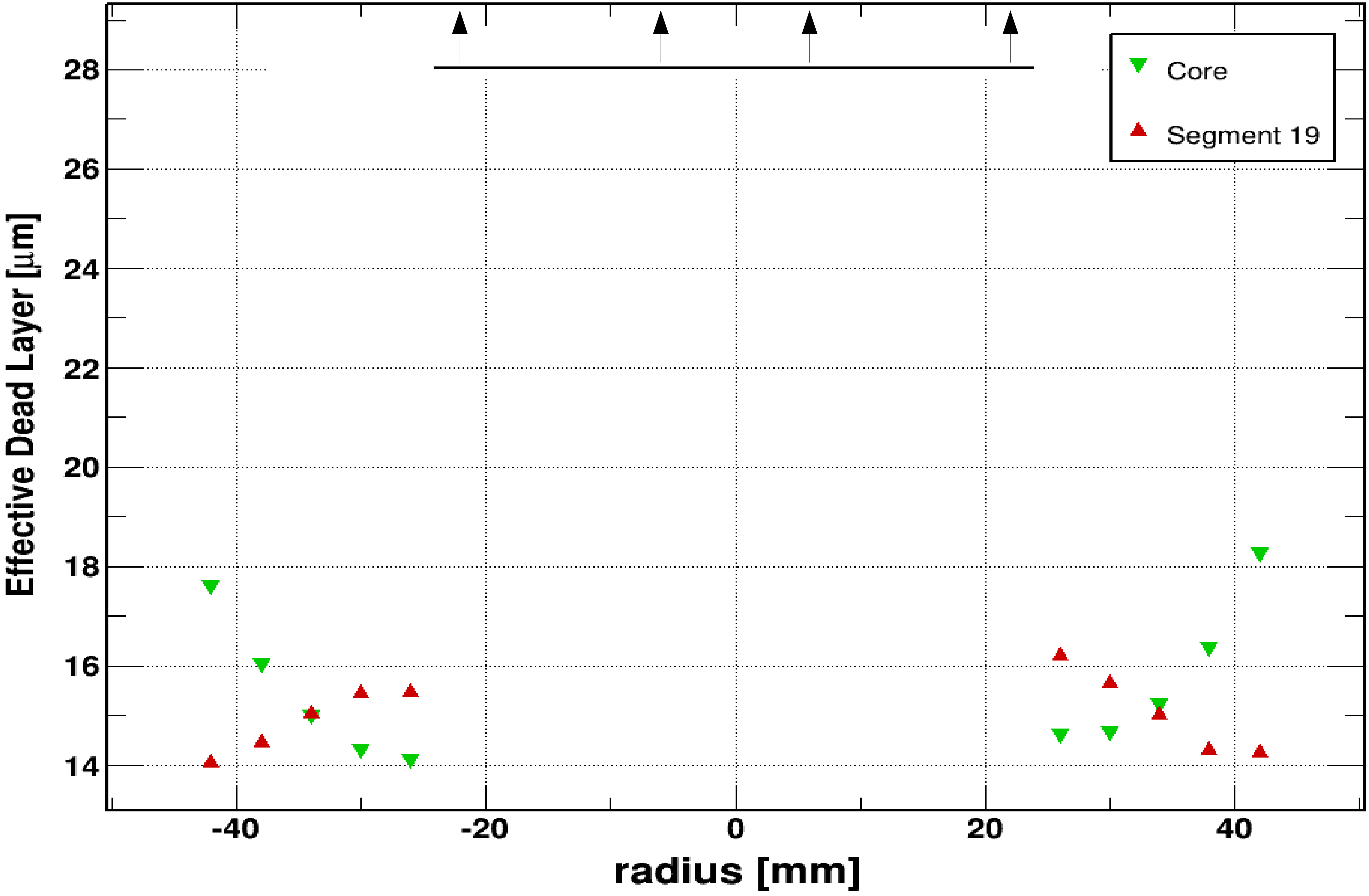
- E_m → measured energy of the alpha
  - fit the alpha bump with a gaussian
  - get the mean of the gaussian

- **dE/dx** → energy loss for unit of distance: = **0.2 MeV/µm**
  - by an alpha particle at 5.637 MeV
  - in Germanium

- **d** → length of the path done in a non sensitive volume
  => the **thickness of an effective dead layer**

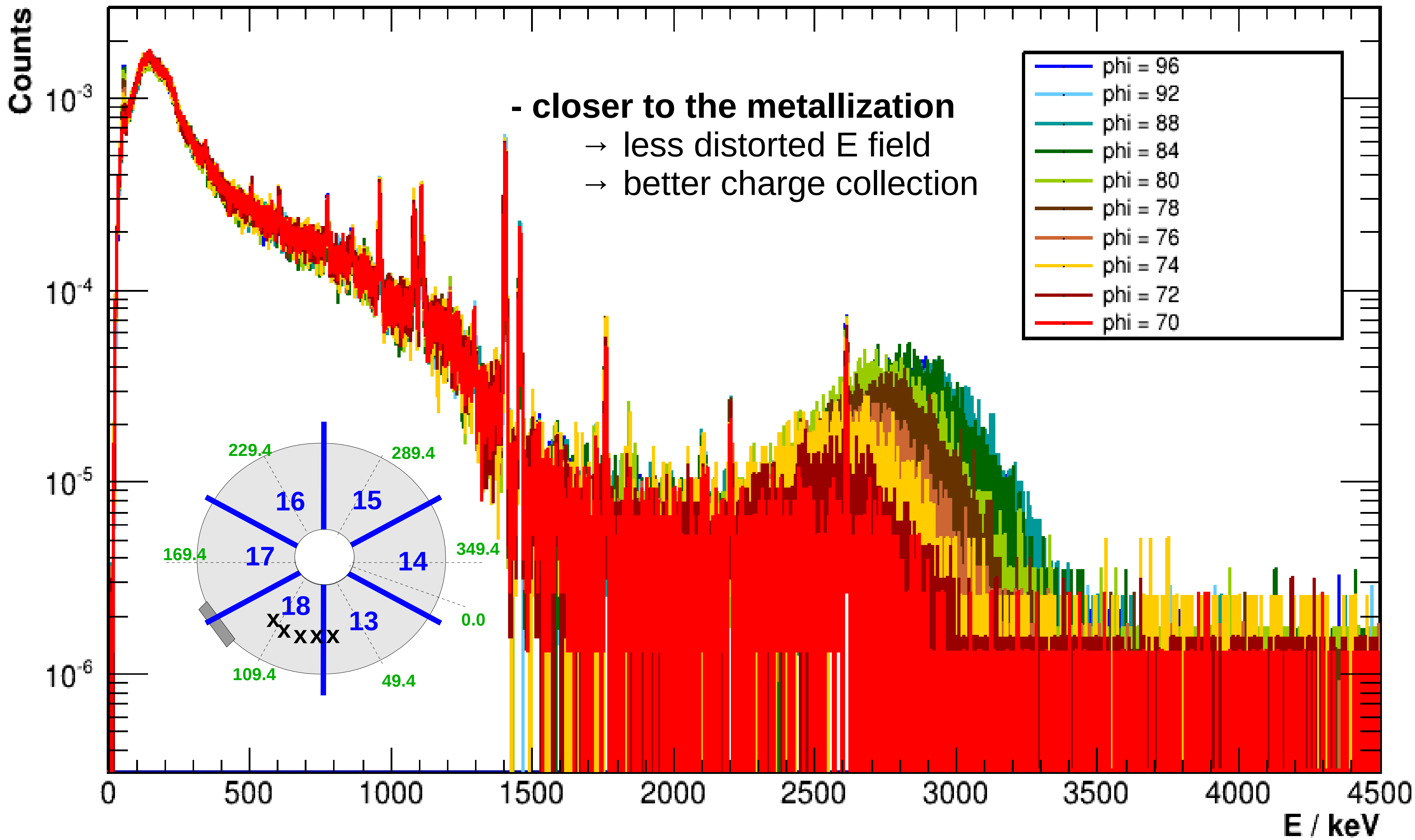
Thickness of the effective dead layer

Scanning along the radius



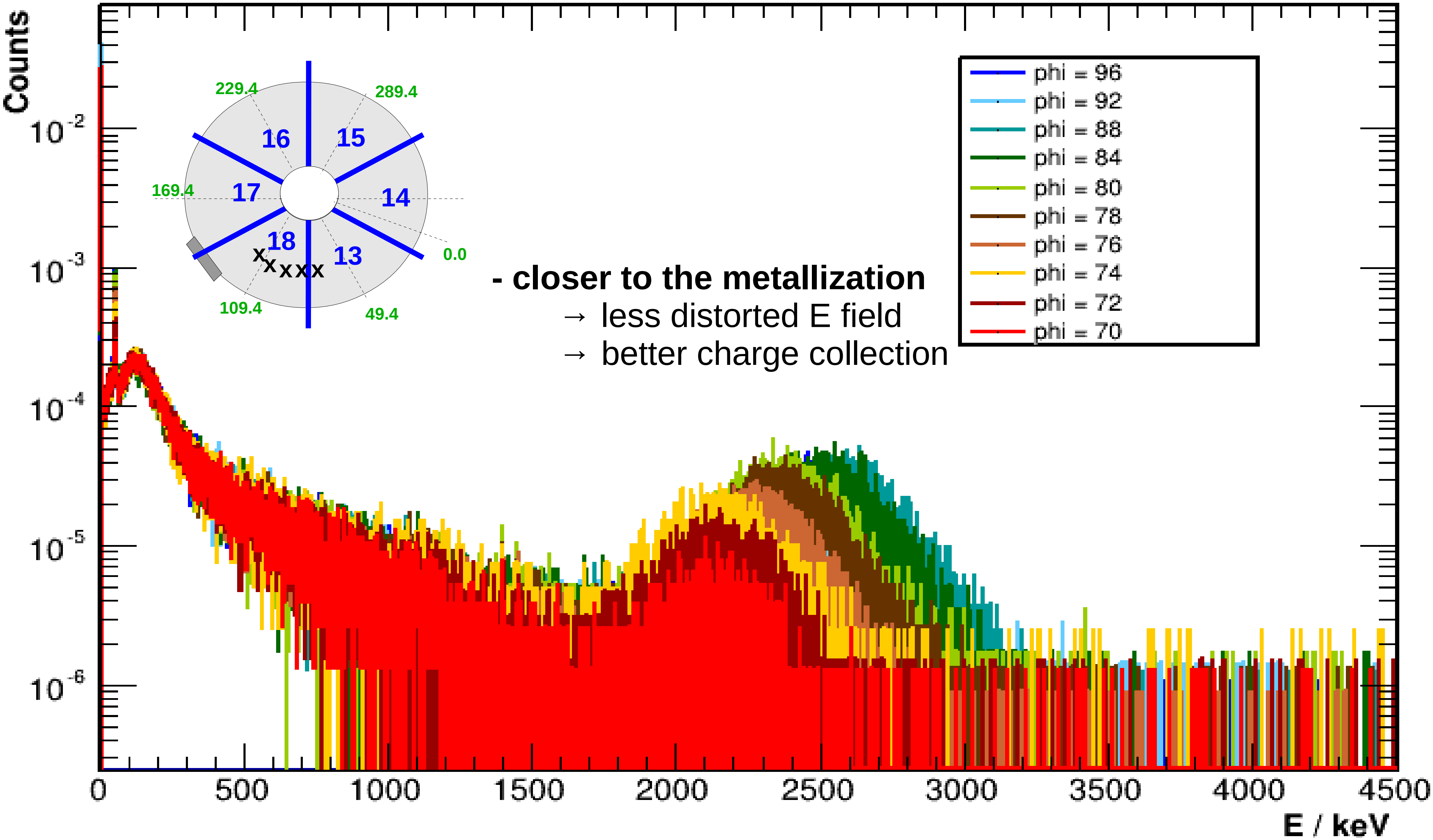
Scanning points along azimuthal angle: core comparison

Core Spectra for different azimuthal angle and r = 26 mm



Scanning points along the azimuthal angle: seg19 comparison

Seg19 Spectra for different azimuthal angle and r = 26 mm

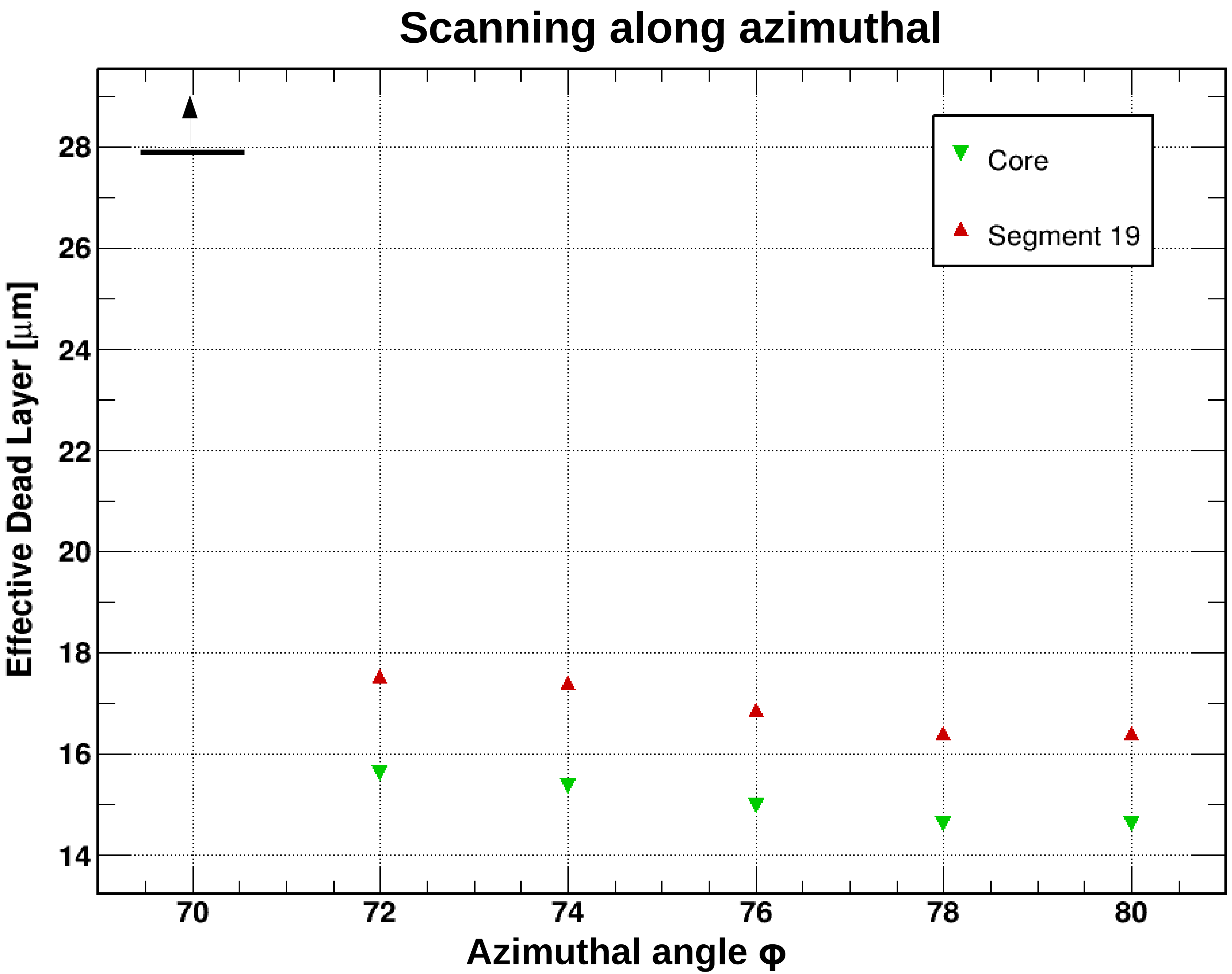


- closer to the metallization

→ less distorted E field

→ better charge collection

Estimated thickness of the effective dead layer:



R&D with Ge detectors (III): GALATEA test-stand from outside

Pressure controllers

Lake Shore controller

Motors controllers

High Voltage supplier

Pulser

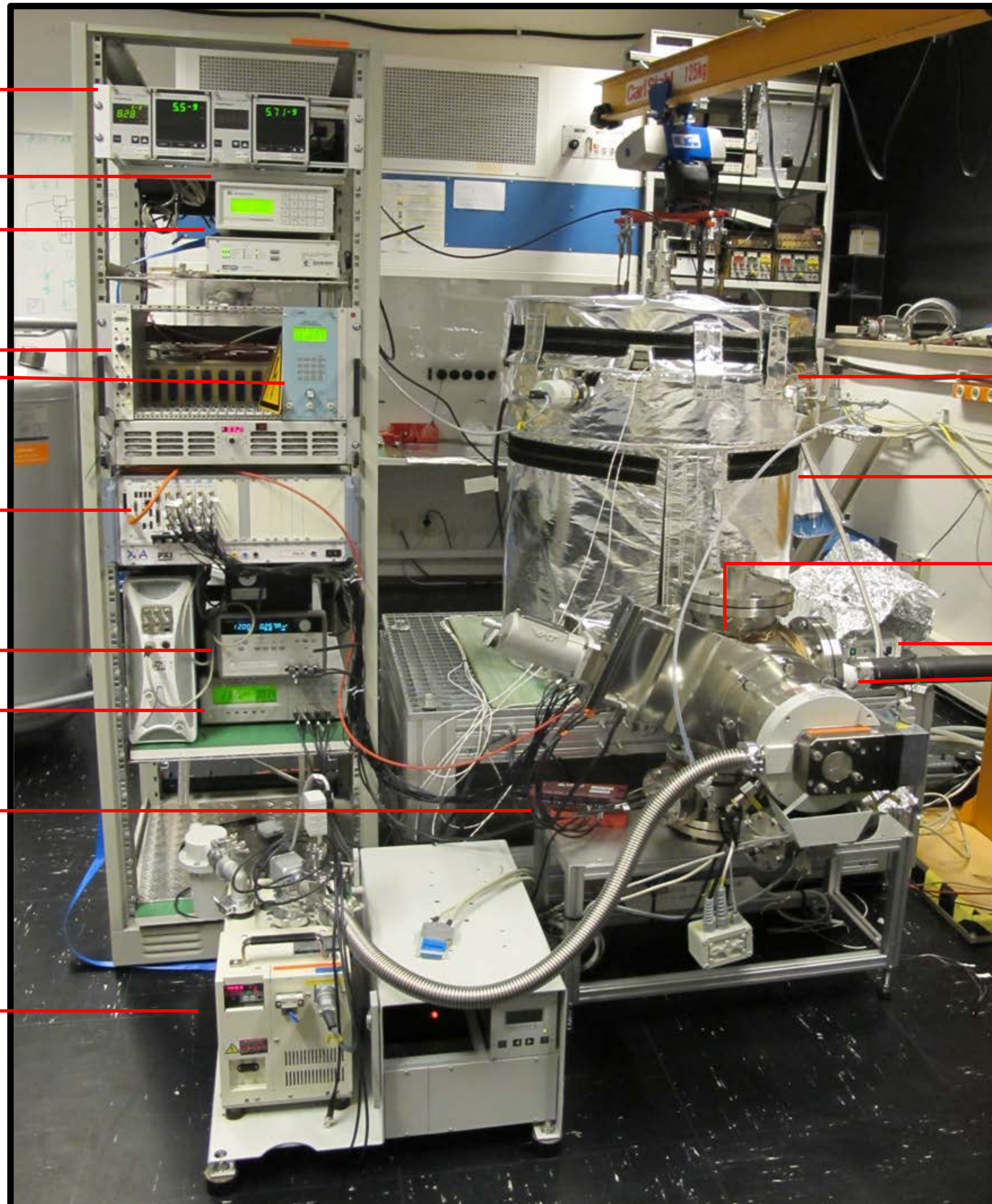
DAQ: Pixie modules from XIA

Low Voltage supplier

LCR meter

LabJack voltmeter

Pump



Heating Jacket

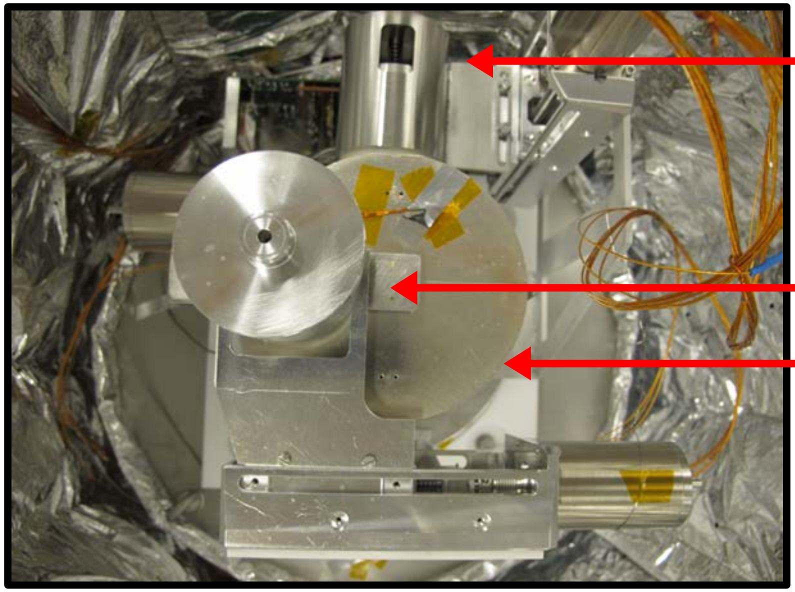
Tank

Shutter

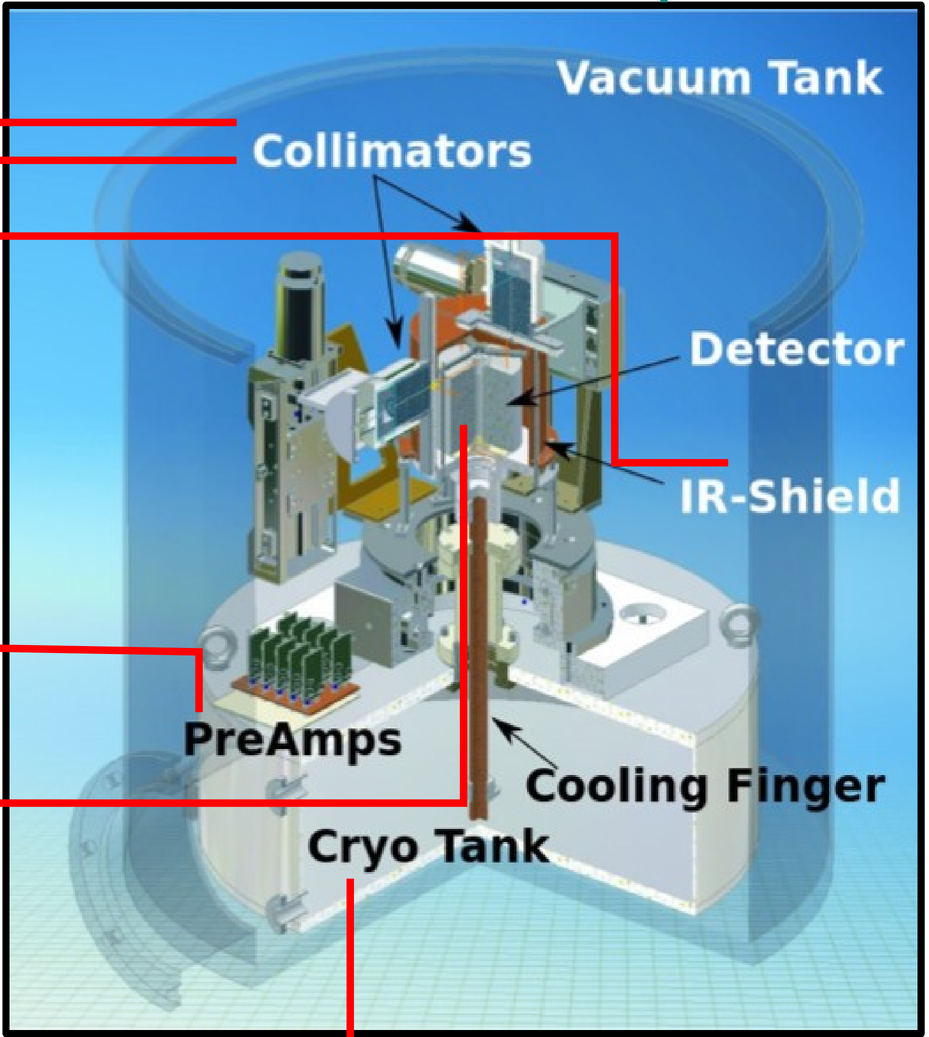
LN2 controller

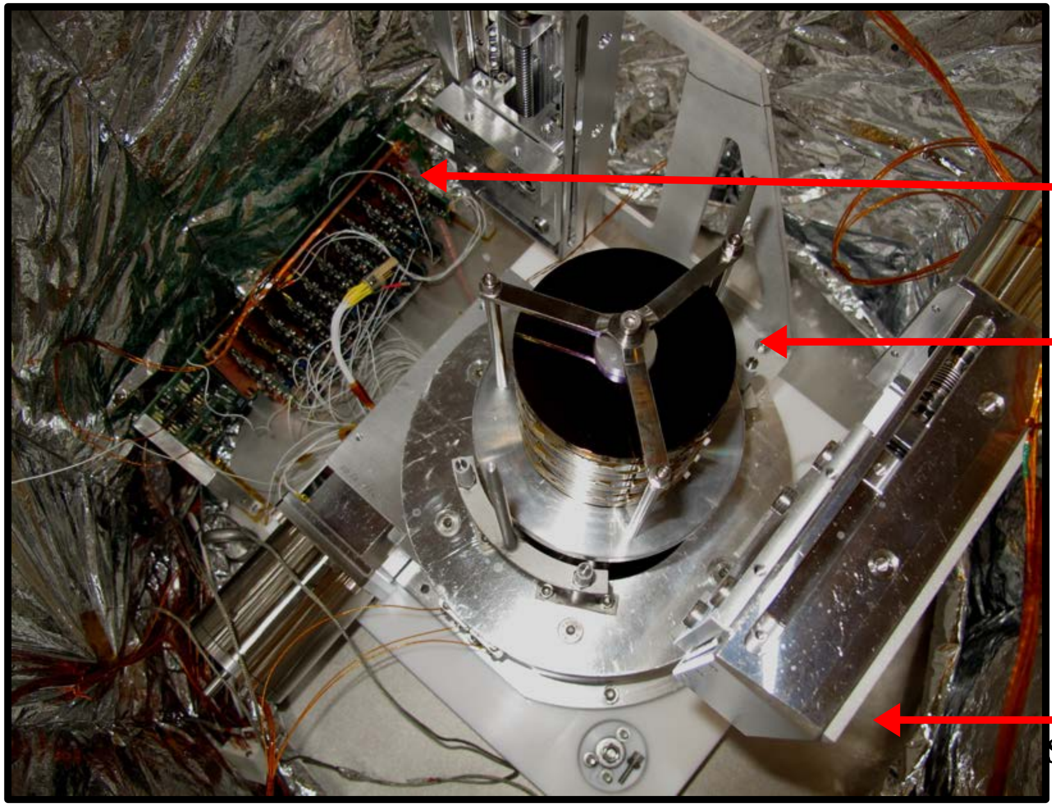
LN2 Inlet-Outlet

GALATEA: from the inside



GALATEA I: to be updated!





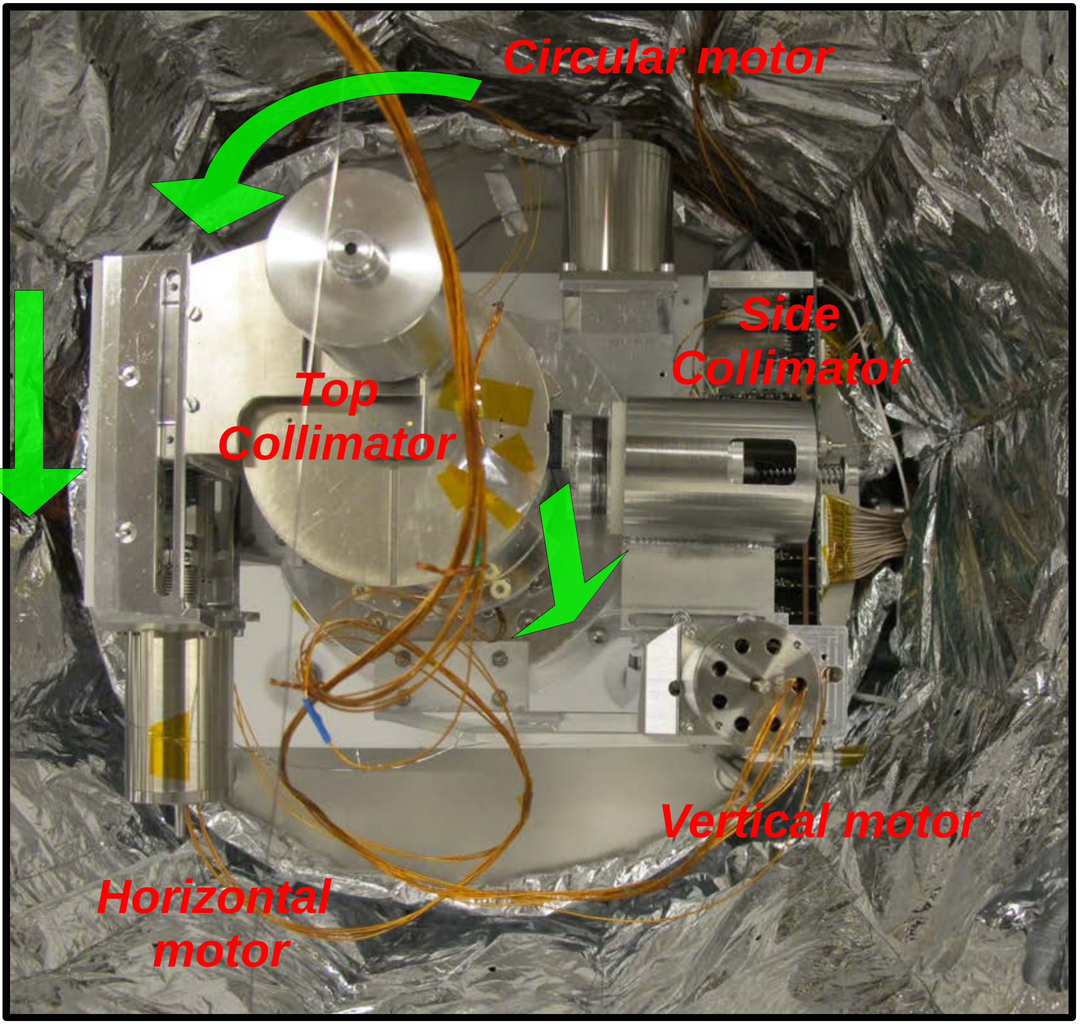
Something has to move

→ **WHY?**

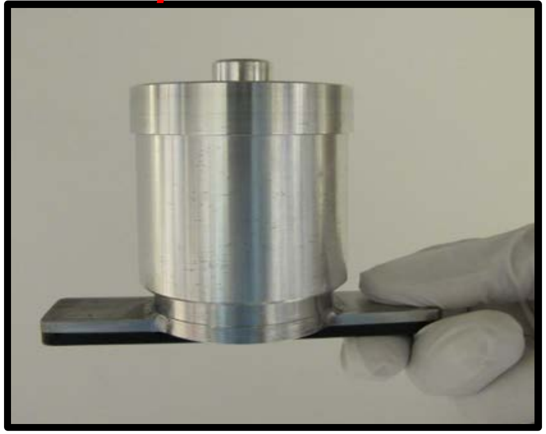
- perform a **3D scan of the detector**
  - multiple sources

→ **HOW?**

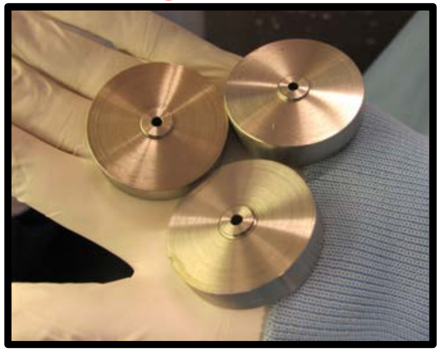
- **3 UHV compatible motors**
  - vertical
  - horizontal
  - circular
- **2 collimators**
  - SIDE: solidal with VM
  - TOP: solidal with HM



Top Collimator

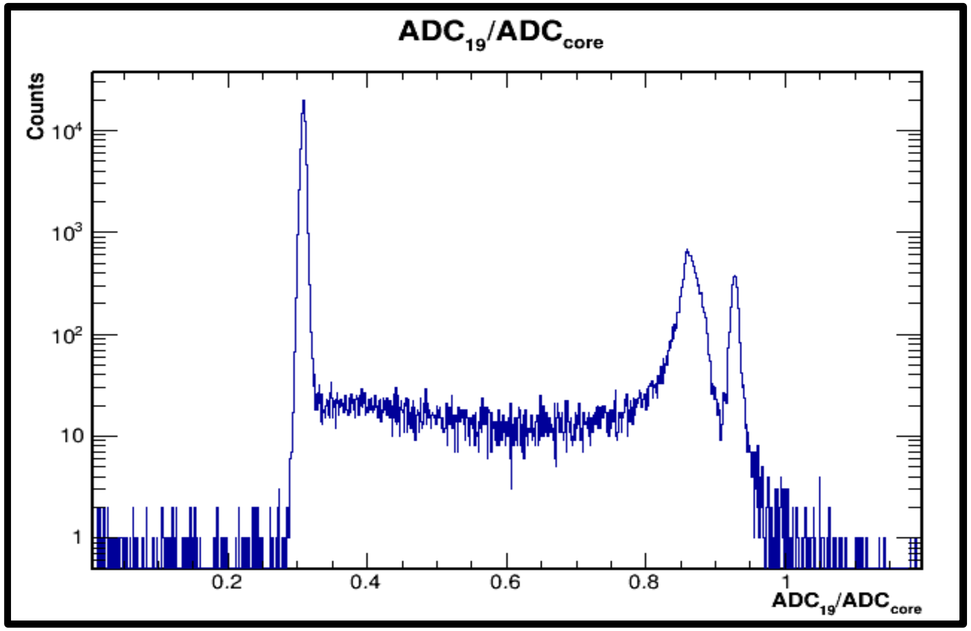


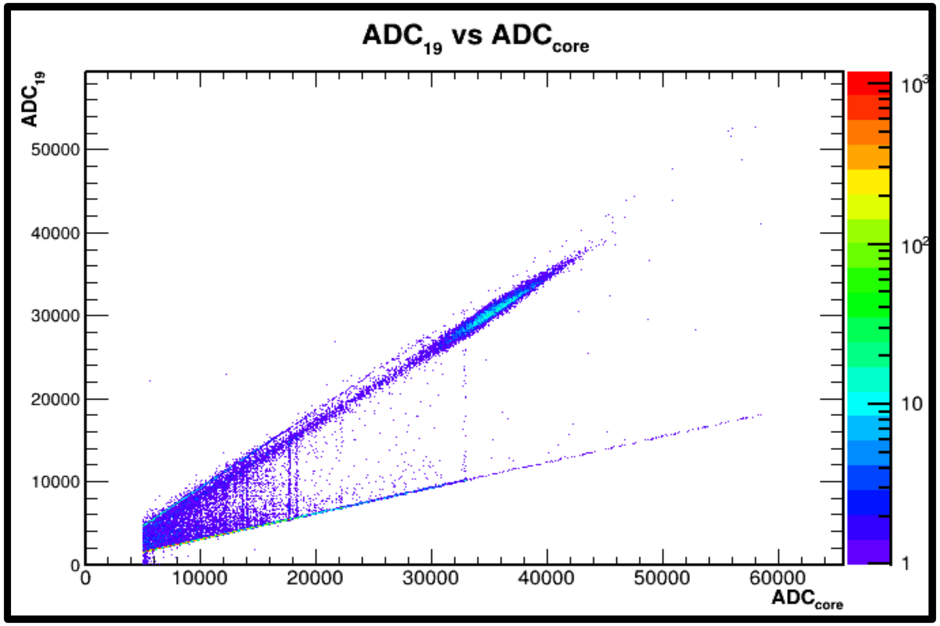
Tungsten segments



Calibration: need a strategy

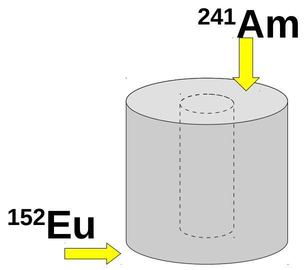
From a top surface scanning point:





USING a source data set:

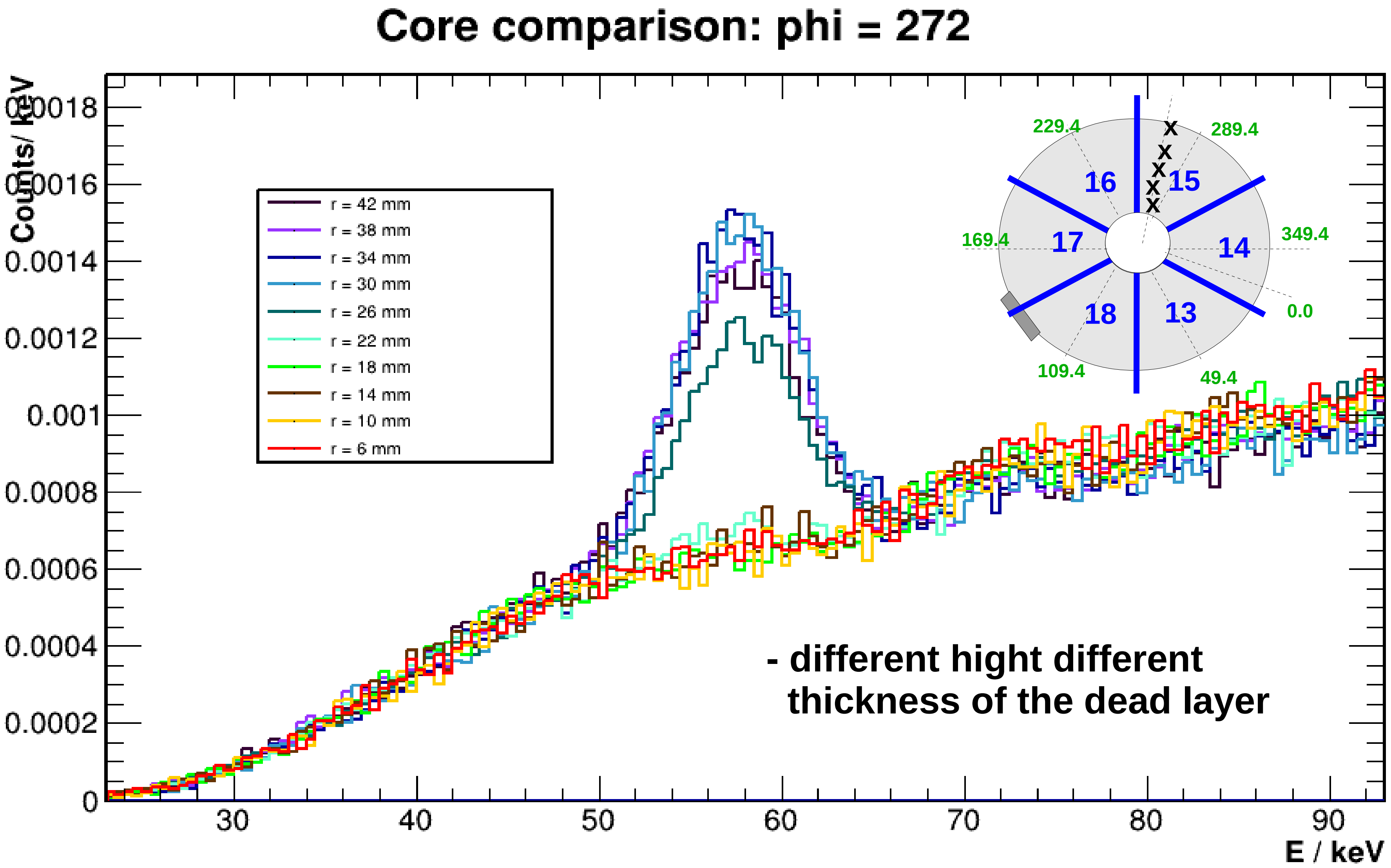
- clear **structure** due to alphas
  - ratio plot
  - correlation plot
- **difficult to avoid the misidentification**
- **not only in the 19th segment**
  - also in the segments underneath (→ mirror pulse)
- possible way to get rid of the alphas:
  - scan on the energy of the alphas
- **still MISSING the automation**



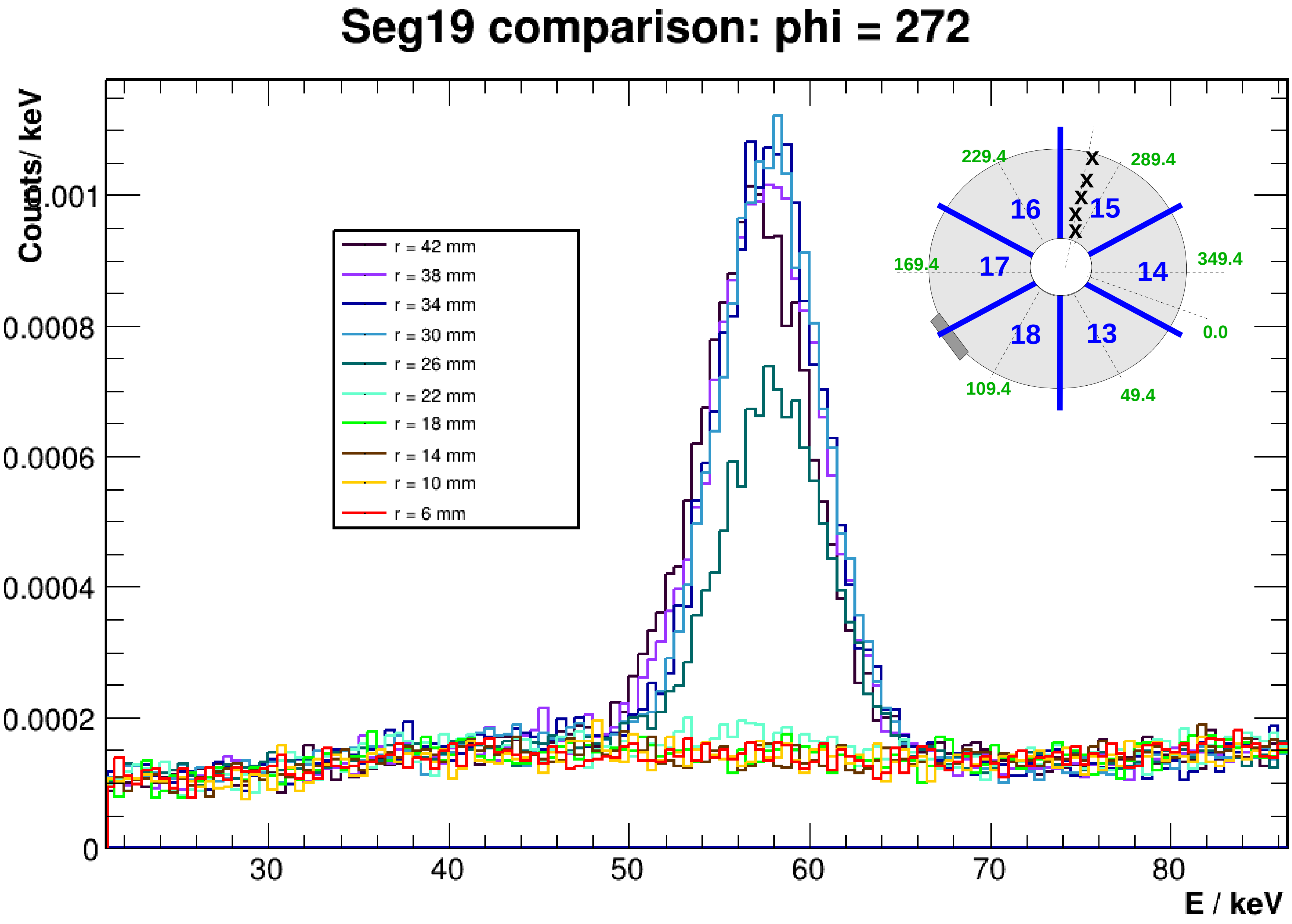
Data Analysis: alphas in the pulses

Zoom on the low energies:

- 59 keV gamma from the ^{241}Am
- 57 keV kα from ^{74}W



Data Analysis: alphas in the pulses



Data Analysis: scanning points along the radius

Zoom on the low energies:

- 59 keV gamma from the ^{241}Am
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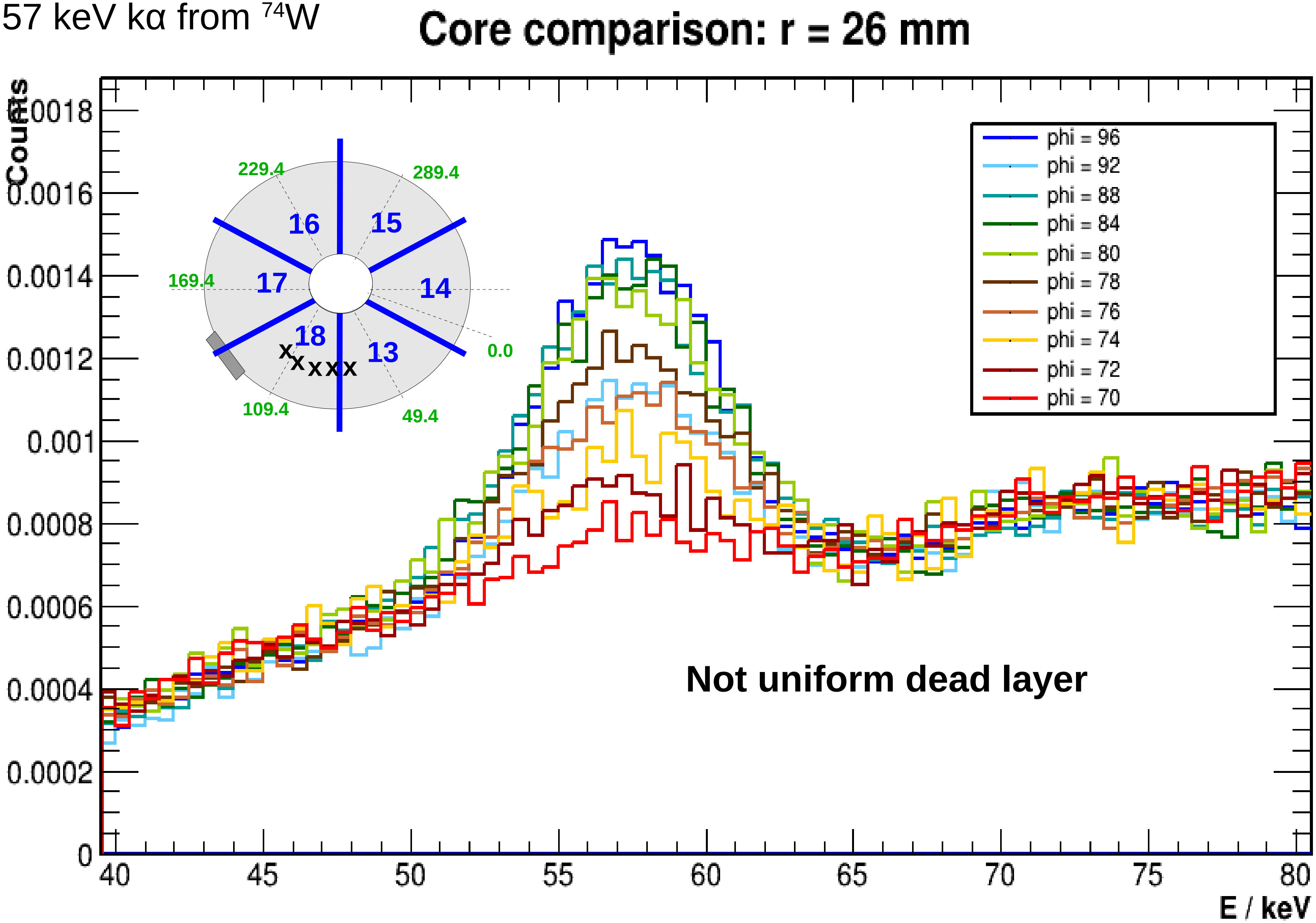

Data Analysis: scanning points along the radius