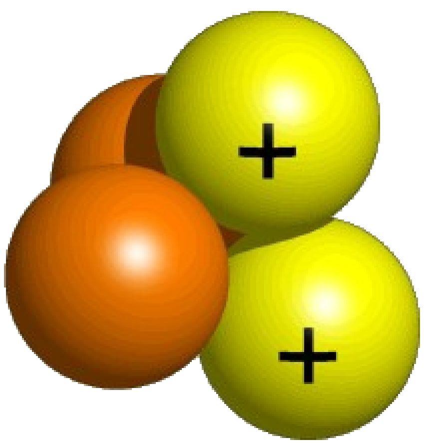
Young Scientist Workshop
July 2014, Ringberg

Alpha interactions in high purity germanium detectors



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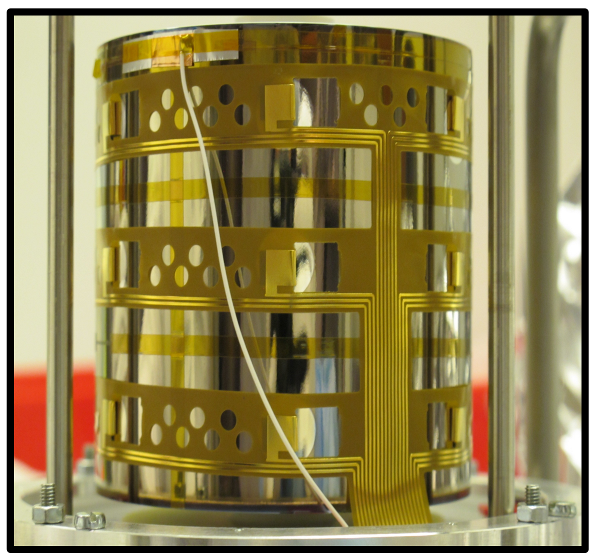

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Lucia Garbini - GeDet group

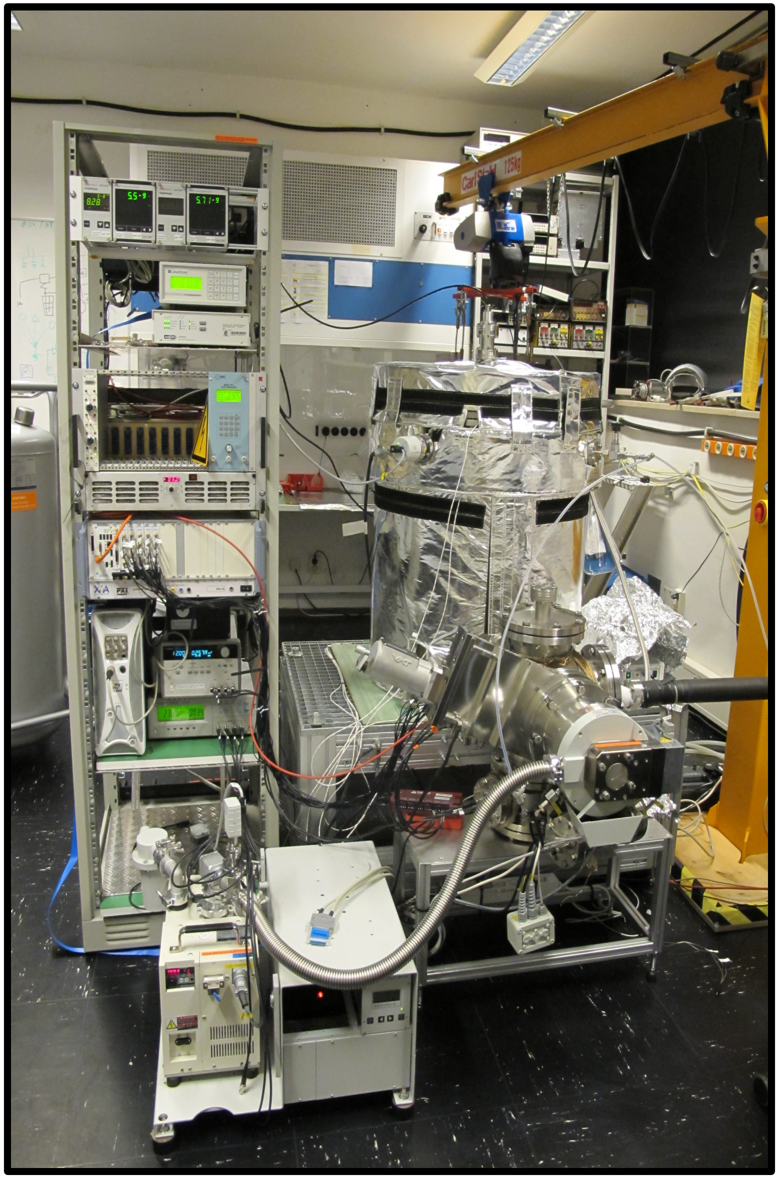
Outline

- 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
- effective dead layer thickness

- Summary and Outlook



Physics goal and motivations

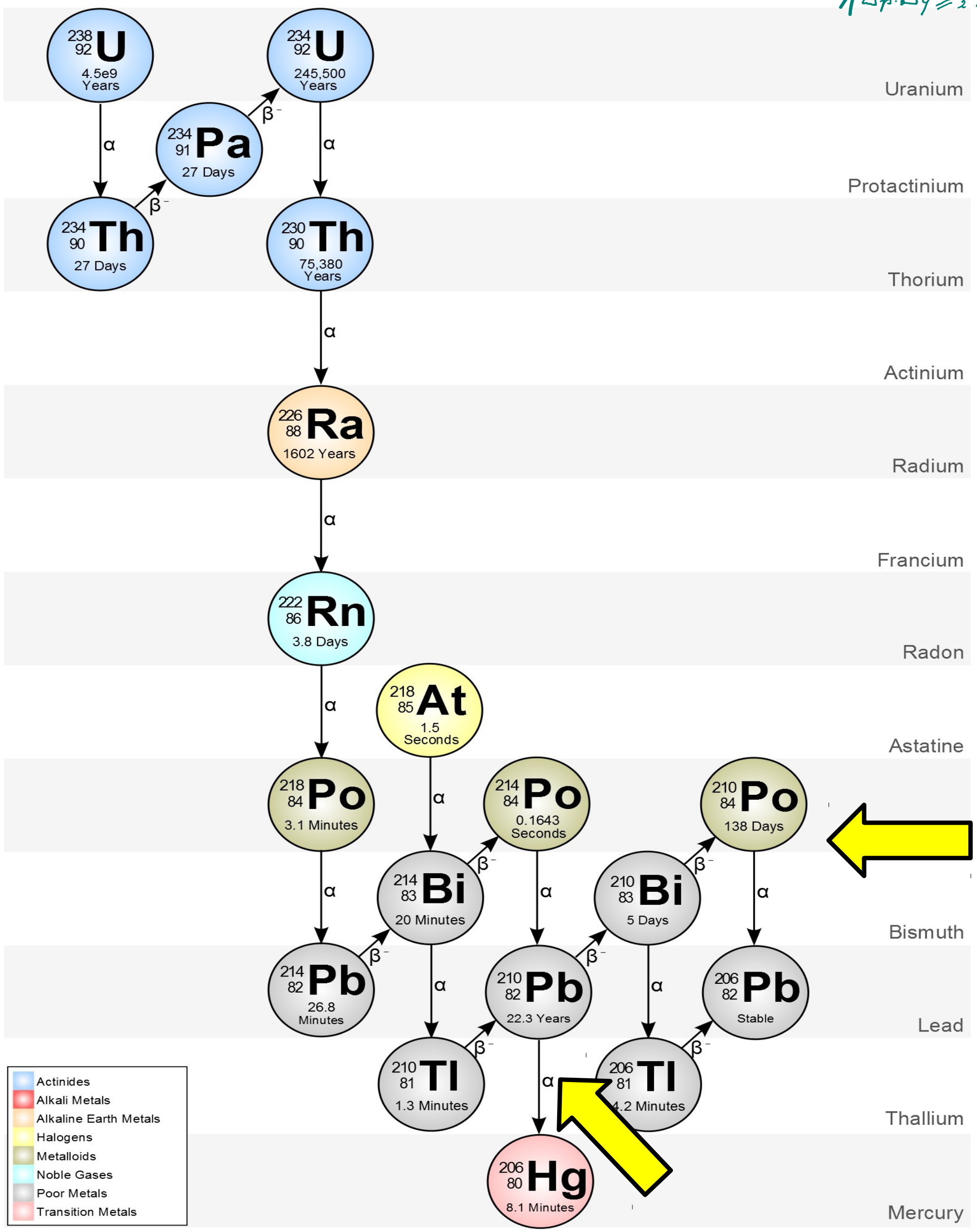
GOAL:

characterization of
detector response
for **alphas signal**

MOTIVATION:

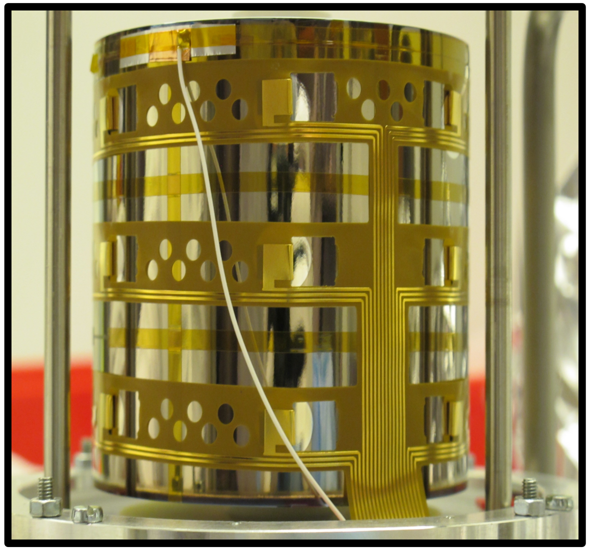
Alpha Background:
- Lead contamination on surfaces
- serious and often limiting
- 0νββ, Dark Matter searches

Study alpha events in a controlled environment
- charge trapping
- detector's dead layer



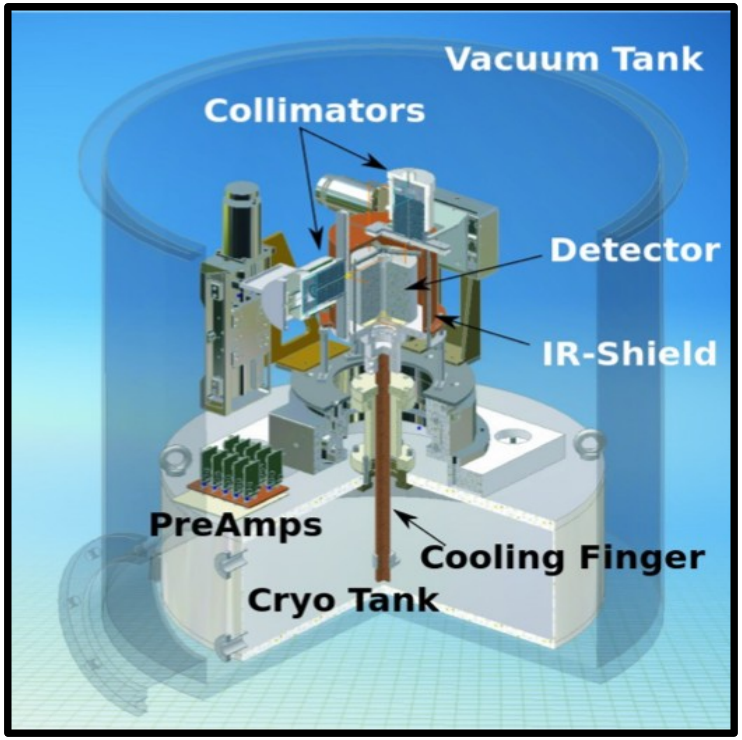
Experimental set-up

Shooting alpha particles on detector prototypes inside a test facility



SuperSiegfried:

- true coaxial n type HPGe detector
- 18 segments: 6 in φ, 3 in z
- 19th segment unsegmented in φ

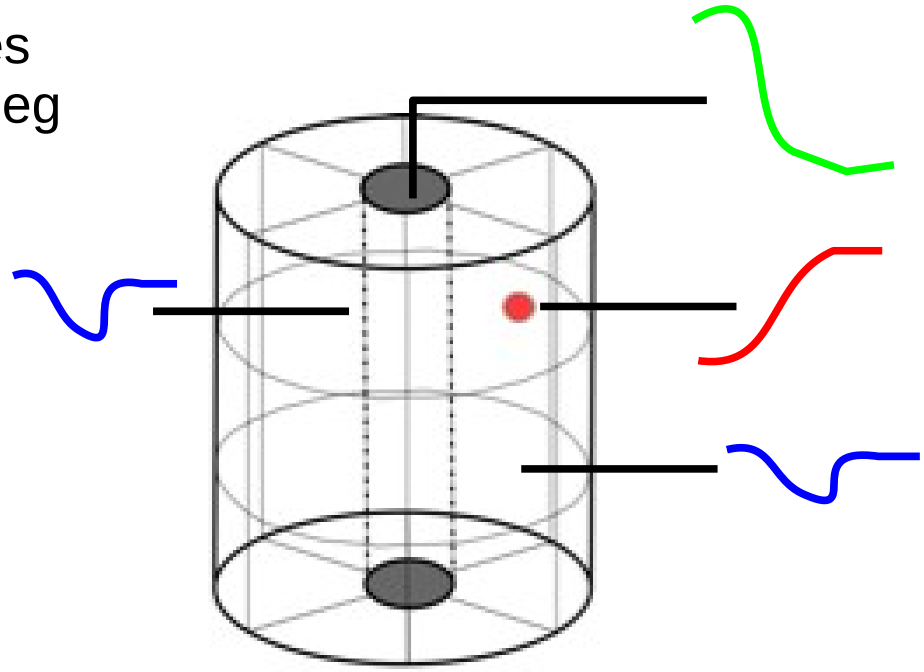


GALATEA:

- vacuum chamber
  - low penetrating sources
- cryo tank to cool down the detector
- 3 motors to move 2 collimators in 3D
  - alpha source placed in the top one
- electronics inside

Signal creation:

- **radiation interacts with Ge: e-h pairs created**
  - **electrons** go to the core electrode
  - **holes** go to the segment electrodes
  - charges induced in neighbouring seg
    - → possible **mirror pulses**



- **2 possible scenarios:**
  - single segment event (**SIGNAL**)
  - multi segment event (**BKG**)

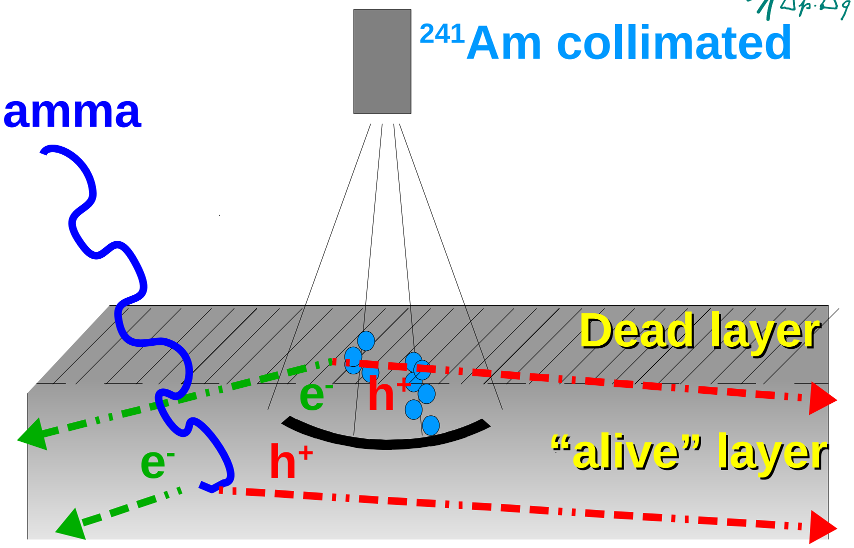
What do we obtain:

- **pulses** in all channel
  - pulse shape analysis
- **energy spectra** from all channels
  - spectroscopy

Alphas in Germanium Detectors

Alphas = heavy charged particles

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

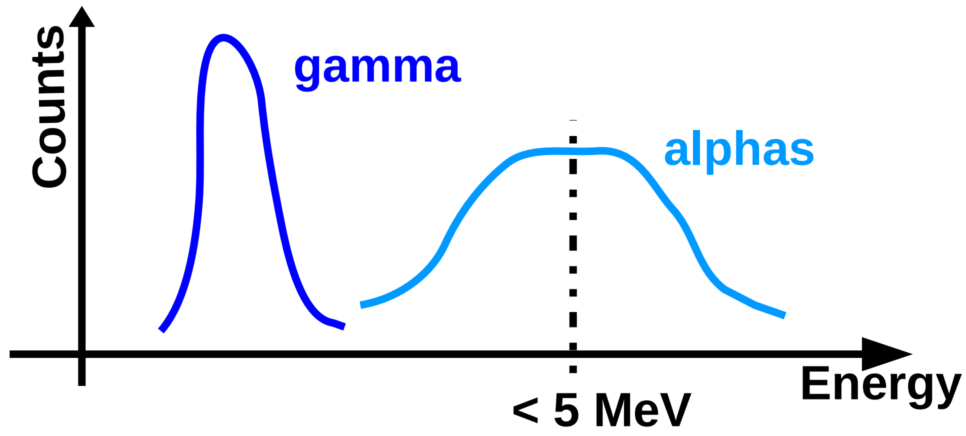


- **alphas from the ^{241}Am**
  - all with the same Energy ~ 5.6 MeV
  - all the same penetration depth

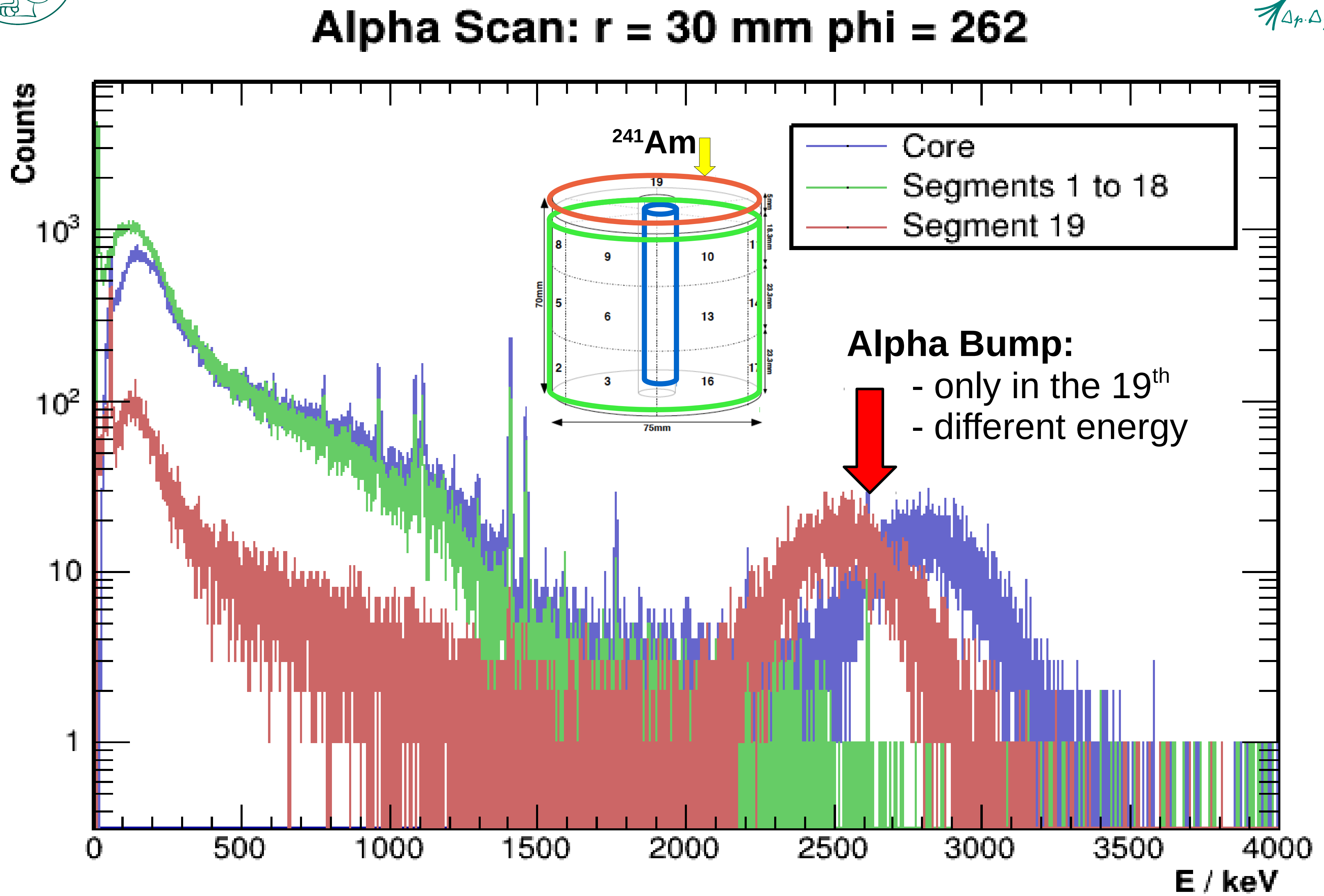
The final result depends on the combination of:

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

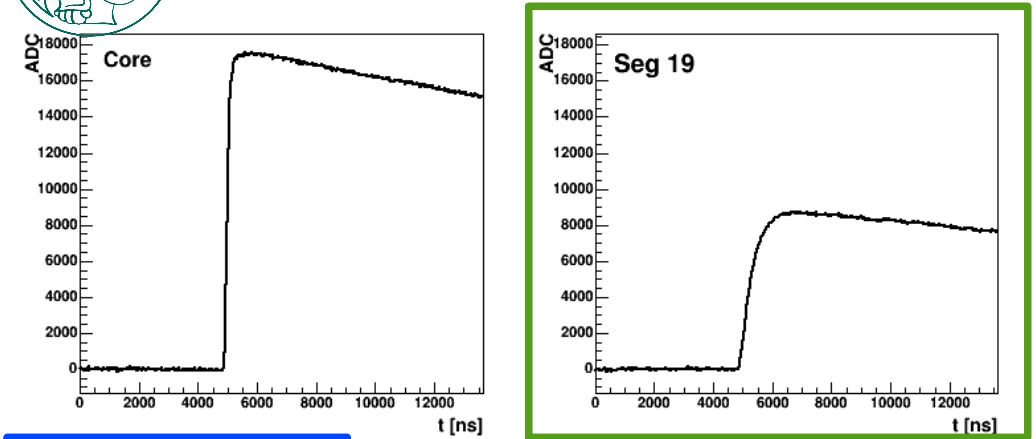
2) stochastic effect *(main one)*
- charge trapping



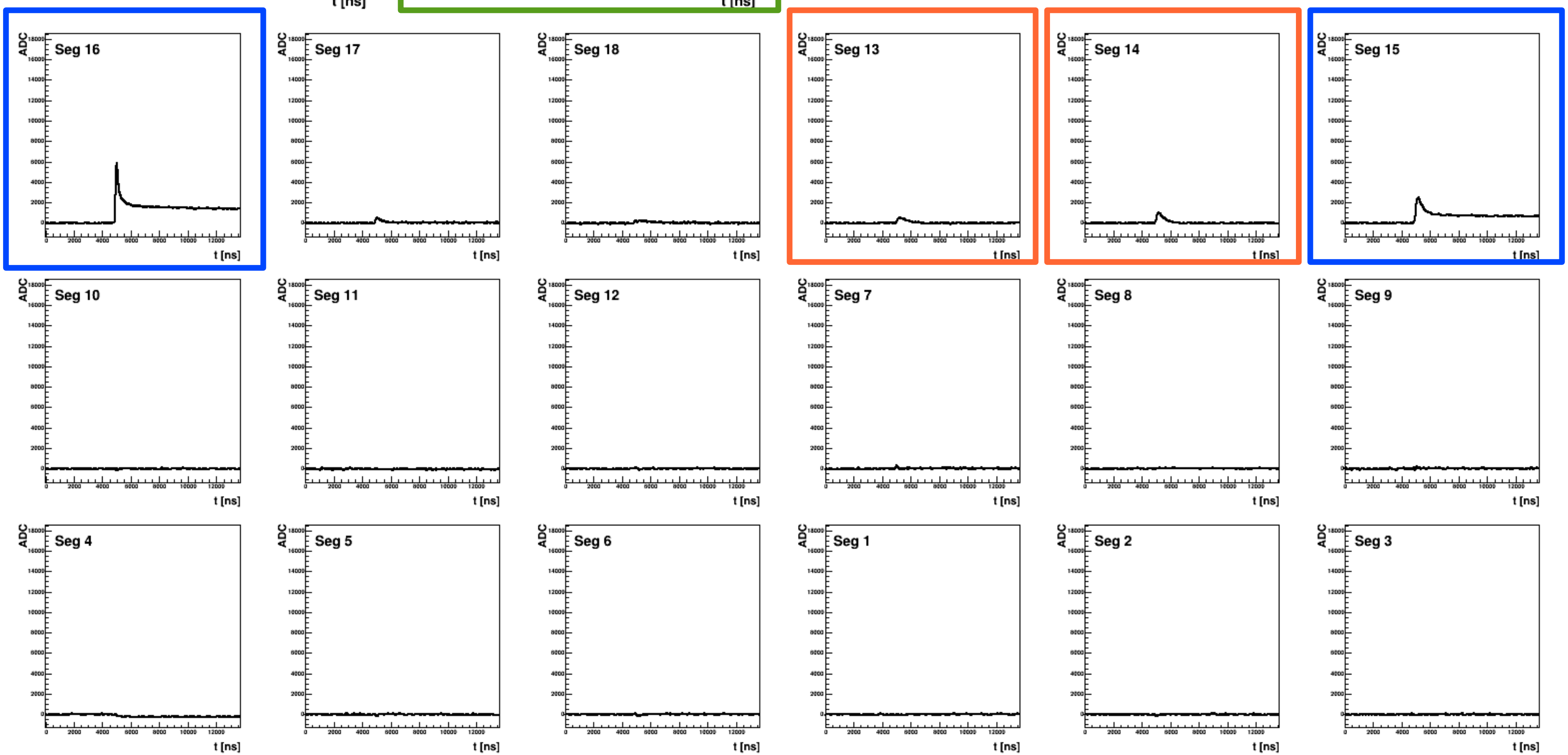
Alphas in energy spectra



Alphas in the pulses



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



Top Surface scanning

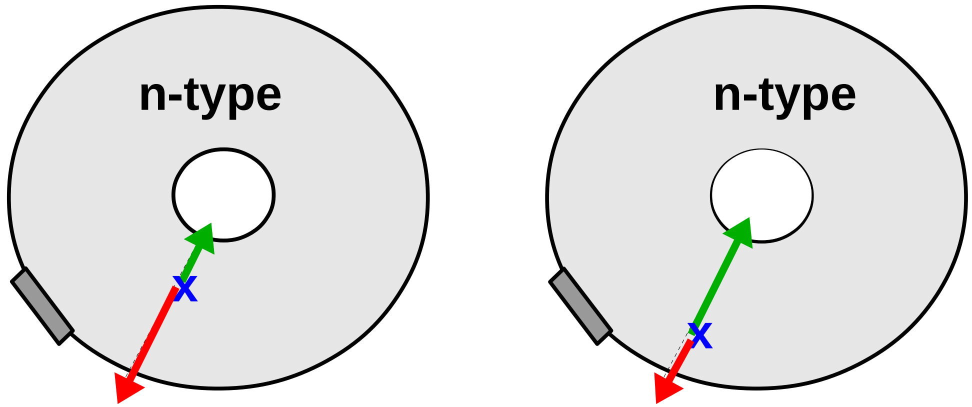
Scanning along the radius:

- 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



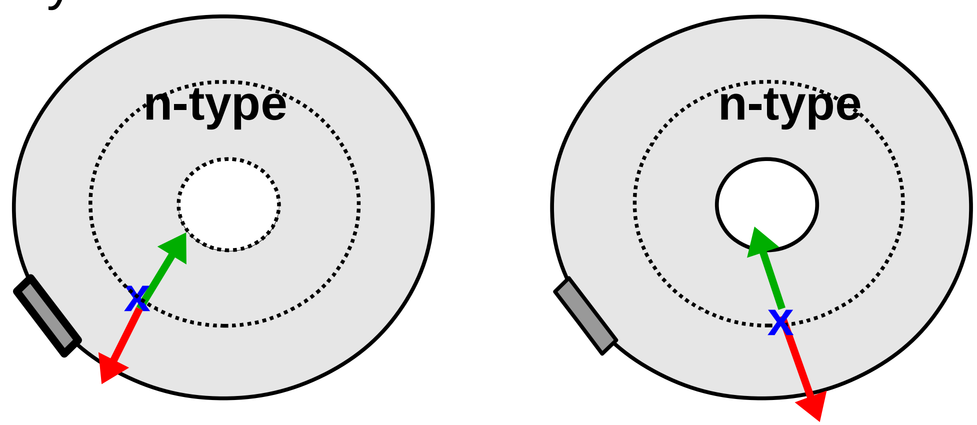
Scanning along the azimuthal angle:

- 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

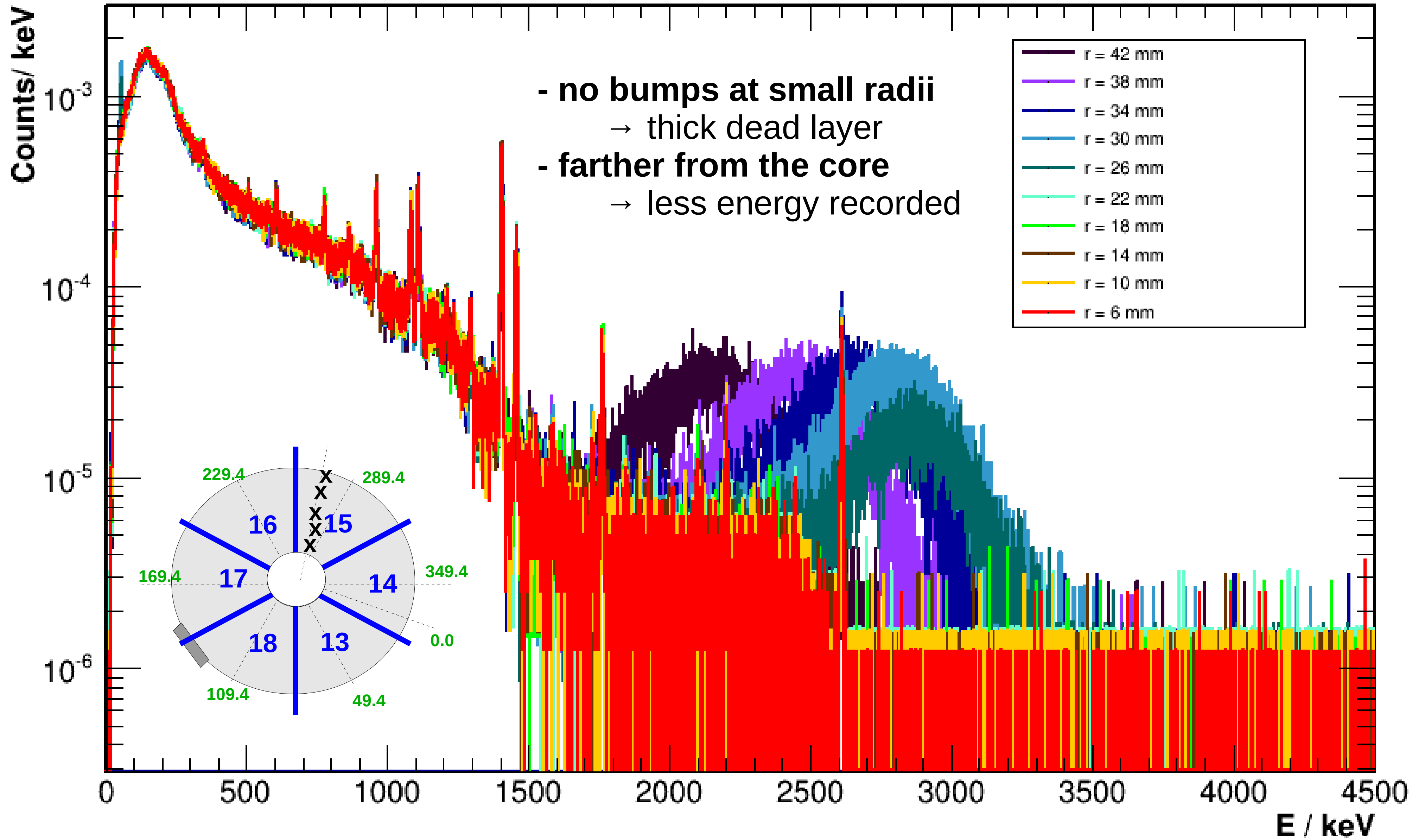
→ electrons

→ holes



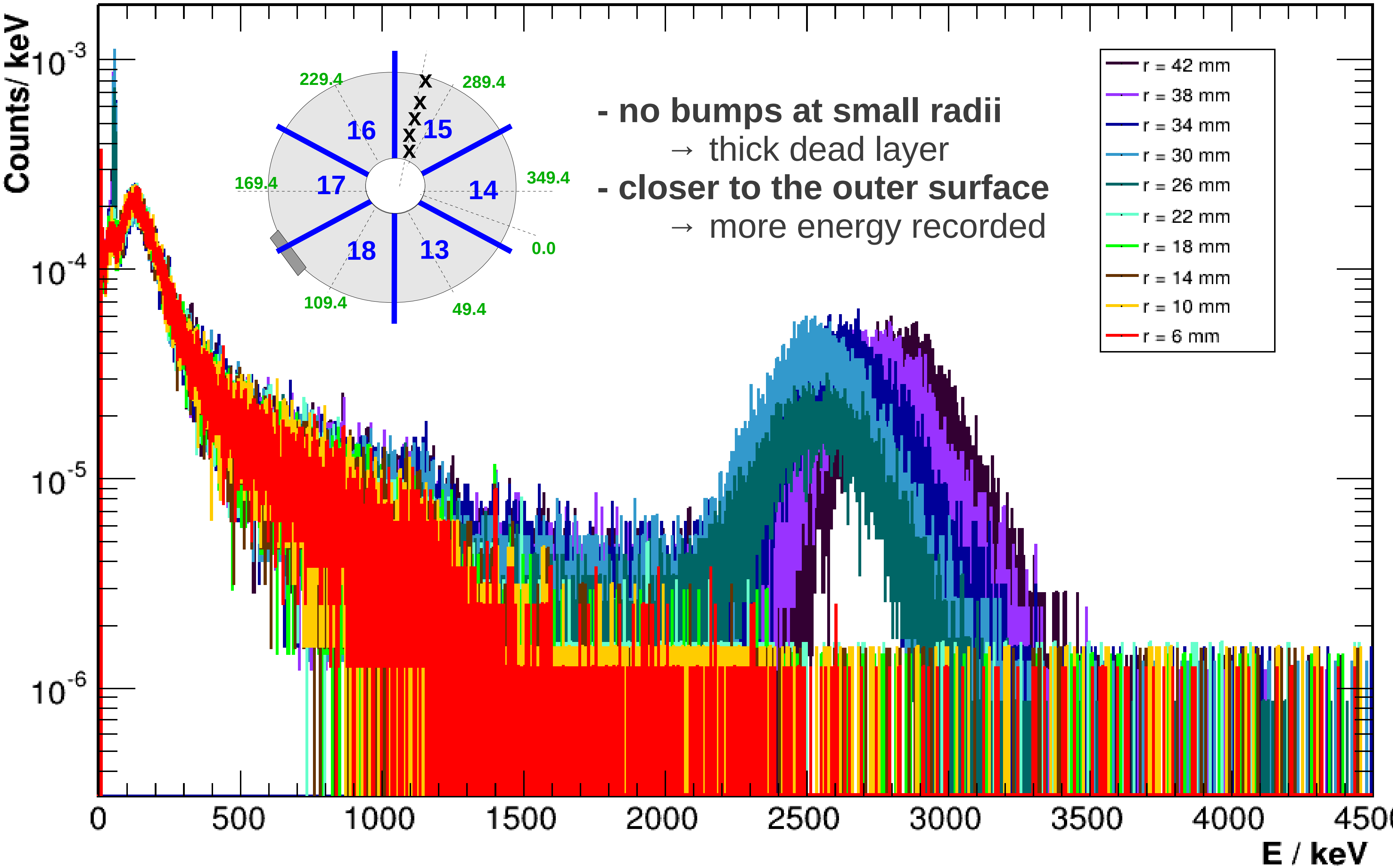
Scanning points along the radius

Core Spectra for different radius and φ= 272°

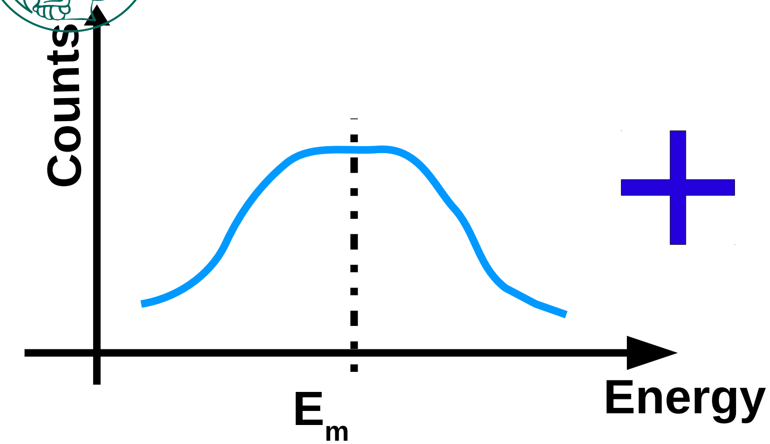


Scanning points along the radius

Seg19 Spectra for different radius and φ= 272°



Thickness of the effective dead layer



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

?? µm

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

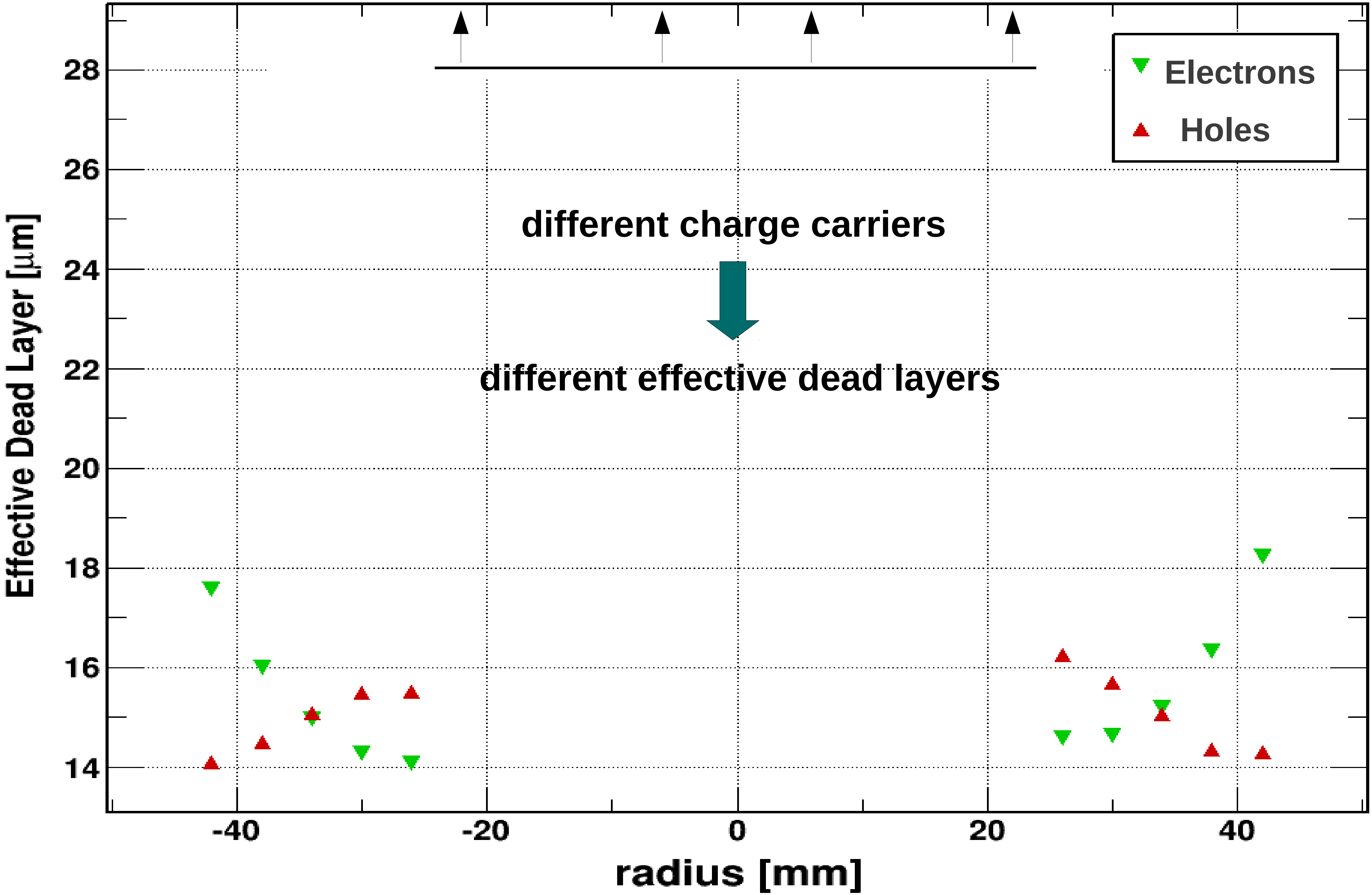
- E_m → measured energy of the alpha
  - fit the alpha bump with a gaussian
  - get the mean of the gaussian

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

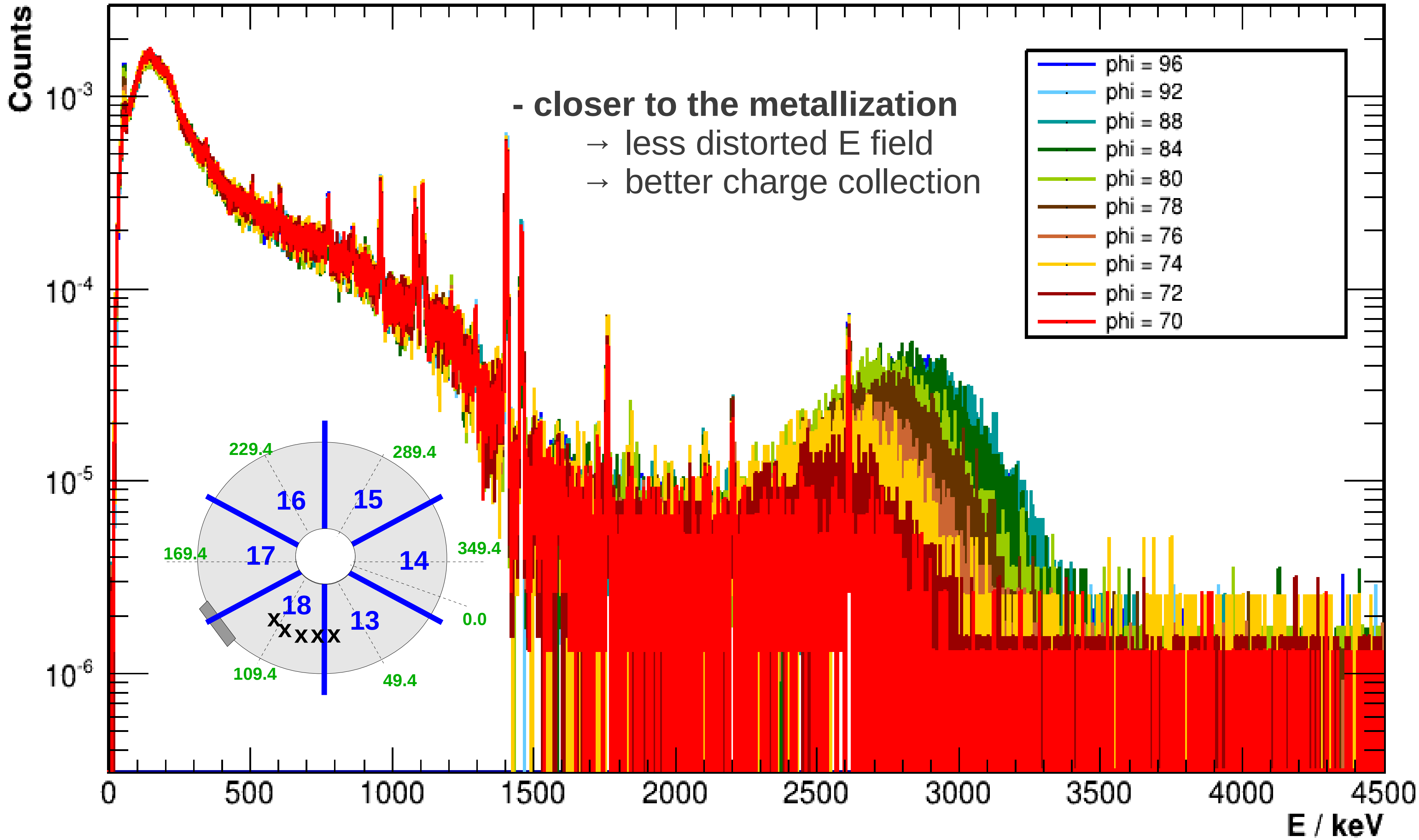
- **d** → length of the path done in a non sensitive volume
  => the **thickness of an effective dead layer**

Thickness result

Scanning along the radius

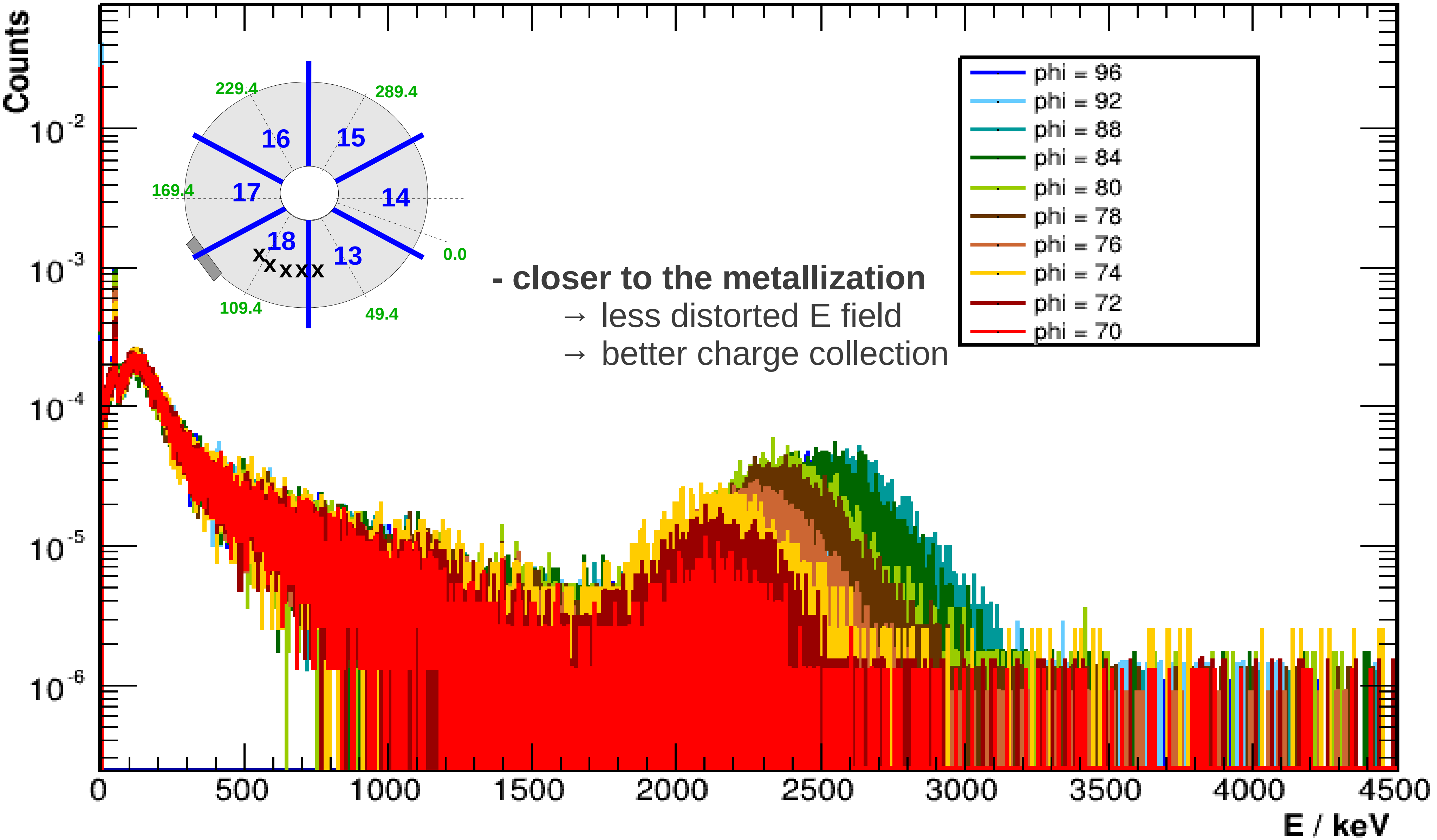


Core Spectra for different azimuthal angle and r = 26 mm



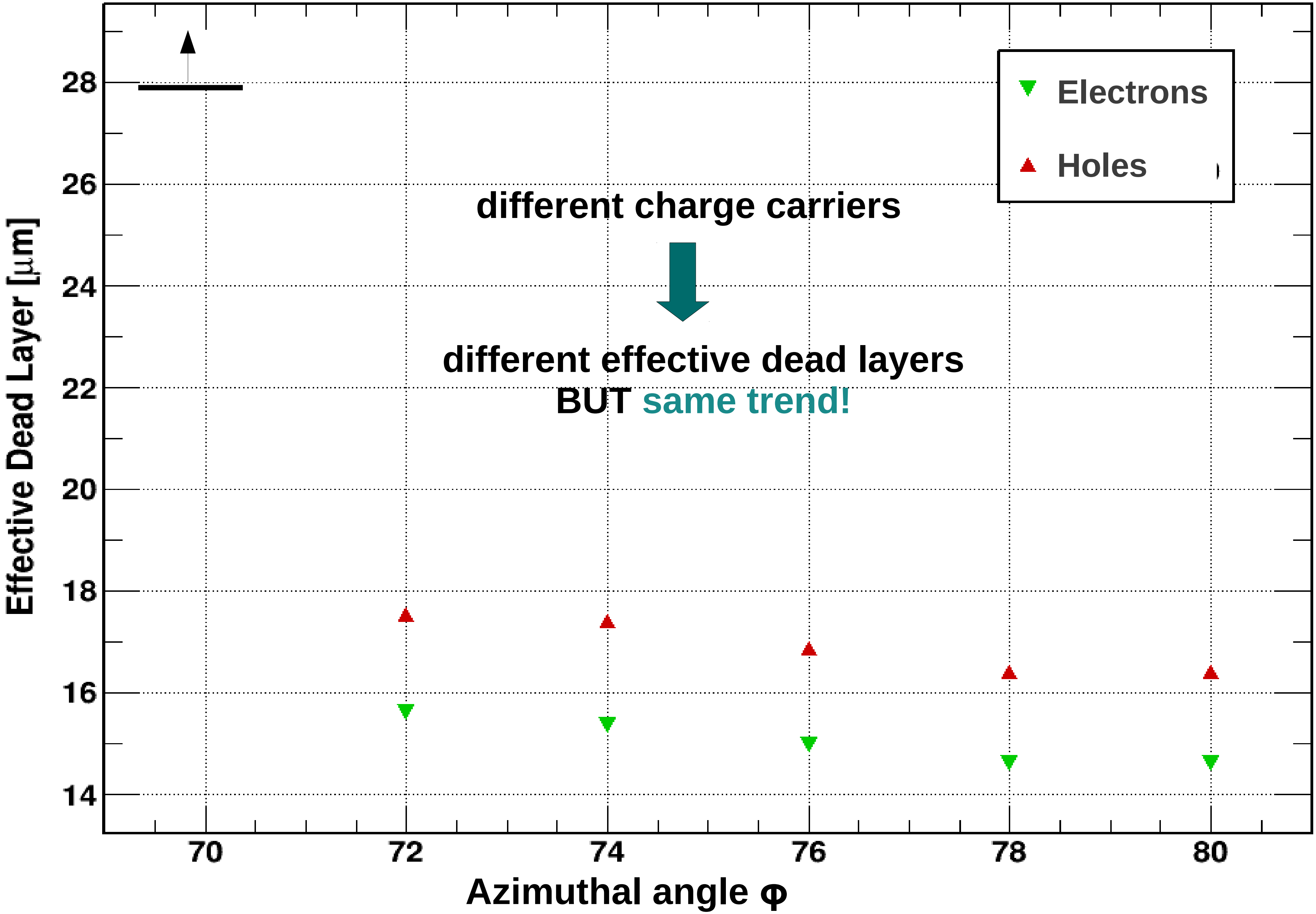
Scanning points along the radius

Seg19 Spectra for different azimuthal angle and r = 26 mm



Thickness result

Scanning along azimuthal



Summary and outlook

Conclusions:

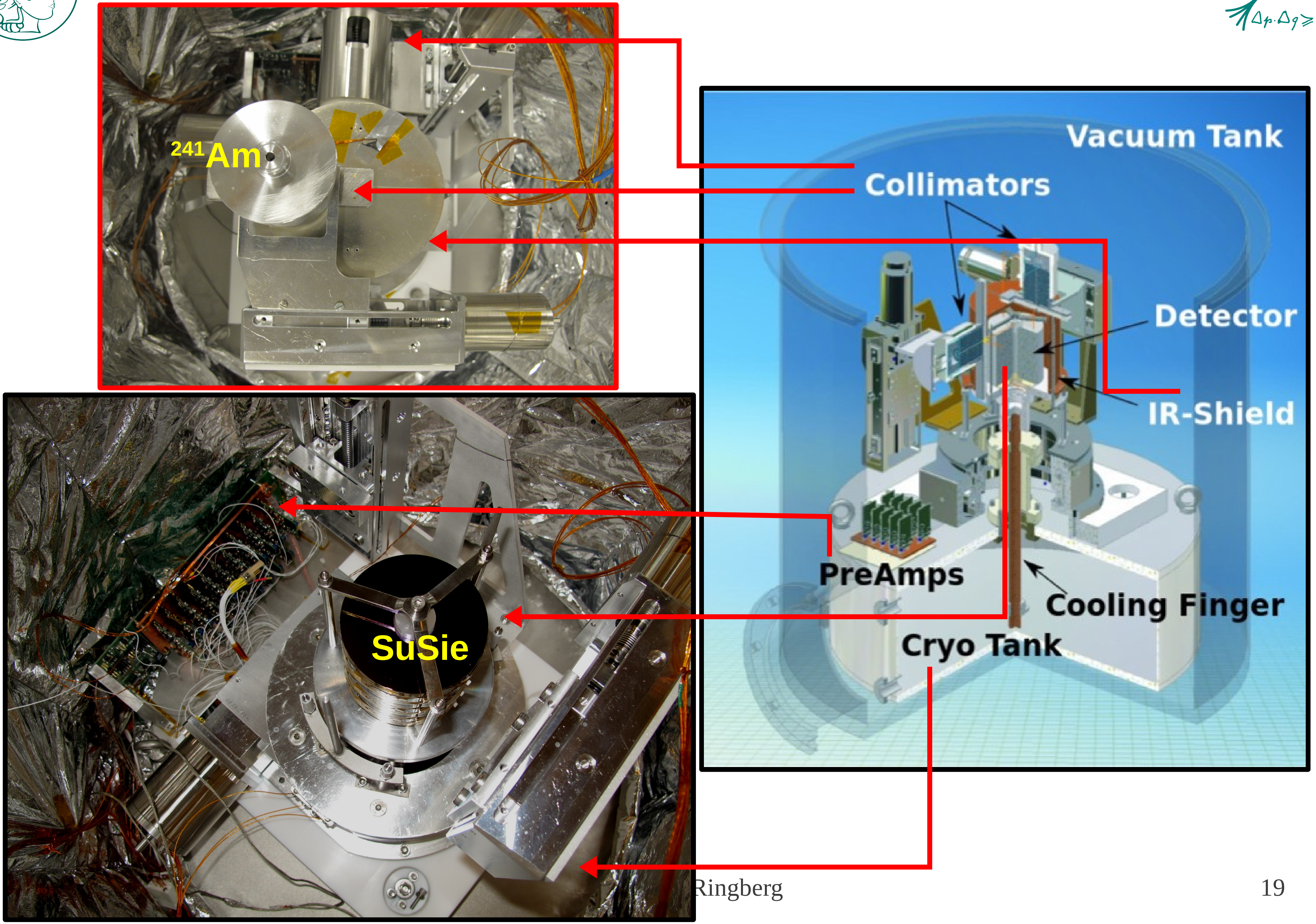
- **GALATEA:** facility to scan Ge detector in vacuum
- **alpha events:** perfect candidates to study surface effects in Ge detectors
- **difference of energy read by the core and the segment**: clear tracer of surface effects → reject these events as bkg events
- **effective dead layer**: extraction of the thickness from the energy spectra

What's next:

- **complete top surface scanning**: improve knowledge about dead layer
- **complete characterization** of the response to alpha particles
- define a **parameter to reject alpha background** based on the difference between the core energy and the segment energy

BACKUP SLIDES

GALATEA: a closer look inside!



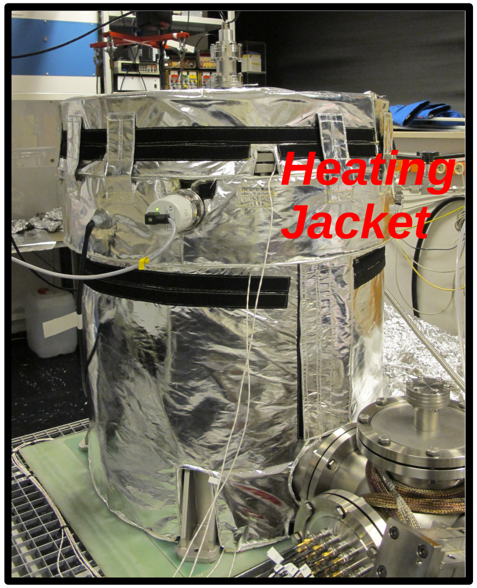
It has to be in an EMPTY space

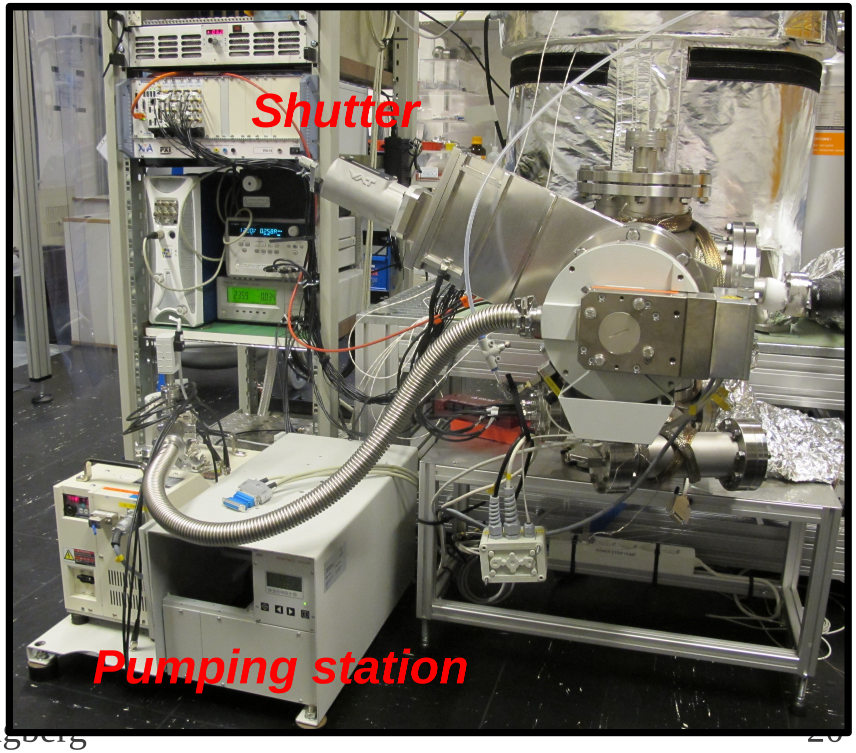
→ **WHY?**

- **sources nearer to the detector**
  - possible scan with **αs** and **βs**
- **detector not immersed in LN2**
  - less technical requirements for the detector

→ **HOW?**

- **Turbo Pump**
- big **VAT valve** (shutter)
- GALATEA tank → big surface
  - **outgassing**
  - **tank CONDITIONING**
    - heating & pumping (110-130 °C)
    - 2-3 weeks cycles
  - **after CONDITIONING:**
    - system pumped:
      $p = O(5x10^{-9}$ mbar)
    - system not pumped:
      $p = O(10^{-5}$ mbar) for ca. 2 weeks

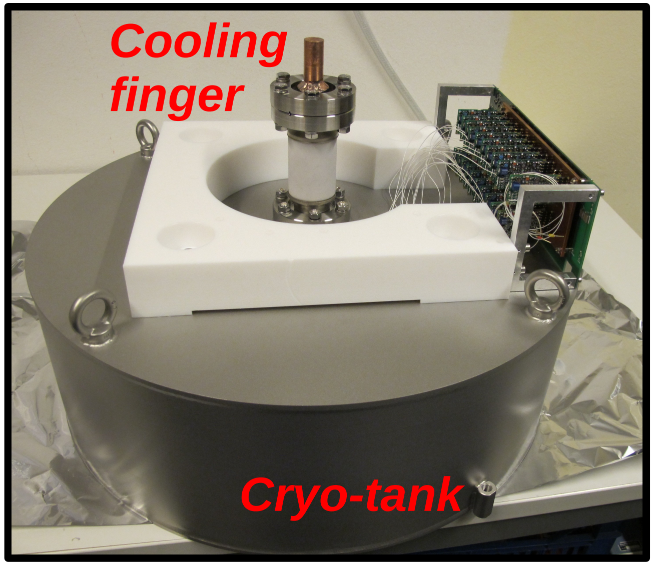


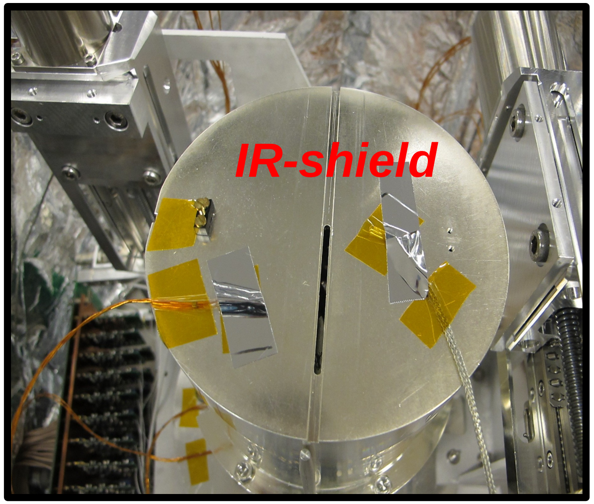


It has to be cooled

→ **WHY?**
- semiconductor detector
  - **cryogenic operating temperature**

→ **HOW?**
- **cooling finger**
- **IR shield**
- **Cryo-tank**
  - automatic refilled LN2 level controller
  - LCR meter for a decoupled information
    - **super insulation foil**
  - around the cryotank
  - inside the tank walls

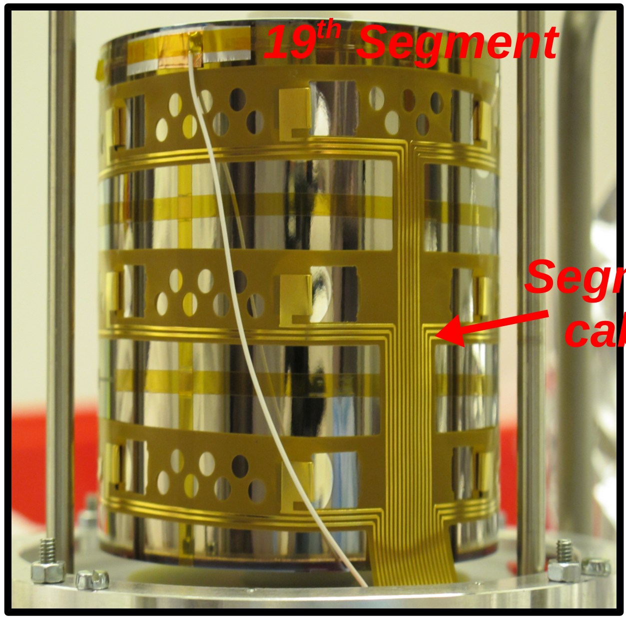


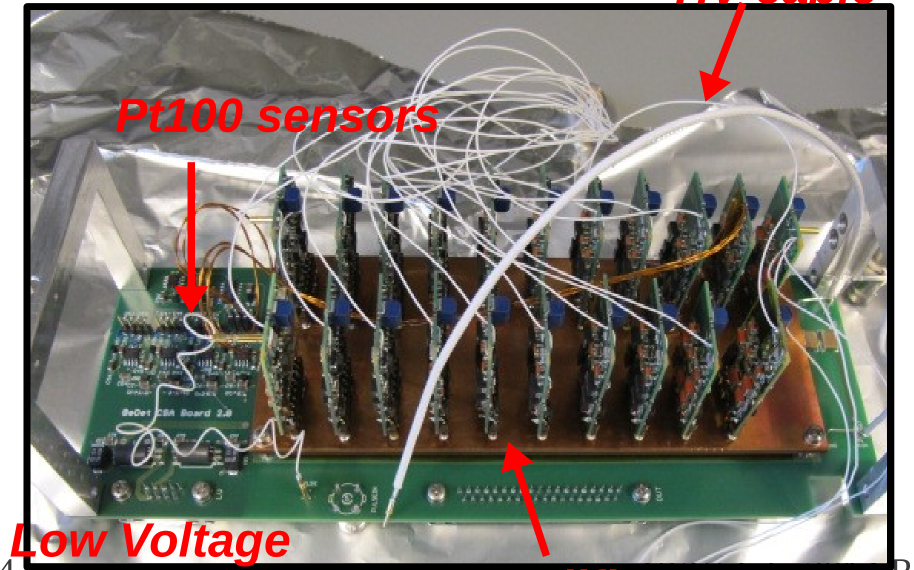


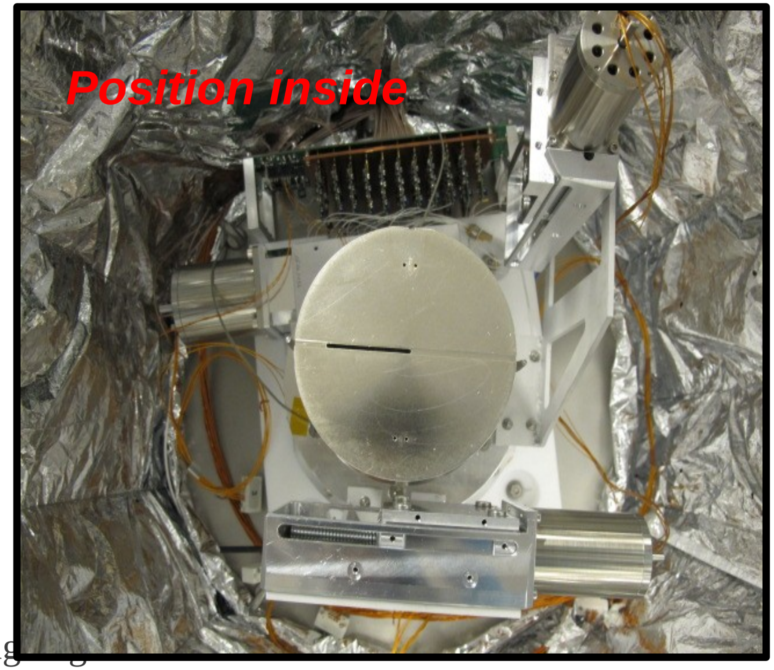
NOTE: the detector should not be the coolest place in the system!!

It has to be turned ON and read out

- How?
    - detector equipped with readout cables
        - **19th segment has a stand alone cable**
    - electronic board inside the tank
        → reduce the noise level BUT...
        PROBLEMS FOR THE **VACUUM**!!
        - preamplifier modules
        - HV connection for the detector
        - LV connection
        - 4 Pt100 sensors







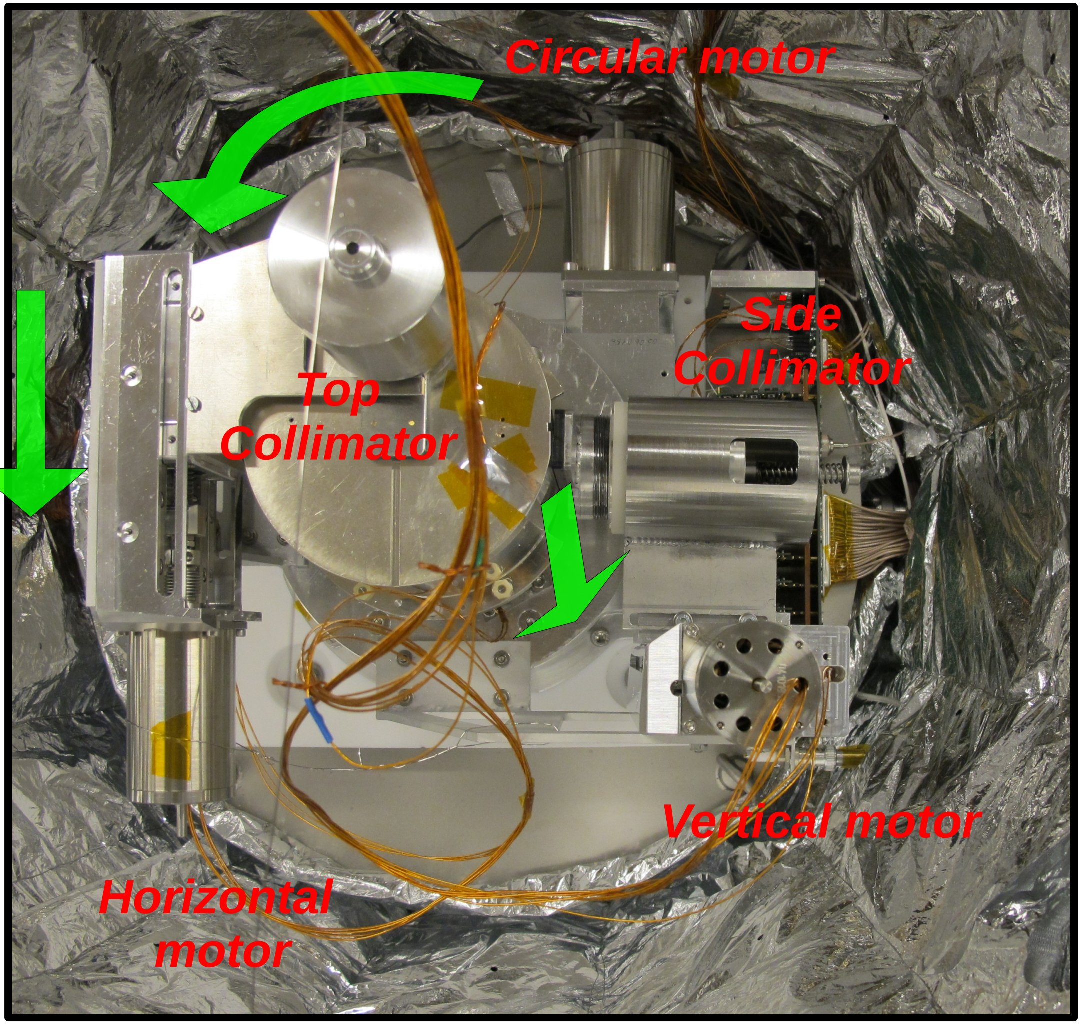
Something has to move

→ **WHY?**

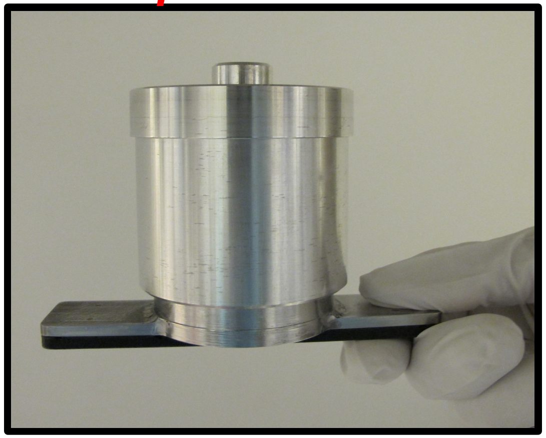
- perform a **3D scan of the detector**
  - multiple sources

→ **HOW?**

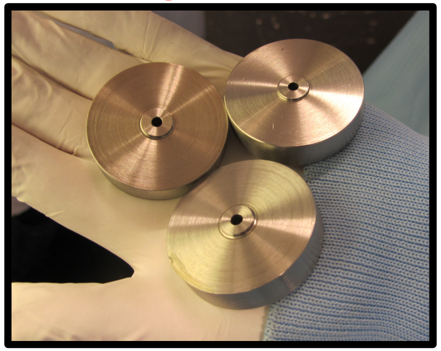
- **3 UHV compatible motors**
  - vertical
  - horizontal
  - circular
- **2 collimators**
  - SIDE: solidal with VM
  - TOP: solidal with HM



Top Collimator



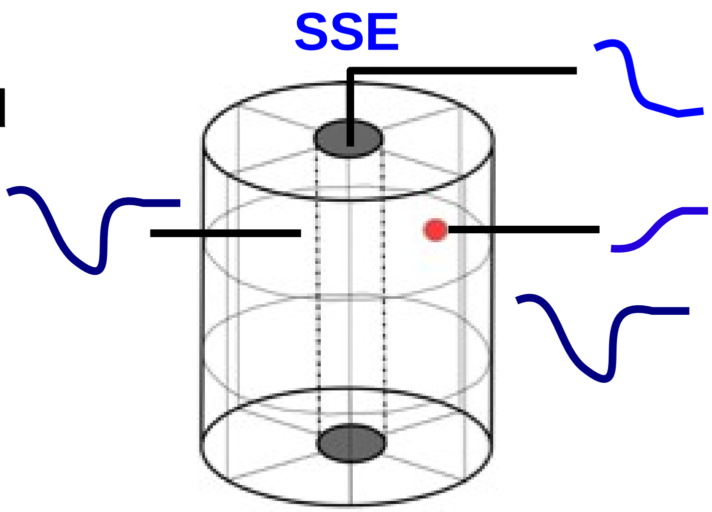
Tungsten segments



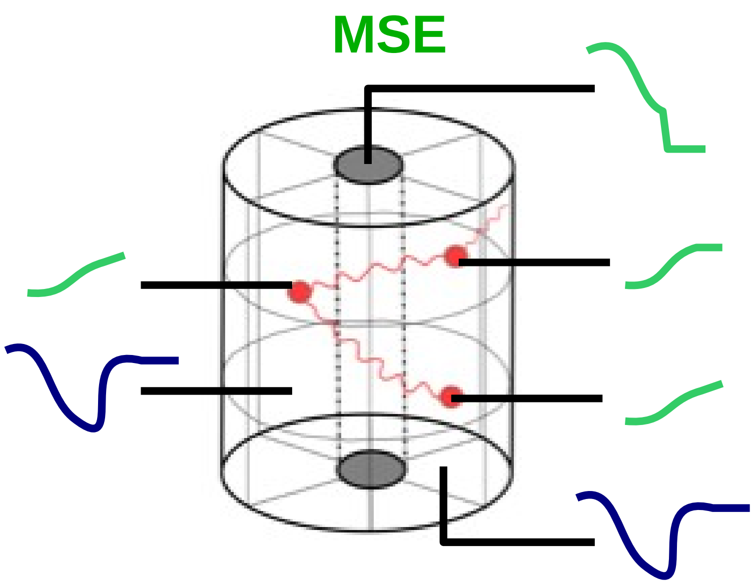
INTERMEZZO: signal creation in segmented Ge detectors

Signal creation:

- **radiation interacts with Ge → e and h created**
  - electrons go to the core electrode
  - holes go to the segment electrodes
  - charges induced in neighbouring segments
    → possible **mirror pulses**



- **2 different situations:**
  - **single segment events (SSE)**
  - **multi segments events (MSE)**



What do we obtain:

- **pulses** in all channel
  - pulse shape analysis
- **energy spectra** from all channels
  - spectroscopy