Young Scientist Workshop
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Germanium Detector R&D with the GALATEA TEST-STAND

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for the GeDet collaboration

Outline

→ **Introduction**
- research fields with Ge detectors
- importance of Ge detector R&D

→ **GALATEA phase 2:**
- experimental setup
- data taking
- data analysis

→ **Conclusions**
- summary & outlook

Research and development with Germanium Detector

Where can germanium detectors be used?

- **gamma ray spectrometry**
  - AGATA, GRETA
  - astronomical spectroscopy: INTEGRAL
- **neutrinoless double beta decay**
  - Heidelberg Moscow, GERDA, Majorana
- **dark matter**
  - CoGeNT, TEXONO, CDEX, HEDELWEISS

Next generation experiment:

- higher **sensitivity**
- more **Germanium** (→ 1 Ton)
  - general purpose
- **combine different requirements**
  - different region of interest
  - different detection techniques

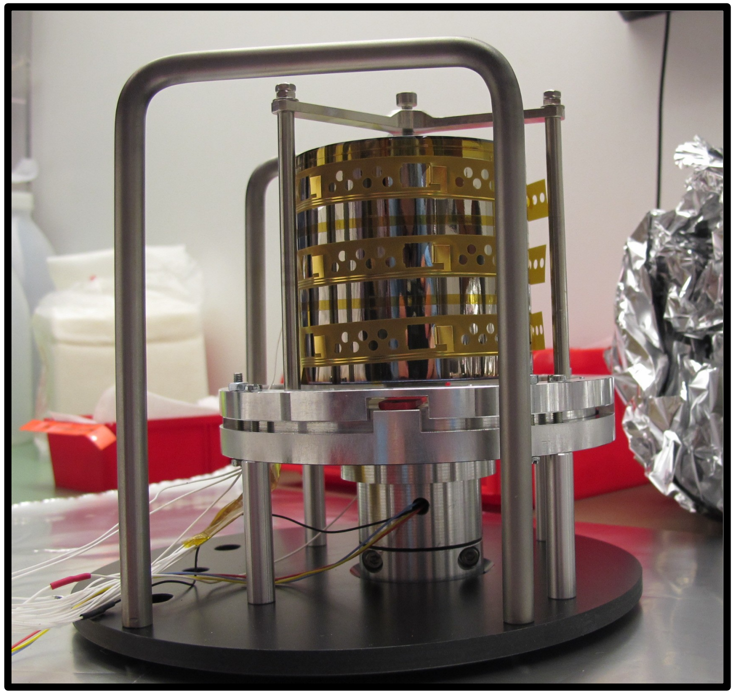
→ central role of detector research and development

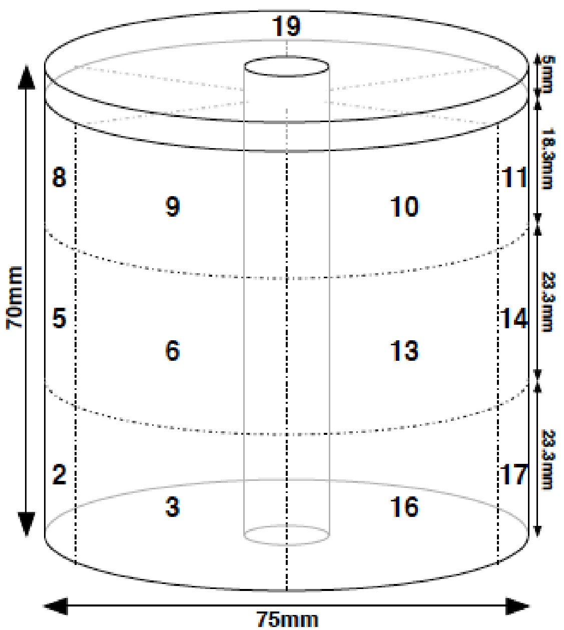
- simulate **new geometries**
- try to have a **new prototype** produced
- and then **TEST IT!!!**

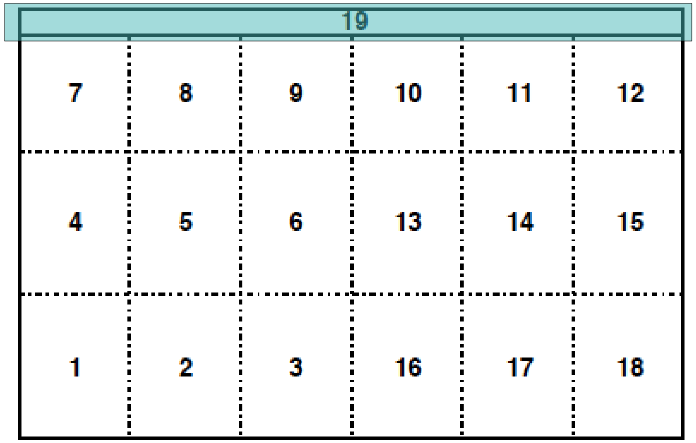
R&D with Ge detectors (II): SuSie detector prototype

Cylindrical true-coaxial n-type HPGe detector

- **18 + 1** fold segmentation(**3z and 6φ**)
- additional **top segment**
    - study **surface effects**
    - **not fully metallized**: field effects
- charge trapping and mobility
- segmentation effects
- crystallographic axes
- impurities uniformity







- Dimensions:

→ h = 70 mm

→ r_{inner} = 5.05 mm

→ r_{outer} = 37.5 mm

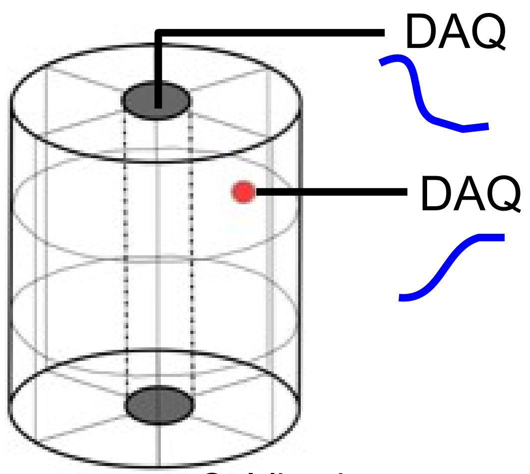
How is the signal created in SuSie?

Signal creation:

- **radiation interacts with Ge → e and h created**
  - electrons go to the core electrode
  - holes go to the segment electrodes

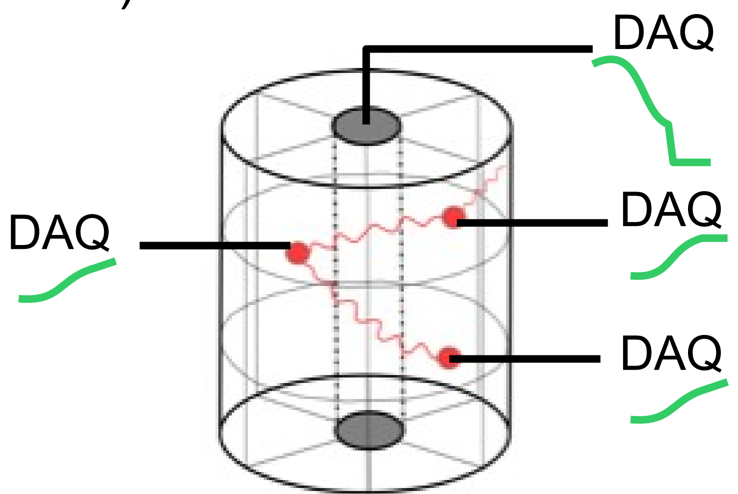
- **2 different situations:**
  - **single segment events**
  - **multi segments events**

- **signals both from:**
  - hit segments (total of **19 channels to read out**!)
  - core (triggering channel)

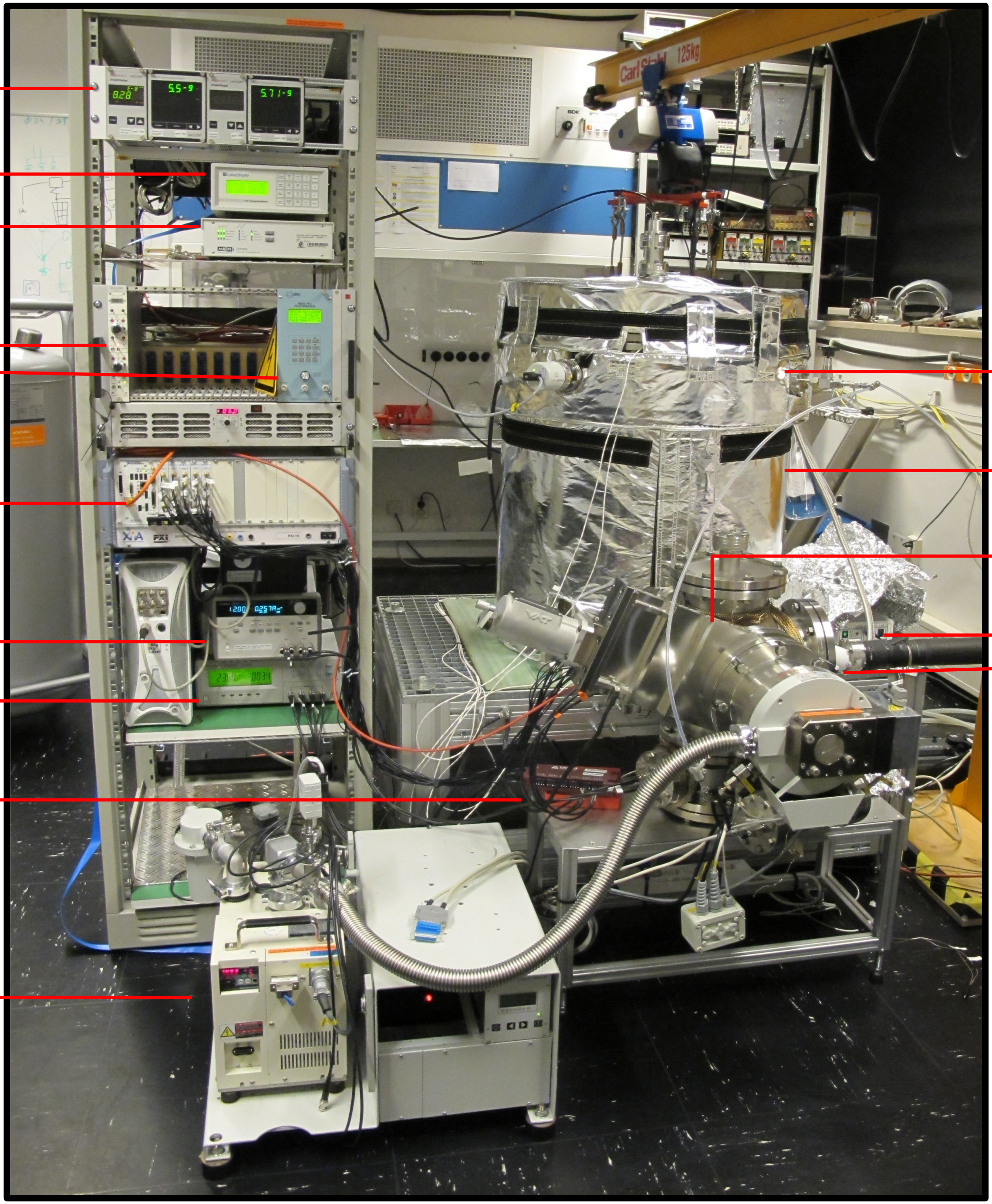


What do we obtain:

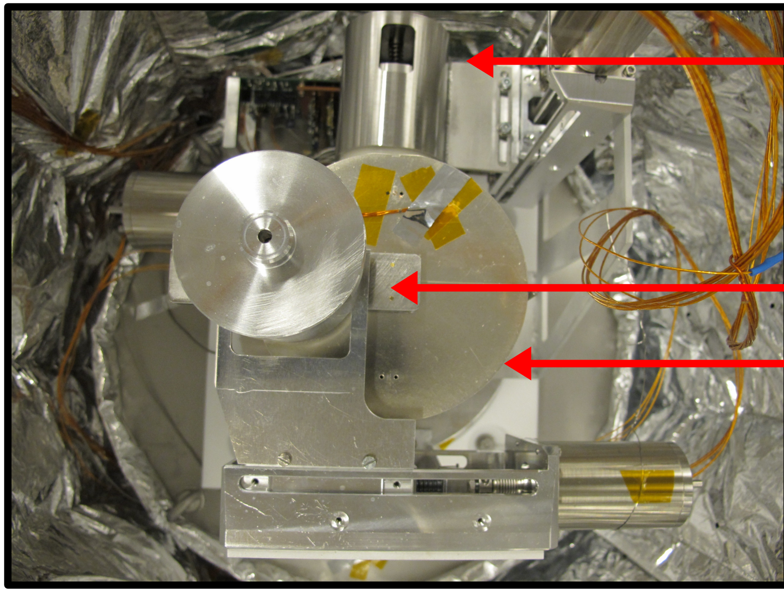
- **pulses** in all channel
  - pulse shape analysis
- **energy spectra** from all channels
  - spectroscopy



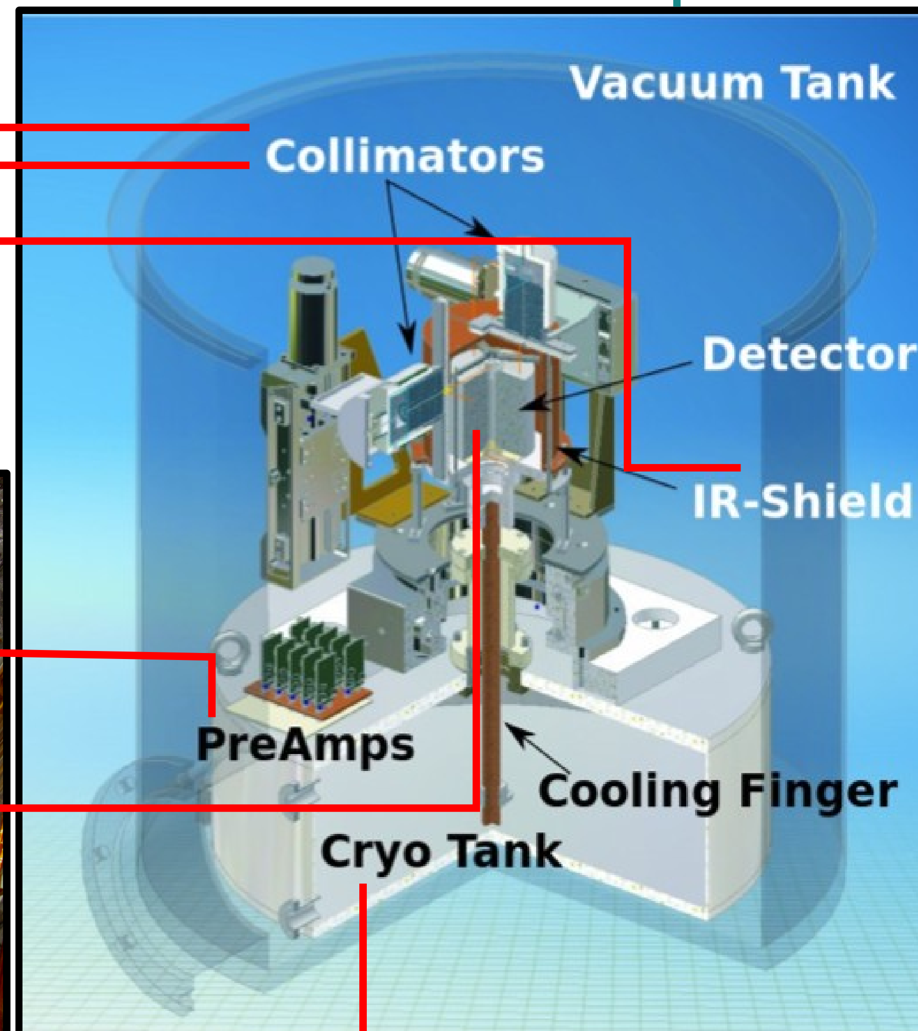
R&D with Ge detectors (III): GALATEA test-stand from outside

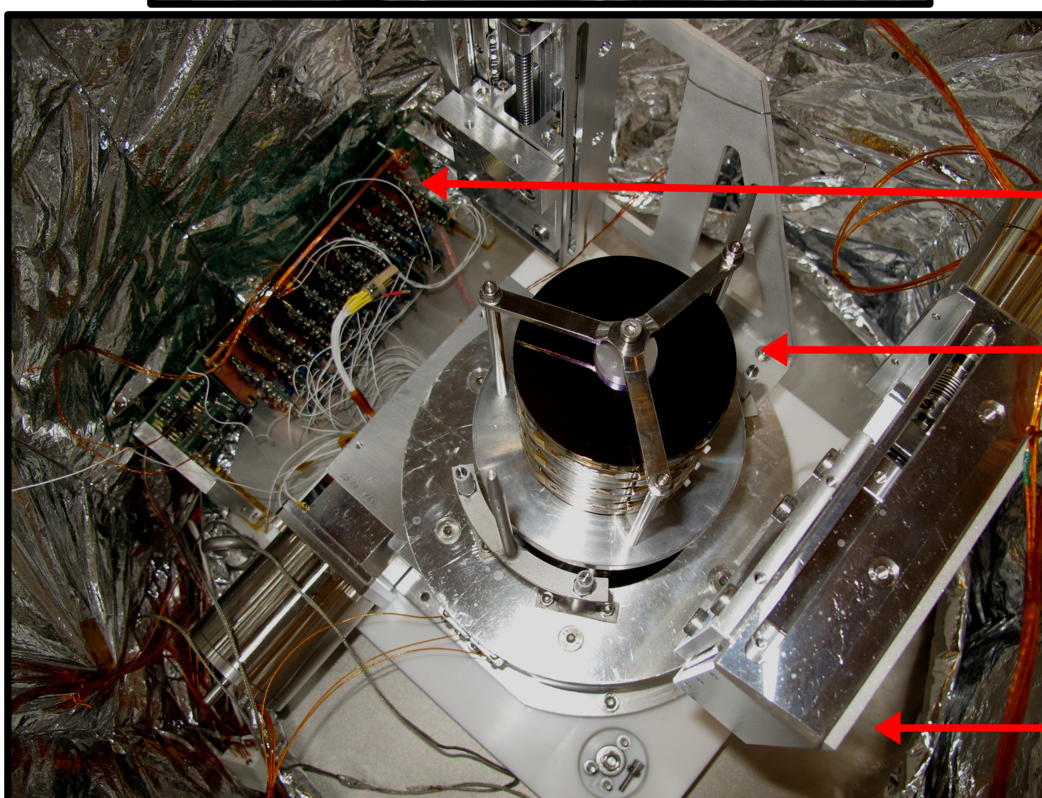


GALATEA: from the inside



GALATEA I: to be updated!

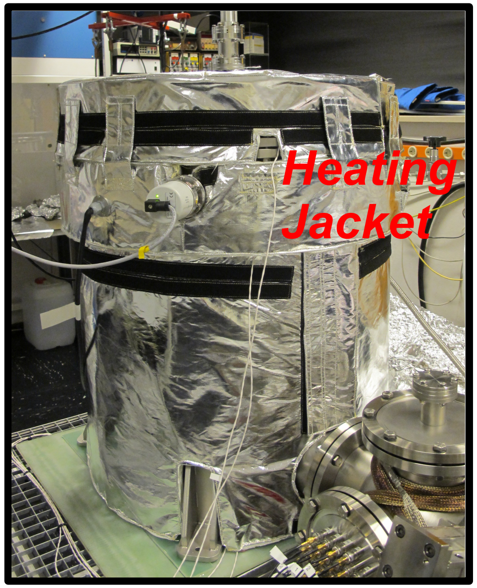




It has to be in an EMPTY space

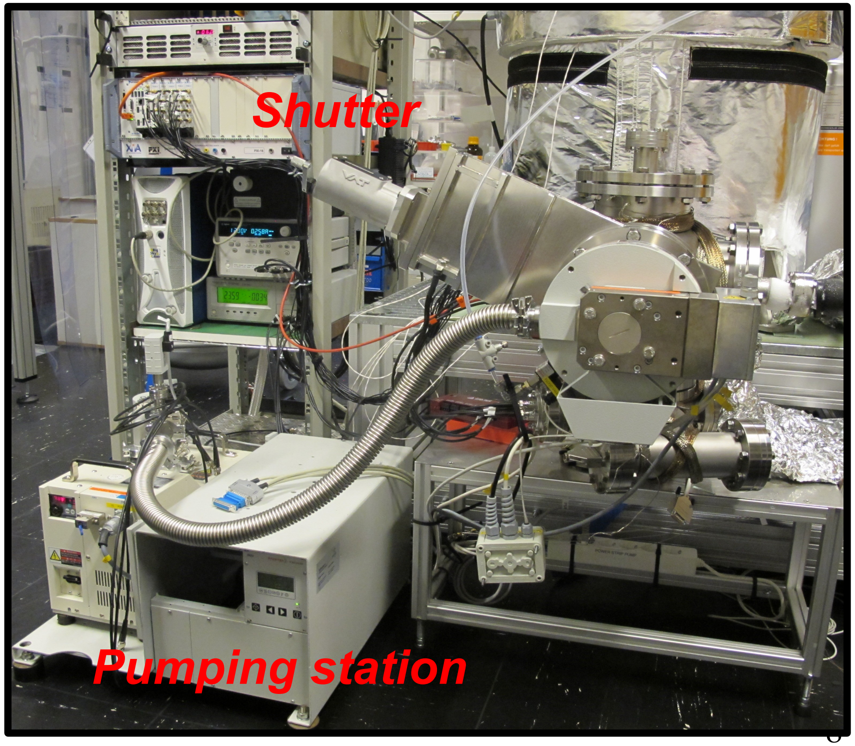
→ **WHY?**

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



→ **HOW?**

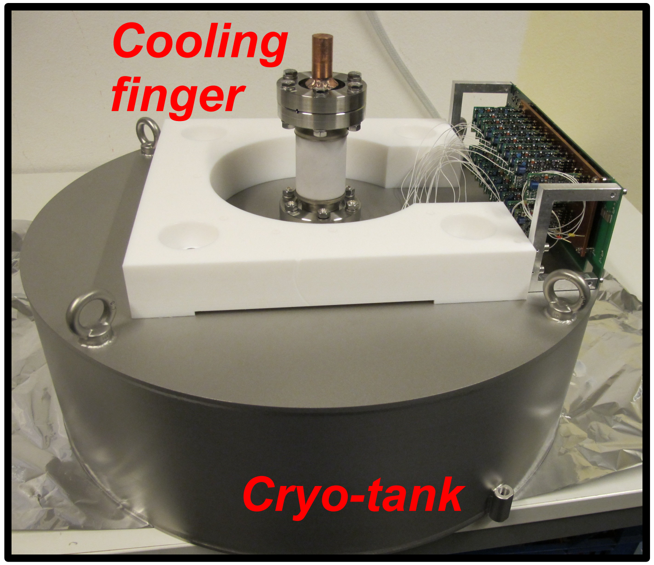
- **Turbo Pump**
- big **VAT valve** (shutter)
- GALATEA tank → big surface
    - **outgassing**
    - **tank CONDITIONING**
        - heating & pumping (110-130 °C)
        - 2-3 weeks cycles
    - **after CONDITIONING:**
        - system pumped:
          p = O(5x10^{-9} mbar)
        - system not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

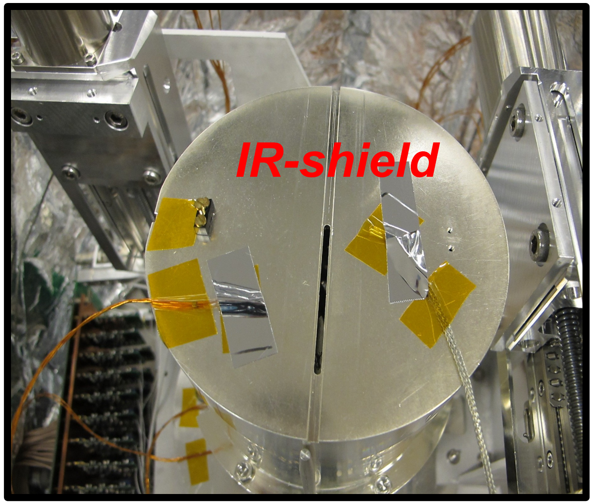


It has to be cooled

→ **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

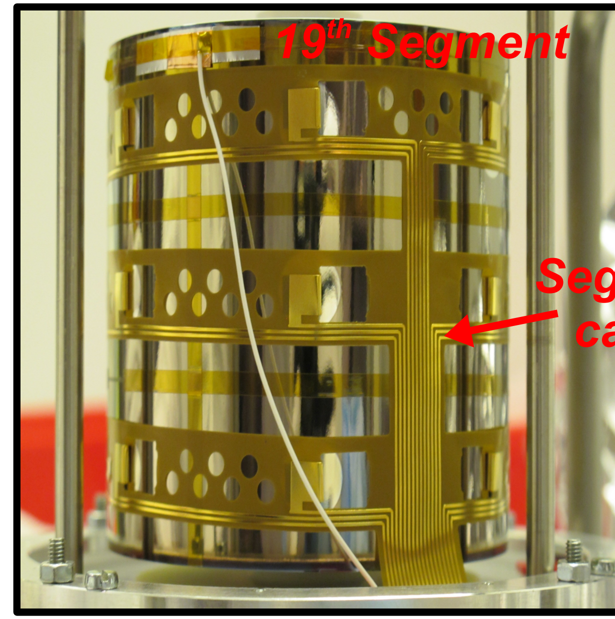


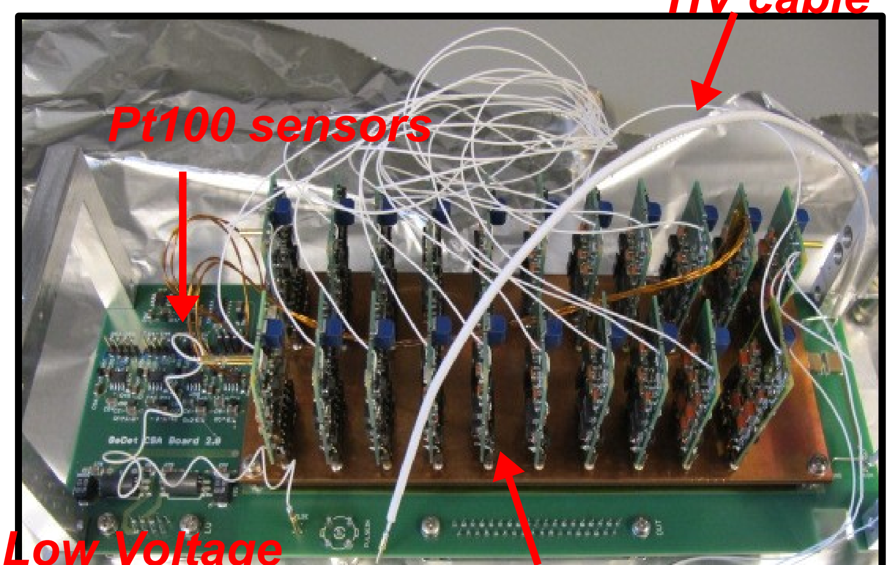


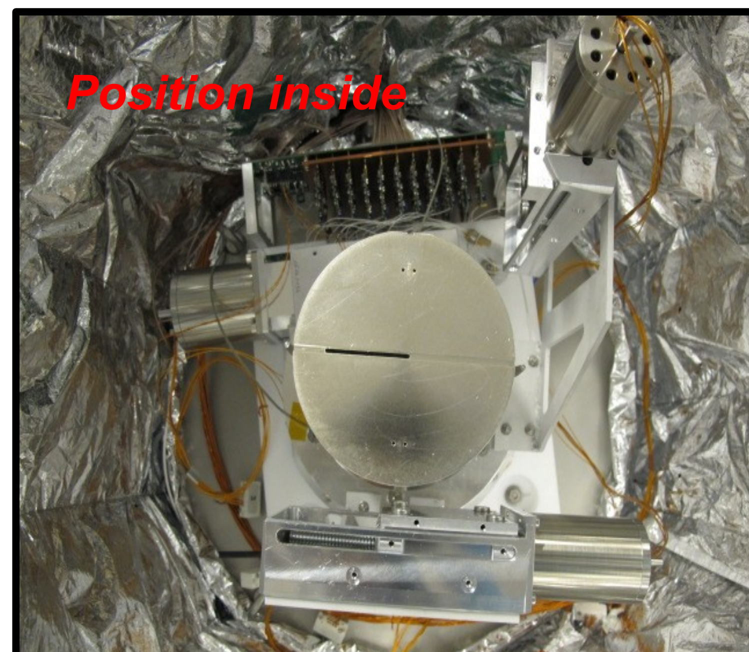
NOTE: the detector should not be the coolest place in the system!!

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



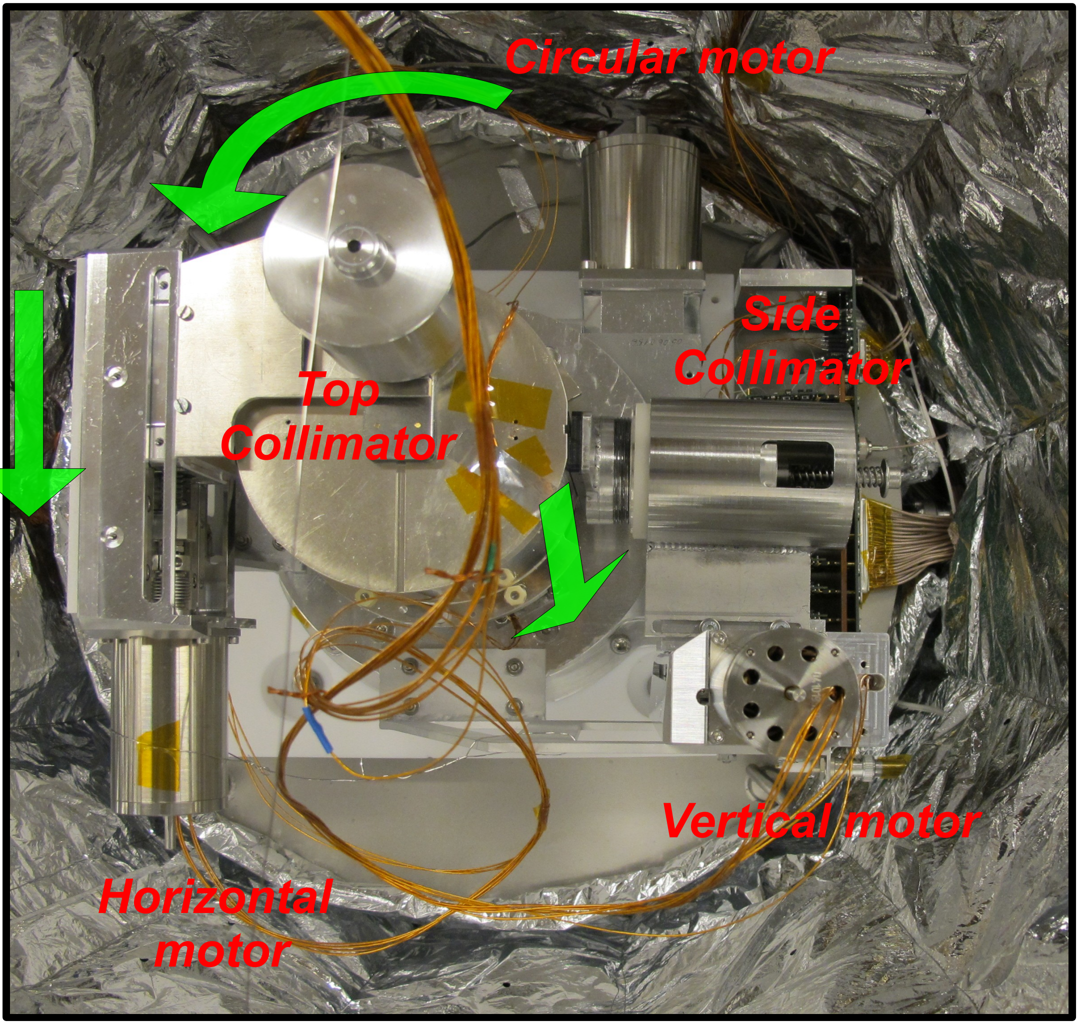




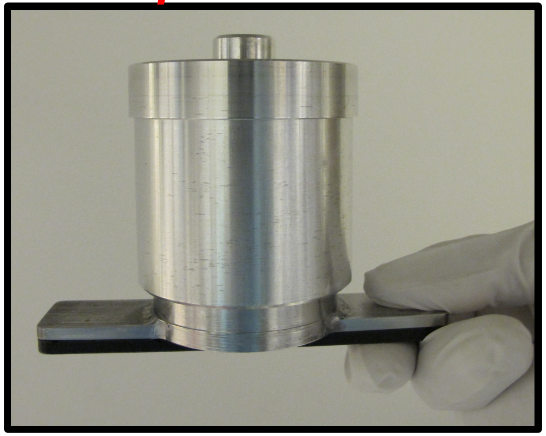
Something has to move

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

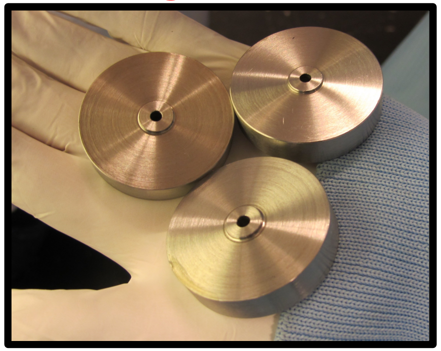
→ **HOW?**
- **3 UHV compatible motors**
    - vertical
    - horizontal
    - circular
- **2 collimators**
    - SIDE: solidal with VM
    - TOP: solidal with HM



Top Collimator

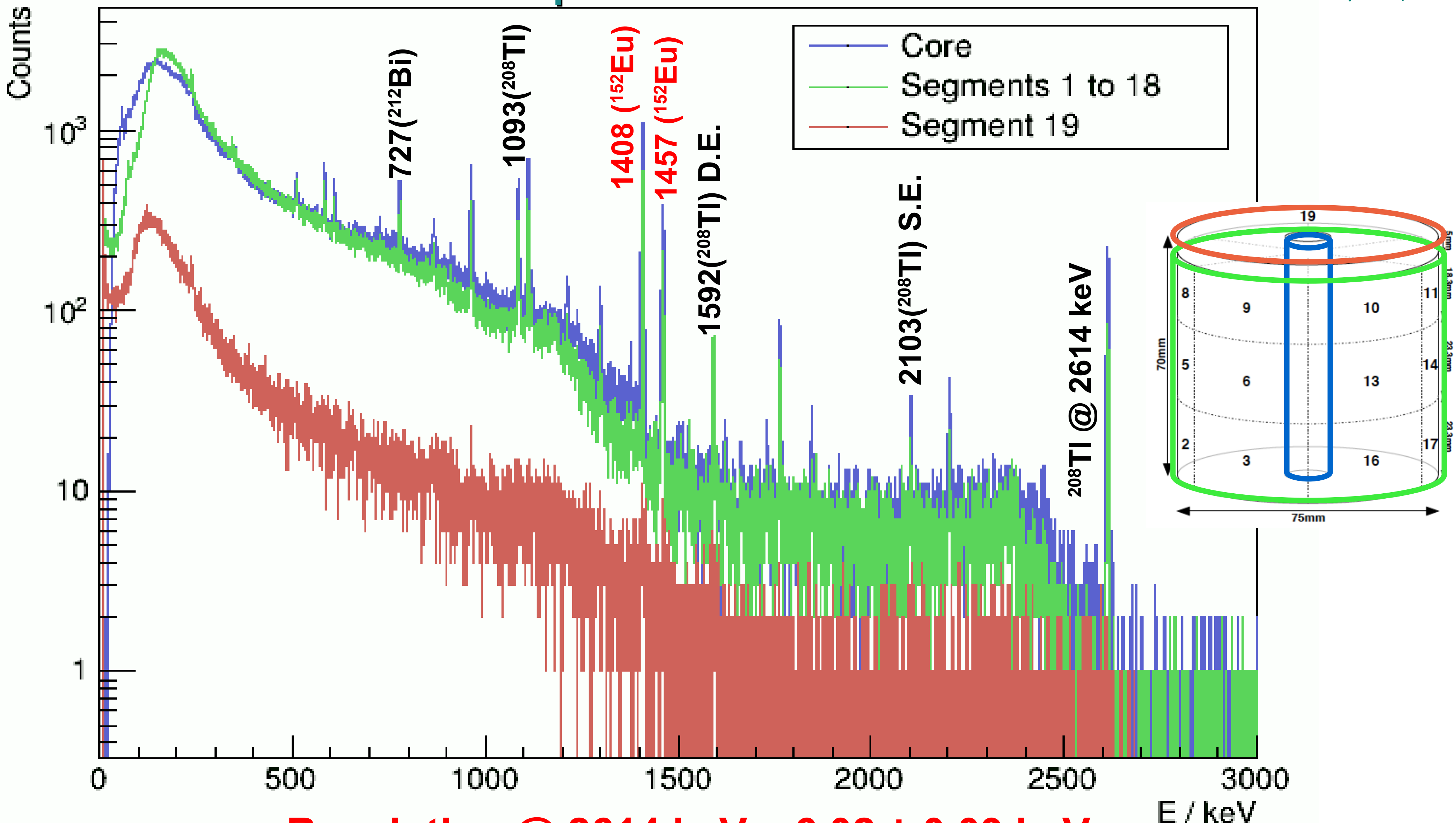


Tungsten segments



First data set : 29th of April 2013

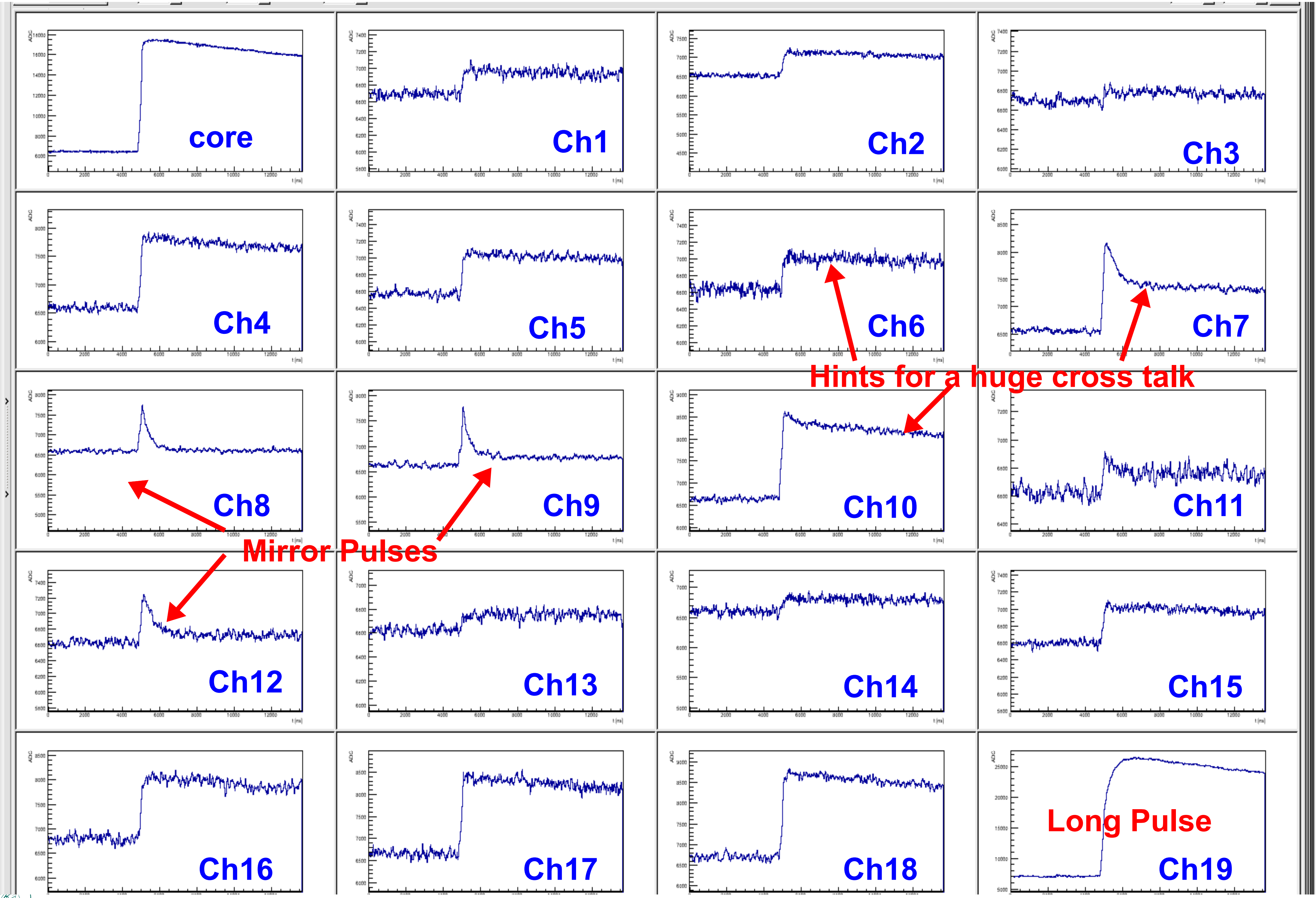
First ^{228}Th spectrum with SuSie detector



Resolution @ 2614 keV: 6.02 ± 0.09 keV

- studies about the **noise level due to sensors** were performed
  → in the best configuration: **resolution @ 2614 keV of 3.94 ± 0.03 keV**

Event Display: pulses in all the channels



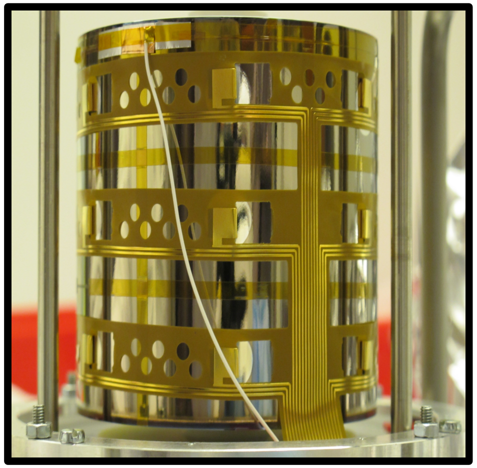
Cross talk effect

- Cross talk form capacitive coupling among segments and core:

- Lithium drift on the core (**metallic surface**)
- **metallization** of the external surface (segments)
  - → capacitance core-seg: **core to segment cross talk** O(0.1%)
  - → capacitance seg-seg: **segment to segment cross talk** O(0.1%)

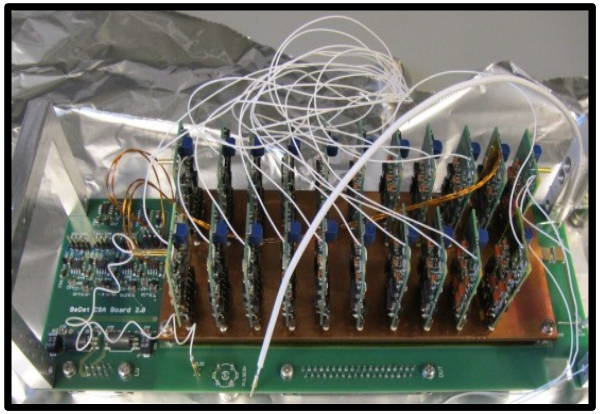
- Cross talk from the cabling:

- **core signal pre-amplified close to the detector** (FET):
  - → big and negative
- segment cables on the detector **well shielded**
- core + segments cables to the preamp board **not well shielded**
  - → **possible big core-to-seg cross talk**



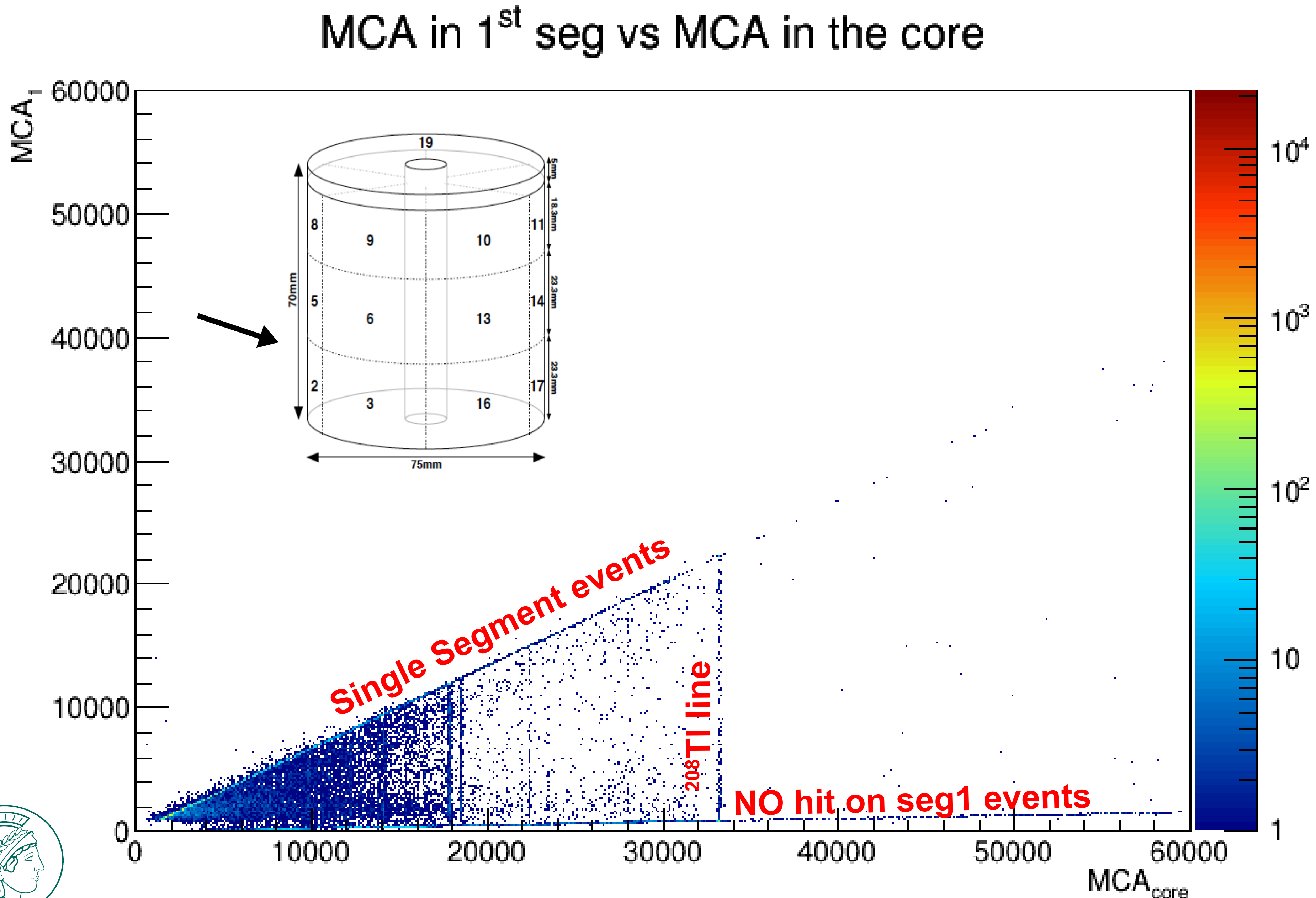
- Cross talk from the preamplifiers:

- **charge sensitive preamplifiers**
- charges go in and go out amplified
- they become **capacitors** facing one to each other
  - → **possible big seg-to-seg cross talk**

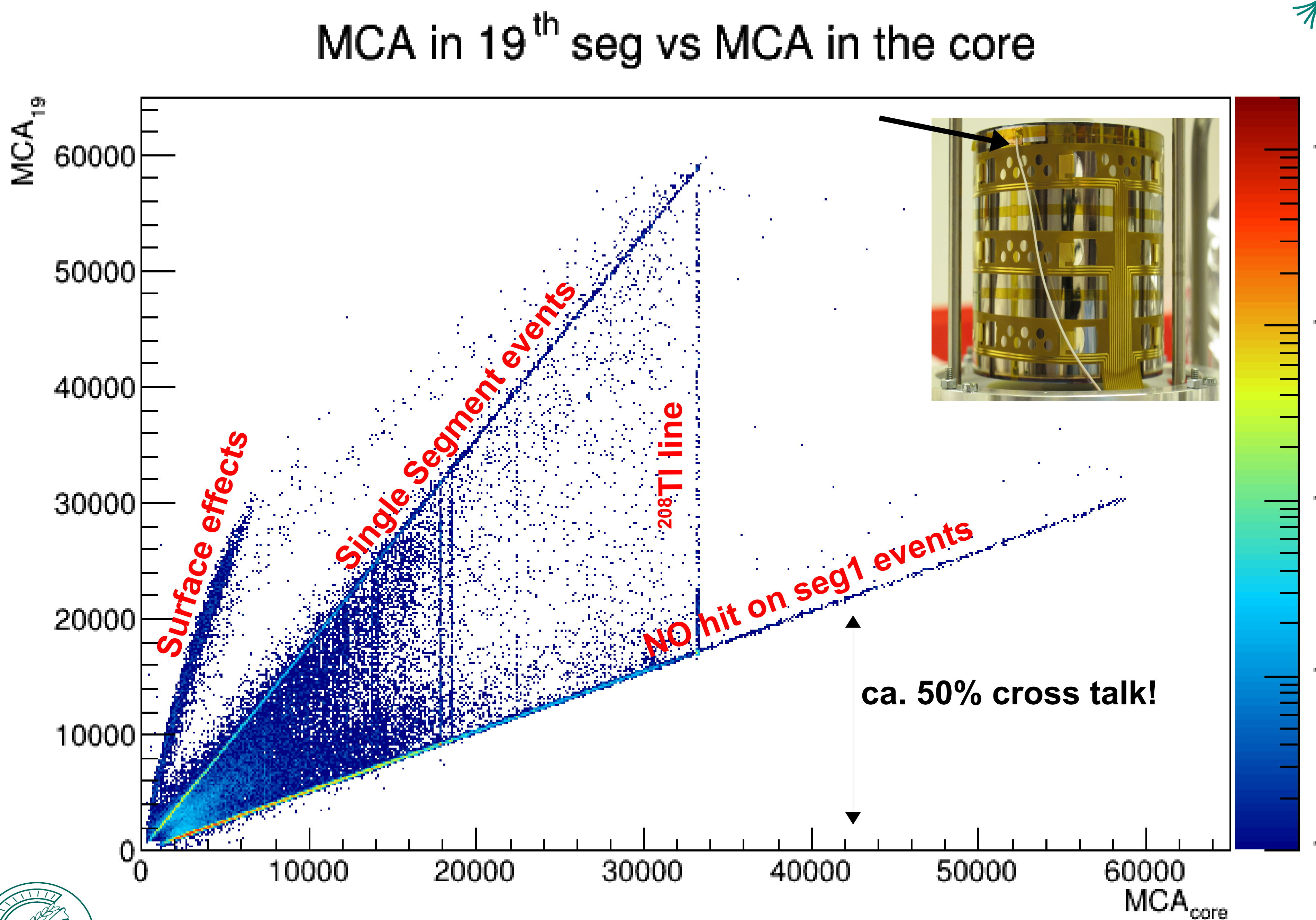


Core to Seg1 cross talk

- Everything what is **read by a segment** is **read by the core as well**!
  → strong **correlation between the MCA values**



Core to Seg19 cross talk



Cross talk correction

Main ideas to find CORE-TO-SEGMENT cross talk:

- **Single Segment event selection**
  - energy deposited in only one segment
  - signal seen ONLY from the segment and the core
  - selection: $| E_{core} – E_i| < 20$ keV
    - assumption: Core independently calibrated
    - rough calibration for segments
- root minimizer used for each segment separately

- **Not Hit Segment**
  - **CORRECTED energy SHOULD be zero**

$$MCA_i + x_{0i} MCA_0 = 0$$

→ **cross talk correction factors x_{0i}**

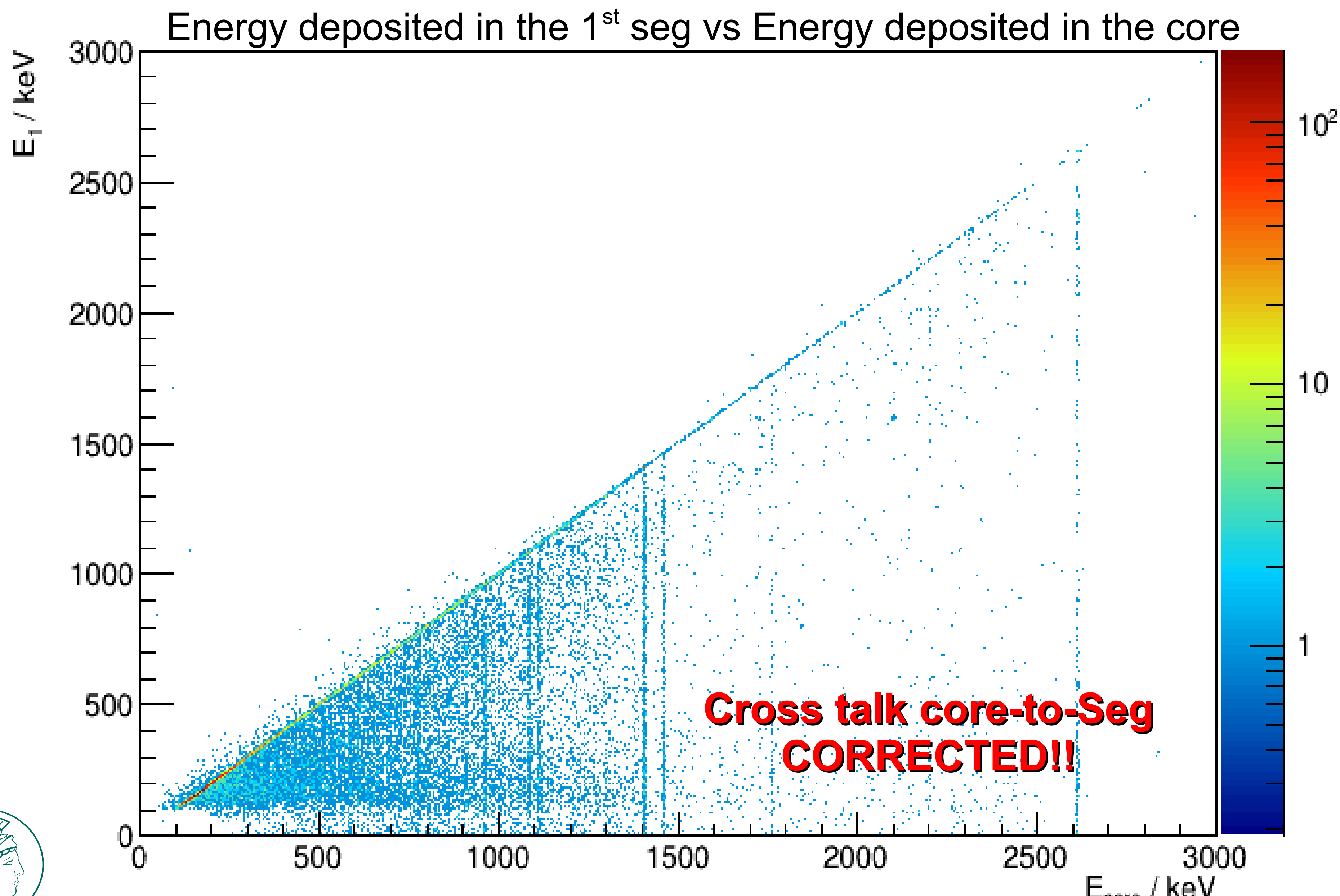
- **Hit segment**
  - **CORRECTED energy SHOULD be equal to the CORE ENERGY**

$$E_0 - (a_i + b_i(MCA_i + x_{0i} MCA_0)) = 0$$

→ **offset and slope calibration factors: a_i b_i**

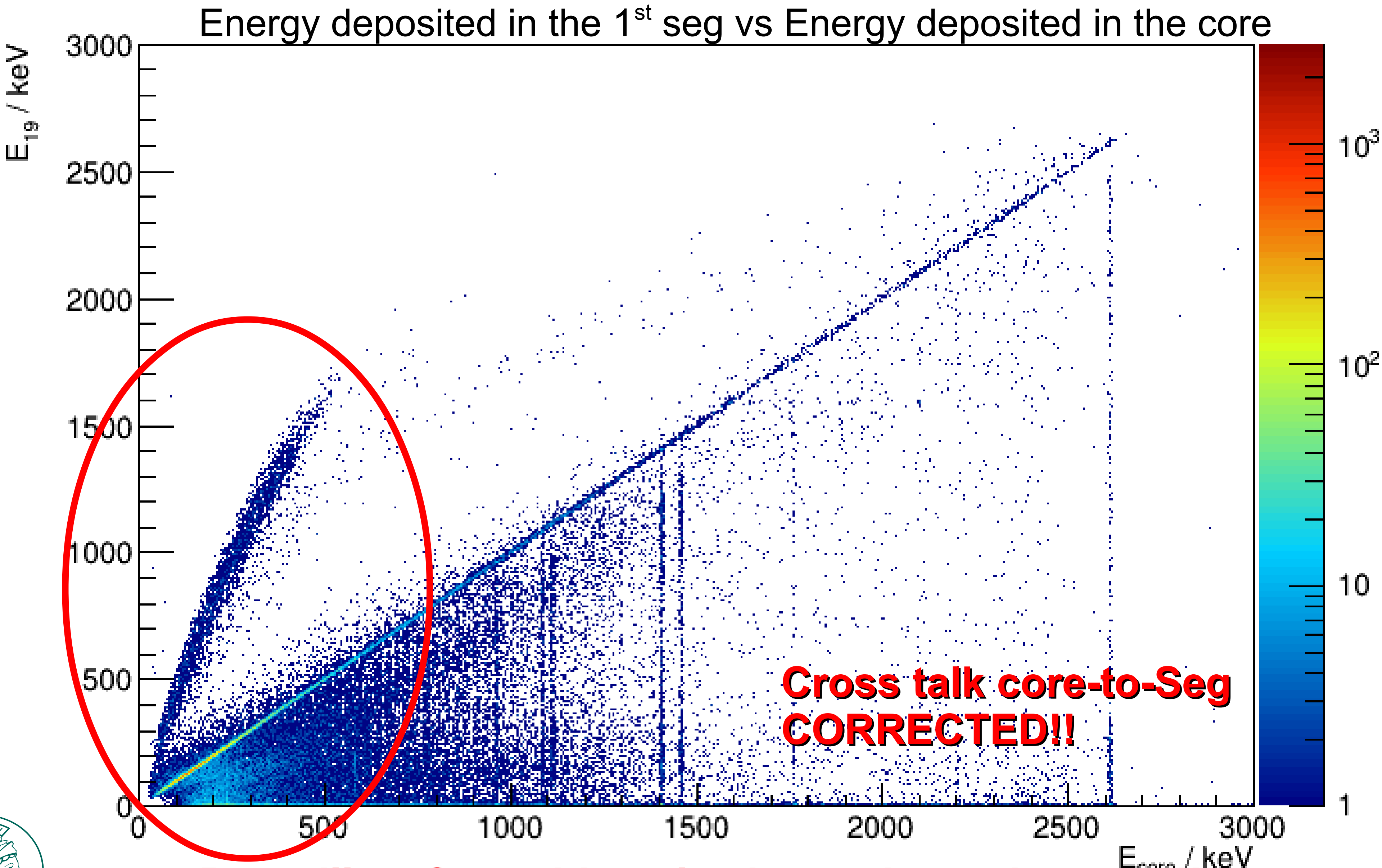
Corrected correlation plots: Core-to-Seg1

- energies **corrected and calibrated**:
    - only **core-To-Seg** correction applied



Corrected correlation plot: Core-to-Seg19

- energies **corrected and calibrated**:
  - only **core-To-Seg** correction applied



But still..... Something else has to be understood!!

Conclusions

What we achieved:

- **GALATEA IS FINALLY RUNNING**
  - ca 3 years of commissioning
  - vacuum and cryogenics totally under control
- the noise effects due to each sensors were studied
- first order x-talk correction obtained in an automatized way
- first scanning of the detector has been done

What we want to achieve:

- characterization of the entire system

- segment mapping (ch3 is really seg3??)
- seg-to-seg cross talk determination and correction

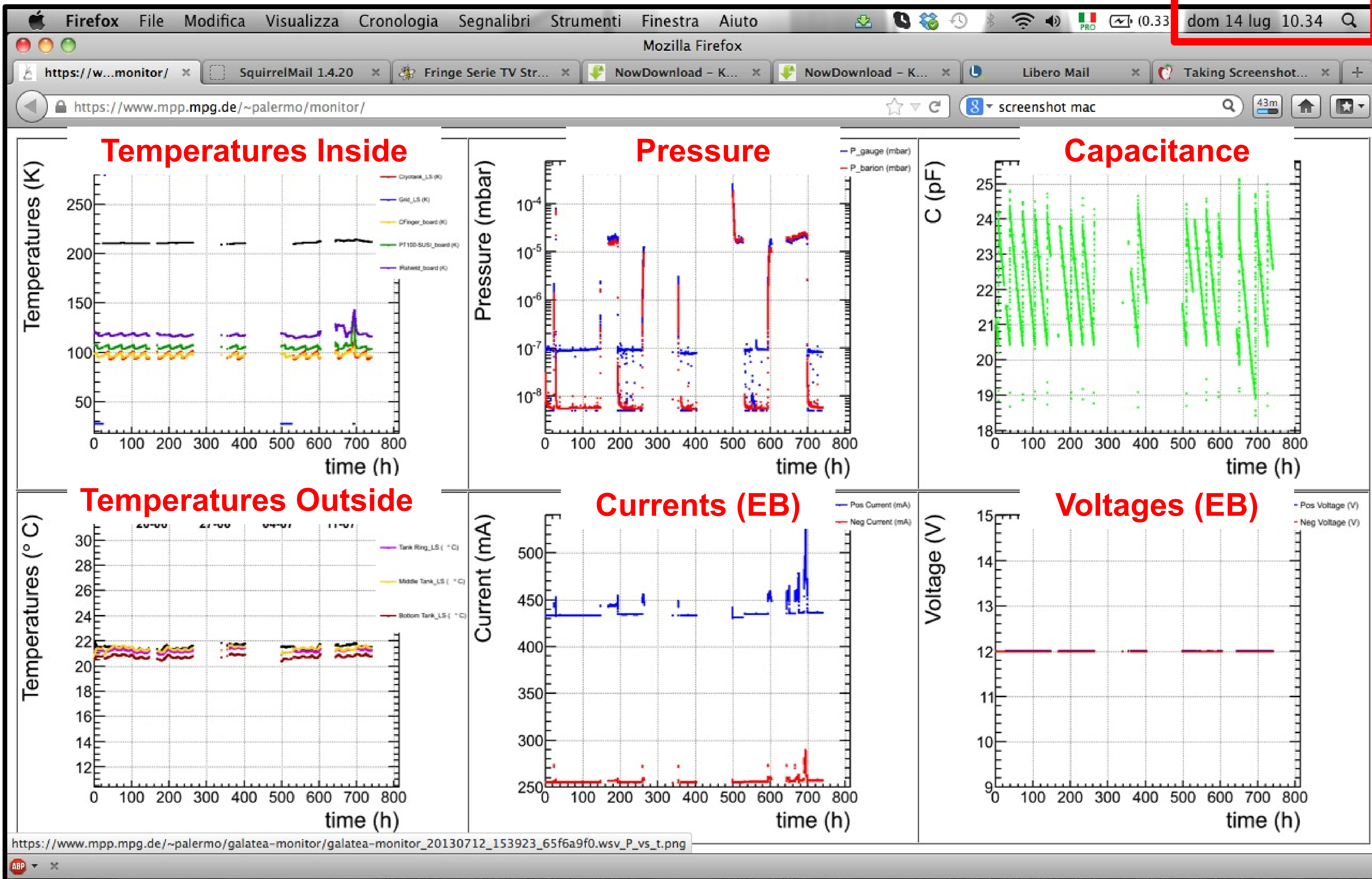
- characterization of the detector

- axes determination
- charge trapping effects
- surface effects on the 19^{th} segment
- mirror pulses

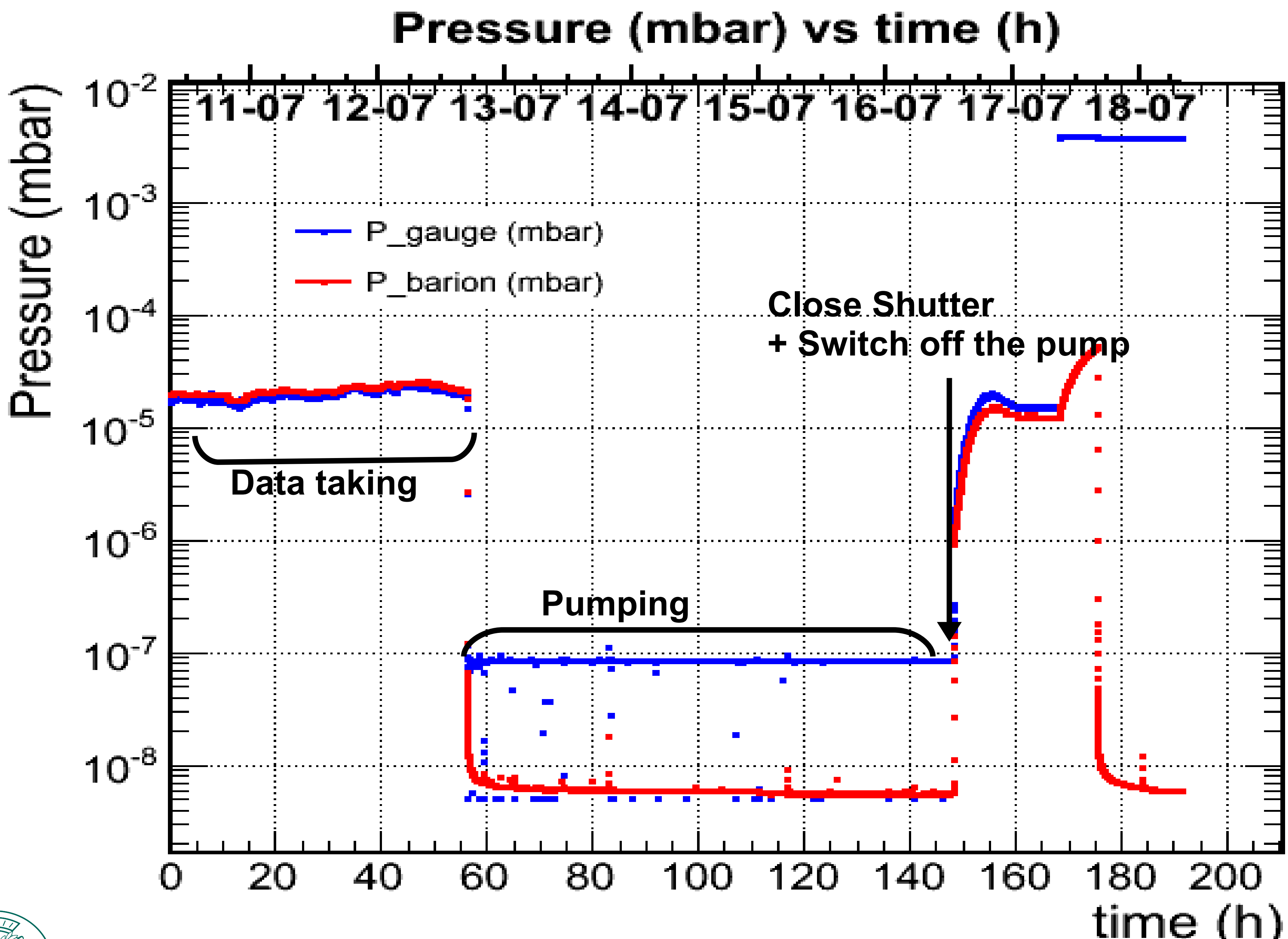
BACKUP SLIDES

… moreover has to be monitored!!

Online monitoring… remotely controllable!!

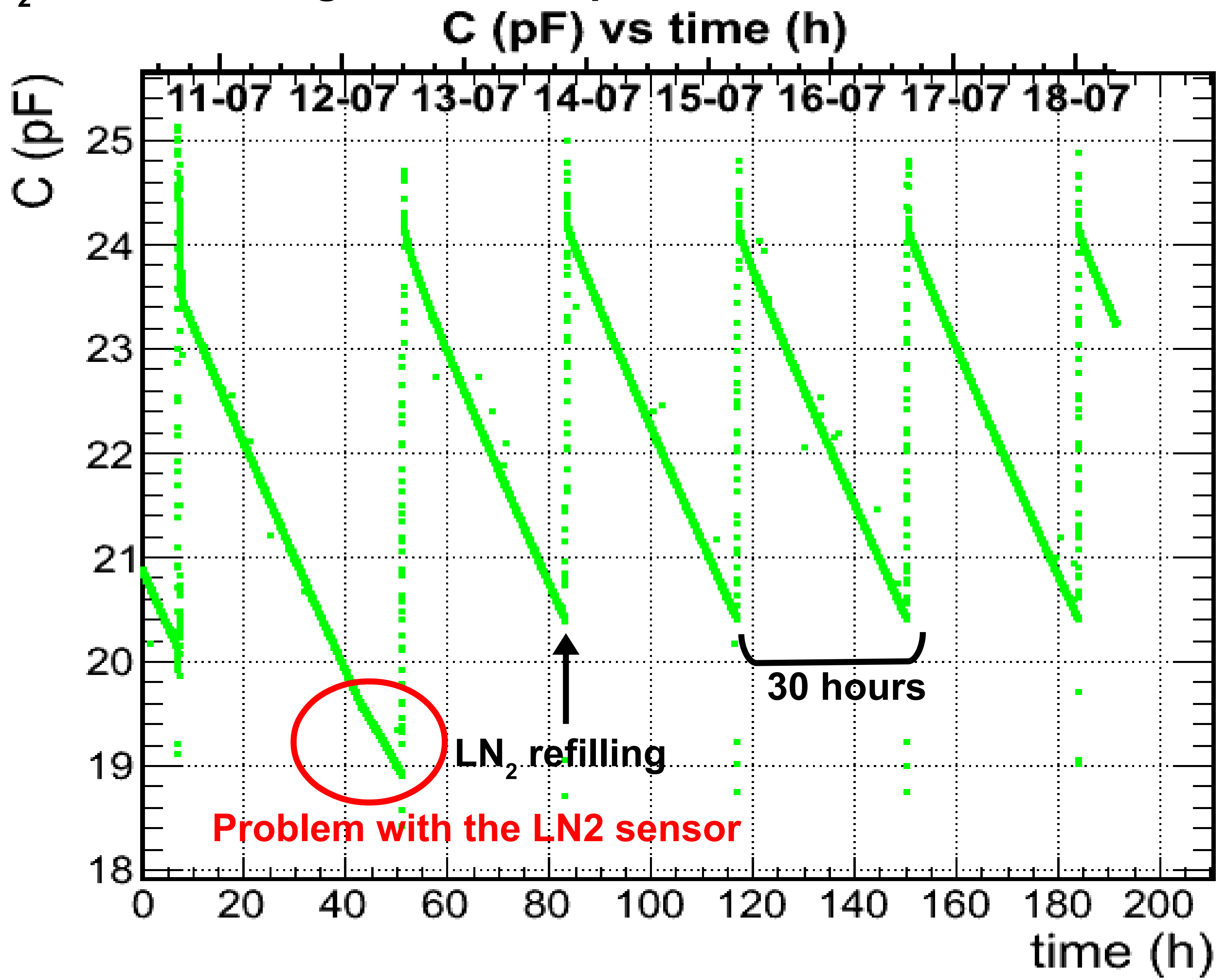


Monitoring the pressure inside

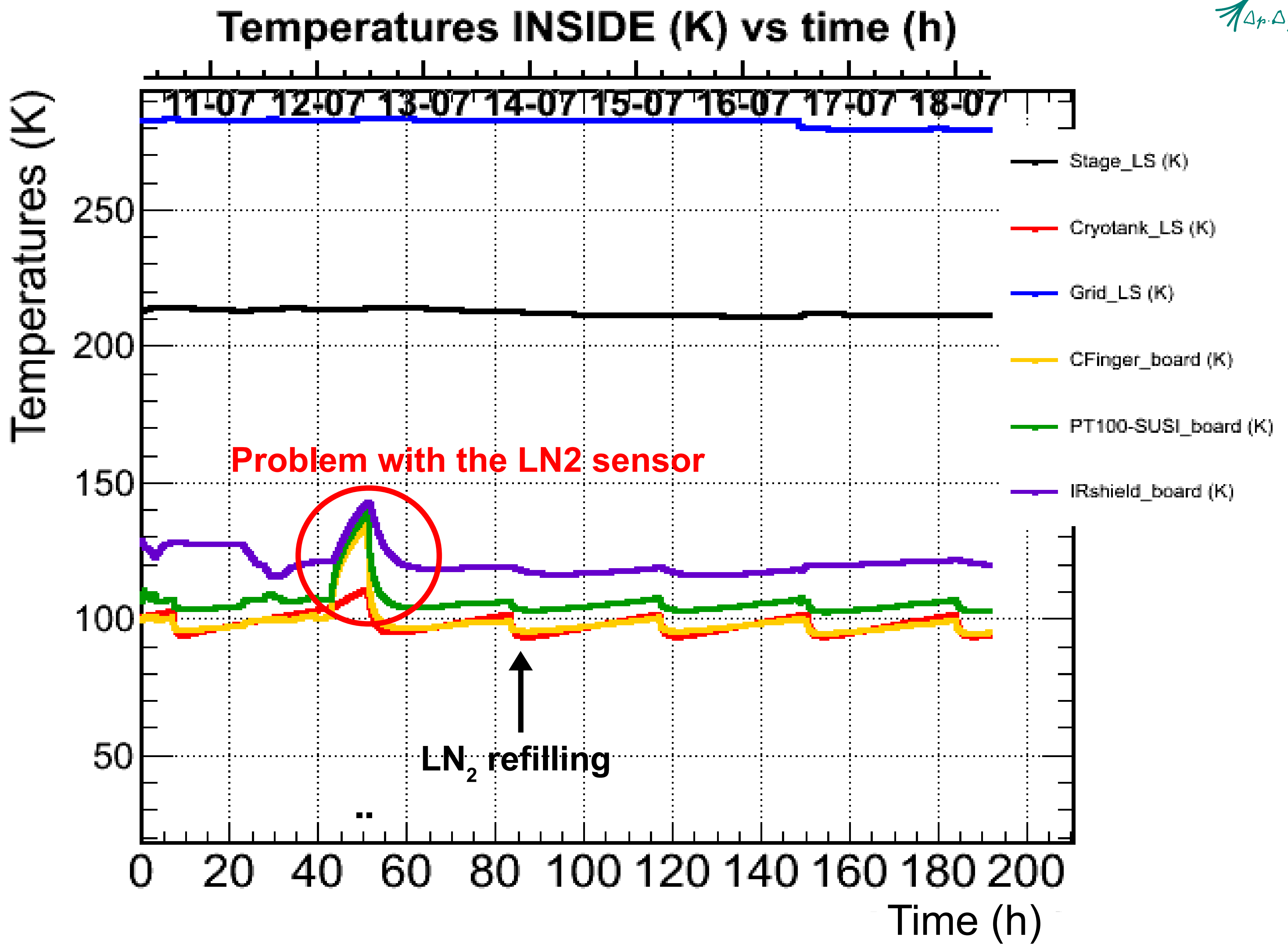


Monitoring the capacitance

- the capacitance **C** change with the **level of the LN_2**
- **more LN_2** is **inside** → **higher is the capacitance**



Monitoring the temperature inside



NOTE: the detector is not the coolest place in the system!!

Single Segment and Multi Segment events