SiPM and Scintillator characterisation for highly granular calorimeters

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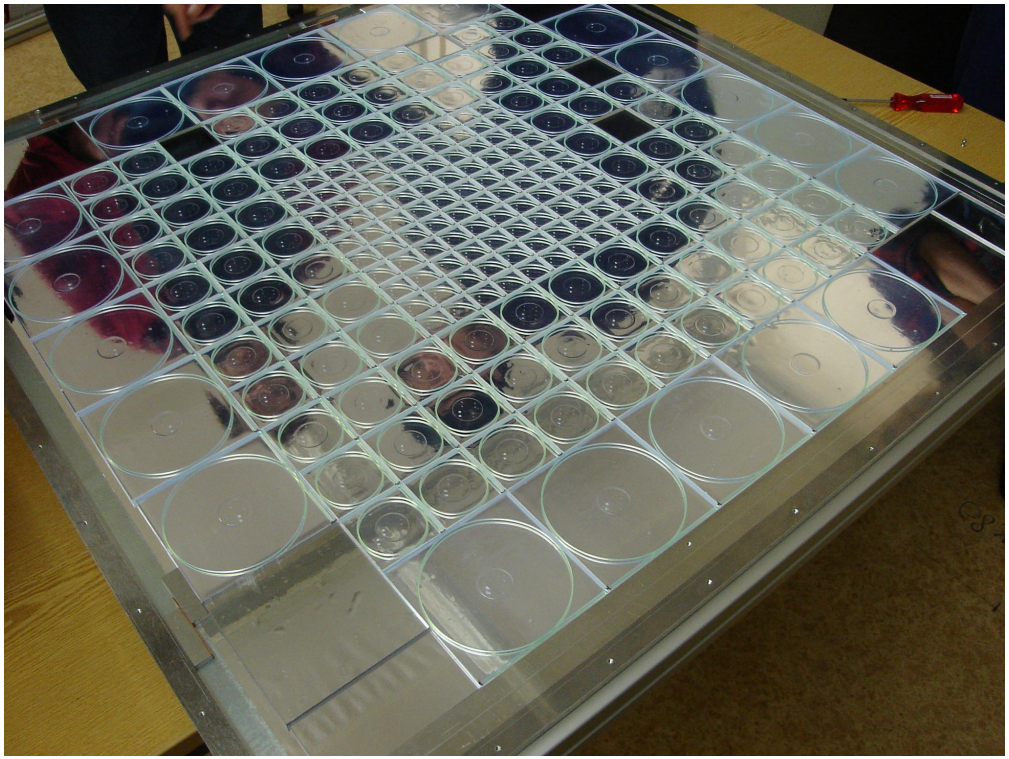
CALICE Collaboration Meeting

Motivation

- Improve understanding of scintillators and SiPMs and related systematic effects in HCAL and ECAL applications
- Characterise impact of scintillator wrappings and tile size on measured light yield



Sensitive layer of the CALICE AHCAL

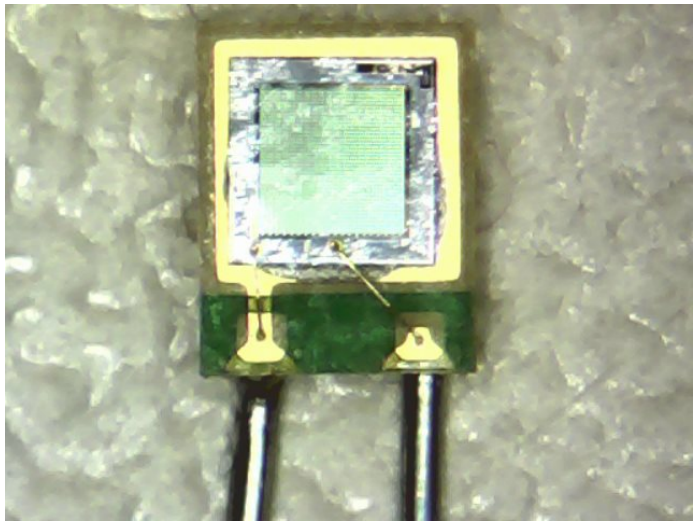
Overview

1. Calibration - Gain vs. Temperature
2. The experimental setup at CERN
3. Comparison of different tiles
4. Future setups
5. Summary and Outlook

Calibration of the SiPM: Gain vs. Temperature

Reminder: The SiPM

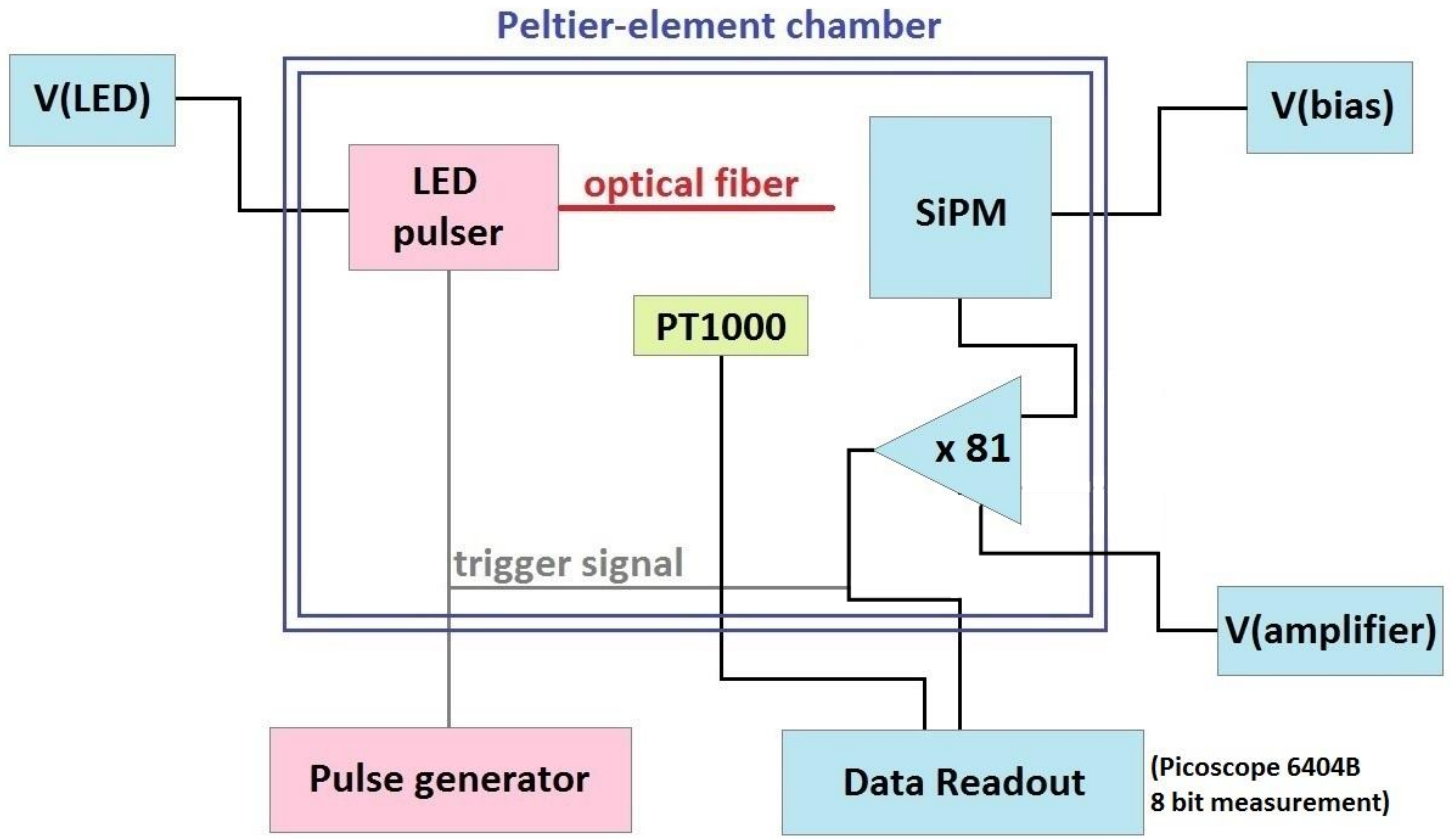
- Silicon Photomultipliers (SiPMs) are photon sensitive devices built from an avalanche photodiode array on common Si substrate
- The gain (G) of a SiPM depends on the temperature (T)
- For a correct signal reconstruction, the temperature dependence needs to be known $\rightarrow$ Gain-Temperature calibration
- Gain can be estimated using well-defined signal from single photons



Schematics of the Gain vs. Temperature measurement

- Optical fibre in front of the SiPM connected to an LED pulser
- Measure SiPM signal from individual photons for gain calibration

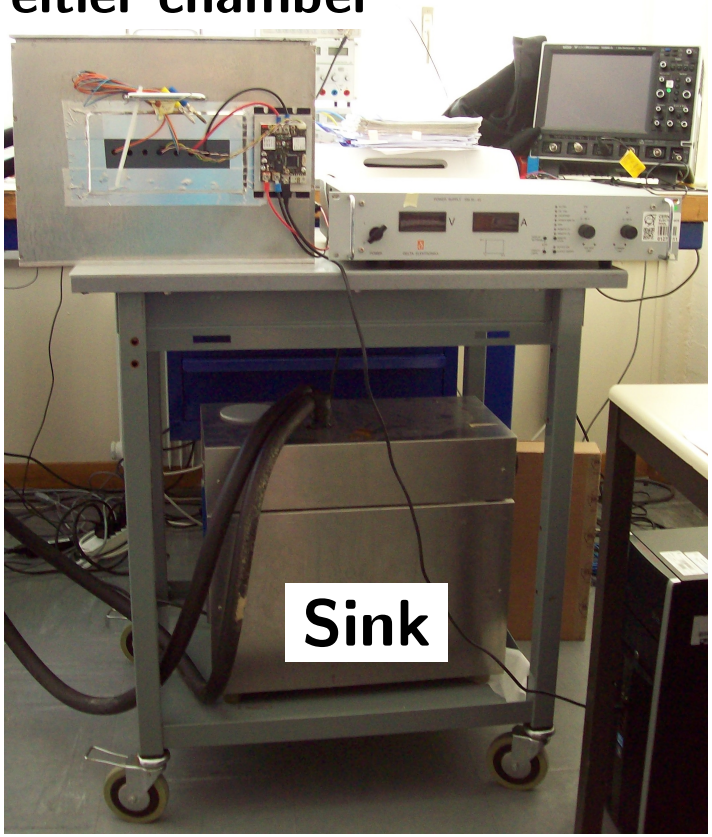
Simplified schematic of the setup for the characterization of the SiPM with the Peltier-element chamber



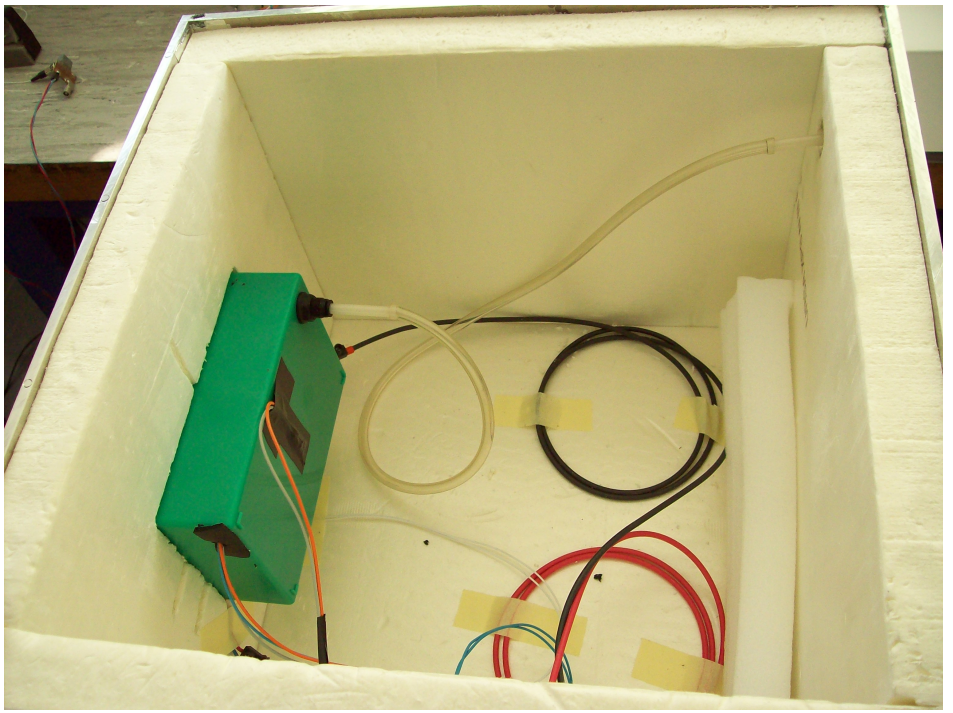
The Peltier-element chamber

- Temperature regulation is done by a thermally isolated Peltier-element chamber with temperature range covering well region of interest [15°C - 30°C]
- The setup (SiPM + pre-amplifier + LED) is placed inside the green box (size: $160 \times 40 \times 105\,\mathrm{mm}^3$)

Peltier chamber

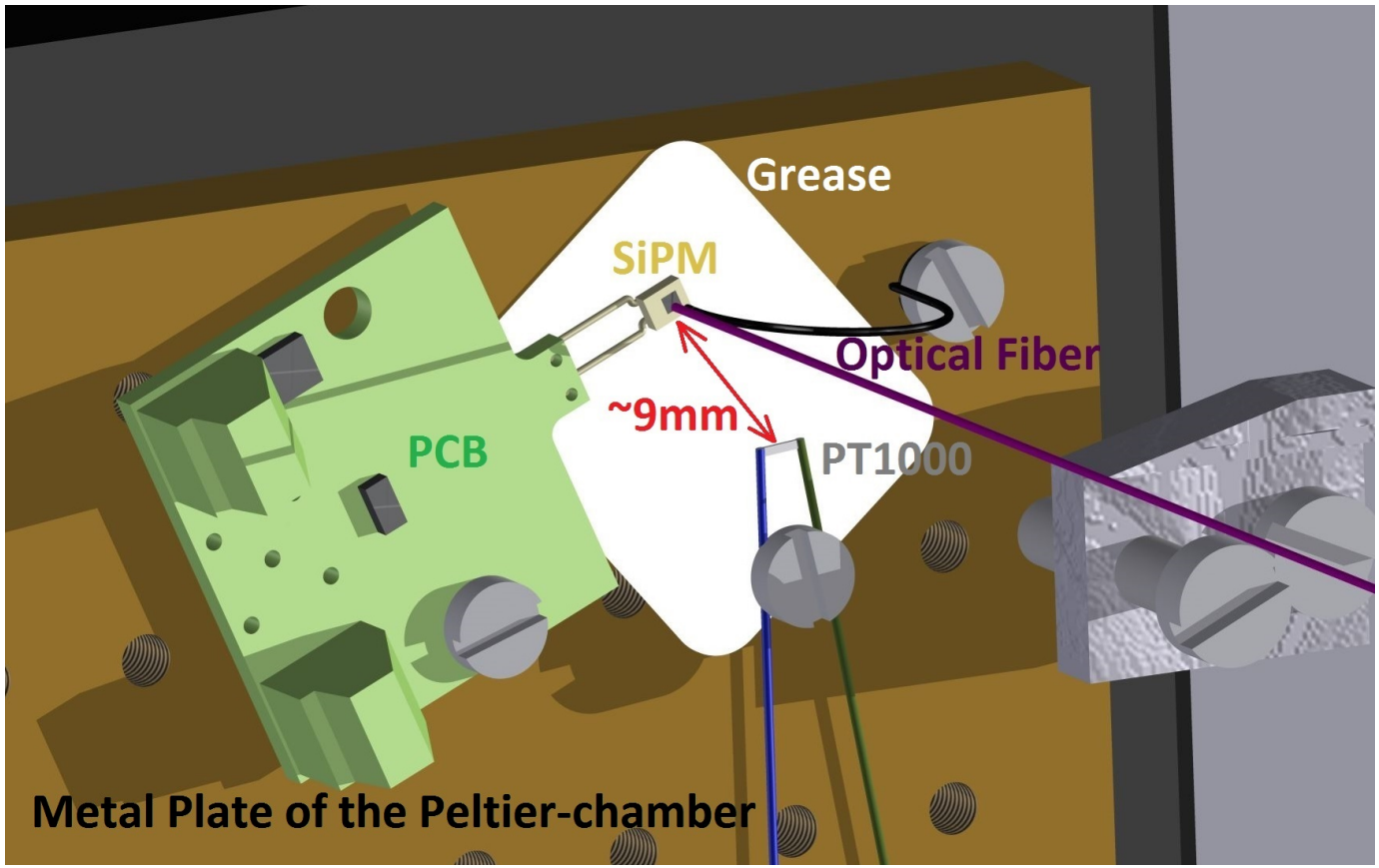


The interior of the Peltier chamber

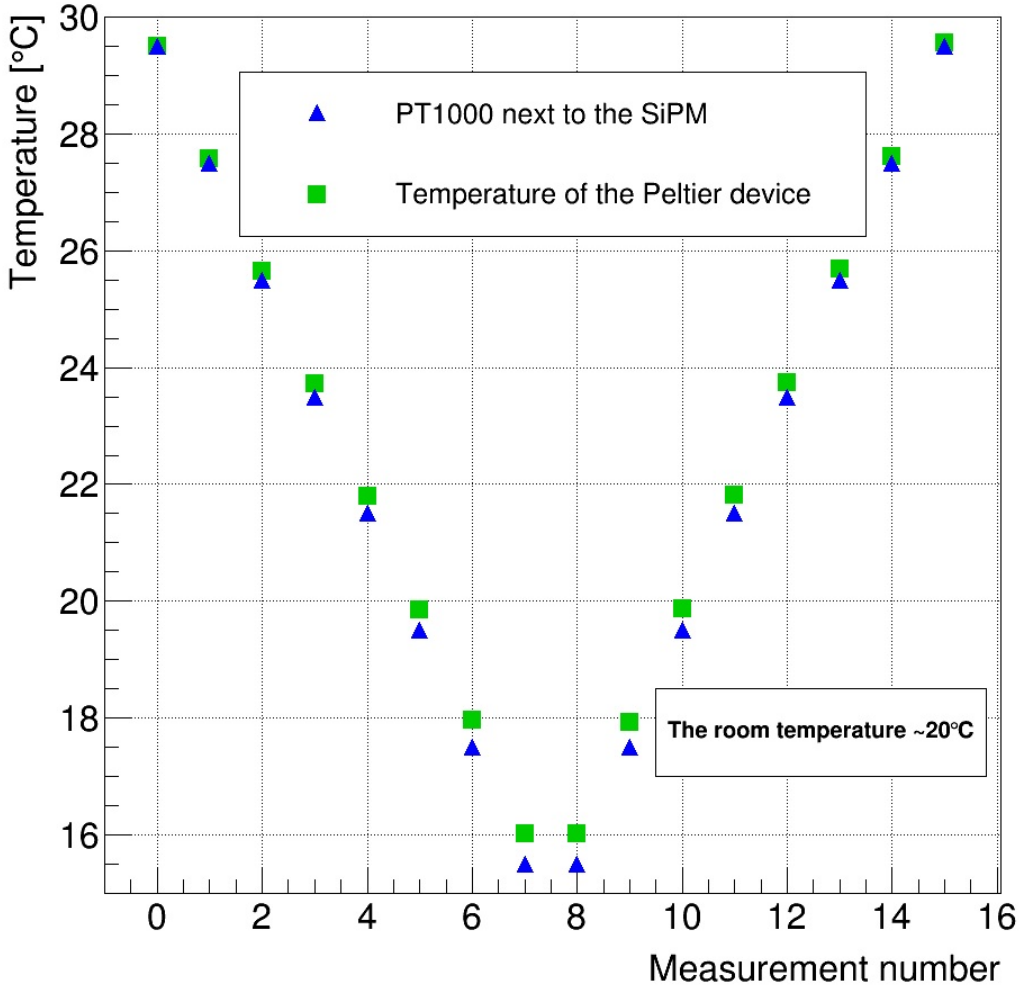


Inside of the Peltier-element chamber

- The temperature of the metal plate inside is adjustable
- Ensure good heat flow between metal plate, SiPM and thermometer (PT1000) by using thermally conductive grease
- The temperature of the SiPM is measured with the PT1000 thermometer
- Temperature of metal plate is measure directly on metal plate

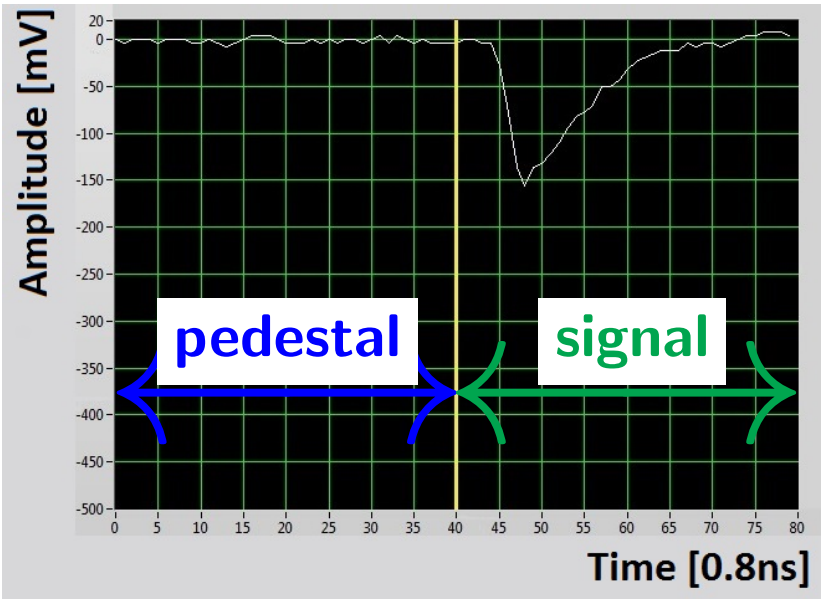


Temperature variation



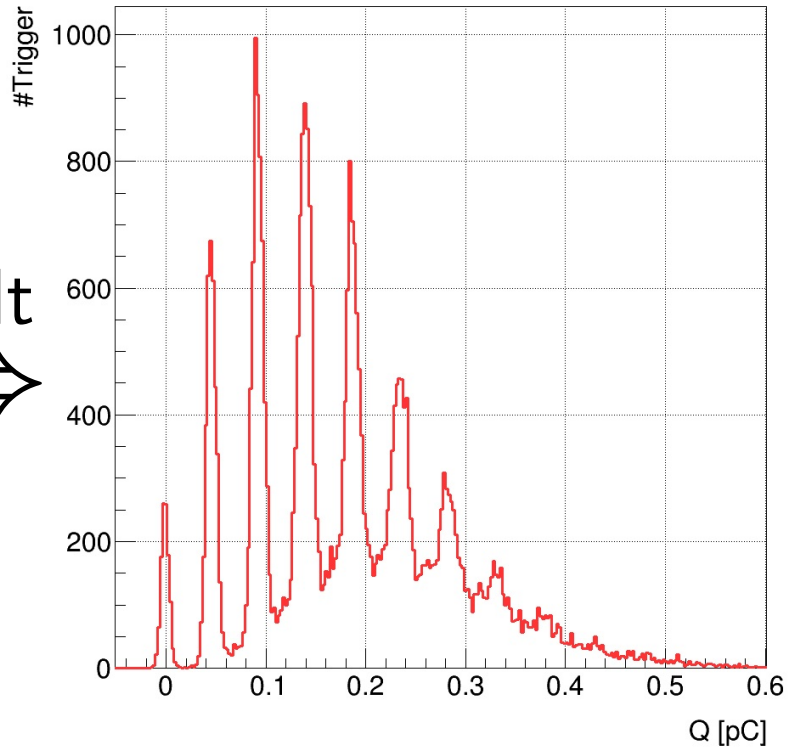
- Scanned a temperature range [15.5°C - 29.5°C] two times
- Measurement time for each temperature 10×50s
- Between two measurements the time to thermally stabilise was ~ 4 min
- $T_{PT1000} - T_{plate} = 0$°C - 0.5°C
- The signal of the SiPM was measured for every temperature value

The method of the charge measurement



Signal-Pedestal

$\int dt \Rightarrow$

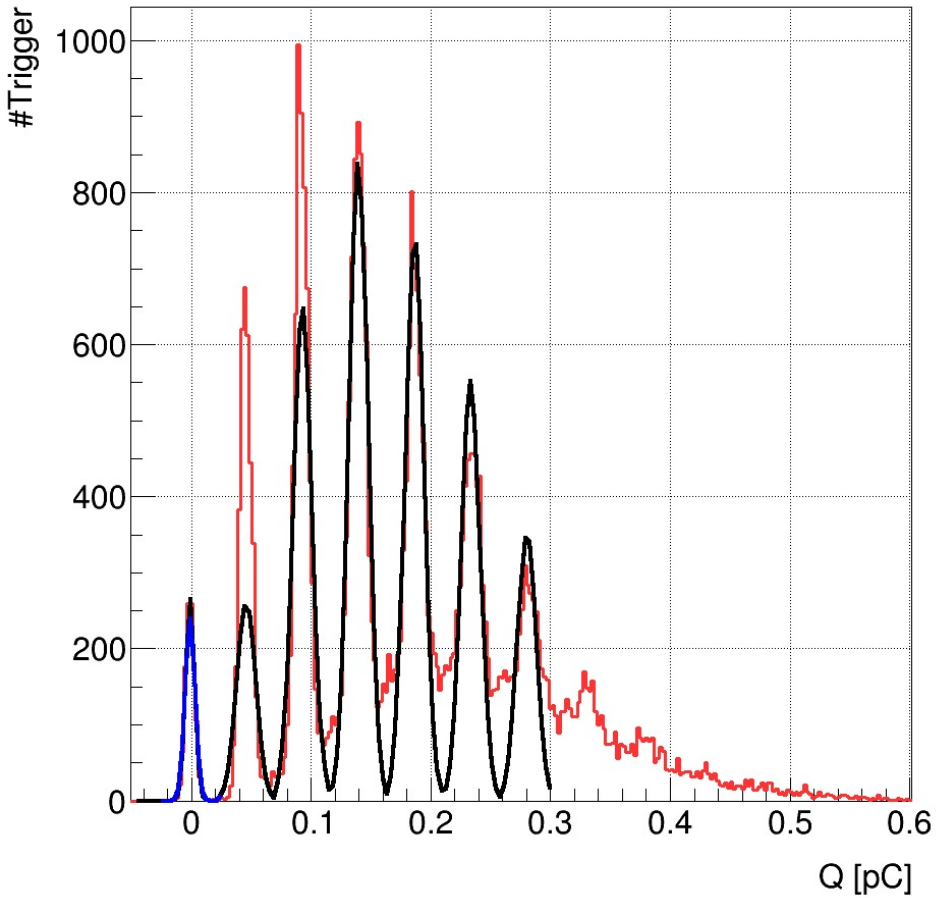


- Two time windows for pedestal and signal measurement
- Convert signal and pedestal response to charge by time integration
- Subtract pedestal from signal event-by-event

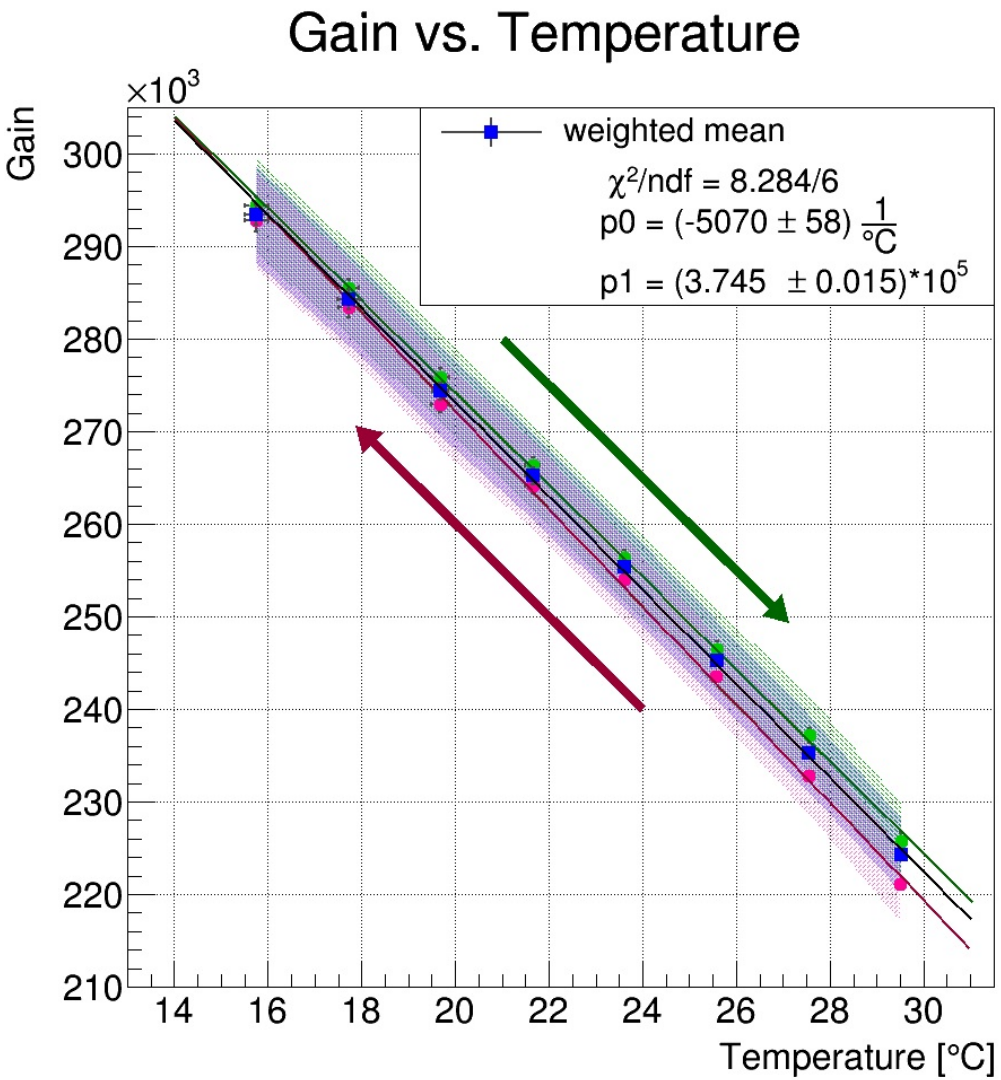
The fitting procedure

- Measure the charge of single photons
- Measure T simultaneously

- Fit as many peaks as possible using separate Gaussian functions with correlated parameters:
  - $\Rightarrow$ for the **noise peak**:
    $i = 0 \rightarrow A_0;\ \sigma_0;\ x_0$
  - $\Rightarrow$ for the **photo electron peaks**:
    $i \neq 0 \rightarrow A_i;\ \sigma_i = \sigma_{i+1};\ x_i = x_0 + i \cdot d$
- d = distance between the peaks
  $\Rightarrow$ Gain (=G)
- Repeat the method for every T value
  - $\Rightarrow$ G – T dependence



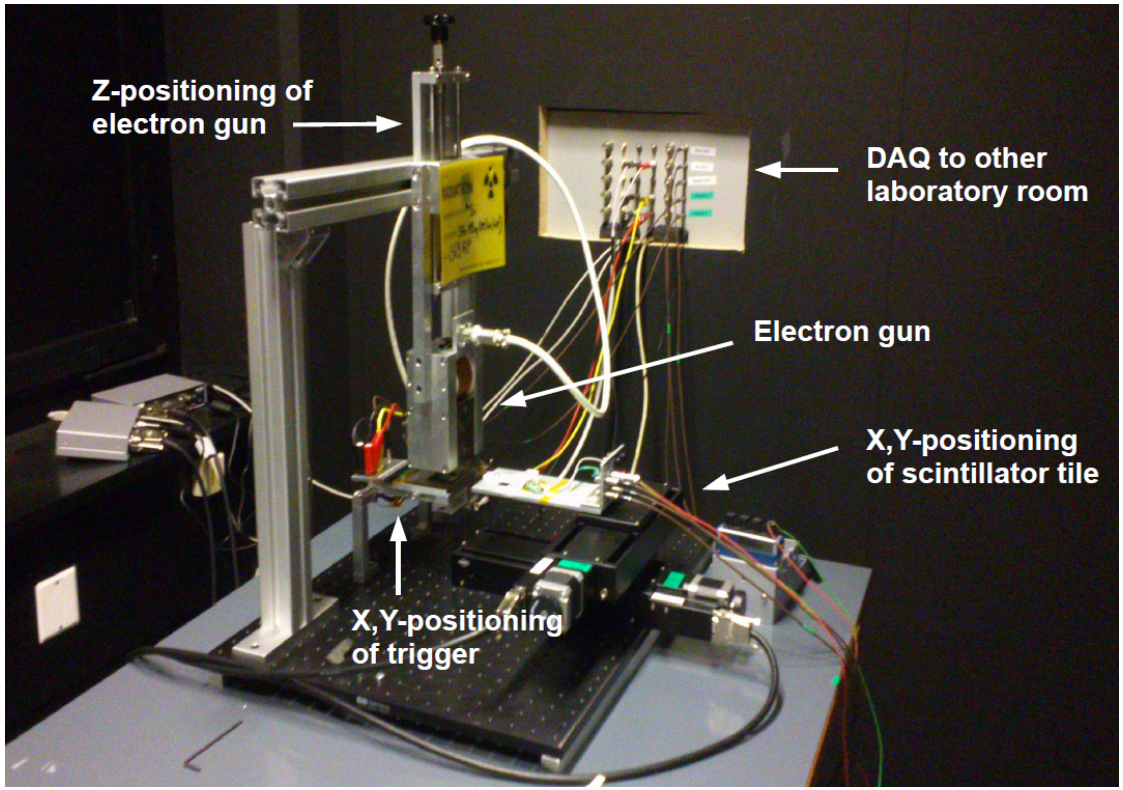
G - T calibration results

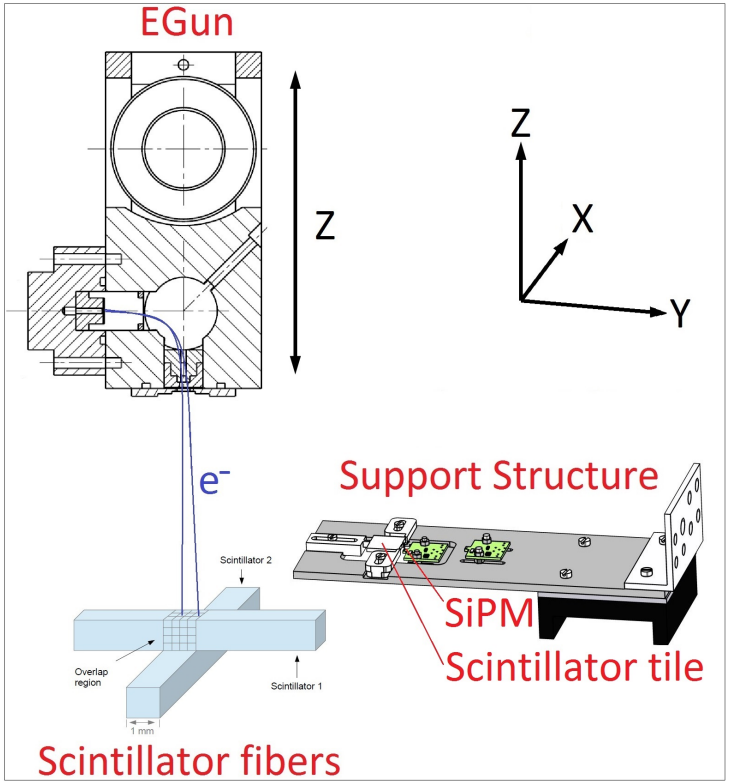


- Scanned the temperature range two times in opposite direction
- Fit G – T with linear function: $G(T) = p_0 \cdot T + p_1$
- Stable results within $\sim \pm 2\%$ when changing N_{bins}, N_{peaks}, time window, measurement range, LED settings
- Data sets agree within the uncertainties
- Next steps:
  - $\Rightarrow$ additional studies of the temperature stabilisation of the SiPM
  - $\Rightarrow$ optimise fit function

Results of the scintillator tile scans

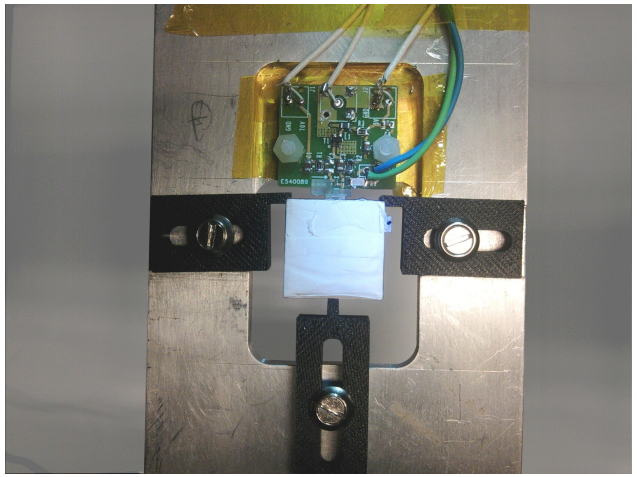
The experimental setup for tile measurements at CERN



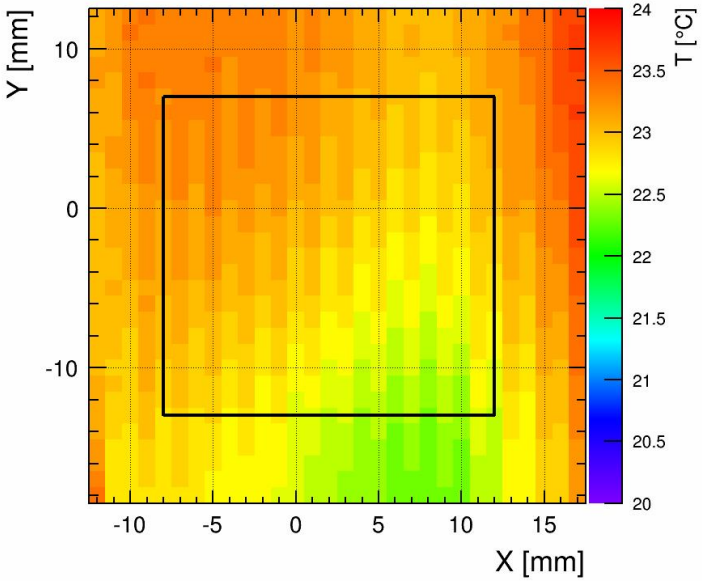


Immediate environment of the scintillator tile

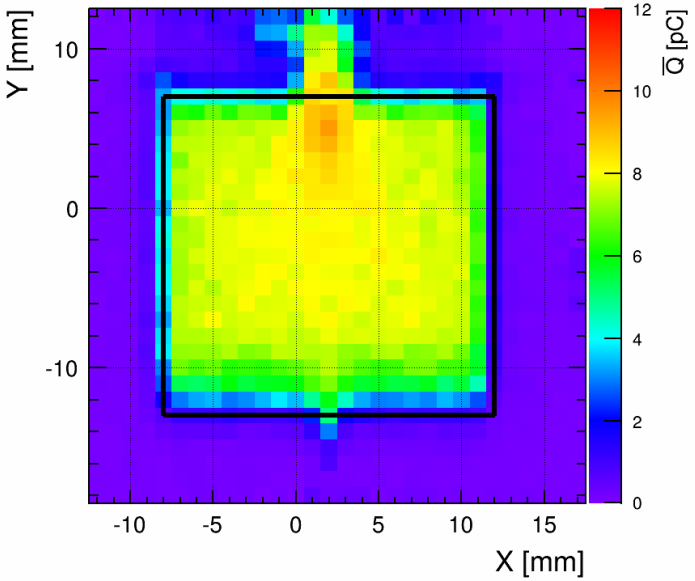
- Use tile support structure with low material close to the tile to avoid signal from stray electrons in support structure in the $\overline{Q}$ map
- 1 mm step size, 100 s measurement time for each step
- correct the signal to $T_{ref} = 19$ °C



Temperature map of a tile scan

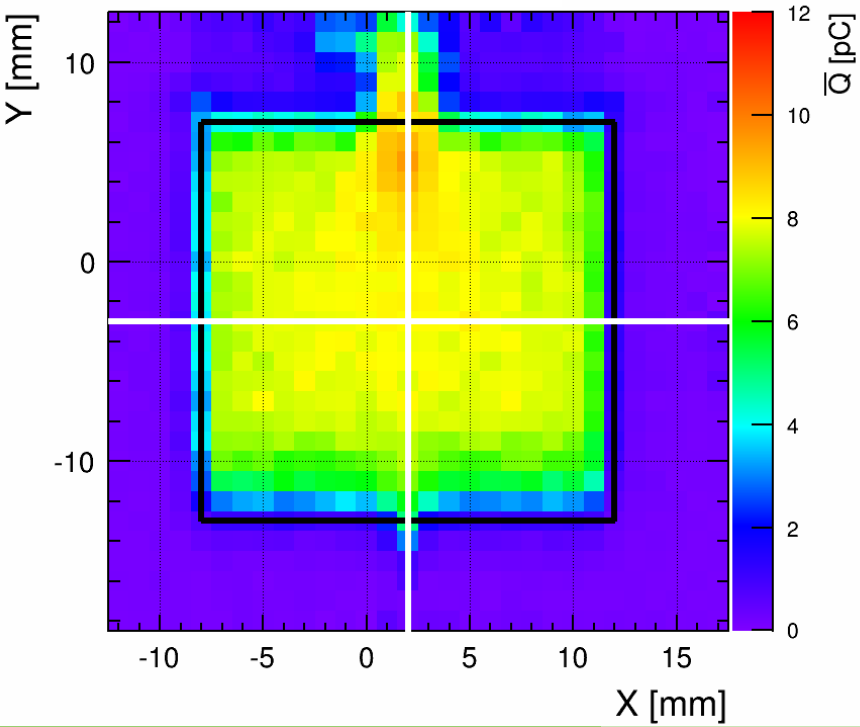


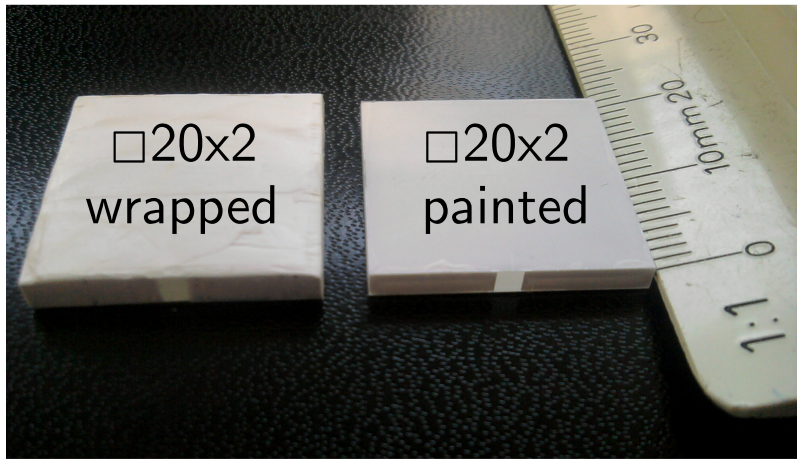
$\overline{Q}$ map of a scintillator tile

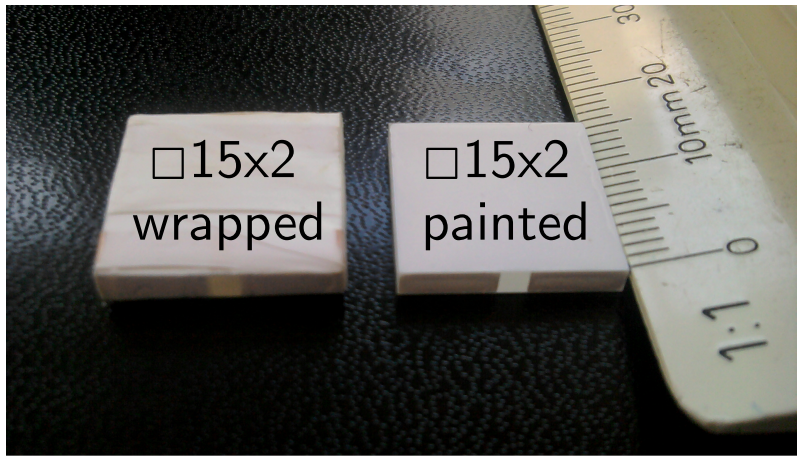


Comparison of different tiles

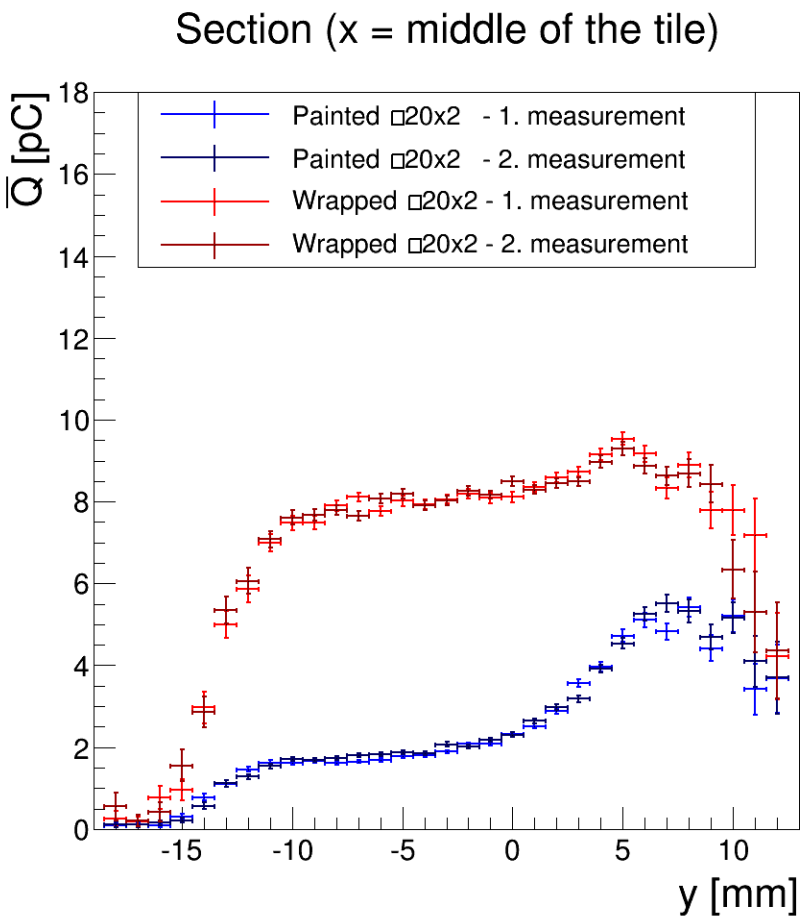
- Tested scintillator tiles:
  - ⇒ coating:
    - wrapping (3M foil)
    - reflection paint
  - ⇒ size:
    - □20x2 mm^3
    - □15x2 mm^3

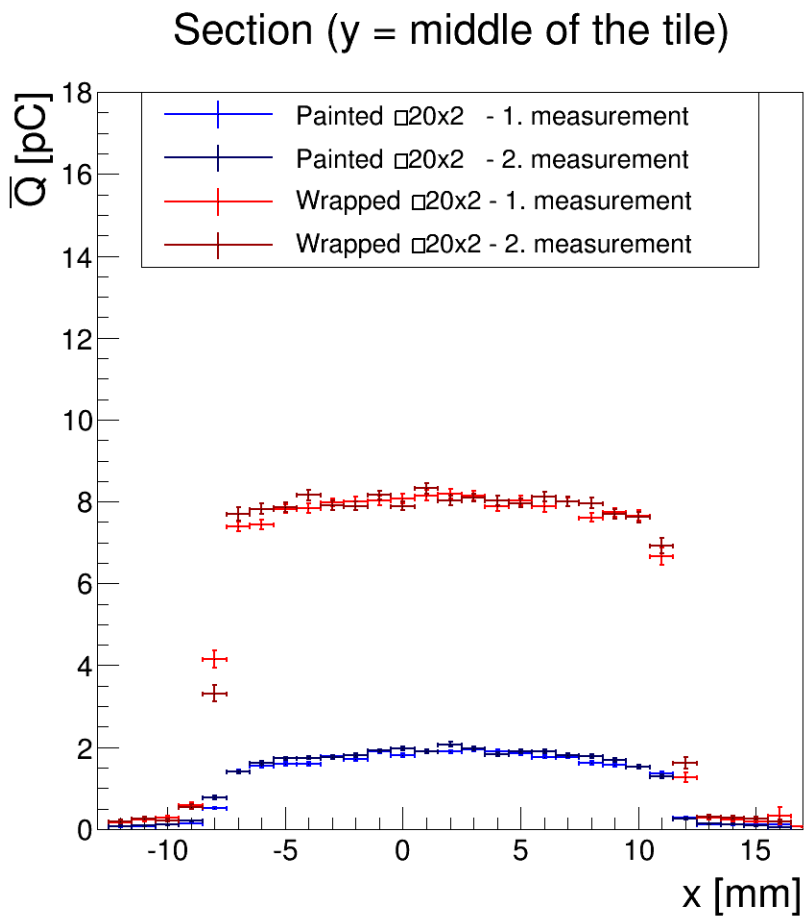






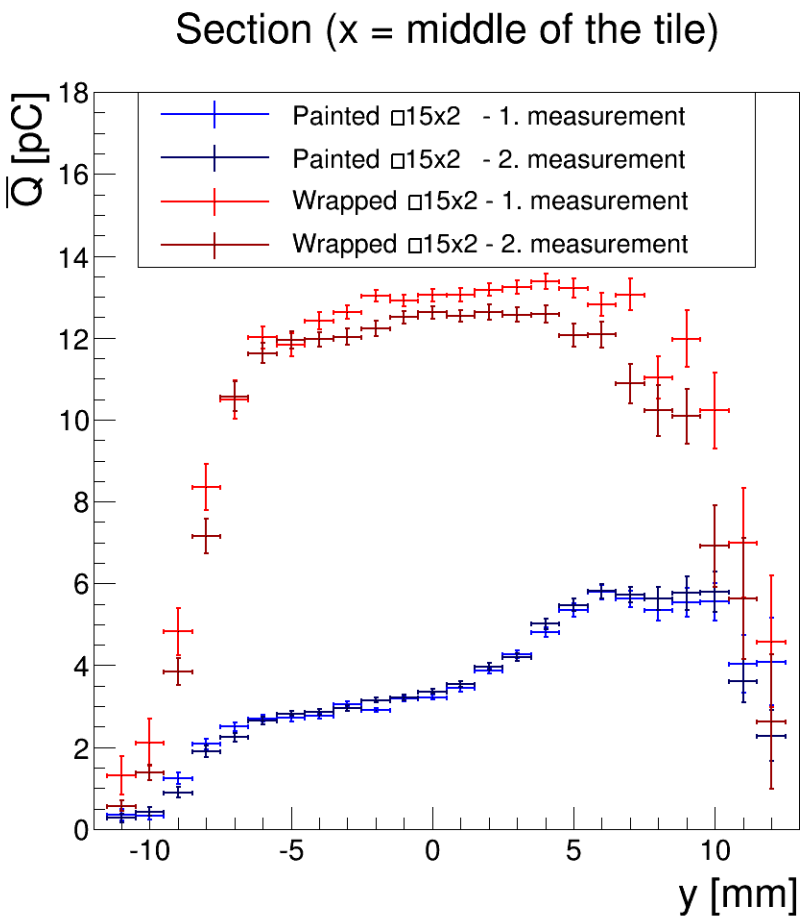
Slices of the □20mm tiles

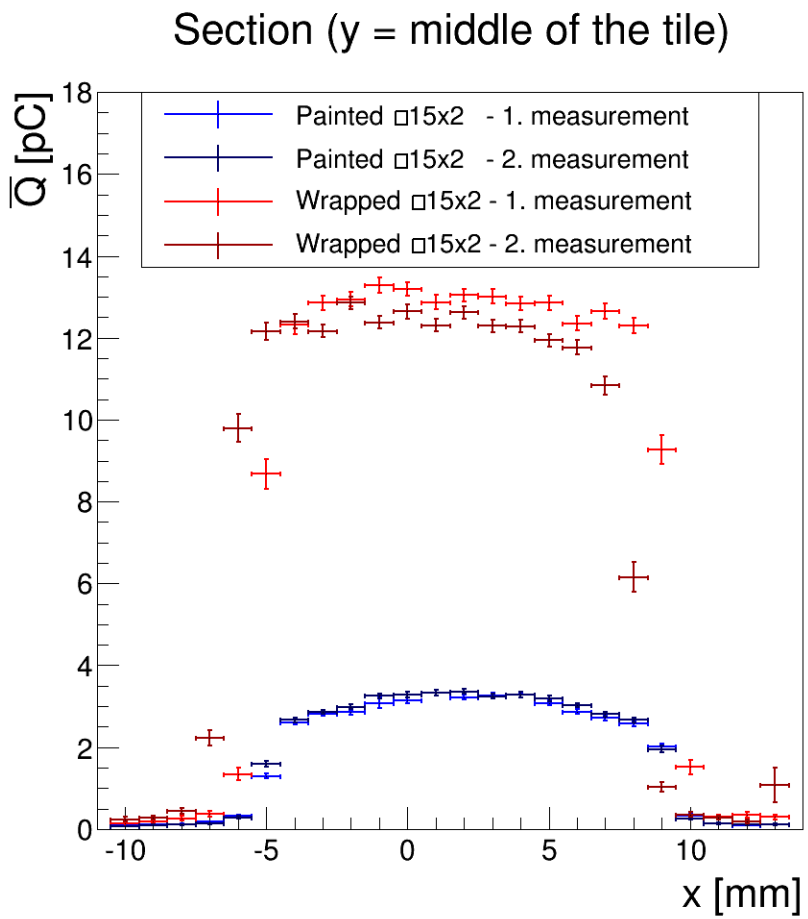




- The light yield of the wrapped tile is ~ 4 times higher than for the painted tile
- $Y\overline{Q}$ section: peak at the SiPM $X\overline{Q}$ section: uniformity
- Peak at SiPM is smaller for wrapped tile $\Rightarrow$ more uniform in Y direction
- The measurements agree within uncertainties

Slices of the □15mm tiles

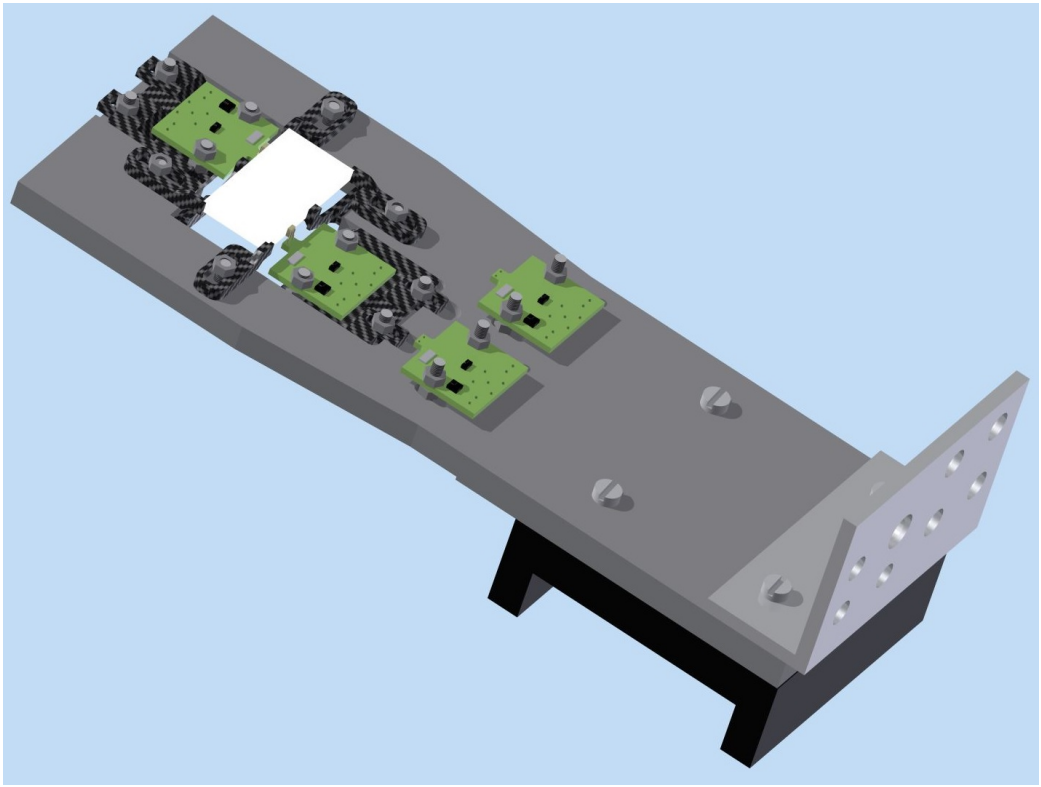


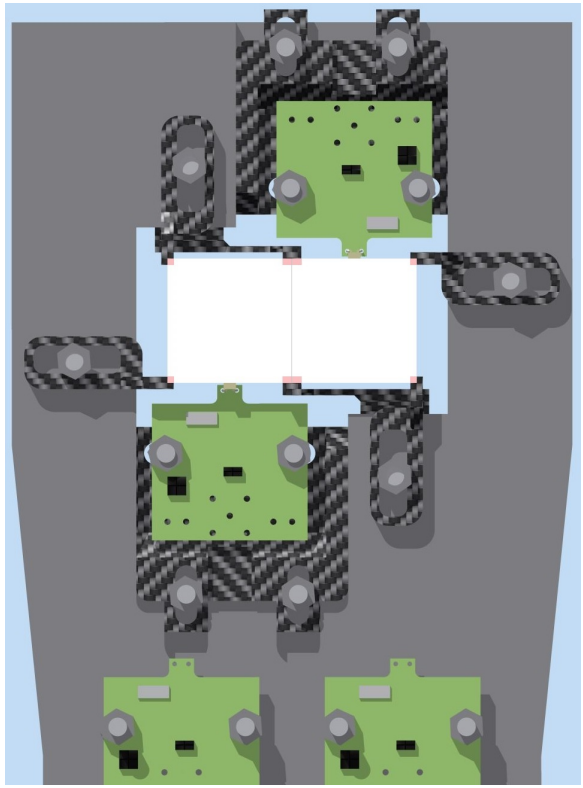


- Same light yield difference as observed for the □20 mm tiles
- Peak at SiPM is smaller for wrapped tile ⇒ more uniform in Y direction
- The light yield of the □15 mm tiles is ∼ 1.5 times higher than for the □20 mm tiles. This effect is understandable due the aspect ratio of the tiles with different sizes

Outlook:
Multi-tile scans

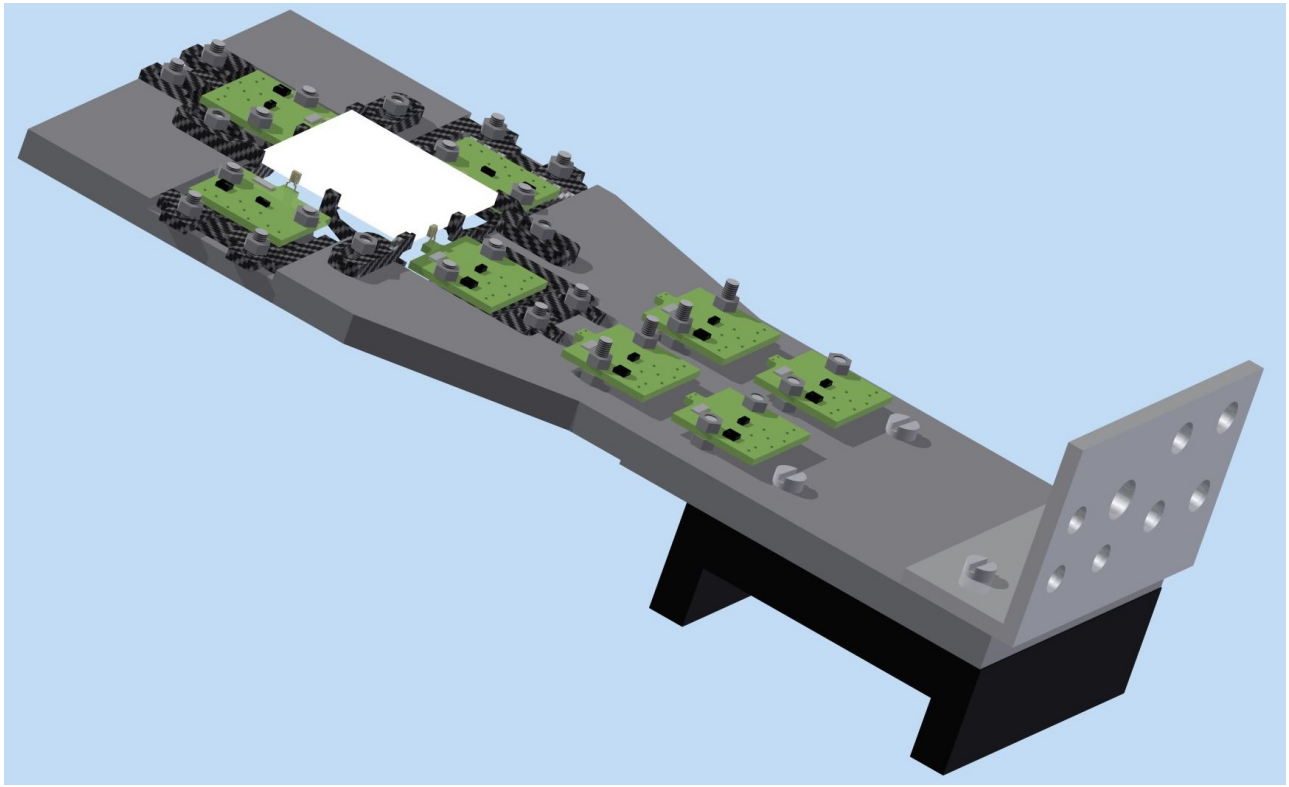
Outlook: Tile scans with 2 tiles

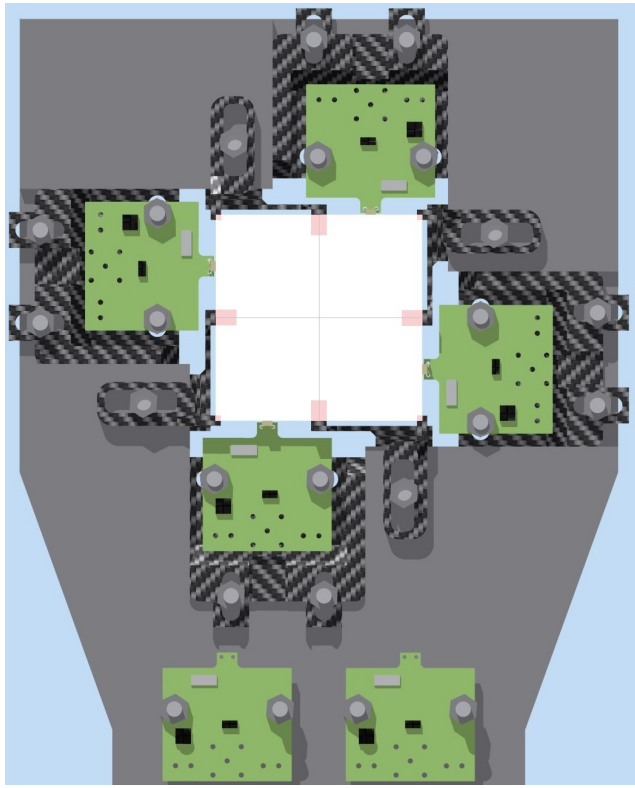




- Multi-tile setup for investigation of edge effects
- Setup allows for investigation of different tile sizes ($20\text{x}20\,\text{mm}^2$, $15\text{x}15\,\text{mm}^2$, $10\text{x}10\,\text{mm}^2$)
- The setup will be available imminently (mid-September 2015)

Outlook: Tile scans with 4 tiles





- Setup allows for investigation of different tile sizes (20x20 mm^2, 15x15 mm^2, 10x10 mm^2)
- The setup will be available imminently (mid-September 2015)

Summary and Outlook

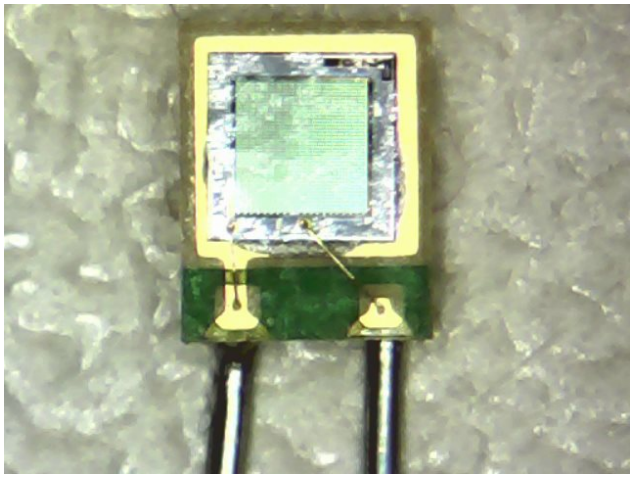
- Gain-temperature calibration
  - ⇒ Controlled temperature with Peltier-element chamber [15.5℃- 29.5℃]
  - ⇒ Ensured good heat flow between all components using thermal grease
  - ⇒ Calibrated gain as a function of temperature and studied systematic uncertainties
- Tile scans
  - ⇒ Reduced effect of stray electrons from tile support in the tile-scan setup
  - ⇒ Provided the possibility to test tiles of different sizes
  - ⇒ The light yield of the wrapped tile is ~ 4 times higher than for the painted tile independent of the size
  - ⇒ The light yield of the □15mm tiles is ~ 1.5 times higher than for the □20mm tiles independent of the coating
- Outlook
  - ⇒ Multi-tile scans with 2 or 4 tiles of different sizes
  - ⇒ Study edge effects
  - ⇒ Compare different SiPMs
  - ⇒ Test reproducibility/systematic uncertainties of tile scans

Thank you for your attention!

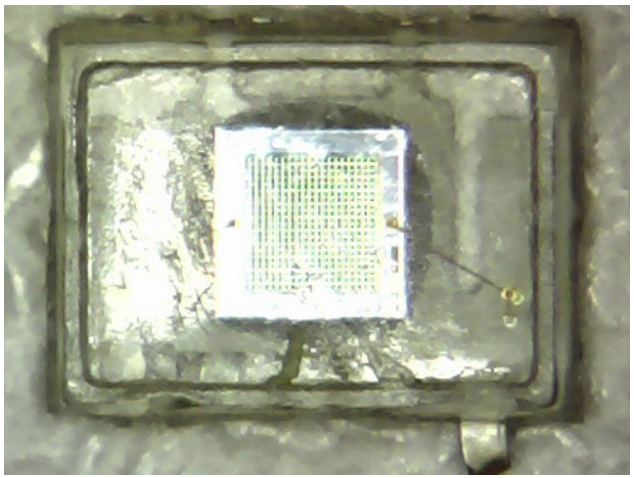
Backup

Technical information about the introduced measurements

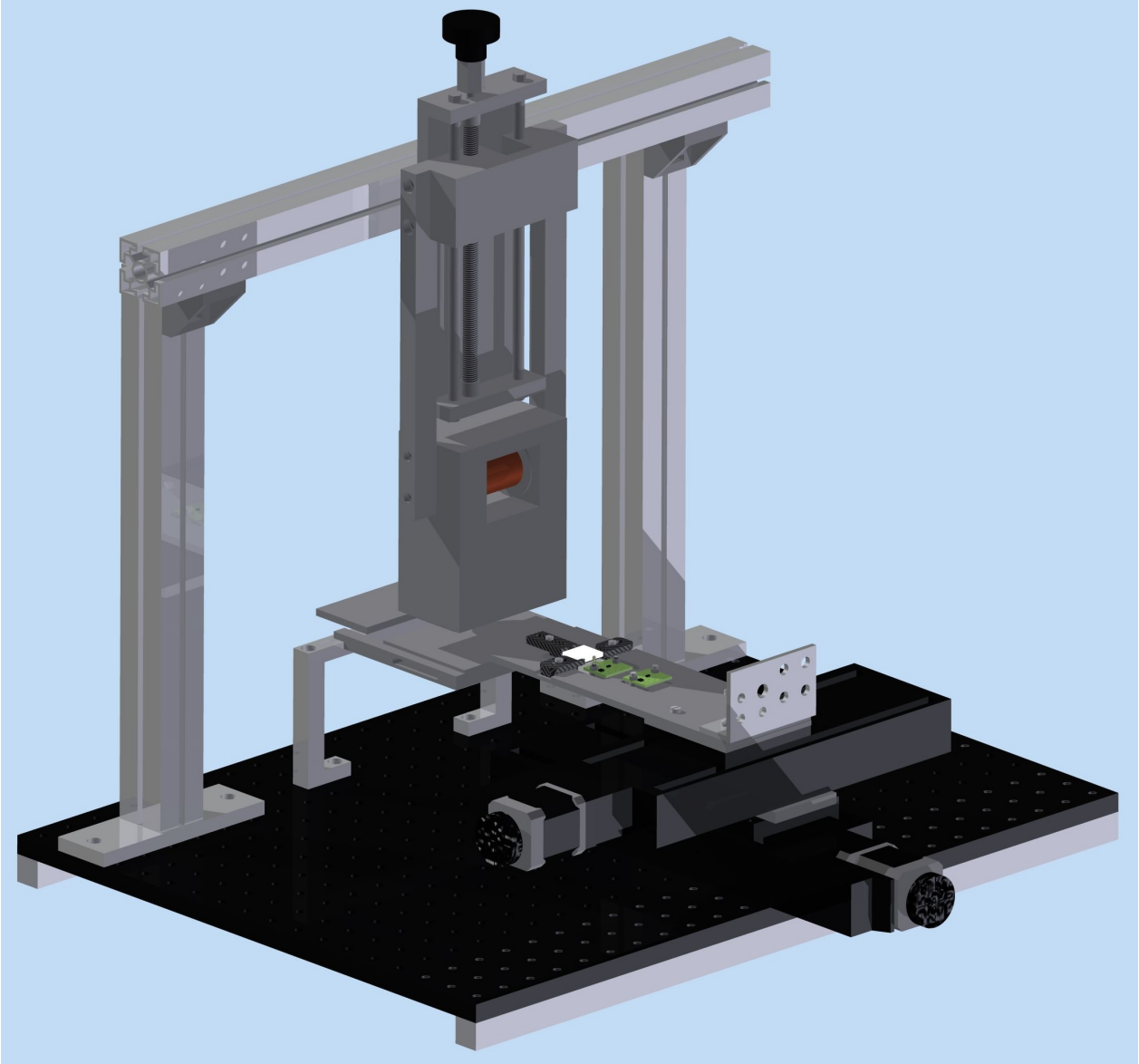
- The SiPM used for the Gain vs. T calibration:
  - ⇒ Hamamatsu MPPC 25 µm pitch
    1x1 mm2, 1600 pixels
    Type No.: S10362-11-025P
    Serial No.: 225



- The SiPM used for tile scans:
  - ⇒ Hamamatsu MPPC 50 µm pitch
    1x1 mm2, 400 pixels
    Type No.: S10943-8584(X)
    Serial No.: 11770

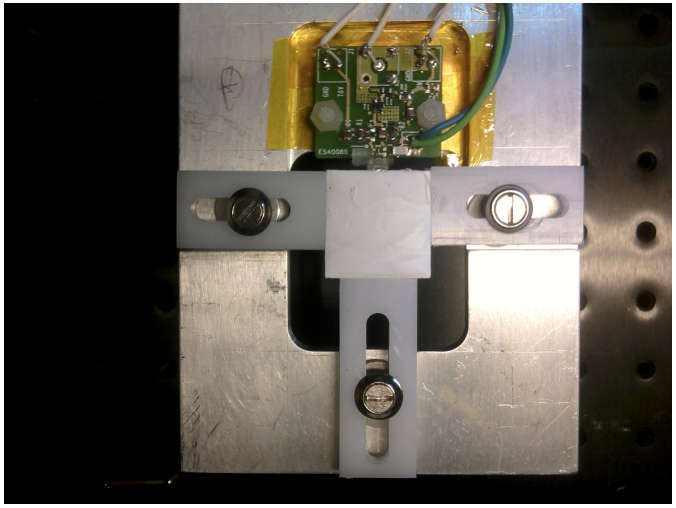


Rendered setup in September 2015

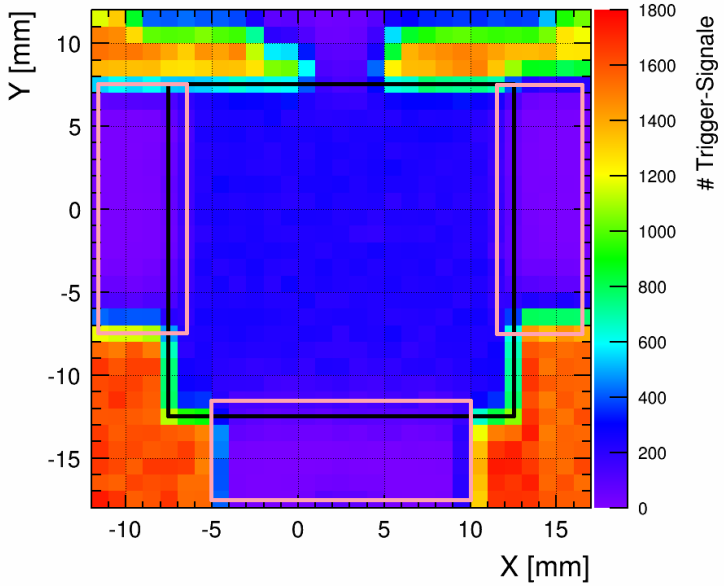


Setup at November 2014

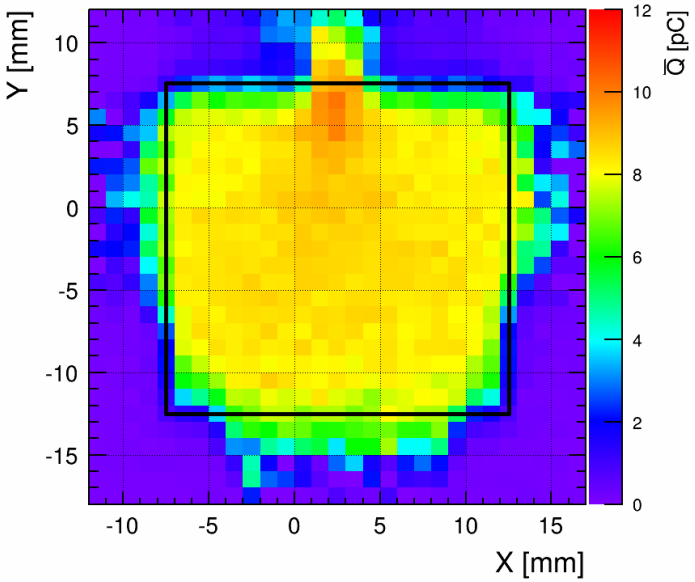
- At the beginning:
  use "high-material" tile holders to hold the scintillator in place
- The #Trigger map shows the transparency of the support structure
- Even if the electron beam does not hit the scintillator, stray particles produced in the tile holders leak into scintillator resulting in a measurable signal



#Trigger map of a tilescan



$\overline{Q}$ map of a scintillator tile



Inside view of the Peltier-element chamber