# SiPM and Scintillator Studies

## at MPP Munich

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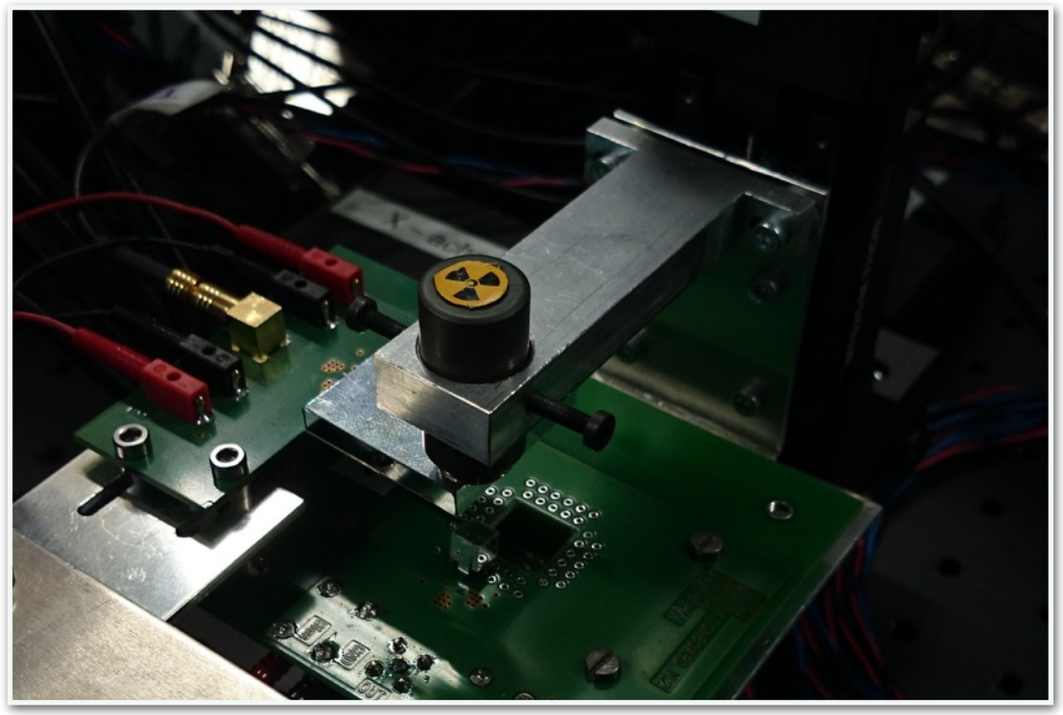
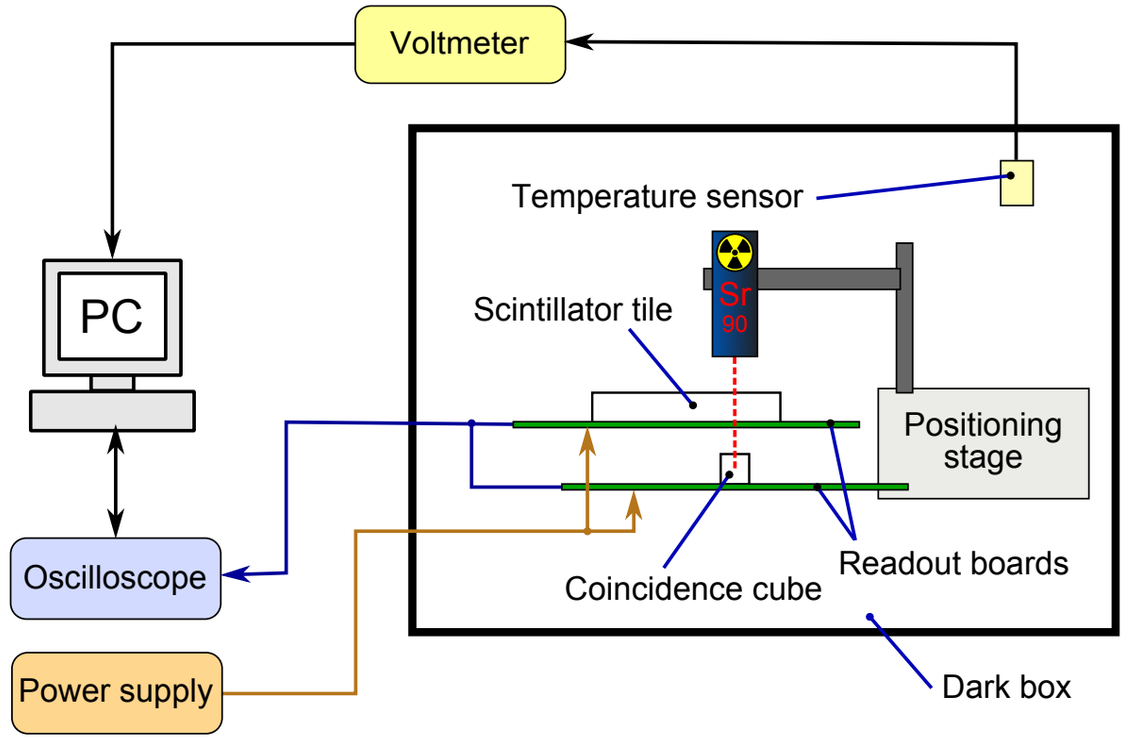
# Topics

- Tile Scanner setup and simple simulation
- Low noise SiPMs (MPPCs)
- Optical tile separation for mega-tiles

# Tile scanner setup

- Setup to test the uniformity of the response of scintillator tiles
  - Sr90 source (13.9 MBq): electrons up to 2.27 MeV
  - Trigger cube (5x5x5mm2 scintillator on a SiPM) and source connected to a positioning stage
  - Tile with readout board (amplifier and SiPM)
  - All inside a light tight box with a temperature sensor
  - Readout the two SiPMs with a picoscope

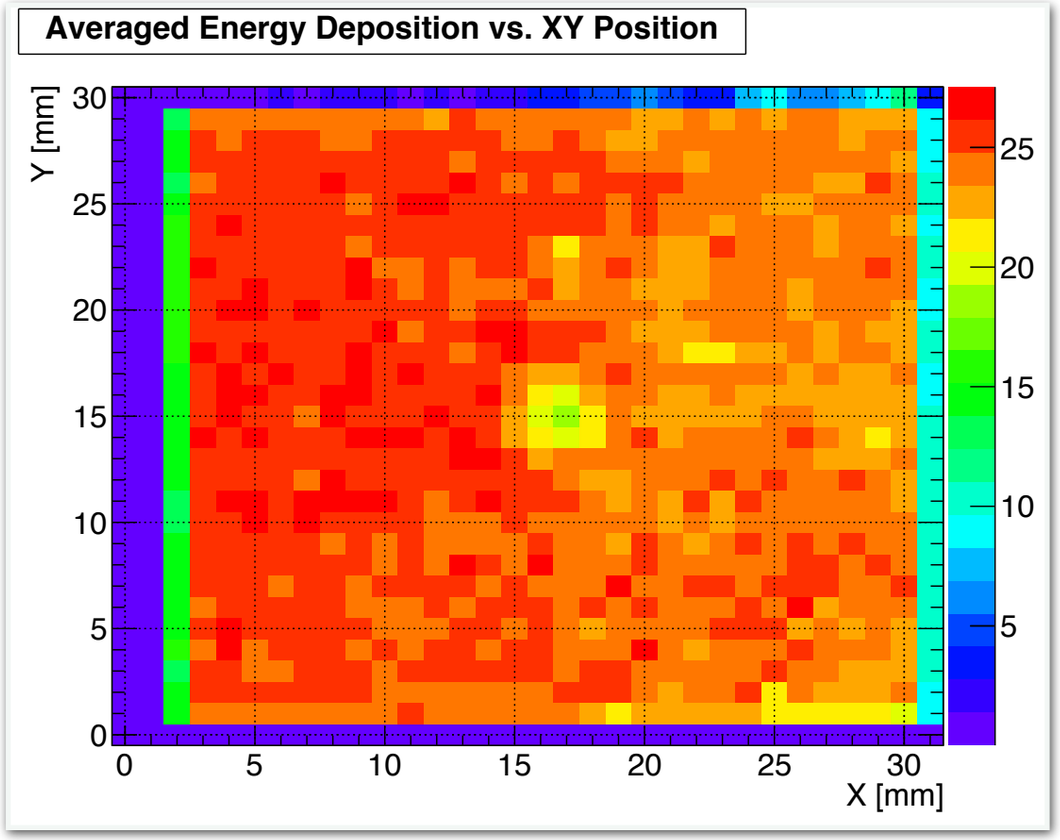




# Scan results

- Scan over the entire surface of the tile and collect 1000 signals (wave forms) at each position that pass the trigger requirement of a signal of at least 6 p.e.
- Scanned tiles: tiles from Mainz with double dimple for bottom mounted SiPM
- Step sizes of either 0.5 mm (32x32) or 1 mm (64x64)
- data processing based on T3B waveform analysis, intrinsic temperature correction through the recorded 1 p.e. waveform

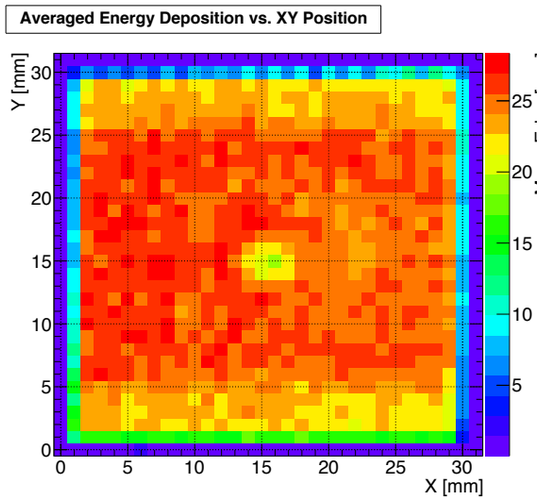
Apparent non-uniformity; but the tile is uniform, a 180 degree turn gives a similar result



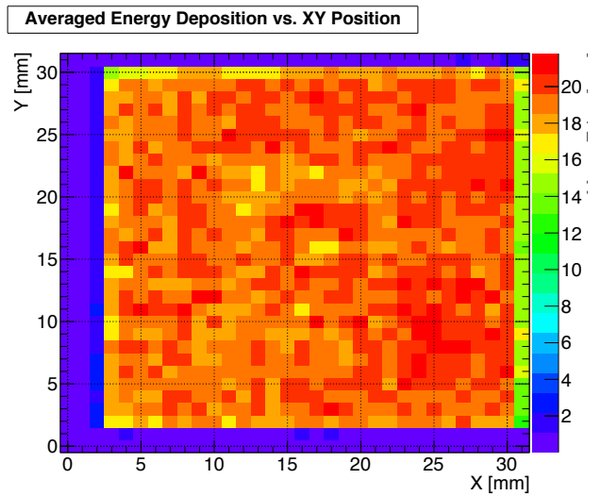
# Scan results

- Each measurement point normalised by the number of recorded wave forms shows effects dependent on the setup

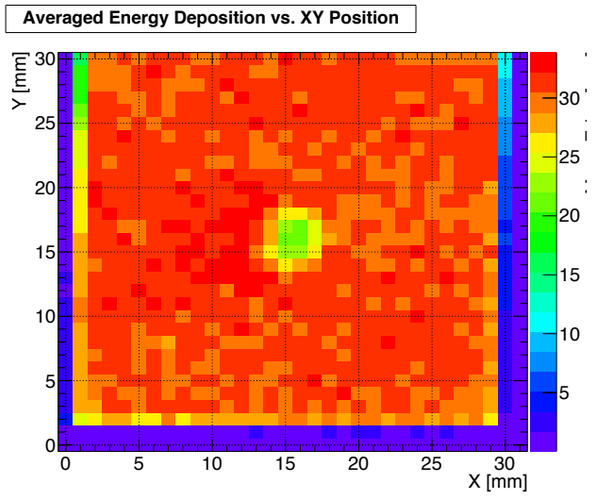
**Extra material is visible**




**Tilting of the tile is visible**




**Trigger cube closer**




- Normalising by the number of events with a signal in the tile removes these effects
- They are caused by the dark noise from the trigger cube

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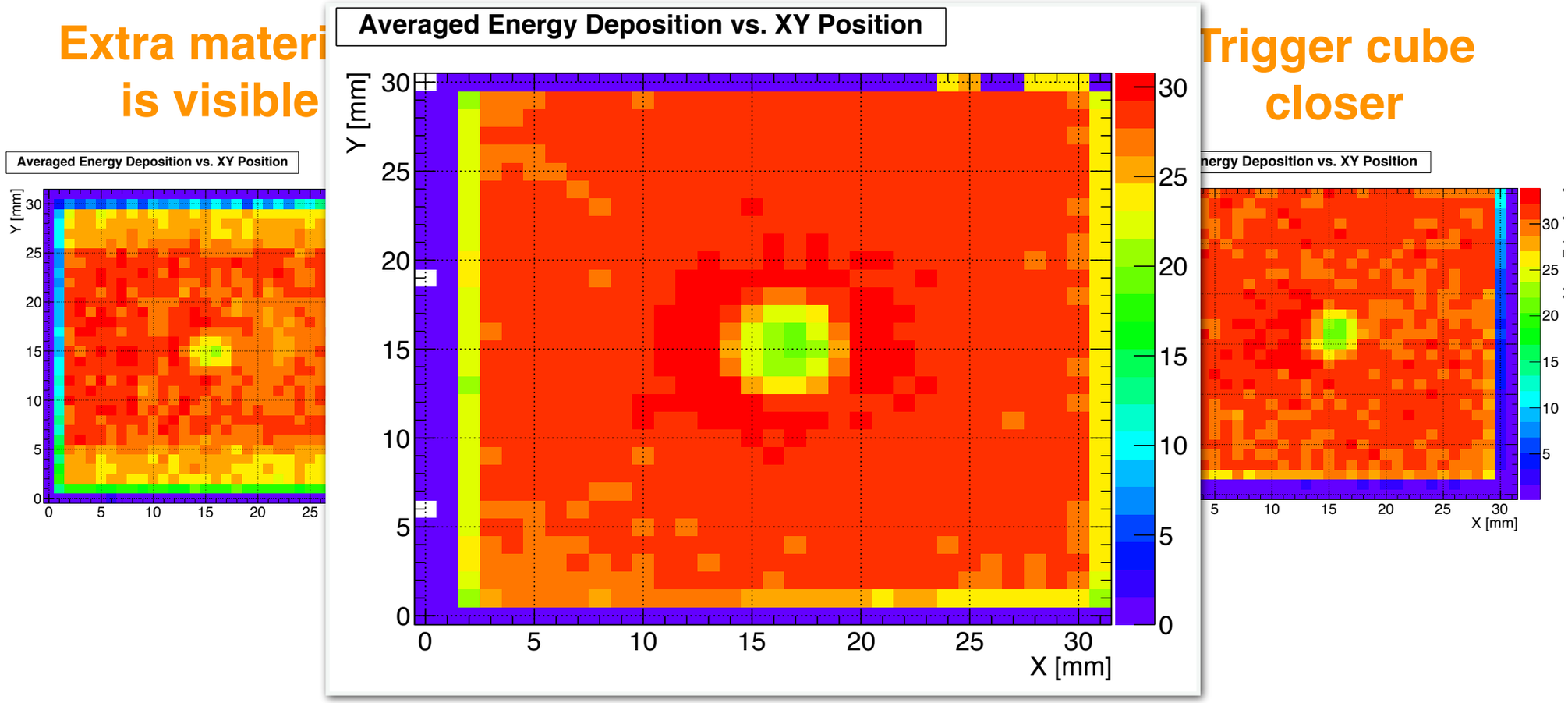


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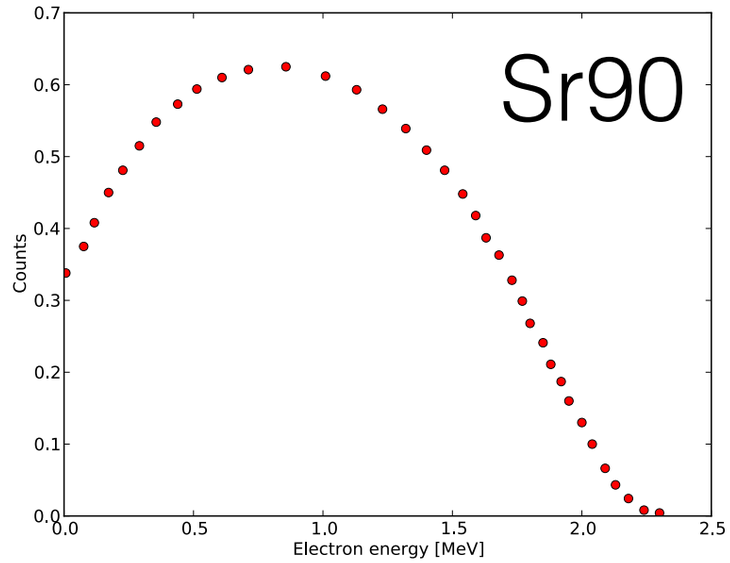
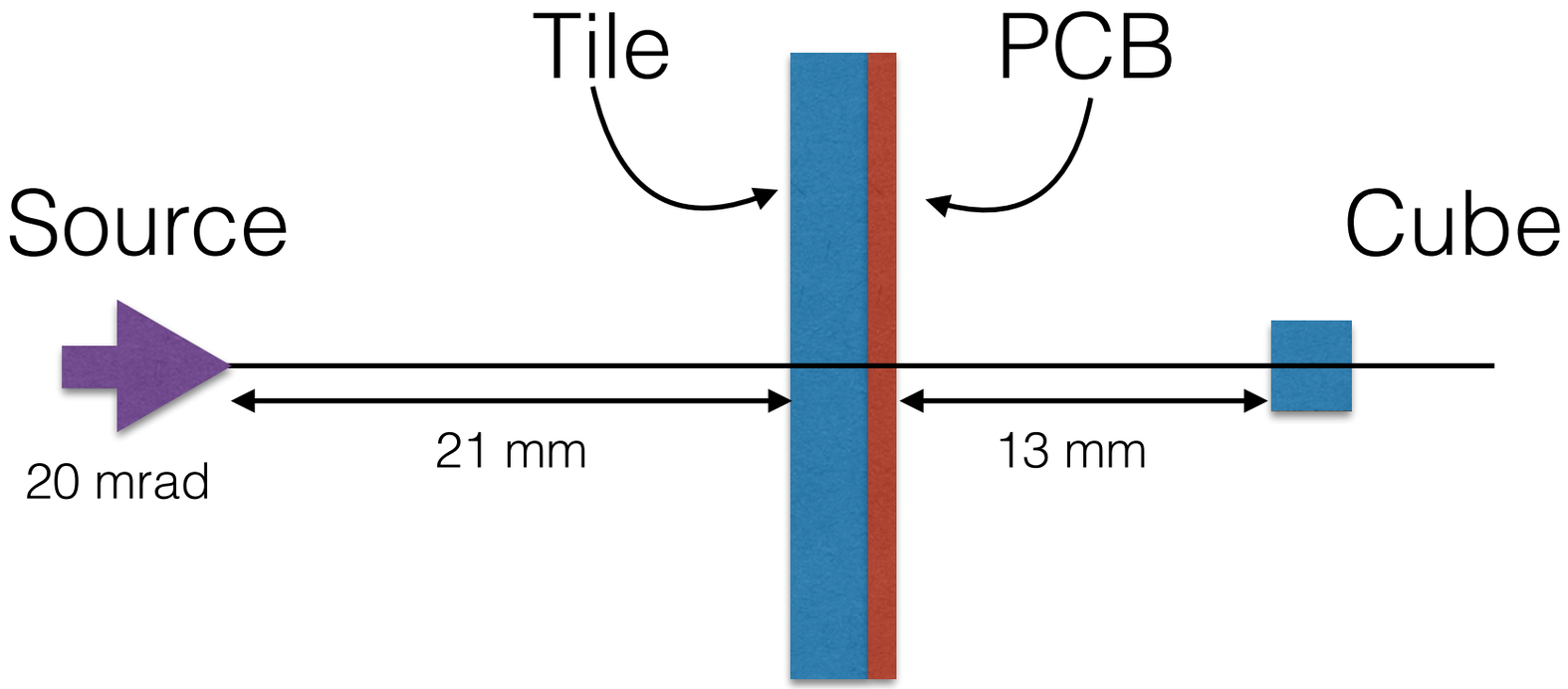
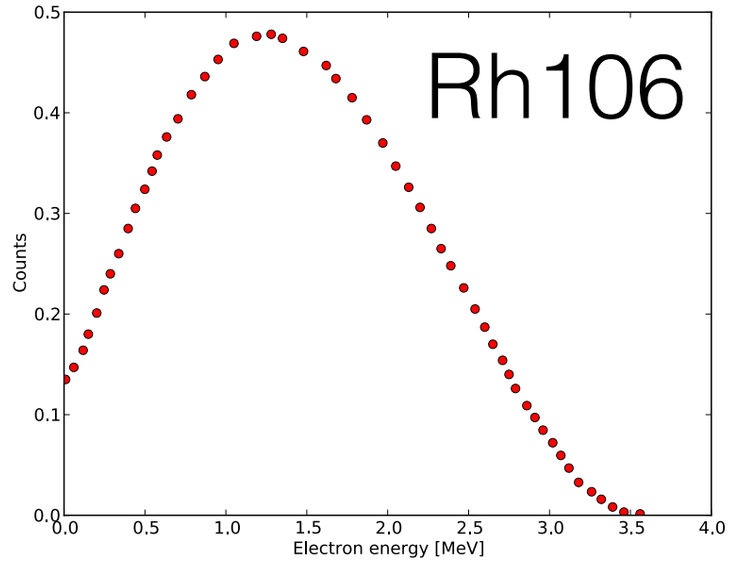
- They are caused by the dark noise from the trigger cube

# Simple Geant4 simulation

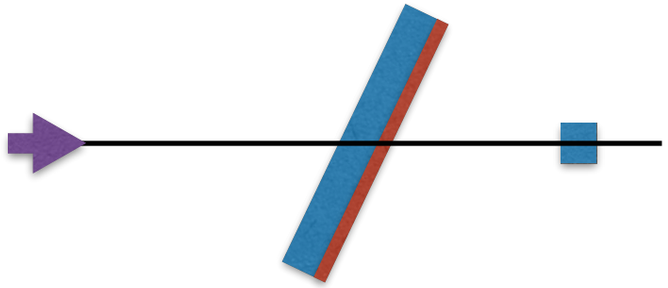
- In order to better understand the sensitivities in the scanning setup and what would improve the setup started a simple simulation
- Input spectrum for a Sr90 and a Rh106 source

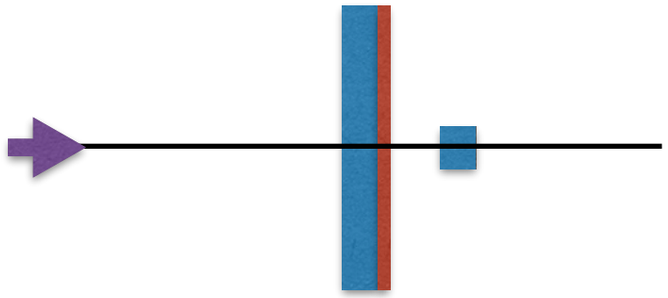


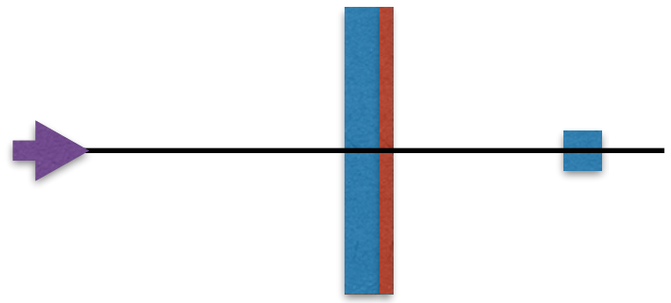



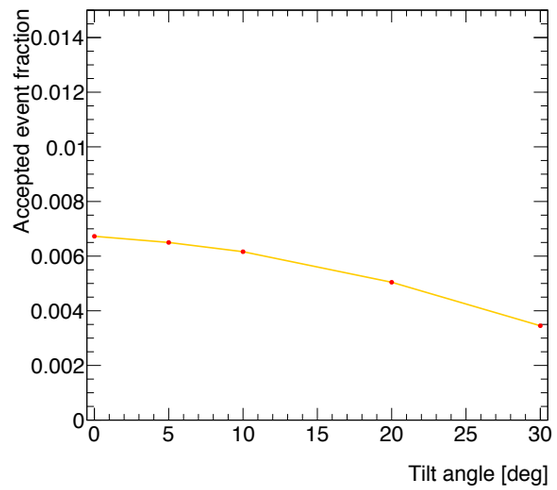



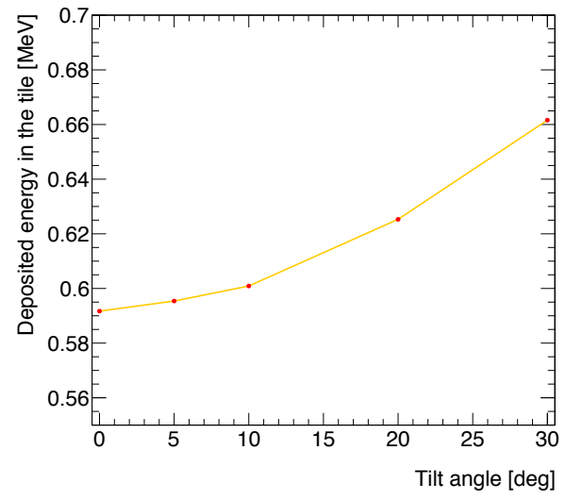
# Simulation results

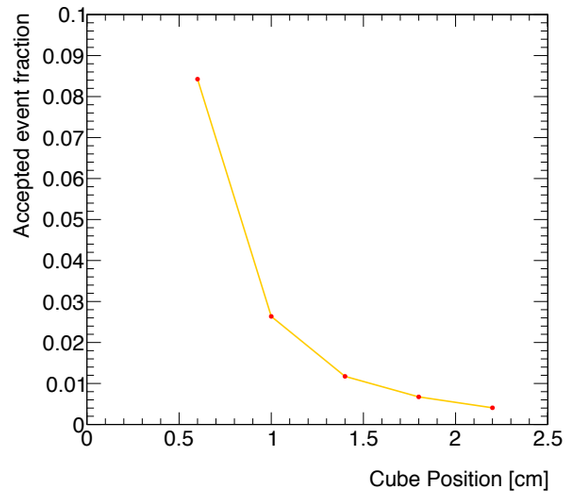


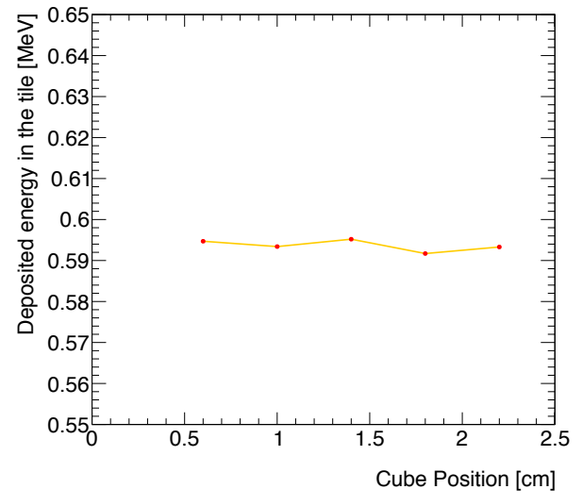


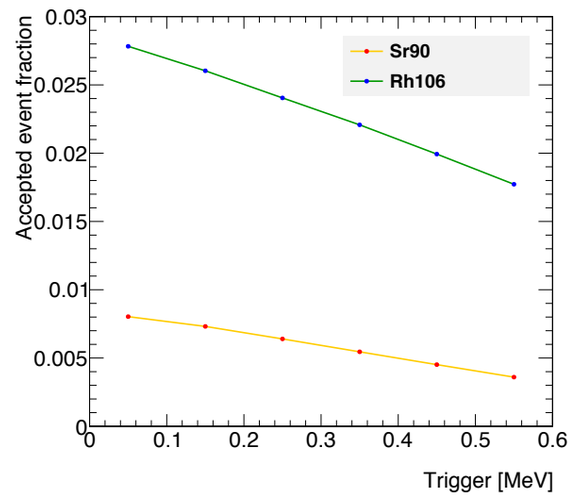


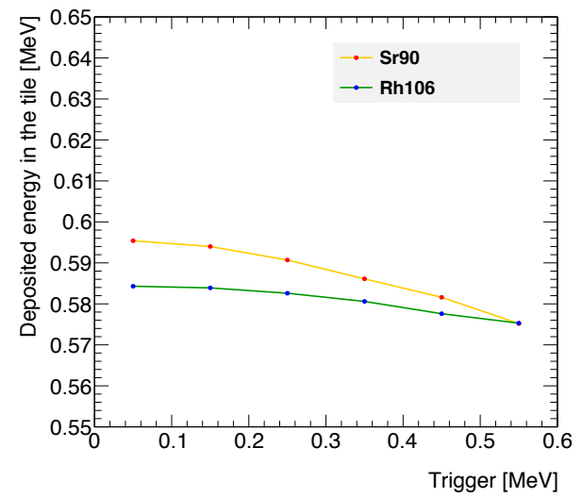


# Improvements to the scanning setup

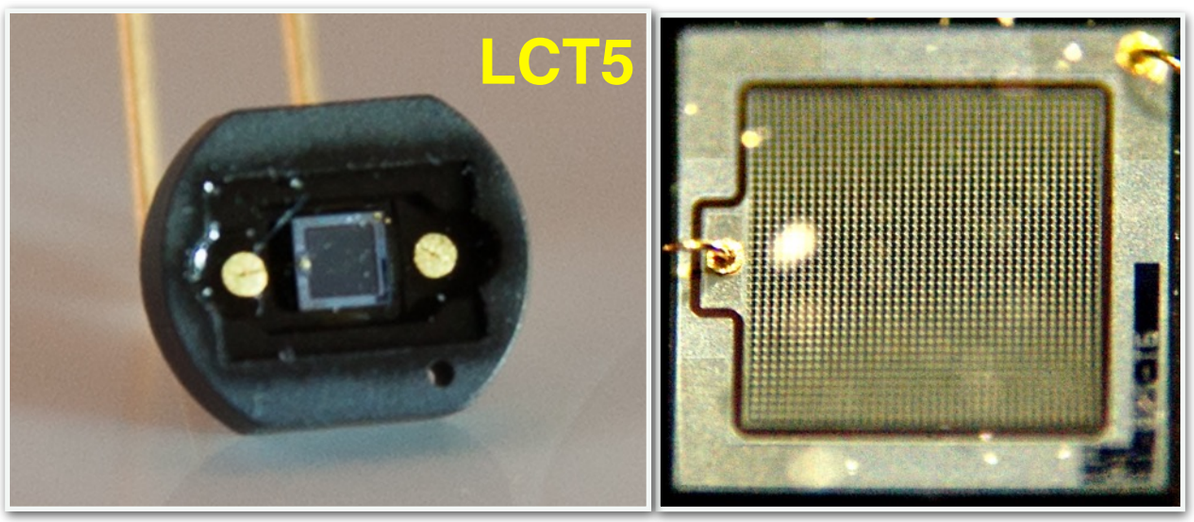
- The signal strength depends highly on the setup geometry: needs to be stable
  -> Improve reproducibility of the geometry and move the setup inside a climate chamber

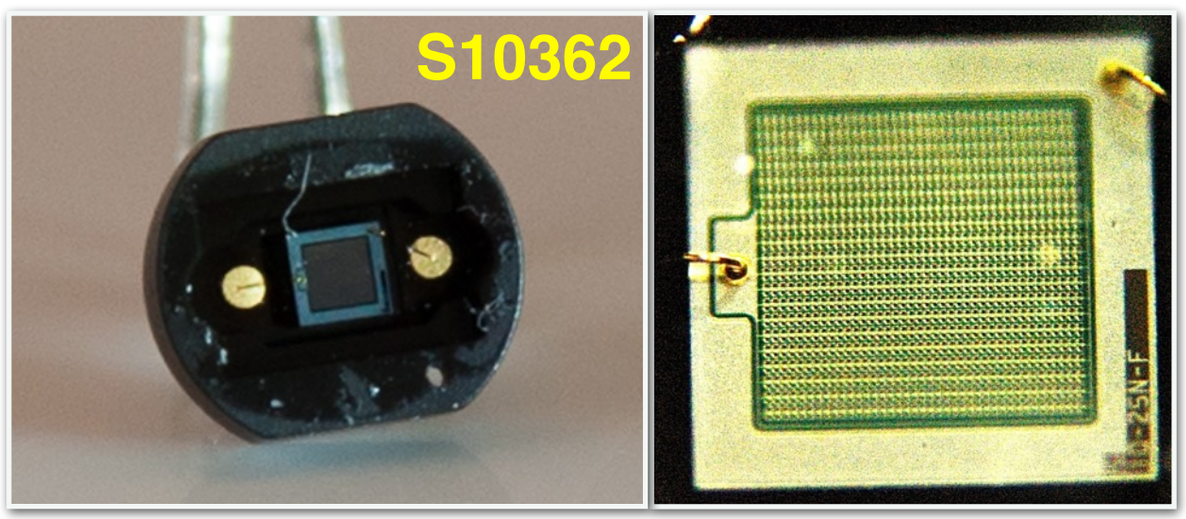
- Dark noise in the coincidence cube influences the measurement
  -> low noise SiPM

- Rh106 source would increase measurement speed and decrease noise effects

- Add LED for gain measurements

# New Hamamatsu MPPC



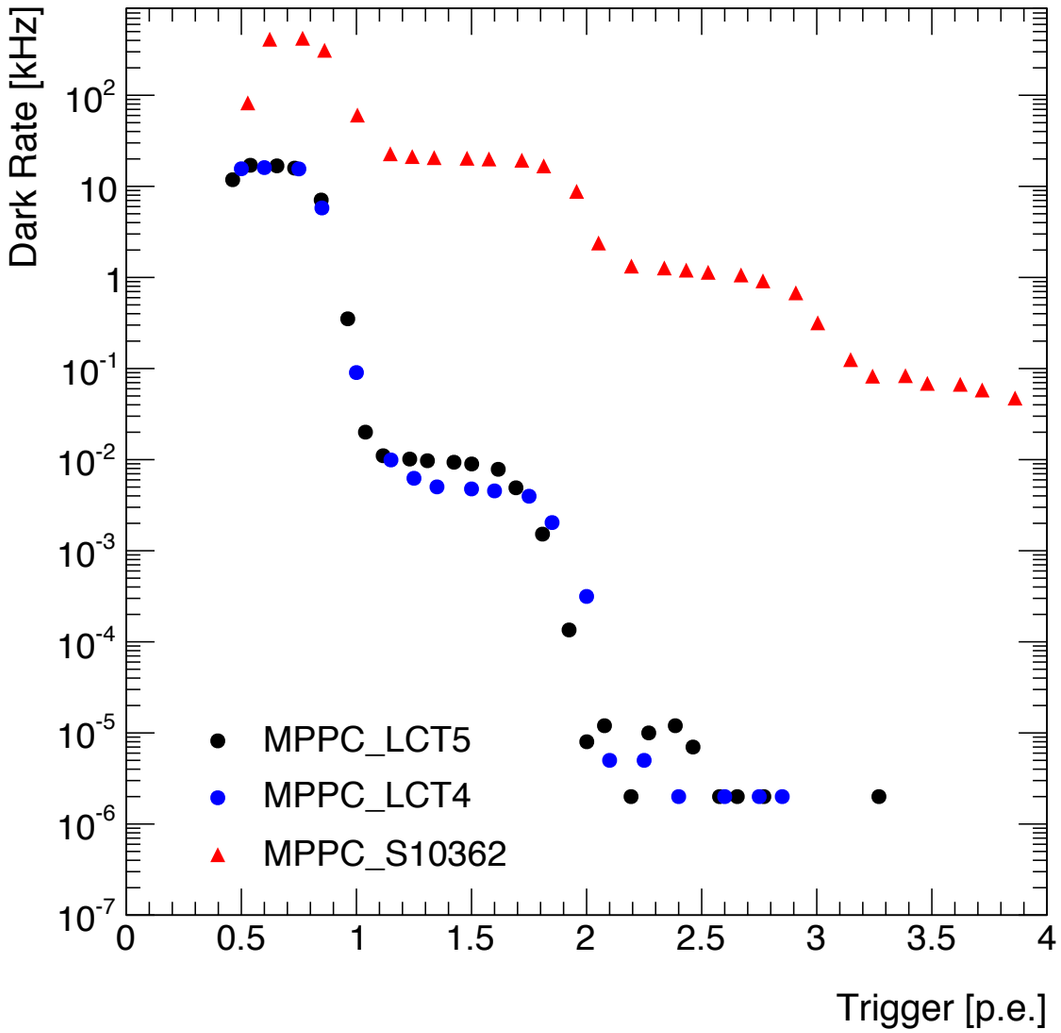



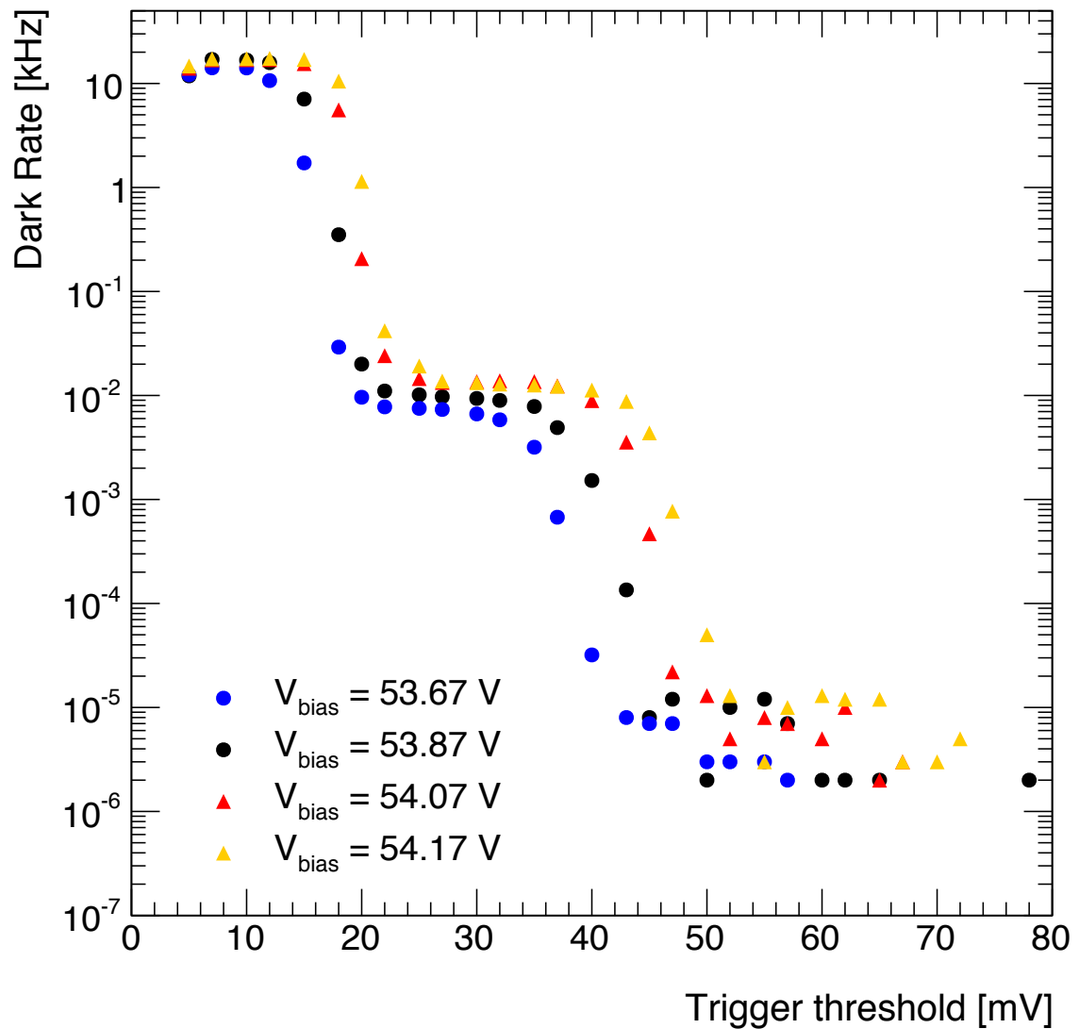

- 1x1 -25µm sample LCT5 (sample number 1) and
  1x1 -25µm sample LCT4 (sample number 124):
  area 1x1 $mm^2$, pixel size 25 µm (1600 pixels)
  -> reduced dark rate and crosstalk (optical trenches and additional pn-junction), smaller fill factor (improved for LCT5) and PDE, but able to operate at larger $V_{over}$

- Compare the performance of the LCT5 with an older MPPC with the same size and packaging; S10362-11-025C (sample number 516)

# Dark Count Rate and Crosstalk

- Count the number of signals from the SiPM above the trigger value
- LCT5 has a low dark count rate compared to S10362, and similar to LCT4
- Very low crosstalk for LCT5 and LCT4 due to trenches



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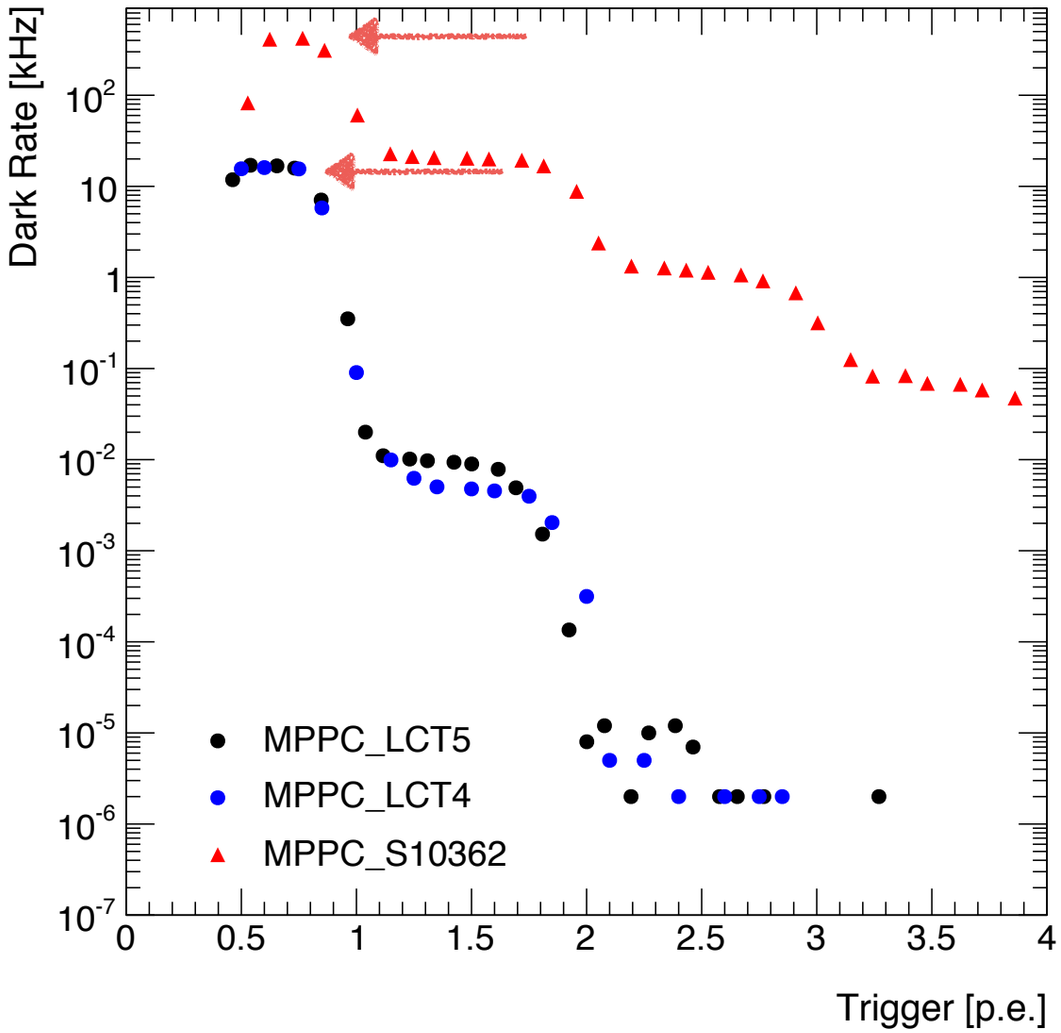


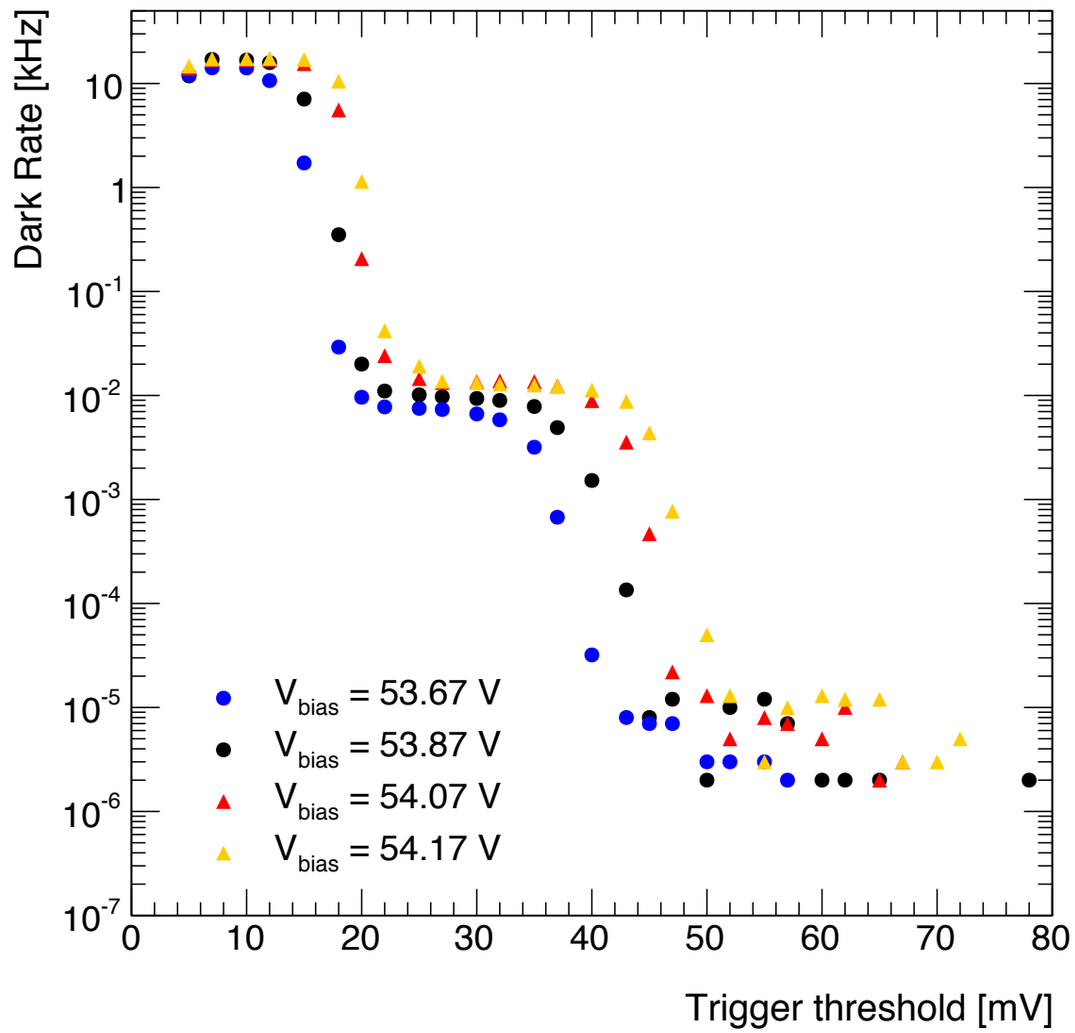

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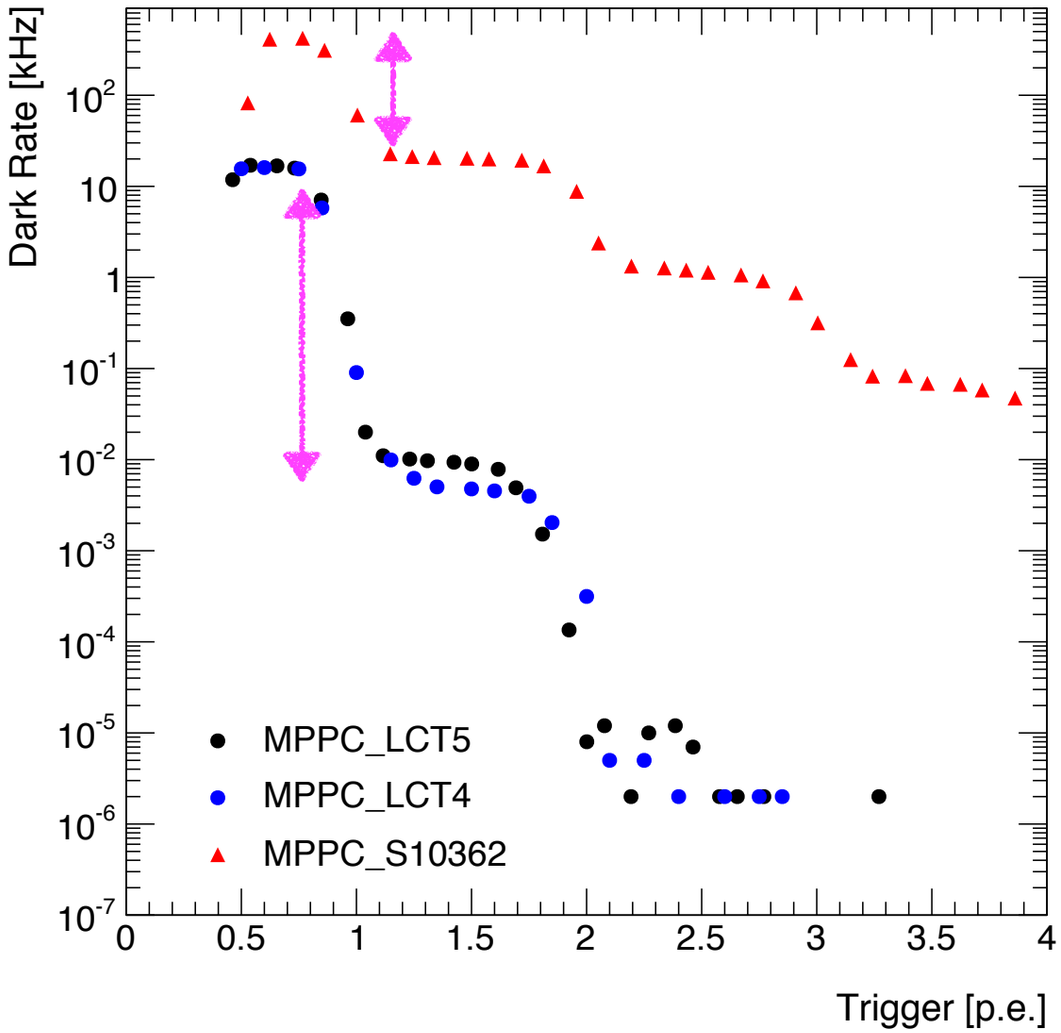
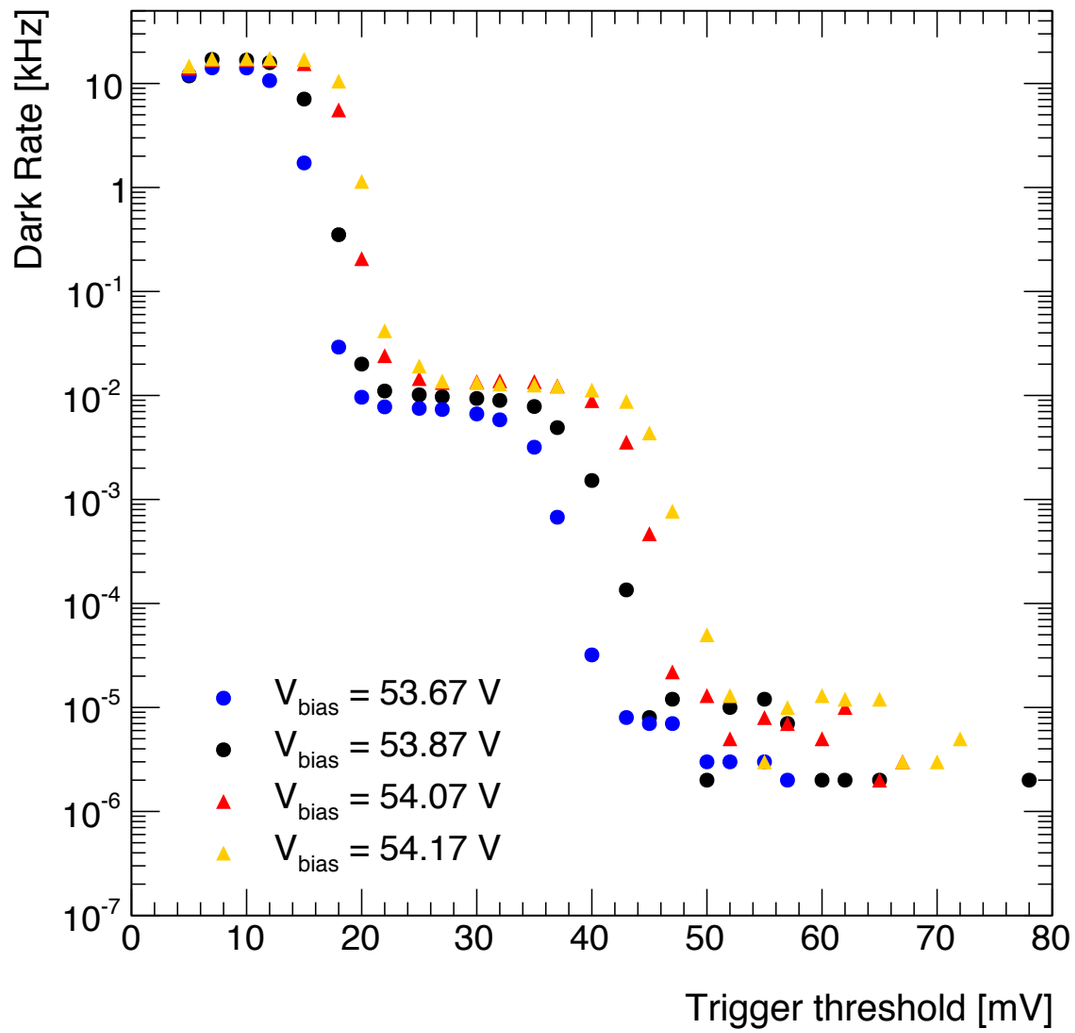
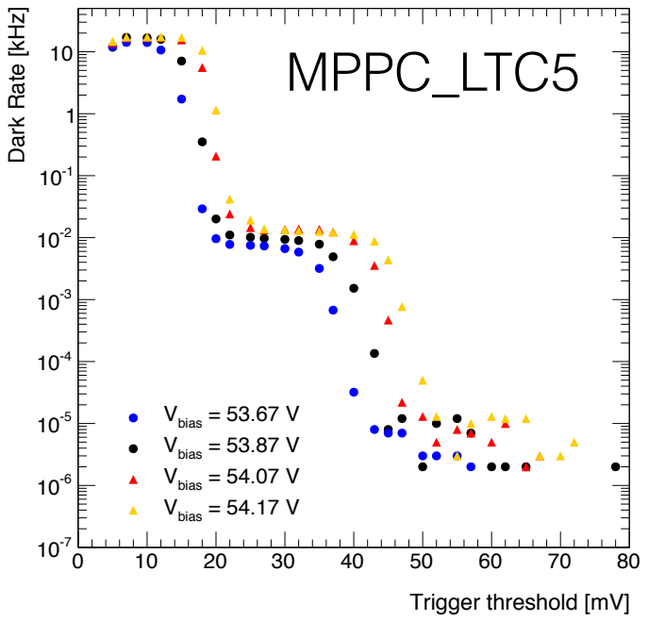
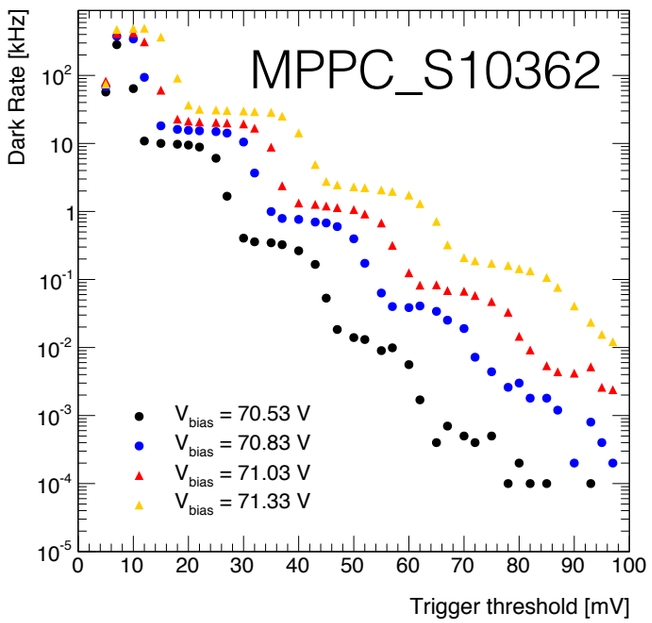
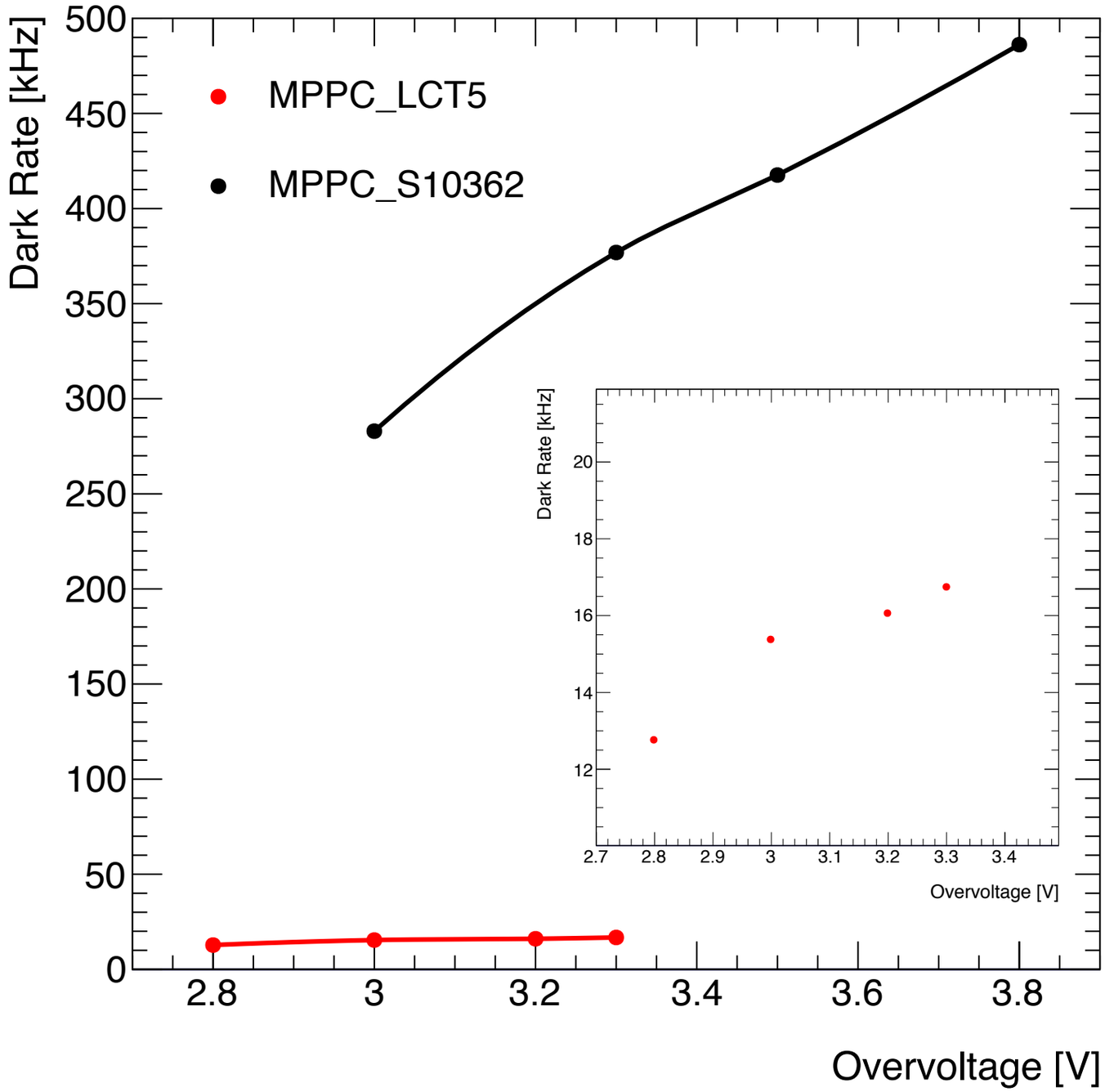


# Dark Count Rate vs $V_{bias}$

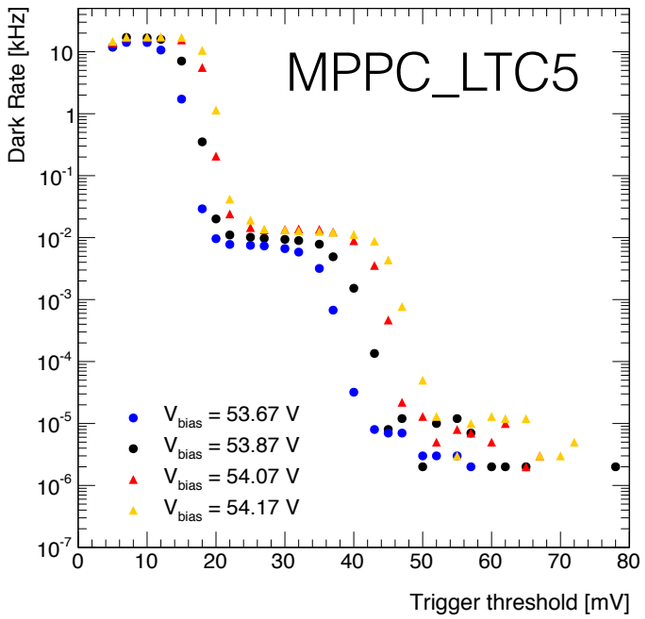


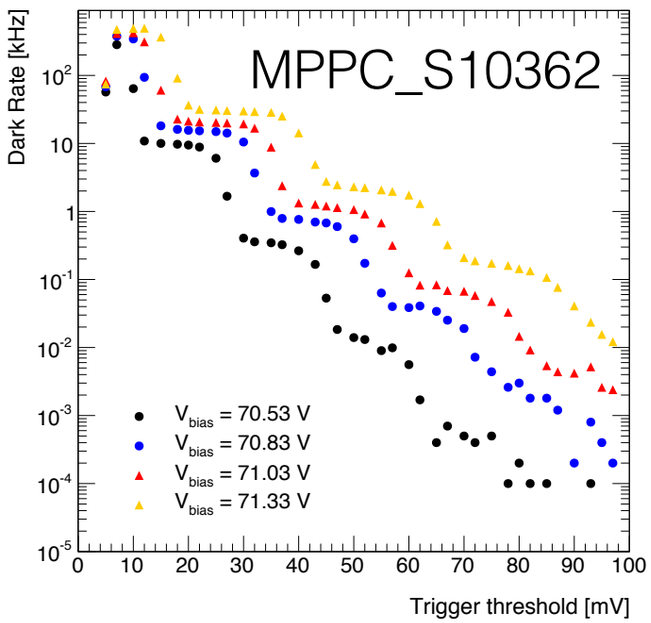



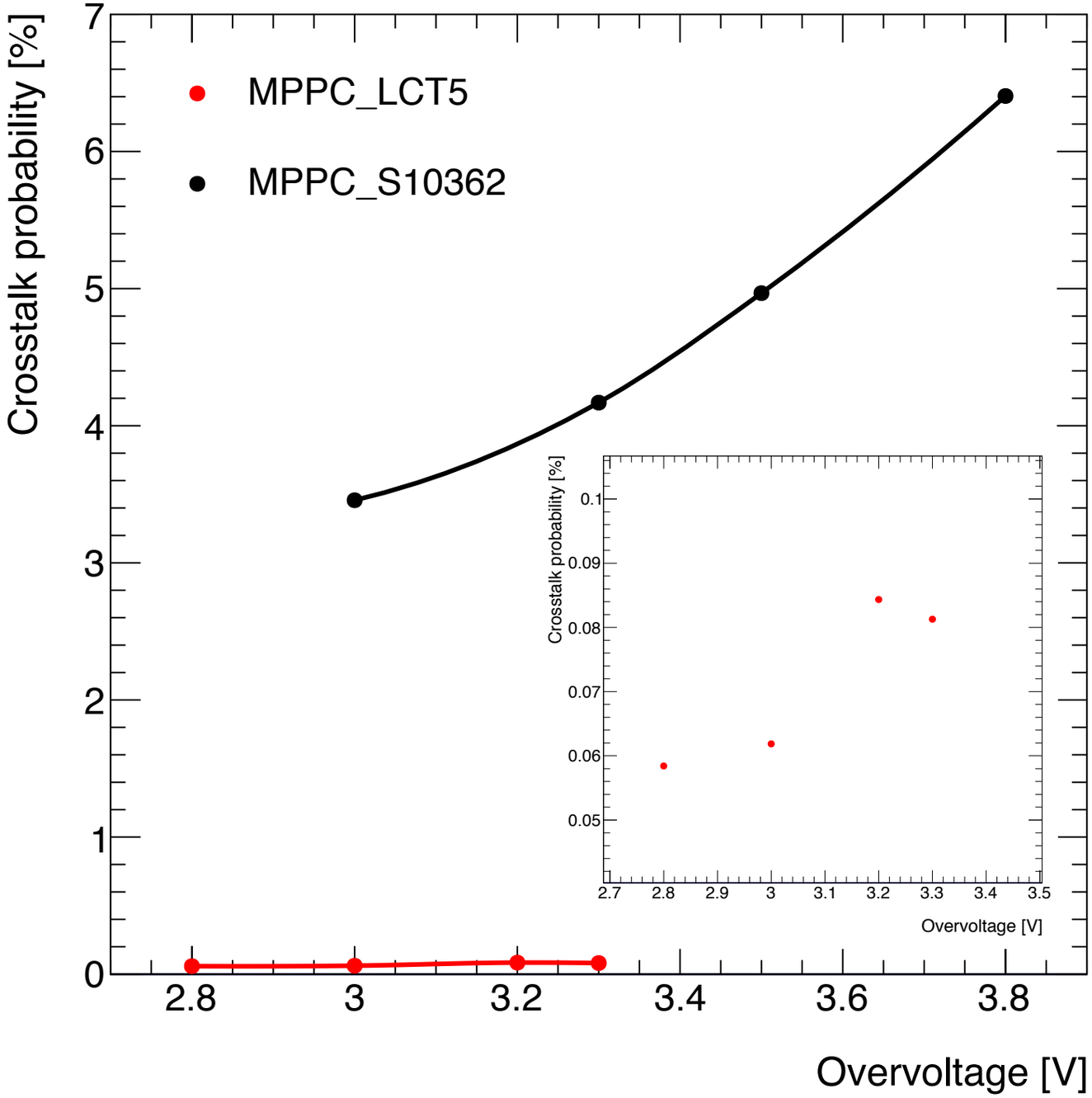




The dark count rate is between 12 and 17 kHz.
A factor ~20 smaller than for S10362.

# Crosstalk vs $V_{bias}$



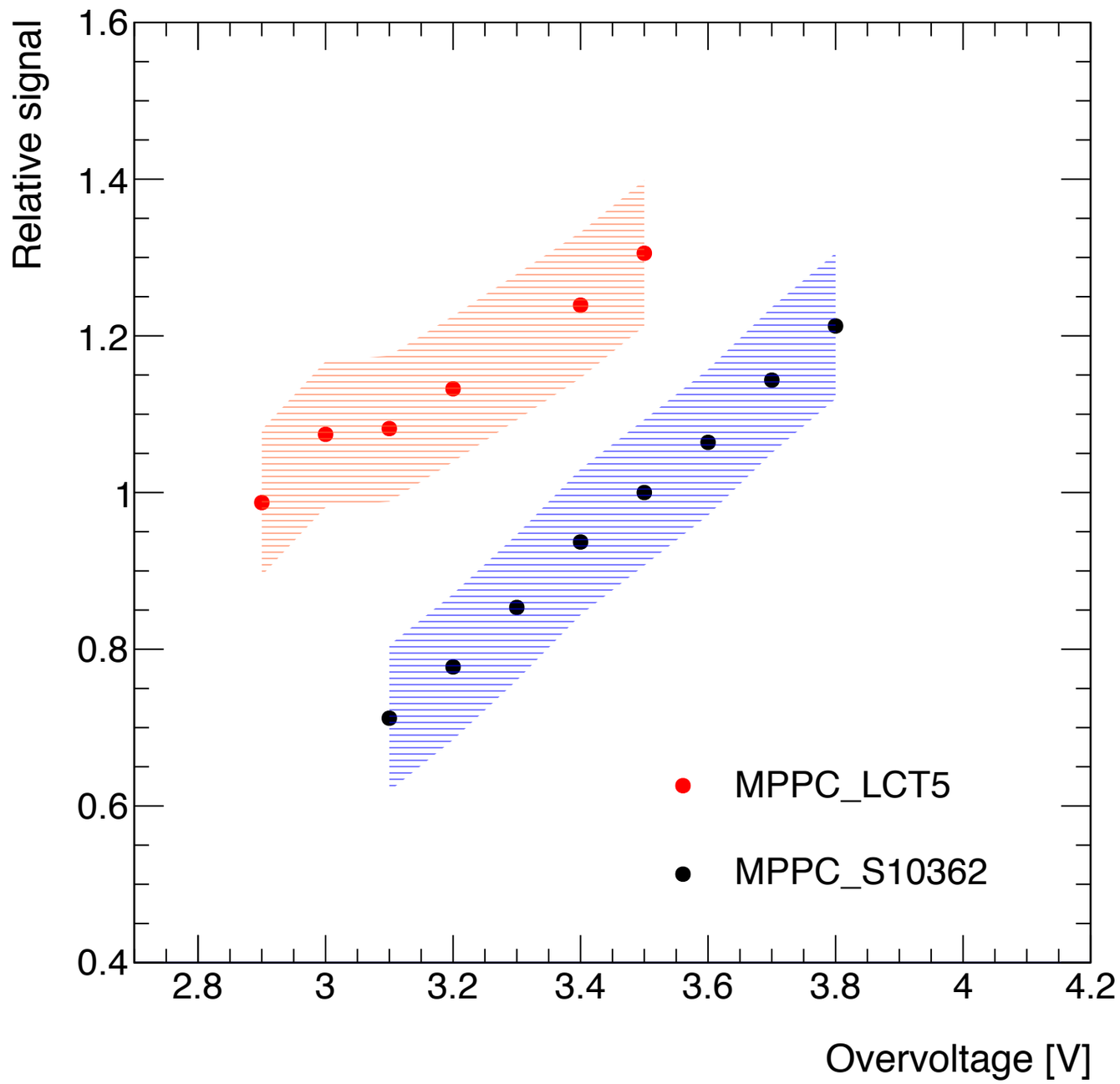




The crosstalk probability is smaller than 0.1%.
A factor ~60 smaller than for S10362.

# Signal vs $V_{bias}$

- Signal recorded in the SiPM from a tile irradiated by a Sr90 source
- The SiPM is loosely connected to the tile -> not an optimal setup, resulting in lower signals -> serves only as a comparison of performance!
- The signal from LCT5 is higher for the same overvoltage than that of S10362



# Optically isolated mega-tiles

- Test a possible new technique to optically isolate neighbouring channels in a mega-tile: subsurface laser engraving

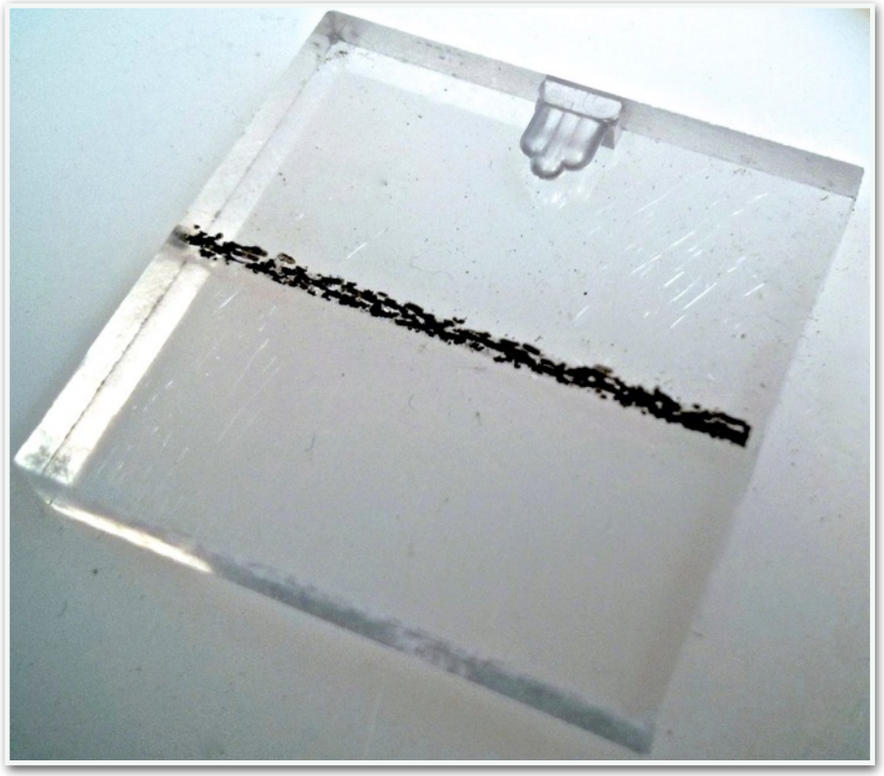
- Potential of this technique:
  - Very good mechanical stability of the tiles
  - Easily scalable to mass production
  - Reasonable costs and time per channel

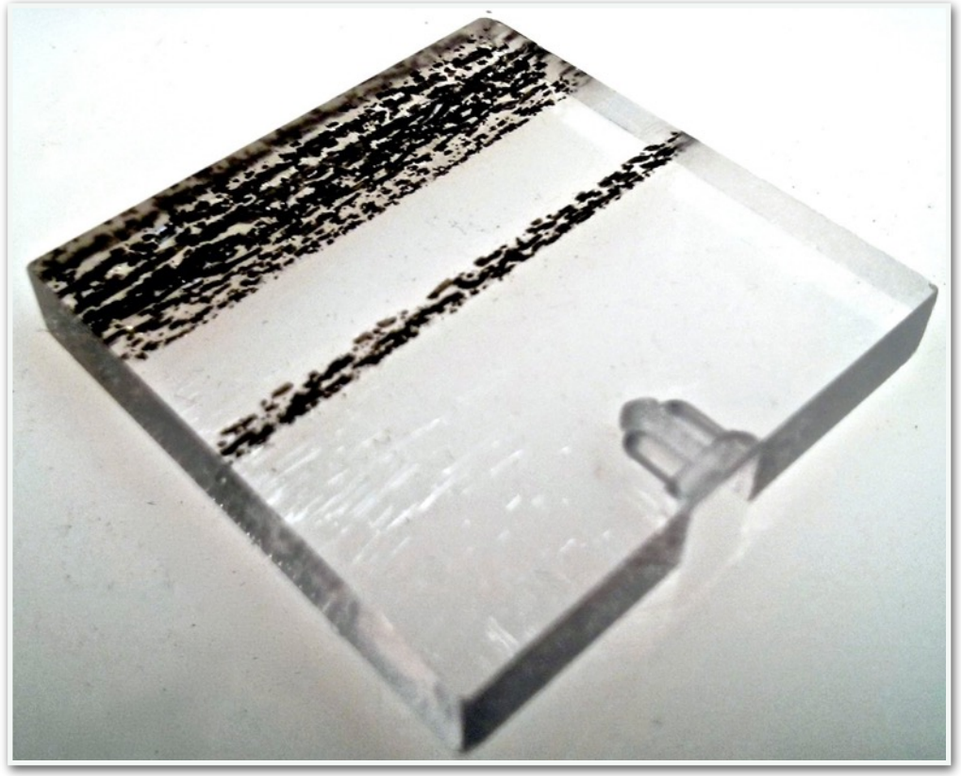
- Company in Munich which engrave on site and accept custom materials

- Proof of principle prototypes tested


# First prototypes

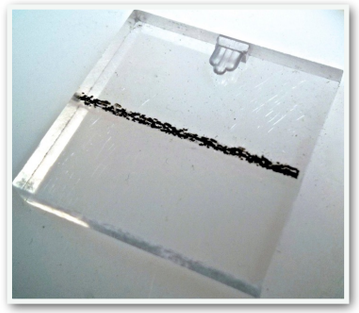
- First cautious attempt on PVC plastic
- The laser spots are black due to carbonisation
- Quite low spot density in the lines

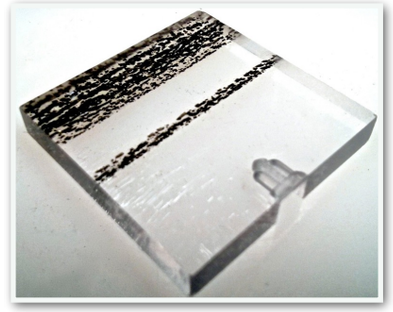


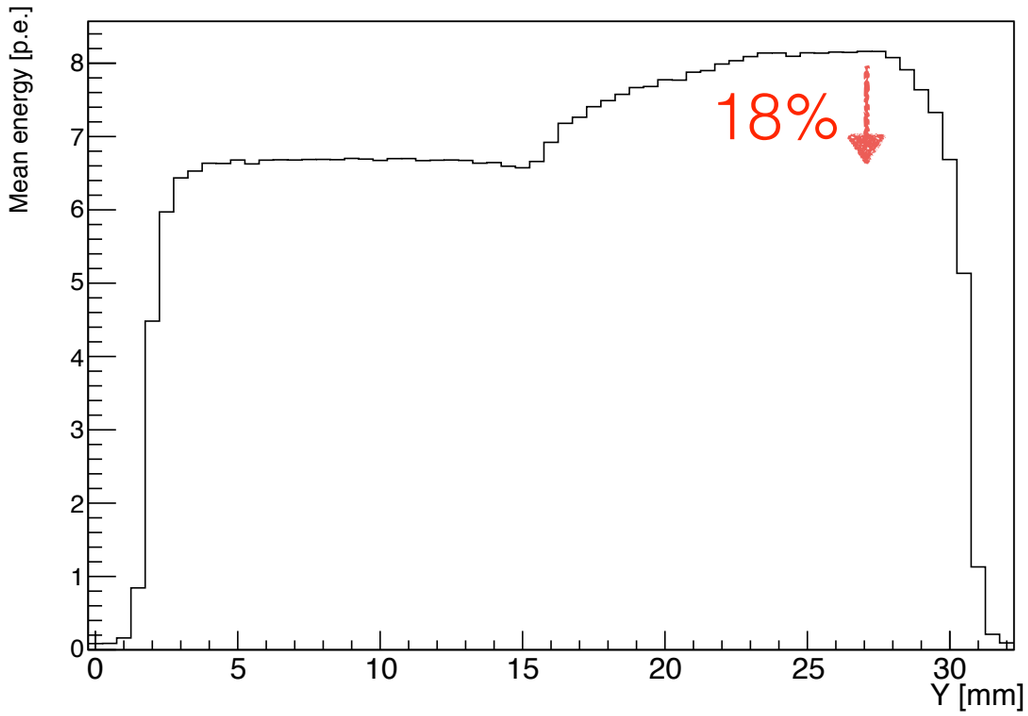


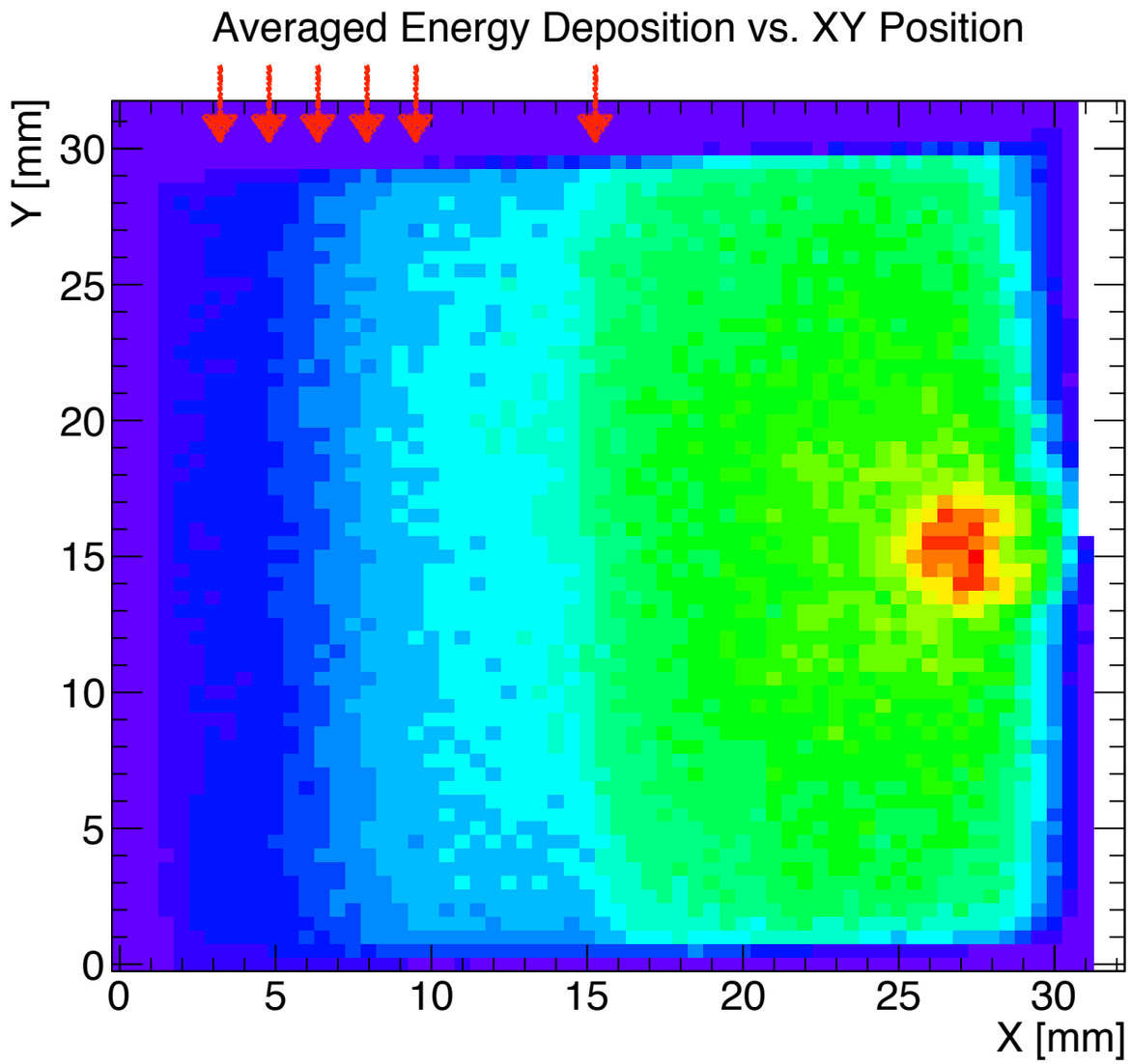
- Test: Packaged the tiles in reflective foil, attached a SiPM and scanned the surface with a Sr90 source, recorded the SiPM signal

# Scan of the prototypes







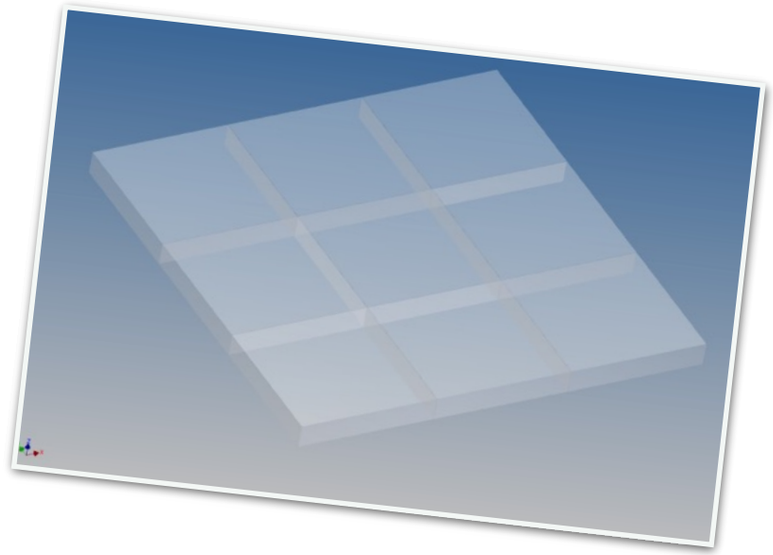




A single line reduces the signal by 18%, multiple lines improve the signal reduction.

# Ongoing...

- The first tests have been encouraging, however the crosstalk and non-uniformity are still much too high

- New prototypes are underway: 9x9 $cm^2$ mega-tiles, with 9 segments for bottom coupled SiPMs



- Improved laser parameters;
  higher spot density and smaller inter line distance

- Two configurations:
  - single lines
  - multiple lines close together with a total thickness of 0.4 mm (probably 5 lines)

- Encountered problems with the material:
  First tests on BC420 (St. Gobain) -> OK
  EJ-200 (Eljen technology) is damaged by the laser and after a few lines the laser cannot focus at the desired depth anymore
  Now testing BC408...

- Thank you for your attention