

HERD PSD tile

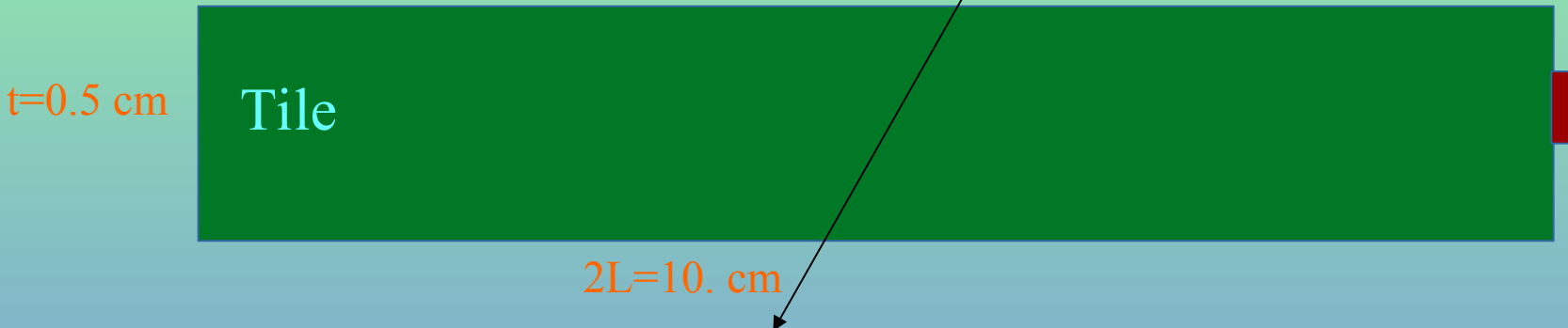
22-02-2021

The INFN Pavia PSD group

Estimation of photon flux on SiPMs

Signals on SiPM

Estimation of the signals on SiPM



$dN_{\gamma}/dE \sim 10^4 / \text{MeV}$ is the number of photons per MeV

$dE/dx \sim 2 \text{ MeV/cm}$ (m.i.p.)

$t=0.5 \text{ cm}$ thickness of tile

$2L=10 \text{ cm}$ tile size

$n = 1.6$ refraction index of tile scintillator

$\cos \theta = 1/n$ is the limiting angle

The number of photons emitted within θ is

$$N_{\gamma} = (dN/dE) * (dE/dx) * (\cos \theta) * t$$

Hitting the side surface with area $A = 4 * 2L * t$

Signals on SiPM (2)

The photon flux is: $\Phi_y = dN_y/dA = (dN/dE) * (dE/dx) * (\cos \theta) / (4 * 2L)$

Rough estimation assuming effective reflection !!

$$dN_y/dA = 300 \text{ ph/cm}^2$$

Assuming a quantum efficiency $QE=50\%$

The photoelectron flux is $dn_{p.e.}/dA = 150 \text{ p.e./cm}^2$

The number of phototelectron on a cell:

$$dn_{p.e.}/dCell \text{ (mip)} = 1.5 \cdot 10^{-2} (d/100 \mu\text{m})^2 \text{ p.e./Cell} \text{ (d is cell size)}$$

Occupancy very low for m.i.p. with $d \leq 50 \mu\text{m}$.

For iron the number of photons per unit of length is ~ 400 larger accounting for Birks' effect.

$$dn_{p.e.}/dCell \text{ (Fe)} = 6 (d/100 \mu\text{m})^2 \text{ p.e./Cell}$$

Retaining linearity for Fe requires $< 0.1 \text{ p.e./Cell} \rightarrow d < 15 \mu\text{m}$.

Therefore high gain large area SiPMs can have $d=50 \mu\text{m}$ while low gain small area SiPMs $d=10-15 \mu\text{m}$.

To be verified in detail with simulation.

Signals on SiPM: time structure

Time profile of scintillation photons driven by scintillation time

Following an exponential shape with decay time $\sim 1-2$ ns.

Additional broadening due to propagation in the tile comparable to 1 ns.

Dead time of SiPM is ~ 10 ns $\gg 1-2$ ns (scintillation time).

Longer tails due to multiple reflections are possible but their contributions are negligible.

Therefore each cell can detect only one photon per particle.

Test with radioactive source

Setup of radioactive source test

^{90}Sr source (β emitter up to 2.2 MeV)



Tile: Scintillator EJ200 thickness 5 mm

Readout 3 SiPM S14160-3050hs (3.0 mm side and 50 μm cell size)

on each side readout in parallel $V_b=42.5$ V

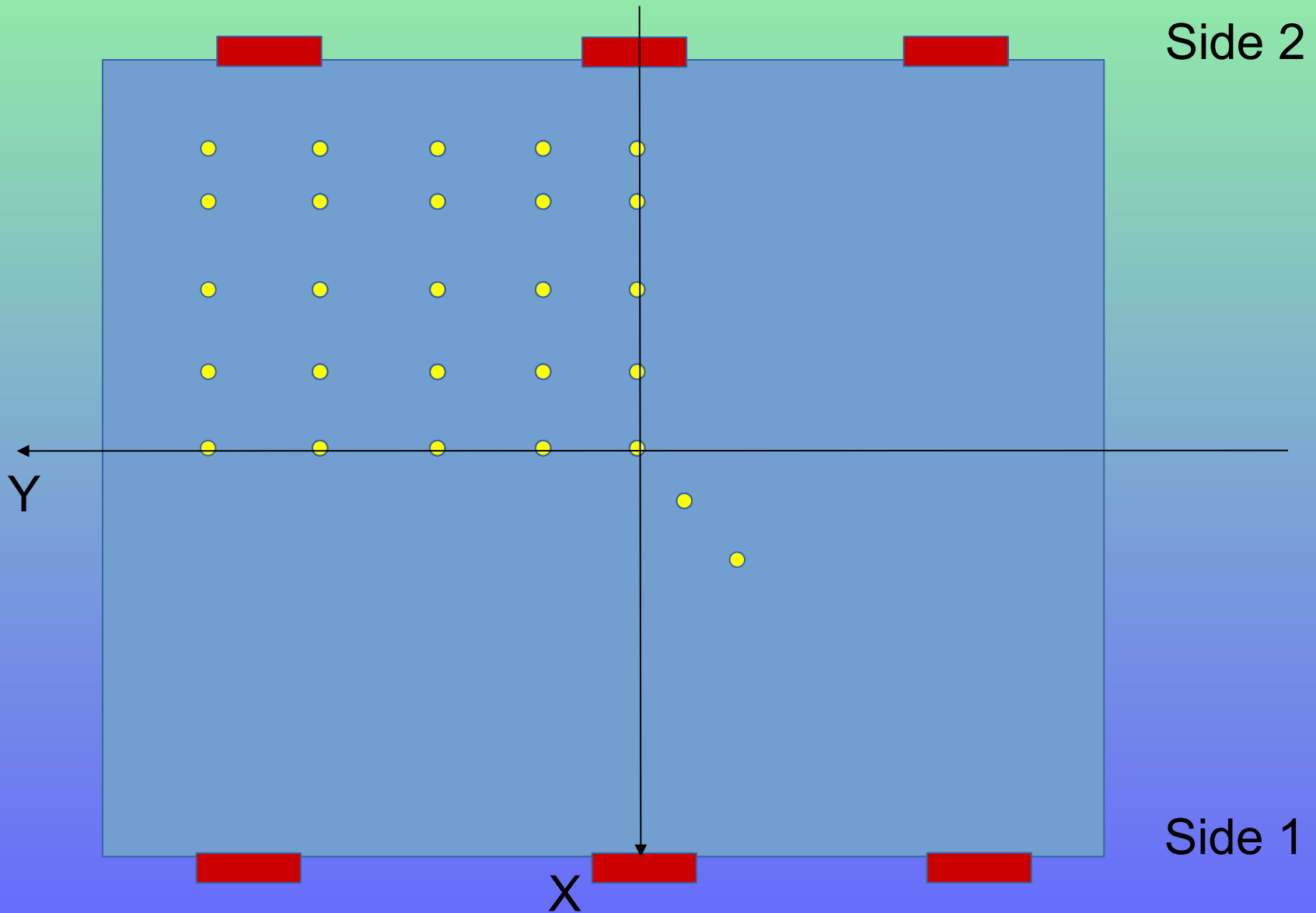
Wrapped with Teflon and with black paper

Cube: MEG scintillator (several years old) 12 mm side

Covered with white coating BaS

Readout on single side with array SiPM SensCell C-60035-4p-gevb (4 6x6 35 μm)

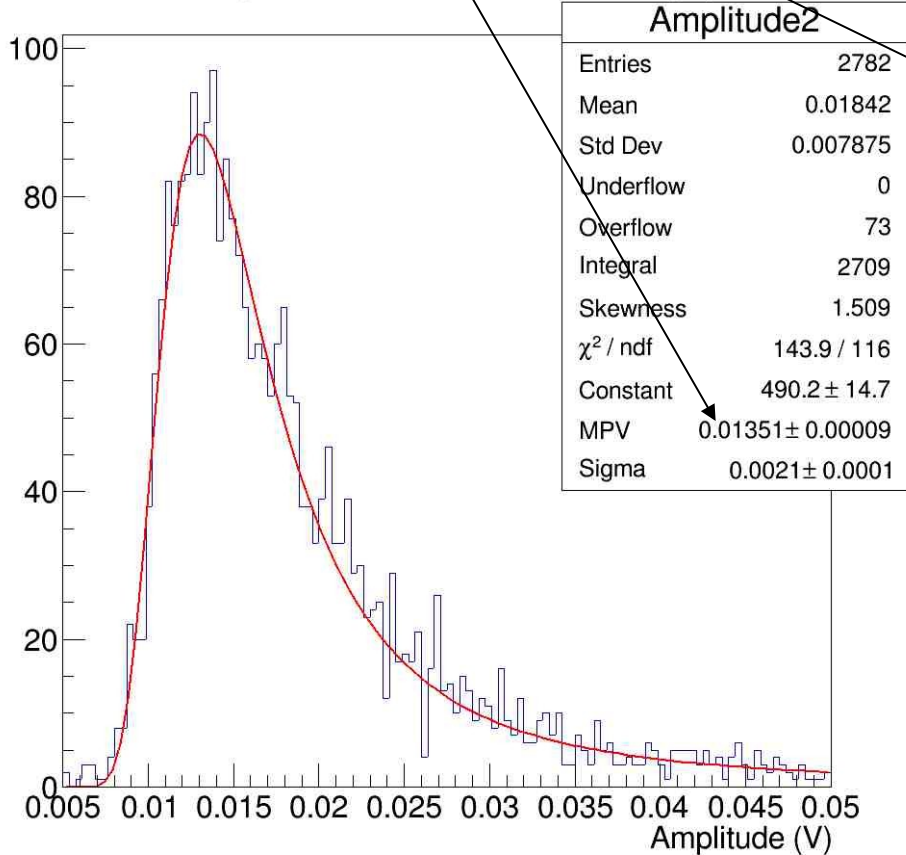
Test with radioactive source



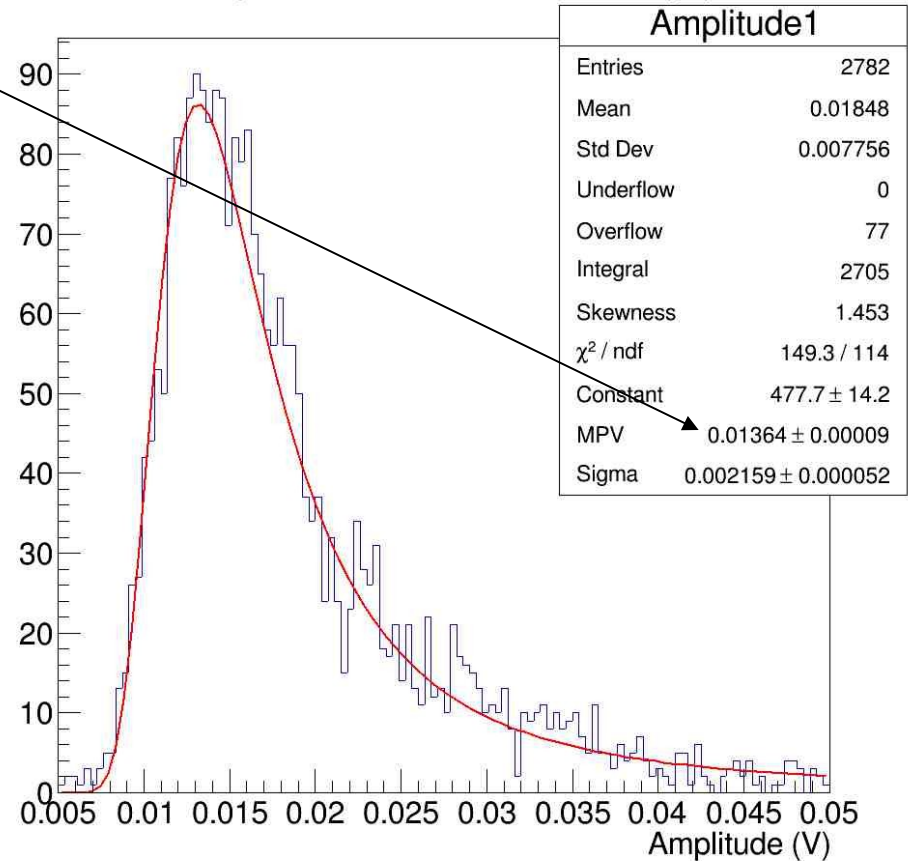
Signal amplitude X=0 Y=0

Signals on both sides when source is in the centre X=0.0 Y=0.0
They are equal. The SiPM gains and optical coupling on both sides are equal.

Amplitude SiPM board 2 (V)



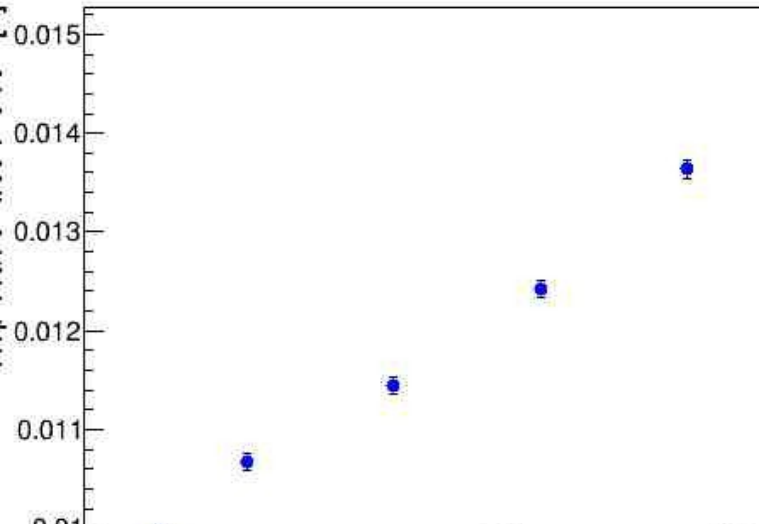
Amplitude SiPM board 1 (V)



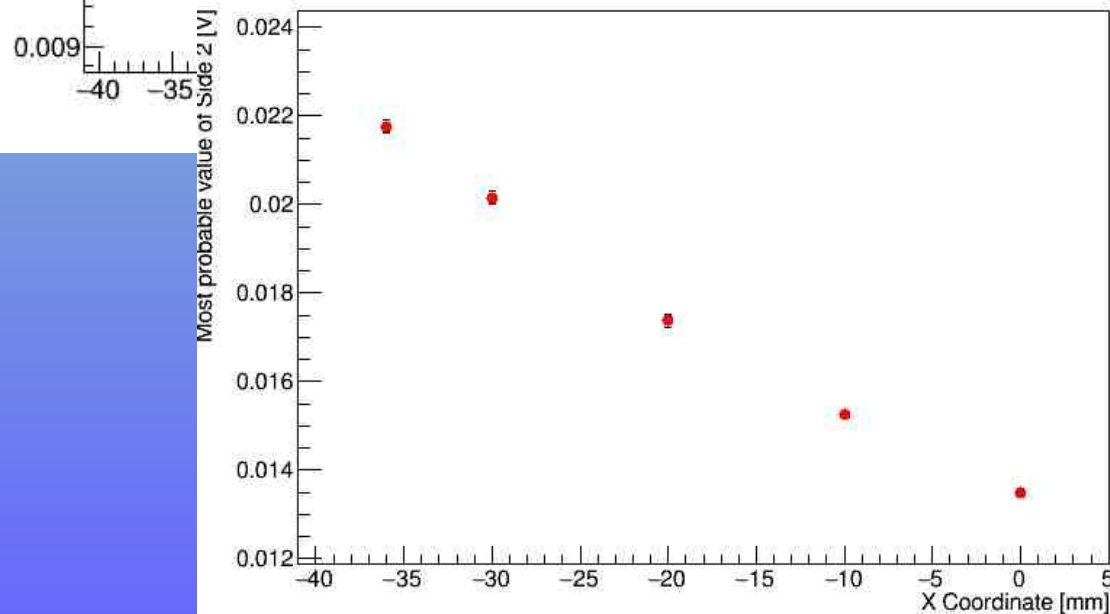
MPV1/2 versus X

Side 2

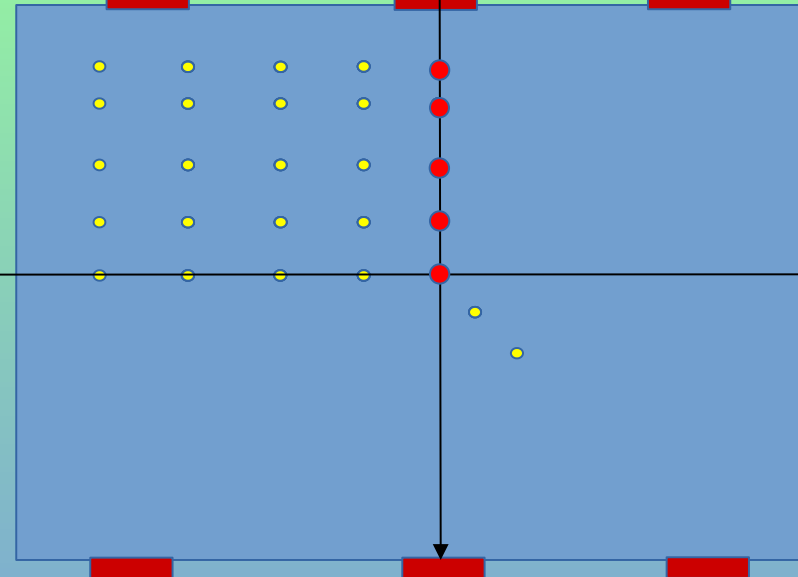
YCoord0.000000: MPV1 vs XCoord



YCoord0.000000: MPV2 vs XCoord



Y



Side 1

Signal increases (decreases) going closer (farther) to the SiPMs.

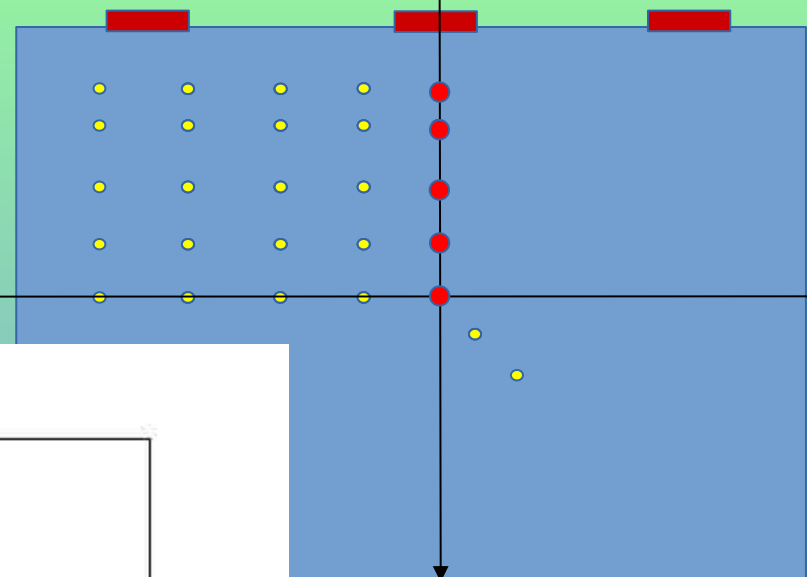
The solid angles subtended by SiPMs grows larger (smaller).

MPV3=MPV1+MPV2 versus X

Side 2

Total signal increases going closer to SiPMs.
Reflection on the sides limits the effect of solid angle reduction.

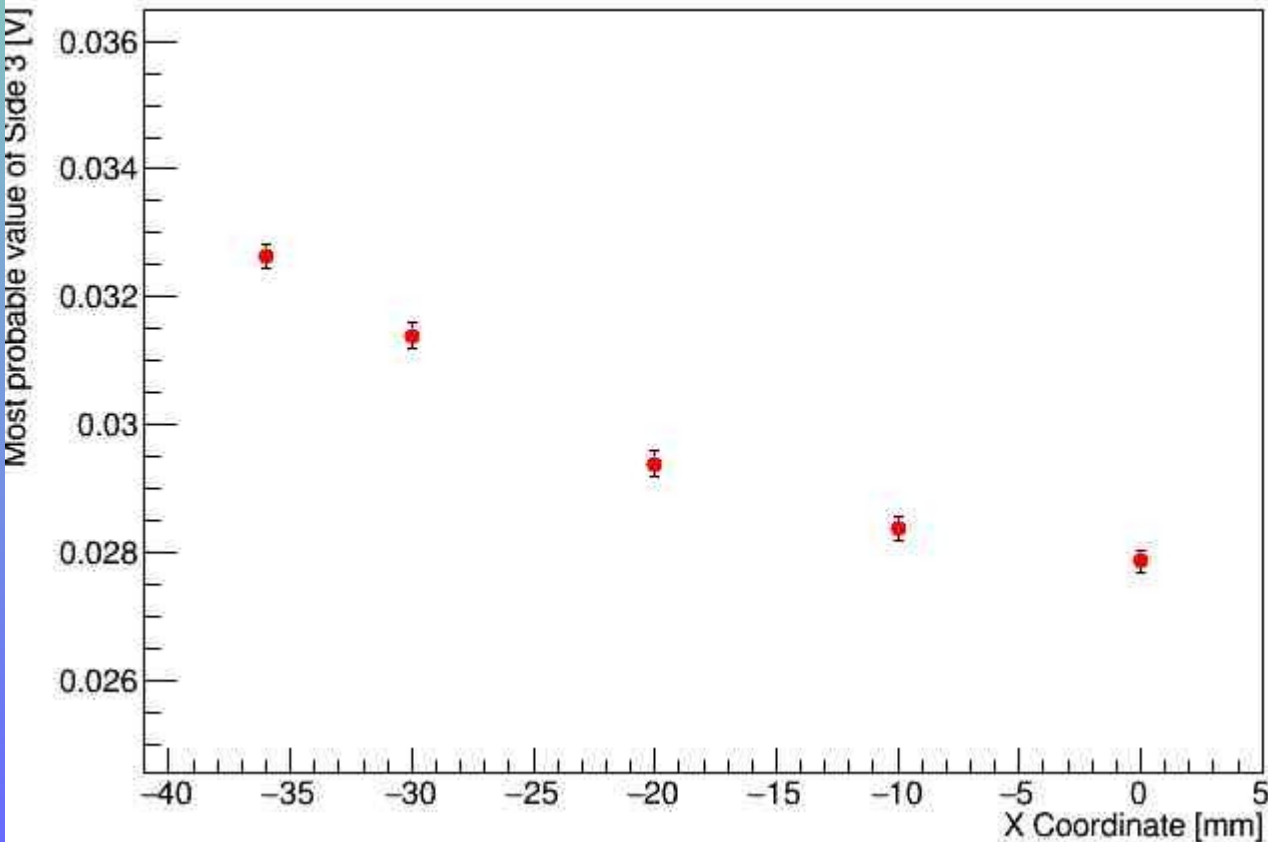
Y



Side 1

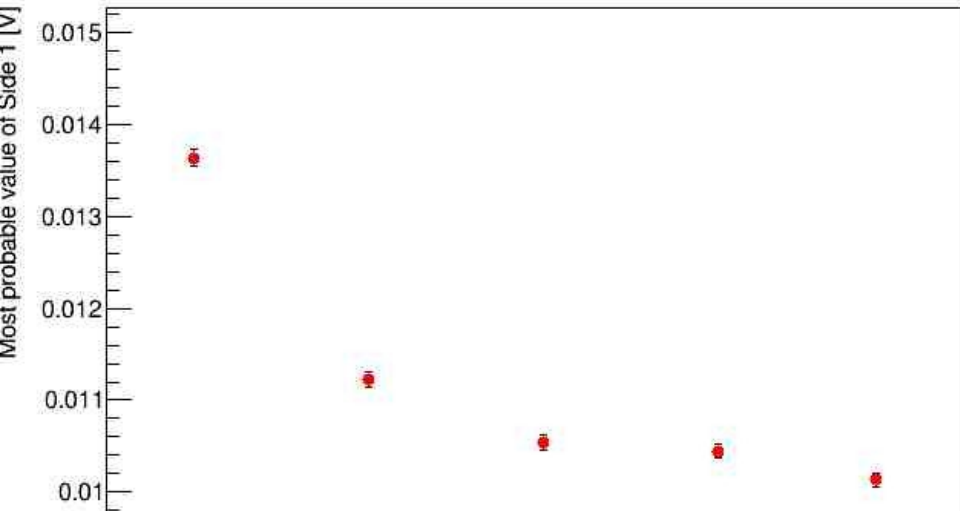
X

YCoord0.000000: MPV3 vs XCoord

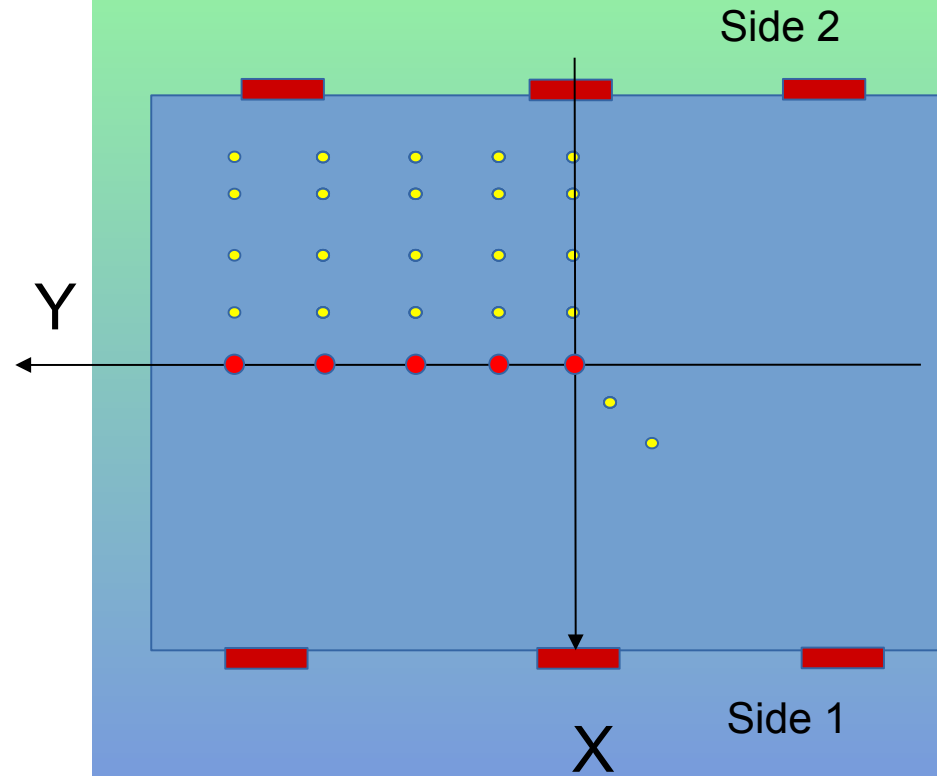
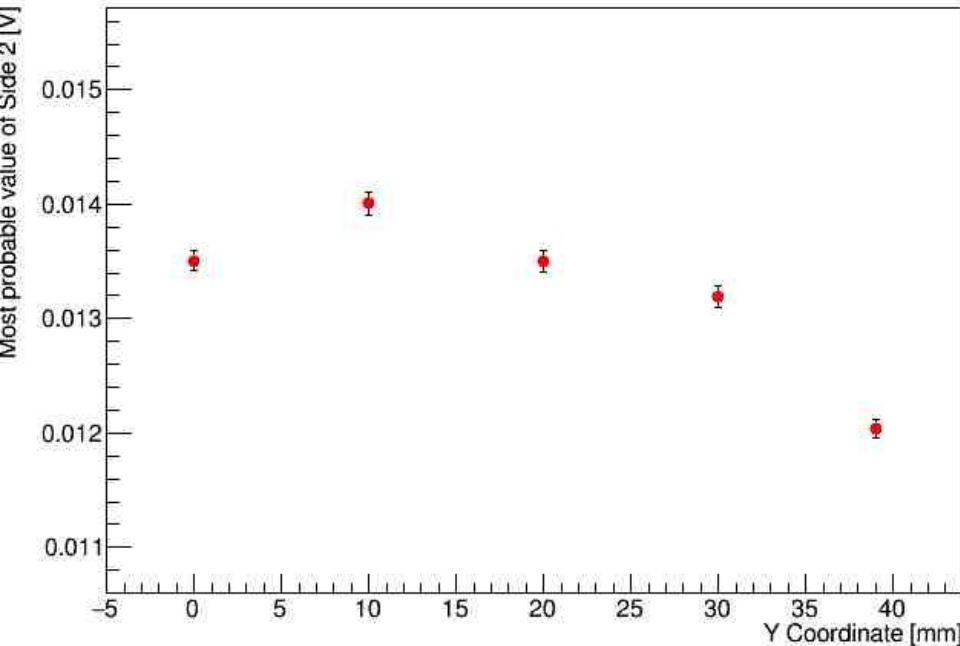


MPV1/2 versus Y

XCoord0.000000: MPV1 vs YCoord

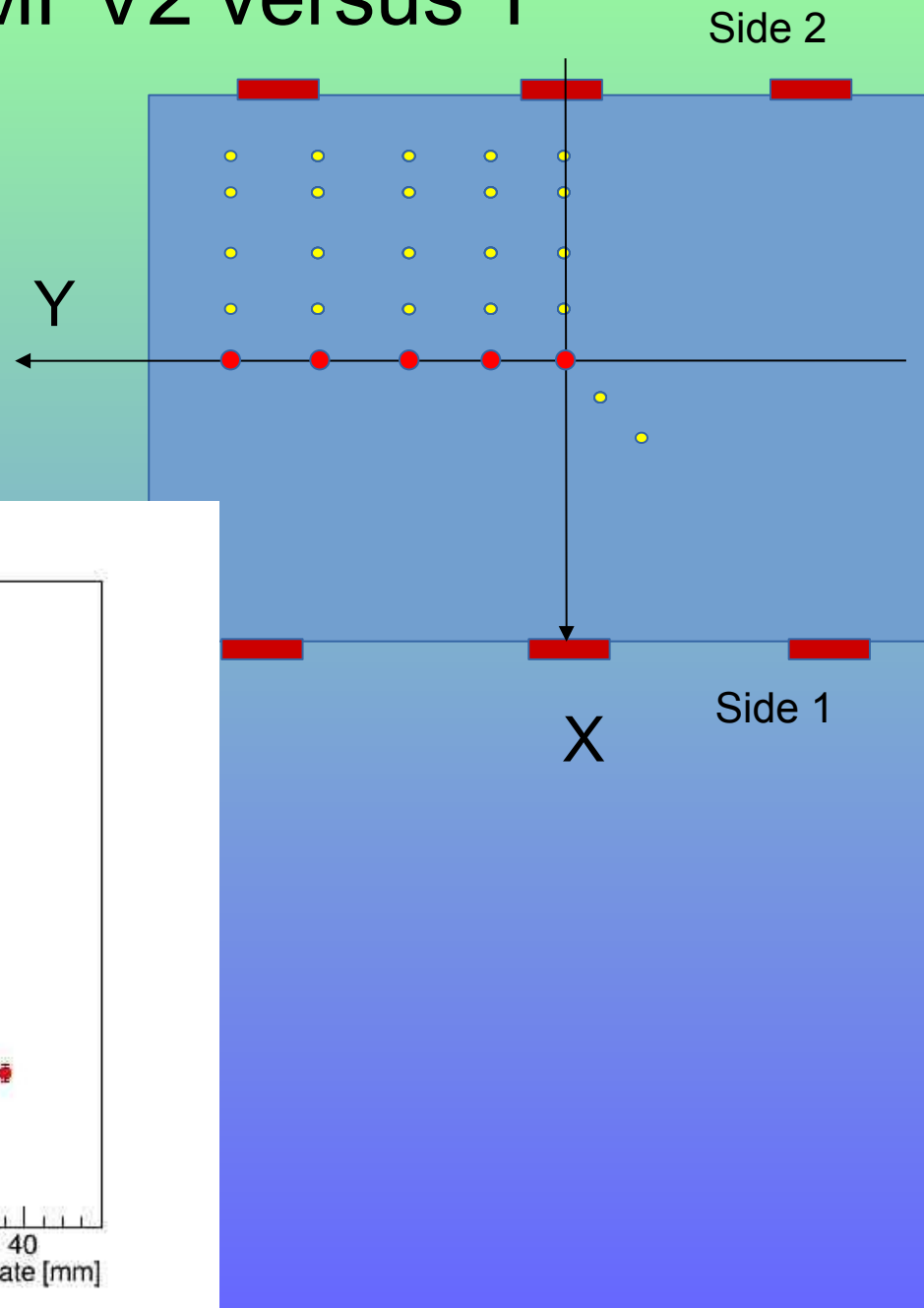


XCoord0.000000: MPV2 vs YCoord

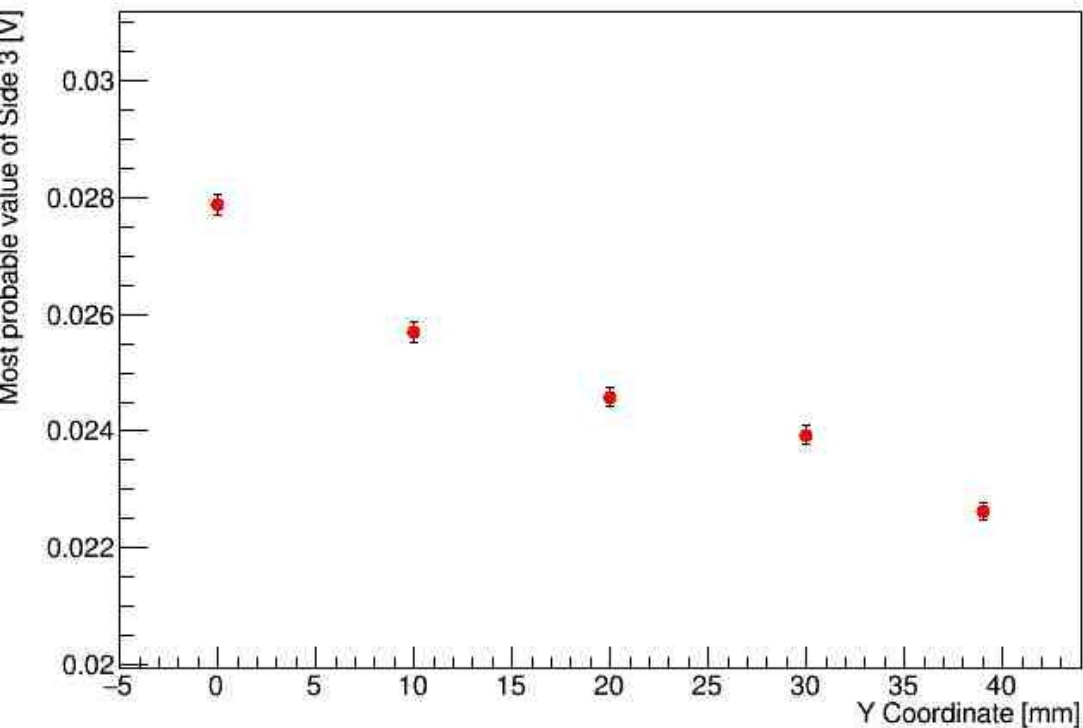


Total signal decreases moving toward the edge.
Probably due to decreasing solid angle subtended by SiPMs and poor reflection on the side.

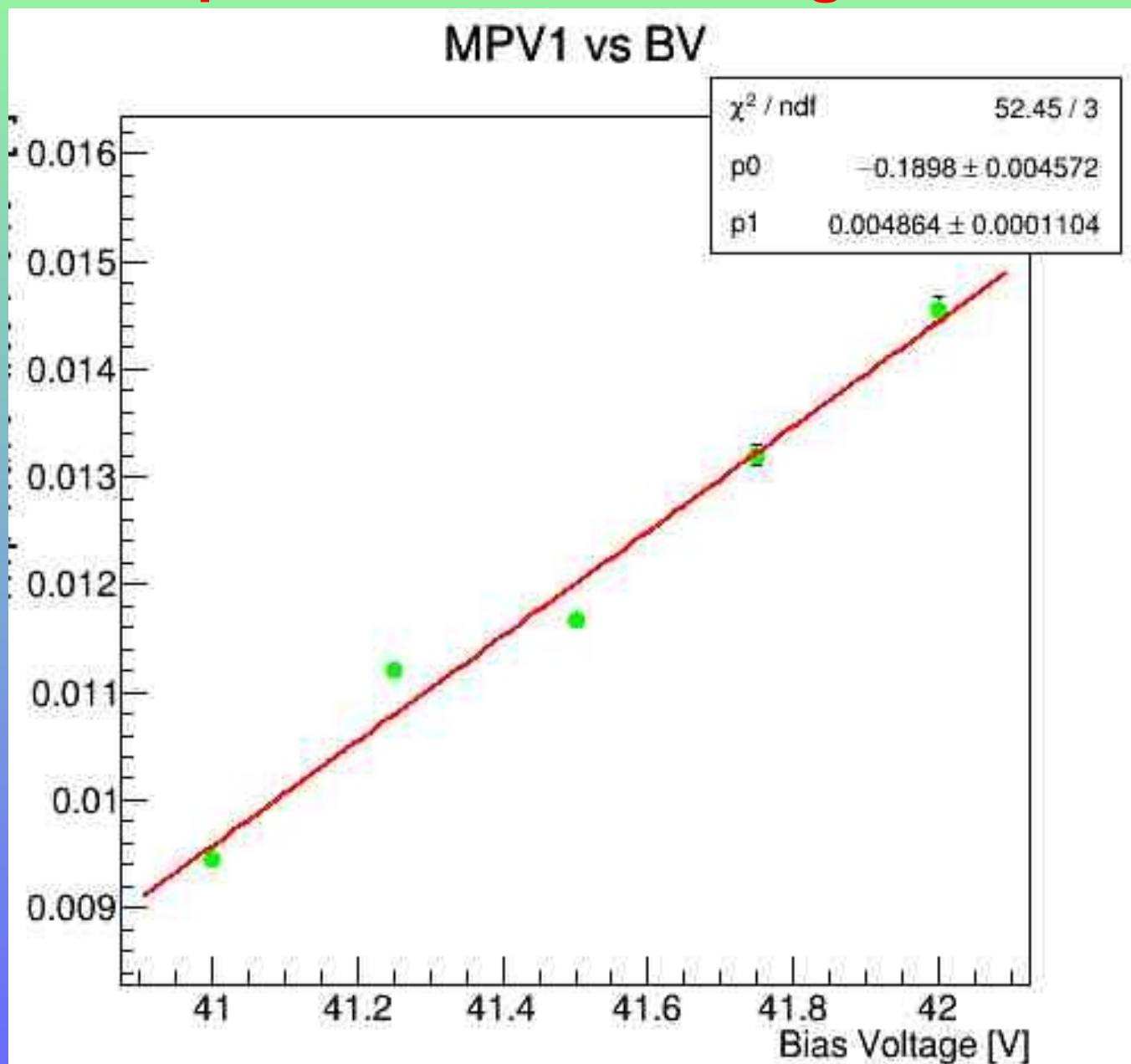
MPV3=MPV1+MPV2 versus Y



XCoord0.000000: MPV3 vs YCoord



Signal amplitude vs Bias Voltage at X=0 Y=0



MPV distributions on tile surface

An estimator of the uniformity of the signal distribution on the tile is the relative spread (σ) of the Most Probable Values of the Landau fits on the points on the tile surface.

Ideally the points should cover the whole surface.

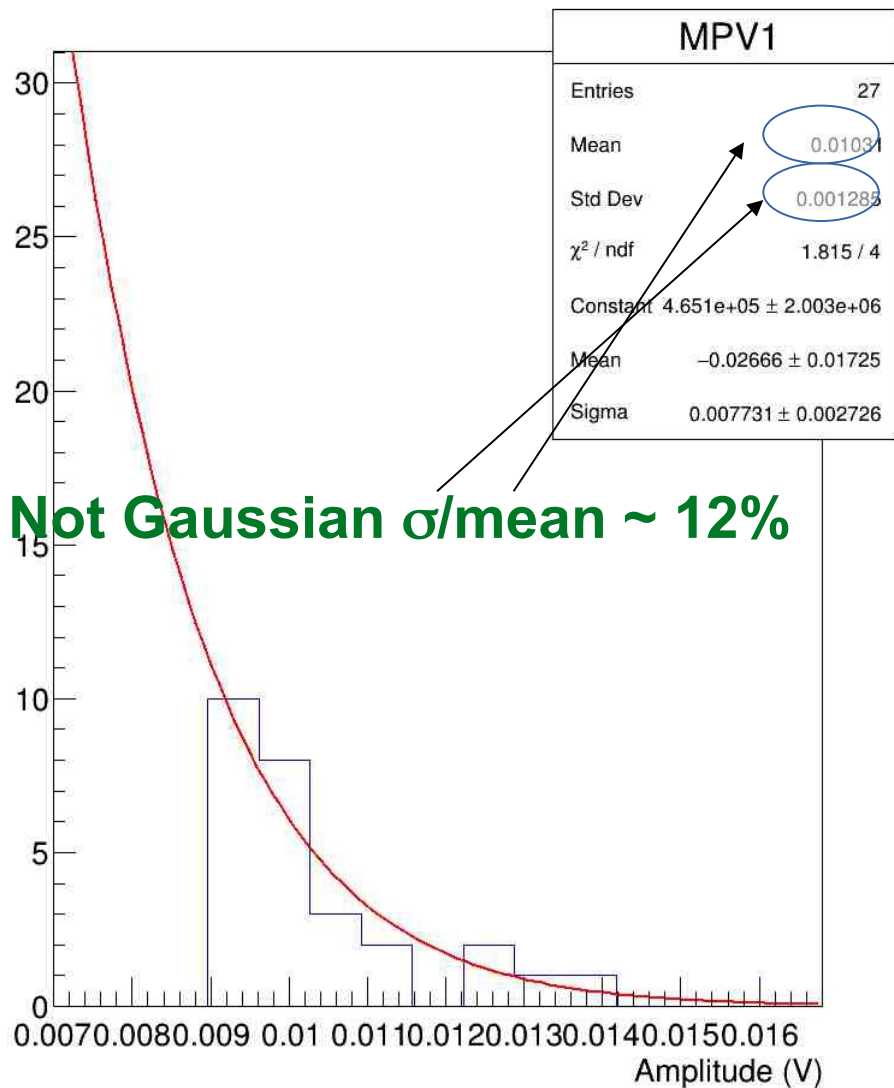
Now we rely on the set of points already collected.

This estimator should be compared with the relative spread of the Landau distribution.

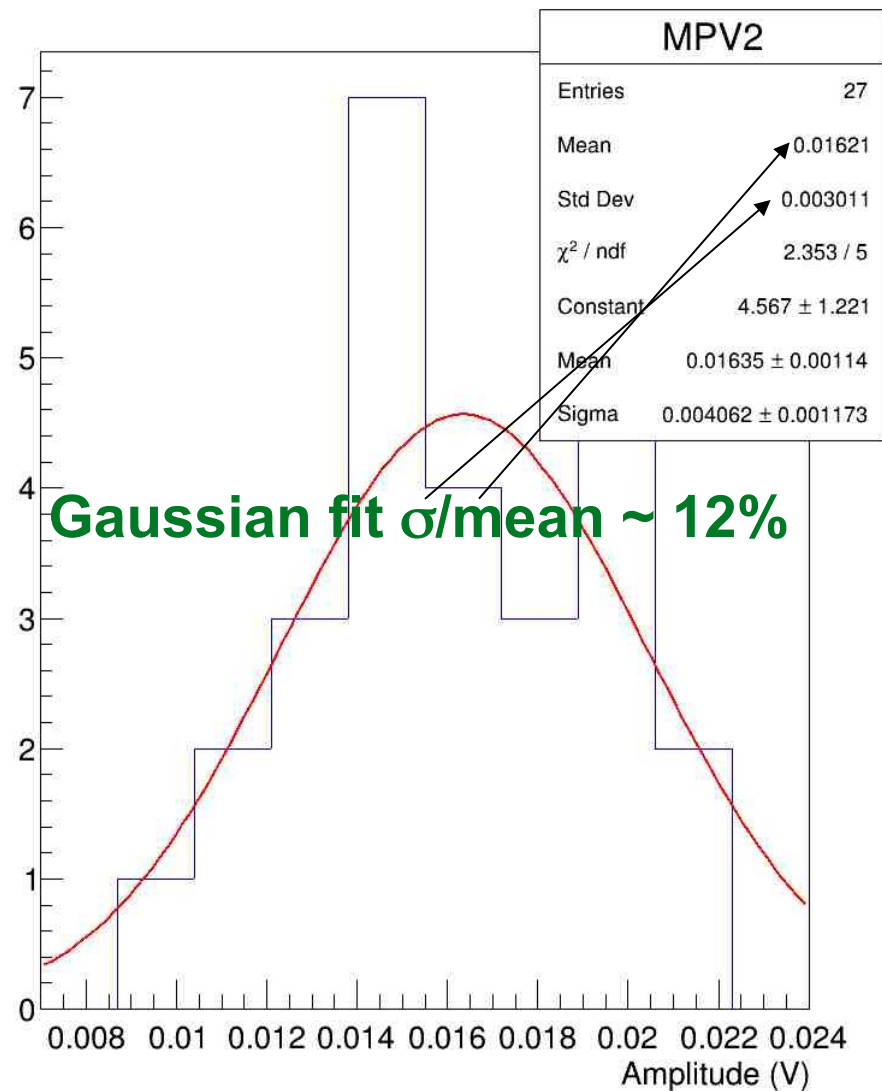
If smaller the charge measurement is not limited by non uniformity in light collection.

MPV distributions on tile surface

MPV1

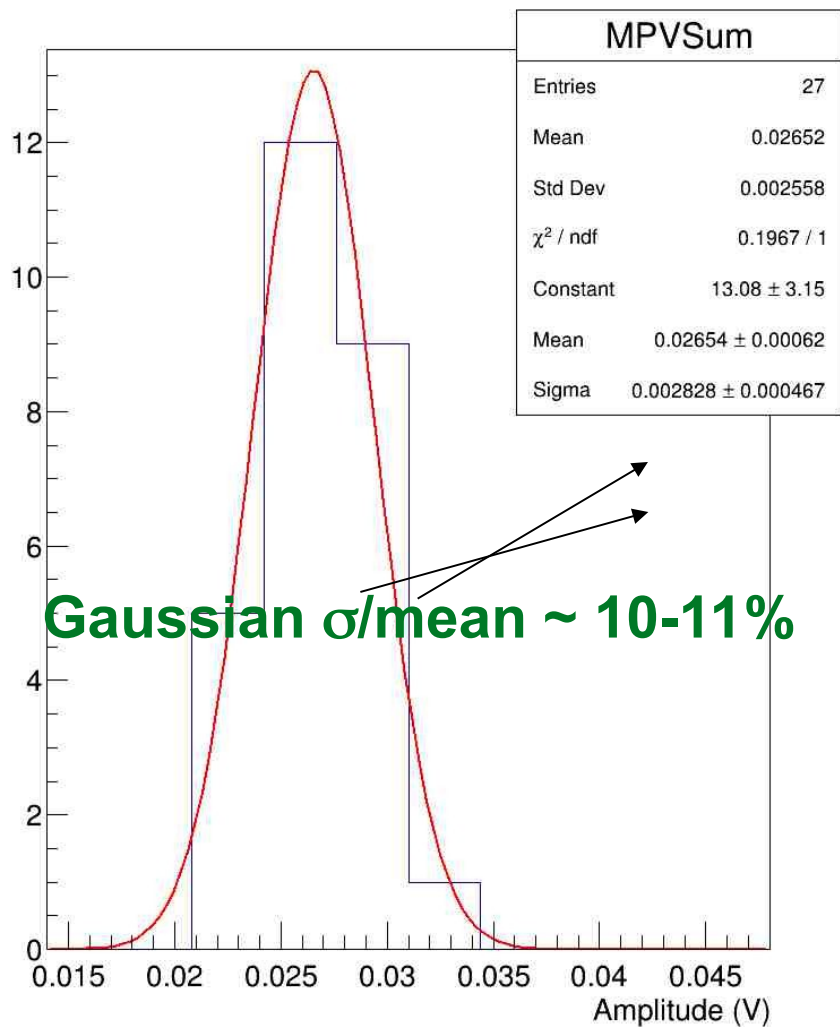


MPV2

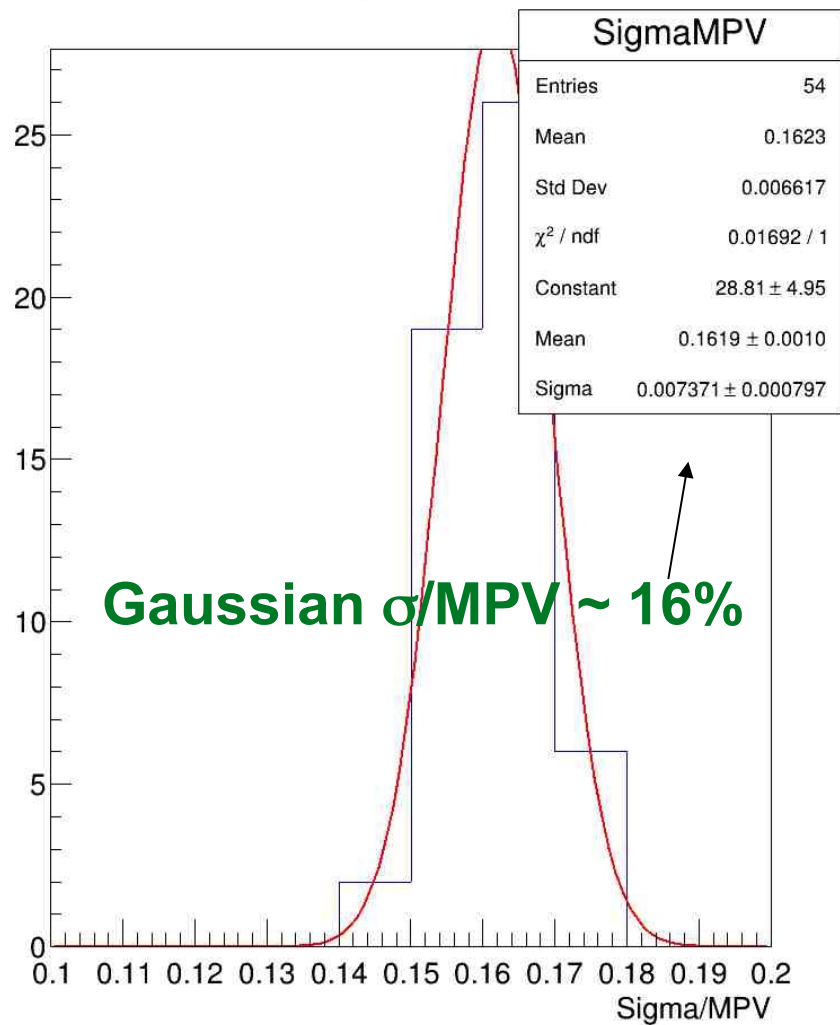


MPV distributions on tile surface

MPVSum



SigmaMPV



Landau fluctuations are larger than non uniformity for m.i.p..

Charge measurements and tracking

If tracking is available, like in Herd, the energy loss required to estimate the particle charge Z can be obtained by the estimation of the position of the track hitting the tile and a function

$F(x,y)$ relating measured amplitude and charge loss.

$F(x,y)$ can be estimated by the measurements with source in many points.

To be done

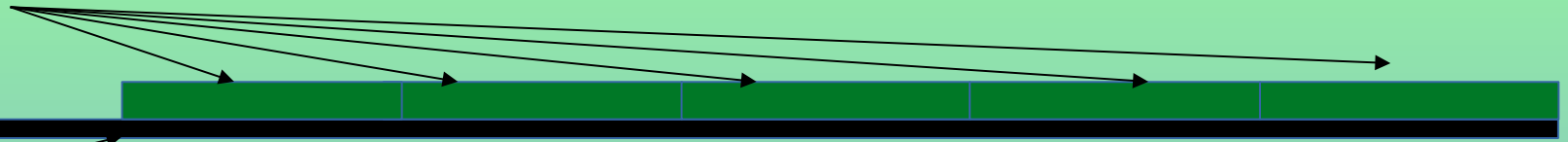
- Completing the set of measurements on tile surface (long because of weak source, 1d/point).
- Estimating $F(x,y)$, first approximation can be evaluated now
- Using signal area rather than peak amplitude ?
- Simulating the apparatus to understand contributions
- Better understanding of the reflections on the sides

Long PCB for tile beam test

Long PCB for 5 tiles

5 Tiles

PCB

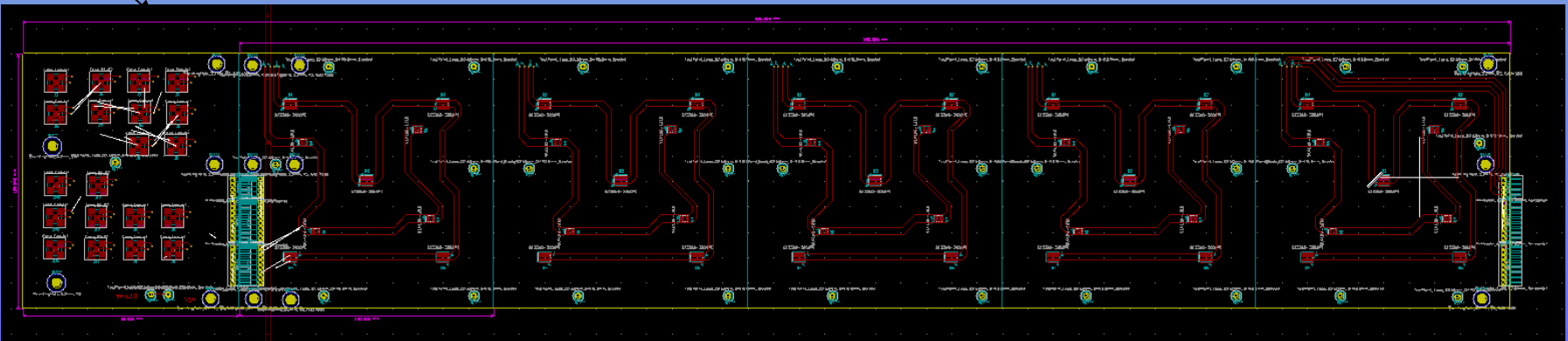


5 SiPM 3x3 mm² model S13360-3050PE (Hamamatsu)

4 SiPM 1.3x1.3 mm² model S14160-1310PS (Hamamatsu)

Inner paths connecting tiles and the MCX connector are matched 50 Ω in the second layer between two ground layers for shielding.

Connectors

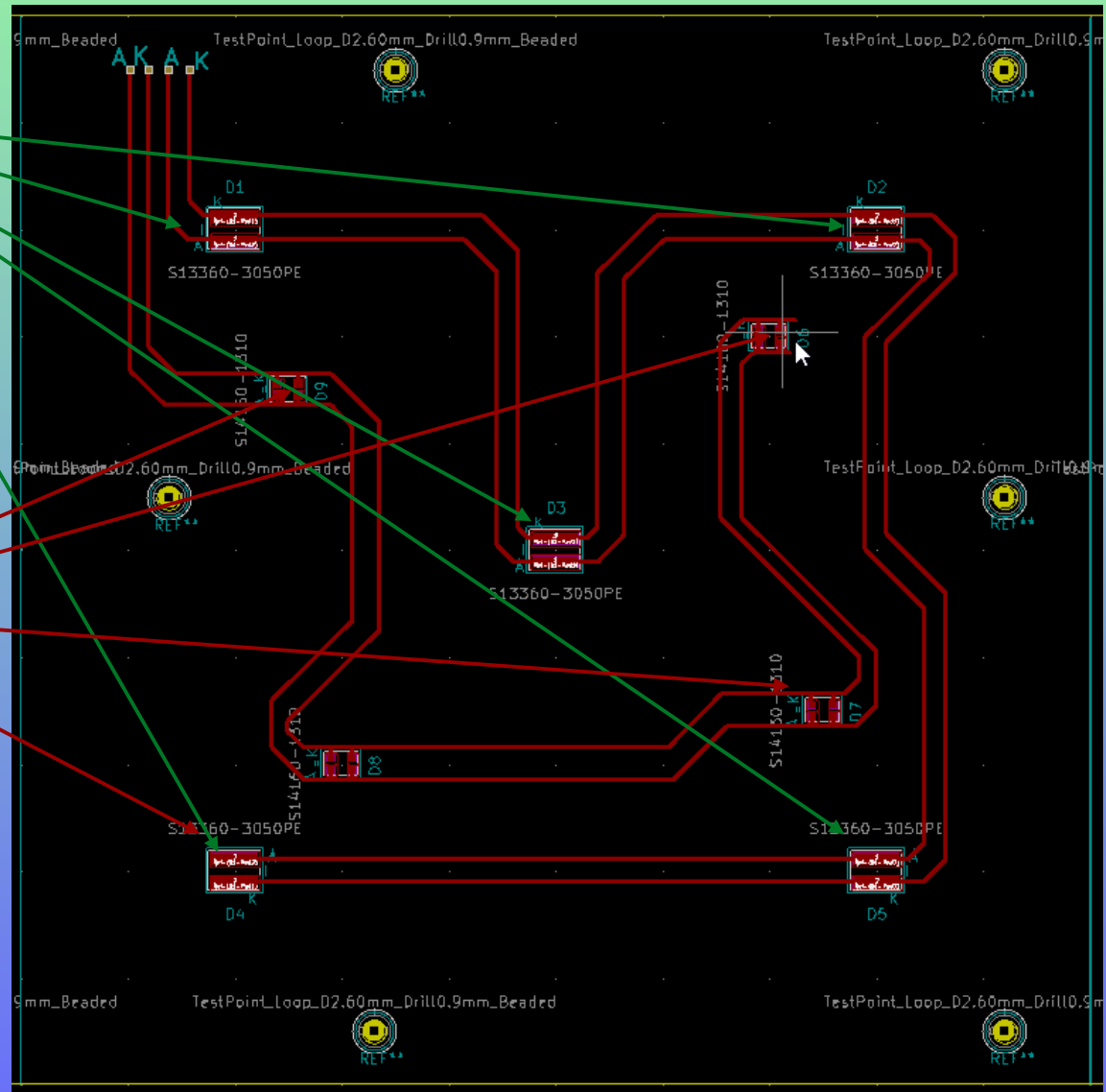


$$58.5 \text{ cm} = 5 \times 10 \text{ cm} + 8.5 \text{ cm}$$

Layout for single tile

SiPM 3x3 mm²

SiPM 1.3x1.3 mm²



Long PCB for 10 tiles

Building 1m long PCB is technically challenging.

2 PCBs 50 cm long can be ganged together with connectors.

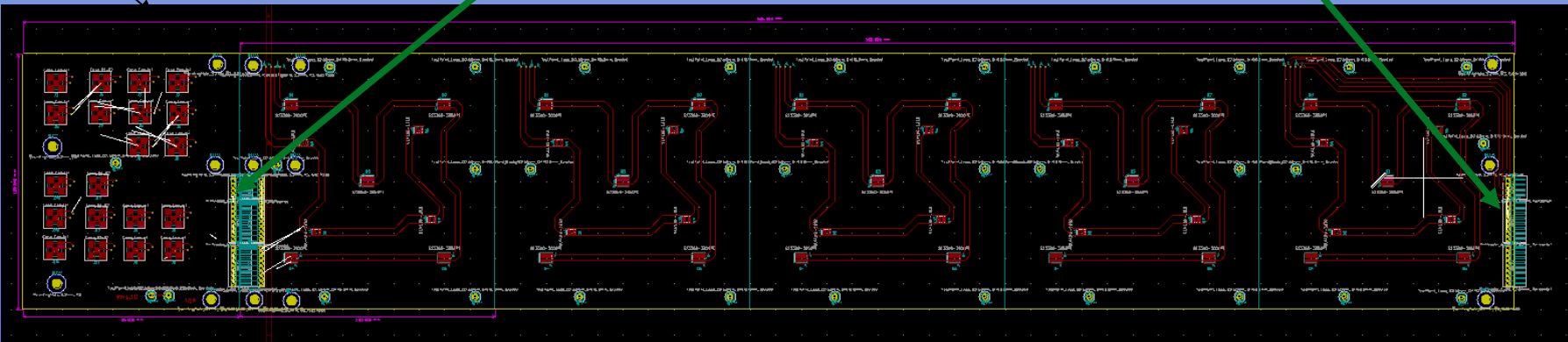
For testing purpose in the laboratory (non for beam test) connectors on both sides of the long PCB are available.

That will allow testing tile mounted 1 m away from the output: signal attenuation and cross talk.

Connectors

10 cm

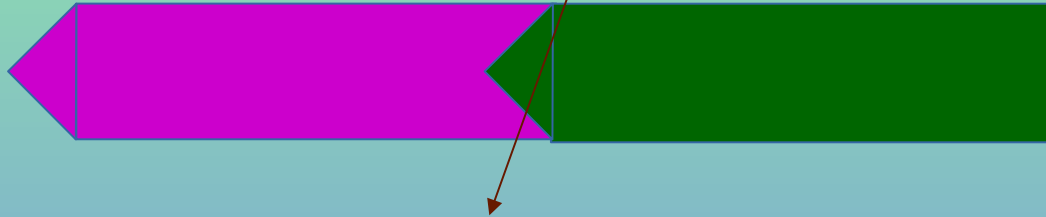
$$58.5 \text{ cm} = 5 \times 10 \text{ cm} + 8.5 \text{ cm}$$



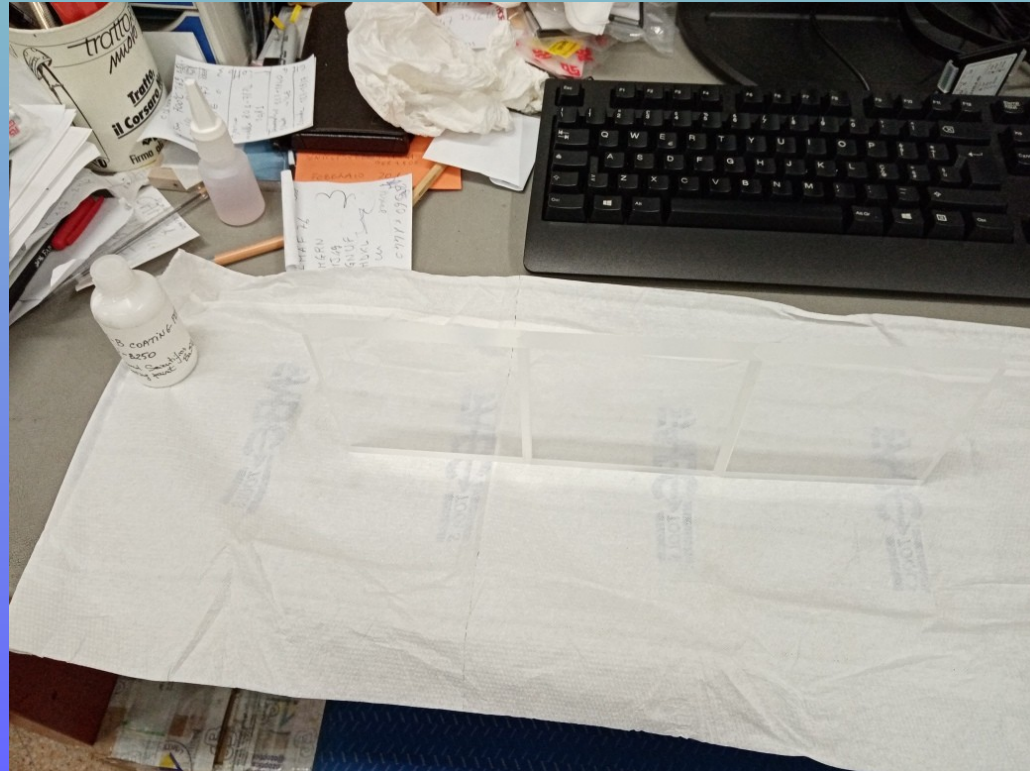
Dove tailed tiles

Tiles dovetailed to requires no additional material:

To cover $10 \times 10 \text{ cm}^2$ $10 \times 10 \text{ cm}^2$ suffices.

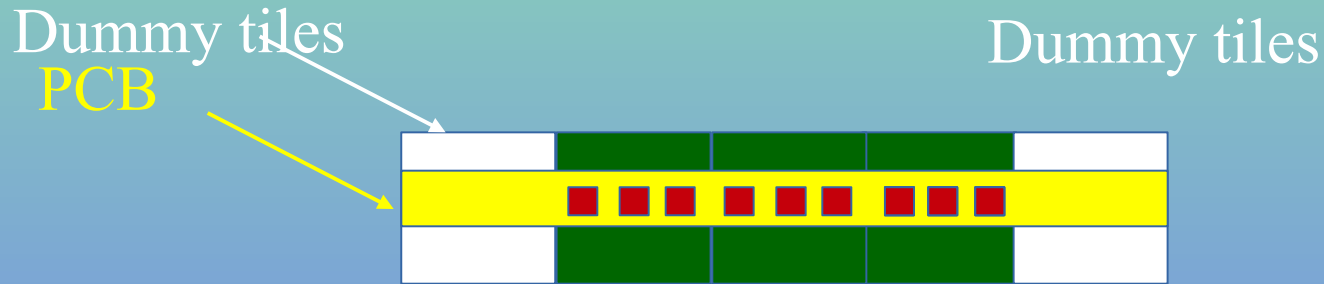


Today we have 3 tiles with dovetailed edges to be positioned.
Plus one with straight edges.



Number of PCBs

Plan to produce a few 58.5 cm PCB for and start testing in laboratory.
Due to available scintillator and SiPMs we can arrange e.g. 3 active tiles together along a single long PCB.
Dummy tiles (plexiglass) can be positioned along the rest of PCB.

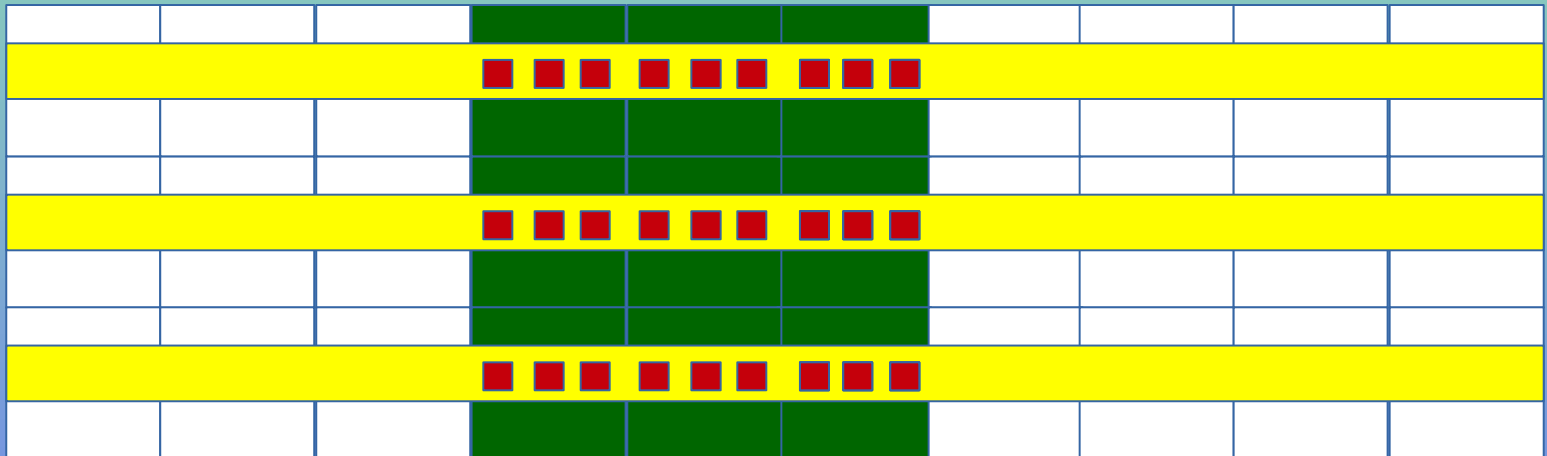


Crosstalk along a long PCB to be studied in laboratory with radioactive source.

Test at CERN

If tests are successful for CERN beam test we will arrange 2-3 long PCB side by side with 3 active tiles.

With HG ($3 \times 3 \text{ mm}^2$) and LG channels ($1.3 \times 1.3 \text{ mm}^2$).



Example: this is a $30 \times 30 \text{ cm}^2$ active area.

To be installed side by side with another tile prototype.

We are planning the mechanical support for the beam test.

