HERD PSD tile

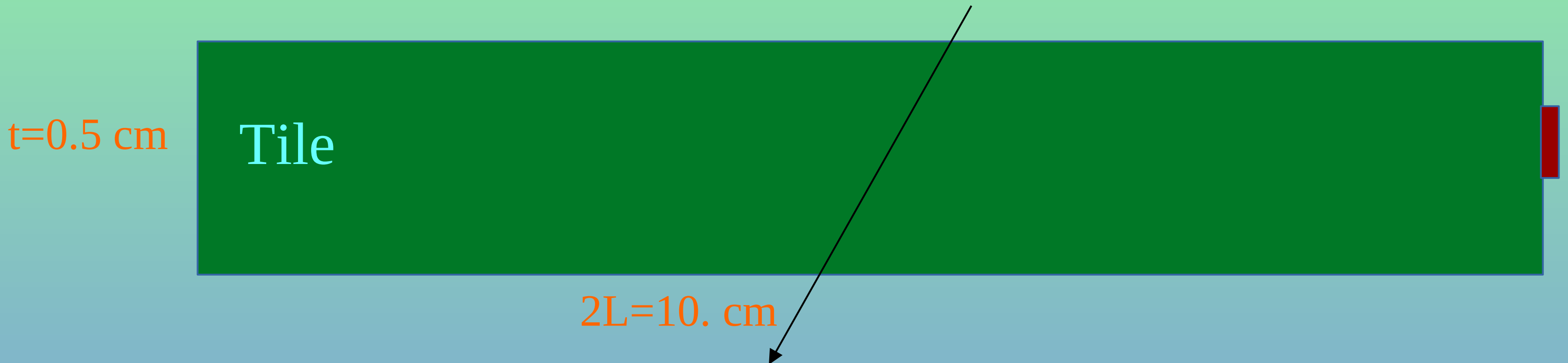
22-02-2021

The INFN Pavia PSD group

Estimation of photon flux on SiPMs

Signals on SiPM

Estimation of the signals on SiPM



dN$_\gamma$/dE~10^4 /MeV is the number of photons per MeV

dE/dx ~ 2 MeV/cm (m.i.p.)

t=0.5 cm thickness of tile

2L=10 cm tile size

n = 1.6 refraction index of tile scintillator

cos θ = 1/n is the limiting angle

The number of photons emitted within θ is

N_γ = (dN/dE)*(dE/dx)*(cos θ)*t

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

Signals on SiPM (2)

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

Rough estimation assuming effective reflection !!

$dN_\gamma/dA = 300$ ph/cm^2

Assuming a quantum efficiency QE=50%

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

The number of phototelectron on a cell:

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

Occupancy very low for m.i.p. with d<= 50μm.

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

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

Retaining linearity for Fe requires <0.1 p.e./Cell → d < 15 μm.

Therefore high gain large area SiPMs can have d=50 μm while low gain small area SiPMs d=10-15 μm.

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 ~1-2 ns.
Additional broadening due to propagation in the tile comparable to 1ns.

Dead time of SiPM is ~10 ns >> 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

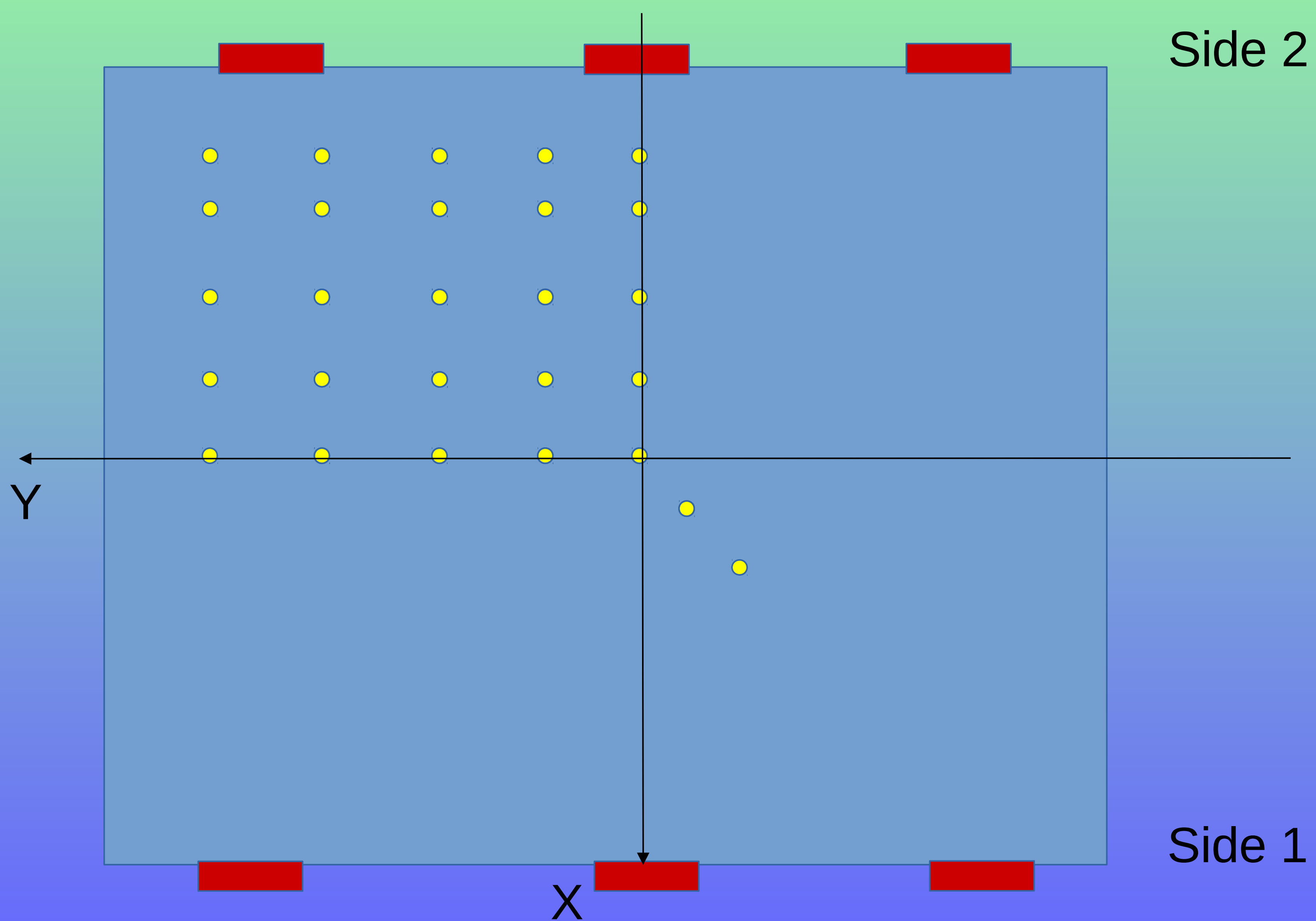
Wrapped with Teflon and with blac paper

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

Covered with white coating BaS

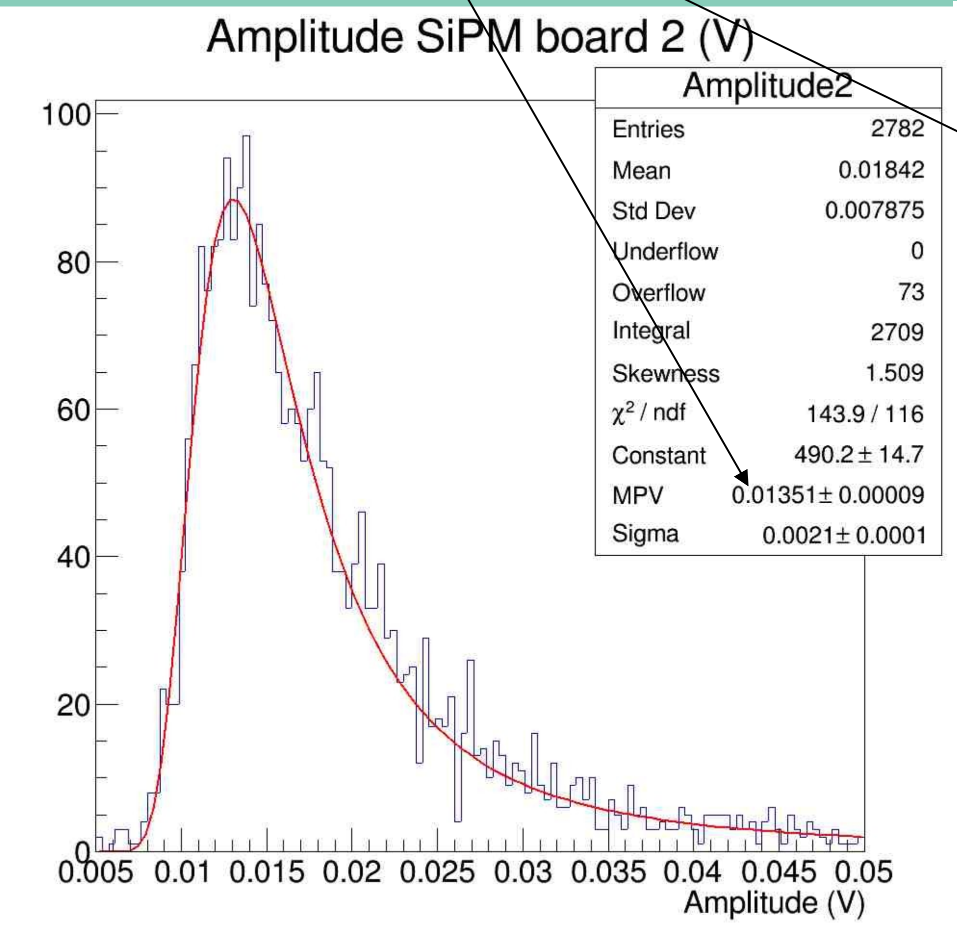
Readout on single side with array SiPM SensCell C-60035-4p-gevb (4 6x6 35 μm)

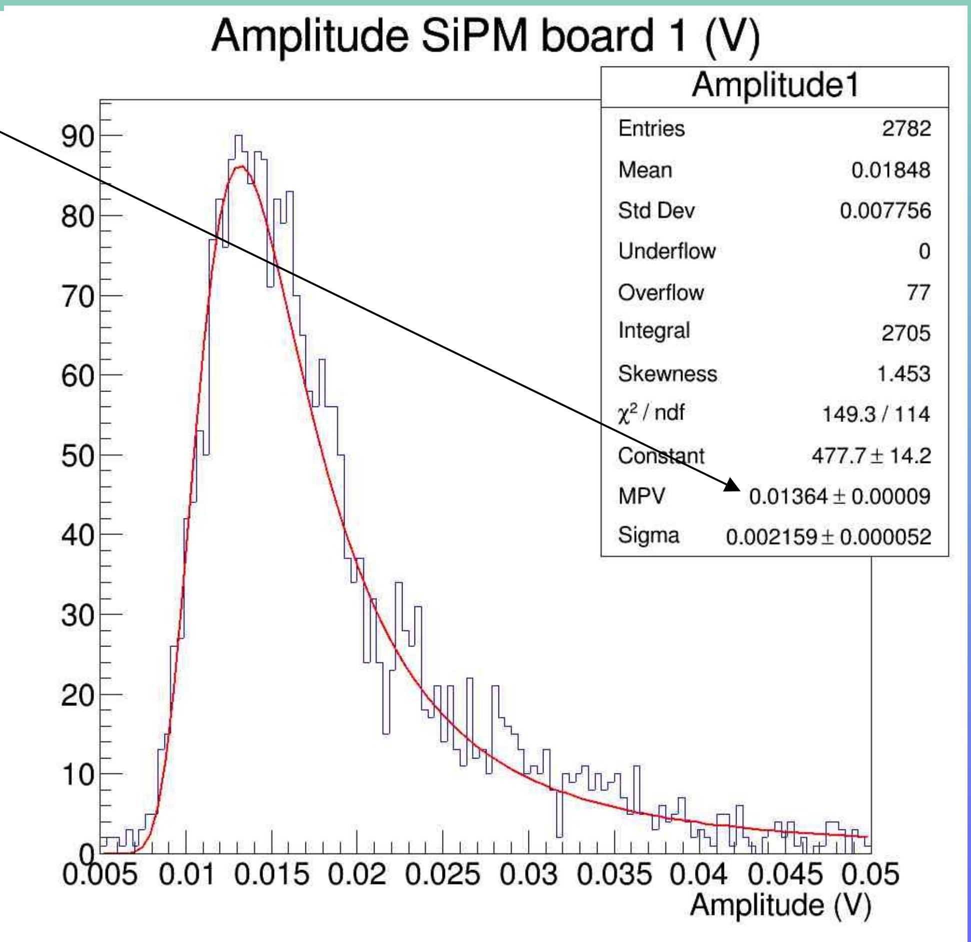
Test with radioactive source



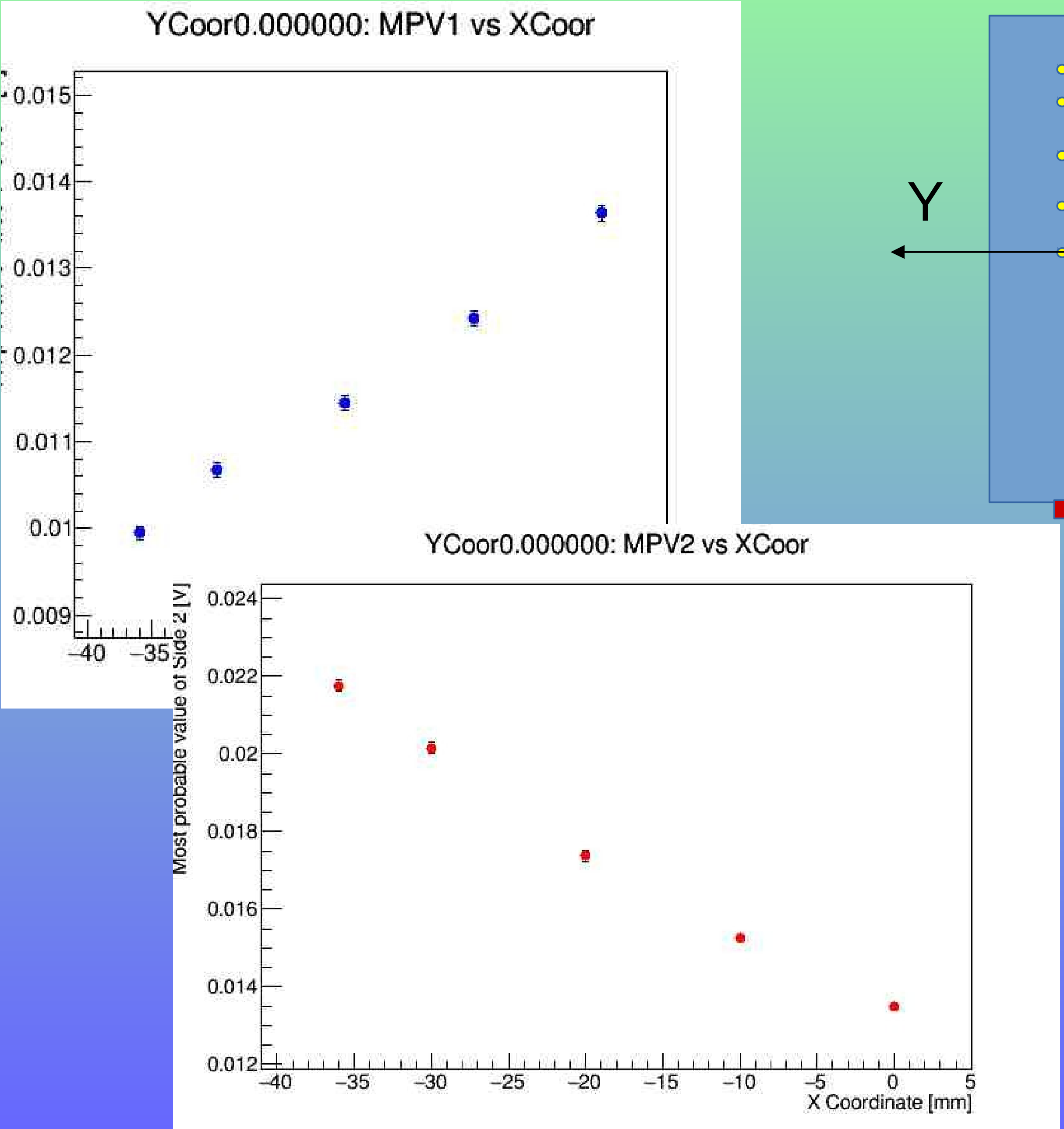
Signal amplitude X=0 Y=0

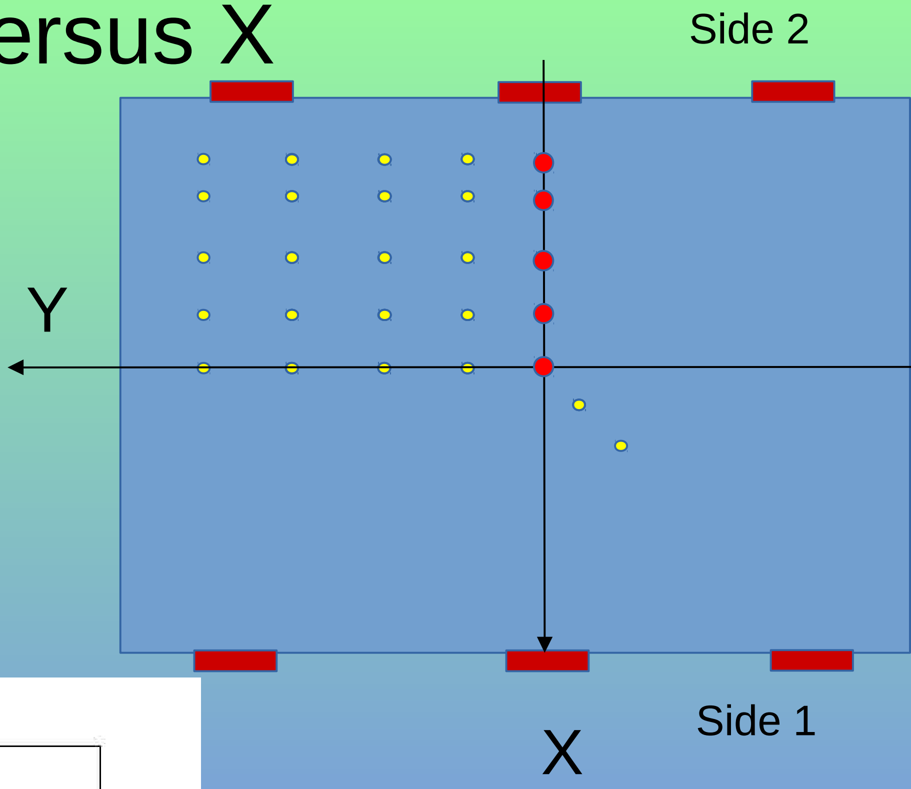
Signals on both sides when source is in the centre X=0.0 Y=0.0
They are equal. The SiPM gains and optical coupling on both sides are equal.





MPV1/2 versus X

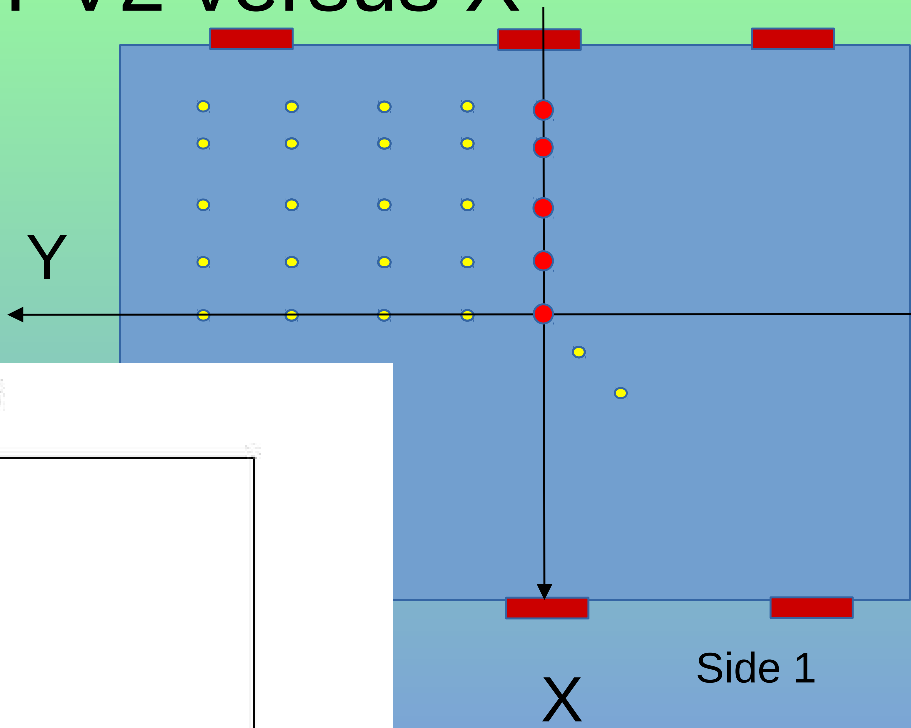


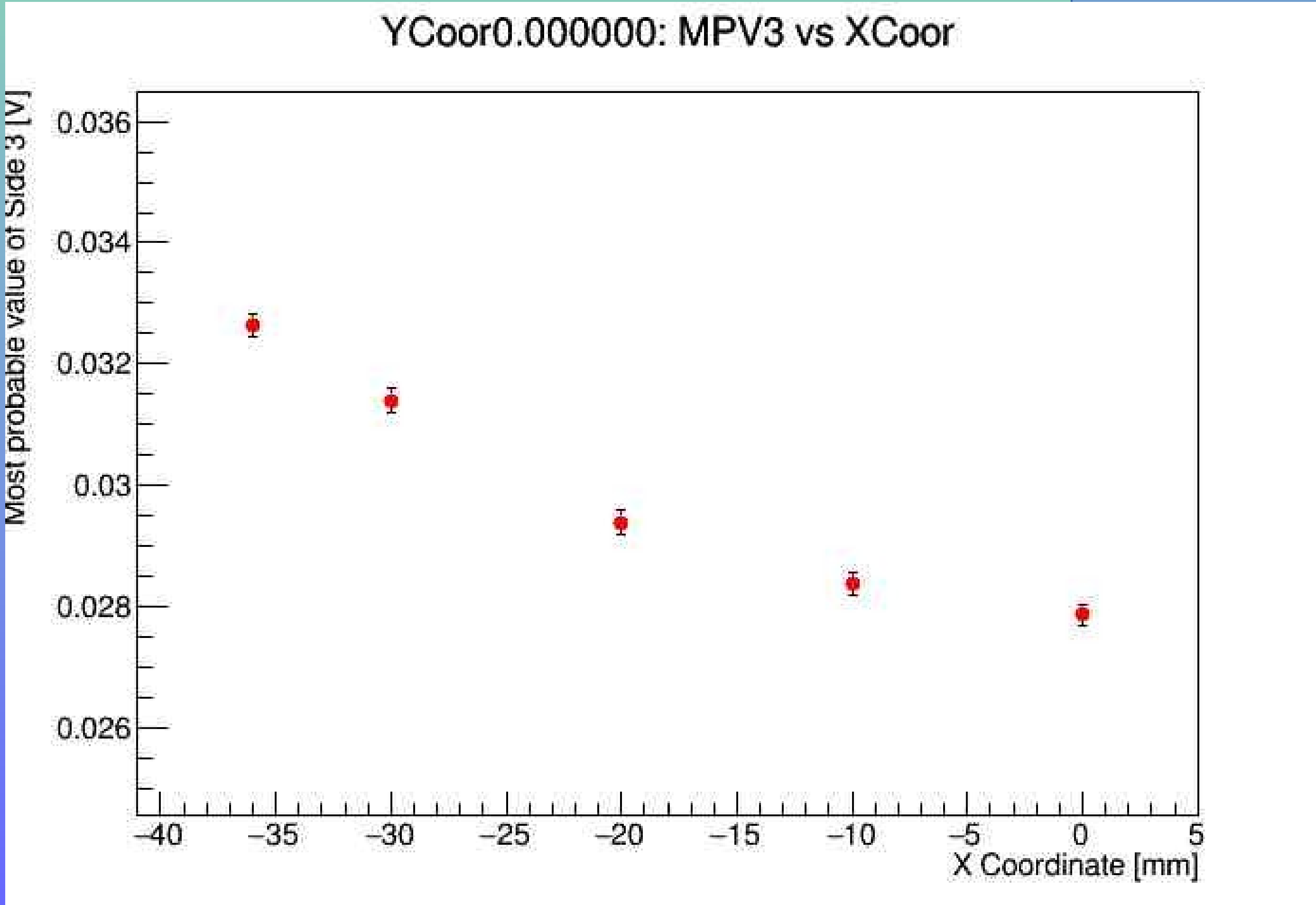


Signal increases (decreases) going closer (farther) to the SiPMs.
The solid angles subtended by SiPMs grows larger (smaller).

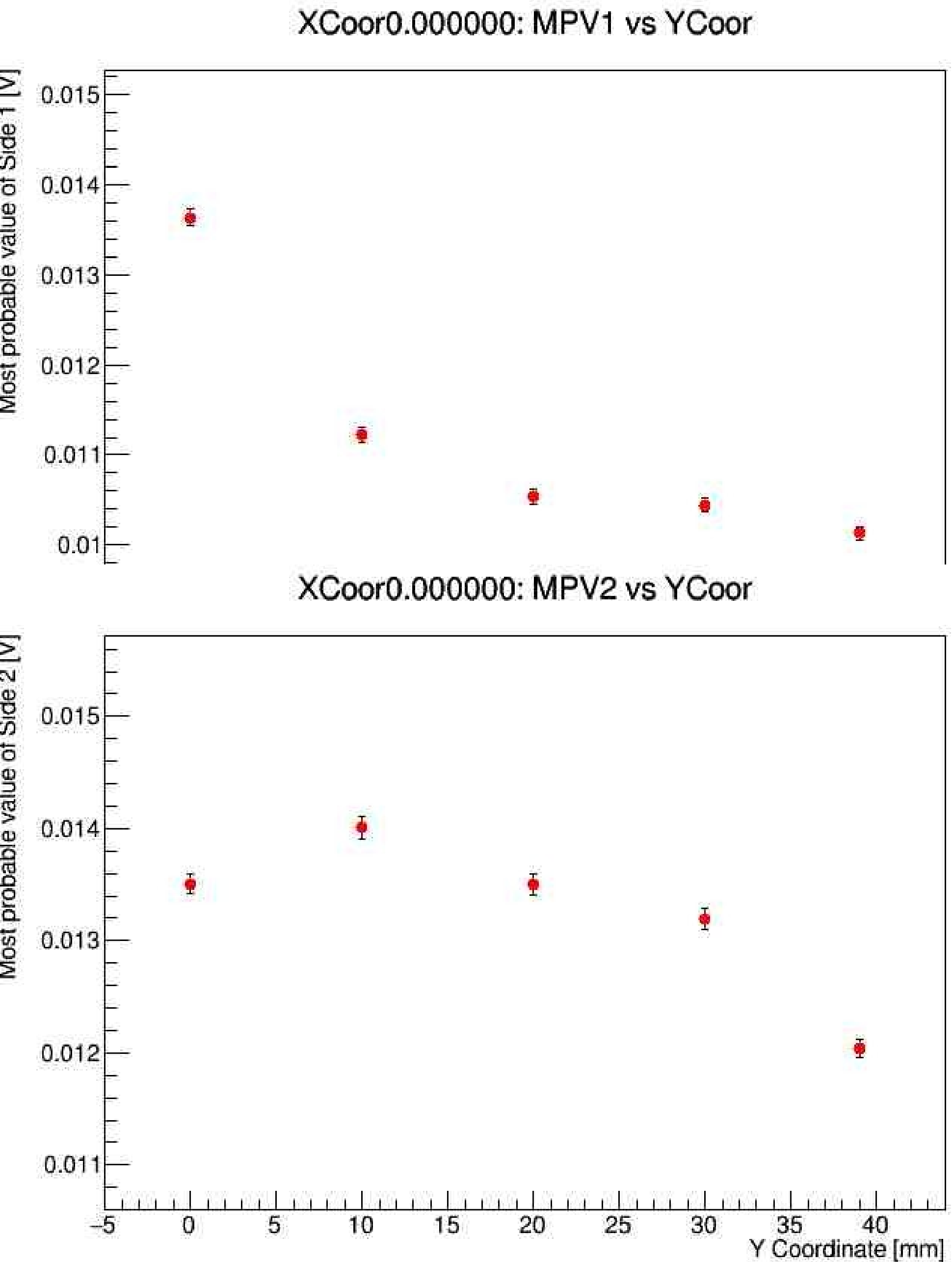
MPV3=MPV1+MPV2 versus X

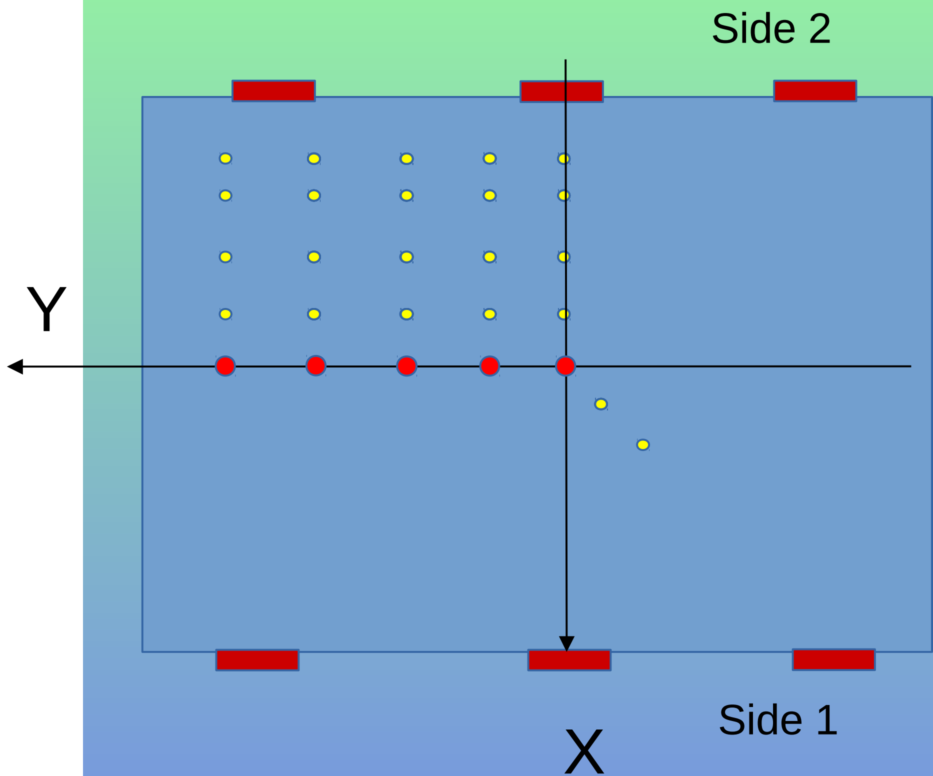
Total signal increases going closer to SiPMs.
Reflection on the sides limits the effect of
solid angle reduction.





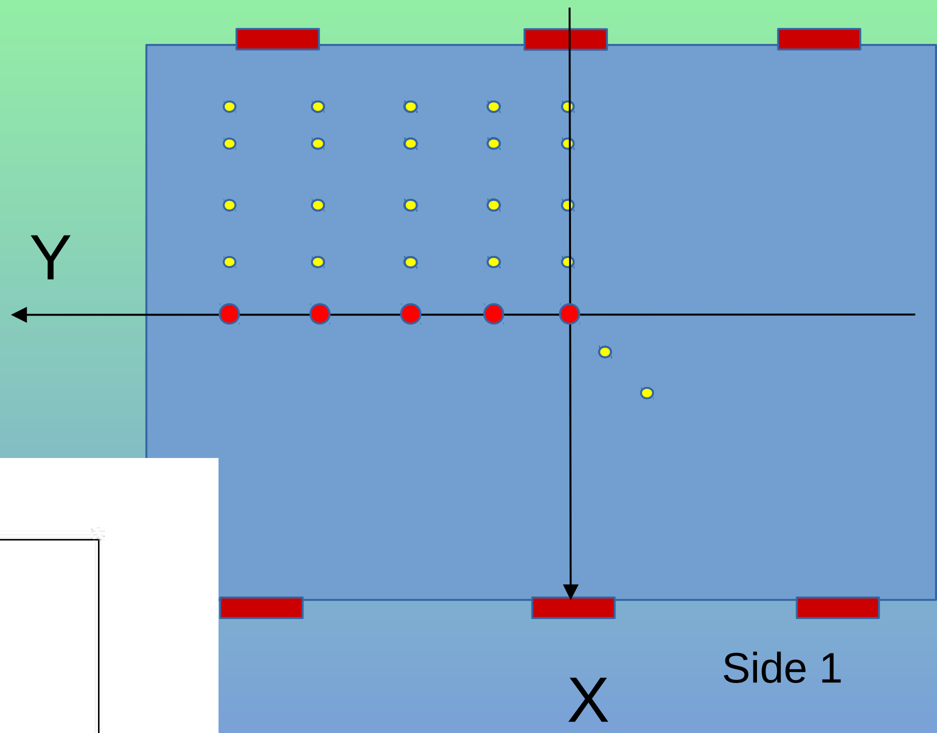
MPV1/2 versus Y

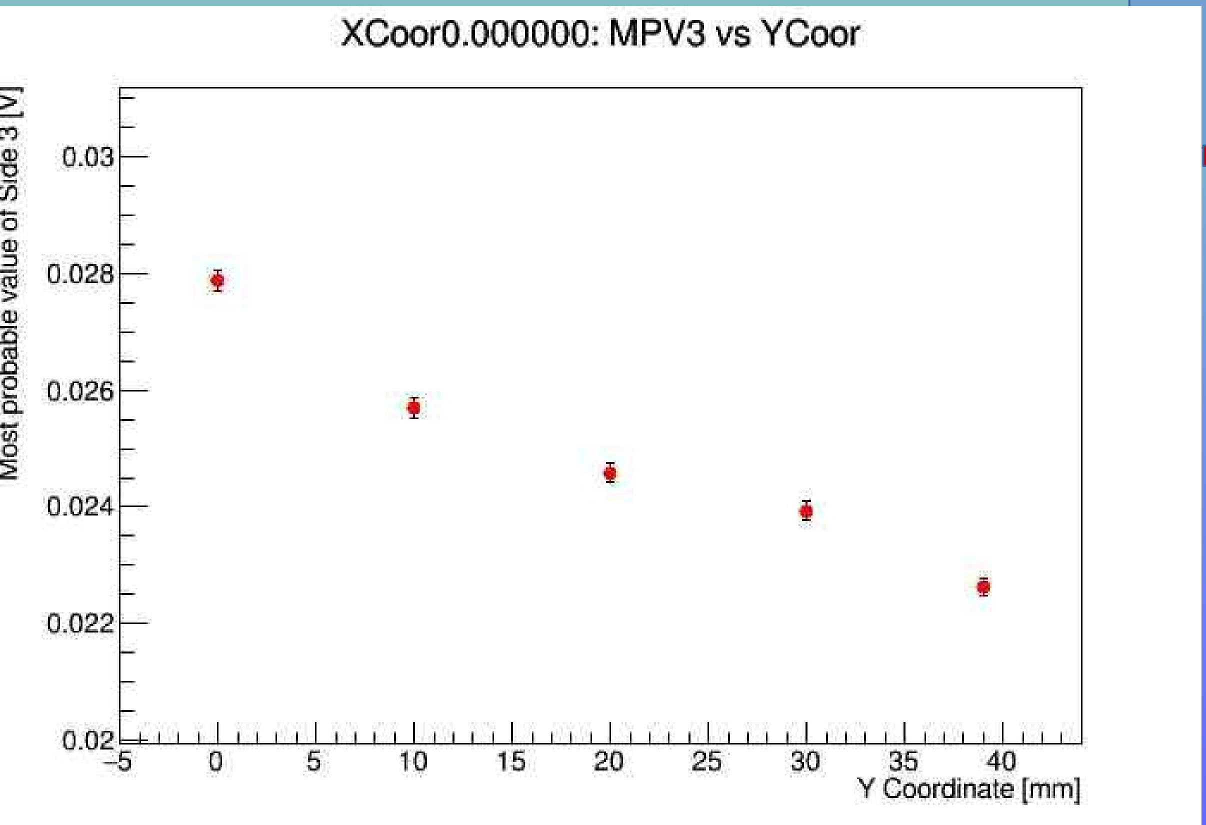




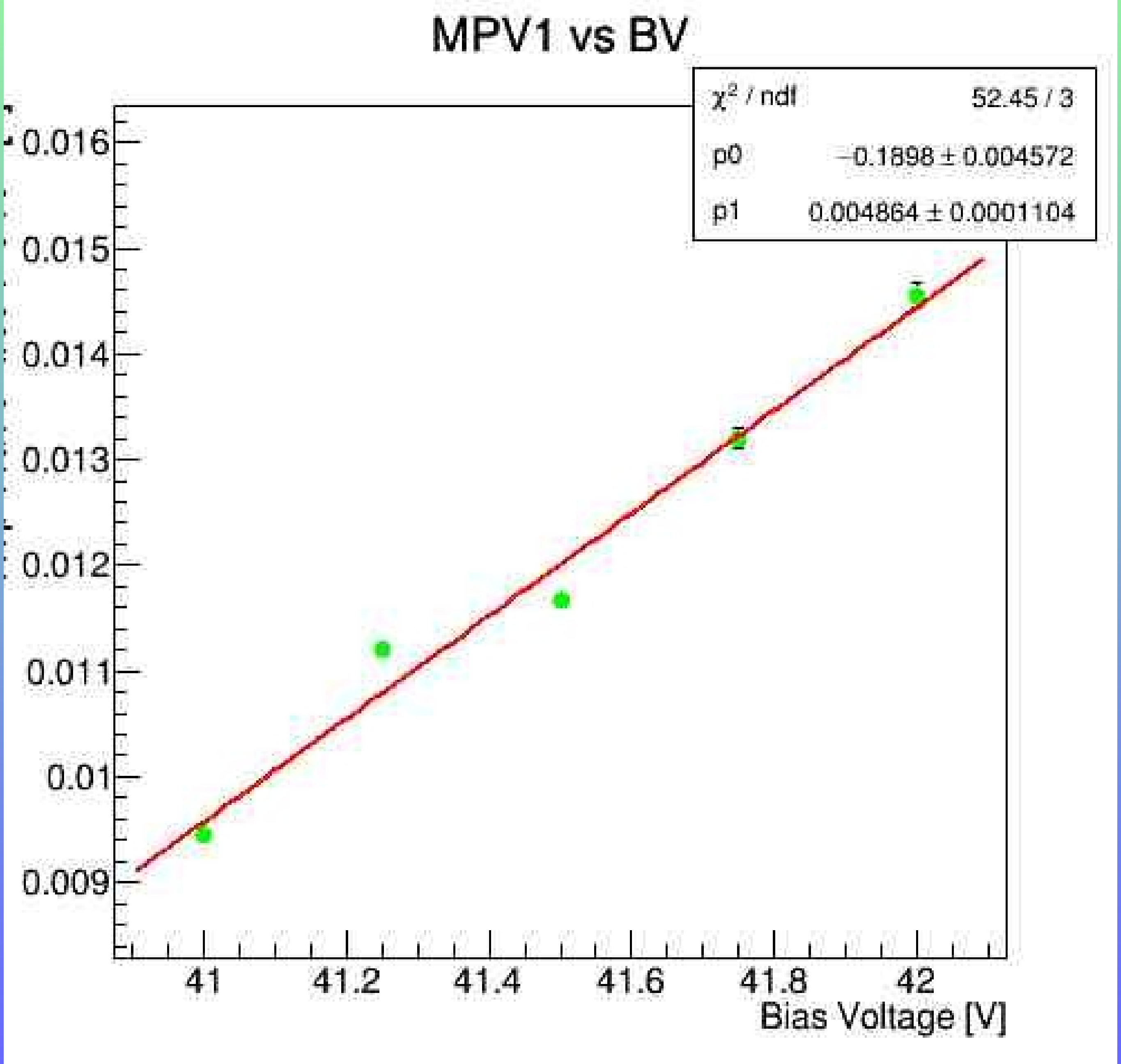
Total signal decreases moving toward the edge.
Probably due to decreasing solid angle subtended by SiPMs and poor reflection on the side.

MPV3=MPV1+MPV2 versus Y





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.

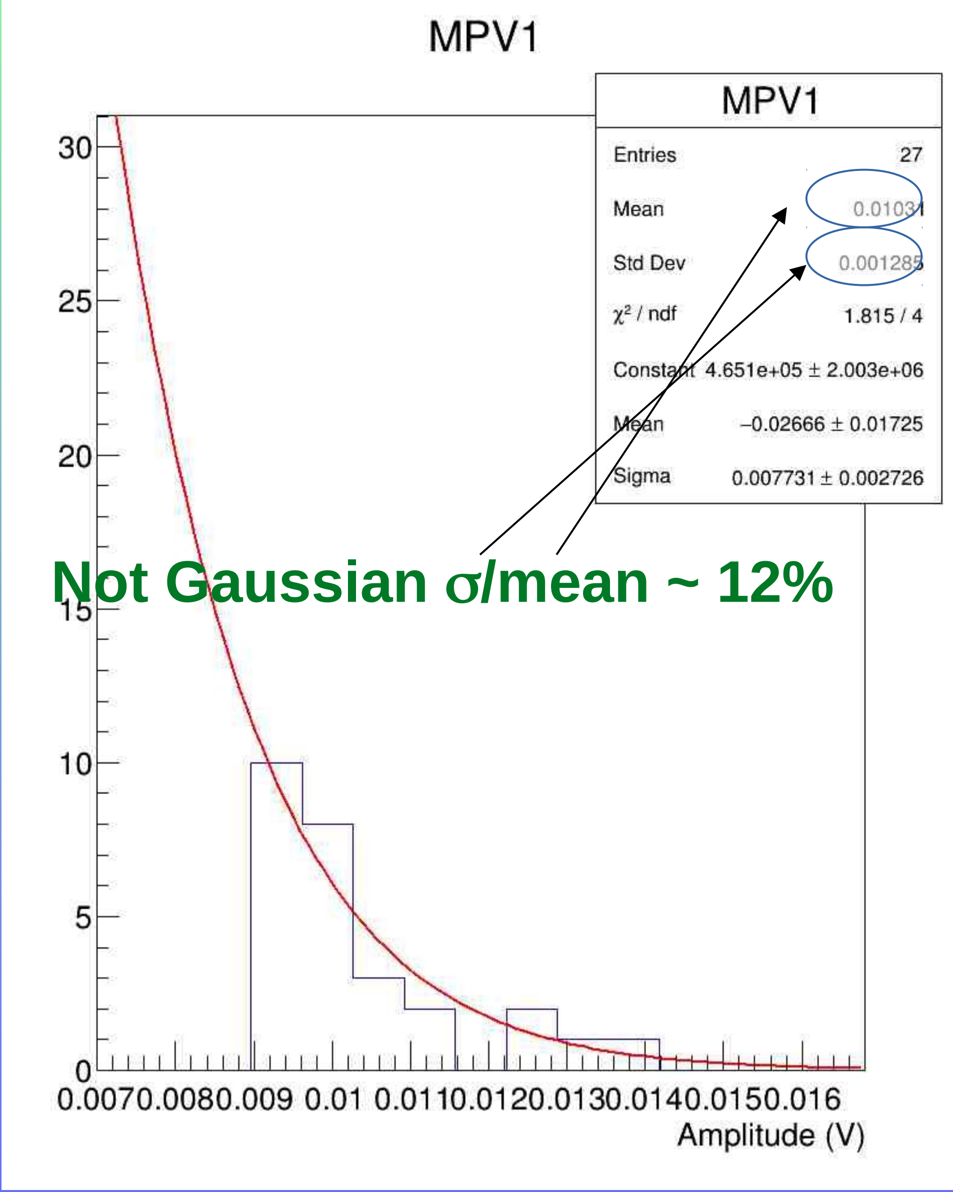
Ideally the points should cover the whole surface.

Now we rely on the set of points already collected.

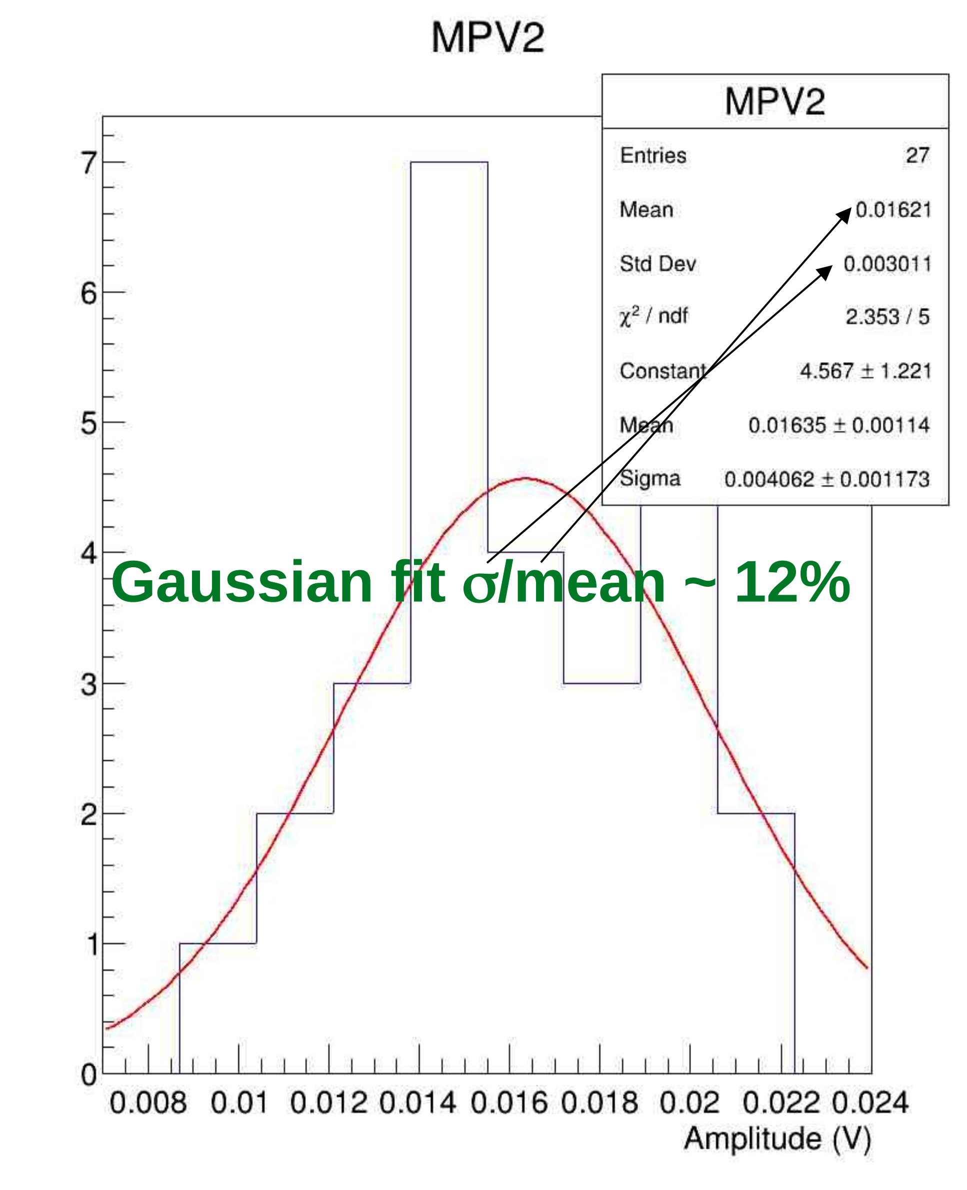
This estimator should be compared with the relative spread of the Landau distribution.

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

MPV distributions on tile surface

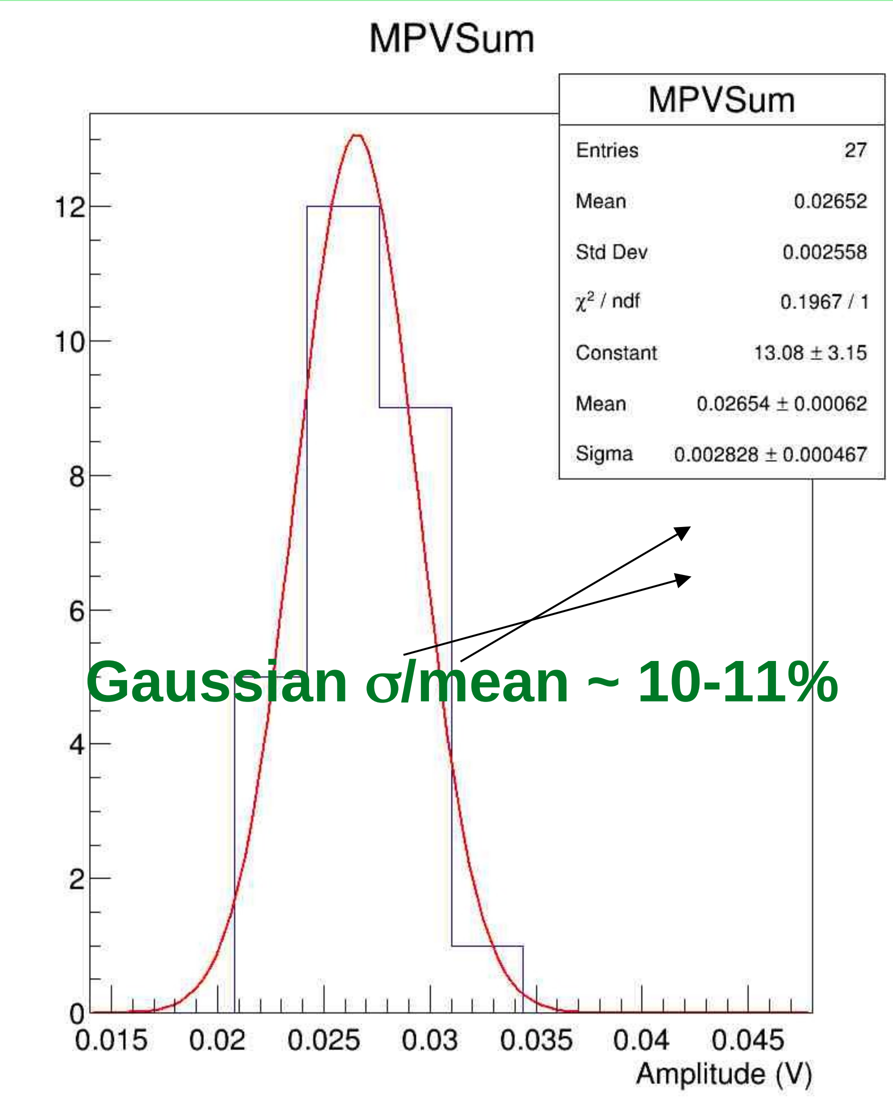


Not Gaussian σ/mean ~ 12%

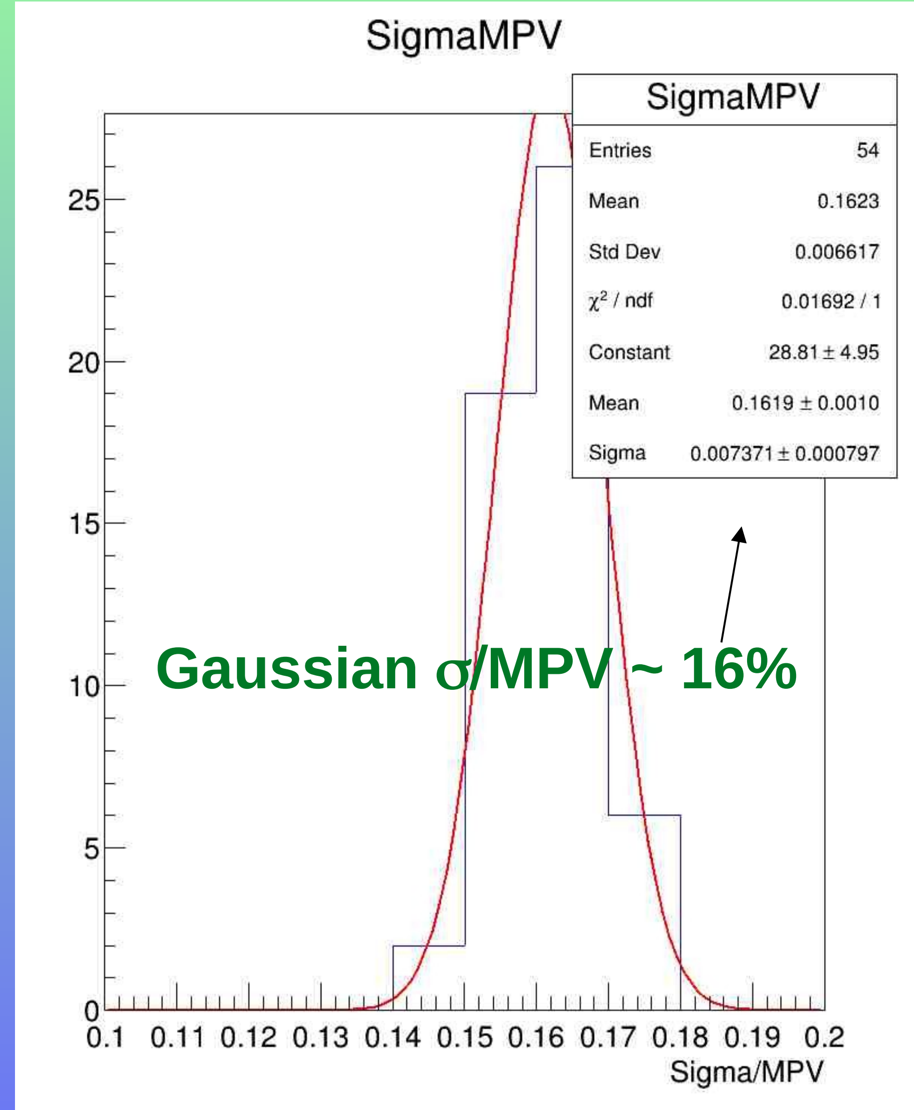


Gaussian fit σ/mean ~ 12%

MPV distributions on tile surface



Gaussian σ/mean ~ 10-11%



Gaussian σ/MPV ~ 16%

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.

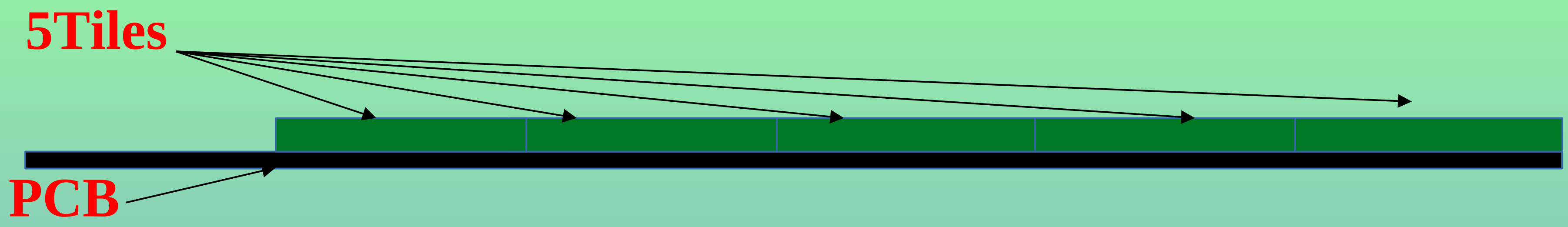
F(x,y) can be esitmated by the measurements with source in many points.

To be done

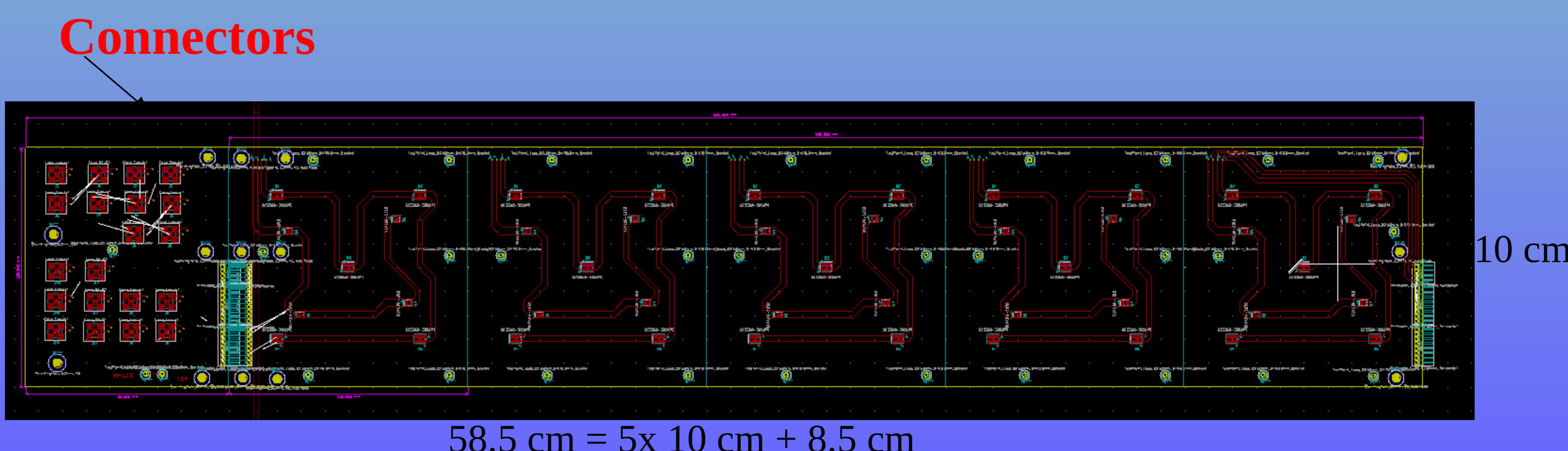
- Completing the set of measurements on tile surface (long because of weak source, 1d/point).
- Estimating F(x,y), first approximation can be evaluated now
- Using signal area rather than peak amplitude ?
- Simulating the apparatus to understand contributions
- Better understanding of the reflections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

Long PCB for tile beam test

Long PCB for 5 tiles



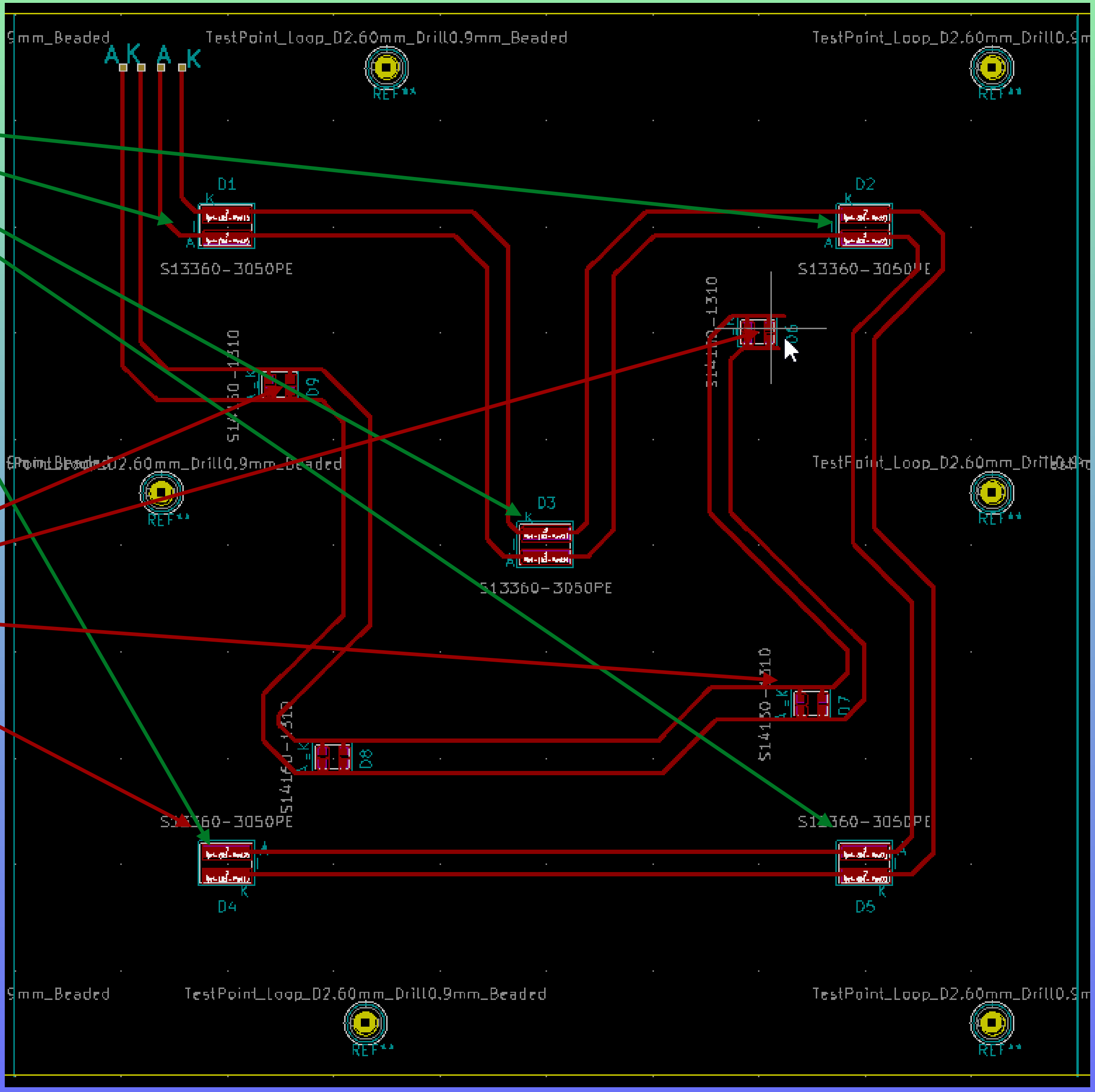
5 SiPM 3x3 mm^2 model S13360-3050PE (Hamamatsu)
4 SiPM 1.3x1.3 mm^2 model S14160-1310PS (Hamamatsu)
Inner paths connecting tiles and the MCX connector are matched 50 Ω in the second layer between two ground layers for shielding.



Layout for single tile

SiPM 3x3 mm^2

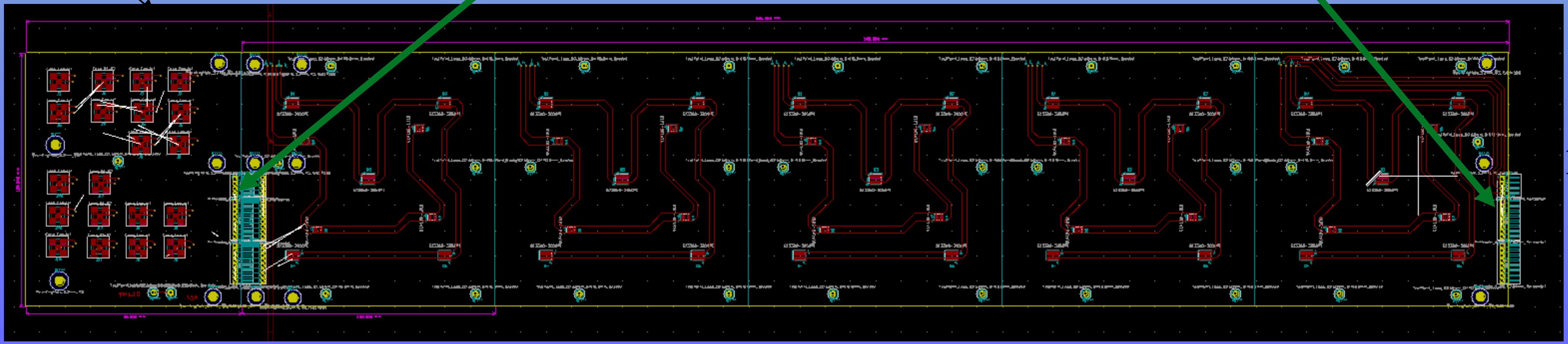
SiPM 1.3x1.3 mm^2



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



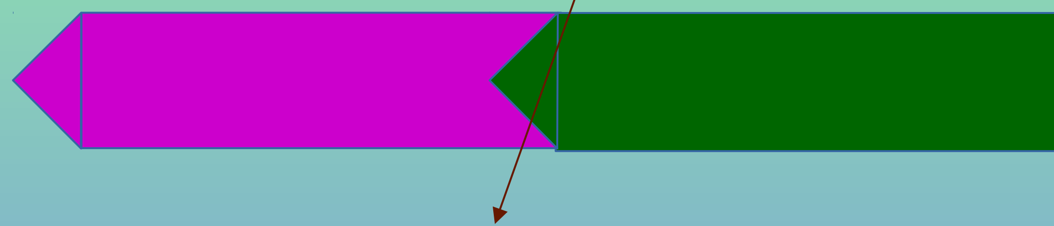
10 cm

58.5 cm = 5x 10 cm + 8.5 cm

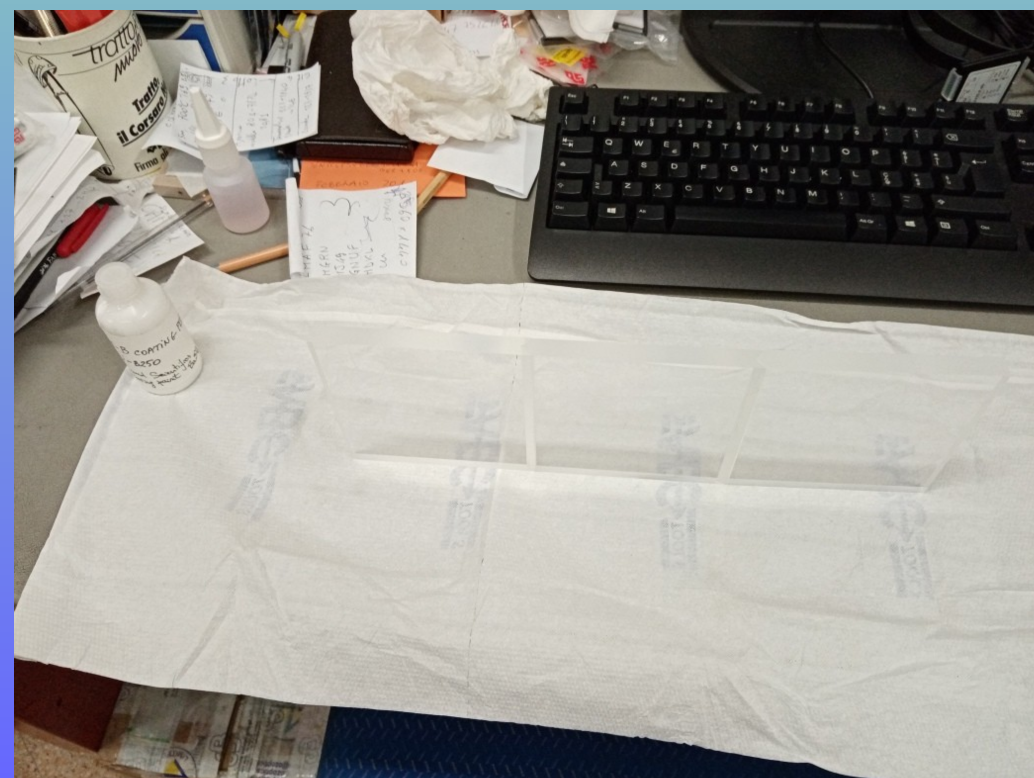
Dove tailed tiles

Tiles dovetailed to requires no additional material:

To cover 10x10 cm^2 10x10 cm^2 suffices.

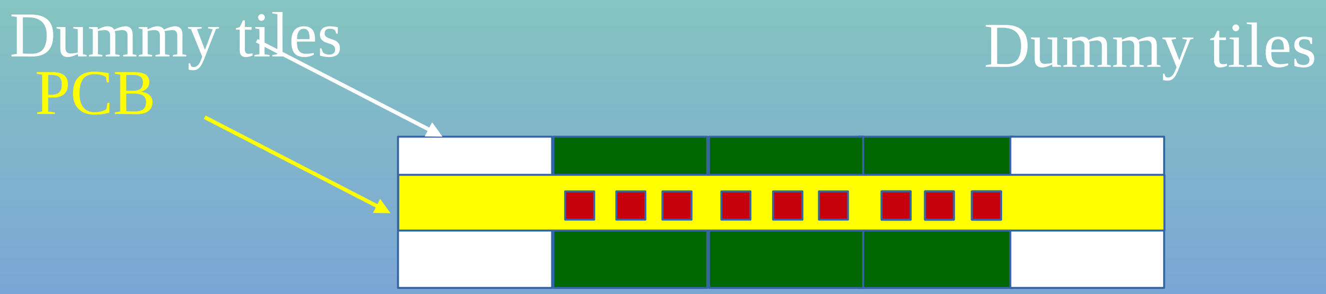


Today we have 3 tiles with dovetailed edges to be positioned.
Plus one with straight edges.



Number of PCBs

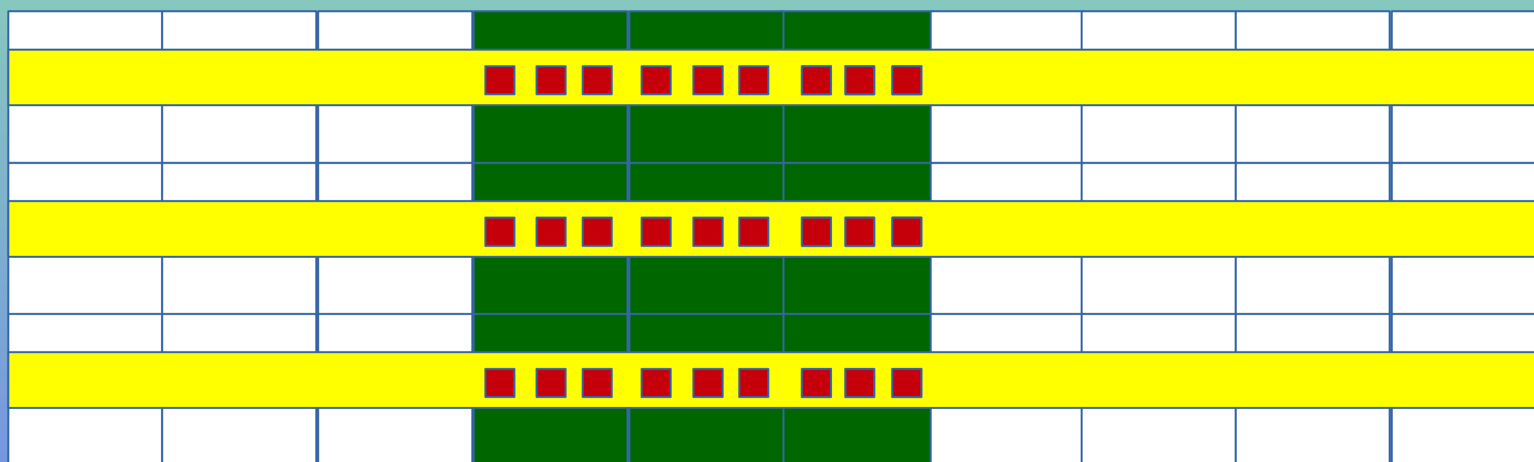
Plan to produce a few 58.5 cm PCB for and start testing in laboratory.
Due to available scintillator and SiPMs we can arrange e.g. 3 active tiles together along a single long PCB.
Dummy tiles (plexiglass) can be positioned along the rest of PCB.



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

Test at CERN

If tests are succesful for CERN beam test we will arrange 2-3 long PCB side by side with 3 active tiles.
With HG (3x3 mm^2) and LG channels (1.3x1.3 mm^2).



Example: this is a 30x30 cm^2 active area.
To be installed side by side with another tile prototype.

We are planning the mechanical support for the beam test.