HERD PSD tile

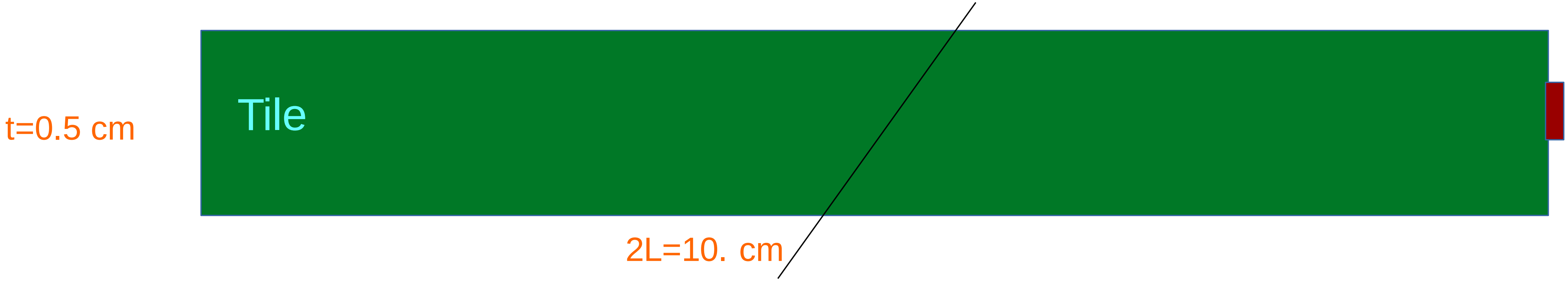
23-02-2021

The INFN PSD group

Estimation of photon flux on SiPMs

Signals on SiPM

Estimation of the signals on SiPM



$dN_{\gamma}/dE \sim 10^4$ /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

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

The number of photons emitted within θ is

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

Hitting the side surface with area A = 4*t2L*tt

Signals on SiPM (2)

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

Rough estimation assuming effective reflection !!

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

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:

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

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

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.

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

To be verified in detail with simulation (see later).

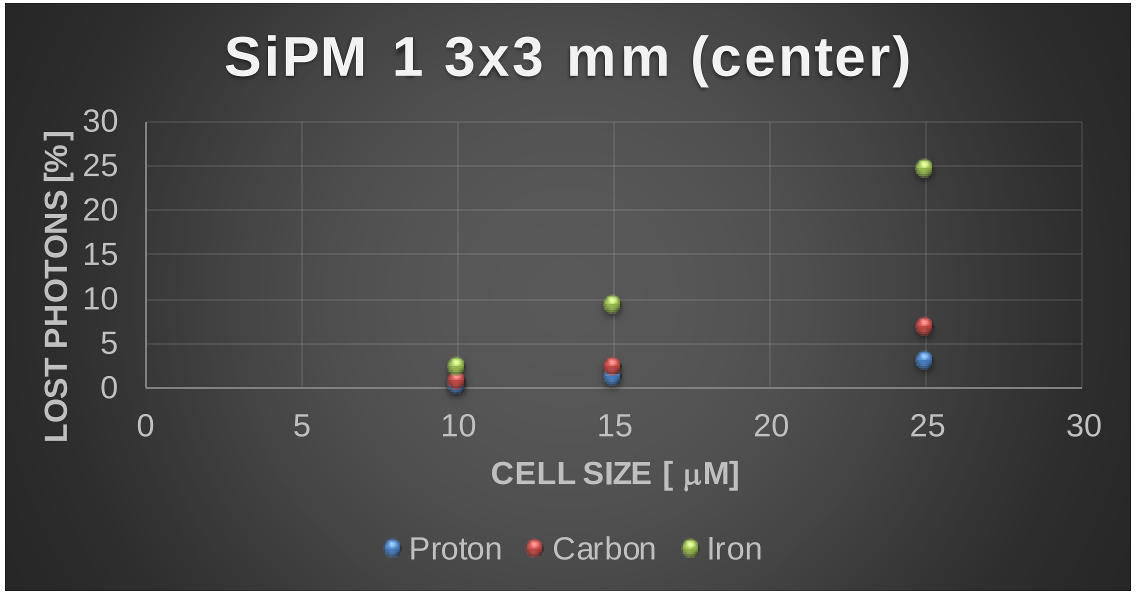
Signals on SiPM: time structure

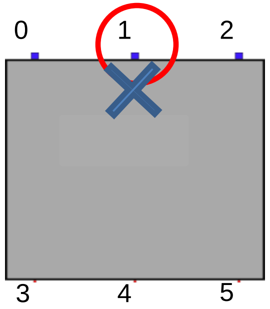
Time profile of scintillation photons driven by scintillation time
Following an exponential shape with decay time ~1-2 ns.
Additional broadening due to propagation in the tile comparable to 1ns.

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.

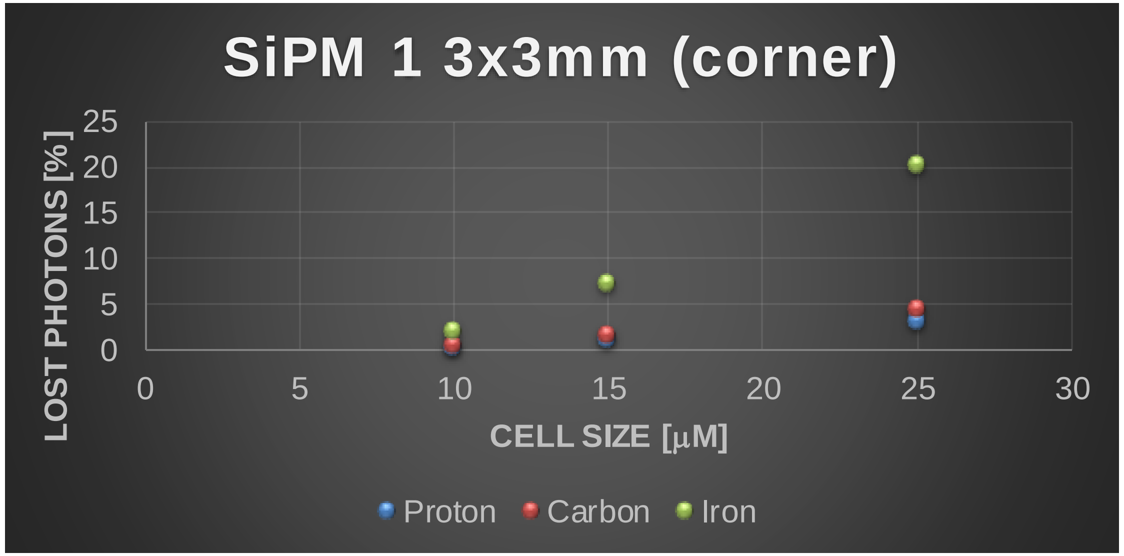
The tile is equipped with 3 SiPM 3x3 mm^2 on one side and 3 SiPM 1x1 mm^2 on the other site

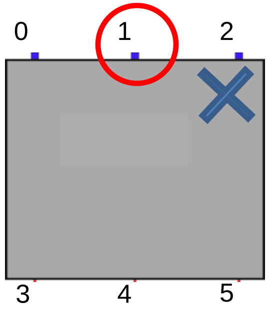
In the following plots you can see the fraction of photons lost due to cell saturation as function of cell size for different particle species and for two particle crossing positions



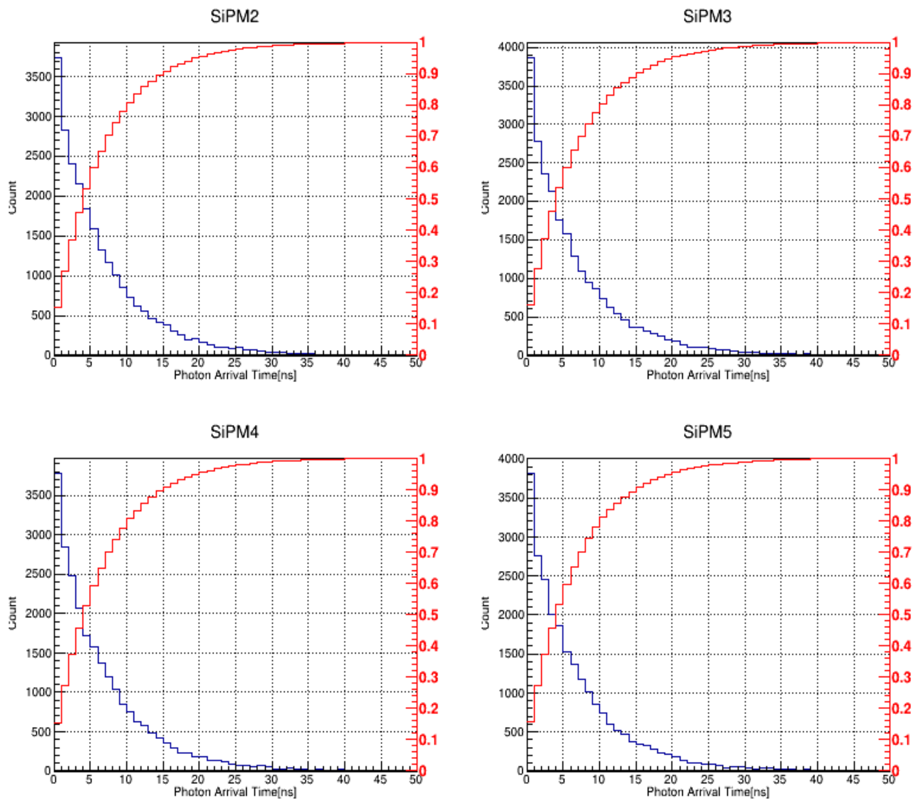


The saturation effect is the same for SiPM of different size since it is only related to the photon density on the sensor

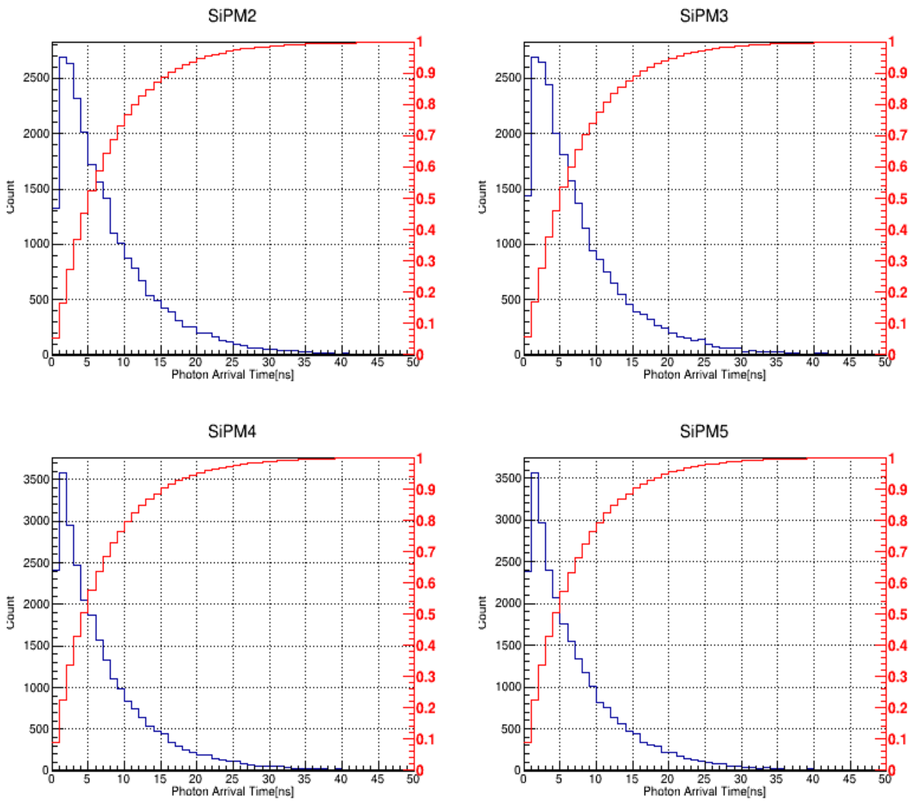


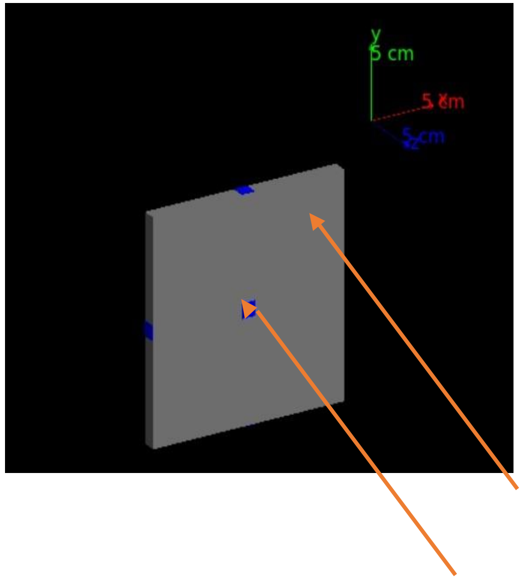


Center



Corner





50% of photons are collected in 5 ns

80% of photons are collected in 10 ns

The collection time does not change with particle species

The collection time of the bulk of the photons is shorter than the SiPM dead time. Therefore each SiPM detects at most 1 photon.

Test with radioactive source: Pavia

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 mm cell size)

on each side readout in parallel V_b=42.5 V

Wrapped with Teflon and with black paper

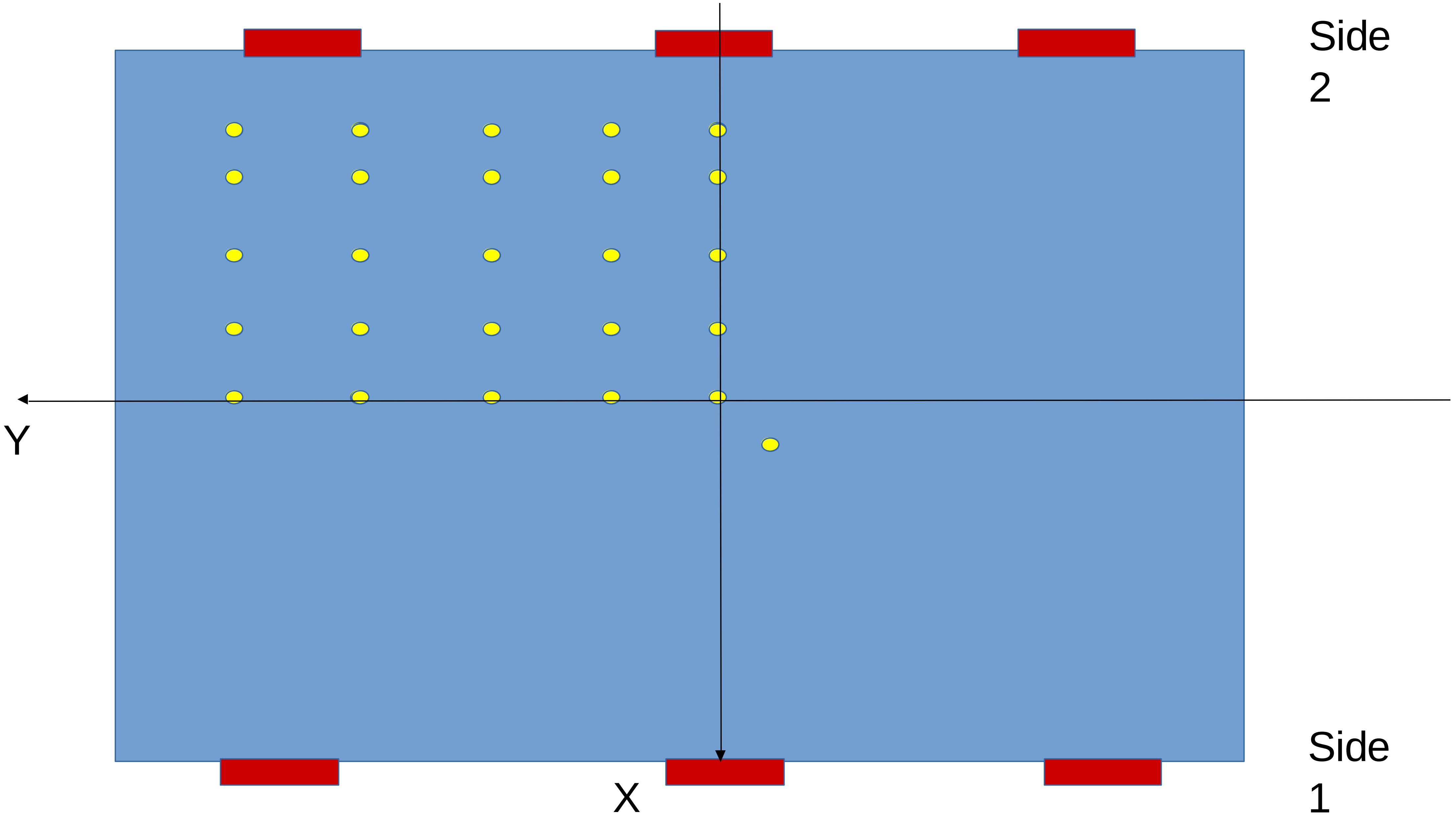
Cube: MEG scintillator (several years old) 12 mm side

Covered with white coating

BaS

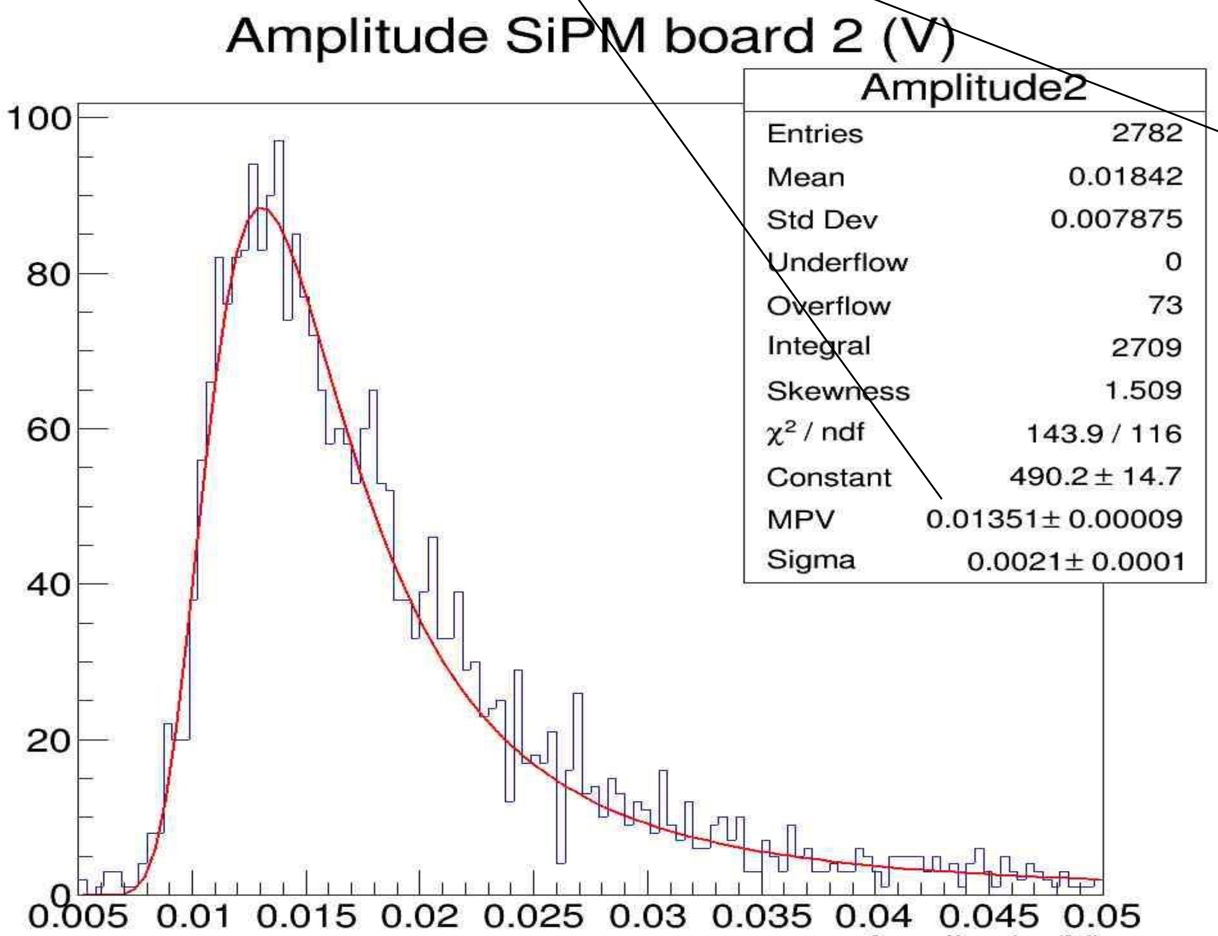
Readout on single side with array SiPM SensCell C-60035-4p-gevb (4 6x6 35 ▯m)

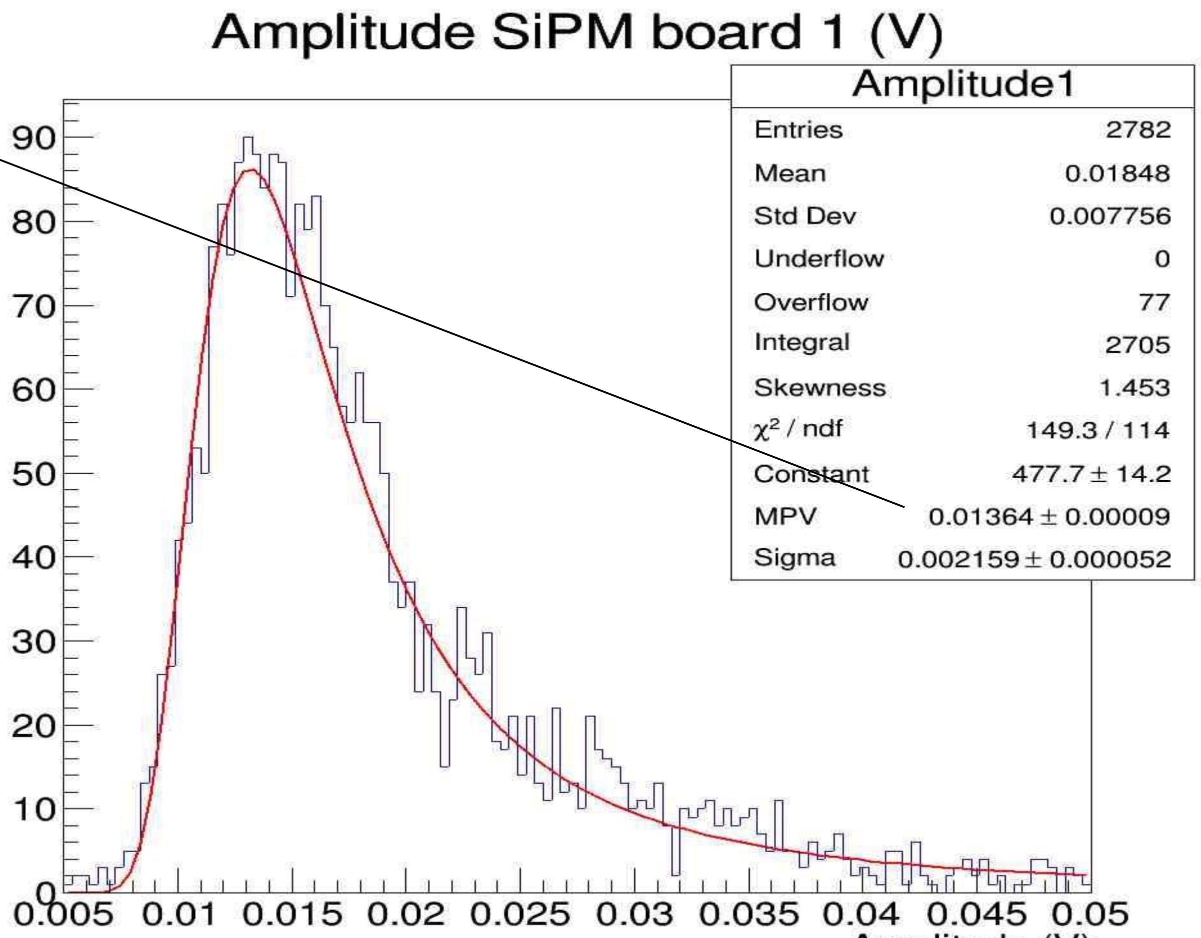
Test with radioactive source



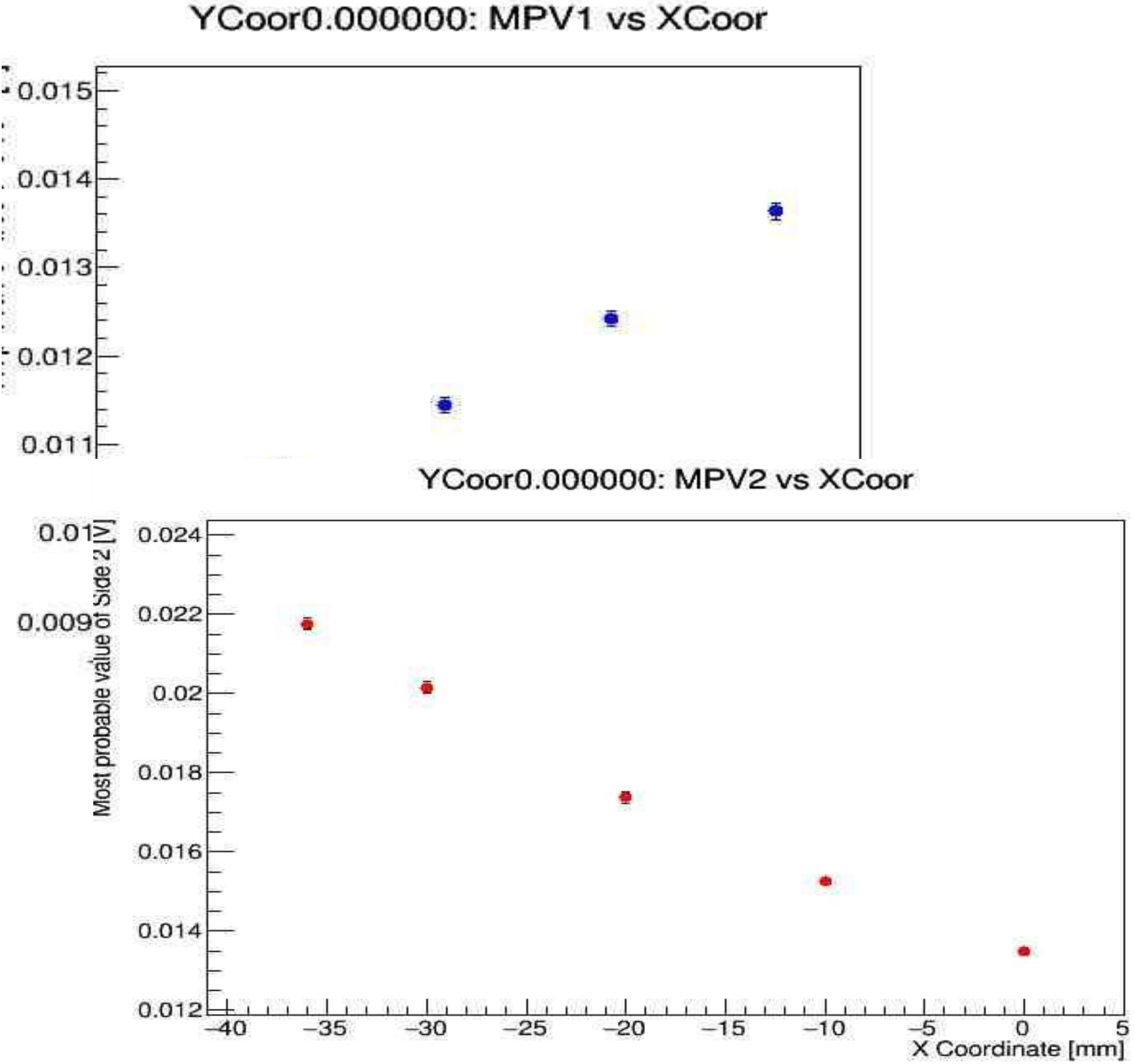
Signal amplitude X=0 Y=0

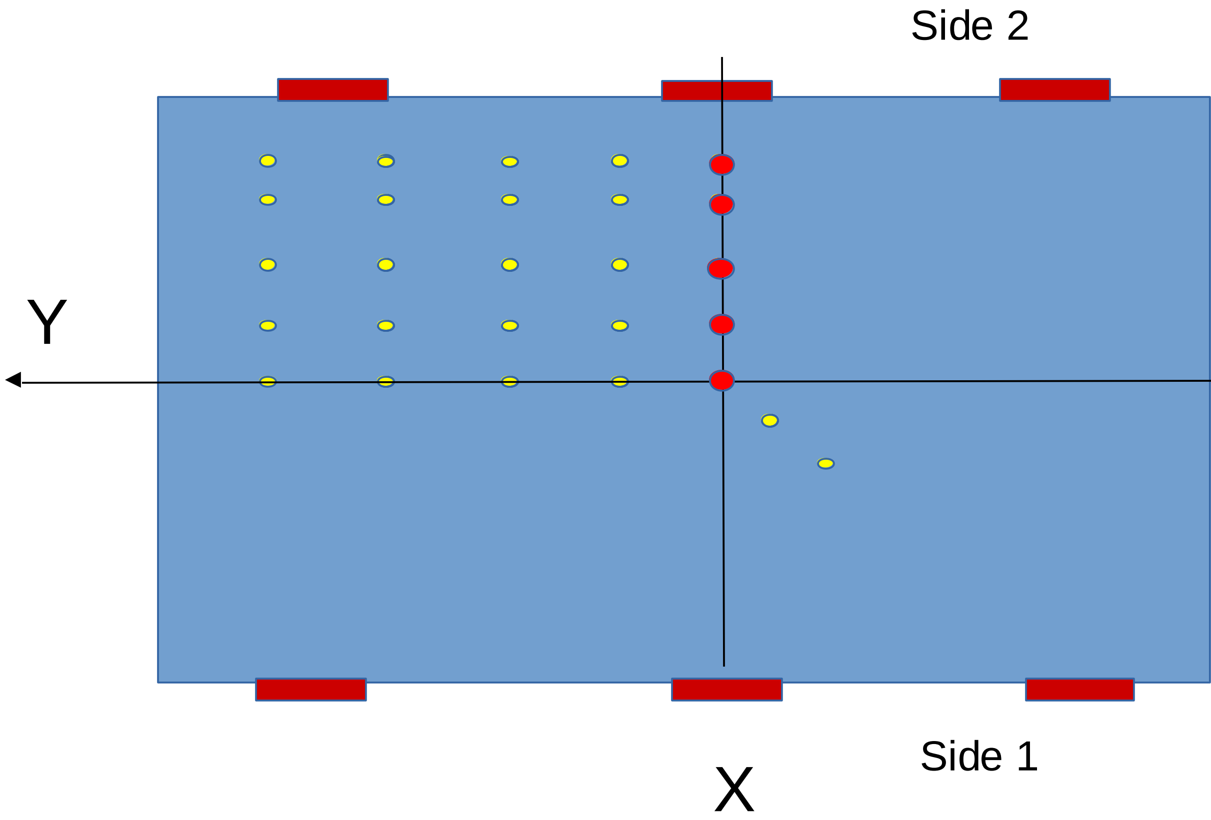
Signals on both sides when source is in the centre X=0.0 Y=0.0
They are equal. The SiPM gains and optical coupling on both sides are equal.





MPV1/2 versus X

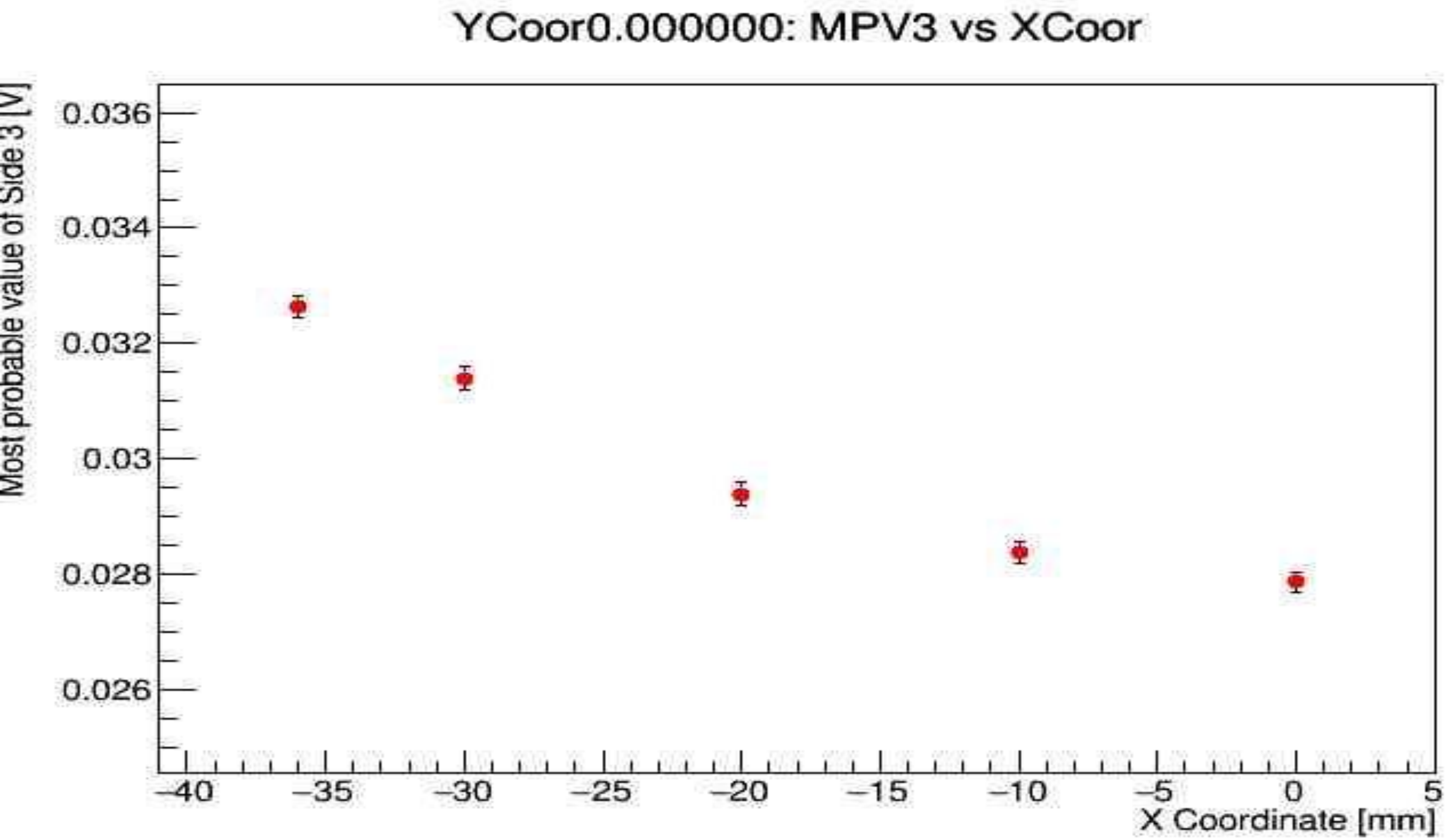


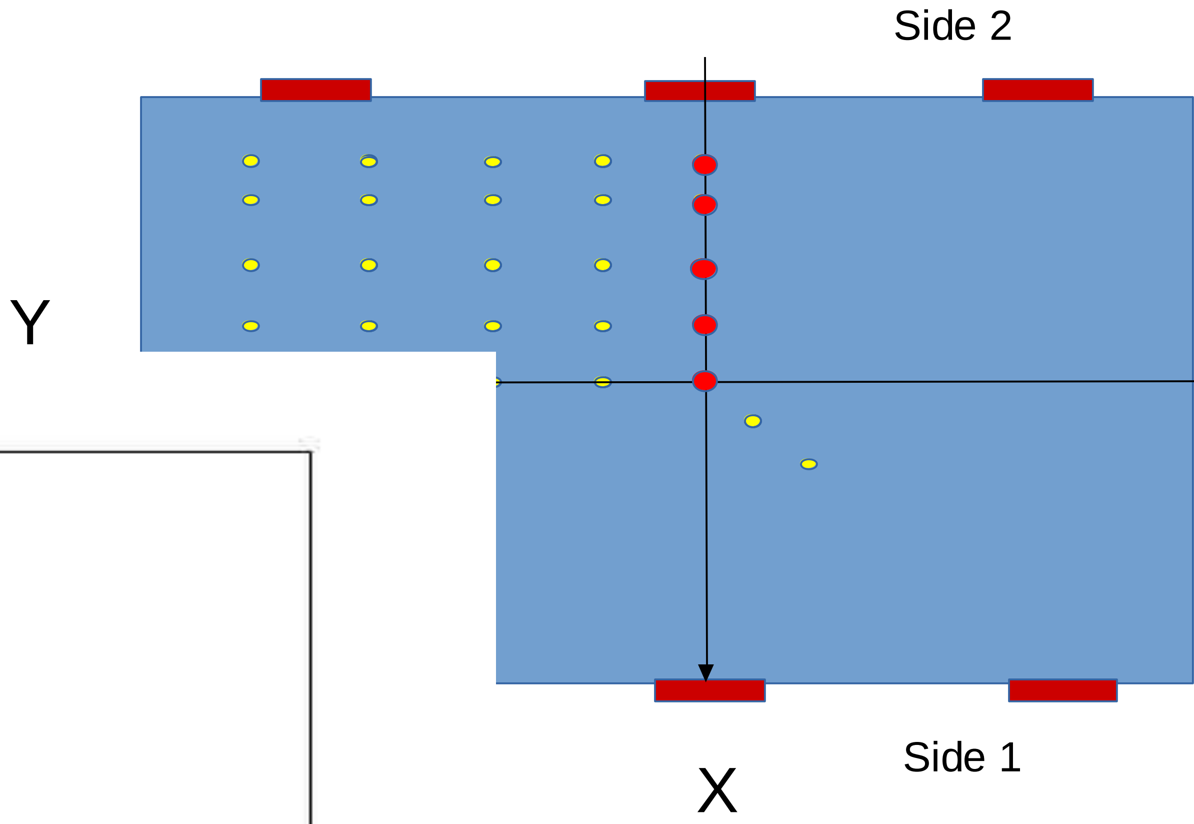


Signal increases (decreases) going closer (farther) to the SiPMs.
The solid angles subtended by SiPMs grows larger
(smaller).

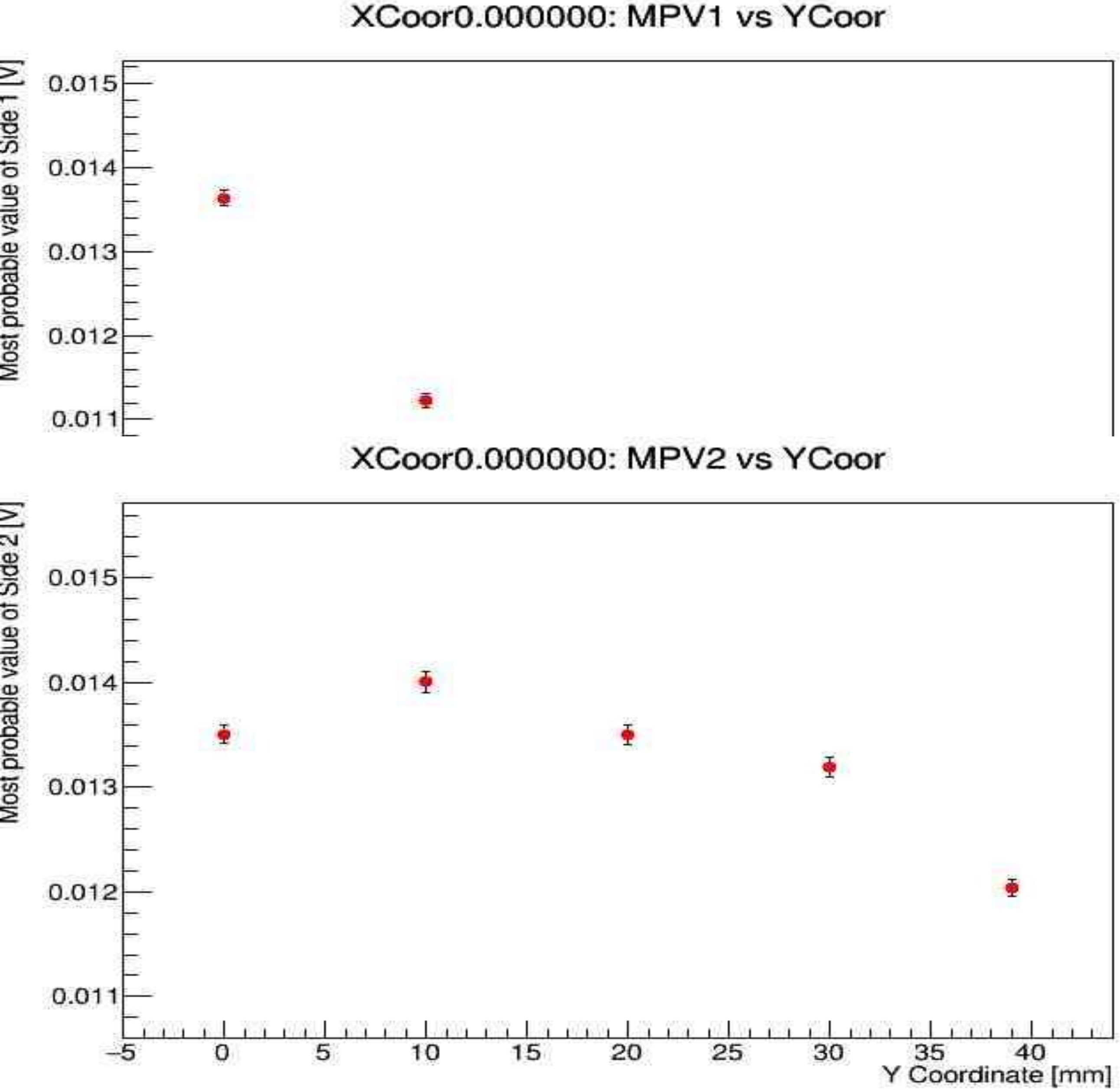
MPV3=MPV1+MPV2 versus X

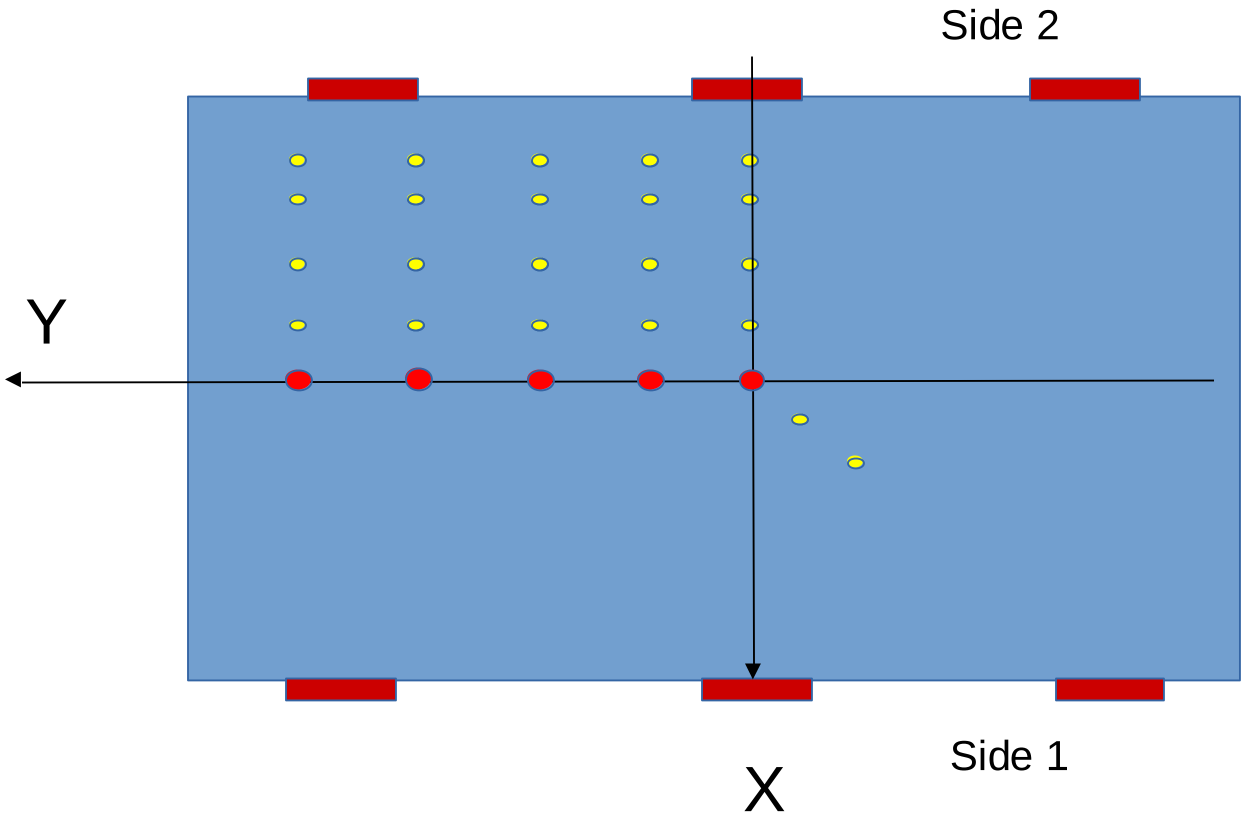
Total signal increases going closer to SiPMs.
Reflection on the sides limits the effect of solid angle reduction
.





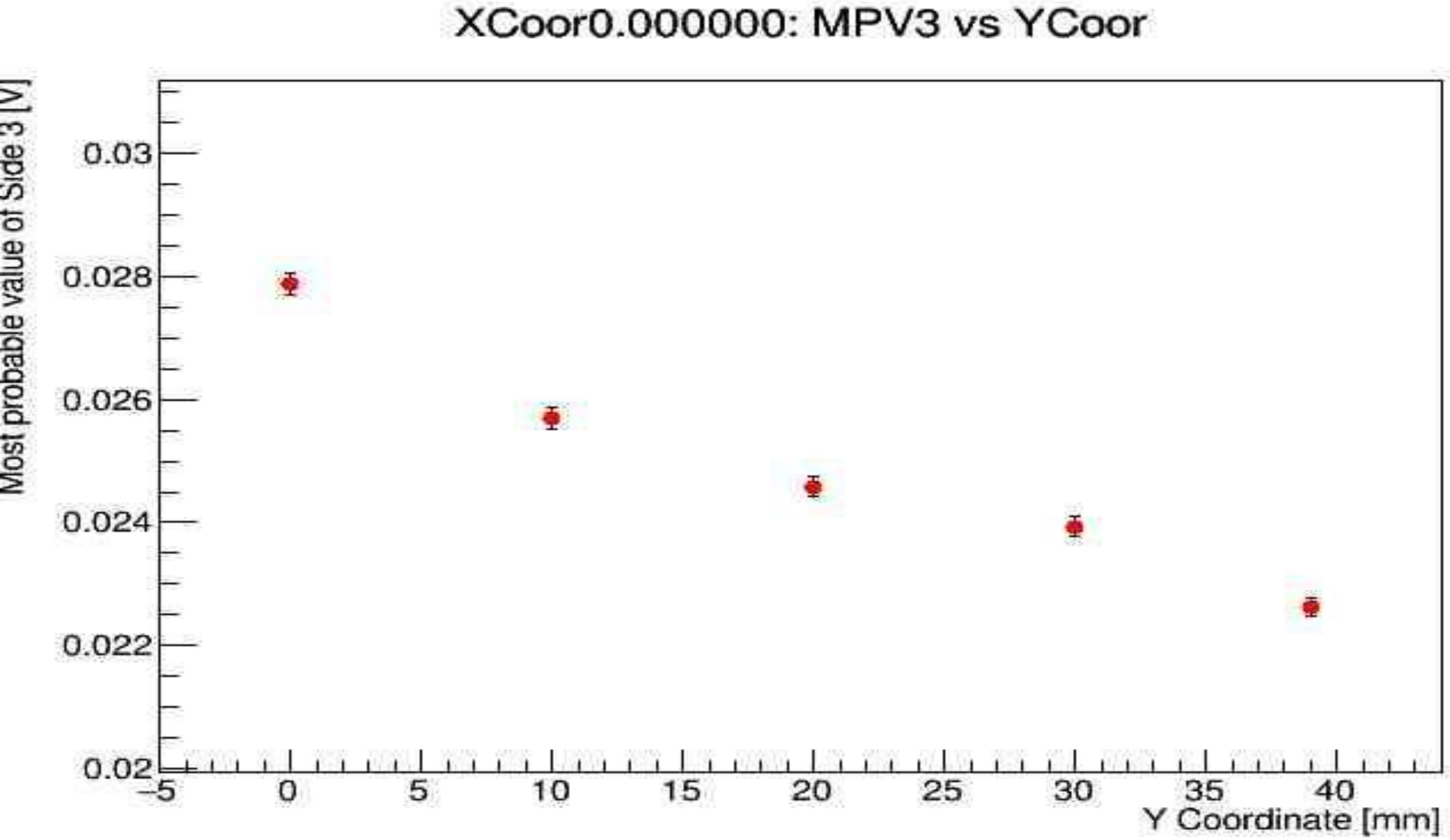
MPV1/2 versus Y

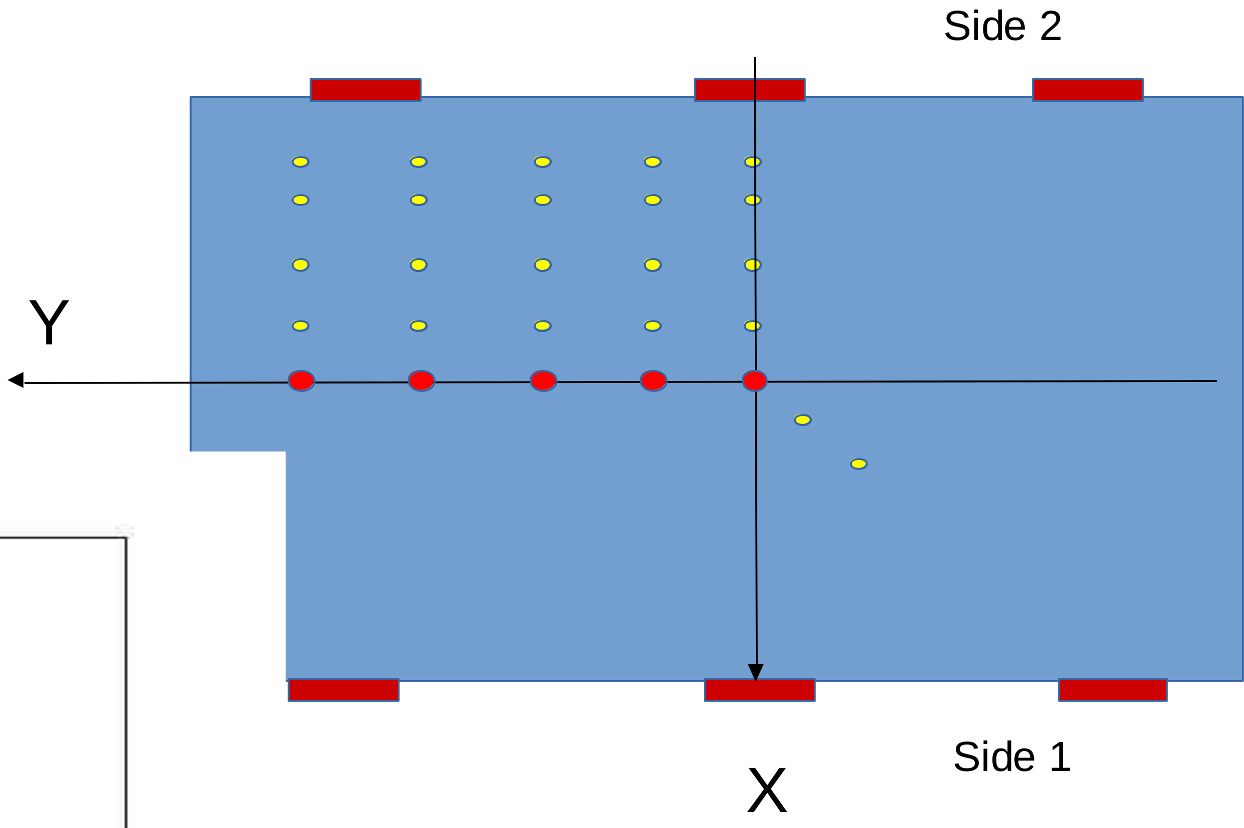




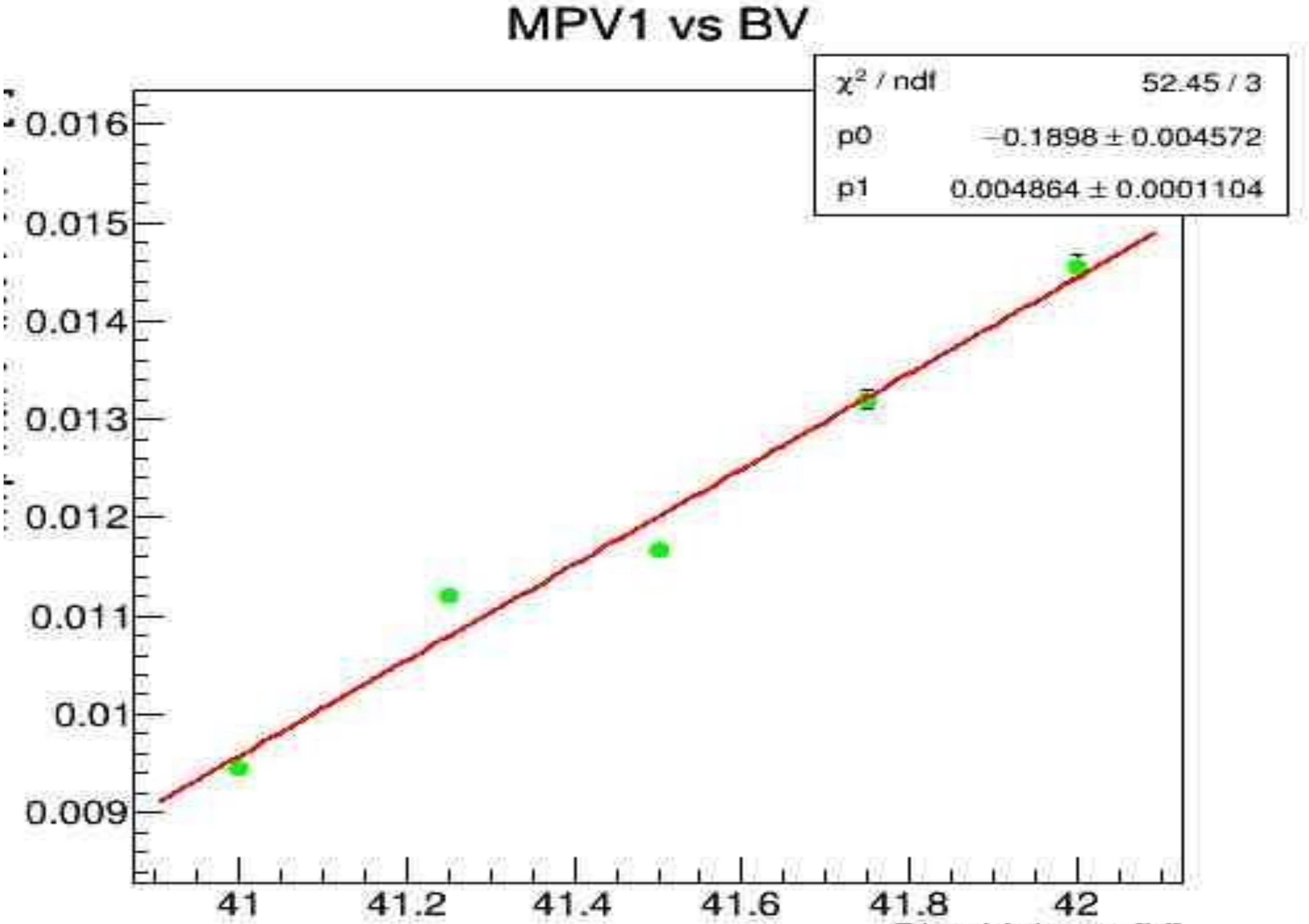
Total signal decreases moving toward the edge. Probably due to decreasing solid angle subtended by SiPMs and poor reflection on the side.

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.

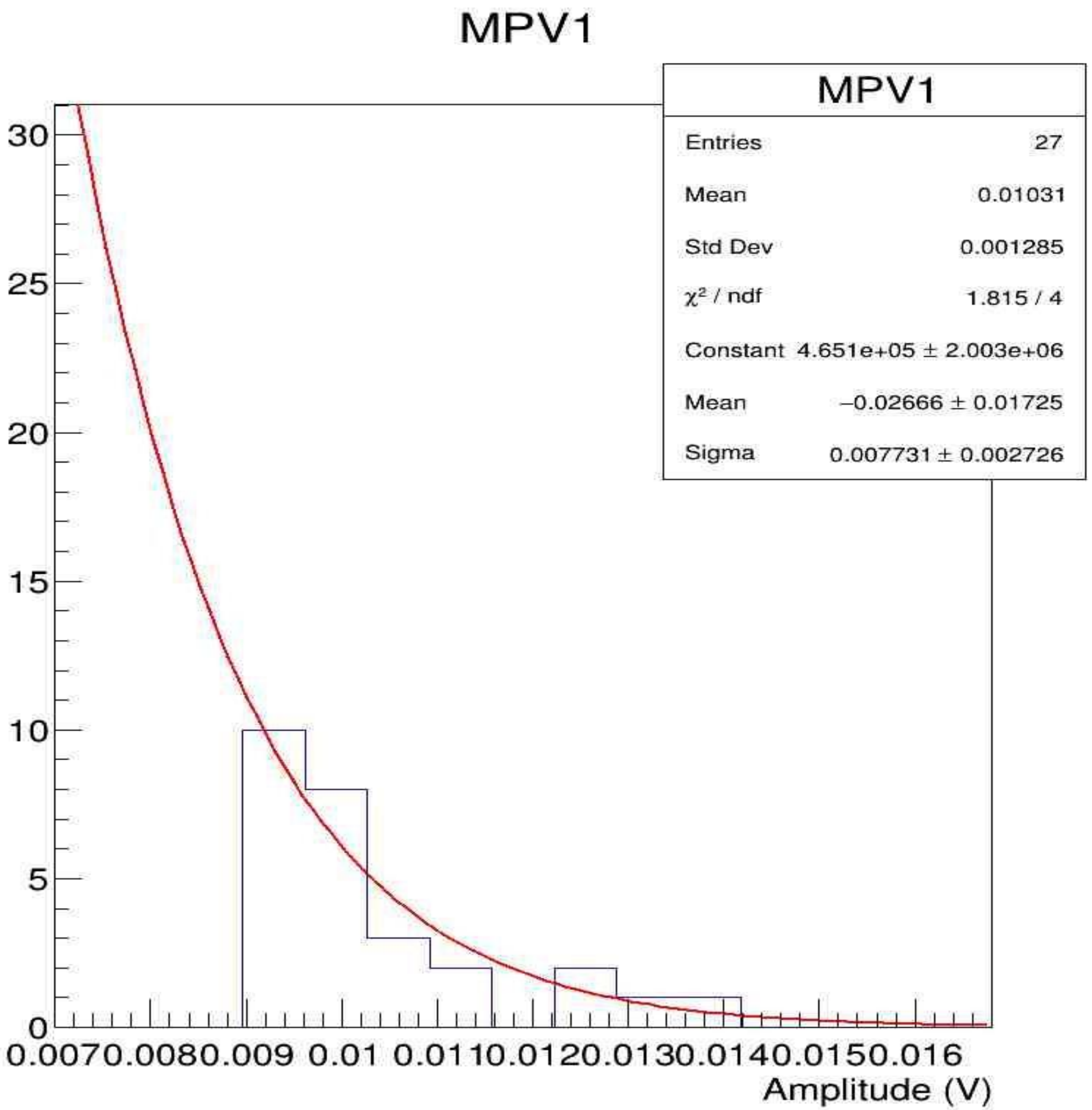
Ideally the points should cover the whole surface.

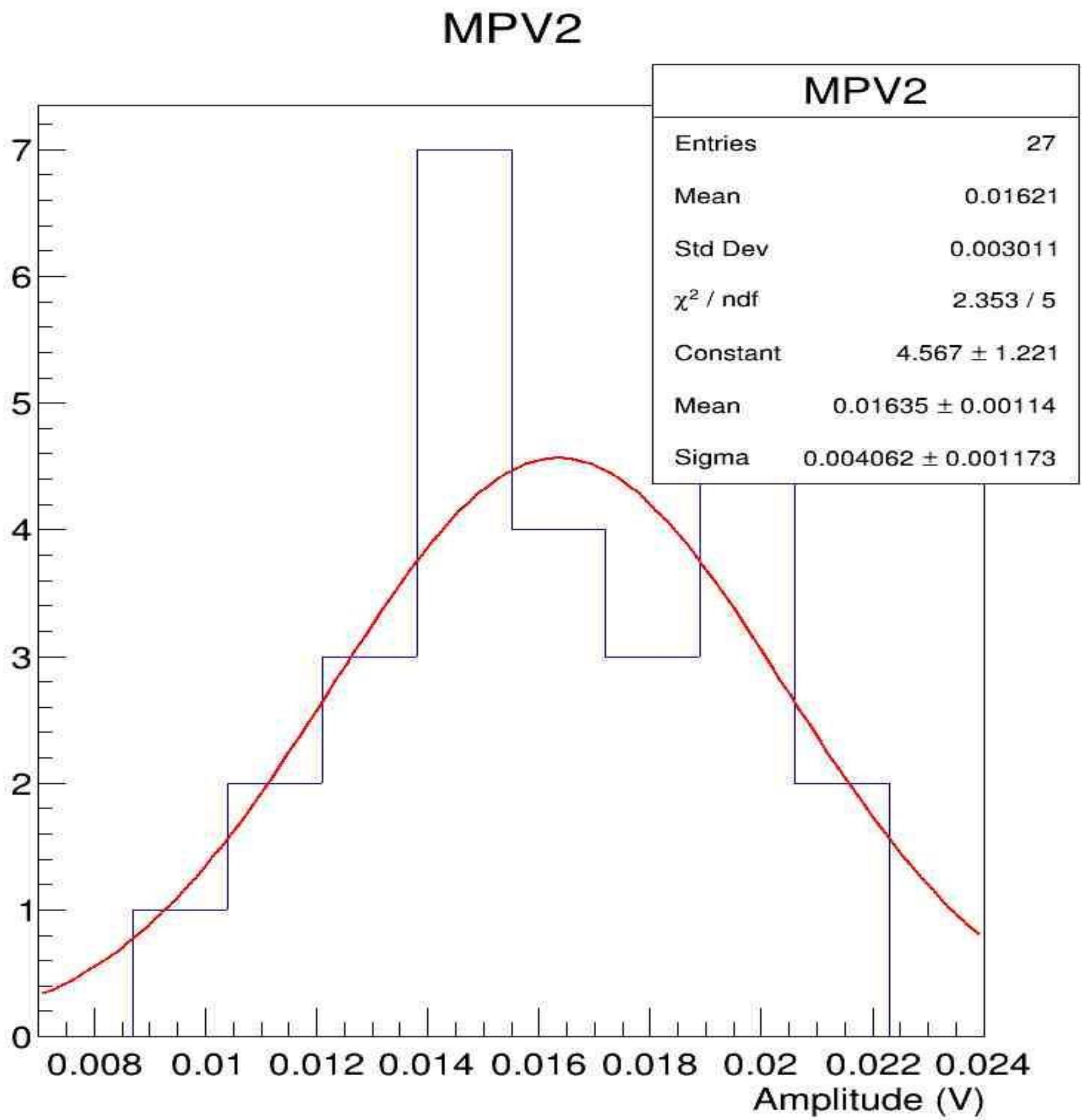
Now we rely on the set of points already collected.

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

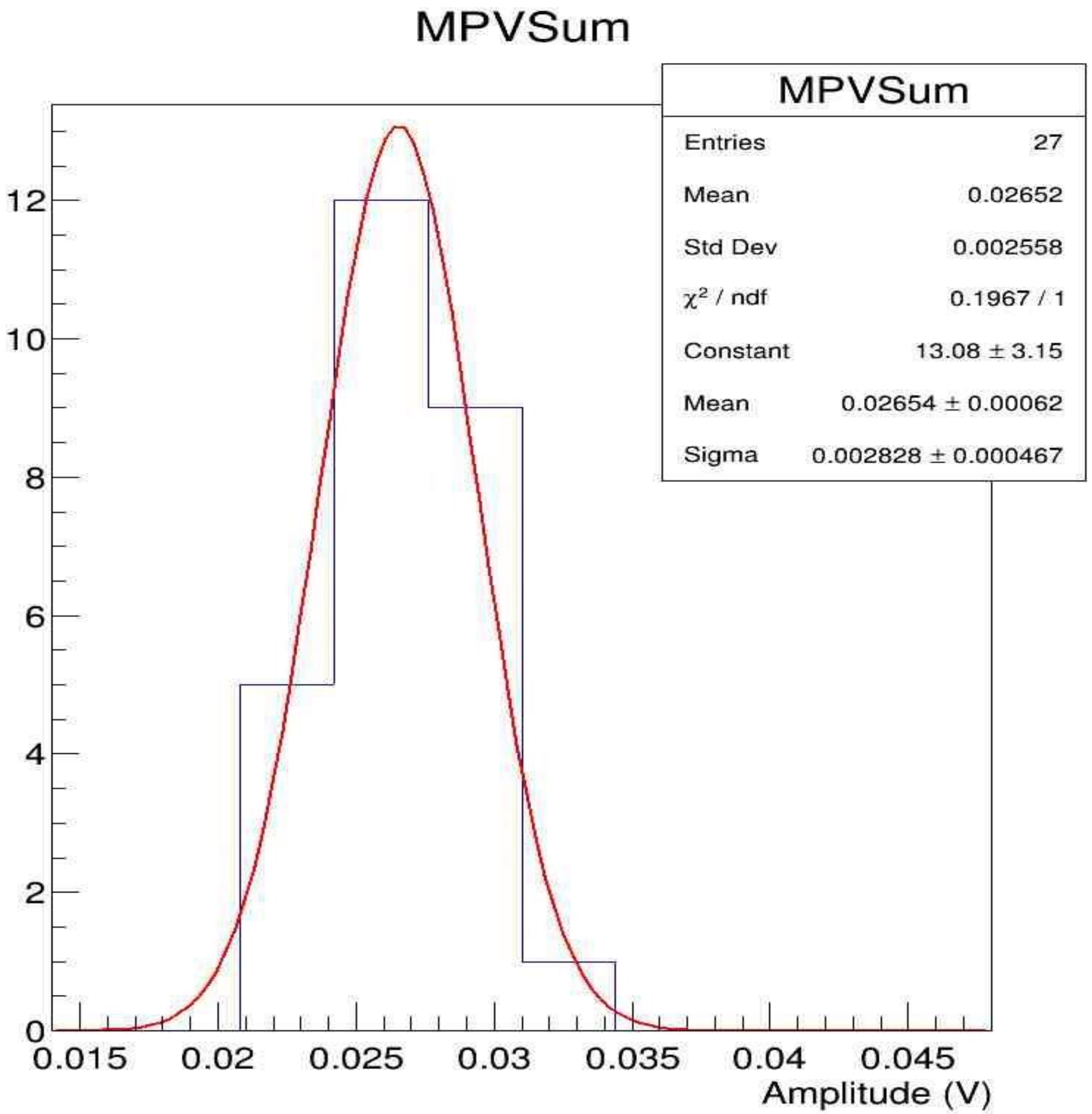
If smaller the charge measurement is not limited by non uniformity in light collection.

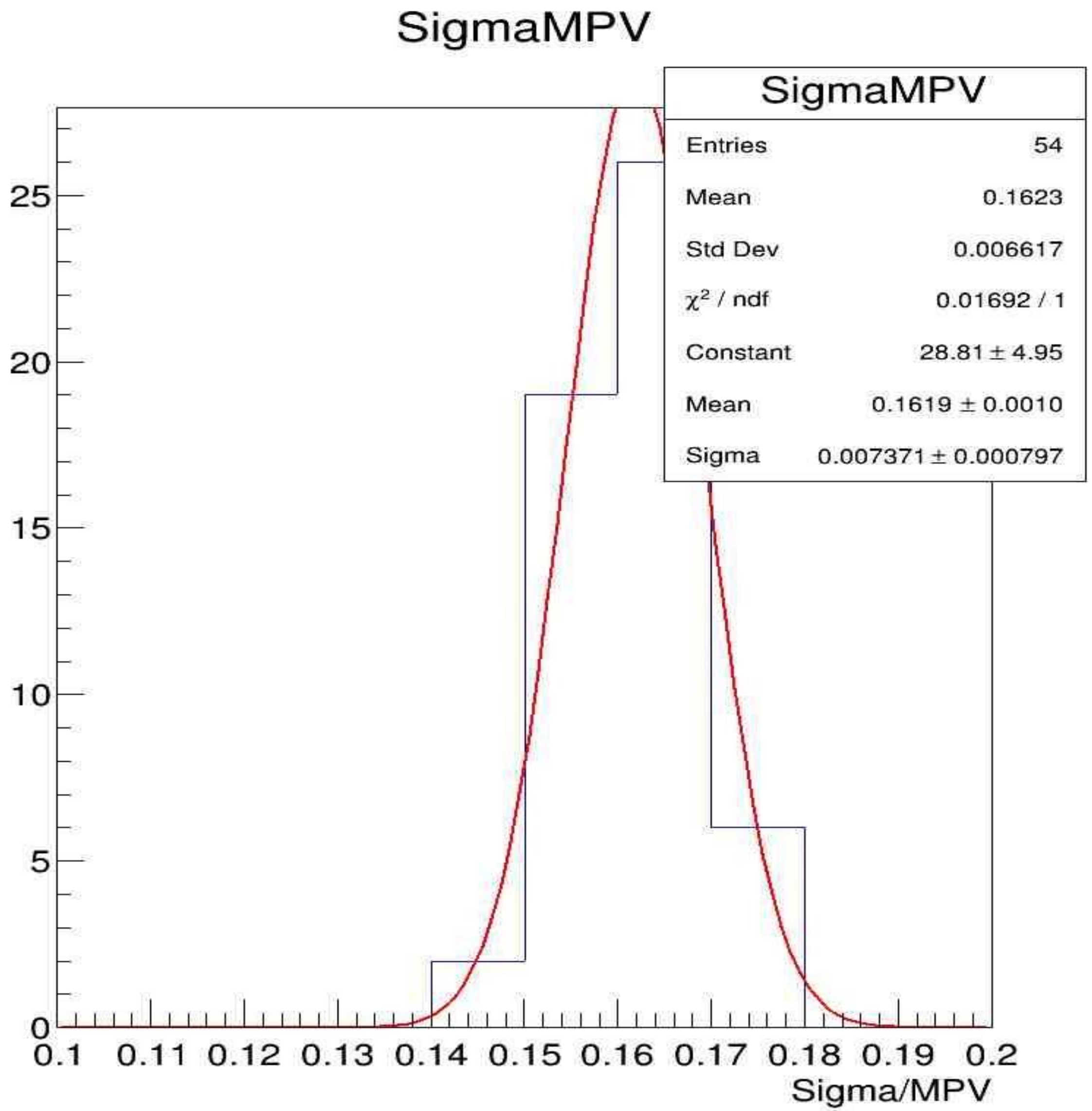
MPV distributions on tile surface





MPV distributions on tile surface





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, 1point/1d).

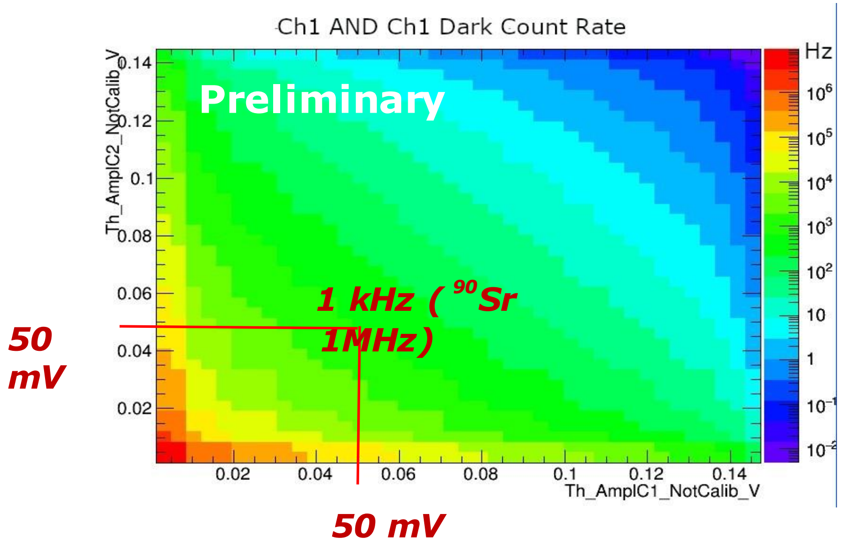
- Estimating F(x,y), first approximation can be evaluated now
- Using signal area rather than peak amplitude ?
- Simulating the apparatus to understand contributions
- Better understanding of the reflections on the sides

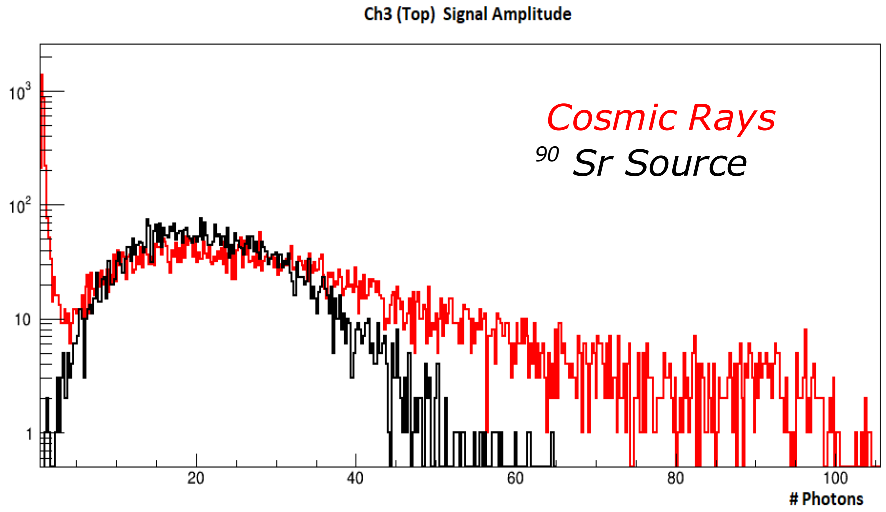
Test with radioactive source: Bari

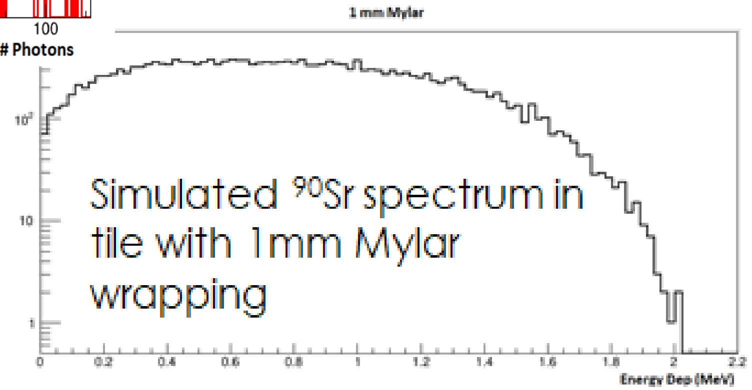
- BC-404 scintillator 10x10x1 cm^3 tile tested with Cosmic rays and ^{90}Sr radioactive source coupled to AdvanSid NUV SiPMs (4x4 mm 4 μm cell)

Activity 39,5 μCi -> 1.49 MBq

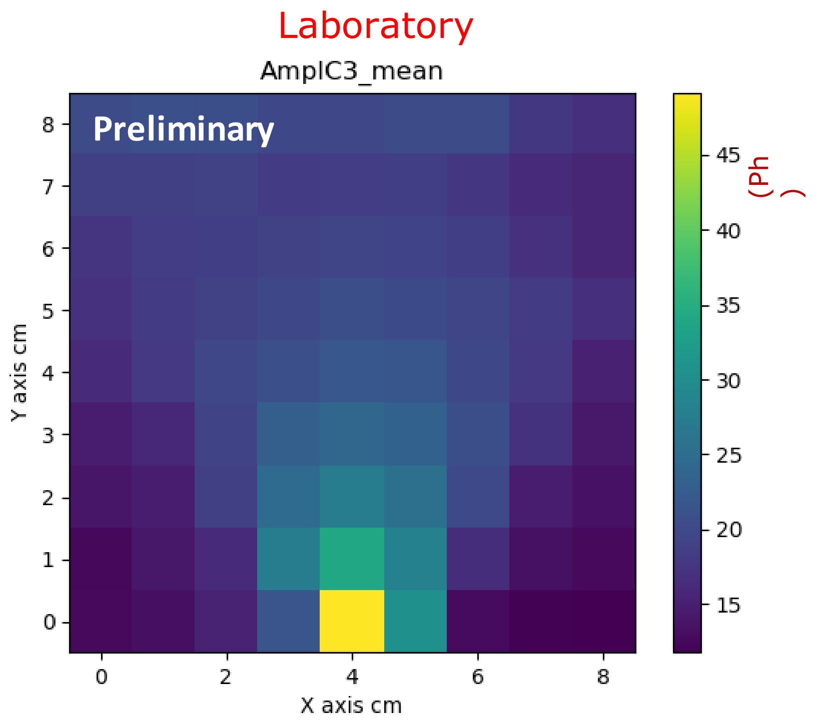
- AdvanSid trans-impedance preamplifier
- Trigger obtained from logic AND of two opposite SiPMs
  - Threshold set to reduce the noise trigger rate due to coincidence of dark noise of two SiPMs
    Souce rate 1MHz Bkg rate 1kh

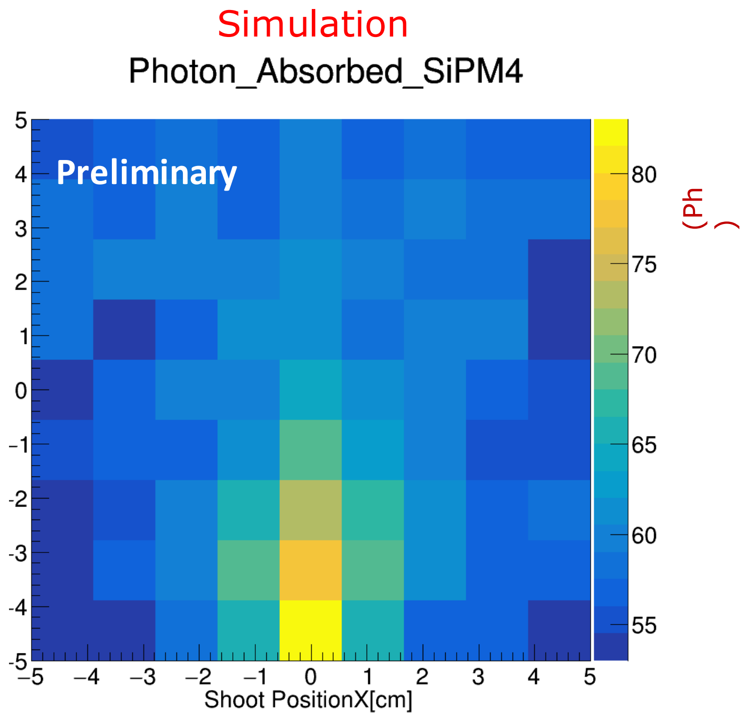


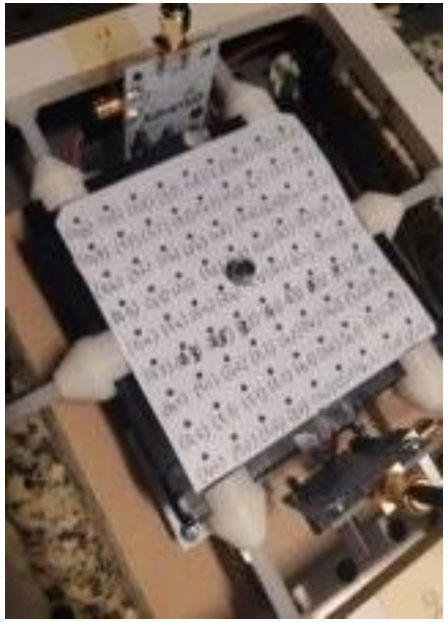




- ^{90}Sr radioactive source placed in different positions with a 1 cm step in both X and Y to study the uniformity in light collection
- The radioactive sources was simulated in different position with 1mm step in both X and Y and the results have been clustered in 1cm step



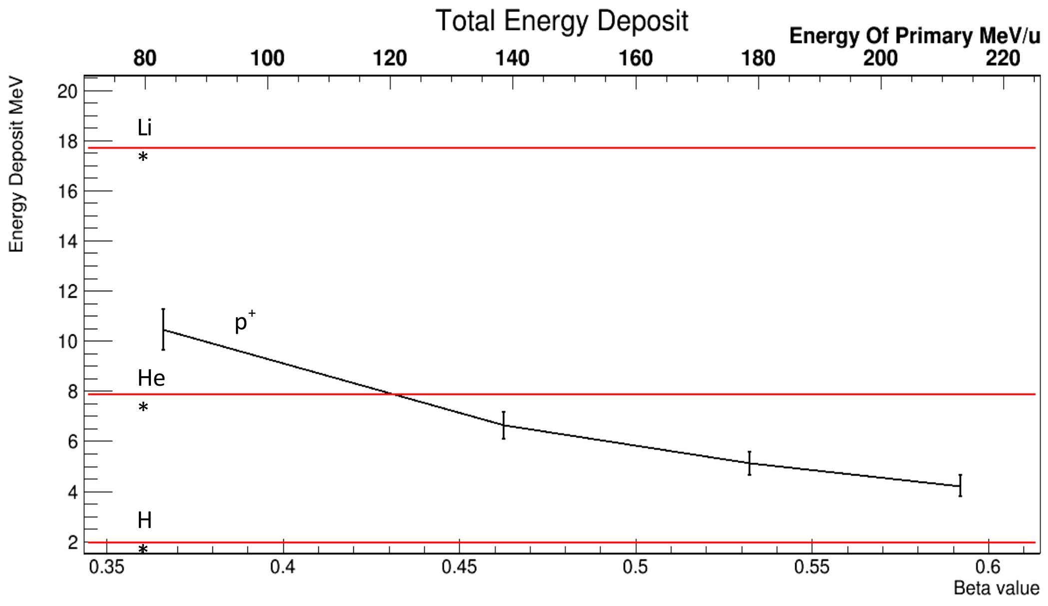




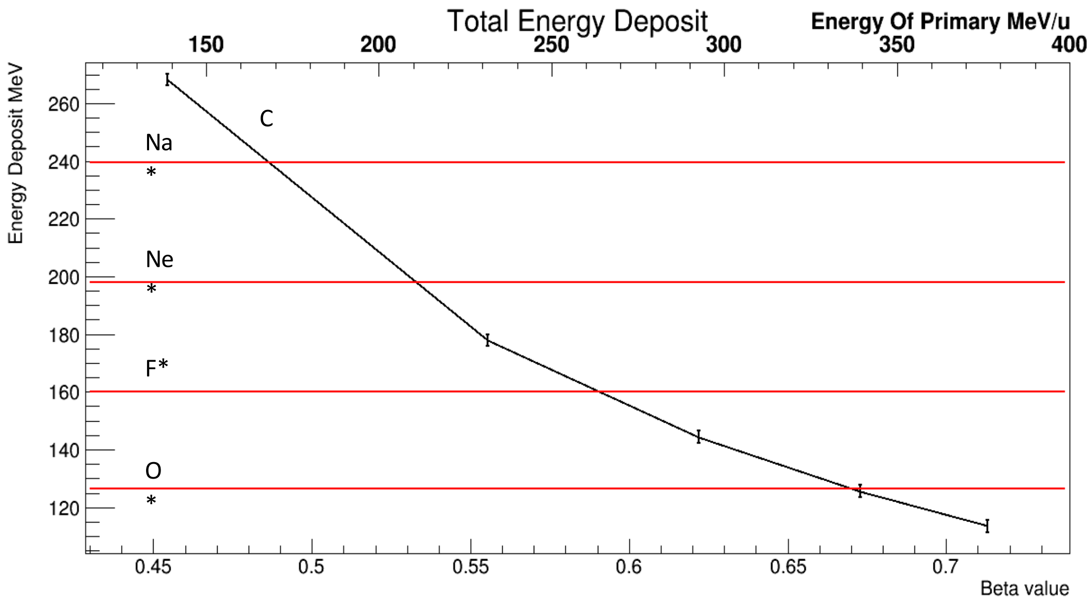
Similar distributions, but simulation does not take into account SiPM/Scintillator optical coupling and real wrapping reflectivity.

Test at CNAO: Bari tiles

- We have performed a beam test @ CNAO in July 2020
- The energy release of high Z particle with β=1 in plastic scintillator can be mimicked by low Z low β protons and C nuclei.
- At CNAO we can request different beam configuration with proton energies ranging from 80 MeV/n to 220 MeV/n and C nuclei energies ranging from 140 MeV/n to 380 MeV/n



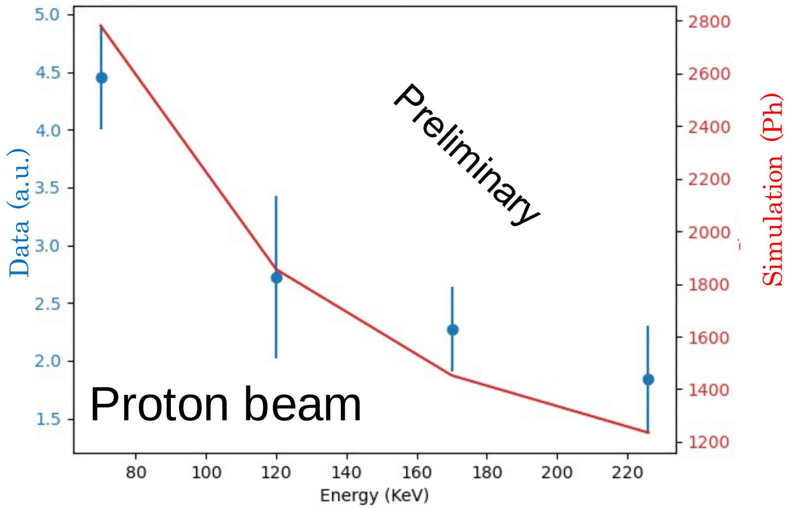
* Kinetic Energy 150GeV/n, β ~ 1

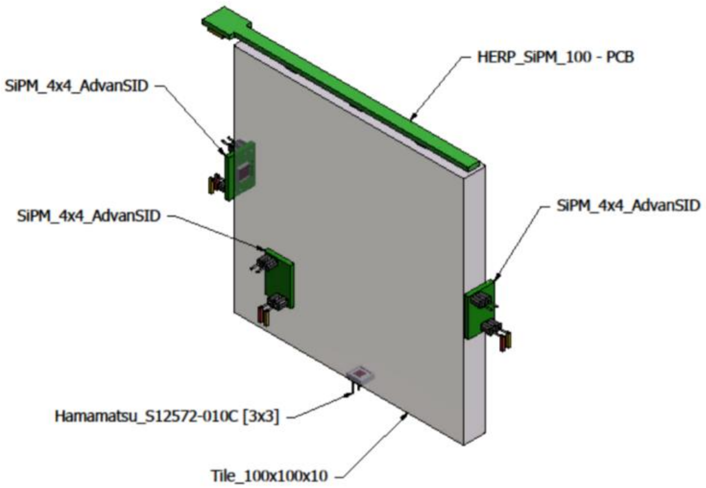


* Kinetic Energy 150GeV/n, β ~ 1

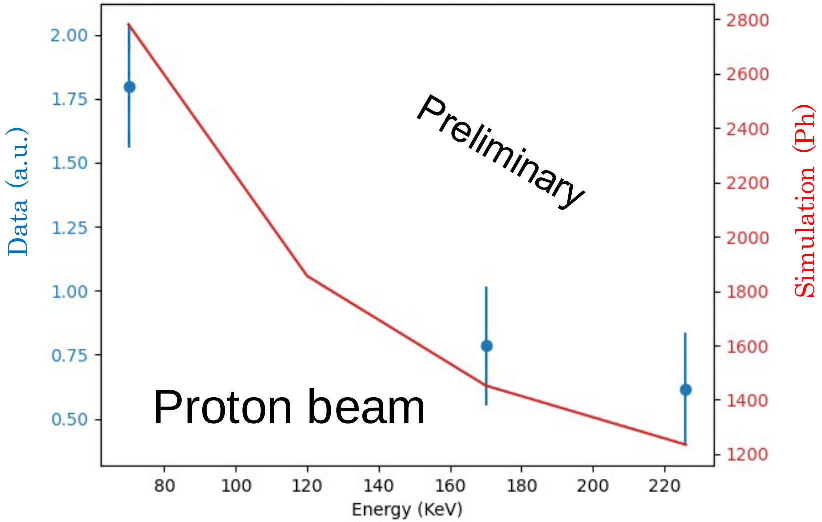
BC-404 tile coupled with Hamamatsu SiPMs 3x3 mm (15 and 50 µm cell)
Trigger obtained from logic AND of two opposite AdvansSID SiPMs

3 x S13360-3050 3x3mm - 50 µm cell

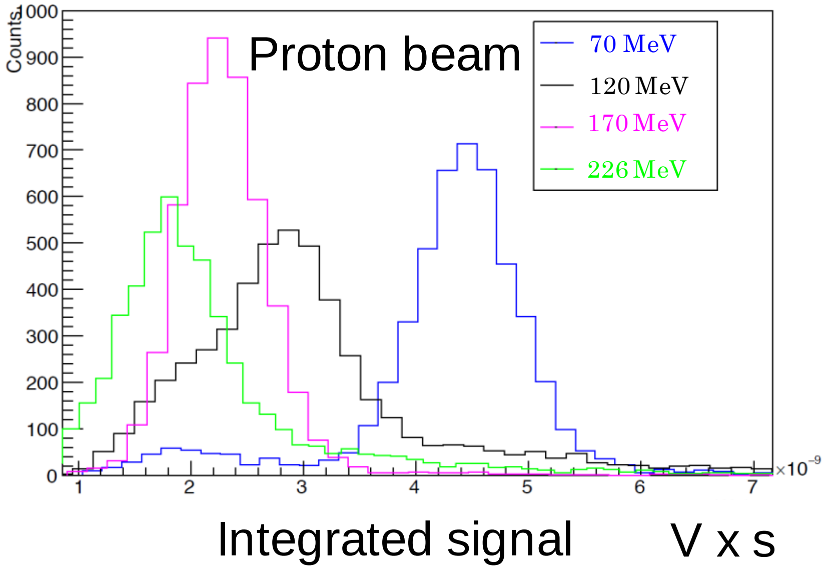




S12572 3x3 mm-15 µm cell

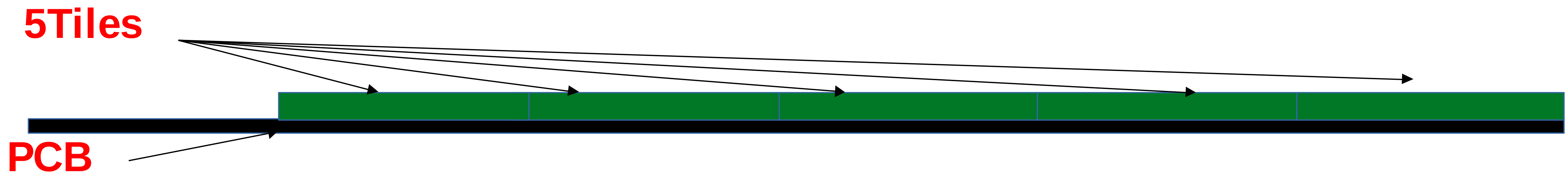


3 x S13360-3050 3x3mm - 50 µm cell



Long PCB for tile beam test

Long PCB for 5 tiles

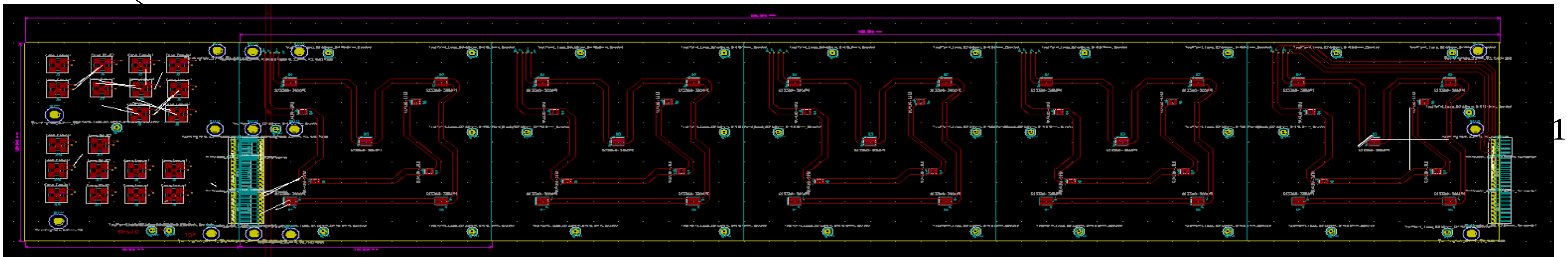


5 SiPM 3x3 mm^2

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.

Connectors

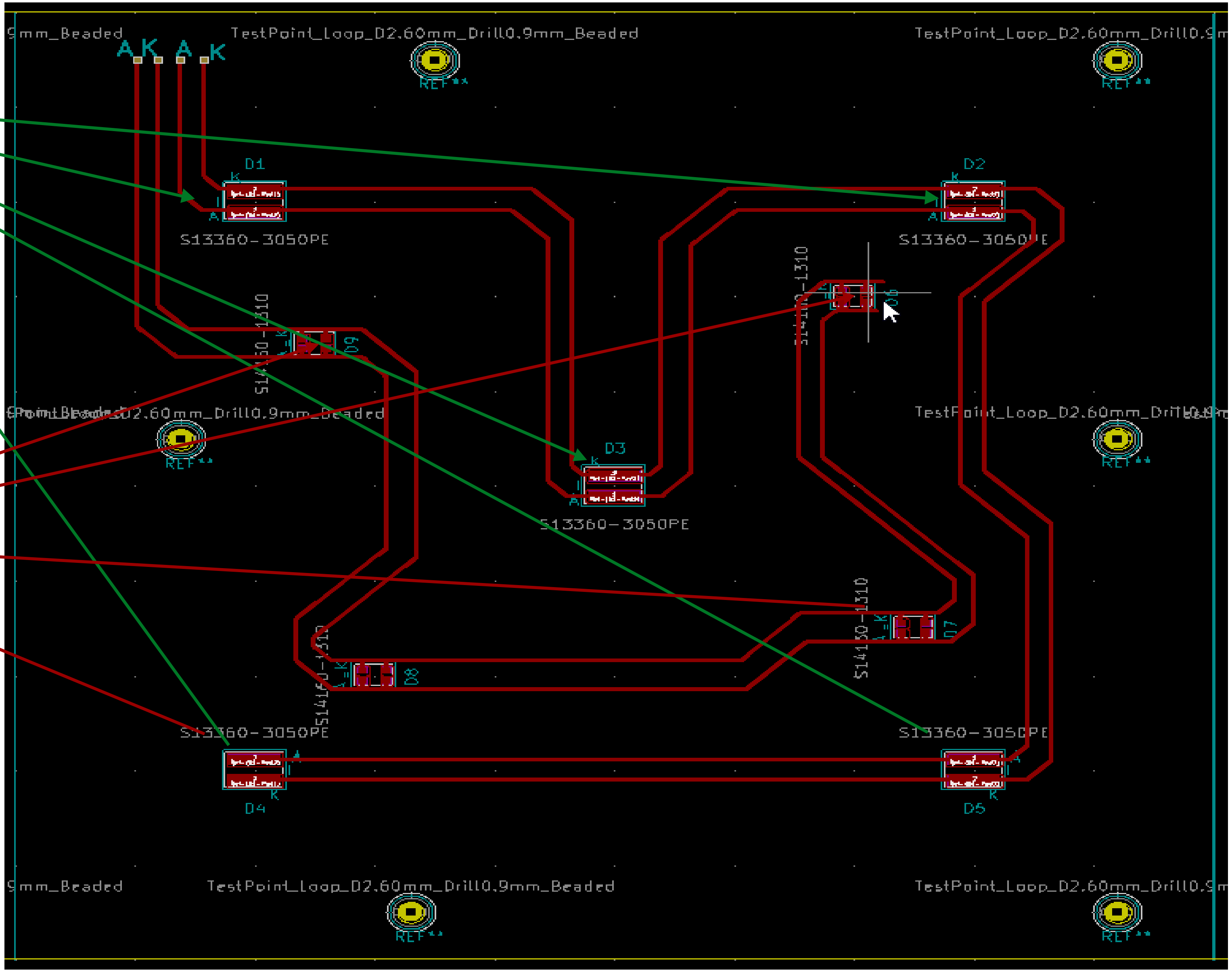


10 cm

Layout for single tile

SiPM 3x3 mm^2

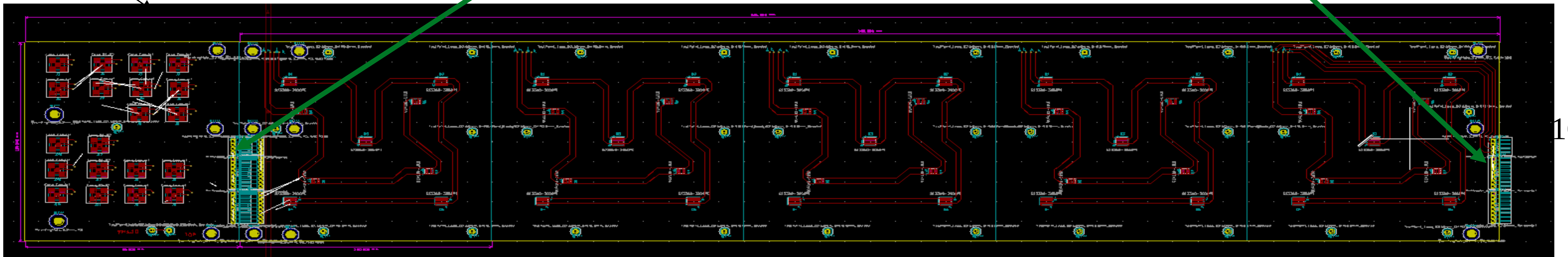
SiPM 1.3x1.3 mm^2



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

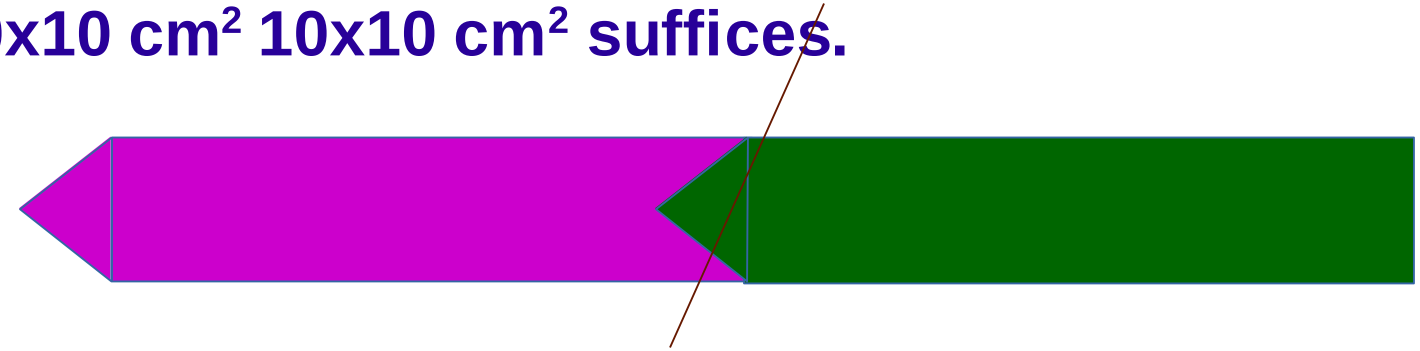


10 cm

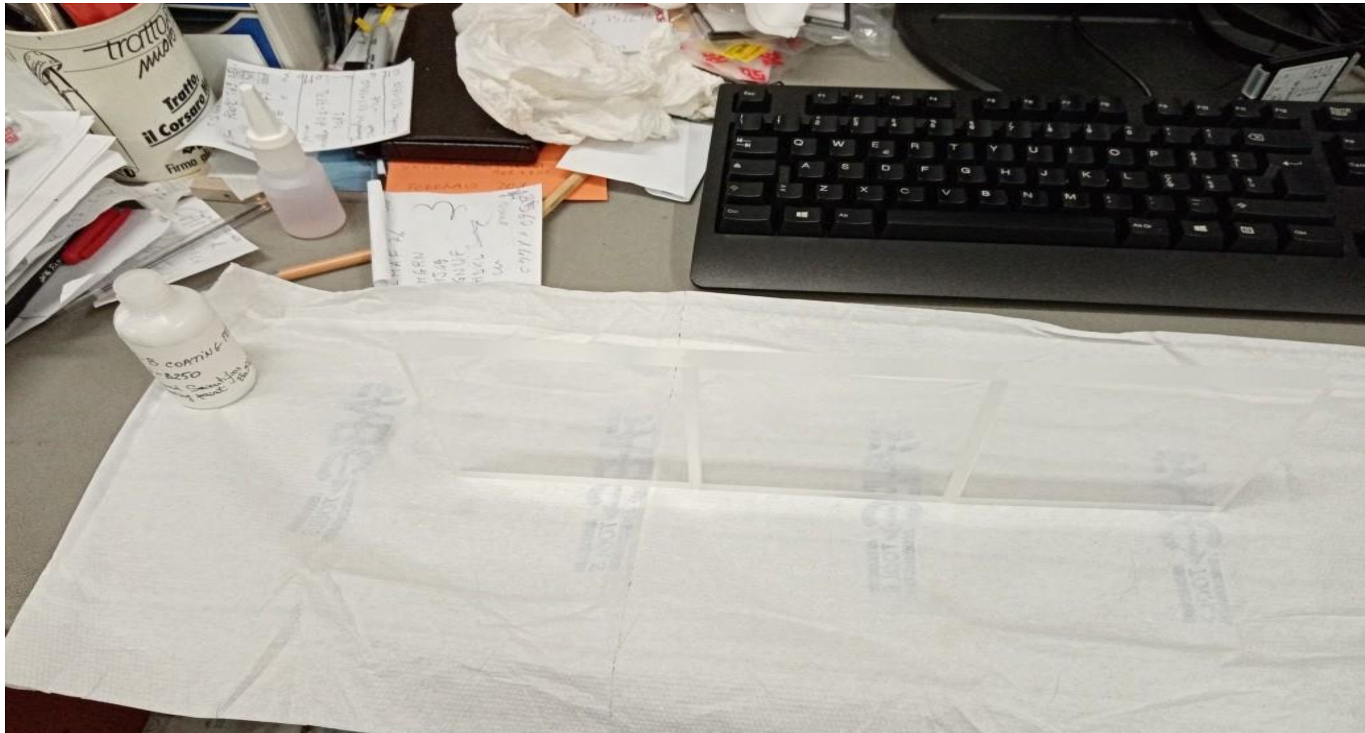
Dove tailed tiles

Tiles dovetailed to requires no additional material:

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

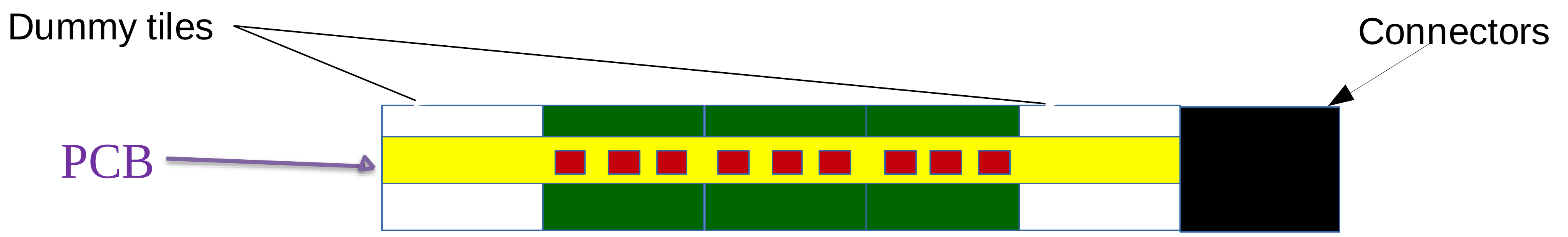


Today we have 3 tiles with dovetailed edges to be positioned.
Plus one with straight edges.



Number of PCBs

Plan to produce a few 58.5 cm PCB for and start testing in laboratory.
Due to available scintillator and SiPMs in Pavia we can equip e.g. 3 active tiles along a single long PCB.
Dummy tiles (plexiglass) can be positioned along the rest of PCB if components and scntillating material are missing.

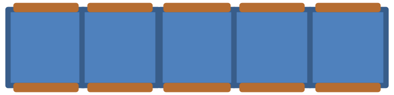


Crosstalk and attenuation along a long PCB to be studied in laboratory with radioactive source.
Also ganging together two long PCB to have a 1m long PCB equivalent.

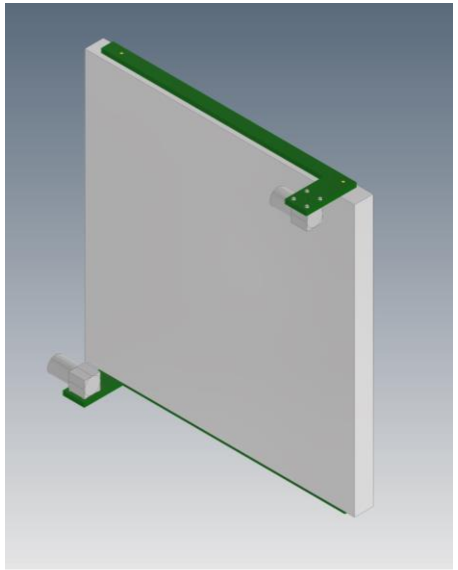
Beam Test @ CERN

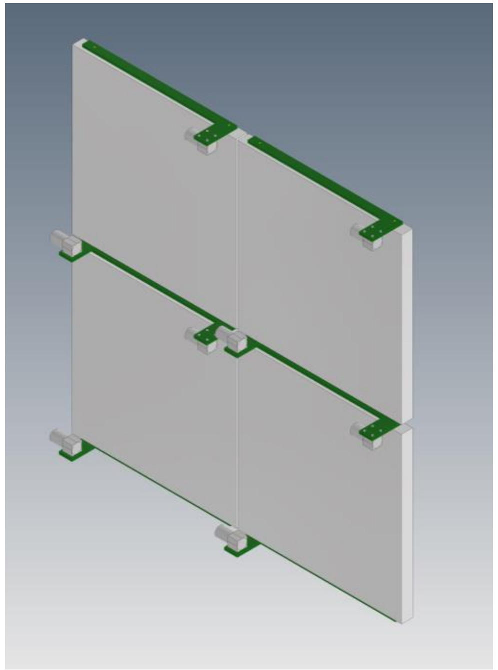
We plan to build a tile prototype with two different kind of Tile+PCB configuration: one from Pavia and one from Bari

PV Ladder: 5 Scinitllating tiles (10x10cm)+ 1 long PCB (10x60cm)

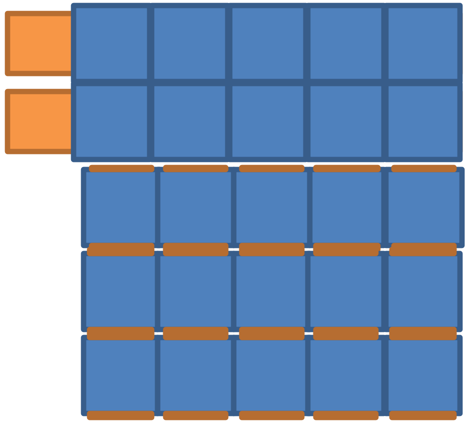


BA Ladder: 5 Scinitllating tiles (10x10cm)+ 10 short PCBs - two per tile





Tile prototype active area 50x50cm



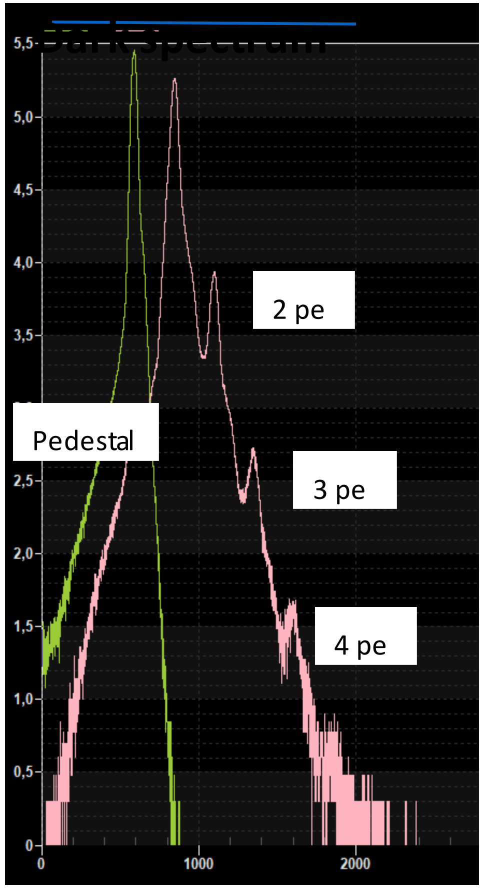
With the support of our engineer colleagues, we will design a mechanics similar to the one designed for the bars prototype

Read out for Beam Test at CERN

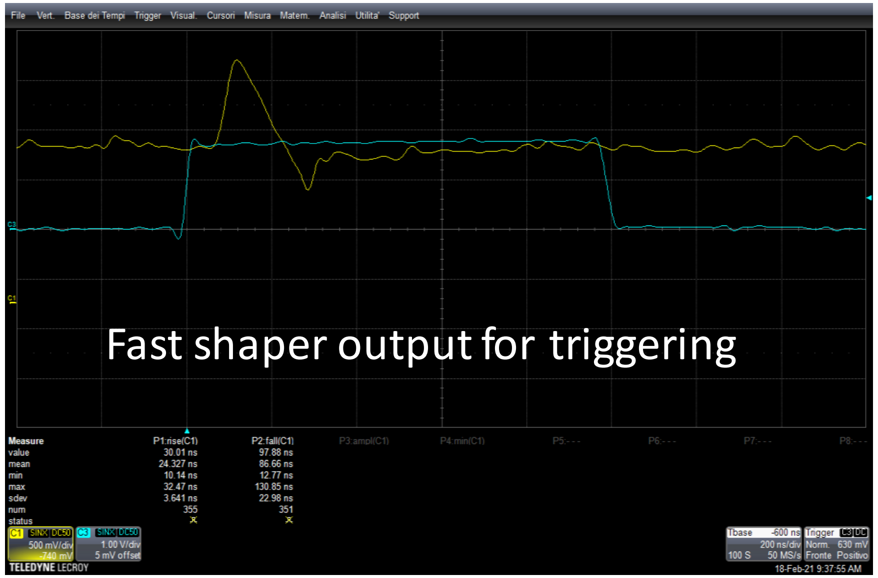
We plan to use the CAEN DAQ board DT550W equipped with 4 CITIROC chip to readout the PSD prototypes at 2021 CERN beam test both for tiles and bar configurations

We are performing some very preliminary test with SiPM in order to understand better all the functionalities

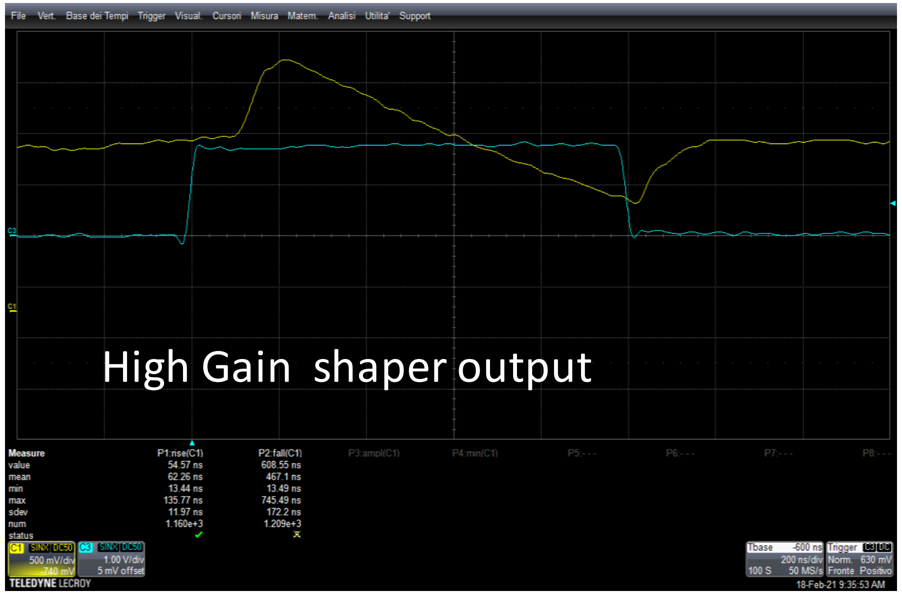
S13360-3050CS



HV: 55V Ampl Gain: x600



We plan to write a new FPGA firmware to implement the PSD prototype in the onlina DAQ system @ beam test



The End