HERD PSD

The “Tiles” option

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INFN BARI

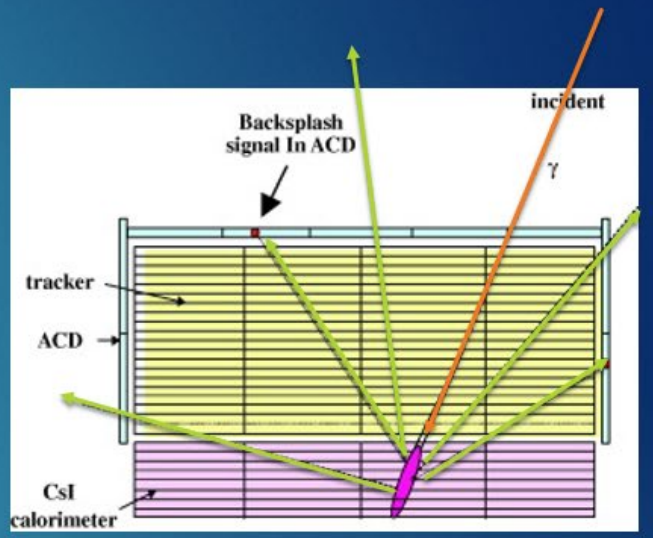
INFN support to PSD R&D

- INFN is supporting the Italian groups (Bari, Lecce, GSSI, Pavia) in the R&D activities on the HERD-PSD design for the next 3 years
- In 2019 we will perform different tests both on the SiPM readout and on the readout chain
- We need to join our effort to reach a common design that can fulfill all the request for the science of HERD (both gammas and charged particles)

Recap on backsplash

Back splash

- This is a preliminary study of the effect of back splash both for charged particles (namely protons) and gammas
- The back splash is due to low energy particles (charged and neutral) produce in the shower development and that travel backwards and may reach the plastic scintillator
- Gamma ray back splash could rise a VETO in the PSD that reject good photon events lowering the detection efficiency and the effective area at high energy
- Proton back splash could increase the charge deposit in the PSD bars or tiles and therefore lead to a misidentification of the incoming particle



Fermi-LAT detector

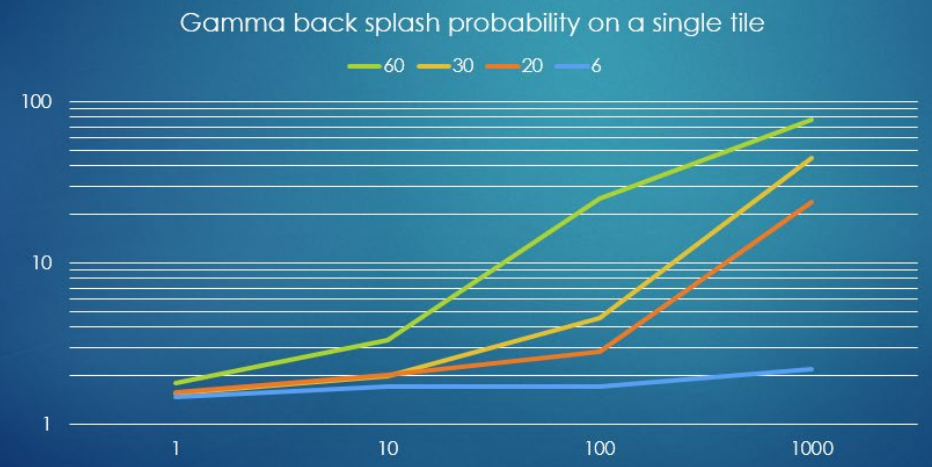
F.G.
Beijing meeting March 2018

Recap on backsplash

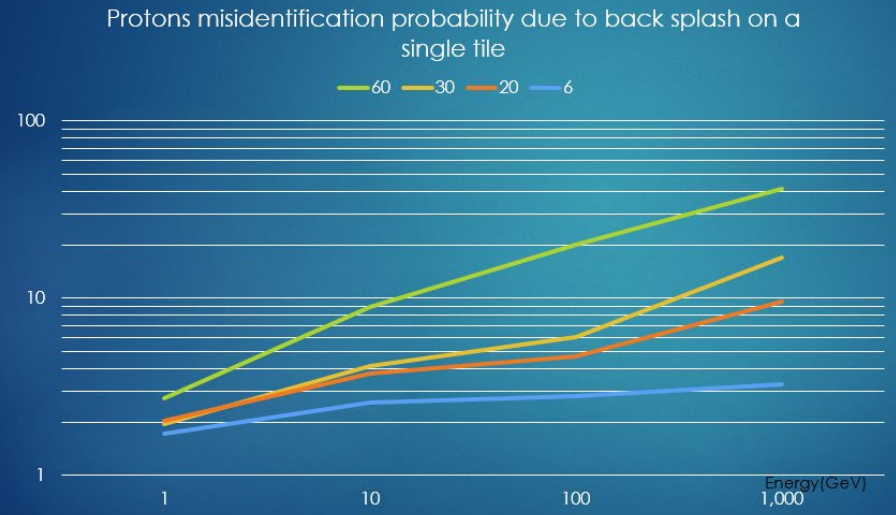
F.G.
Beijing meeting March 2018

Back splash for gamma

- To estimate the effect of the back-splash on the self VETO for high energy gammas we have considered as vetoed all the events with at least a signal (**0.25MIP**) in the PSD tile crossed by the photon.



Back-splash for protons



- As expected the effect of backsplash increase with energy and with tile size

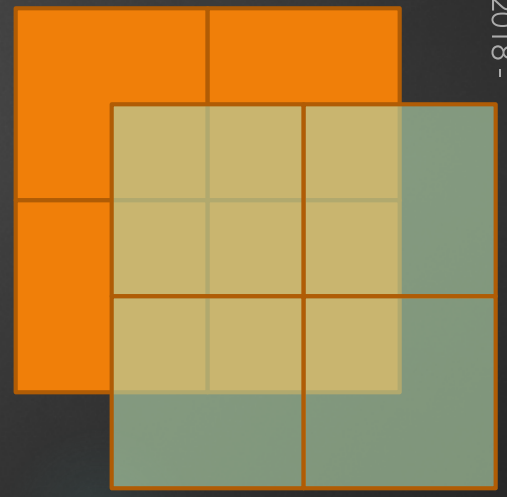
This work

- We have studied different solution (Tiles, Bars, WLS fiber readout) with a very simple approach based on analytic calculations
- This work could be used as a first guide to the selection of the different configurations that will be studied in details in the next month
- We are already developing a dedicated GEANT4 simulation to better study all the solutions. This is not in the general simulation framework since it is very specific for the PSD.

Tile configuration

- The tile solution could be very valid in rejection of backsplash but it has higher costs in terms of readout channels and power consumption
- To be effective in Z identification we need a double measurement of the ionization so we need two layers of tiles
- A possible solution could be place the tiles in a staggered way as in the picture
- With this solution we can consider an “effective” tile as the overlap between two “real” tiles
  - Half the number of tiles and readout channels
  - This should be verified with the simulation

Real tile size (cm)	Effective tile size (cm)	# Tiles in a TOP layers
20	10	81
10	5	324



Bar configuration

- This is the standard configuration with a long bar 1800x120x10 mm3
- Readout at both ends with 4 SiPM

Light output

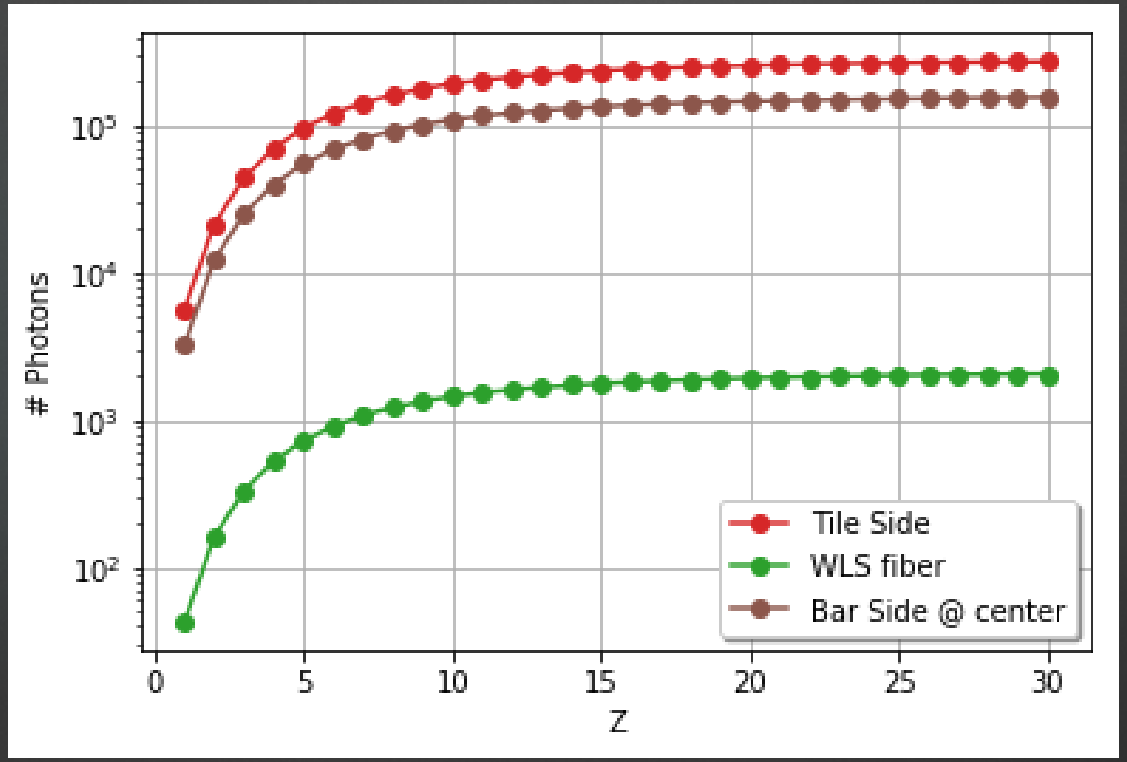
- BC400 Light yield: 25000 ph/MeV
- The light that exit from each side of the tile is the same:
  - 3700 ph/MeV (taking into account 10% of trapped light)
- Energy Loss in BC400: 1.5 MeV/cm
- We can consider also a readout of a tile with a WLS fiber (as in the figure)
- The WLS fiber trapping efficiency is 15% (to be verified)
- The WLS fiber transmission efficiency is 5% (to be verified)
- We have taken into account Birks Saturation

CALICE collaboration

$$\frac{dL}{dx} = S\frac{\frac{dE}{dx}}{1 + k_B\frac{dE}{dx}}.$$

Light output vs Z

- We have analytically calculated the light output for different Z value of the incident particle
- We have take into account the Birks saturation formula
- We have assumed that the light output is the same from each side
- For the bar we have assumed the ionization event at the center of the bar and taken into account the attenuation length

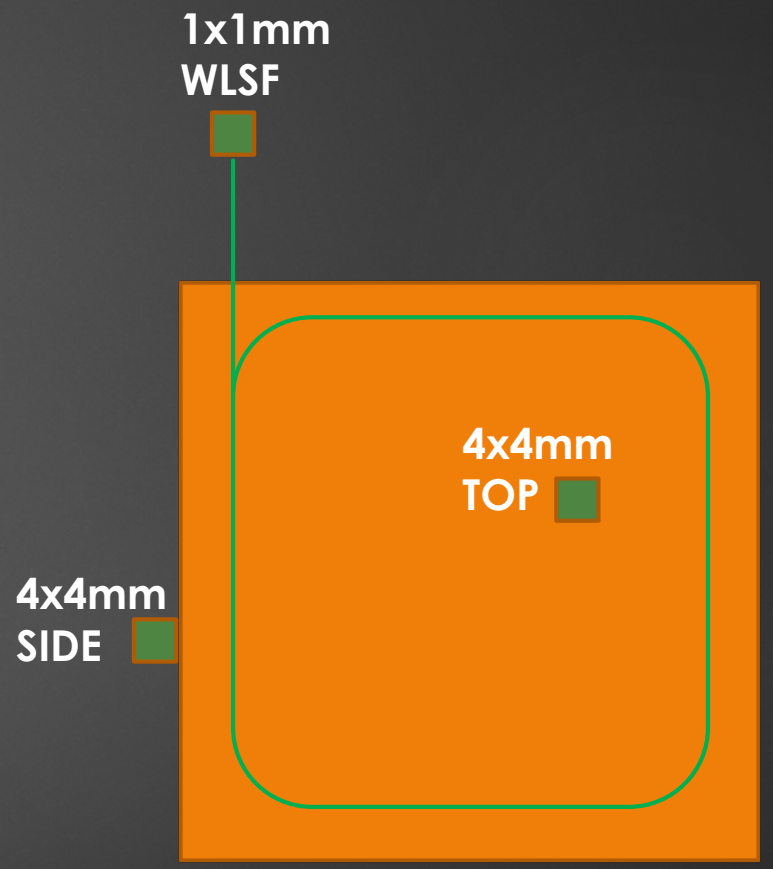


Readout with SiPM

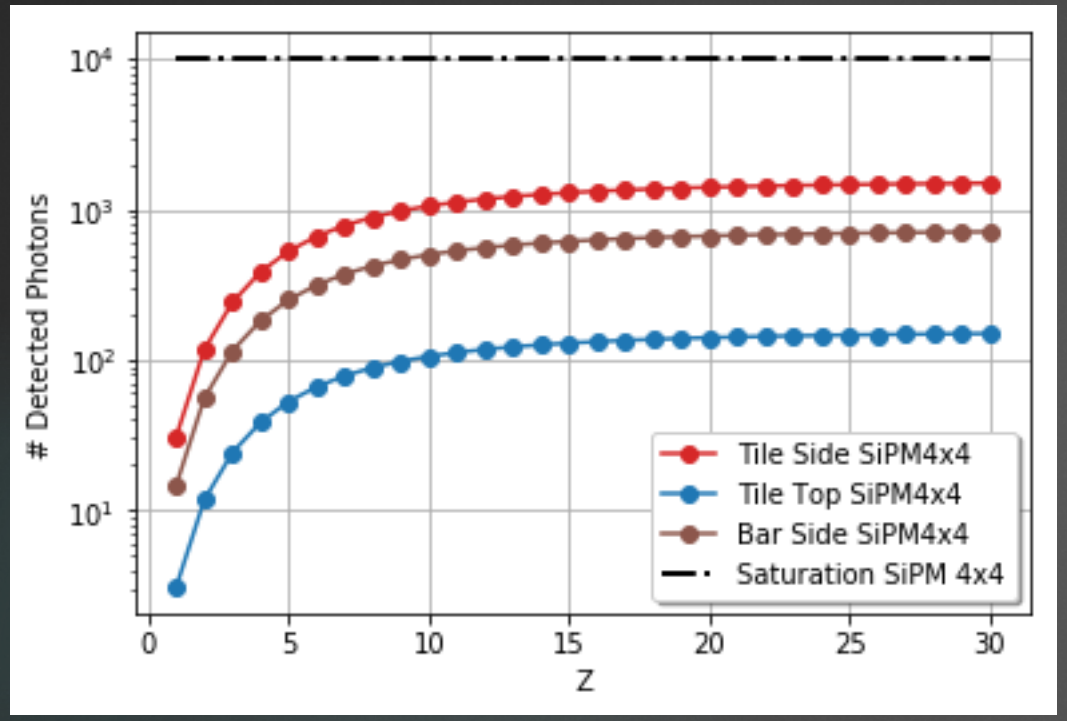
- We have considered a SiPM 4x4 mm2 with 40um cells for the readout of the tile and a SiPM 1x1 mm2 with 40um cells for the WLS readout
- The filling factor is 60%
- The number of cell is:
  - 4x4mm2: 10000
  - 1x1mm2: 625
- The PDE @ 420nm is 43%
- The coupling efficiency between tile/wls and SiPM has been fixed at 80% (to be verified)

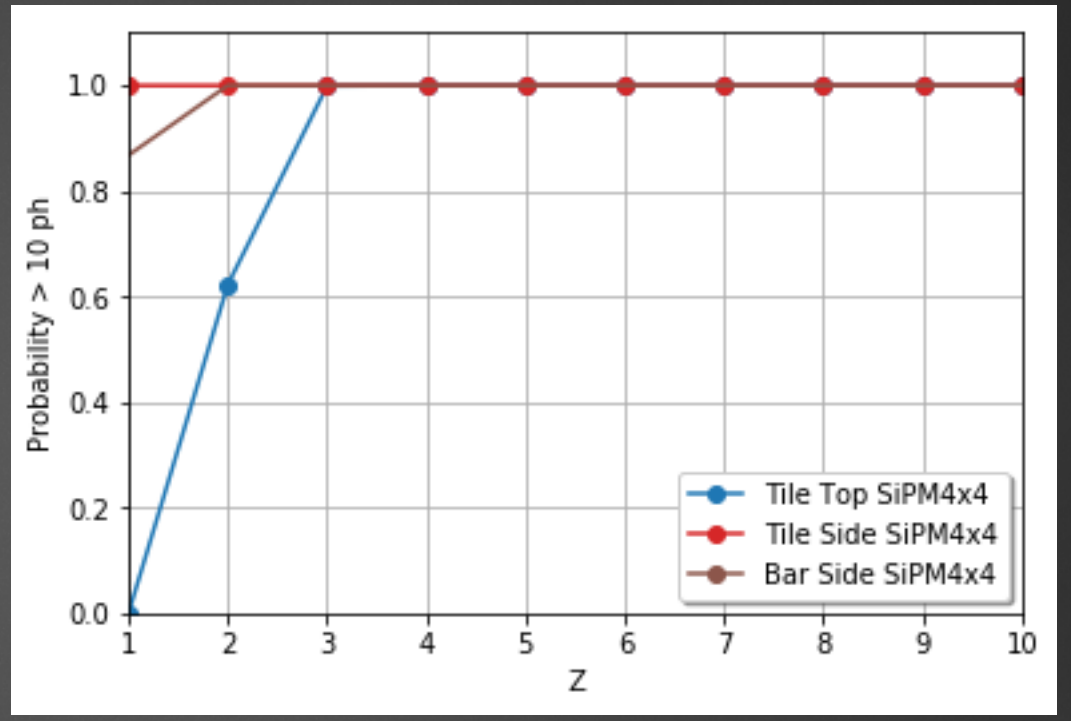
SiPM position

- We have considered two position of the SiPM on the tile:
  - side of the tile
  - top of the tile
- The WLS fiber is directly coupled to the SiPM
- For redundancy we should consider at least two SiPM for each type
- To roughly evaluate the detection efficiency we have assumed Poisson statistic and evaluated the probability to detect a signal above the noise level (10 photons)



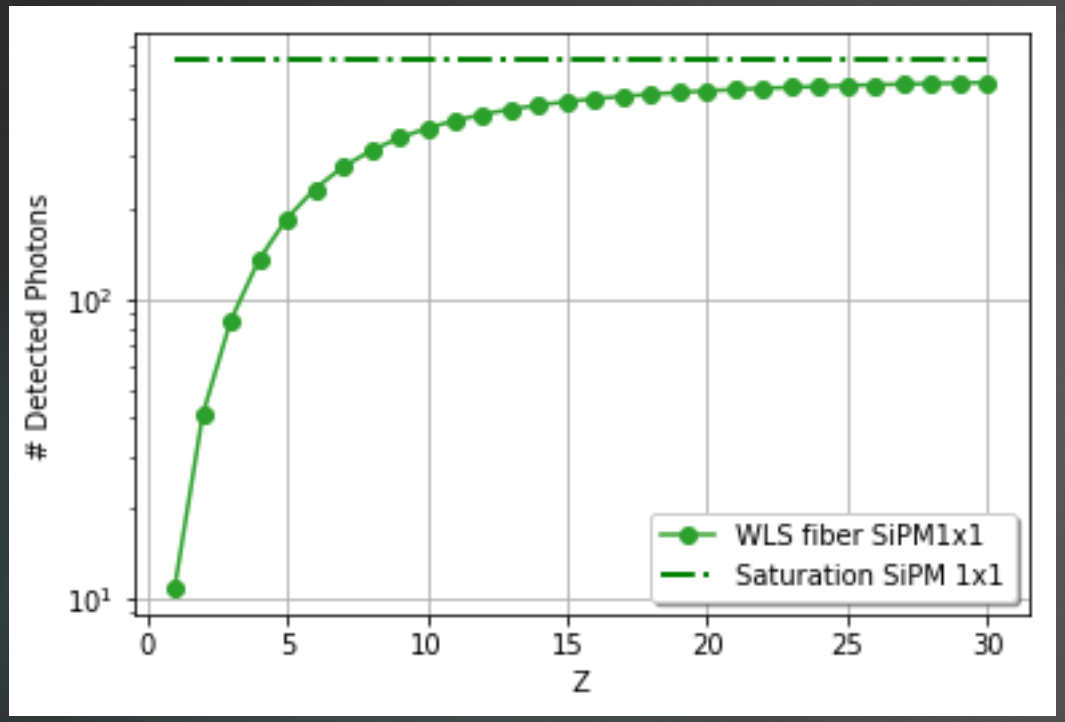
SiPM 4x4 mm^2 on tile and bar

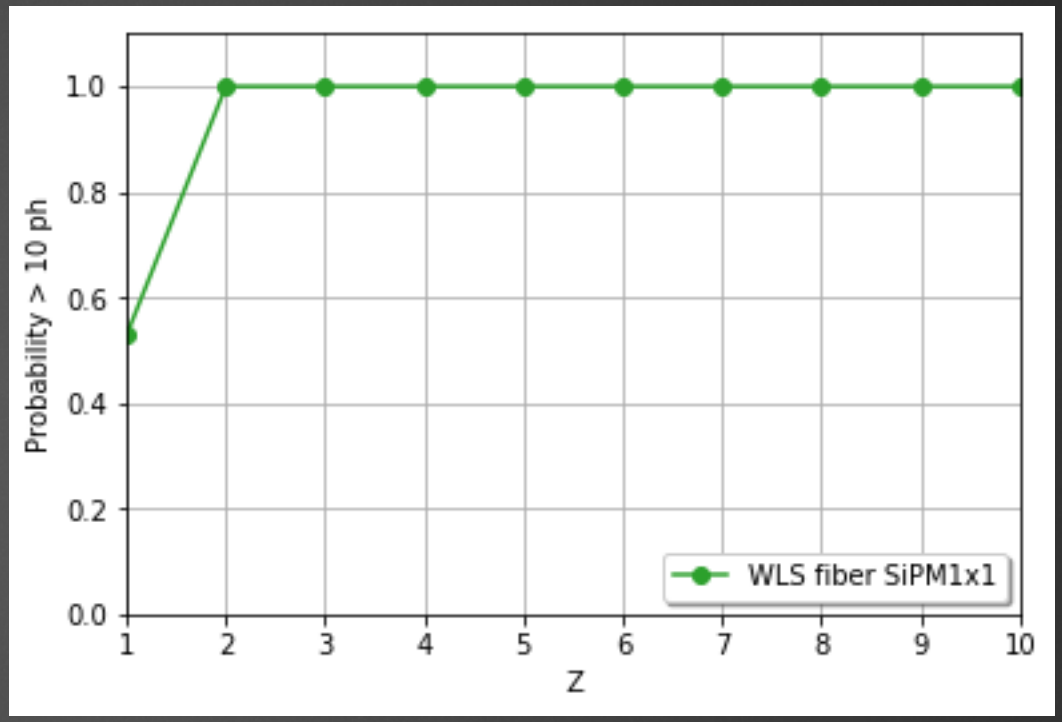




- All the configuration are far from the saturation of the SiPM (10^4 cells)
  - This is due to the Bircks saturation effect in the light output and needs to be carefully studied with simulation
- The SiPM on the TOP side of the Tile and the SiPM on the SIDE of the bar collect very few photons especially at low Z and therefore cannot be safely used as veto (very low efficiency)

SiPM 1x1mm^2 for WLS fiber





- With the WLS fiber readout we are close at the saturation of the SiPM (625 cells) at high Z
- The SiPM collects very few photons especially at low Z and therefore cannot be safely used as veto (very low efficiency)

Comparison

	Bars (1800x120mm^2)	Tile (100x100mm^2)	Tile (200x200mm^2)	Tile w/ WLS (200x200mm^2)
# elements	30	324	81	81
# SiPM	240	648 (1296)	162(324)	162

- For all the configurations we have assumed two layers of plastic scintillators
- Bars: 8 SiPM (4 for each side) per bar
- Tile: 2(4) SiPM per tail
- Tile with WLS readout : 2 SiPM per fiber

Comparison

Configuration	PRO	CONS
Tile Side SiPM 4x4mm^2	• Very high light yield at low Z	• Non Uniform light collection
Tile Top SiPM 4x4mm^2		• Very low light yield at low Z(no good for veto) • Non Uniform light collection
Tile WLS Fiber - SiPM 1x1mm^2	• Uniform light collection • Good light yield in all Z range (some caveat at high Z)	• More complex • Very low light yield at low Z (no good for veto)
Bar Side SiPM 4x4mm^2		• Low light yield at low Z (no good for veto) • Non Uniform light collection

Comparison

- According to this very preliminary study a promising solution is the one with tiles readout by two or more SiPM in the side
- The number of SiPMs and their position should be optimized with simulation and test
- We have not taken into account the readout electronics that could introduce an other kind of saturation. Probably a two gain readout is needed.

What Next

- Setup a simulation of a single tile to study:
  - Light output
  - Uniformity of light collection
  - Position and number of SiPMs
- Setup a test stand to study with Cosmic Rays (and possibly for Beam Test)
  - Light output
  - SiPM performances (saturation, gain, cross-talk, …)
  - Uniformity of light collection
  - Detection efficiency
- Study of a readout chain with a low power consumption and two gains