Herd meeting

Beijing 27-3-2018

SiPM readout for PSD

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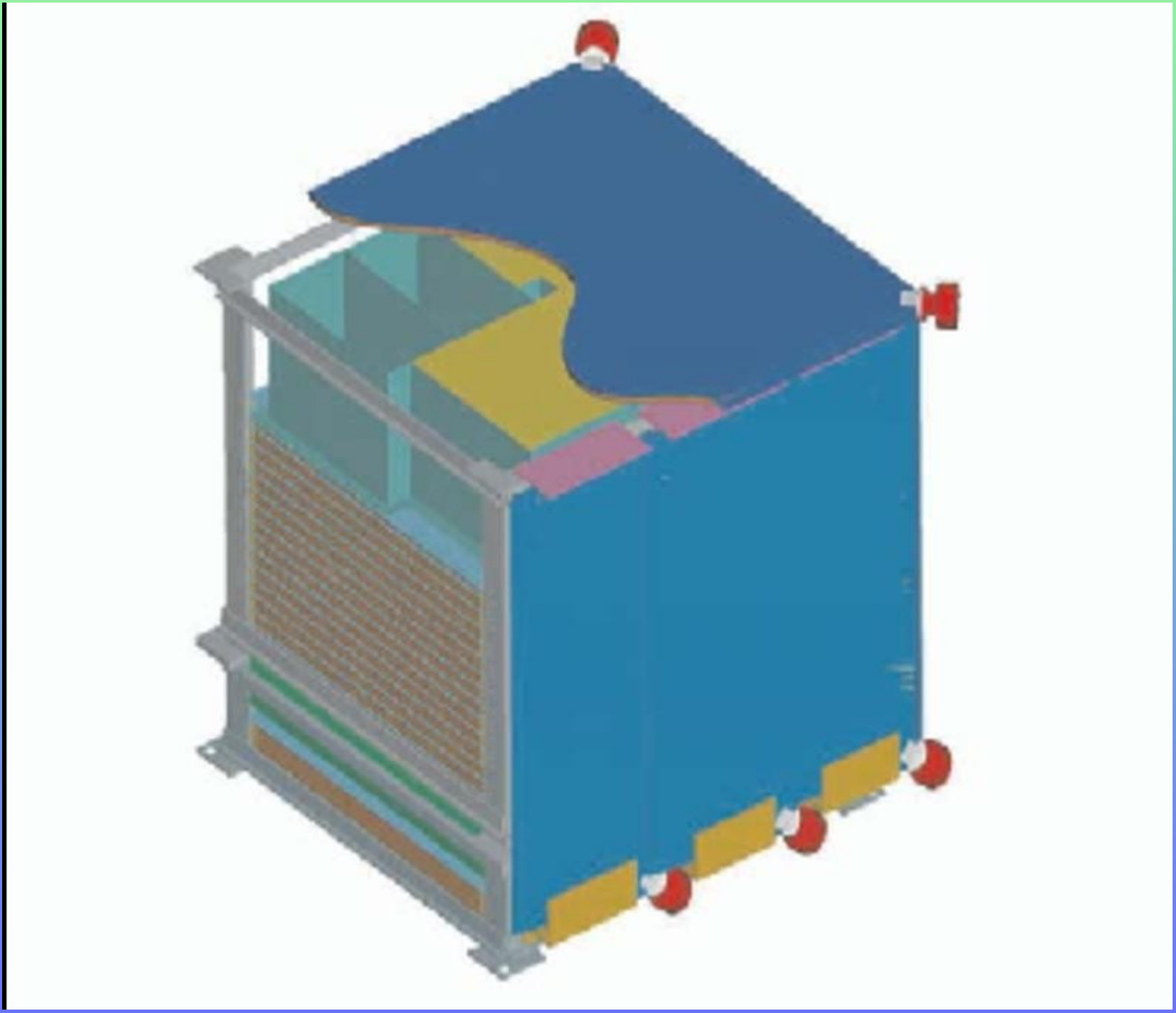
on behalf of the INFN-Pavia group

Agile AntiCoincidence



3 slabs fr each side readout by PMTs in a corner

On the top a slab readout by 4 PMTs on each corner

Used only as Veto

γ-ray astronomy

EGRET AntiCoincidence/Trigger

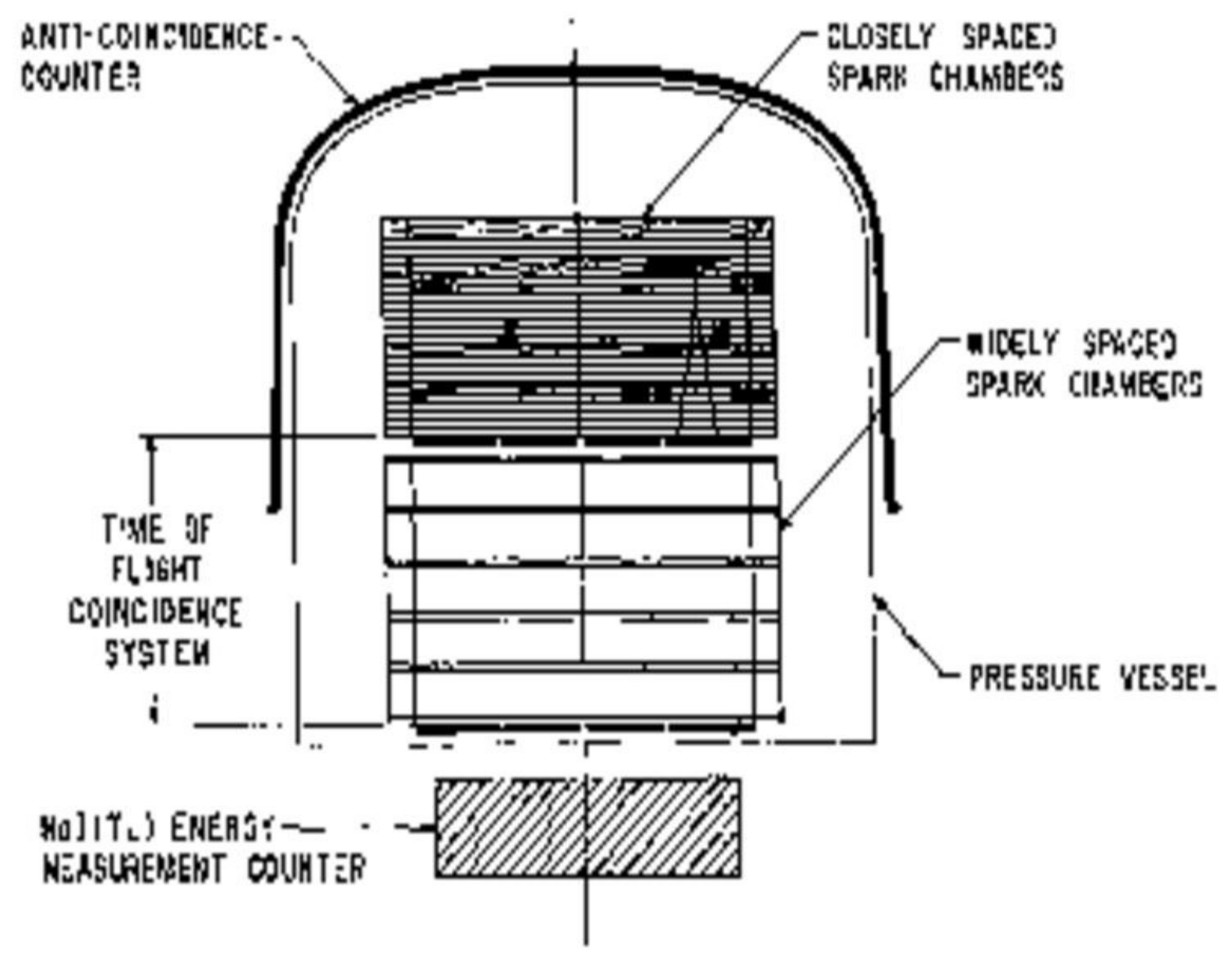
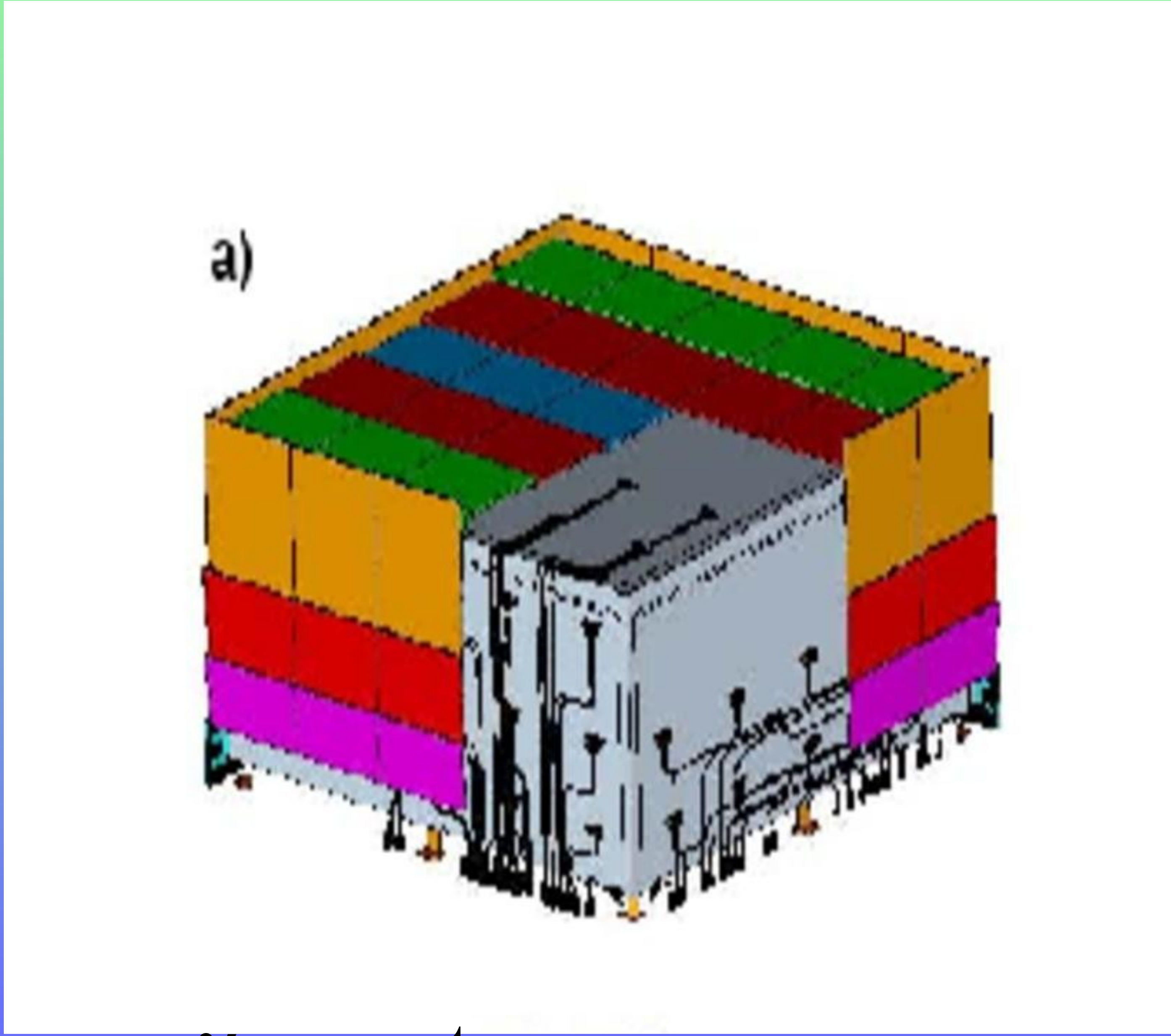


FIG. 1.—EGRET schematic diagram

Scintillator slabs /planes for trigger, TOF and Veto readout by PMTs.

γ-ray astronomy

FERMI AntiCoincidence

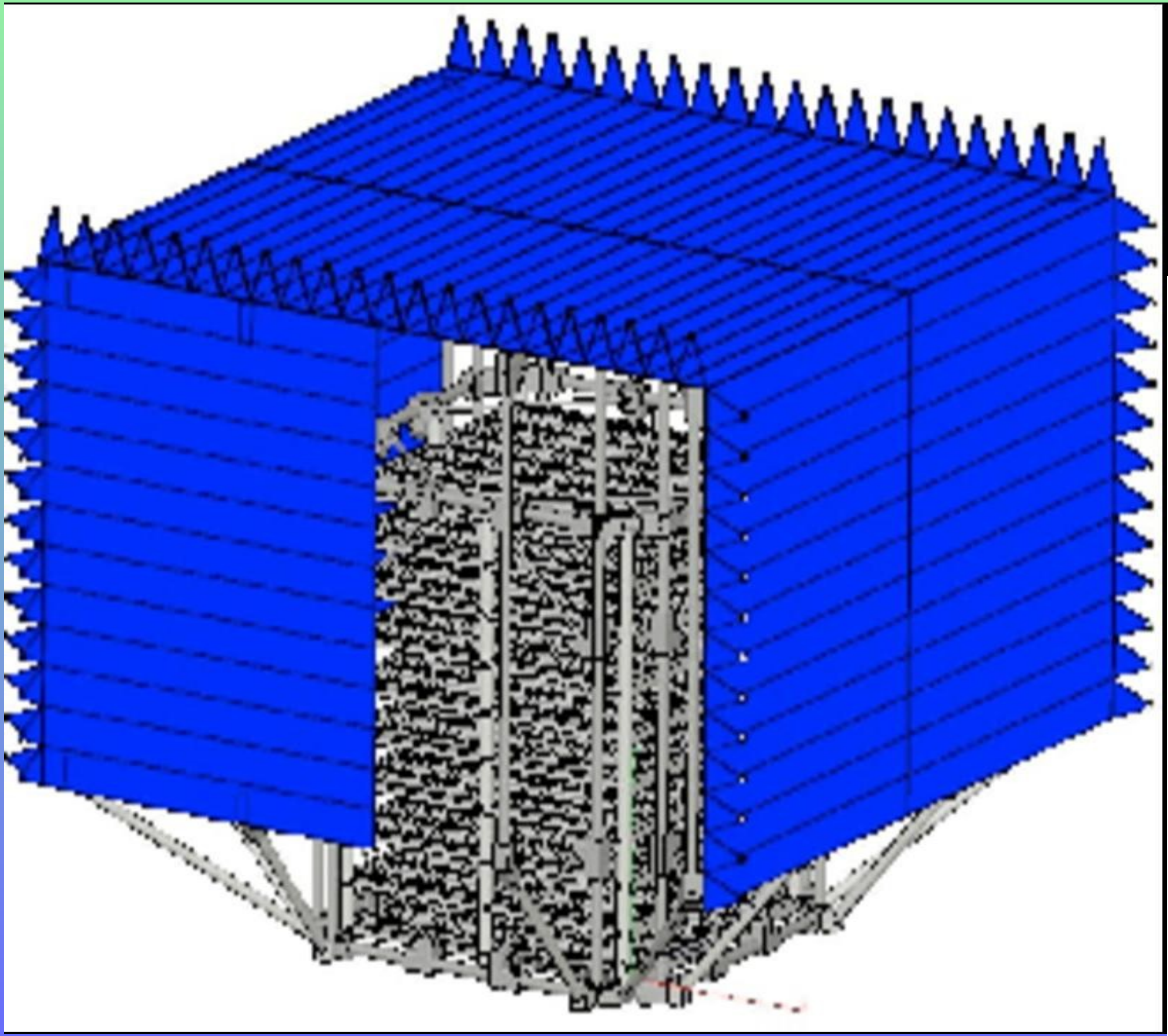


Scintillator layer segmented in 89 pads for AC (Veto) readout by wavelength shifters and miniature PMTs

Used also in electron event reconstruction

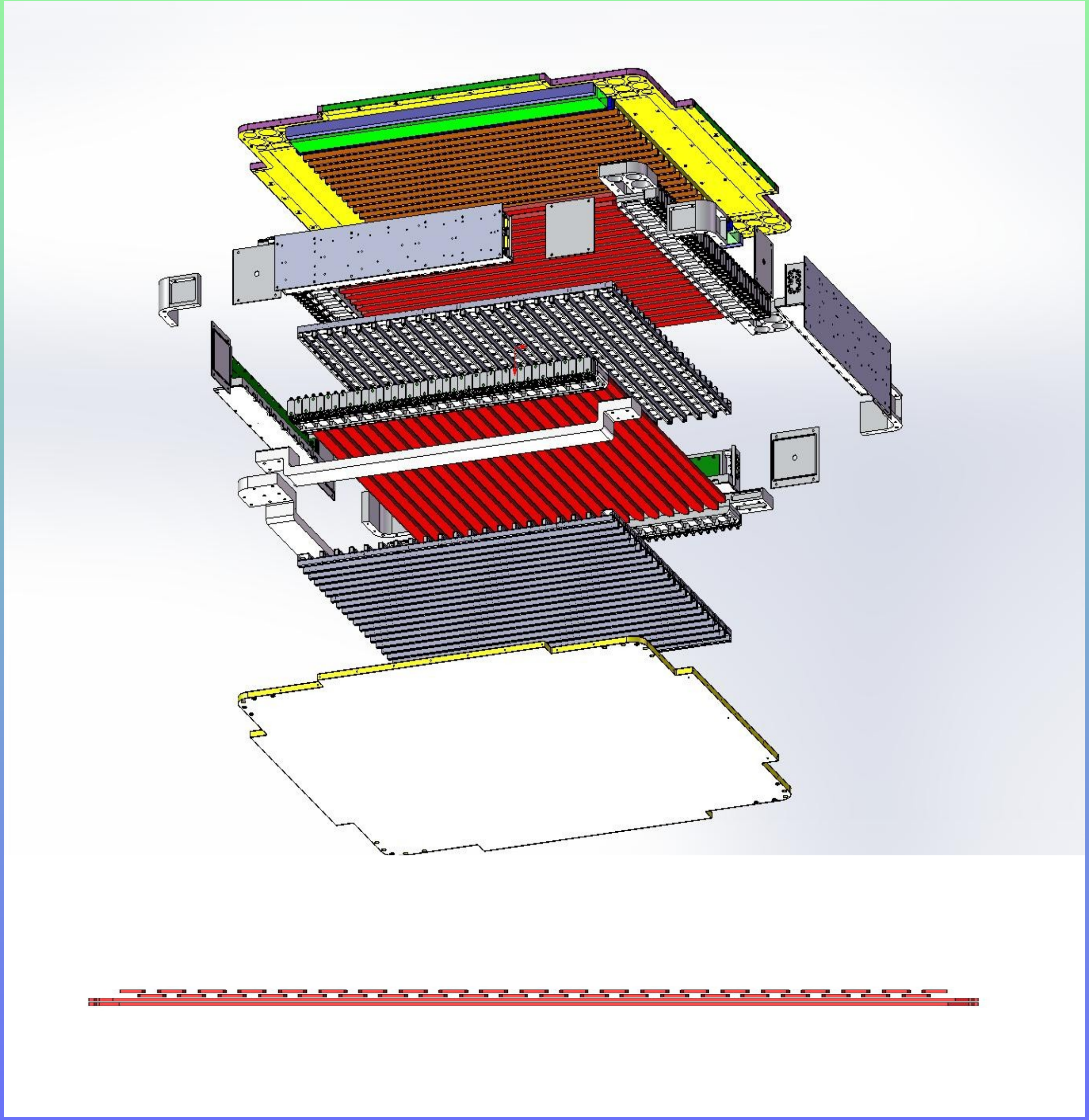
γ-ray astronomy

GAPS TOF



215 scintillators slabs for TOF

DAMPE PSD



Scintillator segmented in 82 bars for AC (Veto) readout by PMTs crossed and staggered

Used also in electron event reconstruction

Problems with backsplash

Limitations in the use of PMTs vs SiPMs

PMTs are large, heavy (for space application), requires heavy voltage (additional weight), have circular shape ill suited to scintillator slab geometry.

The advantages of SiPMs:

- small
- low operational voltage (few tens Volts)
- easily matched to any configuration
- high QE
- low costs
- gain depends linearly on overvoltage $G=C\Delta V$

The disadvantages of SiPM:

- their gain and linearity are limited
- their operation point is strongly temperature dependance
- they are radiation sensitive (dark current)

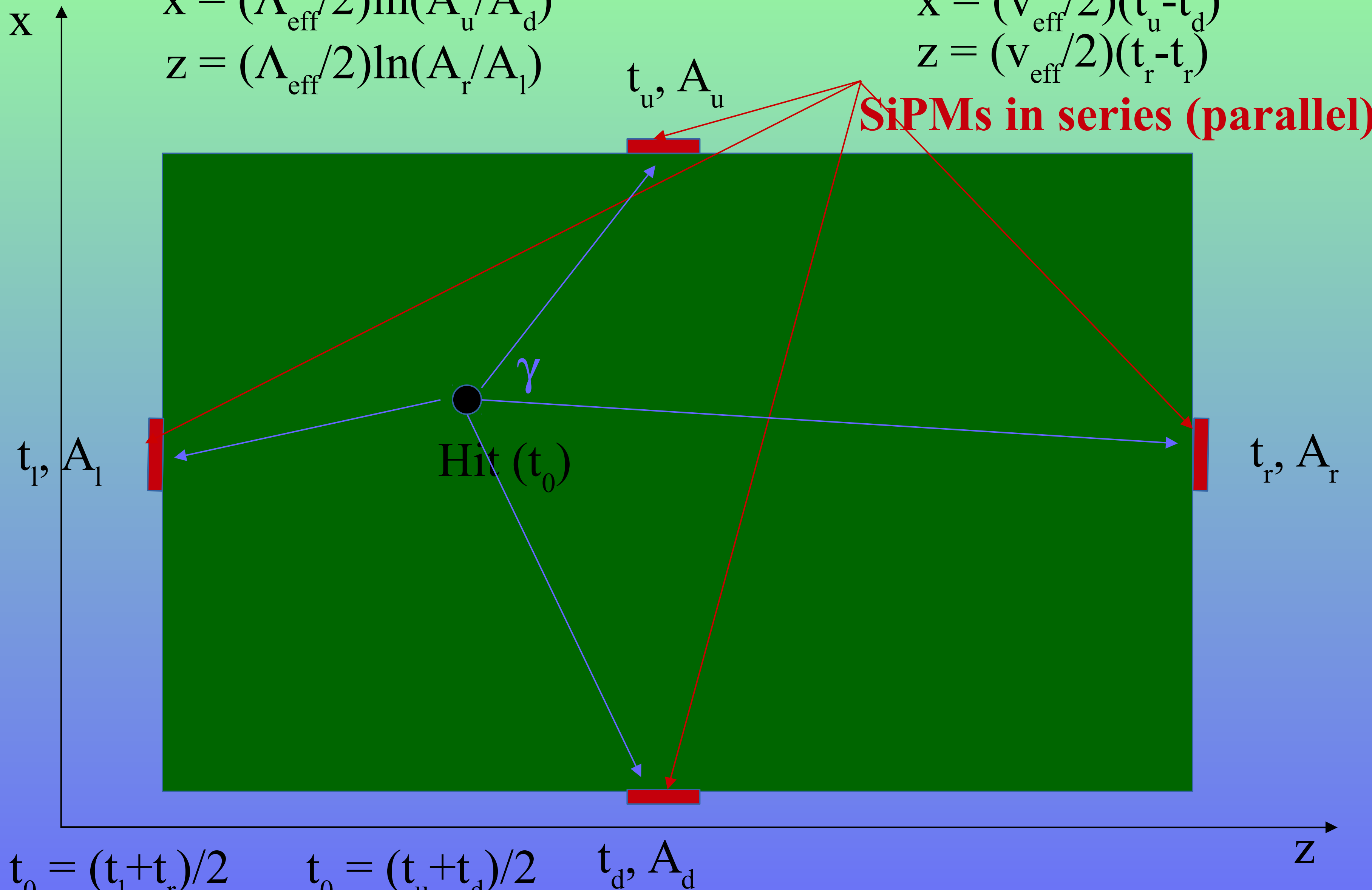
Most general readout with SiPMs of a slab

$x = (\Lambda_{eff}/2)\ln(A_u/A_d)$

$z = (\Lambda_{eff}/2)\ln(A_r/A_l)$

$x = (v_{eff}/2)(t_u - t_d)$

$z = (v_{eff}/2)(t_r - t_r)$



$t_0 = (t_l + t_r)/2$ $\qquad$ $t_0 = (t_u + t_d)/2$

If high precision timing is available. Readout by 1, 2 o 4 sides.

Reading one or more sides

The SiPMs can be located on 1, 2 or 4 sides.
Choice depends also on request on time and space resolution.

SiPMs can be used connected in series or in parallel to increase the area of light collection. Or using SiPM array.

SiPM can measure the integrated charge and the time of arrival of scintillation photons on the SiPMs.

Which time and space resolutions are required in HERD?
Is high time resolution (<100ps) required?

Slab readout by SiPMs

A single slab can provide measurements of two coordinates and of time with SiPMs (in series or parallel) on 4 sides.

For small slabs 5x12x0.5 cm^3 and readout only on two sides
Many results for the MEGII experiment in:
P.W. Cattaneo et al., Development of high precision timing counter based on plastic scintillator with SiPM readout, physics.ins-det arXiv 1402.1404

Time and space resolution $\sigma(t_0) \sim 50$ ps $\sigma(z) <\sim 1$ cm with adequate readout
Somehow depending on slab size ~1 m

PSD time resolution

SiPMs can provide very precise time measurement. Limitations can come from scintillator decay time, readout system and correction for time propagation along the bar.

The last limitation is removed taking $t_0 = (t_l+t_r)/2$

For slabs with small sizes, the main limitation come from the readout resolution unless specialized electronics is chosen.

PSD space resolution

PSD space resolution can be obtained in three ways:

- the size of the slab/sqrt(12) regardless of the readout
- exploiting the attenuation of the signal with the distance
  $x = (\Lambda_{eff}/2)\ln(A_u/A_d)$
- measuring accurately the signal time at the SiPMs
  $x = (v_{eff}/2)(t_u - t_d)$

The first approach comes for free.
The second is a consequence of the charge measurement.
The third requires specialized electronics.

PSD as charge detector (1)

PSD used for Particle Identification measure the integrated charge.
At least two readout sites required for compensation of light attentation along the slab.

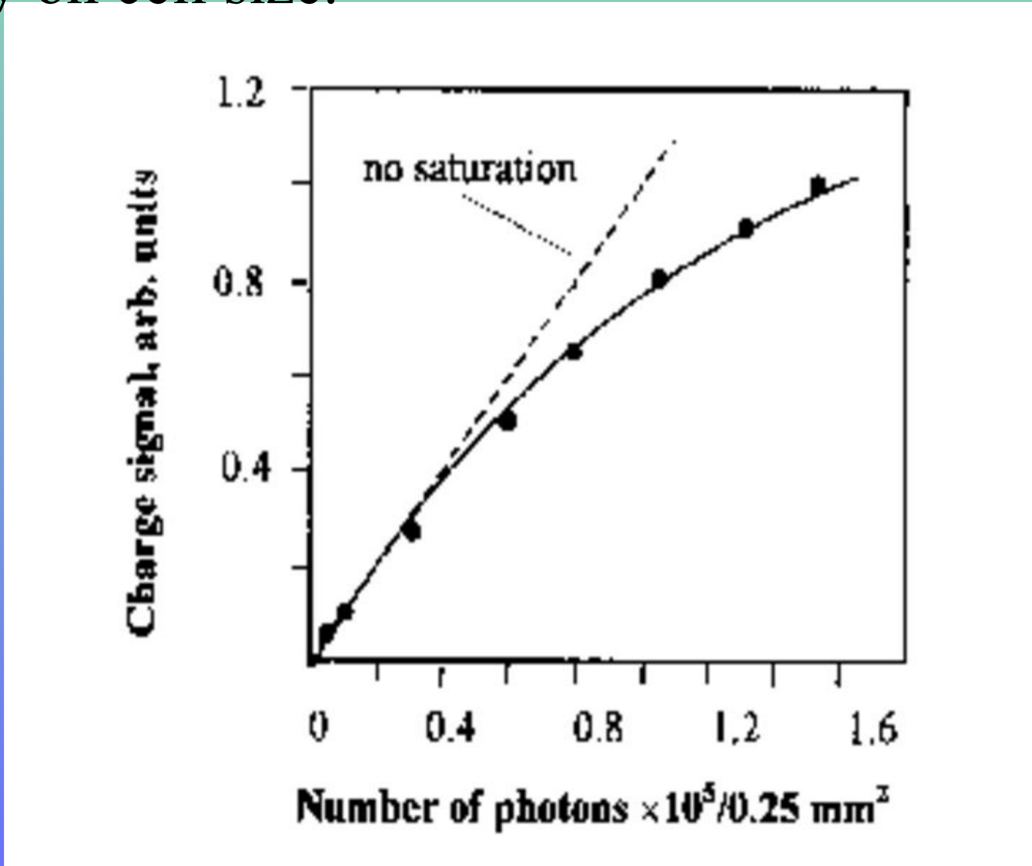
Dynamic range > Z^2 (Z=1,26) to be sensible from proton to iron.
Not perpendicular crossing angles increases the range by a factor 2-3.

Somehow reduced because of saturation effect in the scintillator.

Additionally to guarantee high rejection power for m.i.p. for gamma veto, S/N for m.i.p. must be 5-10.
All together a dynamic range ~1000-2000 or more.

PSD as charge detector (2)

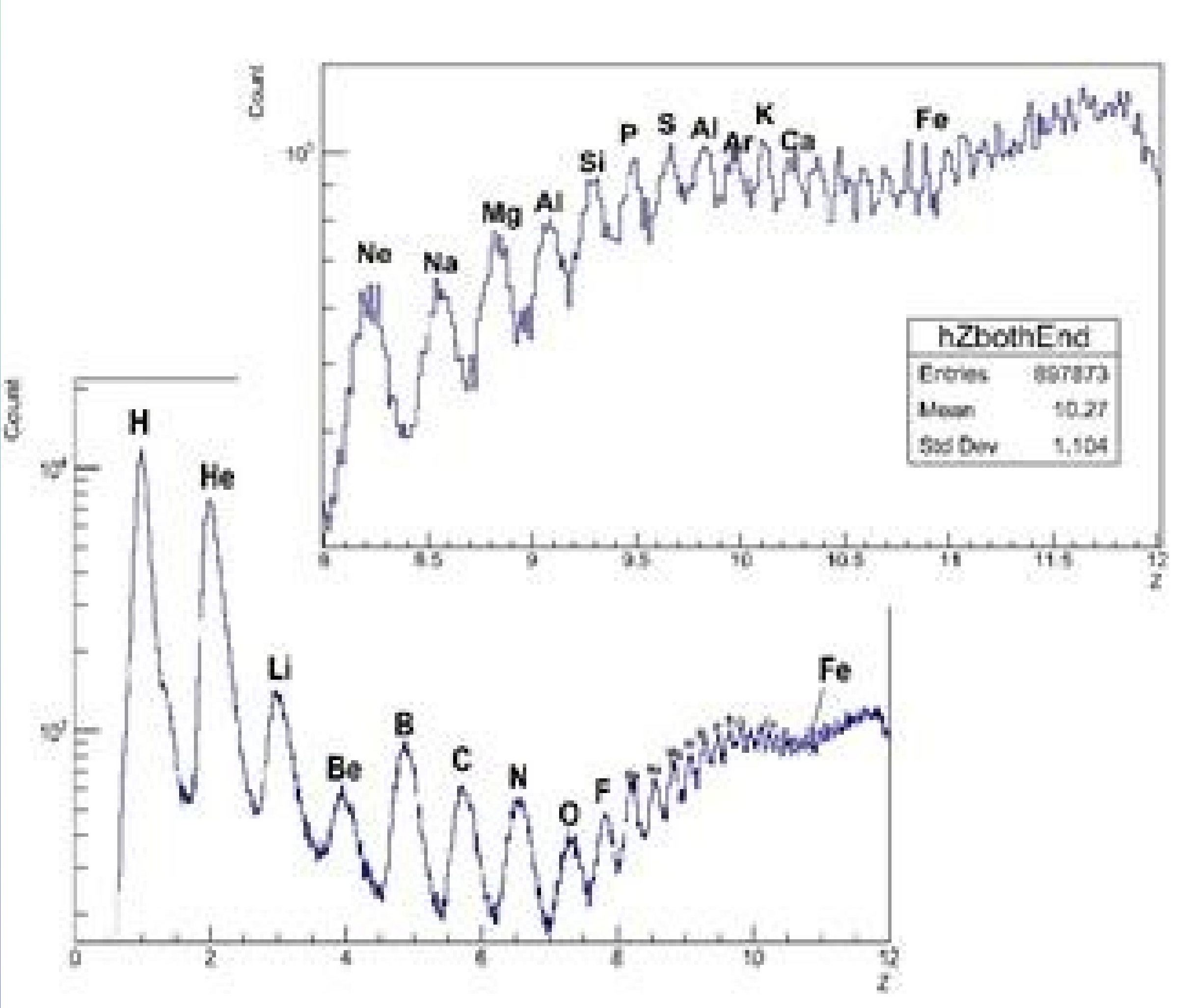
SiPM works on Geiger principle.
The signal is the sum of the charge CΔV stored the hit cells.
If average photon per cell ~1, signal saturates.
Depends mainly on cell size.



SiPM non-linearity and saturation depends on cell dimension (~40 um).

Results from beam test with SiPMs

Long bars readout by 4 SiPMs each side.



Electronic Readout

If high time resolution is required as in MEG(II)

The high frquency (~1GHz) sampler DRS4 is a possibility:

high time resolution off line or on line (without storing waveforms)

System complex with high power consumption.

Limited in dynamic range?

Simpler:

- TDC with a lower time resolution .
- ADC for charge measurement 10-12 bit?

For a 1000-2000 dynamic range is it sufficient only one SiPM gain? Or at least two different gains?

Same issue for the readout elettronics.

Calibration

For measurement of charge (energy) we need a calibration and monitoring system to guarantee response uniformity between pads.

Calibration in energy before launch:
- beam test on ground
- mip from cosmic rays on ground

Monitoring in flight is required to correct for drift in SiPM gain due to temperature, aging, radiation damage in SiPM and scintillator :
- mip in space (non interacting proton?)
- radioactive sources (alpha) on scintillator surface?
- LEDs? (what about drift in LED output?)

SiPMs models

There are several companies producing SiPMs:

- Hamamatsu (Japan)
- Ketek (Germany)
- Excelitas (USA)
- SensL (Ireland)
- AdvanSID (Italy)

We (Pavia) have worked (MEG, PSI) with AdvanSID successfully.

Readout PSD Herd

There are different scintillator arrangements:

- 2 Dimension: plane

- 1 Dimension: bar

- 0 Dimension: tile

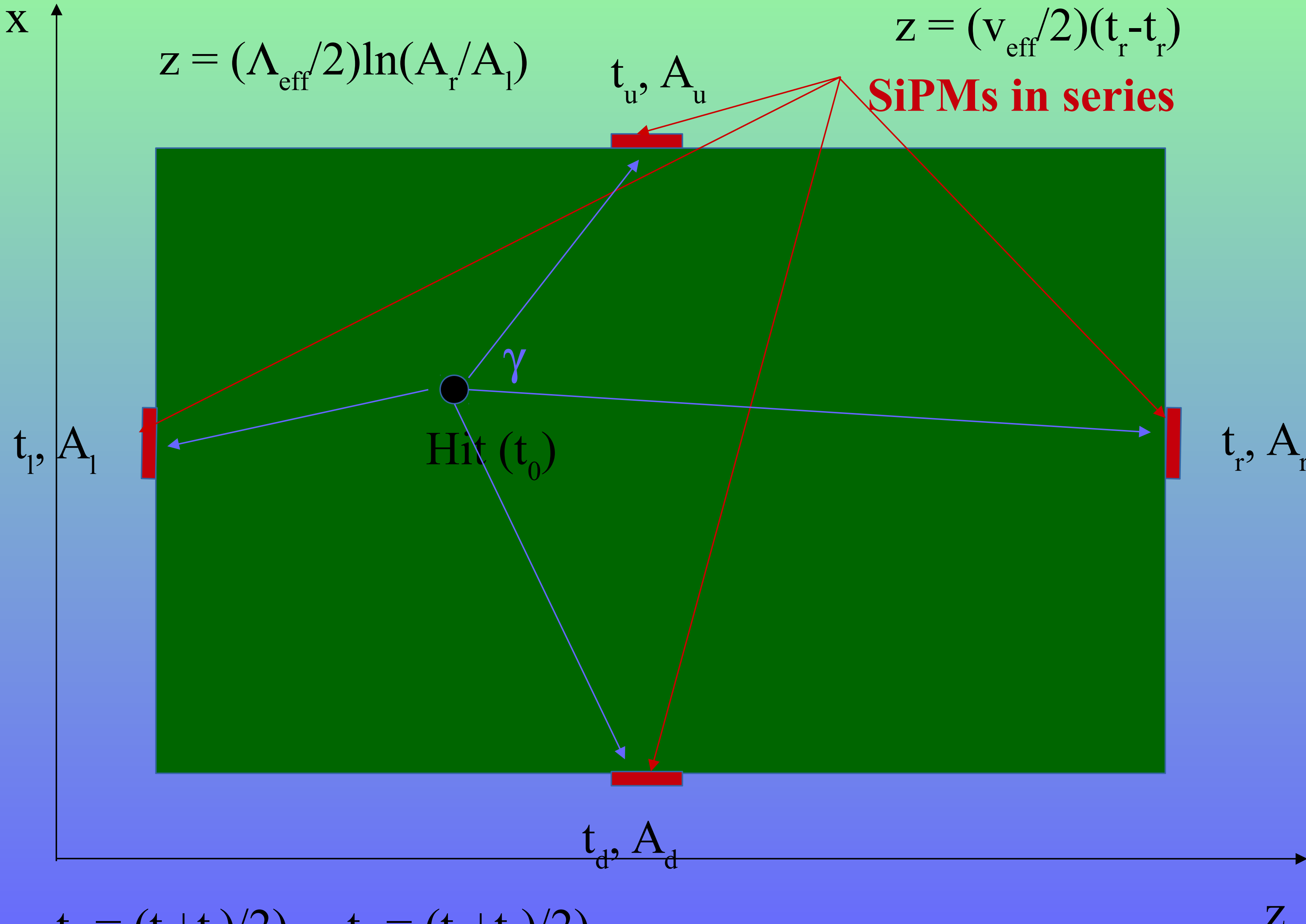
Readout:

$$x = (\Lambda_{eff}/2)\ln(A_u/A_d)$$

$$z = (\Lambda_{eff}/2)\ln(A_r/A_l)$$

$$x = (v_{eff}/2)(t_u - t_d)$$

$$z = (v_{eff}/2)(t_r - t_r)$$



$$t_0 = (t_l + t_r)/2 \qquad t_0 = (t_u + t_d)/2$$

Limiti di scintillatori segmentati

La segmentazione dei piani di scintillatore moltiplica i canali che diventano N per segmentazione in una dimensione e NxN in due dimensioni. In particolare se pensati come TOF.
Inoltre si possono creare zone morte tra le lastre.