Performance studies of Micromegas electronics In a high radiation environment At the CERN Gamma Irradiation Facility (GIF++)

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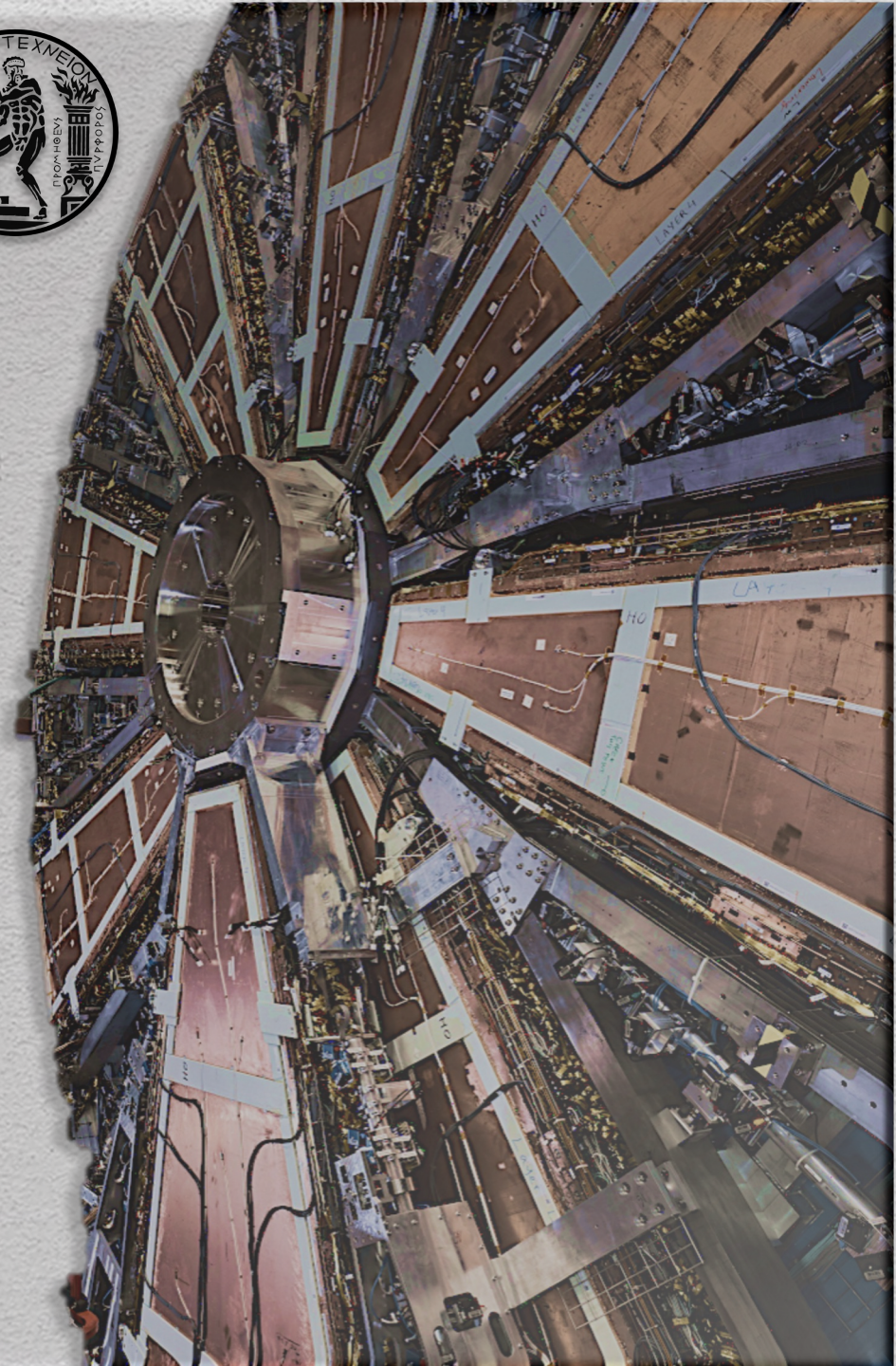


HEP2022 - 39th Conference on Recent Developments in
High Energy Physics and Cosmology | 15-18 Jun2022

Outline

- The ATLAS Experiment Upgrades
  - The New Small Wheel project
- The Micromegas
  - Structure layout
  - Readout and Trigger electronics
- The Micromegas tests at the GIF++
  - The test bench
  - Tests with gamma and muons
- Conclusions
  - Next steps

LHC / HL-LHC PLAN

LHC: Large Hadron Collider
HL: High Luminosity

2015-2018

LHC- RUN #2

190 fb^{-1}
2xNominal Luminosity

2019-2021

LHC – SHUTDOWN #2

ATLAS UPGRADE- PHASE I

2022-2024

LHC- RUN #3

350 fb^{-1}
2xNominal Luminosity
$\mathcal{L} = 2{,}5\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

2025-2027

LHC – SHUTDOWN #3

ATLAS UPGRADE- PHASE II

2027

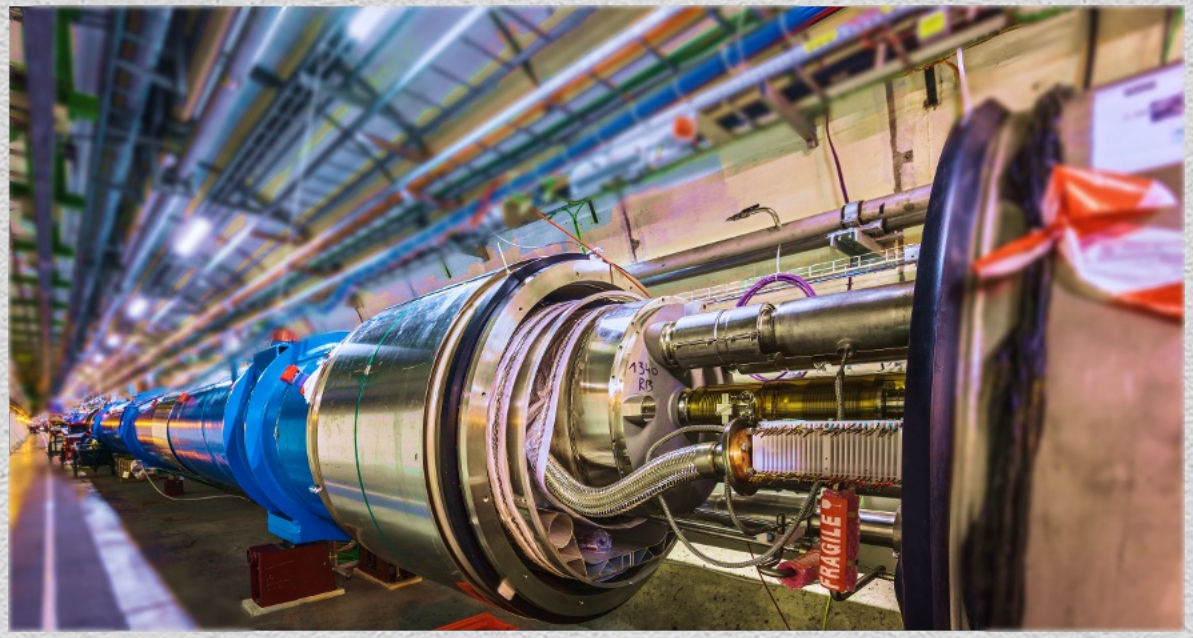
HIGH LHC- RUN #4-5..

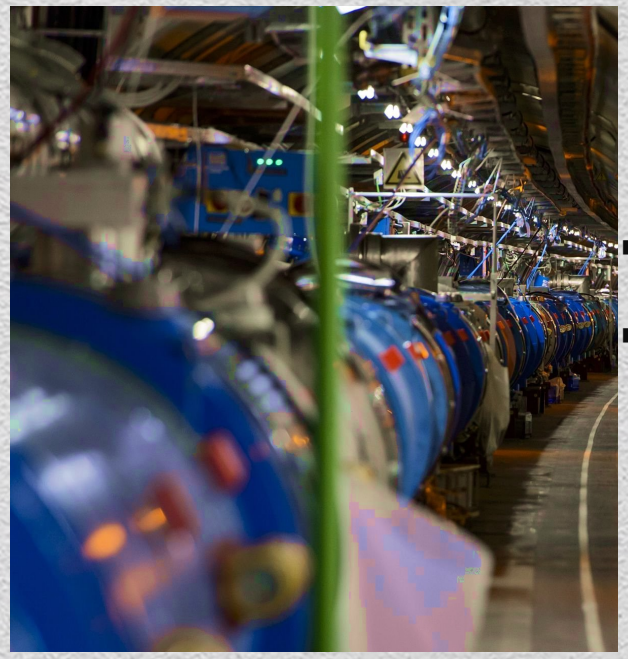
3000 fb^{-1}
5-7.5xNominal Luminosity
$\mathcal{L} = 5\sim7{,}5\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

The ATLAS Upgrades

LHC Upgrades

- Higher data rates
- Higher background radiation environment
- Higher magnetic field

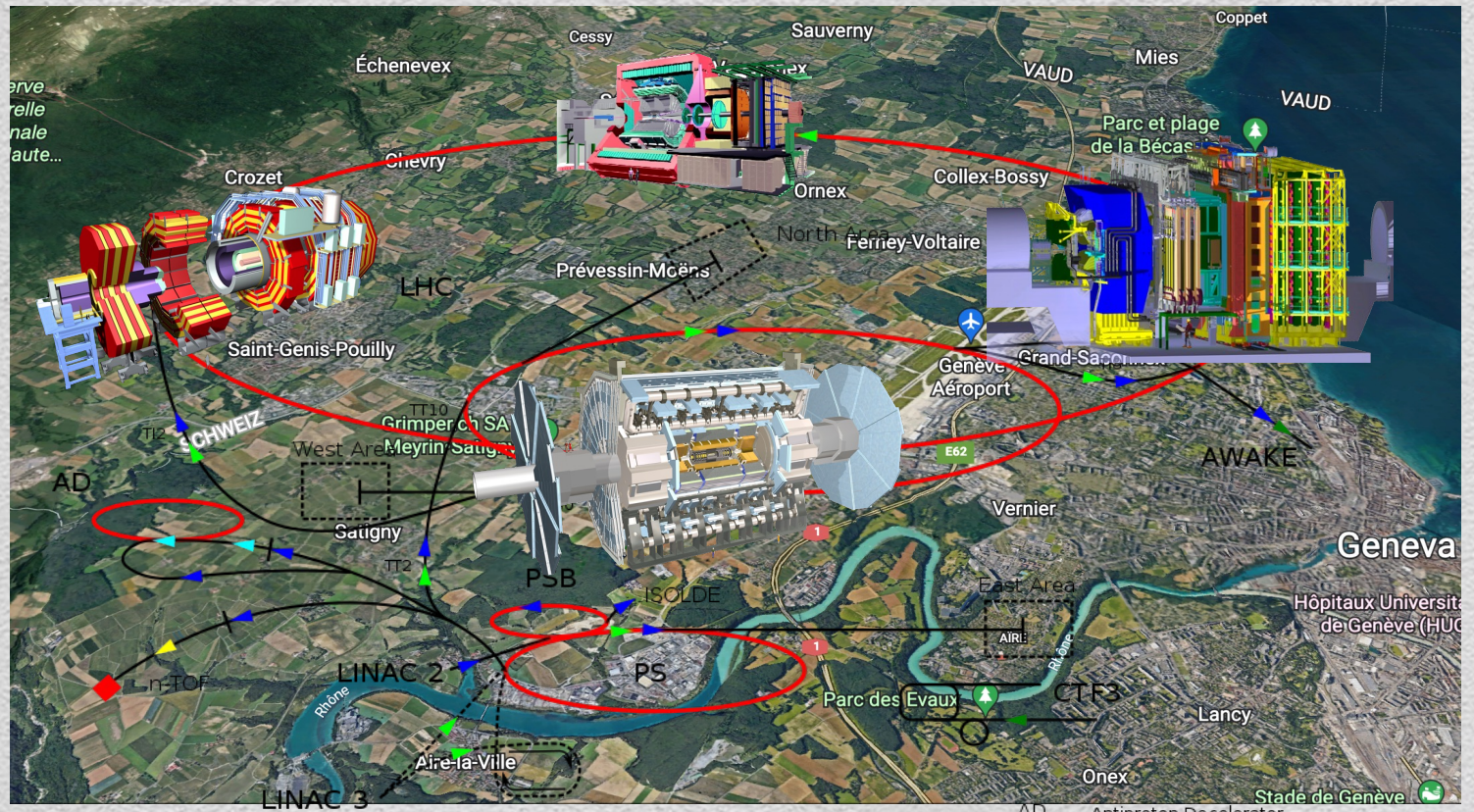




- ATLAS upgrades it's sub-detectors, readout and trigger electronics
- Phase-I Upgrade most complex & challenging project :
  - It will replace the Small Wheels detector stations
  - New detector technologies: Micromegas & small Strip Thin Gas Chambers

  comprises ~2.4×10^6 readout channels
  - Trigger : rate 1MHz, latency 2μs

The ATLAS Upgrades

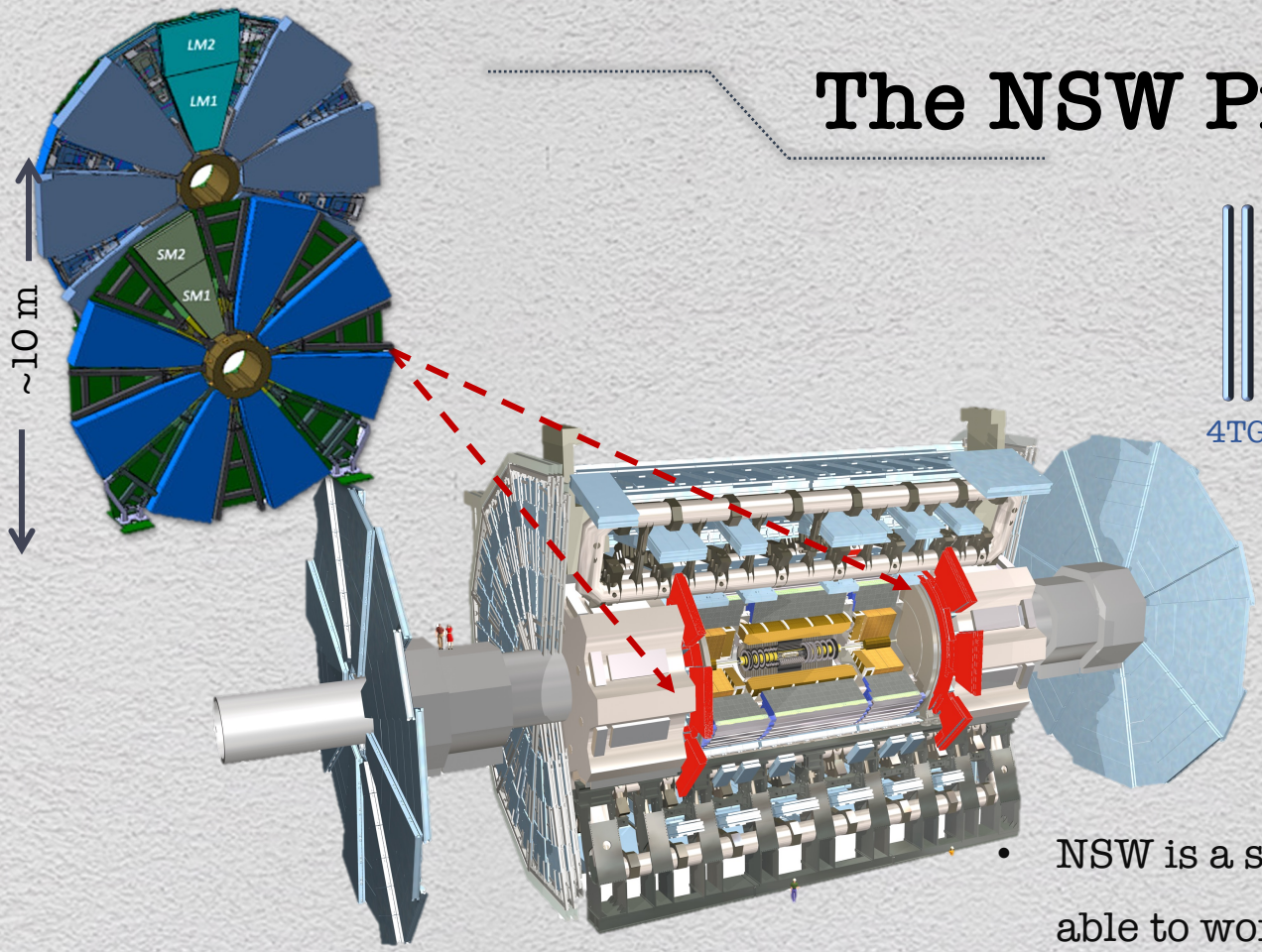


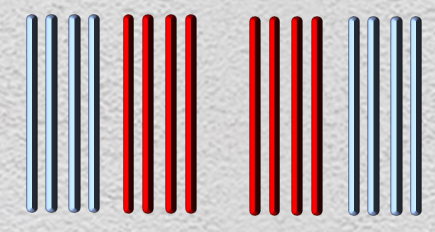
protons
ions
neutrons
antiprotons
electrons
neutrinos

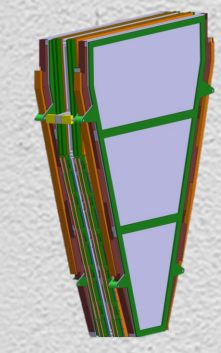
PS	Proton Synchrotron
SPS	Super Proton Synchrotron
LHC	Large Hadron Collider

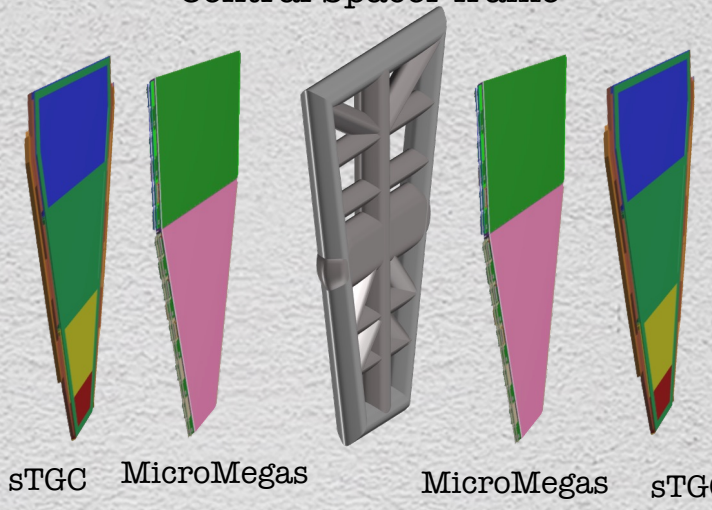
AD	Antiproton Decelerator
n-TOF	Neutron Time Of Flight
AWAKE	Advanced Wakefield Experiment
CTF3	CLIC Test Facility 3

The NSW Project









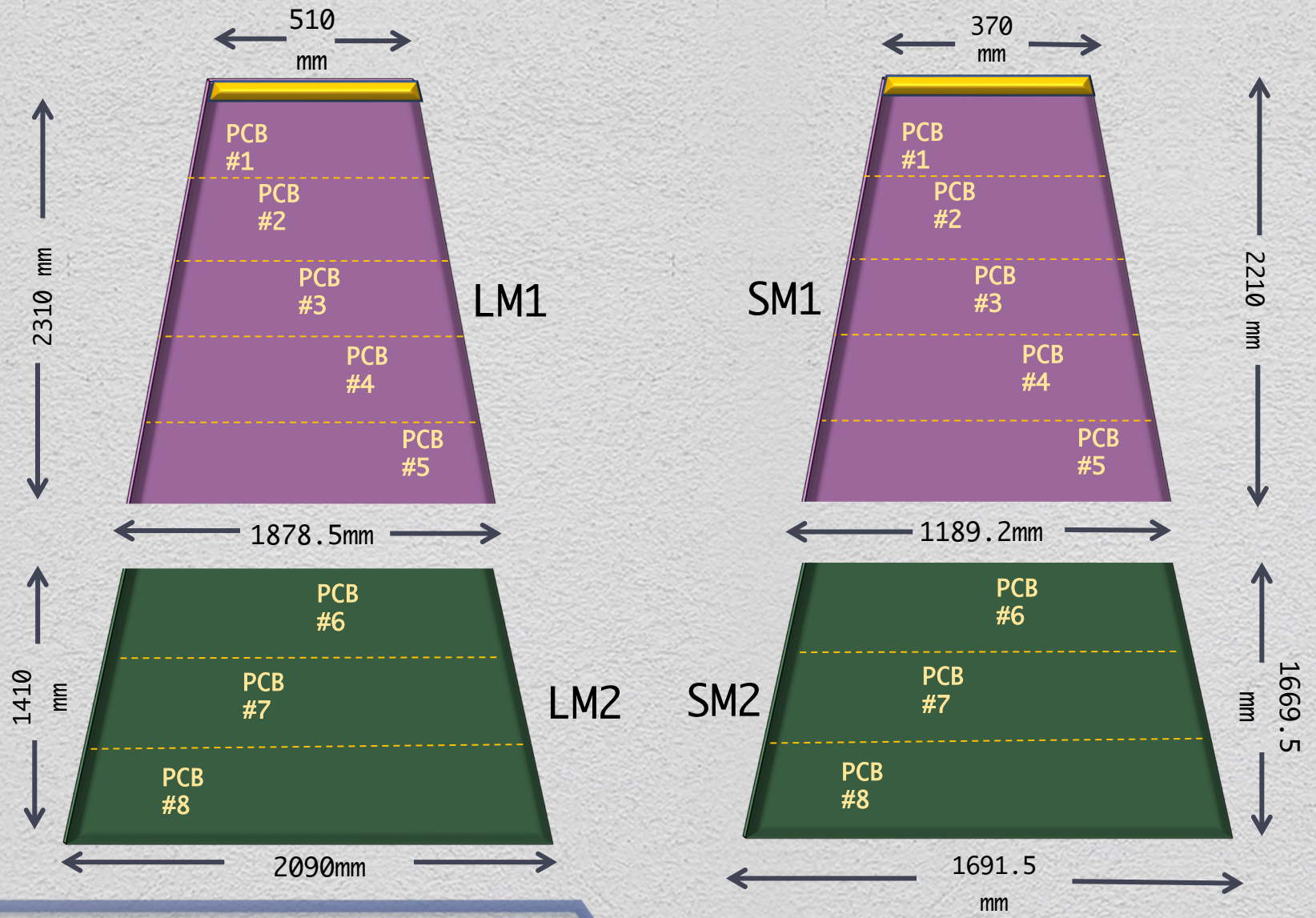
- NSW is a set of precision tracking and trigger detectors able to work at high rates
- 2 technologies sTGCs and Micromegas detectors will provide tracking and trigger information
- 8 small + 8 large sectors per wheel
- 8 sTGCs + 8 Micromegas planes per sector

Readout Channels:

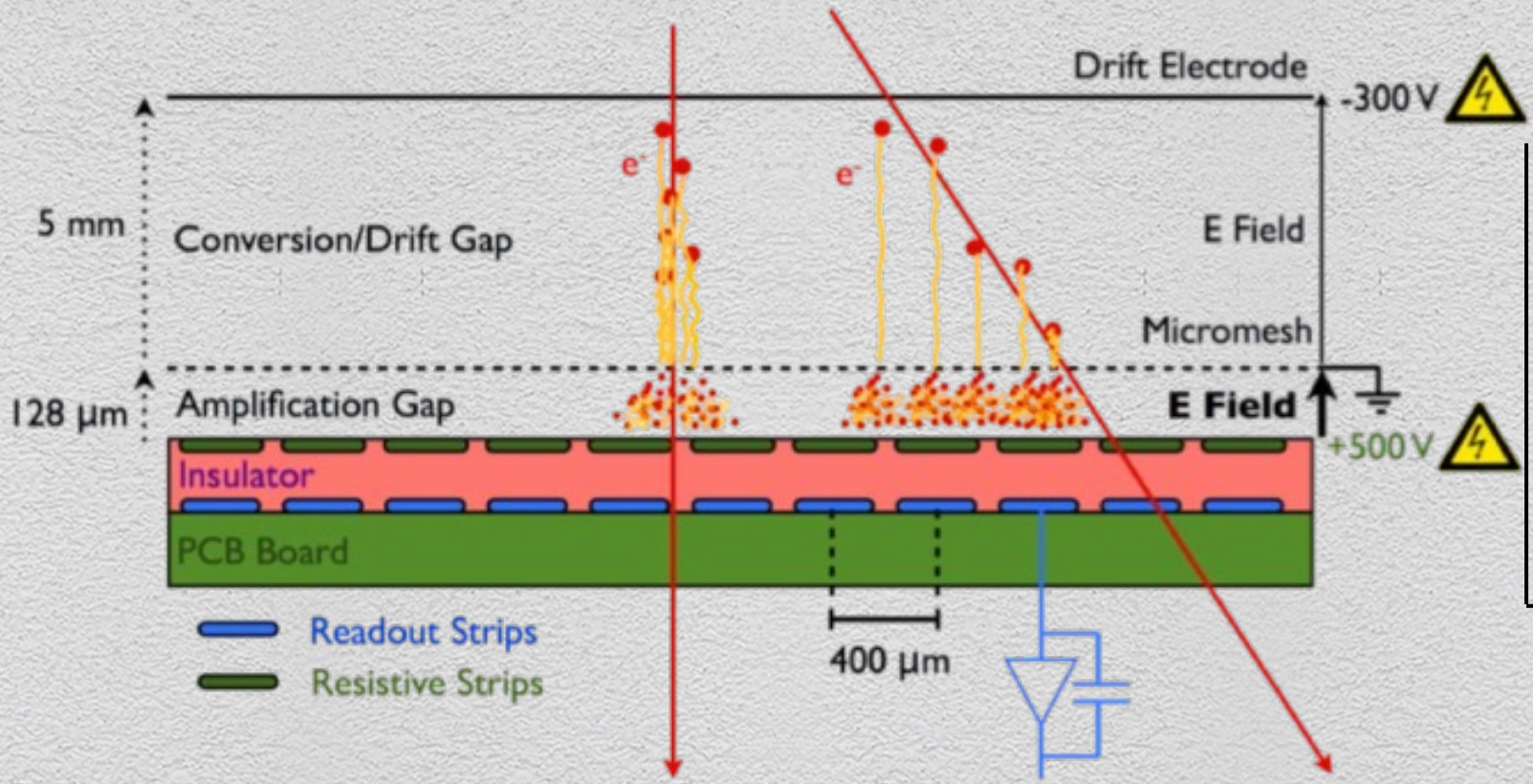
- MM :~ 2.1M
- sTGC : 280k(strip)+46k(pads)+28k(wires)=354k

MicroMegas-Structure Layout

Area closer to interaction point



MicroMegas-Readout and Trigger electronics

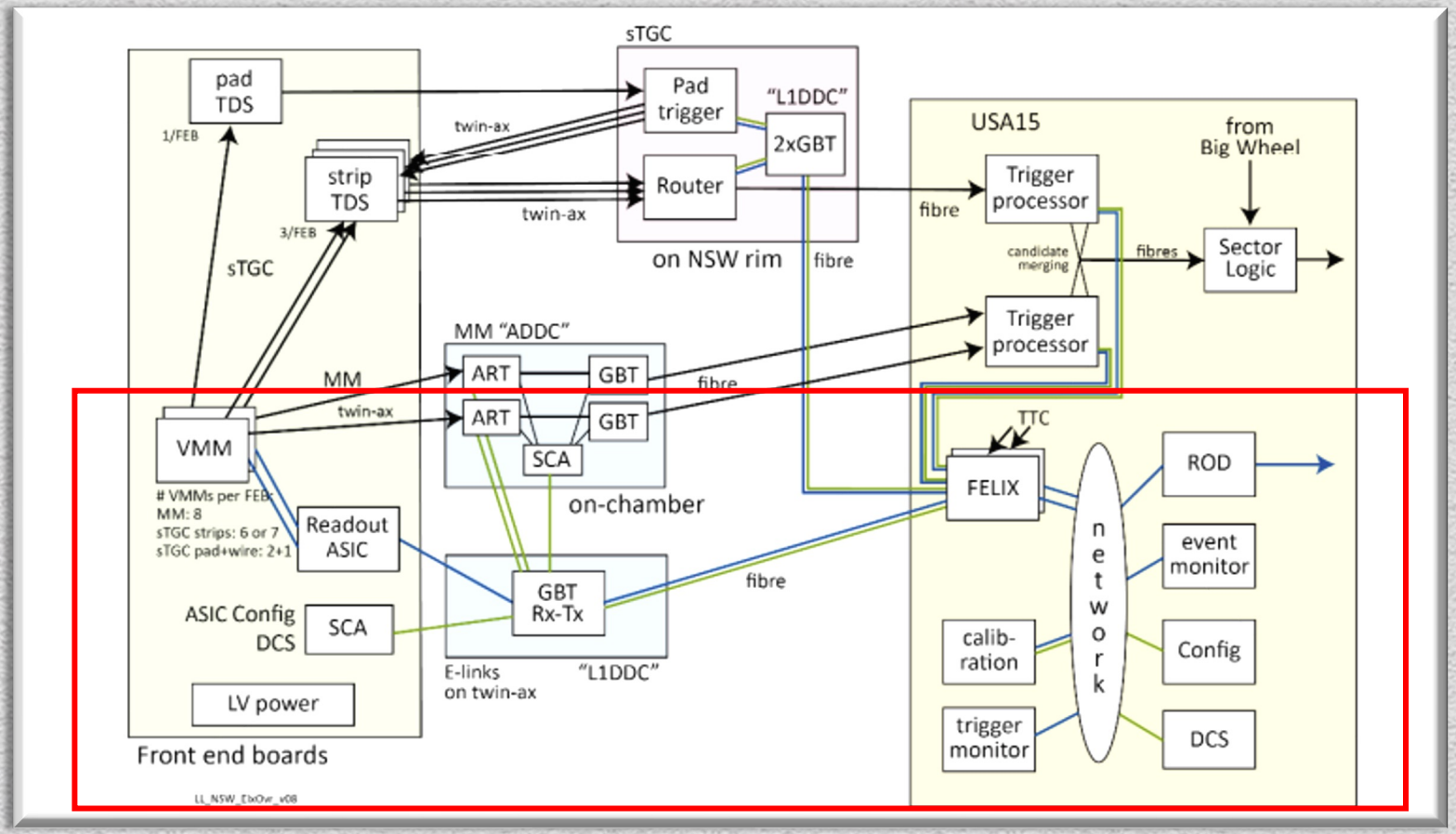


- Gap is made up of drift gap of ~ 5 mm and amplification gap of ~128 µm.
- Drift panel holds the drift electrode and mesh (glued on the mesh frame attached to drift panel).

Cluster

- set of RO strips that fired in the same event, and are consecutive in the detector

MicroMegas-Readout and Trigger electronics



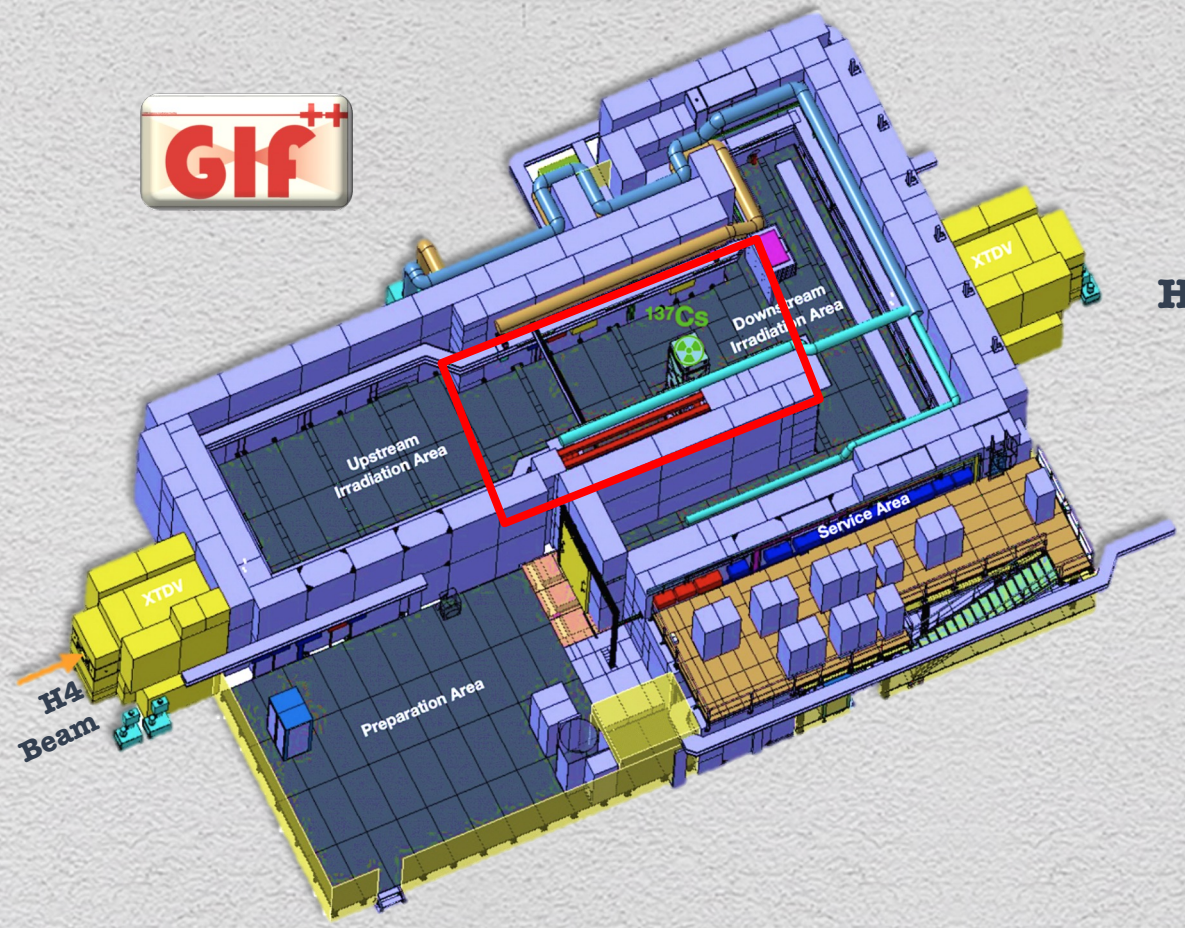
- **SCA** Slow Control Adapter
- **ASIC** Application Specific Integrated Circuit
- **GBTX** GigaBit Transceiver
- **L1DDC** Level1 Data Driver Card
- **ROD** Readout Controller
- **TTC** Timing Trigger & Control
- **FELIX** FrontEnd LInk eXchange
- **DCS** Detector Control System

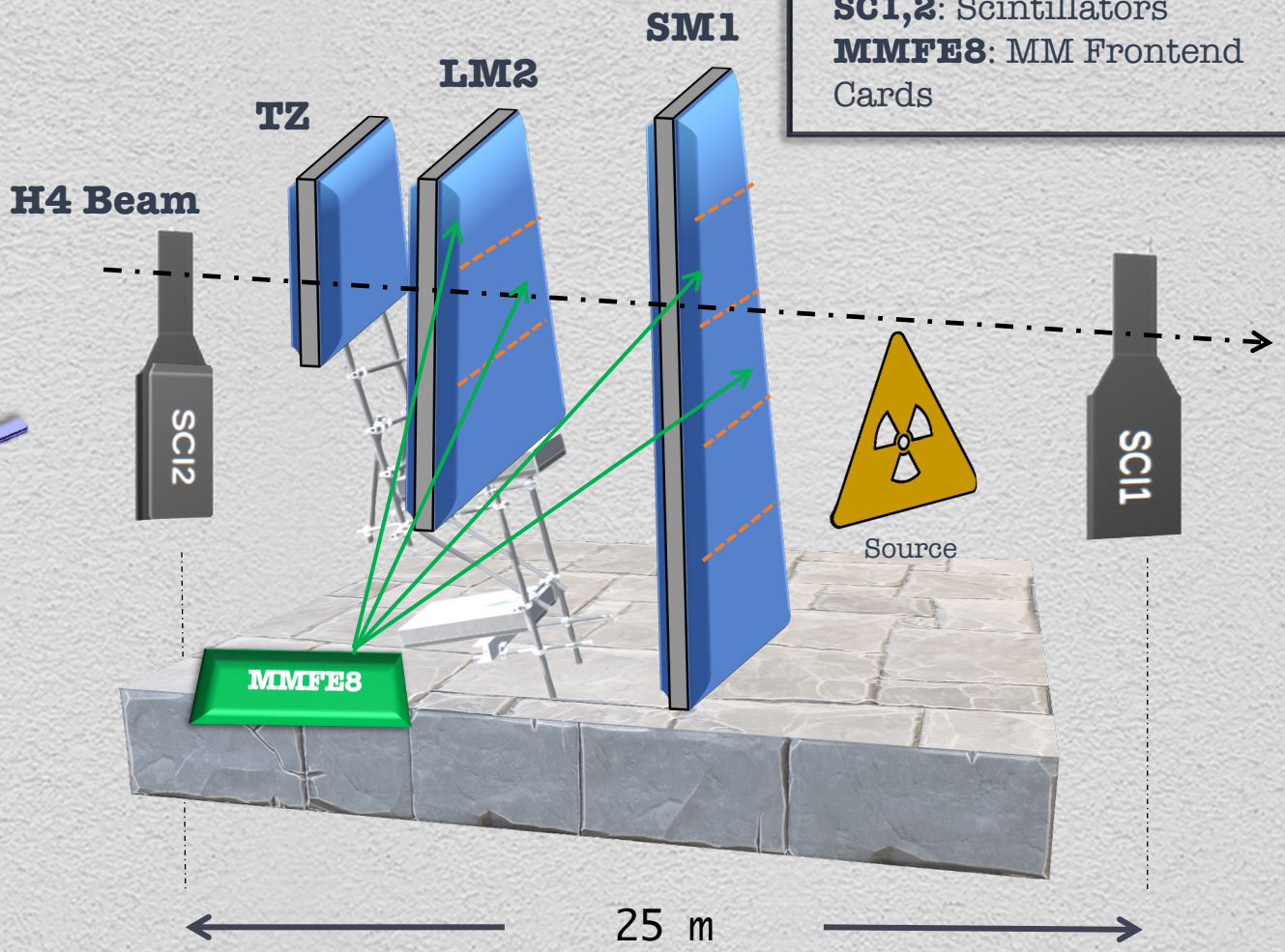
VMM CHIP

- 130 nm CMOS technology – 6 million transistors
- 64 channels per chip – each channel connects to one readout strip
- ~200 ns dead time per channel

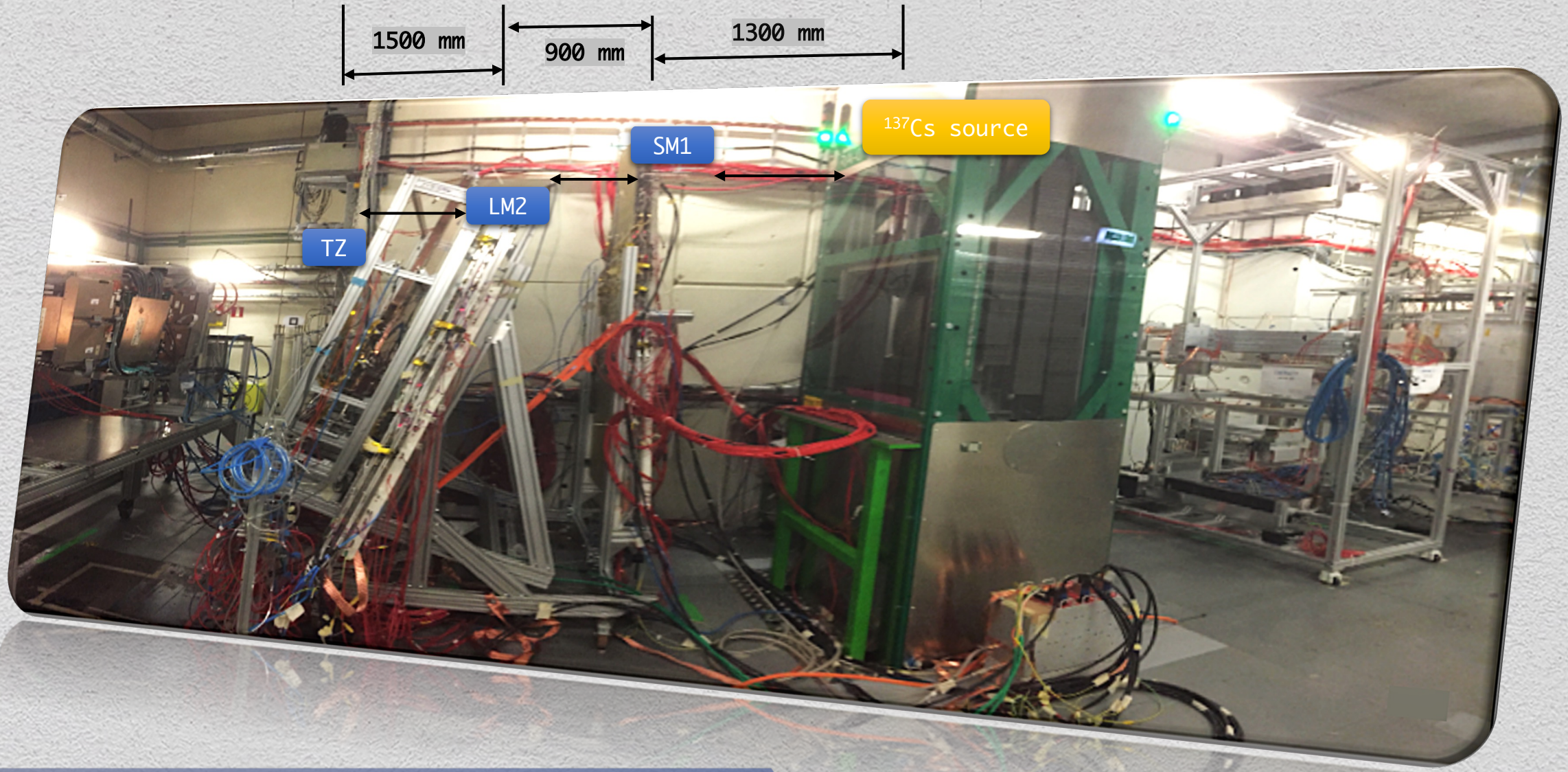
The MicroMegas tests at the GIF++

TZ: Prototype Chamber
LM2: Large sector
SM1: Small Sector
SC1,2: Scintillators
MMFE8: MM Frontend Cards



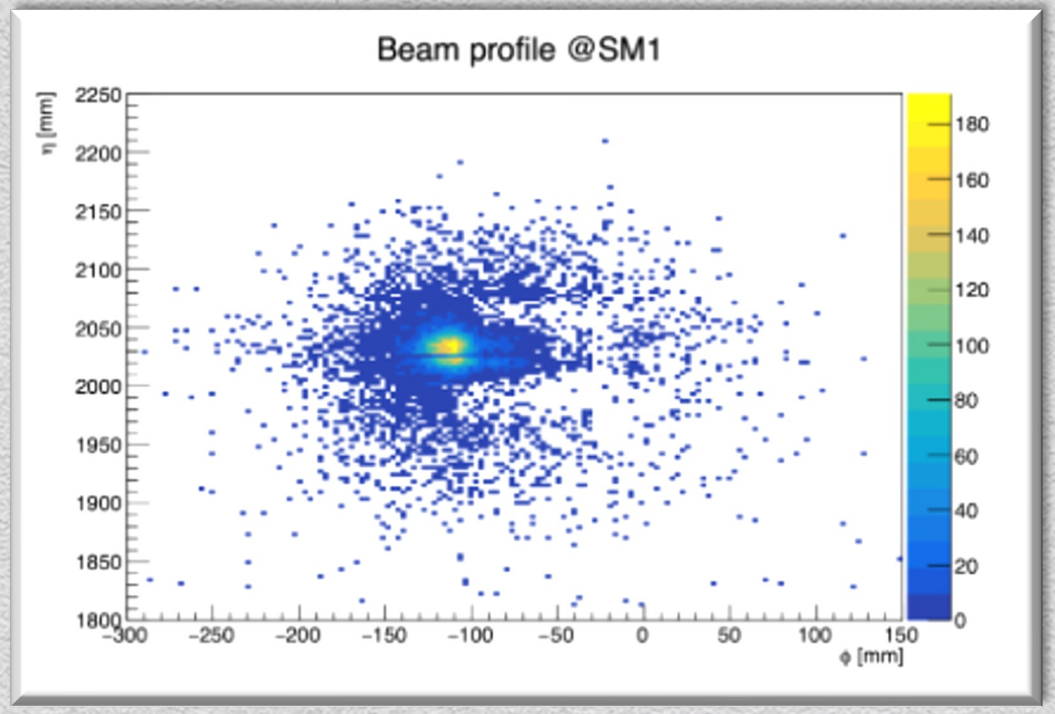


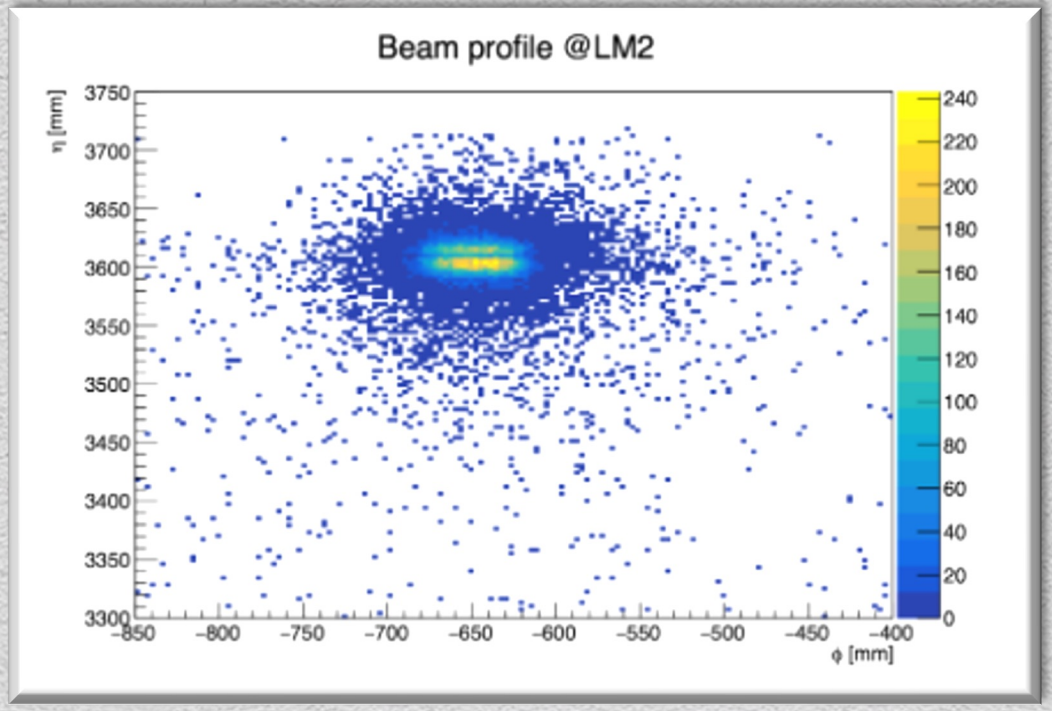
The MM tests at the GIF++ | The test bench



The MM tests at the GIF++ | Tests with muons

Source OFF Beam ON



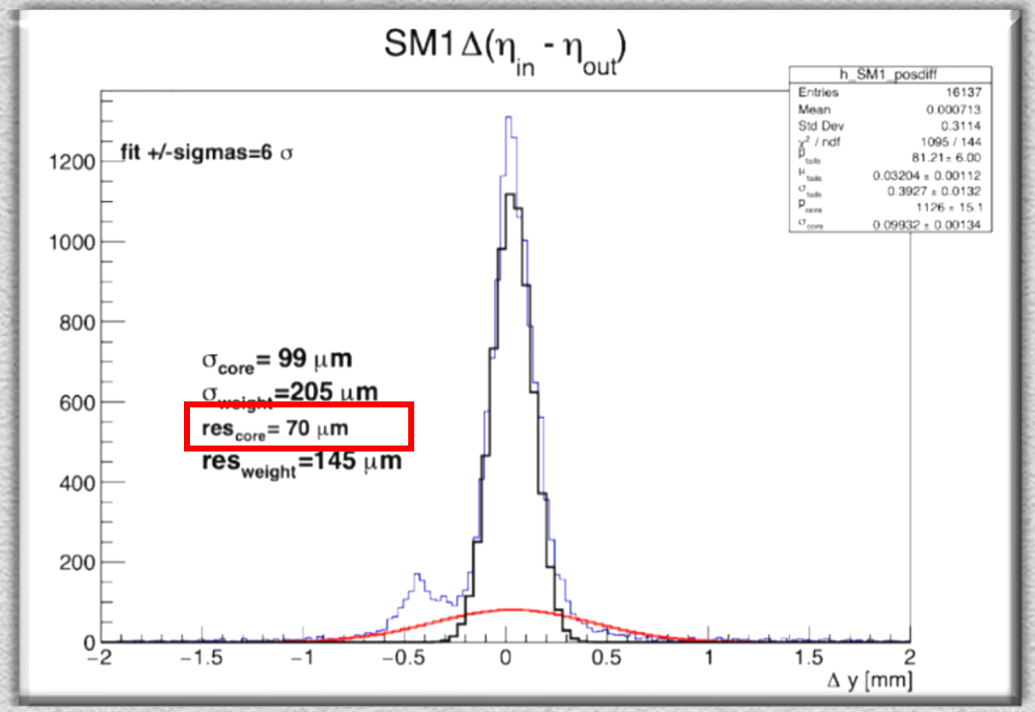


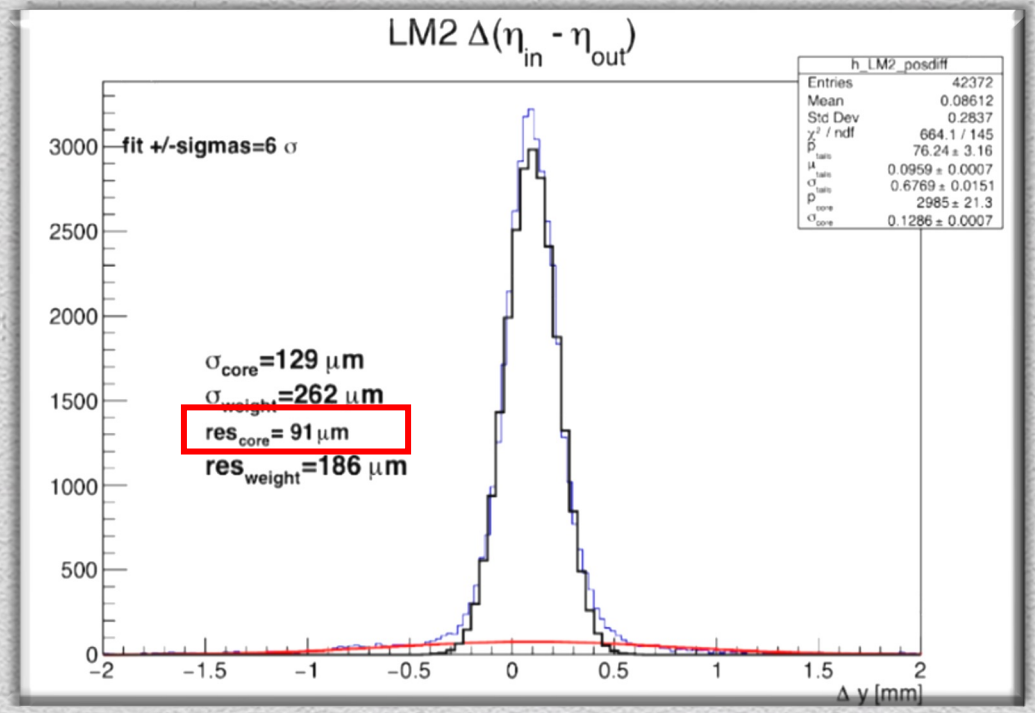
Beam Profile

- Beam profile provides clusters position
- The SM1 detects better the muon beam due to its position

The MM tests at the GIF++ | Tests with muons

Source OFF Beam ON





Spatial Resolution

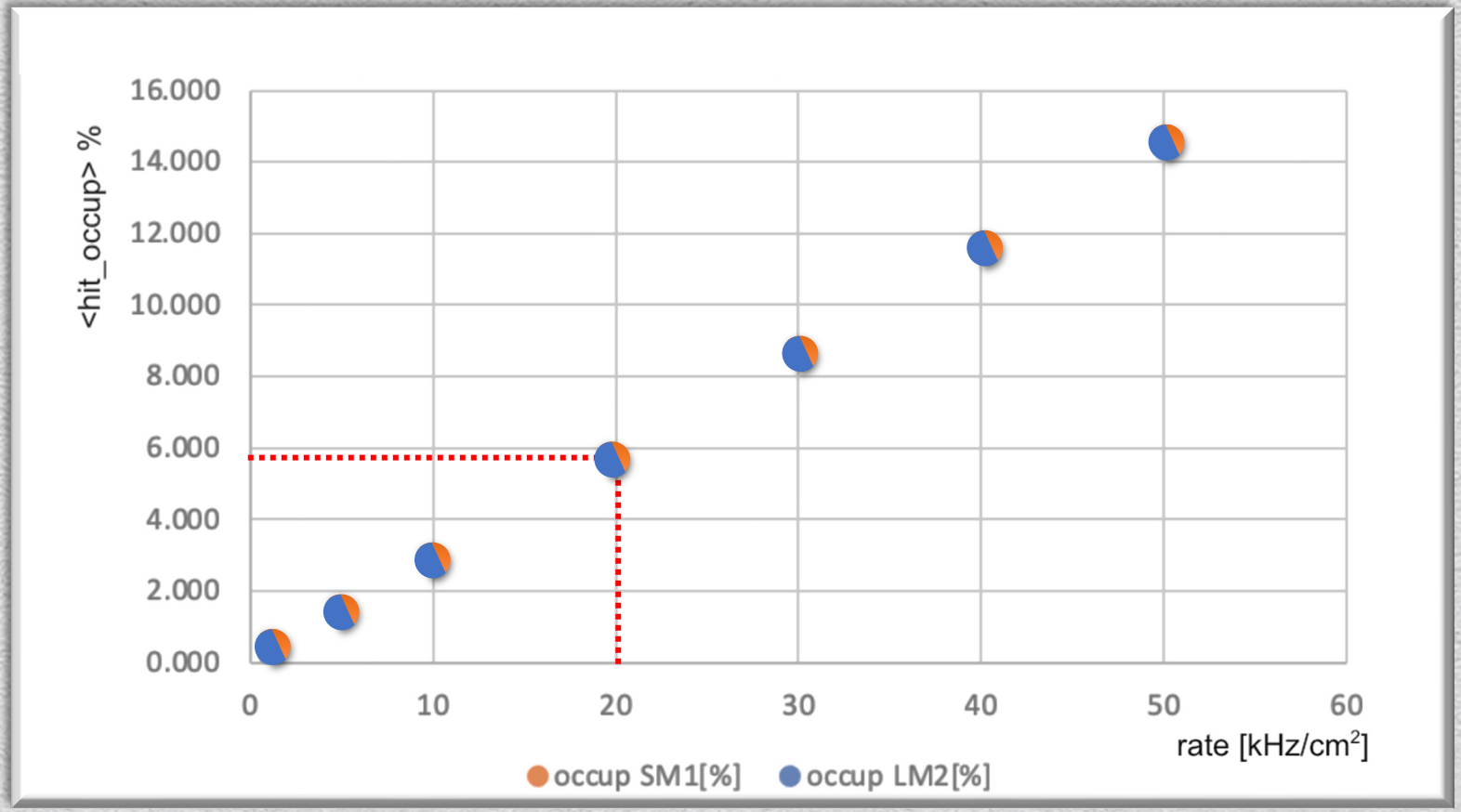
- Substract cluster coordinate of 2 eta layers
- Good Res < 100 μm

- Centroid method for cluster position

The MM tests at the GIF++ | Tests with gamma & muons

$$\text{Hit\_Occupancy} = Rate \times sectorPitch \times PCBlength \times NumberHitsPerCluster \times PeakingTime$$

- HV : 520 V
- GAS: ISO (iC4H10)
- GAIN: 9mV/fC
- PEAKING TIME: 200ns



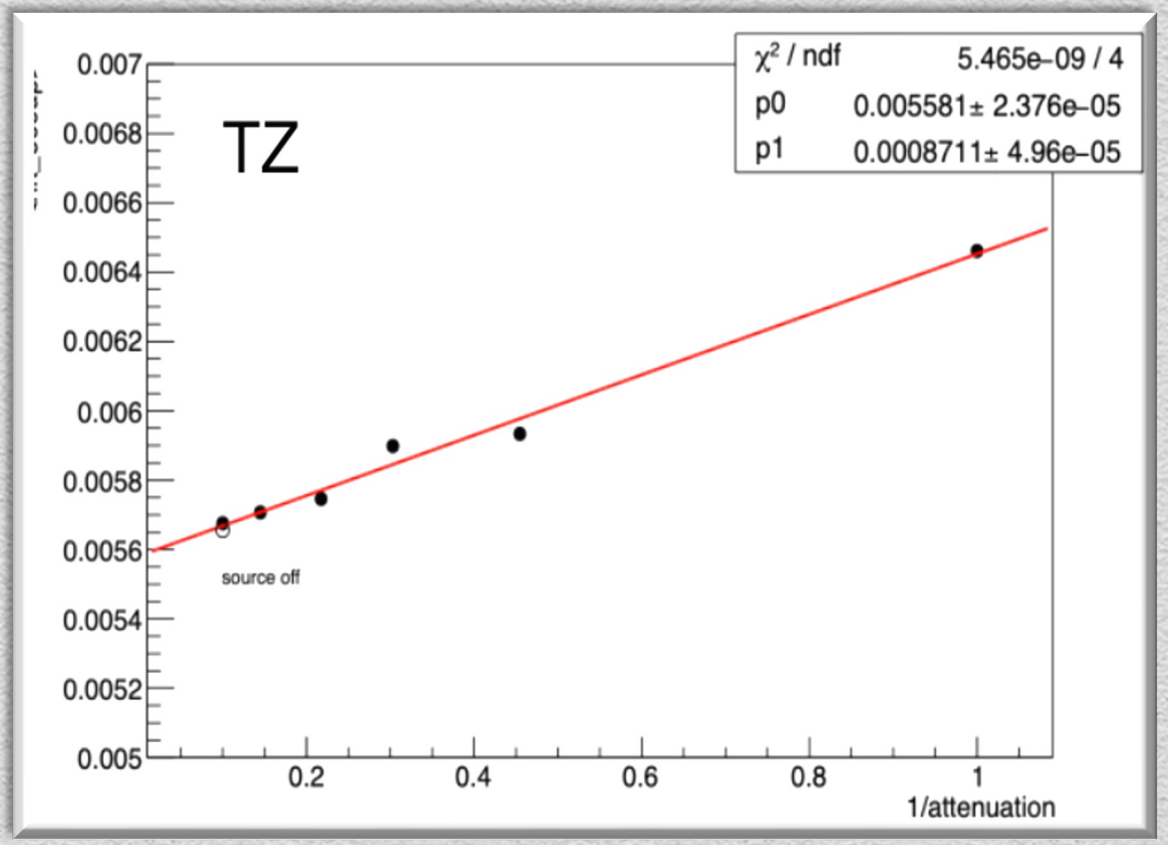
Theoretical Expected Occupancy Vs Rate

- 20 $\frac{kHz}{cm^2}$: measured rate
- $0.0425cm$: SM1 pitch
- $68cm$: length of pcb(SM1)
- 5 $\frac{hits}{cluster}$:hits per cluster
- $200ns$:peaking time

- Hit Occupancy= **0.058**

The MM tests at the GIF++ | Tests with gamma & muons

Source ON Beam ON



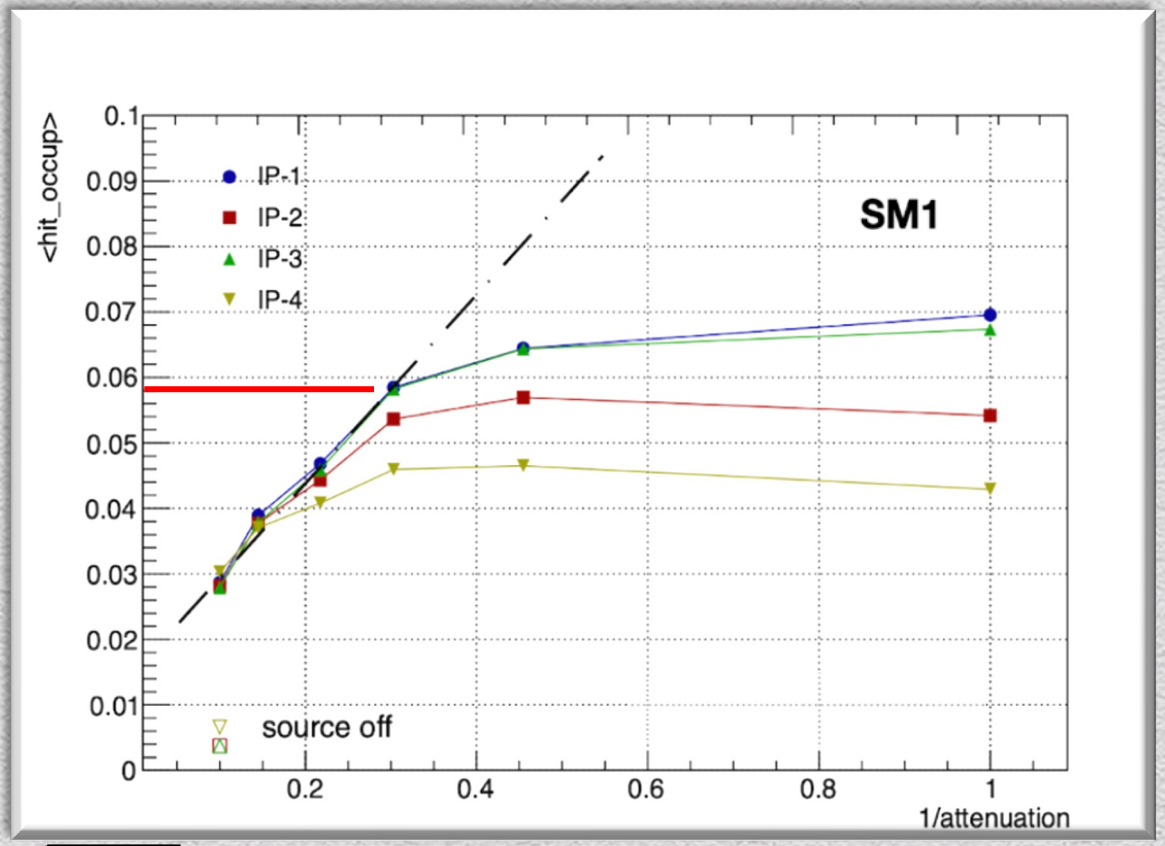
TZ Chamber

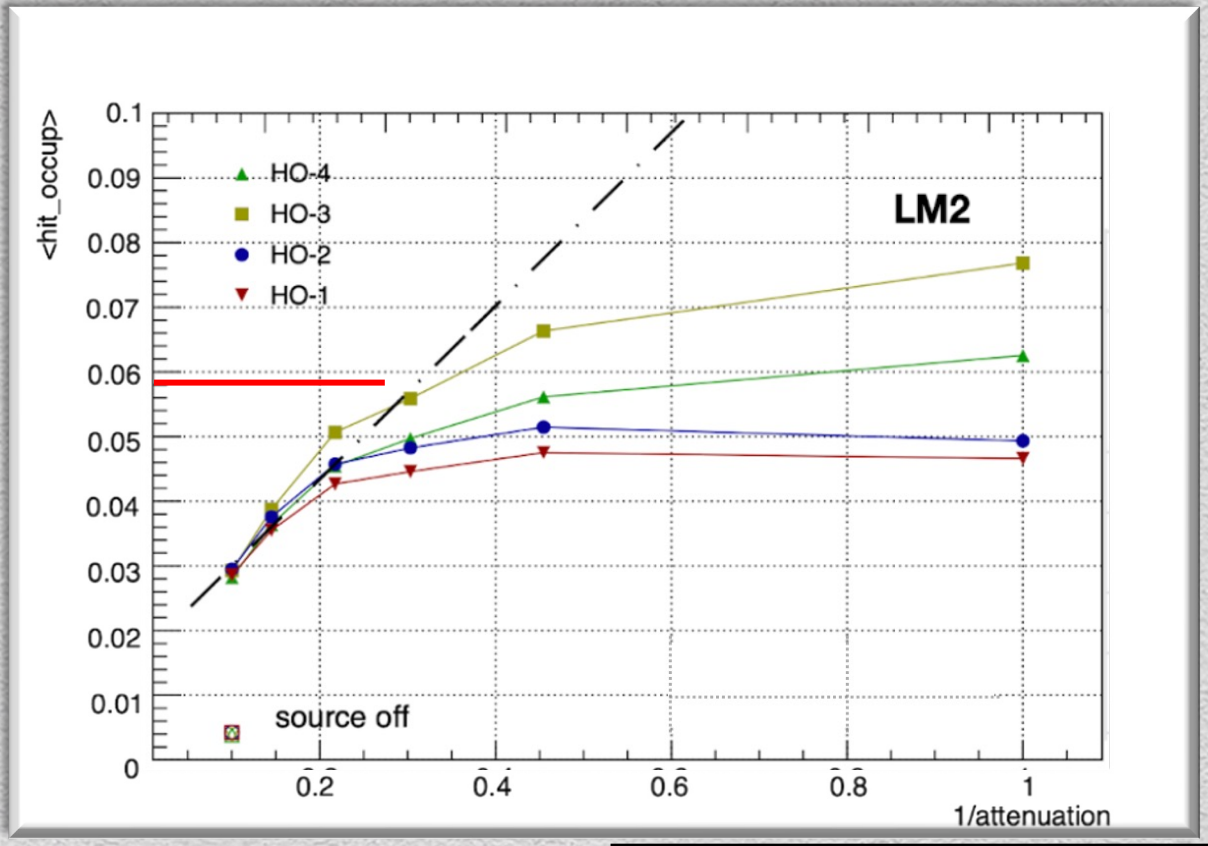
- Small prototype
- One layer, read- out by one board connected to 256 strips
- Active area 10 x 10 cm^2,
- Small capacitance

- TZ used only for reference
- Ideal linearity behavior

The MM tests at the GIF++ | Tests with gamma & muons

Source ON Beam ON

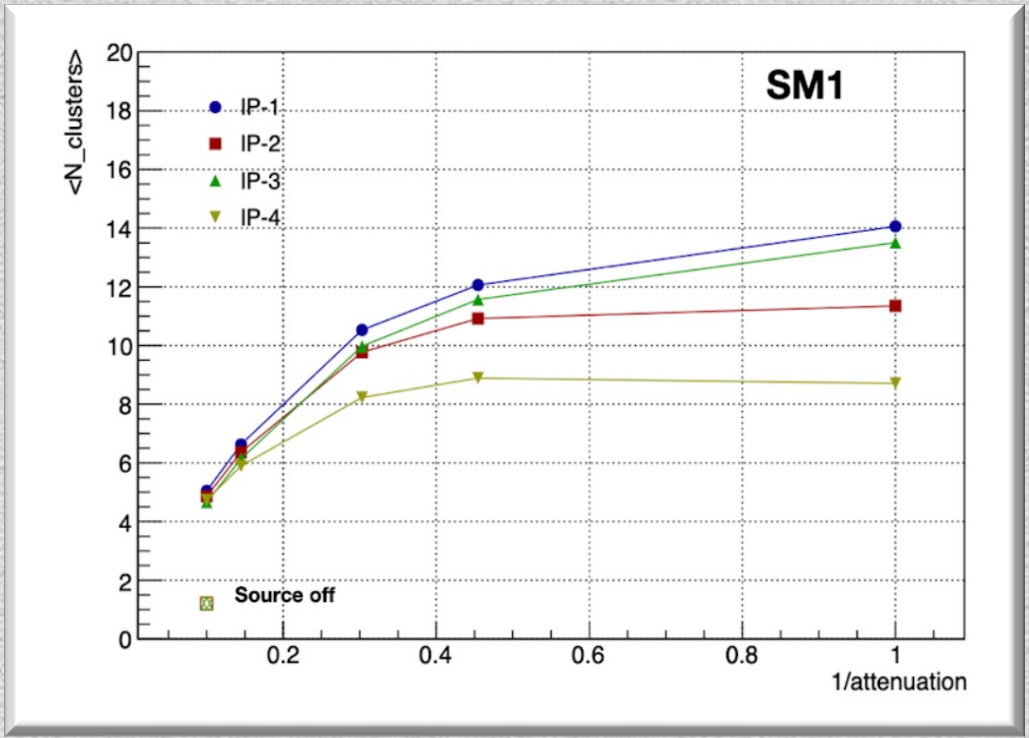


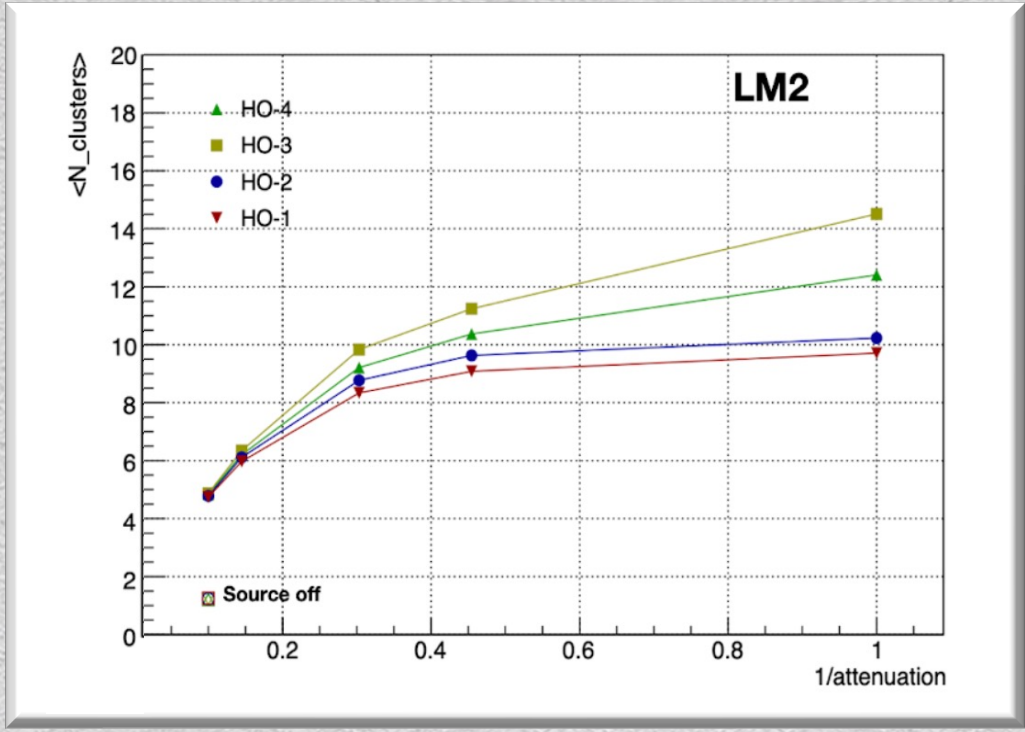


- Linearity up to ~20 kHz
- Layer differences are due to VMM thresholds and layer position

The MM tests at the GIF++ | Tests with gamma & muons

Source ON Beam ON

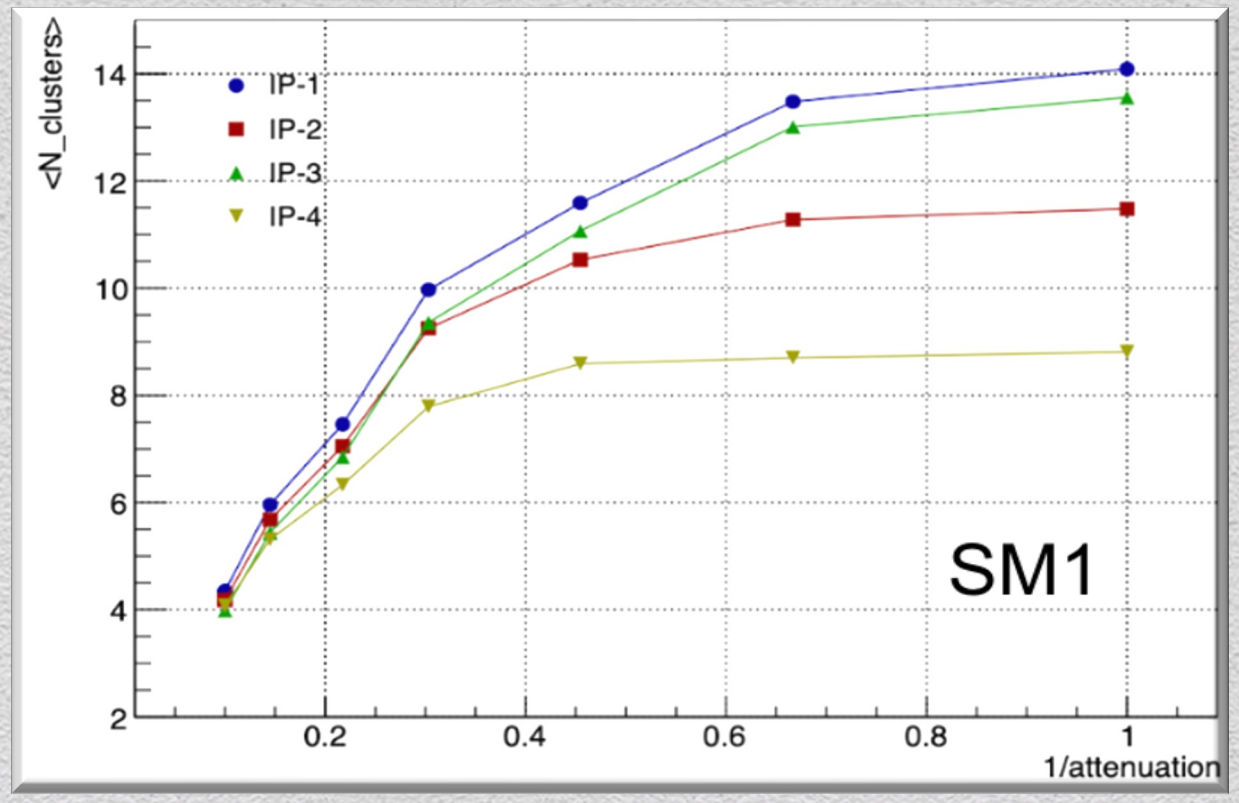


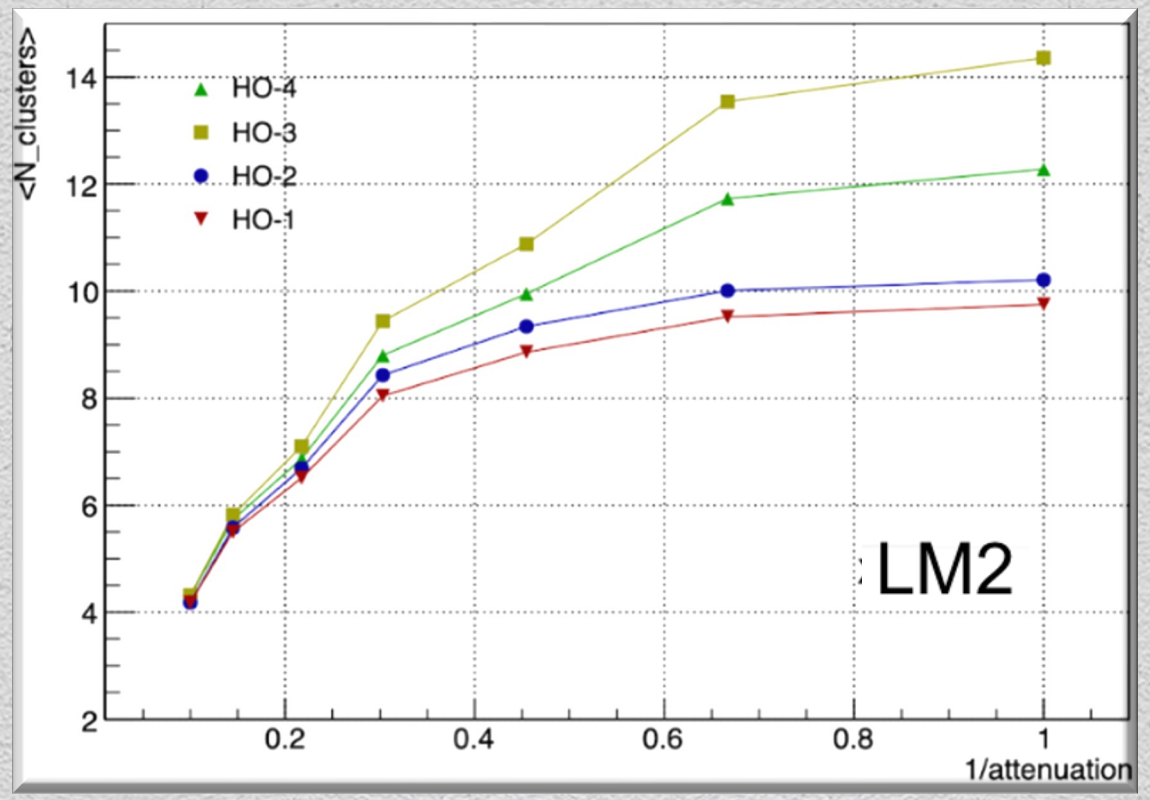


- Number of clusters presents linearity similar to hits occupancy for all layers
- Saturation after 20 kHz

The MM tests at the GIF++ | Tests with gamma

Source ON Beam OFF



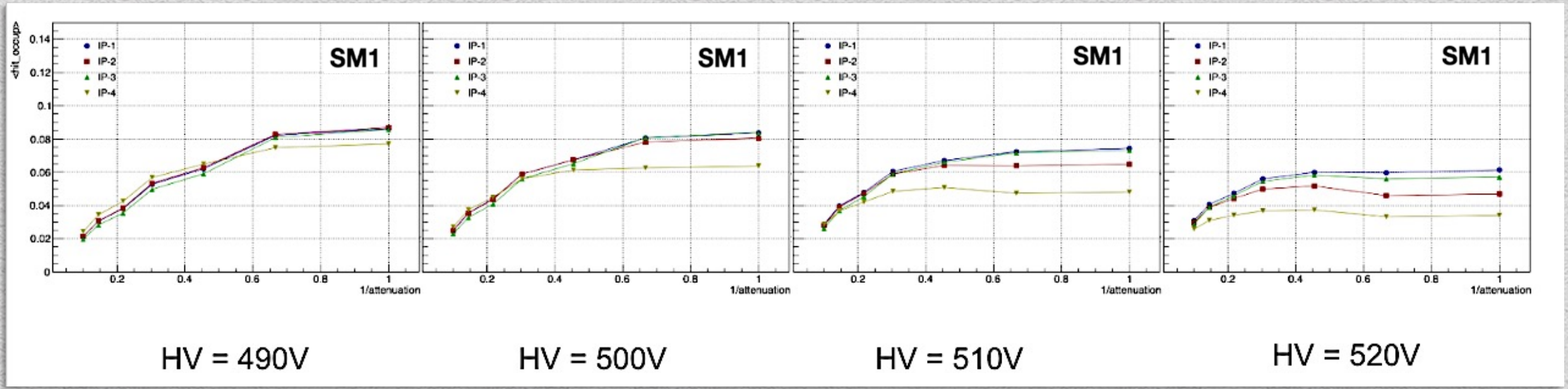


- No muons beam
- Random trigger ~500Hz
- The number of clusters increases as the background of the source becomes more intense

The MM tests at the GIF++ | Tests with gamma

Source ON Beam OFF

HV scan



- No muons beam
- Random trigger ~500Hz
- Higher HV value, lower hit occupancy
- Binds charge due to the geometry of the chamber

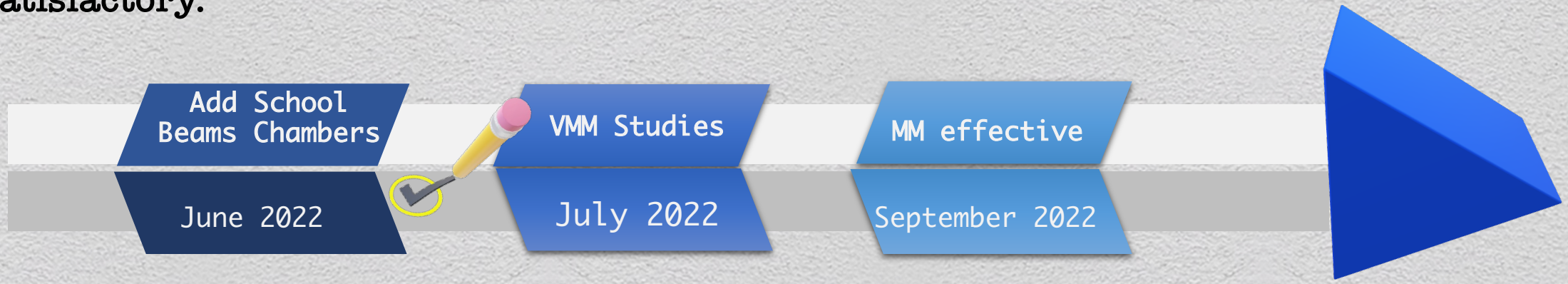
Conclusions- Discussions

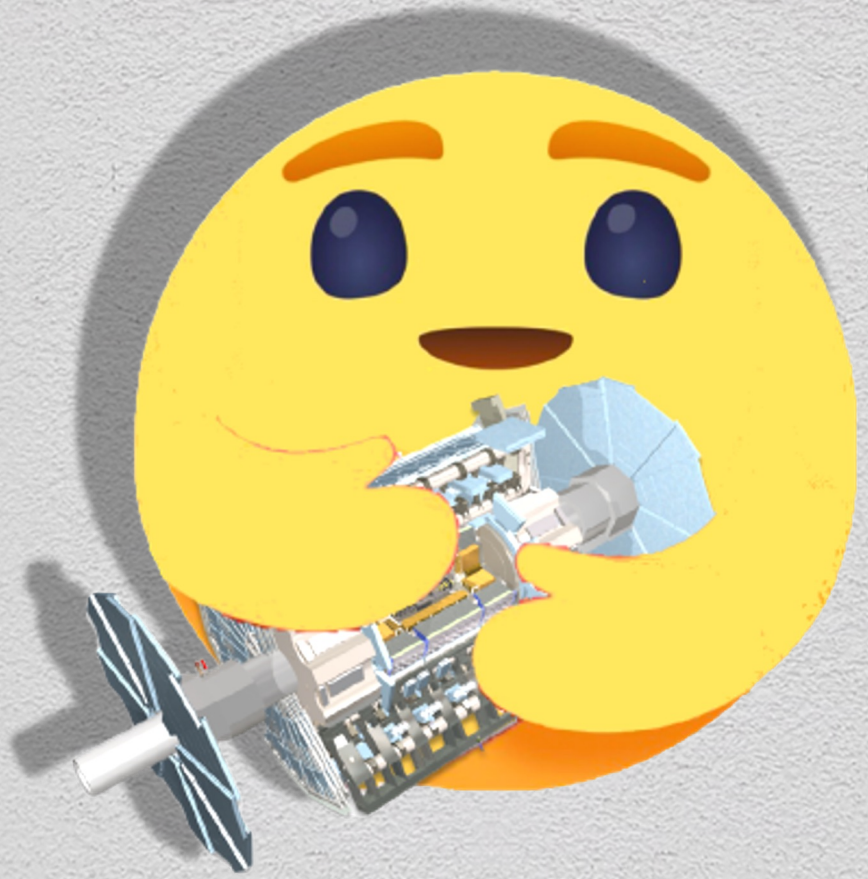
- The linearity of the entire detector chain including electronics in a high radiation environment has been studied.

- GIF++ : high energy beam of muons (80-150 GeV) combined with background
  - ☢ ^{137}CS 662 keV Gammas - 14 TBq

- By changing the VMM parameters, HV, gas and turning ON/OFF the muons beam or the source we have studied at high adjustable gamma rates
  - the hits occupancy,
  - the number of clusters
  - the clusters' multiplicity

- **Up to rate 10 times higher than phase 1 (~ 22 kHz) the performance of the detector is satisfactory.**

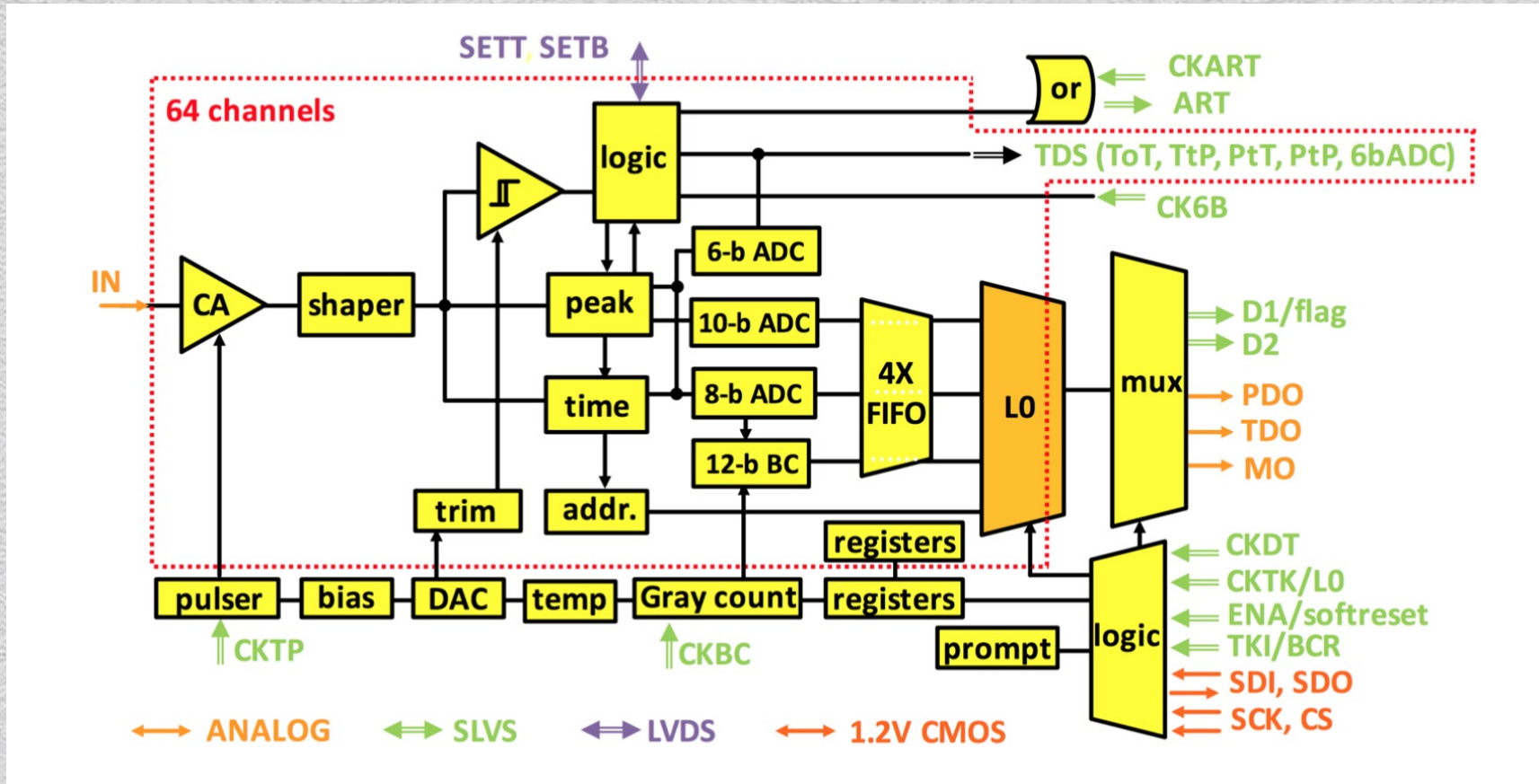




THANKS

Spare Slides

VMM Architecture



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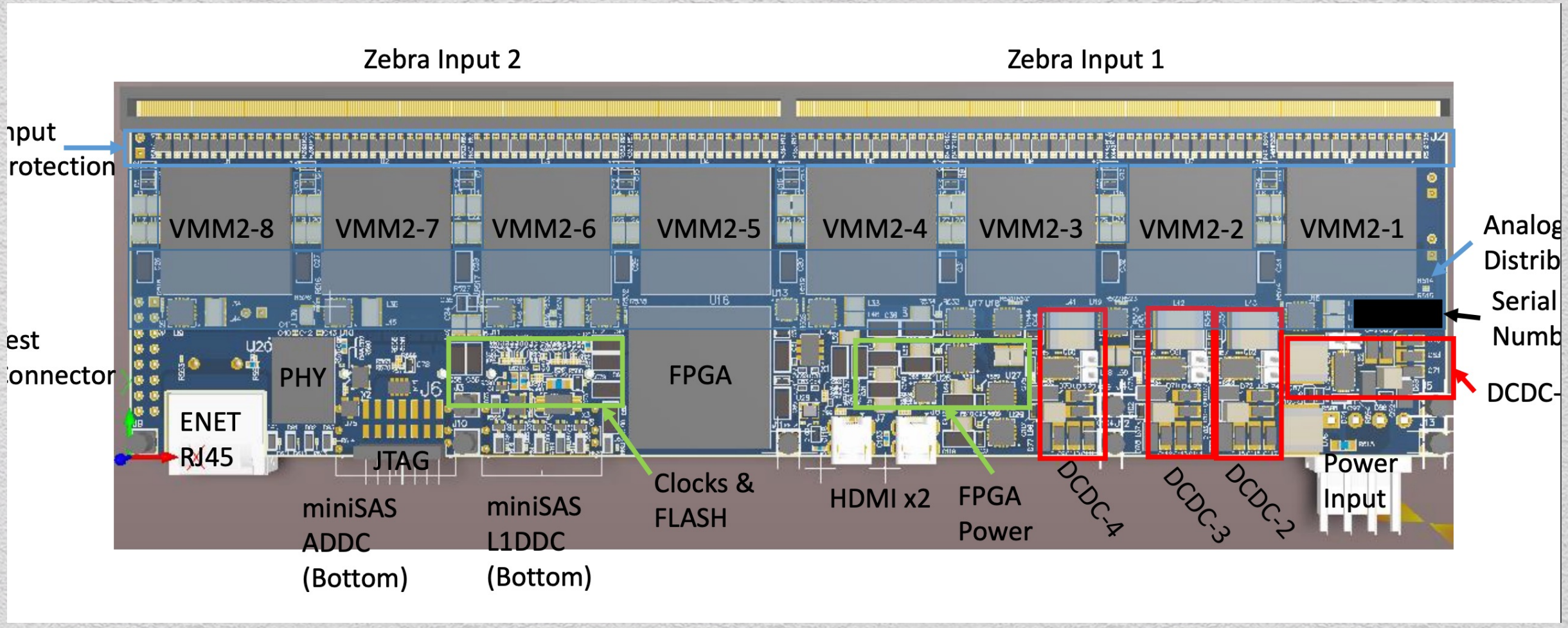
MMFE-8 Demonstrator Placement – 3D - Top



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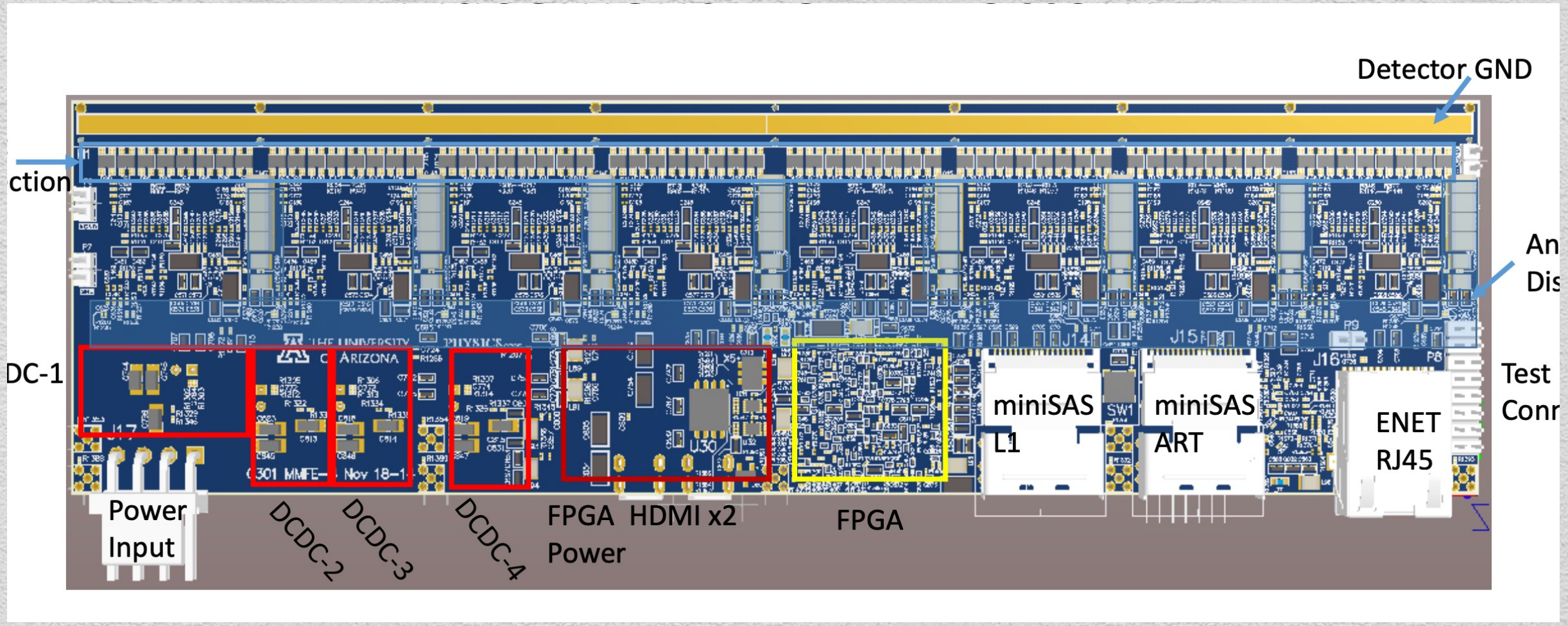
MMFE-8 Demonstrator Placement – 3D - Bottom



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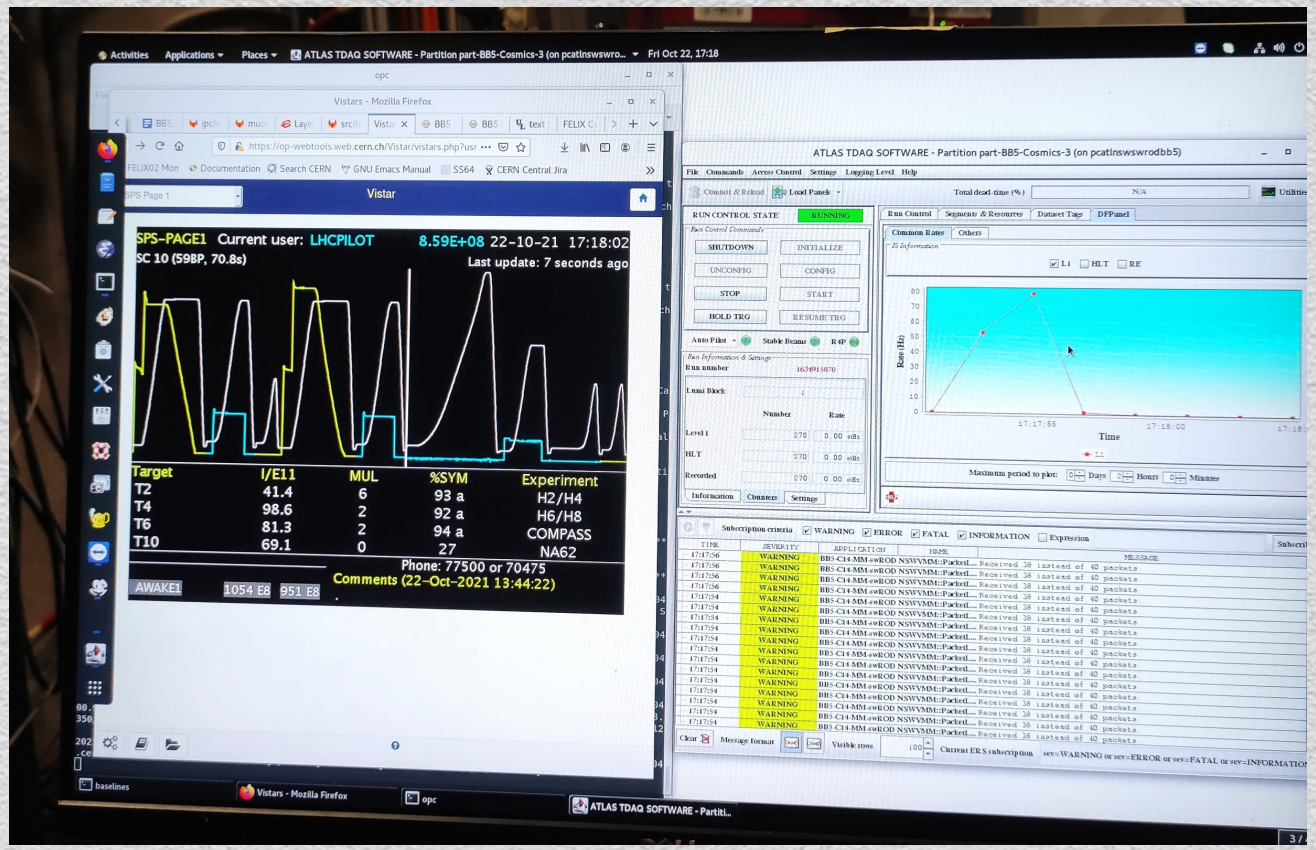

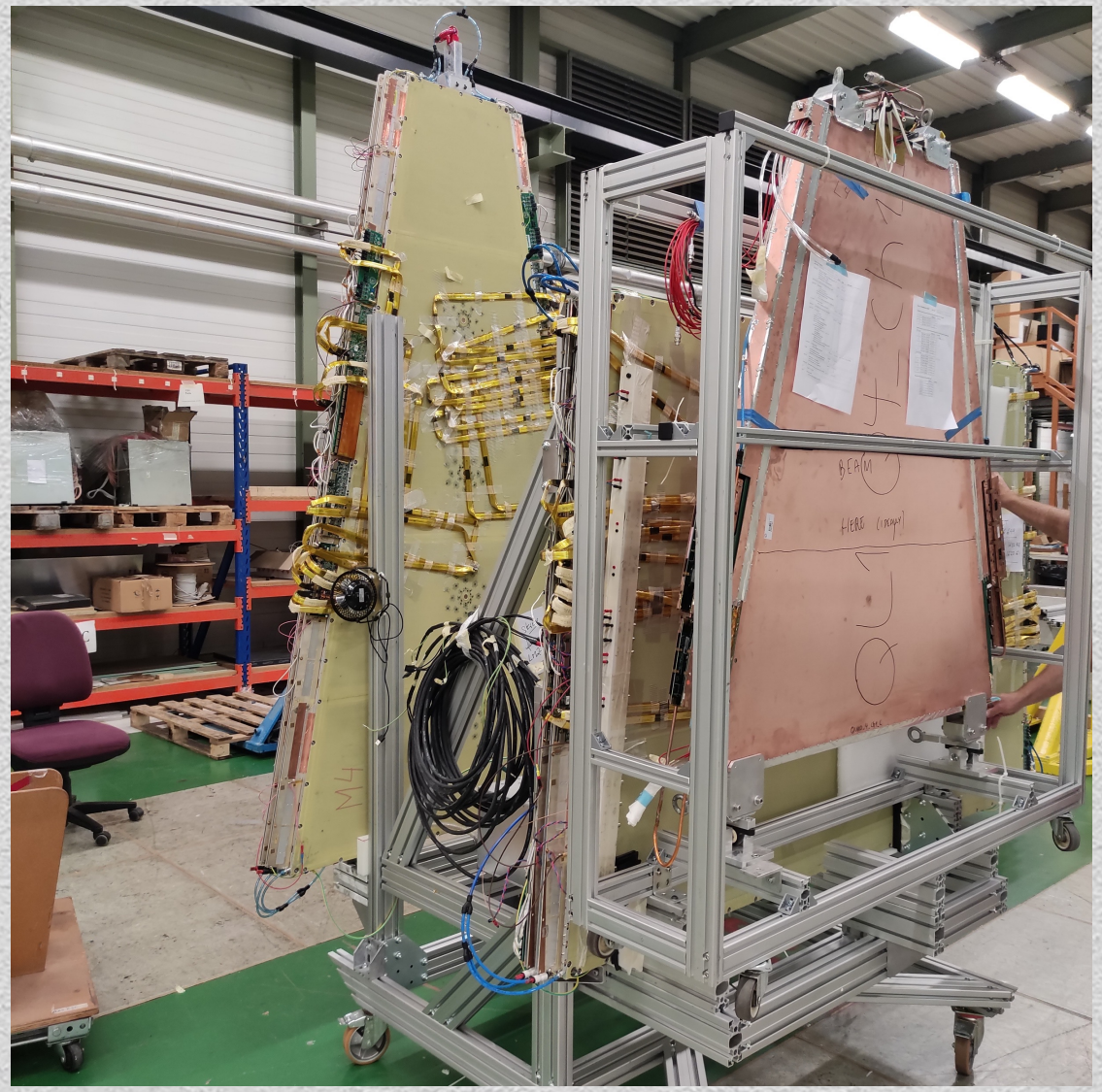

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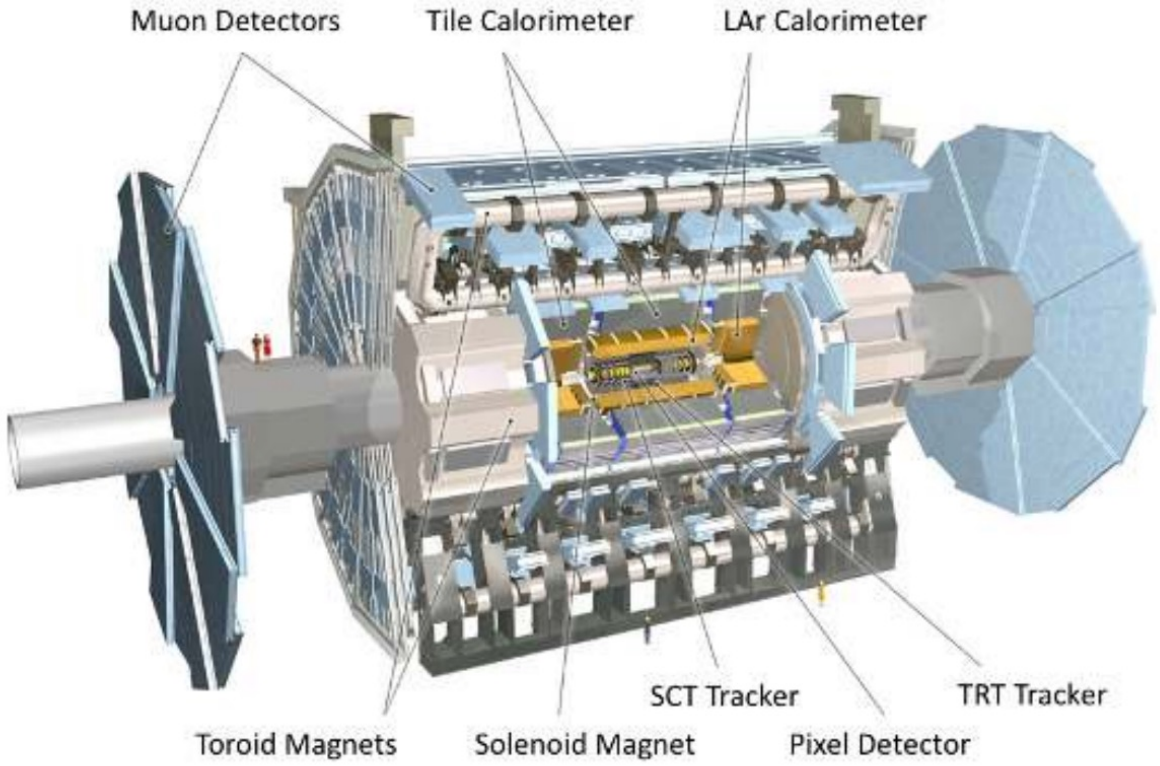
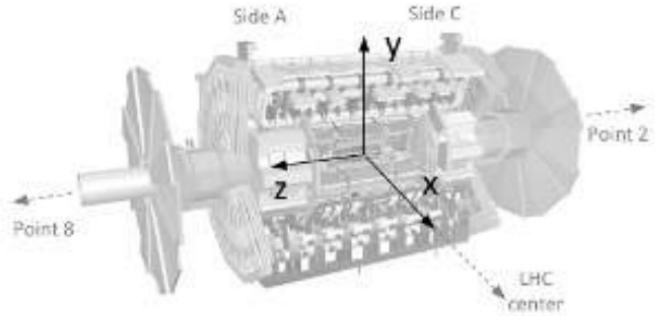
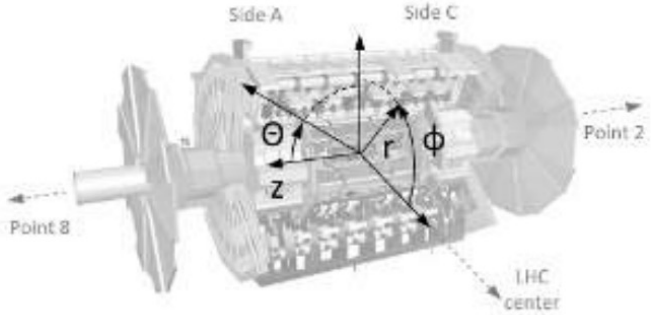
$$\eta = -\ln\left(\tan\left(\frac{\Theta}{2}\right)\right)$$





x-y-z right-handed Cartesian coordinate system



r-ϕ-z cylindrical coordinates and **Θ** - visualization