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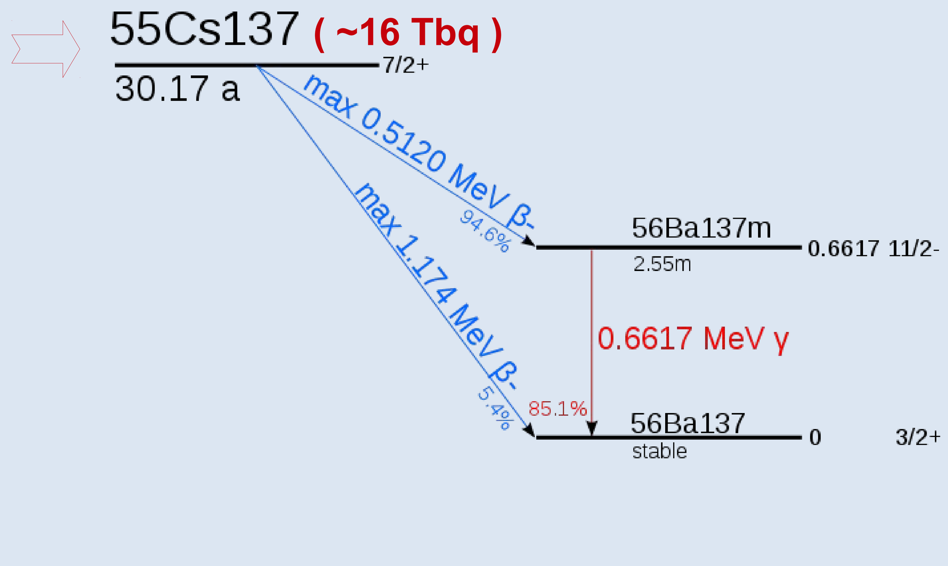
Performance studies under high irradiation and ageing properties of resistive bulk micromegas chambers at the CERN Gamma Irradiation Facility

Resistive bulk micromegas chambers, produced at CERN, have been installed at the new CERN Gamma Irradiation Facility (GIF++) in order to study the ageing effects on the detector performance and evaluate their behaviour under high irradiation. The chambers have an active area of 10 x 10 cm^2, strip pitch of 400 μm and amplification gap of 128 μm.

We present the detector performance as a function of the photon flux up to 64 MHz/cm^2 [1].

Gamma Irradiation Facility (GIF++) at CERN

A dedicated irradiation facility with photon energy of ~662 KeV and flux up to 10^8 cm^{-2}s^{-1} [1]:



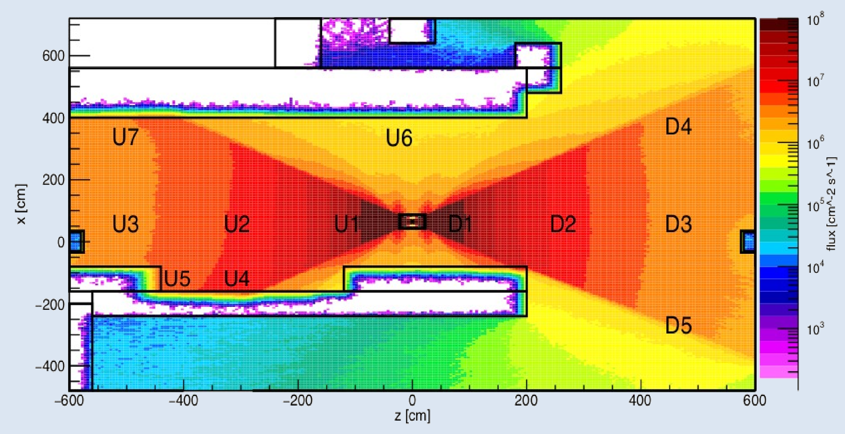
100 GeV muon

- 10^4 muons/spill
- core beam size 10 x 10 cm^2

Filter system permits attenuating the photon flux in several steps to reach attenuation factors of several orders of magnitude (~1 - 10^5)

Allows to study effects induced by photon radiation:

- Detector occupancy due to instantaneous particle rate
  - Detector efficiency
- Cumulative effects → ageing
  - Integrated particle influence, dose and current in the detector
  - Detector performance vs accumulated charge
- Rate capability
- Sensitivity to photon radiation
- Detector performance with gas circulation system
  - Pollutants in gas mixtures
  - Gas chromatography



Total flux simulated with source fully opened [1]

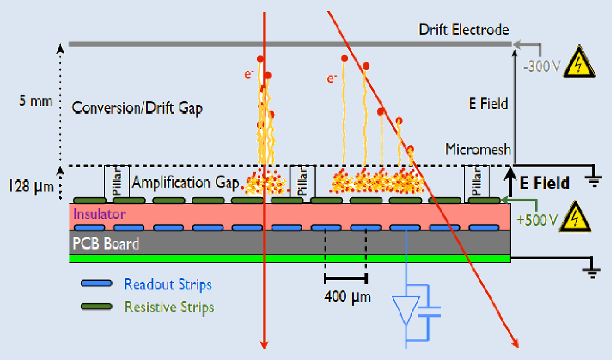
Source placed in the middle of the bunker creating 2 different radiation zones upstream (indicated by U) and downstream (indicated by D)

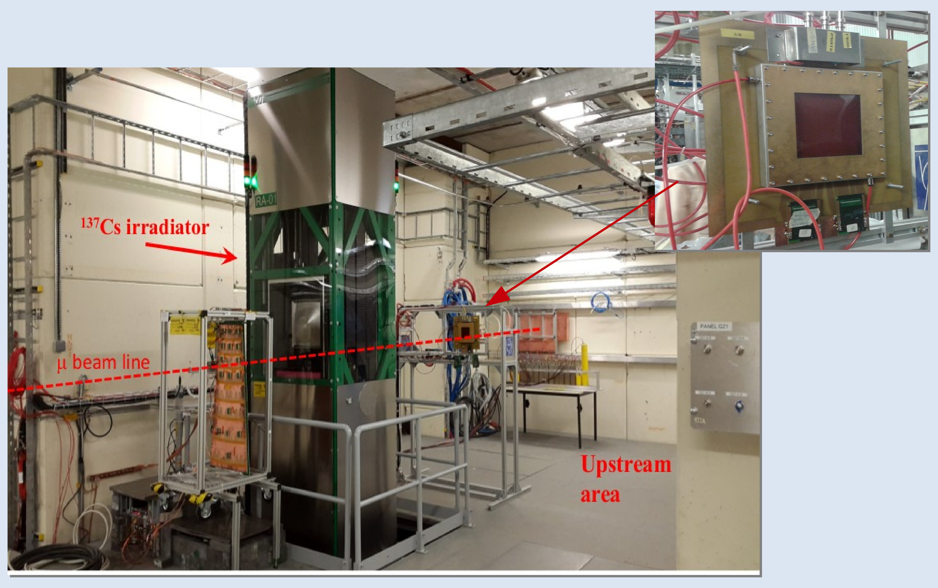
Resistive Bulk Micromegas

Planar structure consisting of two asymmetric E-field regions, separated by a thin metallic micro mesh

- *E_{drift} ≈ 0.6 kV/cm*
- *E_{amp} ≈ 39 kV/cm ⇒ Gas gain ~10^4 (for Ar + 7% CO_2)*

Readout strips covered with a 50 μm thick Kapton foil carrying high resistivity (~ 1 MΩ/sq) carbon strips to improve spark protection [3]





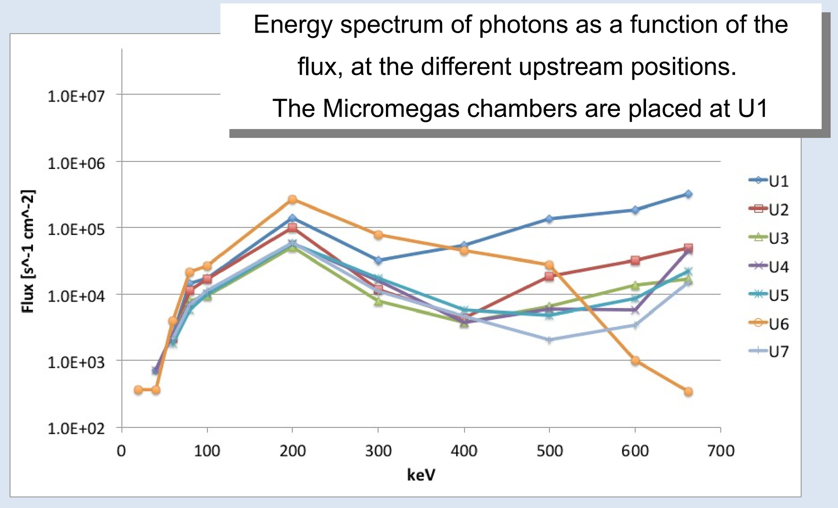
Installation at GIF++

- Two bulk Micromegas chambers 10 x 10 cm^2, operated with Ar:CO_2 (93:7), installed in the upstream position (U1) ~1 m from the source
  - *250 metallic readout strips (400 μm strip pitch, 300 μm strip width)*
  - *Mesh embedded in pillars providing the amplification gap of 128 μm*
- To avoid gas impurities, the gas line supplying the premixed gas mixture to the chambers has been equipped with a 0.5 μm filter

Energy Deposition and Spectrum in Micromegas detectors at GIF++

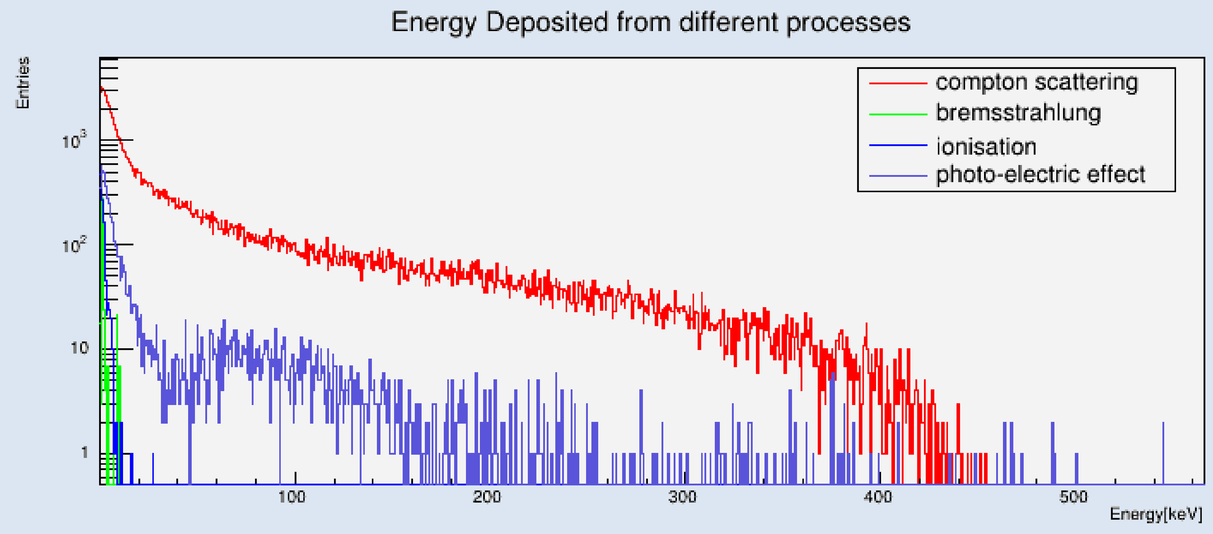
Gamma radiation ionizes via 3 processes:

- **Photoelectric effect:** dominant process for γ with energies below 50 keV
- **Compton scattering:** the principle mechanism for 0.1-10 MeV (main @ GIF++)
- **Pair production:** becomes important at energies over 5 MeV



(a) US positions DS open

Energy Deposited from different processes

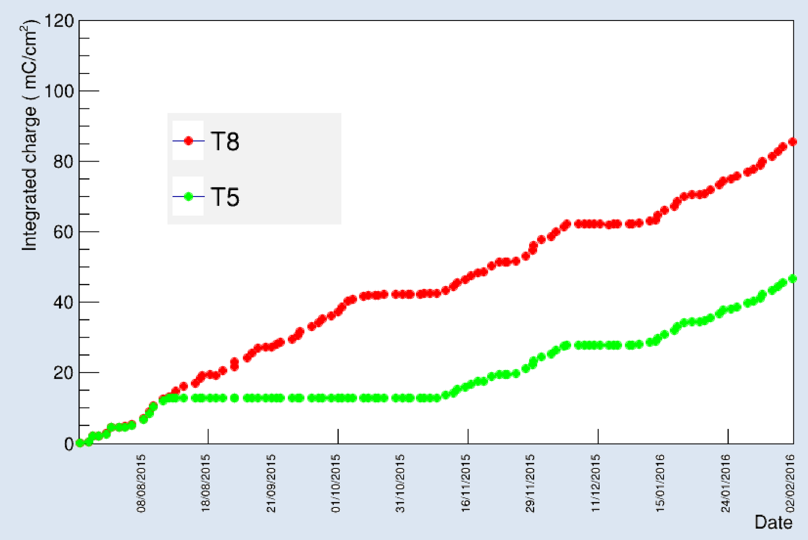


Energy deposition by different processes, in the Micromegas chambers ~1 m from the source, as described in GEANT simulation.

Studies at GIF++

Ageing studies

The aim of the ageing studies is to accumulate up to 0.2 C/cm^2, the equivalent charge expected after 10 years of sLHC operation towards the ATLAS Micromegas New Small Wheel upgrade [3]



The Detector Control System (DCS) that has been implemented stores HV, current values, source conditions (On/Off), temperature and humidity inside the bunker.

Integrated charge accumulated in 9 months

Flat periods correspond to the movement of the chambers outside the bunker for lab tests

Particle rate

The converted particle rate has been determined by comparing the observed interaction rate in the Micromegas with the incoming photon flux (known by the simulation and the activity of the source), taking into account the efficiency of the detector and the sensitivity to photons (the probability of interaction of a single photon in the chamber, estimated ~ 10^{-3}).

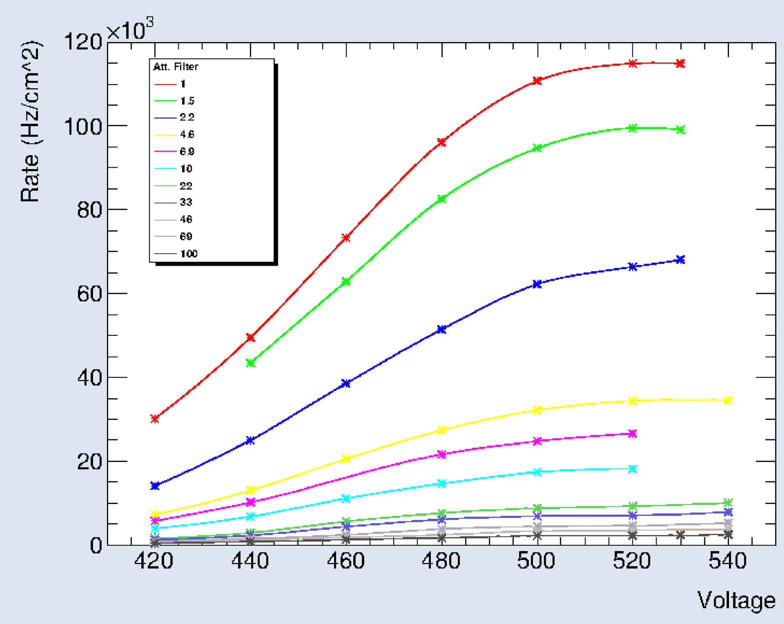
The rate has been calculated by dividing the number of observed interactions by the total acquisition time window:

$$\Delta t = N_{evt} \times N_{tb} \times 25$$

N_{evt} : number of events

N_{tb} : number of time bins

25 ns : single time bin duration of APV clock



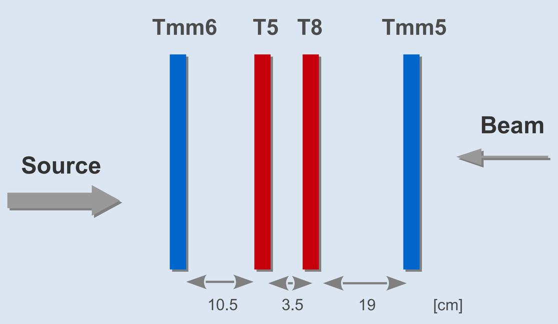
The APV-25 Front End ASICs [4] were used to record charge and time information. These chips were connected to the Front-End Card (FEC) of the RD51 Scalable Readout System [5]. The Gigabit Ethernet output of the FEC was connected to a data-acquisition computer (DAQ-PC) running a dedicated DAQ software.

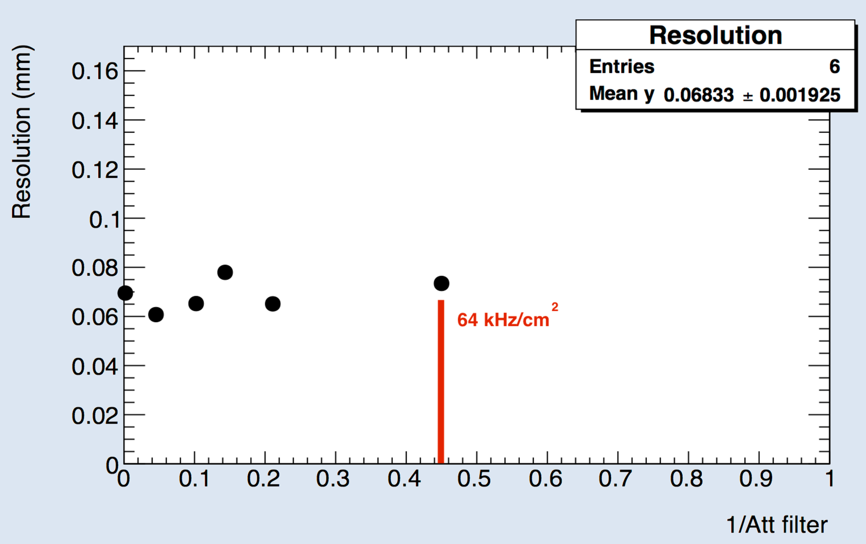
Attenuation		Rate (Hz/cm^2)		Sensitivity
nominal	measured	γ flux	measured rate	
2.2	2.2	2.91E+0.7	6.80E+0.4	2.34E-0.3
4.6	4.5	1.42E+0.7	3.40E+04	2.39E-0.3
6.9			2.60E+0.4	
10	8.8	7.27E+0.6	1.80E+0.4	2.48E-0.3
22			1.00E+0.4	
33			7.90E+0.3	
46			5.30E+0.3	
69			3.70E+0.3	
100	72	8.89E+0.5	2.50E+0.3	2.81E-0.3

- The sensitivity values suggest that there is a slight dependence of the interaction probability with rate. For very high rates (~3x10^7 Hz/cm^2) the Micromegas 'see' 10–20% fewer interactions than they should. This may be a S/W effect (at very high rate muon signals are no longer properly separated) or an efficiency drop.

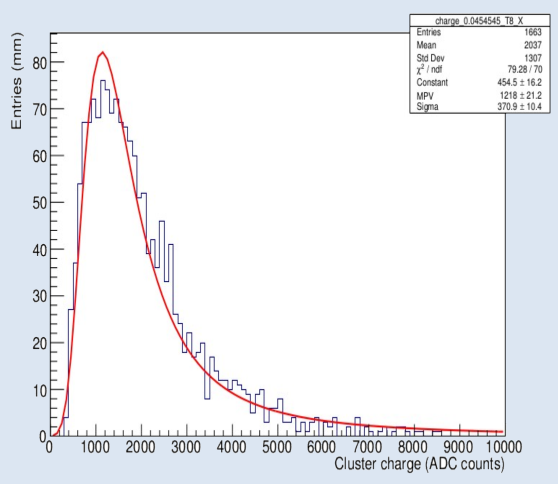
Tracking with muon beam

The performance of the Micromegas detectors after 6 months of irradiation has been studied by combining the high rate photon flux (tuned with different attenuation filters) with muon beam. The Hough transformation has been implemented in order to distinguish muon tracks from photons

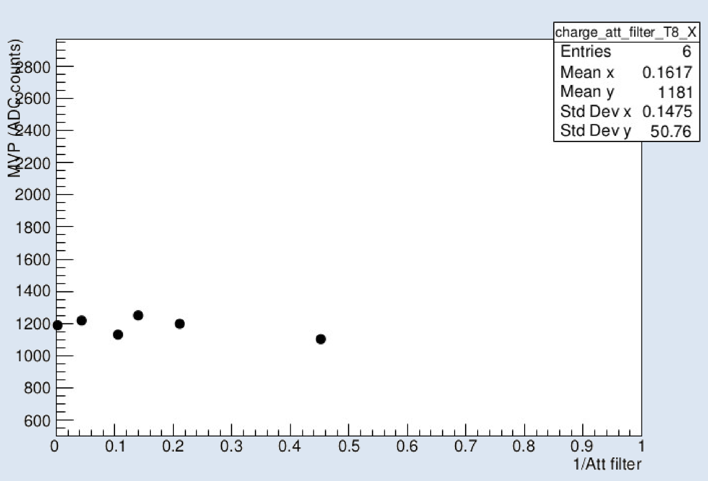




The resolution of the resistive bulk chambers as a function of the 64 kHz/cm^2 (~4 times more than expected rate in the NSW region during sLHC operation)



Muon signal distribution with attenuation factor 200



Muon signal distribution as a function of different attenuation factors

Conclusions / Plans

- Detector ageing effects in terms of currents, efficiency and noise stability as a function of the integrated charge are evaluated in the GIF++ facility.
- After 9 months of irradiation no degradation of the detectors performance was observed.
- The chambers will remain until the accumulated charge reach ~0.2 C/cm^2 (10 years of sLHC operations).

References

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