The Muon Portal Project: design and construction of a scanning portal based on muon tomography

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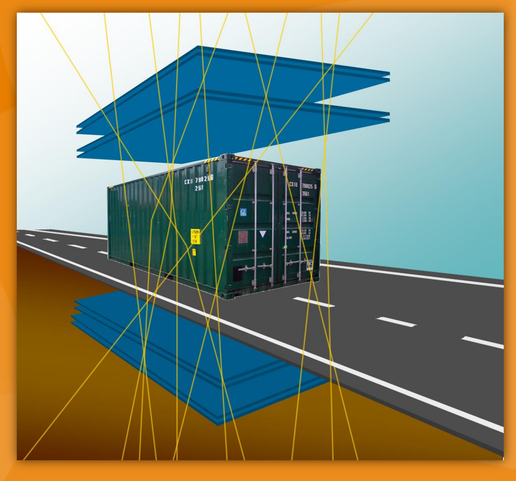


Abstract:
The Muon Portal is a real-size prototype detector for the inspection of cargo containers by the muon tomography technique. The detector is based on 48 detection modules, each built by 100 scintillator strips with WLS fibers and Silicon Photomultipliers readout, properly organized into four X-Y 18 m^2 detection planes. This contribution reports the activity concerning the construction and test of the first detection modules and the mass characterization of the photosensors, together with an overview of the present status of the Project.

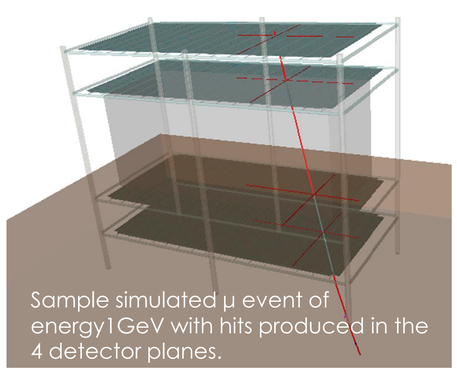
The problem:

Cargo containers which travel worldwide may be a potential source of illicit fissile material. Traditional inspection techniques are not suited to control in real time the content of a container.

The Muon Portal:

Apparatus designed to inspect the travelling cargo containers using the muon tomography technique.

This technique is based on the determination of the scattering angle of cosmic muons induced by heavy materials. Proper algorithms allow to produce a 3D image of the interior of the container.

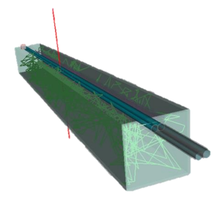


Sample simulated μ event of energy1GeV with hits produced in the 4 detector planes.

Specifications of the Muon Portal Detector:

A Muon Tomograph is based on a large area muon tracking detector, to reconstruct muon tracks above and below the container.

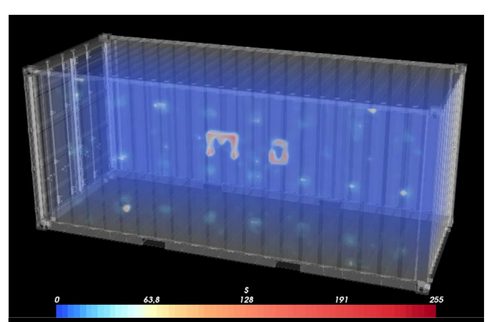
- ✓ 8 physical detection planes (4 XY logical planes)
- ✓ Each plane made of 6 modules (1m x 3m)
- ✓ Modules segmented into 100 strips of extruded scintillator with double WLS fibre readout
- ✓ High PDE, high fill-factor SiPM as readout sensors
- ✓ Smart readout strategy to combine the information from the 9600 channels



Design of an extruded scintillator strip with 2 WLS fibres, to be coupled to the SiPMs

Algorithms and simulation results:

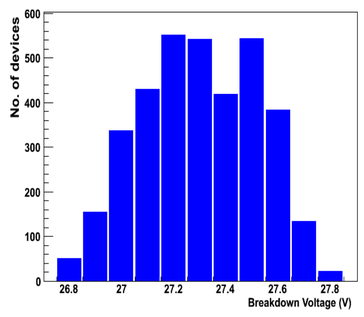
Several reconstruction and visualization algorithms were tested and implemented, among which the POCA (Point of Closest Approach), a Log-likelihood iterative algorithm, the Friends-of-Friends algorithms as well as Clustering methods



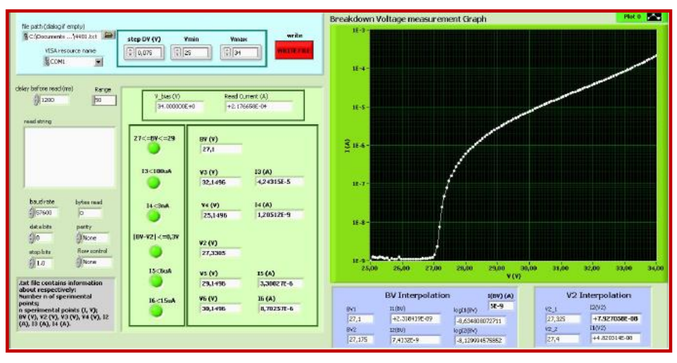
Tomographic imaging of a simulated scenario (MUON shape surrounded by washing machines, with M: U, U:Fe,

Silicon Photomultipliers:

Several prototypes were built by STMicroelectronics, customized for this application.
SiPMs were tested individually in order to select devices with similar characteristics (in terms of breakdown voltage BV and current)

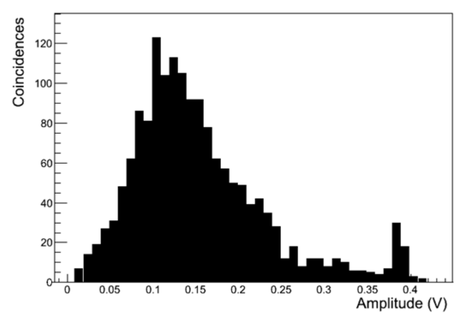


Parameter	MUON60	MUON75
Sensitive area size (mm^2)	1.97	1.80
Number of cells	548	320
Cell capacitance (fF)	280	445
Cell quenching resistor (kΩ)	550	800
Cell fill factor (%)	67.4	73.8
Typical breakdown voltage (V)	27.4	27.4
Optimal operation OV (V)	3÷4	3÷4
Gain	6.8×10^6	7.6×10^6
Typical dark current (μA)	~2	~2
Typical Dark Count Rate (MHz)	~2	~2
Optical Crosstalk (%)	1.5	1.5
Photon Detection Efficiency at $\Delta\lambda$ = 500-550 nm (%)	28	31

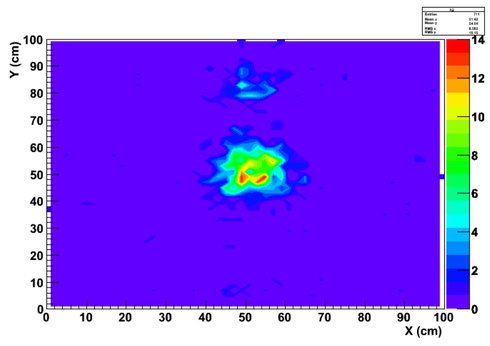


First tests of the detection modules:

Preliminary tests of the detection modules, were carried out with an external trigger scintillator.



Amplitude spectrum of the SiPM, in coincidence with a trigger scintillator (125 cm from the photosensor). Average measured signal = 7-8 p.e.



2D map of two orthogonal detection modules in coincidence with the external scintillator.

Present status of the Project:

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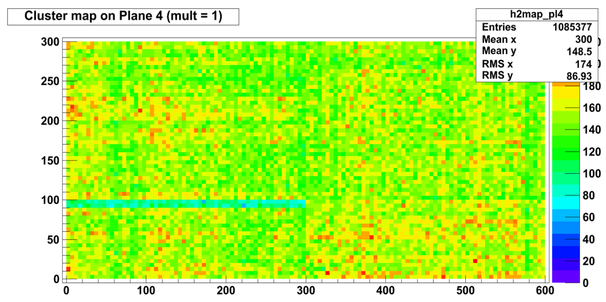
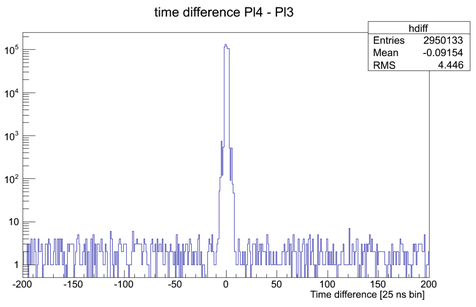
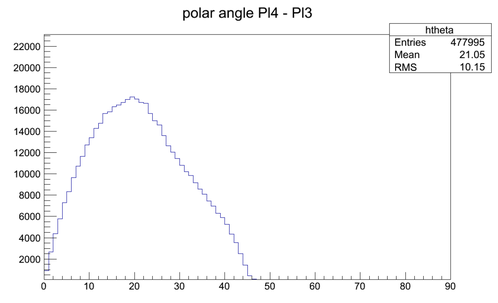
- ✓ All detection modules already built, with all SiPM tested
- ✓ Two X-Y plane installed and under test
- ✓ All electronics and data acquisition/analysis working and tested
- ✓ Completion of the Project envisaged within few months



2D map of one detection plane in coincidence with another detection plane.



Coincidence events between two detection planes.



Polar angle distribution measured with 2 detection planes.

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