Development of (M)RPC for muon tomography

IP2I

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Outline

- Muon radiography
- RPC-MRPC detectors
- Collaboration project

Using cosmic muons to probe large structure is not a new idea:

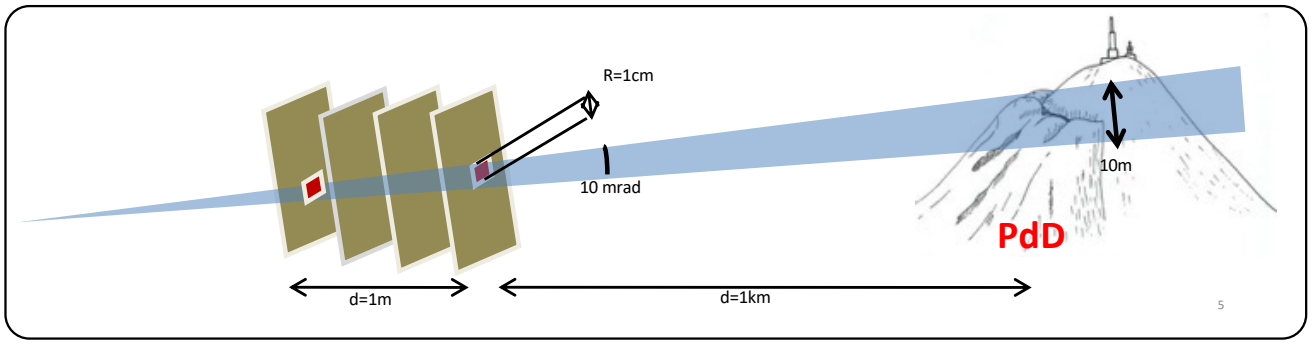
1950: E. George proposed it to measure the width of the overburden of a tunnel
1960s: L. Alvarez proposed to use it to look for hidden room in the in Chephren pyramid in Gisa, Egypt
2007: Tanaka et al : proposed it to probe volcanic structure.

Since then, many collaborations were built to exploit the muon tomography:
Mu-Ray, Diaphane, **Tomuvol**...

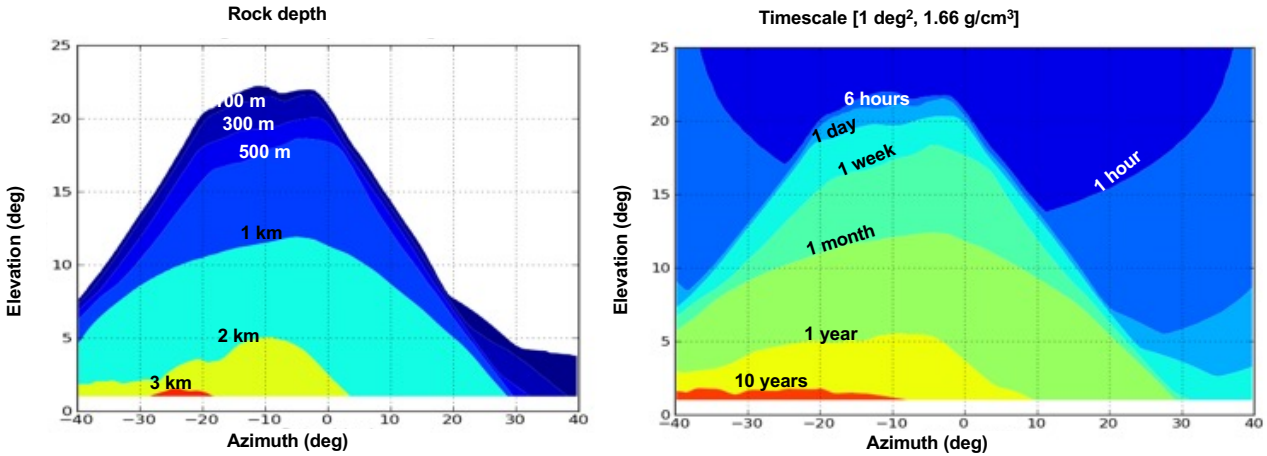
Different technologies were proposed: Nuclear Emulsion, Scintillators and gaseous detectors
(**RPC**, MicroMegas..)

TOMUVOL

IP2I-OPGC-MLMV-LPCC



Muons crossing the volcano is a powerful tool to explore its structure density. A resolution of 10-20 m is needed to achieve a relevant study from the geological point of view.



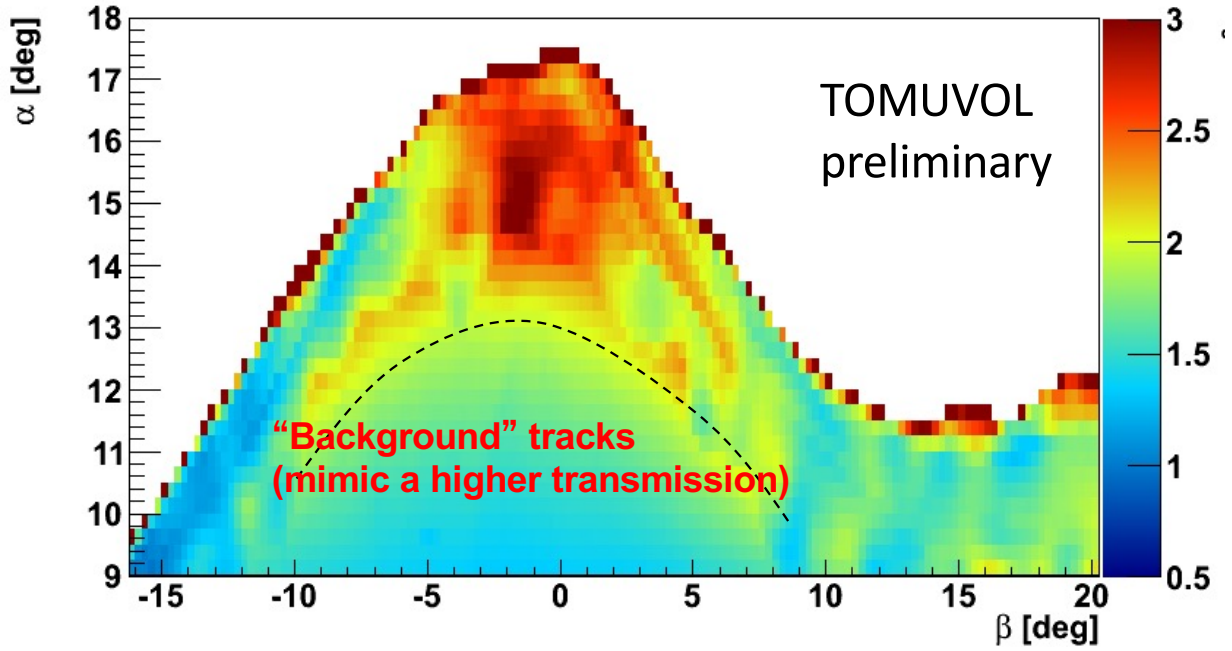
Computation for a uniform target with ρ=1.66g/cm^3 and 1 m^2 ideal detector

RPC in muography

TOMUVOL is made of 4 large planes of GRPC
Using the same technology of the SDHCAL

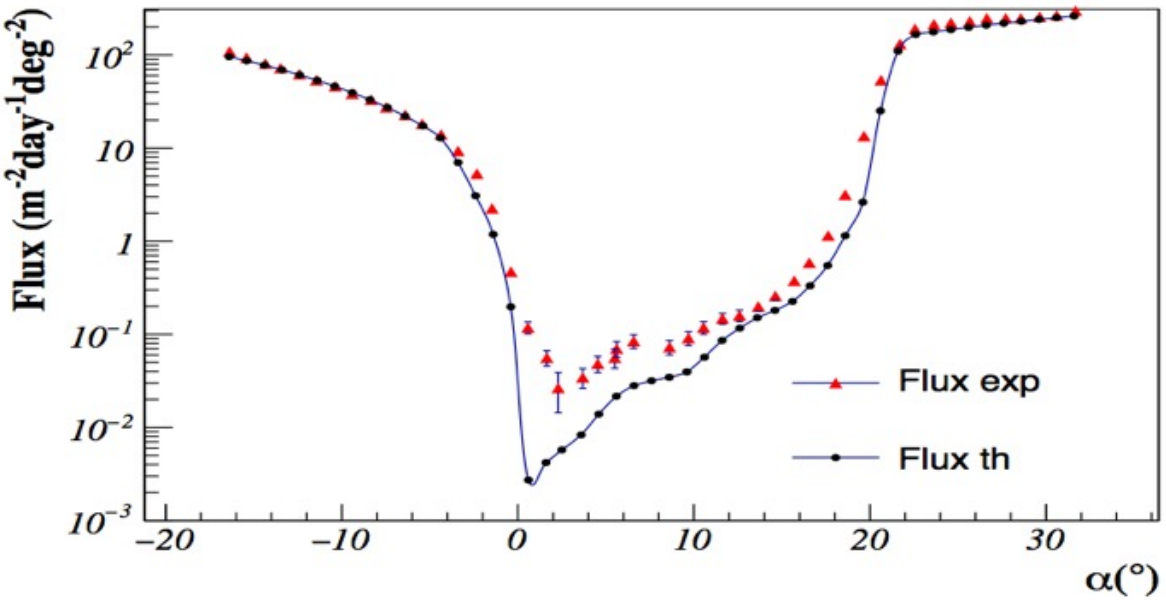
Several test campaigns at different positions
Allowed us to study the PdD structure.

Opacity coefficient : “Density-like”



Low energy particles (muons, protons and electrons) blur the volcano image

Opacity coefficient : “Density-like”



An important problem is the low energy particles that blur the image

To eliminate them one needs to estimate their momentum. For this

- Multiple scattering : This requires precise position measurement (Multiple Scattering)
- Time of Flight : This requires an excellent time precision

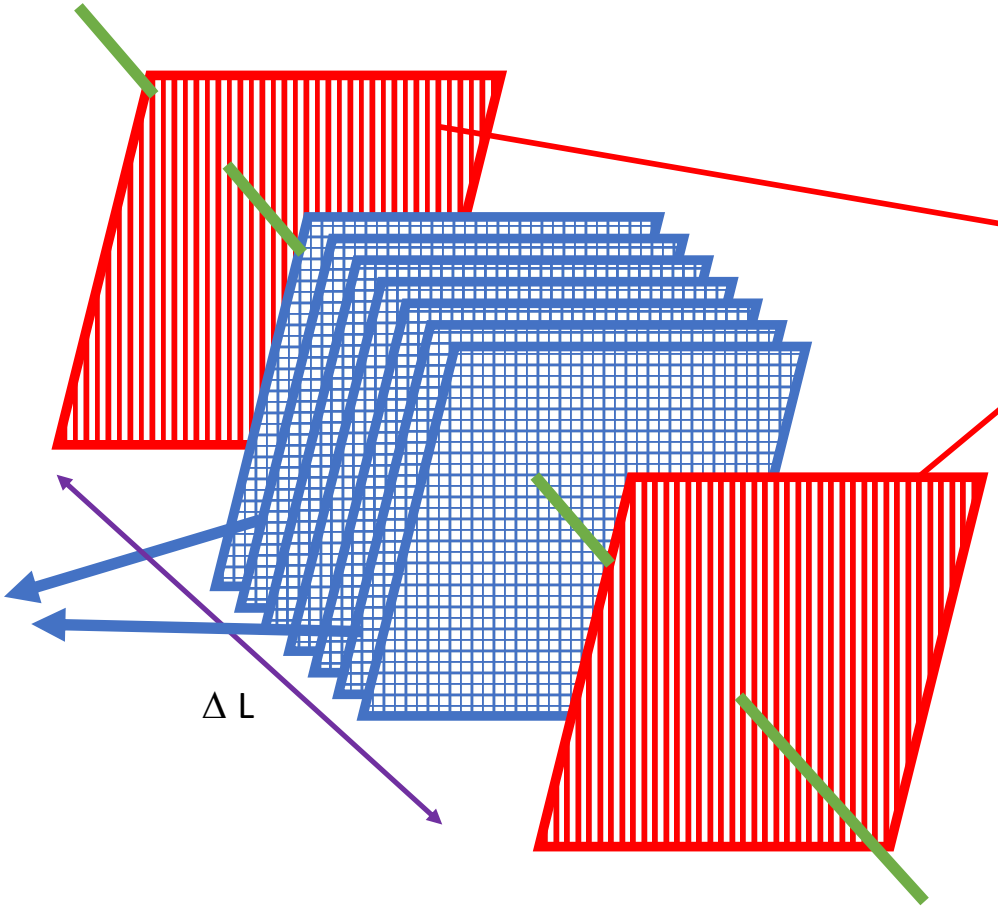
$$T_2-T_1 = (1+ (m.c^2/p)^2)^2 (L_2-L_1)/c$$

One can estimate the muon momentum by measuring T_2-T_1

For **1 GeV/c** muon the resolution of the momentum measurement is :

σ_p = **1 GeV/c** if σ_t = **100 ps** and L_2-L_1 = **4 m.**

Detection setup proposal



MRPC
Time + position
2D-readout

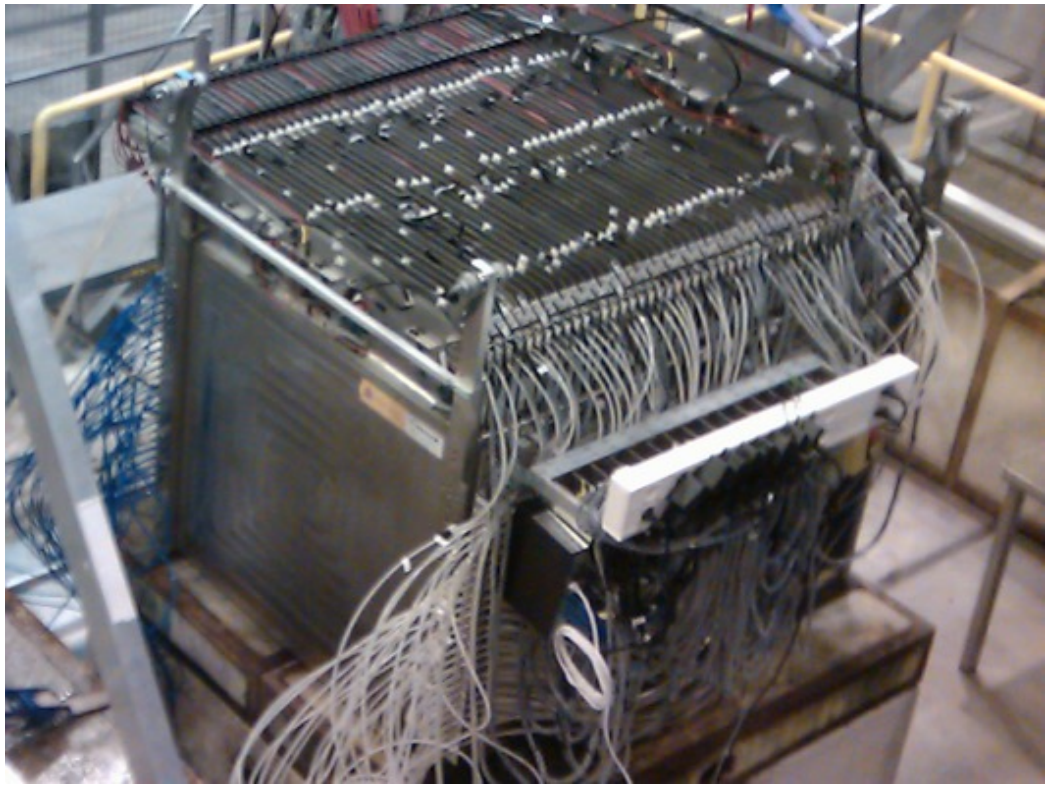
RPC
Position
Pad-readout

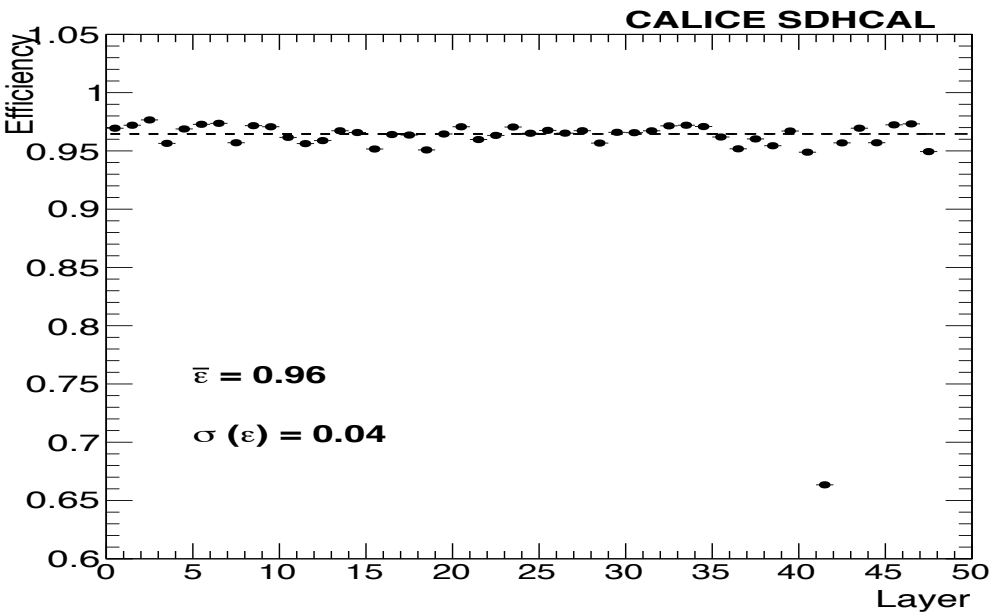
Δ L

- RPC to provide a precise angular measurement
- MRPC to provide precise time measurement

RPC

Single GAP glass RPC of 1m x 1m read out with 1 cm x 1 cm pads used in SDHCAL



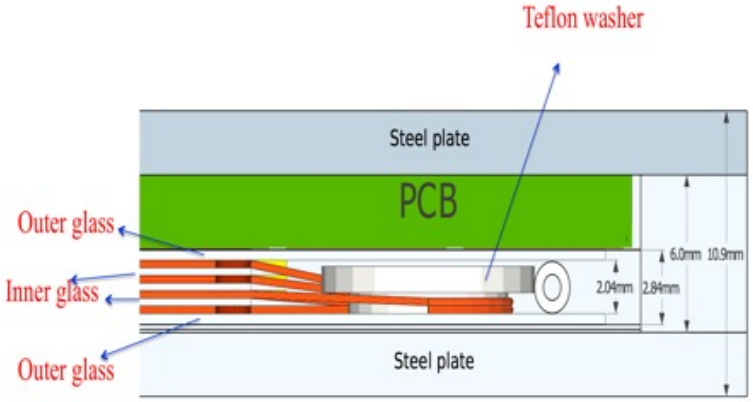


Position resolution/layer < 4.6 mm

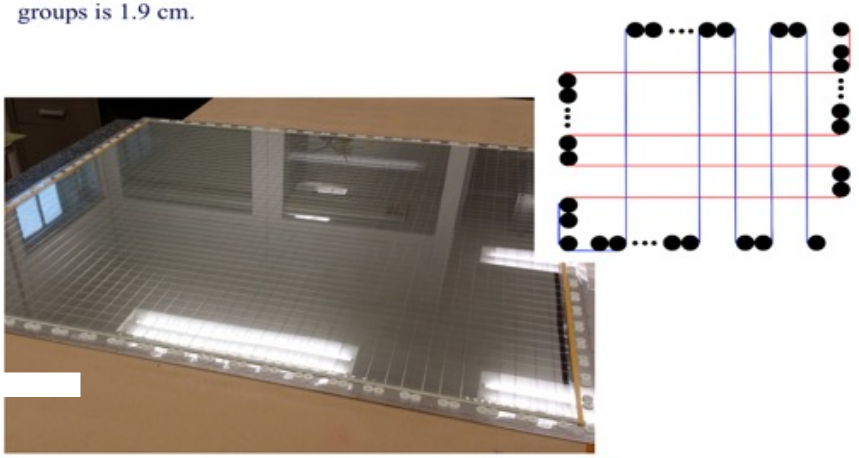
With 8 layers → < 2 mrad

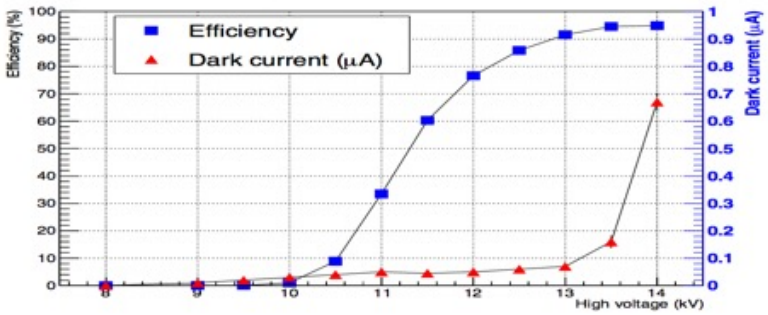
JINST 10 (2015) P10039

MRPC



groups is 1.9 cm.



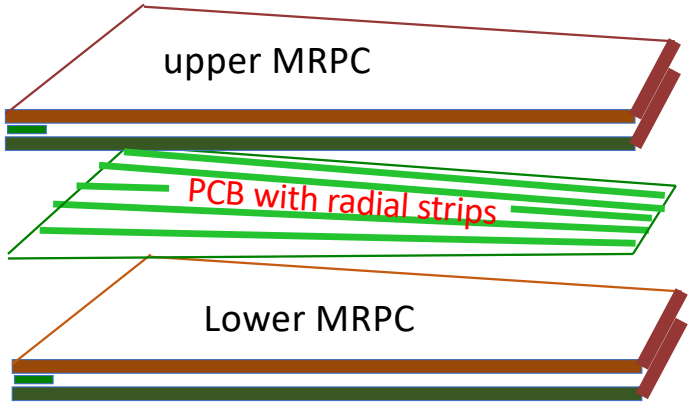


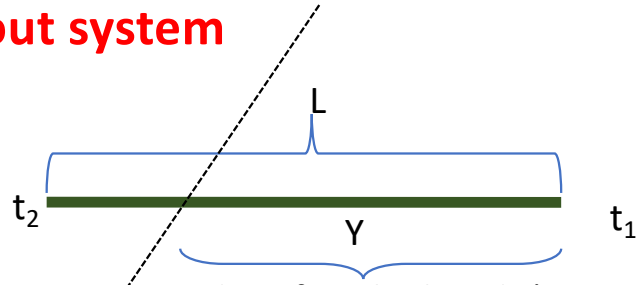
Threshold set at 114 fC

NIMA, volume 871,
November 2017,113-117

MRPC 2D readout system

CMS-iRPC-like



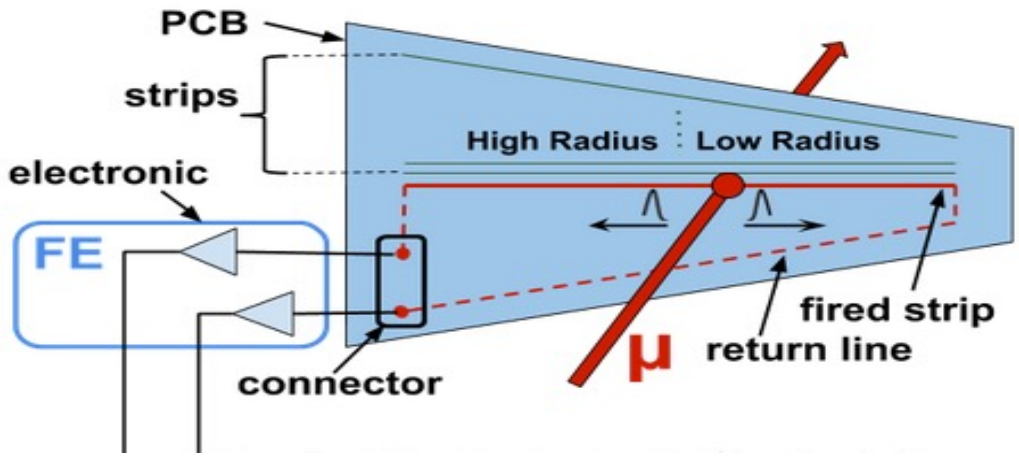


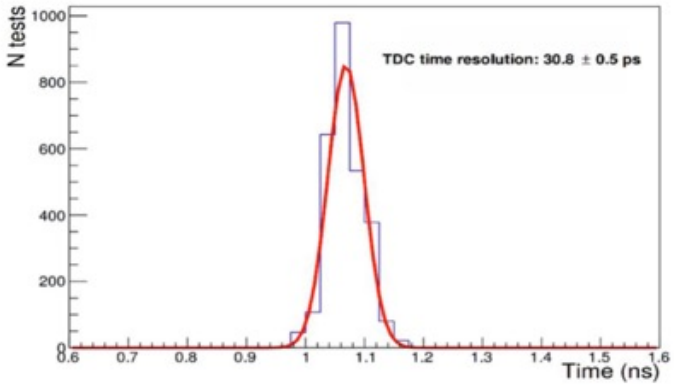
The strips are read out from both ends (2D readout) with good timing FE.
Y determination:

$Y = L/2 - v*(t_2 - t_1)/2 \rightarrow \sigma(Y) = v*\sigma(T_2 - T_1)/2$

With Y we can determine the time arrival.

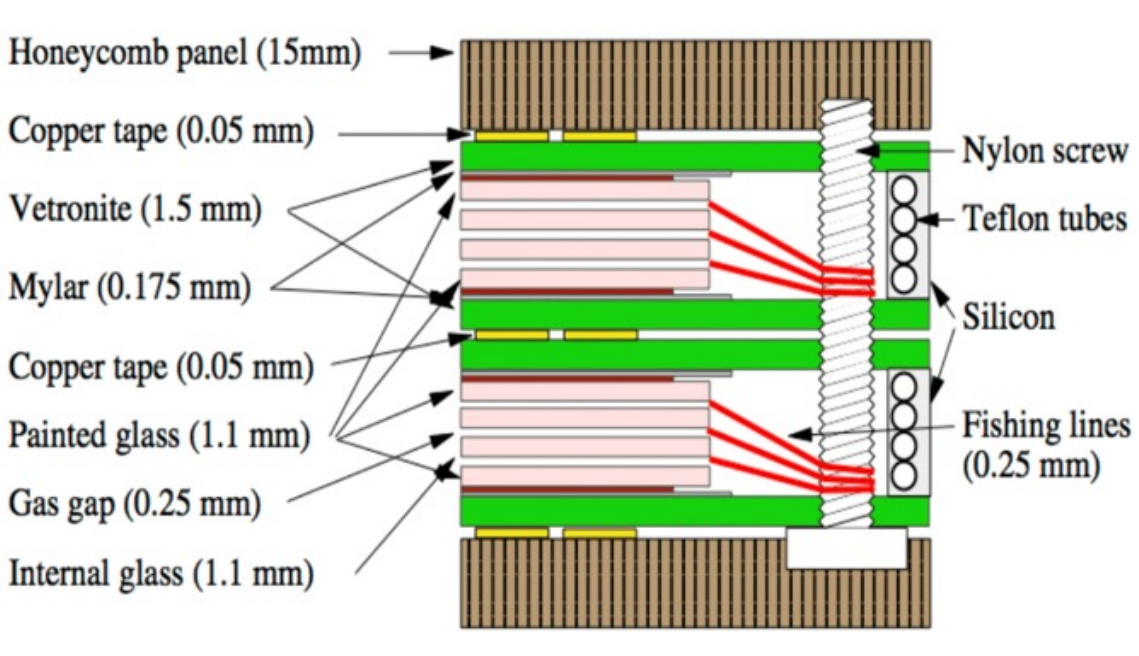
With 2 X 5 gaps we expect a time resolution better than 100 ps

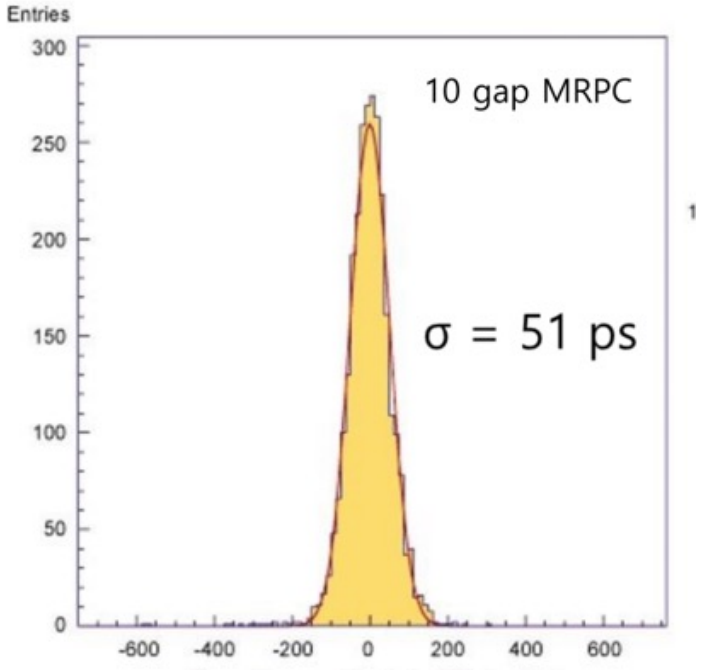




We propose to use a 2-stack MRPC for the time measurement. Each MRPC is made of 5 gas gaps and we expect to obtain a time resolution of better than 100 ps

2-stack MRPC





Conclusion

- GWNU and IP2I combine their expertise to produce a new and a powerful muon tomography system

- Almost all the components of the new setup are available including the DAQ system allowing to read two different FE electronics.

- The collaboration will be extended to include other groups (BISEE of Beijing)

- Test campaigns to take place in both France and South Korea.

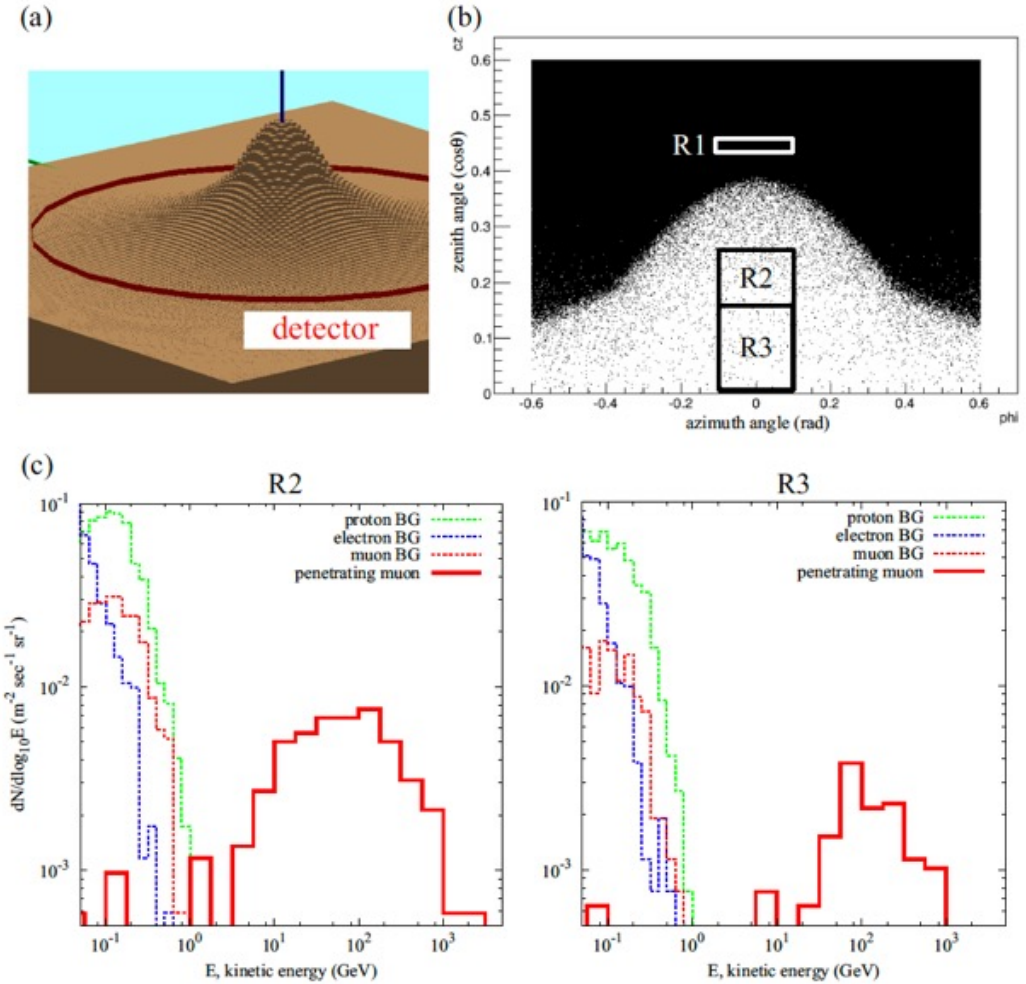


Figure 4. (a) Virtual mountain and detector constructed in GEANT4 computational space. (b) Angular distribution of particles arriving at the virtual detector, showing three angular regions R1, R2 and R3 defined for quantitative analysis. (c) Number histogram of particles arriving at the virtual detector. The energy distributions of the penetrating muons and background (BG) particles are drawn with solid lines and dashed lines, respectively.