MUOGRAPHERS

The MURAVES muon telescope: technology and expected performances.

Giulio Saracino[1,2]
on behalf of the MURAVES collaboration

INTERNATIONAL WORKSHOP ON MUON & GEO-RADIATION PHYSICS FOR EARTH STUDIES
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University of Naples Federico II, Italy[1] , INFN-Naples, Italy[2]

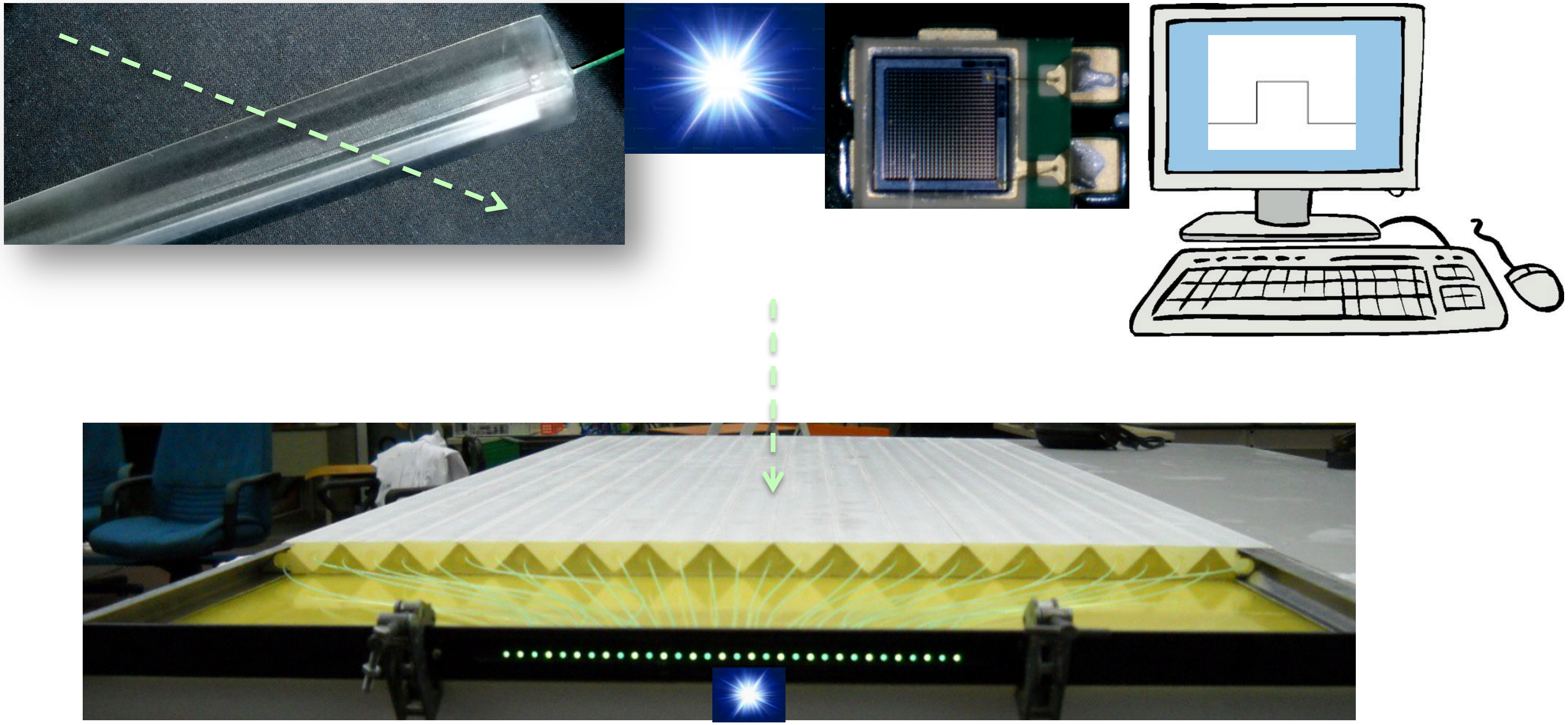
SUMMARY

- Muon telescopes working principles and features
- The MU-RAY R&D project and up-grades
- First MU-RAY measurement campaigns
- The MURAVES telescope
- MURAVES feasibility studies
- Conclusions

Muon telescope working principles

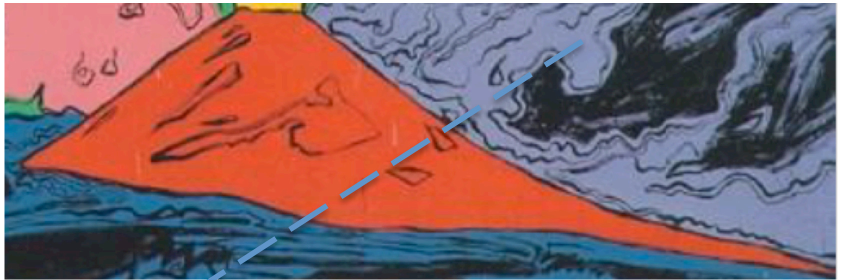
When muons pass thought a plastic scintillator a small flash of light is produced. Special photo sensors convert this light in electrical signals that can be registered.

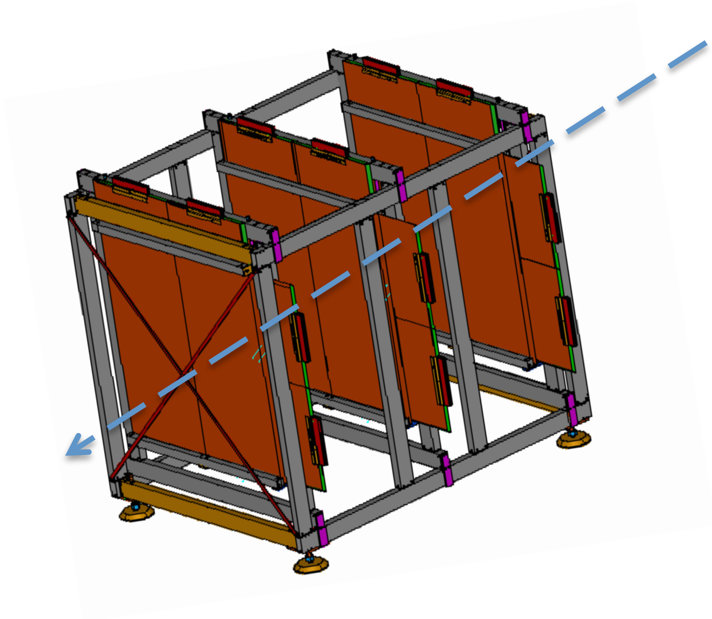
Arranging the plastic scintillators in bars the position of impact of the muon is measured and the muon track reconstructed

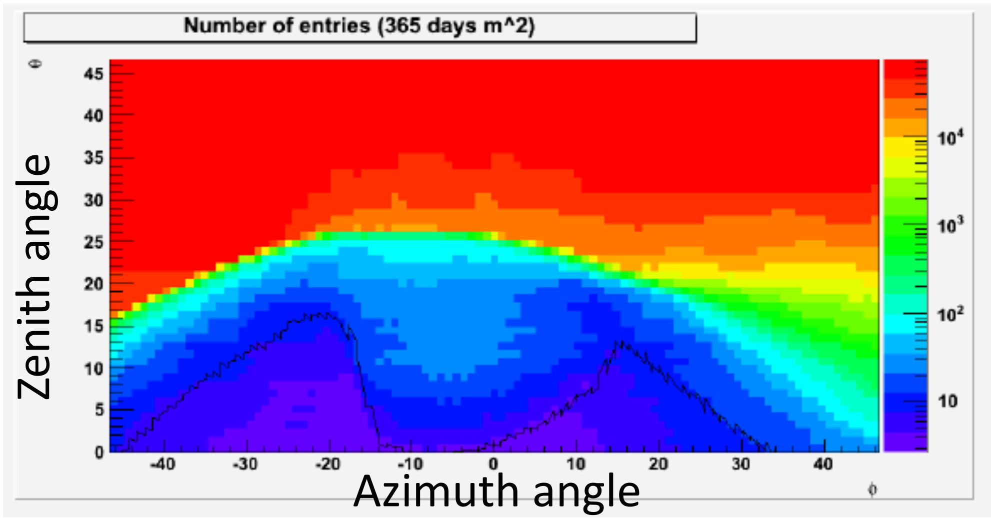


Muon telescope working principles

The telescope measures the number of muons crossing the volcano as function of the direction and compare this number with the expected one, in order to estimate the quantity of material that muons crossed





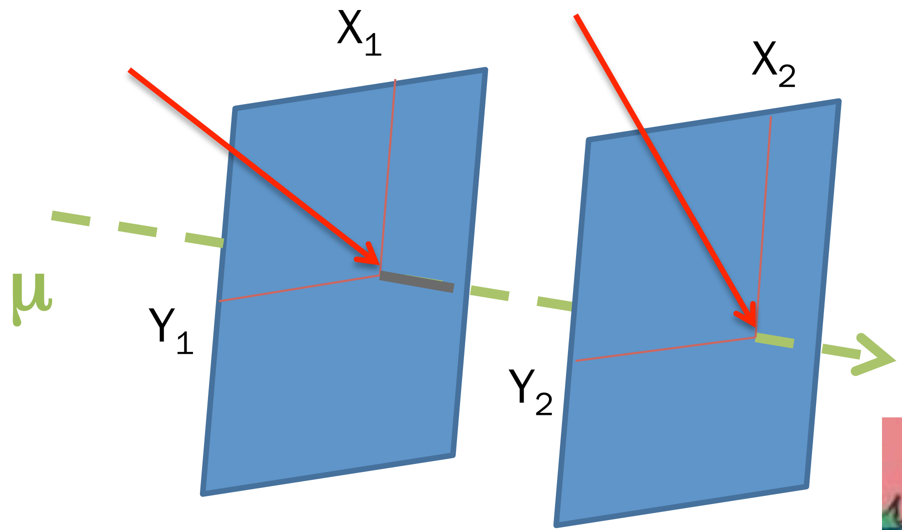


Muon telescopes requirements

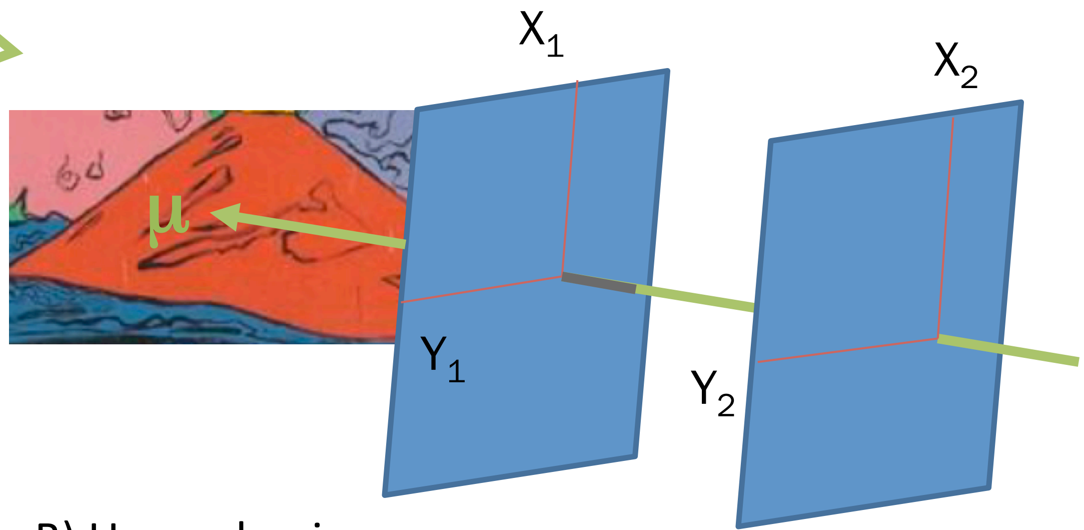
- Transportability
- Low electric power consumption
- Reliability
- Robustness
- Remotely controlled
- Background suppression

Background

Typically the rate of muons to measure is very low.
Background must be kept under control carefully to reduce systematic errors
Possible sources of background:
A) Fake tracks, produced by multi-particle events, interpreted as real muons
B) Real muons coming from the rear side of the detector (upward-going muons)



A) multi particles shower fake track

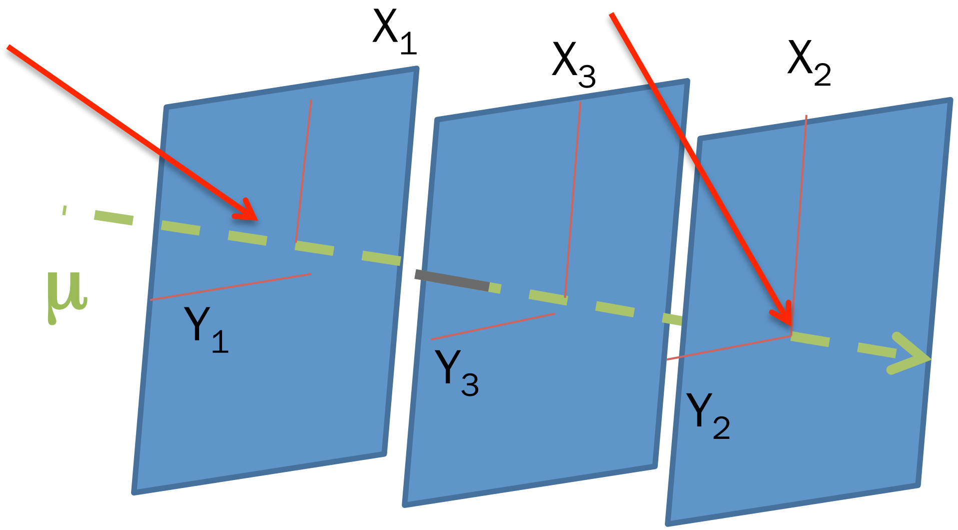


B) Upward-going muons

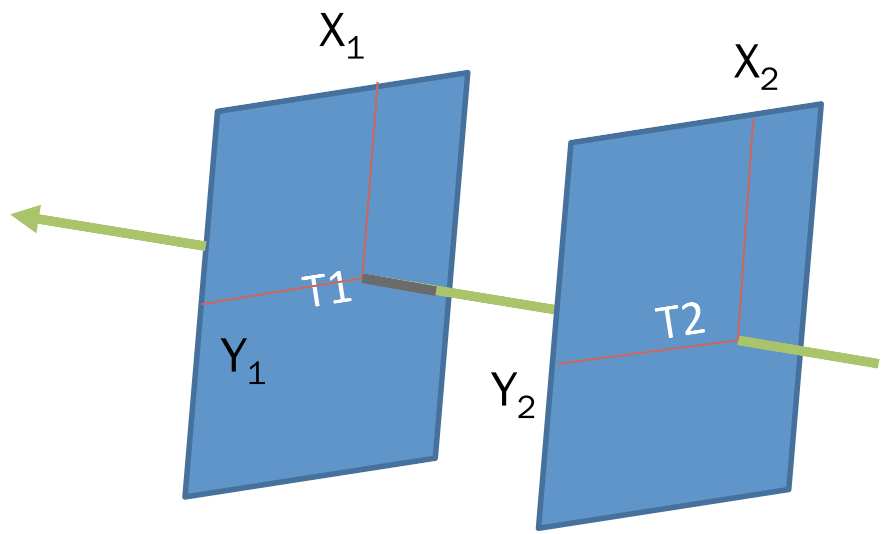
Background suppression

Possible solutions:

- Increase the number of scintillator bars (A)
- Increase the number of planes (A)
- Shielding (A)
- Reduce the coincidence time window (A)
- Measuring the direction using the time of flight muon (B)



multi particles shower fake track



T1 > T2 good muons
T2 > T1 upward going muon

The MU-RAY R&D project

The origins of the MURAVES project are in the INFN MU-RAY experiment.

MU-RAY was conceived for the design and realization of a new generation of muon telescopes for large rock thickness volcanoes.

Main requirements:

- Large number of scintillators bars
- Introduce a third plane for the tracking
- Increase spatial resolution
- Time of flight measurement

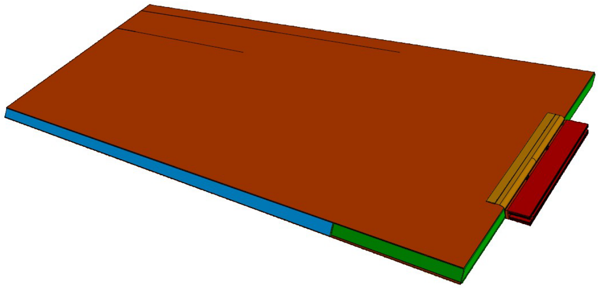
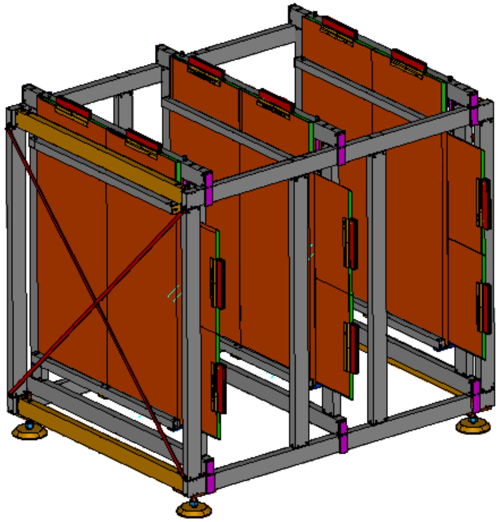
Technological choice:

- Plastic scintillator bars with WLS fiber and Silicon Photomultiplier sensors
- SiPM specific ASIC for the front-end electronic
- Dedicated low power consuming read-out
- Time expansion technique for sub-ns time resolution measurement

Preserving low-power consumption, transportability and robustness

The MU-RAY detector

The detector was designed with three x-y planes assembled with 12 modules.
Each module is 1m long and half meter large, with a weight of ≈18 kg, so that they can be carried by hand

12 x  = 

The MU-RAY detector

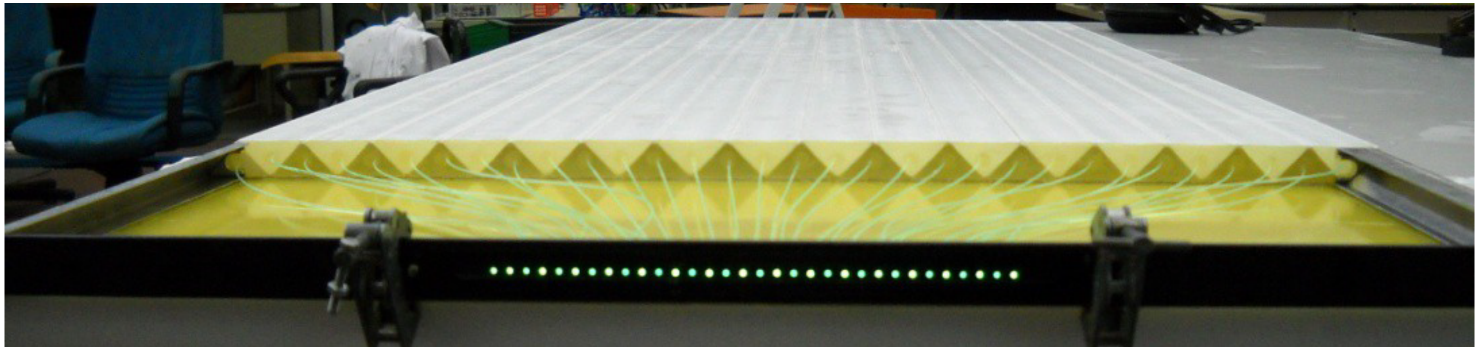
Planes height can be modified

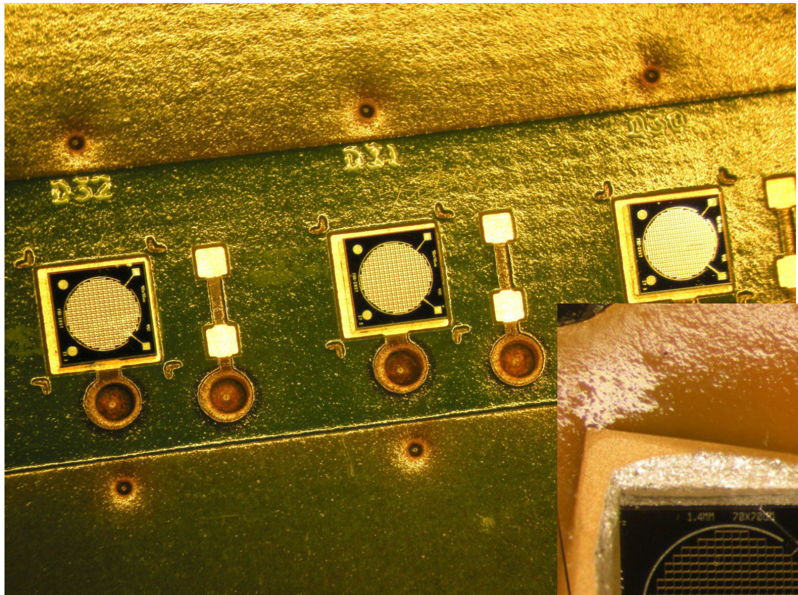
Adjustable feet

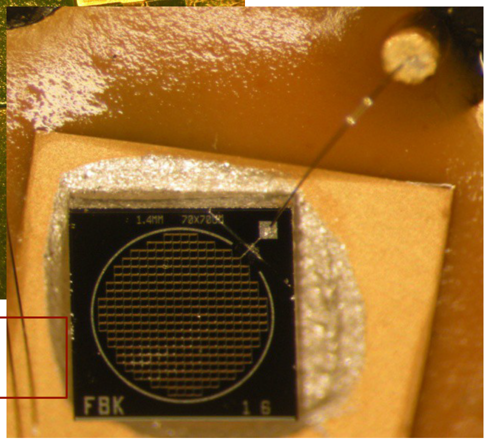
Detector Rotation

The MU-RAY detector: module and SiPM

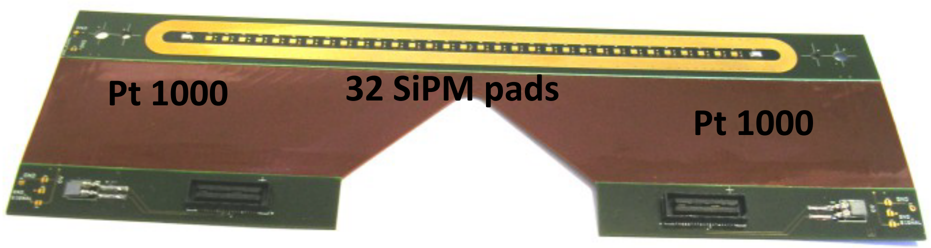
EACH module consists of 32 scintillator bars with triangular shape and with WLS fibers collecting the light to SiPM. One fiber edge is mirrored with sputtered Al. The other edges are grouped on a custom connector for the photo-sensor coupling.

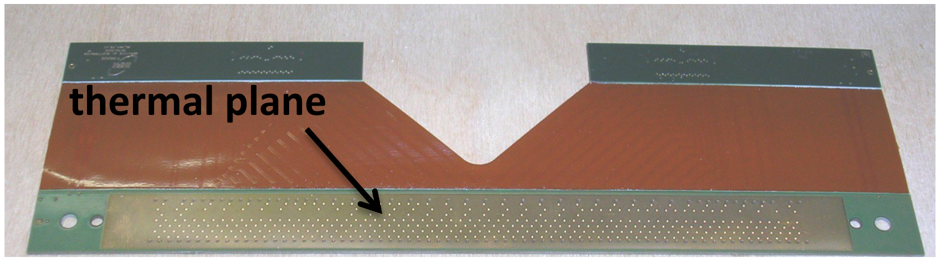






Hirst-FBK 1.4 mm, 70 μm

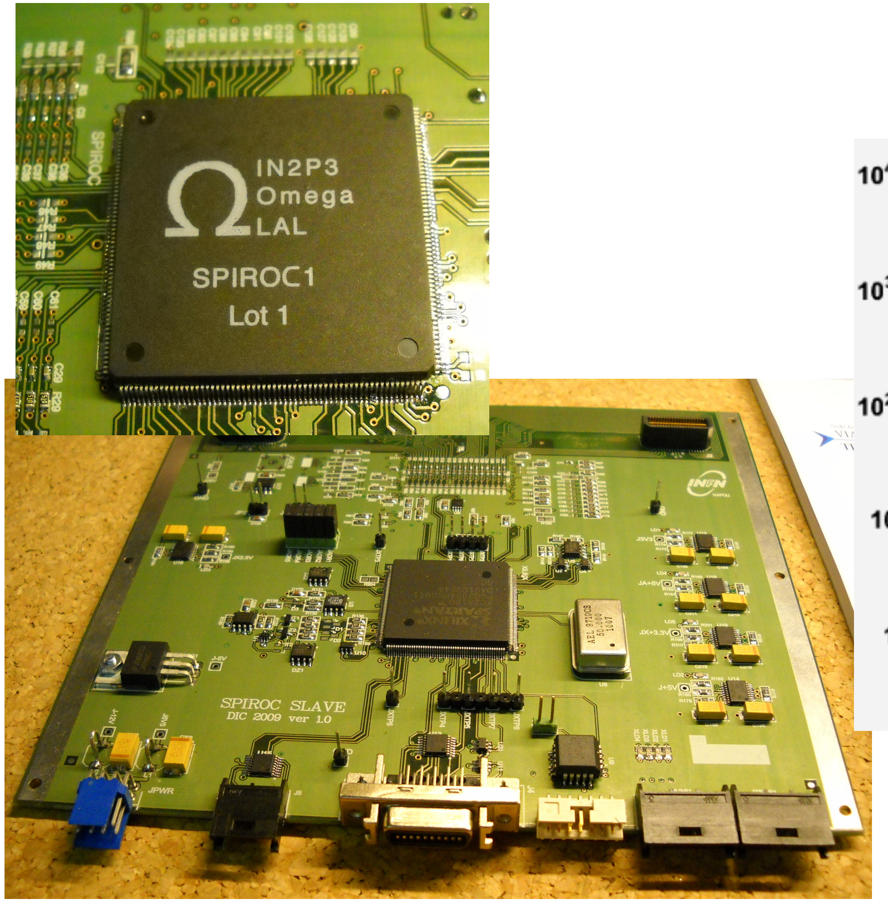


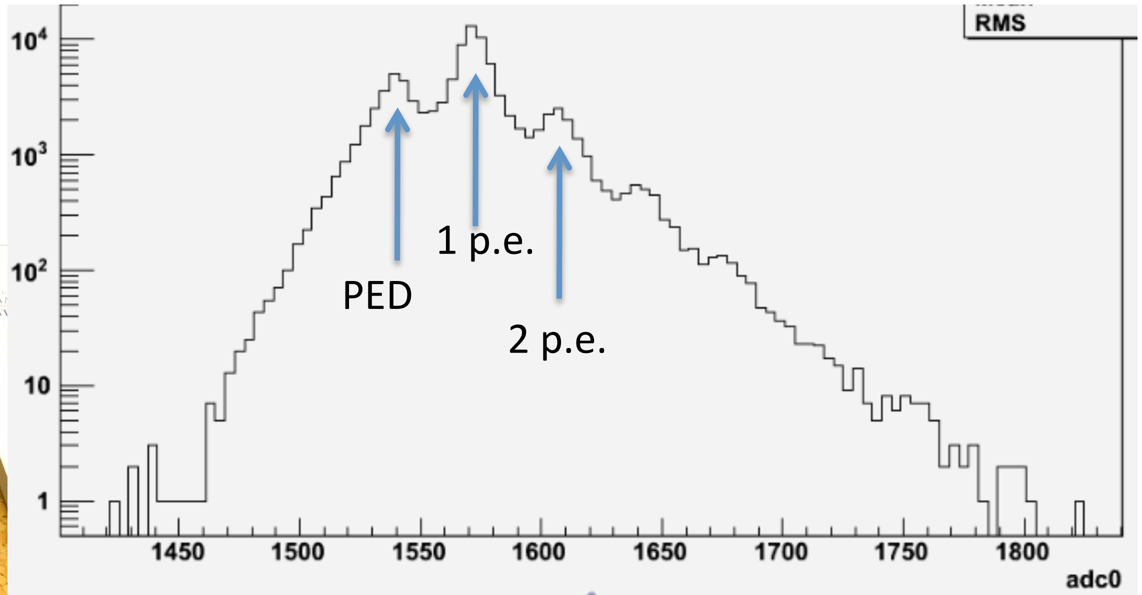


The MU-RAY detector: FEE

Main features

- 36 channels/chip (32 used)
- Individual bias voltage tuning (0÷4.5 V ;17 mV step)
- Fast discriminator response (Logic OR of all ch.)
- Individual Sampling and Hold of the signals stored in analog memory





Dark noise spectrum

The MU-RAY up-grades

- Mechanic
- Photo-sensors
- Front-end electronic
- Data acquisition

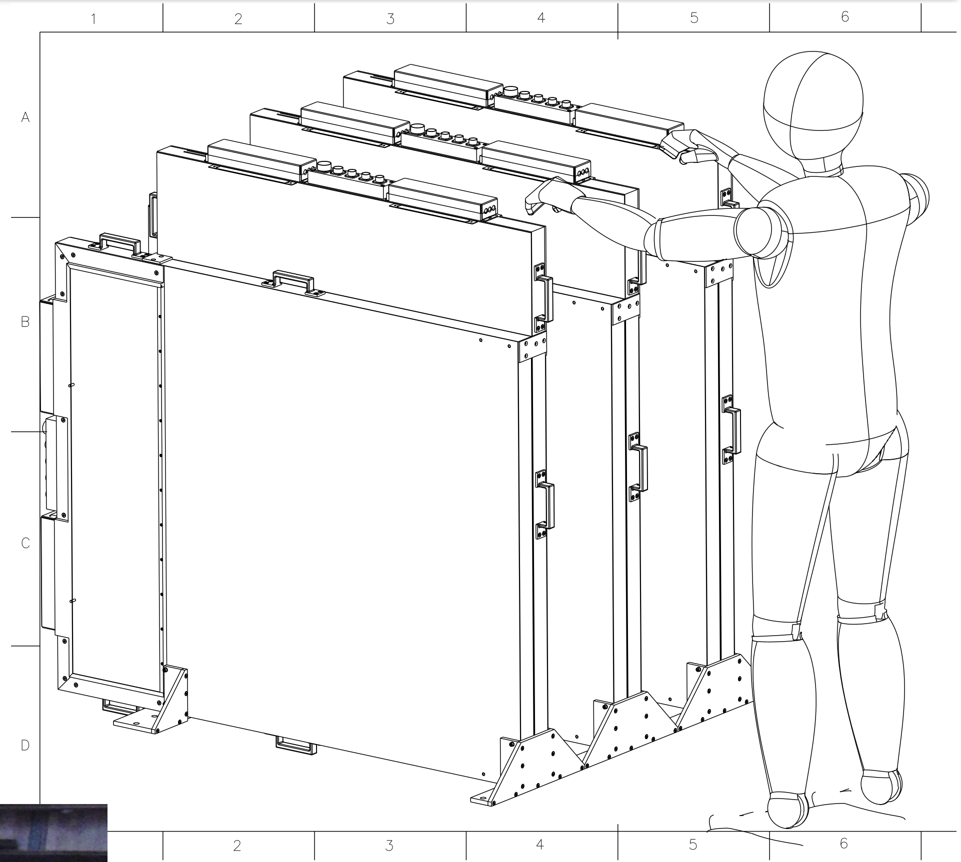
Mechanic up-grades

- Two modules are inserted in an Al shell, with handles. Total weight 50 kg -> easy to transport

- The shell is self sustaining, no need of an external frame -> easy to install

- Round multi pin connectors -> easy to cable.

- Sealed for outdoor use



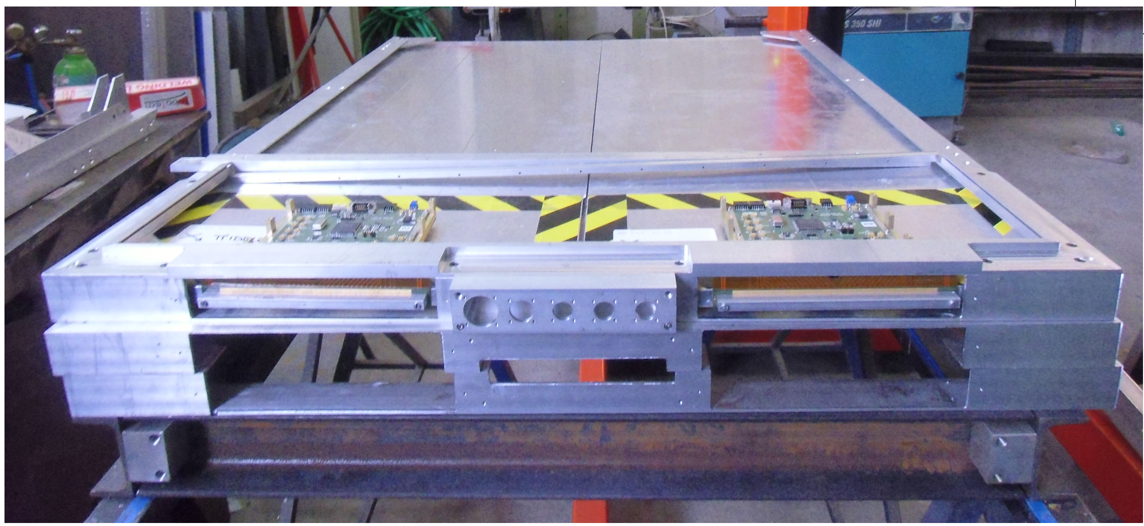
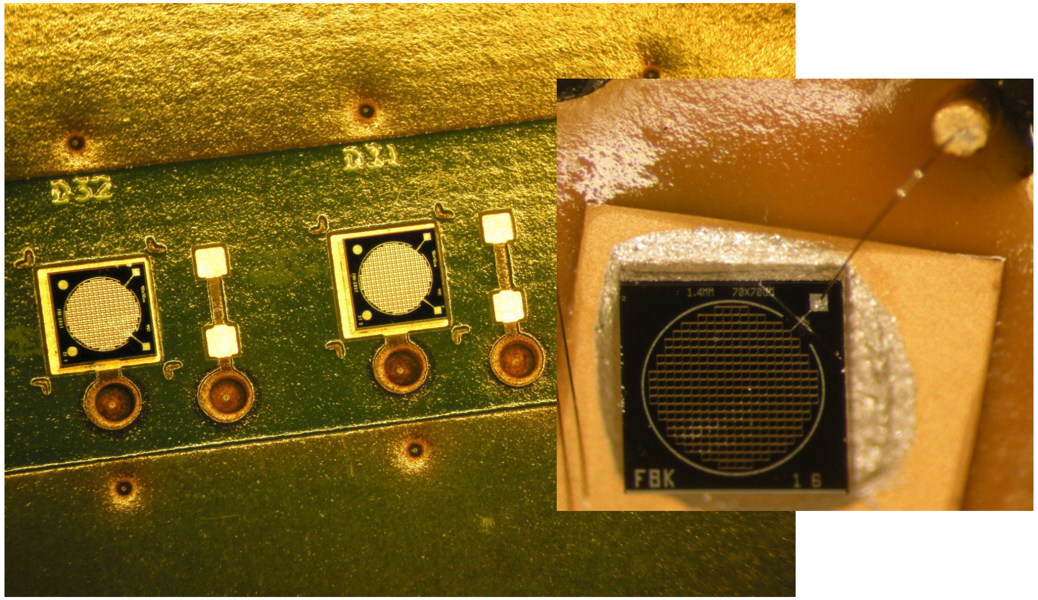


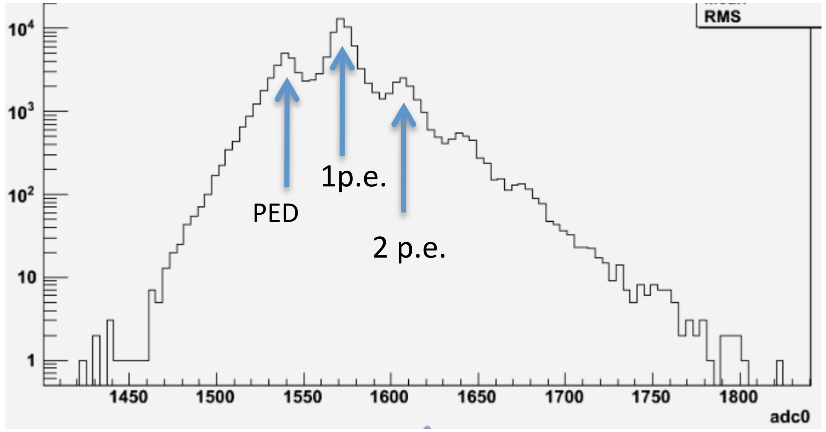
Photo-sensor up-grade

FBK die SiPM wire bonded

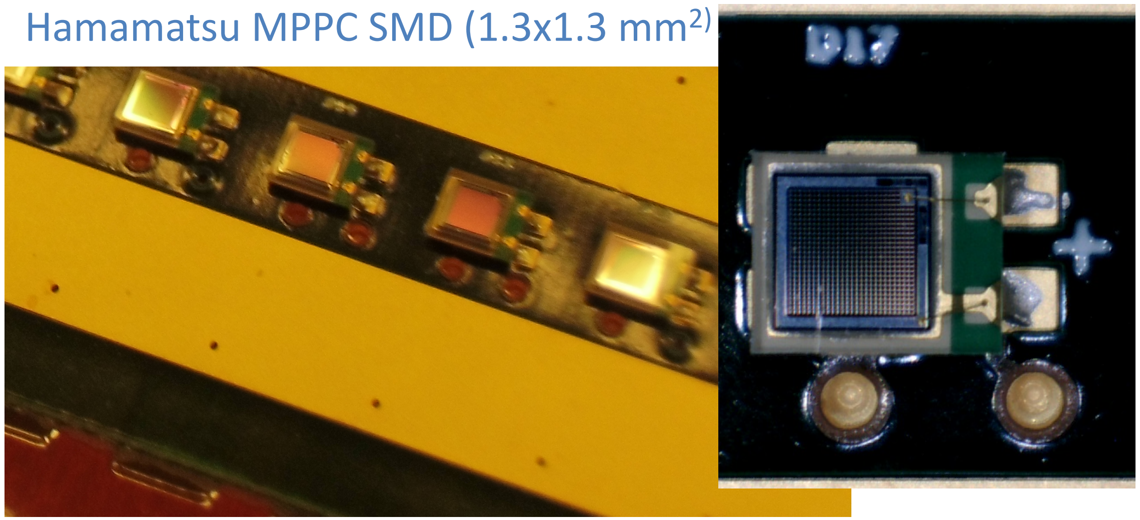


Dark noise spectrum

Typical dark rate: 2 MHz

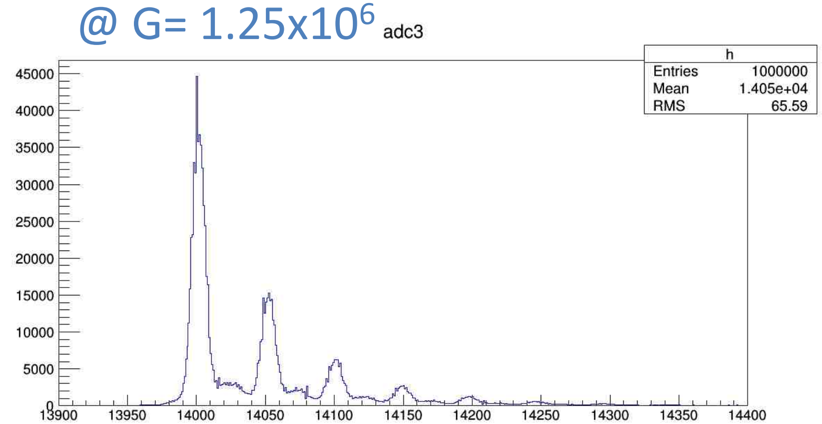


Hamamatsu MPPC SMD (1.3x1.3 mm^2)



Typical dark rate: 170 kHz

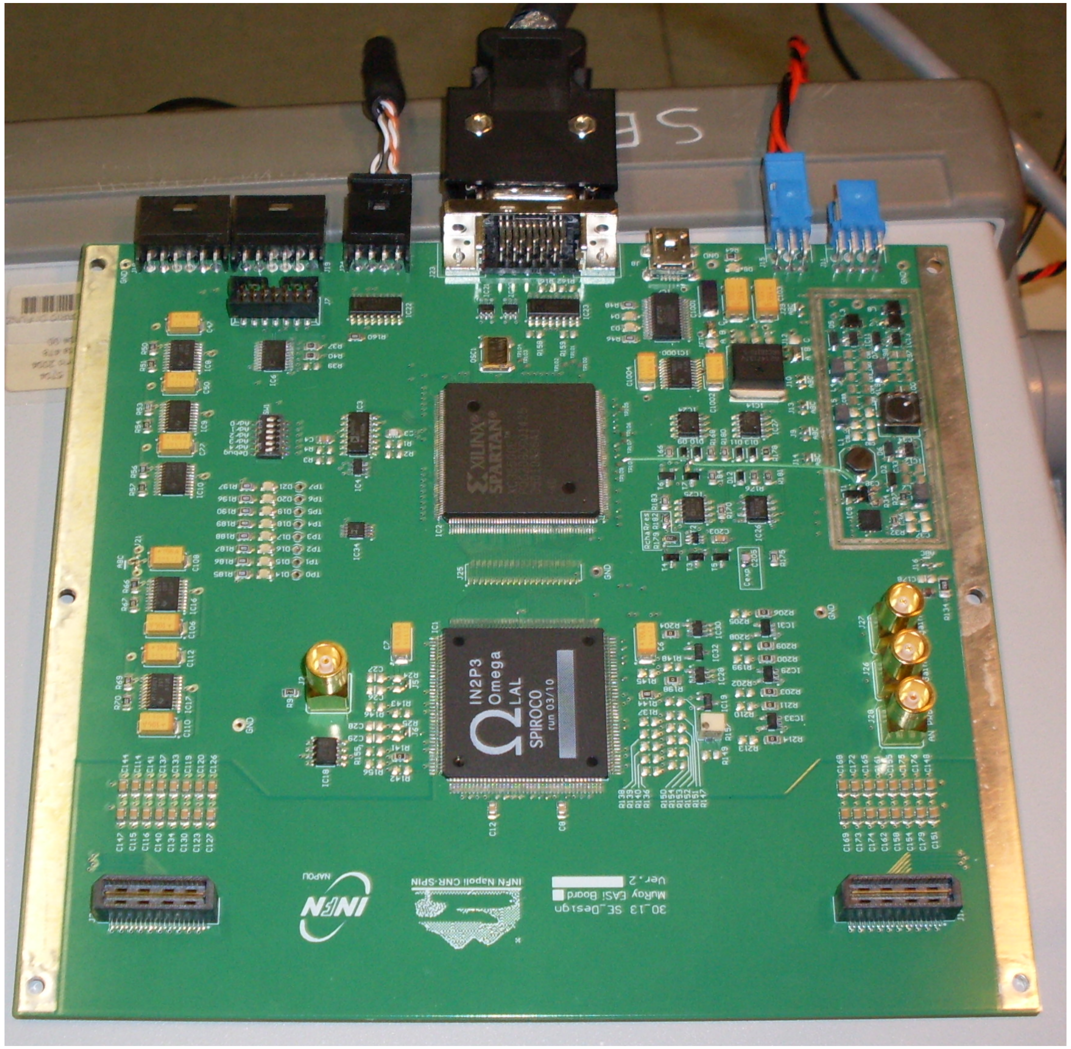
@ G= 1.25x10^6



Front-end electronics up-grade

- ASIC EASIROC (32 ch)
- FPGA SPARTAN III
- Single power supply
- SiPM Bias generated on board and programmable
- Time expansion (16):
  - 250 MHz clock,
  - 250 ps time resolution
- Programmable digital potentiometer for hold and fast reset signal
- 32 counter 32 bits
- 12 bit ADC
- 3 W/board power consumption

SiPM Bias
40÷100 V 80 mV step

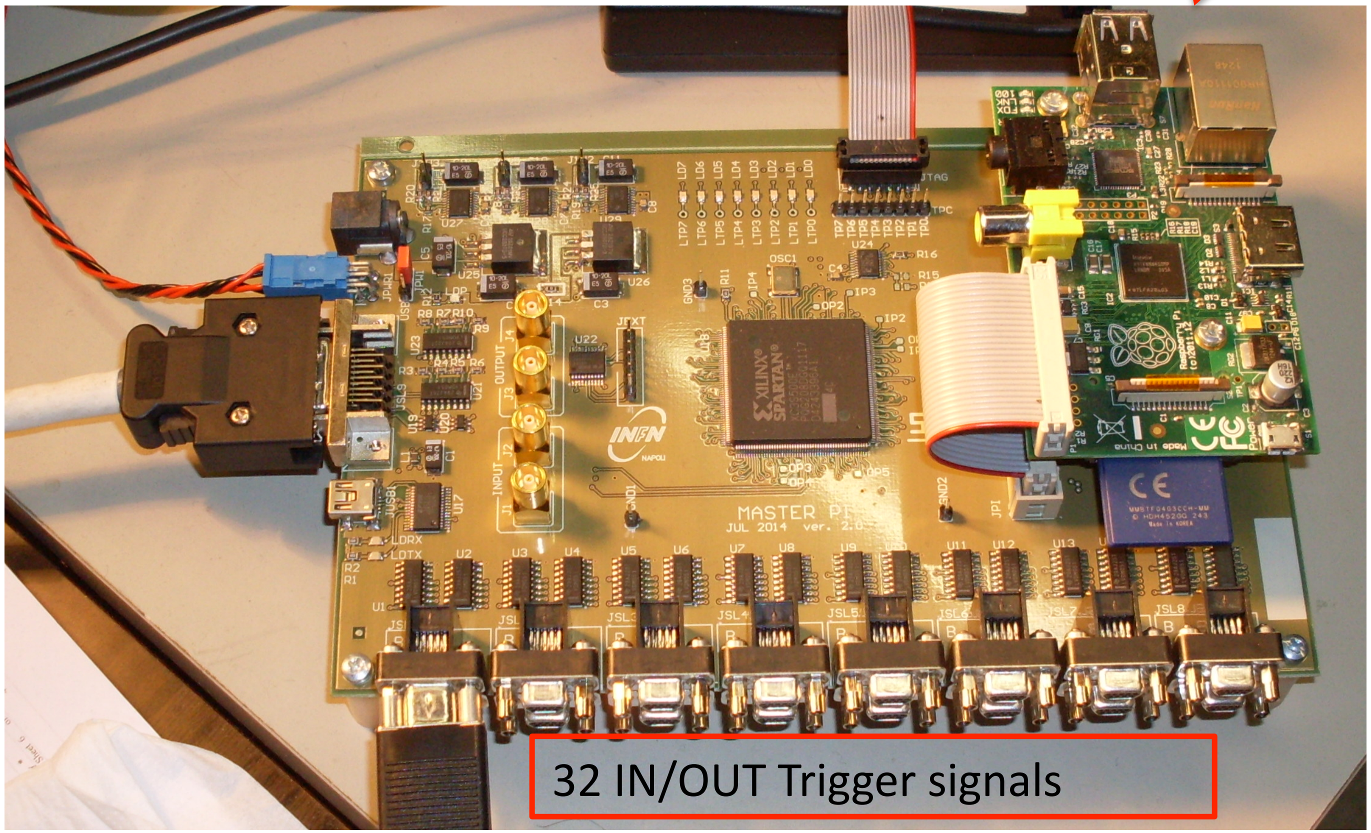


Data acquisition up-grade

New Master Board:

- Raspberry-PI GPIO directly connected to the FPGA
- Up to 32 SLAVES (1024 SiPMs) connected
    - ✓ Programmable trigger logic
    - ✓ EASIROC configuration
    - ✓ MULTIPOINT BUS
    - ✓ Trigger counter
    - ✓ 4.5 W power consumption

Raspberry-PI

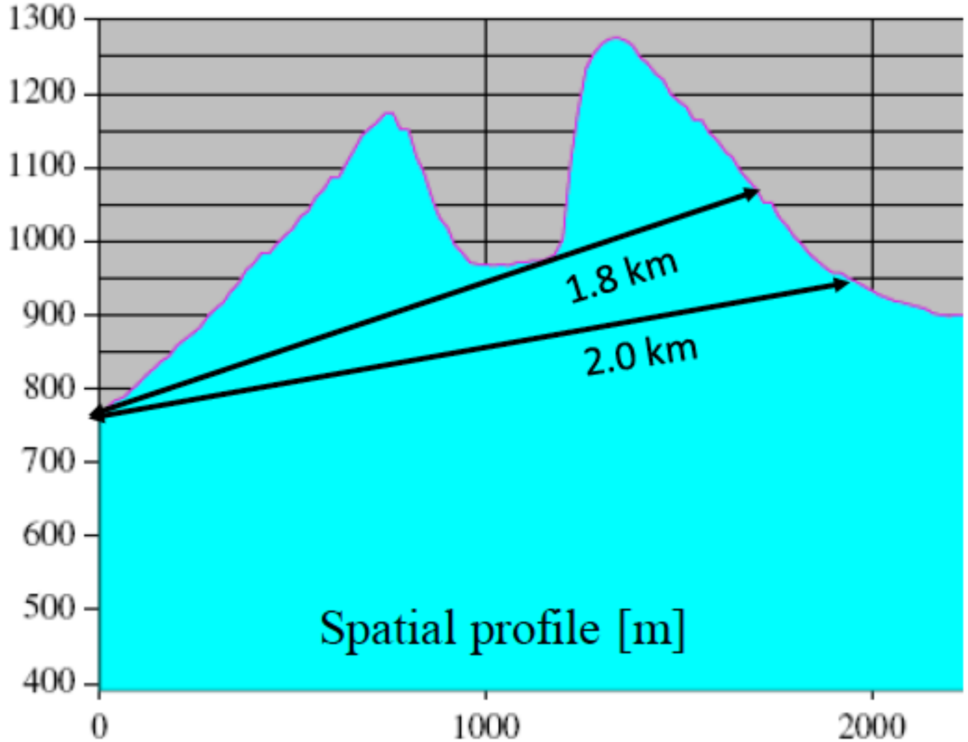


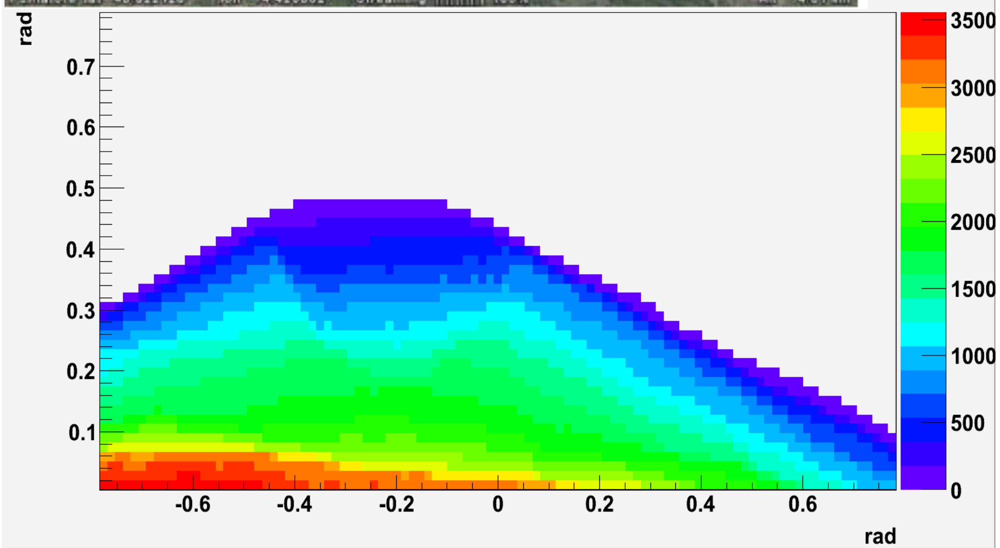
See L. Cimmino talk for more details.

MU-RAY first measurement campaigns

- The Vesuvius technical campaign
- The Puy de Dôme campaign

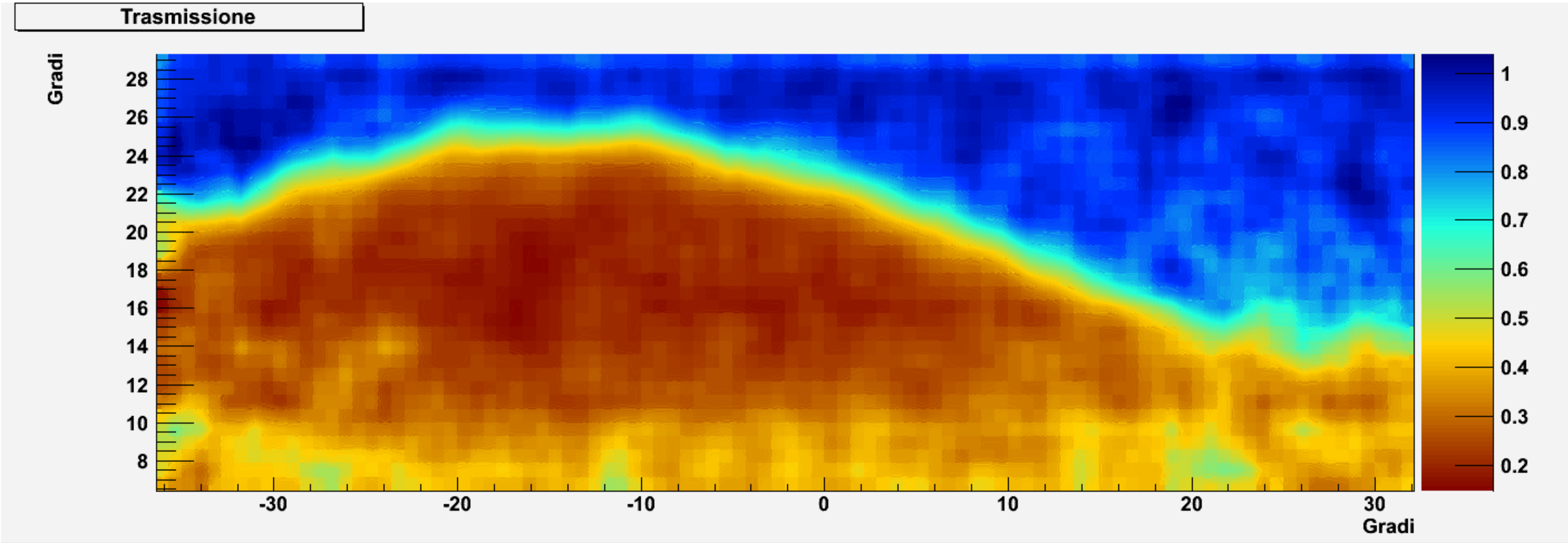
The Vesuvius technical campaign





- Short technical measurement to test the detector in a real field (4 week of data taking)
- No time of flight available

The Vesuvius technical campaign



The Puy de Dôme measurement campaign

The Puy de Dome at the Massif Central (France) as test laboratory.

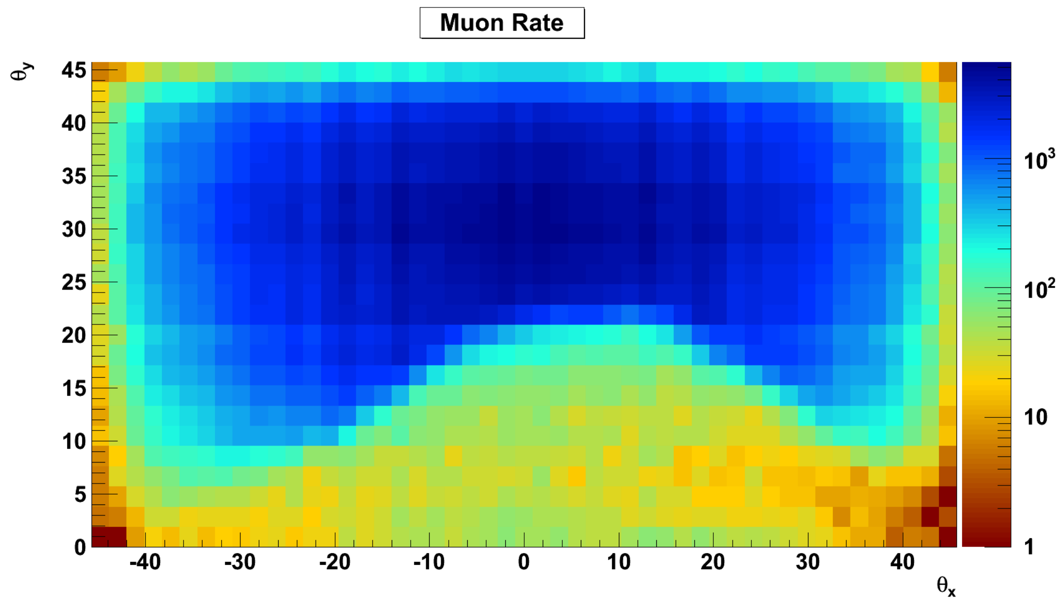
MU-RAY and TOMUVOL collaboration:

- Testing two different technologies on the field (GRPC and Scintillator)

- Share analysis methodologies

LPC/IN2P3/CNRS

- 105 days of data taking
- Stable operation condition
- Data analysis in progress



More details in P. Noli talk

The MURAVES project

The Muon Radiography of Vesuvius project MURAVES will attempt the first muon radiography measurement of Mt Vesuvius.

4 m^2 of sensitive area will be realized producing 4 detectors MU-RAY like.

MURAVES will operate for at least 2 years and muography results will be integrated with gravimetric results.

The main challenge is the large rock thickness

The location site

Different locations have been considered. Feasibility studies allow to understand the expected results. Beside the expected results, logistic must be considered too.

Feasibility studies

To estimate the expected results we simulated the number of events measured as function of time, detector size for different density. The estimator is defined as

$$S(\theta_x, \theta_y) = \frac{N(\theta_x, \theta_y)(\rho) - N(\theta_x, \theta_y)(\rho + \delta\rho)}{\sqrt{\sigma^2_{N(\rho)} + \sigma^2_{N(\rho+\delta\rho)}}}$$

- No background is considered
- Typical value of linear density variation is 10%

The "Casina Imbò" site (970 m)

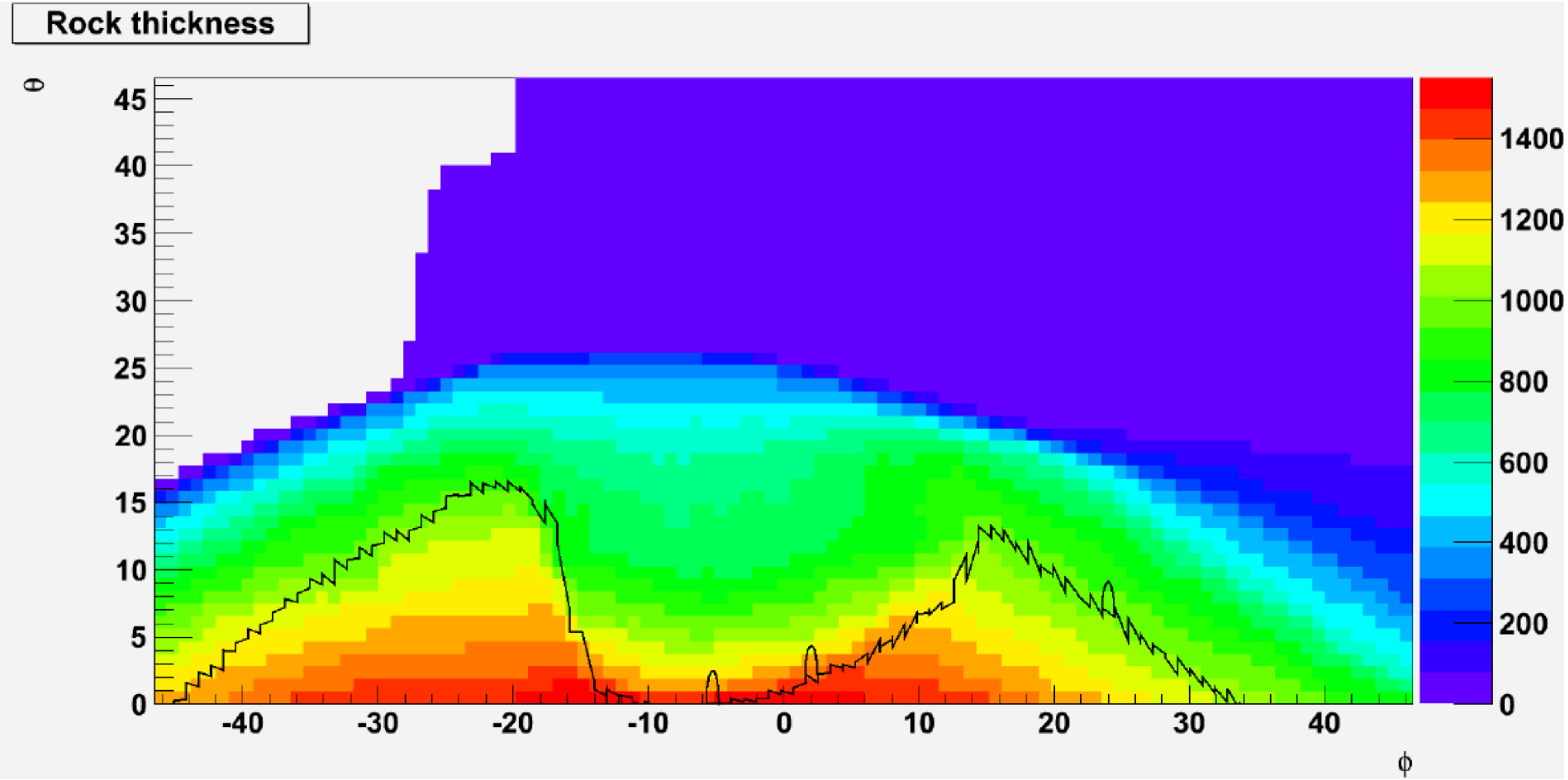
One possible location is the so called "Casina Imbò", at 970 m of altitude.

From this site only the upper part of the "Gran Cono" can be investigated with favorable rock thickness.

The old building is under restructuration and is connected to the electric network

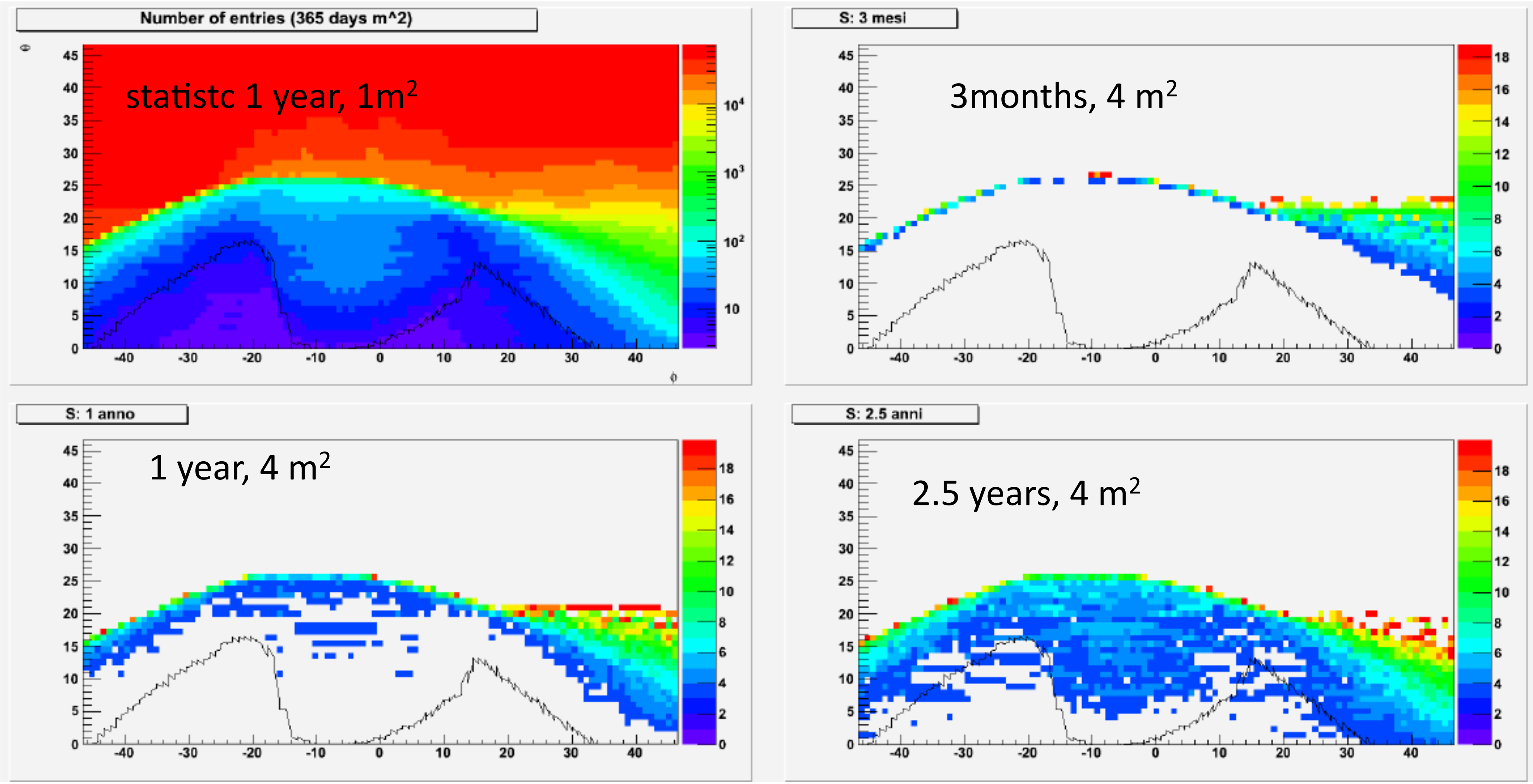
The "Casina Imbò" site

Rock thickness



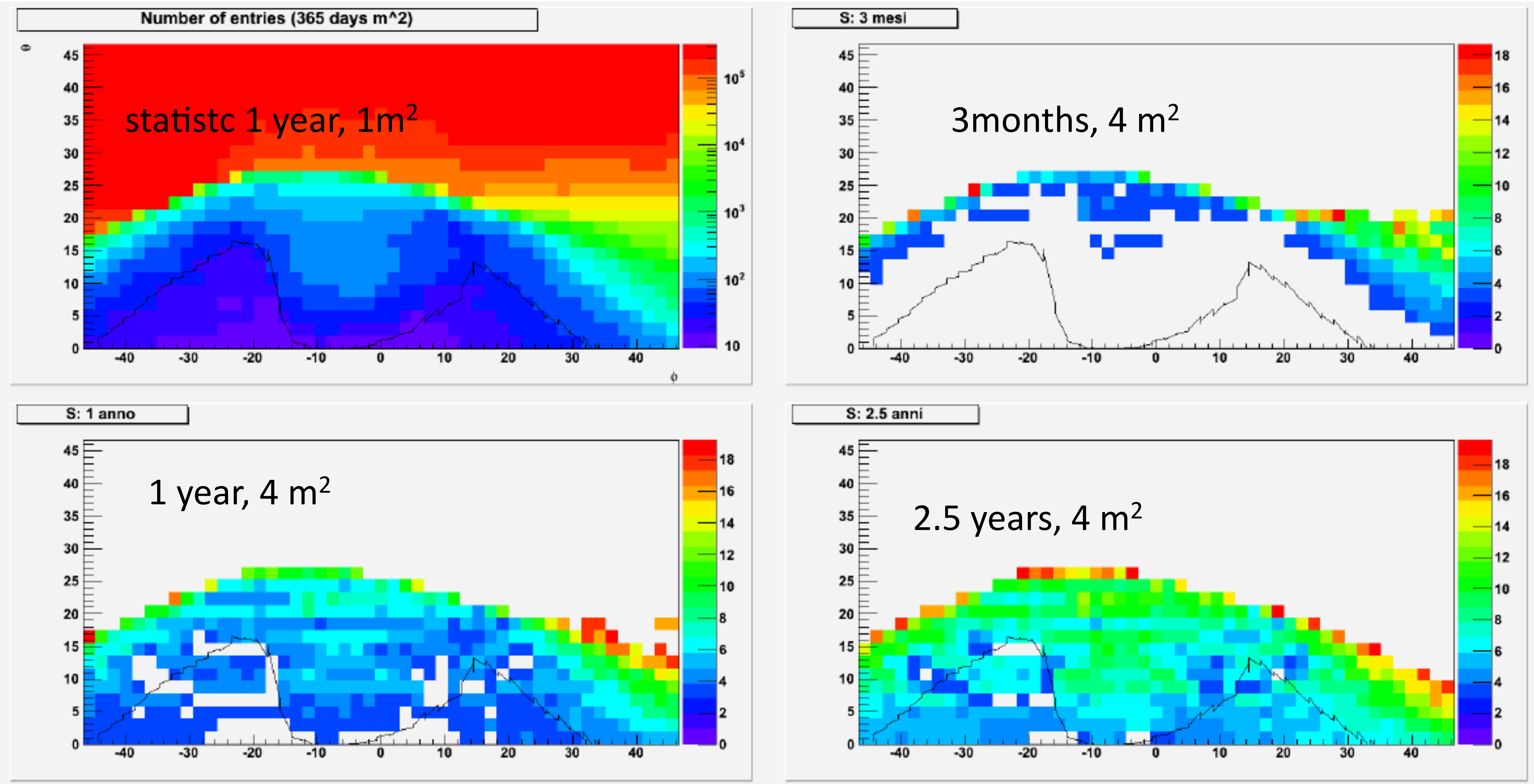
The "Casina Imbò" site

Expected results with 16 mrad x 16 mrad resolution



The "Casina Imbò" site

Expected results with 32mrad x 32 mrad resolution



Conclusions

- THE MURAVES project has been approved
- The final design of the detectors is completed and the prototype is ready for the commissioning
- The four telescopes construction will start in 2015
- Different sites are under valuation