Muon radiography applications to nuclear waste characterization. Status and prospective collaborations

Giulio Saracino

Florence 21 July 2014

INFN-NNL meeting on cosmic ray muons applied to the imaging of storage silos

Where we started

- First contacts during WCI 2013 (February)
- A first meeting in Naples in may 2013
- One 6 months contract (Nicola Mori)
- About 9 Skype meetings
- A second meeting in Florence in October 2013
- A final report from Nicola
- One article in preparation

Where are we going?

This is the main issue of this meeting....

Status of the MURAY project

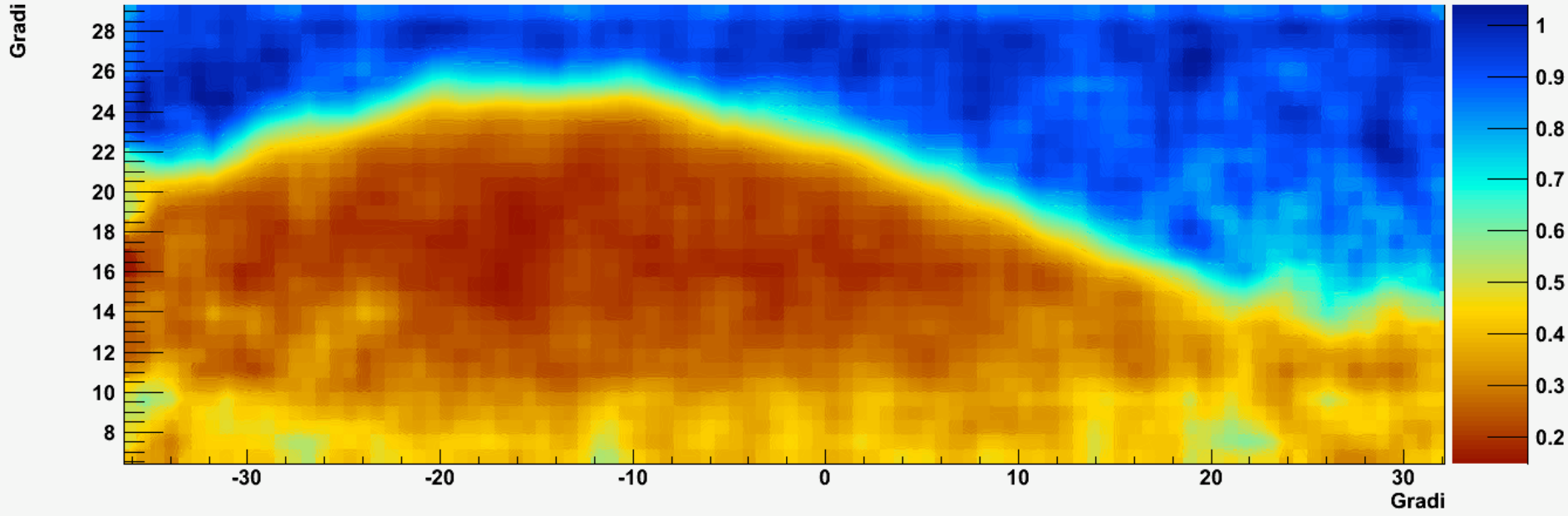
- The INFN MU-RAY project is the only group active in Italy on the muon radiography applied to Volcanoes
- At the same time we tried to explore possible different applications to other field:
  - Geological prospecting in engineering and archeology
  - Mining
  - Nuclear waste characterization

Status of the muography applied to volcanoes

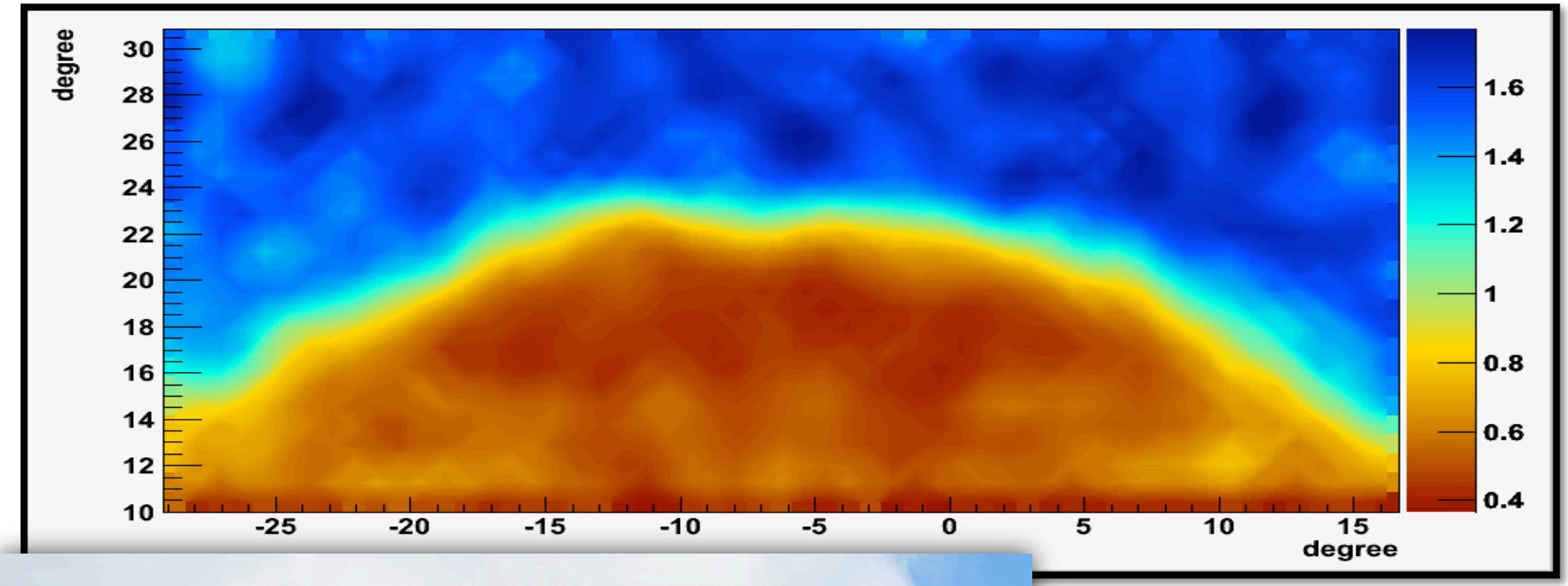
- In the last years we developed a first 1mq prototype and we had two on the field measurement campaigns:
- In May 2013 we had the first technical run on the Vesuvio, mainly devoted to the understanding of the real problem on the field
- In Summer 2013 we had a long (some months) campaign measurement at the Puy De Dome, France, in collaboration with the TOMUVOL experiment (IN2P3 Clermont-Ferrand)

First data from Vesuvio
(six days of data acquisition)

Transmission

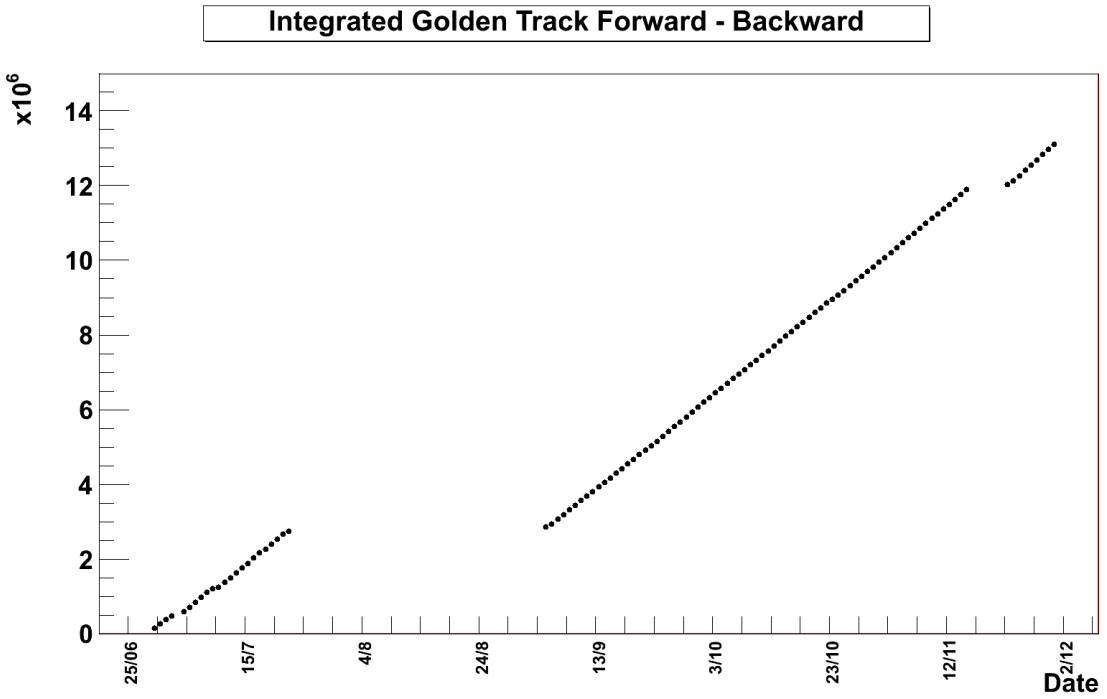


The Puy de Dome's "Shadow"



MuRay - Tomuvol Experiments collaboration in Clermont-Ferrand (France)

The puy De dome campaign measurement



An article MU-RAY/TOMUVOL is in progress

The MURAVES project

- In 2013 we presented to the Italian Ministry of University and Research a joint research project INFN-INGV in the frame of the “Premiale Call” : MURAVES (MUon RAdiography of Vesuvius)
- It consists in the realization of a 4 mq muon telescope to be installed at the Vesuvius and into a gravimetric measurement campaign in order to have an integrated model of the Vesuvius' structure based on muon radiography, gravimetric and seismological data.
- The project was approved and we are waiting for the final bureaucratic acts to access to the funding and start the construction.


Istituto Nazionale di Geofisica e Vulcanologia

INFN Istituto Nazionale di Fisica Nucleare

DECRETO MIUR N. 949/RIC DEL 19.12.2012

PROGETTO PREMIALE - LINEA DI INTERVENTO 2

Radiografia Muonica del Vesuvio

(MURAVES)

STRUTTURA DI RIFERIMENTO
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

EPR COINVOLTO
ISTITUTO NAZIONALE DI FISICA NUCLEARE

Le Scienze
EDIZIONE ITALIANA DI SCIENTIFIC AMERICAN

4 luglio 2014

INFN - INGV: Mare, vulcani e terremoti: INFN e INGV rafforzano la loro collaborazione

Comunicato stampa - Dal monitoraggio vulcanico e sismico allo studio dell'ambiente marino profondo. Un patto per intensificare la collaborazione sui progetti di ricerca nei settori di comune interesse. Infn e Ingv puntano sulla sinergia e la multidisciplinarietà

SULLO STESSO ARGOMENTO
AL SITO
05/07/2003
La possibilità di essere colpiti da un fulmine
08/03/2003
L'energia delle onde dell'oceano
05/12/2001
pericoli del radon
02/01/2014

fisica scienze della terra fisica delle particelle ambiente

Roma, 14 luglio 2014 - Lo studio dell'ambiente marino di alta profondità e il monitoraggio vulcanico e sismico: sono queste le attività di ricerca su cui l'Istituto nazionale di fisica nucleare (INFN) e l'Istituto nazionale di geofisica e vulcanologia (INGV) hanno deciso di puntare in sinergia. I due enti, la cui collaborazione è sancita fin dal 2001 da una Convenzione Quadro, hanno individuato gli obiettivi su cui incentrare e ulteriormente sviluppare la collaborazione nei prossimi a

Il primo obiettivo, internazionale, è intensif

Il secondo obiettivo, tramite il progetto Premiale MURAVES, finanziato dal Ministero dell'Istruzione, dell'università e della ricerca (Miur), prevede l'allestimento di due dispositivi alle pendici del Vesuvio per misurare il flusso di muoni (particelle di origine cosmica). I ricercatori Ingv e Infn faranno così una "radiografia" al vulcano per produrre una mappa di densità in 2D e in 3D ad alta risoluzione della sua struttura sommitale e per tenerlo sotto monitoraggio continuo.

Status of the volcanoes muography

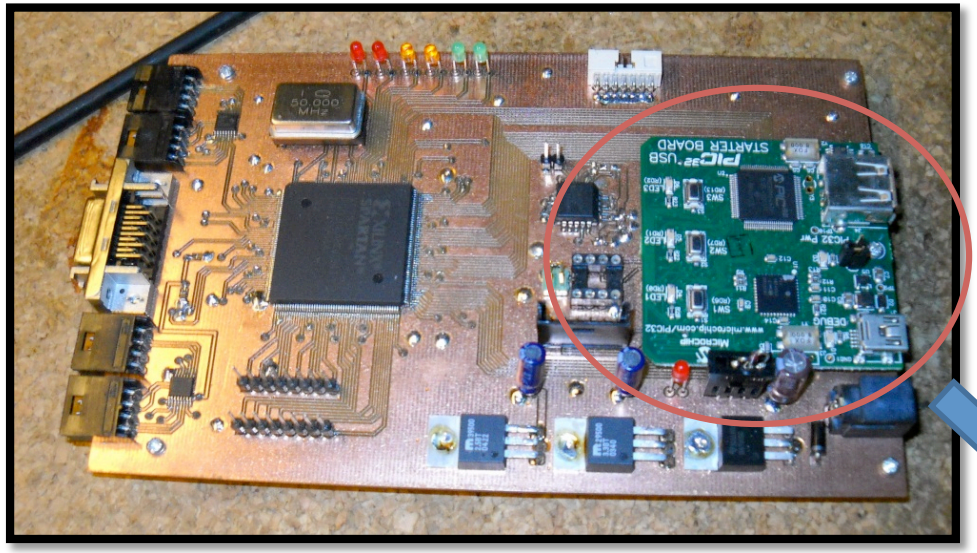
- Main groups active in Europe are TOMUVOL and DIAPHANE, both in France
- Some contacts with a group located in Bristol (.....)
- Outside Europe, Japan, leaded by H. Tanaka, has an important program supported by ERI.
- Probably in the future a more structured collaboration will be needed, to join the forces and make a step further in the volcanoes study.
- We have an Italian-Japan researcher mobility project supported by the Italian Foreign Affair Ministry, that hopefully will give the chance to have a more stable collaboration. The next meeting in Tokyo, in November.

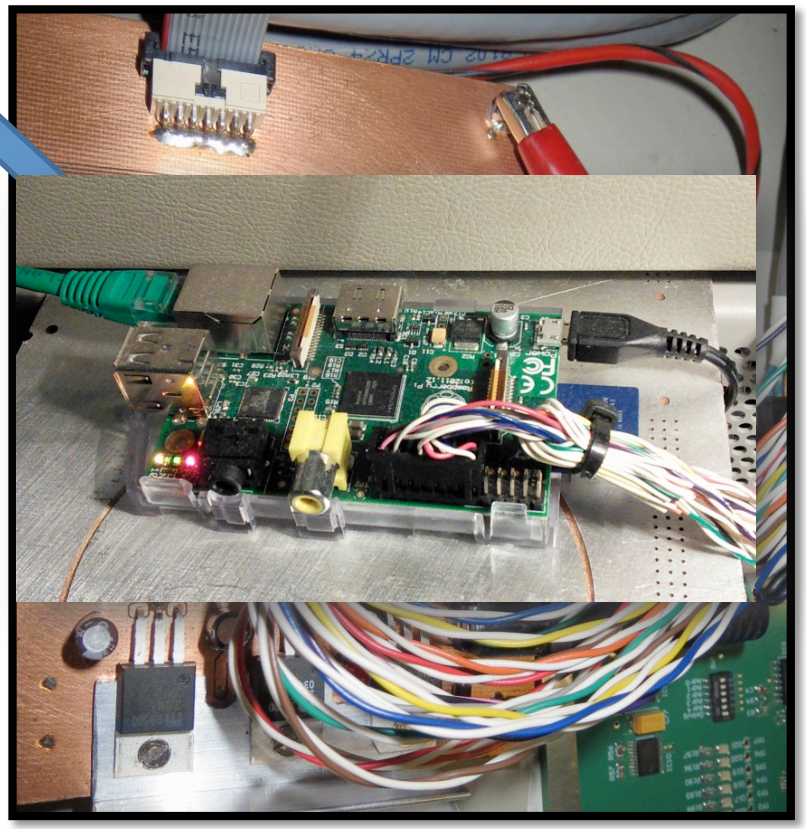
MU-RAY upgrades

- Front-End electronic based on the EASIROC ASIC and Hamamatsu SiPM
- New DAQ based on a Raspberry-pi micro computer directly connected to the MASTER FPGA
- Slow control based on ARDUINO and Raspberry-pi
- Modules containers for easy and safe transportation and installation.

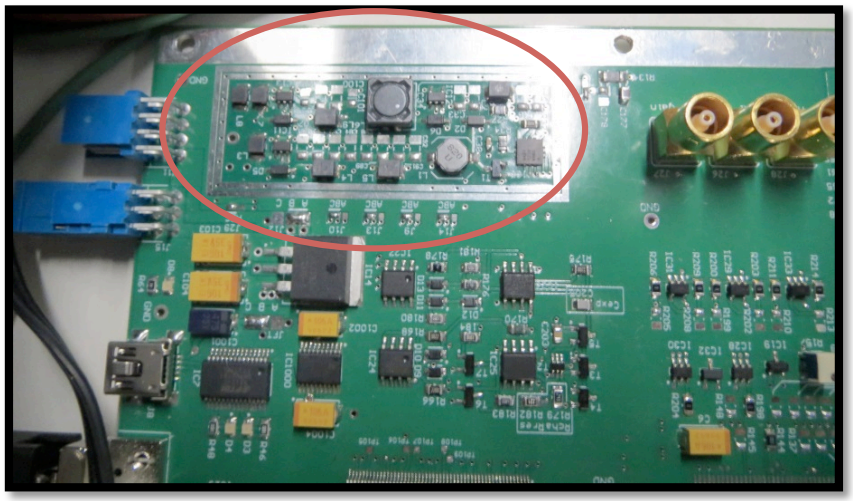
ELECTRONICS UPGRADE

- PIC Board has been replaced by a pin-to-pin connection with the Raspberry Pi GPIO
- Allow for an interrupt based protocol
- Low level management of the communication
- Increase of the data transmission bandwidth
- Reduction of the dead times





- Each slave board has a Switching Power Supply

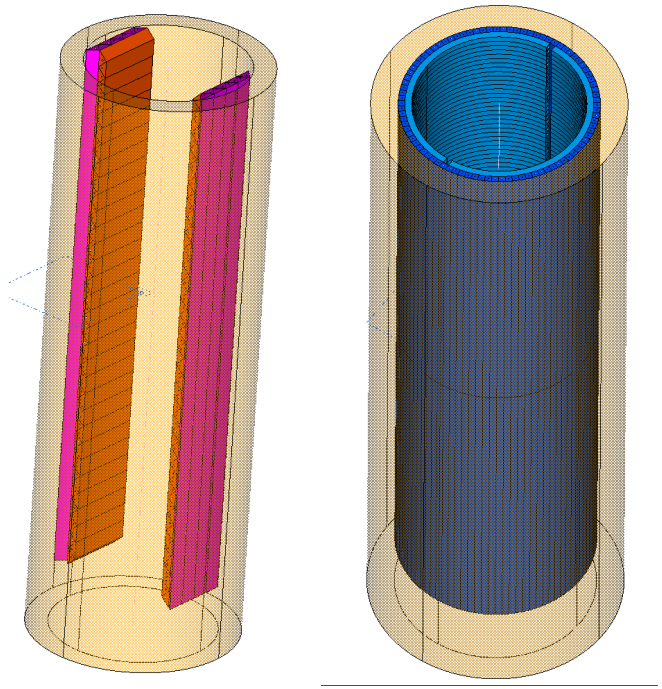


Other MUOGRAPHY applications beside Volcanoes

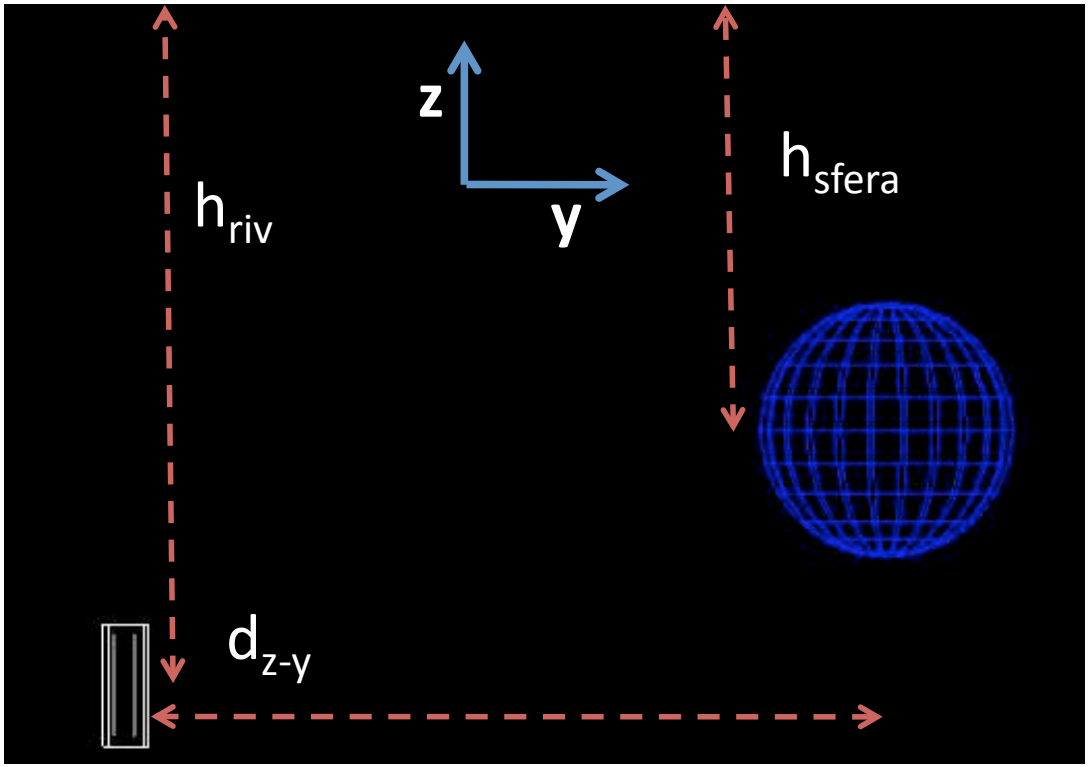
- Since summer 2013 our project MUOGRAPHY is supported by the INFN Technological Transfer group in order to evaluate possible industrial partners interested in muon radiography. Main possible field:
  - Mining
  - Geological prospecting in civil engineering and archeology
  - Nuclear Waste classification

Geological Prospecting in civil engineering and archeology

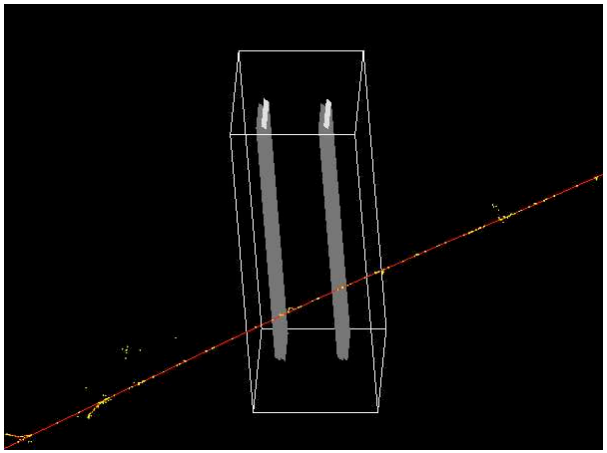
- Use of bore-hole detectors to have less intrusive (and expensive) underground prospecting
- A project has been approved (and funded) in collaboration with an industrial partner.

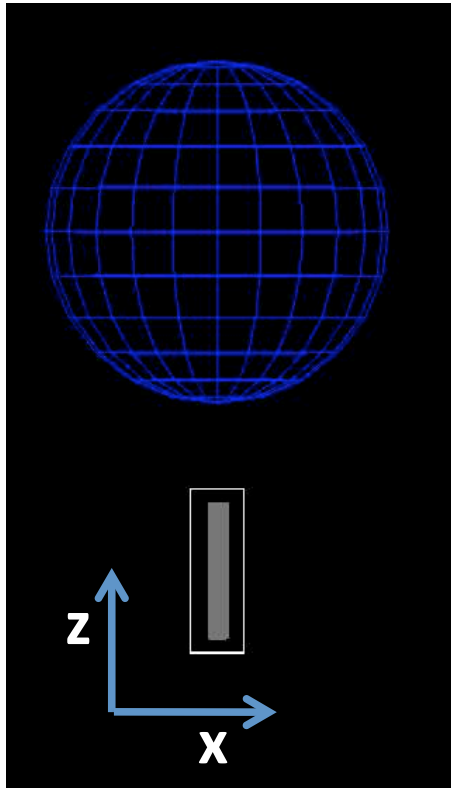


Feasibility study software

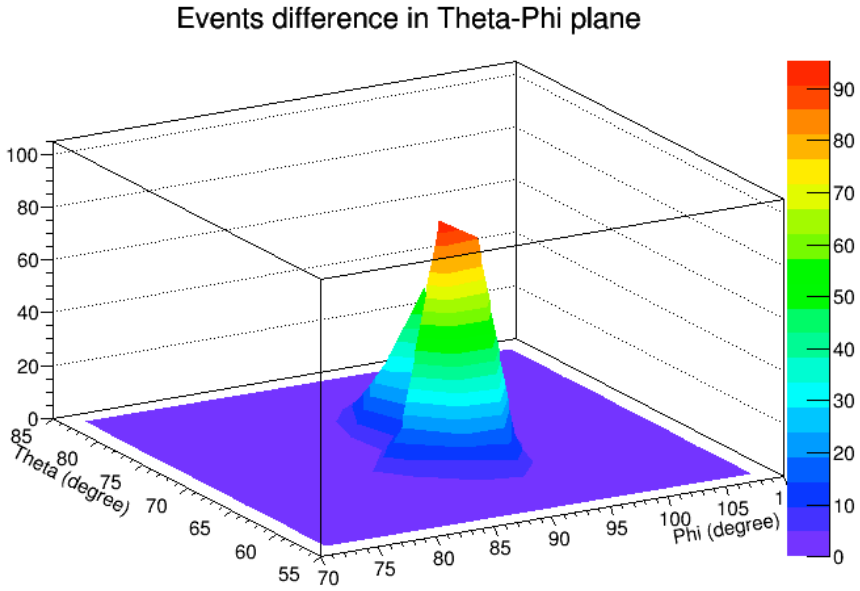


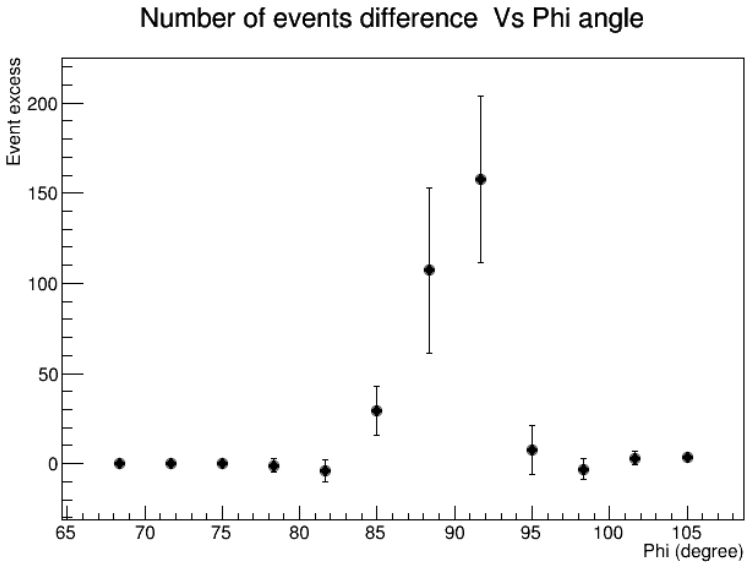
- h_{riv} = 10 m
- h_{sfera} = 7.5 m
- d_{z-y} = 7.5 m
- R_{sfera} = 1.25 m ($8m^3$)
- $\rho_{terreno}$ = 1.5 g/cm^3

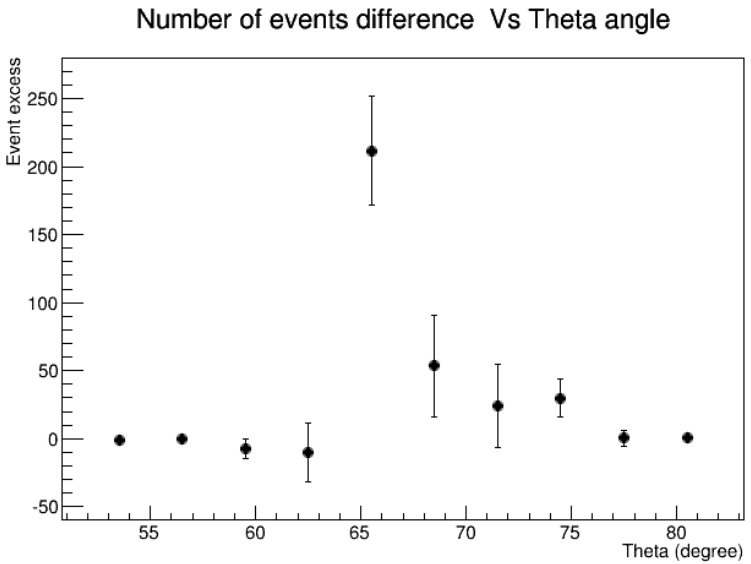




Spherical cavity (90 hours)







Applications in archaeology

- **Contacts with archaeologists** of the Florence and Bologna Universities since 2013
- Muon radiography could **replace other methodologies** in particular cases and could give complementary information in the general case
- Possible **interesting sites already identified**:
  - Tharros (Oristano, Sardegna)
  - Grotta d'Oriente and Grotta delle Uccerie (Favignana, Sicilia)
  - Grotta del Romito (Cosenza, Calabria)

GROTTA D'ORIENTE (~ 40 m. a.s.l.);

THARROS NECROPOLIS

What about the Nuclear Waste Classification?

- Since our collaboration started we had several opportunities to show the possible applications to the Sellafield case to INFN management.
- We had always positive feedbacks
- We had also some contacts with industrial partners and with SOGIN, the state society in charge for the decommissioning in Italy.

Real applicability of muography in the Nuclear Waste characterization

The main feedback from these interactions concerned:

- Minimum quantity of material detectable
- Time needed for the measurement
- Costs

Monte Carlo simulation

Some of these answers from the work of Nicola and David

see next talks, Nicola final report, article in progress.

More work needed?

not all the question have been answered, short time

some experimental test needed?

Muography by absorption: Experimental set-up

A tank filled with concrete can be charged with different sample of material.
At the moment lead under measurement.

Final remarks

The main questions to answer are:

- From the results we obtained until now which are the prospective applications to the Sellafield scenario (in particular for the absorption technique) ?

- Which kind of collaboration can we image, if any, ?