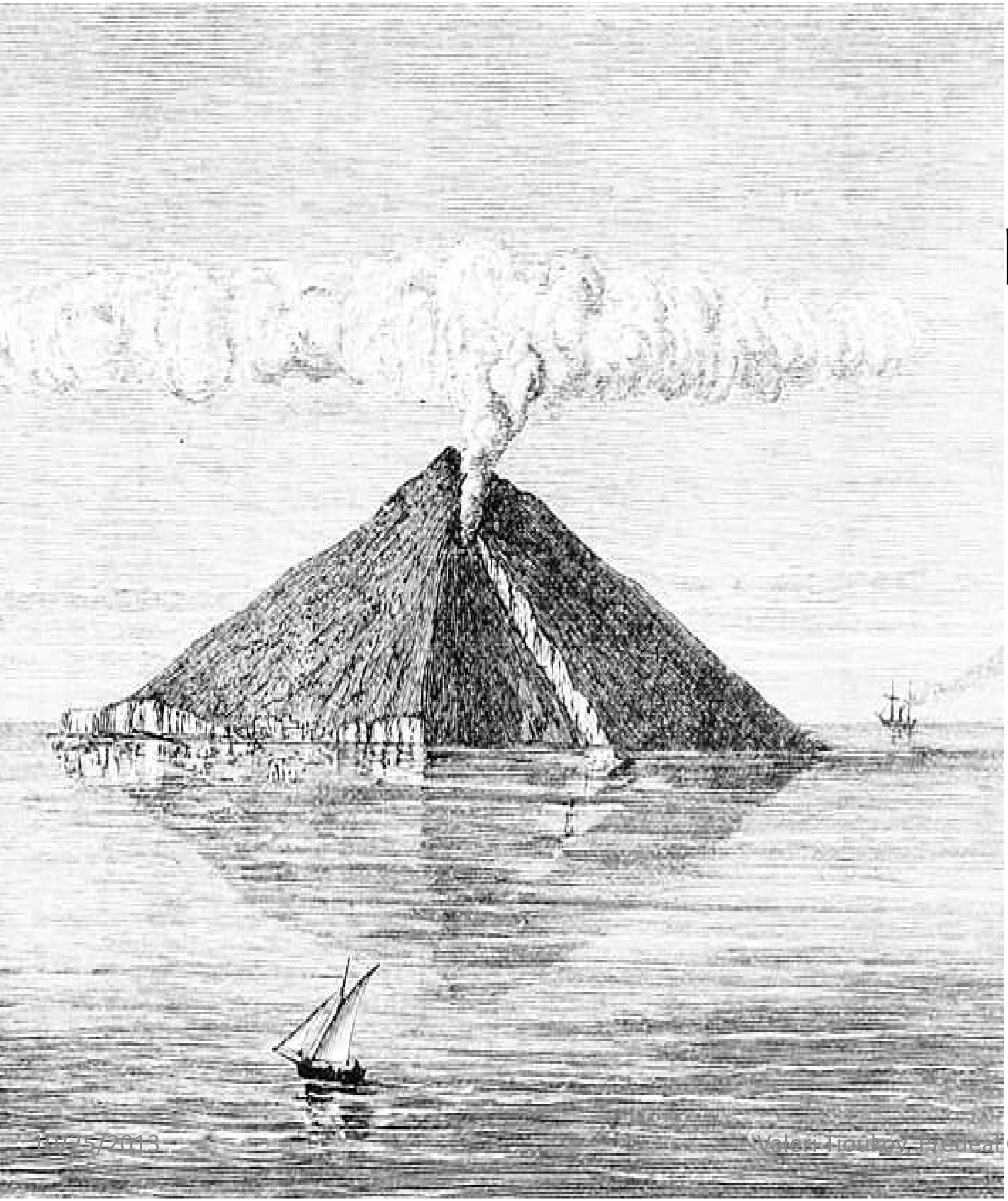


Muography with nuclear emulsions Italy

Valeri Tioukov[1], Giovanni De Lellis[1], Andrey Aleksandrov[1], Lucia Consiglio[1], Andrey Sheshukov[1], Tatiana Shchedrina[1], Massimo Ora Rosario Peluso[2], Cristiano Bozza[3], Chiara De Sio[3], Simona Maria Stellacci[3], ChiaraSirignano[4], Nicola D'Ambrosio[5], Seigo Miyamoto Ryuichi Nishiyama[6], Hiroyuki Tanaka[6], Mikhailo Vladimirov[7]

[1]University of Napoli / INFN, Italy, [2]INGV - Napoli, Italy, [3]University Salerno / INFN, Italy, [4]Universityof Padova / INFN, Italy, [5]INFN - LN Italy, 6University of Tokio, Japan, , [7]LPI - Moscow

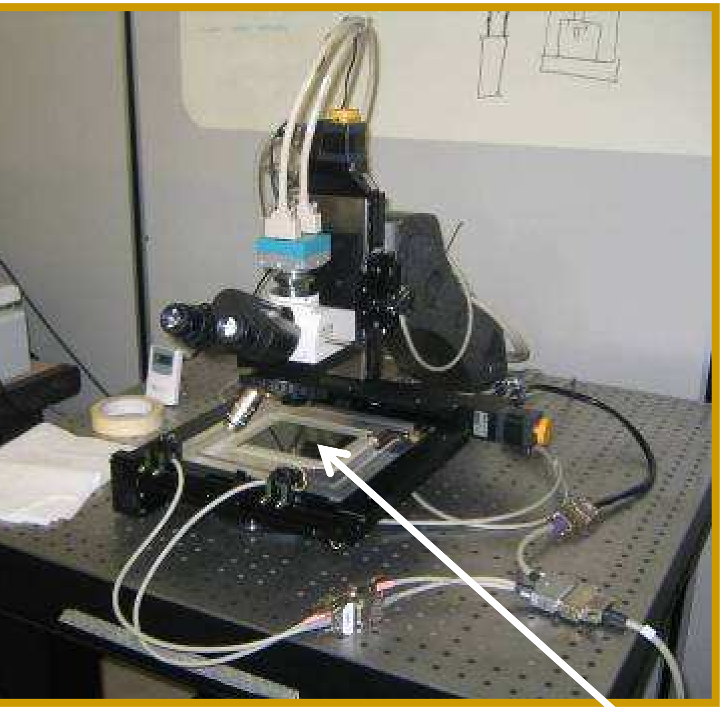
Outlook

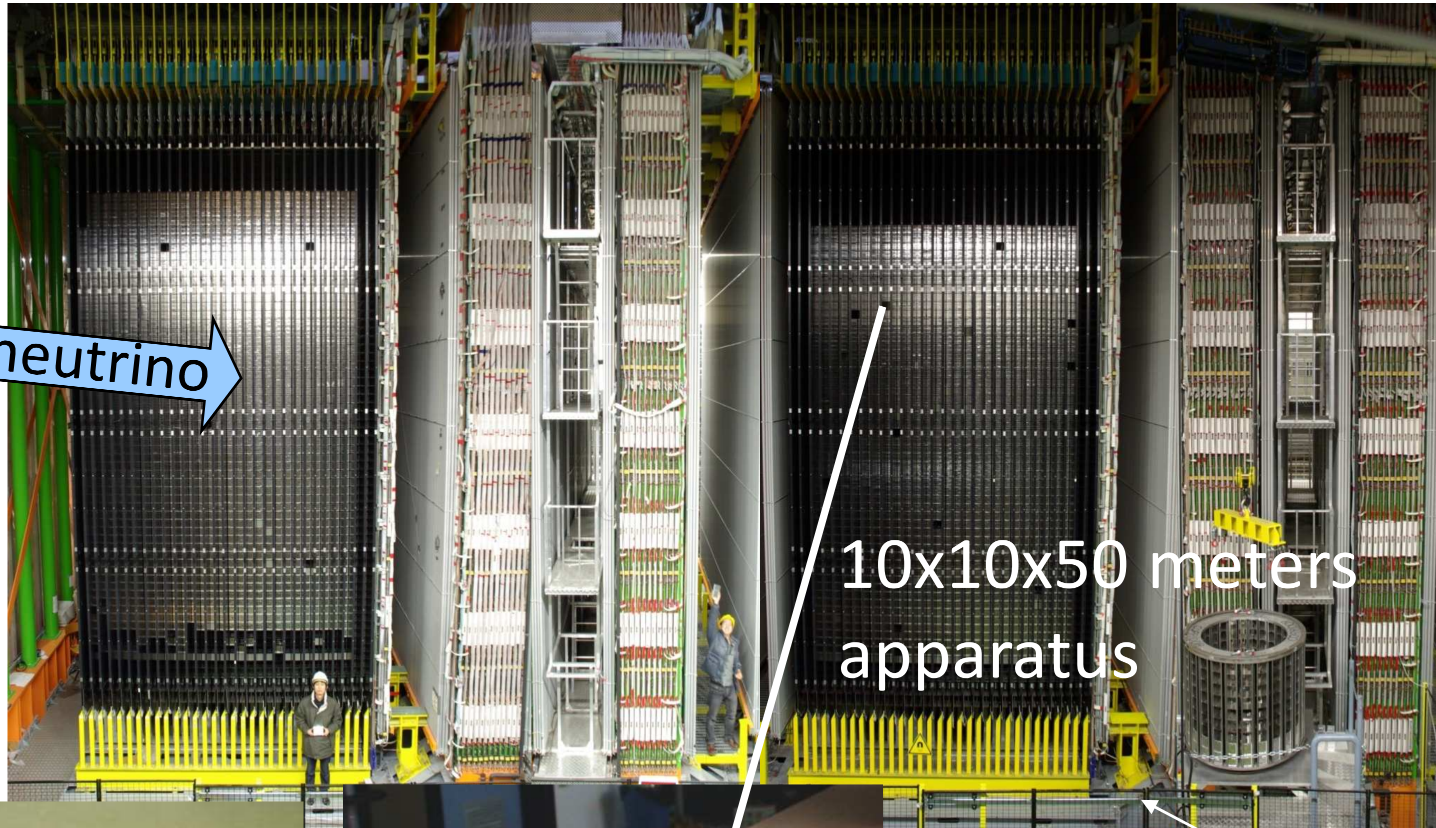
- Nuclear emulsion laboratories and experiments in Italy
- Recent Muon radiography projects with Italian emulsion laboratories involved
- Stromboli exposure 22-Oct-2011 - 24-Mar-2012 for 154 days
- Potential and prospective of muography with nuclear emulsion in Italy

Emulsion projects and laboratories in Italy

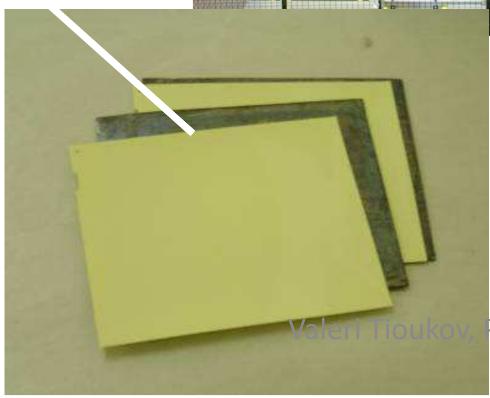
- Main business is fundamental Particle Physics (neutrino experiments in particular)
- 1990 – 2002 CHORUS experiment
- 2002 – now OPERA project
- Emulsion scanning laboratories in Italy (OPERA participants)
  - Napoli, Salerno, Gran Sasso, Bari, Bologna, Padova
  - About 30 scanning systems were constructed in Italy for OPERA scnning
- Since 2011 – some laboratories are involved in Muography projects
  - Napoli, Salerno, Gran Sasso

The OPERA detector: 8.9 mln films with the total emulsion sensitive surface of 200000 m^2



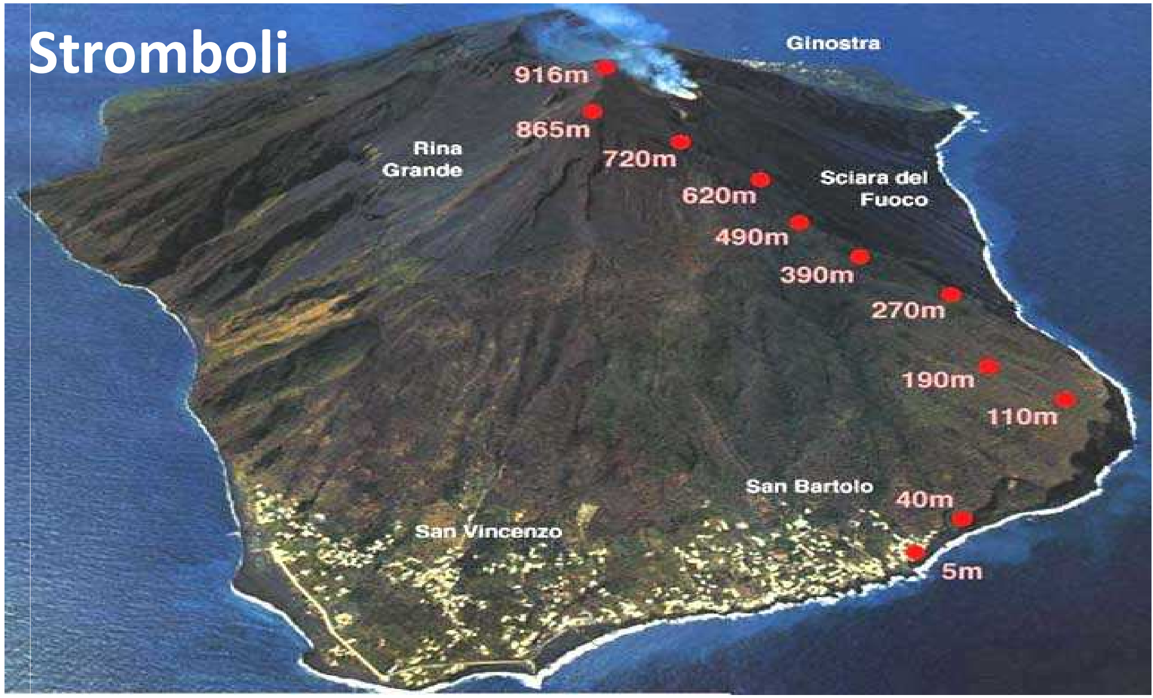


CC “brick”
7 emulsion plates
6 lead plates
0x12x7 cm, 8 kg



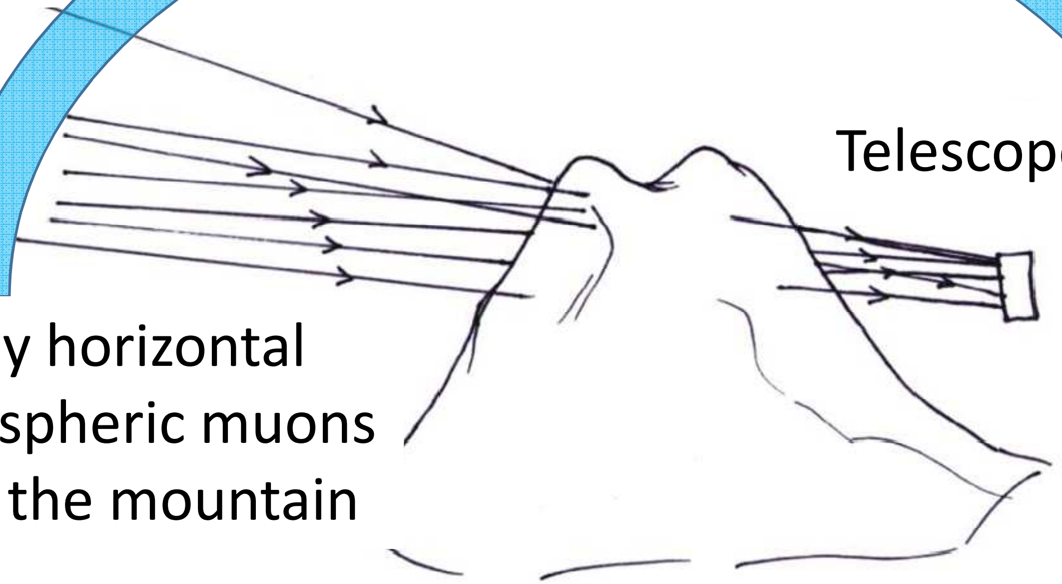
ıography emulsion projects with
rticipation of Italian laboratories

Jnzen - data analysis is in the final phase
Stromboli – half statistics, first results
Teide – exposure is completed, scanning is started



kov,

The principle of muon radiography



rly horizontal
ospheric muons
s the mountain

- The method is limited to the upper part of the mountain above the detector
- Low muons rate do not allow to have short exposure – months is a typical time scale
- 1 km of the rock thickness is an approximate upper limit for 1-few m^2 detectors with few months exposure

- It's assumed that the muon flux and spectrum well known and nearly constant
- Assumed the precise knowledge about the mountain shape
- What we can obtain is the angular map of the average rock density using the muons **absorption** information
- Detector should provide precise angle for each particle passed through

Emulsion is a good candidate!

Motivations for the Stromboli exposure

- Stromboli is one of the most known and most active volcanoes in the world
- Great amount of monitoring equipment is installed on the volcano slopes, but the exact internal structure of the region below craters is not well understood yet
- There is a possibility that the explosion source mechanism is representative of two cracks dipping $\sim 60^{\circ}$ that are located approximately 220-260 m, beneath the active craters, probably representing parts of an echelon system of fissures
- muon radiography can be an independent technique for investigating the internal structure of the cone and revealing the location and extent of the conduits that feed the continuous explosions
- Region under "Sciara del Fuoco" is the one of our interest

Motivations for muon radiography of active volcanoes,
G. Macedonio and M. Martini, *Earth Planets Space*, **61**, 1–5, 2009


3
collasso vulcano
Vancori
4
collasso vulcano
Neostromboli
bocca
eccentrica
Neostromboli
ordo caldera
romboli II°
Sciara del
Fuoco
5
cratere
attuale
da 5000 anni fa
ordo caldera
tromboli I°

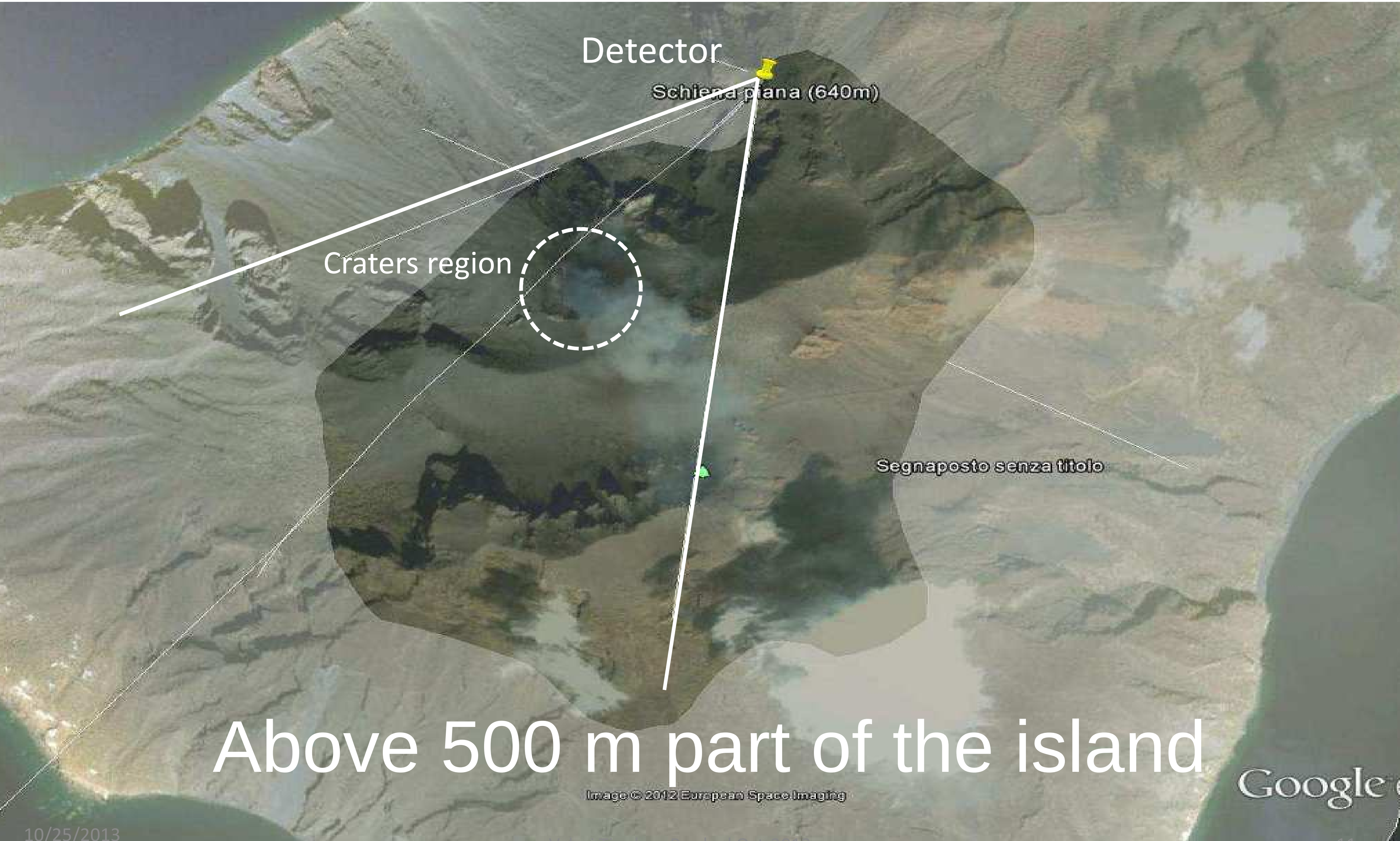

Ginostra
916m
865m
720m
620m
490m
390m
270m
190m
110m
40m
5m
Rina
Grande
Sciara del
Fuoco
San Bartolo
San Vincenzo

Good place for the detector installation was individuated in May 2011 (the only relatively flat at this altitude)

View from the detector position (6

Craters region (750 m)

Sciara del fuoco


Detector
Schiena piana (640m)
Craters region
Segnaposto senza titolo
Above 500 m part of the island
Image © 2012 European Space Imaging
Google

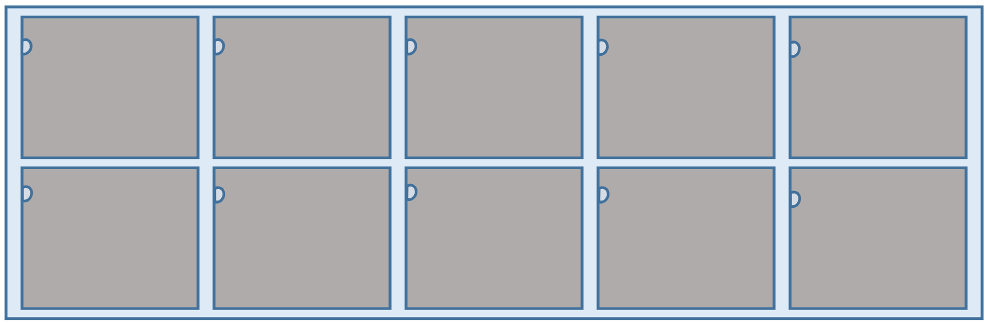
Example of the elevation profile

Stromboli has not so sharp cone - only a part of edifice can be monitored with a middle-size muon telescope

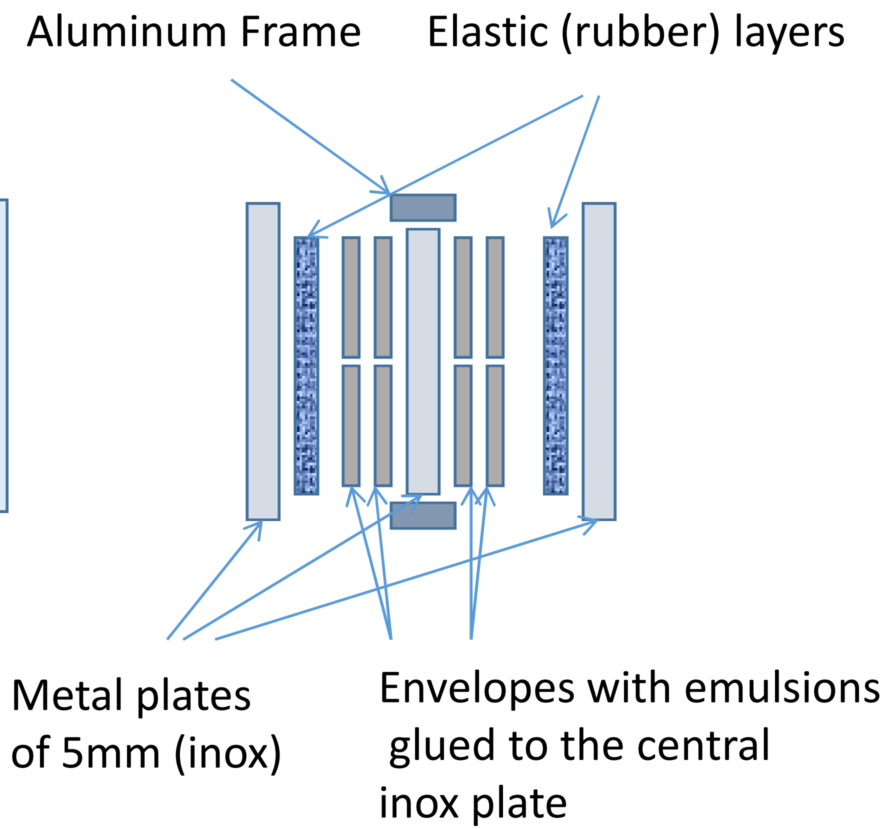
Scheme of the internal module structure

One module with 10 emulsion “cells”
Each cell has 2 emulsions doublets attached to both sides of the central metal plate.

Front view of the central plate (26 x 80 cm)



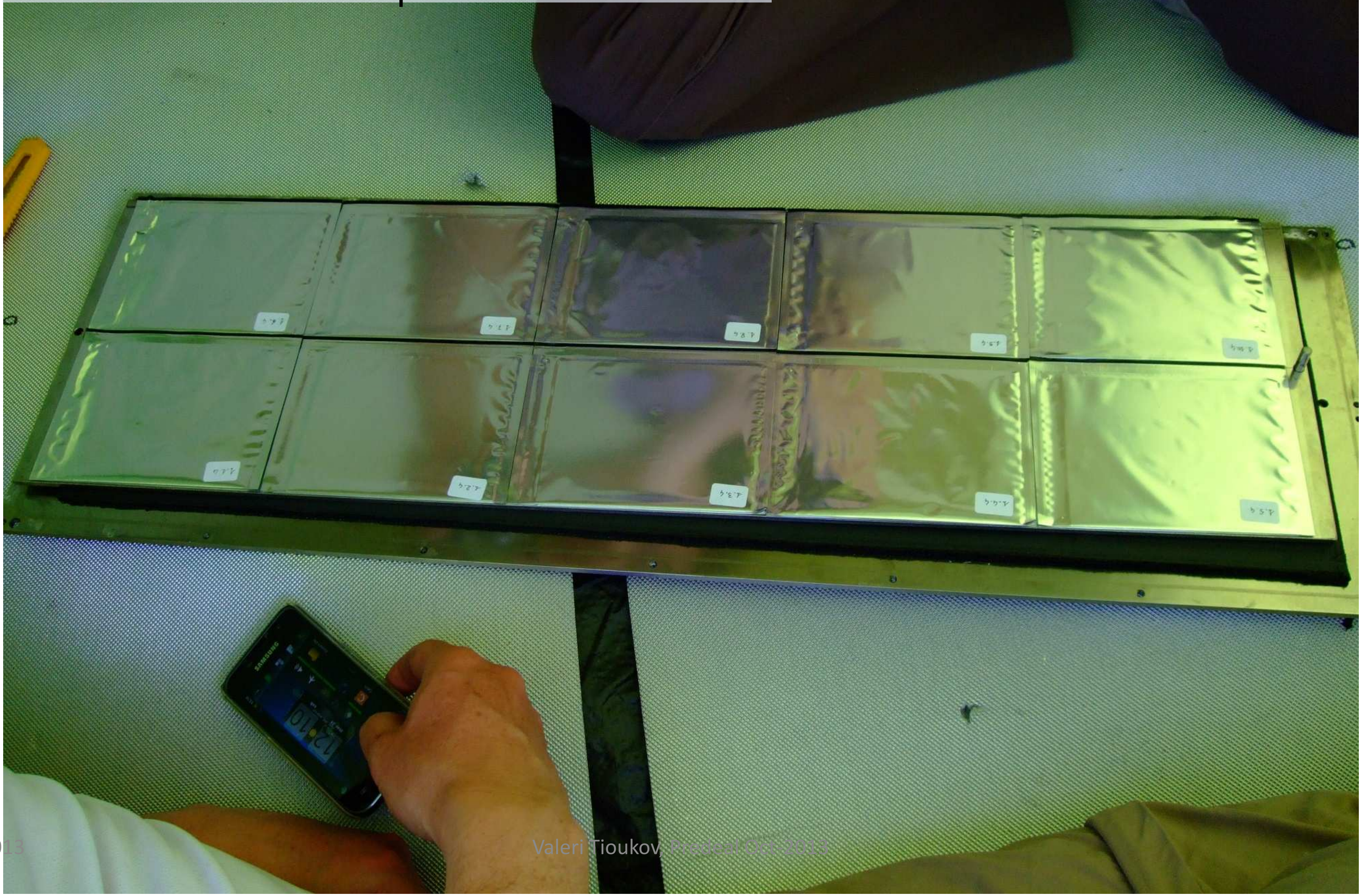
“Exploded view”

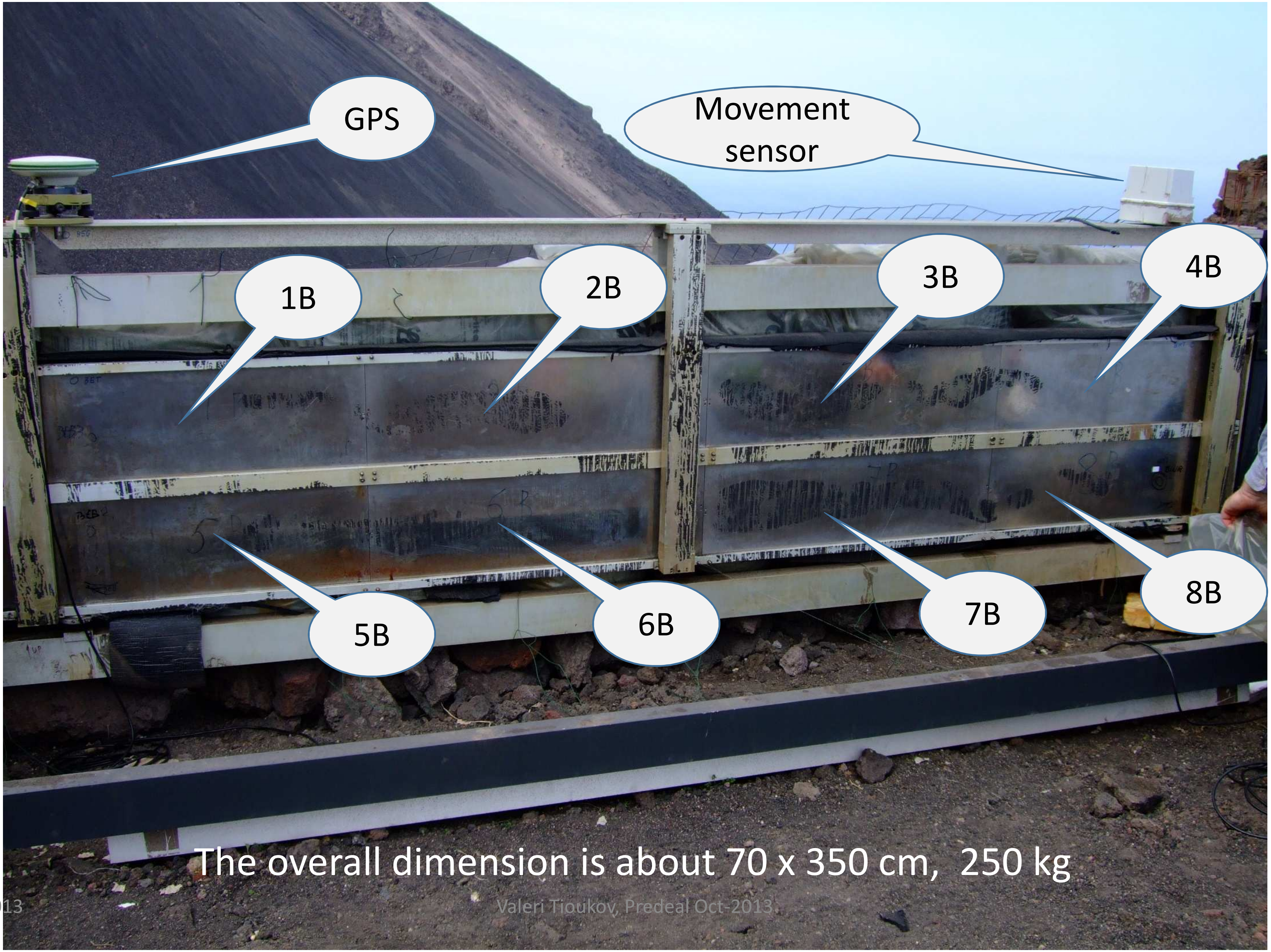


The total weight of one module is of 26 kg
Total amount of emulsions/module: 40
The active surface covered is of 1200 cm2

The overall weight of 8 modules and the support frame is about 250 kg

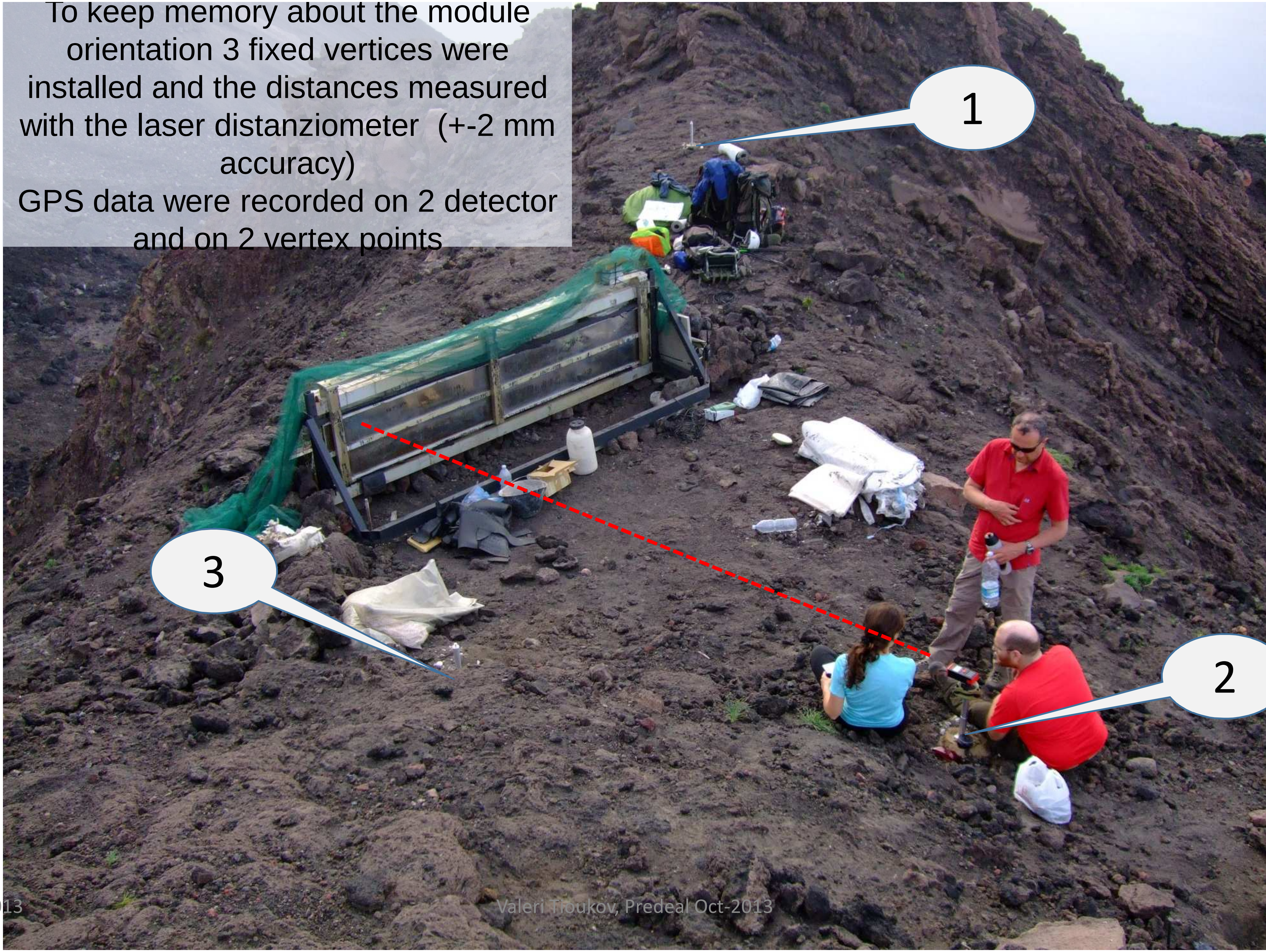
Emulsions extraction after 5 months exposure. The envelopes are in a good shape




GPS
Movement sensor
1B
2B
3B
4B
5B
6B
7B
8B
The overall dimension is about 70 x 350 cm, 250 kg

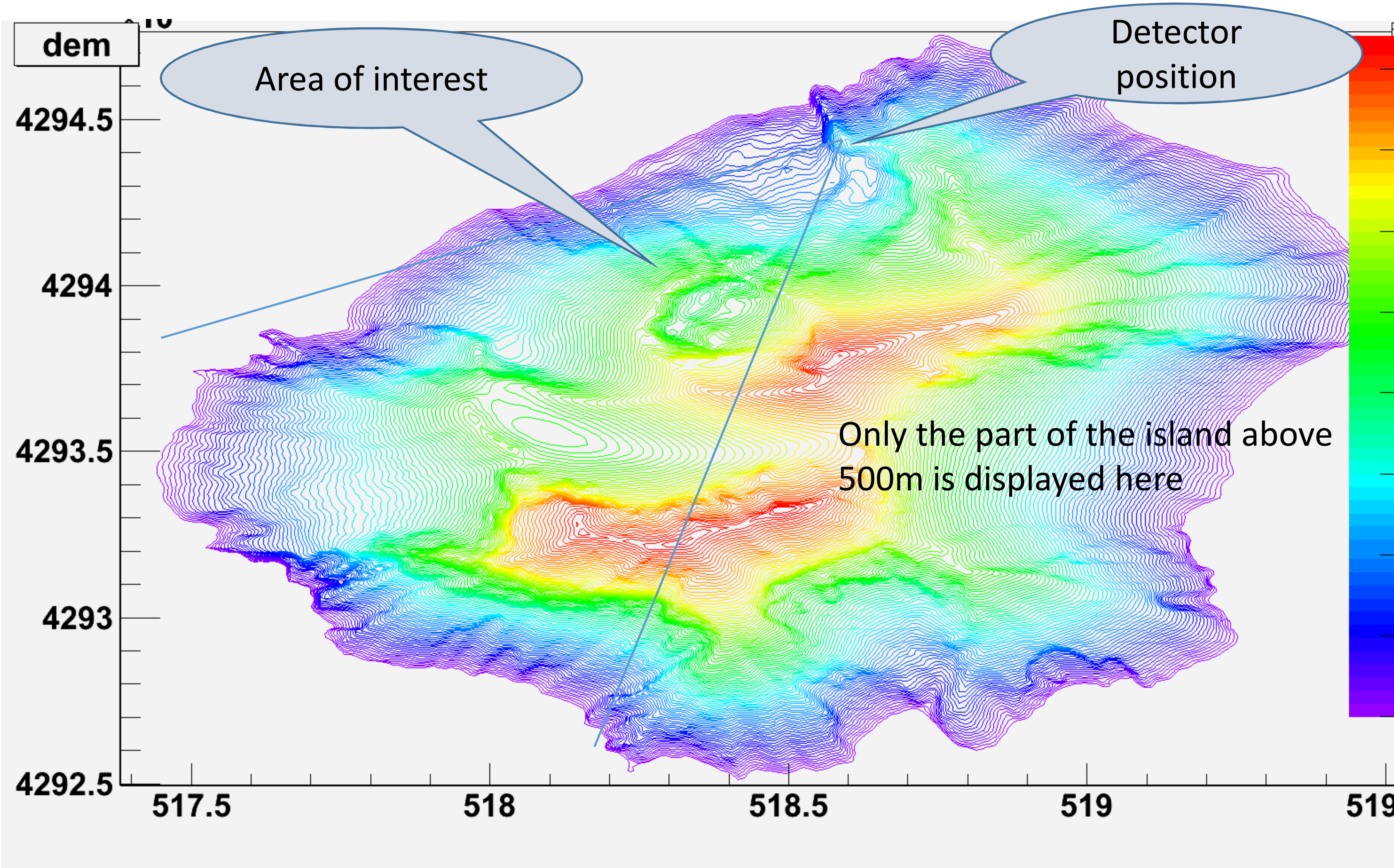
After 5 months of data taking we found the detector in a good shape well protected from sun heating and from moisture by rubber foam (armaflex) and by expanded clay

To keep memory about the module orientation 3 fixed vertices were installed and the distances measured with the laser distanziometer (+-2 mm accuracy)
GPS data were recorded on 2 detector and on 2 vertex points



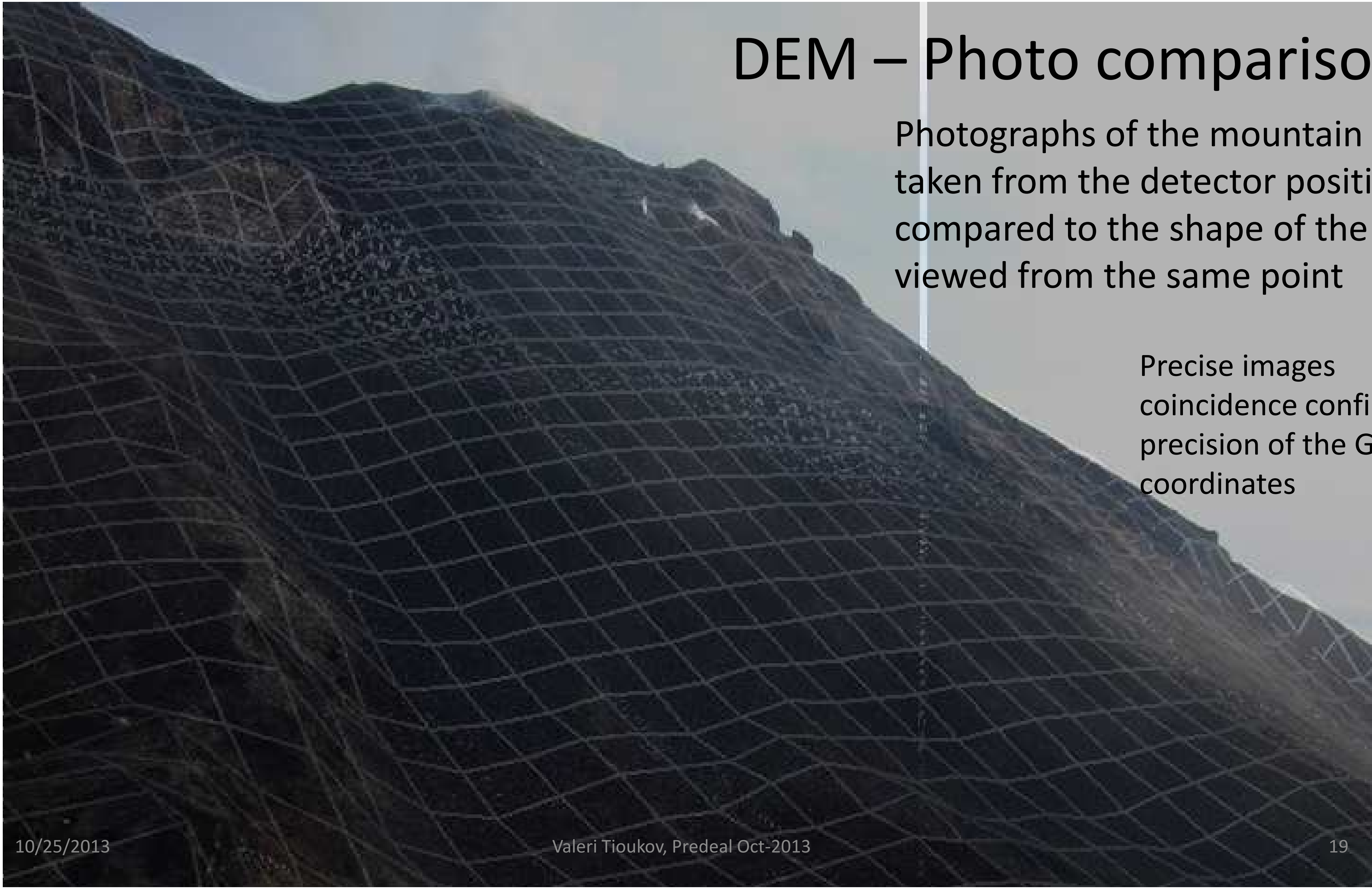
e data analysis assume the precise owledge about the mountain shape

ise and up to date
tal Elevations Map
M) Is required



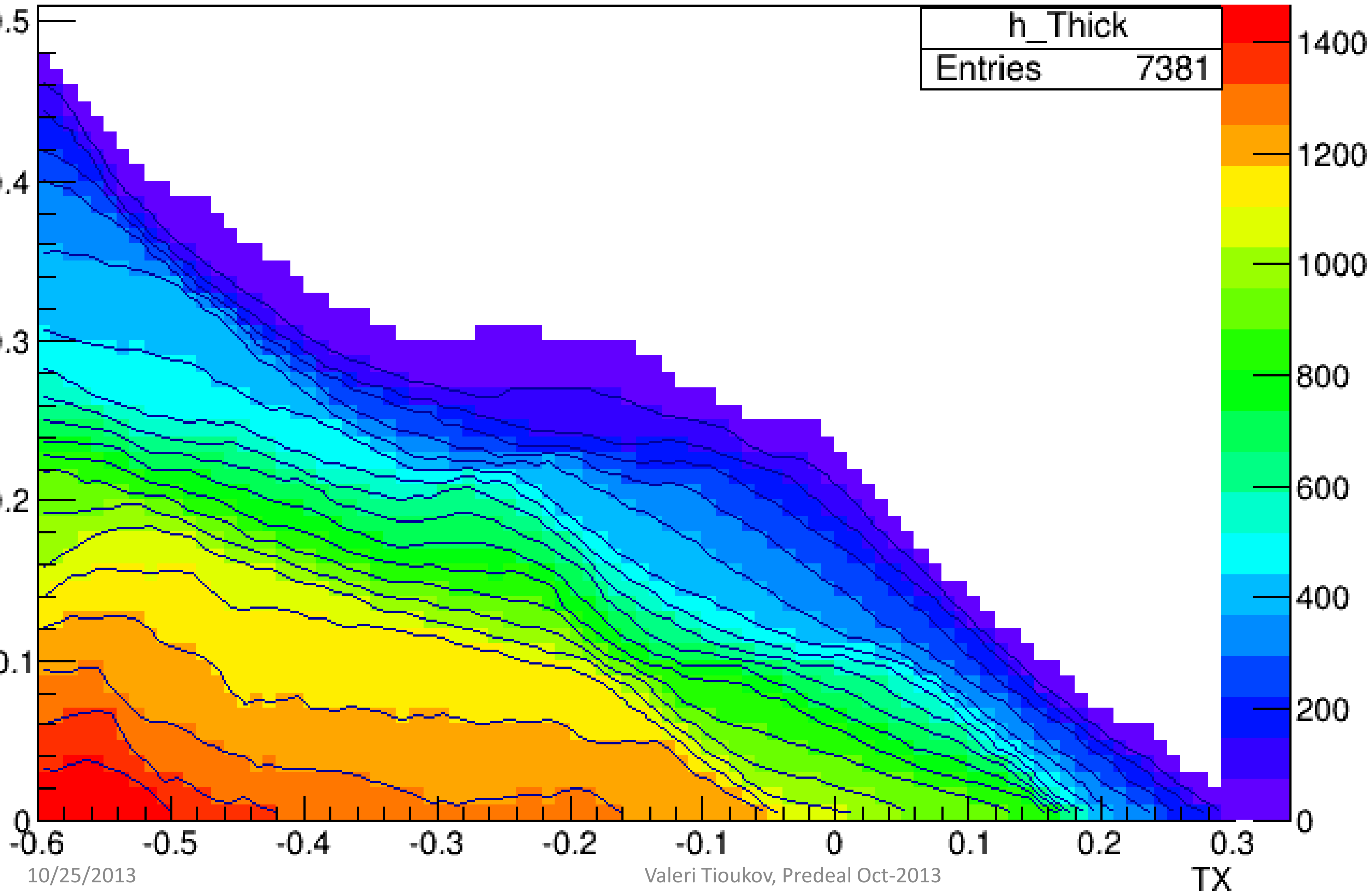
DEM – Photo compariso

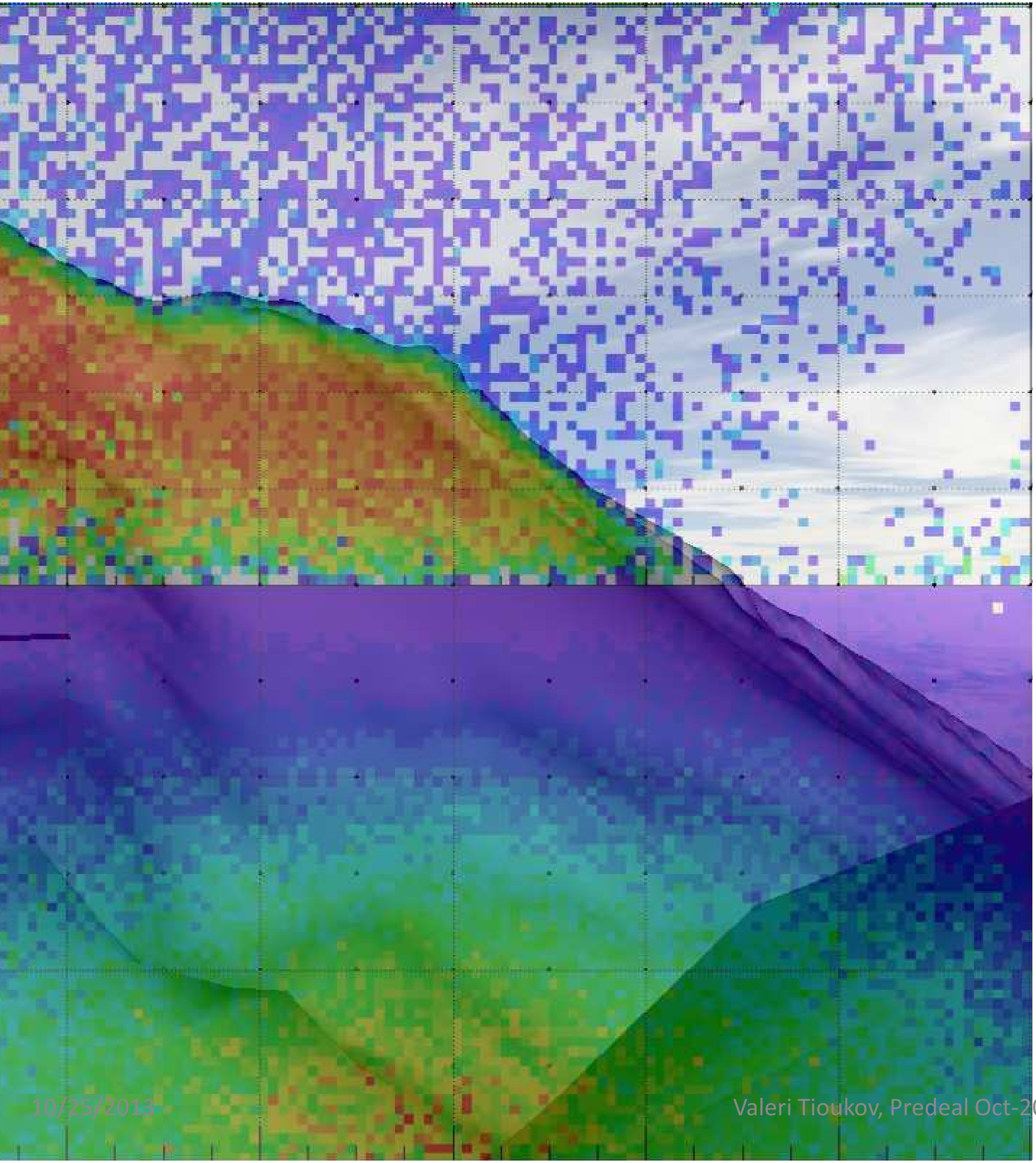
Photographs of the mountain
taken from the detector positi
compared to the shape of the
viewed from the same point



Precise images
coincidence confi
precision of the G
coordinates

Rock thickness

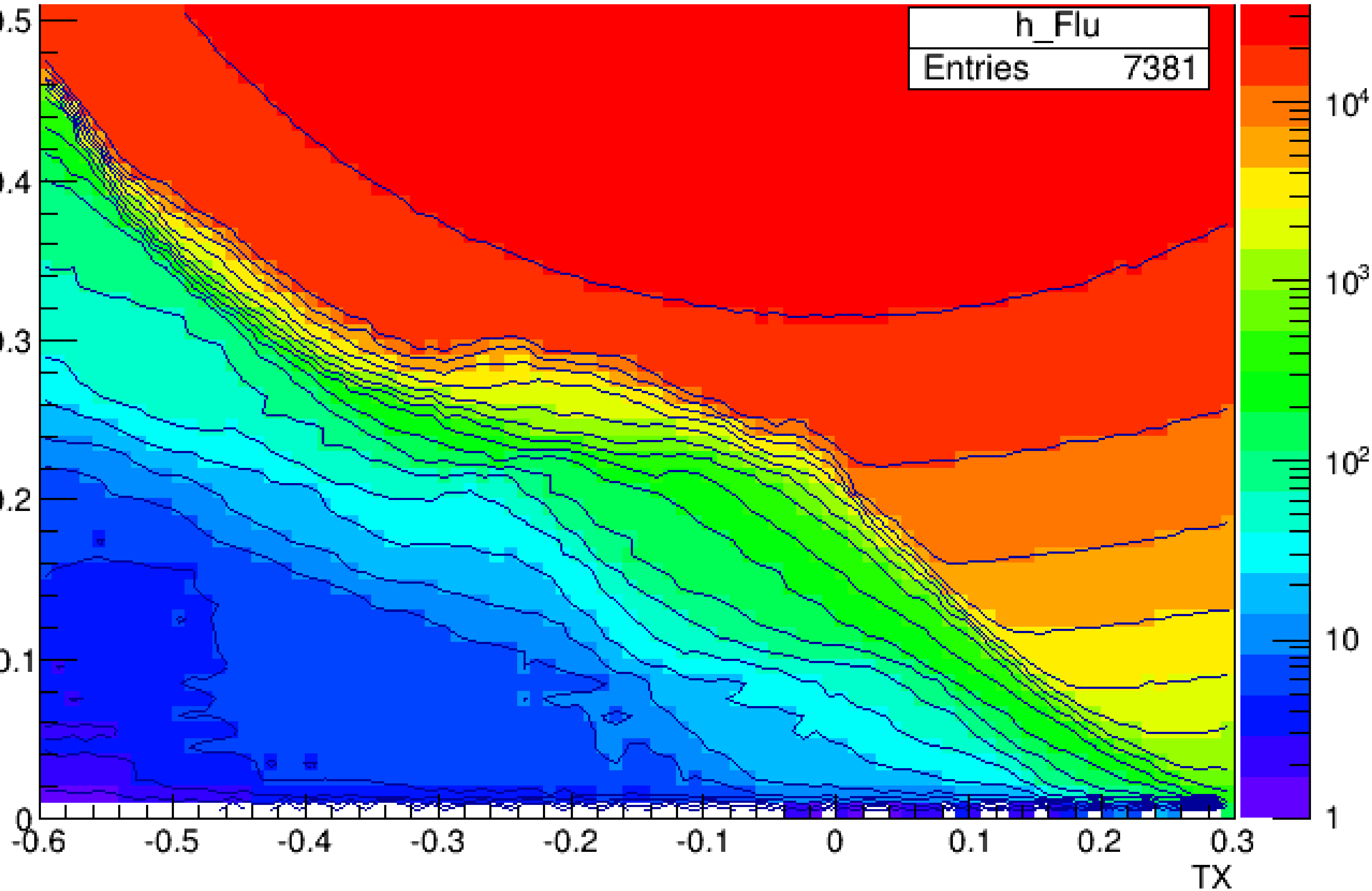


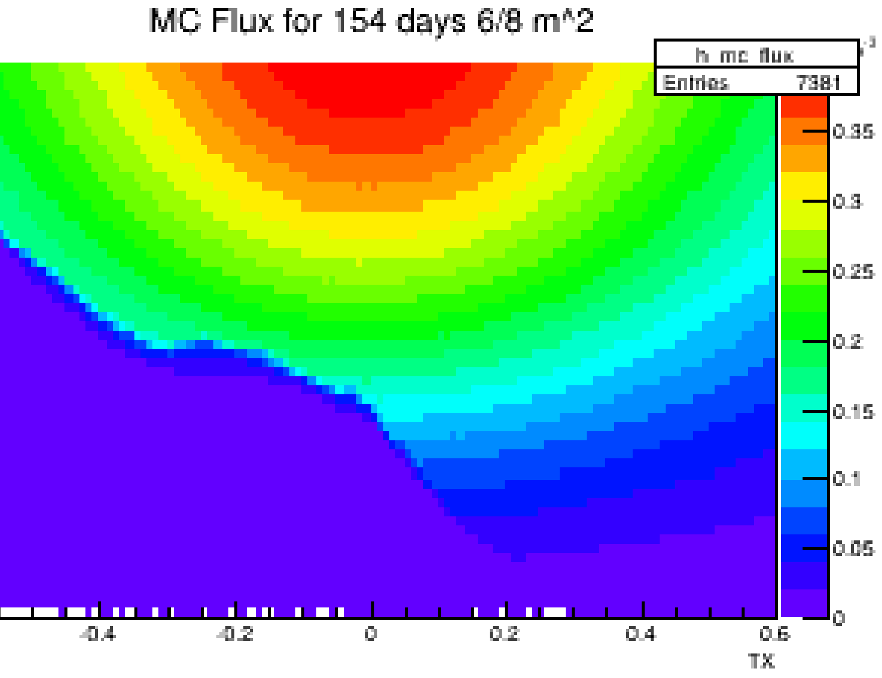


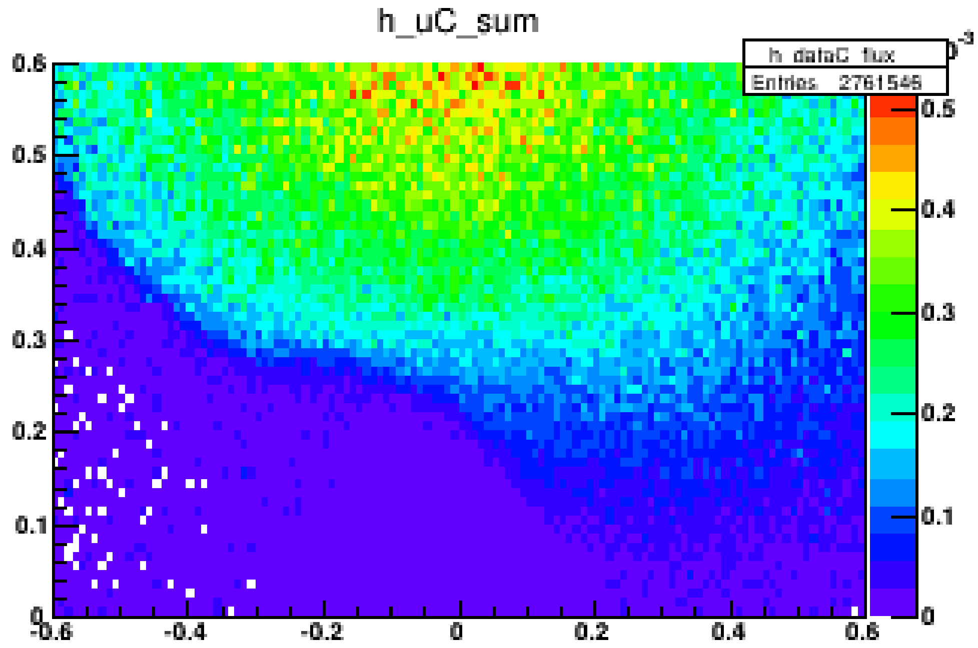
DEM – Data comparison

- Dem view
- Data tx-ty distribution
- Dem-data superimposed
- Data absorbed part
- em-data absorbed superimposed

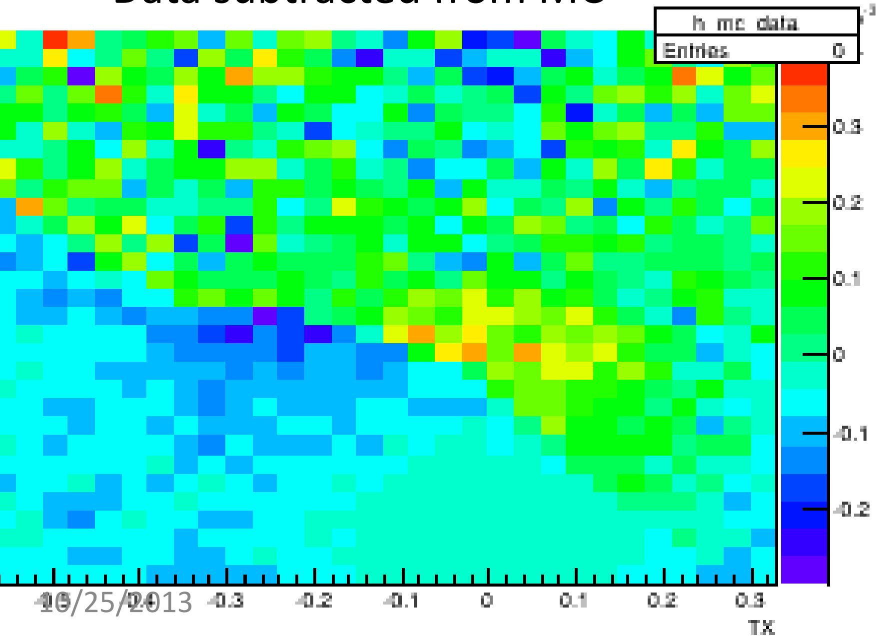
MC Flux for 154 days 10 m^2







Data subtracted from MC



The first exercise of data-MC comparison on the incomplete statistics

- We observe some data excess in a crater region in respect to MC, this can be a sign of lower density
- It is difficult yet to judge about more fine effects
- We plan to perform additional study to refine efficiency and background angular dependency corrections

Nuclear emulsions as a detector for muon radiography

Advantages

•Perfect intrinsic angular resolution (better then 2 mrad)
•Compact and easy to transport
•No electricity required
•Can be installed in a harsh environment
•Modular, can be installed inside narrow locations

Disadvantages

•No time information (can be solved in some cases)
•Complicated and time-consuming data acquisition – required special scanning systems
• accepted temperature range for long-term exposures is below 25 C
•Single-use sensitive part

Able to provide new information complimentary to other methods used for volcanoes survey

Prospective and potential for emulsion muography in Italy

- Currently - a by-product of the technology developed for neutrino physics
- The scanning power used in Italy for Unzen-Stromboli-Teide emulsions scanning is equivalent to 2 scanning systems used 30% of time
- Resent scanning speed is about 20 cm^2/h/layer so minimum time required for the full scanning of Stromboli-like detector ($1m^2$ x 8 layers) is of 170 days
- In a near future (1-2 years) with OPERA load going down the available scanning power may become about 10-20 SS 100% available for muography - this means factor 30 speedup
- Scanning systems HW upgrade is coming (see morning talk) with additional factor of 5 minimum increase of the scanning speed
- In a short time scale we can acquire a potential to perform the analysis of 1 m^2 emulsion telescope in just a few days!
- This makes emulsions an attractive option also for a large-scale muon telescopes, multy-points exposure (tomography) and for industrial applications


La Sciara del Fuoco al tramonto
Thank you for your attention!