Applications and perspectives of Muon Radiography: the experience in Italy

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- **Outline**
- **Vesuvius and the MU-RAY Project**
- **Stromboli**
- **Etna:** ***see the contribution by D. Gibert***
- **Final remark**

Outline: Vesuvius and Stromboli

- **Vesuvius**
  - **Extraordinary public interest**
  - **1.8 km rock to see the bottom of the 300 m deep caldera**

⬇

Improve the sensitivity, a challenge
MU-RAY plastic scintillator telescope
Prototype being tested in lab
(talks F. Ambrosino, R. D'Alessandro)

- **Stromboli**
  - **Special scientific interest**
  - **~ 2 km rock to see the conduit, harsh environment: MU-RAY telescope in some future?**
  - **Top part of the conduit:** ***nuclear emulsion exposure just finished (talk A. Russo)***

Outline (2)

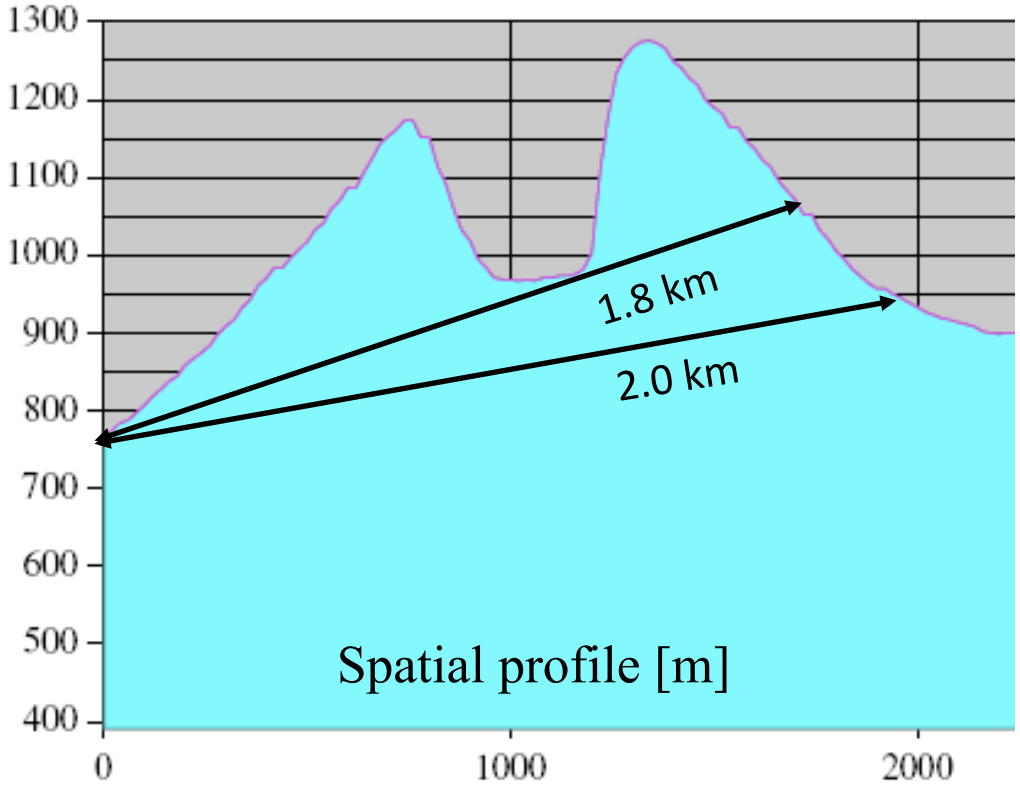
- **Phlegrean Fields**
  - system of small volcanoes north of Naples
  - bottom of calderas ~ at level of surroundings

- **Etna**
  - large rock thickness

  (see contribution to Round Table by D. Gibert)


Marigliano
Nola
Punta del Nasone
(1132)
Cognoli di S.Anastasia
(1086)
Cognoli di Ottaviano
(1112)
Canalone
dell'Arena
Mt. Somma
and its caldera
Valle del Gigante
(885)
Sommità
del cono
(1281)
Valle
dell'Inferno
(830)
Atrio del Cavallo
(831)
Stazione Superiore
(1158)
Fondo del Cono
(951)
La Capannuccia
(1170)
"Gran Cono" of Mt. Vesuvius
with its 300 m deep caldera

Rock thickness at Mt. Vesuvius



1.8-2 km rock thickness from a telescope at 750 m a.s.l.

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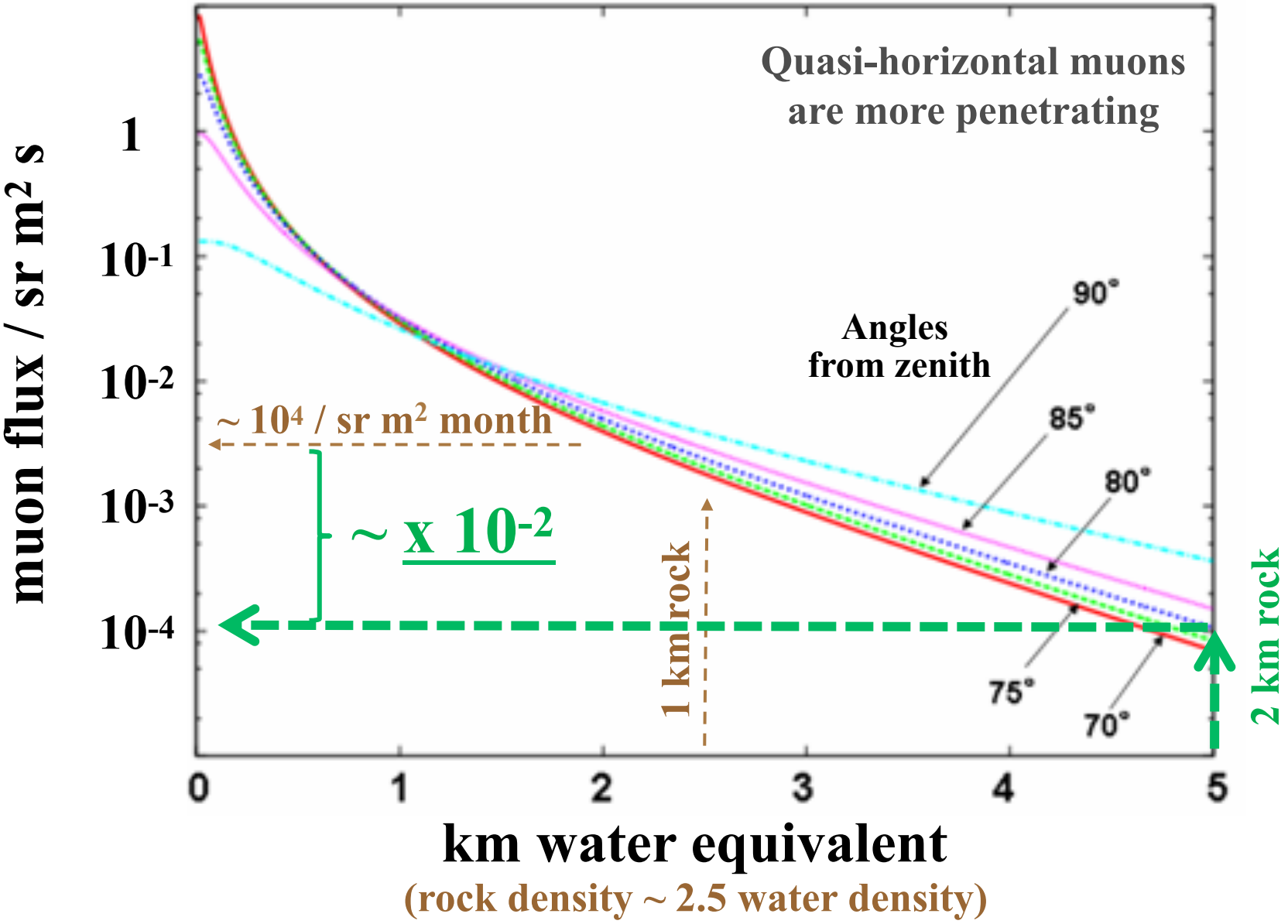
Improve the sensitivity

with respect to previous radiographies (< 1 km rock)

The sensitivity must be improved by 10^2



Plot from HTM Tanaka et al., EPS 62 (2010) 119

How to improve the sensitivity x 10^2

- **Area: 1 → 10 m² or more** (array of telescopes)
- **Data taking: months → years**
- **Background rejection: new tools**

Background is the critical issue

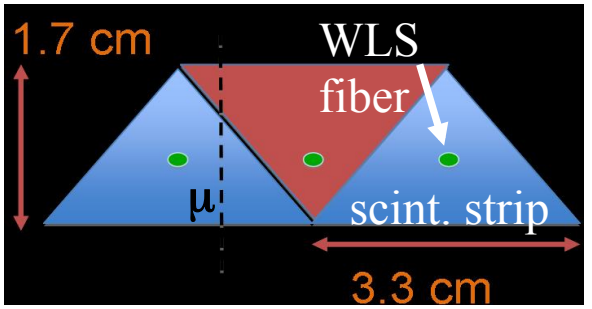
Large number of channels

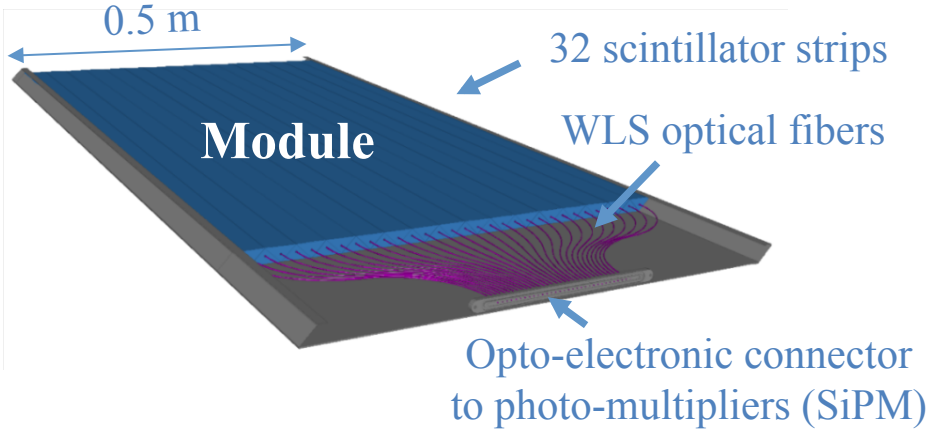
New technology: Silicon Photo-Multipliers (SiPM)

→ **r***educe cost and power consumption, investment in time*

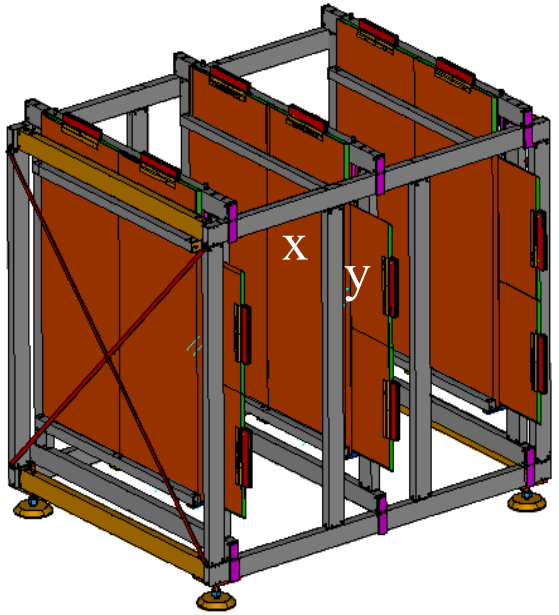
The MU-RAY muon telescope

(talks by F. Ambrosino and R. D'Alessandro)





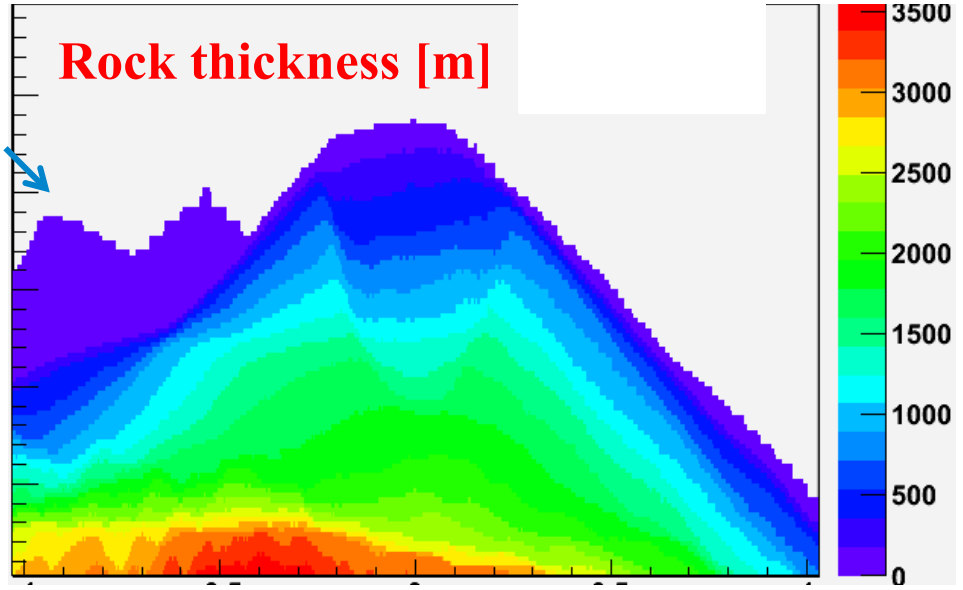
- Plastic scintillators strips of triangular section with 3.3 cm base
- Readout by WLS fibres and SiPMs
- Front-end ASIC chip Spiroc-Easyroc
- **Precise and redundant tracking**
  3 x-y measuring stations or more
  ~ 5 mm space resolution: ~~**fake tracks**~~
  ~ 10 mrad **angular resolution**
- **Time of Flight**
- **Event-by-event information**: p.h. …
- **1 m² prototype telescope being tested**

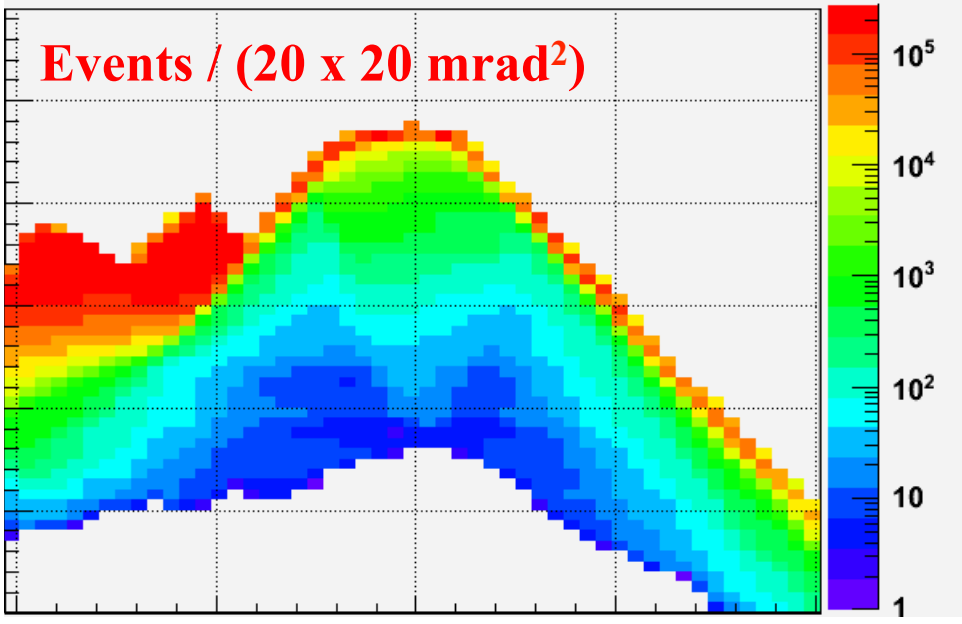


Expected from the 1 m^2 prototype telescope

(one year run, no background)

Mt. Somma





A first step in the
"Mt. Vesuvius challenge"

Stromboli

- **“Strombolian” activity**
  - essentially open conduit
  - intermittent eruptions due to increase in gas pressure
  - rare effusive activity
- **Summit at 926 m a.s.l.**
- **Crater at ~ 750 m a.s.l.**

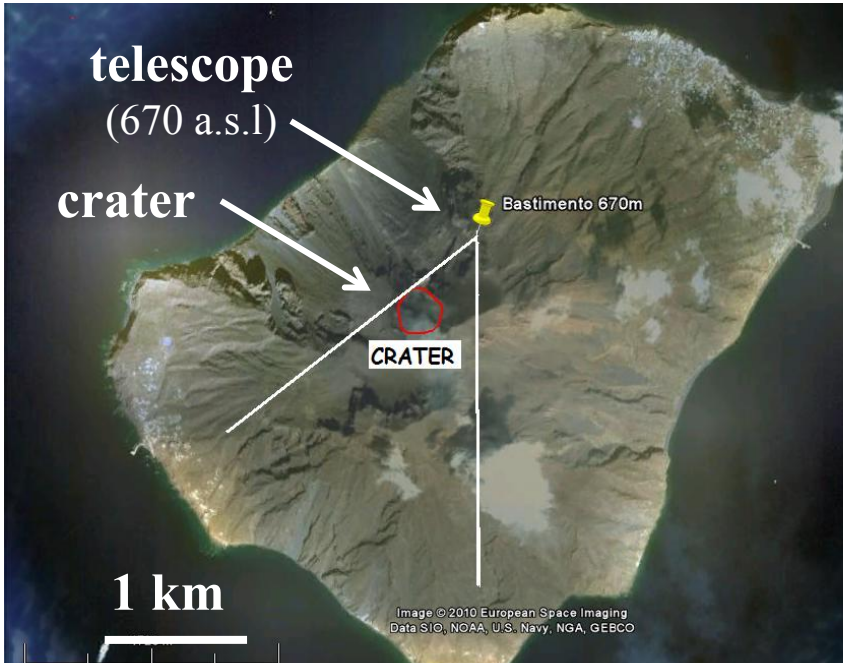
Muon Radiography of Stromboli

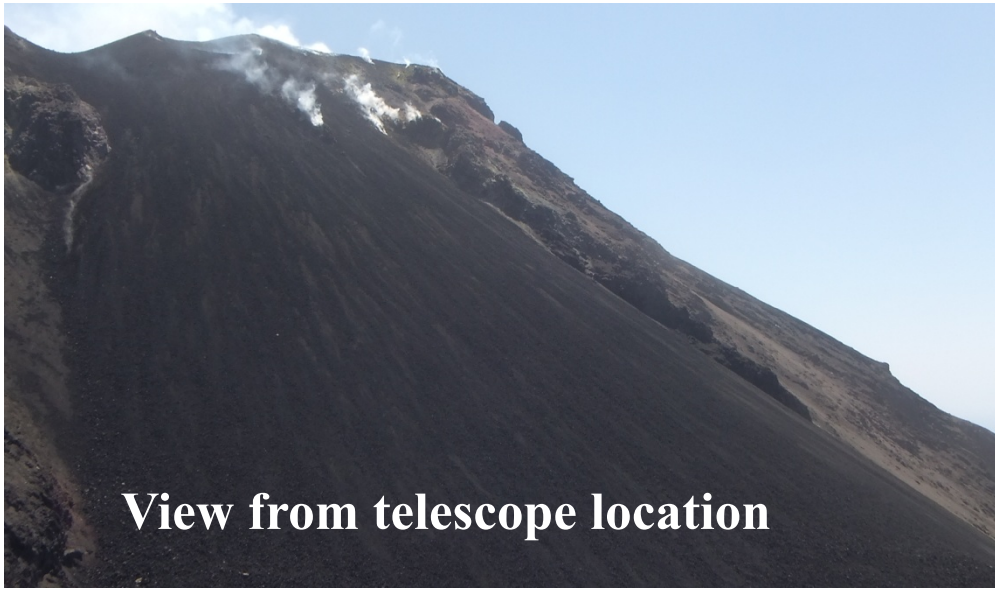
- **Scientific interest**
  - Open conduit
  - Stromboli well studied using other techniques
  - Combine information by different techniques

- **Large rock thickness**
  - similar problems as for Mt. Vesuvius
  - harsher environment
  - MU-RAY telescope in some future?

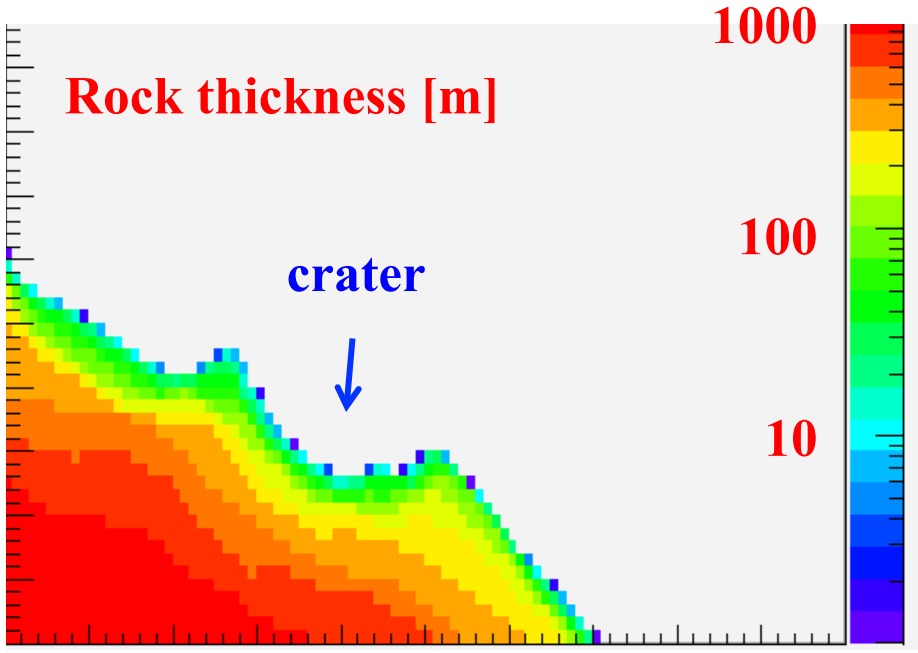
- **Top part of the conduit (crater region)**
  Investigated using nuclear emulsion
  (same Italian-Japanese team as for Unzen lava dome)

Muon Radiography of the crater region

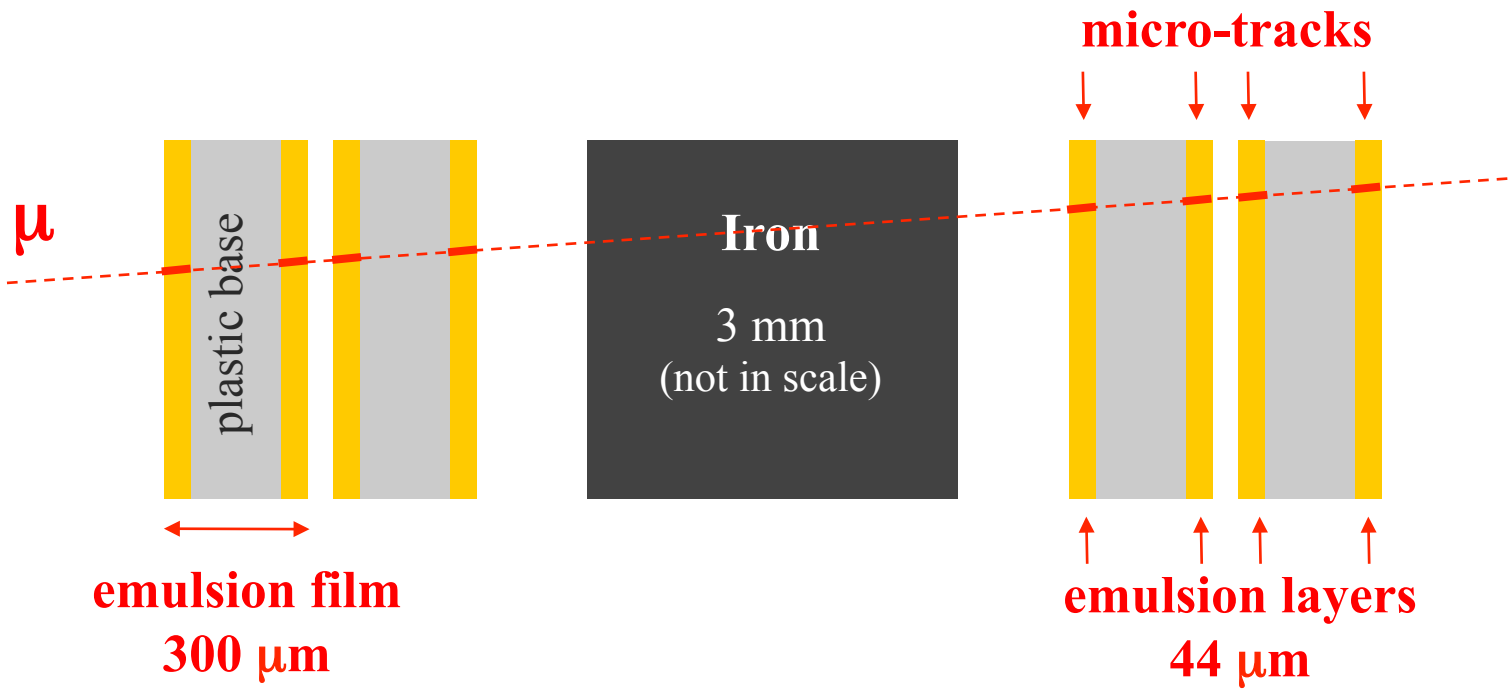




A 1 m^2 nuclear emulsion telescope has taken data last winter (5 months)



Emulsion telescope *(talk by A. Russo)*



4 emulsion films / 8 emulsion layers / 8 micro-tracks

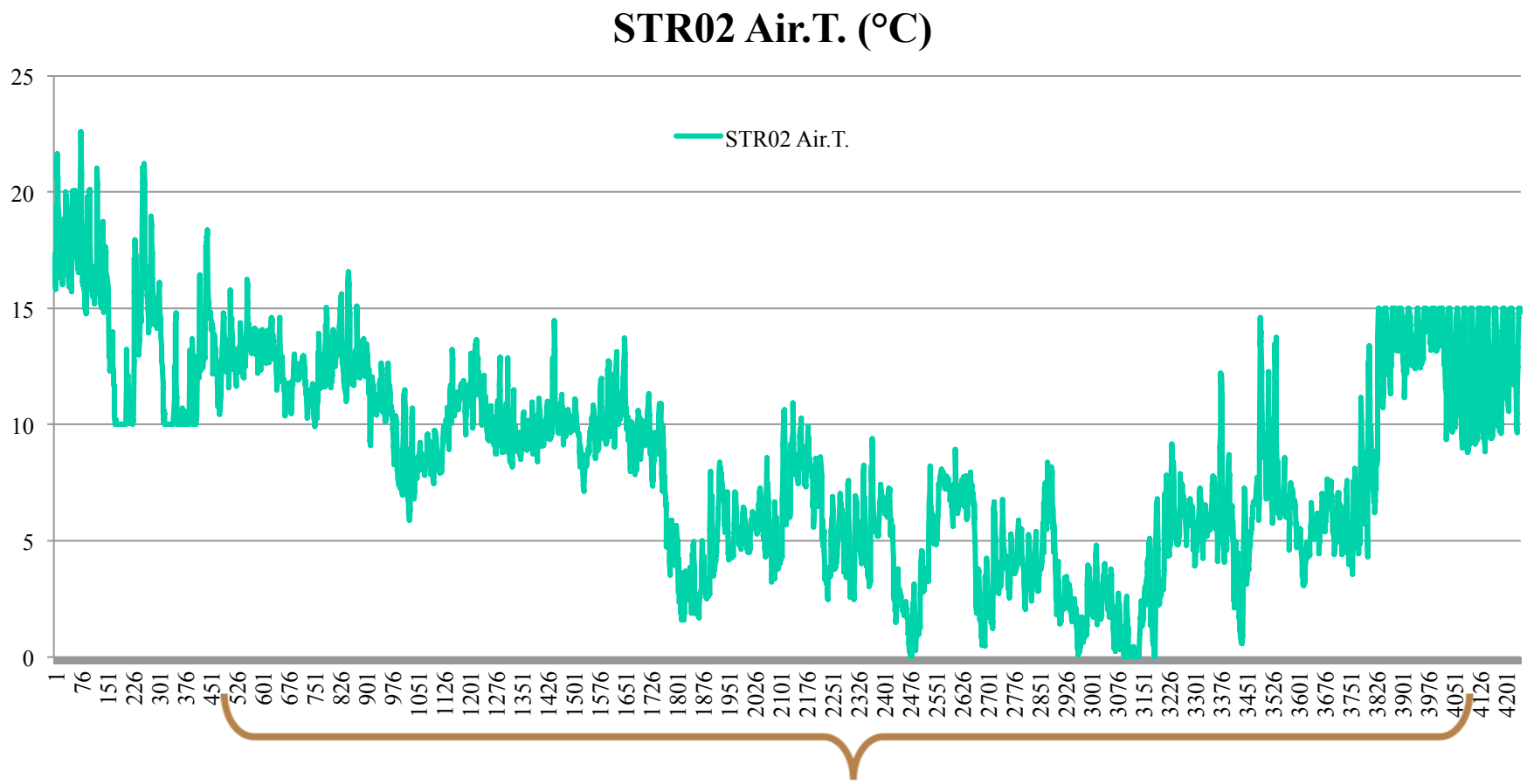
Redundant and precise (μm resolution) tracking: ~~fake tracks~~

Angular resolution: a few mrad

Iron: absorb soft electrons, identify low en. μ (scattering)

Very compact, easily transportable, no infrastructure

Nuclear emulsion suffer high temperature: acceptable during the exposure

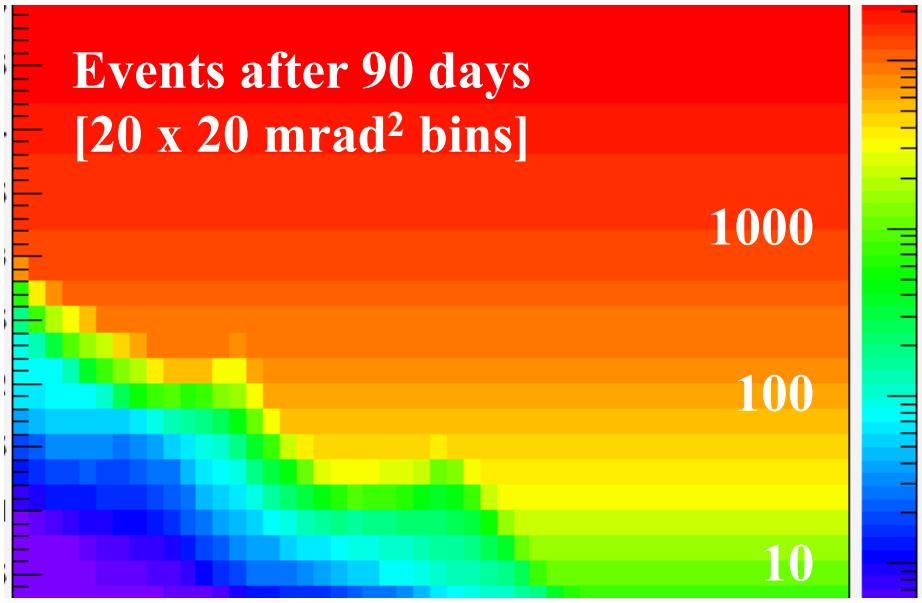


Exposure 22/10/2011 – 24/3/2012


Protected from rain and moisture
Protection from sun by rubber foam and expanded clay
The exposure started on 22/10/2011
After 5 months the emulsion appeared in good conditions

The telescope frame has been left in place
Notice the harsh environment

Expected events
(in absence of background)



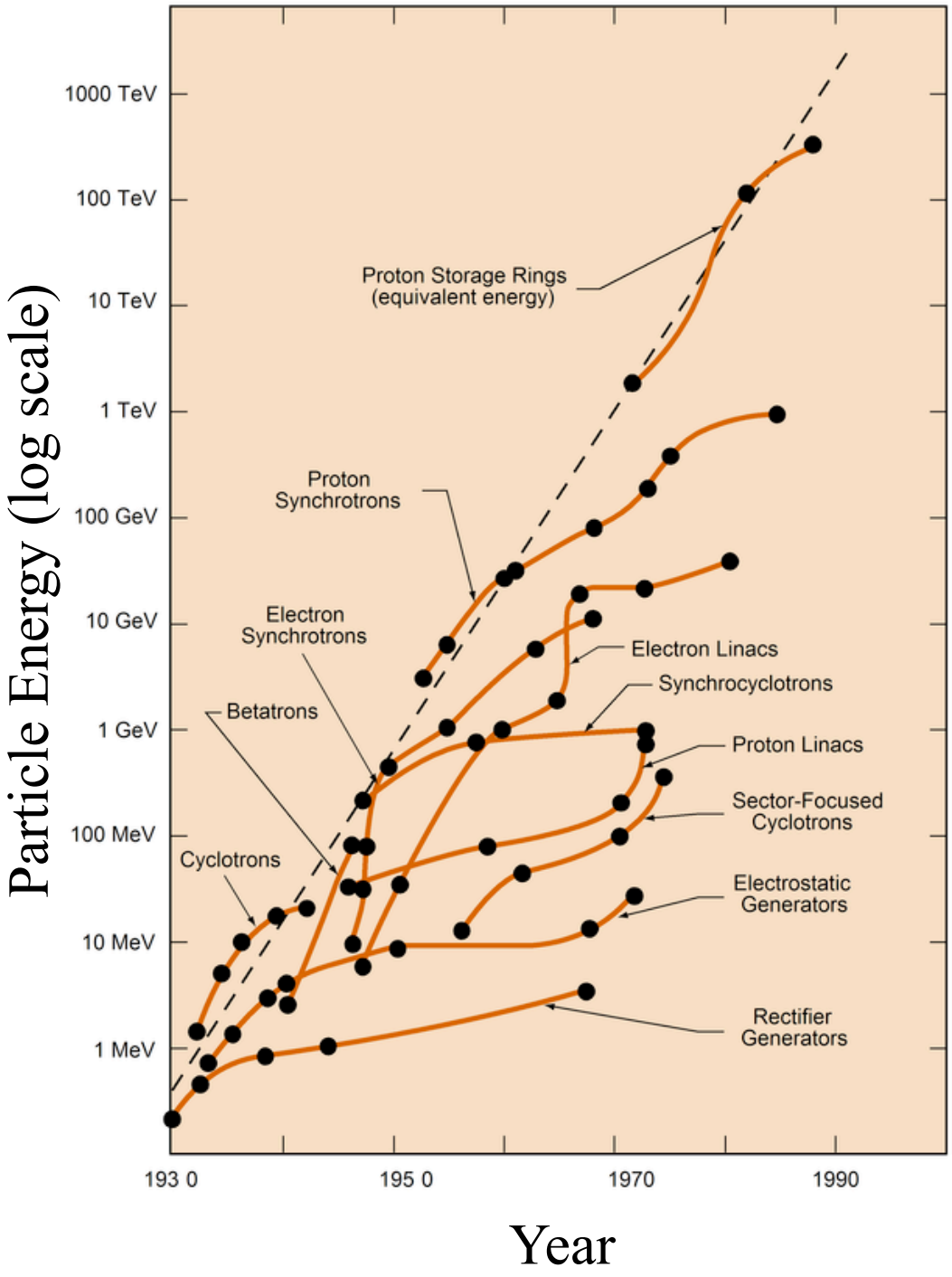
For future needs of larger areas:
R&D on faster automated microscopes
(Italy and Japan for Particle Physics)

In any field, the progress is linked to developments in technology

The "Livingston" plot

Saturation in particle energy for any accelerator technology

<u>The progress comes from new technologies</u>



New technologies for Muon Radiography

NUCLEAR EMULSION

Faster automated microscopes

Developed for Particle Physics: ready for use

PLASTIC SCINTILLATORS

Multi-anode PMTs

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Silicon Photo Multipliers

Tested in MU-RAY

Need special R&D for Muon Radiography

GASEOUS DETECTORS

See talks by C. Carloganu and P. Salin

We should unite forces and find resources in the framework of an important geophysics project