International Conference on Advanced Technology and Particle Physics

14th ICATPP Conference on
Astroparticle, Particle, Space Physics,
Detectors for Physics Applications

Applications of Cosmic Muon Tracking at Shallow Depths Underground

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25th September 2013

Outline

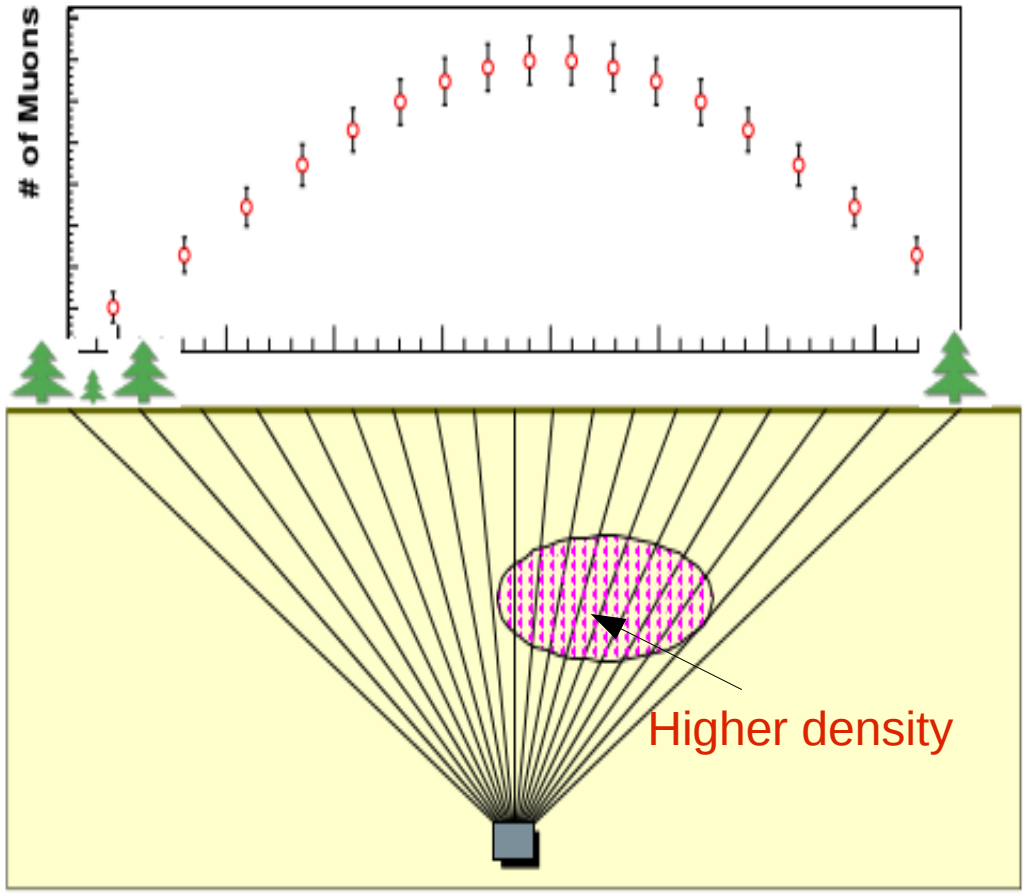
I. Motivation

II. Structure of the Portable Tracking Detector

III. Detector Tests

IV. Applications of Cosmic Muon Tracking

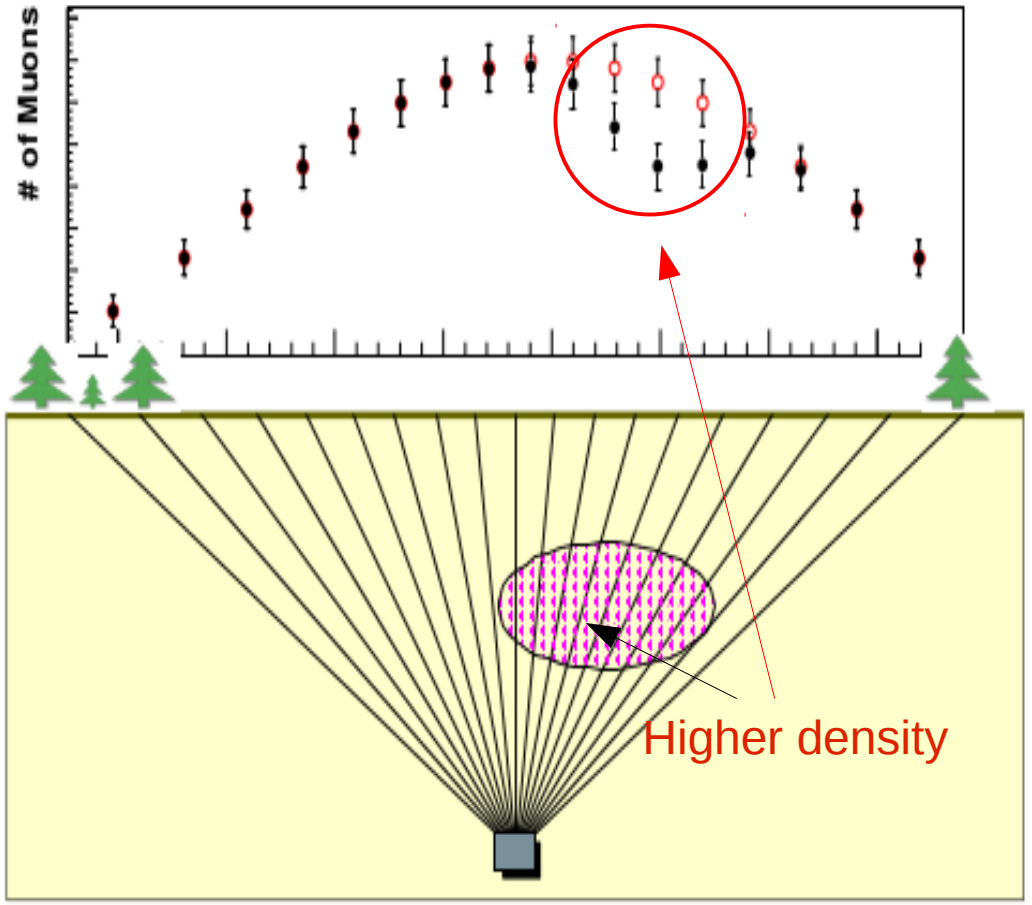
I. Motivation



- **Aim of our research:** detect large scale density inhomogeneities by measuring the cosmic muon flux

See Zhiyi Liu talk at MNR2012 (Clermont Ferrand)

I. Motivation



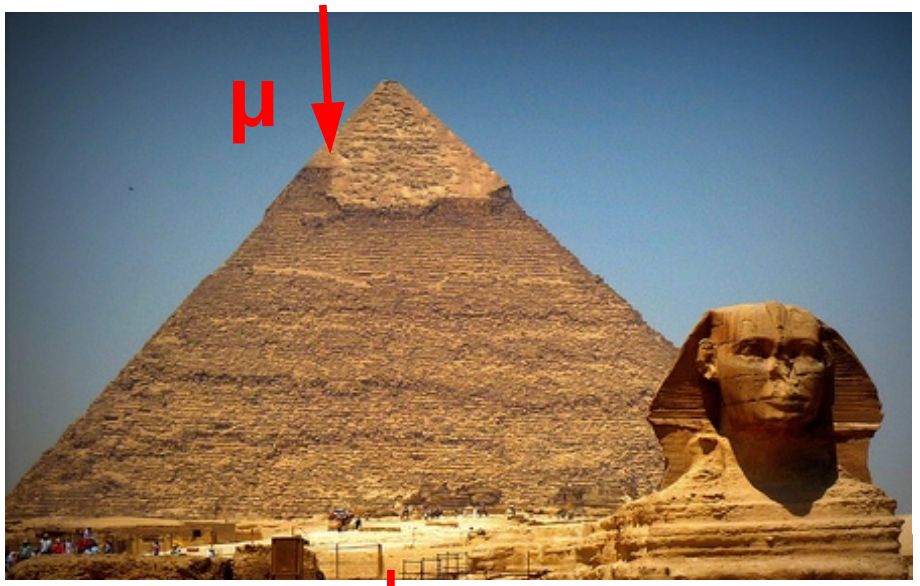
See Zhiyi Liu talk at MNR2012 (Clermont Ferrand)

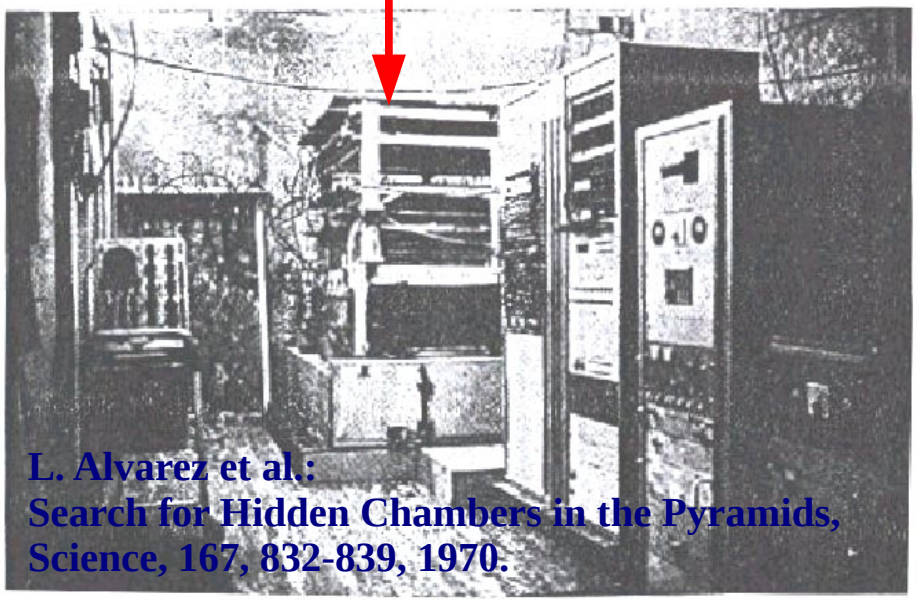
- **Aim of our research:** detect large scale density inhomogeneities by measuring the cosmic muon flux

Underground density inhomogenity with higher (lower) density the cause of the decrease (increase) in muon flux.

Archeology:

search for hidden chambers

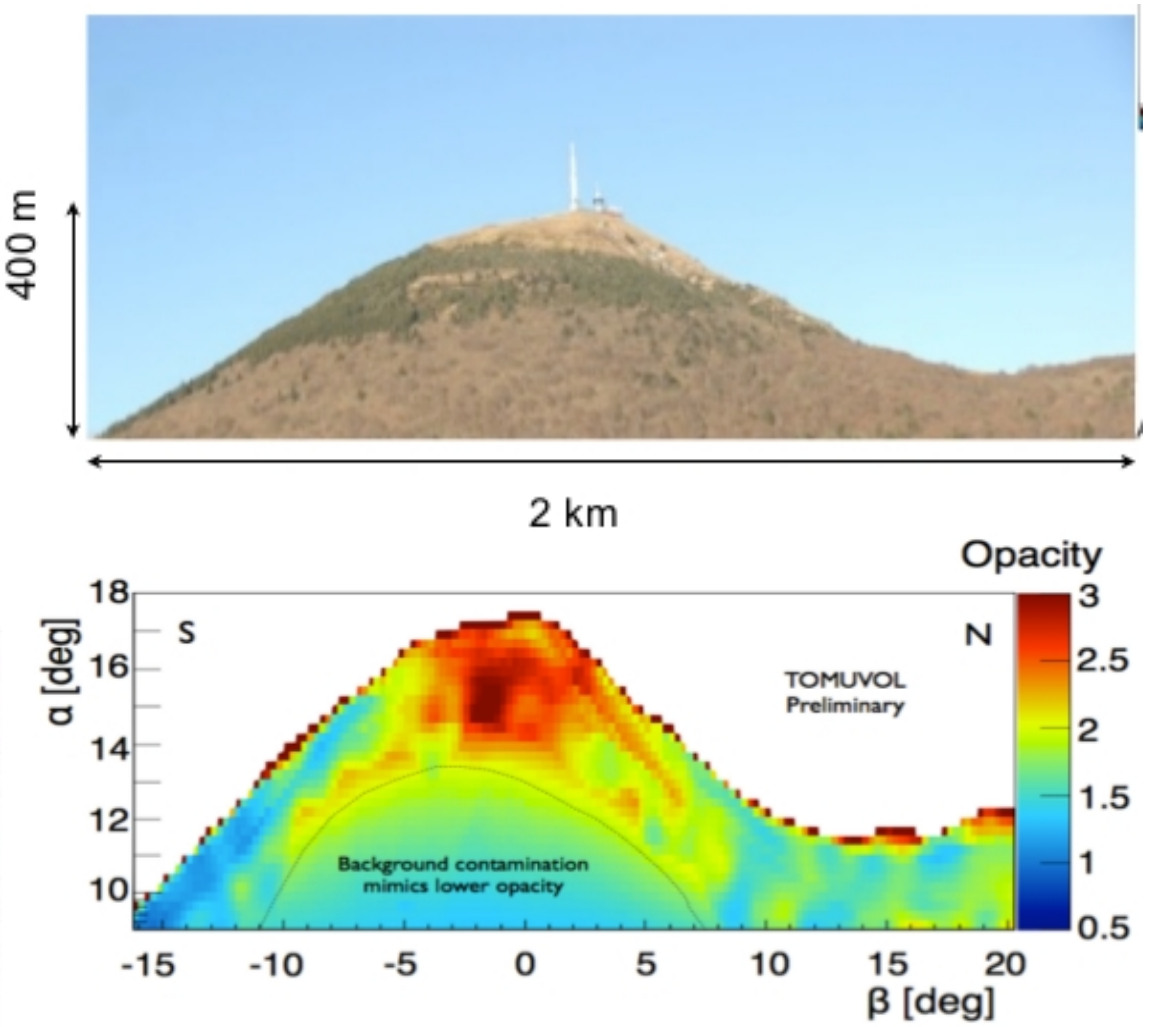




L. Alvarez et al.:
Search for Hidden Chambers in the Pyramids,
Science, 167, 832-839, 1970.

Vulcanology:

predict the eruptions



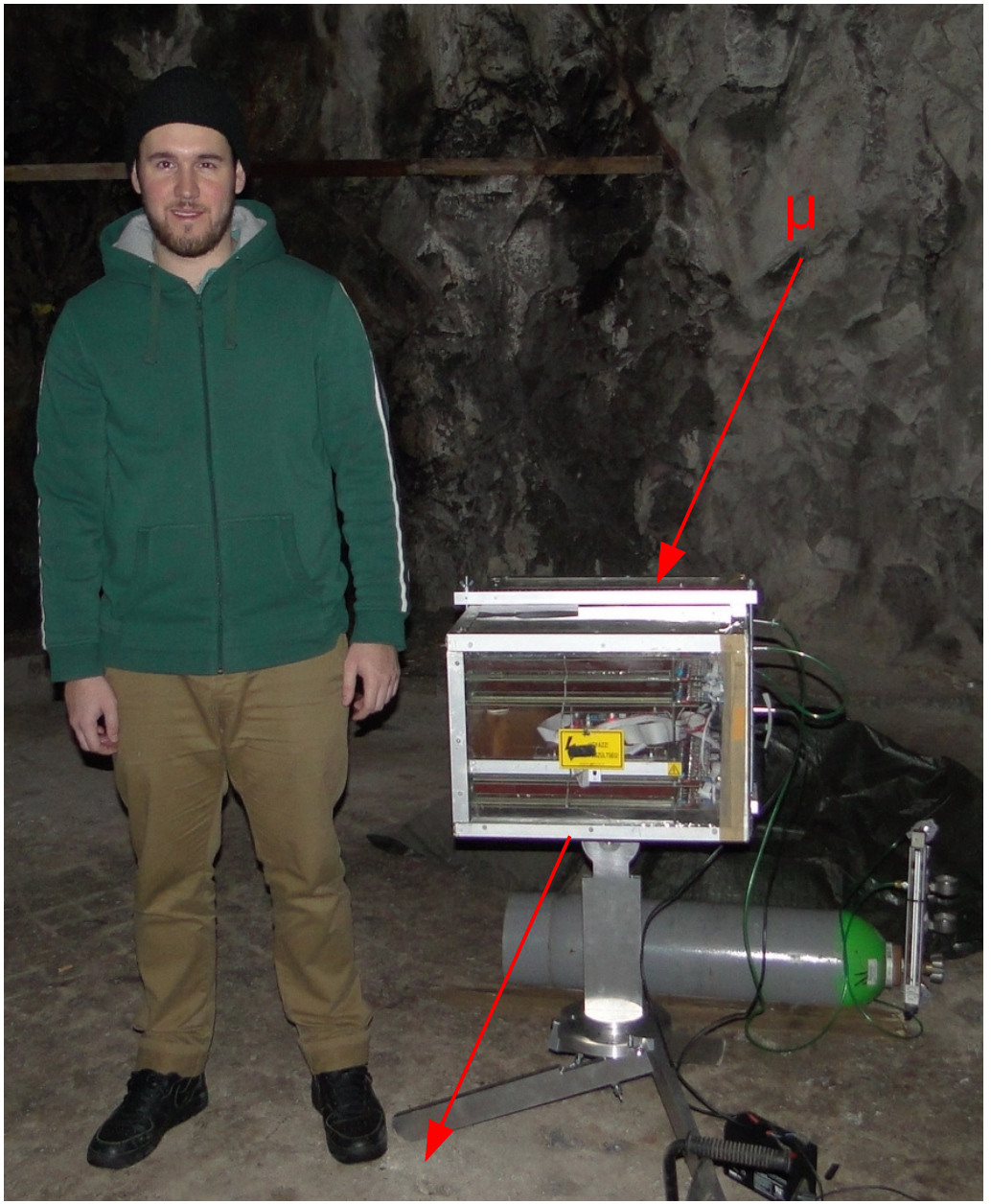
See C. Carloganu's talk at the session of CRs Ground Experiments, Villa Olmo (2013)

Geosci. Instrum. Method. Data Syst., 2, 55-60, 2013

II. The Structure of the Portable Tracking Detector

NIM A 689 (2012) 60-69
Adv. in HEP, 560192 (2013) 1-7

- 5 Close Cathode Chambers (CCC)
  - Sensitive area per layer: 32 cm by 32 cm
- Plexiglass box (can work in 100 % humidity environmental)
- Easy to handle manually:
  - volume: 51 x 46 x 32 cm^3
  - total weight: 15 kg
- Data acquisition (DAQ) system integrated into one unit
- Human Machine Interface (HMI):
  - LCD display, SD card



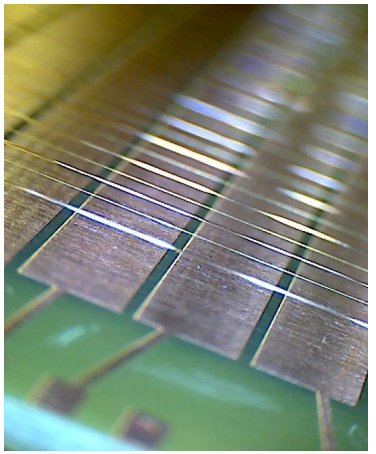
CCC Technology for Muon Detection

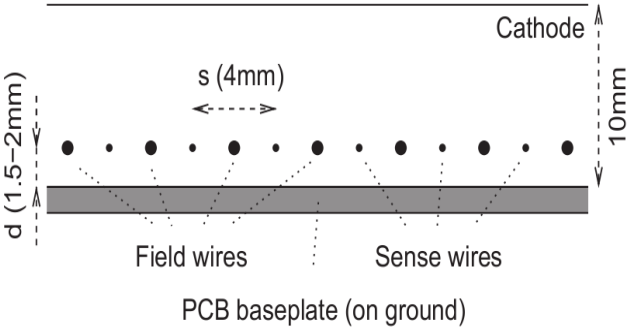
- **Close Cathode Chamber**
  - Asymmetric Multiwire Proportional Chamber which does not require weighty outer support frames
  - High tolerance against mechanical inaccuracies (100-200 μm)

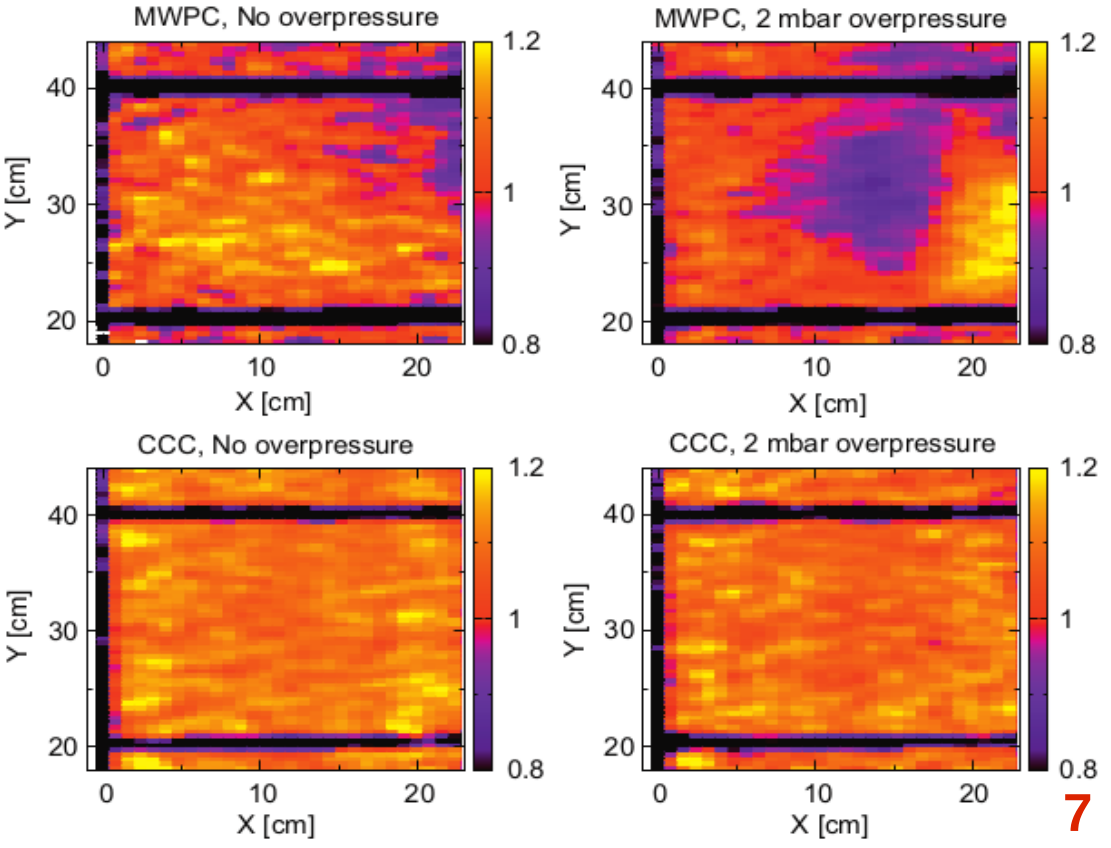
D. Varga et al.: NIM A 648 (2011) 163

D. Varga et al.: NIM A 698 (2013) 11

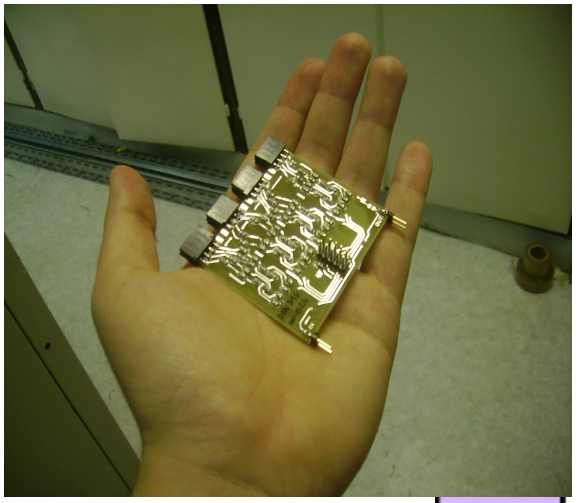
- 2 dimensional location (wires and pads)
- Triggering on coincidence of sense wires' signals
- Requires continuous gas flow during operation: non-flammable Ar – CO_2



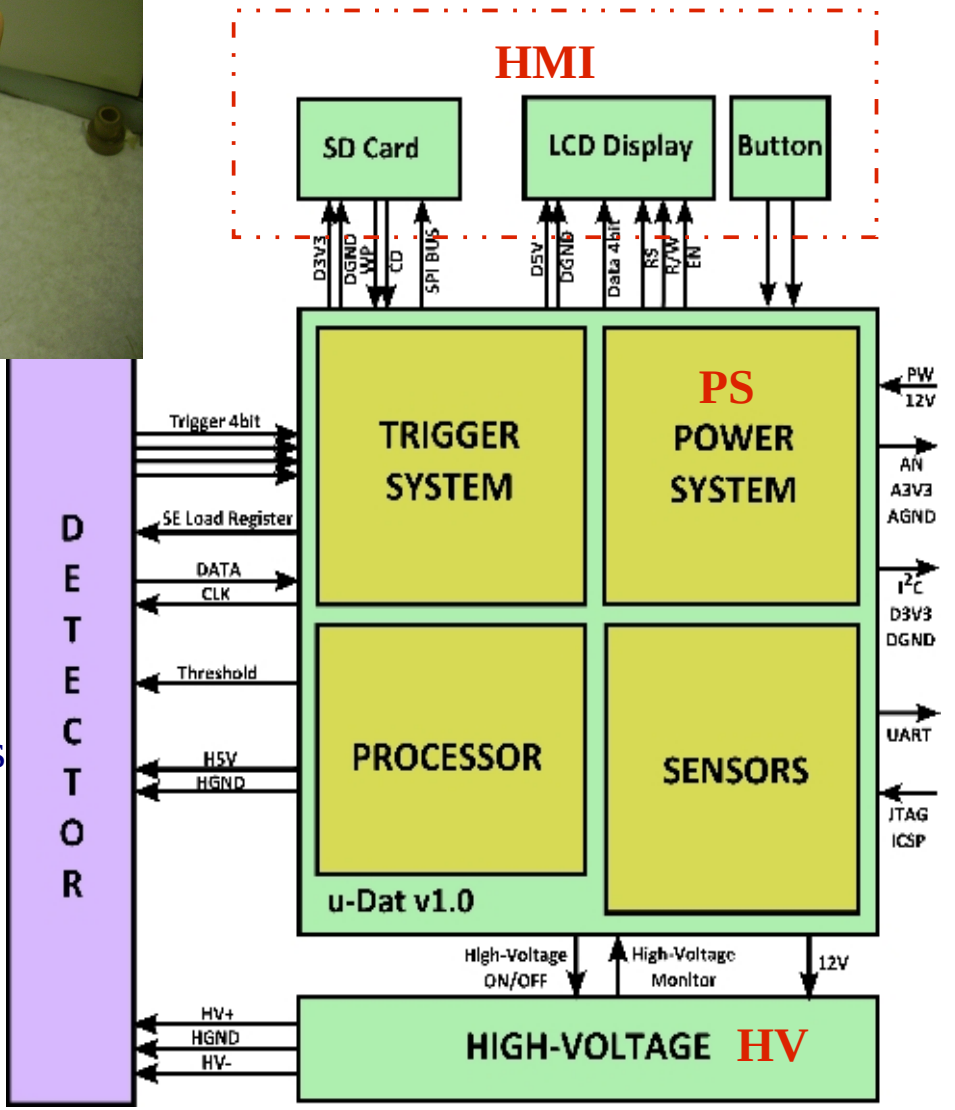




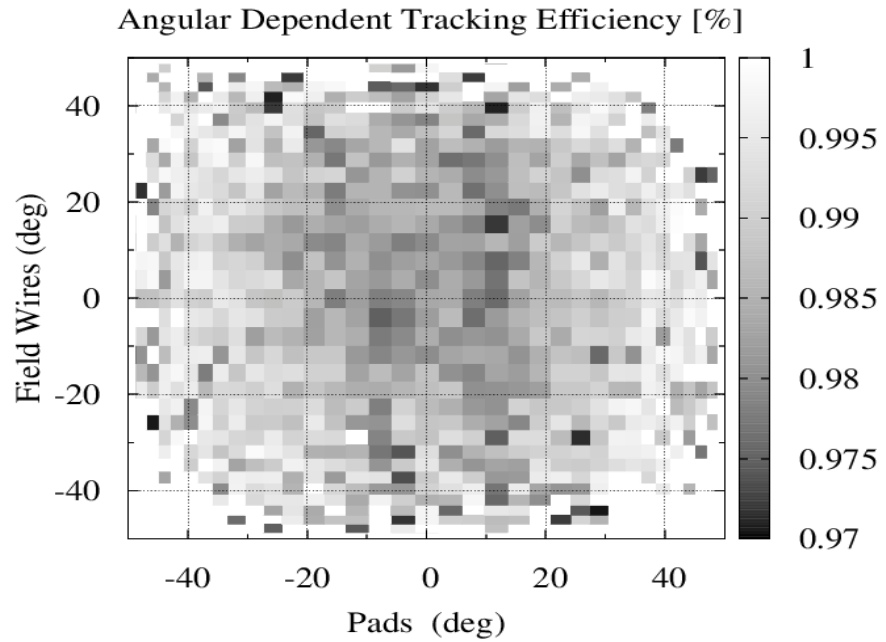
Front-End Electronics and Integrated DAQ

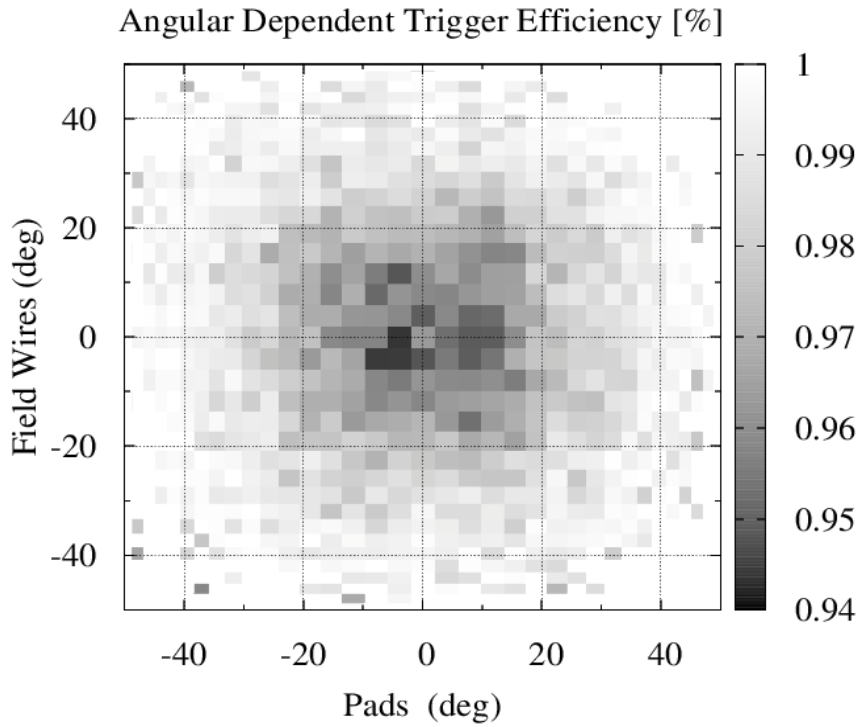


- **Front-End Electronics:**
  - 16 channels per electronic (10 FEE/chamber)
  - Analog amplification and discrimination with commercial logic ICs
  - Serial readout, all electronics can be put into one chain
- **PIC32 based DAQ**
  - All functions are integrated into a common system plan
  - Small unit: placed between the middle CCC layers
  - **Total power consumption:**
    - 380 mA at 12 V: **power < 5 W !!!**
    - Complete unit can operate for more than 5 days with a 50 Ah battery



Analysis methodes

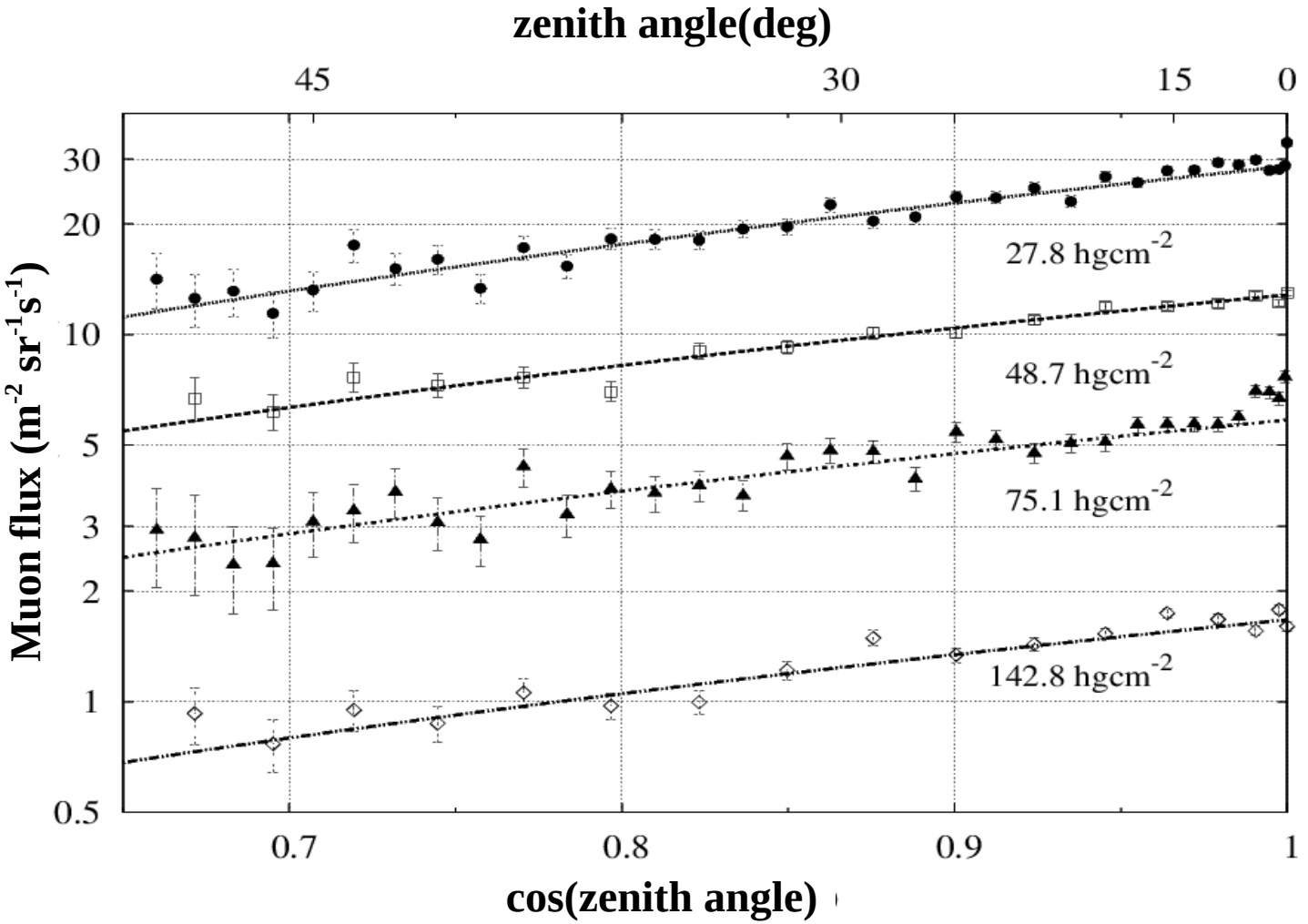




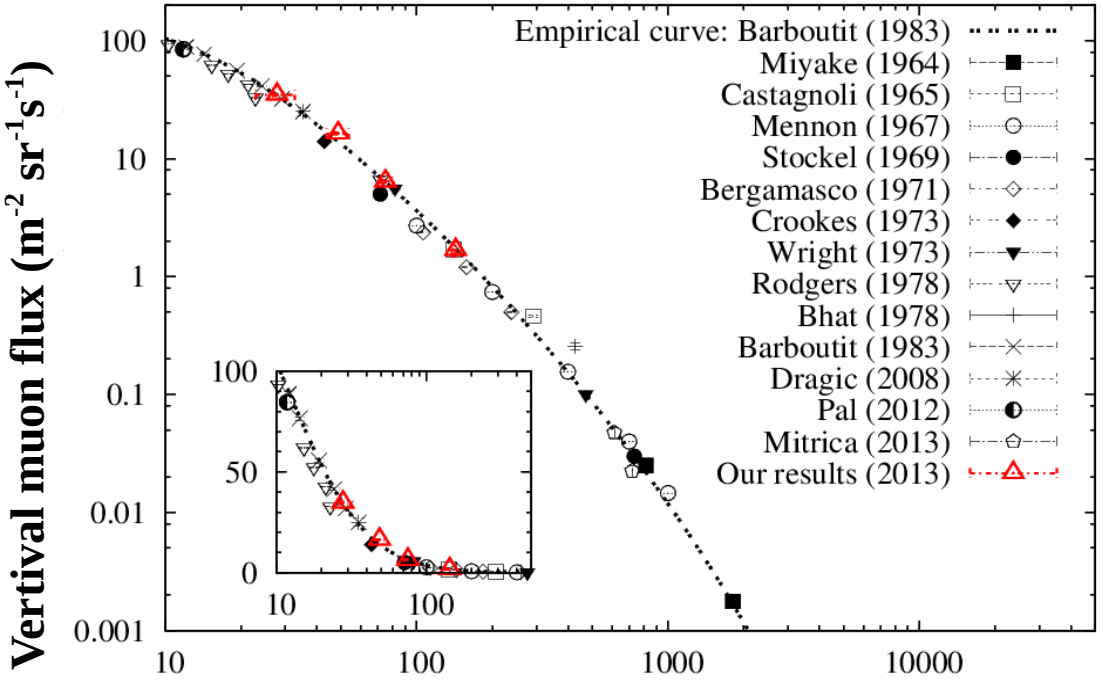
- Standard HEP analysis methodes have been applied
- OFFLINE alignemt of the tracking layers
- Cluster finding on layer by layer
- Combinatorical tracking
- Muon flux has been corrected by
  - tracking efficiency,
  - trigger efficiency,
  - detector acceptance,
  - duration of the measurement.

III. Detector tests

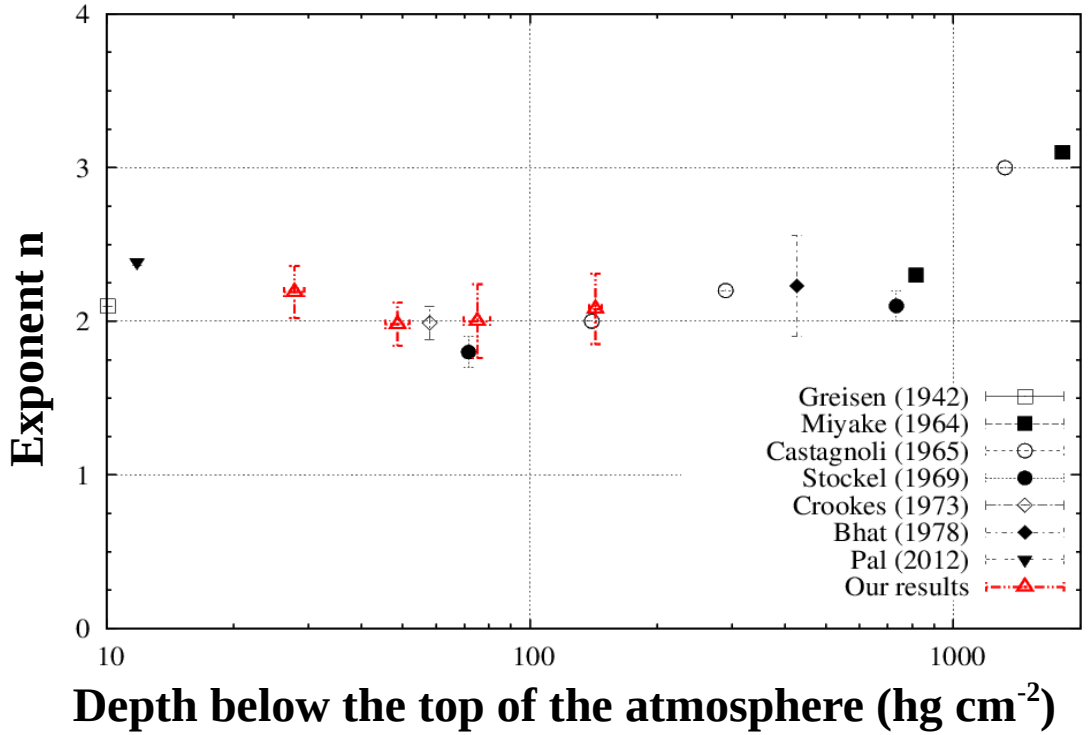
- Muon flux measurements have been done at 4 different depths (Jánossy Pit and Felsenkeller) by the REGARD Muontomograph



Our versus Earlier Measurements



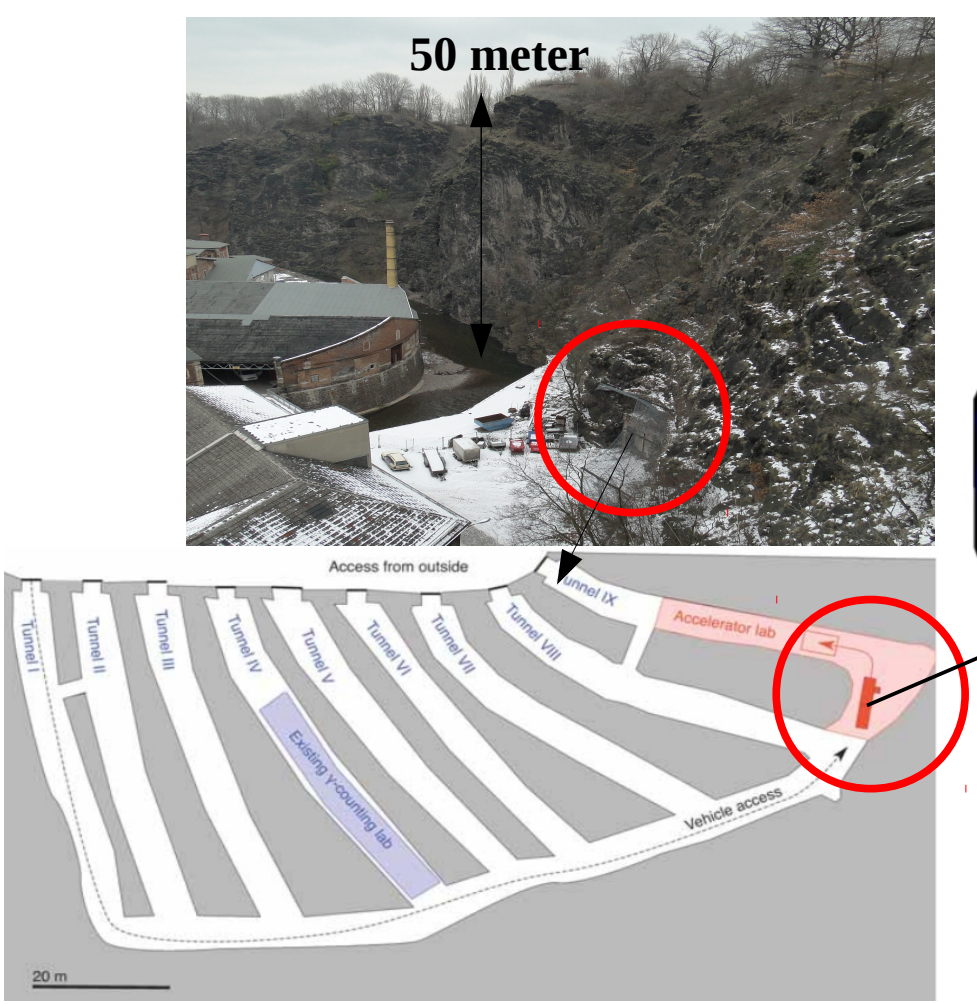
- The measured vertical muon fluxes *(red triangulars)* are in good aggreement with the „world data” at shallow depth undeground!

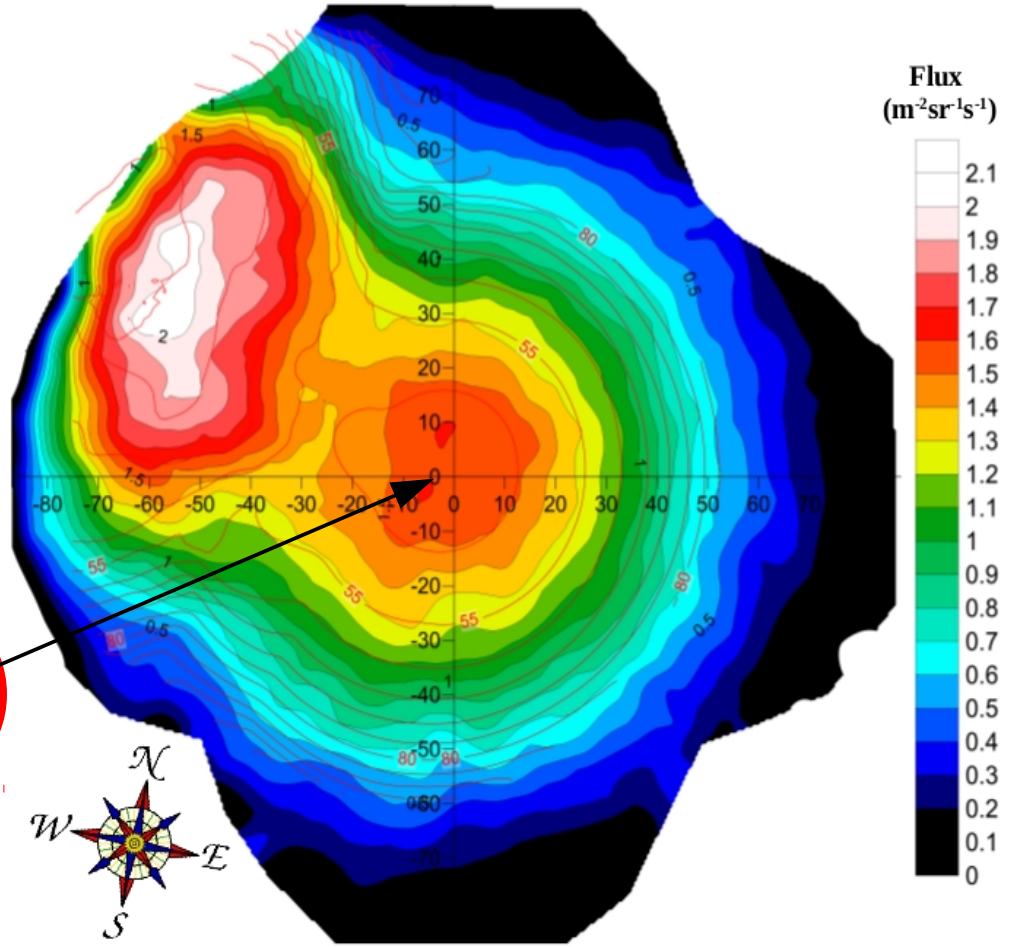


- Angular distribution: $f(\theta) \sim \cos^n(\theta)$
- Our exponents *(red triangulars)* are in aggreement with the „world data”!

IV. Applications of Cosmic Muon Tracking

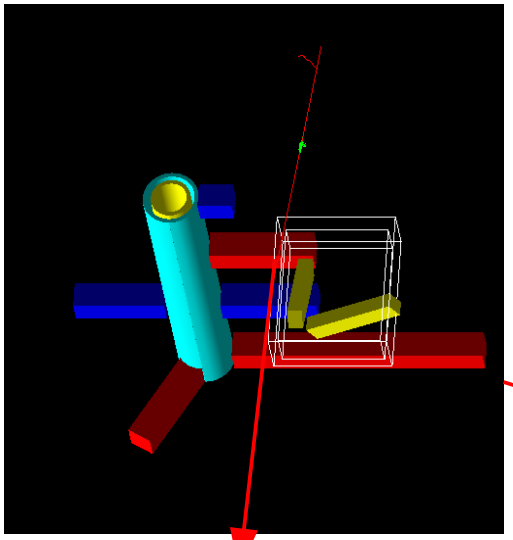
- Cosmic background measurements at the site of a proposed underground accelerator based experiment in Felsenkeller, Dresden:
  - Maximum muon flux found below 2.5 $m^{-2}sr^{-1}s^{-1}$





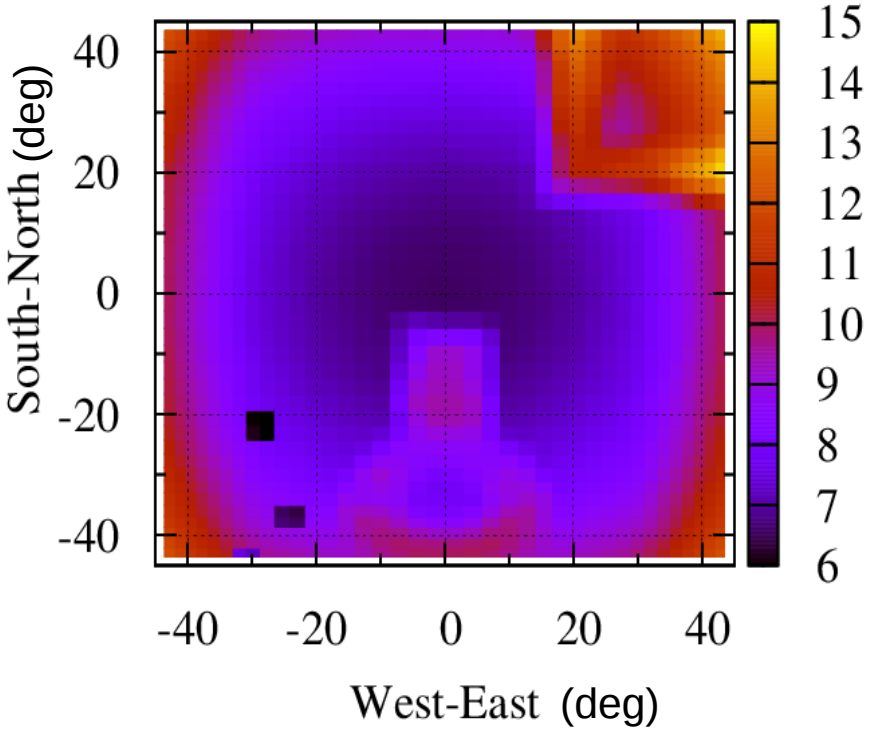
Submitted to Journal of Physics: Conference Series 2013 (NPA6, Lisbon)

Geant 4 Simulation of the Jánossy Pit (Preliminary Results)

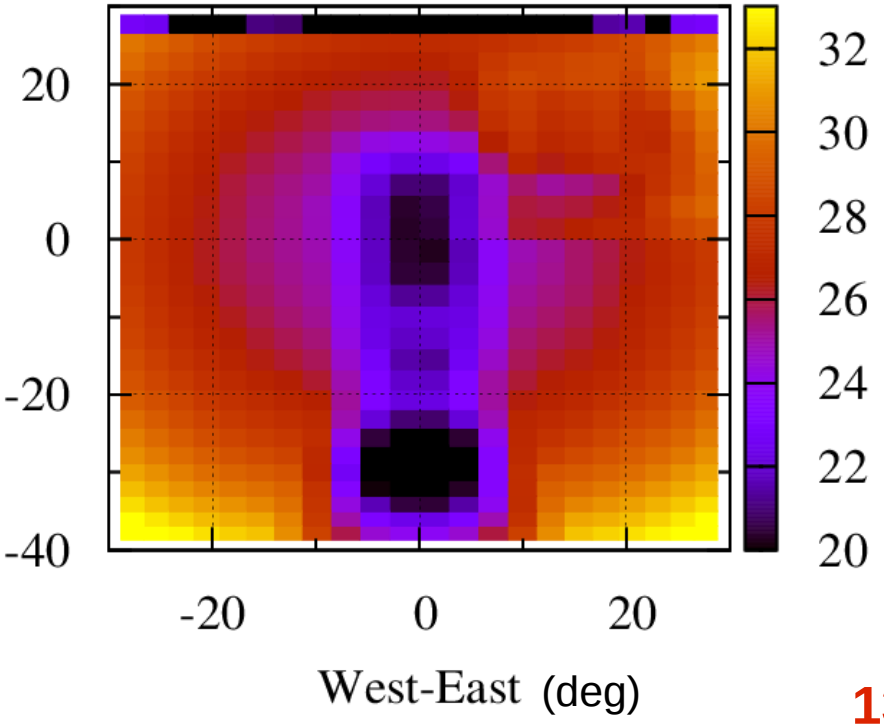


- Geometry of the Jánossy Pit has been built in Geant4
- Rock thickness has been calculated by the energy loss of muon beam
- Muon flux have been calculated by empirical formulae
  J. Phys. G: Nucl. Phys. 9 (1983) 1577-1595.

Rock thickness from First level

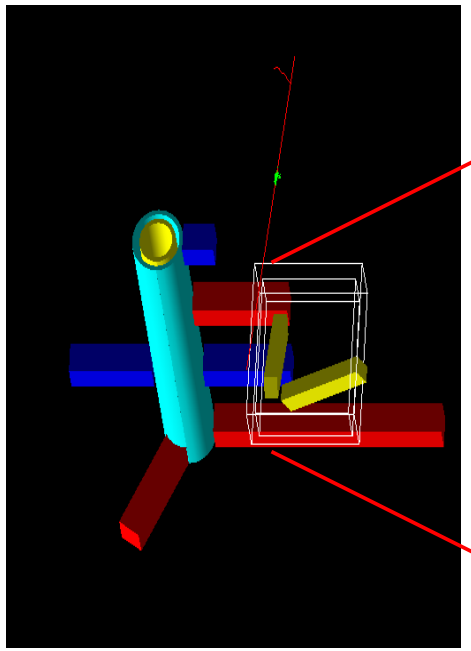


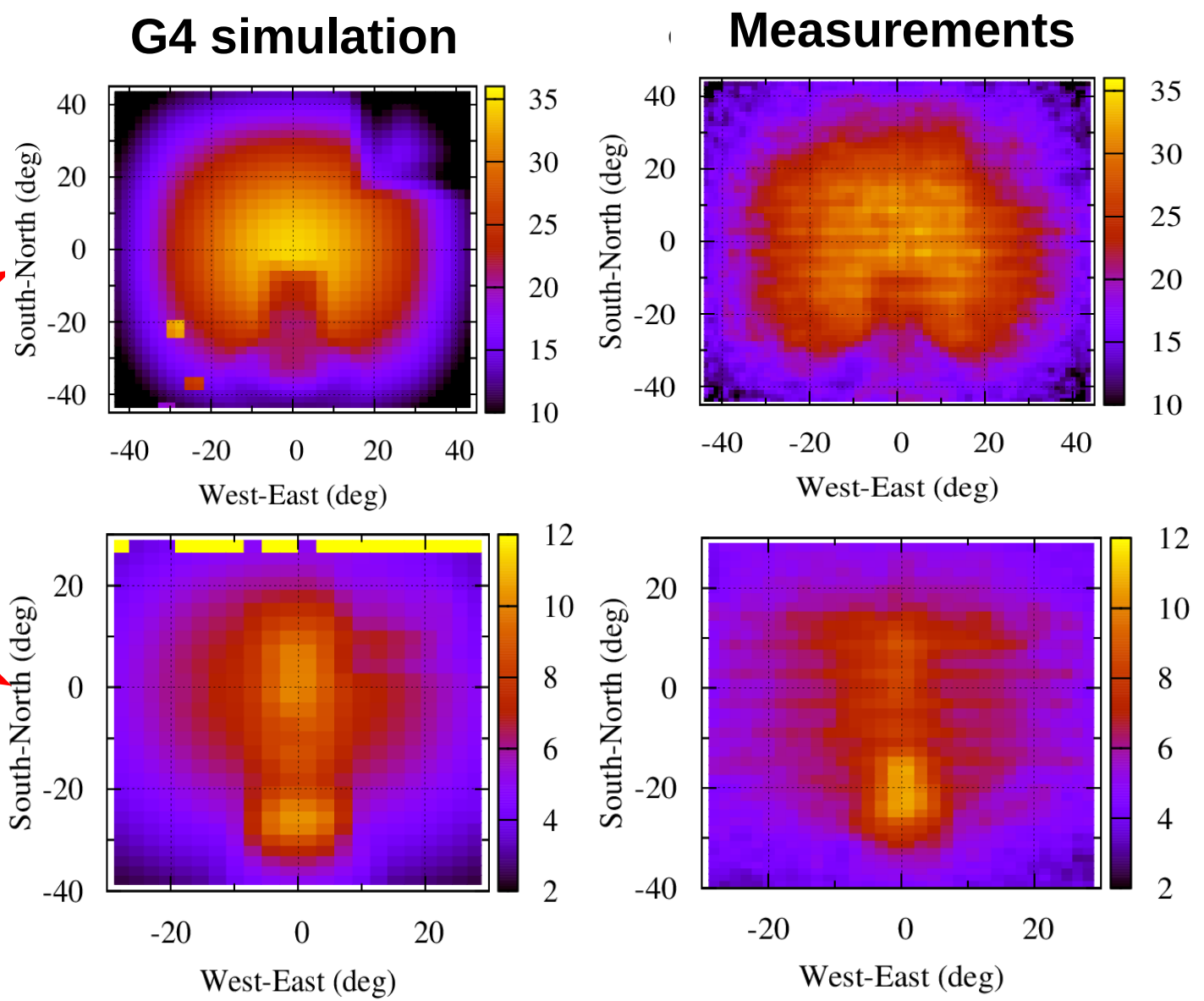
Rock thickness from Third level



Geant 4 versus Our Measurements (Preliminary Results)

- Our measurements are not in precisely aggrement with the simulation
- Building and tunnel structures are visible by our measurements !

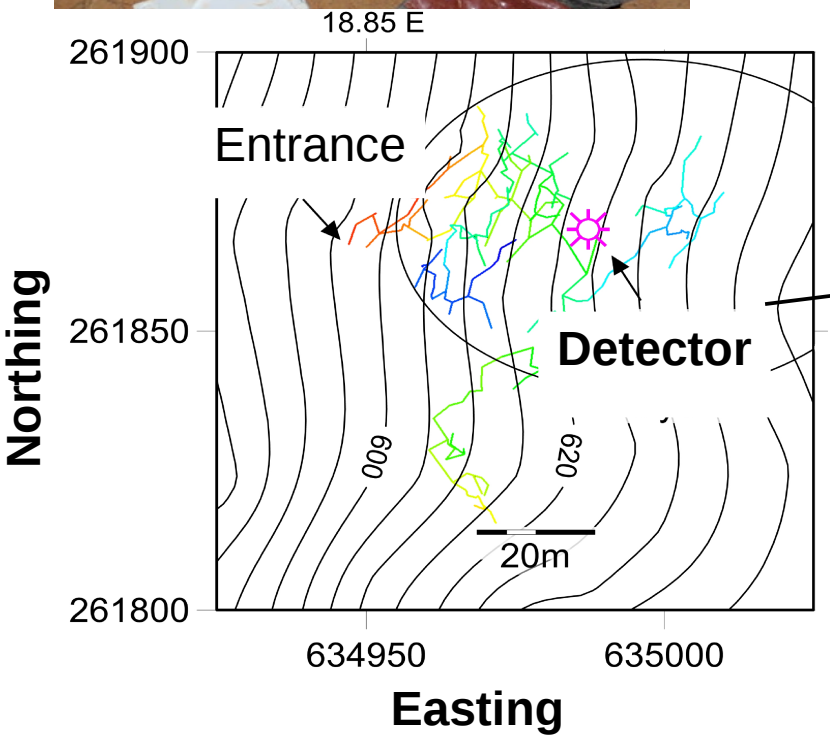




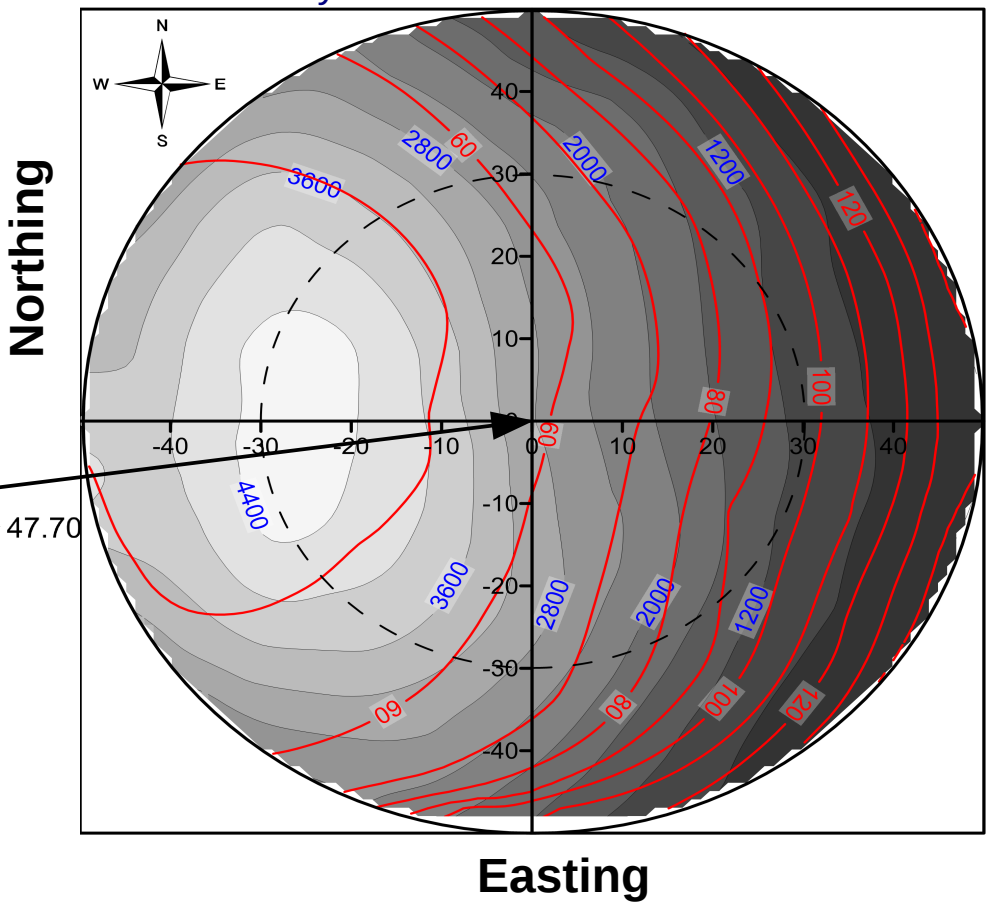
Speleological Research by Cosmic Muons

NIM A 689 (2012) 60-69

- 50 days of measurments in a natural cave system under 60 meters rock in Pilis, Hungary
- **Muon flux vs thickness of the rock: show correlation**



Red contours: rock thickness (m)
Grayscale contours: muon counts



Summary

- **REGARD Group's Muontelescope:**
  - Mobile (< 15 kg, 51 x 46 x 32 cm^3) and power efficient (< 5 W)
  - Precision: 1.5 mm spatial and 10 mrad angular resolution
  - Cost efficient CCC technology (total cost 2000-3000 €)
  - Integrated DAQ including High Voltage, Trigger System, HMI, etc
- **Applications of cosmic muon tracking:**
  - Cosmic background measurements at a proposed underground accelerator based experiment at Felsenkeller, Dresden, Germany
  - Reconstruction of underground tunnels
  - Speleological research in the Ajándék Cave, Pilis, Hungary

1. Nuclear Instruments and Methodes A 689 (2012) 60-69
2. Geoscientific Instruments, Methods and Data Systems 2 (2012) 781
3. Advances in High Energy Physics, Article ID 560192 (2013) 1-7
4. Cosmic Background Measurements at a Proposed Underground Laboratory by the REGARD Muontomograph, submitted to Journal of Physics: Conference Series (NPA6, Lisbon, Portugal, 2013)

Thanks for Your Attention!

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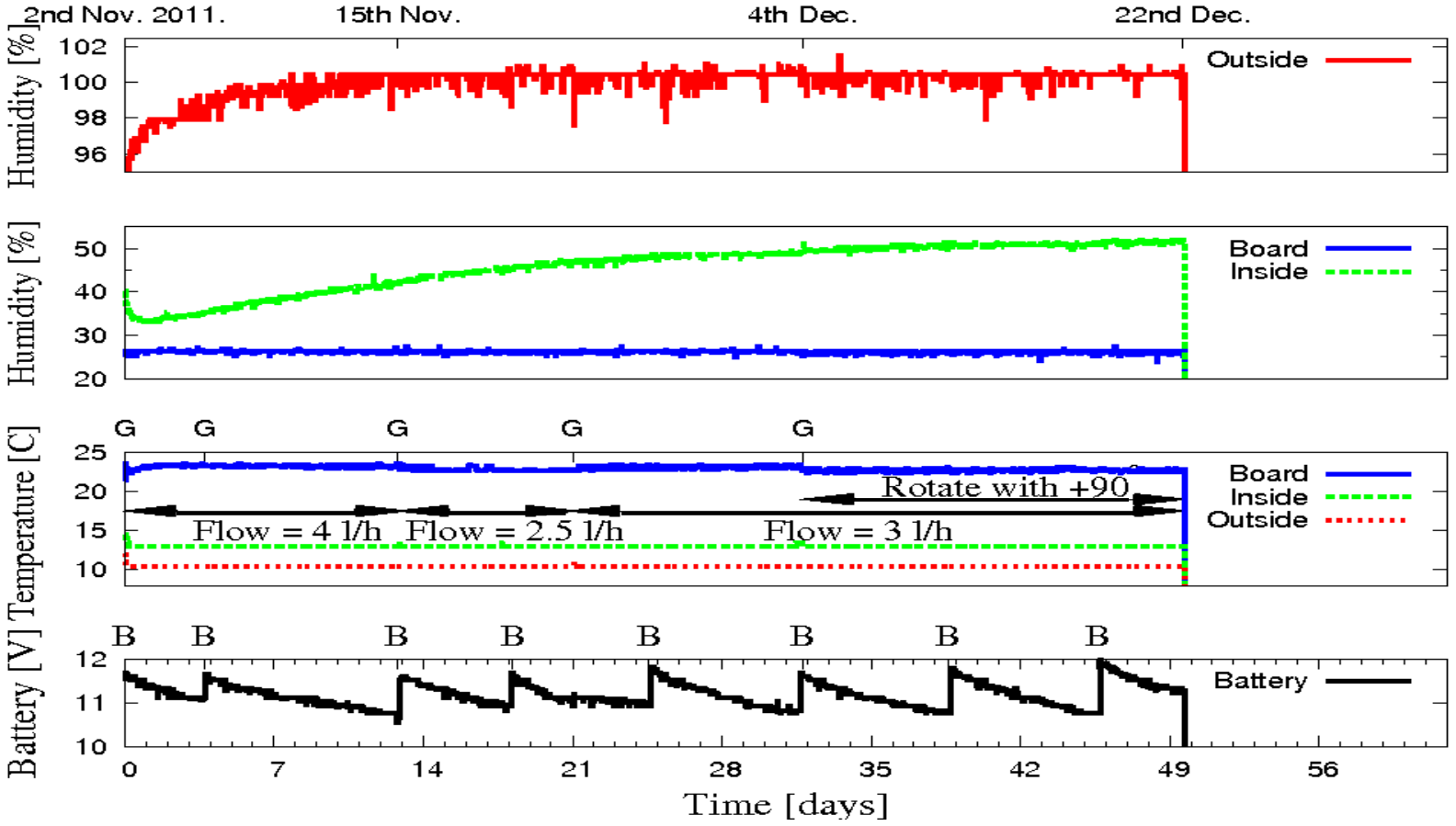
Backup Slides

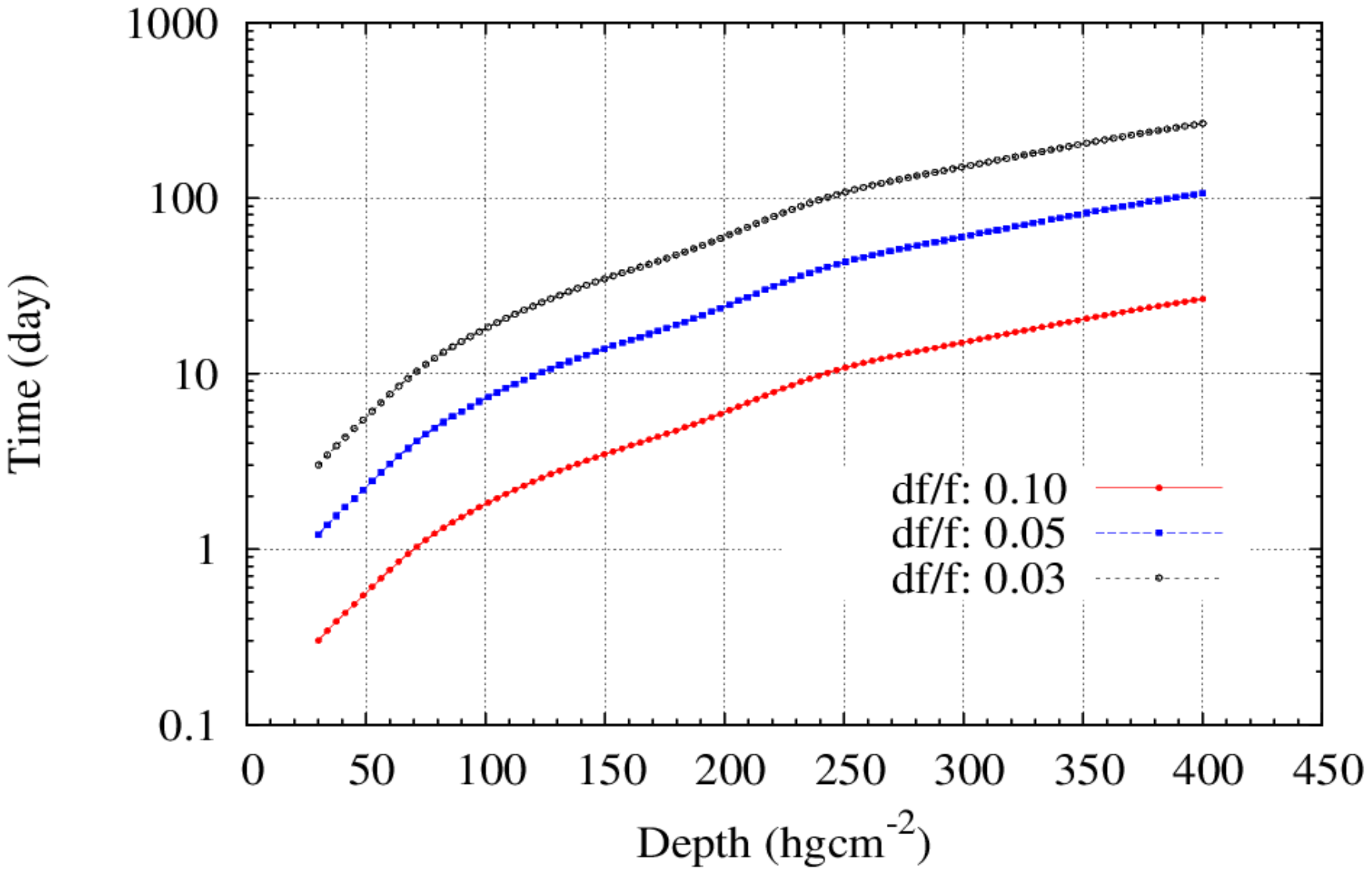
Environmental Control in the Ajándék Cave

- Enviromental parameters and detector signals were monitored
- Visual control took place regularly on weekly basis
- One 10 l bottle of 150 bar filling is sufficient
  for 20 days of continuous operation with 3 l/h flow.



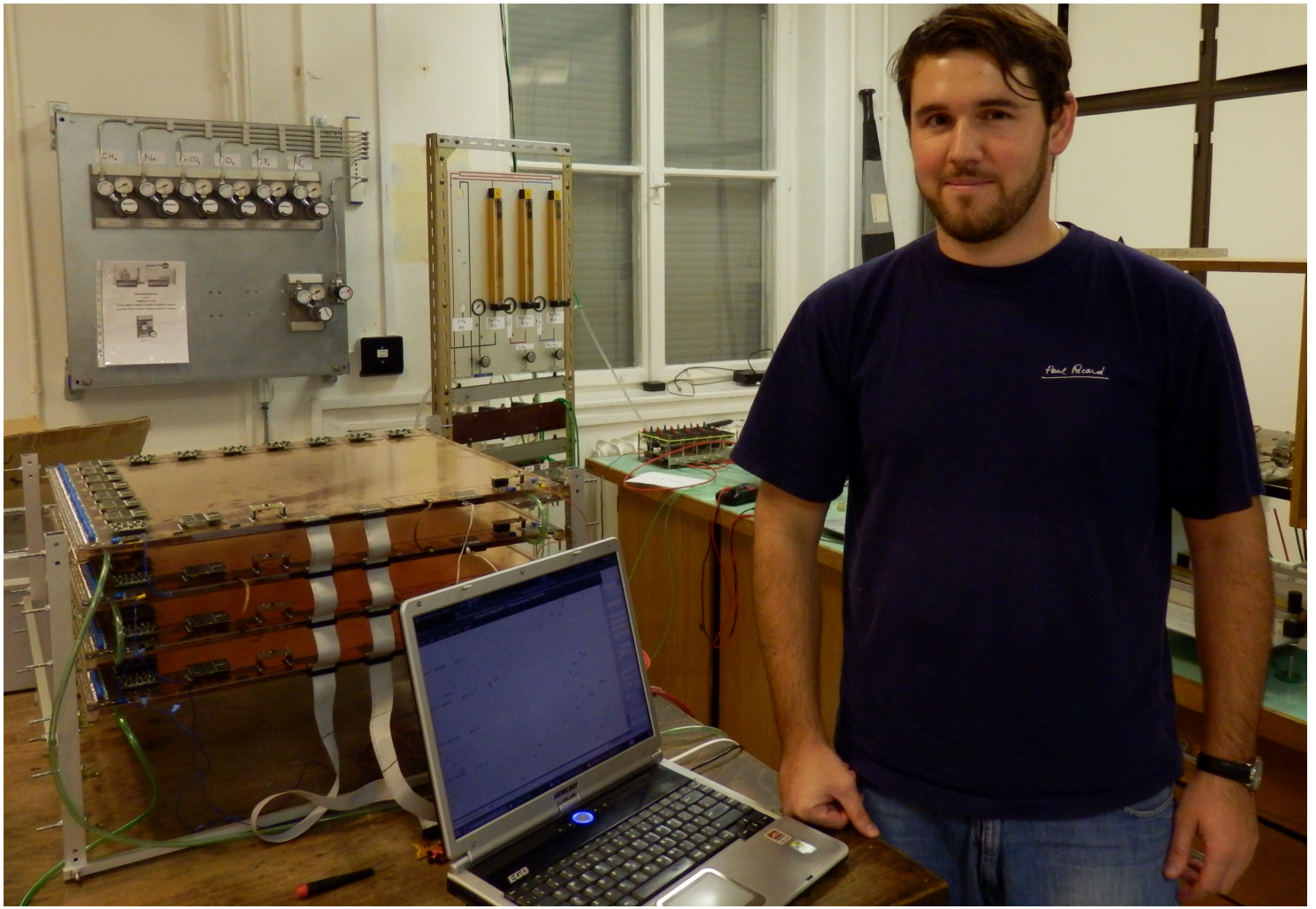
The Duration of Muon Flux Measurements

- depends on the depth and the precision (df/f, relative error)

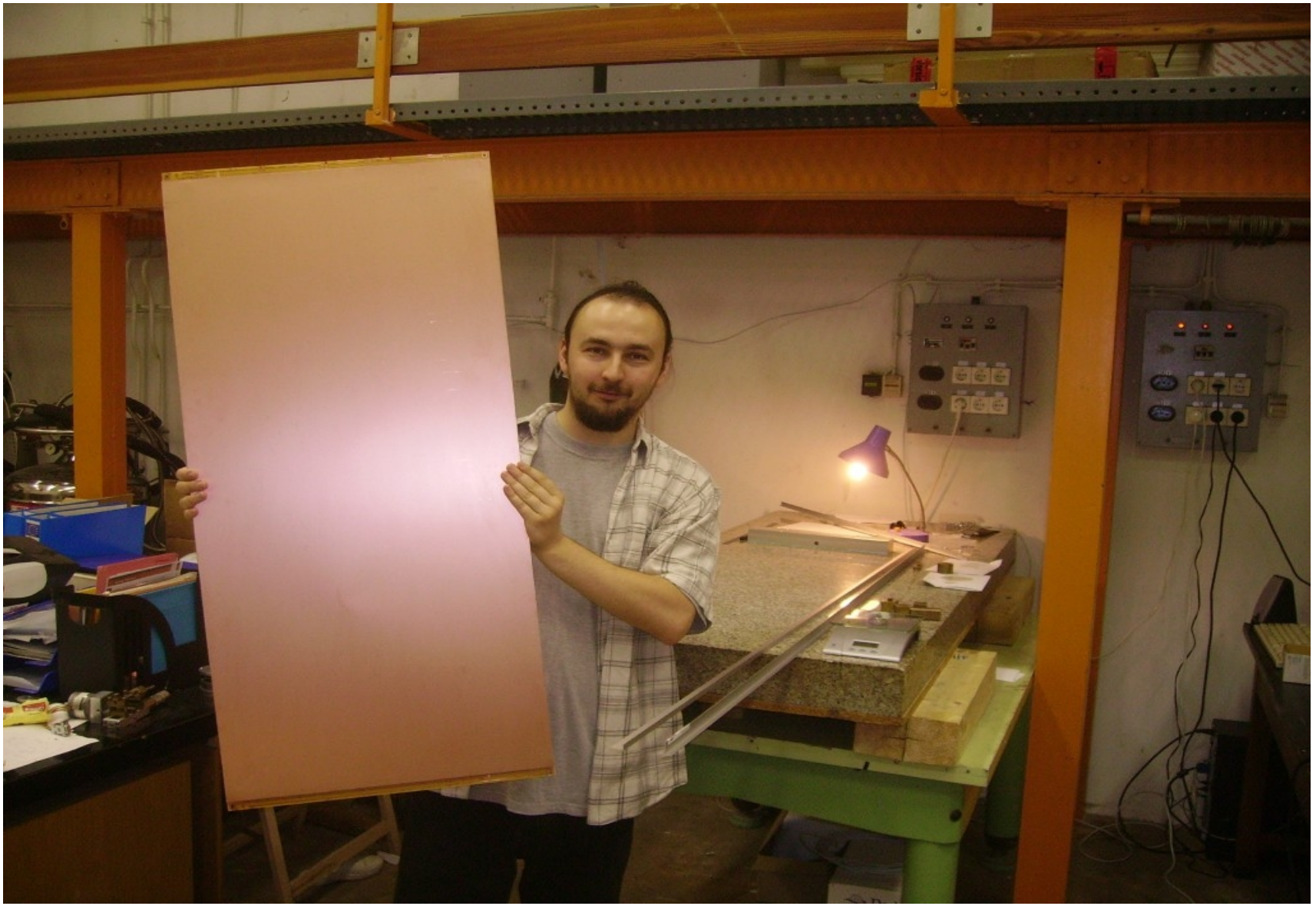


Cosmic setup with area of 0.5 × 0.5 m^2

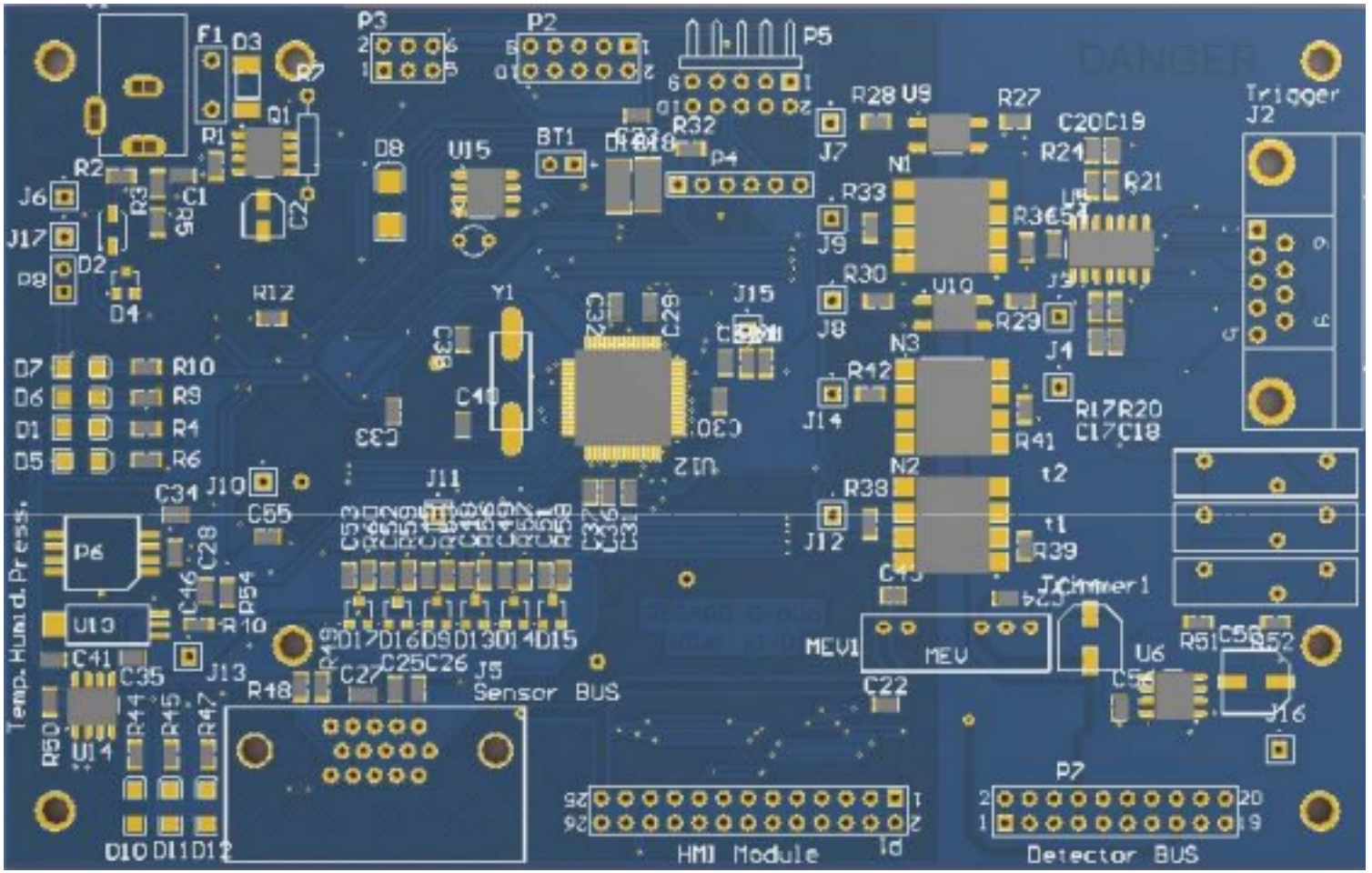
- It's also working in the lab! :)
- Underground tests are coming soon ...



CCC with 1 m x 0.5 m Sensitive Area

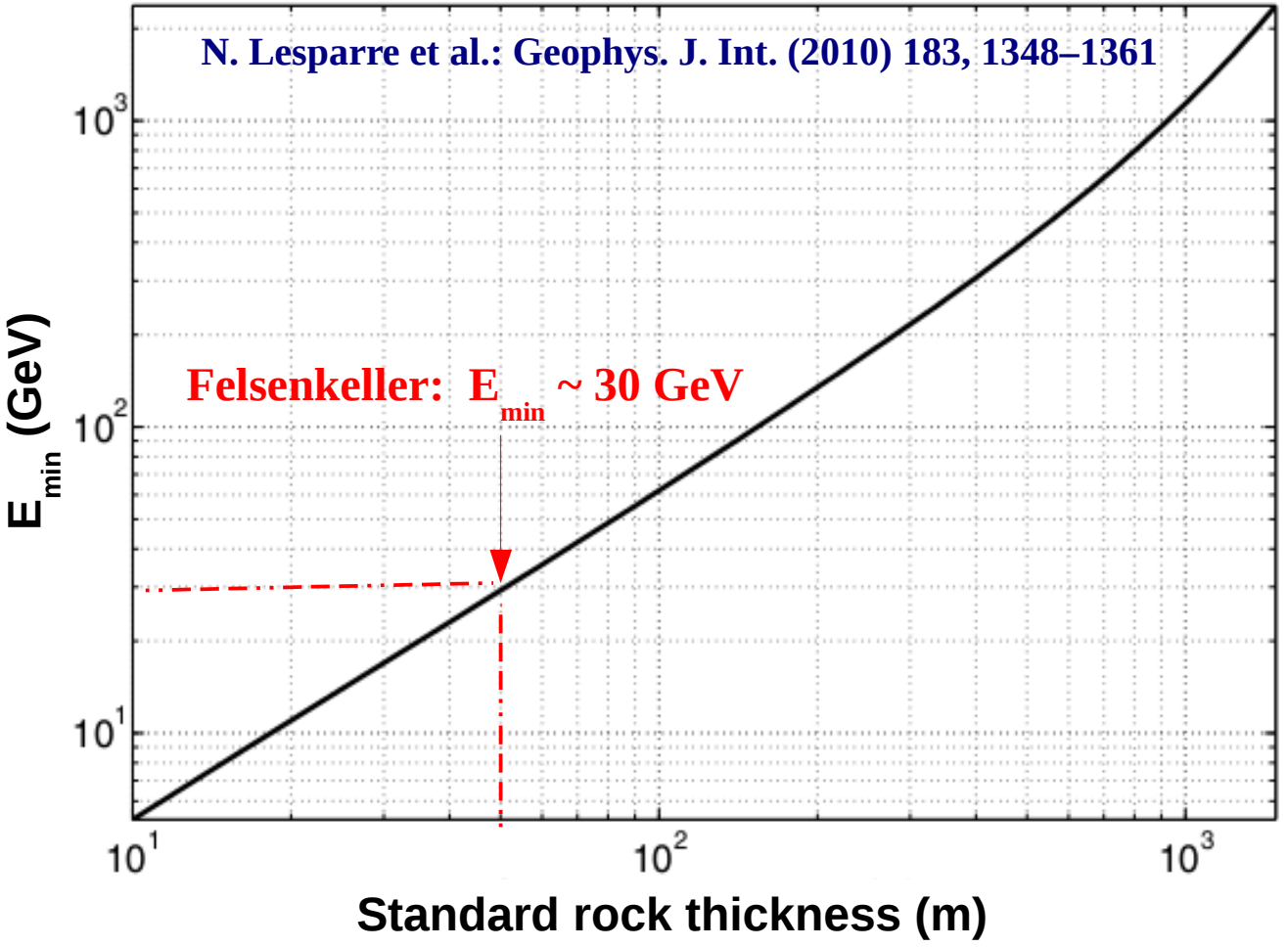


The Board of DAQ



Penetration of Cosmic muons into underground

- Cosmic muons mainly loss their energy by ionization:
  $-dE/dL/\rho = a(E)+b(E)E$
- Bremstrahlung, nuclear interactions and direct e^-- e^+ pair production from Monte Carlo modelling



- 5 GeV → 10 m
- 30 GeV → 50 m
- 50 GeV → 100 m
- 1 TeV → 1 km