microCAD 2013 Miskolc

Portable Cosmic Particle Detector for Investigation of Underground Rock Inhomogeneities

László Oláh

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21th March 2013

Outline

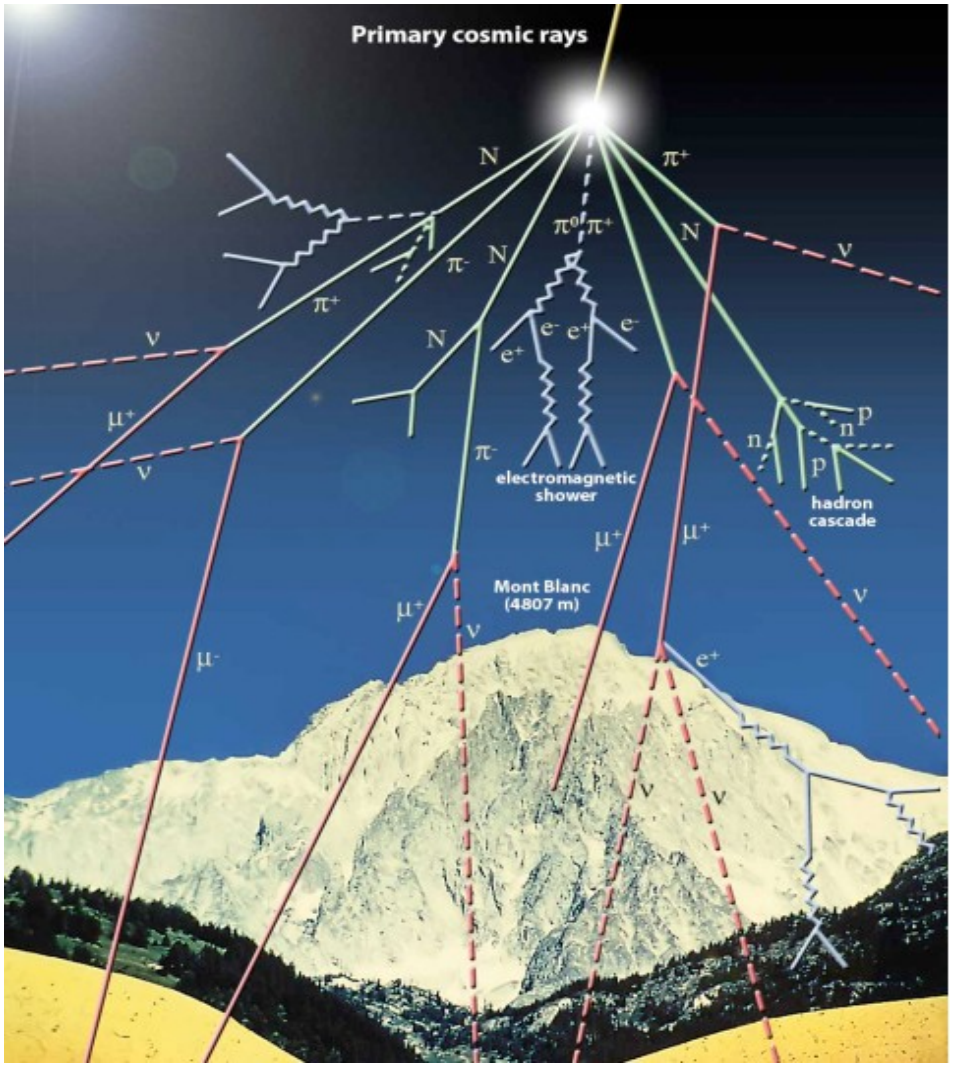
I. Motivation

II. Structure of the Portable Muontelescope

III. Underground Tests

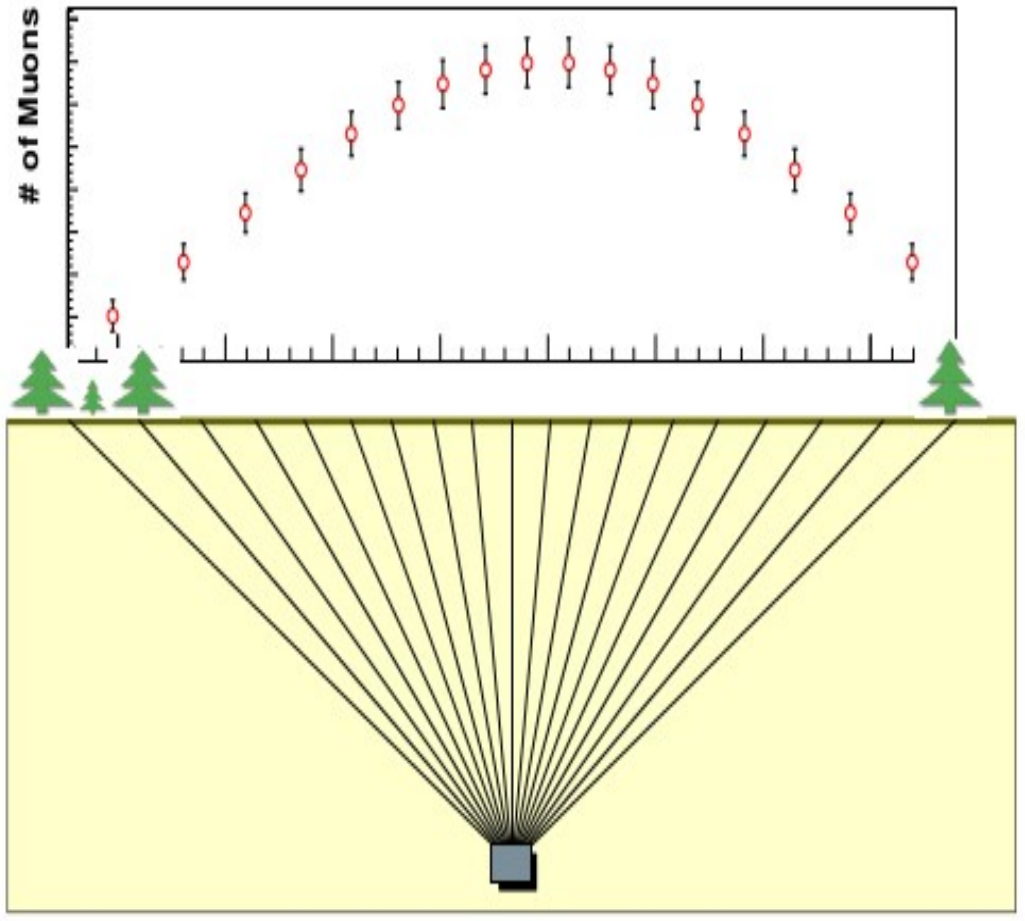
IV. Our measurements in the Ajándék Cave

I. Motivation: Cosmic Rays at Earth



- Our Earth is continually bombarded by high energy particles (p, ...).
- They interact with the atmosphere: producing pions, muons, etc.
- Cosmic muons reach the surface of the Earth, and penetrate to underground!

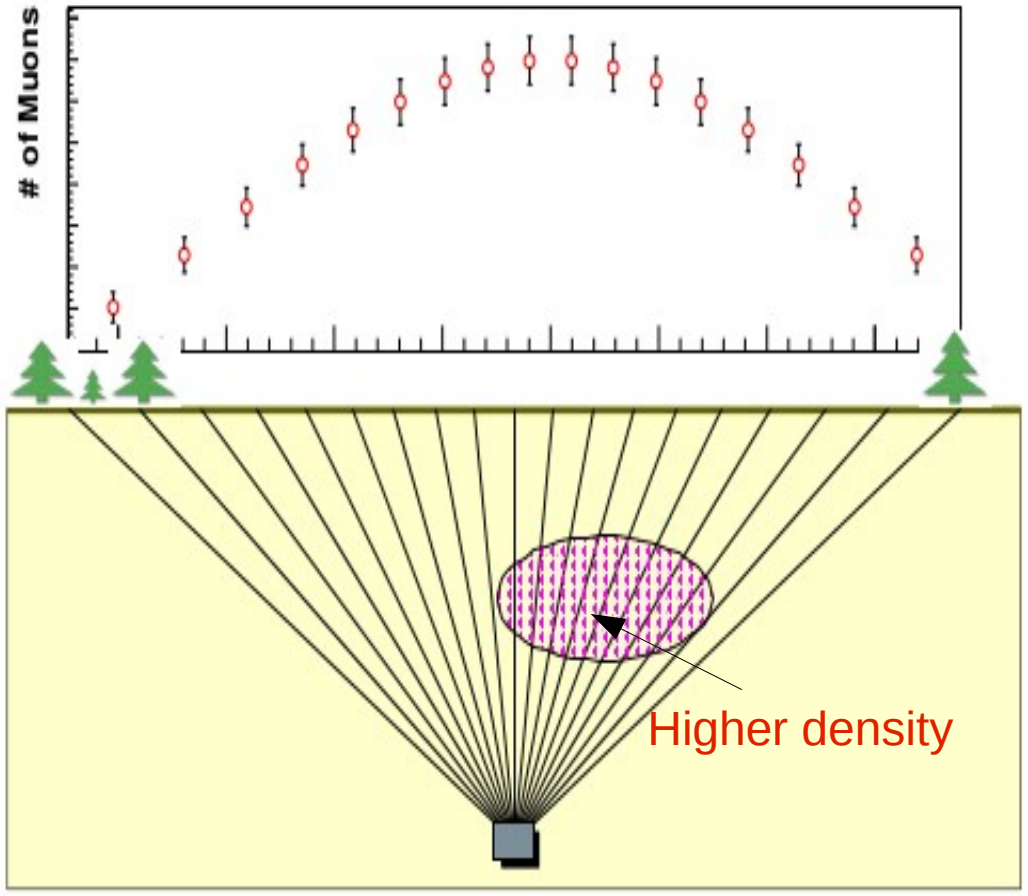
I. Motivation: Muon Tomography



- Cosmic muons angular distribution: $N(\theta) \sim \cos^2(\theta)$.

See Zhiyi Liu talk at MNR2012 (Clermont Ferrand)

I. Motivation: Muon Tomography



- Cosmic muons angular distribution: $N(\theta) \sim \cos^2(\theta)$.
- Energy loss with ionization: $-dE \sim \rho\, dx$.
  - 5 GeV → 10 m rock
  - 60 GeV → 100 m rock
  - 300 GeV → 500 m rock
  - 1 TeV → 1000 m rock

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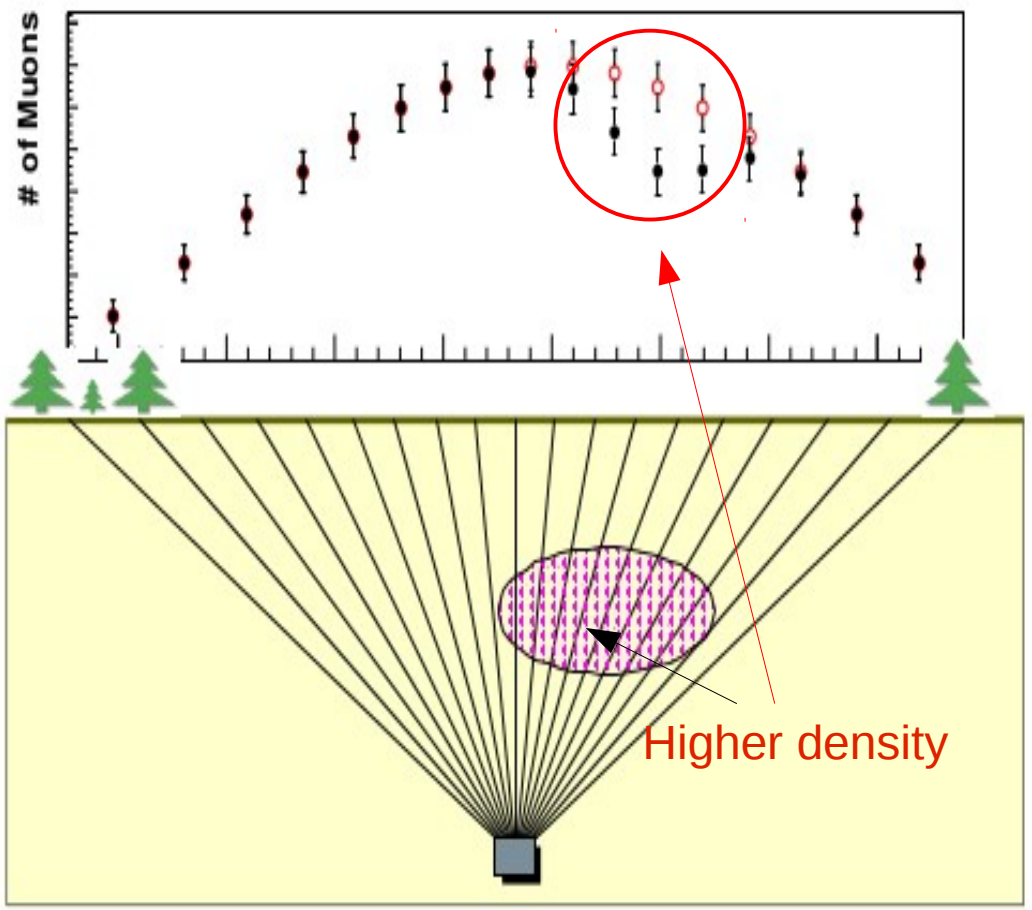

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  - 5 GeV → 10 m rock
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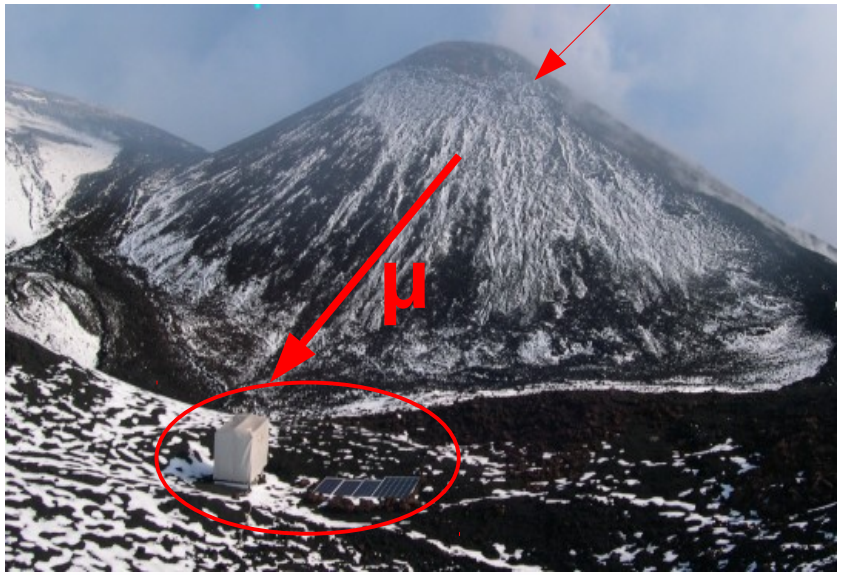
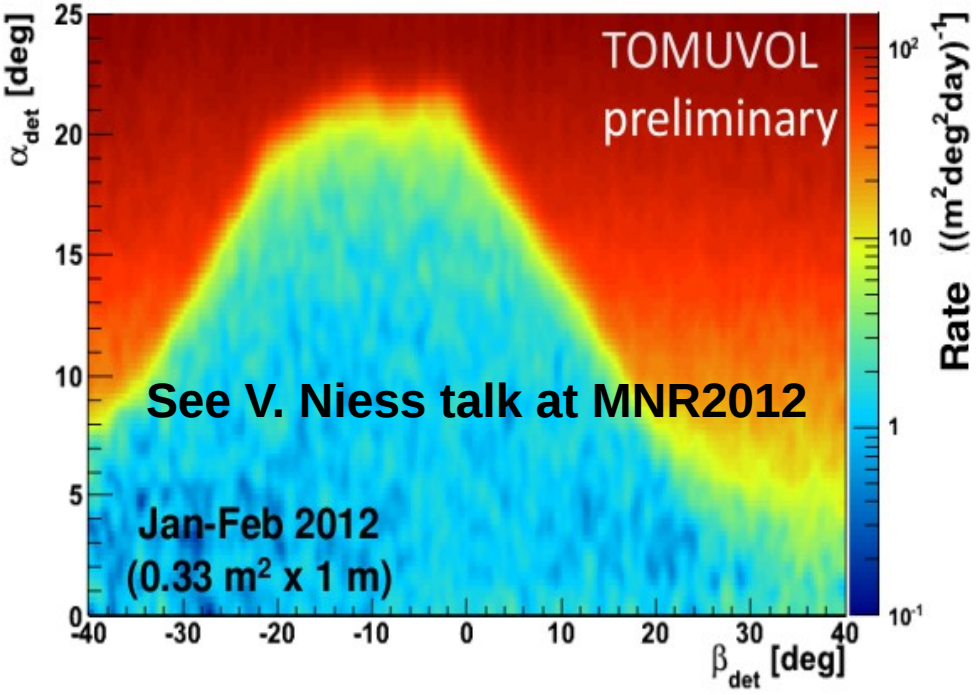
  - 1 TeV → 1000 m rock
- Underground rock inhomogenity with higher (lower) density the cause of the decrease (increase) in muon flux

Vulcanology:

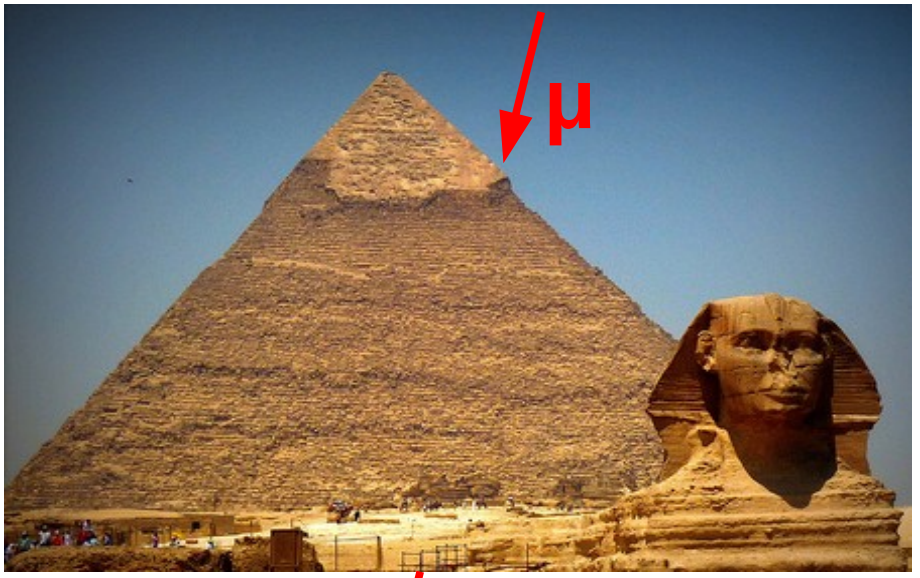
predict the eruptions

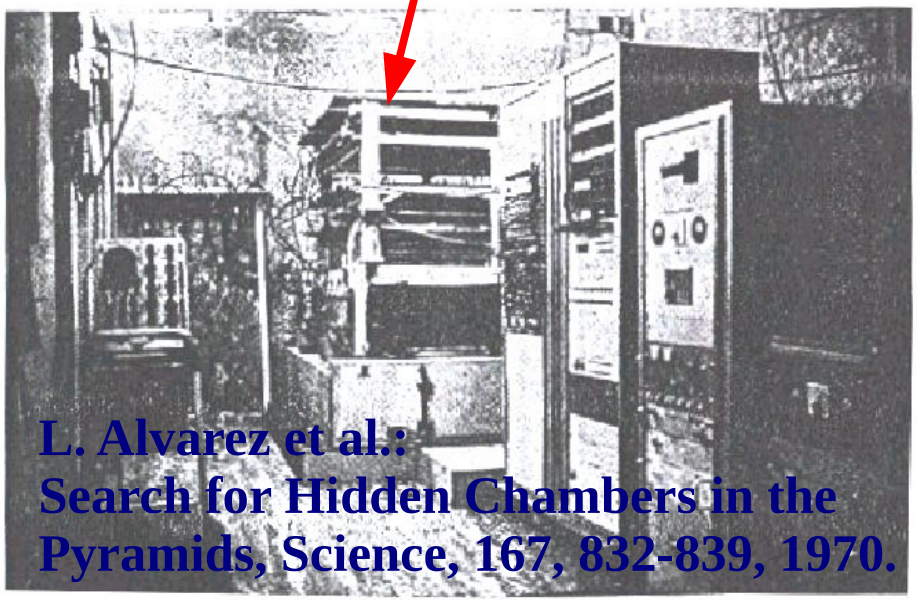




Archeology:

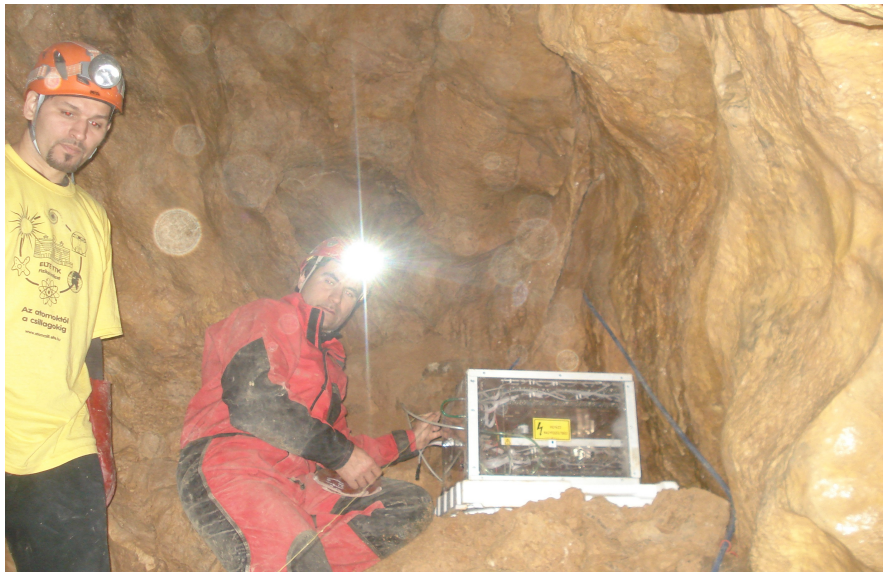
search for hidden chambers

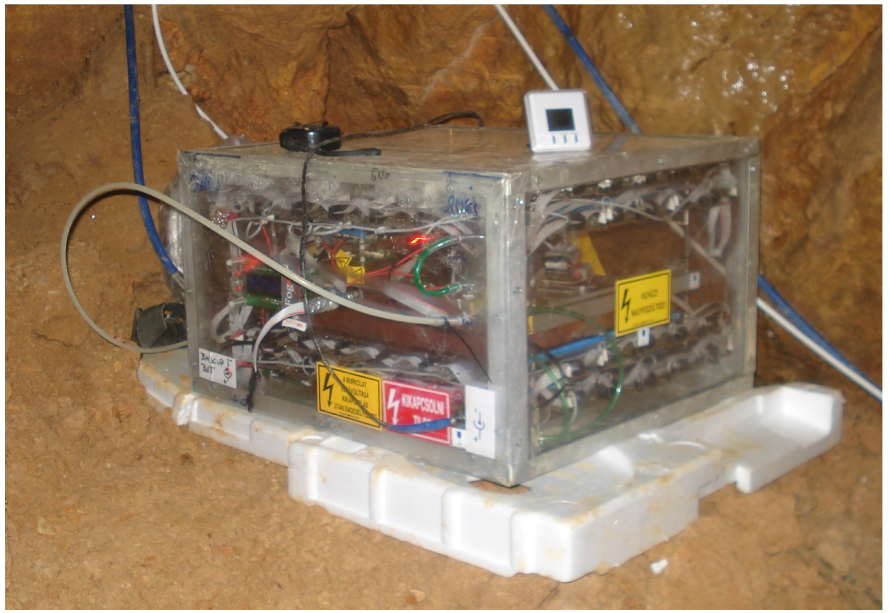




L. Alvarez et al.:
Search for Hidden Chambers in the Pyramids, Science, 167, 832-839, 1970.

I. Our Motivation

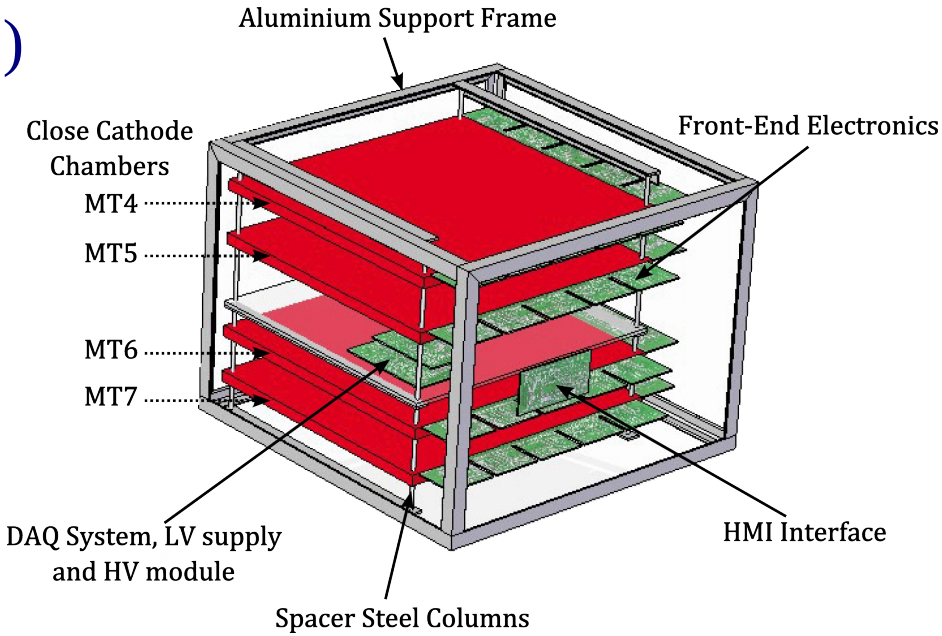


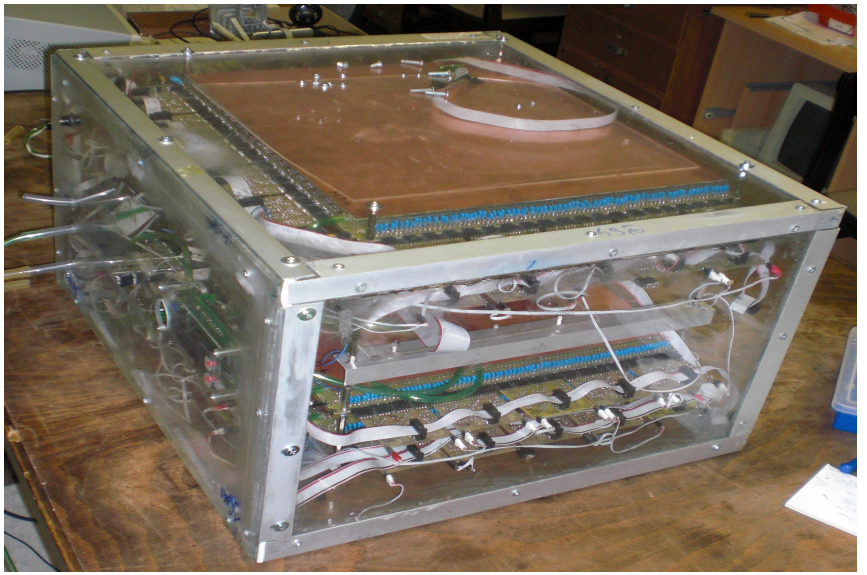


- **Aim of Our Research:**
  - investigating unexplored part of caves
  - Searching underground rock inhomogeneities
- **Portable Muontelescope:**
  - precision:
    - 1.5 mm spatial resolution
    - 10 mrad angular resolution
  - use in high humidity (~ 100%) environment
  - cheap and power efficient (< 5 W)

II. Structure of the Portable Muontelescope

- 4 (or 5) Close Cathode Chambers (CCC)
- Sensitive area per layer:
  32 cm by 32 cm
- Plexiglass box
- 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





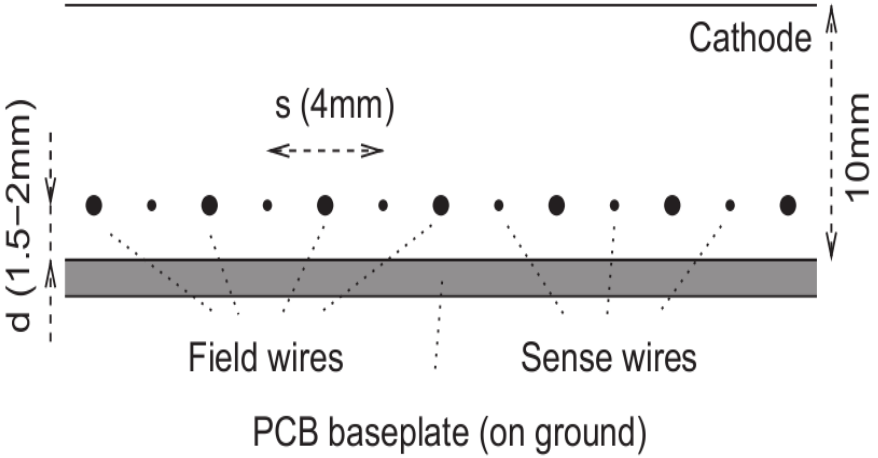
CCC Technology for Muon Detection

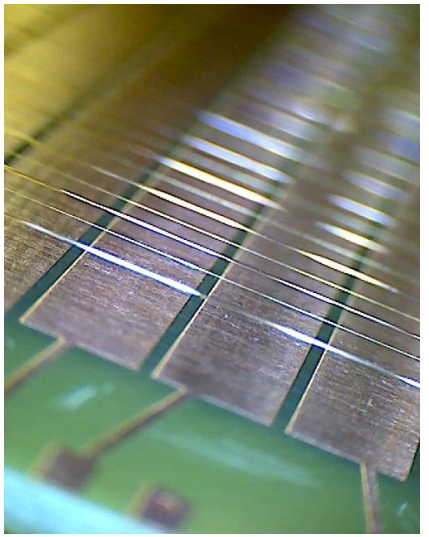
- **Close Cathode Chamber** is an Asymmetric **Multiwire Proportional Chamber**

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

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

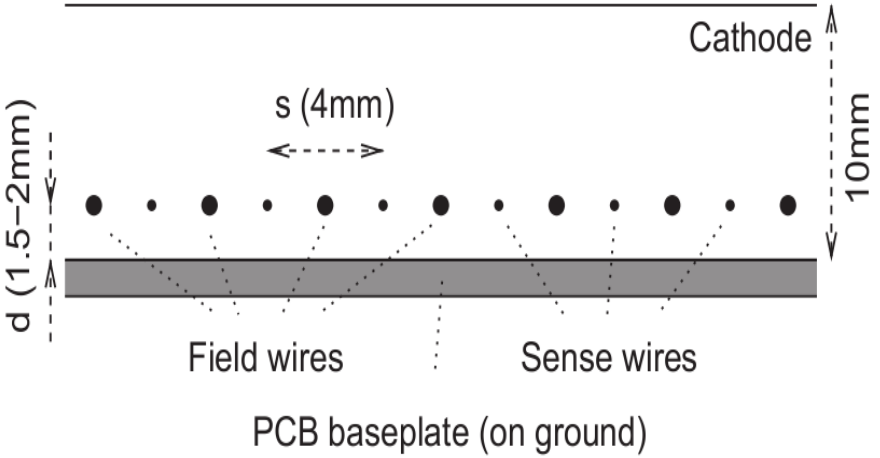
- 2 dimensional location:
  - field wire: distance 4 mm
  - The lower cathode is segmented into 4 mm wide strips (pads) perpendicular to the wires
- Triggering on coincidence of sense wires' signals
- Requires continuous gas flow during operation: non-flammable $Ar - CO_2$

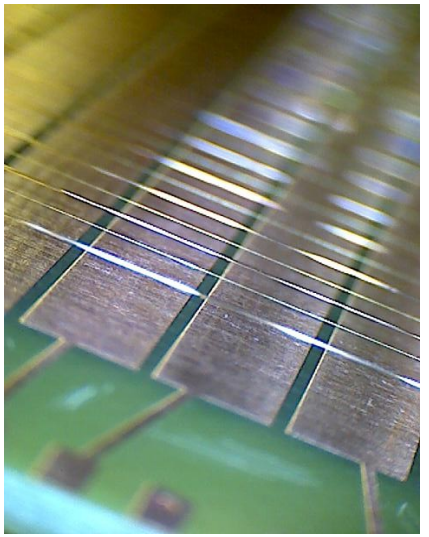




CCC Technology for Muon Detection

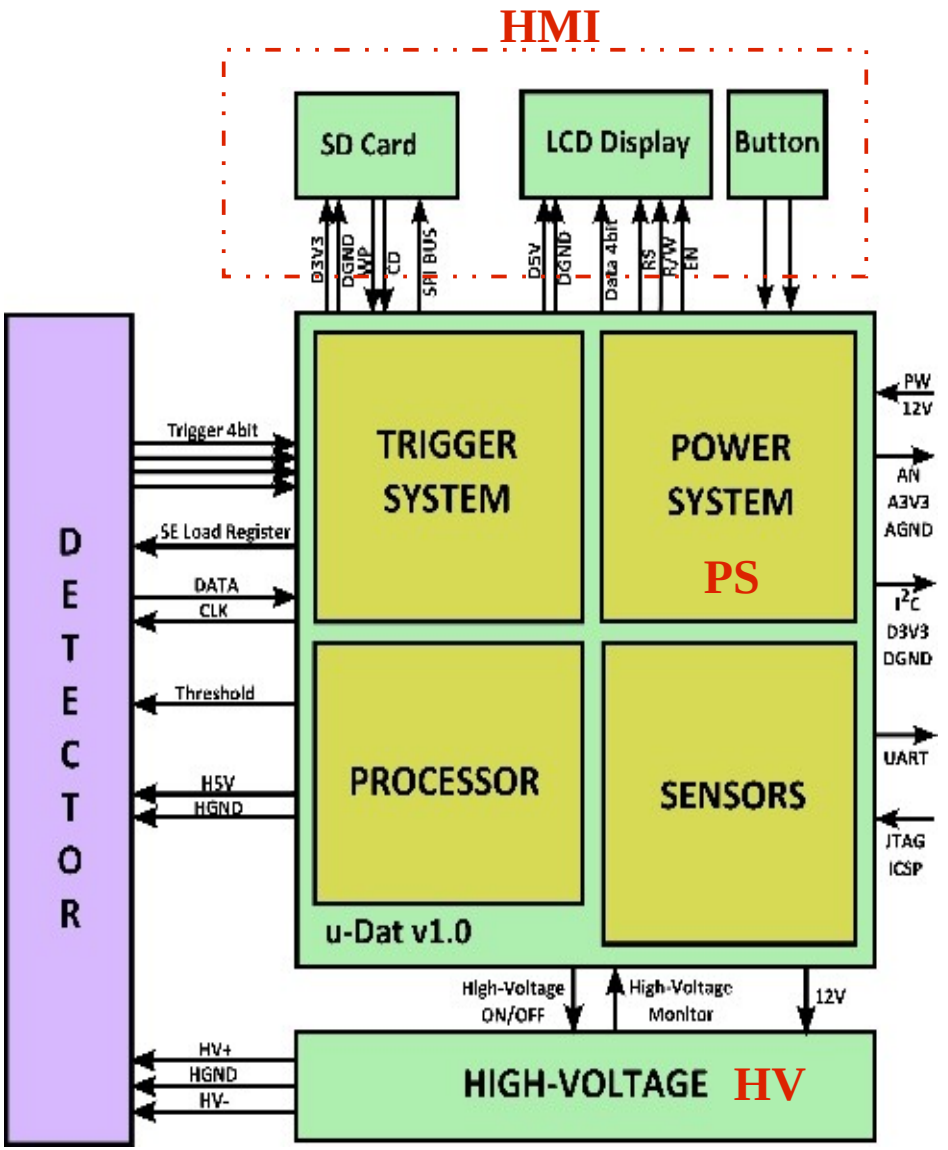
- **Why CCC?**
  - MWPC which does not require weighty outer support frames
  - Optimizes:
    - Weight/Layer (0.88 kg)
    - Position resolution (1.5 mm)
    - Efficiency (> 95 %)
    - Cost
  - High tolerance against mechanical inaccuracies (100-200 µm)



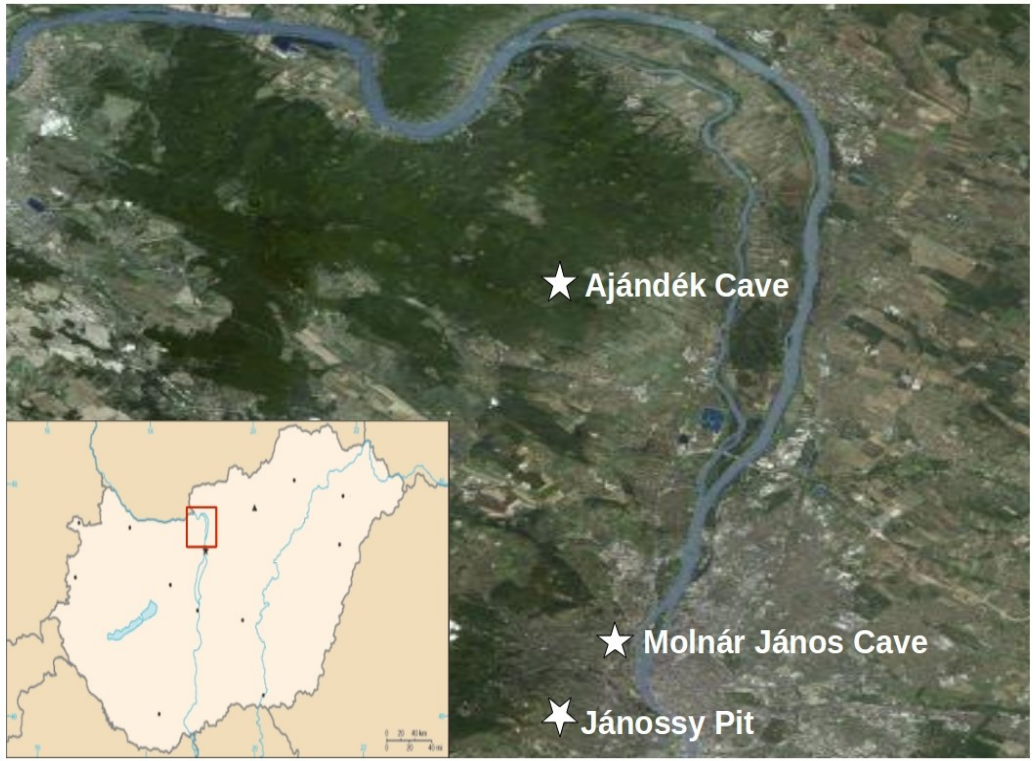


Integrated Data Acquisition System

- PIC32 based DAQ
- All functions are integrated into a common system plan
- Small unit: placed between the middle CCC layers
- **Main functions:**
  - Low Voltage, Power System (PS)
  - High Voltage:
    - 1000-1050 V for sense wires
    - -600 V for field wires and cathode
  - Trigger System
  - Detector Data Handling
  - Environmental Control
  - HMI for maintance and data storage
- **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

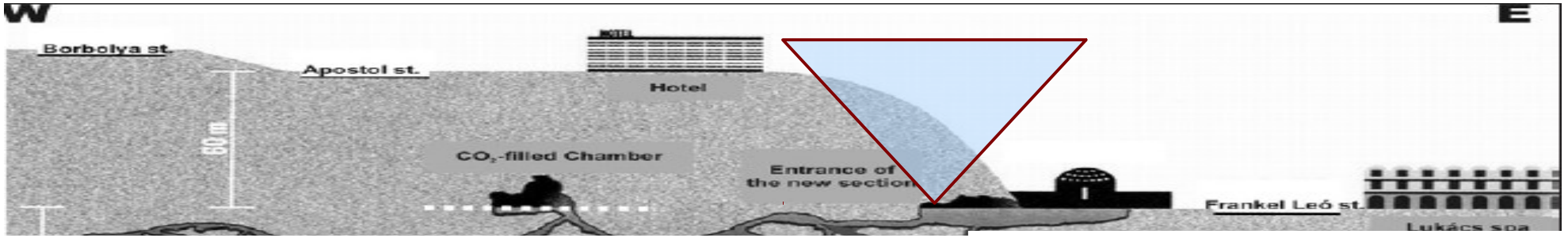


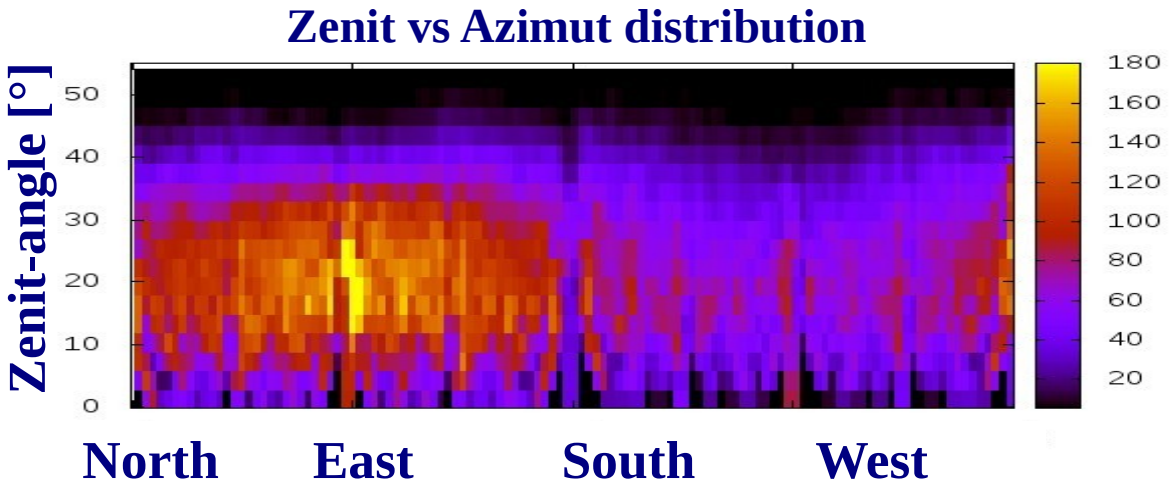
II. Fieldwork: Natural Caves and Artificial Pits

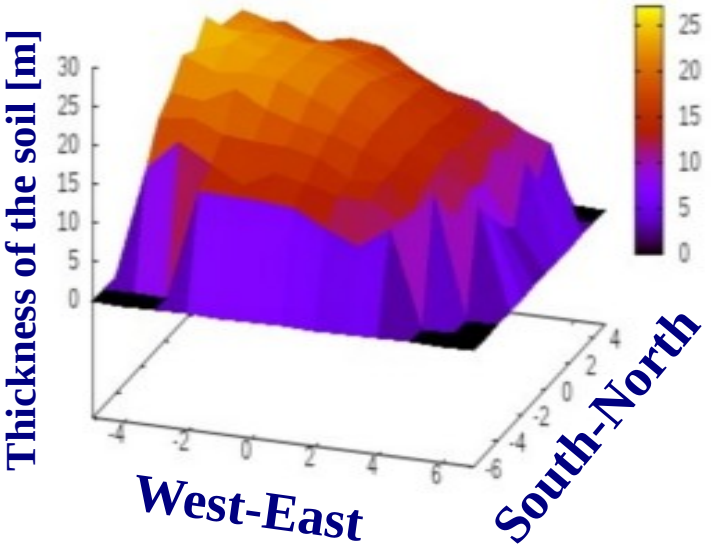


- **Lab (0 m):**
  > 100 days, > 100 M muon events
- **Jánossy Pit (-10, -20, -30 m):**
  30 days, 4 M muon events
- **Molnár János Cave (-45 m):**
  77 days, 1.1 M muon events
- **Ajándék Cave (-60 m):**
  50 days, 170 k muon tracks
- **Pilis Mountain (0 m):**
  1 day, 300 k muon events
- **Brewery Cave (-20 m):**
  30 days, 500 k muon events

Detector Tests in the Molnár János Cave



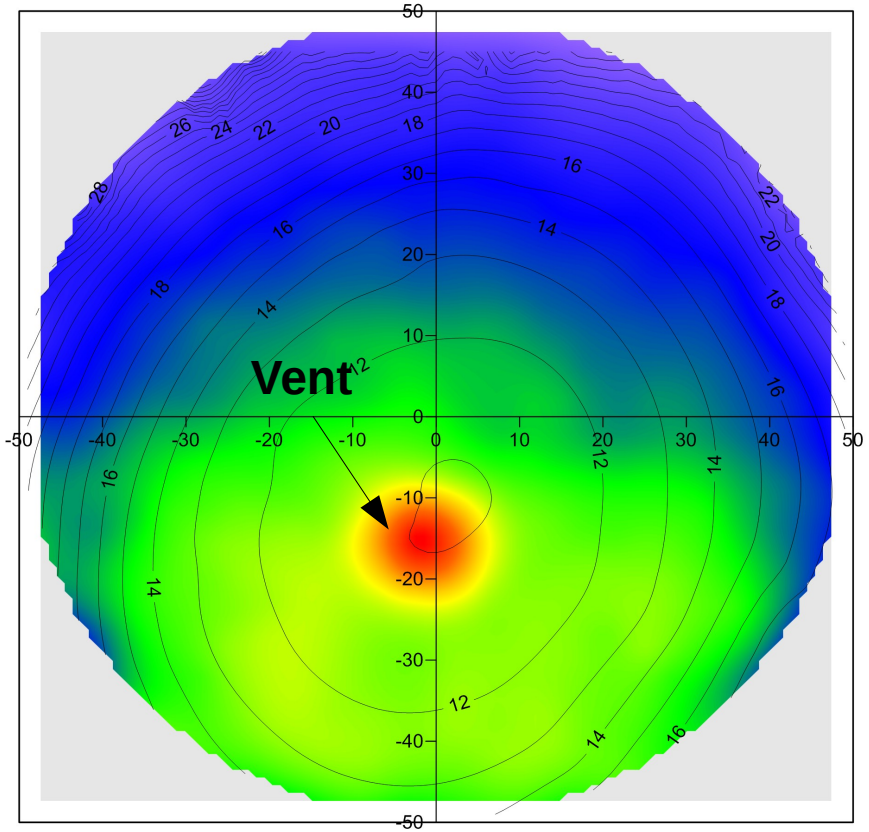


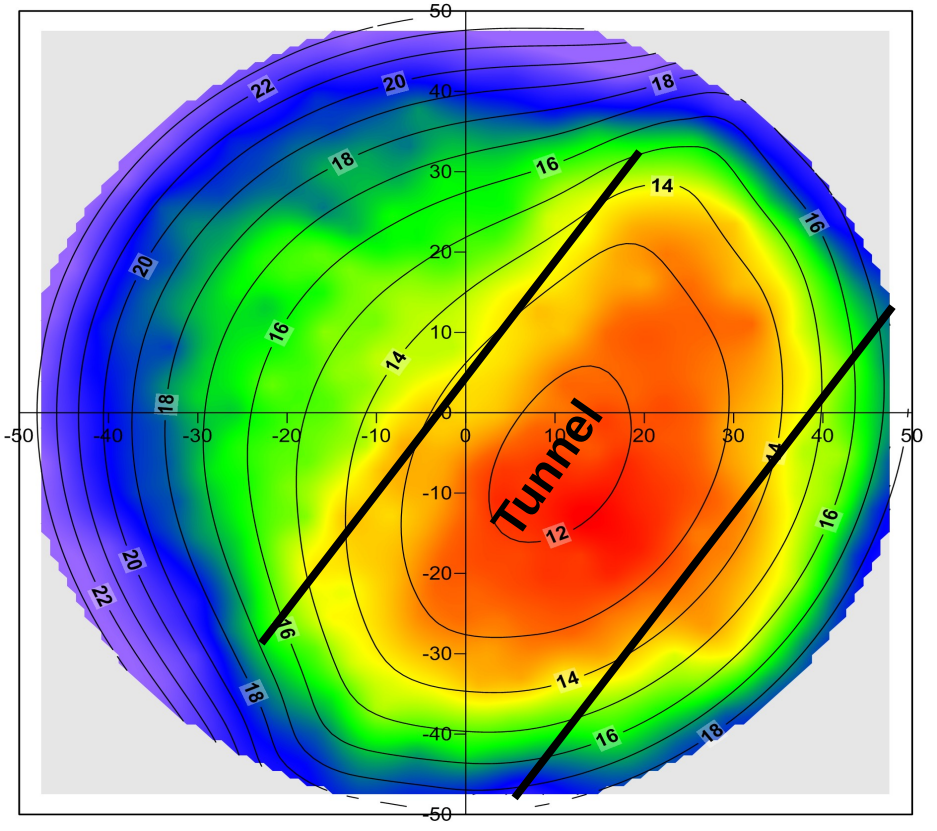


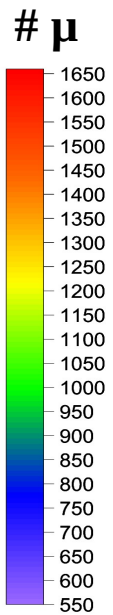
- Measurements in the Molnár János Cave, Budapest: 18 days with 850 k events
- Zenit-Azimut angle distribution and relief reconstruction both show the correlation between the amount of material above the detector and muon yield

Detector Tests in Kőbánya Tunnel System

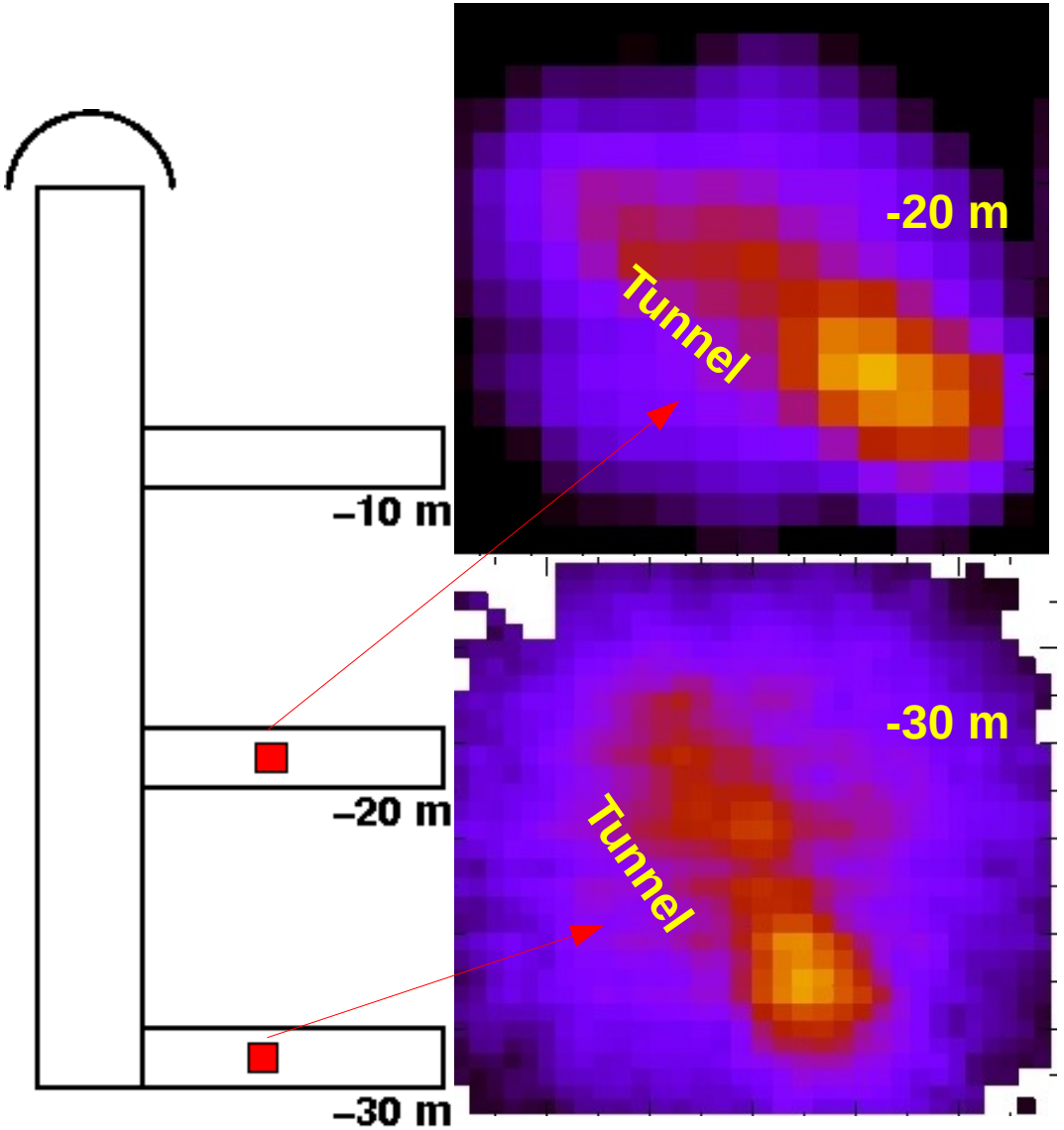
- 1-2 weeks measurements at 10-20 m depths with 100k – 500k muon tracks
- Measured muon flux correlates with the transversed material:
  the muon telescope could detect the sharply differences in soil thickness
  (e.g. the vents, the walls of tunnels)!







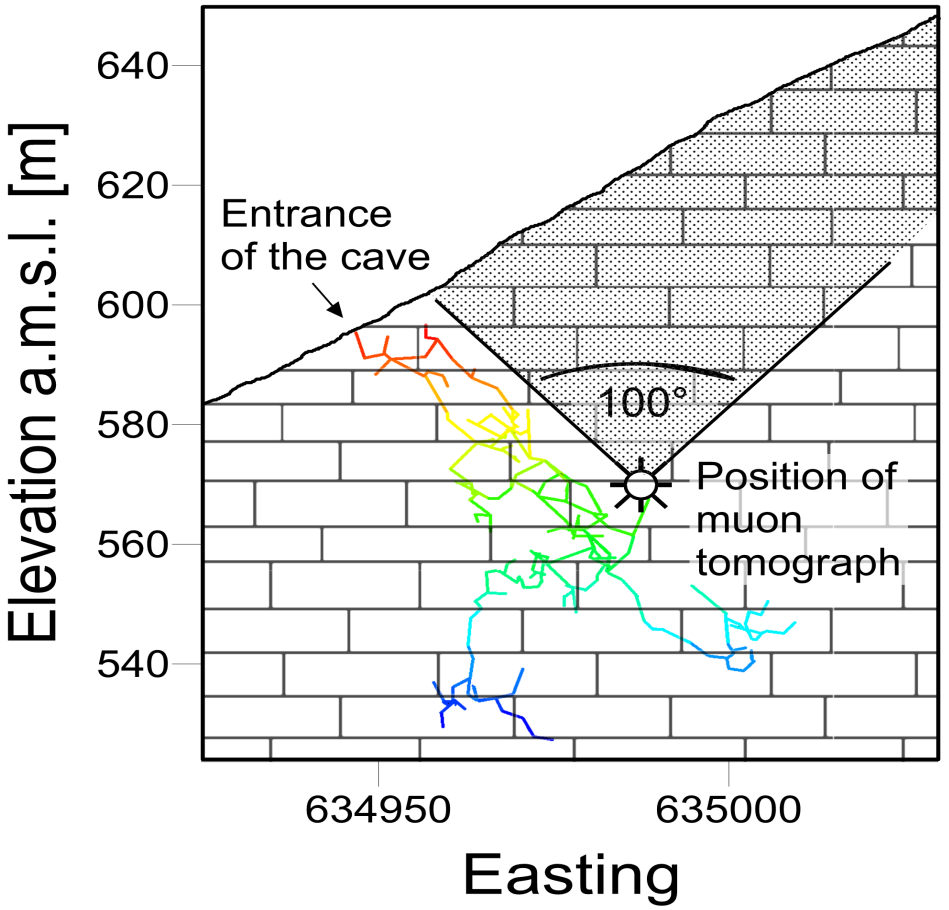
Tunnel Detection in the Jánossy Pit



- 3-5 days measurements at different depths (-10 m, -20 m, and -30 m) with 100k-200k muon tracks
- Measured muon flux clearly shows the ,,image" of the tunnels

IV. Measurements in the Ajándék Cave

- Natural cave system
  close to Pilis mountain, Hungary
- Search for unknown natural caverns
  or chambers at scale 2-4 m
- Time of data taking: 50 days
- The gas and 3 power supply batteries
  were deposited at the cave entrance,
  and were connected with 100 m
  long cable and tube



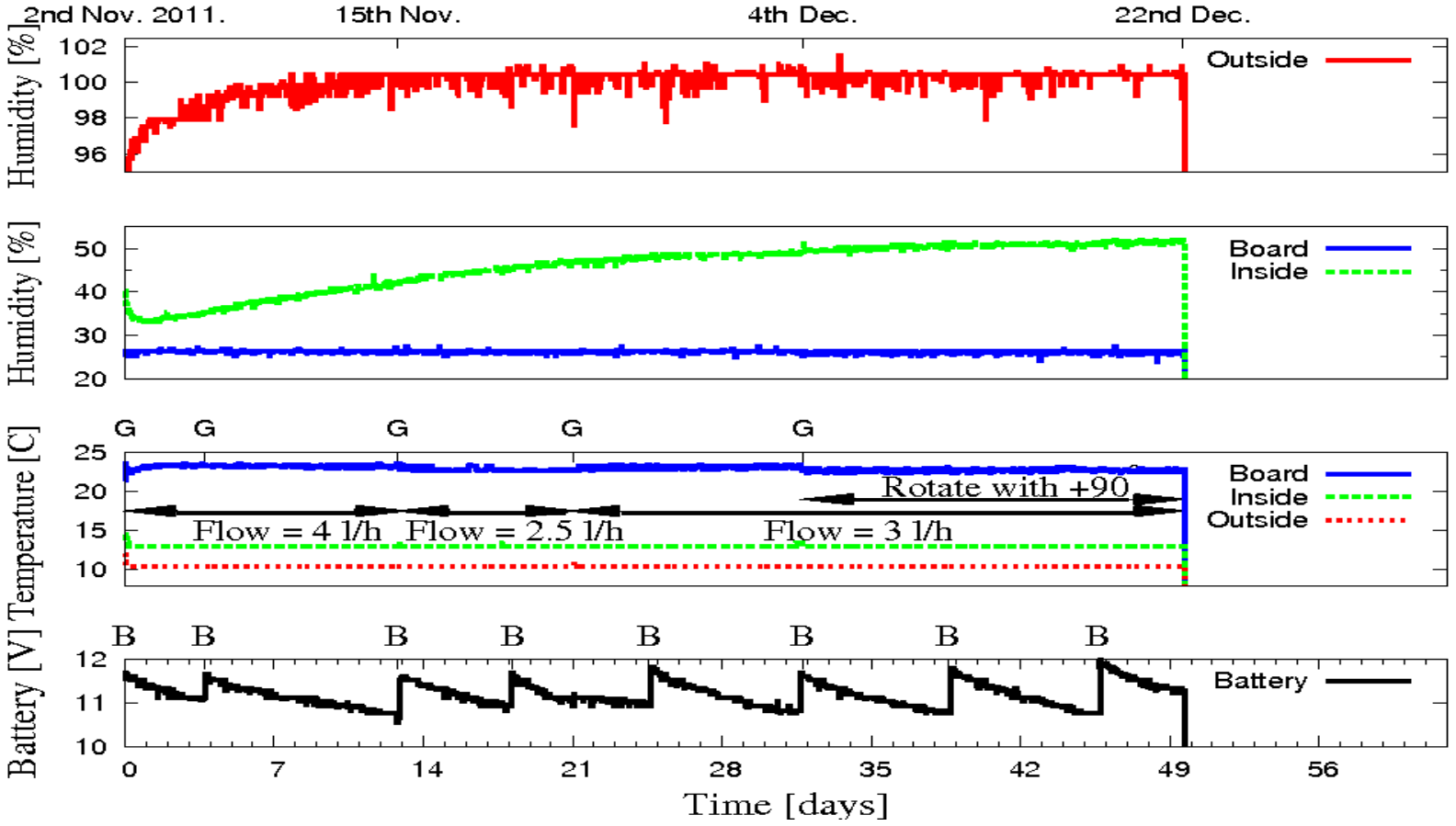
Deployment at the entrance of the Ajándék Cave

- Cave entrance: batteries and gass bottles (detector before deployment)

Deployment in the Ajándék Cave

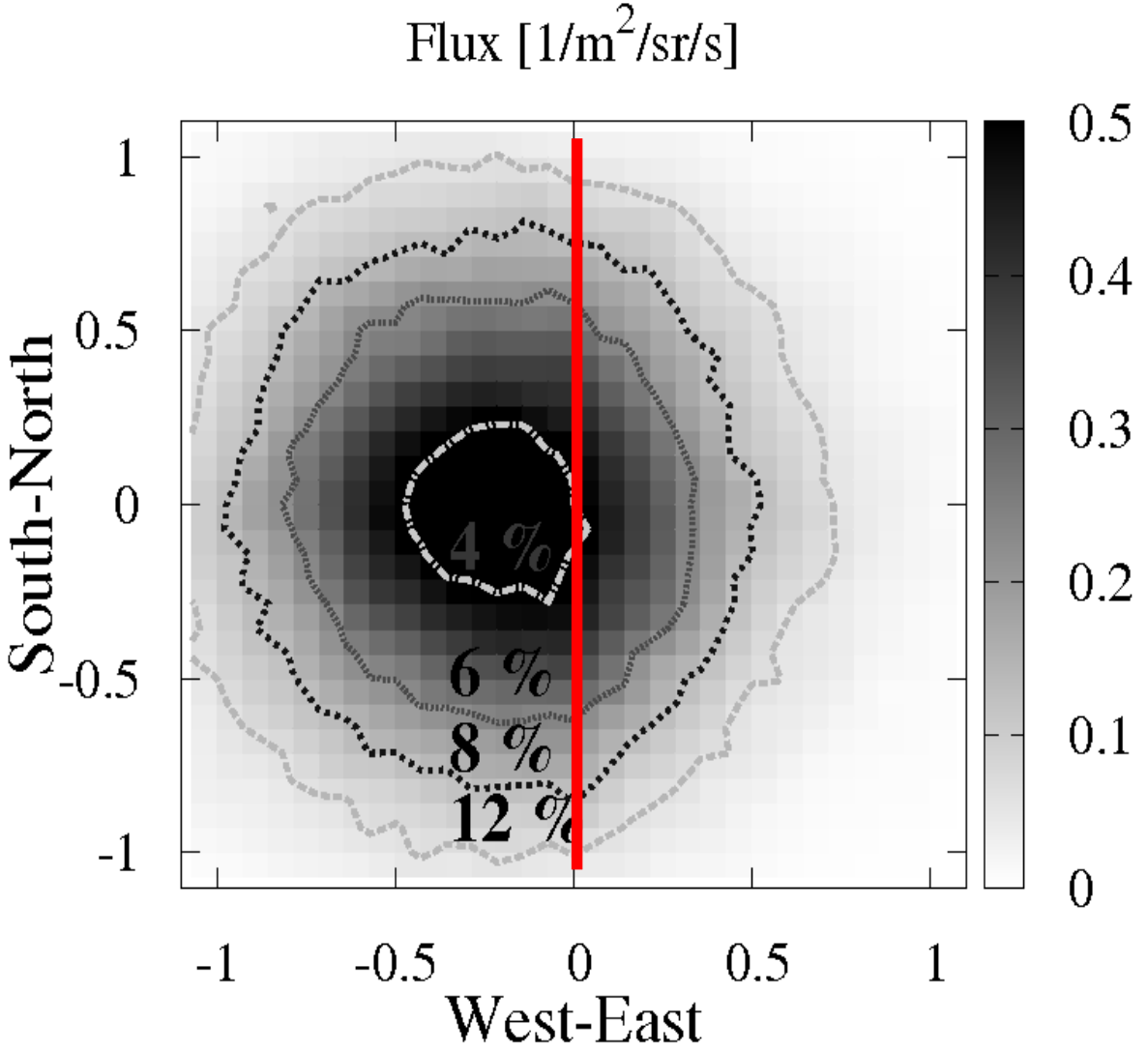
Environmental Control

- 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.



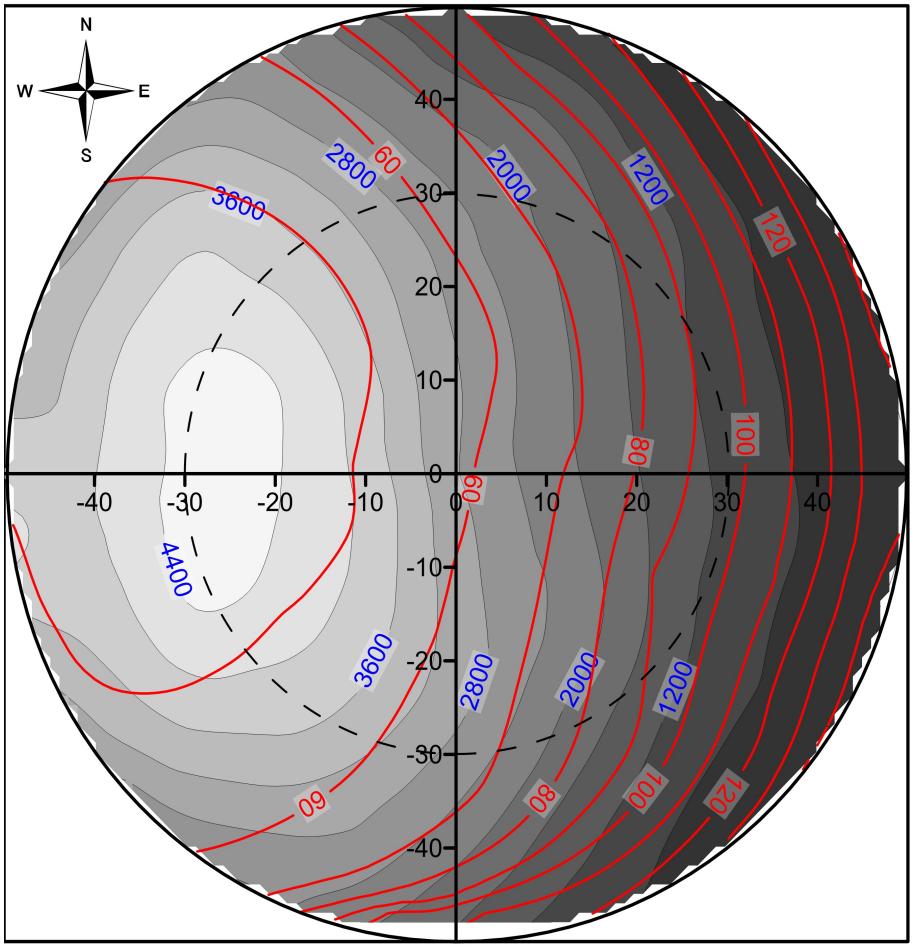
Measured Muon flux in the Ajandek Cave

- During the 50 days of data taking: 170 k muon tracks (60m underground)
- Flux with pixel-by-pixel statistical error
- Main yield is shifted to the Western direction



Mountain Relief above the Ajándék Cave

- Muon flux vs thickness of the rock: shows strong correlation
- Found no evidence for unknown caverns



Summary

- **REGARD Group's Muontelescope:**
  - Mobile (< 13 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 €)
  - Integrated DAQ + HV + LV + Trigger System + HMI
- **Measurements in Natural Caves:**
  - MWPC-based tracking telescope can work in high humidity conditions
  - Relief reconstruction has been done above the Molnár János Cave, Kőbánya tunnel system, and tunnels have been detected in the Jánossy Pit
  - 50 days of data taking in the Ajándék Cave: found no evidence for unknown caverns

G. G. Barnaföldi et al.: NIM A 689 (2012) 60

L. Oláh et al.: Geoscientific Instruments, Methods and Data Systems 2 (2012) 781

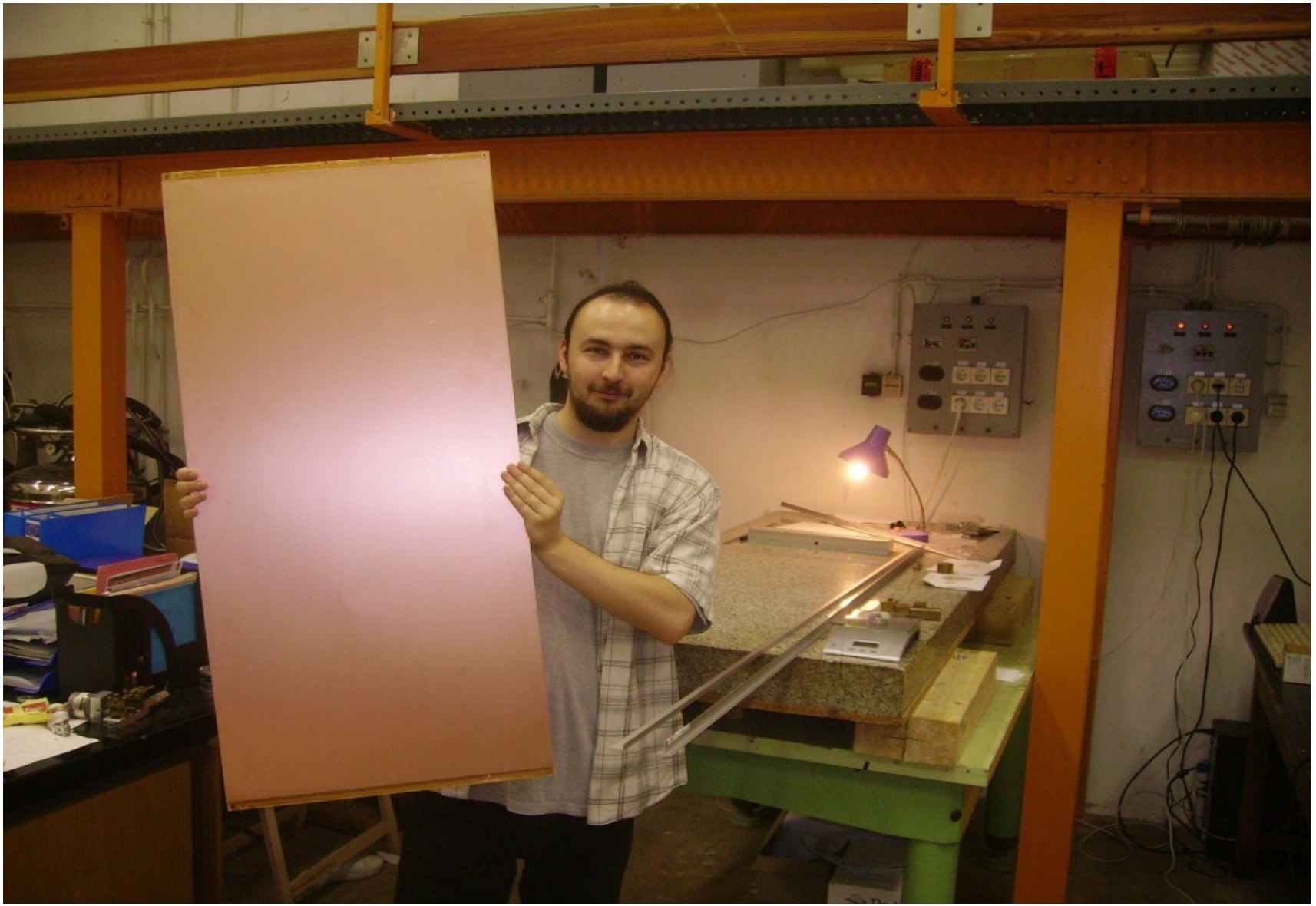
Oláh L.: Szerkezetvizsgálat kozmikus részecskékkel, Természet Világa 2013 április

Thanks for Your Attention!

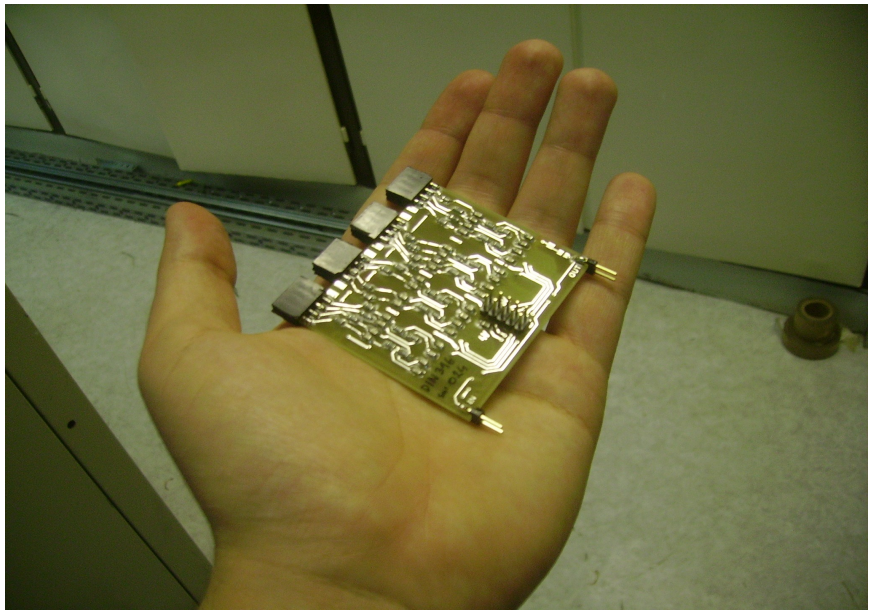
Our research is supported by OTKA KTIA CK 77719, OTKA KTIA CK 77815 and the OTKA NK-77816, OTKA PD-73596 grants.

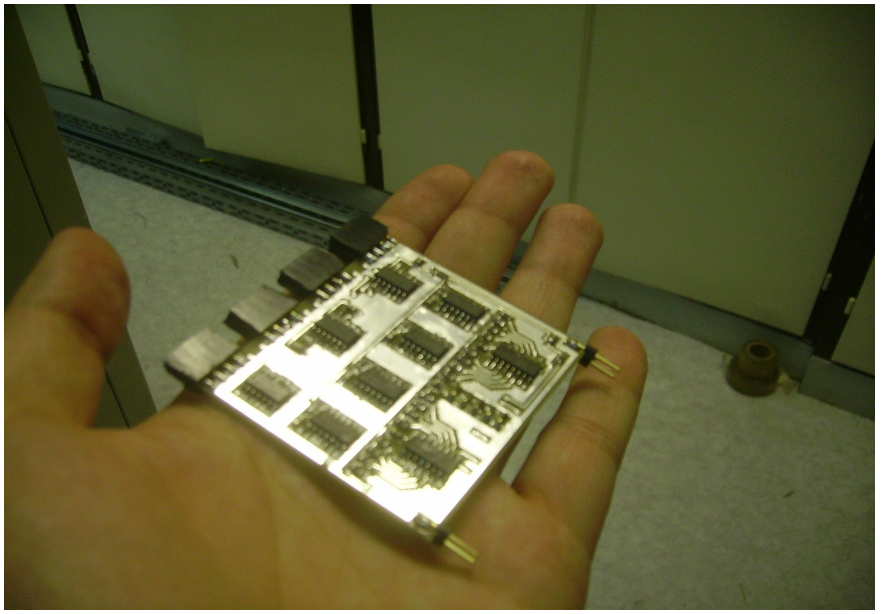
Backup Slides

CCC with 1 m x 0.5 m Sensitive Area



Front-End Electronics

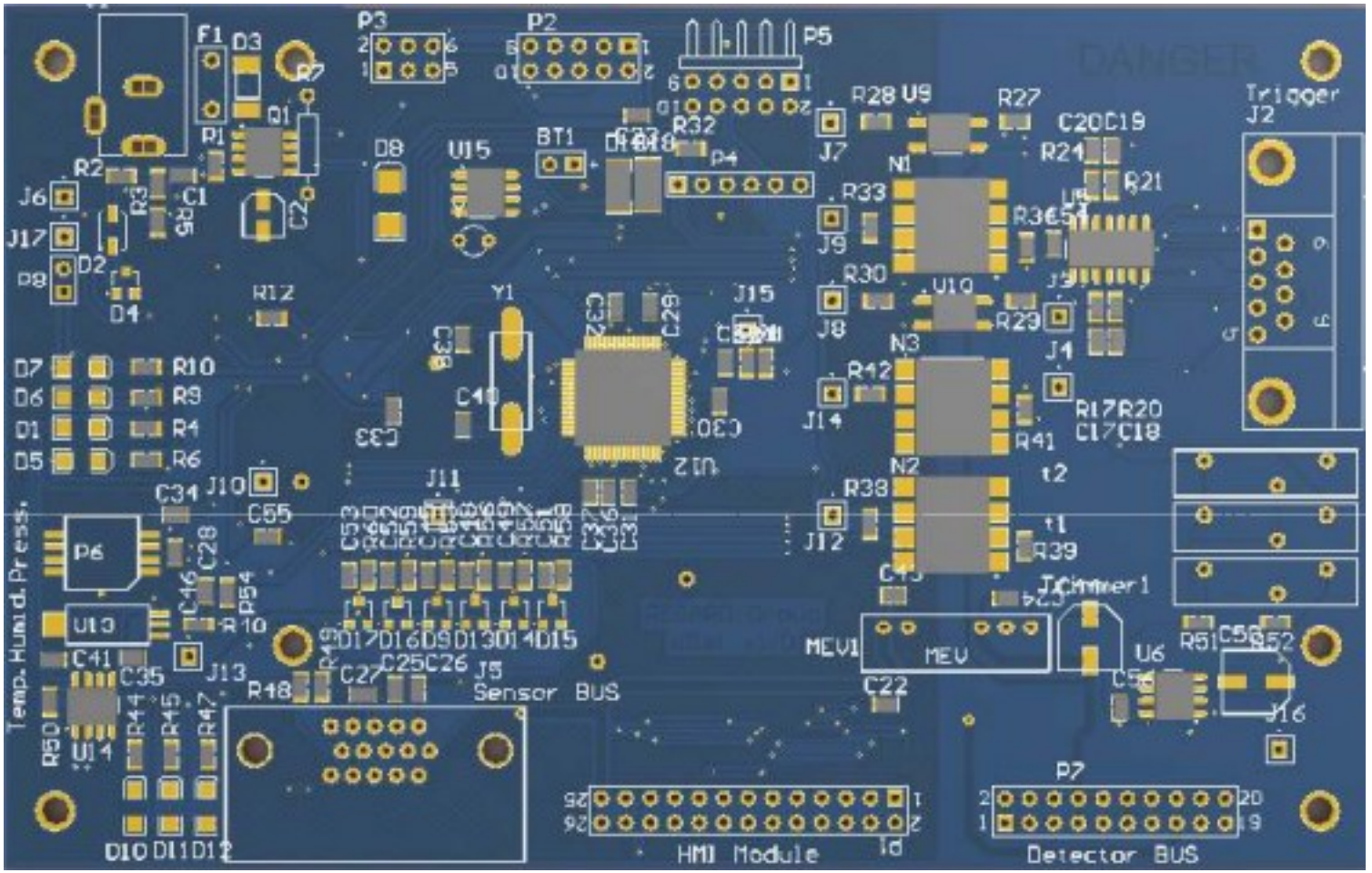




- 16 channels per electronic
- Analog amplification
  with commercial logic ICs
  (CD4001 and CD4069)
- Discrimination →
  1 bit per channel
- Local storage
  in a shift register (74HCT165)
- Serial readout

- All electronics can be put into
  one chain

The Board of DAQ



DAQ