

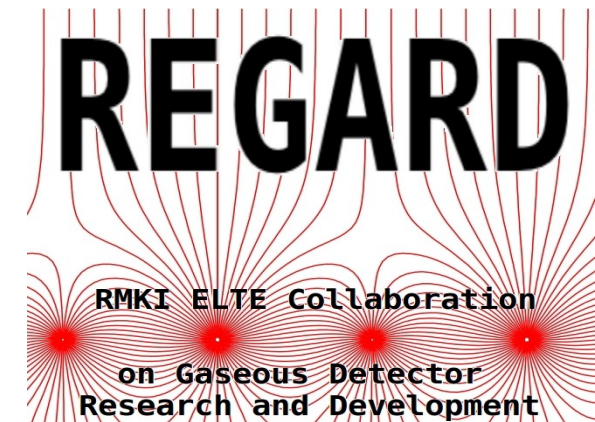
Zimanyi Winter School on Heavy Ion Physics

Portable Tracking Detector for Muon Tomography Experiments

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G. Surányi, D. Varga

5th December 2012



Outline

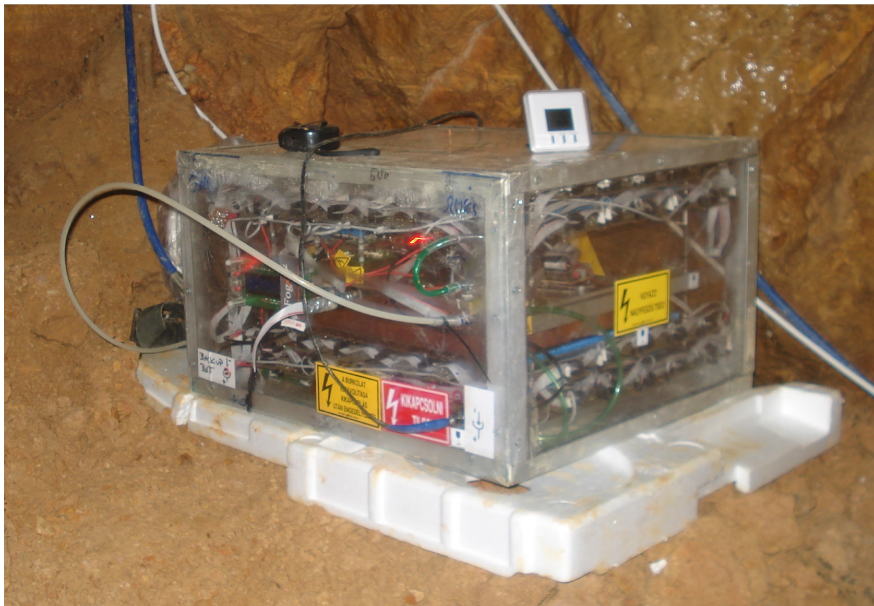
I. Motivation

II. Structure of the Muontelescope

III. Detector Tests at Kőbánya Tunnel System

IV. Our Measurements in the Ajándék Cave

I. Motivation



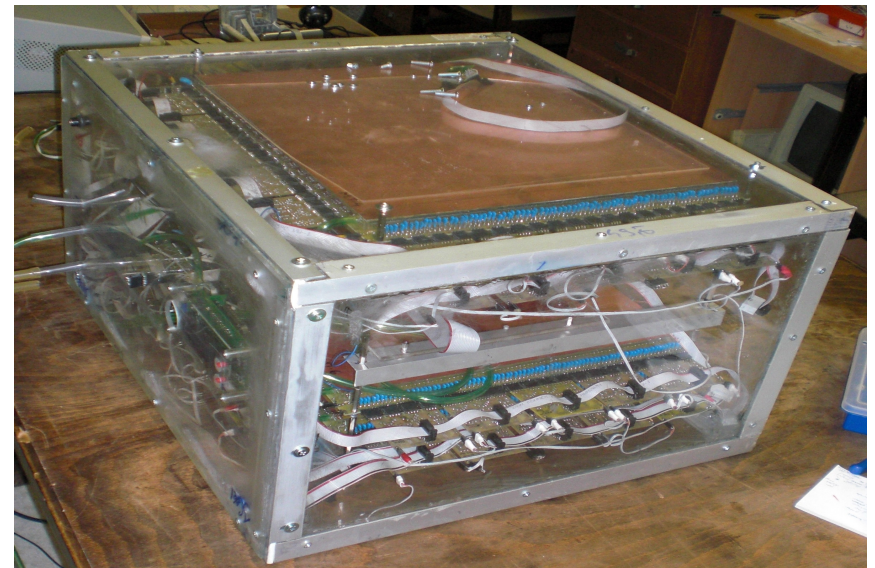
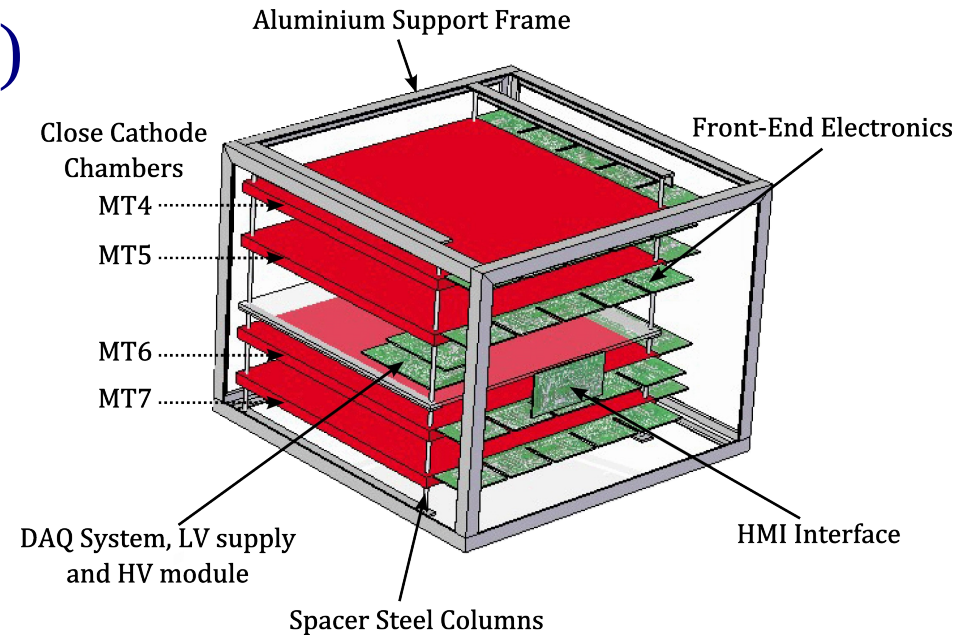
- **Physics Motivation:**
 - measure the cosmic muons angular distribution with good precision at shallow depths (10-100 m)
- **High Energy Geophysics Application:**
 - investigating unexplored part of caves
 - mapping the structure of mountain-relief
- **Portable Muontelescope:**
 - precision:
 - 1.5 mm spatial resolution
 - 10 mrad angular resolution
 - use in high humidity (~ 100%) environmental
 - cheap and power efficient (< 5 W)

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

L. Oláh et al.: GID 2 (2012) 781

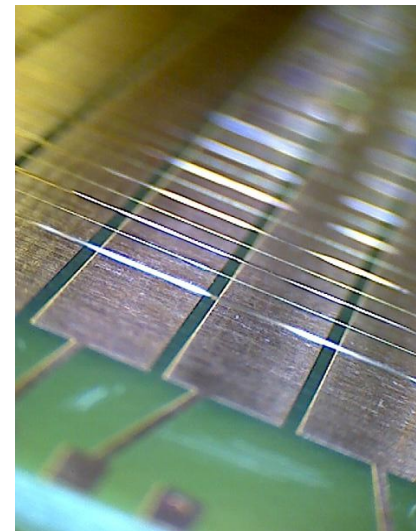
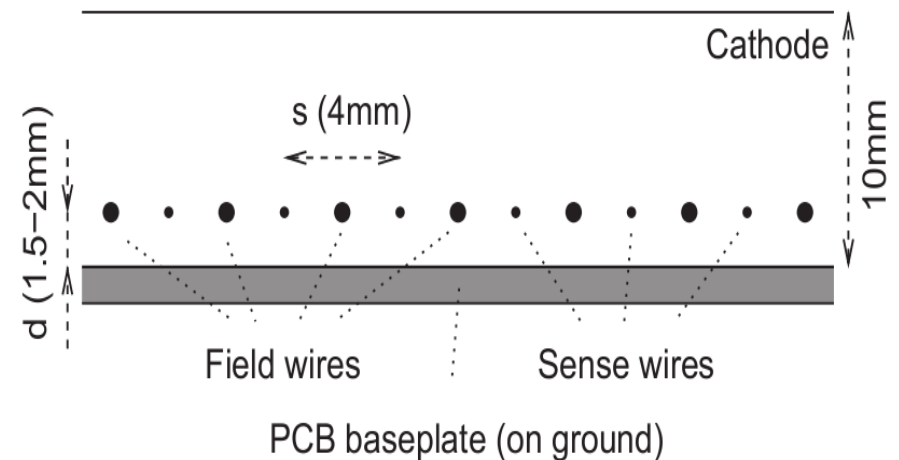
II. Structure of the Muontelescope

- 4 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 cm³
 - total weight: 13 kg
- Data acquisition (DAQ) system integrated into one unit
- Human Machine Interface (HMI):
 - LCD display, SD card



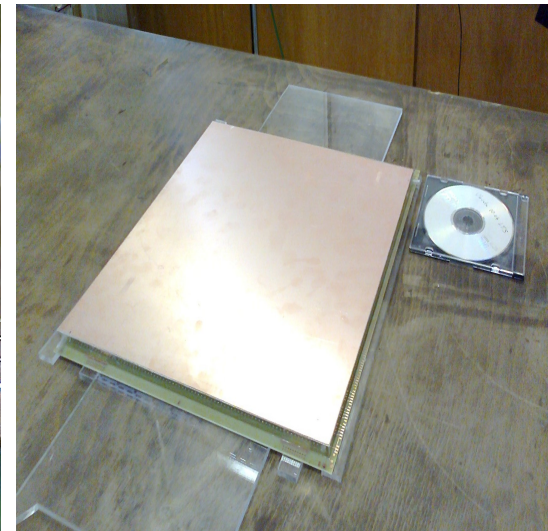
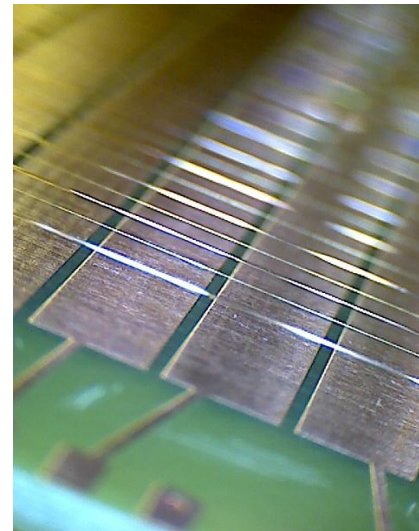
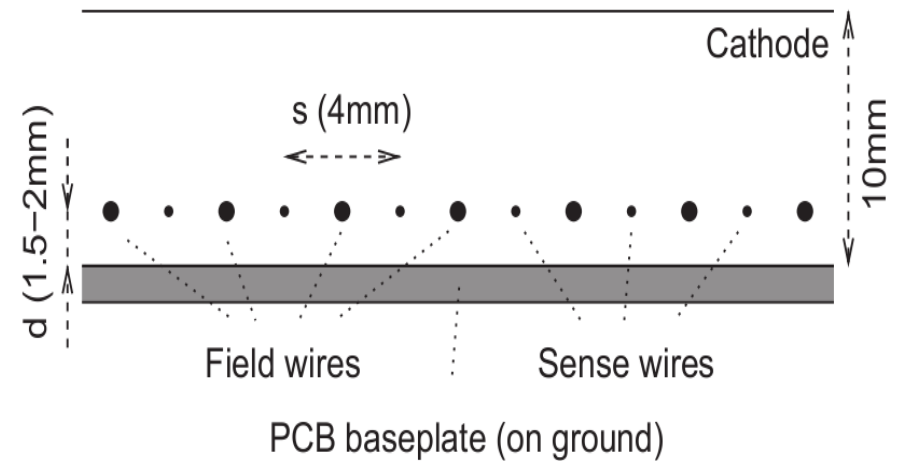
CCC Technology for Muon Tomography

- **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
- Requires continuous gas flow during operation: non-flammable Ar – CO₂



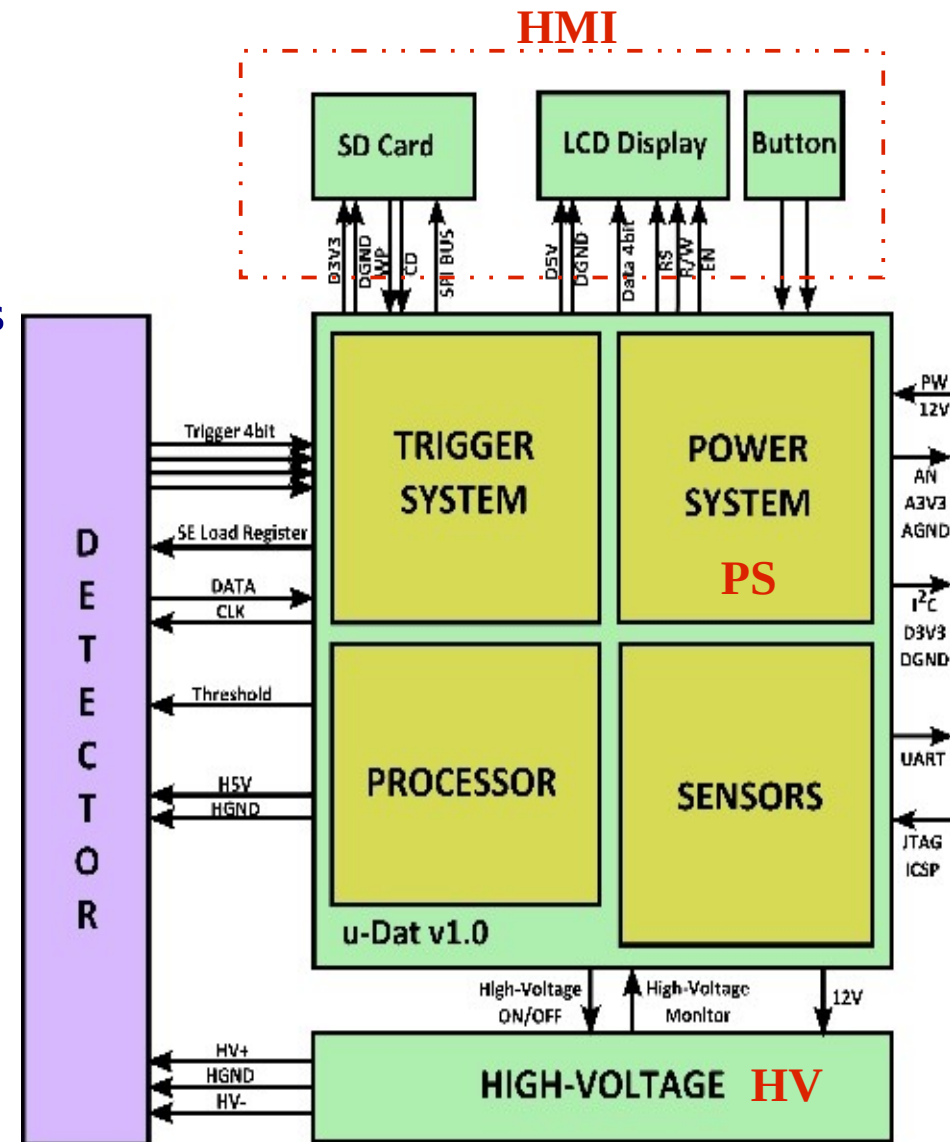
CCC Technology for Muon Tomography

- **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)

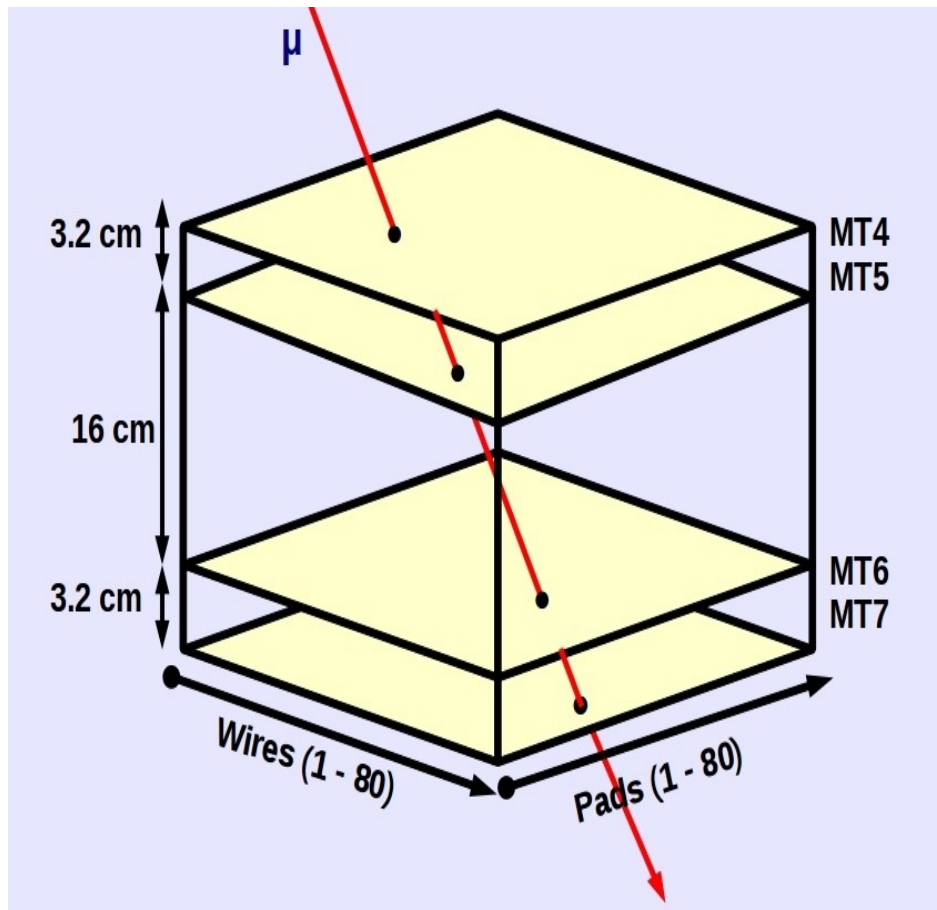


Data Acquisition System

- 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:
 - 1100 V for sense wires
 - -600 V for field wires and cathode
 - Trigger System
 - Detector Data Handling
 - Environmental Control
 - HMI for maintenance 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

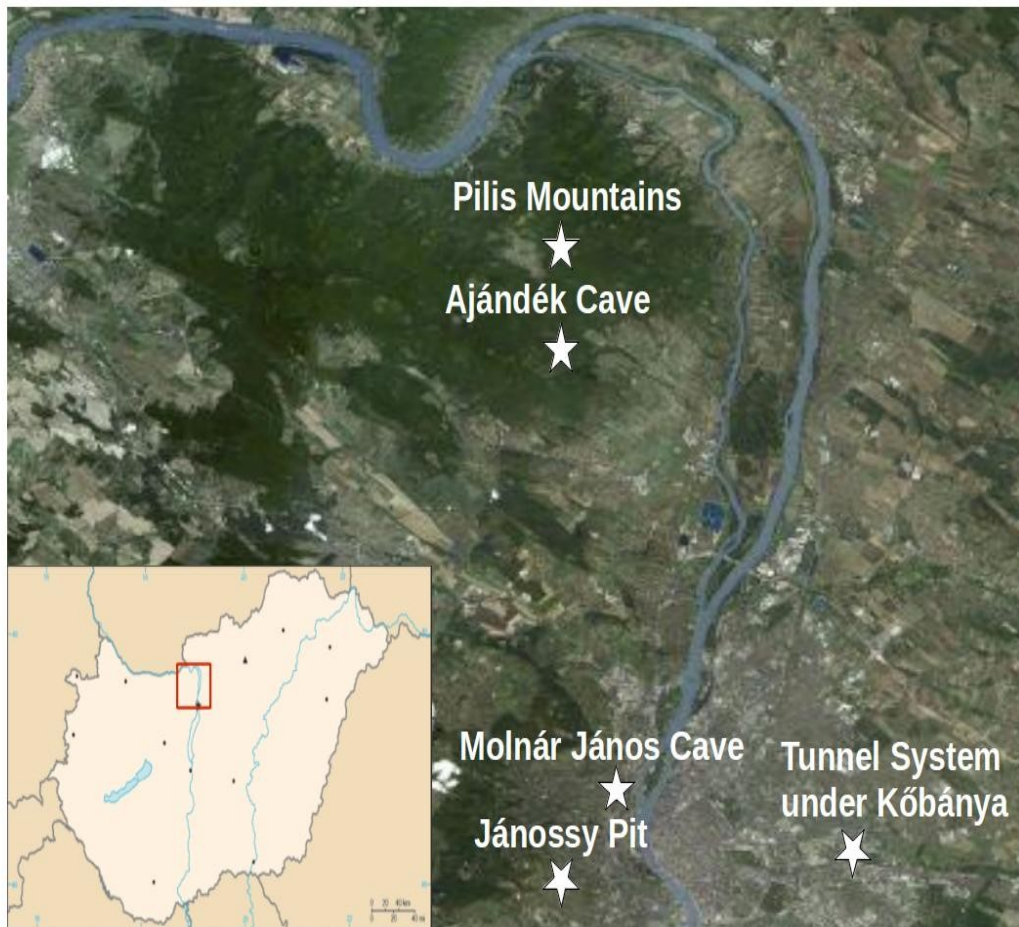


Event-by-Event Data Analysis



- Analysis initiates with forming clusters
 - Particle trajectories are found by a combinatorial tracking algorithm
 - Angular distribution
 - Muon flux with geometrical and acceptance correction
 - Surface reconstruction
- L. Malmquist et al.: GEOPHYSICS, VOL. 44, NO. 9, (1979) 1549

Fieldwork: Natural Caves and Artificial Pits



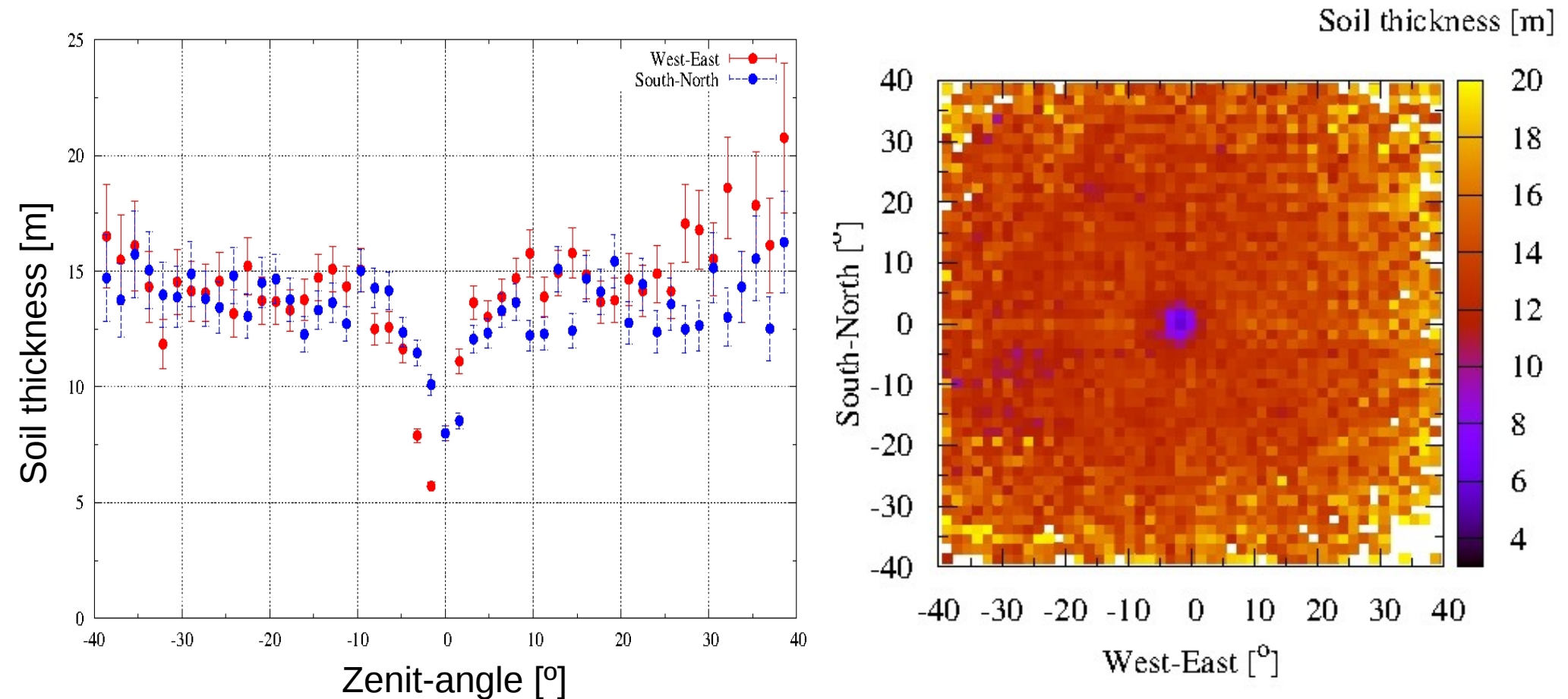
- **Lab (0 m):**
> 100 days, > 100 M muon events
- **Jánossy Pit (-10, -20, -30 m):**
15 days, 2 M muon events
- **Molnár János Cave (-45 m):**
77 days, 1.1 M muon events
- **Ajándék Cave (-60 m):**
50 days, 170 k muon events
- **Pilis Mountain (0 m):**
1 day, 300 k muon events
- **Brewery Cave (-20 m):**
50 days, 1 M muon events

III. Detector Tests at Kőbánya Tunnel System



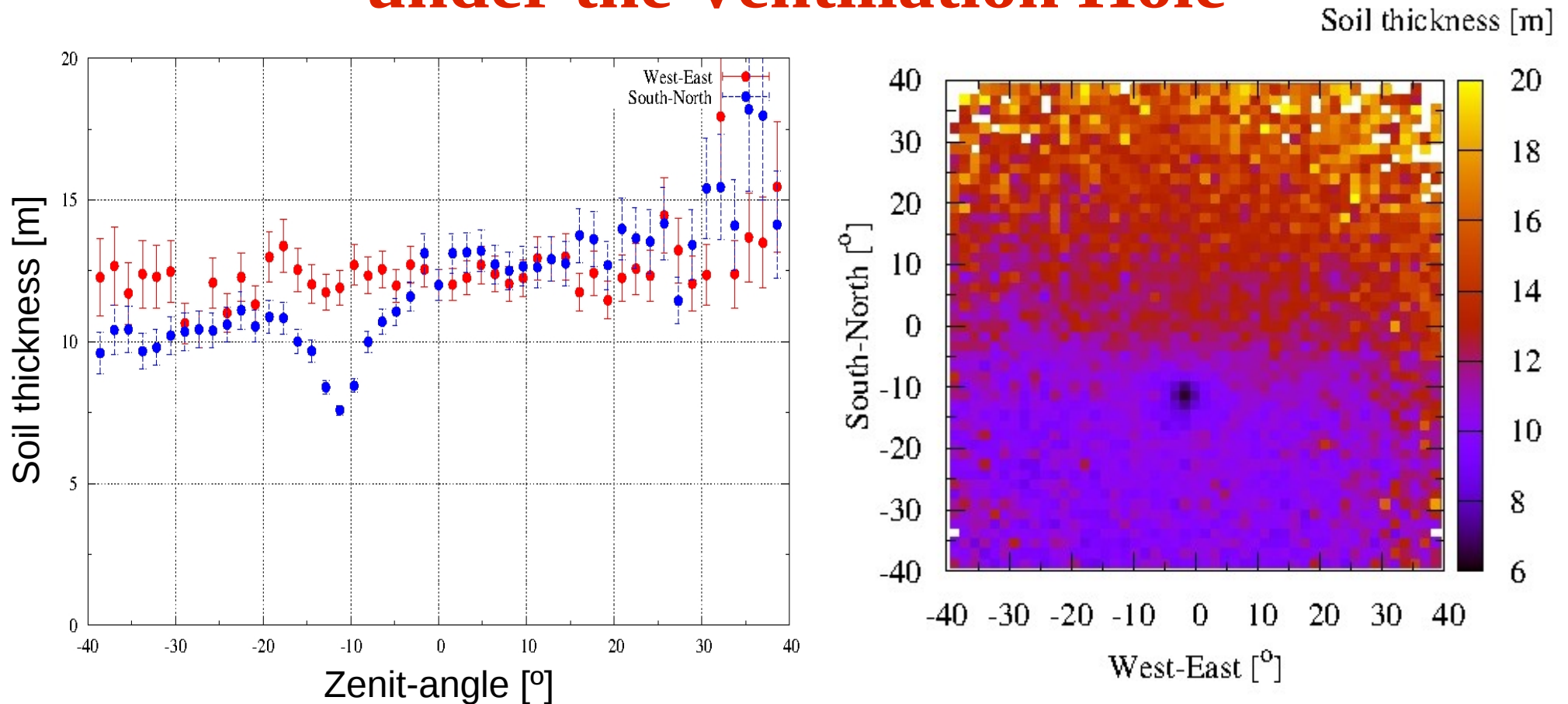
- Several tunnels at 10-30 soil-meter-equivalent depth
- Homogen soil density
- Flat surface above the tunnel system
- Ventillation holes are good targets for our tests
- **Aim of our tests:**
 - Reconstruct the soil thickness above the detector
 - Tomography the vetillation holes

Measurement under a Ventillation Hole



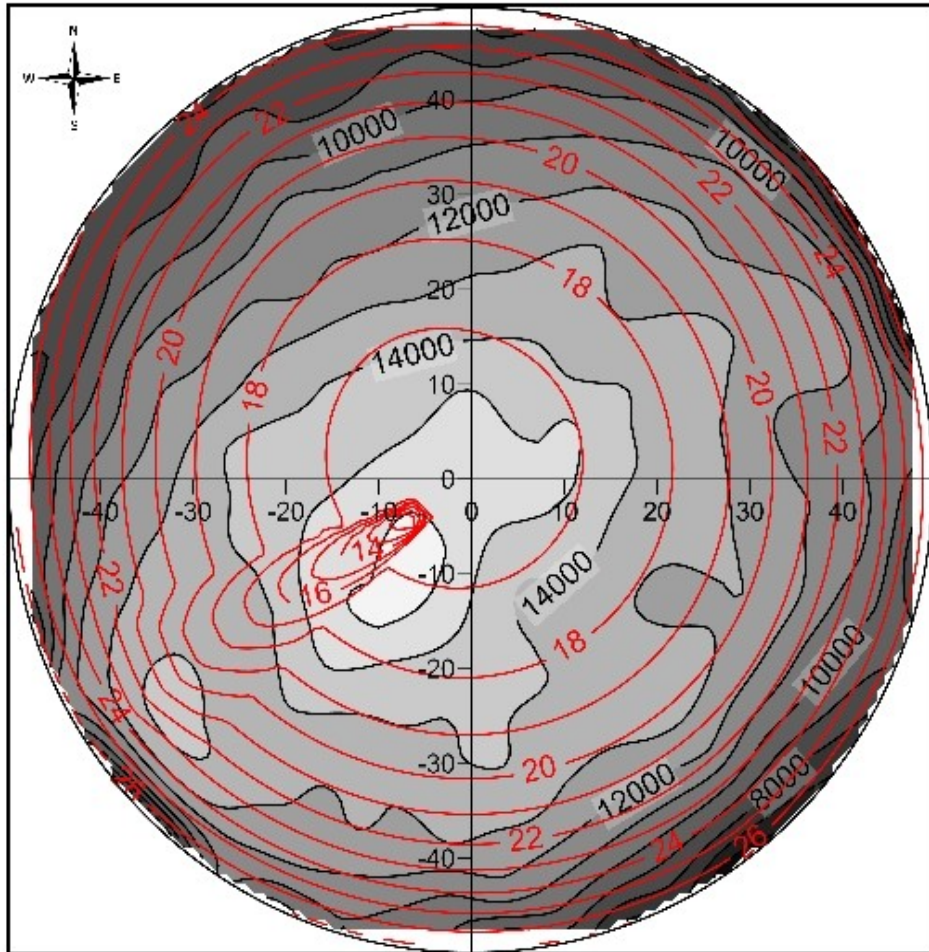
- Detector was exactly under the ventilation hole
- Surface reconstruction has been done:
 - Flat surface above the tunnel system
 - Ventillation hole with 6 m length has been detected

12° Tilted Measurement under the Ventillation Hole



- Detector has been tilted with 12° to South
- The ventillation hole is shifted to 12° and tilted with 12° !!!

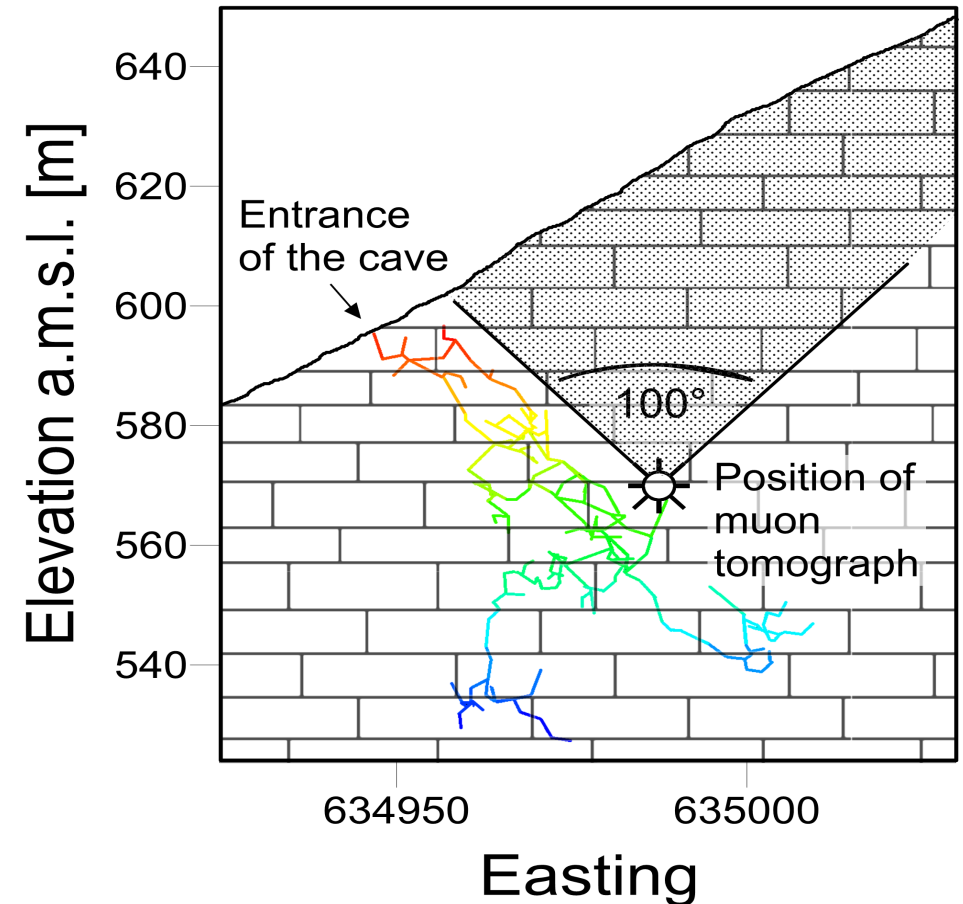
Measurement at South-West from the Ventillation Hole



- All in the three cases, the vertical tunnels have been seen clearly by the muon telescope.
- The detector is applicable for search underground soil inhomogenities at 10-30 meter-rock-equivalent depths with relatively short time (~ 1-2 weeks)

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



IV. Measurements in the Ajándék Cave



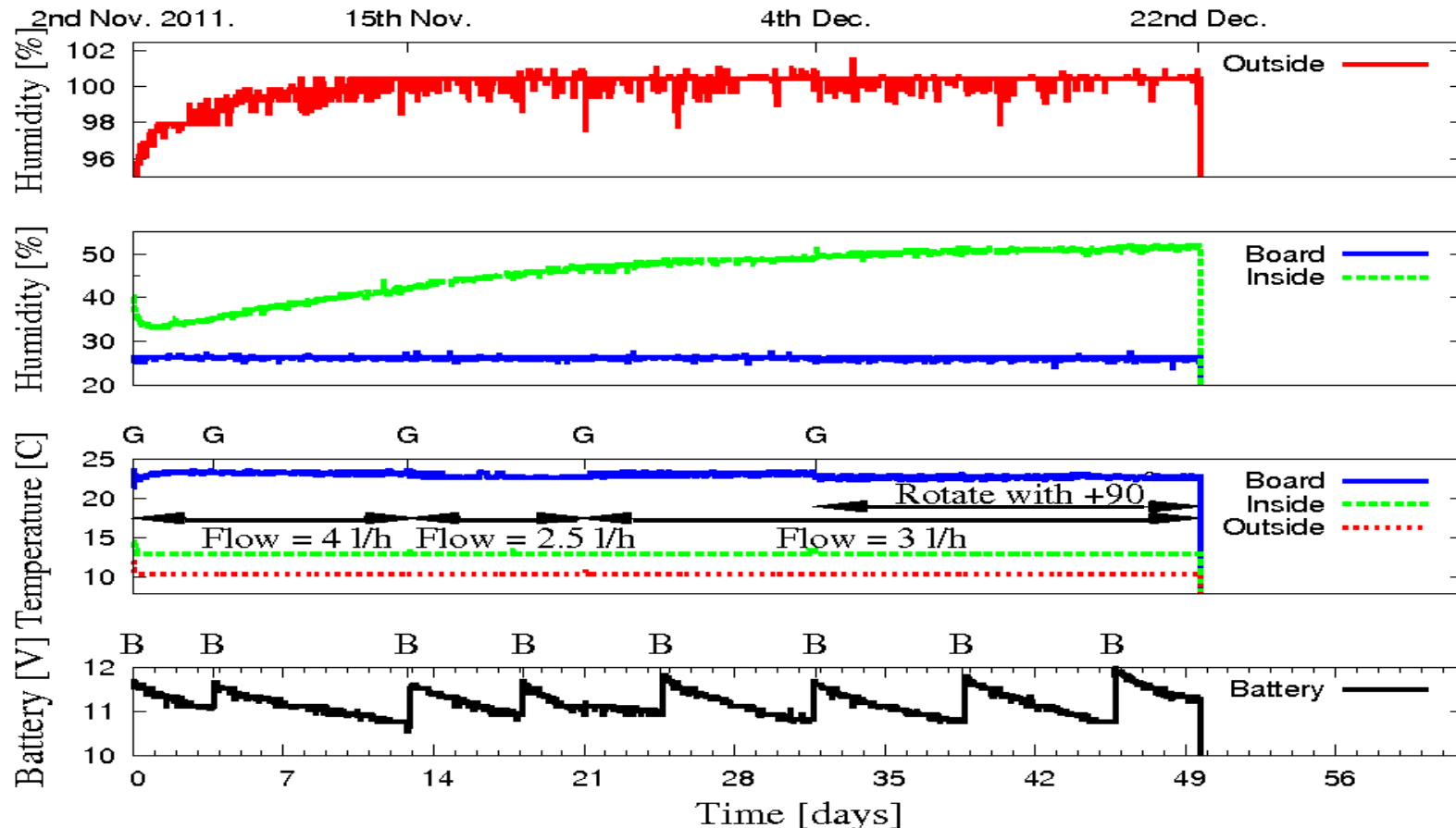
- Cave entrance: batteries and gass bottles (detector before deployment)

Deployment at the Ajándék Cave



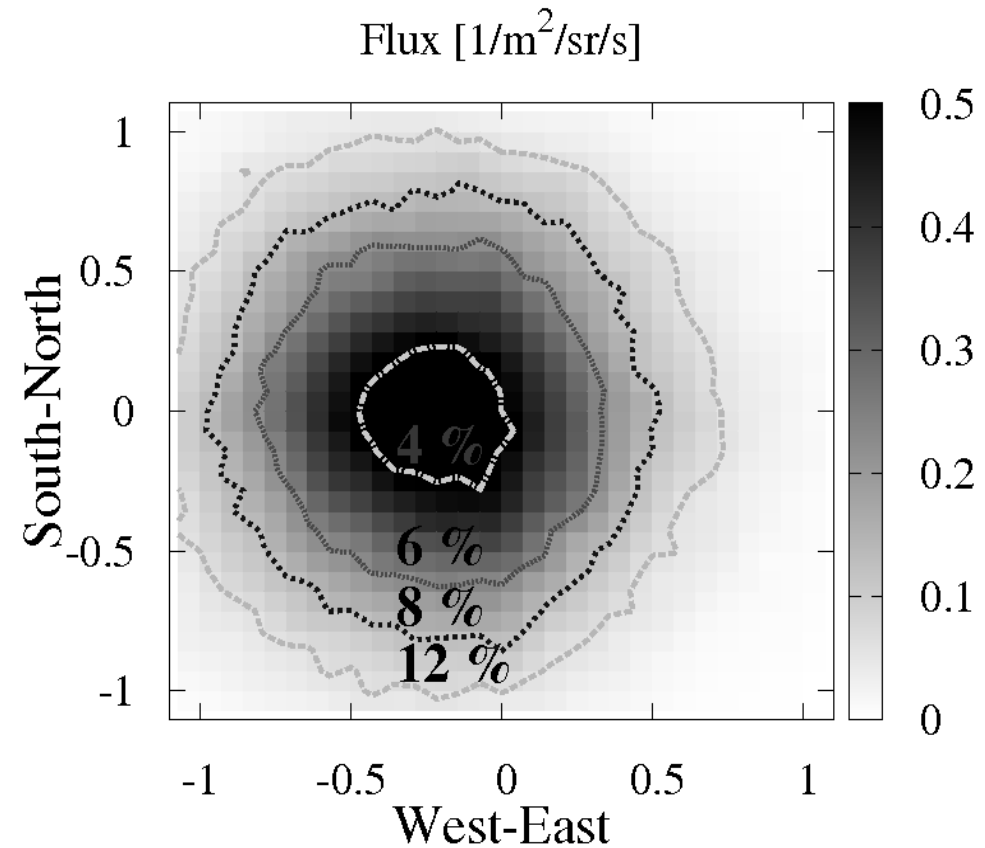
Environmental Control

- Environmental 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.

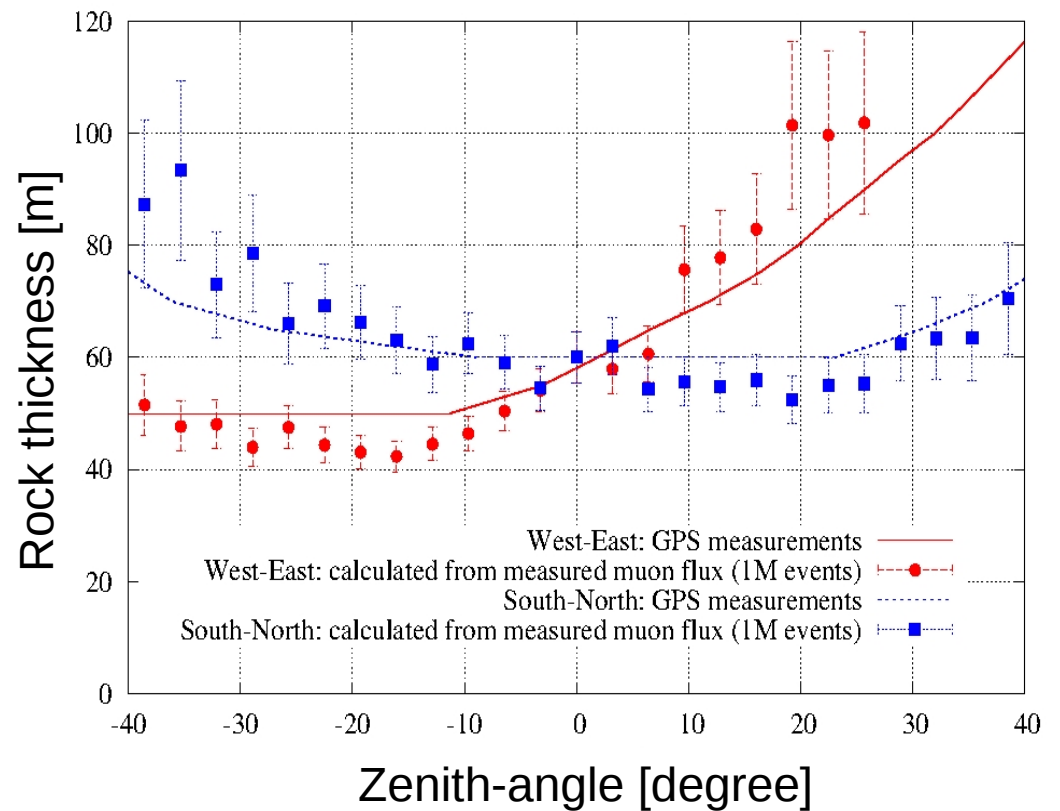
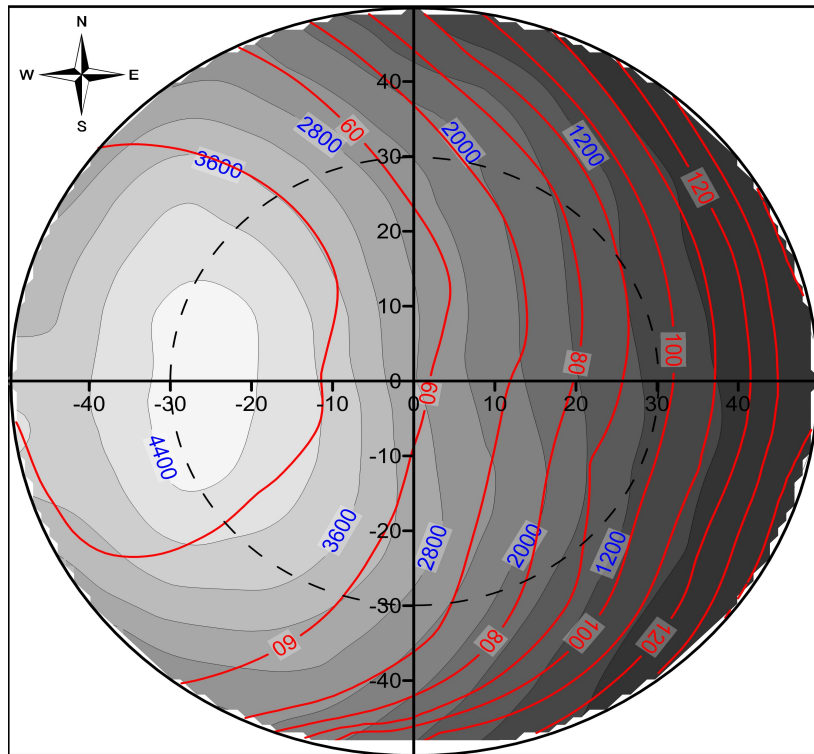


Muon flux in the Ajandek Cave

- During the 50 days of data taking: 170 k muon tracks at 60 meter underground (~ 3 track/min)
- Flux with point-by-point statistical error
- Main yield is shifted to the Western direction



Muon data vs GPS data



- Rock thickness has been measured by GPS and calculated from measured muon flux: shows strong correlation
- Found no evidence for unknown caverns

Summary

- **REGARD Group's Muontelescope:**
 - Mobile (< 13 kg, $51 \times 46 \times 32$ cm³) 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 Artificial Pits and Natural Caves:**
 - MWPC-based tracking telescope can work in high humidity conditions
 - Relief reconstruction has been done above the Kőbánya tunnel system
 - 50 days of data taking in the Ajándék Cave:
found no evidence for unknown caverns
- **Plans for the Next Year, Applications:**
 - Cosmic muon flux will be measured in HZDR Underground Laboratory in Dresden in January and February → provides the cosmic muon background for their measurements!!!

Thanks for Your Attention!

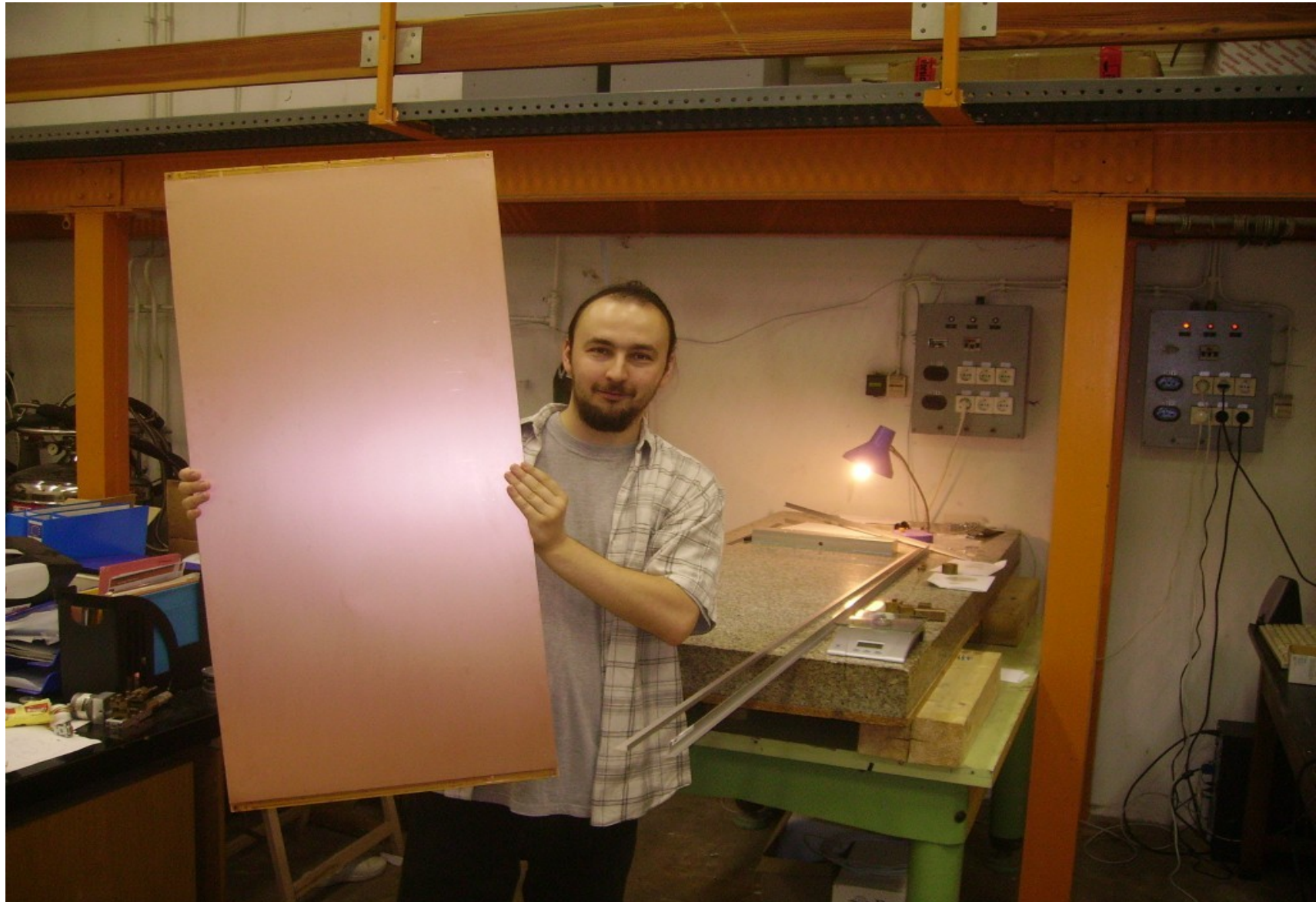


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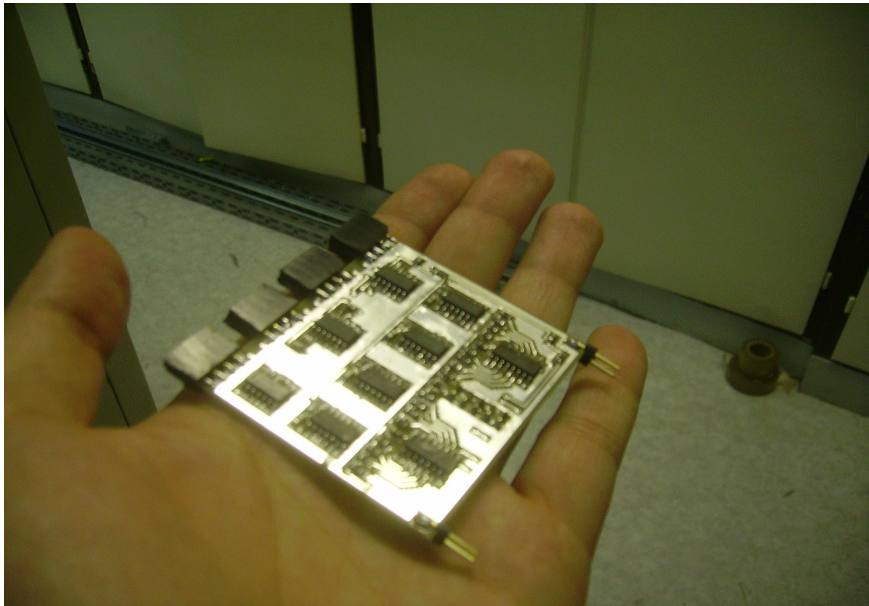
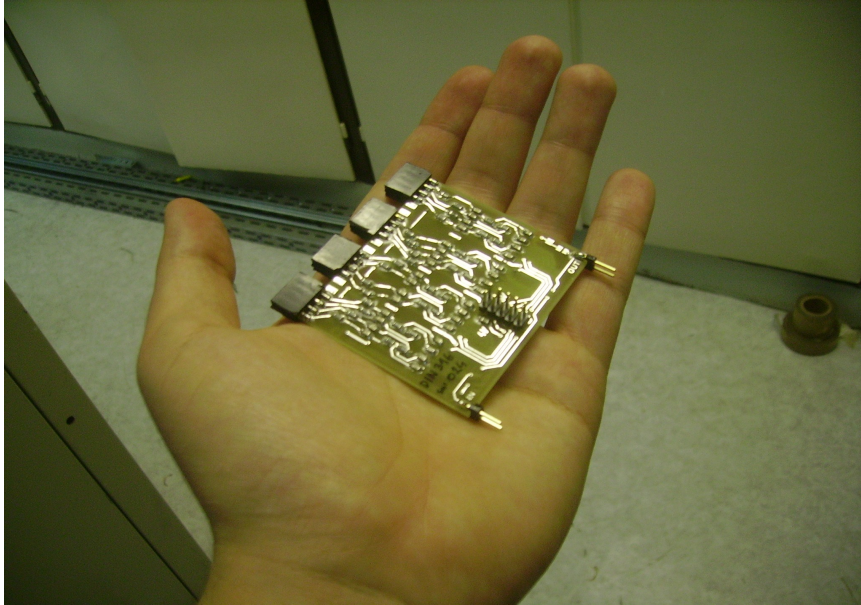
Our research is supported by OTKA KTIA CK 77719, OTKA KTIA CK 77815 and the OTKA NK-77816, OTKAPD-73596 grants.

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