Muon and Neutrino Radiography 2012

CCC-based Muontelescope for Examination of Natural Caves

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REGARD

RMKI ELTE Collaboration

on Gaseous Detector Research and Development

Outline

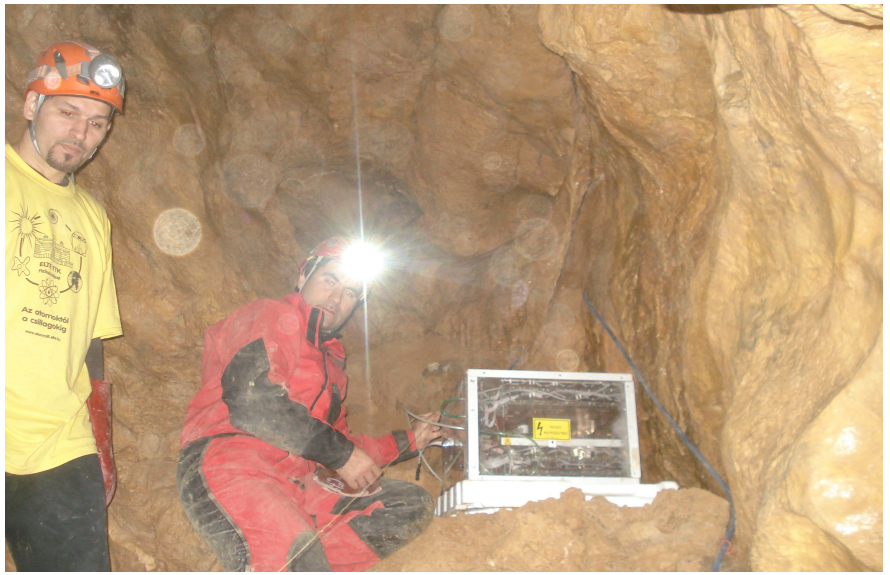
I. Motivation

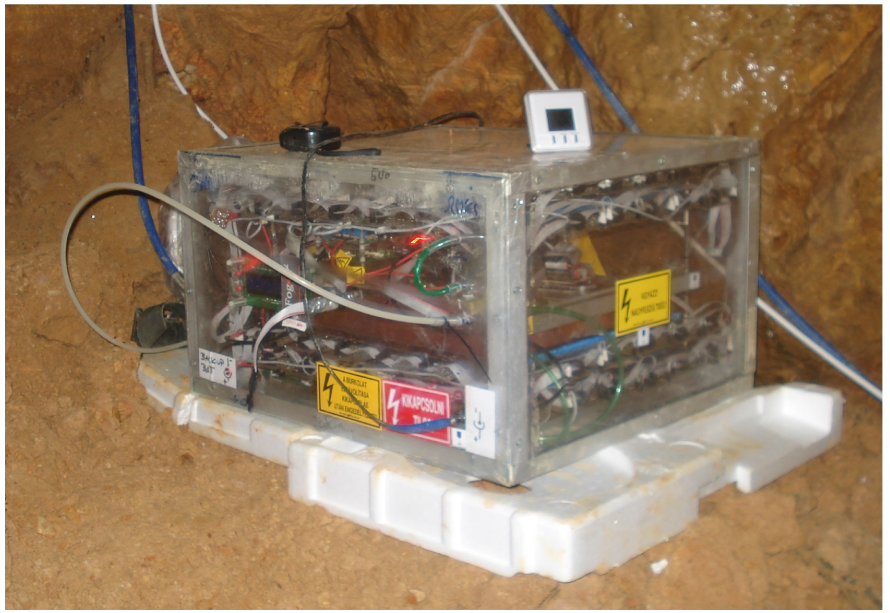
II. Structure of the CCC-based Muontelescope

III. Detector Performance

IV. Our measurements in the Ajándék Cave

I. Motivation

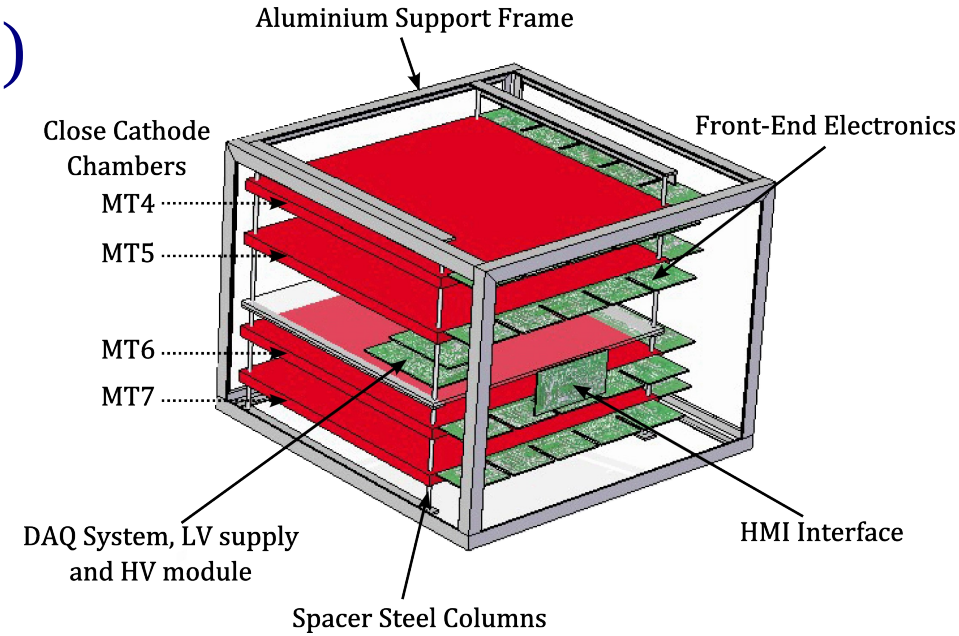


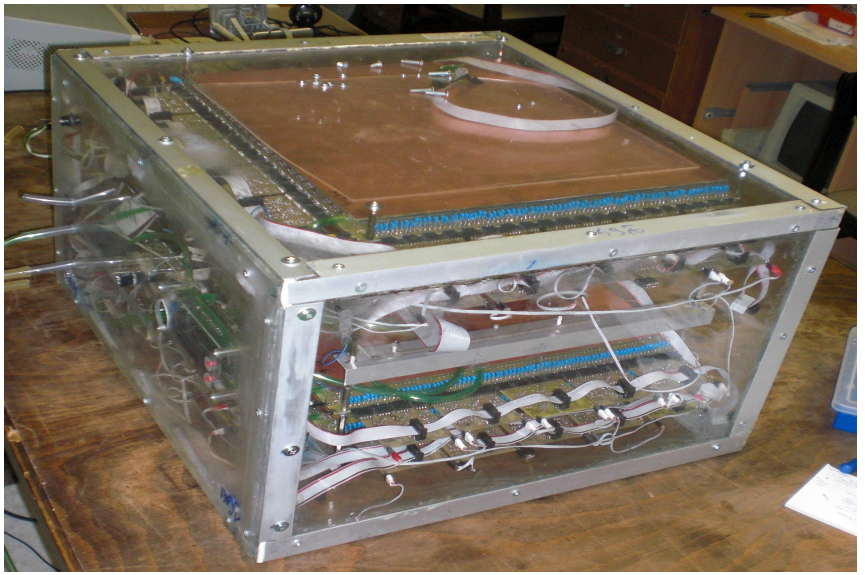


- **Aim of Our Research:**
  - investigating unexplored part of caves
  - mapping the structure of mountain-relief
- **Portable Muontelescope:**
  - precision:
    - 1.5 mm spatial resolution
    - 10 mrad angular resolution
  - use in high humidity (~ 100%) environmental
  - cheap and power efficient (< 5 W)

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 cm^3
  - total weight: 13 kg
- Data acquisition (DAQ) system integrated into one unit
- Human Machine Interface (HMI):
  - LCD display, SD card



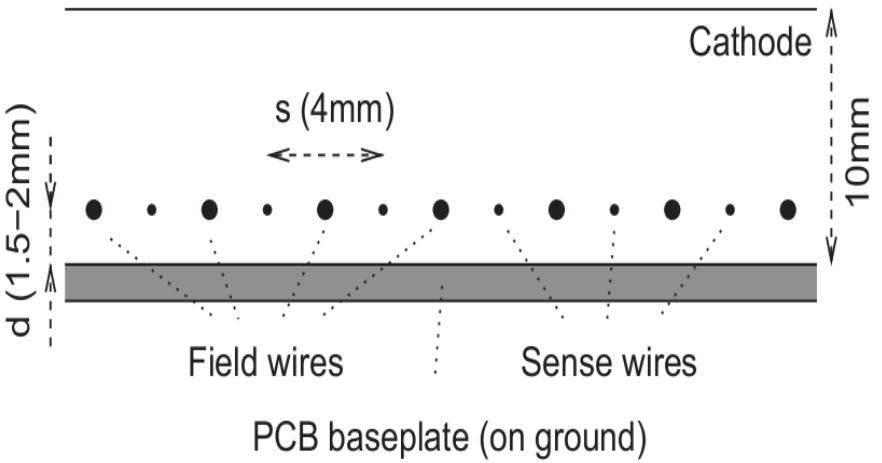


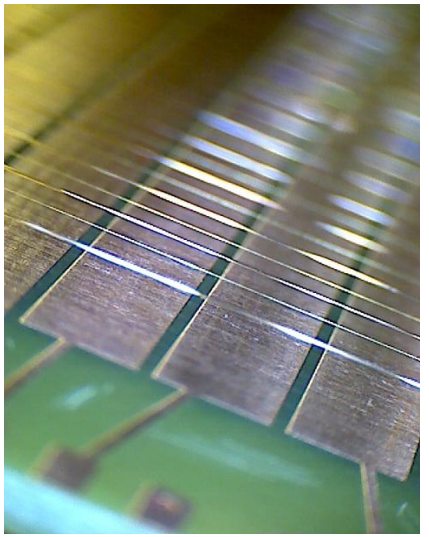
CCC Technology for Muon Tomography

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

  D. Varga, G. Hamar, G. Kiss: NIM A 648 (2011) 163

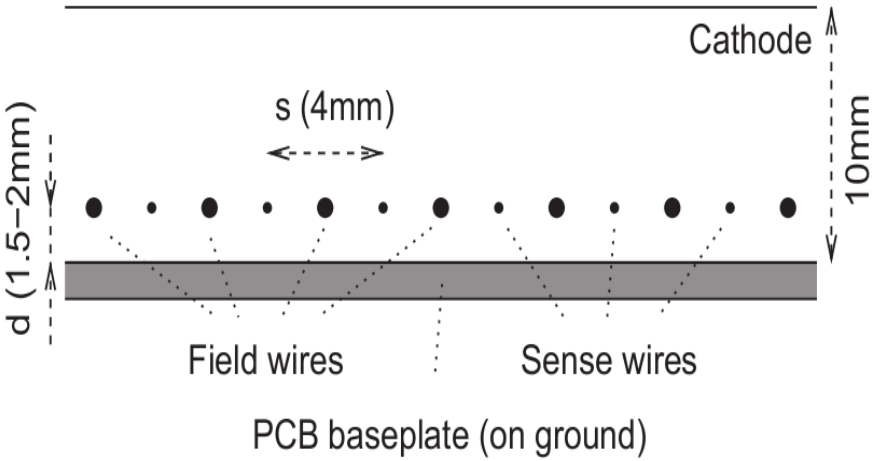
- 2 dimensional location:
  - field wire: distance 4 mm
  - The lower cathode is segmented into 4 mm wide strips (pads) perpendicular to the wires
- Requires continuous gas flow during operation: non-flammable $Ar - CO_2$

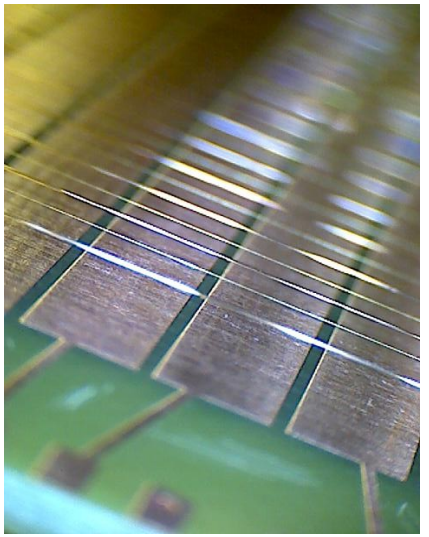




CCC Technology for Muon Tomography

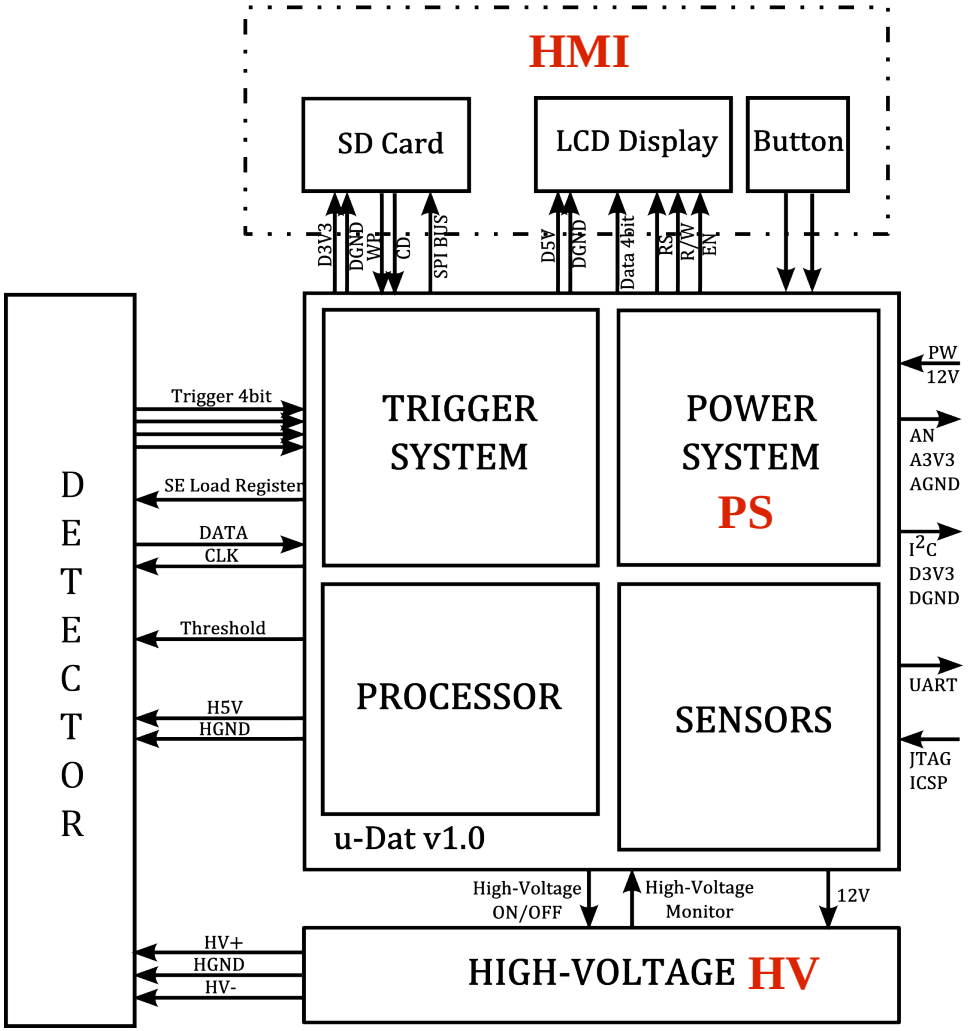
- **Why CCC?**
  - MWPC which does not require weighty outer support frames
  - Optimizes:
    - Weight/Layer (0.88 kg)
    - Position resolution (1.5 mm)
    - Efficiency (> 95 %)
    - Cost
  - High tolerance against mechanical inaccuracies (100-200 µm)





Data Acquisition

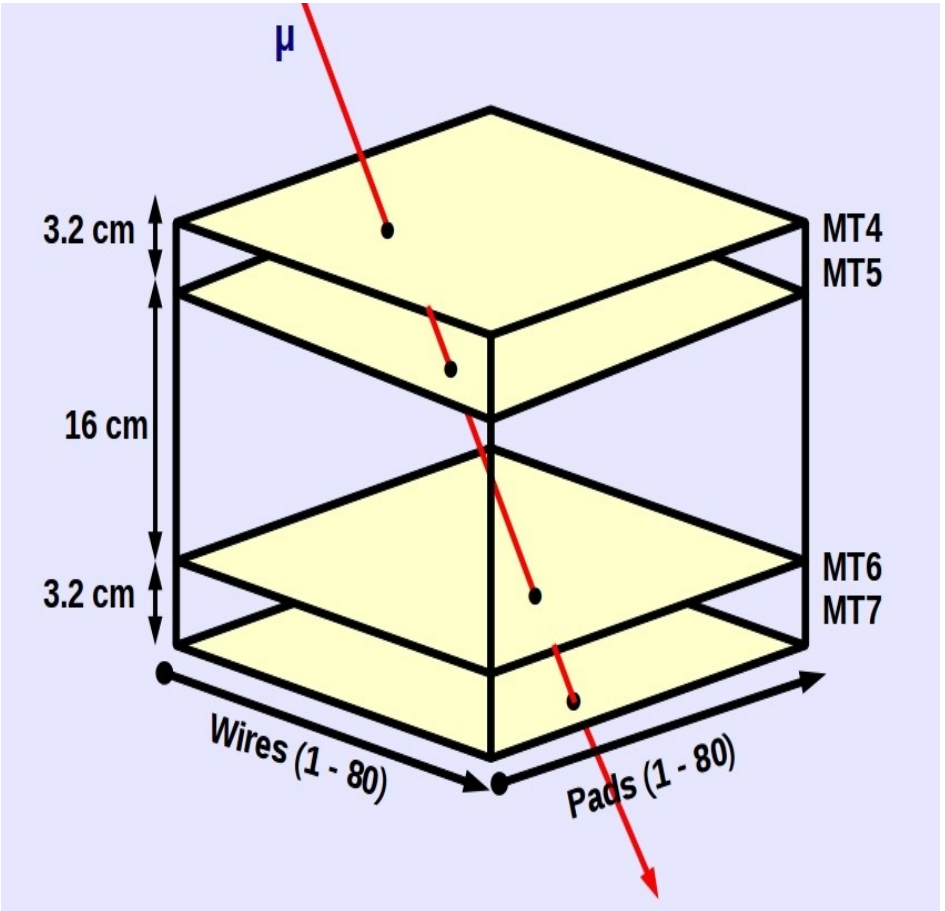
- PIC32 based DAQ
- All functions are integrated into a common system plan
- Small unit:
  placed between the middle CCC layers
- Main functions:
  - Low Voltage, Power System (PS)
  - High Voltage (HV)
  - Trigger System
  - Detector Data Handling
  - Environmental Control
  - HMI for maintance and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



Power System and Trigger Unit

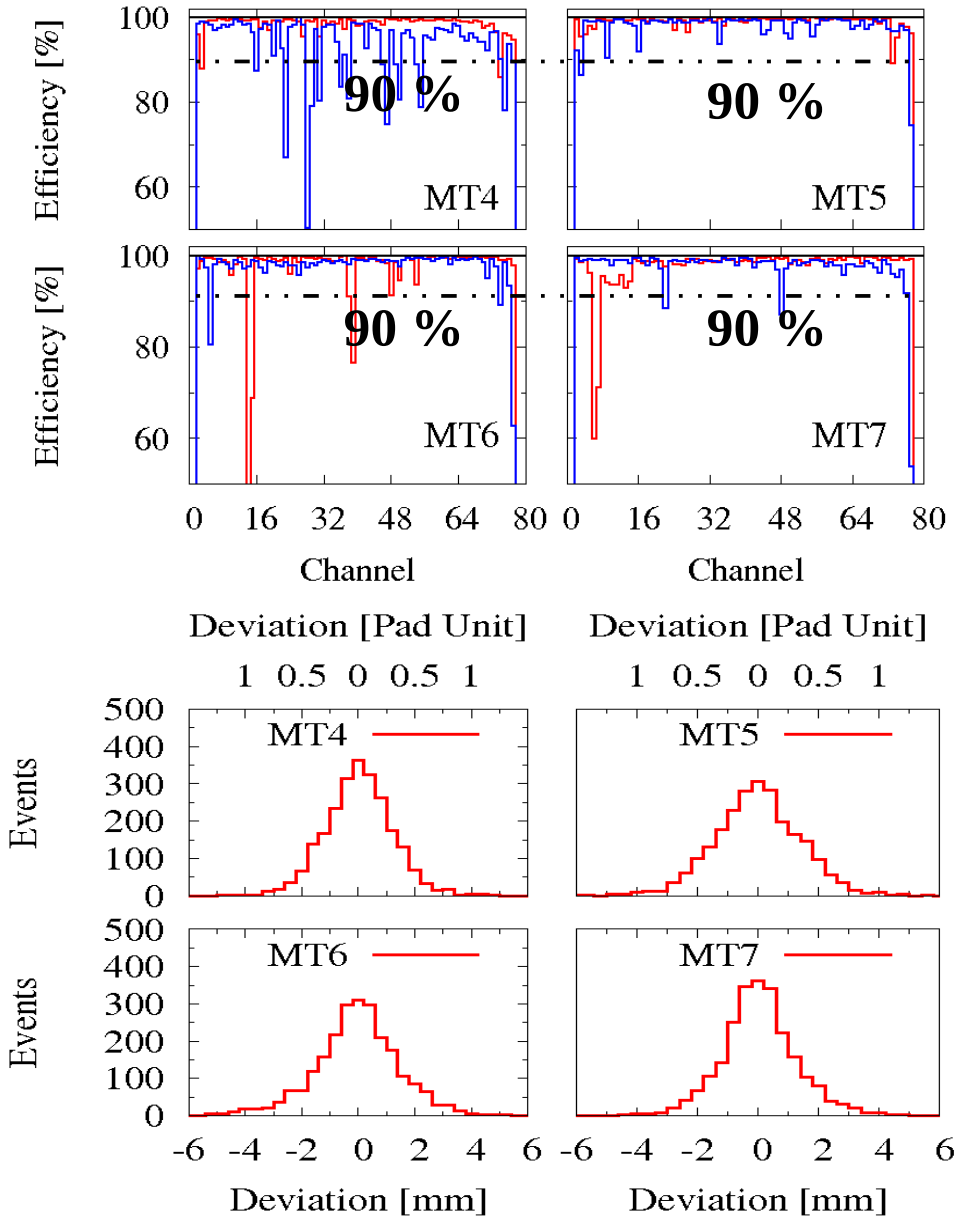
- **Low- and high-voltage power supply:**
  - HV: 1100 V for sense wires,
    -600 V for field wires and cathode
  - LV: power efficient regulation from 12V input (10-16V)
- **Total power consumption:**
  (Including LV, HV, Trigger Scheme, Data Readout, FEE, HMI)
  - 380 mA at 12 V (power < 5 W)
  - Complete unit can operate
    for more than 5 days with a 50 Ah battery
- **Trigger Scheme:**
  - direct signal from CCC layers are exploited to form DAQ trigger
  - trigger efficiency: 93.1 %
  - (dependence on detector gasflow has been observed
    at the Ajándék Cave)

III. Detector Performance



- Analysis initiates with forming clusters
- Particle trajectories are found by a combinatorical tracking algorithm

Detector Efficiency and Position Resolution



- Detection efficiency is above 95%

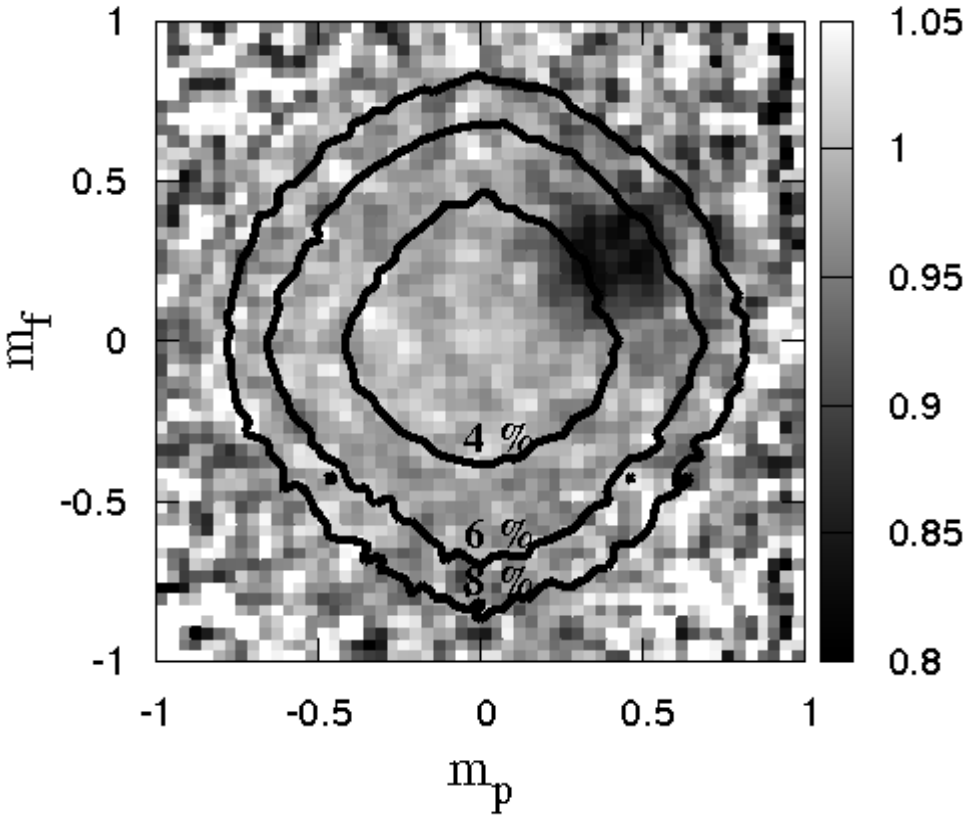
  Three point tracklets are extrapolated to the fourth layer, checking if a cluster is found within its fiducial region

- Spatial resolution is 1.5 mm

  Difference between actual hit position and fitted trajectory position

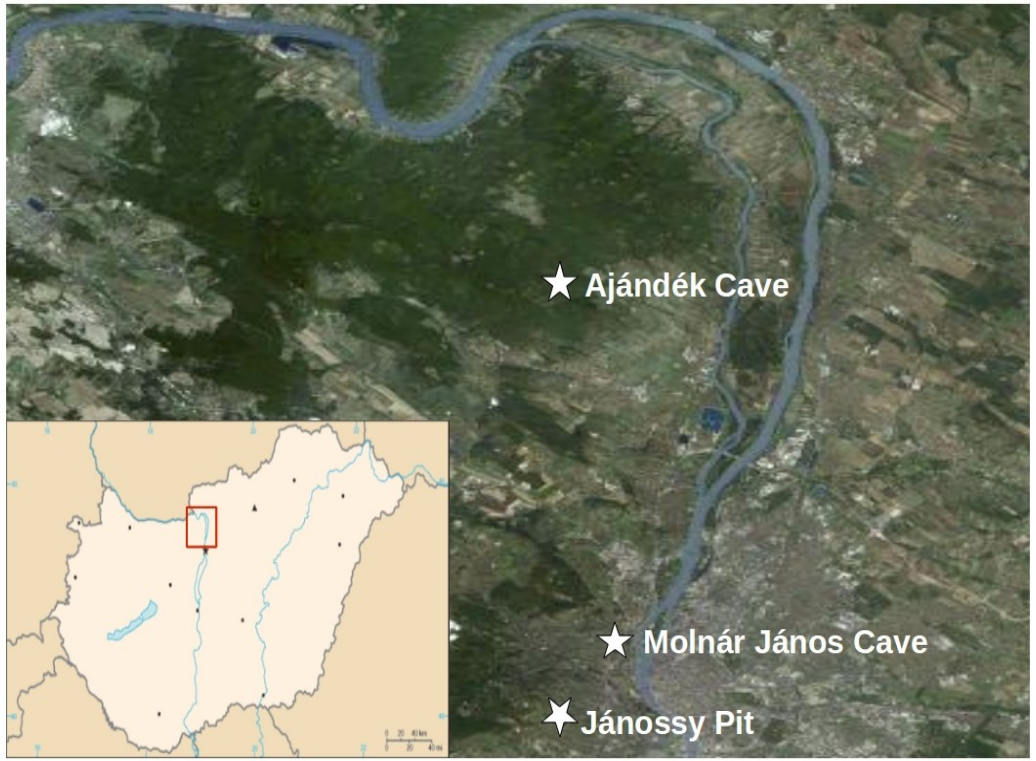
- Angular resolution is 10 mrad

First Step to Tomography: Direct Demonstration of Absorption



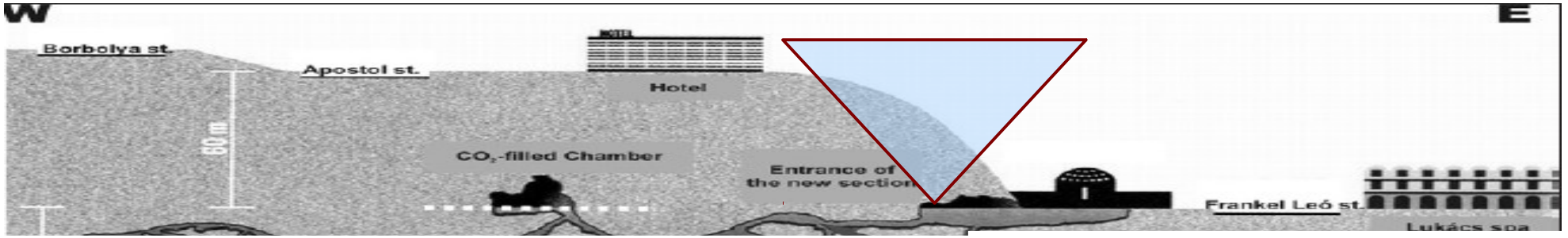
- Ground level, laboratory conditions
- Pile of lead and iron blocks (total mass of 200 kg, 20cm by 20cm wide)
- Data at the same detector position with / without absorber
- 20% reduction in muon flux locally (Figure: ratio of flux with / without absorber)
- Total of 7M events, total 10 days data taking

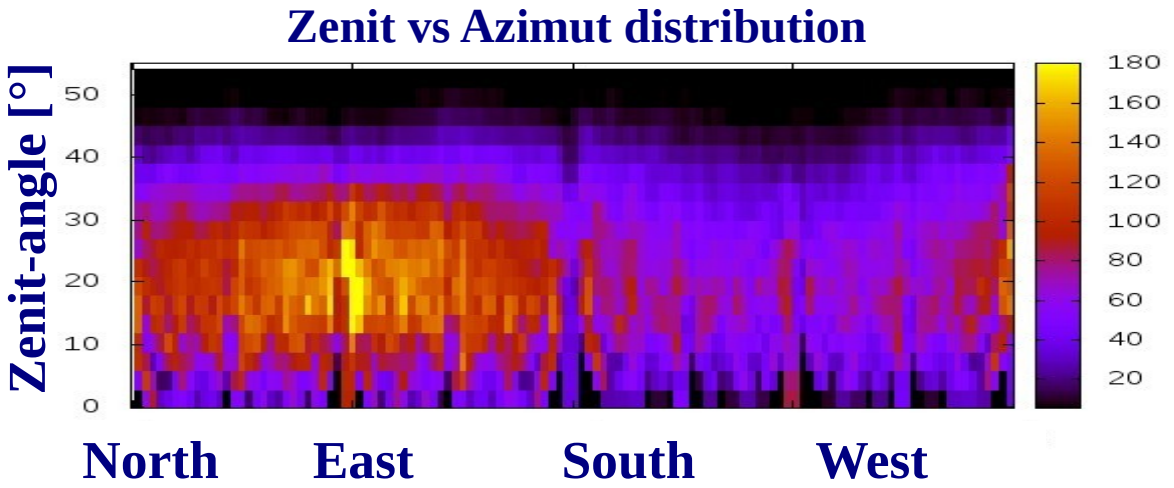
Fieldwork: Natural Caves and Artificial Pits

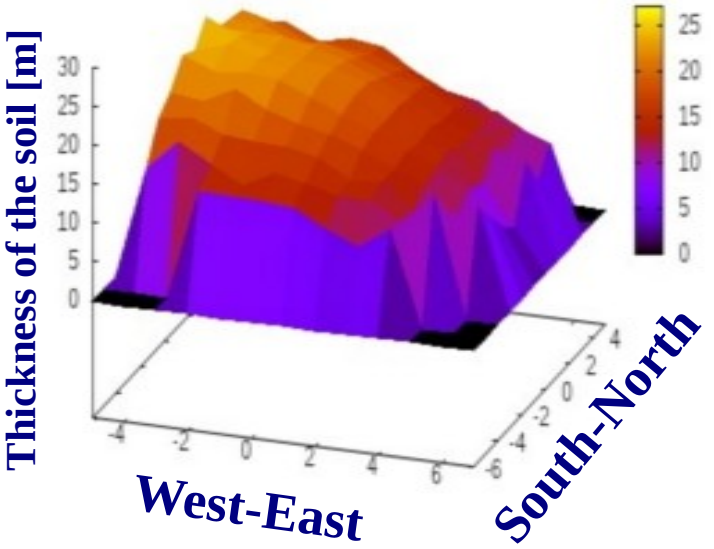


- **Lab (0 m):**
  > 100 days, > 100 M muon events
- **Jánossy Pit (-10, -20, -30 m):**
  15 days, 2 M muon events
- **Molnár János Cave (-45 m):**
  77 days, 1.1 M muon events
- **Ajándék Cave (-60 m):**
  50 days, 170 k muon events
- **Pilis Mountain (0 m):**
  1 day, 300 k muon events
- **Brewery Cave (-20 m):**
  30 days, 500 k muon events

Detector Test in Molnár János Cave



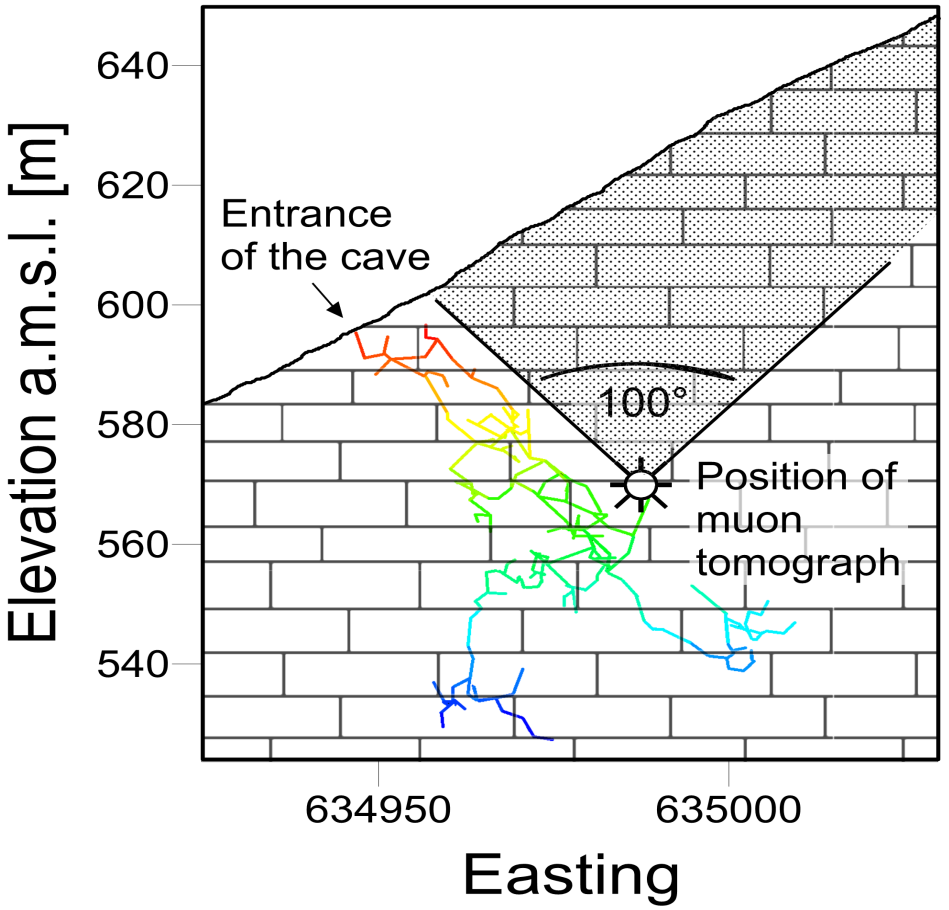




- Measurements in the Molnár János Cave, Budapest: 18 days with 850 k events
- Zenit-Azimut angle distribution and relief reconstruction both show the correlation between the amount of material above the detector and muon yield

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



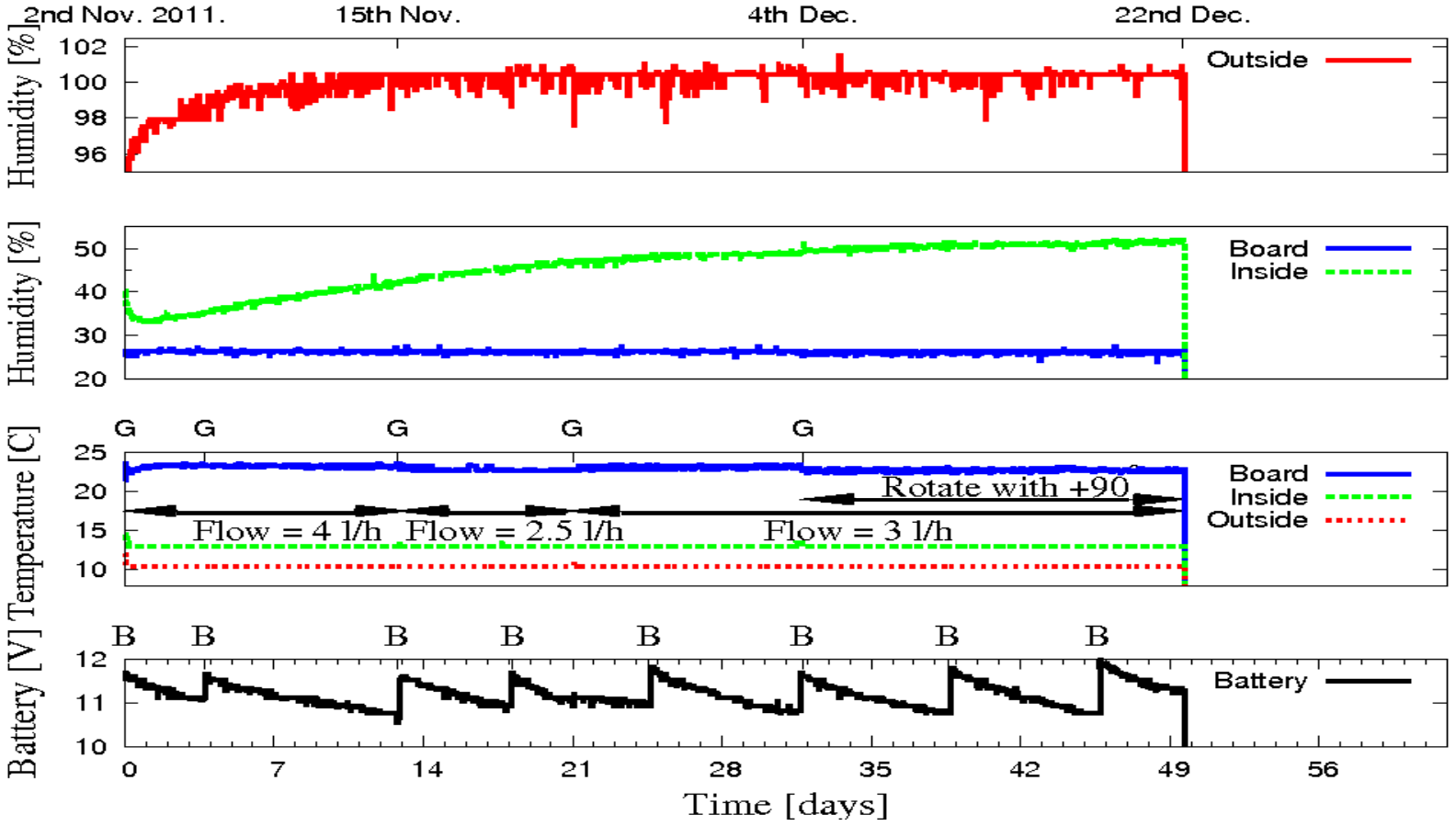
IV. Measurements in the Ajándék Cave

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

Deployment at the Ajándék Cave

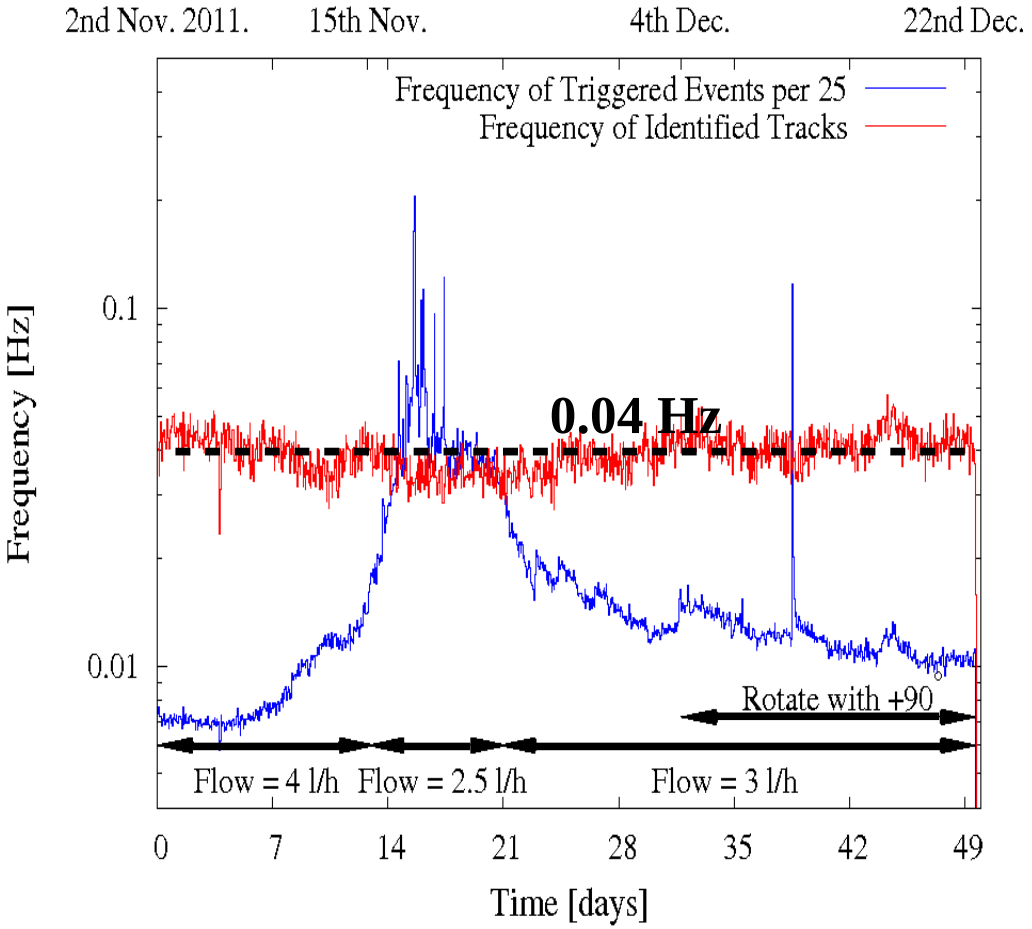
Environmental Control

- 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.



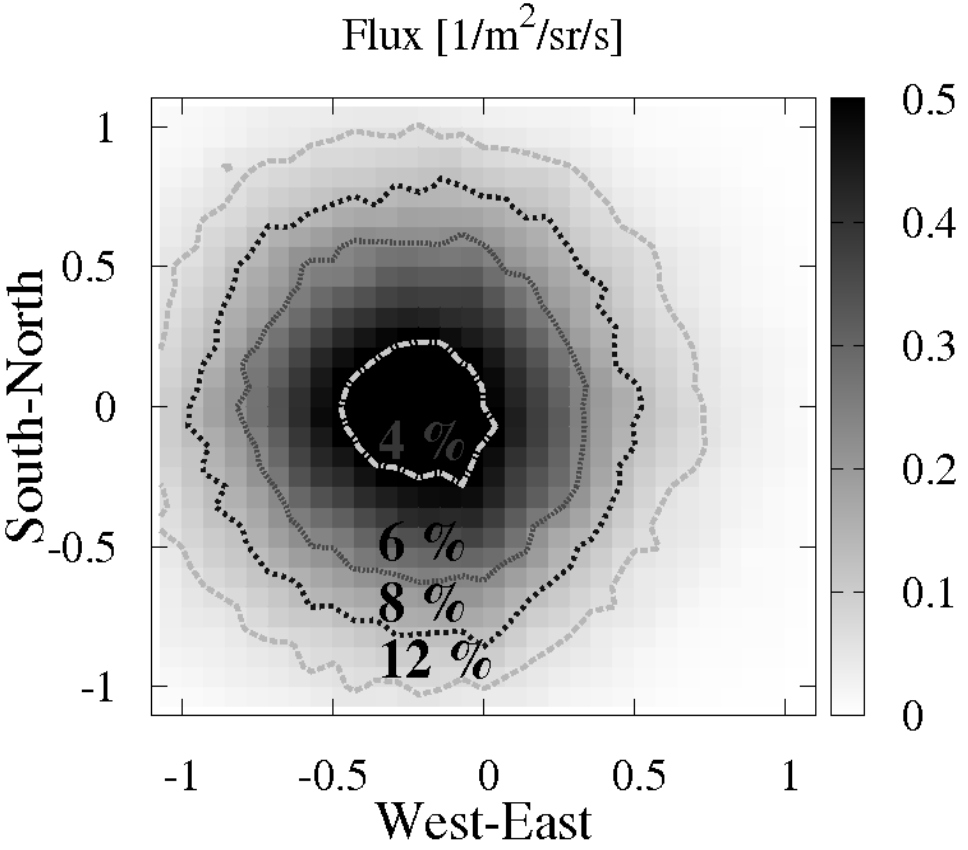
Results in the Ajándék Cave

- During the 50 days of data taking:
  170 k muon tracks (60m underground)
- Noisy region during reduced gas flow:
  increased "empty" event rate,
  track trigger efficiency reduced by 15%
- No correlation with other environmental parameters



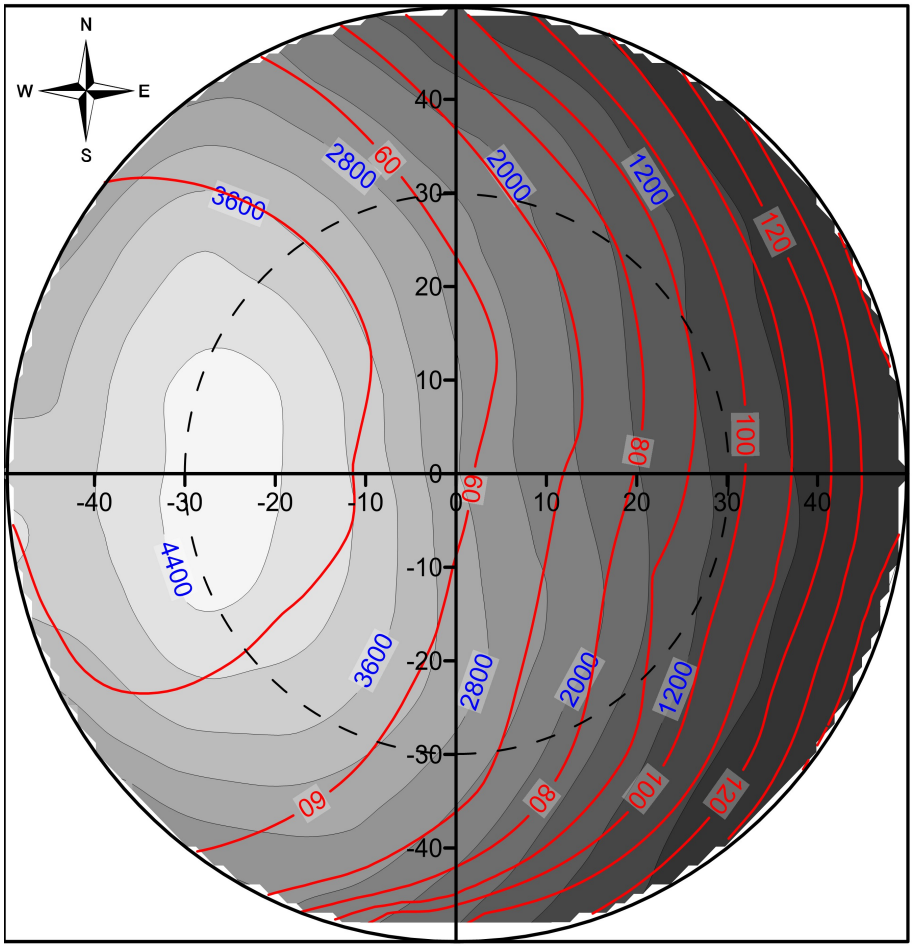
Muon flux in the Ajandek Cave

- Flux with point-by-point 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
  - Mountain-relief reconstruction has been done above the Molnár János Cave
  - 50 days of data taking in the Ajándék Cave: found no evidence for unknown caverns

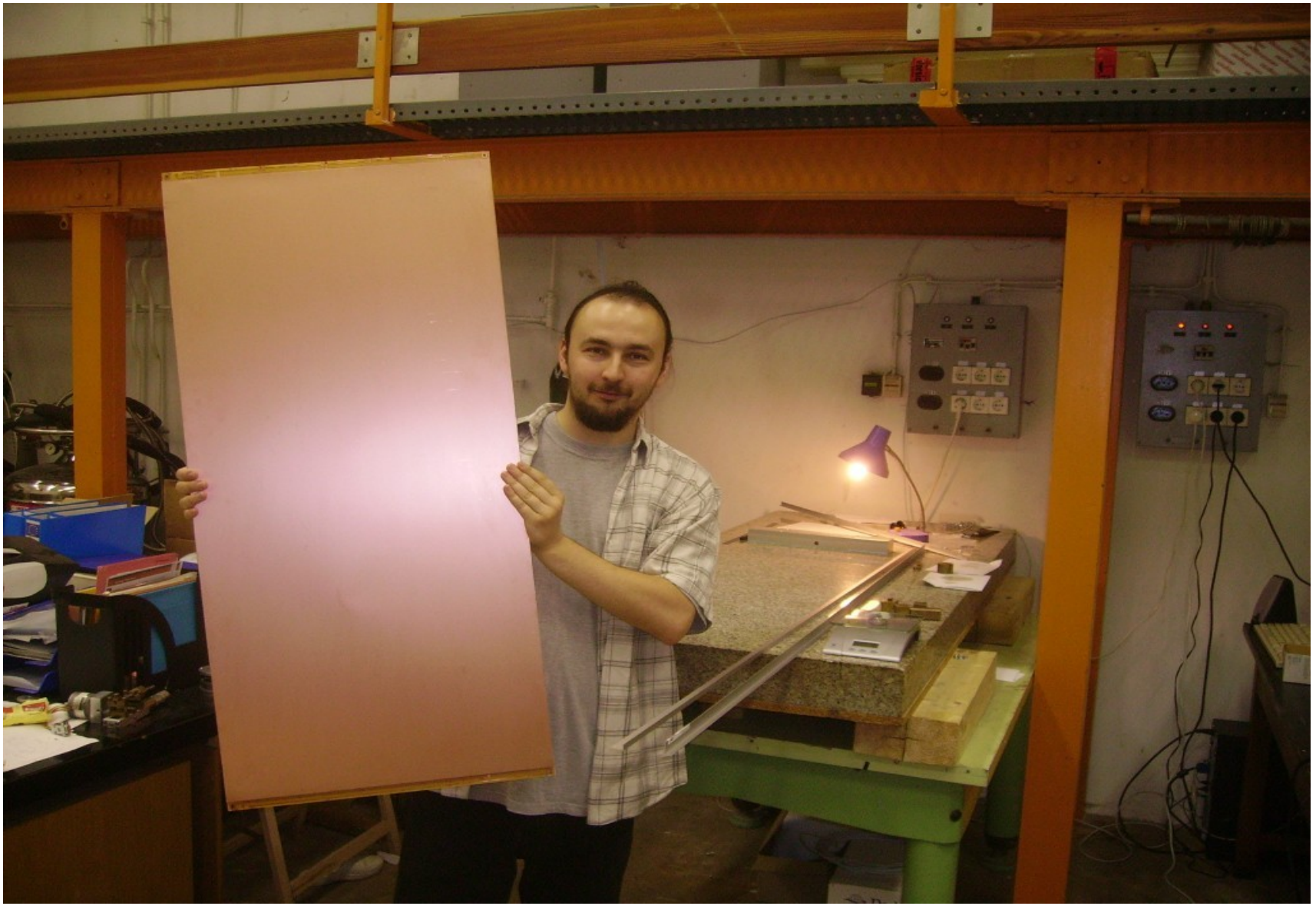
G. G. Barnaföldi et al.: Portable Cosmic Muon Telescope for Environmental Applications, Submitted to NIM A (2012)

Thanks for Your Attention!

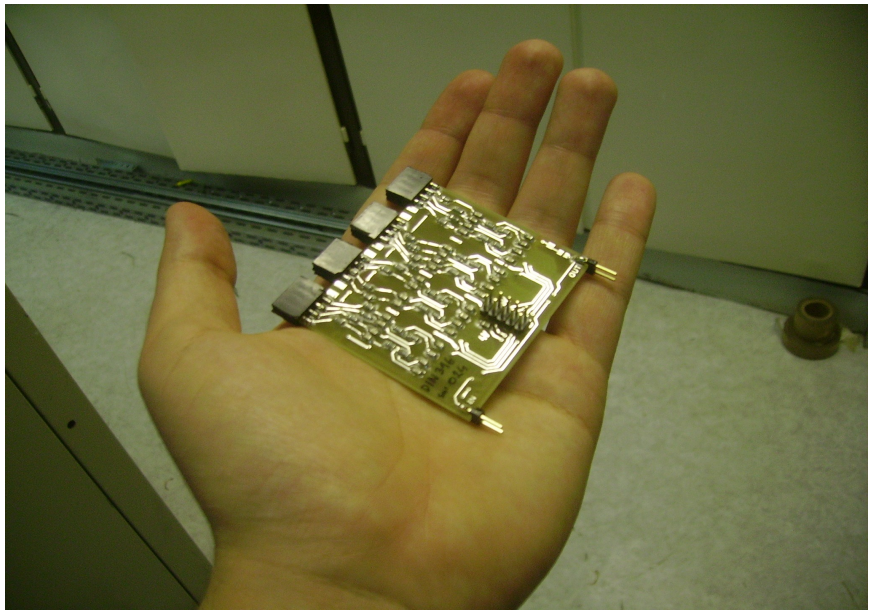
Our research is supported by OTKA KTIA CK 77719, OTKA KTIA CK 77815 and the OTKA NK-77816, OTKA PD-73596 grants.

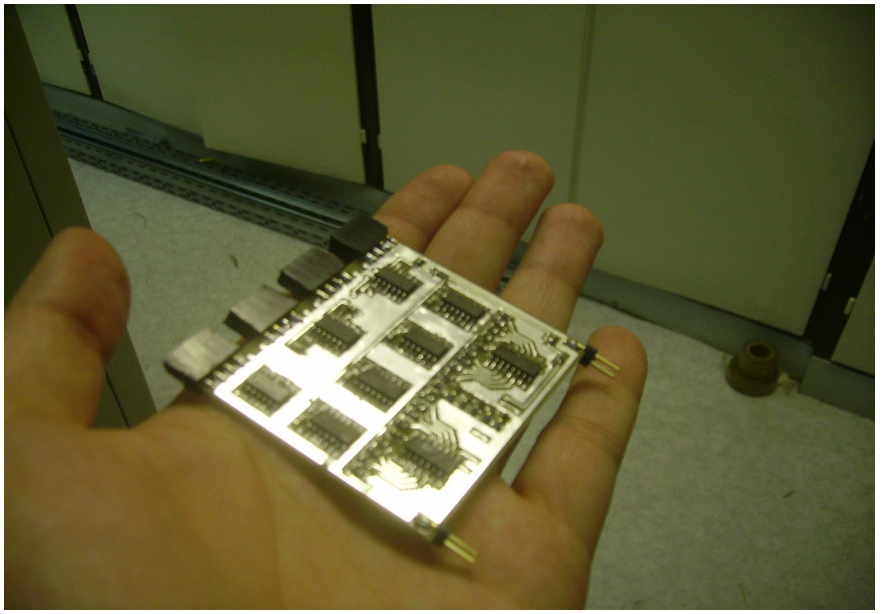
Backup Slides

CCC with 1 m x 0.5 m Sensitive Area



Front-End Electronics

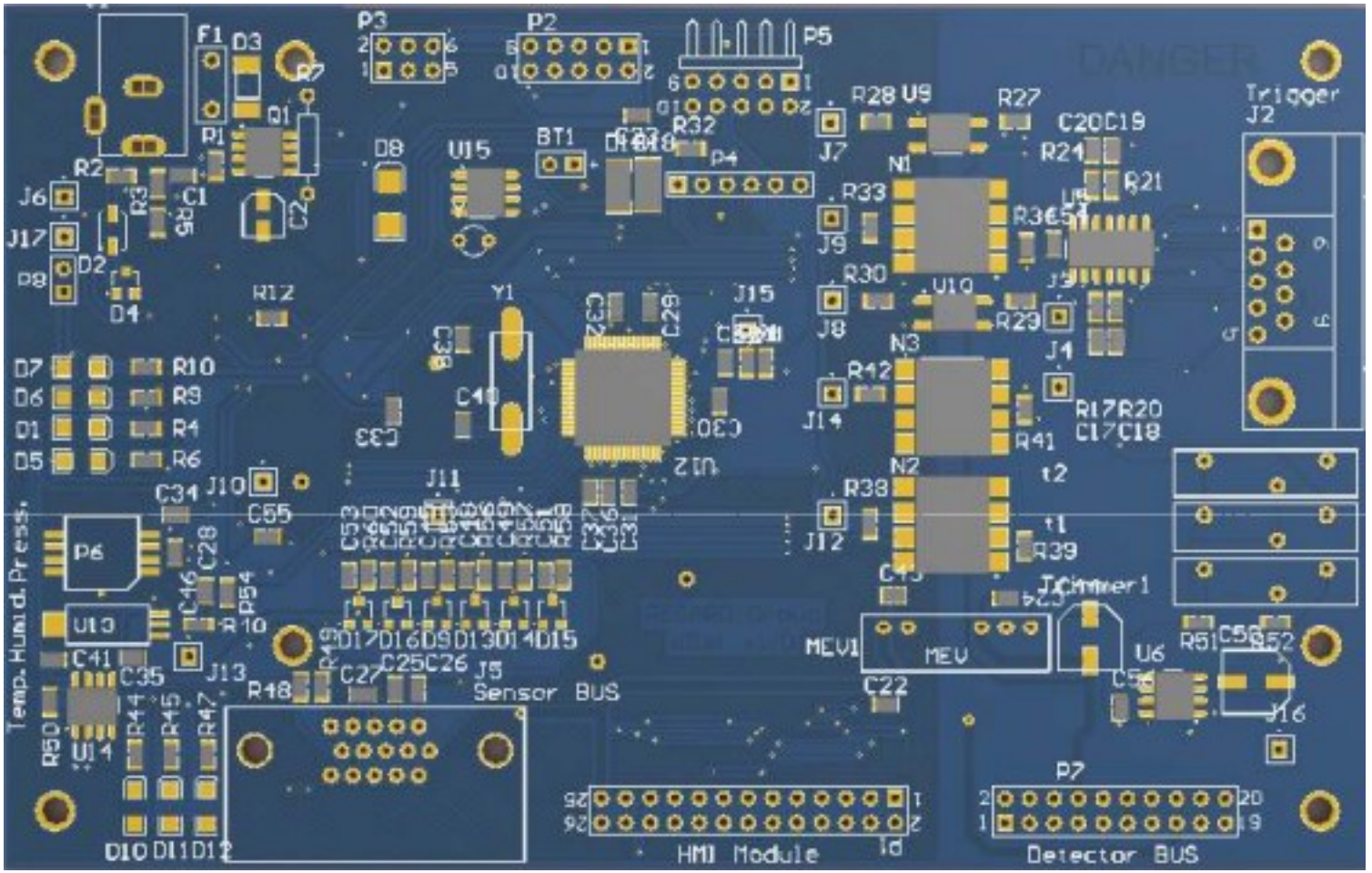




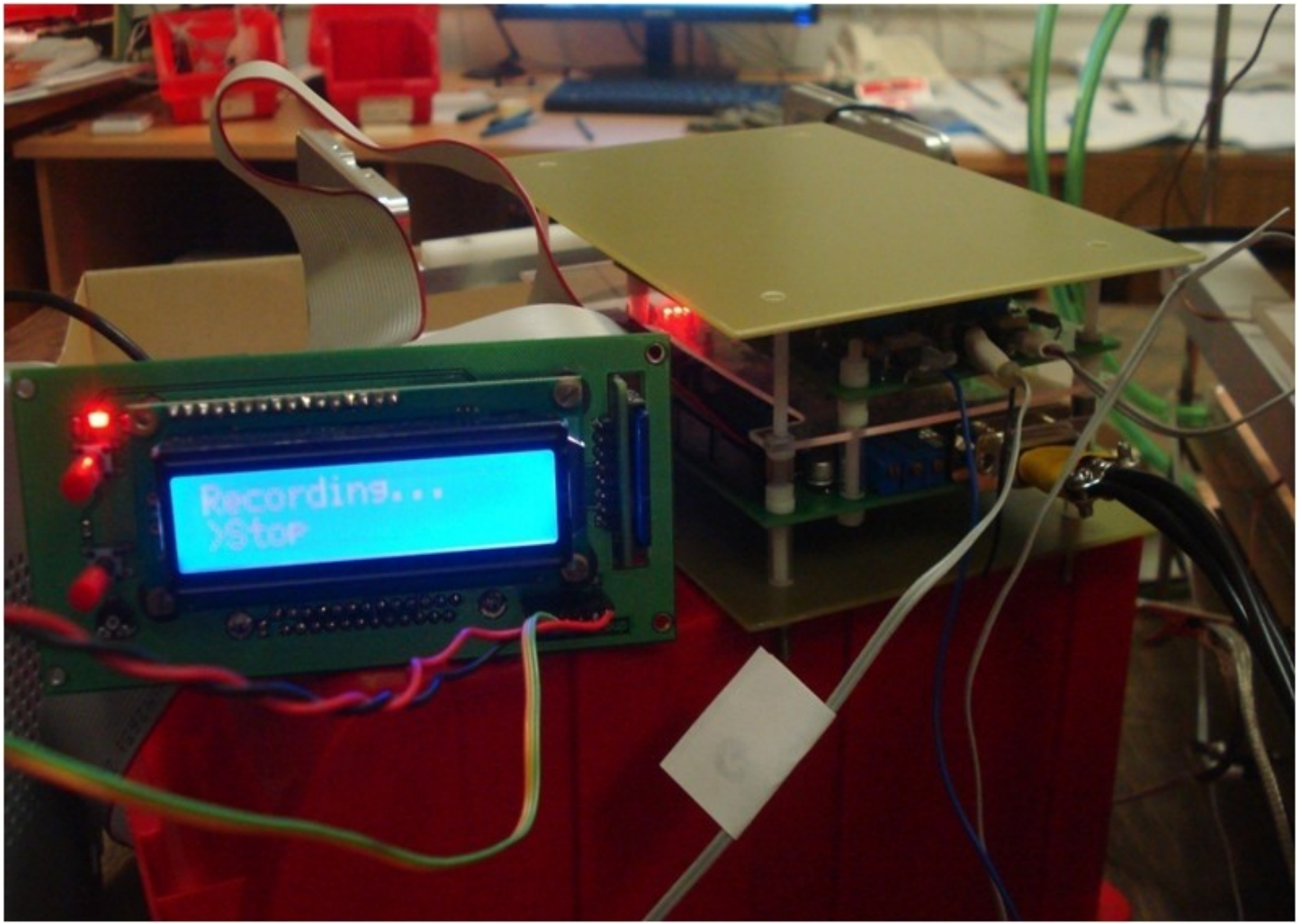
- 16 channels per electronic
- Analog amplification
  with commercial logic ICs
  (CD4001 and CD4069)
- Discrimination →
  1 bit per channel
- Local storage
  in a shift register (74HCT165)
- Serial readout

- All electronics can be put into
  one chain

The Board of DAQ



DAQ



Angular Resolution with Monte Carlo