ECRS 2014 KIEL

Close Cathode Chamber Technology for Cosmic Particle Tracking

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3rd September 2014

REGARD

RMKI ELTE Collaboration on Gaseous Detector Research and Development

Outline

I. Close Cathode Chamber Technology

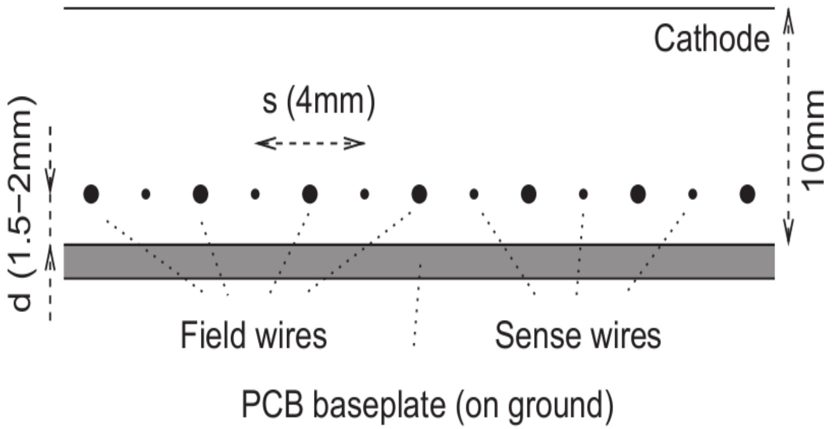
II. Measurements at Shallow Depths Underground

III. Applications on Ground Level

I. Close Cathode Chamber Technology

- **Asymmetric Multiwire Proportional Chamber without outer support frames:**

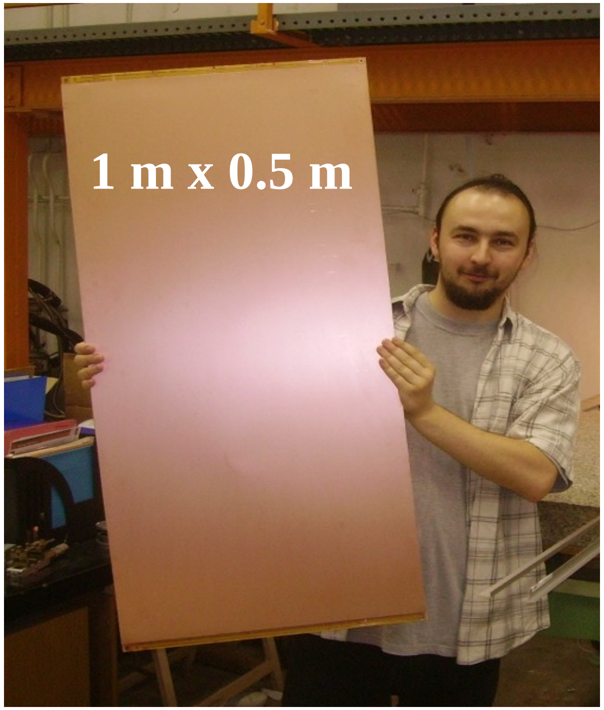
NIM A 648 (2011) 163
NIM A 698 (2013) 11



  - Low material budget (~ 1.5 % radiation length)
  - Reduced (~ 100-200 μm) mechanical tolerances
  - Simplified construction
- Requires **continuous gas flow (~ 1 L/h)**: non-flammable Ar – CO_2 (82% - 18%)
- **High Voltage**: +1 kV on sense wires, -500 V on field wires and cathode
- **2 dimensional location** (wires and pads)
- **Self triggering** by the sum of sense wire's signals

Close Cathode Chamber Technology

A CCC with 1 m long wires.



- Optimizes:
  - Weight/Layer (2 kg)
  - Position resolution (1.5 mm)
  - Efficiency (> 95 %)
  - Cost

Chambers at the CERN Proton Synchrotron test beam.

NIM A 698 (2013) 11

II. Measurements at Shallow Depths Underground

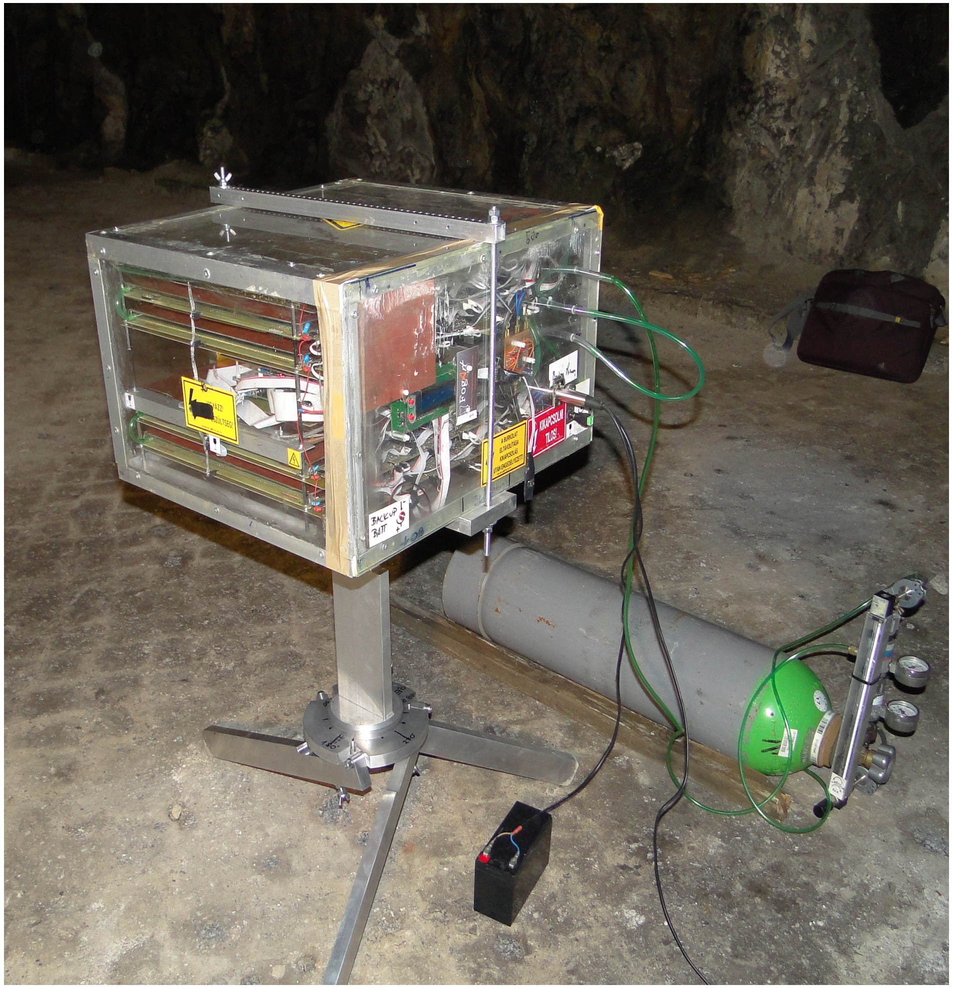
II. Measurements
at Shallow Depths Underground

- <u>**Aim:**</u>
  search for underground rock inhomogeneities (Caverns/Minerals)
  by measuring the flux of cosmic particles
- <u>**Detector requirements:**</u>
  - Stable operation in outdoor environmental (in 100 % humidity)
  - Low power consumption (10-50 Watt)
  - Reliable tracking information:
    - Fair angular resolution (< 5 deg)
    - Good Tracking Efficiency (> 90 %)
- <u>**Limits of muon imaging at underground:**</u>
  - Detector is deployed under the investigated object
  - Particles are Multiple Scattering in rock/soil
  - Duration of measurements increase by the transversed density-length

Portable Tracking Detector for environmental applications

- **5 Close Cathode Chambers (CCC)**
  - Sensitive area per layer: **32 cm by 32 cm**
  - Angular resolution: **10 mrad**
  - Low Energy cut off: **~ 10 MeV**
- Plexiglass box (can work in 100 % humidity environmental)
- Easy to handle manually:
  - volume: **47 x 51 x 25 cm^3**
  - total weight: **20 kg**
- PIC32 based Data acquisition (DAQ) system integrated into one unit
- Environmental parameters (humidity, temperature and pressure) are monitored
- Human Machine Interface (HMI):
  - LCD display, SD card
- Total Power Consumption: **5 W**

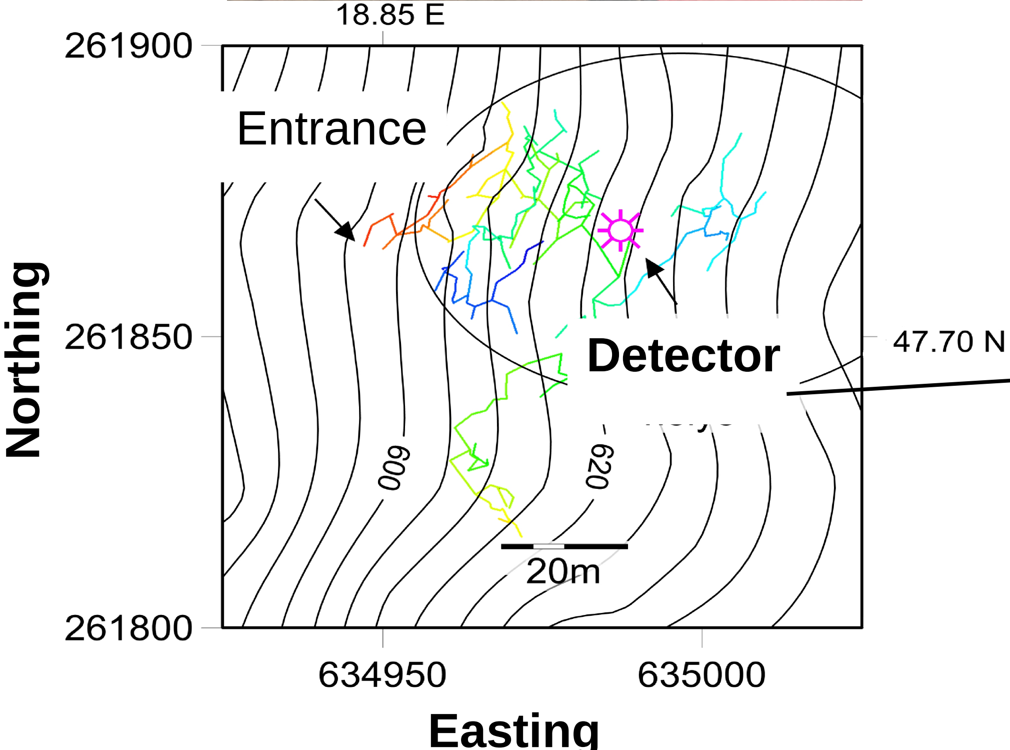
NIM A 689 (2012) 60-69
Adv. in HEP, 560192 (2013) 1-7



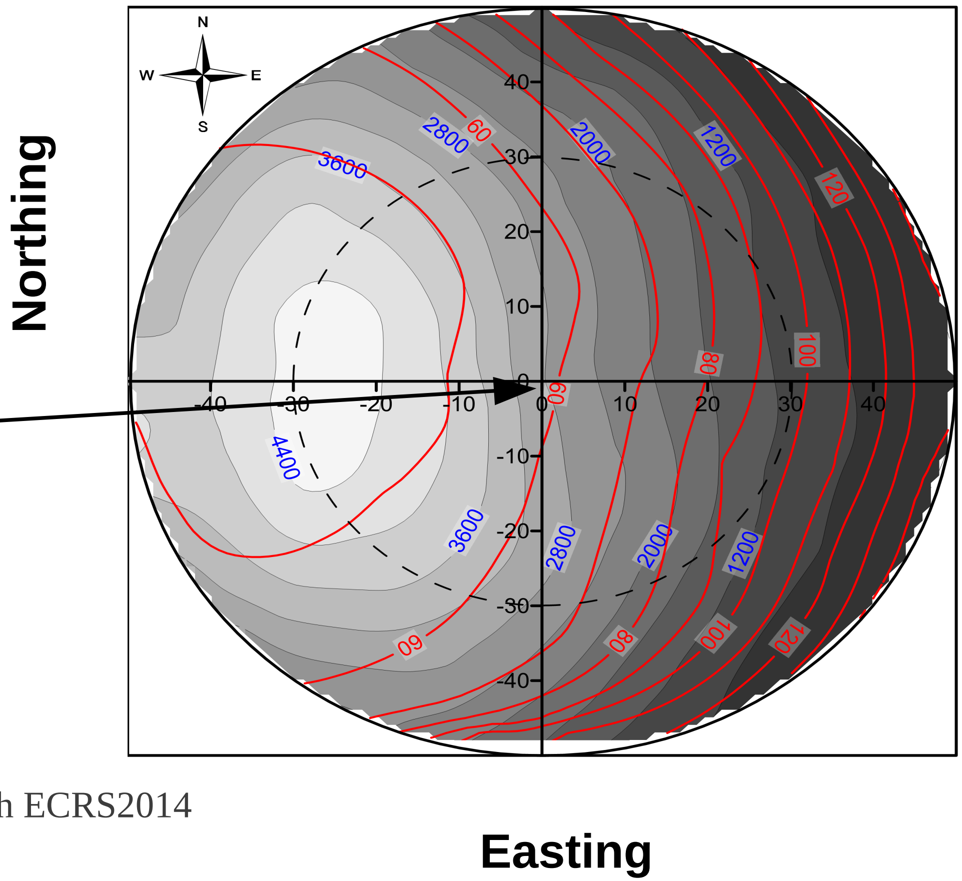
First Detector tests in a Natural Cavern System

NIM A 689 (2012) 60-69

- The detector was reliably operated during the 50 days of measurments in under 60 m rock in Ajándék Cave, Pilis, Hungary (170k tracks)
- **Muon flux correlates with rock thickness: No cavern**

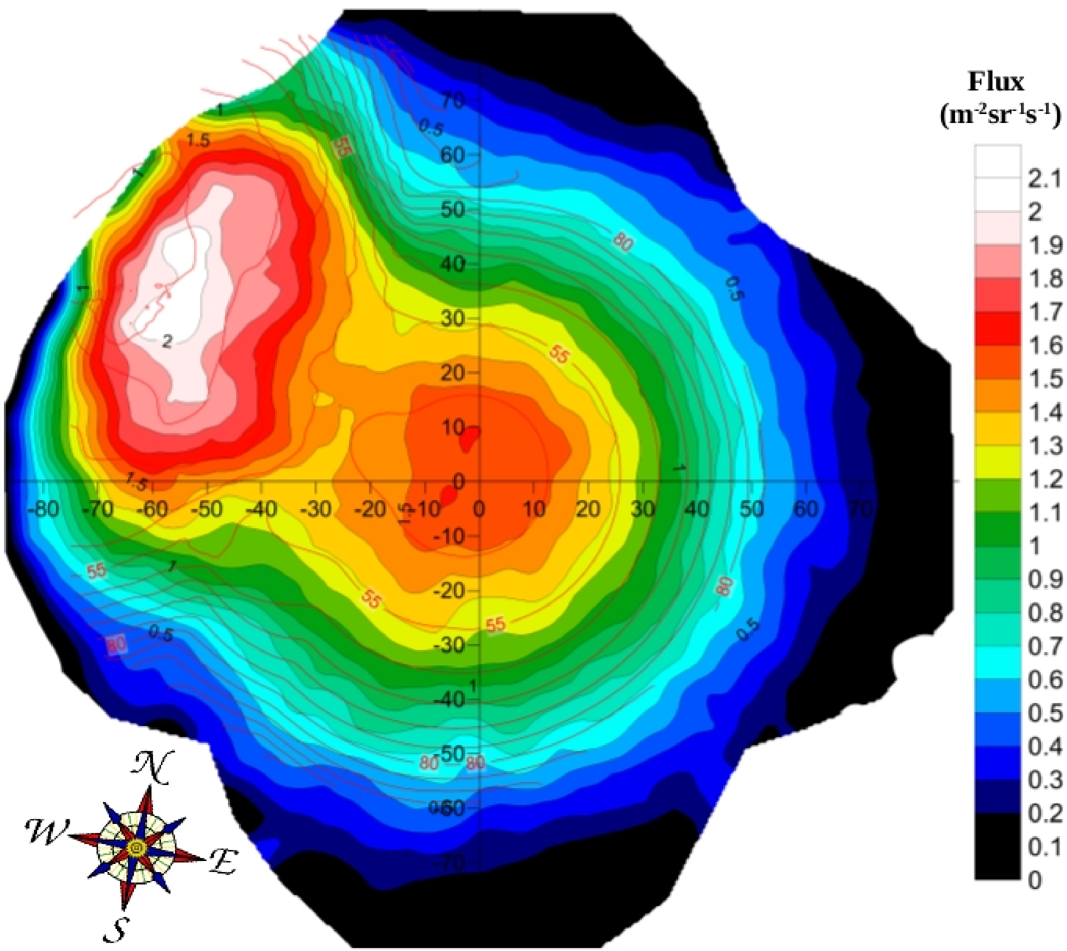


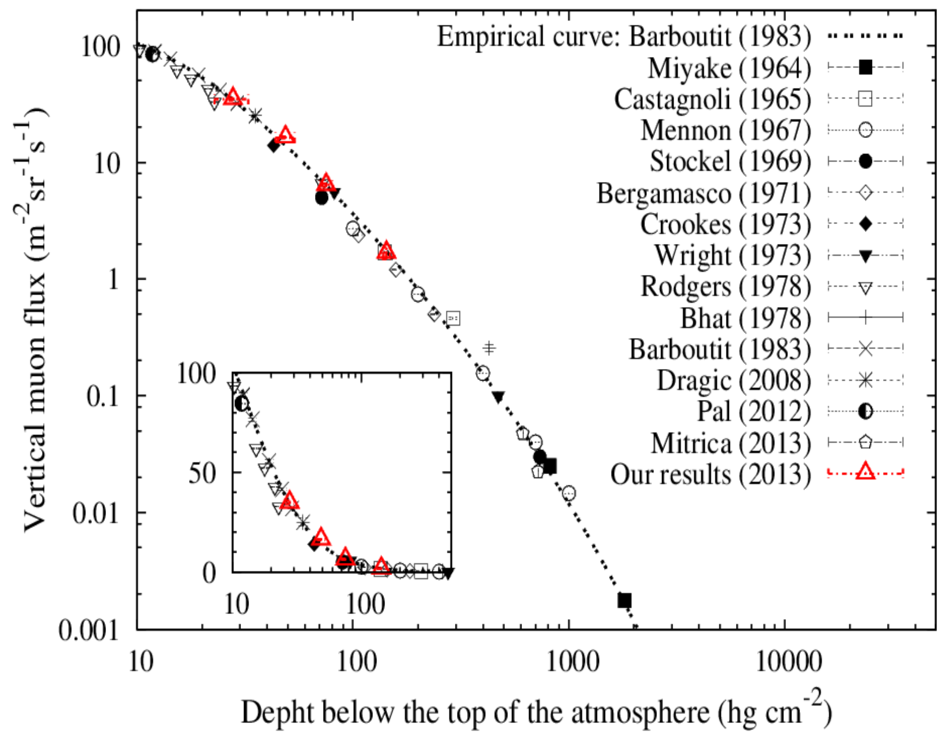
Red contours: rock thickness (m)
Grayscale contours: muon counts



Cosmic Background Measurements at Proposed Underground Experiments

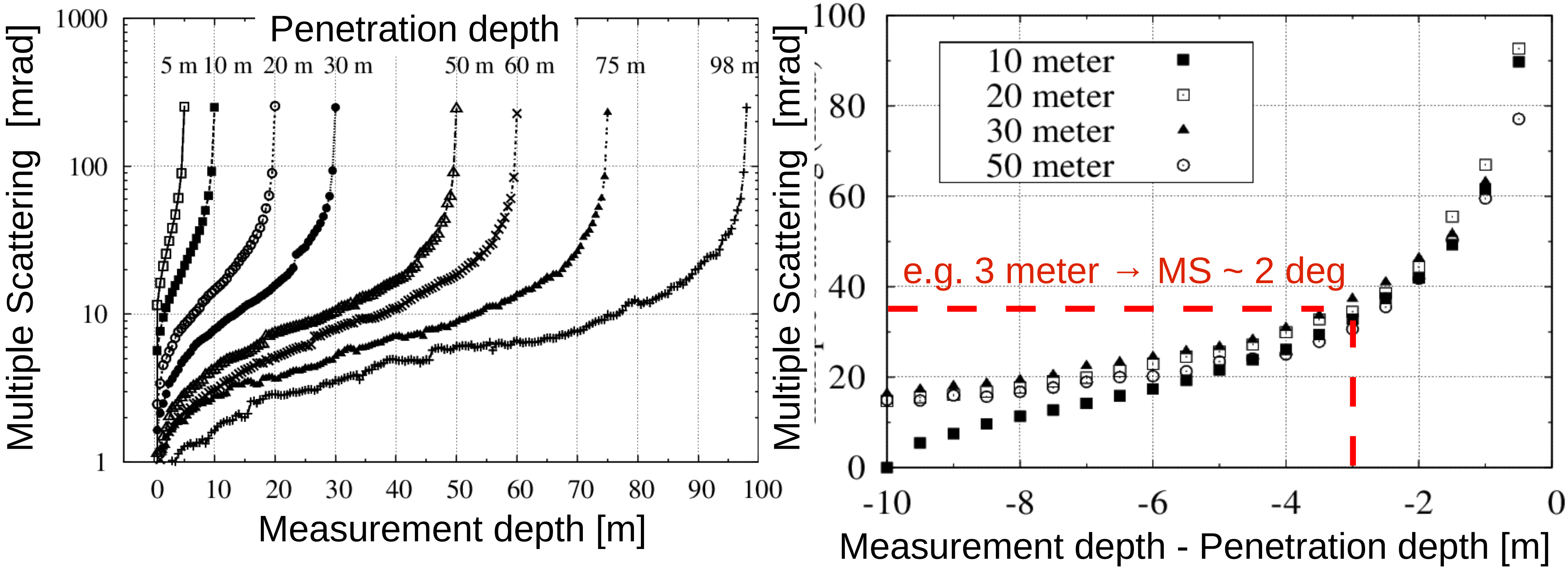
- **Measurements (40 days at 50 m.r.e. depth) cover the full 2π of the upper hemisphere:**
  - provide a well define baseline for the design of a proposed underground accelerator based experiment in Felsenkeller, Dresden, Germany
  - maximum flux value found below 2.5 $m^{-2}sr^{-1}s^{-1}$ (statistical + systematical errors: 3-10 %)





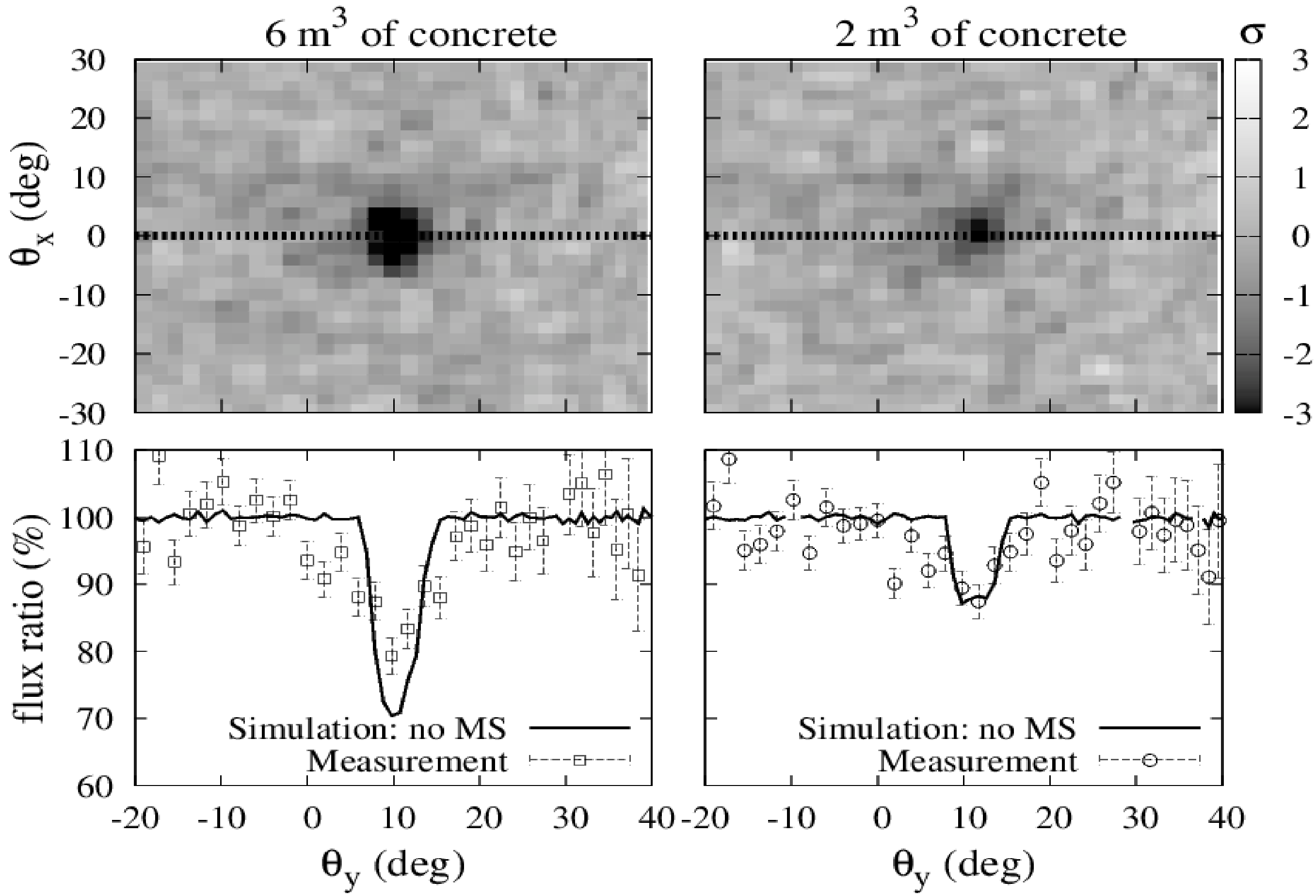
- The measured vertical muon fluxes *(red triangulars)* are in good aggreement with the „world data"!

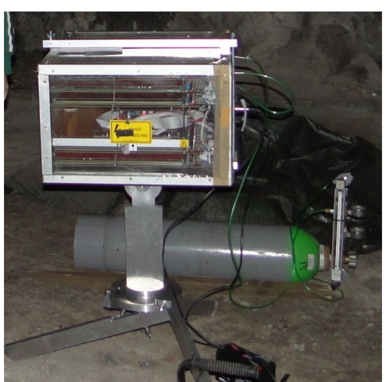
GEANT 4 simulation of Muon Multiple Scattering in rock



- The scattering angle of muons increases by the transversed material
- GEANT4 simulates the multiple scattering (MS) of muons along their path:
  - **MS independent from the penetration depth**
  - **MS depends on the size of density inhomogeneity above the detector**
    - e.g. for tunnel with 3 meter diameter → ~ 35 mrad (2 deg) of MS

Direct verification of absorption



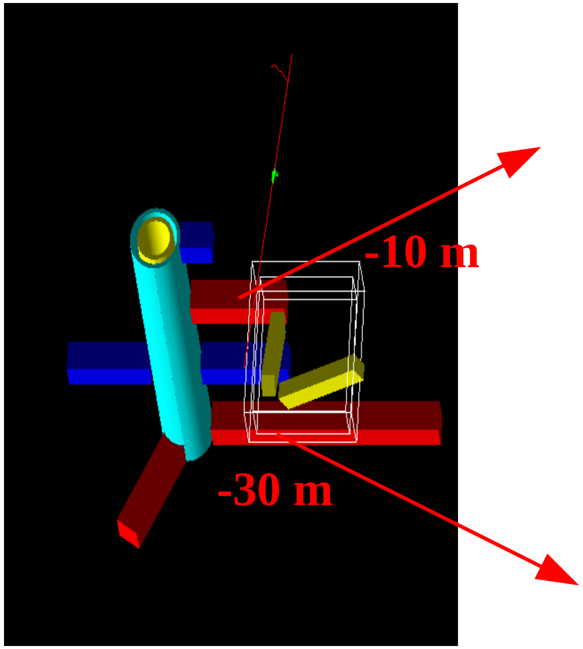


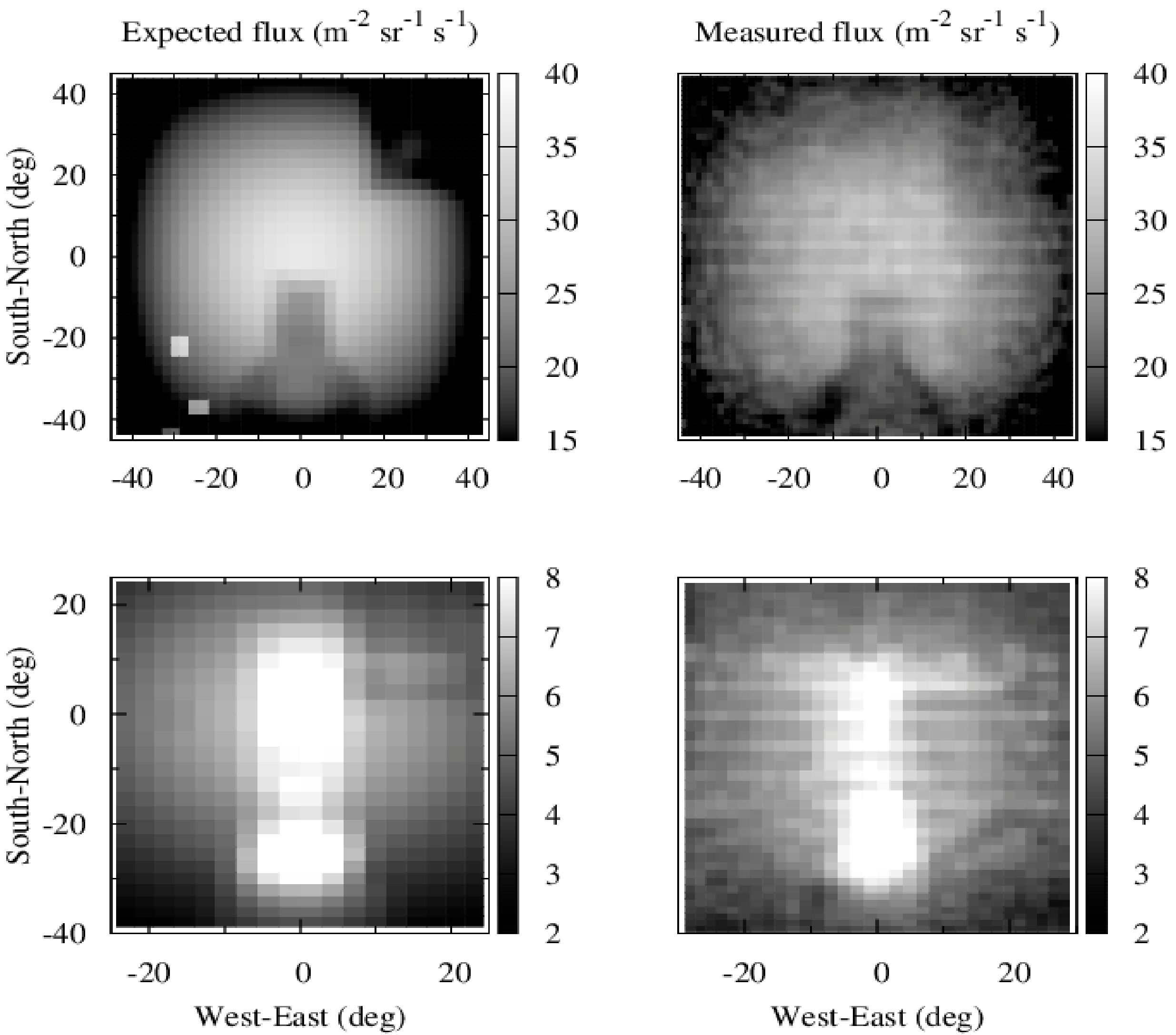
@ 10 meter depth

- Detector has been deployed at 10 meter depth (27.8 hgcm^{-2})
- Measurements have been done with/without concrete absorbers (6 m^3 and 2 m^3) deployed on ground level
- **Total absorption well predicted by simulation; note small but visible broadening by MS**

Reconstruction of Underground Tunnels

Building and tunnel structures are visible by **our measurements** !





1. Geometry in Geant4
2. energy loss of muon beam → Rock thickness
3. Rock thickness → Muon flux by empirical formulae
J. Phys. G: Nucl. Phys. 9 (1983) 1577-1595.

III. Applications on Ground Level

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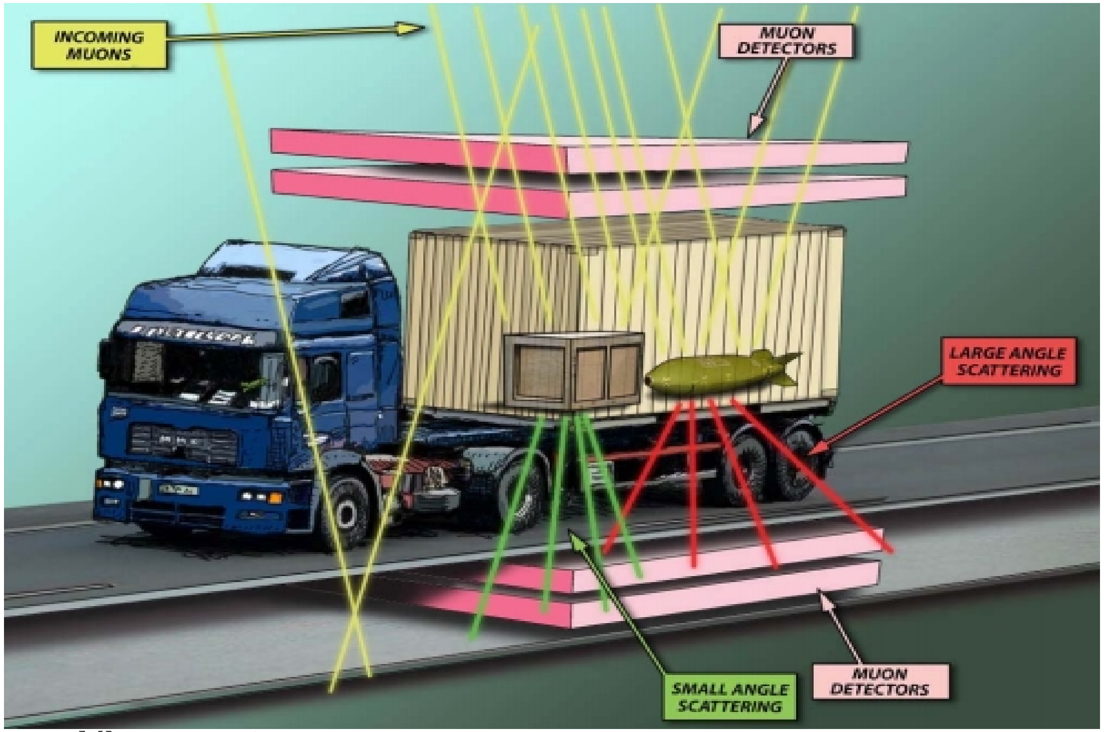
Aim: search for hidden high-Z materials
by measuring the multiple scattering and absorption of cosmic particles

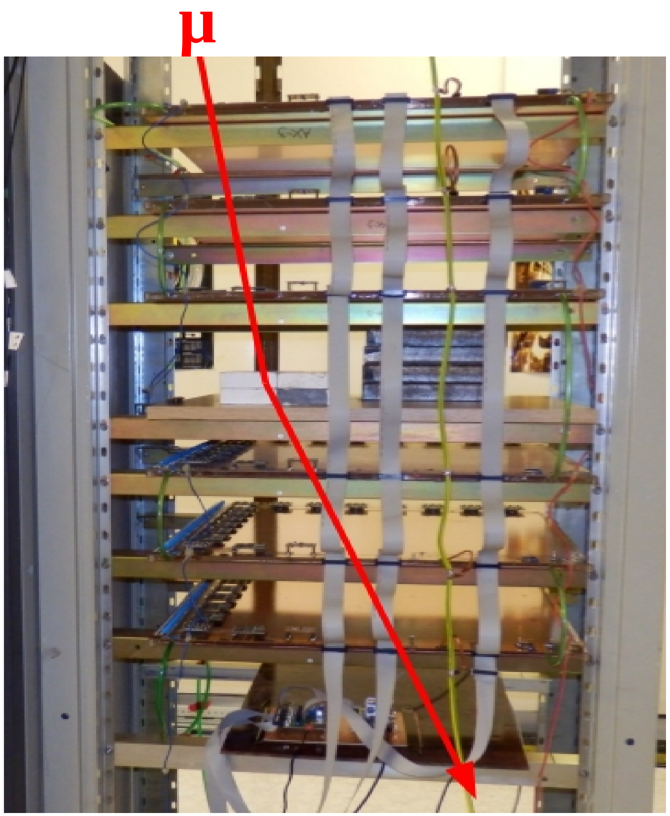
K. Borozdin et al.: Nature 422, 277 (2003)
L. Morris et al.: AIP Advances 2, 042128 (2012)

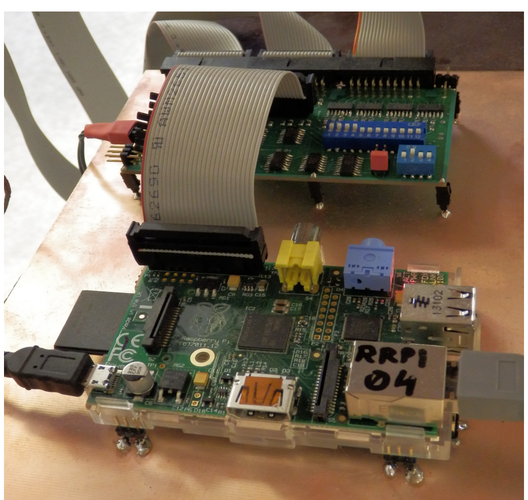
- **Advantages:**
  - **Environmental radiation → No exposure**
  - Higher sensitivity for high-Z materials
  - Big penetration power: can investigate thick metals also

- **Questions:**
  - What time is needed?
  - How much resolution is needed?
  - What are we measuring (muon/electron)?



Tracking Detector for Material Discrimination

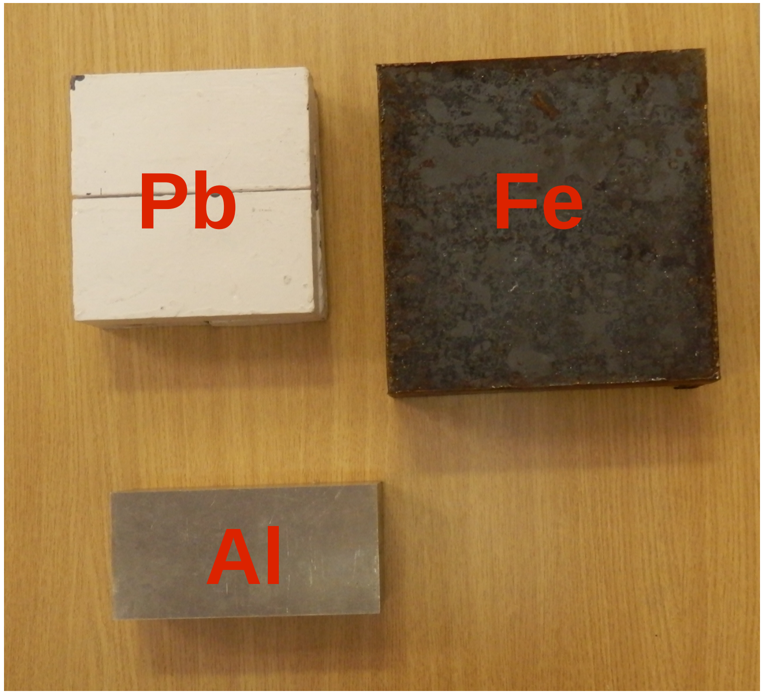


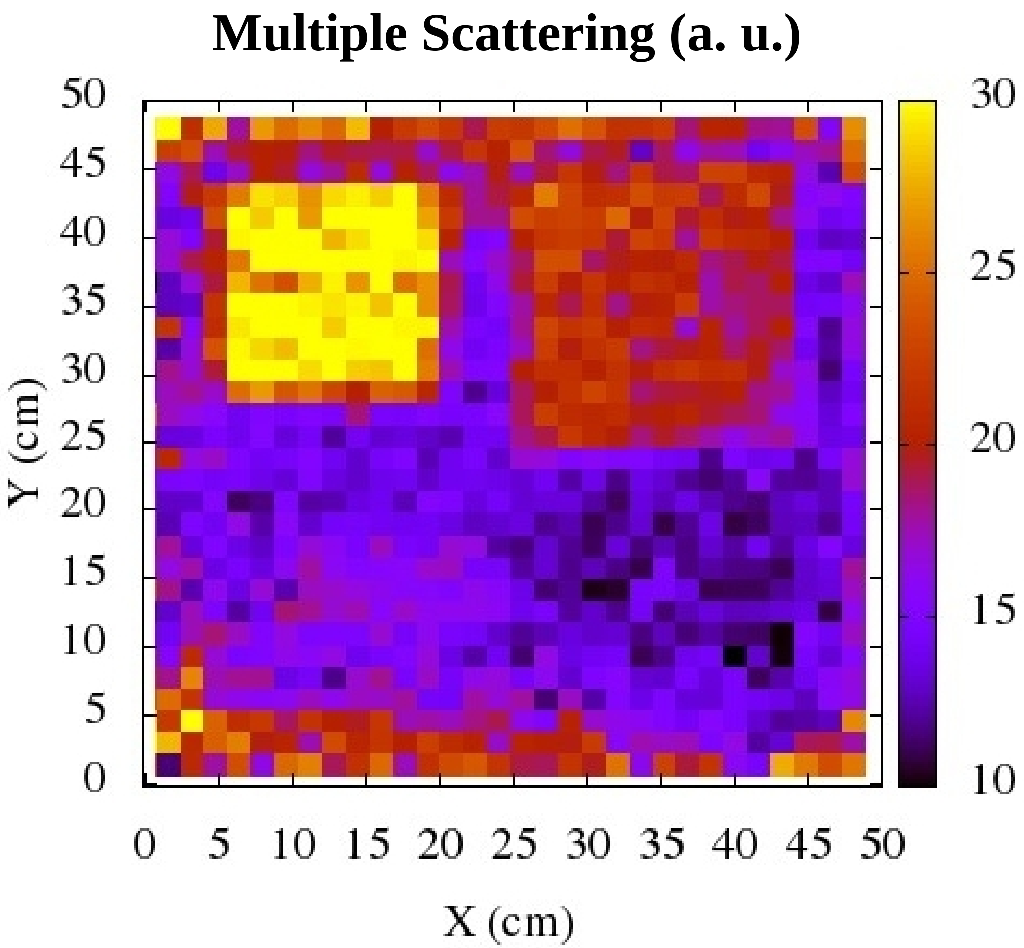


- 3+3 Close Cathode Chambers (CCC):
  - Sensitive area per layer:
    50 cm by 50 cm
  - Raspberry Pi Computer based DAQ:
    - small size (10 cm x 10 cm x 3 cm)
    - allowing remote control and data management
  - Power Consumption: ~ 10 W

Material Discrimination by Cosmic Particle Tracking

- **Material discrimination achived by the <u>MEASUEMENT</u> of absorption and multiple scattering of cosmic particles**





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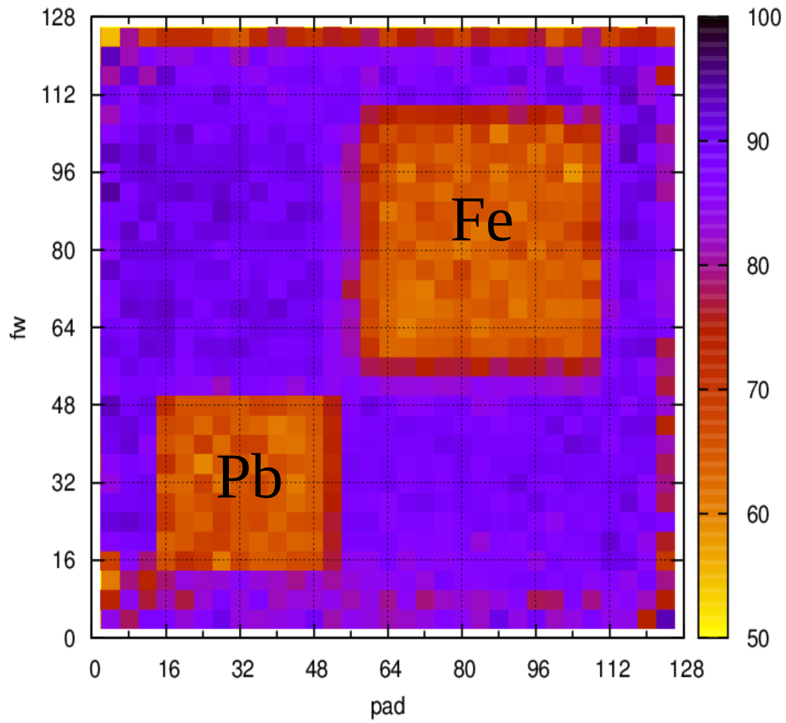
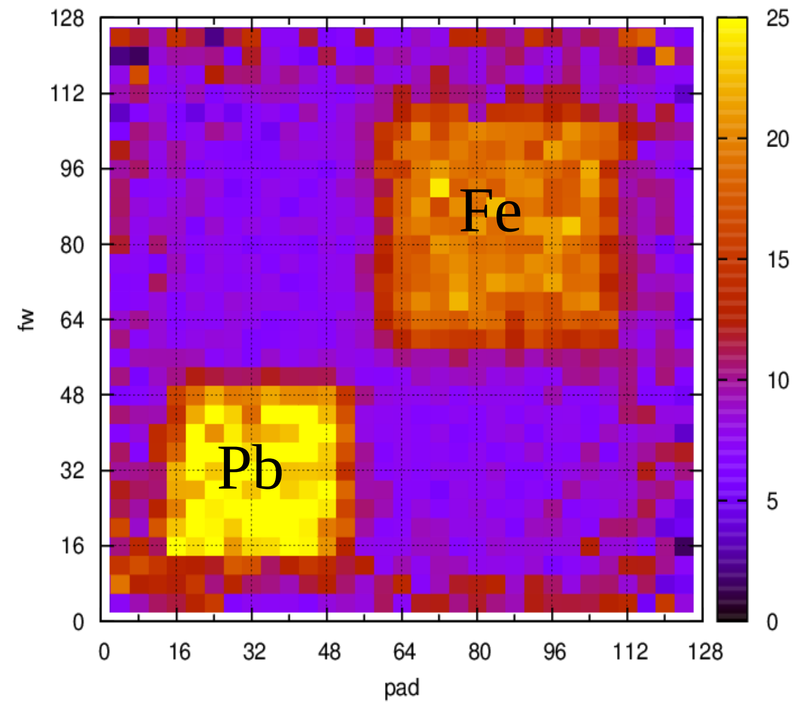
Absorption



Multiple Scattering



Summary

- **Close Cathode Chamber based tracking detectors:**
  - Mobile and power efficient (5-10 W)
  - Precision: 1.5 mm spatial and 10 mrad angular resolution
  - Cost efficient CCC technology
  - Integrated Data Acquisiton Systems based on PIC or Raspberry Pi
- **Applications of cosmic particle tracking:**
  - Cosmic background measurements at a proposed underground experiment in Felsenkeller, Dresden, Germany
  - Reconstruction of underground tunnels
  - Material identification is demonstrated
- **Next Steps:**
  - Develop infrastructure for the manufacture of CCC-based detectors

Thanks for Your Attention!

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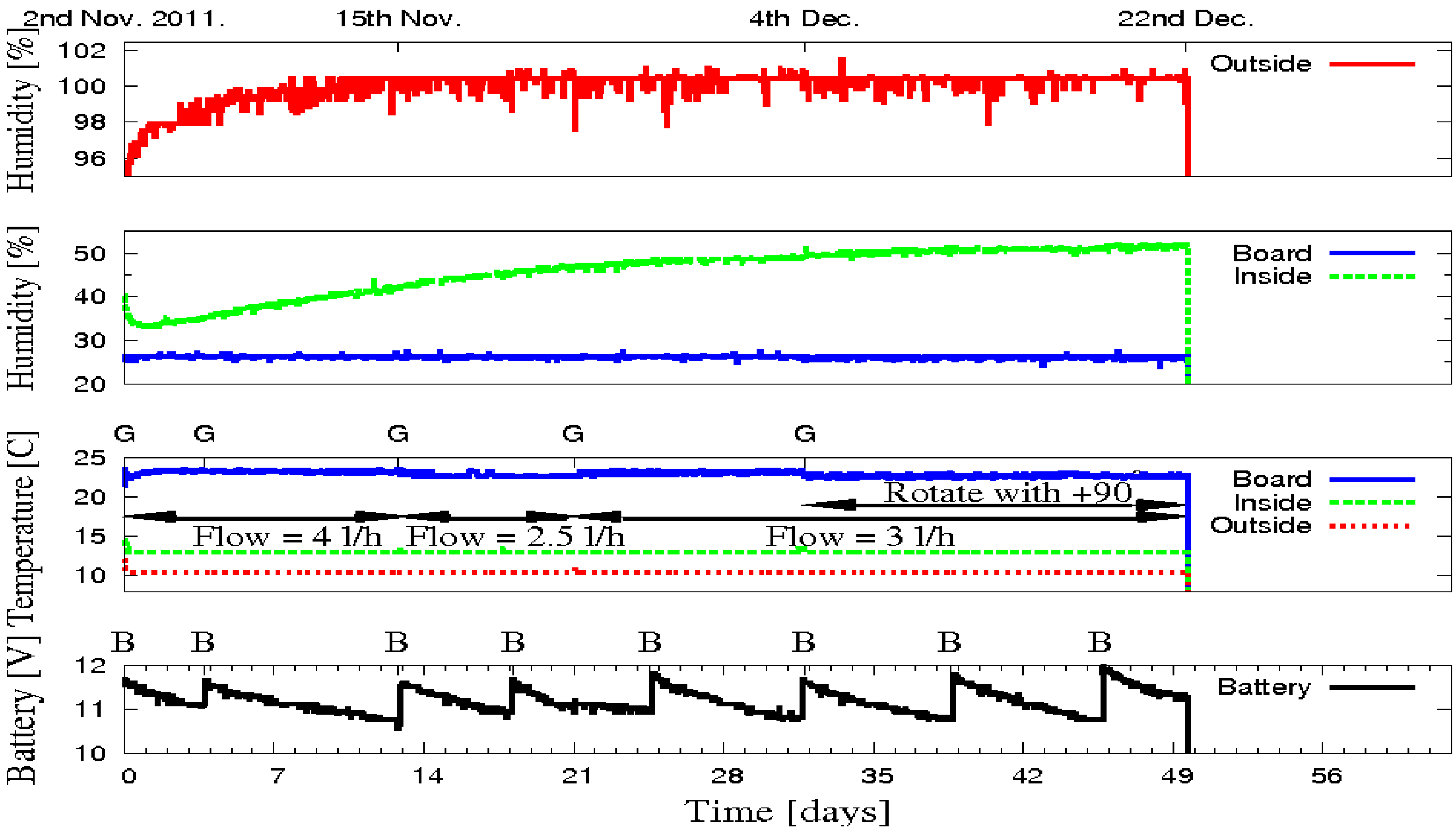
Our research is supported by the OTKA NK-77816, OTKA PD-73596 grants and Momentum („Lendület”) grant of the Hungarian Academy of Sciences.

Backup Slides

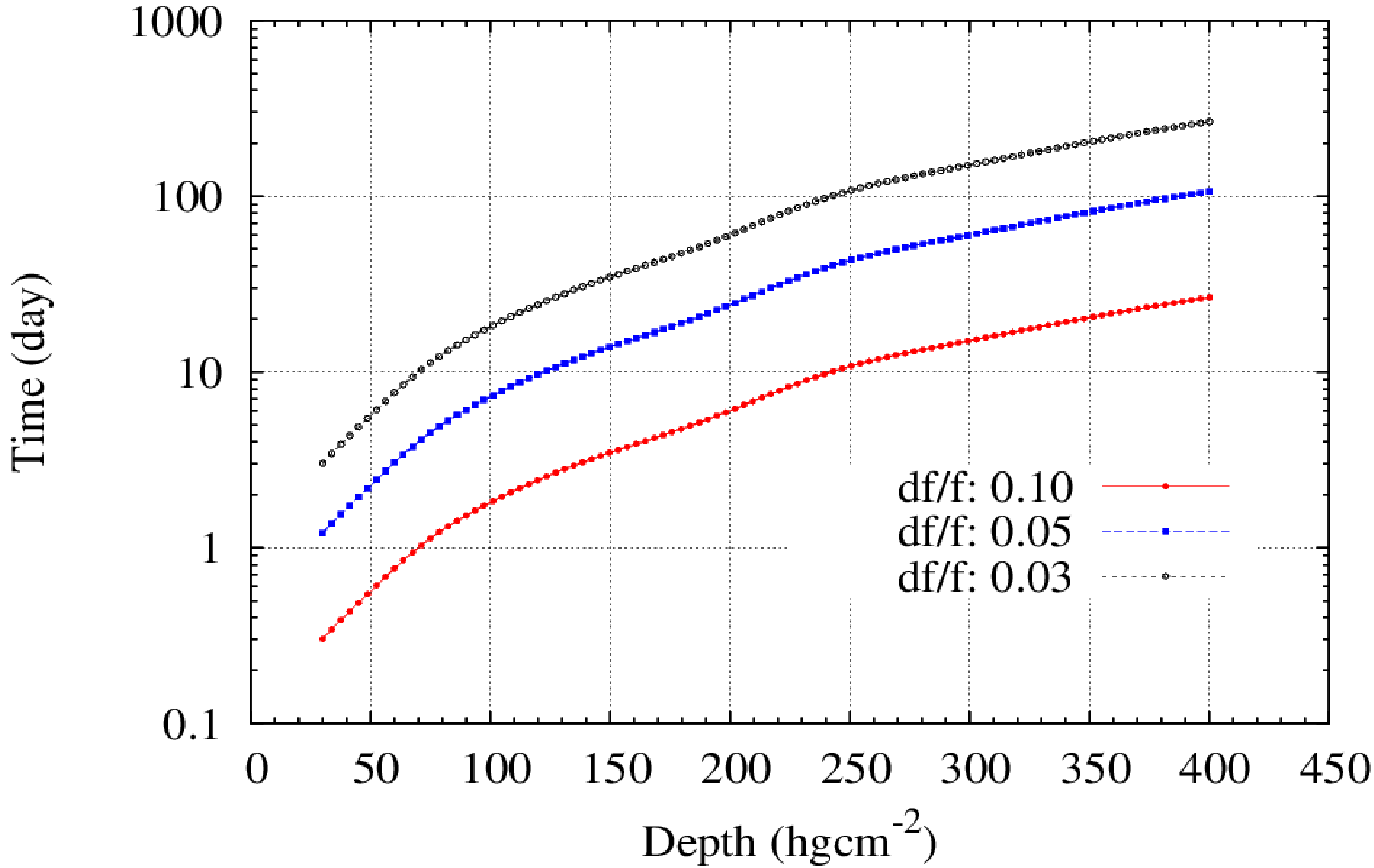
Environmental Control in the Ajándék Cave

- 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 (presently operating with 1 L/h).



The Duration of Muon Flux Measurements

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



Front-End Electronics and Integrated DAQ systems

- **Front-End Electronics:**
  - 16 channels per electronic
  - Analog amplification and discrimination by commercial logic ICs
  - Serial readout: electronics put into a chain
- **PIC32 based DAQ**
  - All functions are integrated into a common system plan
  - **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