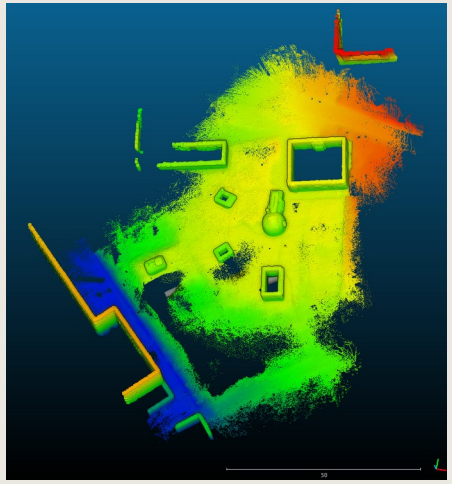

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MUOGRAPHERS

Precision parameter analysis based on a series of measurements conducted at the Jánossy Underground Laboratory

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2026.06.02.

HUN-REN Hungarian Research Network

MTA Kiváló Kutatóhely

National Research, Development and Innovation Office Hungary

PROJECT FINANCED FROM THE NRDI FUND

EKÖP University Research Scholarship Programme

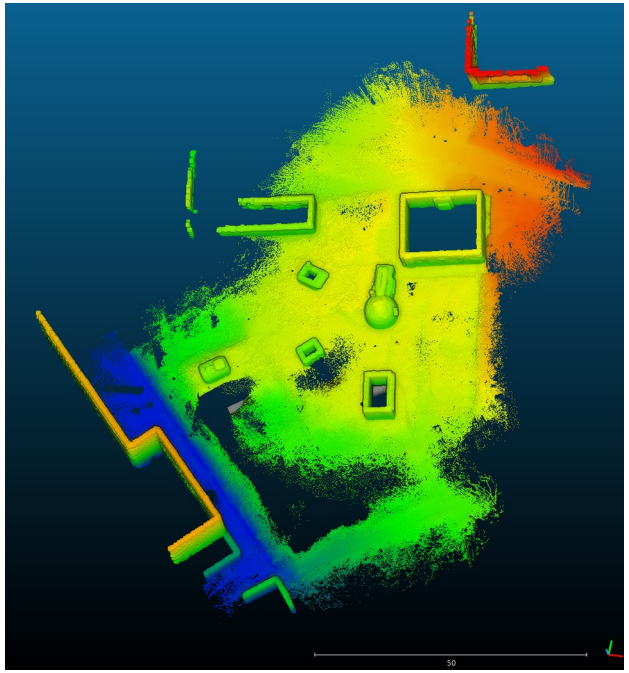
Jánossy Underground Laboratory

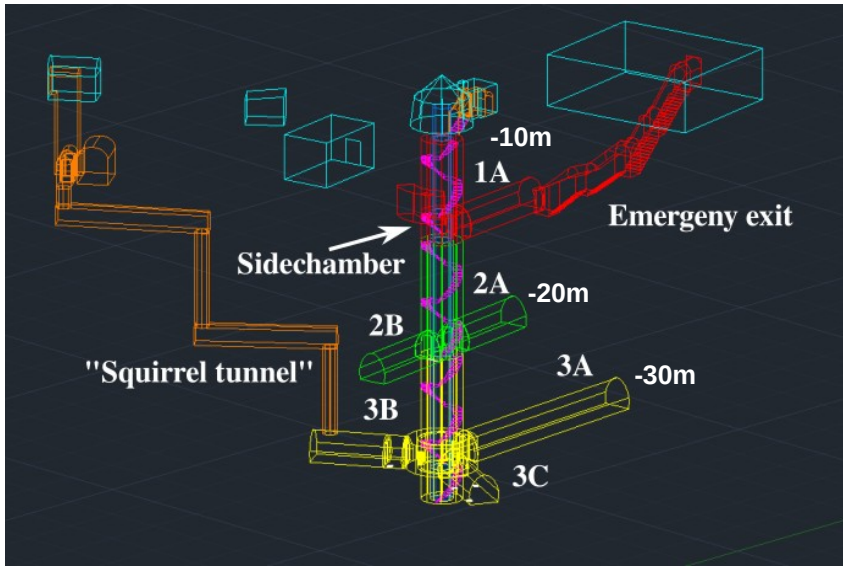
- It was one of the first buildings constructed on the KFKI Campus in the 1950s and is well known for its simple geometry
- The site model was created based on laser scans, AutoCAD drawings provided by KFKI Üzemeltető Kft., and data from the archives
- The program we developed was initially capable of calculating only surface and tunnel models
-

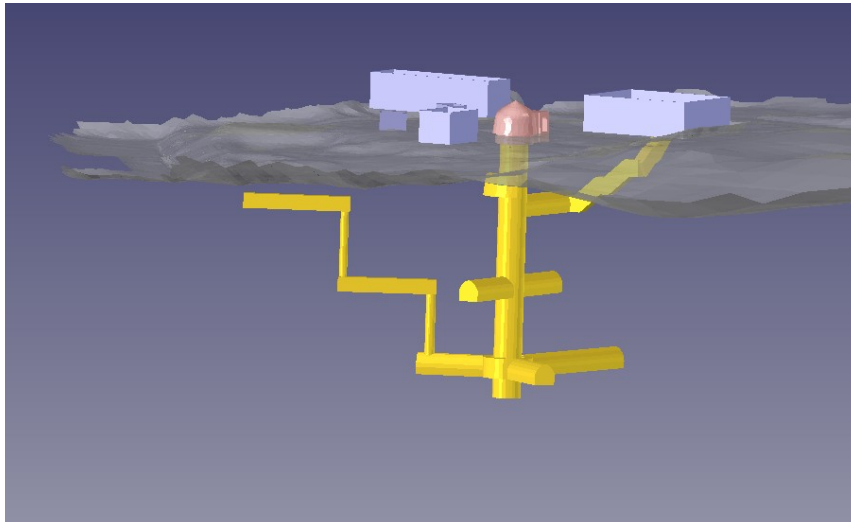
↓

Simple model

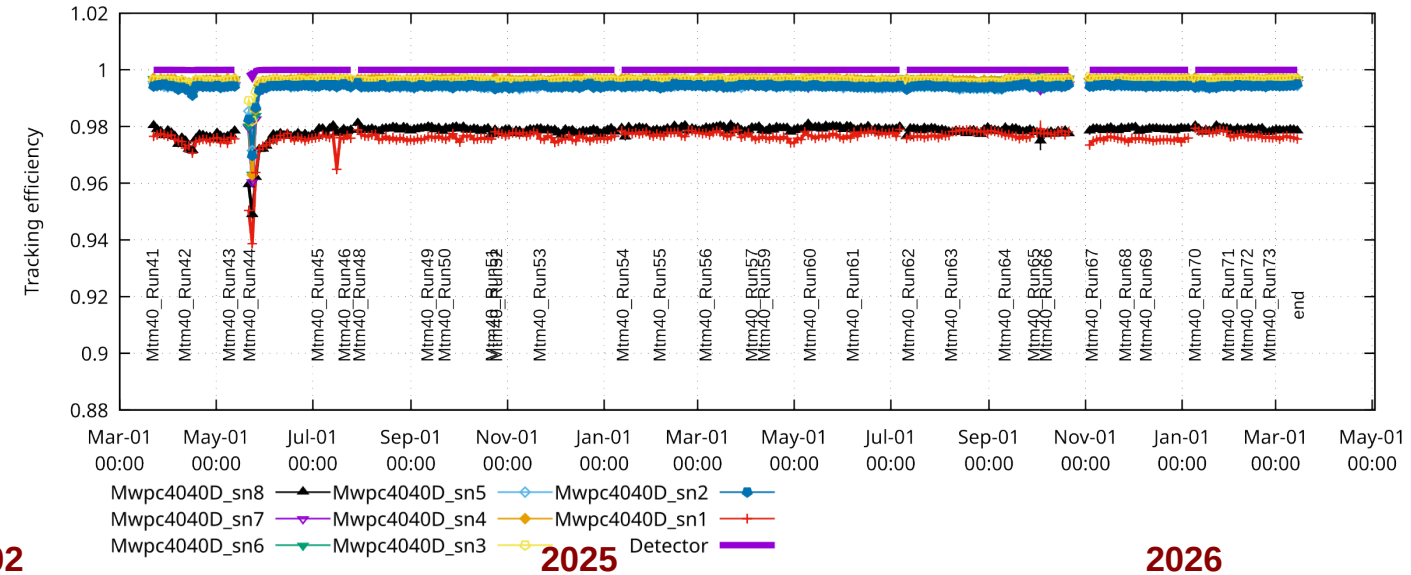
- Complex density model including surface buildings, tunnel walls, service tunnels.

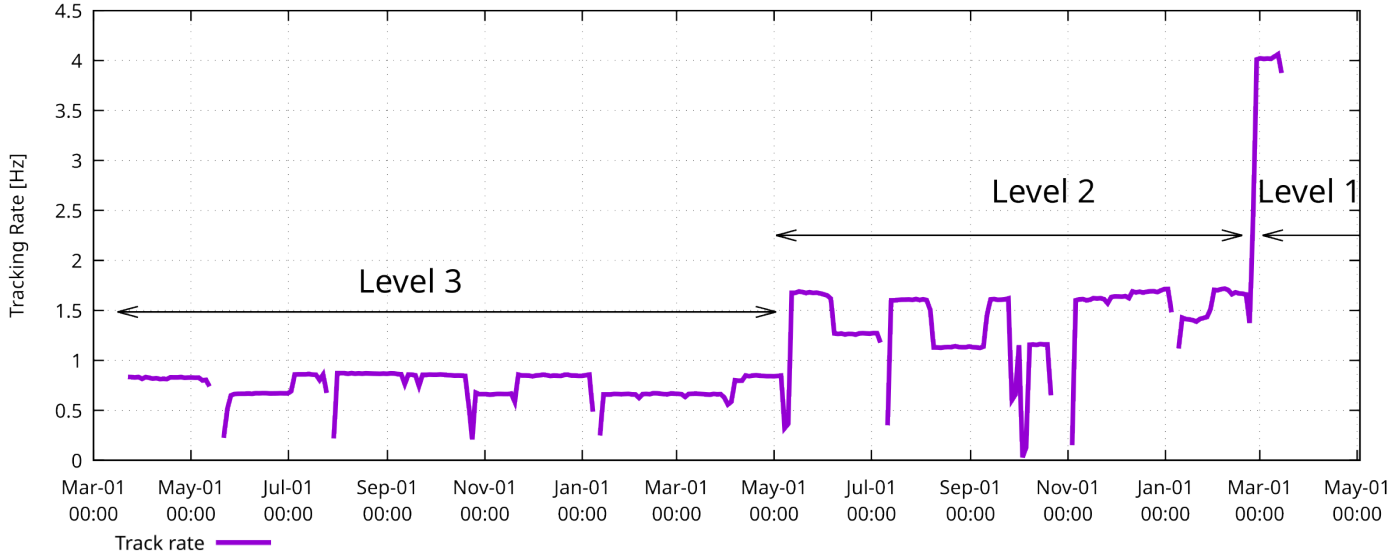






Measurements





- JURLab well-defined geometry is suitable test measurements
- High statistics series of measurements will be basis for further studies
- Detectors: Mtm40 (40cm) and Mts54 (50cm), angular resolution 5mrad
- Duration: 2 years, 5 month
- Number of measurement points: 19, 5
- Number of measurements: 29, 7

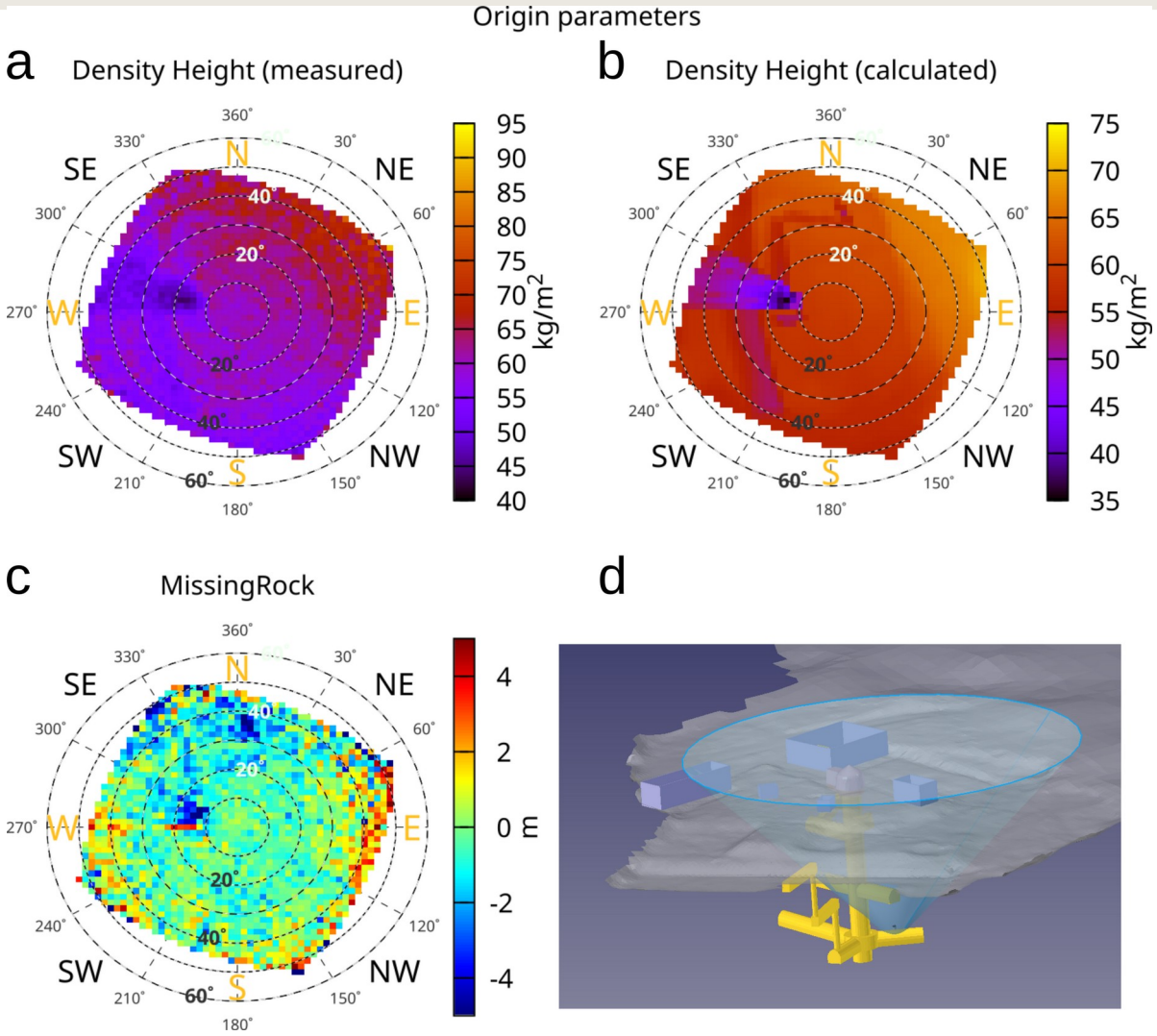
Sensitivity for measurement parameters

Myographic measurements are characterized by the following parameters: position, rotation, and tilt

Verifying these parameters is very important because they can cause characteristic anomalies in the final result, as they indicate anomalies that do not actually exist

The accuracy of these parameters can be verified using known objects visible in the given myogram

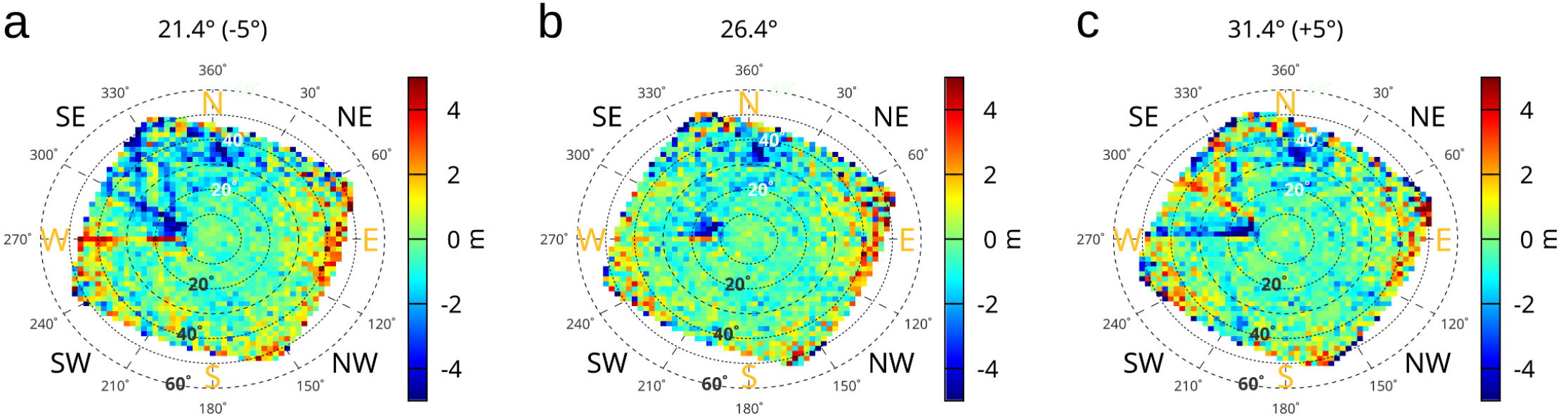
In the case of the Run41 measurement, I examined the correctness of the rotation angle

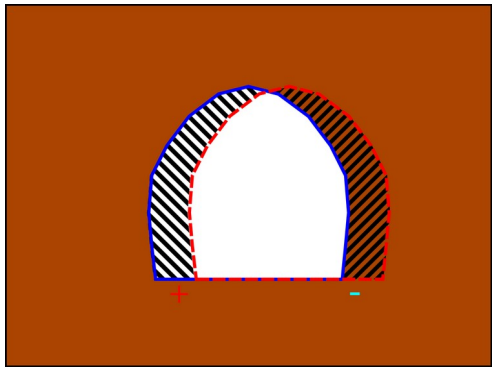


Run41 measurement results

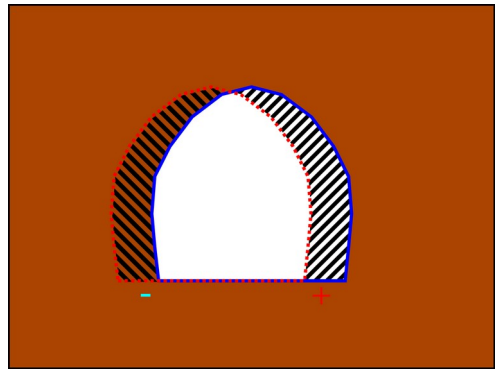
Sensitivity for measurement parameters

Missing Rock

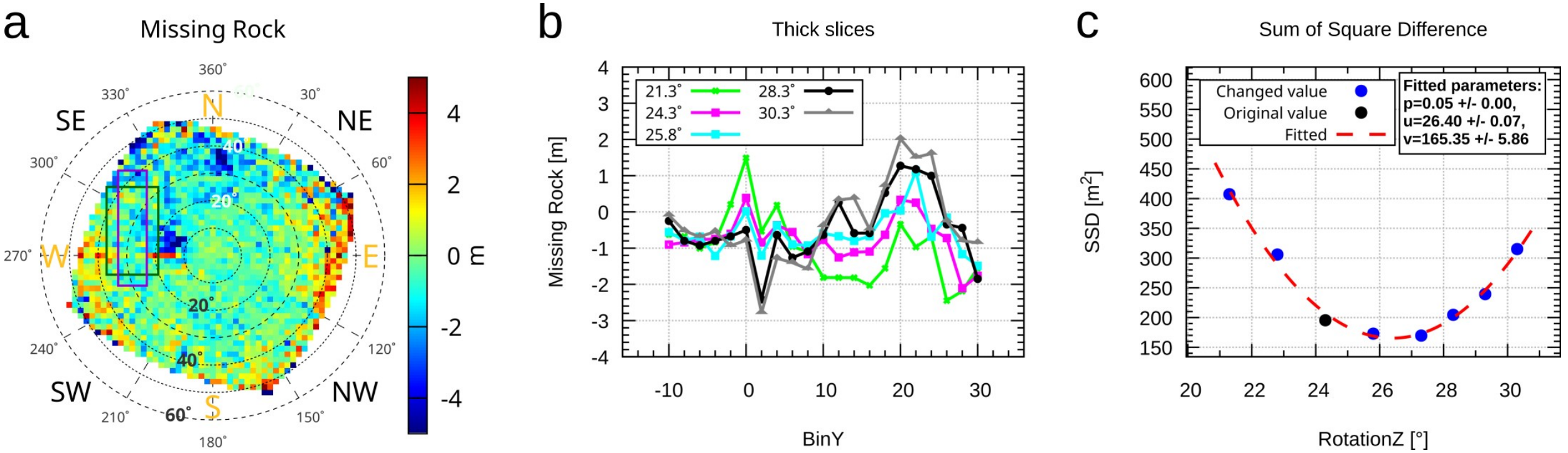




Muograms of the missing rock in Run41 at different rotation angles

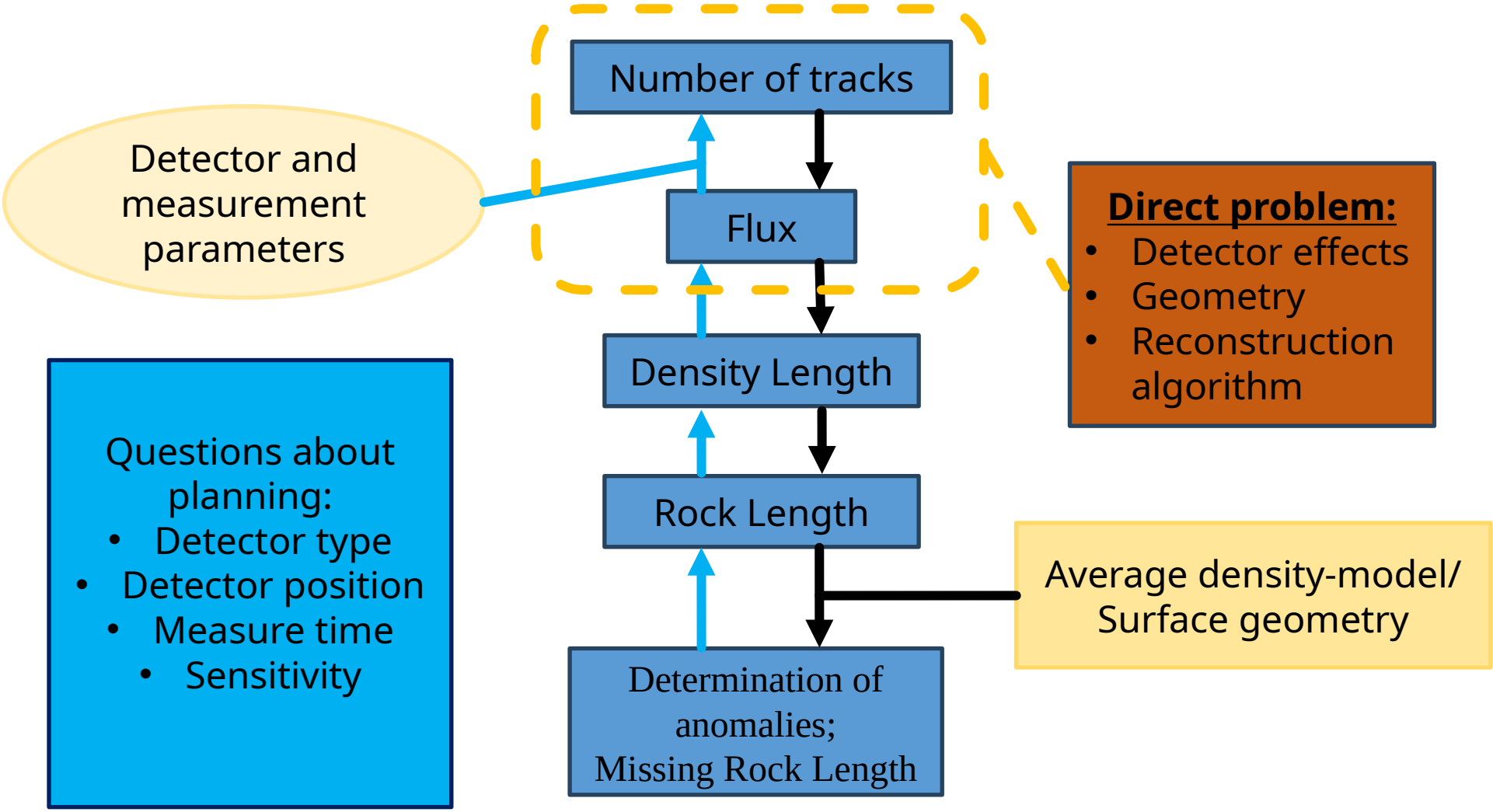


Sensitivity for measurement parameters



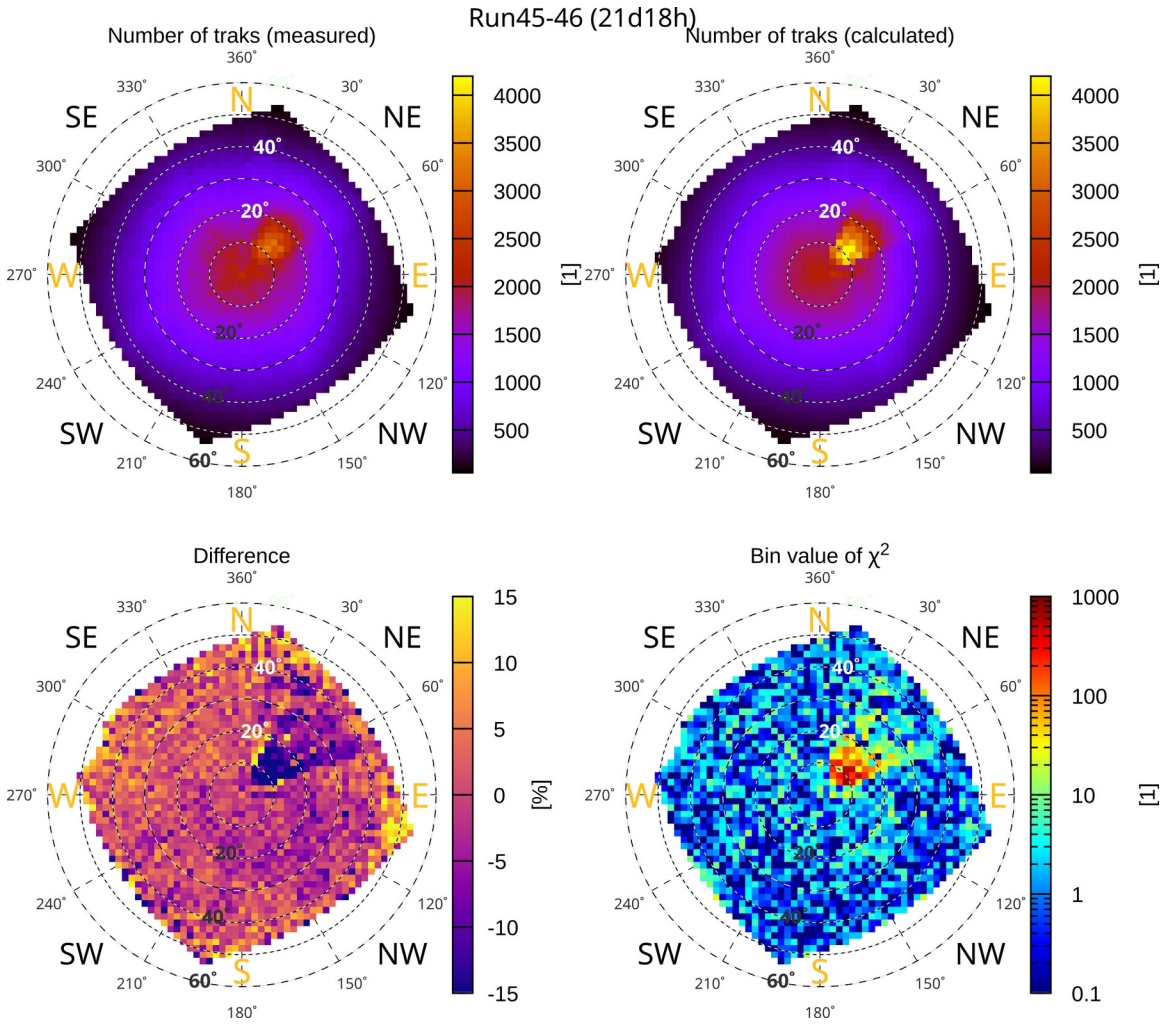
Determining the rotation angle parameter for the Run41 measurement

Data processing



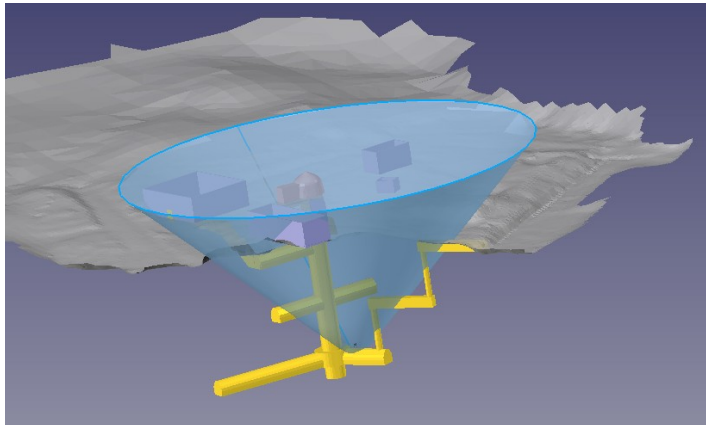
Steps on the data processing

Direct model



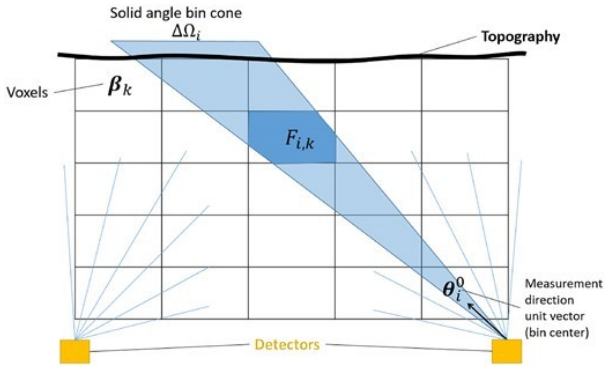
- I used the data from the Run45-46 measurement to validate the problem directly.
- Since I was still using the simplified geological/density model, we still see significant discrepancies caused by surface structures (e.g., the JURLab entrance and dome, etc.).

$$\frac{(N_{meas} - N_{calc})^2}{N_{calc}}$$

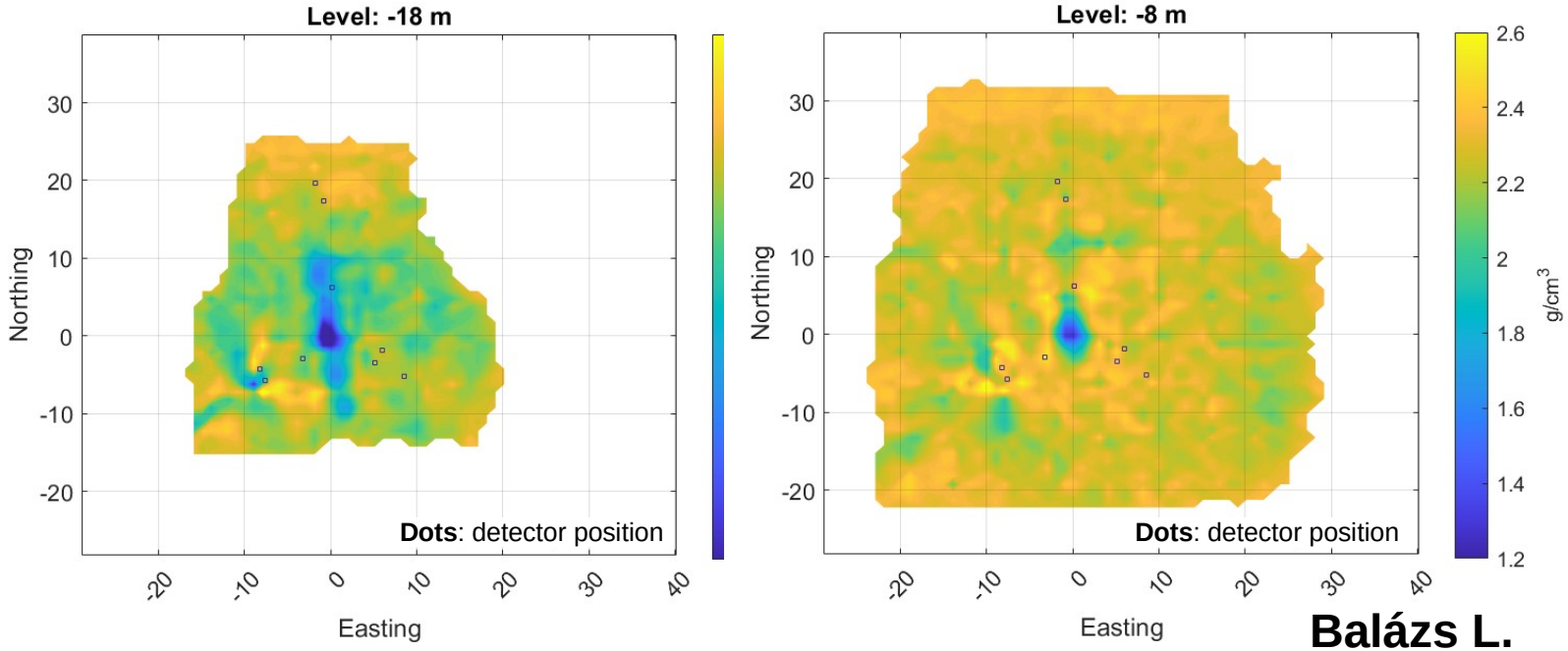


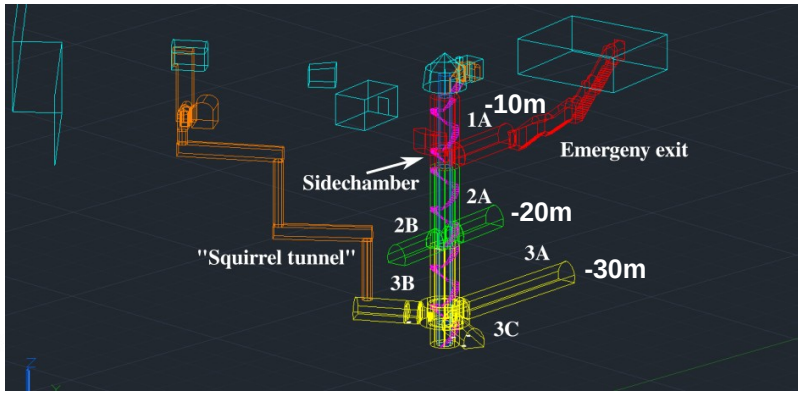
3D tomography[1]

- The 3D muon tomography method we use is based on a maximum likelihood inversion method, combined with Bayesian constraints derived from our geological knowledge

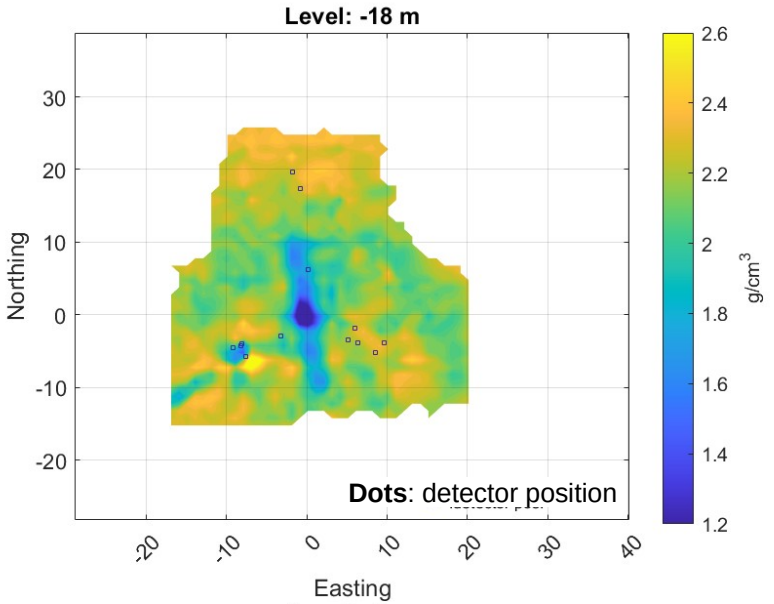


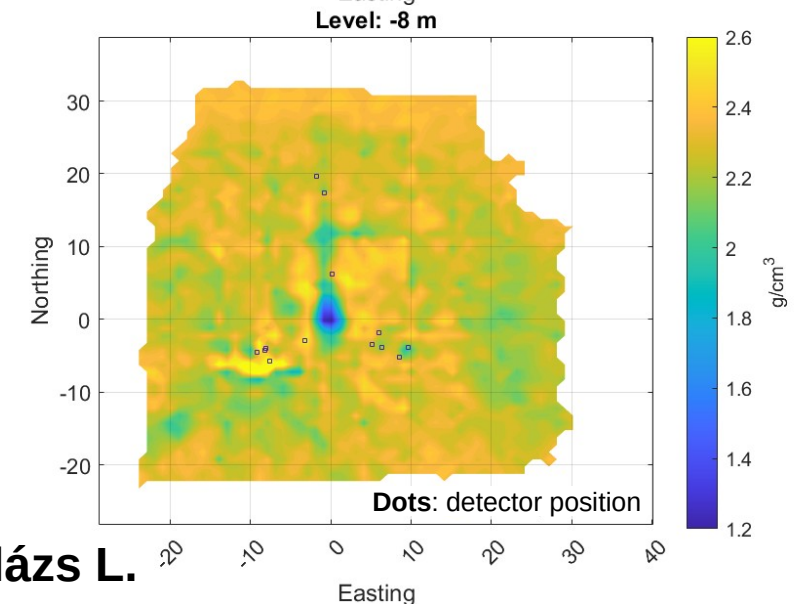
- **First inversion case:**
- a) only Mtm40 measurement on the -30m level
- b) 14 measurements
- c) aim: the -20m and -10m deep levels





3D tomography[1]

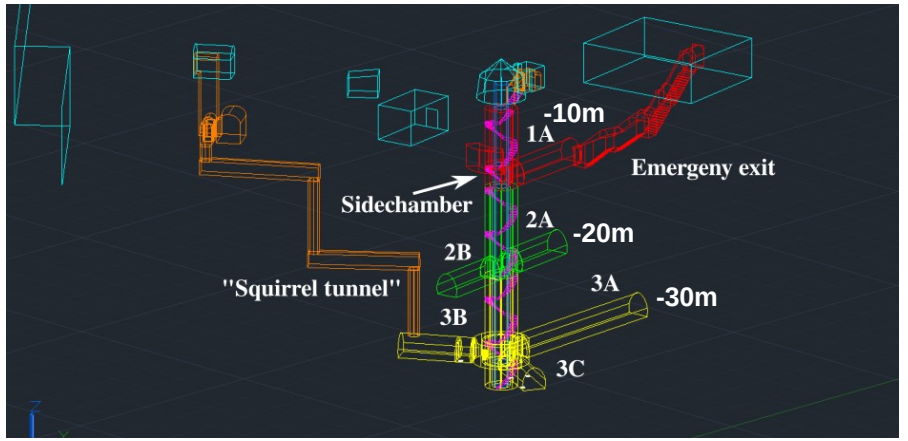


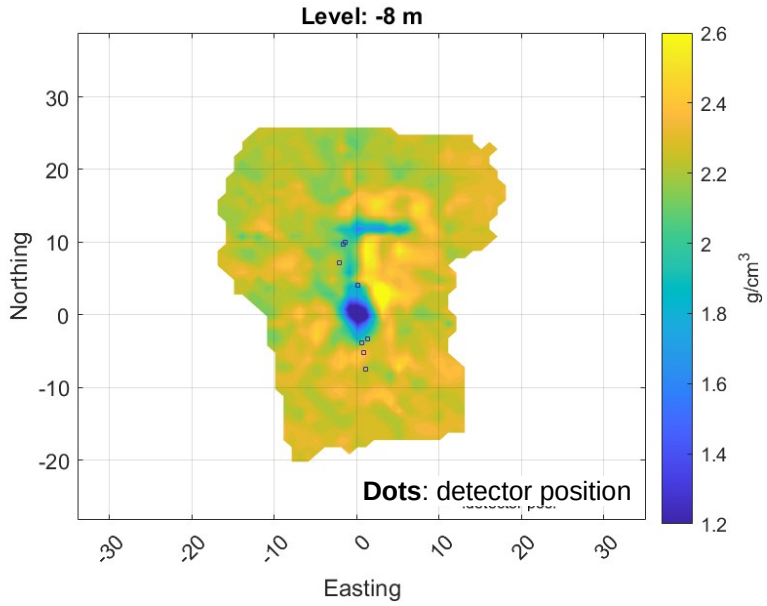


- **Second inversion case:**
- a) Mtm40 and Mts54 combined measurements on the -30m deep level
- b) 20 measurements
- c) aim: the -20m and -10m deep levels

What has changed compared to before?

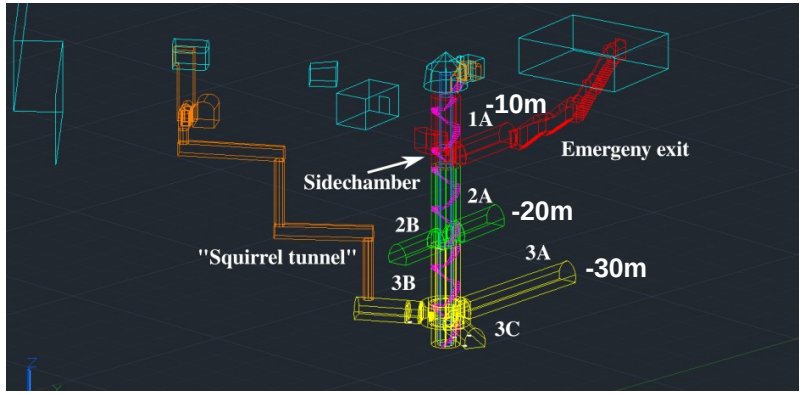
- **Third inversion case:**
- a) Mtm40 measurements on the -20m level
- b) 12 measurements
- c) aim: the -10m deep level





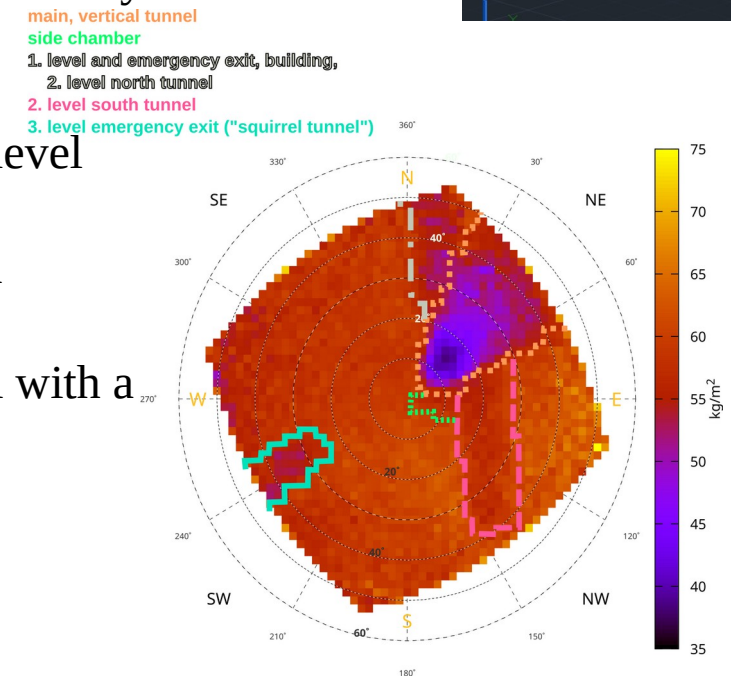
Precision parameter scan

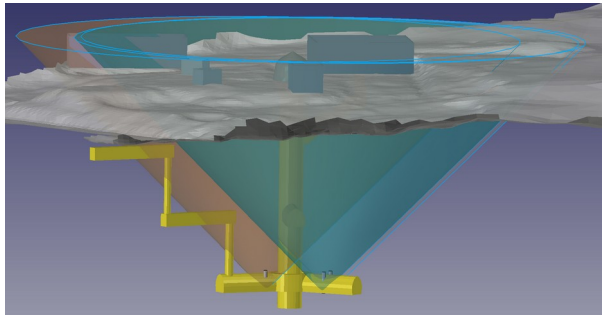
- The tomography results provide a 3D density distribution of the area, but this introduces various distortions due to the nature of the tomography
- Therefore, it is quite difficult to determine the parameters regarding the extent and position of the assumed objects
- Using the direct problem model, these parameters can be easily examined by modifying the input geological model



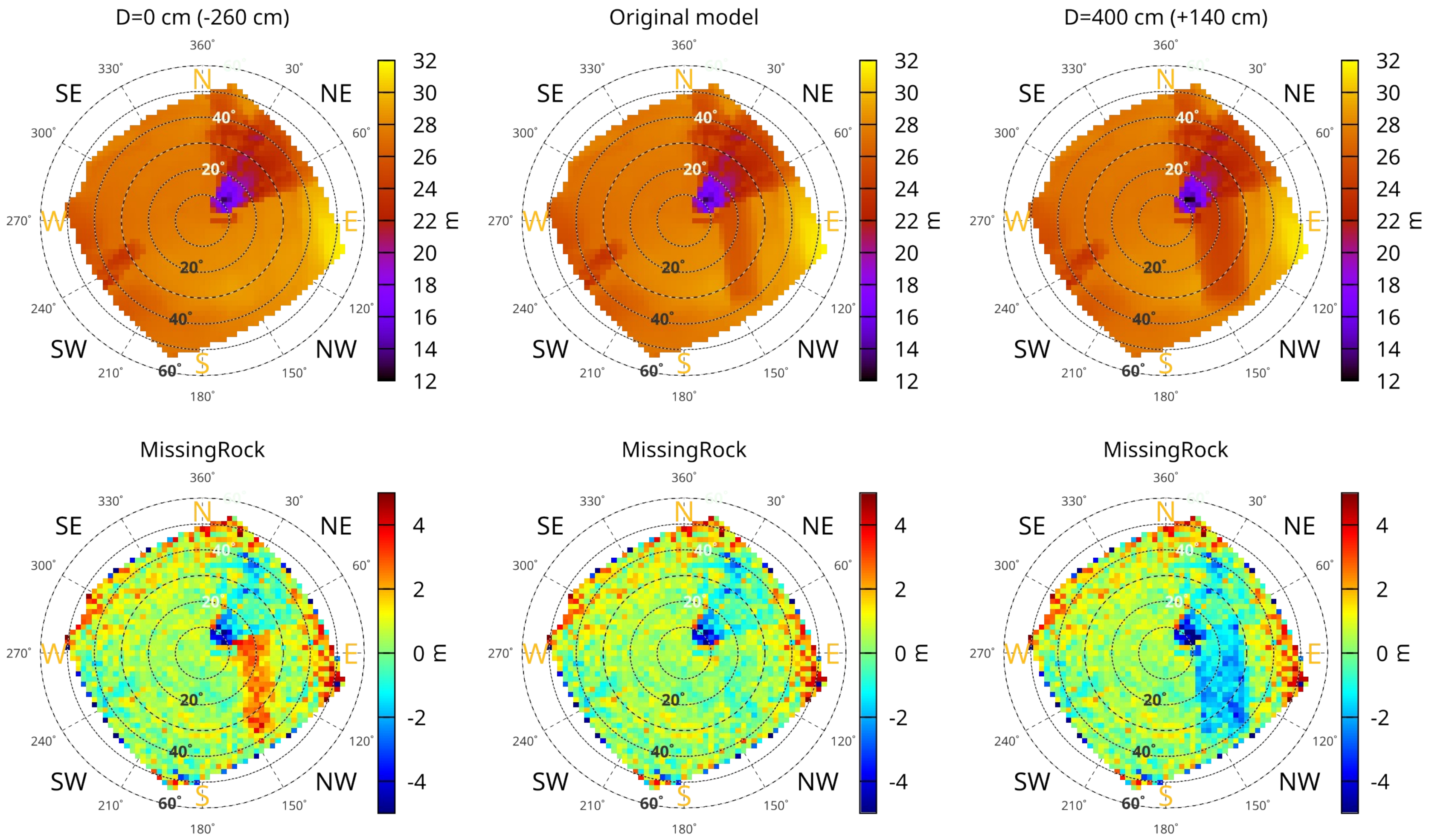
In the case of JURLab:

- Target object: south tunnel (2B) on the -20m deep level
- Parameter to be determined: tunnel diameter
- Fixed parameters: tunnel direction, position, length
- Measurement used: Run42, 44, 48
- Input geological models: I approximated the tunnel with a cylinder whose diameter is [0:400:50] cm





Precision parameter scan



First column is the case of the model without 2B tunnel

- In this case we can see more rock on the 2B tunnel's place on the MR figure

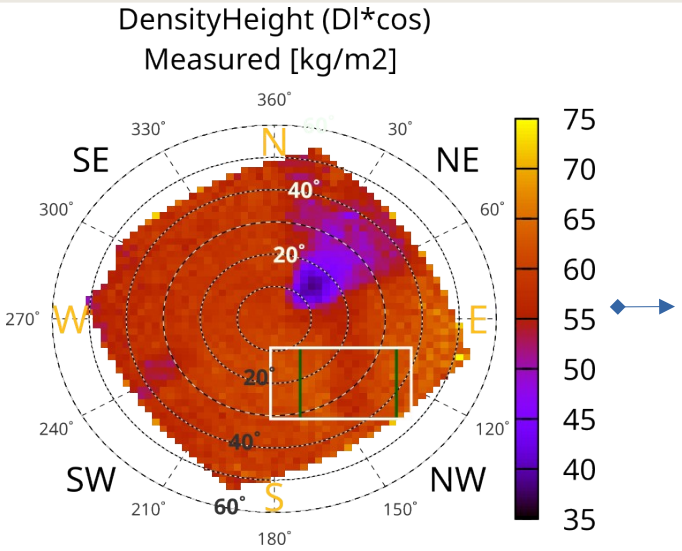
Second column is the original simple model

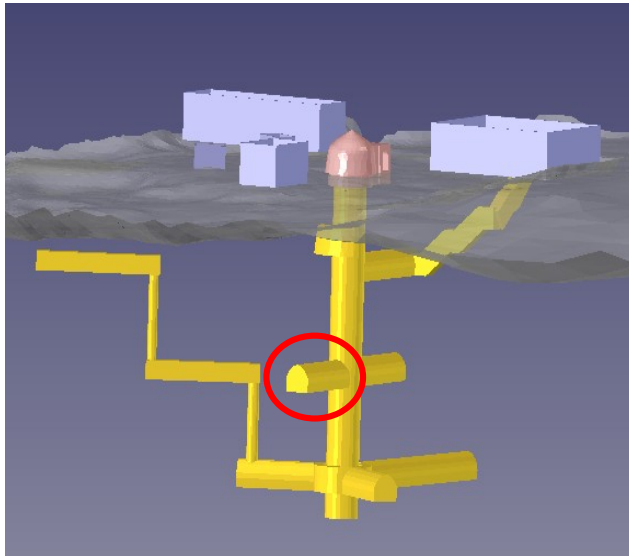
- the difference is around 0

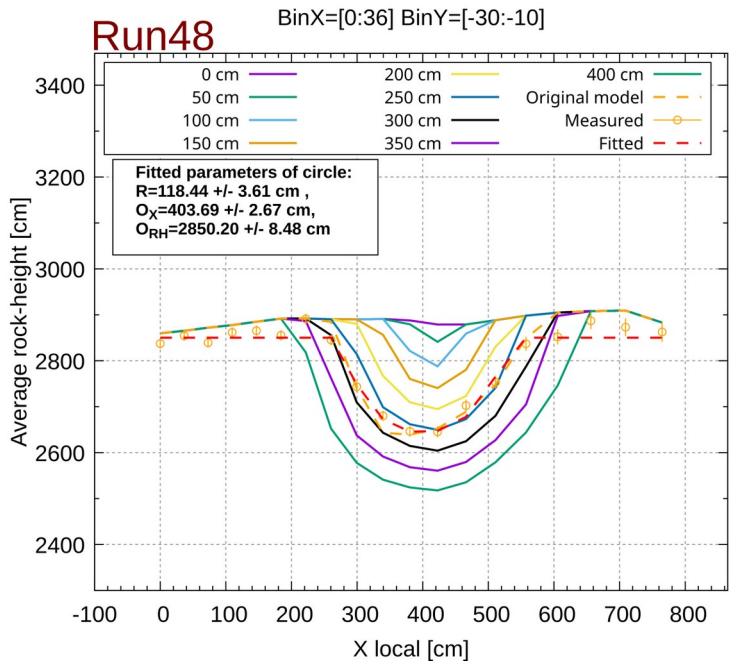
Third column is the case of the model with cylinder of 400 cm

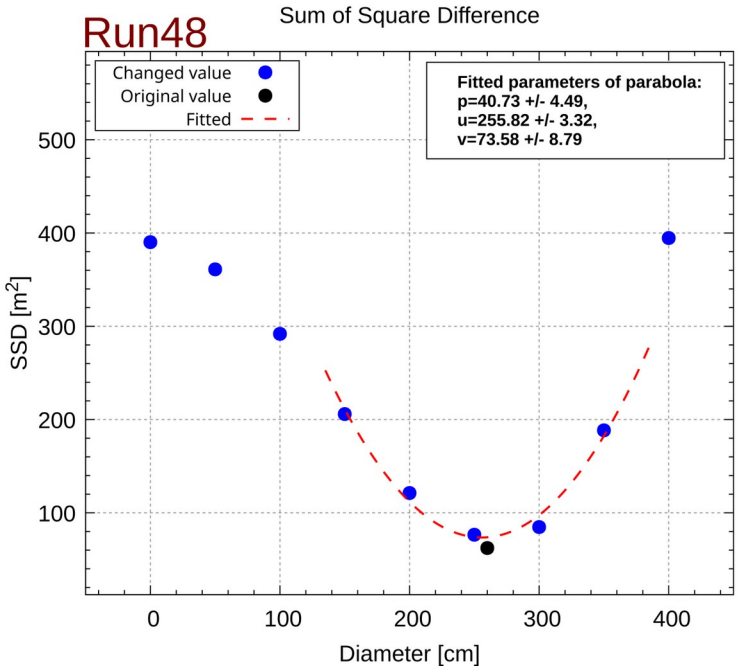
- In this case the cylinder cut more rock so there will be a shortage of rock

Precision parameter scan









- Test area: white rectangle
- Thick slice perpendicular to the tunnel for the different models

RH: Rock-height
O_x,O_{RH}: position of cylinder/tunnel
R: radius of cylinder/tunnel
Z: zenith
x: local x coordinates in a reference height

$$RH_{mean}(x,Z) = \begin{cases} O_{RH} - 2\cdot\cos(Z)\cdot\sqrt{(R^2-(x-O_x)^2)}, & x > O_x - R \quad and \quad x < O_x + R \\ O_{RH} \end{cases}$$

- Test area: green rectangle
- The diameter of the southern tunnel on the -20m depth was successfully determined based on measurements taken in several tunnels on the -30m deepth

$$SSD(RL_{meas}, RL_{calc}) = \sum (RL_{meas} - RL_{calc})^2$$

RL: Rock length

unprecedented precision

Acknowledgments

I would like to thank all my colleagues in the High Energy Experimental Particle and Heavy Ion Physics, and the High-Energy Geophysics Research Group, Innovative Gaseous Detector Development Research Group.

Supported by the EKÖP-25 University Research Scholarship Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund.

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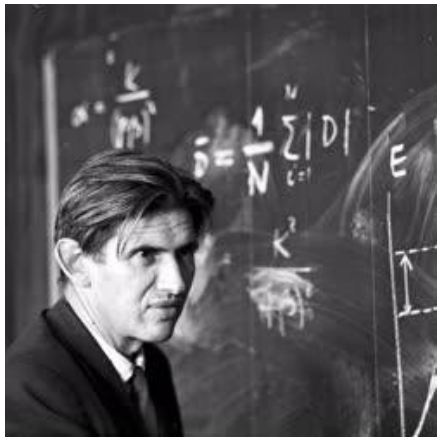
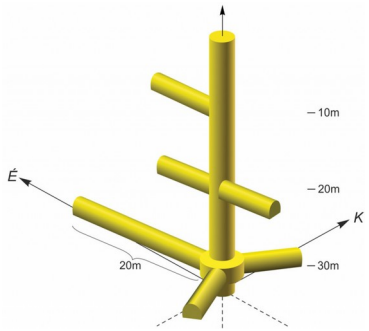
Thank you for your attention!

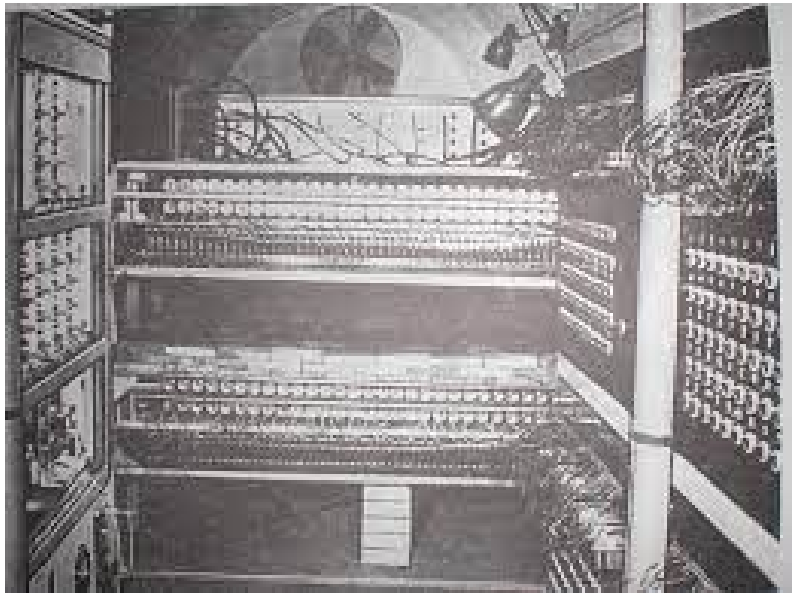
JURLab short story and records management



Lajos Jánossy[2]

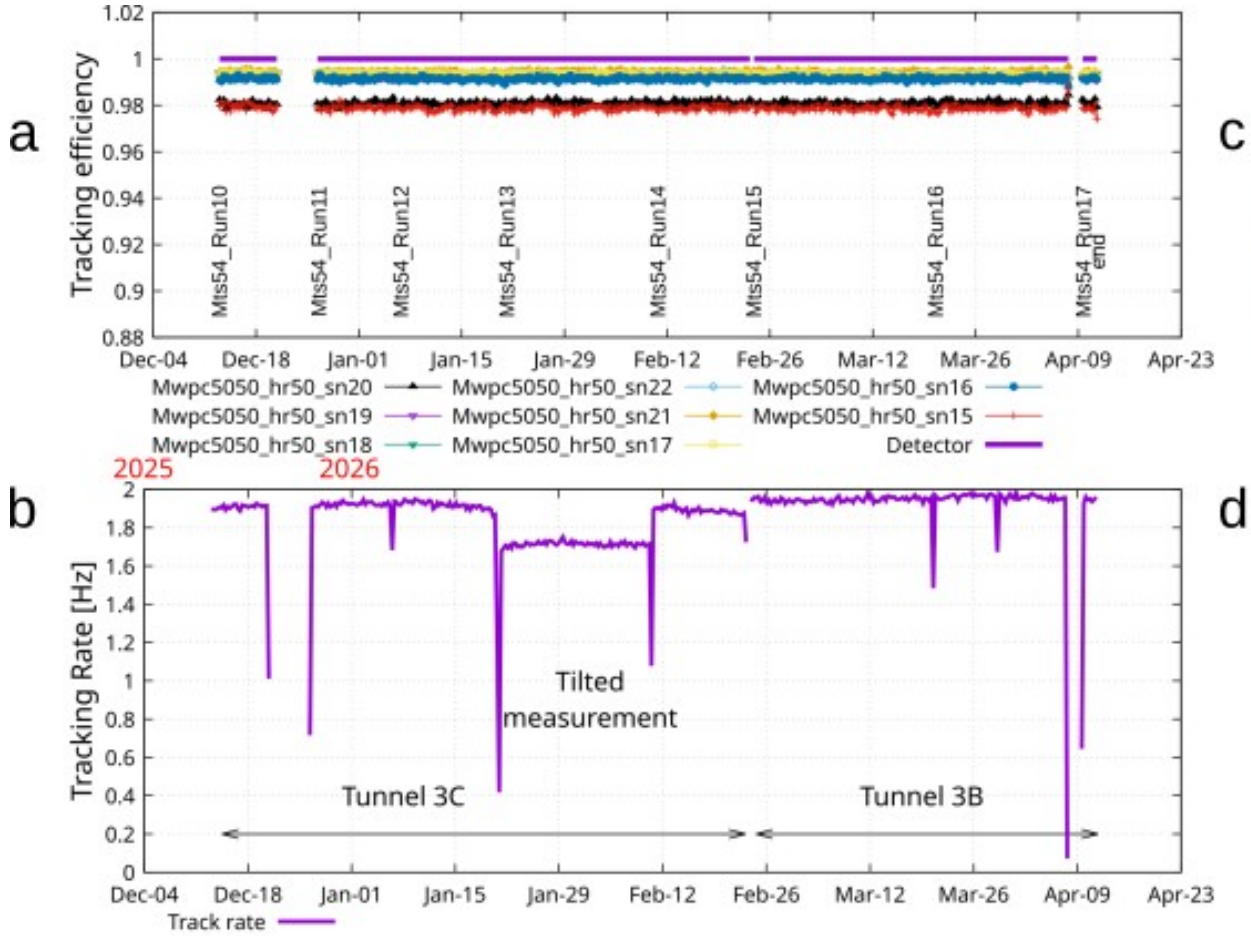


JURLab geometry[4]



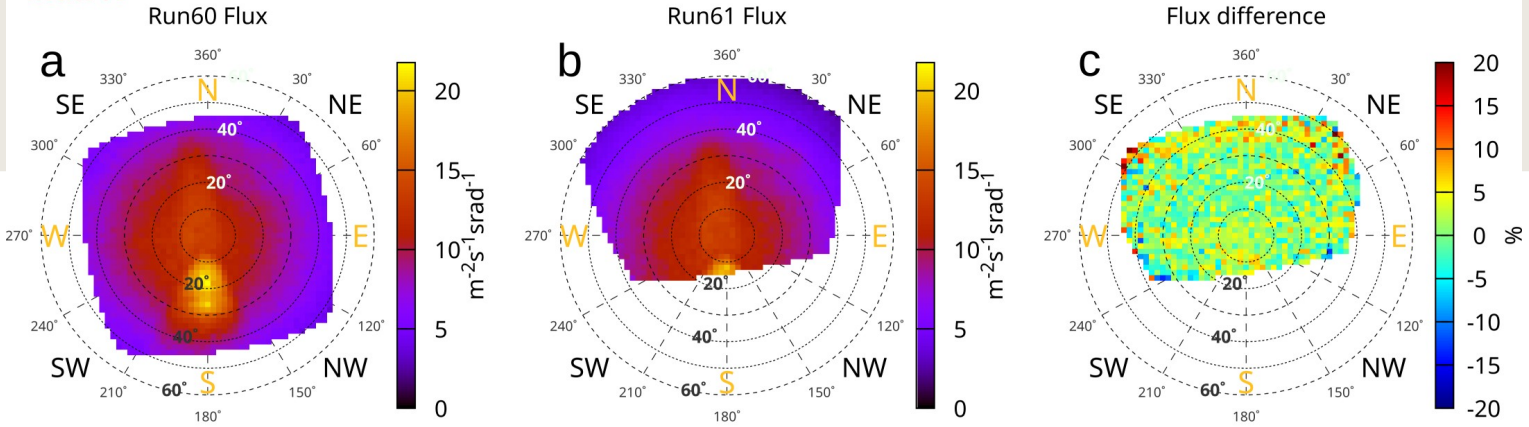
Cosmic ray measurements[3]

- Lajos Jánossy, who was living abroad, had become a leading authority in the field of cosmic radiation by the 1940s
- In the 1950s, the István Dobi government made significant efforts to entice Jánossy to return home:
  - **Full membership in the Hungarian Academy of Sciences (MTA)**
  - **A faculty position at ELTE**
  - **The position of department head at the soon-to-be-established KFKI, and the position of director of the Cosmic Radiation Laboratory**
- As a result, one of the first buildings constructed was an underground laboratory with limited facilities
- Measurements were conducted here using GM tubes
- After the political transition, the lab fell into disuse, then was revived in the 2000s
- Current experiments: muography test measurements, Eötvös pendulum, 137Cs
- The goal of my project is to examine data processing, validate the direct problem model, and verify the accuracy of the inversion using known passages, based on the series of measurements I have conducted.

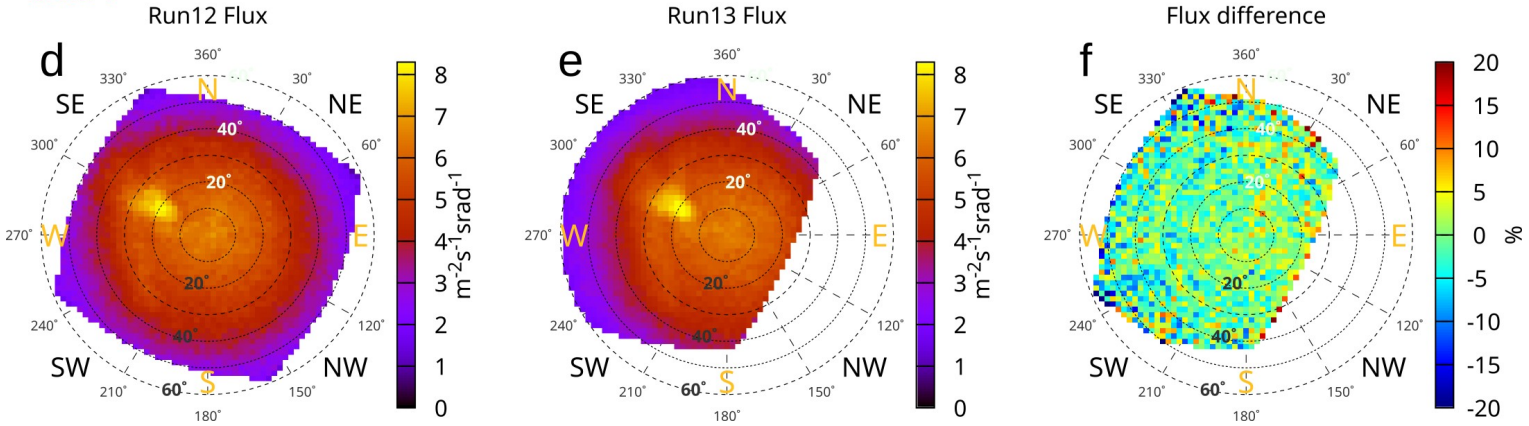


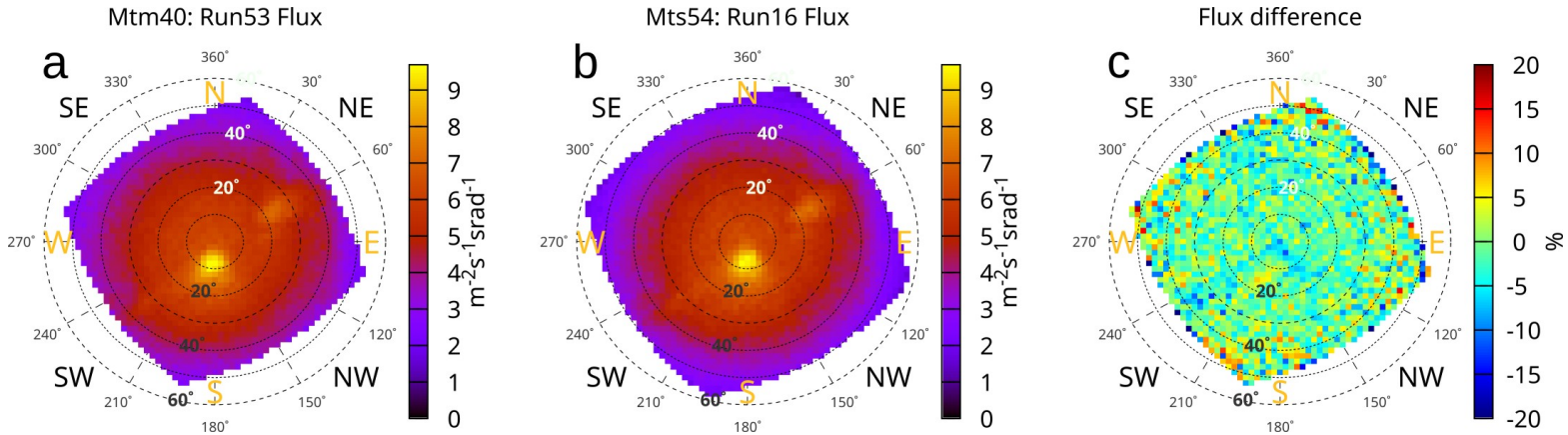
The tracking efficiency and rate of the Mts54 detector during the measurement period

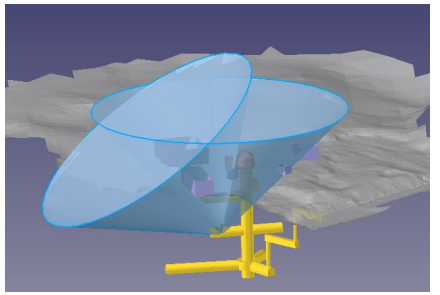
Mtm40



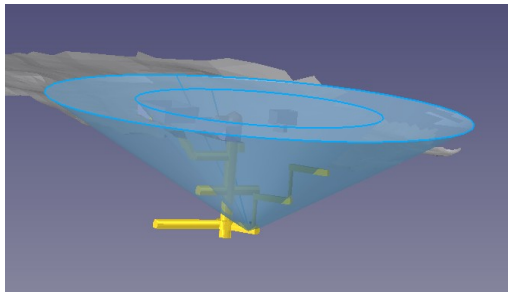
Mts54



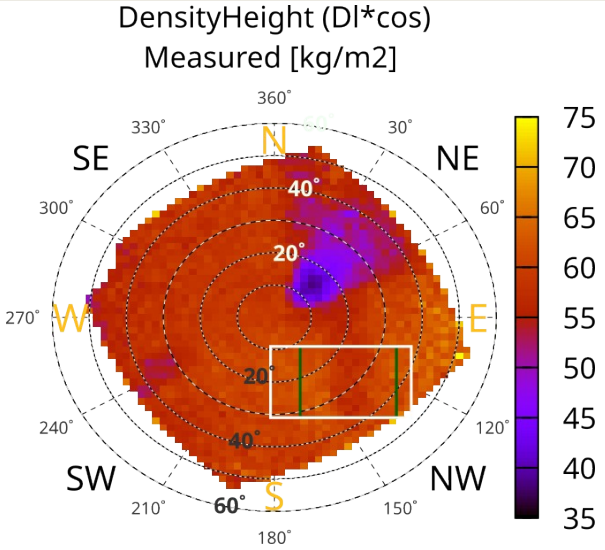


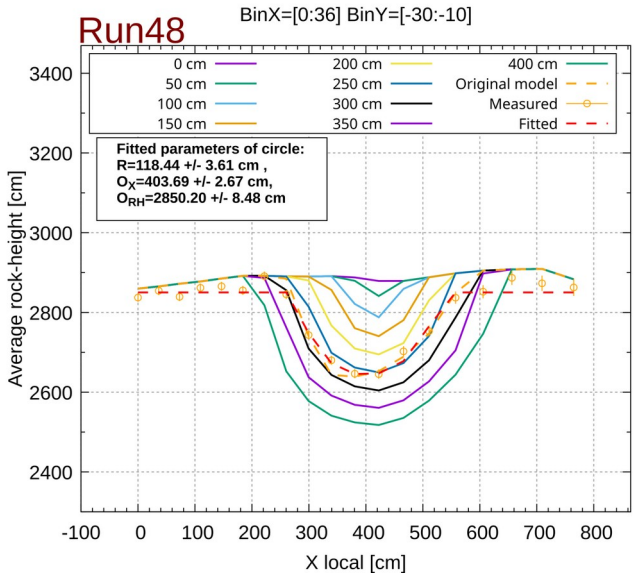


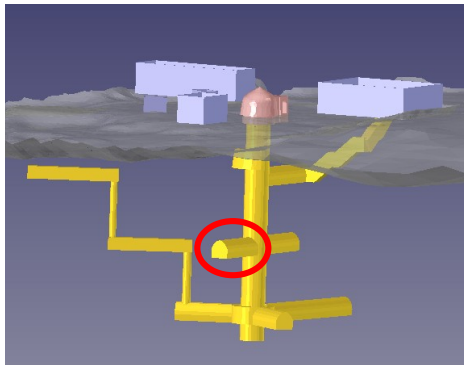
Accuracy of muography detectors

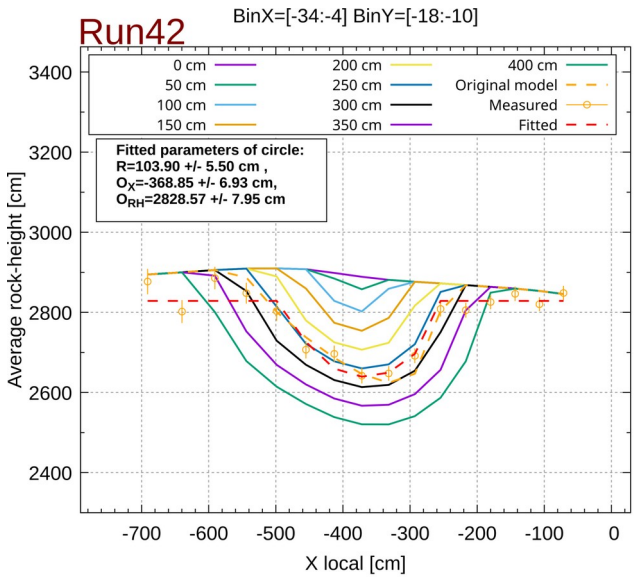


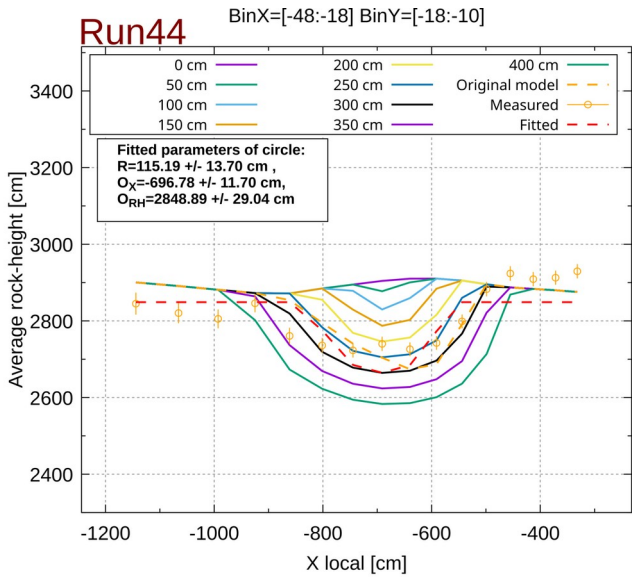
Precision parameter scan











- Test area: white rectangle
- Thick slice perpendicular to the tunnel for the different models

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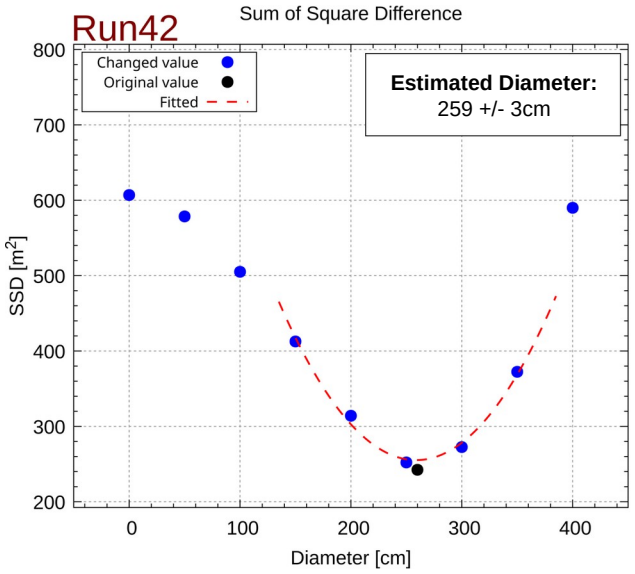
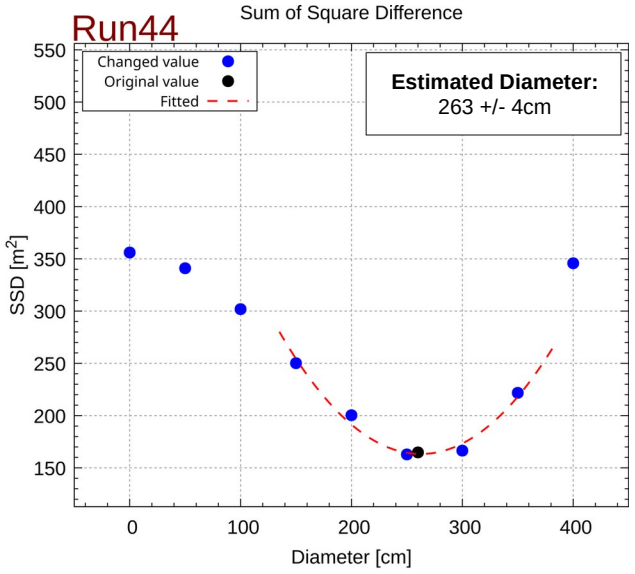
Precision parameter scan

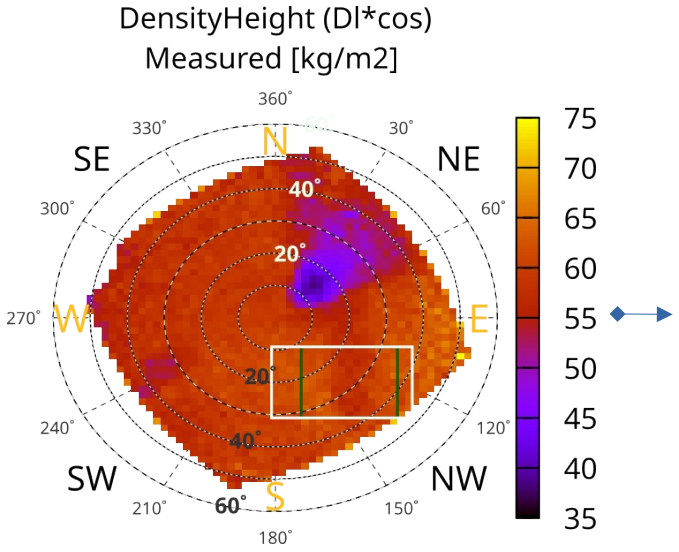


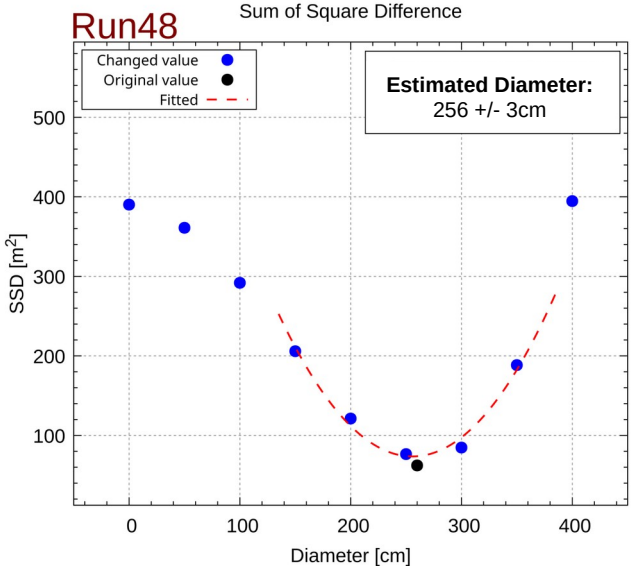


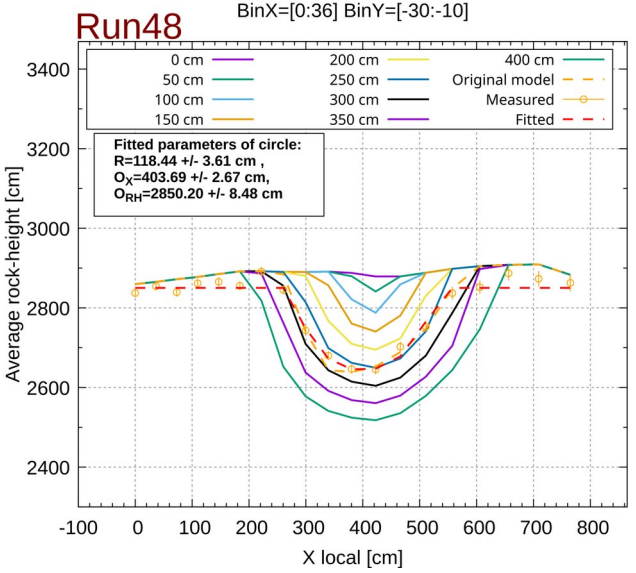
- Test area: green rectangle
- The diameter of the southern tunnel on the -20m depth was successfully determined based on measurements taken in several tunnels on the -30m deepth

$$SSD(RL_{meas}, RL_{calc}) = \sum (RL_{meas} - RL_{calc})^2$$

RL: Rock length







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