

# **Muography for Structural Health Monitoring of Hydraulic Dams: A Field Experiment on a Reservoir Auxiliary Dam**

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# Outline

**01 / Motivation**

**02 / Field Experiment**

**03 / Inversion Results**

**04 / Conclusion**

# Motivation : Hydraulic dam safety

## ➤ Detection Requirements for Dam

Potential Hazards

- Seepage, Internal Erosion, Slope Instability

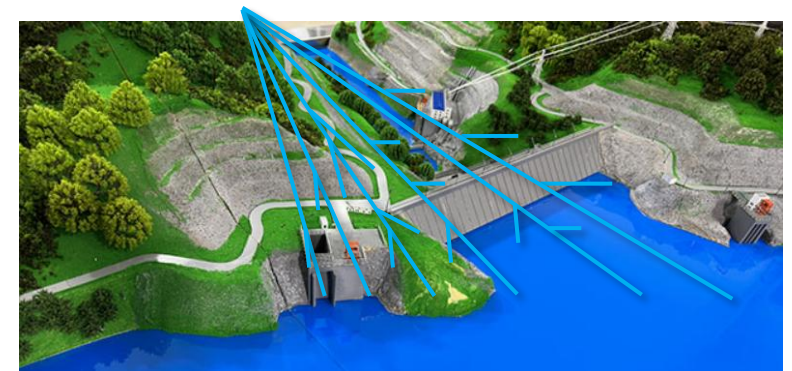
Detection Challenges

- Concealed, Deep-Seated



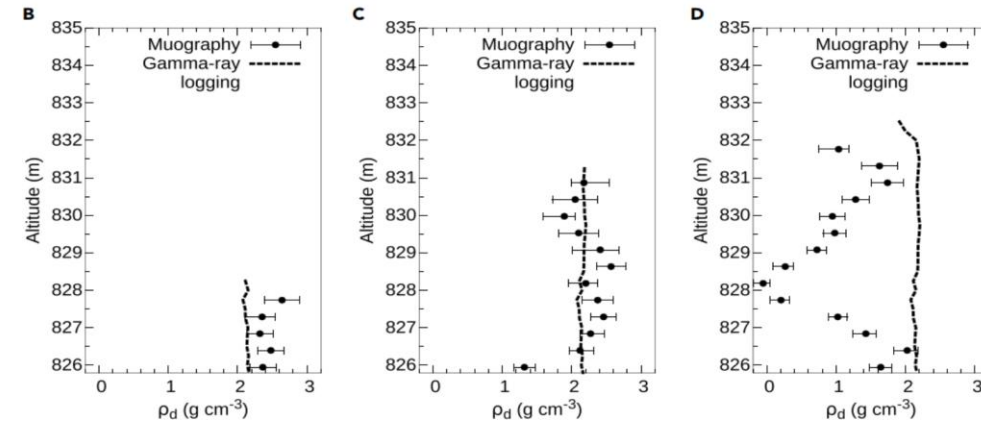
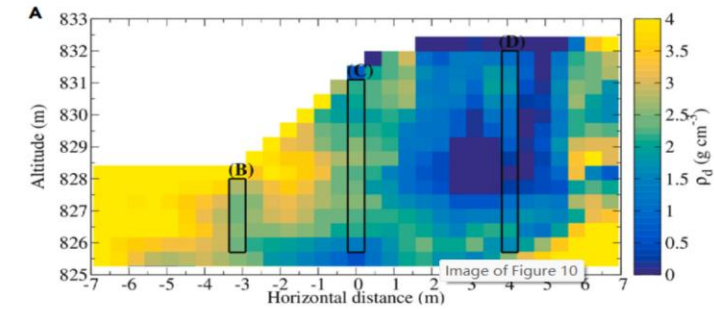
| Method             | Limitation  |
|--------------------|---|
| Drilling           | Destructive, Limited Inspection Efficiency  |
| Seismic Survey     | Complex Data Processing, Limited Resolution   |
| Electrical Methods | Limited Investigation Depth, Strongly Affected by Surface Conditions, Sensitive to Metallic and Magnetic Interference |

Muography



Muon imaging utilizes natural cosmic-ray muons and offers non-invasive detection, deep penetration capability for large-scale structures, and strong immunity to environmental interference.

# Motivation : Demonstration Case



## ➤ Karasu River Sabo Dam, Gunma Prefecture, Japan

Cement loss was observed in the downstream section of the dam (highlighted by the white boxed area).

- Non-uniform density distribution detected within the dam
- High consistency with gamma-ray logging results

## Mangshan Reservoir Auxiliary Dam

### ➤ Basic Information

Dam type: Asphalt Concrete Core

Rockfill Dam

Crest elevation: 400.6 m

Maximum dam height: 41.1 m

Dam length: 124 m

Crest width: 8 m



Potential seepage hazards at the dam–hillside interface.



## Large-Area Flat-Panel Muon Detector

### Key Features:

4 Layers of **Plastic Scintillators**

Sensitive Area: **1 m × 1 m**

Spatial Resolution: **4.6 mm**



## Integrated Muon Detector

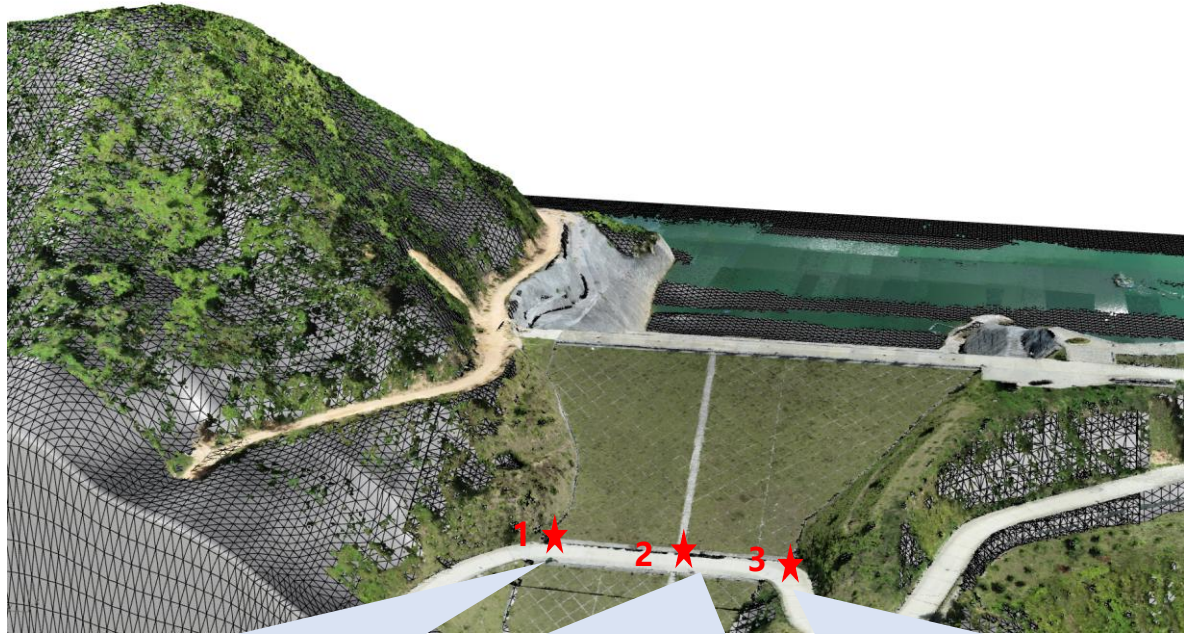
### Key Features:

4 Layers of **Plastic Scintillators**

Sensitive Area: **48 cm × 48 cm**

Spatial Resolution: **2.5 mm**

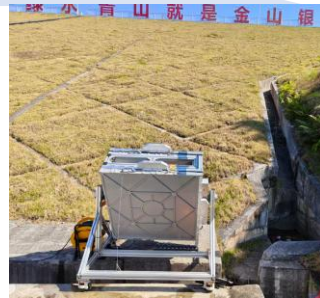
# Data Acquisition Overview



Location 1



Location 2



Location 3

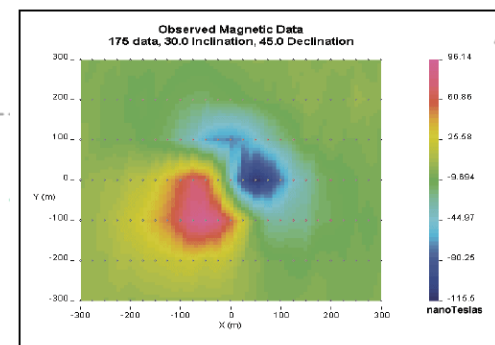
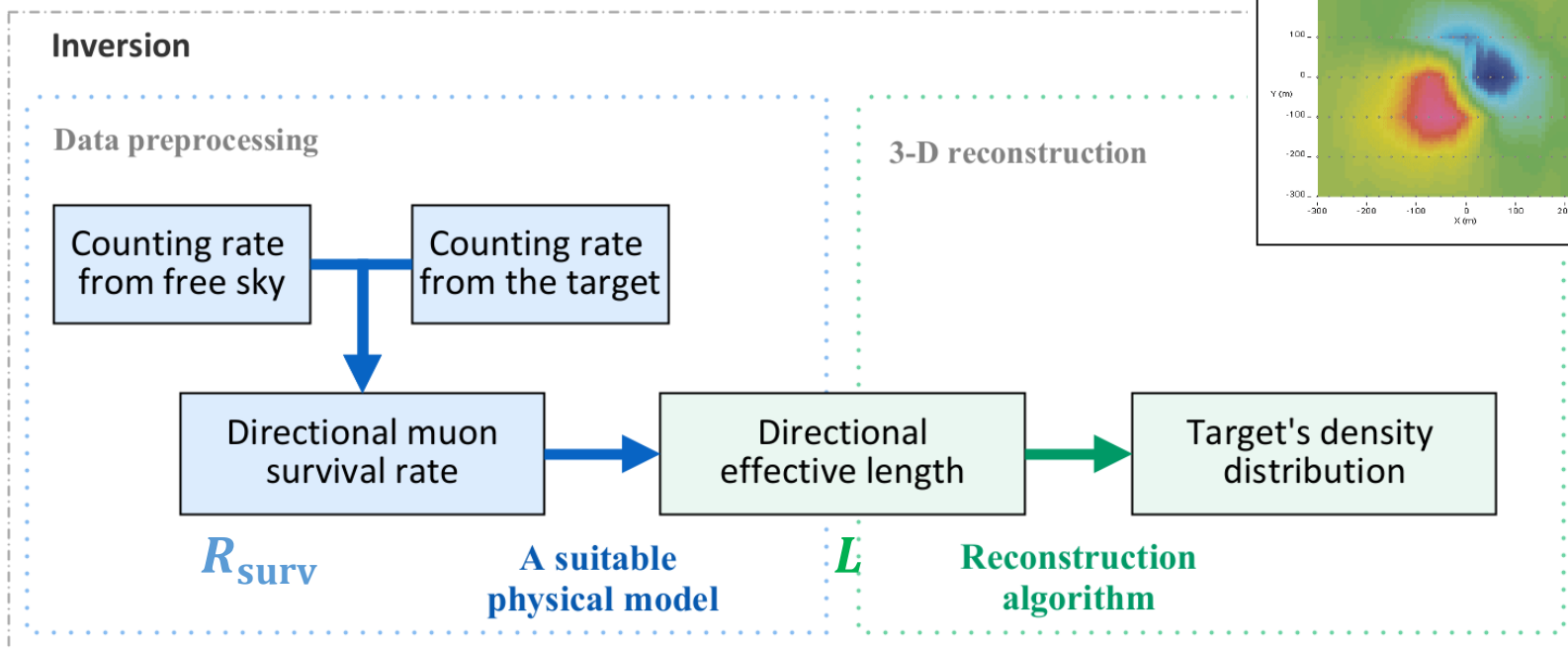
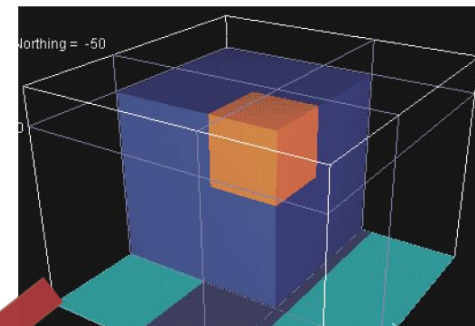
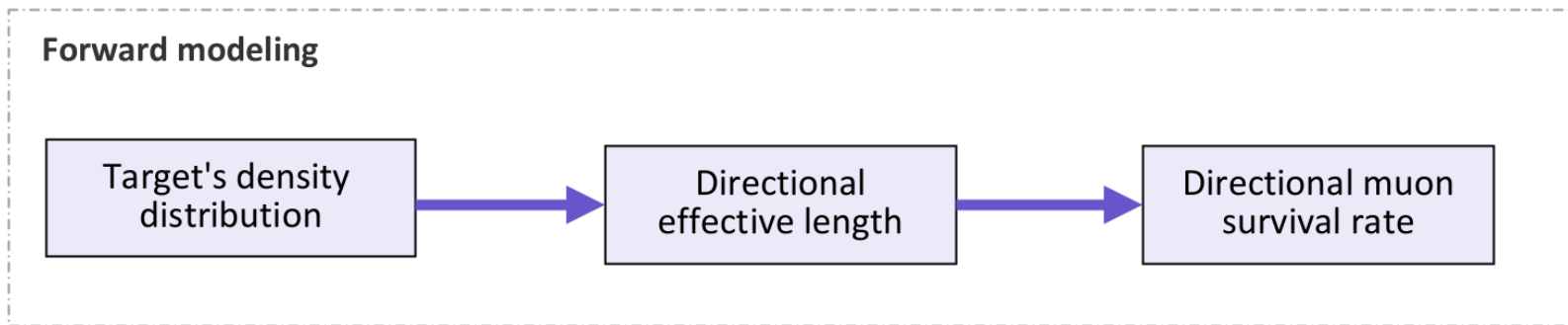
| Measurement Location | Measurement Duration (days) | Count Rate (counts/day) |
|----------------------|-----------------------------|-------------------------|
| 1                    | 11                          | 1834414                 |
| 2                    | 56                          | 379442                  |
| 3                    | 30                          | 2067482                 |

Measurement Period: **Sep–Nov 2025**

Number of Measurement Locations: **3**

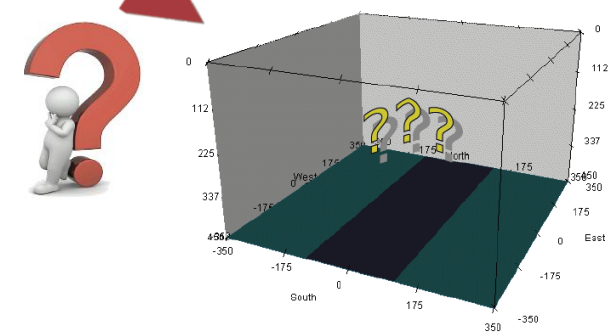
Coverage: Entire auxiliary dam and portions of the surrounding mountain slopes

# Method



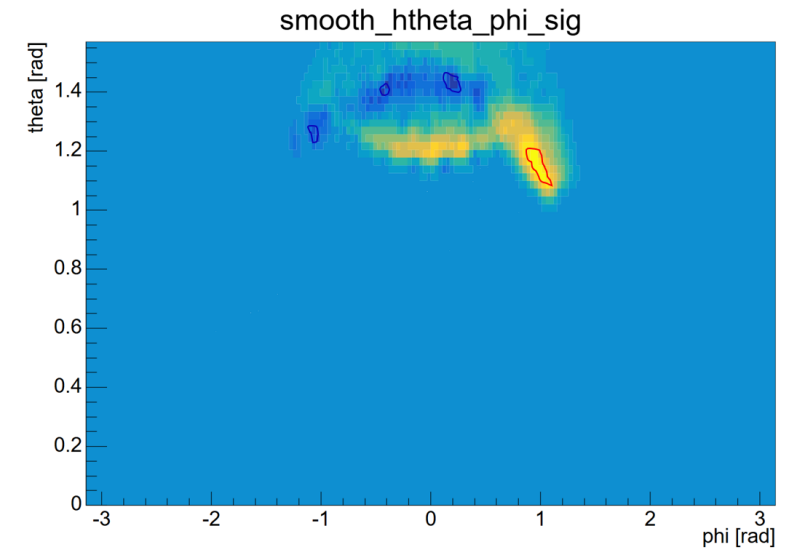
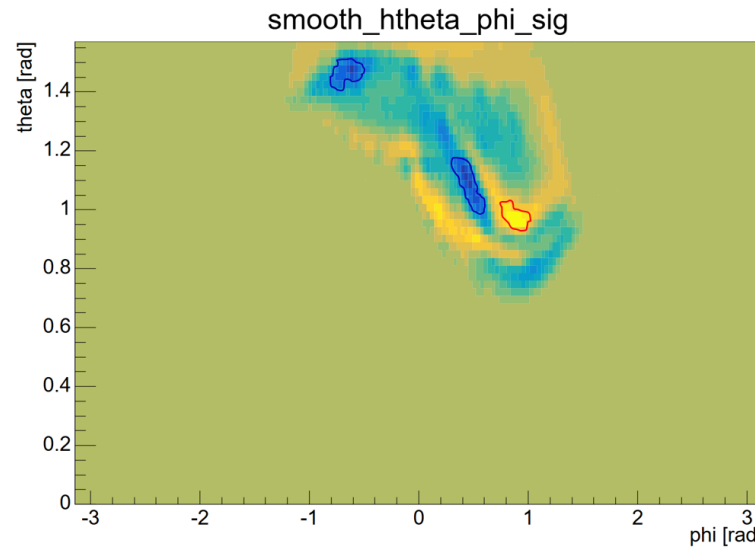
**Forward modeling**

**Inversion**

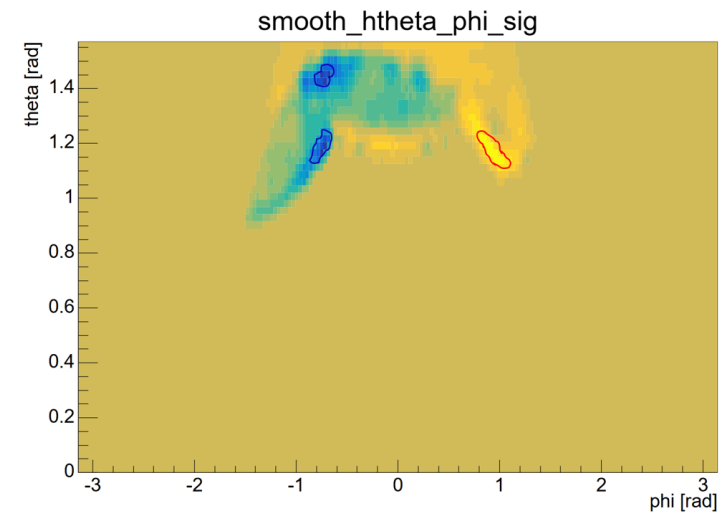


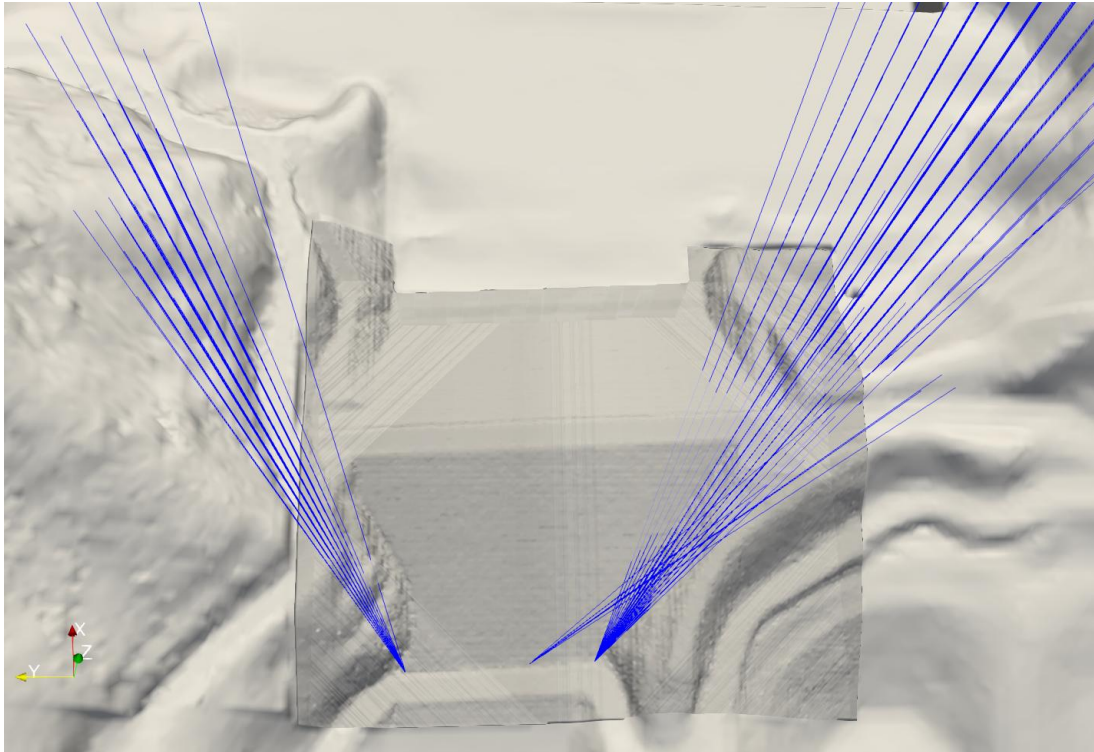
Significance:

$$\text{Sig}(\theta_x, \theta_y) = \frac{R_{\text{meas}}(\theta_x, \theta_y) - R_{\text{pre}}(\theta_x, \theta_y)}{\sigma_{\text{meas}}(\theta_x, \theta_y)}$$

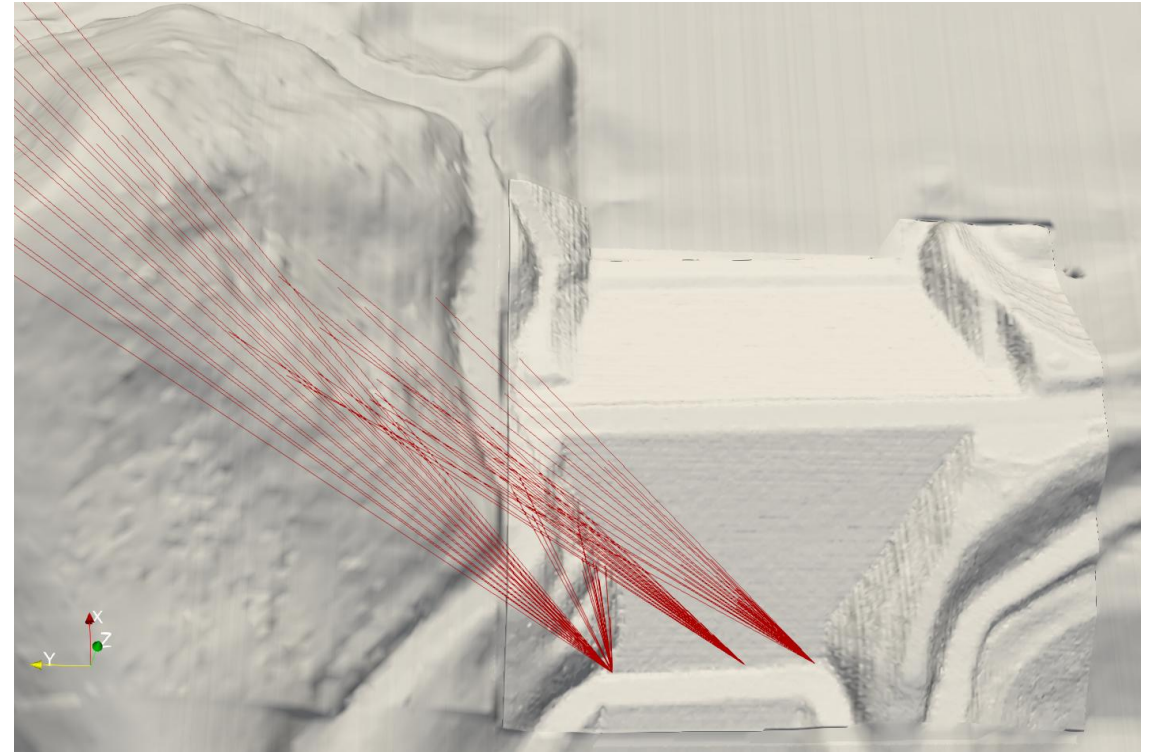


- **Sig:** Characterizing the degree of significance of the difference between the measured and predicted values, the larger the absolute value of Sig indicates that the more significant the difference between the measured and forward predicted results in this direction, the higher the confidence level of the existence of density anomalies.



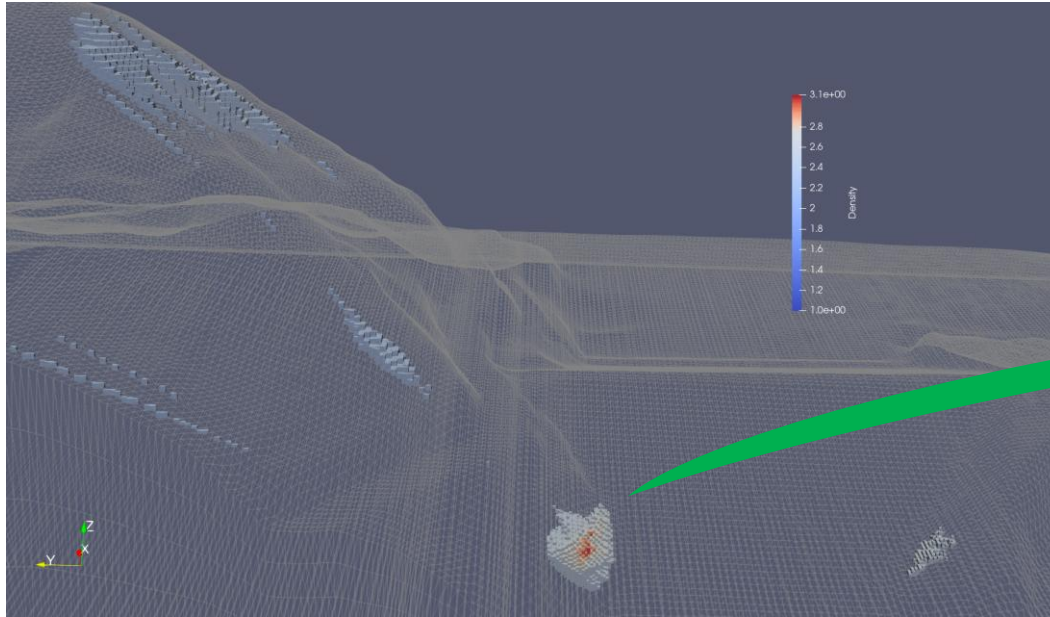


Rays Passing Through High-Density Anomalies



Rays Passing Through Low-Density Anomalies

# Inversion Results (Preliminary)



High-Density Regions in the Inversion Results

## Inversion Results

- A high-density anomaly was detected. The anomalous region appears to be associated with an artificial structure. Further review of construction records may help determine whether additional reinforcement was applied during dam construction.

# Inversion Results (Preliminary)



## Inversion Results

Low-density anomaly detected at the top of the northern hillside

Density contrast:  $> 0.25 \text{ g/cm}^3$

## Spatial Characteristics

Depth: 5–10 m

N–S extent:  $\sim 40 \text{ m}$

E–W extent:  $\sim 20 \text{ m}$

- Successfully achieved density imaging of critical dam structures.
- Demonstrated the applicability of muon imaging for long-term monitoring, hazard detection, and structural integrity assessment.
- Provided valuable guidance for future technology development and large-scale deployment.
- Gained extensive experience in practical engineering applications.



- **Dynamic monitoring can be implemented during the rainy season if necessary**
- **To investigate seepage, crack propagation, and other common hazards**

**Thank You for Your Attention!**

