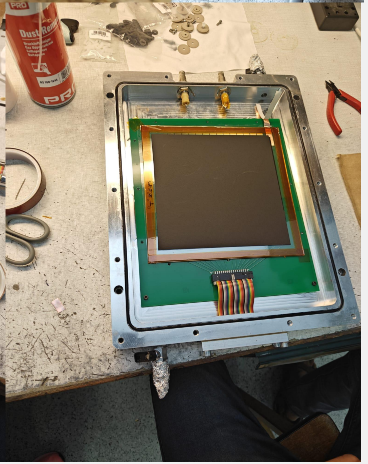
Development of a portable particle detector for muon imaging

Sumaira Ikram
Centre for Cosmology, Particle Physics and Phenomenology (CP3)

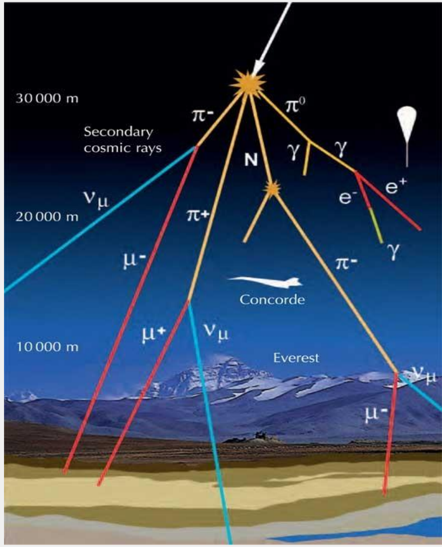


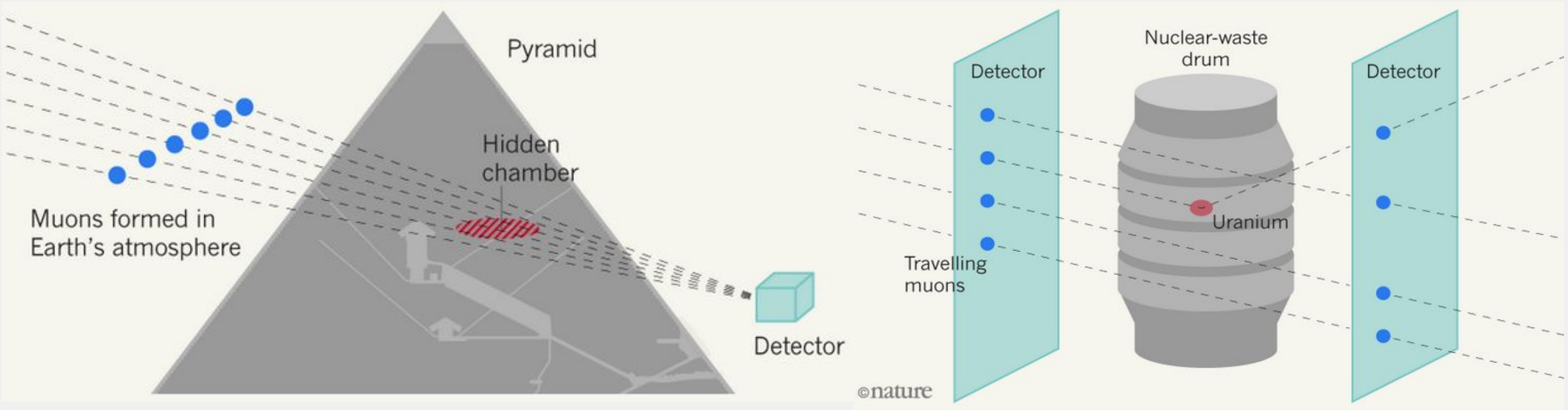
Contents

Muography

An imaging technique that utilizes naturally occurring cosmic-ray muons to probe the internal structure of large-scale objects.

- Cosmic ray Muons are produced freely and abundantly in the interaction of primary cosmic rays with the upper atmosphere
  - Most penetrating part of the cosmic shower
  - At sea-level, cosmic muons have an average energy of roughly 4 GeV and their flux is around 1 muon sr^{-1} cm^{-2} min^{-1}.



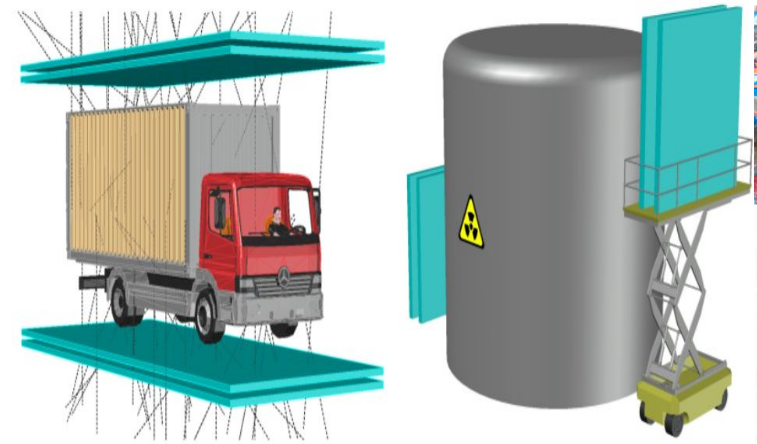


Motivation

Portable muon telescopes are mainly used for experiments conducted in confined or restricted environments

- Logistical challenges → power supply, cabling, gas cylinder, etc.
- Gas detectors → Poses hazard issues (anoxia, explosion, etc).
- Applications: Archeological and mining explorations, underground geophysical surveys, civil infrastructure integrity checks etc.

Silent Border Tomograph



Left: Cargo Inspection, right: Nuclear Storage inspection.

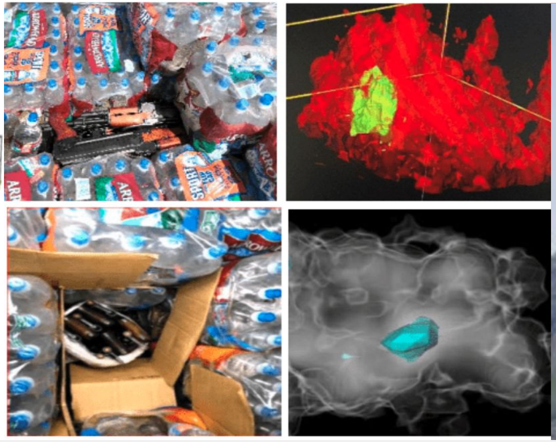
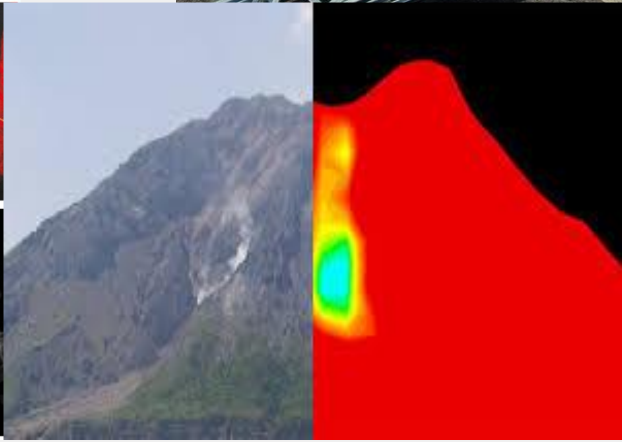
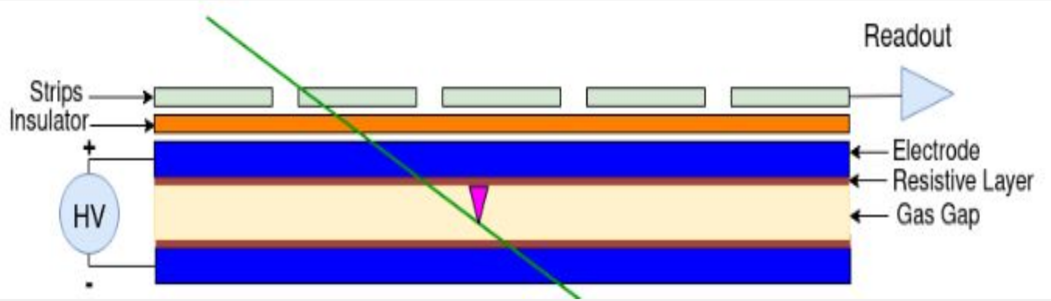


Image of weapons using Discovery Scanning system

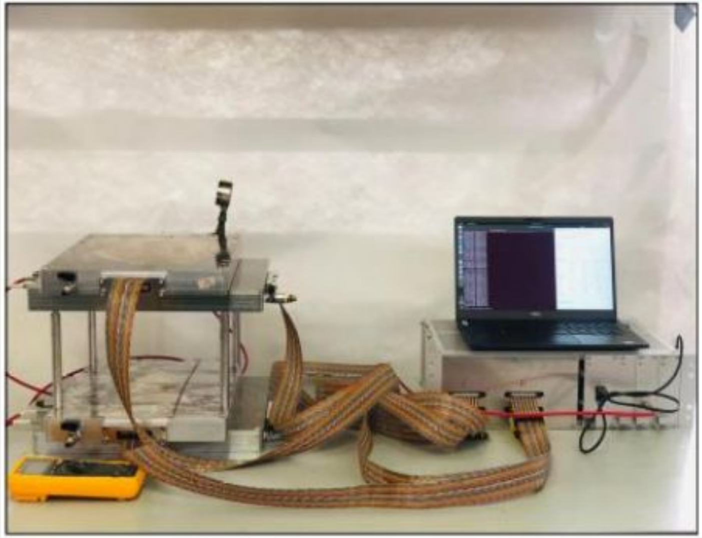


Muon Radiography of Mount Asama

Resistive Plate Chambers



An ionizing particle passing through the gas gap and creating an electron avalanche towards the anode in RPC



- **ADVANTAGES**
  - Easily fabricated and transported
  - Large chamber sizes: low price
  - Good intrinsic spatial resolution <100 µm.
  - Excellent timing resolution (<50 ps).
  - Large area usage popular in muography (volcanology)

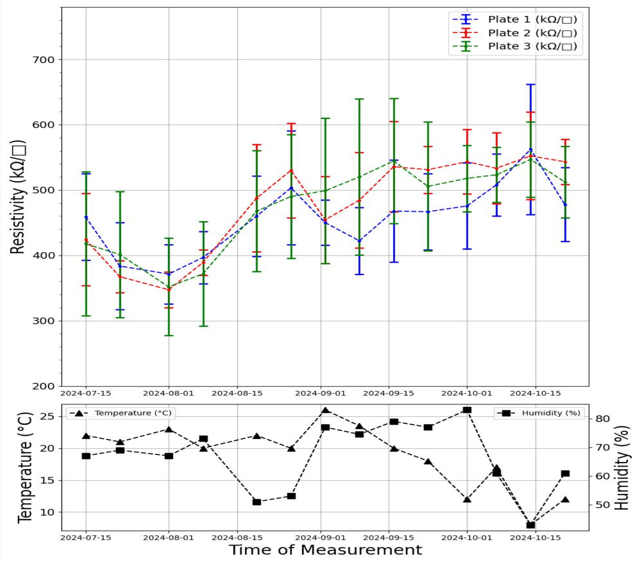
- **SOME CONSIDERATIONS**
  - Static state of gas mixture: contribute to acceleration in polymerization on the detector surface
  - Stability in various environmental parameters such as temperature, humidity, pressure variations etc.
  - Power consumption for readout channels

Glass Painting ,Chamber Assembly And Performance Analysis

Glass Painting

- The RPCs are constructed using glass plates of thickness 1.1 mm and an active area of 16 x 16 cm^2 coated with resistive paints with a surface resistivity ranging from 0.5 to 1.0 MΩ/□.

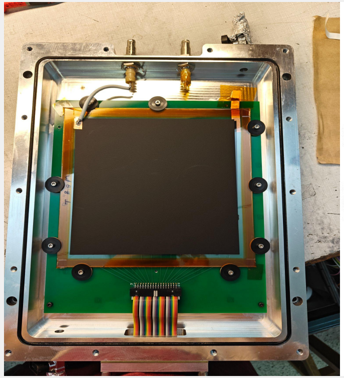
- To calculate Mass Ratio of paint , We use relation: $r_c = \frac{m_r}{m_c + m_r}$

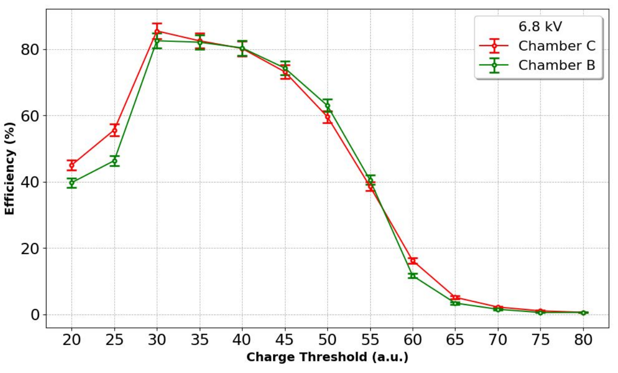


Temporal evolution : average surface resistivity and external measurements of temperature and humidity.

Assembling and Performance Testing

- In our lab, after detector assembly
  - filling with gas,
  - verify leak current and Optimizing High Voltage.





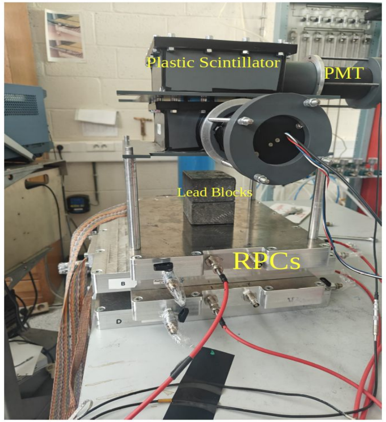
- Efficiency Scan shows: Developed detectors are operating with **>85% efficiency**

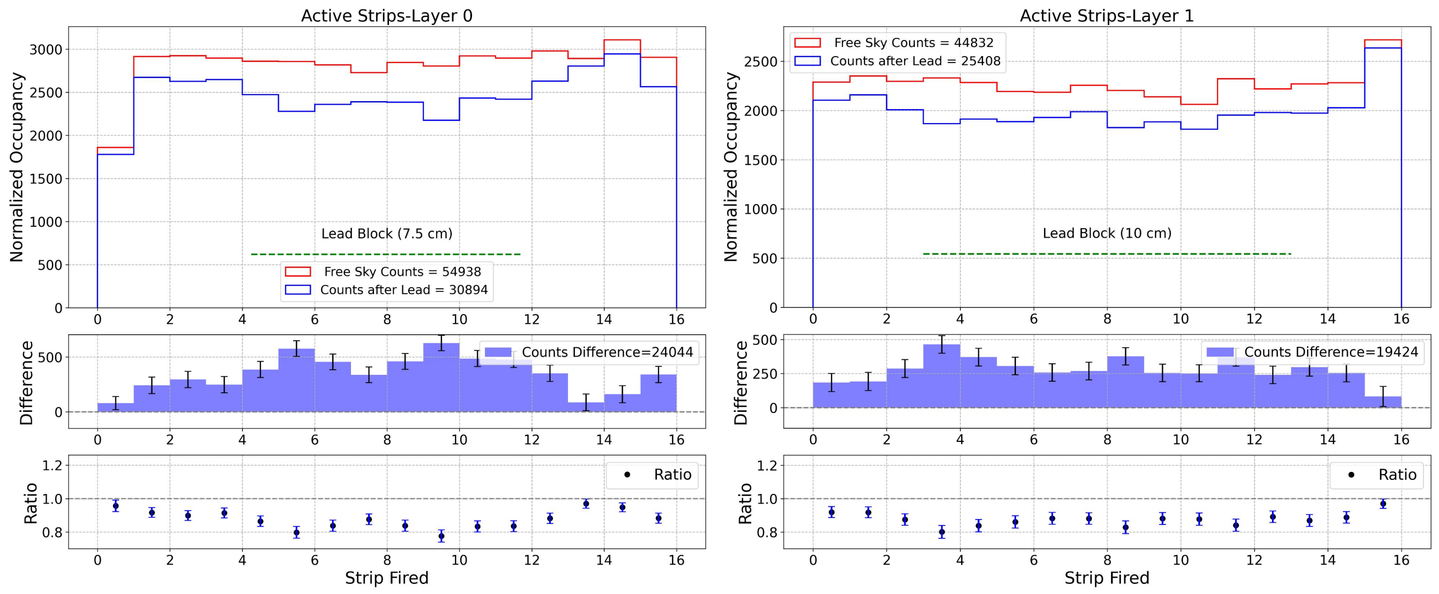
Absorption Muography

A small scale muon absorption feasibility study was carried in the lab:

- The experimental setup consists of two plastic scintillators on top and two orthogonally arranged RPCs (labeled "Layer 0" and "Layer 1") acquired data for bidimensional (XY) spatial information.

- Two Lead blocks (Length= 10cm, width = 7.5cm, height =4.5cm+4.5cm)in the region between the scintillators and RPCs

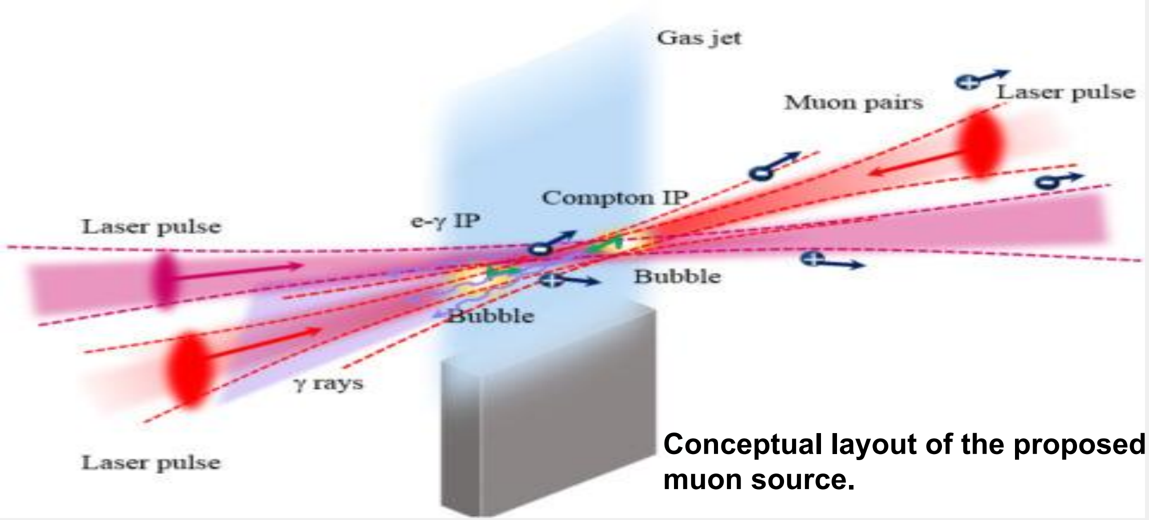




Beam Test at ELI (Prague) (April-May, 2025)

ELI (The Extreme Light Infrastructure)

The world's largest and most advanced high-power laser infrastructure and a global technology.



Conceptual layout of the proposed muon source.

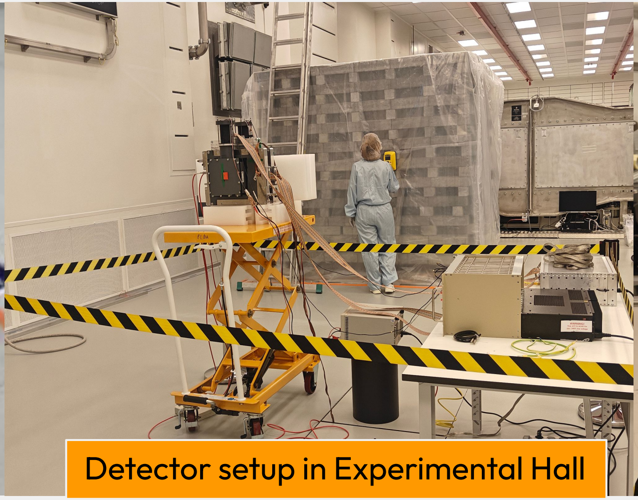
- **Higher Particle Flux**: The flux is significantly higher than that of cosmic muons.
- **Controllable Energy:** Unlike cosmic muons, whose energies vary unpredictably, beamline allows for control over the energy of the beam.
- **Known Directionality:**The beam direction is well defined, unlike cosmic muons which arrive from random directions.

★ Muons are **not hazardous** to life forms or the environment

Portable System Validated

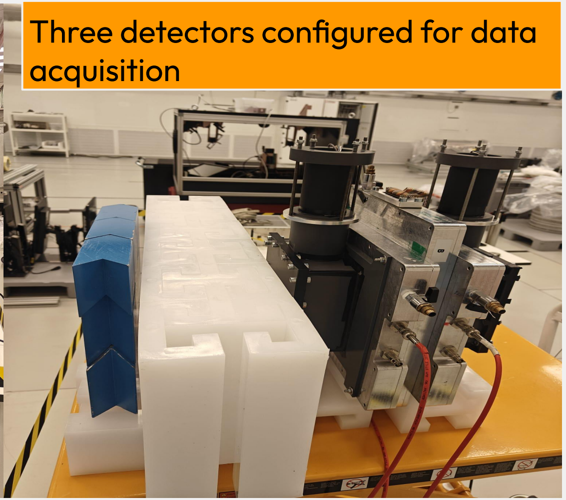
Muons could be a game changing technology if there were a compact active source of muons available.

Detector Shipment



Detector setup in Experimental Hall

Three detectors configured for data acquisition



- We successfully transported our detector to the test site (Prague).
- Over a two-week period, we collected data under stable operating conditions.
- The analysis of this dataset is currently underway.

Summary

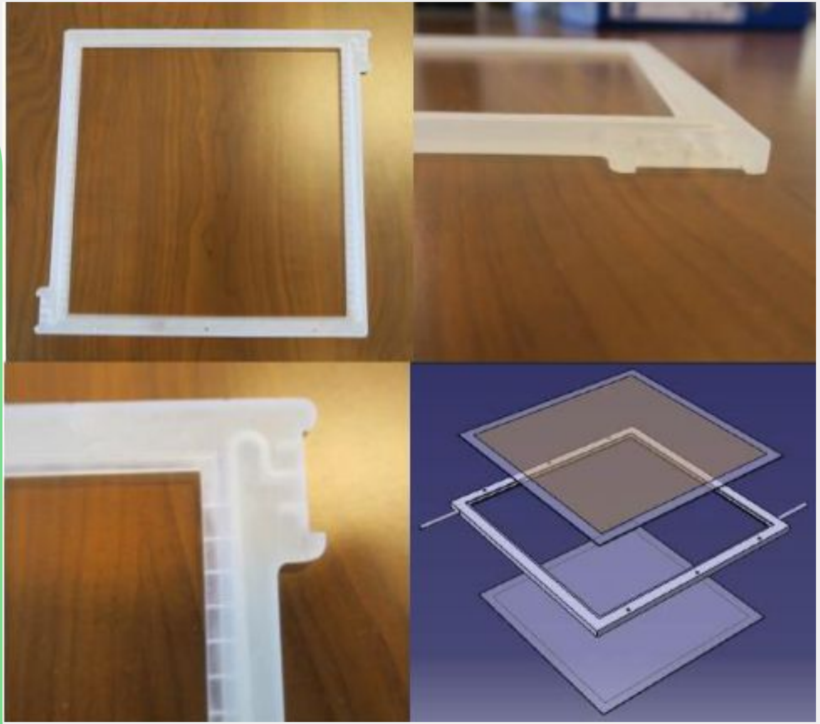
➔ **Stable and Uniform Glass Coatings Achieved**
Successfully coated glass plates with consistent surface resistivity and uniformity — a key step in detector reliability.

➔ **High Detector Efficiency**
Developed detectors are operating with **>85% efficiency**, confirming solid performance for muon detection.

➔ **Small scale Muon Absorption Test**
Muon absorption test was successfully conducted in the lab, demonstrating basic proof of concept.

➔ **Successful Beam Test at ELI**
BeamTest at ELI validated the **portability** and **robustness** of the prototype in real operational conditions

➔ **Detector Upgrade in Progress**
Current upgrades target **lower gas consumption**, **improved modularity**, and **reduced casket dimensions**.



3D printed frame that requires lower gas volume only in the gas gap instead of the entire outer casing in the current version

Meet the team






Active Members in RPC R&D

- S. Ikram
- E. Cortina Gil
- A. Giammanco
- P. Demin

Former Members

- S. Wuyckens
- R. M. I. D. Gamage
- M. Al-Moussawi
- S. Basnet
- R. Karman
- V. Kumar

Other Members of Muography Team

- M. Lagrange
- Z. Zaher

Collaborators

- M. Tytgat (VUB)
- D. Ahmadi (VUB)
- R. Karnam (NISER)
- V. K. S. Kashyap (NISER)
- B. Mohanty(NISER)

Thank you for your attention!