



Non-Destructive Evaluation of Static Objects Using Cosmic-Ray Muons

Nayana Majumdar¹, Subhendu Das¹, Promita Roy¹, Sridhar Tripathy², Jaydeep Datta³, Purba Bhattacharya⁴, Supratik Mukhopadhyay¹, Sandip Sarkar¹

¹Applied Nuclear Physics Division, Saha Institute of Nuclear Physics, A CI of Homi Bhabha National Institute, Bidhannagar, Kolkata 700064, India

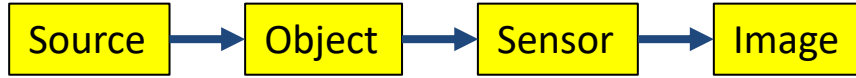
²Dept of Physics & Astronomy, University of California, Davis, California 95616, USA

³Dept of Physics & Astronomy, Stony Brook University, Stony Brook, New York 11794, USA

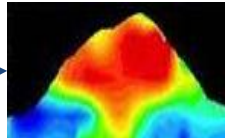
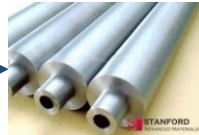
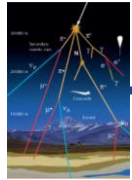
⁴Dept of Physics, Adamas University, Adamas Knowledge City, Kolkata 700126, India



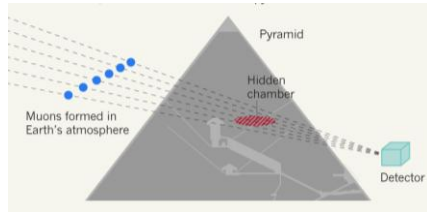
Muon Tomography / Muography



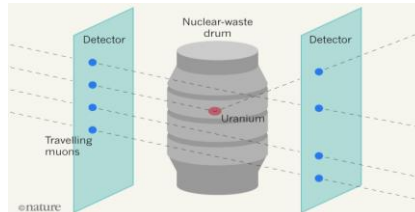
Photography



Muography



Transmission



Deflection

p = Momentum

$\beta = v/c$

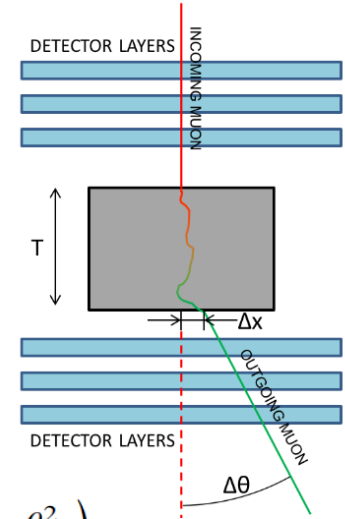
X_0 = Radiation Length

L = Thickness

A = Atomic Mass

Z = Atomic Number

ρ = Density



$$f_{\theta}(\theta) \approx \frac{1}{\sqrt{2\pi}\sigma_{\theta}} \exp\left(-\frac{\theta^2}{2\sigma_{\theta}^2}\right)$$

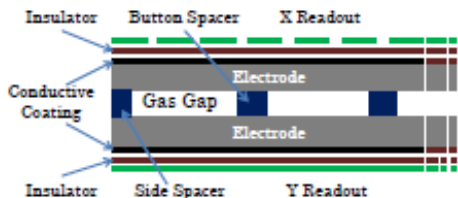
$$\sigma_{\theta} = \frac{13.6 \text{ MeV}}{\beta c p} \sqrt{\frac{L}{X_0}} \left(1 + 0.038 \ln \frac{L}{X_0}\right)$$

$$X_0 = \frac{716.4 \text{ (g/cm}^2\text{)}}{\rho} \frac{A}{Z(Z+1) \ln(287/\sqrt{Z})}$$

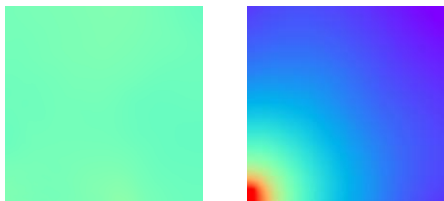


R&D on Muon Tracking Detectors

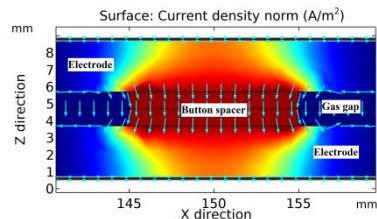
Journal of Instrumentation **17**, P09041 (2022)



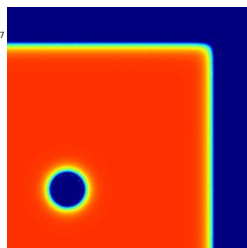
RPC Model



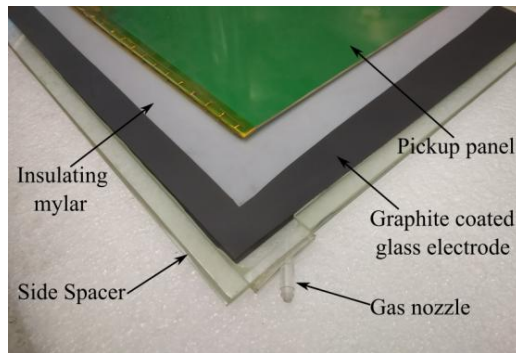
Potential Distribution



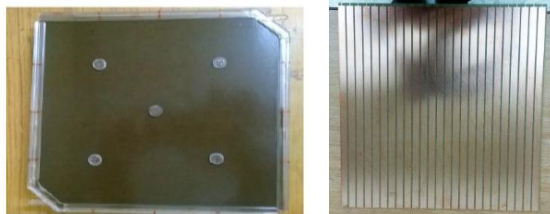
Dark Current



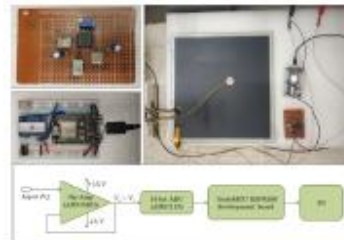
Field Configuration



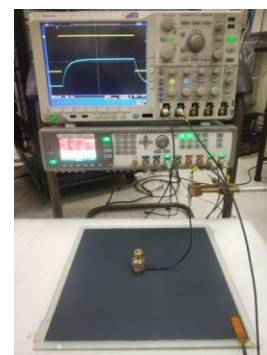
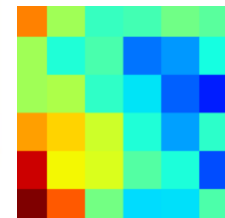
Resistive Plate Chamber (RPC)



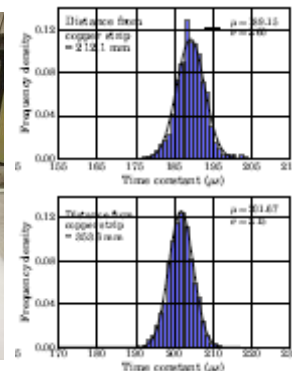
RPC Components



Potential Measurement



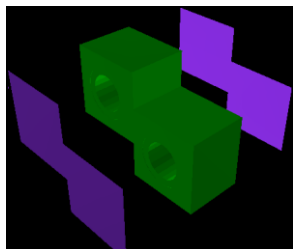
Time Constant Measurement



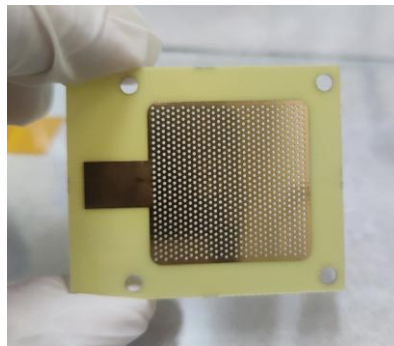


R&D on Muon Tracking Detectors

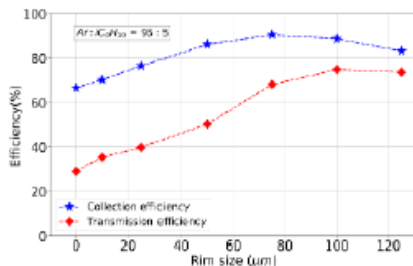
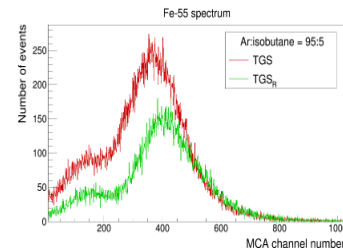
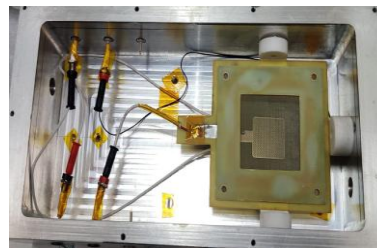
Journal of Instrumentation **16**, C05001 (2021)
Nuclear Instruments & Methods in Physics Research A (in press)



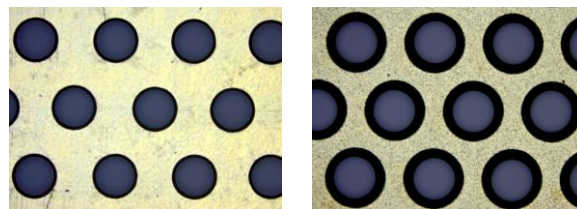
ThGEM Model



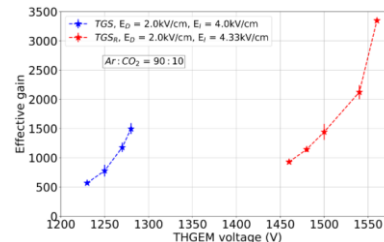
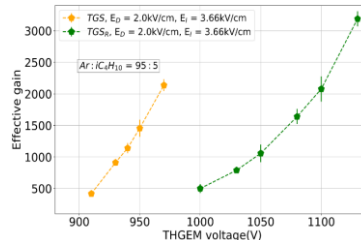
Thick Gaseous Electron Multiplier (ThGEM)



Collection & Transmission Efficiency



ThGEM Foils

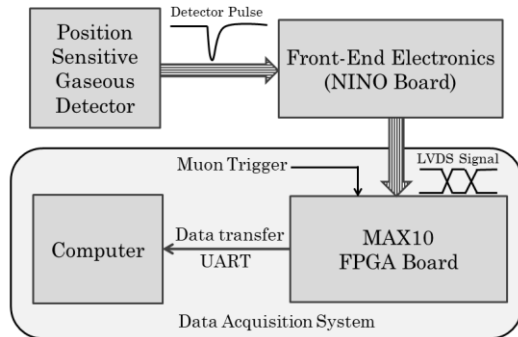


Characterization of ThGEM

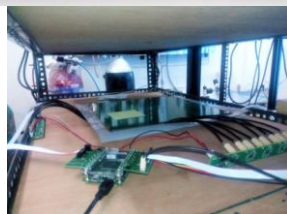
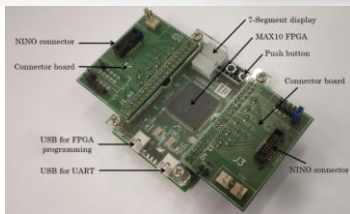
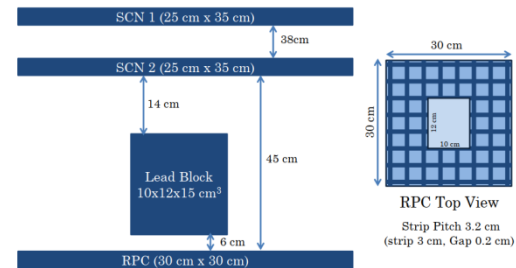
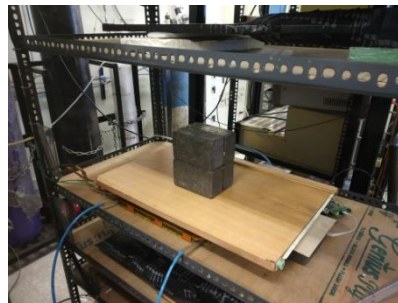


R&D on Data Acquisition (DAQ) System

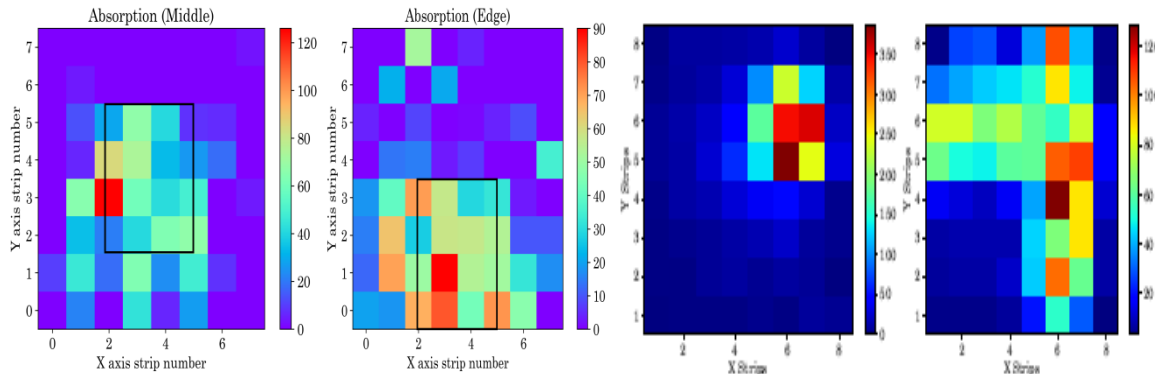
Journal of Instrumentation **15**, C11013 (2020)
Journal of Advanced Instrumentation in Science **261**, 1 (2022)



DAQ Scheme



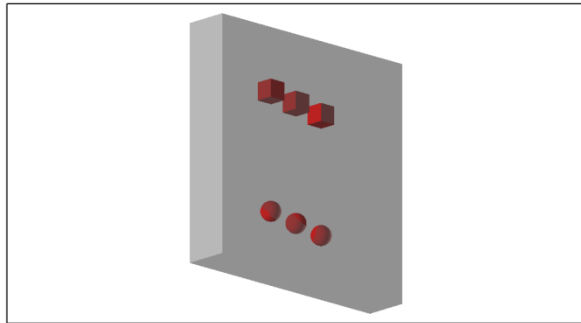
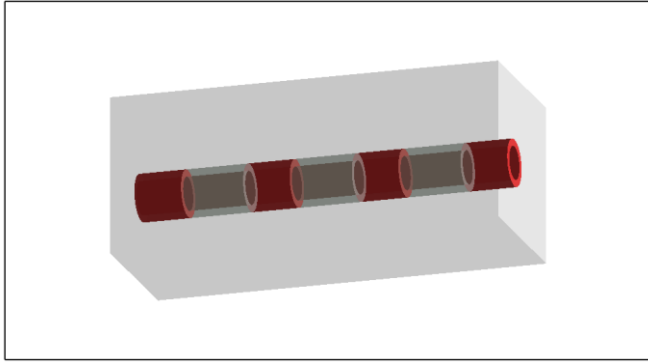
DAQ Components



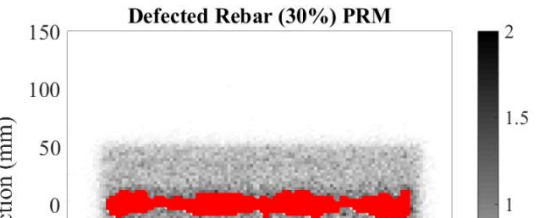
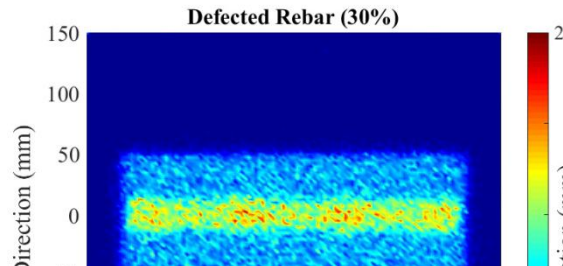
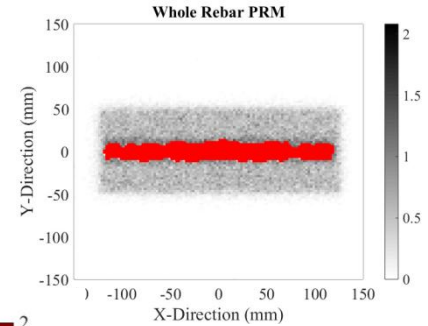
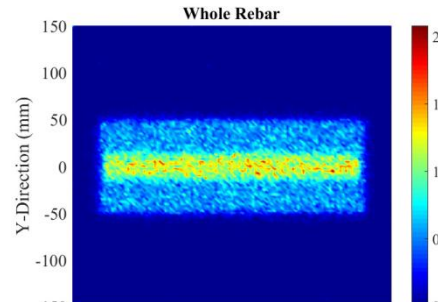
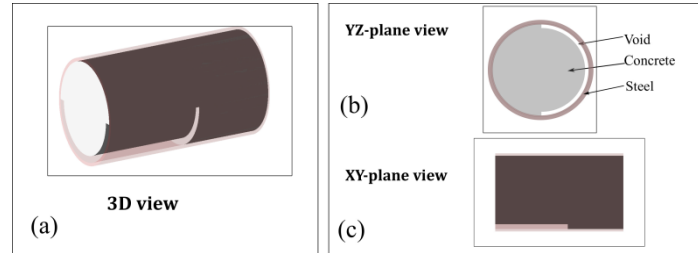
DAQ Testing



Application in Civil Structure Inspection



10-14 July, 2023





Application in Nuclear Waste Imaging

