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2D Imaging using Synthetic Muon Beams

Prepared by
Lahore Grammar School Gulberg

Presented to
BL4S

Table of Contents

Introduction

We are a group of highly curious individuals from Lahore Grammar School, Pakistan, brought together by our shared passion for science. Our goal is to push the boundaries of scientific research and make a meaningful impact in the world. We believe that the BL4S competition organized by CERN is the perfect platform for us to showcase our skills and experiment with cutting-edge technology.
Our team has devised a proposal for an experiment that uses muons for 2-D imaging, and we are excited to put our ideas to the test at CERN. Given the lack of resources in Pakistan, we believe that our experiment can truly make a difference, and we are excited to have the opportunity to test it out at one of the world's leading research institutions. We are honored to have the opportunity to participate in such a prestigious competition and are excited to see where this journey takes us.

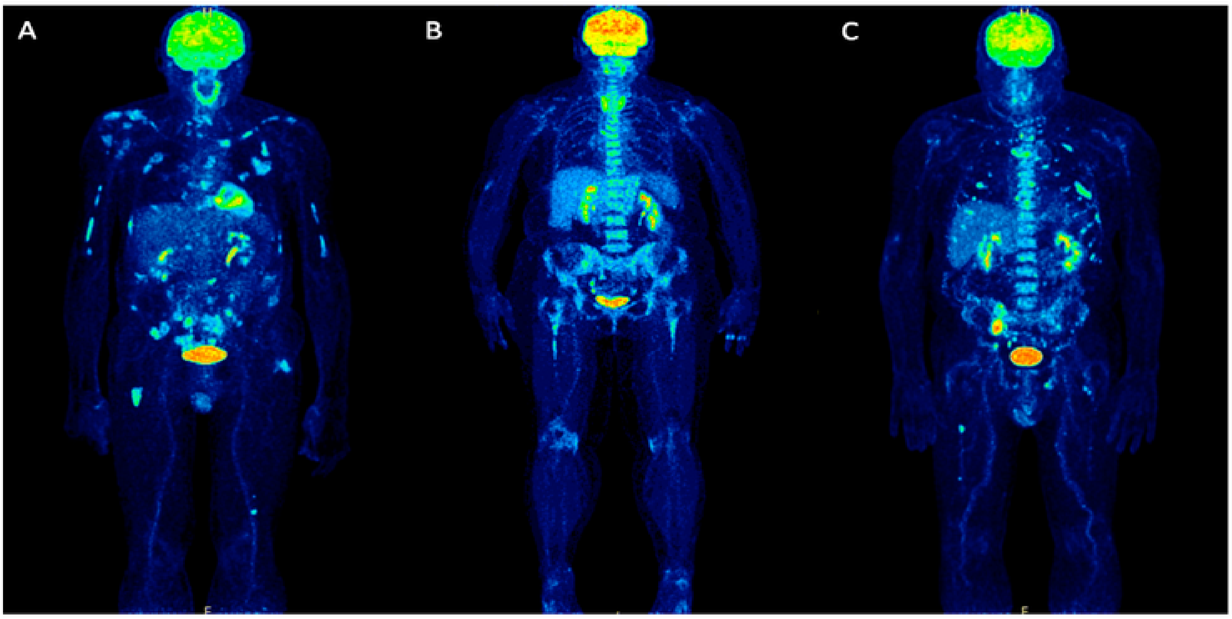
Our Aim

Our objective is to use muons to image through large and thin samples and then use MRPCs to figure out the otherwise unclear internal structure of the sample.

Alternative Methods of Imaging

- ***Positrons***

Positron emission tomography (PET) is a medical imaging technique that is a combination of nuclear medicine and biochemical analysis. It involves injecting a positron-emitting radiotracer into the body, which emits positrons. There are electrons in the surrounding tissue which then interact with the positrons, thus producing gamma rays. These rays are detected and used to produce images. PET scans have a wide variety of uses. They can be used to evaluate organs and tissues for the presence of any diseases.



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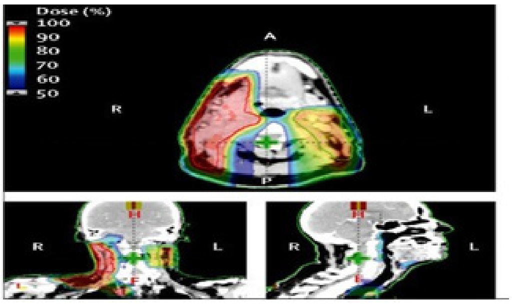
- ***Protons***

Proton beam imaging is a medical imaging technique that uses a beam of protons to produce images of the body. The technique involves the injection of a proton-emitting radiotracer into the body, which emits protons that interact with the tissue, producing signals that can be detected and used to produce high-quality images.



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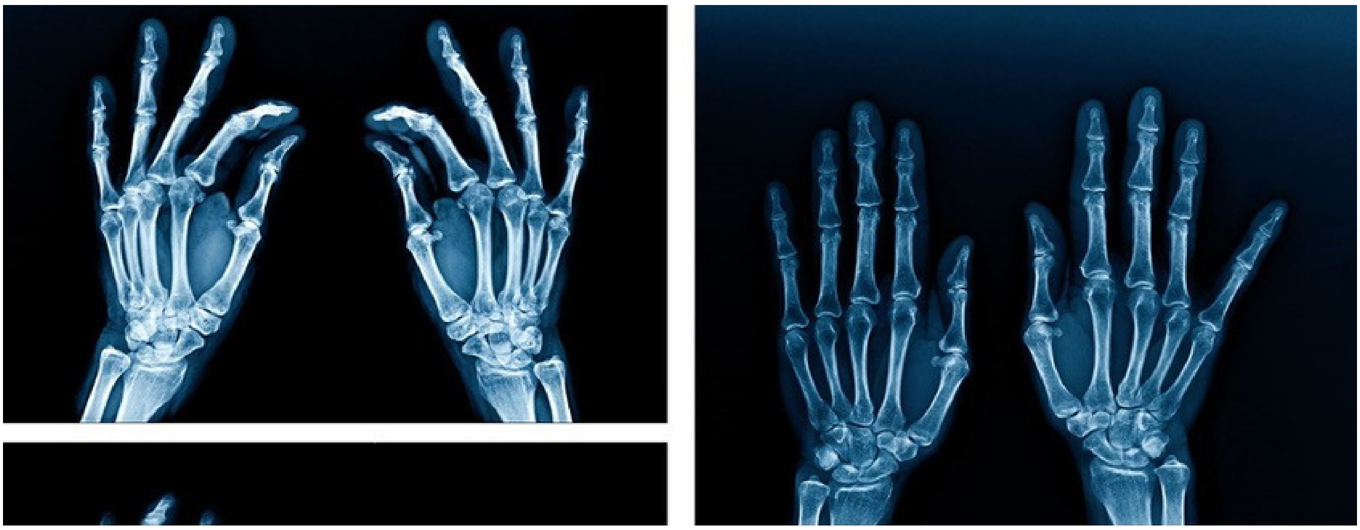
- ***X-rays***

X-ray imaging is a sort of medical imaging that creates images of the inside of the body using electromagnetic radiation. A small, precisely regulated amount of ionizing radiation is used throughout the technique to expose a bodily component, which is subsequently detected by a specialized detector and used to produce an image. X-ray imaging is frequently used to identify malignancies, diagnose bone fractures, and track the development of illnesses including pneumonia and tuberculosis. Nonetheless, x-ray imaging should only be carried out when medically essential and with the appropriate safety precautions because the radiation utilized can be dangerous in excessive amounts.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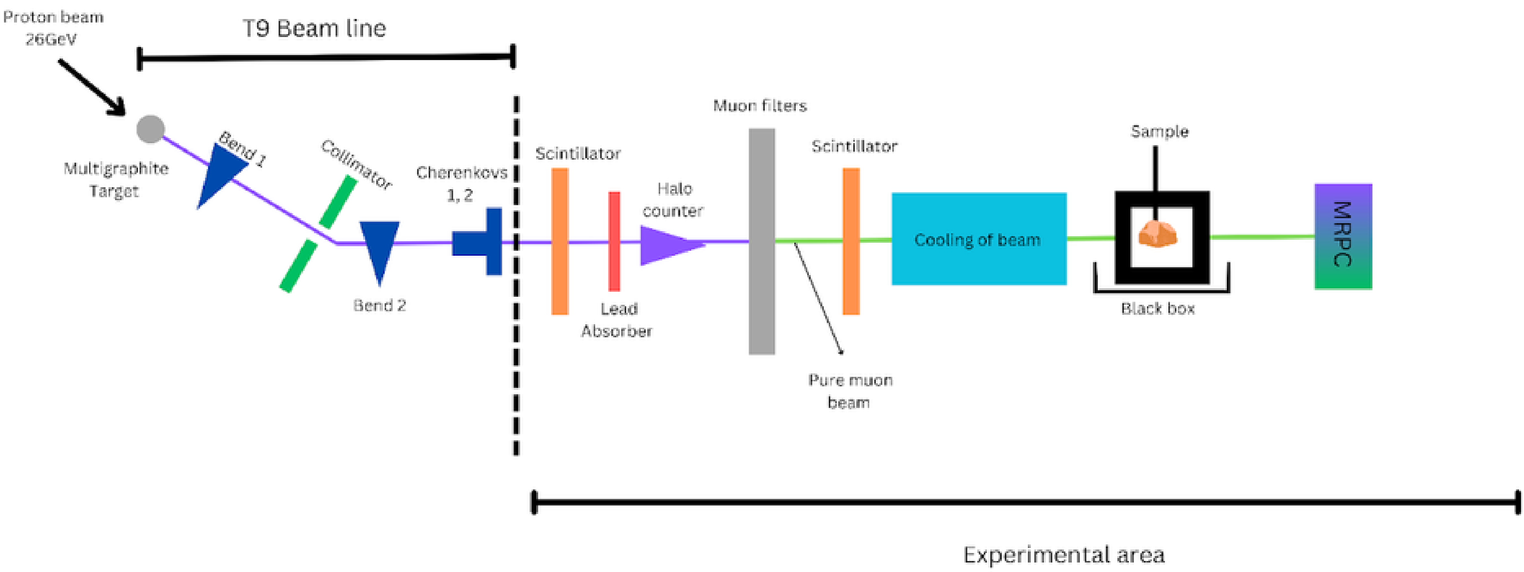
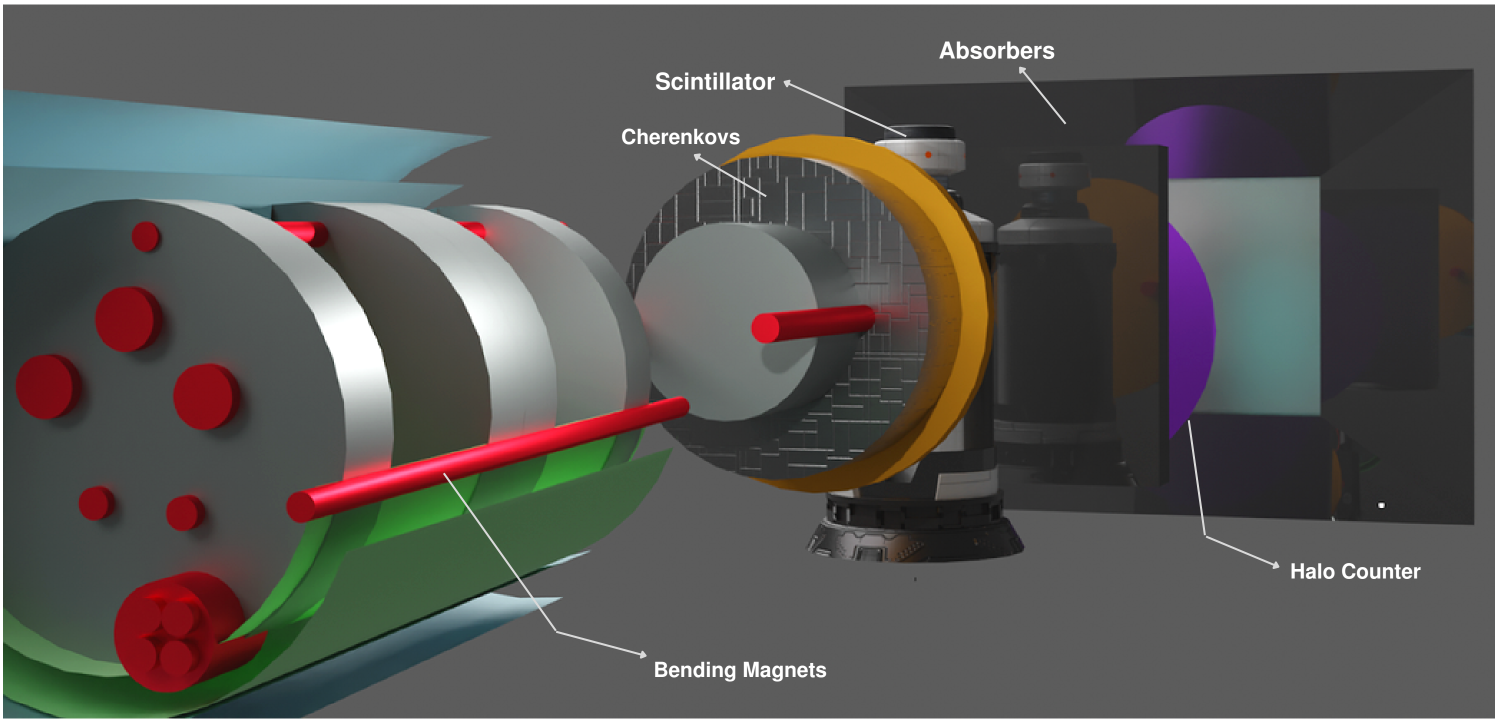
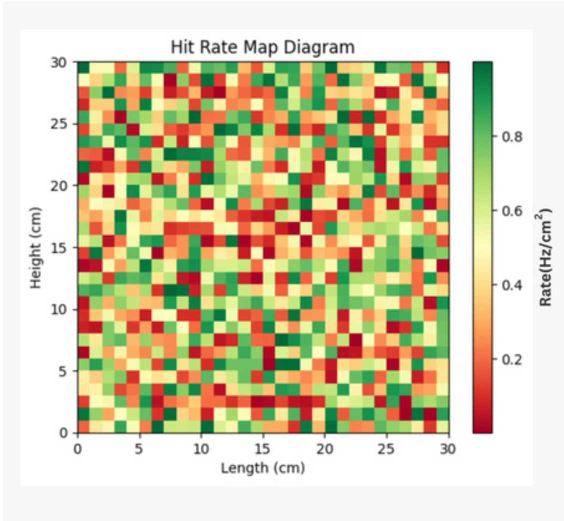
Experimental Design and Setup





Before testing our sample, we will pass the muon beam through our MRPC detector in order to generate a reference 2D image map. Next, we will use a material of a known density as our sample and then we will repeat the experiment by placing this sample before the MRPC detector and will generate the 2d map of detected muons on the detector. Denser regions will absorb more muons as compared to the lower dense regions. Areas with no material will allow muons to pass through. Therefore the image produced will portray a concordant result depicting a visual colour definite. We shall then compare this image with reference image and the observed muon data will then be inverted by to 2D density contrast map.



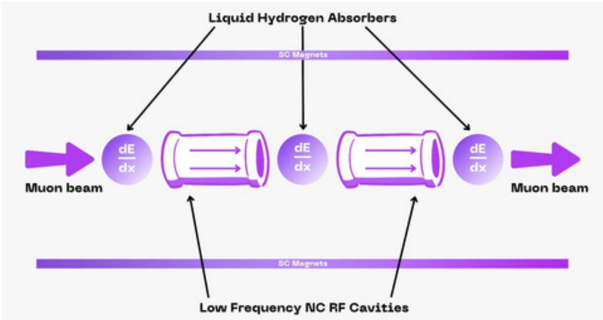
Sample of density map

Methodology

1. A proton beam of 26 GeV will pass through the bend 1, the collimator, bend 2, and then the Cherenkovs thus entering the experimental area.
2. The first scintillator will measure the intensity of the unfiltered beam (proton beam) which will be used for comparison with the beam intensity measured by the second scintillator.
3. Photons in the beam will be absorbed by the lead absorber.
4. The halo counter will then identify any particles on the periphery of the beam.
5. The muon filter will remove all particles except muons.
6. The second scintillator will measure the intensity of the pure muon beam. With these measurements, we can compare the beam intensities between the two points.
7. The beam will be cooled using ionisation cooling in order to slow down and limit the scattering of beam particles.
8. The beam will be incident upon the sample and muons will be absorbed based on different densities throughout the material.
9. We will follow muon transmission radiography using muon absorption imaging technique. In muon radiography, material density can be inferred from the attenuation of muon flux.
10. We will use an MRPC gaseous detector to track the number of muons that pass through the selected muti density target volume to determine the densities of the inaccessible internal structures.
11. The observed muon data will then be inverted by to 2D density contrast maps

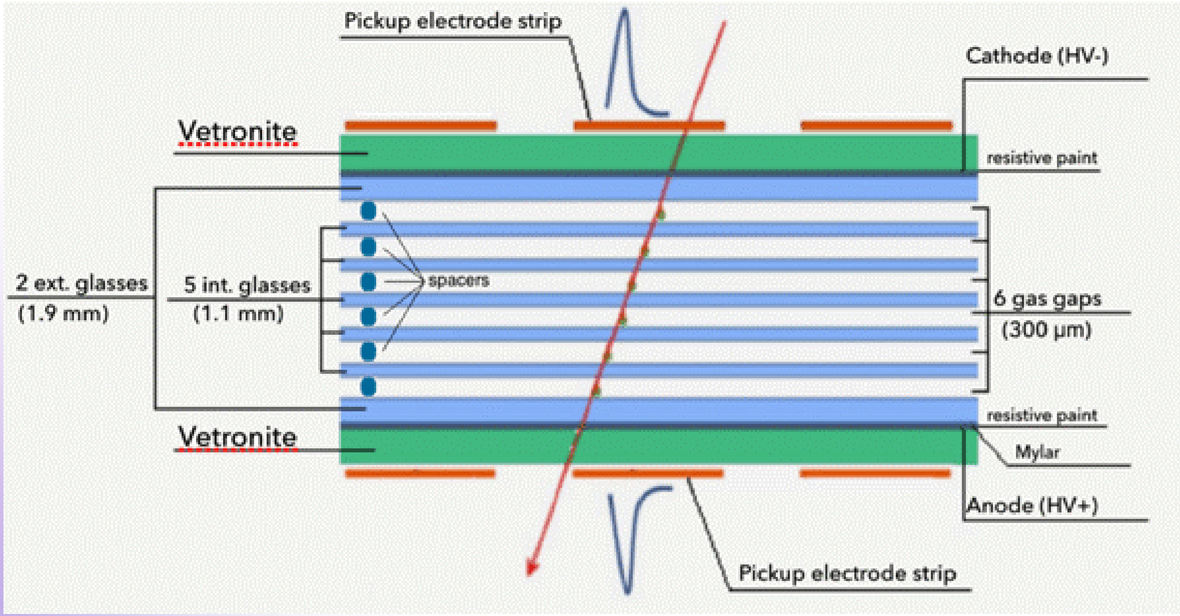
Cooling of the Beam

Ionisation cooling of the muon beam will reduce scattering and help focus it on the sample. In our cooling mechanism, ionisation energy loss occurs in all three planes before the RF cavities restore the longitudinal component only. The process occurs multiple times with superconducting solenoids present for beam focusing.



Materials

The document uploaded by Beamline for Schools mentions materials available for us to use during our experiment. The majority of materials and apparatus we require are in the file. We also require a mechanism to cool the muon beam before being fired on the sample. We require two sample materials: multi-carbon rocks (approx 20cm * 20cm * 5cm) and a block of titanium of known density. (20cm * 20cm * 5cm)



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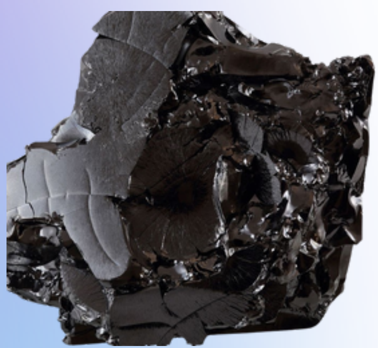

Applications

Muon Tomography is used to tackle geophysical problems regarding the investigation of the interior of volcanic structures. A muon beam telescope can be used to determine the densities of rocks and other internal structures. It helps eliminate or minimize the the hazards of excavation and route planning including but not limited to the collapse of the integrity of the structure. Archeologists can accordingly work out the optimum route for exploration.
Other Applications include:

- Underground measurements (especially used during mining practices)
- Seismic studies of Temples and mounds (Previously tested in Asia)
- Facilitation and regulation of international trade; used to detect narcotics, explosives, living organisms, and nuclear/ radioactive materials
- Nuclear Waste Categorization

Pros & Cons

Advantages:

1. Non-destructive imaging, particularly adapted to the context where structures may be fragile or unstable
2. Relatively direct interpretation: whereas electric, acoustic, thermal or gravimetric measurements often require complex corrections and interpretations, many structural details can already be seen in a raw muography image making it comparatively feasible and more efficient
3. Only the detector is required, which makes it radiologically safe for people around;
4. Possibility to scan large structures;
5. High sensitivity to density variations, and thus suitable for void detection

Disadvantage:

Muon Tomography cannot be used in medical procedures since the heavy particle would move through at too high a speed to detect the beam and take a reading of plausible value

Conclusion

Muon tomography can be performed using synthetic muon beams. Our findings have shown that using this method, density maps of relatively small samples can be procured. We believe that this method would also allow us to image the internal structures of larger objects such as pyramids and volcanoes in a more efficient way.

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Social work proposal

The proposal aims to provide a unique learning experience to underprivileged or disabled children by teaching them about astronomy and the fundamentals of light and lenses. Through interactive quizzes and group activities, children will learn about different galaxies, stars, and planets via virtual universe tours and hands-on projects.
The virtual universe tour will allow children to explore and learn about complex astronomical concepts such as black holes, supernovas, and the Big Bang theory using interactive models and videos. For the hands-on project, children will be encouraged to work together in groups to create representations of planets or asteroids using paints, clay, and markers.
In addition, children will be taught about light and lenses and how they are used to observe the universe, linking it back to astronomy. Children with hearing impairments will be able to participate in visual experiments to enhance their learning experience. Furthermore, children will have the opportunity to express their creativity by making telescopes out of recycled materials and observing the night sky.
By providing this unique learning experience to underprivileged or disabled children, we hope to ignite their passion for science and inspire them to pursue careers in STEM fields.