Making a novel infused silica based hodoscope

Precision Pathfinders

Quartz fibre-based hodoscope for particle detection and trajectory

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https://s3.cern.ch/inspire-prod-files-d/decb32a2f0547ba7dda4433c2a87addb

https://www.researchgate.net/figure/ariations-of-the-S-parameter-for-fused-silica-and-polyethylene-at-E-5-keV-as-a-function_fig1_330852339

Why we want to go

As a group of students who are highly engaged in Physics and STEM, CERN and DESY represent the forefront of scientific research happening in the world.

Tasks
Krish Agrawal - Work on Overall Design
Arnav Tiwari - Introduction + Theory (Cherenkov Radiation)

Soumik Agarwalla - Work on Overall Design +
- Saturation Writeup and why its useful.

Methodological Advantages and Explanations -
5* angle minimizes deviations
Collimator - makes the beam narrow
Magnetic Filter - Filters positron by energy
Aluminium Foil - Induces scattering
Scintillators - Tell us when beam goes in and when beam comes out
SiPM - Capture Cherenkov Radiation and reconstruct trajectories
Calorimeter - Measures residual energy

Cherenkov Radiation - helps us measure velocity and trajectory both
Advantages of using Quartz Fibers -

1) Cheaper than Csl Scintillators

2) Work for Longer Duration - can sustain more prolonged exposure
3) Resistance to Saturation
4) Better Spatial Resolution - Can predict trajectories which traditional scintillators can't.

How our hodoscope works

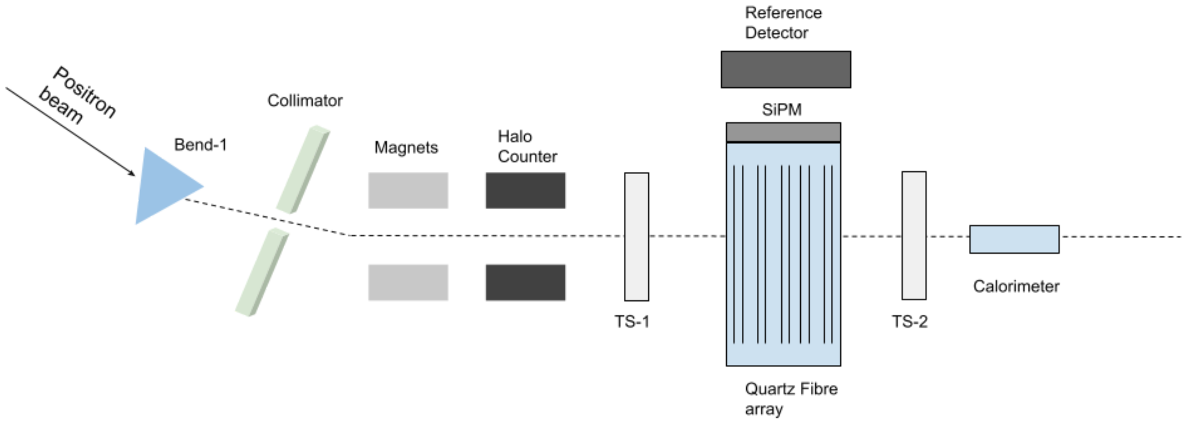
We are proposing making a hodoscope that instead of the standard CsI Scintillators, uses Fused Silica (Quartz Fiber) as the primary medium. The Hodoscope will consist of multiple 2-array layers of Quartz Fiber connected to a Silicon Photomultiplier.

Why –
We plan on using quartz fibre due to its increased spatial

Cherenkov Radiation (Theory, Equation and Quartz Fibre)

https://docs.google.com/document/d/18Y1uhrkNQSaLm5nBkgkTbqbjFLLjYD6zkoF3dUotRzM/edit?tab=t.0

Below is the proposed experiment layout



Beam Type

We plan on using the DESY Beamline, where we plan on using the secondary positron beam of 1.5 GeV. We have chosen this energy level due to the relatively high flux of positron beams, alongside the required energy to induce cherenkov radiation in the quartz fibre. Line

The Hodoscope will be kept at the focal length of the positron beam,

Additional Tasks

Finding which GeV to use – Krish
Why we want to go to CERN - Tiwari and Krish

Outreach Activity – Soumik Agarwalla and Jajoo
All formatting and writing in LATEX - Avighna

Novelty and Scientific Question: While the components are well-understood, the combination and the specific scientific question you're addressing are key to winning BL4S. You need to go beyond simply saying "track positron trajectories." What **physics questio**n will you answer by doing this? Some possibilities, which you should research in more detail, include:
Precise **Measurement of Cherenkov Ang**le: Can you measure the Cherenkov angle with unprecedented precision using this setup? This could test fundamental aspects of **Cherenkov radiation theory.**
Comparison of Simulation and Experiment: Can you create a detailed simulation of your hodoscope (using software like **GEANT4**) and compare its predictions to the experimental results? This would test the accuracy of the simulation tools used in high-energy physics.
Material Studies: Could you use your setup to study the properties of different types of quartz fibers or other materials? This could have implications for future detector development.
Positron Interactions: Focus on a specific aspect of positron interactions in matter that your setup can uniquely probe. This could be related to multiple scattering, energy loss, or annihilation processes.

Photon Yield is Low – Cherenkov radiation produces fewer photons than scintillation, requiring a high-efficiency SiPM.
Fiber Geometry Optimization – The diameter, packing density, and alignment of quartz fibers must be optimized for tracking resolution.
Background Noise & Alignment – Quartz fibers must be aligned precisely at the focal plane of the beam to achieve useful trajectory reconstruction.

Purpose:

Our team is proposing to make a quartz (infused silica) based hodoscope that surpases the traditional CsI scintillators in detecting the trajectory of charged particles-positrons-,CsI scintillators are more expensive, and suffer from saturation;our design aims to exploit the cherenkov radiation released by particles travelling through the quartz fibre medium to detect the trajectory of the particles.

We plan on executing this by employing the following design :

GeV

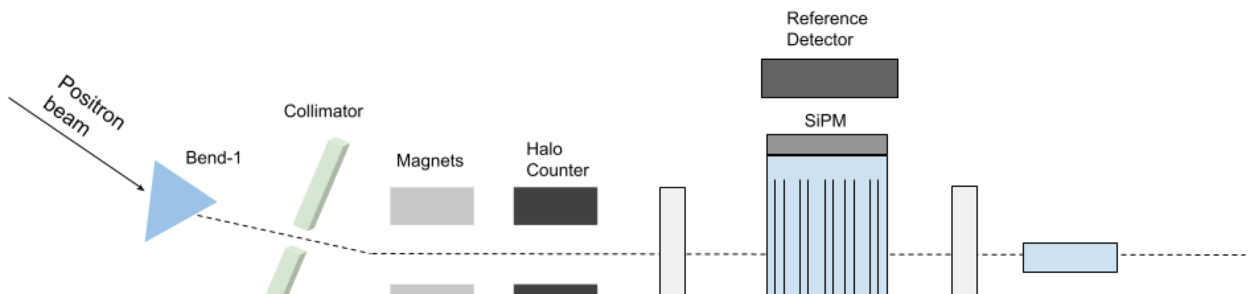


Figure 1.1(2-d Schematic Diagram of the experimental setup)

Method:

The positron beam is carefully targeted at a 5° angle and positioned at the focal point of the bend, ensuring an optimal approach to the subsequent stages. After exiting the bend, it proceeds through a collimator that narrows its diameter to approximately __ mm, thereby producing a more refined, uniform beam profile. Next, the beam passes through a magnet which filters the positrons to a desired energy of __ GeV, further enhancing the precision of the beam's energy distribution. Following this, the positrons encounter the first scintillator (TS-1) and then traverse an aluminum foil measuring __ mm in thickness. This foil induces slight scattering, altering the trajectories of the positrons and broadening their angular spread. Ultimately, the scattered beam enters the hodoscope—a structured array of silica-infused quartz fibers—where charged particles emit Cherenkov light. By capturing and analyzing this light via silicon photomultipliers (SiPMs), the setup enables accurate tracking of the positrons' paths.

Hodoscope Design:

Saturation and Advantages:

Our method provides an alternative method to track the trajectory of positrons compared to traditional Csl scintillators, which face saturation due to high intensity signals in high particle density systems. Our hodoscope faces no limitations regarding the number of particles in the beam, as each positron can generate Cherenkov radiation without interference, providing a linear response allowing SiPMs to process photons independently without saturation, increasing the reliability of the system.