Scintillator Bars for Position Reconstruction with e, π, and μ Beams

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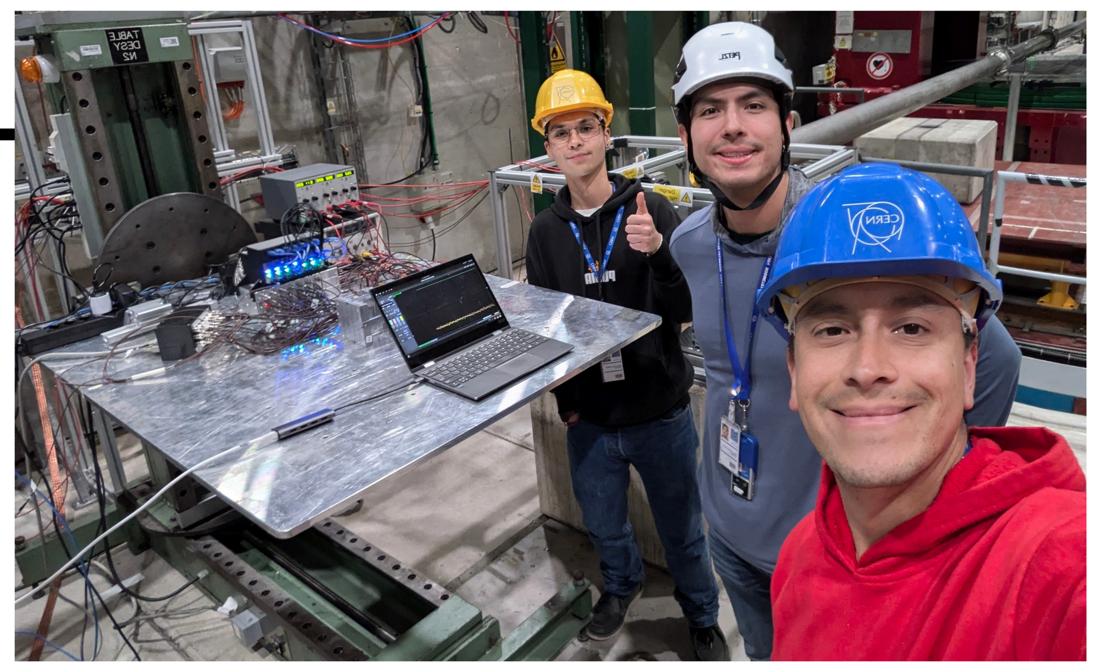
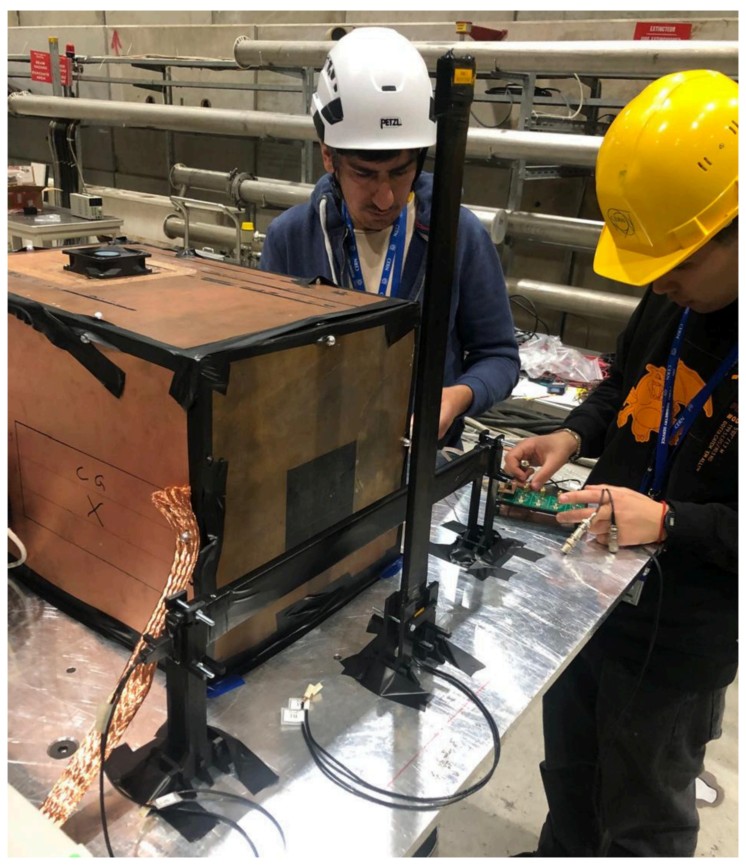
Abstract or a question that could summarize the research

Particle detectors play a crucial role in high-energy physics experiments by enabling precise beam characterization. This study evaluates the performance of a detection system based on plastic scintillator bars coupled with Wavelength Shifter optical fibers and MPPC sensors. The system was tested SPS - H4 beam line with electron, muon, and pion beams at 100 and 150 GeV in CERN's North Area. The analysis focused on signal persistence, energy deposition, and acquisition timing. Results demonstrated uniform detector response, with minimal amplitude variations between sensors. Energy deposition estimations using Landau fits and Bethe-Bloch simplify integration confirmed the system's accuracy. Furthermore, by analyzing acquisition times during beam spills, we ensured proper data collection and minimized dead time, reinforcing the system's reliability for particle tracking applications.

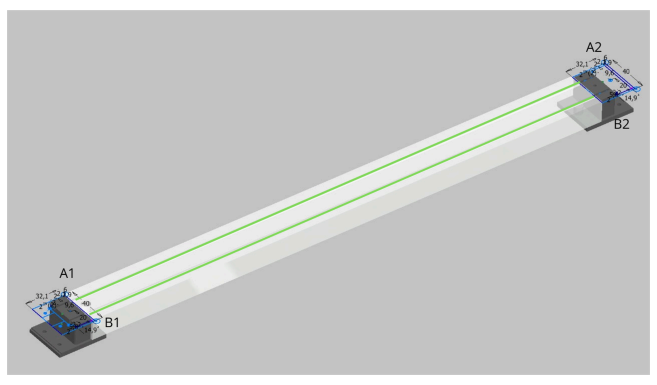


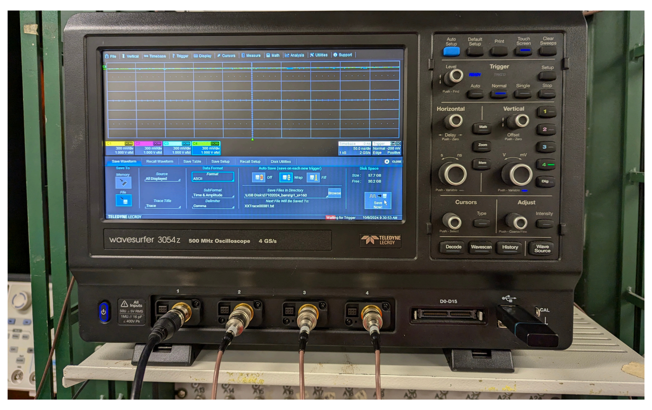
Motivation / Introduction

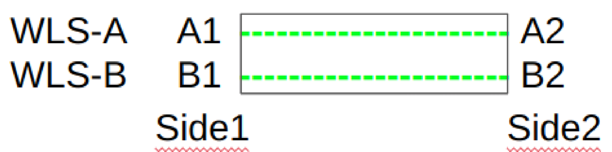
High-energy physics experiments require highly precise and efficient particle detectors to study interactions occurring in accelerators. Among the most widely used technologies are plastic scintillation detectors, valued for their fast response time and robustness. However, their performance depends on factors such as light collection efficiency, sensor sensitivity, and timing measurement stability. In this context, the development of reliable solutions for particle position reconstruction is essential, as it enables the acquisition of high-quality data and enhances the analysis of underlying physical processes.



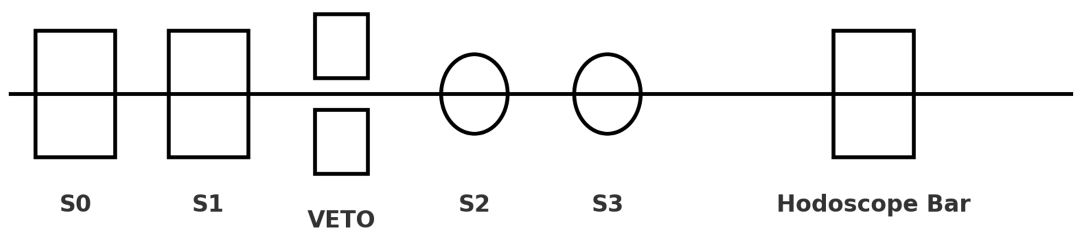
Experimental Set-up





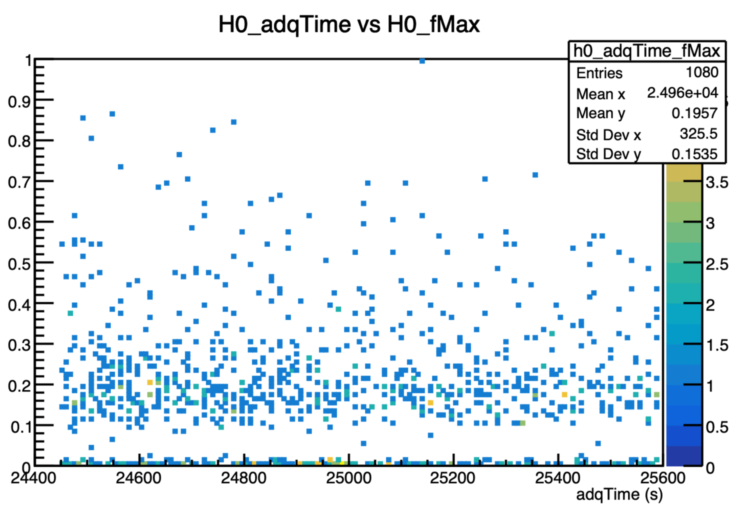


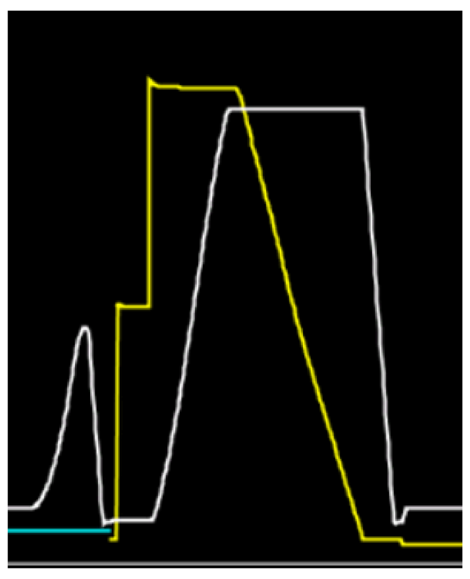
The detection system consists of scintillator bars measuring 50 cm × 4 cm × 7 mm, coupled with four MPPC detectors, two on each side of the bar. The sensors share Wavelength Shifter optical fibers to efficiently transmit light emitted from the interaction of charged particles with the scintillator material.
Measurements were performed using a WaveSurfer 3054z oscilloscope with a sampling rate of 4 GS/s and a trigger based on the beam counter S3, set with a 30 mV threshold and a 500 ns window. Multiple positions were scanned to evaluate the detector's spatial response.
Vbias= 40V with +- 5 V for the buffer.



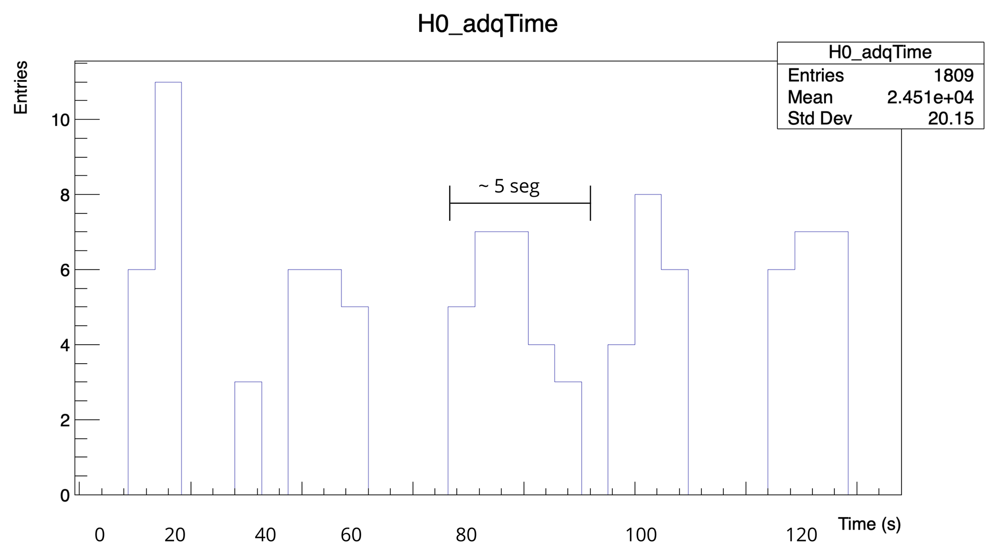
Data adquisition and Spill Over

During data collection, the particle beam was released in defined time intervals (spills), directly impacting the detectors. The acquisition times of each event were analyzed, filtering those in which the oscilloscope correctly recorded the data. Histograms of the variable adqTime were generated to identify effective detection periods and discard dead times.



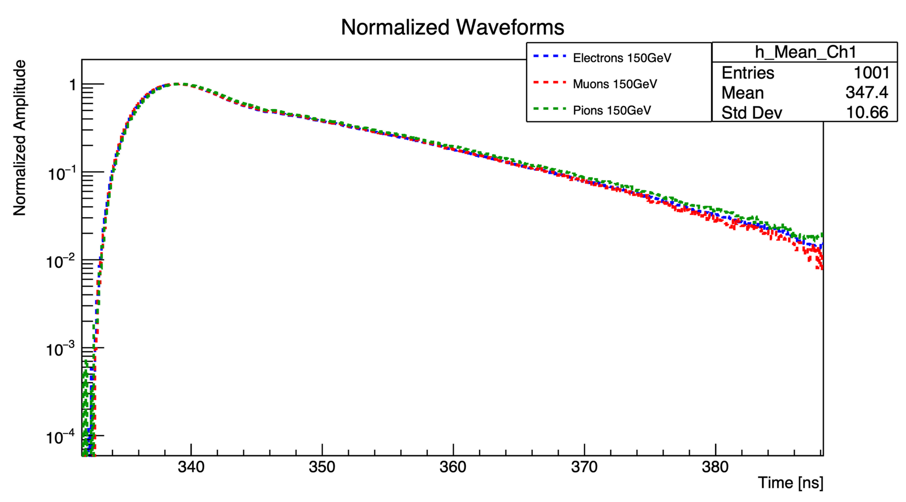


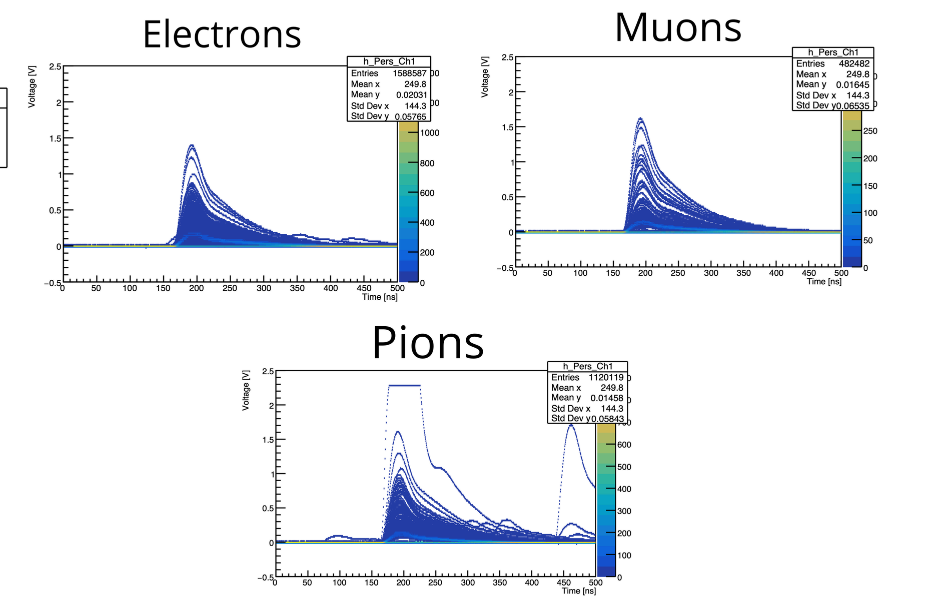
The variable adqTime represents the time the system was actively recording data during spills, which appear as periodic peaks in the histogram. These peaks correspond to the controlled release of the particle beam and indicate when the detector was fully acquiring data. Analyzing adqTime ensures uniform detector illumination and stable conditions throughout the measurement process.

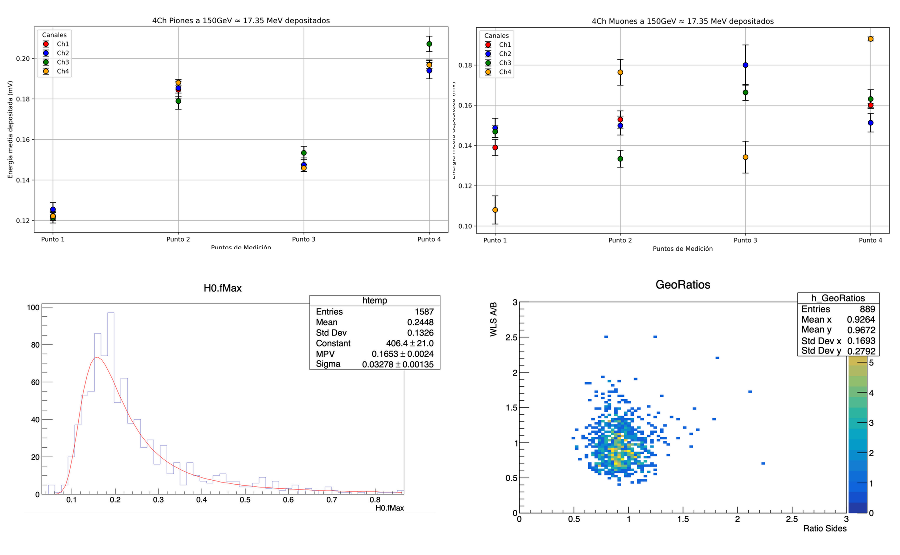


Results and/or Prospects

The detector's performance was evaluated by analyzing signal parameters, including persistence times and average waveforms. While differences in response to electrons, muons, and pions at 150 GeV were observed, signal decay times showed no significant variation.

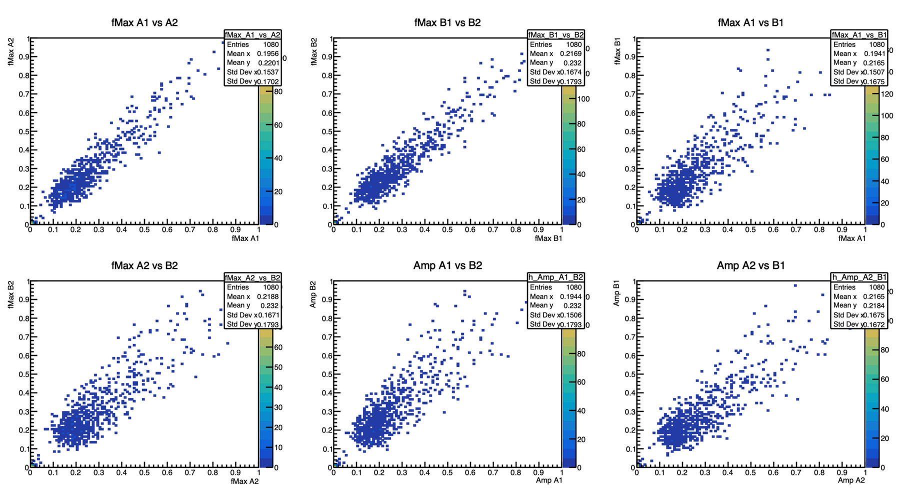






Energy deposition was estimated using a Landau fit and Bethe-Bloch simplify integration, with both methods providing consistent and accurate results.

$$E_{dep} = \int_0^x \left\langle \frac{dE}{dx} \right\rangle \rho \, dx$$



Correlations between MPPC sensors were analyzed to assess response uniformity, showing consistent detector performance with minimal amplitude variations.

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