A cosmic muon test facility with the MRPC telescopes of the EEE Project

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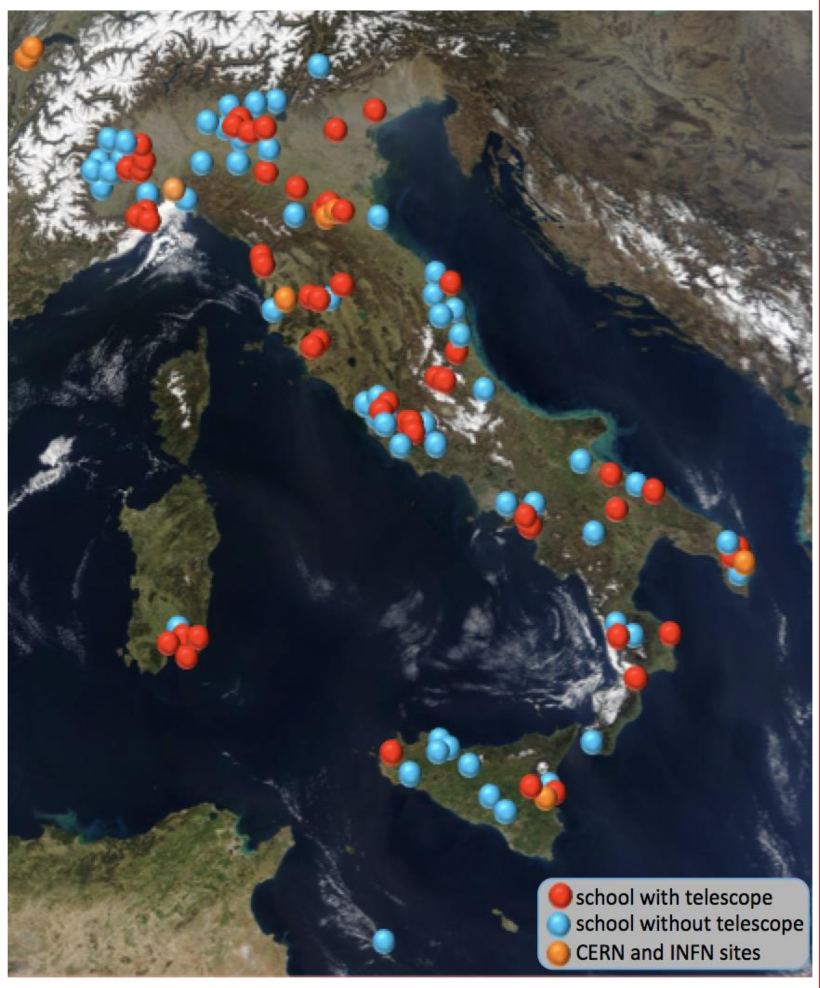
Extreme Energy Events (EEE) detectors are designed to measure secondary cosmic ray tracks, mainly muons, to study cosmic rays. The EEE 'telescope' is made by 3 Multigap Resistive Plate Chambers (MRPC), each with an active area of 158x82 cm^2 in size. Each detector is part of a large network of about sixty telescopes spread over the Italian territory. GPS time synchronization of the telescopes allows the detection of extensive air showers produced by primary cosmic ray interactions in the Earth atmosphere. Due to the good tracking capabilities (200 ps time resolution and cm^2 spatial resolution) the EEE telescope can be used also as test station for large area detectors. The link between the EEE track and signals from the detector under test is obtained by implementing a streaming DAQ with a common time reference between the two systems given by the GPS signal. In this contribution I will present the installation and first results of the cosmic muon test facility with the MRPC telescopes based on the low-cost, streaming-compatible 12ch, 250MHz, 14 bits digitizer (INFN-WaveBoard or WB) developed by the JLAB12 Collaboration. According to the detector under examination, different measurements can be performed: in a scintillator crystal bars, for example, the efficiency and optical attenuation along the detector length can be easily tested. In a first test run, we characterized some scintillator crystal of $PbWO_4$ from the POKER detector. The system can be easily replicated, instrumenting any EEE telescopes , and providing a convenient cosmic ray test facility across Italy.

EEE Project

The Extreme Energy Events (EEE) joint project, of Centro Fermi and INFN[1][2], is designed to study high-energy Cosmic Rays (CR).

It is a network of several muon telescopes based on Multigap Resistive Plate Chambers (MRPC) **synchronized by GPS.**

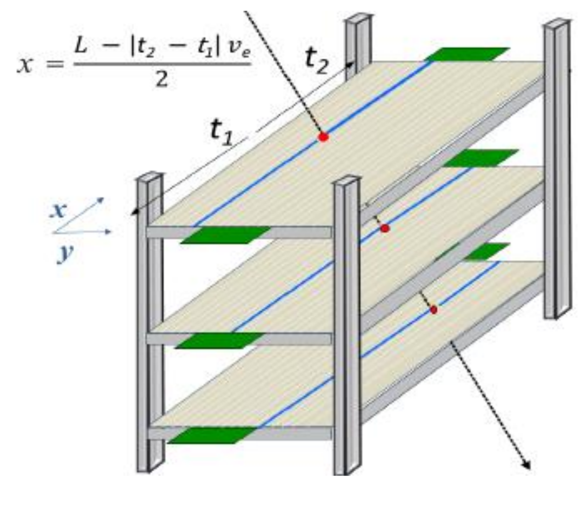
The EEE network (see map) is composed of 60 muon telescopes organized in clusters and single telescope stations installed in Italian High Schools, built and operated by students, constantly supervised by researchers.



EEE Detector & Performance

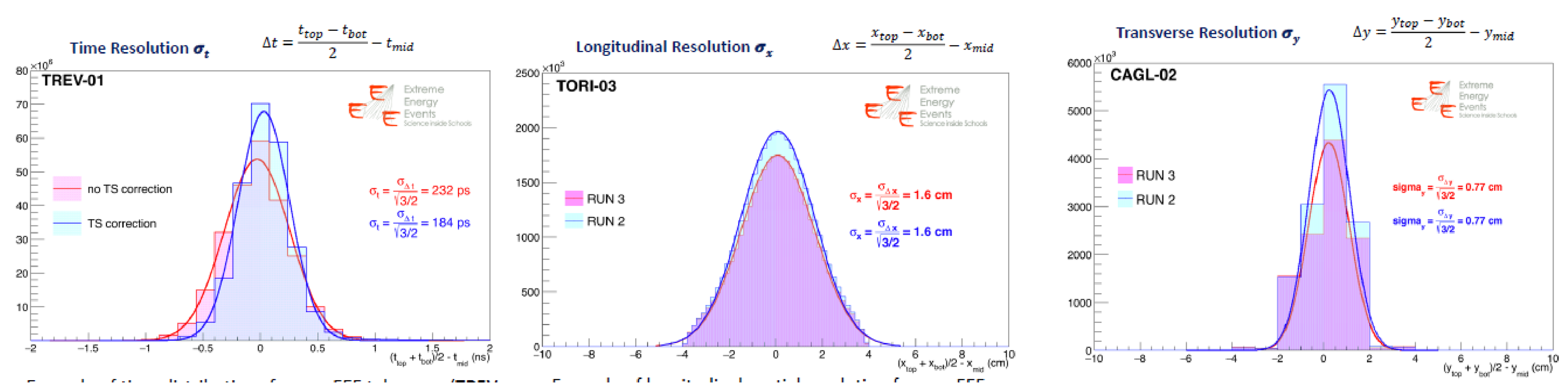
Three Multigap Resistive Plate Chambers (MRPC), providing the impact coordinates of incoming muons (see figure below), hence the reconstruction of its track, with **high efficiency and good angular resolution**:

- 3 MRPCs of 1.58 x 0.82 m^2 sized
- 24 readout copper strips as electrodes, pitch of 3.2 cm
- DATA are transferred and stored at INFN-CNAF, where an all data reconstruction algorithm is immediately applied to all events



The time resolution is obtained by the hit time on the top and bottom chambers and using these values to determine the expected time on the middle chamber. The same strategy is used for the spatial resolution [3].

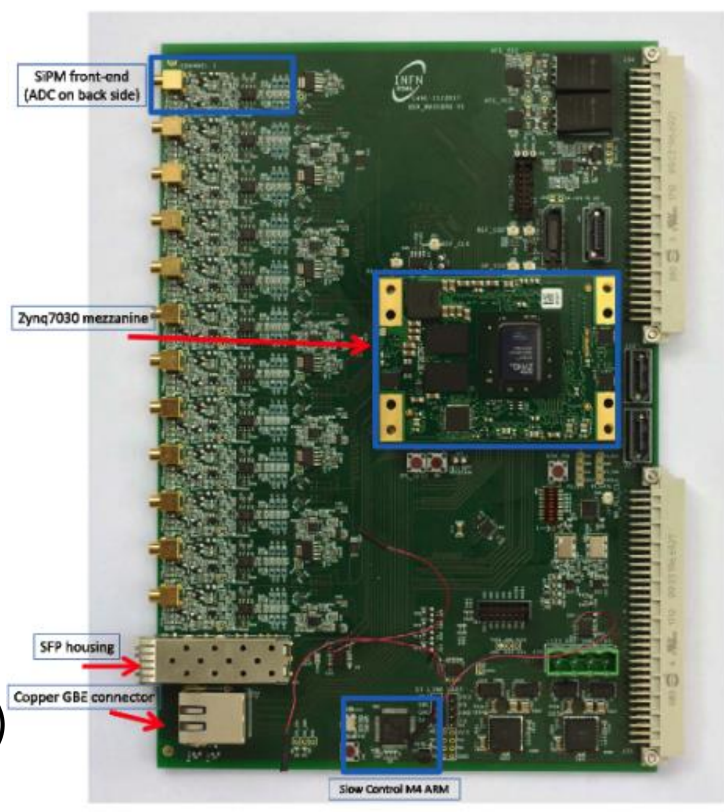
	Average value
Time Resolution σ_t	238 ±40 ps
Longitudinal Res. σ_x	1.47 ±0.23 cm
Transverse Res. σ_y	0.92 ±0.02 cm
Efficiency ε	93%



INFN-WaveBoard

Highly configurable digitizer board (**Waveboard**) is developed for Beam Dump eXperiment (BDX) at Jefferson Laboratory (Jlab)[4] but is usable also for other kind of detectors. The board is based on a Commercial-Off-The-Shelf (COTS) System On Module (SOM) mezzanine card hosting a Zynq-7030:

- There are 12 analog front end channels
  - 6 dual-channel ultra low-power ADCs (12/14 bit up to 250MHz)
  - Pre-amplifier on board: selectable gain
  - HV provided and monitored on-board
  - Pedestal set by DAC
- Timing interfaces:
  - PLL to clean, generate, and distribute clocks
  - External clock and reference GPS signals (IRIG-B and 10 MHz with ad hoc receiver)

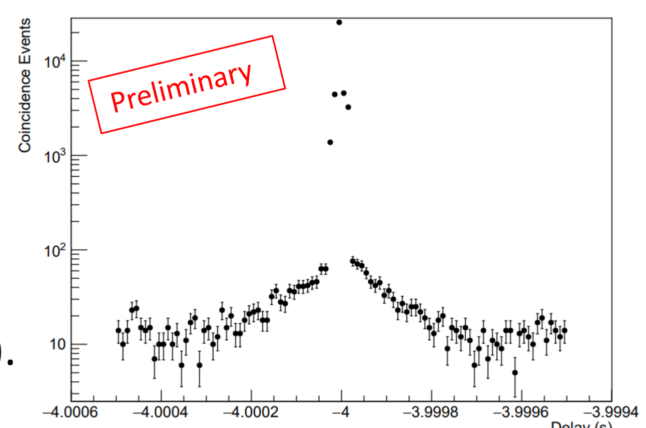


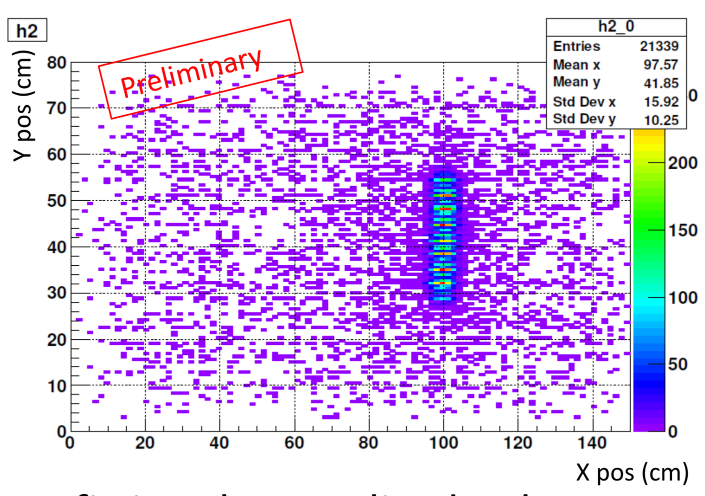
The board can operate in **triggerless mode** (Streaming)

Analysis & Results

The acquired waveforms were processed through a data reconstruction algorithm to extract, event by event, the corresponding amplitude and charge.

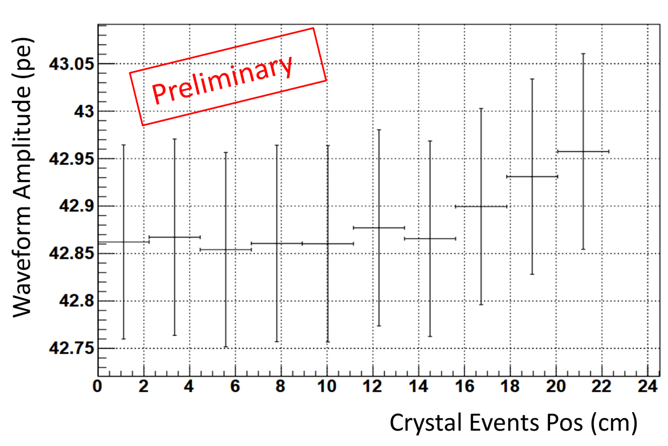
Although used GPS, to synchronize the data, it is necessary to determine the constant time offset between the two systems. This can be done by measured the coincidence events, in a fixed time window (10 μs), as a function of a constant delay added to the WB events in GPS time (Right Figure).





To measure the crystals' response uniformity we studied the light emission as a function of the longitudinal position on the crystal. Hit position on crystals is obtained by using EEE data and is build a 2D-Map (Left Figure).

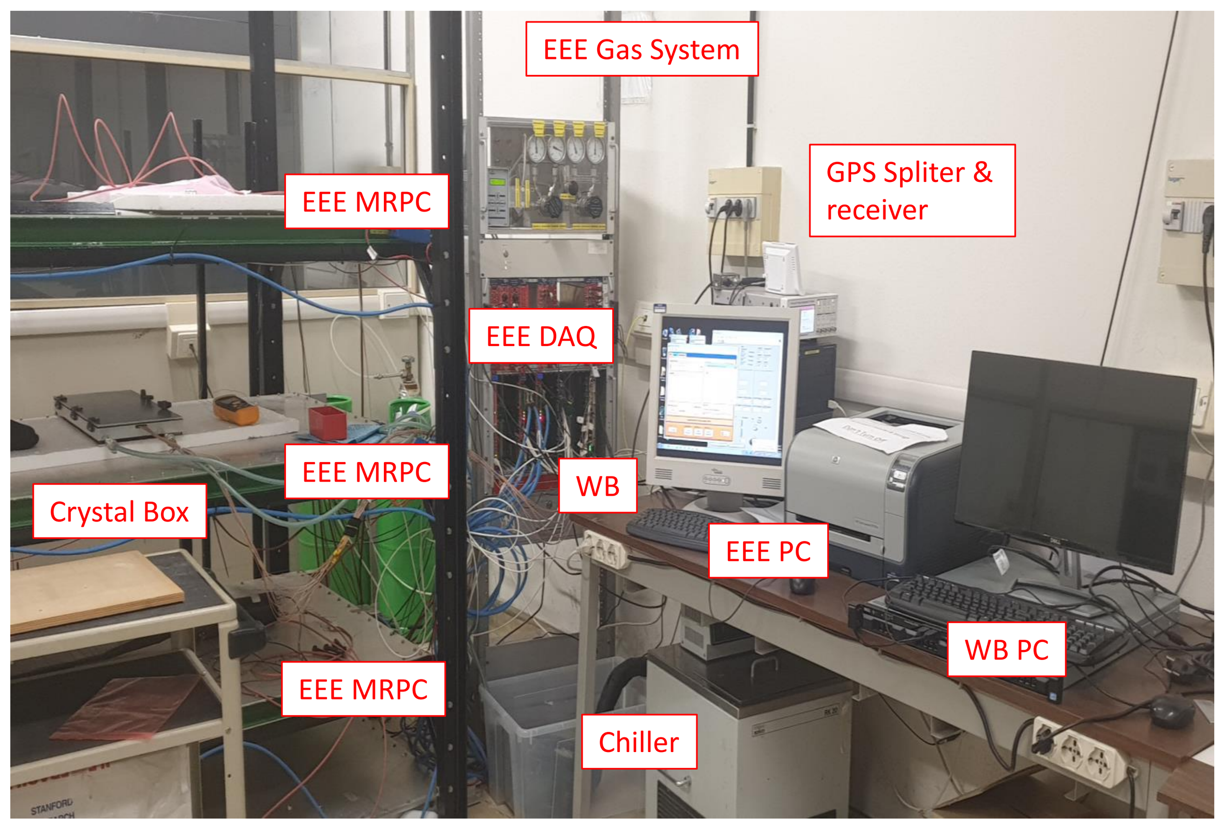
By fitting the amplitude plot at specific longitudinal portion of crystal is possible to evaluate the light attenuation long crystal (Right Figure). The results are preliminary and the measurements will be repeated to increase statistics, **but a trend of the values due to attenuation (high value near SiPM) can be noted but the variation results in some %.**



Testing facility :

The simultaneous presence, in the INFN section of Genova, of an EEE telescope, the INFN-Waveboard (WB) and experts in both devices led to the creation of a collaboration. The result is the development of a detectors test facility that integrated the EEE large area detector tracking capabilities with the WB's multi-device simultaneous streaming data acquisition. The facility also found immediate application in the characterization of the light emission of $PbWO_4$ crystals (20x20x220 mm^3) of the POKER experiment [5].

- In crystal test configuration (see picture), the reconstructed trajectories can be used to evaluate the hit point of the cosmic ray on the studied detector.
- The SiPM signals were collected by 12 independent acquisition channels on WB.
- The WaveBoard works in so-called triggerless mode: every signal exceeds a programmable threshold, the corresponding samples are collected.



- The online event filtering was performed by using the TriDAS software [6]. In particular, the waveforms are collected only if a trigger from EEE DAQ line is present.
- Both on EEE and WB data give a timestamp provided by a GPS system. The antenna signal is the same (using a splitter) for both independent DAQ system.

Thanks to this configuration, it is possible to perform an offline time correlation study between data collected by the two systems separately. During the offline analysis, the two datasets are simultaneously analyzed searching for coincidence events in a narrow time window, to be used for the crystals characterization.

Conclusion

The EEE Testing Facility has demonstrated the possibility for EEE telescopes to work in conjunction with other independent measurement systems for purposes other than the study of cosmic rays. Fundamental was the contribution provided by INFN-WaveBoard, which thanks to its specifications allows to prepare a streaming and synchronized GPS acquisition system for different types of detectors. The test performed on the crystals of the POKER experiment demonstrate how to exploit the tracking characteristics of the EEE telescope to characterize several detectors simultaneously. The system is scalable to include more WBs and can be deployed quite easily at any site where an EEE telescope operates and in particular for those installed in research laboratories.

Reference

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