# The New Trigger/GPS Module for the EEE Project

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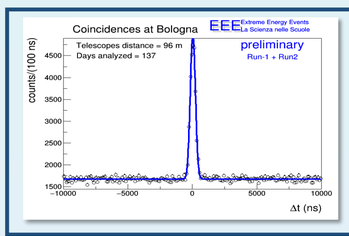
## The Extreme Energy Events (EEE) Project

RED – EEE Stations
BLUE – Schools involved in the project

**The EEE Project** [1] [2] is an experiment devoted to the **study of the Extensive Atmospheric Showers** (EAS). This is accomplished through a network of muon telescopes based on position-sensitive Multigap Resistive Plate Chambers (MRPCs). The telescopes are located inside Italian High Schools so **young students** are directly involved in assembling and monitoring telescopes, with the aim to introduce them to the methods and results of **High Energy Physics.** The EEE muon telescope network has been extended since 2008, reaching at present 57 MRPCs telescopes, spread across **a very large area of 3 x $10^5$ km$^2$**

**Frontier studies in high energy cosmic rays on ground need large detection areas. These can be done with EAS detector. To act as a huge network they require a precise time synchronization to correlate the information collected from each single detectors.**

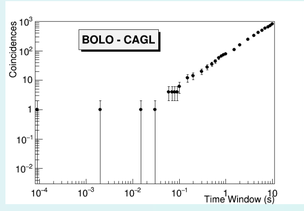
**Precision timing of muon arrival is fundamental for studies as EAS and the search for long distant correlations between EAS.**




The detection of an EAS is achieved by measuring the coincidences in time recorded at different sites of the EEE Telescopes Array [3]

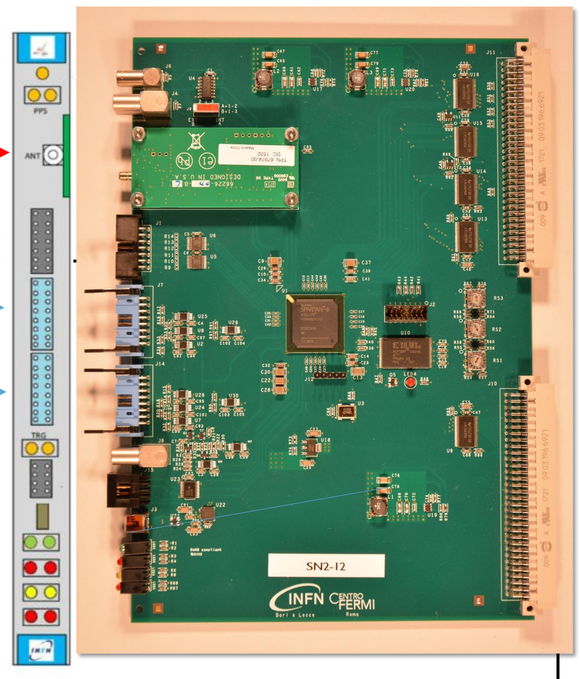
Coincidences between stations at Savona ~1.2 km apart

N. of coincident events as a function of the time window, between Bologna and Cagliari stations (610 km) [4]



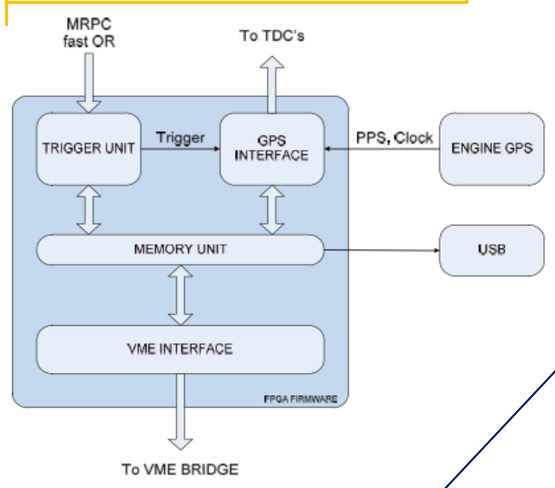

## The New Trigger/GPS Module

**A novel VME trigger unit for the EEE telescopes was developed, including an embedded GPS engine for timing application.**
That allows extracting the event time stamping at level of the trigger unit, avoiding time drifts.




### The Trigger Unit

- A 6-fold coincidence (within a 500 ns window) of the OR-signals from both FRONT-END cards of the 3 MRPCs, generates the data acquisition **Trigger**
- The trigger unit performs the count values of the triple (Trigger) chambers coincidences, the 3 doubles, the 3 single, and 6-FRONT-END outputs for testing purpose (efficiency measurements)




### The GPS Interface

- The GPS unit feeds both the TDCs with its clock disciplined to the one pulse per second signal (1PPS) to synchronize the TDCs internal counters
- At each 1PPS pulse the TDCs internal counters are reset
- Every time an event trigger occurs, the module feeds into each TDC a signal and the TDC stamps its time. The **absolute time** of an event is built as the **TDCs event time plus the GPS timestamp for each 1PPS**.
- The LabView DAQ system directly sorts out and puts the data from the two TDCs into single events, reads out the module at appropriate times and insert the GPS time values within the data stream at the correct record.

### The EEE Data acquisition System

The DAQ of the EEE system is based on VME standard.

**Each telescope is equipped with a trigger unit and a GPS receiver to record the universal time of each event.**

EEE Telescope at Liceo *L.B Alberti,* Cagliari

- 24 readout copper strips (pitch 3.2 cm) for each MRPC
- 6 FRONT-END cards with NINO ASICS (FEA) to amplify and discriminate the readout signals from the strips
- 2 MULTI-HITS TDCs (128 + 64 channels) to reconstruct particle impact point.
- **TRIGGER CARD + GPS UNIT gets the event timestamp in UTC time**

3 MRPC Layers of 1.60 x 0.80 m$^2$ for tracking particles [5]

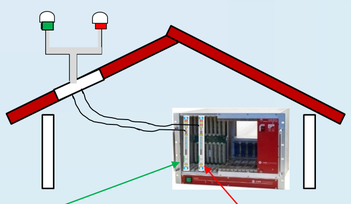
20 Trigger/GPS modules (+4 prototypes) were produced

The Global Time Stamping resolution of the cosmic ray event $\sigma_{GTS}$ should be the sum of :

- $\sigma_{HITS}$, which depends on the signals from MRPCs [5] and on TDC resolution (100 ps)
- $\sigma_{1PPS}$, time resolution for 1PPS:

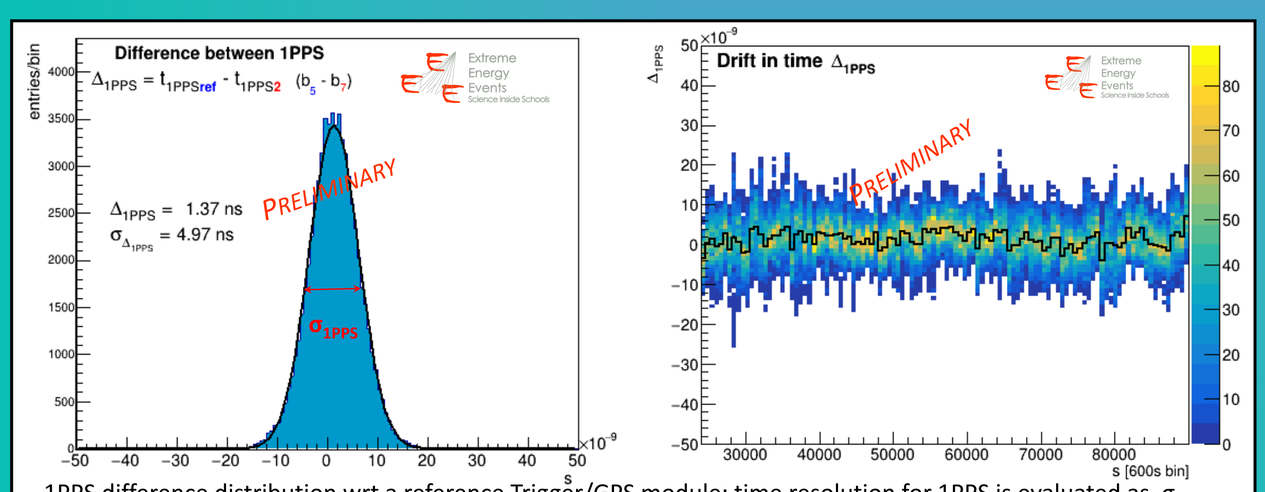
$$\sigma_{GTS}^2 = \sigma_{HITS}^2 + \sigma_{1PPS}^2$$

**Trigger/GPS Module**
**Time resolution for the 1PPS - $\sigma_{1PPS}$**
Test between 2 different modules (same VME Crate)

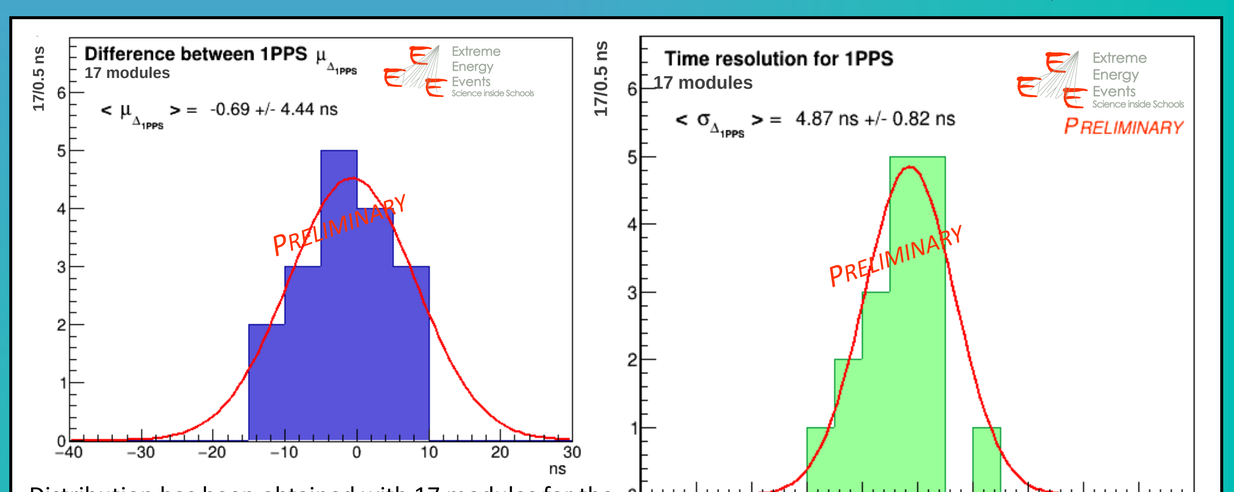



The difference between the signals from the **reference module** $1PPS_{ref}$ and from the other modules $1PPS_{N.}$ was measured with an oscilloscope.

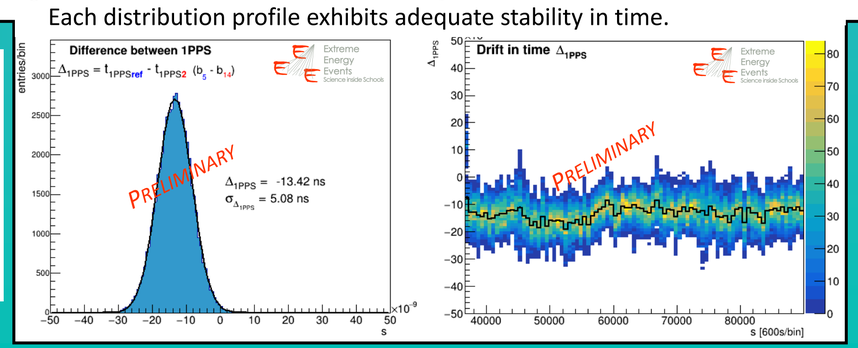
$$\Delta_{1PPS} = T_{1PPSref} - T_{1PPSN.}$$




1PPS difference distribution wrt a reference Trigger/GPS module: time resolution for 1PPS is evaluated as $\sigma_{1PPS}$ from a distribution gaussian fit, for module SN7, SN16 (using module SN5 as reference).
Each distribution profile exhibits adequate stability in time.




Distribution has been obtained with 17 modules for the mean 1PPS difference $\mu_{\Delta 1PPS}$ (above) and for the time resolution $\sigma_{1PPS}$ (on the right).




## Summary

The Trigger/GPS Modules have been produced and tested. Time resolution measurements for 1PPS between 2 different boards and the mean distribution variability exhibit adequate stability in time. Time Stamp jitter measurements are perfectly compatible with the precision timing requirement of the EEE telescopes.

## References

[1] Centro Fermi web site: http://www.centrofermi.it/eee.
[2] A. Zichichi, "La Scienza nelle Scuole" - Progetto EEE : Extreme Energy Events, SIF (2004).
[3] M. Abbrescia et al. (EEE Collaboration), Eur. Phys. J. Plus (2014) 129, 166.
[4] M. Abbrescia et al. (EEE Collaboration), Eur. Phys. J. Plus (2018) **133**, 34.
[5] M. Abbrescia et al. (EEE Collaboration), JINST 7 (2012) P11011 .