EEE Event Reconstruction On GPUs

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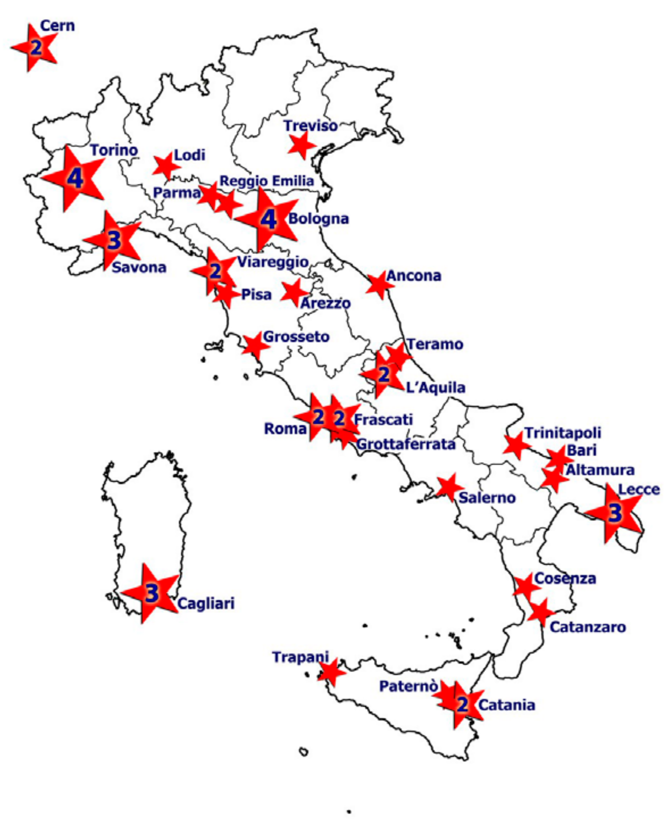
The EEE project is a detector array of Multigap Resistive Plate Chambers located at selected sites on the Italian territory. Goals of the Project includes the study of the properties of the local muon flux and its dependence on planetary and solar environment, the detection of high energy extensive air showers created in the Earth atmosphere by time and orientation correlations between several telescopes, and the search for possible long range correlations between far telescopes.

The EEE Project

The EEE Project is a joint educational and scientific initiative by Centro Fermi (Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi), in collaboration with INFN (National Institute for Nuclear Physics), CERN and MIUR (the Italian Ministry of Education, University and Research). The Project has built and installed an array of cosmic ray detectors, distributed in several sites, spanning all the Italian territory, over an area larger than 3 × 105 km2. The research goals of the Project include the study of the properties of the local muon flux and its dependence on planetary and solar environment, the detection of high energy extensive air showers created in the Earth atmosphere by time and orientation correlations between several telescopes, and the search for possible long range correlations between far telescopes. A powerful impact on education is also envisaged by the EEE Project, which is strongly contributing to introduce a large number of school teachers and students to the problems and results of particle and astroparticle physics. Several results from the EEE Project have already been reported. At present, more than 40 telescopes are actively taking data since several years, and after a Pilot Run at the end of 2014, which resulted in a number of collected events of the order of 10^9, the RUN1 was successfully organized, with about 40 telescopes participating to the data taking for a two months period (March-April 2015) and an overall number of collected events around 4 x 10^9.



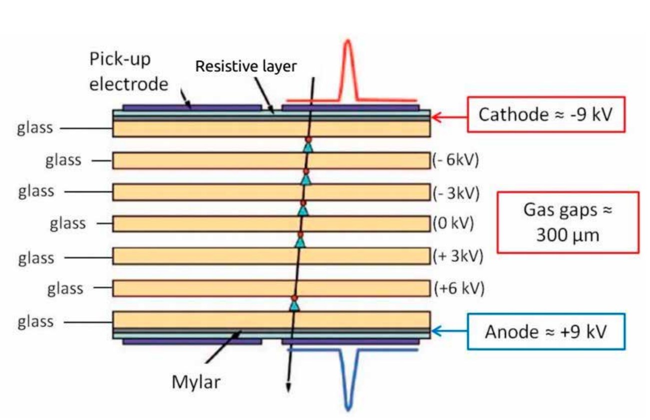
MRPCs in Italy and at CERN.

Liceo *"Cagnazzi"*	Altamura (BA)	Liceo *"A. Scacchi"*	Bari
Liceo *"A.B. Sabin"*	Bologna	Liceo *"E. Fermi"*	Bologna
Liceo *"L. Galvani"*	Bologna	Liceo *"Pacinotti"*	Cagliari
Liceo *"L.B. Alberti"*	Cagliari	Liceo *"Michelangelo"*	Cagliari
ITIS *"S. Cannizzaro"*	Catania	Liceo *"E. Fermi"*	Catanzaro
Istituto *"Villa Sora"*	Frascati (RM)	ITIS *"E. Fermi"*	Frascati (RM)
Polo Liceale *"G. Marconi"*	Grosseto	Liceo *"B. Touschek"*	Grottaferrata (RM)
ITIS *"Amedeo d'Aosta"*	L'Aquila	Liceo *"A. Bafile"*	L'Aquila
Liceo *"G. Palmieri"*	Lecce	ITIS *"E. Fermi"*	Lecce
Liceo *"G. Banzi Bazoli"*	Lecce	Liceo *"G. Marconi"*	Parma
IIS *"L. Nobili"*	Reggio Emilia	Liceo *"G. da Procida"*	Salerno
Liceo *"Chiabrera"*	Savona	Liceo *"O. Grassi"*	Savona
ITIS *"G. Ferraris"*	Savona	ITIS *"E. Alessandrini"*	Teramo
Liceo *"Galileo Ferraris"*	Torino	Liceo *"Giordano Bruno"*	Torino
Liceo *"A. Volta"*	Torino	Liceo *"M. d'Azeglio"*	Torino
Liceo *"S. Staffa"*	Trinitapoli (BT)	Liceo *"E. Barsanti"*	Viareggio (LU)
Istituto Nautico *"Artiglio"*	Viareggio (LU)		

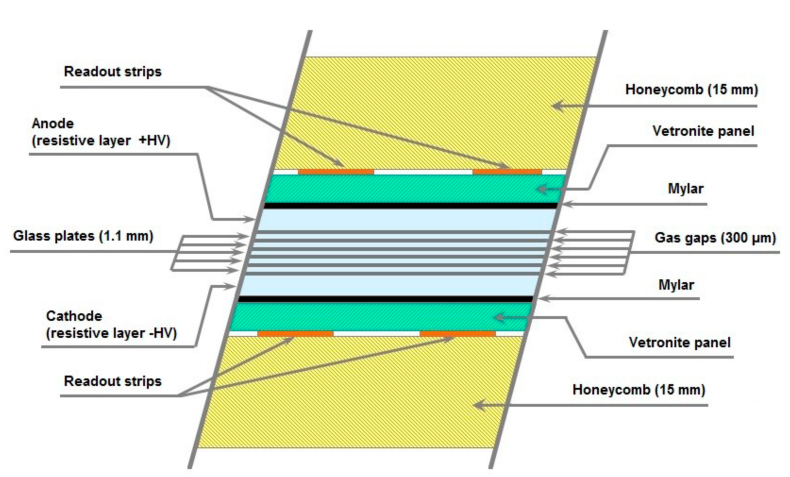
List of schools involved in the project.

Multi-gap Resistive Plate Chambers

The MRPCs consist of six gas gaps, consists two thicker glassplates (1.9mm thick), coated with resistive paint,with five thinner glass plates (1.1mm thick), spaced by 300µm by means of commercial nylon wire; the glass volume resistivity is 1013 Ωcm. Each MRPC features 24, 2.5 cm-wide copper readout strips, separated from each other by 0.7 cm (i.e., a strip pitch of 3.2 cm) and an overall active area of 0.82×1.58 m2; these readout strips are mounted on external fiberglass panels. The MRPCs are flushed with a 98% of C2H2F4 and 2% of SF6 gas mixture. The chambers are operated in avalanche mode with a typical operating voltage around 18 kV supplied by DC/DC converters.



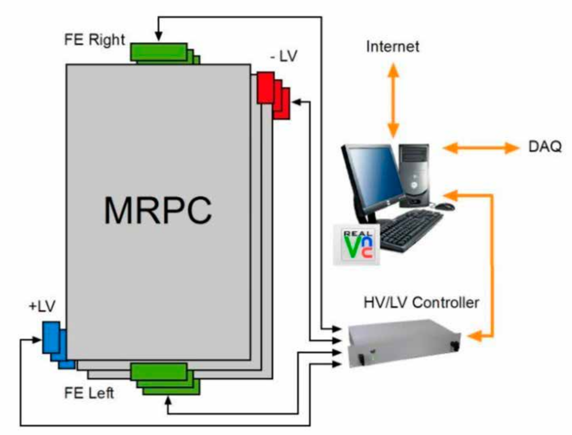
Inner structure of an MRPC



MRPC with mechanical structure

EEE Events and Reconstruction

When an ionising particle passes through the gas, it creates a number of primary ion-electron pairs, which exponentially grows in the avalanche process. Since MRPCs glass plates have high resistivity, they act as dielectric plates for the fast signal produced by the drift of the electrons in the gas avalanches. The induced signal, picked up by the copper strips, corresponds to all gas avalanches in all the gas. These signals are transmitted to the front-end boards (FEA) mounted at the two ends of the chamber. The signals coming from the FEAs on each telescope are processed by a trigger card in order to provide information to the VME-based data acquisition. A six-fold coincidence of both front-end cards of the three MRPCs generates the data acquisition trigger. The particle impact point is determined by the position of the hit strip in one direction; in the other direction the difference of signal arrival time at the strip ends, measured by two multi-hit TDCs, localises the position along the lenght of the strip. At the operating voltage, the measured MRPC efficiency is typically 95%. The TDCs are operated with a 100ps bin width, so that strip dimension and time difference provide an overall spatial resolution of about 1 cm along the two coordinates. The absolute time of each event is recorded and synchronised by means of Global Positioning System modules, in order to get the event time stamp and to correlate the information collected by different telescopes. The data acquisition is controlled by a LabView program running on a PC connected to the VME crate via an USB -VME bridge.

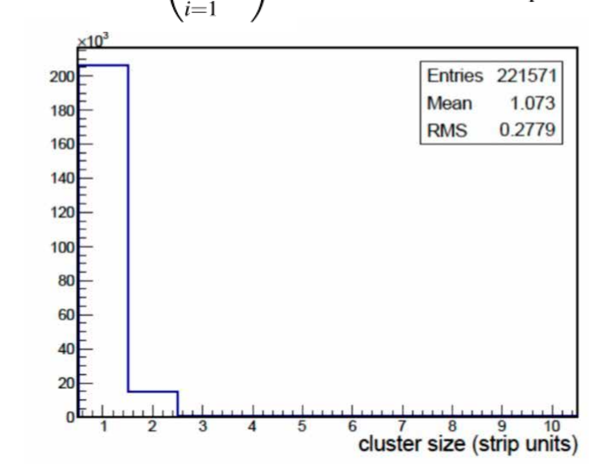


EEE Telescope setup

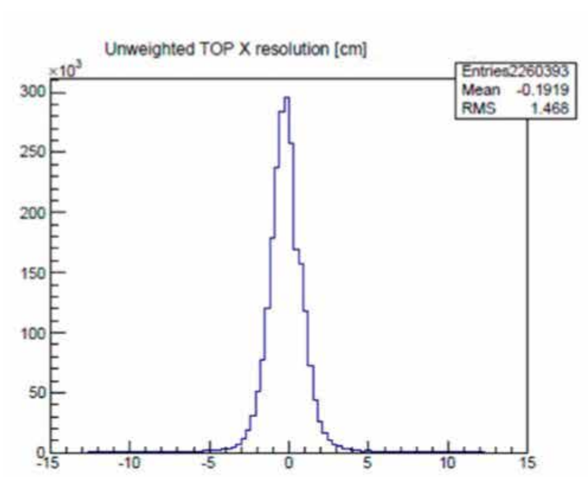
NINO Frontend card

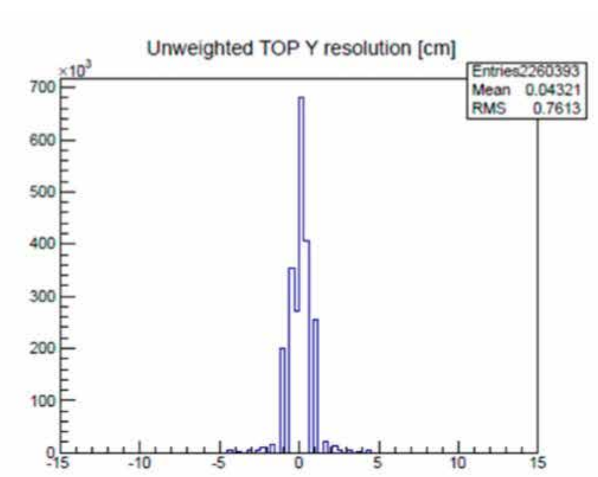
The first step of the event reconstruction is a clustering stage, where hits in the detector that are contiguous to each other are grouped into clusters. The average cluster multiplicity for typical atmospheric-muon events is low—one cluster per plane for the majority of the events. We feed the cluster coordinates into two independent unweighted linear fits to triplets of points in the two orthogonal x–z and y–z views. The two fits are then combined to provide the best-fit track parameters, i.e., the direction cosines and the track intercept with the middle MRPC plane. We define the square root d of the quadratic sum of the three-dimensional distances d_i between the cluster positions and the best-fit track

$$\bar{d} = \left(\sum_{i=1}^{3} d_i^2\right)^{\frac{1}{2}} \qquad \beta = \frac{v}{c} = \frac{l}{cT_f}$$



and use it as an indicator of the fit quality (the index i in the sum is running over the three MRPC planes). When the cluster multiplicity in one or more planes is greater than 1, all the possible triplets of points are fitted and the track with the lowest d is used in the analysis. The ¯ d value for the best track can amount to several cm for low-energy particles, and in the remaining of this work we do require events to have d < 10 cm in order to be included in the analysis. We anticipate, however, that our conclusions are largely independent from the precise choice of the cut value. The time of flight T_f of each event is measured as the time difference between the hits in the uppermost and lowermost MRPC planes. These two planes are physically fed into the same time-to-digital converter and the resolution on the time of flight is of the order of a few hundreds of ps or better. For a typical track length l~1 m (or T_f~3 ns), this translates into a relative error on the measurement of the velocity of ~10% for an ultra-relativistic particle.

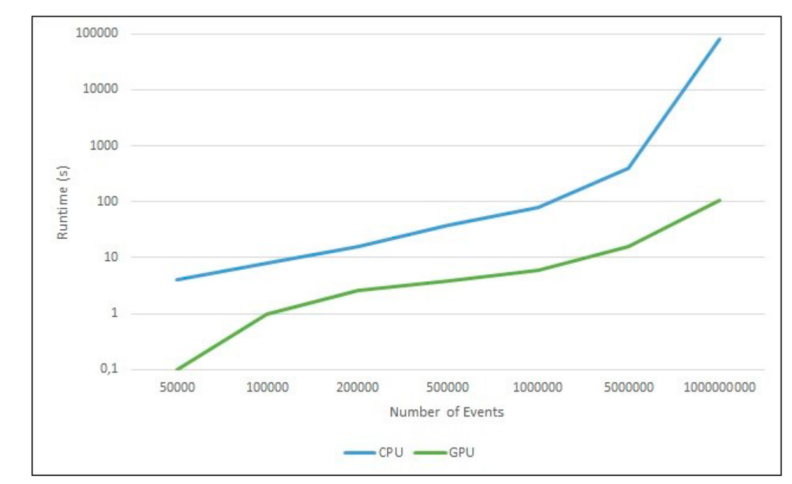




Results, conclusions

To test our approach we compared it to the exisiting reconstruction program, that is running on the CPU, running on real world data collected from the italian telescopes.

Test system			
CPU	GPU	Memory	OS
Core i7 4710 @2.5 GHz	GTX 980M 4 GB	24 GB	Windows 10 x64



Evaluating the runtimes from the original system and from the GPU accelerated solution, we can see that the peformance of the proposed system is a 100 times faster than the current system. Have to point out that the actual reconstruction is a sequential process.

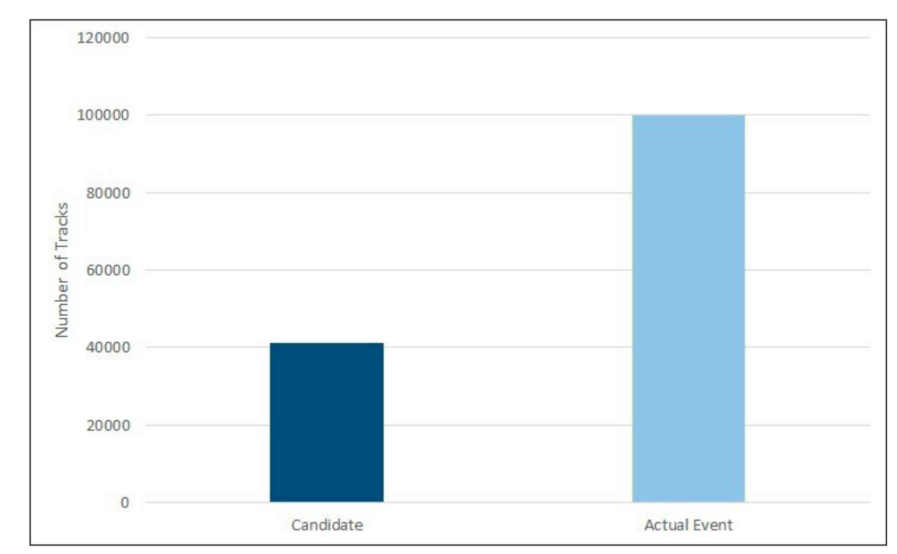


Chart representing the number of the candidate tracks and the number of the real events (Data file of Telescope CT-01 from 02-2013).

Conclusions

1. Thanks to the GPUs the reconstruction phase of the EEE projects data can be very fast and efficient,
2. With the proposed method the runtime of the system is a 100 times faster compared to the actual sequential solution,
3. This way further analyzation and processing can be started sooner on more reconstructed data at once,
4. More telescopes are joining the data taking, which will result in even more data,
5. Many candidate tracks are not real events (noise or hardware error),

Goals

6. Involve in the modification the analyzer algorhtms too, make them run on the GPU as well,
7. Evaluate the possibility to do online reconstruction to send the real event candidates only,
8. Involve the students in the reconstruction part after the development phase.

Reference

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