The Extreme Energy Events Project and its most recent results

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The Extreme Energy Events (**EEE**) **Project** [1] [2] is devoted to the study of the **Extensive Air Showers (EAS)** produced by the impact of primary cosmic rays with an energy greater than 10^{11}eV on the Earth's atmosphere. This is accomplished through a network of muon telescopes on ground level distributed throughout the Italian territory plus CERN. Each telescope consists of three **Multigap Resistive Plate Chambers** (MRPC) used for particle detection and tracing. They are operated **in avalanche mode** with characteristics similar to the ones built for the Time Of Flight array of the ALICE at LHC [3]. The project started with **a few pilot stations taking data since 2008**, and it has been constantly extended, reaching **at present more than 50 MRPCs telescopes,** spread across an area of 3 x 10^5 km^2. The telescopes stations are located inside italian High Schools and **young students are directly involved in operating and monitoring the telescopes,** with the aim to introduce them to **the methods and results of particle and astroparticle physics**.

References

[1] Centro Fermi web site: http://www.centrofermi.it/eee.
[2] A. Zichichi, Progetto "La Scienza nelle Scuole" - EEE:Extreme Energy Events, SIF (2004)
[3] M. Abbrescia et al. (EEE Collaboration), JINST 7 (2012) P11011 .
[4] F. Noferini et al. (EEE Collaboration), Nucl. Instrum. Meth. A 820 (2016) 329-300.
[5] M. Abbrescia et al. (EEE Collaboration), Eur. Phys. J. Plus (2014) 129, 166.
[6] https://eee.centrofermi.it/monitor/
[7] M. Abbrescia et al. (EEE Collaboration), Nucl. Instrum. Meth. A 816 (2016) 142-148.
[9] M. Abbrescia et al. (EEE Collaboration), Eur. Phys. J. Plus (2013) 128, 62.
[8] M. Abbrescia et al. (EEE Collaboration), Eur. Phys. J. Plus (2015) 130, 187.

Geographical latitudes between 37° and 46° North

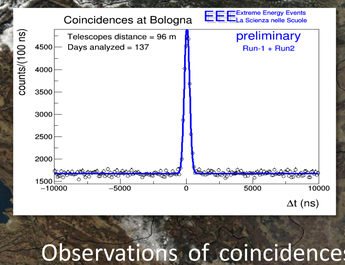
The EEE MRPC **telescopes are housed in High Schools and managed by groups of students and teachers, who previously took care of the MRPC construction at CERN** [1]

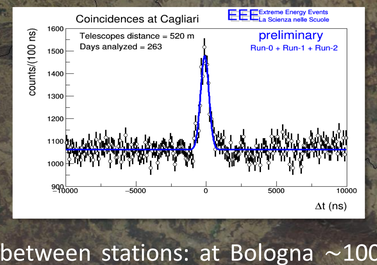
The network is organized in **clusters of 2, 3 and 4 telescopes within the same city**, and **single telescopes** stations tens or hundreds of kilometers apart.

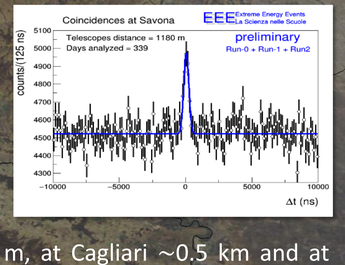
The EEE Clusters

Extensive Atmospheric Showers Detections

The detection of an EAS is achieved by measuring the coincidences recorded at the different sites of the EEE Telescopes Array.

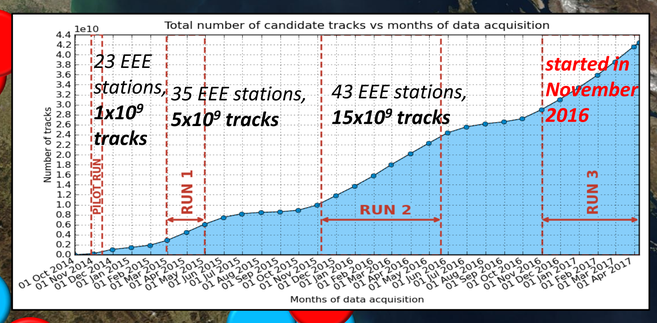




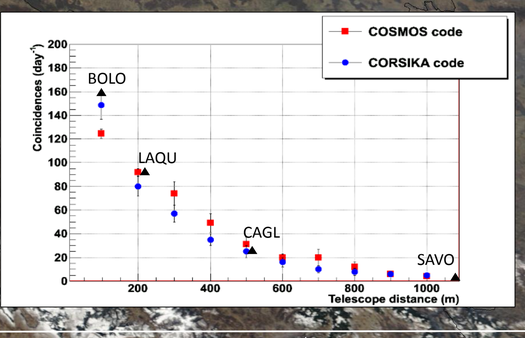


Observations of coincidences between stations: at Bologna ~100 m, at Cagliari ~0.5 km and at Savona ~1.2 km. The results are in agreenment with the monte carlo simulation [5]

The Coordinated Data Acquisition



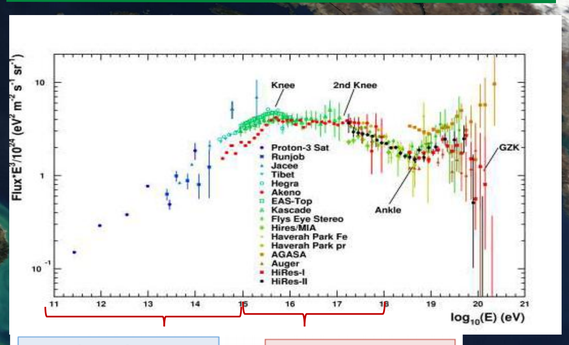
The EEE network data taking is organized in **coordinated runs**, during which the telescopes **inside the schools** are regularly monitored by means of automated reports from CNAF and daily report from the EEE student teams [6].



EEE Sparse Array

The EEE Clusters

The EEE Sparse Array



Single telescope sensitivity

Multi-telescope analyses

- 46 EEE Station in school buildings
- 4 at INFN sections
- 2 at CERN
- 20 new stations under costruction at CERN

The EEE Station

The design of the EEE telescope allows to detect muons with high efficiency and back-tracked with good angular resolution [3].

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

- **3 MRPCs** of 1.60 x 0.80 m^2 sized
- filled with a mixture of $C_2H_2F_4$ **(98%)** and SF_6 **(2%)**
- **24 readout copper strips** as electrodes, pitch of 3.2 cm
- **HV** up to **20 kV**
- **GPS UNIT** gets the event time stamp in UTC time
- Weather Station
- DATA are transferred and stored to INFN computer centre (CNAF), an all data reconstruction algorithm is immediately applied [4].

Single EEE Station

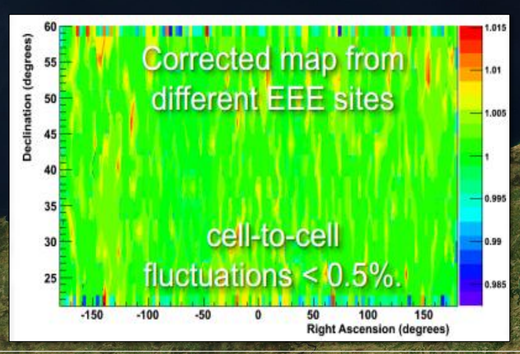
Single EEE Station

Single EEE Station

EEE Sparse Array

Anisotropy at Sub-TeV Scale

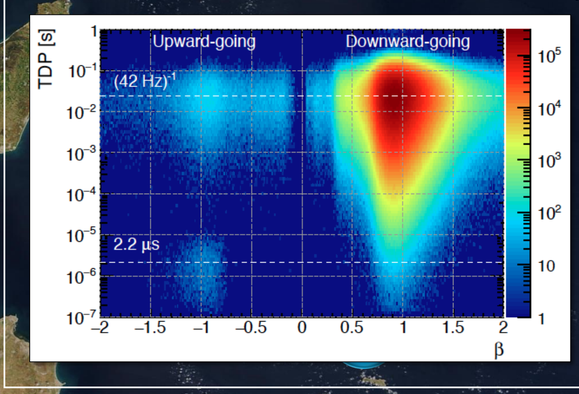
An analysis of 10^9 dataset of cosmic muon tracks has been carried out in order to search for small anisotropies of the muon **flux at the subTeV sky** [9]. Data maps are compatible with an **isotropic distribution at the level of 5 × 10^{-3}-10^{-2}**.



Muon Decay in Up-going Events

Up-going events are observed, ~0.05%, in EEE telescopes.

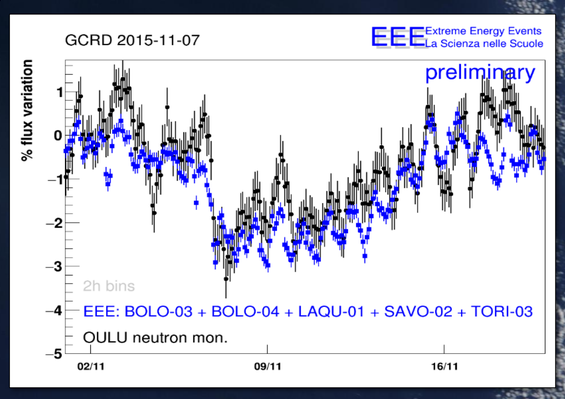
A fraction of them < 6% can be clearly identified as **electrons coming from muon which** stops in the ground and decays. The two events are discriminated in time with a **delay equal to the muon lifetime** τ~2.2 μs [8].



Distribution of the delay between the upward track and the previous downward event

Galactic Cosmic Ray Decreases

The MRPC network is able to detect the rapid variations, ~ 5% , of the Galactic Cosmic-Ray flux GCRDs [7], associated to solar phenomena as Coronal Mass Emissions, solar flares. **The EEE observations are highly correlated with neutron monitor stations.**



Flux decrease as observed by 5 EEE stations compared to neutron rate from the Oulu neutron monitor station Finland.

Map of the EEE Network sites (in red)