OUTREACH AND EDUCATIONAL ACTIVITIES WITHIN THE EEE COSMIC RAY NETWORK

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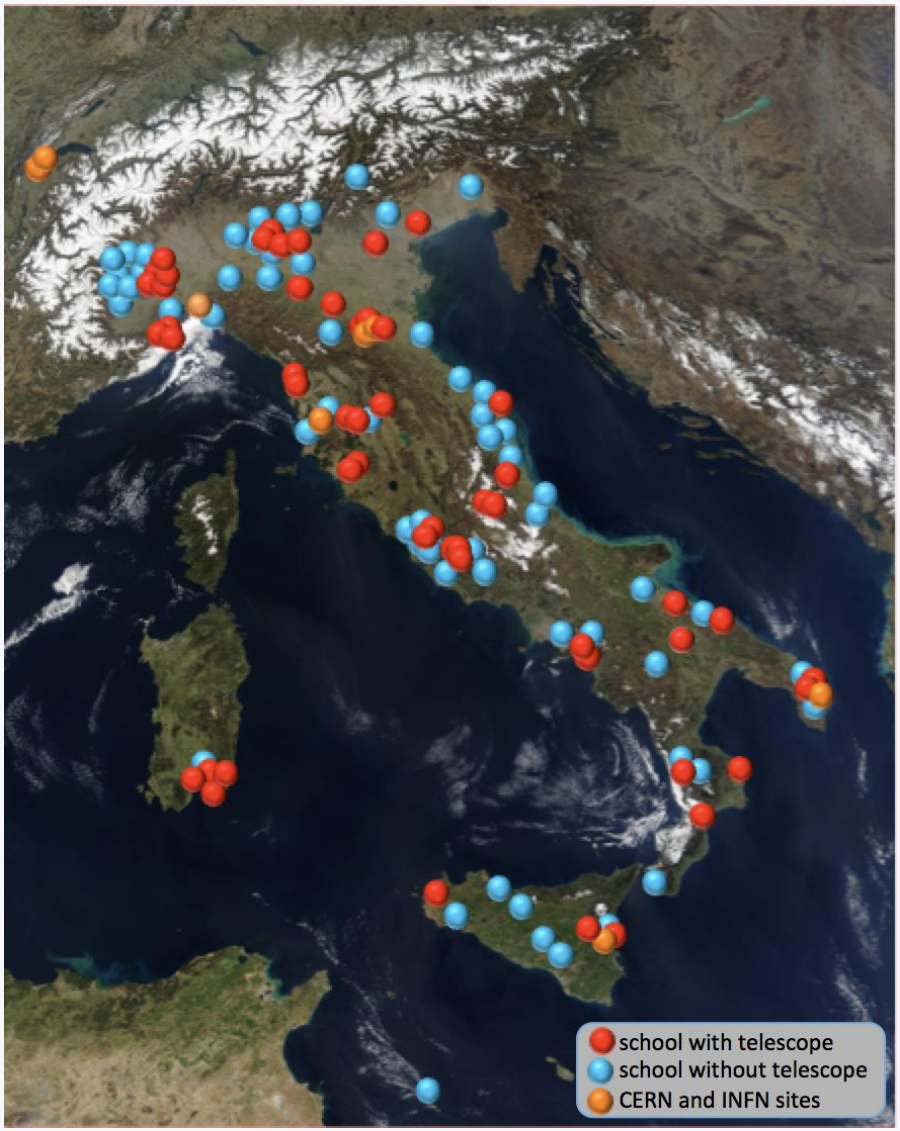
CENTRO RICERCHE ENRICO FERMI

Extreme Energy Events Science inside Schools

EEE network

https://eee.centrofermi.it/

Extreme Energy Events Project: collaboration of Centro Fermi, INFN, CERN & MIUR



It aims at the detection of cosmic ray muons by means of a *sparse array of telescopes*, distributed over the Italian territory and at CERN, spanning an area of over 10^5 km^2

- > 50 telescopes in high schools
- 2 telescopes at CERN
- 5 at INFN Sections + Centro Fermi

Total: ~ 60 telescopes

(+50 institutes on the waiting list)

Network of telescopes based on Multi-gap Resistive Plate Chambers (MRPC)

EEE Telescopes

EEE station → telescope of 3 MRPC (~ 80 x 160 cm^2)

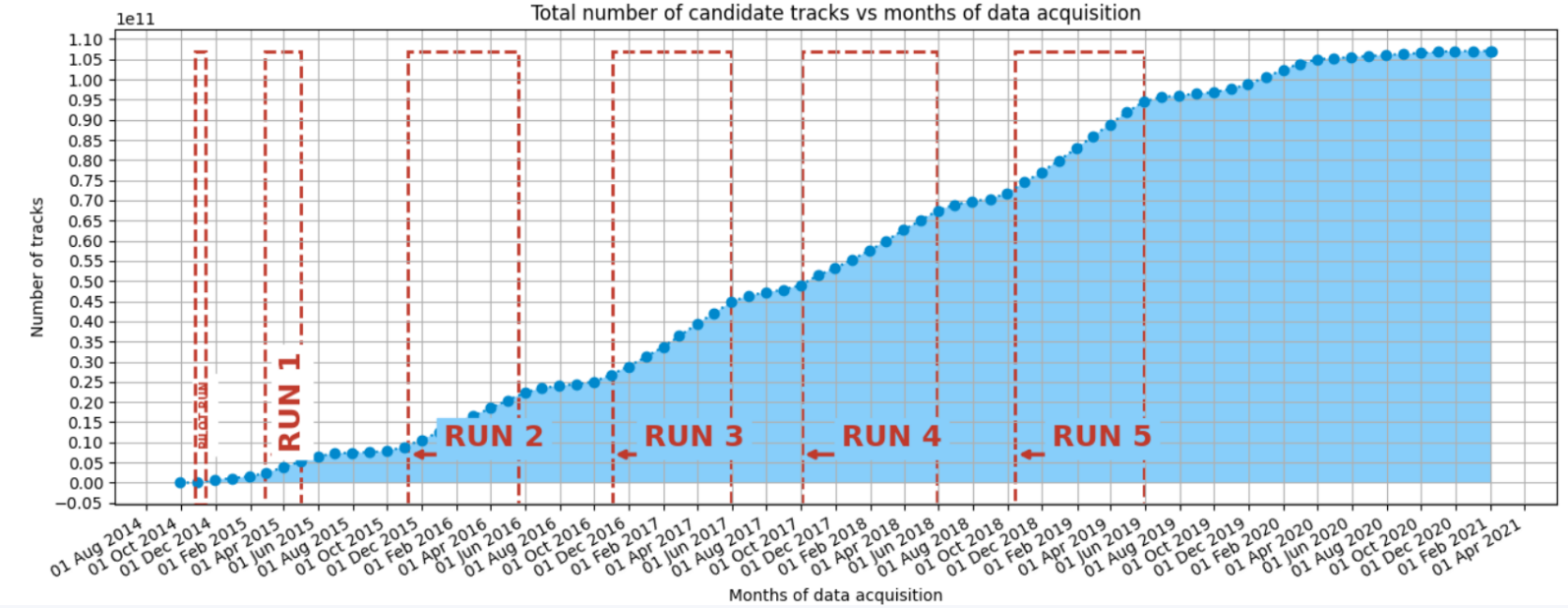
- Chambers built by students and teachers at CERN
- Reasonable cost
- Long term operation required
- Reconstruction of muon orientation
- TOF measurements

Performance of the MRPCs:

- Time Resolution ~ 240 ps
- Longitudinal Spatial Resolution ~ 1.5 cm
- Transverse Spatial Resolution ~ 1 cm
- Efficiency > 90 %
- Synchronization guaranteed by a GPS unit (precision of ≈ 40 ns)

EEE data taking and upgrade

About 100 billion events collected since the start of organized data taking



http://eee.centrofermi.it/monitor

UPGRADE PLANS:

- Recently built new 50 chambers (new telescopes and spares)
- New test protocol at CERN
- New 250 µm six-gap chambers (lower operating voltage, eco-friendly gas)
- Improved FE boards
- New trigger & GPS board

EEE project goals

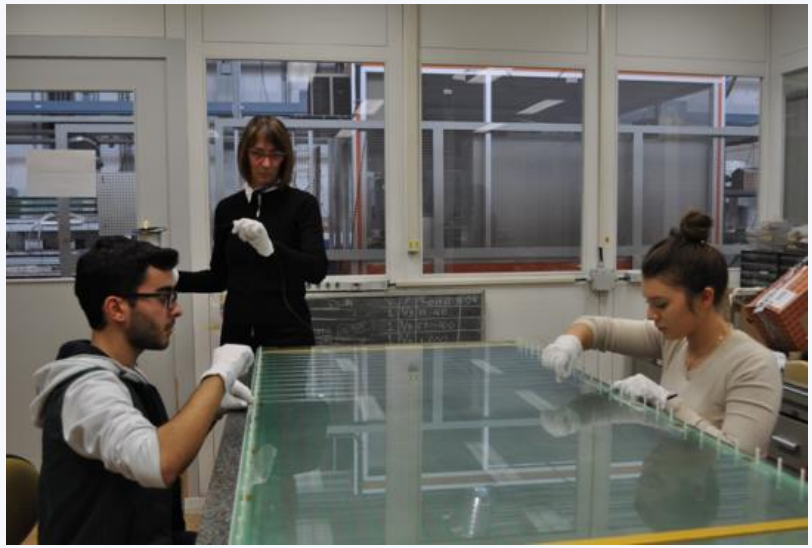
* See talk by P. La Rocca @Presenter Forum

- **Scientific activities** of EEE project mainly focused on:
  - search for anisotropies of the secondary component,
  - extensive air shower detection,
  - long distance correlation studies*,
  - performance and simulation tools development,
  - monitoring of the muon flux,
  - study of solar phenomena (Forbush decreases, ...),
  - applications of cosmic ray physics
  - …

- **Educational activities** of EEE project → to provide a full research experience to high-school students
  - EEE telescopes are installed in Italian high-schools
  - students take part to the detector construction at CERN, to its installation and commissioning in their schools
  - students attend monthly meetings, presenting updates on ongoing analysis, tests and detector status
  - students attend bi-annual conferences where masterclasses, measurement campaigns and general lectures are organized
  - data-analysis sessions, such as the International Cosmic Day

Detector construction @CERN

- MRPCs are built at CERN by students and teachers of the EEE network, under the supervision of CERN and EEE researchers
- After the construction, the telescopes are sent and installed in schools
- After commissioning of the station, data taking operations start
- Students take care of the operation, monitoring and maintenance of the telescopes



Students play an active role in the experiment!

Daily activities and monitoring

Students take care of the daily monitoring activities

1. Report of data acquisition conditions into an online elog
   - weather parameters,
   - HV and current settings
   - acquisition rate, ...

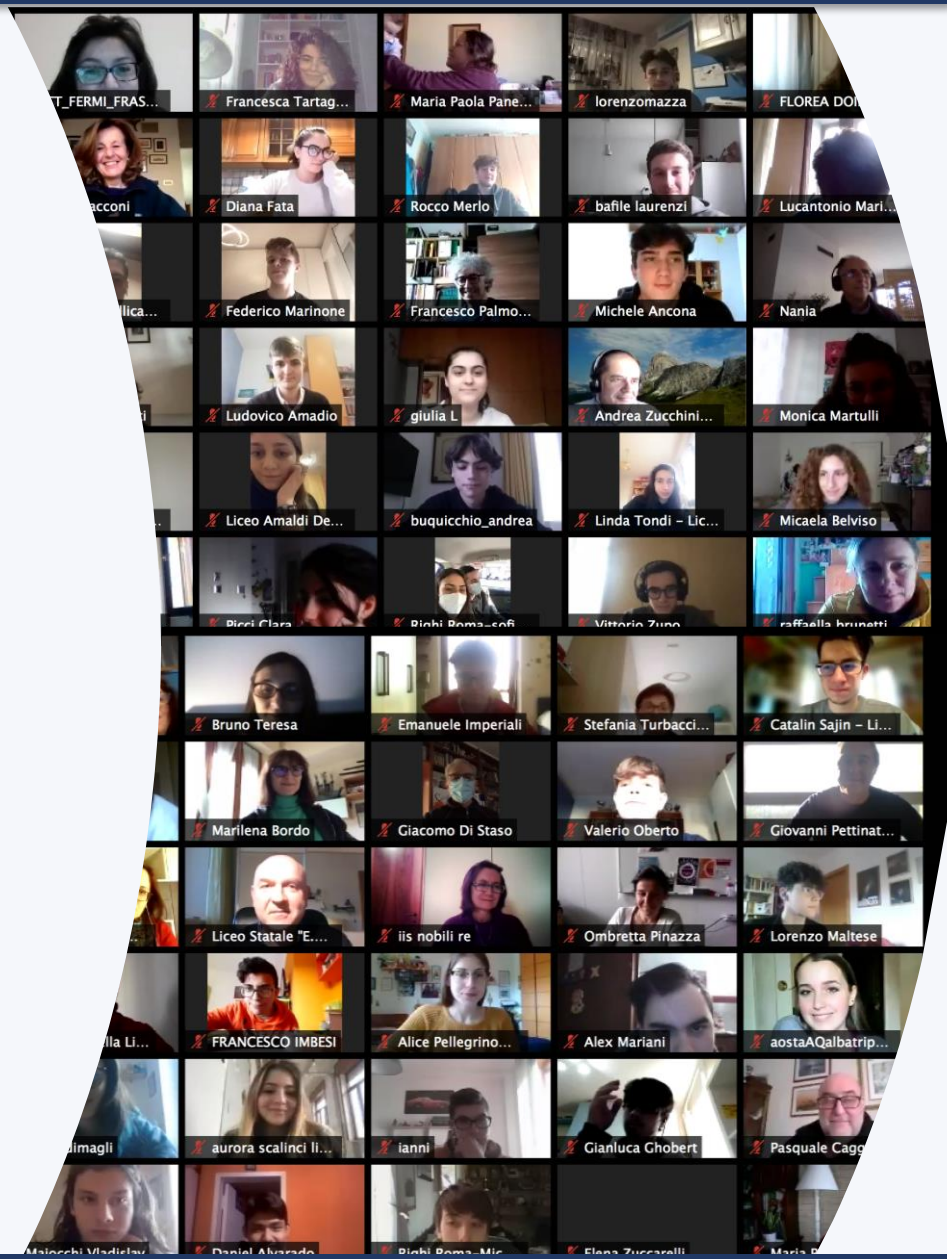
2. Quality checks of data on the local acquisition system for each run

3. In case of issues, students and teachers refer to a local referent (EEE researcher)

General meetings...

Run Coordination Meetings – every month

- Online meetings (through vidyo or zoom) organized to allow all participating students (hundreds) to review the RUN status, exchange ideas, doubts and experiences, and to present their own work
- Lectures on Cosmic Rays and Data Quality Monitoring are provided
- Masterclasses on the relevant tools for data analysis (ROOT, statistics etc)



...and symposia

Conferences with schools of the network – every 6 months

- 3-days events, once per year hosted by *Ettore Majorana Foundation And Centre For Scientific Culture* @Erice

- students present their work, take part to masterclasses and participate to measurement campaigns

- also aiming to encourage cooperation between distant schools

International Cosmic Day

https://icd.desy.de/

ICD with schools of the network – every year

- Students, teachers and scientists get together to talk and learn about Cosmic Rays and perform an experiment with atmospheric muons
- Students work together like in an international collaboration, discussing their results in joint video conferences
- Scientists join the video conferences and give lectures to provide an insight into current astroparticle physics research

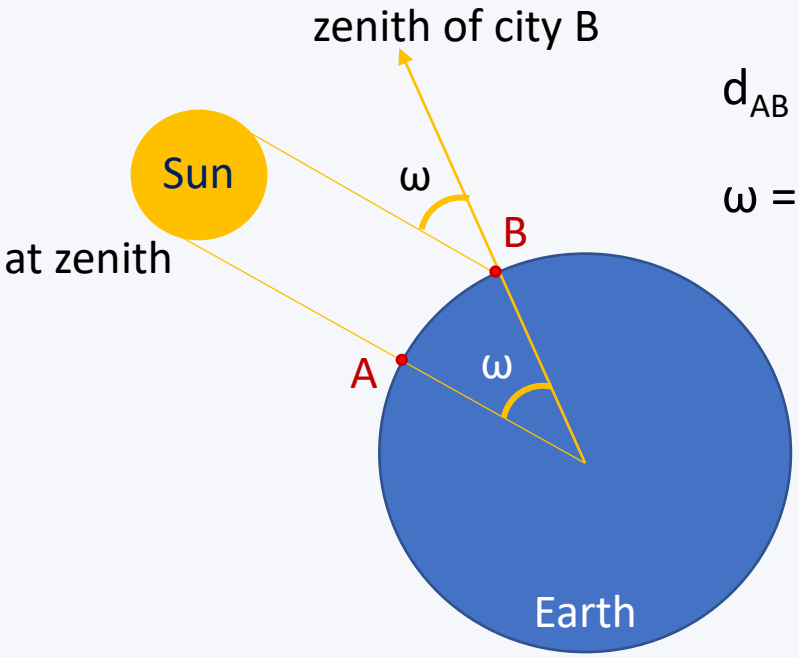
Outreach activities

Measurement of Earth radius – Eratostene's experiment

Erice, Lodi, Torino, Treviso & Milano

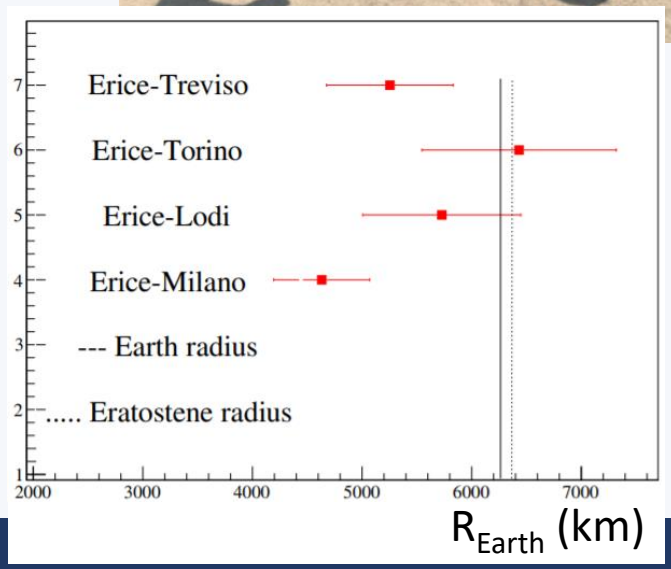
What is needed?

- wooden pole
- flat floor
- bubble level, set square & measuring tape
- a lot of high-school students!



$$d_{AB} = \omega \, R_{Earth}$$

$$\omega = \arctan\left(\frac{L_{shadow}}{L_{pole}}\right)$$

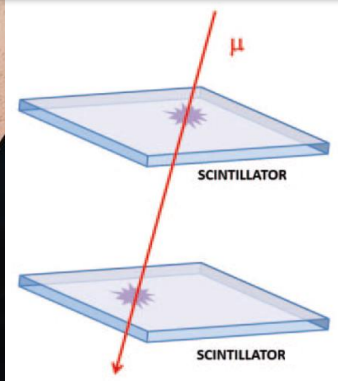


Outreach activities

Measurement of cosmic ray flux variations with altitude

How Using a *cosmic box* made of 2 scintillator tiles

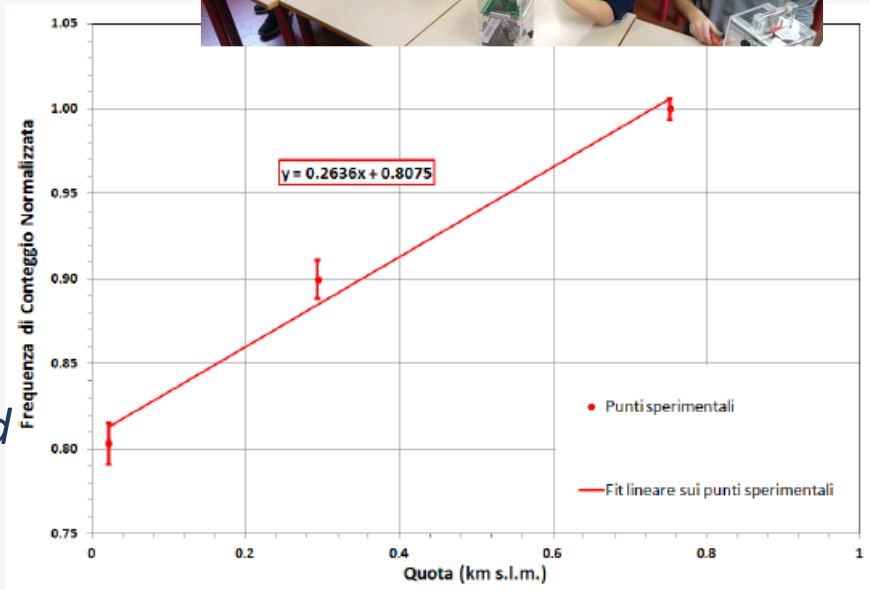




What Measurement of the cosmic ray flux carried out from the sea level up to an altitude of 760 m

Who Students and teachers from 44 Italian high-schools

Where At the *Ettore Majorana Foundation and Center for Scientific Culture* in Erice, Segesta, Castellammare (Sicily)

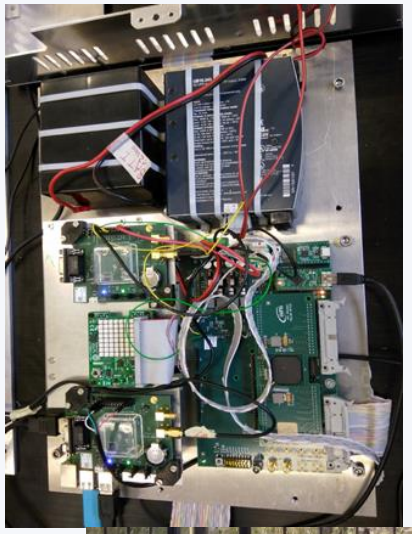


Polar quEEEst project – I

See talk by M. Abbrescia @Presenter Forum

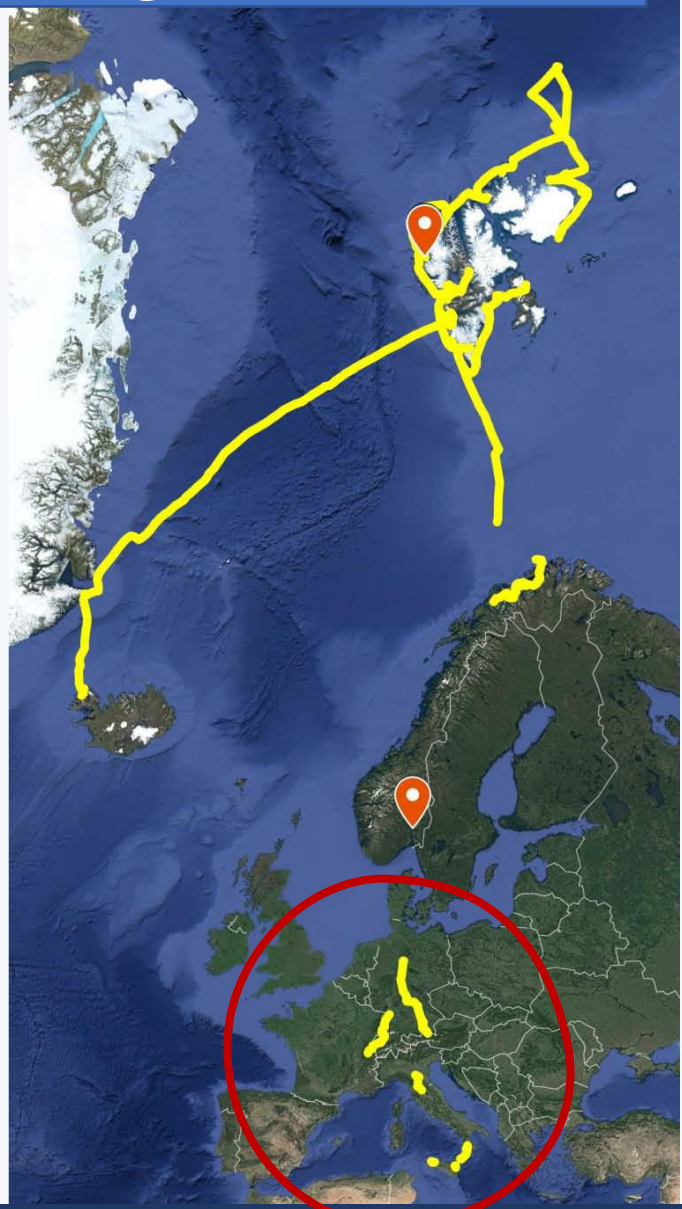
Polar is one of the three detectors of the PolarquEEEst project by Centro Fermi

Assembled at CERN by high school students



- 2 Plastic scintillator planes
- Distance between planes: 11 cm
- 4 Tiles for each plane: 30 cm x 20 cm
- 2 SiPMs per tile (16 SiPMs in total)

- ✓ Nanuq
- ✓ Genova
- ✓ Vigna di Valle (Rome)
- ✓ Cosenza
- ✓ Messina
- ✓ Cefalù (Palermo)
- ✓ Erice (Trapani)
- ✓ Catania-Etna
- ✓ Lampedusa
- ✓ Bologna
- ✓ Munich
- ✓ Hannover
- ✓ Frankfurt am Main
- ✓ CERN



Polar quEEEst project – II

- Cooperation with CNR to systematically study cosmic rays at extreme latitudes
- EEE and CNR researchers installed in the arctic base Dirigibile Italia in Ny Ålesund (Norway) a cluster of *Polar* detectors to observe extended showers
- Since May 2019 the cluster of *Polar* detectors is taking data and it is daily monitored by students and researchers of the EEE Collaboration

Summary

- Network continuously *growing* and successfully *operating* for 17 years
- Coordinated data taking periods over a long time → *100 billion tracks* collected
- Excellent performance in terms of time and spatial resolution and efficiency allow a *large physics program*
- *Educational aspects* are the strong point of the EEE project
- *High-school students* strongly involved in all the relevant steps of the project: from the construction to data taking operations

(Non-comprehensive) publication list

❑ Construction and performance

- Performance of a six gap MRPC built for large area coverage, NIM A593(2008)263
- Extreme Energy Events project: construction of the detectors and installation in italian high schools, NIM A588(2008)211
- The EEE Project: cosmic rays, multigap resistive plate chambers and high school students, JINST (2012) 7 P11011
- Recent results and performance of the multi-gap resistive plate chambers network for the EEE Project, JINST, 11 (2016) C11005
- The Extreme Energy Events experiment: an overview of the telescopes performance, JINST (2018) 13 P08026
- The cosmic muon and detector simulation framework of the extreme energy events (EEE) experiment, Eur. Phys. J. C (2021) 81:464

❑ Physics results

- Observation of the February 2011 Forbush decrease by the EEE telescopes, Eur. Phys. J. Plus (2011) 126, 61
- Time Correlation measurements from extensive air showers detected by the EEE telescopes, Eur. Phys. J. Plus (2013) 128, 148
- The EEE experiment project: status and first physics results, Eur. Phys. J. Plus (2013) 128, 62
- Looking at the sub-TeV sky with cosmic muons detected in the EEE MRPC telescopes, Eur. Phys. J. Plus 130 (2015) 187
- Results from the observation of Forbush decreases by the Extreme Energy Events experiment, PoS (ICRC 2015) 097
- A study of upward going particles with the Extreme Energy Events telescopes, NIM A 816 (2016) 142–148
- The EEE MRPC telescopes as traking tools to monitor building stability, JInst 14 (2019) C05022
- New high precision measurements of the cosmic charged particle rate beyond the Arctic Circle with the PolarquEEEst experiment, EPJ C (2020) 80:665

❑ Upgrade

- The new trigger/GPS module for the EEE project, NIM A936 (2019) 376
- Test of new eco-gas mixtures for the multigap resistive plate chambers of the EEE project, NIM A936(2019)493
- New eco-gas mixtures for the Extreme Energy Events MRPCs: results and plans, JInst 14 (2019) C08008
- First results from the upgrade of the Extreme Energy Events experiment, JInst 14 (2019) C08005

❑ Outreach

- EEE Project - Students from all parts of peninsula collaborate to study cosmic rays, PoS Volume 314, (EPS-HEP2017) 823
- How does cosmic ray flux vary with altitude? Let's ask it to EEE project students, Giornale di Fisica, VOL. LIX, N. 3, Lug – Sett 2018
- Gli studenti del progetto EEE sulle orme di Eratostene per la misura del raggio della Terra, Giornale di Fisica 60 (2019) 107

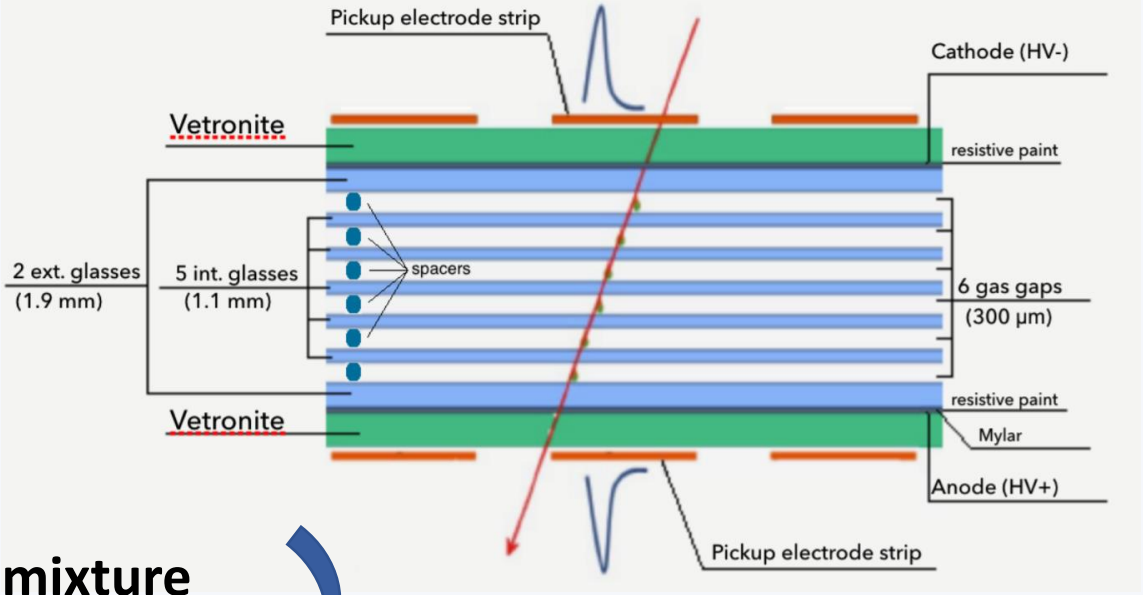
see more @ https://eee.centrofermi.it/research/pubblicazioni

BACKUP

EEE Telescopes

- Chambers built by students and teachers at CERN
- Reasonable cost
- Long term operation required
- Reconstruction of muon orientation
- TOF measurements

INNER STRUCTURE



Chambers filled with a gas mixture 98% / 2% of Freon and SF_6

TOP VIEW