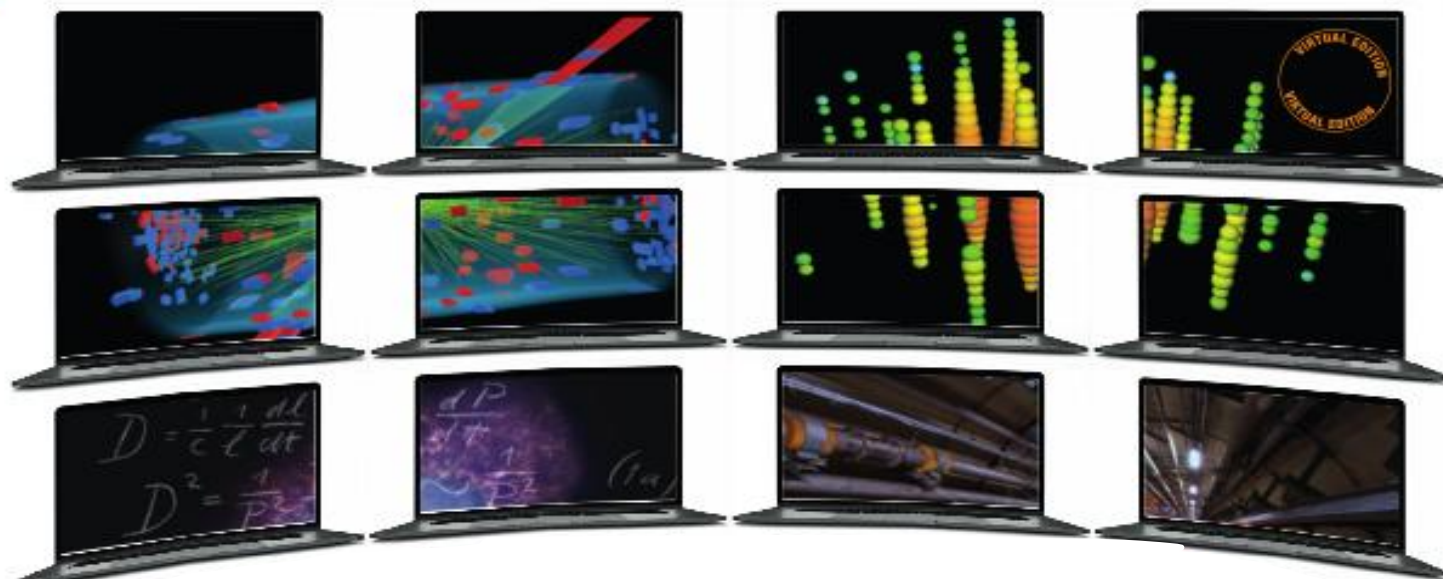




- Astroparticle Physics and Gravitational Waves
- Cosmology
- Neutrinos and Dark Matter
- Flavour and CP Violation
- Standard Model and Beyond
- Electroweak Symmetry Breaking
- Quantum Field Theory and String Theory
- QCD and Heavy Ions
- Accelerators and Detectors
- Outreach, Education and Diversity



International Advisory Committee:
Luca Ballelli (Zurich, CH), Martina Bussan (Bari, IT),
Fabioazzi (INFN, IT), Clément Caprini (Paris, FR),
Marcello Caruso (INFN, IT), Roberto Corin (Padova, IT),
Lance Dawson (SLAC, US), Anne-Kristine Eklund (RFS-CERN, FR),
Fabrice Gianotti (CERN, CH), Christophe Graben (DESY, DE)

Education and outreach activities in the Extreme Energy Events Project

M. P. Panetta* for the EEE Collaboration

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The EEE Project

The **Extreme Energy Events (EEE)** Project is an experiment for the detection of **Extensive Air Showers (EAS)**

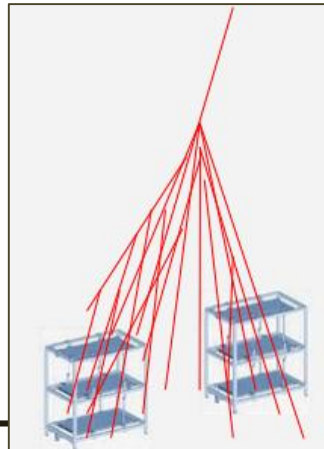
It is a joint **scientific** and **educational** collaboration between CENTRO FERMI, INFN and CERN



The project consists of a **Network** of **cosmic ray muon telescopes** distributed over the Italian territory and at CERN

The detection of an EAS is achieved by measuring the coincidences recorded at the different sites of the EEE cosmic ray Network.

The EEE muon telescopes are based on **tracking detectors** each made of 3 **Multi-gap Resistive Plate Chambers (MRPCs)**.



The EEE telescopes distribution



11 deg Latitude

10 deg Longitude

The EEE Network distribution

EAS studies need “extreme” large detection areas for several years.

First pilot stations (2008)  **> 60 EEE telescopes** across an overall area of $\sim 3 \times 10^5 \text{ km}^2$

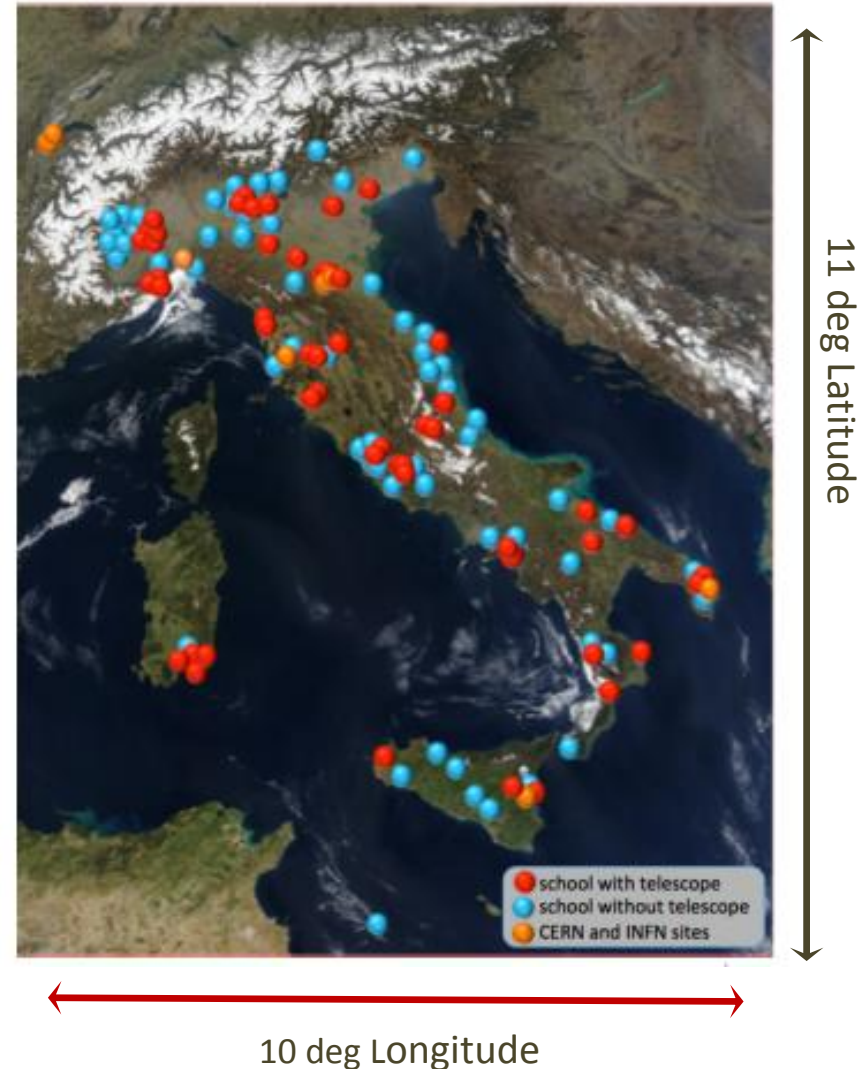
In 2019  8 new stations

- 55 EEE Station in school buildings
- 5 at INFN sections
- 2 at CERN

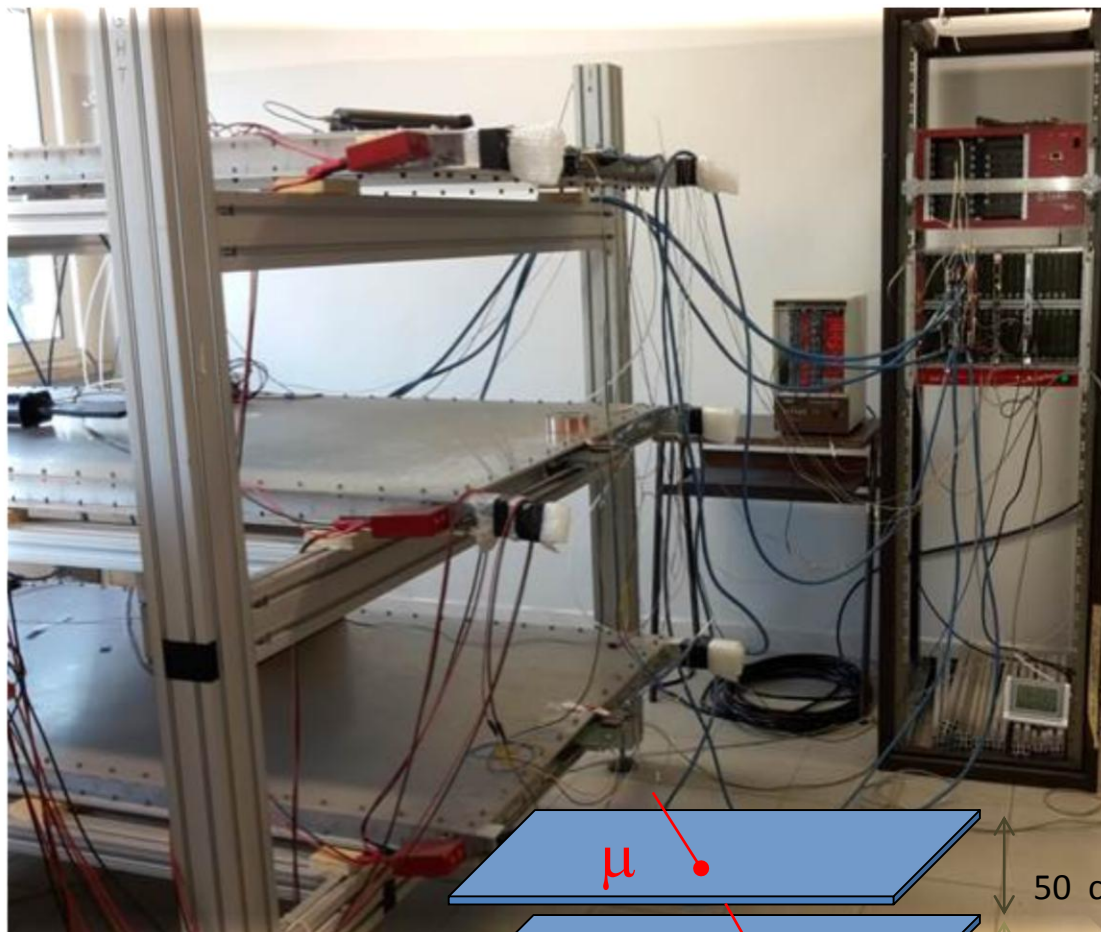
The EEE Network is organized in telescopes clusters (10m -4 km d.) and single telescope stations.

Most of the EEE telescope stations are located inside Italian High Schools !

The EEE telescopes distribution



3 MRPC Layers for tracking particles



- ✓ **Large MRPCs** $1.60 \times 0.80 \text{ m}^2$
Gas detectors
Tracks reconstruction and ToF measurements
- ✓ VME Bridge, Multi-Trigger Card, Multi-hits TDCs
- ✓ DAQ connected to a PC via USB, controlled by LabView program
- ✓ **GPS unit** provides the event time stamp to synchronize information
- ✓ **Performance:**
Time Resolution $\sim 240 \text{ ps}$
Longitudinal Spatial Resolution $\sim 1.5 \text{ cm}$
Transverse Spatial Resolution $\sim 1 \text{ cm}$
- ✓ **Mean muon rate in the telescopes**
30 Hz
- ✓ Data sent to **INFN CNAF** (Bologna) to be stored, reconstructed and analysed

The EEE Project: a dual role

Scientific instrument for physicists

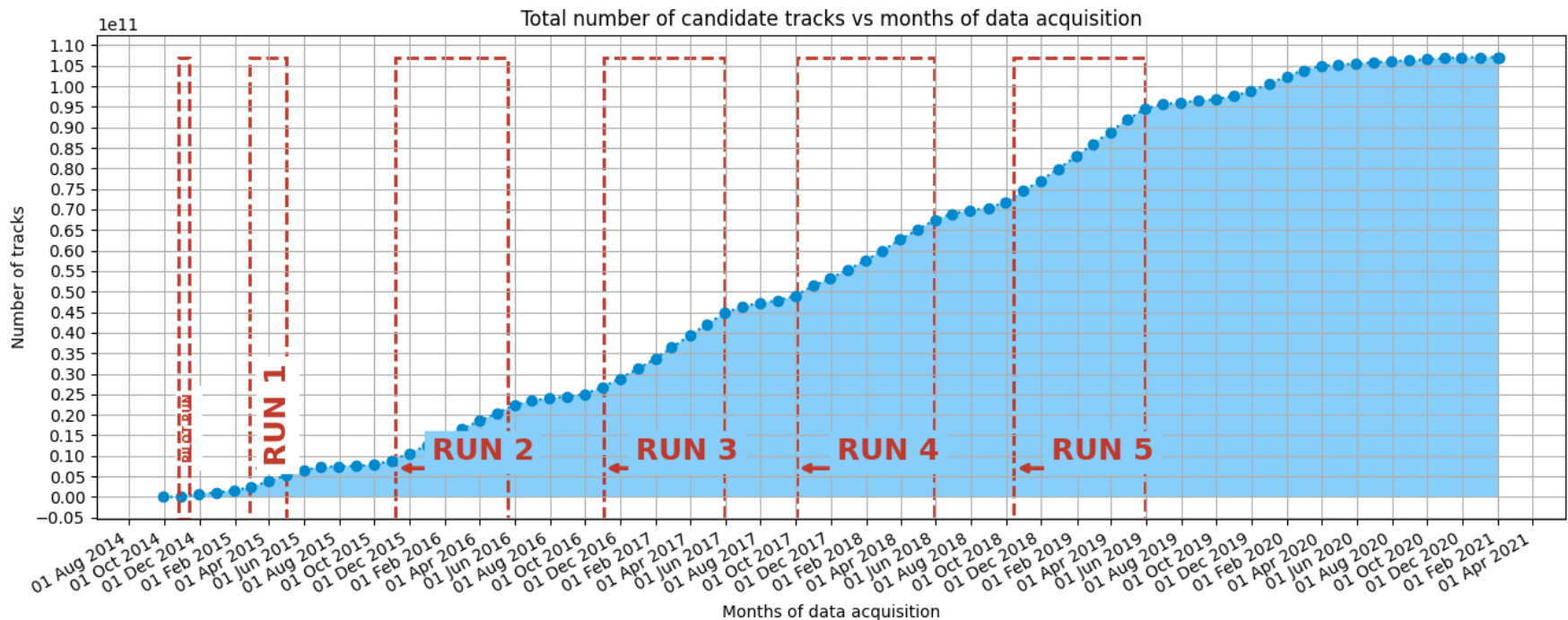
EEE Collaboration involves ~ 60 physicists.

The Network acts as a cosmic ray observatory which is able to study many different topics:

- Muon flux monitoring,
- Correlations between solar activity and muon flux,
- Search for anisotropy in the secondary component,
- Application of the cosmic ray physics ,
etc

The NETWORK data taking is organized in **Runs** which follow the school year, from October to June

➔ **100 10⁹ tracks** collected during 5 coordinated data taking in 5 years



The project was born with the direct intent to involve high school students and teachers in its advanced physics research

The EEE school teams act with the continuous support and supervision of the EEE researchers through a close cooperation with local referents !

- The MRPCs are mounted and managed at CERN by small teams of students and teachers.
- The MRPCs are sent to their station in the school institution, where they are installed and the EEE school teams take care of the commissioning and start of data taking operation
- During the data taking school teams help to monitor and operate the telescope
- Students attend meetings to confront their activities: tests and detector status, ongoing analysis etc.
- School teams take part in measurements campaigns to improve the telescope performance



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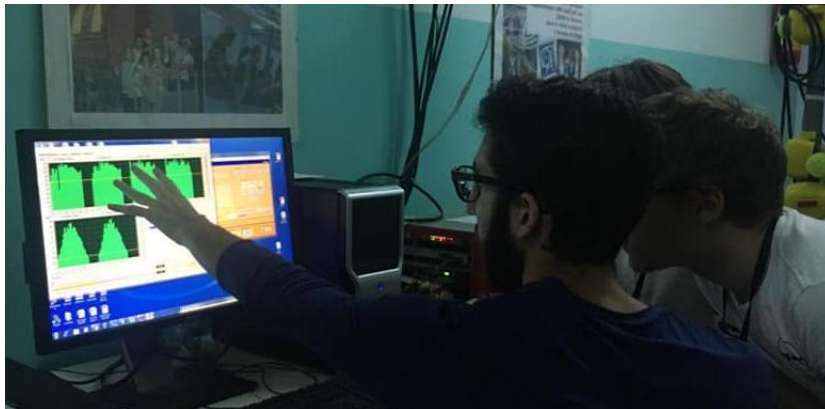
Education instrument for students

~ **100 italian high schools** join the EEE Project

Schools teams which do not host a telescope in their institution take part in remote monitoring and data analysis

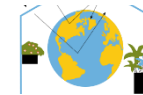
Students daily report the mainly data acquisition condition in an [online elog](#)

- ✓ HV and current values in the MRPCs
- ✓ muon count rate
- ✓ weather condition
- ✓ check the data quality by means of special tools



Measurements campaign: Gas flow reduction

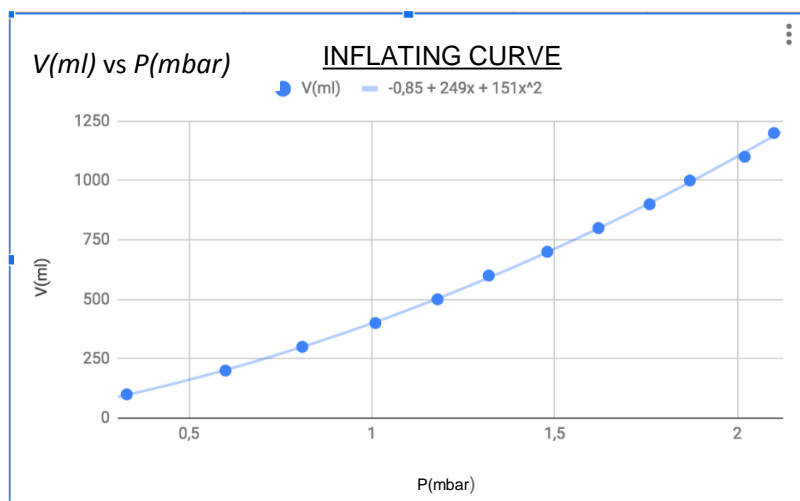
The MRPCs are gas detectors which do not use **ecofriendly gases** - $C_2H_2F_4$ (98%) + SF_6 (2%).
The EEE collaboration is studying new eco-gas mixture !



A short-term strategy is to reduce the gas flow in the MRPCs from the standard value of **2-3 l/h** to **1 l/h**.

Gas tightness of the MRPCs was checked with the help of teachers and students !

MRPC Tightness Gas Test

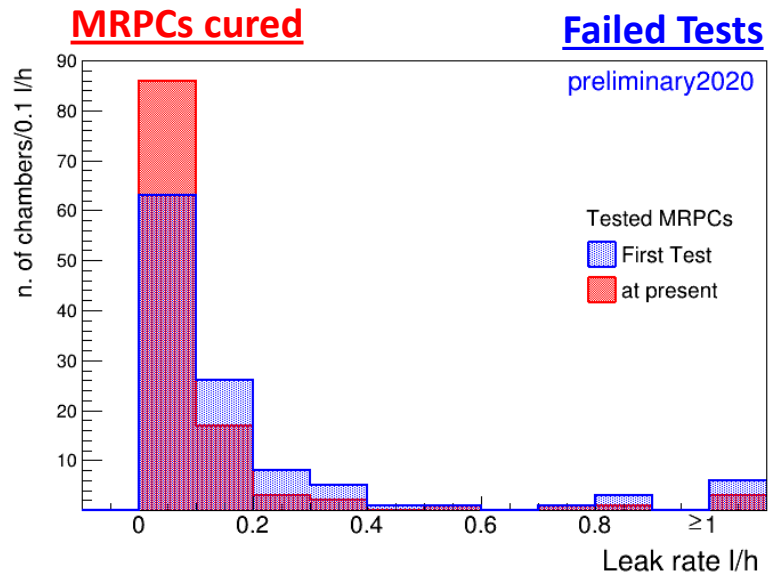


A chamber is accepted if its leakage rate is lower than the maximum value: **0.1 l/h**

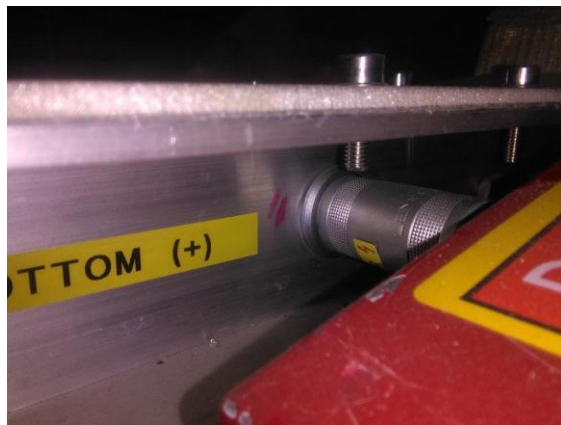
MRPCs with a leakage rate > 0.1 l/h have been cured

The EEE Telescope array are able to operate at an overall flow ~ 1 l/h

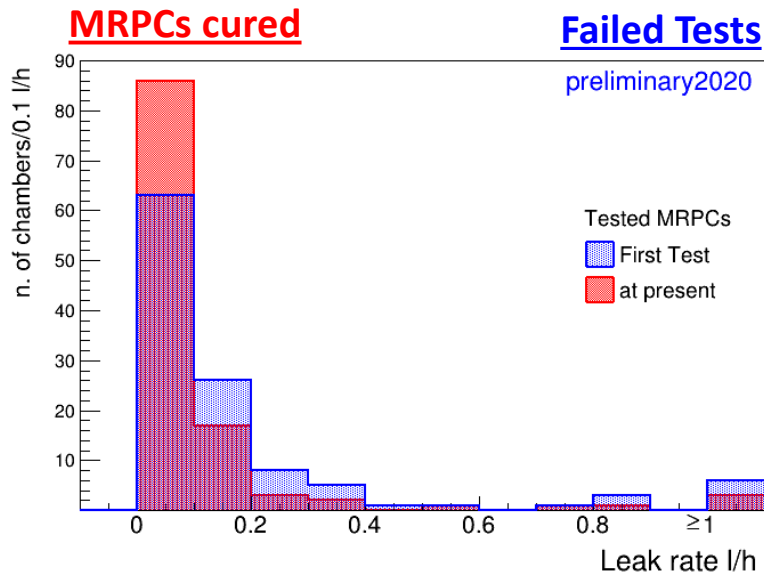
Measurements campaign: Gas flow reduction



School teachers and students helped to check and repair HV connectors, gas connectors and gas pipes, to seal screws and MRPC edges by silicone, etc



Measurements campaign: Gas flow reduction



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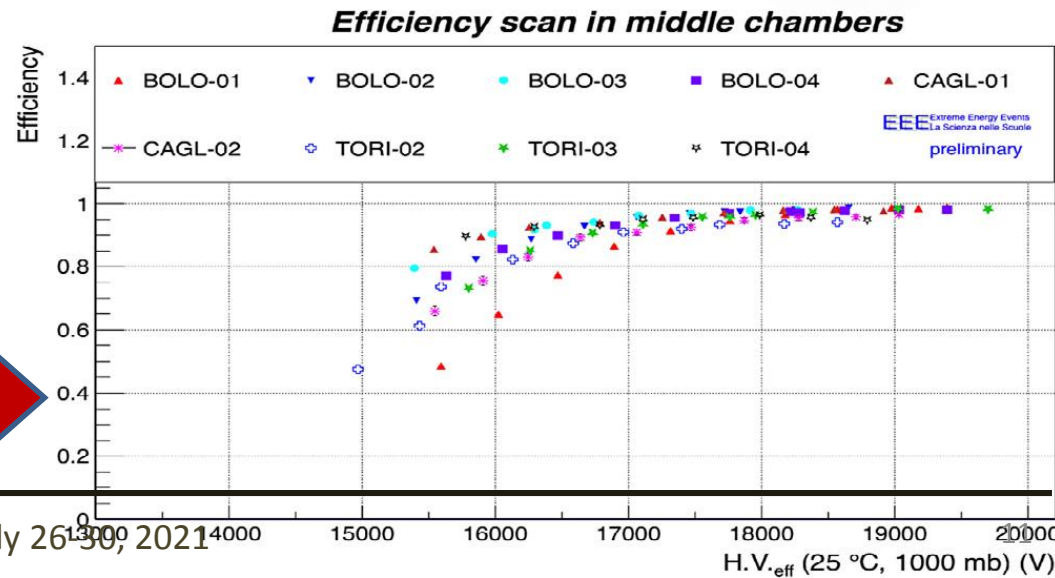


The flow reduction campaign started in September 2019 → stopped in March 2020 when ~65% of the EEE Telescope array was able to operate with a flow ~ 1 l/h

The EEE Collaboration is planning new measurements campaign next year:

Network MRPC efficiency measurements

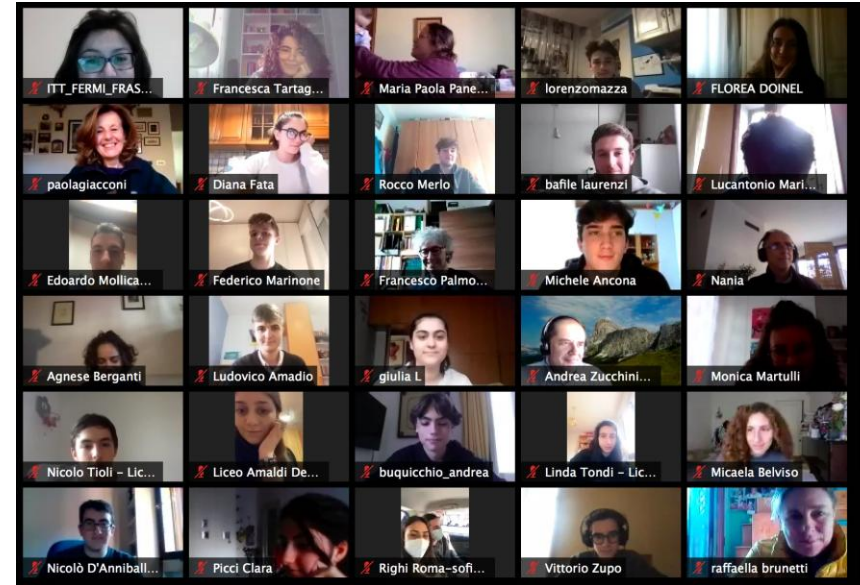
Results from 2017-2018 campaign



The EEE collaboration organizes **monthly online meetings** and **biannual conferences** with school teams

Run coordinating meeting

- Lectures on Cosmic Ray physics and Data Quality Monitoring
- Masterclasses on data analysis: muon flux studies, Statistics, ROOT framework
- Students present their own activities: data analysis, tool development for monitoring the telescopes etc.
- Students confront their ideas, problems and results



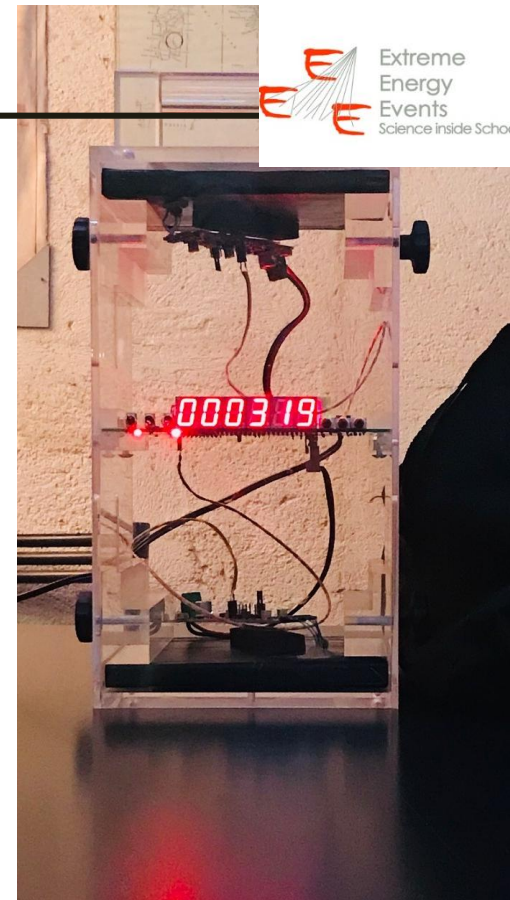
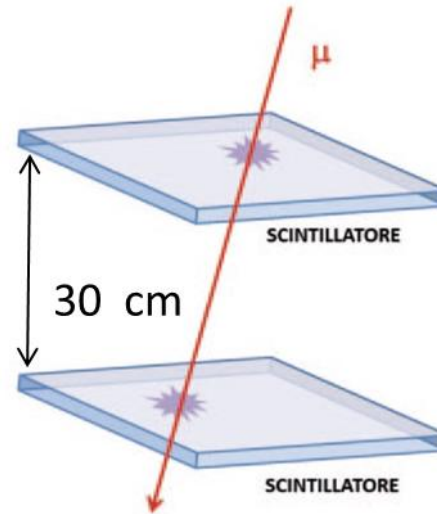
Autumn/Spring Conference

- 3-days events Conference dedicated to the EEE Project and cosmic rays
- School teams report their annual work
- Groups of students from different schools (with the aim to share their different skills) take part to masterclasses and participate to measurement campaigns.

Cosmic Boxes

15 portable detectors, based on 2 scintillator planes, were built by a team of EEE students under the supervision of the EEE researchers.

- ✓ 2 scintillator planes $15 \times 15 \times 1 \text{ cm}^3$,
- ✓ The light signals are read by SiPM
- ✓ The detector can be operated with a single and double coincidence trigger



The Cosmic BOX Contest!

The contest has been organized since 2019
EEE school teams are invited to plan and submit a research project using the detector

The best projects are awarded with a Cosmic Box to carry on the proposed activity

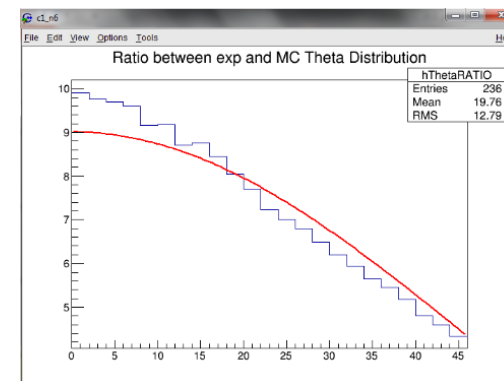


International Cosmic Day



International Cosmic Day (ICD) – An international event dedicated to Cosmic ray physics (DESY)

- During the day students from all over the world perform measurements on the atmospheric cosmic ray flux
- As an international collaboration they share and discuss their results with other groups worldwide in a online conference,
- Scientists join the video conferences and give lectures to provide an insight into current astroparticle physics research
- Students prepare their results for publication **in the ICD conference booklet**



Polar quEEEst Project

The **Polar Quest 2018 mission** is a scientific multidisciplinary exploration within the Svalbard archipelago.

The EEE Project and INFN contribute to the mission with a **cosmic ray detector, POLA**, to observe Cosmic Rays at very high latitude: up to $82^{\circ}07'N$.

POLA - 2 scintillator plane detector, characterized by low weight (60kg) and low power consumption (13W)

3 POLA detectors were assembled at CERN by high school students.

- ✓ POLA-01 → installed on PolaQuest sailboat
- ✓ POLA-02 → installed in a Italian high school (Bra)
- ✓ POLA-03 → installed in a Norwegian high school (Nesodden)

On the 90th anniversary of the Italian expedition with Dirigibile Italia, led by Umberto Nobile, took place the mission **PolarQuest2018**, coordinated by Paola Catapano (CERN Communications).

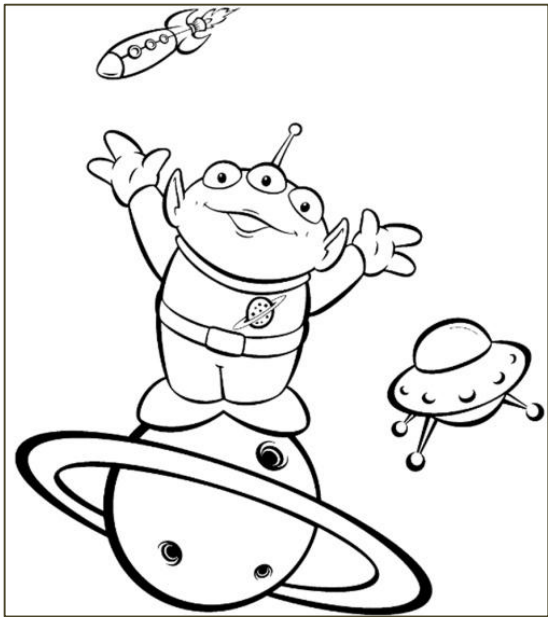


The PolarQuEEEst 2019 and CNR

A Cluster of 3 POLA detectors has installed in the CNR arctic base at **NyÅlesund** (Svalbard) with the aim to study extensive air showers at the extreme latitudes. Data taking is daily monitored by students and researchers.

- ✓ **The EEE Network act as a Cosmic Ray observatory with a large physics programme.**
- ✓ The Network has growing and successfully operating for 17 years with very stable performance.
- ✓ Every year the EEE community introduce new students and teachers in all the relevant steps of the experiment: from the construction to data taking operations and detector upgrade.
- ✓ The EEE outreach program is continuously enriched with new activities.
- ✓ The EEE project constitute a close and **“extreme”** fruitful collaboration between high-school students, teachers and researchers.

*THANKS FOR
YOUR
ATTENTION*

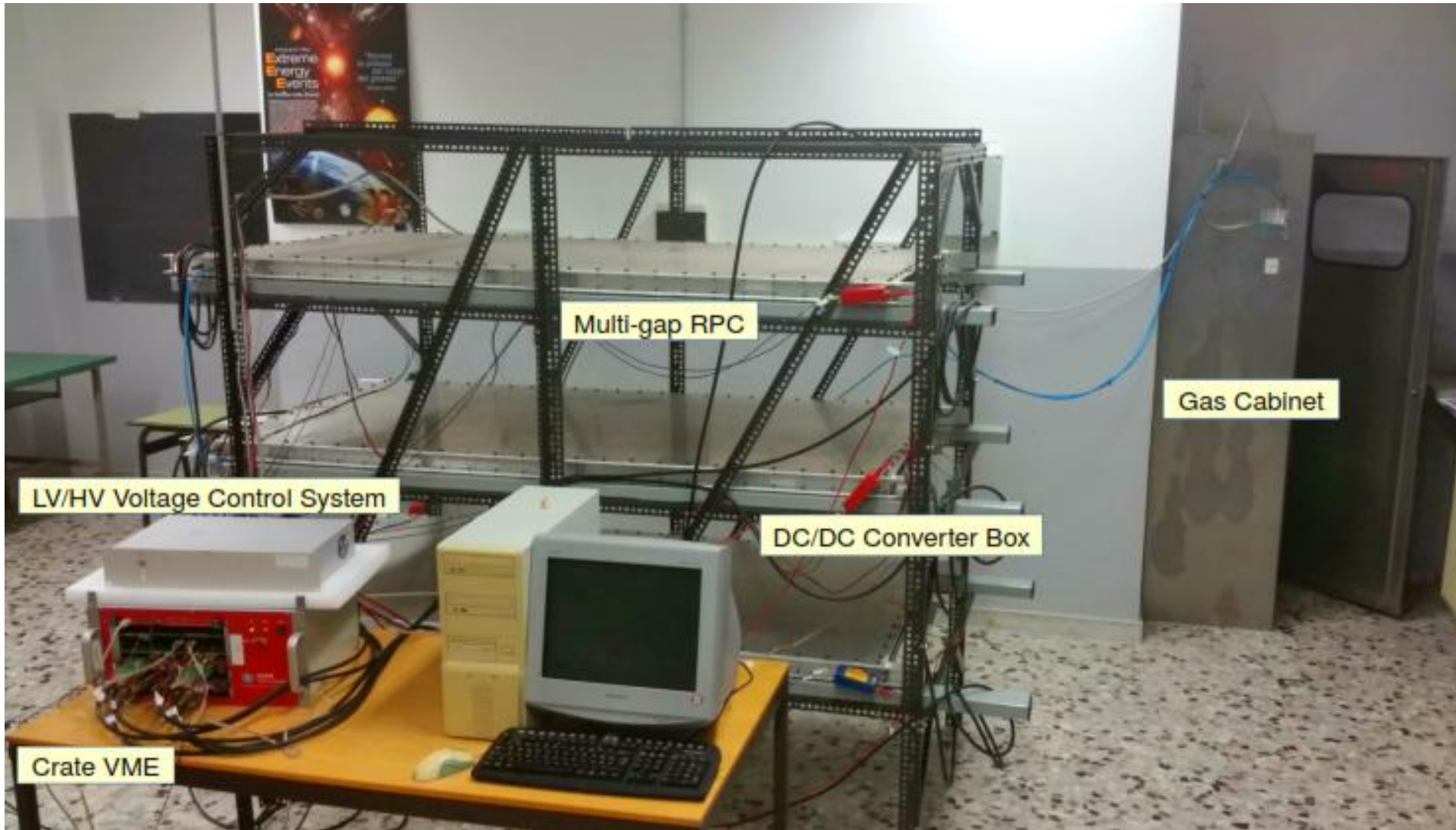


...*SPARES*

The EEE Telescopes

3 Multigap Resistive Plate Chambers (MRPCs) for tracking particles

Large chambers $1.58 \times 0.82 \text{ m}^2$



The EEE Project : a dual role

Scientific instrument for physicists

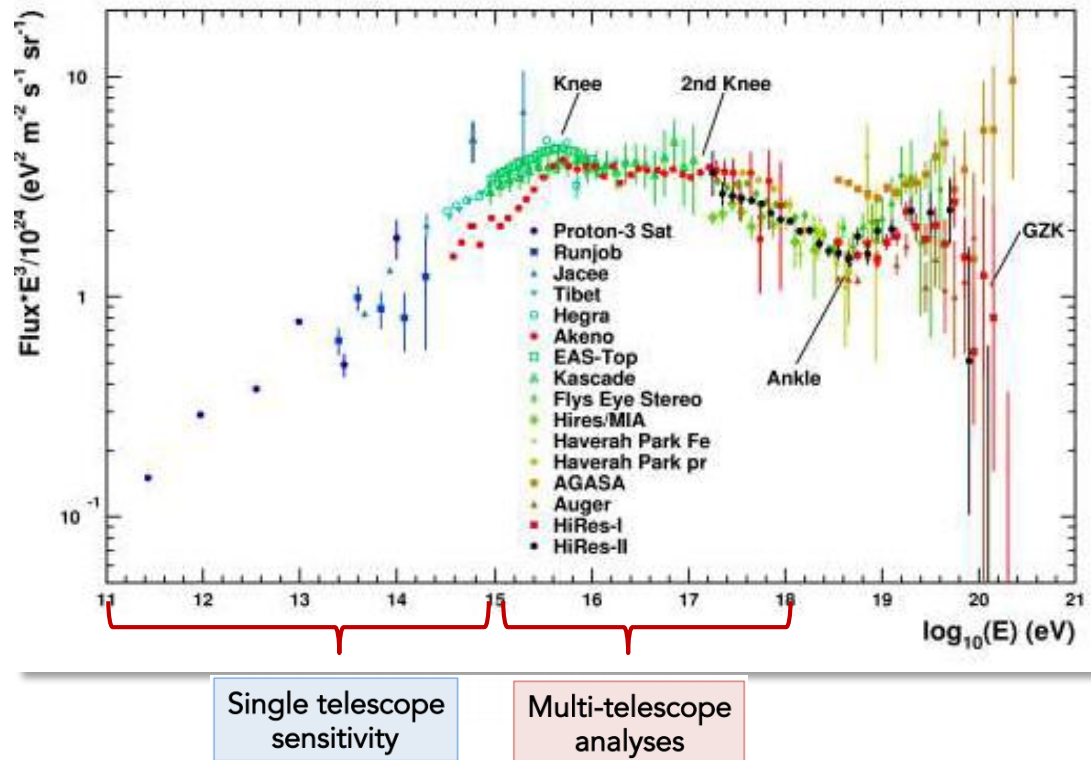
EEE Collaboration involves ~ 60 physicists. Many different topic in the cosmic ray physics:

Search of coincidences, Long distance correlation
Correlations to solar activity, Upgoing tracks, Large scale anisotropy, ...

As a single detector : the EEE telescope is a high precision tracking detector that can study the flux of secondary cosmic muons.

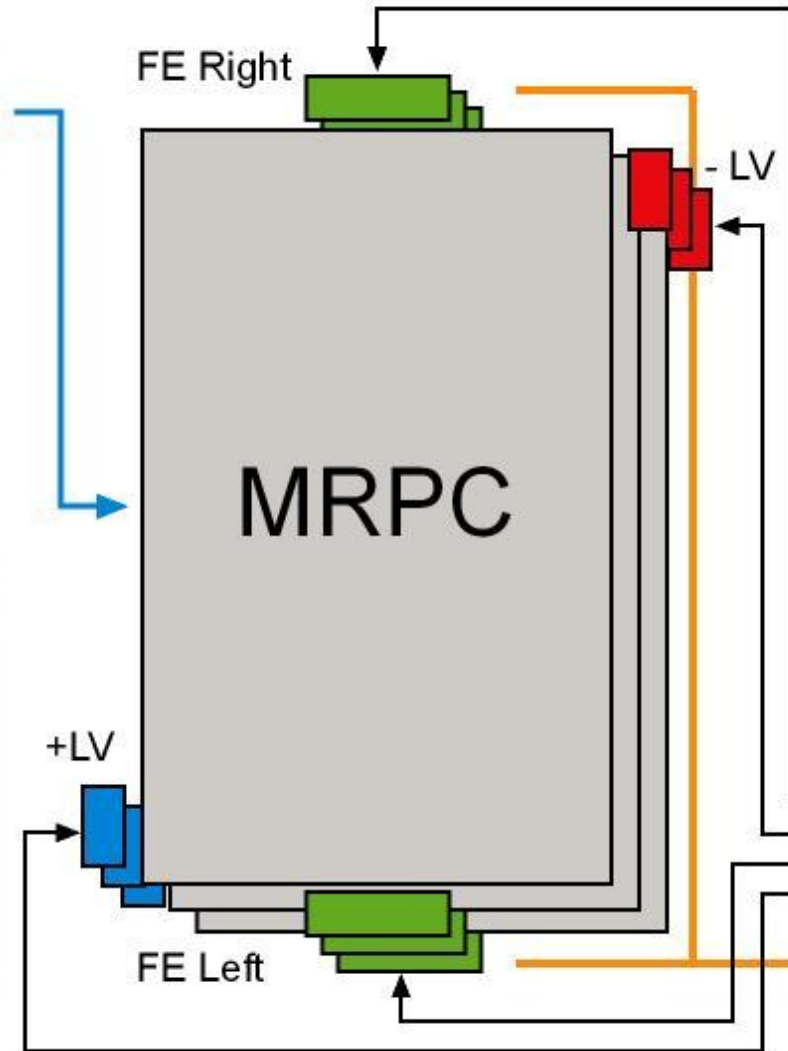
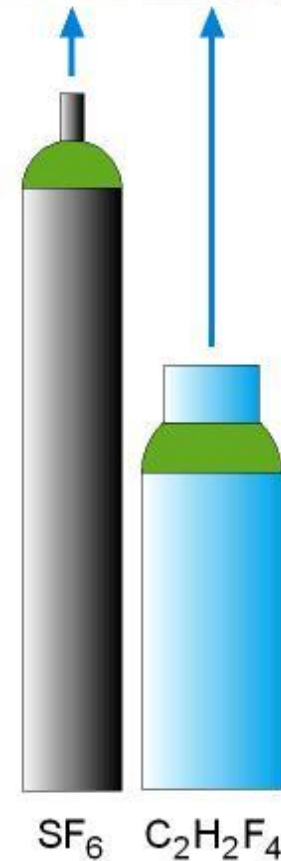
As telescopes cluster: in the same town, it aims to study the properties of the EAS in which muons are originated,

As an array using sites far apart: it makes possible to investigate time correlations between different EAS events (es. *Gerasimova-Zatsepin effect*)



The EEE Telescopes

GAS controller



DAQ