

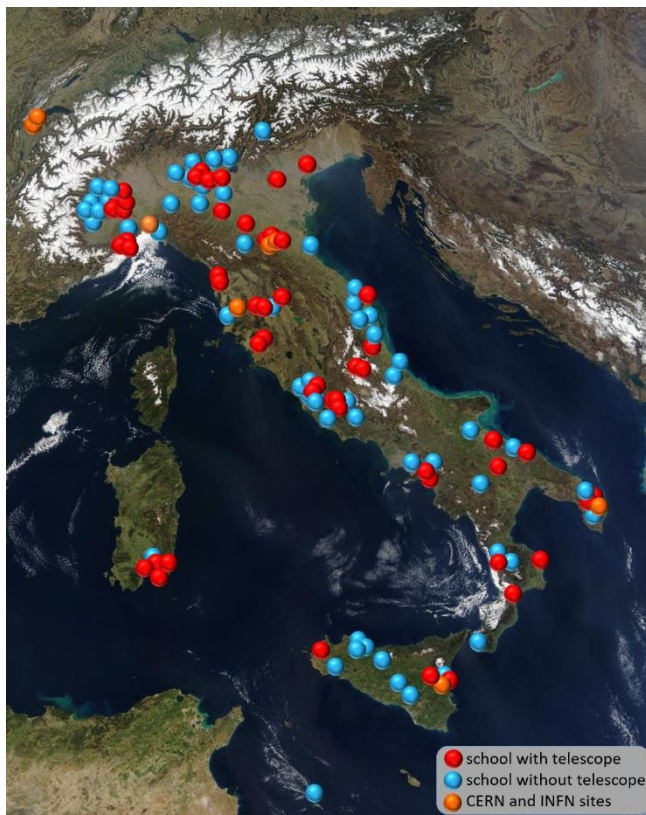
60 years of Subnuclear Physics in Bologna

7 November 2018

R. Nania

For the EEE Collaboration

The EEE - Extreme Energy Events project





MUSEO
STORICO DELLA FISICA
E
CENTRO
STUDI E RICERCHE
ENRICO FERMI



A **Research Institute funded since 2001** by the Italian *Ministero per Istruzione Università e Ricerca* and dedicated to frontier research in physics and its wide applications for the benefit of humankind (**Education and Outreach**), in the spirit of E. Fermi legacy.

First President A. Zichichi



Three main focus points:

- **Grants** for Junior/Senior researchers
- **Interdisciplinary Research Projects**
- **Dissemination of Scientific Culture and Historic Memory** also through the restoration of the "Monumental Complex" of Via Panisperna, to be used in part for the Museum dedicated to E. Fermi.
Researchers : 7 permanent , ≈40 Grants , > 100 associated

Present President L. Cifarelli



HISTORY
OF
PHYSICS

EEE



MUSEUM



Centro Fermi



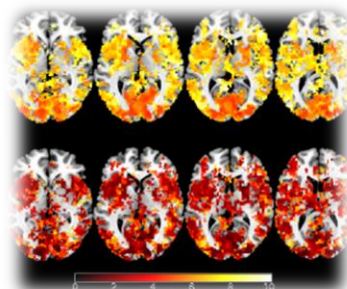
Fundamental
PHYSICS



CULTURAL
HERITAGE



MEDICINE



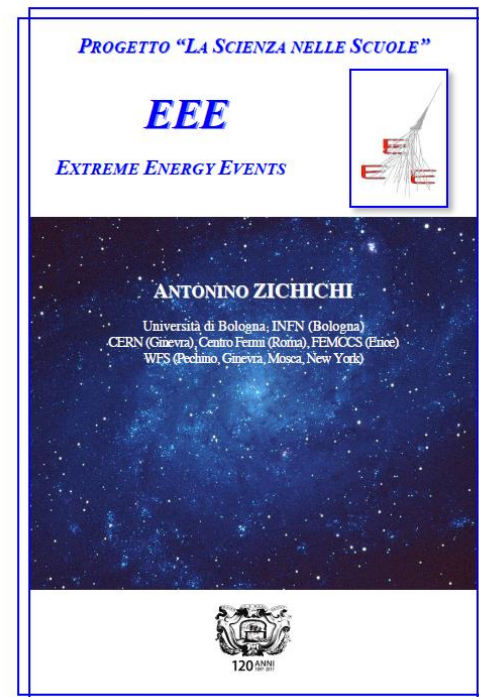
ENERGY



The Extreme Energy Events (EEE) Science inside Schools Project Leader A. Zichichi

Since 2004 , EEE conjugates a *real experiment on Cosmic Rays*, with the largest area coverage, with a *direct participation of students and teachers* in all aspects of the experiment, from building the detectors, to monitoring the operations/data taking and analyzing the data.

INFN, CERN, MIUR (Italian Ministero Istruzione e Università) collaborate to the project.

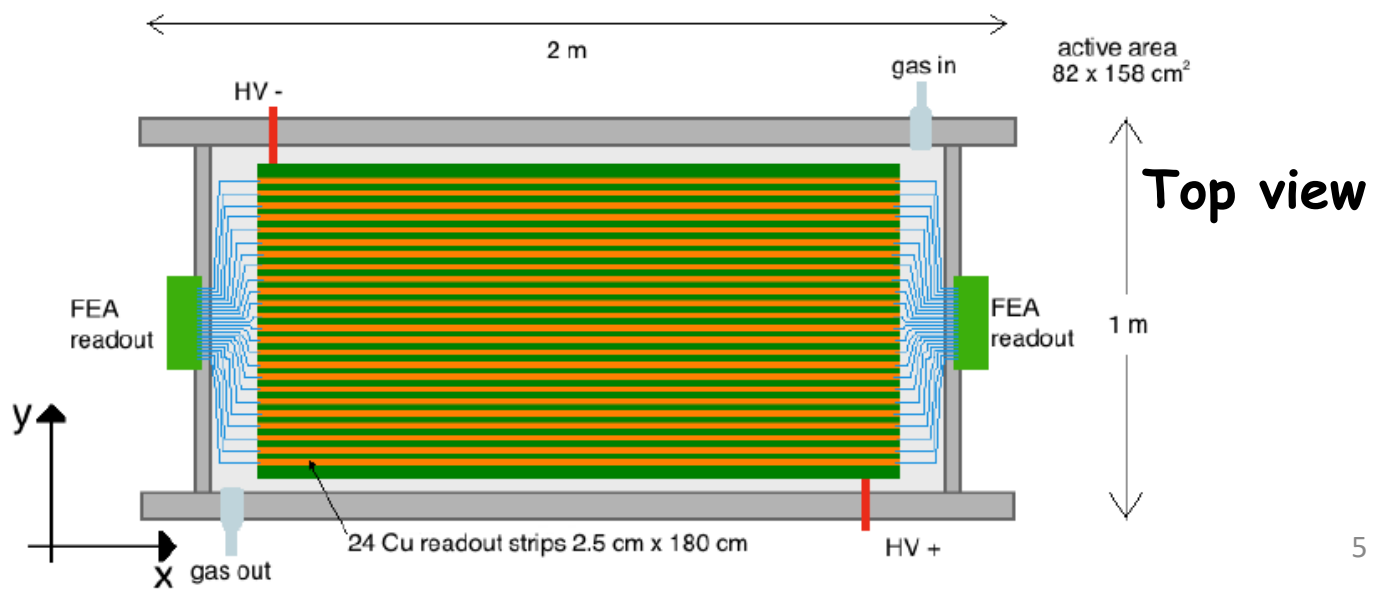
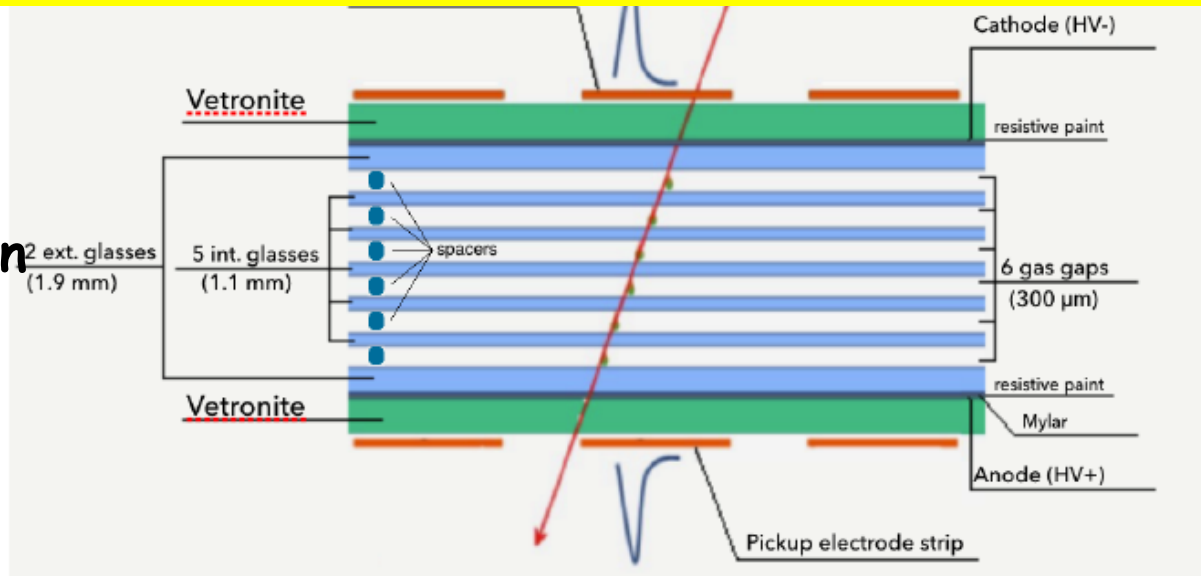


The Multigap Resistive Plate Chambers (MRPC) of EEE

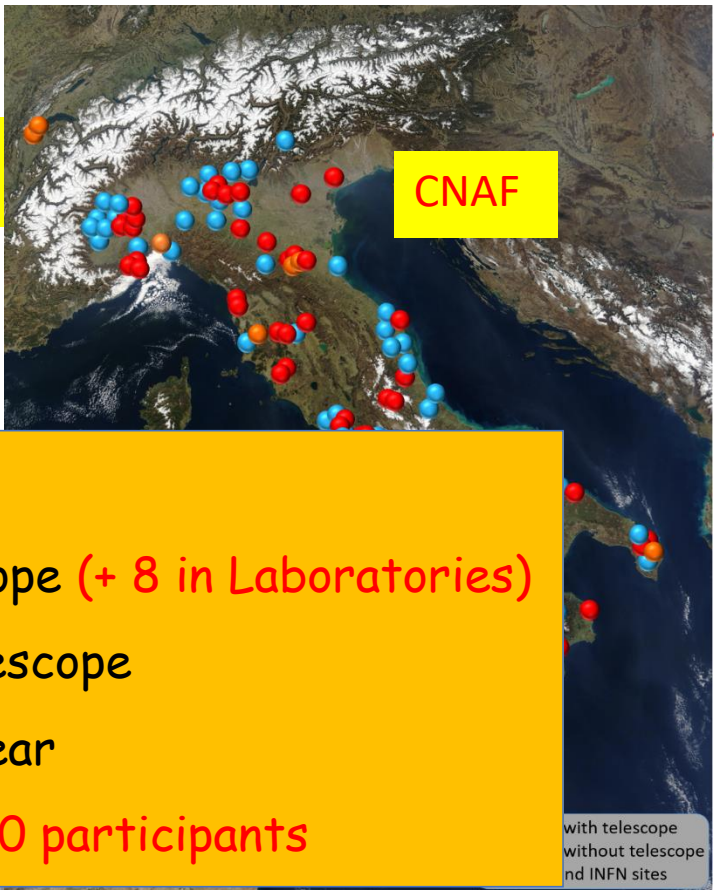


An evolution of the ALICE TOF

Cross section

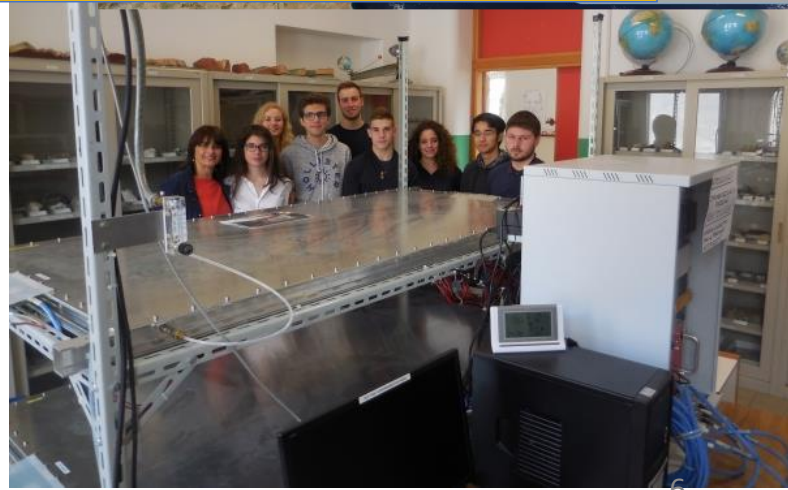
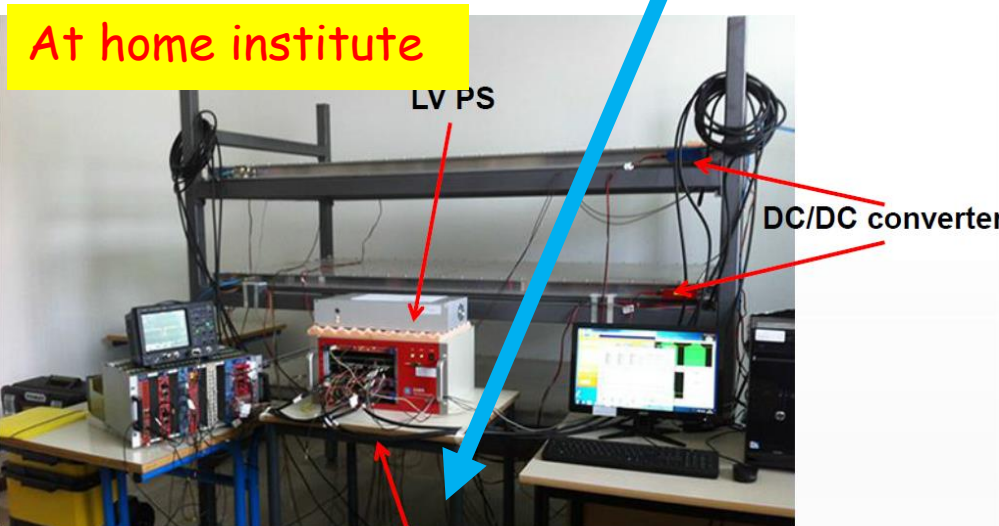


The EEE project



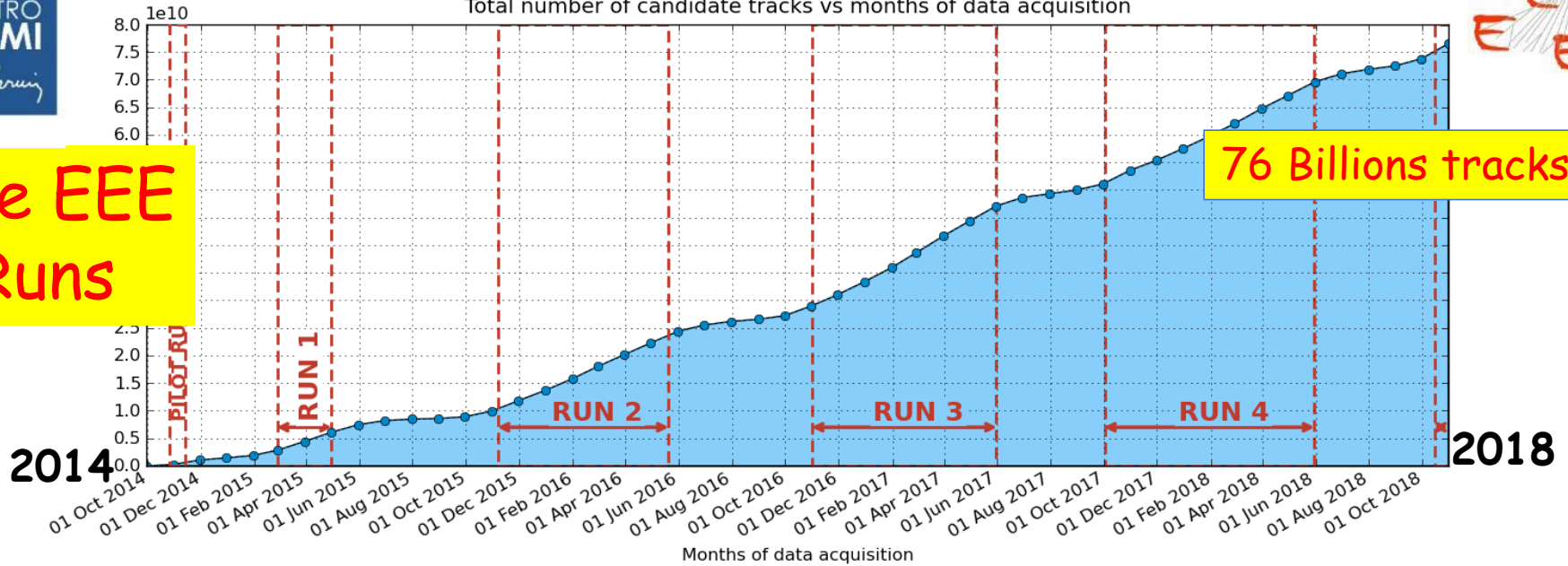
Few numbers for EEE:
≈ 51 Institutes with a Telescope (+ 8 in Laboratories)
≈ 47 Institutes without Telescope
≈ 1000 students-teachers /year
Since 2004 more than ≈ 10000 participants

At home institute





Total number of candidate tracks vs months of data acquisition



**The EEE
Runs**

76 Billions tracks



SCHEDA TECNICA DELL'ESPERIMENTO PER LA RILEVAZIONE DELLA FREQUENZA DEL SUONO EMESSO DALLA BOMBOLA DELE TELESCOPIO EEE

MATERIALE OCCORRENTE:

- Un computer portatile con un microfono interno oppure un computer collegato ad un microfono esterno.
- Il software open source Audacity, scaricabile da questo link <http://www.audacityteam.org/>
- Un martelletto gommato, come quelli utilizzati per colpire i diapason negli esperimenti di acustica



Project Conferences
 Monthly vidyo meetings
 Institutes visits
 Masterclasses ...

How to measure the amount of gas in a bottle by means of sound frequency
 Liceo F. e M. Campana (Osimo)

EEE in Erice 2017

Both measurements are published in the *Giornale di Fisica* with students' signature.

Measurement of the Earth Radius



Measurement of Cosmic rays flux at different altitudes



FISICA PER TUTTI

Come varia il flusso dei raggi cosmici con la quota? Basta chiederlo agli studenti del progetto EEE

How does cosmic ray flux vary with altitude? Let's ask it to EEE project students

Collaborazione EEE (*)

*Centro Fermi - Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi"
Piazza del Viminale 1, 00184 Roma, Italia*

Scuole

Ilaria Veronesi (Prof), Eduardo Gaudiosi, Giorgio Monteforte.
Liceo Scientifico P.S. Mancini, Via Lorenzo de Conciliis, 1, 83100 Avellino, Italia

Ilaria Iusco (Prof), Daniela Moretti, Marco Falotico.
Liceo Scientifico A. Scacchi, Corso Cavour, 241, 70121 Bari, Italia

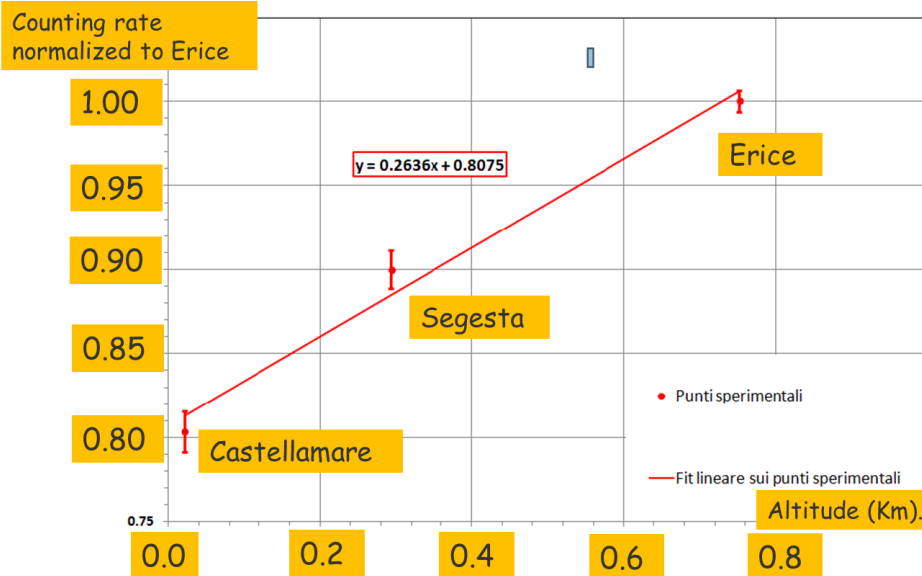
Roberta Quadrio (Prof), Luca Melega, Sofia Musi.
Liceo Classico L. Galvani, Via Castiglione, 38, 40124 Bologna, Italia

Elisabetta Fioramonti (Prof), Antonella Bilotta, Eugenio Fissore.
Liceo G. Giolitti - G. B. Gandino, Via Fratelli Carando, 43, 12042 Bra (CN), Italia

Gianfranco Lazzaroli (Prof), Luca Ramo, Letizia Marini.

.....

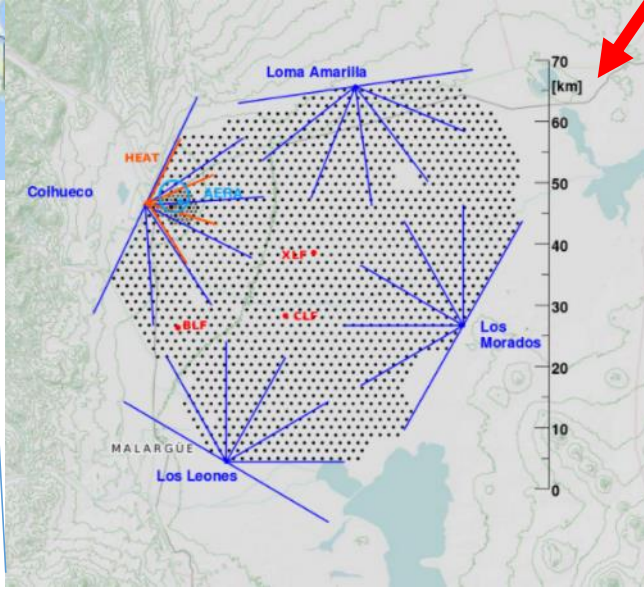
**Article signed by EEE collaboration
and 140 students/teachers**



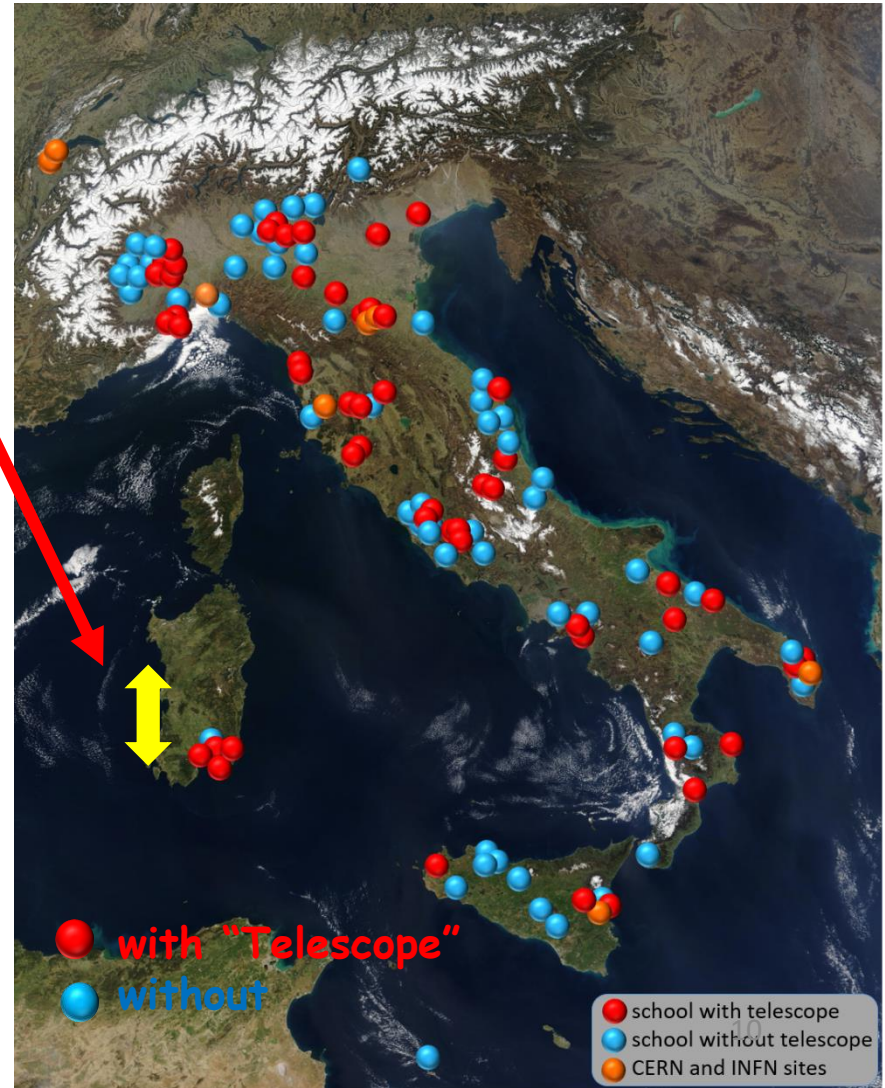
Very large area experiments for Cosmic Rays studies

Pierre Auger Observatory

Centro Fermi
Extreme Energy Events Project
EEE



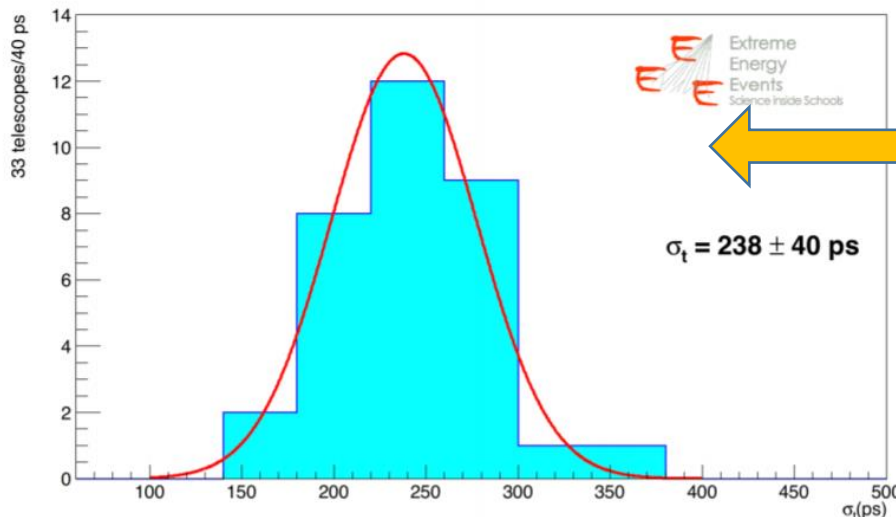
70 km



- with "Telescope"
- without
- school with telescope
- school without telescope
- CERN and INFN sites

MRPC performances on the telescopes

EEE Collaboration 2018 JINST 13 P08026

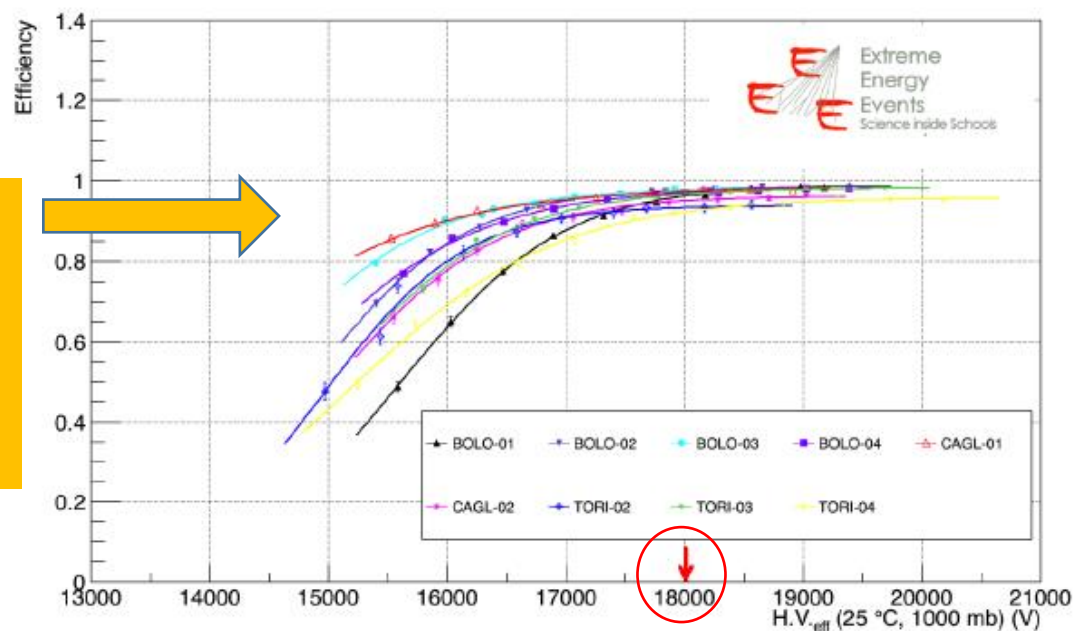


Time resolution measured with data taken in Run 3, for 33 telescopes:
Average $\sigma_t = 238 \pm 40 \text{ ps}$

Space resolution measured with data taken in Run 3, for 44 telescopes:
Transverse to strip $\sigma_y = 0.92 \pm 0.02 \text{ cm}$
Parallel to strips $\sigma_x = 1.44 \pm 0.23 \text{ cm}$

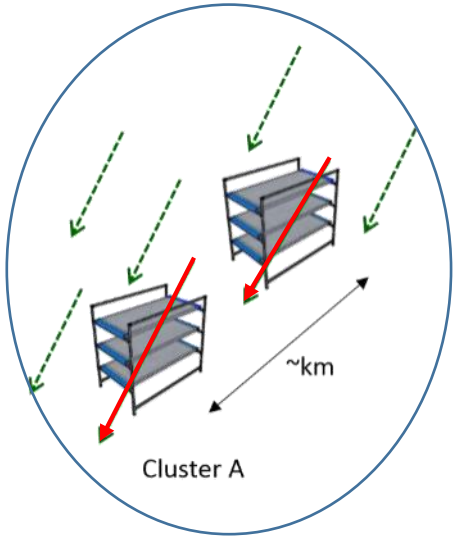
Efficiency measured with data taken in Run 3, for 9 telescopes:

Average efficiency over 31 telescopes : 93%

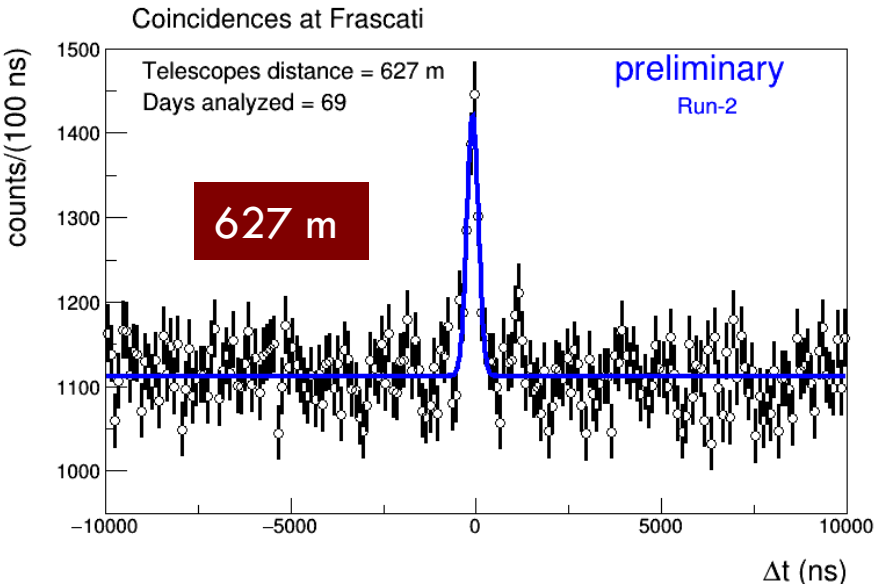
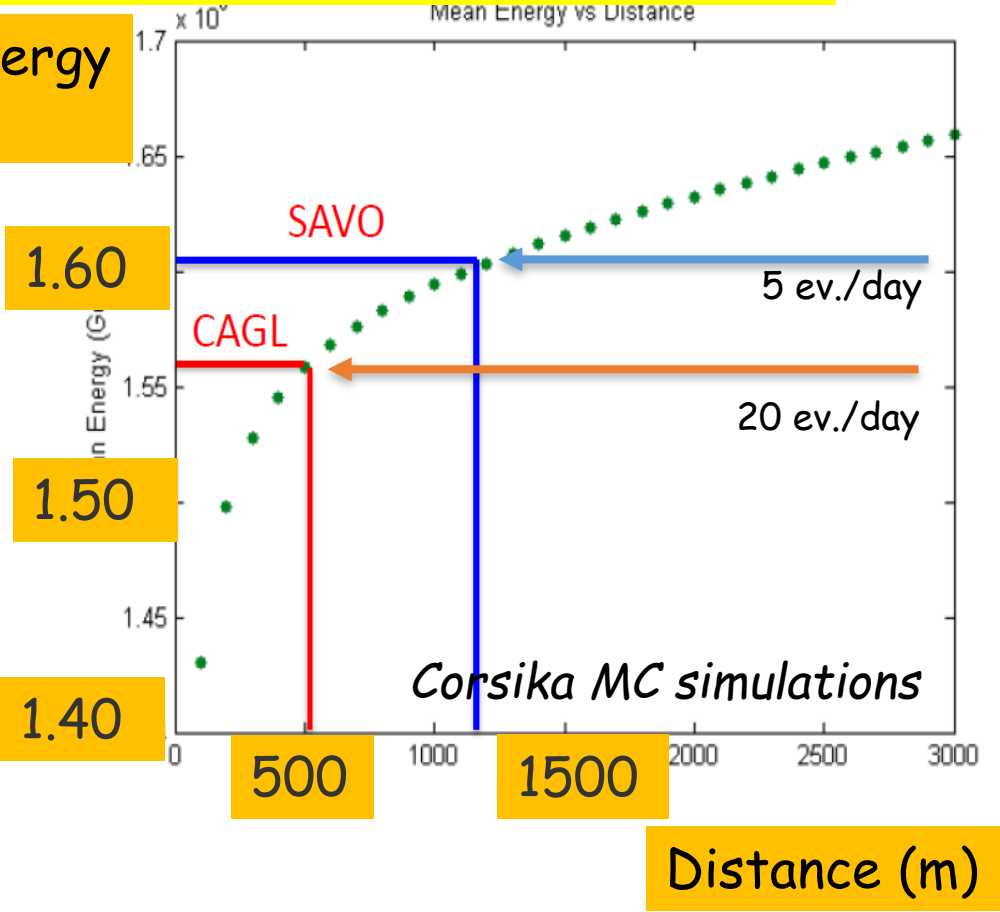




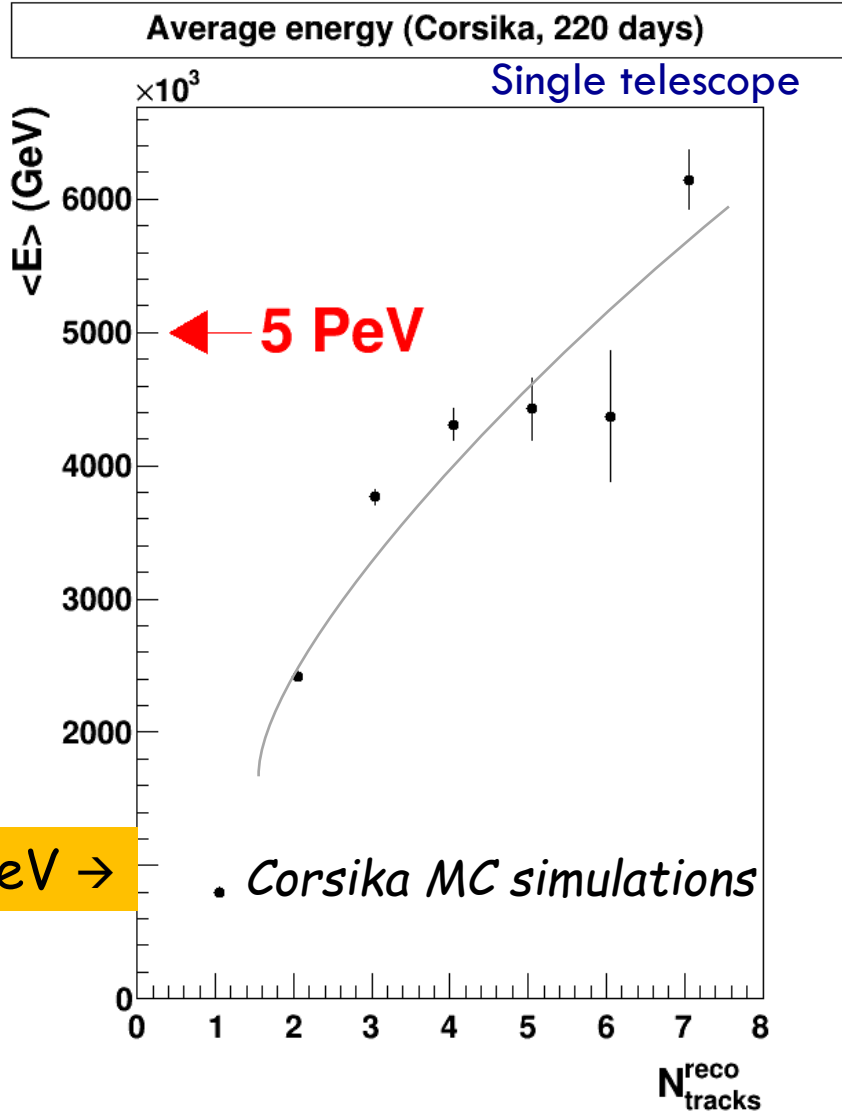
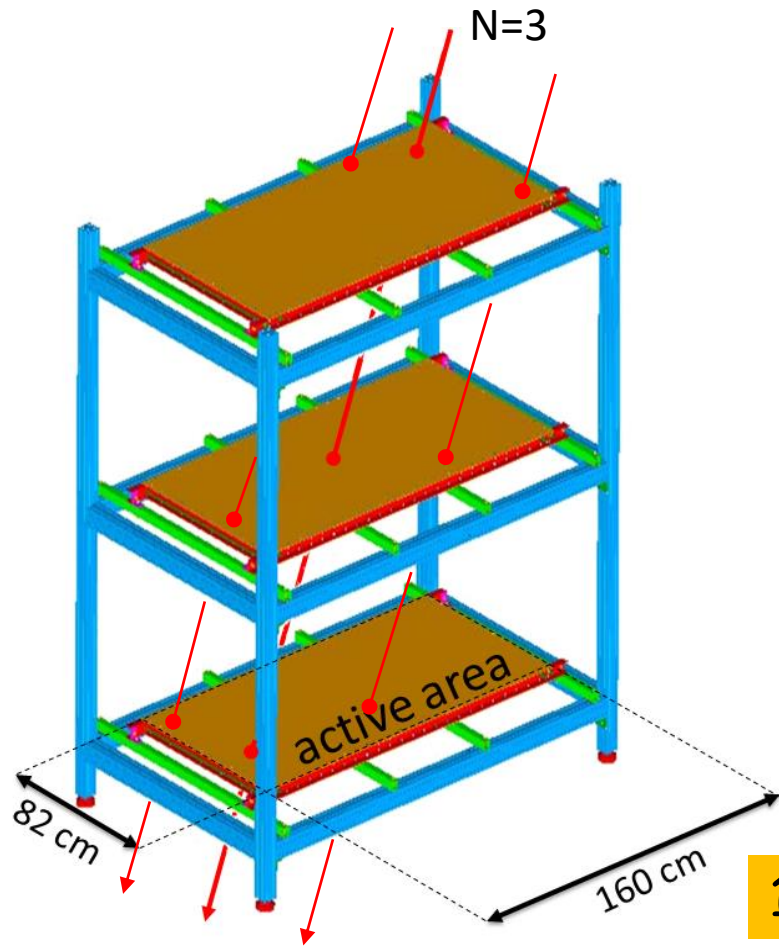
Select High energy events via coincidences between distant telescopes



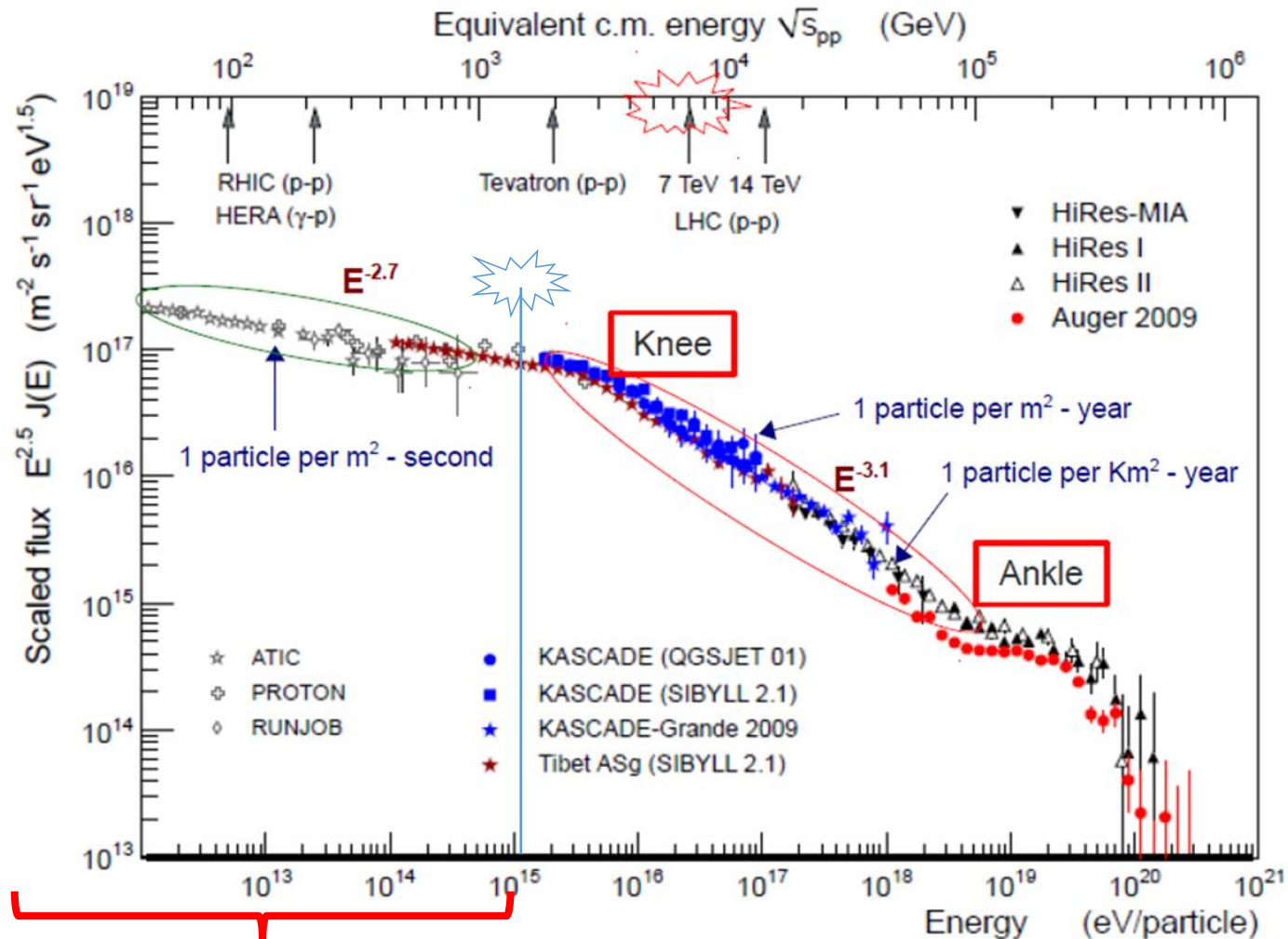
Mean energy
 10^{15} eV



Select high energy events via multitrack



Cosmic rays flux and EEE



Single track

Multiple tracks

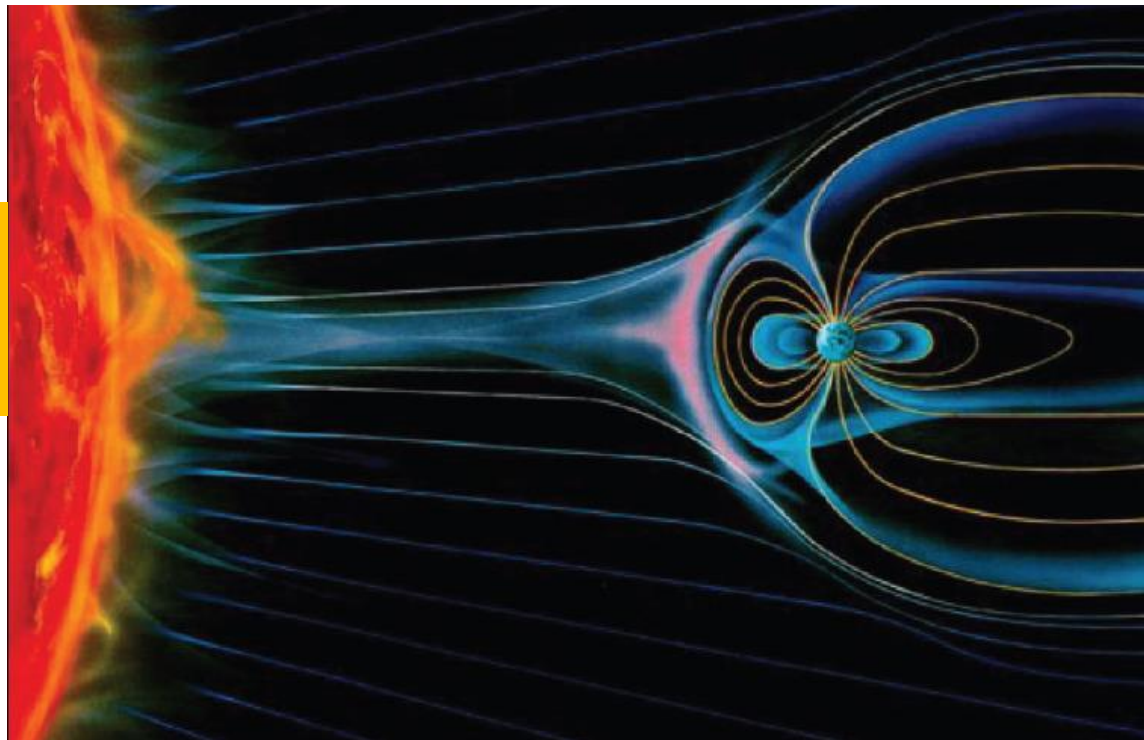
Multi-telescope

Galactic Cosmic Ray Decrease (GCRD)



Among the non-periodic intensity variations, rapid (few hours) decreases of the galactic cosmic-ray (GCR) flux due to solar activity (the so-called Forbush decreases) followed by a slow recovery in a few days time range

Probably related to solar flares and the associated geomagnetic disturbances

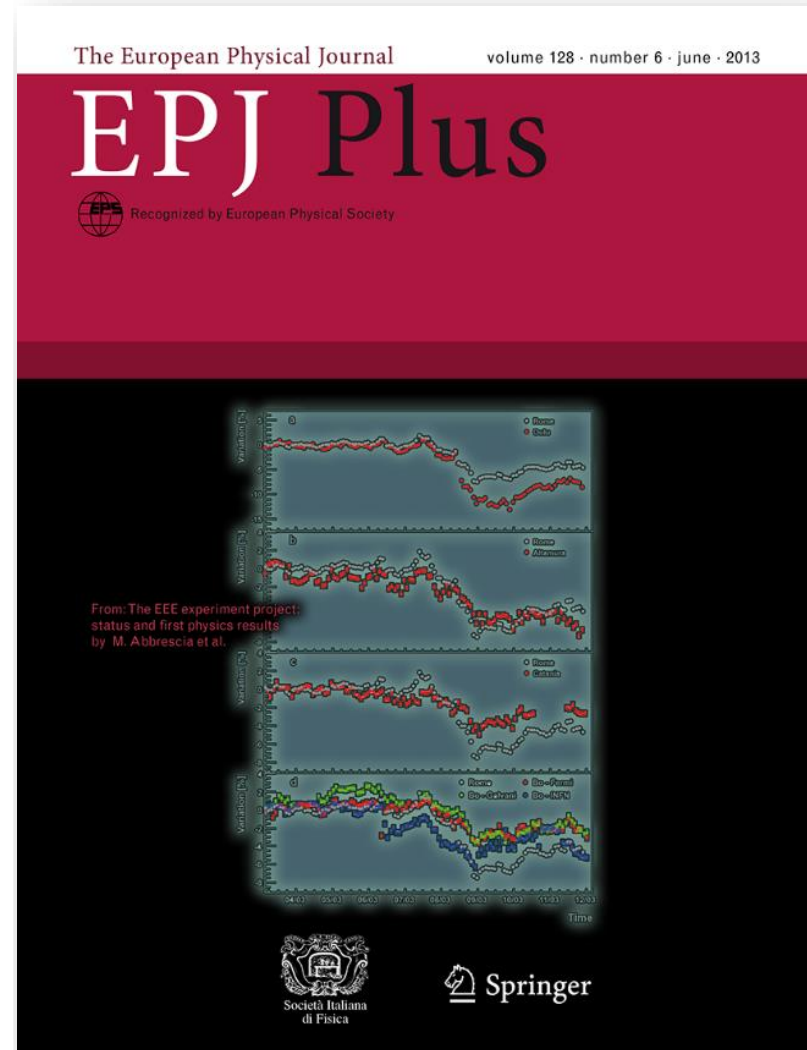
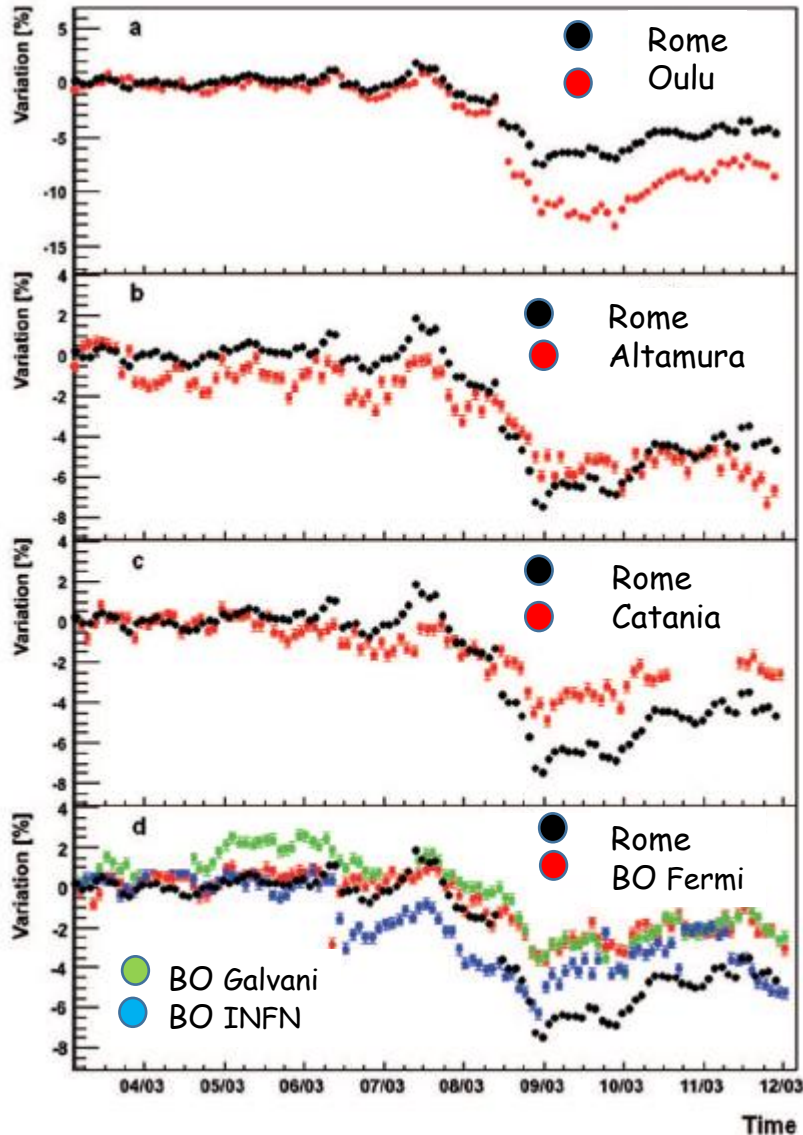


GCDR with EEE

EEE Collaboration

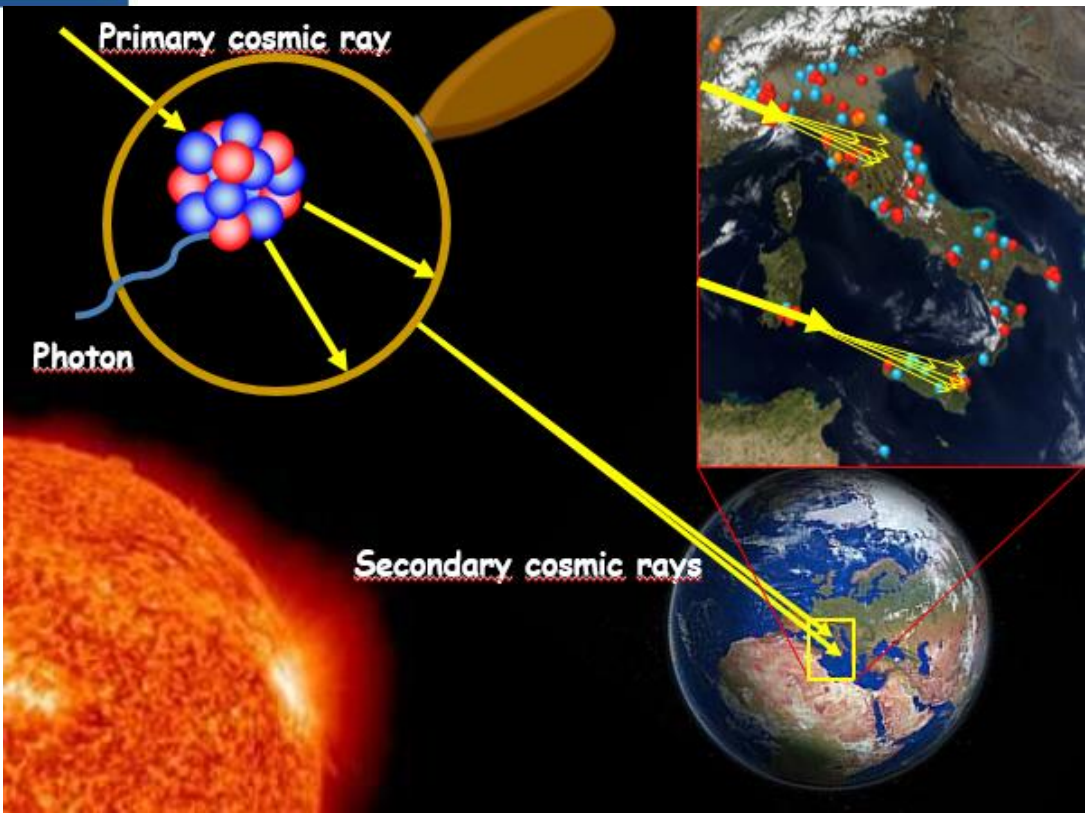
Eur. Phys. J. Plus (2011) 126, 61.

Eur. Phys. J. Plus (2013) 128, 62.



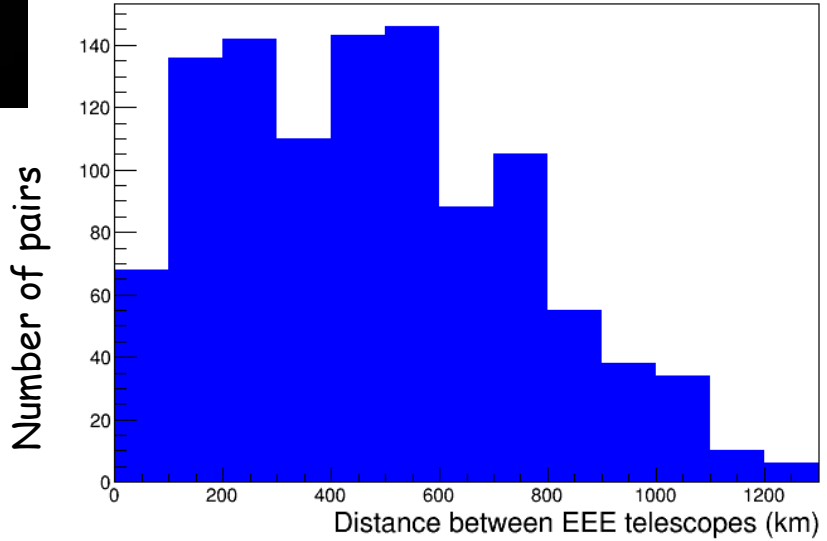
Unprecedented with muons in High Schools !!!

Long distance shower correlations



One example:
Nuclear fragmentation via photodisintegration
(Gerasimova-Zatsepin effect
Soviet Phys., JETP, vol. 11, 899, 1960)

EEE typical distances between 2 telescopes

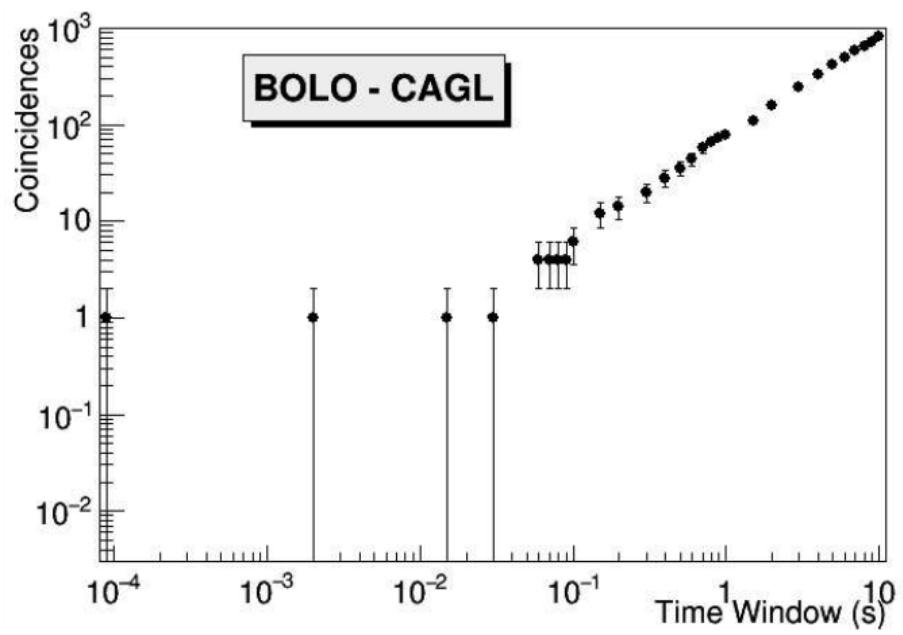




Eur. Phys. J. Plus (2018) 133: 34

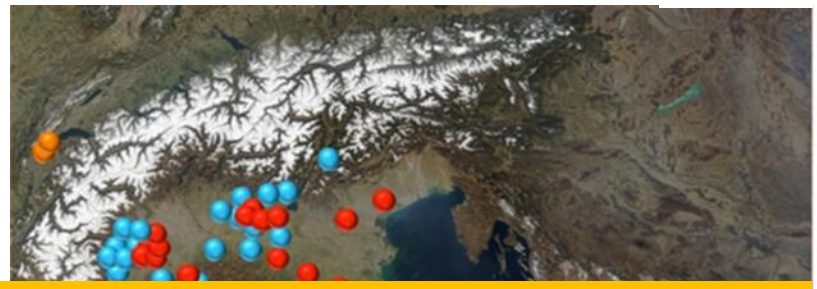
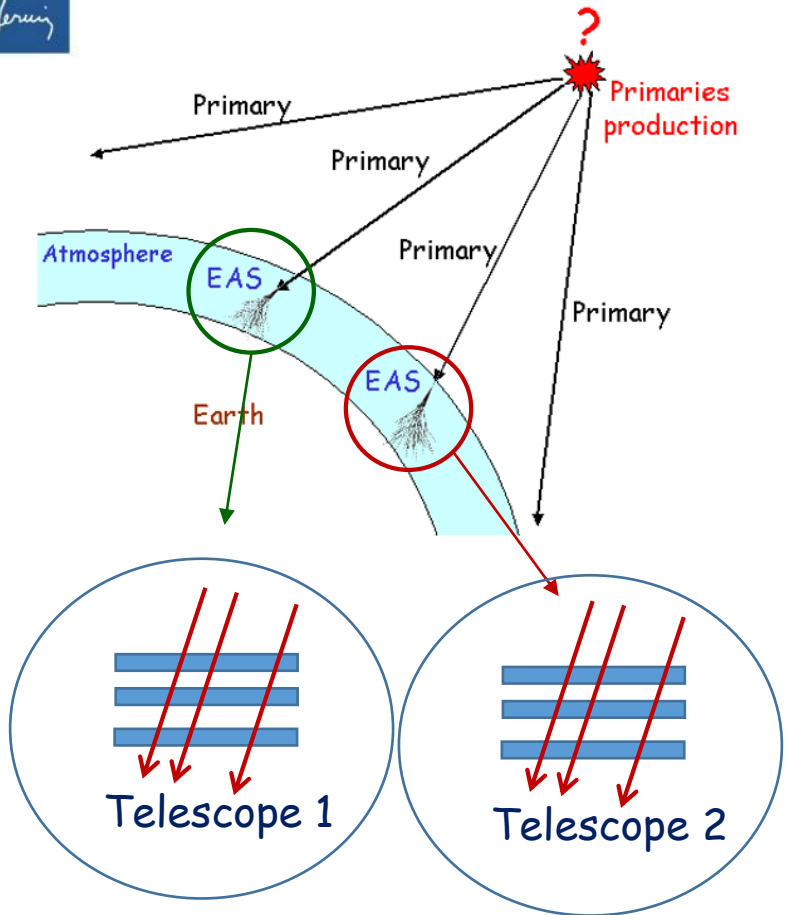
Correlations between telescope pairs

- Analyzed coincidences between the 45 pairs of the 10 EEE cluster sites
- 3968 days of time exposure
- **96 observed events against 77.8 estimated background**
- 5 candidate events with a p-value < 0.05



Event	EEE pairs	Distance (km)	$ t_1 - t_2 $ (μ s)	ϑ_{rel} (deg)	Expected events	p-value
(A)	BOLO-CAGL	614	86	27.1	0.0069 ± 0.0002	0.007
(B)	BOLO-LAQU	290	740	9.1	0.014 ± 0.001	0.014
(C)	CATA-TORI	1040	88	9.2	0.0265 ± 0.0005	0.026
(D)	GROS-TORI	377	297	14.4	0.032 ± 0.001	0.031
(E)	CERN-CATA	1200	248	9.3	0.049 ± 0.001	0.048

Long Distance Shower Correlations - multitrack



Preliminary results

- 816 days of time exposure
- 50 million events
- 11 observed events in a time window $\approx 10^{-5}$ - 10^{-4} s with expected background ≈ 5



Extensive Air Showers (EAS) reconstructed via **multitrack events** i.e. telescope coincidences within $1 \mu\text{s}$

Analysis searches for **coincidences of 2 EAS** over 39 telescopes + 5 clusters

Search for Multi-messenger events with EEE telescopes



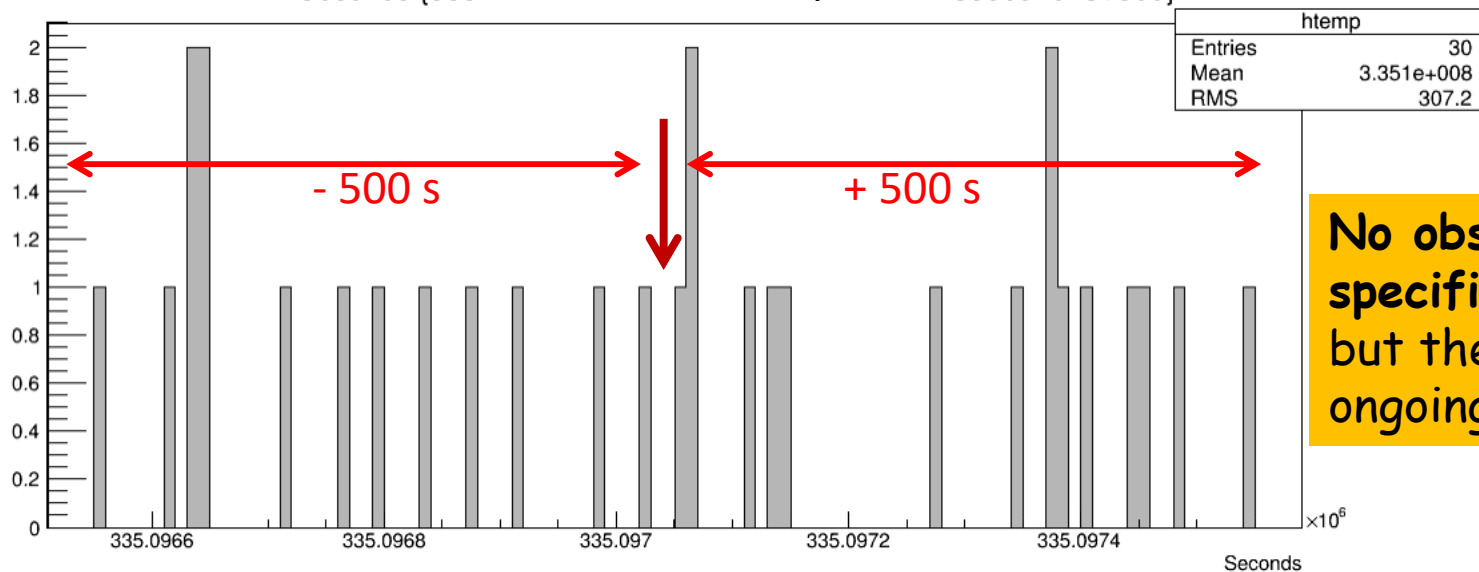
VERY PRELIMINARY analysis of *GW* events observed in August 2017

- *GW170814*: First measurement of *GW* polarization
- *GW170817*: First detection of EM counterpart of *GW*

Analysis strategy: search for multi-track events

- Rate of multi-track events: 10-60 events in 1000 s
- First analysis carried out in +/- 500 s around the *GW* event of interest with $N_{\text{track}} \geq 3$

CERN-02 telescope **GW170817**

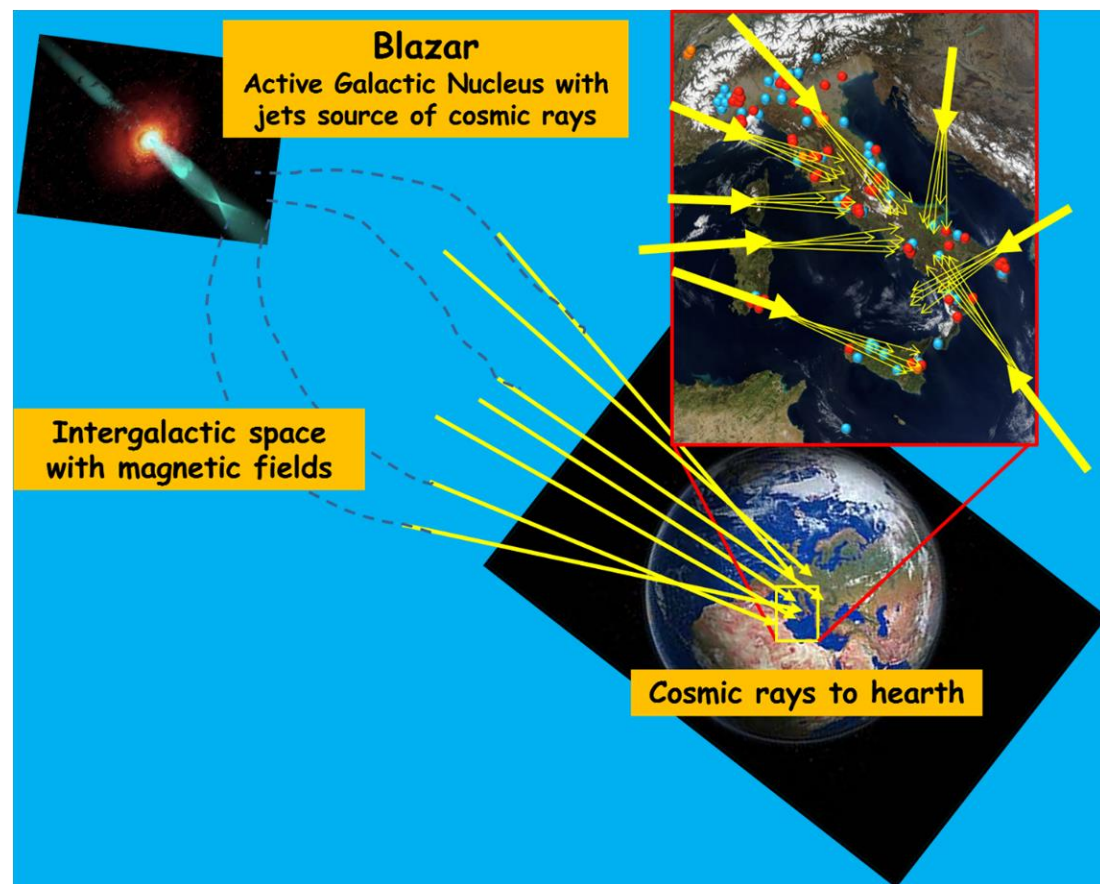


No observation of any specific anomaly but the analysis is still ongoing

Search for Multi-messenger events with EEE telescopes



On **Sept. 22, 2017** a high energy (290 TeV) neutrino event was observed by the IceCube km³ neutrino Observatory. An association with a blazar emitting γ -rays was found, suggesting that **blazar jets may be an important source of very high energy cosmic rays**.



Starting new analysis for EEE:
search for n telescopes with time coincidence ($n > 10-12$).

With 59 telescopes it requires a strong computational control of the many combinations of n of them.

The PolarQuEEEst experiment

Measure Cosmic Rays flux at the north Pole



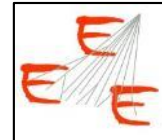
Airship Italia 1928
Umberto Nobile



PolarQuest 2018
20 July - 4 September 2018
<http://www.polarquest2018.org/>



Previous cosmic ray measurements underwater at the North Pole



A. Chilingarov and A. Zichichi – 2007

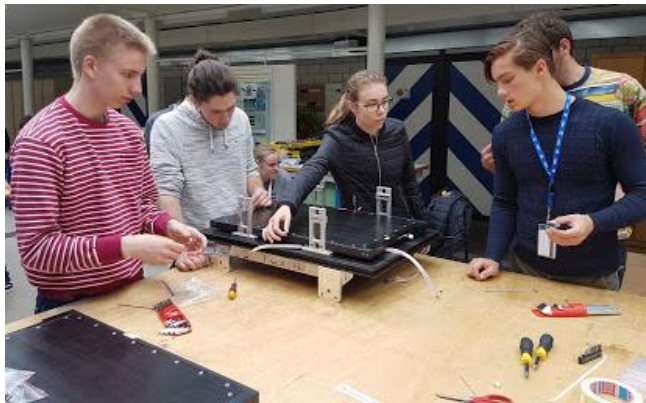
Measurements done at the North Pole in a submersible for few hours down to more than 4000 m depth

→ «No rate anomaly»

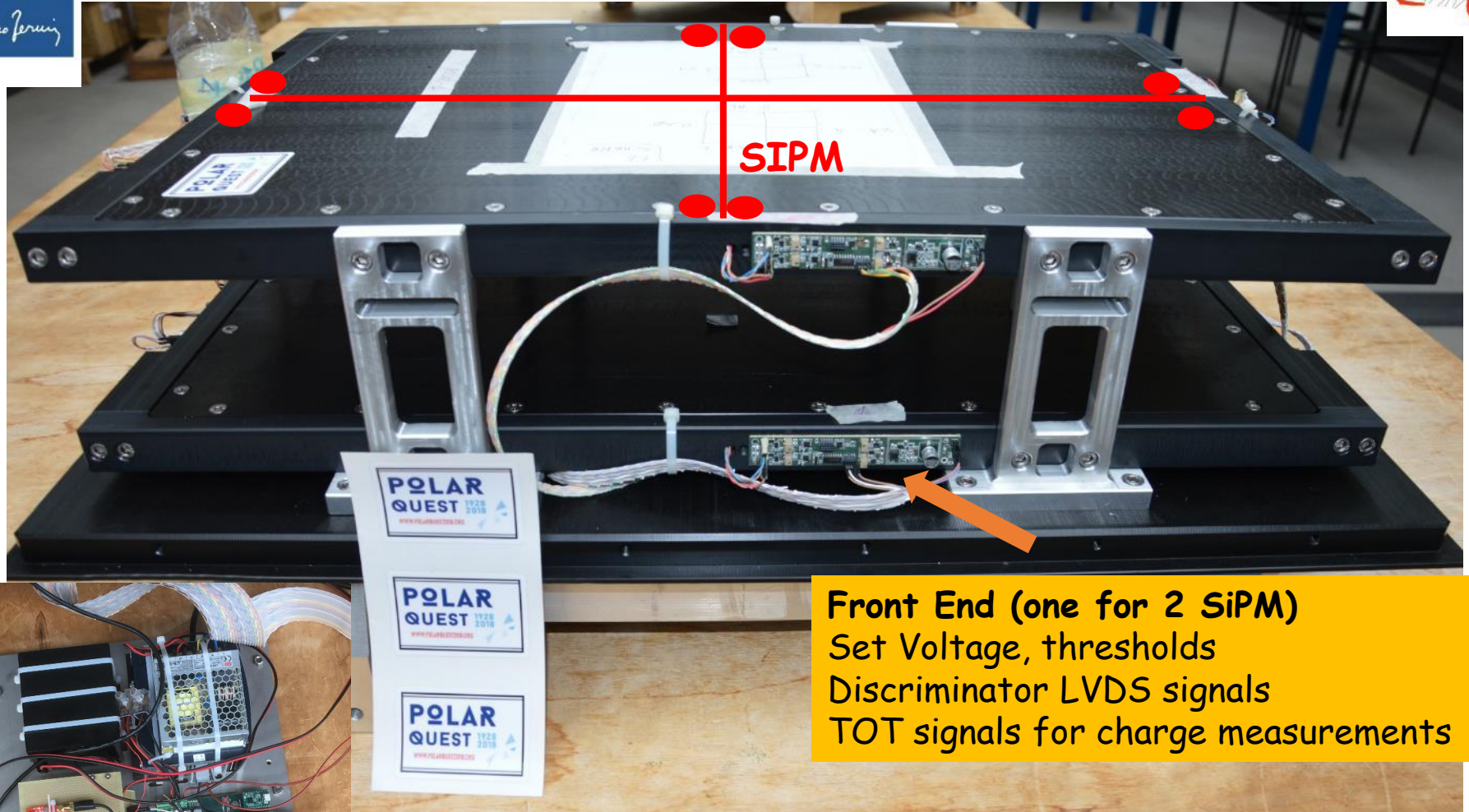


CERN: May 22nd- May 25th 2018

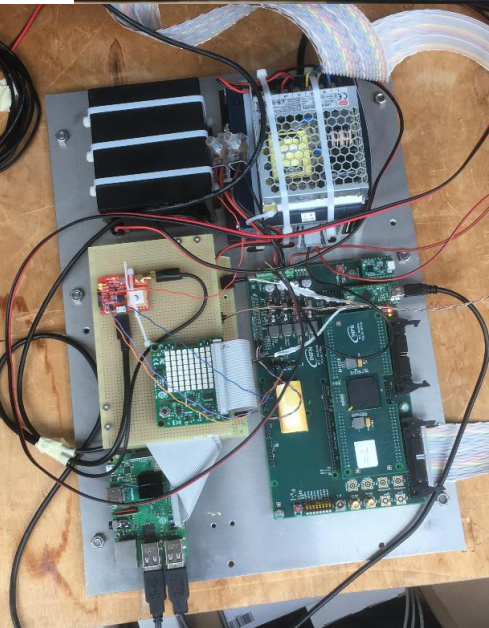
23 students from Italy, Norway and Switzerland at CERN to build the detectors.



Movie available here
<http://www.polarquest2018.org/adventure-for-climate-change/cosmicrays/>



Front End (one for 2 SiPM)
Set Voltage, thresholds
Discriminator LVDS signals
TOT signals for charge measurements



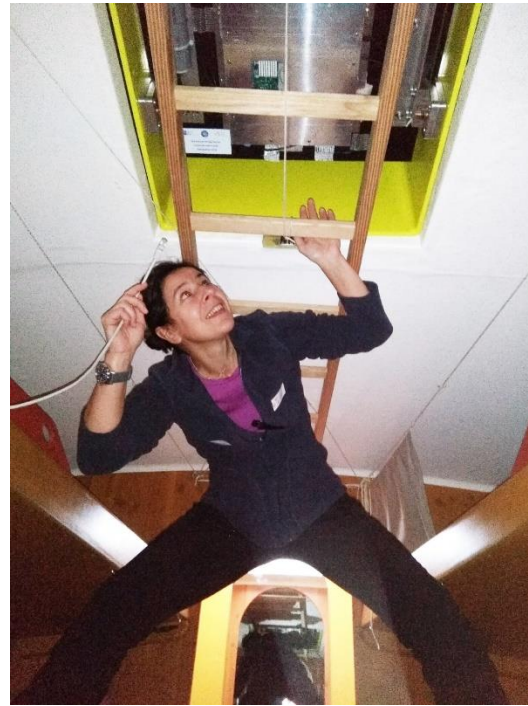
Total power consumption 12,5 W
16 ch TDC-TOT , Trigger, DAC, GPS, Controls



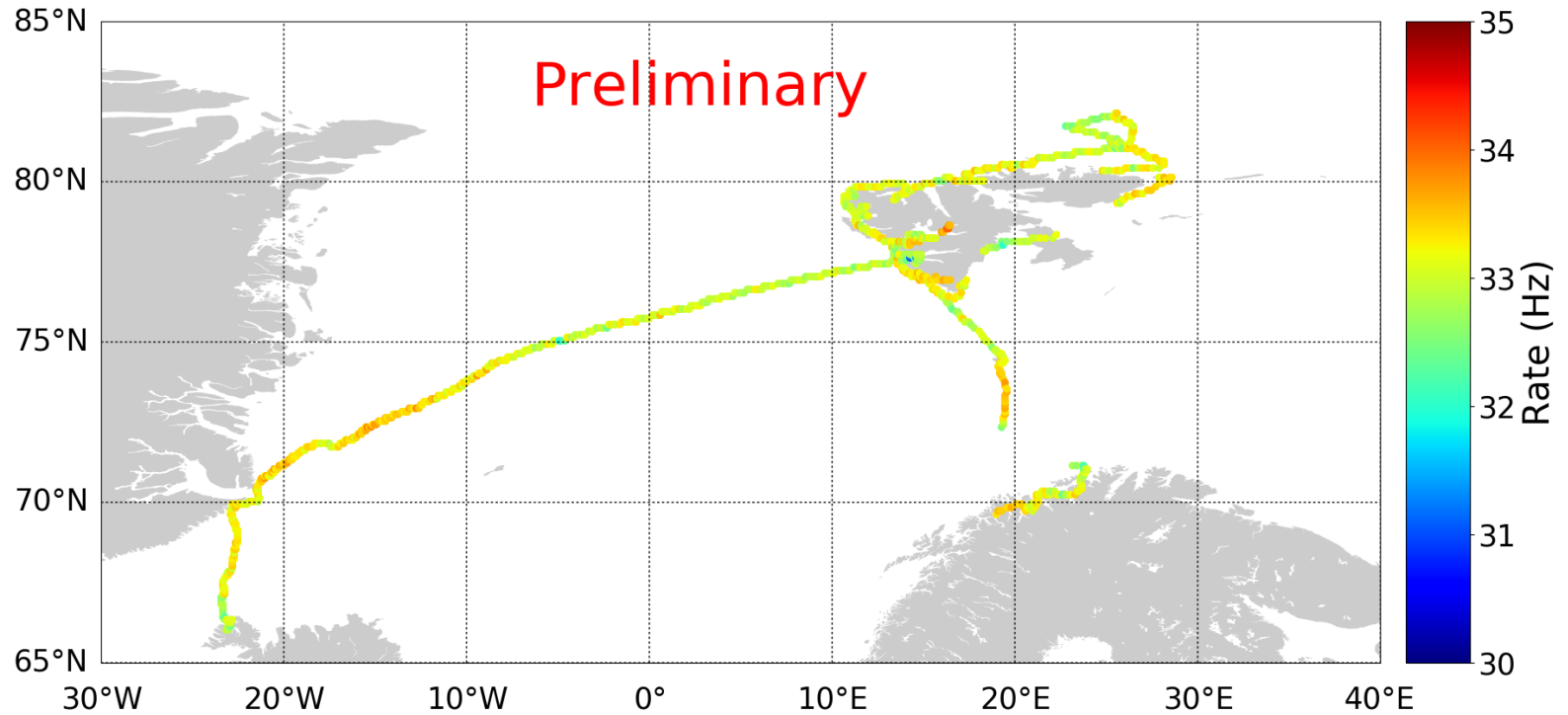
Polar-01 on boat Nanuq



Polar-02
Nesodden (Oslo)



Polar-03 Bra (Turin)



POLA-01 on boat 22/07 → 02/09 2018

- 3500 NM long voyage and 865 hours of data taking
- more than 110 M events collected

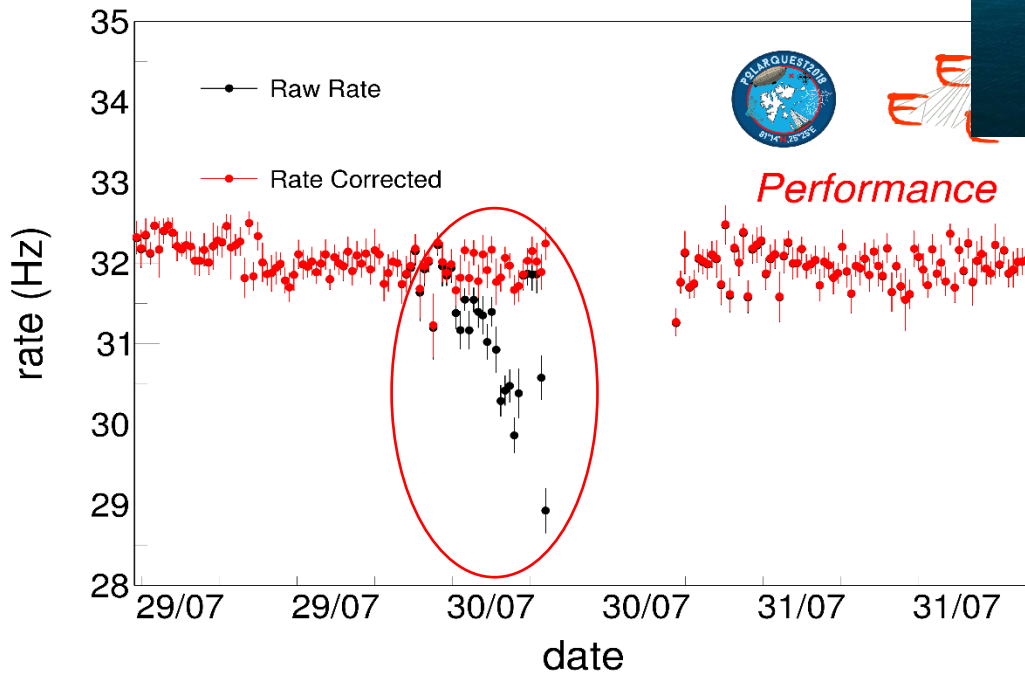
CENTRO
FERMI
Lucrezia Fermi



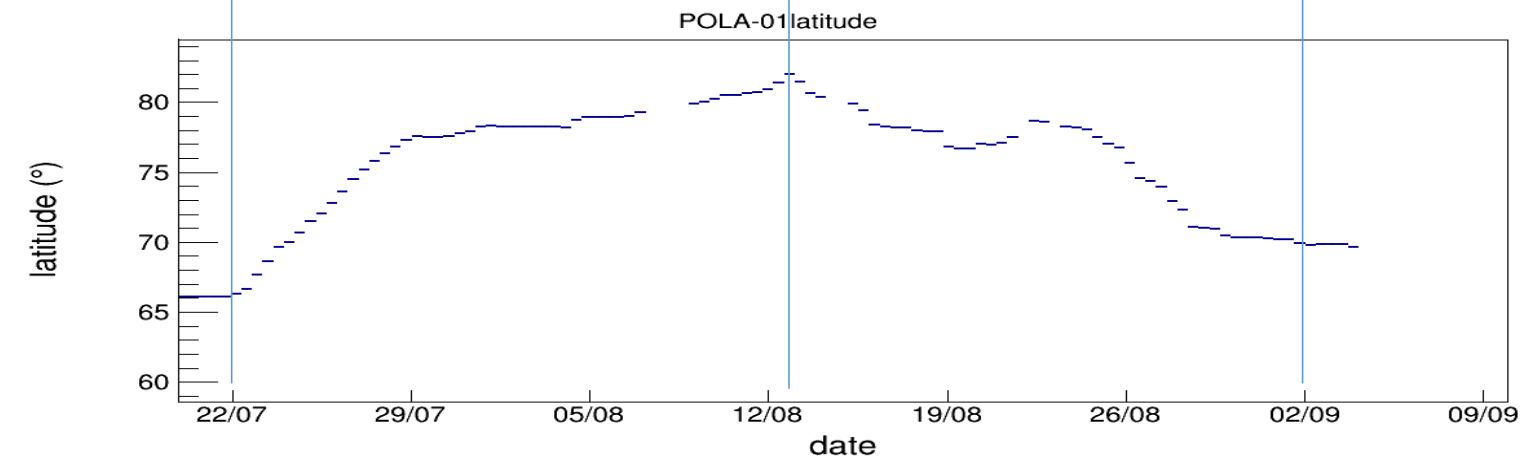
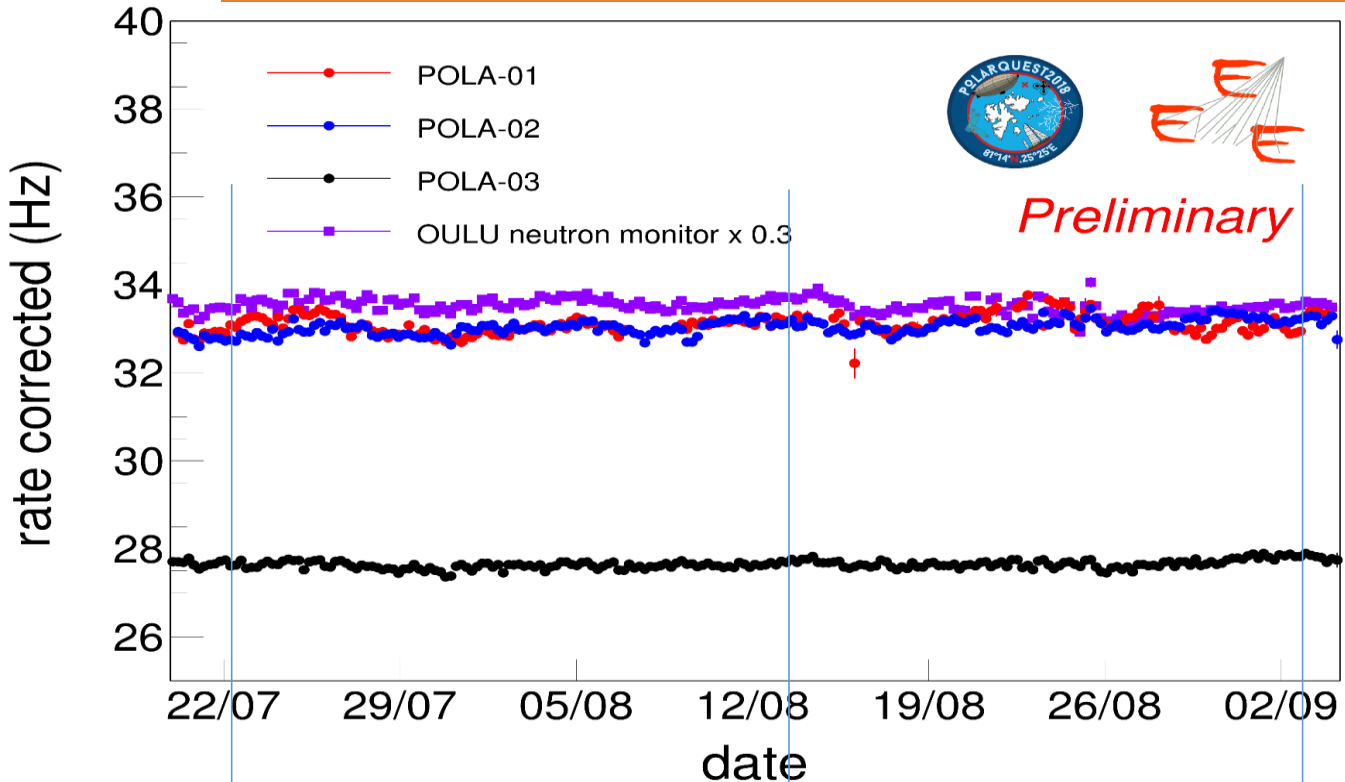
Orientation correction: an example



On 30th July a problem occurred for Nanuq (during low tide) ...



PolarQuEEEst : Rate (corrected)



Conclusions



- The EEE project is an experiment based on scientific research AND dissemination of scientific culture for high school students
- The EEE project has a very large area coverage, with 59 stations in high schools and laboratories distributed all over Italy and Switzerland.
- The EEE project detector performances have reached an exceptional level of quality and uniformity, considering its large extension and the involvement of high school students as for operation controls.
- The EEE project is presently working to increase the number of telescopes and improve the stability of operation through the whole year
- The EEE project is an experiment exceeding Italian borders, with many and increasing international connections and extending its measurements up to the North Pole.
- The EEE project has developed/is developing several analysis on multi-messenger events (Solar Forbush, Long range EAS correlations, Gravitational waves, Blazar jets) and is looking for further and more precise contributions to these studies