

Extreme Energy Events: la scienza nelle scuole



Scientific responsible: prof. Antonino Zichichi

Coordinator: Marcello Abbrescia

Participants: 87 people among which:

8 assegni di ricerca CF

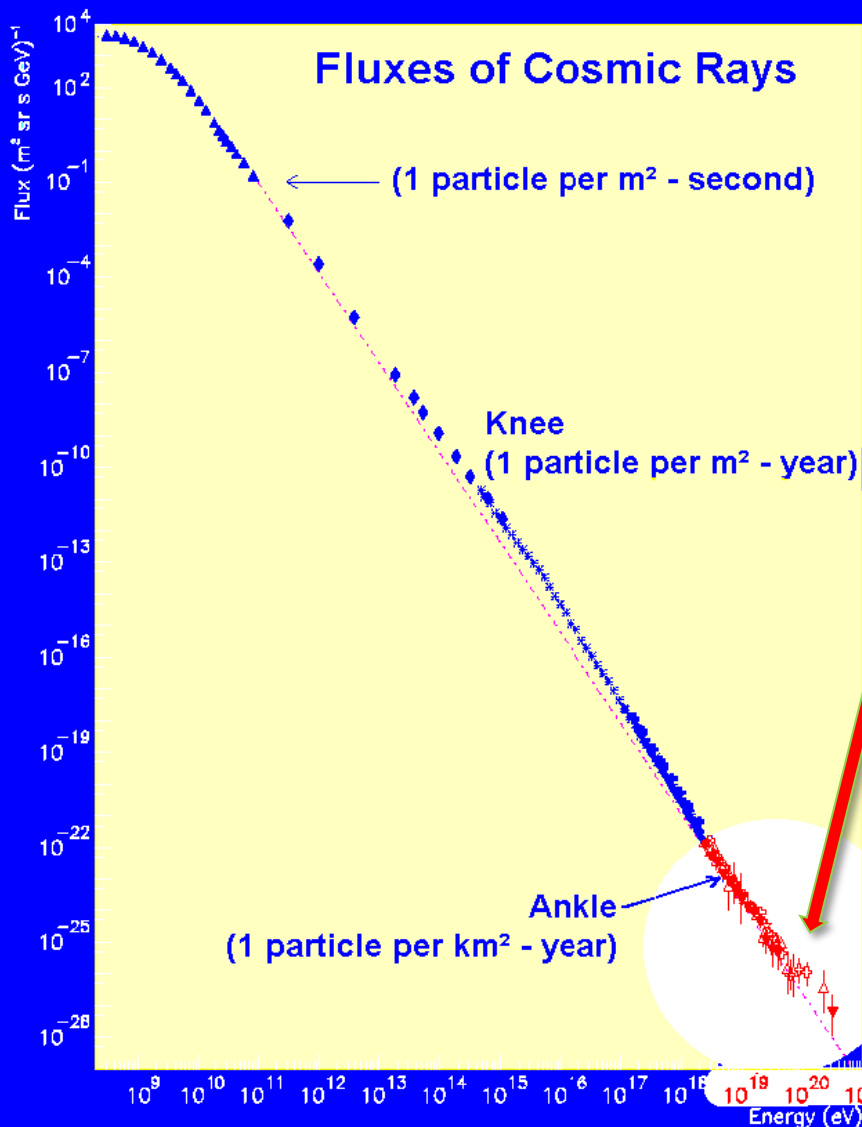
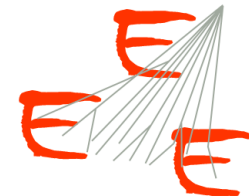
1 researcher + 1 tecnologo t.i. CF

(a detailed list will be attached)

Place of Work & Collaborations:

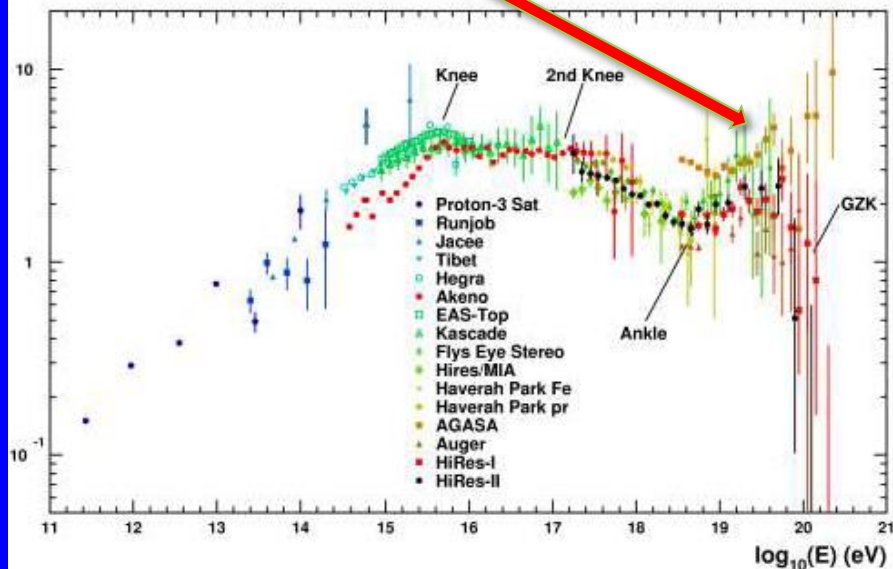
Centro Fermi + 17 INFN sections and/or Physics Departments + CERN +
INFN/CNAF + around 100 high schools in Italy

The project

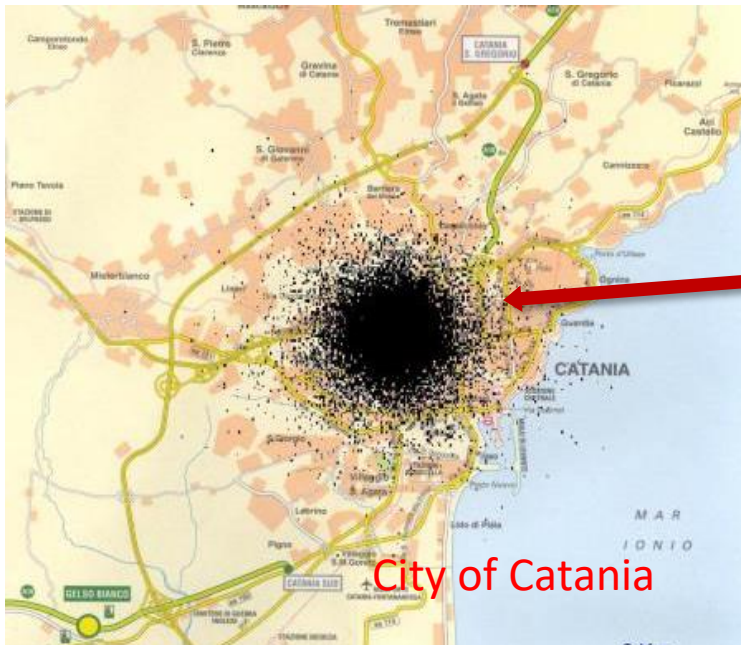
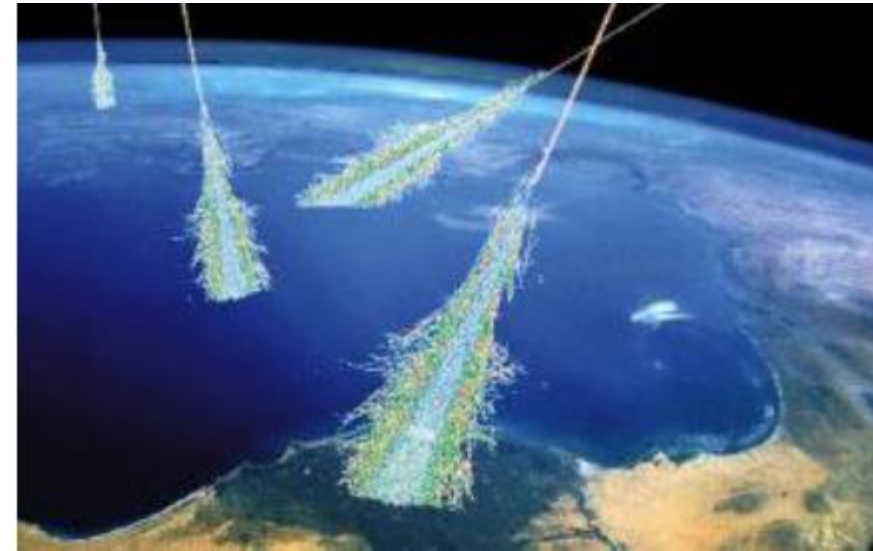
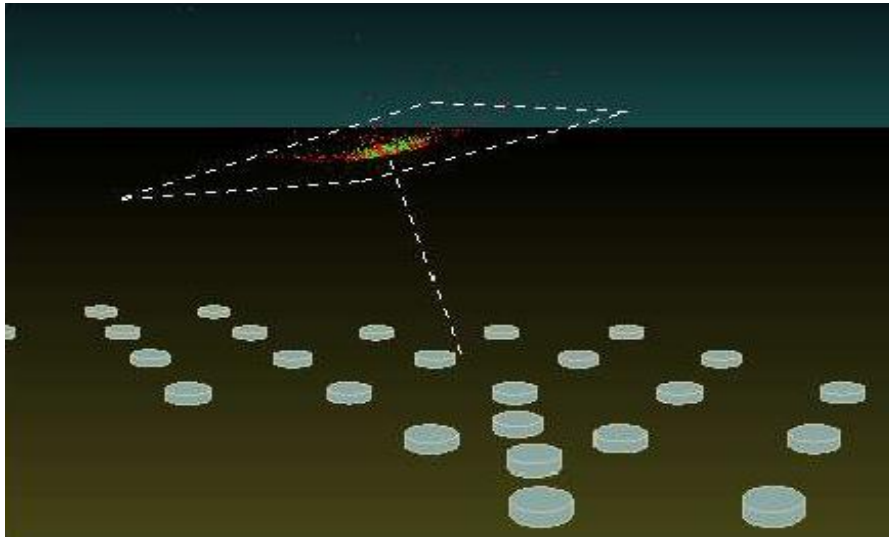
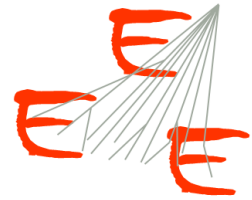


Aims at covering the most interesting, and still partially unexplored, region of the cosmic ray spectrum:

- ✓ $E > 10^{18}$ eV
- ✓ Extragalactic sources
- ✓ GZK cutoff
(Greisen, Zatspein and Kuz'min)



Method of observation



City of Catania

Detect muons arriving at the surface

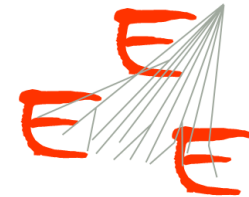
✓ Many, low cost, easy to operate stations

Simulation of the shower induced by a 10^{16} eV proton

✓ At ground level 1 million muons arrive, over an area with radius at least 2 km.

High energy showers revealed by detecting muons at different stations at **the same time** (“coincidences”)

Present status



50 telescopes at High Schools

+ 2 telescopes at CERN

+ 4 at INFN Units

Total: 56 telescopes

+ \approx 50 institutes on the waiting list

✓ **Largest (in terms of total detector area) system using MRPCs**

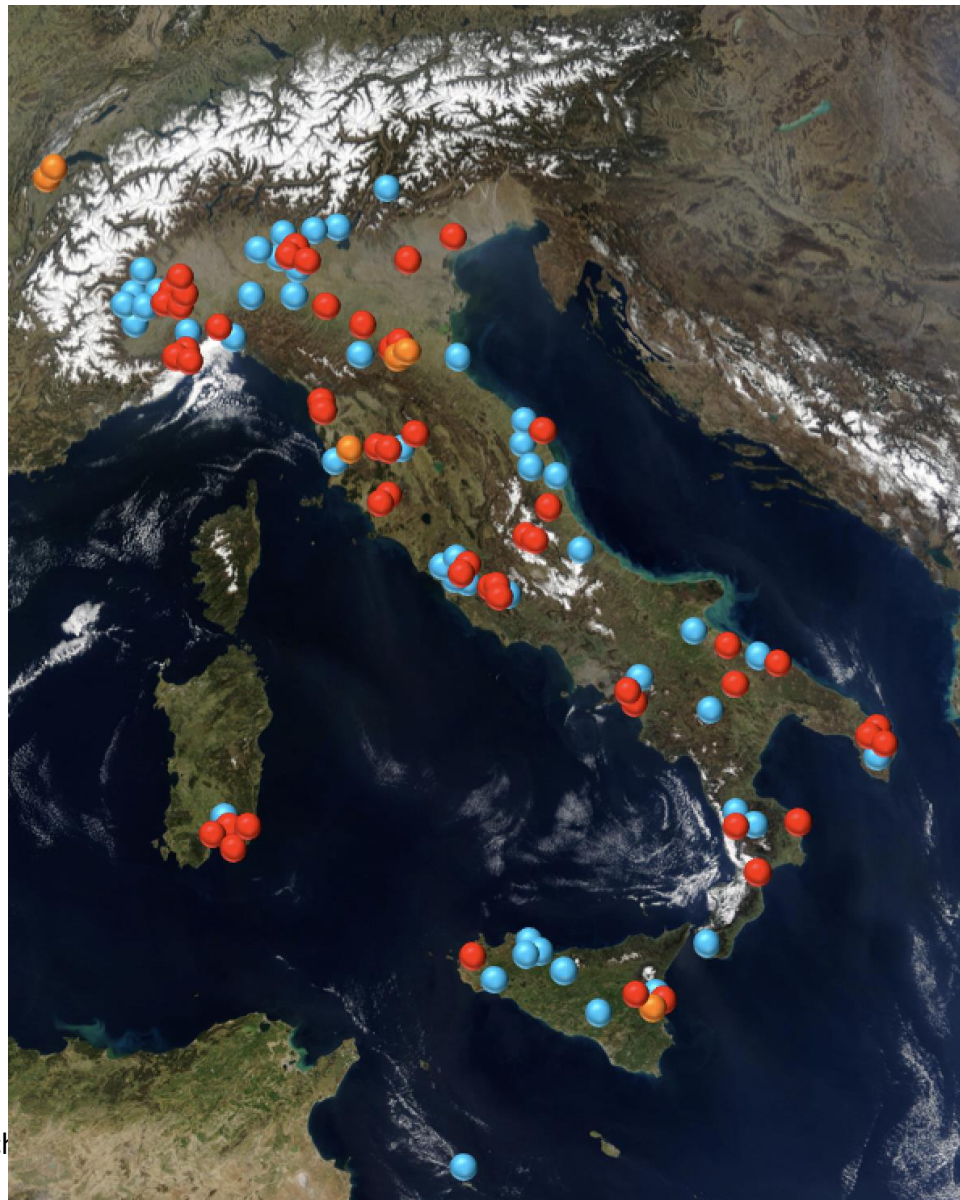
✓ **Largest cosmic rays experiment in Europe**

● *Stations in operation at schools*

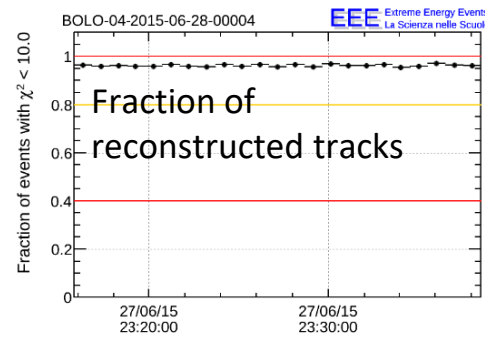
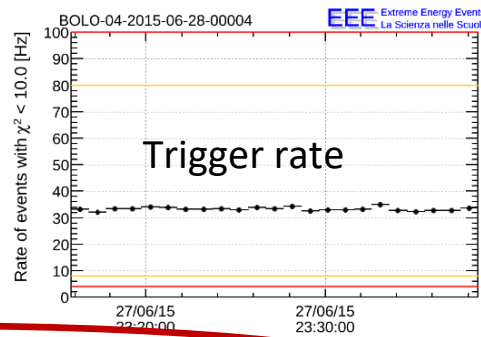
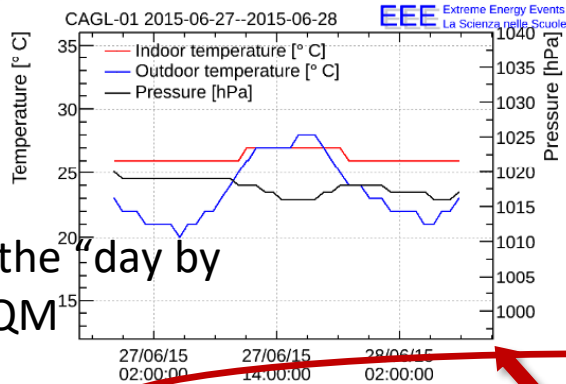
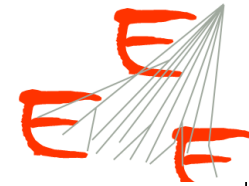
● *Stations in operation at research centers*

● *Institutes taking part to the analysis*

Roma, March



EEE Online monitoring



Link to the “day by day” DQM

[SCHOOLS ELOGBOOK for RUN 4](#)
[SHIFTERS ELOGBOOK](#)
[Set Automatic Shift REPORT Messages](#)
[Automatic Shift Report ARCHIVE](#)

[Home Page EEE](#)
[Masterclass](#)
[Download the Excel Sheet](#)
[Coincidences](#)
[Connectivity Report](#)
[Data Request](#)

Two e-logs and automatic shifter reports

[EEE Monitor] RUN4: October 2, 2017 - May 30, 2018
[EEE Monitor] RUN4 - Data Taking - Day number: 137
Total number of candidate tracks ($\chi^2 < 10$) in the database: 60963257193

Questa tabella mostra la situazione dei telescopi in acquisizione:
 In **verde** sono indicati i telescopi in presa dati e trasferimento nelle ultime 3 ore con parametri di acquisizione ragionevoli nell'ultimo run analizzato.
 In **giallo** sono indicati i telescopi in cui trasferimento e/o acquisizione sono sospesi da più di 3 ore o con tracce ($\chi^2 < 10$) minori di 10 Hz nell'ultimo run analizzato.
 In **rosso** sono indicati i telescopi in cui trasferimento e/o acquisizione sono sospesi da più di due giorni o con tracce ($\chi^2 < 10$) minori di 5 Hz nell'ultimo run analizzato.

Link to the “run by run” DQM

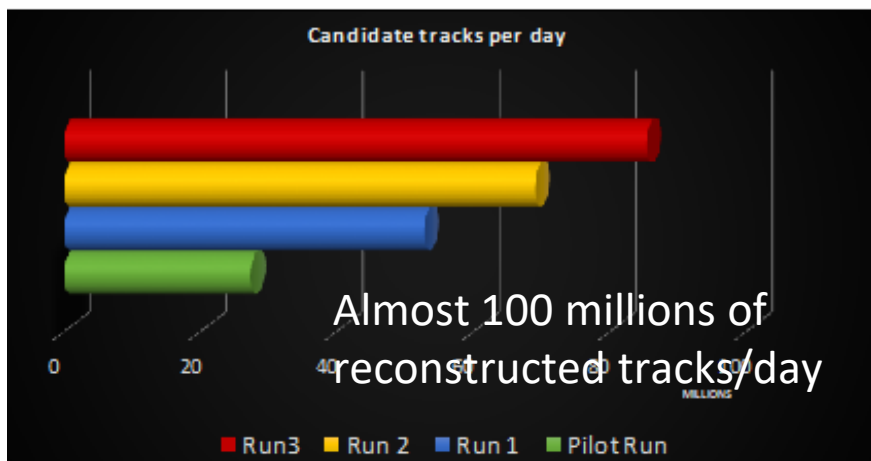
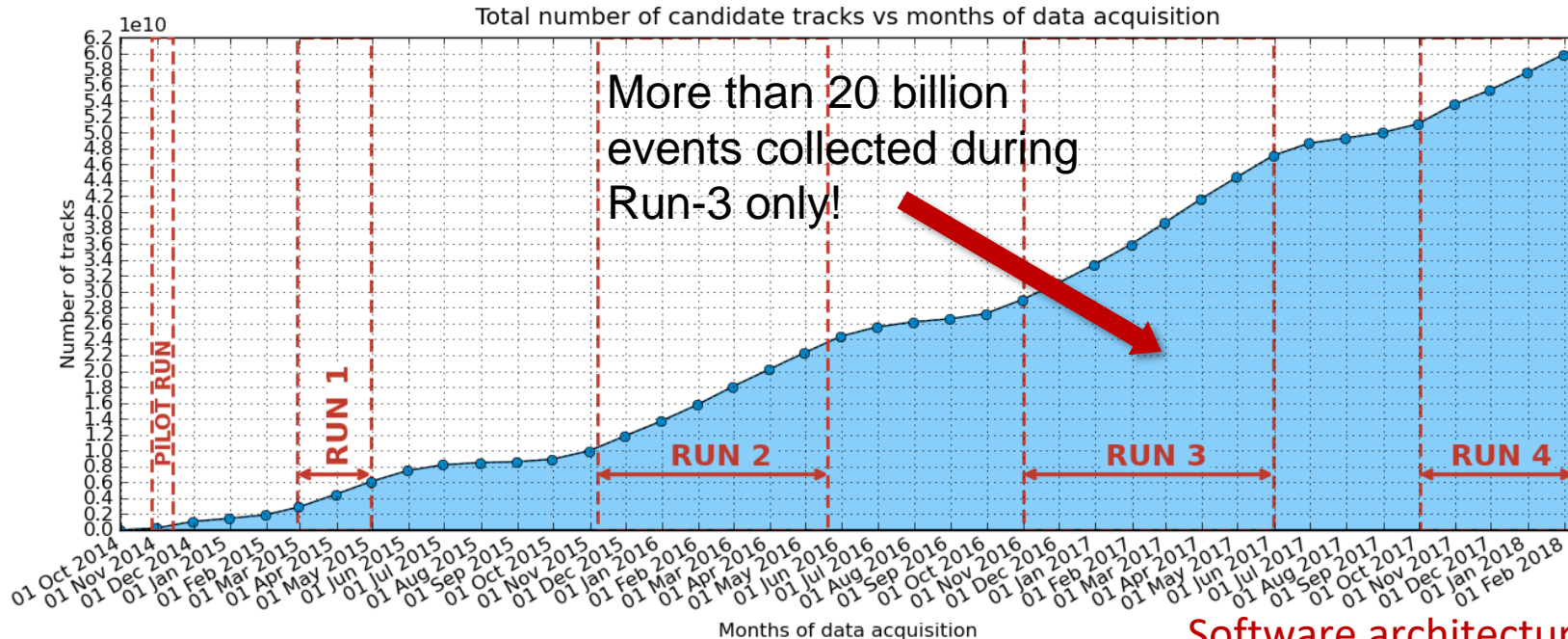
School	Day	Time	Name of the last transferred File	Number of Files transferred today	Last Entry in the e-logbook of the Schools	Name of the last File analyzed by DQM	DQM daily report	RATE of Triggers for the last Run in DQM	RATE of Tracks for the last Run in DQM	Link to DQM
ALTA-01 [Event Display]	sab 10 febbraio	10:58	ALTA-01-2018-02-10-00030.bin	0 [History]	11:35 10/02/2018	ALTA-01-2018-02-10-00030.bin	11/02 [History]	37.0	31.0	ALTA-01
ANCO-01 [Event Display]	gio 15 febbraio	09:19	ANCO-01-2018-02-15-00012.bin	13 [History]	12:16 14/02/2018	ANCO-01-2018-02-14-00032.bin	15/02 [History]	17.0	13.0	ANCO-01
AREZ-01 [Event Display]	gio 15 febbraio	08:36	AREZ-01-2018-02-15-00020.bin	23 [History]	13:00 14/02/2018	AREZ-01-2018-02-14-00064.bin	15/02 [History]	36.0	32.0	AREZ-01
BARI-01 [Event Display]	gio 15 febbraio	09:33	BARI-01-2018-02-15-00019.bin	20 [History]	08:36 12/02/2018	BARI-01-2018-02-14-00048.bin	15/02 [History]	28.0	24.0	BARI-01
BOLO-01 [Event Display]	gio 15 febbraio	09:54	BOLO-01-2018-02-15-00034.bin	33 [History]	14:02 30/01/2018	BOLO-01-2018-02-14-00057.bin	15/02 [History]	47.0	42.0	BOLO-01

eee.centrofermi.it/monitor

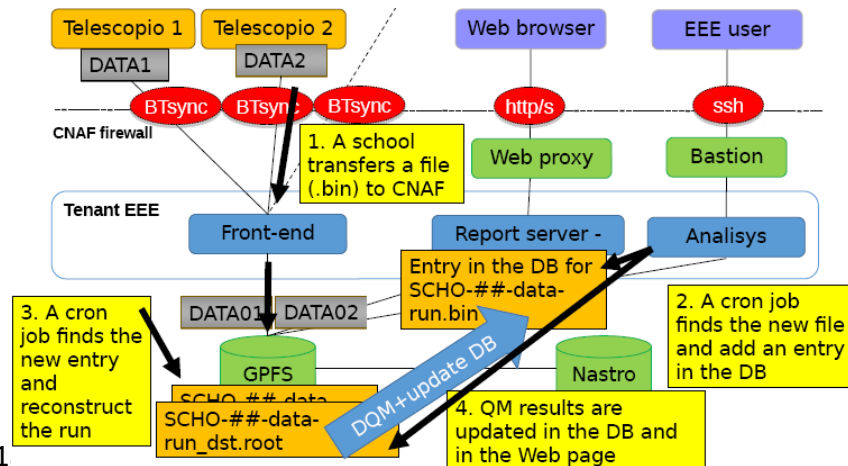
Data taking



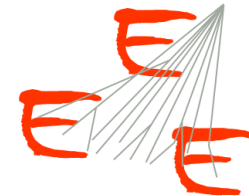
✓ About 62 billion events collected since the start of organized data taking



Software architecture



The EEE network upgrade



- ✓ Plan to build another 20 telescopes
- ✓ Will increase the capability of the EEE network to study the high-energy part of the cosmic rays spectrum
- ✓ Huge effort for 2017-19!

First bunch already completed

- ✓ 20-27 February → Lampedusa
- ✓ 12-18 March → Genova
- ✓ 23-29 April → SIEN-02
- ✓ 7-13 May → TORI-05 + Moscow
- ✓ 21-27 May → LODI-03
- ✓ 10-14 July → LODI + Korca
(spare chambers)
- ✓ 25-29 September → CAGL-04
- ✓ 21-24 November → BOLO-05
- ✓ + three sets of “spares”



Lampedusa: the southernmost point of Italy

New chambers for new telescopes



250 μm six-gap chambers

- ✓ Conceived for new eco-friendly gases
- ✓ Reduce operating voltage
- ✓ EEE plans to soon operate some telescopes with eco-friendly gases:

Improved front-end boards

- ✓ Amphenol cables and connectors replaced by Nugent ones
- ✓ New boards in production

New test protocol at CERN

- ✓ Tests on electrical (strip) connectivity
- ✓ Tests on gas tightness
- ✓ Tests on current, rate and efficiency
- ✓ Everything stored in a dedicated DB

MRPC 20170405007

N. gaps: 6 Gap size (μm): 250

High Voltage

HV- on TOP side and HV+ on BOTTOM side
 Correctly labeled

Strips

Solderings
 Strips connectivity test
 List problematic strips (solderings or connections) if any:

Left connector (HV- side) [Grid]

Right connector (HV- side) [Grid]

Notes: colored solderings have been soldered several times

Gas Tightness: 0.39 l/h

MRPC leak

Notes: Leaks found and cured on strip connector left side, by adding silicon on the mask

Glass Res. (MΩ)

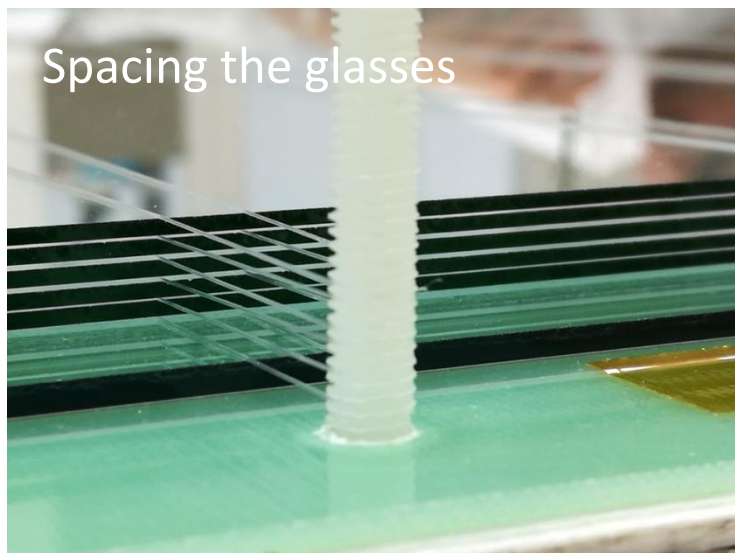
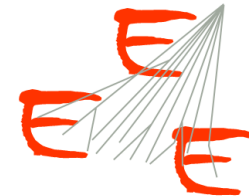
2.1	5.3	1.4	2.5
3.4		5.6	
1.4	0.9	2.5	4.1

Efficiencies, dark rate and currents

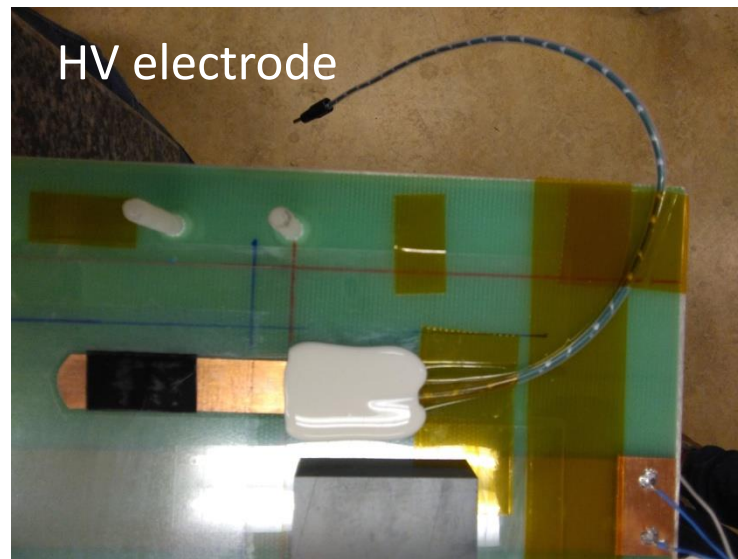
Supervisors:

Geneva
May 5th 2017

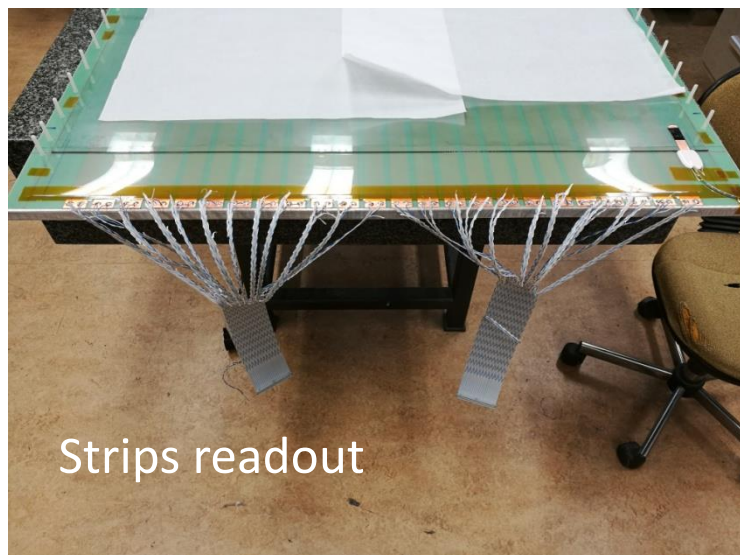
Costruction details



Spacing the glasses



HV electrode

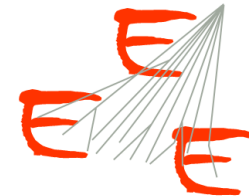


Strips readout



Moscow arrives to EEE

EEE arrives to Moscow

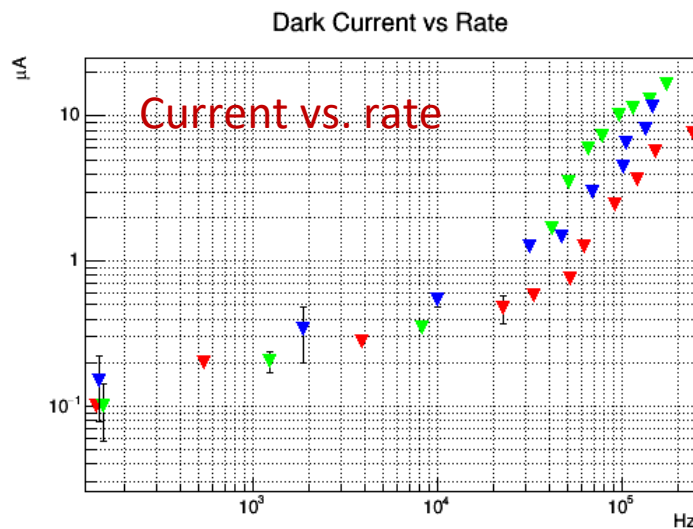
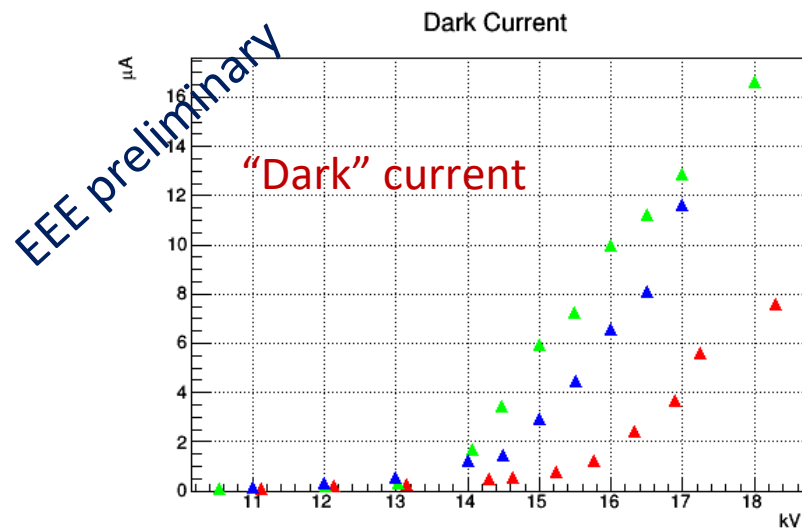
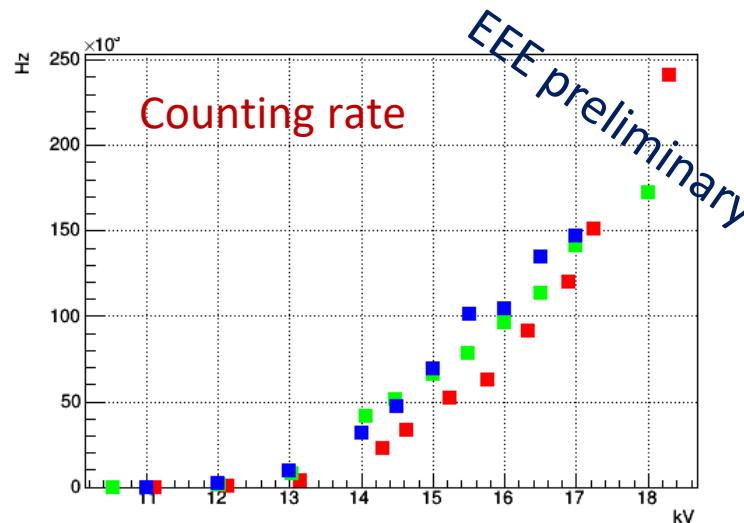
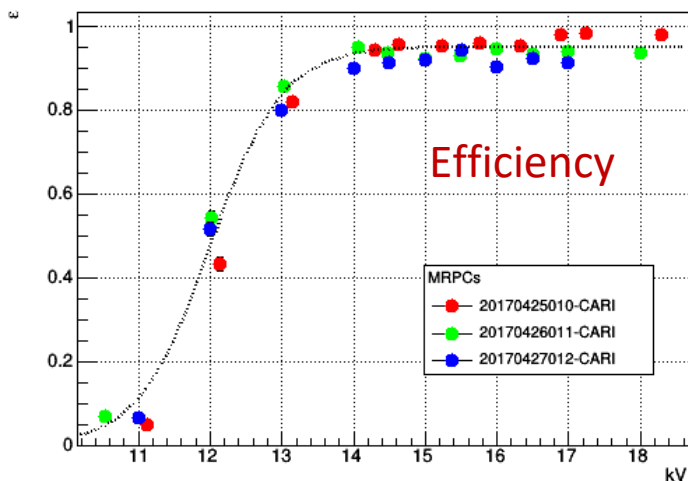


MOSCOW 20128

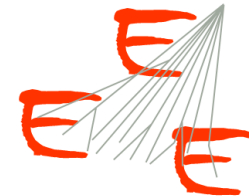
Some tests results



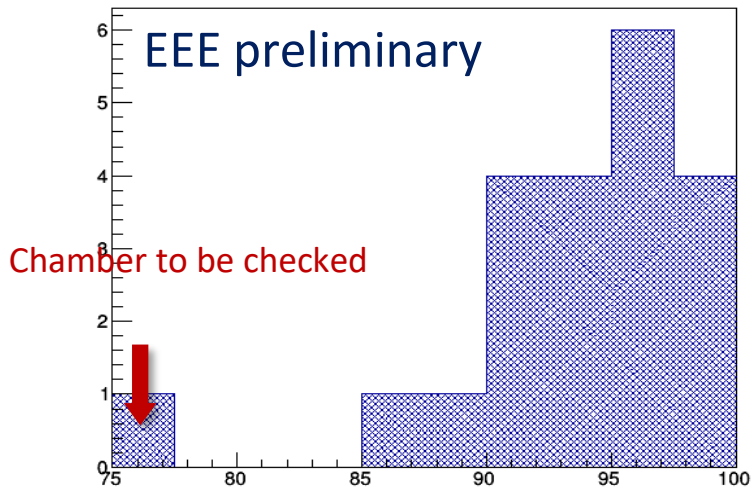
Typical curves for a set of 3 new MRPCs. These chambers are now installed as the new EEE telescopi at Cariatì (CARI-01)



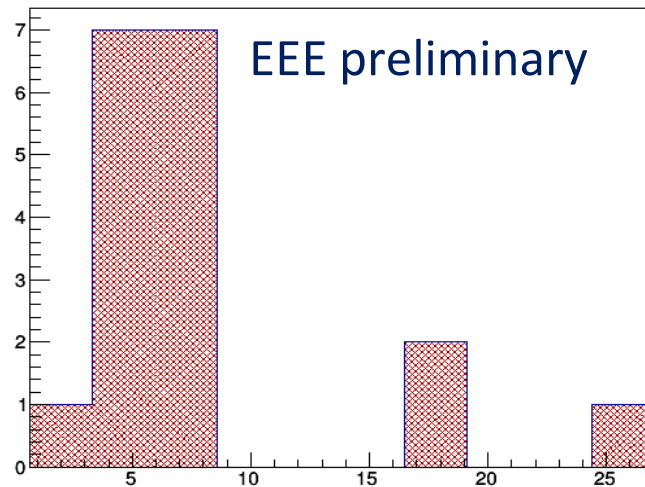
Some overall statistics



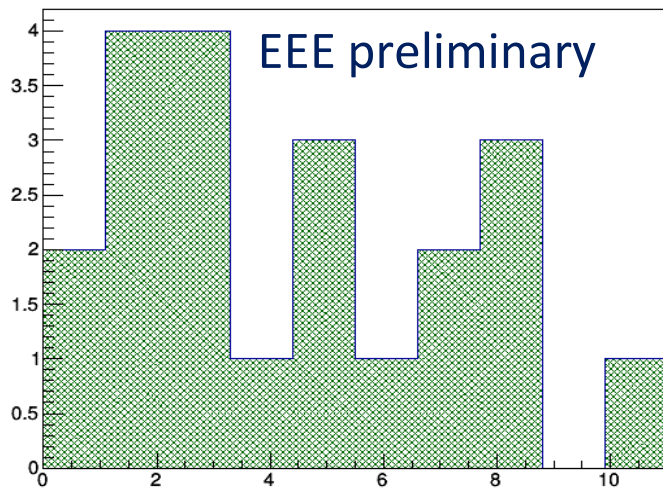
Efficiency summary (%)



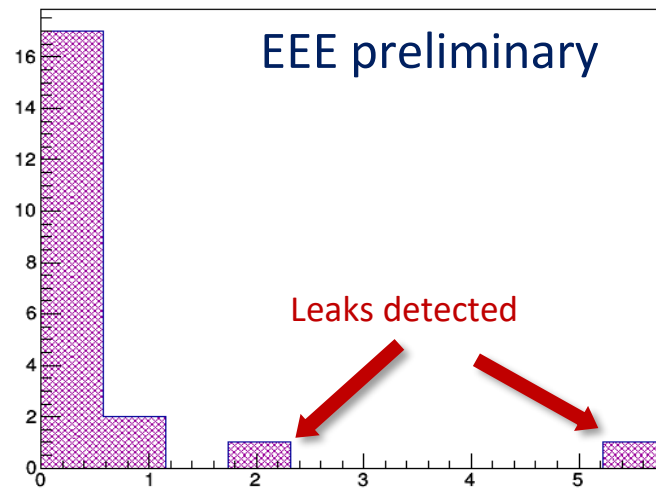
Dark Rate summary (Hz/cm²)



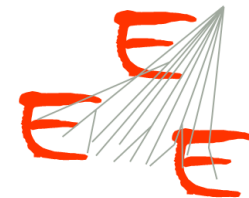
Dark current summary (nA/cm²)



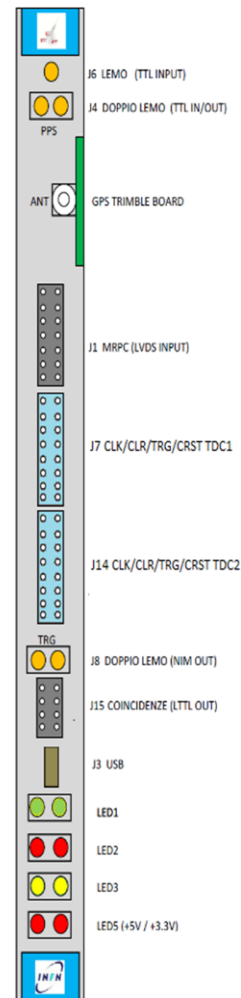
Gas tightness summary (l/h)



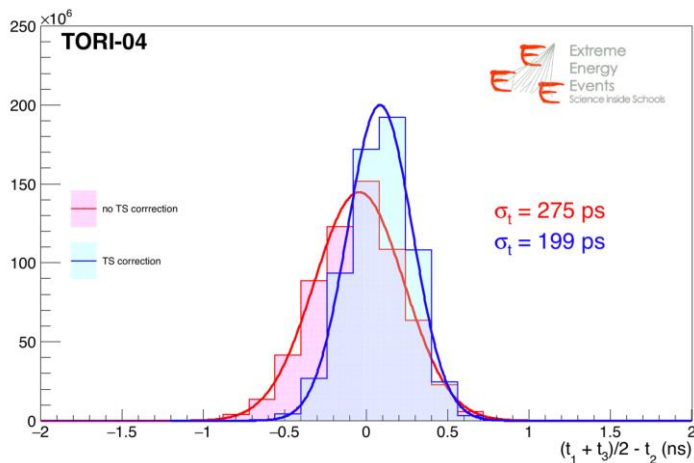
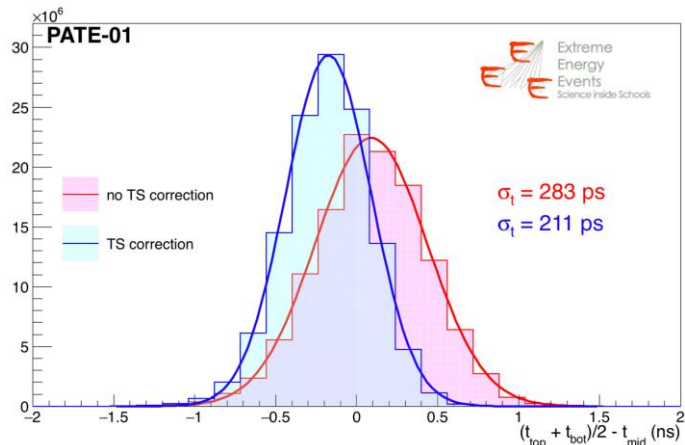
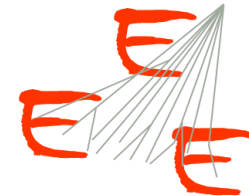
New trigger/GPS cards



- ✓ Developed between Bari and Lecce INFN sections
- ✓ Joins the functionalities of the present trigger and GPS boards (+ GPS interface)
- ✓ Additional functionalities:
 - clock distribution
 - counters accessible via VME
 - trigger logic programmable via VME
- ✓ Already installed at Lodi-02, FRAS-02, SIEN-01, TORI-02, VICE-01
- ✓ Plan to be deployed in all stations
- ✓ Proposal to be commercialized from CAEN

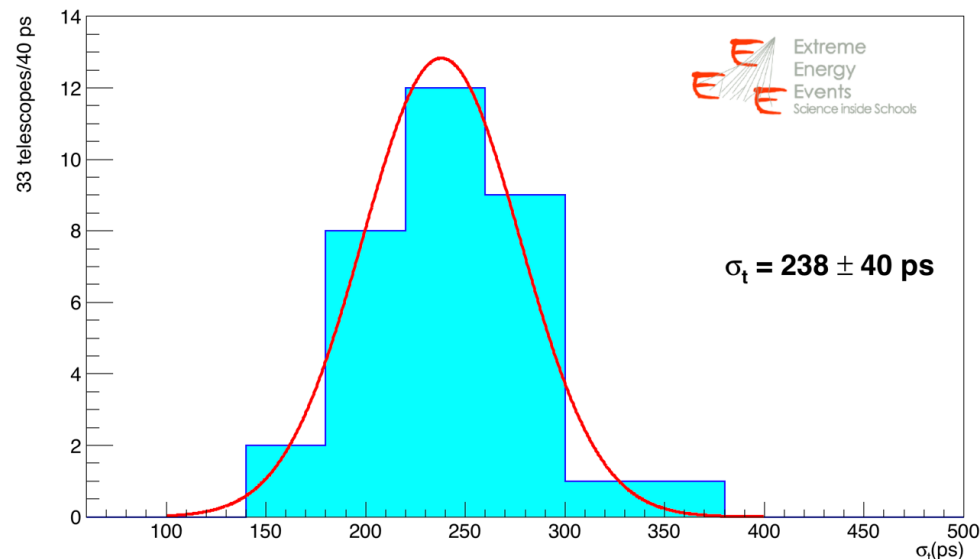


Chamber performance



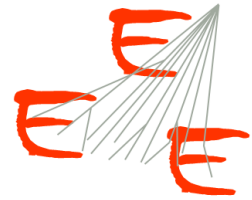
Effect of time slewing correction on chamber time resolution

Dedicated runs have been performed to monitor the performance of the chambers in the EEE array

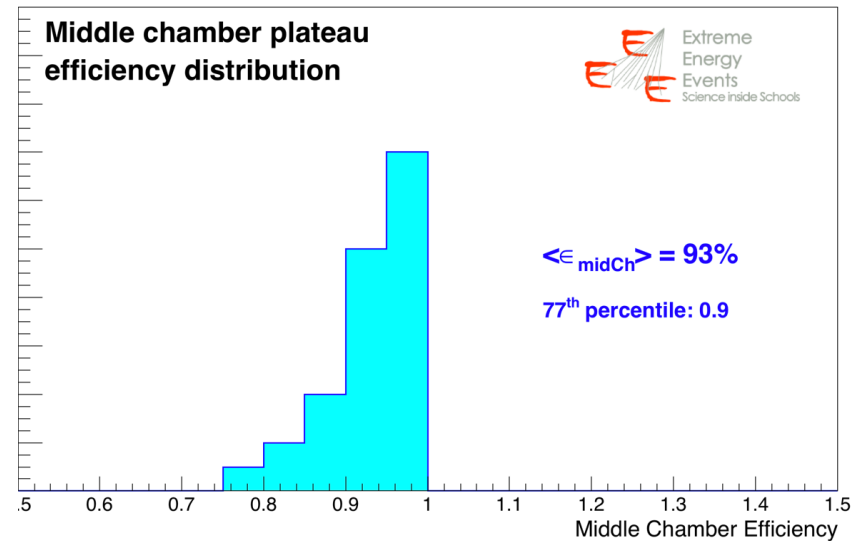
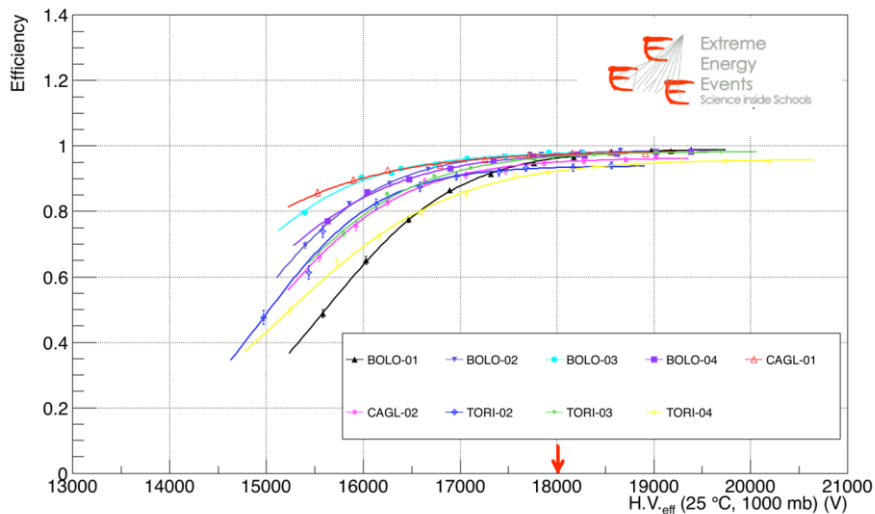


Time resolution of the chambers of the EEE array after time time slewing correction

Chamber efficiency

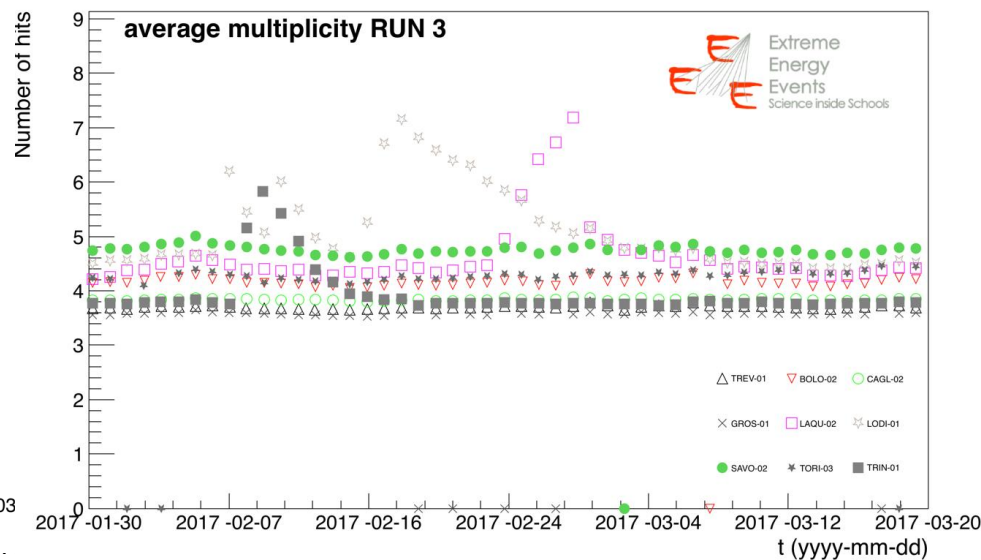
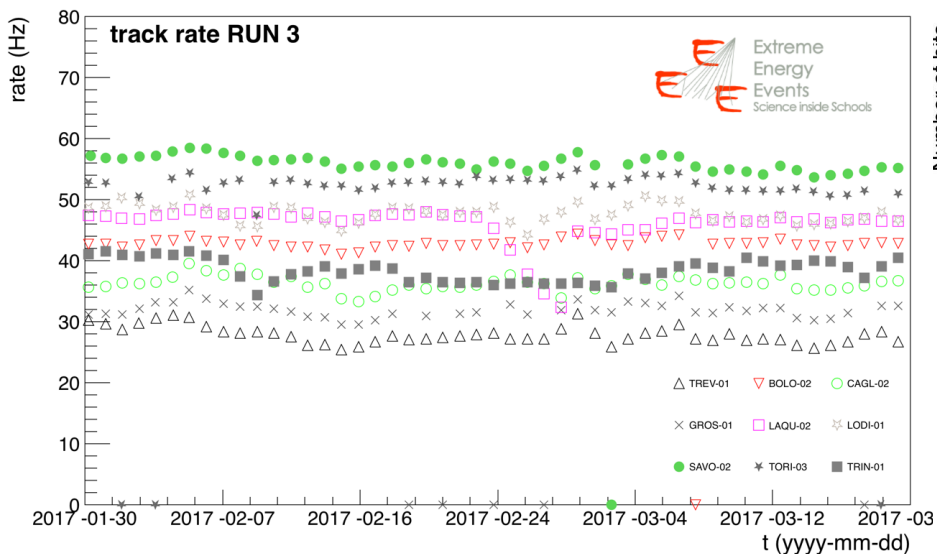
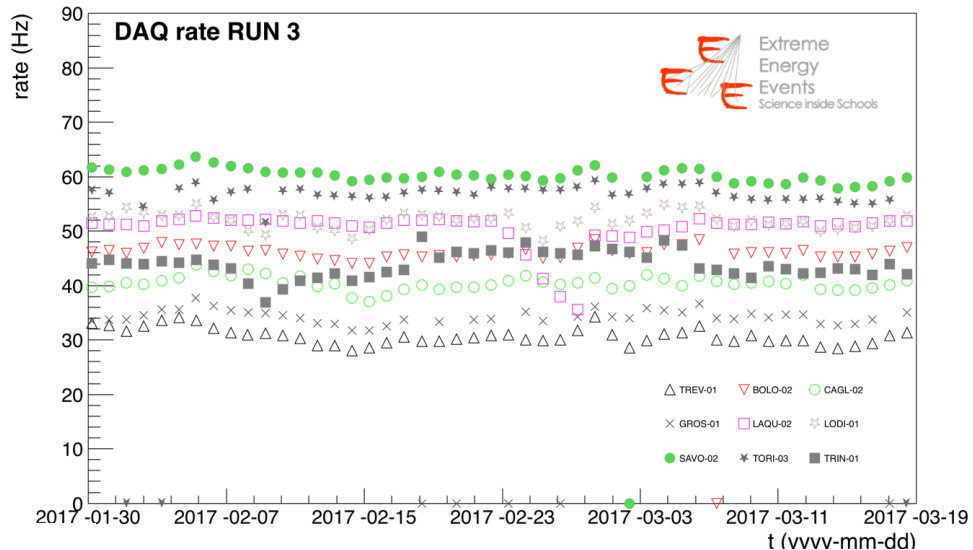
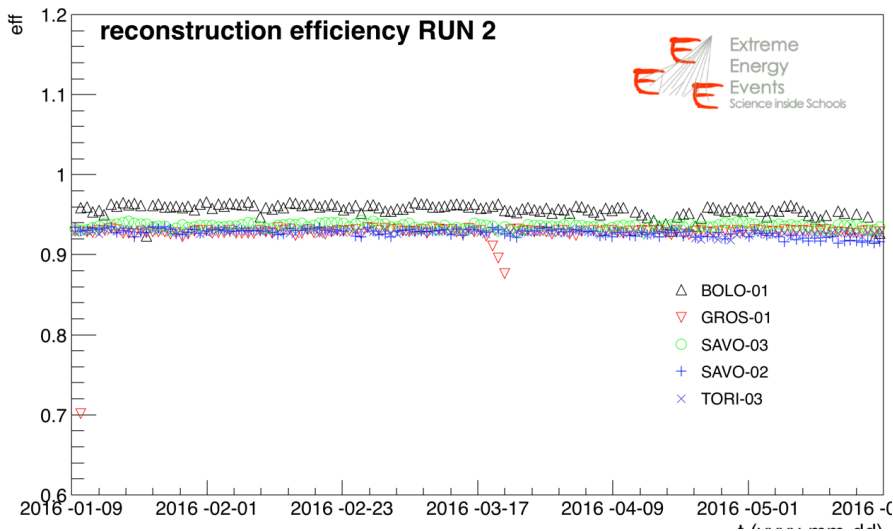
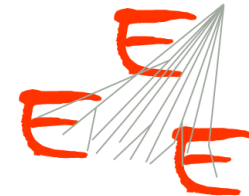


Measured using top and bottom chambers in each telescope as trigger and tracking
 Extrapolating the track and looking for a hit in a fiducial region around the intersection point

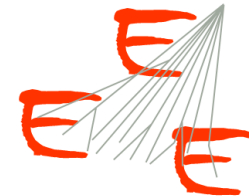


- ✓ average efficiency of the telescope network ~93 %
- ✓ compatible within expectations and with the results from beam-tests performed at CERN
- ✓ efficiency better than 93 % is reached by 77% of the network

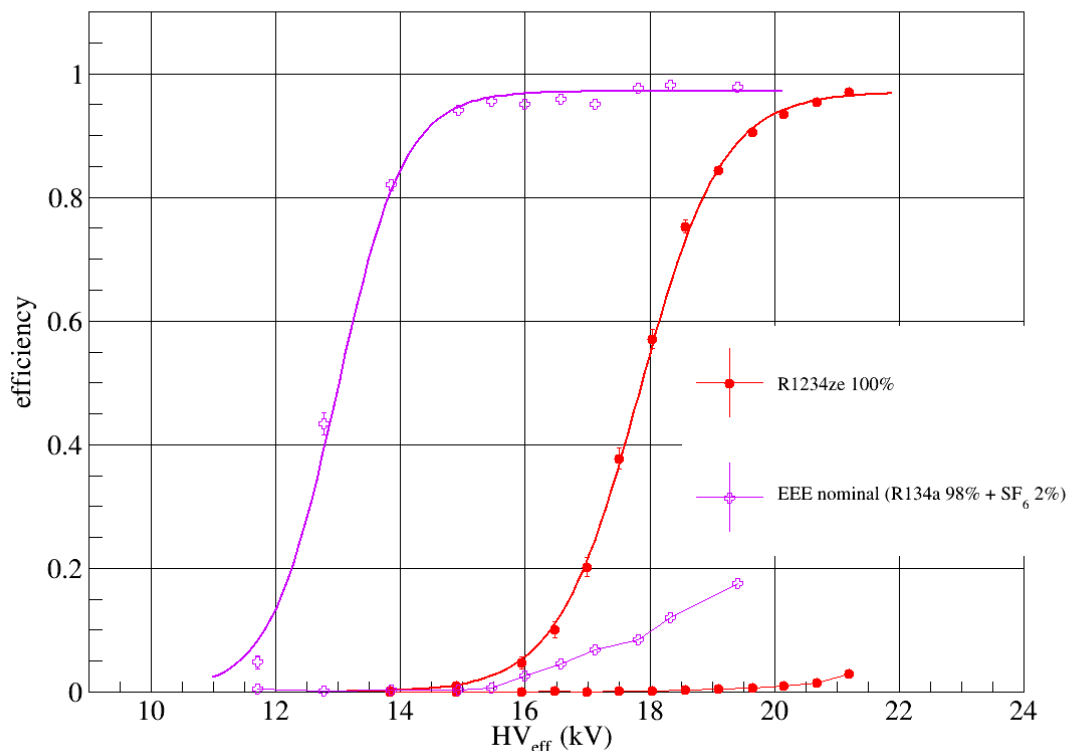
Long term stability



The QuEEEst for EE Eco-gas



- ✓ Global Warming Potential(GWP) measures the greenhouse effect of a gas normalized to CO_2 ($GWP_{CO_2}=1$)
- ✓ Gas mixtures with $GWP > 150$ have been banned by EU (scientific laboratories exempt)
- ✓ Present RPCs adopt mixtures with high GWP



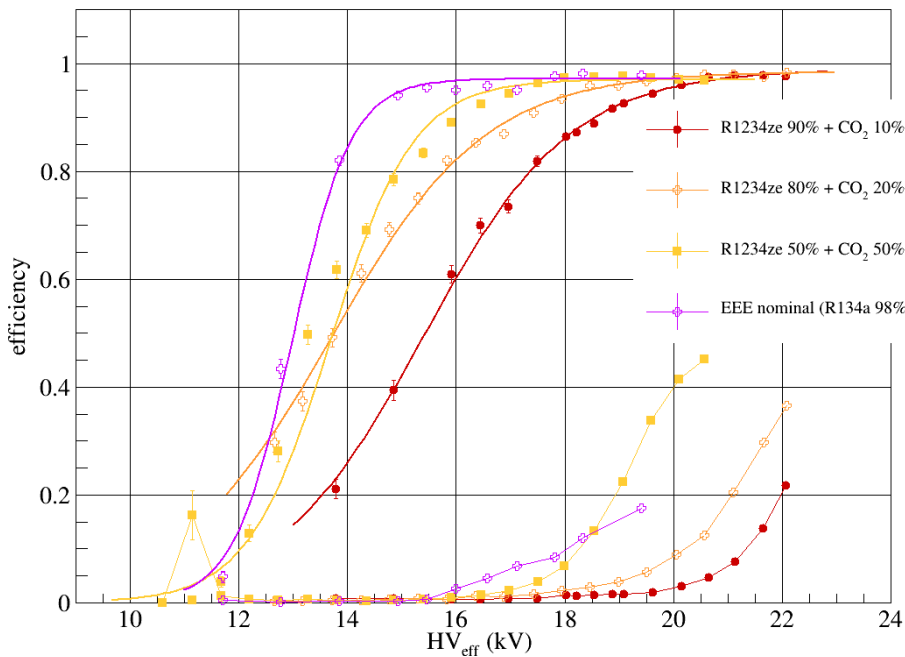
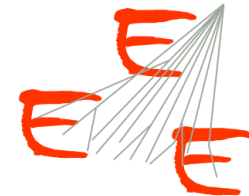
First tests performed with tetrafluoropropane (R1234ze)
 ✓ High efficiency, low streamers
 ✓ Promising, but high operating voltage



Further tests with:
 ✓ R1234ze + CO_2
 ✓ R1234ze + SF_6
 ✓ R1234ze + He (to do)

Binary mixtures with $HV < 18$ kV are requested

Tests on EEEco-gas

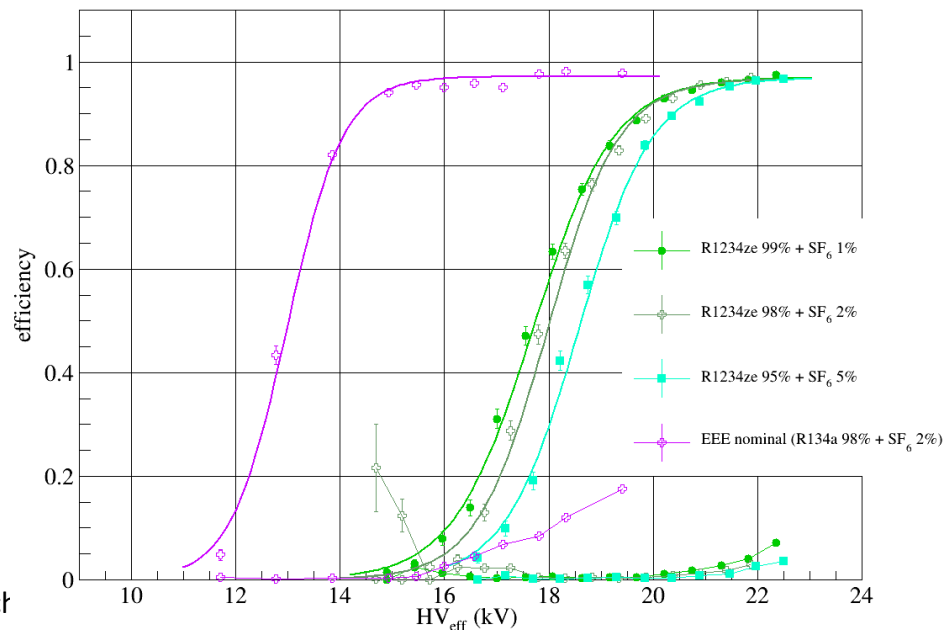


R1234ze + CO₂

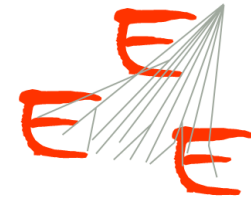
- ✓ Lower HV with respect to standard mixtures
- ✓ However, noisy behaviour observed

R1234ze + SF₆

- ✓ Higher HV with respect to standard mixtures
- ✓ Noise highly suppressed by SF₆
- ✓ However, only SF₆ 0.5% max percentage fullfills UE requirements

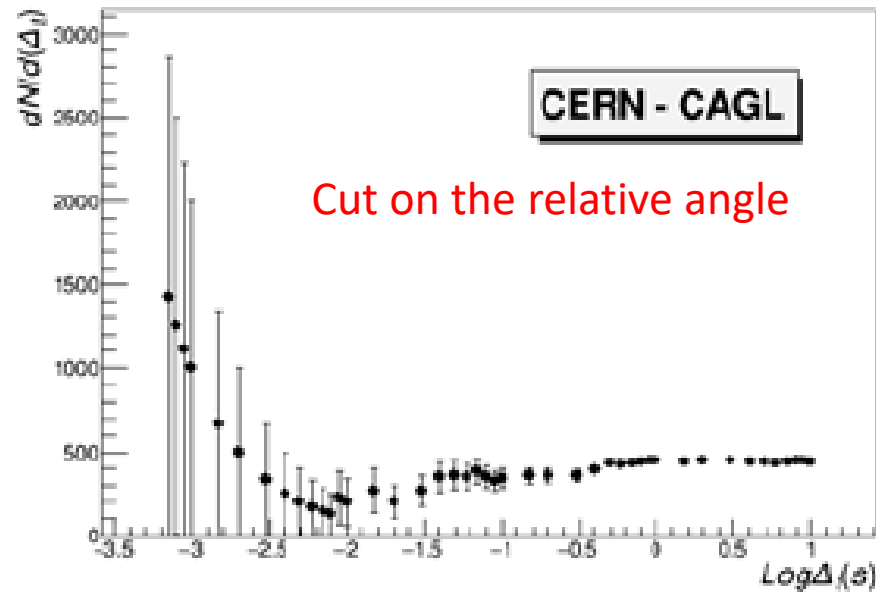
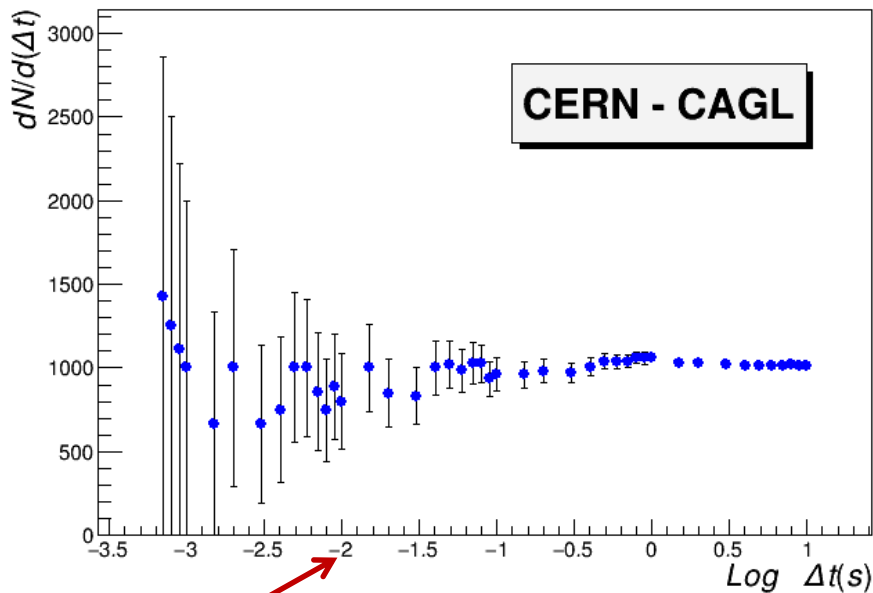


Long distance correlations



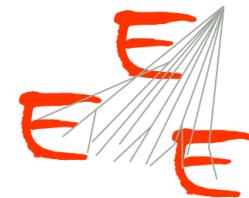
- **Strategy: correlations between individual showers in telescopes clusters**
- ✓ Shower rate: 0.001 - 0.04 Hz (depending on cluster and S/N ratio)
- ✓ Spurious rate in 1 ms: 10^{-8} - 10^{-7} Hz (0.001 - 0.01/day)

Number of events $dN/d(\Delta t)$ for decreasing time window



10 ms

Not the same results for all pairs of clusters: studies ongoing!



➤ Software tasks :

- ✓ DAQ → [R. Zuyeuski](#)
- ✓ Data Transfer and Reconstruction → [F. Noferini](#)
- ✓ Monitor, e-log, indico → [F. Coccetti](#)

➤ Analysis groups:

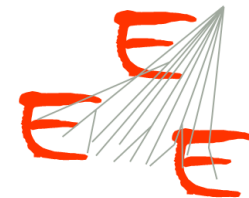
- ✓ Search for coincidences and study of CR spectrum → [F. Noferini](#)
- ✓ Search for Forbush decreases → [I. Gnesi](#)
- ✓ Monte Carlo simulations → [M. Battaglieri](#)
- ✓ Angular distributions → [P. La Rocca](#)
- ✓ Detector Performance Group → [D. De Gruttola](#)
- ✓ Long distance correlations → [F. Riggi](#)
- ✓ "Exotica" → [F. Nozzoli](#)

EEE 2018 Milestones



- ✓ Construction of six other telescopes
- ✓ Taking another 30 billions of events
- ✓ Defining an EEEco-gas mixture
 - Equip a station for a long period data taking (first experiment taking data with eco-friendly gas mixtures)
- ✓ Taking part to PolarQuEEEst
- ✓ Analysis on long distance correlations with doubled statistics

External collaborations



- EGO-VIRGO collaboration interested in having one (or more) EEE telescopes hosted at their lab in Cascina
- As a veto for cosmic ray showers in coincidence with possible signals coming from gravitational waves
 - There is a similar device at LIGO
 - There is some literature on that
- Possibility to sign up an agreement



- University of Santiago de Compostela (Spain) interested in analyzing EEE data looking for correlations between the cosmic rays flux and temperature and pressure conditions in the throposphere
- ✓ An Memorandum Of Understanding has been signed up
- ✓ Some data already sent for analysis



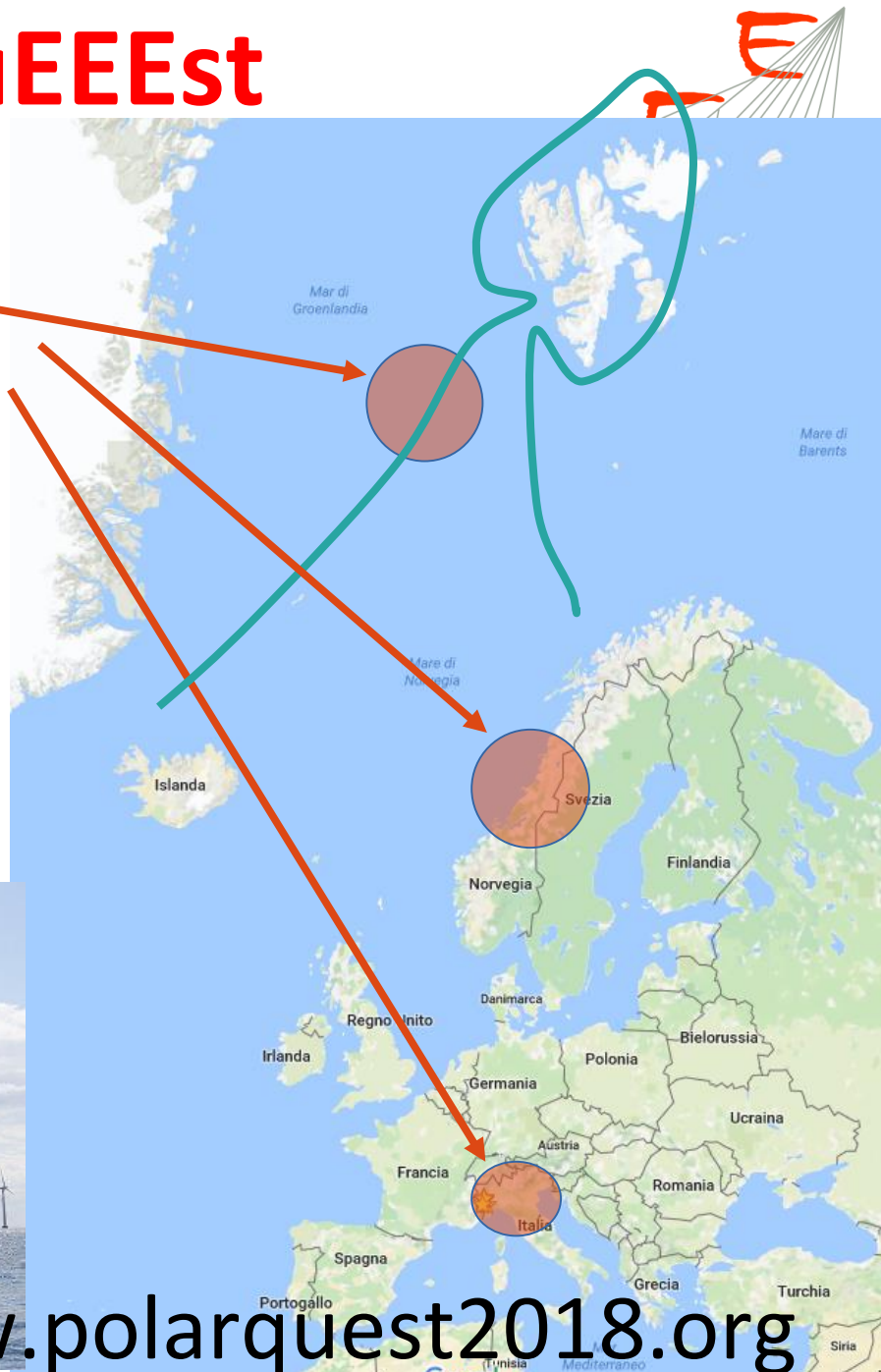
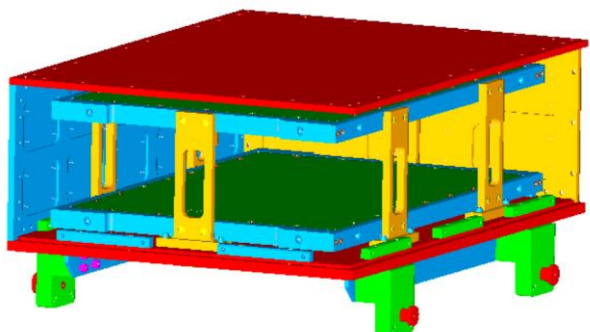
And, of course, Polar QuEEEst!

Polar QuEEEst

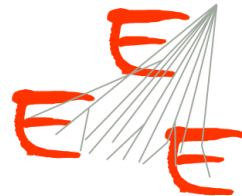
3 PolarQuEEEst detectors

- ✓ onboard on boat Polar Nanuq
 - ✓ installed in a Norwegian High School
 - ✓ installed in an Italian High School
- Mounted by students, in the EEE tradition

45° in latitude, span 5000 km



EEE meetings with schools



- Since end of 2016 monthly EEE run coordination meetings open to schools
- ✓ Using dedicated Vidyo virtual rooms
- ✓ Around 100 schools connected → hundreds of participants!

VidyoDesktop™ - EEE_run_coordination_meeting_-_open_to_schools@vidyoportal.cern.ch

Participants: 105

(Guest) Maserati_Voghera
 (Guest) Matteo Coviello
 (Guest) Michele Valerio
 (Guest) mimlig
 (Guest) Morelli Enriques
 (Guest) Oscar Iaccarino PPP
 Paola La Rocca
 (Guest) Pietro Basentini
 (Guest) Raffaele Palese
 (Guest) respighi
 (Guest) riggi
 (Guest) Righi - Albertelli R...
 (Guest) Rosaria's iPhone

Marina Trimarchi
 Liceo Banfi
 Bianchi - Lodi

CENTRO FERMÍ MUSEO STORICO DELLA FISICA E CENTRO STUDI E RICERCHE ENRICO FERMÍ

Extreme Energy Events Scuola Inglese Roma

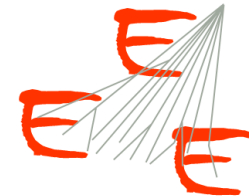
Ci vediamo il 30 Novembre all'ICD!

Per chiarimenti o domande rivolgersi a:
Paola La Rocca (paola.larocca@ct.infn.it)
Marina Trimarchi (mtrimarchi@unime.it)
 referenti EEE locali

open to schools 24 8 Novembre 2017

00:30:58

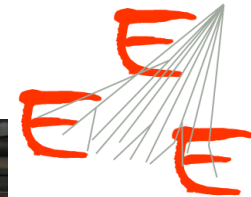
15:11 08/11/2017



Official participation of the EEE community to the International Cosmic Day

- ✓ 550 students and 47 schools registered
- ✓ Each getting a diploma and with their contribution in the ICD booklet
- ✓ Millions of CR tracks analyzed
- ✓ Video-message of prof. Zichichi on the ICD home page





EEE plenary meetings

Erice 2017

- ✓ May, 29, 30 and 31
 - ✓ Measure of the Earth radius with the Eratosthene method
- ✓ December, 6, 7 and 8
 - ✓ Measure of the CR flux at different altitudes
- ✓ Both experiences to be reported in papers on the “Giornale di Fisica”
- ✓ Organizing two meetings in 2018 (Cagliari, Torino)





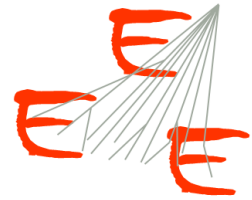
Expected funding in the 3-year period:

- Request of funding by Centro Fermi

- Consumables/inventory: Stay at the current level
- Grants: needed a couple more units for the upgrade

- Potential external funding

- In 2014 funding for 1.3 M€ from Bandi Premiali 2012 MIUR → Upgrade
- Schools contributing in-kind
- Sometimes INFN sections/physics departments contributing in-kind
- Various applications to regional funds, ERC, MIUR calls, etc.



Plan of activities 2018 - 2020

- Organize a coordinated Run each year
- Perform an HV scan to study detector performance each year
- Continue all the analysis outlined in the previous slides
- Organize plenary meeting once or twice a year
- Complete the upgrade to arrive at about 70 EEE stations



The End:

- ✓ Thanks for the attention
- ✓ Questions?