

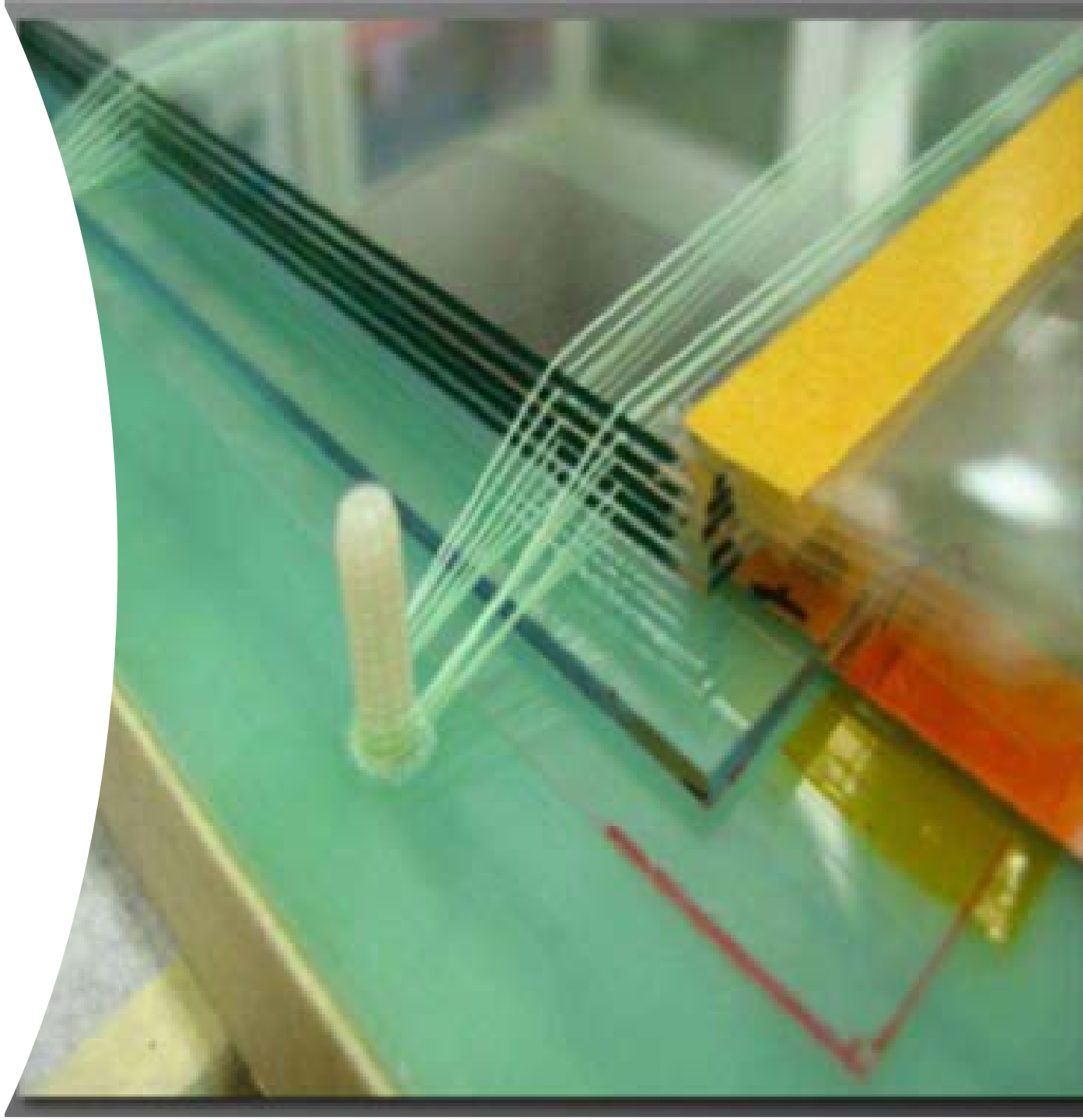
Characteristics and performance of the Multigap Resistive Plate Chambers of the **EEE** experiment

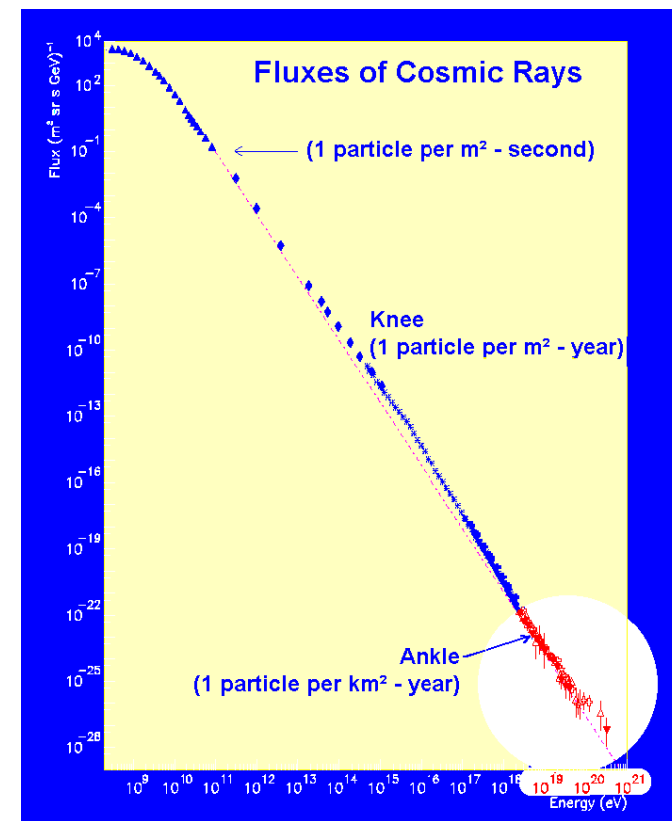
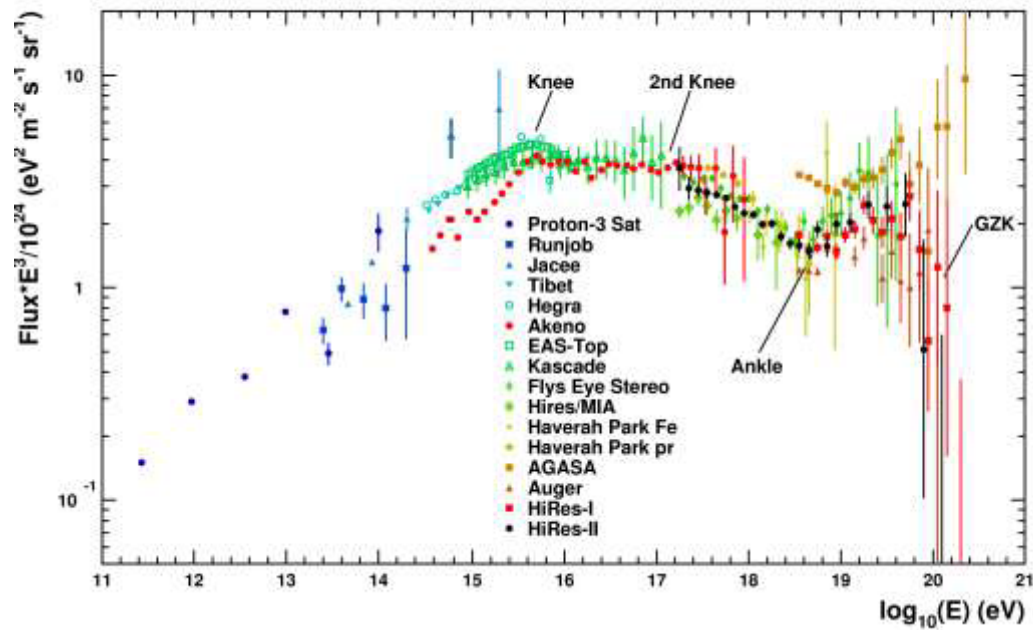
F. Coccetti for the EEE Collaboration

fabrizio.coccetti@centrofermi.it



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E
CENTRO
STUDI E RICERCHE
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The aim of the
EEE experiment

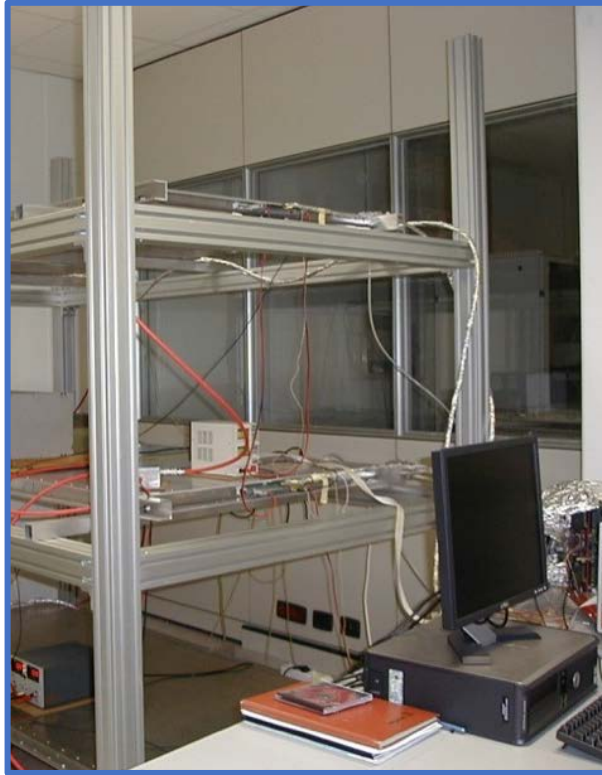
Covering the most interesting region of the cosmic ray spectrum:

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

EEE experiment

- **array of MRPC telescopes** covering more than 3000 km²
- each telescope is made of 3 MRPCs
- 59 telescopes (+ 4 Polar)
- more than 100 billion candidate muons currently detected
- clusters and standalone telescopes
- project started in 2004
- long-living MRPC-based system (15 years)
- Telescopes are hosted in Italian Secondary Schools, INFN sections and CERN
- unconventional working sites (High Schools), with heterogeneous maintenance conditions and sometimes without controlled temperature or dedicated power lines.





Surface covered by
EEE's MRPCs:
59 telescopes
x 3 MRPCs
 \approx
230 m²

Second largest system using MRPCs:
ALICE TOF: 144 m²

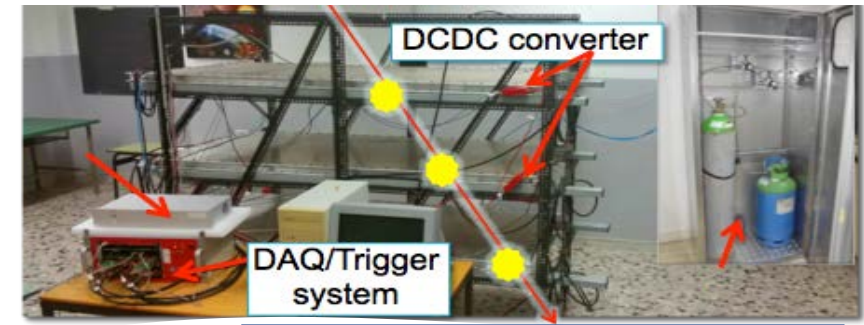
The **MRPCs** of the EEE experiment

- The EEE network is a system of detectors operating in a coordinate way
- All the telescopes are synchronized at ≈ 10 ns
- **Collaboration with INRIM to improve sync between telescopes**
- Taking data at the same time in Coordinated RUNs
- Data transferred to a central repository

EEE Telescope

- 6 Front-End boards (FEAs) with 24 channels to process readout signal (pre-amplification + discrimination)
- 2 Multi-hits Time to Digital Converters (TDCs 128 + 64 channels)
- 1 Trigger Card: a six-fold coincidence of both FEAs of the three MRPCs generates the Data Acquisition trigger
- GPS unit (with an external antenna) provides the event time stamp to synchronize time between telescopes
- A Weather Station records pressure and temperature inside and outside the building
- 100 ps, time resolution of the TDC bin.
- ~cm, spatial resolution for both coordinates.
- > 95%, MRPC efficiency at the operating voltage of 18 kV.
- tens of ns, GPS time resolution

Achieving **reliability**: Lot of effort to improve all components of the detector



New DCDC Converters



New Trigger/GPS Card

- clock distribution
- counters accessible via VME
- trigger logic programmable via VME

Online monitor and DAQ

eee.centrofermi.it/monitor

- Quasi real-time
- EEE-log
- Detailed automated daily report

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Progetto Extreme Energy Events - La Scienza nelle Scuole

EEE MONITOR - DQM

[Official address: <http://eee.centrofermi.it/monitor>]

Ultimo aggiornamento: ore 17:28 - venerdì 07 febbraio 2020 [by e3monitor]

[EEE Monitor] RUN 6 is in progress

Total number of candidate tracks ($X^2 < 10$) in the database:
104783935239

[SCHOOLS ELOGBOOK for RUN 6](#)
[Telescope ELOGBOOK](#)
[EEE Tech Coord](#)

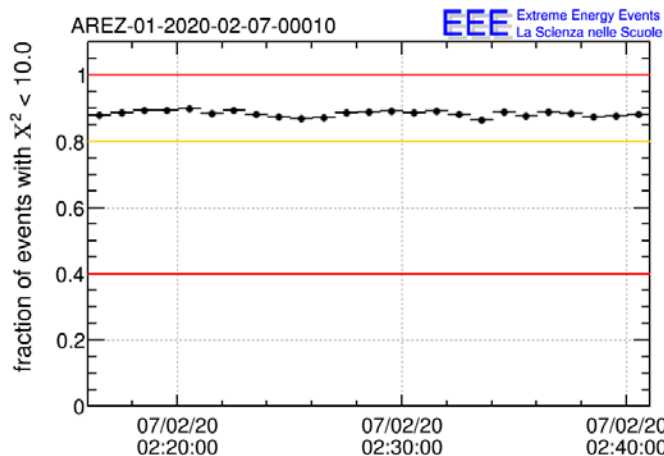
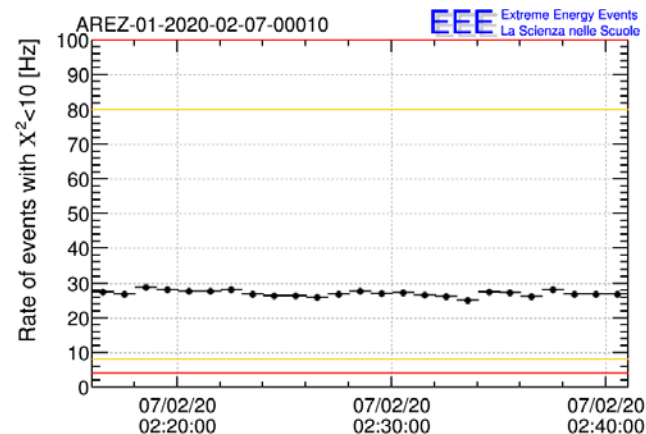
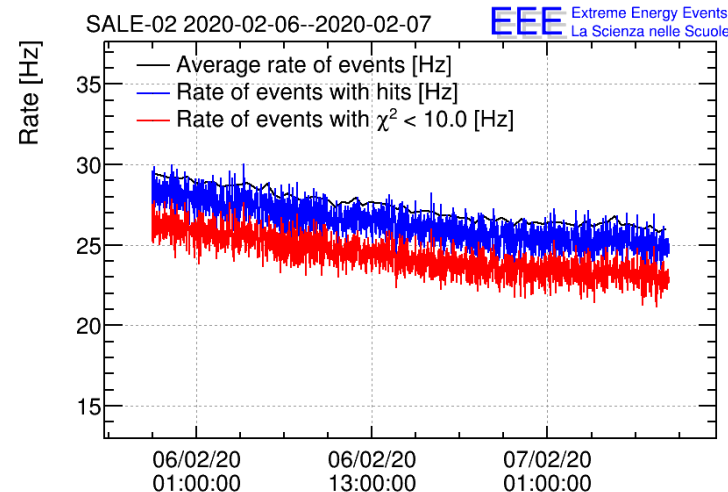
[Set Automatic Shift REPORT Messages](#)
[Automatic Shift Report ARCHIVE](#)

[Home Page EEE](#)
[Run 5 SuperSummary](#)
[Download the Excel Sheet](#)

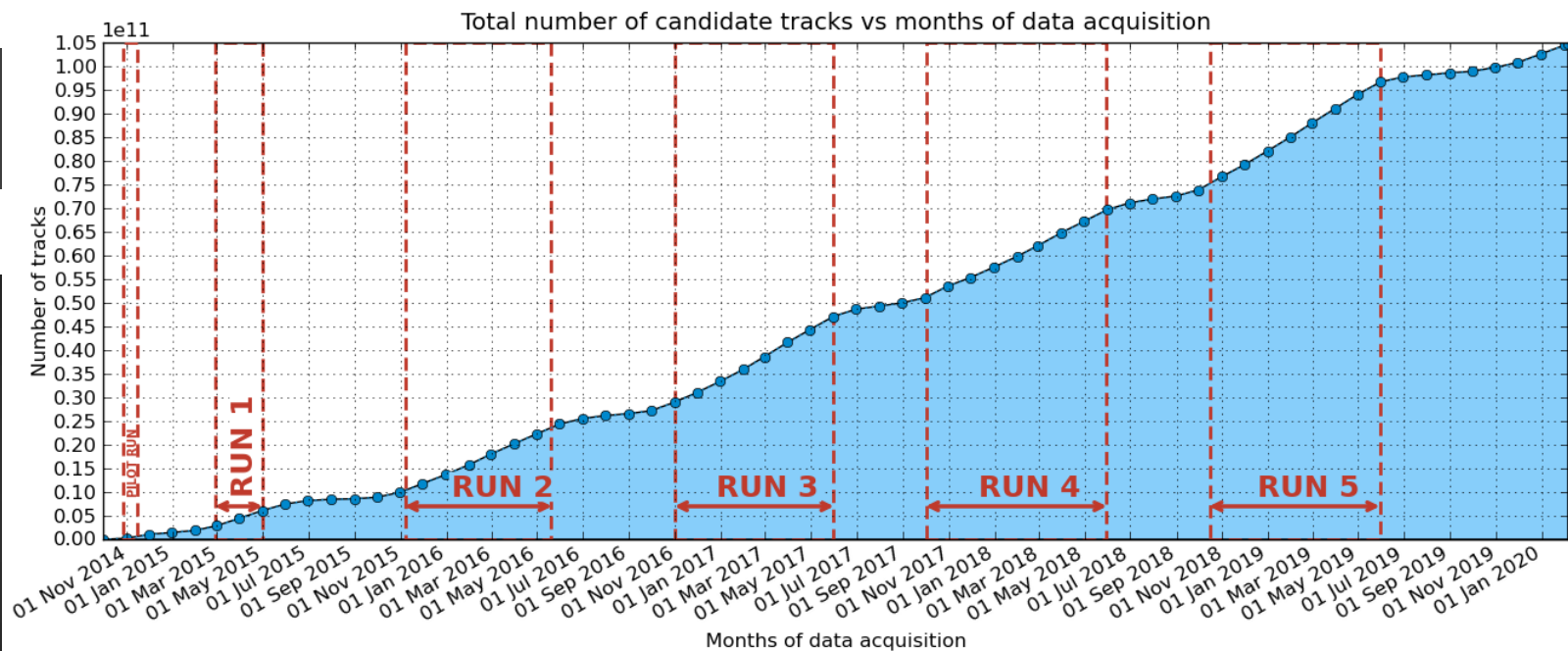
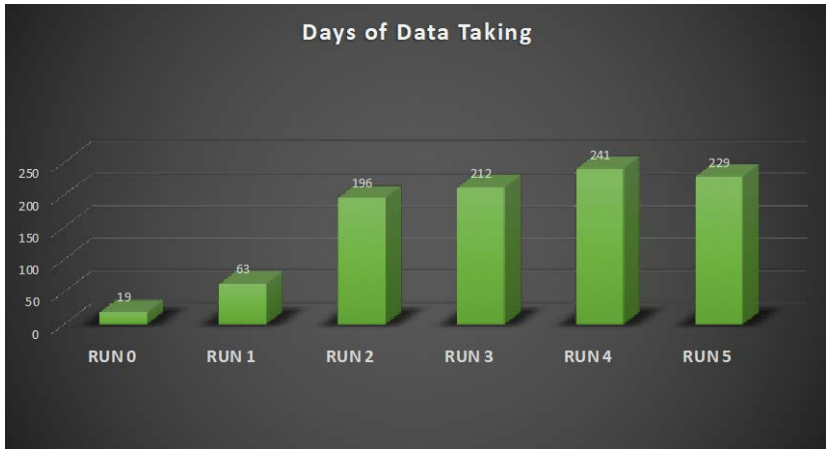
[Coincidences](#)
[Connectivity Report](#)
[Data Request](#)

La tabella qui sotto mostra la situazione dei telescopi in acquisizione:
 In **verde** sono indicati i telescopi in presa dati e trasferimento nelle ultime 3 ore
 e 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 ($X^2 < 10$) 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 ($X^2 < 10$) minori di 5 Hz nell'ultimo run analizzato.

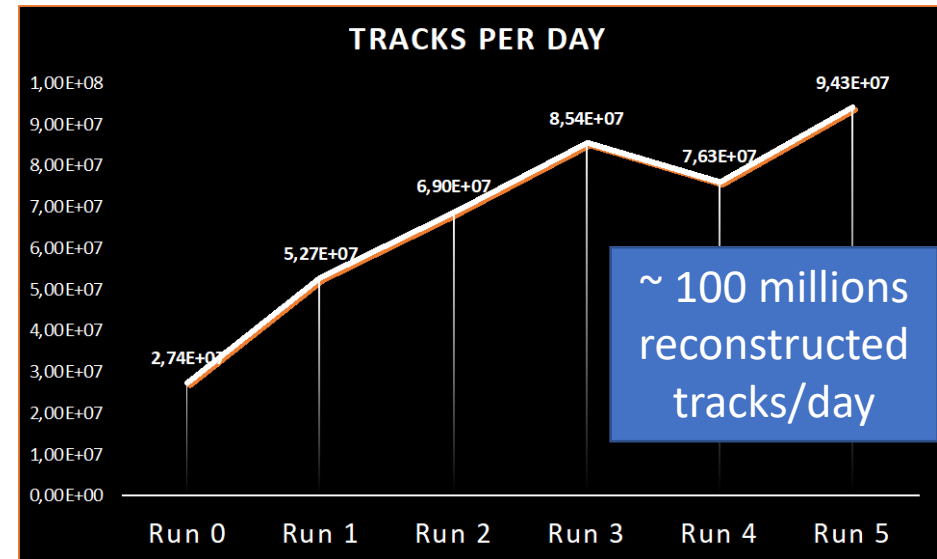
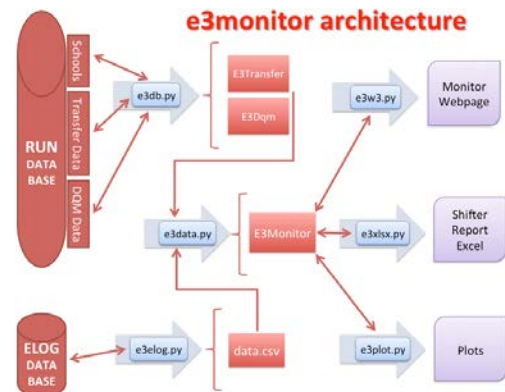
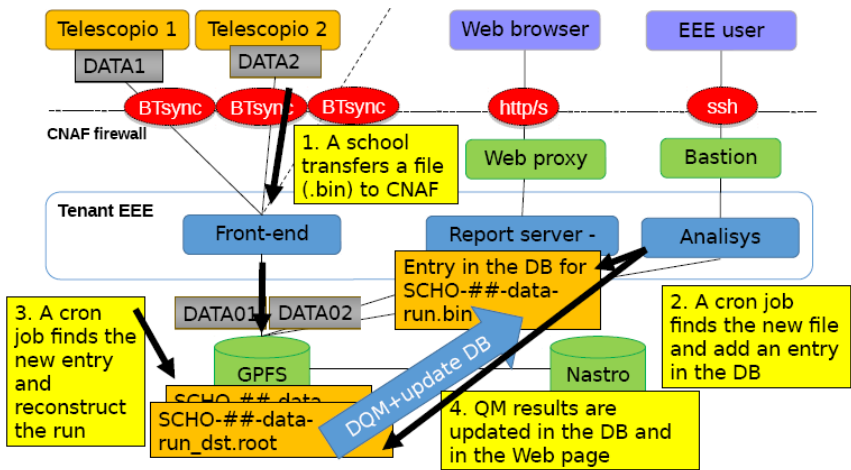
School	Day	Time	Name of the last transferred File	Number of Files transferred today	Last Entry in the e-logbook of the Schools	Name of the last File analyzed by DQM	DQM daily report	RATE of Triggers for the last Run in DQM	RATE of Tracks for the last Run in DQM	Link DQM
ALTA-01 <small>[Event Display]</small>	ven 07 giugno	13:33	ALTA-01-2019-06-07-00023.bin	0 <small>[History]</small>	*	ALTA-01-2019-06-07-00022.bin	08/06 <small>[History]</small>	12.0	10.0	ALTA-01
ANCO-01 <small>[Event Display]</small>	ven 07 febbraio	17:02	ANCO-01-2020-02-07-00025.bin	26 <small>[History]</small>	12:20 07/02/2020	ANCO-01-2020-02-07-00024.bin	07/02 <small>[History]</small>	18.0	14.0	ANCO-01
AREZ-01 <small>[Event Display]</small>	ven 07 febbraio	17:07	AREZ-01-2020-02-07-00039.bin	40 <small>[History]</small>	10:13 07/02/2020	AREZ-01-2020-02-07-00038.bin	07/02 <small>[History]</small>	30.0	26.0	AREZ-01



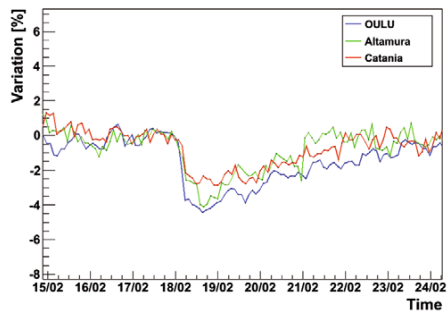
Data taking



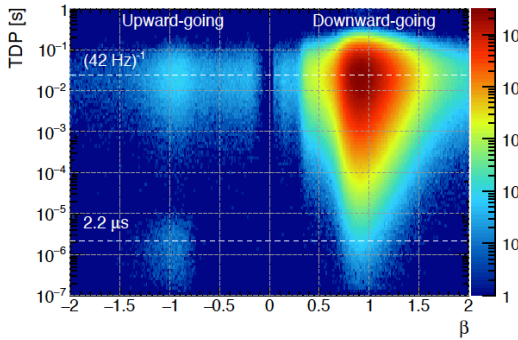
More than 100 billion events collected since the start of organized data taking



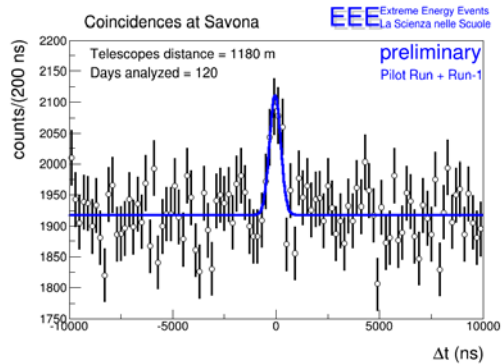
Scientific results



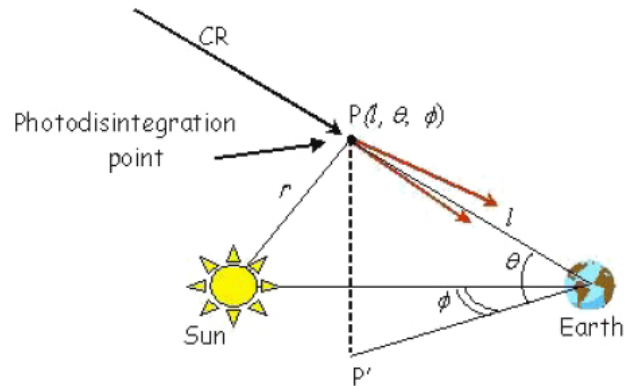
Forbush decrease



Upward going particles



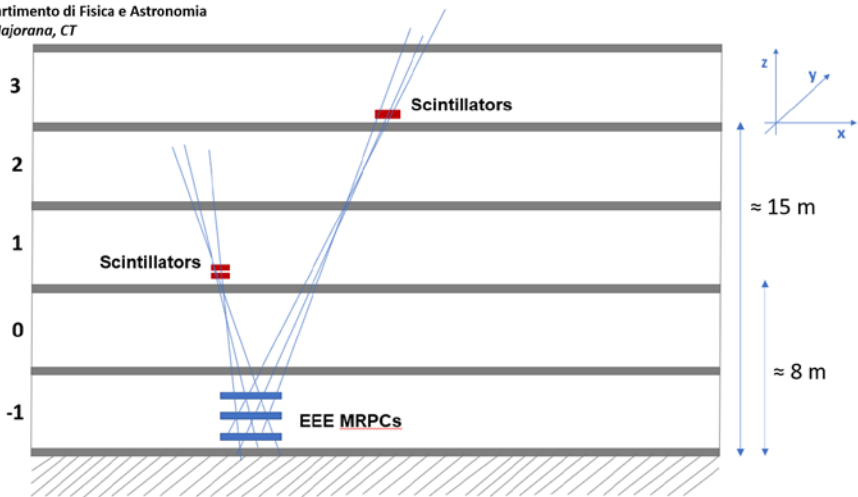
Detection of EAS



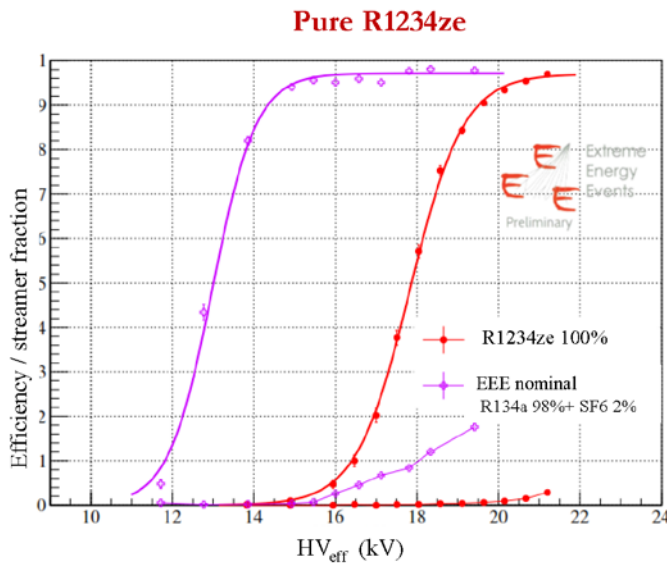
Long Distance Correlations (LDC)

New studies

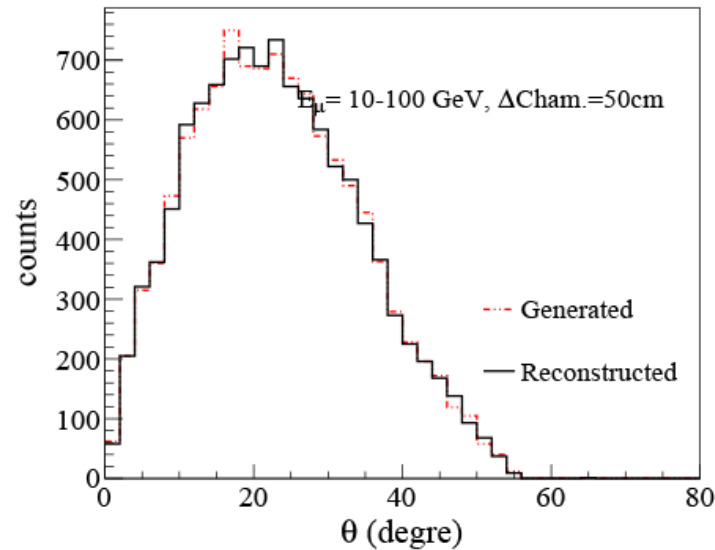
Dipartimento di Fisica e Astronomia
E. Majorana, CT



Chiara Pinto's talk
on long time scale
structure stability

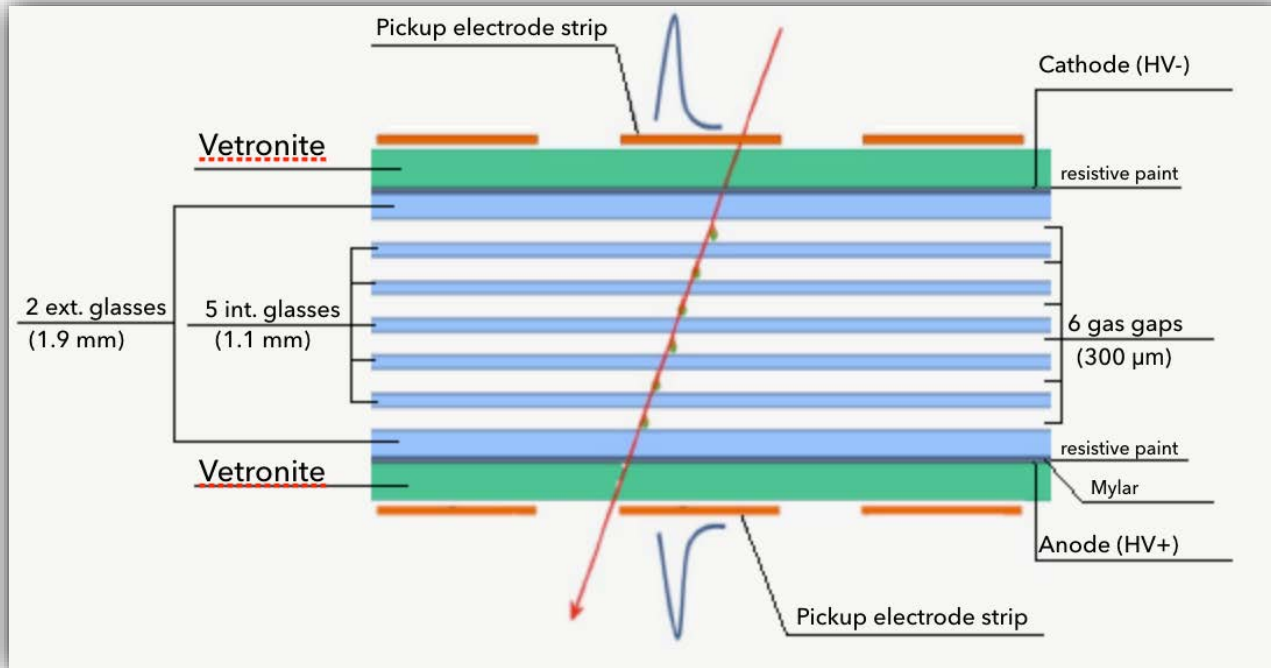


Maria Paola Panetta's talk
on strategies to reduce
the Global Warming Impact



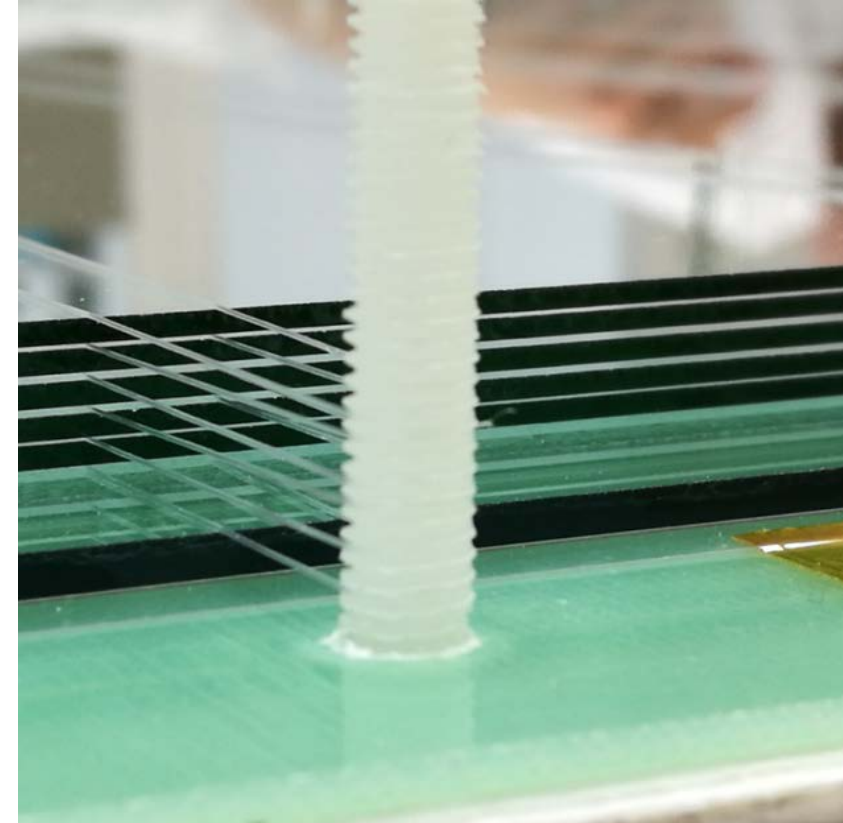
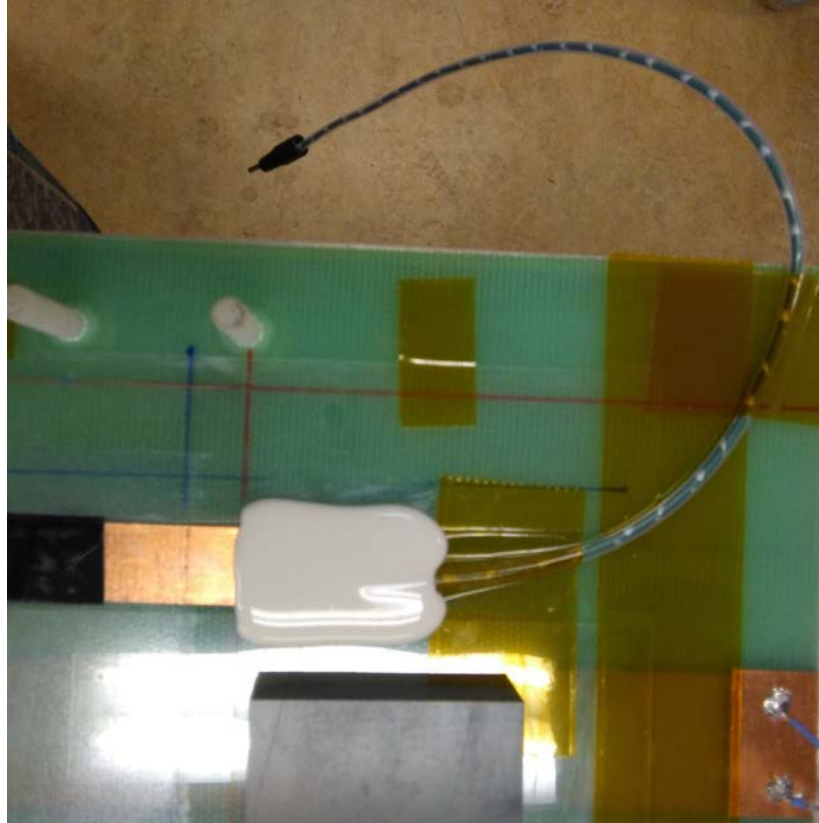
Giuseppe Mandaglio's talk
on GEANT-GEMC simulation
for EEE telescopes

EEE Multigap Resistive Plate Chambers



- 6 gas gaps 300 μm → 250 μm
- two external glass sheets anode and cathode – 160 cm x 85 cm, 1.9 mm thick (resistive paint 5-20 MΩ/□)
- 5 intermediate (electrically floating) glass sheets - 158 cm x 82 cm, 1.1 mm thick
- 24 copper strips (anode and cathode) to pick up the signal – 158 cm x 2.5 cm, spaced by 7 mm



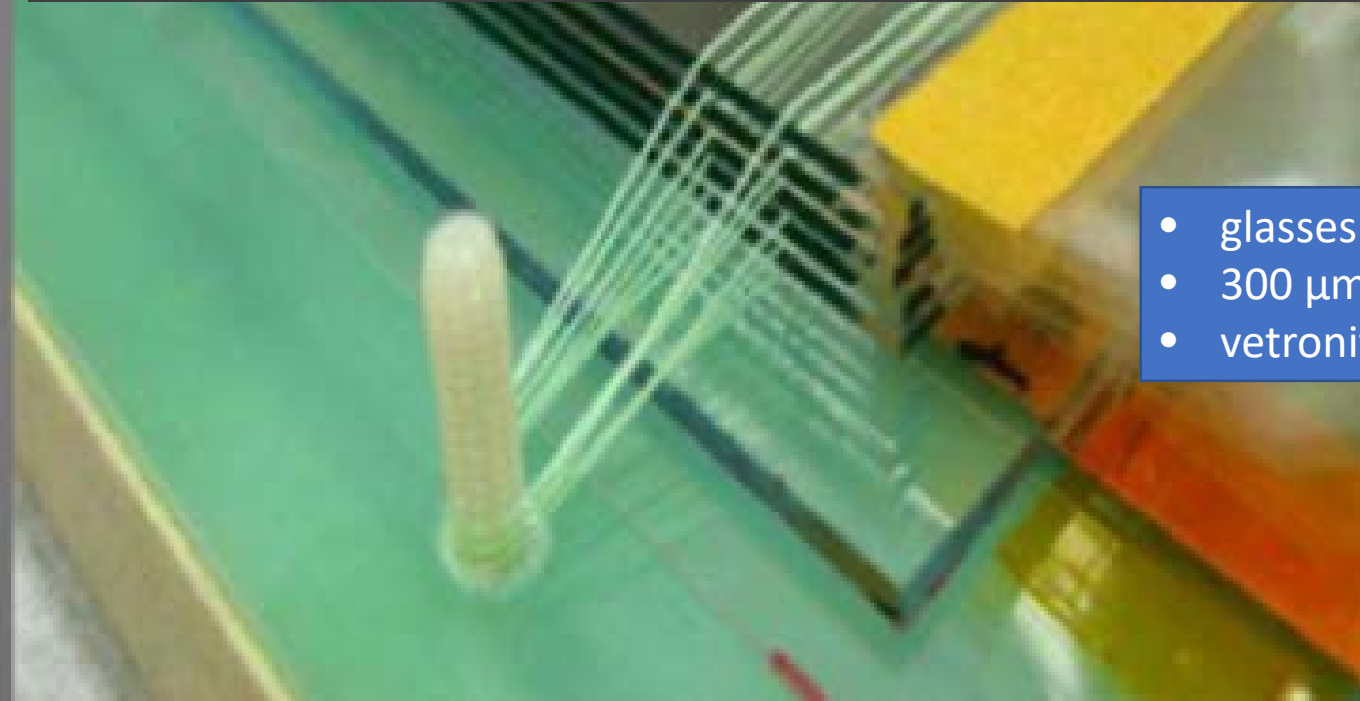


High Schools and Students

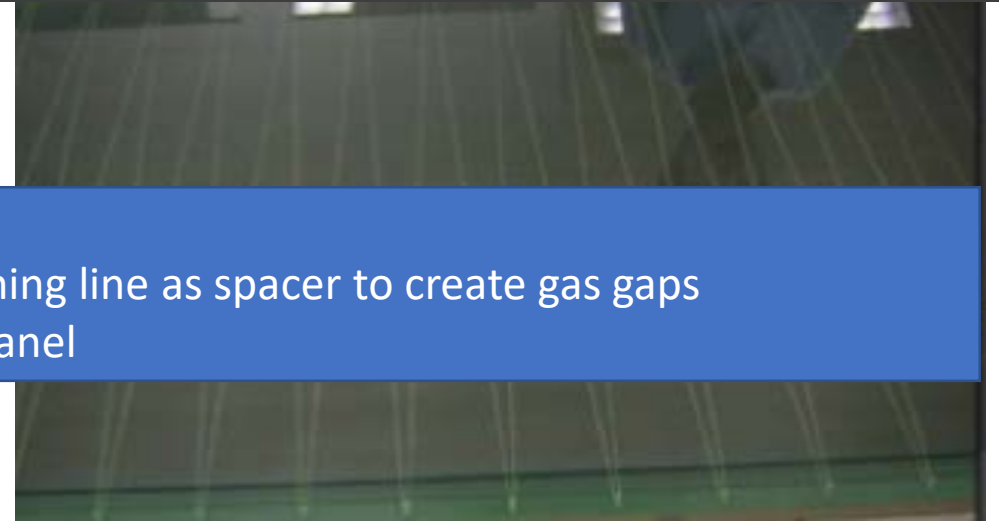
- one week at CERN to build 3 MRPCs under researchers' supervision
- setup of the telescope at School
- Check every day that the Telescope is working correctly (E-log)



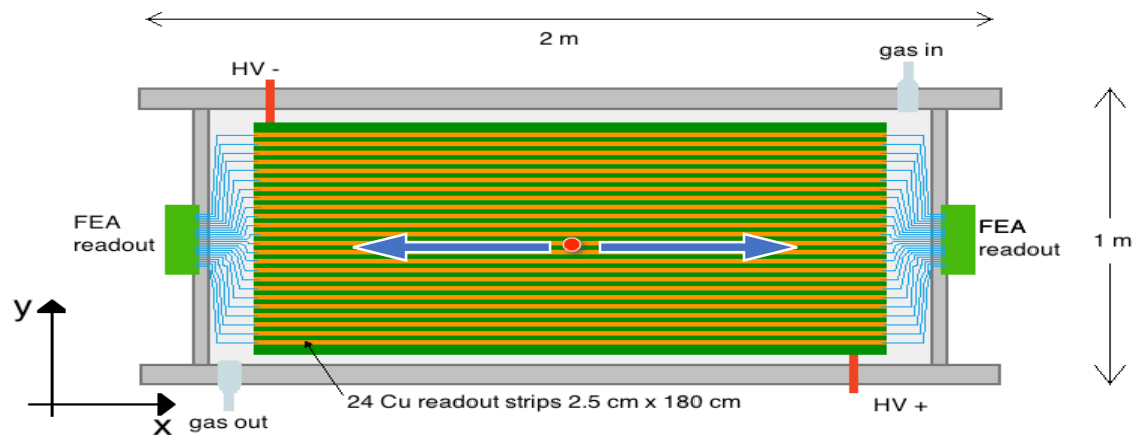
Making the EEE MRPCs



- glasses
- 300 μm fishing line as spacer to create gas gaps
- vetronite panel



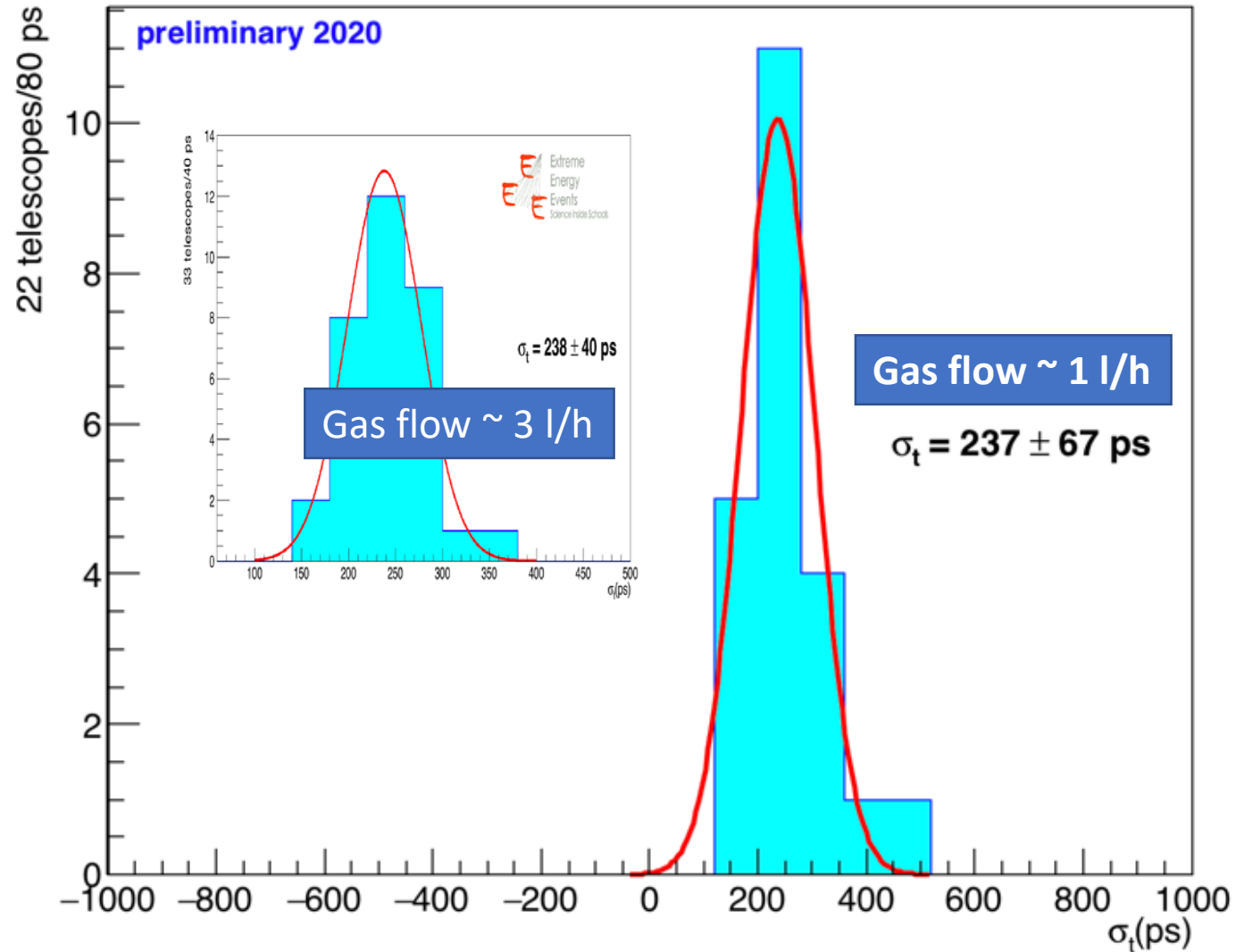
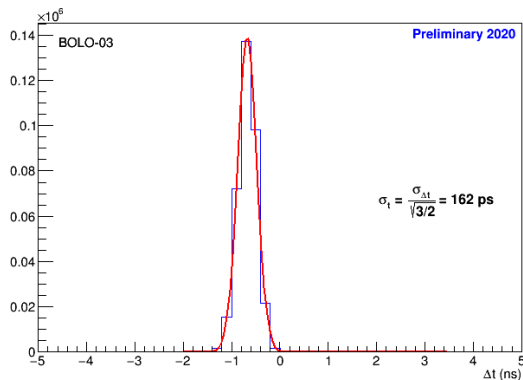
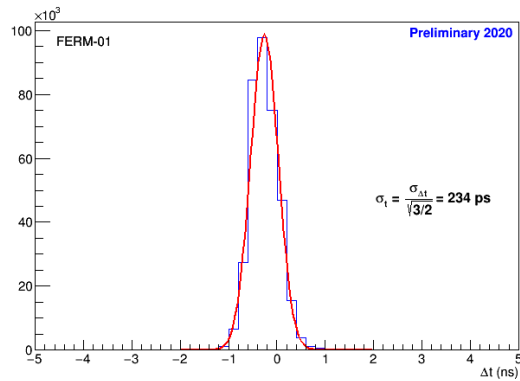
- 24 copper strips to pickup the signal
- Pitch 3.2 cm



Time resolution

$$\Delta t_{hit} = (t_{top} + t_{bot})/2 - t_{mid}$$

$$\sigma_t = \sigma_{\Delta t} / \sqrt{3/2}$$



Time slewing correction applied

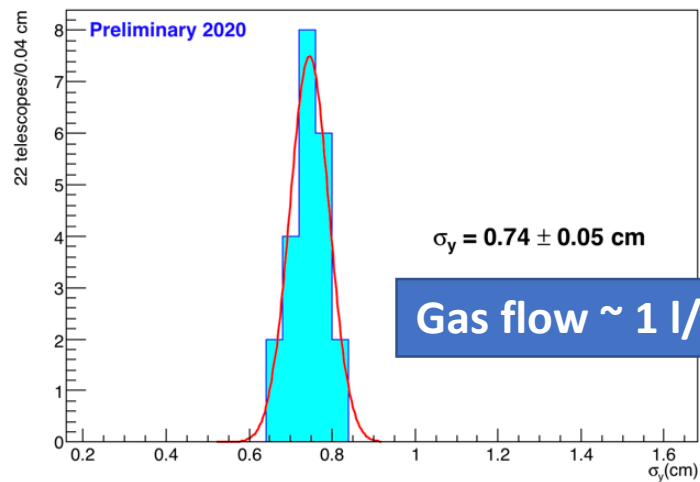
- the hit time depends on the signal amplitude
- the effect of its jitter has to be corrected in order to get the real hit time

Spatial resolution

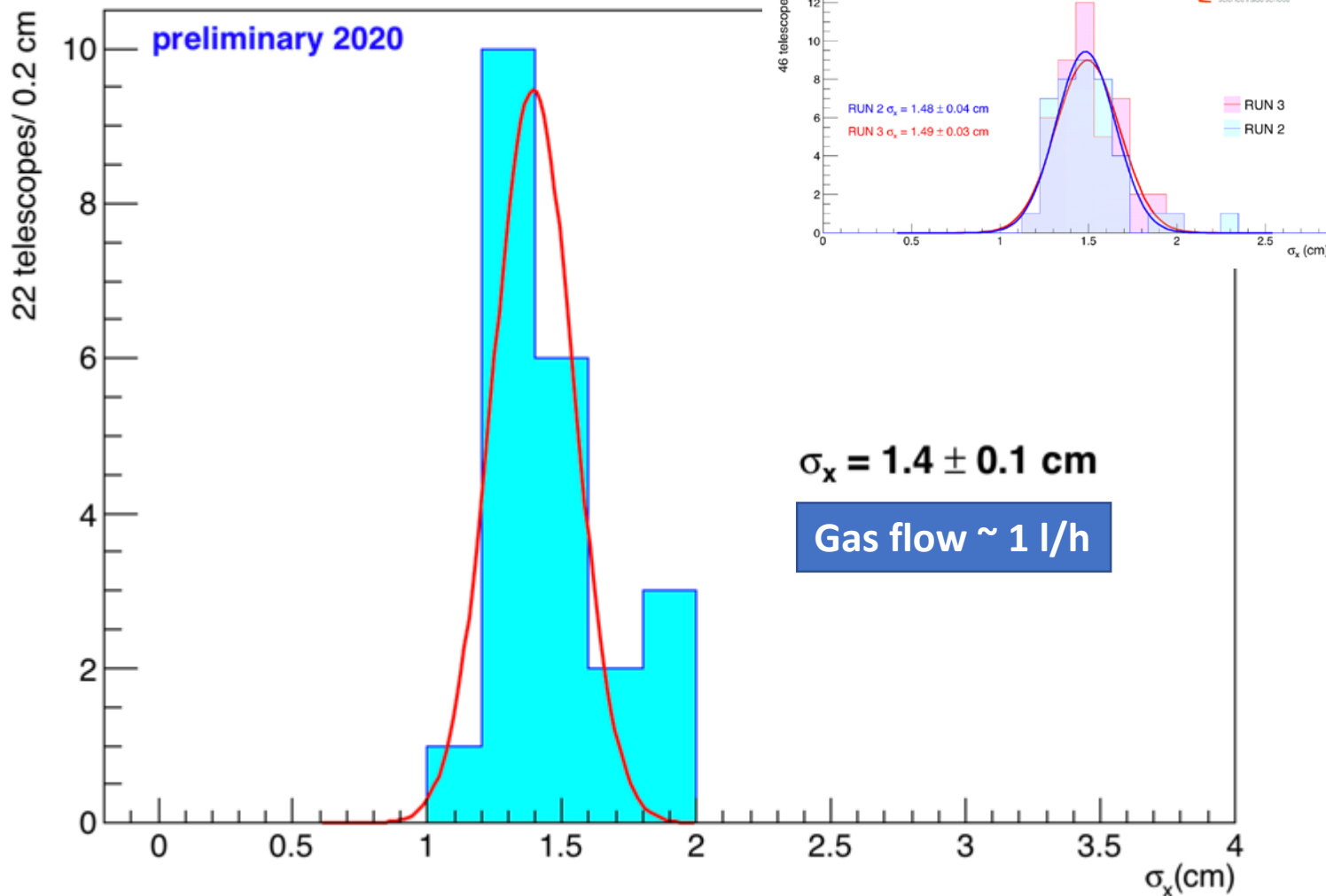
$$\Delta x_{hit} = (x_{top} + x_{bot})/2 - x_{mid}$$

$$\sigma_x = \sigma_{\Delta x} / \sqrt{3/2}$$

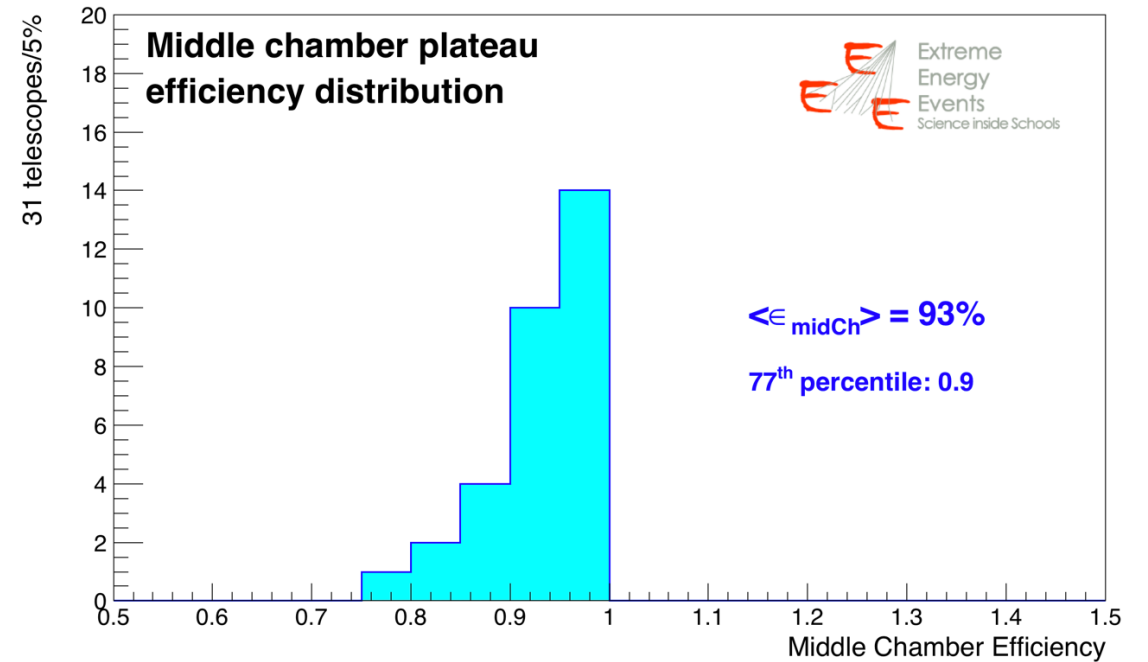
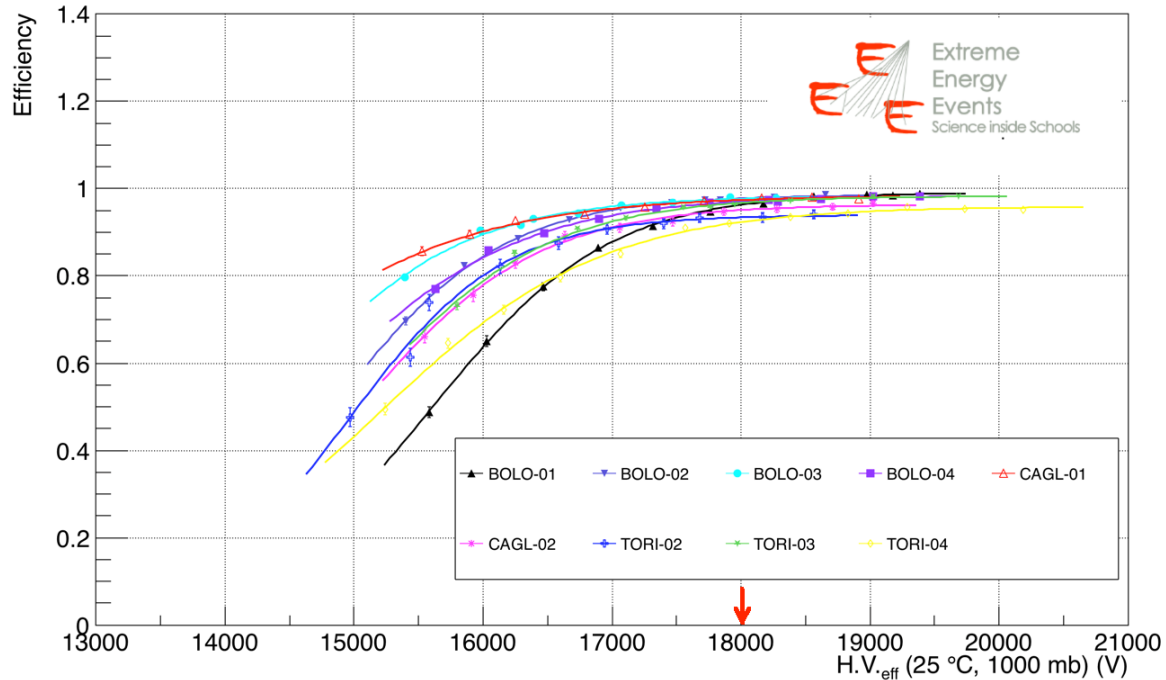
Short side



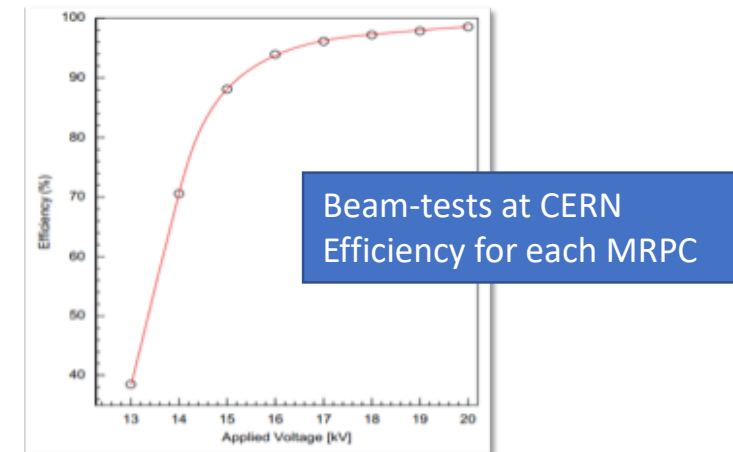
Long side



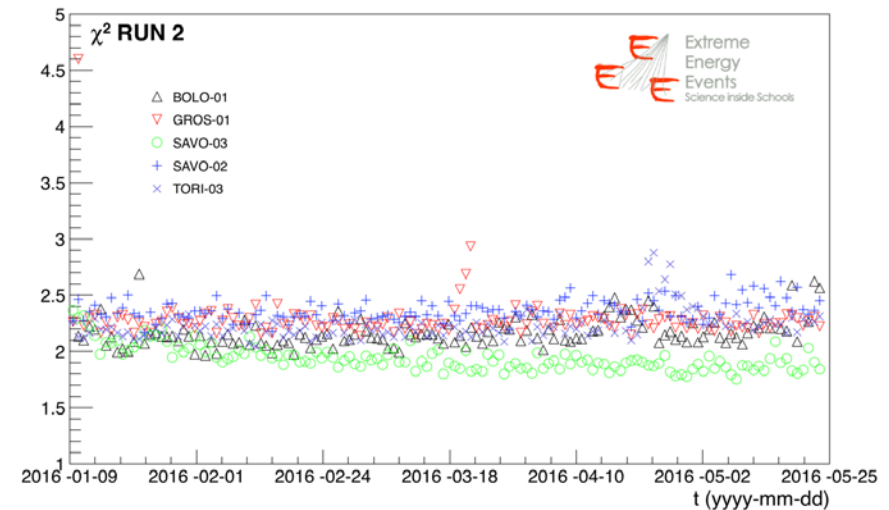
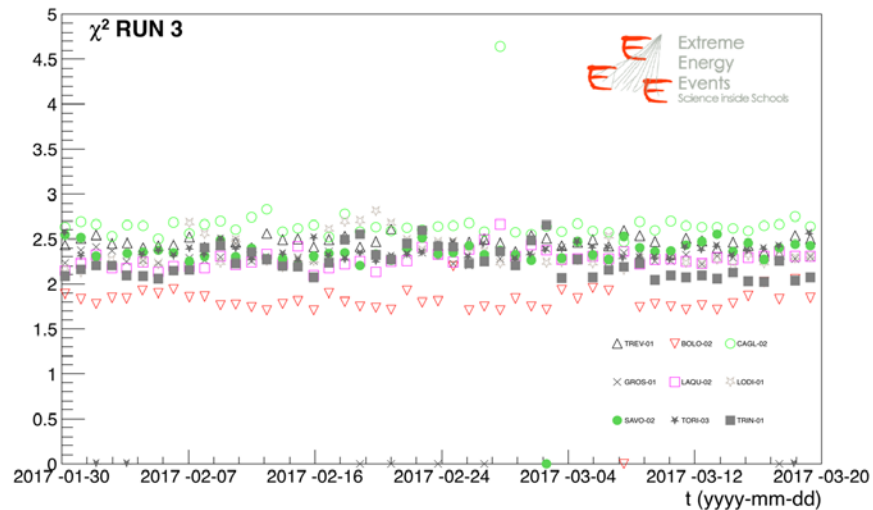
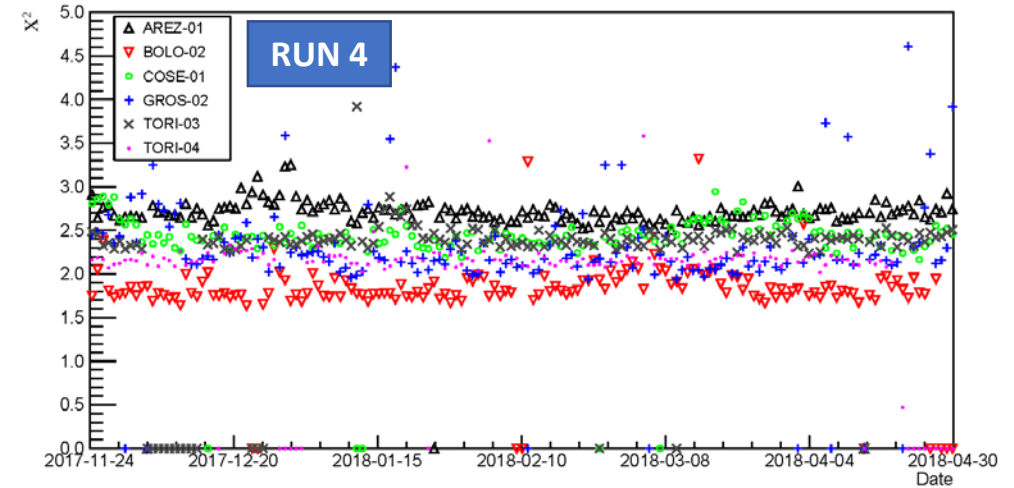
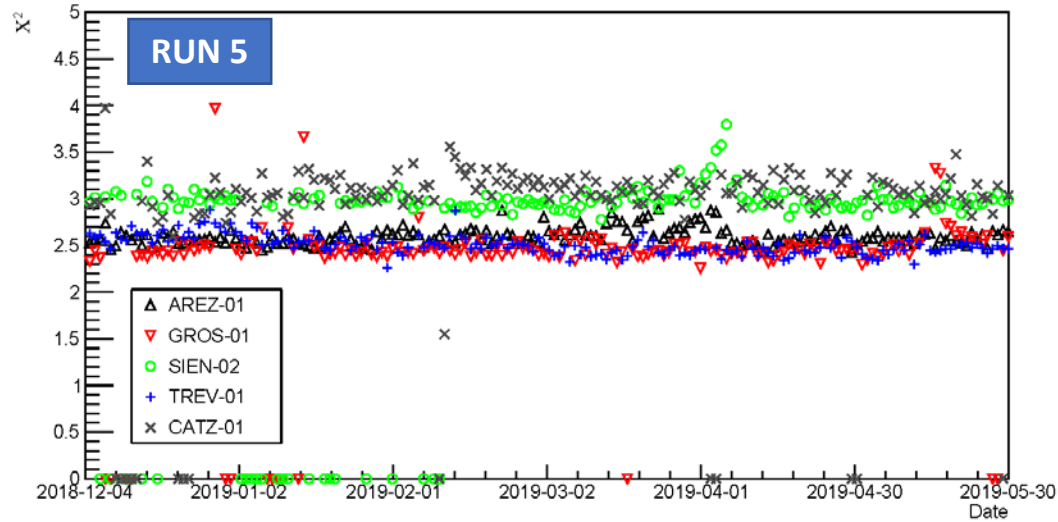
Efficiency



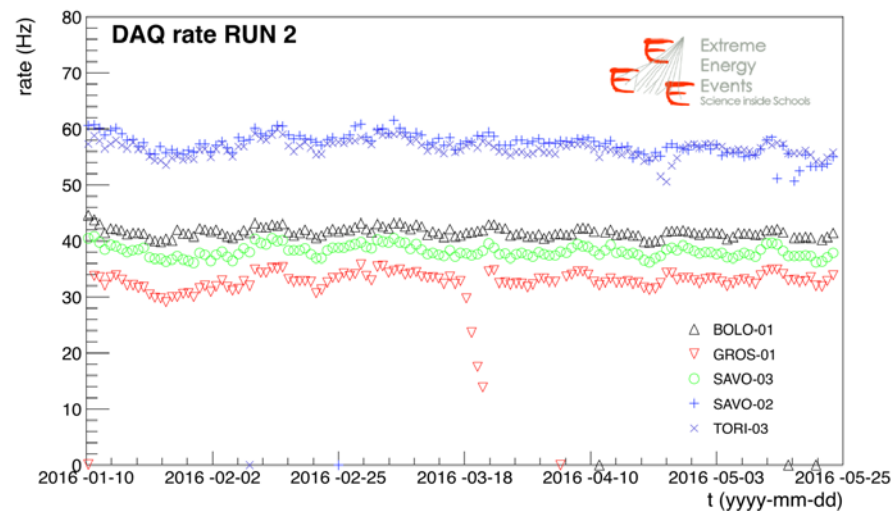
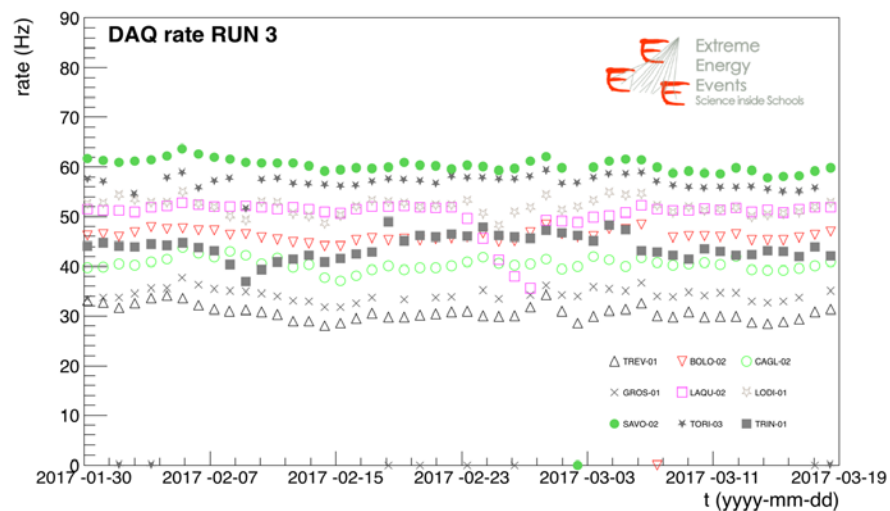
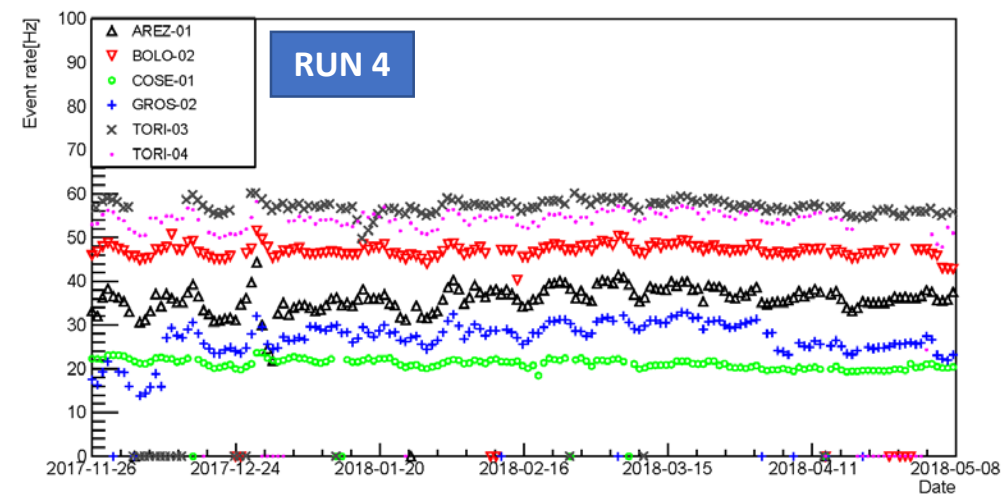
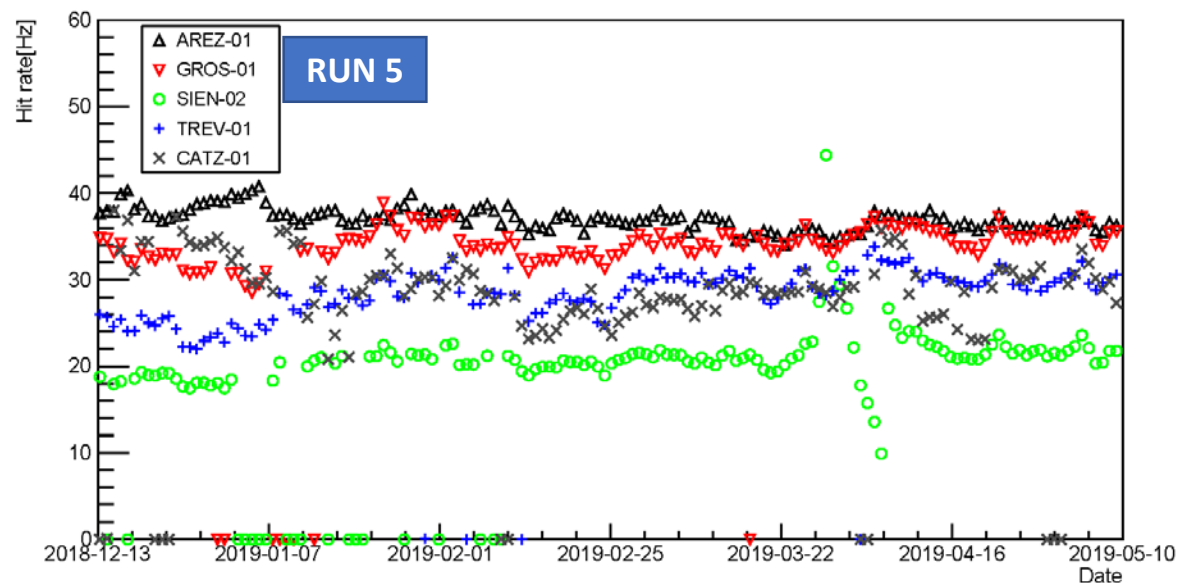
- average efficiency of the EEE telescope network ~ **93 %**
- compatible with the results from beam-tests performed at CERN
- efficiency better than 93 % is reached by 77% of the network
- efficiency of the middle chamber measured on all telescopes
- students involved in the measurement



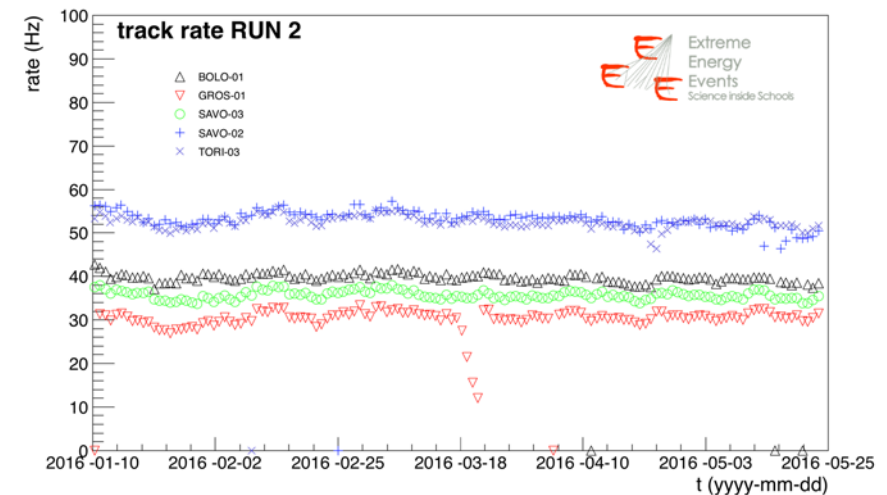
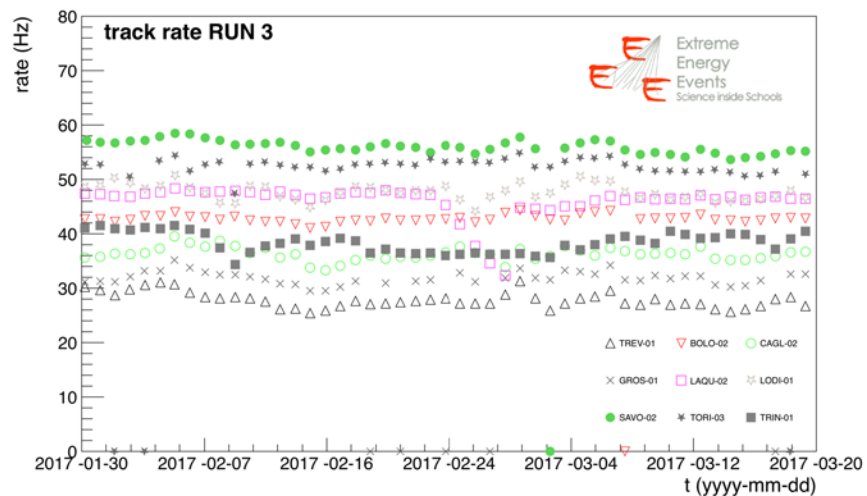
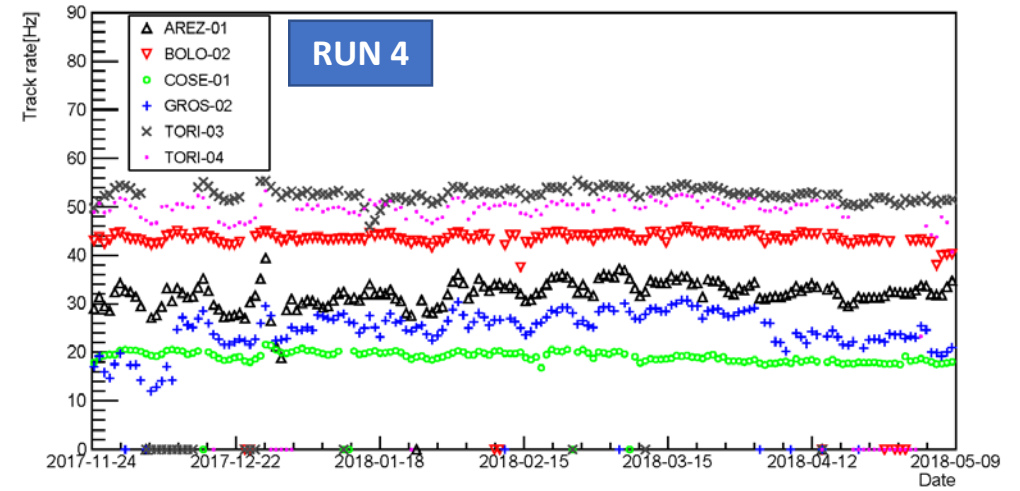
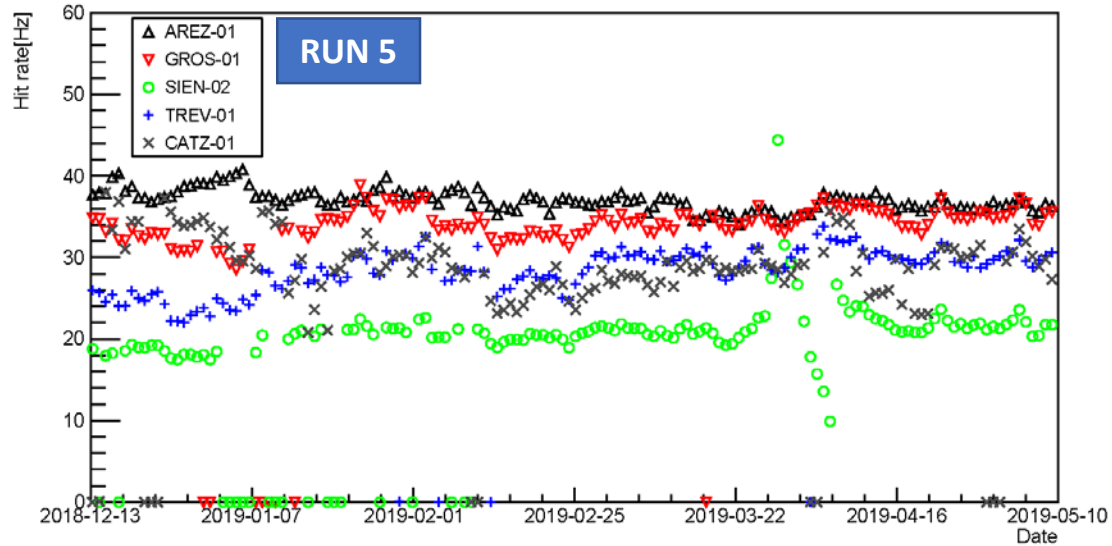
Long term stability: average track χ^2



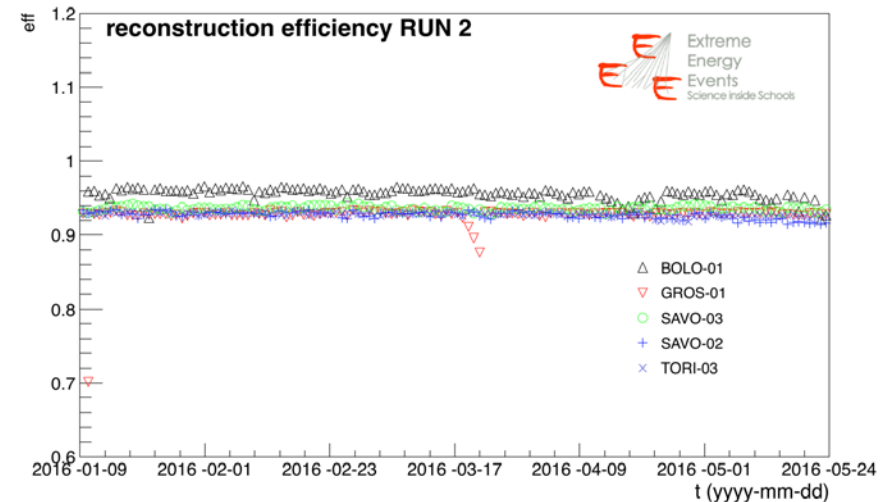
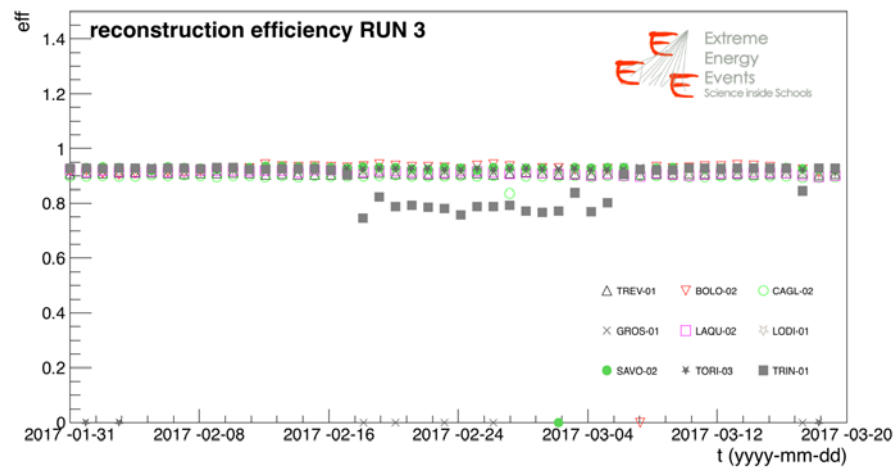
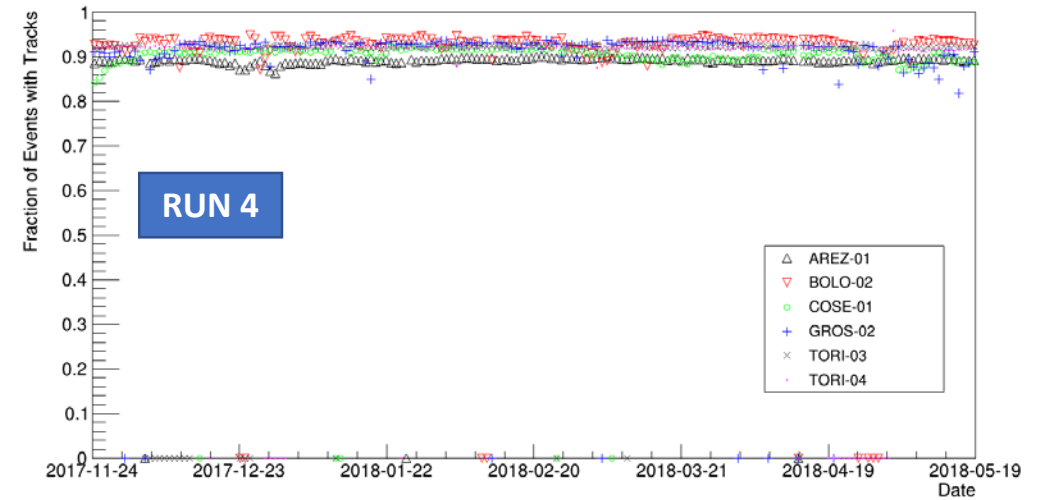
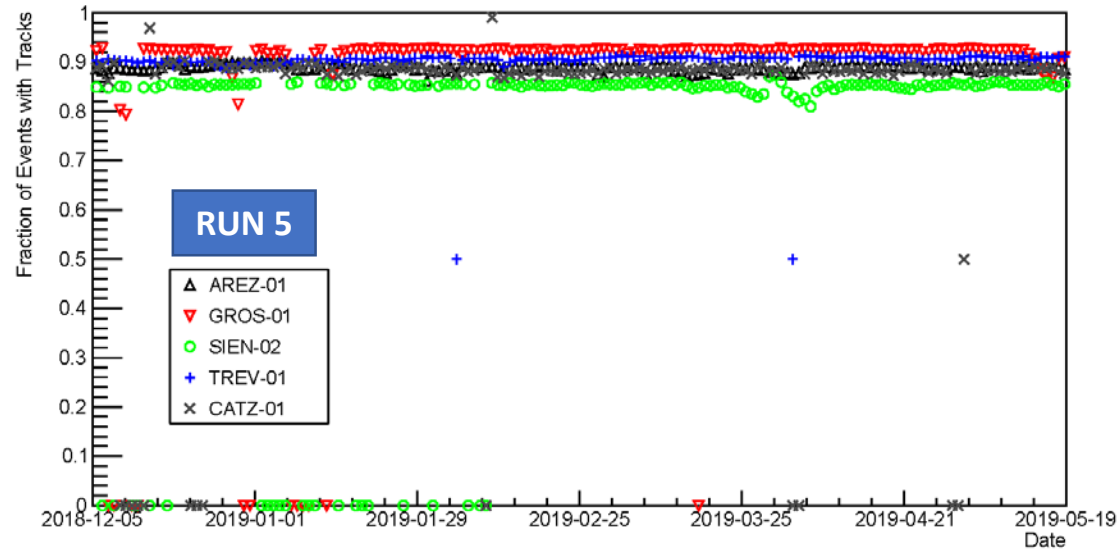
Long term stability: DAQ rate



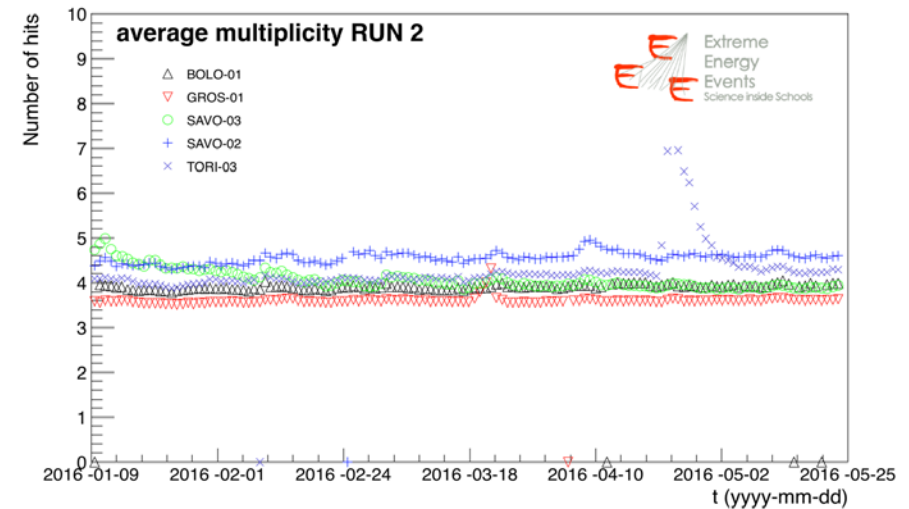
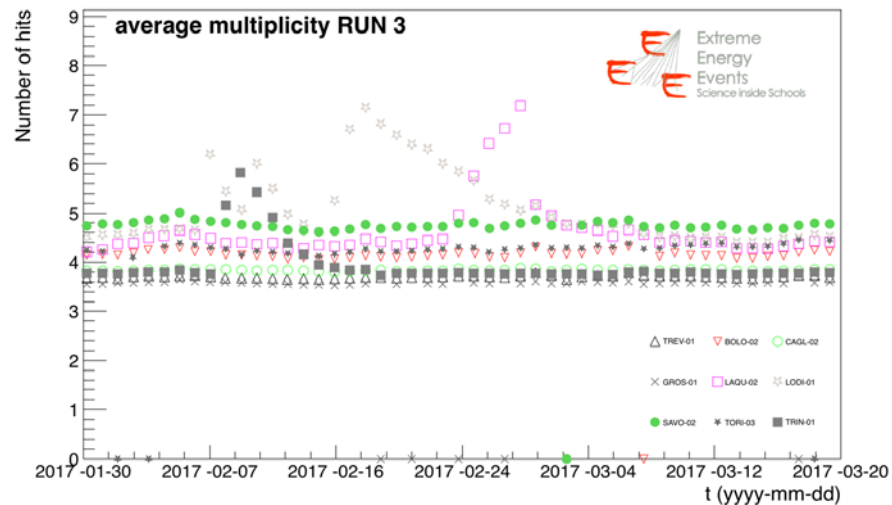
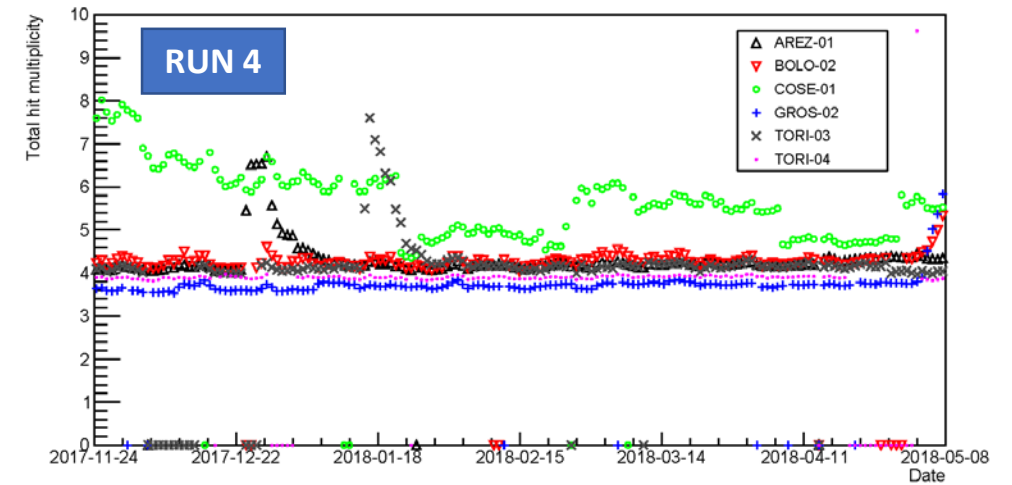
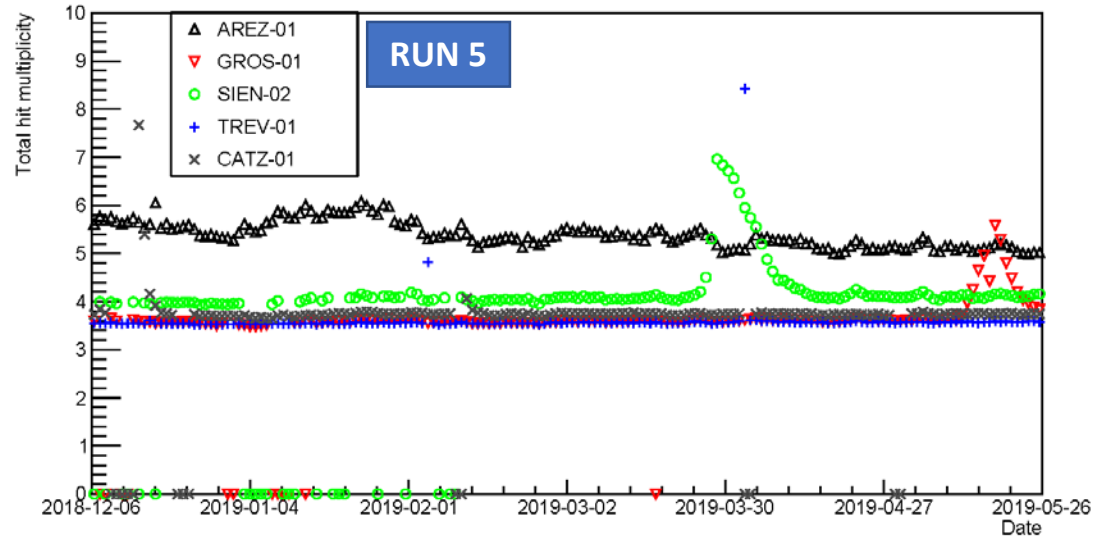
Long term stability: track rate



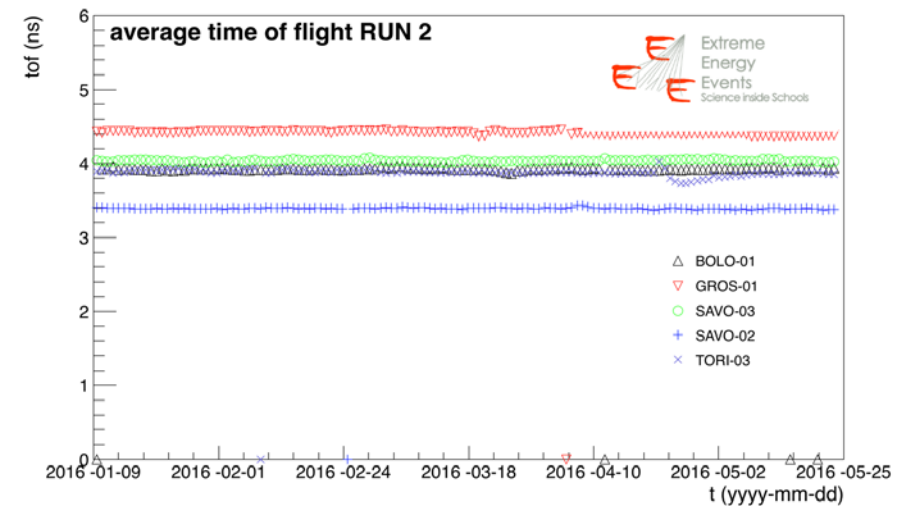
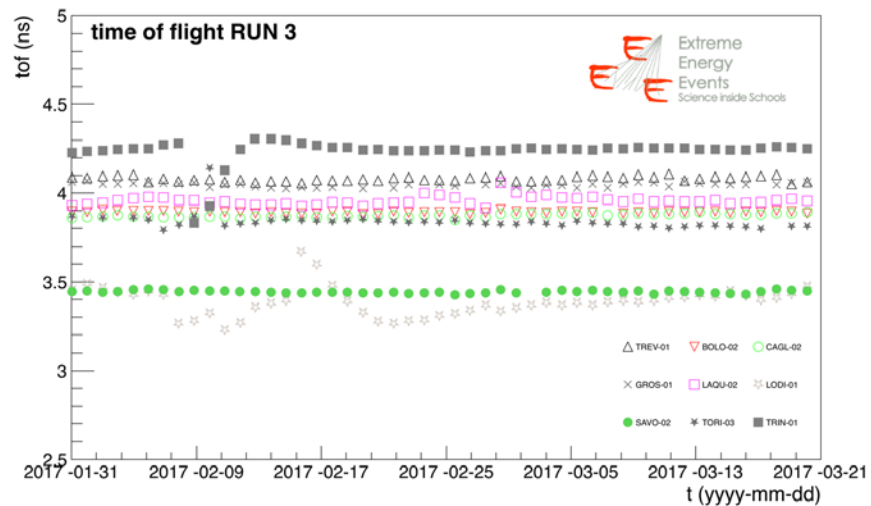
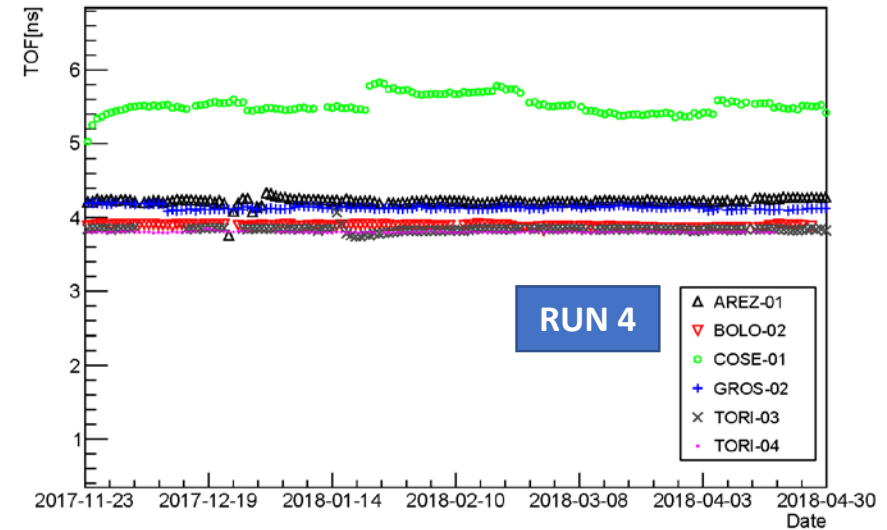
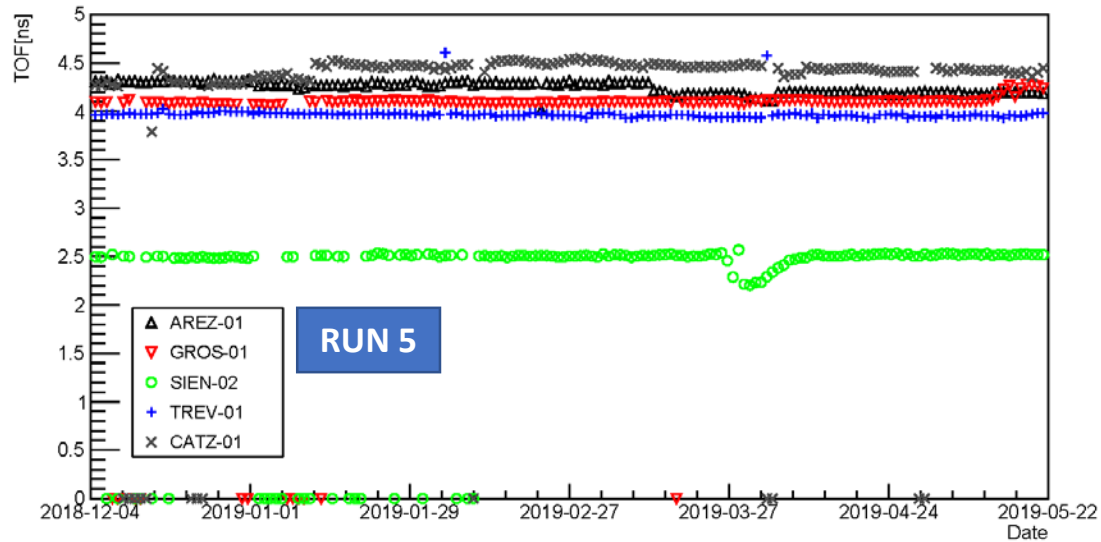
Long term stability: reconstruction efficiency



Long term stability: average multiplicity



Long term stability: Time of Flight



Final summary

- ~ 180 MRPCs (1.6 m x 0.8 m) [59 sites] - **230 m²**
- ~ 15 years of data taking
- Performance in heterogeneous conditions

