

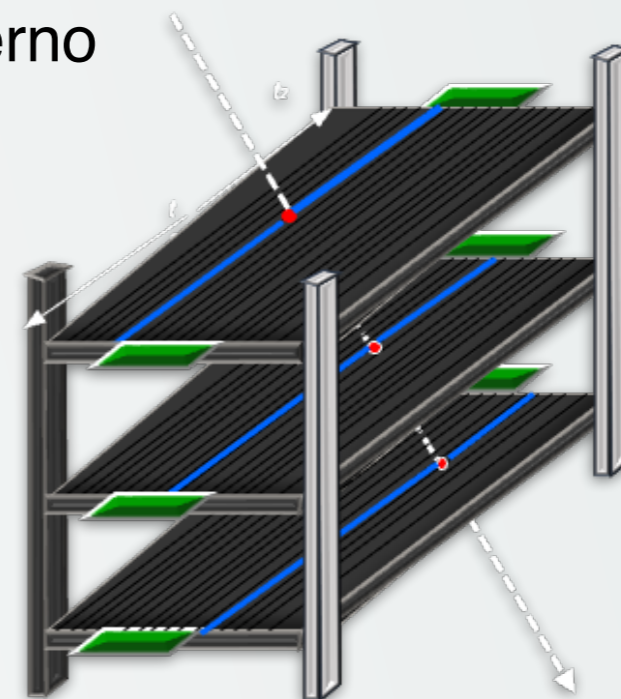
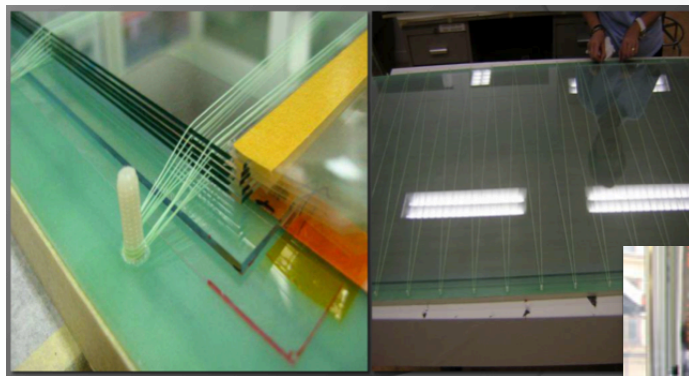


27 - 29 Novembre 2023 - Laboratori Nazionali di Legnaro (PD)

News and recap from Extreme Energy Events

D. De Gruttola

University and INFN Salerno



Restarting

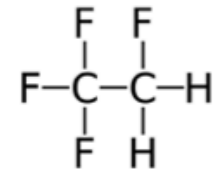
Eco-friendly gas mixtures



Standard mixture adopted in the MRPC EEE telescopes

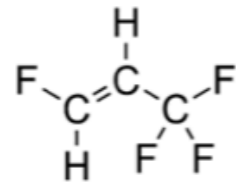
$C_2H_2F_4$ (98%) + SF_6 (2%)
GWP of ~ 1880

98% $C_2H_2F_4$ + 2% SF_6



$C_2H_2F_4$
Tetrafluoroethane
GWP = 1430

Just one carbon!



$C_3H_2F_4$
Tetrafluoropropene
GWP = 6

$C_3H_2F_4$

is a good candidate to replace

$C_2H_2F_4$

- ✓ $C_3H_2F_4$ is a good quencher
- ✓ Too high operating voltage



98% $C_2H_2F_4$ + 2% SF_6



SF_6
Sulfur hexafluoride
GWP=23900



He
GWP<1

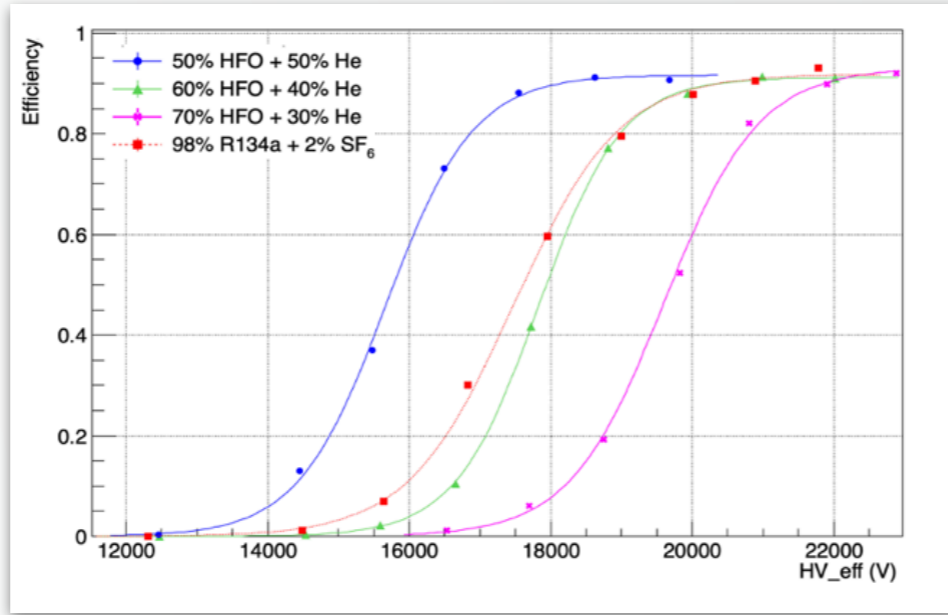


$O=C=O$
 CO_2
GWP=1

- ✓ He and CO_2 are used to reduce the operating voltage wrt pure HFO
- ✓ Less quenching wrt standard mixture



50% $C_3H_2F_4$ + 50% He
has **GWP < 3.5**



- Very good results from tests with eco mixture
- Excellent efficiency (He reduces working point)
- Slightly noisier, but still inside requirements
- **Let's restart!!**

Restarting

Operational

16 telescopes

Telescopio	Sito	Miscela
BOLO-01	INFN Bologna	R1234ze+CO ₂
BOLO-02	Liceo Fermi Bologna	R1234ze+He
BOLO-05	Liceo Galvani Bologna	R1234ze+CO ₂
CAGL-01	Liceo Pacinotti Cagliari	R1234ze+He
CAGL-02	Liceo Michelangelo Cagliari	R1234ze+CO ₂
CARI-01	ISS Cariati	R1234ze+He
CATZ-01	Liceo Fermi Catanzaro	R1234ze+He
CERN-01	CERN	R1234ze+CO ₂
LECC-01	Liceo Banzi Bazoli Lecce	R1234ze+CO ₂
LNLE-01	Laboratori Nazionali Legnaro	R1234ze+He
PISA-01	INFN Pisa	R1234ze+He
REND-01	Dipartimento Fisica Rende	R1234ze+He
REND-02	Dipartimento Fisica Rende	R1234ze+He
SALE-02	Liceo Regina Margherita Salerno	R1234ze+He
SALE-03	Dipartimento Fisica Salerno	R1234ze+He
VICE-01	Liceo Quadri Vicenza	R1234ze+He

Restarting

Work in progress

9 telescopes

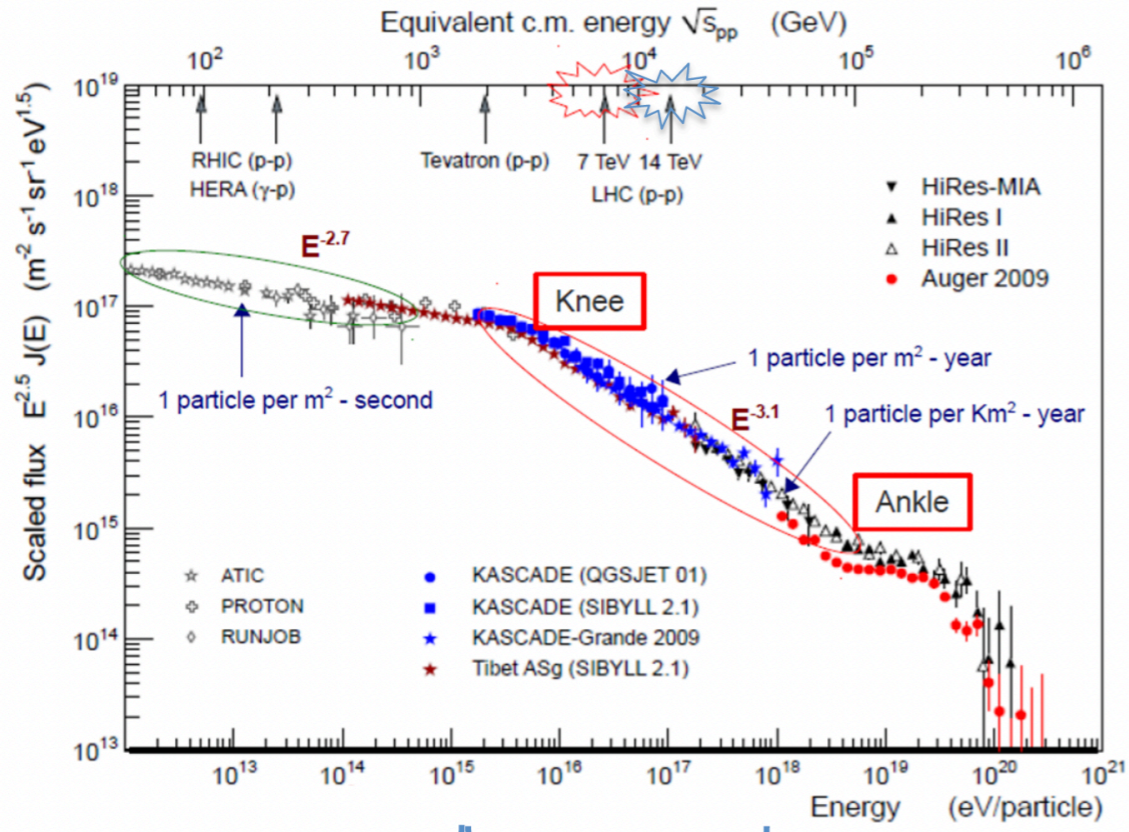
Telescopio	Sito	Miscela
COSE-01	Liceo Scorza Cosenza	R1234ze+He
LAQU-01	Liceo Bafile L'Aquila	R1234ze+He
AREZ-01	ITIS Galilei	R1234ze+He
GROS-01	IIS Manetti	R1234ze+He
TREV-01	Liceo Duca degli Abruzzi	R1234ze+He
FRAS-02	ITT Fermi	R1234ze+He
TRAP-01	Liceo Fardella	R1234ze+He
BOLO-03	Liceo Galvani Bologna	R1234ze+He
BARI-01	Liceo Scacchi	R1234ze+He

Starting procedures

5 telescopes

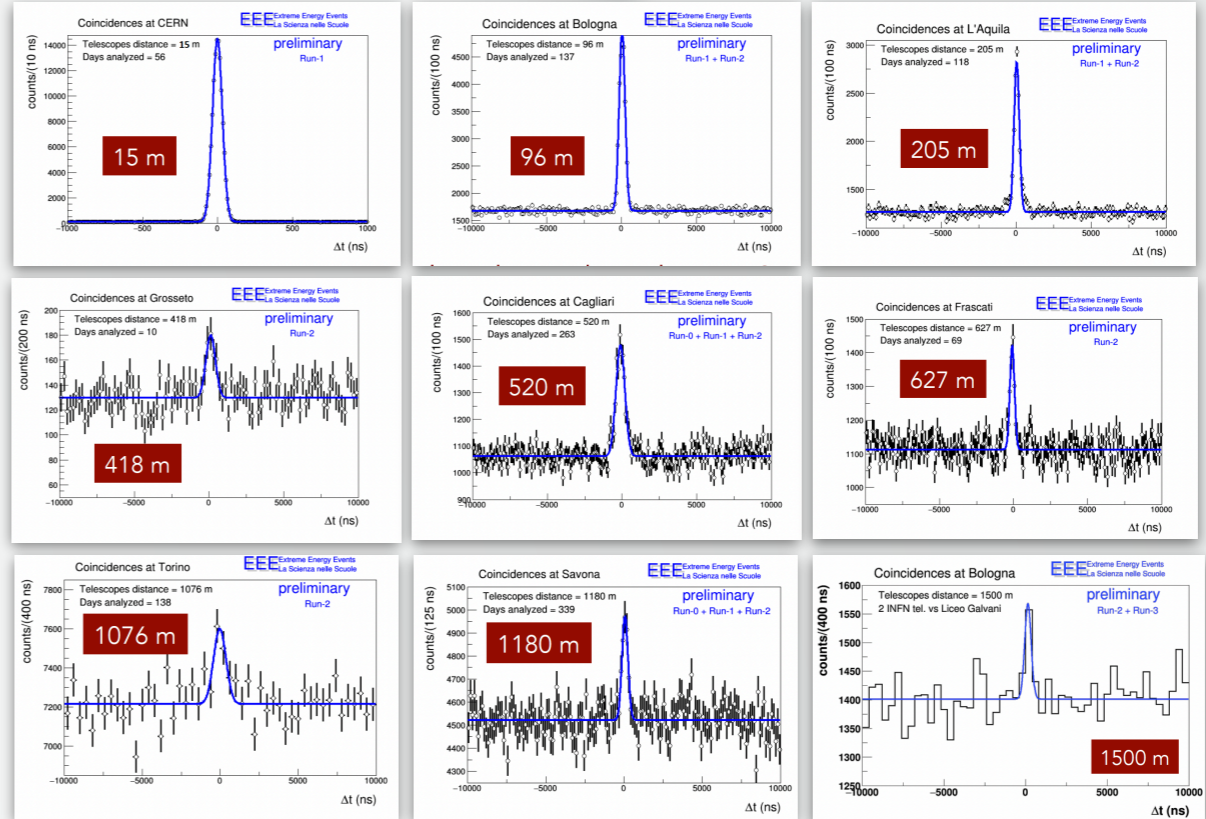
Telescopio	Sito	Miscela
LODI-01	Volta	R1234ze+He
TERA-01	IIS Alessandrini-Marino	R1234ze+He
CAGL-04	IIS Levi	R1234ze+He
MESS-01	Dipartimento Fisica Messina	R1234ze+He
GENO-01	INFN Genova	R1234ze+He

Physics goal of the experiment



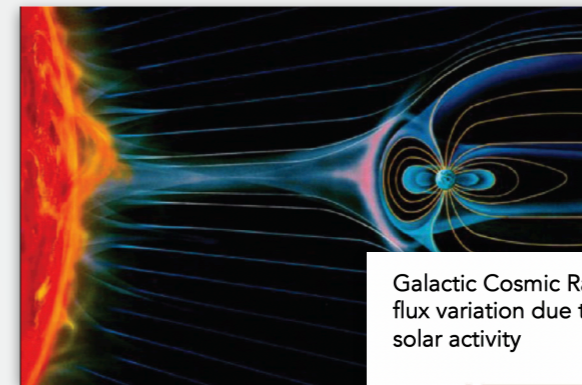
Single telescope sensitivity

Multi-telescope analyses

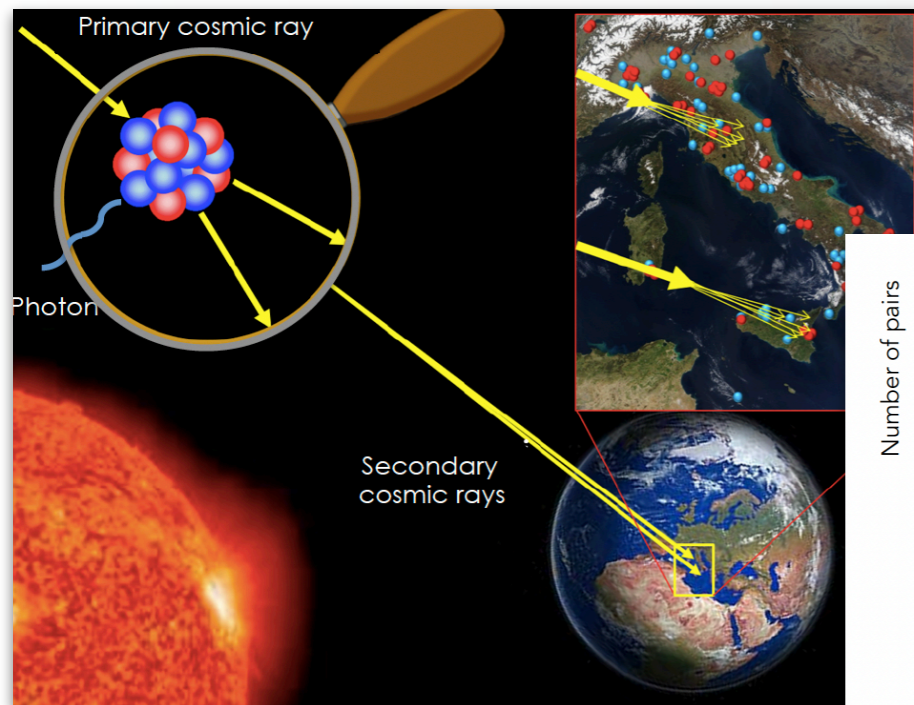


Coincidences

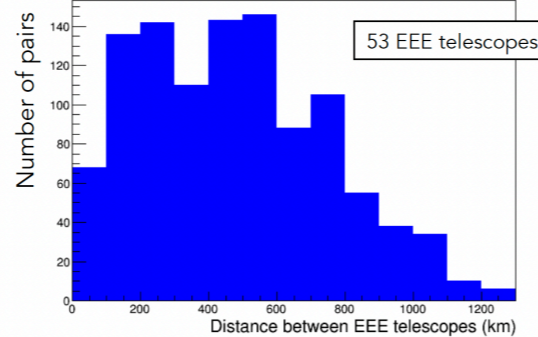
Increasing distance



Forbush decrease



Gerasimov-Zatsepin GZ effect



EEE typical distances between 2 telescopes

Galactic Cosmic Ray (GCR) flux variation due to solar activity

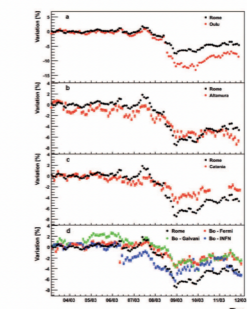
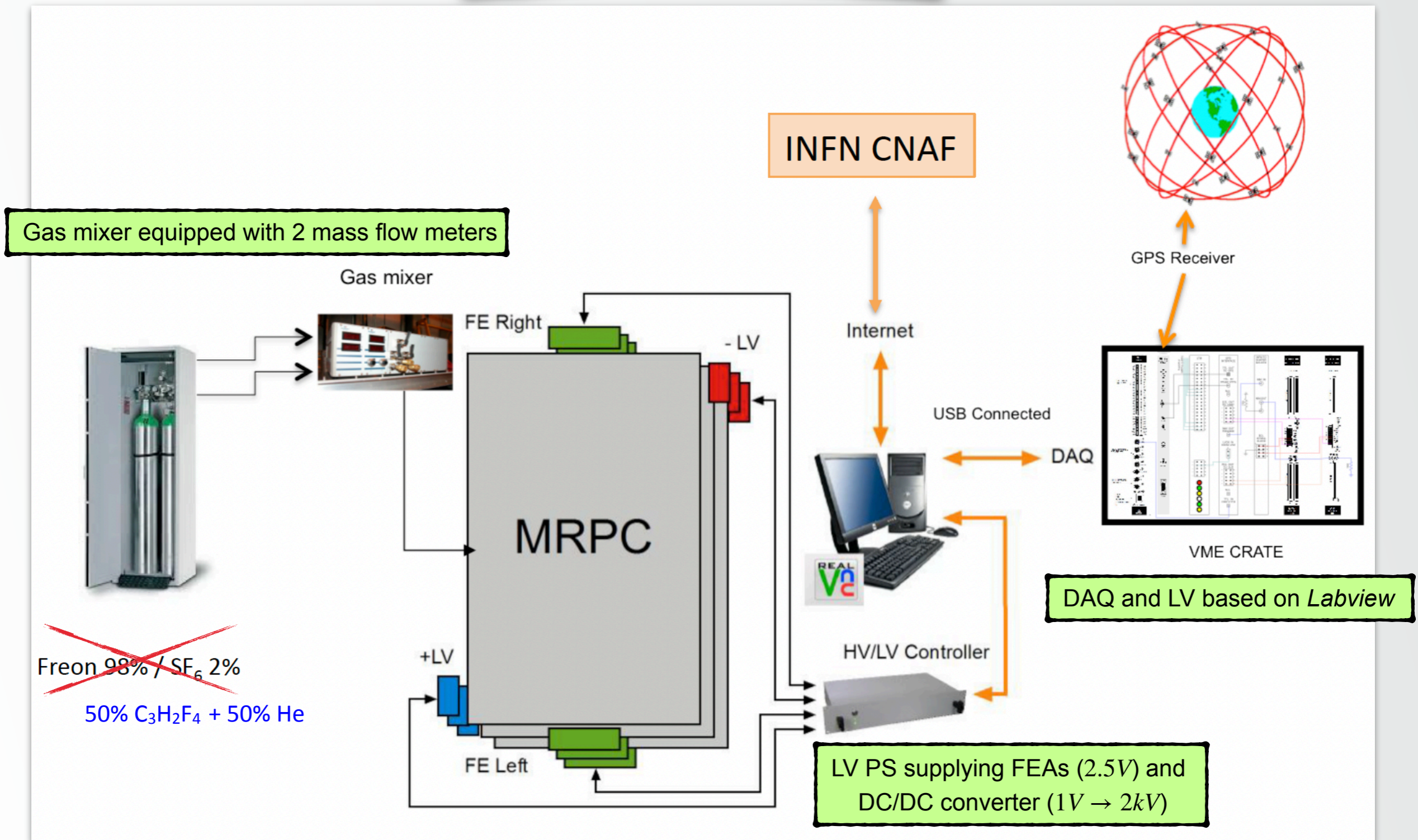


Fig. 5. The March 2012 GCR decrease, as observed by (a) the Oulu and Bussu detectors of the Neutron Monitor Network led by (b) the Akeno, (c) Catania, and (d) Bologna EEE telescopes. For an easier comparison, the EEE measurements are superimposed to the Neat data.

Unprecedented with muons in High Schools !!! 57

..and much more (see F. Riggi slides)

Telescope and electronics



● Muons are detected and reconstructed with $\sim cm^2$ spatial resolution and hundreds of ps time resolution

● The telescopes are **GPS synchronized** for offline analysis on time correlated events

● Data from each station are sent to Bologna INFN **CNAF** for the **track reconstruction** and **storage**

Data Acquisition

The screenshot displays the 'EEE Data Acquisition' software interface. The window title is 'EEE Data Acquisition - SALE-01-2015-02-19-00020'. The interface is divided into several sections:

- Run/Station/Configuration:** The 'Station' tab is active.
- Output Directory:** Set to 'E:\'.
- Comment:** Contains weather station data: 'VWS Data: 2015-02-19 18:50', 'Indoor Temperature: 16,0 °C', 'Outdoor Temperature: 10,0 °C', and 'SL Barometer: 1021 hPa'.
- Min Events per Run:** Set to 50000.
- Auto Restart:** Checked.
- Runs:** Set to 0.
- Average Rate:** 12,94Hz.
- Run No.:** 141.
- Acquired Events:** 49535.
- Rate Monitor:** A gauge showing an instantaneous rate of 16 events.
- Binary File:** 'SALE-01-2015-02-19-00020.bin'.
- STOP:** A green button with a checkmark.
- EXIT:** A red button with an 'X'.
- Time Information:** Current Time: 19:54:50 19/02/2015; Start Time: 18:51:03 19/02/2015; Stop Time: 19:54:50 19/02/2015.

Data folder

Weather station data

Average rate of triggered events

Average number of triggered events

Instantaneous rate of triggered events

Current data file

Max Nb of events per run

HV system

High Voltage system (2 different types)

Applied **VOLTAGE (V)**

Monitored **CURRENT (μA)**

VOLTAGE (V) setting

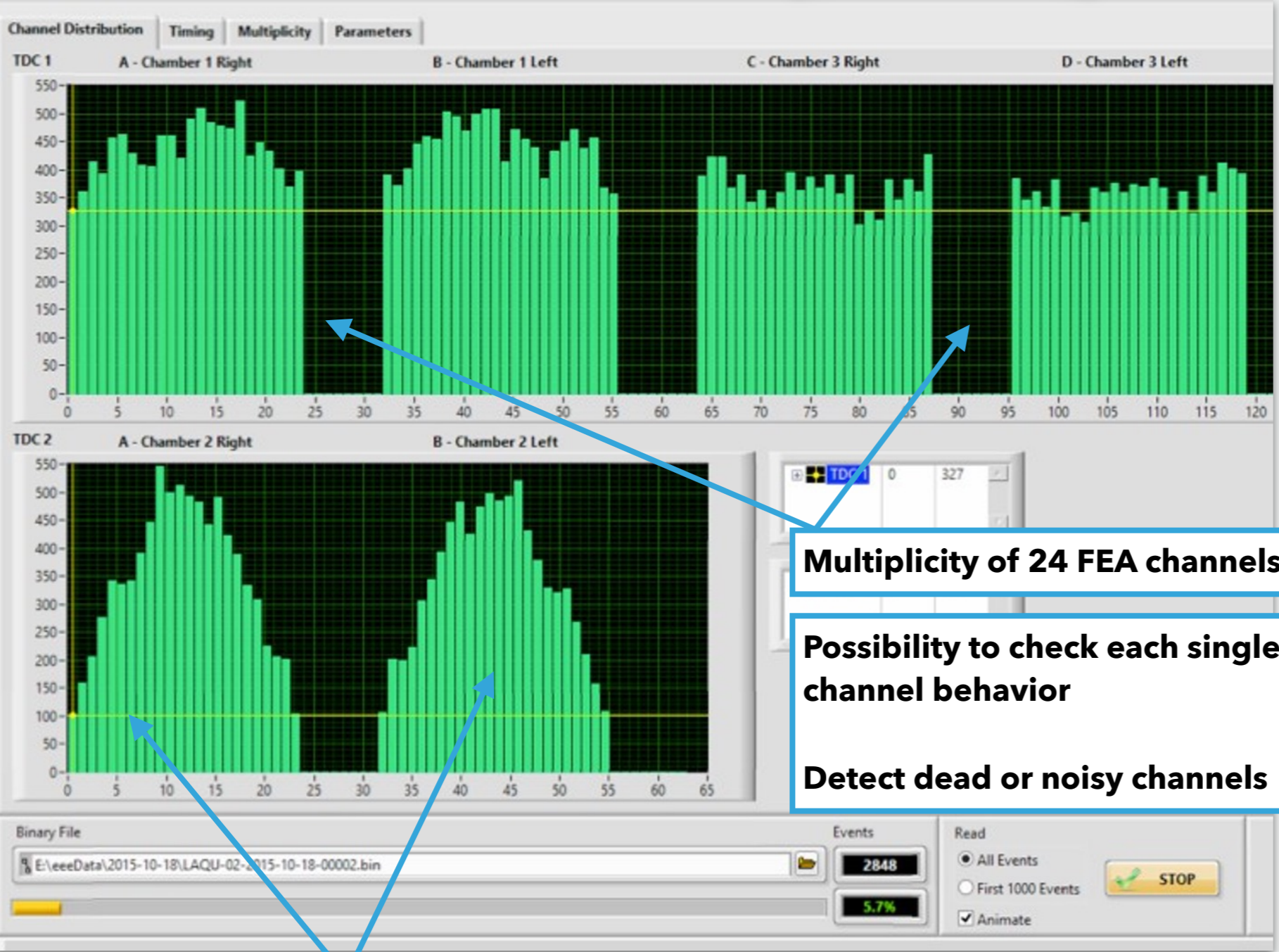


C.A.E.N. A7512 12000V / 20uA SW Rel. 2.02

Board	U _{mon}	I _{mon}	Stat	P _v	U _{set}	I _{set}	R _{up}	R _{dwn}	P _{dwn}	T _{rip}	T _{emp}
00(+)	09003.1 U	01.1150 uA	->ON		09000.0 U	07.000 uA	050 U/S	050 U/S	Ramp	0010 S	+29.0 °C
01(+)	09002.2 U	00.8575 uA	ON		09000.0 U	07.000 uA	050 U/S	050 U/S	Ramp	0010 S	+29.0 °C
02(+)	09002.2 U	00.5700 uA	ON		09000.0 U	07.000 uA	050 U/S	050 U/S	Ramp	0010 S	+29.0 °C
03(-)	09003.3 U	01.0910 uA	ON		09000.0 U	07.000 uA	050 U/S	050 U/S	Ramp	0010 S	+29.0 °C
04(-)	09002.5 U	00.8690 uA	ON		09000.0 U	07.000 uA	050 U/S	050 U/S	Ramp	0010 S	+29.0 °C
05(-)	09002.8 U	00.5655 uA	ON		09000.0 U	07.000 uA	050 U/S	050 U/S	Ramp	0010 S	+31.0 °C

CURRENT (μA) limit

Local DQM

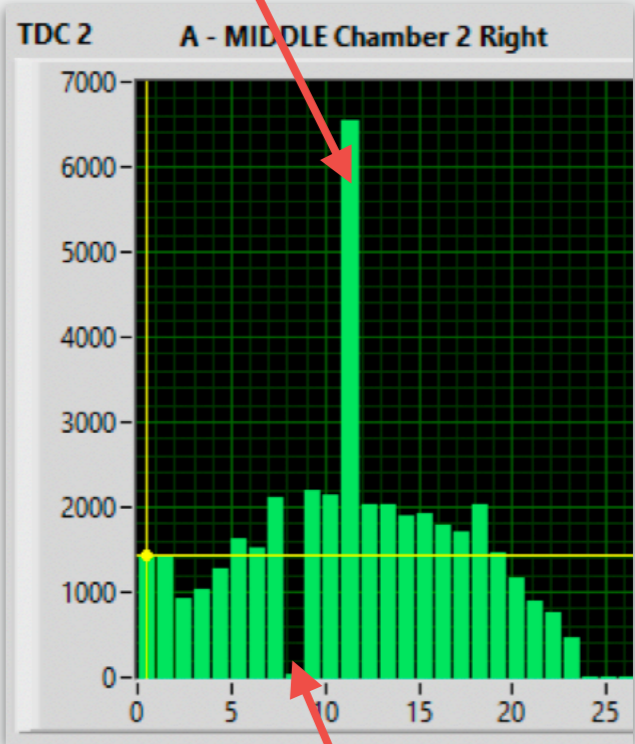


Noisy channel

Multiplicity of 24 FEA channels

Possibility to check each single channel behavior

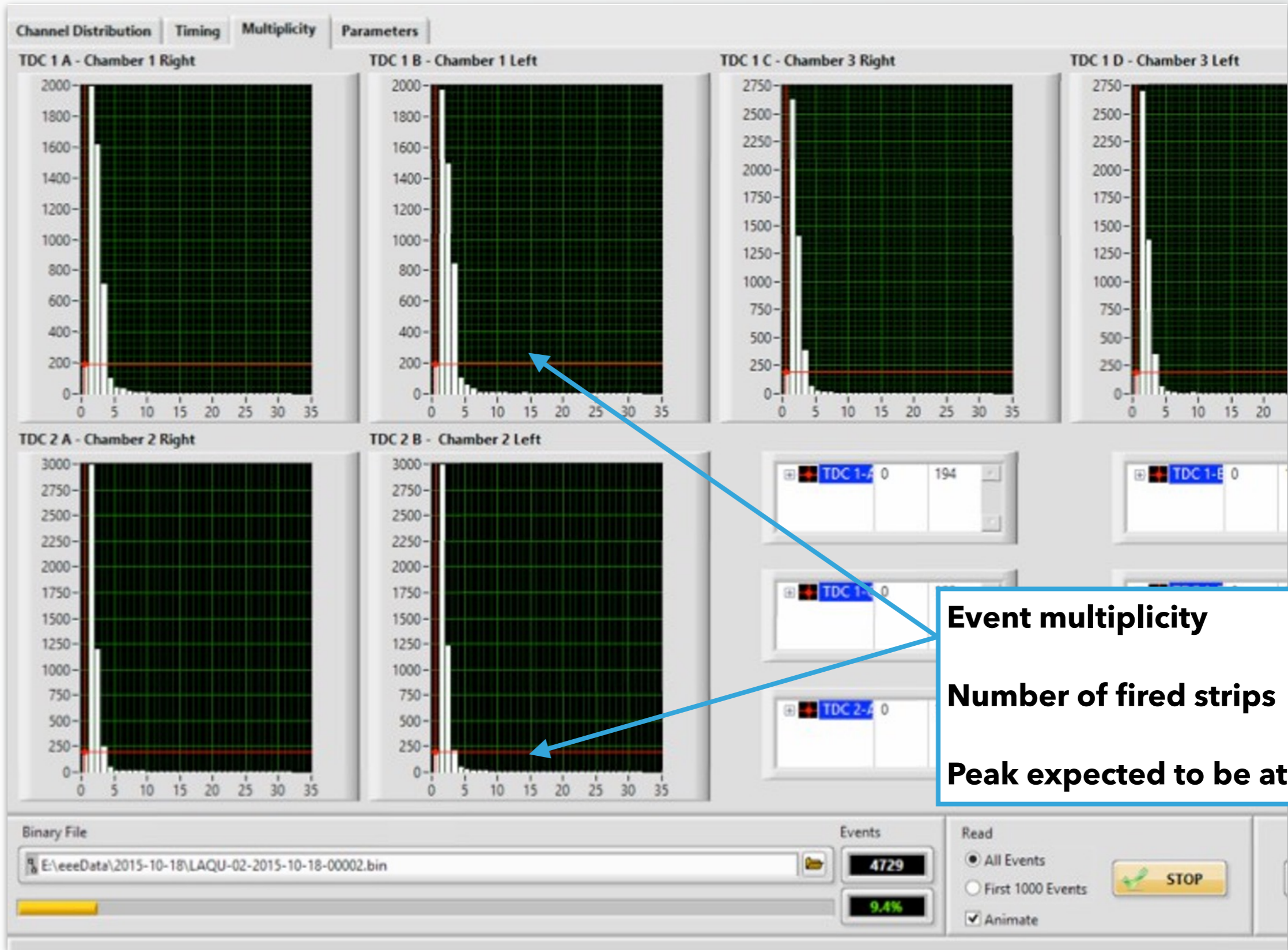
Detect dead or noisy channels



Multiplicity shape of middle chamber (acceptance)

Dead channel

Local DQM



Event multiplicity
Number of fired strips
Peak expected to be at 1

Data Quality Monitor

<http://eee.centrofermi.it/monitor>

INFN CNAF

La tabella sottostante mostra la situazione dei telescopi:

- 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.

- In **grigio** sono indicati i telescopi in attesa di ripartire con la nuova miscela di gas ecosostenibile.

- In **beige** sono indicati gli archivi storici dei dati dei telescopi che ora sono stati spostati in altre scuole.

School	Day	Time	Name of the last transferred File	Number of Files transferred today	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 <i>[Event Display]</i>	sab 15 febbraio	11:08	ALTA-01-2020-02-15-00032.bin	0 <i>[History]</i>	ALTA-01-2020-02-15-00032.bin	16/02 <i>[History]</i>	31.0	10.0	ALTA-01
ANCO-01 <i>[Event Display]</i>	dom 08 marzo	19:08	ANCO-01-2020-02-25-00002.bin	0 <i>[History]</i>	ANCO-01-2020-02-25-00022.bin	13/02 <i>[History]</i>	22.0	15.0	ANCO-01
AREZ-01 <i>[Event Display]</i>	ven 12 marzo	17:36	AREZ-01-2021-03-12-00005.bin	0 <i>[History]</i>	AREZ-01-2021-03-12-00004.bin	13/03 <i>[History]</i>	14.0	11.0	AREZ-01
BARI-01 <i>[Event Display]</i>	mar 16 marzo	15:22	BARI-01-2021-03-16-00013.bin	0 <i>[History]</i>	BARI-01-2021-03-16-00012.bin	17/03 <i>[History]</i>	10.0	9.0	BARI-01
BOLO-01 <i>[Event Display]</i>	lun 27 novembre	14:36	BOLO-01-2023-11-27-00018.bin	18 <i>[History]</i>	BOLO-01-2023-11-27-00018.bin	27/11 <i>[History]</i>	15.0	12.0	BOLO-01
BOLO-02 <i>[Event Display]</i>	lun 27 novembre	14:45	BOLO-02-2023-11-27-00036.bin	37 <i>[History]</i>	BOLO-02-2023-11-27-00035.bin	27/11 <i>[History]</i>	31.0	27.0	BOLO-02

Complete monitoring of all EEE telescopes

Basic quantities to monitor the stability of the telescopes

Green detectors are currently running (**Restarting**)

Extreme Energy Events Monitor

Ultimo aggiornamento: ore 16:49 - mer 13 aprile 2016 [by e3monitor]

ELOGBOOK delle SCUOLE	ELOGBOOK dello SHIFTER	New DB Interface (BETA)
Home Page EEE	Masterclass	Download the Excel Sheet for the Shifter's Report

Daily report

[EEE Monitor info] **RUN 2 - Data taking - Day number 159**
Total number of candidate tracks ($X^2 < 10$) in the database: 22145455079

Questa tabella mostra la situazione dei telescopi in acquisizione:

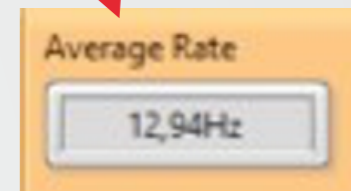
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Scuola	Giorno	Ora	Nome dell'ultimo File trasferito	Numero Files trasferiti oggi	Ultima Entry nell'e-logbook delle Scuole del Run2	Nome dell'ultimo File analizzato dal DQM	Report giornaliero DQM	RATE of Triggers for the last Run in DQM	RATE of Tracks for the last Run in DQM	Link DQM
ALTA-01	mer 13 aprile	16:27	ALTA-01-2016-04-13-00032.bin	20 [History]	11:16 13/04/2016	ALTA-01-2016-04-13-00031.bin	13/04 [History]	25.0	18.0	ALTA-01
AREZ-01	mer 13 aprile	16:38	AREZ-01-2016-04-13-00036.bin	38 [History]	11:04 13/04/2016	AREZ-01-2016-04-13-00034.bin	13/04 [History]	34.0	25.0	AREZ-01

Trigger rate



(slide 7)

- Complete monitoring of all EEE telescopes
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Scuola	Giorno	Ora	Nome dell'ultimo File trasferito	Numero Files trasferiti oggi	Ultima Entry nell'e-logbook delle Scuole del Run2	Nome dell'ultimo File analizzato dal DQM	Report giornaliero DQM	RATE of Triggers for the last Run in DQM	RATE of Tracks for the last Run in DQM	Link DQM
ALTA-01	mer 13 aprile	16:27	ALTA-01-2016-04-13-00032.bin	20 [History]	11:16 13/04/2016	ALTA-01-2016-04-13-00031.bin	13/04 [History]	25.0	18.0	ALTA-01
AREZ-01	mer 13 aprile	16:38	AREZ-01-2016-04-13-00036.bin	38 [History]	11:04 13/04/2016	AREZ-01-2016-04-13-00034.bin	13/04 [History]	34.0	25.0	AREZ-01

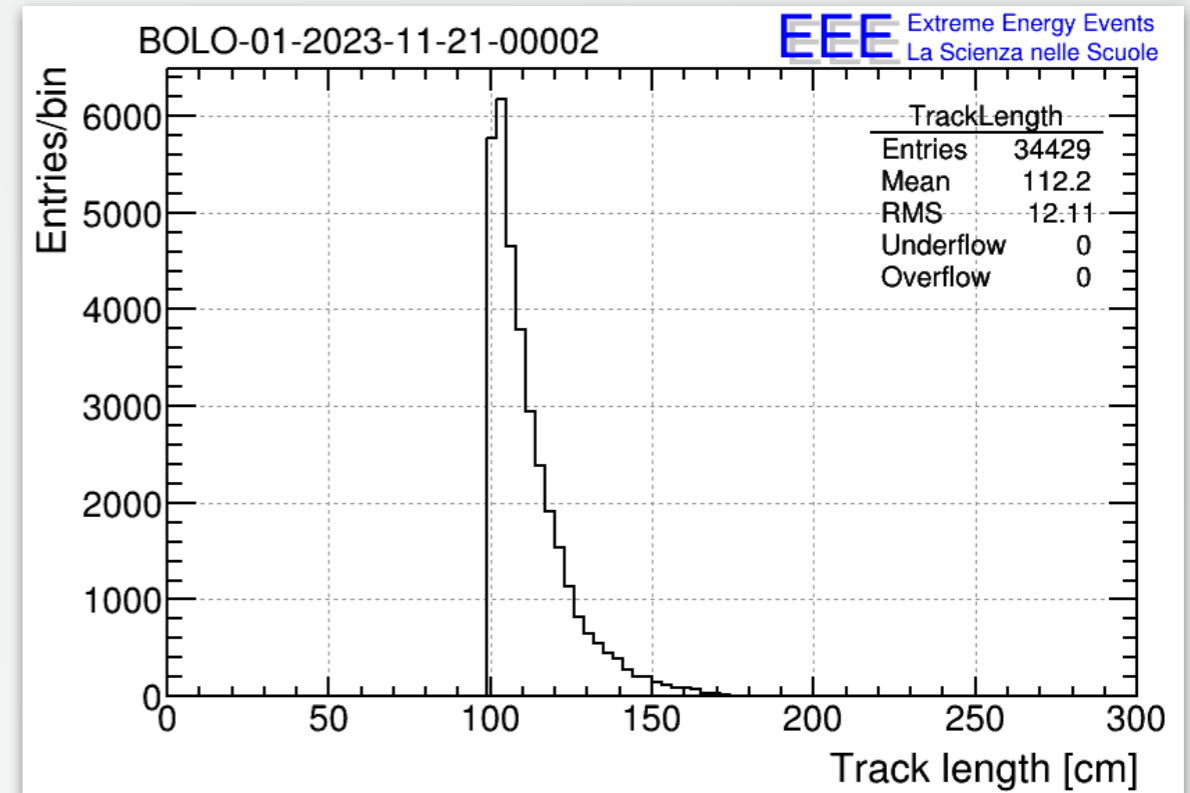
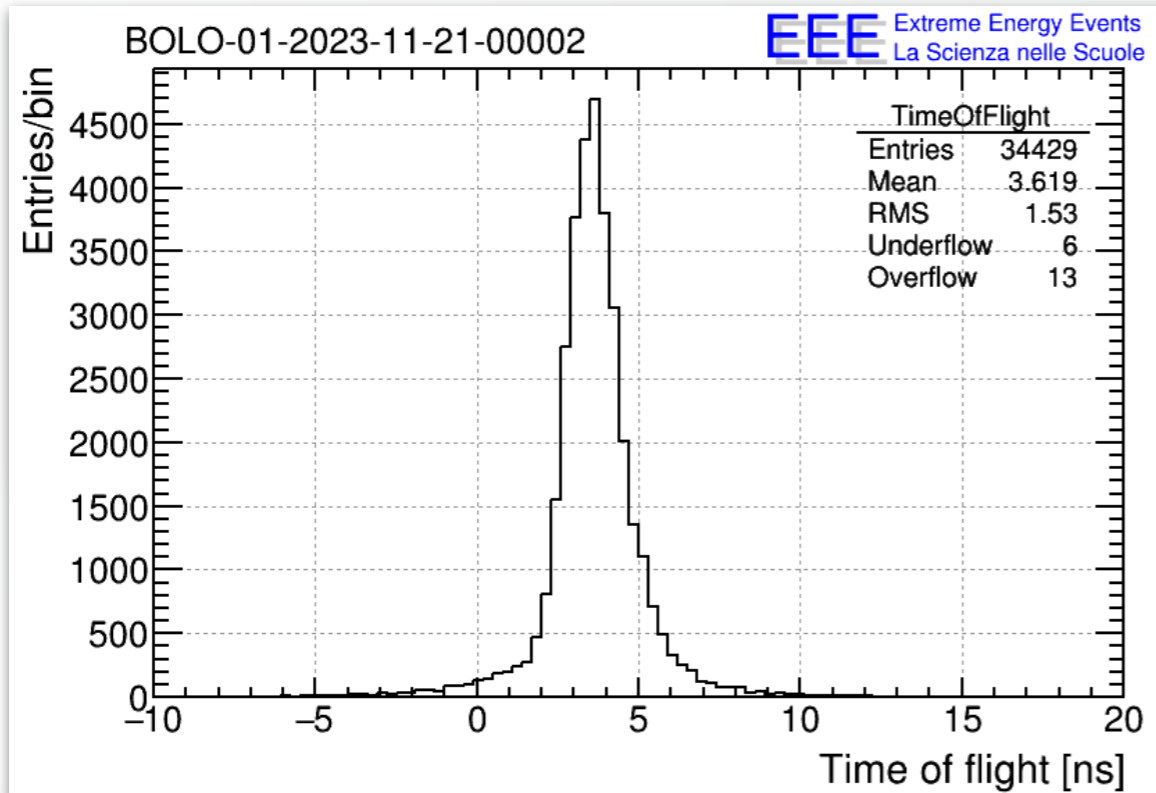
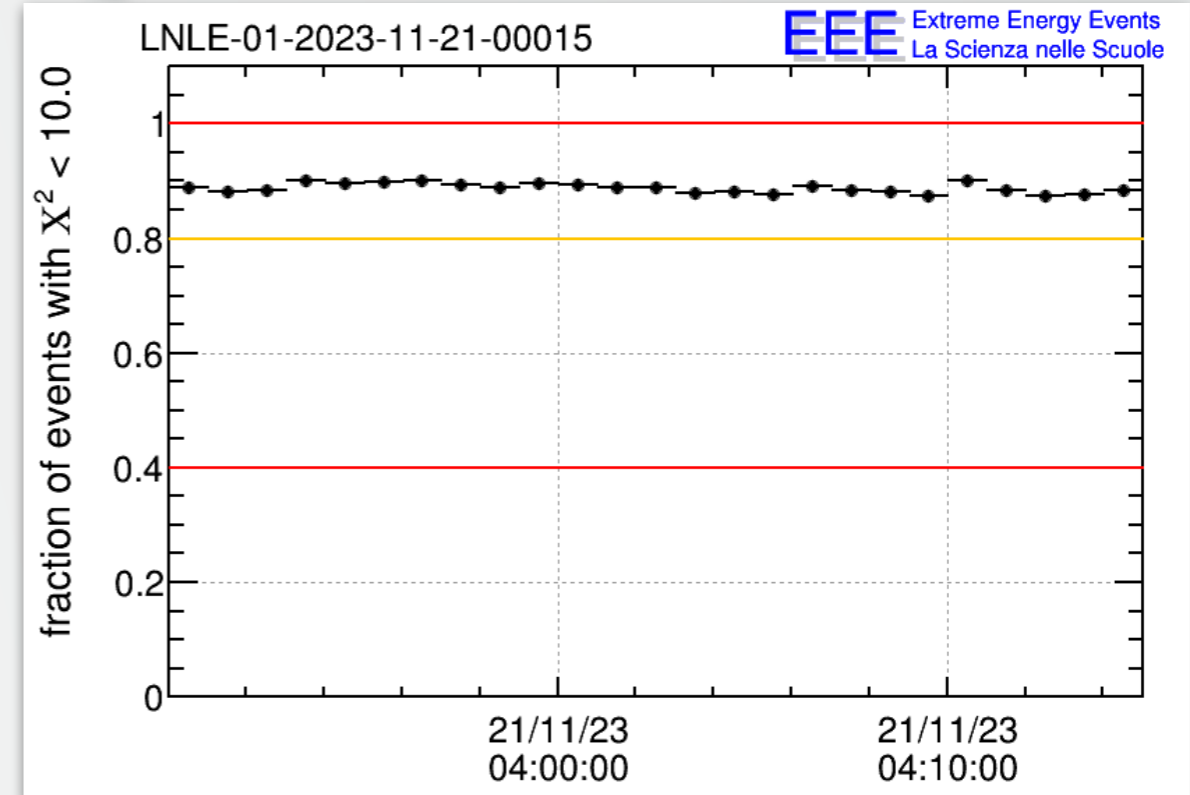
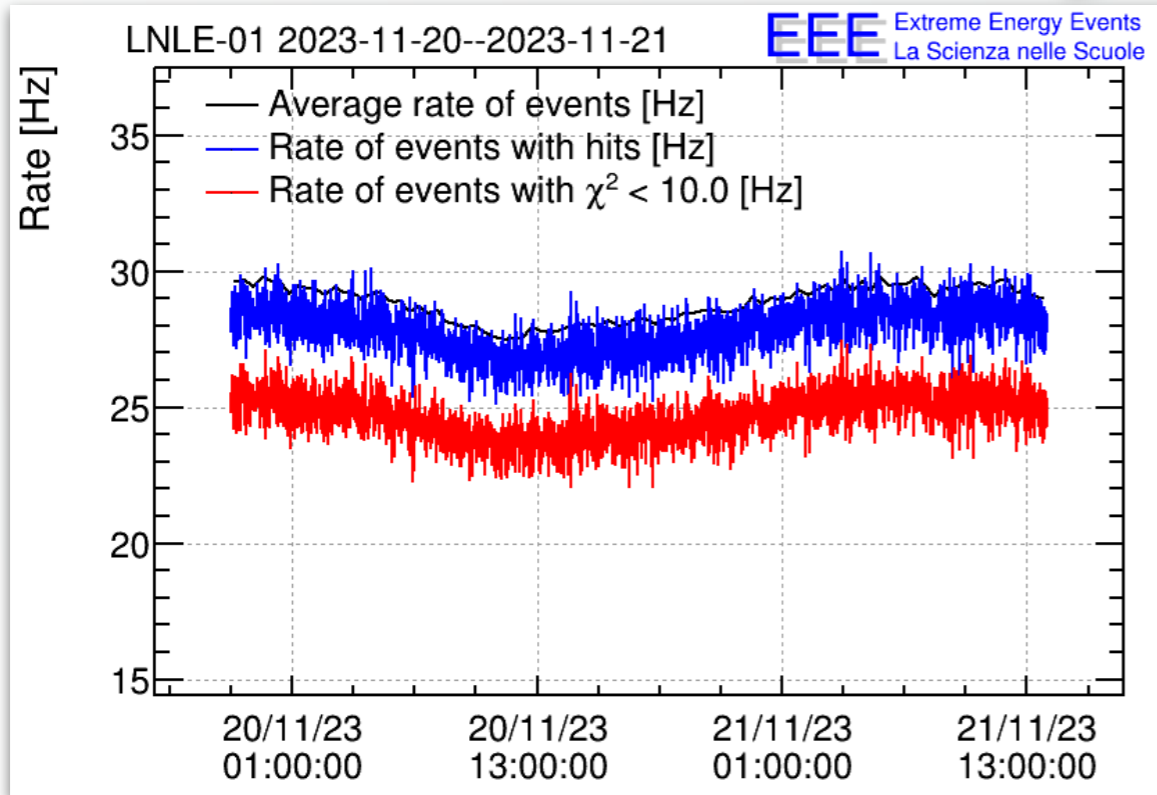
Rate of reconstructed tracks

(after timing and space selection)

- Complete monitoring of all EEE telescopes
- Basic quantities to monitor the stability of the telescopes
- Green detectors are currently running (**Restarting**)

Tracks

<http://eee.centrofermi.it/monitor>



+ angular distributions, hit and cluster multiplicity, track χ^2 ...

Trending day by day

<http://eee.centrofermi.it/monitor>

Daily report

SALE-02-2023-11-28-00022.bin	27/11 <i>[History]</i>
------------------------------	---------------------------

Possibility to download trending data - root files and cdv files

SUMMARY

- Station: SALE-02
- Time period: 2023-11-26--2023-11-27
- Number of runs processed: 97
- Total number of events: 4470134
- Number of events with hits: 3535724
- Number of events with a track: 2204374
- Data files: [root](#), [csv header](#), [csv trending](#), [csv weather](#)

SALE-02 Daily Report History

2023-11-27	2023-11-26	2023-11-25	2023-11-24	2023-11-23
2023-11-22	2023-11-21	2023-11-20	2023-11-19	2023-11-18
2023-11-17	2023-11-16	2023-11-15	2023-11-14	2023-11-13
2023-11-12	2023-11-11	2023-11-10	2023-11-09	2023-11-08
2023-11-02	2023-11-01	2023-10-31	2023-10-30	2023-10-29
2023-10-28	2023-10-27	2023-10-26	2023-10-25	2023-10-24
2023-10-23	2023-10-22	2023-10-21	2023-07-01	2023-06-30
2023-06-29	2023-06-28	2023-06-27	2023-06-26	2023-06-25
2023-06-24	2023-06-23	2023-06-22	2023-06-21	2023-06-20
2023-06-19	2023-06-18	2023-06-17	2023-06-16	2023-06-15
2023-06-14	2023-06-13	2023-06-12	2023-06-11	2023-06-10
2023-06-09	2023-06-08	2023-06-07	2023-06-06	2023-06-03

The EEE Project



- **Largest surface** covered by a detector of cosmic muons on ground, with both tracking and timing capabilities

• $\approx 0.5 \times 10^6 \text{km}^2 \approx 10^\circ$ of latitude/longitude

- **Largest area of MRPC** detectors built and operating, in unconventional working sites

• $\approx 200 \text{m}^2$

- mainly school buildings
- non-professional electrical lines
- non-controlled environmental parameters
- heterogeneous maintenance conditions

Challenge

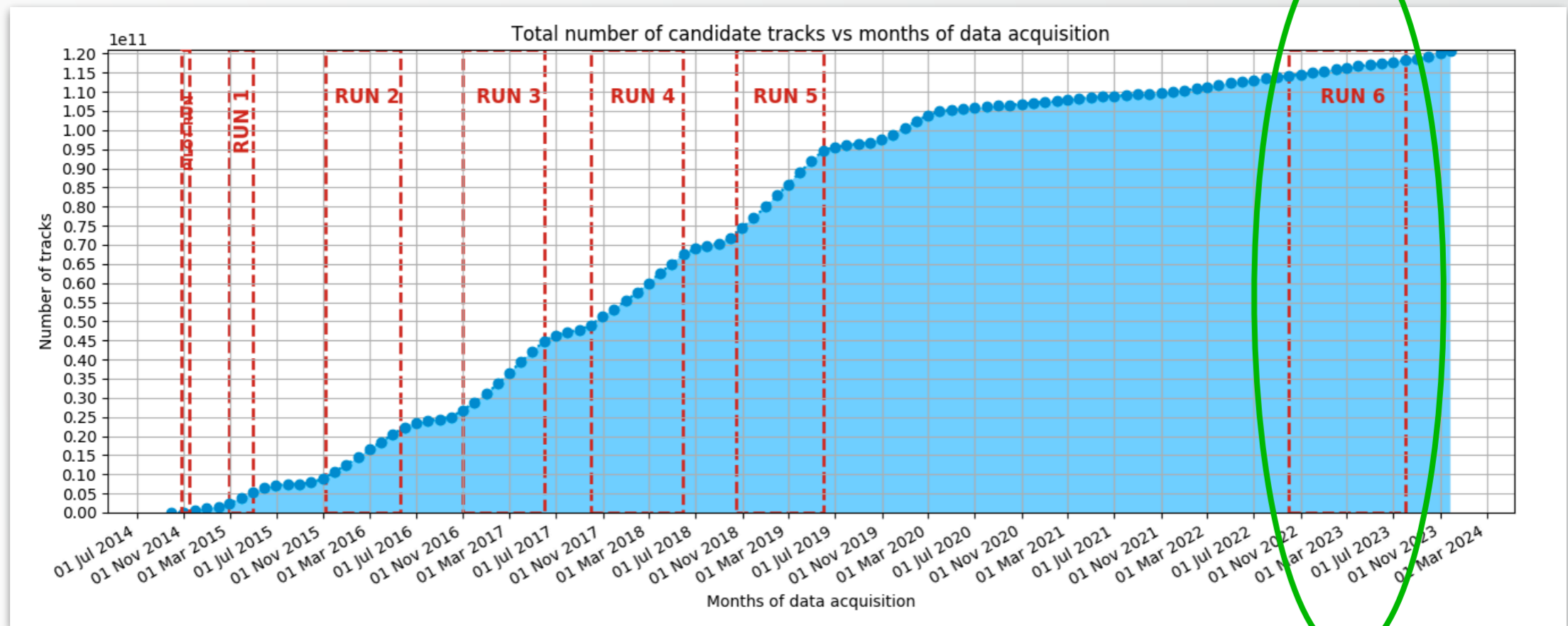
- **Long-living** MRPC-based system (19 years)
(see F. Riggi slides)
- **Number of involved people** comparable to big experiments at colliders (researchers/students/teachers)
- **Schools with and without telescope equally involved in the project**

Conclusions

● **RUN 6** - 16 telescopes running after Covid stop and tests with eco-gas mixtures

● New telescopes joining

● Collected tracks increased even during the stop



● Restarting limited by availability and cost of gas

Thank you for the attention!