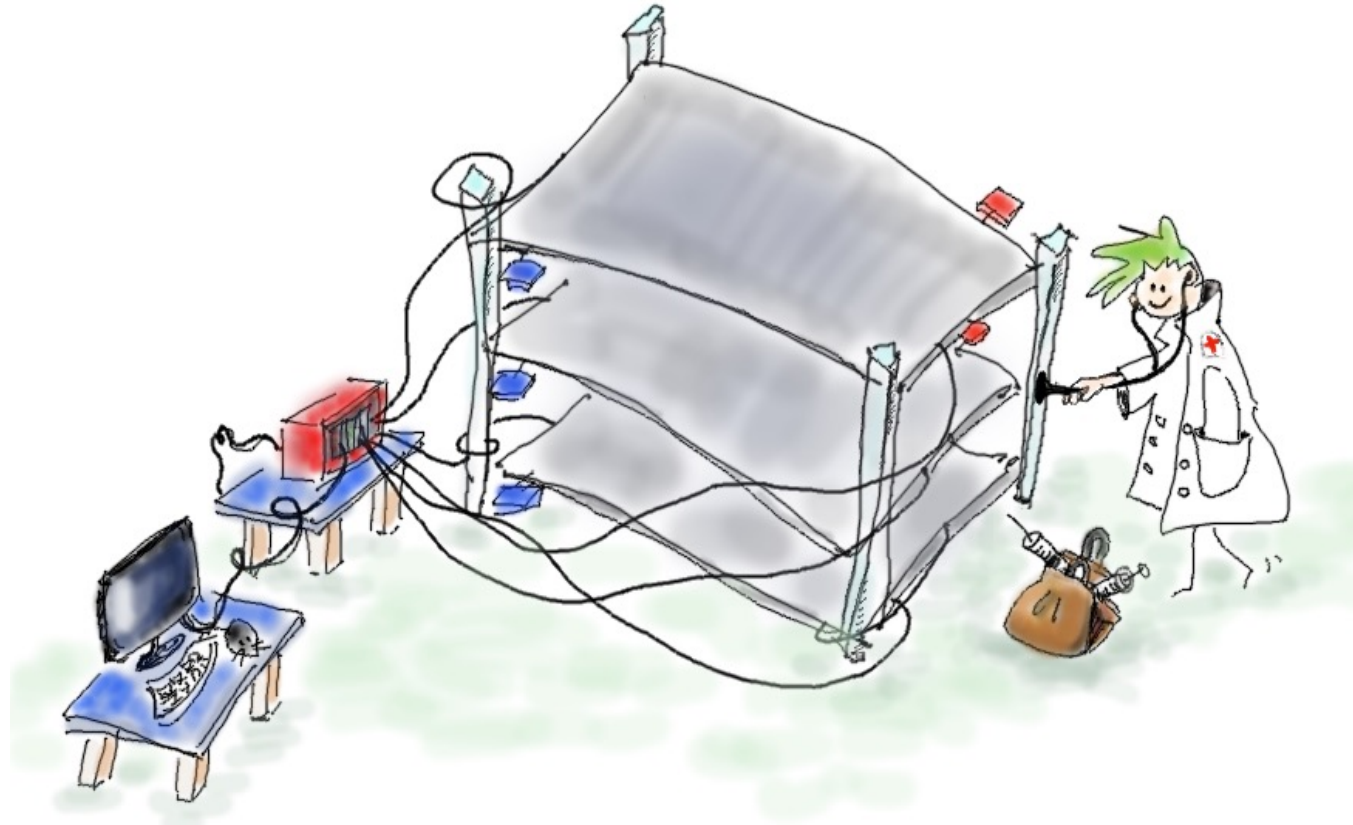


NEW **ECO-GAS** MIXTURES FOR THE EEE PROJECT



Credit to TORI

C.Ripoli* on behalf of the EEE Collaboration

*University and INFN of Salerno

EEE Project Ecological Transition

The EEE Collaboration started actions to reduce the GreenHouse Gases (GHG) emissions



NEW GAS MIXTURE

First Meeting of the EEE Project after COVID
shutdown, 17-19 November 2021 Erice



EEE Project Ecological Transition



66th INFN ELOISATRON WORKSHOP:
New gas mixtures for RPC and MRPC detectors

RESTARTING WITH ECOGAS FOR EEE PROJECT

C.Ripoli on behalf of the EEE Collaboration

November 20 -23, 2022

Ettore Majorana Foundation and
Centre for Scientific Culture

EEE Project Ecological Transition

The EEE Collaboration started actions to reduce the GHG emissions

2017 – 2020

- Gas leak reduction campaign
- Gas flow reduction campaign
- Re-circulation system prototype test
- Test and analysis data on alternative mixtures (several % combination)

2021 – 2022

- Choice of ecofriendly gas mixtures adopted
- Long term studies to validate the stability
- Ecofriendly gas mixtures deployment
- Data taking with complete replacement of GHG with an ecofriendly gas mixture

Gas leak reduction



The gas flow reduction has been preceded by a
MRPCs Gas Tightness Test campaign

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



HV connectors, gas connectors, gas pipes,
screws and MRPC edges
checked and repaired

Gas flow reduction



Started in September 2019 and stopped in March 2020 due to Covid-19

Flow reduction 2-3 l/h → 1l/h

~ **65%** EEE detectors work with a flow ~ 1 l/h

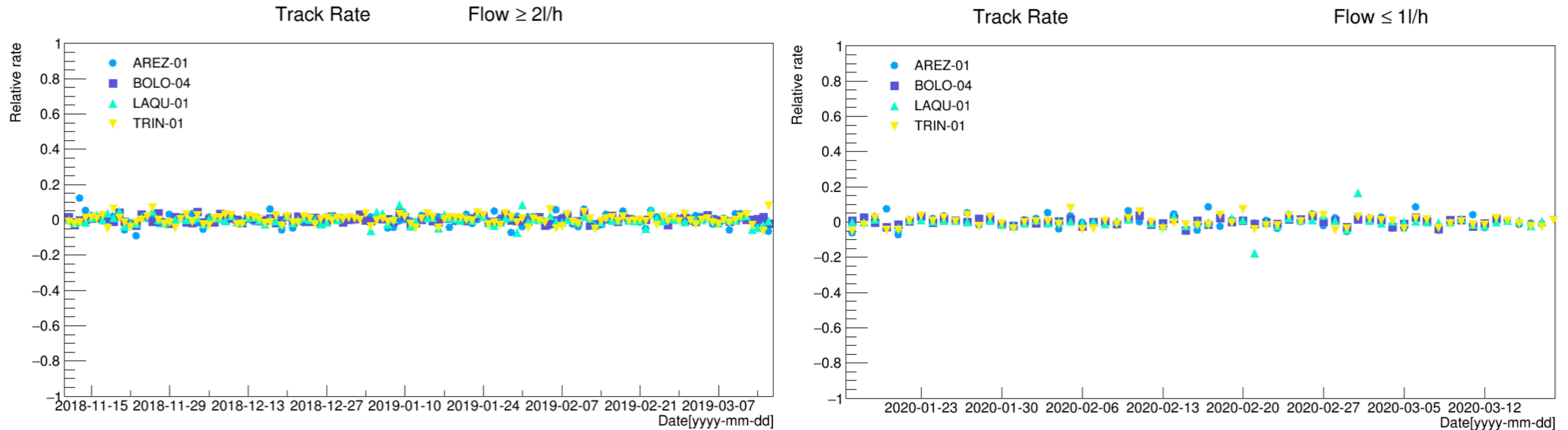
Gas waste decreased by **50%** thanks to flow reduction



The MRPCs for cosmic muons tracking can operate at lower flows, with no impact on performance

Gas flow reduction campaign

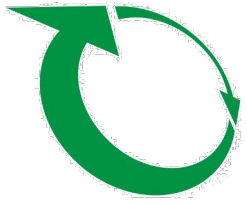
Muon track rate before and after the flow reduction



Remarkable stability

considering the different conditions in: **Temperature, external pressure, efficiency fluctuations** in a time lapse of **a year between the two data samples.**

The EEE gas re-circulation system



A recirculation system was installed and studied on a EEE Telescope at CERN

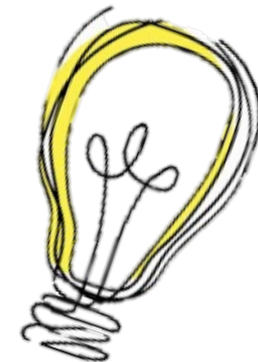
*** thanks to CERN Gas Group**

The consumption of gas in the EEE array could be reduced by recycling the gas mixture thanks to this gas recirculation system

**Last test with prototype
can reuse a flow fraction $\approx 60\%$**

The idea:

A simple, small, easy-to-use, low-cost system to be eventually installed in each EEE Station



Eco-friendly gas mixtures

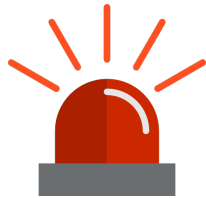
New mixture main features required:

- Similar performance in terms of:
 - Working point < 20 kV
(as per the current HV power supply)
 - Spatial and time resolutions compatible with physics
 - **Safety** hydrocarbons cannot be used due to flammability issues.
It could be unsafe and leaks in the current MRPC system would need to be detected adding complexity to the system
 - **Cost saving**
 - **Binary** EEE telescopes have just 2 flowmeters
The number of flowmeters in EEE Telescope array cannot be changed
- LAST BUT NOT LEAST**
- **Lower GWP** compared to the standard mixture

Eco-friendly gas mixtures

LAST BUT NOT LEAST

- Lower **GWP*** compared to the standard mixture



EU regulations
set an upper limit to **GWP**
allowed in gas-operated devices

GWP > 150
have been banned by EU

* **Global Warming Potential (GWP)**
measures the greenhouse effect of
gas normalized to CO_2 ($GWP\ CO_2=1$)

Standard mixture adopted in
the MRPC EEE telescopes:

$C_2H_2F_4$ (98%) + SF_6 (2%)

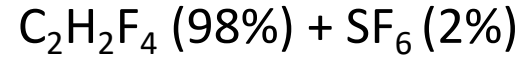


GWP of ~ **1880**



Eco-friendly gas mixtures

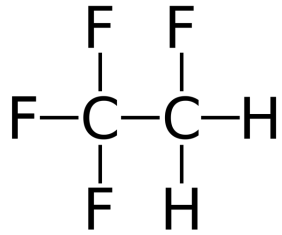
Standard mixture adopted in the MRPC EEE telescopes



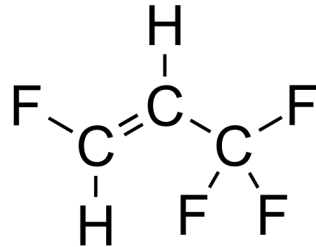
GWP of ~ **1880**



Just one carbon!



$\text{C}_2\text{H}_2\text{F}_4$
Tetrafluoroethane
GWP = 1430



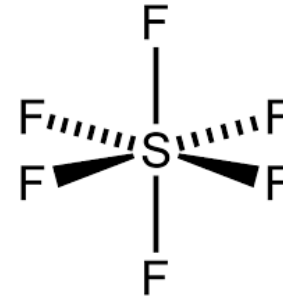
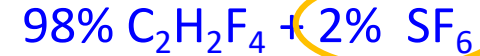
$\text{C}_3\text{H}_2\text{F}_4$
Tetrafluoropropene
GWP = 6



is a good candidate to replace



- ✓ $\text{C}_3\text{H}_2\text{F}_4$ is a good quencher
- ✓ Too high operating voltage



SF_6
Sulfur hexafluoride
GWP = 23900



He
GWP < 1



$\text{O}=\text{C}=\text{O}$
 CO_2
GWP = 1

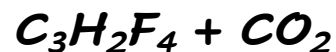
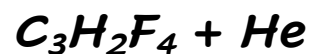


- ✓ He and CO_2 are used to reduce the operating voltage wrt pure HFO
- ✓ Less quenching wrt standard mixture

$C_3H_2F_4$ based gas mixtures

Mixtures based on $C_3H_2F_4$ with different percentages of He and CO_2 have been tested in order to optimize the HV curve.

Chosen mixtures based on performed tests



Telescopes involved in gas test

TELESCOPE	MIXTURE
REND-01	$C_3H_2F_4 + He$
PISA-01	$C_3H_2F_4 + He$
CERN-01	$C_3H_2F_4 + CO_2$
BOLO-01	$C_3H_2F_4 + CO_2$

Percentage of gas (%)				
$C_3H_2F_4 + He$		$C_3H_2F_4 + CO_2$		Pure $C_3H_2F_4$
90	10	60	40	100
70	30	50	50	↓ $C_3H_2F_4$ is a good quencher the streamer percentage is under control, but..
60	40	40	60	
50	50			

High value of the HV setting point,
above the upper HV limit
supplied by DC/DC converters

Studies on ecofriendly gases

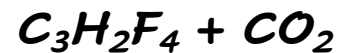
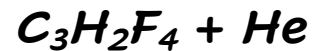
Test on ecofriendly gases

3 MRPC chambers:

- two used for trigger and tracking
- one filled with new mixture (under test)

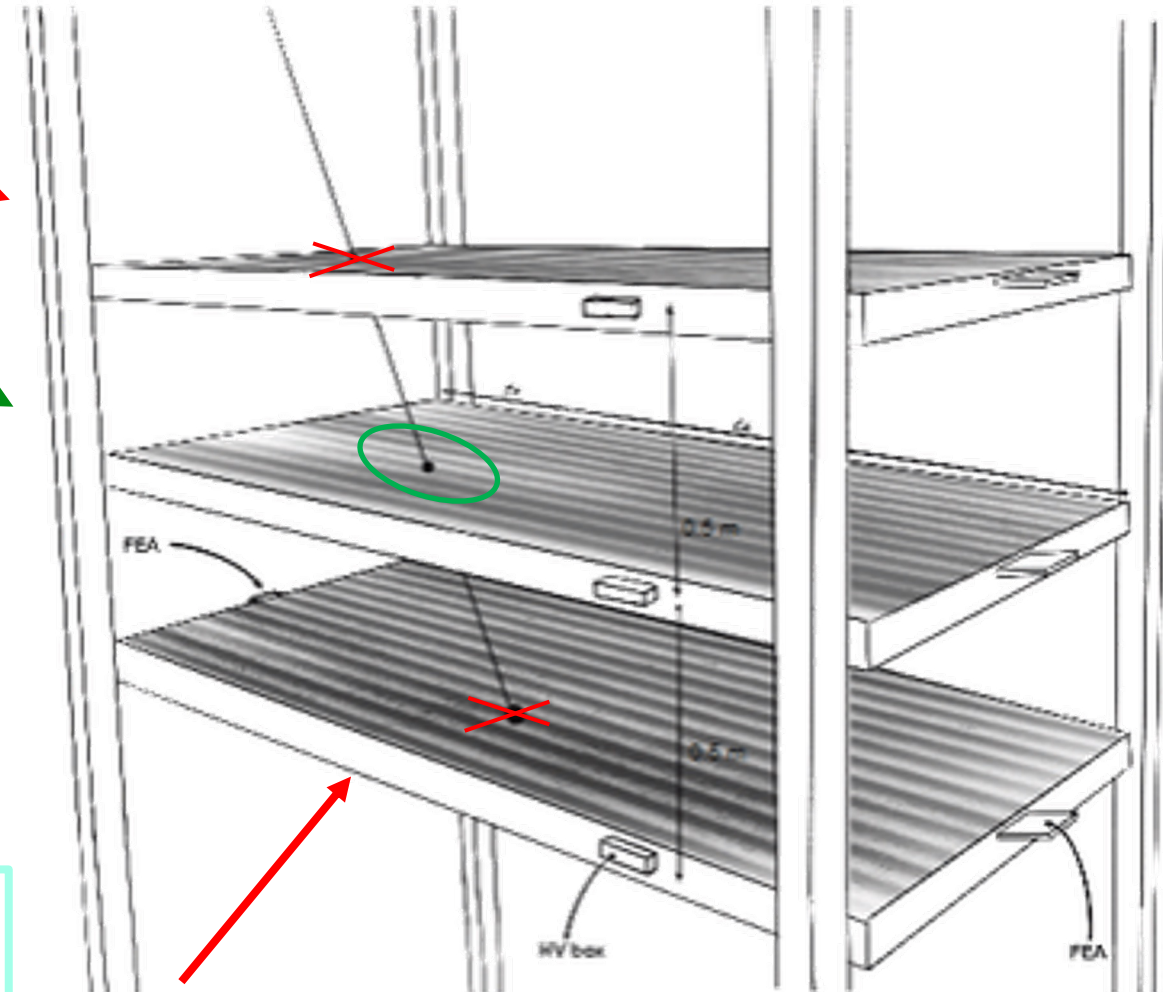
Chamber considered efficient if a cluster is found within 10 cm from the extrapolated intercept point

Chosen mixtures based on performed tests



WORK IN PROGRESS with CO_2

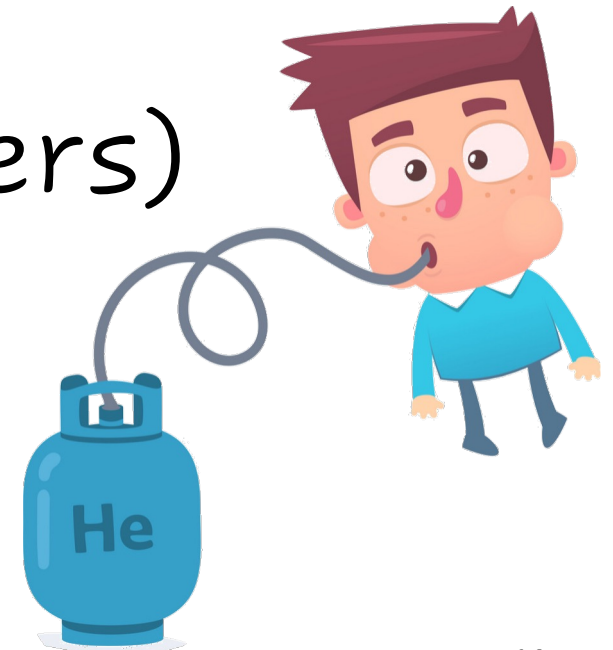
- Many tests done
- Analysis ongoing



Data taking

HFO + He

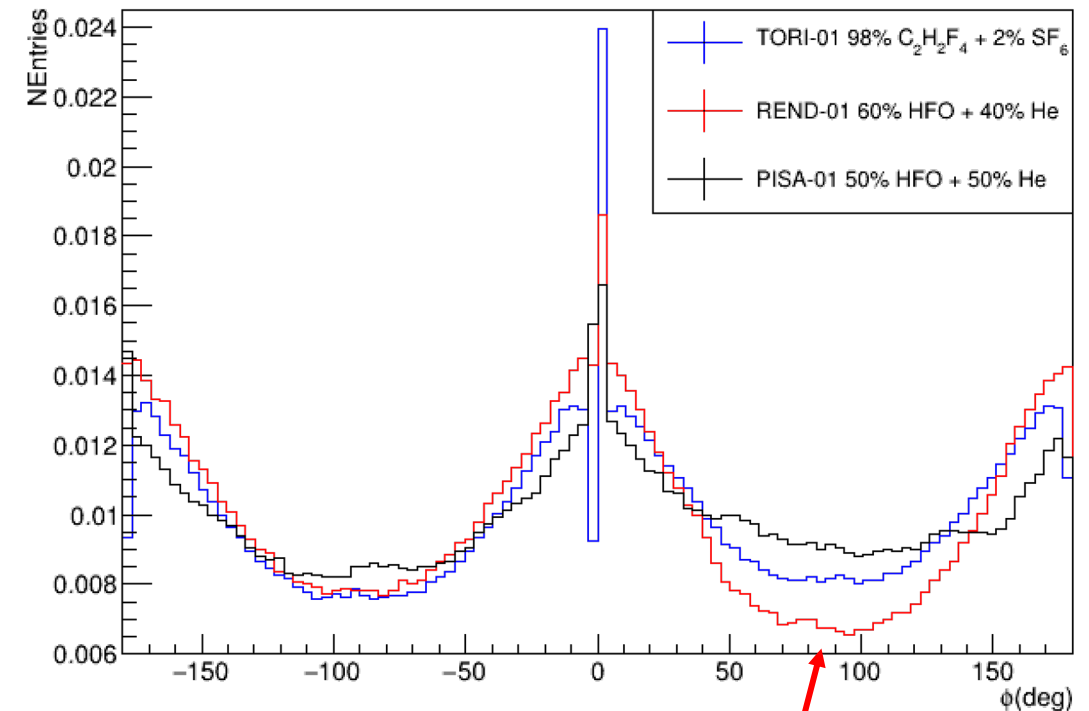
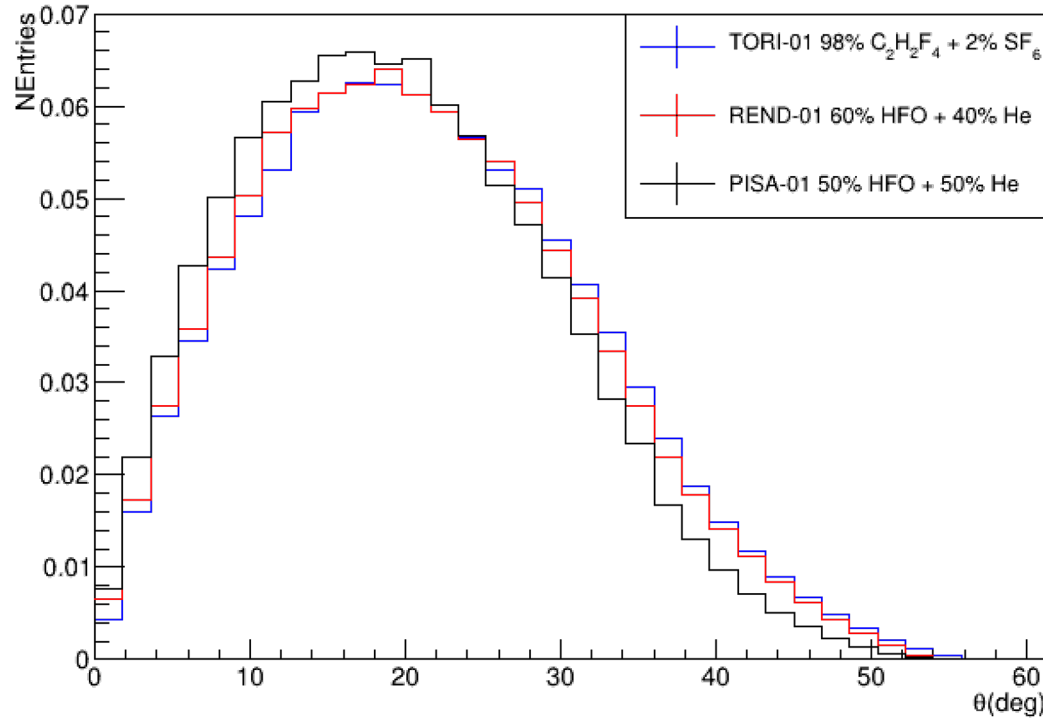
(ECOGAS in all 3 chambers)



Muon tracks triple data taking - HFO + He

Angular distributions

Two telescopes REND-01 and PISA-01 with all 3 chambers filled with HFO + He mixtures in different percentages



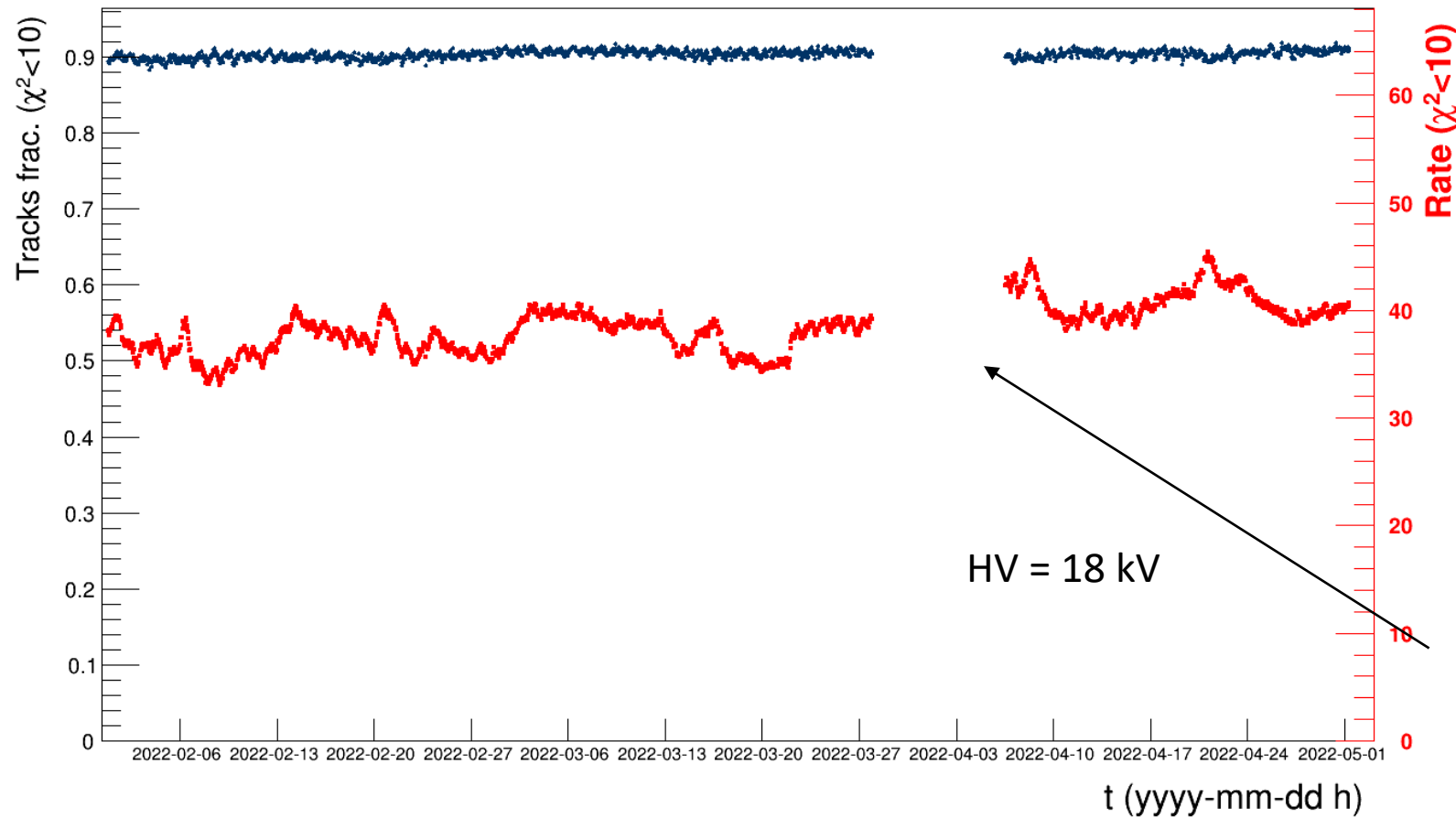
LONG term data taking:

- REND-01 from the beginning of 2022 to now (11 months)
- PISA-01 from March 2022 to June 2022 (4 months) for an electronic problem

The telescope detect the presence of a close six floor building

Track rate stability PISA-01

PISA-01



Test telescopes fluxed
for more than three months

All chambers fluxed with new mixture
50% HFO + 50% He

Interruptions due to efficiency
study and telescope maintenance

HFO + He



Great long term stability and no degrade of performance

RESTARTING for EEE telescopes

Test phase completed - new data acquisition

Telescopes completely filled with: HFO + He

TELESCOPE	MIXTURE
CAGL-01	50% C ₃ H ₂ F ₄ + 50% He
CARI-01	65% C ₃ H ₂ F ₄ + 35% He
PISA-01	50% C ₃ H ₂ F ₄ + 50% He
REND-01	60% C ₃ H ₂ F ₄ + 40% He
SALE-02	50% C ₃ H ₂ F ₄ + 50% He



Telescopes completely filled with: HFO + CO₂

LECC-01	50% C ₃ H ₂ F ₄ + 50% CO ₂
BOLO-05	60% C ₃ H ₂ F ₄ + 40 % CO ₂
CAGL- 02	50% C ₃ H ₂ F ₄ + 50% CO ₂
CERN-01	50% C ₃ H ₂ F ₄ + 50% CO ₂
BOLO-01	50% C ₃ H ₂ F ₄ + 50% CO ₂



RESTARTING for SALE-02 telescope

Telescope: SALE-02 Liceo Regina Margherita - Salerno (Campania)

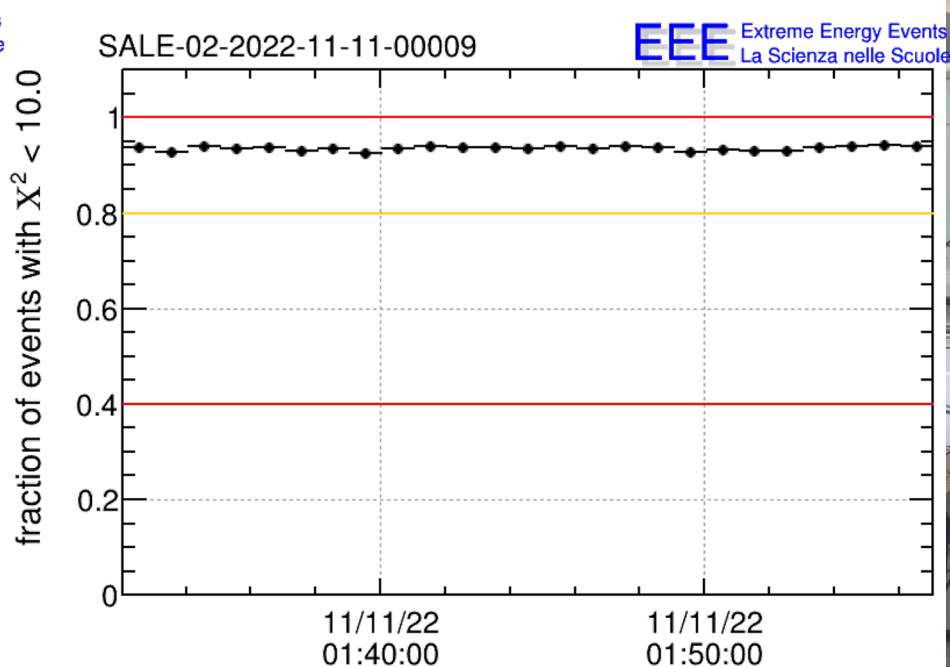
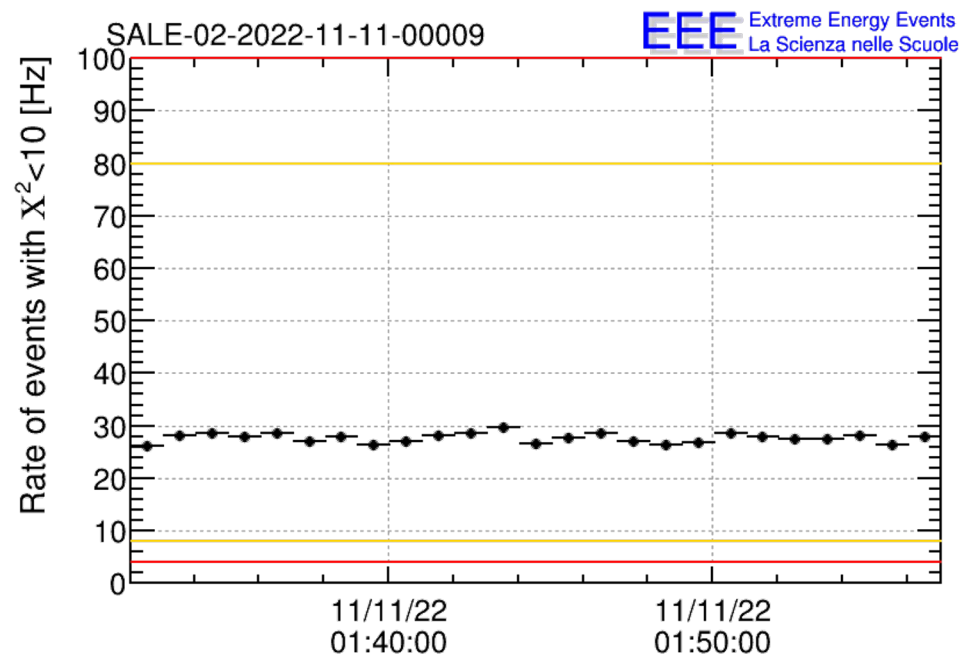
Term data taking: from october 2022 to now

Mixture: 50% $\text{C}_3\text{H}_2\text{F}_4$ + 50% He

HV: 19kV

Flow: 1.2 l/h

**First restarting in
a school!**



RESTARTING for SALE-02 telescope

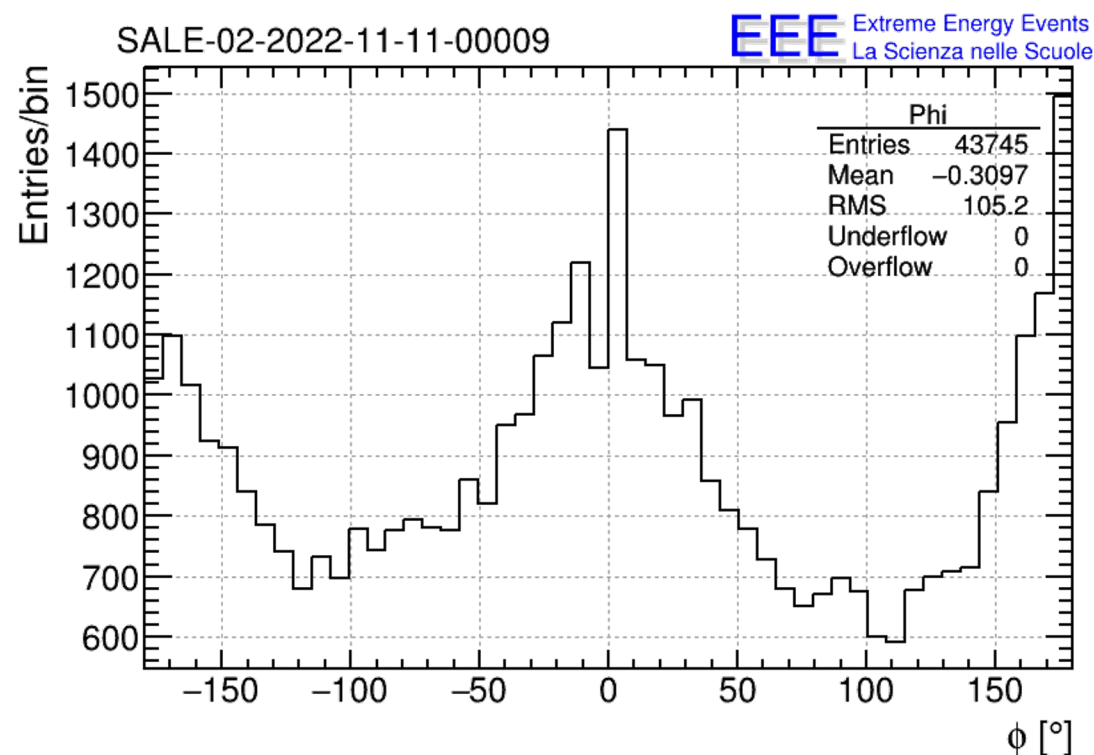
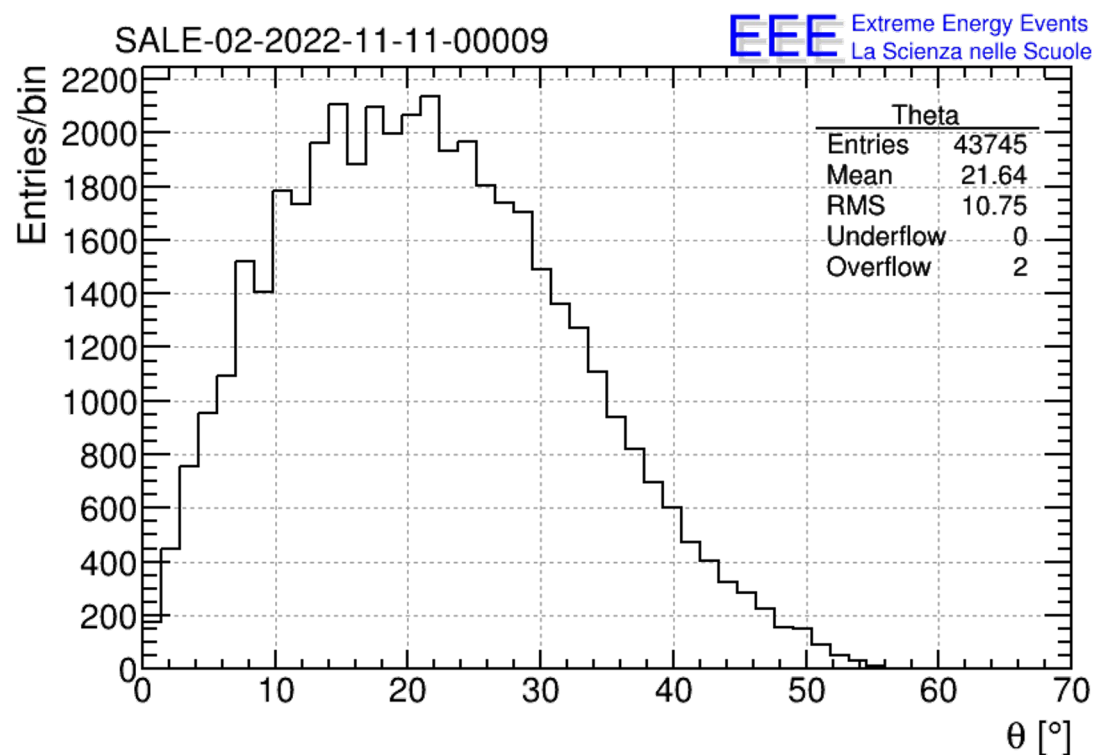
Telescope: SALE-02 Liceo Regina Margherita - Salerno (Campania)

Term data taking: from october 2022 to now

Mixture: 50% $C_3H_2F_4$ + 50% He

HV: 19kV

Flow: 1.2 l/h



ECOGAS
Raw data

RESTARTING for REND-01 telescope

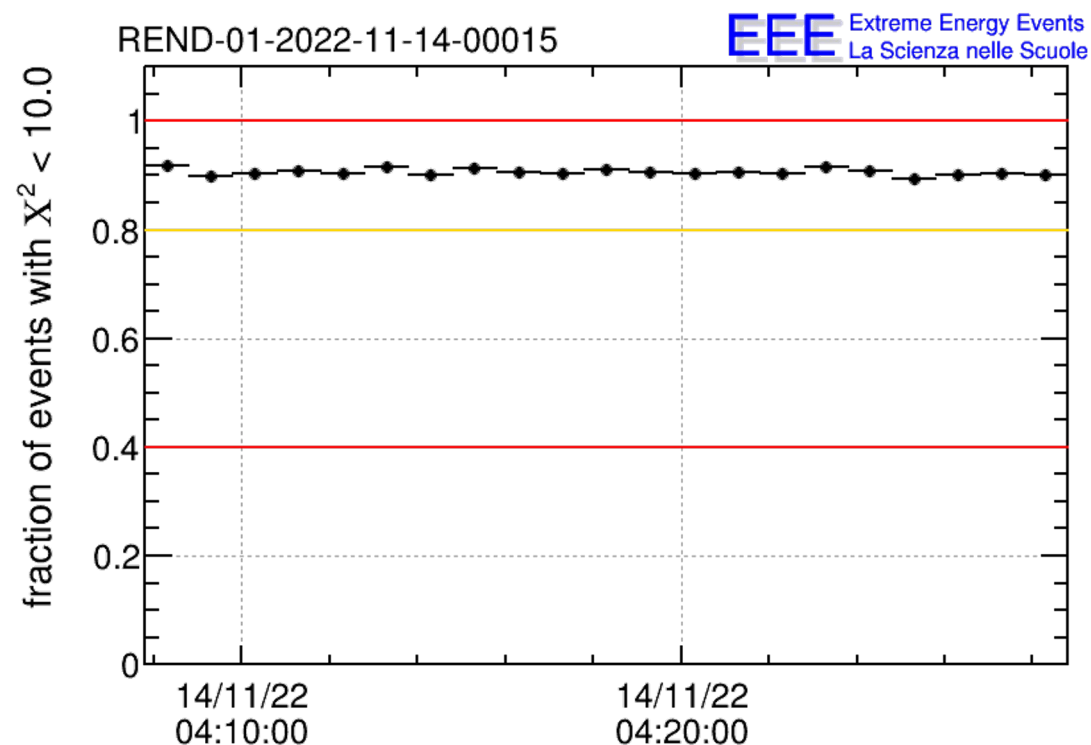
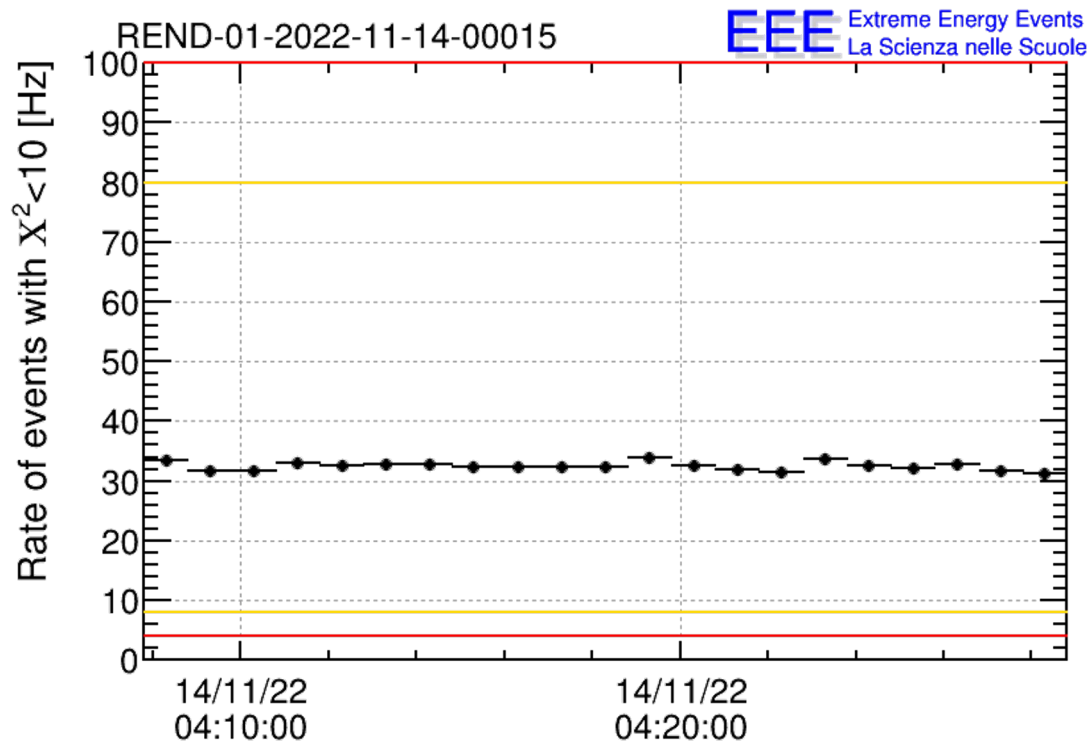
Telescope: REND-01 Rende (Calabria)

Term data taking: from february 2022 to now

Mixture: 60% $C_3H_2F_4$ + 40% He

HV: 19 kV

Flow: 0.9 l/h



RESTARTING for REND-01 telescope

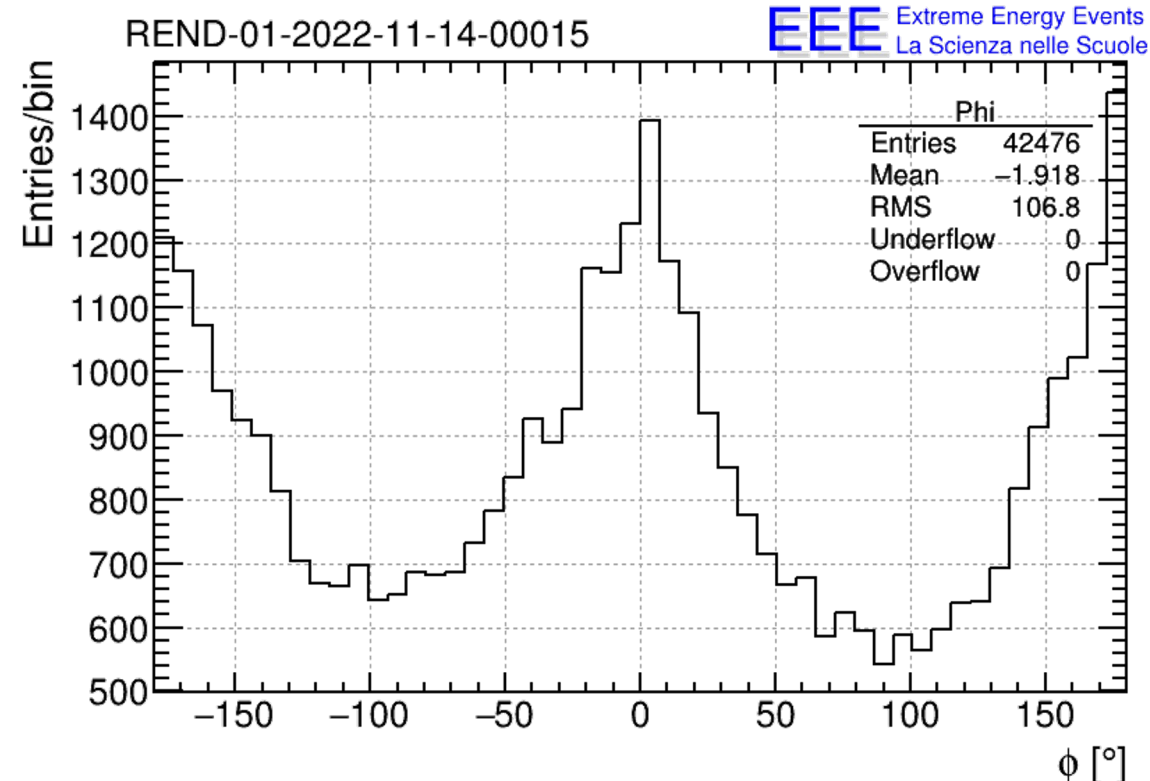
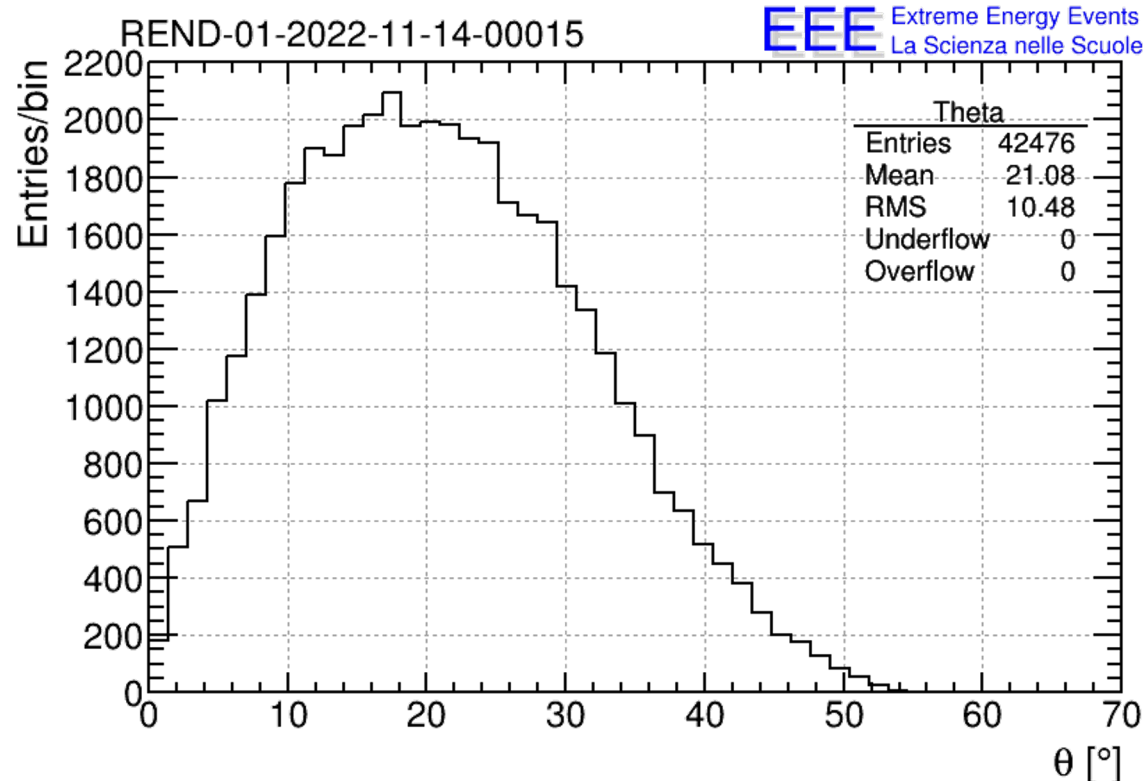
Telescope: REND-01 Rende (Calabria)

Term data taking: from february 2022 to now

Mixture: 60% $C_3H_2F_4$ + 40% He

HV: 19 kV

Flow: 0.9 l/h



RESTARTING for CAGL-01 telescope

Telescope: CAGL-01 Liceo Pacinotti - Cagliari (Sardegna)

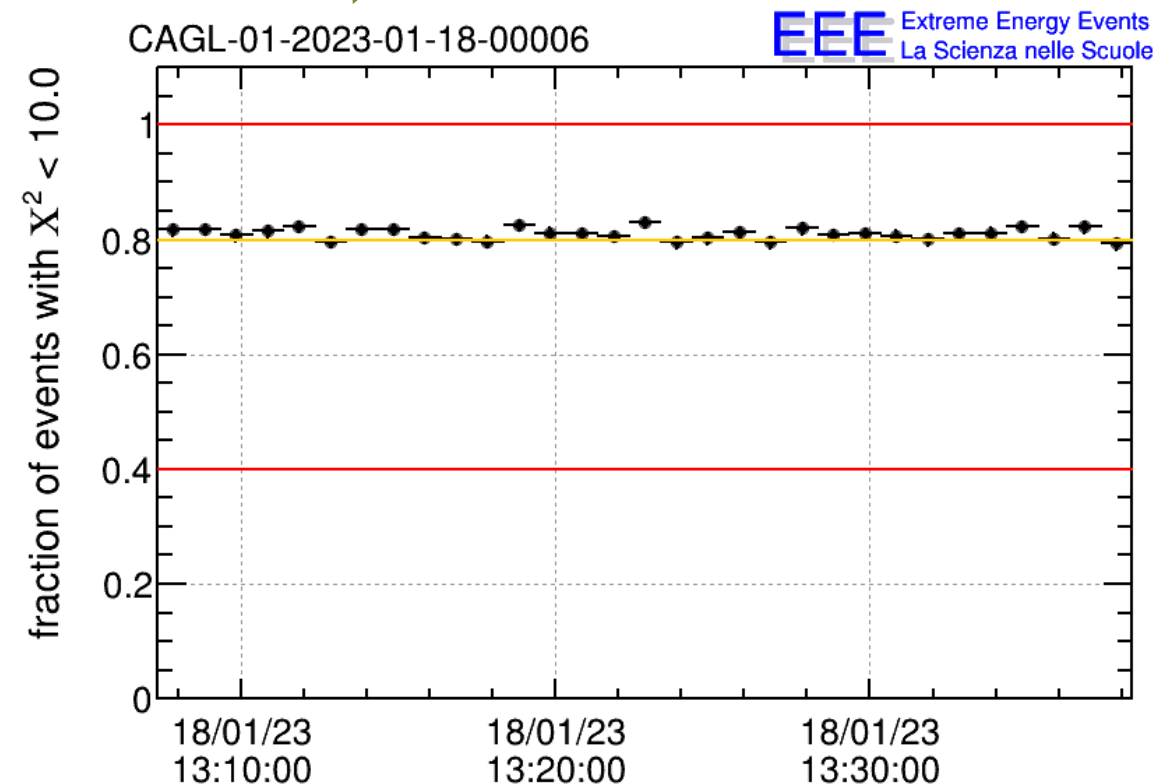
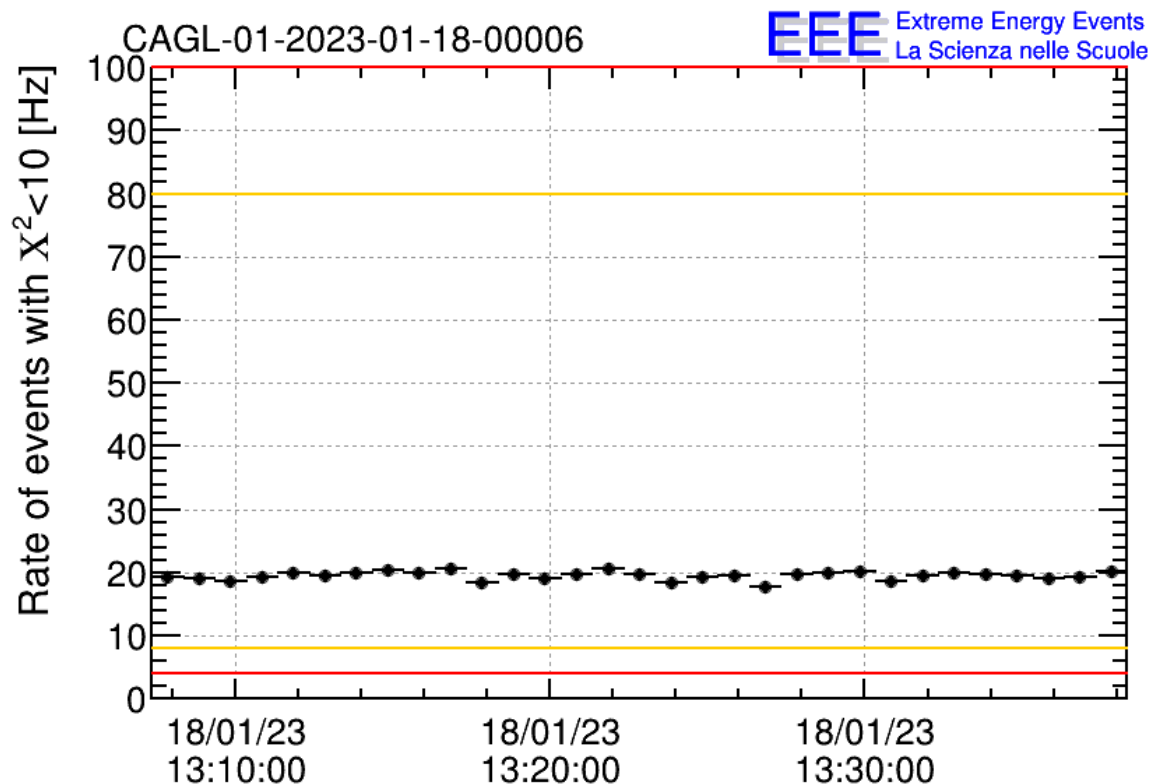
Term data taking: from december 2022 to now

Mixture: 50% $C_3H_2F_4$ + 50% He

HV: 19 kV

Flow: 1.2 l/h

DATI 2023



RESTARTING for CAGL-01 telescope

Telescope: CAGL-01 Liceo Pacinotti - Cagliari (Sardegna)

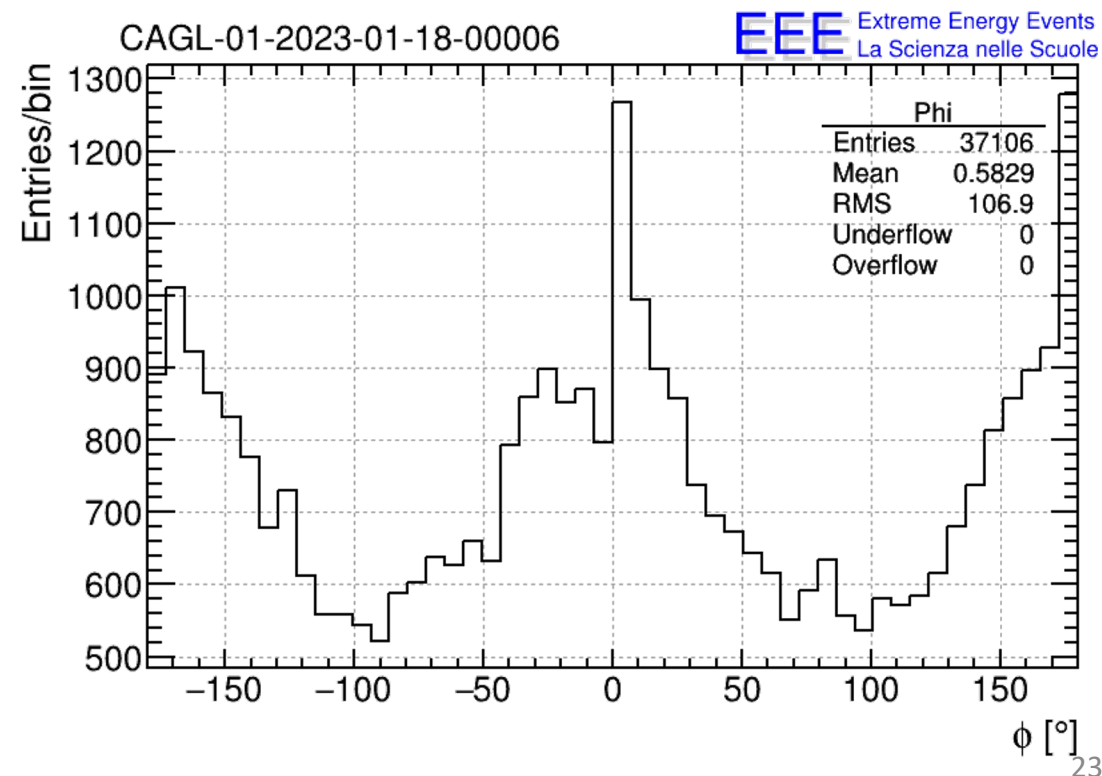
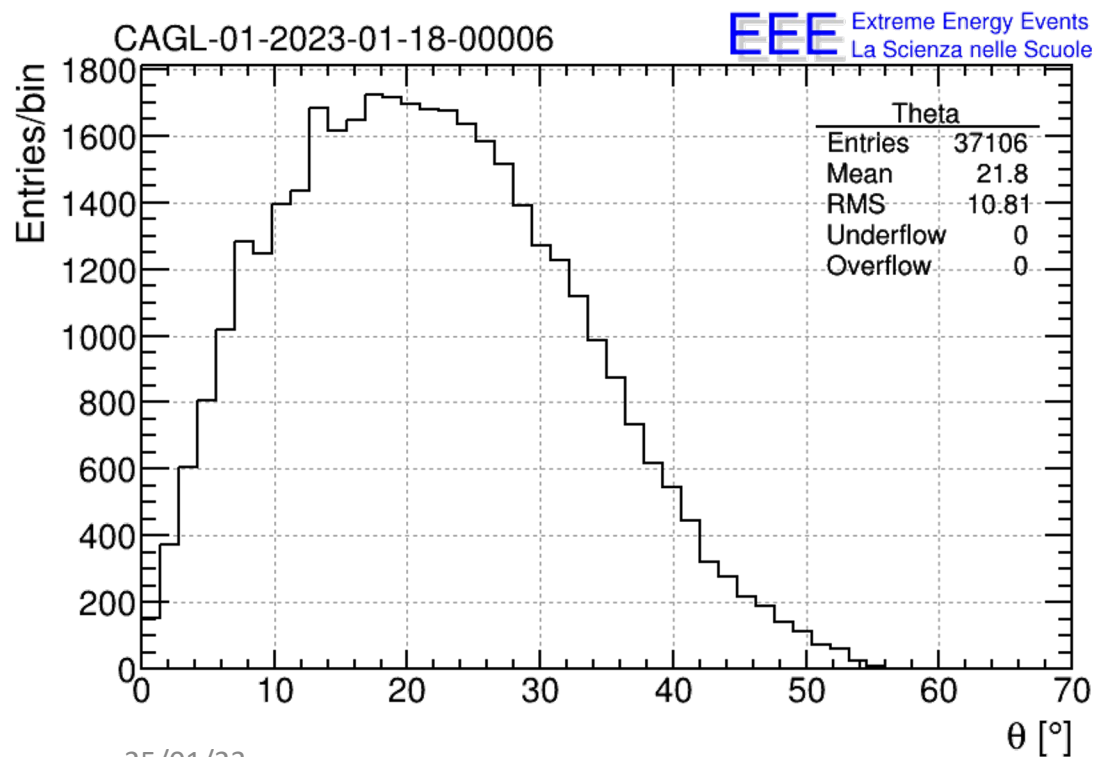
Term data taking: from december 2022 to now

Mixture: 50% $C_3H_2F_4$ + 50% He

HV: 19 kV

Flow: 1.2 l/h

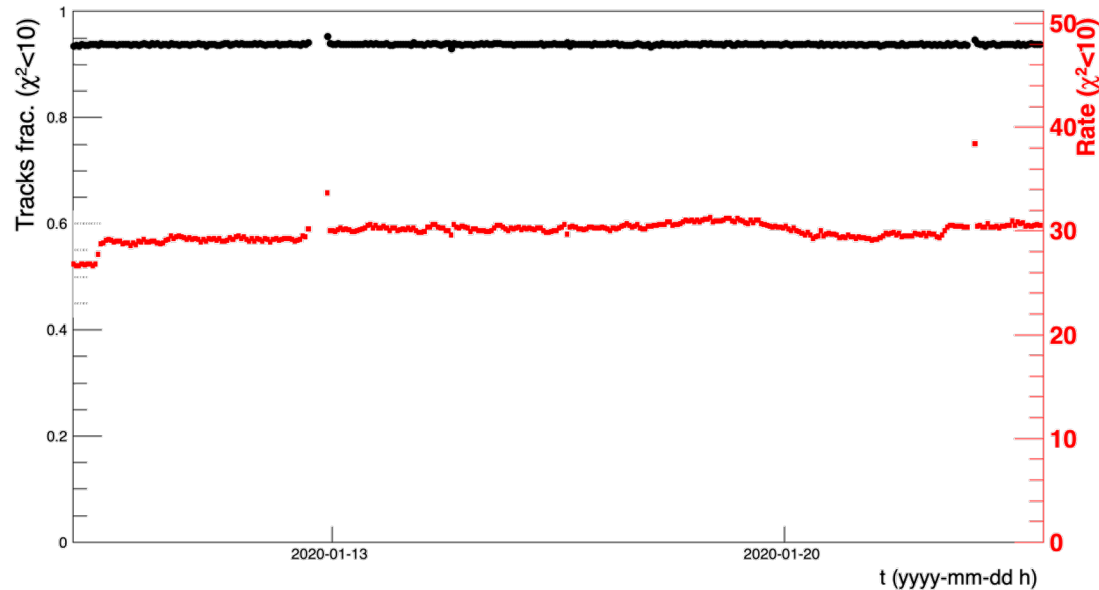
DATI 2023



RESTARTING for SALE-02 telescope

2020 standard mixture

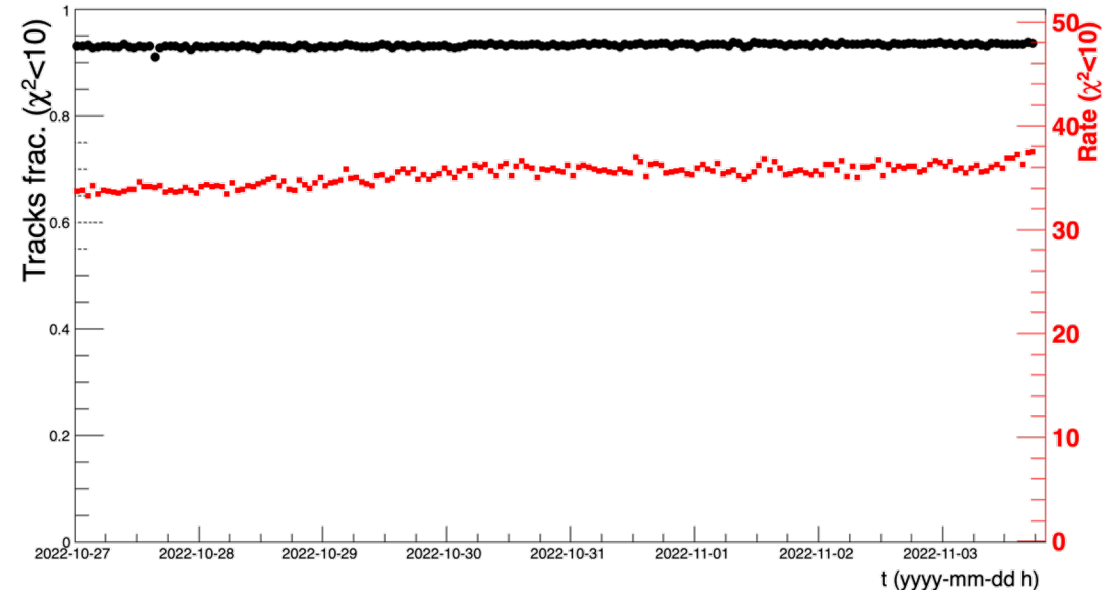
SALE-02



2022

New ecofriendly mixture

SALE-02



Stable rate

WORK IN PROGRESS

Other stations equipped with new eco-friendly ready to restart!

Thank you!