

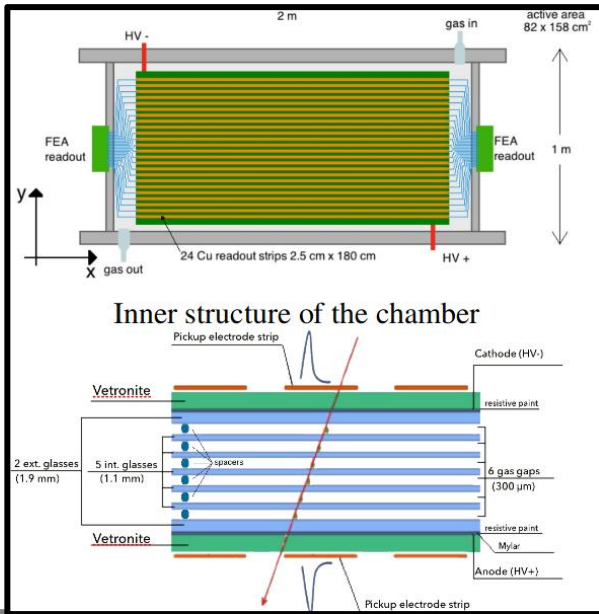


EEE

Upgrade status
Ongoing actions
Studies

Giornate di Studio dei Progetti del Centro Fermi
11-12 Dicembre 2020

MRPC chamber construction and test Summary



13 new telescopes

including telescope at
Centro Fermi

- **39 delivered MRPCs**
+ **13 spare MRPCs**

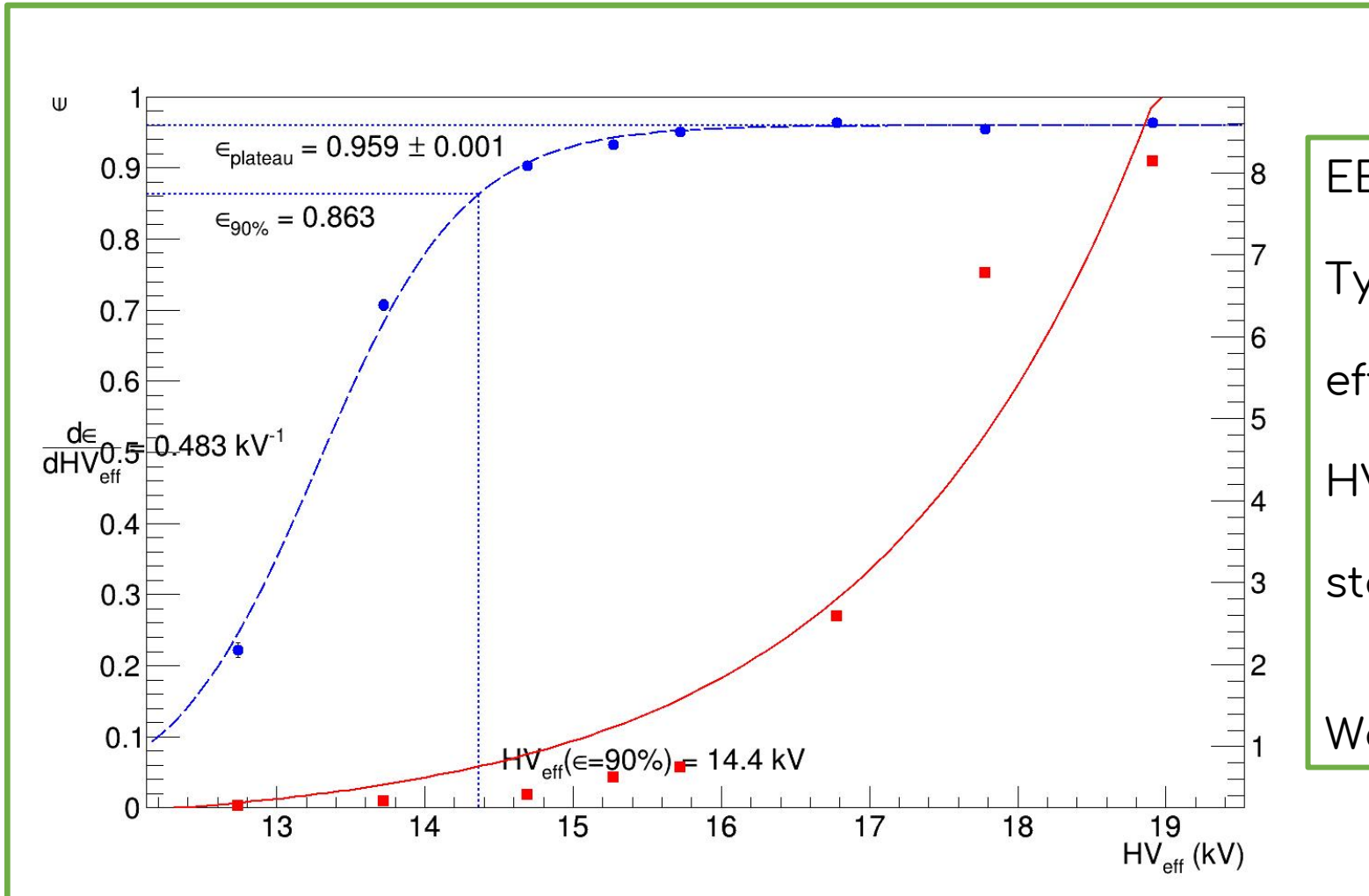
- 7 delivered
- 1 available
- 5 under test

52 chambers
6 gaps/250 µm

20170719019	spare – ROMA-01
20170921020	spare – FRAS-01
20171026024	spare – COSE-01
20180222029	spare – REGG-01
20180227030	spare – SAVO-03
20180228031	spare – TRAP-01
20180320032	spare – CARI-01
20180322033	spare
20190315048	spare (under test)
20190410049	spare (under test)
20190411050	spare (under test)
20190917051	spare (under test)
20191025052	spare (under test)

20170222001	LAMP-01	20171121025	BOLO-05
20170223002	LAMP-01	20171123026	BOLO-05
20170225003	LAMP-01	20171124027	BOLO-05
20170314004	GENO-01	20190115037	BITE-01
20170316005	GENO-01	20190117038	BITE-01
20170317006	GENO-01	20190118039	BITE-01
20170405007	SIEN-02	20190130040	BRA-01
20170406008	SIEN-02	20190214041	BRA-01
20170407009	SIEN-02	20190215042	BRA-01
20170425010	CARI-01	20190226043	CARC-01
20170426011	CARI-01	20190227044	CARC-01
20170427012	CARI-01	20190301045	CARC-01
20170509013	TORI-05	20190312046	REGG-01
20170510014	TORI-05	20190314047	REGG-01
20170511015	TORI-05	20170928023	REGG-01
20170523016	LODI-03	20180725034	CF
20170524017	LODI-03	20180726035	CF
20170524018	LODI-03	20180727036	CF
20170926021	CAGL-04		
20170927022	CAGL-04		
20180221028	CAGL-04		

MRPC chamber construction and test Summary



EEE MRPCs 6 gaps/ 250 μm

Typical parameters:

efficiency > 90%

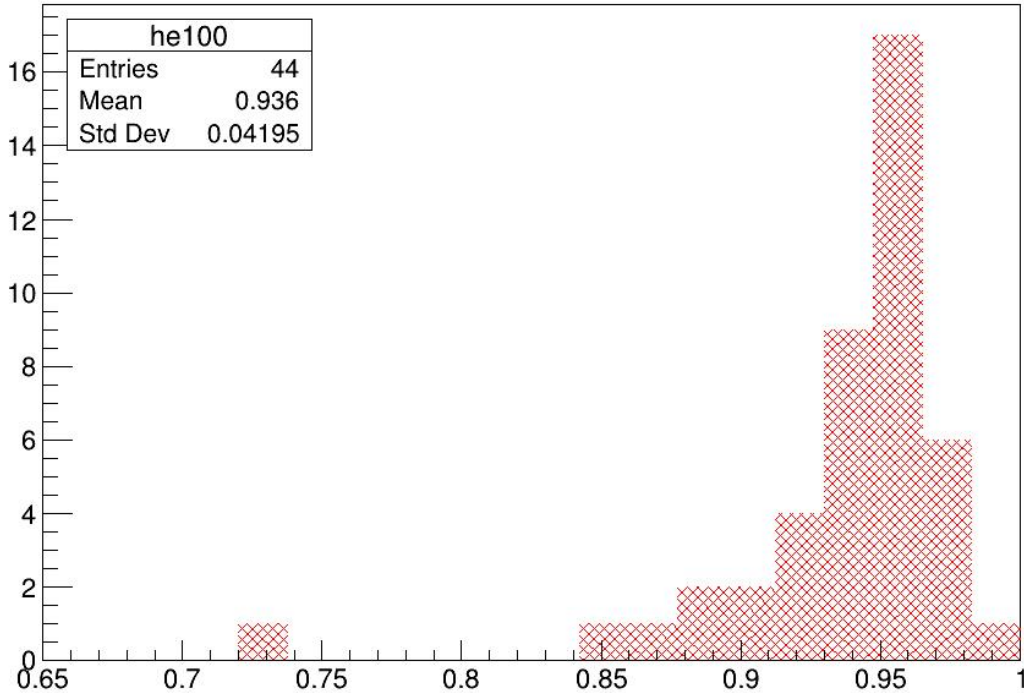
$HV@90\%$ eff ~ 14 kV

stable and wide plateau
>3 kV

Working Dark Current < 1 μA

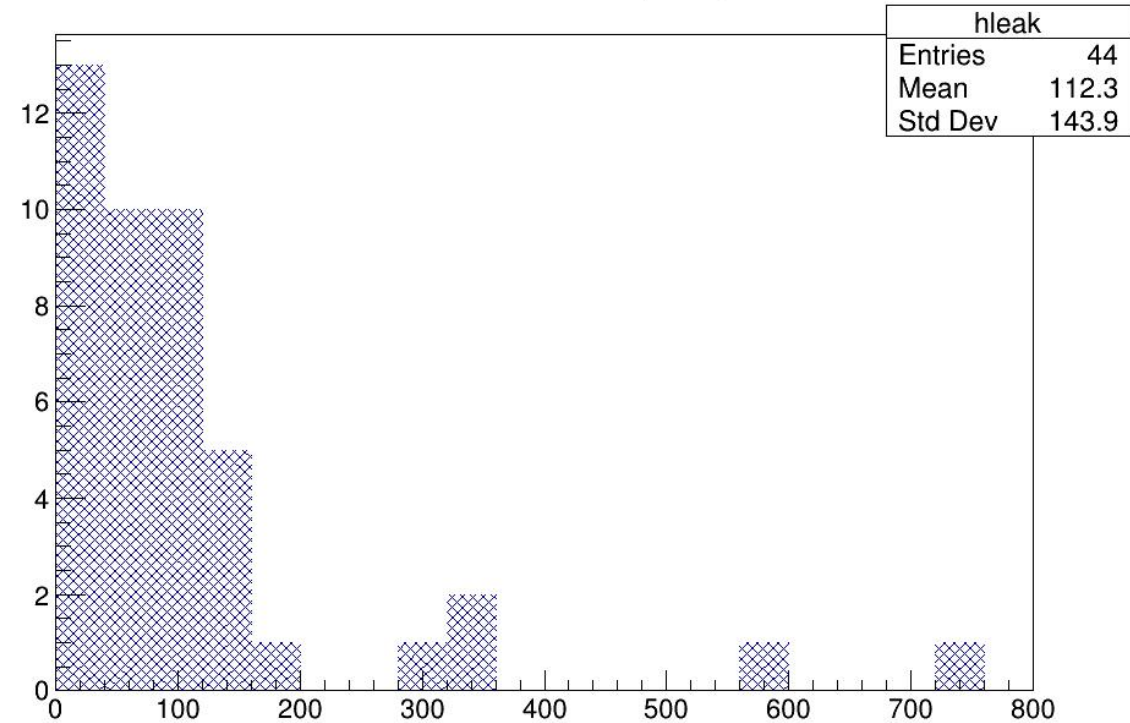
MRPC chamber construction and test Summary

Efficiency distribution



89% shows efficiency > 90%
Once conditioned on the
telescopes performances increase

Leak distribution (ml/h)



89% shows leakage < 0.2 l/h

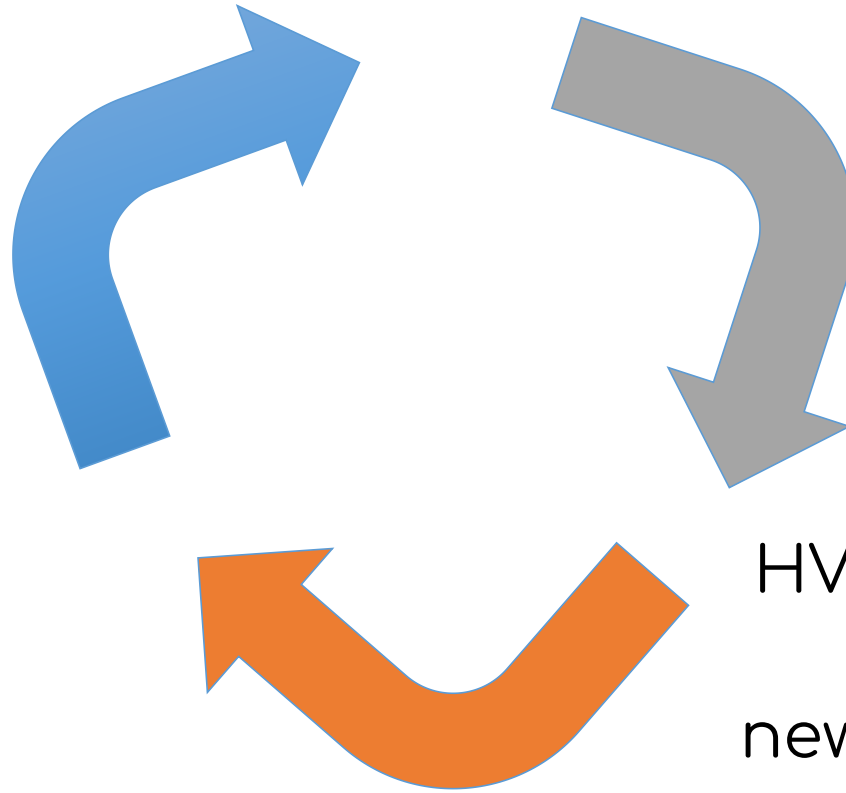
Updates on gas studies

Costs:
Max EEE
expected
consumption 2l/h
per telescope:

1Ml/y
5t/y
40keuro/y

as of today the
prize got a factor
2-5 times

80-200 keuro/y



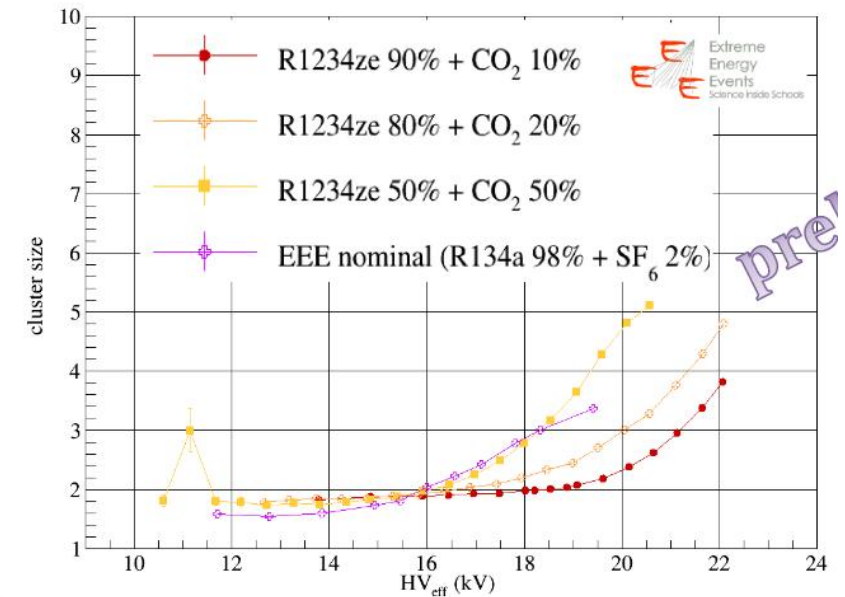
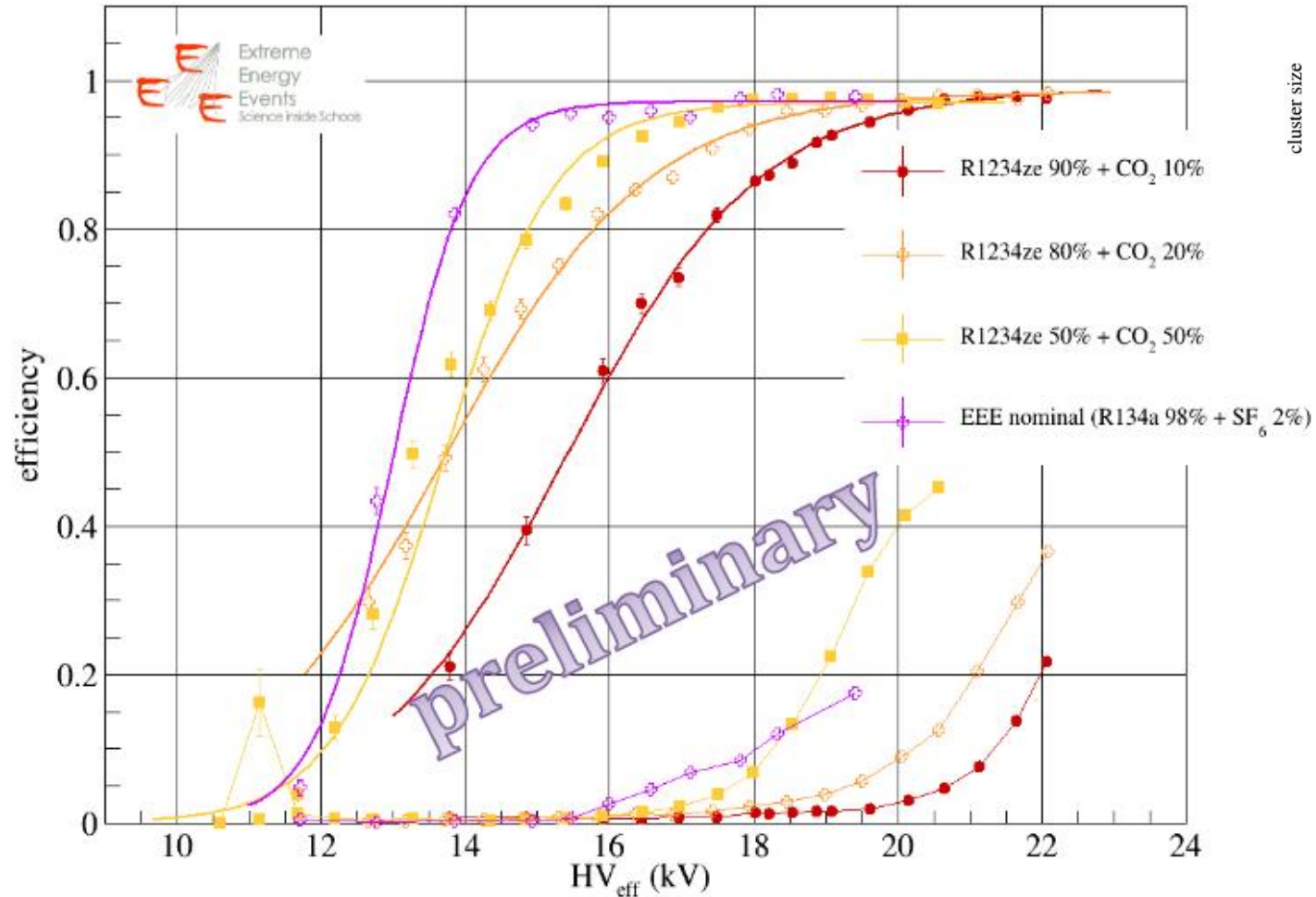
Gas mixtures with
GWP>150
banned by EU

98% C₂H₂F₄ + 2% SF₆
GWP=1889

HV working
point:
new eco gas
C₃H₄F₄ GWP=4
HV>20-21 kV

Updates on gas studies / new mixtures

R1234ze+CO₂



50% CO₂

- similar to EEE nominal
- working point within 20 kV

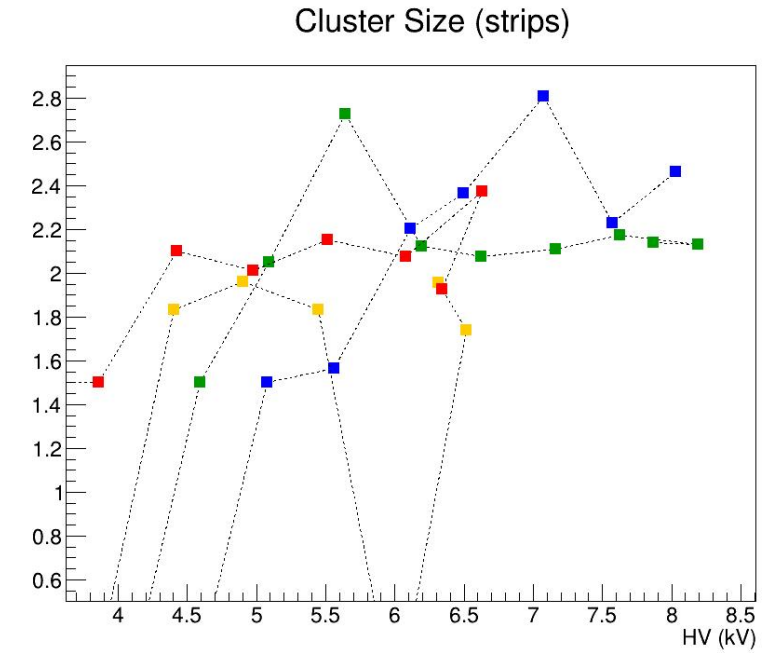
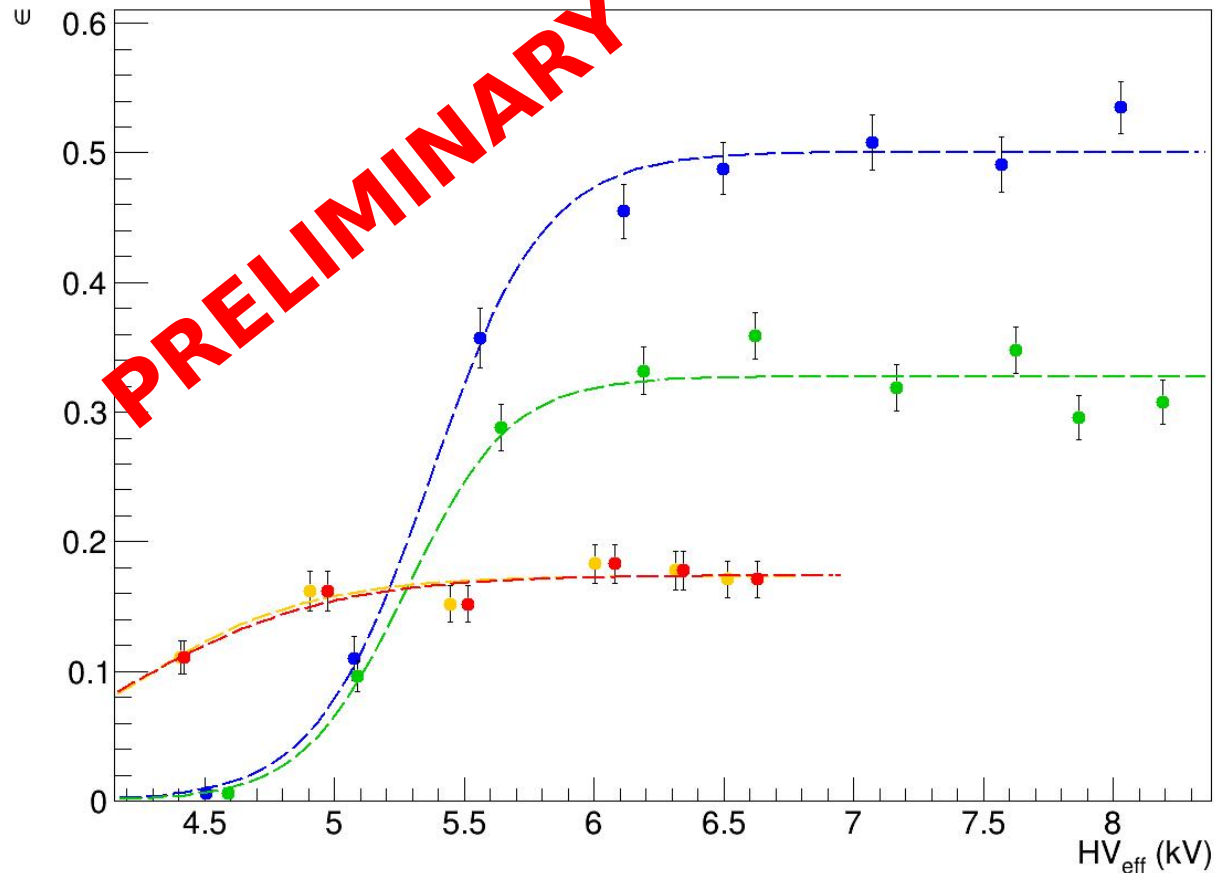
Pure R1234ze

- very good s/n ratio
- high working HV
 - new CAEN HV ± 12 kV / <100mV ripple
- high cost

Updates on gas studies / new mixtures

Ar+CO₂

93/7
95/5
90/10
80/20



- Promising
- Largely used on MPGD
- very high charge
 - (FE elex to be revised?)
- cheap 30 euro / m³

Updates on gas studies / actions on telescopes

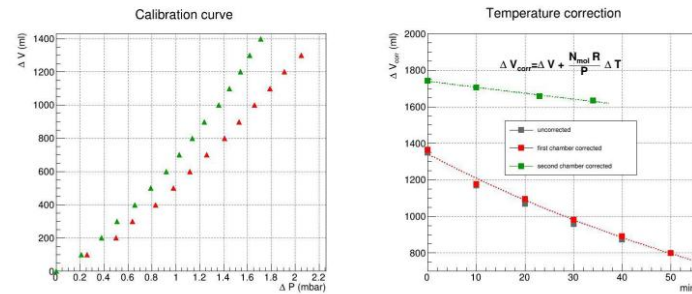
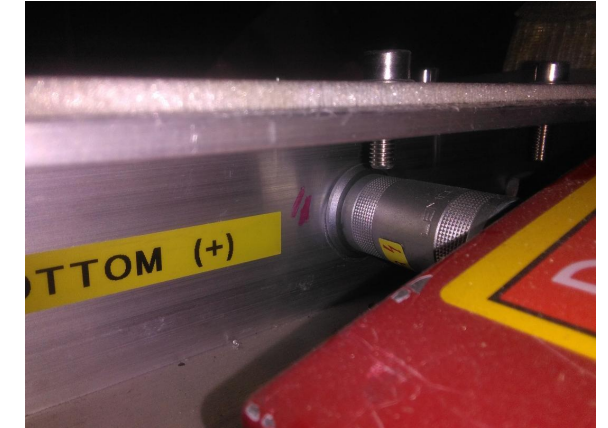
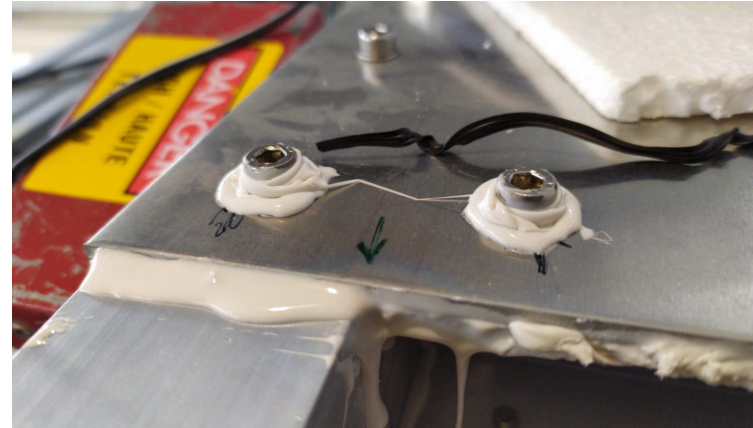


Fig.4: left: calibration curves for two different EEE MRPCs. Right: Air volume drop due to chambers leak. Temperature correction is applied as given in the plot.

Gas Tightnes Calibration Curve			Gas Tightnes Test						
P(mbar)	V(ml)	T(°C)	P(mbar)	V(ml)	Vcorr	T(°C)	RH(%)	Time (min)	
0	0	28.7	2.17	399.67	399.67	28.7	25	0	
1.28	100		1.18	68.41	68.41	28.7	25	10	
1.69	200		1.16	64.30	55.99	28.8	25	10	
1.94	300		1.14	60.30	51.99	28.8	25	10	
2.17	400		1.13	58.34	41.71	28.9	26	10	
2.4	500		1.12	56.40	31.46	29	26	10	
2.54	600		1.11	54.49	29.54	29	26	10	

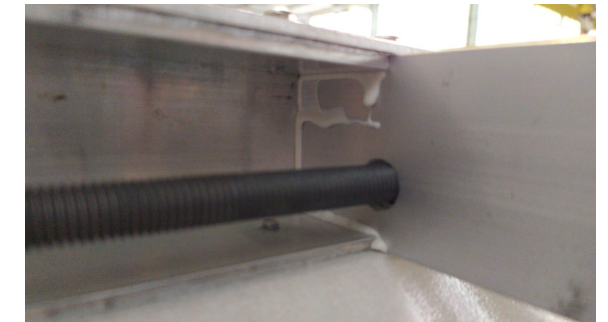
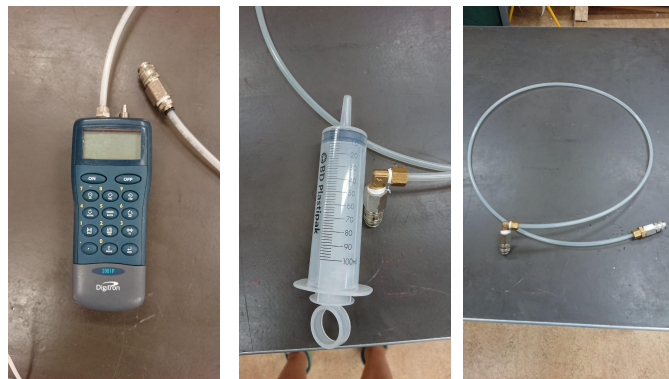
Fig.5: a typical data set. First two columns: calibration curve. P(mbar): pressure measured at the different time with the chamber isolated. V(ml) remaining air volume given by the second order polynomials for the actually measured pressure value. Vcorr: temperature corrected volume (according to formula in Fig. 4 right plot). T: temperature during the measurement. RH(%): relative humidity (not essential). Time: time span between two subsequent



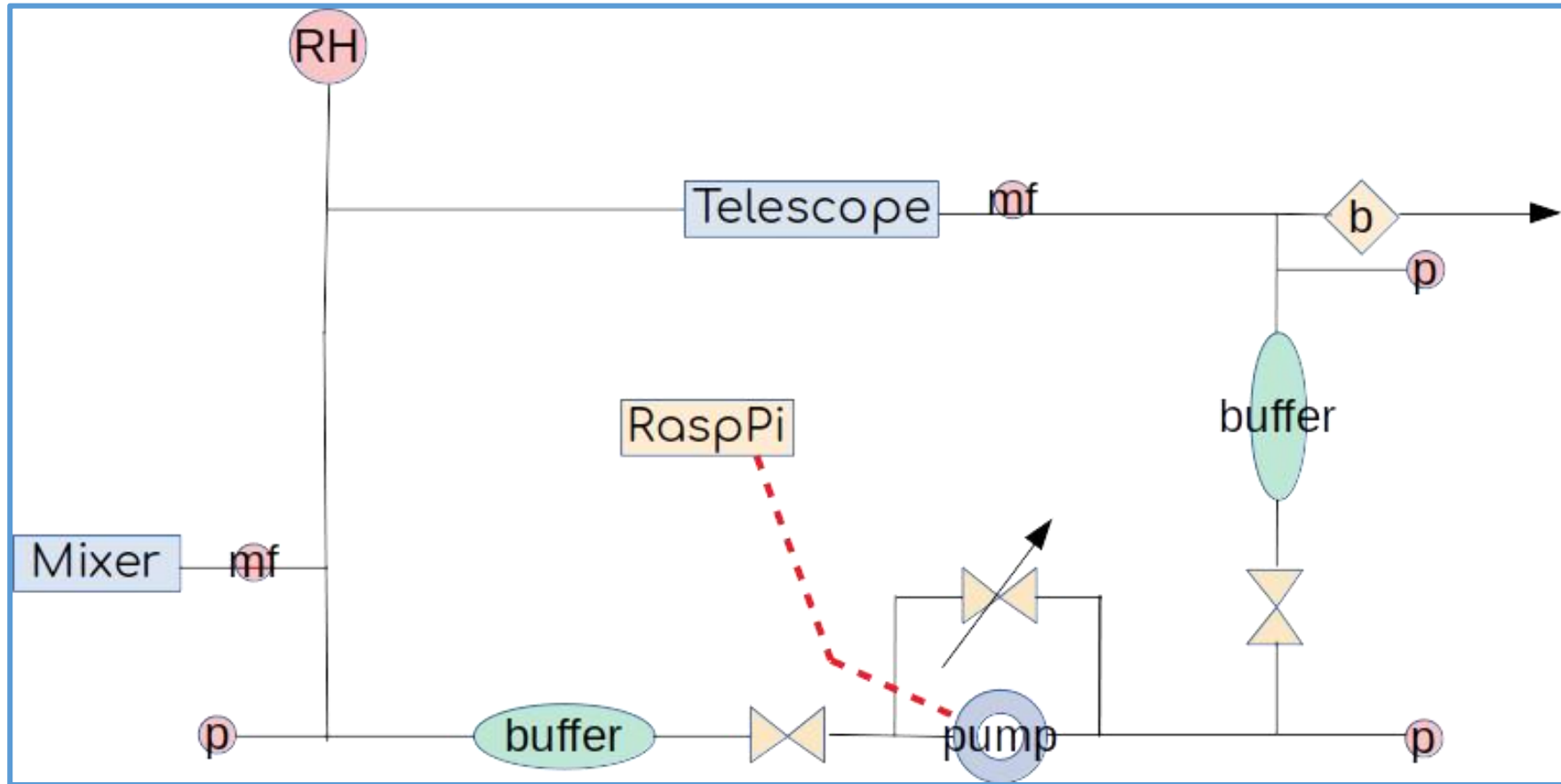
Gas tightness of telescopes is being measured by teachers and researchers

Leakages have been cured in order to reach a maximum leakage of 0.1 l/h

TARGET: cured telescopes can operate at an overall flow ~ 1 l/h

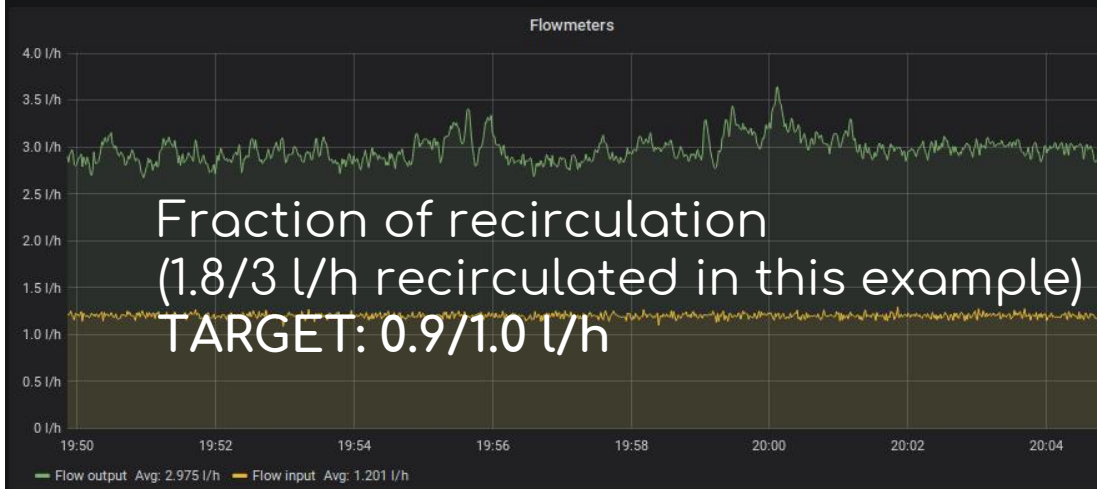
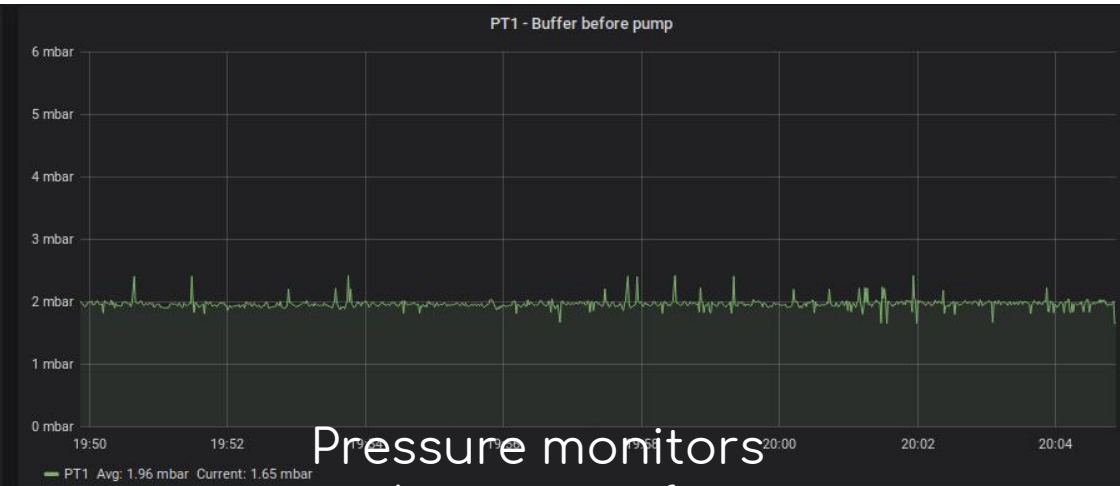
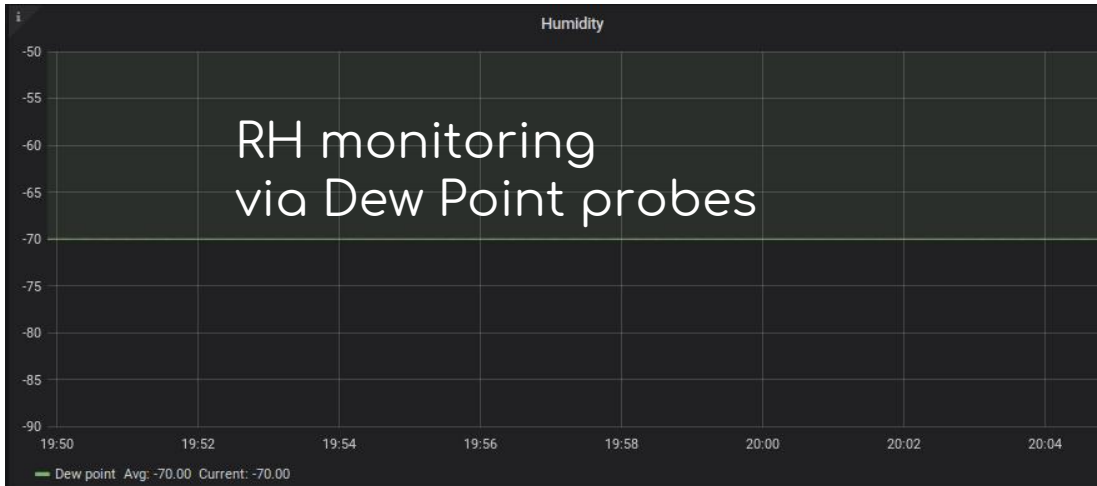


Updates on gas studies / recirculation



- A recirculation system is under study on CERN-02 telescope at CERN
- complexity (should be monitored by students)
 - cost (at the moment the prototype is ~ 2 keuro --> target is < 1 keuro)
 - reliability (contamination of mixture /RH)

Updates on gas studies / recirculation



GPS characterization and timing CF-INRIM collaboration

INRIM – Centro Fermi Agreement



Letto, approvato e sottoscritto.

per:
Istituto Nazionale di Ricerca Metrologia
INRiM

Il Presidente
Prof. Diederik Sybolt Wiersma

Firmato da:
WIERSMA DIEDERIK SYBOLT
Motivo:

Data: 16/10/2019 16:41:08

per:
Museo Storico della Fisica e Centro di Ricerche e
Studi "Enrico Fermi" – Centro Fermi

Il Presidente
Prof. Luisa Cifarelli

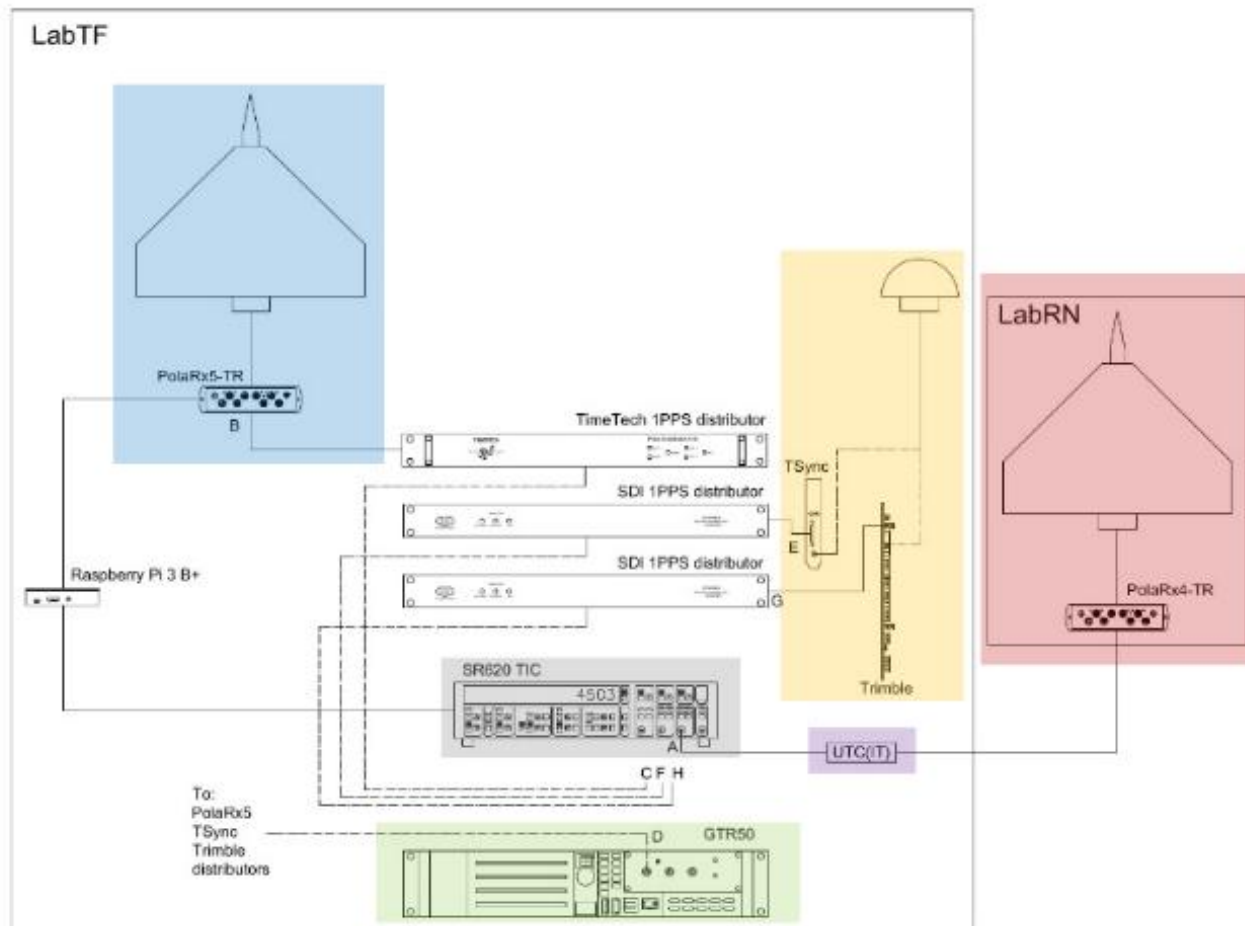
Firmato digitalmente da
CIFARELLI
LUISA
C=IT

INRIM Team

- **Davide Calonico** - II level researcher - Head of the INRIM "Quantum metrology and nano technologies - QN" Division
- **Elena Cantoni** - III level researcher
- **Giancarlo Cerretto** - III level researcher - INRIM scientific coordinator for the INRIM - Centro Fermi agreement
- **Filippo Levi** - I level researcher - responsible of Time and frequency Scientific Sector under QN Division
- **Alberto Mura** - CTER
- **Marco Sellone** - III level researcher

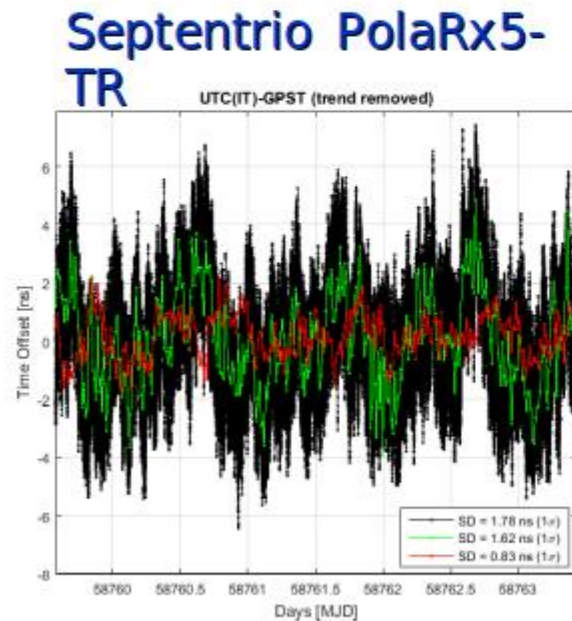
GPS characterization and timing CF-INRIM collaboration

- **Metrological characterization** of a representative set of EEE telescopes currently deployed **GPS receivers** (Spectracom **Tsync** and Trimble **SMT360**), in terms of **stability** and **accuracy** and their **calibration** with respect to a **calibrated geodetic dual frequency receiver for timing applications**

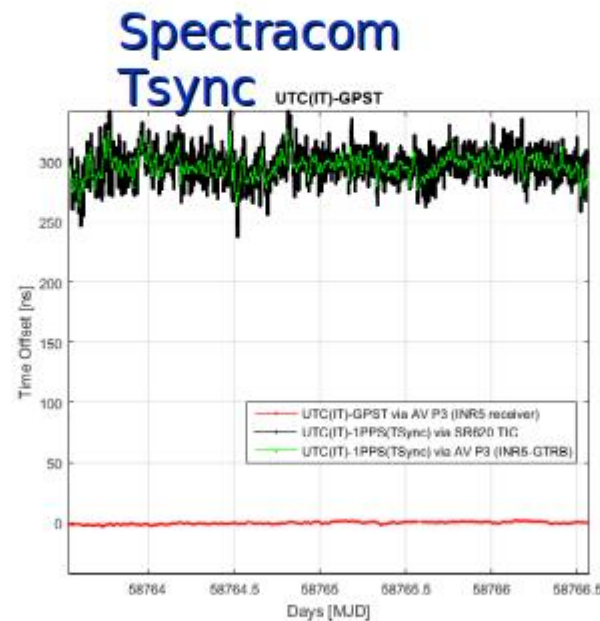


GPS characterization and timing CF-INRIM collaboration

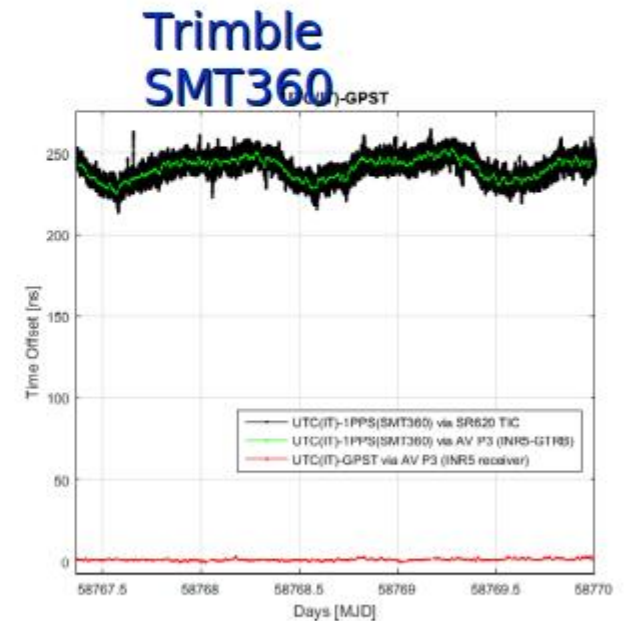
- Use of UTC(IT) atomic Italian Standard Time as timing reference for the proposed metrological characterization



Stable and accurate



Less stable and not accurate



Less stable and not accurate

GPS characterization and timing CF-INRIM collaboration

- Identification of a potential transportable calibration device and of a candidate receiver for improving EEE telescopes GPS timing system
- Feasibility study of a Possible “on-site” calibration of (all?) EEE currently deployed GPS receivers and future ones

Option
1



Septentrio
PolaRx5-
TR
(Candidate
receiver)

+



RaspberryPi

+



Time
Counter

Interval
Counter

Option
2

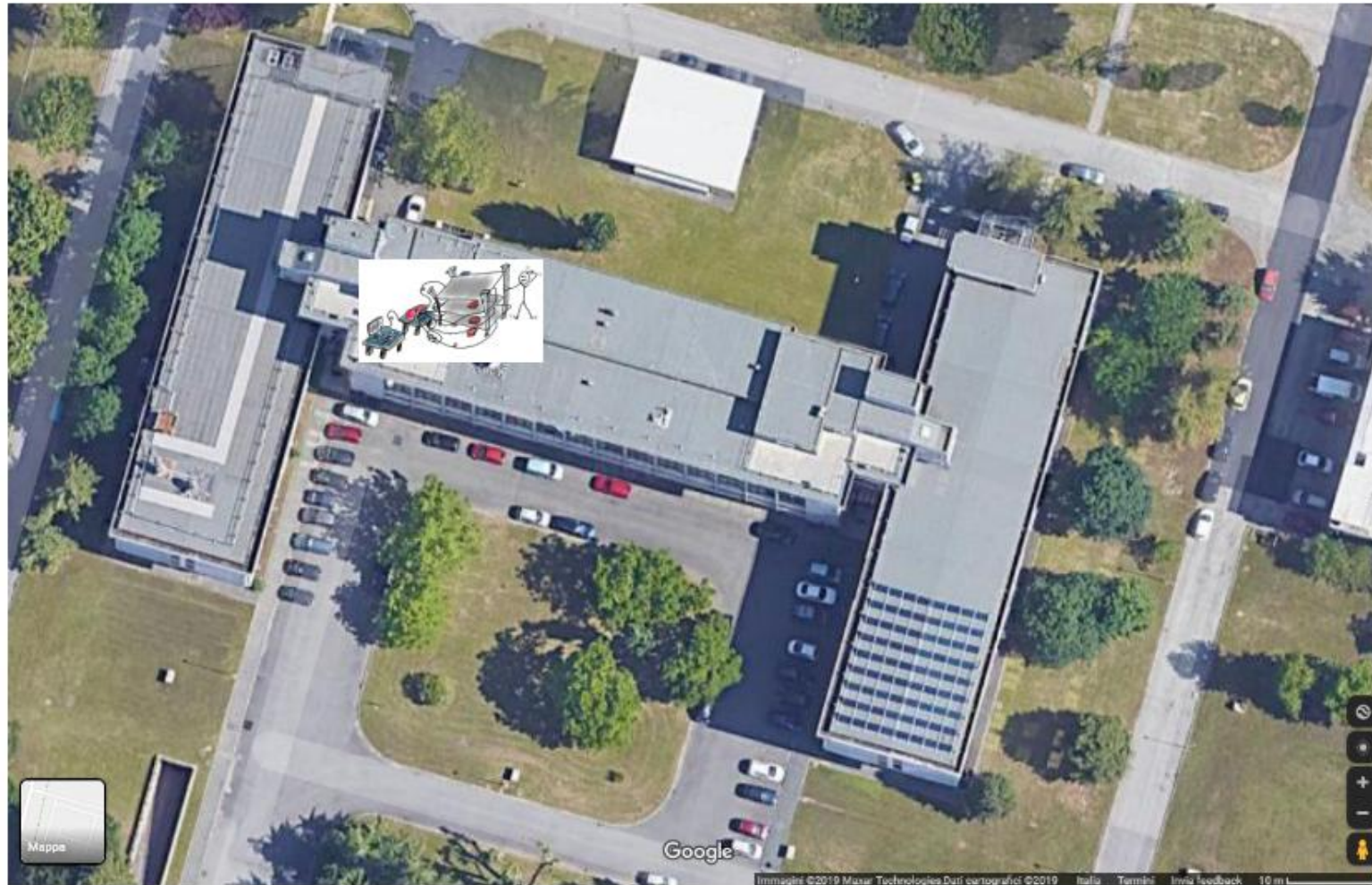


MESIT
Receiver

GTR50

GPS characterization and timing CF-INRIM collaboration

- **Installation of at least one EEE telescope at INRIM, synchronizing it directly with UTC(IT) via coaxial cables and/or optical fibers**



GPS characterization and timing CF-INRIM collaboration

- Feasibility study of a possible **UTC(IT) synchronization of already deployed EEE telescopes**, via **White Rabbit technique**, over **Optical Fiber**, using the **Italian Quantum Backbone**

ITALIAN QUANTUM BACKBONE, 1800 km



- Quantum Technologies
- T/F dissemination
- Radioastronomy
- High accuracy spectroscopy
- Space – Galileo
- Finance

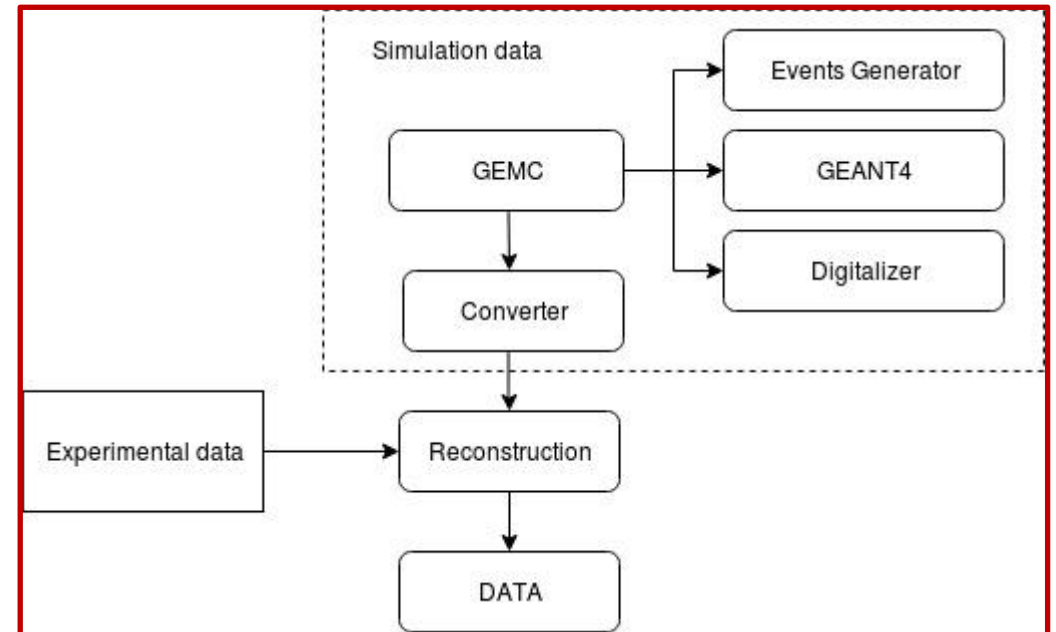
7 Research Institutes linked among:
CNR – National Research Council
ASI – Italian Space Agency
INAF – Italian Astrophysics Institute

5 Industrial Users
Consortium Top-IX
Leonardo; Telespazio;
Telsy; Thales Alenia Space Italy

EEE telescopes MC: a complex surrounding environment

Simulation framework description:

- Cosmic muon flux model
- MRPC detector response
- Telescope geometry
- Location description GEANT4/GEMC
- Simulated data reconstruction

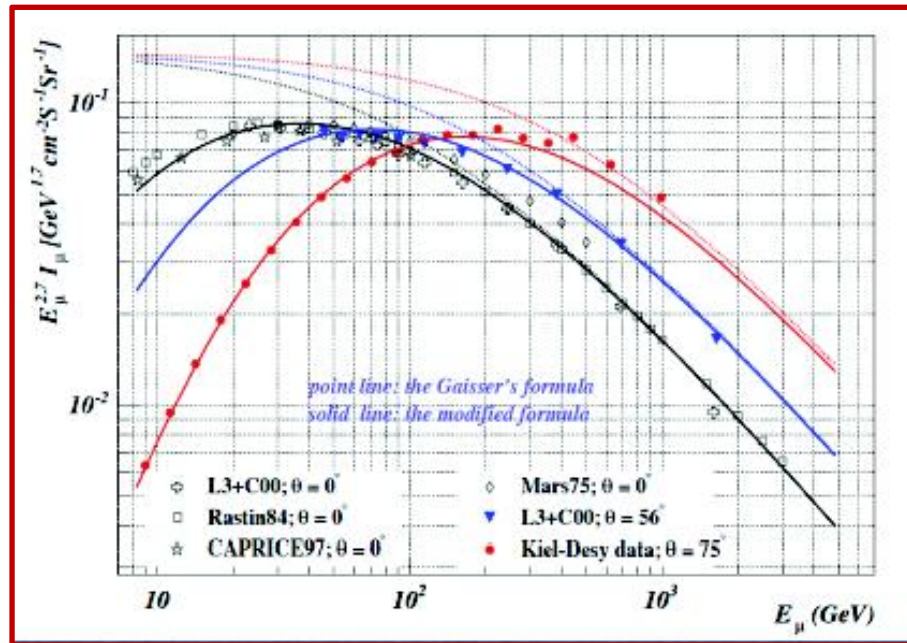


Results:

- Paper on simulation tool in progress
- Validation Simulation with data
- Estimation of angular and spatial resolution

EEE telescopes MC: a complex surrounding environment

- Single-muon generation
- Improved Gaisser parametrization for Flux(E_μ, Θ) to include Earth curvature
- low energy muons (<100GeV)



$$\frac{dI_\mu}{dE_\mu} = 0.14 \left[\frac{E_\mu}{\text{GeV}} \left(1 + \frac{3.64 \text{ GeV}}{E_\mu (\cos \theta^*)^{1.29}} \right) \right]^{-2.7} \left[\frac{1}{1 + \frac{1.1 E_\mu \cos \theta^*}{115 \text{ GeV}}} + \frac{0.054}{1 + \frac{1.1 E_\mu \cos \theta^*}{850 \text{ GeV}}} \right]$$

$$\cos \theta^* = \sqrt{\frac{(\cos \theta)^2 + P_1^2 + P_2 (\cos \theta)^{P_3} + P_4 (\cos \theta)^{P_5}}{1 + P_1^2 + P_2 + P_4}}$$

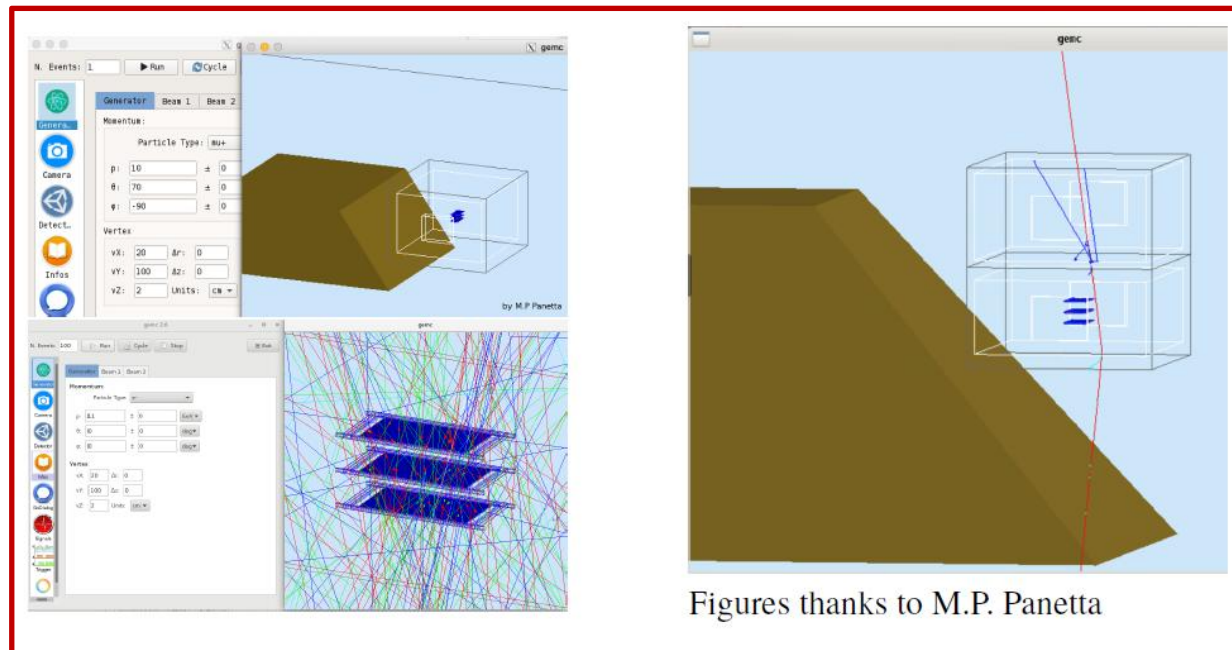
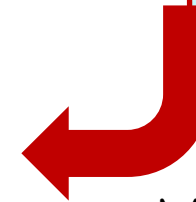
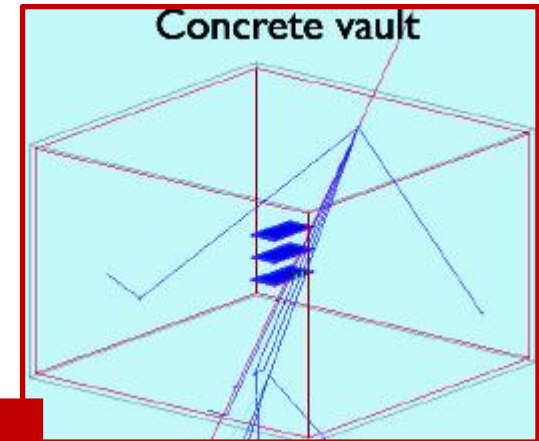
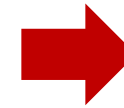
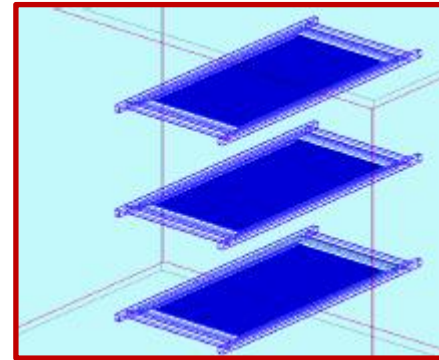
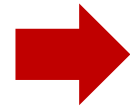
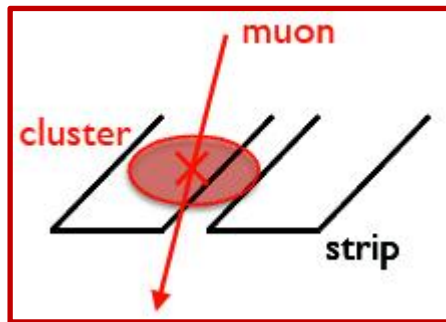
P_1	P_2	P_3	P_4	P_5
0.102573	-0.068287	0.958633	0.0407253	0.817285

arXiv:1509.06176

Generation split in 3 E_μ intervals:

1. [0.2 GeV - 2 GeV]
2. [2 GeV - 10 GeV]
3. [10 GeV - 100 GeV]

EEE telescopes MC: a complex surrounding environment



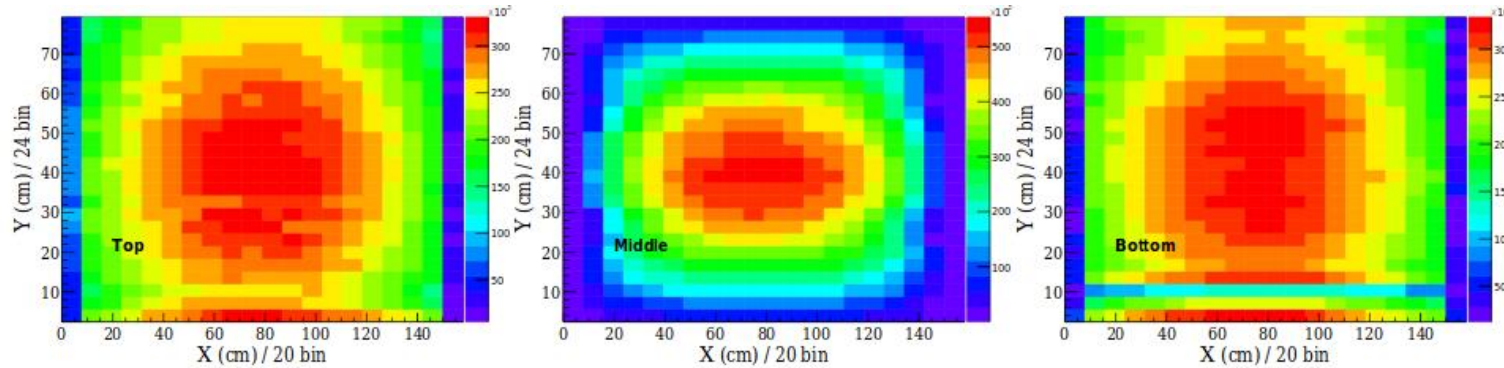
Figures thanks to M.P. Panetta

MRPC geometry, material ...

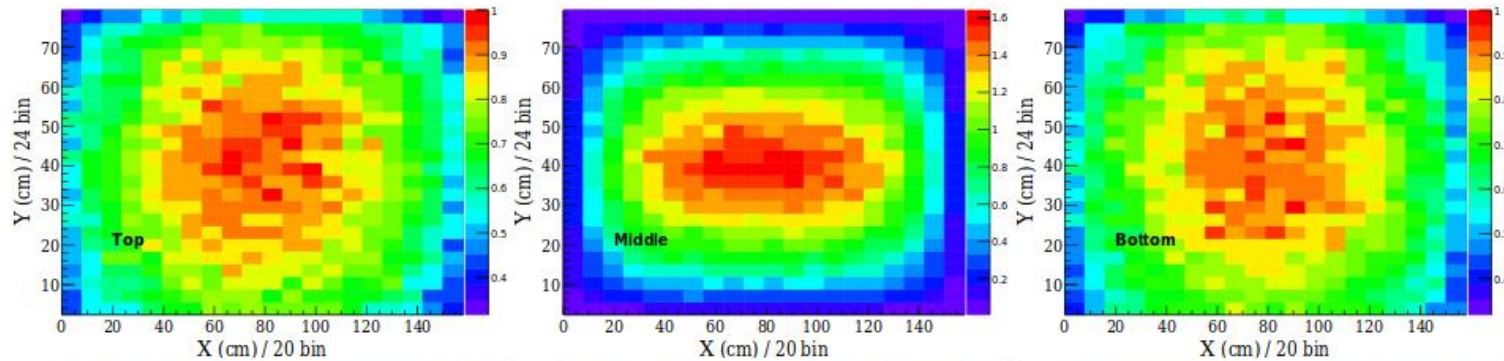
- MRPC response
- Telescope response (geometry, trigger, ...)
- Telescope location: roof, walls, surroundings

MRPC parameters:
JINST13(2018)P08026

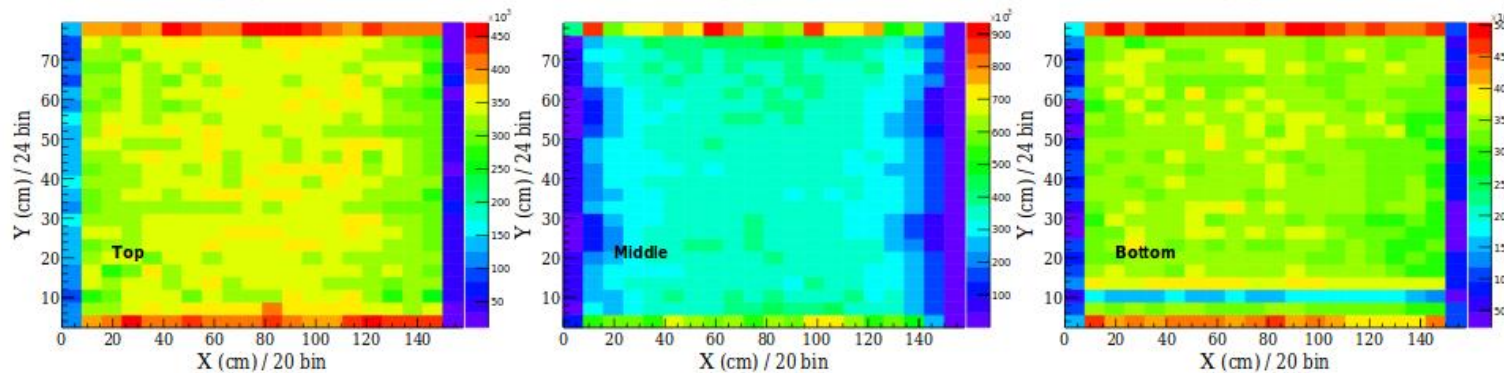
EEE telescopes MC: a complex surrounding environment



Exp Data (TORI-03)



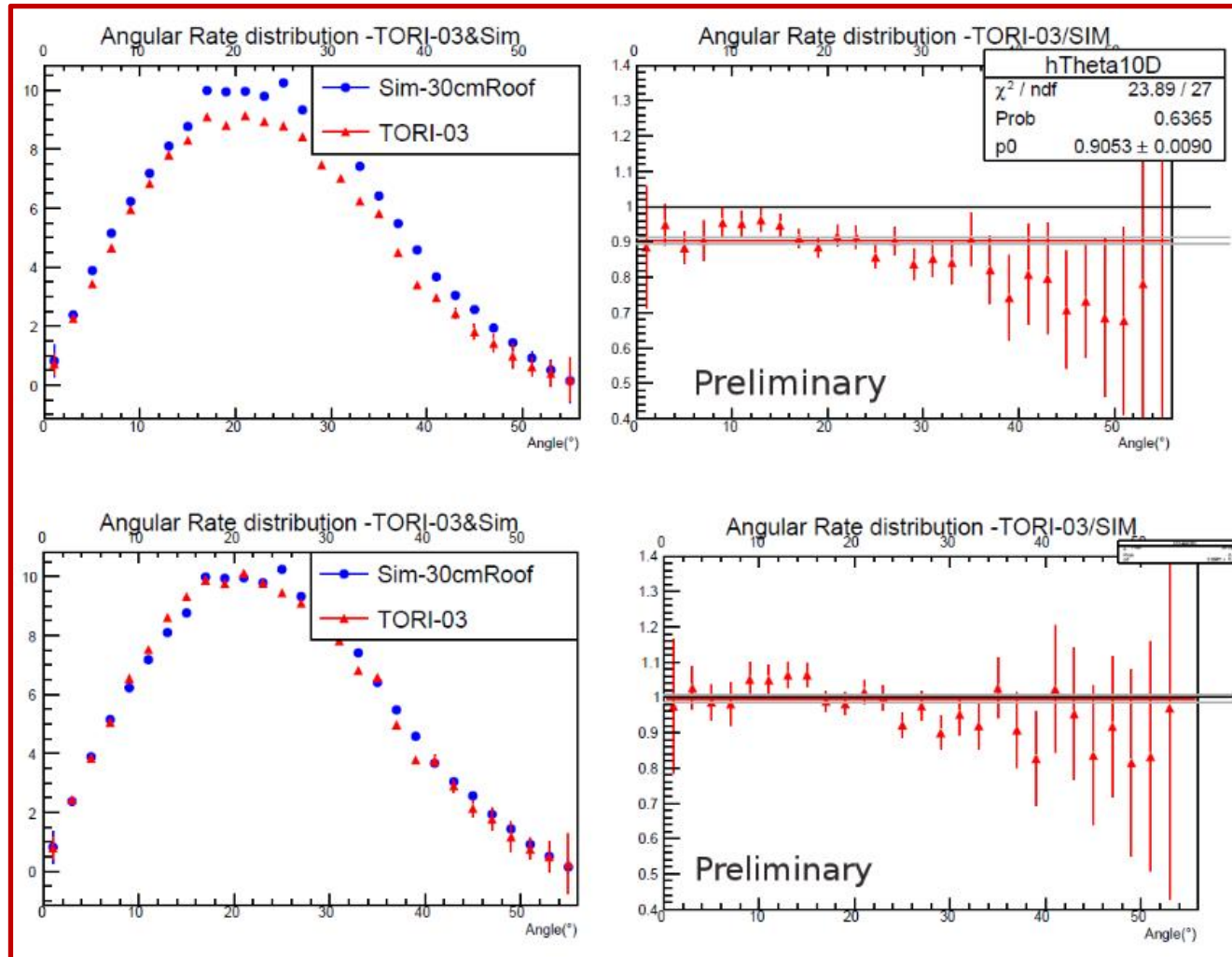
Sim Data



Maps ratios

inefficiency corrections

EEE telescopes MC: a complex surrounding environment

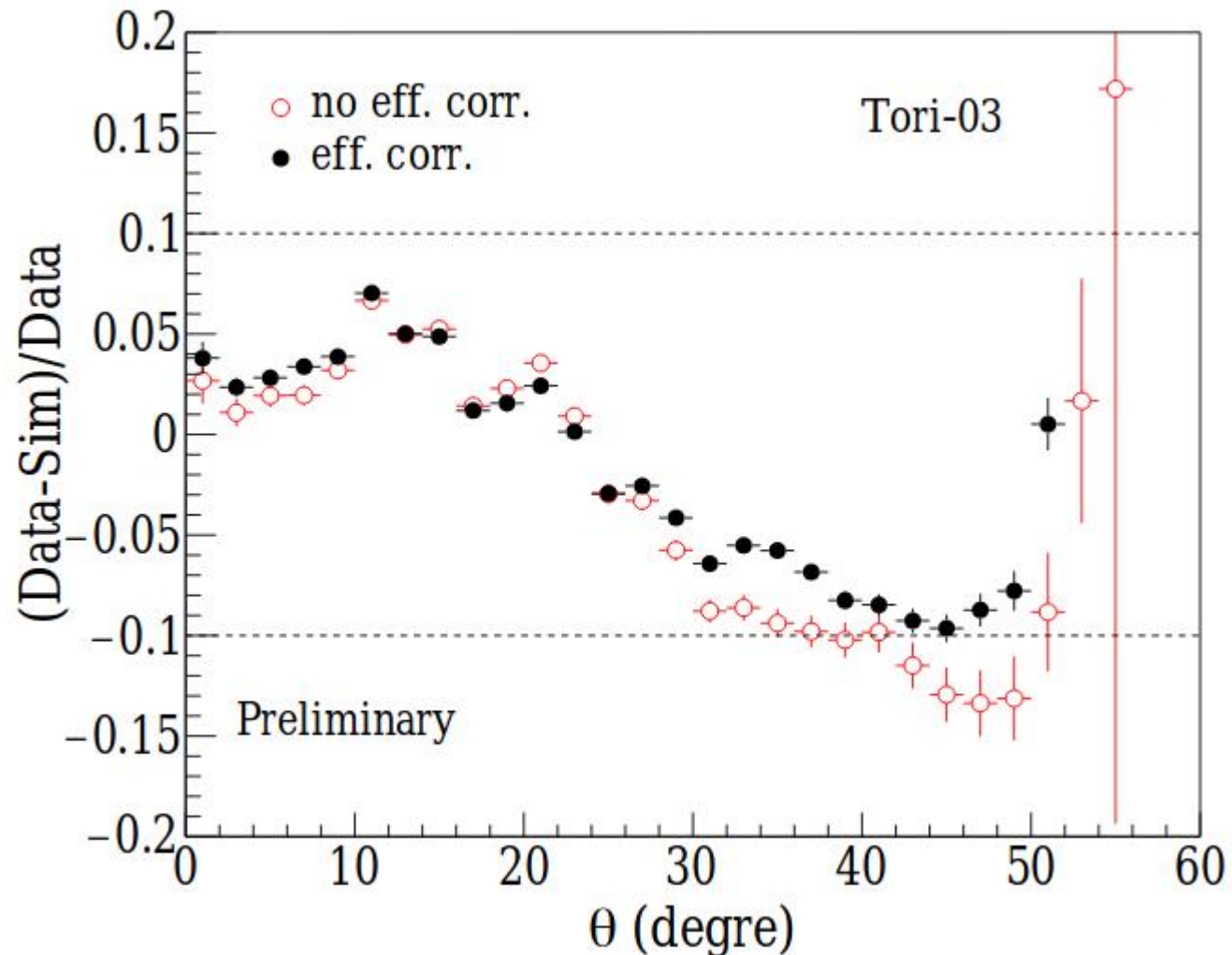


NO Efficiency corrections

Efficiency corrections

Thanks to Stefano Grazzi

EEE telescopes MC: a complex surrounding environment



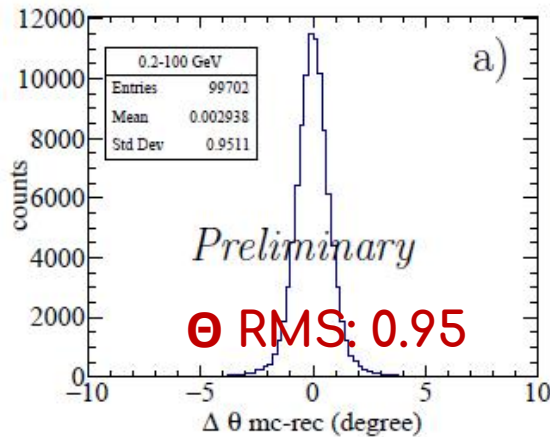
The experimental and simulated data, **without correction and with efficiency correction** are in agreement **within 5-6%** in both cases angles **below 35 degrees**.

With efficiency correction the agreement remains **within 10%** above 35 degrees.

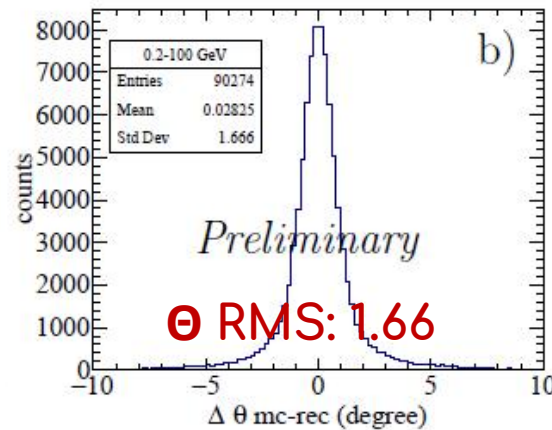
EEE telescopes MC: a complex surrounding environment

200 MeV-100 GeV

Angular residuals
no roof/walls

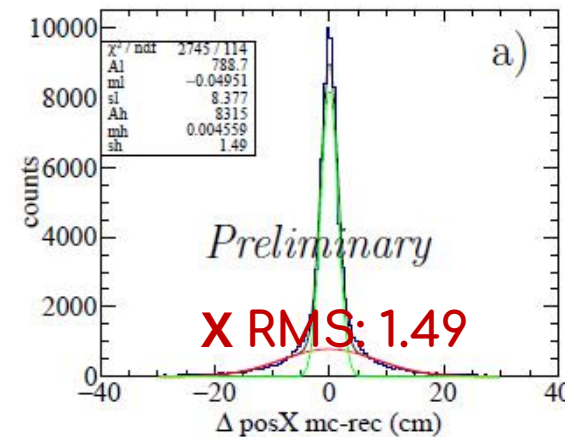


with roof/walls

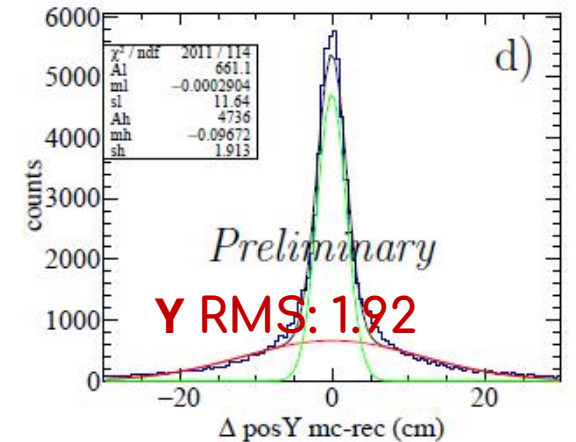
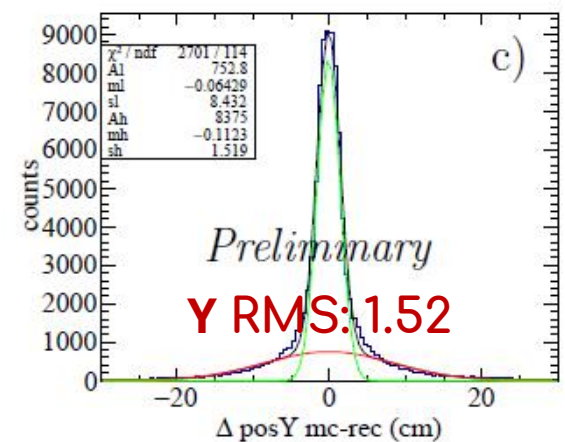
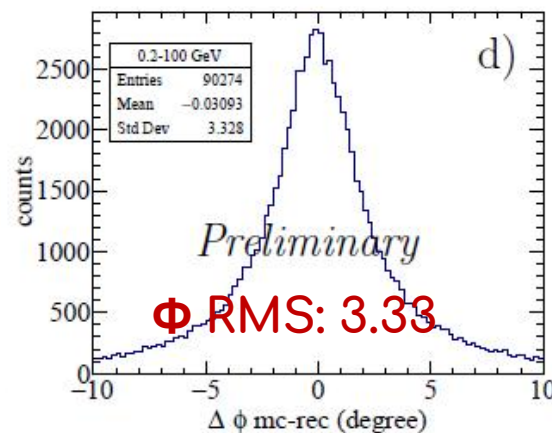
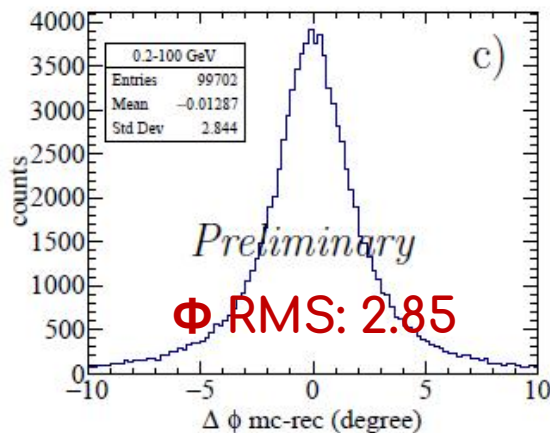
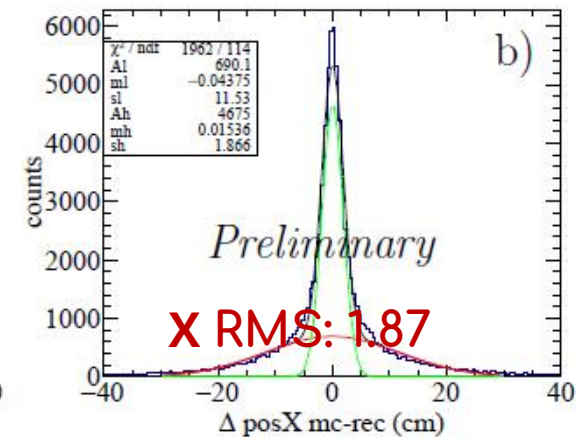


Position residuals

no roof/walls



with roof/walls



Summary

- Telescopes constructions:
 - 13 new telescopes 250 um + 13 spare MRPCs (17 chambers built in 2019)
- Gas studies
 - HFO based very promising
 - HV > 21 kV --> new EEE CAEN power supply
 - Ar/CO2 also promising --> under study
 - recirculation system R&D ongoing
- CF-INRIM collaboration
 - spectracom/trimball GPS tested
 - 250/300 ns bias found + 20/30 ns stability
 - characterization station ready via a Septentrio PolarX
 - Quantum backbone @ CF?
- MC
 - telescope response
 - surroundings
 - residuals < 10% below 35 degrees
 - with efficiency corrections also above 35 degrees