AGEING OF ATLAS RPC WITH ADDITIONAL CO2 AND THE OTHER ACTIVITIES

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On behalf of ATLAS RPC Group

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ATLAS EXPERIMENT

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INTRODUCTION

50 cm x 50 cm ATLAS-like (a doublet with 2 mm gas gaps) RPC detector was mounted on ~ 60 cm x 2 m trolley, which includes also a LV PS.

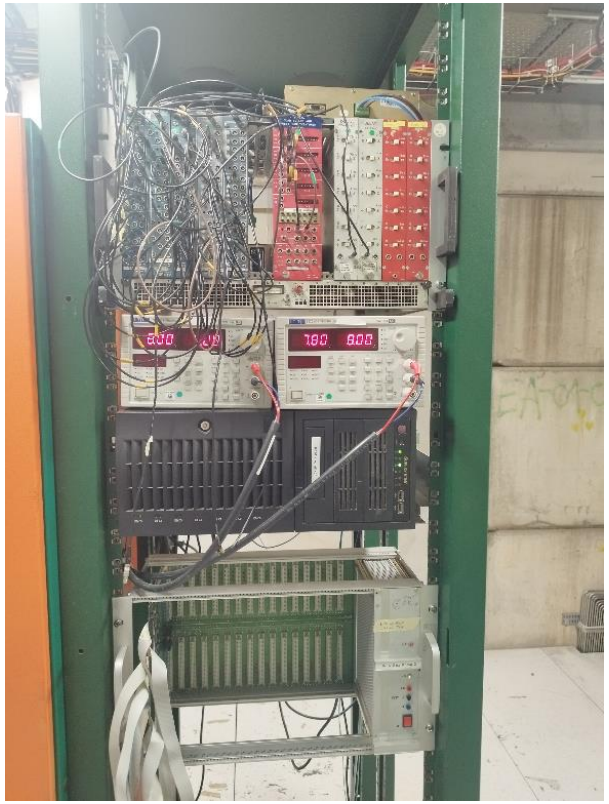
Gases:

- **Standard Gas Mixture:** 0% CO2, 5% C4H10, 0.3% SF6 and 94.7% C2H2F4
- **30% Co2 Mixture: 30% CO2, 5% C4H10, 1% SF6 and 64% C2H2F4 (finished)**
- **40% Co2 Mixture:** 40% CO2, 5% C4H10, 1% SF6 and 54% C2H2F4
- **0.5% SF6 Gas Mixture:** 30% CO2, 5% C4H10, 0.5% SF6 and 64.5% C2H2F4

Control parameters:
Gas mixture
High Voltage
Front-End thresholds
Photon background intensity

Observables:
Gap Currents
Panel Counts
Gap Efficiencies
Cluster Size
HPL Resistivity

DAQ Setup



Setup inside the GIF++ bunker

THE ATLAS-LIKE CHAMBER IN GIF++ BUNKER

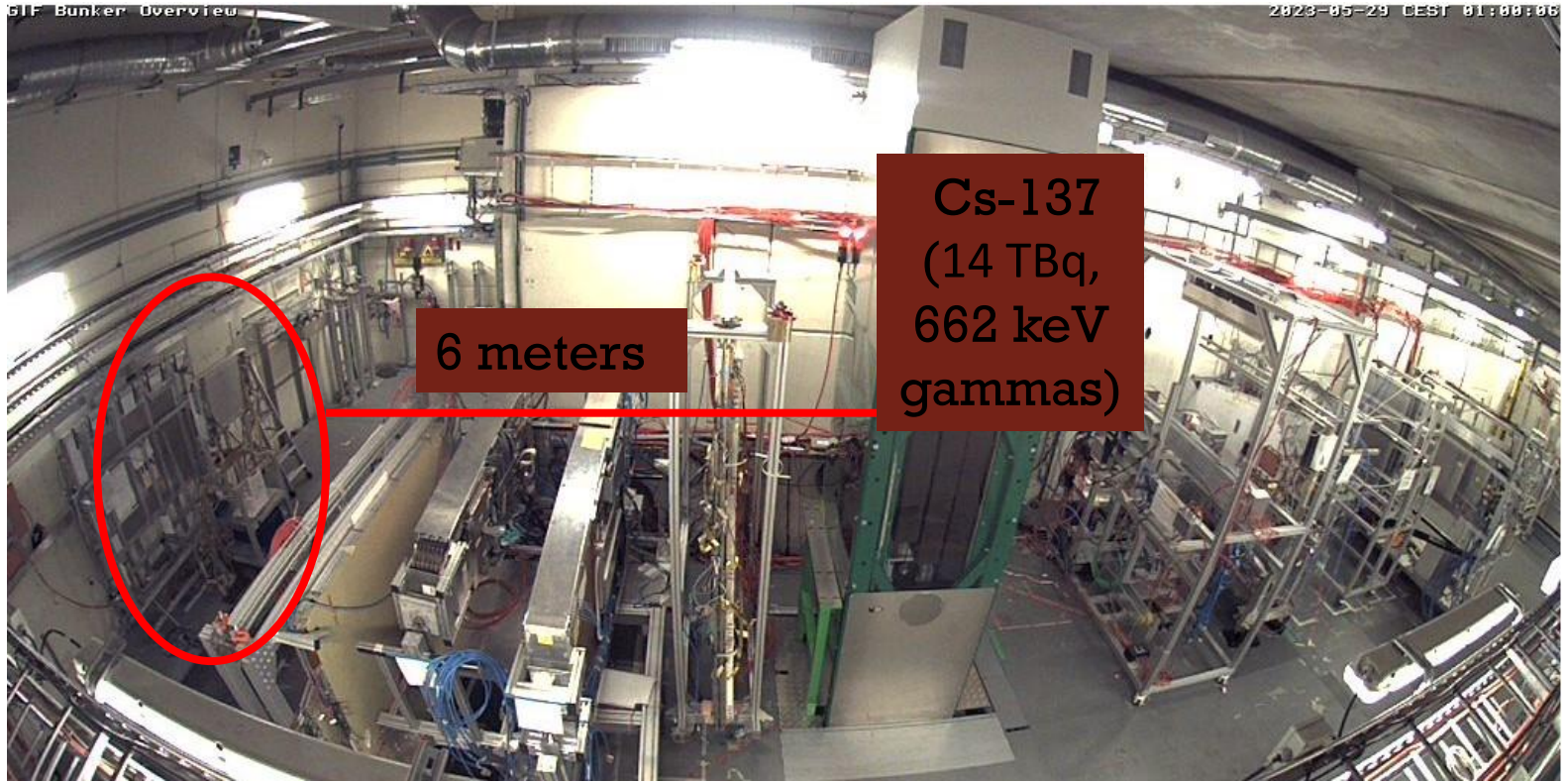
The prototype was located in the downstream area, in front of the the ATLAS RPC Module 0 since March 2023 for:

Performance measurements are done at each available muon beam period

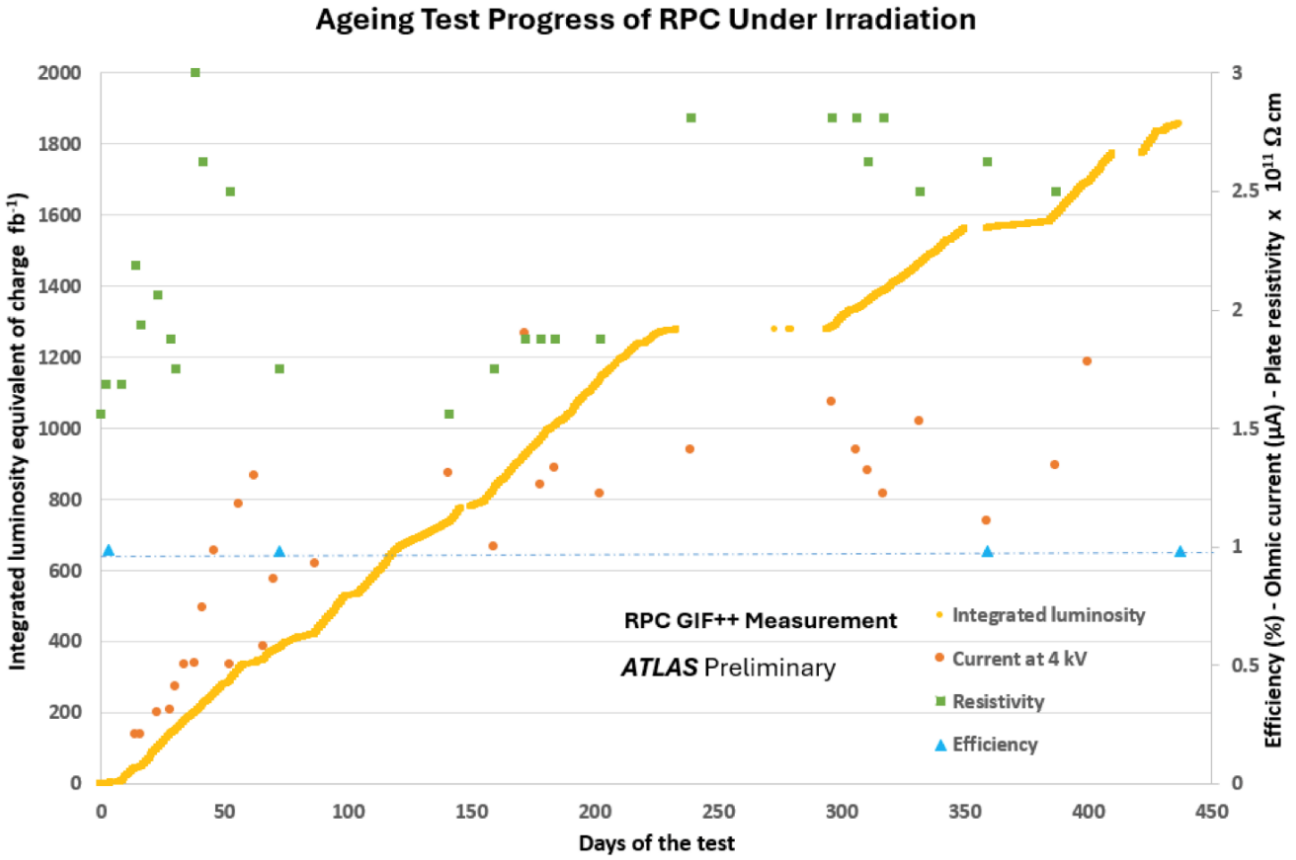
Ageing test: Integrated a significant fraction of the equivalent of HL-LHC total work load

This ageing test was the first performed with this mixture, and thanks to that, ATLAS adopted this mixture in July 2023.

64% $C_2H_2F_4$ - 30% CO_2 - 5% iC_4H_{10} - 1% SF_6



NEW RPC GAS: AGEING RESULT



64% $C_2H_2F_4$ - 30% CO_2 - 5% iC_4H_{10} - 1% SF_6

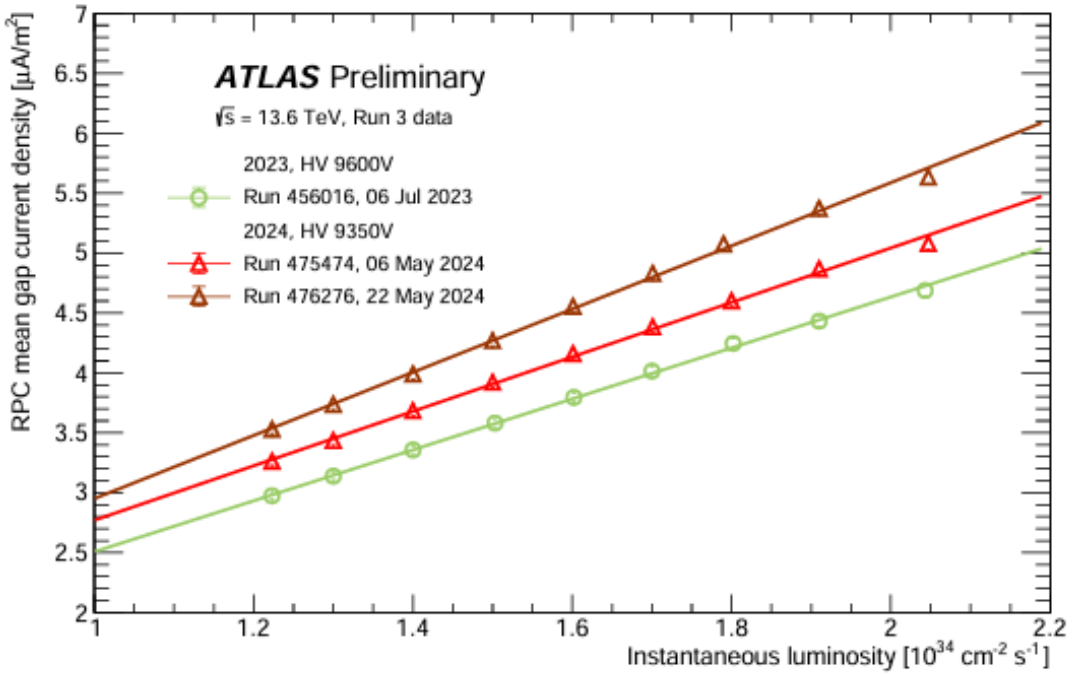
- Test and validation campaign started ~ 2 years ago
  - ATLAS like RPC doublet at GIF++ (same gas gap, electronics, Farady cage structure and power) → longevity: performance vs. equivalent integrated luminosity
  - Validation of the first candidate: 30% TFE replaced with CO_2 + increased SF_6 to 1% for precaution
  - @GIF++ integrated the equivalent of 1900 fb^{-1}. The performance measured along the test did not show significant variations. The current is about ~15% higher but the Fluoride production rate is the same as for the standard mixture

- Ohmic current is very good; it increased slightly probably due to the accelerated ageing at the beginning
- Electrode resistance started very high and is not changing much
- Efficiency is not changing after 1.5 years and the equivalent of half of the HL-LHC program

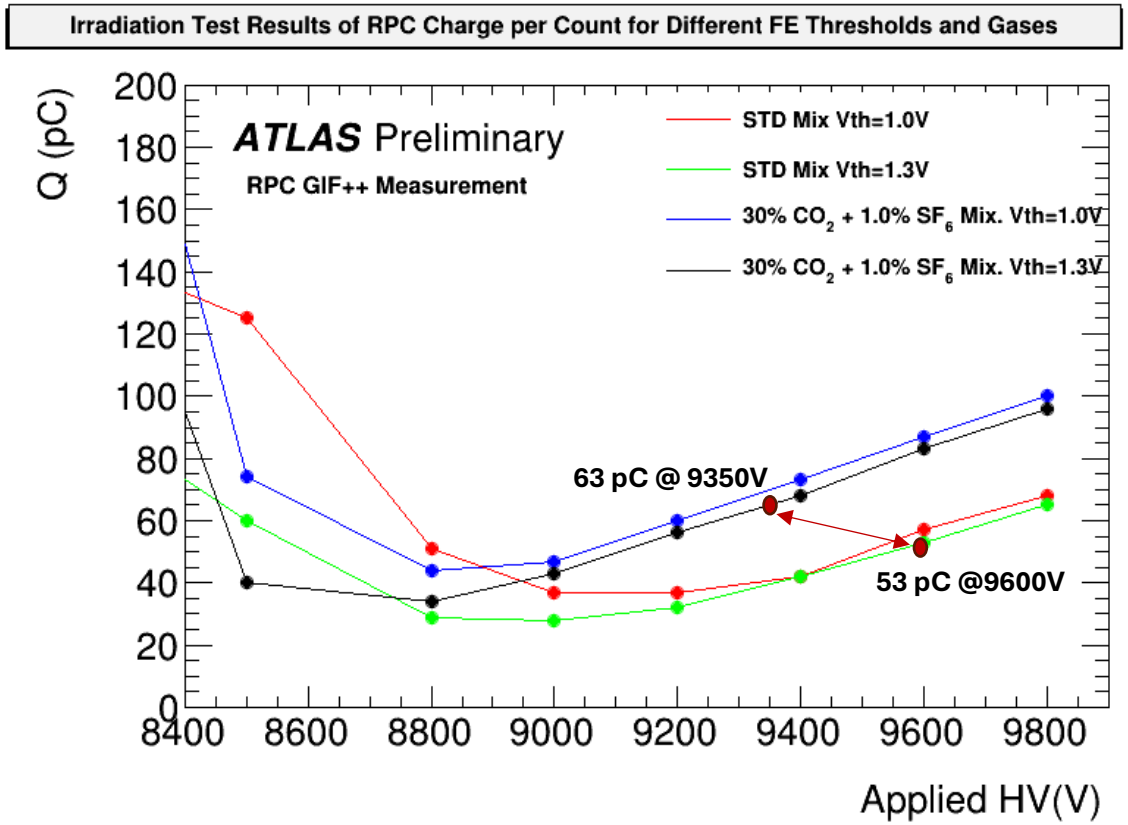
S. Simsek, "Mitigation of the ATLAS RPC environmental impact" ICHEP2024

COMPARISON OF OLD & NEW RPC GAS MIXTURES

@ATLAS a study confirmed the current rate observed at GIF++. See Eric Ballabene's the talk: Performance of ATLAS RPC detectors and L1 Muon Barrel Trigger with a new CO2 based gas mixture in ICHEP 2024.

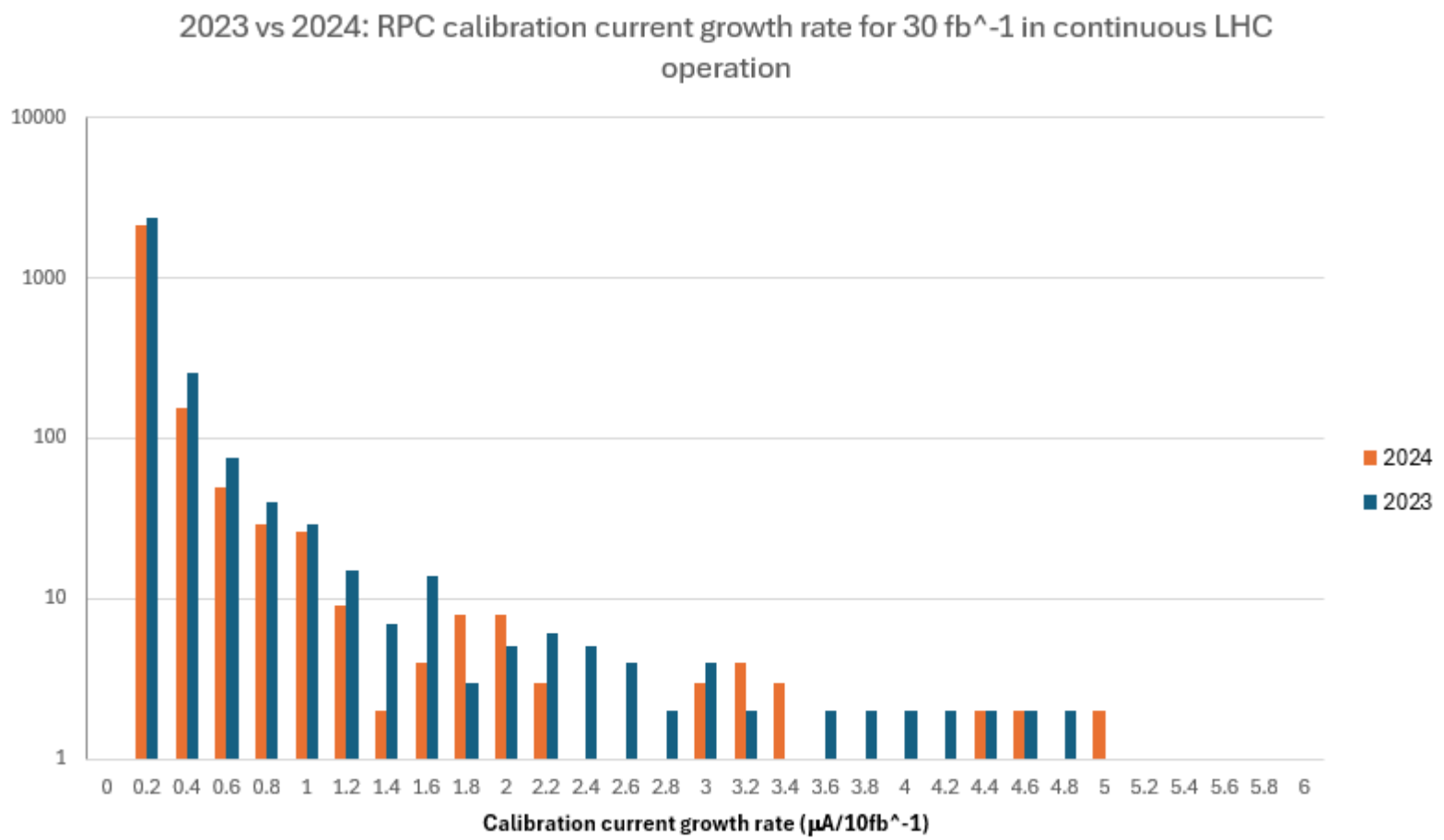


The ratio between gas gap current and Inst. Lumi (which is proportional to charge/count) is increased by **~17%**



- For 30% CO_2, the charge per count is ~19% higher
  - This is due to the presence of an higher amount of undetected photons (less counts).

COMPARISON OF OLD & NEW RPC GAS MIXTURES IN ATLAS CAVERN



@ ATLAS the impact on the longevity has been evaluated by comparing the evolution of the calibration current vs. integrated luminosity, for 2023 and 2024, where standard mix and new mix have been used respectively. The study shown that the in comparable periods and integrated luminosity the, new mix had a lower calibration increase rate.

NEW RPC GASES: PERSPECTIVES

- We started the validation study of 3 new mixture candidates, with a lower GWP with respect to the presently used one

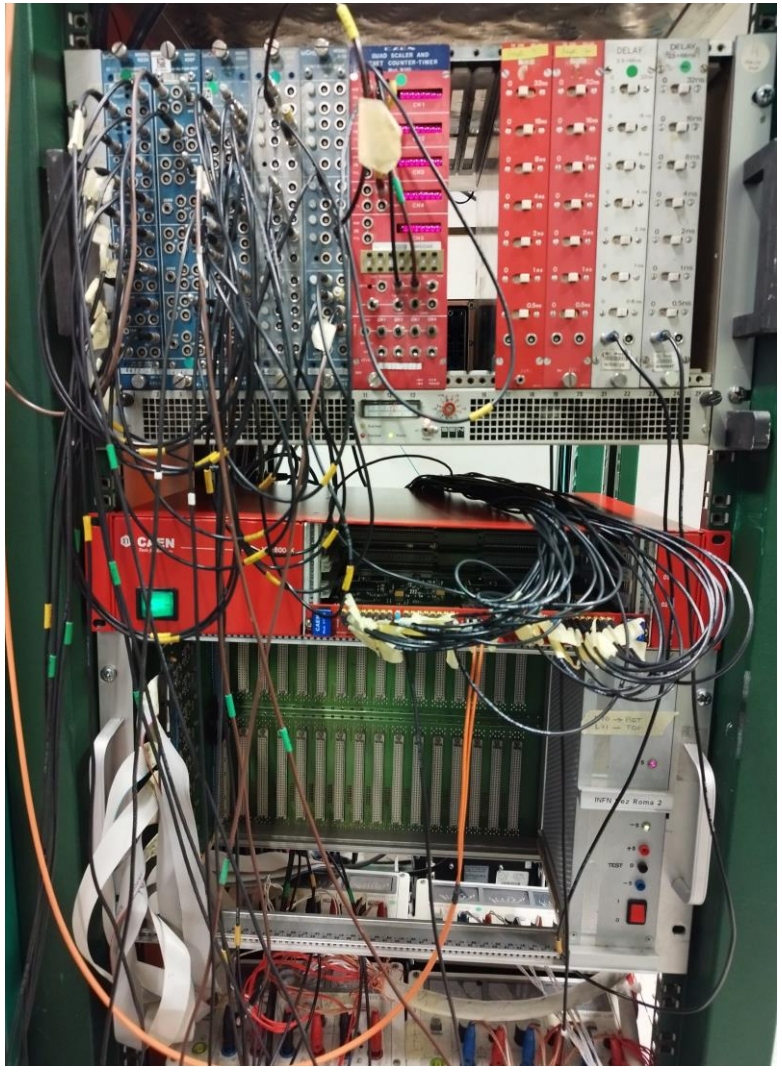
1. 40% of CO_2 with 1% of SF6 → further lowering the TFE by 10% (GWP ~ 1002)
2. **30% CO_2 with 0.5% of SF6 → halving the impact of SF_6 (GWP ~ 1037)**
3. **30% or 40% CO_2 with 1% or 2% of Chlorotrifluoropropene ($C_3H_2ClF_3$) a low GWP substitute of SF_6 which has been recently[*] validated for performance at the GIF++ using 1 mm gas gaps prototype for the ATLAS RPC upgrade (GWP ~793)**

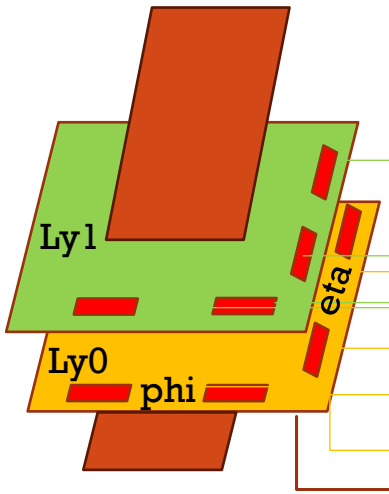
- All mixtures will be also validated for Phase-2 1 mm gas gaps, having a halved gaseous target
- We starts the validation at GIF++ of 2. and 3. above.
- Longevity tests requires several months to be completed. We expect to start the 2025 run with the current mixture and aim to identify the best mixture candidate to reduce the GWP already during Run3.

*G. Proto, "Study of environment friendly SF_6 substitute for the Resistive Plate Chambers", RPC2024

NEW DAQ SETUP AND TEST IN GIF++

New setup includes also a digitizer to the system for the further analysis





Receivers Crate

Each board has its own fast or here to combine the panel.

Fan In/Out

Discriminator

Ly1 OR

Ly0 AND

Counter

All Coincidence Logic with. Scint.

Ly1+Ly0 +Scint Counts

Ly0 + Scint Counts

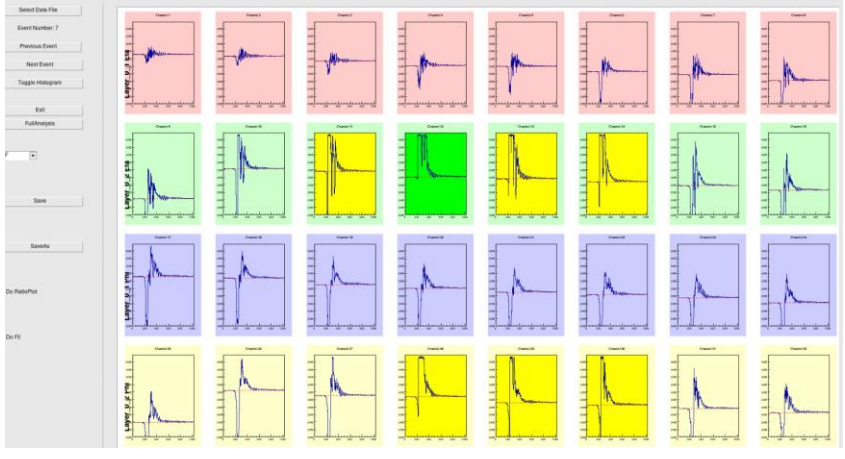
Test

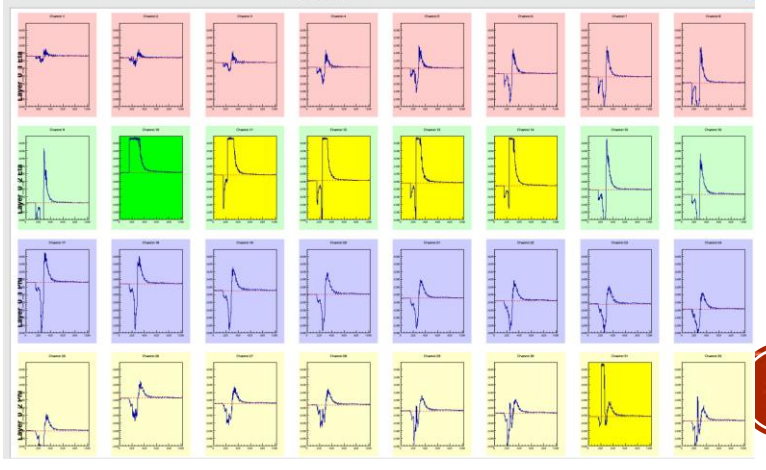
Trigger

LV PS
Vee + Vth

HV PS

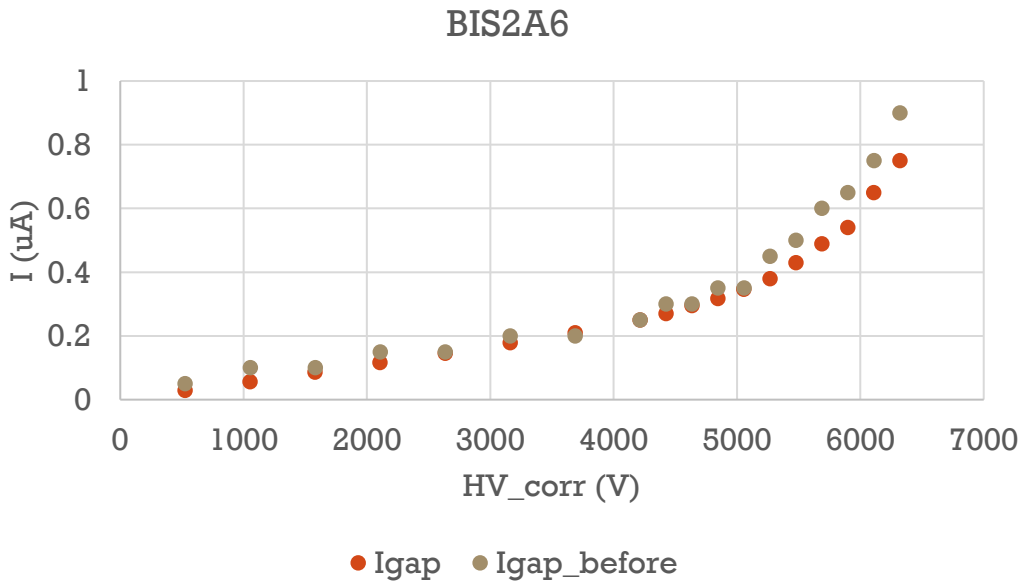
Digitizer

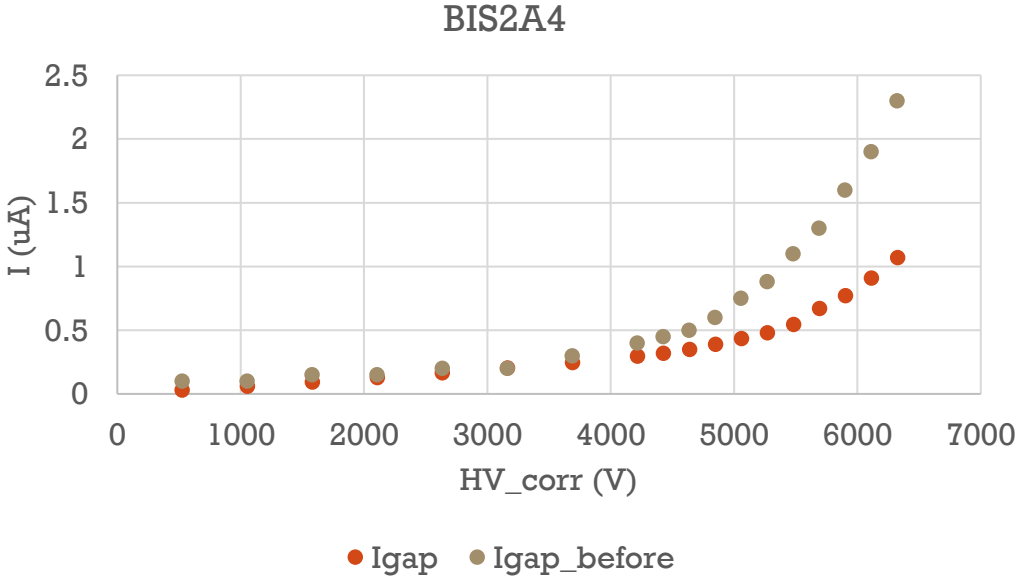


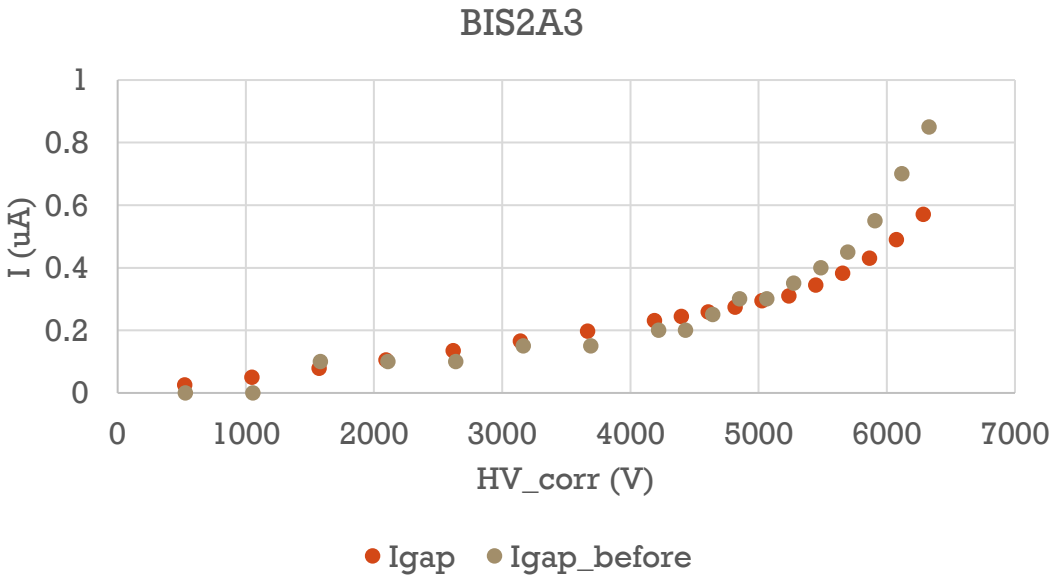


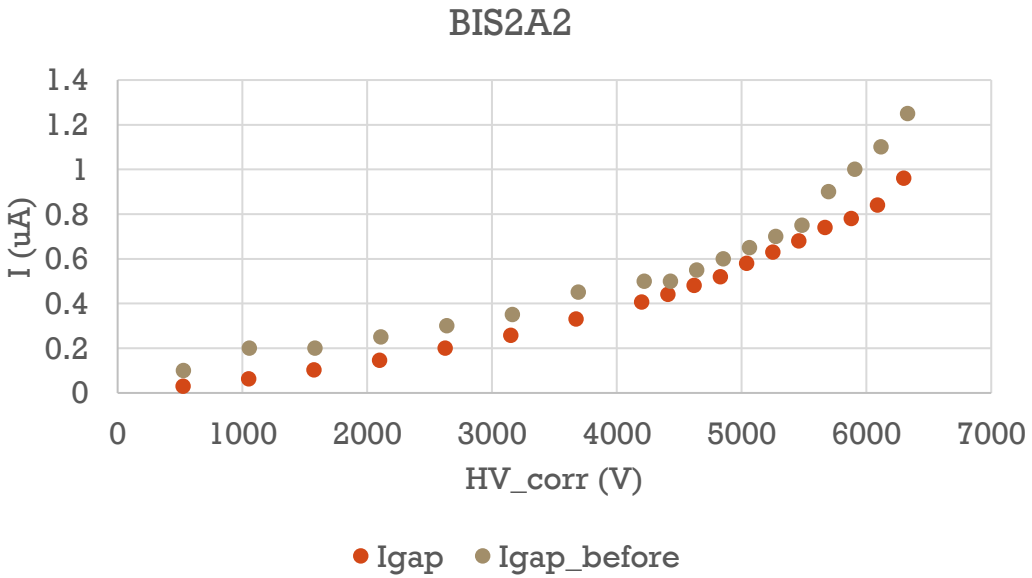
RPC PHASE-2 BI GAP CONDITIONING

The first small batch (4 gas gaps) of the BI Upgrade (Phase-2) chambers was placed in GIF++ for 1 week as a part of the certification process
Improvement of the exponential current is 15% - 48%









RPC PHASE-2 BI GAP CONDITIONING

• Based on initial results, 12 GIF++ conditioning steps were incorporated into the project.

• By the end of March, the first BI package was installed in a trolley equipped with a minicrate and transported to GIF++ for irradiation testing.

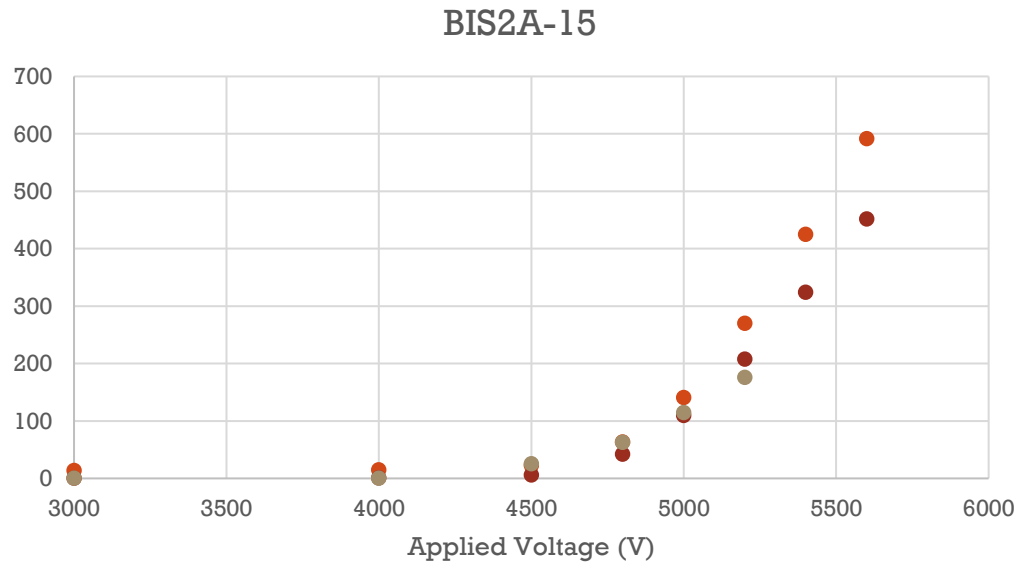
• During testing at GIF++, it was immediately observed that three gaps were leaking. This was confirmed by the lack of output flow in the flowmeters and verified with a bubbler measurement.

• The leakage issue was also detected in two other packages, leading to a suspension of the conditioning process until the problem was resolved.

•After a couple of months, conditioning was restarted last month and we tested 2 more package→ no leaks observed.

METHOD TO MEASURE THE RESISTIVITY

- Using athe average gain function as an observable
- This provides the total charge per incident particle as a function of the electric field
- It can be obtained at GIF++ by measuring current as a function of the voltage normalized by the expected intensity of incident photons
  - This last is more or less corresponding to the inverse of filter absorption factor



- The average gain function is depending just on the gas physics so one can find the electrode R from the voltage drop

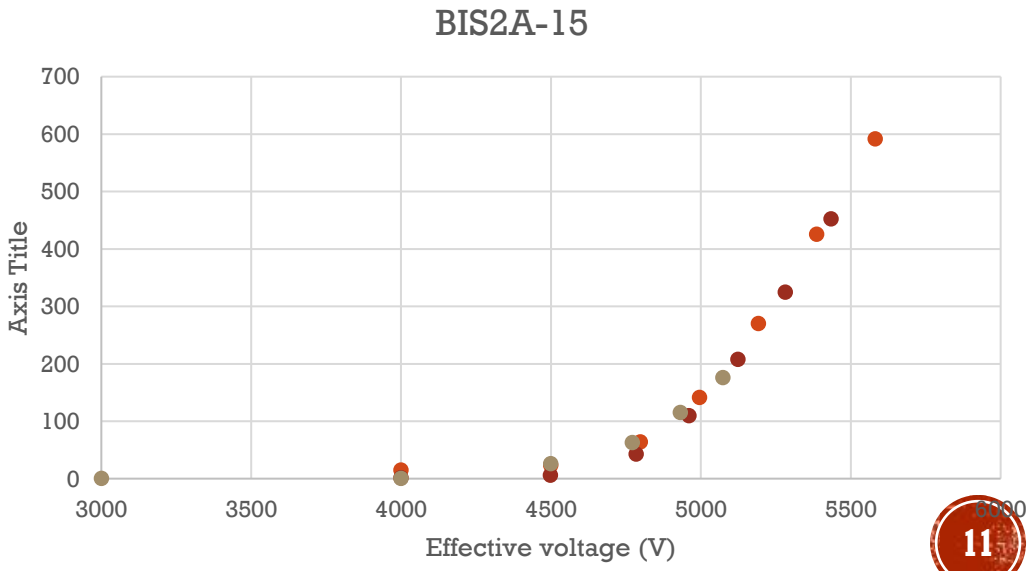
$$V_{eff} = V_{app} - IR$$

- Rho is obtained by applying the appropriate geometrical factor

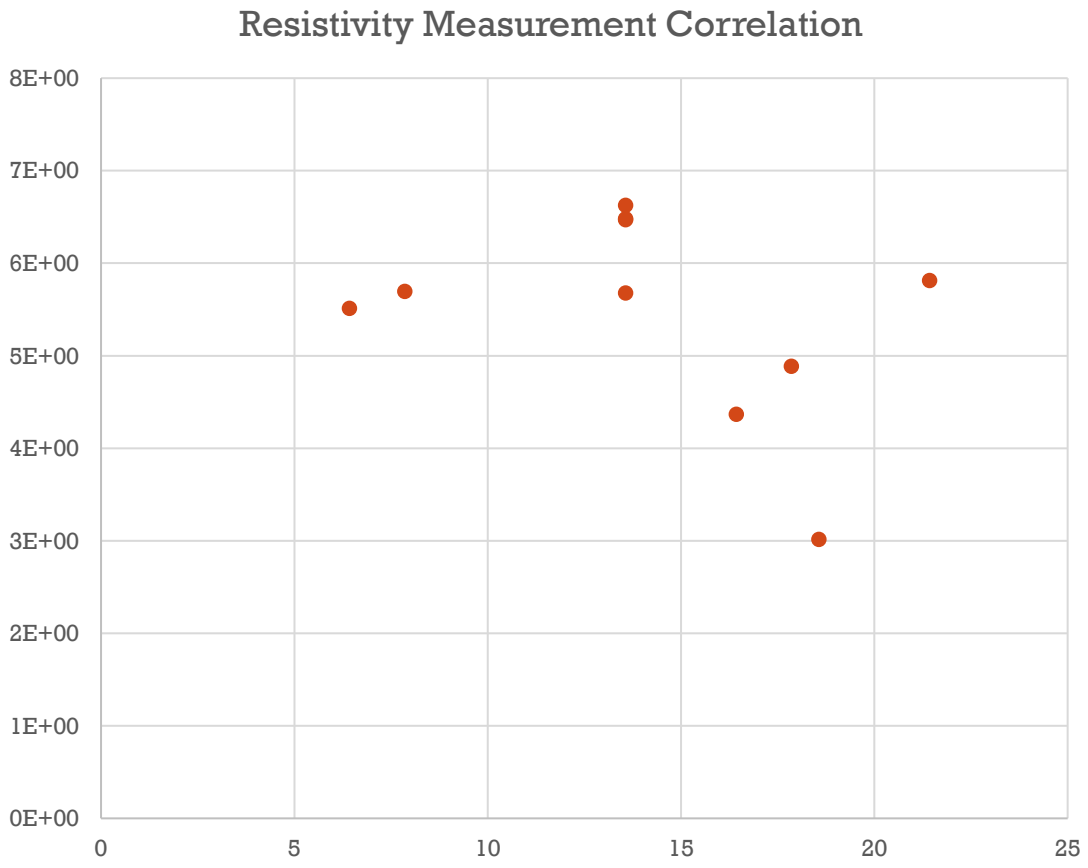
$$\rho = R\frac{S}{d} = \mathrm{R}\frac{2{\cdot}10^4}{0.28}\ \Omega\ cm$$

- For BIS2A-15 R=2.2 M Ω

→ ρ=7.9*10^10 Ohm cm



COMPARISON TO THE DIRECT MEASUREMENT OF THE HPL PLATES



Gas volume	HPL plate 1	HPL plate 2	Res HPL plate 1 [Ohm x cm]	Res HPL plate 2 [Ohm x cm]	Average
BIS2A-7	70	54	9E+10	5E+10	7E+00
BIS2A-8	5	80	3.25E+10	1.00E+11	7E+00
BIS2A-9	4	69	5.45E+10	9E+10	7E+00
BIS2A-1	48	64	5E+10	6.49E+10	6E+00
BIS2A-11	71	90	9E+10	4E+10	6E+00
BIS2A-12	72	50	9E+10	4.20E+10	6E+00
BIS2A-13	1	74	4.10E+10	8.50E+10	6E+00
BIS2A-15	104	141	4.33E+10	7.05E+10	6E+00
BIS2A-16	99	140	4E+10	7E+10	6E+00
BIS2A-17	115	137	3E+10	6.51E+10	5E+00
BIS2A-18	111	143	5E+10	7E+10	6E+00
BIS2A-19	91	119	3E+10	3E+10	3E+00
BIS2A-20	93	138	2E+10	7E+10	4E+00
BIS2A-21	117	129	3E+10	7E+10	5E+00
BIS2A-22	125	135	4E+10	5.70E+10	5E+00
BIS2A-23	96	148	5E+10	7E+10	6E+00
BIS2A-24	116	134	3E+10	5.70E+10	5E+00
BIS2A-25	92	146	2.00E+10	7E+10	4E+00
BIS2A-26	127	128	4E+10	4E+10	4E+00
BIS2A-27	95	147	5.70E+10	6E+10	6E+00
BIS2A-28	102	108	7E+10	8E+10	7E+00
BIS2A-29	97	103	7E+10	7E+10	7E+00
BIS2A-30	120	123	3E+10	4E+10	4E+00
BIS2A-31	131	133	6E+10	5E+10	5E+00

THE PLANS FOR THE NEXT YEAR

- The leak issue has been solved and the production and conditioning restarted.
  - Certification of the RPC BIL/BIS gas gaps –>50 l/h gas is needed
    - 1 package is including 24 gas gaps
    - Almost each week (~3 out of 4 weeks) 1 package will be in the bunker.
- Ageing of the Chinese made RPC chambers → 5 l/h gas is needed
- 1 BI chamber for the performance tests → 6 l/h gas is needed
- Ageing of the 2mm ATLAS legacy RPC type chamber with the new gas

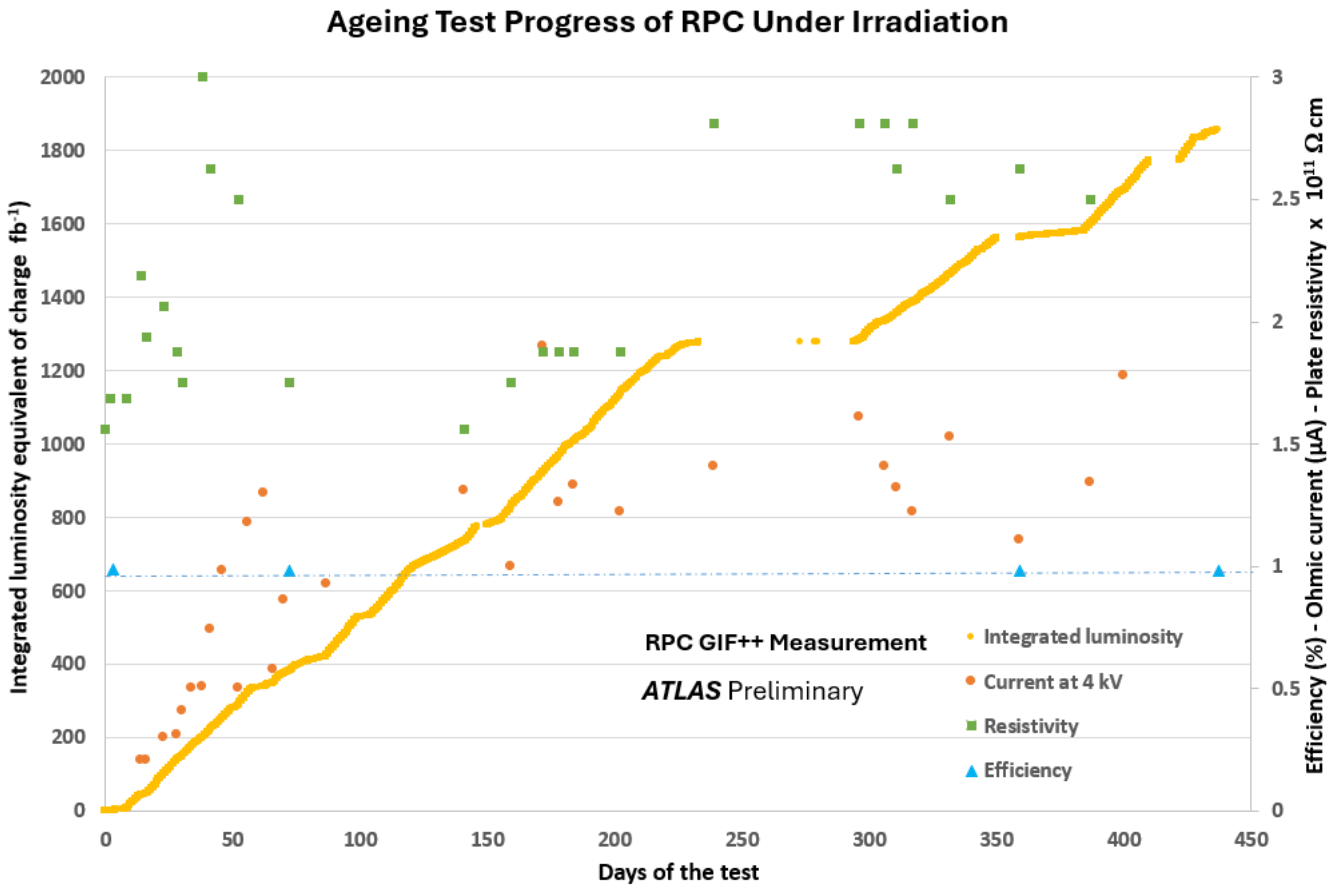
64.5% $C_2H_2F_4$ - 30% CO_2 - 5% iC_4H_{10} - 0.5% SF_6

→ 6 l/h and max 2 change per h --> 12 l during the irradiation

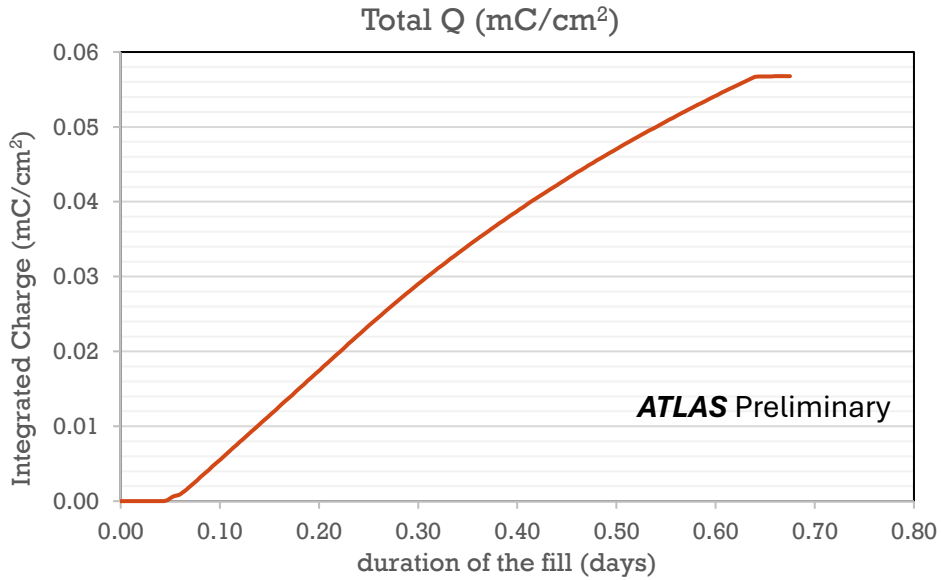
Until the end of the year we will share the gas 50 – 50 with CMS RPC.

THANK YOU!!

BACK UP: AGEING STUDY WITH 30% CO_2 + 1% SF6



High background ref. chamber
(BML6A13.CO.Ly0 in ATLAS cavern)



Calibration Q vs. Lumi

fill lumi	0.821	fb^{-1}
int. charge	0.05677	mC/cm^2
conversion factor	0.069145	$mC/cm^2 \cdot fb$

- Target →Full HL-LHC program corresponds to ~ 3000 fb^{-1}
- We are in more than half of the target corresponding to ~1900 fb^{-1}
- Ohmic current is very good! It increased slightly due probably the accelerated ageing at the beginning
- Electrode resistance started very high and is not changing much
- Efficiency is not changing after 1.5 years!

METHOD TO MEASURE THE RESISTIVITY

- Using as observable the average gain function
- This provides the total charge per incident particle as a function of the electric field
- It can be obtained at GIF++ (except for a multiplicative constant corresponding to the sensitivity) by measuring current as a function of the voltage normalized by the expected intensity of incident photons
- This last is more or less corresponding to the inverse of filter absorption factor
- In reality this must be calibrated since the filters effect deviates from the nominal values
- The calibration was done measuring the resistivity with the efficiency method (which does not depend explicitly on the source intensity) using a test chamber
- In alternative we will do an absolute calibration by using the rad monitor device available at GIF++