ECOgas weekly meeting
Resistivity studies + TB comparison

***Luca Quaglia*[1]**

[1]INFN Torino

22/02/2024

Overview

- Data set for resistivity → all RPCs
- Resistivity analysis
- Resistivity results
- TB comparison 2022 vs 2023 → ALICE only

Dataset

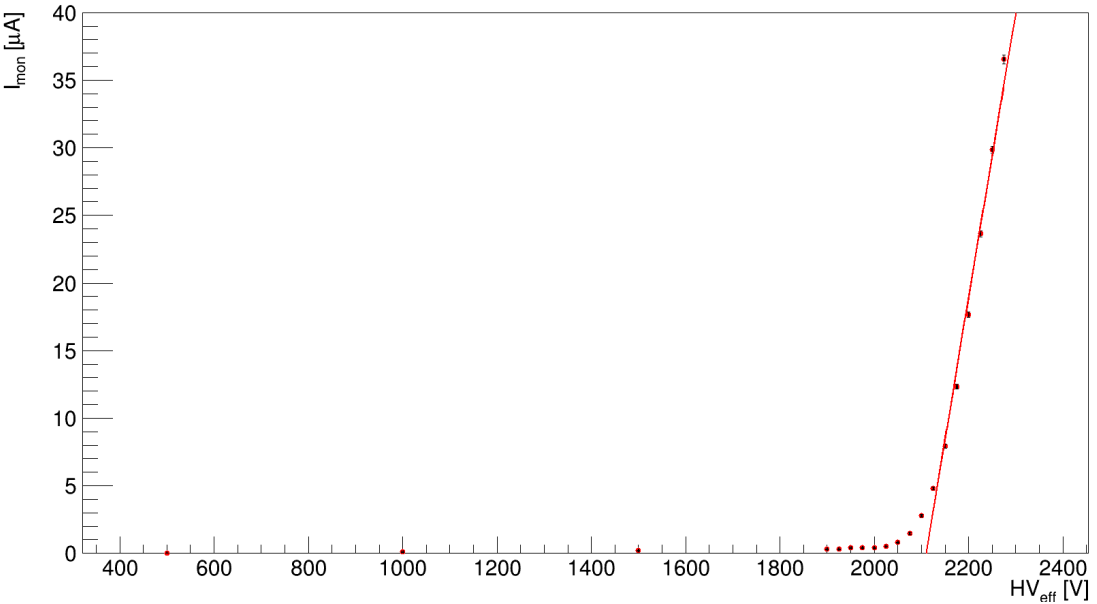
- **Resistivity studies**
  - Scans taken from the start of the aging studies with ECO2 (after scan #254) → except for RE11 for which we have a baseline in 2021
  - All plots are in this folder (on our CERNbox)

    https://cernbox.cern.ch/files/spaces/eos/project/r/rpc-ecogas/acquisition%20data?items-per-page=100&view-mode=resource-table&tiles-size=1&sort-by=name&sort-dir=asc&pending-sort-by=name

- **TB comparison**
  - 2022 and 2023 data taken with the ALICE detector
  - Same position, same FEB and threshold → different number of strips and pitch only
  - Aged detector

Resistivity studies

Resistivity calculation



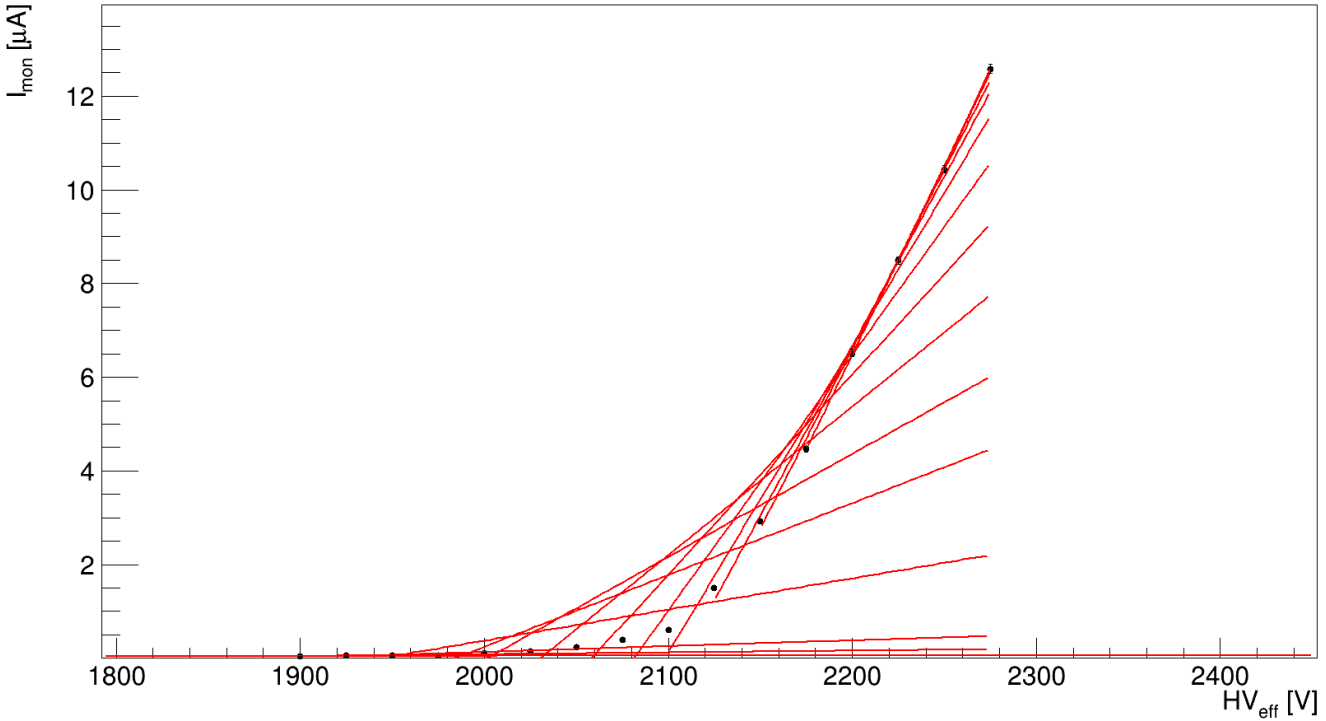
- Linear fit to the ohmic part of the I(V) curve
- Starting point of the fit is decided according to procedure in the following slide
- Function used y = a + bx

- Parameter b = 1/R (R = resistance of the electrodes)
- ρ(resistivity) = R*S(surface)/2d(electrode thickness) = 1/b*S/2d
- Resistivity values shown in the following are normalized to **T_0 = 20°C** using the following formula:

$$\rho(T) = \rho(T_0) * 4.4^{\frac{T_0 - T}{12\,^\circ C}}$$

From: *https://doi.org/10.1016/S0168-9002(00)00979-7*

Resistivity calculation



First point 2250 last point 2275 chiSq 61702.5
First point 2225 last point 2275 chiSq 2.55757e-14
First point 2200 last point 2275 chiSq 0.880579
First point 2175 last point 2275 chiSq 1.25192
First point 2150 last point 2275 chiSq 1.3321
First point 2125 last point 2275 chiSq 34.4608
First point 2100 last point 2275 chiSq 125.108
First point 2075 last point 2275 chiSq 574.374
.....
First point 500 last point 2275 chiSq 61702.5

- Linear fit executed from last HV point backwards
- Adding one point at a time
- Calculate chi square for all the ranges and take minimum value (if there are at least 3 HV points in the range)

Resistivity dataset

Analyze?	Run	SHiP	ALICE	RE11BOT	RE11TW	RE11TN	EPDT RPC6	ATLAS	Bari	EPDT RPC25	KODELH-TOP	KODELH-BOT	Temp	Press	Humi	timestamp	start	end
0	217	1	1	1	1	1	1	0	0	0	0	0	20.84	959.02	3.53	1631710323	2021-09-15	12:52:00
0	218	1	1	1	1	1	1	0	0	0	0	0	21.01	958.3	4.5	1631718980	2021-09-15	15:16:00
0	219	1	1	1	1	1	1	0	0	0	0	0	20.61	960.75	-70.55	1631796484	2021-09-16	12:48:00
0	221	1	1	1	1	1	1	0	0	0	0	0	19.9	960.58	4.43	1645014801	2022-02-16	12:33:00
0	222	1	1	1	1	1	1	0	0	0	0	0	19.5	960.01	-71	1645025799	2022-02-16	15:36:00
0	223	1	1	1	1	1	1	0	0	0	0	0	19.6	956.15	-72	1645185027	2022-02-18	11:50:00
0	224	0	0	0	0	0	0	1	0	0	0	0	20.81	951.01	5.86	1649271900	2022-04-06	19:05:00
1	254	1	1	0	0	0	1	1	0	0	0	0	21.83	956	3.22	1655890626	2022-06-22	09:37:00
1	255	1	1	0	0	0	1	1	0	0	0	0	22.23	954.08	3.55	1655906034	2022-06-22	13:53:00
1	406	0	1	0	0	0	0	0	0	0	0	0	20.72	962.18	-72	1665407200	2022-10-10	15:06:00
1	410	1	1	1	1	1	1	1	1	0	0	0	20.68	959.67	4.81	1666516351	2022-10-23	09:12:00
1	411	1	1	1	1	1	1	1	1	0	0	0	20.6	959.1	5	1666565884	2022-10-23	22:58:00
1	412	1	1	1	1	1	1	1	1	0	0	0	20.8	960.62	4.93	1666621769	2022-10-24	14:29:00
1	413	1	1	0	0	0	1	1	1	0	0	0	21	957.8	4.2	1667469033	2022-11-03	10:50:00
1	439	0	1	1	1	1	1	1	0	0	0	0	20.7	967.7	0.5	1671487160	2022-12-19	21:59:00
1	440	1	1	1	1	1	1	1	0	0	0	0	20.44	965.4	0.62	1671525361	2022-12-20	08:36:00
1	441	1	1	1	1	1	1	1	0	0	0	0	20.6	963.97	1.02	1671534203	2022-12-20	11:03:00
1	442	1	1	1	1	1	1	1	1	0	0	0	20	962.73	3.51	1673696400	2023-01-14	11:39:00
1	443	1	1	1	1	1	1	1	1	0	0	0	20	957.5	3.8	1673736840	2023-01-14	22:54:00
1	444	1	1	1	1	1	1	1	1	0	0	0	20	958.3	3.39	1673822460	2023-01-15	10:41:00
1	456	1	1	1	1	1	1	1	1	0	0	0	20.5	952.6	3.85	1677227340	2023-02-24	08:29:00
1	484	1	1	1	1	1	0	1	0	1	0	0	20.82	960.87	5.1	1686920418	2023-06-16	13:00:00
1	485	1	1	1	1	1	0	1	0	1	0	0	20.8	959.95	4.8	1686930699	2023-06-16	15:31:00
1	685	1	1	1	1	1	0	0	0	1	1	1	21.1	955.7	4.5	1697522640	2023-10-17	18:04:00
1	686	1	1	1	1	1	0	0	0	1	1	1	21.1	955.6	4	1697536200	2023-10-17	21:50:00
1	687	1	1	1	1	1	0	0	0	1	1	1	21.2	951.5	4.3	1697619960	2023-10-18	09:06:00
1	688	1	1	1	1	1	0	0	0	1	1	1	21.2	947.5	4.4	1697645880	2023-10-18	16:18:00
1	709	1	0	1	1	1	0	0	0	1	1	1	19.6	960.3	4.6	1702541632	2023-12-14	09:13:00
1	710	1	0	1	1	1	0	0	0	1	1	1	19.9	962.7	4.7	1702557600	2023-12-14	12:40:00
1	711	1	0	1	1	1	0	0	0	1	1	1	19.9	972.1	3.6	1702599055	2023-12-15	00:10:00
1	712	1	0	1	1	1	0	0	0	1	1	1	19.9	977.2	3.4	1702632441	2023-12-15	09:27:00

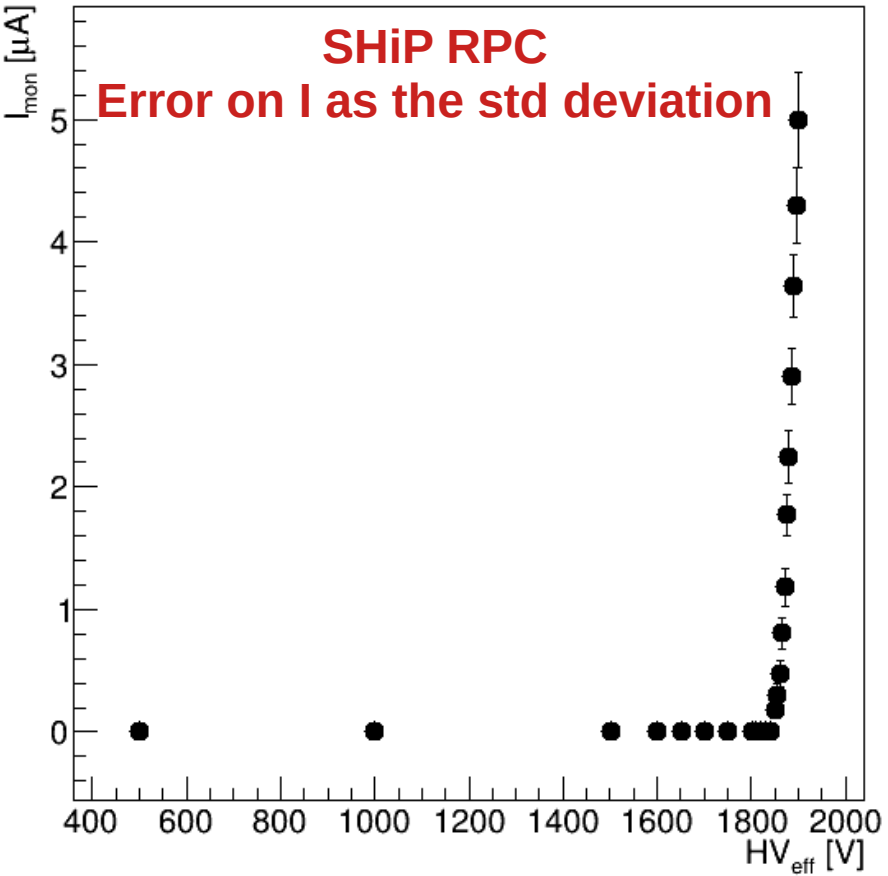
Caveats

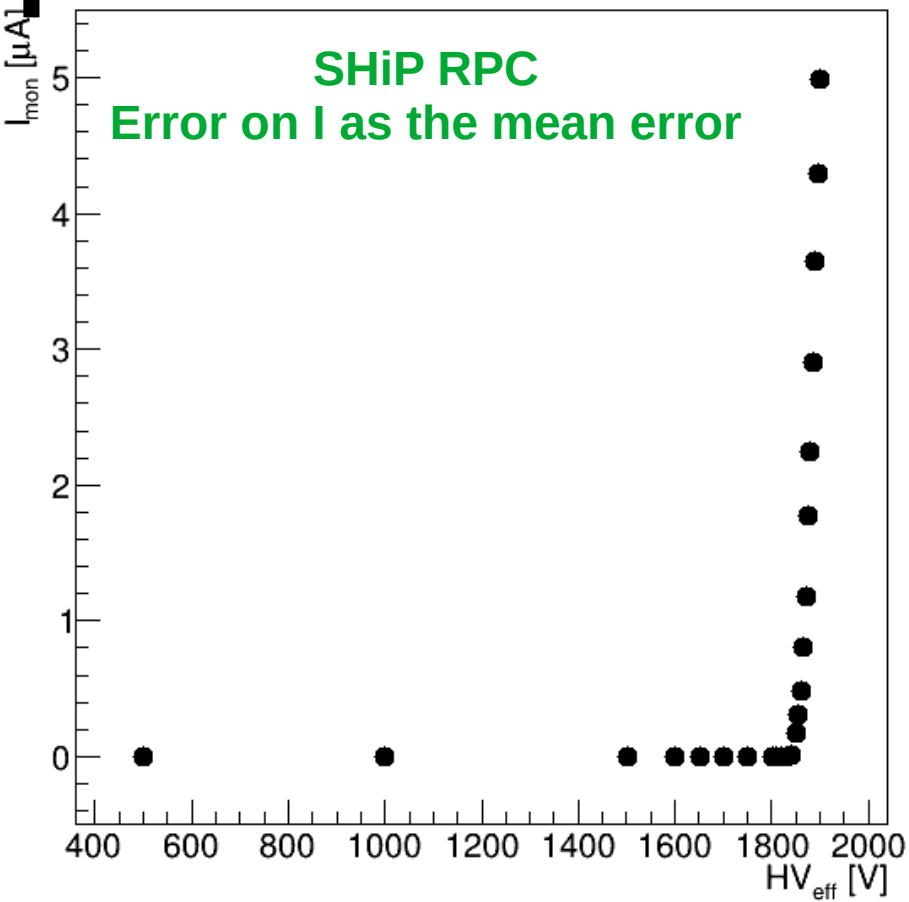
- We mesure HV/current for 4 minutes per HV point
  → We have quite some variability in the measurements
  → What is the best way to take this into account? I've tried both the standard deviation (σ from the histogram directly) and the error on the mean (σ/√N wherw N is the number of samples)
  → Both possibilities taken into account in the following

- The process to find the minimum value of chi square almost always returns the third-last point
  → Reduced fit range to the last 4 HV points, can we improve it?
  → I have tried to use also the last 5 HV points to see what changes

- Only errors on the fit parameters are considered in the resistivity calculation
  → i.e. no errors on the detector area/thickness

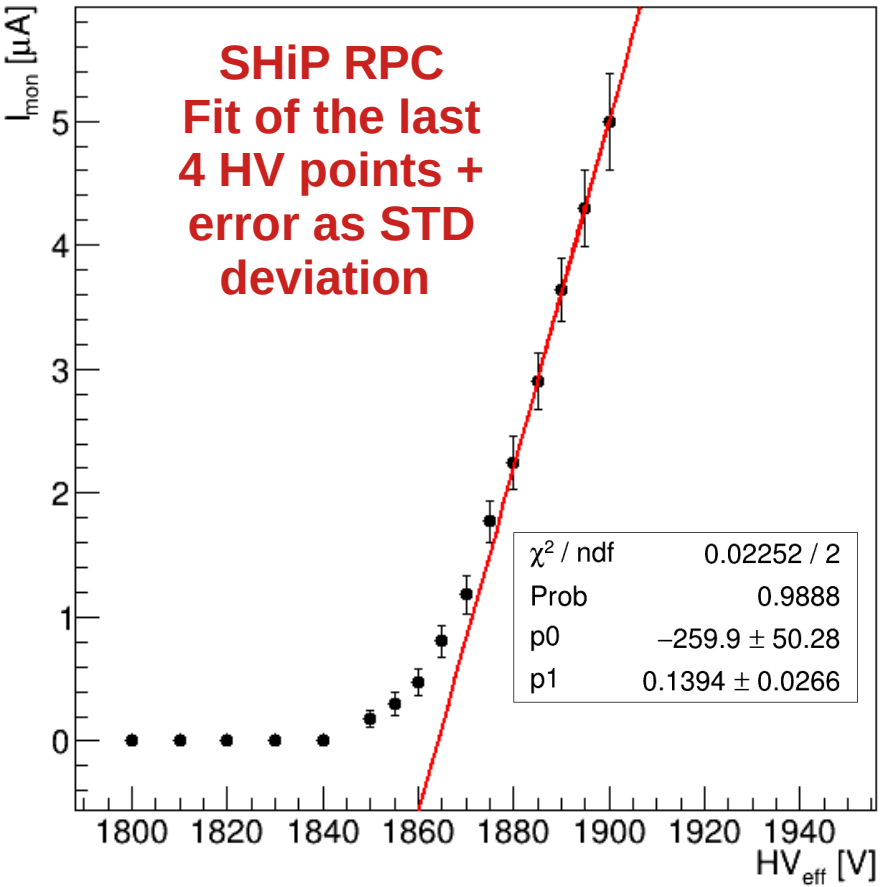
Examples - 1

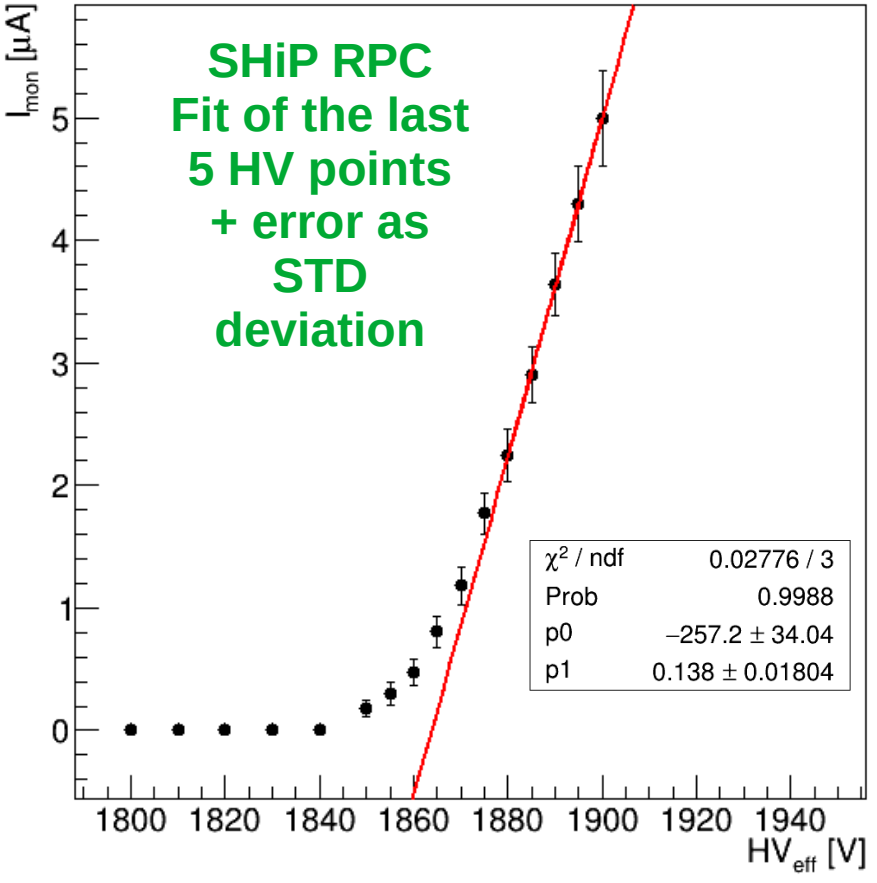




- Much smaller error if we consider the error on the mean
  → This will translate to very small errors on the computed resistivity

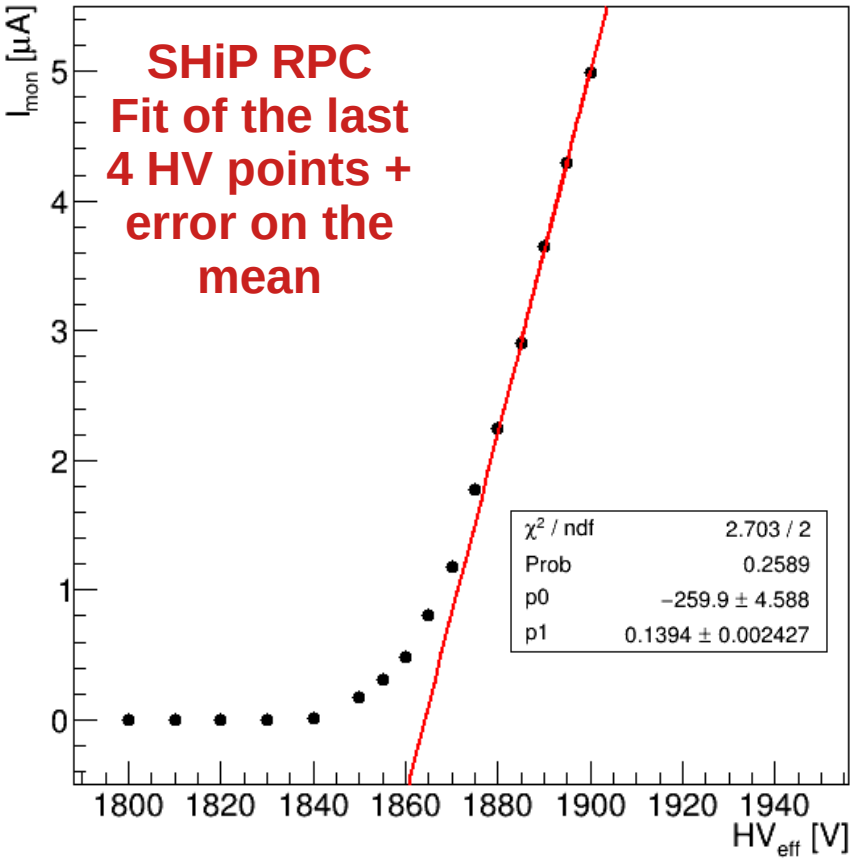
Examples - 2

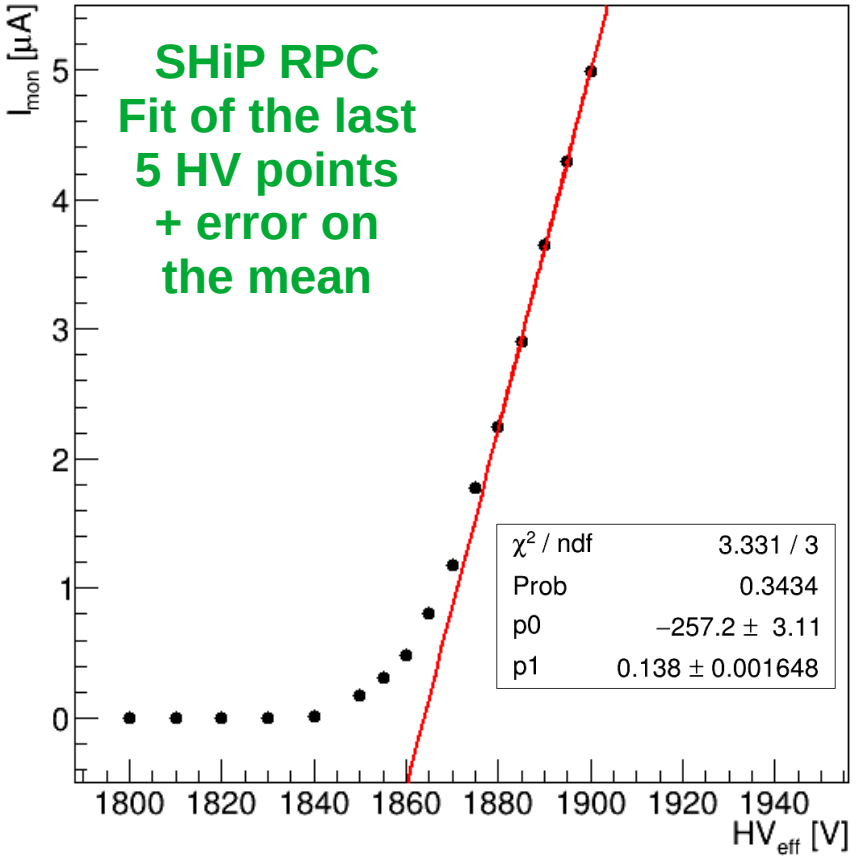




- If we consider STD deviation as the error on the current there is not much change in the fit results

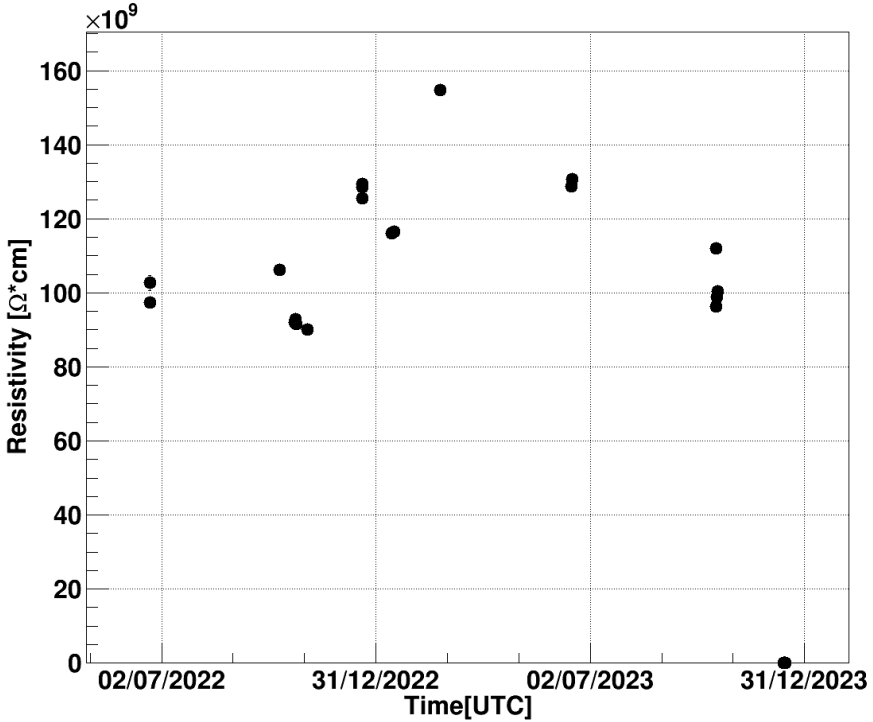
Examples - 3





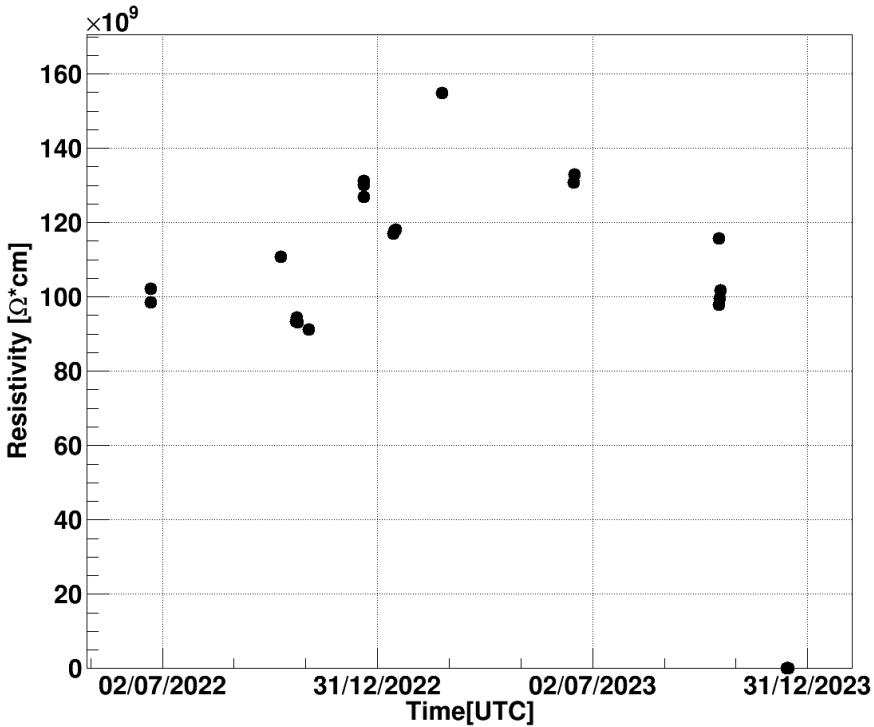
- If we consider the error on the mean things change slightly in this example but more significantly in other cases (other detectors or other runs for SHiP)
  → Next slides for all the trends in time

Resistivity trend in time - ALICE

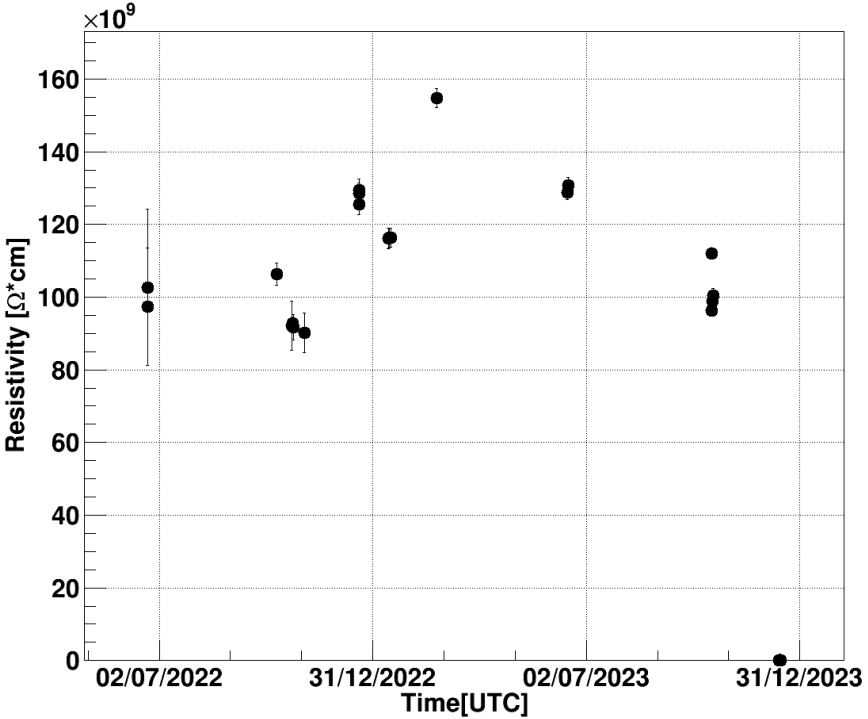


ALICE RPC
Fit of the last 4 HV points + error on the mean

ALICE RPC
Fit of the last 5 HV points + error on the mean

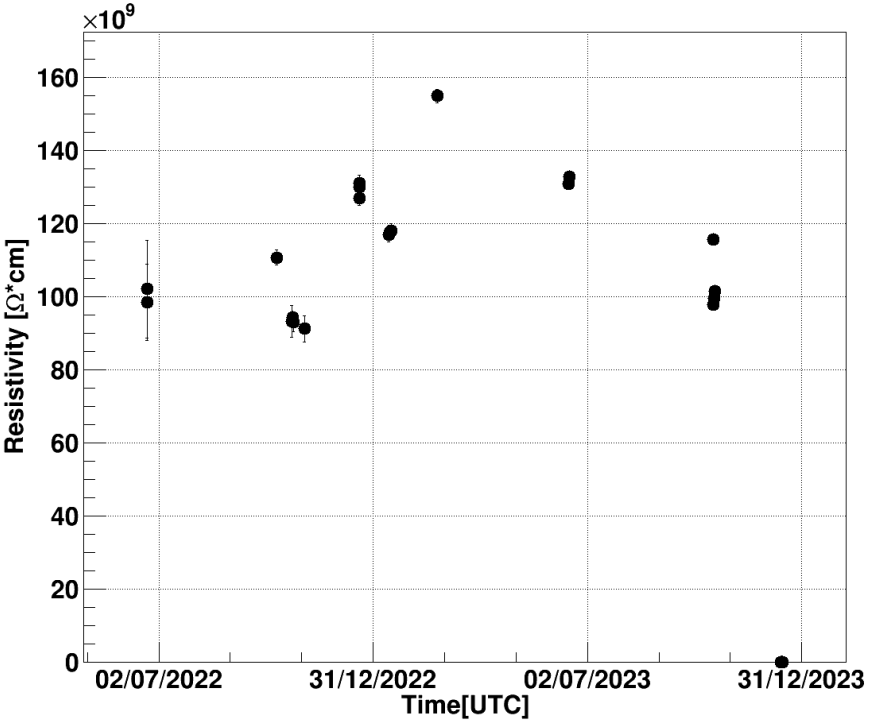


Resistivity trend in time - ALICE

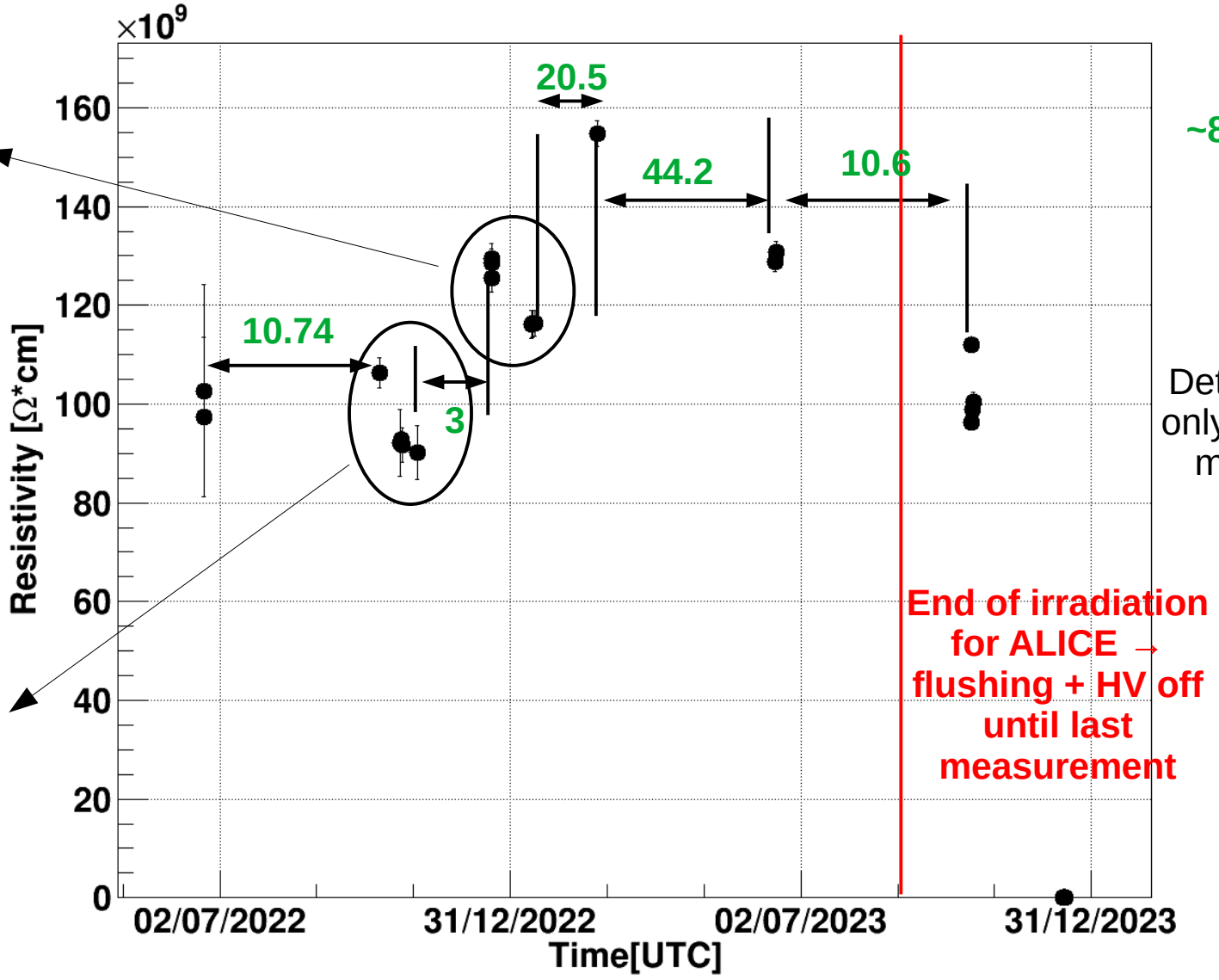


ALICE RPC
Fit of the last 4 HV points + STD deviation

ALICE RPC
Fit of the last 5 HV points + STD deviation



ALICE



~87 mC/cm²

Before and after the Christmas break (no gas and no irradiation)

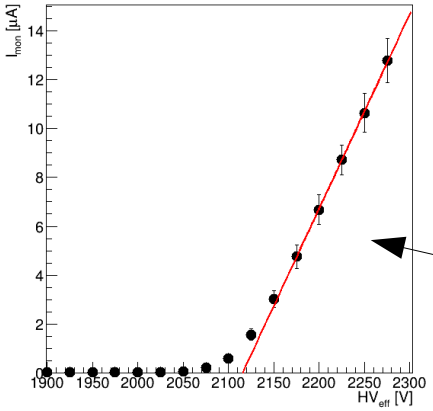
Numbers in between points = integrated charge in mC/cm²

No irradiation (but gas flushing)

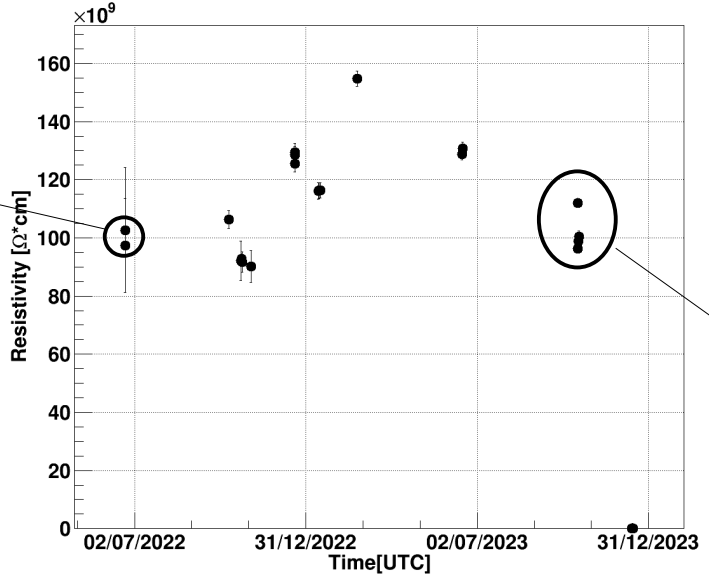
Detector excluded only from the latest measurements

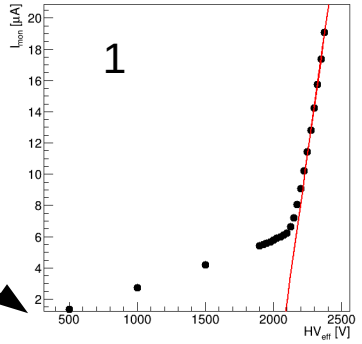
End of irradiation for ALICE → flushing + HV off until last measurement

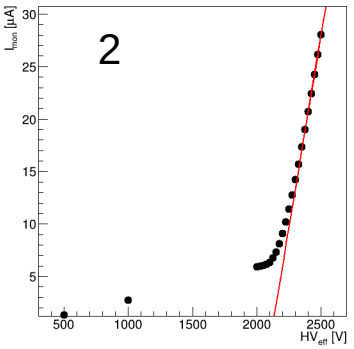
Resistivity trend in time - ALICE

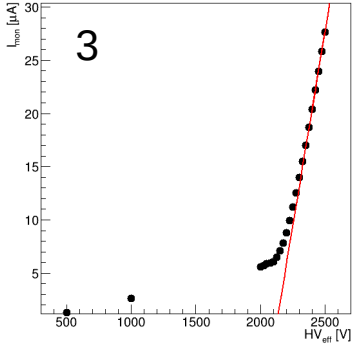


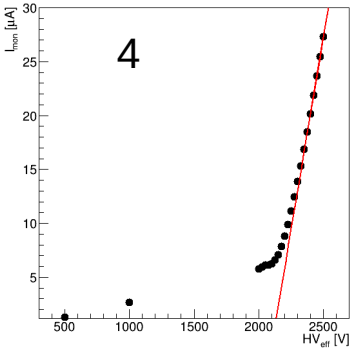
Large errors on the currents visible also in the resistivity





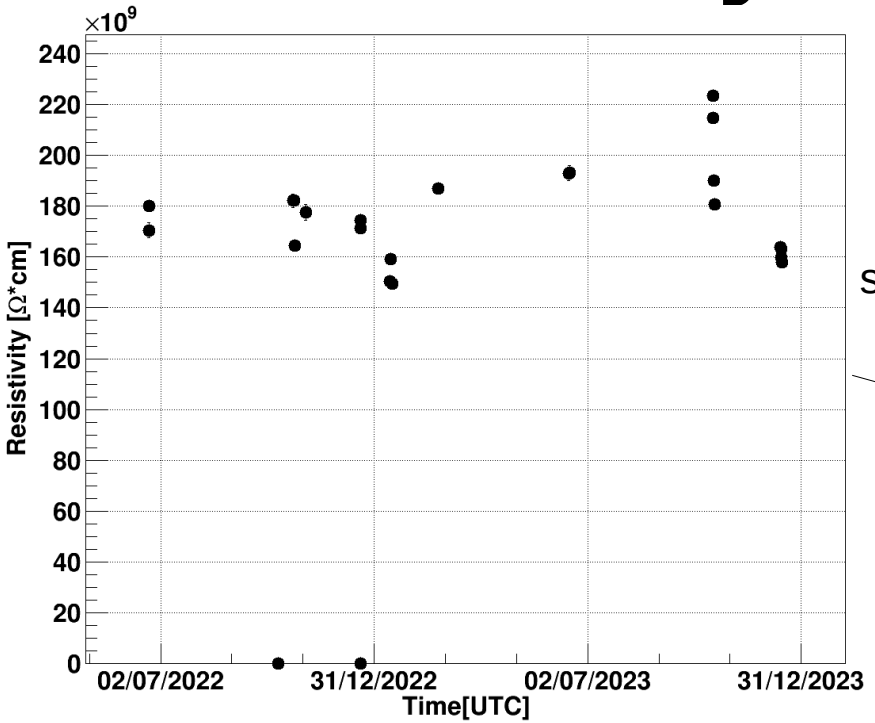






Added one HV point from scan 1 to other 3, could explain the variation observed

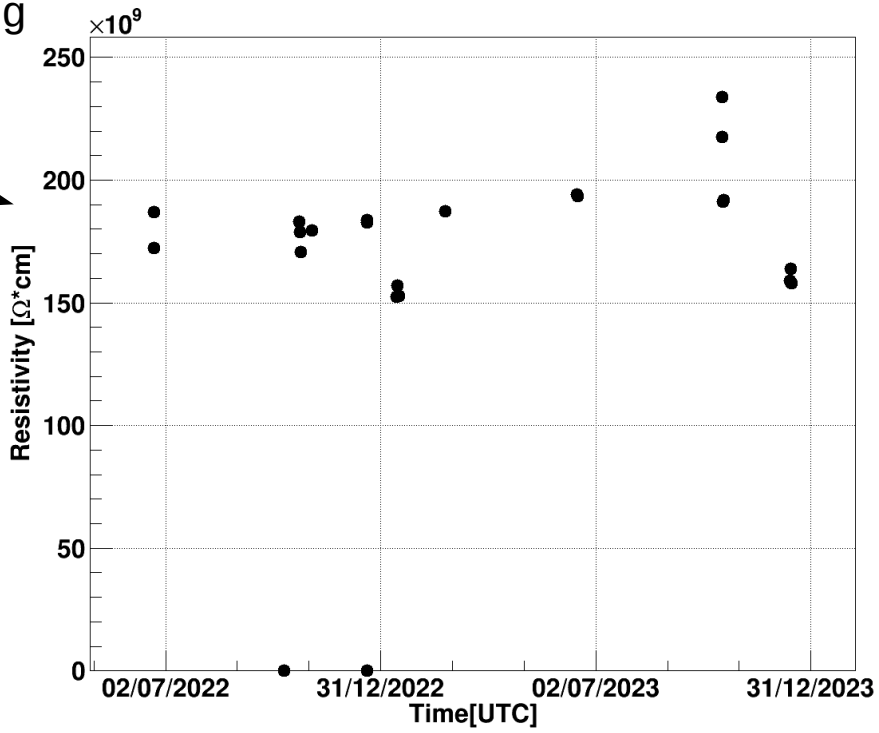
Resistivity trend in time - SHiP



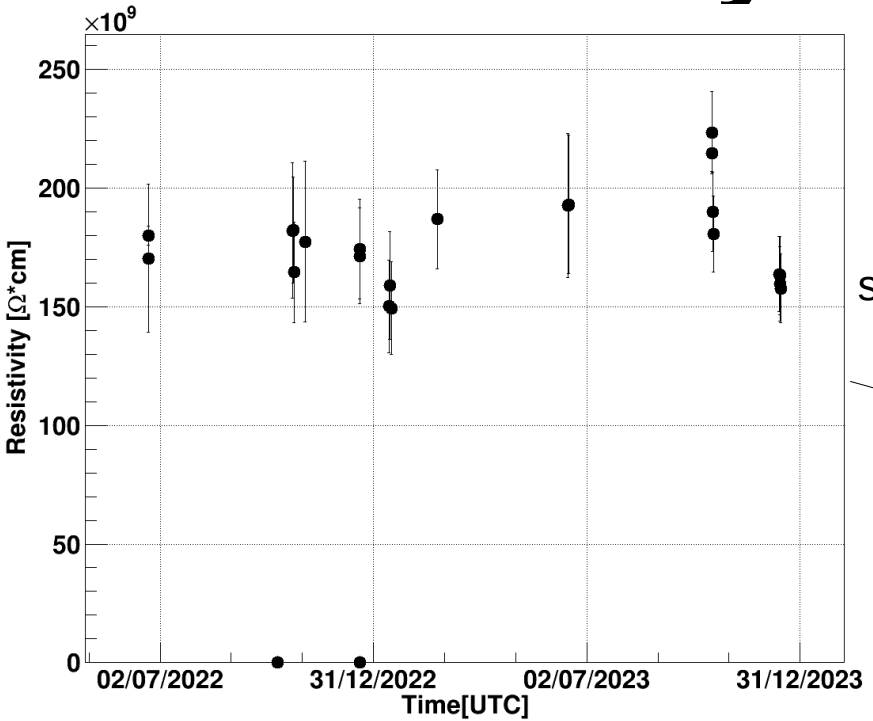
SHiP RPC
Fit of the last 4 HV points + error on the mean

Measurements seem to be getting closer to each other

SHiP RPC
Fit of the last 5 HV points + error on the mean



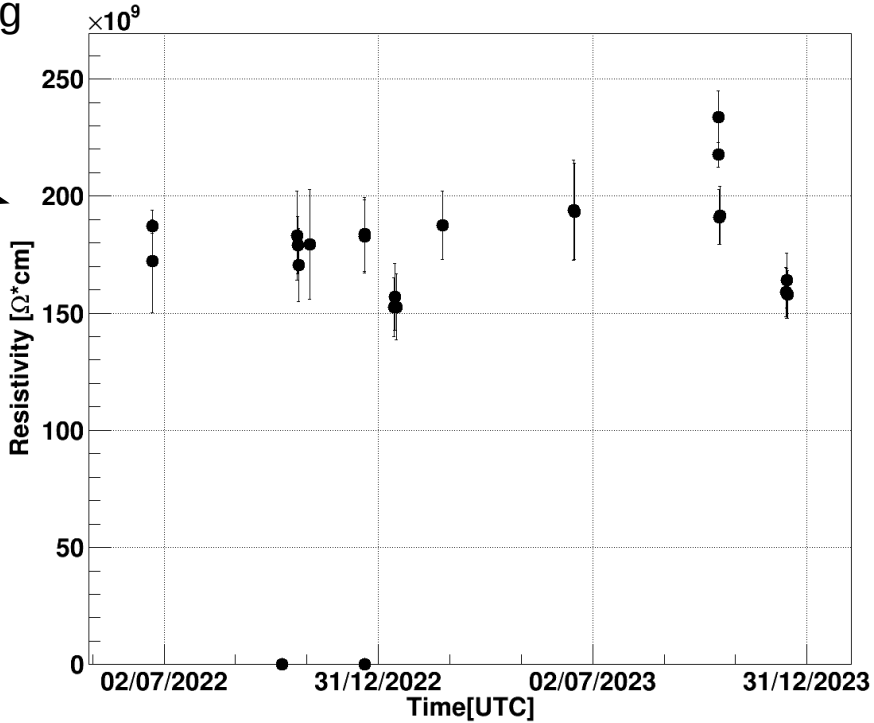
Resistivity trend in time - SHiP



SHiP RPC
Fit of the last 4 HV points + STD deviation

Measurements seem to be getting closer to each other

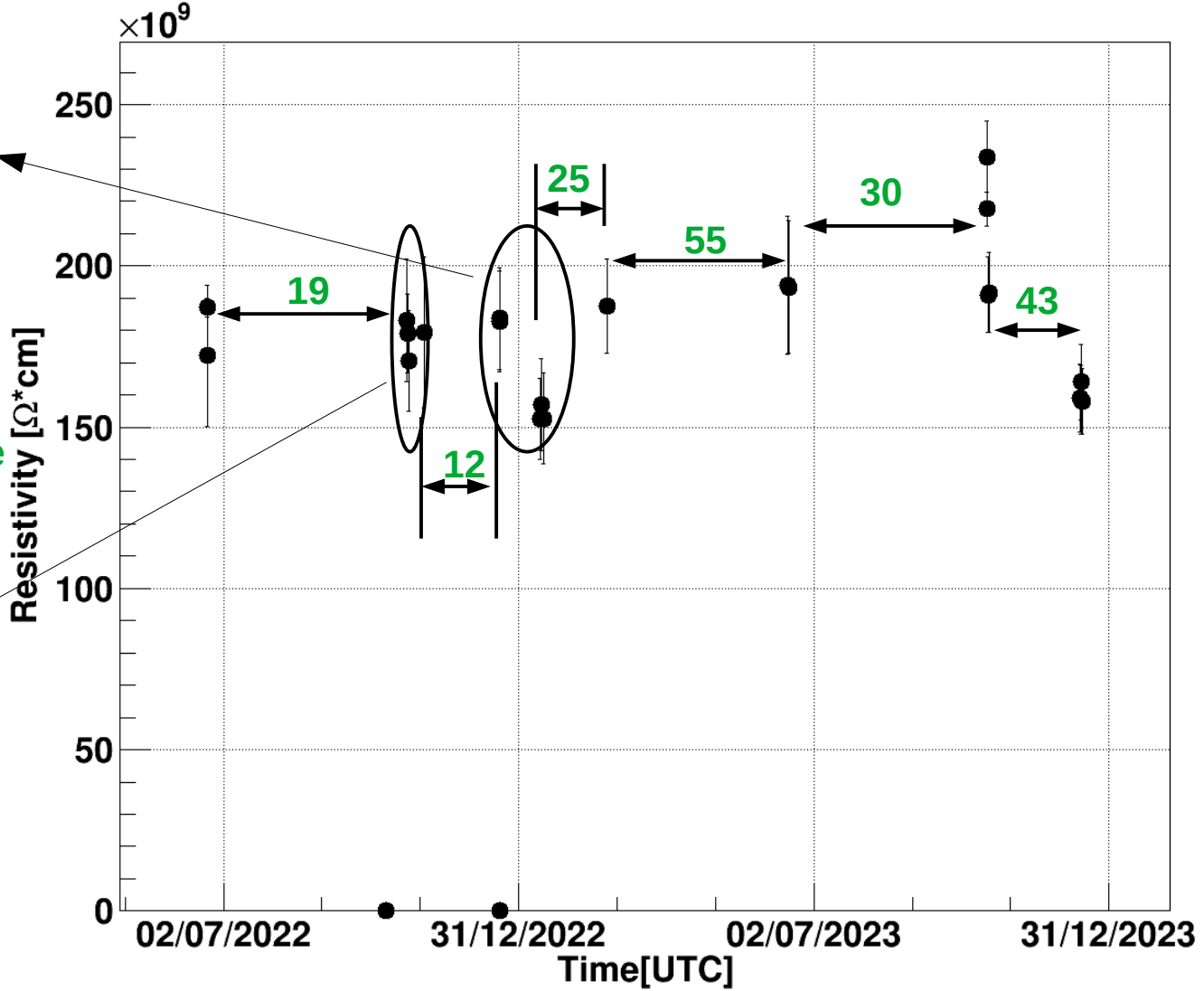
SHiP RPC
Fit of the last 5 HV points + STD deviation



Before and after the Christmas break (no gas and no irradiation)

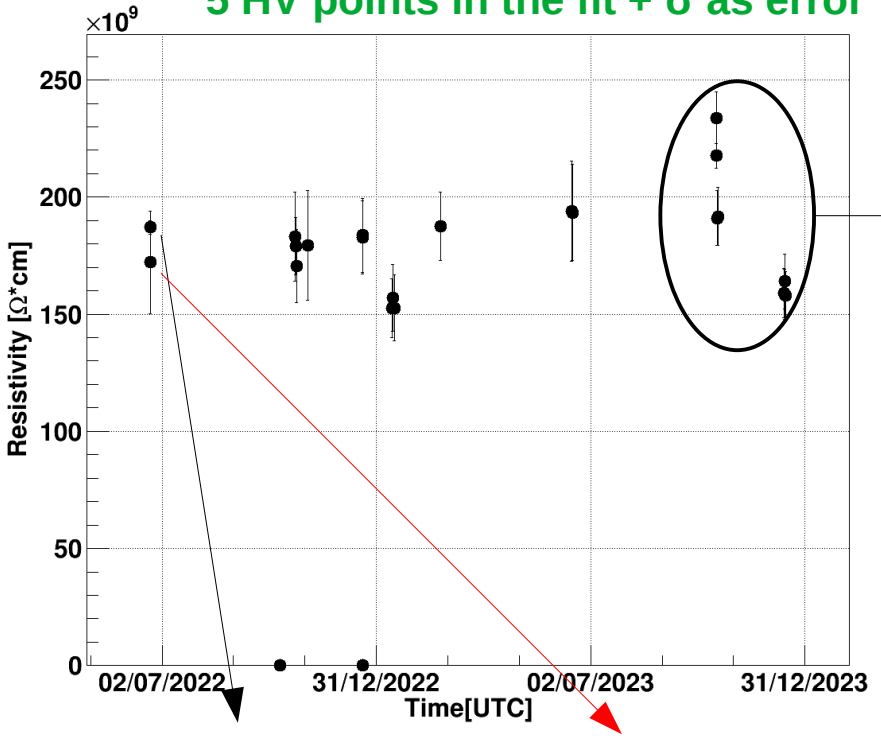
Numbers in between points = integrated charge in mC/cm²

No irradiation but flushing



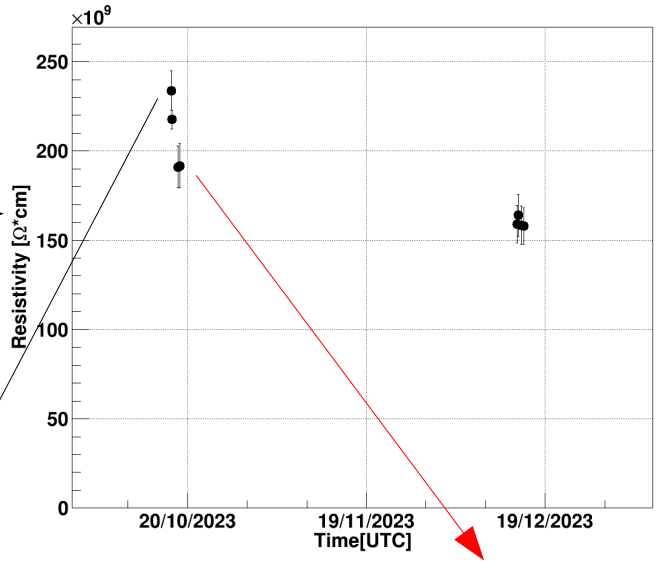
~ 185 mC/cm²

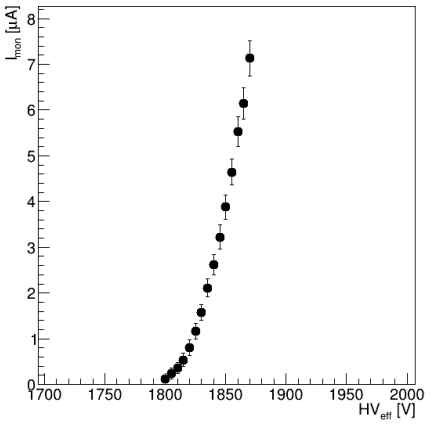
5 HV points in the fit + σ as error

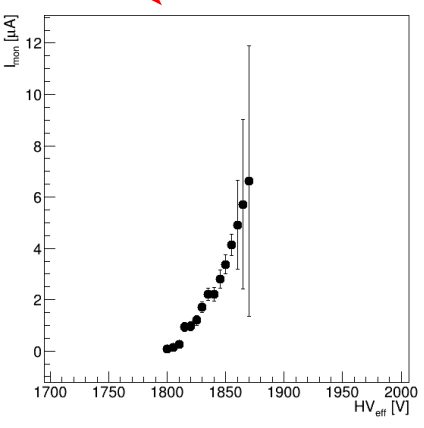


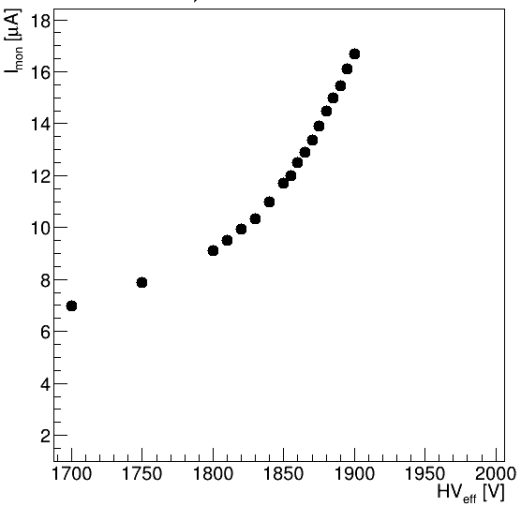
First two measurements farther apart and others closer

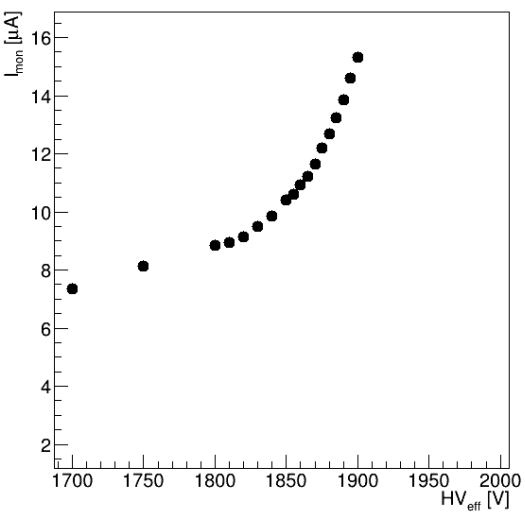
→ maybe effect of the gas?



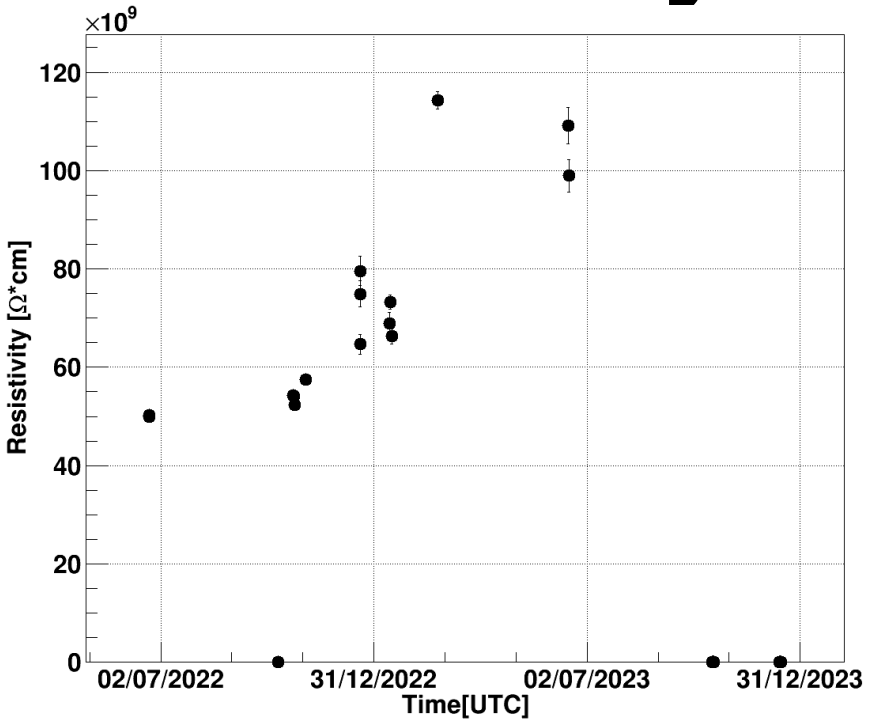






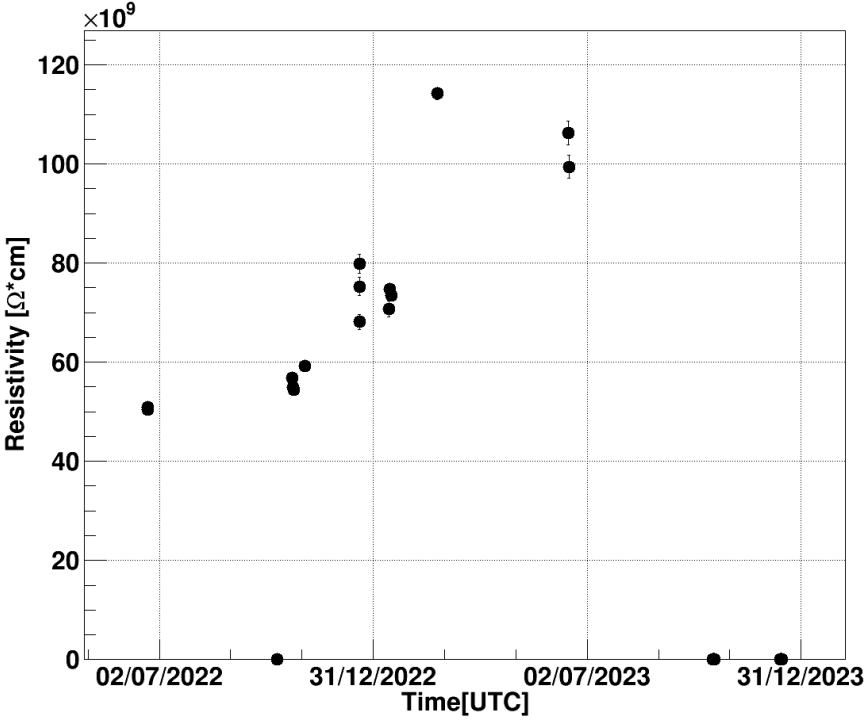


Resistivity trend in time - ATLAS

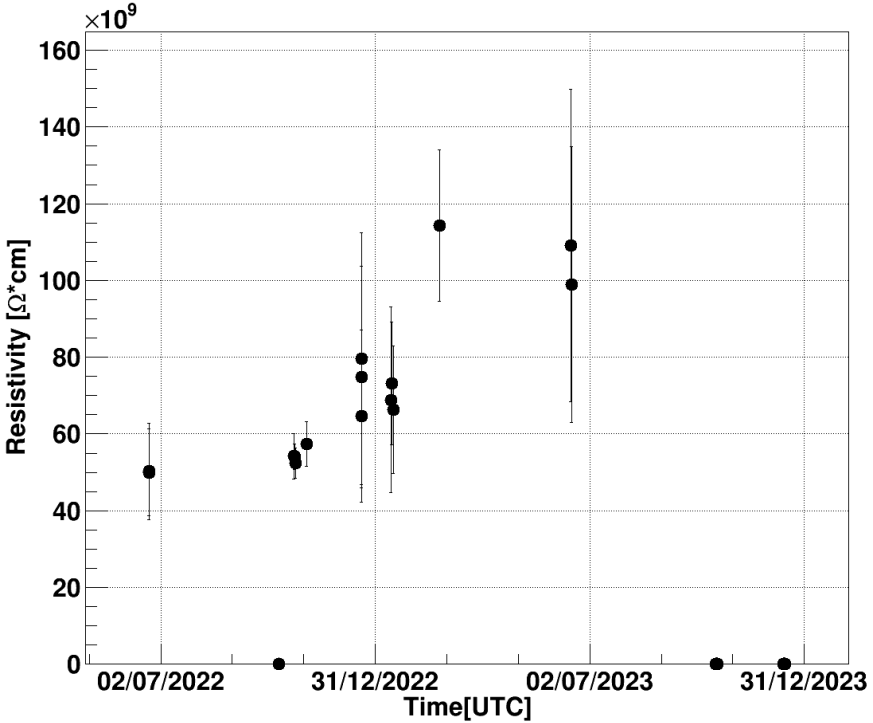


ATLAS RPC
Fit of the last 4 HV points + error on the mean

ATLAS RPC
Fit of the last 5 HV points + error on the mean

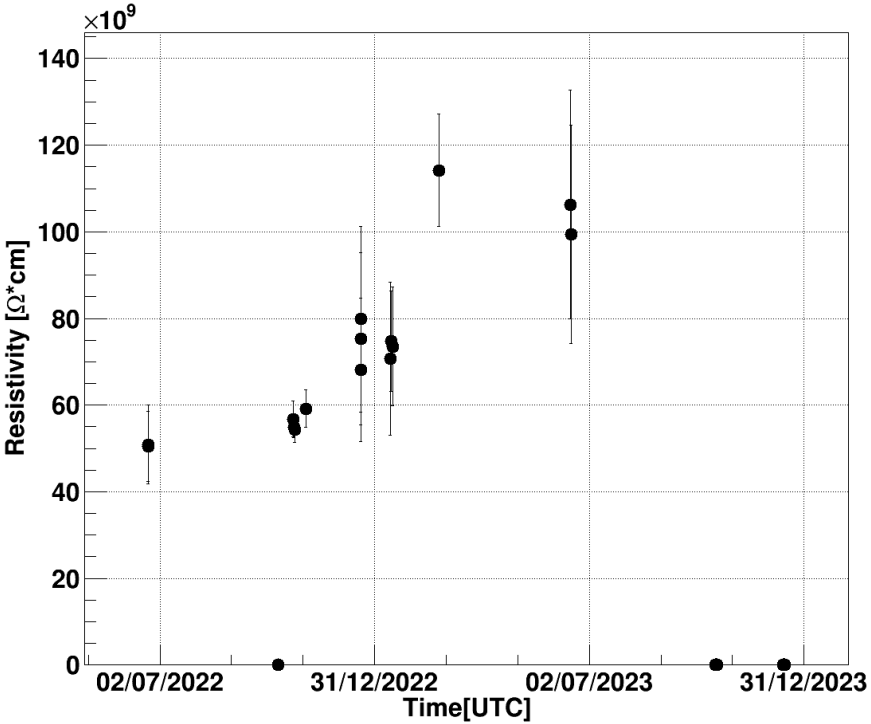


Resistivity trend in time - ATLAS



ATLAS RPC
Fit of the last 4 HV points + STD deviation

ATLAS RPC
Fit of the last 5 HV points + STD deviation

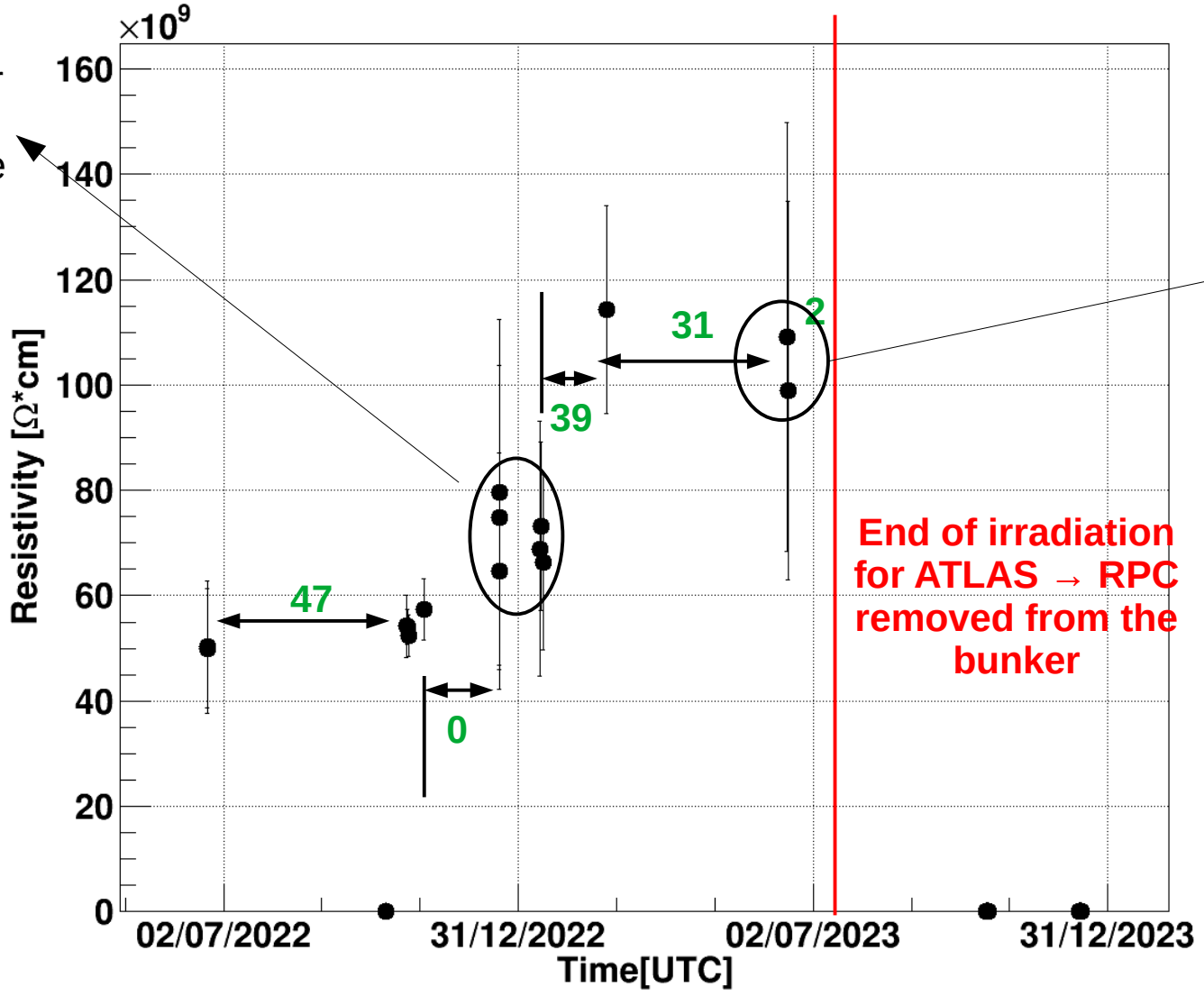


ATLAS

~ 120 mC/cm²

Before and after the Christmas break (no visible change)

Numbers in between points = integrated charge in mC/cm²

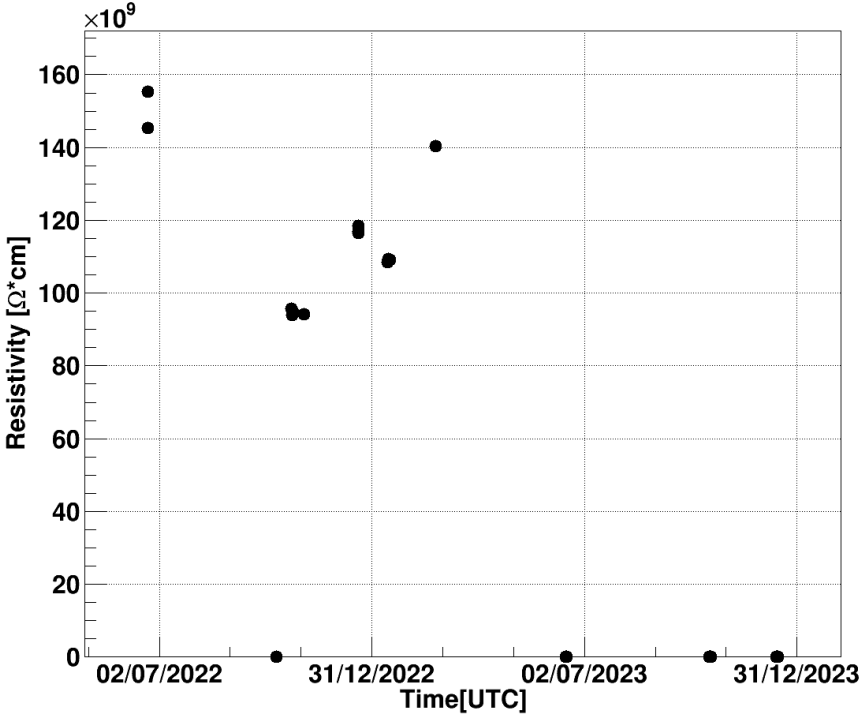


End of irradiation for ATLAS → RPC removed from the bunker

Large oscillations in the absorbed current (also in other measurements)

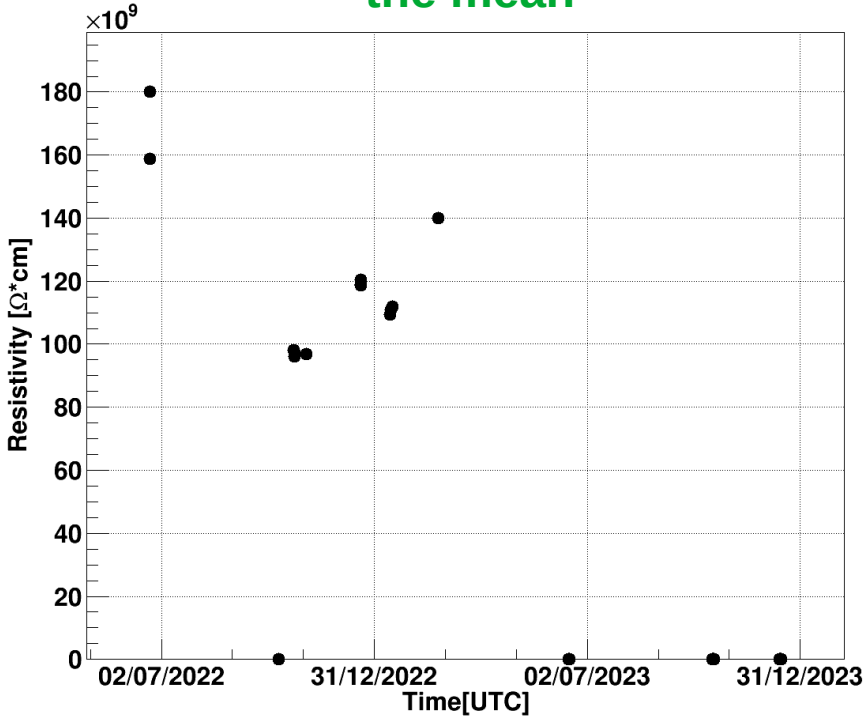
Longer measuring time needed?

Resistivity trend in time – EPDT RPC6

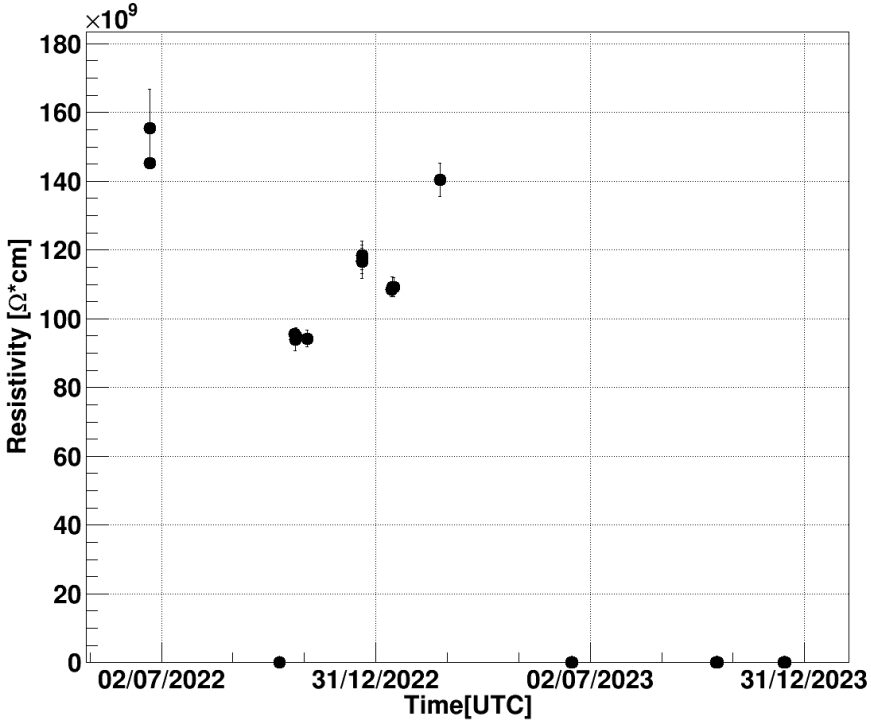


EPDT RPC 6 (OLD)
Fit of the last 4 HV points + error on the mean

EPDT RPC 6 (OLD)
Fit of the last 5 HV points + error on the mean

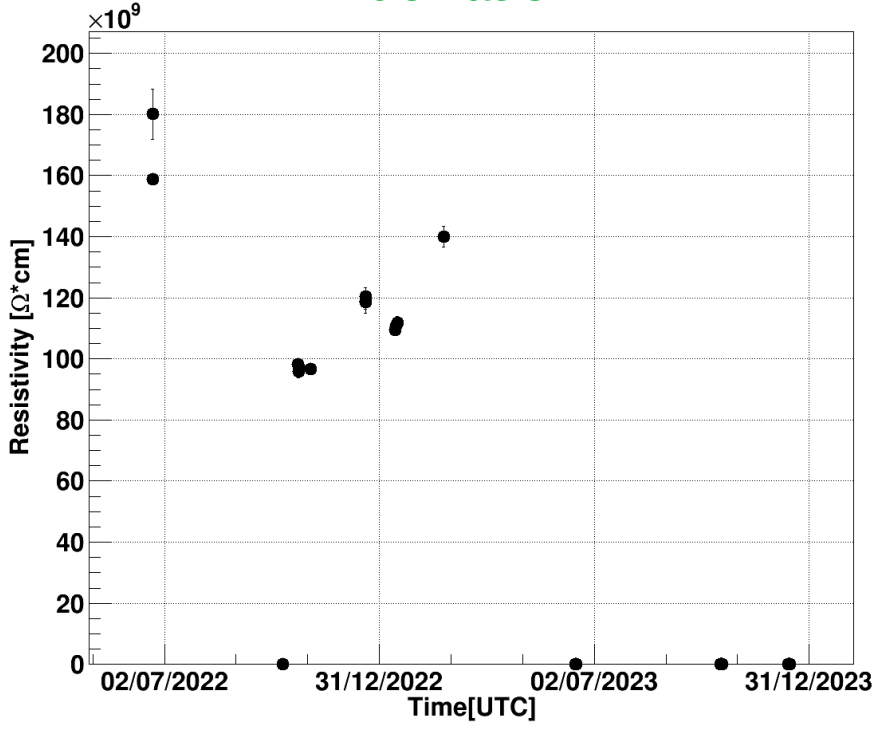


Resistivity trend in time – EPDT RPC6



EPDT RPC 6 (OLD)
Fit of the last 4 HV points + STD deviation

EPDT RPC 6 (OLD)
Fit of the last 5 HV points + STD deviation

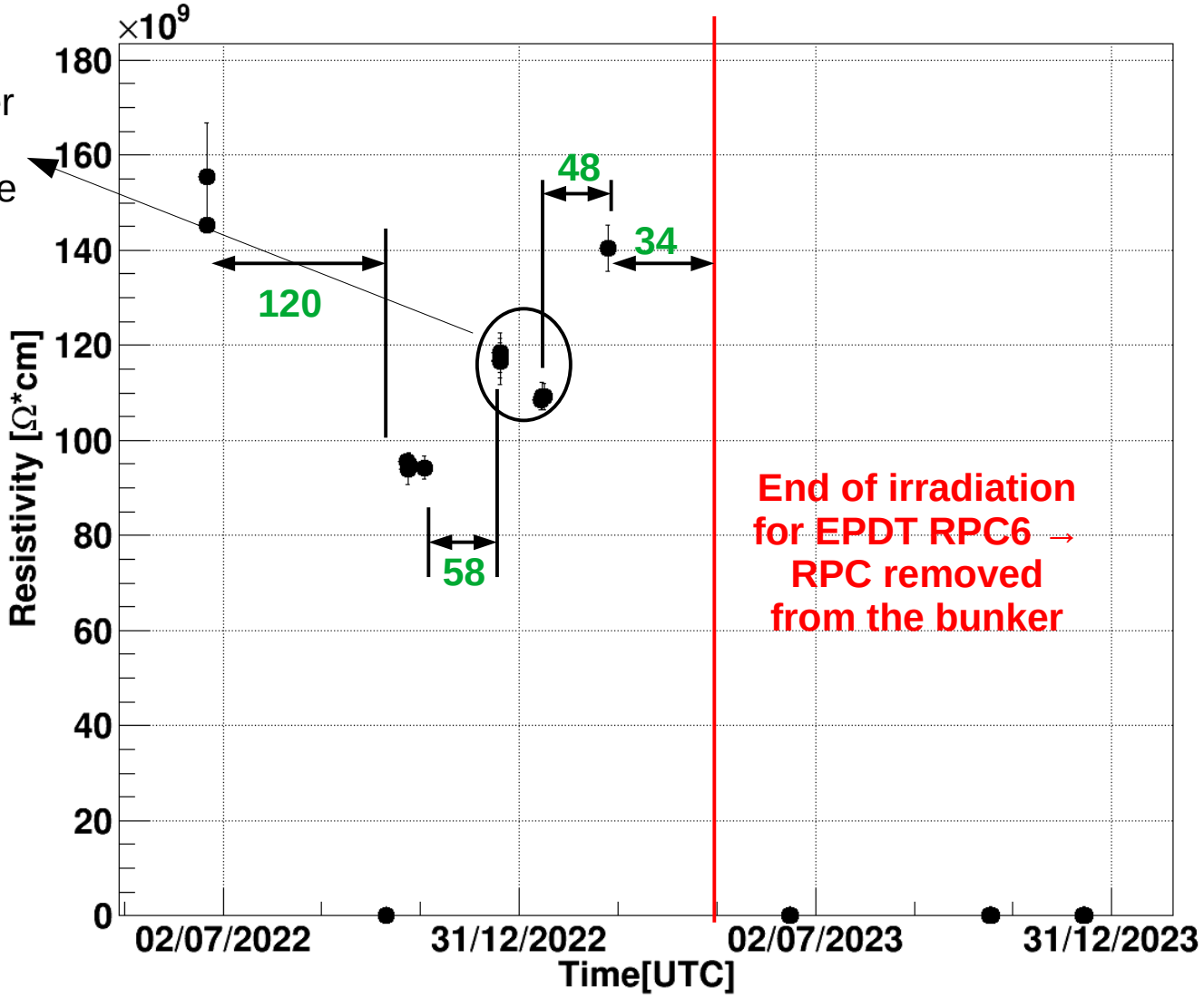


EPDT RPC6

~ 260 mC/cm²

Before and after the Christmas break (no visible change)

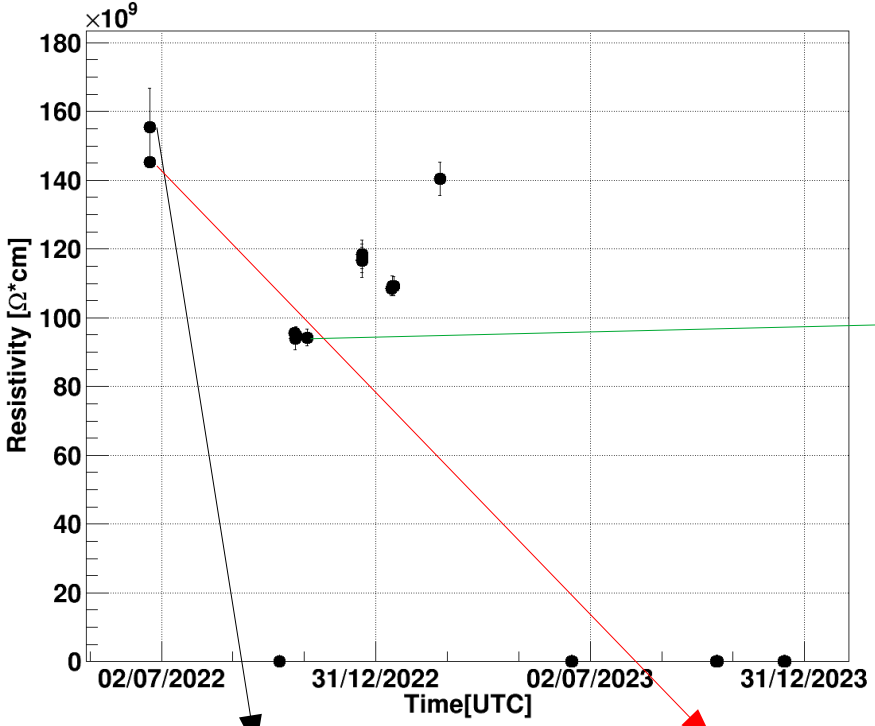
Numbers in between points = integrated charge in mC/cm²

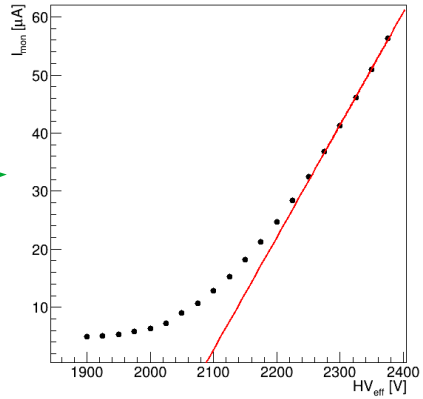


5 HV points in the fit + σ as error

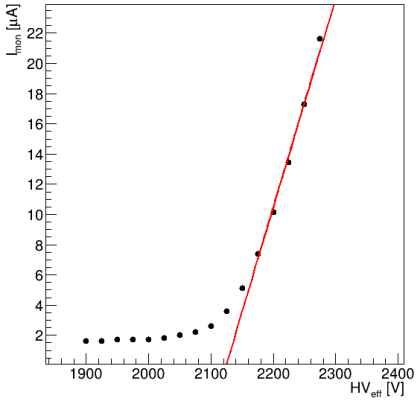
EPDT RPC6

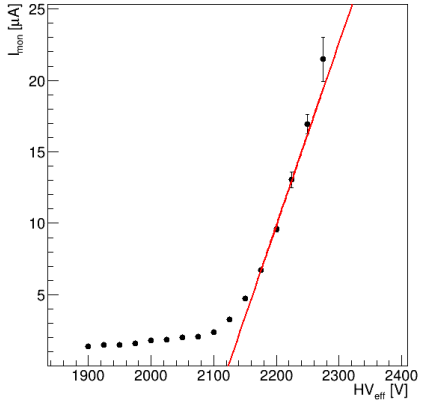
~ 260 mC/cm²





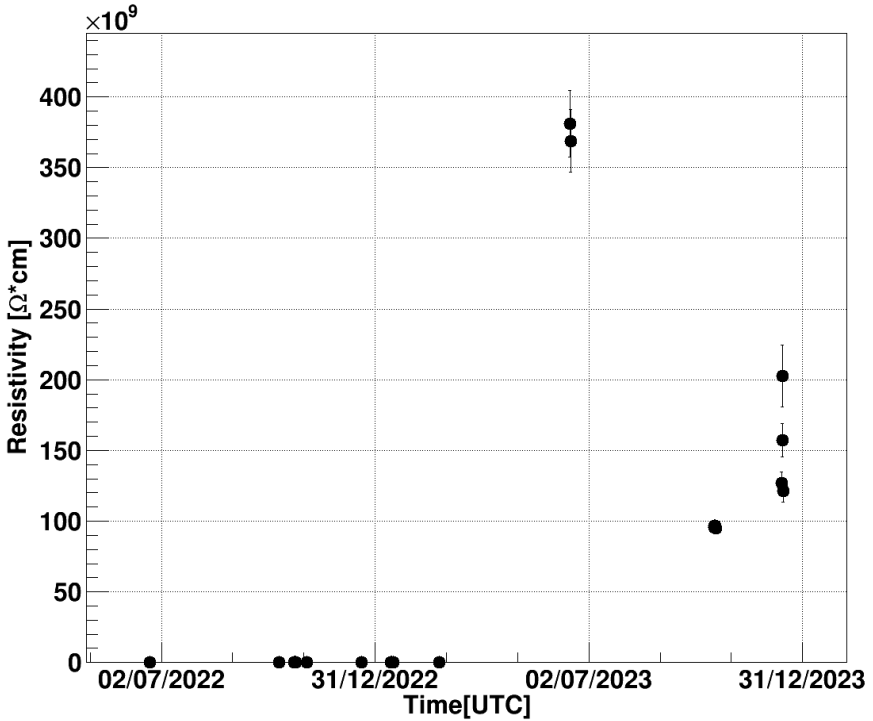
First two scans were taken at too low voltages? Fit not trustable?





Resistivity increase seems to be related to irradiation?

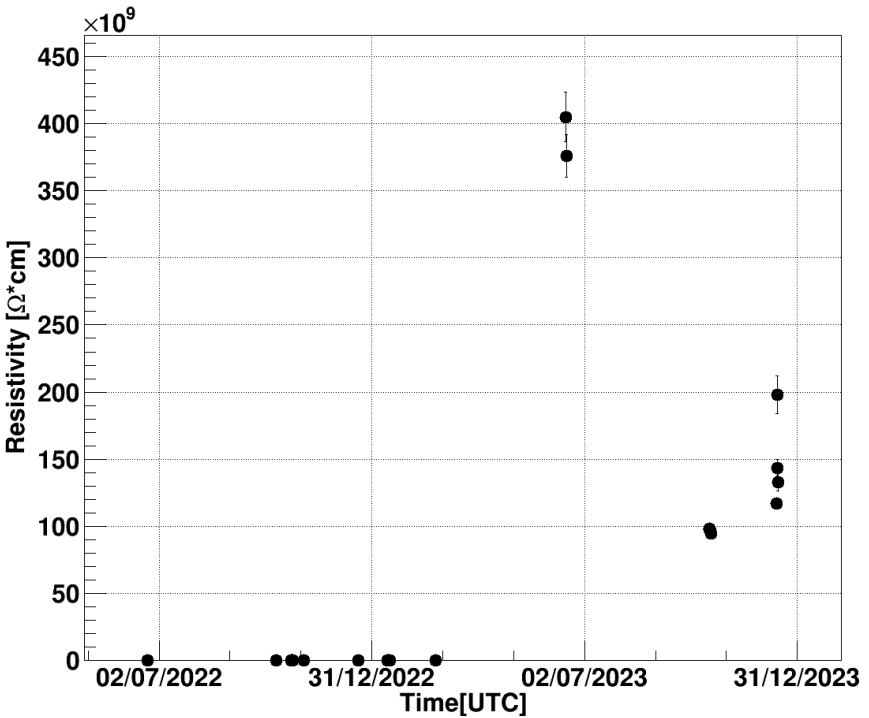
Resistivity trend in time – EPDT RPC25



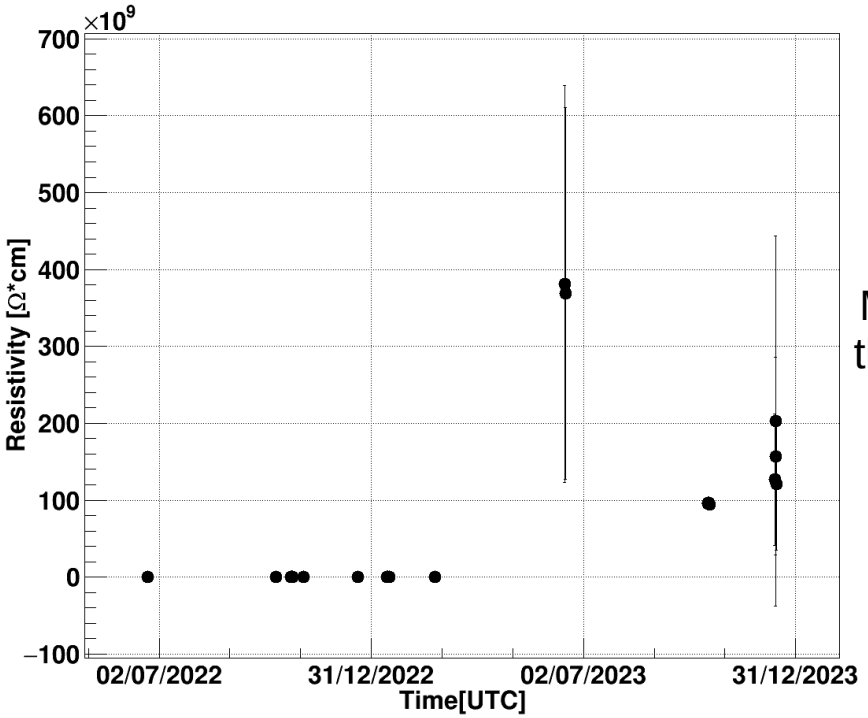
EPDT RPC 25 (NEW)
Fit of the last 4 HV points + error on the mean

Variability in the measurements

EPDT RPC 25 (NEW)
Fit of the last 5 HV points + error on the mean



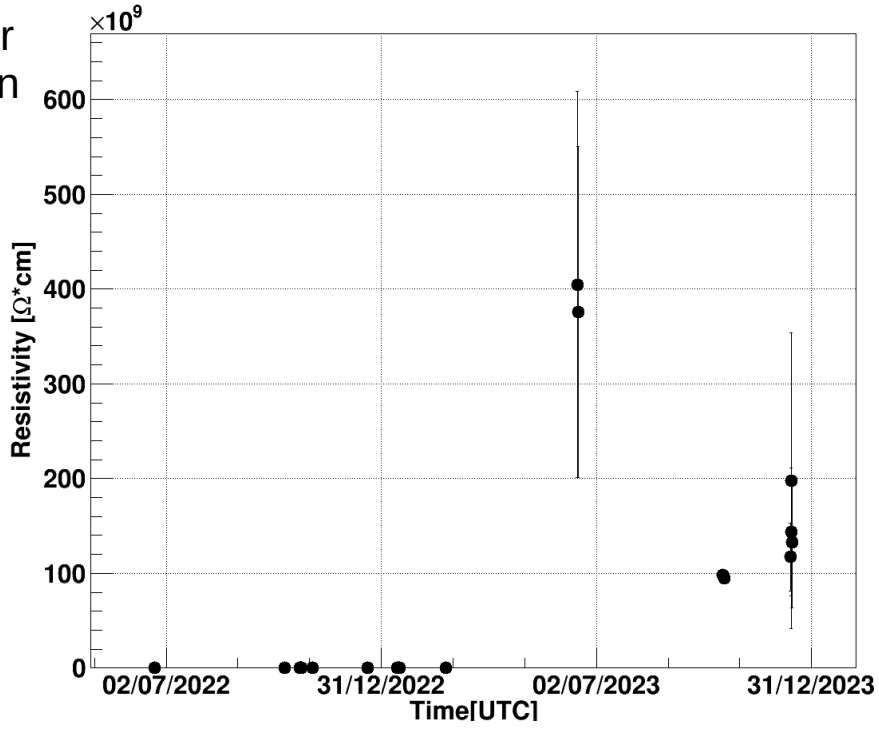
Resistivity trend in time – EPDT RPC25



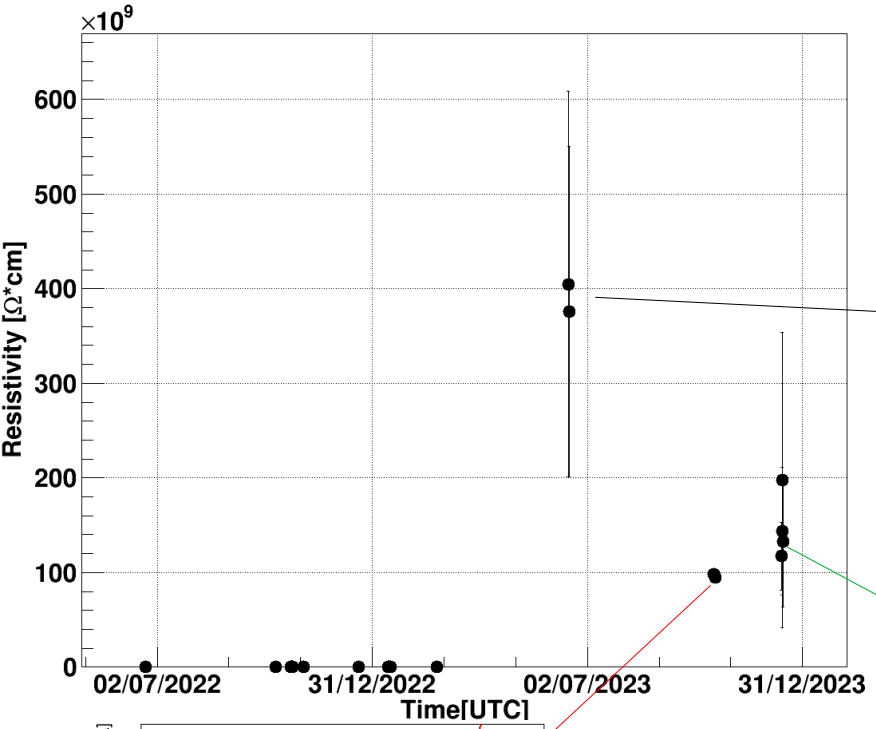
EPDT RPC 25 (NEW)
Fit of the last 4 HV points + STD deviation

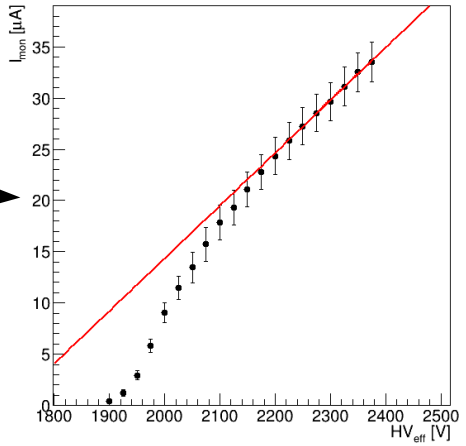
Much bigger error than if the error on the mean is considered

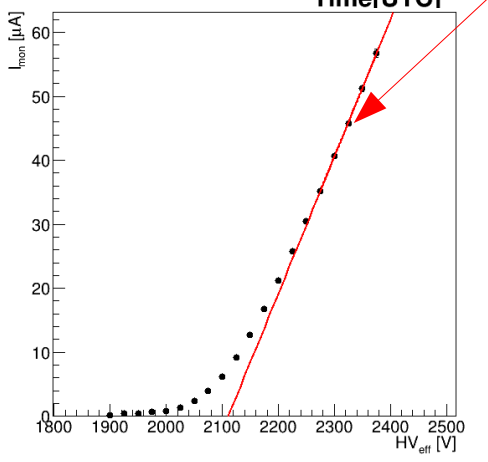
EPDT RPC 25 (NEW)
Fit of the last 5 HV points + STD deviation

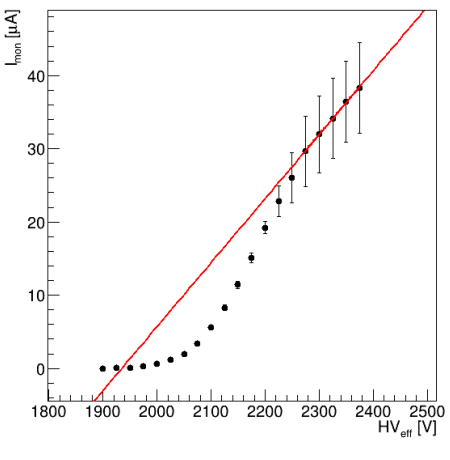


EPDT RPC 25 (NEW)



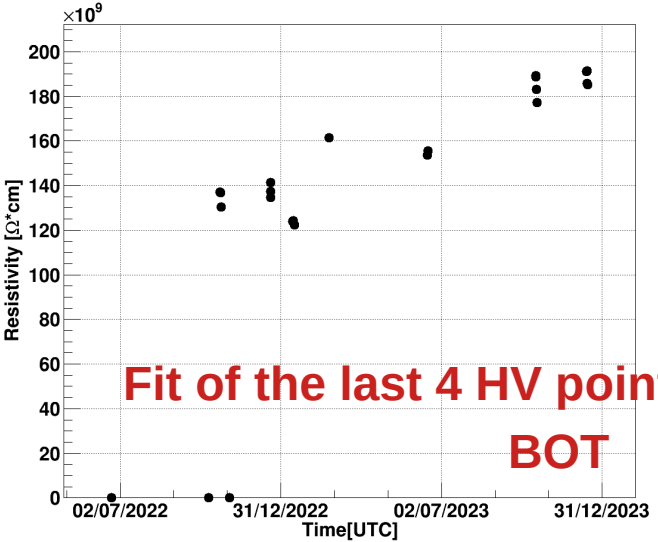






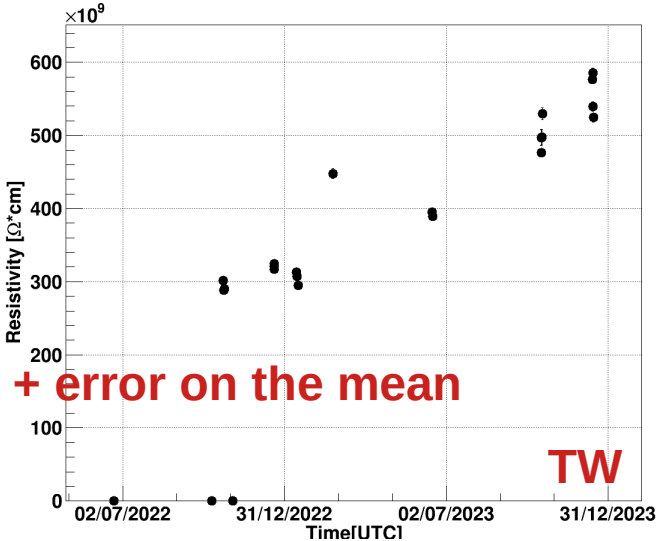
Shape of the curve changes a lot → Not yet analyzed aging of this RPC, **to be done**

Resistivity trend in time - RE11

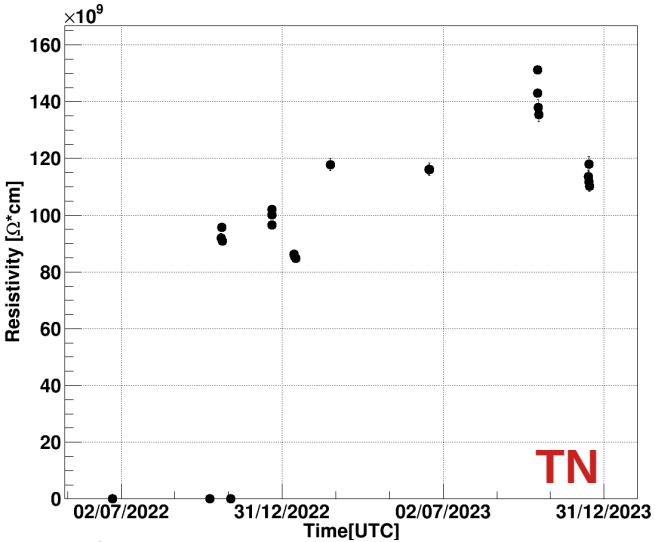


Fit of the last 4 HV points + error on the mean

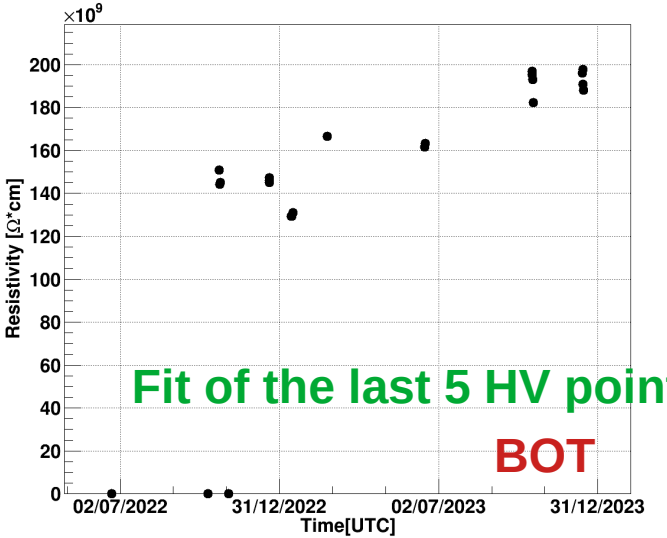
BOT



TW

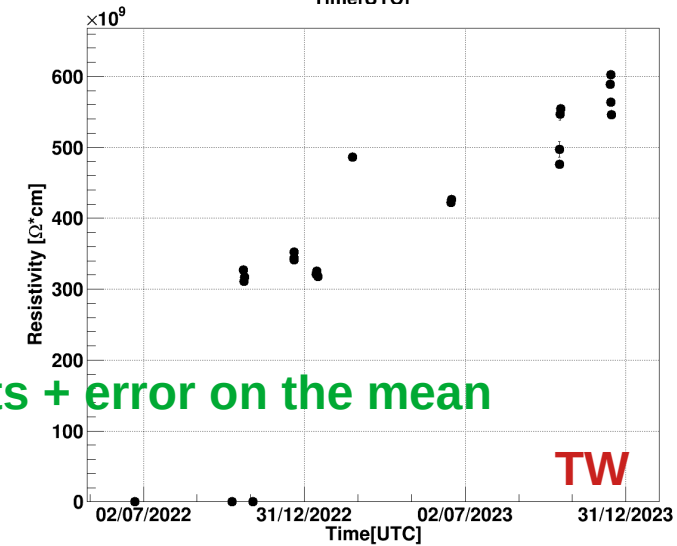


TN

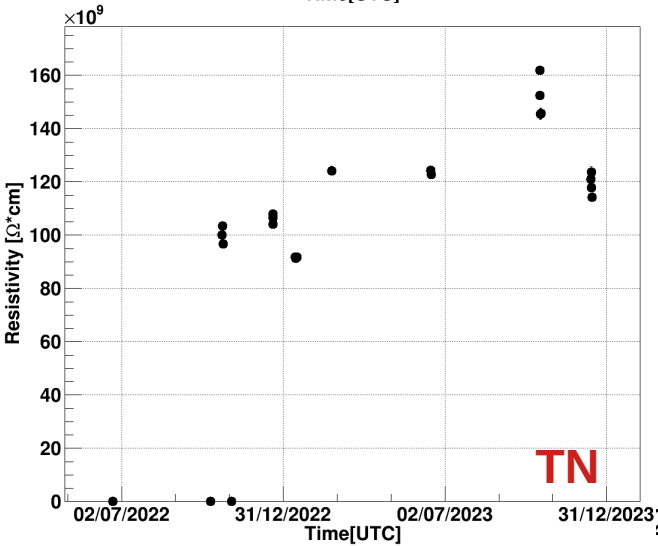


Fit of the last 5 HV points + error on the mean

BOT

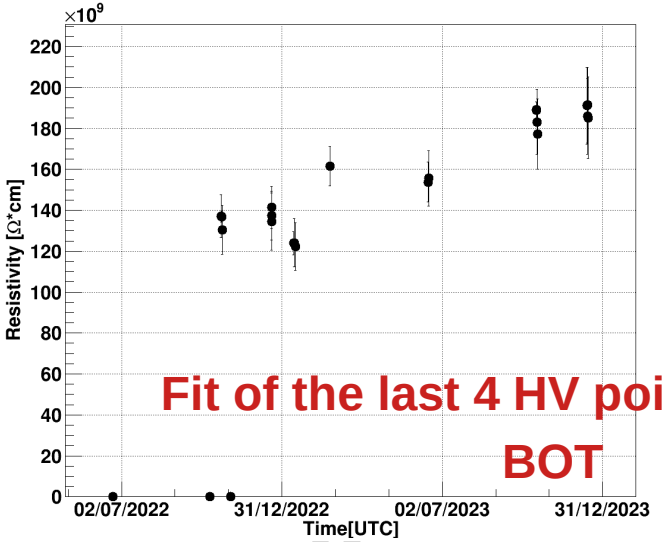


TW



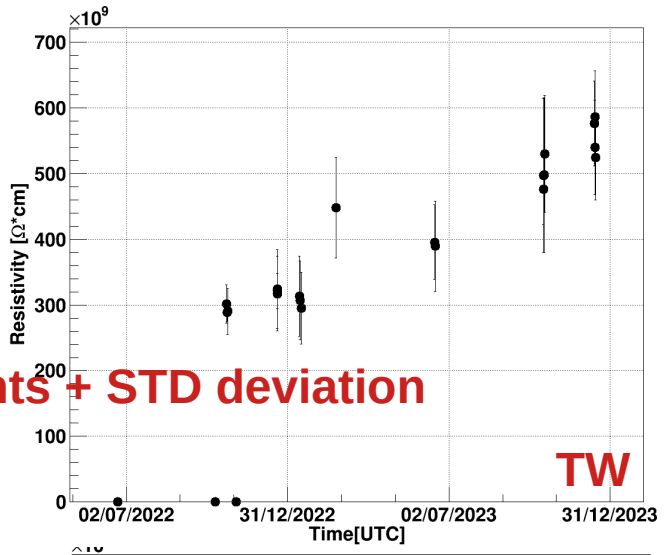
TN

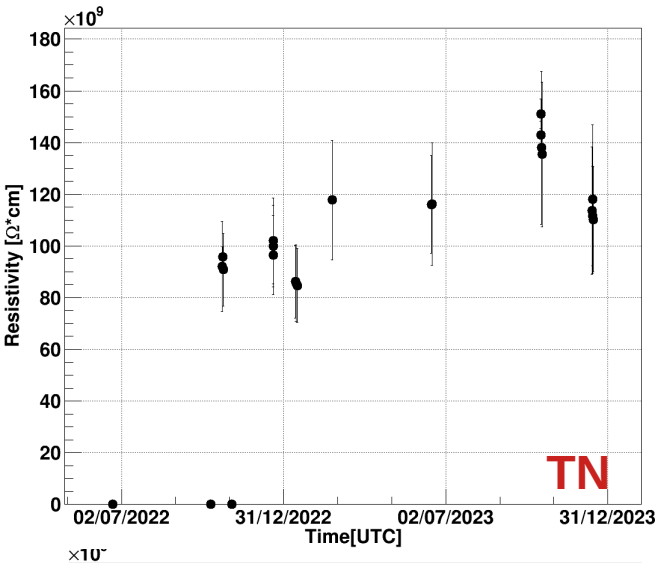
Resistivity trend in time - RE11

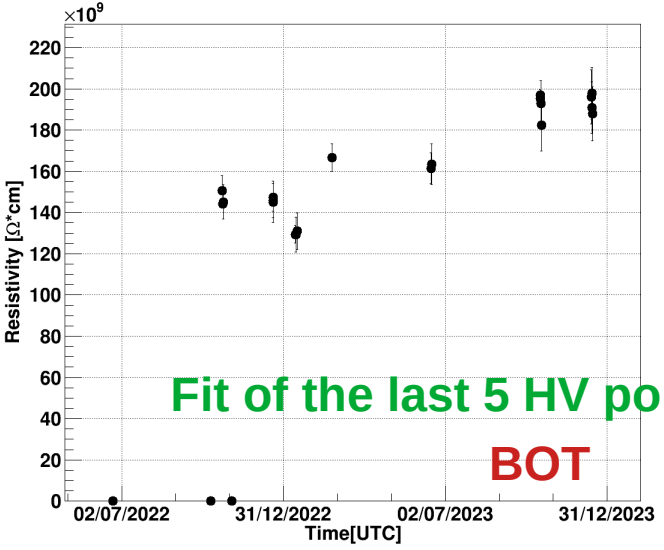


Fit of the last 4 HV points + STD deviation

BOT

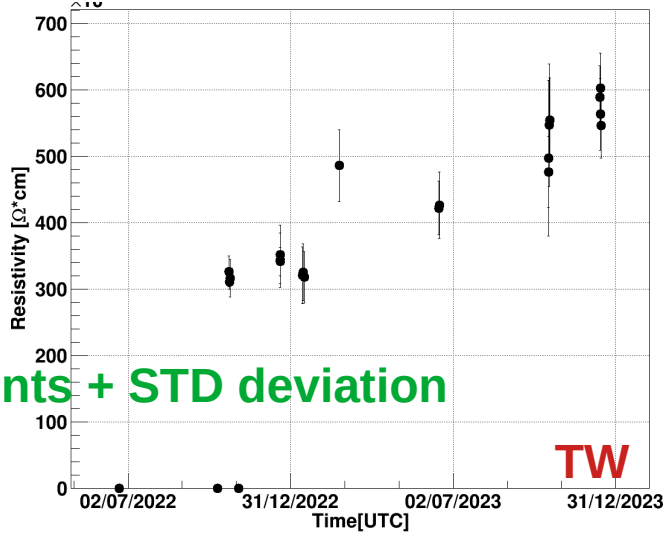


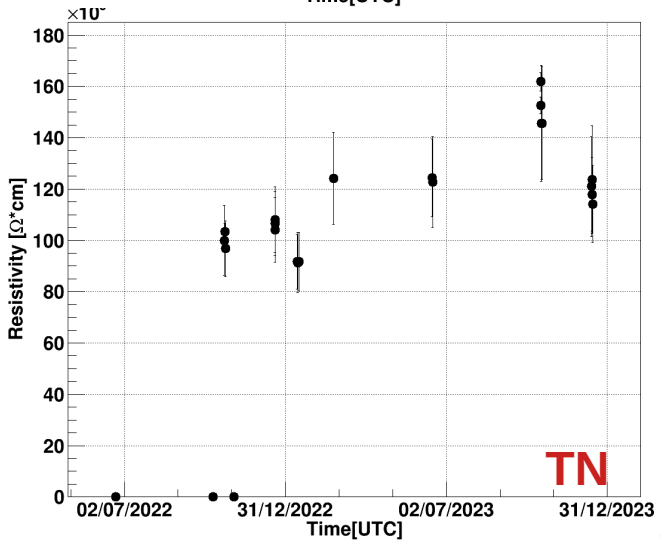




Fit of the last 5 HV points + STD deviation

BOT





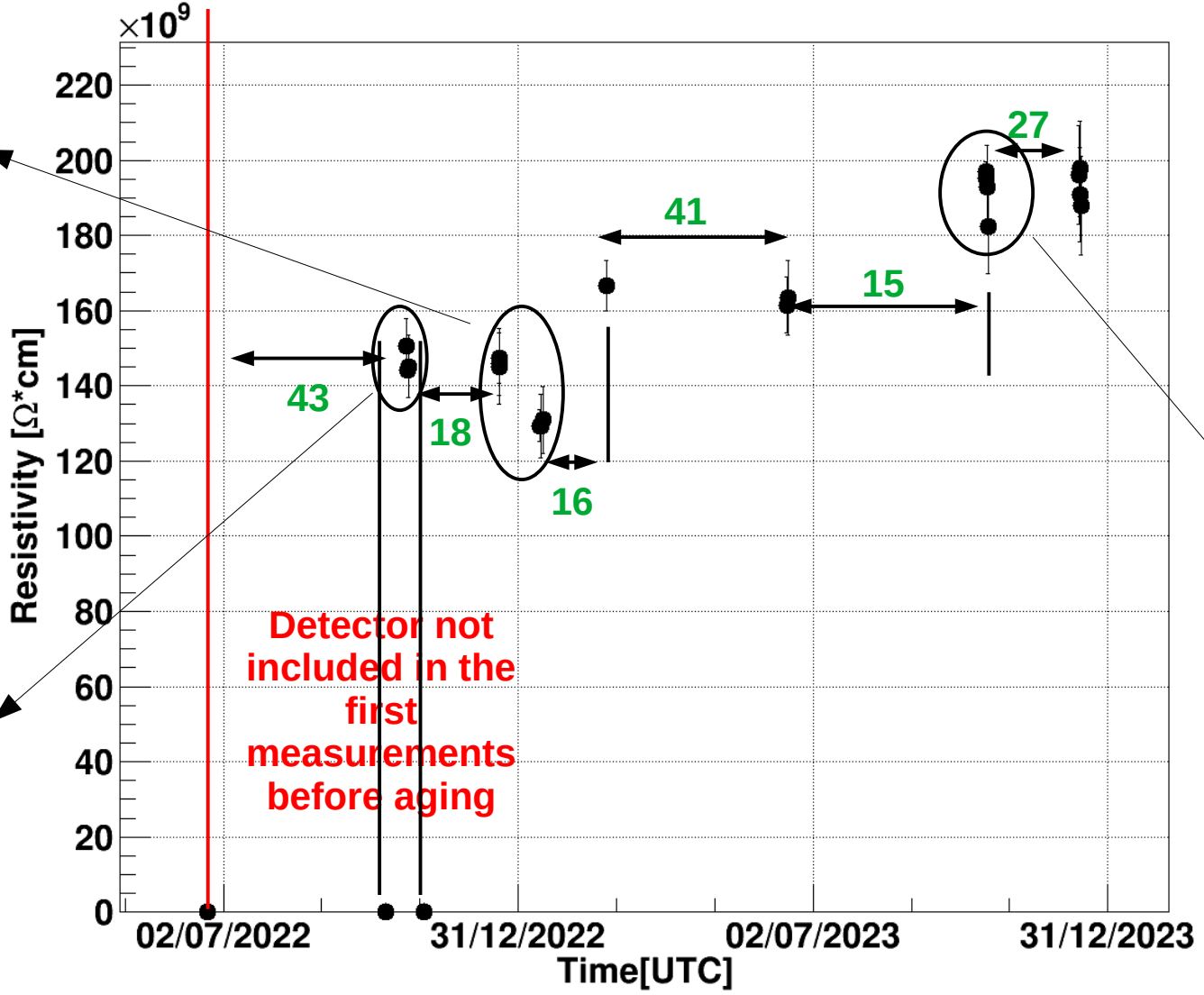
RE11 B0T

~ 160 mC/cm²

Before and after the Christmas break (no gas and no irradiation)

Numbers in between points = integrated charge in mC/cm²

No irradiation but flushing (TB ongoing in parallel)



Increasing oscillations between consecutive measurements

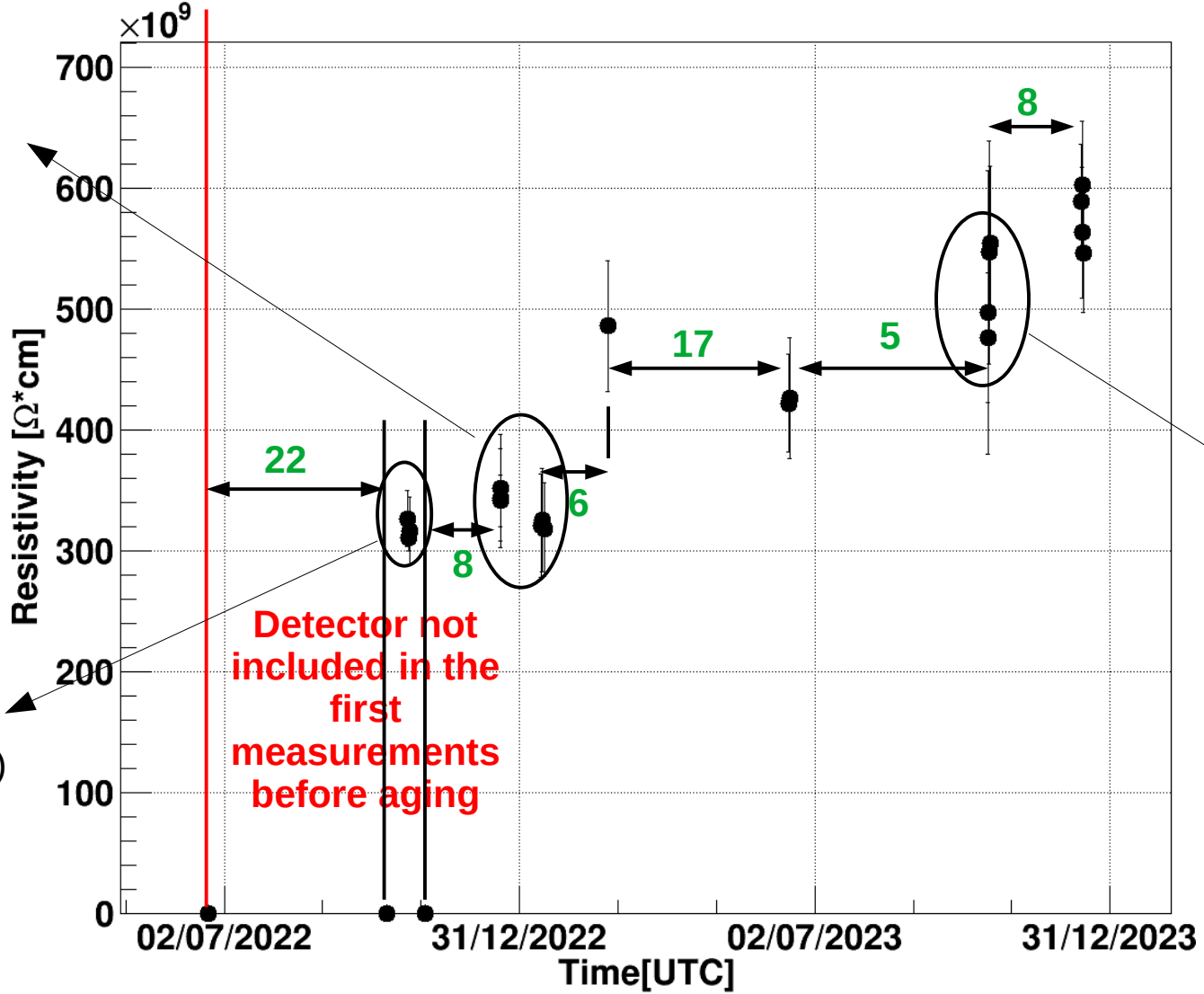
RE11 TW

~ 65 mC/cm²

Before and after the Christmas break (no gas and no irradiation)

Numbers in between points = integrated charge in mC/cm²

No irradiation but flushing (TB ongoing in parallel)



Increasing oscillations between consecutive measurements

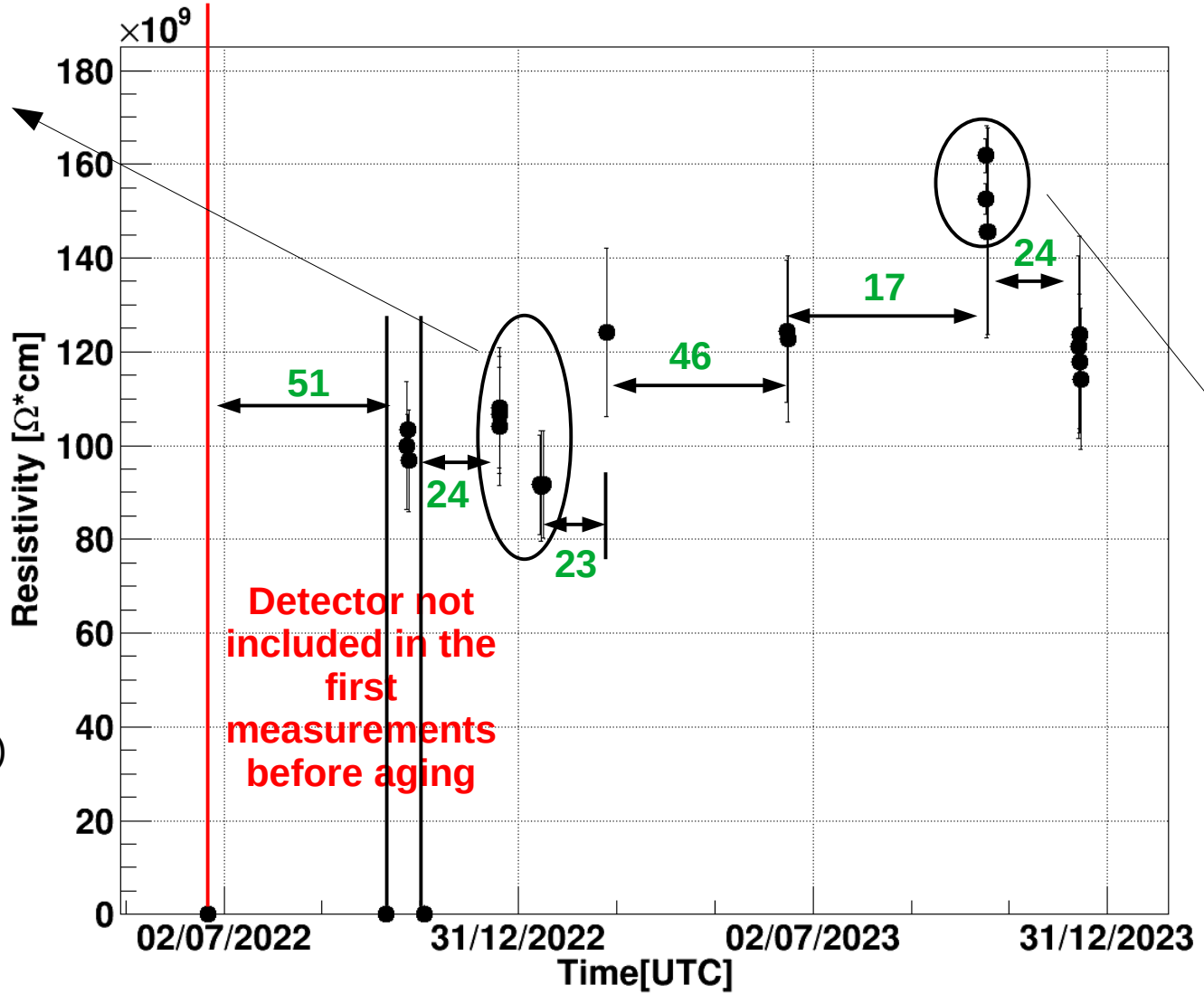
RE11 TN

~ 185 mC/cm²

Before and after the Christmas break (no gas and no irradiation)

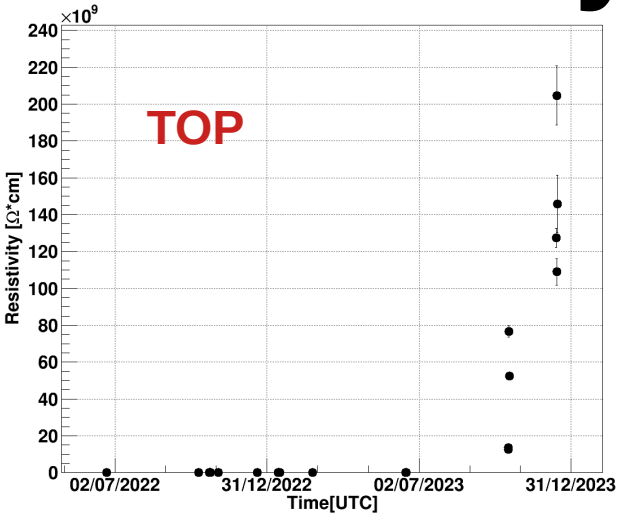
Numbers in between points = integrated charge in mC/cm²

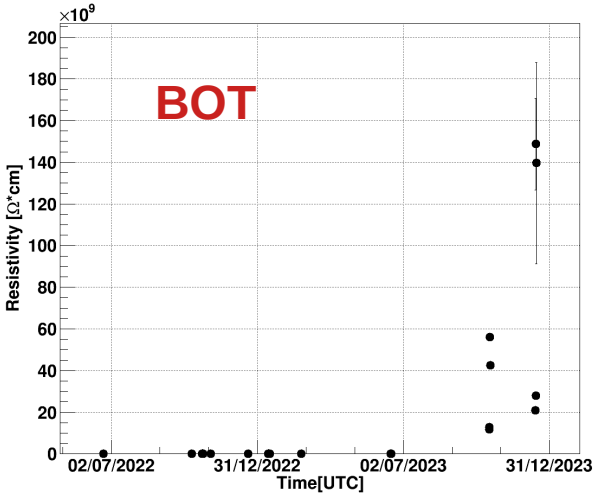
No irradiation but flushing (TB ongoing in parallel)



Increasing oscillations between consecutive measurements

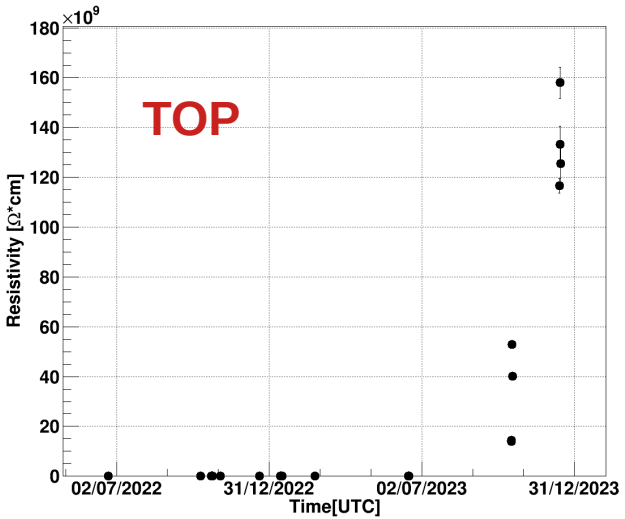
Resistivity trend in time – KODEL H

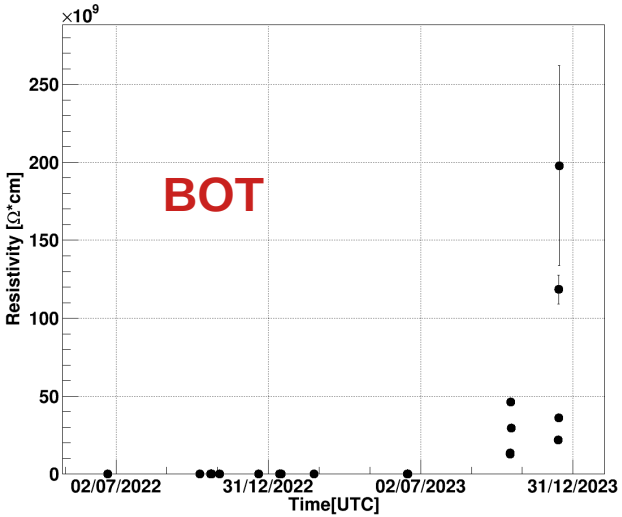




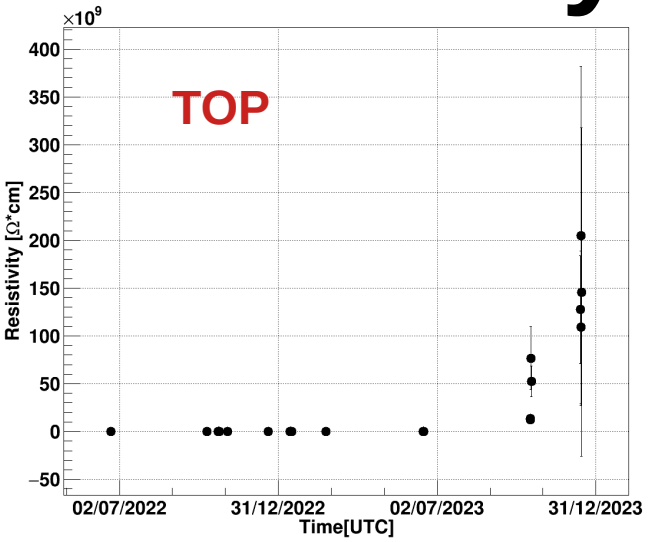
Fit of the last 4 HV points + error on the mean

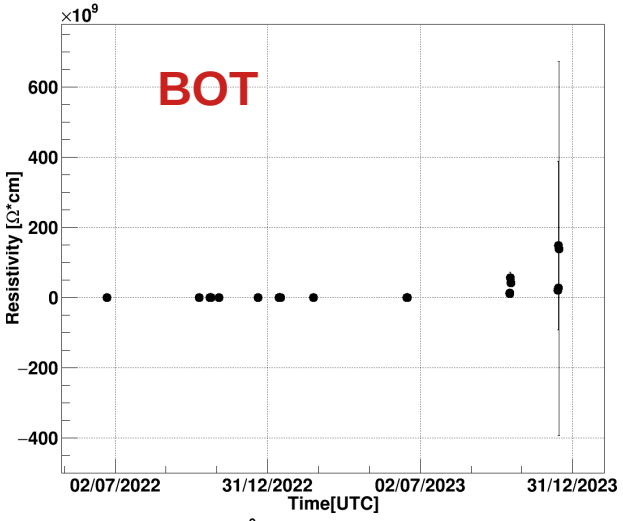
Fit of the last 5 HV points + error on the mean





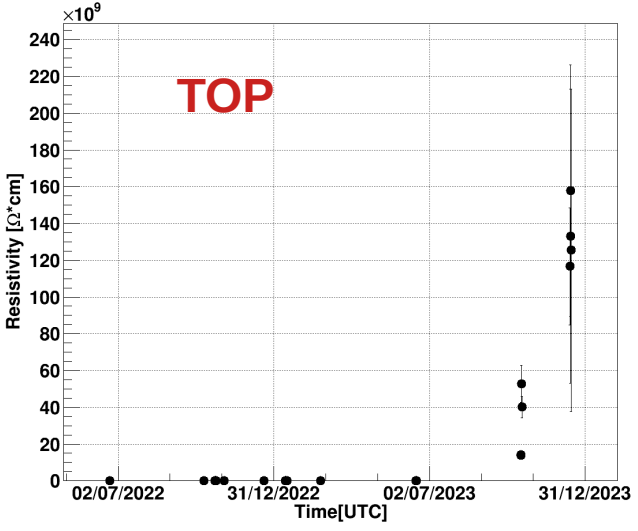
Resistivity trend in time – KODEL H

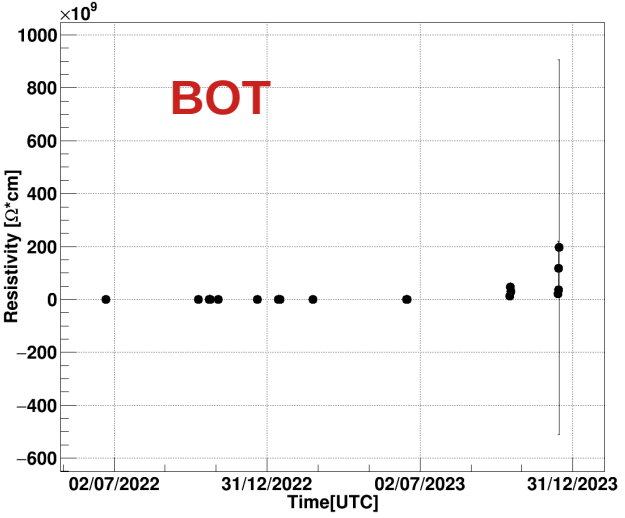




Fit of the last 4 HV points + STD deviation

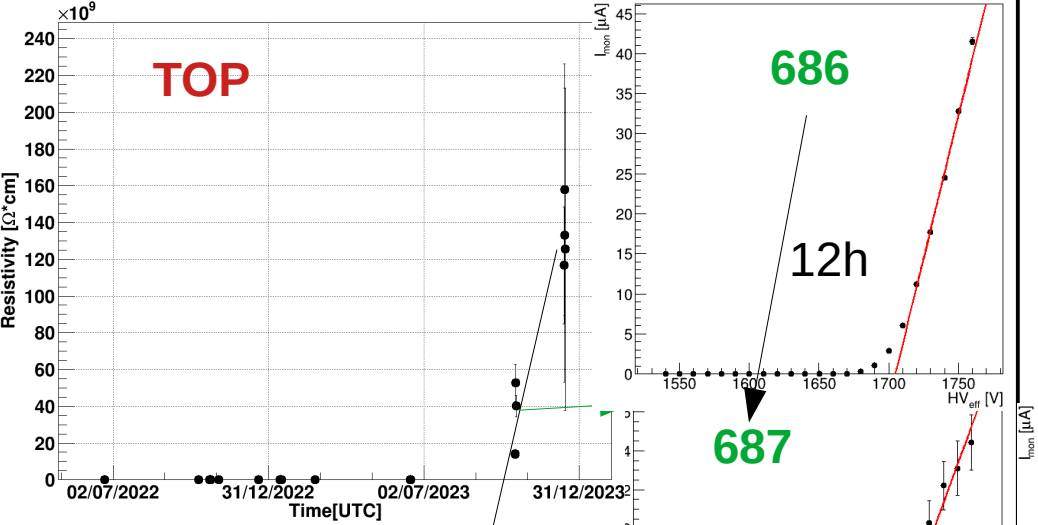
Fit of the last 5 HV points + STD deviation

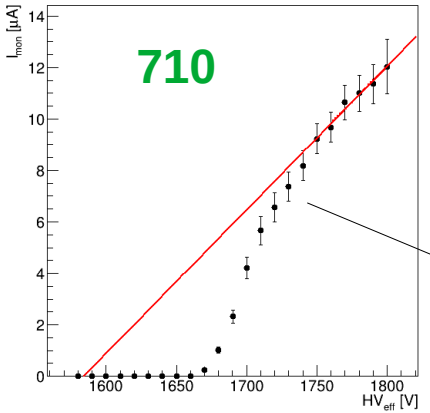


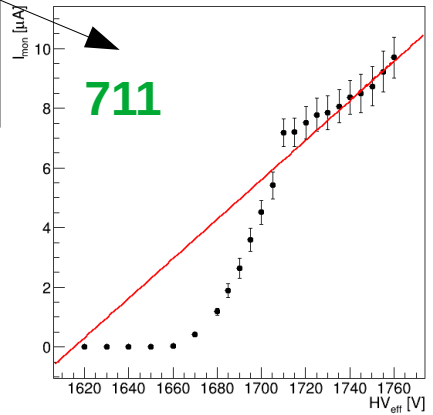


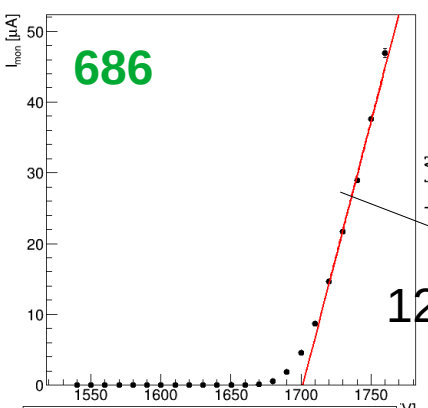
KODEL H

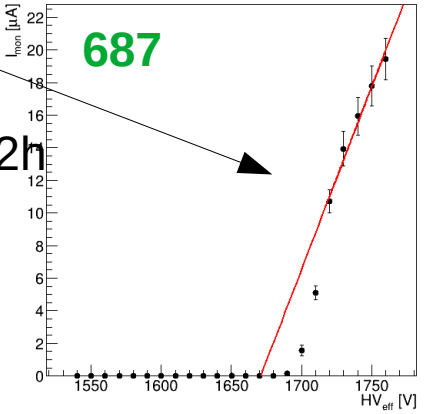
Fit of the last 5 HV points + STD deviation

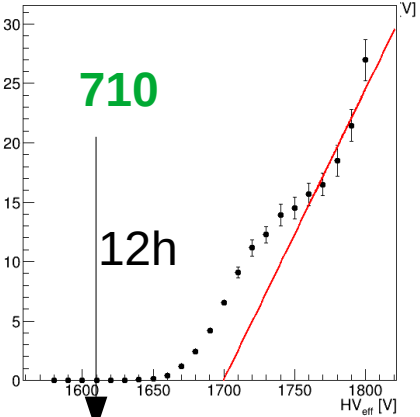


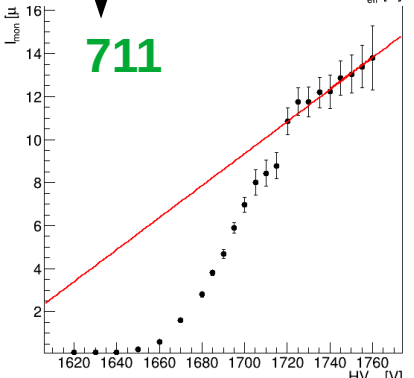


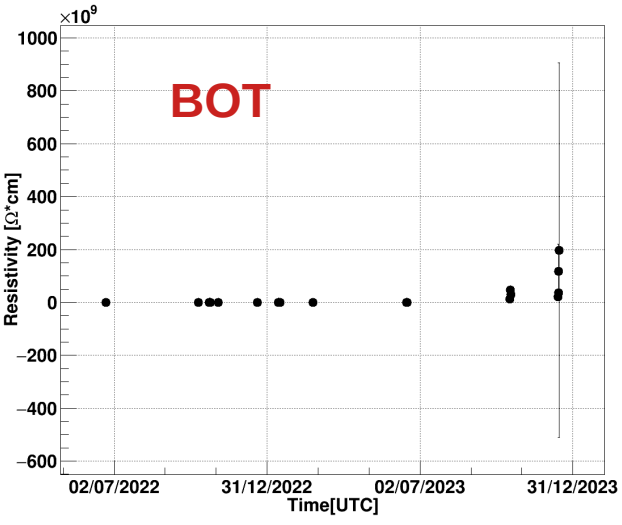












Conclusions

- Very different behavior among the detectors but some patterns can be observed
  - After xmas break 2022/23 the resistivity seems to decrease
  - It remained stable also during the non irradiation period

- Different methods to calculate resistivity yield better results for some detectors and worse for others
  - Using STD deviation as error on I_{mon} gives larger error on resistivity making measurements more compatible with each other
  - Increasing number of fit points seems to have a similar effect as well

- EPDT RPC25 and KODEL-H shape of the curves have to be studied

- Increase measuring time for detectors with high variability in absorbed current? (mainly ATLAS and RE11)

- Go to higher voltages to have more points with linear behavior?