École d'ingénieurs
Télécom Physique Strasbourg

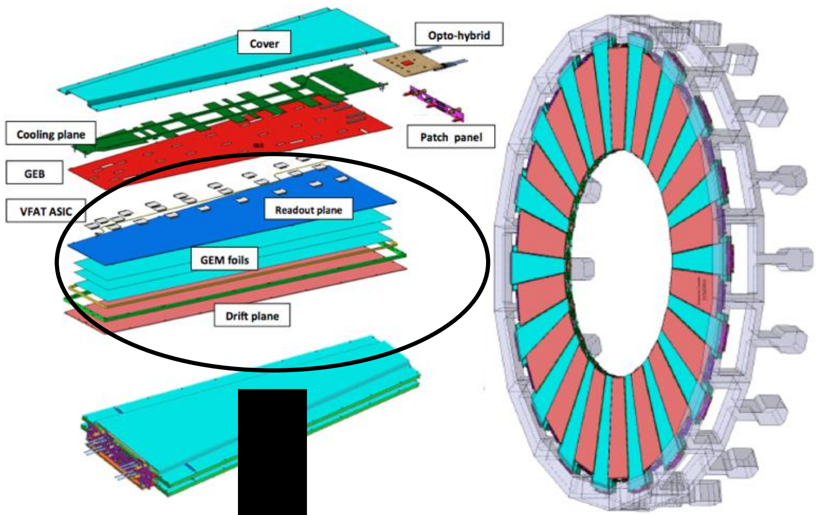
QC6 Test: Stability and I-V Characteristics of GEM foils

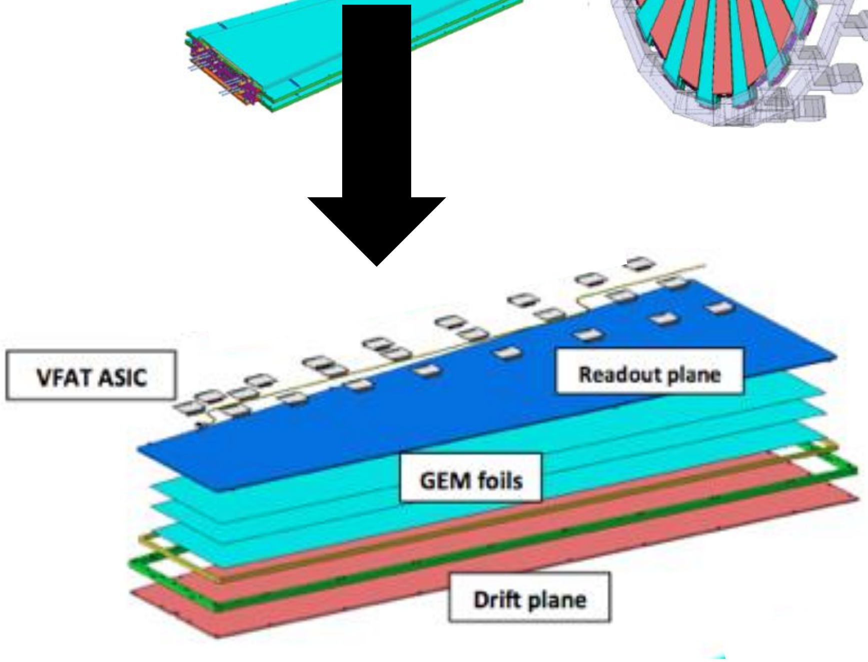
Student: Margaux Forge

Internship from 27/05/19 to 30/08/19

Supervisors: J. Merlin & F. Fallavollita

Introduction



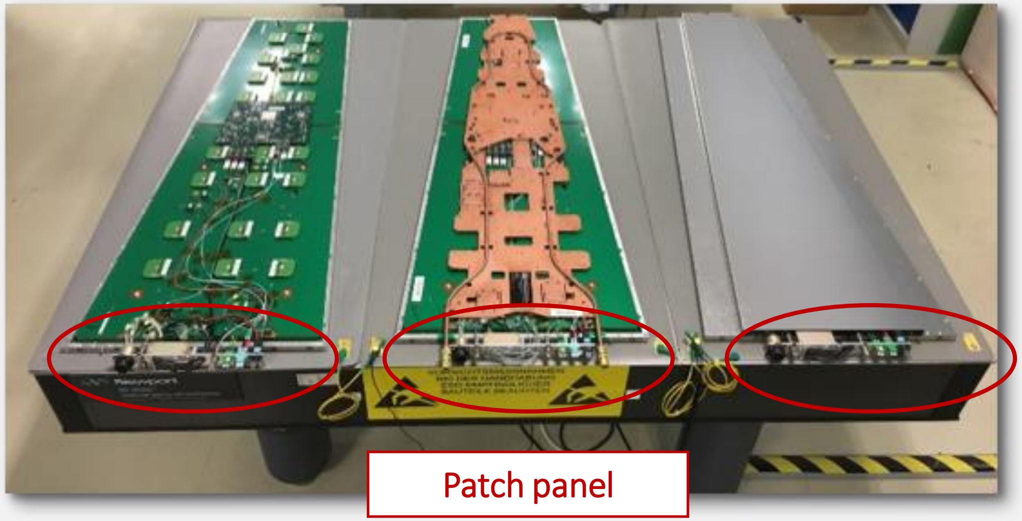


Muon Detection Part of the CMS Experiment:

- Track a muon's path
- Detection through GEM foils

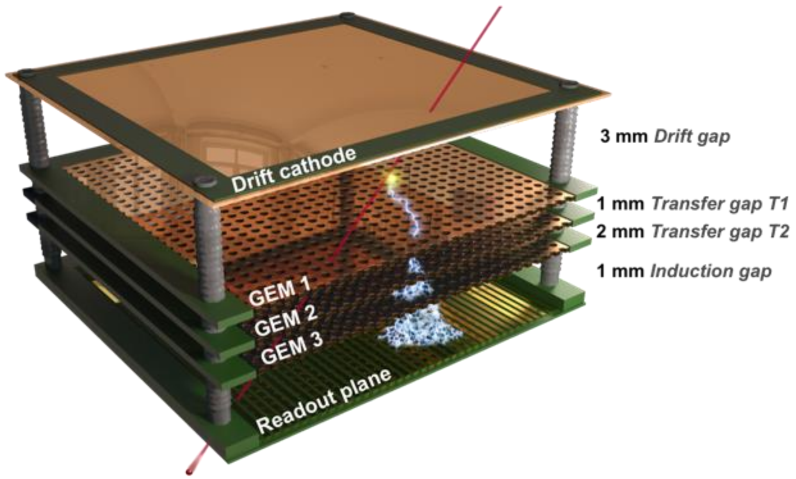
The interesting parts are located on :

- The triple-GEM system (detection part)
- The patch panel (electronic part)



I. QC6 Stand

Purpose of the test ?
Evaluate the high-voltage stability of detectors and ”clean” the GEM foils of impurities that could promote discharges in the future operation of the chamber



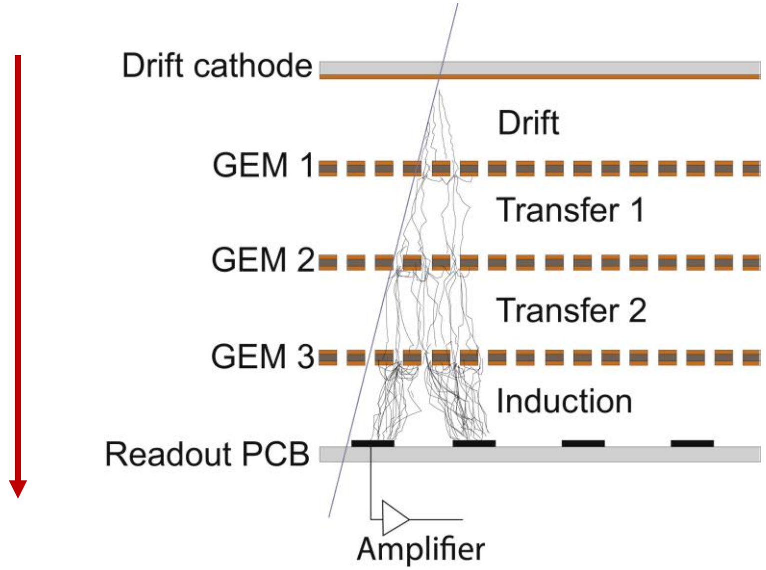
But, what is a discharge ?
When the avalanche of electrons-ion pairs exceed 10^7 in the sensitive volume

(See Océane Perrin's presentation on discharges studies)

≠

Ionizing particle (muon here) which creates also an avalanche of electrons-ion pairs

Cascade of electrons amplify through the GEM foils

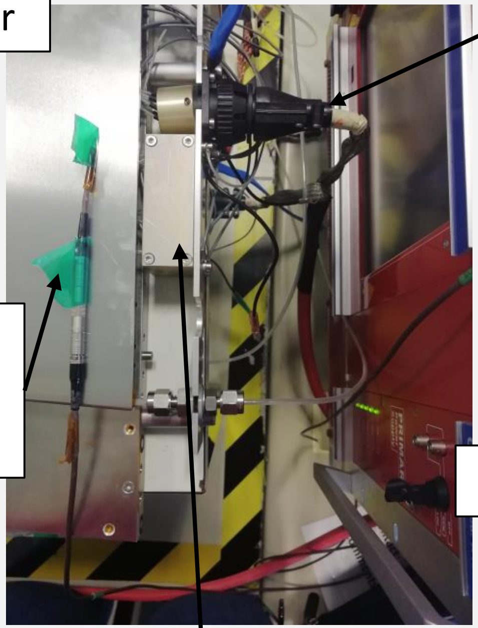


I. QC6 Stand

Application of an unique voltage which is divided into the chamber for each GEM by using an HV supply

I/V monitoring (by LabVIEW programs)

GEM Chamber



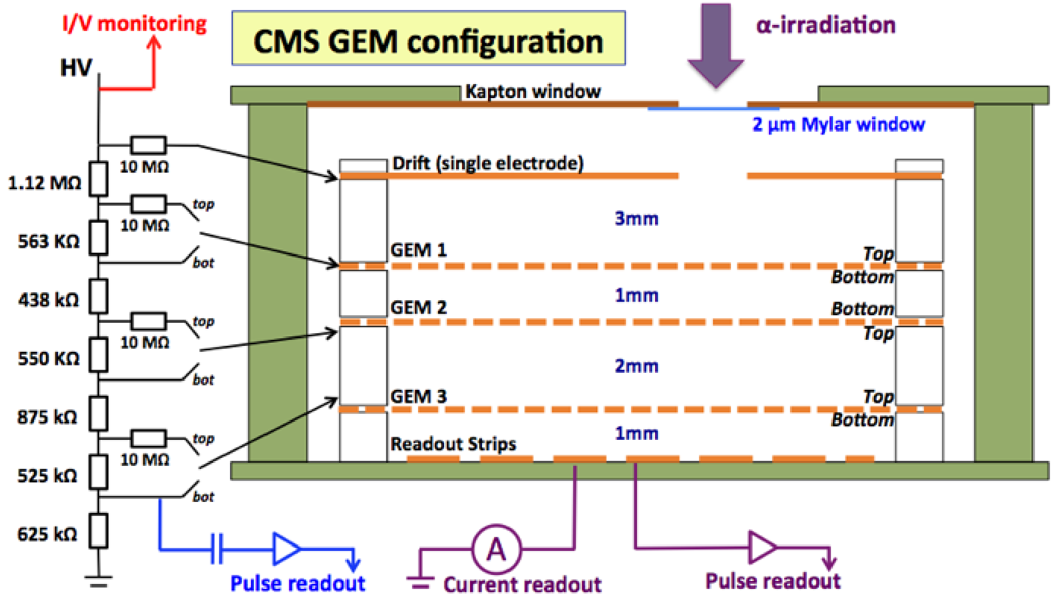
Antenna connected to a scope and gives a display of discharges

HV Supply

HV Divider box

GEM Top is an cathode (+) and GEM Bottom is a anode (-)

Configuration used to create an electrical field into the holes and attract the electrons inside (provoking the avalanche of electrons)

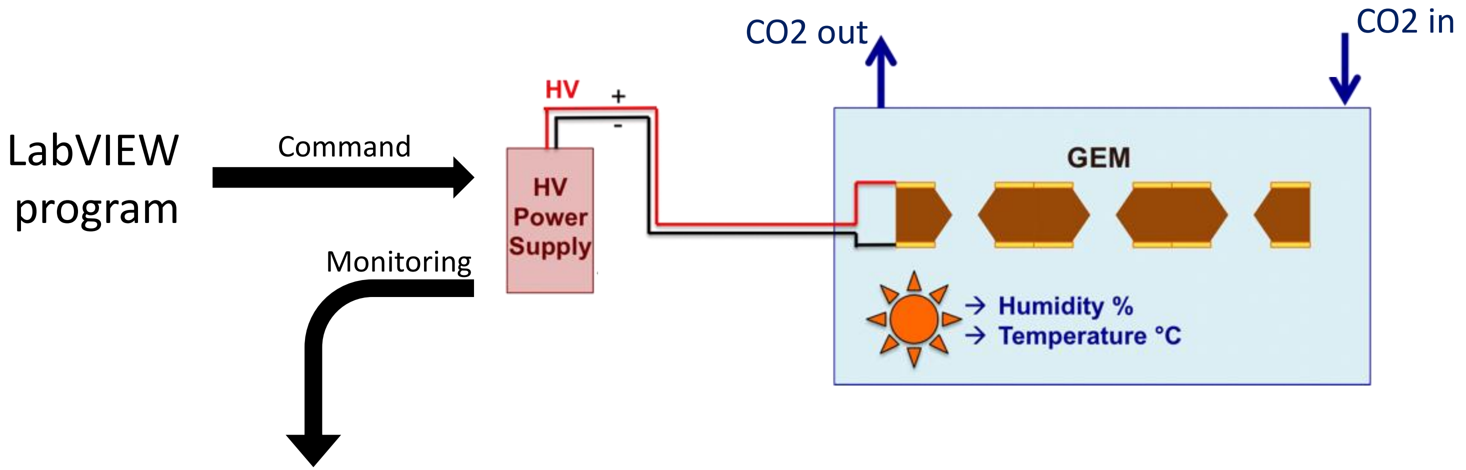


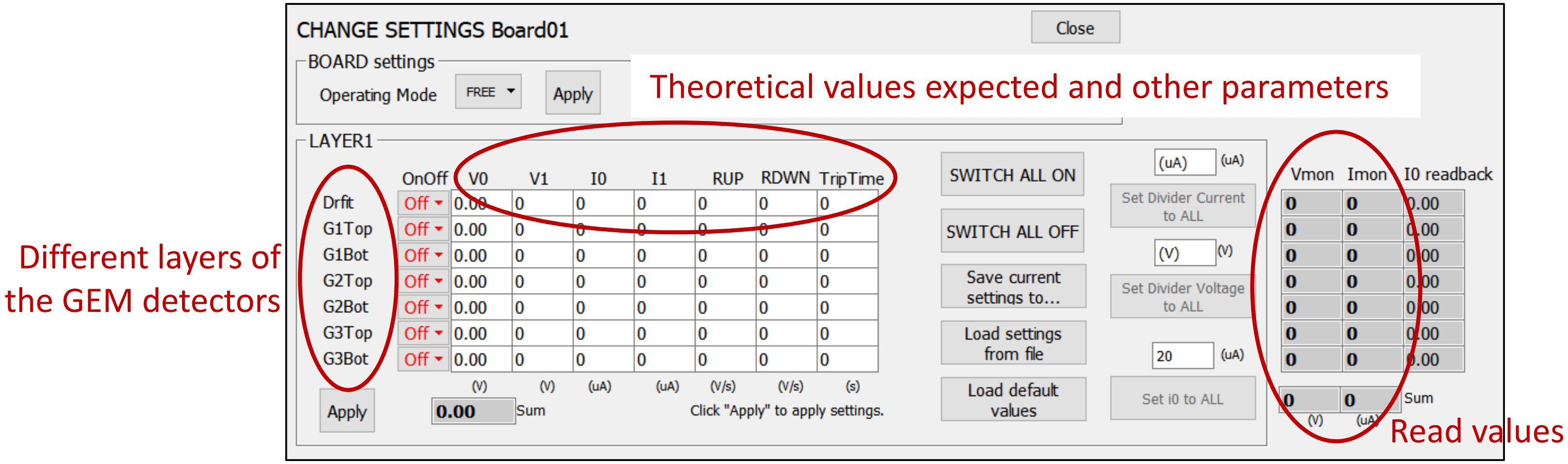
I. QC6 Stand

The procedure is almost done automatically from the beginning until the end

LabVIEW programs command the HV Power Supply (V0, I0, RUP)

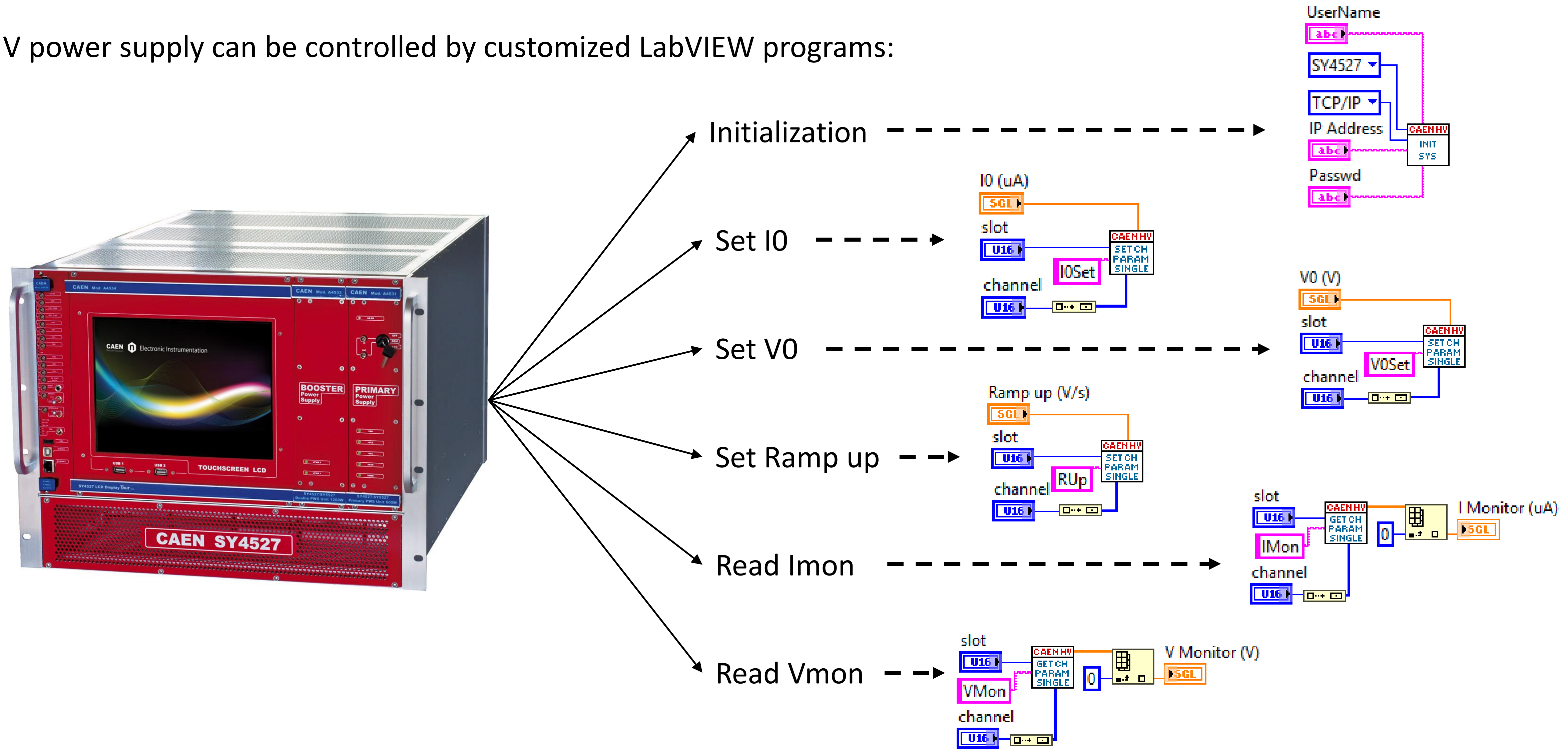
WinCC Environment measures the real values inside the GEM foils (Vmon, Imon)





I. QC6 Stand

HV power supply can be controlled by customized LabVIEW programs:



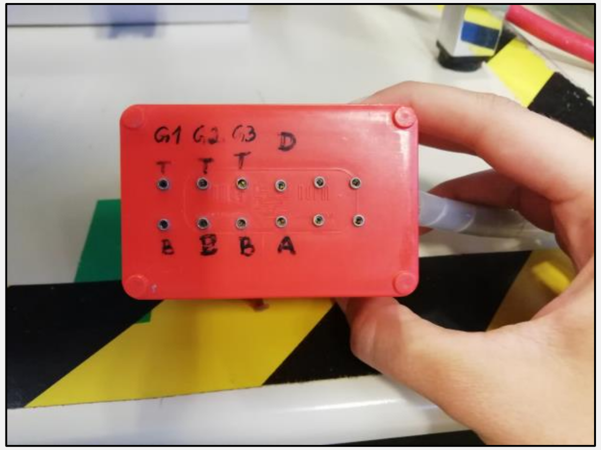
II. Procedure adopted and its results

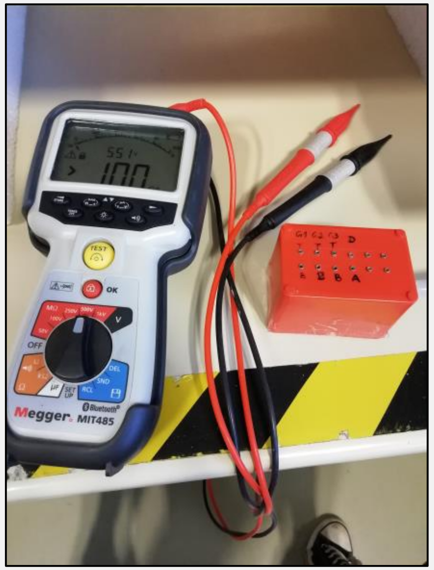
1. Megger Test

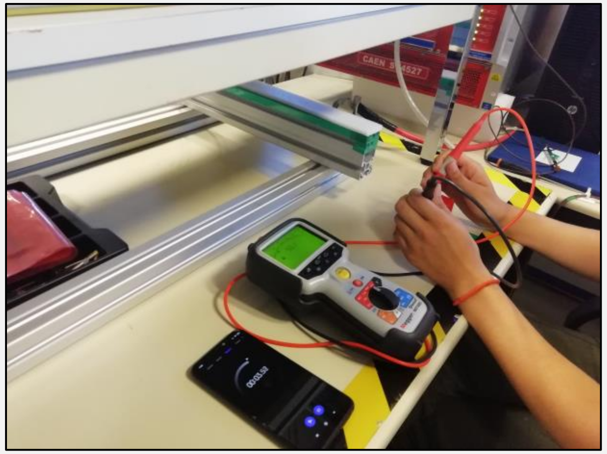
→ Burn the eventual dust and stabilize the chamber

Procedure:

- Measure impedance applying 500 V to each G1T, G2T, G3T.
- Measure the number of discharges in one minute.
- Measure continuity between Anode and the detector's shield.





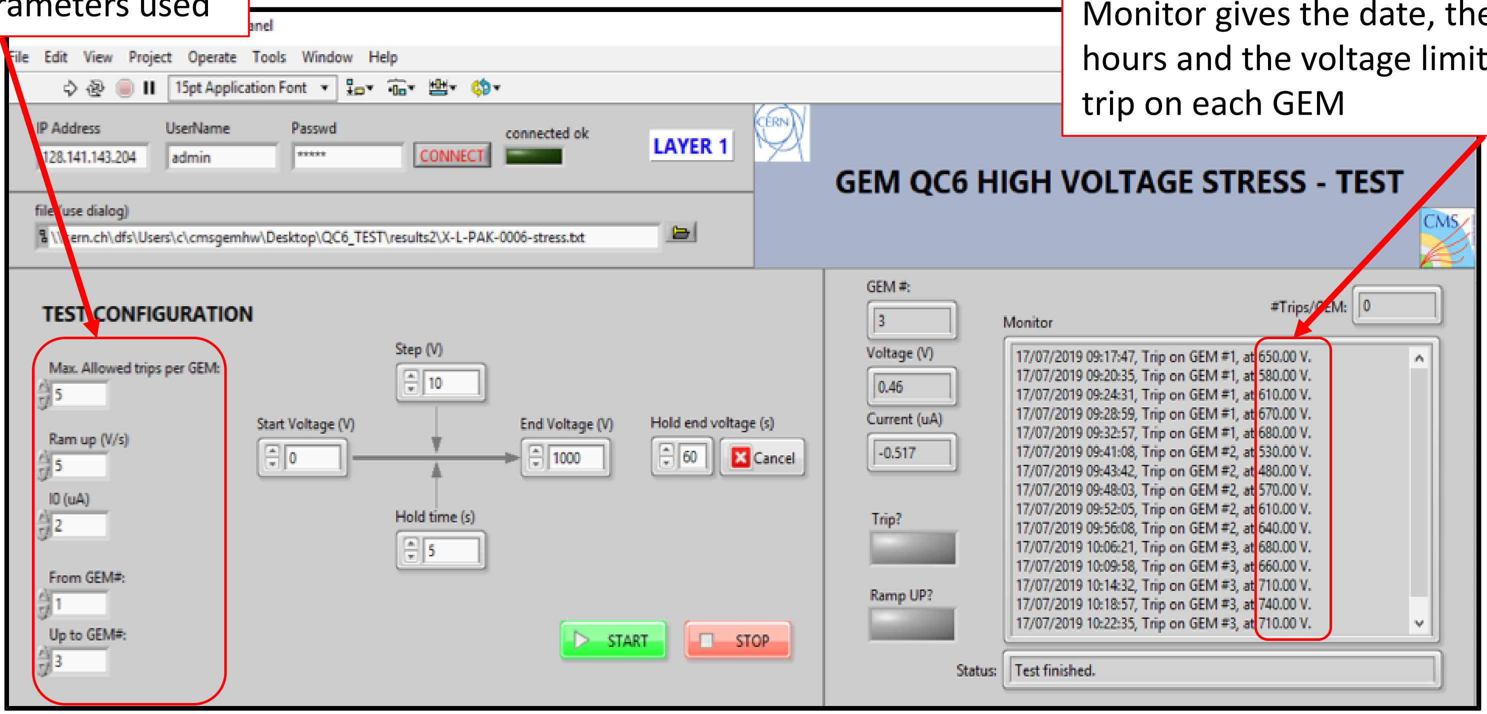


2. Stress Test

➞ Improve the voltage limit when a trip occurs

Parameters used

Monitor gives the date, the hours and the voltage limit for a trip on each GEM



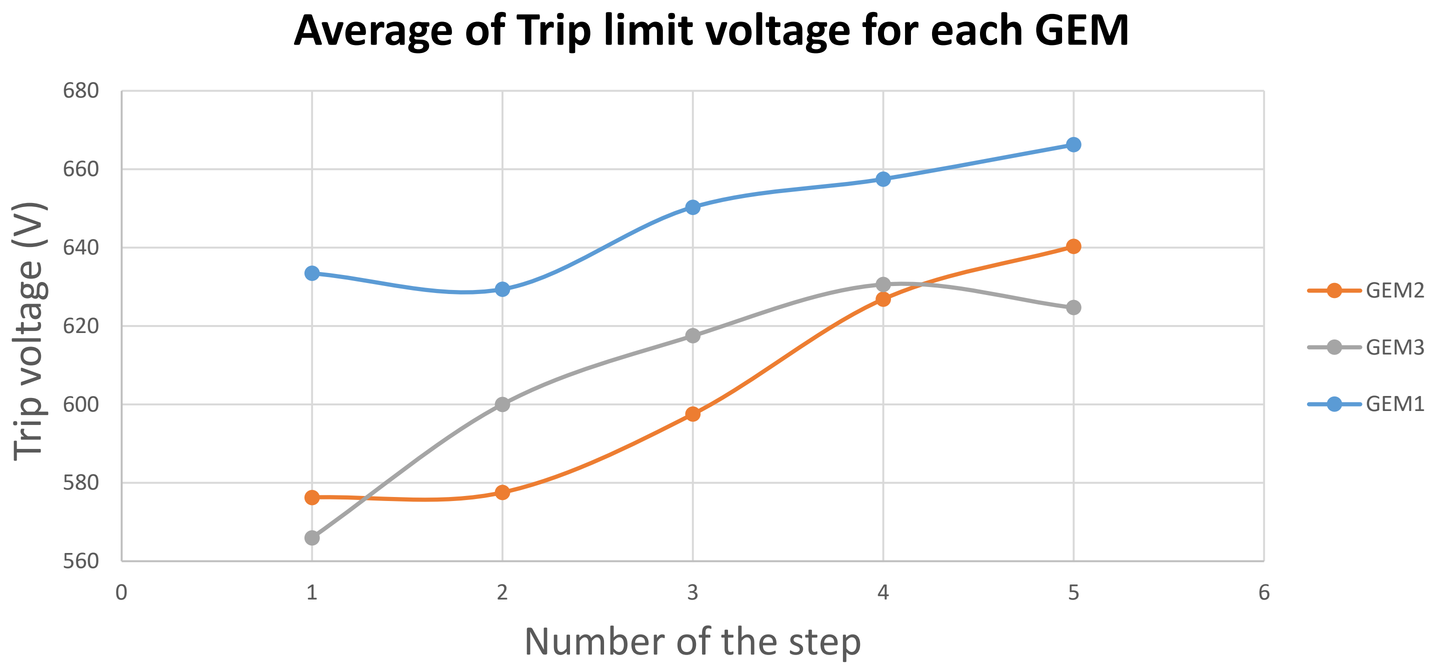
Procedure:

- On each GEM foil, perform a voltage scan from 0 V to 1000 V, with 10 V steps until it trips. Hold each step during 5 seconds.
- Repeat this step 5times on each GEM foil.

II. Procedure adopted and its results

2. Stress Test

Some results we can get after a stress test (performed on 33 chambers for now with CO_2 gas):



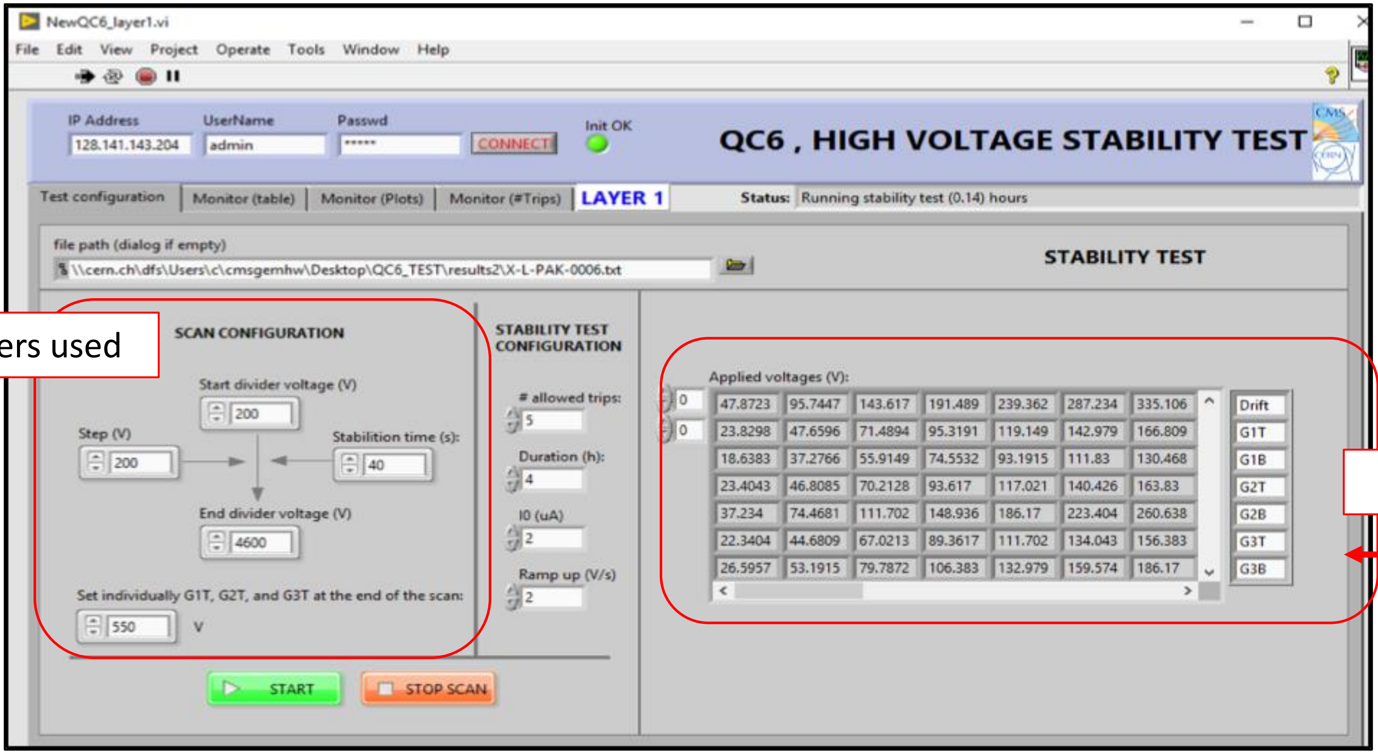
Range	Standard deviation		
	GEM 1	GEM 2	GEM 3
1	42,31	53,28	60,42
2	53,31	76,69	38,33
3	49,98	55,21	48,36
4	49,98	45,44	51,83
5	41,18	37,58	60,76

➞ Improvement of the maximum value per GEM by 50V around

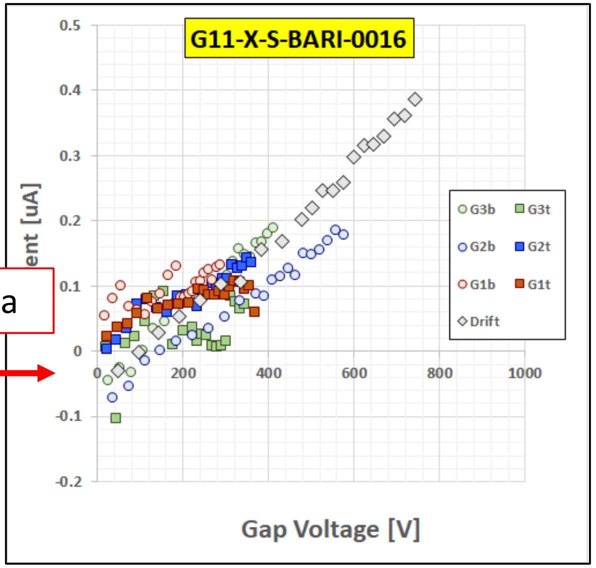
3. Scan Test

➞ Have the tendency of the current according the Gap Voltage

Parameters used



Collected data



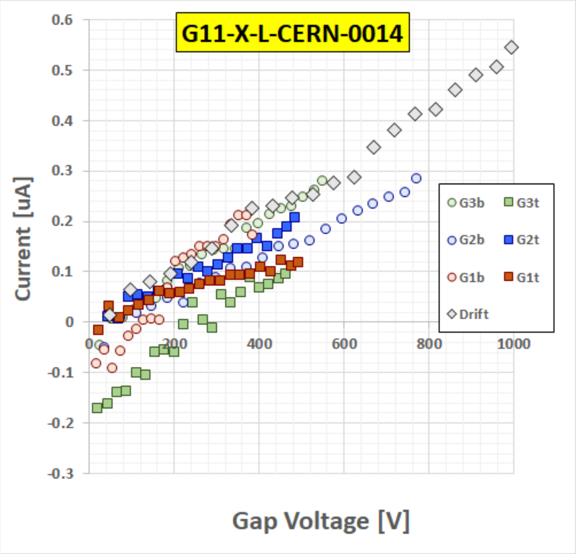
Procedure:

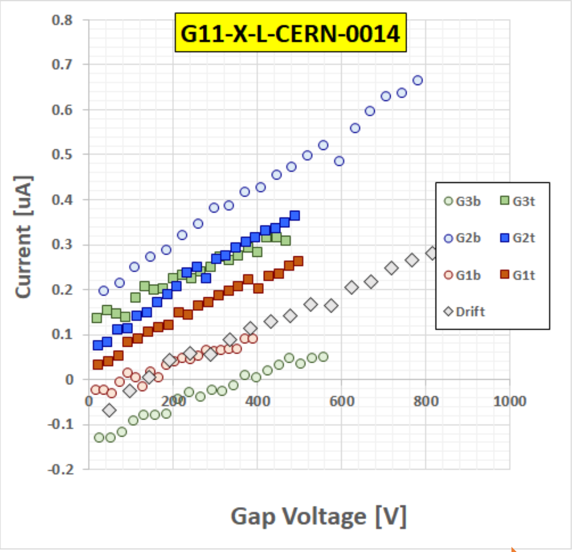
- On each GEM foil, simultaneously ramp up from 200V to 4600V (end divider voltage) with a step of 200V.
- Hold each step during 40 seconds.
- Collect data at the end of the scan.

3. Scan Test

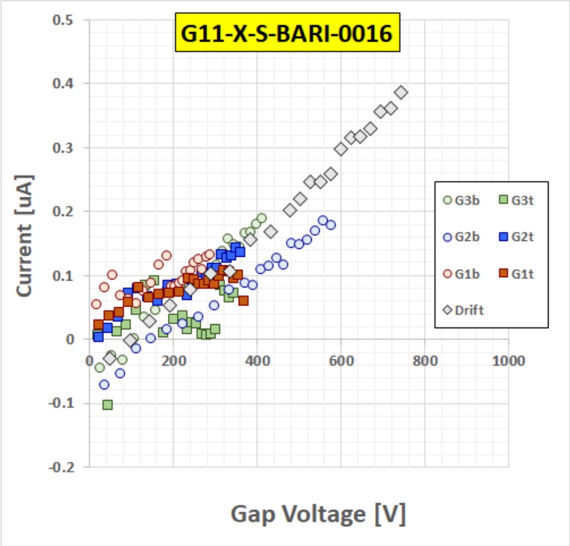
Comparison with previous procedure:

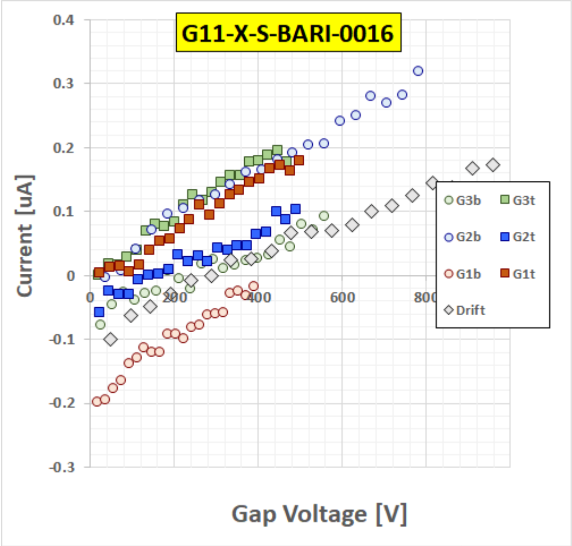
Isolation between top and bottom of one GEM because of the gas (CO_2 here) ➞ Current should be at 0A theoretically





Before / after the new procedure





Before / after the new procedure

Plots more linear ➞ stability increased

II. Procedure adopted and its results

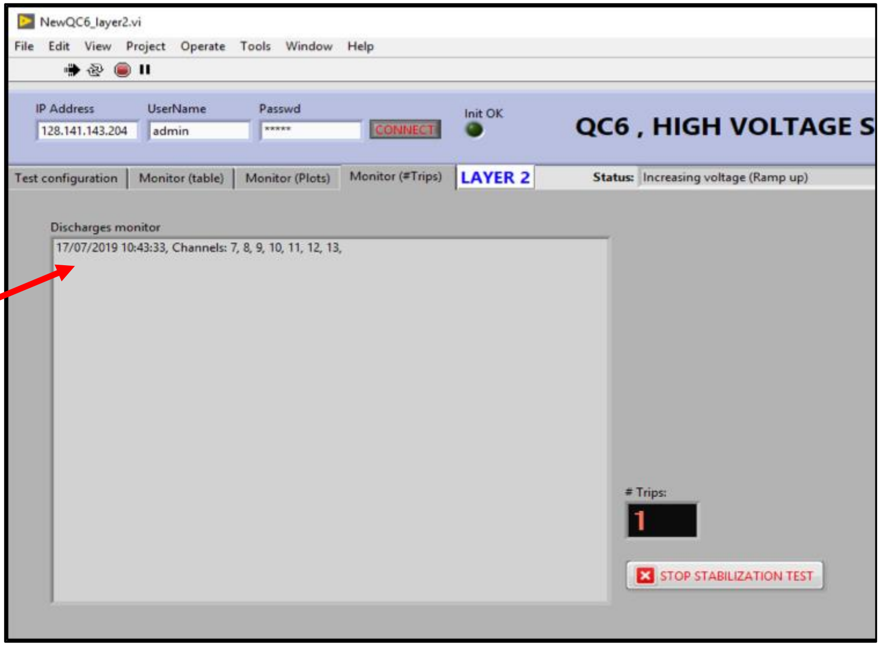
4. Short Stability Test

➞ Test the stability of the chamber <u>under nominal voltage</u>

Procedure:

- Let for ~ 2hours all GEM ON at working values and count the number of trips.
- When a trip occurs, the system starts again until it reaches the maximum number of trips allowed (5 by default).

Monitor gives the time of a trip and the GEM concerned



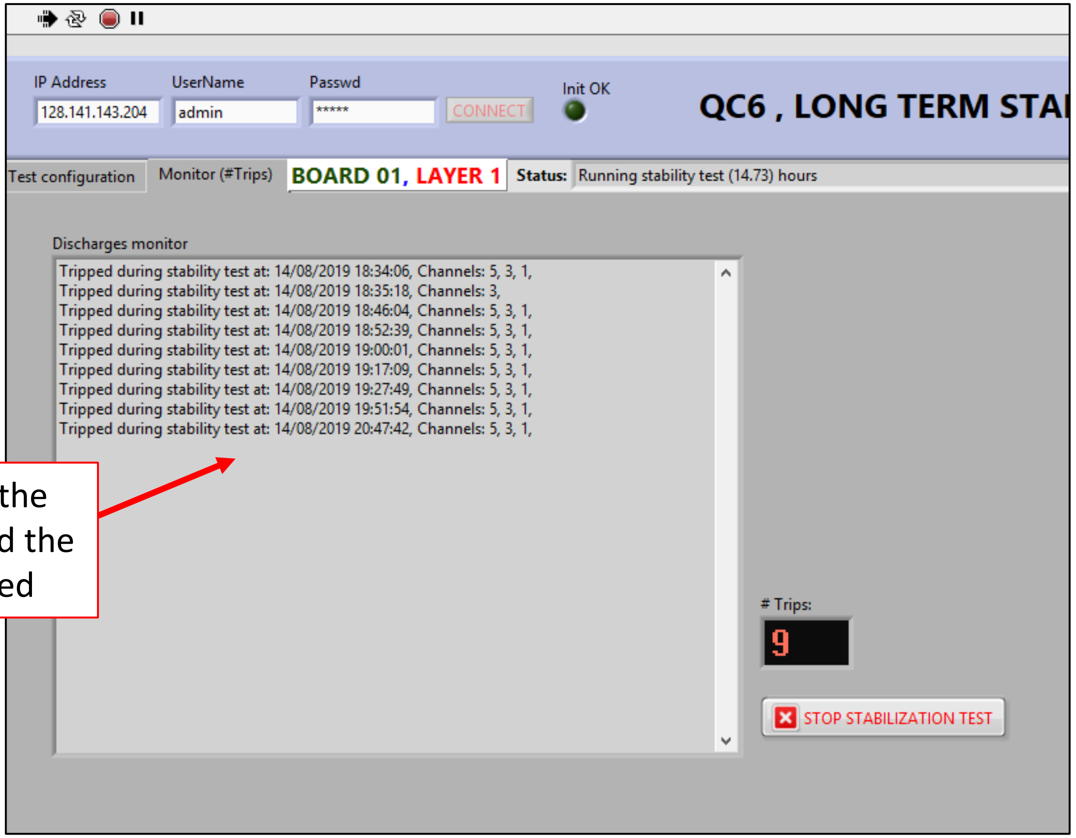
Drift	**1000V**
G1Top	**550V**
G1Bot	428V
G2Top	**550V**
G2Bot	856V
G3Top	**550V**
G3Bot	612V

<u>Values applied on each pin for 4hours</u>

II. Procedure adopted and its results

5. Long Stability Test

➞ Improve the stability of the chamber <u>on a long time at limit values</u>



Monitor gives the time of a trip and the GEM concerned

Procedure:

- Let for ~ 12hours (all night) all GEM Top ON at maximum values and count the number of trips.
- When a trip occurs, the system starts again.

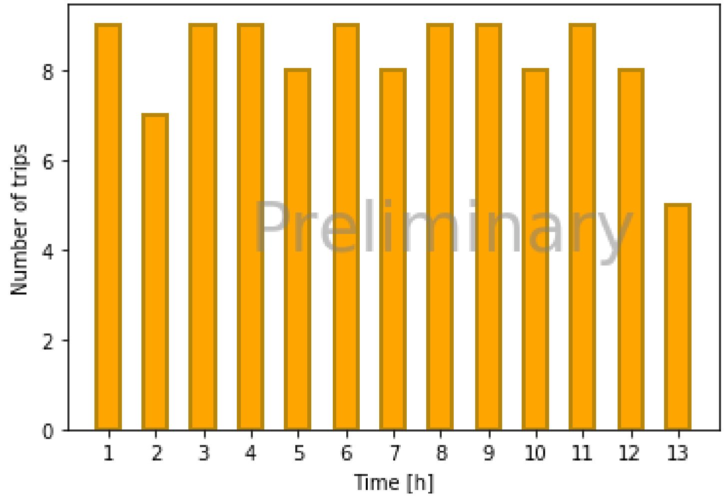
Drift	0V
G1Top	**650V**
G1Bot	0V
G2Top	**650V**
G2Bot	0V
G3Top	**650V**
G3Bot	0V

<u>Values applied on each pin for all night</u>

II. Procedure adopted and its results

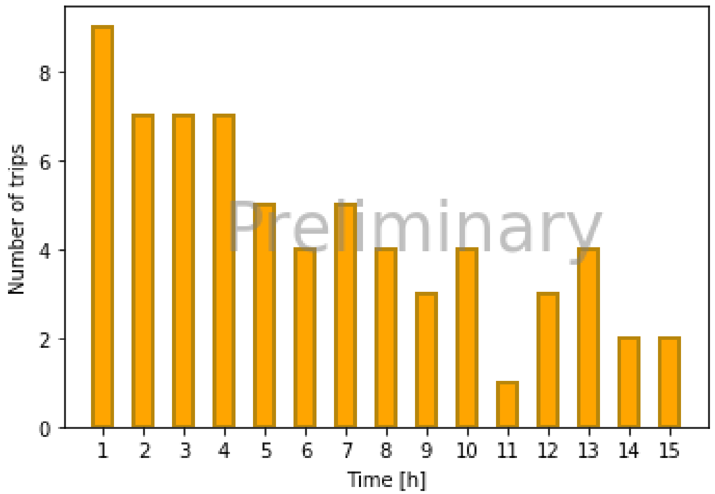
5. Long Stability Test

Some results (did with a Python program) we can get after a long stability test:



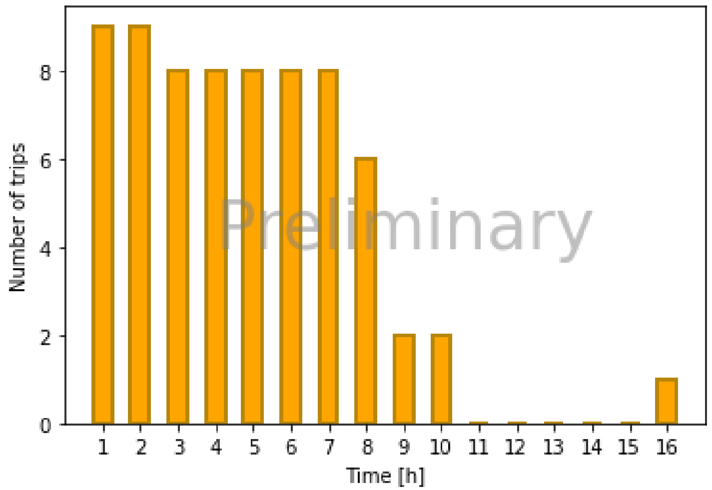
GE1/1-X-S-INDIA-0005

Bad improvement
(~15% of chambers)



GE1/1-X-S-INDIA-0008

Normal improvement
(~ 70% of the chambers)



GE1/1-X-S-BARI-0013

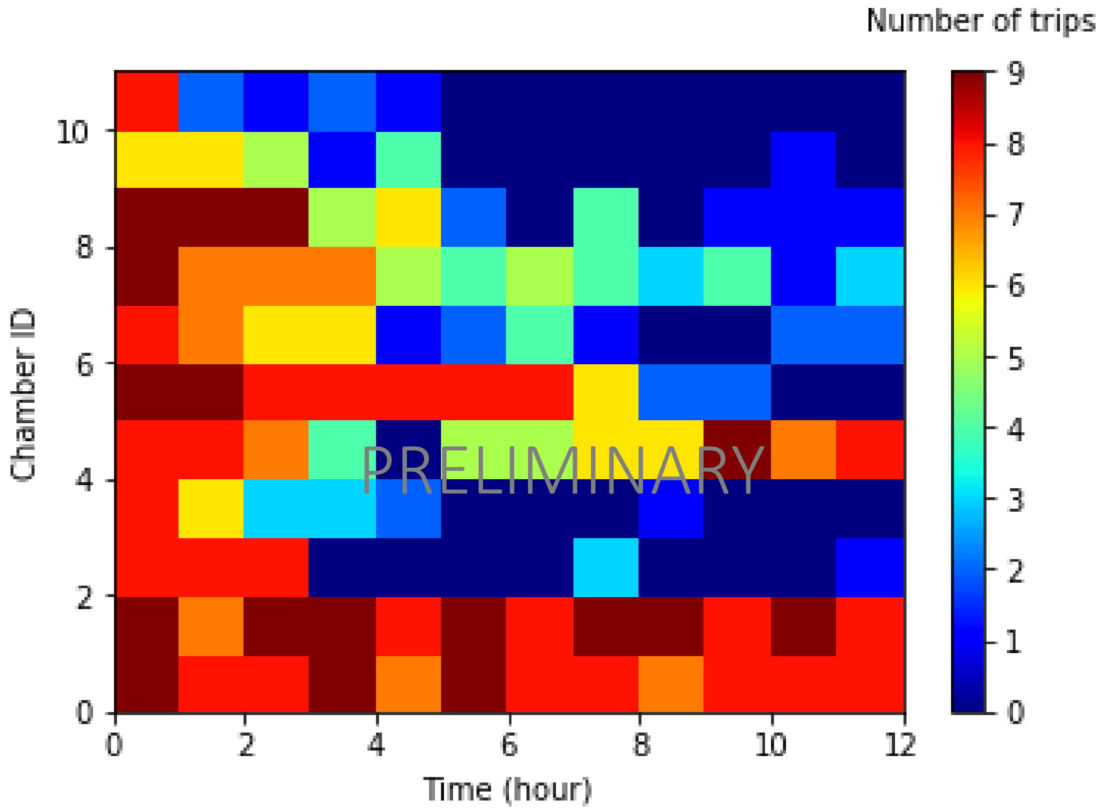
Idealistic improvement
(~ 15% of the chambers)

5. Long Stability Test

Overview improvements:

- Tested on 11 chambers under C02
- After an average of 5 hours, chambers become stabilized
- Only 2 chambers keep an high frequency of trips

A PROCEDURE WHICH IMPROVES CAPACITY OF CHAMBERS



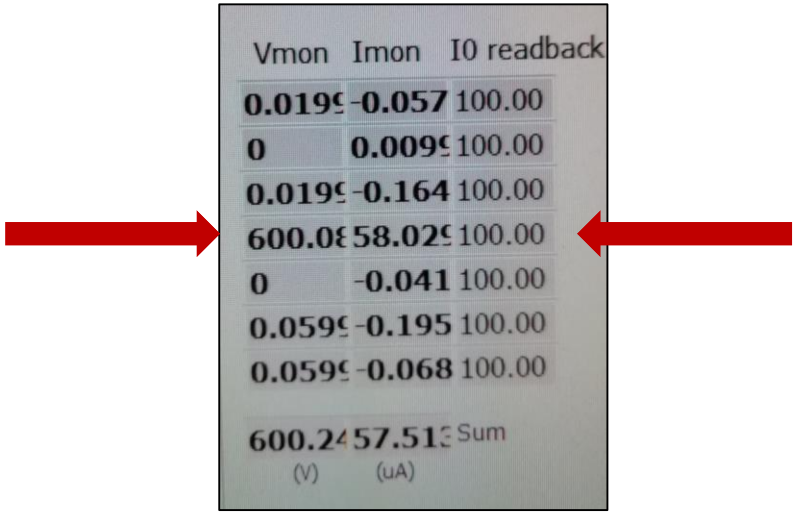
III. And if the QC6 Test fails ?

Test is a failure if:

- The chamber is not stable at the end of the procedure

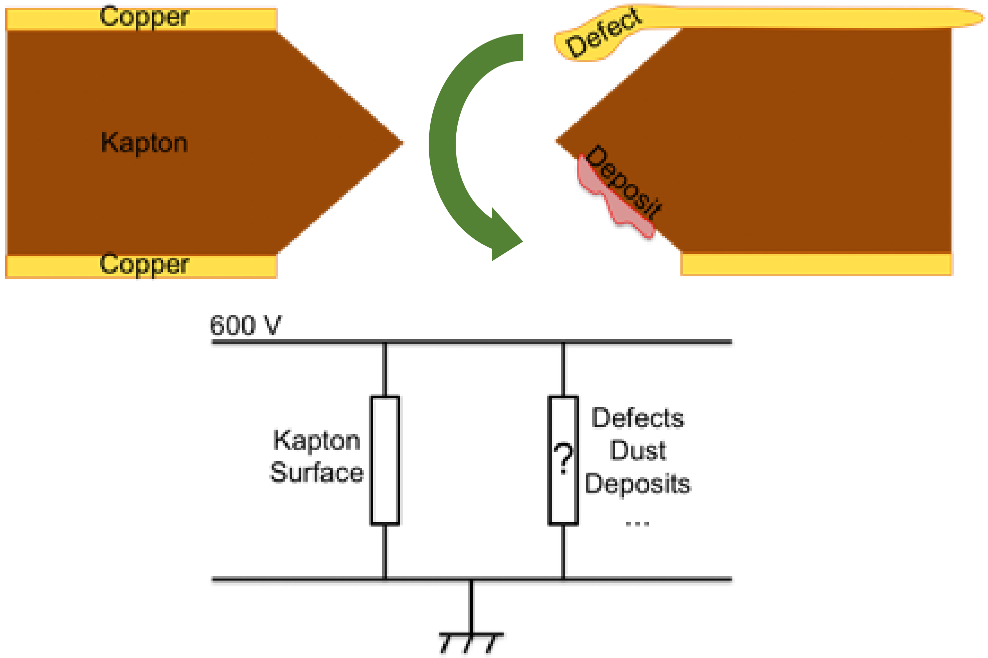
OR

- A short occurs
  ➞ “High” current inside the GEM which can damage the electronics (>1uA)



Vmon	Imon	I0 readback
0.019[illegible]	-0.057	100.00
0	0.009[illegible]	100.00
0.019[illegible]	-0.164	100.00
600.0[illegible]	58.02[illegible]	100.00
0	-0.041	100.00
0.059[illegible]	-0.195	100.00
0.059[illegible]	-0.068	100.00
600.2[illegible]	57.51[illegible]	Sum
(V)	(uA)	

Electrical bridge formed and connects the top and the bottom of a GEM

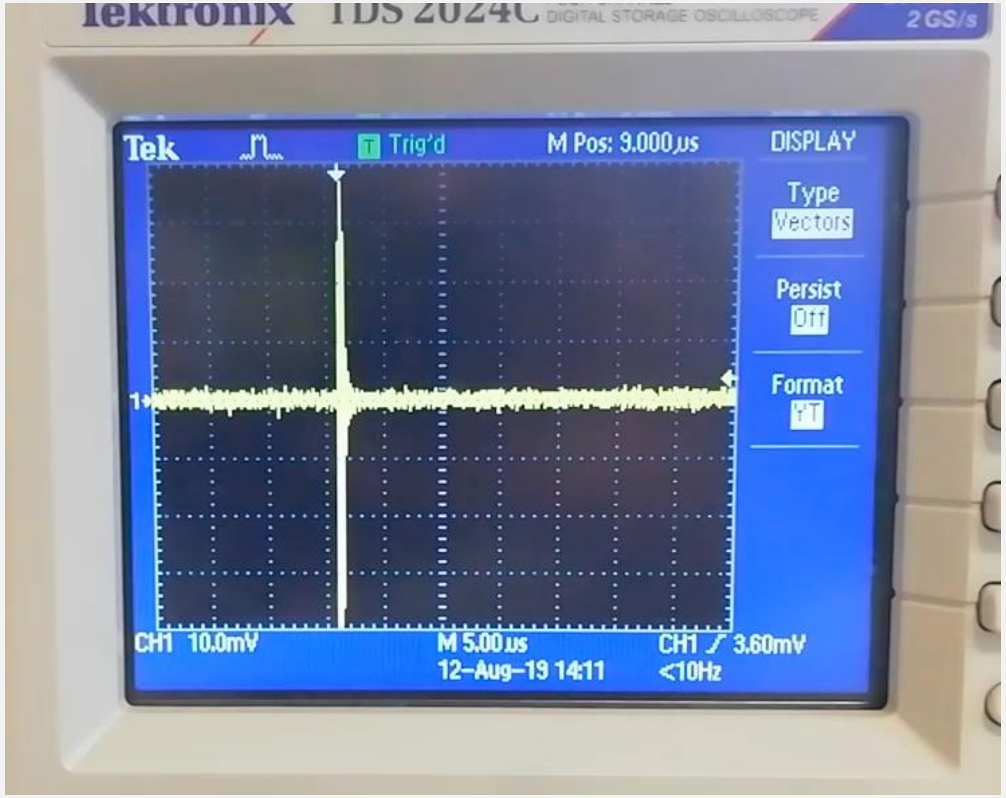


III. And if the QC6 Test fails ?

Methods used to ”clean” a short:

1. Use (again) the megger
   - At 550V by letting the electrodes several minutes, touching the pins intermittently and reversing the +/-
   - At 1000V a short time (risk of damage)

2. Use the HV supply
   - Clean the two others GEMs perfectly (reach a good stability)
   - Applying ~ 600V on all GEMs a long time (several hours)



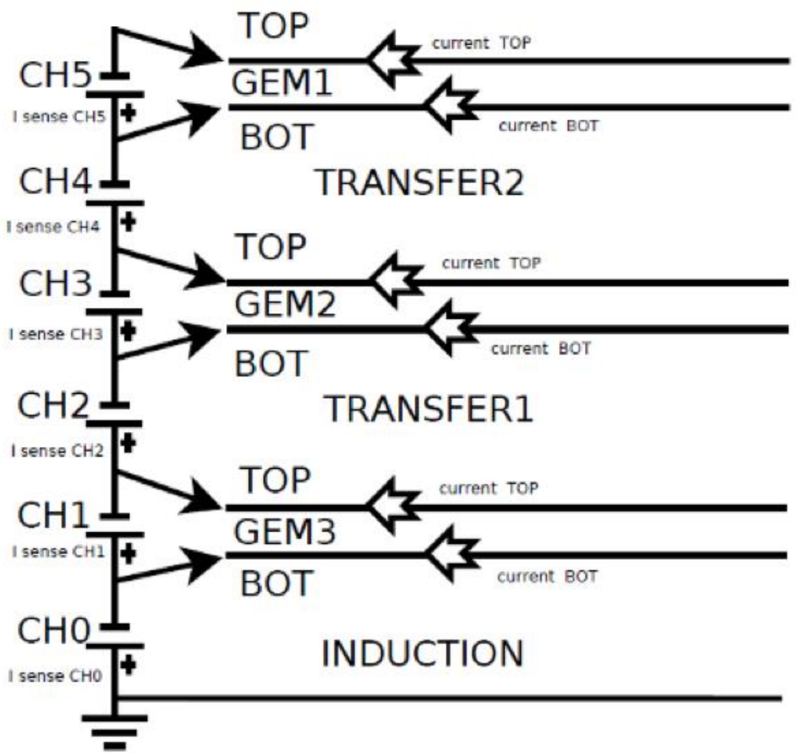
Conclusion

- New procedure shows a real improvement (stabilization, less discharges, increase of the capacity of the chamber)
- Need to apply this procedure quickly on all remaining chambers, two extra stands added to perform the QC6 Test and reach four tested chambers per day

Thank you for your attention!

Backup slides

GEM current distribution

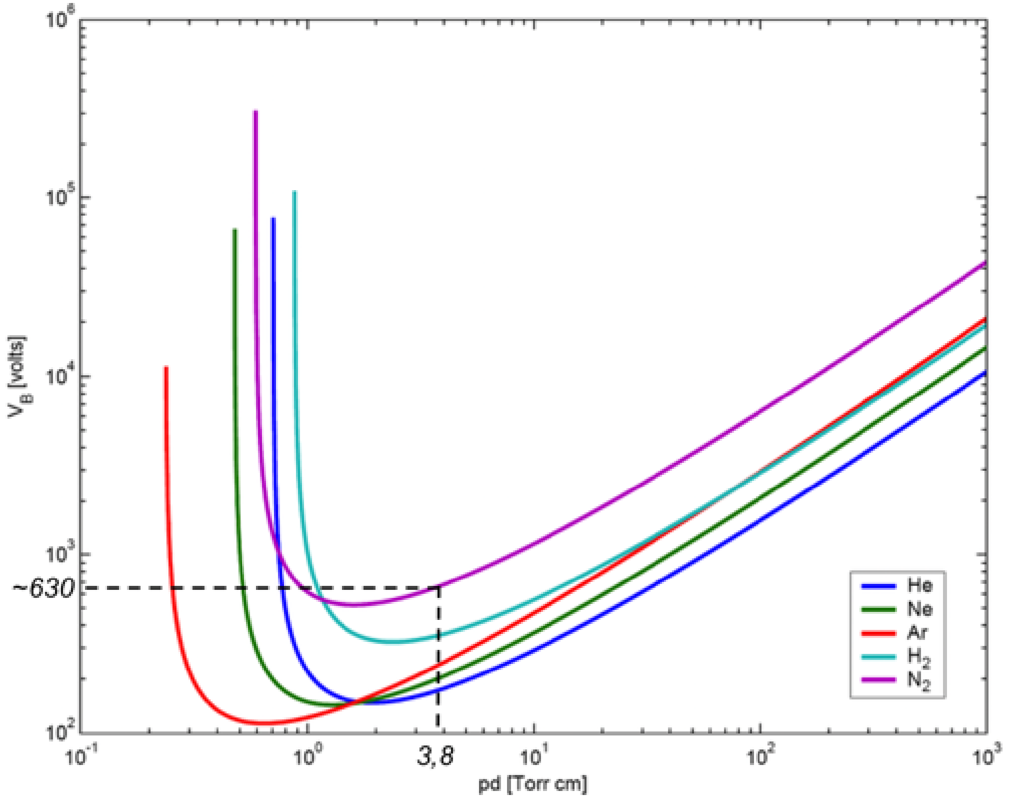


Electrical field configuration at the nominal voltage 4400V

Region	**Gap [mm]**	**Electric field [kV/cm]**
Drift	3	2.4
Transfer 1	2	3.6
Transfer 2	2	3.6
Induction	2	3.6
Region	**Voltage [V]**	**Average Electric field [kV/cm]**
Δ_{GEM1}	400	80
Δ_{GEM2}	360	72
Δ_{GEM3}	325	65

Backup slides

Paschen's curves for different medias



Breakdown voltage is the empirical value necessary to start a discharge in a GEM foil :

$$V_b = \frac{B.pd}{C + \ln(pd)} \quad \text{with} \quad C = \frac{A}{1+1/\gamma}$$

- A and B: experimental constants related to the gas
- $\boldsymbol{\gamma}$: second Twonsend coefficient
- P: gas pressure
- D: distance between two electrodes

Backup slides

Relation between the gain G, the current on the readout PCB I_{anode} and the primary ionization:

$$G = \frac{I_{anode}}{I_{primary}}$$

but $I = \frac{dq}{dt}$ which leads to $I_{primary} = Rate * q_e * N_{primary}$

- *Rate* (KHz): ionization counted experimentally for 1min
- q_e: charge of electron
- $N_{primary}$: Number of ionizations counted experimentally depending on the gas mixture injected

Backup slides

Example: Scan test LabVIEW Program (back window)