CMS GEM GE1/1 detector production status

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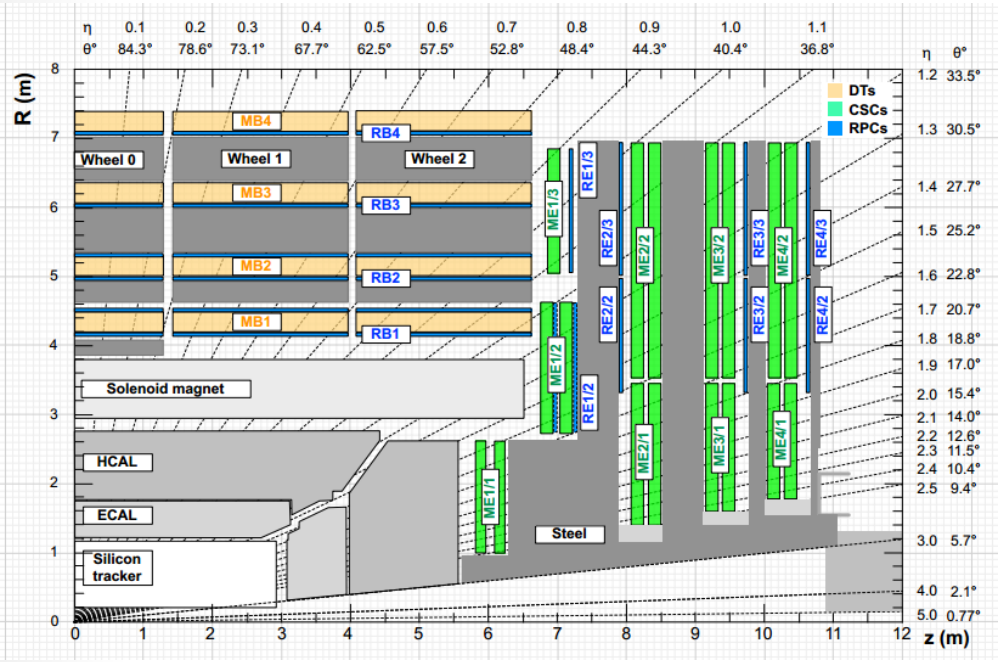
Outline

- The CMS Muon System
- CMS Forward Muon Spectrometer Upgrade
- The GE1/1 chambers
- GE1/1 chambers production status
  - Infrastructures
  - Material procurements
  - GEM Foils production and tests
  - Production sites
- The Slice Test exercise
- Summary

The CMS Muon System

Highly hermetic and redundant muon system, at least four stations on a muon path in all directions



3 technologies:

- **Drift Tubes** and **Cathode Strip Chambers** (for tracking and triggering);
- **Resistive Plate Chambers** (for triggering).

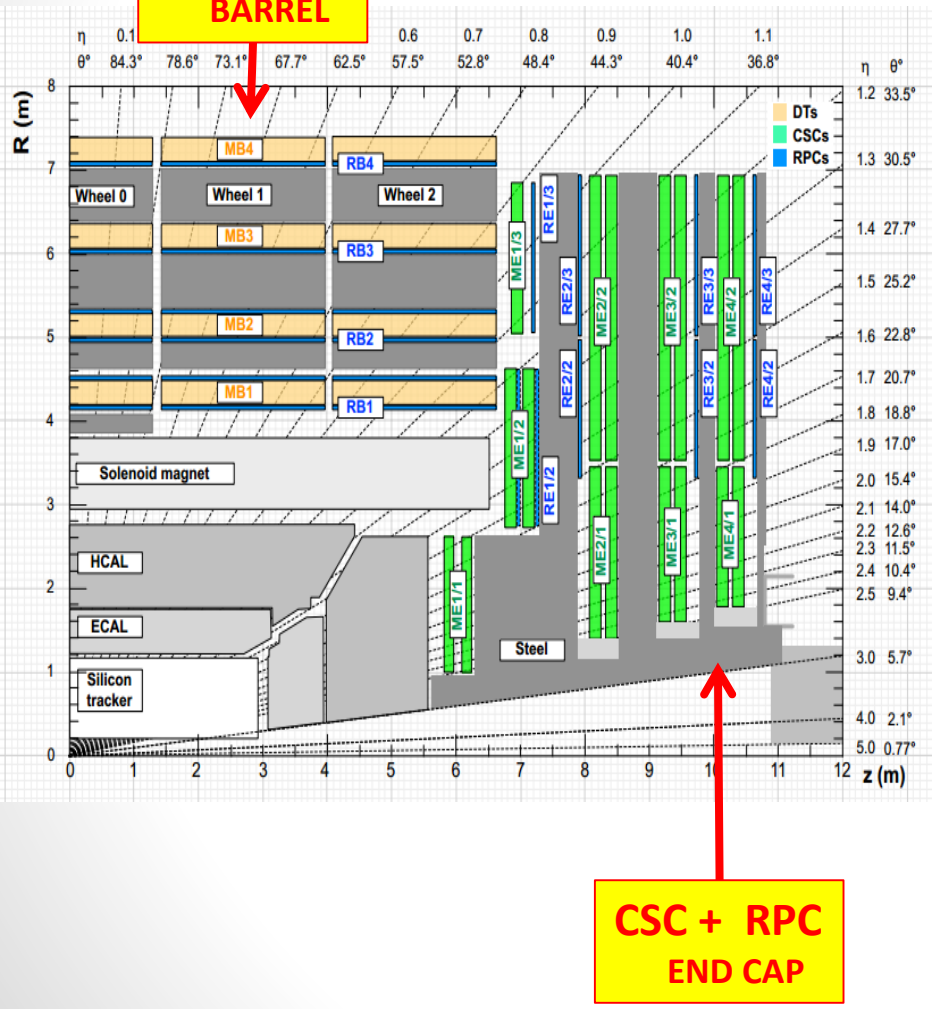
Eta coverage:

- $|\eta|<1.6$: 4 layers of CSCs and RPCs, DTs
- the $|\eta|\geq1.6$: CSCs only;

GOALS:

- **robust**, **redundant** and **fast** identification of the muons
- **Level-1 trigger** has access to muon information only
- **Momentum measurement**: the muon system is relevant for high pt muon (>100 GeV) and in the high η region (large lever arm of the muon system)

Gas detectors technologies in CMS



Drift Tubes (DT)

- Central coverage: $|\eta| < 1.2$
- Measurement and triggering
- 12 layers each chamber: 8 in φ, 4 in z

Cathode Strip Chambers (CSC)

- Forward coverage: $0.9 < |\eta| < 2.4$
- Measurement and triggering
- 6 layers each chamber: each with φ, z

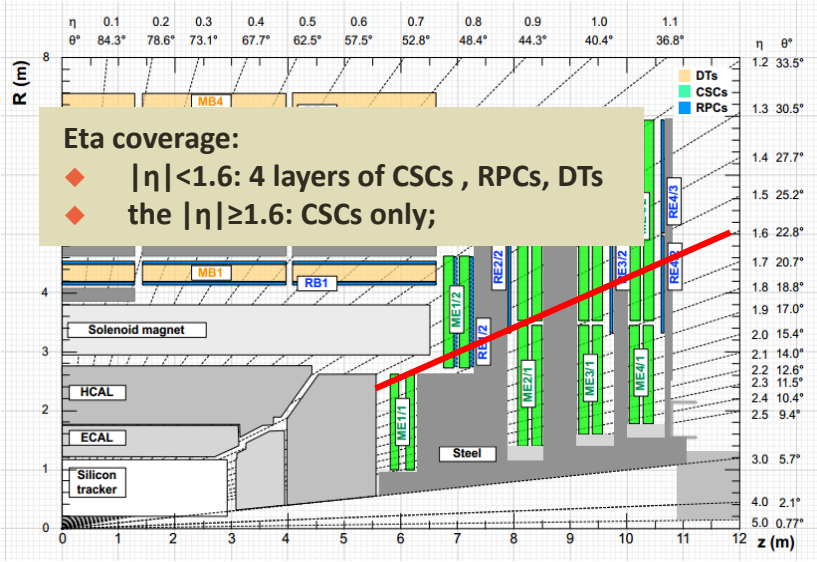
Resistive Plate Chambers (RPC)

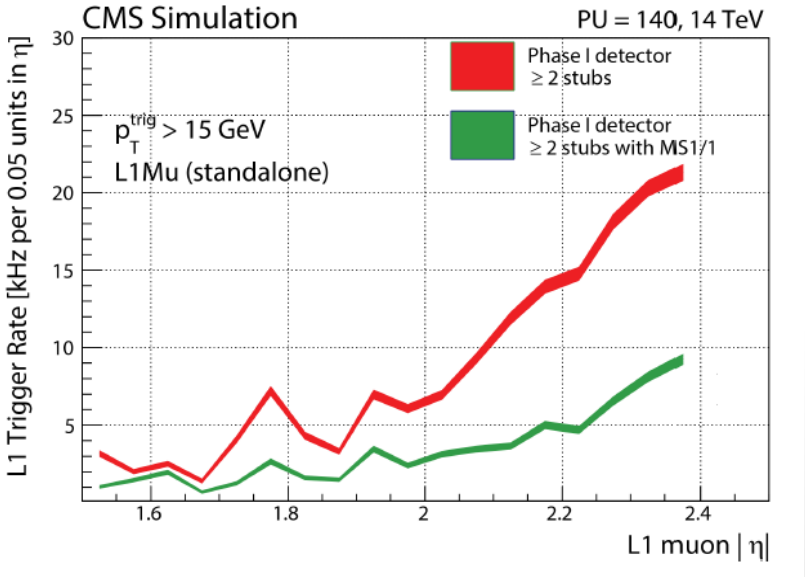
- Central and Forward coverage: $|\eta| < 2.1$
- Redundancy in triggering
- 2 gaps each chamber, 1 sensitive layer

CMS Forward Muon Spectrometer Upgrade

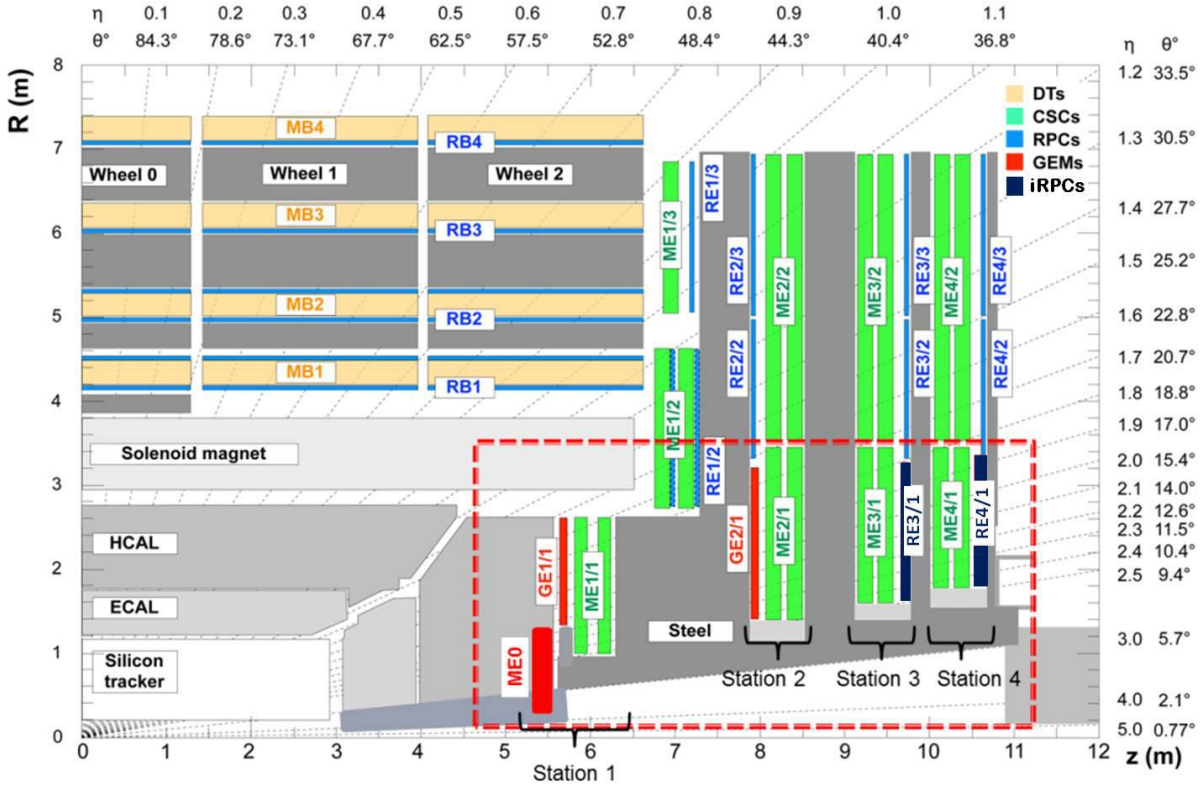
The forward region |η|≥1.6 is very challenging

- **Redundancy**: the highest rates in the system vs fewest muon layers
- **Few** handles for the new Track finder postLS2 and for the track-trigger in HL-LHC
- **Rate** : in 10's of kHz/cm^2 and higher towards higher eta and worse momentum resolution
- **Longevity:** Accumulated charge after many years of LHC operation
- **Electronics:** High occupancy/rate and latency increases exceed capabilities of the existing electronics





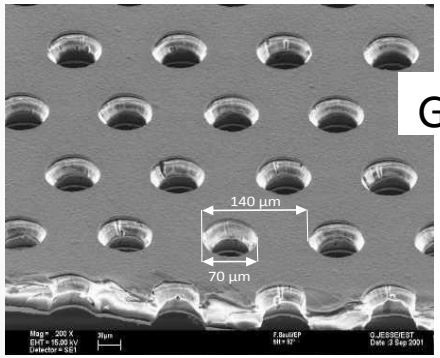
CMS Forward Muon Spectrometer Upgrade



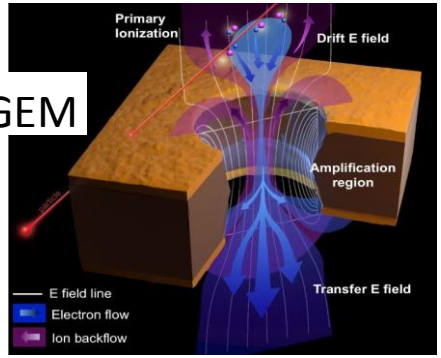
- Objectives:
  - Sustain triggering at current trigger thresholds
  - Increase offline muon identification coverage
  - Maintain existing envelope by mitigating aging effects

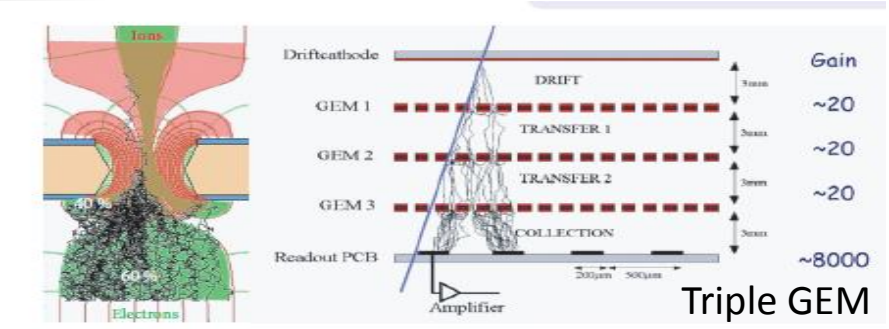
GEM Detector as technology for the CMS Muon System Upgrade

Micro-Pattern Gas Detectors (MPGD) due to their proven performance at HEP experiment (high rate capability and fine space resolution, high gain stability) are ideal tools for the Upgrade of the Forward Muon Spectrometer in CMS



GEM



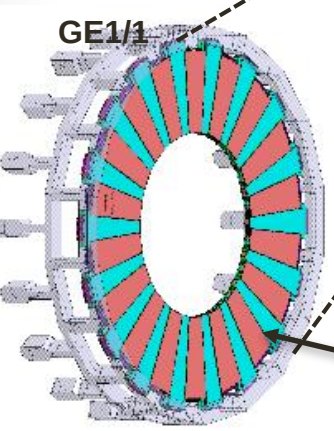


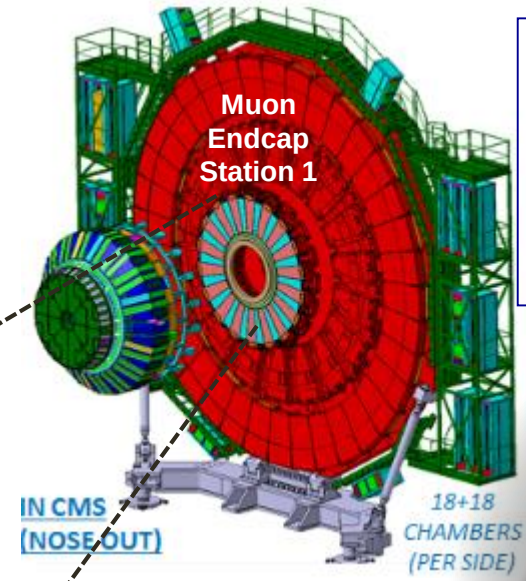
Triple GEM

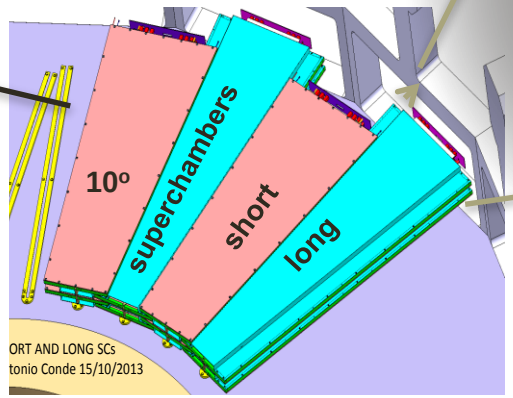
Triple GEM technology as adopted detector

- **Maximum geometric acceptance within the given CMS envelope**
- **Rate capabilities up to 100's kHz/cm2 .**
- **Single-chamber efficiency > 98 % for mips**
- **Gain uniformity of 10% or better across a chamber and between chambers and no loss due to aging effect after 3000 fb^{-1}**
- **High spatial and good time resolution**

GE1/1 design







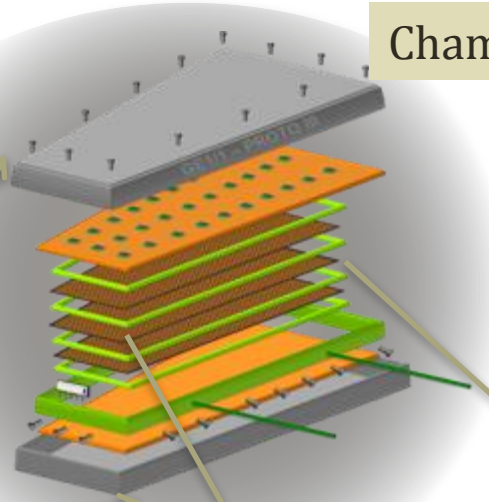
GE1/1 in high-η region 1.5<|η|<2.2

10^0 trapezioidal triple-GEM Superchambers

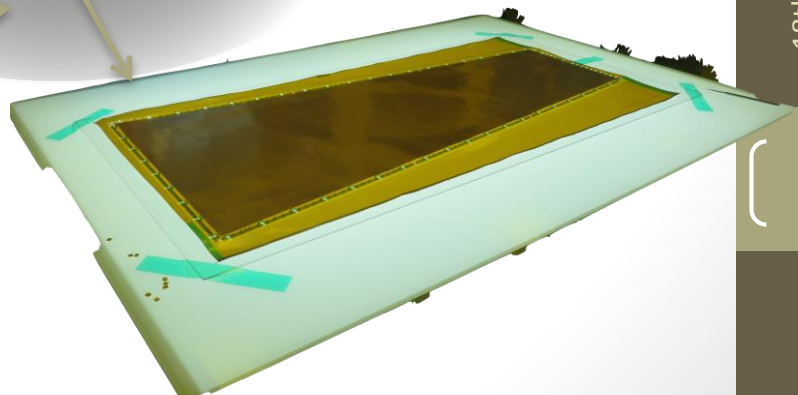
Long (1.5<|η|<2.2) and short (1.6<|η|<2.2) version

36 superchambers in each endcap

Chamber



Foils



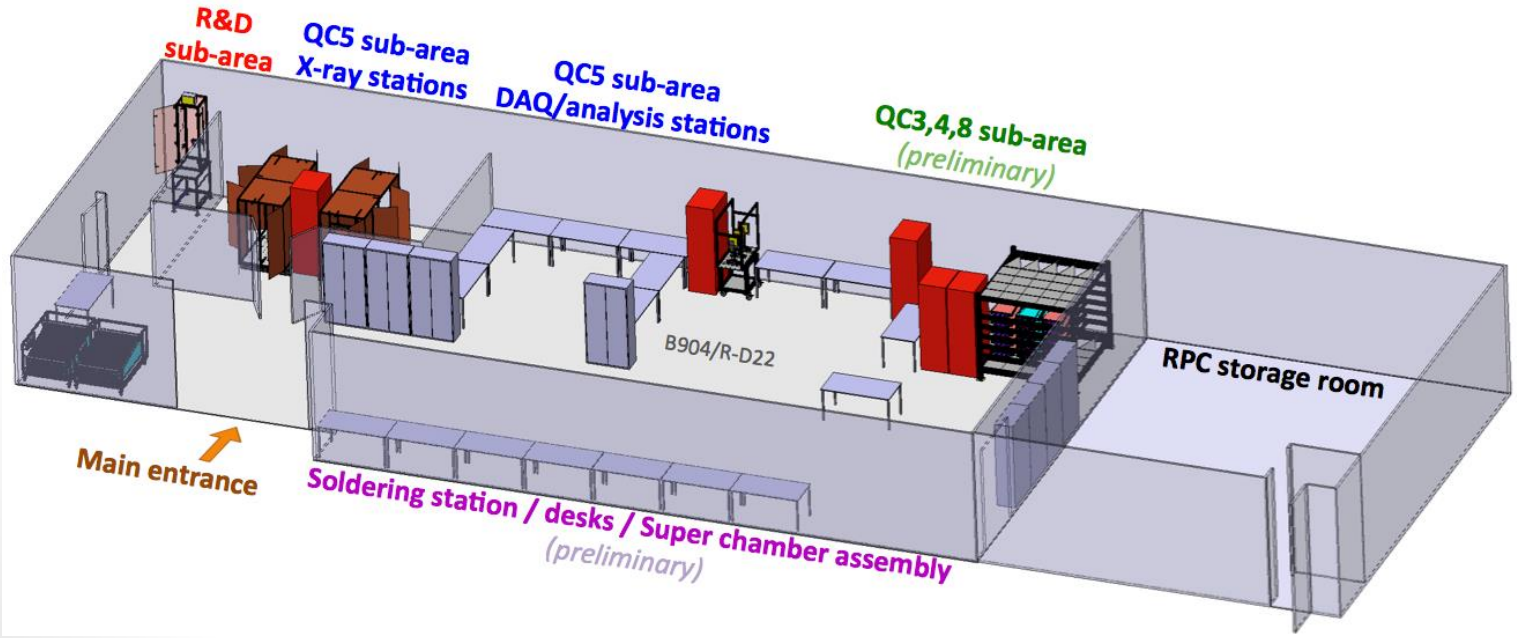
Installation in LS2

GE1/1 chambers production status

- Infrastructures

New GEM lab @ CERN for QA/QC of the GE1/1 chambers

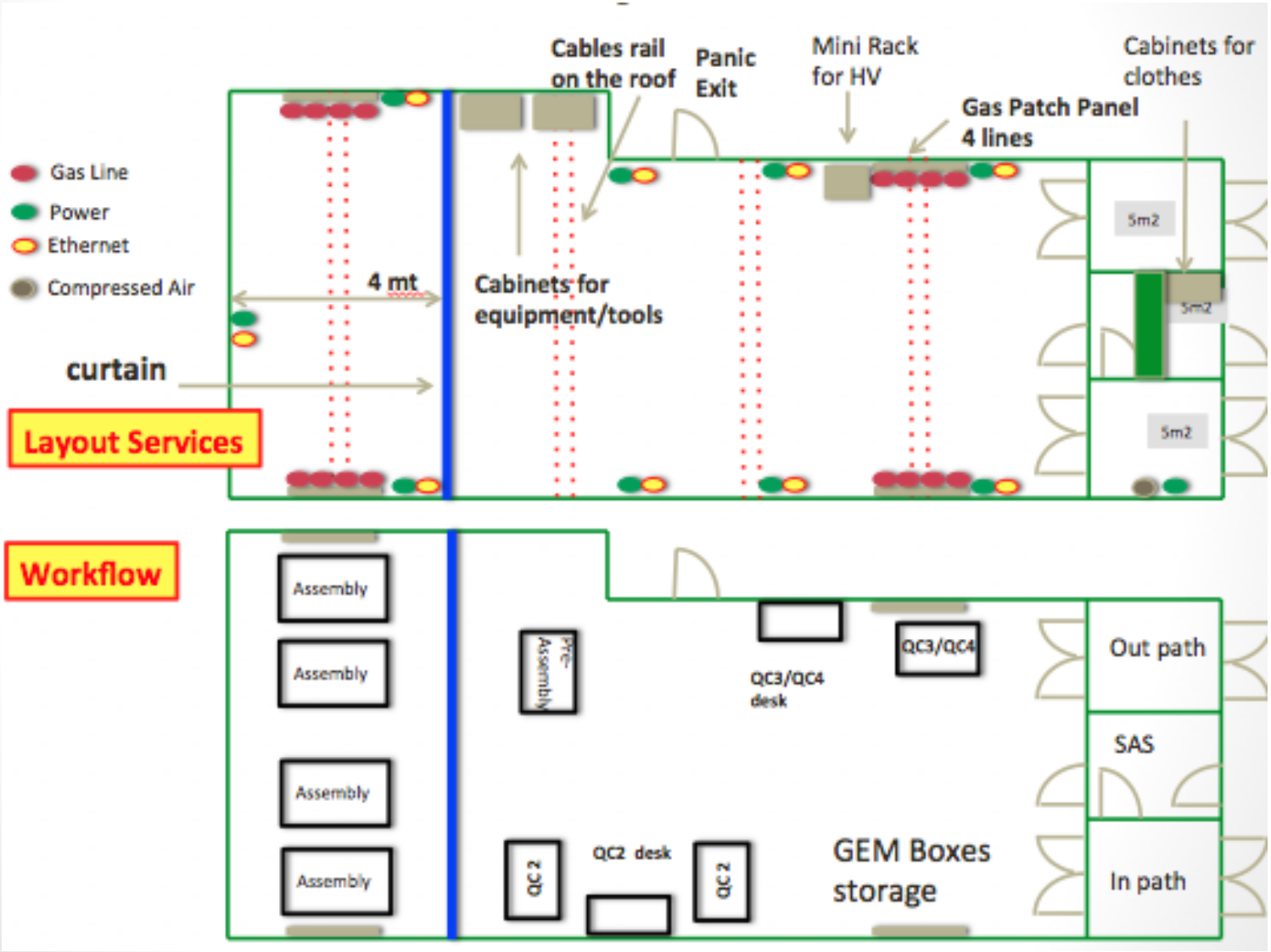
- The new GEM lab for LS2 chamber certification and qualification is under refurbishment and preparation.
- Design of services (gas, power, …) finalized



New Clean Room @ CERN (Bd. 904)

- New facility for GEM chamber assembly
- **Total surface ~120 m^2** (~102 m^2 proper clean room + 18 m^2 SAS)
- Certified as "**Class 1000 in operation**"
- Partition (~ 40 m^2) with improved "Class quality"
- The total flow rate will be distributed through 42 housings with absolute filtration 1220x610x70mm (each one 1200m3/h)
- **180 air cycles / hour, ceiling coverage** (in the class 1.000 area) **above 30%**.
- **Clean Room able to host two** (or more) **GE1/1 production lines**
- **Now in construction, commissioning expected in November 2016**

New Clean Room @ CERN (Bd. 904)



GE1/1 chambers production status

- Material Procurement

Material procurement

- GE1/1 chambers are the results of the coupling of several components (PCB, GEM Foils, Frames, O-rings, HV/Gas connectors, …)
- Bill of material finalized
- Material procurement is ongoing
- Quotations for each piece received
- Several components already at CERN

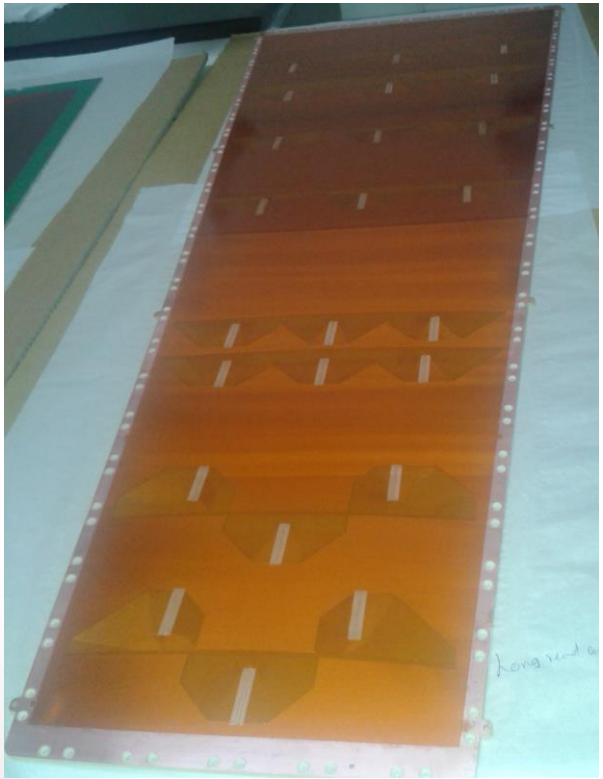
Material Procurement: Full List

Component	Supplier
GEM Foils	Rui Workshop
RO PCB	Micropack
Drift PCB	Micropack
Internal/ External Frame	Eltos
Pull Out	MANSNER (FINLAND)
O-ring	ANGST & PFISTER AG
Screws / washers	Bossards
Gas Plug	Parker Legris
Panasonic Connectors Inst.	Peninunsula
HV dividers	Hybrid SA
SMD components	Farnell/Mouser Elec
HV pins	Fixtest
Brass Insert (Internal)	Kerb-Konus
Brass Insert (Flanges)	Titanox

Material procurement

Drift and R/O PCB:

Preproduction almost ready, good results from the visit at production site (Micropack 22th)



GE1/1 chambers production status

- GEM Foils, production and test

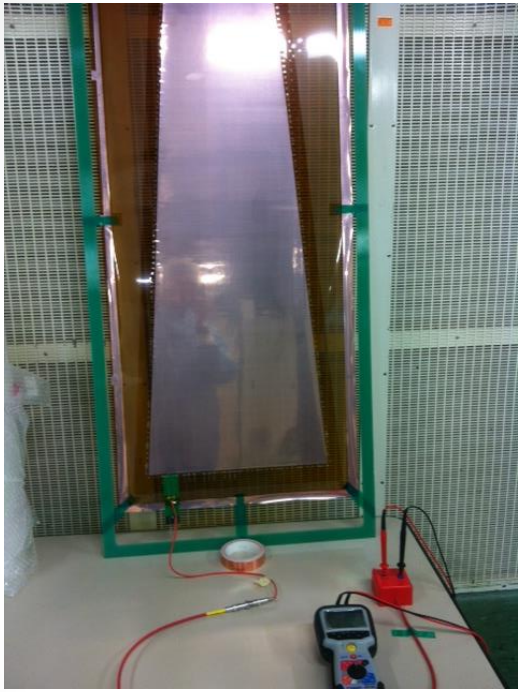
Foil Production and Tests

- The mass production of the GE1/1 foil for LS2 chambers started on 7th March 2016, initial delay (~ 2 month) due to problems with the base material
- From the production schema we expected a initial production rate of 20 Foils/month (60 foils every quarter of year), this rate should increase to 80 foils/quarter in future.
- The production rate sustained until now is close to the expected rate
- Foils received at the GEM QA/QC lab are regularly tested, certified and stored

Foil Tests

- Foils produced in the MPT workshop are delivered to CMS GEM clean room, where they undergo to dedicated QA/QC test. This is the so called QC2 step in the CMS GEM QC flow chart.
- QC2 is divided in two steps: “Fast” and “Long”.
- QC2 Fast: Current and sparks measurements in air for 10 minutes, QC2 Fast test is performed both in MPT workshop before the foils delivered and as soon as the foils arrive in the QA/QC lab.
- QC2 Long: Current and sparks measurements in N_2 15 min
- Foils fails the first test (QC2_Fast) it is promptly sent back to the MPT workshop for cleaning.

QC2 FAST TEST

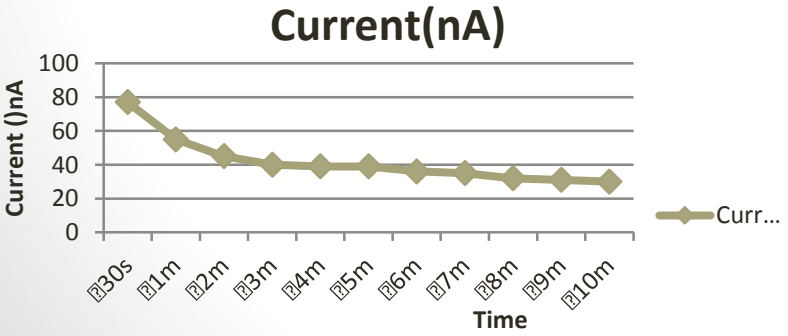


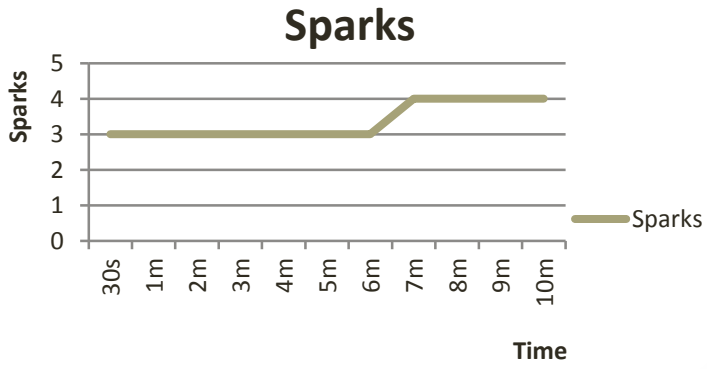
The QC2 fast test is conducted with the help of a Mega Ohm Meter (Megger) over a period of 10 minutes.

A foil is characterized by the ramping of the impedance (current decay) and sparks exhibited by the foil.

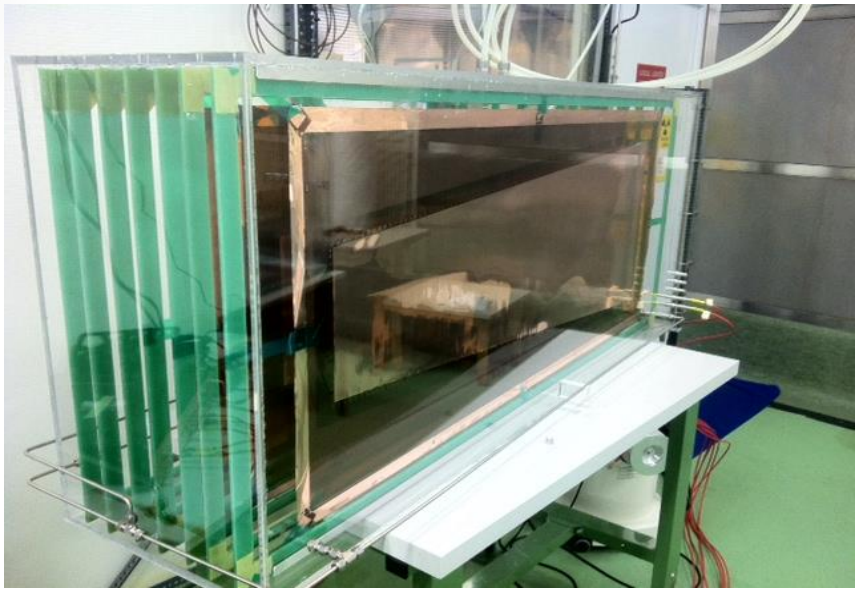
Foil is accepted if the impedance measured is above 12 Giga Ohm (Current < 40 nA) with less than 10/15 sparks over the 10 minutes. If the number of sparks exceed the limit than the foil have to be re-cleaned with the roll or, in the worst case, with DI water. (Impedance value is strongly dependent from relative humidity)

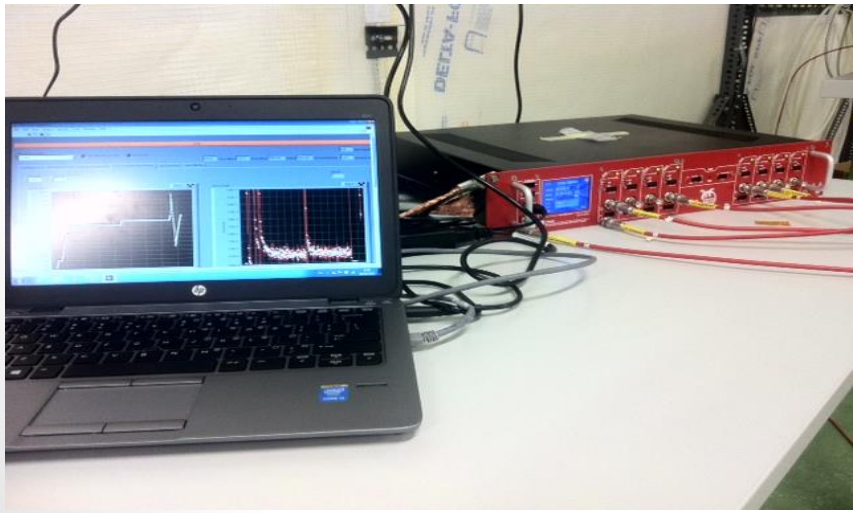
QC2 Fast performed on all 88 delivered foils, 6 foils failed this steps, all of them belong to the first batch (20 foils), to prevent additional failures QC2 fast has been introduced as standard check in the MPT workshop from the second batch, since them no failures in QC2 fast has been observed





QC2 LONG TEST





Goal of the QC2 long test is the ultimate certification of the GEM foils before the installation in the GE1/1 chambers

QC2 Long test is conducted using CAEN HV module with 50 pA of current resolution acquired through LabView based software.

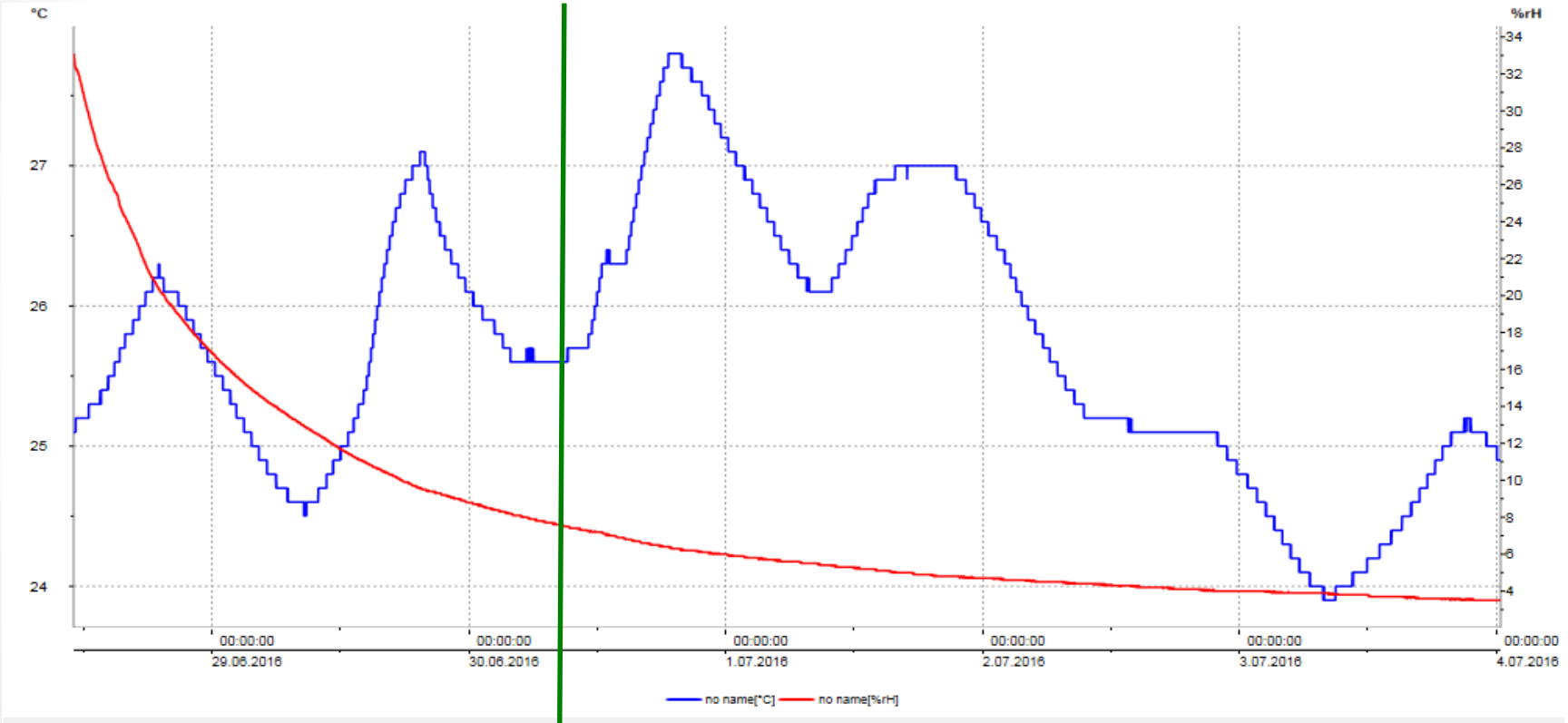
The foils are kept at low humidity level (~5%) in a dedicated box by flushing pure dry Nitrogen.

QC2 LONG TEST

- From our experience, foils improve their quality (sparks become less frequent, if any) keeping the foils under voltage
- The Long test is divided into **preliminary characterization phase and 3 steps with data monitoring**:
  - During the "first gas flushing period" ~36/48 hours, needed to reduce the relative humidity, the GEM foils are kept at 500/550 Volts, (Current limit 100 nA, trip time 1sec)
  - **Step 1:** Slow rump up to 500V, plateau monitor at 500 and 550 Volts; step is passed if no sparks occurred for 10 minutes for each HV value
  - **Step 2:**HV fixed at 600 volts, current and sparks are monitored; step is passed if no sparks occurred for 15 minutes or no more than two spark in 30 min. (Current limit 50 nA, Trip Time 0 sec)
  - **Step 3:** Voltage switches between 100 volts and 600 volts, to evaluate the off-set in current measurement, if any.

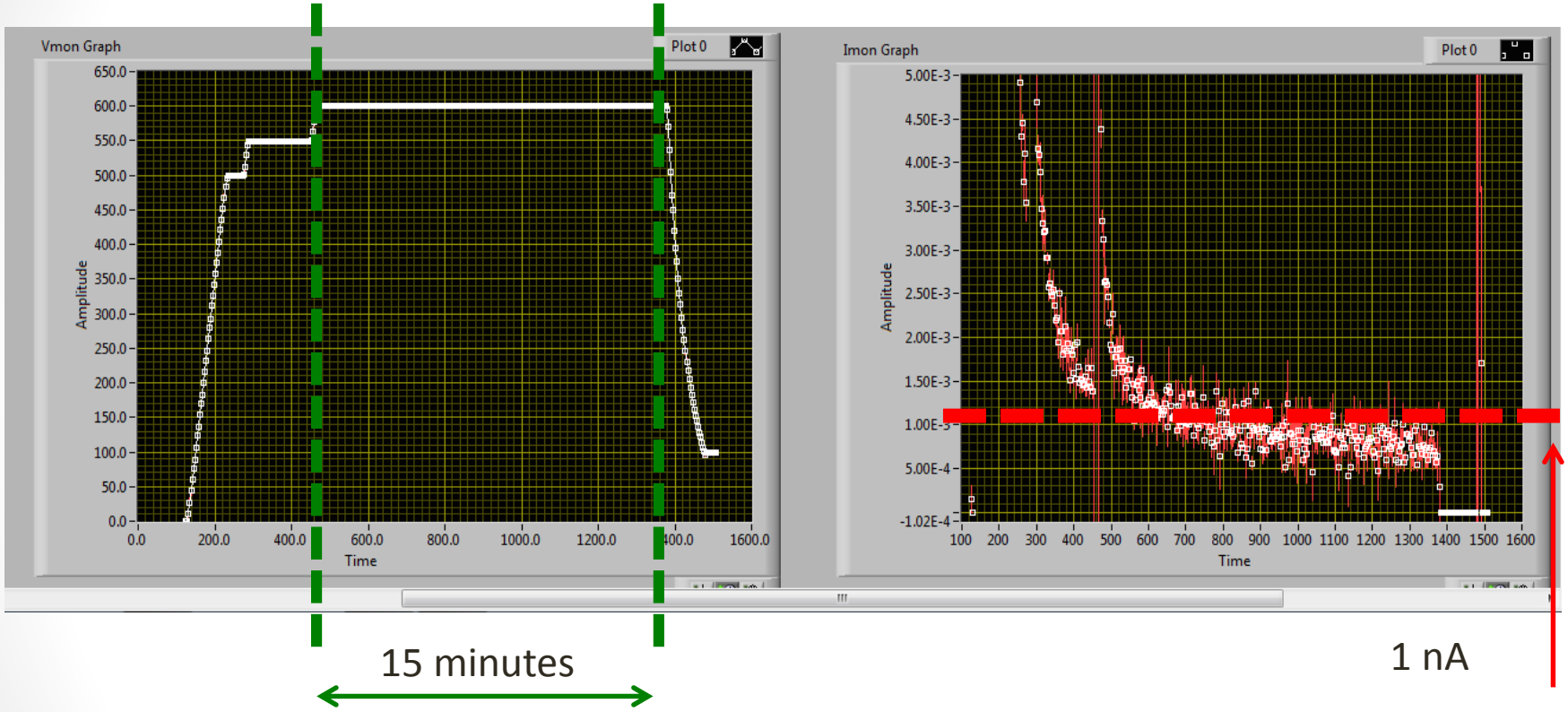
QC2 LONG TEST

Temperature and Humidity monitoring during the QC2 Long test



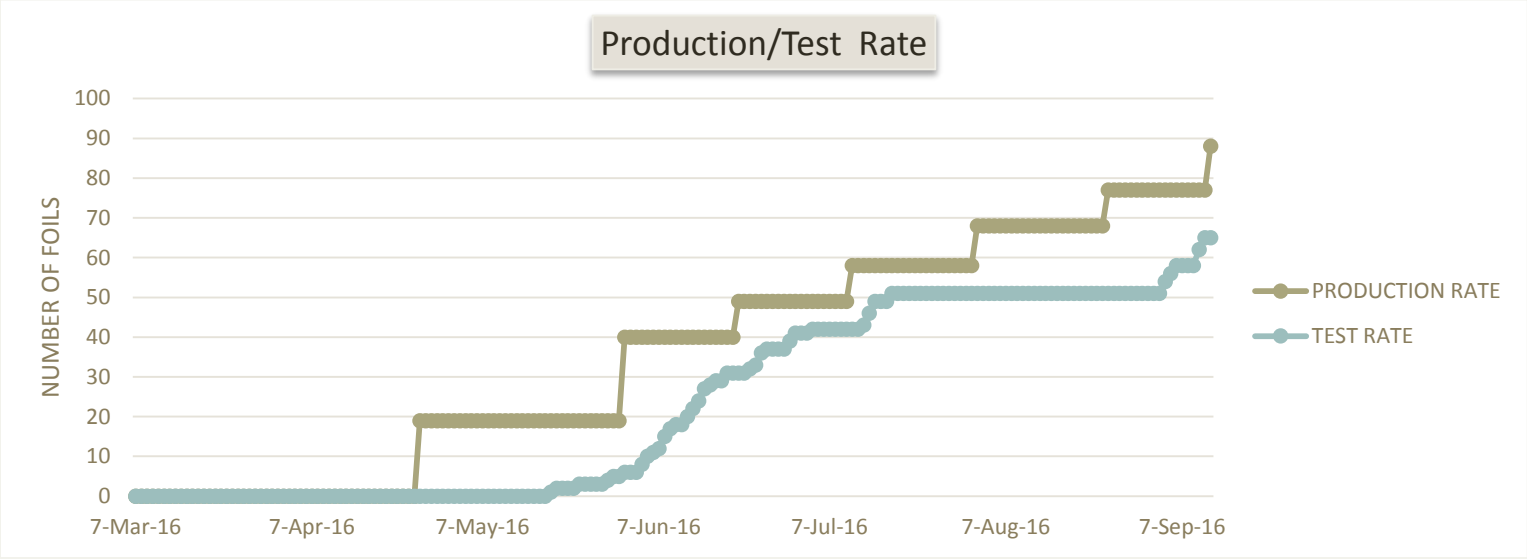
preliminary characterization phase

QC2 LONG TEST (Step 2)



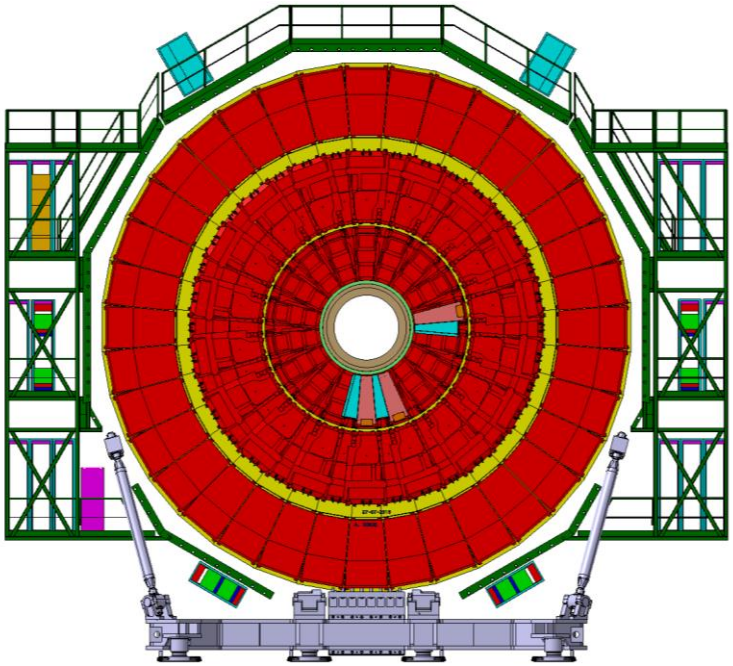
HV fixed at 600 volts, current and sparks are monitored; step is passed if no sparks occurred for 15 minutes or no more than two sparks in 30 min
Foils are rejected if the test is failed more than three times.

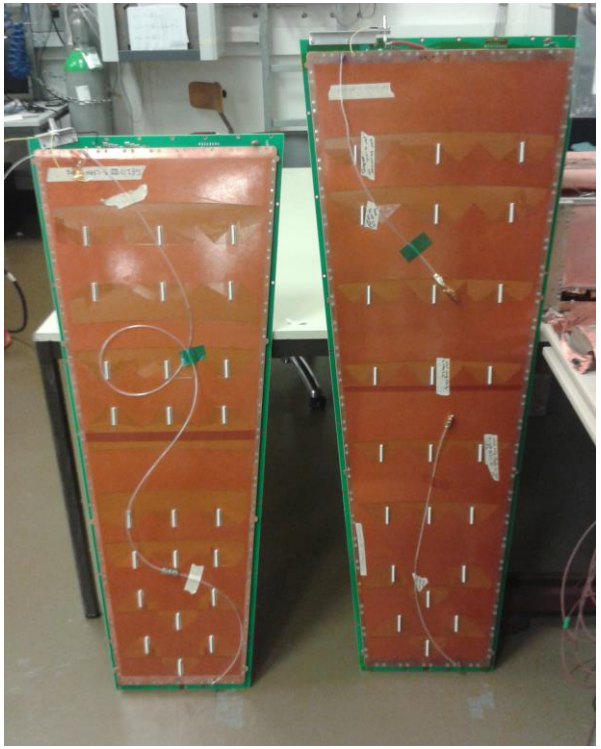
QC2 Long: Test Rate



- ✓ **88 Foils produced up to now**
- ✓ 6 Short Foils used for the production of two additional Slice Test Chambers
- ✓ 82 Foils delivered to GEM QA/QC lab; 65 Foils tested up to now, now 7 under test, 10 to be tested next week.
- ✓ Up to now only 2 foils didn't pass **the QC2 long test** up to now **(97% fine!)**
- ✓ One foil passed the test after re-cleaning in the MPT
- ✓ One foil to be re-cleaned

Slice Test





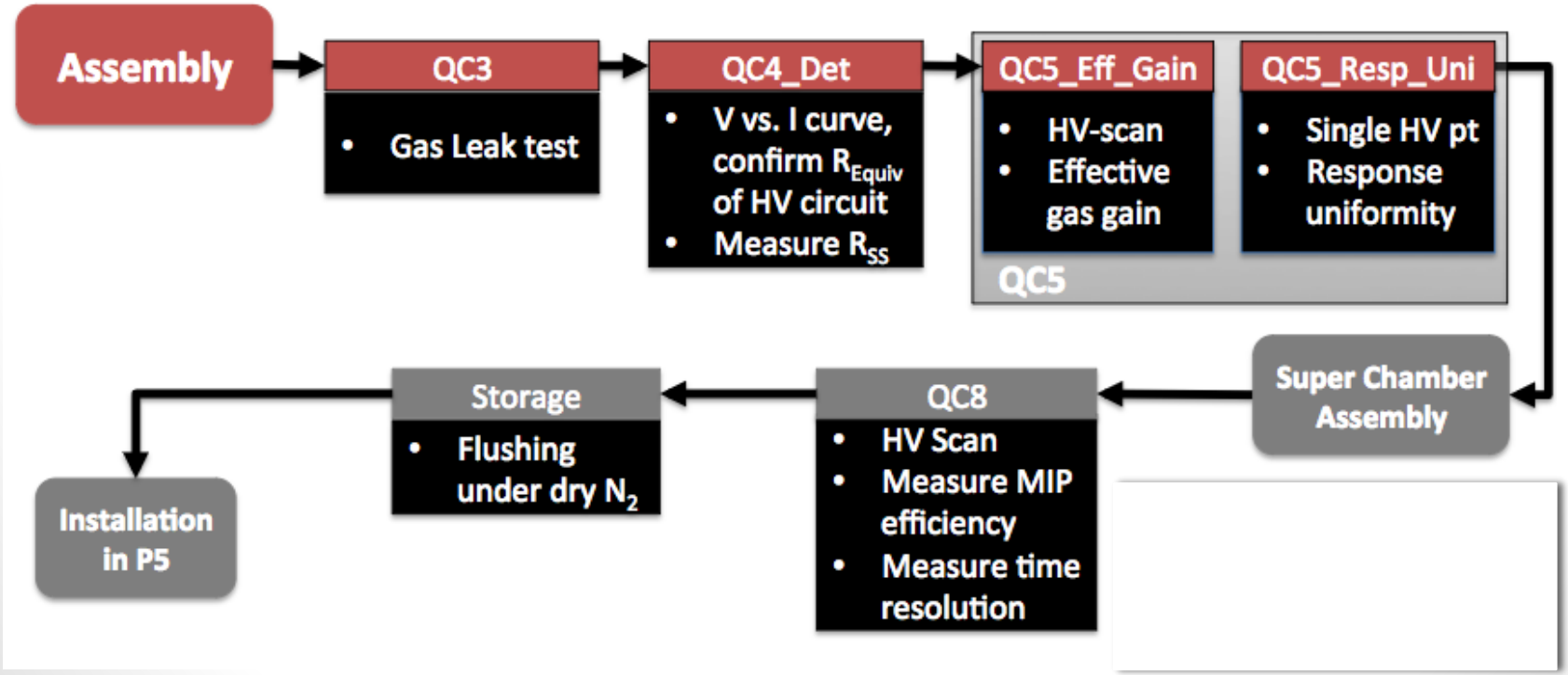
5 Super chambers will be installed during next EYETS2016

10 Detector (4 Long / 6 Short) already assembled, now under certification

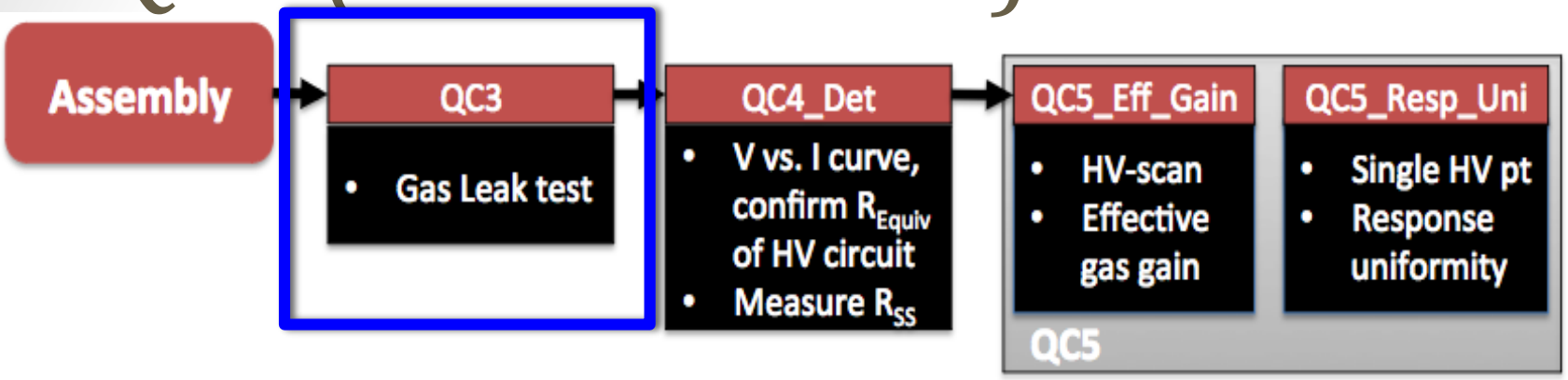
The Slice Test chamber is a unique opportunity to test the GE1/1 detectors in situ, as well as to run in and tune the mass production chain

Slice Test QA/QC

- Each Chamber/Super Chamber have to undergo through detailed QA/QC path
- QA/QC test on the GE1/1 LS2 chambers will be the same adopted for the Slice Test Chambers
- The Slice Test is exceptional occasion to setup and test the full QA/QC chain



QC3 (Gas Leak Test)

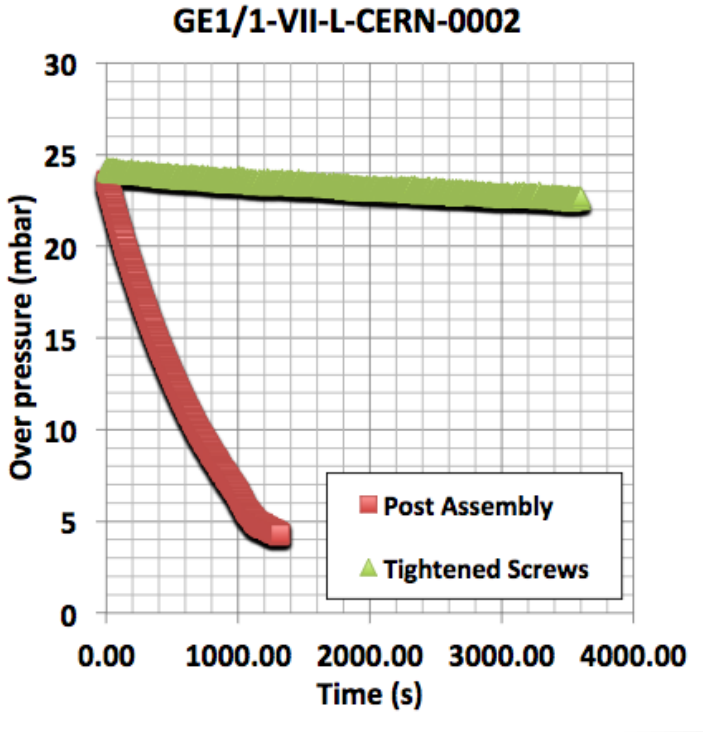


QC3 post assembly and
after tightening gas volume screws

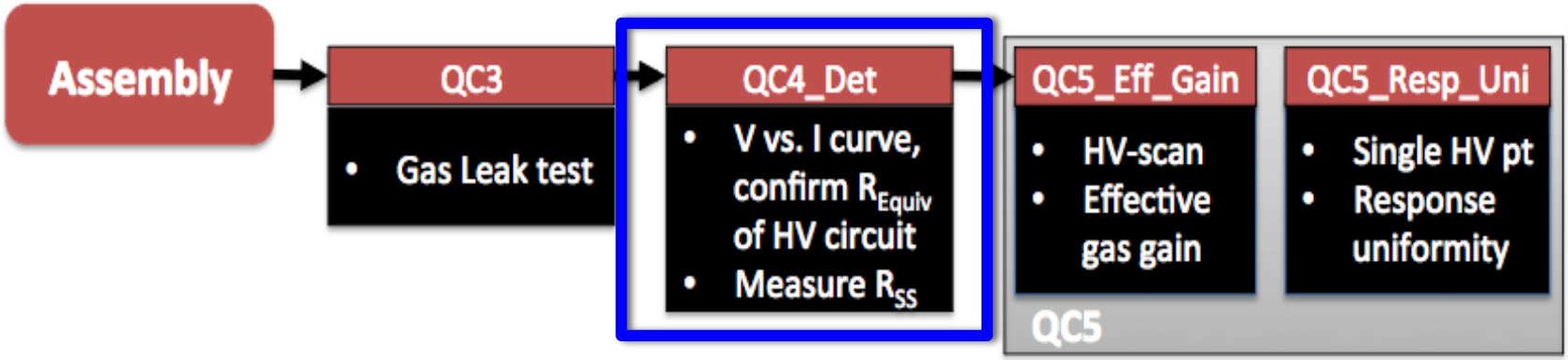
Need torque control when closing detectors!

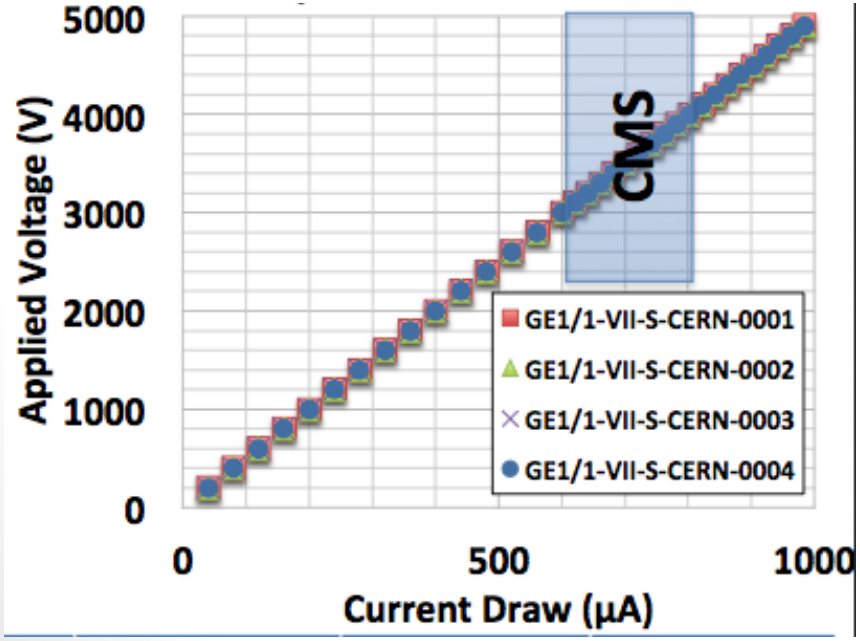
Use torque screwdriver when sealing detectors

Apply 0.7/0.8 Nm to all sealing screws



QC4 (HV Testing)





HV circuit R_{equiv} from slope of V vs. I
–Also measured with multimeter
–Percent difference between two values less than 2%

QC4 is performed in pure CO2
– Non--amplifying gas to identify, if any, internal discharge

QC5 (Effective Gain / Uniformity)

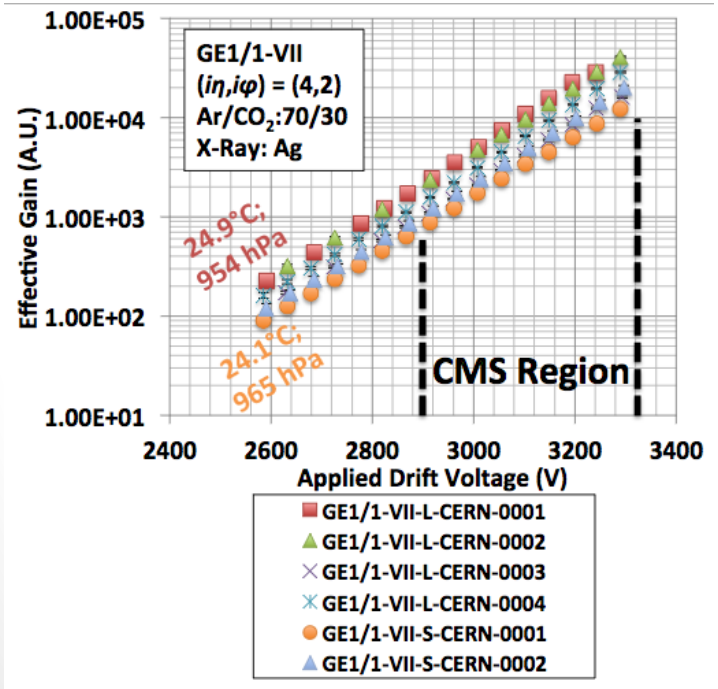
Assembly → **QC3**
- Gas Leak test

→ **QC4_Det**
- V vs. I curve, confirm R_{Equiv} of HV circuit
- Measure R_{SS}

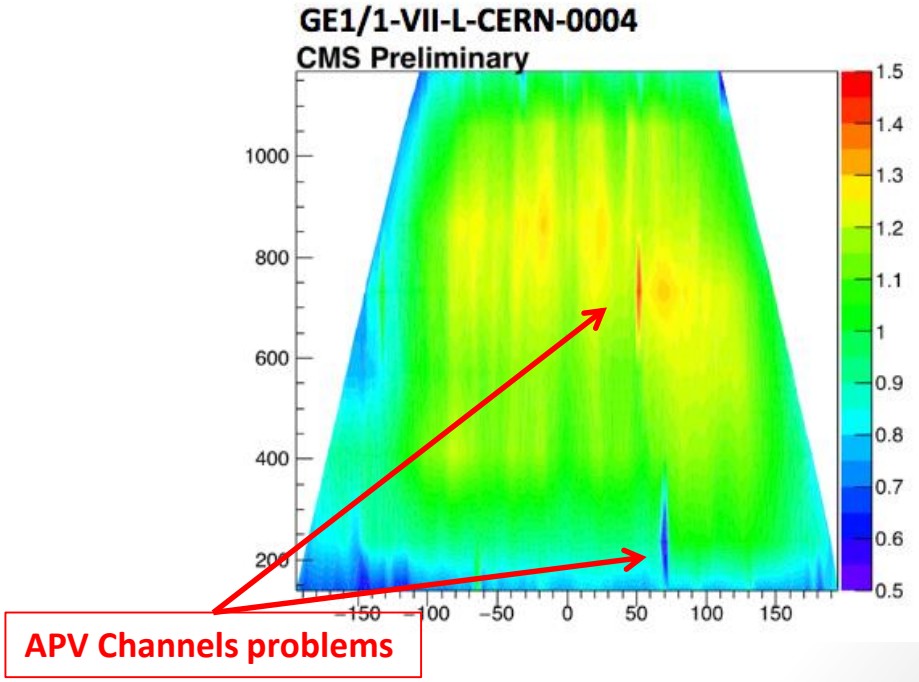
→ **QC5**

QC5_Eff_Gain
- HV-scan
- Effective gas gain

QC5_Resp_Uni
- Single HV pt
- Response uniformity



Effective gain vs. drift voltage



Normalized response

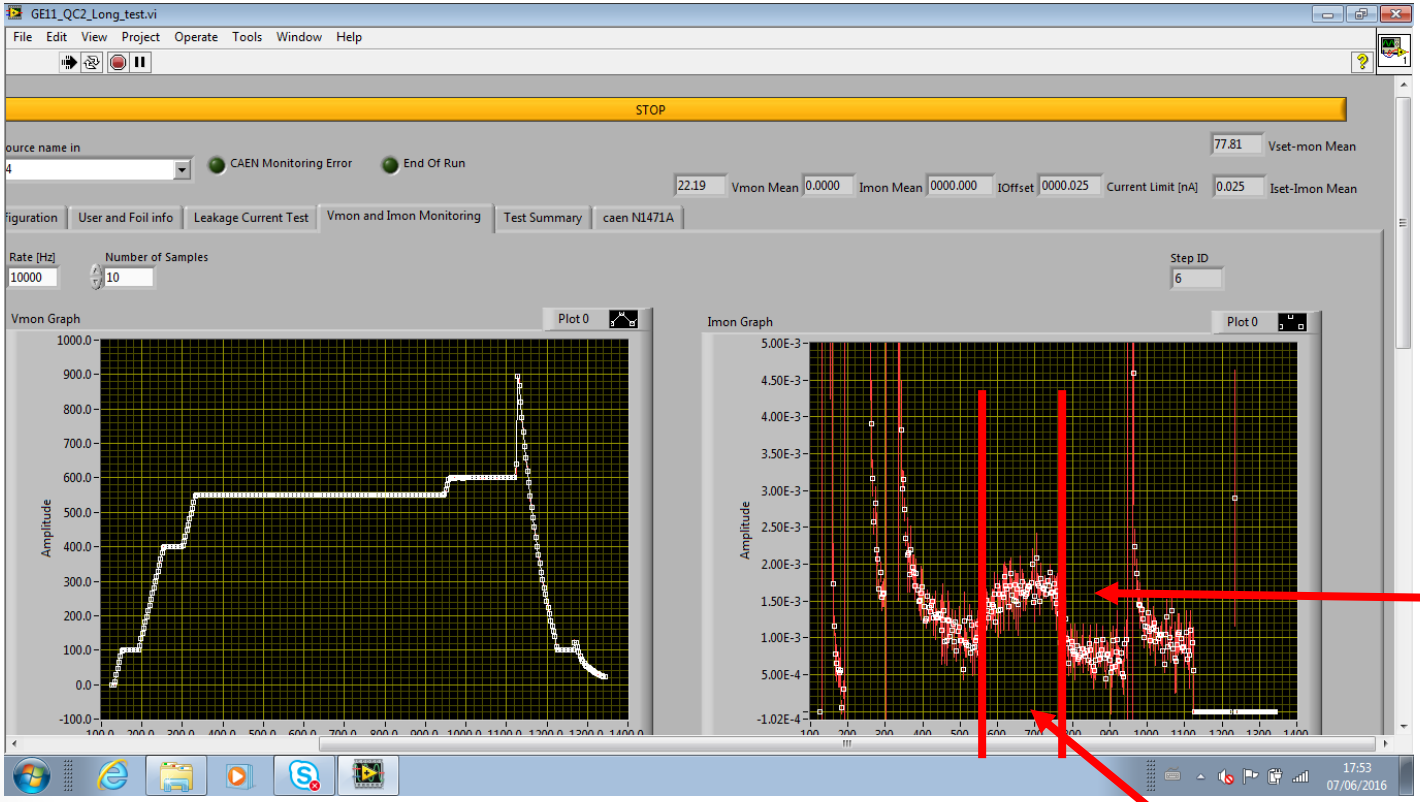
Slice Test: Summary

- All Chambers needed for the Slice Test
- QA/QC on each single chamber almost finalized
- Ready for integration in Super-Chamber
- Super-Chamber cosmic test under commissioning
- Services in P5 cavern in preparation

Summary

- GE1/1 chamber production is ready to start
- Infrastructure for GE1/1 chamber assembly almost ready
- Material procurement in advanced status
- GEM foils production is running smoothly with very good yield
- Detector mass production is like a puzzle: all pieces have to be under control, if a single pieces is lost the resulting picture is broken
- Slice Test exercise is on track

QC2 LONG TEST

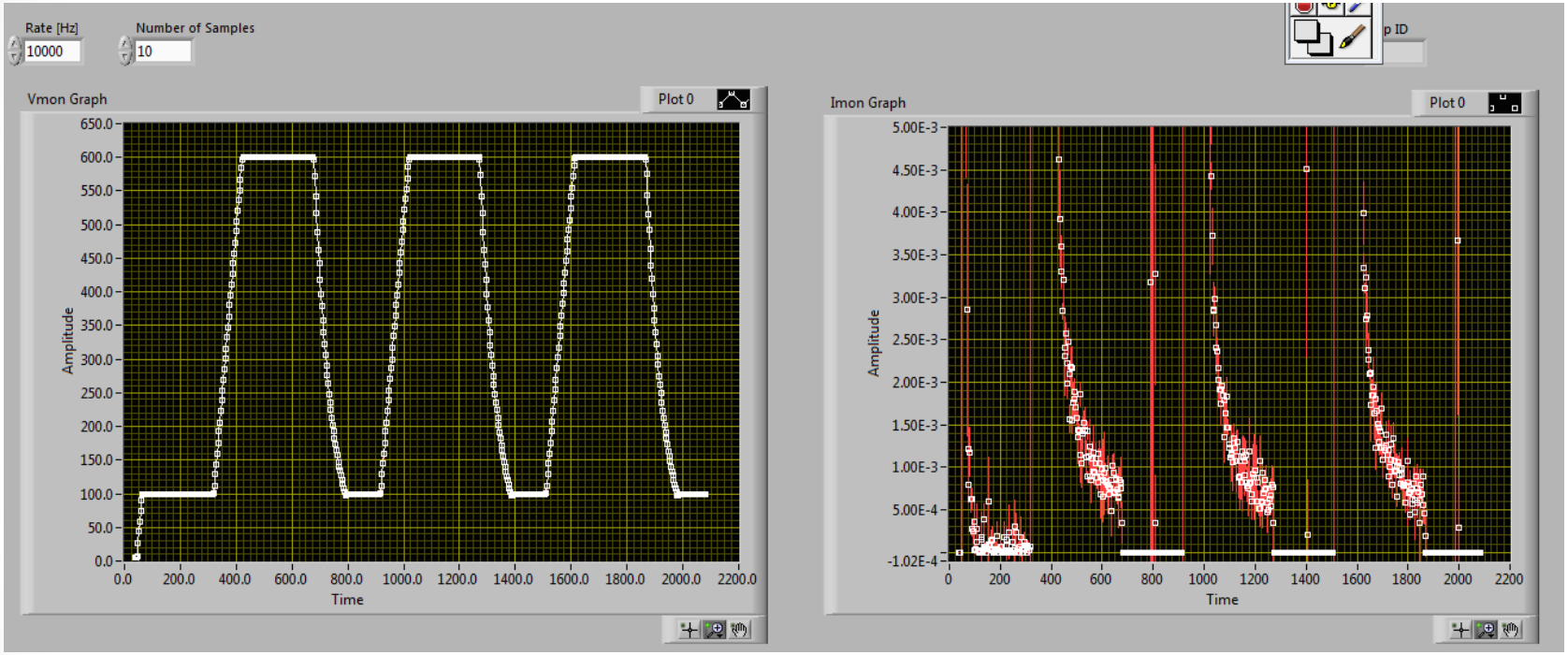


~ 1 nA jump

Lighting lab ON

Very powerful and sensitive setup, we are able to evaluate the current, through the GEM foils, induced by the photons of lighting lab (standard neon),

QC2 LONG TEST (Step 3)



Voltage switches between 100 volts and 600 volts, to evaluate the off-set in current measurement