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Quality assurance and control of LEM and Anode at IRFU-Saclay

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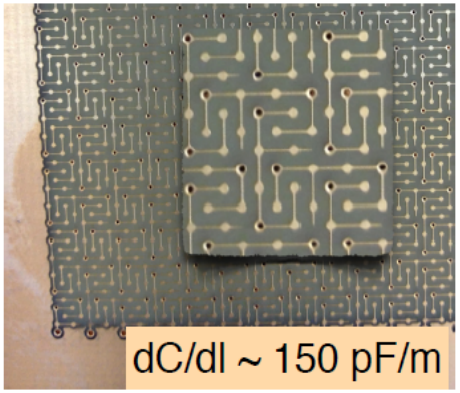
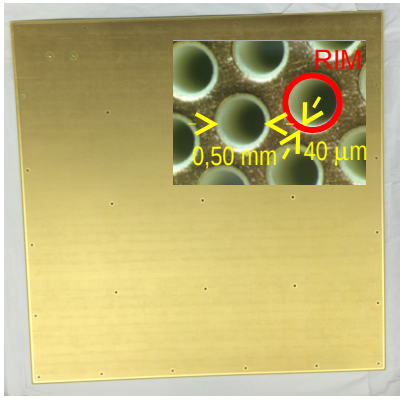
Based on the talk given by A. Delbart at the March 2017 WA105 Collaboration Meeting

Anode



LEM



Proto DUNE DP Technical Design Review, April 24 2017

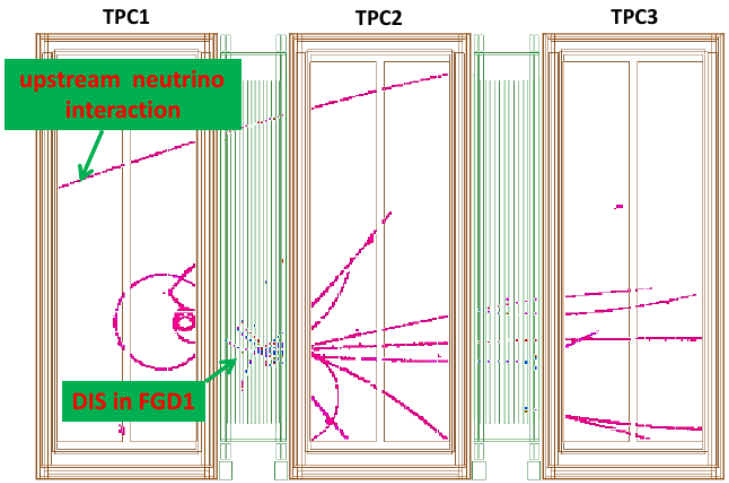
outline

- LEM specifications
- Production and QA/QC procedures of the LEMs
  - ✓ In the PCB industry
  - ✓ By the WA105 collaboration @ Saclay
    - Assembly and cleaning + baking
    - Final qualification for Breakdown Voltage @ $P_{abs} \approx 3.3$ bar
  - ✓ By the WA105 collab. @ CERN : LEM + Anode + assembly on CRP
- Status of the call for tender for the LEM production
- Anode PCB : specifications, QA/QC
- Conclusion

IRFU CEA Saclay

IRFU CEA Saclay has a long experience in building large detectors, in particular tracking detectors (eg CDHS, NA48, DELPHI TPC, NOMAD ….)

- Since 1996 it has played together with CERN a pioneering role in the development of MicroPattern Gas Detectors with the invention of Micromegas detectors
- Our group has designed and built the Micromegas for the first large TPCs based on MPGD for T2K (9 m**2), operating flawlessly since 2010

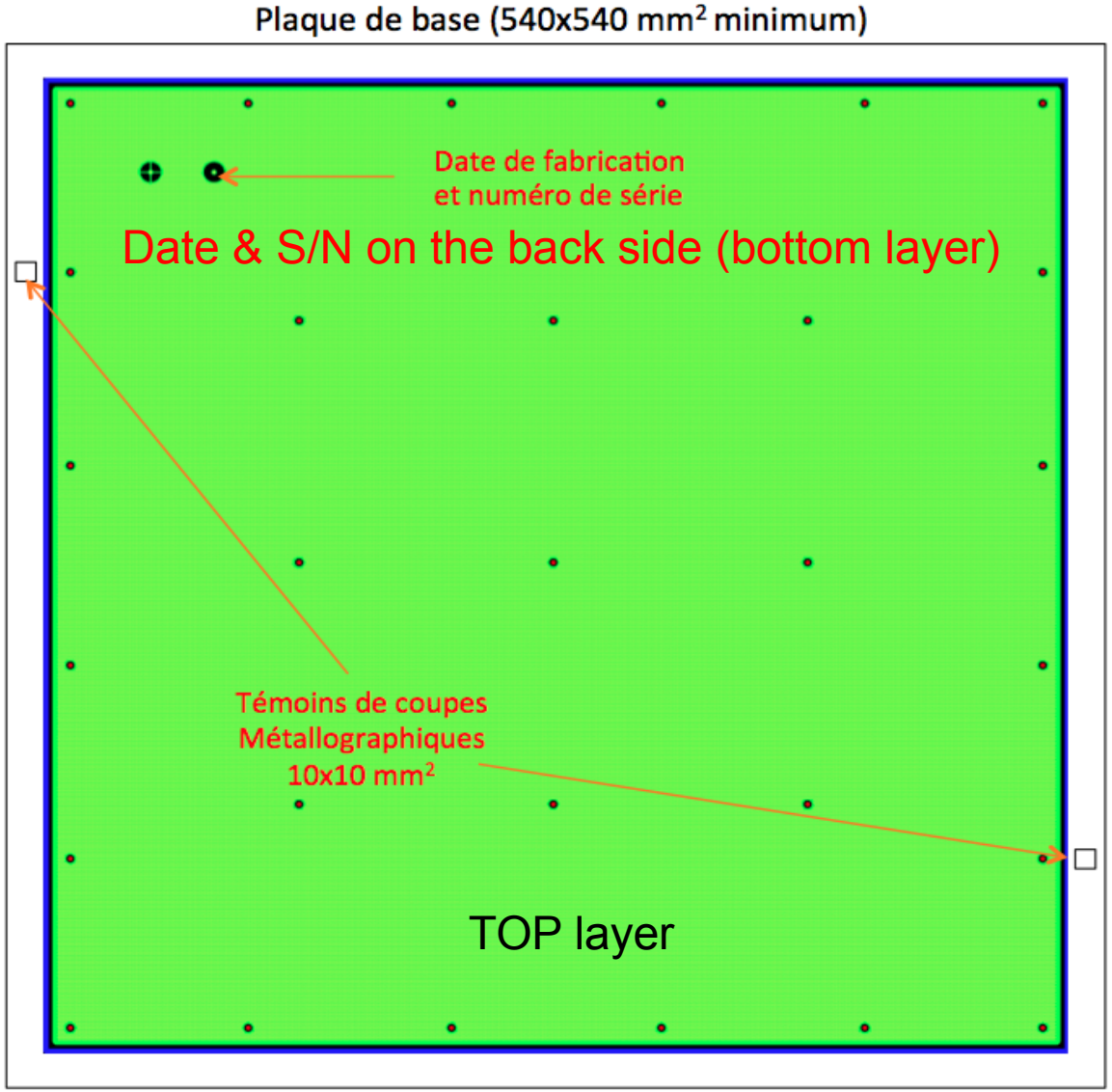


x50 cm² LEM (3x1x1 m³ design) specifications for WA105 demonstrator

Raw material	Procurement in one batch with thickness selection
Material	PANASONIC R-1566W (halogen free)
Dimensions	540 mm x 540 mm
FR4 mean thickness	1 mm (-0.04 /+0 mm according to the specifications of the delivered batch)
Copper layer thickness	105 µm on both sides
Mean total thickness	1,21 (-0.04/+0) mm +/- 0.04 mm (mean thickness of all the LEMs produced)
Total Thickness uniformity	+/- 0.04 mm (thickness uniformity over each LEM surface)
Produced LEM	
Dimensions	499.5 mm x 499.5 mm +0/-0.2 mm
Ni/Au finish	YES: 5 µm Ni + 0.1 µm Au
Screen printing	YES (for LEMs serial number printing)
Solder resist mask	NO
Final thickness (Ni/Au included)	1.15 (-0.04/+0) mm +/- 0.04 mm (mean thickness of all the LEMs produced) +/- 0.04 mm (thickness uniformity over each LEM surface)
« active » holes with RIM	≈ 400 000 non-plated 0.5 mm diameter holes
RIM (after Ni/Au treatment)	40 µm +/- 4 µm

These specifications are the ones used in the call for tender

LEM gerber files
design modifications Vs 3x1x1 m³

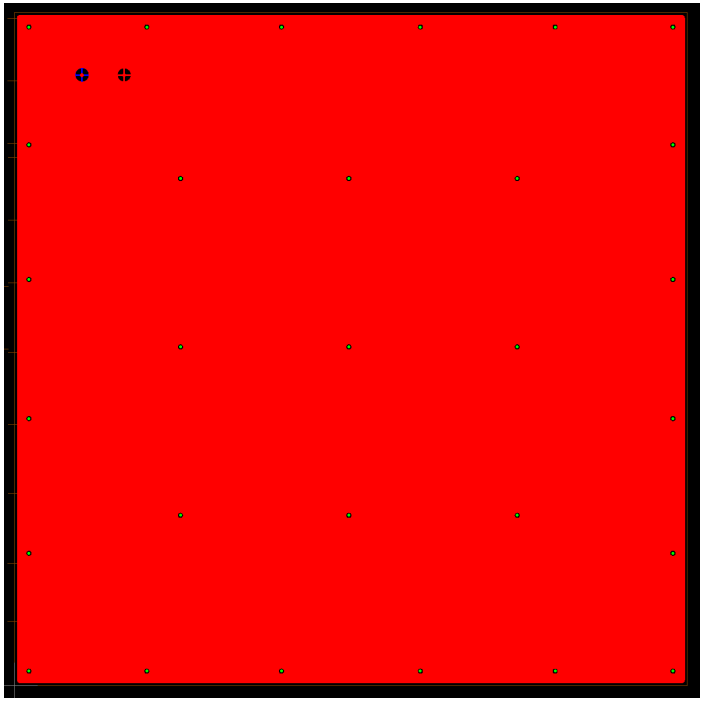


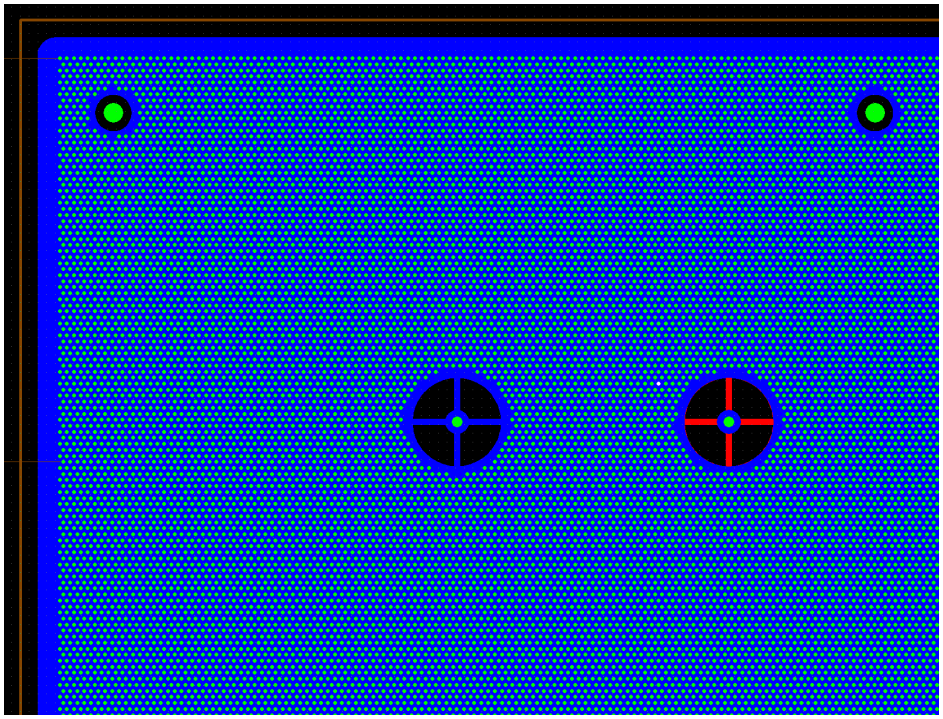
The gerber files which will be used for the production are those of the 3x1x1 m³ LEMs with the following modifications (next slide)

LEM gerber files for 6x6x6 m³ design modifications Vs 3x1x1 m³

- Raw material changed from R-1755C to R-1566W (halogen free)
- The diameter of the 2 holes for pin soldering increased to 1.2 mm
- The 2 holes for pin soldering are no longer plated

TOP gerber layer : MACOR cylinders are glued on this side
LEM identification (date & S/N on BOTTOM side)





M manufacturing and QA/QC procedure

- Procurement of raw material in one batch at the beginning of the production
- Raw FR4 sheets selection for mean thickness and uniformity better than 4%

0/ QA/QC by manufacturer

By LEM manufacturer

CNC drilling	Change drills every 1000 holes Drilling of stack of PCBs is forbidden
mechanical polishing	with pumice powder 4 steps (+/- 90°, top/bottom)
permanganate bath +rince	*removes glass fiber from holes*
Rims by global etching	*acide sulphuric bath*
passivation (Chromic acid)	
Ni/Au plating	Baking 3 hrs at 50° + rinsing with DM water (R> 2 Mohm)

By WA105

ultrasonic bath DM water	Dioinised water (R≈18 Mohm)
lessive (soap) bath at 60°C	
karcher DM water	
baking 3 hrs at 80 degrees	
HV test	

HV test not ok | HV test ok → storage

1/ LEM thickness metrology
2/ Soldering of HV pins
3/ Mounting on aluminum handling plate
(dismounted when LEM is packed for shipping)

- The handling plate is used to prevent the LEMs to be touched during the following production tasks

4/ "Saclay Cleaning"
3 mn Ultrasonic bath with "soap NGL 17.40 ALU" at 65°C

+ regular water rinsing BEFORE DM water

5/ Gluing of HV insulating MACOR cylinders
6/ Final qualification @ 3.3 bar (abs)

- Thickness metrology will be done on the first LEM batches to check the conformity with the raw material thickness measurements by the manufacturer

If Breakdown Voltage (BV) and spark rate test in air is passed, **final polymerization @ 160°C can be done**

0/ LEM Q/C by manufacturer

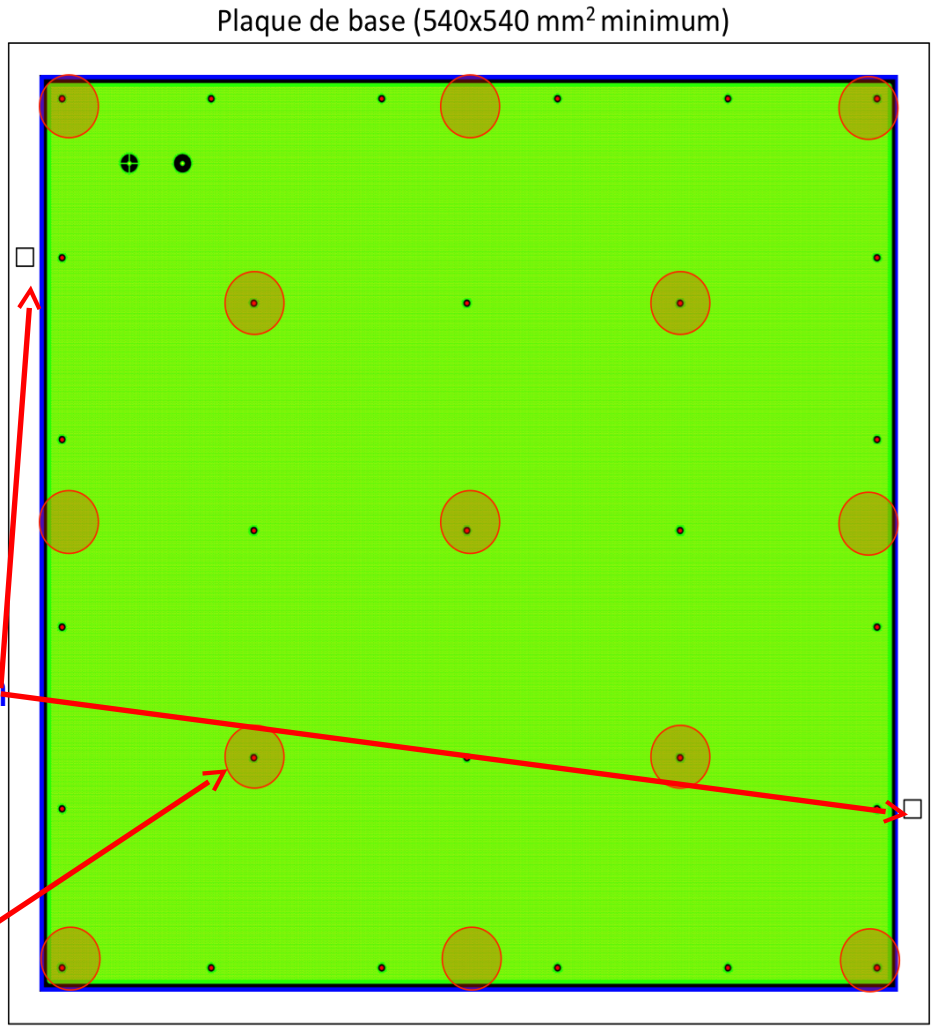
1/ Raw FR4 thickness selection (1.21 -0.04/+0 mm)

2/ LEM visual inspection

a/ Copper aspect : scratches, …
b/ Copper etching defects (Vs gerber)
c/ Defects in hole locations.
d/ Defects of LEM holes : « filled » hole, drilling defect (diameter, cylindricity)

A picture of the defects is joint to the LEM travelling sheet.

Type a/ defect requires LEM validation by WA105. Other types of defects are considered critical and the LEM rejected.



3/ LEM Automated Optical Inspection

Thickness and rim measurement in the 2 metallographic sections

4/ LEM Automated Optical Inspection

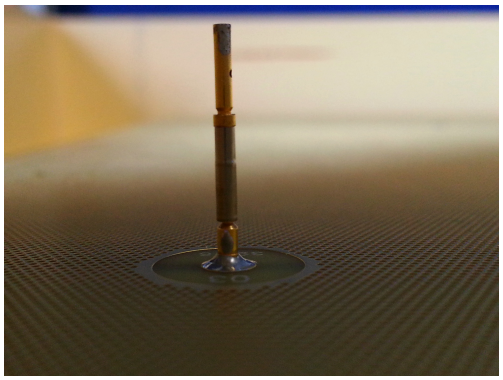
RIM dimension measurement in 13 locations

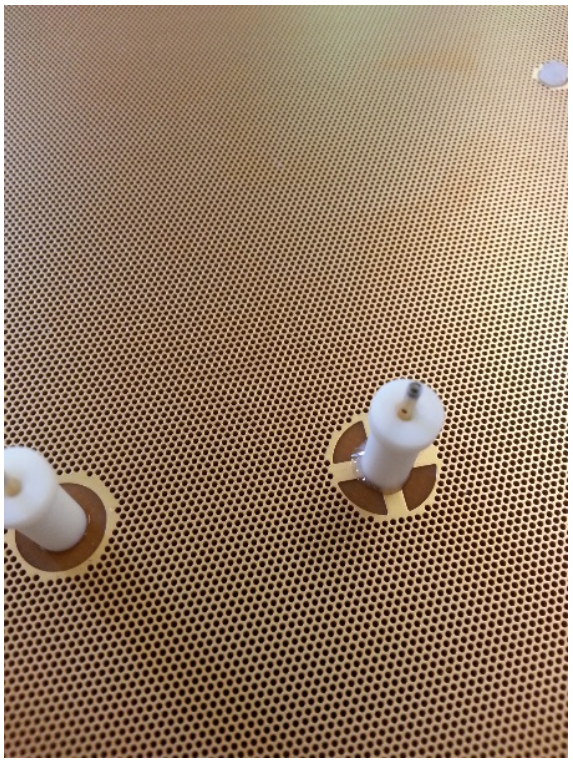
5/ LEM insulation measurement

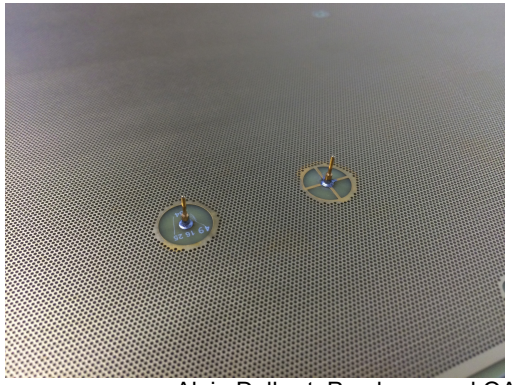
Done at least @ 500 V with R > 1 GΩ

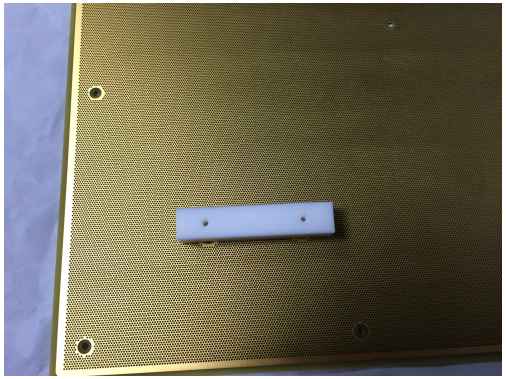
2/ LEM HV connections

- Solder pins with Core 230 no-clean wire solder
- Use of a dedicated tool to position and maintain pins while soldering
- Unplated Φ1.2 mm holes
- Gluing of the insulating cylinders with 2011 Araldite (AW 106/HV 953U) using a centering tool : POM (used on 3x1x1 m^3) changed to MACOR (used for 3 l prototype)
- Order to be placed : Φ4,8 mm 30 cm long Macor rod is ≈300 € (15 LEM) + machining









LEM manufacturing procedure
LEM final qualification

By LEM manufacturer

- CNC drilling
- mechanical polishing
- permanganate bath +rince
- Rims by global etching
- passivation (Chromic acid)
- Ni/Au plating

By WA105

- ultrasonic bath DM water
- lessive (soap) bath at 60°C
- karcher DM water
- baking 3 hrs at 80 degrees
- HV test

HV test not ok | HV test ok → storage

Uniform electric field between two // plates at ΔV

$$G = \exp(\alpha . d) \qquad \alpha = \frac{P}{T} A \exp\left(-\frac{B}{E}\frac{P}{T}\right)$$

G : Gain (primary charge multiplication)

α : first Townsend coefficient

A and B : parameters depending on the gas

P : Pressure T: Temperature d : amplification gap

Same gas density 88 K / 1 bar (Dlar)⇔ 293 K / 3.3 bar

Same BV and same gain (assuming same gas purity and no A,B dependence with P,T)

°C

LEM final test

Breakdown voltage and sparking rate measurement at $P_{abs} \approx 3.3$ bar

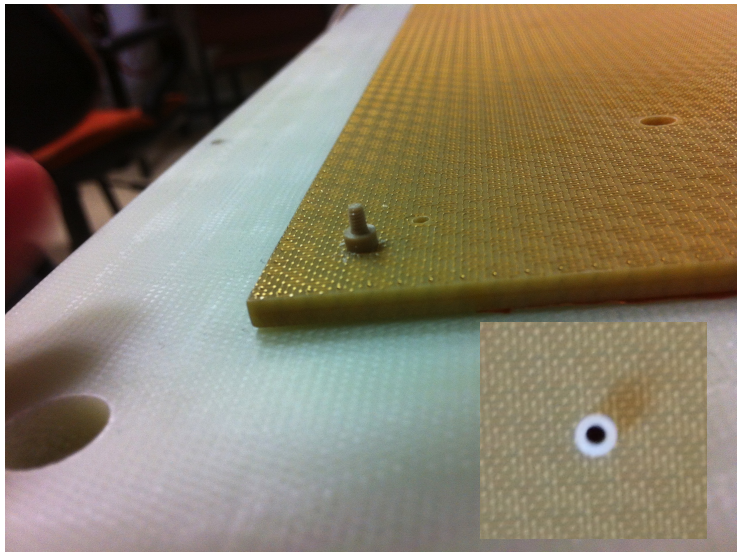
Optional Gain measurement at $P_{abs} \approx 3.3$ bar with ^{241}Am

Acceptance criteria (BV & sparking rate) will be fixed after the tests of the first 6 LEMs

LEM + anode assembly on CRP

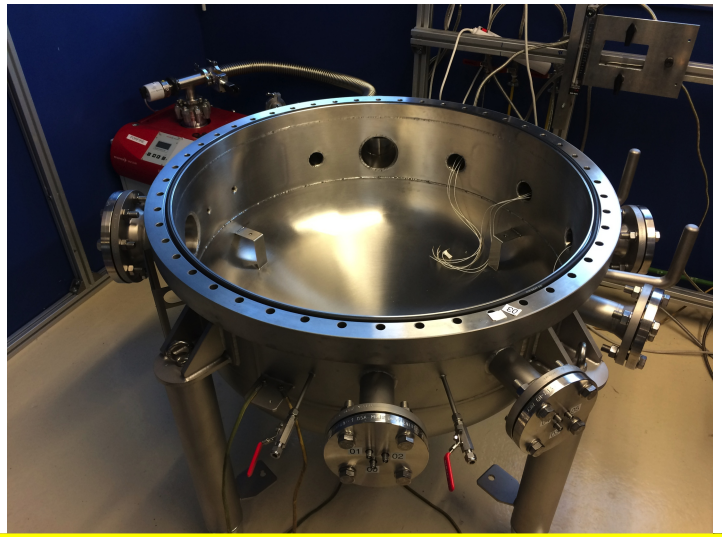
Dealing with the 20 individual spacers which are free to move during LEM+Anode assembly on CRP

- Assembly: using specific M2 screws + 2 nuts + spacers. First mount & align anode on CRP, then assemble LEM with nuts.
- A new solution with a PE spacer with smaller inner diameter has been adopted

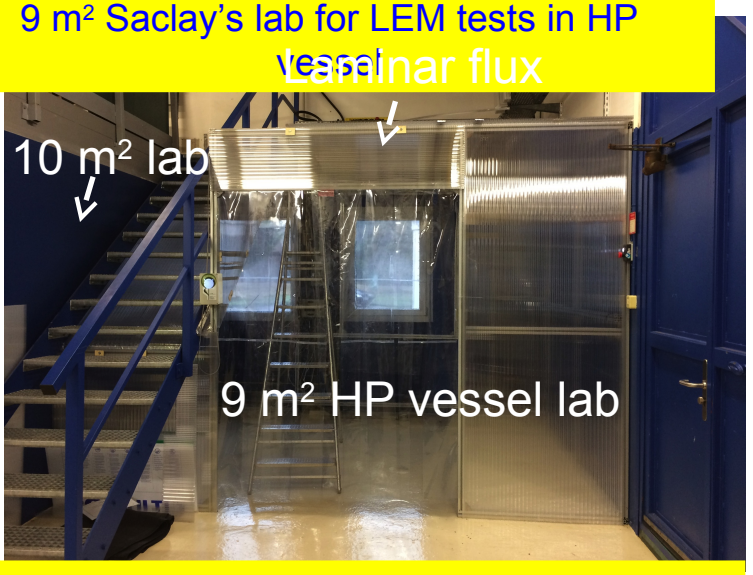


h pressure vessel test bench for lem final qualification @ P_{abs}≈3.3 bar

HP vessel (with gas P,T monitoring)

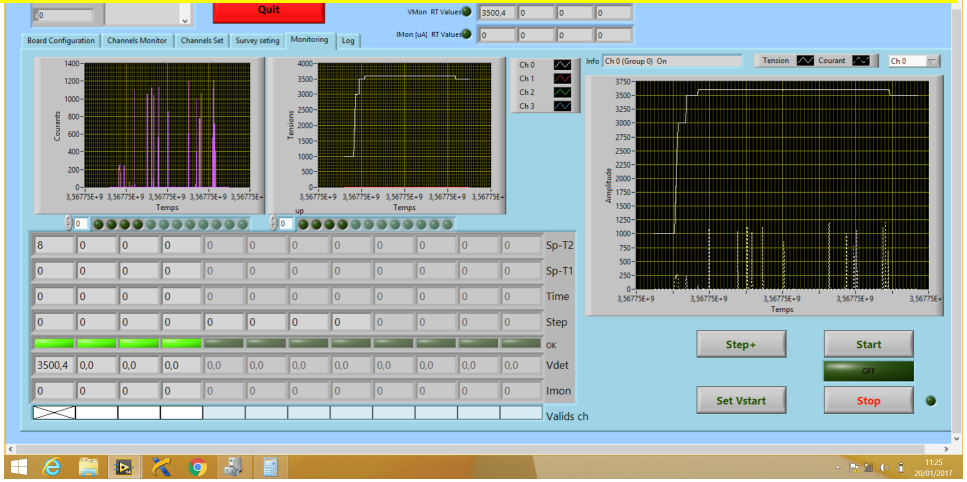


9 m² Saclay's lab for LEM tests in HP vessel



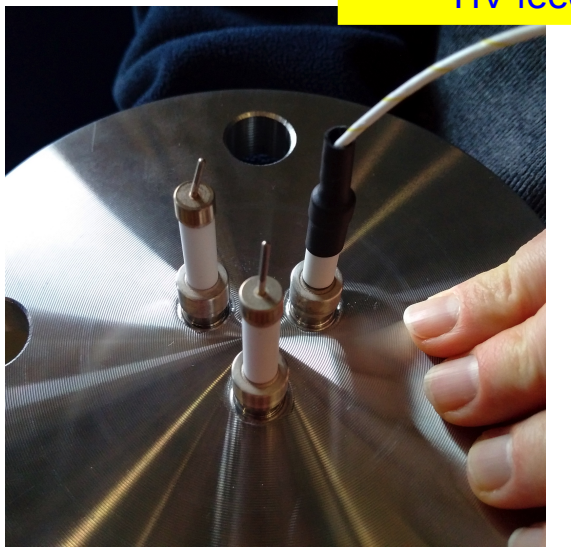
A tower of 6 LEMs can be simultaneously tested in the HP vessel

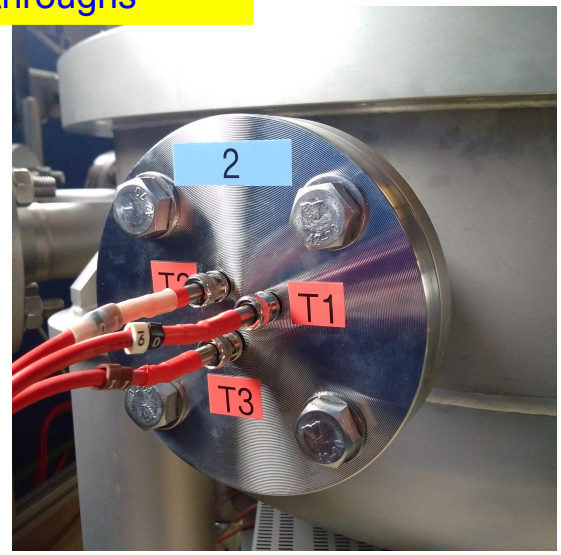
Labview automated procedure to increase LEM HV up to Breakdown Voltage with sparking rate measurement



WA105 3,3 bar vessel : feedthroughs

HV feedthroughs

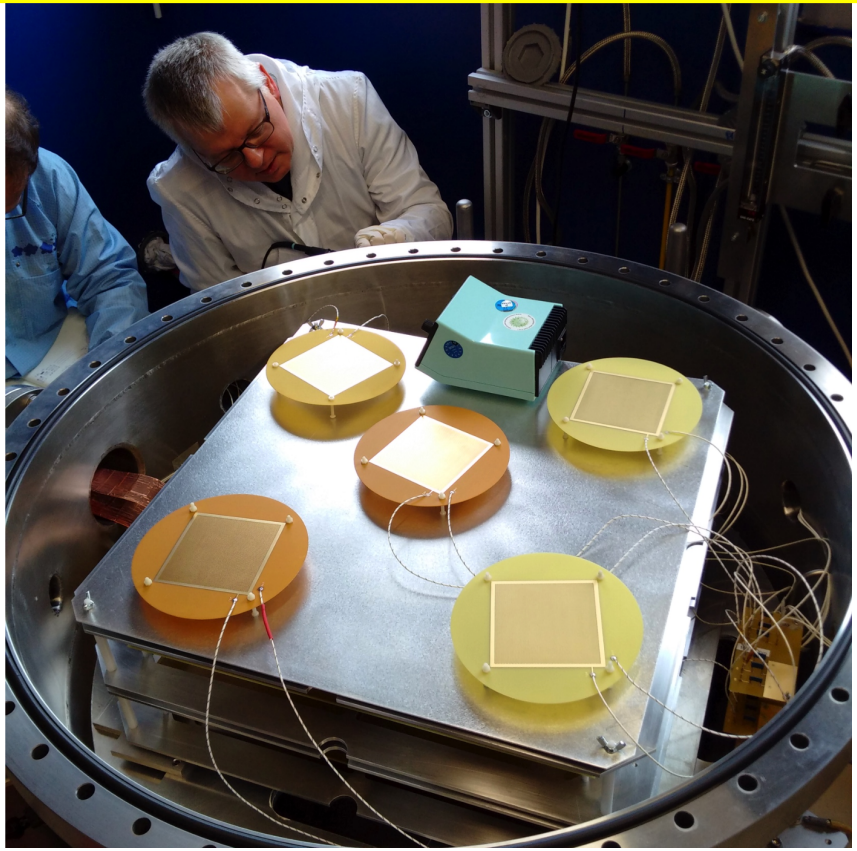




Front-End electronics feedthroughs

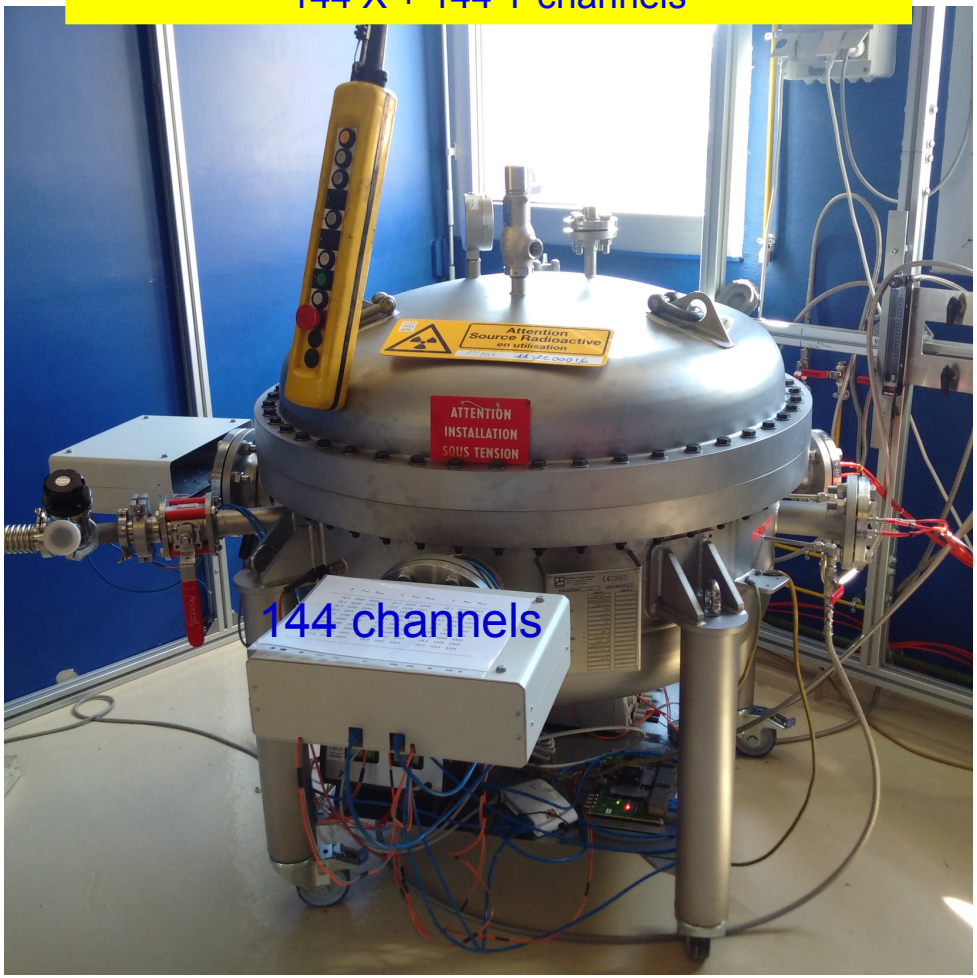
WA105 Pressure wessel
BV measurement @ NTP (air & argon)

Mounting of a tower of 5 LEMs in the HP vessel
Tuning of the Labview Automated procedure for BV



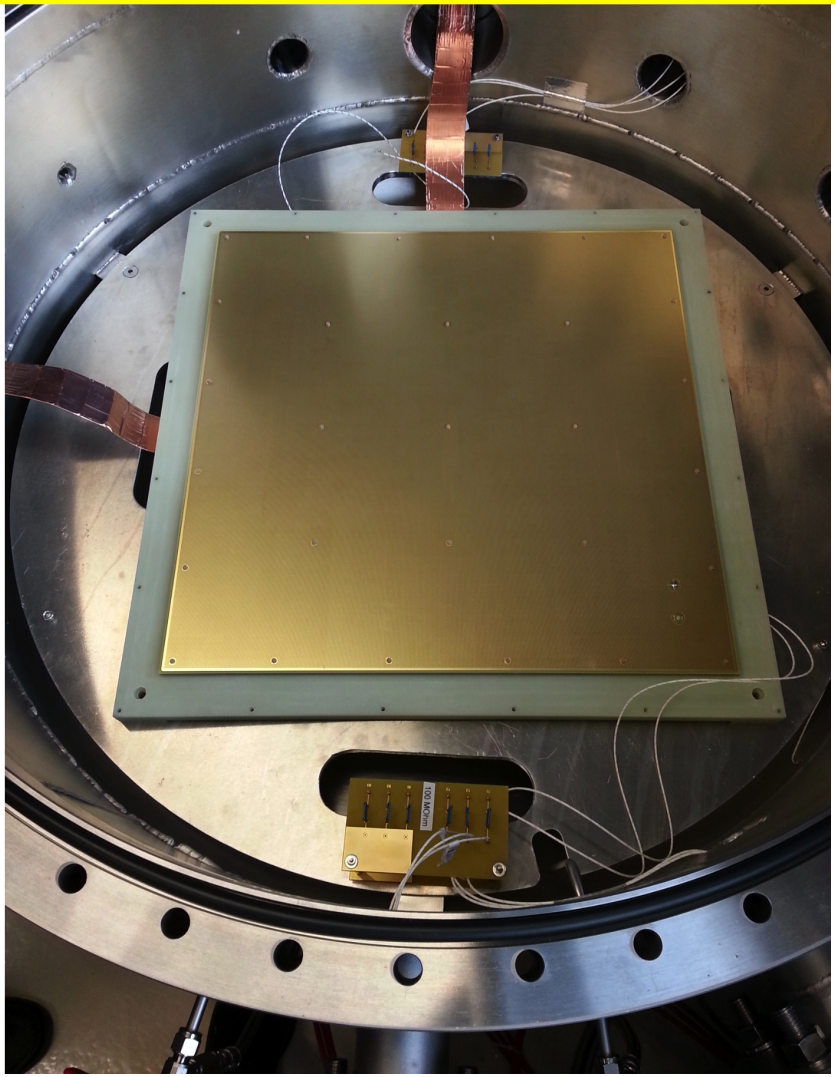
Tuning with four 50x50 and five 10x10 cm^2 LEMs

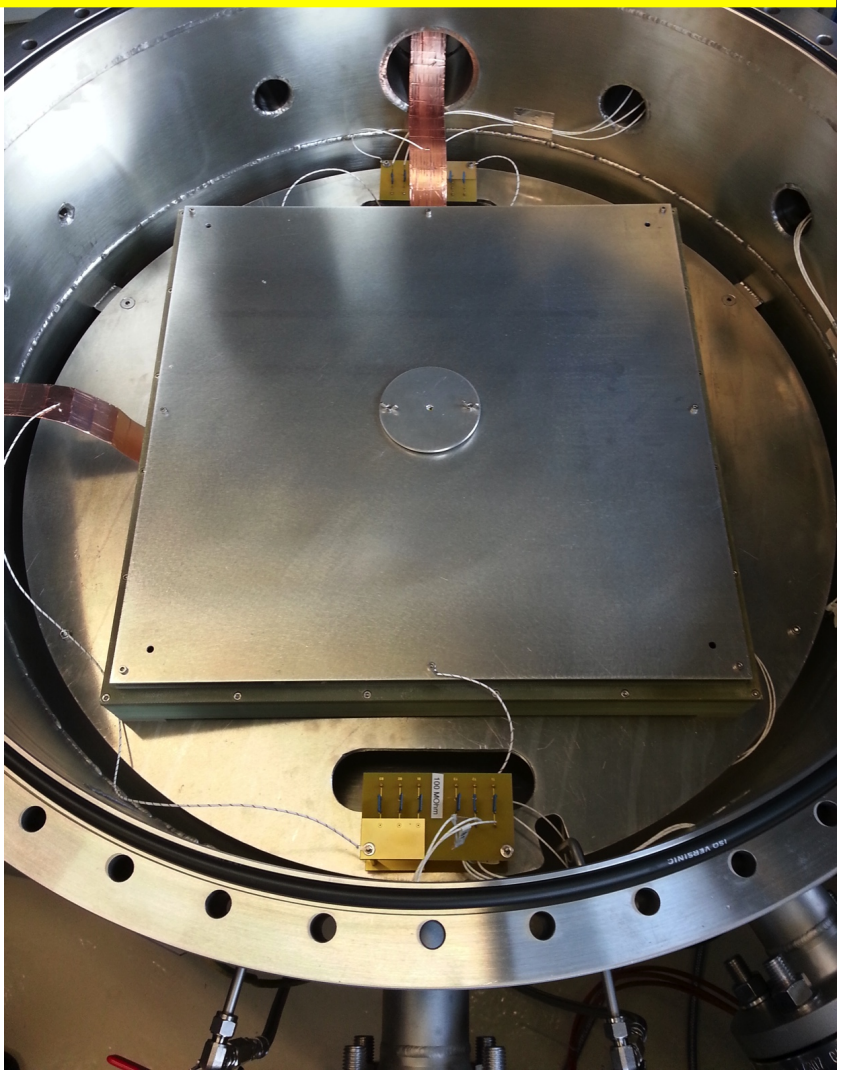
AFTER based electronics readout
144 X + 144 Y channels



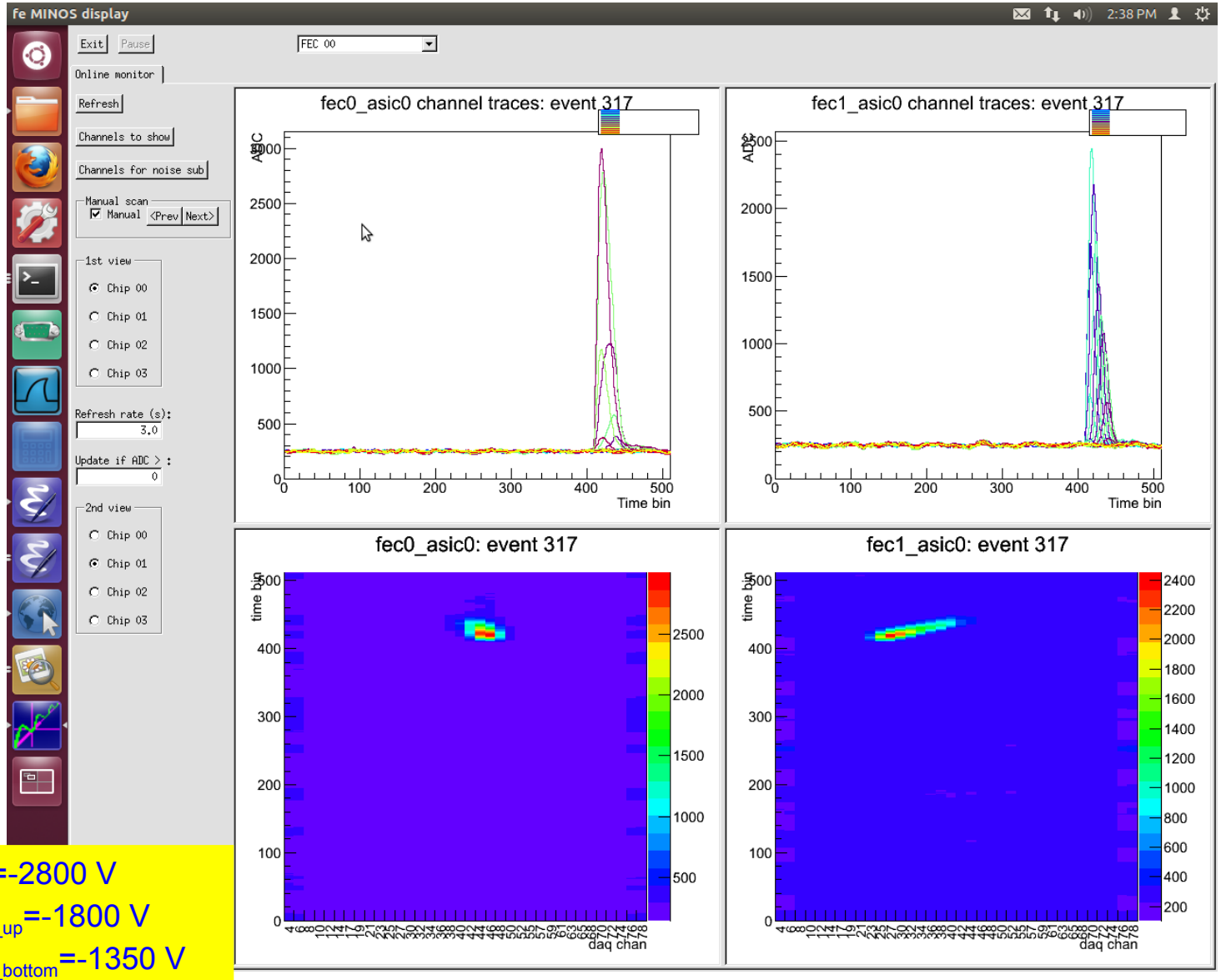
WA105 Pressure wessel
^{241}Am source setup @ NTP 5.7 argon

ELTOS# LEM + anode + cathode with ^{241}Am source (5 cm above LEM)





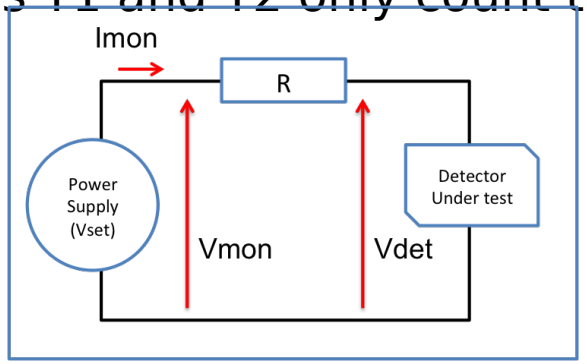
First ^{241}Am source track on a 50x50 cm^2 LEM+anode in NTP 5.7 ar

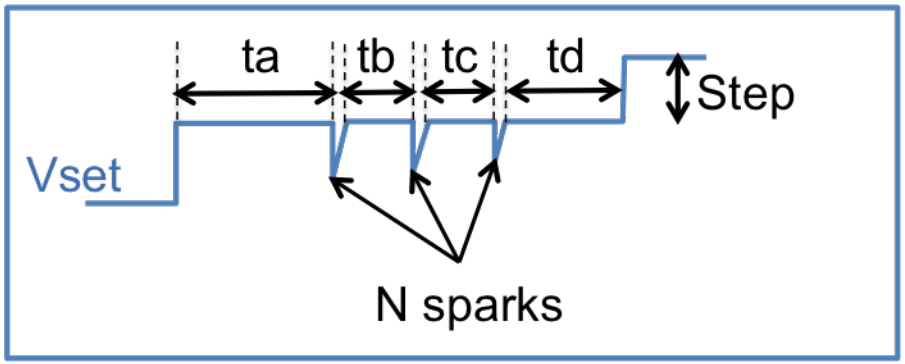


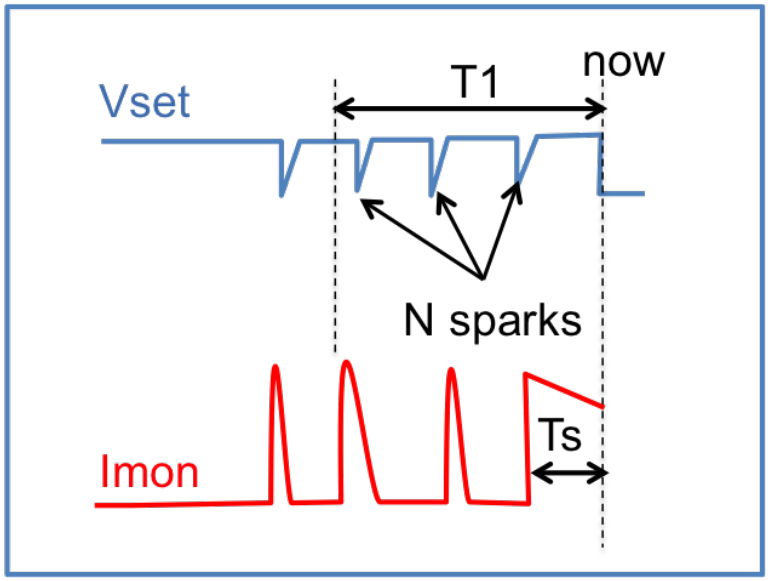
V_{cath}=-2800 V
V_{LEM_up}=-1800 V
V_{LEM_bottom}=-1350 V

bview automated procedure to increase LEM HV up to Breakdown Voltage

- The Labview procedure can handle up to 12 HV independent channels. V_{det} and current I_{mon} are monitored, on-line displayed and recorded in an ASCII file at 1 Hz. Sparks are detected and counted when Imon>Imax with Vdet=Vset +/- **ΔV**
- Timers T1 and T2 only count the time the LEM is at Vdet=Vset +/- **ΔV**



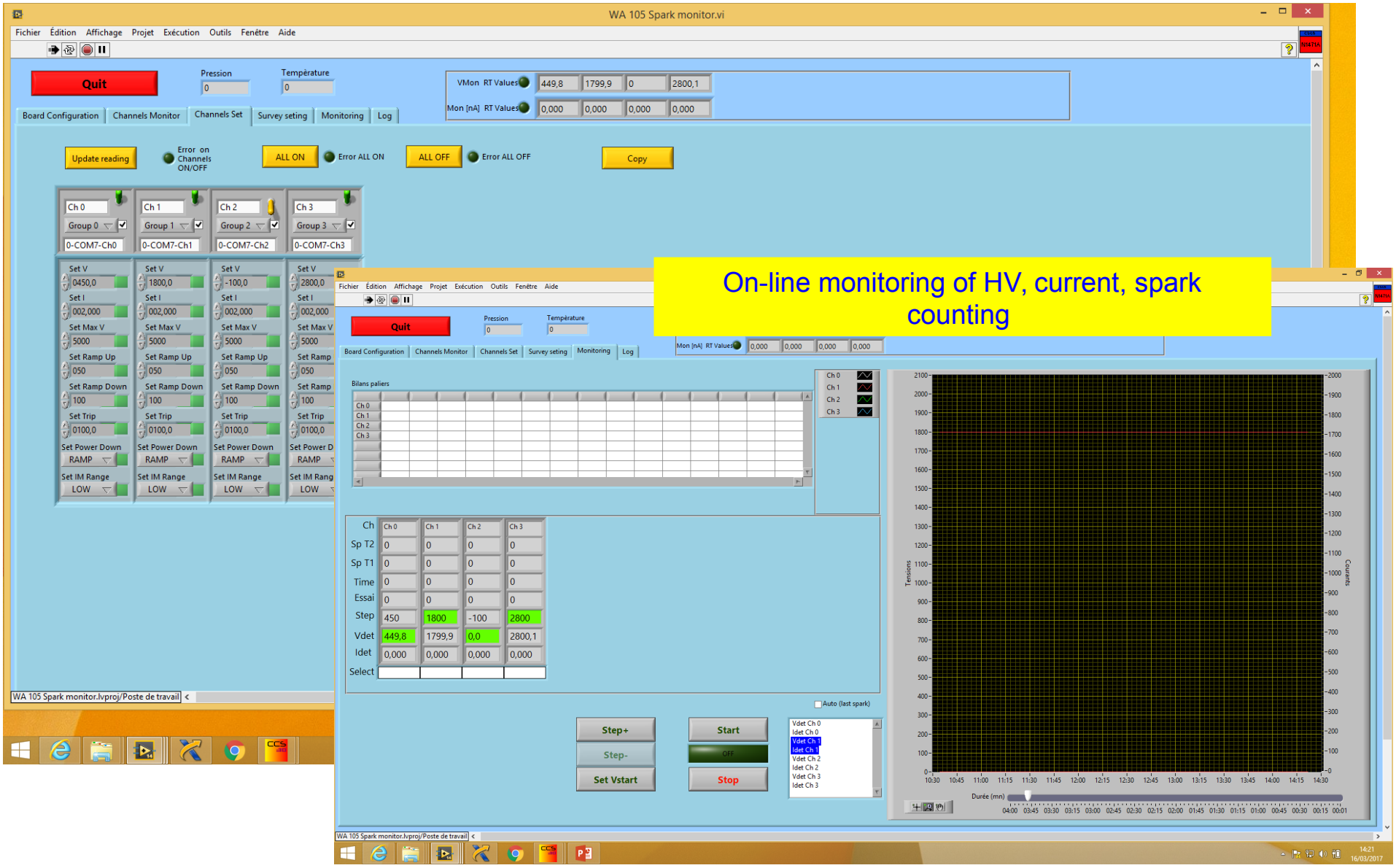




HV is increased of **HV_STEP** if :
V_{Det} < Vmax AND maintained at least for **T2**
Nbre of sparks SpT2 < **$SpT2_{max}$** during **T2**

HV is decreased of **HV_STEP** if :
I_{mon} > **Imax** during **TiMax**
Spark duration Ts > **TspMax**
Nbre of sparks SpT1> **$SpT1_{max}$** during **T1**

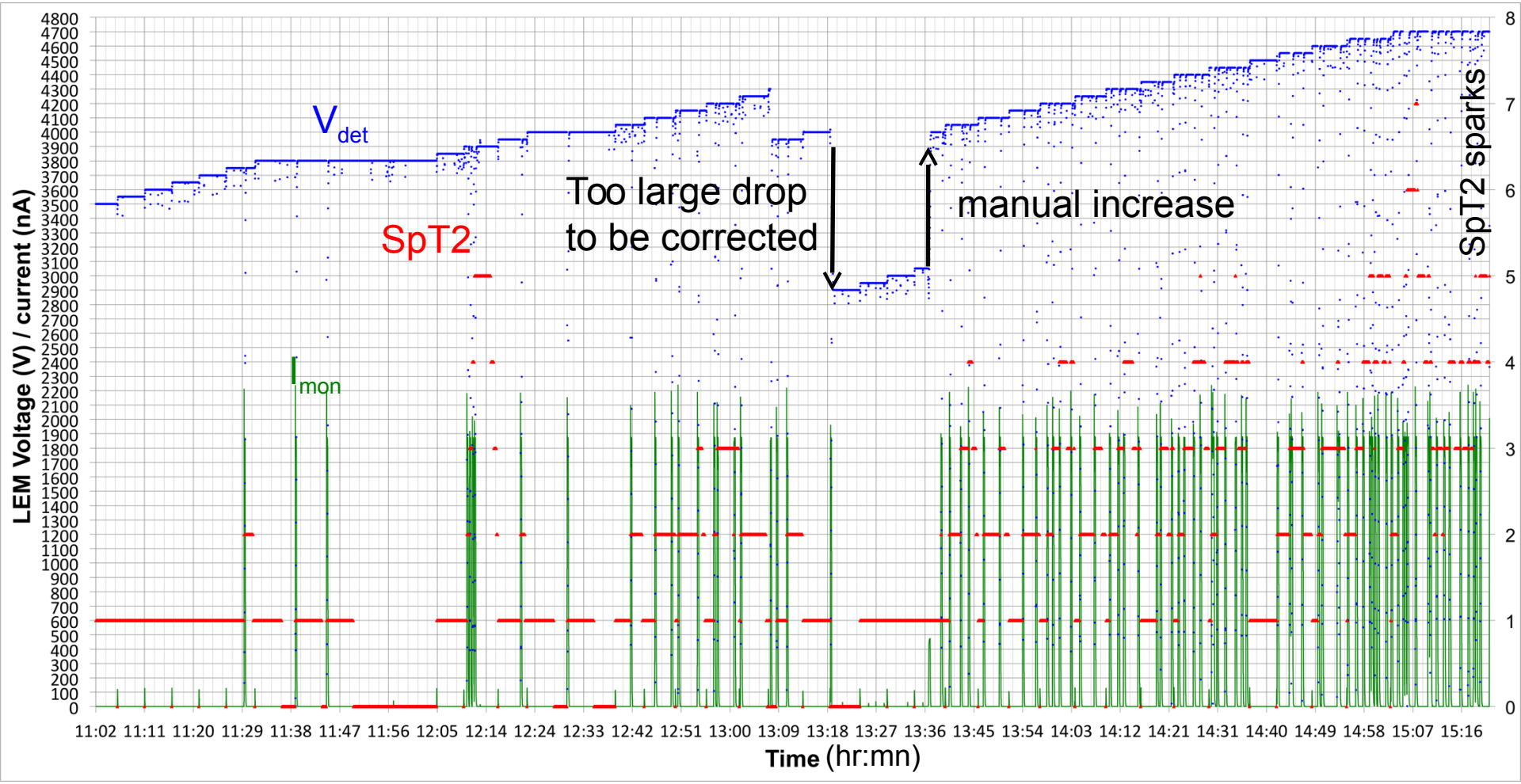
Labview automated procedure



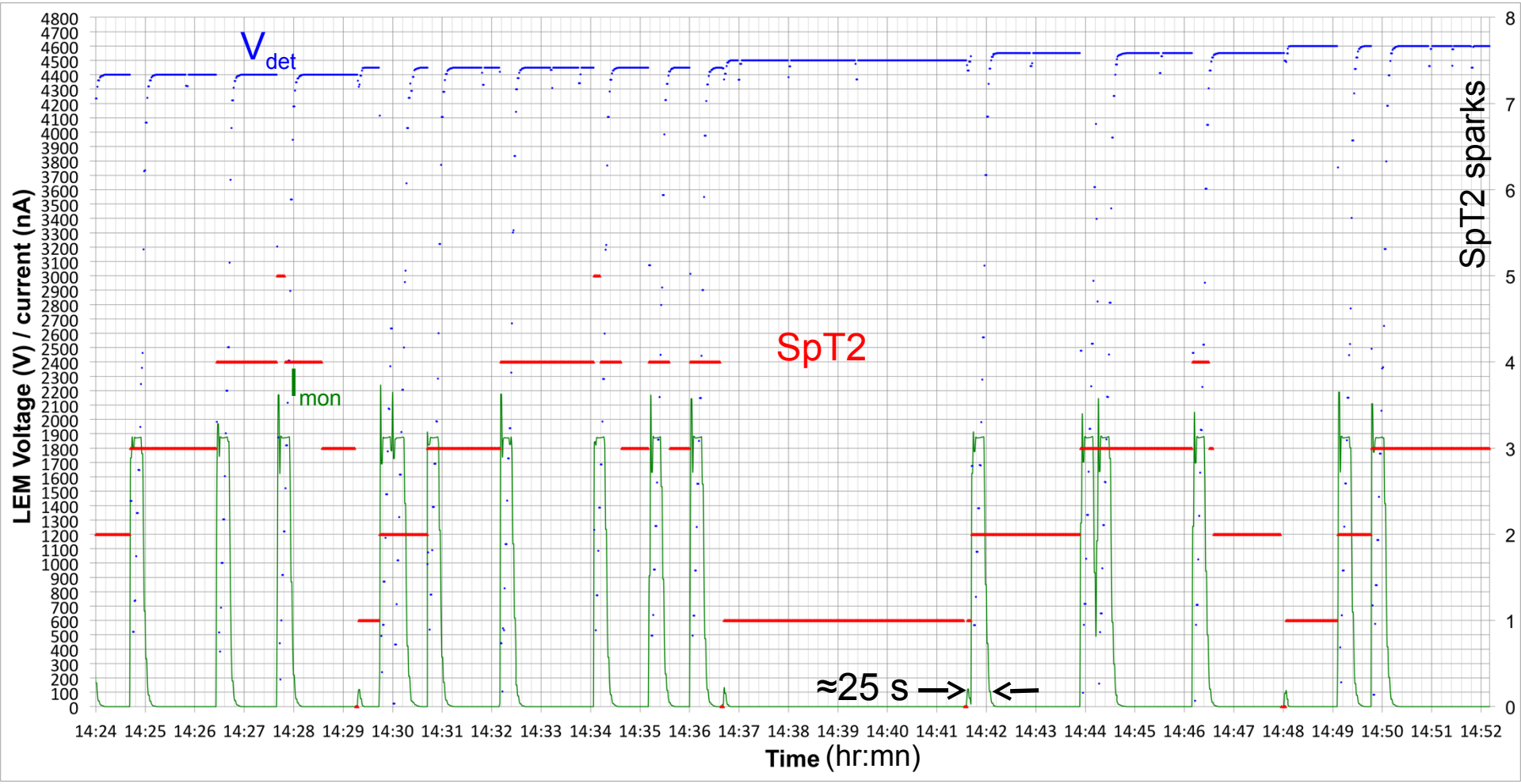
On-line monitoring of HV, current, spark counting

HV increase in synthetic air NTP
ELTOS#2

- ELTOS#2 was raised from 3400 V up to 4700 V in 4 hours
- T1=30s, $SpT1_{max}$=10, T2=300s, $SpT2_{max}$=10, ΔV=100 V, HV_STEP=50 V, Imax=100 nA
- Tuning of the procedure and parameters is going on …



HV increase in synthetic air NTP
ELTOS#2



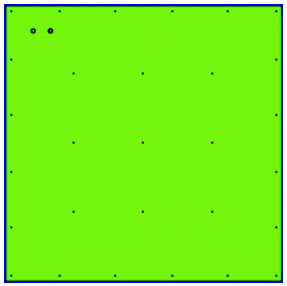
LEM specifications document
Final version « DB » validated on Feb 16th

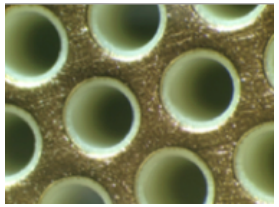
Irfu cea saclay	Cahier des charges	Réf : CdCLEMWA105Fr
	LEM DU PROTYPE WA105 (DUNE/DP)	Date création : 30/09/2016
		Page 1 sur 23

Irfu cea saclay	LEM DU PROTYPE WA105 (DUNE/DP)	Réf : CdCLEMWA105Fr
		Page 2 sur 23

CAHIER DES CHARGES ET DES SPECIFICATIONS TECHNIQUES

PRODUCTION DES LEM DU PROTOTYPE WA105 (DUNE/DP)





HISTORIQUE DES MODIFICATIONS

Version	Date	Pages modifiées	Motifs
DRAFT	30/09/2016	Création	Pour diffusion restreintes et corrections
DRAFT2	19/01/2017		Modifications et corrections après l'appel à candidatures
DA	01/02/2017		Version A pour corrections par la collaboration WA105
DB	16/02/2017		Version B pour diffusion de l'appel d'offre

	Rédacteurs		Vérificateurs	Approbateur
Nom	A. DELBART	E. MAZZUCATO	Y. PENICHOT	M. ZITO
Fonction	Chef de Projet	Resp. Physicien	Resp. QA	Resp. Scientifique
Date				
Visa				

Table des matières

LEM production tendering status

- A first call for applicants was launched by the CEA Commercial Division on December 15th 2016 and several companies were selected on January 10th 2017.

- The "Technical specifications" document was finalized and validated by the WA105 Technical Board on February 16th. The commercial documents needed for the call for tender were finalized by the Commercial Division of CEA-Saclay at the end of February.

- The call for tender has been launched March 24th for an application deadline April 14. With 2 weeks needed for the contract to be signed, LEM Production process by the manufacturer could be planned to start at beginning of May.
- The quotations received are in line with our previous estimations and with the secured budget

Proposed delivery schedule for lem (call for tender)

- With help from 1 additional technician (from another lab of the WA105 coll.) , cleaning and QA/QC of a maximum of 12 LEMs per week could be done @ Saclay (limited by ≈3.3 bar test)

Proposed schedule for CEA/Irfu Call for Tender (78 LEMs)	
T0	**Signature of the contract & kick-off meeting**
T0 + 2 weeks	- Pre-production kick-off meeting - Delivery of the LOFC (PAQ), gerber files validation, documentation as described in section 3.1
T0 + 4 weeks	- Delivery of **6** pre-series LEM and associated documentation
T0 + 6 weeks	- Production kick-off meeting - Delivery of **12 batches of 6 LEMs every week**
T0 + 18 weeks	- Delivery of the last batch - Closing meeting (T0+21 semaines)

Beg. of May

Mid May

Beg. of June

Mid June

October

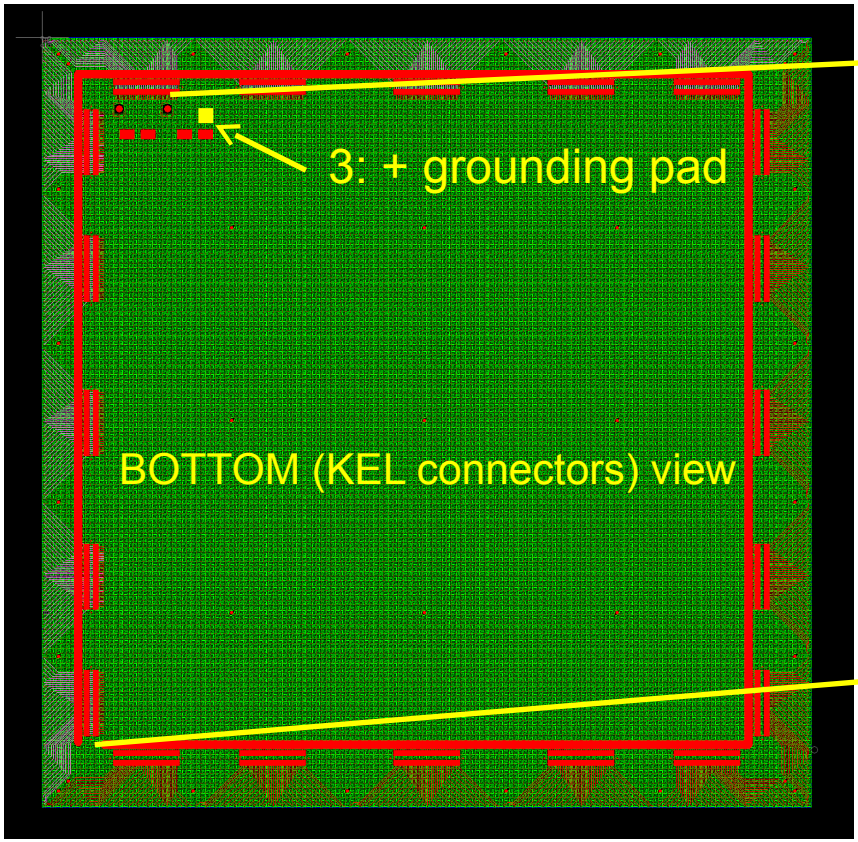
Indicative dates

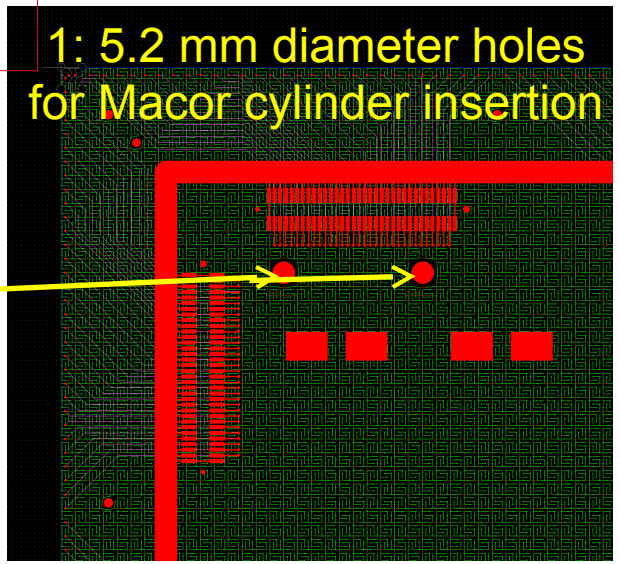
- The second half of the 144 LEMs (and anodes) needed for the WA105 demonstrator will be provided by ETHZ through a separate Call For Tender with the same technical specifications and a similar production schedule.

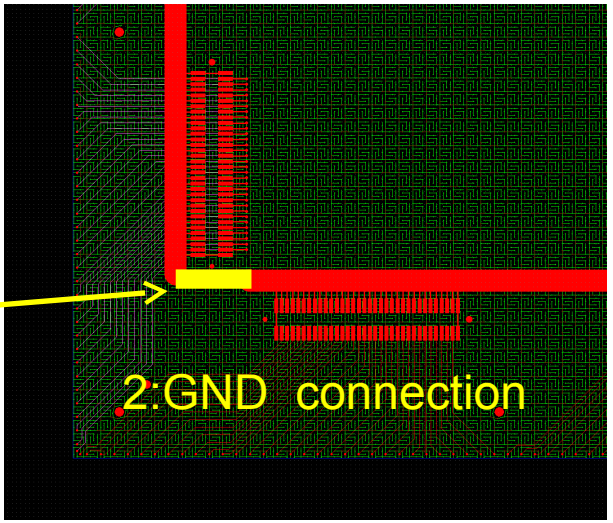
- The production, QA/QC and final testing at P_{abs}≈3.3 bar of the 144 LEMs needed for the WA105 demonstrator could therefore be done in ~20 weeks. No contingency.

Anode manufacturing gerber files design modifications Vs 3x1x1 m³

The WA105 anode is using the same 3.5 mm thick, 4 layer PCB as for the 3x1x1 m³ with the following modifications





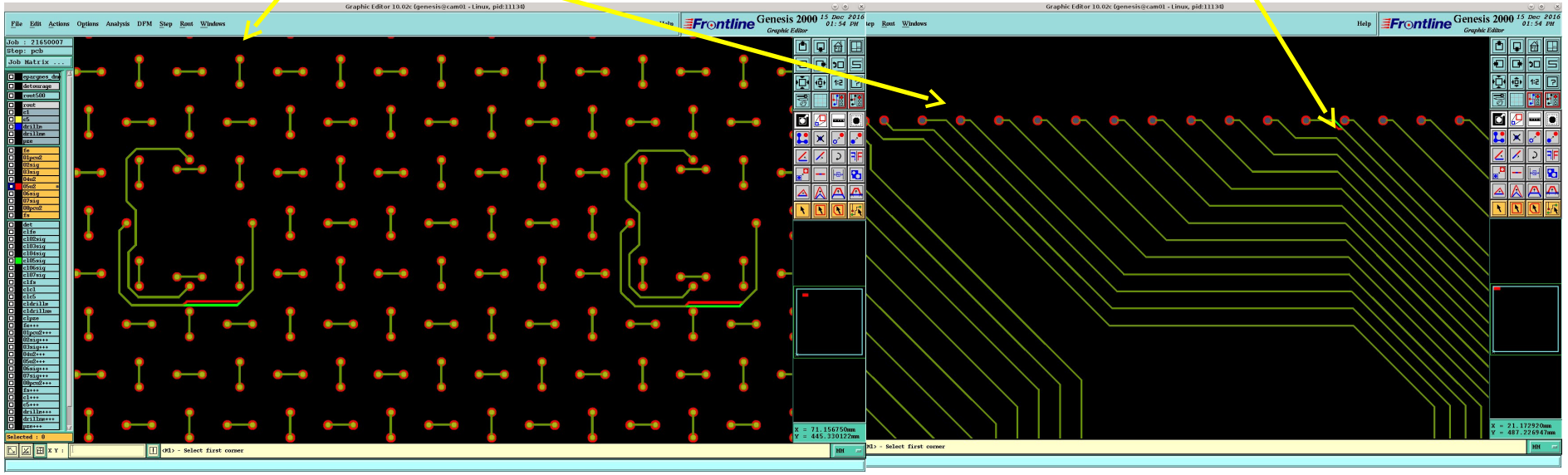


Anode manufacturing gerber files requested modifications from manufacturers

- 2 anode PCBs were ordered to the ELVIA company on January 15th in order to check their capability to produce the anode.
- Some modifications were requested by ELVIA to cope with their manufacturing tolerances.

Φ0.45 mm holes increased to Φ0.5 mm
and corresponding vias increased to Φ0.8 mm

Example of modified routing line (red)



Anode tendering and QA/QC

We have received a quotation (delivery in 46 working days) and will place the order (1/2 by IRFU)

- Soldering of 20 connectors per anode will be done by an external company

According to PCB industry IPC standards, 2 QCs are done to insure the quality of the circuit :
- A.O.I. tests of inner layers before assembly & external layers on the final PCB.
- Tests of electrical continuities and insulations with a Flying Probe Tester of the final PCB

Conclusion

- The procedure for LEM production and QA/QC, both in the PCB industry and in laboratory, is well established. Tendering documents are finalized and technical specifications were validated by the Technical Board.

- Several companies were selected by a call for applicants in January.

After receiving the quotations April 14th, the start of the production is expected beginning of May.

- Equipments and procedures for LEM Q/C are ready.

- Production of the LEM can start middle of June with a rate of 6 LEMs/week per company