Irfu CEA Saclay: charge readout for WA105 towards DUNE

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CEA Saclay, Irfu

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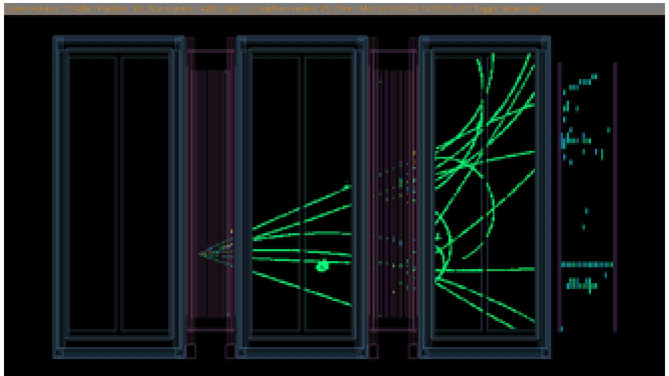
Ph. Cotte: PhD student on WA105
A. Delbart: chef de projet
M. Karolak: LEM QA/QC
E. Mazzucato: WA105 Tcn member
M. Zito: responsable scientifique

Outline

- Introduction: Irfu expertise in TPC and MPGD, Laguna-Laguna/LBNO
- Charge readout activities for WA105
- Perspectives for DUNE

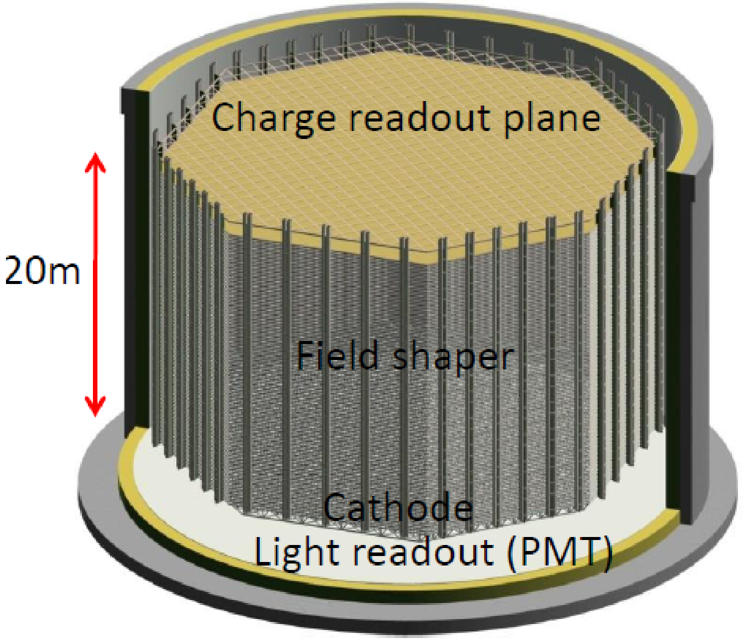
IRFU CEA Saclay: neutrinos, TPCs and MPGD

- IRFU CEA Saclay has a long experience in building large state-of-the-art 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 Near detector (9 m^2), operating flawlessly since 2010, together with the full front-end electronics



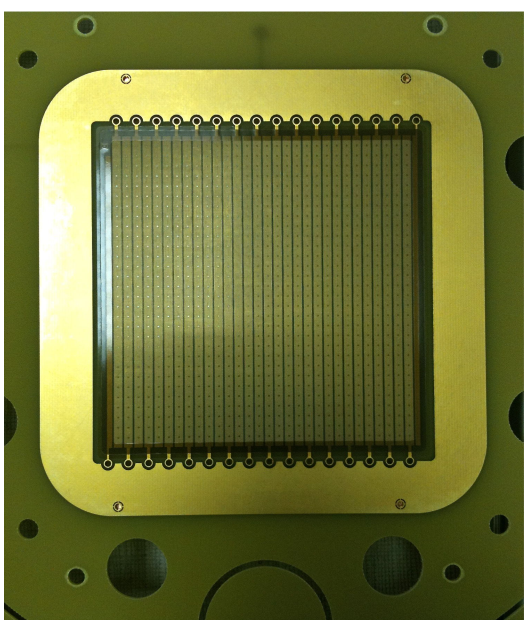
EU LB design studies: EuroNu-LAGUNA-LAGUNA/LBNO

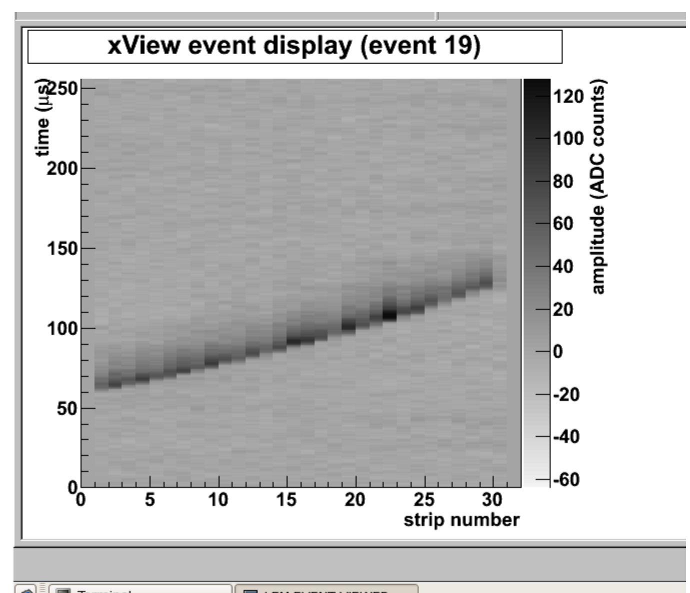
- Irfu participated in Euronu (coordination of the SuperBeam Work Package), Laguna (physics studies) and Laguna-LBNO (chair of the Technical Board)
- Laguna-LBNO studied the concept of the membrane tank and other engineering and technical solutions, including the beamline optimization, and many aspects of the physics relevant for DUNE



R&D for Micromegas in Liquid Argon TPC

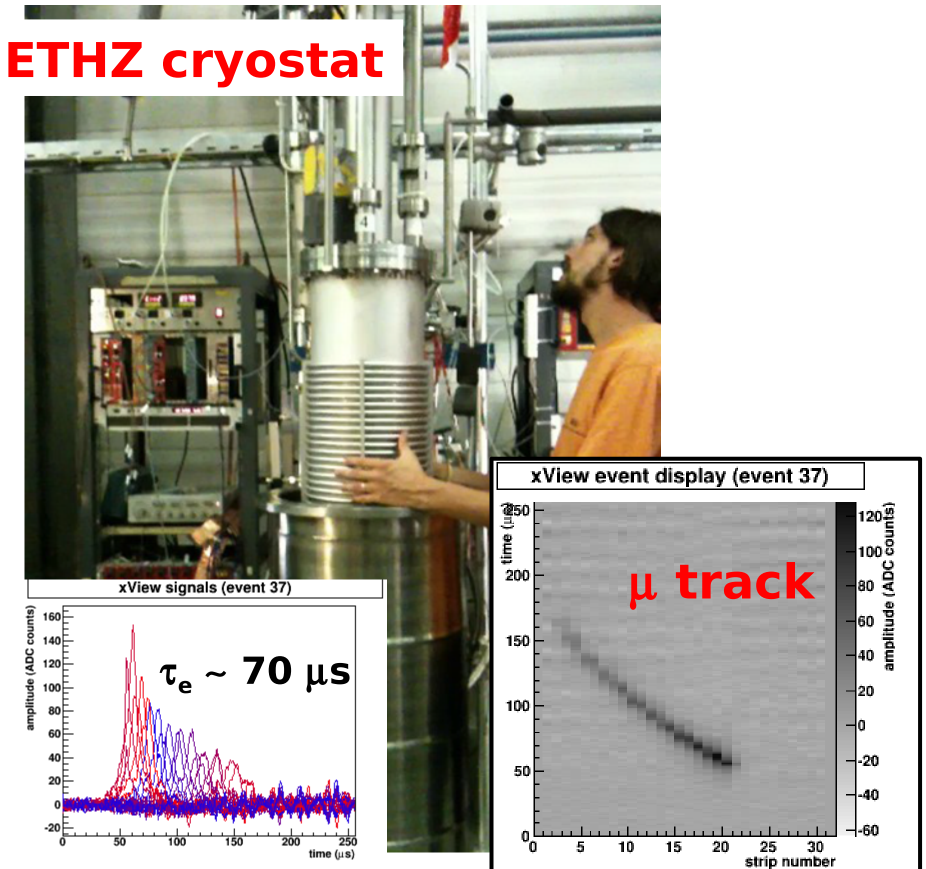
- Since 2010 Irfu has been involved in R&D with Liquid Argon TPC, in particular proposing to use Micromegas as the gas amplification device
- Micromegas have been tested in Double Phase LAr TPCs together with ETHZ and the Liverpool groups, (with K. Mavrokoridis, C. Touramanis) successfully showing gas amplification





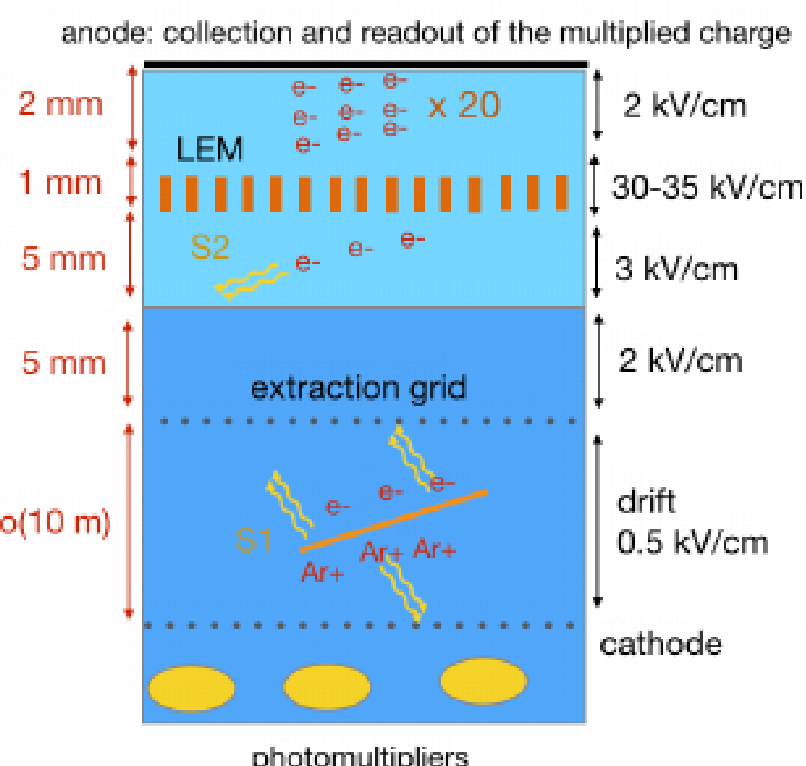
Détecteurs bulk-MicroMegas (MM) dans une TPC DLAr

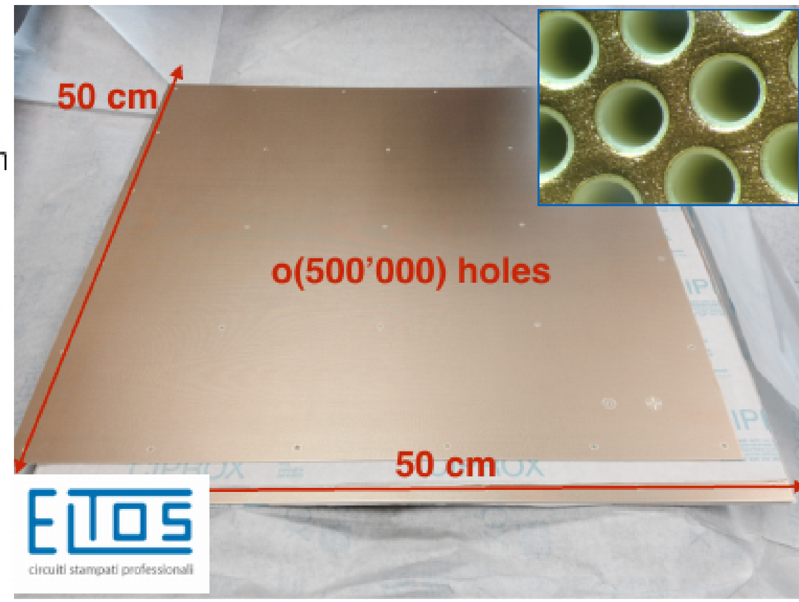
Premiers tests au CERN en 2010 avec un prototype MM de 102µm

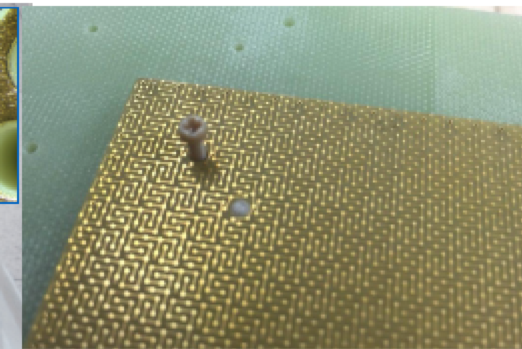


Tests fin 2013 à Liverpool avec des prototypes MM de 115µm et 192µm

The double phase charge readout: LEM-Anode

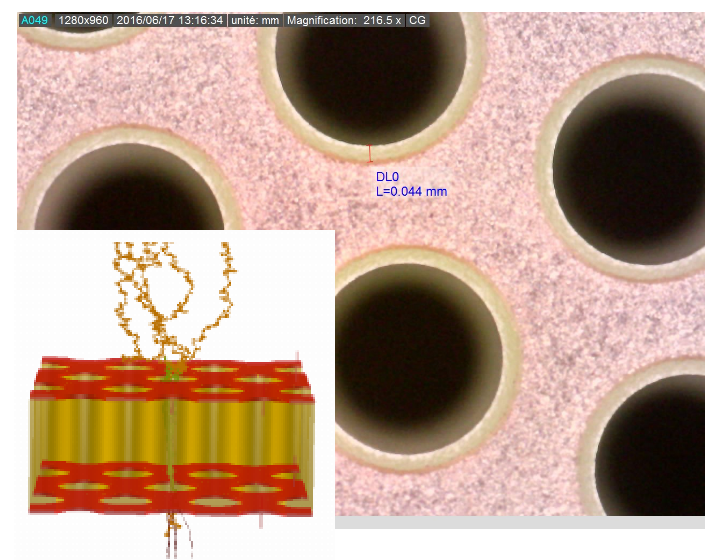






Anode: charge sharing and low capacitance for x,y strips in inner PCB layers

- LEM: PCB, 1mm thick, 50x50cm^2, ~500 000 CNC drilled holes
- 500 μm hole, 800 pitch
- 40 μm rim (by chemical etching)
- Achieves gain up to ~100 at E~ 35 kV/cm in ultra-pure argon thanks to "mechanical quenching" (amplification in the holes)
- Similar detectors used in Compass RICH
- 144 LEMs for WA105, 2880 for 10kt



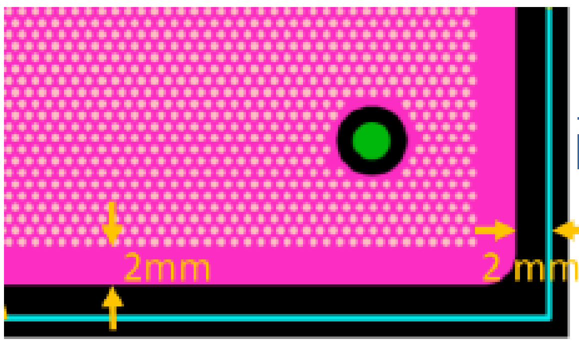
IRFU activities within WA105

1) Electrostatics modeling and effect of LEM dead areas for physics (Ph. Cotte)
2) Tests of LEM prototypes: from 10x10 cm^2 to 50x50 cm^2
3) Characterization of LEM gain and HV properties
4) Optimization of LEM design
5) Definition of LEM technical specification for tendering
6) LEM post-production processing
7) LEM QA/QC for mass production: procedure and instrumentation
8) Validation of a second company (ELVIA) for LEM and anode production
9) LEM procurement and validation for WA105: in progress

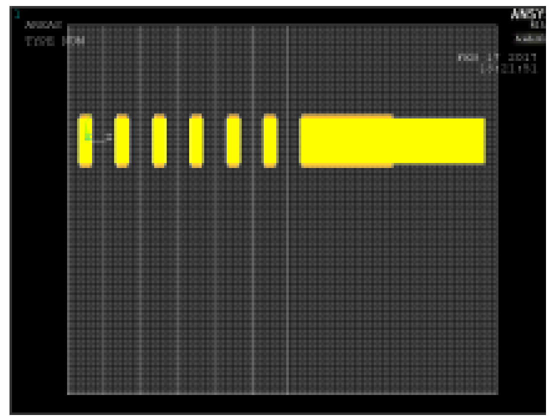
Simulation of the impact of the dead zones of the LEMs on the Charge collection Efficiency

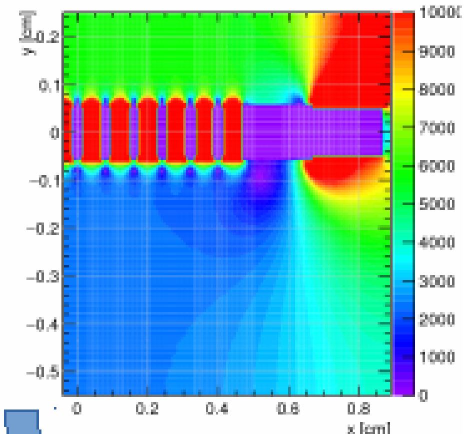
-Done with ANSYS and GarField

Gerber of LEM's Border and screw hole

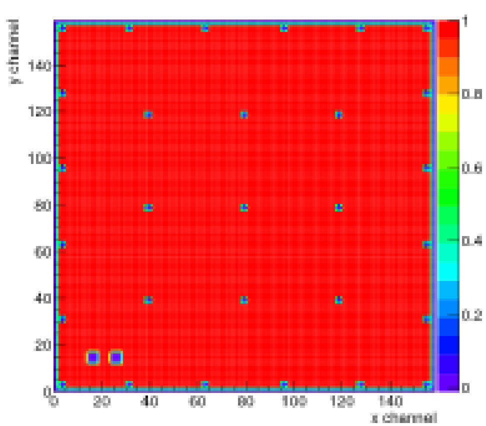


ANSYS simulation of LEM's Border

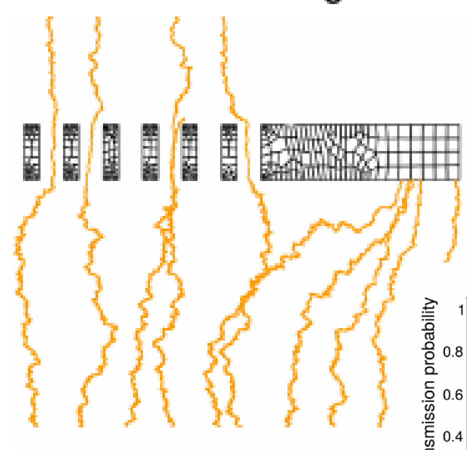


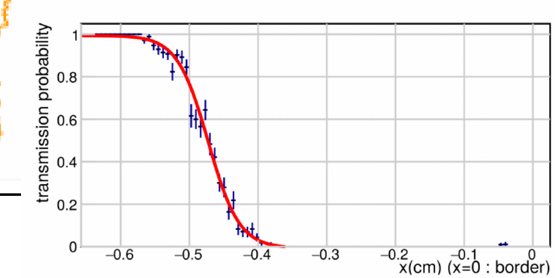


Collection efficiency of entire LEM



Drift of electrons through LEM's border (GarField)





Gas amplification

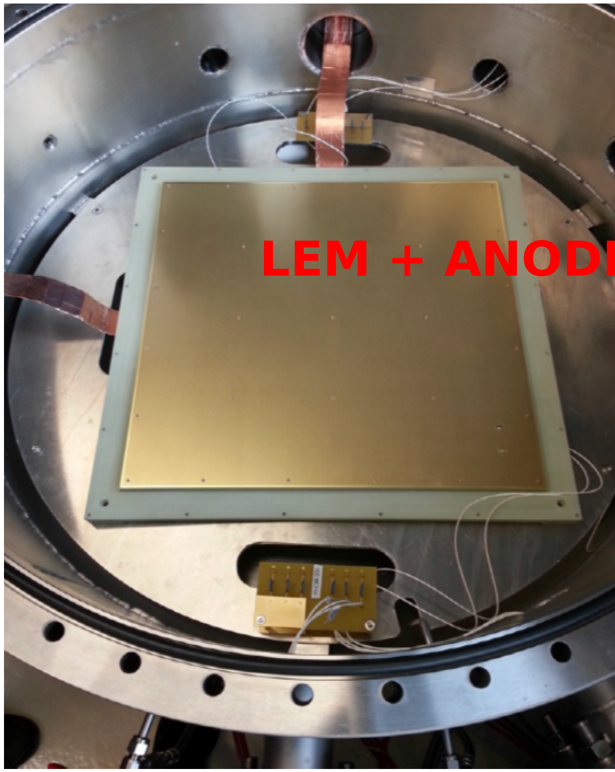
- The gas amplification can be written $dN = N\alpha\, ds$

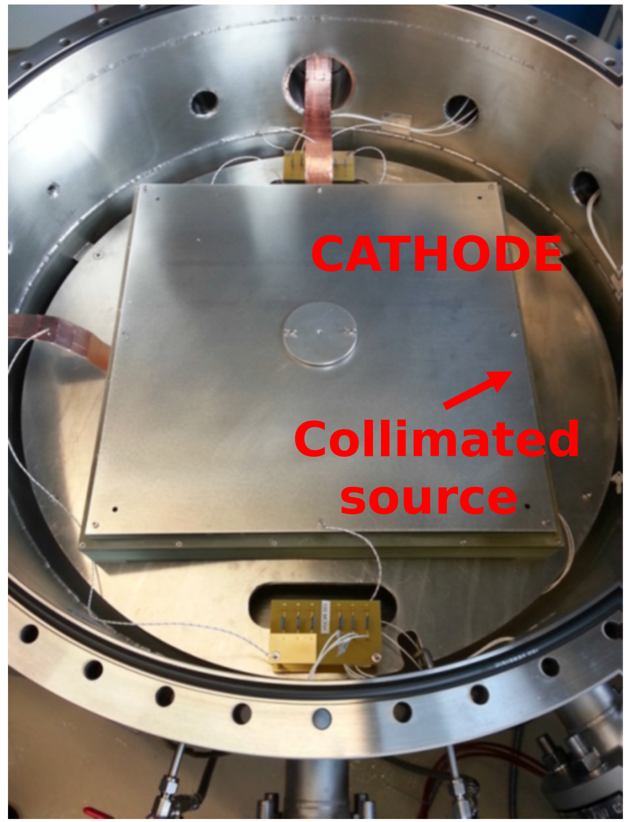
  where the first Townsend coefficient α can be written $\alpha(E/\rho,\rho) = f(E/\rho)\rho$

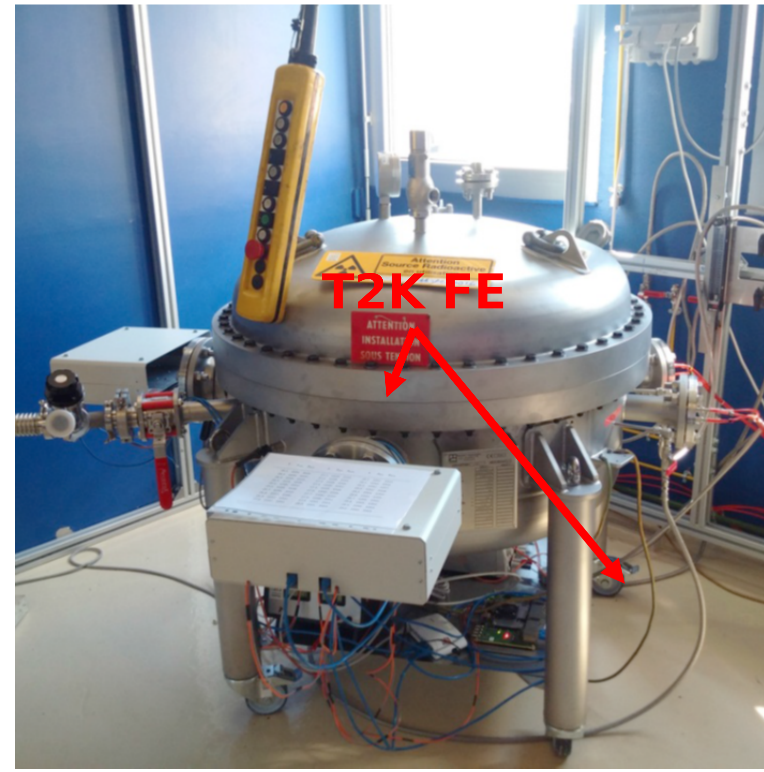
  ie α depends only on the density (and not separately on T or p).

- For a mass production of LEM, it is more convenient to test the device at room temperature at the same density of cold Ar gas. This requires a pressure $p_{eq} = p_{atm}\, T_{room}/T_{cold} \sim 3.3$ bar

Gain measurements with ^{241}Am source

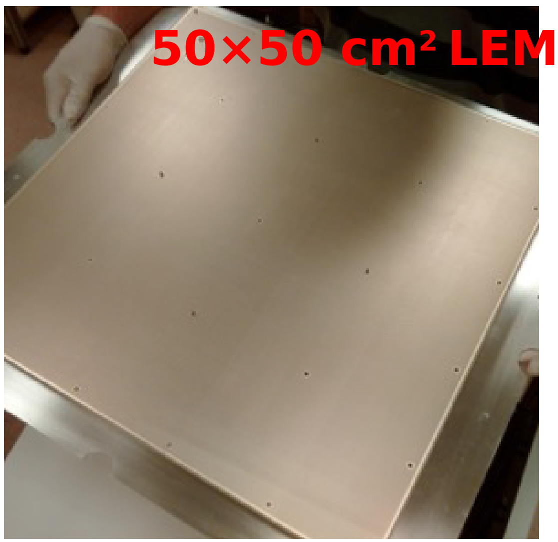


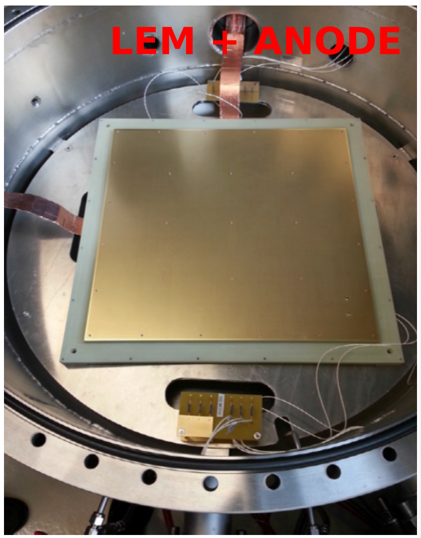




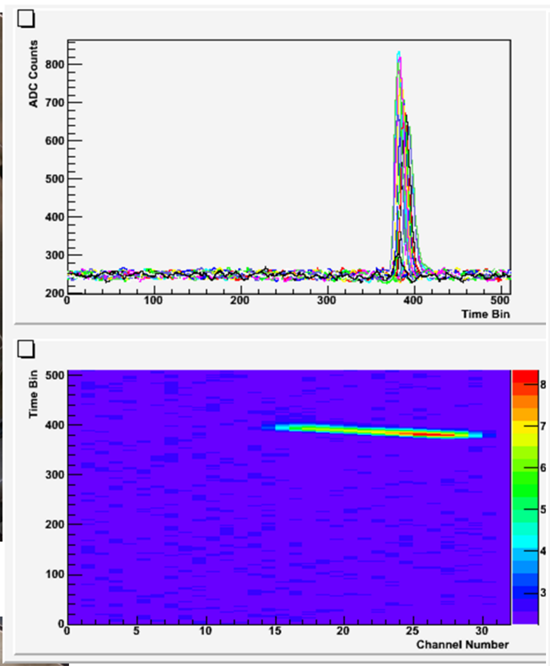
Pressure vessel capable of operating at 4 bar

HV Tests and Gain measurements

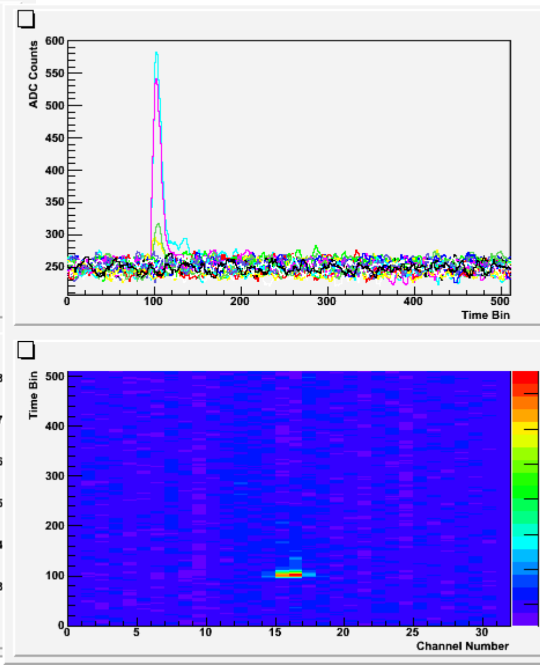


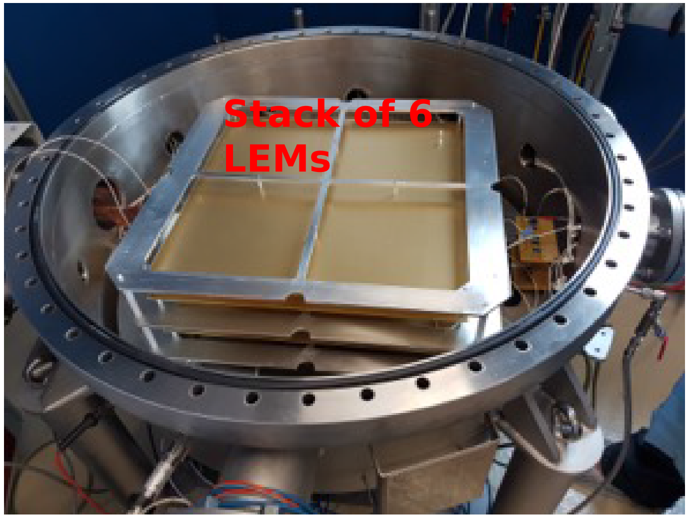


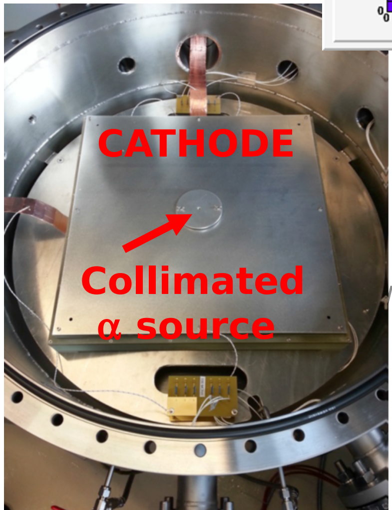
Ar @ 1 bar



Ar @ 3.3 ba



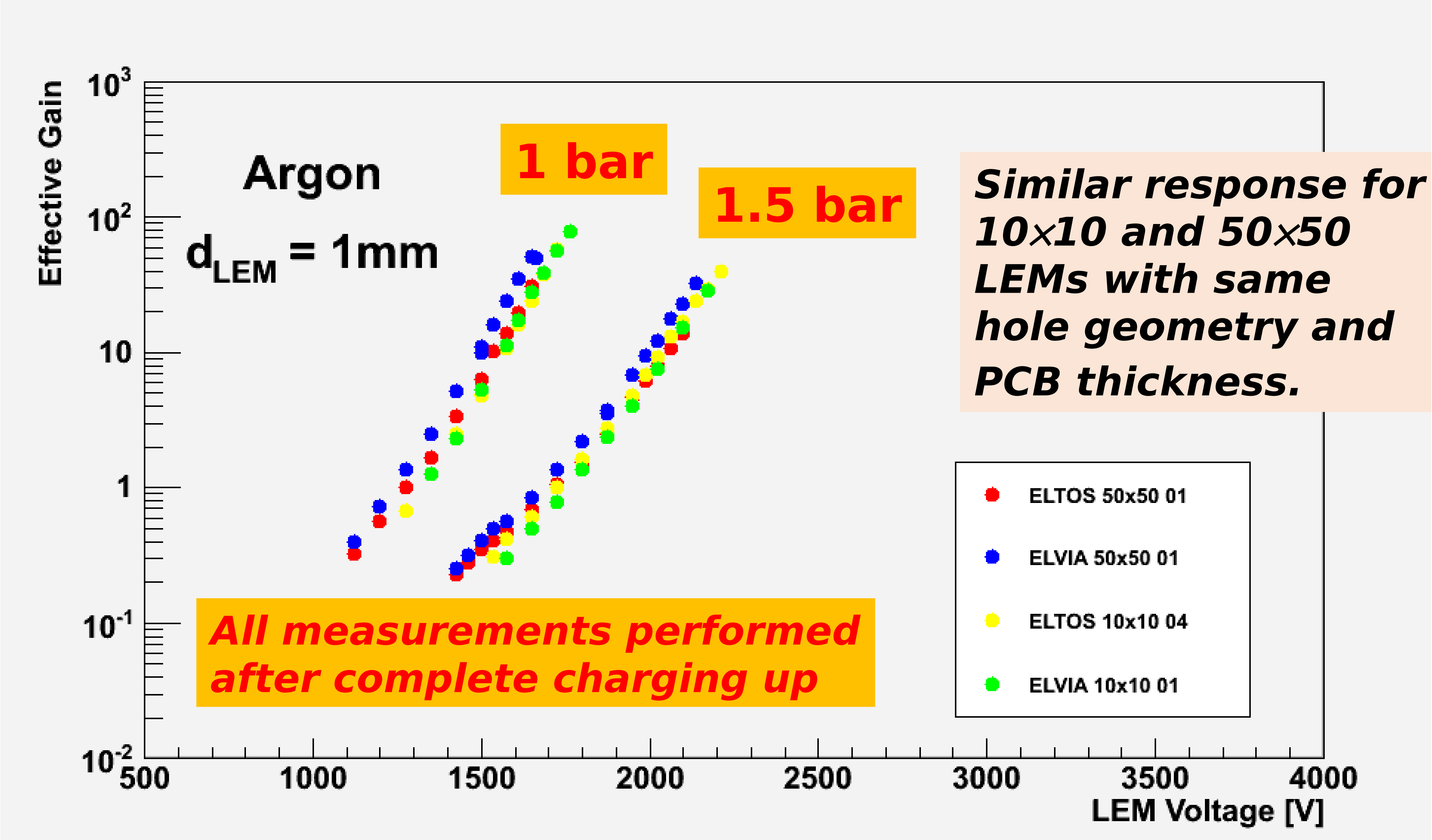




First track ever observed with a 50×50 LEM!

^{241}Am α tracks

Gain measurements

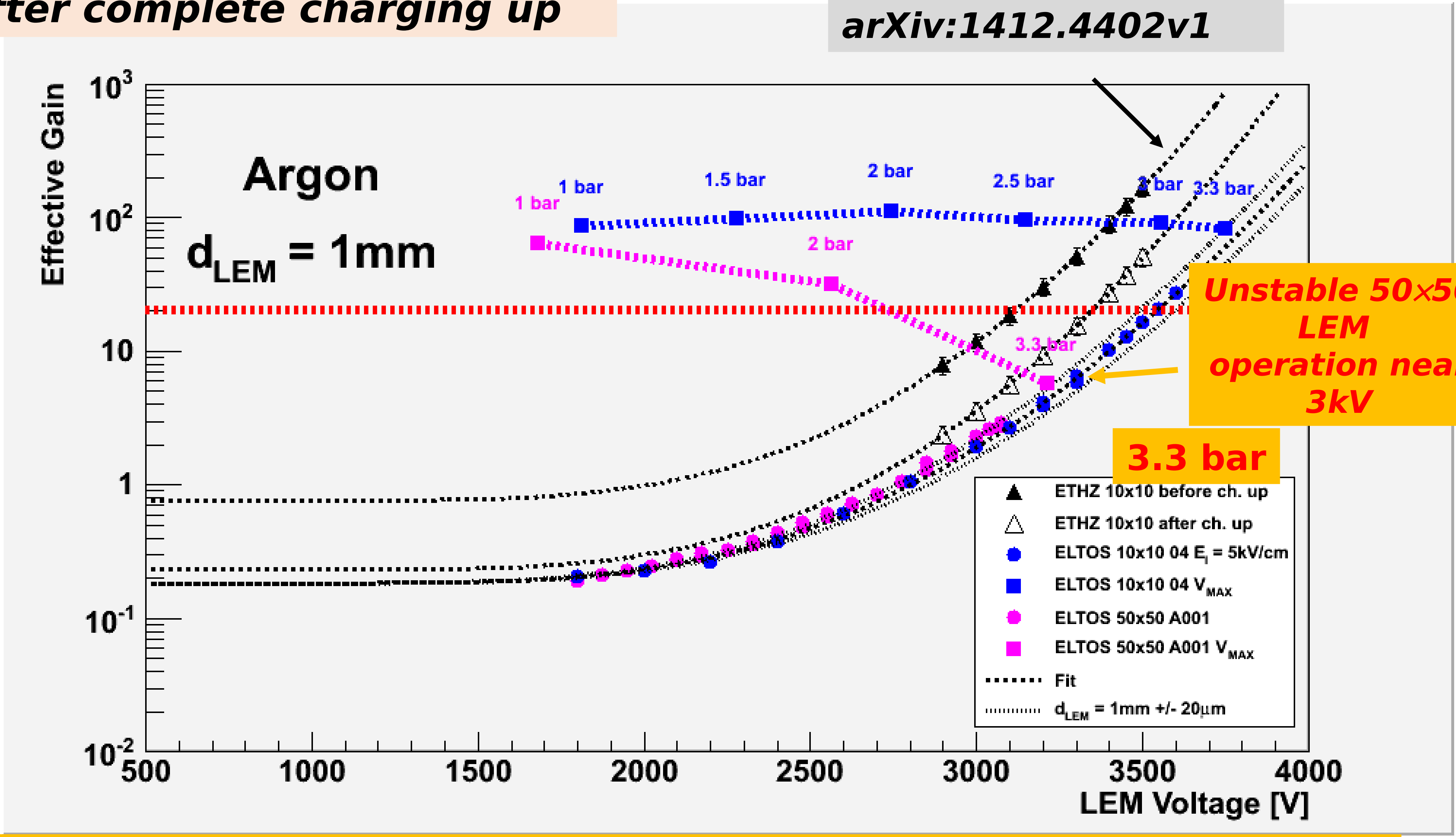


Same performance for the LEM produced by the two companies ELTOS and ELVIA

LEM tests : 50×50 -vs- 10×10

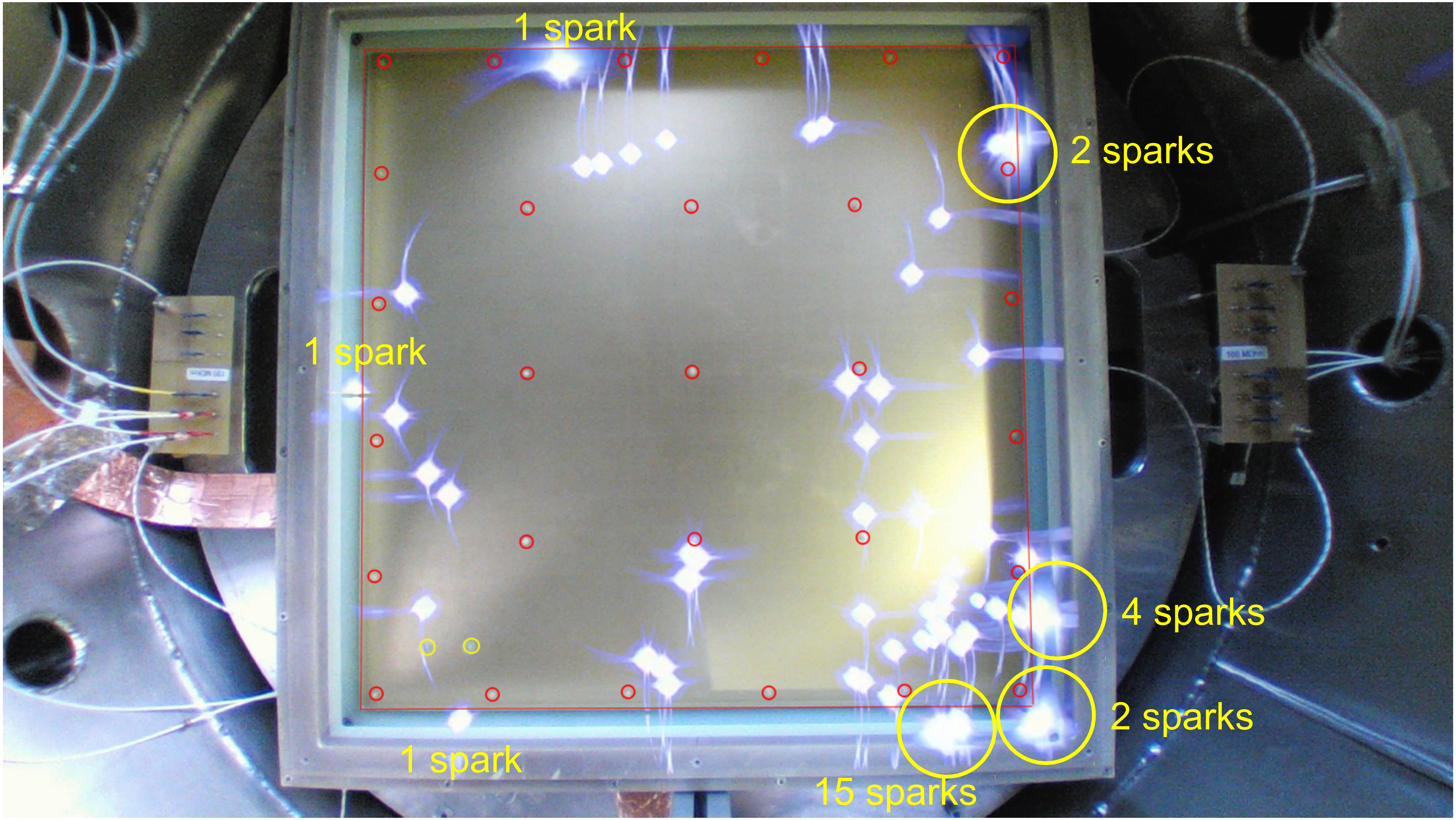
All measurements performed after complete charging up

From A. Cantini et al. arXiv:1412.4402v1



Unlike the 10×10 module which exhibits ~ constant max. gain up to 3.3 bar, there is a clear drop for the 50×50 one.

67 sparks : 24 (36%) close to borders (with 15 in bottom right), 41 (61%) randomly spread on the LEM active area (with 20 in bottom right) and 2 (3%) in bottom right corner

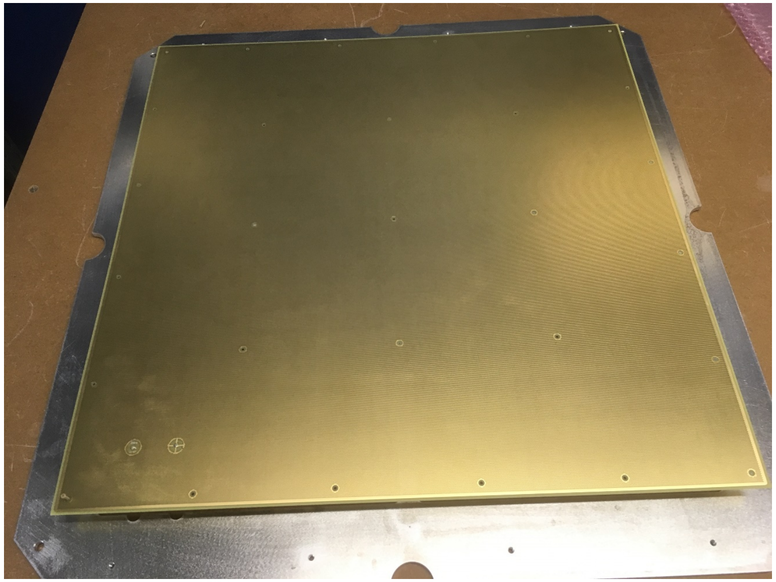


Motivation for a new LEM design

- Since 2015, the IRFU group has measured a LEM maximum gain which is not compatible with the goal of WA105/DUNE (ie gain = 20)
- This has led to a new design with larger guard ring (copper) and clearance (FR4 with no copper)
- This design is conservative to assess the improvement
- The dead area can be optimized, under study
- <u>The new design attains the design goal for DUNE</u> (see next slides)

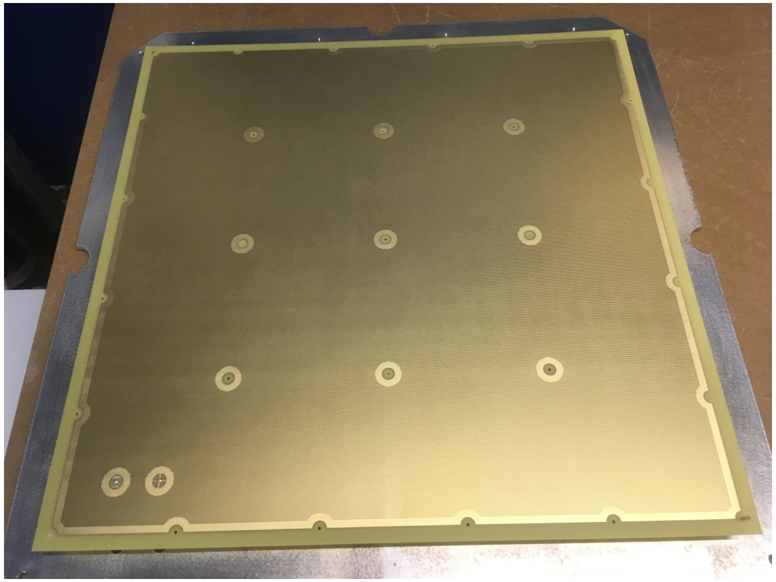
IRFU new LEM Design

Current



~ 96% active area

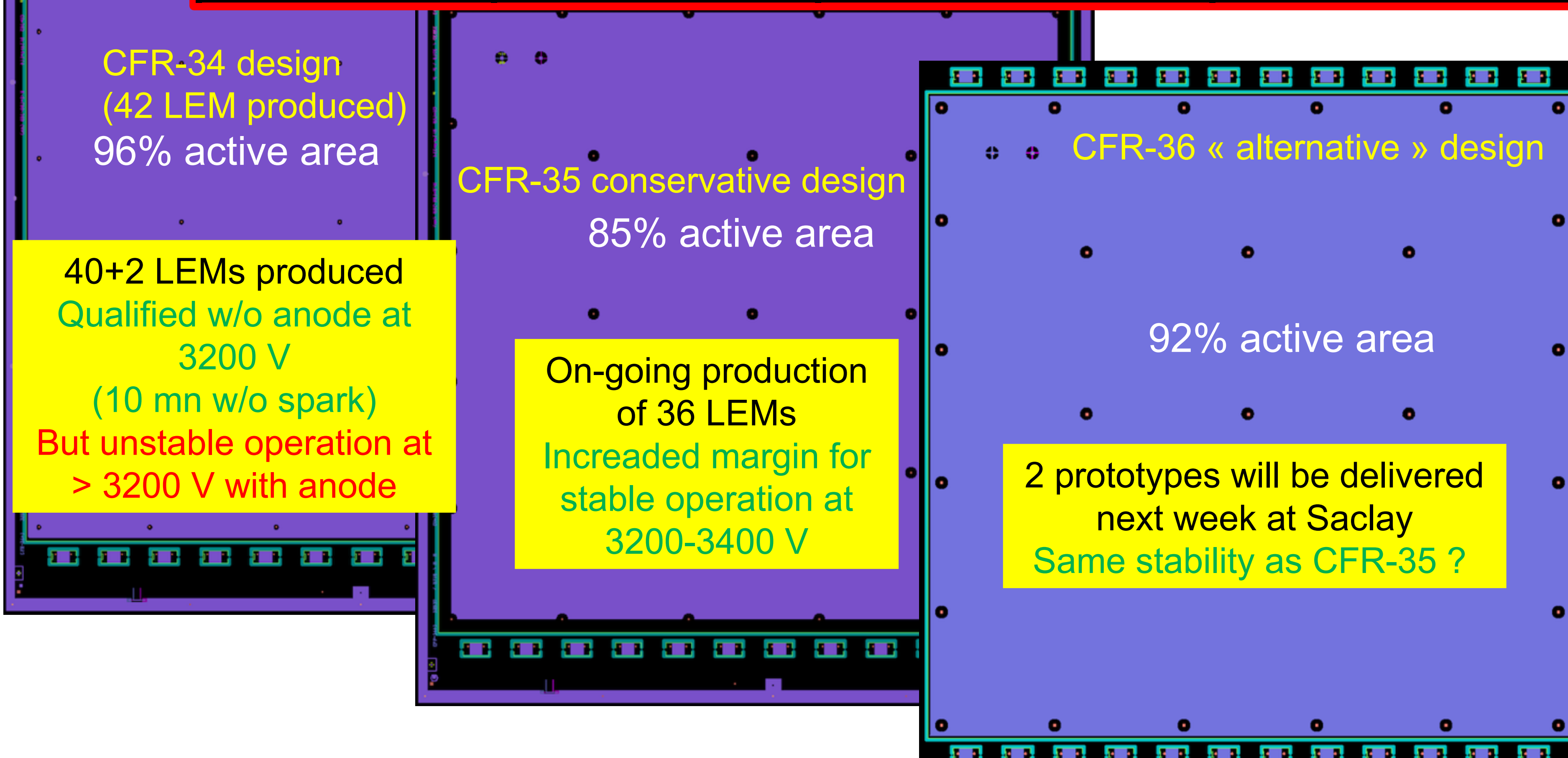
Modified



~ 86% active area

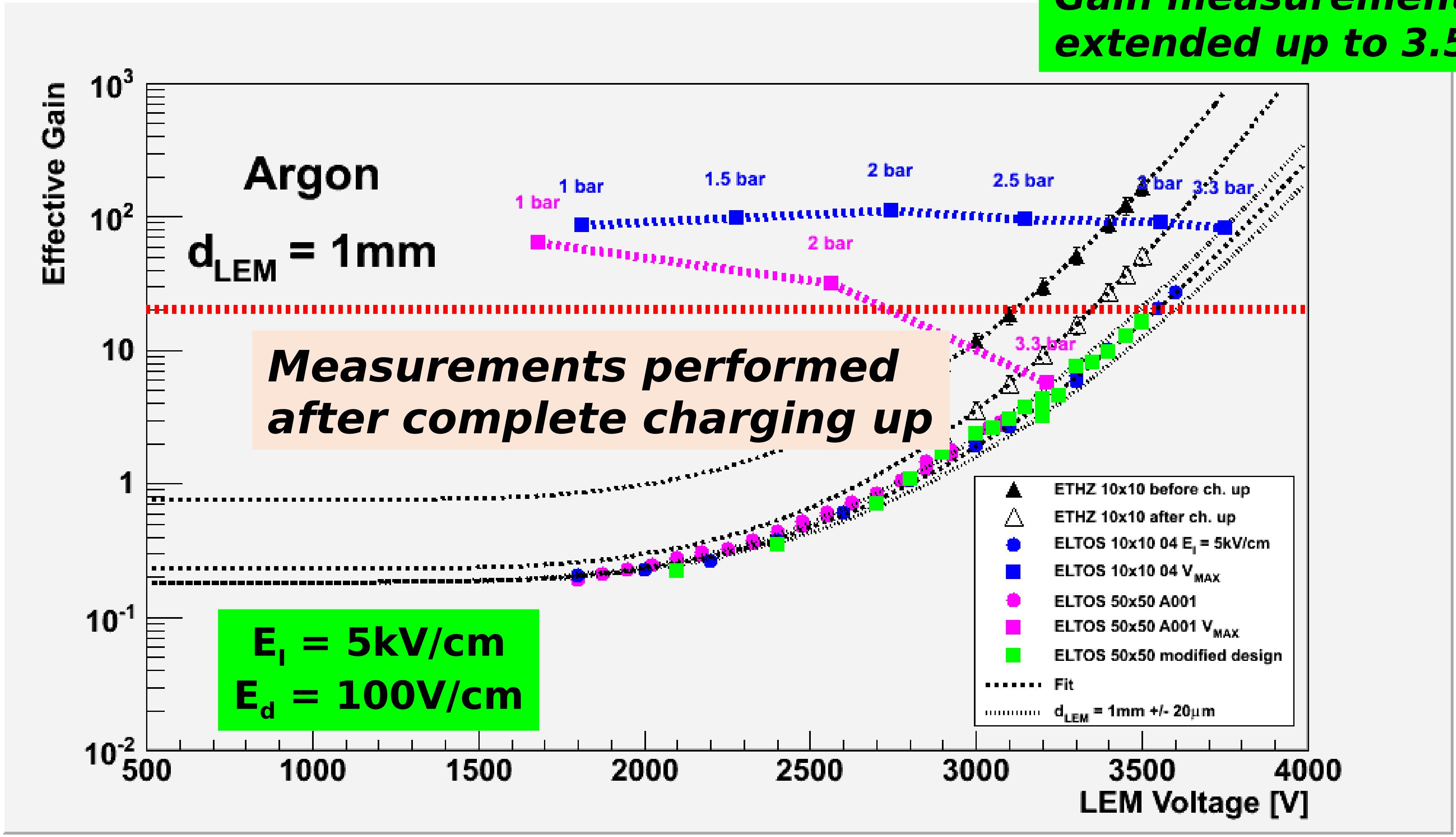
The 3 LEM Designs

		LEM borders		Screw holes		HV connections	
LEM design	%Active area	FR4	copper guard ring	FR4 ring Φ	copper guard ring Φ	FR4 ring Φ	copper guard ring Φ
CFR-34	96.2	2 mm	2 mm	4.2 mm	6 mm	10 mm	12 mm
CFR-35	85.8	10 mm	5 mm	10 mm	20 mm	10 mm	20 mm
CFR-36	92.1	2 mm	5 mm	10 mm	20 mm	10 mm	20 mm



LEM tests : 50×50 modified design

Gain measurements extended up to 3.5kV



A. Delbart

LEM specification document

Irfu cea saclay	Cahier des charges	Réf : CdCLEMWA105Fr
	LEM DU PROTYPE WA105 (DUNE/DP)	Date création : 30/09/2016
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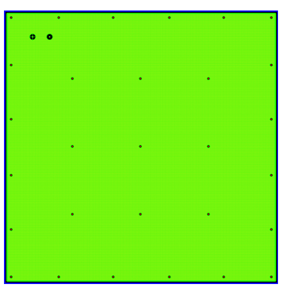
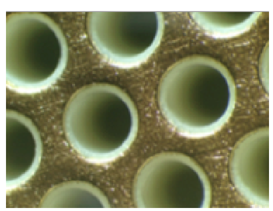
CAHIER DES CHARGES ET DES SPECIFICATIONS TECHNIQUES

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
DA			Pour diffusion initiale pour 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				

Irfu cea saclay	LEM DU PROTYPE WA105 (DUNE/DP)	Réf : CdCLEMWA105Fr
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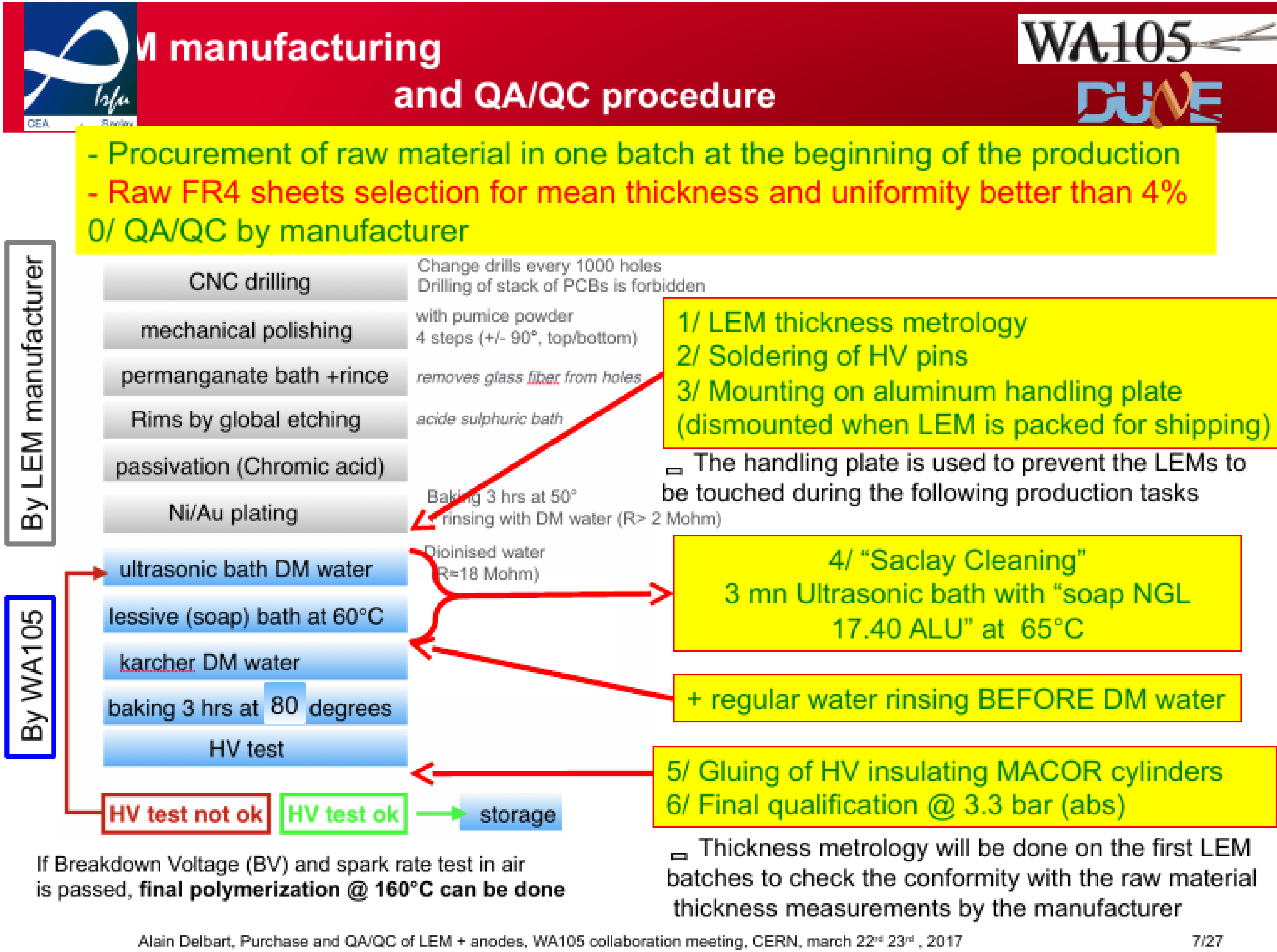
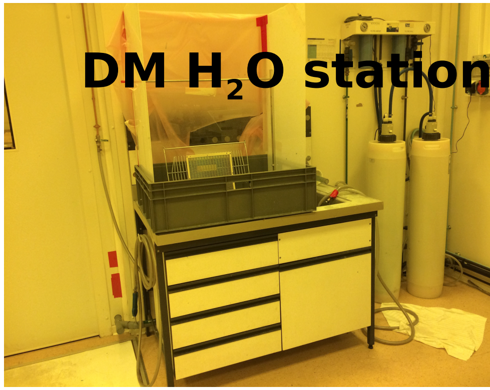
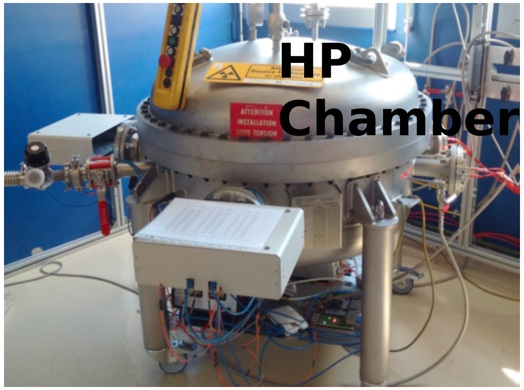


Procedure discussed and agreed with Rui de Oliveira (CERN EP-DT)

LEM procurement and QC/QA in Saclay

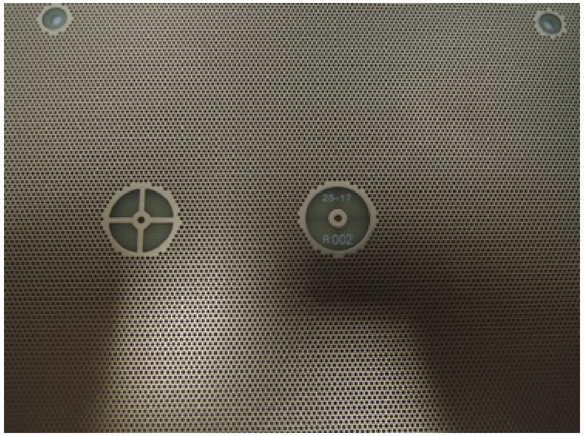
- CEA-IRFU responsible for the procurement of 1/2 of the 144 LEMs + anodes for the 6×6×6 + their validation.
- Irfu has contributed to the current LEM design, LAS assembly and to detector simulation.
- All the infrastructures necessary for the preparation and tests of the LEMs available at Saclay (cleaning, baking, polymerization, metrology, etc…).
- A High Pressure chamber has been built in order to perform LEM tests in argon at same gas density as in DLAr conditions (P ~3.3 bar at room temperature).
- LEM production started last July and is progressing well (contract with ELTOS for 78 LEMs).

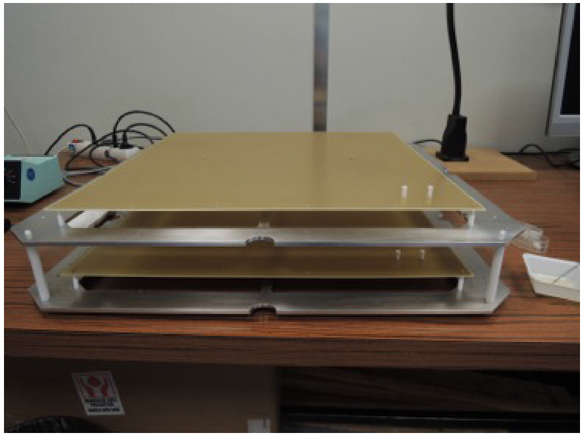


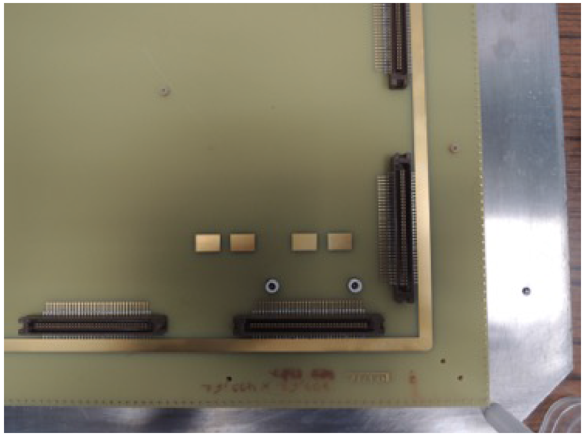


LEM preparation and cleaning

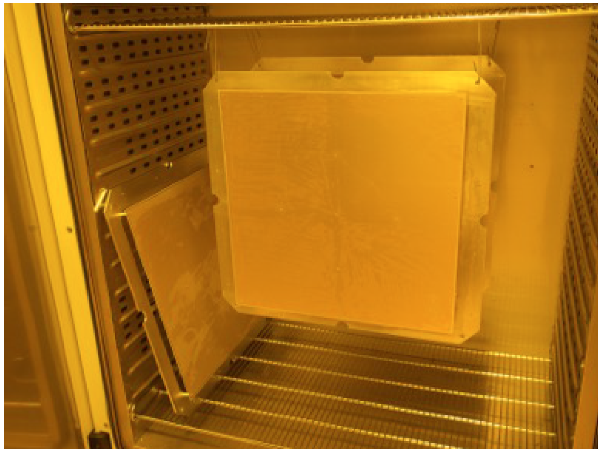
Soldering HV pins + glueing MACOR insulation

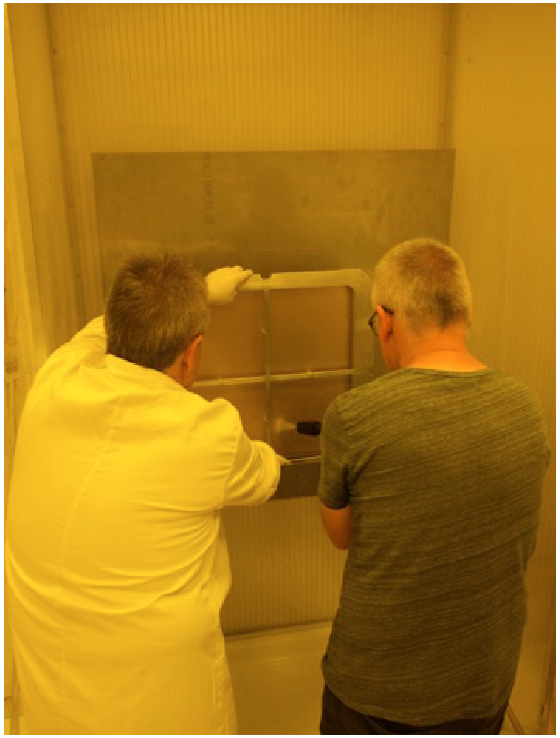






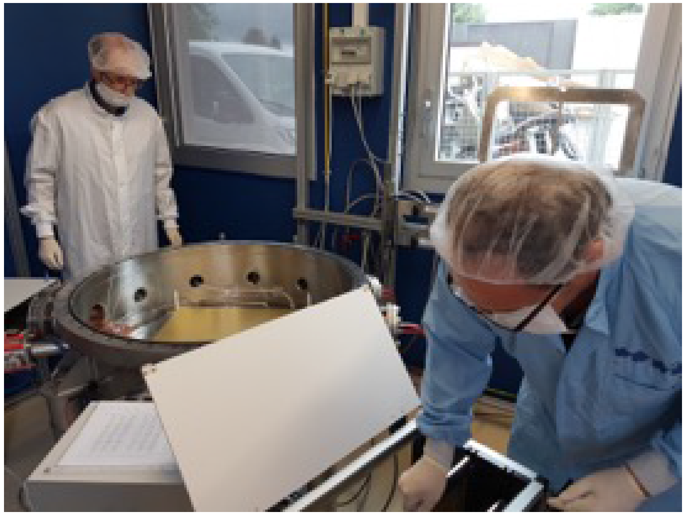
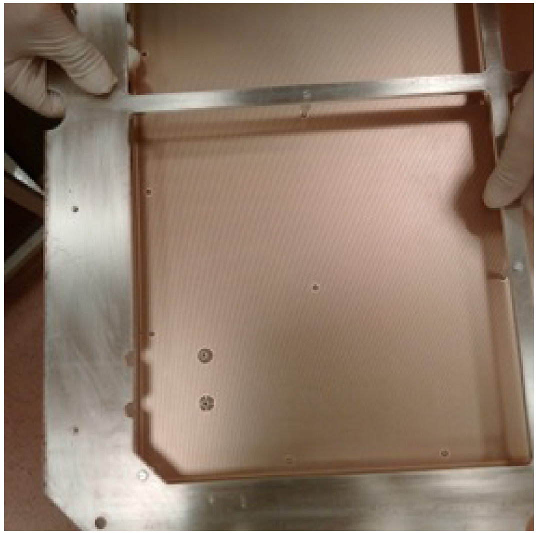
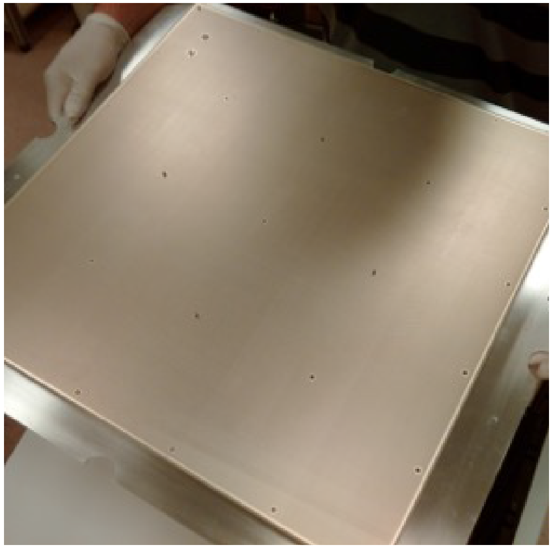
LEM preparation and cleaning

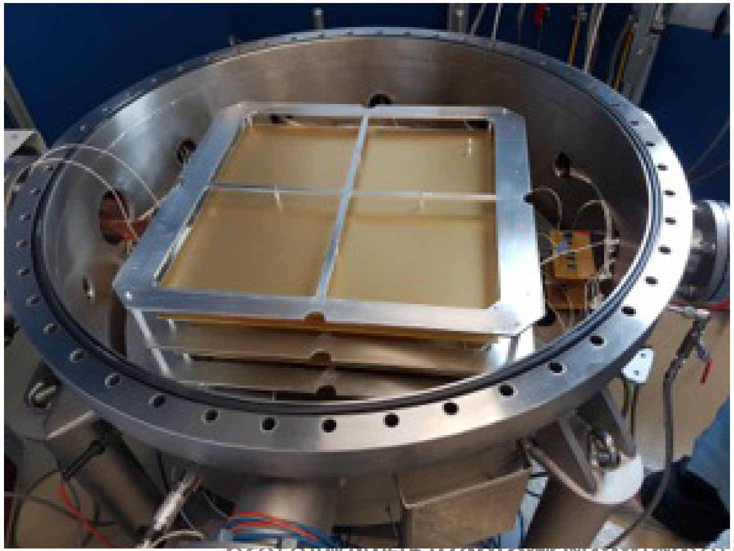




Cleaning + drying + polymerization

HV tests in HP chamber

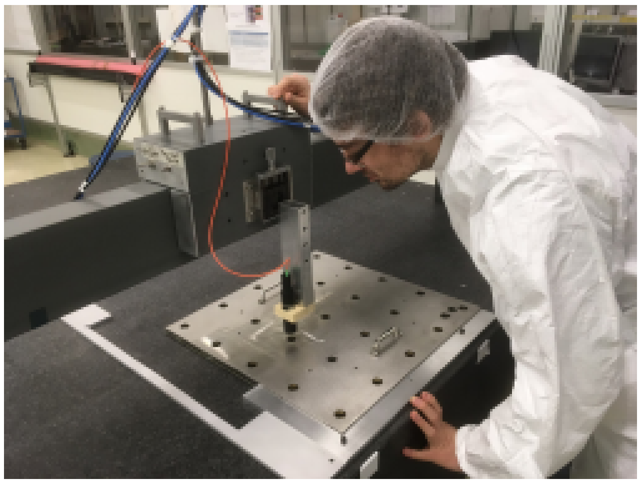




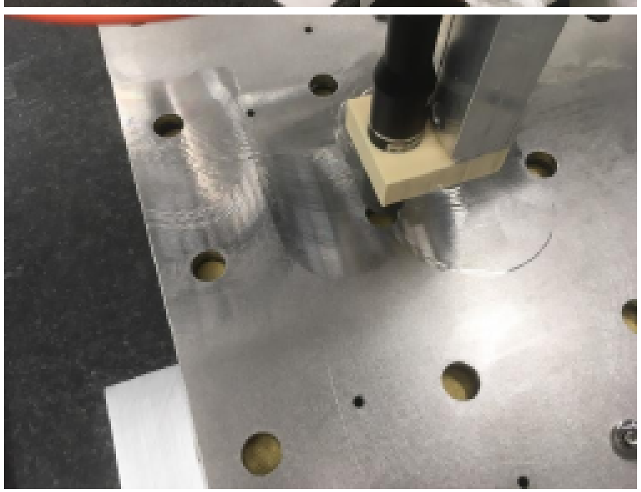



Status of LEM Production

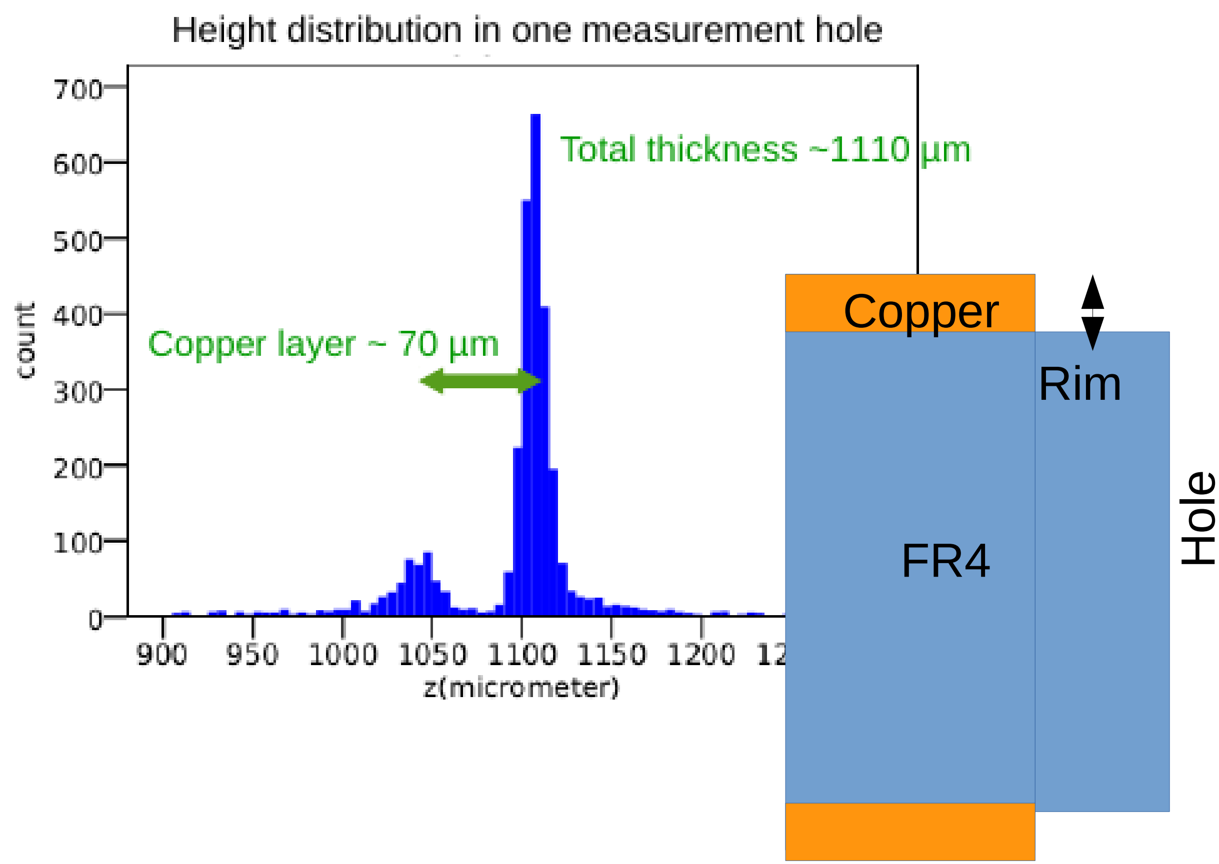
- Tendering Process (for 72 LEMs) started April 2017
- Production started in June 2017
- Established rate of 6 LEM/week at production and QA/QC
- 42 LEM produced (CFR-34), nn validated
- Production paused in November 2017
- Production resumed with the new LEM design in December 2017
- First batch of LEM CFR-35 expected for week 4, production completed by end of February 2018
- NB: ELTOS is equipped with a new drilling machine and can produce 12 LEMs/week
- Schedule in line with WA105 completion in November 2018

Measurement of LEM thickness





-LEM is flattened by a 10 kg aluminium plate
-Thickness measured with an optical pen at 25 different places



From WA105 to DUNE 10kt-DP

- IRFU is seriously considering to participate to the construction of DUNE DP 10kt
- Subject to a scientific strategy decision by IRFU, and subject to availability of funds and personnel
- IRFU could consider providing a significant fraction (~25%) of the LEM-anodes for one 10kt module
- A fact-based cost model derived from WA105 construction has been established (little contingency needed)
- LEM marginal cost could be reduced by ~25% with respect to WA105 for a mass production of ~1000 LEMs

DUNE 10kt-LEM/anode cost items

Mech. Frames and jigs :
HP chamber +vacuum pumps
High Voltage :
Lab Instrumentation + PC :
Tools, gas etc :
Shipment :
Métrologie
Clean room with laminar flux
Oven + cleaning/rinsing devices :
Additional personnel

DUNE 10kt-LEM/anode cost items

Mech. Frames and jigs :
HP chamber +vacuum pumps
High Voltage :
Lab Instrumentation + PC :
Tools, gas etc :
Shipment :
Metrology
Clean room with laminar flux
Oven + cleaning devices :
Additional personnel

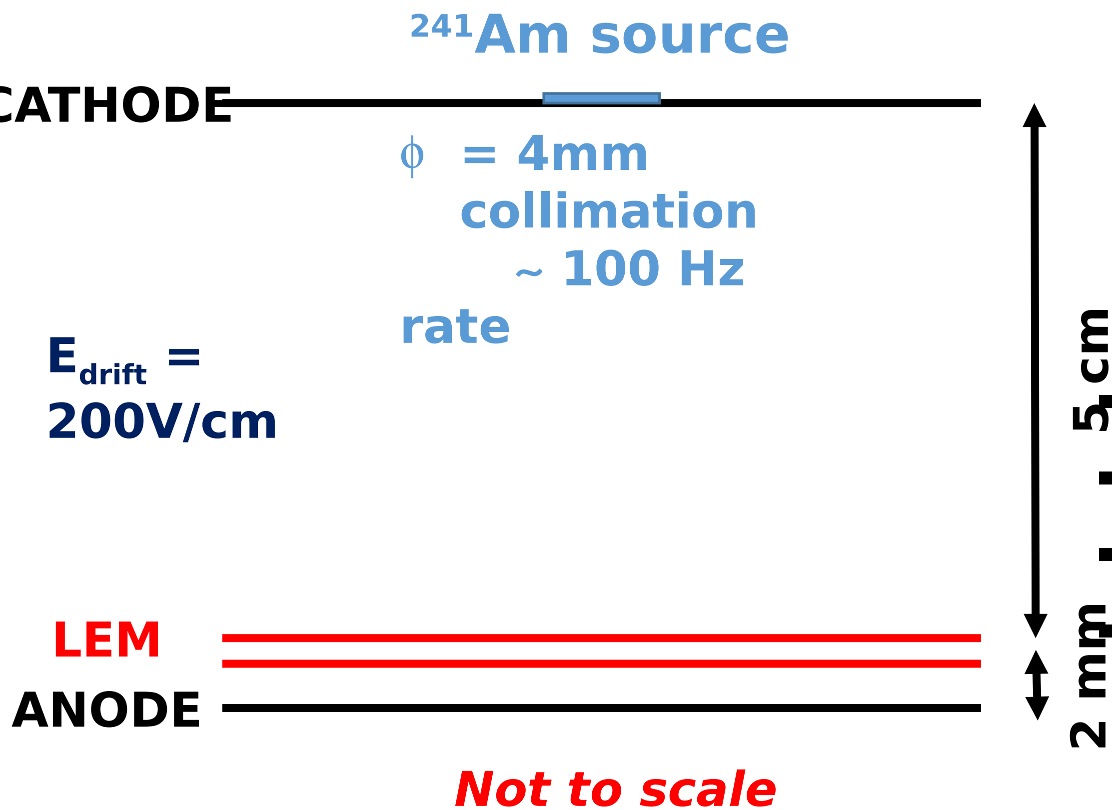
Conclusions

- Irfu Saclay has a long experience with gaseous detectors, MPGD, and TPC, applied to HEP and neutrino physics in particular
- It has studied and improved the design of the LEM for WA105 and defined the QA/QC procedure for LEMs
- Production of ½ of LEMs and anodes for WA105 in progress, in line with IRFU MOU commitment
- A proposal for participation to 10kt DUNE DP is being evaluated with a detailed cost estimate based on in house know-how

Backup

Setup for gain measurements with an α source

E_α = 5.5 MeV   L = ~ 4.5 cm tracks @1 bar

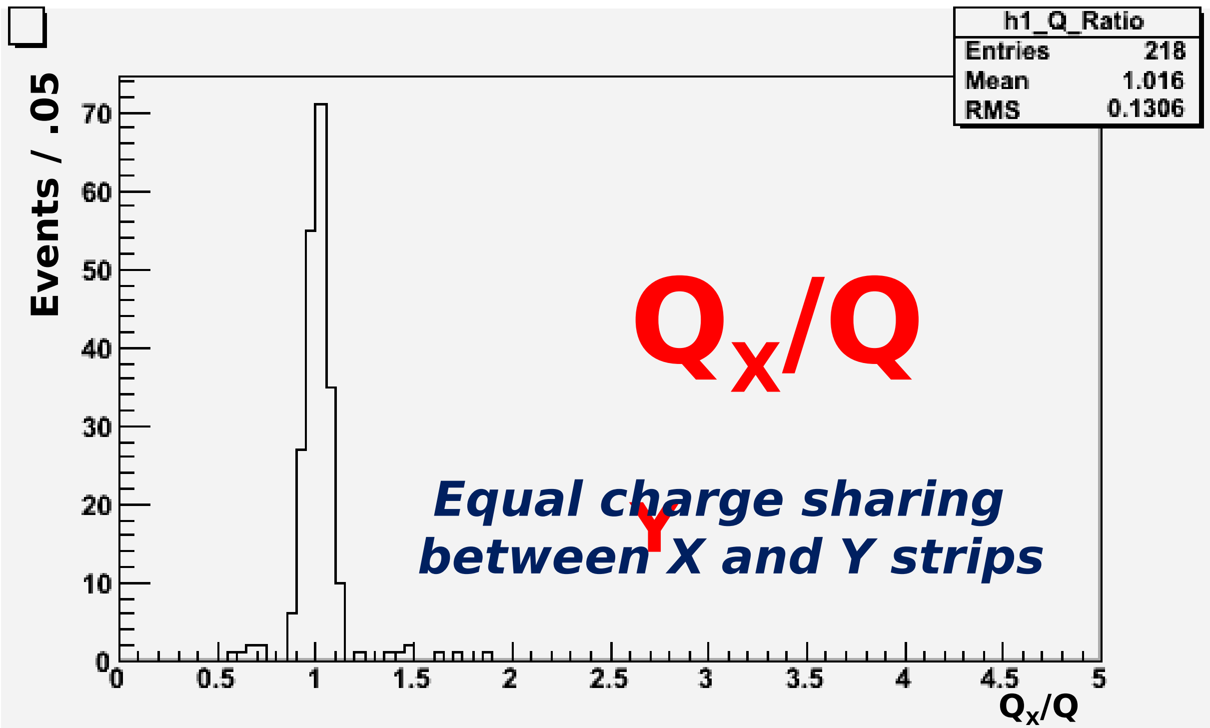


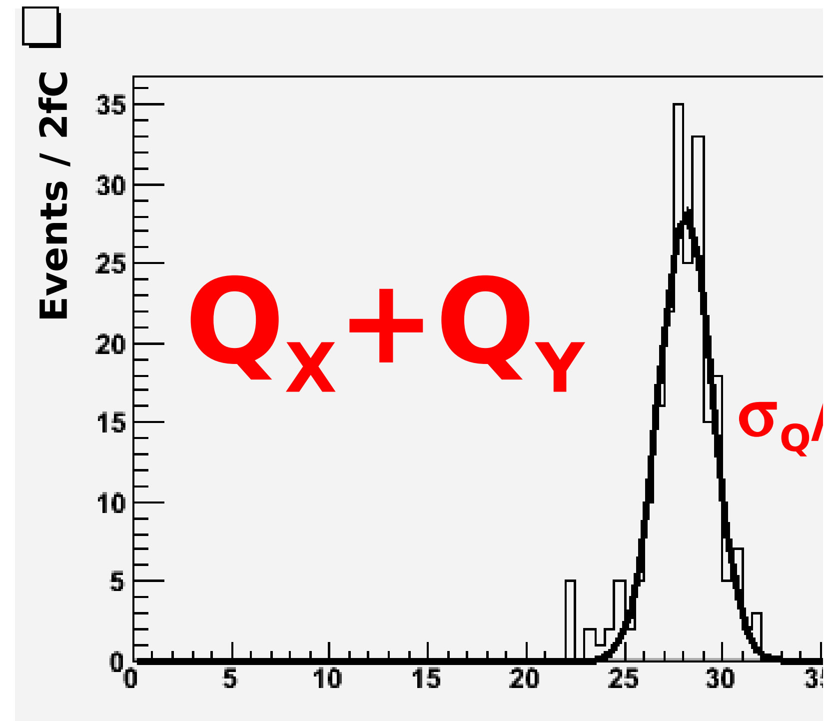
- FE : T2K ASIC AFTER + FEMINOS R/O + TCM :
  - 12 bit ADC
  - 120fC - 600fC full range range
  - 1.9 μsec peeking time
  - 511 time bins R/O @ 6.66 MHz (150ns)
  - 32 channel R/O per view (X,Y)
  - E noise : ~0.2-0.4fC
  - Measurement range : ~ 2 – 1600fC / view
- Ar (5.7) purity : > 99.9999%
- < 10^{-4} mbar pumping before Ar filling
- ~60 ppm of impurities after 30h of operation
- Charging up time : 2-3h @ 1bar and G^{eff} ~ 10

N.B. Gain measurements performed after charging up and usually with E_{LEM} / E_I = 6.

Test with ^{241}Am source @ 3.3 I

E_{LEM} = 30 kV/cm and E_I = 5kV/cm





LEM design : 50×50 -vs- 10×10

- Although hole geometry and PCB thickness is the same, the 10×10 LEM designs (ETHZ or IRFU) differ from the 50×50 one : no screw hole, no HV connector in active region but large area insulating material surrounding the LEM edges.
- Difference in LEM maximum voltage may not be due uniquely to size effects.