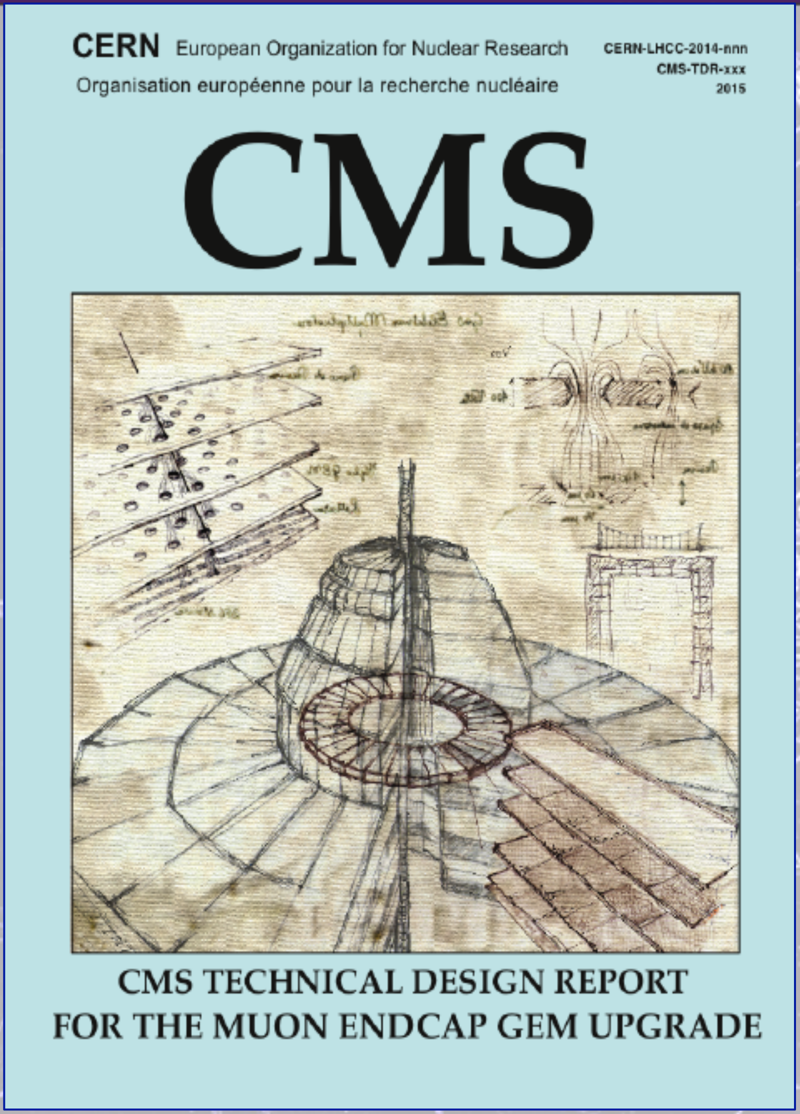


CMS GEM upgrade from TDR submission

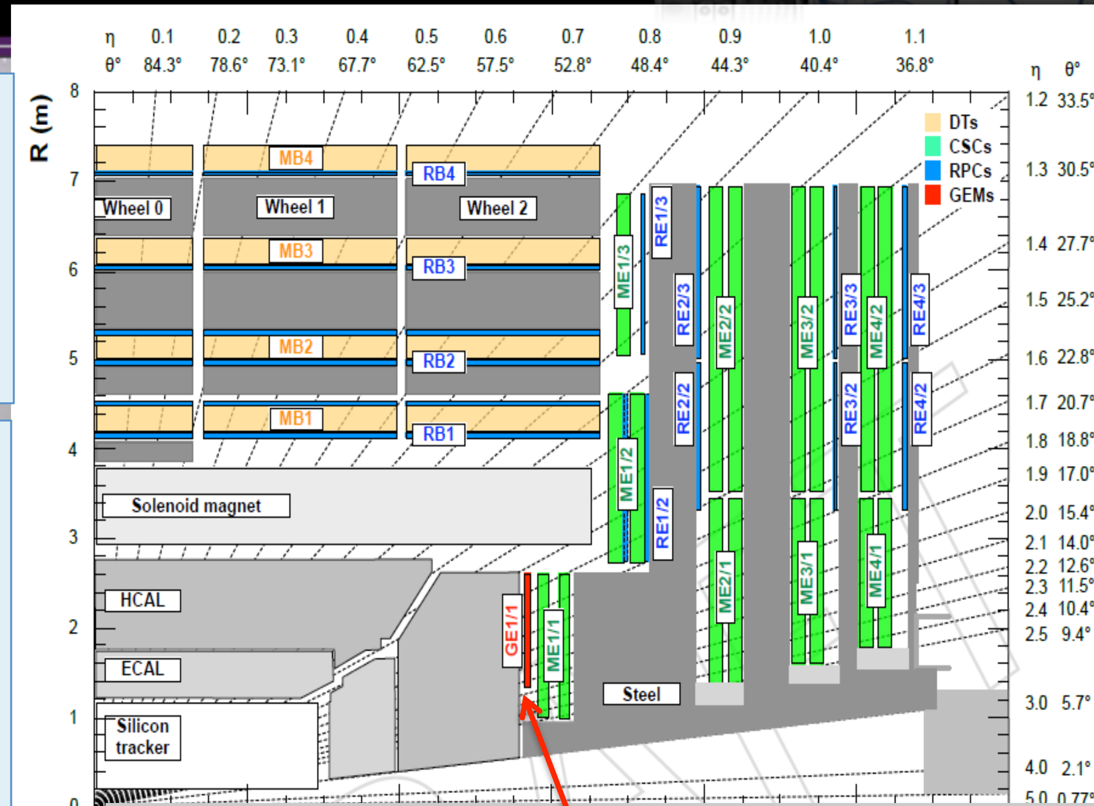
Jeremie Merlin

08/03/2015

On behalf of the CMS GEM collaboration

CMS GEM Proposal

→ ONLY CSC at |η| > 1.6
- Lowest redundancy in CMS
+ Rate flattening (L1 trigger)
- Non optimal triggering system (92% identification of BX)
- Max coverage is |η|< 2.4



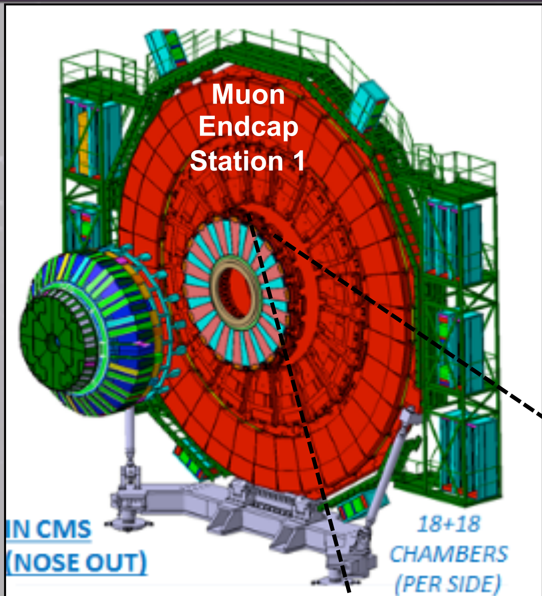
https://twiki.cern.ch/twiki/bin/view/MPGD/CmsGEMCollaboration

Solution: add detection layer for |η|> 1.6

Requirements:
- higher BX identification efficiency
- σ_x comparable comparable to CSC
- rate capability > 10kHz/cm^2
- Large active area
- operation in high magnetic field (3.1T)
- resistant to aging > 20 years (HL-LHC/ Phase II)

GE1/1:
- improve L1 and HLT muon momentum resolution, to reduce or maintain global muon trigger rate
- restore redundancy

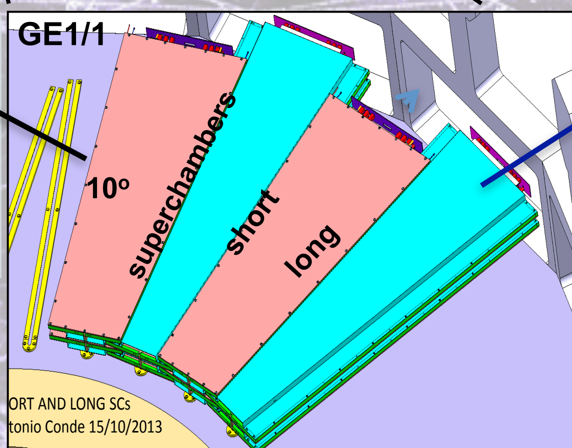
GE1/1 station



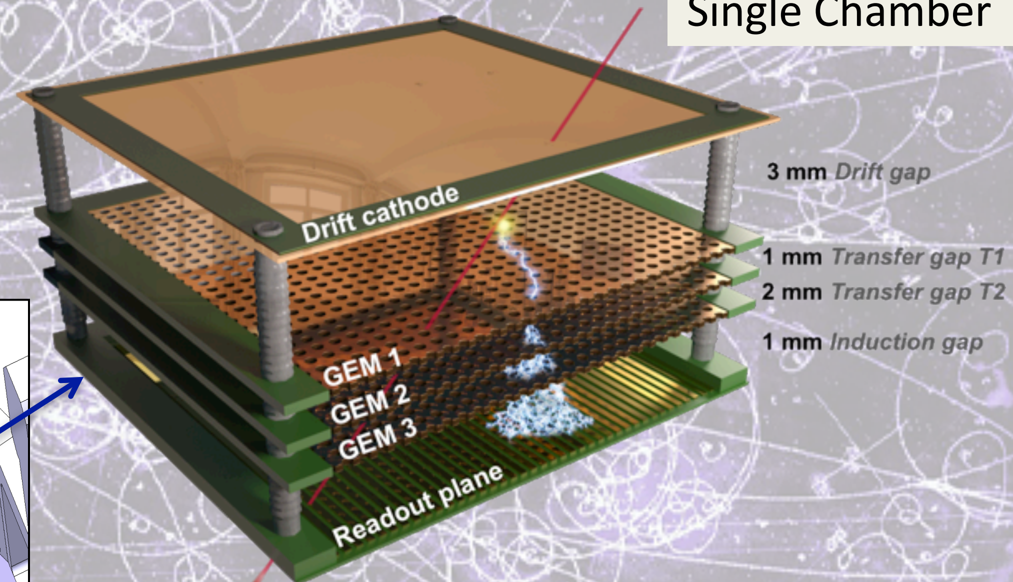
- GE1/1 : 10°in Φ **triple-GEM**
- 2 GEM chambers form a“**super chamber (SC)**”
- 144 total chambers (36 super chambers in one station per endcap)

Short SC
eta=1,61-2.18

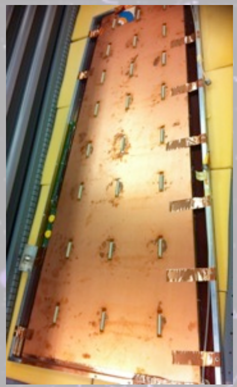
Long SC
eta=1.55-2.18

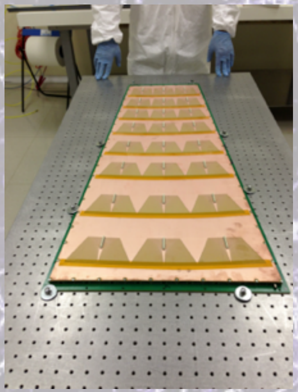


Single Chamber



Project schedule



2010 — 2011 — 2012 — 2013 — 2014 — 2015

Generation I
The first 1m-class detector ever built but still with spacer ribs and only 8 sectors total.

Generation II
First large detector with 24 readout sectors (3x8) and 3/1/2/1 gaps but still with spacers and all glued.

Generation III
The first sans-spacer detector, but with the outer frame still glued to the drift

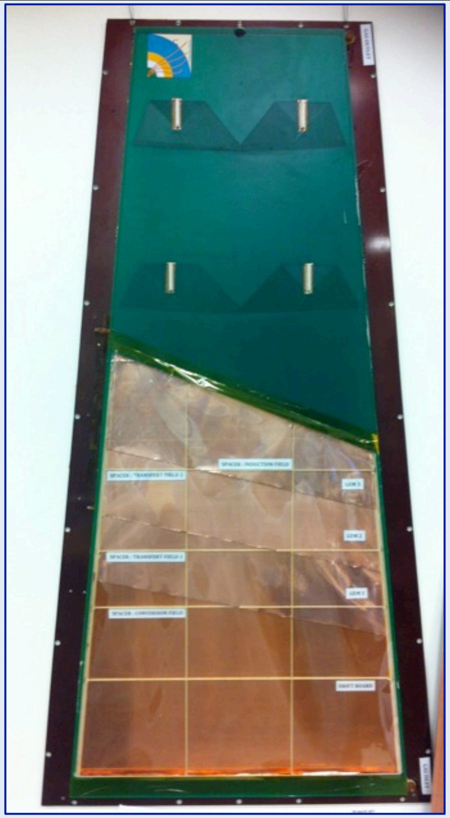
Generation IV
First detector with complete mechanical assembly; no more gluing parts together!

Generation V
Stretching apparatus that is now totally inside gas volume. test beam campaign for final performance measurements.

Generation VI
Latest detector design; Optimized final dimensions for maximum acceptance and final eta segmentation.

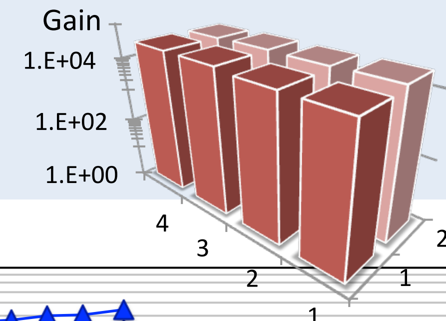
2015	YETS 2016	2016/17	2017/18	2018/19
Prototyping, DAQ &trigger and QC procedure of detectors. First prototype of VFAT3	electronics&chamber prototype installation	Slice and trigger commissioning.	Production GE1/1 chambers with final electronics	Full installation of GE1/1 with final electronics

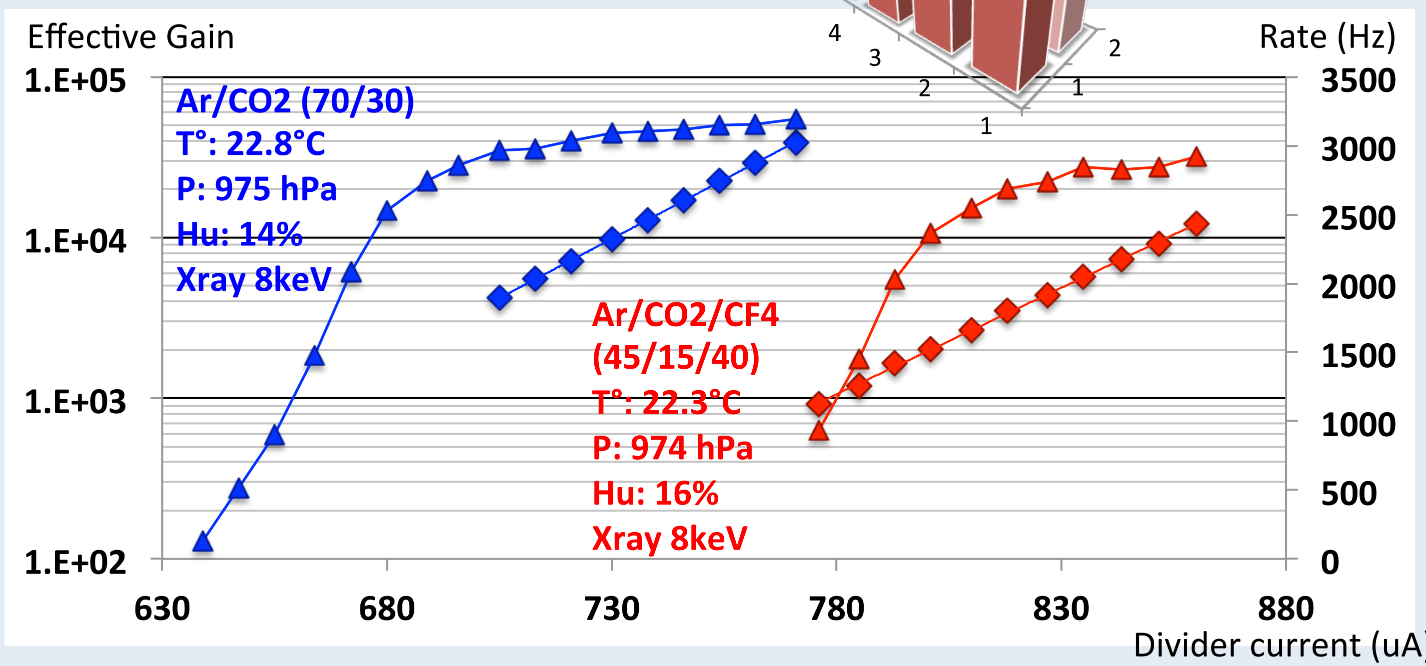
GE1/1 prototypes



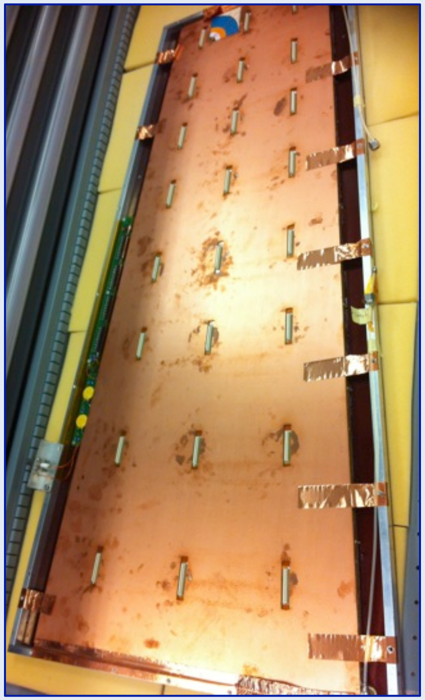
GE1/1- prototype I:

- Size : 99x(22-45) cm^2
- Single mask
- Gap configuration : 3/2/2/2
- 8 readout sectors (1024 channels)
- Glue/Spacers



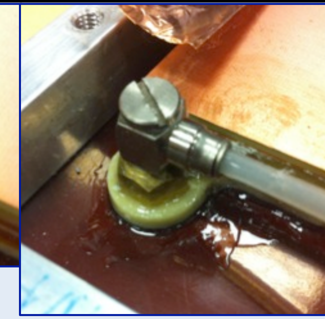


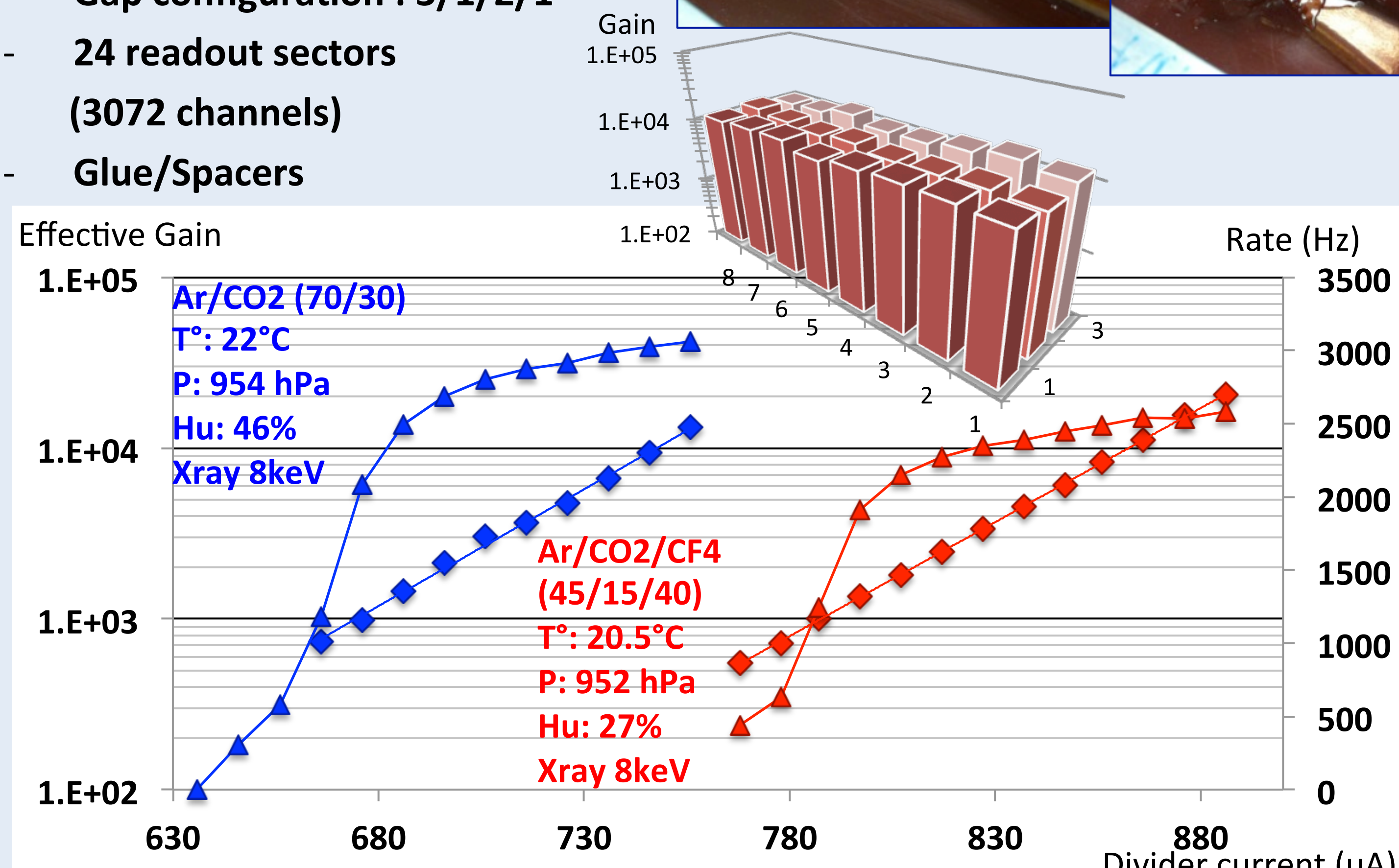
GE1/1 prototypes



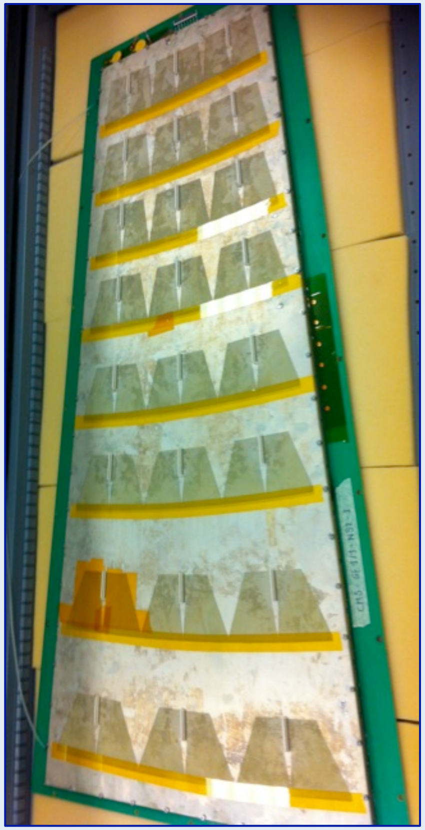
GE1/1- prototype II:

- Size : 99x(22-45) cm^2
- Single mask
- Gap configuration : 3/1/2/1
- 24 readout sectors (3072 channels)
- Glue/Spacers



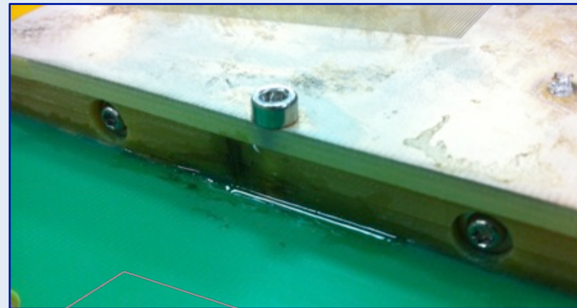


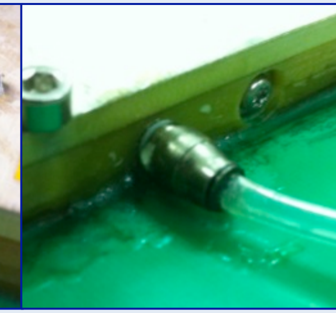
GE1/1 prototypes

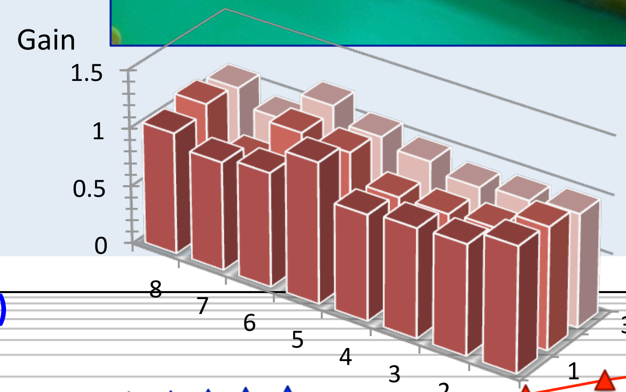


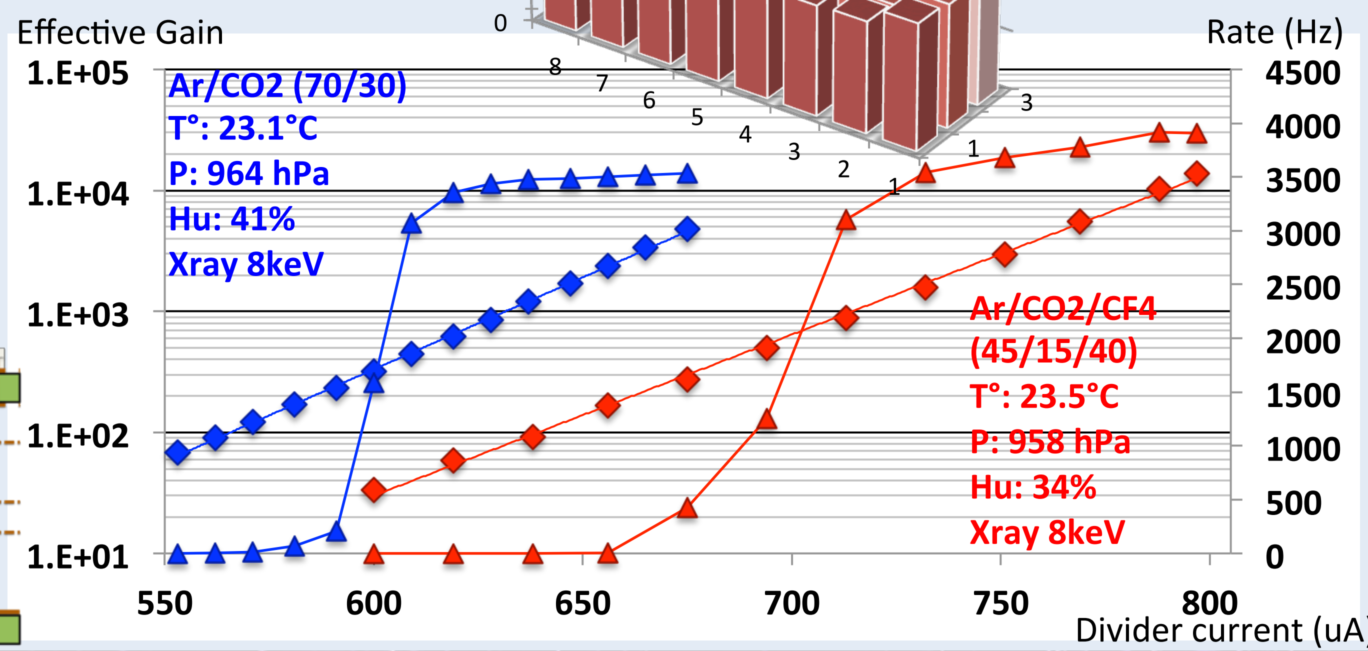
GE1/1- prototype III:

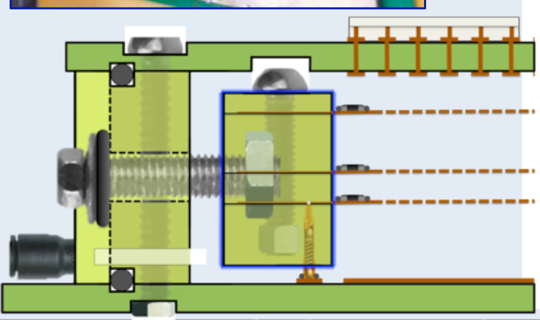
- Size : 99x(22-45) cm^2
- Single mask
- Gap configuration : 3/1/2/1
- 24 readout sectors (3072 channels)
- No Glue/No Spacers







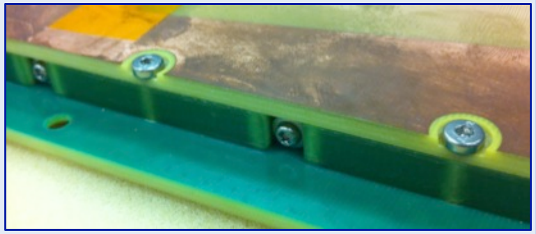


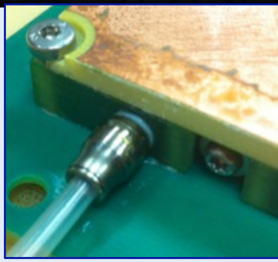


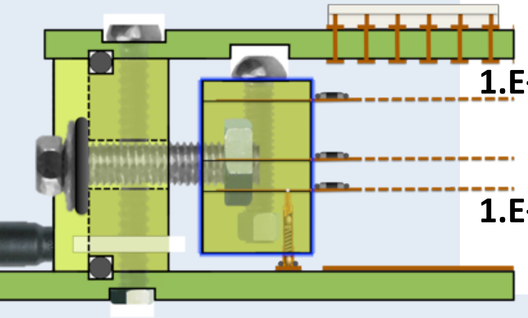
GE1/1 prototypes

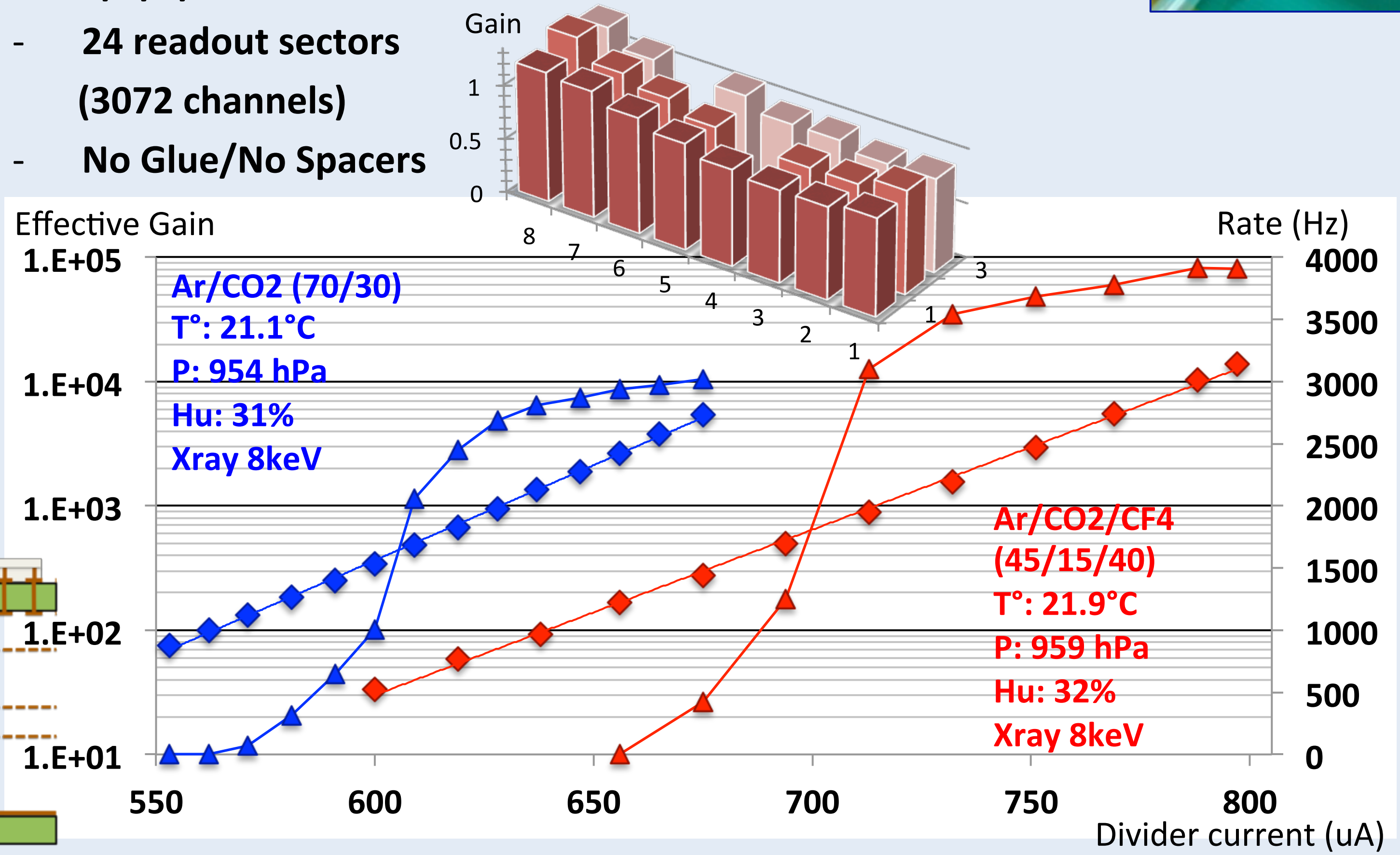
GE1/1- prototype IV:

- Size : 99x(22-45) cm^2
- Gap configuration : 3/1/2/1
- 24 readout sectors (3072 channels)
- No Glue/No Spacers

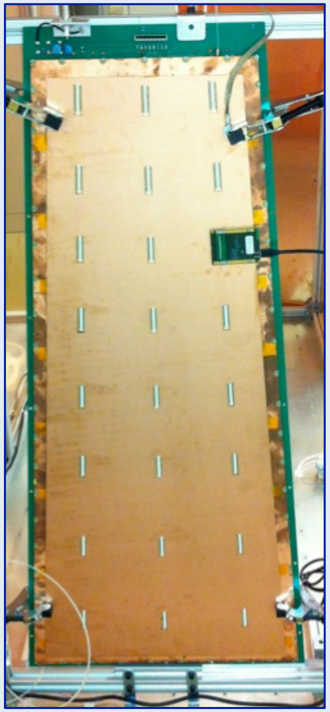






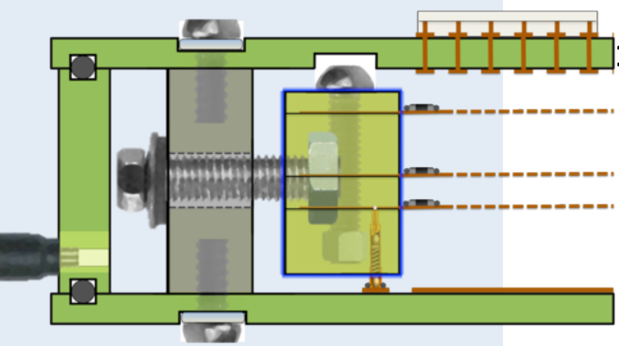


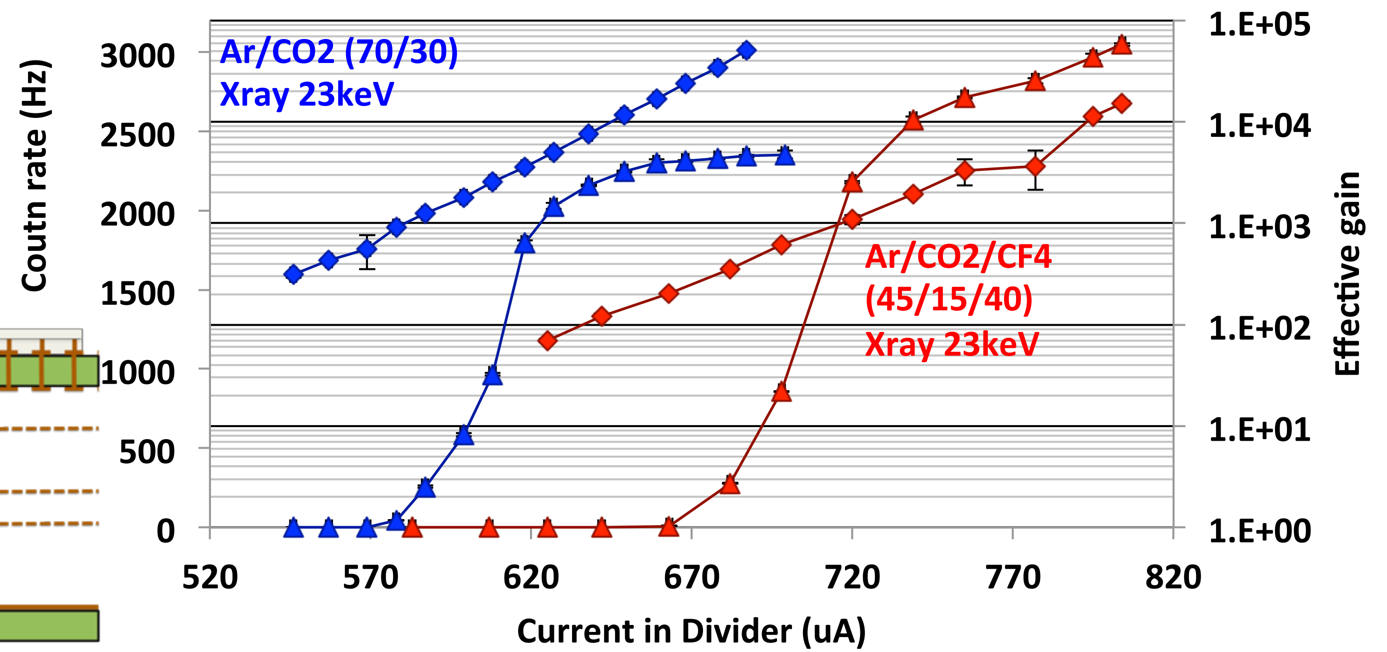
GE1/1 prototypes

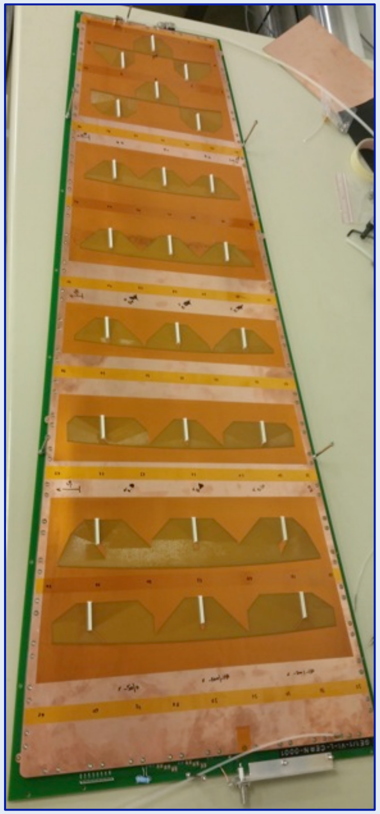


GE1/1- prototype V:

- Size : 99x(22-45) cm^2
- Single mask
- Gap configuration : 3/1/2/1
- 24 readout sectors (3072 channels)
- No Glue/No Spacers



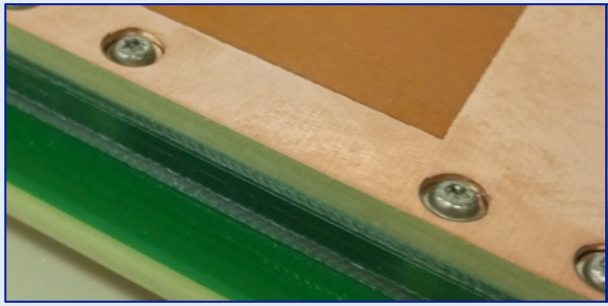


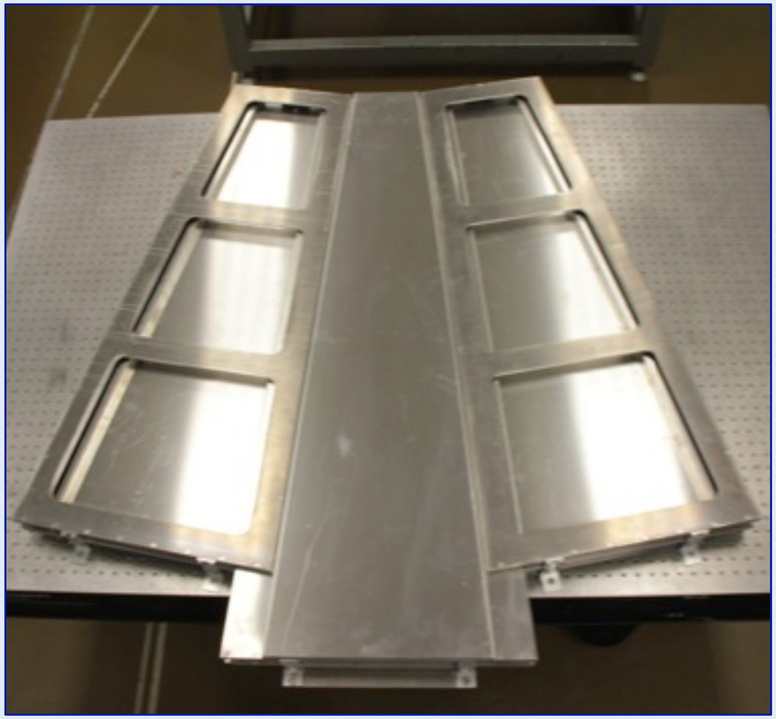


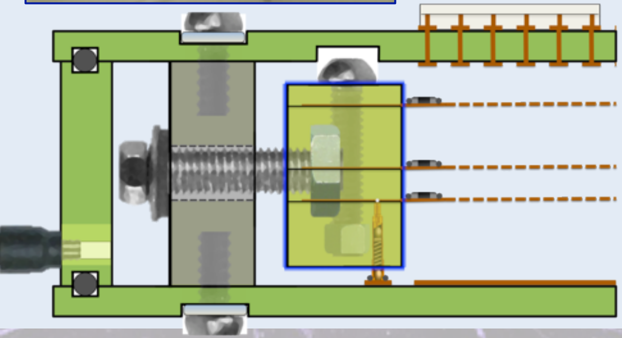
GE1/1- prototype VI:

- Size : 120x(20-50) cm^2
- Single mask
- Gap configuration : 3/1/2/1
- 24 readout sectors (3072 channels)
- No Glue/No Spacers

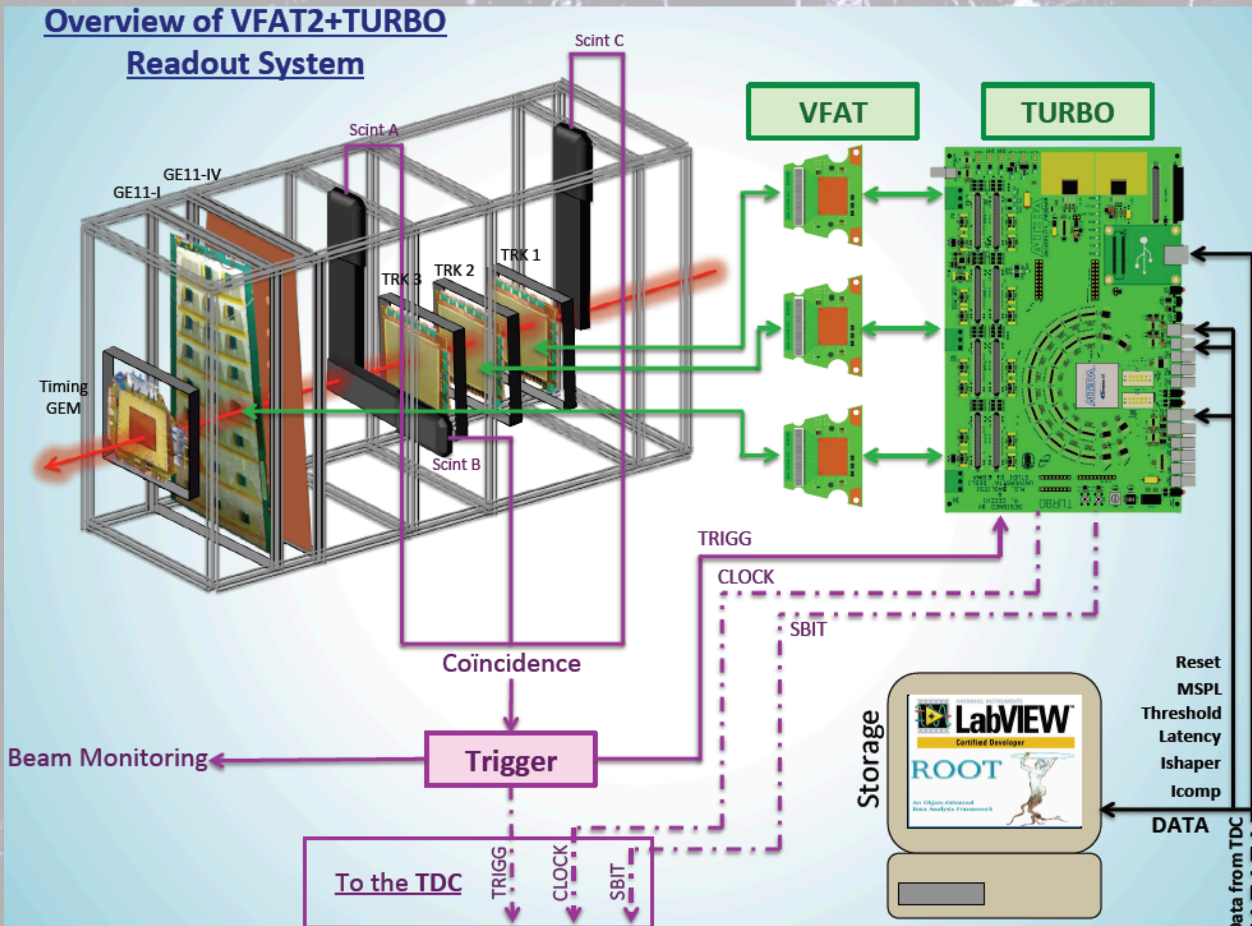
-> Super chambers

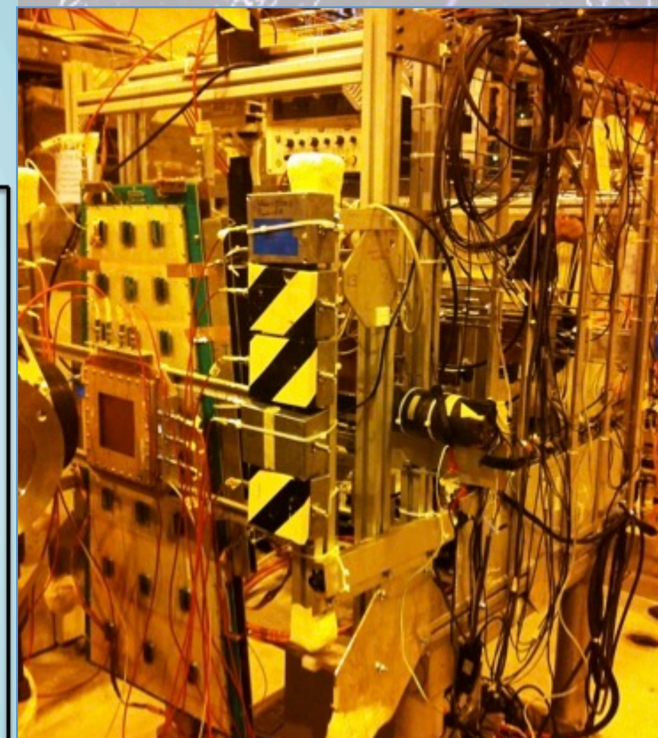






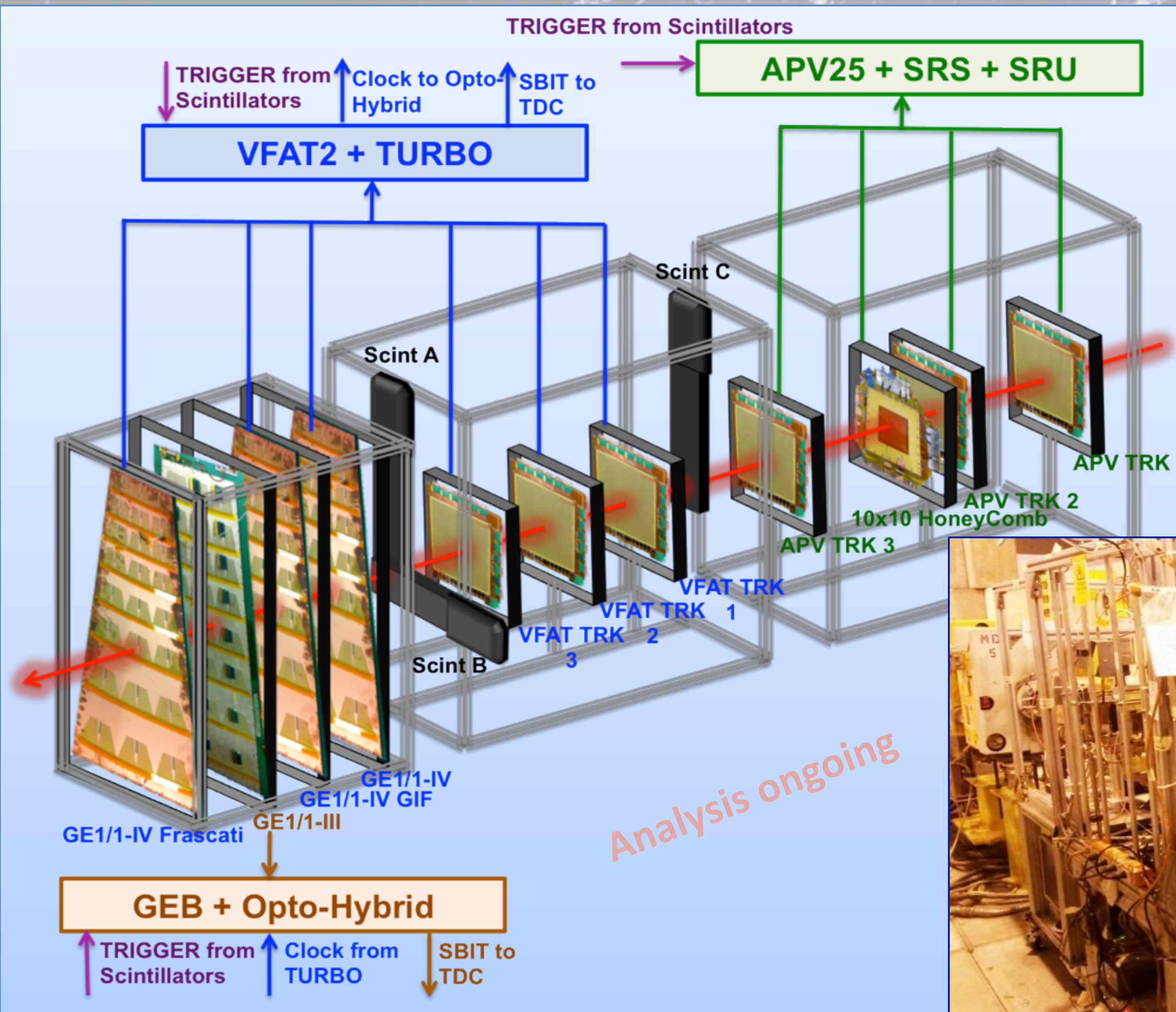
Test Beam campaign





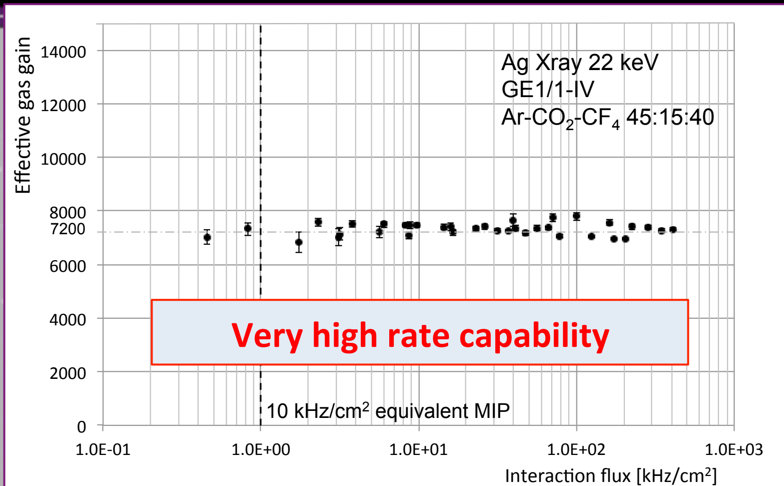
2012 setup

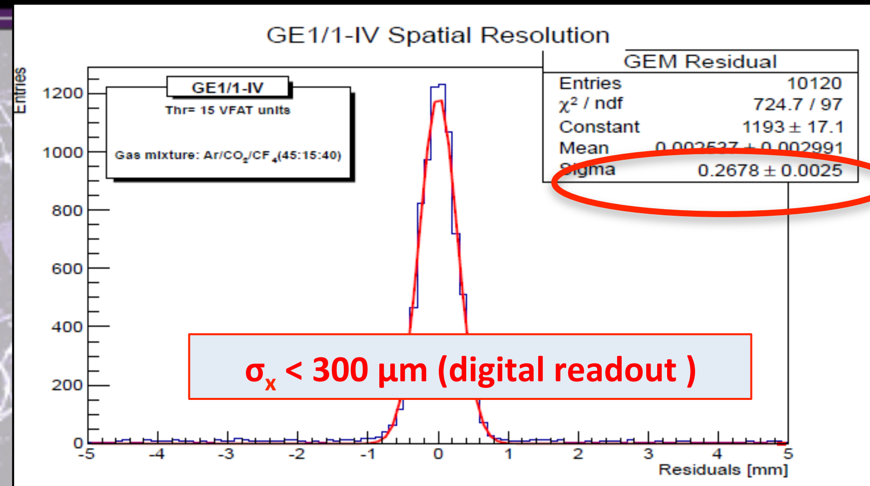
Test Beam campaign

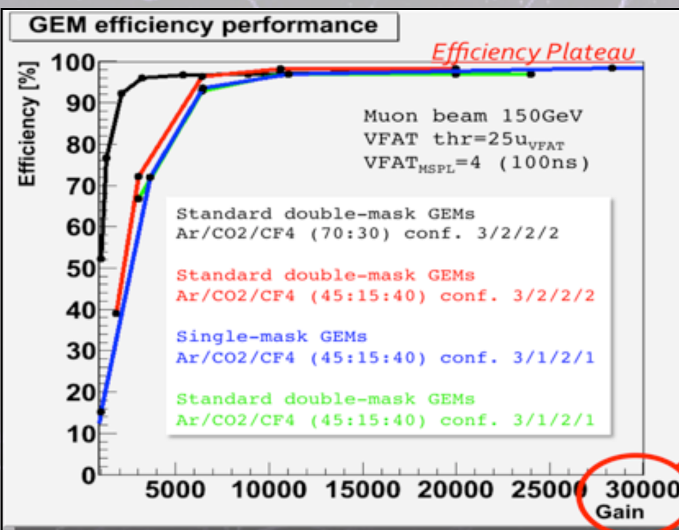


2014 setup

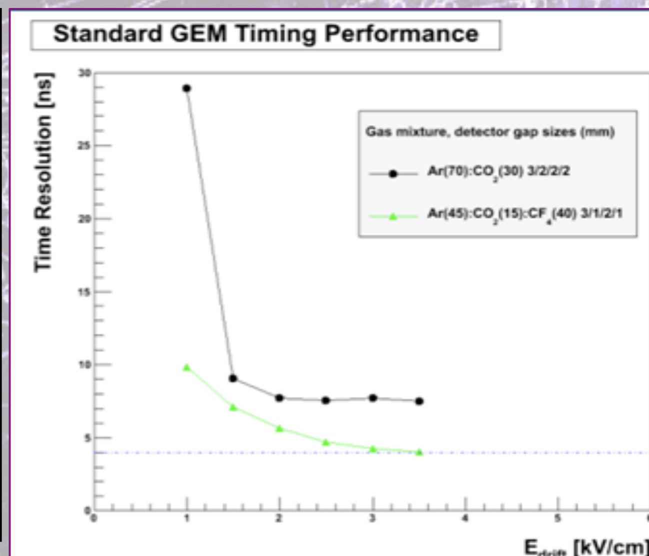
GE1/1 performences

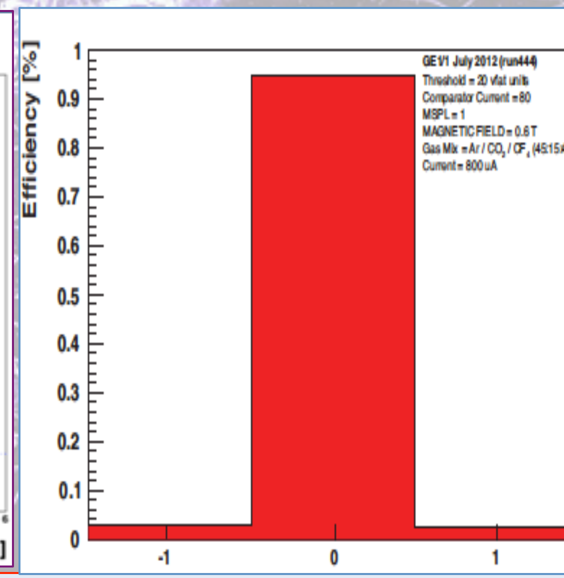






Detector efficiencies above 98%



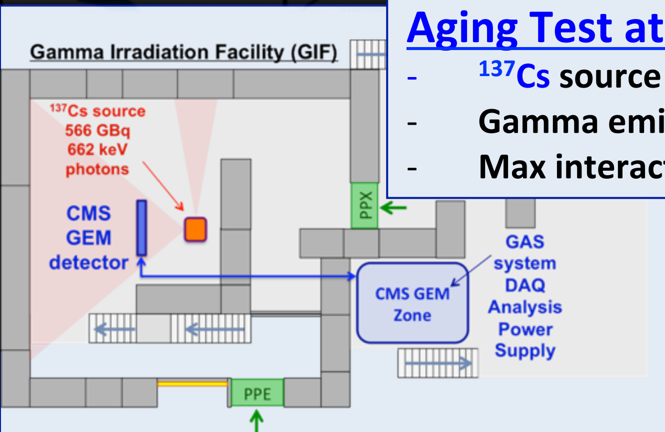


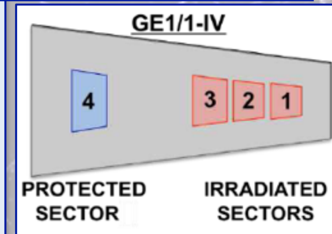
Reached ∾4-5 ns with $Ar/CO_2/CF_4$(45:15:40) ; >95% BX identification

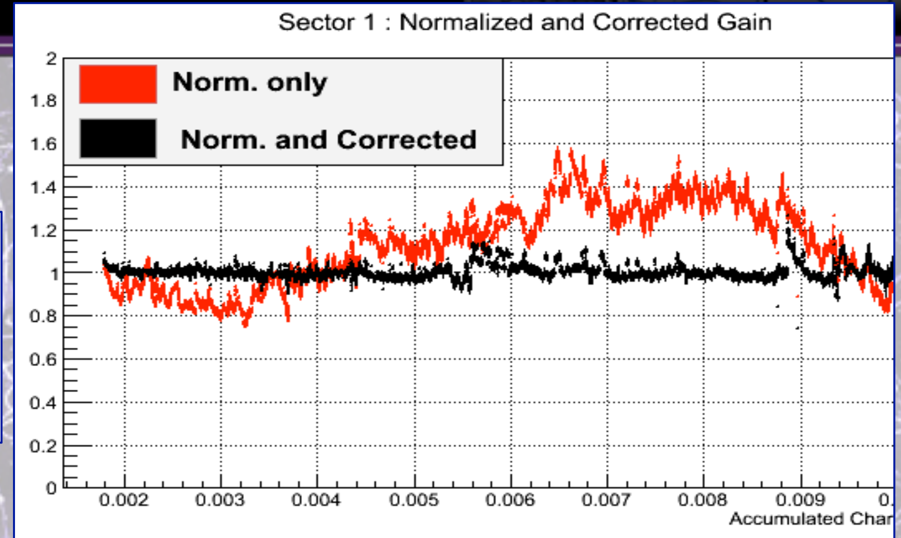
GE1/1 longevity

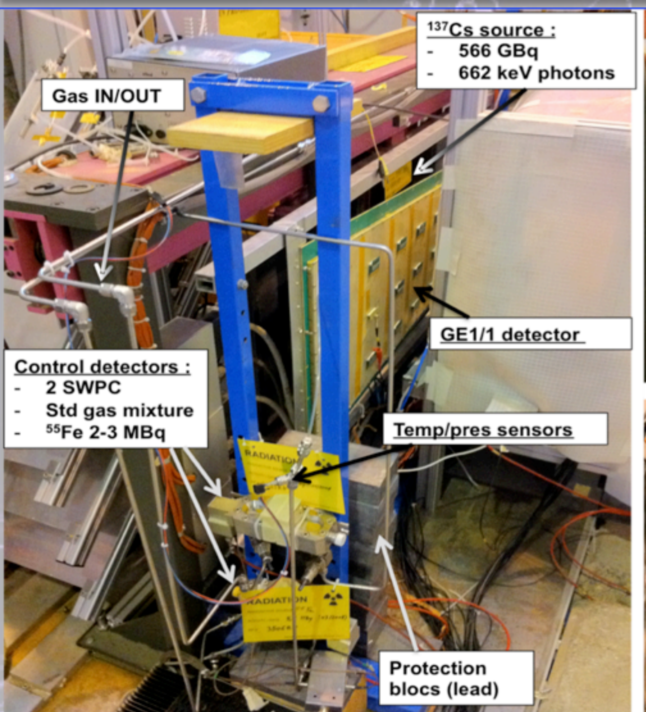
Aging Test at GIF

- ^{137}Cs source 566 GBq
- Gamma emission 662 keV
- Max interaction rate : kHz/cm²

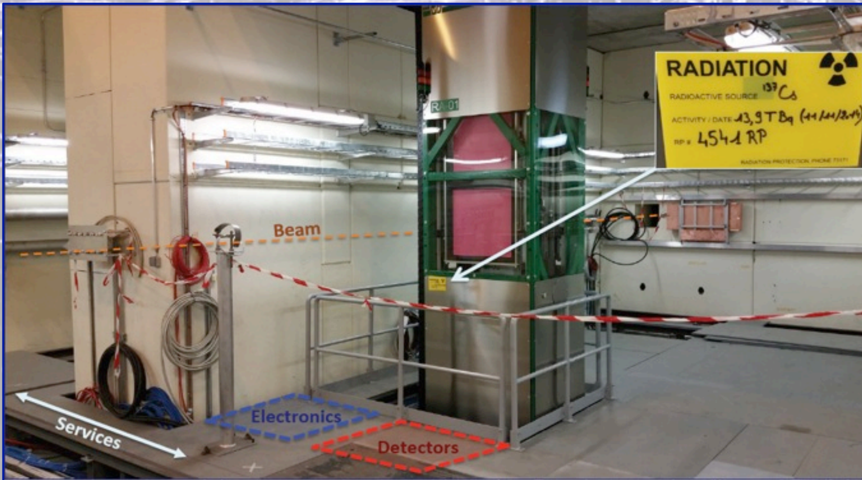






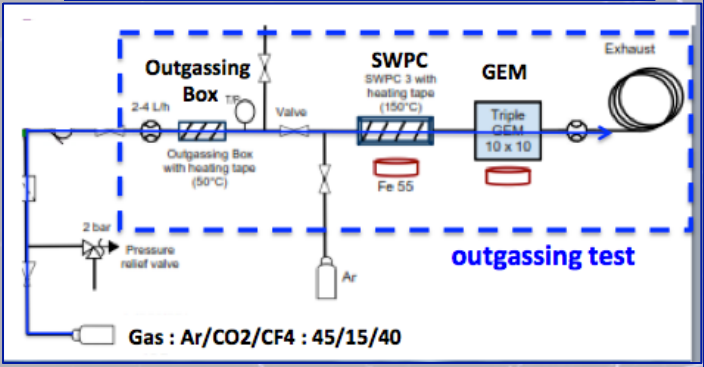


NEW SETUP at GIF++ (reach > 200mC/cm²)



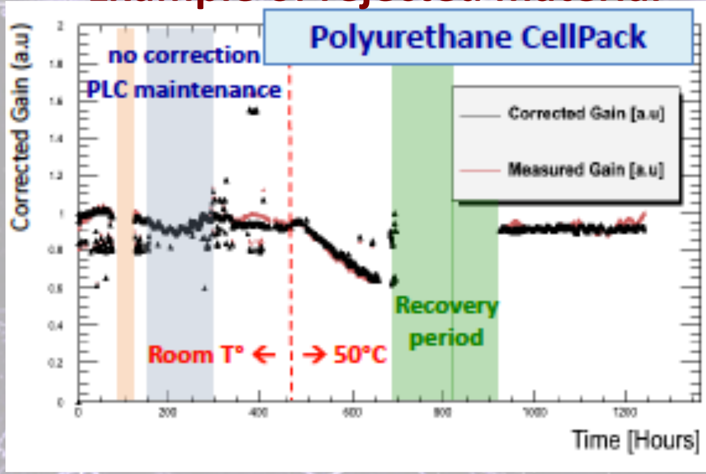
GE1/1 longevity

Outgassing Test at GIF

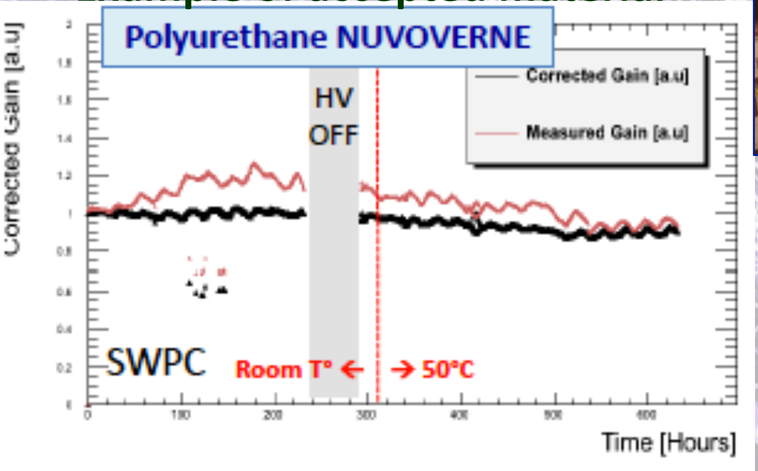


NEW SETUP at TIF

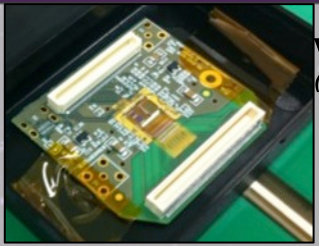
Example of rejected material

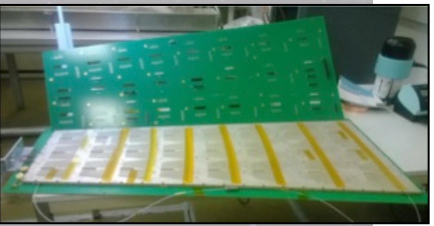


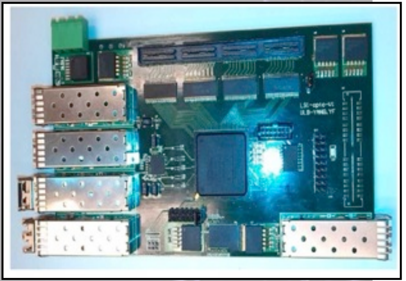
Example of accepted material

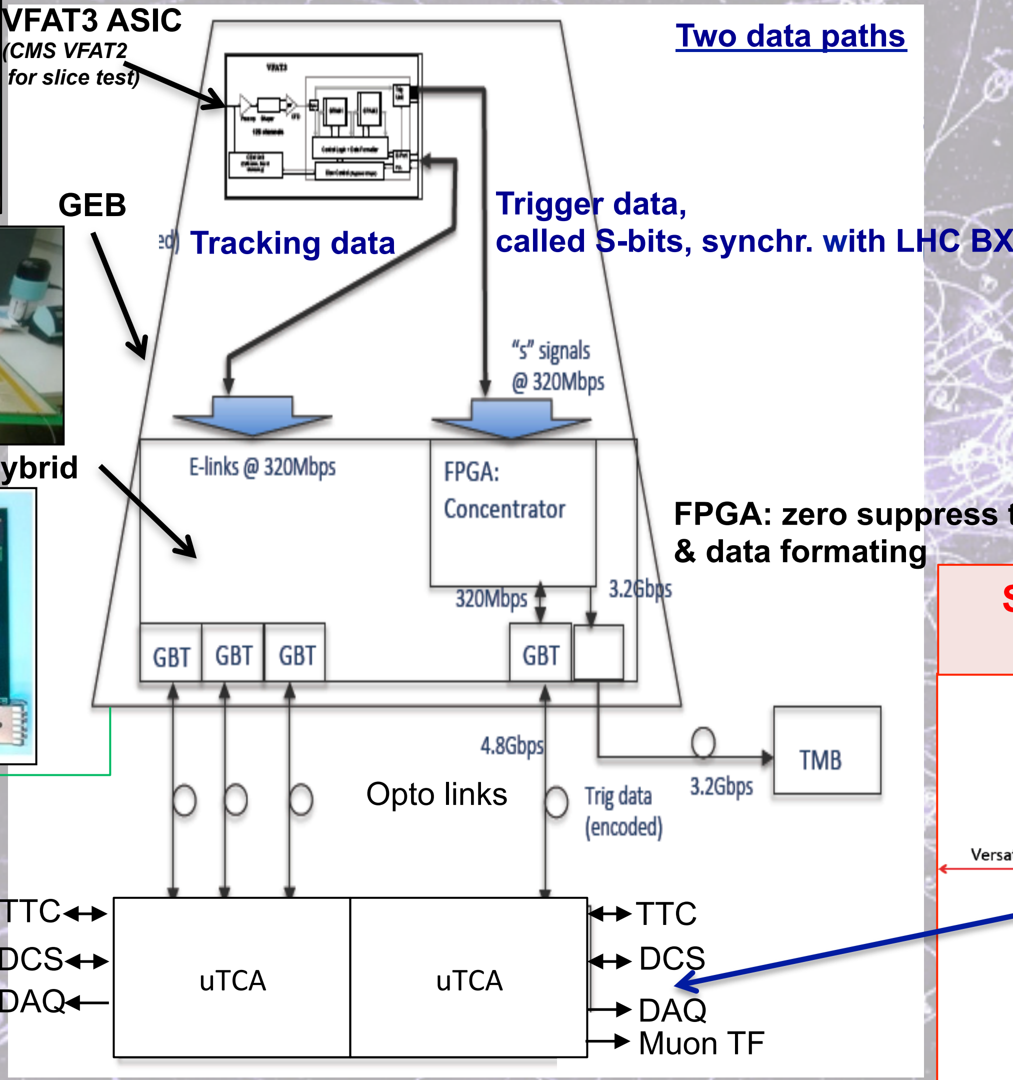


GE1/1 Electronics





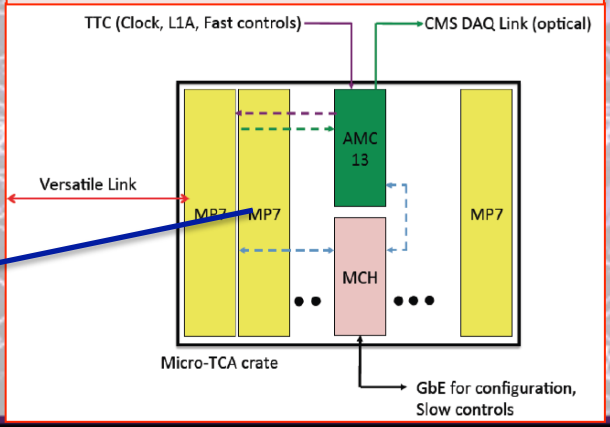




single detector:
- 3 GBT
- 1 Opto-hybrid
- 4 opto-fibers

One SC 2 X single detector

Standard CMS upgrade off detector electronics



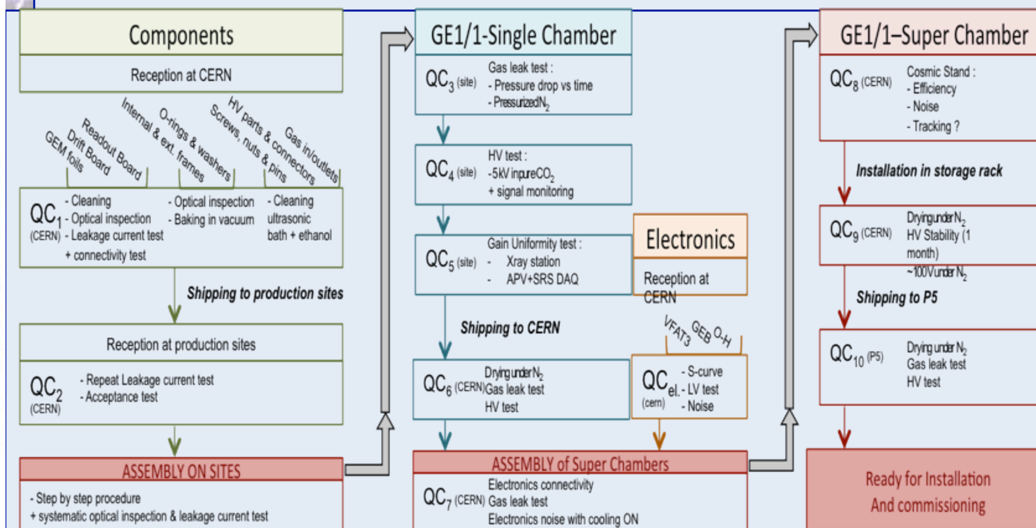
Production & QC

Various production sites

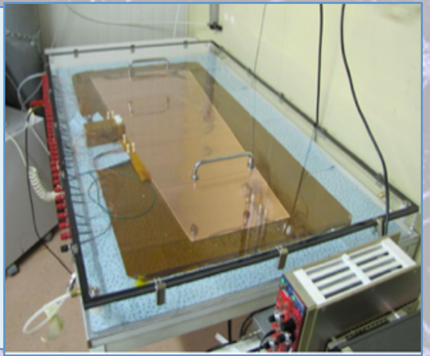
Figure 5.2: Pictures from differents assembly site candidates.

	BARC	INFN - Bari	CERN	FIT	INFN - LNF	UGent
Cleanroom		X	X	X	X	
Leakage current setup		X	X	X	X	X
Gas system	X	X	X	X	X	X
X-ray setup	X	X	X	X	X	X
Shipping logistics	X	X	X	X	X	X
GE1/1 prototypes assembled	X	X	X	X	X	X
Past experience	X	X	X	X	X	X

6 production sites are ready for final production, all have already assembled GE1/1-IV prototypes



Production & QC



Proper operation = clean GEM foils with precise geometry :
- Optical inspection
- Stability check
- Discharges test
- Cleanliness

(Stability check, Discharges test, Cleanliness) } GEM leakage current

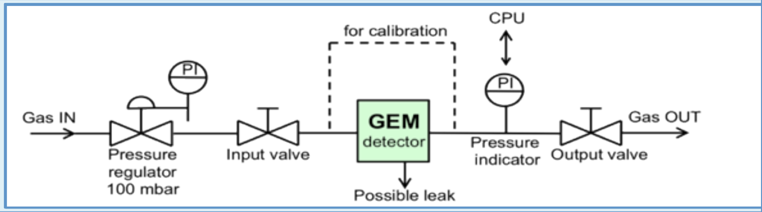
Precise assembly of the detector :
- Inspection and cleaning of all the parts

→ Ultrasonic bath, baking, sand blast

- Strict assembly procedure (clean room)
- Repeat dust cleaning after each assembly step

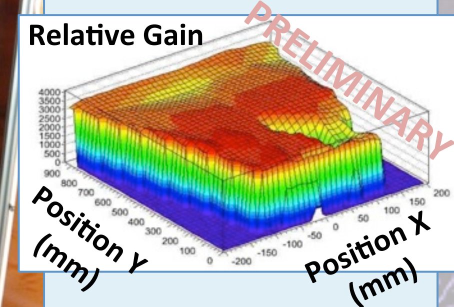
→ **movie :** https://www.youtube.com/watch?v=Ssuqh5GAVZ4&feature=youtu.be

Control of the chamber :
- Gas leak test (ensure gas purity)
- High Voltage (HV) connectivity and stability



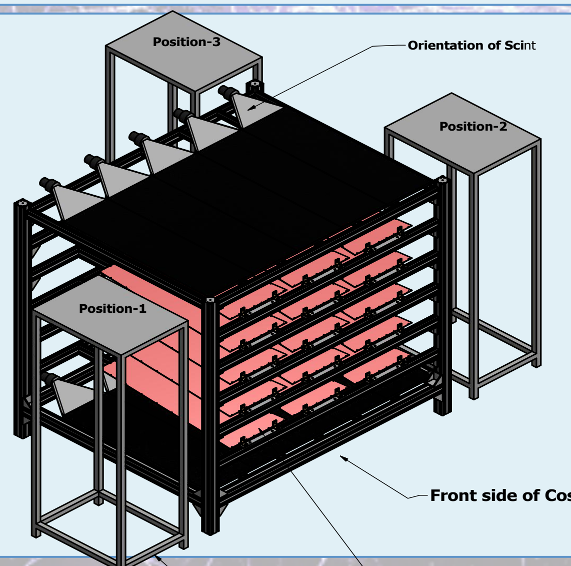
Production & QC

Gain Uniformity test :
- wide X-ray beam (23 keV)
- APV + SRS +SRU
- Copper fluorescence
- Compare photo peak position (2D map)
- Infer gain fluctuations



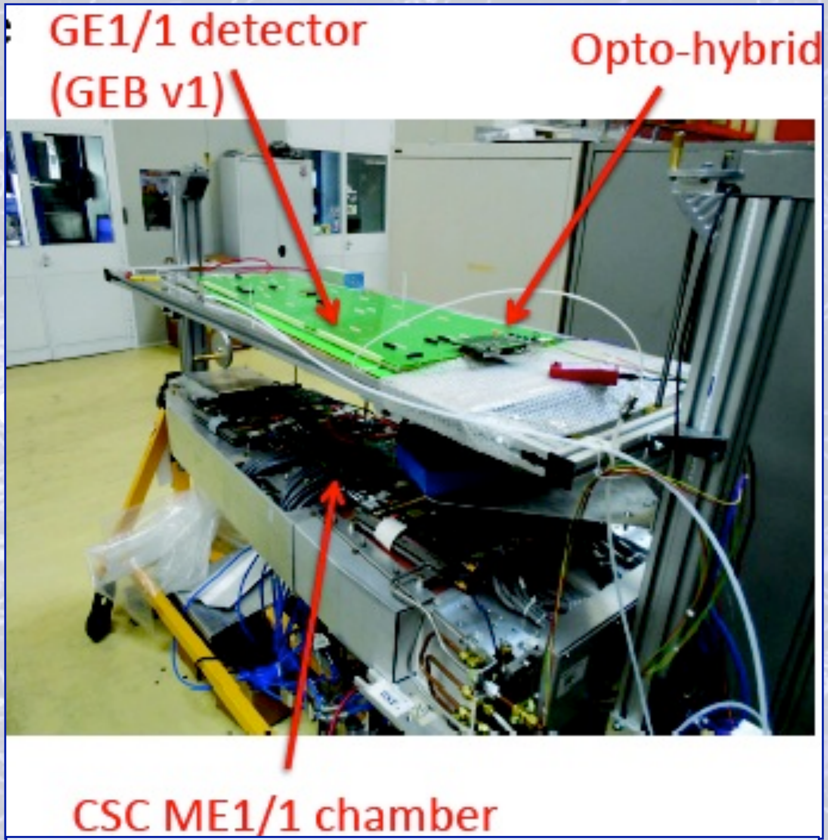
Cosmic Stand :
10 scintillators+PMTs
15 x GE1/1 S-chambers
- Final electronics
- Cooling system

Goals :
Efficiency measurement
Tracks reconstruction
Timing analysis



GE1/1 Integration Test

The test bench at bd 904 will provide up to six fully equipped chamber electronics, read-out chain, DAQ and trigger for testing GE1/1 electronics configuration in P5 configuration.



1 ME1/1 CSC & 1 GE1/1 fully equipped including TTC and AMC13 (for GE1/1)

Goals :
- CSC-GEM Trigger integration
- CSC-GEM synchronization
- The GE1/1 Electronics with in realistic conditions
- The GE1/1 performance with the ME1/1 detector
- GE1/1 Cooling, Mechanics, Vibrations
- Electromagnetic compatibility

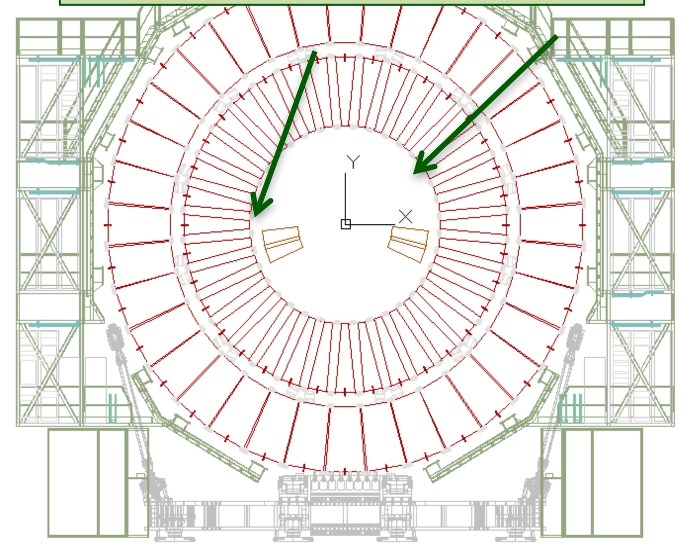
Achievements :
- Synchronization of both electronics
- Dummy trigger data sent

Slice Test

Installation of 4 SuperChamber in 2016-2017

- DAQ system will be integrated in CMS DAQ
- combined CSC+GEM trigger
- Operation procedure implemented
- reconstruction included in official CMS software
  - validation done with standard tool
  - background and noise rate included in simulation

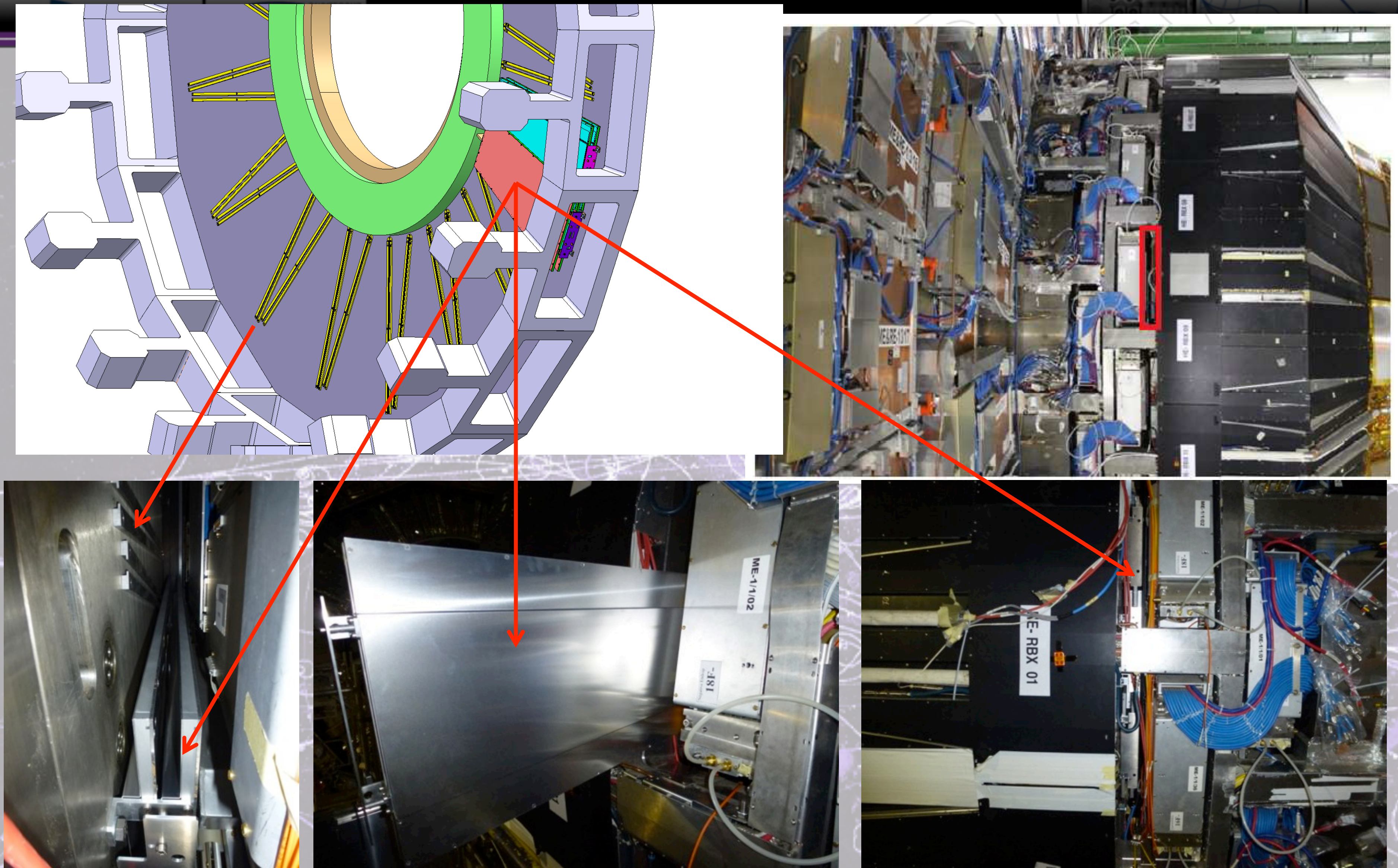
4 super chambers in slots 1,2,35, 36 on YE-1



Motivations:

- gain integration experience with the final electronics system
- reduce the GEM commissioning period:
  - Back-end electronics installed and commissioned in advance
  - All components (Incl. detectors) will have been qualified beforehand at the TIF
- trigger commissioning and performance check
- background measurement
- opportunity to cross-check with data what expected by simulation

Installation trial



Conclusions

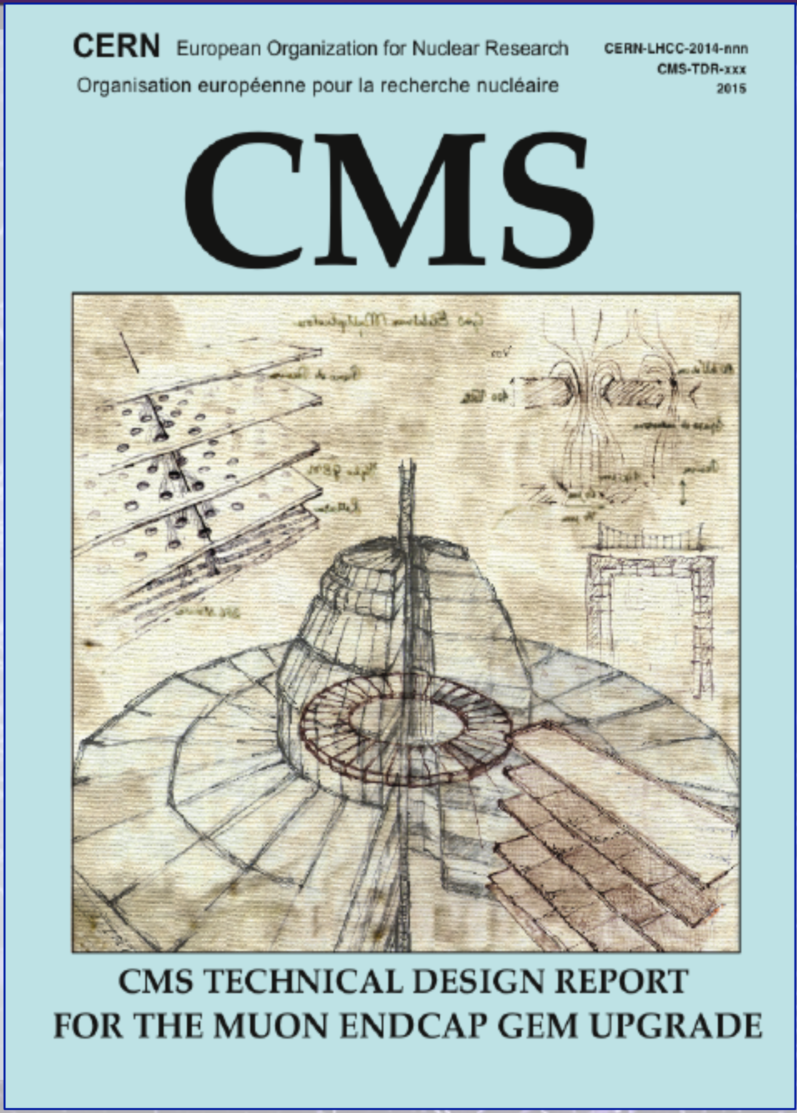
- Detector R&D near complete, construction project can begin
- Electronics : On track for LS2 installation
- DAQ and Online System -> Slice test : Readiness towards commissioned track finder
- GEM Community ready to go for GE1/1 project

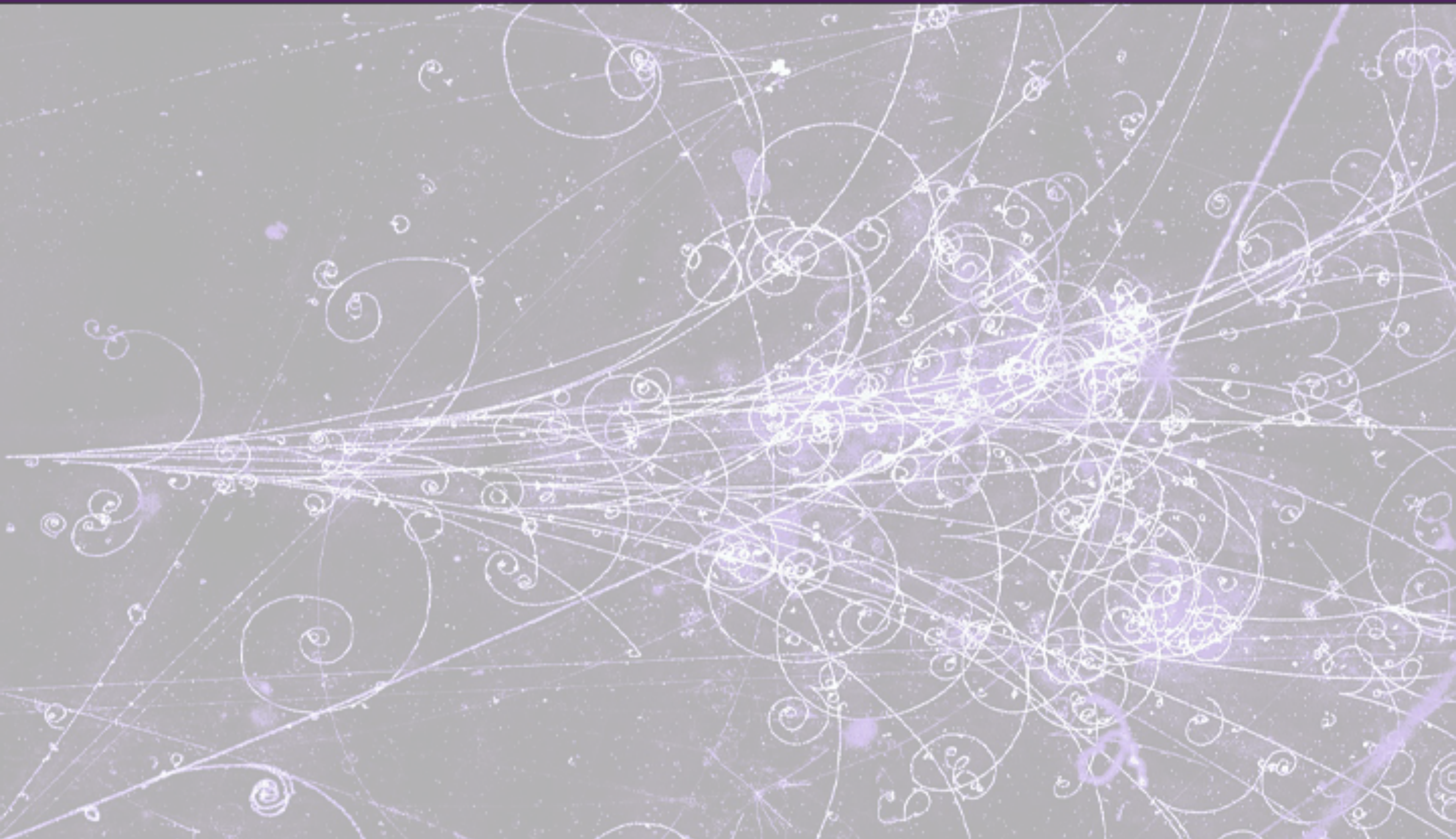
TDR submitted on 3rd of March to LHCC

→ Very positive report from referees

→ awaiting green light

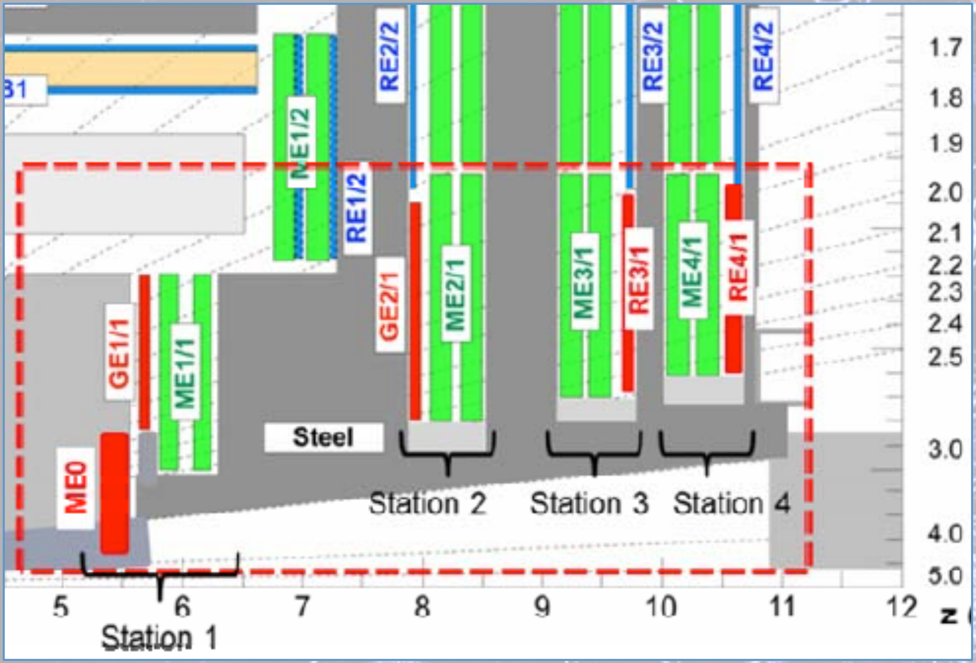
Thank you

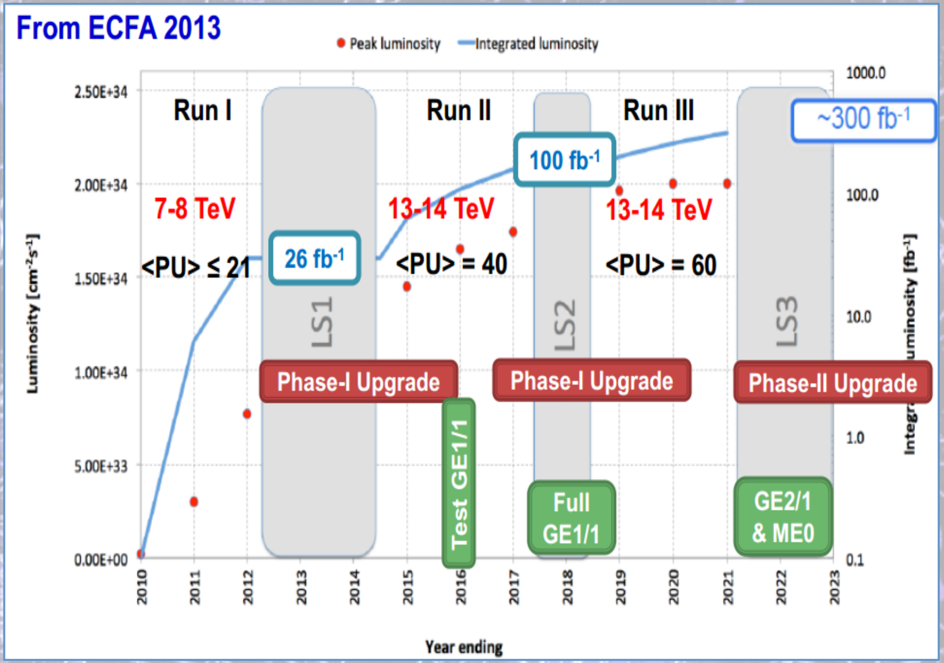




CMS GEM Proposal

Introducing Gas Electron Multiplier technology in the CMS endcaps





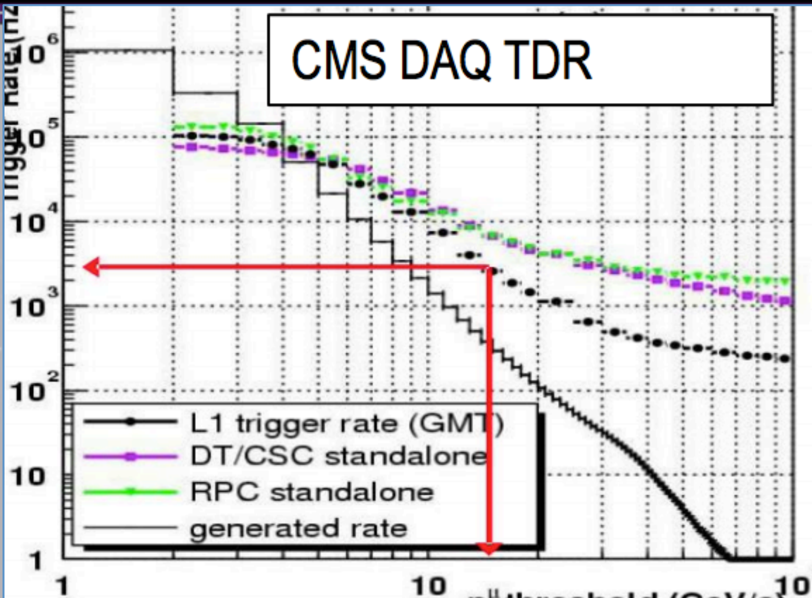
<u>**Three main projects :**</u>

GE1/1 → 1.55 < |η|< 2.18, 144 chambers, Expected rate : few 1-10kHz/cm^2

GE2/1 → 1.55 < |η|< 2.45, 72 , Expected rate : few 1 kHz/cm^2

ME0 → 2 < |η|< 3, 6 layers of detectors, 216 chambers, Expected rate : MHz/cm^2

Physics Issues

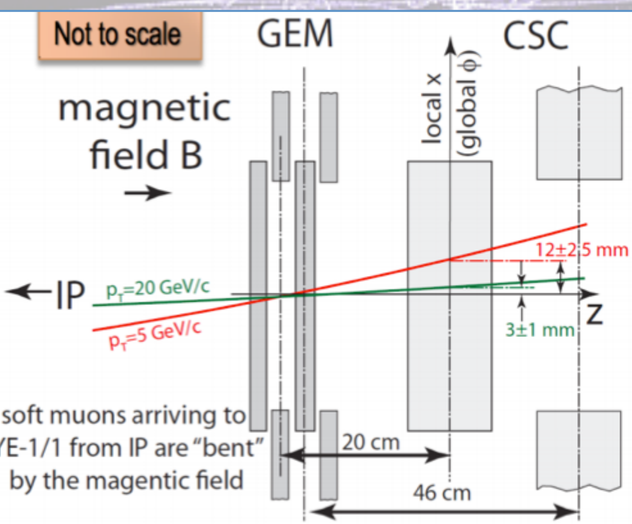


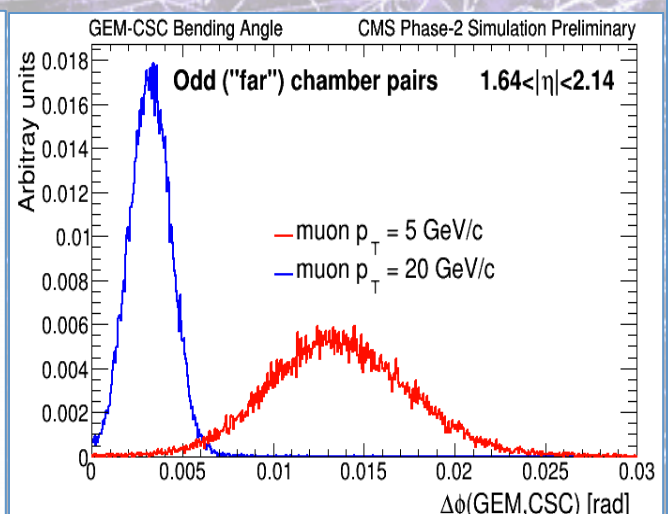
Rate flattening

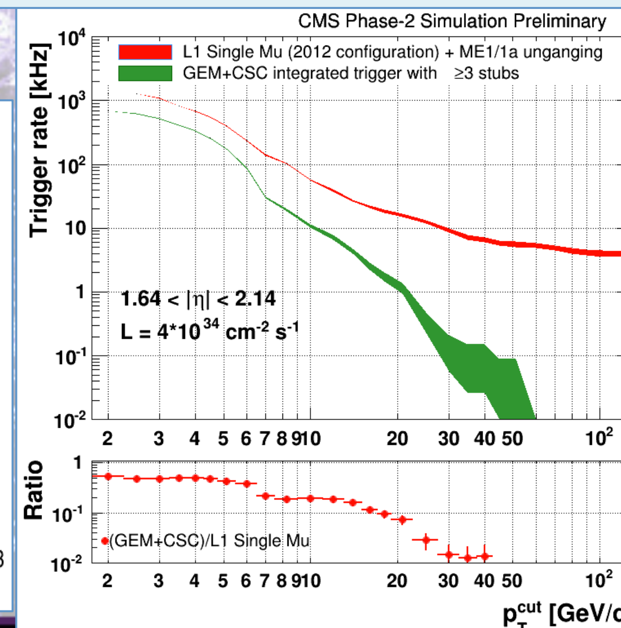
- Soft muons scatter in the steel return yoke
- Tracks incorrectly reconstructed as hard muons

← Cause large tail in L1 muon trigger P_T resolution (flattening)

Solution : add detection layer in front of CSC

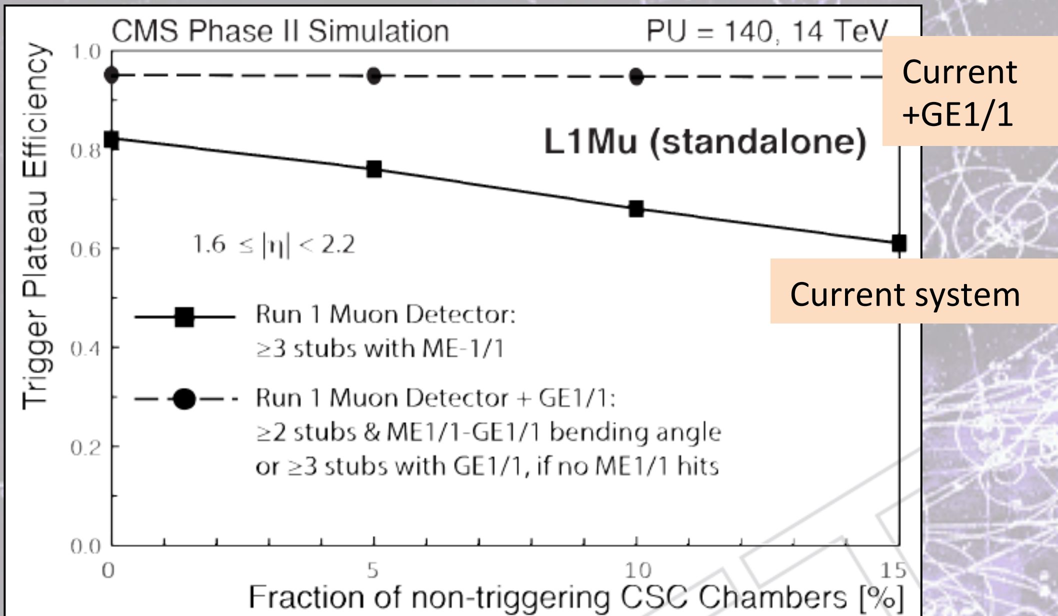


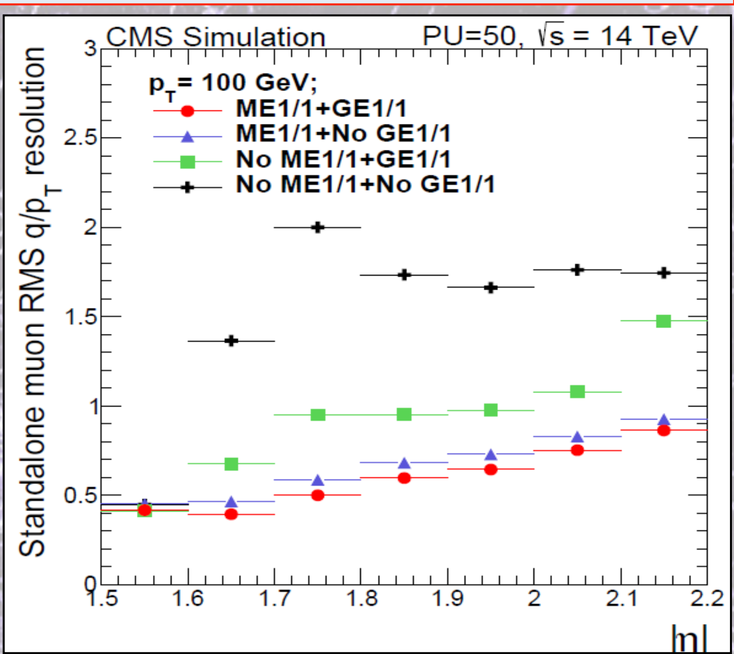




Longevity Issues

Potential degradation in performance of the aging of ME1/1 chambers is a concern

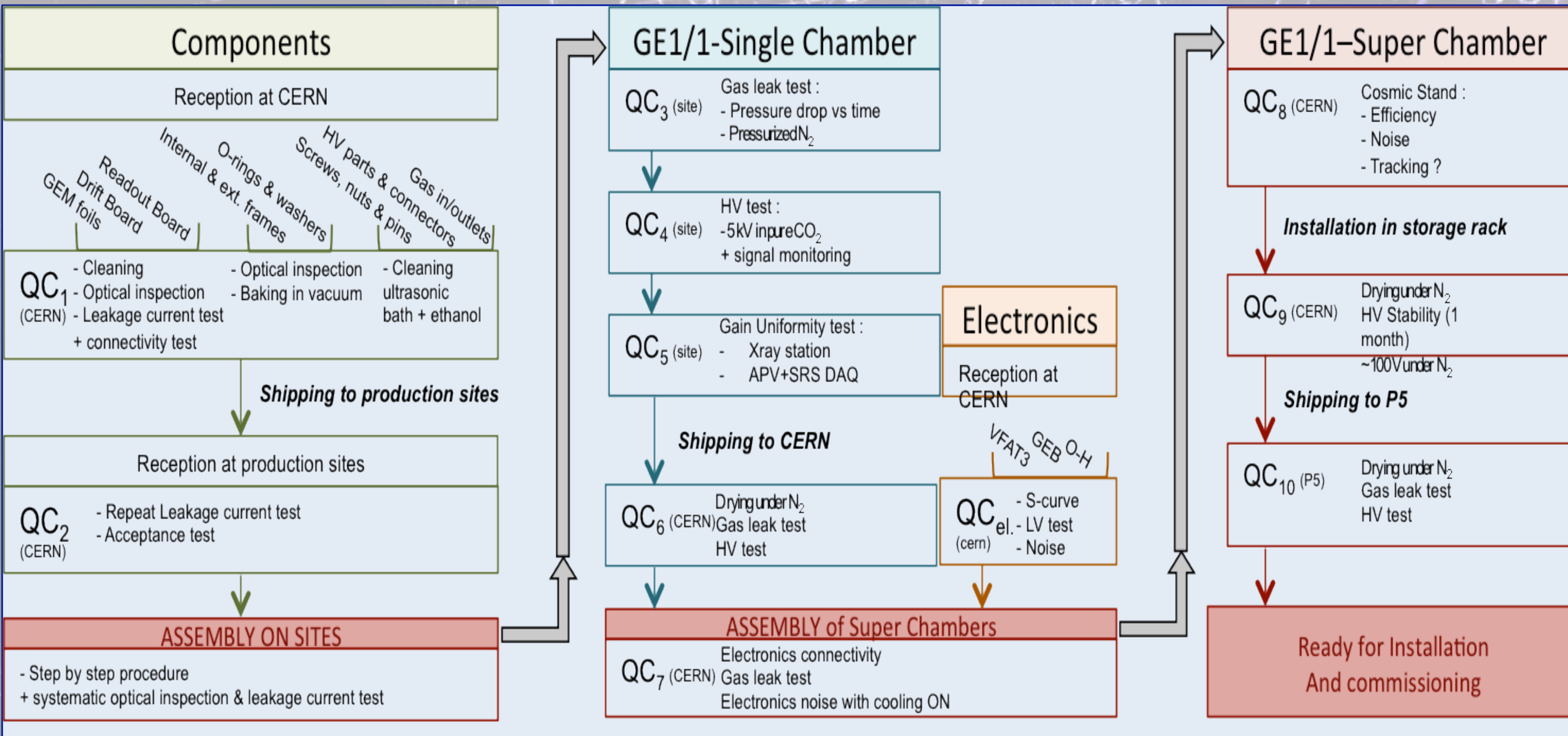




Added redundancy due to GE1/1 helps:

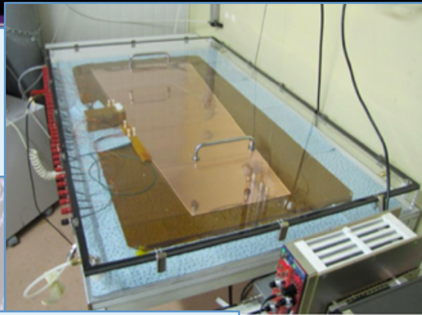
- **Reducing the deterioration of Level-1 muon trigger performance**
- **Reducing the large deterioration in momentum resolution**
- **Obviously mitigating otherwise large efficiency losses if a sizeable fraction of CSC chambers in ME1/1 become partially or fully inoperational**

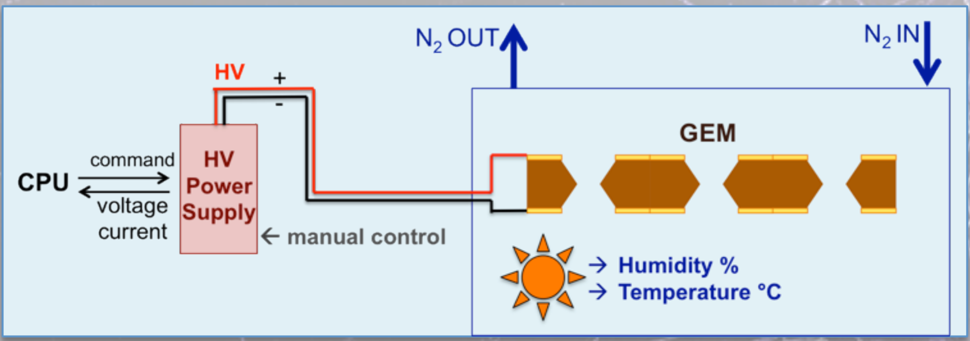
Production & QC



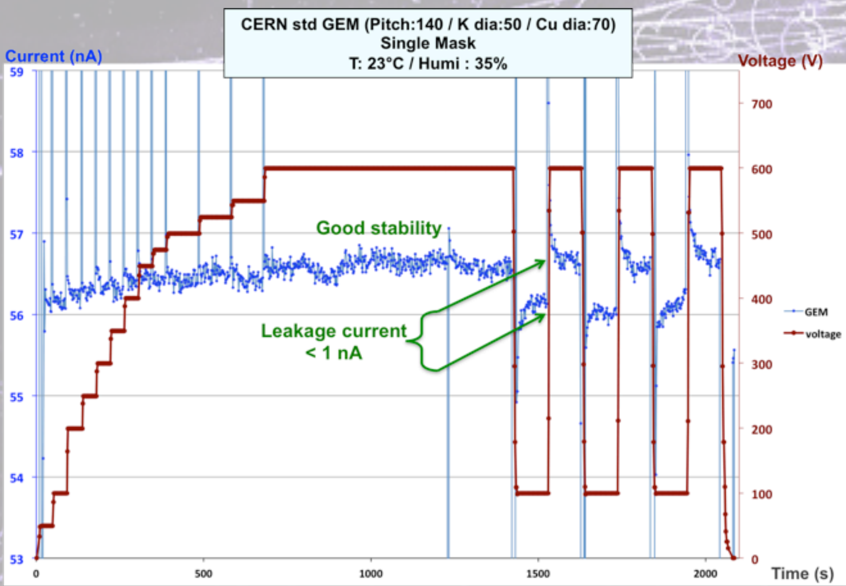
Leakage current test

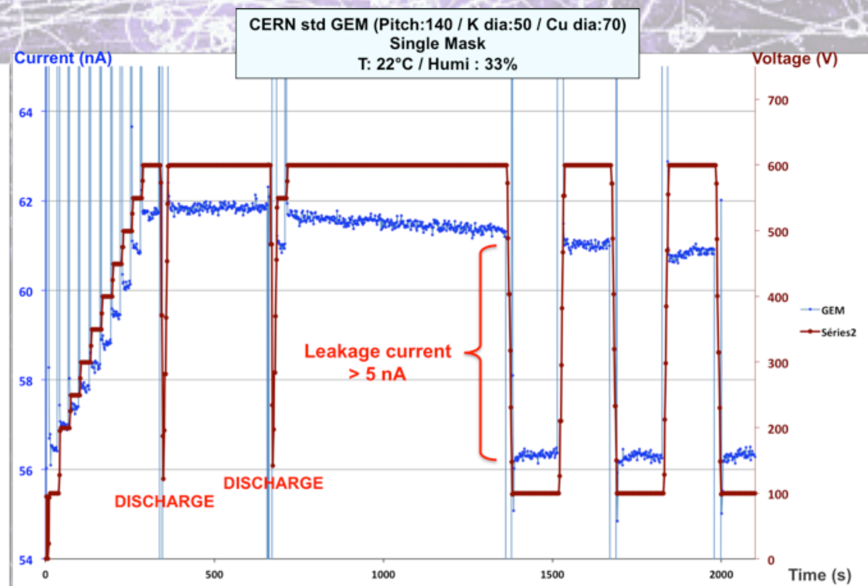
Ensure the cleanliness and proper operation of the GEM foils by measuring the leakage current at 600V



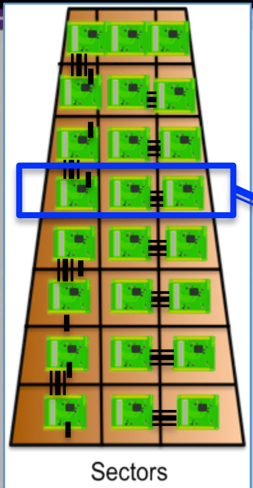


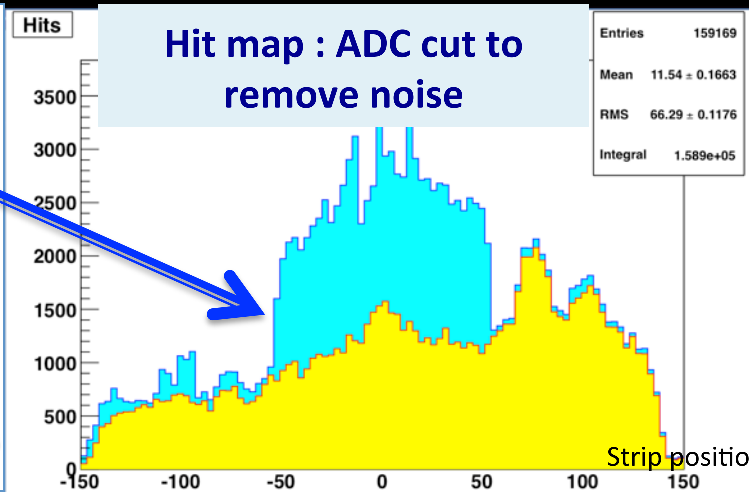
- -> Burn the dust
- -> Good stability
- -> No discharges
- -> GEM current : < 1 nA / 100 cm^2

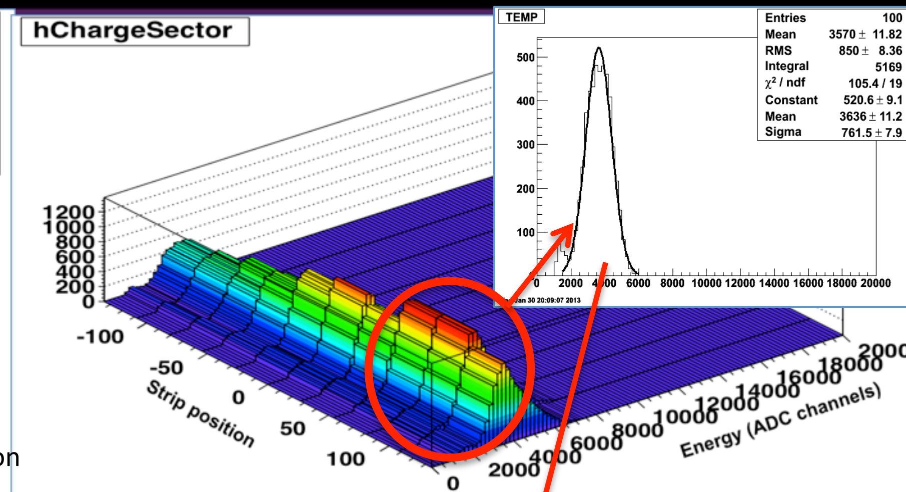


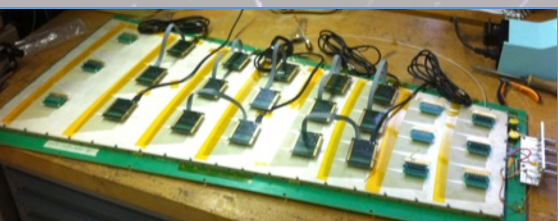


Gain Uniformity test

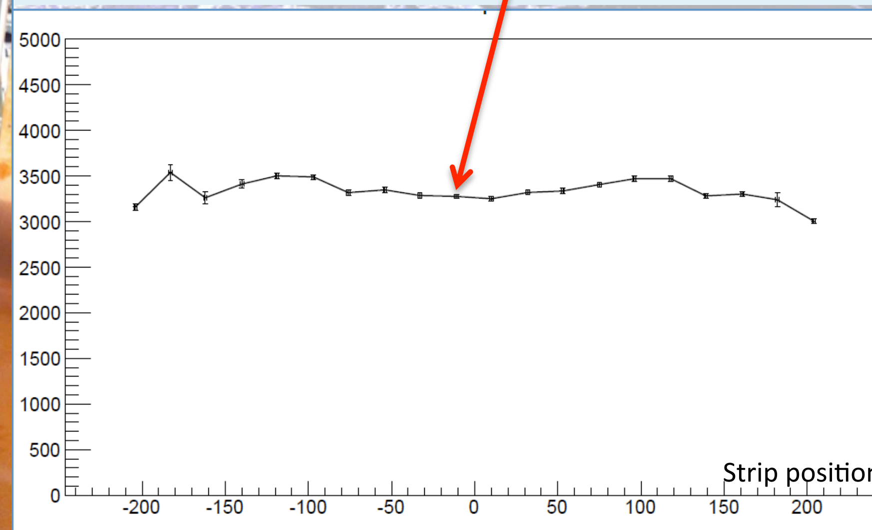


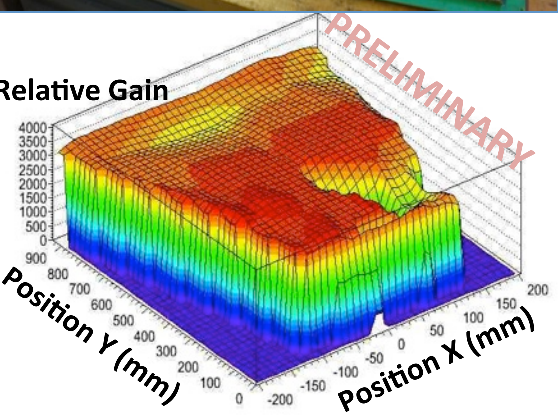






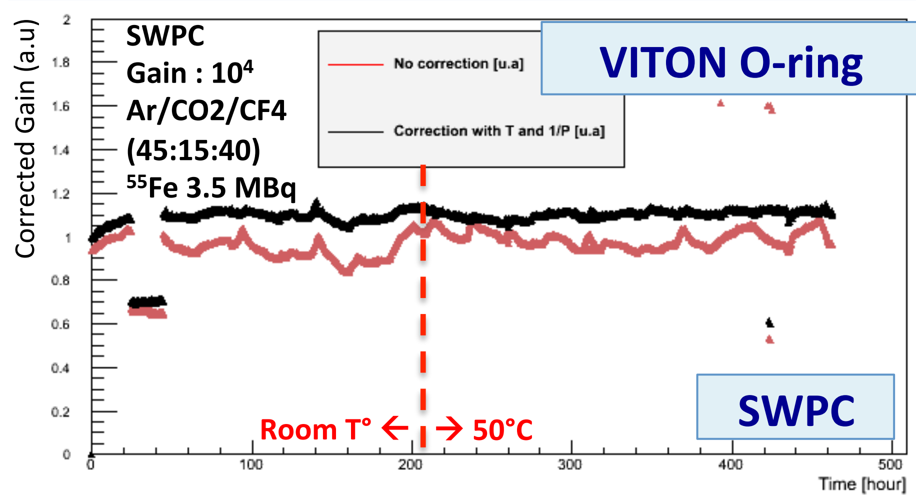
Main peak (ADC channel) vs X position (mm)





Outgassing study

Outgassing studies : Gas tubing purity check with Proportional Counter



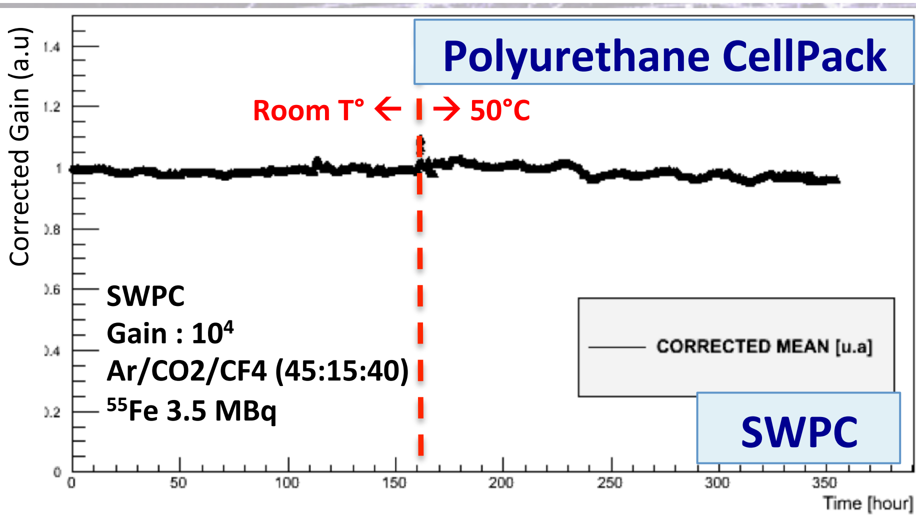
As first step -> all tubing is validated with SWPC (extremely sensitive to pollution)

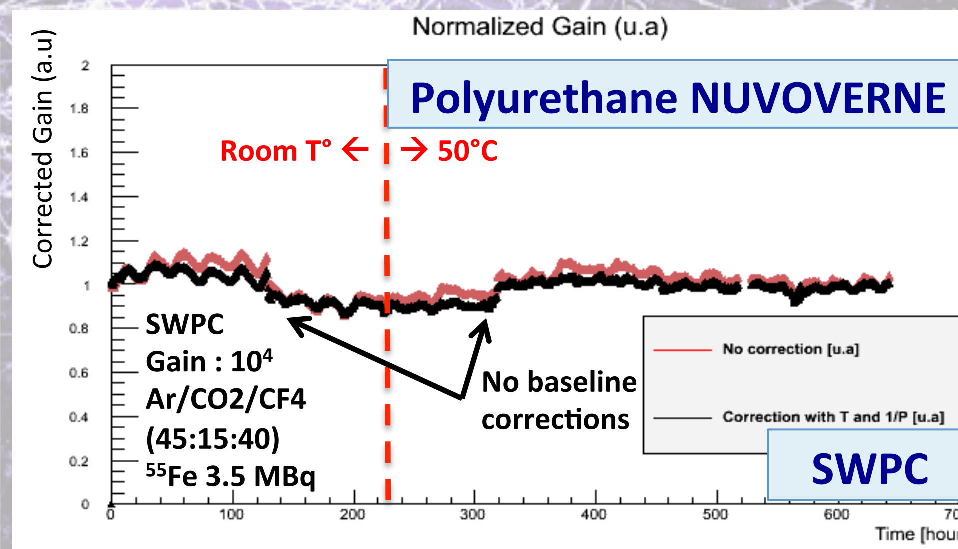
→ 2 weeks at room T°

→ 2 weeks at 50°C

(No materials in the gas line)

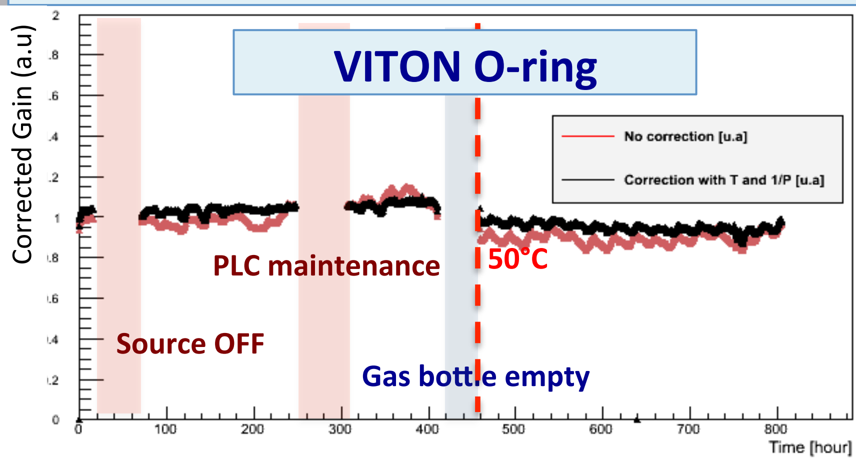
→ Clean tubing for the 3 tests





Outgassing study

Outgassing studies : Preliminary results with Single Wire Proportional Counter

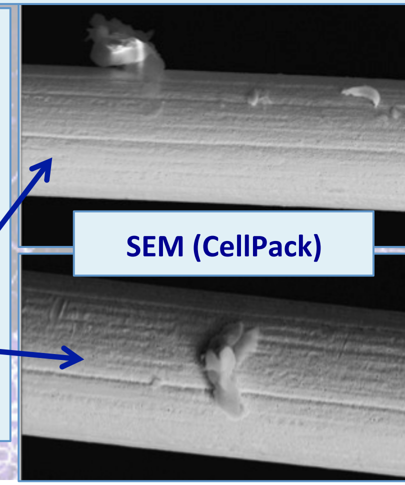


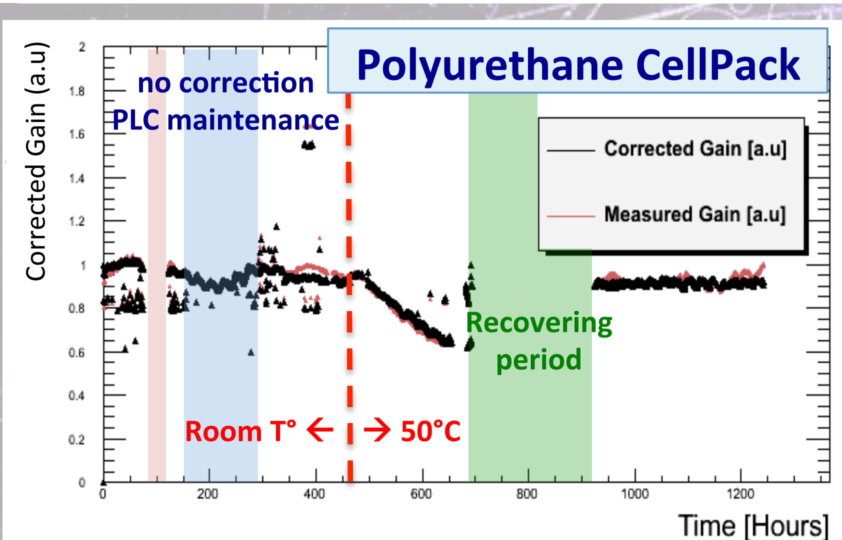
SWPC

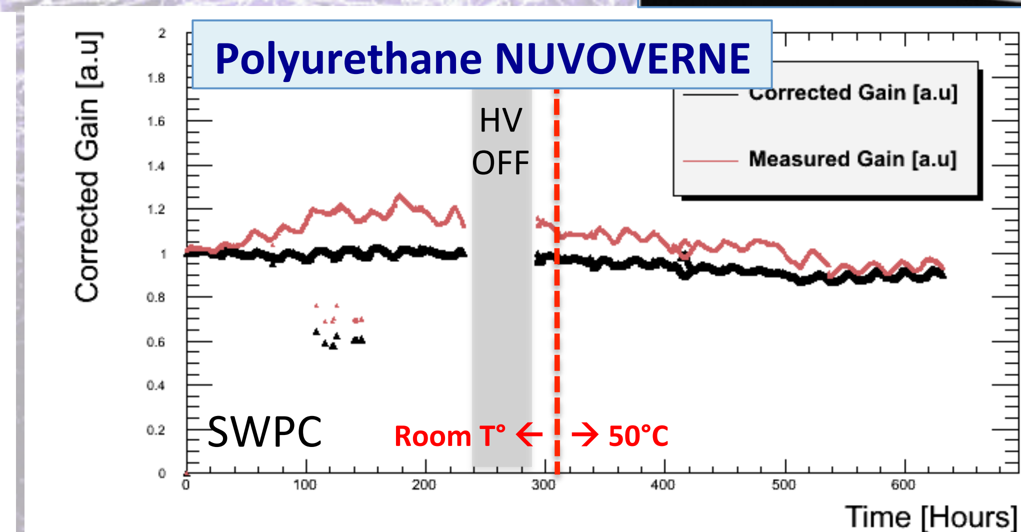
→ No effect with VITON O-ring

→ No significant effect with NUVOVERN (extension of the test)

→ Strong gain drop with CellPack

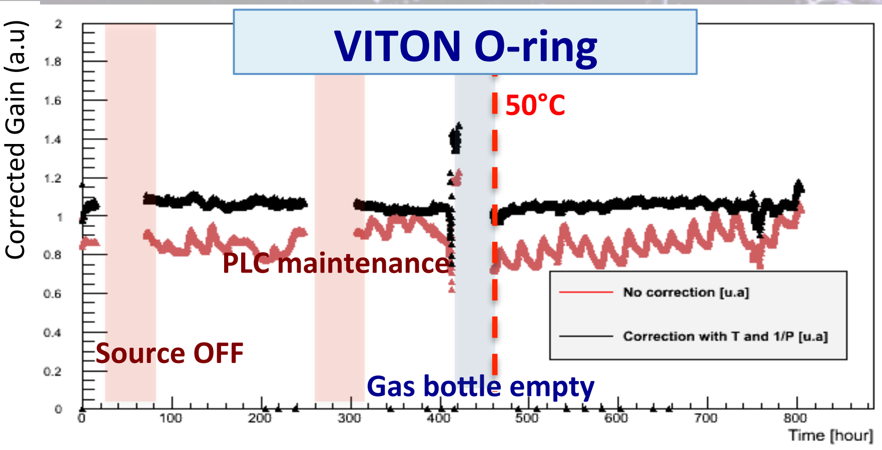






Outgassing study

Outgassing studies : Preliminary results with 10x10 cm^2 triple-GEM detector

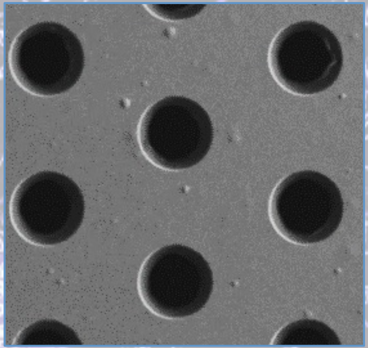


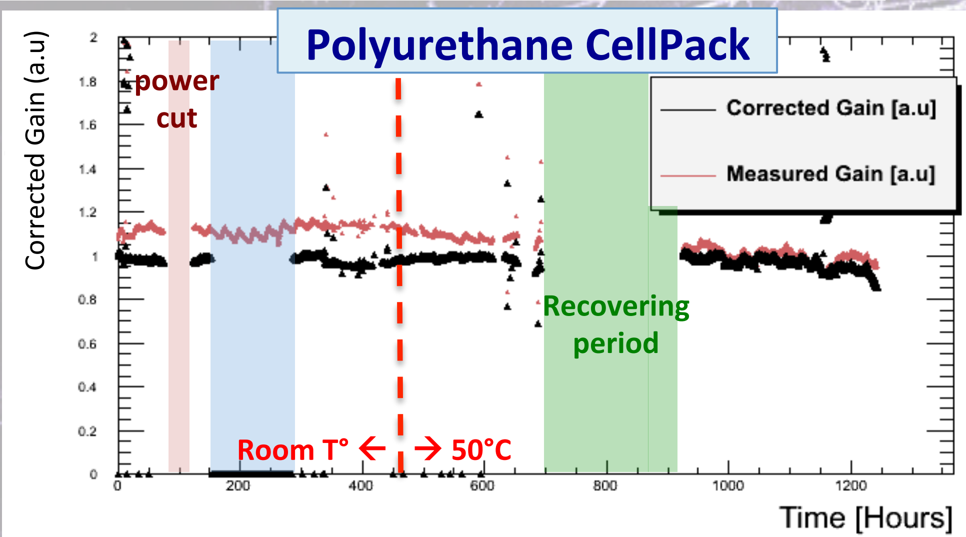
GEM 10x10

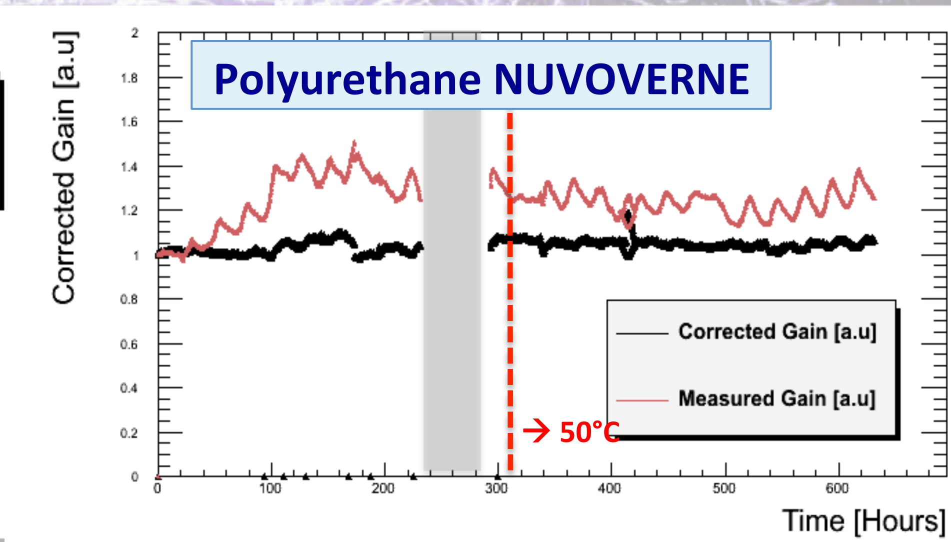
→ No effects on gain for all samples
(event if outgassing material)

→ Does the polymers affect other properties of the GEM foils ?

SEM (CellPack)

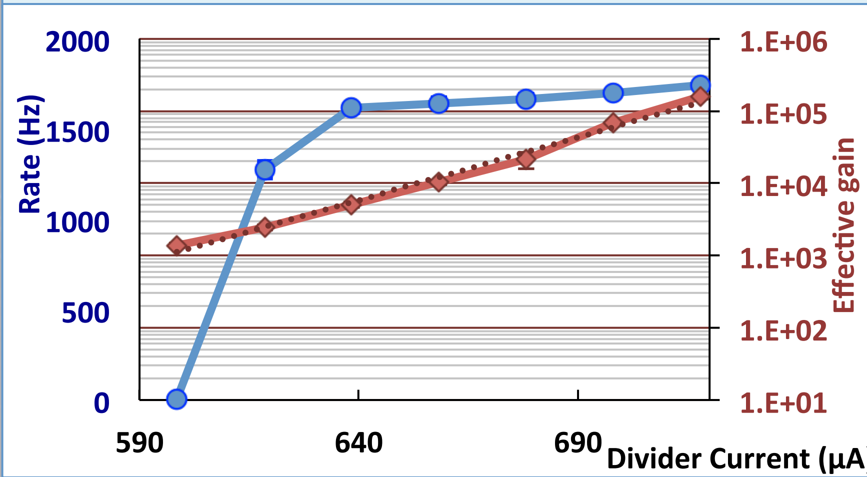


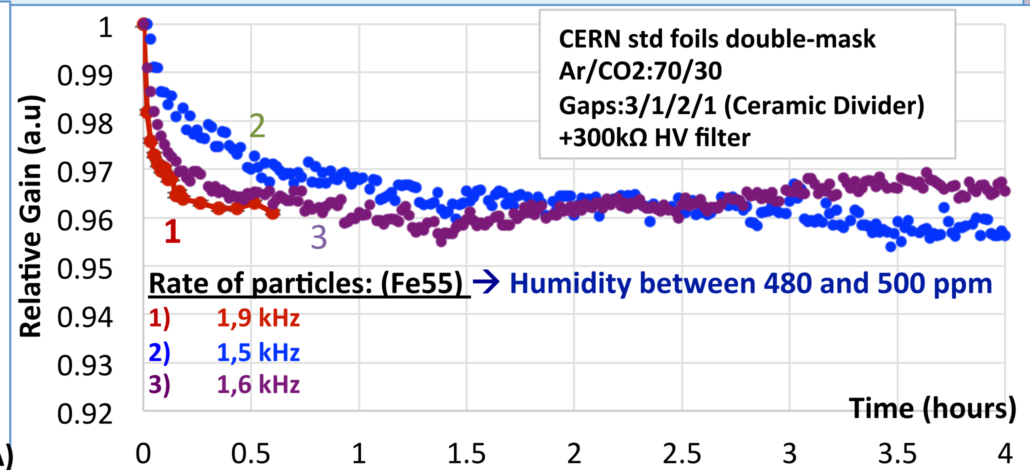


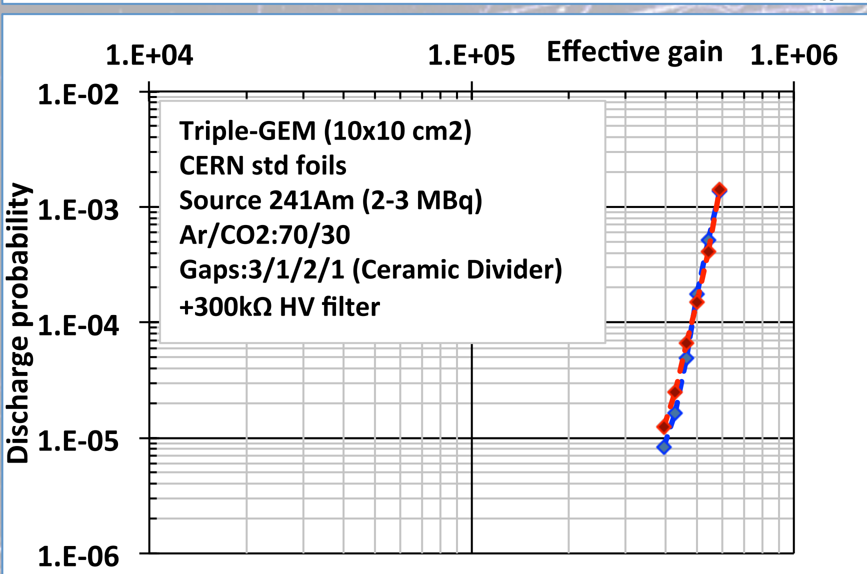


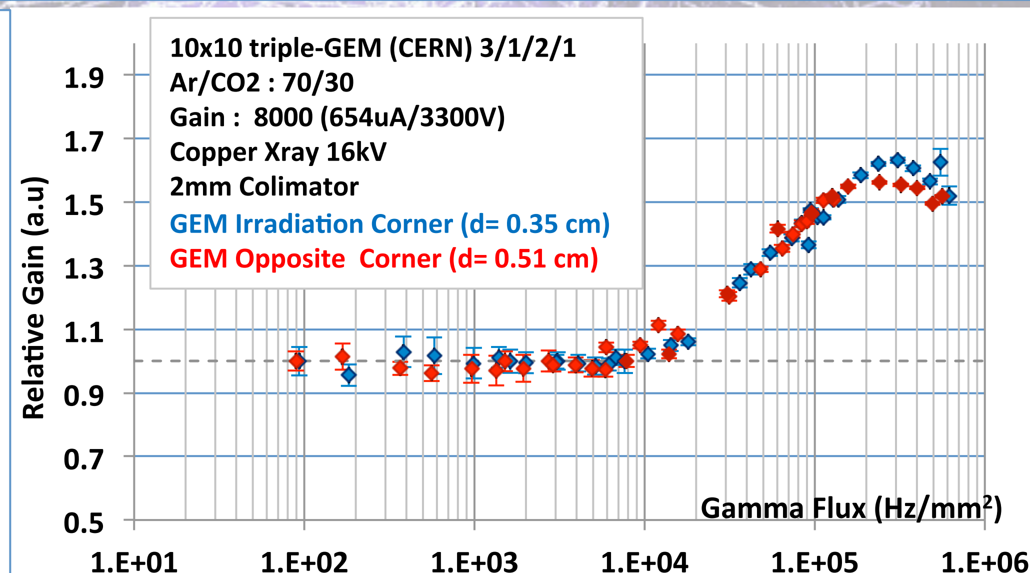
Prototype R&D

Additional procedure : Reference measurements with 10x10 cm² GEM detector



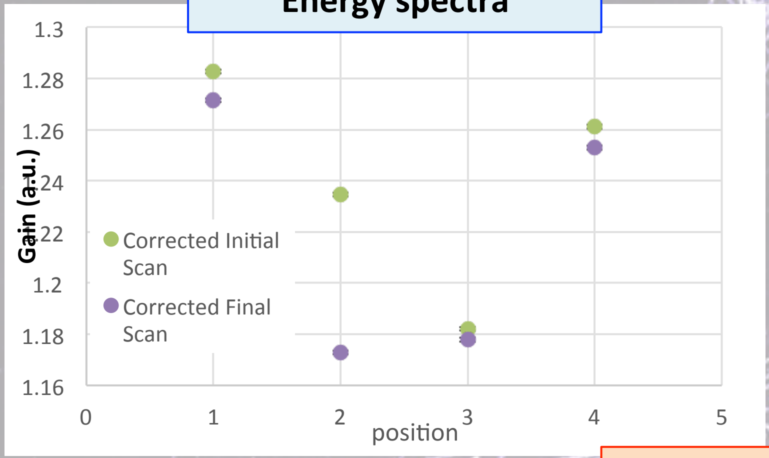




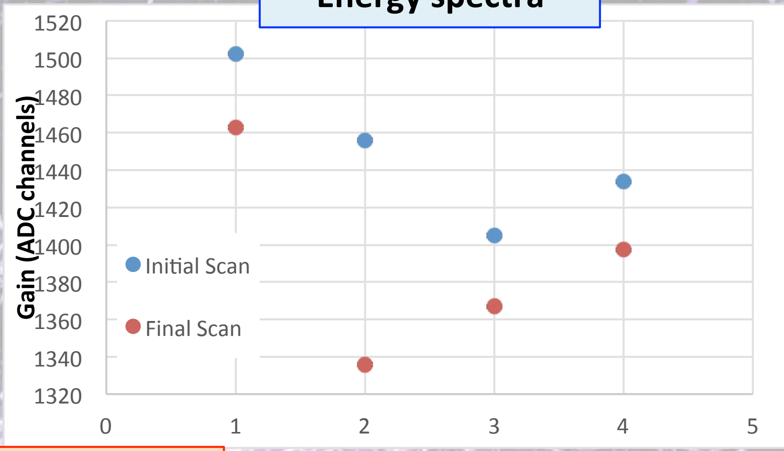


Prototype R&D

15/04/2014
Energy spectra

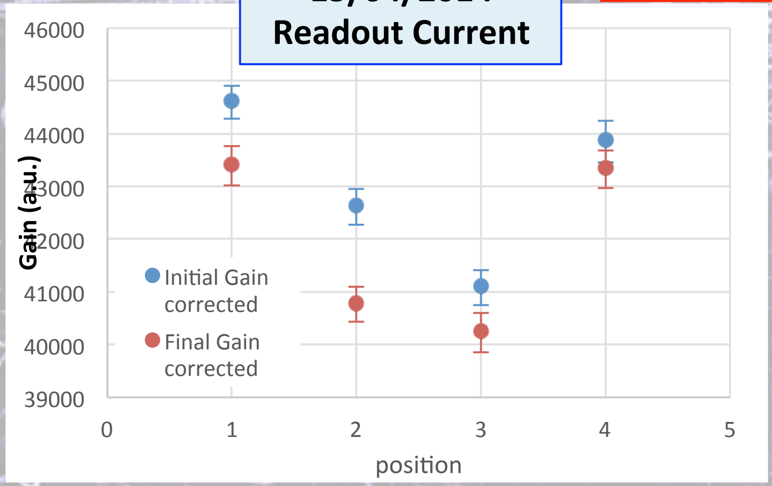


22/04/2014
Energy spectra



Irradiation only in Position 2

15/04/2014
Readout Current



22/04/2014
Readout Current