EXPERIENCE OF CONSTRUCTION OF GE1/1 FULL SIZE DETECTORS

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on behalf of CMS-GEM Group Collaboration

RD51 meeting CERN 16-19 June 2014

Outlook

- The CMS muon system
- the CMS GEM project
- GEM design evolution
- Experience of construction @ CERN, LNF, Bari, Gent, FIT
- Summary

The CMS Muon System

•CMS detector designed to detect and reconstruct muons with precision

•The CMS Muon system combines different technologies

- DT & CSC for tracking and triggering
- RPC for triggering

•After LHC LS1 the $|\eta|<1.6$ end-cap region will be covered with 4 layers of CSC and RPC;

•The $|\eta|>1.6$ region will have only CSC …

•Present CMS RPC design not suitable for high rate environment

•New technology needed for $|\eta|>1.6$ region of muon system:

- sustain Mhz/cm^2 environment
- need for good spatial resolution (100 μm) (for tracking
- need for good timeresolution: for triggering

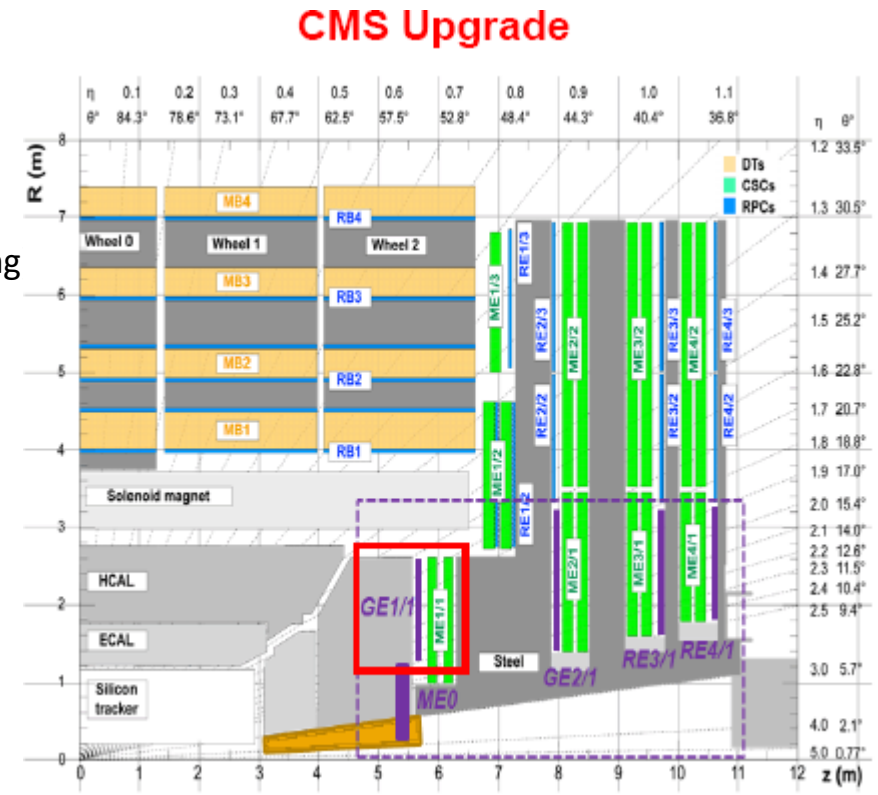
LS2

New system in $1.6<|\eta|<2.4$ considered
to improve L1 and HLT muon momentum resolution
to reduce trigger rate and ensure high trigger efficiency
in high PU environment

A GEM-based detector in stations 1

LS3

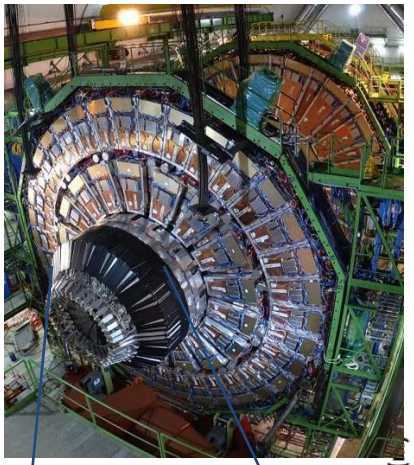
R&D on new super-high eta detectors:
GEM/GRPC has been proposed as a candidates
for stations further away



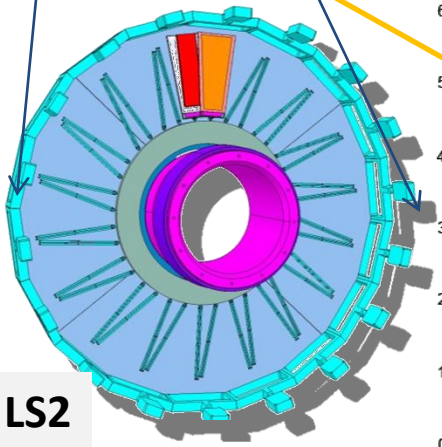
The CMS GEM Project

Install triple-GEM detectors (double stations) in 1.6<|η|<2.1-2.4 endcap region:

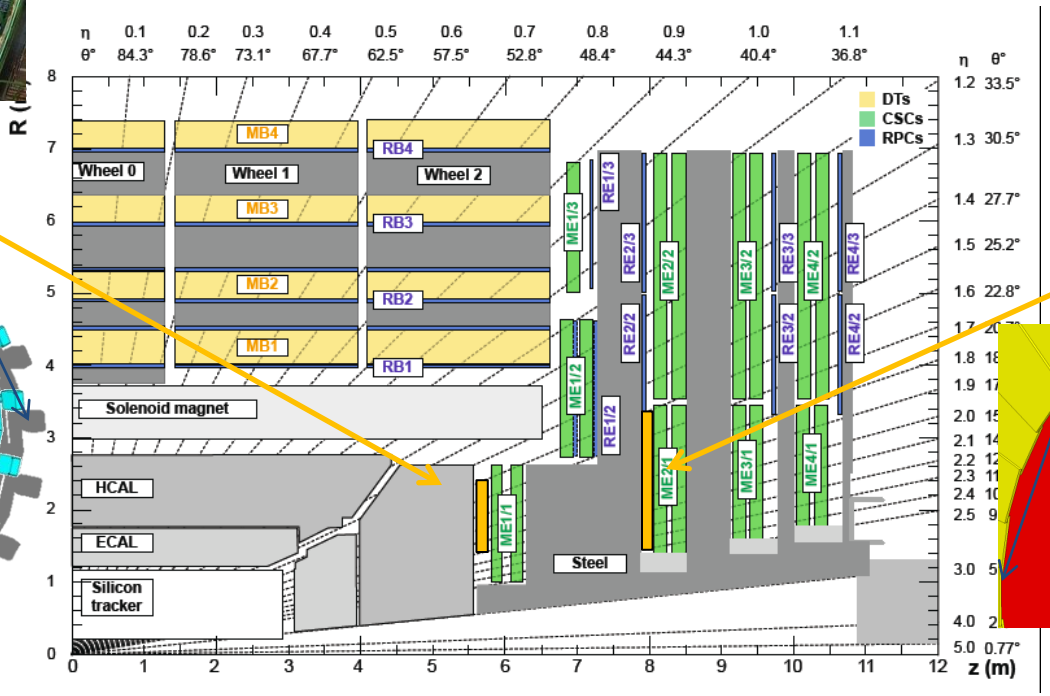
- ✓ Restore redundancy in muon system for robust tracking and triggering
- ✓ Improve L1 and HLT muon momentum resolution to reduce or maintain global muon trigger rate
- ✓ Ensure ~ 100% trigger efficiency in high PU environment

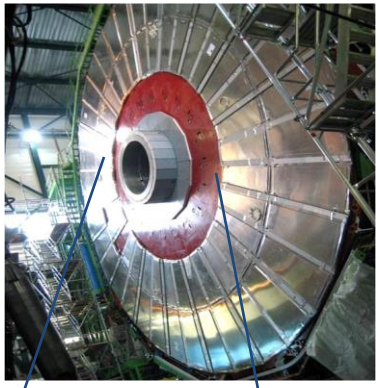


GE1/1



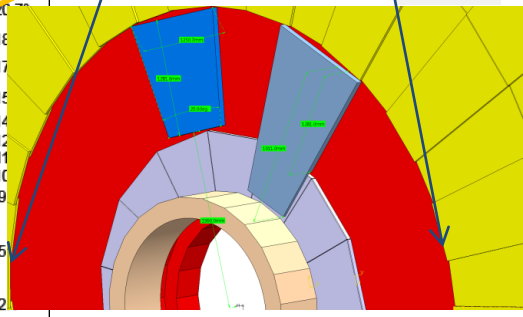
LS2





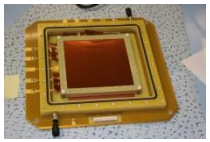
GE2/1

LS3

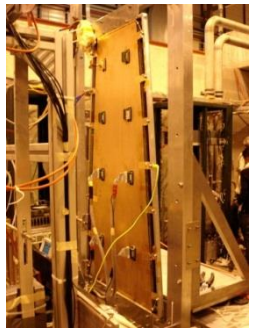


CMS GEM Collaboration Project Milestones (i)

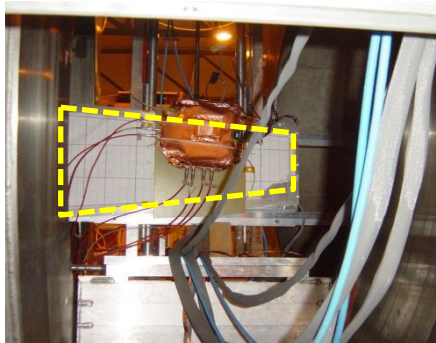
OVER FOUR YEARS OF R&D



- **2009-2010**
  - Small prototypes, bench tests; picked GEMs among MPGDs for further study
  - Established space and time resolution achievable
  - First Large-area GEM foils produced with Single Mask technology
  - First large-area GE1/1 prototype; beam test



- **2011**
  - Second redesigned GE1/1 prototype (smaller gaps b/w GEMs)
  - "GEM Collaboration (GEMs for CMS)" constitutes itself in May CMS week (76 collab. from 15 inst.)
  - Summer beam tests (including first test in CMS test magnet)
  - Established 100μm (300μm) spatial res. with analog (binary) r/o chip
  - NS2 GEM foil assembly technique w/o spacers
  - Preliminary electronics design starts



CMS GEM Collaboration Project Milestones (ii)

2012

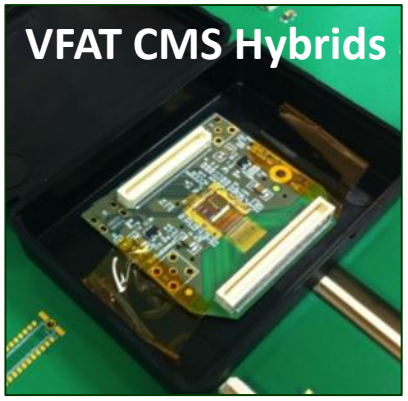
- Beam tests – Magnetic Field Operation and fine space and time resolution on large size established
- **Working Groups (Physics, Trigger Simulations, Integration Services, Electronics and DAQ, Detector HW) with weekly meetings**
- Third GE1/1 prototype designed (new GEM design "NS2"; and readout),
  5 detectors produced! One more to be assembled outside of CERN
- Started GIF long term aging test
- Collaboration Expanded 42 Institutions, 183 collaborators EOI

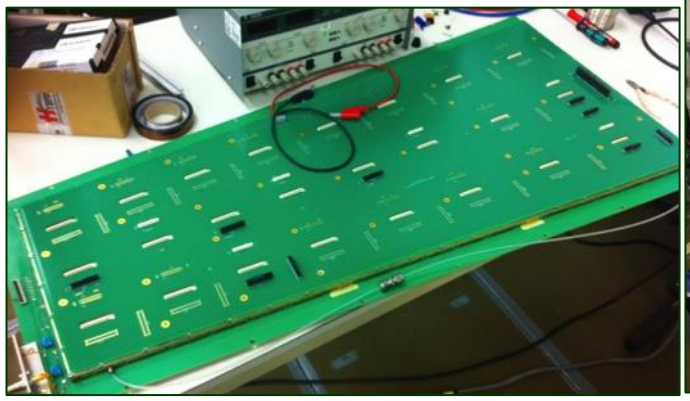
2013

- GE1/1-IV prototype designed (mechanical stretching)
- Collaboration Expanded 42 Institutions, more than 200 collaborators
- GE1/1-IV – 6 produced in 2013 (three outside CERN); 6 potential production sites
- Beam test at Fermilab with GE1/1-IV + 6 smaller detectors
- Long term tests + Materials study Launched

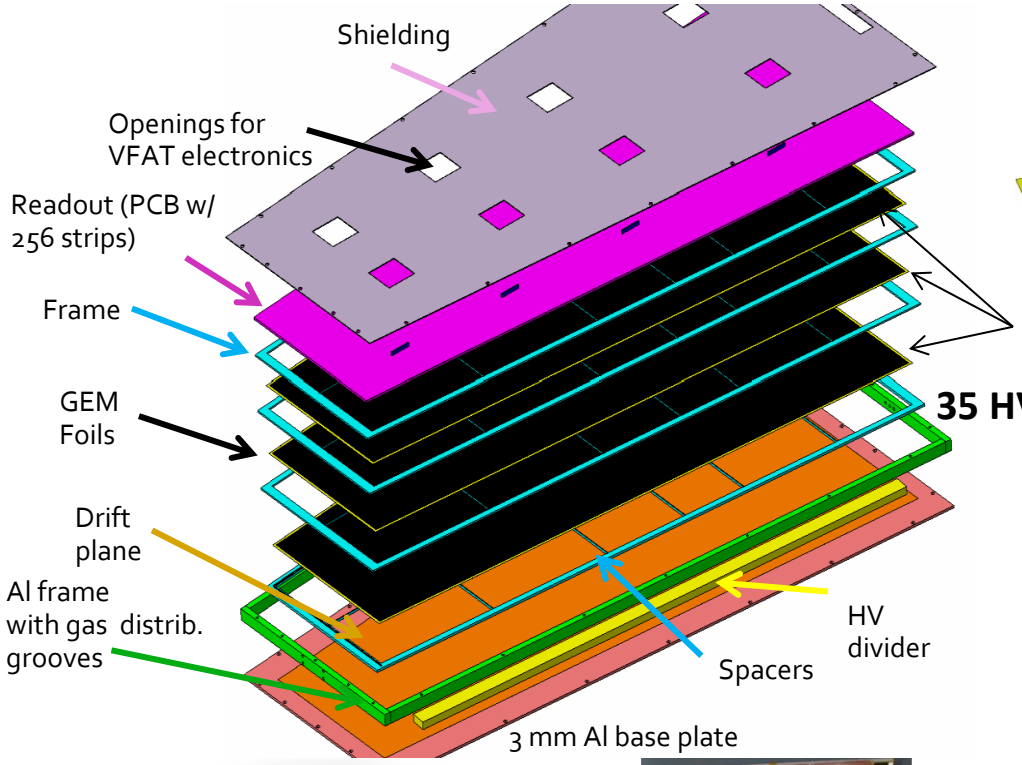
CMS GEM Collaboration Project Milestones (iii)

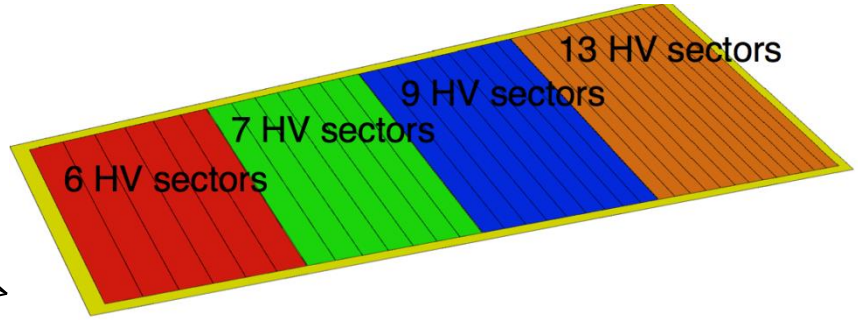
- **2013 continued**
  - Electronics and DAQ groups take big steps : proto FPGA /GEB/uTCA in hand
  - **TDR requested by CMS management; Slice Test Approved (DESY MB 2013)**
  - Simulations, Reconstruction Group advance; Geometry GE1/1-V Final
  - GE1/1-V -> 10 “Final” detectors launched for production: 3 Long on way
  - TIF Area being readied for “Proto-Slice Test”, Production and QC
- **2014**
  - Optohybrid at the TIF Lab
  - GE2/1 & ME0 Geometry Advances to version 2
  - Simulations
  - Training sessions





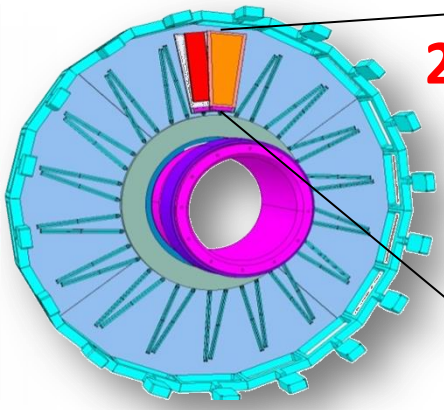
Design of full-size CMS GE1/1



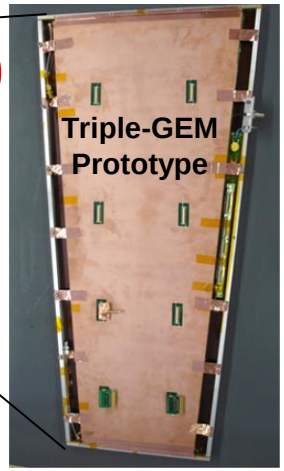


35 HV sectors per GEM foil with area of ~100 cm^2 each

Single mask GEM foil with spacer frame at CERN
Gap sizes:3/1/2/1 mm
Sectors: 3 columns x (8-10) η partitions
Strip pitch: 0.6-1.2 mm
Readout of up 3840 channels
35 HV sectors

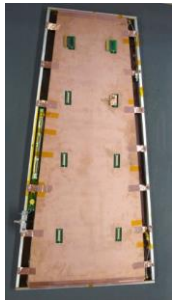


2010

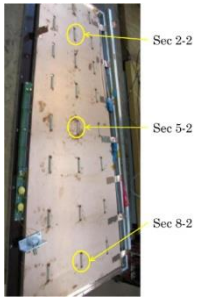


~1m

Full-size GE1/1 Detectors Developments in Time



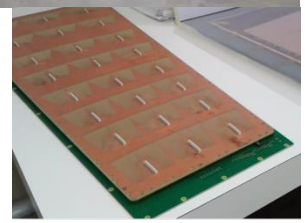
2010



2011

2012

2013



2013/14

Generation I

The first 1m-class detector ever built but still with spacer ribs and only 8 sectors total. Ref.: **2010 IEEE (also RD51-Note-2010-005)**

Generation II

First large detector with 24 readout sectors (3x8) and 3/1/2/1 gaps but still with spacers and all glued. Ref.: 2011 IEEE. Also **RD51-Note-2011-013.**

Generation III

The first self-stretched without-spacer detector, but with the outer frame **still glued** to the drift. Ref.: **2012 IEEE N14-137.**

Generation IV

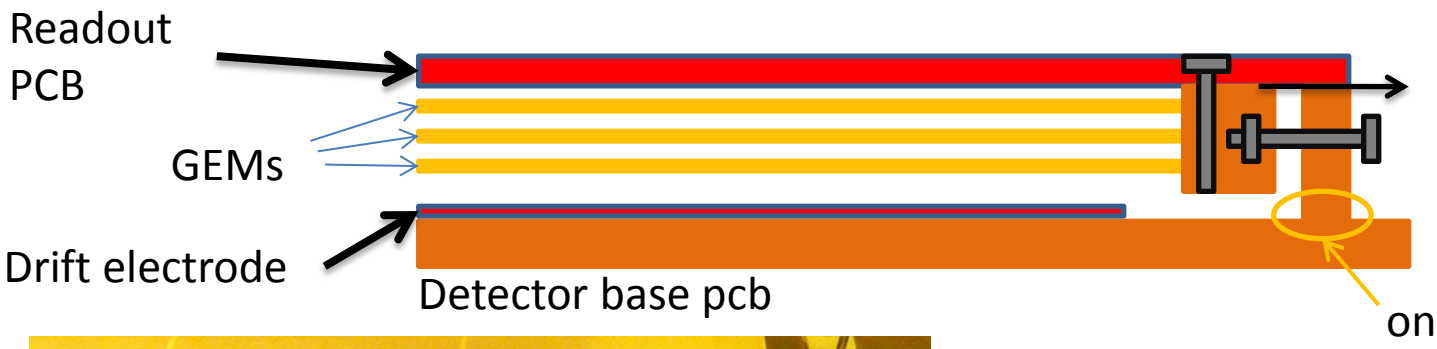
We have built four one at CERN and other outside. **No more gluing whatsoever**. Ref.:**MPGD 2013, IEEE2013**

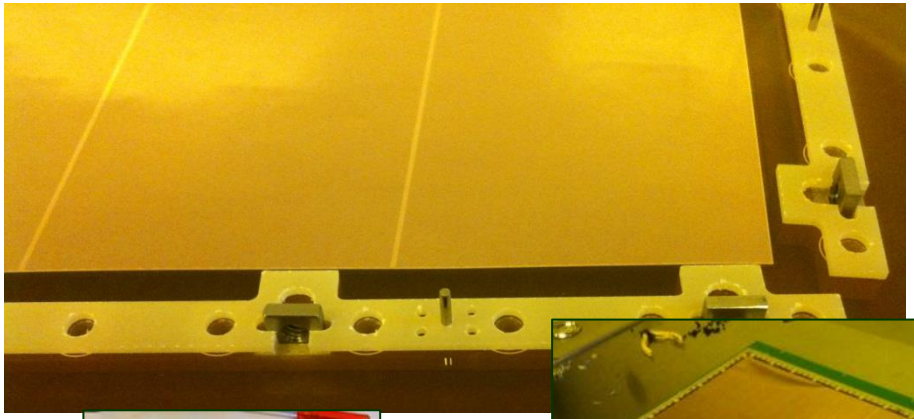
Generation V

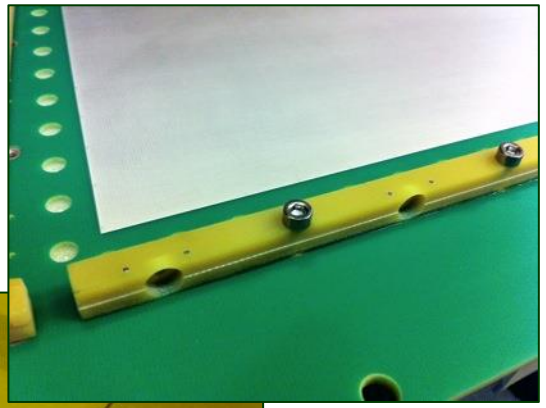
The upcoming detector version that we will install. One long and one short version. Optimized final dimensions for max. acceptance and final eta segmentation.

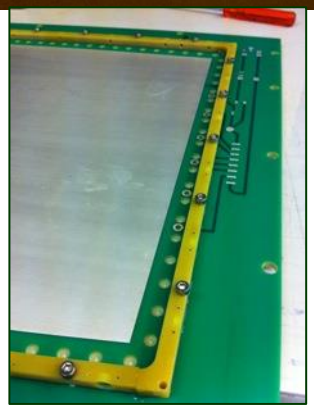
Evolution - GEM foil stretching

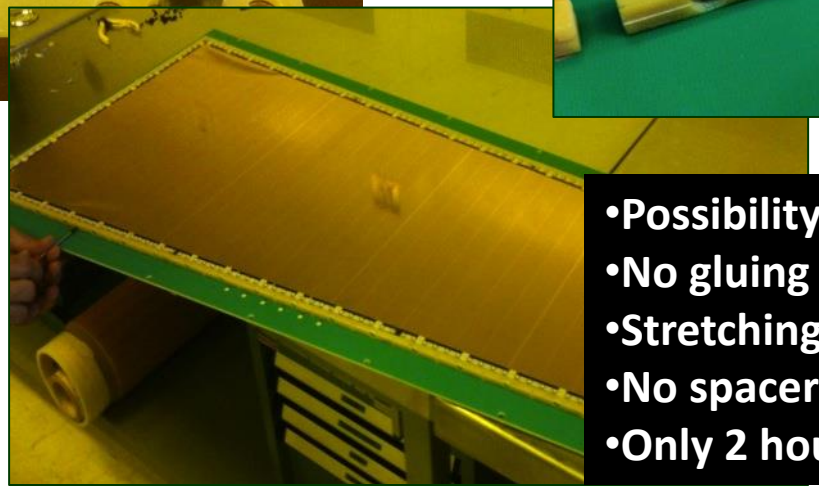
2012 **Self-stretching assembly without spacers (CERN)**





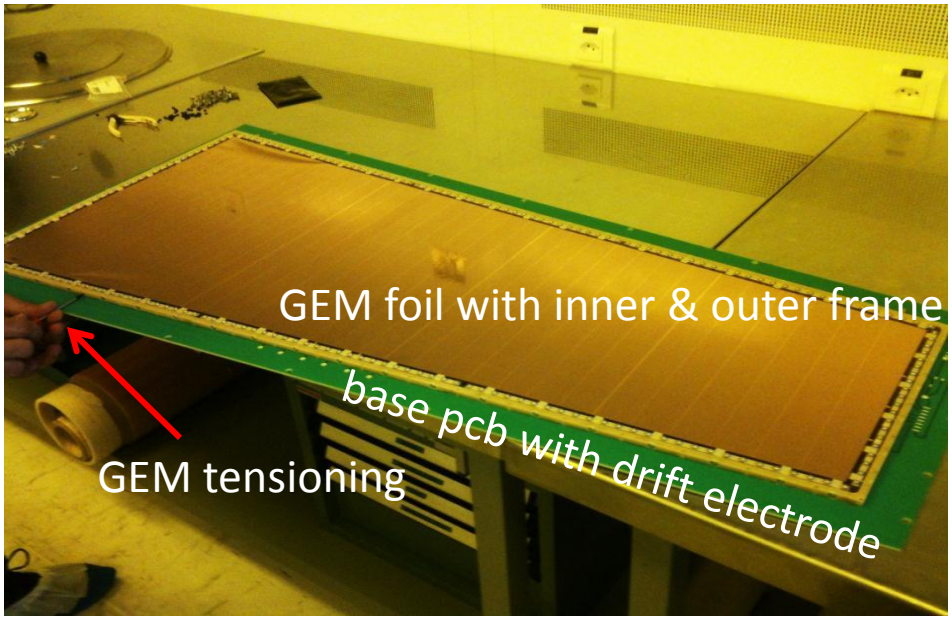


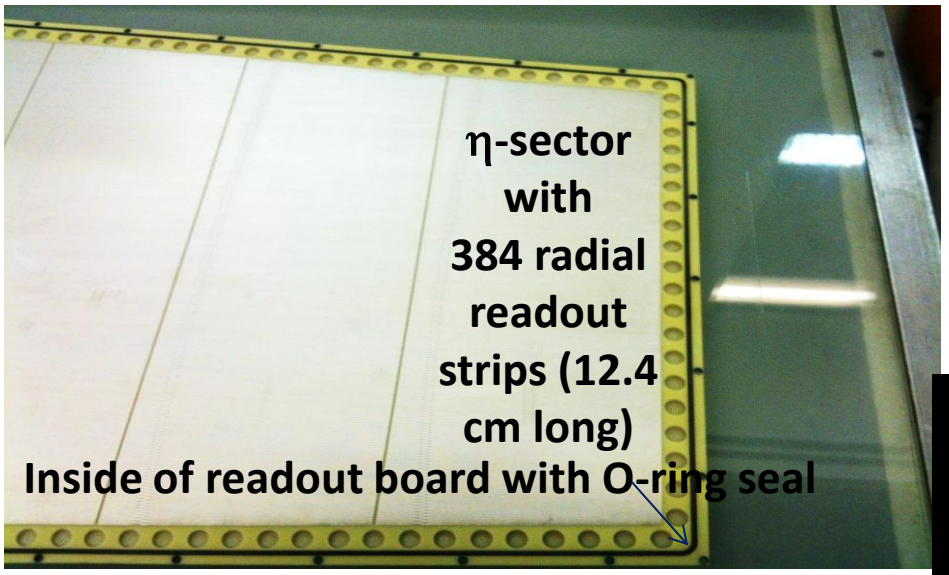




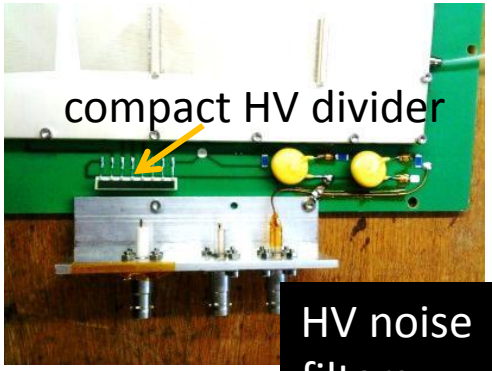
- **Possibility to reopen**
- **No gluing in gas volume**
- **Stretching can be adjusted**
- **No spacers in the active area**
- **Only 2 hours for assembly**

3rd CMS GE1/1 Prototype: Self-stretched





Chamber closed by readout board with Panasonic connectors for frontend electronics



HV noise filters

2012

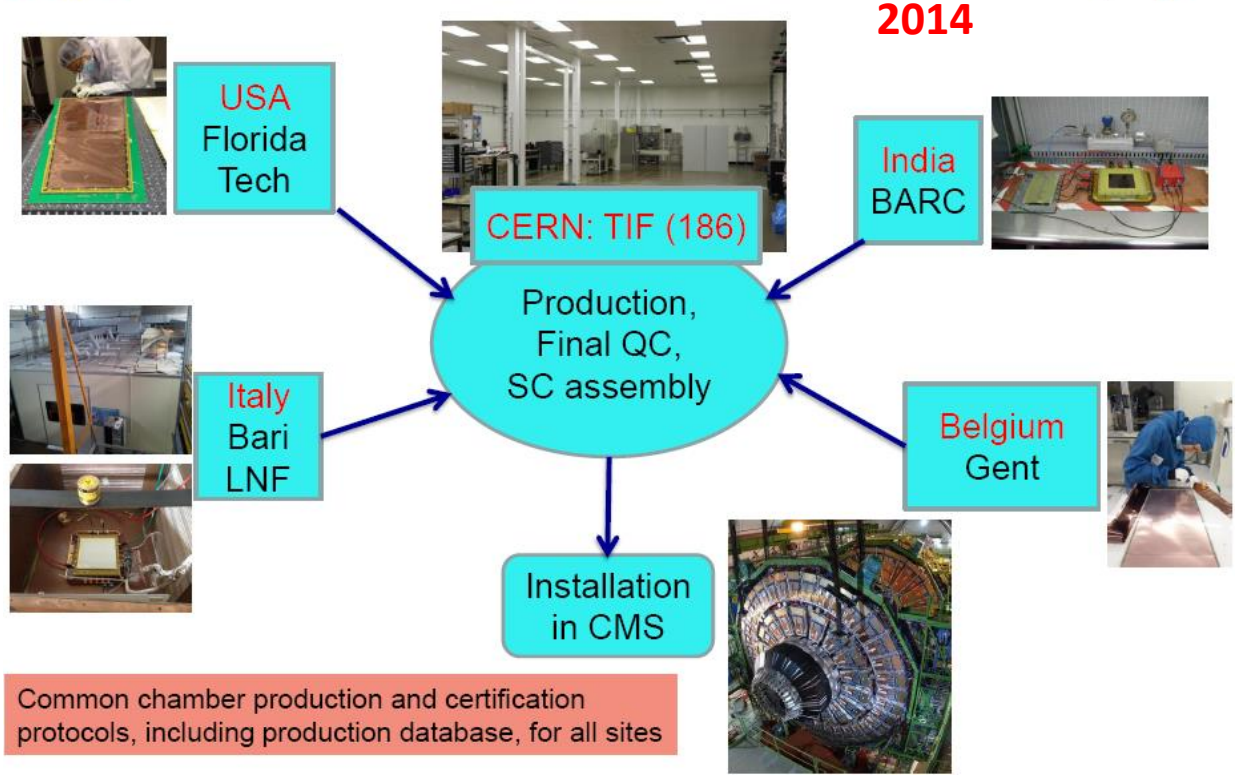
GE1/1-IV outside assembly

- All the IV-generation prototypes were assembled without any particular problem also at FIT, Bari, UGent and LNF. **2013**
- IV-generation prototypes gave signals and shown good performances (CERN X-ray and FNAL test beam)

➢ <u>However during their assembly we identified several issues and aspects to be improved.</u>

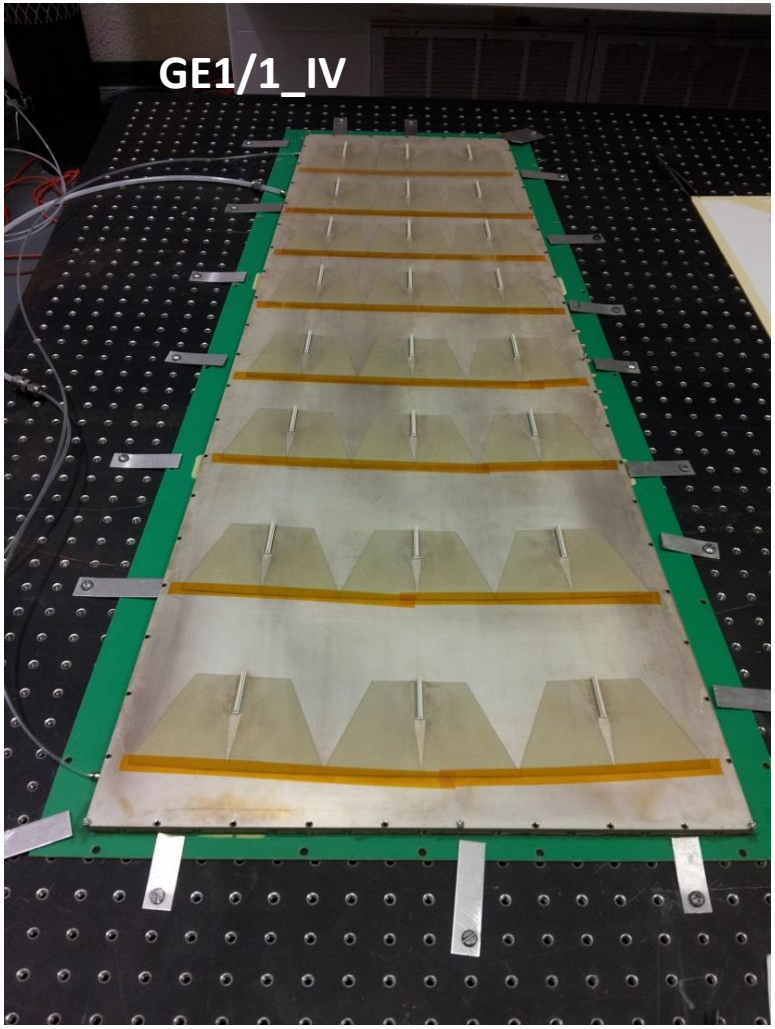
Production Site Candidates

2014

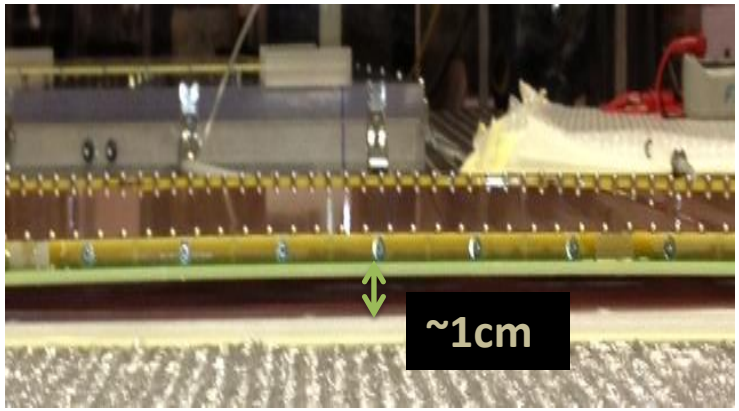


Florida Inst. Of Tech.

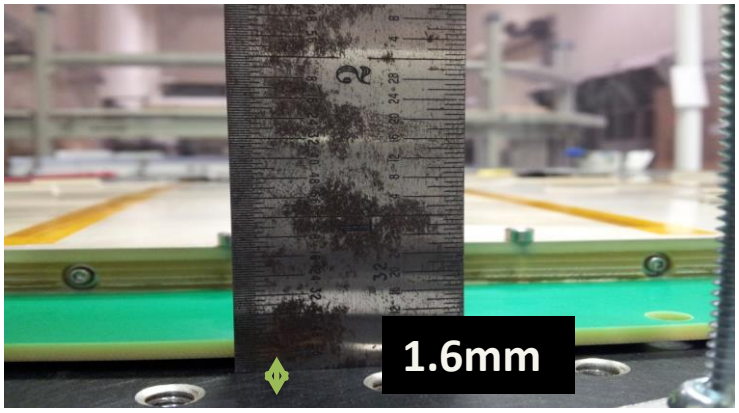
problems with bending (September 2013)



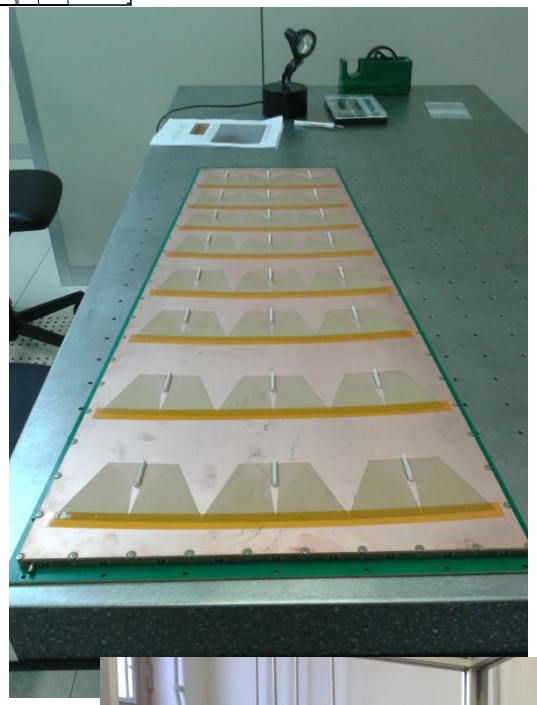
Before flattening the drift



After flattening the drift

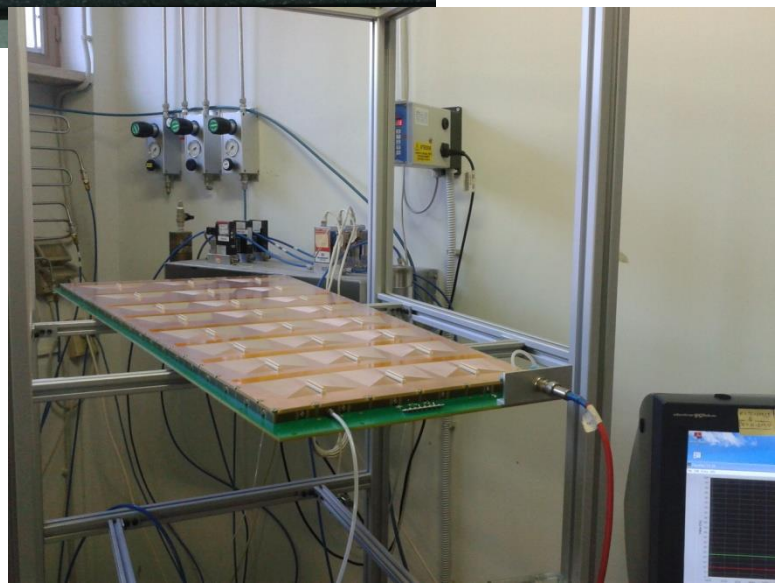


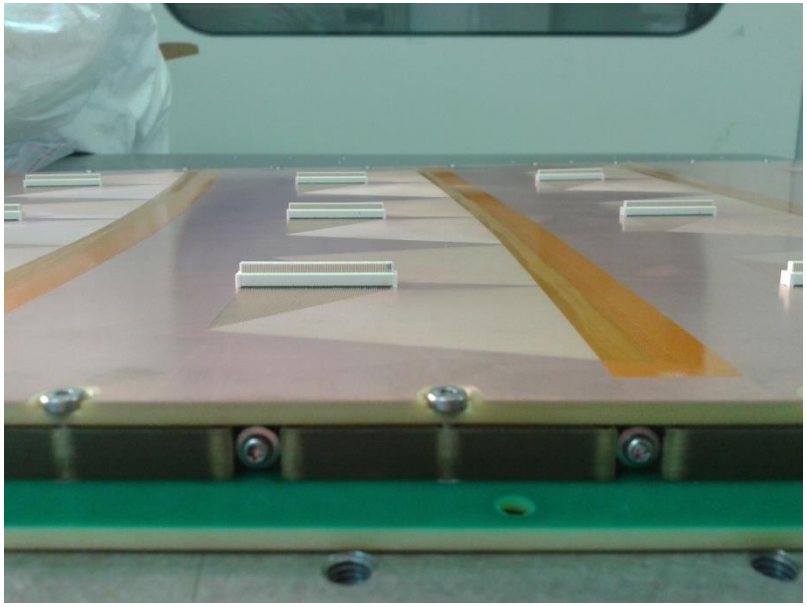
Mounting experience @Bari
GE1/1 IV



1. No serious problems encountered with first assembly
2. One O-ring for strectching screw came out of the hole
3. Planarity after completion of assembly was OK
4. Flushed with Ar/CO2 under HV (700 uA@3300V)
5. No gas-leak at all observed after a few hours

(October 2013)

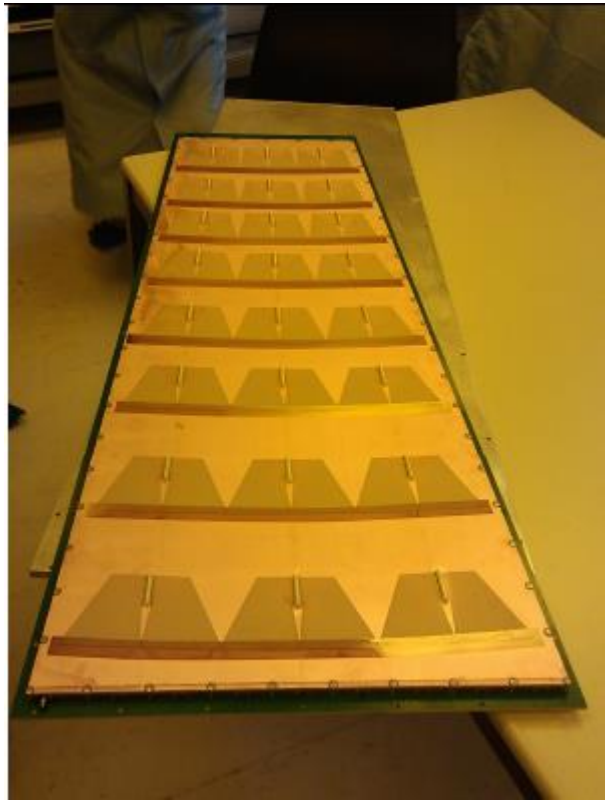


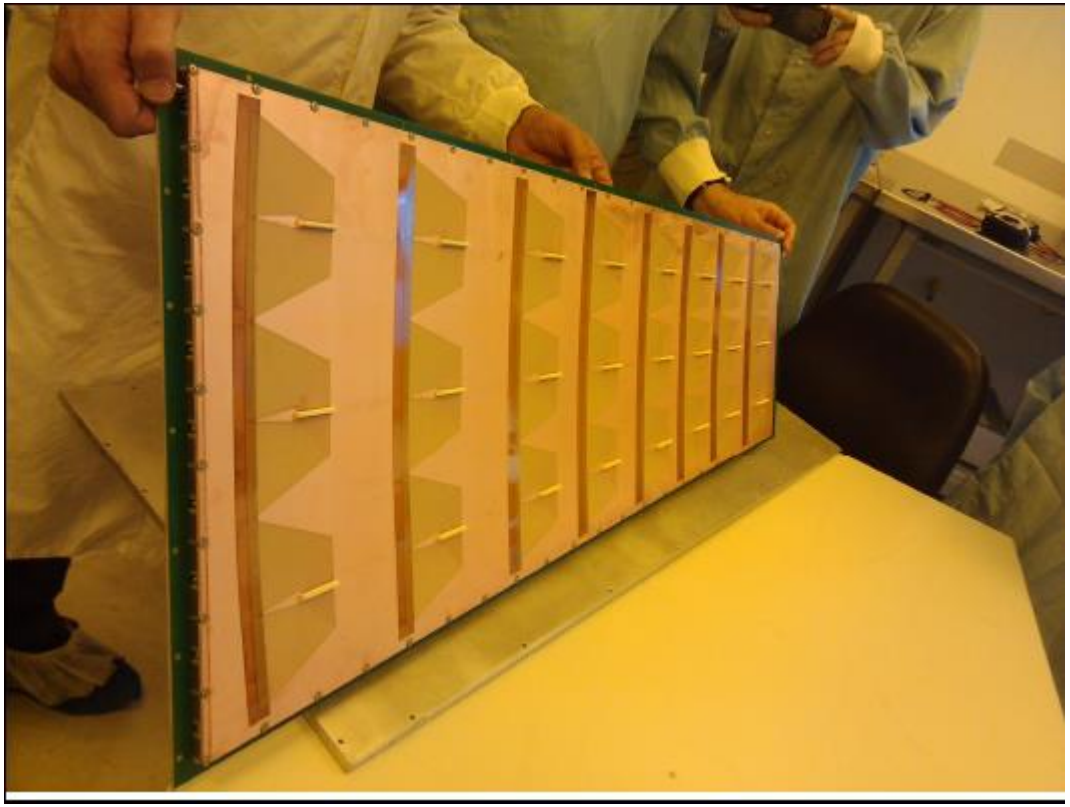


Experience in Univ. Of Gent

Mounted on November 2013

University of Gent had any problems with flatness





GE1/1-IV issues and problems

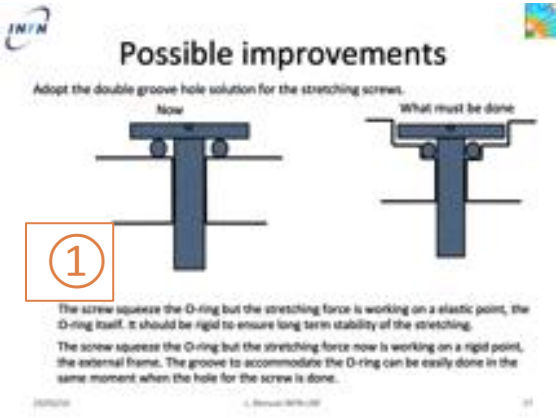
① The stretching force was applied to an O-ring used to seal the screws used to apply the tensile load. Concerns about its time stability and reliability.

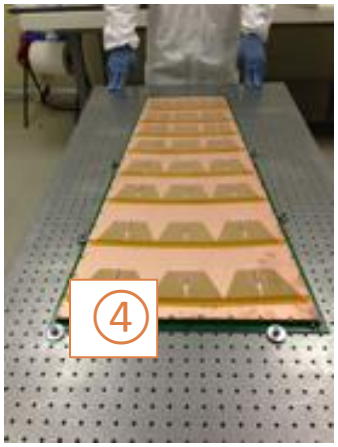
② Was impossible to quantify the tensile load due to the presence of the small O-rings between the screw-heads and the external frame

③ The external frame is to big (and fragile) to be handled by firms during the drilling of the holes. Stretching holes done by hand one-by-one

④ Once closed the chamber was sometime bended due to:

- to the mechanical tension of the GEM stack. We tried the to be cure the chamber curve by pre-bending the PCBs in the "opposite" direction. This not seem to work and the pre-bending was not 100% reliable (sometimes PCB recover its original flat shape?)
- The O-ring used to seal the drift and read-out boards (placed on the external frame) was of the hard type. While closing the chamber with screws it was acting as a pivot enhancing the chamber bending.
- To avoid the chamber bending the chamber must be fixed on the working bench increasing the assembly complexity





GE1/1-V GENERATION

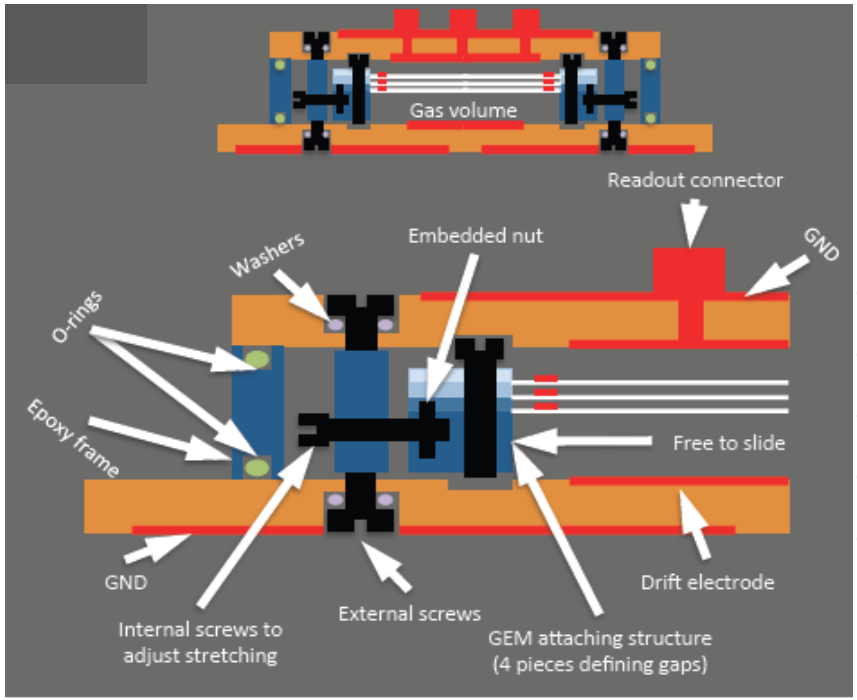
In the new prototypes we tried to fix and improve all the open issues.

- ✓ We have adopted a brand new solution for stretching the GEM stack
  Brass pullouts fixed on drift board to allow GEM stack stretching
- ✓ New external frame without holes (only gas in-out)
- ✓ Soft O-ring all along the external frame for gas tight
- ✓ No pre-bended PCB boards
- ✓ Almost the same assembly procedure and assembly time.
- ✓ No changes in GEM foils layout or production. Same GEM stack assembly procedure

- ➢ There was an attempt to assemble one GE1/1-V prototype at LNF middle of May.

  In case you are interested you can see GE1/1-V assembly full movie at
  https://www.youtube.com/watch?v=Ssuqh5GAVZ4&feature=youtu.be

Mechanical stretching method (version 3)



- **Internal movable structure to hold the GEM foils**
- **Lateral screws to pull the internal structure**

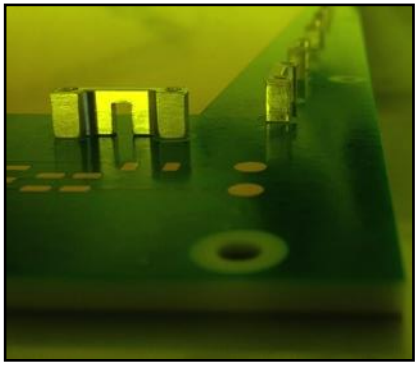
-> Possibility to open the chamber and replace foils

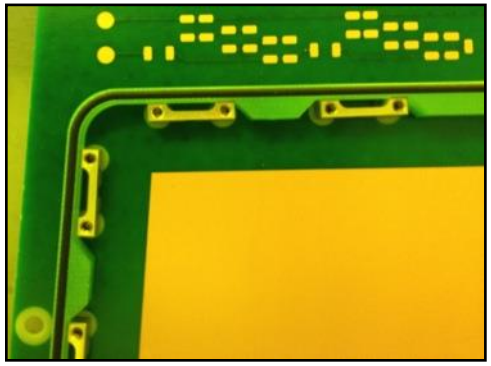
-> Stretching can be adjusted

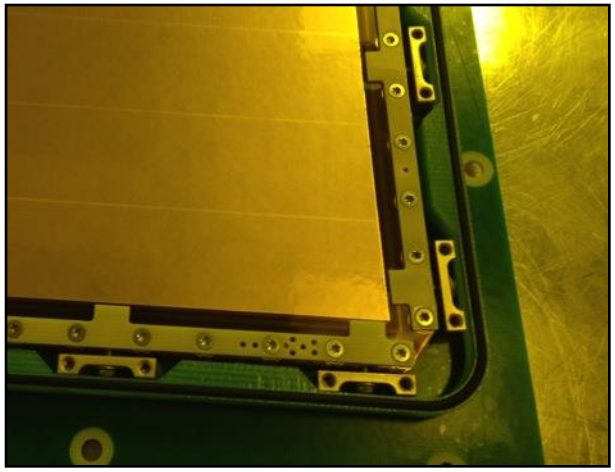
-> No glue in the gas volume

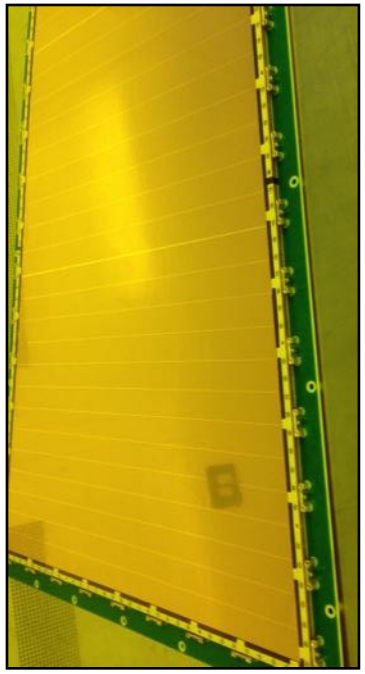
-> No spacers in the active area

-> Only 2 hours for the assembly

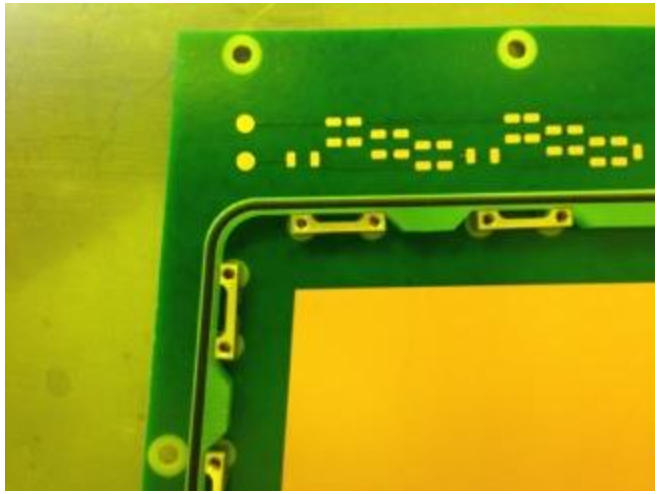


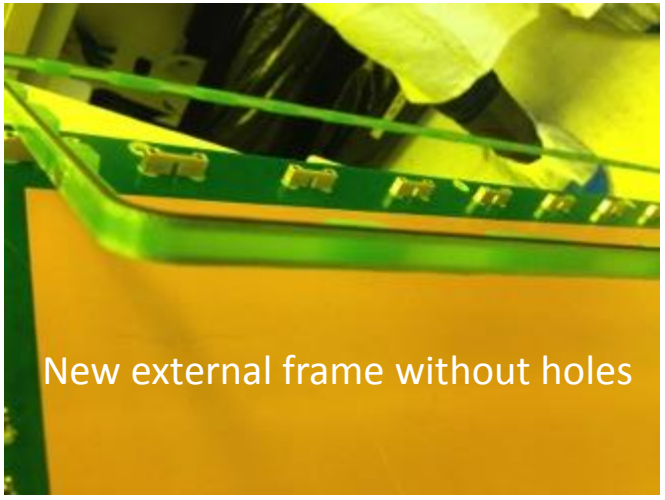


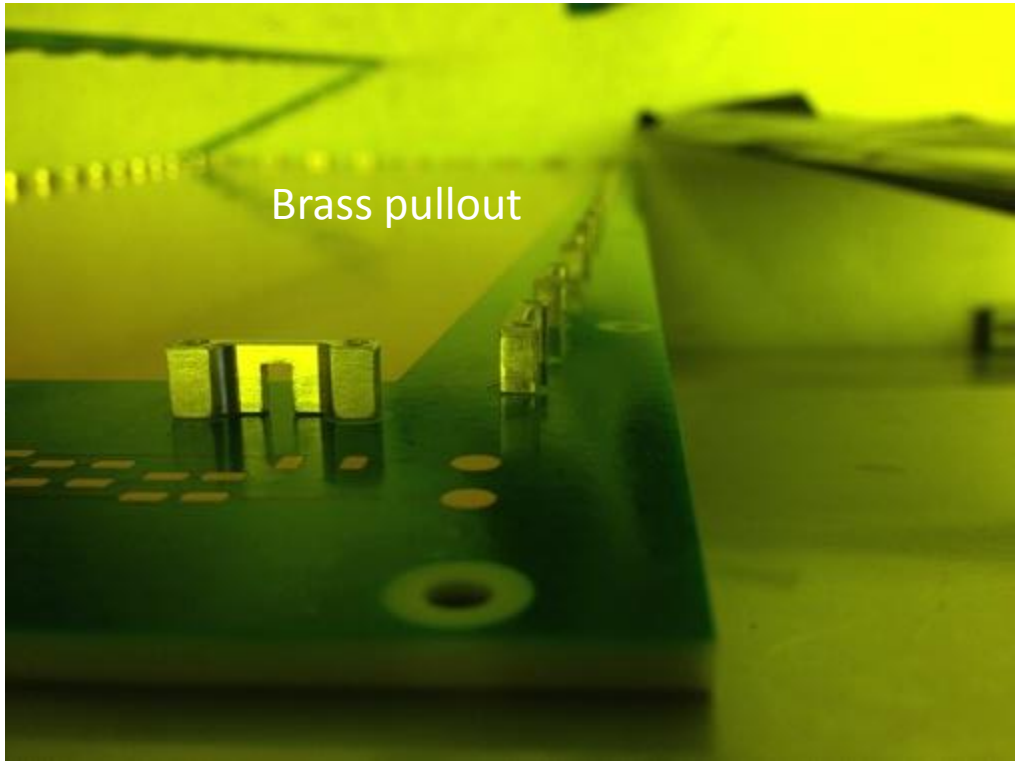




GE1/1-V GENERATION assembly @CERN



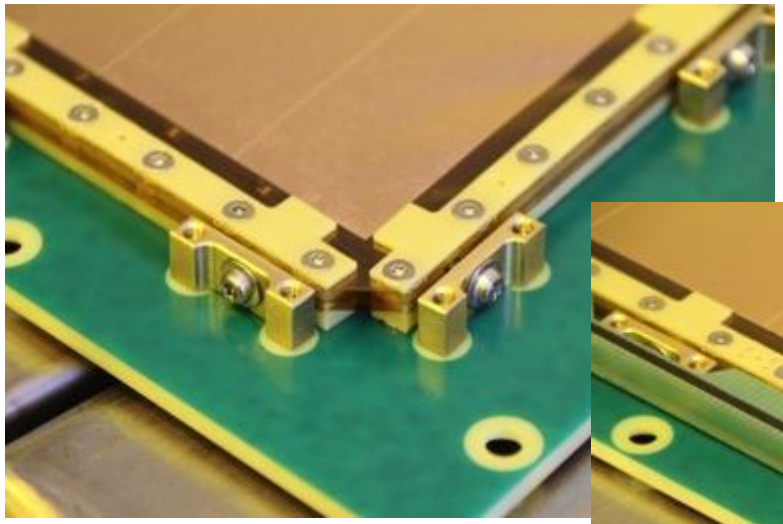




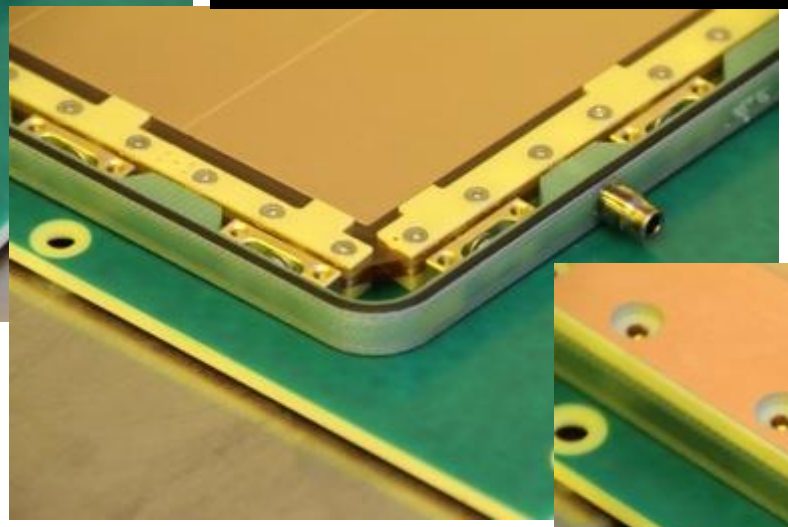
Some pictures from CERN

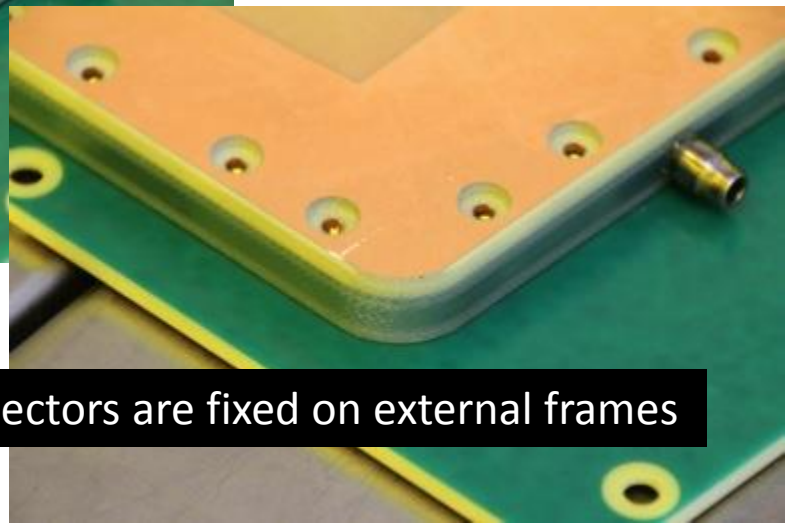
GE1/1-V GENERATION assembly @CERN

Details of pulling system fixing frames before to close chamber



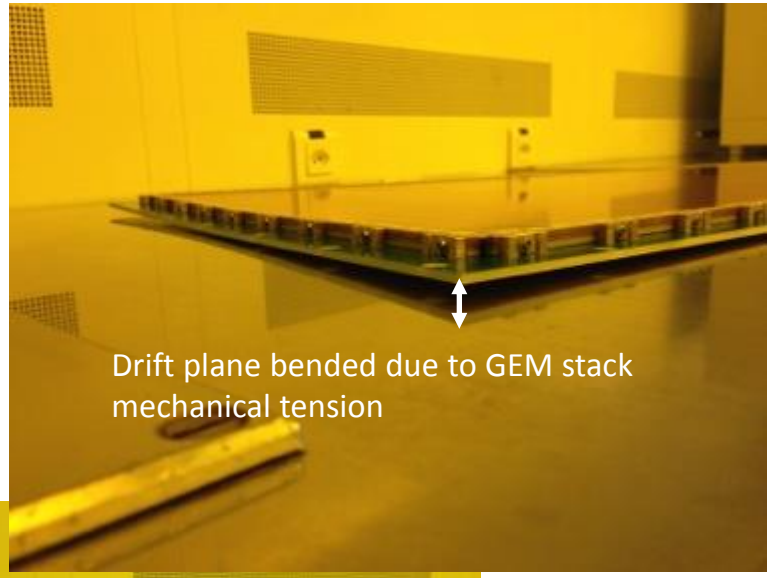
The external frames closes the gas volume

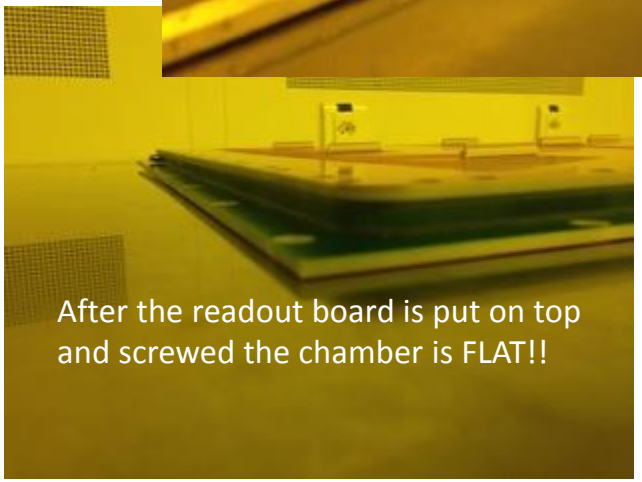




Only gas connectors are fixed on external frames

GE1/1-V GENERATION assembly @CERN

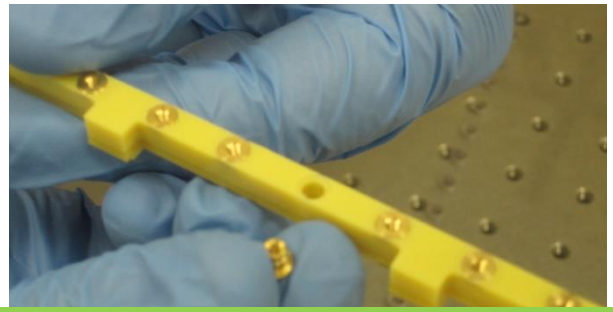




Mounting experience of V'th generation

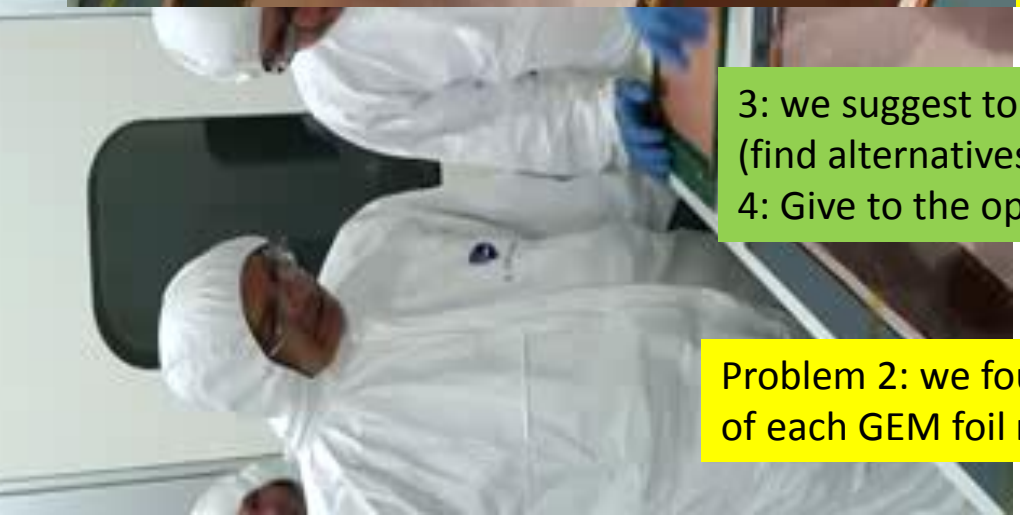
Frascati 28/05/2014

Issues found and hints



5: the schema of the cuts for HV contacts is vital to avoid uncertainties and unrecoverable errors (feedback sheet?)

Problem 1: brass inserts not well fixed to the frame



3: we suggest to find other way to pack FR4 spacers for shipping (find alternatives to kapton adhesive ribbon and cardboard)
4: Give to the operator a better type identification of FR4 spacers

Problem 2: we found a not perfect copper deposit only on one side of each GEM foil received

Summary

GE1/1_V fully assembled (@CERN and Frascati)

The last generation seems to comply all the assembly requirements in terms of simpleness of construction and as reliability…

CERN

✓Fully assembled. Looks flat.

✓ Did not use optical bench to keep the drift flat during assembly

✓Gas leak test ongoing w/overpressure 20-30 mbar for 24h in a temperature controlled environment

✓Leakage current test

✓HV test stability (I-V measurements)

✓Gain calibration and Gain uniformity test

✓Spark probability

✓etc…

Frascati

- ~30% of brass inserts used to close GEM stack escaped from holes during assembly
- (Would not stay in holes.)
  - Also noticed several brass inserts had their threads stripped during assembly.
  - ✓Chamber will be used mainly by Moire team in Frascati for mechanical studies.

✓ other two assembly kit have to be shipped to FIT and another one to Bari (after Summer)

Thank you

spares

Stretching method (version 1)