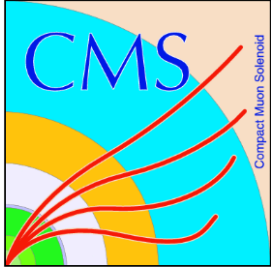


Overview of Production for CMS GE1/1

Andrey Marinov

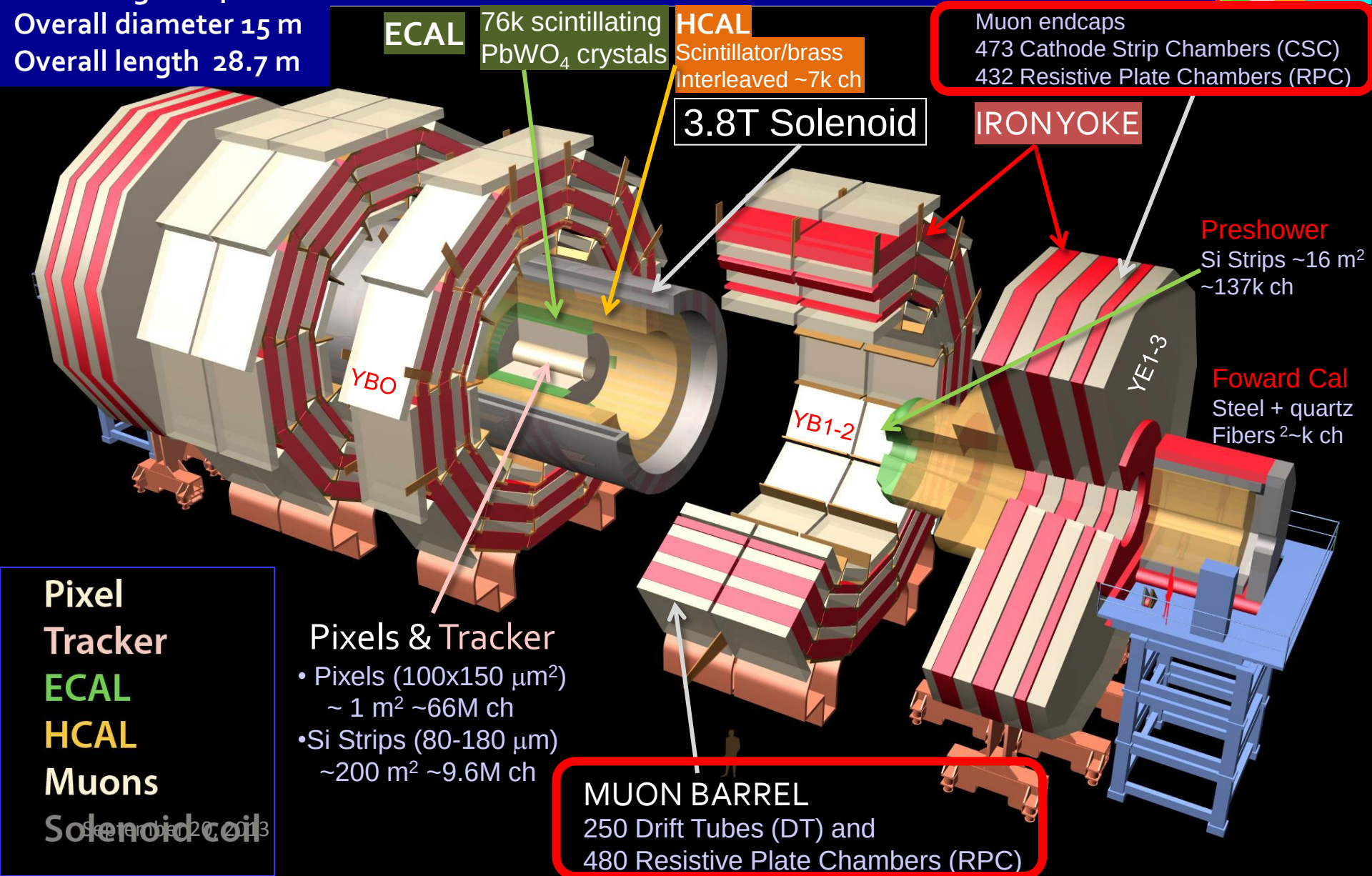
On behalf of CMS GEM collaboration

Outline

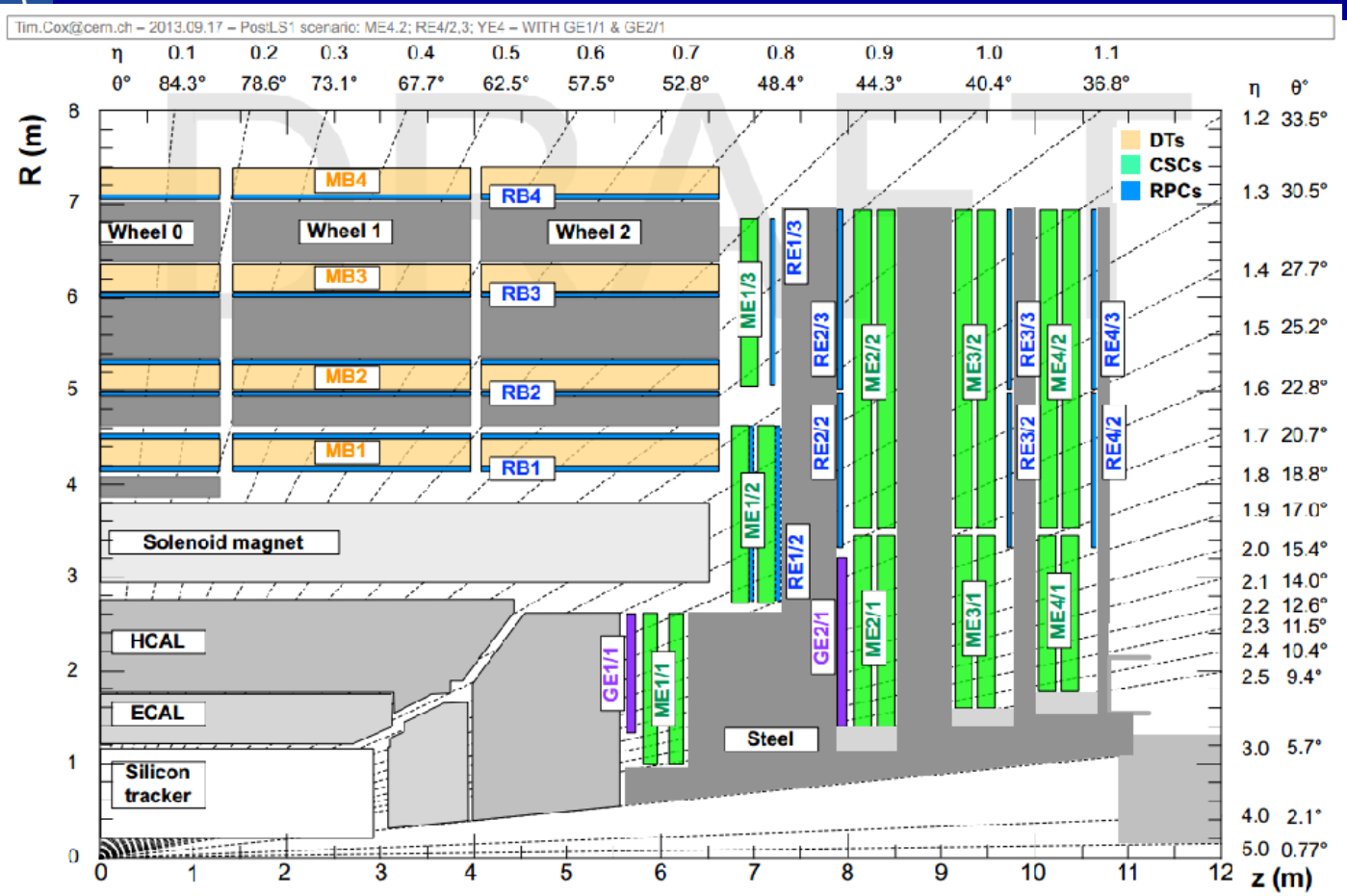
- Introduction
- Small Prototypes
- First Full-Size Prototype
- Validation in Test Beams
- Final Full-Size NS2 Detector
- Production sites
- Conclusions

The CMS experiment

Total weight 14000 t
Overall diameter 15 m
Overall length 28.7 m



The CMS Muon System



The CMS Muon System combines different technologies:

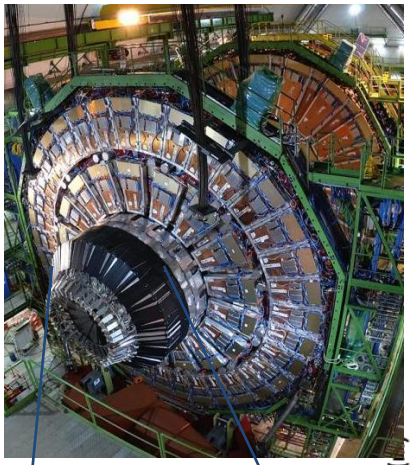
- Drift Tubes & Cathode Strip Chambers for tracking and triggering
- Resistive Plate Chambers for triggering

After LHC LS1, the $|\eta|<1.6$ endcap region will be covered with 4 layers of CSCs and RPCs; **the $|\eta|>1.6$ region not instrumented**

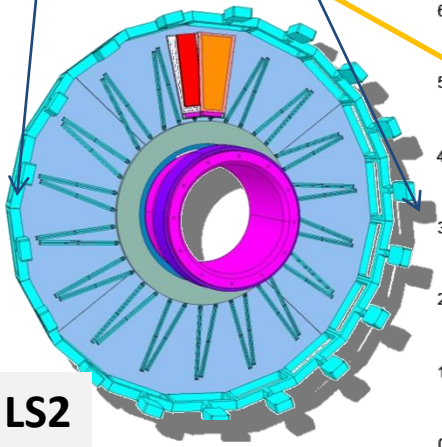
The CMS GEM Project

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

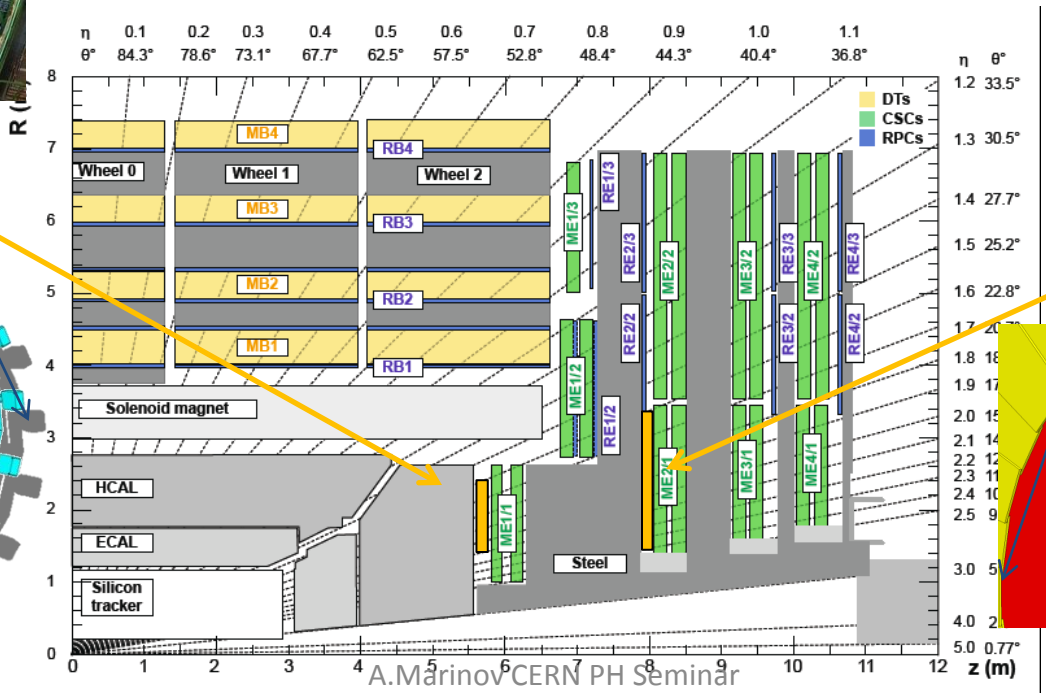
- ✓ Restore redundancy in muon system for robust tracking and triggering
- ✓ Improve L1 and HLT muon momentum resolution to reduce or maintain global muon trigger rate
- ✓ Ensure ~ 100% trigger efficiency in high PU environment

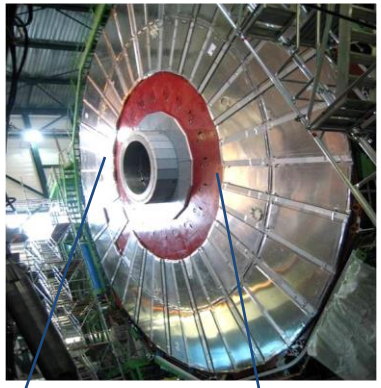


GE1/1



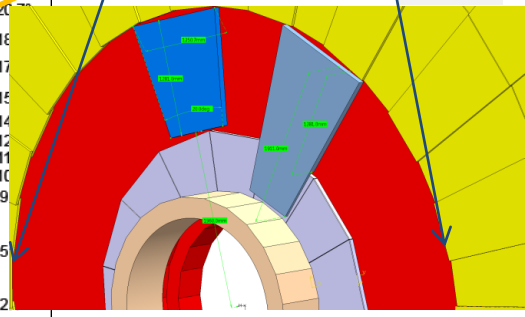
LS2



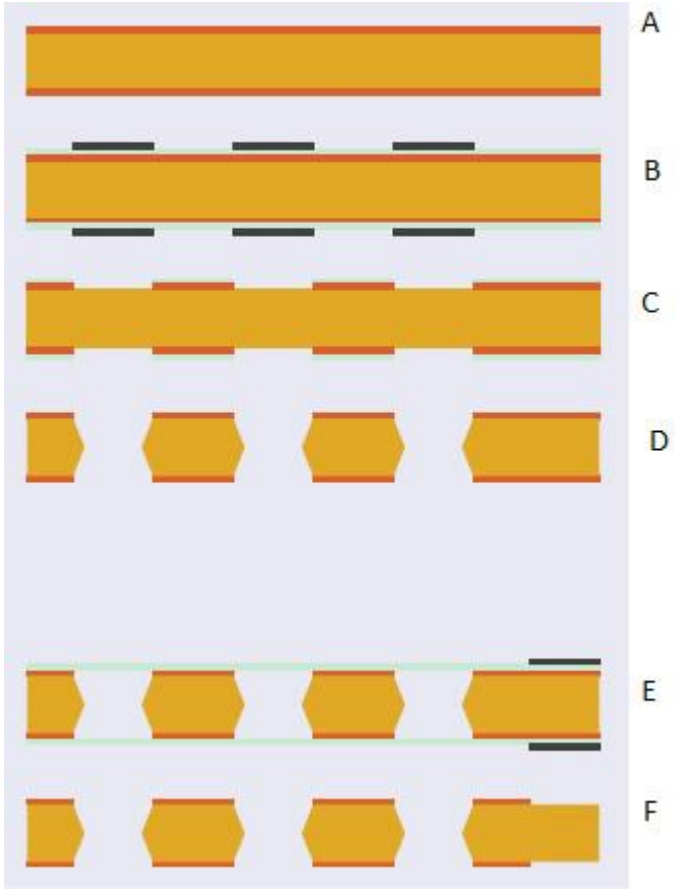


GE2/1

LS3



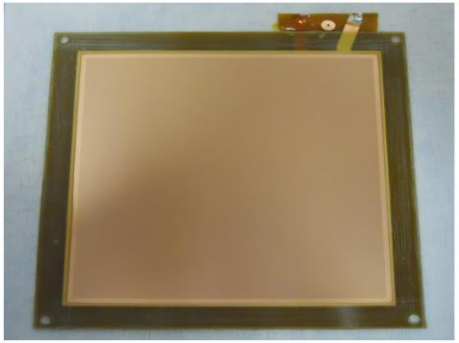
Limitations for large size applications ~ 4 Years ago



Double mask technology process.

A-the GEM foil copperclad,

B- Photomask for top and bottom layer. Photoressist exposure,



C-Metal etching,

D-Kapton etching,

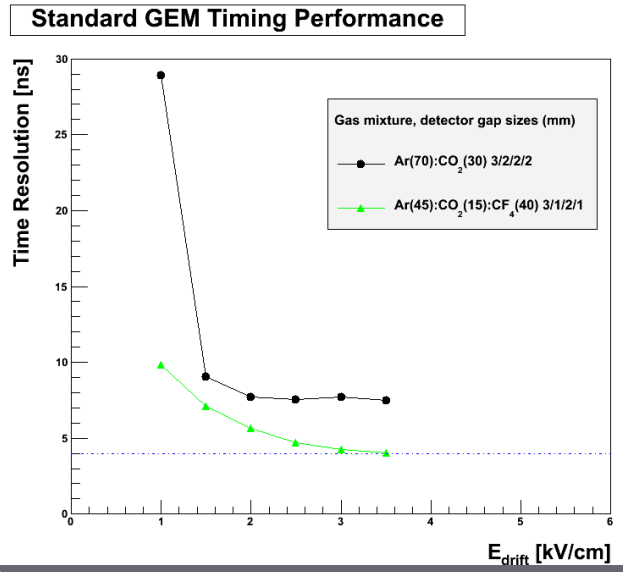
E-second masking,

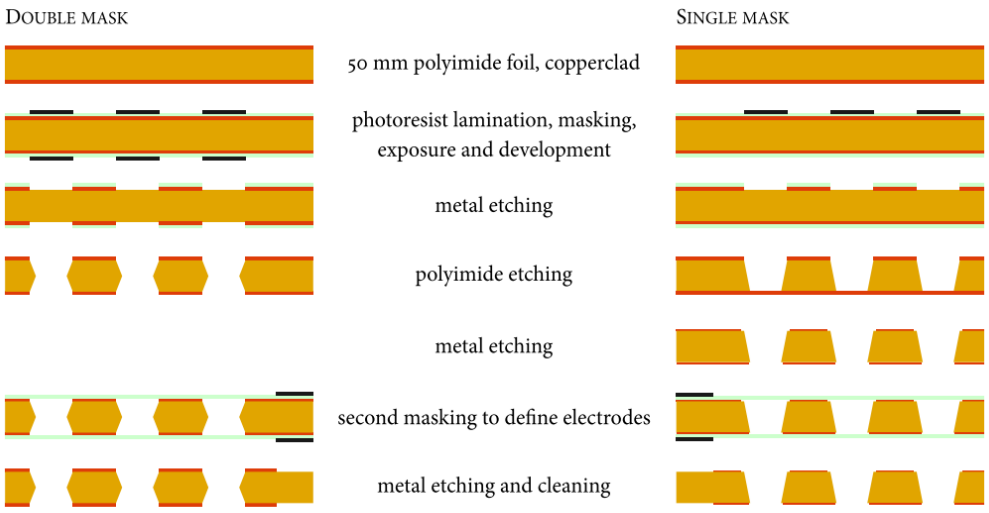
F-metal etching and cleaning

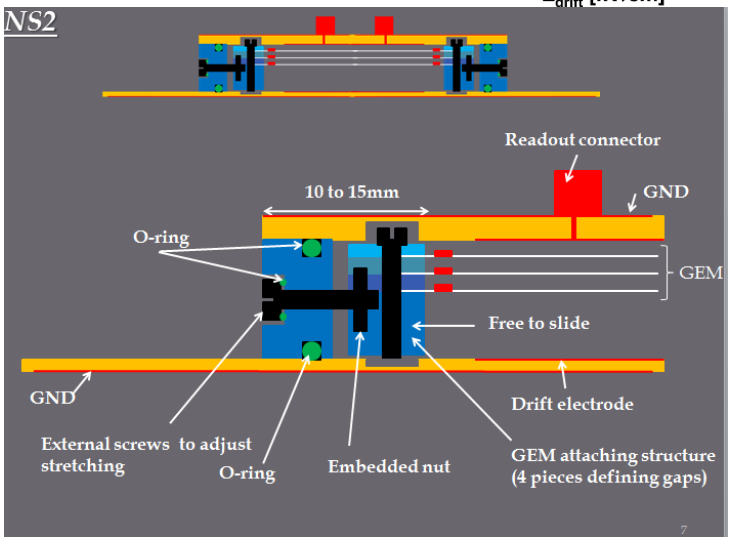
Based on this technique the maximum size of the GEM foils was limited to 30x30 cm

CMS Project Achievements Together RD51 and CERN Surface Treatment Workshop

- Detector efficiencies above 98%
- Spatial resolution of about 290µm with VFAT2 (digital) and <110µm APV (analog) readout chip
- Time resolution of 4ns
- Operation of GEMs in magnetic field
- **Validation of single-mask technology**
- **Production of large area GEM foils**
- **New self-stretching technique for GEM assembly**

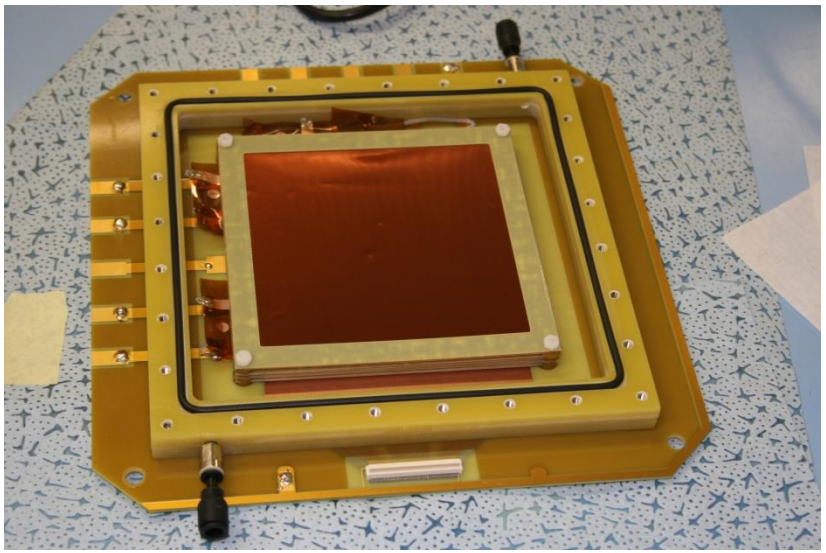


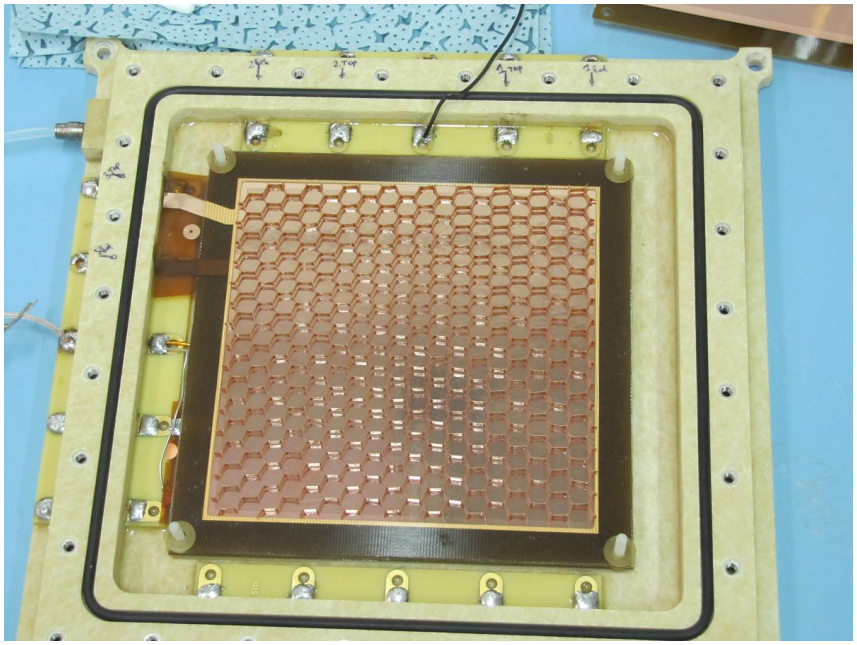




Small Prototypes (2009-2010)

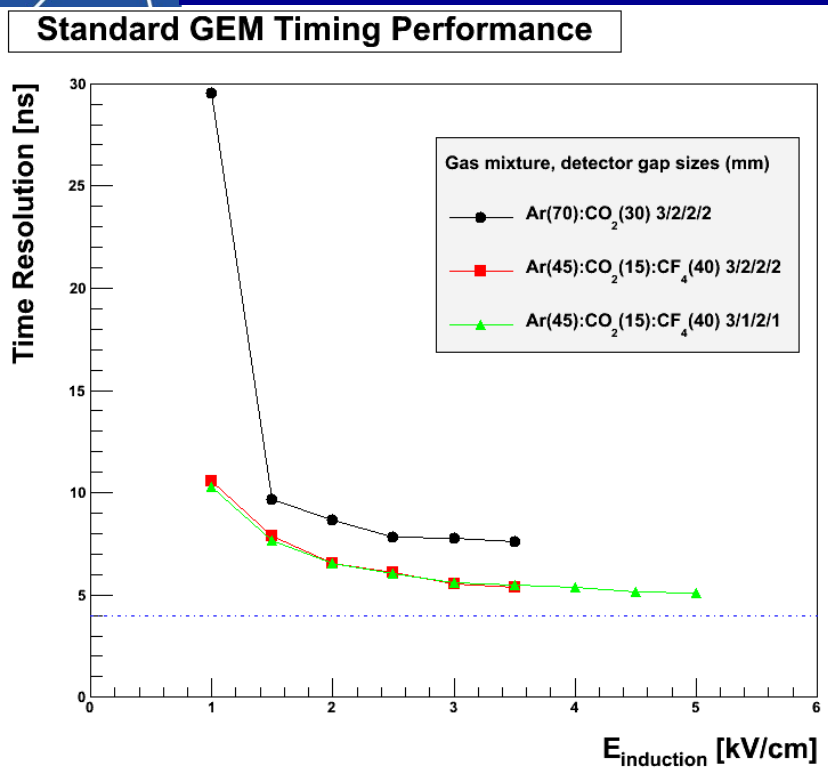
- **10x10 cm^2 triple-GEMs, 1D or 2D readout, 128 or 256 channels :**
  - ❑ Standard double-mask triple-GEM - "Timing GEM"
  - ❑ Single-mask triple-GEM
  - ❑ "Honeycomb" triple-GEM

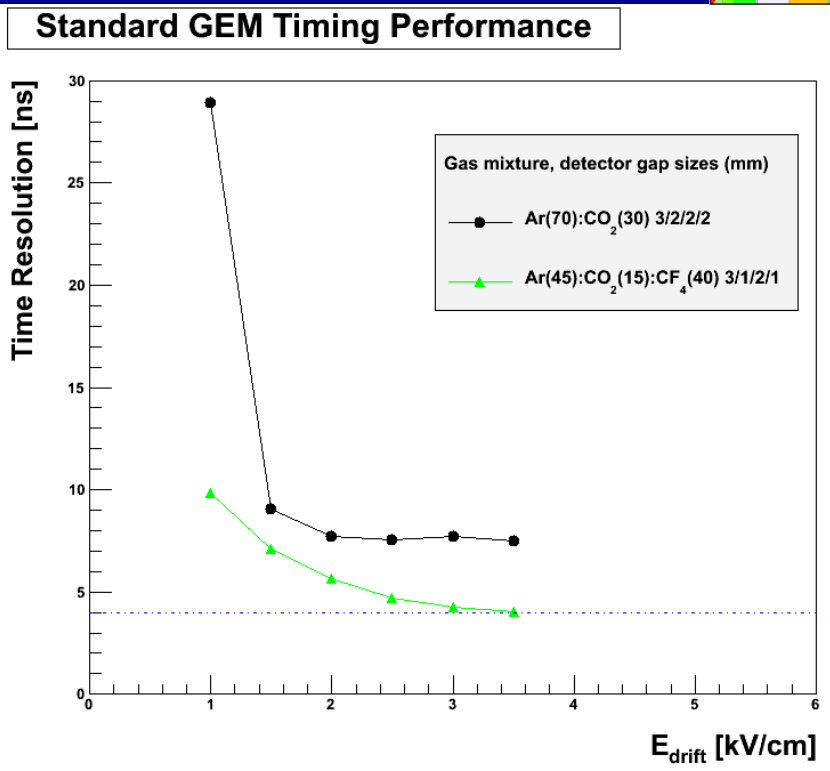




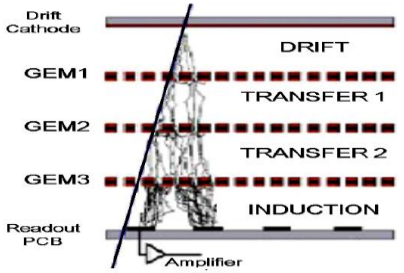
Characterization of GEM Detectors for Application in the CMS Muon Detection System
2010 IEEE Nucl. Sci. Symp. Conf. Rec. 1416-1422; RD51 Note 2010-005; arXiv:1012.3675v1 [physics.ins-det]

Timing Studies



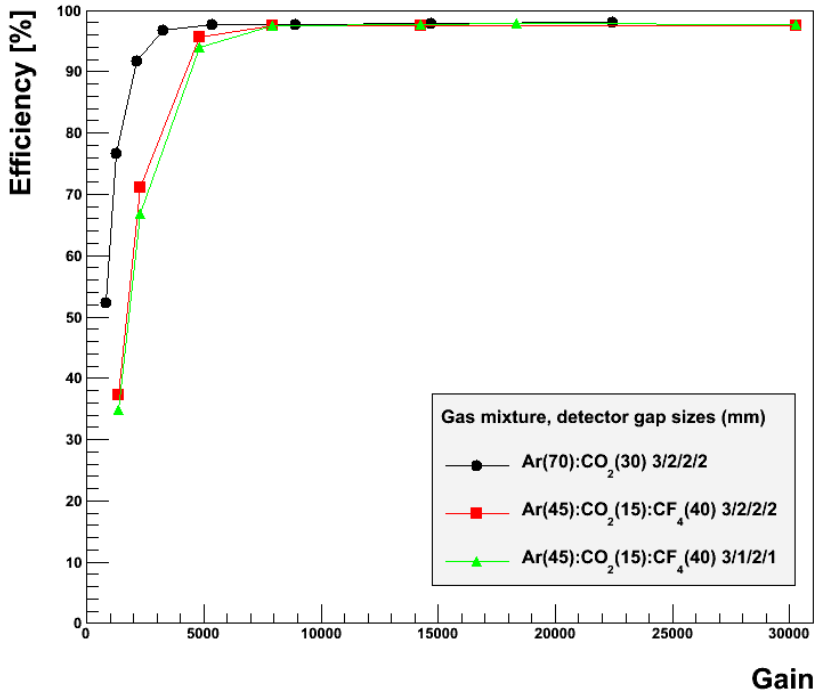


- **Custom made HV divider for Standard triple-GEM**
- **Clear effect of gas mixture, and induction and drift fiel**
- **Timing resolution of 4 ns reached**

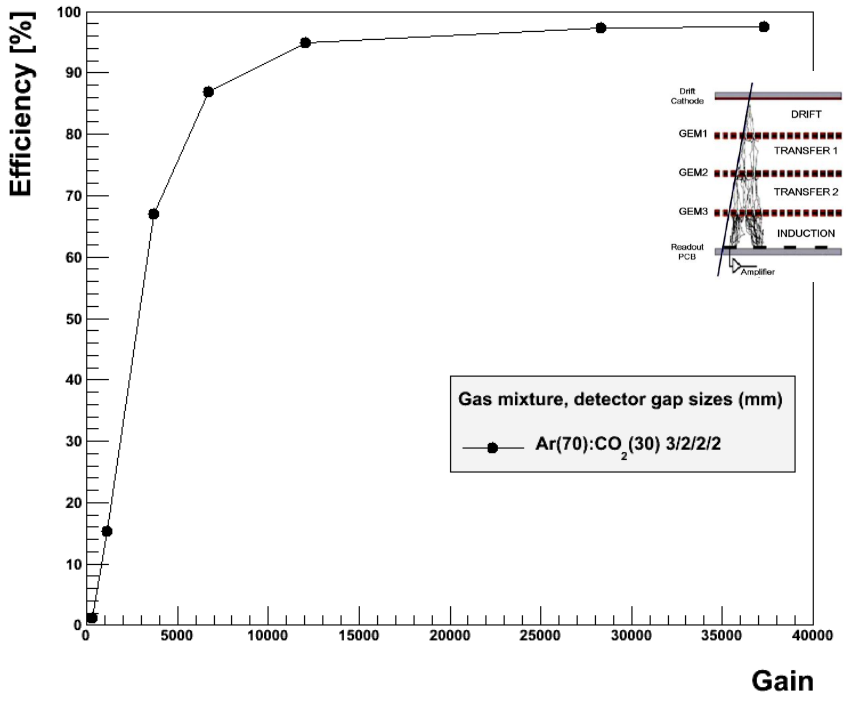


Validation of Single-Mask Technique beam test 2010-2011

Standard GEM Efficiency

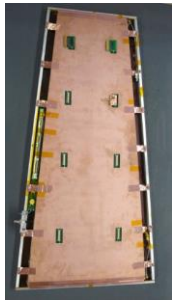


Single Mask GEM performance

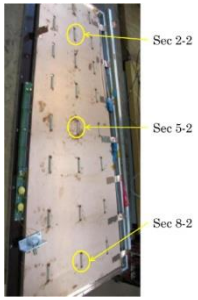


- **Single-mask GEM reaches similar performance level as double-mask GEM**
- **Single-mask technique used for large CMS-size prototypes**

Full-size GE1/1 Detectors Developments in Time



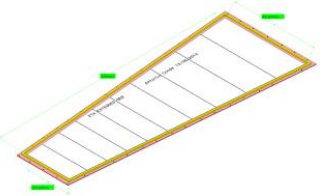
2010



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)**

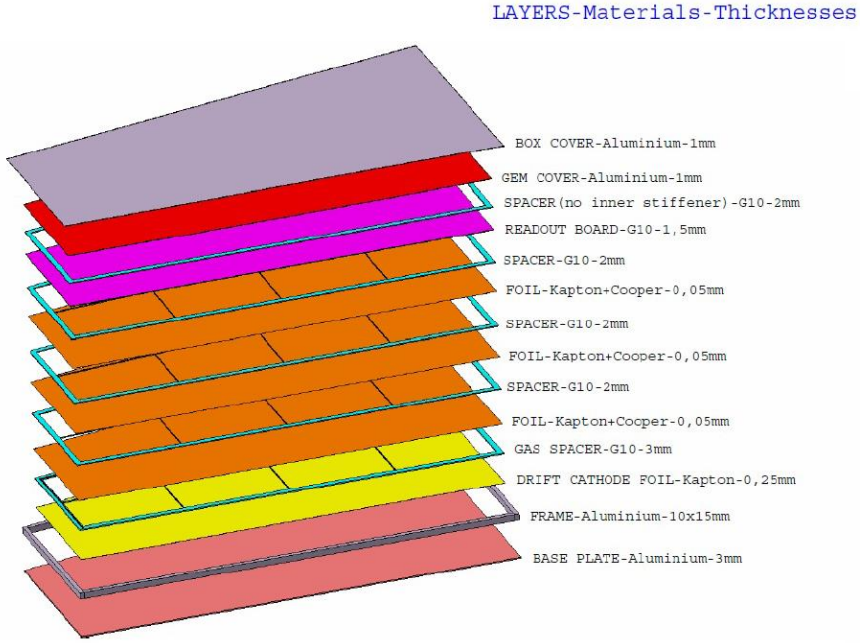
Generation II
First large detector with 24 readout sectors (3x8) and 3/1/2/1 gaps but still with spacers and all glued. Ref.: 2011 IEEE. Also **RD51-Note-2011-013.**

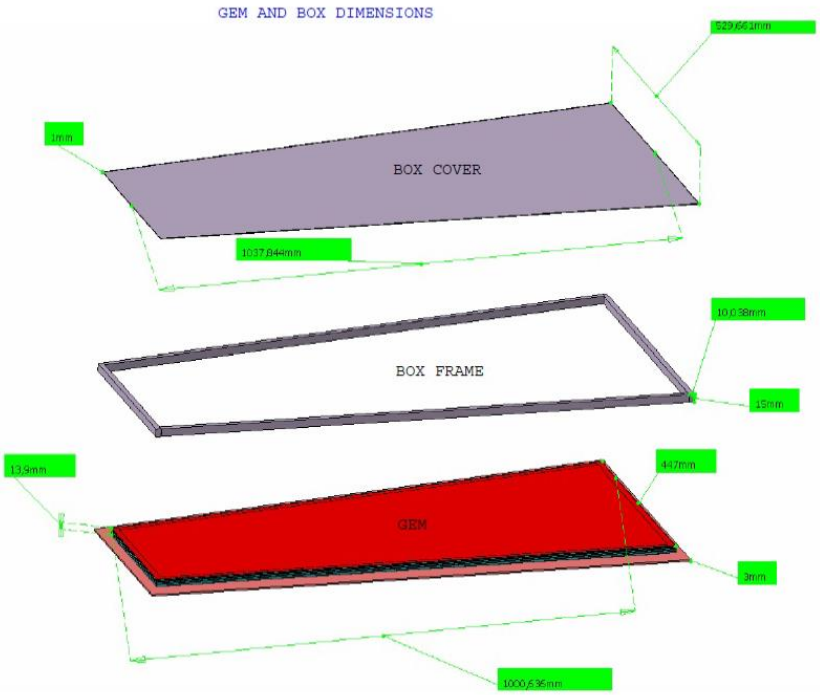
Generation III
The first self-stretched sans-spacer detector, but with the outer frame still glued to the drift. Ref.: **2012 IEEE N14-137.**

Generation IV
The current generation that we have built two of at CERN so far, with four more to come from the different sites. No more gluing whatsoever. **Upcoming papers from MPGD 2013.**

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.

GE1/1 Prototypes
Proto1 Generation I (2010)



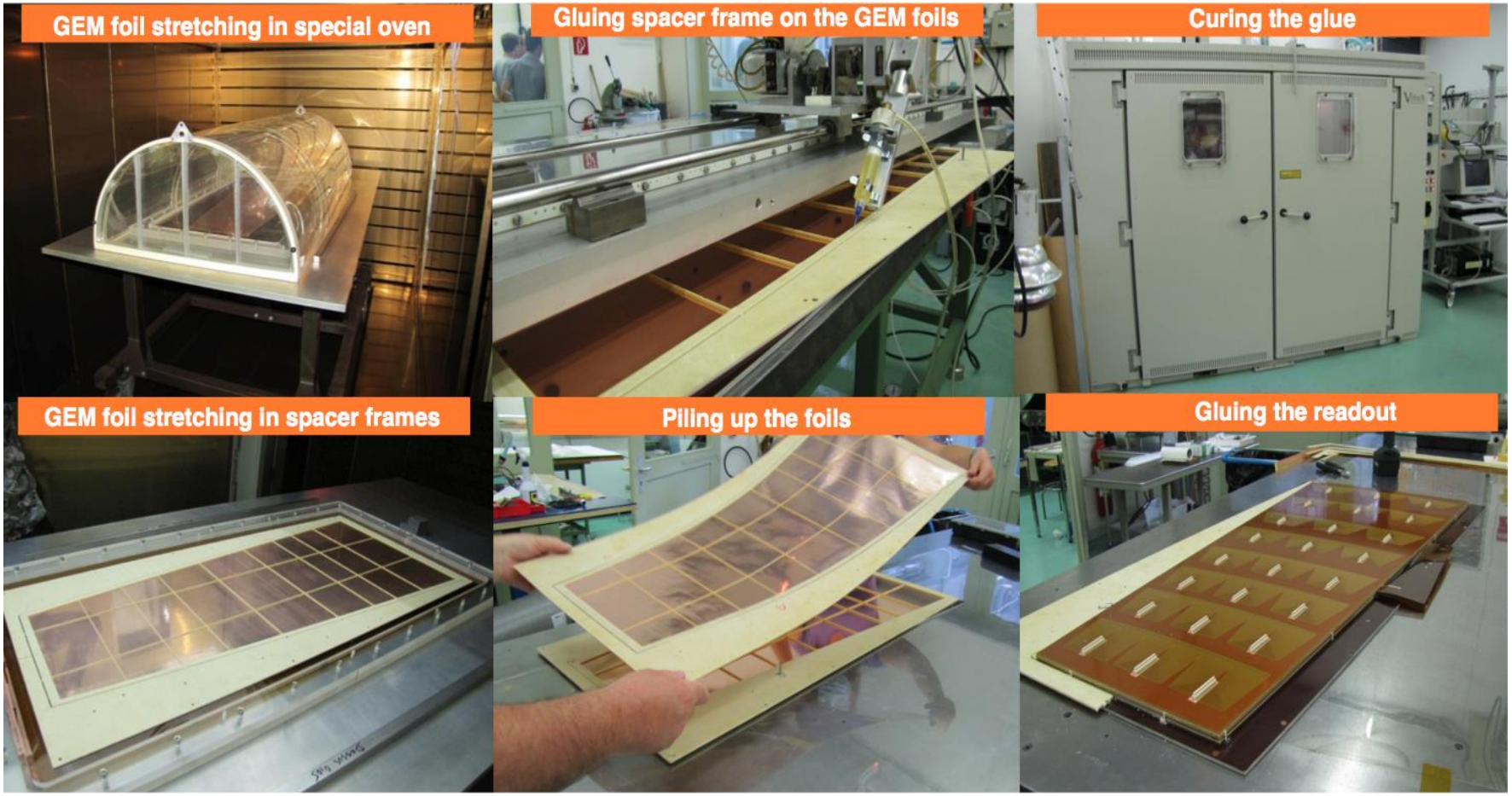


Drift - GEM1	3mm
GEM1 - GEM2	2mm
GEM2 - GEM3	2mm
GEM3 - Readout	2mm

A. Conde Garcia

GEM Foil Stretching and Assembly (I)

Thermal stretching in large oven (CERN)

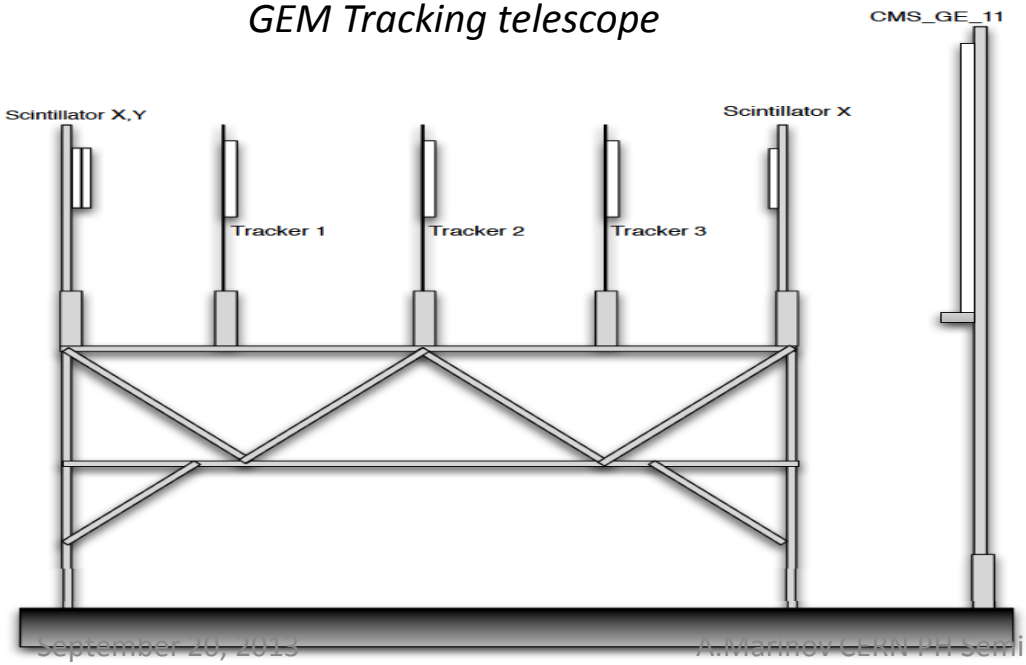


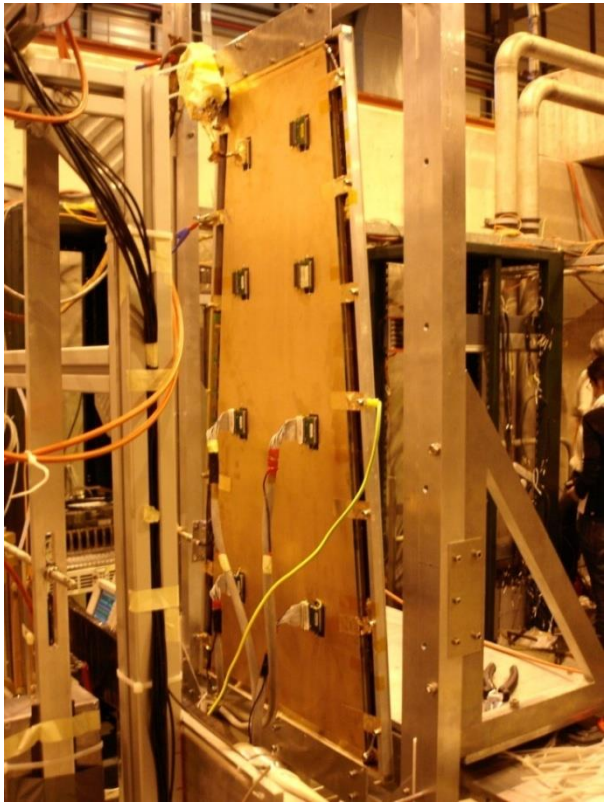
The assembly time for this detector was 1 week

CMS-RD51 Test Beams

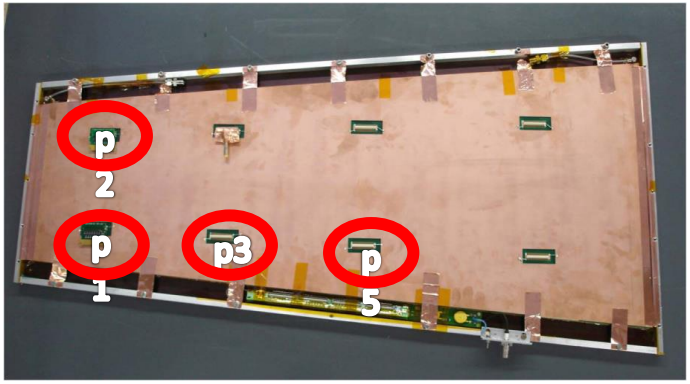
- SPS H4 beam line, 2010
- RD51 GEM tracking telescope
- VFAT2/Turbo frontend electronics
- 20 million events taken with CMS Prototype I

GEM Tracking telescope





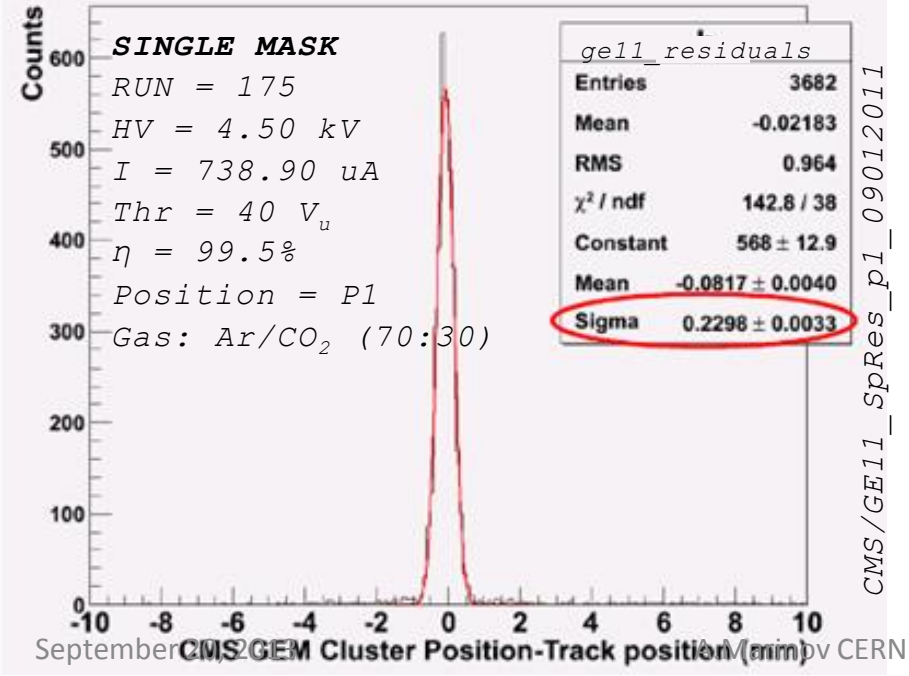
1st Generation I - GE1/1 Detector



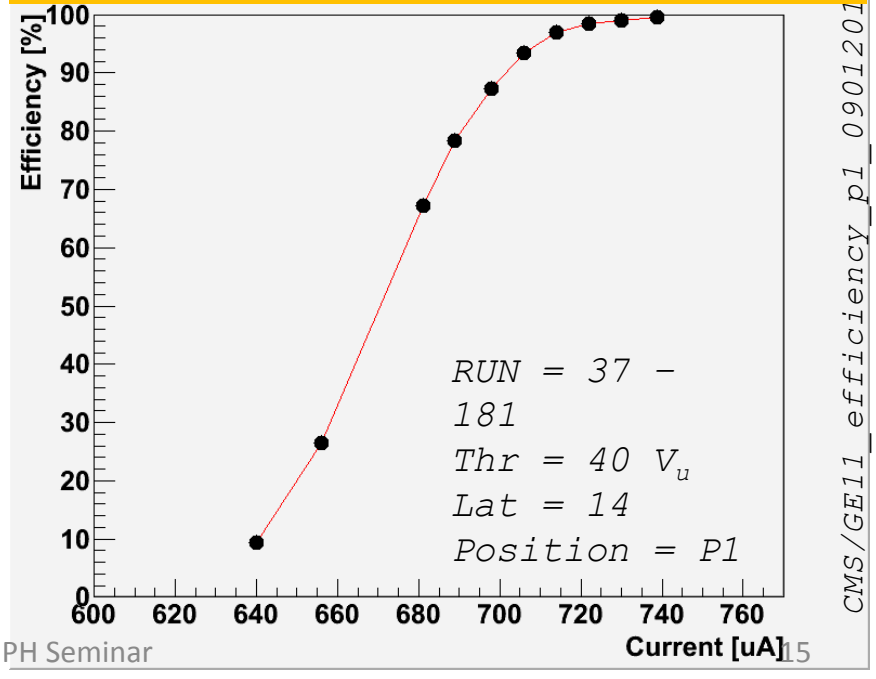
Excellent performance observed:

- ≥ 98% efficiency
- 230 μm resolution
  (≈ pitch/√12 for binary electronics)
- uniform performance in different sectors

Track residuals

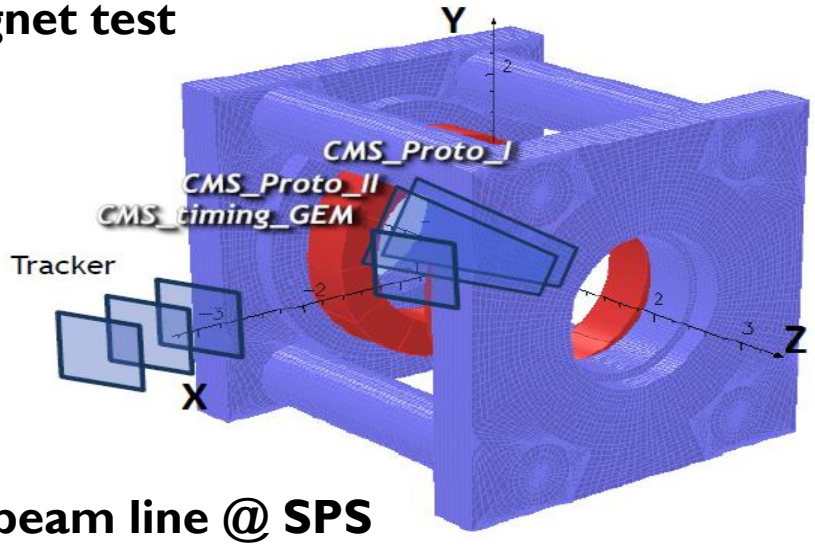


Efficiency

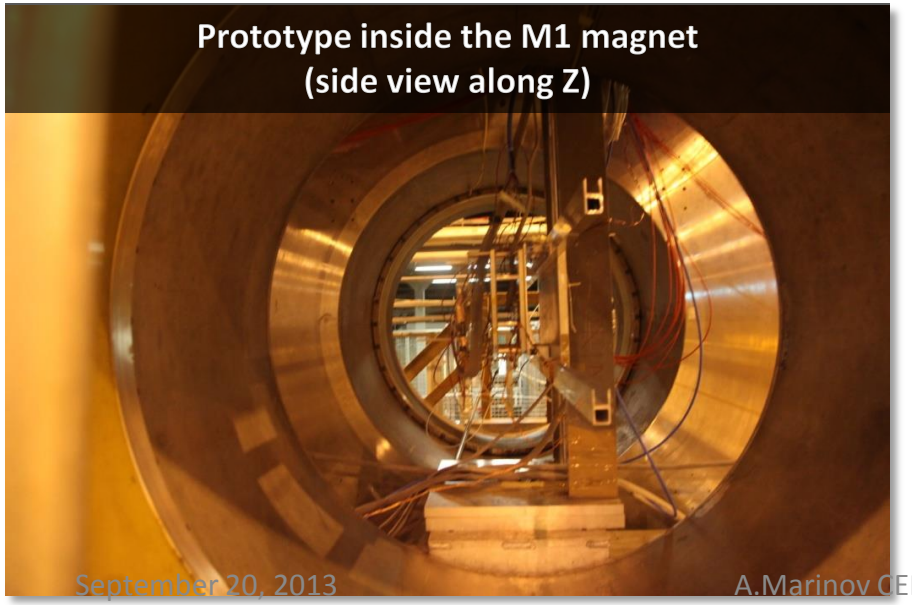


2nd GE1/1 Detector (2011)

Magnet test

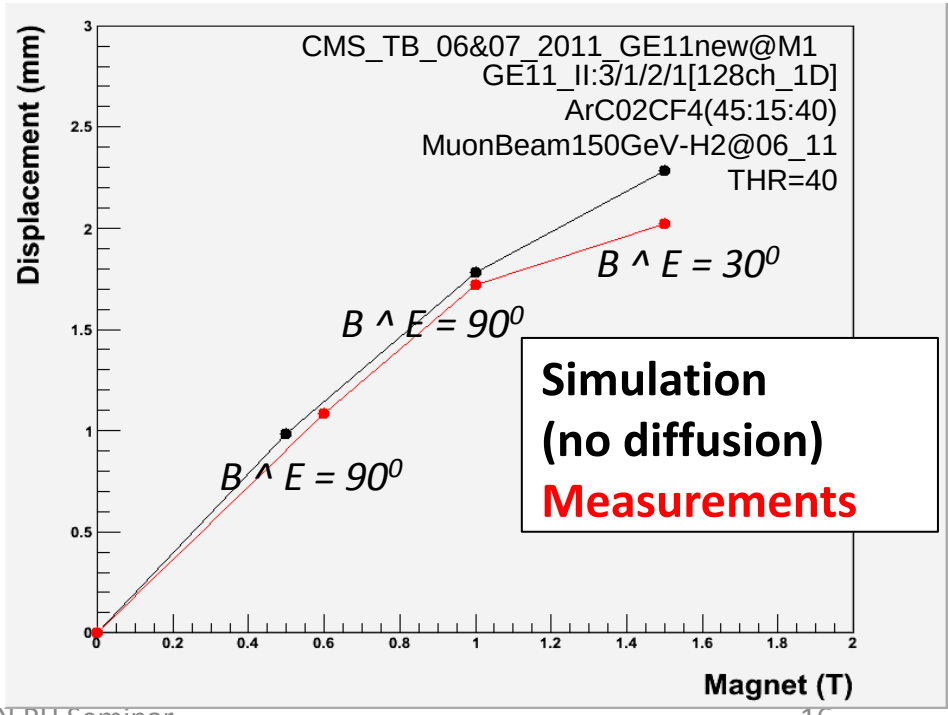


H2 beam line @ SPS



- Smaller GEM gap sizes: 3/1/2/1 mm
- More sectors: 3 columns, 8 η partitions
- Smaller strip ptich: 0.6-1.2mm
- 3072 channels, 1D readout

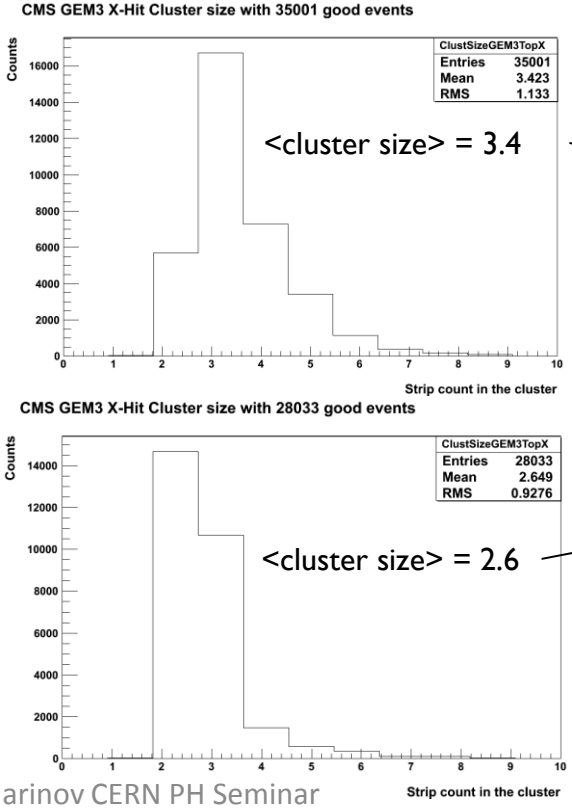
- Expect max. $B_{\perp}$~0.6T, $B_{\parallel}$~3T and B^E~8° for GE1/1



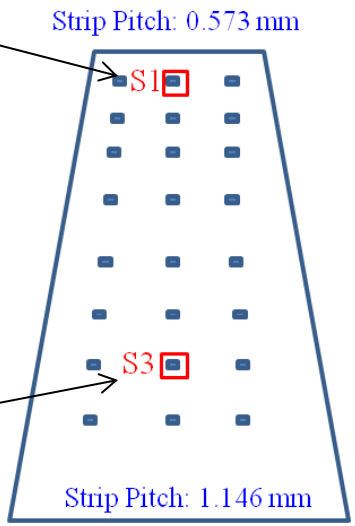
2nd GE1/1 Detector (2011)

- Successful data taking with analog APV chip and Scalable Readout System in addition to TURBO/VFAT2 DAQ system
- Measured resolution σ_x<103μm in section with smallest pitch

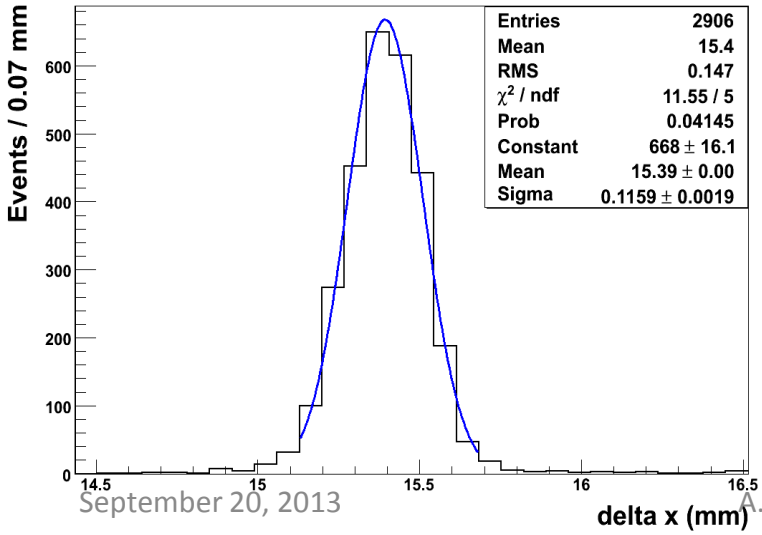
Strip cluster size



μ^-/π^- beams

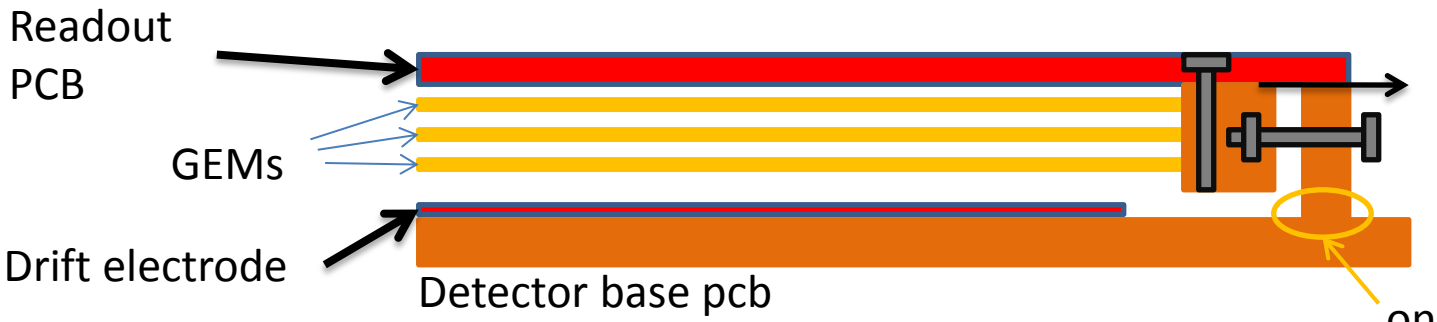


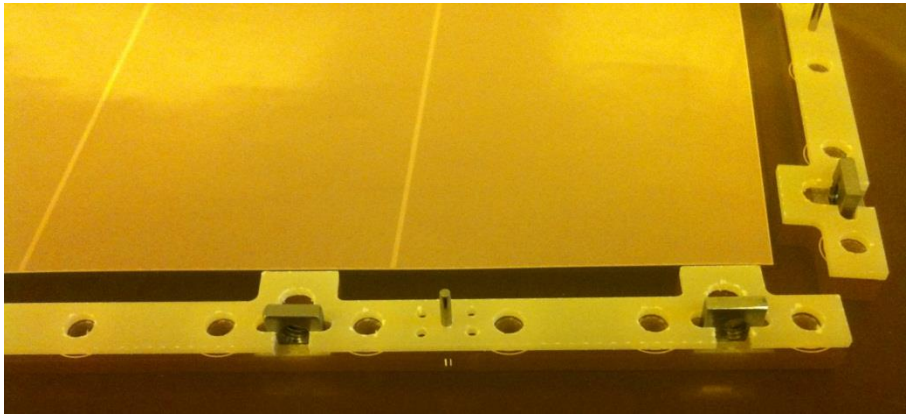
Δx_{hit} measurement : Tracker GEM vs. CMS full-size GE1/1



GEM Foil Stretching (III)

Current state-of-the-art: Self-stretching assembly without spacers (CERN)

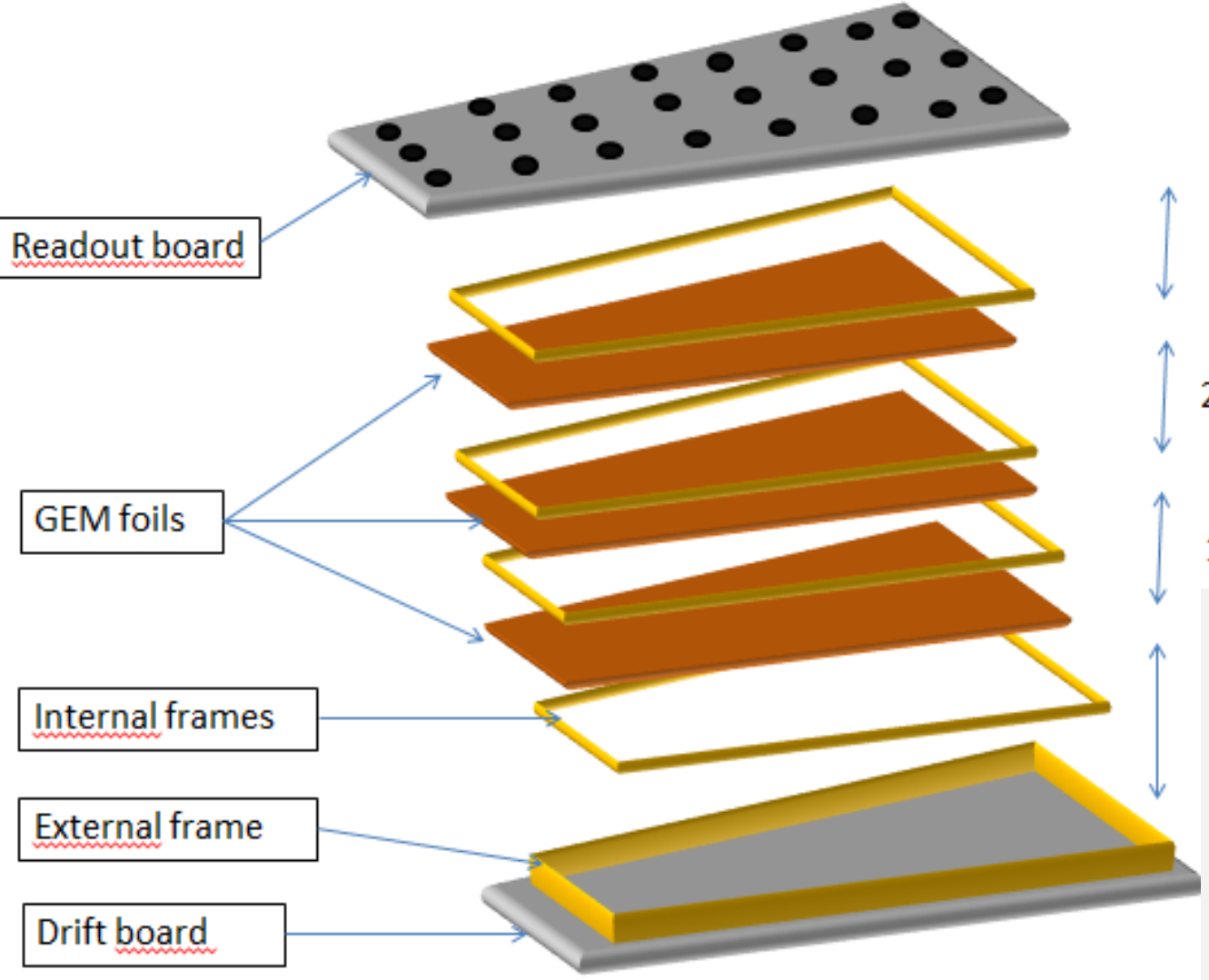




2012

Allows re-opening of assembled detector for repairs if needed

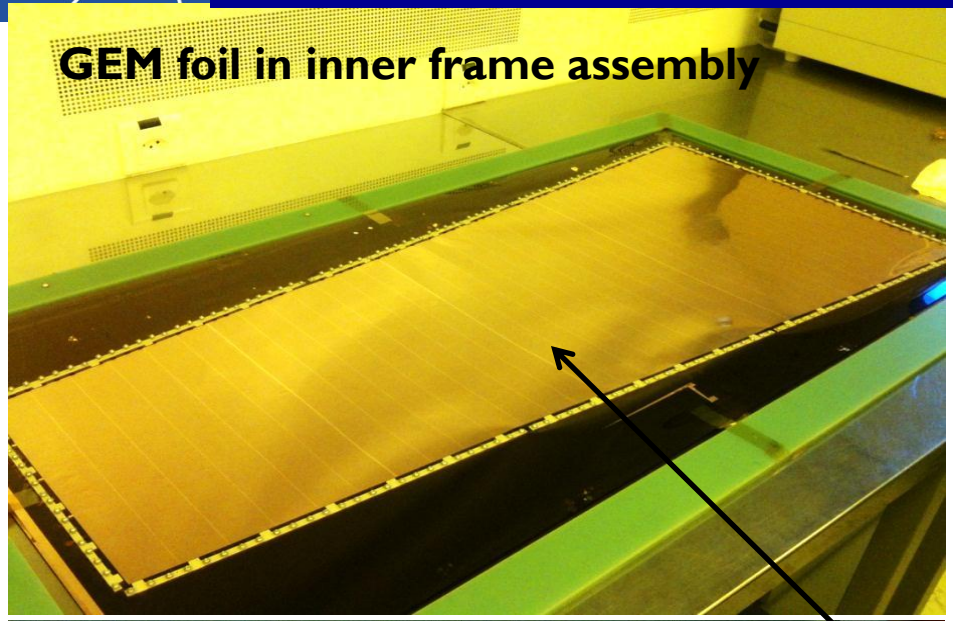
Generation IV - GE1/1 Detectors (2012)

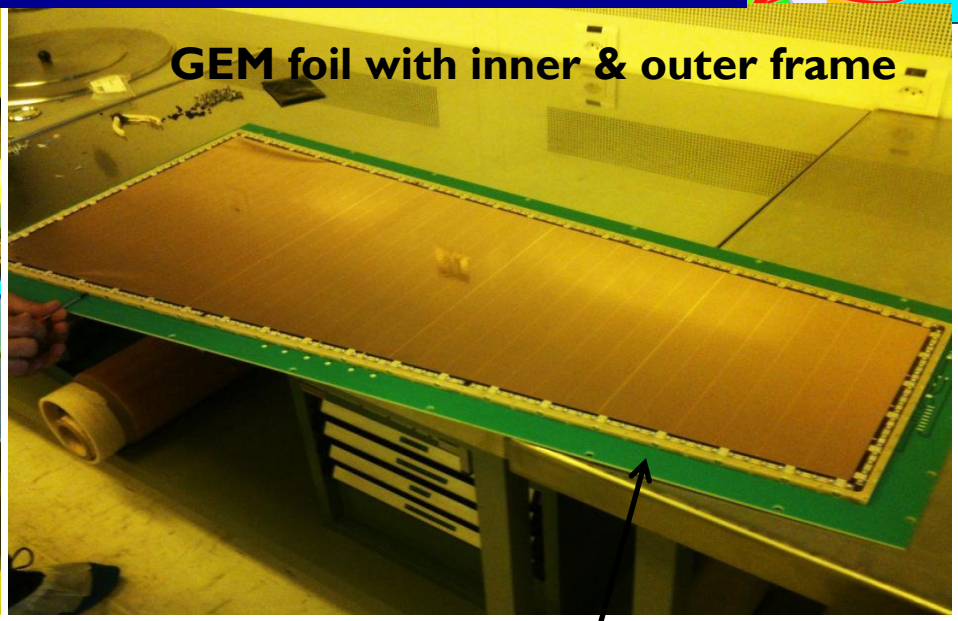


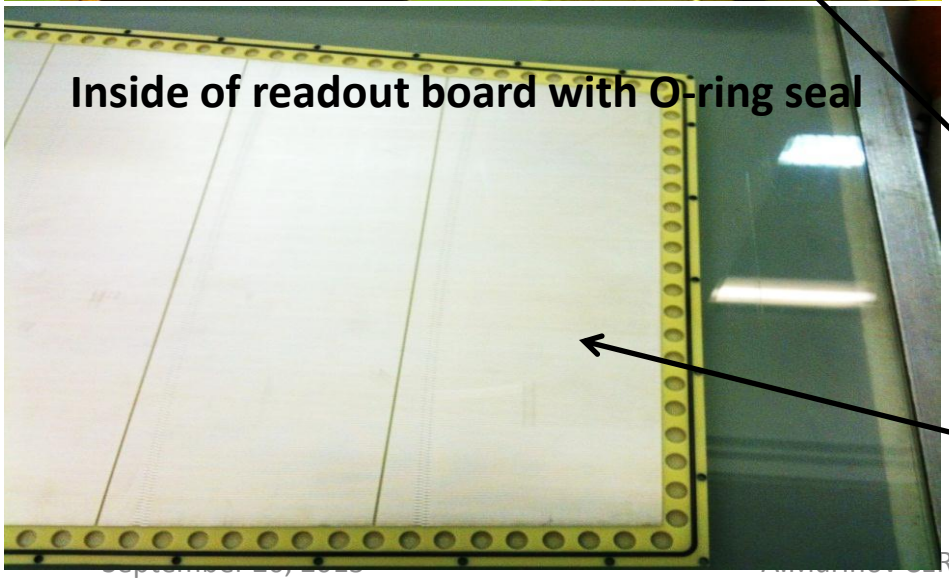
- Single-mask & self-stretching techniques
- Gap sizes: 3/1/2/1 mm
- Sectors : 3 columns x (8-10) η partitions
- Strip pitch: 0.6-1.2mm
- 1D readout of up to 3840 channels
- 35 HV sectors

Generation IV GE1/1 Prototype Full-size NS2

Generation IV - GE1/1 Detectors (2012)







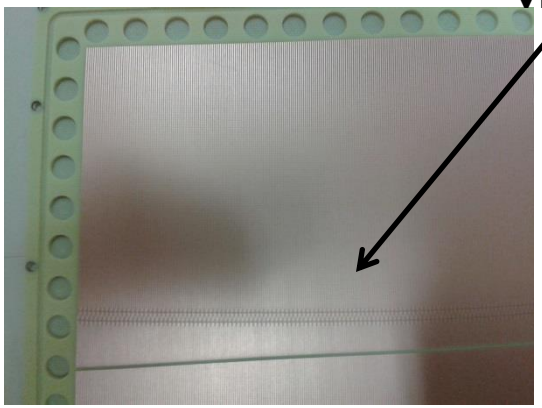
Base pcb with drift electrode

No spacers in active volume

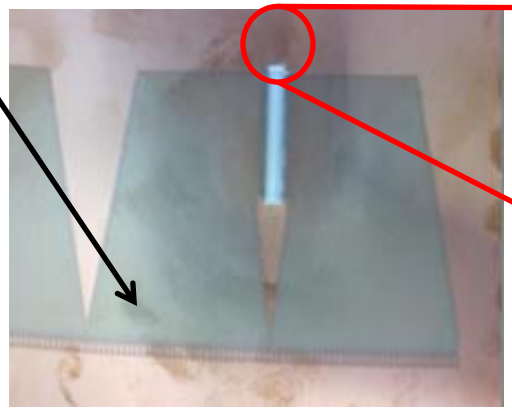
η-sector with 384 radial readout strips

Add-film 1 min

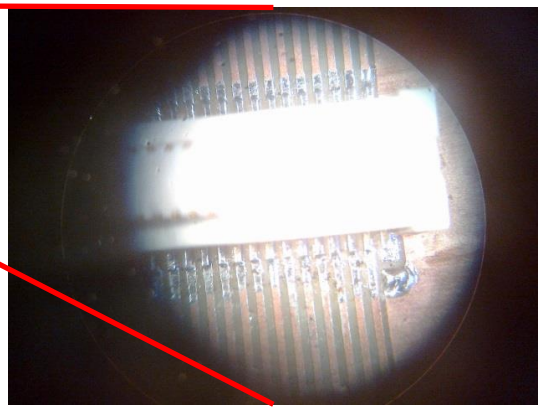
GE1/1 Readout & Drift Board



Strip side

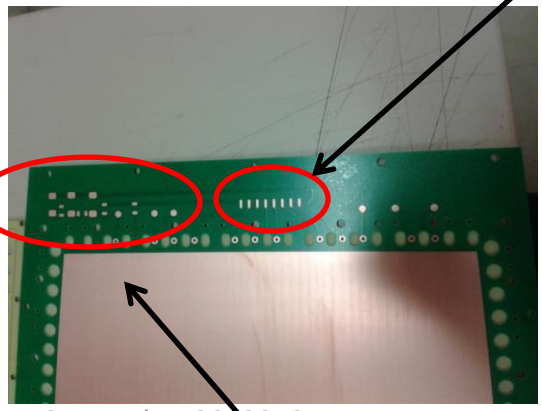


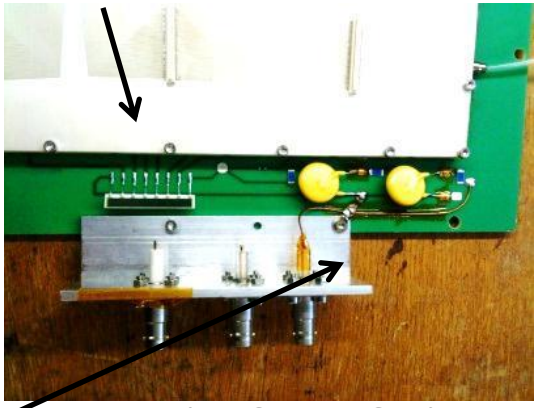
External side

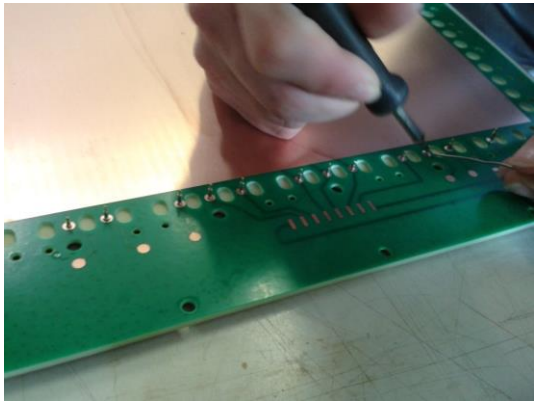


Readout board: metalized vias bring the signal to the other side of the board; panasonic connector with 128 entries is soldered on the strips

Drift board: HV spring contacts to connect foils to HV; 4 contacts per GEM (Top/Bottom + redundant connection)

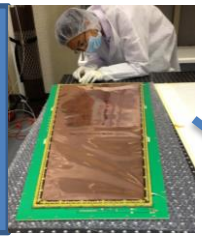




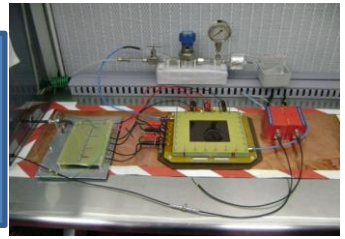


Soldering spring contacts

Possible Production Sites



USA
FIT



India

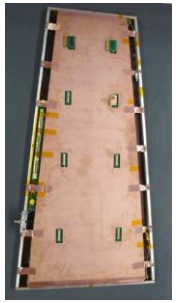
CERN
Production and
final QC

Italy

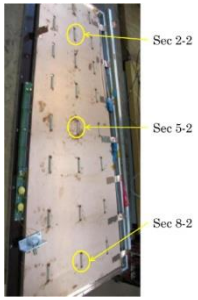
Belgium
Gent
University

Installation in
CMS

Full-size GE1/1 Detectors Developments in Time



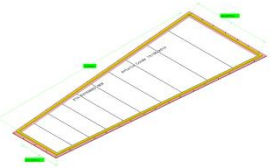
2010



2011

2012

2013



2013/14

Production and QC of detectors First prototype of VFAT3

2014/15

Slice installation

2015/16

Slice and trigger commissioning

2016/17

QC of Production GE1/1 chambers with final electronics

2017/18

2018/19

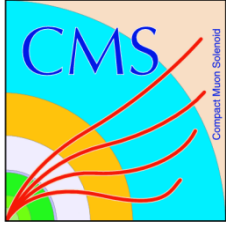
Full-production of chambers and electronics started

Full installation of GE1/1 with final electronics

Conclusions

- GEM a viable technology for CMS Upgrades established
- Extensive R&D program launched and carried out
- Large size GEM foils made with single mask technology
- 6 Full scale GE1/1 detectors built and assembled with NS2 technology
- Performance commensurate with requirements demonstrated by test beams and lab tests
- Long term sustained operation tests ongoing
- Services for the slice test in 2016 must be finished and commissioned before the end of LS1 period.
- Production sites gearing up for final chamber assembly and test
- QC and validation procedures optimized
- Next steps
    - Launching production of 10 final detectors for slice test and other laboratory tests

For more Information you can refer to our twiki page:
https://twiki.cern.ch/twiki/bin/view/MPGD/CmsGEMCollaboration



Thank You !