Update on GE21 and ME0 projects

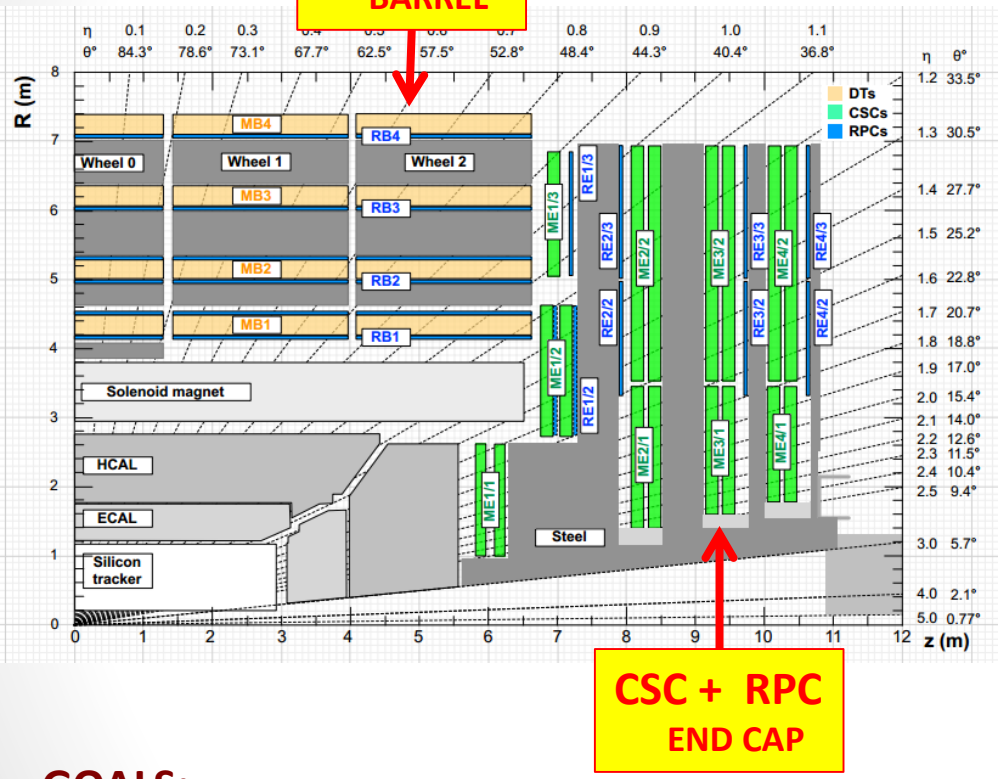
M. Bianco on behalf of CMS-GEM group

OUTLINE

- CMS Muon Spectrometer upgrade with GEM
- GE 2/1
  - GE2/1 Layout
  - GE2/1 prototypes
    - First assembly of working module (GE2/1-M4)
    - Characterization of M4 prototype: Gain and Uniformity
    - GE2/1 chamber assembly test
  - GE2/1 project schedule
- ME0
  - Stack layout finalization
  - ME0 project schedule
- On-going R&D
  - Readout board layout studies
  - External frames alternative solution studies
- Common feature with GE1/1
- Summary

The CMS Muon System

Highly hermetic and redundant muon system, at least four stations on a muon path in all directions



3 technologies:

- **Drift Tubes** and **Cathode Strip Chambers** (for tracking and triggering);
- **Resistive Plate Chambers** (for triggering).

Eta coverage:

- $|\eta|<1.6$: 4 layers of CSCs and RPCs, DTs
- the $|\eta|\geq1.6$: CSCs only;

GOALS:

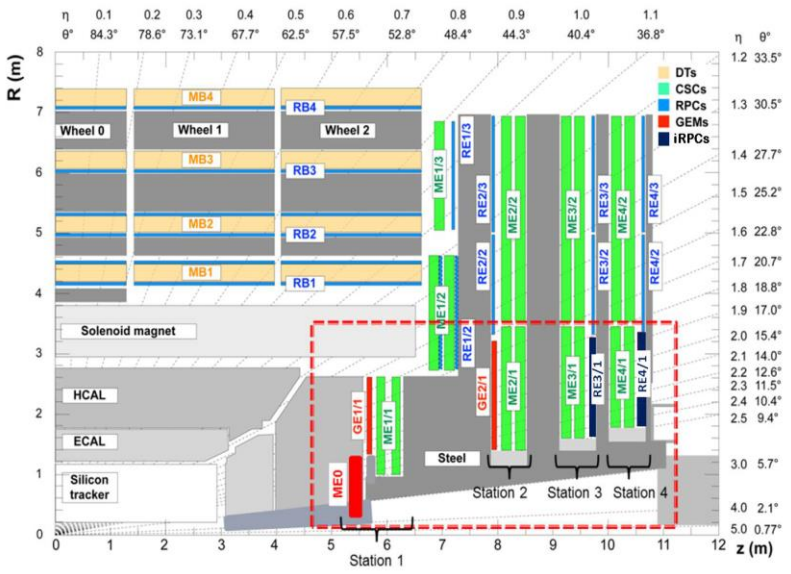
- **robust**, **redundant** and **fast** identification of the muons
- **Level-1 trigger** has access to muon information only
- **Momentum measurement**: the muon system is relevant for high pt muon (>100 GeV) and in the high η region (large lever arm of the muon system)

CMS Forward Muon Spectrometer Upgrade

The forward region |η|≥1.6 is very challenging,

- **Redundancy**: the highest rates in the system vs fewest muon layers
- **Few** handles for the new Track finder postLS2 and for the track-trigger in HL-LHC
- **Rate** : in 10's of kHz/cm^2 and higher towards higher eta and worse momentum resolution
- **Longevity:** Accumulated charge after many years of LHC operation
- **Electronics:** High occupancy/rate and latency increases exceed capabilities of the existing electronics

Eta coverage:
- **|η|<1.6: 4 layers of CSCs , RPCs, DTs**
- **the |η|≥1.6: CSCs only;**



- Objectives:
  - Sustain triggering at current trigger thresholds
  - Increase offline muon identification coverage
  - Maintain existing envelope by mitigating aging effects

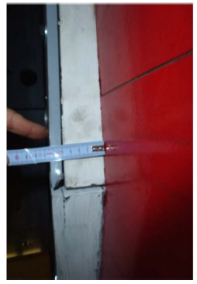
GE2/1 Position and constraints

GE2/1 will be mounted on the back of YE1, station 2. Thus All the services should be installed on YE1 to secure minimum lengths, specially for the LV lines. LS2 is the best moment for the GE2/1 services installation

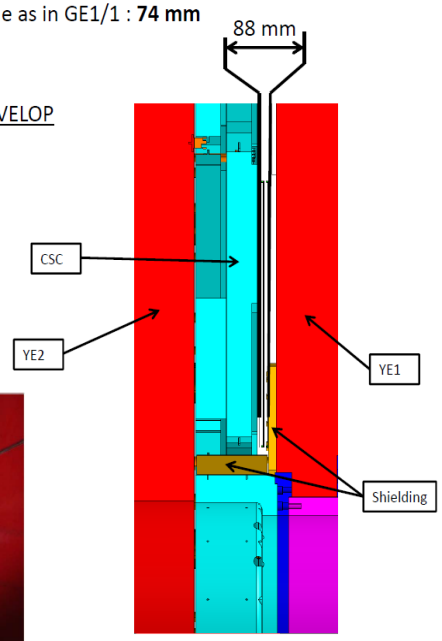
The thickness of the superchambers pile is same as in GE1/1 : **74 mm**

WE ARE DEALING WITH THE LIMITED ENVELOP

DISTANCE FROM YE1 TO CSC CHAMBERS:	153mm
SHIELDING:	- 65mm
GAP:	88mm
SUPERCHAMBER:	-74mm
CLEARANCE:	**14mm**



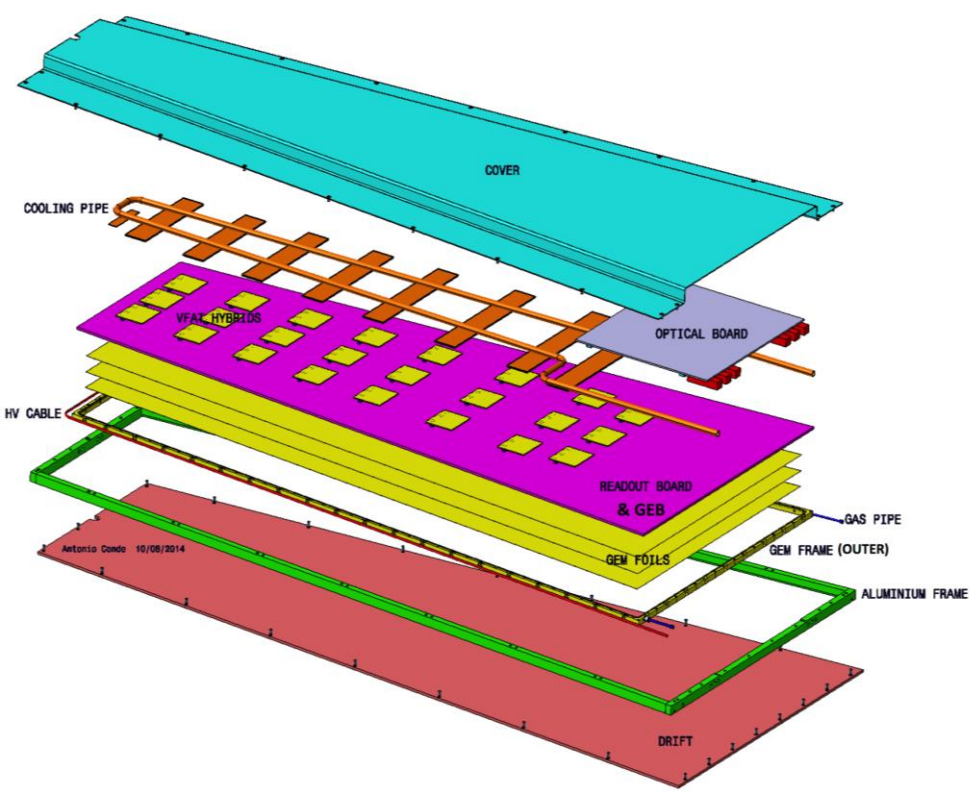
(Shielding thickness 65mm)

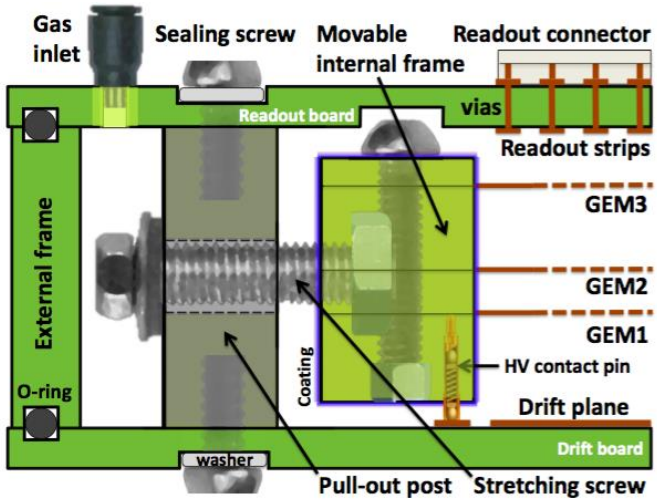


CMS Triple-GEM detector

Same mechanical design principle as GE1/1 with 3/1/2/1 mm gaps

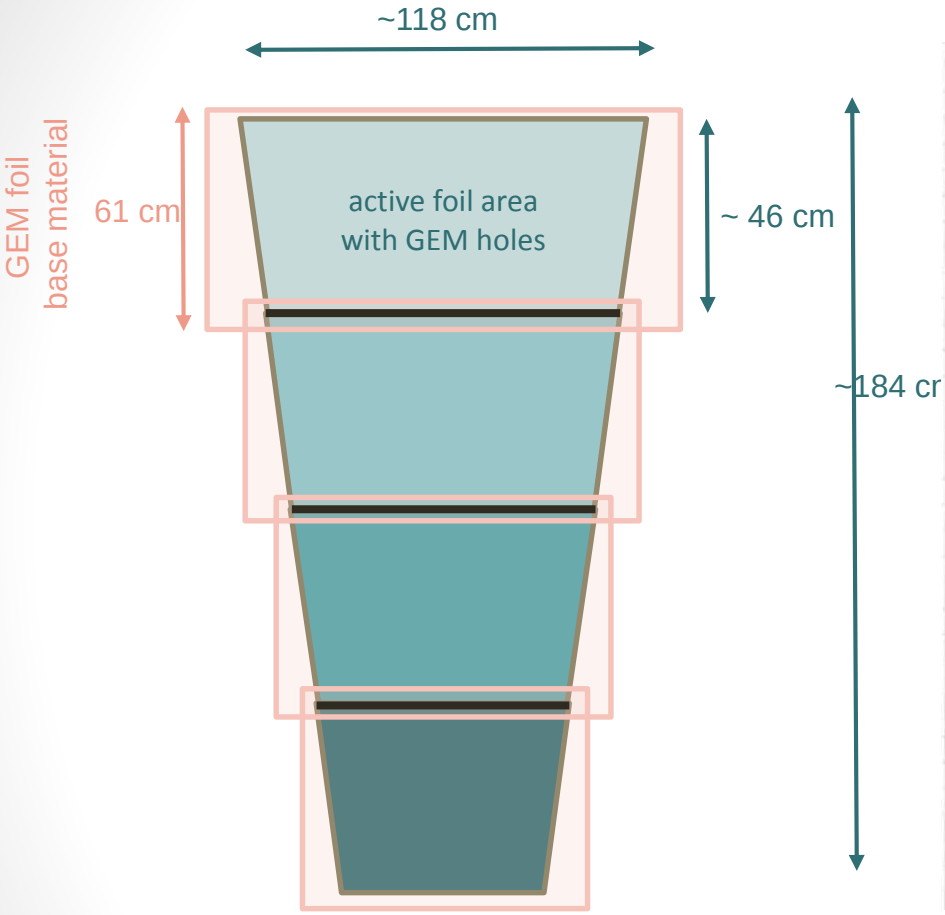
Mature technology based on mechanical foil stretching used for all three GEM detectors:

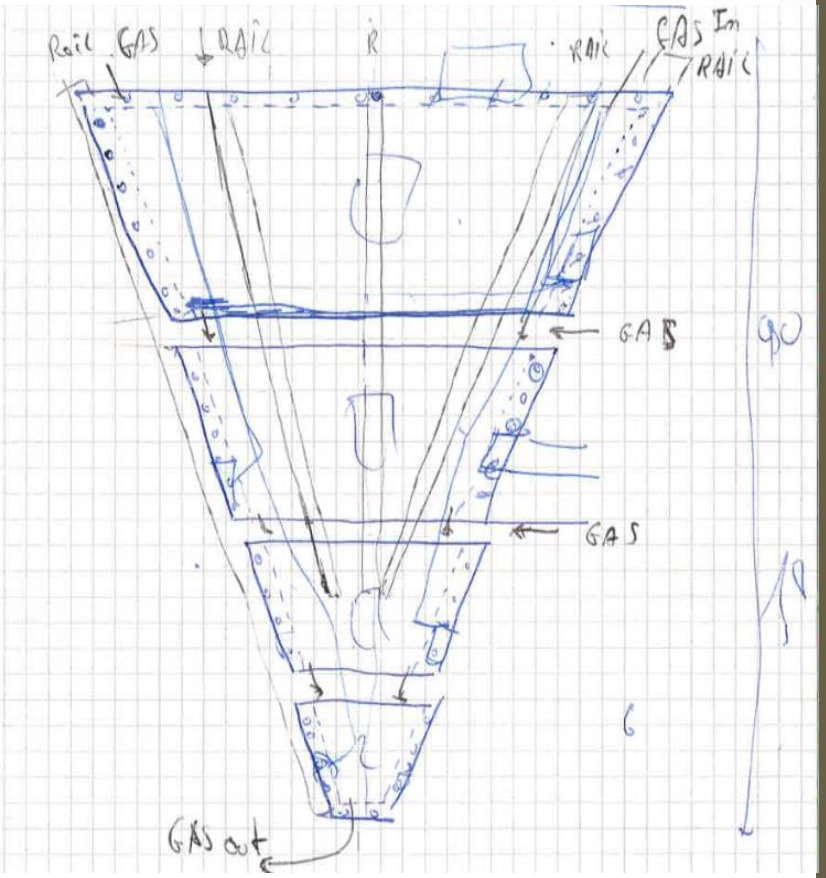




GE1/1, GE2/1, ME0 with 3/1/2/1 mm gaps

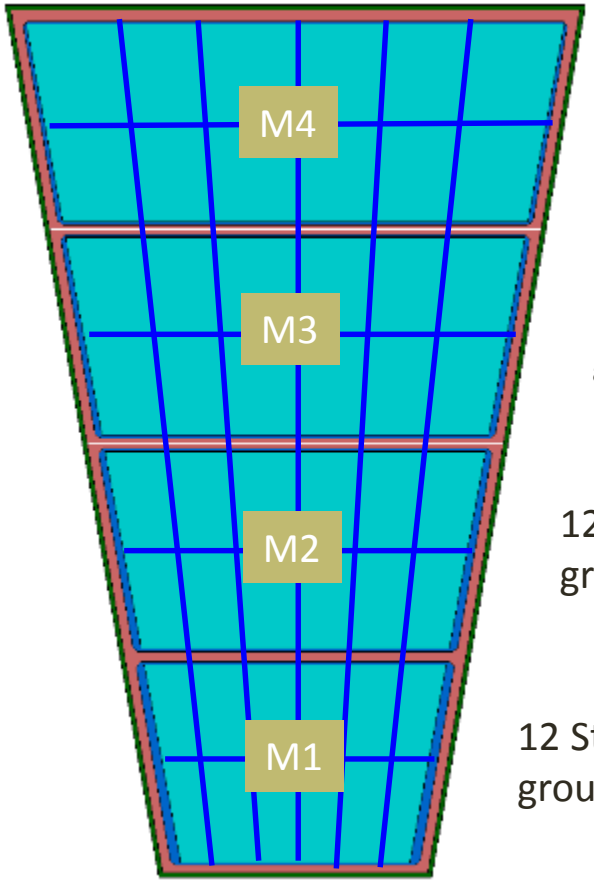
GEM 2/1: 20 degree, four independent module option





- Four independent detectors to be coupled together
- No splice
- Same technologies and mechanical solution adopted for GE1/1 (Frame/stretching/….)

GE2/1 Chamber - Conceptual Layout

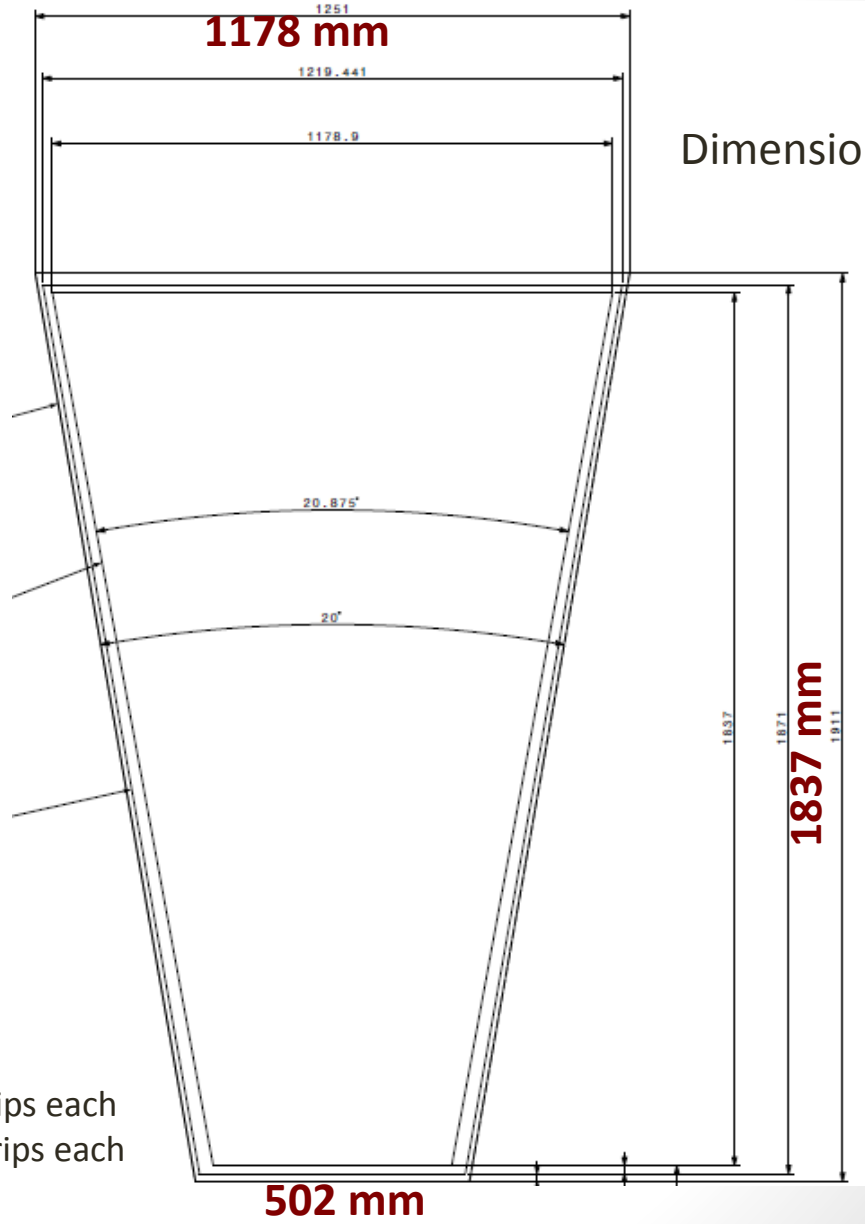


12 Strip groups

12 Strip groups

12 Strip groups

12 Strip groups



Dimensions

- Each chamber consists of 4 modules
- Each module segmented into 2 η-partitions with 768 strips each
- Each η-partition organized into 6 groups of 128 radial strips each

GE2/1 Project

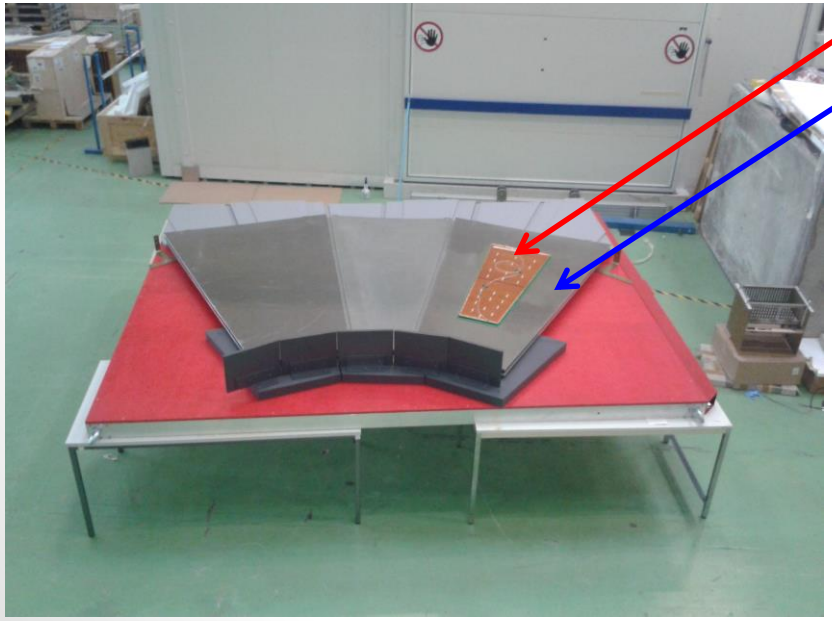
Installation in *EYETS* (2022 and 2023)

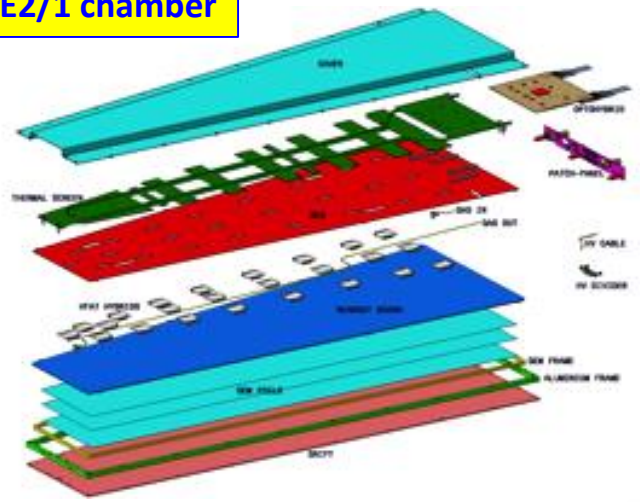
The baseline GE2/1 station consists of 36 20^0 Super Chambers, the layout will be similar to GE1/1, but covering much larger surface. ($1.62<\eta<2.43$)

Limits in space make the GEM technology perfect candidate for GE2/1

Same technical solution successfully adopted for the GE1/1 (3/1/2/1 mm gaps)

Each GE2/1 Superchamber realized with two single chambers

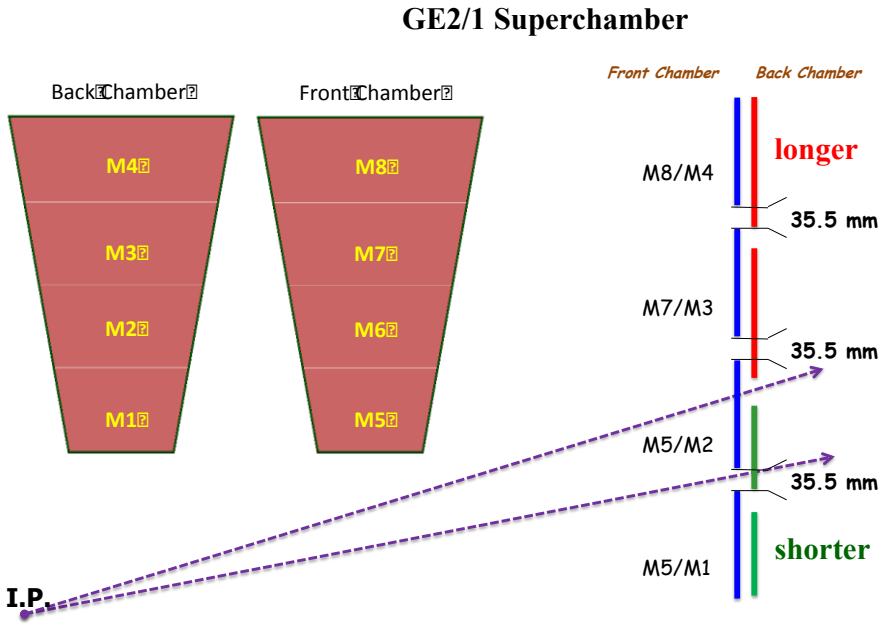


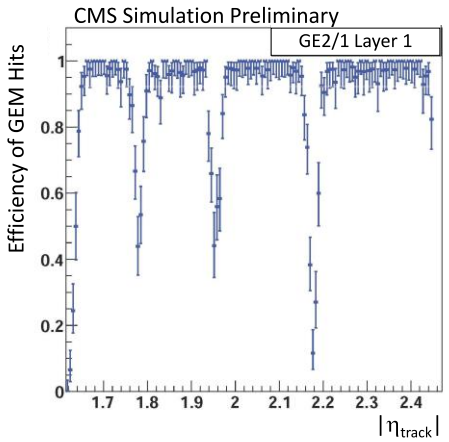


GE2/1 Project

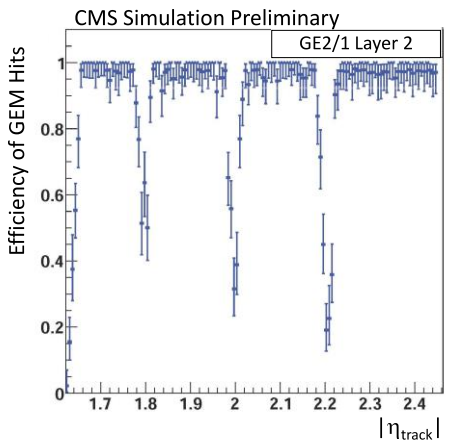
GE2/1 Chambers will consist of 4 modules each (288 in total)

To achieve the maximum coverage modules which realize Front and Back chambers will be staggered, as a consequence 8 different modules are foreseen for the GE2/1 production

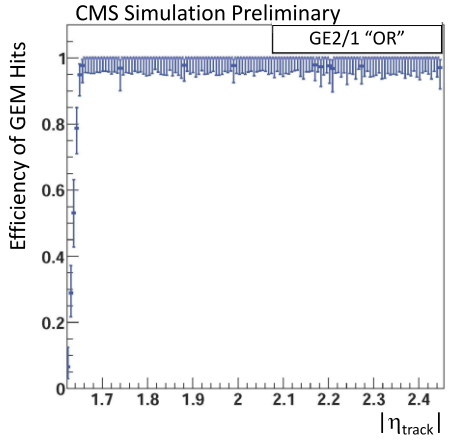




Front Chamber Hits Efficiency



Back Chamber Hits Efficiency



Super Chamber Hits Efficiency (OR)

GE2/1 Chamber prototype

GE2/1 design is on going, general chambers dimensions as well as single module dimensions are fixed

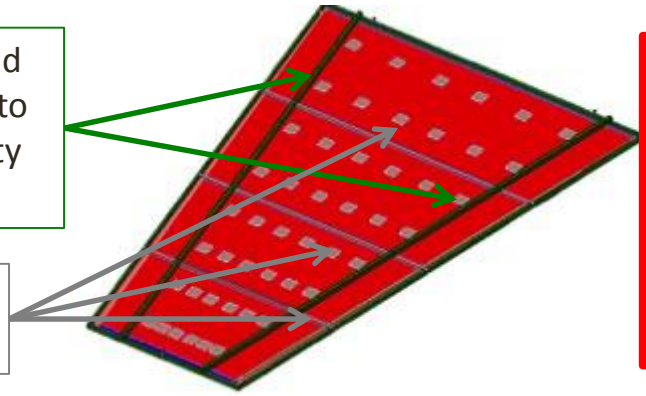
First GE2/1 module (the largest one) already build at CERN and tested

GE2/1 full chamber assembled to fully validate the GE2/1 chamber mechanics

Start of GE2/1 mass production foreseen during second half of 2019, when the GE1/1 production will finish

Two transversal bars, which hold the modules have been added to increase the mechanical stability of the full chambers

Three stiffener bars to join the modules together

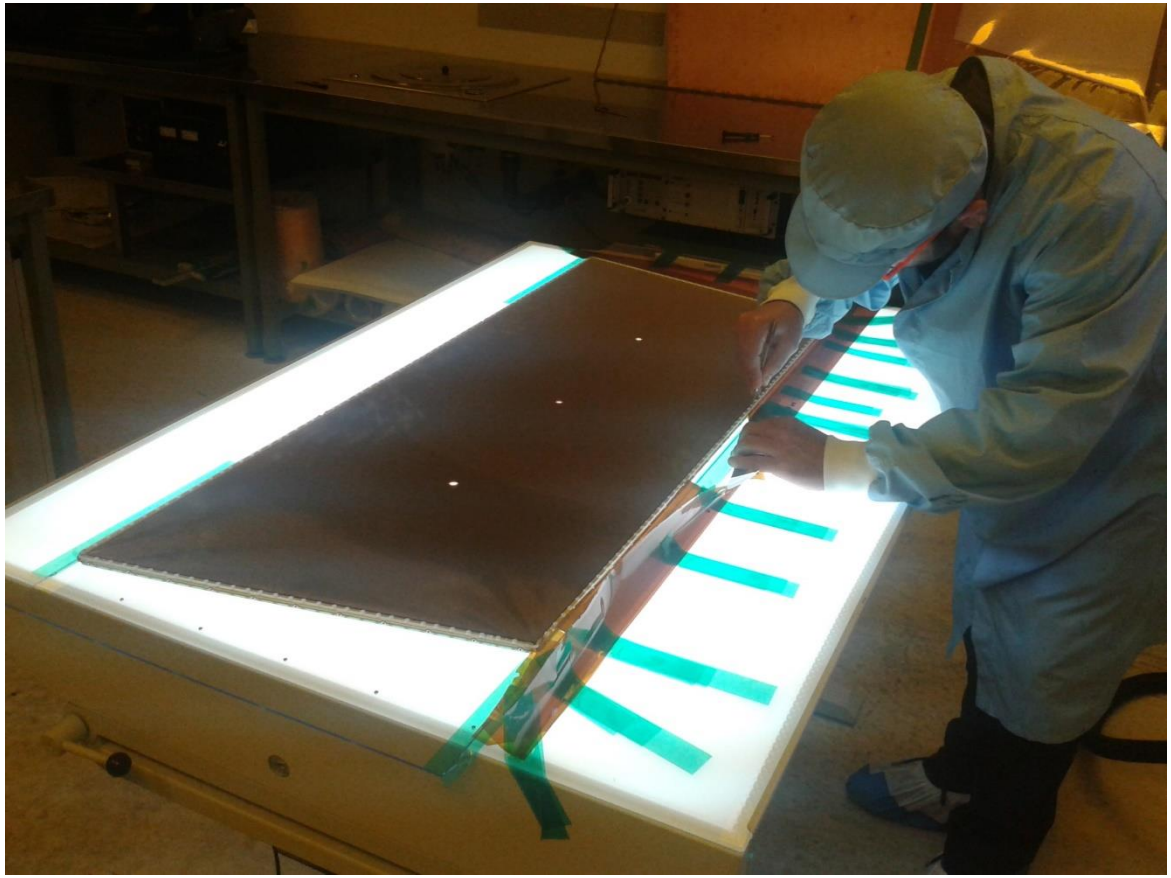


Several synergy are foreseen between the GE1/1 and GE2/1 project (e.g. Same QA/QC strategy, same production sites, same front-end electronics, similar cooling strategy, …….)

First working module - M4

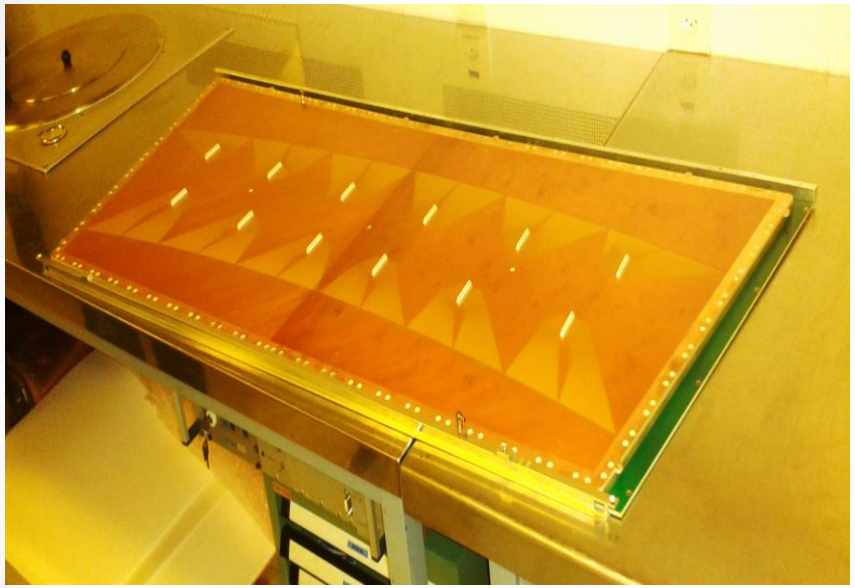
The first working GE2/1 module (M4) was successfully assembled in 2017.

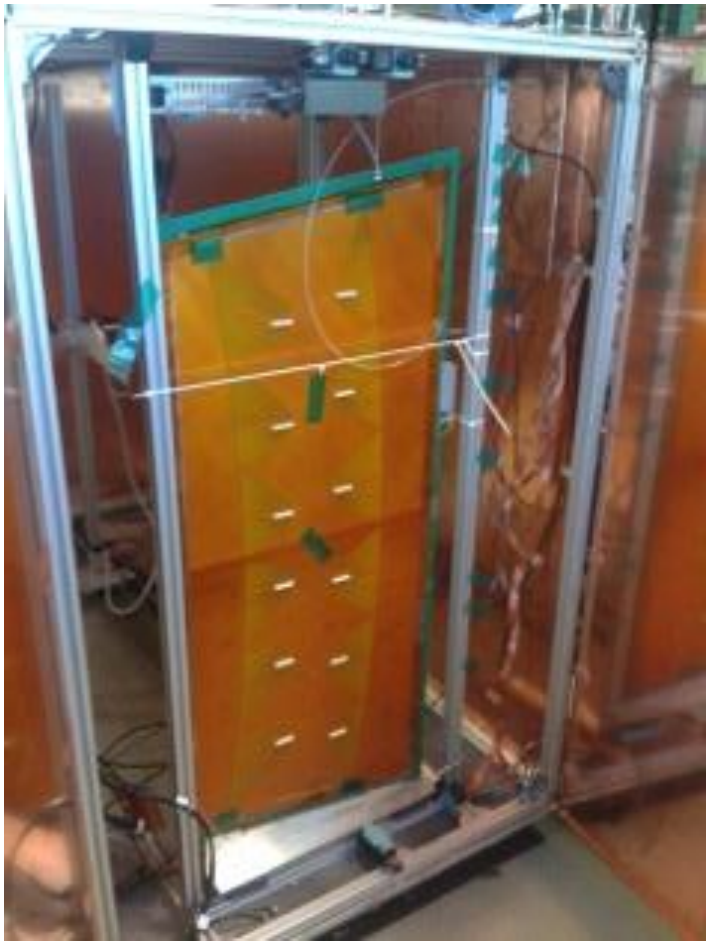
The module has been fully tested following the same qualification procedure adopted for the GE1/1 chambers (QC1-QC5).



First working module - M4

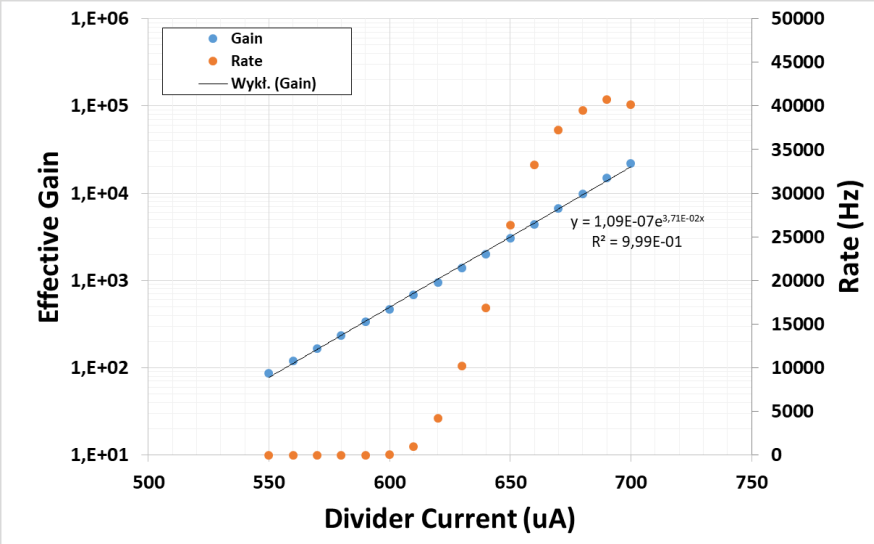
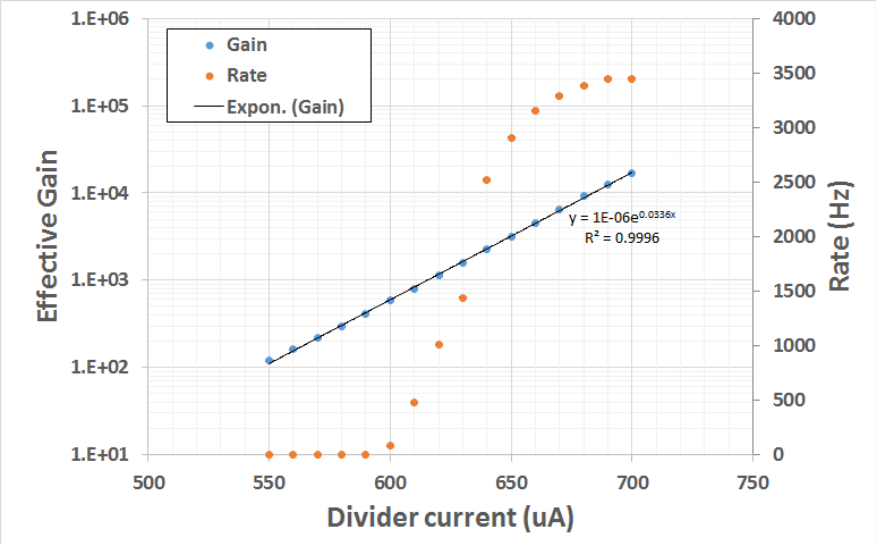
First M4 prototype module built by GEM team at CERN:





Tested with X-rays
(QC as for GE1/1)

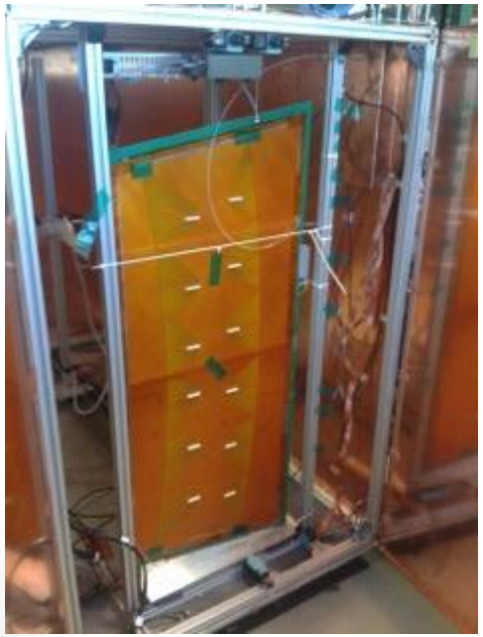
GE2/1 M4 Gain calibration

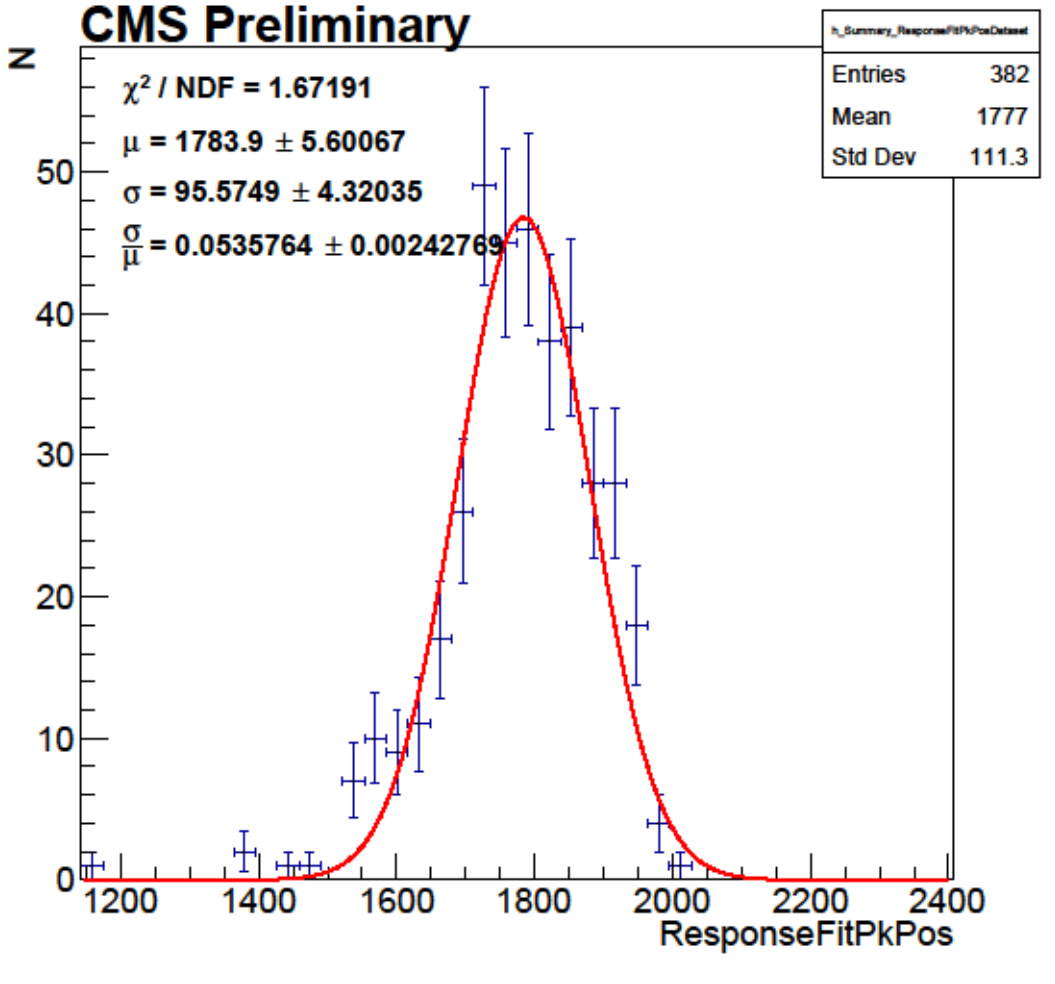
GE 2/1 M4 gain curve	GE1/1-X-S-CERN-0003 gain curve
	
Measured in the (η,ϕ)=(1,4)	Measured in the (η,ϕ)=(4,2)

Same stand, same electronics, same settings

GE2/1 M4 gain uniformity res.

- Prototype gain uniformity <6 % !



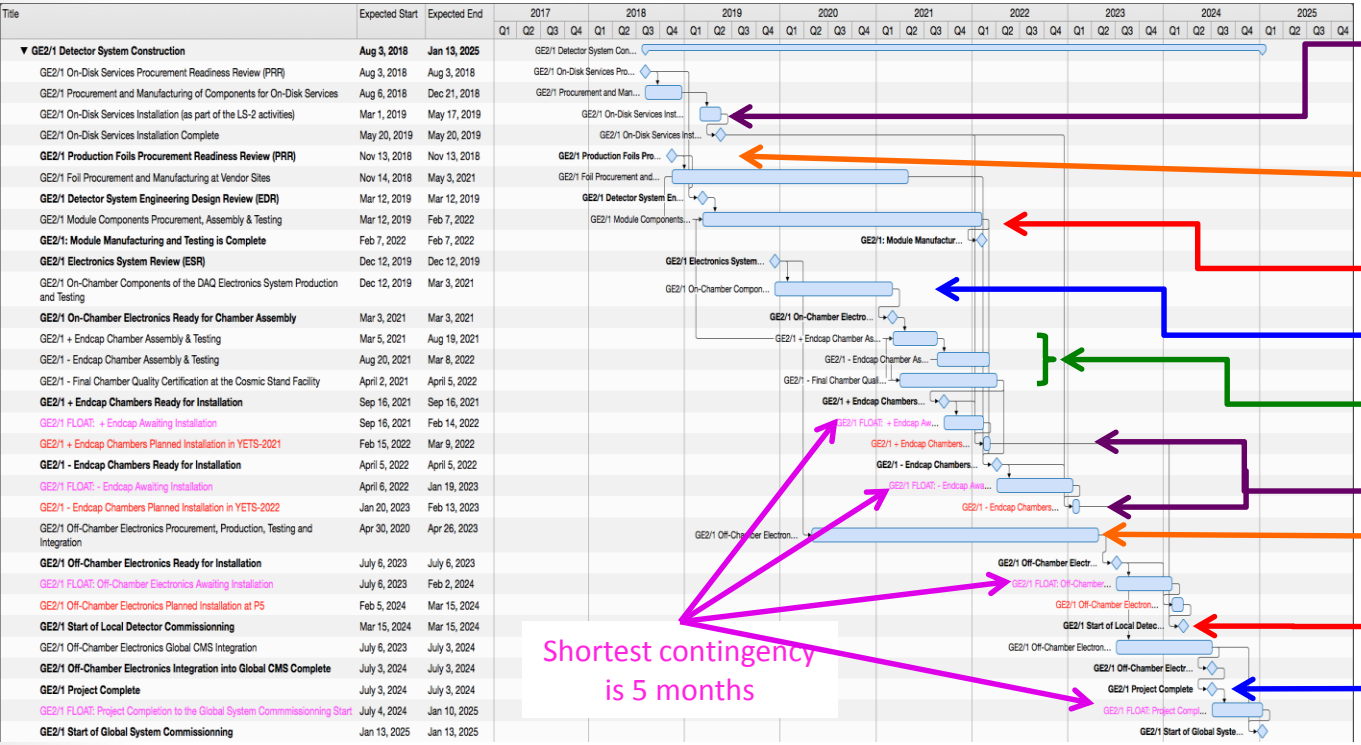


GE2/1 M4 QC5 summary

- Operational gain value of the GE2/1 is similar to the GE1/1 > 10^4
- Gain uniformity on a very good level < 6%.
  - Very flat PCBs
  - Cylindrical structural supports „inside” the module.

Feature	GE2/1	GE1/1
Gain value @700 [uA]	Order of 10^4	Order of 10^4
Gain uniformity level	6 %	5 - 30%
comments	Single module tested	Large # of the chambers tested

GE2/1 Schedule Overview

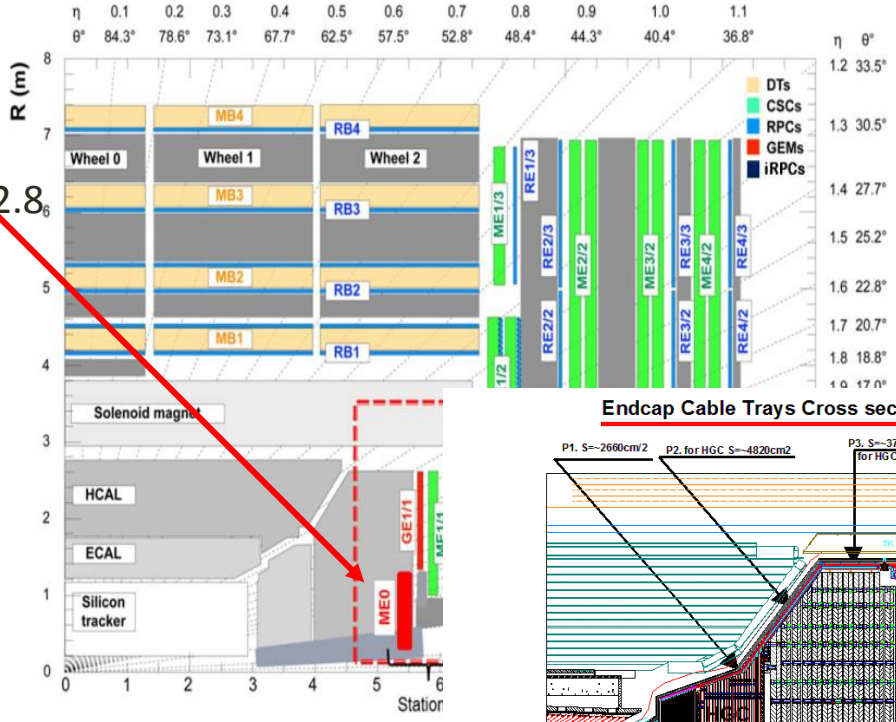


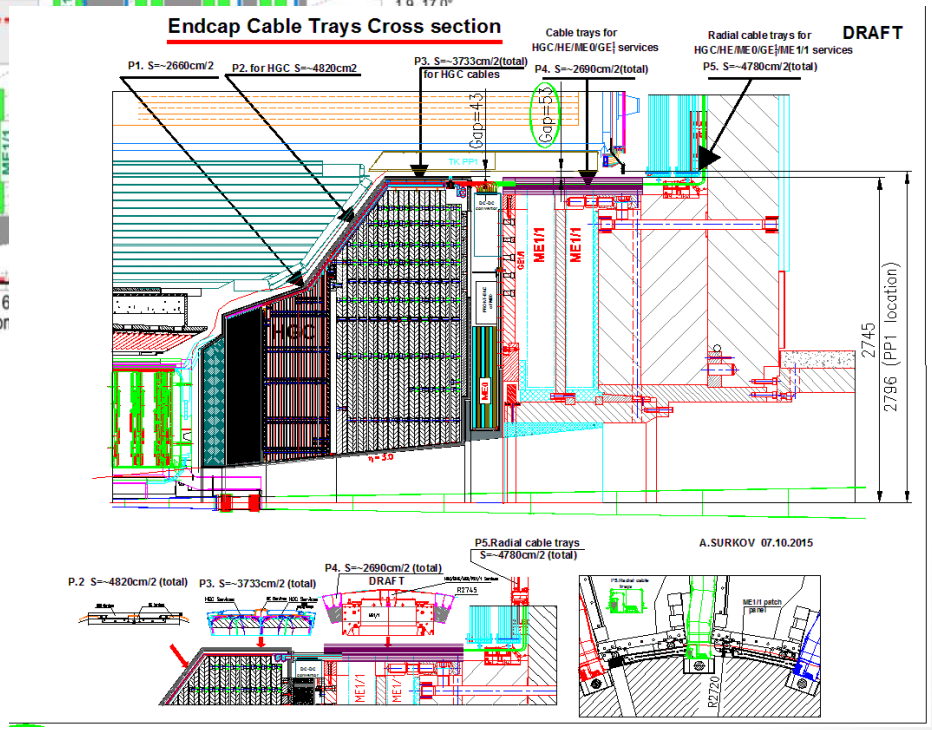
ME0 position

Muon Endcap ME0:

LS3 upgrade, $\eta < 2.8$

GEM: GE1/1-like station, with more layers to reject background

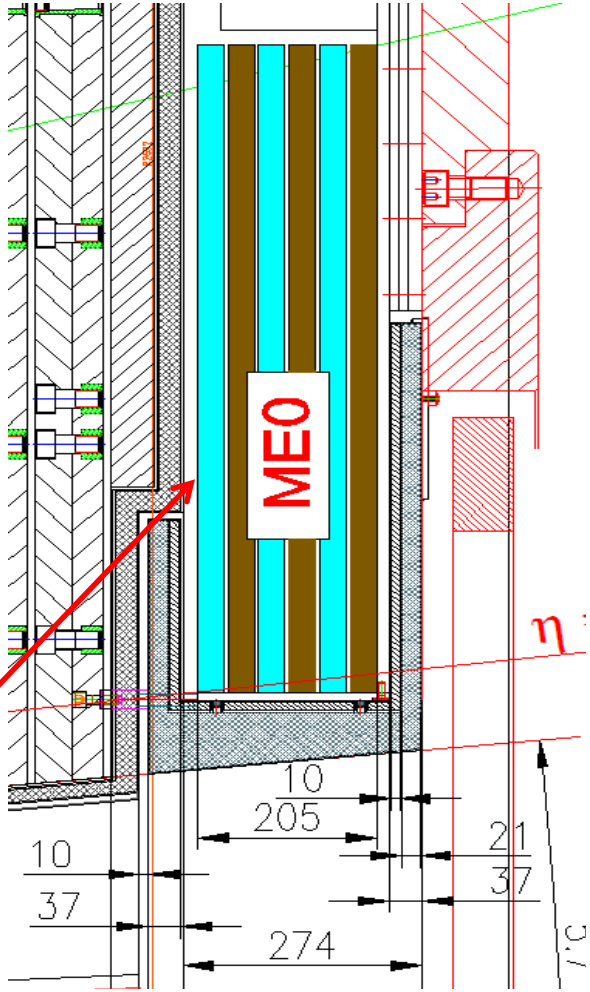




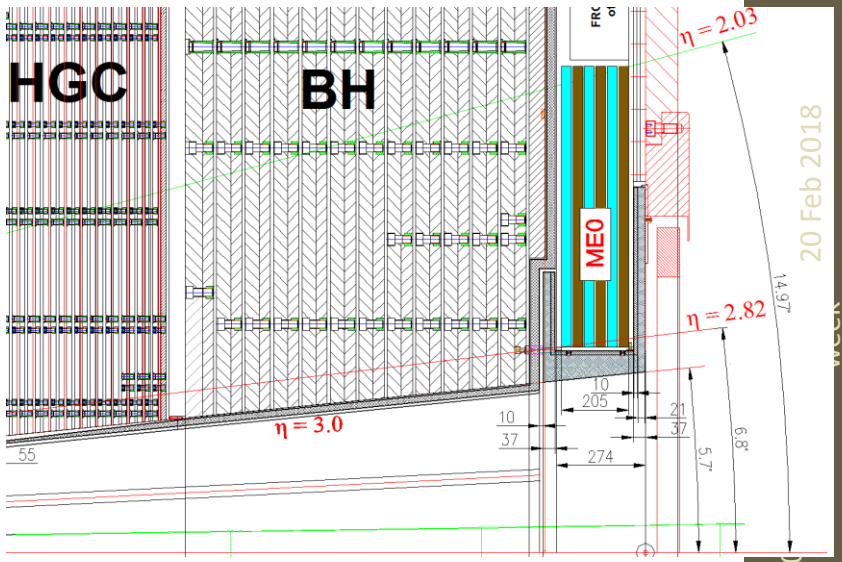
Detector to be installed in the new nose under design

ME0 detector constraint

In the actual layout 209 mm are available for the stack plus 15 for the base support plus ~14 mm for clearance

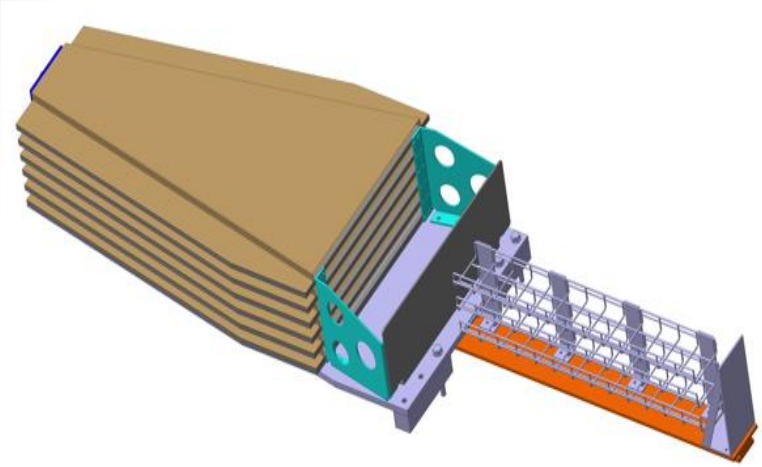


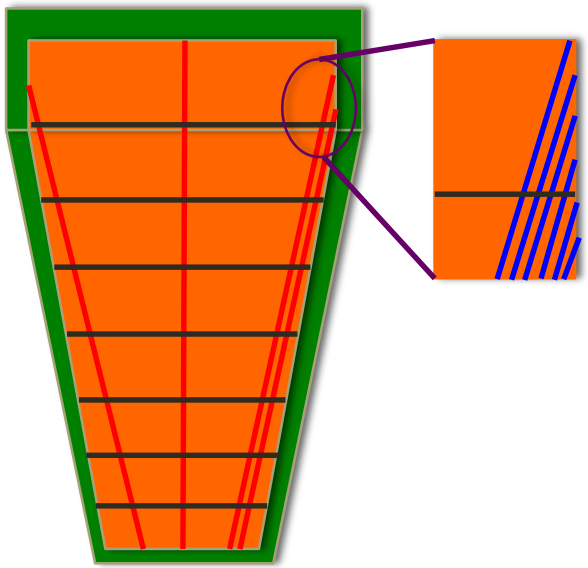
14 mm



ME0 will cover the forward region $2<\eta<2.8$

ME0 Stack layout

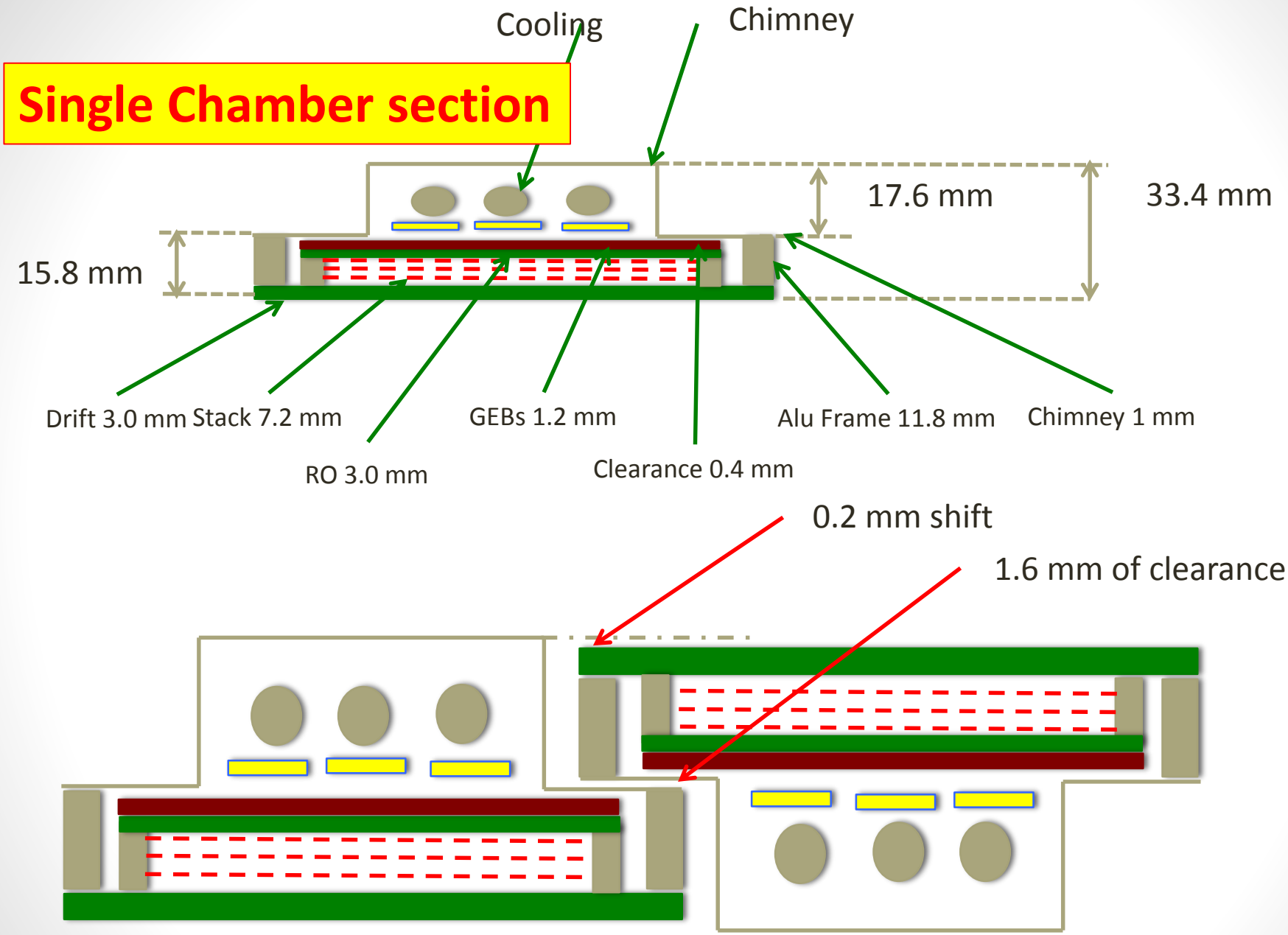


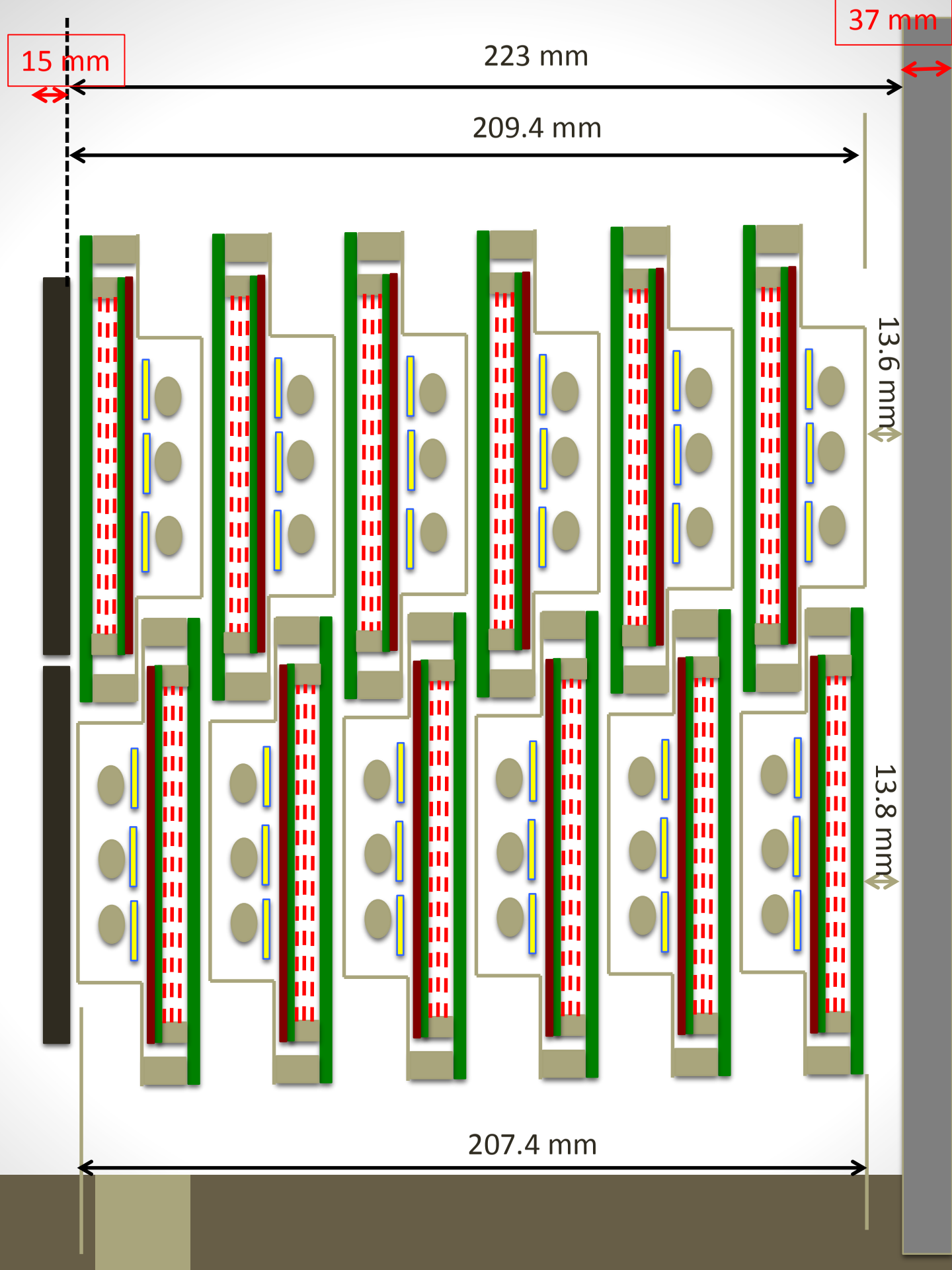


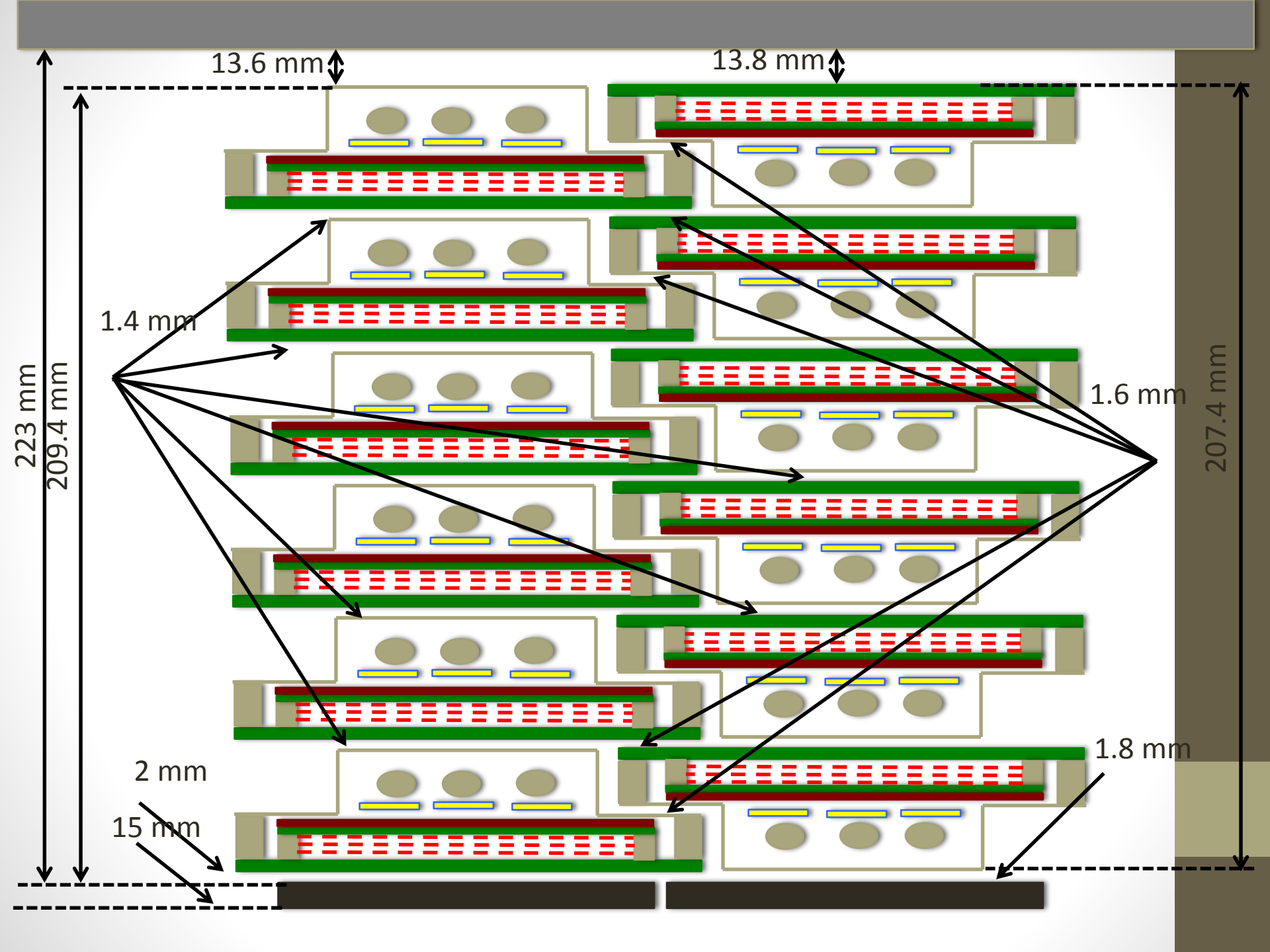
- 20 Deg. stack is made up of 6 chambers
- 18 Stacks per end-cap
- 216 Modules to be produces

- 128 strips for 8 eta partitions

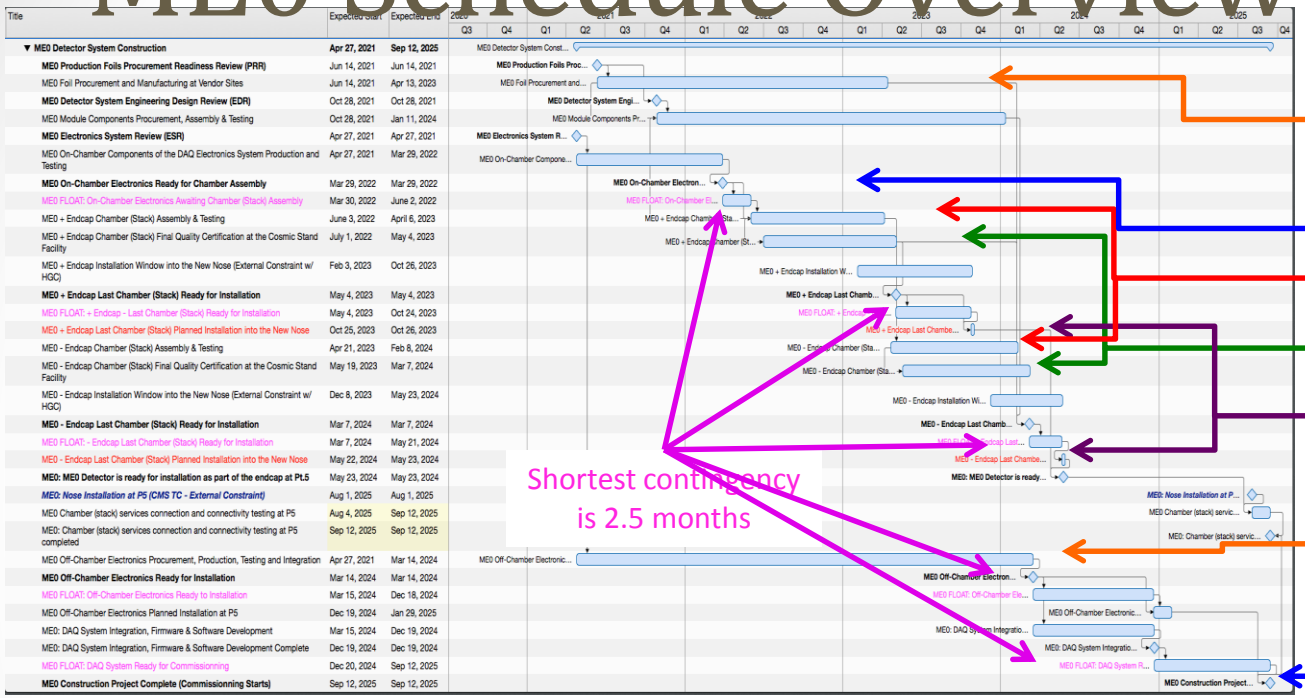
Single Chamber section




37 mm
15 mm
223 mm
209.4 mm
13.6 mm
13.8 mm
207.4 mm


13.6 mm
13.8 mm
1.4 mm
1.6 mm
223 mm
209.4 mm
207.4 mm
2 mm
15 mm
1.8 mm

ME0 Schedule Overview

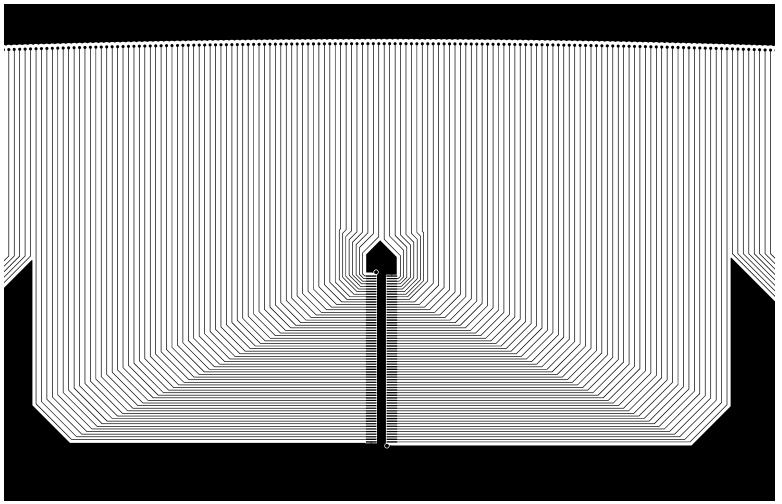


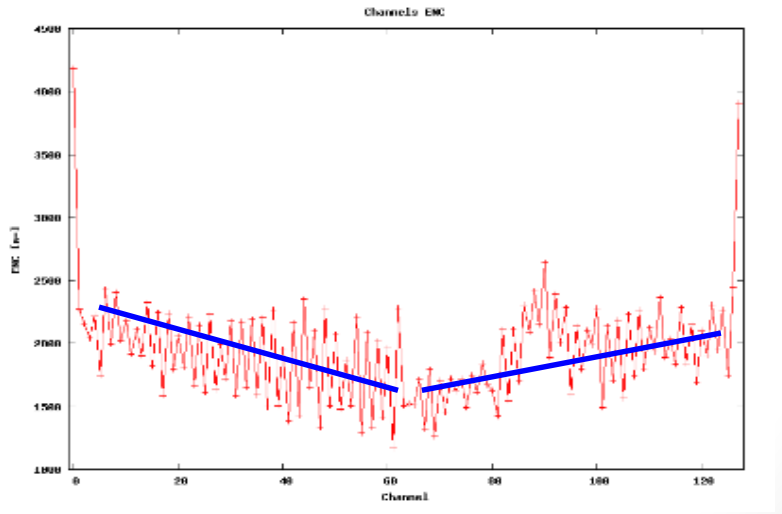
- Critical path for the ME0 project:
  - Chamber (stack) assembly has to finish in time to allow HCG electronic installation
  - Assembly is driven by GEM module production
    - On-chamber electronics production is not on the critical path
  - Shortest float is currently 2.5 months for the last stack of the “-” Endcap
    - The pace is driven by the module production, not stack assembly
    - Baseline schedule assumes that module production pace is the same both early and late in the production cycle
    - There is potential to speed up module production if necessary (also tracked in risk register)

On going R&D (common GE2/1-ME0)

Readout board layout studies

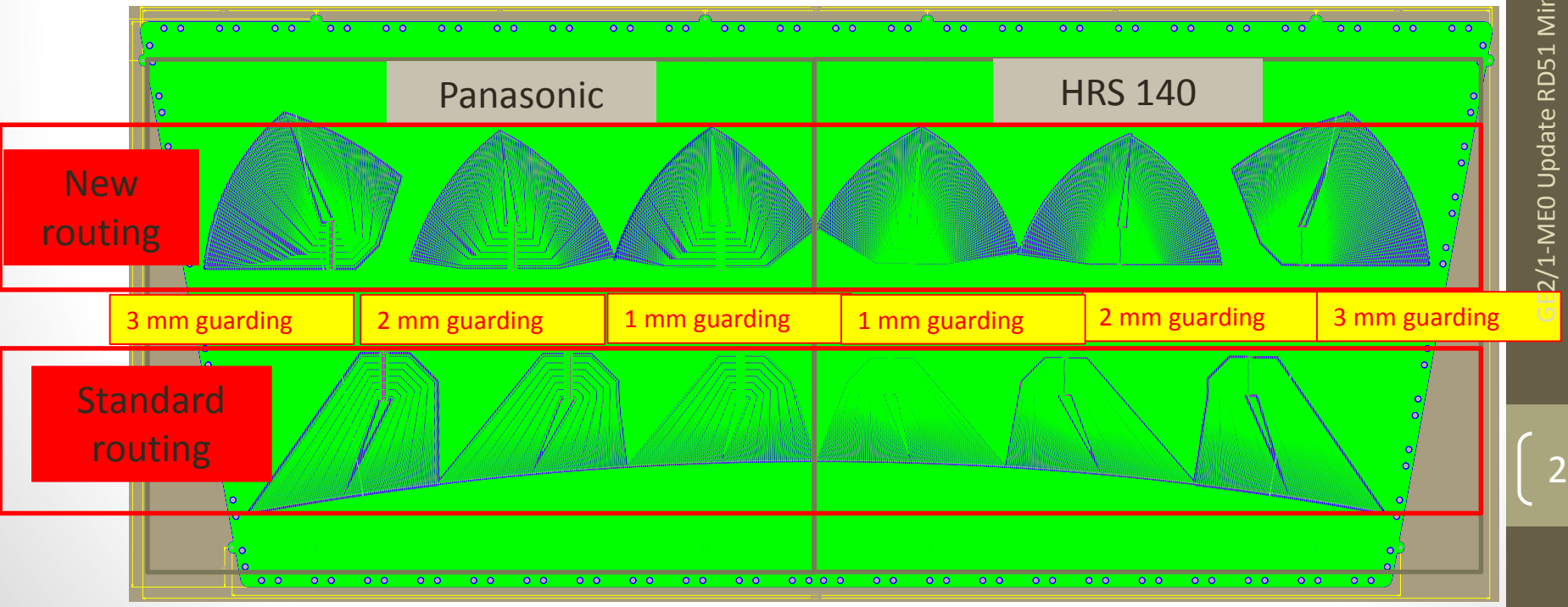
- Different noise in the VFAT was observed
  - Difference in the capacitance generated by the ground plate coupled with the last strips?
  - Different lengths of the traces routing the signal to the R/O connectors?





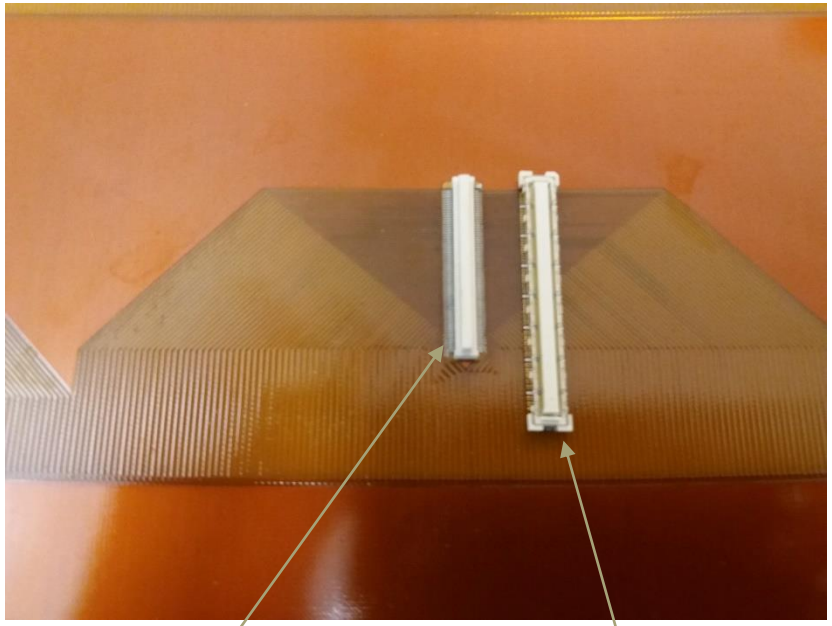
R&D board design

- 2 different types of the connectors (6 panasonic and 6 HRS 140)
- 2 different strip routing schemes
- 3 different distances between the Readout board copper and strips

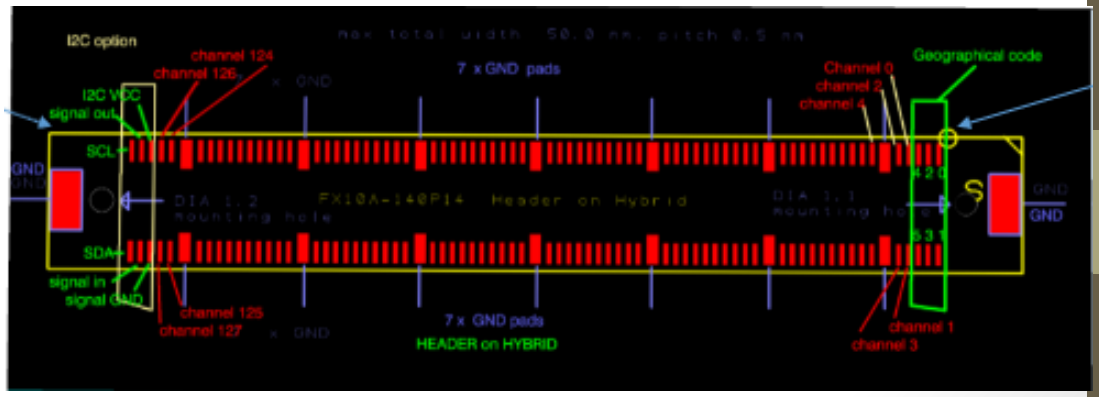


New R/O connectors

- Panasonic connectors will soon be not available in the store
- HRS 140 are claimed to have better properties (grounding, more channels, new possible applications of the „spare channels”

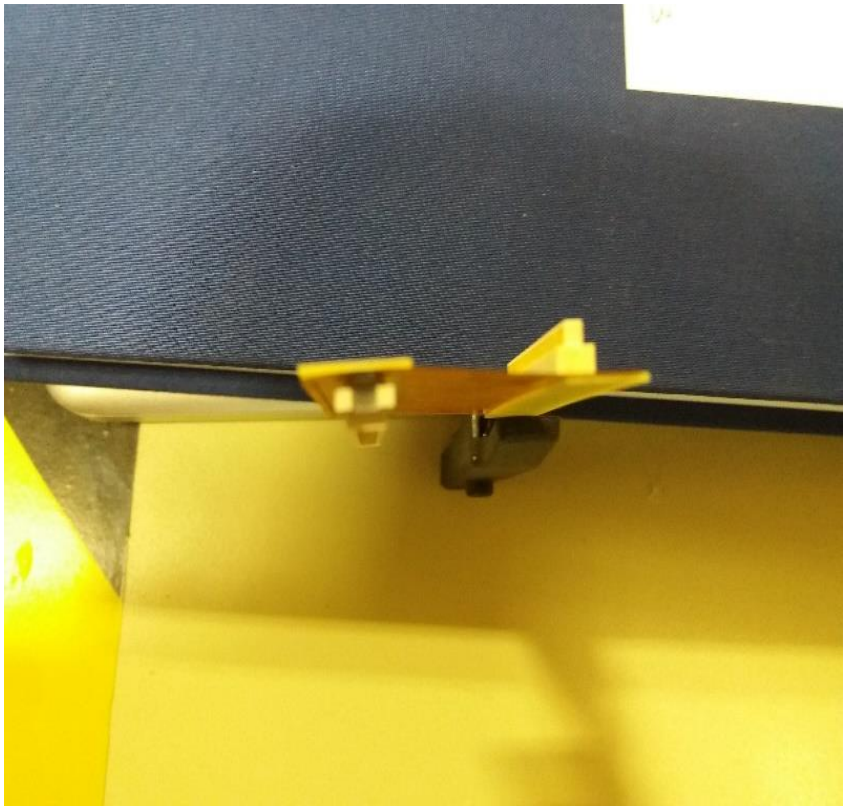


Panasonic 130 HRS 140



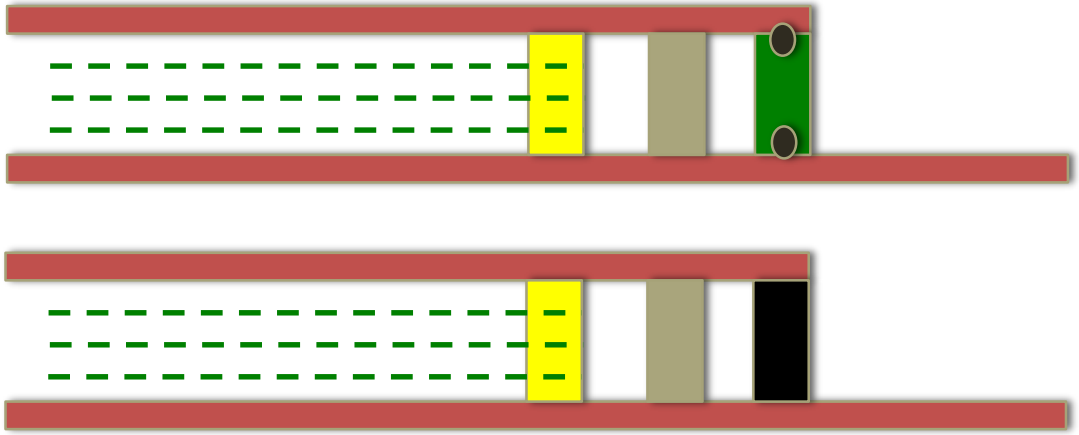
New R/O connectors

- The proposed „translators” need to be tested though.



External frame alternative solution

To simplify the material procurement and reduce the number of chamber components, studies to totally replace the FR4 external frames and the to small o-ring actually used with unique large o-ring are ongoing



Synergies with other projects

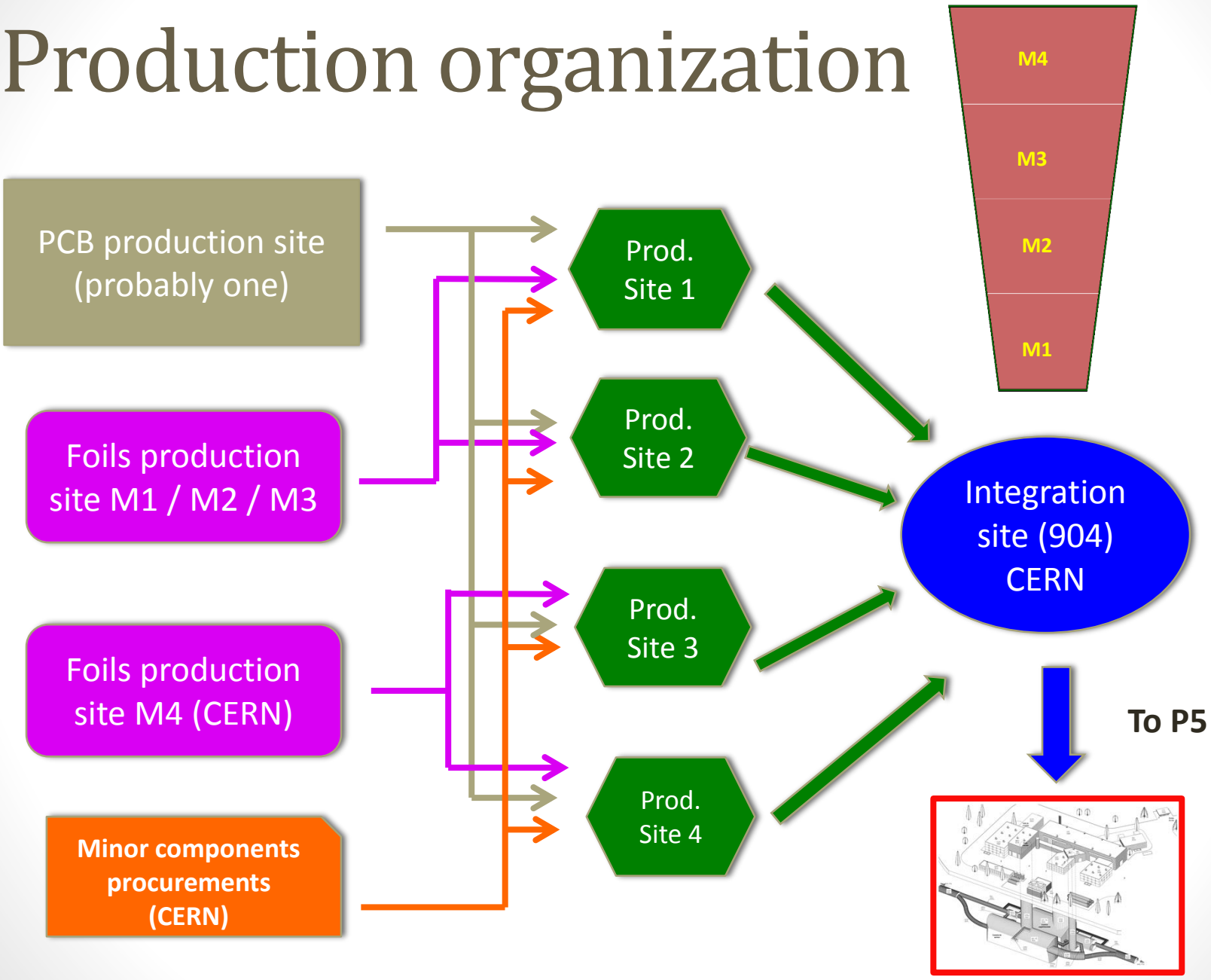
- The Baseline detector for the GE2/1-ME0 chambers, shares several aspect with the ongoing GE1/1 project.
- In the GE2/1 20 deg. **the largest module** will have dimensions **comparable with the GE1/1** Long chambers == > tooling and setups prepared for the GE1/1 can be mostly re-used.
- The new **CMS GEM clean room & GEM QC Lab**, prepared in bd. 904 (Prevessin) are large enough to **host the production & Quality Control of the GE2/1-ME0 chambers**
- Electronics developed for the GE1/1 (**VFAT3 frozen**) can be **easily adapted to the GE2/1-ME0 modules**

Synergies with other projects

The triple GEM detectors, the baseline option chosen for the GE2/1-ME0 modules, is the same technology used by GE1/1 this mean:

- **Well known performances**
- **Aging test as an extension of GE1/1 aging tests**
- **No different materials compared to GE11**
- **Production & QC Tooling and setup**, (some of them quite expensive: X-ray, copper boxes, cosmic ray stand, …) prepared **for the GE1/1** production **to be reused for the GE2/1-ME0** production and tests.
- **Crew** trained for the production and test of the **GE1/1 will be easily moved** to the production of new modules.
- **Production sites** "certified" for the production of GE1/1 chambers **don't need to be certified again**
- Production of **GE2/1-ME0** modules can be seen as **continuation of the GE1/1 chambers**

Production organization

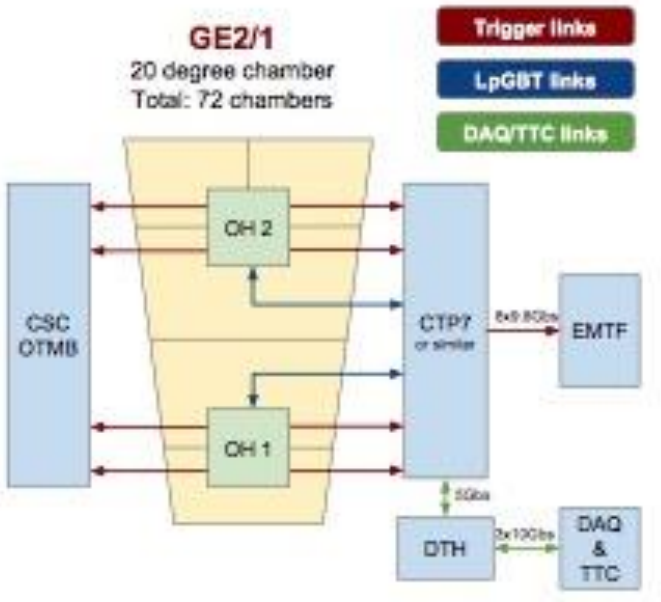


Summary

- GE2/1 and ME0 project are moving toward the production phase
- Physics R&D completed for GE2/1, aging test to be completed soon for ME0 (see F. Fallavollita talk)
- Minor R&D on the layout of the GE2/1-ME0 modules are on-going (RO connectors & Ext. Frames)
- Production phase will profit of the GE1/1 production experience and tooling

Backup slide

GE2/1 Electronic RO system



Two optical paths to the Opto-hybrid.

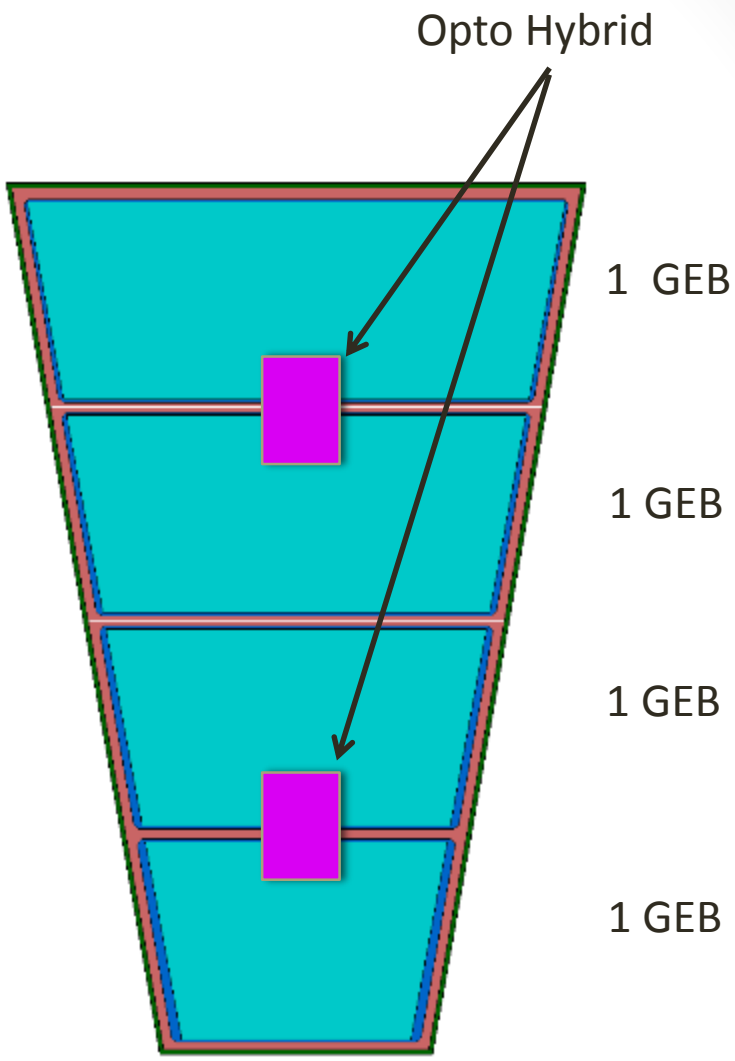
- The first, bidirectional, runs between the µTCA crates located in the counting room and the Opto-hybrid. This path is used to set-up and control signals to the front-end chips. The return path is used for VFAT3 tracking data packets and return slow-control data

- The second path is unidirectional and takes the VFAT3 fixed latency trigger data from the GEM system to the CSC system.

GE2/1 electronics

Components for the whole GE2/1 system

- 3456 VFT3 chips (48 x 2 x 36)
- 144 OH with 24 VFAT3 input
- 4 different GEB boards per chamber4
- 288 GEB in total for the GE2/1 project



Routing on the YE1 yoke – GE2/1 Mockup in b 904

GE2/1 services studies in details by means of dedicates prototype, mockup (scale 1:1)), survey in the cavern, continuous interaction with the CMS TC.