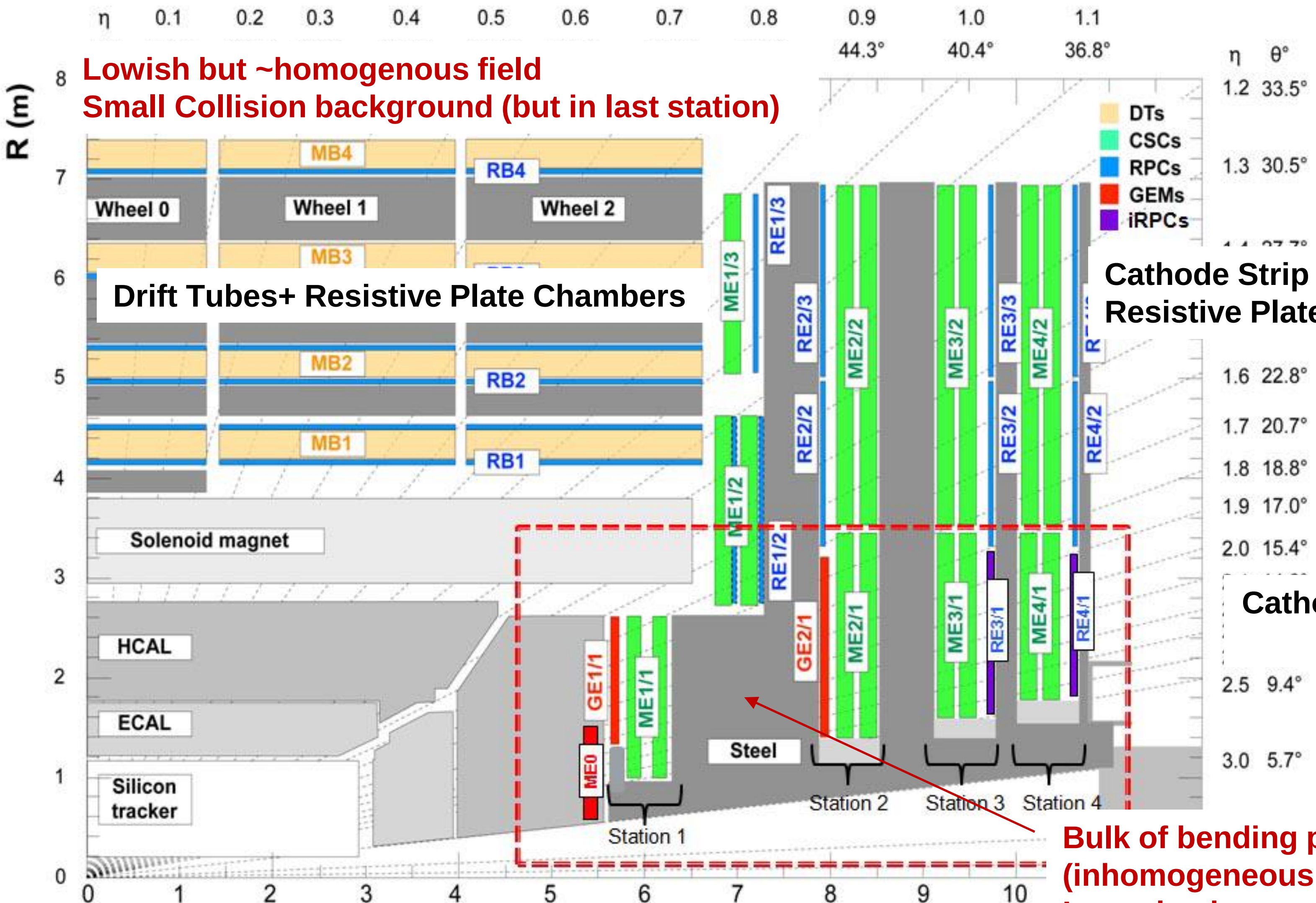
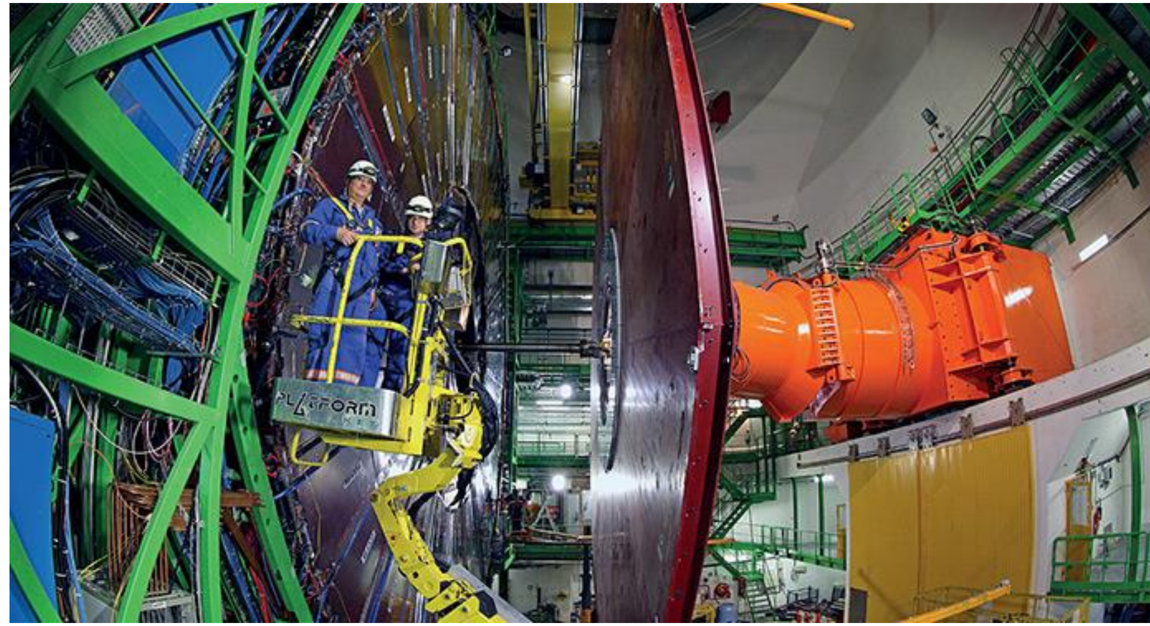
Overall CMS talk presenting the different systems



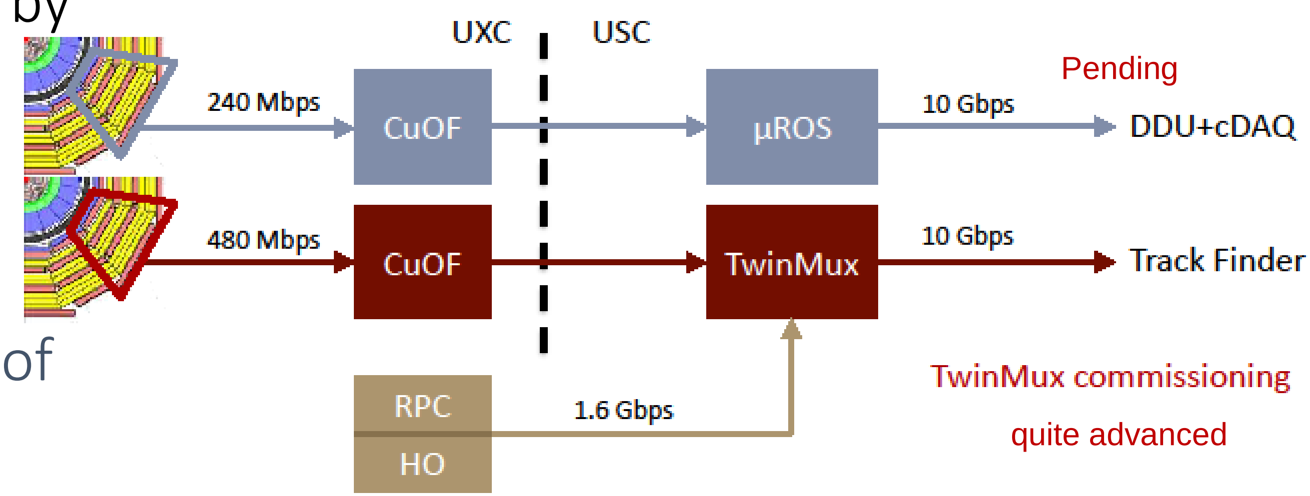
Ignacio Redondo (CIEMAT) on behalf of CMS Muon System

Phase 1 upgrades well advanced

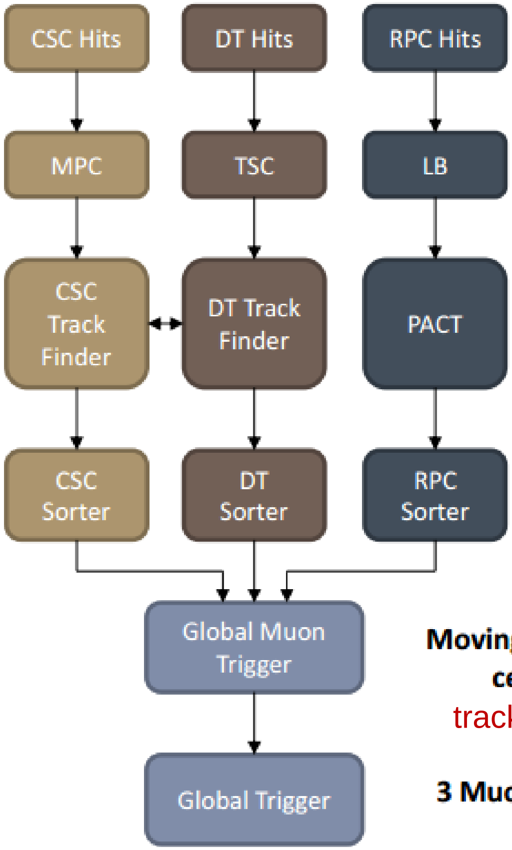
- 4th endcap station (CSC+RPC) and associated shielding (YE4) installed in LS1

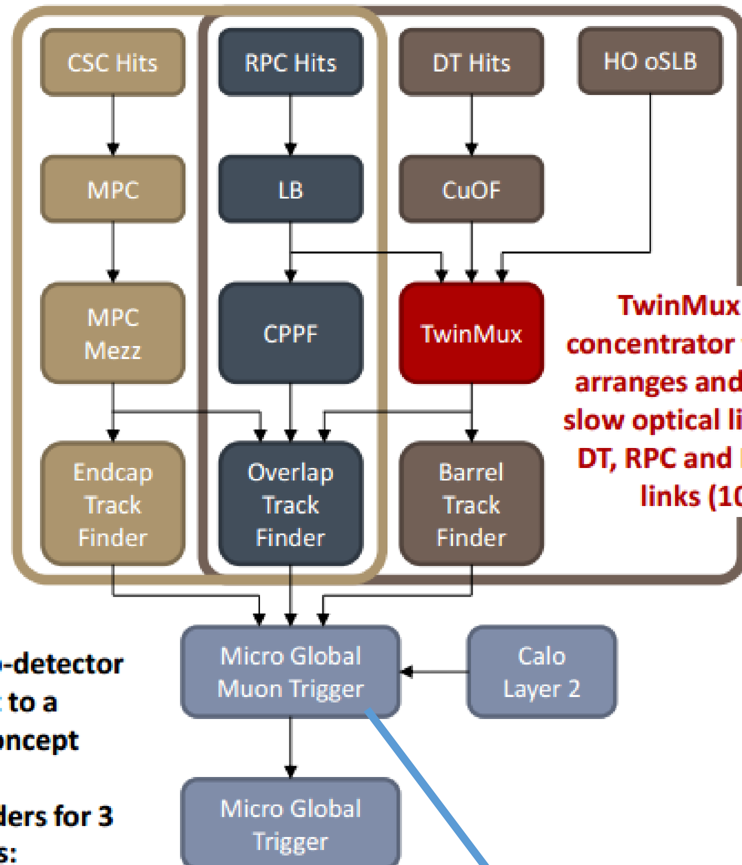


- CSC ME1/1 increased granularity in LS1
- DT: Secondary electronics moved to the service cavern in LS1, trigger leg replaced by µTCA electronics this shutdown
  - Twinmux system installed, under commissioning as part of L1 trigger upgrade



Muon L1-Trigger Upgrade being commissioned

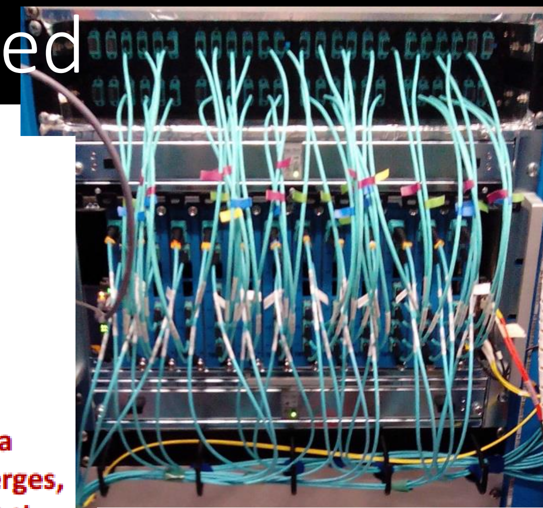




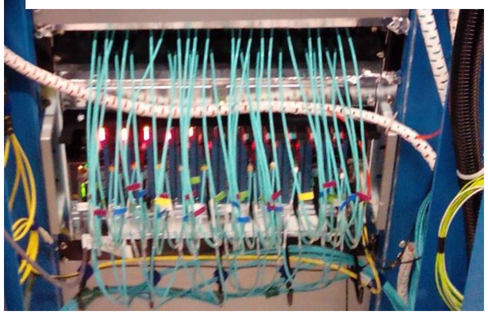
TwinMux is a data concentrator that merges, arranges and fan-out the slow optical links from the DT, RPC and HO in faster links (10 Gbps)

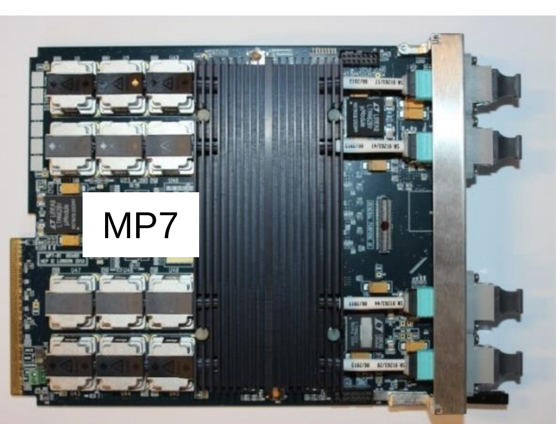
Moving from a sub-detector centric layout to a track-centric **concept**

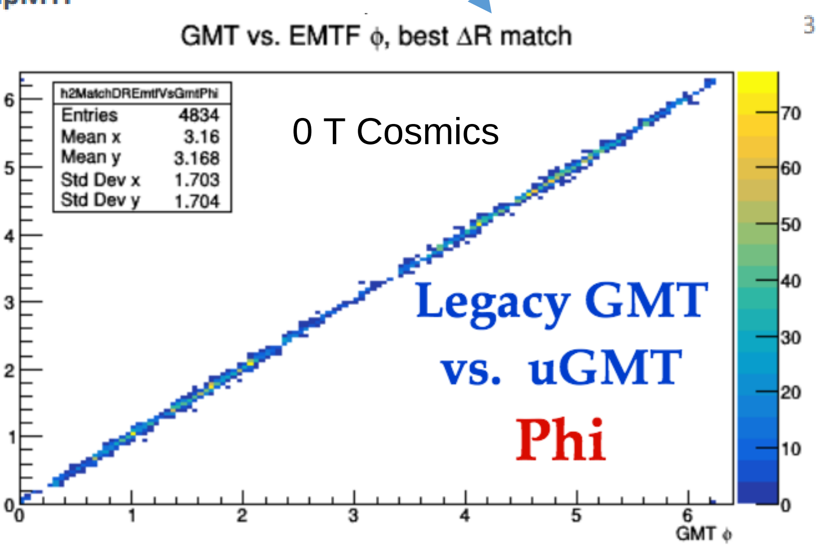
3 Muon Track Finders for 3 eta regions:
BarrelMTF OverlapMTF
EndcapMTF



60 boards in 5 μTCA crates
2000 input legacy links
480 Mbps→ 10 Gbps







Plenty of Challenges Ahead

- Aging of chambers and associated electronics
  - ➔Gif++ accelerated irradiation tests to qualify for HL_HLC doses
- Aging of services in a radiation environment …over decades
  - Power supply system
  - Water Cooling
  - Gas, eco-friendly mixtures

➔Muon Special needs
Sergei LUSIN talk

Larger Backgrounds in HL_LHC

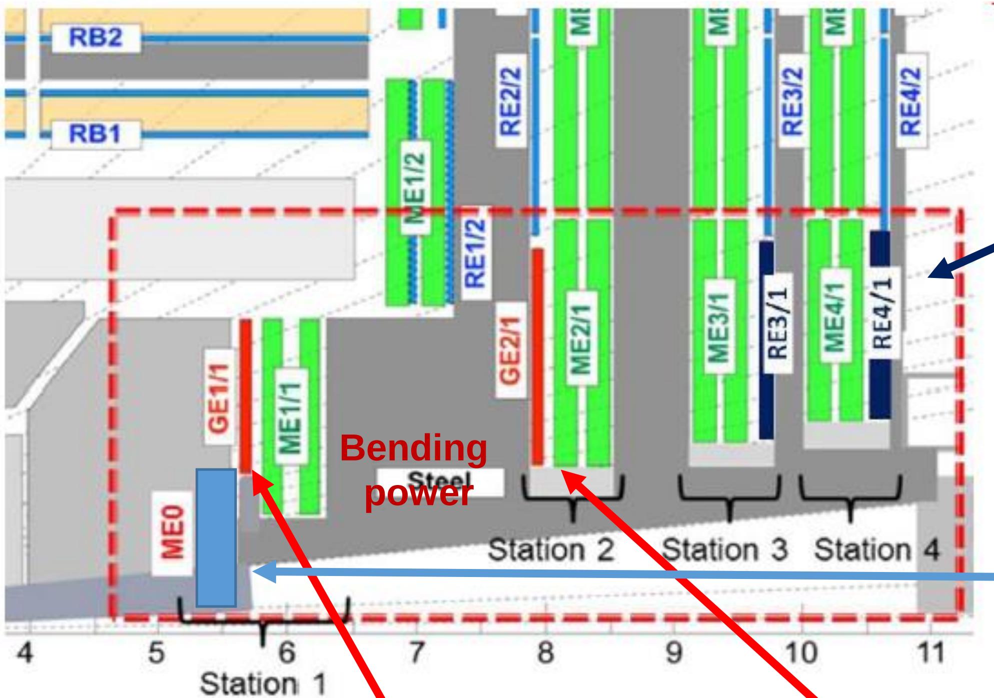
- X 10, if scaling as inst. Luminosity

1. Different CMS-wide DAQ conditions
   - L1A rate: 750 KHz X 7.5
   - L1A Latency: 12.5 µsec X 3.9
2. Triggering in a tracking trigger environmen
3. Extension in rapidity coverage

➔CMS FE electronics replacement
(DT mini-crate upgrade; CSC consolidation)
Benjamin Glenn BYLSMA
- CSC inner ring LS2, DT LS3

New detectors at large rapidity

➔ CMS MPGD + fast timing detector + multi-gap RPC R&D with emphasis on electronics *Herve MATHEZ*



GE1/1

- 36 super-chambers/disc , each spanning 10°
- A SC has 2 triple GEM detectors
- 1.55 (long) 1.60 (short) < η < 2:18,
- Segmentation in η : 8
- Installation: **LS2** (2019-2020)
  - 8 chambers, 40° slice, to be installed YETS 16-17

iRPC

- 18 chambers/disc, each spanning 20°
- 1.80 < η < 2.40, η -segmentation: 5
- Installation: LS3

ME0 tagger

- 6 layers of triple GEM (alternative FTM)
- 18 chambers/disc, each spanning 20°
- 2.00 < η < 2.80, no -part. yet
- Installation: LS3

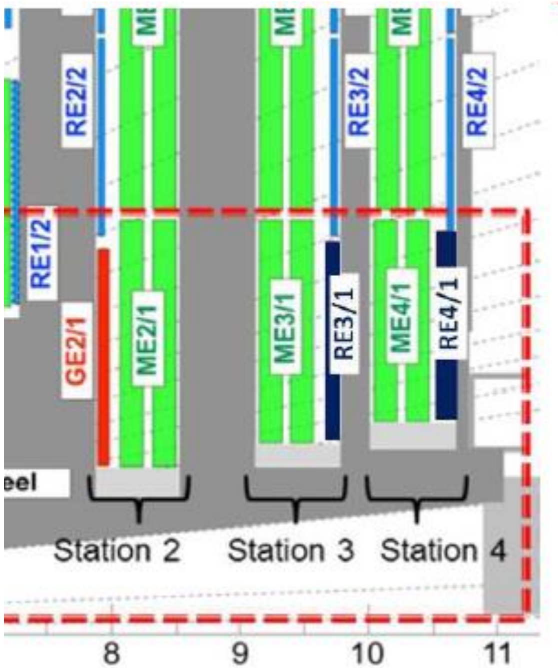
➔CMS GEM electronics
Paul ASPELL

GE2/1

- 2 triple GEMs chambers (alt. -RWell)
- 18 super-chamber/disc, each spanning 20°
- 1.65 < η < 2.45, η -segmentation: 12.
- Installation: LS3

Forward RPC Detectors

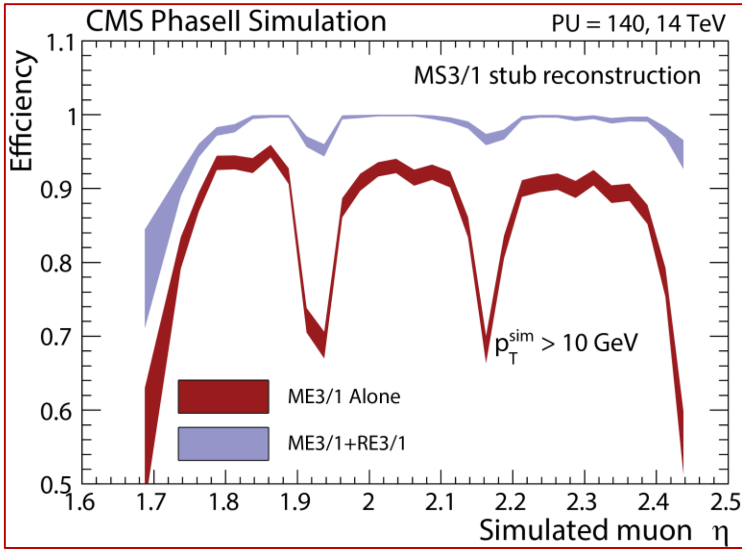
➔ **CMS MPGD + fast timing detector + multi-gap RPC R&D with emphasis on electronics** *Herve MATHEZ*



- ❑ Extension of forward endcaps in the 1.8<|η|<2.4 region with RPCs: RE3/1-RE4/1
  - ➢ Improved RPC performance needed to handle ~2kHz/cm^2
- ❑ Complement existing ME3/1-ME4/1 stations, currently instrumented with CSC only
  - ➢ Improving L1 muon trigger
- ❑ Improve performance at HL-HLC
  - ➢ Option under study includes improved time resolution below 100ps

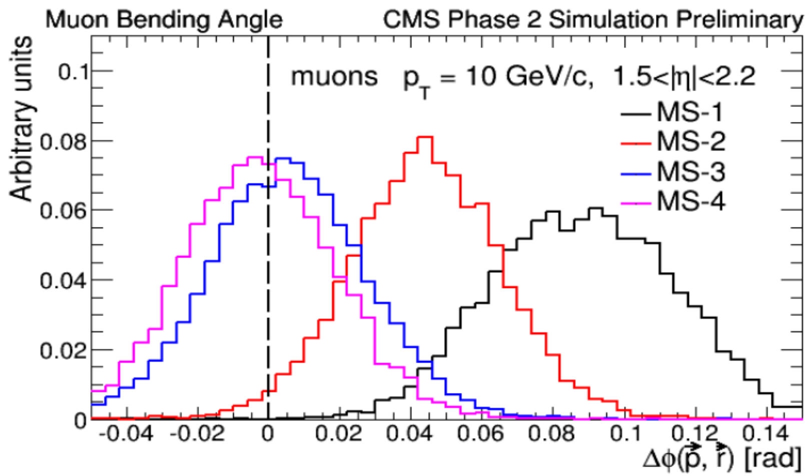
Present design foresees 18 chambers per station, each spanning 20° in φ, i.e. 2 x 2 x 18 = 72 chambers in total: starting point for geometry studies: 5 η partitions containing 192 strips each (pitch 0.30-0.62cm, i.e. 4-6 times smaller compared to present setup)

➢ Rate capability to be improved wrt. present RPC design: study new, low resistivity electrode materials, detector geometries and improved FE electronics



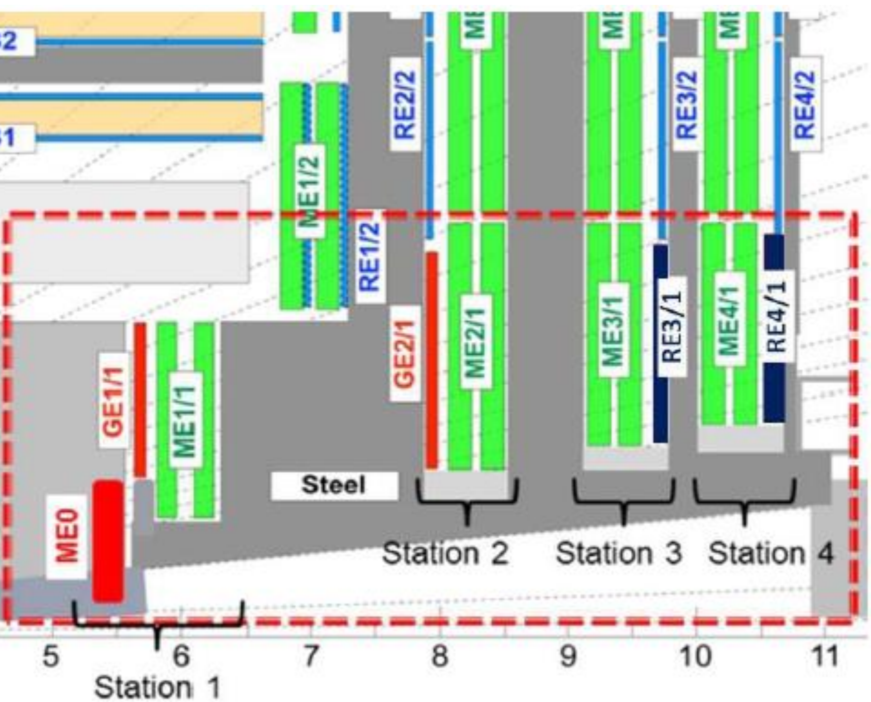
GE2/1

Add detector in front of CSC to measure the muon bending angle in magnetic field between each station, keep the rate under control and add redundancy:
Large improvement from GE1/1 and GE2/1 stations



→ Requirement precise Δϕ meas., spatial resolution

The baseline GE2/1 station consists triple-gem with the layout will be similar to GE1/1, but covering much larger surface



Other options considered:

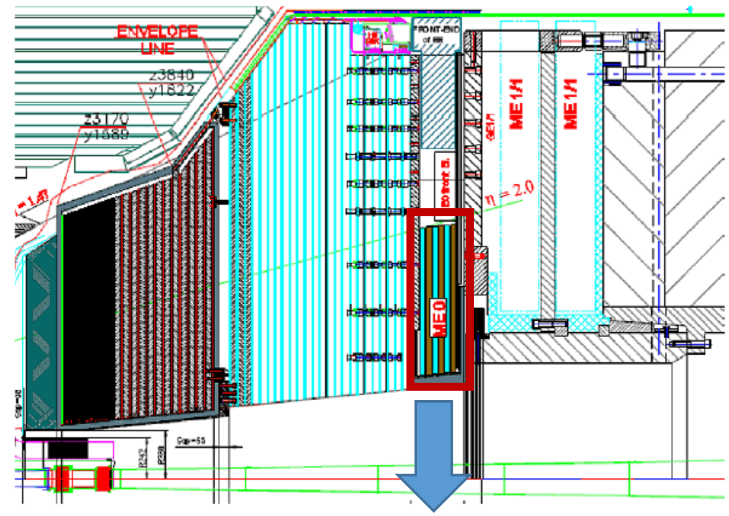
→CMS GEM electronics
Paul ASPELL

- 20^0 versus 10^0- design (which would reduce the need for using more than one gem foil per plane → dead area)
- New MicroPatternGasDetectors (MPGD) such us µWell: compact and easy to build (< 5mm thickness) only two components: a single-amplification stage embedded with the readout +a cathode plane. High spatial (100 mm) and good time resolution (without green house gases).

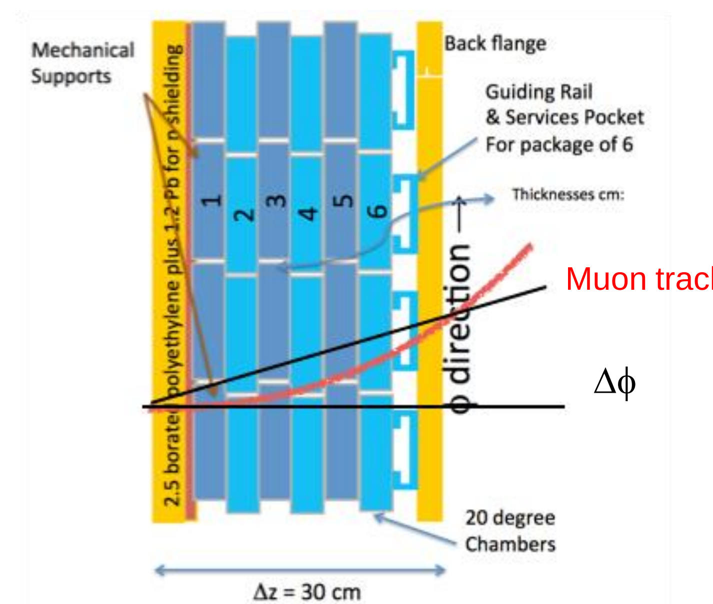
Very forward extension: ME0 tagger

Extend muon coverage behind the new endcap calorimeter to take advantage of the pixel tracking and calorimeter coverage extension.

- Tracking and triggering with p_t measurement (local rec.
- Early tracking for muons (standalone muon at $|\eta| < 2.4$)
- Low sensitive to neutrons
- Improve muon-ID from HGC and tracker



Detector requirement:
- Multilayer structures
- High rate capability O(MHz/cm^2)
- time resolution for triggering
- No green house gases
- Good spatial resolution O(100 mm) for tracking and triggering

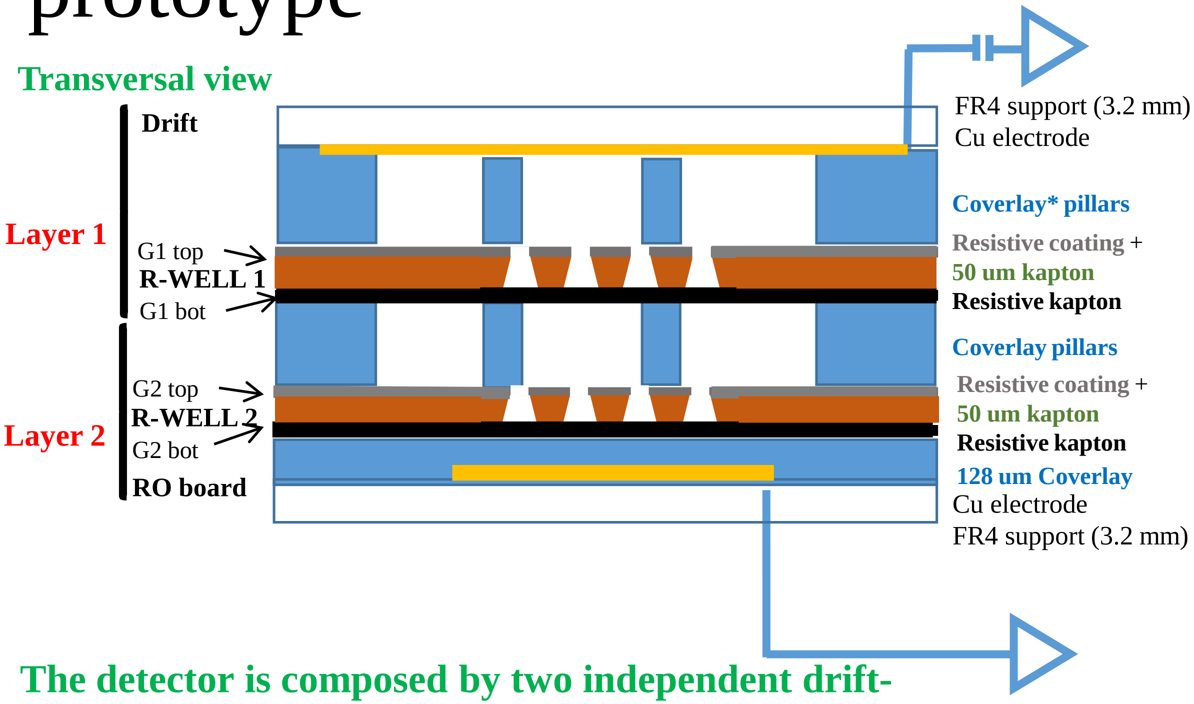


2 technologies under study:

- Six layers of triple-GEMs
- Fast Timing Micropattern gas detector (FTM):

a full resistive multi-gap WELL type detector

The Fast Timing Micropattern detector (FTM) – First prototype



The detector is composed by two independent drift-amplification stages (Layer 1 & 2 in the picture above).

Each amplification region is based on ***a pair of polyimide foils*** stacked due to the electrostatic force induced by the polarization of the foils:

- The first foil, perforated with inverted truncated-cone-shaped holes (bases 100 µm and 70 µm, pitch 140 µm), is a 50 µm thick Apical KANECA, coated with diamond-like carbon (DLC) technique, to reach up to 800 MΩ/□ resistivity.
- The second foil is 25 µm thick XC Dupont Kapton, with a resistivity of 2 MΩ/□.

The ***drift volumes are 250 µm thick***, with planarity ensured by coverlay pillars, with diameter 400 µm and pitch of ~3.3 mm.

The active area (circular) is about 20 cm^2.

Reference: arXiv:1503.05330v1
European Patent Application 14200153.6
M. Maggi, A. Sharma, R. De Oliveira

*__Coverlay__: acrylic-based material used as spacer and for insulation.

Timing resolution measured < 2ns

Further information

- CMS Muon talks in this conference:
- GE 1/1 TDR
  - https://cds.cern.ch/record/2021453/files/CMS-TDR-013.pdf
- Technical Proposal for the Phase II Upgrade of CMS
  - CERN---LHCC---2015---010 https://cds.cern.ch/record/2020886
- CMS Phase II Upgrade Scope Document
  - CERN---LHCC---2015---019 https://cds.cern.ch/record/2055167/files/LHCC---G---165.pdf

Backup

Different Radiation Environment: grows with eta

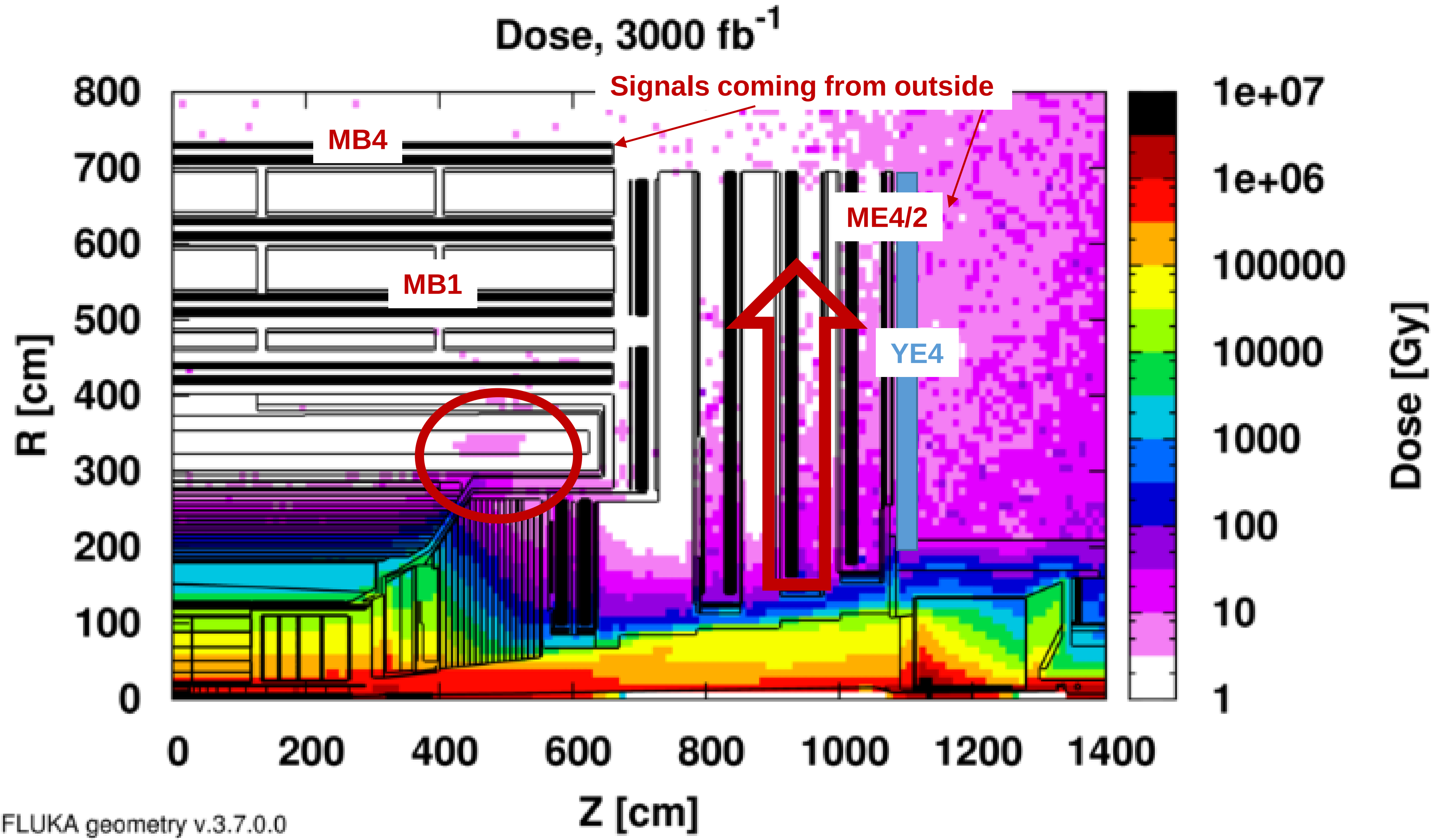
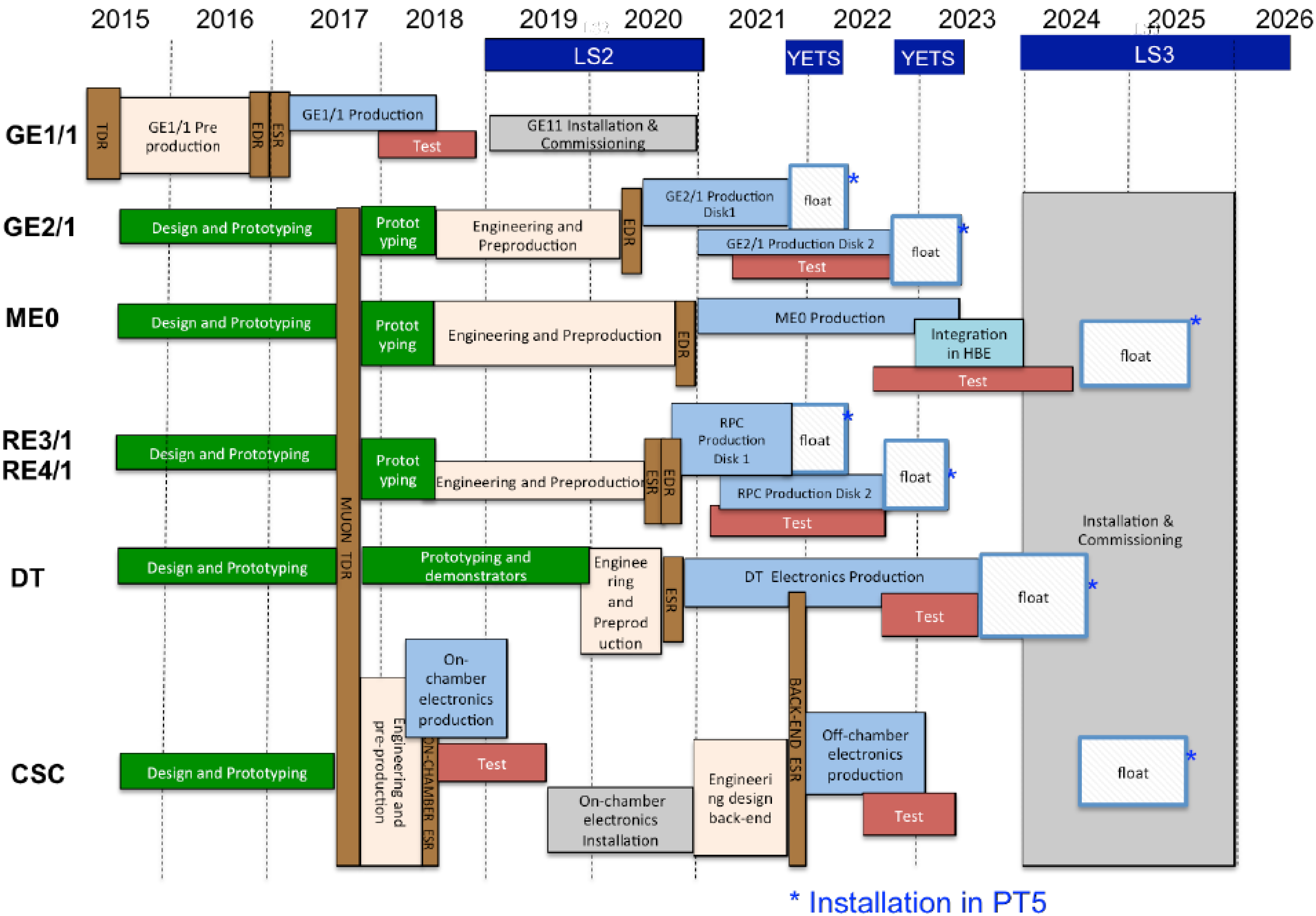


Figure 1.15: Absorbed dose in the CMS cavern after an integrated luminosity of 3000 fb^{-1}. R is the transverse distance from the beamline and Z is the distance along the beamline from the Interaction Point at Z=0.



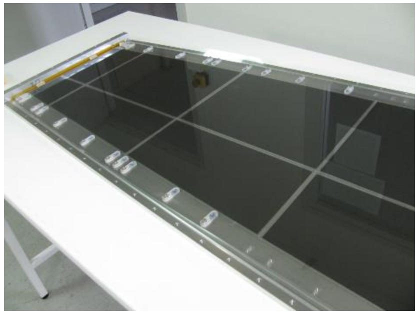
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
LS2
YETS
YETS
LS3
GE1/1
TDR
GE1/1 Pre production
EDR
ESR
GE1/1 Production
Test
GE11 Installation & Commissioning
GE2/1
Design and Prototyping
Prototyping
Engineering and Preproduction
EDR
GE2/1 Production Disk1
float
GE2/1 Production Disk 2
Test
float
ME0
Design and Prototyping
Prototyping
Engineering and Preproduction
EDR
ME0 Production
Integration in HBE
Test
float
RE3/1
RE4/1
Design and Prototyping
Prototyping
Engineering and Preproduction
ESR
EDR
RPC Production Disk 1
float
RPC Production Disk 2
float
Test
Installation & Commissioning
DT
Design and Prototyping
MUON TDR
Prototyping and demonstrators
Engineering and Preproduction
ESR
DT Electronics Production
Test
float
On-chamber electronics production
Engineering and pre-production
ON-CHAMBER ESR
Test
CSC
Design and Prototyping
On-chamber electronics Installation
Engineering design back-end
BACK-END ESR
Off-chamber electronics production
Test
float
* Installation in PT5

iRPC R&D (replaced after the talk)

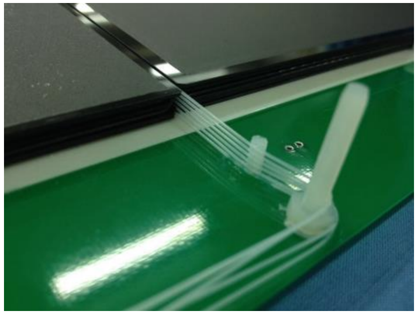
iRPC detector prototypes: Very promising results obtained with small/large prototypes, with *glass and bakelite* electrodes, and *double and multi-gap* geometries

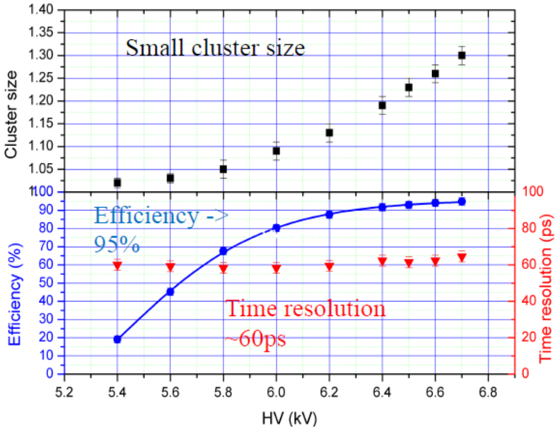
iRPC new FE electronics: Good development progress and promising test results for *Hardroc2* (for double gap RPC) and *Petiroc* (for multi-gap RPC) electronics

GIF Activities: First observations presented on the Muon Phase-II Upgrade Workshop

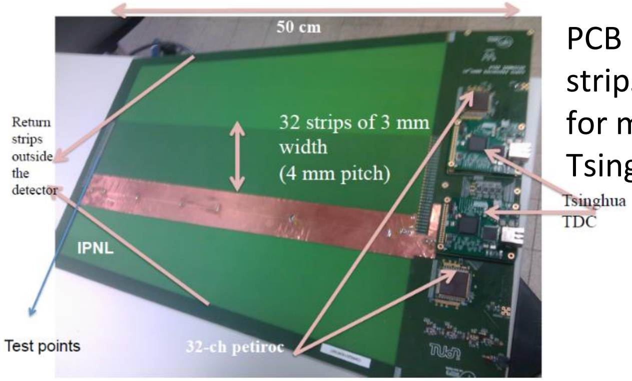


Double and multigap gRPCs constructed with gluing or mechanical fixation procedures (Lyon & Tsinghua)

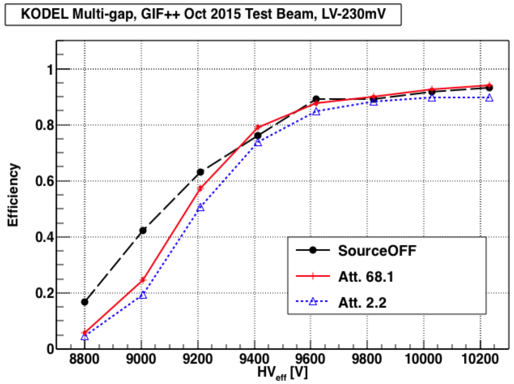




Multigap gRPC @ HZDR test beam, Sept 2015: low noise, ~60ps time resolution



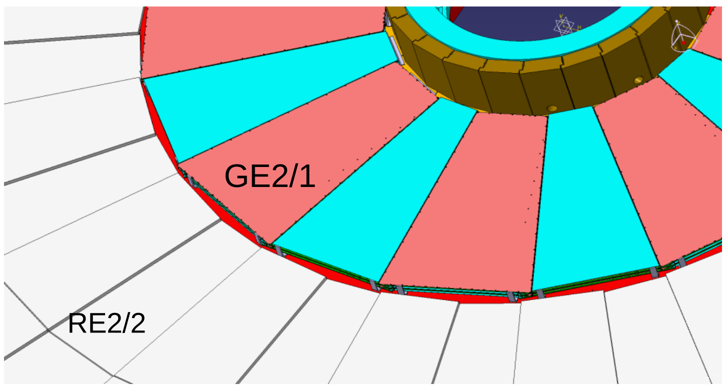
PCB including pickup strips, Petiroc and TDC for multi gap RPC (Lyon & Tsinghua)



Multigap bakelite RPC @ GIF++ 1.4 TBq ^{137}Cs source (KODEL)

GE2/1: Design and technology choice

- 20º Design Option:



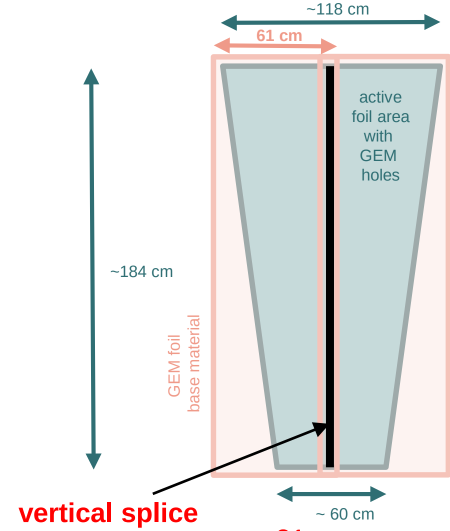
A. Conde, GEM Workshop XII, Oct 8, 2015

\+ covers **1.60**<|η|<2.46

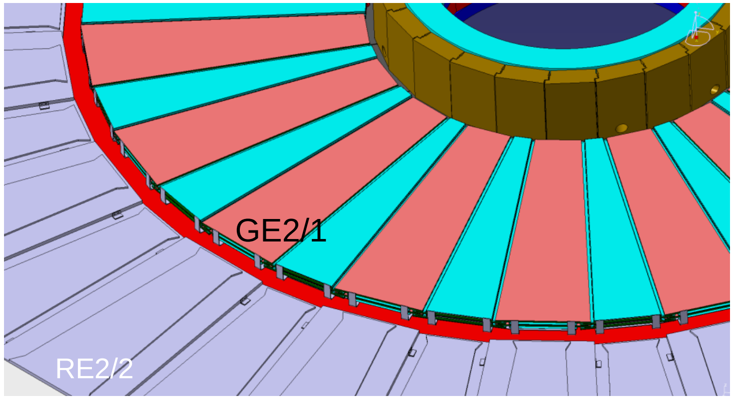
\- need to **splice 2-4 GEM foils** together to build a chamber → untested procedure, gaps

\- need rather large pcbs for readout and drift boards (≈ 2m × 1m)

\+ 72 chambers



- 10º Design Option:

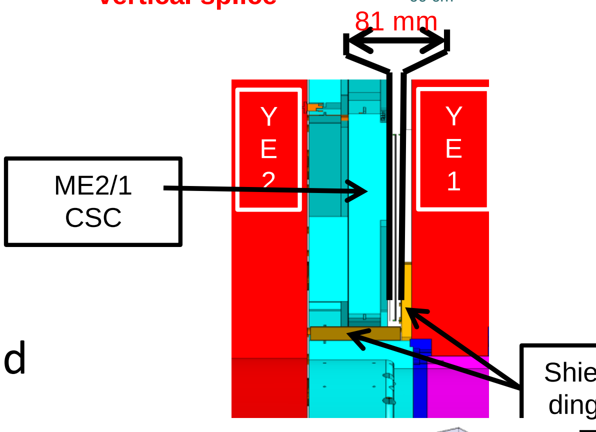


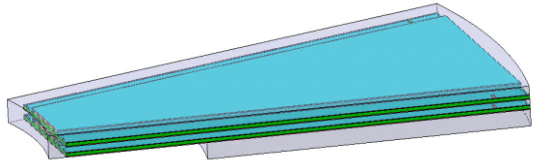
\- covers **1.64**<|η|<2.46; expect impact of smaller range on trigger & physics to be small

\+ can be built from **single foil**

\- chamber long and narrow; need to study mechanical stability in CAD

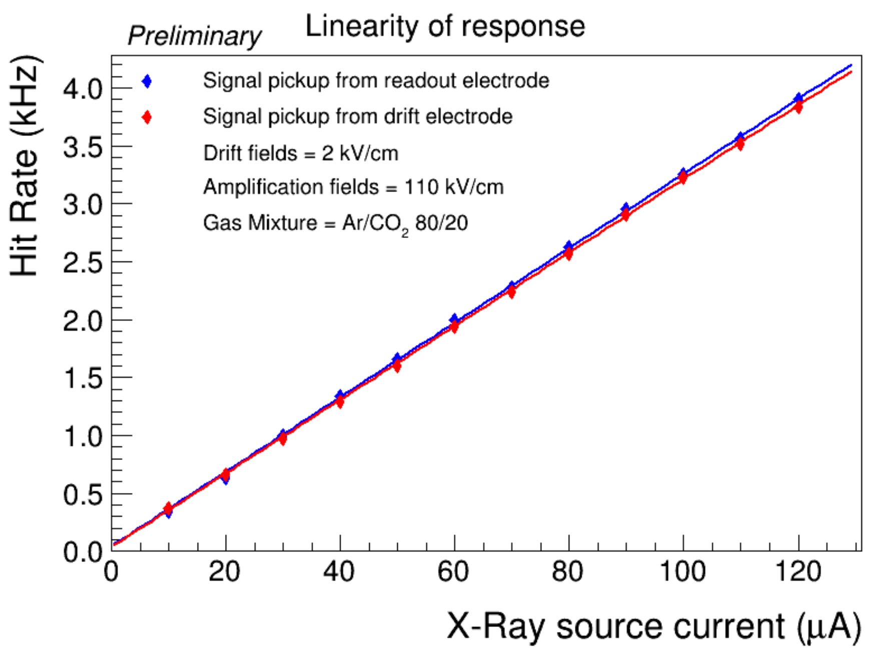
\- 144 chambers





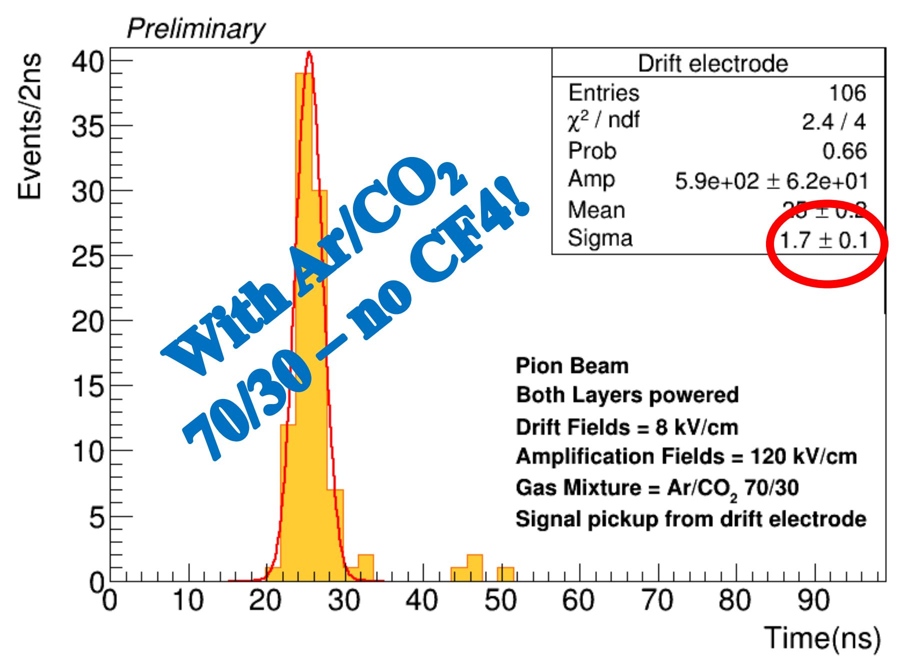
A. Conde, GEM Workshop XII, Oct 8, 2015

Characterization and time resolution results



The time resolution is estimated from the ***sigma of the gaussian fit*** of the distribution.

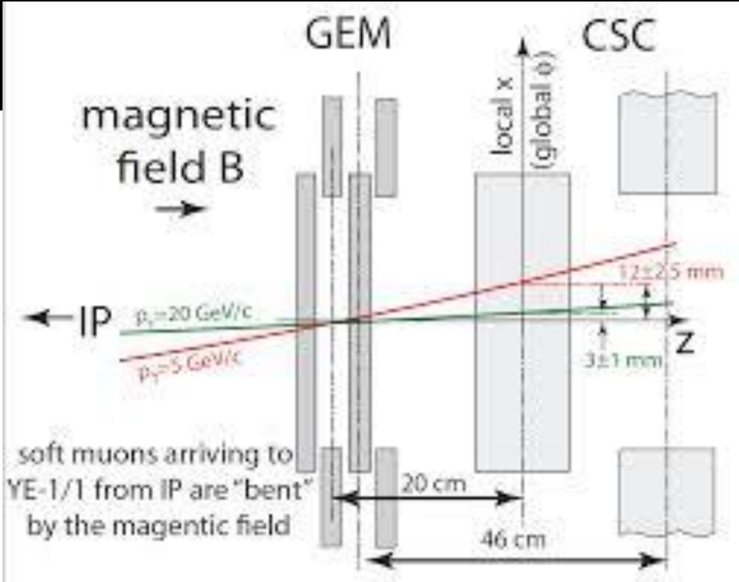
The electronics chain used to readout the signals was composed by a Cividec broadband amplifier (x100) and a Lecroy linear amplifier (x7.5)

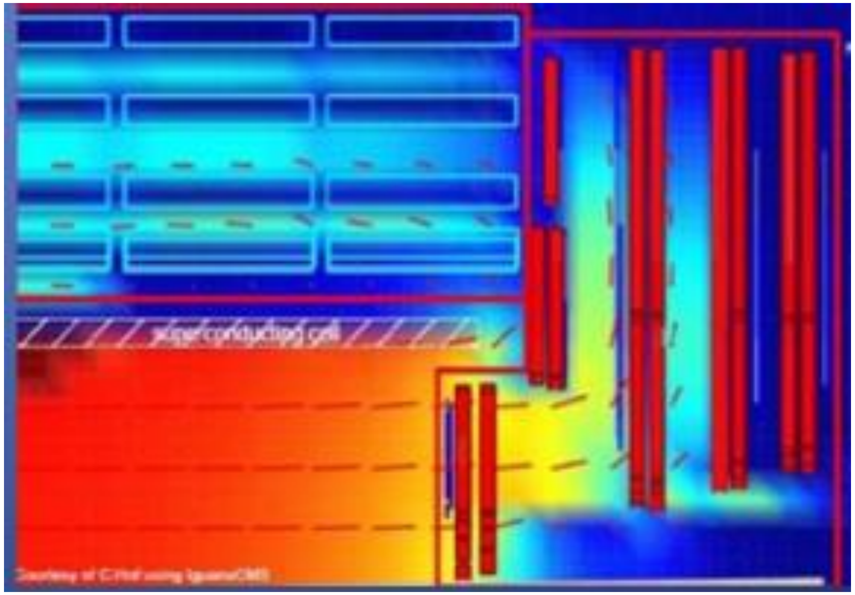


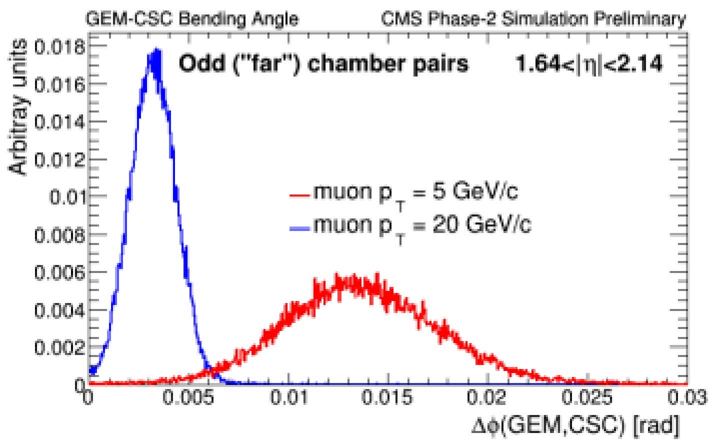
The rates measured from the readout and the drift electrodes are increasing proportionally with the flux. In addition the two datasets are compatible →

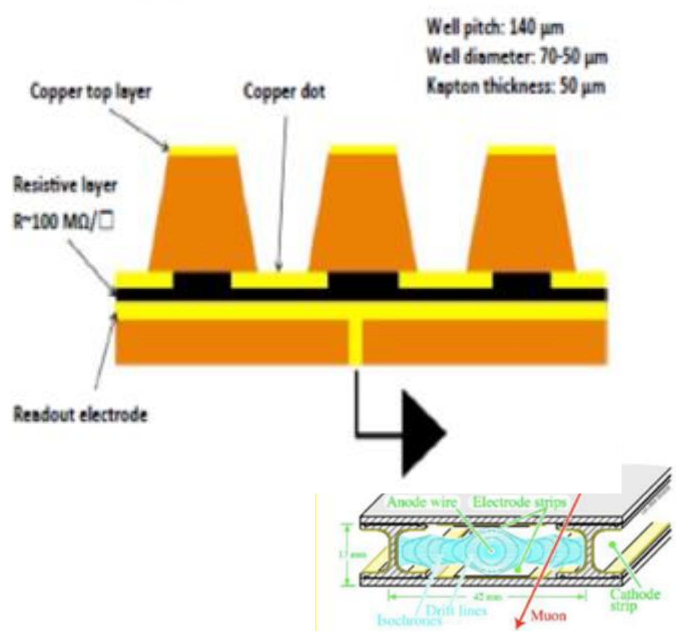
- The detector response is ***linear*** with the flux
- The detector is ***electrically transparent***

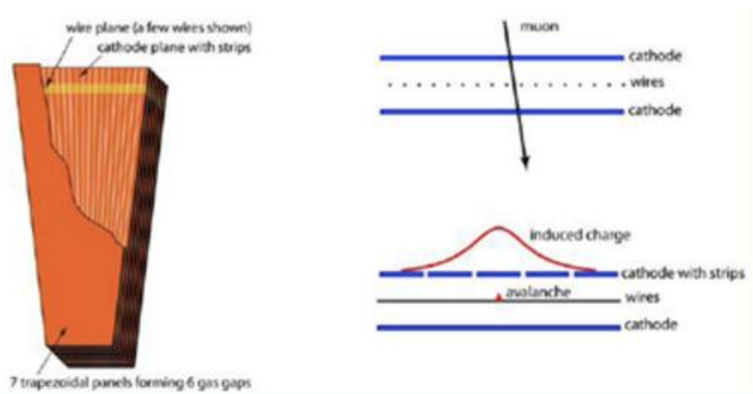
The source used is a Mini-Xray Amptek with Ag cathode.


GEM
CSC
magnetic field B
local x
(global ϕ)
IP
pT=20 GeV/c
pT=5 GeV/c
12±2.5 mm
3±1 mm
Z
soft muons arriving to YE-1/1 from IP are "bent" by the magentic field
20 cm
46 cm




GEM-CSC Bending Angle
CMS Phase-2 Simulation Preliminary
Odd ("far") chamber pairs
1.64<|η|<2.14
muon pT = 5 GeV/c
muon pT = 20 GeV/c
Arbitray units
Δϕ(GEM,CSC) [rad]


Well pitch: 140 µm
Well diameter: 70-50 µm
Kapton thickness: 50 µm
Copper top layer
Copper dot
Resistive layer
R~100 MΩ/□
Readout electrode
Anode wire
Electrode strips
Cathode strip
Drift lines
Muon


wire plane (a few wires shown)
cathode plane with strips
7 trapezoidal panels forming 6 gas gaps
muon
cathode
wires
cathode
induced charge
cathode with strips
avalanche
wires
cathode