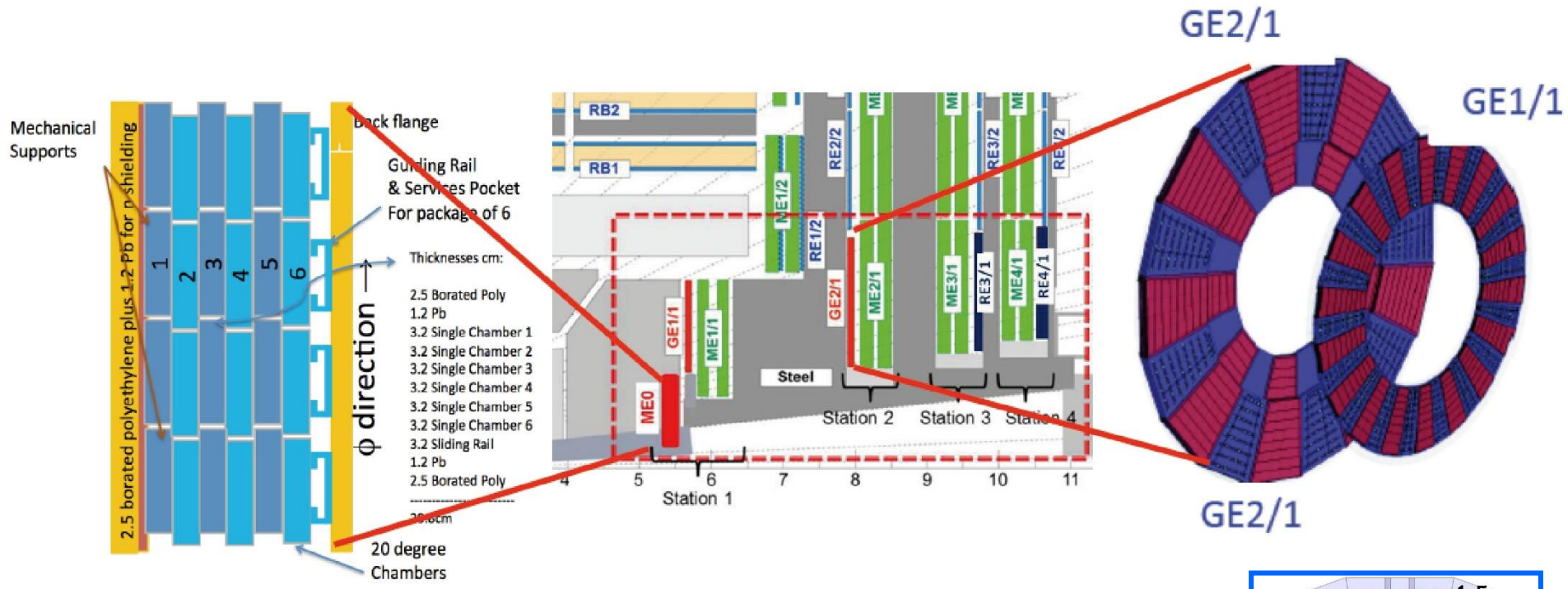
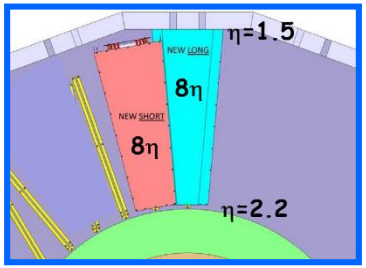
GEM DPG Overview





Slice Test ⟹ QC8 ⟹ P5

CMS DP-2019/010

Teruki Kamon and Jason Lee for GEM DPG Team

GEM Workshop, Sep 30 – Oct 4, 2019

https://indico.cern.ch/event/847049/

GEM DPG Organization (Sep 2019)

[Conveners]
T. Kamon &
Jason Lee

General DPG

- **Trigger** — [Convener] Sven Dildick … Studies of the L1 muon trigger using GEM-CSC integrated hits as well as GEM standalone hits along with development of objects and algorithms; GE2/1 and ME0 triggers. Link to the trigger integration.
- **Detector Response Modelling Simulation** — [Conveners] Othmane Bouhali, Piet Verwilligen … Detector Simulation (GEANT, GARFIELD); Phase-2 Simulation; Background Studies; Link to Phase-2 Upgrade GE2/1 & ME0)
- **Reconstruction + Validation** — [Convener] Ian Watson … Reconstruction & Muon ID; Validation/DQM Code; Unpacker, HLT - Link to online/offline DQM
- **Physics Performance dataset** — [Convener] **Shawn Zaleski (new)…** DQM and Certification, data & MC Validation, Alignment, Calibration and DataBase, detector performance studies, Link to PPD+AlCaDB, QC8 & P5 operation
- **Muon Alignment** — [Convener] **Hyunyong Kim (new)** … Development and maintenance of muon alignment code

Link to O&OS

- **Database / OMS** — [Link] **Adeel Adeel-Ur-Rehman** (with Umesh Joshi) … Production DB, QC1~8, DB; Configuration DB; Construction DB; Strip masking; OMS
- **QC8 (CR) SW** — [Link] Giovanni Mocellin, Ilaria Vai … Unpacker, DB, DQM, and cosmic-ray data analysis

Six Talks at DPG Session on Wednesday

- Alignment … Hyunyong Kim
- Trigger … Sven Dildick
- Monitoring/PPD/Validation/RECO… Ian Watson
- DB and OMS … Adeel Adeel-Ur-Rehman
- Standalone Simulation … Shivali Malhotra
- Phase-2 Radiation Studies … Piet Verwilligen

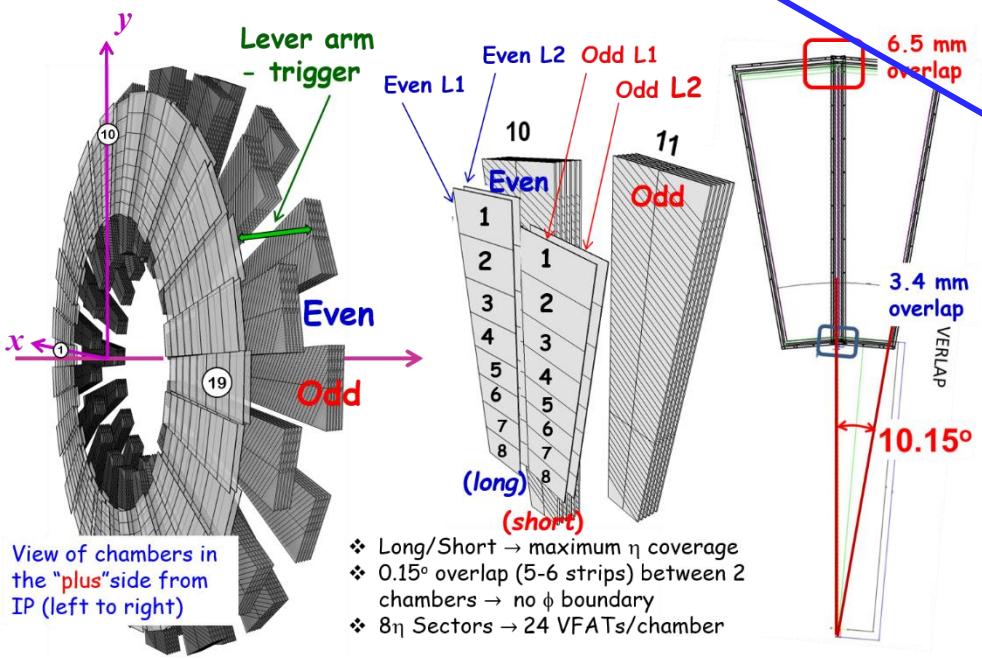
Operation Commissioning Schedule at IRR in June (TO BE UPDATED after the workshop)

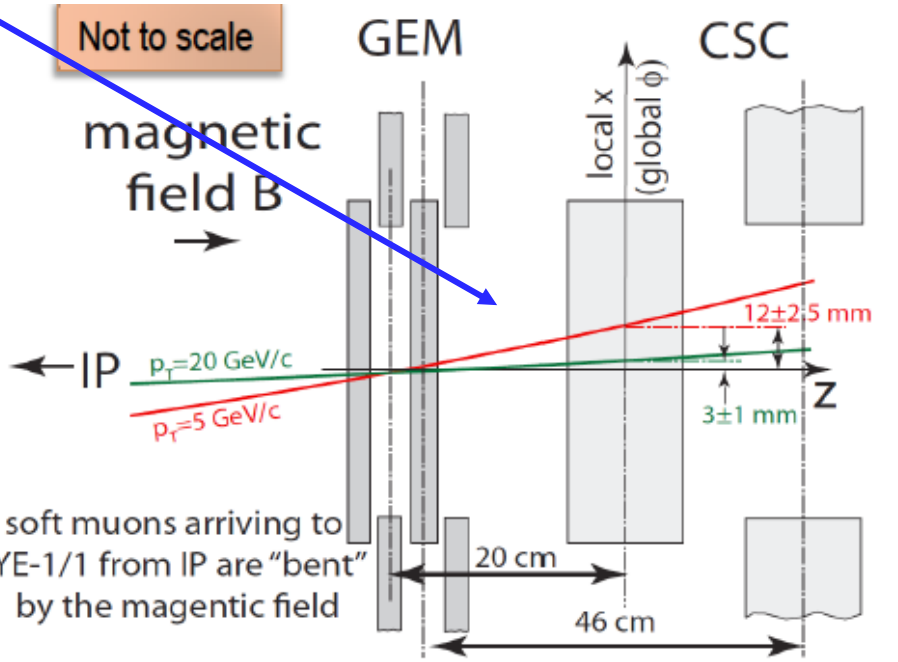
Summer '19	Migrate current SW to full-scale framework, configuration from DB, testing on 904 integration setup. Valuable feedback from initial commissioning of July superchambers
Fall '19	Stress tests with miniDAQ, migrate 904 QC setup to new framework. GE1/1-ME1/1 trigger test in progress at 904.
Winter '19/'20	miniDAQ commissioning P5 (depending on schedule of DAQ infrastructure), development in 904. The earliest MWGR (only DQQ and SCs w/o HV) would be the last one in November 2019. No cosmic data before middle December 2019.
Spring '20	Add monitoring and alarming, feedback from MWGR operations + miniDAQ commissioning.
Summer '20	Function manager improvements. Regular inclusion in MWGR operations after June 2020. Exercise GE1/1 alignment using CR muons using local alignment (GE1/1 and CSC) with stand-alone muon (from June 2020)
Fall '20	Full system operation
Winter '20/21	Final preparation for Run 3. Alignment with collisions (from 2021)

GEM Track-based Muon Alignment

- See Hyunyong's talk for detais
- Developing an alignment algorithm for GEM using the same approach in CSC, starting with local x and ϕ_z.
- GEM position is also needed to be aligned with respect to CSC position for GEM-CSC local trigger.

Tao Huang, "GE1/1-ME1/1 Trigger Commissioning", Level-1 Trigger Operations + DPG: LS2 Kick-Off Workshop, 13-15 Feb 2018



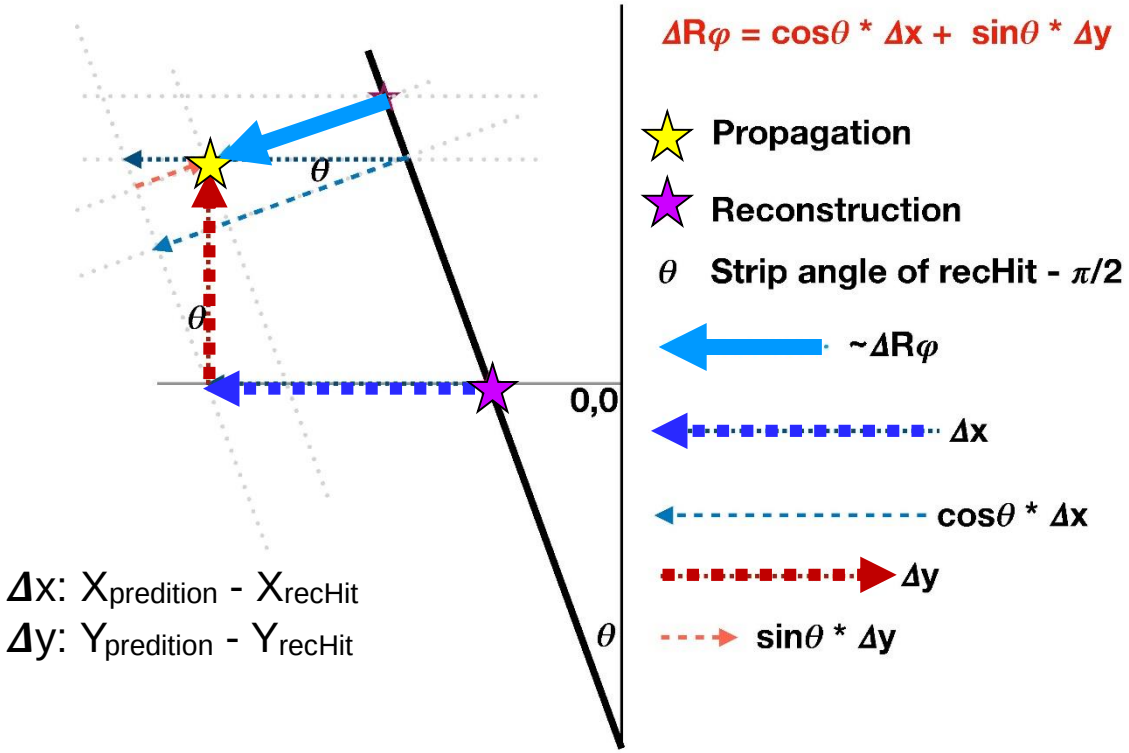


Angular resolution of 300 μrad or better on $\Delta\phi = \phi_{GE1/1} - \phi_{ME1/1}$

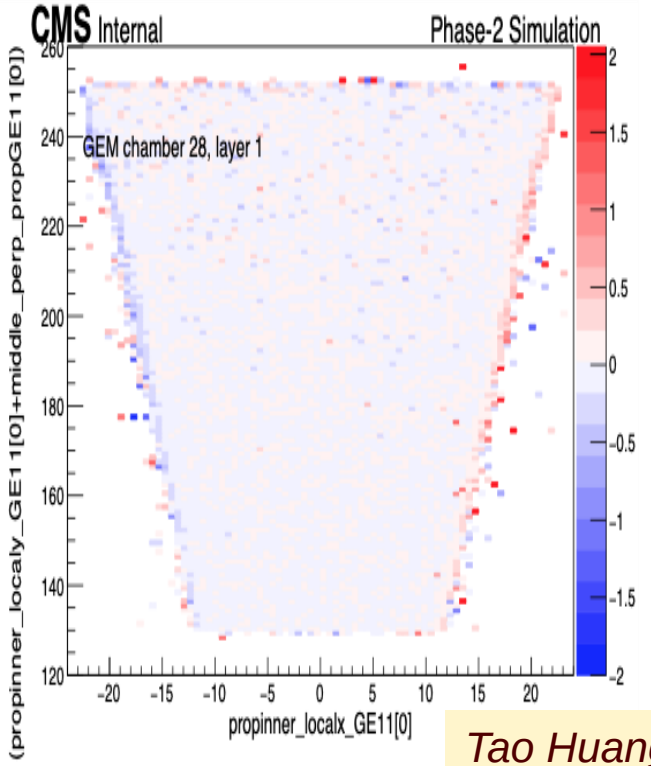
GEM Alignment Residual at Glance

- Residual $\Delta R\phi = \Delta x \cdot \cos\theta + \Delta y \cdot \sin\theta \Longrightarrow$ Two degree of freedom: δx and $\delta\phi_z$

$$\begin{pmatrix} \Delta(R\phi) \\ \Delta y_o \\ \Delta\frac{d(R\phi)}{dz} \\ \Delta\frac{dy}{dz}_o \end{pmatrix} = \begin{pmatrix} 1 & \left[-\frac{x}{R}+3\left(\frac{x}{R}\right)^3\right] & -\frac{dx}{dz} & -y\frac{dx}{dz} & x\frac{dx}{dz} & -y \\ 0 & 1 & -\frac{dy}{dz} & -y\frac{dy}{dz} & x\frac{dy}{dz} & x \\ 0 & -\frac{1}{2R}\frac{dx}{dz} & 0 & \left[\frac{x}{R}-\frac{dx}{dz}\frac{dy}{dz}\right] & 1+\left(\frac{dx}{dz}\right)^2 & -\frac{dy}{dz} \\ 0 & 0 & 0 & -1-\left(\frac{dy}{dz}\right)^2 & \frac{dx}{dz}\frac{dy}{dz} & \frac{dx}{dz} \end{pmatrix} \begin{pmatrix} \delta x \\ \delta y \\ \delta z \\ \delta\phi_x \\ \delta\phi_y \\ \delta\phi_z \end{pmatrix}$$



Δx: $X_{predition} - X_{recHit}$
Δy: $Y_{predition} - Y_{recHit}$



Tao Huang

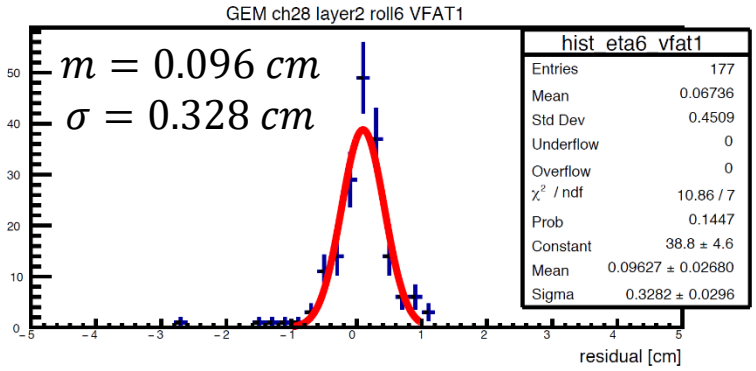
Map of $\Delta R\phi$ residual values in local coordinates, x and y, of GE1/1. The value of $\Delta R\phi$ for each muon is plotted in **red** if $\Delta R\phi > 0$ and **blue** if $\Delta R\phi < 0$. Observing asymmetric distributions at boundaries suggests a requirement of fiducial volume cuts.

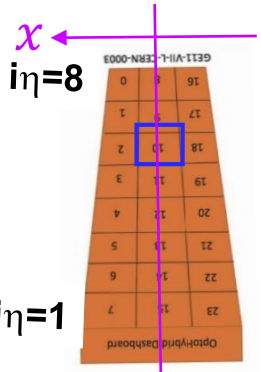
Exercise of GEM Alignment

Tao Huang

- Residual $\Delta R\phi \equiv x_{\text{projection}} - x_{\text{measured}}$
- Minimize the $\Delta(R\phi)$ residual to align local x and ϕ_z.

28L2 $i_\eta = 6$, $i_\phi = 1$

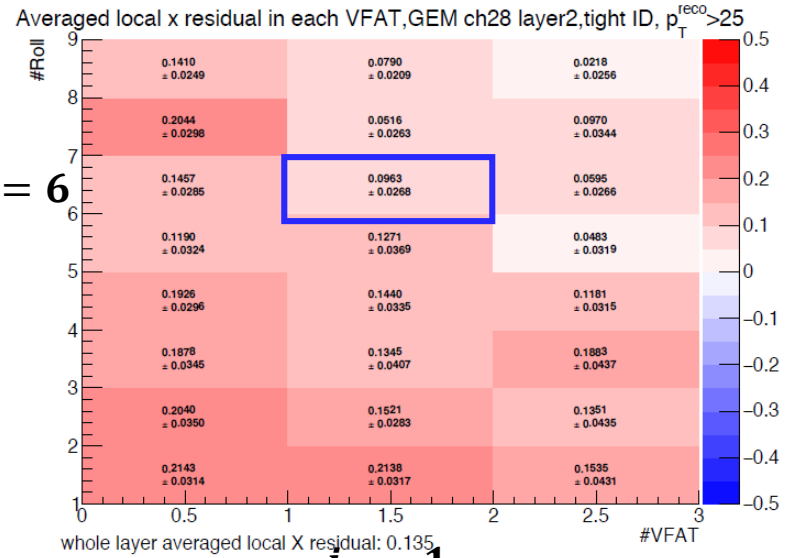




The observed distribution of residual is wider due to multiple scattering, as the p_T of muons at the slice test are dominated at 20-30 GeV. We checked geometry and cluster size and found no obvious reasons for a wider distribution.

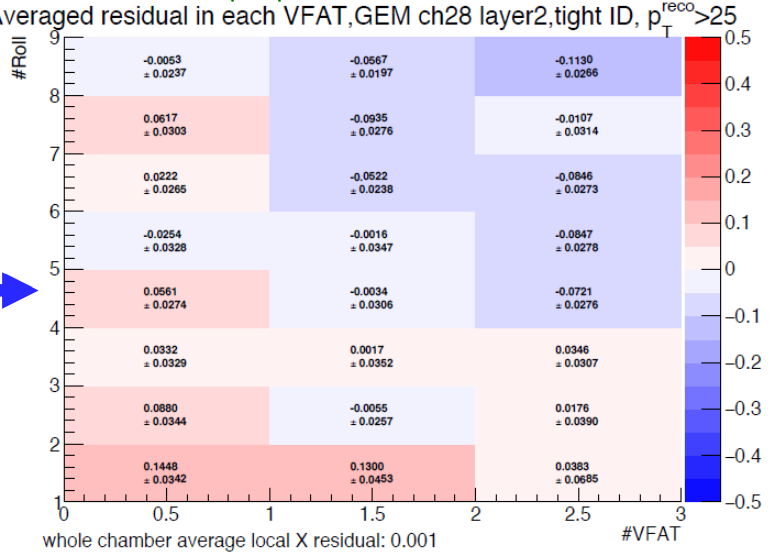
Chamber 28 Layer 2

$\langle m \rangle = +0.135\ cm$



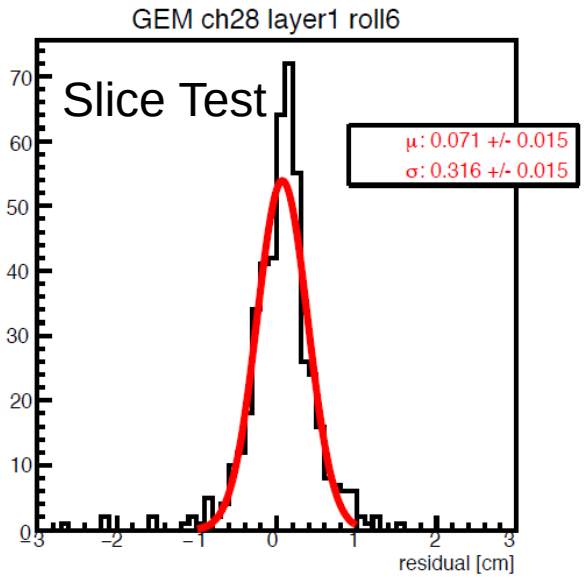
local X shift

$\langle m \rangle = +0.001\ cm$



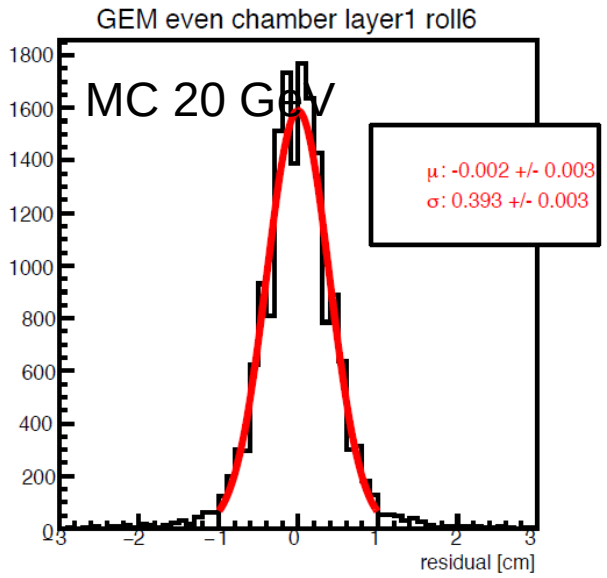
Exercise of GEM Alignment (cont'd)

Tao Huang



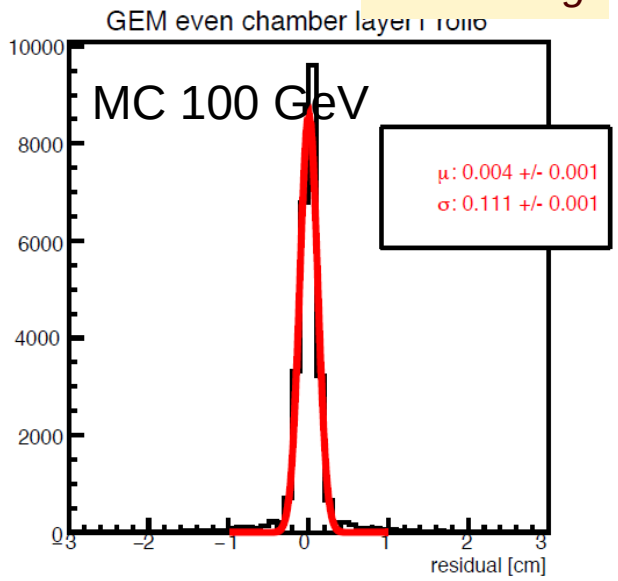
28L1 $i_\eta = 6$

$m = 0.071\ cm$
$\sigma = 0.316\ cm$



Even L1 $i_\eta = 6$

$m = -0.002\ cm$
$\sigma = 0.393\ cm$



Even L1 $i_\eta = 6$

$m = 0.004\ cm$
$\sigma = 0.111\ cm$

- The observed distribution of residual at the slice test seems to be consistent with simulation (20 GeV).

Misalignment from R = 1274.00 mm?

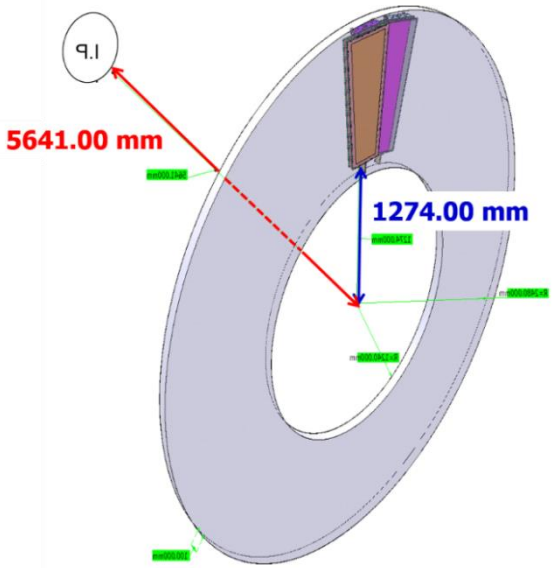
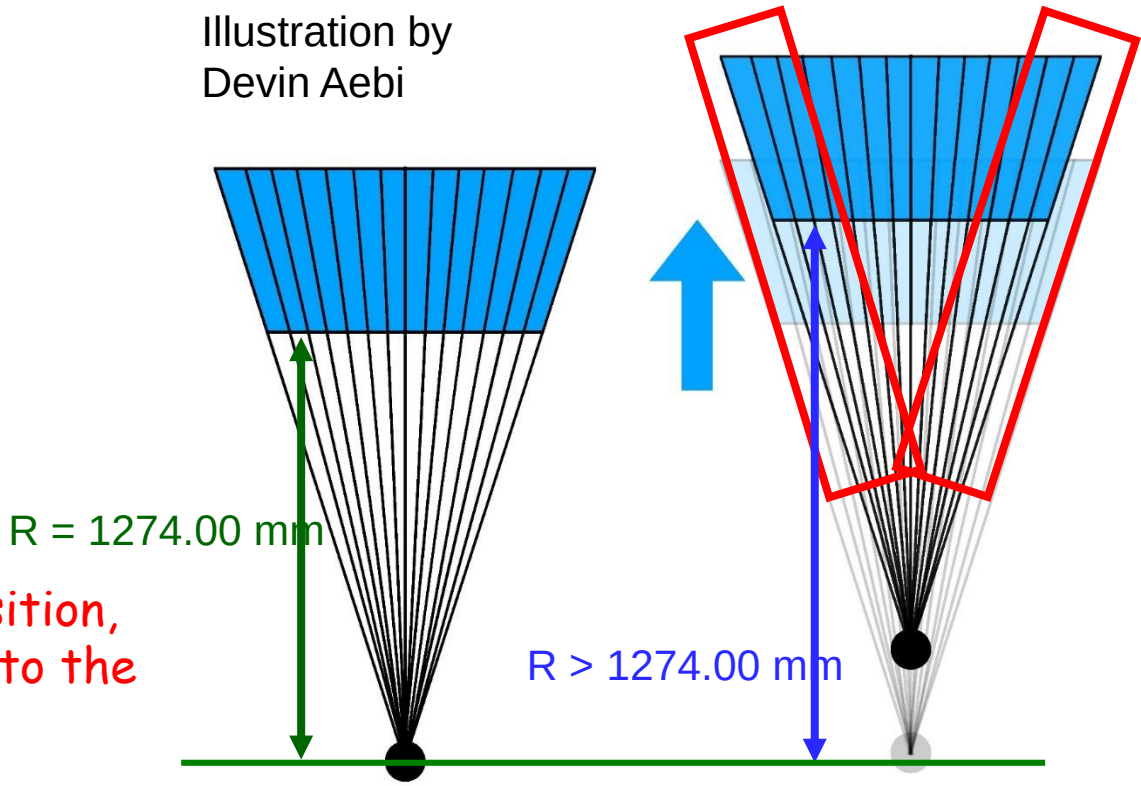


Illustration by
Devin Aebi



[Q] When GE1/1 is at nominal position, the strips should "exactly" point to the beam line. Correct?

[A by Michele on Oct 1, 2019] The "clearance" between the rail and the pivot pin which allow to insert the SC is order mm, but the SCs are then fixed with 4 screws on the large base which are more precise. In any case definitively will be possible to have small misalignment which could revert in not perfect radial strips, misalignment have to be measured and quoted with tracks.

The strip pitch appears to be *smaller* on the left and right edges.

Brief Muon Alignment Workflow

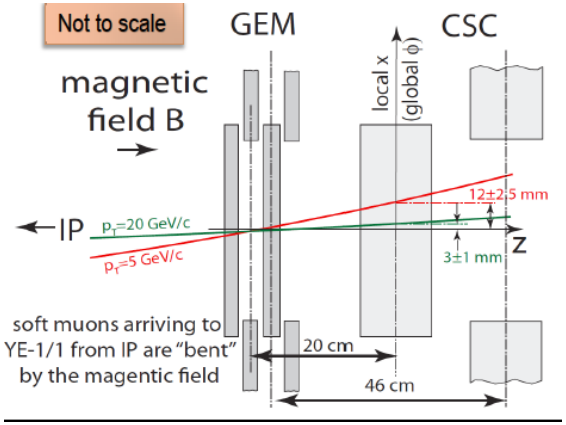
- Strategy at the end on LS2 (cosmics, splash?) in preparation for the beginning of Run3
  - Employ the "reference-to-target" algorithm by the **end of 2019** and test with MC events (see the GEM installation schedule).
  - Although muons from pp collisions are better, we could use muons from cosmic ray (or splash) events when pp collisions are not available.

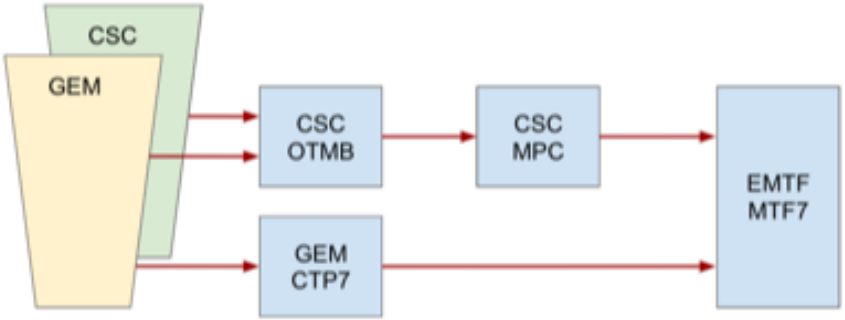
- Integration of GEMs in the alignment workflow
  - GEMAlignment Record is implemented by Ian Watson in CMSSW_11_X in May 2019.
  - The geometry producers consume "records" on request based on an "applyAlignment" parameter in the configuration.
  - Developing the "reference-to-target" algorithm for GEM with single muon gun samples with GEMAlignment Record (see Hyunyong for details).
- Improvements to the alignment workflow in general:
  - The workflow is established with CSC. We mimic it for GEM.

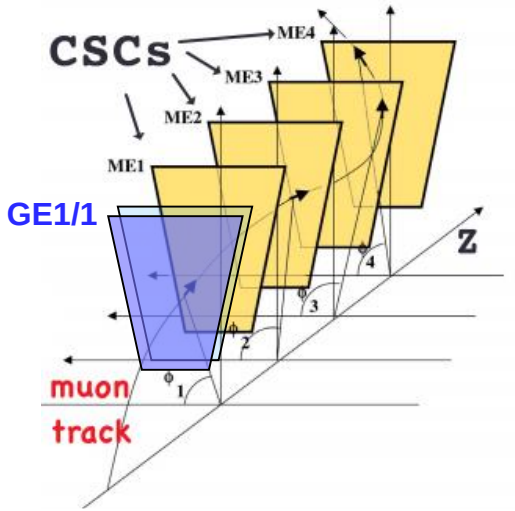
Trigger

Sven's talk is focus on plots for L1T TDR. Thus this page provides a snap shot of GEM+CSC integrated local trigger (ILT) plans (see Tao's talk on Sep 17).

Tao Huang, "GE1/1-ME1/1 Trigger Commissioning", Level-1 Trigger Operations + DPG: LS2 Kick-Off Workshop, 13-15 Feb 2018





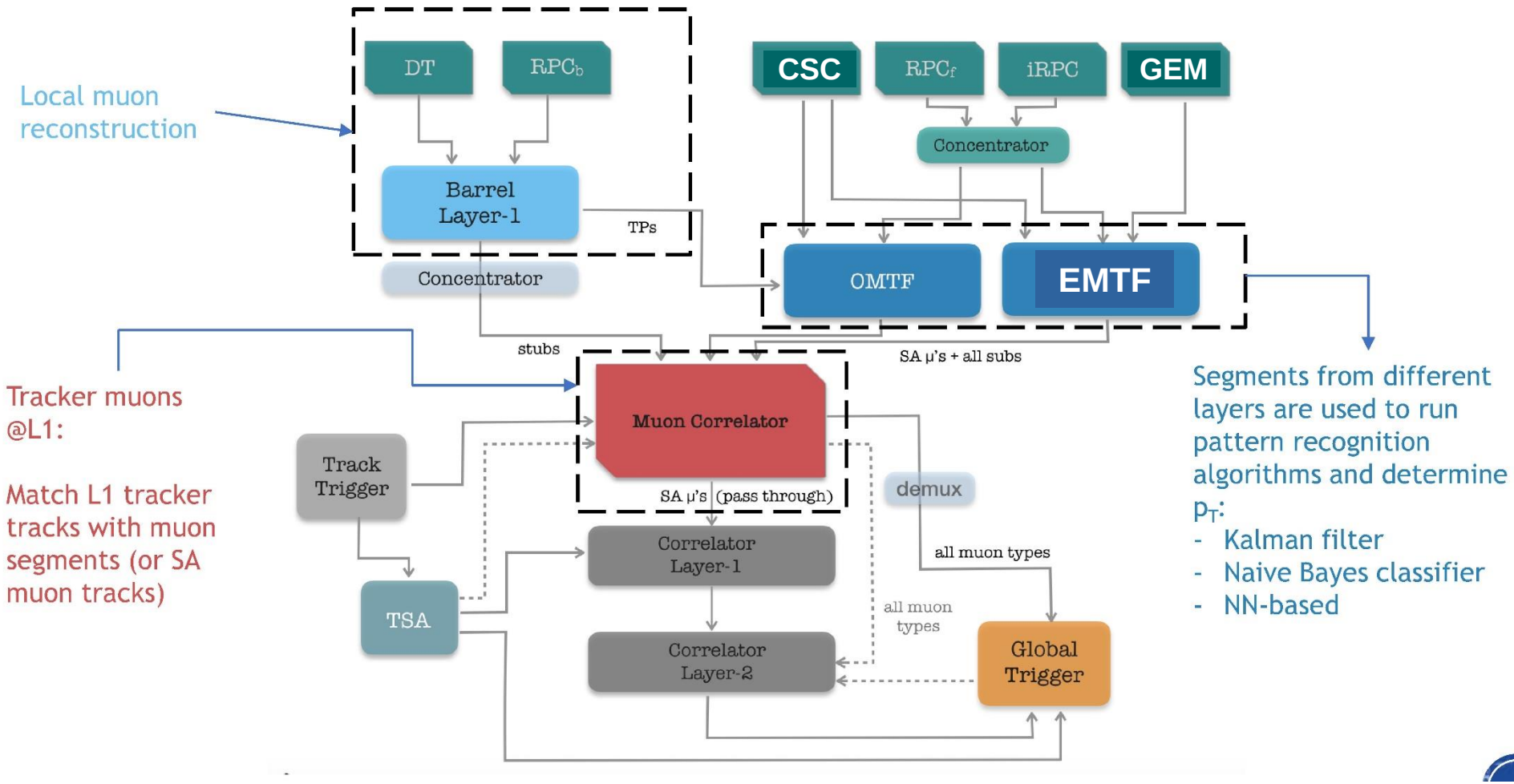


GEM+CSC integrated local trigger (ILT) plans:

- Phase1: GEM+CSC communication and GEM+CSC data readout through OTMB in DAQ path, by 2019 Summer
- Phase2: full GEM+CSC ILT with GEM+CSC matching, first version by 2020 Spring
- Various test stands will be set up to validate and test GEM+CSC OTMB firmware

CSC+GEM in Phase-2 L1 Muon

From J. Konisberg



Local and Global Trigger

[Q] Is GE1/1 integrated into the local and global trigger (releases)? Are the plans for tests of GE1/1+ME1/1 trigger on-going in 904? Do we have a well-defined plan for the commissioning of the trigger in P5?

- The software had been prepared to work long time ago. The hardware verification that data is received by CSC has been done as well. The firmware design for the OTMB is ongoing. Most of the validation and testing/commissioning work is planned for early 2020.

- Tao and a student have worked in August-September at 904. Plan to have full SC in 904 for a continued testing

- There are some open questions related to how and where to do alignment corrections. There are a couple of options there, one of which may be difficult if the misalignments are large. Understanding this requires a good understanding of GE1/1 alignment, which is not yet understood but the work is ongoing.

Muon Trigger Primitives for L1 TDR

https://twiki.cern.ch/twiki/bin/viewauth/CMS/L1TriggerPhase2TDR

Editors for the different subdetectors:

- **CSC:** Jay Hauser
- **DT:** Carlo Battilana
- **GE / ME0:** Sven Dildick
- **(i)RPC:** Brieuc Francois

October 1st-31st : plot approvals with L1DPG and UPSG
End of October : present plots to WGM for approval - all plots approved and integrated into the TDR

[Q] Aging and Failure scenarios for GE1/1, GE2/1. and ME0. Probably okay to assume no aging effect. How about "failure" scenario?

Time to finalise plots up to ~ October 15th (need both GMM and L1T approval)

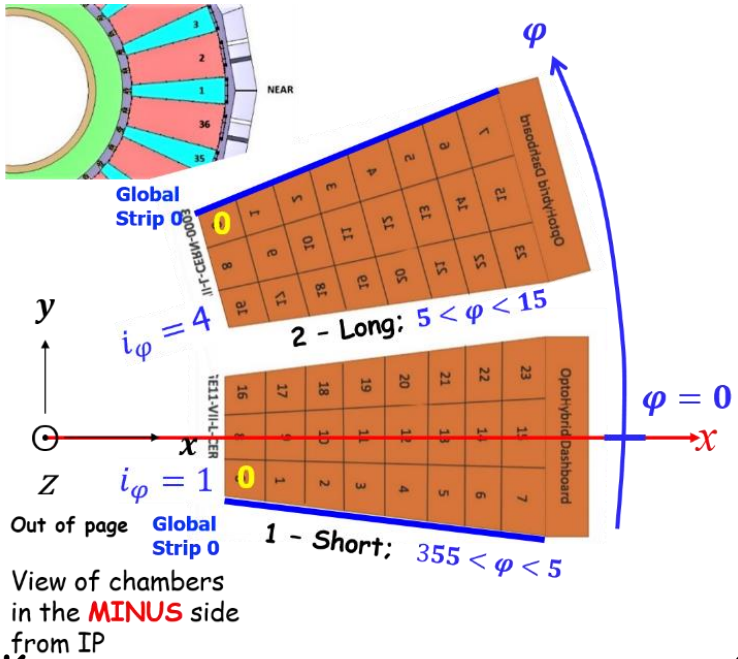
Unpacker/DQM/PPD

- See Ian's talk for details.
- GEM **Unpacker** has been developed and tested in a full chain processing: i.e., RAW → Unpacker → Digi → Reco → DQM at the slice test (v2 electronics) and QC8 (v3 electronics).
- **Online DQM** GUI has been deployed and ran during the slice test at P5. Currently in use for QC8
- **Offline DQM** .. Porting slice test analysis code (Efficiency and Background rates) into CMSSW DQM in progress.
- **Physics Performance dataset (PPD)** - Certification of GEM data
  - Prompt Feedback Analysis (Utilise GEM Online Software from QC8)
    - P5 configurations need to be updated. When configurations in GEM database, takes a day to update for PFA analysis
  - Certification, data & MC Release Validation, Calibration and DataBase, detector performance studies.
- **A dedicated team is formed.**
  - Online DQM – 1 PhD student
  - Offline DQM – 1 PhD student
  - Validation – 1 PhD student
  - DQM with ML – 1 PhD student
  - PPD+Prompt Feedback Analysis team – 1 PD + 2~3 students

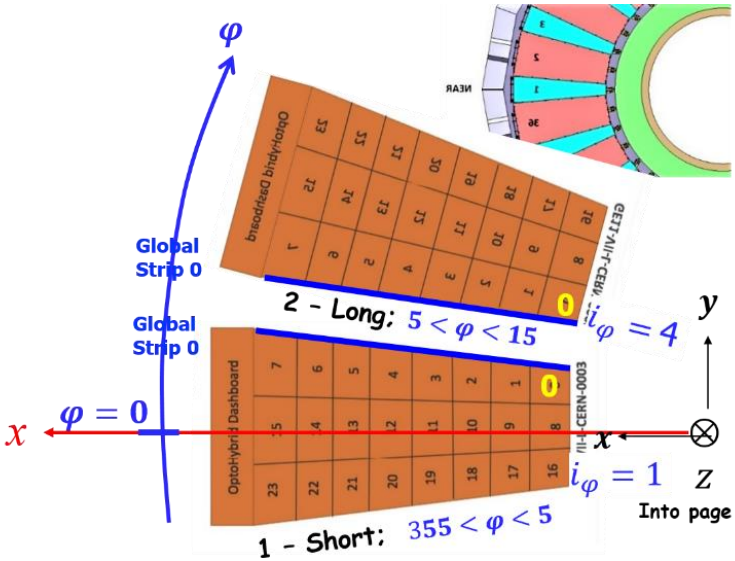
VFAT Readout Map Database

The slice test provided a valuable lesson:

- Validation of the readout format (electronics mapping) – There was a confusion due to the GEM detectors are flipped at P5.
- Timing of AMC vs VFAT (AMC BX != VFAT BX), affecting the muon detection efficiency. Suspecting Firmware → Monitoring at QC8. AMC and VFAT are synchronized.



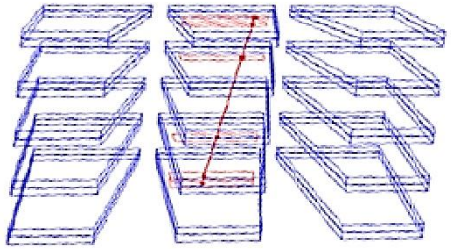
View of chambers in the MINUS side from IP

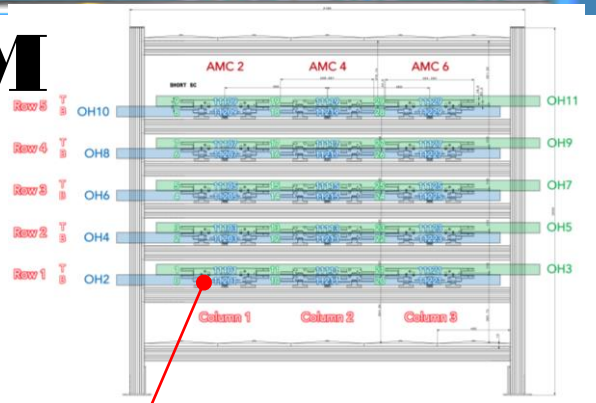


View of chambers in the PLUS side from IP

Snap Shot of DQM

Running GEM online DQM GUI at QC8 (Byeonghak Ko). Ready to deploy at P5.



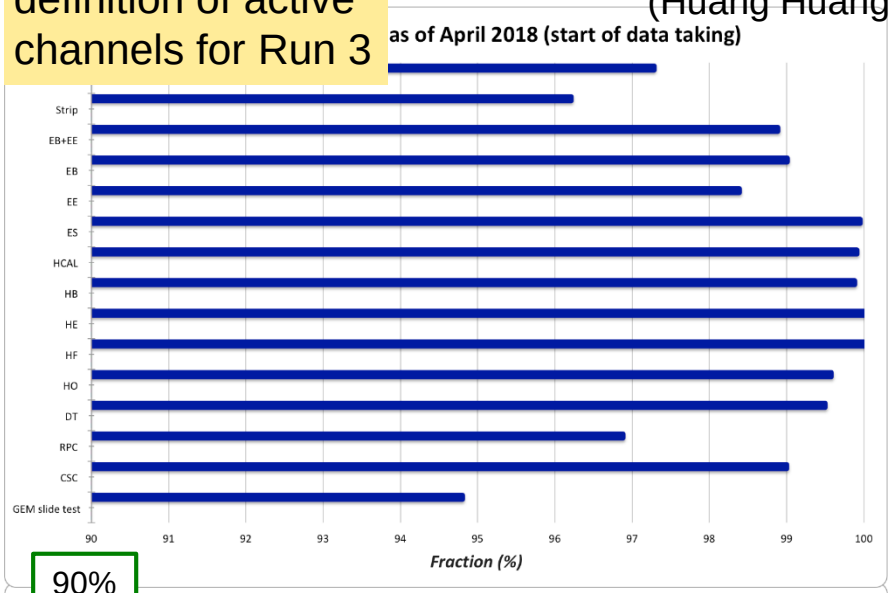


PPD: Active Channels in 2018

PPD task: A clear definition of active channels for Run 3

https://twiki.cern.ch/twiki/bin/view/CMSPublic/ActiveChannelsSummary

(Huang Huang, Elizabeth Starling)



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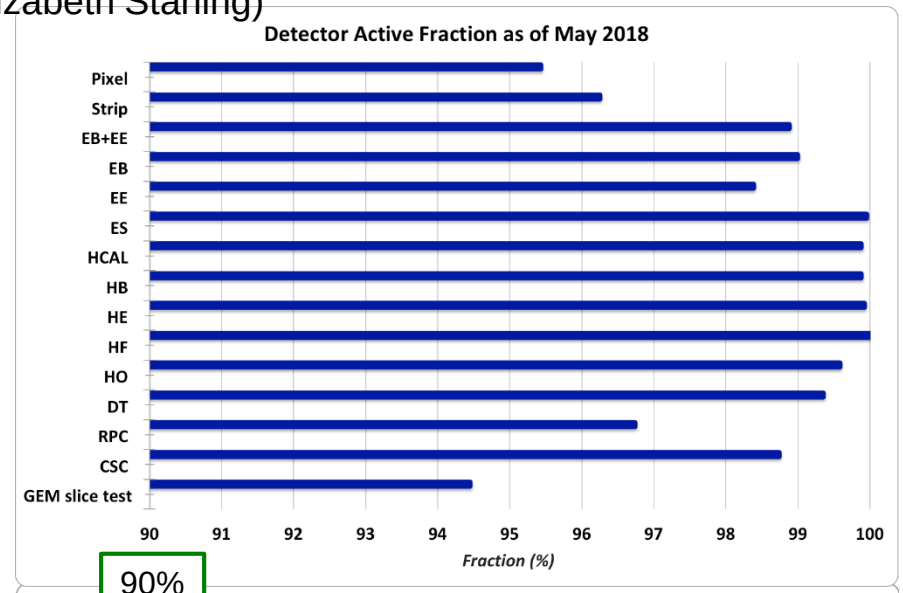

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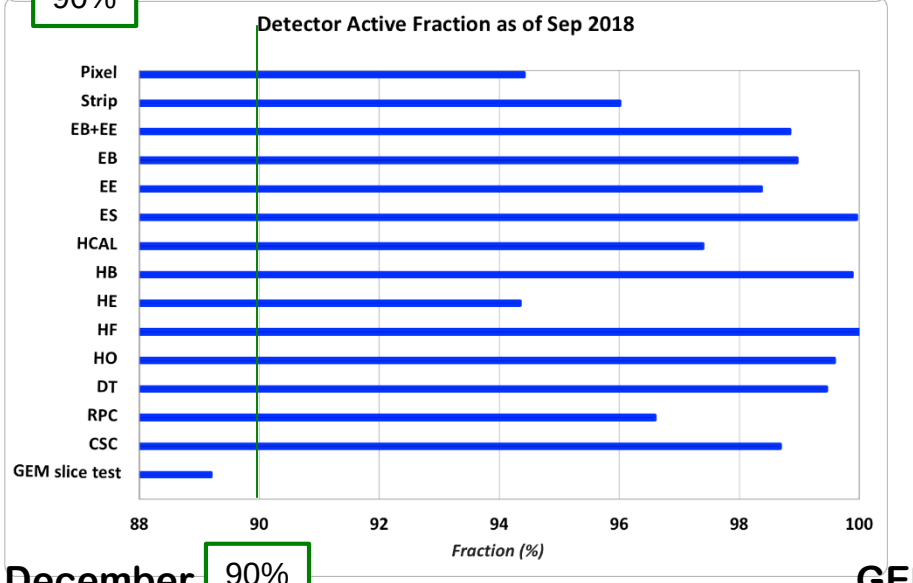

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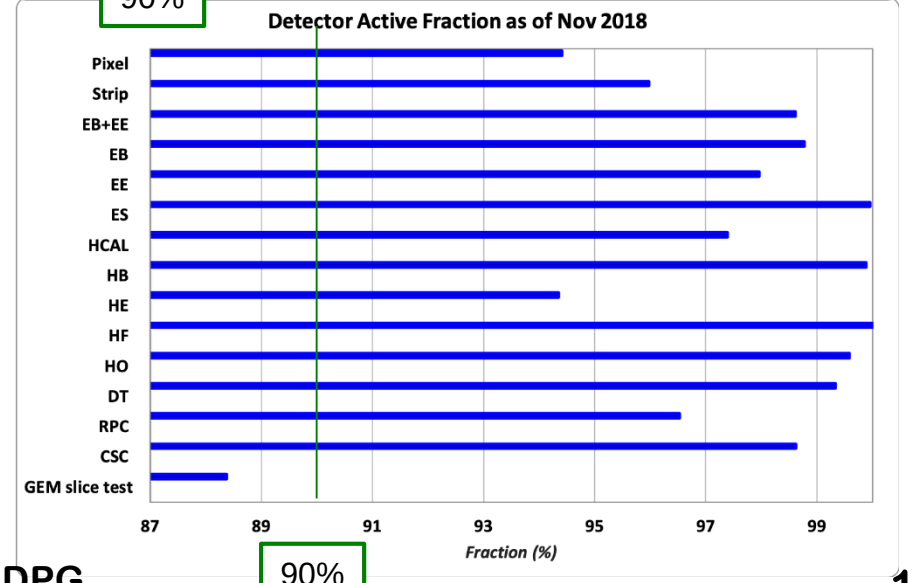

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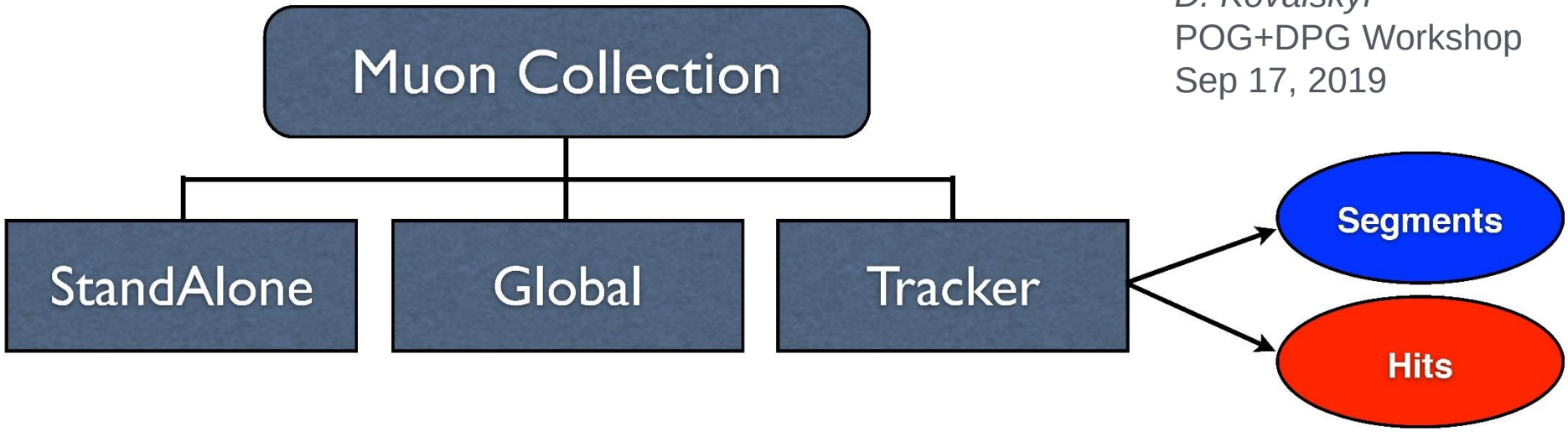
Muons with GEM

D. Kovalskyi
POG+DPG Workshop
Sep 17, 2019

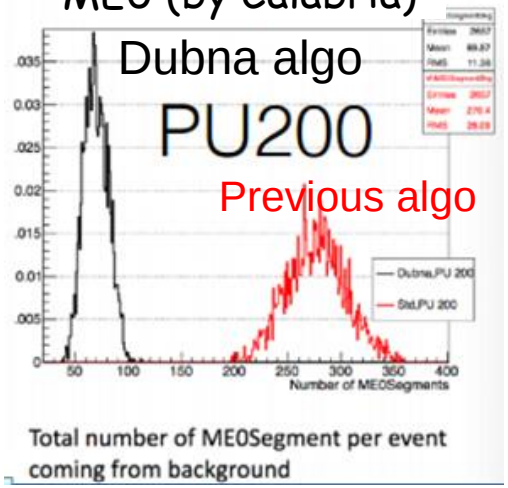


- GEM and RPC hits can be matched to inner track similar to what is done for TrackerMuons
  - Tracks qualify as RPC Muons if the extrapolated tracks matches at least two reconstructed hits in different stations (or RPC layers)
  - Segments have much better Signal/Background ratio
    - RPC/GEM muons are not recommended for analysis

Local and Global RECO

- Local and global reconstruction codes are integrated into the latest release. The workflows are controlled with eras (full GE1/1 geometry with unpacking + local reconstruction + global reco (GE1/1 in muons)). Same for MC.
  - GEM RecHit is built from fired strips, combining adjacent hits in a given η partition using a code based off RPC; segment building with CSC for GEMMuon
  - GEM segment for GE1/1 and GE2/1: mini segments are made from GEM rechits from the superchambers (2 layers)
  - For muon reconstruction, GEM rechits or segments can be used.
  - GEM (GE1/1 and GE2/1) + CSC segment builder has been implemented in the offline code: RecoLocalMuon/GEMCSCSegment
    - Starting from CSC segments, Searches for compatible rechits in GEM rolls.
    - creates new segments with combined CSC + GEM and refit
  - RU algorithm to use combined CSC & GEM hits.
- ME0: RU algorithm (Vladimir Palichik, Nikolay Voytishin) has been adapted for use in ME0 -- RecoLocalMuon/GEMSegment/plugins/ME0SegAlgoRU
  - $2 < |\eta| < 2.4$: ME0 - ME1/1 offline reconstruction based on combined segments applying the developments in CSC segment builder for ME0;
  - $2.4 < |\eta| < 2.8$: ME0 segment builder for HLT & muon identification.

ME0 (by Calabria)



Total number of ME0Segment per event coming from background

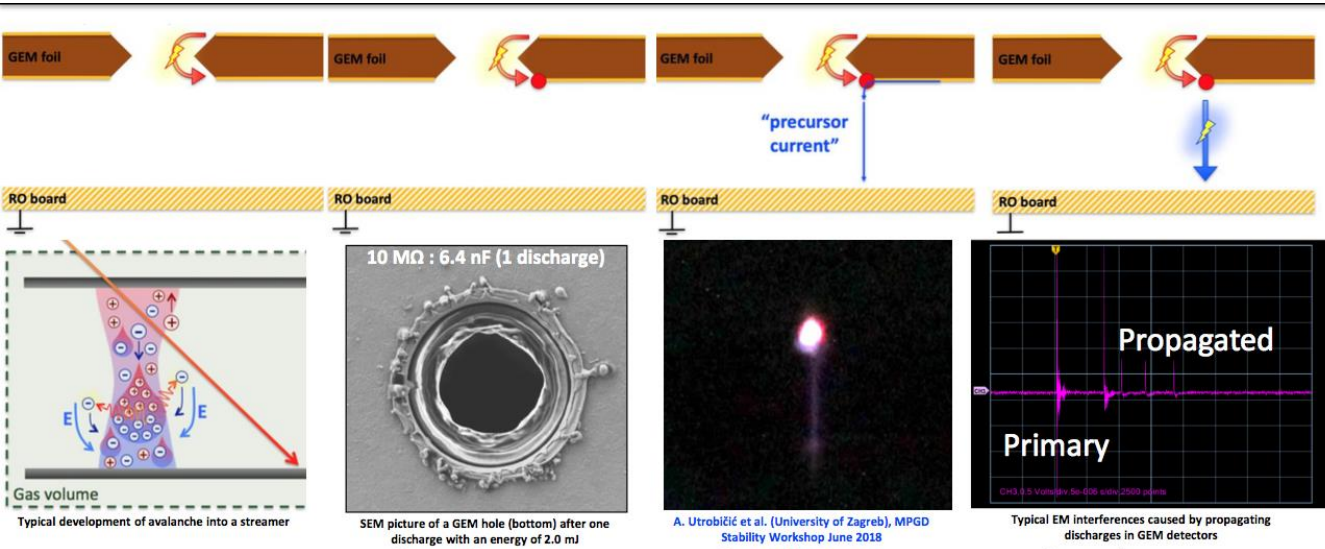
GEM+ME0 Code Merger

- The bulk of ME0 code is prepared with "copy+paste" of the GEM code and developed separately, causing GEM and ME0 states to go out of sync.
- Merging ME0 and GEM code together to ease maintenance

Simulation

Two main subgroups: (A) standalone detector simulation (Interstrip capacitance; Heat transfer; GEANT4 sensitivity and BG studies; Hole asymmetry) and (B) phase-2 simulation. See highlights/details of activities from two talks by Shivali and Piet.

Example 1: Heat Transfer Simulation to understand the dissipation of heat from discharge – How long we should wait to turn on HV?



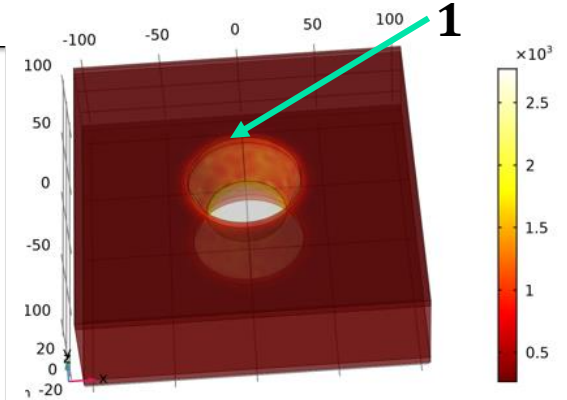
Typical development of avalanche into a streamer

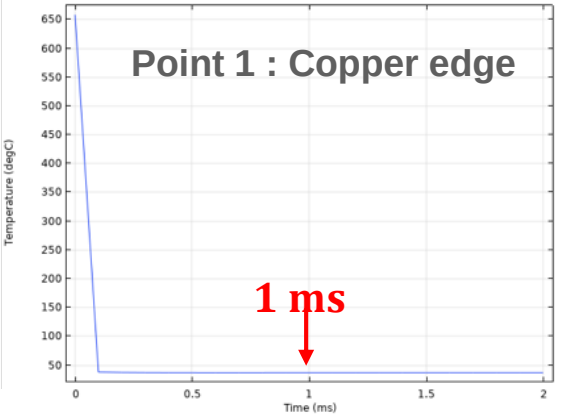
SEM picture of a GEM hole (bottom) after one discharge with an energy of 2.0 mJ

A. Utrobičić et al. (University of Zagreb), MPGD Stability Workshop June 2018

Typical EM interferences caused by propagating discharges in GEM detectors

- **Step 1:** Primary discharged caused by the increase of the space charge density in the avalanche
- **Step 2:** Creation of a hot spot on the copper near the hole rim >2500 °C
- **Step 3:** Thermionic emission of electrons in the gas, enhanced by local electric field (Schottky effect)
- **Step 4:** Development of the precursor current into a streamer causing a second discharge





From Jeremie A. Merlin, MPGD2019, May 2019

Simulation

Example 2: Background rate with HGCAL whose design is continuously changing.

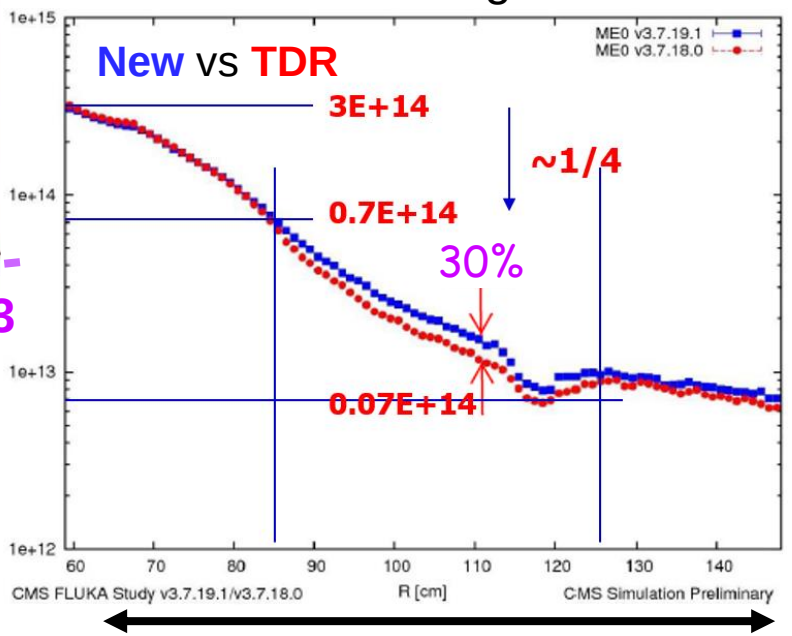
Woojin and Yechan have led the effort using CMSSW, seeing 30-40% increase in hit rate.

Recent FLUKA study:

v3.7.18.0 (10.3 λ and inner cone at η = 3)

v3.7.19.1 (9.3 λ and stepped inner surface beyond η = 3)

Igor Kurochkin



ME0: 62 ~ 150 cm

We formed a GEM team (led by Piet) to study the background rates with detector sensitivities and identify the impact of the reduced shielding of HGCAL in the ME0.

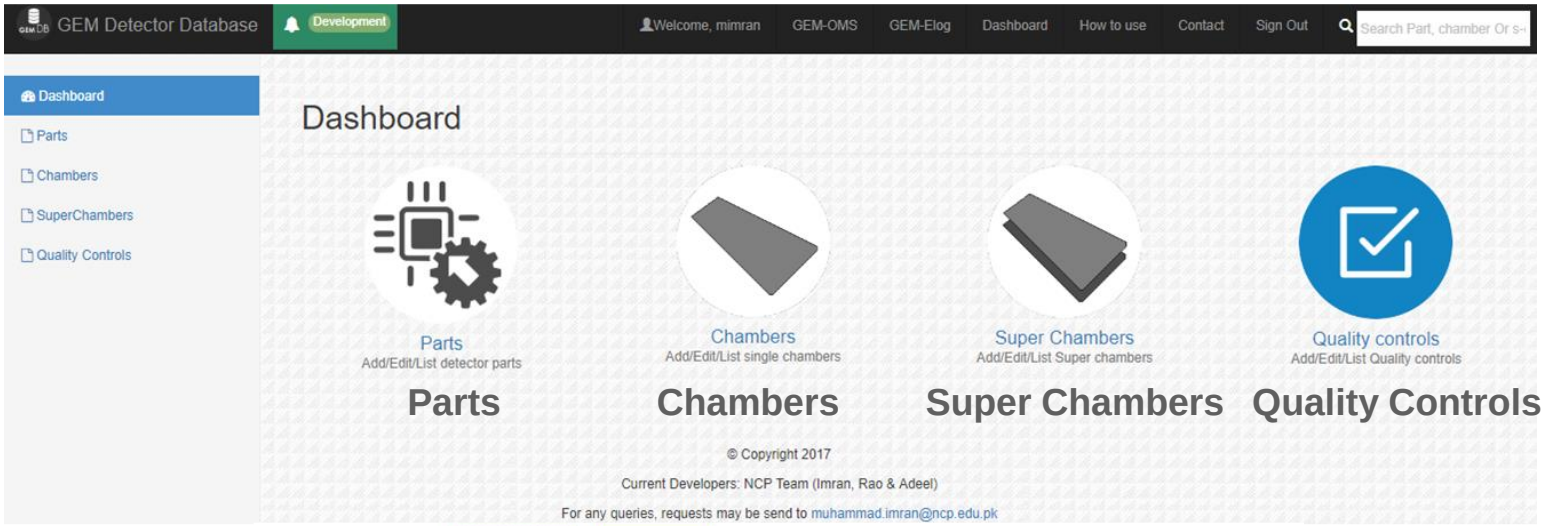
DB and OMS

- Peoplepower: Pakistan NCP team, who is devoted on DB and OMS tasks since late 2017. 2FTEs among 3 software engineers with a constant technical and invaluable advice by Umesh Joshi and Aivaras Silale.
- A substantial development on GEM DB was made, in particular on (A) the new version of the Quality-Control (QC) templates (and loading tools); (B) the tables and the architecture for the SuperChamber assembly and electronics components (C) OMS interface.

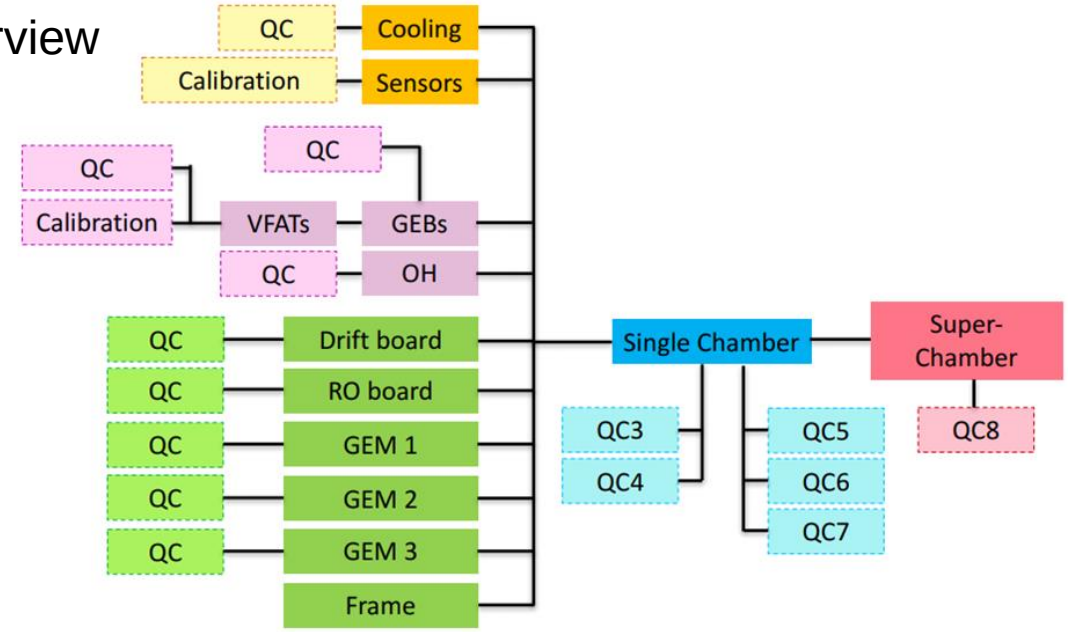
- **Develop templates, webpages for data uploading in GUI , and data visualization in OMS for various tests of QC3, QC4, QC5, QC6 and QC8.**
- **Add Edit feature of Chamber and Super Chamber Module.**
- **Add Registration feature of various new Components, GEB Narrow/Wide,OH, AMC, Cooling Plate, Temperature Sensor and Radmon Sensor.**
- **Develop web pages in GUI for parent/child attachment of various components.**
- **Develop tables/views, templates and OMS pages for Configuration DB.**
- **Develop tables/views, templates and OMS pages for VFAT3 parts DB.**
- **Develop web pages for QC Results in GUI and OMS.**
- **Develop tables/views, templates for QC Components and Electronics (for ULB Group).**
- **Bulk Data Uploading to OMDS using GUI without having account at CMSUSR.**
- **OMS migration from DET to CORE is in progress now.** Monitoring for GEM has been developed based on OMS-DET for the past 2 years. Since new OMS (OMS core with new technology and new functionalities) is available, we are working on the migration. Only CSC has moved to core OMS and the others are in the phase of migration.

GEM DB Web Interface

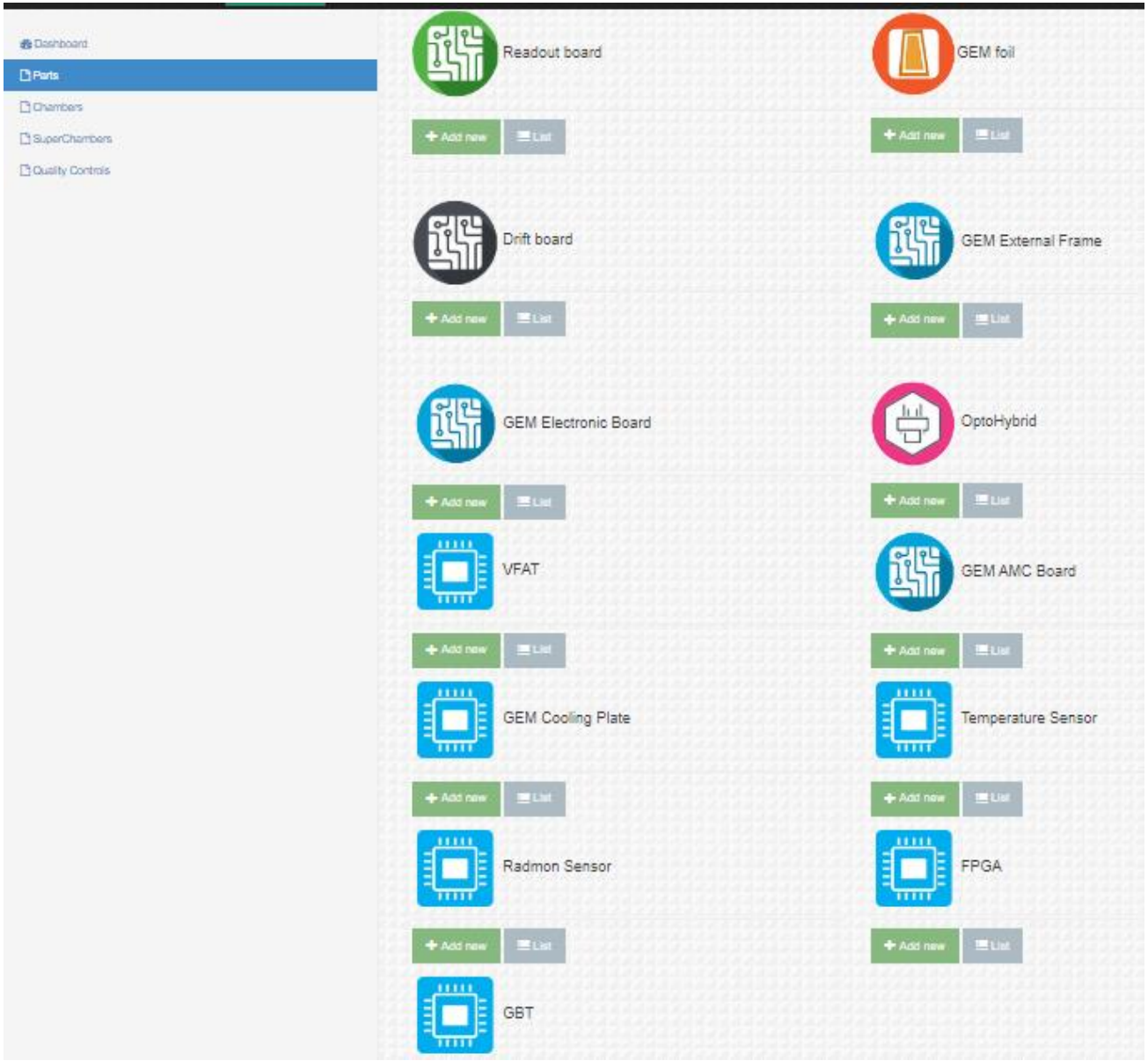
GEM Web Interface



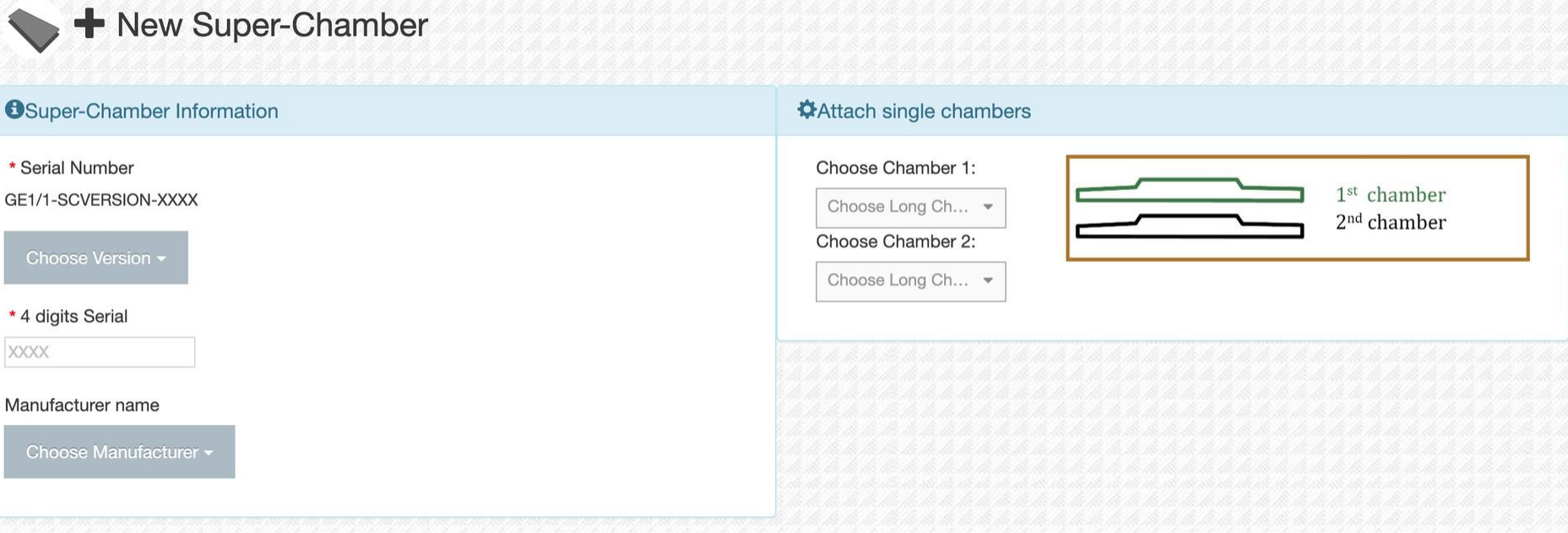
Components Overview



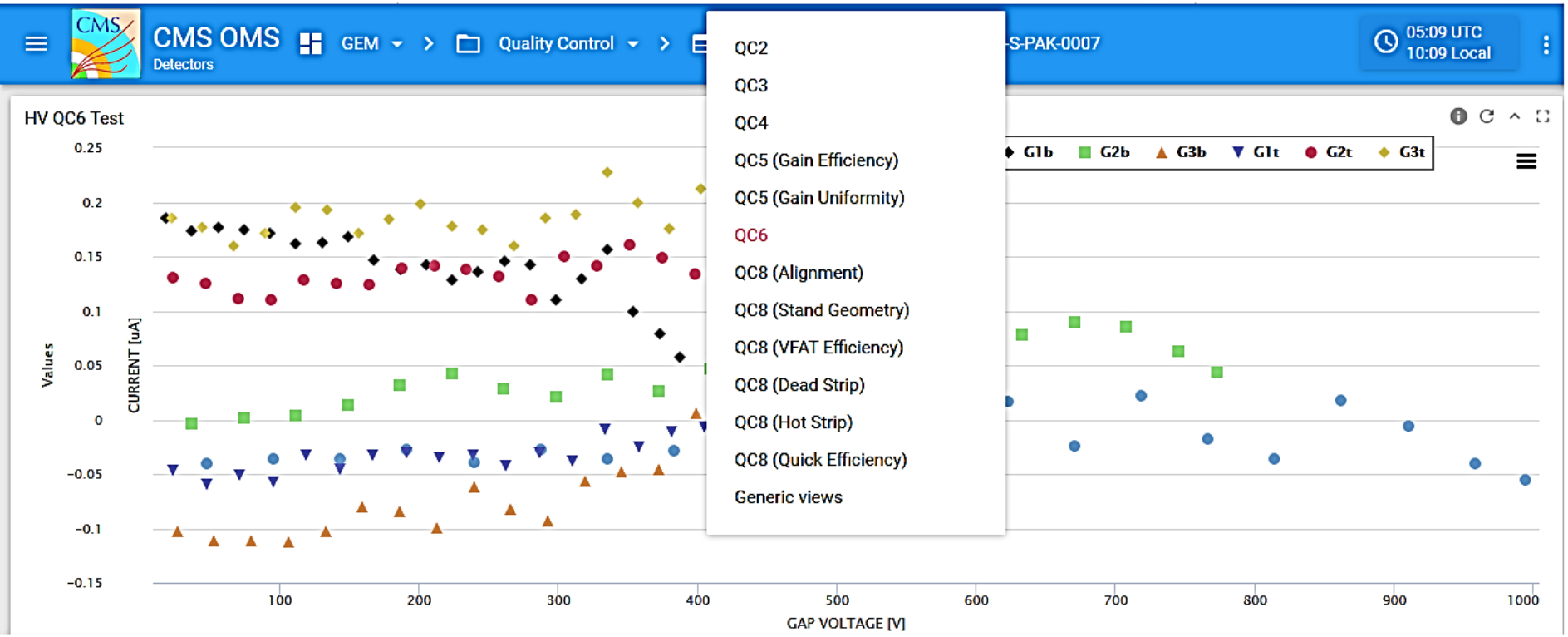
DB Parts View



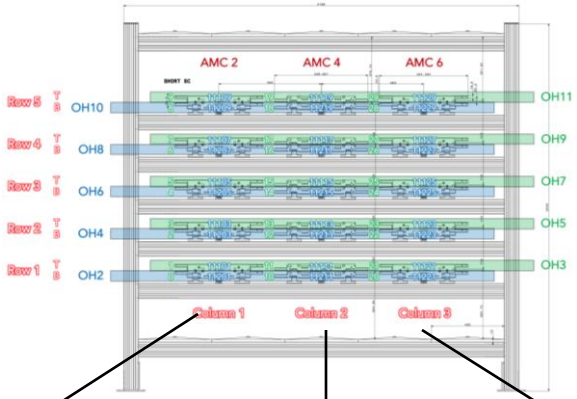
Assembled SC in DB



QC6 (HV Test) at OMS



QC8 Configuration View



Geometry Stand Configuration Test

Column 1:			Column 2:			Column 3:		
Super Chambers	Flip	Flow	Super Chambers	Flip	Flow	Super Chambers	Flip	Flow
Select Super Chamber			Select Super Chamber			Select Super Chamber		
Select Super Chamber			Select Super Chamber			Select Super Chamber		
Select Super Chamber			Select Super Chamber			Select Super Chamber		
Select Super Chamber			Select Super Chamber			Select Super Chamber		
Select Super Chamber			Select Super Chamber			Select Super Chamber		

Submit

Summary

- Working toward Run3 and beyond, collaborating with other coordination groups
- EPR points, especially for online DQM, offline DQM, PPD.
- Although the DB+OMS talk is covered in the DPG session, the EPR assignment is made by the Operation group. Since GE2/1 is shifting to the production phase, we need to maintain the current level of personpower.

Backups

Recent FLUKA study

v3.7.18.0 (10.3 λ and inner cone at η = 3)

v3.7.19.1 (9.3 λ and stepped inner surface beyond η = 3)

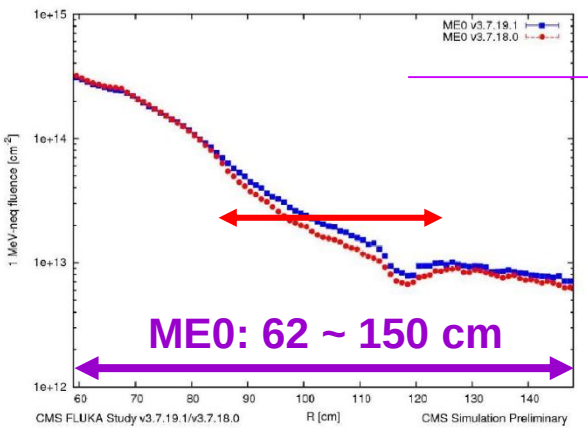
$R = 2.4 \cdot 10^{17}$ p-p int. (3000 fb^{-1})

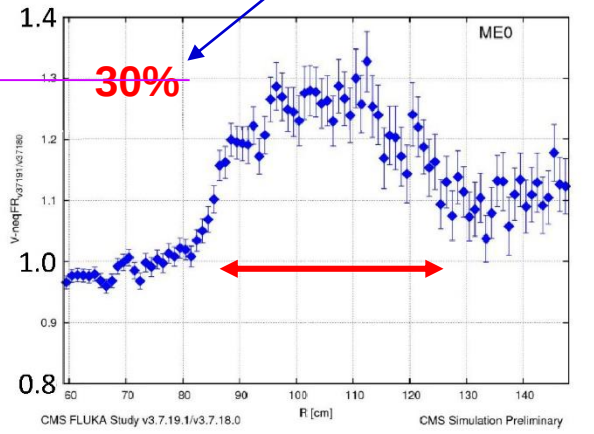
Ratio = New / TDR

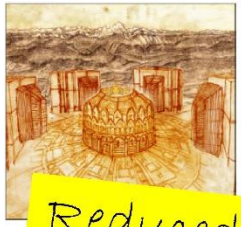
Igor Kurochkin

1 Mev-neq fluence

Fluence ratio = v3.7.19.1/v3.7.18.0







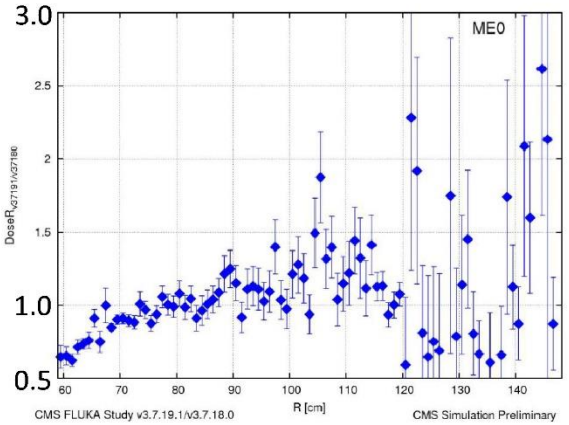
Reduced fluence and dose in ME0 at small r. 40-50% increase at larger r, where dose & fluence are small (effect of reduced CE thickness).

Preliminary results: ME0

$R = 2.4 \cdot 10^{17}$ p-p int. (3000 fb^{-1})

Absorbed dose

Dose ratio = v3.7.19.1/v3.7.18.0

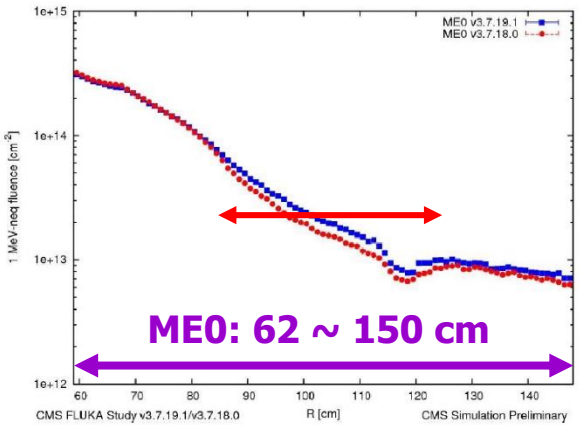


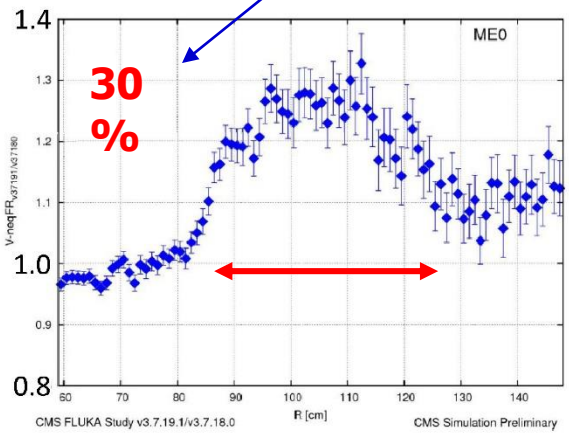
Preliminary results: ME0

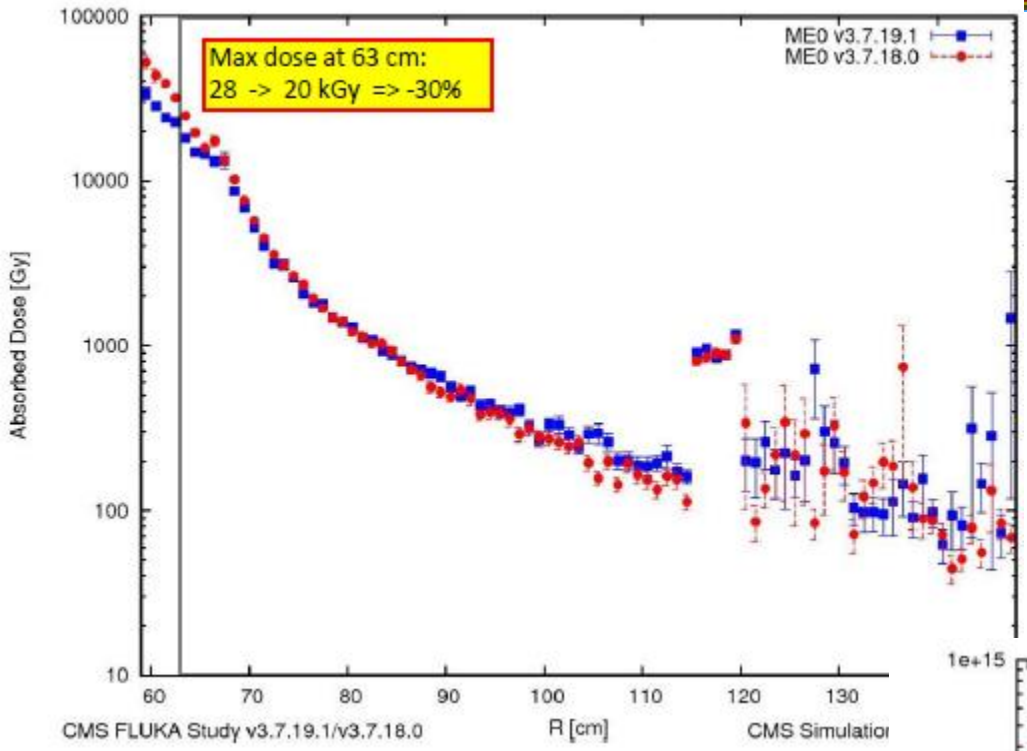
$R = 2.4 \cdot 10^{17}$ p-p int. (3000 fb^{-1})

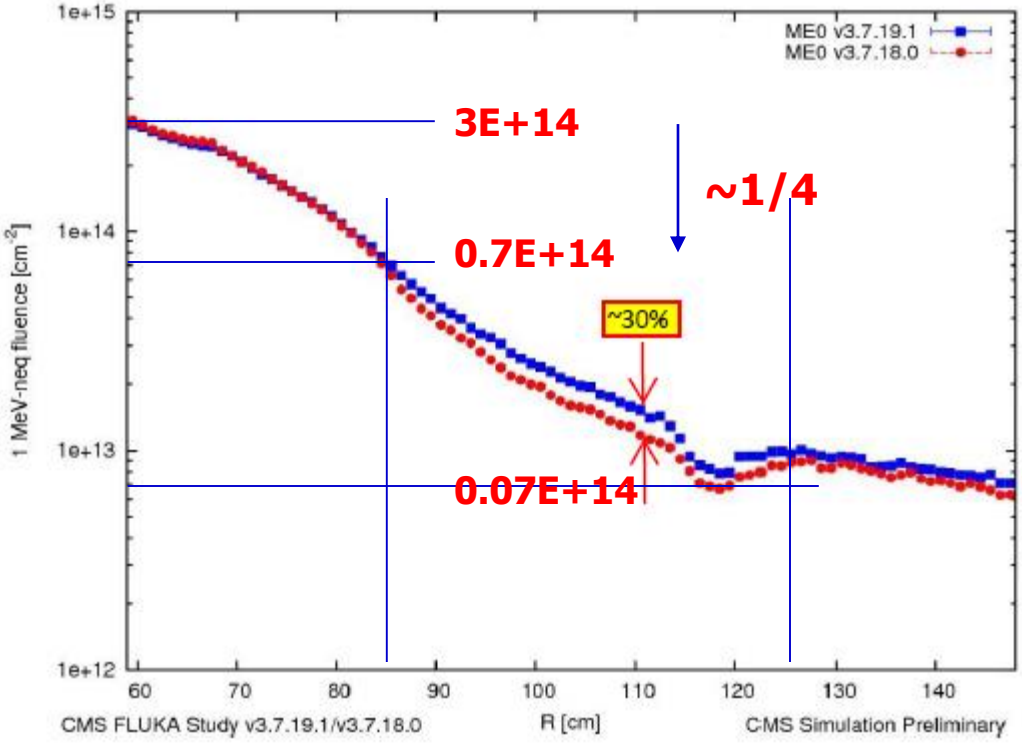
1 Mev-neq fluence

Fluence ratio = v3.7.19.1/v3.7.18.0





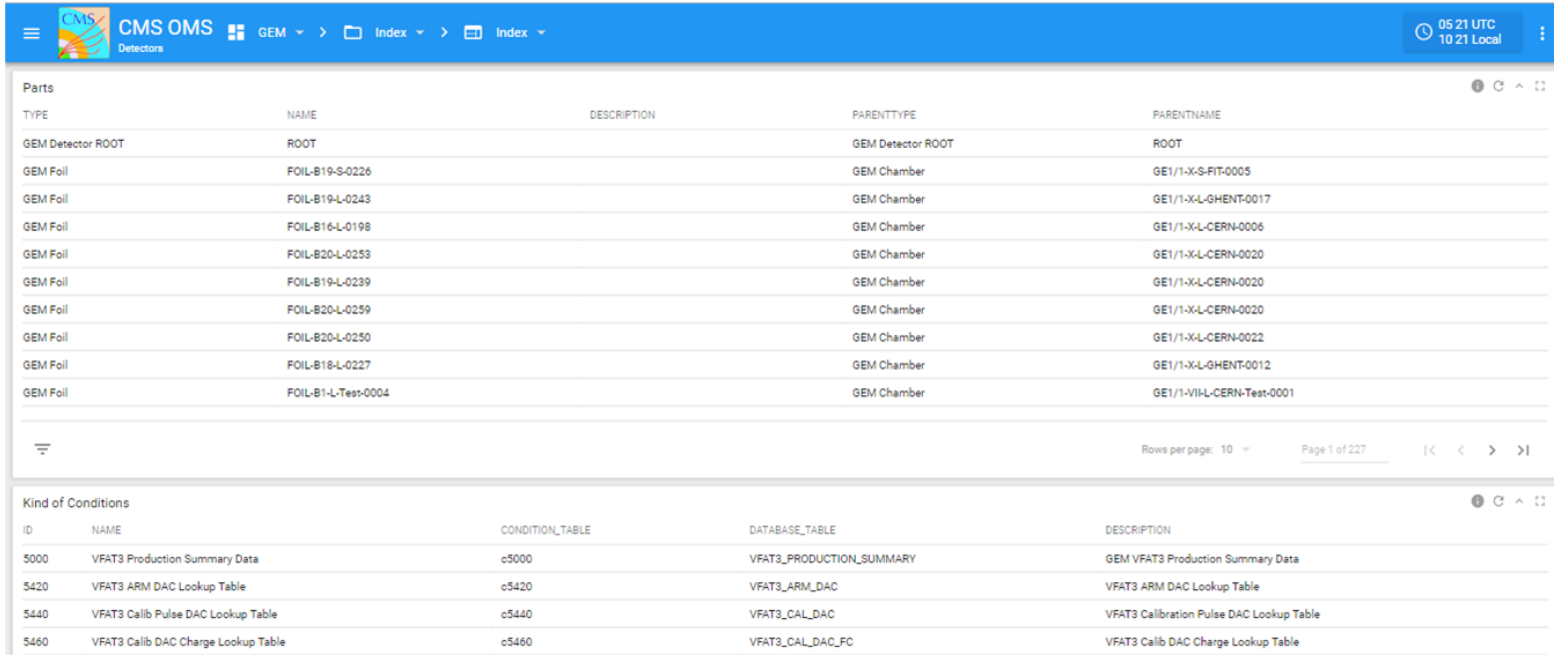

Max dose at 63 cm:
28 -> 20 kGy => -30%
ME0 v3.7.19.1
ME0 v3.7.18.0
Absorbed Dose [Gy]
100000
10000
1000
100
10
60
70
80
90
100
110
120
130
CMS FLUKA Study v3.7.19.1/v3.7.18.0
R [cm]
CMS Simulatior


ME0 v3.7.19.1
ME0 v3.7.18.0
3E+14
~1/4
0.7E+14
~30%
0.07E+14
1 MeV-neq fluence [cm^{-2}]
1e+15
1e+14
1e+13
1e+12
60
70
80
90
100
110
120
130
140
CMS FLUKA Study v3.7.19.1/v3.7.18.0
R [cm]
CMS Simulation Preliminary

ME0: 62 ~ 150 cm

DB and OMS

Online Monitoring System Homepage



QC3 (Leak) at OMS