INTRODUCTION STATUS GOALS

GEM Workshop IX

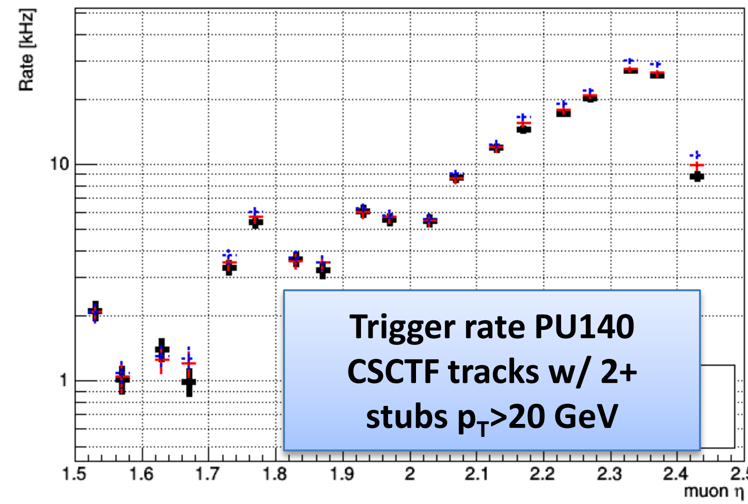
CERN

14-18 July 2014

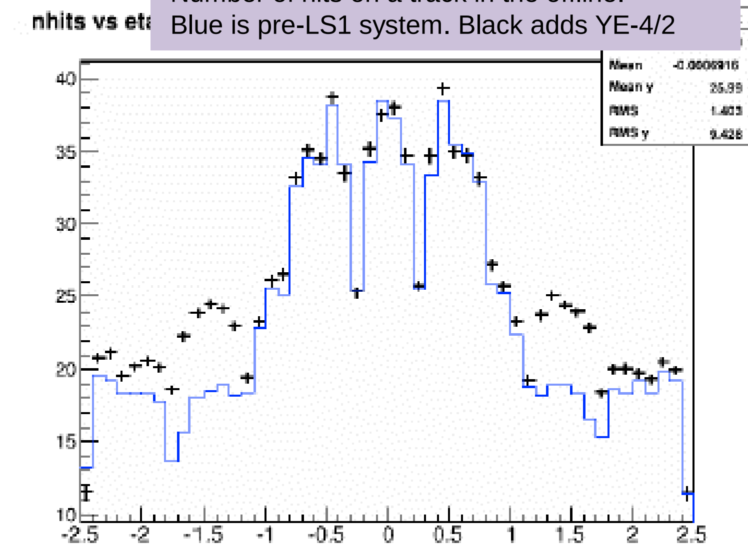
Challenges at High Luminosity

- Forward region is by far the hardest
  - Highest background rates
  - Least redundancy across the entire CMS volume
- Improvements needed, else a risk of deterioration of muon performance beyond $\eta=1$
  - **In 2022, RPCs (& DTs) will be 20 years old**
  - **In 2030, CSCs will be 25 years old**

Fast growth towards high eta illustrated by Level 1 trigger rate

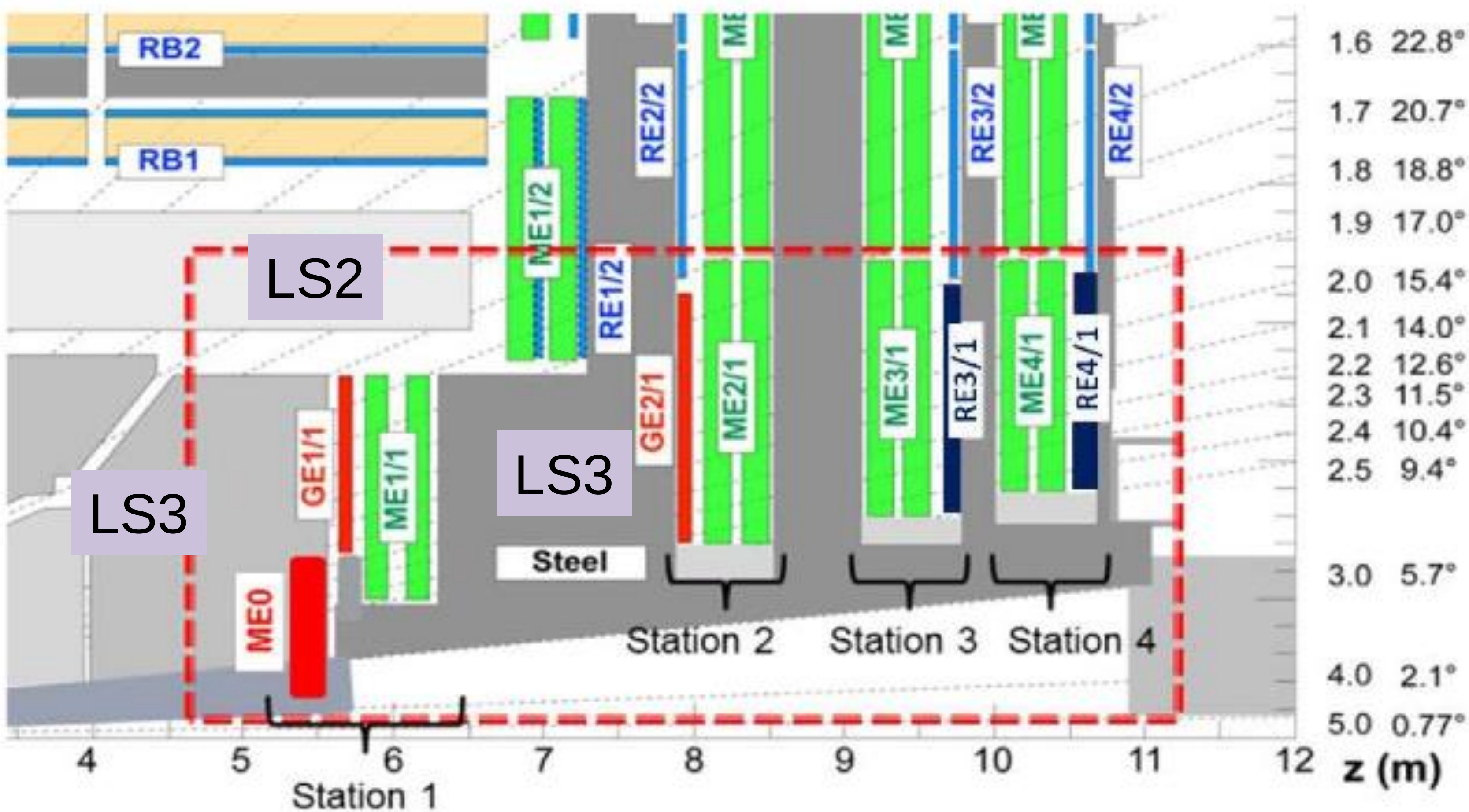


Number of hits on a track in the offline.
Blue is pre-LS1 system. Black adds YE-4/2



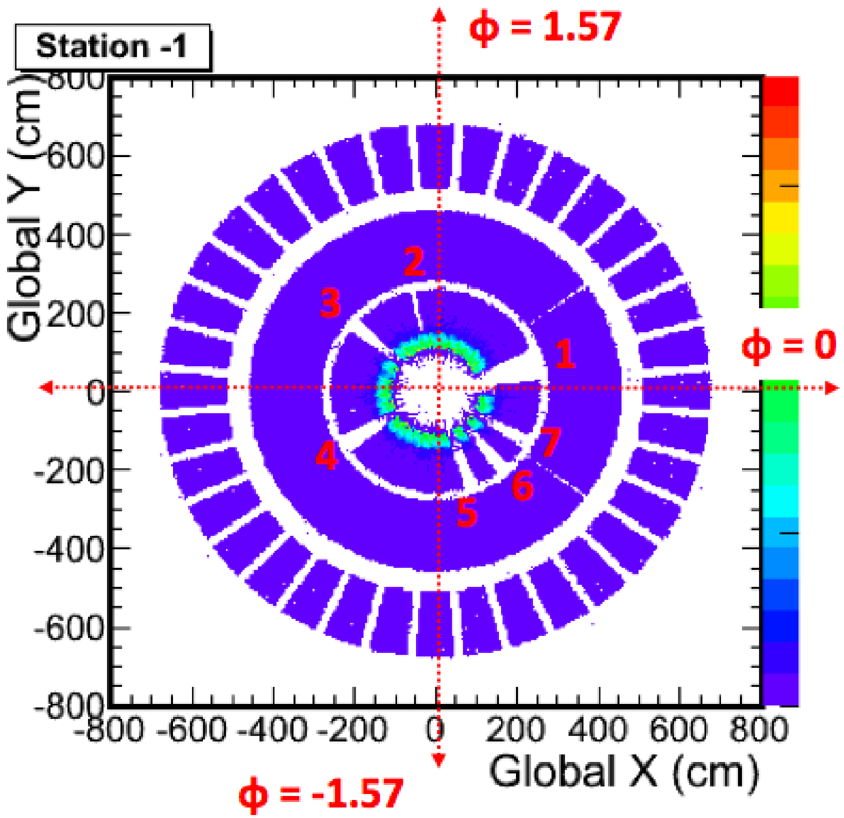
GEMs in PROPOSED MUON UPGRADE

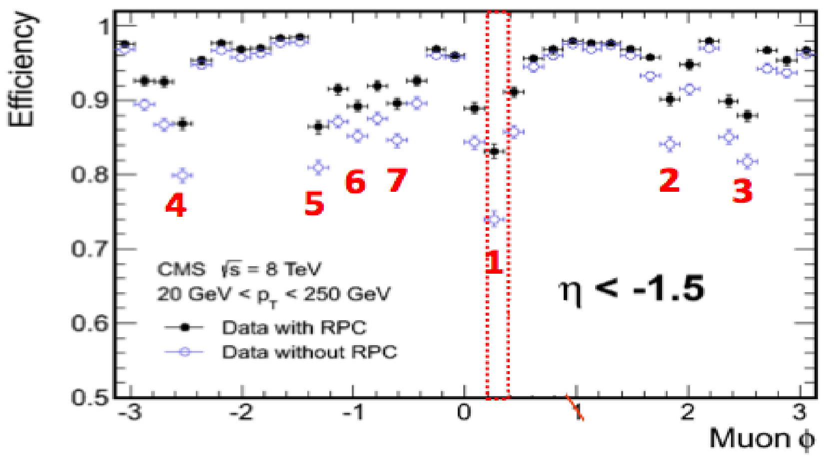
Sustain triggering at current thresholds up to |η|=2.4
Increase offline muon identification coverage Maintain existing envelope; Coping with better understood backgrounds Higher instantaneous and integrated Luminosity Detector degradation through Phase 2 Changes to Trigger (L1 latency and rate)

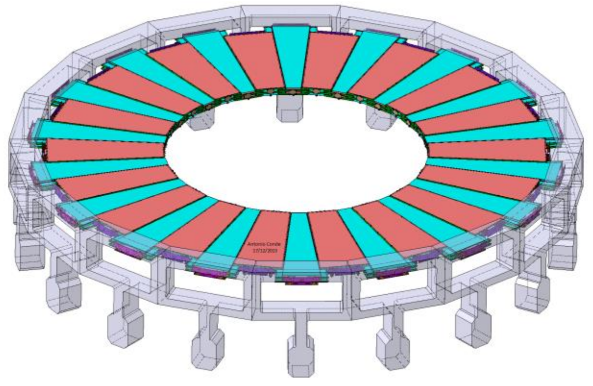


With Neutron Shielding

Redundancy imperative







GE1/1 Physics Arguments

- **Redundancy** in eta region 1.5 – 2.2 with additional GEMs
  - ~20% of interesting physics channels (H4Mu, H2Tau, Z2Mu) in GE1/1 region
- **Lowering the trigger threshold** in H2Tau yields gain in sensitivity
  - Lowering trigger pT from ~20 GeV (post-LS1 plan) to ~15 GeV = ~20% gain
- Challenge of **the forward region**. Impact of PU on muon reconstruction. Fraction of non-prompt muons in forward region increases dramatically with 140 PU.
  - PU studies ongoing in DPG

From K. Hoepfner

Planned Channels for GE1/1 TDR

Channel	Physics argument
H→Tau(mu) Tau(had)	Lowering trigger threshold Tau reco (muon veto)
H→Tau(mu) Tau(mu)	Lowering trigger threshold. Tau reco
H4Mu	Redundancy. Improved pT measurement
High momentum muons	Discontinued. Impact on TeV muon performance marginal.
WH→3mu 3v	One muon is very soft, performance and trigger studies
Redundancy studies	

Samples from **official production.** For GE1/1 TDR **"GEM2019 -- PU50" reflecting our needs**

- Include improved object performance in CMSSW7xy
- GE1/1 to be installed in LS2 (before phase-2 detector upgrade)
- LHC conditions with medium PU

Samples with Muon2023 are for phase-II extension

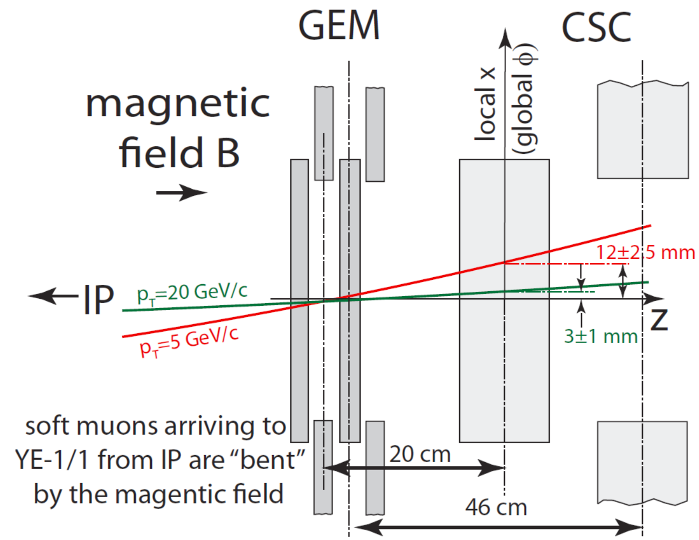
Samples are becoming available for physics studies.

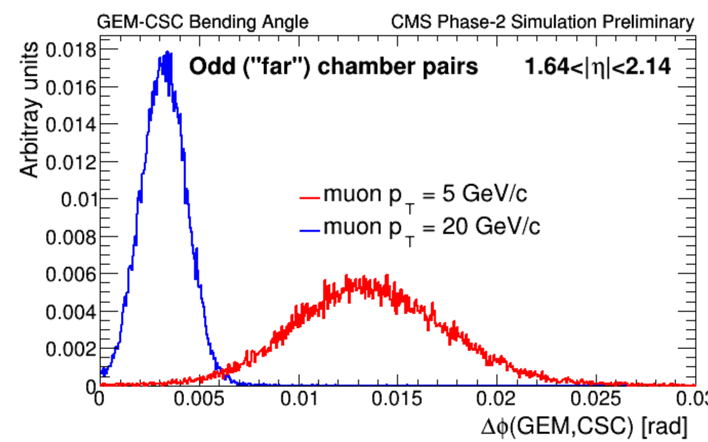
Approval schedule of physics results important !

From K. Hoepfner

GE-1/1: A Critical Post-LS2 Patch

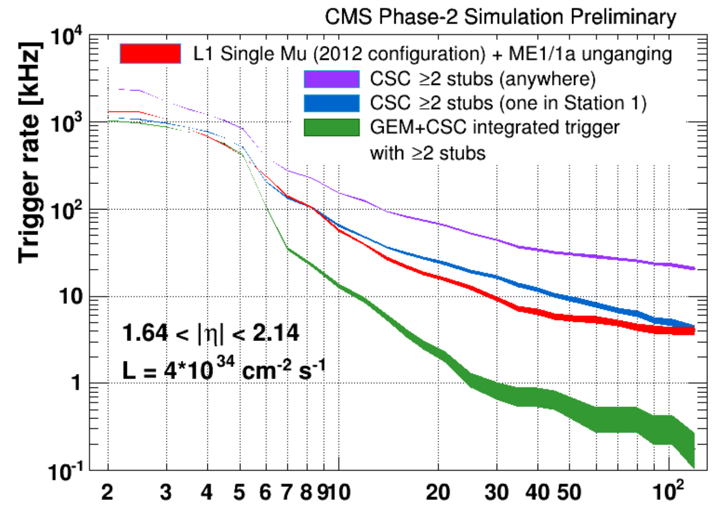
- Allows two critical improvements
  - Restores redundancy in the most critical station YE-1/1
  - Adds a new trick for trigger rate control by measuring muon bending angle in YE-1/1
- Requirements easily satisfied:
  - Good resolution and rate capabilities
  - Enough lever arm between GEM and CSC
- GE-1/1 installation in LS-2 will allow maintaining high efficiency muon trigger all the way until LS-3
  - Right time, right place, right detector technology



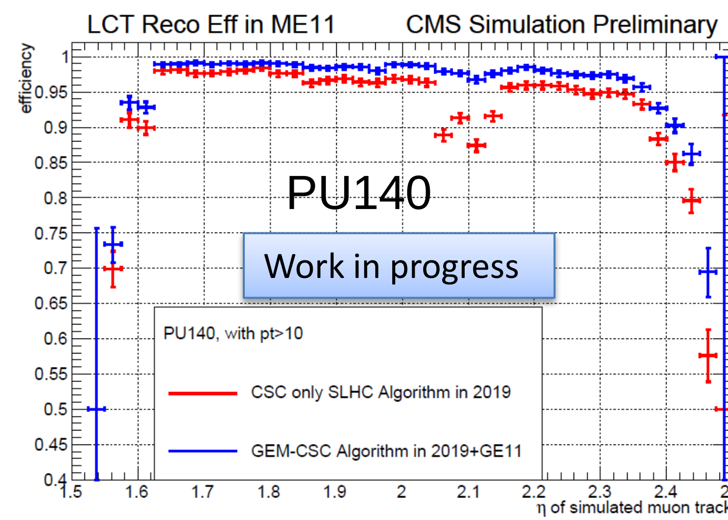


GE-1/1 Performance

- Bending angle allows drastic improvement in trigger rate control
  - Thresholds can be tuned to even further improve performance at low p_T
- Simultaneously, a significant improvement in efficiency
  - Good on its own, critical for trigger
  - Subject to further improvement

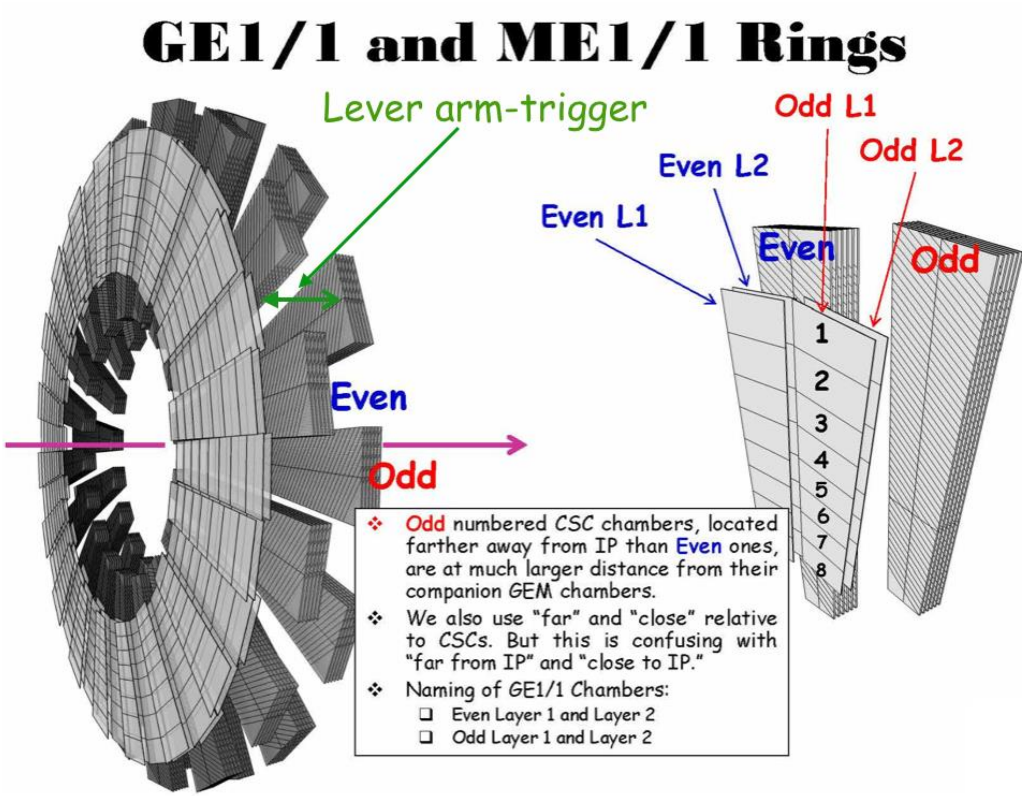


Level-1 Trigger Muon Candidate p_T



Current Focus: GE1/1 System

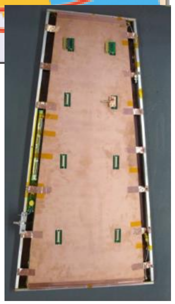
- $1.55 < |\eta| < 2.18$
  - Short and long chambers for maximum coverage
- 36 superchambers (SC) per side of CMS
  - Each chamber spans 10° in φ
  - 2 chambers/SC
  - 144 chambers total
- Total foil area ~170m^2



Four years of R&D has given us five prototype generations; each an improvement of the last!!!

B. Dorney et

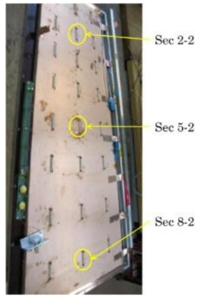
GEM Detector R&D STATUS



2010

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)**



2011

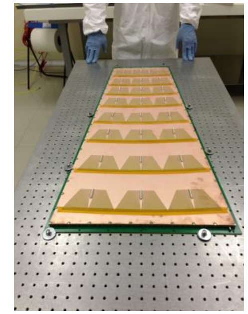
Generation II

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.**

2012

Generation III

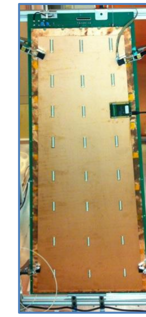
The first sans-spacer detector, but with the outer frame still glued to the drift. Ref.: **2012 IEEE N14-137.**



2013

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. **Papers from MPGD 2013; And IEEE2013.**



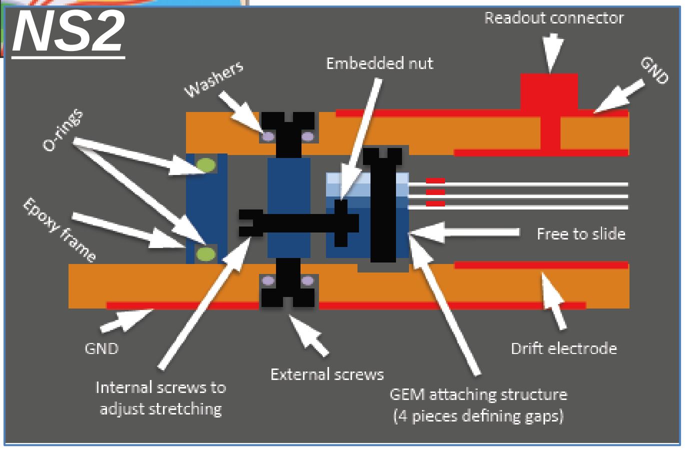
2014

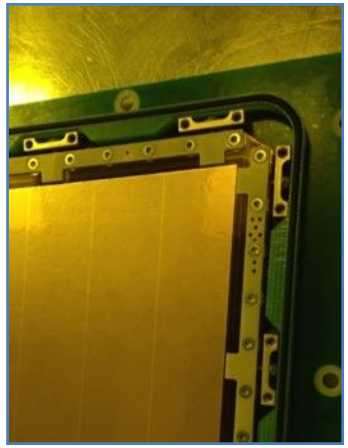
Generation V

The latest detector version; very close to what we will install in CMS. Stretching apparatus now inside gas volume. Optimized final dimensions for max. acceptance and final eta segmentation.

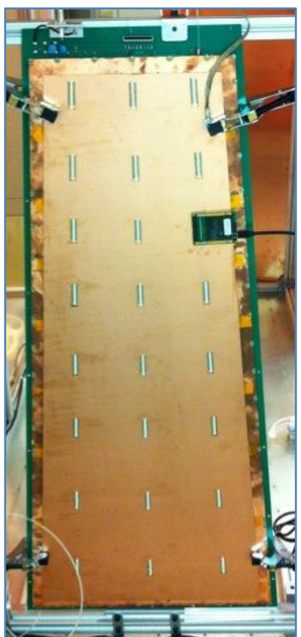
- GEM foil production uses single mask technology for wet etching
  - Dramatically reduces foil production costs and allows large sizes to be manufactured
- Performance same as that of double mask
- NS2 assembly technique developed
  - Construction time reduced from week(s) to two hours per chamber

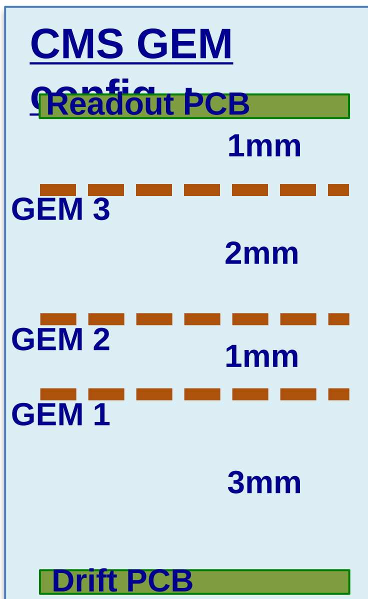
Current CMS GE1/1-V Prototype

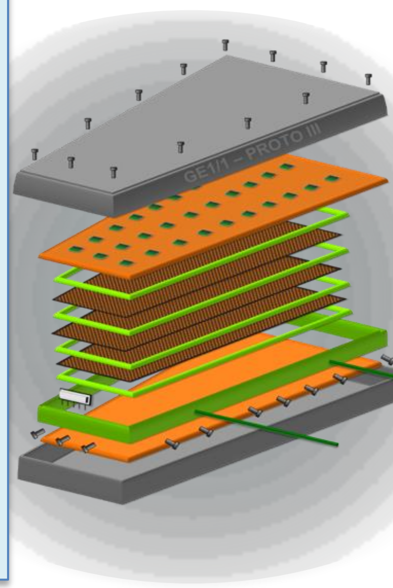


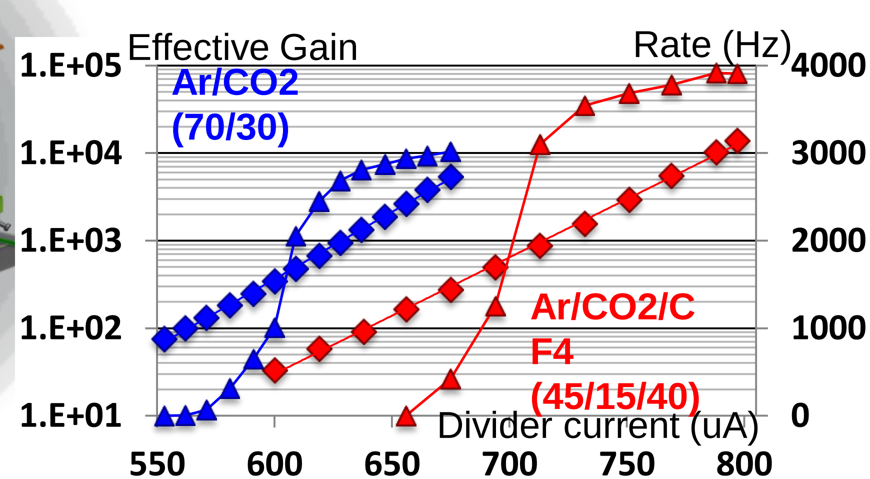


- Size: 99x(22-45)cm^2
- 3 GEM foils (lower field intensity)
- Gap configuration: 3/1/2/1mm
- 24 readout sectors (3072 channels)
- Time resolution O(5ns); gives 96% BX identification efficiency
- Spatial resolution ~80µm
- Rate capability O(MHz/mm^2)



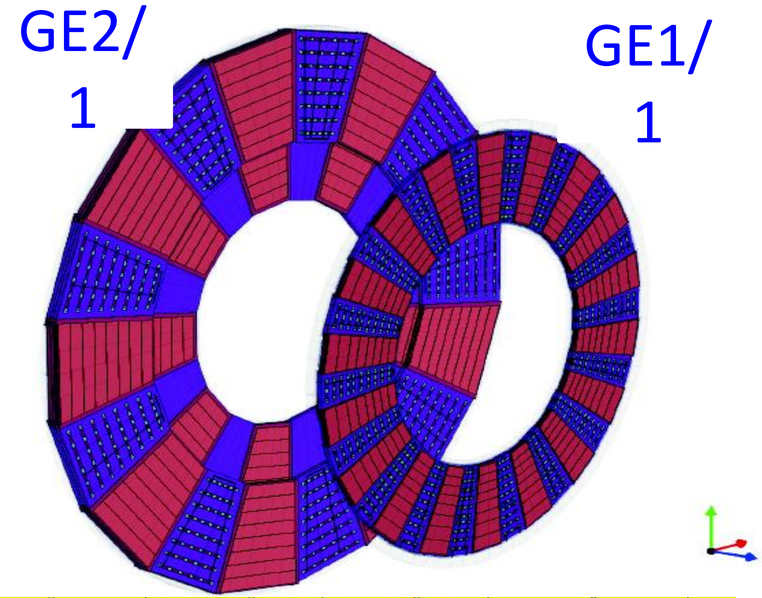




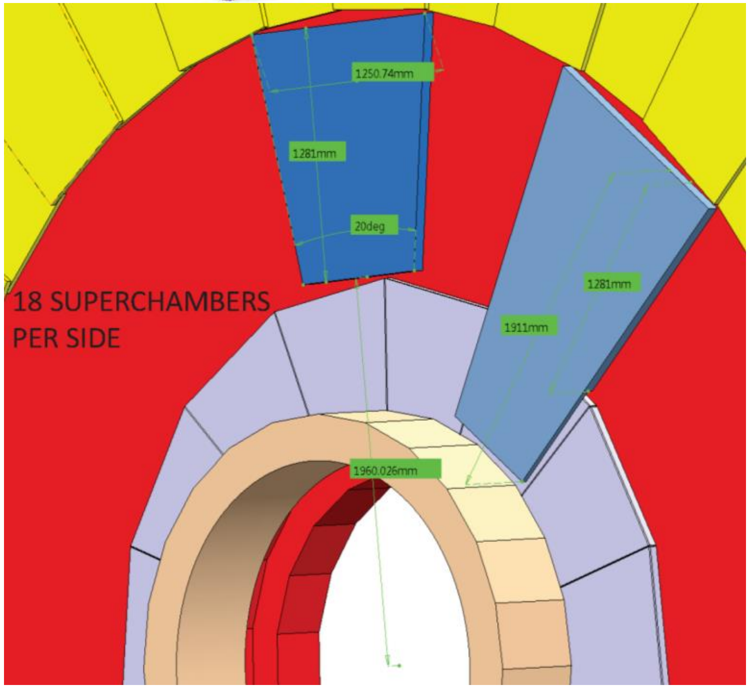


GE2/1 System

- 1.55 < |η| < 2.45
- Each chamber spans 20°



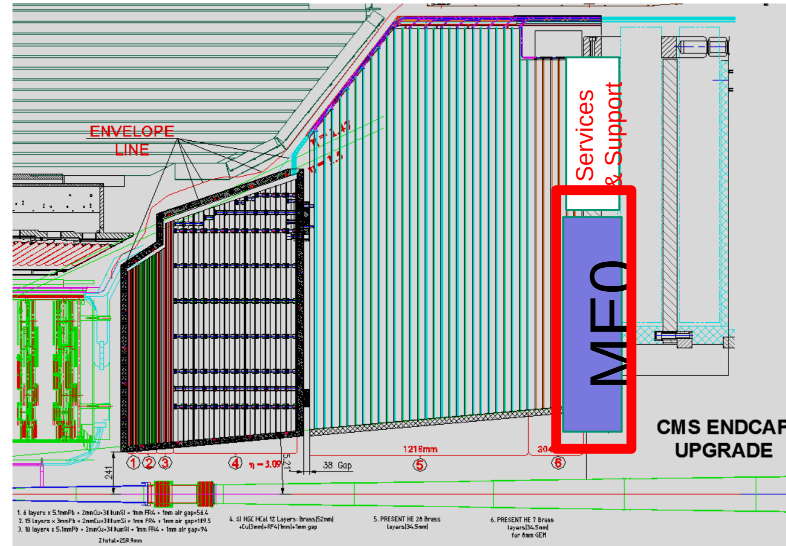
- Design on-going
- Targeting two rings of double-layered triple-GEM detectors

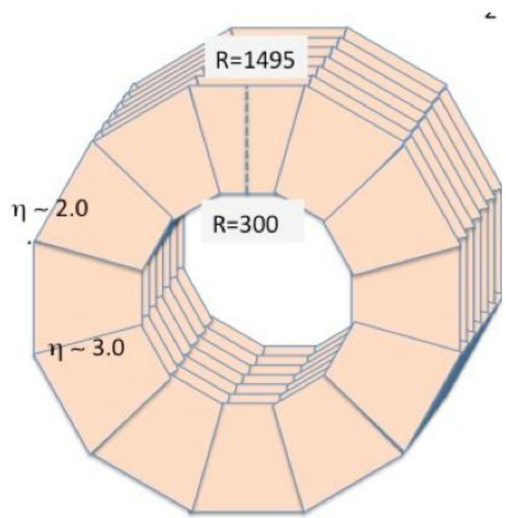


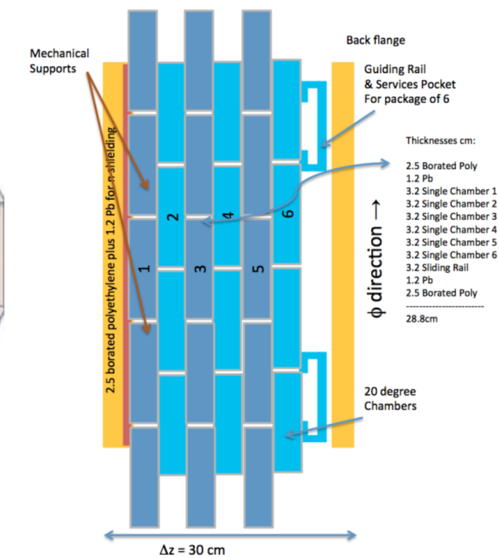
- Total foil area ~330m^2

ME0 System

- 2.0 < |η| < 3.5
  - 20° wedges affixed to back of upgraded CMS HCAL endcap
- Six layers of triple-GEM detectors
  - High number of layers gives ability to cope with “toxic” neutron and muon brem. backgrounds
  - Design ongoing
- **Significantly increases muon acceptance for high profile analyses**
  - H->ZZ->4μ; *20-40% increase!*
  - H->ττ->μτ_{had}; *~10% increase!*



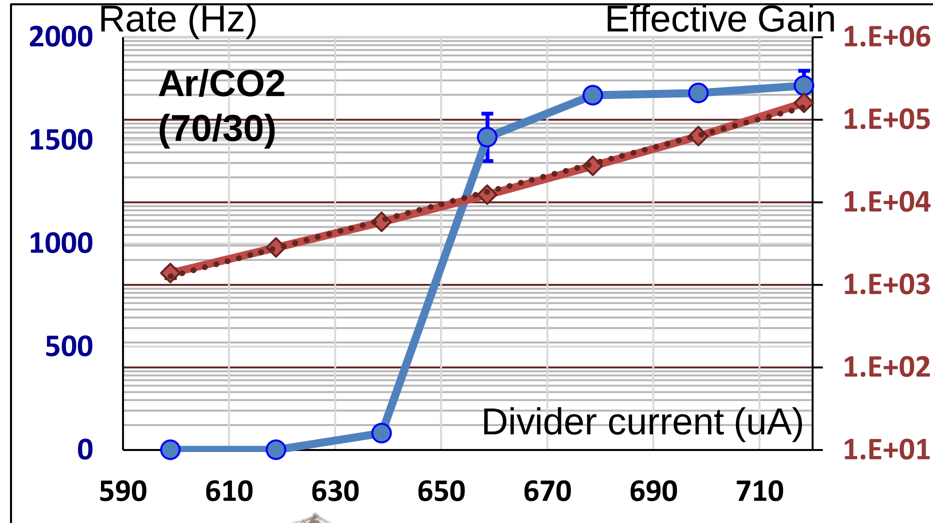


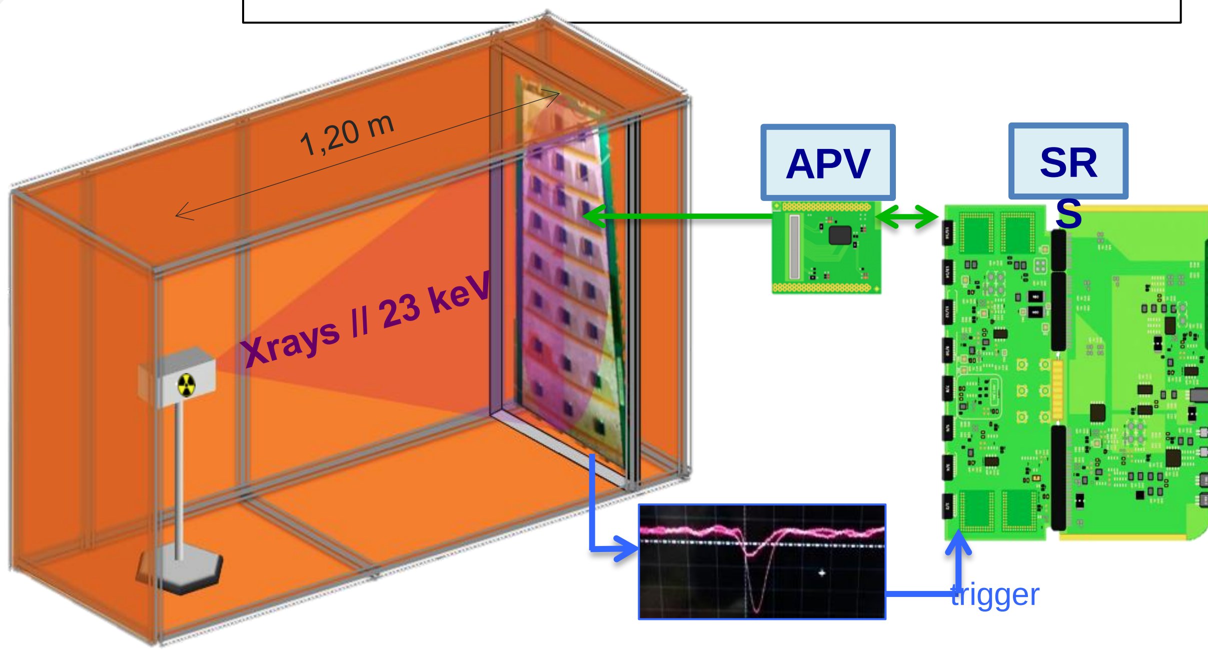


Readiness for Production: Gain Uniformity

- Calibrate gas gain and measure plateau
- Uniformity Scan: measure relative gain of entire chamber for every readout strip
- Need analog readout electronics for 3072 channels
- Needs large X-ray beam to irradiate full detector
- External trigger required
  - No MIPs cannot use scintillators
  - Signal induced on bottom of last GEM foil
- Requires ~10^6 events for high statistics analysis

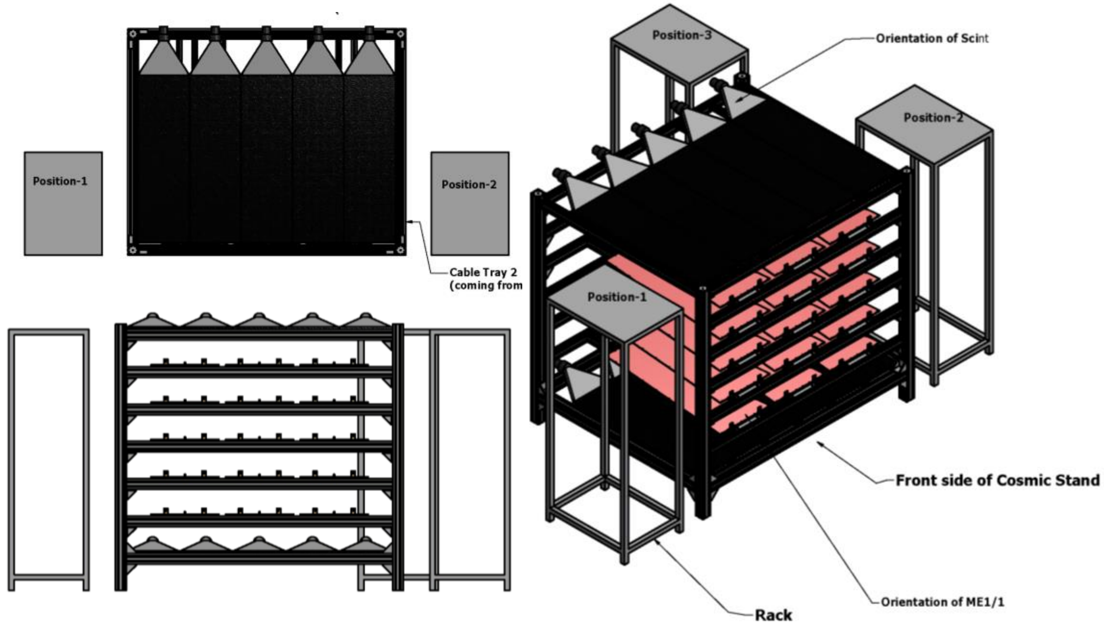
All sites being readied





Cosmic Stand: Quality Control

- Quality control on GE1/1 chambers
- Investigate performance parameters:
  - Cluster size, timing analysis, strip-by-strip efficiency, etc…
- Each chamber has results logged in performance database before it is placed inside CMS
- Equips detector performance group (DPG) with full chamber history before CMS is closed!

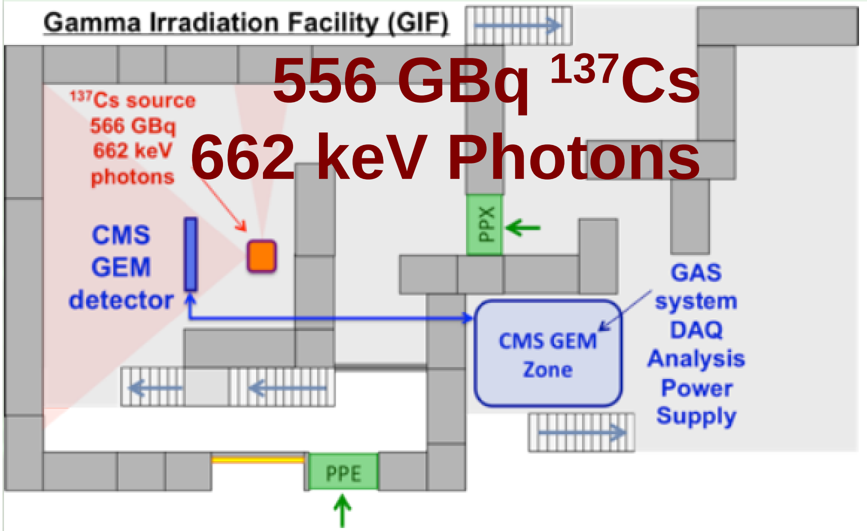


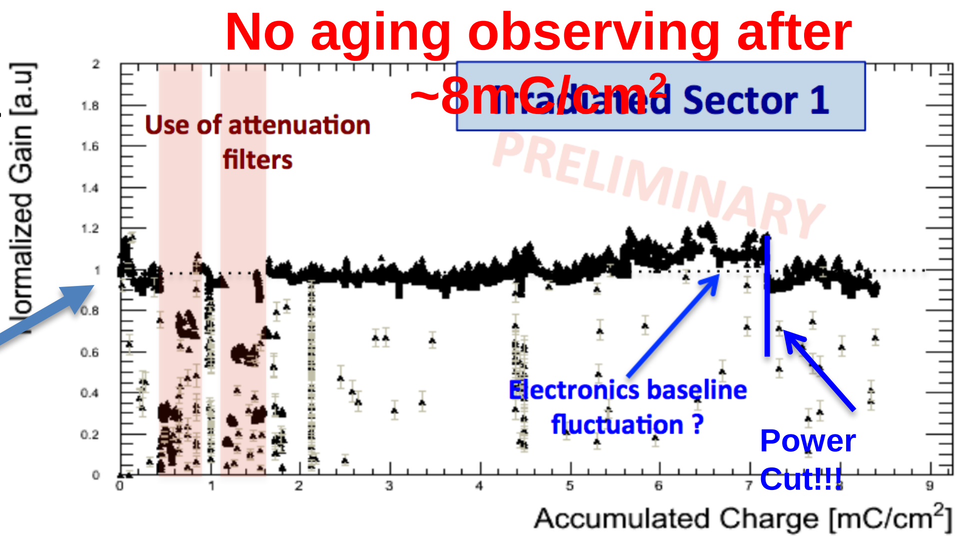
Cosmic stand provides a reference point for all future DPG studies once CMS is closed!

B. Dorney et al. 16/06/14

Classical Aging Studies: CERN Gamma Irradiation Facility (GIF)

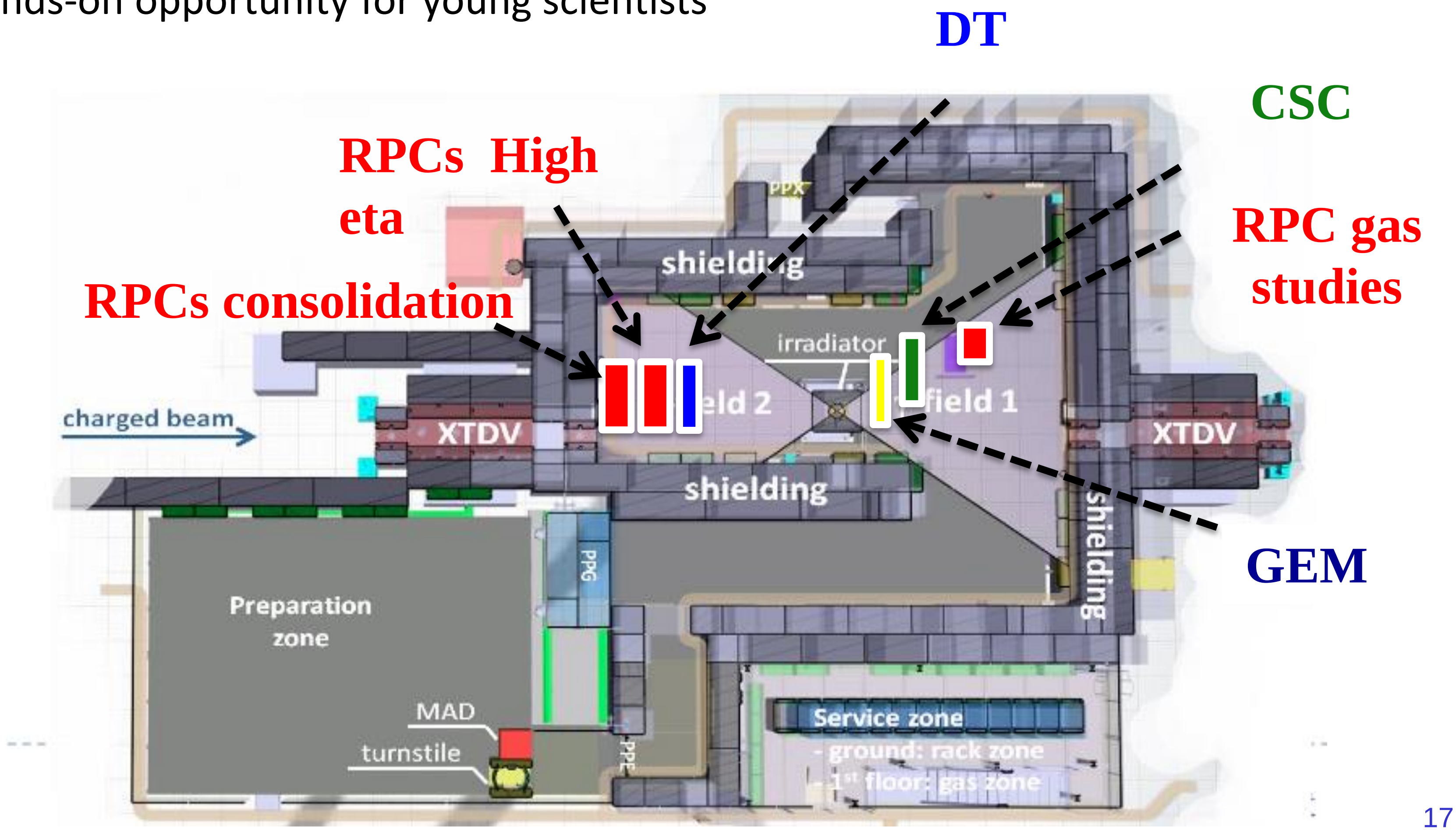
- First time a large area GEM detector is subjected to a systematic long term test!
- *Accelerated aging is not a measure of detector performance over time!*
  - Polymers that cause aging cannot build up on GEM foils; breakdown in heavy plasma environment
  - Need a balance between time and aging acceleration to obtain aging realistic results w/predictive power
- GIF allows investigation of classical aging via realistic radiation environment
  - Continuous gain monitoring performed



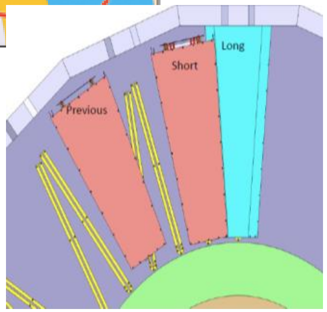


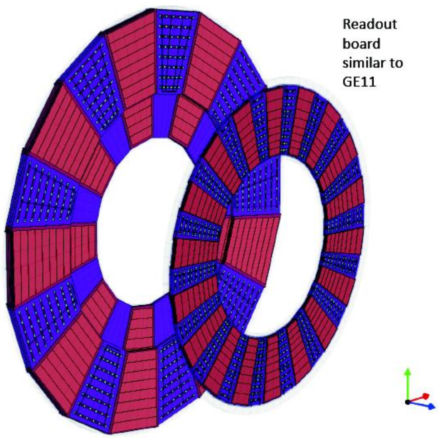
GIF++ Consolidation & Longevity

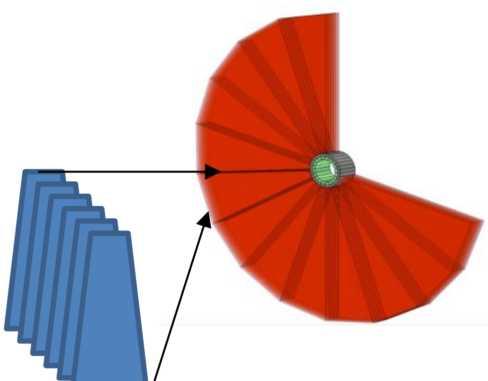
- NB need additional infrastructure, *need for CMS & CERN–wide coordination*
- Numerous chambers into GIF++ (ME1/1, ME1/2) starting late 2014/early 2015, ~8 months irradiation
- Hands-on opportunity for young scientists



Detector geometries







GE1/1 LAYOUT

- Two 10° triple-GEM chambers to form
- 144 total chambers
- Current geometry: 8 eta partitions
- 384 phi strips/eta partition
- Short super-chambers: $1.6 < |\eta| < 2.2$
- Long super-chambers: $1.5 < |\eta| < 2.2$ F

GE2/1 LAYOUT

- 20 degree chambers
- 768 strips/eta partition
- 8 eta partition up to 2.09 (GE2/1short), 1

ME0 LAYOUT

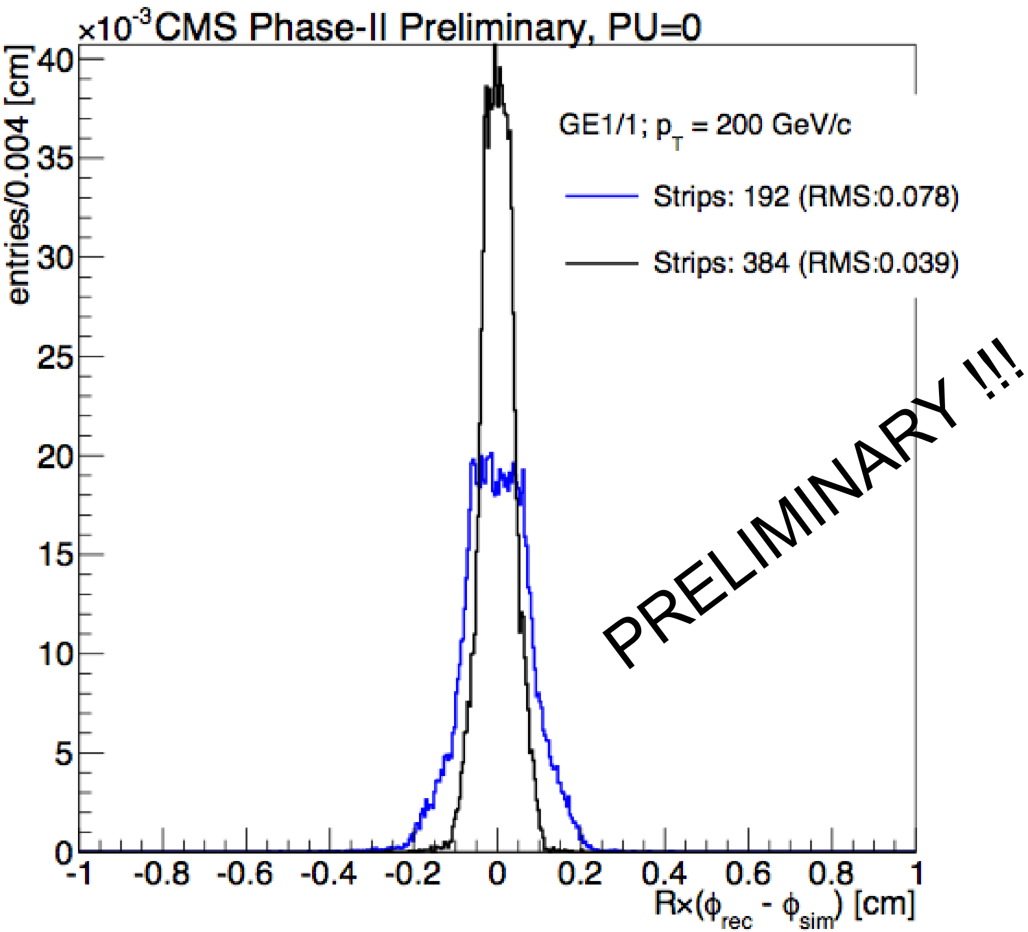
- 2x18 chambers, 6 layers of GEMs
- r_{Min} = 62.3 cm, | $\eta = 3$
- rMax = 149.5 cm

Different scenarios considered

GE1/1 (10° in phi)	GE2/1 (20° in phi) # strips:
384 (Dϕ/strip = 0.45 mrad)	- **768** (Dϕ/strip = 0.5 mrad)
384 (Dϕ/strip = 0.45 mrad)	- 384 (Dϕ/strip = 1 mrad)
192 (Dϕ/strip = 0.9 mrad)	- 384 (Dϕ/strip = 1 mrad)
192 (Dϕ/strip = 0.9 mrad)	- 192 (Dϕ/strip = 2 mrad)

Reconstruction studies

Granularity studies: GE1/1 hit residual



Muon hit residual distribution for two different GE1/1 granularity. Granularity considered: 192, 384 strips.

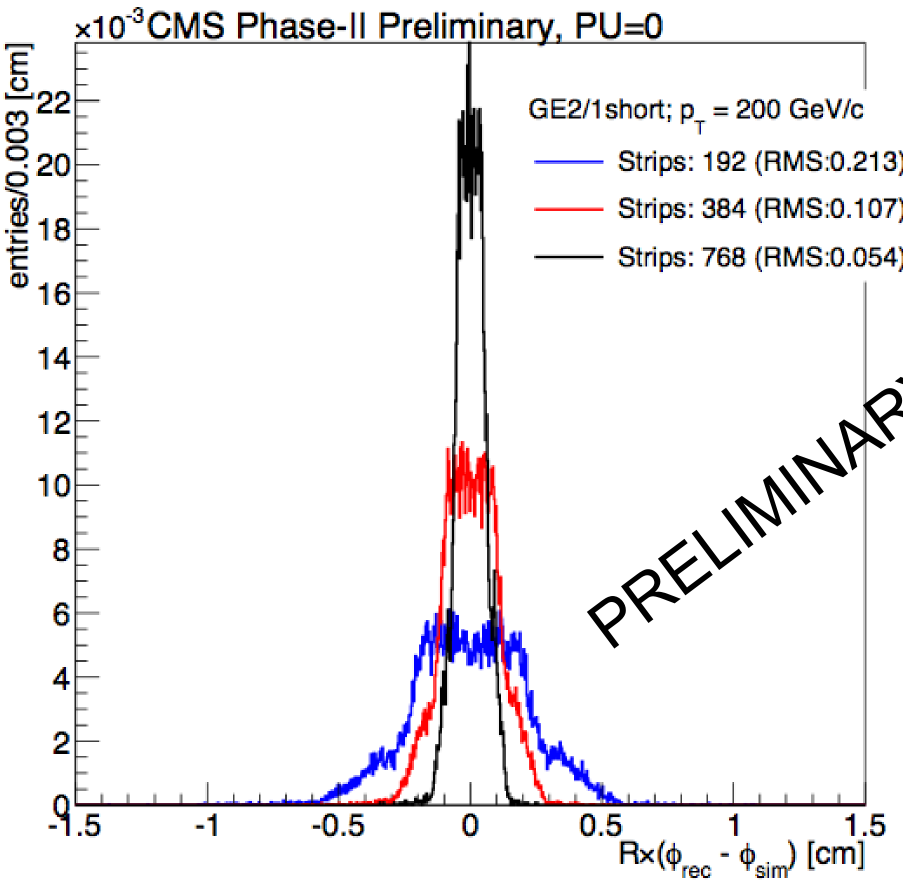
The residuals were computed considering the rec-hit and sim-hit position of simulated 200 GeV muons on GE1/1 surface.

The displacement is obtained as the difference of azimuthal angle times the rec-hit radial distance.

The strip width dominates the resolution in case of low granularity (larger strip pitch).

R. Radogna, C. Calabria, A. Sharma, A. Kaur Kalsi, A. Colaleo,

Granularity studies: GE2/1 short hit residual

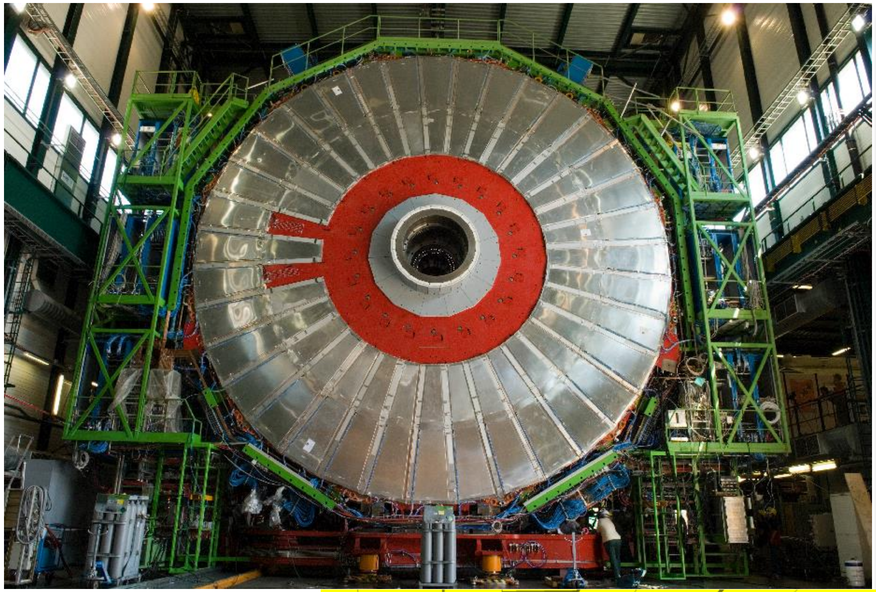


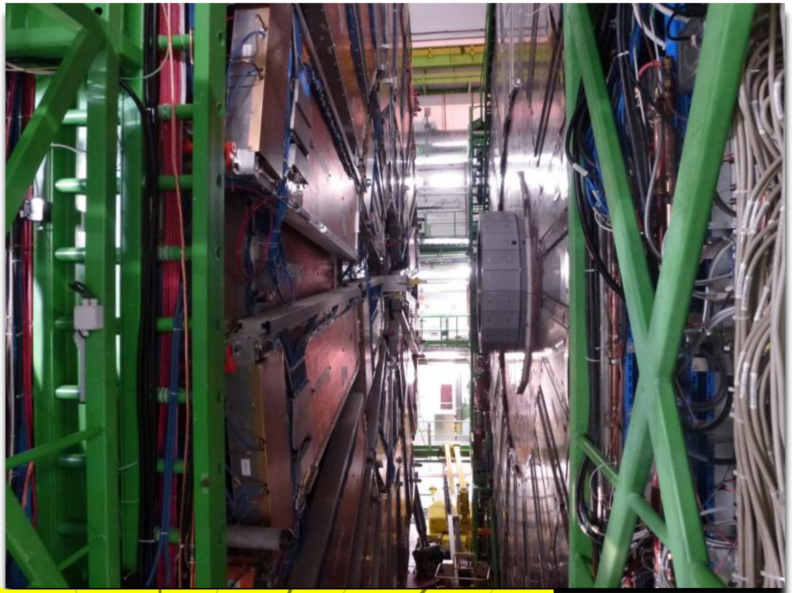
Muon hit residual distribution for three different GE2/1 chambers granularity.
Granularity considered: 192, 384, 768 strips.
This plot is for GE2/1 short chamber.
The residuals were computed considering the rec-hit and sim-hit position of simulated 200 GeV muons on GE2/1 surface.
The displacement is obtained as the difference of azimuthal angle times the rec hit radial distance.

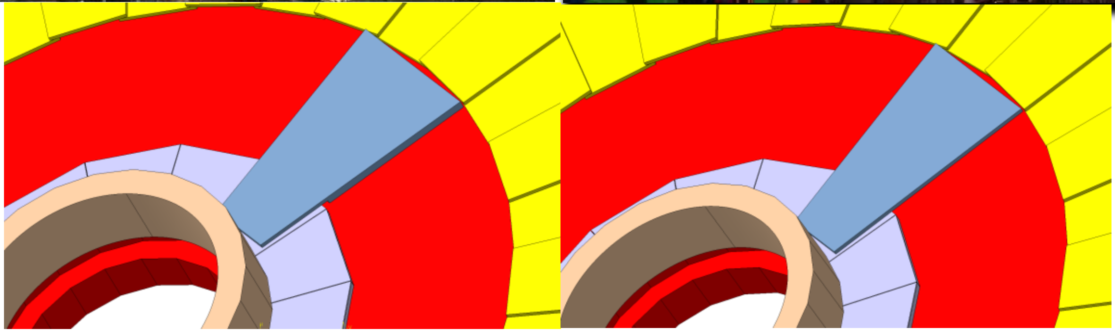
The strip width dominates the resolution in case of low granularity (384, 192) where the cluster structure is also visible.

R. Radogna, C. Calabria, A. Sharma, A. Kaur Kalsi, A. Colaleo,

GE 2/1



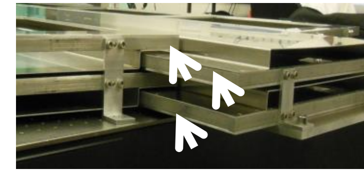




Services (on different disks ?)

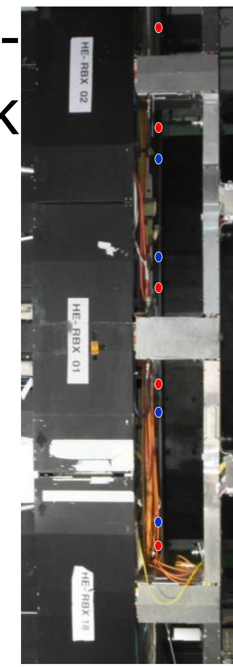
Antonio

ALIGNMENT ISSUES



Concept:

- Survey (partial, during installation)
- Hardware alignment based on capacitive sensors (full measurement)
- Link to the existing Alignment systems (Link-MAB-
- Track-based alignment: connection of the GE-disk CMS, higher accuracy



Open questions:

- Flatness of the base-plate of the nose
- Accuracy of the via holes on the read-out plate

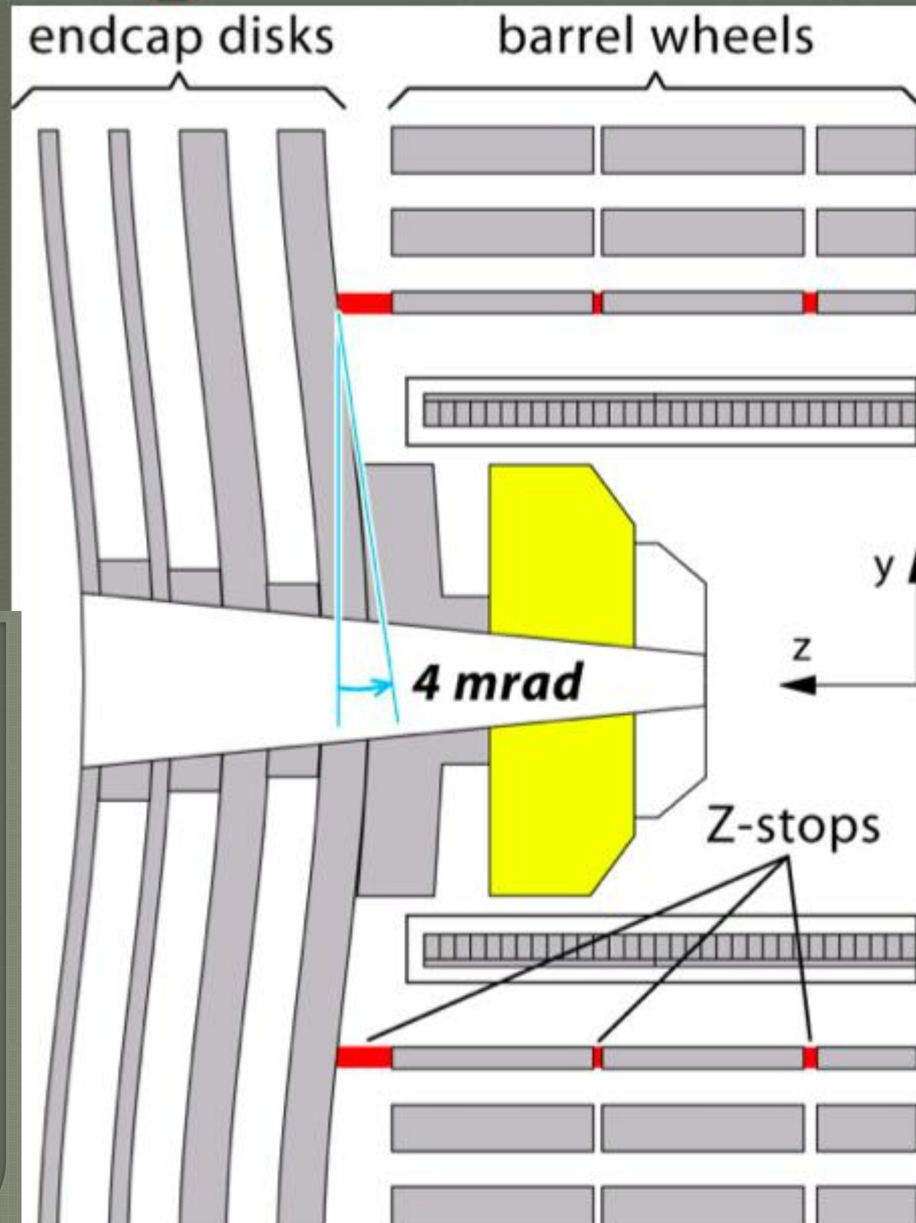
Calibration:

- Connection of the strips to outer side of the chambers
- Location of the alignment elements wrt the strips: scanning, CMM

Zoltan et al

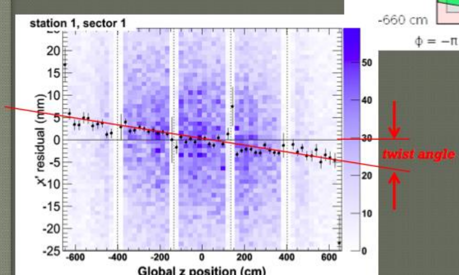
Endcap Deformation

- Disk movement along z
- Disk deformation
- Tracks marginally sensitive
- Physics marginally sensitive
- Link monitors only YE±1
- Need endcap SLMs for others



Weak Mode Constrains

- Tracks vs Barrel HW provides important x-check
- Suggestion for HW: aim for accuracy rather than precision



"twist" example
from Run 1 experience

Agenda and Goals

https://indico.cern.ch/event/319484/other-view?view=standard

Facilitate the GE1/1 LS2 Project
Complete TDR – nearly ready
Launch GE2/1 Prototypes
Test Beam Campaign (Oct-Dec 2014)

BBQ Tomorrow : Previssin Site