CMS GEM Project

Outline

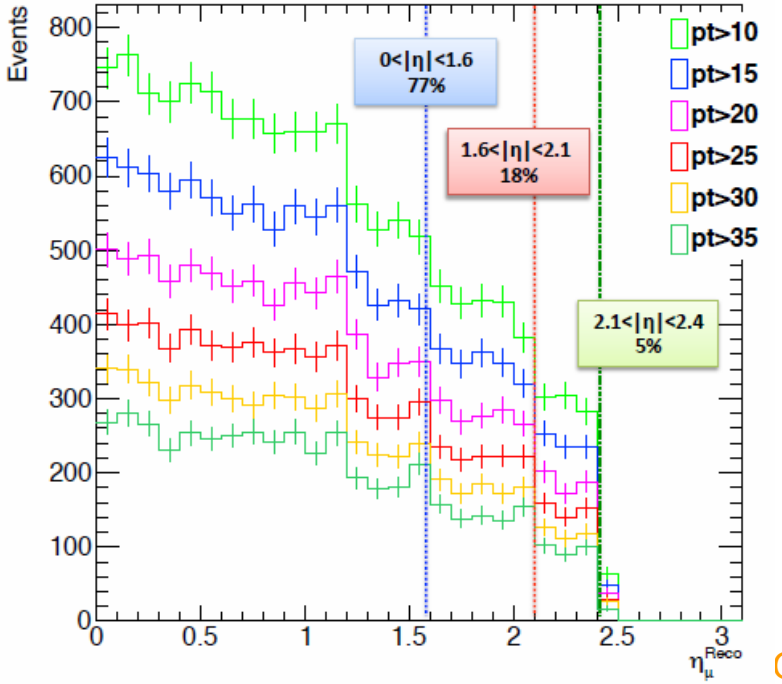
- The CMS GEM project
- CMS Triple-GEM detector v5
- Production site status
- Electronics and DAQ status
  - GE1/1
  - GE2/1 & ME0
- Up-coming activities
- Conclusions

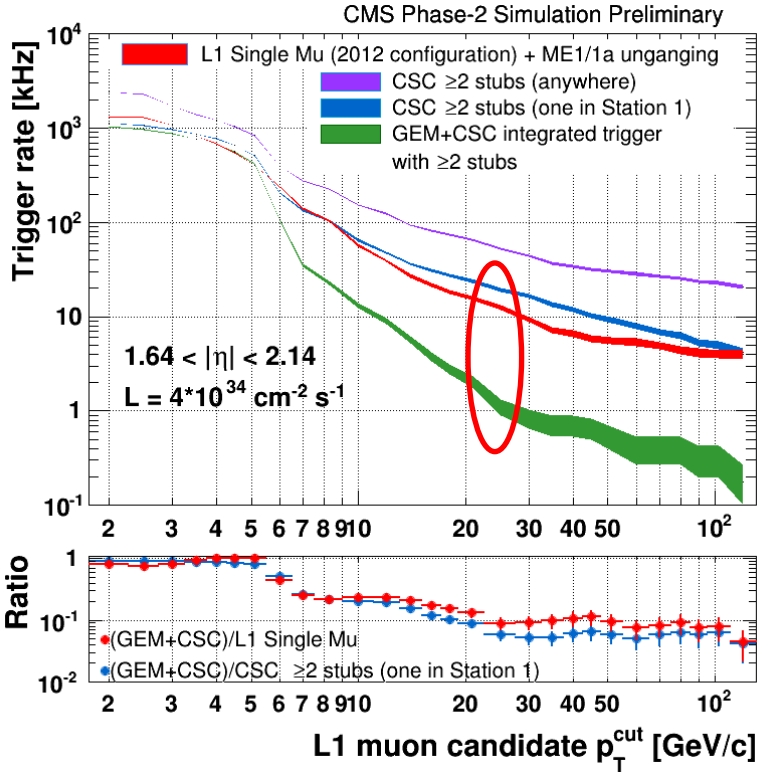
October 30, 2014
IWAD/RD51 Meeting

S. Banerjee
(for CMS-GEM team)

Need for CMS

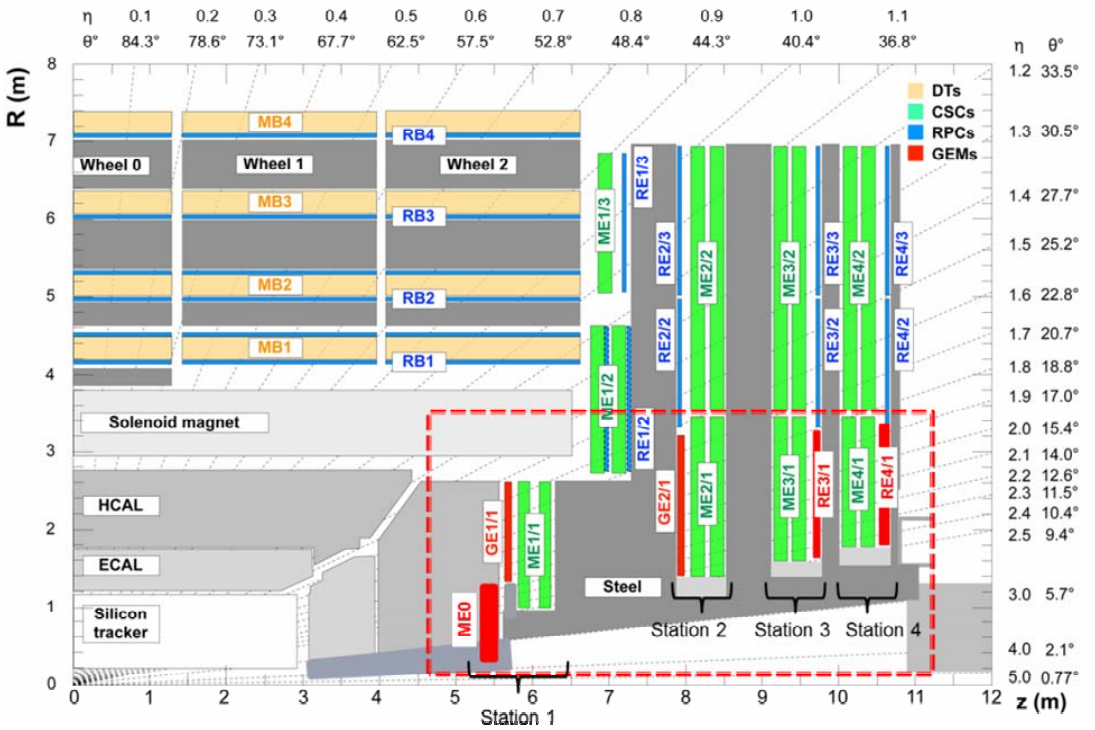
- ~20% of interesting physics channels for ($H \rightarrow 4\mu$, $Z \rightarrow 2\mu$, $H \rightarrow \tau\tau$) in the $1.5 < |\eta| < 2.2$ region
- Lowering the trigger p_T threshold (20 GeV → 15 GeV) provide ~20% gain
- Have to worry about trigger rate in high $|\eta|$ region
  - Scattering of soft μ's in the iron yoke flattens the trigger rate curve
  - GEM's in front of ME1/1 can measure μ-bending angle in B- field
  - GEM+CSC reduce trigger rate for 20GeV μ: 20kHz/cm^2 to 2kHz/cm^2





Motivation

- CMS muon system is built to be redundant for tracking and triggering
- Restore redundancy in the 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
- Increase offline muon identification coverage to $|\eta| = 3.5\text{-}4.0$



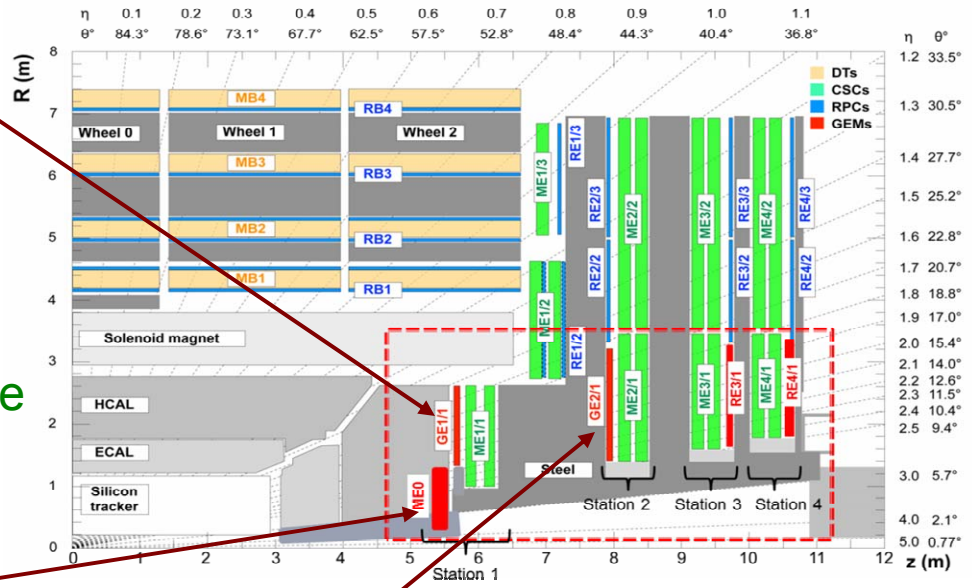
Requirements

- Ageing and longevity
  - The present muon system installed in 2007 must continue to operate w/o significant degradation after higher irradiation and longer operation time than expected
- Trigger
  - At high luminosity the L1 muon trigger in the forward region is compromised
  - This problem can be addressed by the addition new forward muon stations.
- η-coverage
  - If tracker and endcap calorimeter are extended up to η = 4, the coverage for muon identification can be greatly extended with the addition of a small but precise muon detector built into the back of the new endcap calorimeter

The GEM Project

GE1/1:

- Baseline detector for GEM project
- 1.55 < |η| < 2.18
- 36 staggered chambers per endcap, each chamber spans 10°
- One chamber is made of 2 back-to-back Triple-GEM detector
- Will guarantee high trigger performance during late Phase I and throughout Phase II
- Installation: LS2



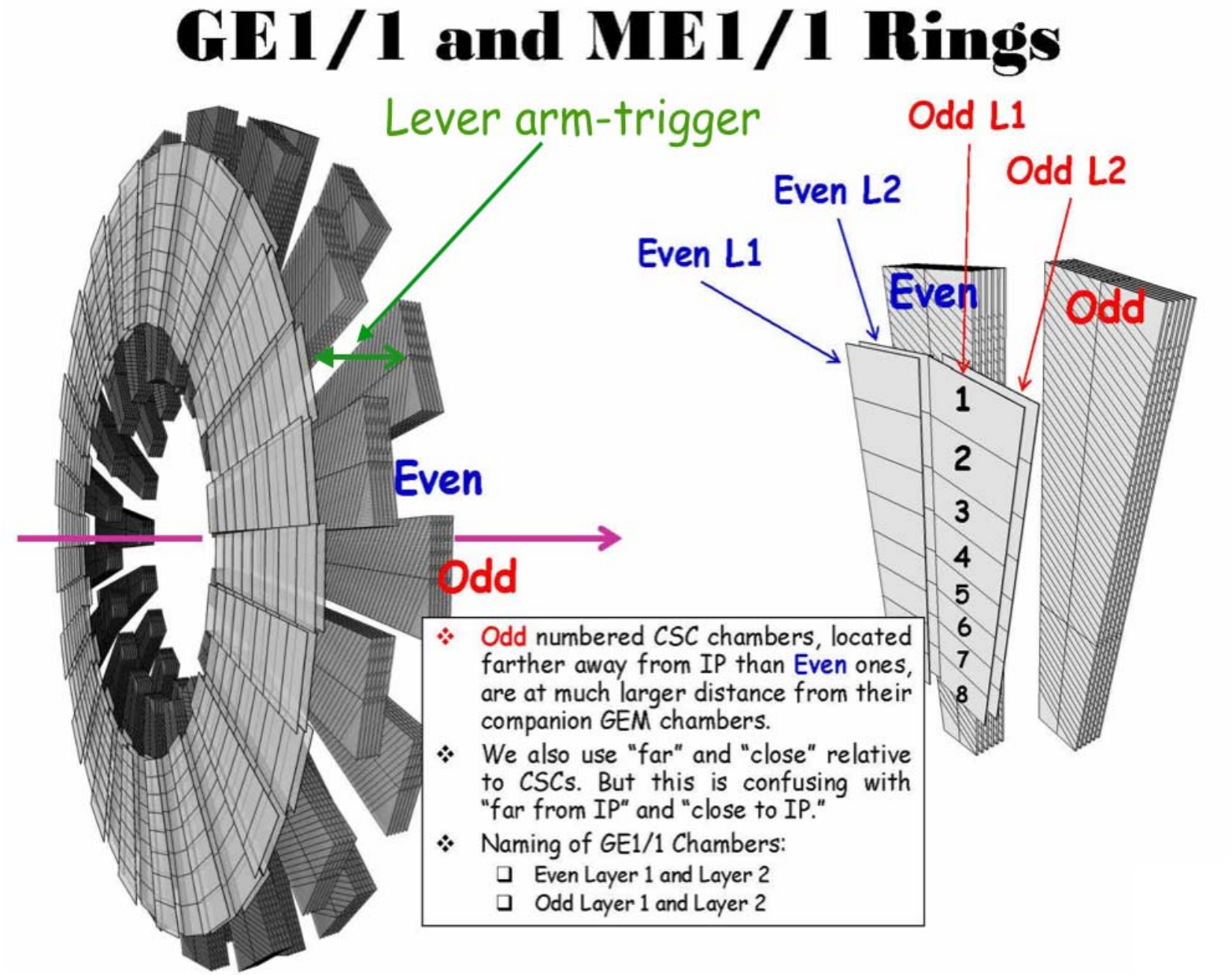
ME0:

- Muon tagger at highest η
- 2.0 < |η| < 3.5
- 6 layers of Triple-GEM
- each chamber spans 20°
- Installation: LS3

GE2/1:

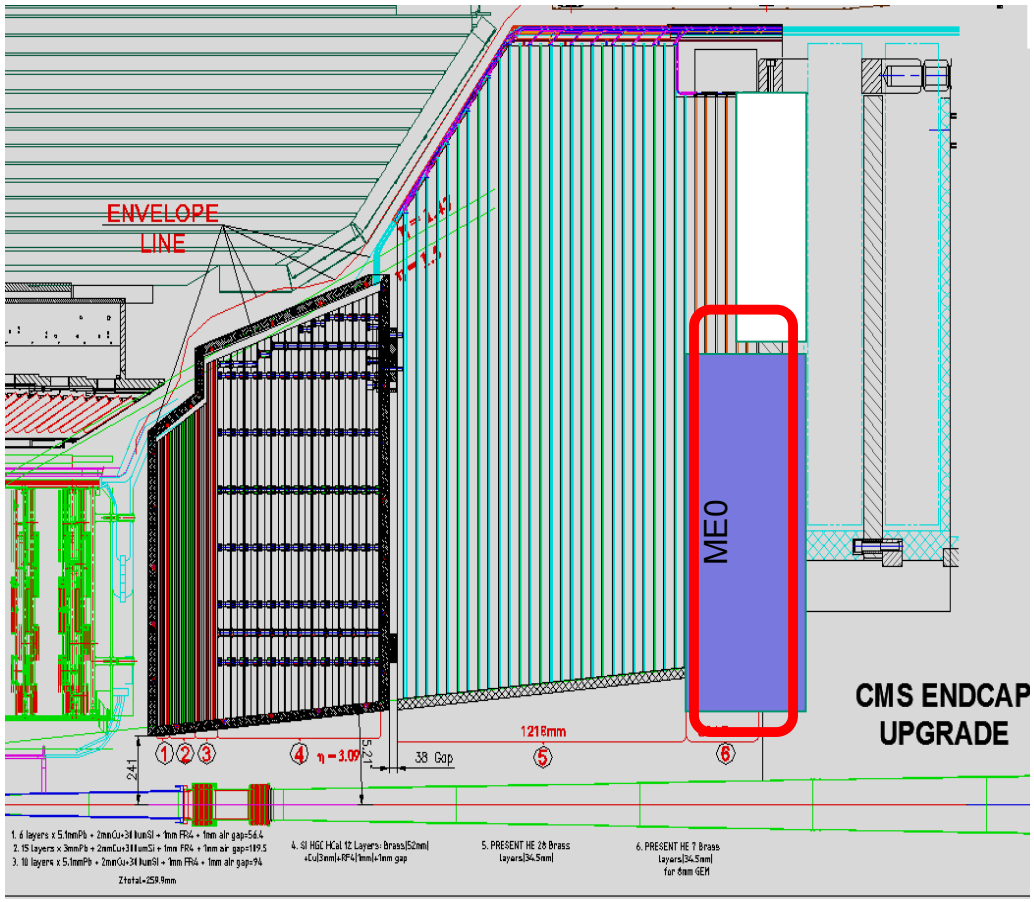
- 1.55 < |η| < 2.45
- 18 staggered chambers per endcap, each chamber spans 20°
- Installation: LS3

GE1/1

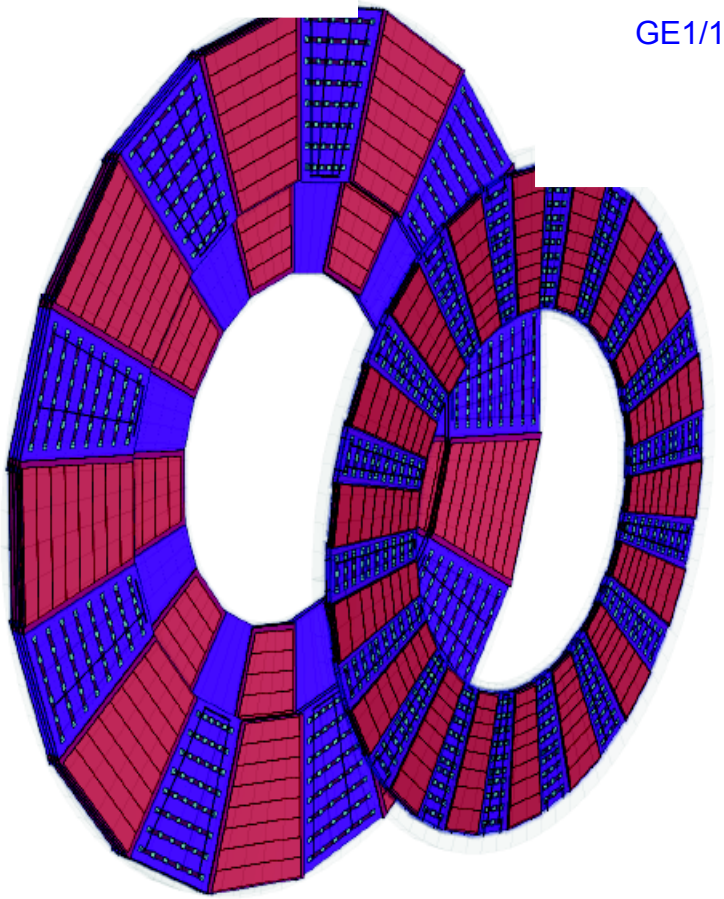

GE1/1 and ME1/1 Rings
Lever arm-trigger
Odd L1
Odd L2
Even L2
Even L1
Even
Odd
1
2
3
4
5
6
7
8
Even
Odd
Odd numbered CSC chambers, located farther away from IP than Even ones, are at much larger distance from their companion GEM chambers.
We also use "far" and "close" relative to CSCs. But this is confusing with "far from IP" and "close to IP."
Naming of GE1/1 Chambers:
Even Layer 1 and Layer 2
Odd Layer 1 and Layer 2

GE2/1 and ME0

GE2/1



GE1/1



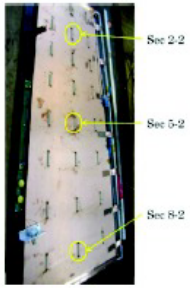
- No proper engineering drawing exists for these two

On-going Activities

- Prototype production
- Cosmic stand
- X-ray station & Ageing studies
- FE electronics and DAQ design
- CSC-GEM integration stand
- Fall 2014 Test Beam & GE1/1 Slice Test in 2016
- + Trigger and physics performance studies, muon reconstruction, …

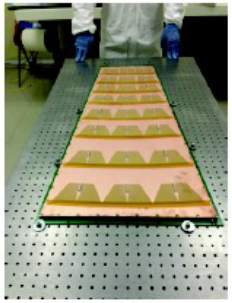
Current focus: GE1/1


2010

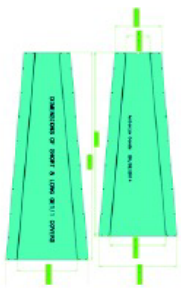


2011


2012


2013


2014


2014/2015

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.**

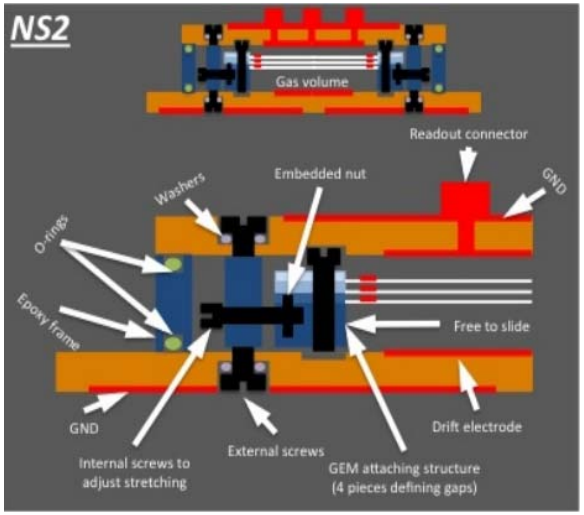
Generation III
The first sans-spacer detector, but with the outer frame still glued to the drift. Ref.: **2012 IEEE N14-137.**

Generation IV
First detector with complete mechanical assembly; no more gluing parts together! **Upcoming papers from MPGD 2013; And IEEE2013.**

Generation V
Very close to what we will install in CMS. Features re-designed stretching apparatus that is now totally inside gas volume. **Upcoming test beam campaign for final performance measurements.**

Generation VI
Latest detector design; **what we will install in CMS.** Optimized final dimensions for maximum acceptance and final eta segmentation. **Upcoming test beam campaign for DAQ chain stress test!**

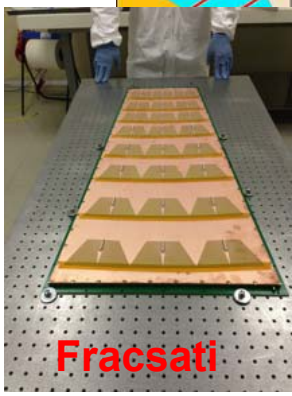
- GEM foil production uses single mask technology for wet etching
  - Dramatically reduces foil production costs and allows large sizes to be manufactured
- Performance same as that of double mask
- NS2 assembly technique developed
  - Construction time reduced from week(s) to two hours per chamber



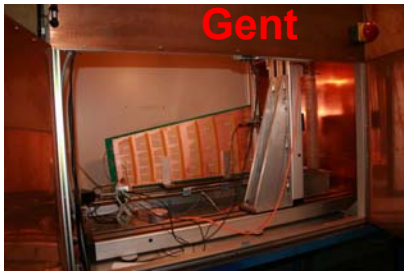
Production

6 production sites are ready for final production:

- Florida Tech (US)
  - New larger x-ray shielding box
  - Refurbishment of table-top electromagnet (~1T)

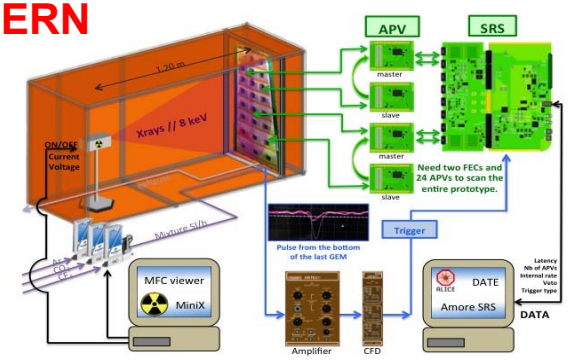


- LNF (IT)
  - Class 100 clean room ready, used to assemble one GE1/1-V prototype
  - Clean gas lines, optical bench, X-ray gun, gas chromatograph,…
- Bari (IT)
  - Ready for tests with X-ray source
- BARC (IN)
  - Refurbishment of existing RPC lab clean room
  - Commissioning of X-ray source and shielding in Sept 2014
- Gent (BEL)
  - Re-use the RPC lab with 1.6x2m2 cosmic stand
  - X-ray gun and shielding cage



- CERN
  - One GE1/1-V prototype already assembled
  - X-ray station used for gain uniformity studies

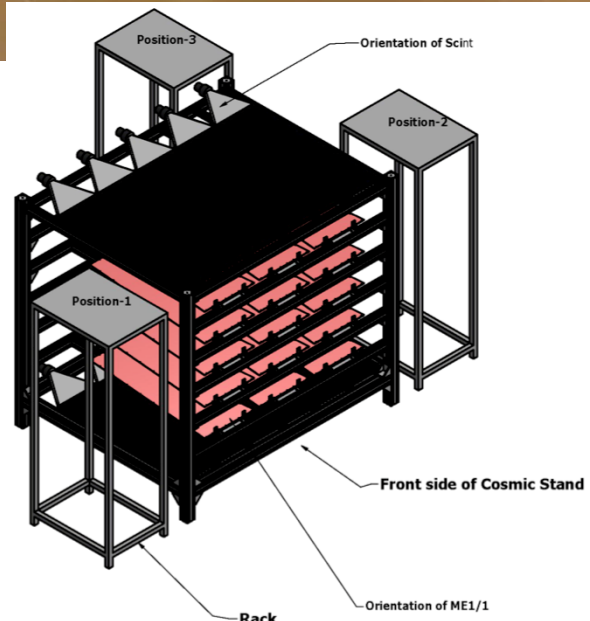
CERN



All have already assembled GE1/1-IV prototypes

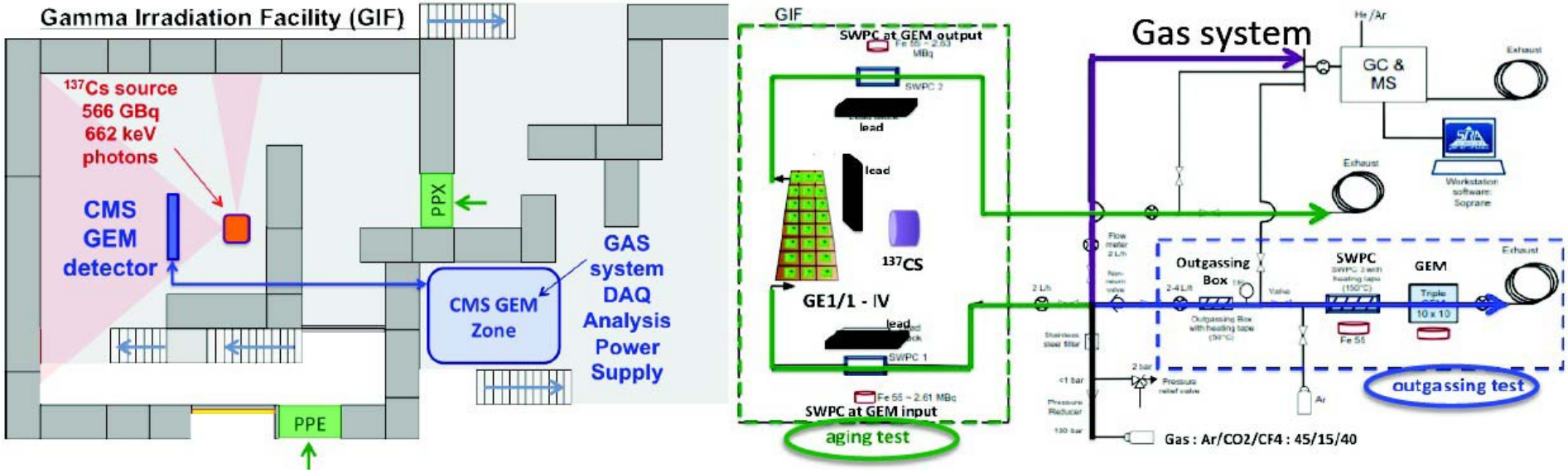
TIF Cosmic Stand (CERN)

- Additional layer of quality control (cluster size, timing, efficiency, etc.)
- Each chamber will have results logged in performance database
  - Reference once CMS is closed
- Construction on-going
- Aluminum superstructure completed
- All scintillators assembled
  - PMT characterization done over the summer
- Trigger logic working



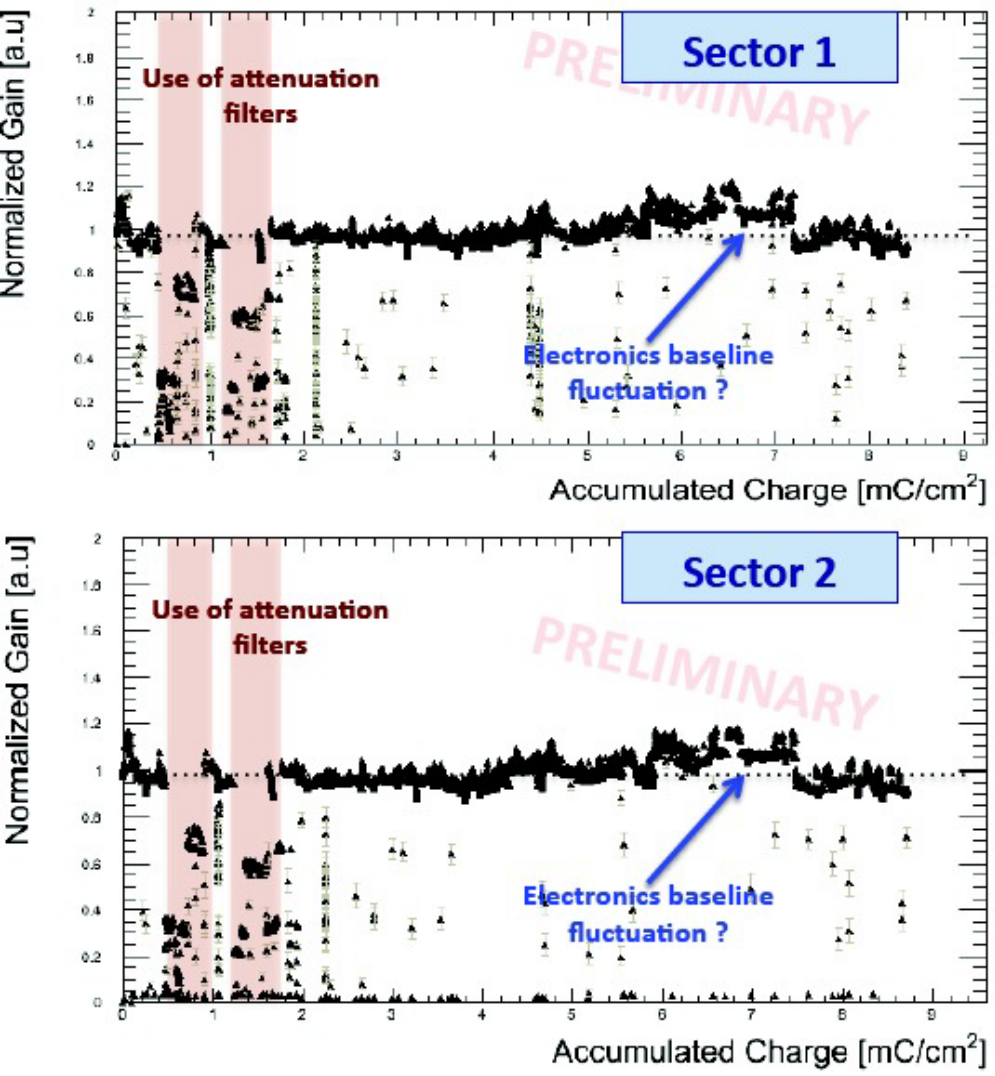
Ageing Studies

- Expected rate: few kHz/cm^2 → few 10s kHz/cm^2
- Expected charge after10 years: 100 mC/cm^2



- Test with GE1/1-IV (no spacer, no glue, final set of material)
- ^{137}Cs source
- ^{55}Fe sources for reference chambers
- ^{109}Cd source for outgassing study

Preliminary Ageing Results

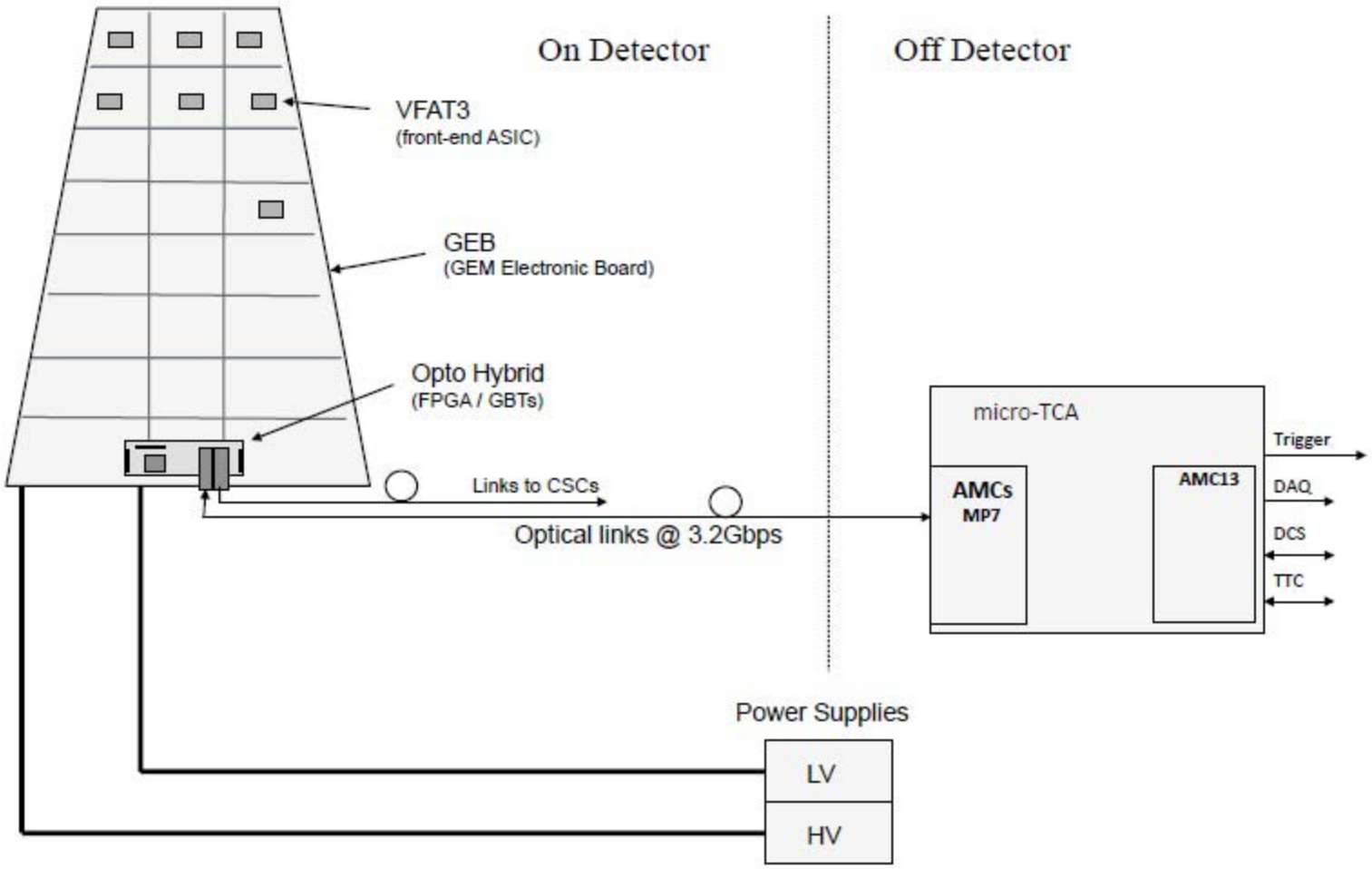


- **GE1/1-IV :**
  - Gas gain : 2×10^4
  - $Ar/CO_2/CF_4$:45/15/40
  - Gas flow rate : 0.5L/h
  - Max interaction rate : kHz/cm^2
- **GIF / common facility**
  - frequent use of lead filters
- **First observations :**
  - interaction rate similar to CMS
  - accumulated charge : 9 mC/cm^2 over 9 months!

→ ***No ageing effect observed in the GE1/1 detector up to 9mC/cm^2 in realistic conditions***

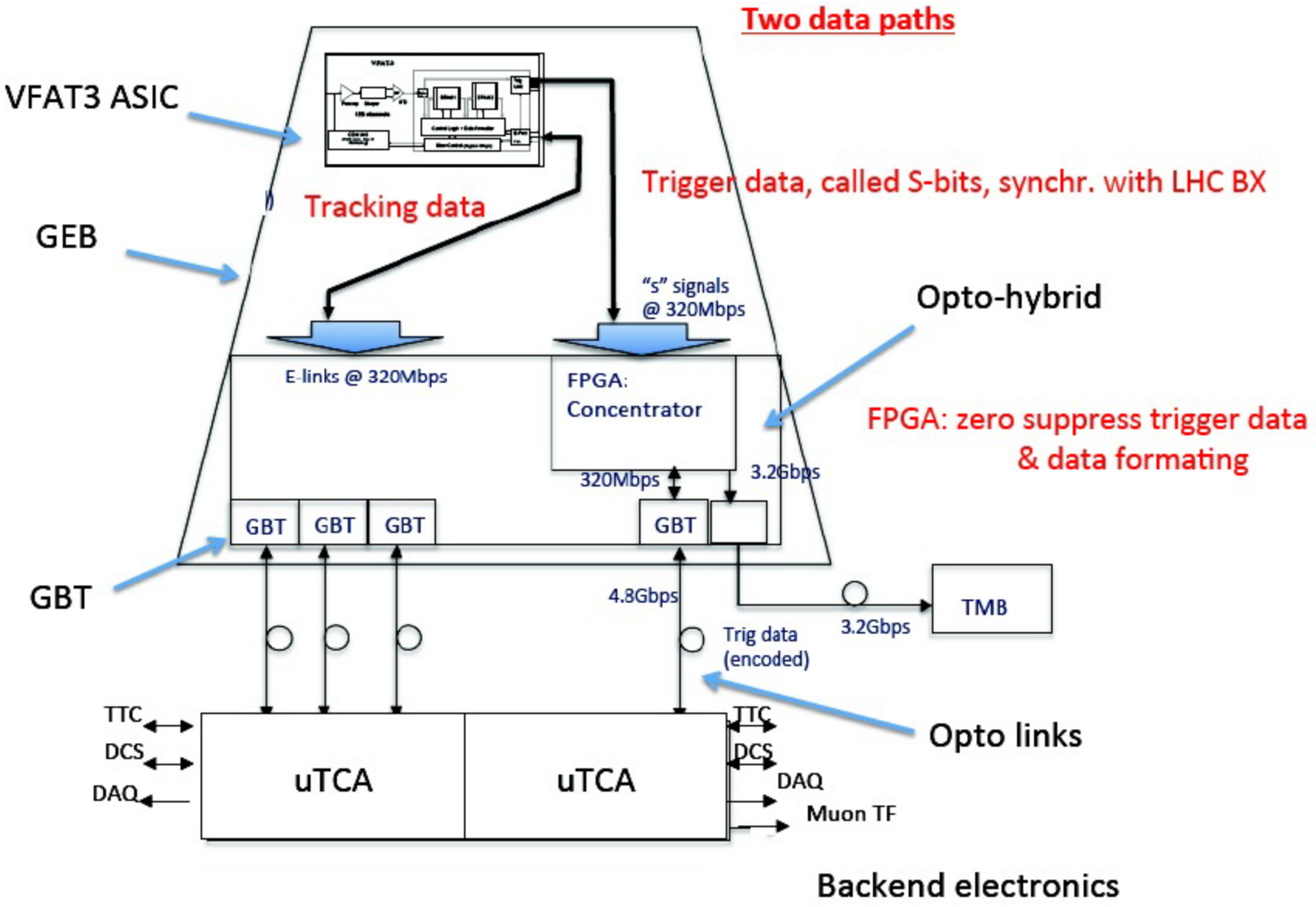
→ ***Investigations for better corrections***

Readout System

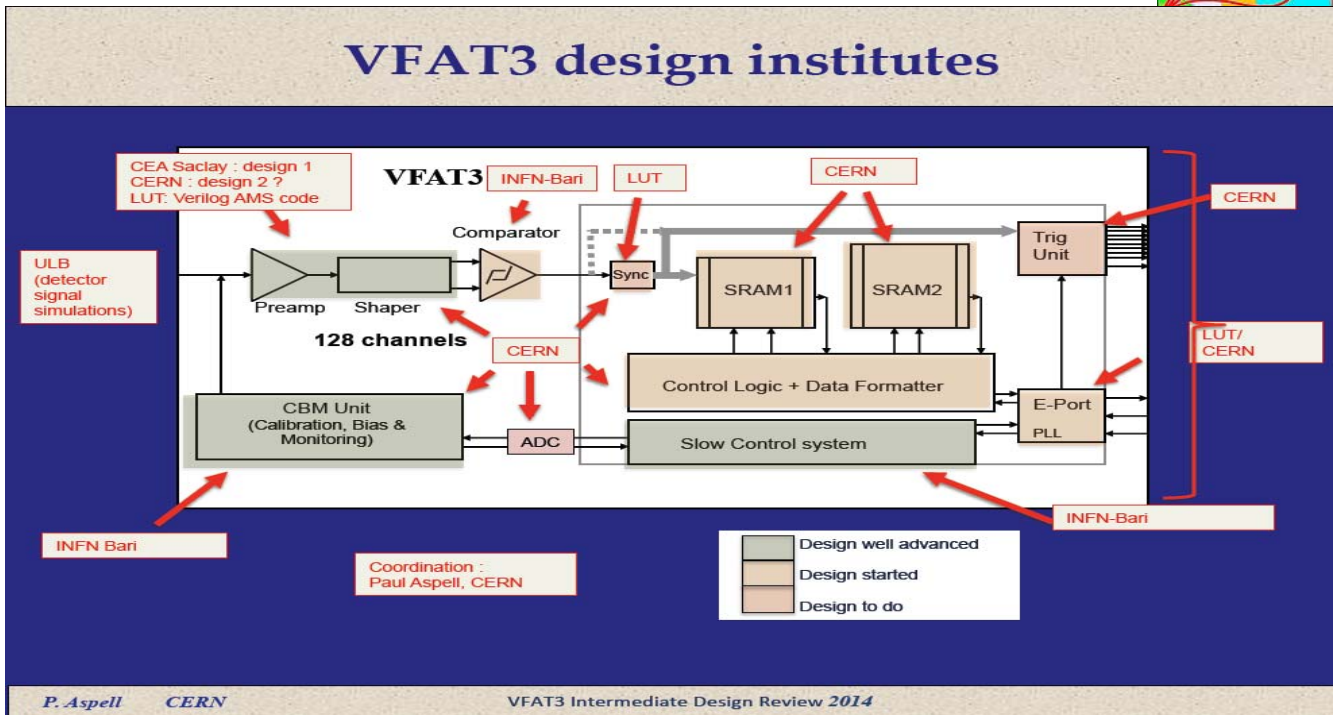


- Philosophy: intention to make full use of these generic projects as far as possible to minimize duplication of effort and ensure that design resources within the project are focused on the project specific designs needed.

GE1/1 System


Two data paths
VFAT3 ASIC
Tracking data
Trigger data, called S-bits, synchr. with LHC BX
GEB
"s" signals
@ 320Mbps
Opto-hybrid
E-links @ 320Mbps
FPGA:
Concentrator
FPGA: zero suppress trigger data
& data formating
320Mbps
3.2Gbps
GBT
GBT
GBT
GBT
GBT
4.8Gbps
TMB
3.2Gbps
Trig data
(encoded)
TTC
DCS
DAQ
uTCA
uTCA
TTC
DCS
DAQ
Muon TF
Opto links
Backend electronics

VFAT3 Design

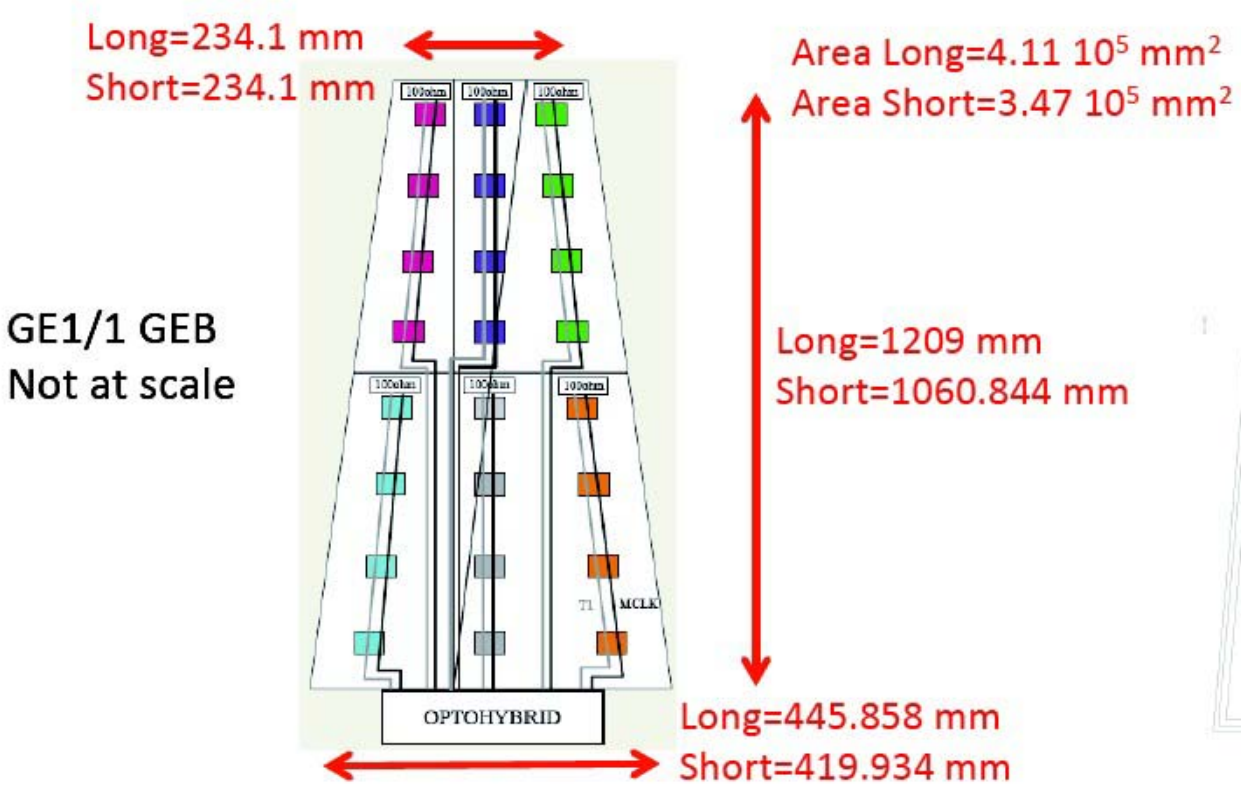


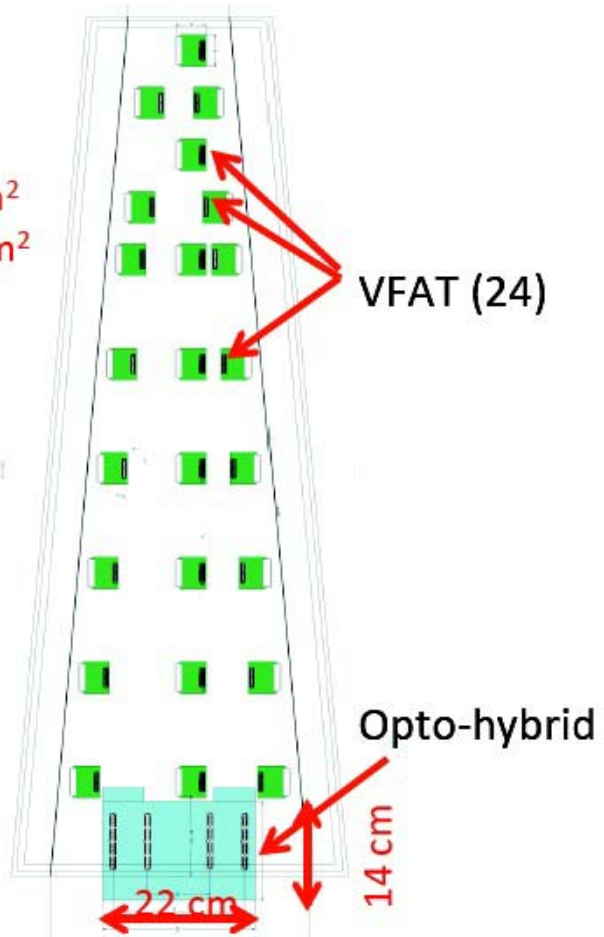
- 128 channel chip
- Both polarity
- Provide tracking and trigger data
- LV1A latency up to 20μs
- Interface to and from GBT @ 320 Mbps
- Radiation tolerant up to 100 MRad
- Design on-going
- 1st prototype of CFD block submitted to IBM in May
- Delivery expected this month

On-detector Electronics

- GEB board
  - GEM Electronics Board: large PCB to avoid cables along GEM
  - Plugged on the GEM readout board
  - Strips segmented in 8η x 3φ partitions, each readout by 1 VFAT

- Opto-hybrid (OH)
  - Board equipped with concentrator FPGA, collecting signals from all VFATs and handling the optical links

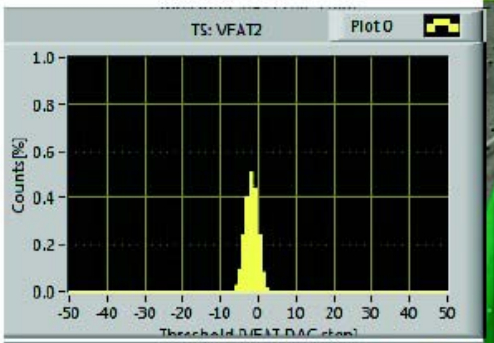


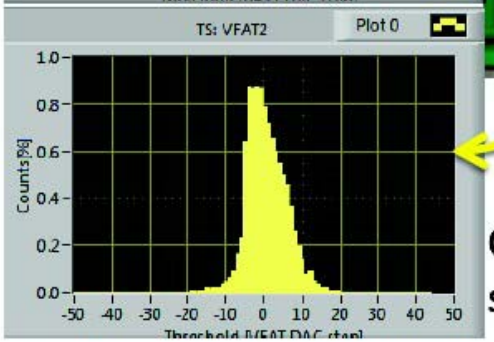


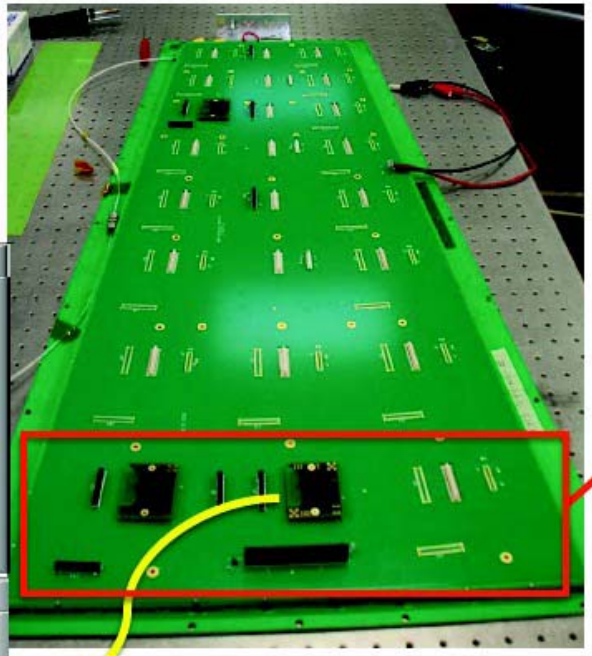
On-detector Electronics

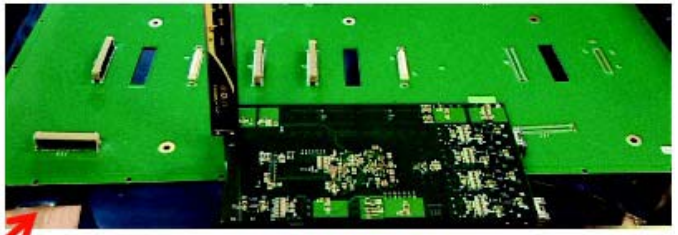
- GEB and Opto-hybrid v1 (6 VFAT2) available since beginning of 2014
- Design of GEB-Long v2 (24 VFAT2s) done, production started
- Design of Opto-hybrid v2 (24 VFAT2s) on-going

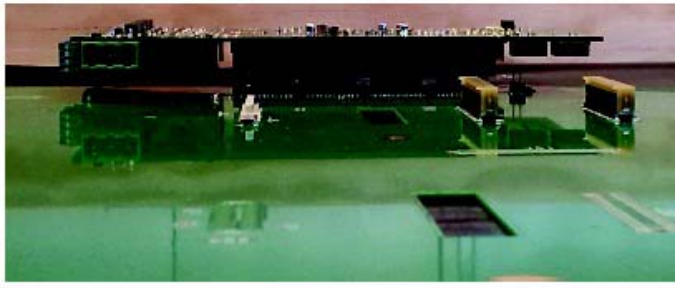
New VFAT2 hybrid
not connected







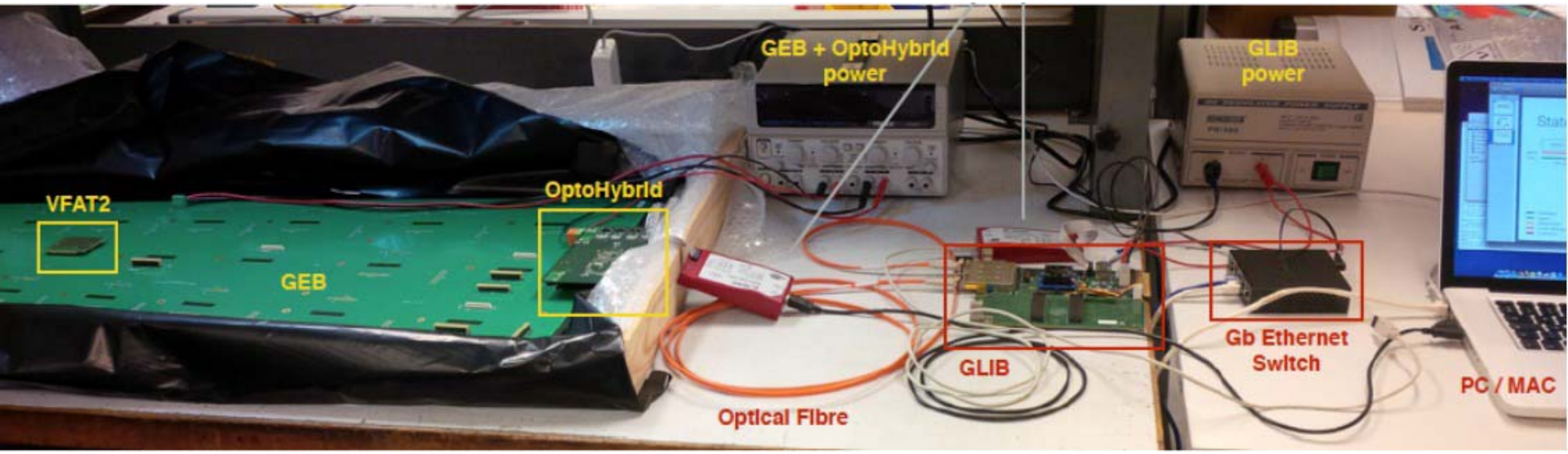




Connected but
strips floating

DAQ – V1

- VFAT – OH – GLIB communication working (also through µTCA)
  - OH FPGA recovering clock from optical link
  - Use IPBus protocol for control
- + separate test bench for GBT testing (with µTCA crate)



Schedule

Full size prototype hardware steps

Prototype 1 :
VFAT2
Compatible with VFAT2 CMS Hybrid or Totem hybrids
GEB v1
OptoHybrid V1
Readout & Programming via UART or Optically to uTCA
Applications of Prototype 1 : Electrical tests – initial firmware and software development

Hardware Jan/Feb 2014

succeeded

Prototype 2 : (At first 8 eta divisions, then sub versions for extended eta options)
VFAT2
VFAT2 CMS Hybrid
GEB v2
OptoHybrid V2
Readout & Programming optically from/to uTCA
Applications of Prototype 2 : Test Beam - CERN Cosmic Stand – Slice Test

Hybrids & GEB2 ~ June 2014,
OH V2 ~ August 2014
System development for TB, CS & ST

On-going

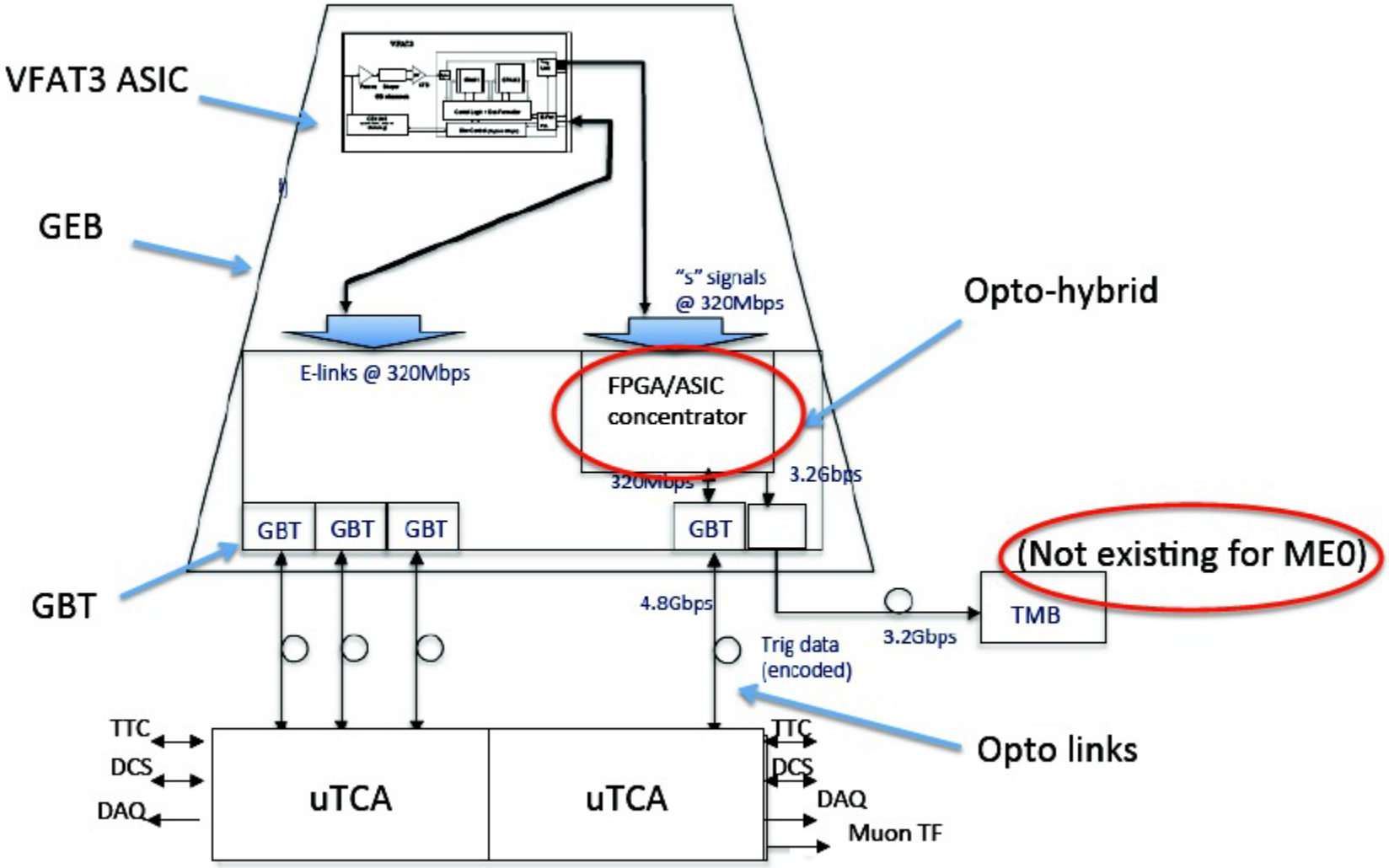
Prototype 3 :
VFAT3 (or VFAT3 emulator to start)
VFAT3 Hybrid Vx....
GEB v3
OptoHybrid V3
Readout & Programming optically via GBT from/to uTCA
Applications of Prototype 3 : CERN Cosmic Stand - Final system

VFAT3 (a) ~ Q4 2015
Initial hardware Q2-3 2015 ?
System development for CS & FS
continuous up until LS2

Integration Activity

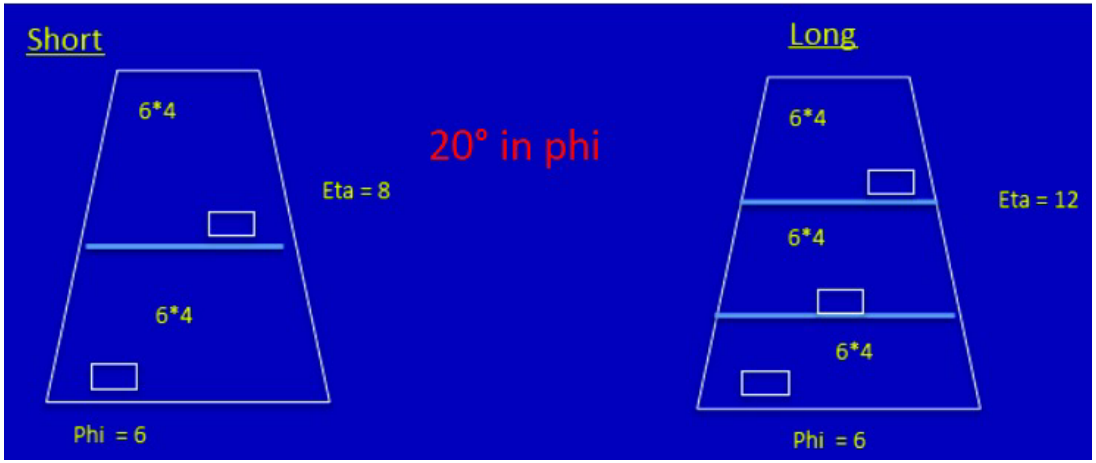
- Goal : Slice test readiness
  - CSC-GEM Trigger integration
  - CSC-GEM synchronization
  - plus integration of AMC13
- Electronics work started on Sept 1st.
- Design phase of test-bench completed

GE2/1 and ME0 System

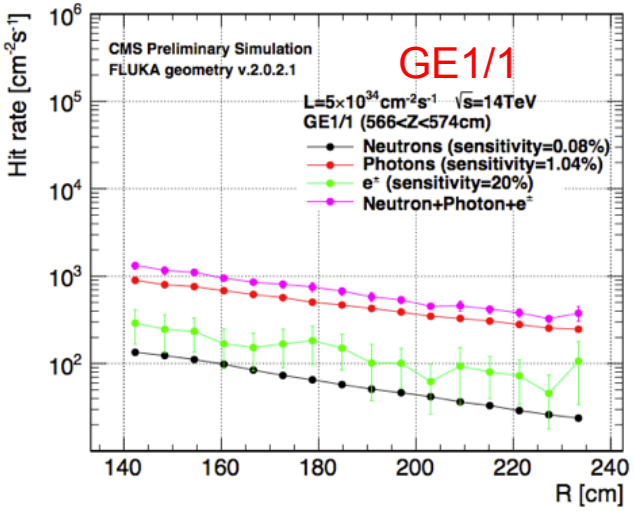


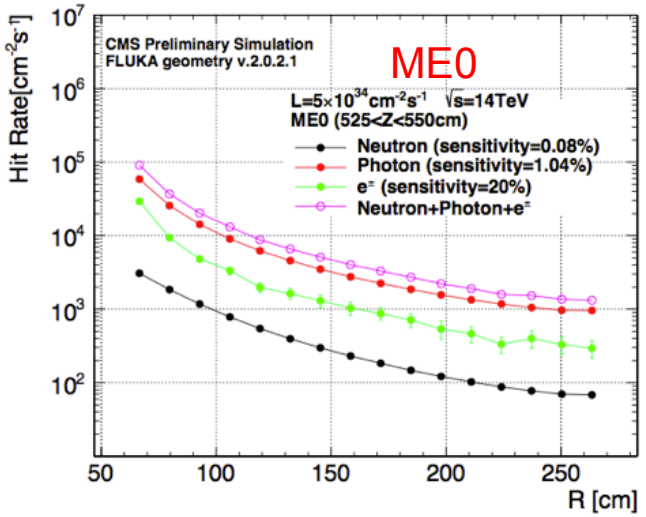
GE2/1 & ME0 System

- GE2/1 Long = 1816mm > manufacturer capability
  - Investigating segmentation of GEB board :



- ME0 will be exposed to rates > 10 x GE1/1 rates
  - Investigating data rates and bandwidth requirements





ME0 Mean Trigger & Tracking Rates

- Probability to hit the optical link bandwidth limit (3.2 Gbps / link):

Trigger	Data rate (Gbps)	Prob with 2 links	Prob with 3 links
Fast OR ZS	2.68	1.34%	0.02%

  - Still investigating other data format
  - Note: optical link bandwidth based on GBT. For LS3, higher speed GBT may be there

Tracking (L1A @ 1MHz)	Data rate (Gbps)	Prob with 1 links	Prob with 3 links
SPZS*	2.15	$<10^{-7}$	$<10^{-7}$

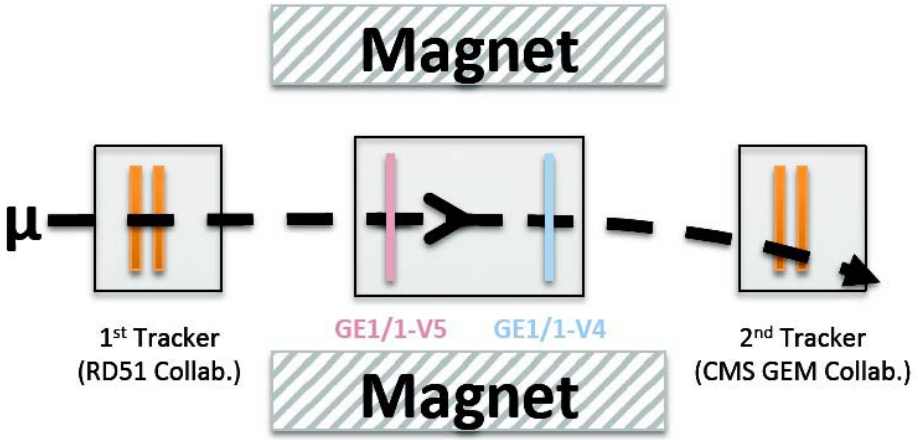
  - *SPZS: Sequential Zero Suppression a variant of the CMS RPC data format

- GE1/1 Probability to hit the optical link bandwidth limit (3.2 Gbps / link):

Trigger	Data rate (Gbps)	Prob with 1 links	Prob with 2 links
Fast OR ZS	0.05	$6\ 10^{-5}$ %	$<10^{-7}$

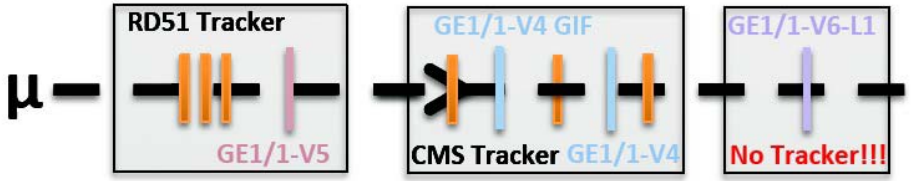
Test Beam Activities

- H2 Test Beam with magnet
- October 13th – November 2nd



- Charge sensitive measurements in high B field
- Test version one of GEM electronics

- H4 Test Beam without magnet
- November 26th – December 15th



- Timing sensitive performance measurement with B=0
- Study impact of radiation dose on performance
- Test of version two of GEM electronics

Summary

- CMS GEM project is well on track
- Many many activities are on-going
- Detector R&D : proto v5, test beam in fall 2014 for final performance measurements
- 6 production sites are ready
- TIF cosmic test bench is being built
- Ageing measurements are on-going (next at GIF++)
- Electronics and DAQ development is going on well
  - VFAT3 CFD block v1 in production, will be tested soon
  - v1 of GEB and Opto-hybrid operational (with µTCA)
  - GE1/1 GEB-Long v2 in production, OH v2 under design
  - Starting integration test with CSC electronics in bdg 904
- 2 long test beam will be coming soon
- More results are expected very soon …