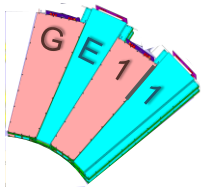
Technical and Political Status of the CMS Muon Chambers Upgrade

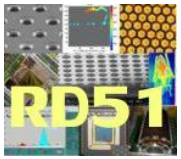
Michael Tytgat

for the CMS GEM Collaboration

RD51 Collaboration Meeting – February 6, 2014

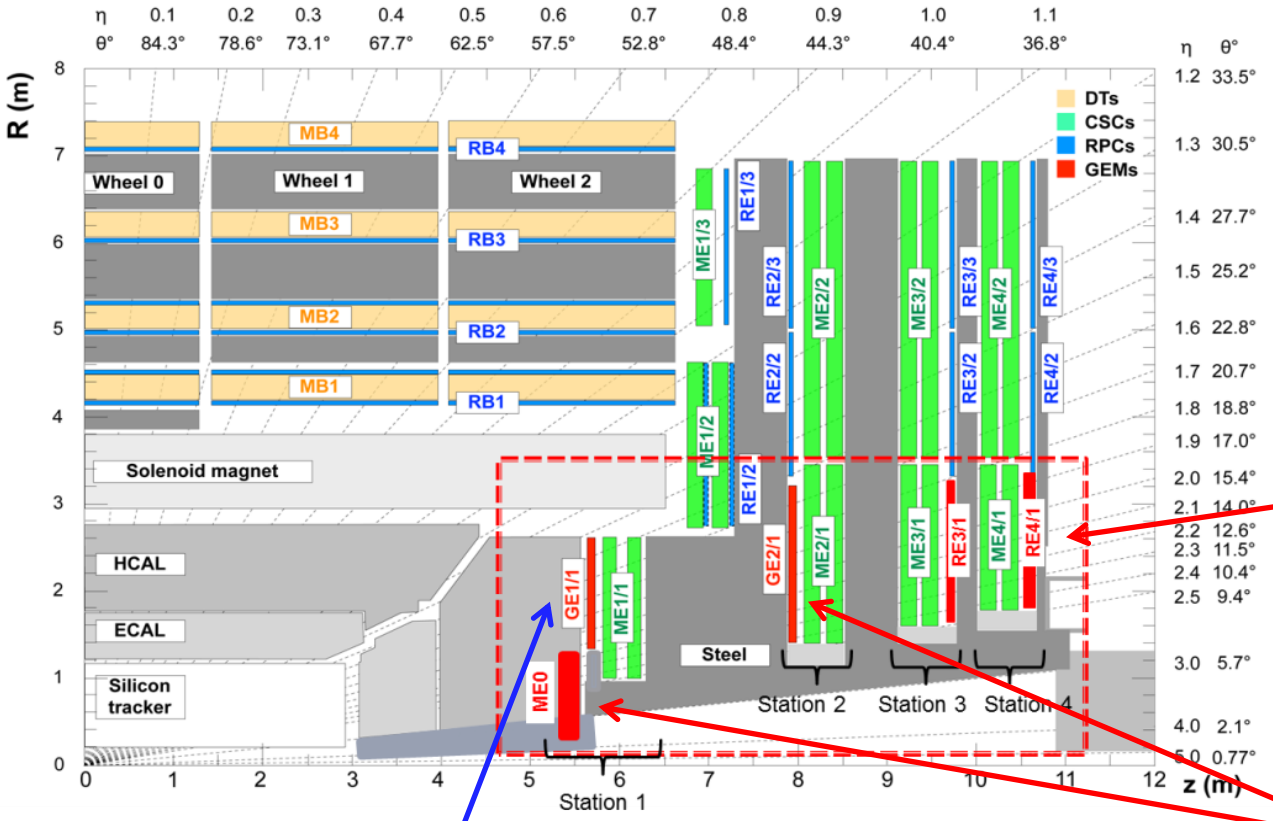


- **CMS Phase-2 Muon System Proposal**
- **Detector Design and Construction**
- **FE Electronics and DAQ**
- **Integration into CMS**
- **Muon Trigger Studies**
- **Physics Examples**
- **GE1/1 Technical Design Report**



UNIVERSITEIT GENT

Proposed CMS Phase-2 Muon System



To be submitted in 2014:

- ❑ GE1/1 Technical Design Report
- ❑ Muon Phase-2 Technical Proposal

Post LS3 2023 scenario

- RE3-4/1location, improved RPCs, GEMs ??

Post LS2 2019 scenario

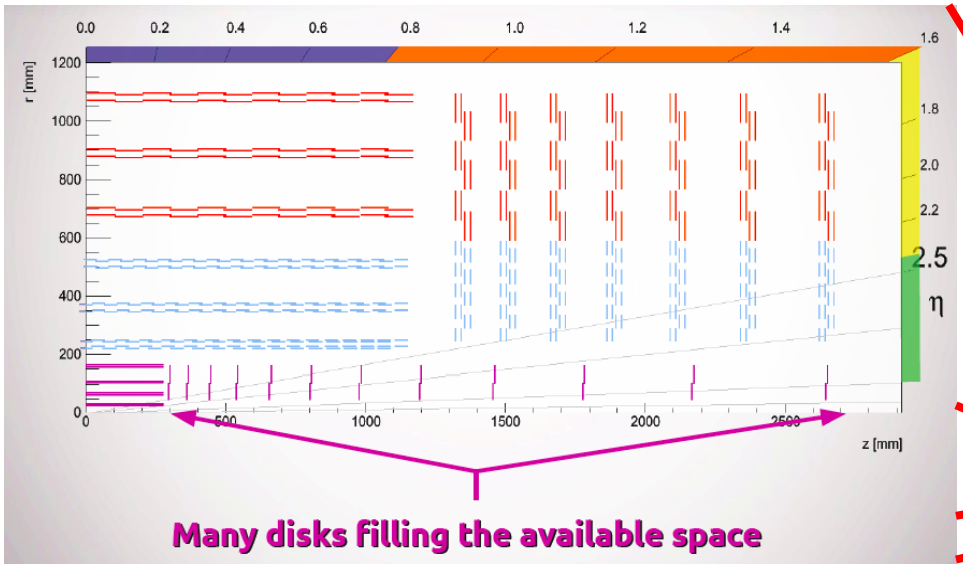
- GE1/1 GEM station
- Demonstrator approved for LHC 2016 YETS
- Full installation proposed for LHC LS2

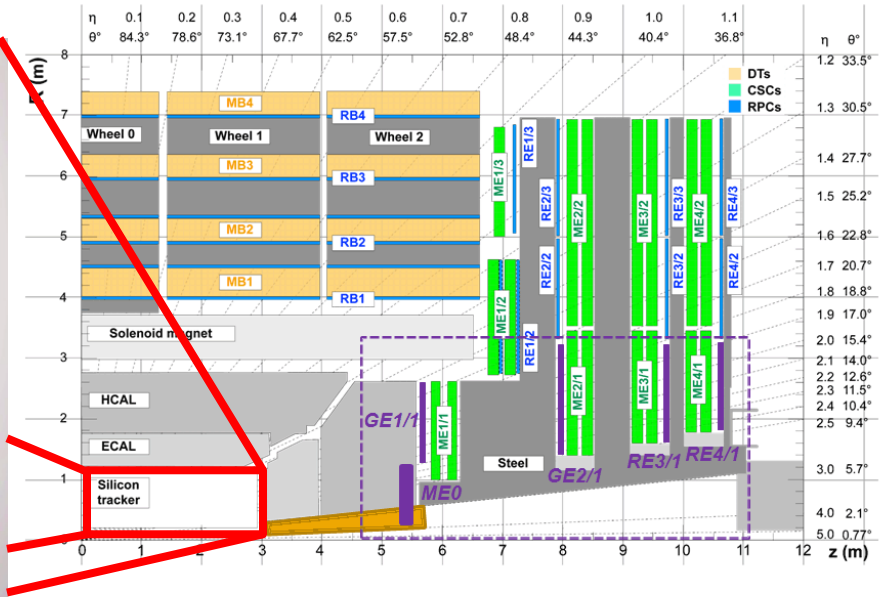
Post LS3 2023 scenario

- ME0 station:
  - extending coverage up to |η|=2.4; under study if going up to |η|=3.5-4 is possible
- GE2/1 GEM station

Near Tagger ME0 Scenario

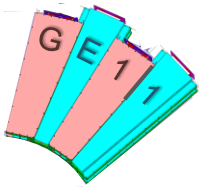
- **Near tagger ME0 at the back of the present Hadronic Calorimeter in the endcap**
- **Coverage: ~2.1<|η|<4.0**





- **Upper portion of 2.1<|η|<2.5 has trigger capabilities**
- **Lower portion is only used in the offline reconstruction**
  - **Muon reconstruction based on matching tracks reconstructed in forward muon extension with hits in the muon system**

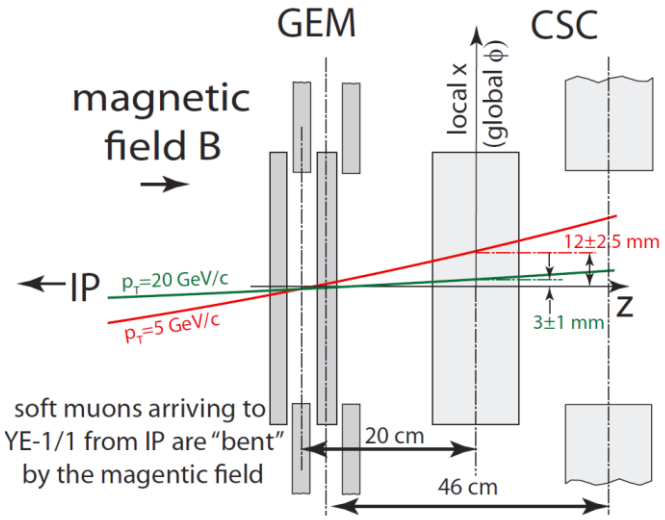
Muon Phase-2 Upgrades



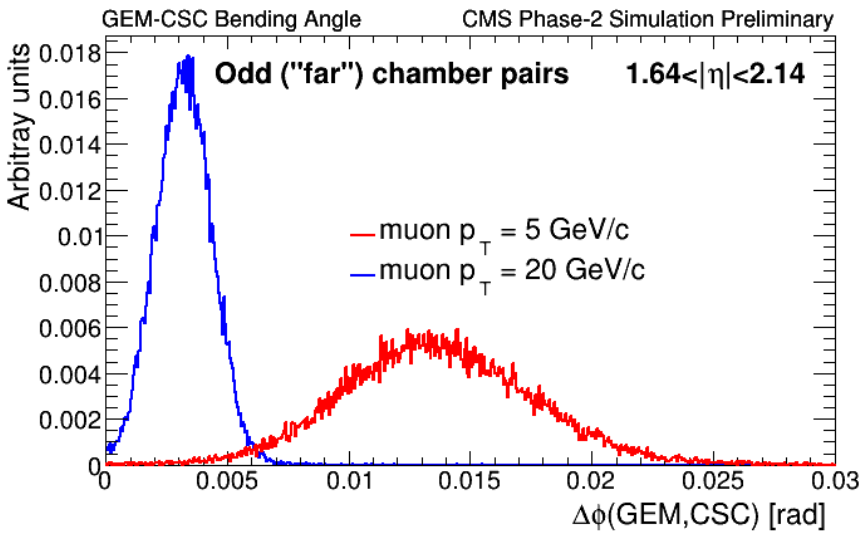
- **Forward muon trigger and redundancy**
  - **GE1/1 and GE2/1 based on improved L1 trigger, redundancy in the most intense region**
  - **GE1/1 will save the day for muon triggering between LS2 and LS3:**
    - **Post-LS2 is the worst time ever: no track trigger yet**
    - **GE-1/1 covers the region 1.5<|η|<2.2 planned to be installed in LS2 as part of "early" Phase-2 upgrades**
  - **RE3/1 and R4/1: timing for background rejection and PU mitigation**

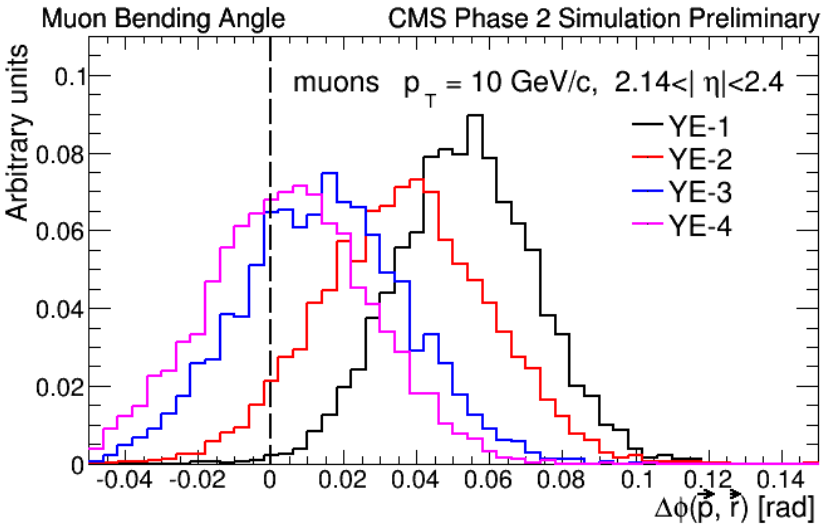
- **Forward muon tagging extension (ME0)**
  - **Large eta coverage (~2.1-4.0) for big acceptance; S/N boosts in modes with muon**
  - **Hermeticity for modes excluding muons**
  - **Critical post LS3 concerns:**
    - **Avert loss of triggering in 2.2<|η|<2.5 (region beyond GE1/1)**
    - **Take advantage of opportunity to expand physics reach by extending offline muon coverage to 2.4<|η|<4.0**

Trigger Motivation



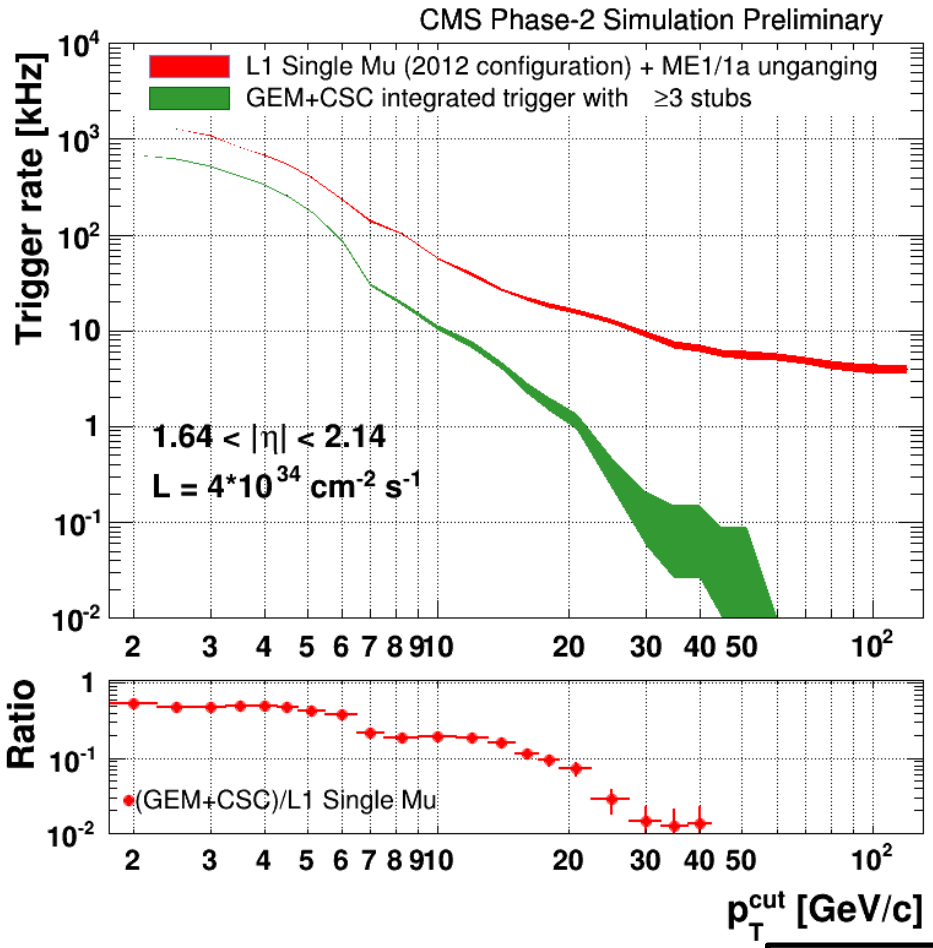
- **Increased trigger efficiency from added redundancy**
- **Reduced trigger rate from GEM-CSC bending angle:**
  - **ME0 & GE1/1 yield the best separation from zero**
  - **Some gain expected from bending angle in GE2/1**
  - **RE3-4/1 no use from bending angle; use those stations only for redundancy or timing**

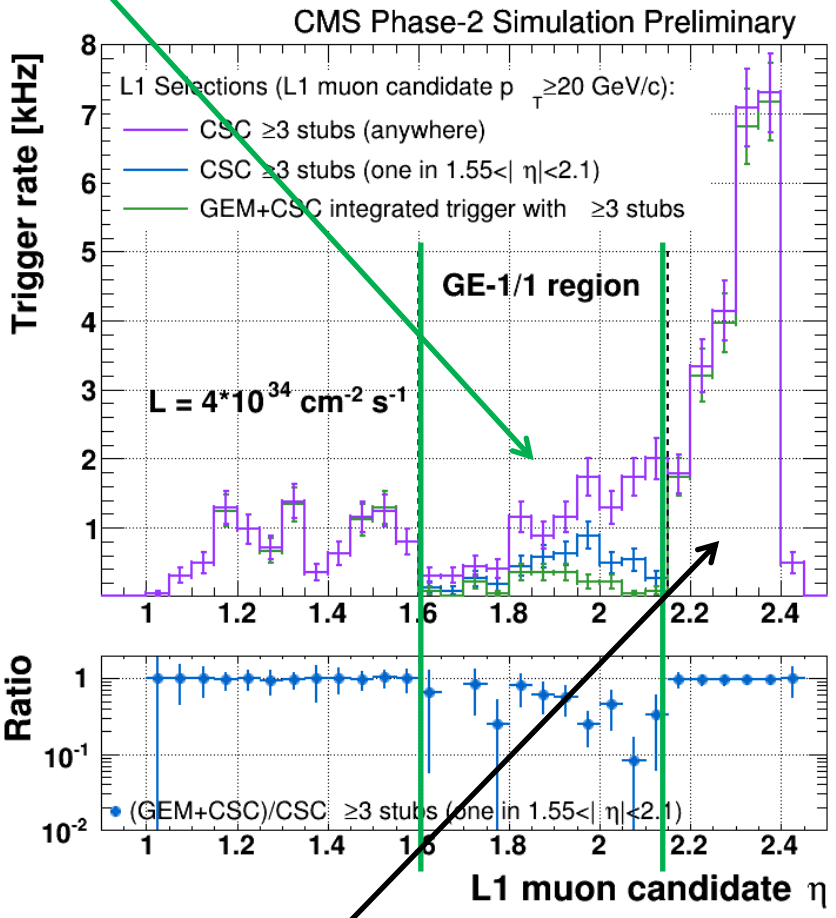




Trigger Motivation

Expected L1 trigger rate reduction with GE1/1

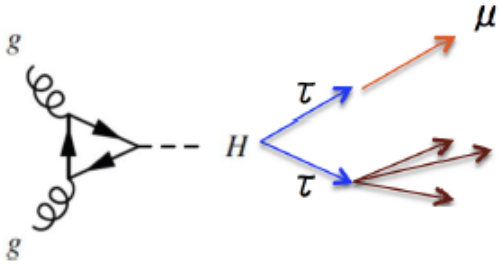




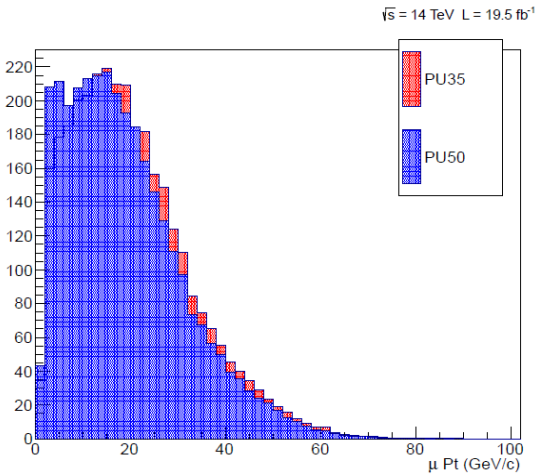
Combining all proposed stations, expect factor ~4.5 rate reduction in 2.1<|η|<2.4 region

Physics Example: H2Tau

Very important to study Higgs coupling to 3rd family
Overall a small signal efficiency (<1%)
Various tau decay channels; cleanest is τ→μ with BR~16%

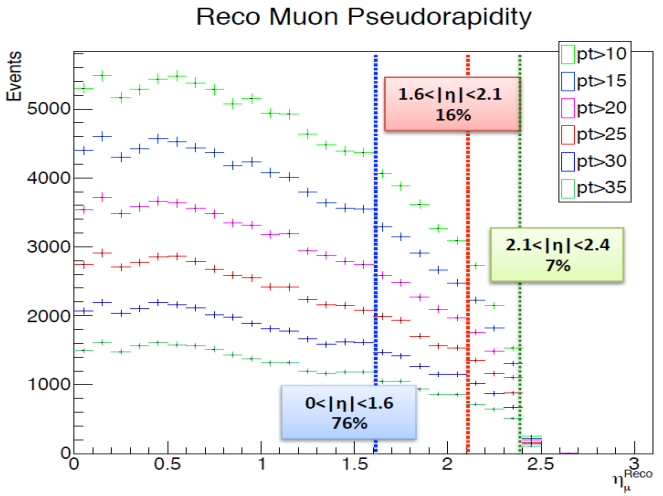


Muons from τ→μ are pretty soft



~23% of H2Tau events in GE1/1 instrumented region

→ trigger threshold matters!

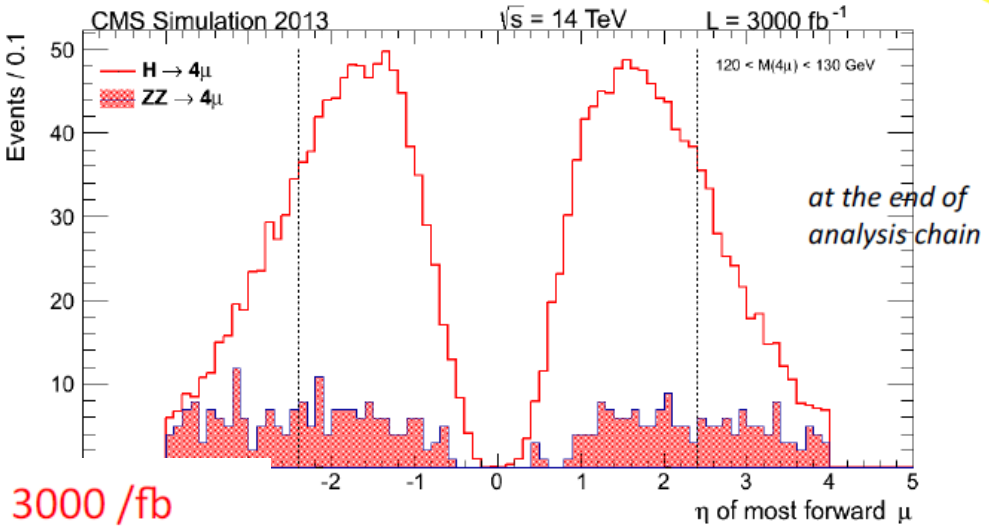


R.Venditti, A.Colaleo, C.Calabria (Bari)

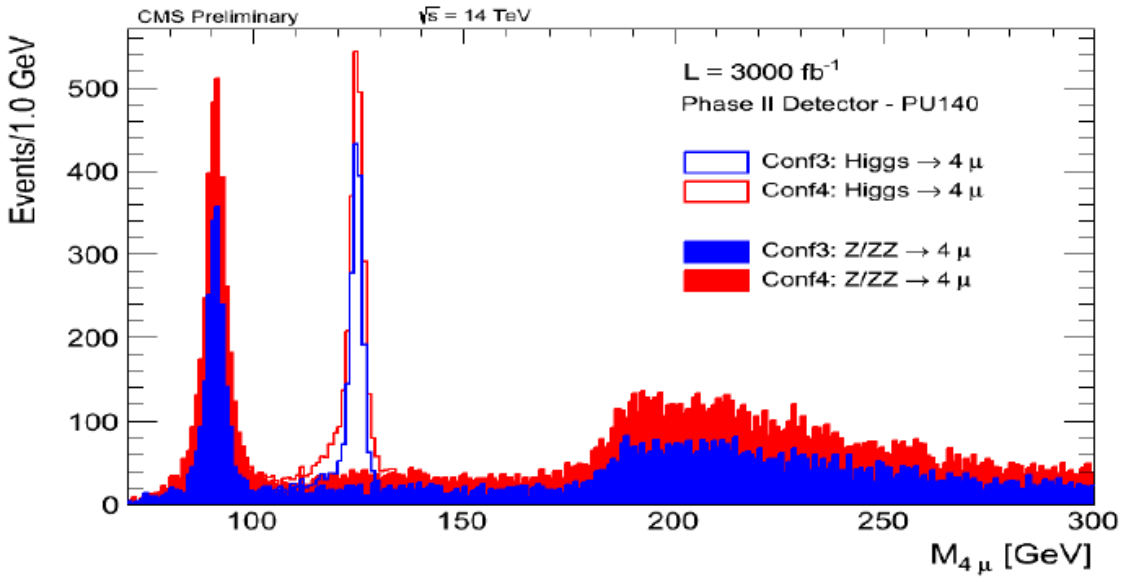
Lowering trigger threshold from ~20 GeV (post-LS1 plan) to ~15% = ~20% gain

Physics Example: H→ZZ→4μ

- ~40% gain in Higgs acceptance
- In the forward region: slightly lower mass resolution + more background (SM ZZ), but still overall gain



Projections for signal and ZZ background with 3000 /fb



4μ invariant mass with and without pixel detector extension to |η|=4

F.Cavallo, S.Braibant, P.Giacomelli (Bologna)

Summary of 2013

- Collaboration expanded to 42 institutions; EOI from 183 collaborators; 75 authors for papers & conferences
- Parts for 6 large GE1/1-IV prototype detectors produced at CERN and shipped to production site candidates
- 5 GE1/1-IV prototypes built @ different production sites
- 2 GE1/1-IV prototypes fully commissioned @ CERN
- Fermilab beam test of first GE1/1 built outside of CERN
- 6 potential mass production sites being developed
- GIF long-term aging test well under way
- Successful trial installation of GE1/1-IV dummy chambers
- Interfacing with Muon POG
- Simulation validation & reconstruction effort ramped up
- "Motivational" Trigger and Physics plots approved by CMS
- GE1/1 TDR on track; first readable draft circulated last Christmas

Priorities & Milestones for 2014

- **GE1/1 LS2 Project:**
  - **Construct and Test Slice Test Detectors**
  - **Commission cosmic stand with QC fully developed**
  - **Integrate electronics with VFAT2 (3 final prototype) + GLIB + FPGA on detectors in CMS GEM Facility @ CERN**
  - **Installation in LHC 2016 YETS**
  - **Services to be completed**

- **GE2/1 : Construct & test first prototypes**

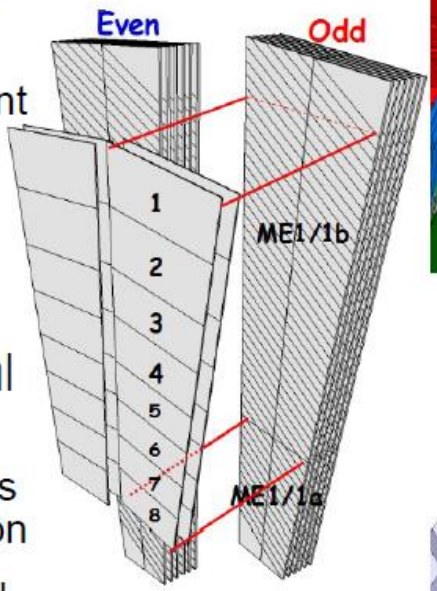
- **ME0 : Finalize layout envelope and geometry for Technical Proposal**

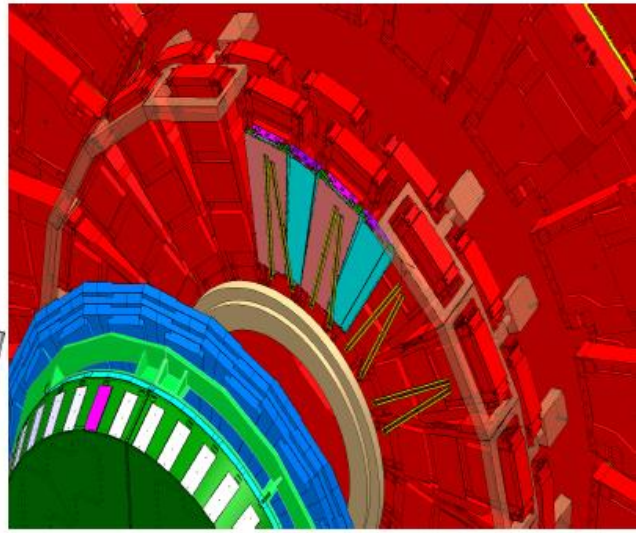
- **Simulation and Physics Studies for Phase 2**

Towards Final GE1/1 Design

LAYOUT

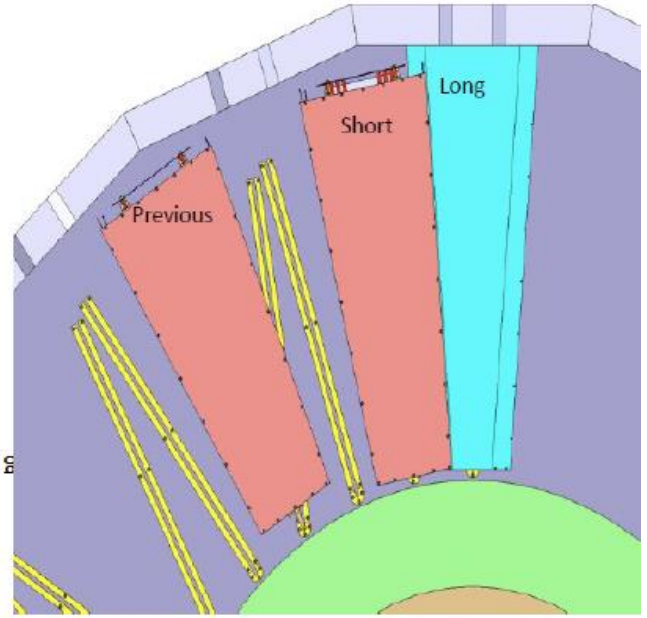
- Two 10° triple-GEM chambers to form a "super chamber"
- 144 total chambers (36 super chambers in one station per endcap)
- Each chamber is segmented into different columns and η region





Final geometry to be finalized:

- Short super chambers extend to 1.6 < |η| < 2.2 (due to the steel brackets):
  - 3 columns and 8 η-partitions with 384 strips per η-partition
- Long super chambers extend to 1.5 < |η| < 2.2:
  - 3 columns and 8-10 η-partitions (under studies) with 384 strips per η-partition

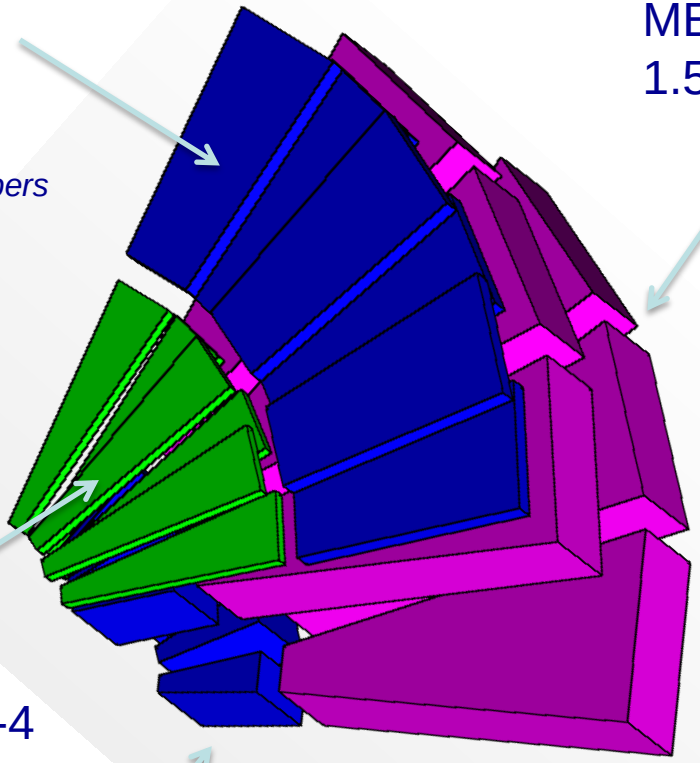


Towards ME0 Design

GE0/2 GEMs
1.5 < |η| < 2

four layers,
i.e. two super-chambers

ME1/1 CSC
1.5 < |η| < 2.4

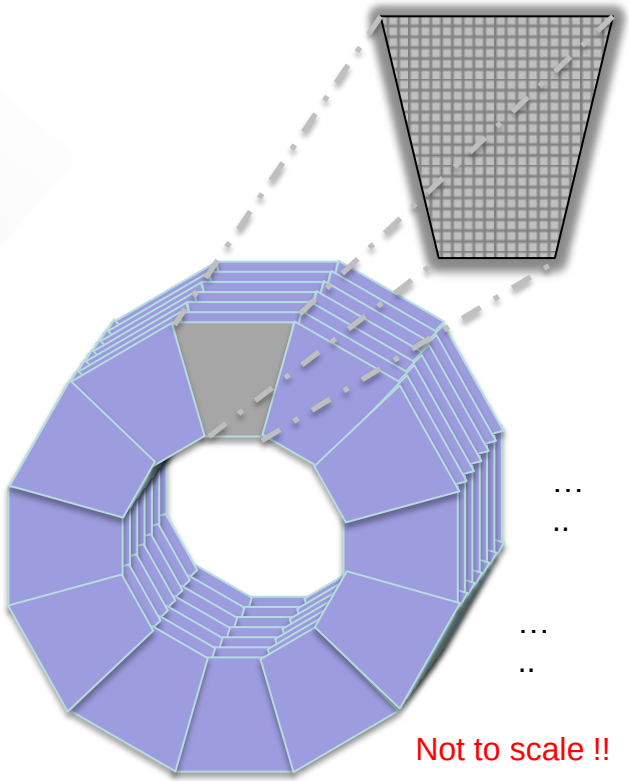


GE0/1 GEMs
2.1 < |η| < 3.8-4

six layers, 180mm total

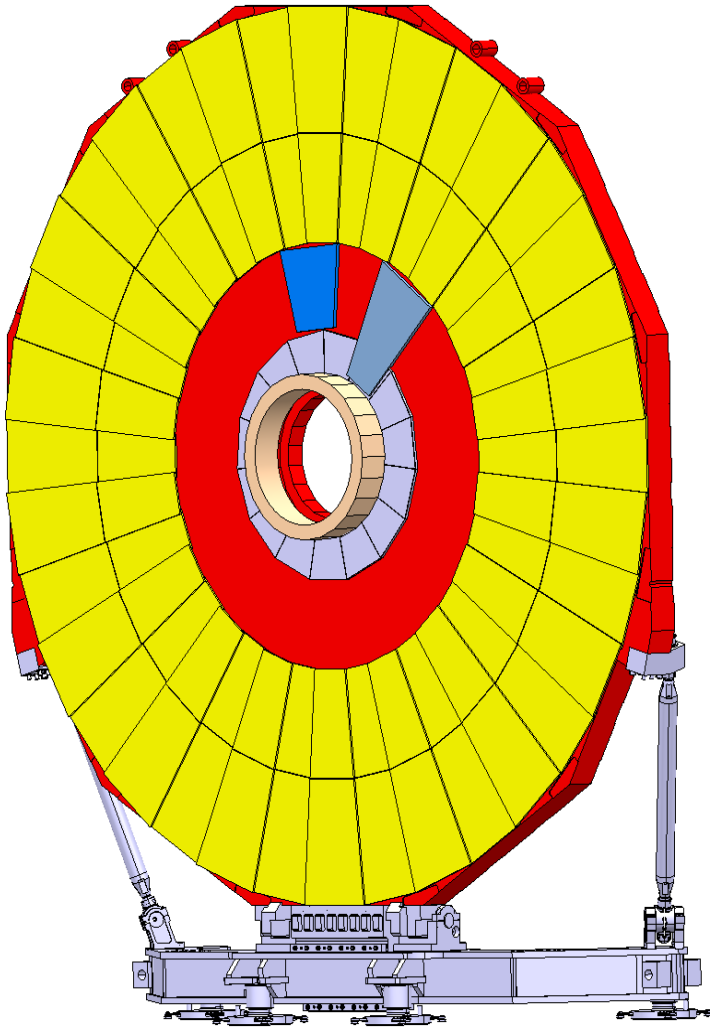
ME1/0 GEMs
Can we extend to 2.4 < η < 3.8-4 ?
(Not really possible due to interference with sliding joint..)

GE0/1 station:
- **18 sectors**
- **6 detector layers**
- **18 sectors x 6 layers x 2 endcaps = 216 chambers in total**
- **Chamber dimensions: ~ 480mm x 1163 mm**
- **~1.7M readout channels**

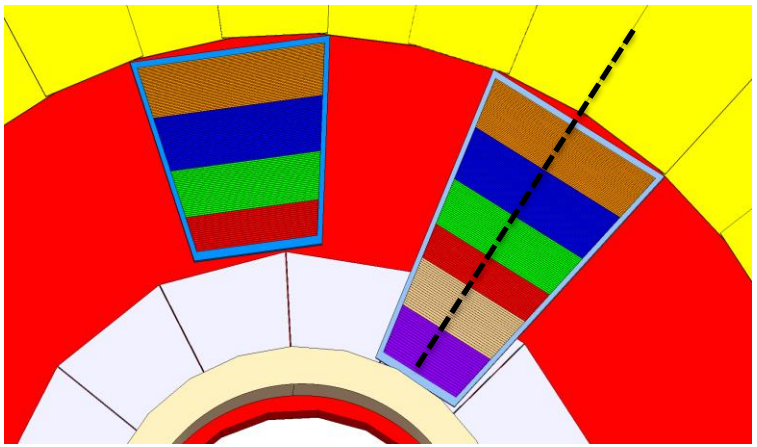


Not to scale !!

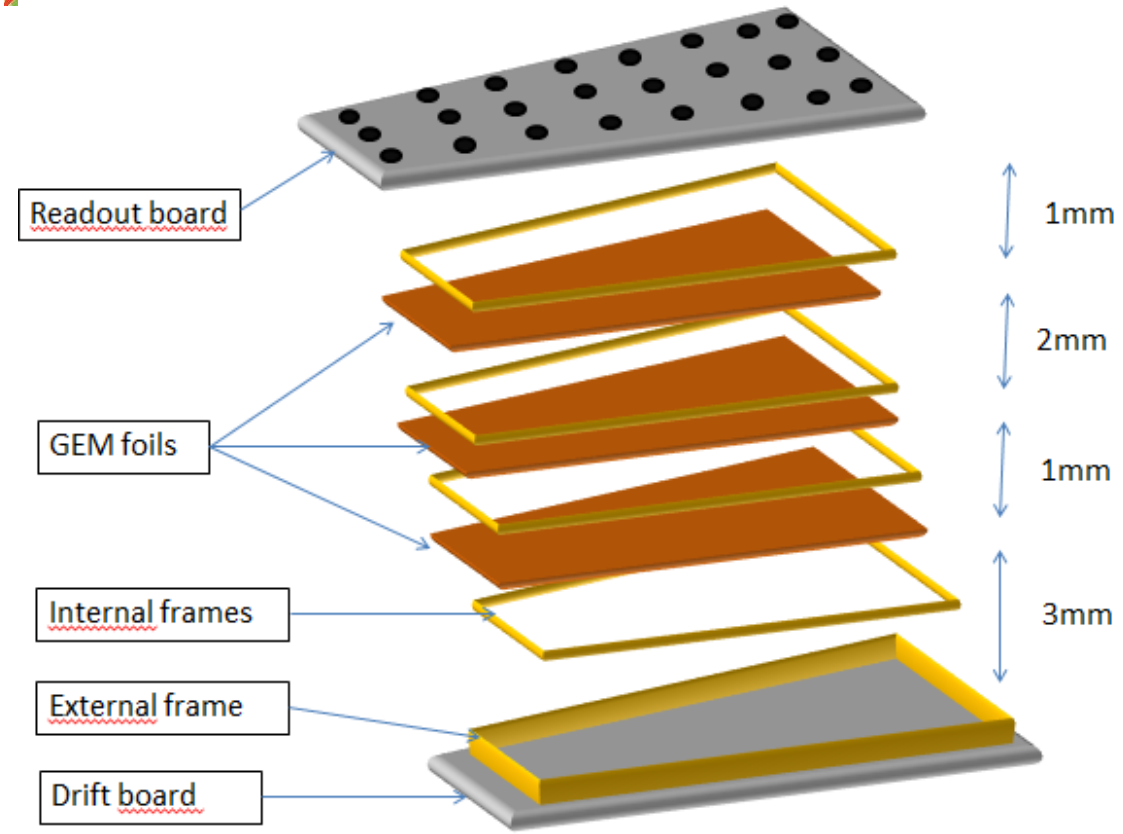
Towards GE2/1 Design

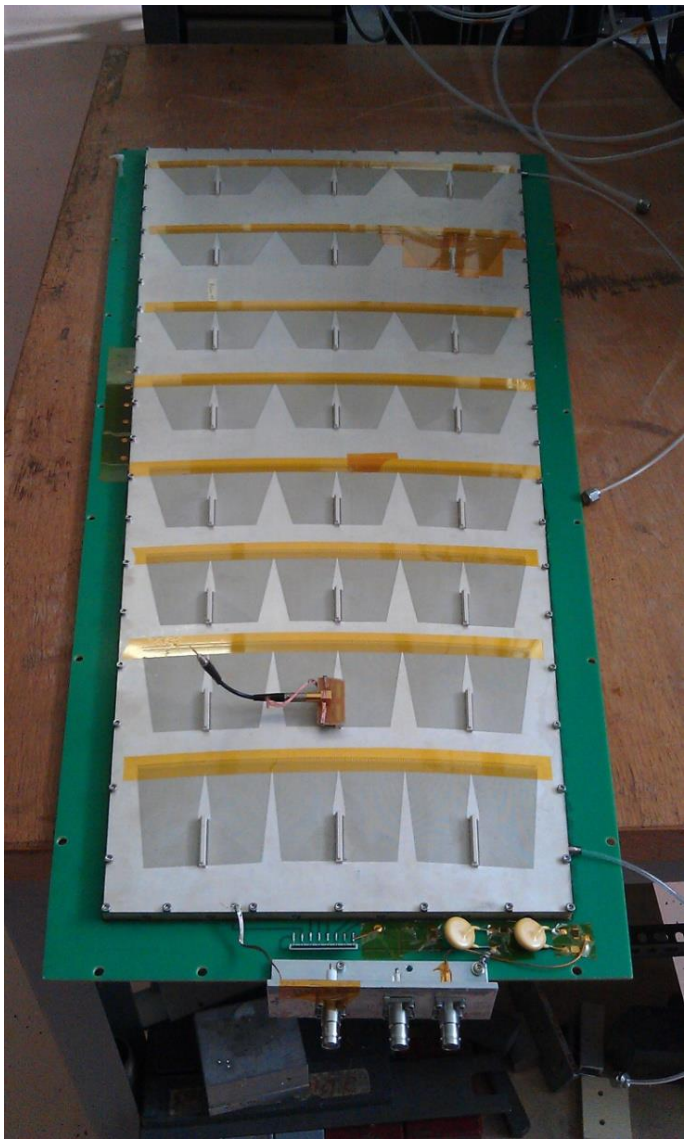


- 20deg super chambers
- 2 stations: 8 rolls up to |η|=2.12 & 12 rolls up to |η|=2.4
- Requires R&D on chambers which will be 1.5m long and >1m wide at wide end
- Readout board similar to GE1/1



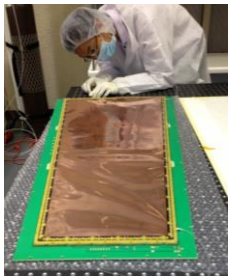
Present GE1/1 Detectors





- **Single-mask & self-stretching techniques**
- **Gap sizes: 3/1/2/1 mm**
- **Sectors : 3 columns x (8-10) η partitions**
- **Strip pitch: 0.6-1.2mm**
- **1D readout of up to 3840 channels**
- **35 HV sectors**

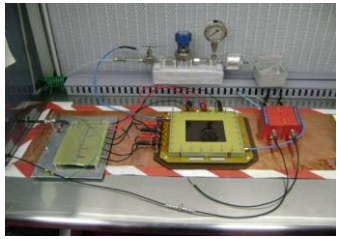
Production Site Candidates



USA
Florida
Tech

CERN: TIF (186)

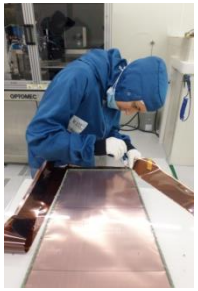
India
BARC



Italy
Bari
LNF

Production,
Final QC,
SC assembly

Belgium
Gent

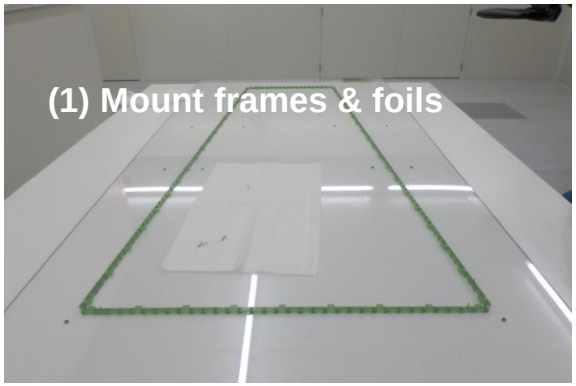


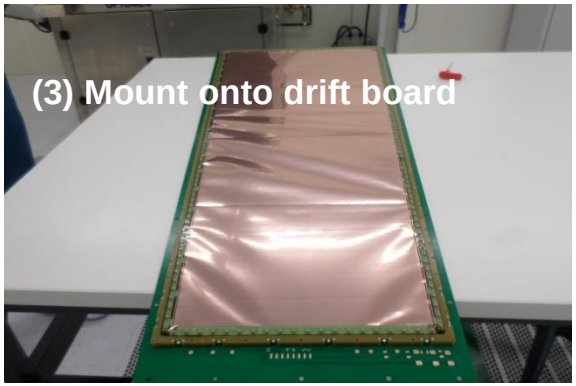
Installation
in CMS

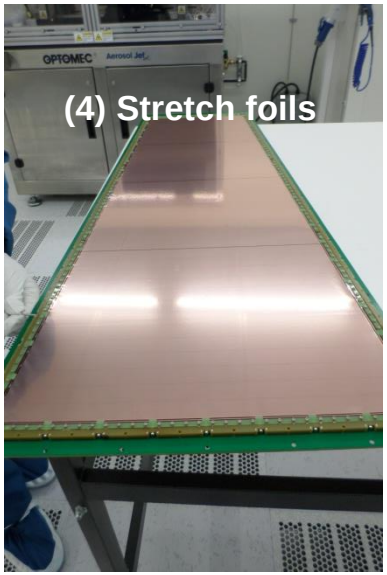
Project Issues: Develop common production and certification procedures and production database for all sites

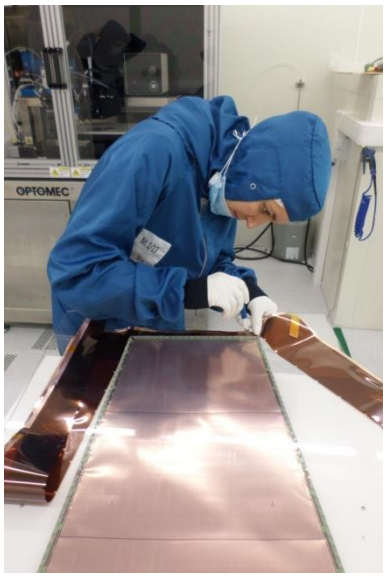
GE1/1 Assembly Procedure

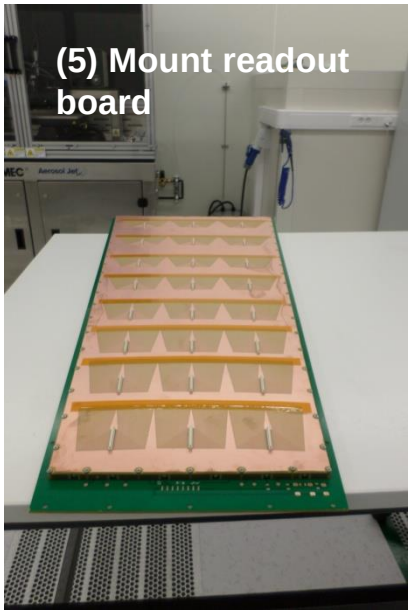
As an example, GE1/1 assembly @ Ghent University in Dec. 2013









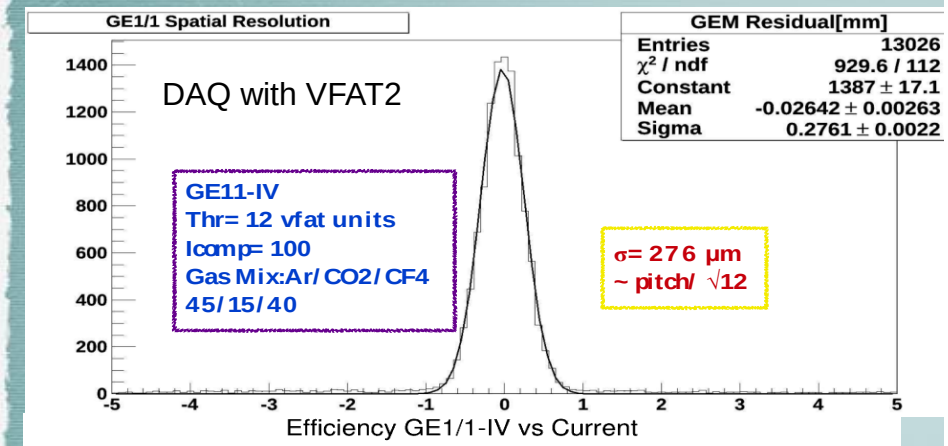


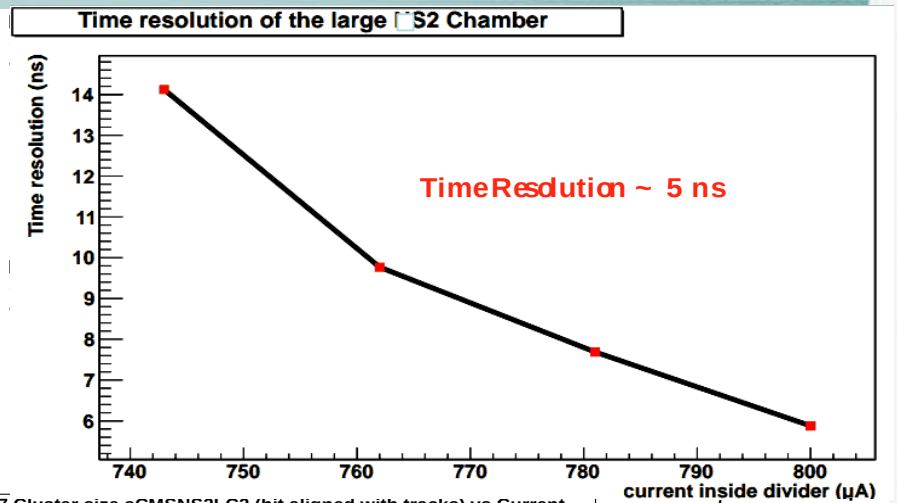
2012 GE1/1 Beam Test @ CERN

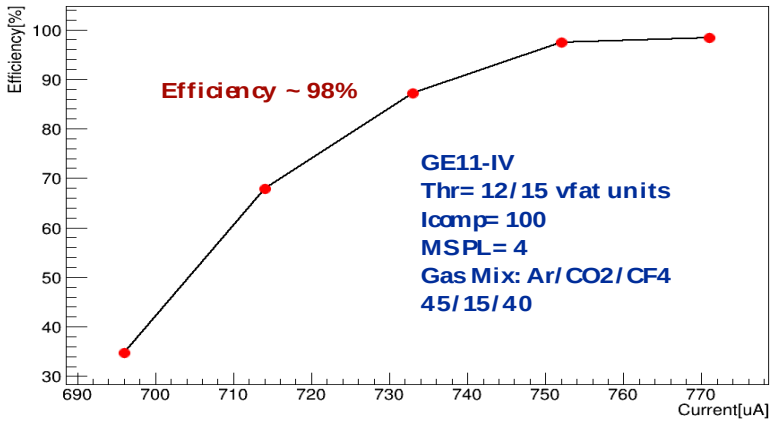
Preliminary Results for pions

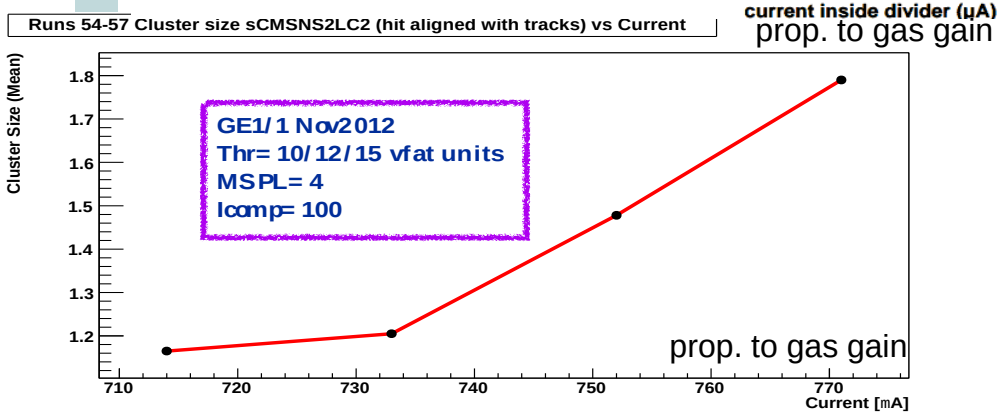
Test Beam Results

P. Barria, GEM workshop VII, Oct 2013

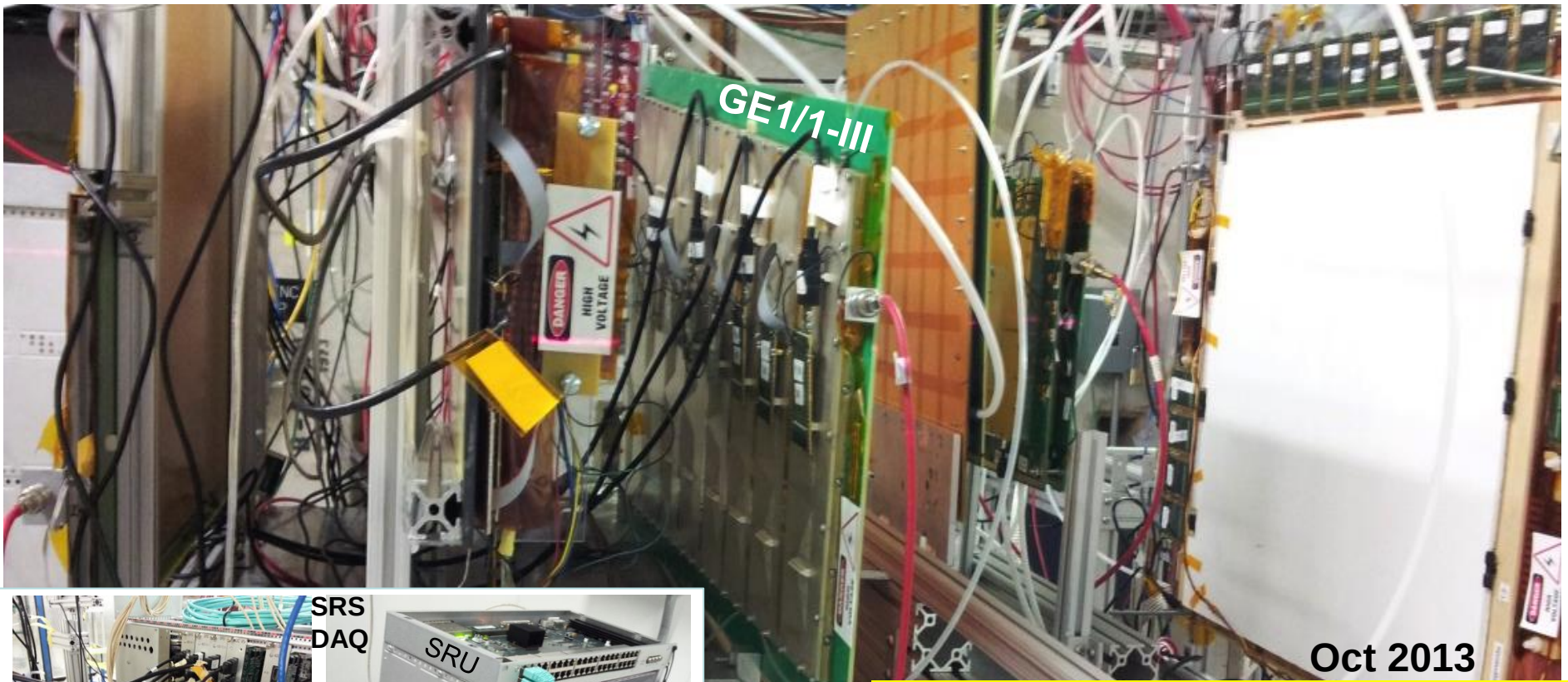


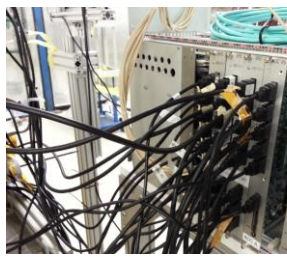


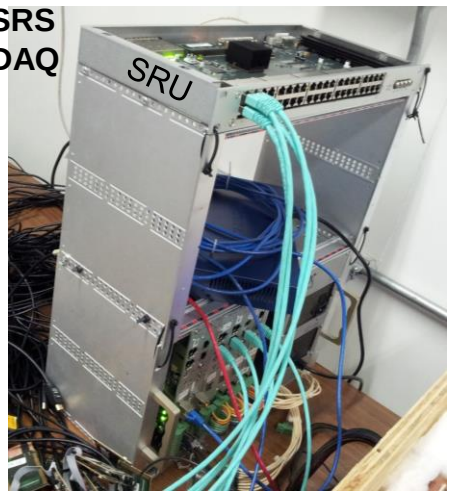




2013 GE1/1 Beam Test @ Fermilab







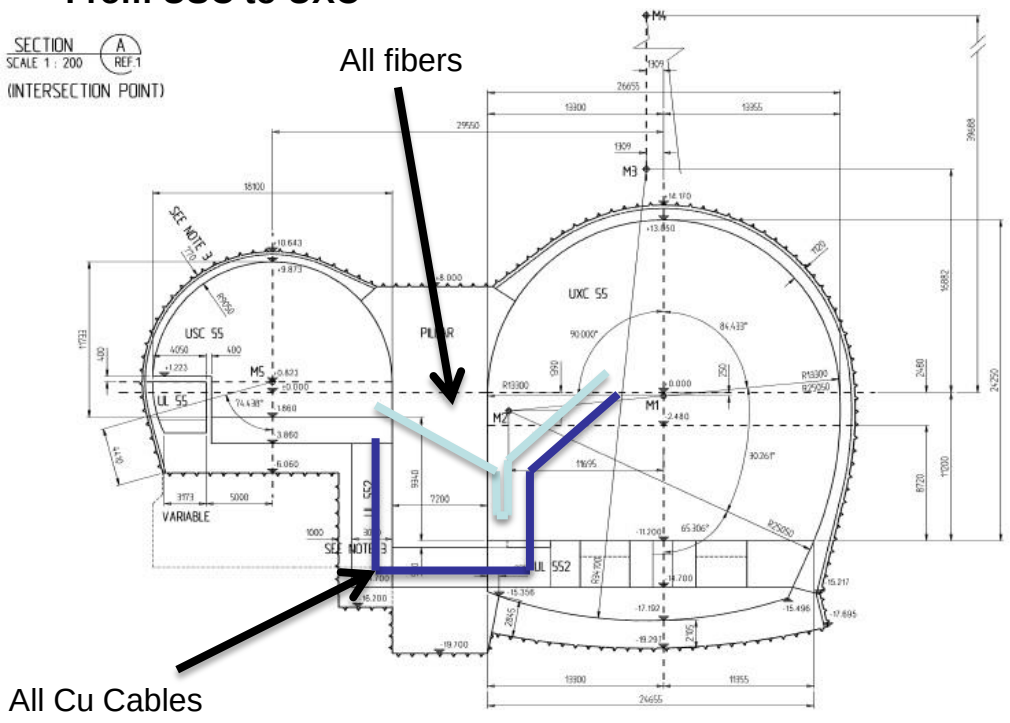
Oct 2013

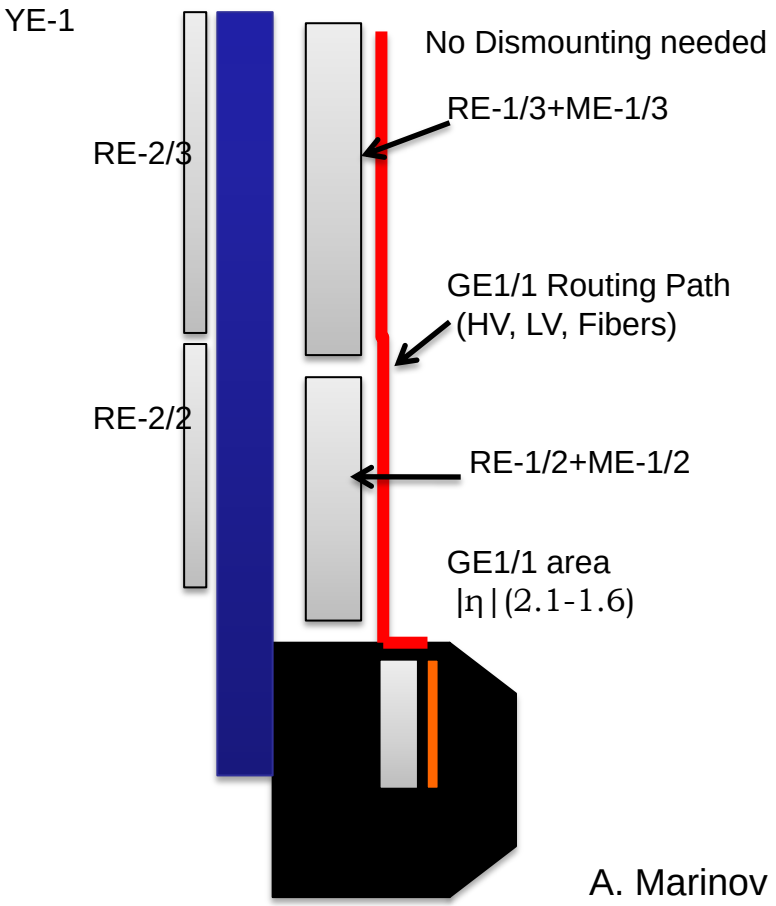
- Beam structure: 4s spills, 1min rep. time
- 120 GeV protons or 20-32 GeV pions & kaons
- Trigger: coincidence of 3 scintillators upstream and downstream of our setup; rate: few kHz
- > 60 APV's read out by Scalable Readout Sys.
- Acquiring data from FECs with an SRU
- SRS DAQ rate is ~150 Hz
- Using 6 or 9 25ns time slices for digitization

Integration and Services @ CMS P5

Ongoing work during LHC LS1 on GE1/1 integration and services at CMS P5:
GE1/1 powering scheme; fibers; space in UXC YE-1 Near Side Towers for LV Power and Electronics; space in USC Racks for HV and Electronics; cable routing; GE1/1 gas system; cooling

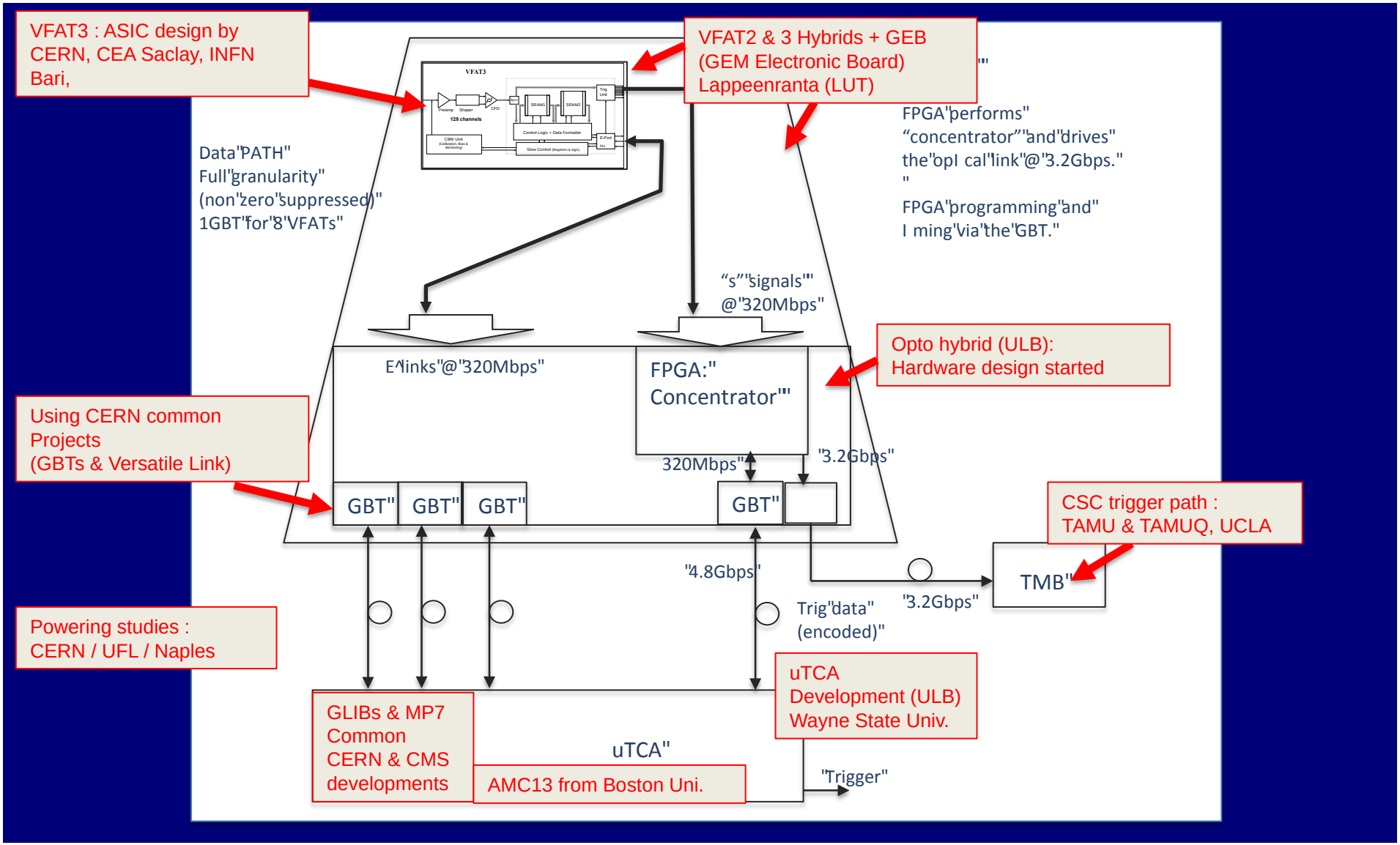
From USC to UXC





A. Marinov

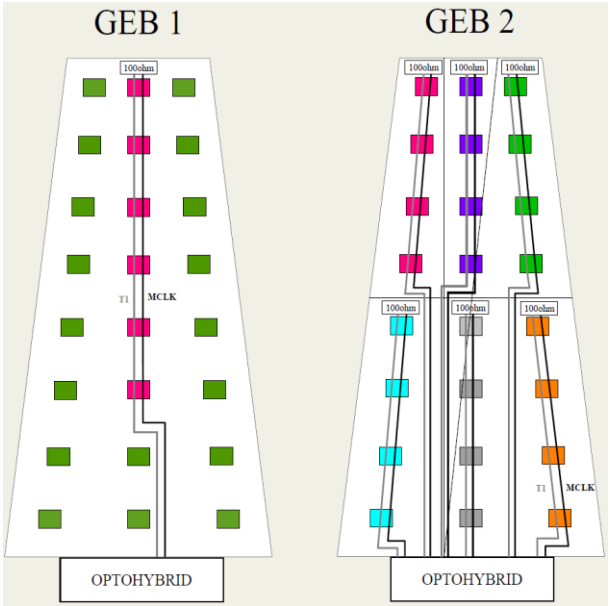
Frontend Electronics & DAQ

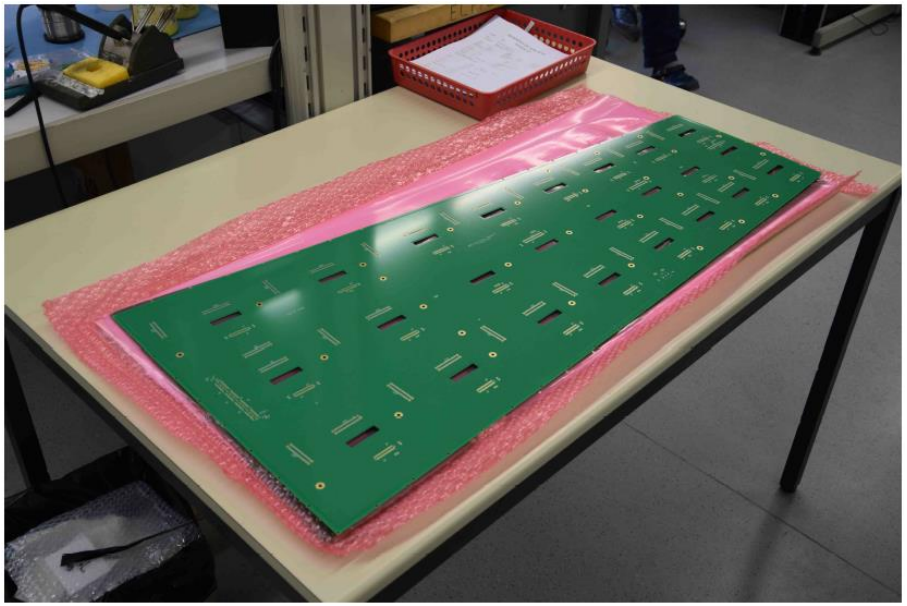


Frontend Electronics & DAQ

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 : S-curve measurements – requires firmware and software development	CMS Hybrid done. GEBv1 design done. OHv1 mostly done. GEBv1 production to do, (5 units) Firmware and software to do.
Prototype 2 : VFAT2 VFAT2 CMS Hybrid GEB v2 OptoHybrid V2 Readout & Programming optically from/to uTCA Applications of Prototype 2 : Cosmic Stand – requires firmware and software development, possible Slice Test	GEB working document written. GEB design to do. OH design to do. Optical readout under development. Trigger emulation to CSC Firmware and software to do.
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 : Final system	VFAT3 design going well. VFAT3 design manual and spec doc well advanced.

Frontend Electronics & DAQ





- First GEB v1 arrived at CERN in Jan. 2014; under test now; GEB v2 design will be submitted as soon as initial GEB v1 tests done

- Standalone tests of Opto-hybrid v1 ongoing since Oct. 2013; FPGA firmware being developped for VFAT2 control; combined tests with GEB v1 in Feb. 2014

Technical Design Report

Main editors: M. Abbrescia, A. Safonov, A. Sharma, M. Tytgat

- Ch. 1 – Motivation and Introduction (J. Hauser, K. Hoepfner)
- Ch. 2 – GEM Detectors (L. Benussi, M. Hohlmann)
- Ch. 3 – Electronics (P. Aspell, G. De Lentdecker)
- Ch. 4 – DAQ and Trigger (G. De Lentdecker, J. Hauser, A. Marinov, A. Safonov)
- Ch. 5 – System Integration and Schedule (O. Bouhali, P. Karchin)
- Ch. 6 – System Performance (P. Giacomelli, A. Colaleo, K. Hoepfner, A. Safonov)
- Ch. 7 – Integration, Installation and Commissioning in CMS (A. Lanaro, A. Marinov, M. Tytgat)
- Ch. 8 – Controls and Monitoring (A. Cimmino, M. Maggi)
- Ch. 9 – Project Organization and Costs (GEM-MB)
- Ch. 10 – Schedule (A. Sharma)

English Editors: M. Hohlmann, P. Karchin

Summary

- **Scope of CMS GEM Project extended to include GE1/1, GE2/1 & ME0 stations**
- **Good progress on detector simulation and performance studies, physics studies, FE electronics and DAQ development, CMS integration studies …**
- **During LHC 2016 Year-End Technical Stop two Triple-GEM super chambers will be installed in YE1/1**
- **Awaiting further green light from CMS for full GE1/1 installation during LHC LS2**
- **Preparing CMS GE1/1 Technical Design Report & CMS Muon Phase-2 Technical Proposal, to be submitted late 2014**

See also CMS GEM talks in WG1 & WG2 sessions by A. Marinov & S. Salva

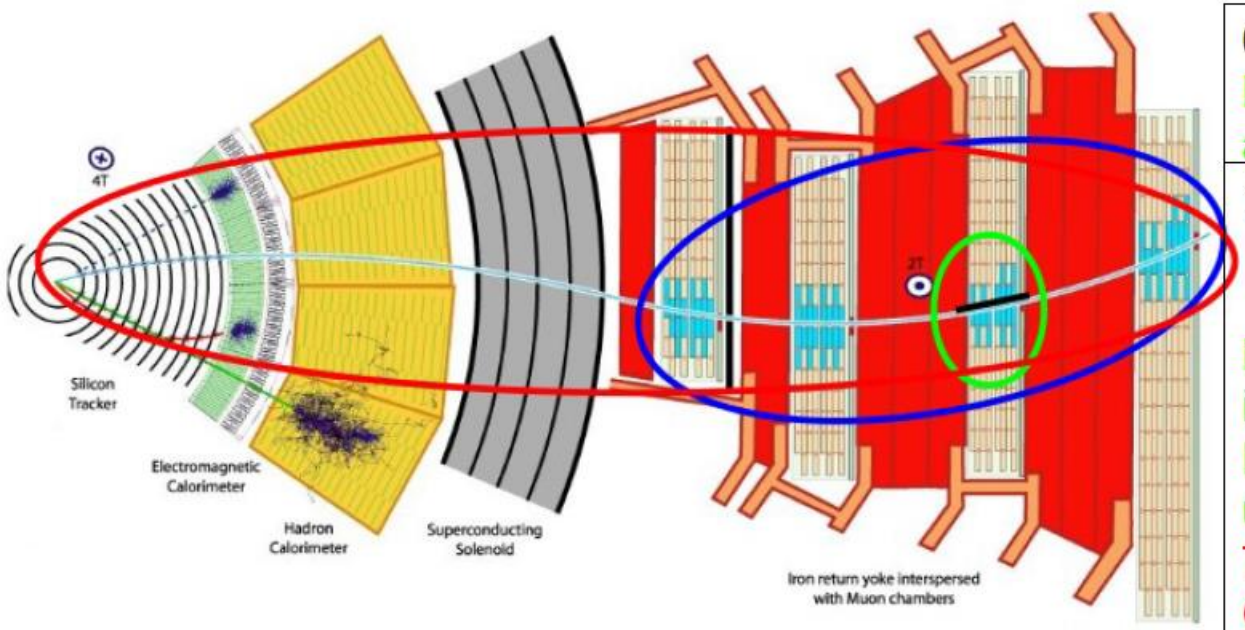
Backup Slides

Precision Timing in YE-3,4

- New physics with B-mesons ($B_{s/d} \rightarrow \mu\mu$)
  - Trigger: two soft forward muons (on the same side)
    - High precision timing (100 ps range?) can be used to confirm that both muons come from the same vertex
      - Need to measure t_1-t_2, many systematics effect can potentially cancel
  - Need simulation to evaluate if it can help or not

- Reduce neutron hits by utilizing timing windows
  - Lower background can potentially benefit the single muon trigger (more reliable points means better momentum measurement and thus lower trigger rate)
  - It appears that windows can't be less than a few nsec
    - That gives the required level of precision for the detectors

Status of Muon Reco with GEMs

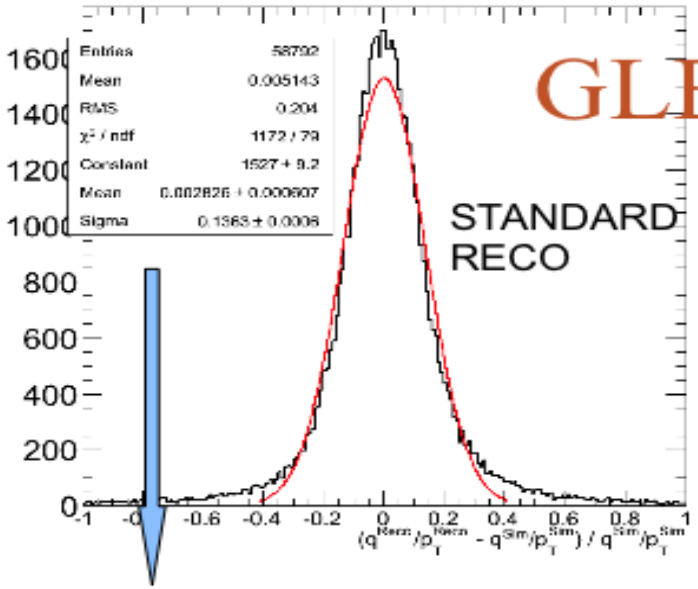


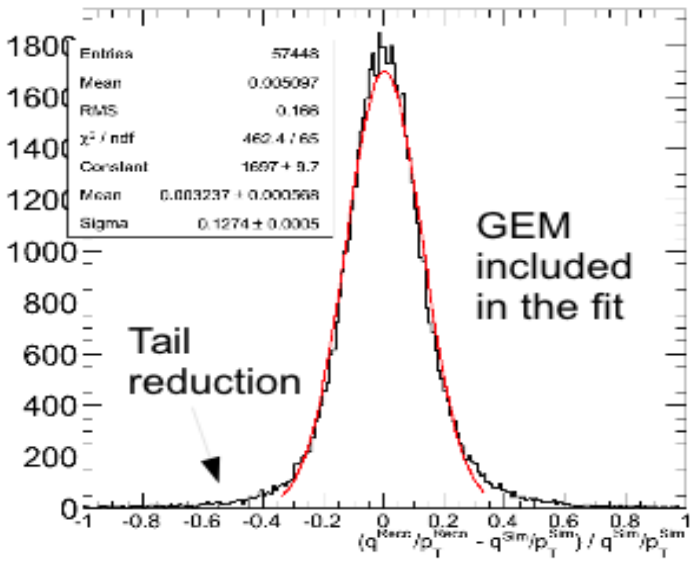
0. Digitization step:
DONE with realistic cluster and background description

1. Local reconstruction:
Reconstruction of **hits** and **track segments** inside a **chamber**
DONE: GEM RecHit implemented for Digital R/O
DONE: Correct RecHit uncertainty implemented
TO BE DONE: Seeding with GEMs

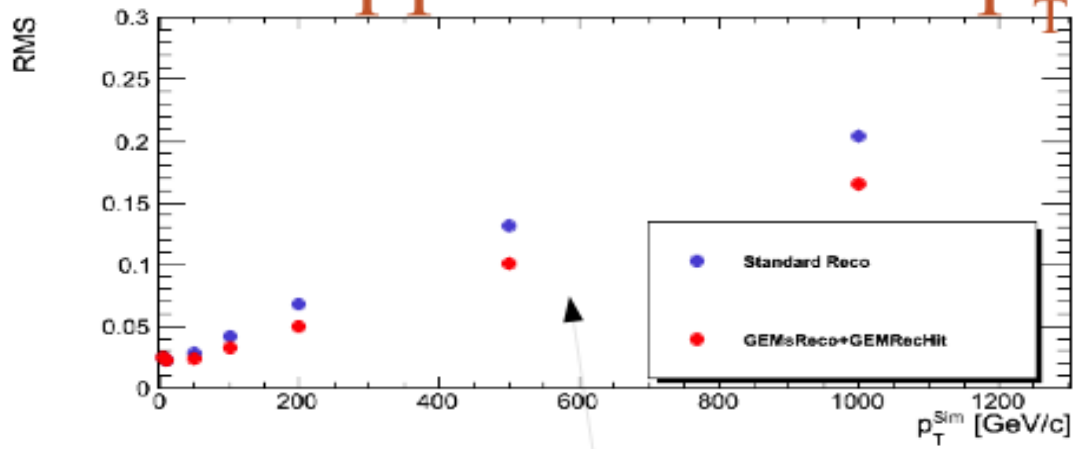
2. Stand-alone Reconstruction (or Level-2 in HLT) Reconstruction of the **track** inside the **muon system**	DONE: GEM RecHits included in the track fittting
3. Global Reconstruction (or Level-3 in HLT) Reconstruction of the **track** combining the information from **tracker** and **muon system**	DONE: GEMs included in the STA muon, GLB muon comes consequently
Cosmin muon, Tracker and TeV muon	TO BE DONE
Muon ID with GEMs	TO BE DONE

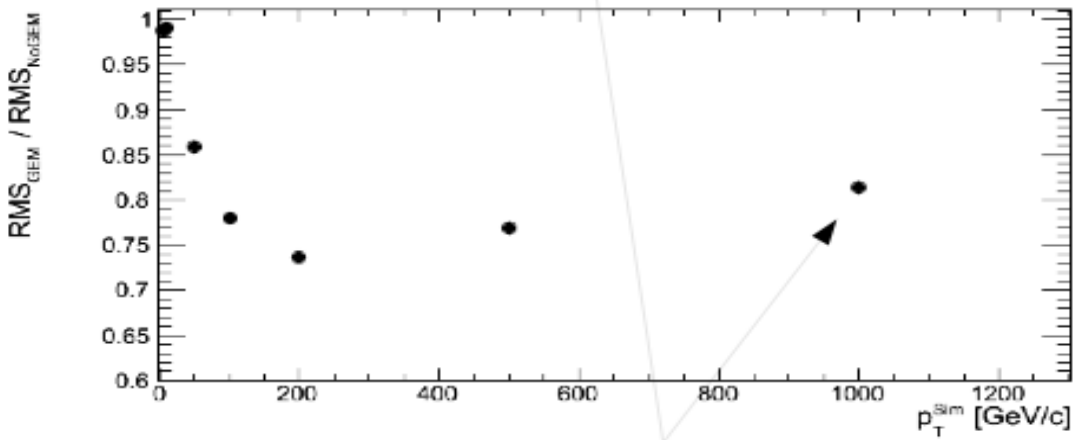
Improved P_T Resolution in Tails





GLB muon: q/p res. vs. sim p_T



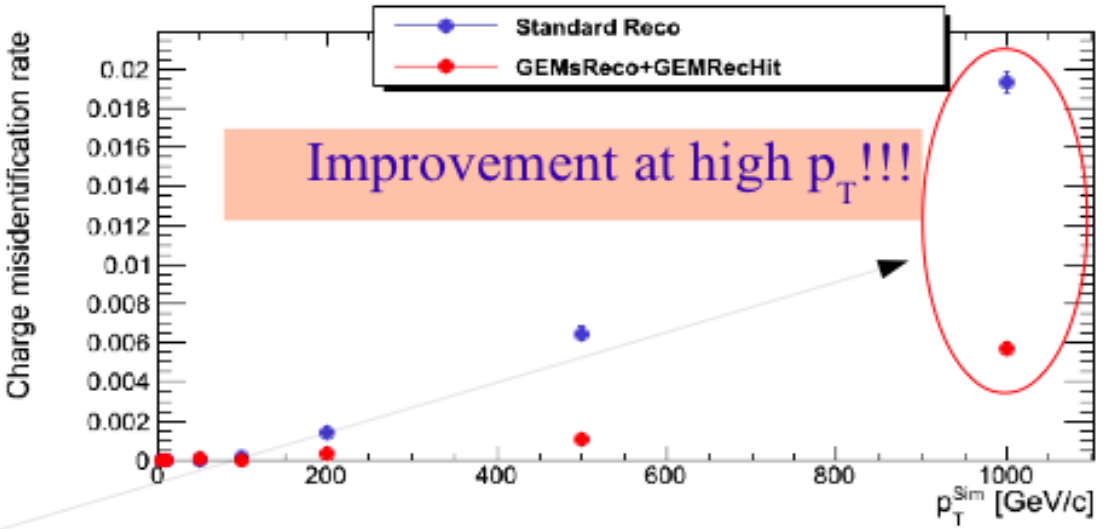


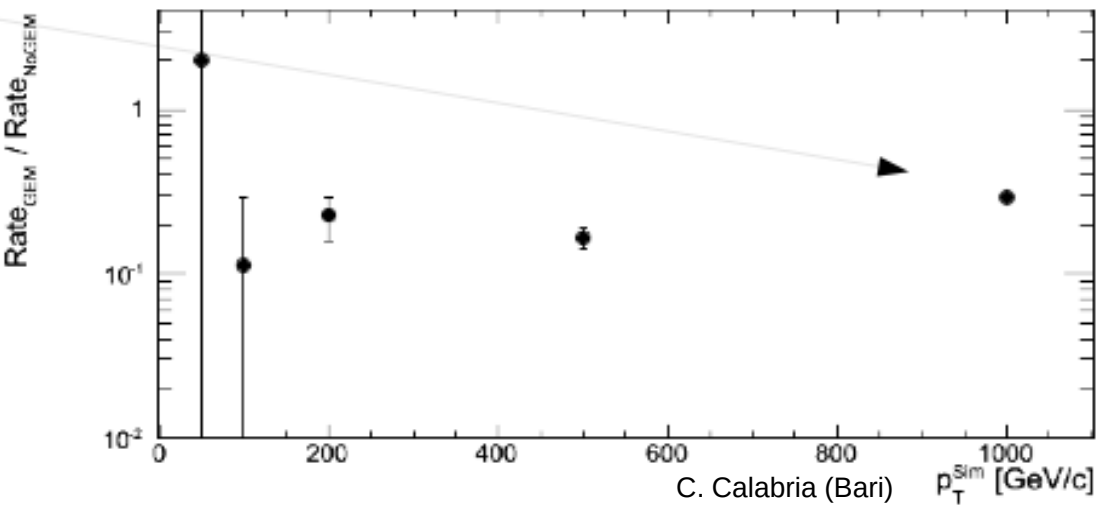
In the case of GLB muon reco, the RMS values are lower than sigma values, with a strong improvement that is visible also at low p_T

Global Muon Fit: Reduced Charge Misidentification

GLB muon: charge mis-ID probability

- Numerator: number of reco muons (matched with gen muon) in the GEM eta region with wrong charge assigment, i.e. (gen charge – reco charge) ≠ 0
- Denominator: total number of reco muons (matched with gen muon) in the GEM eta region
- Comparison of the charge mis-ID probabilities that can be obtained with the standard reco and when the GEMs are used in the fit





Cesare

C. Calabria (Bari)
GEM Workkshop VII