GEM Project Status

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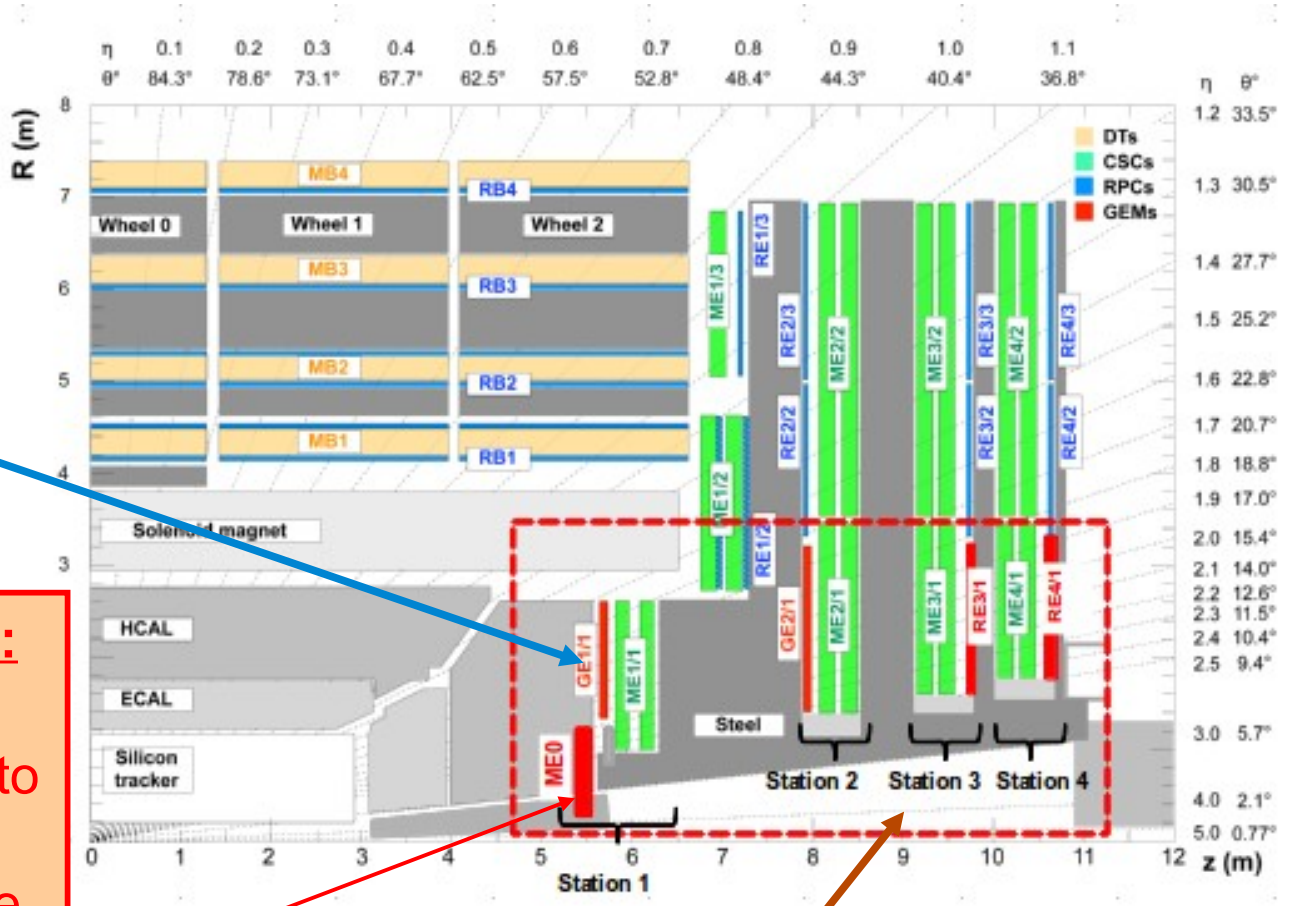
Meeting CMS-GEM Italia Bari, 22-23 Gennaio 2014

Muon Upgrade Scenarios

Post LS2 2019 scenario:

– **GE1/1** GEM technology Demonstrator in YETS2016 approved

Plan for installation in



Post LS3 2023 scenario:

– **ME0** to ensure efficient trigger coverage up to $|\eta| = 2.4$ (under studies if it is possible to go up to $|\eta| = 3.5$-4)

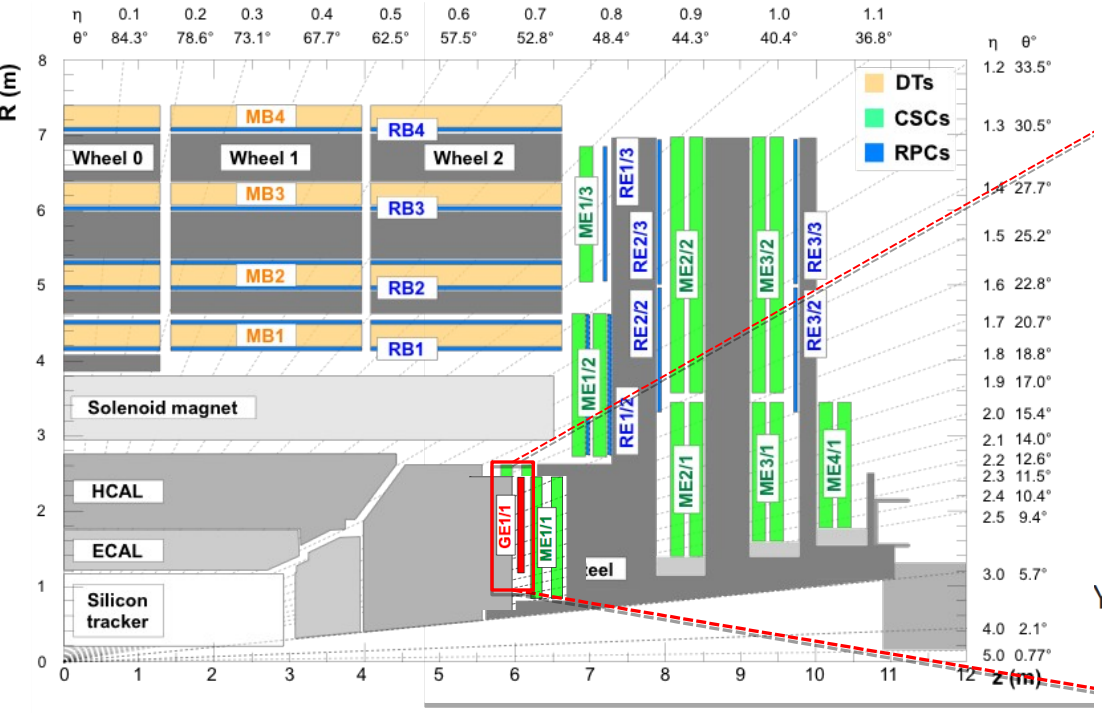
– **Station GE2/1:** GEM technology

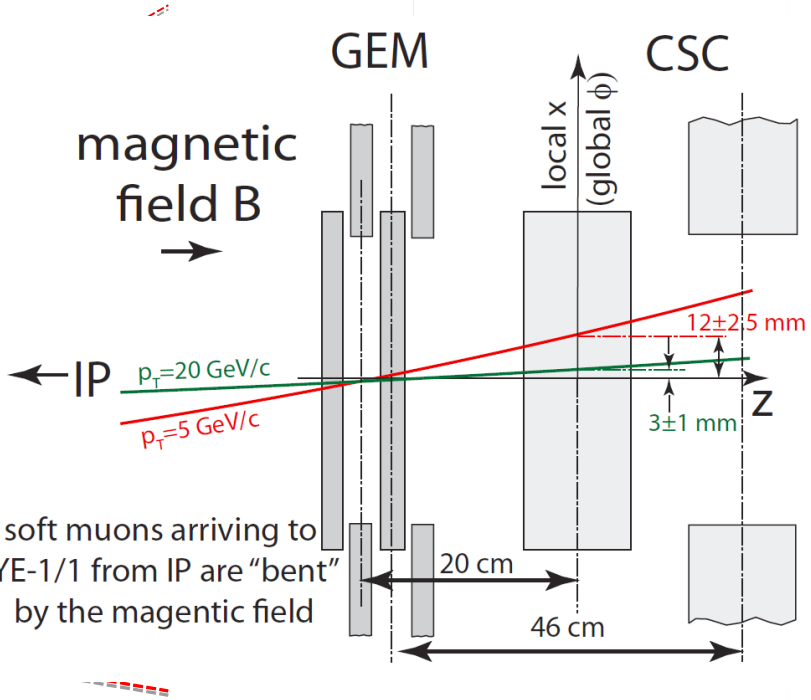
Post LS3 2023 scenario:

– **Station RE3-4:**

Technologies: advanced-RPC, GEMs

GE1/1 project





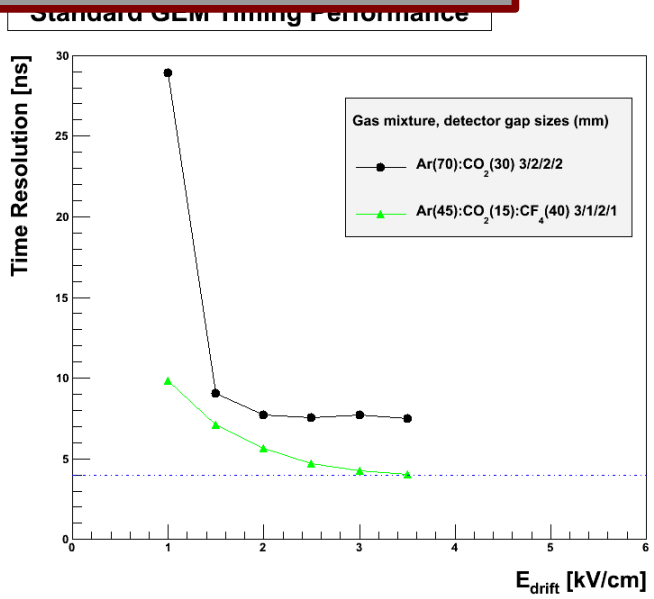
Proposal: Install two layers (super chamber) of triple-GEM detectors in 1.5<|η|<2.2 during LS2

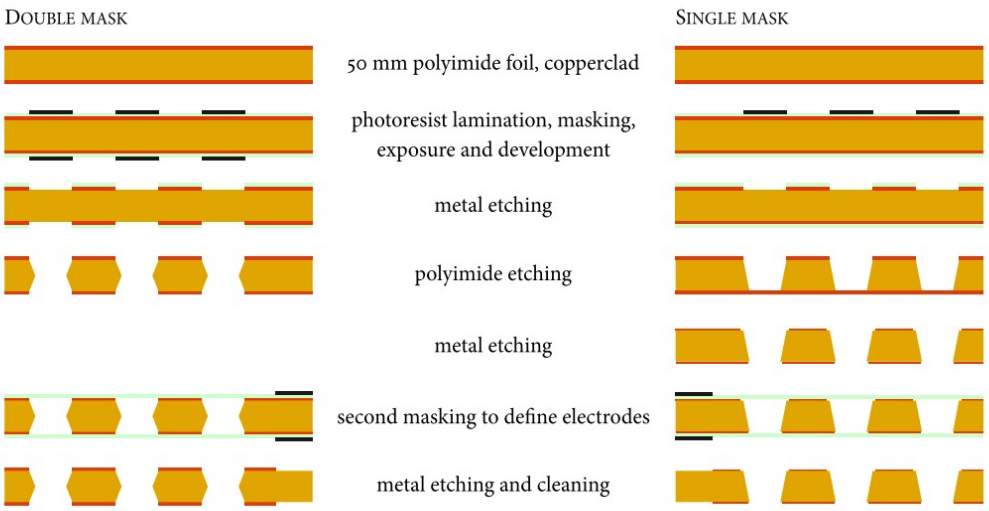
- Improve L1 and HLT muon **momentum resolution;**
- ensure **high trigger efficiency** in high PU environment;
- redundancy for **robust tracking and triggering**;
- provide **local independent pattern recognition** and **seeding** of the track momentum fit (double layer).

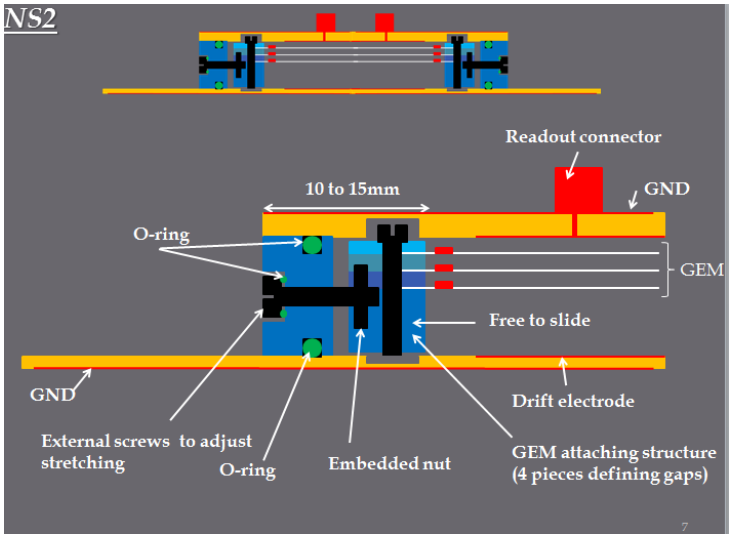
Project achievement

- **Detector efficiencies above 98%**
- **Time resolution of 4ns**
- **Spatial resolution of about 290µm with VFAT2 (digital) and <110µm APV (analog) readout chip**
- **Operation of GEMs in magnetic field**

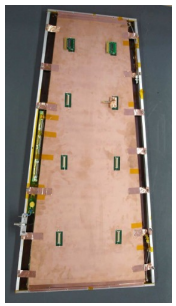
- **Validation of single-mask technology**
- **Production of large area GEM foils**
- **New self-stretching technique for GEM assembly**



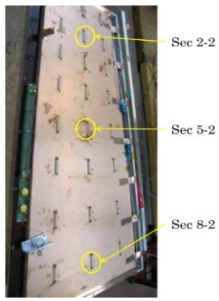




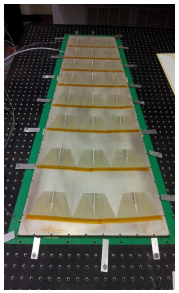
Project development in time



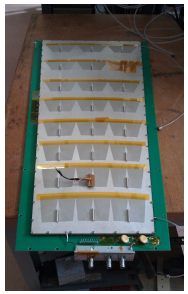
2010



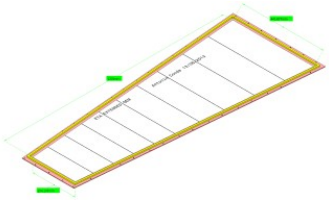
2011



2012



2013



2013/14

Production and QC of slice test detectors; First prototype of VFAT3

2014/15

Slice installation

Mass production of chambers and electronics started

2015/16

Slice & trigger commissioning

2016/17

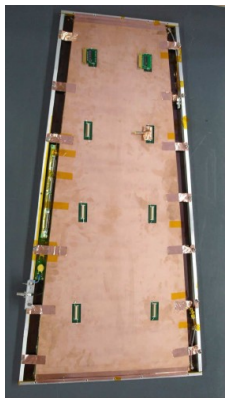
QC of mass produced chambers with final electronics

2017/18

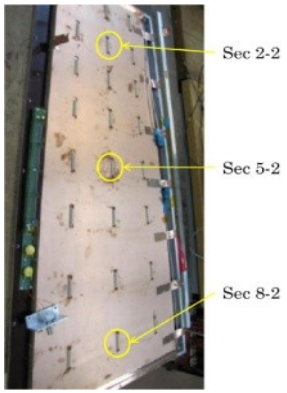
Installation of full GE1/1 with final electronics

2018/19

Chamber design evolution

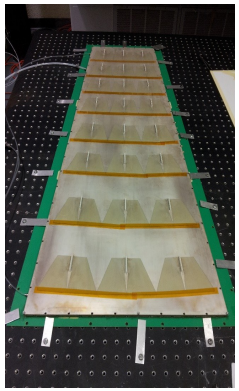


2010



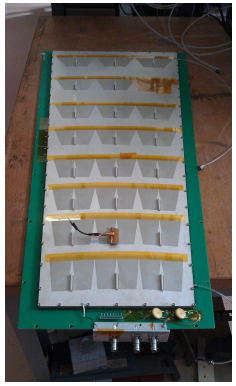
2011

GE1/1-III



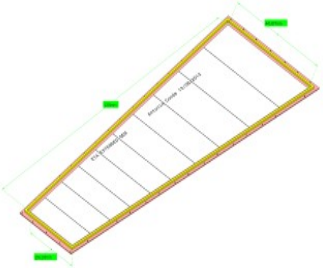
2012

GE1/1-IV



2013

GE1/1-V-long
GE1/1-V-short



2013/14

Generation I

The first 1m-class GEM detector ever built but still with spacer ribs and only 8 sectors total. Ref.: **2010 IEEE and RD51-Note-2010-005**

Generation II

First large detector with 24 readout sectors (3×8) and 3/1/2/1 gaps but still with spacers and all glued. Ref.: **2011 IEEE and RD51-Note-2011-013 .**

Generation III

The first sans-spacer (S2) detector, but with the outer frame still glued to the drift. This was tested extensively in beam test at CERN (2012) and also very recently at FNAL. The first detector ever built outside of CERN is of this design (at Fl. Tech). Ref.: **2012 IEEE N14-137.**

Generation IV

The **current** generation; no more gluing at all. We have built two at CERN and one at Frascati; Bari, Florida Tech, and Gent have received the parts to build one each. An assembled chamber will go to India. Ref.: **MPGD 2013 and 2013 IEEE, COMO2013, SIENA2013**

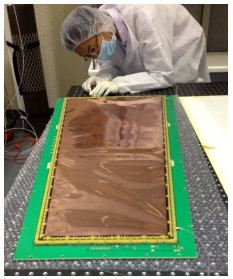
Generation V

The upcoming detector version that we will install for the **slice test.** One long and one short version. Optimized final dimensions for max. acceptance and with final eta segmentation.

Major developments in 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
- 2 GE1/1-IV prototypes fully commissioned @ CERN
- Positve Review from internal committee,
- slice test in YETS 2016 approved → proposal for installation in LS2
- Fermilab beam test of first GE1/1 built outside of CERN
- 6 potential mass production sites being developed
- GIF long-term aging test 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
- Contributions to 6 large conferences and workshops
- GE1/1 TDR on track

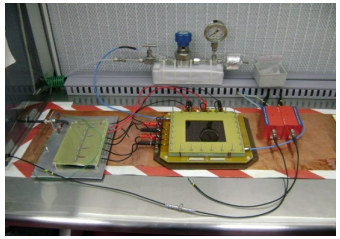
Production sites set-up



USA
Florida
Tech

CERN: TIF (186)

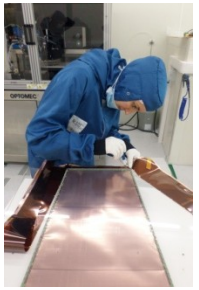
India
BARC



Italy
Bari
LNF

Production,
Final QC,
SC assembly

Belgium
Gent

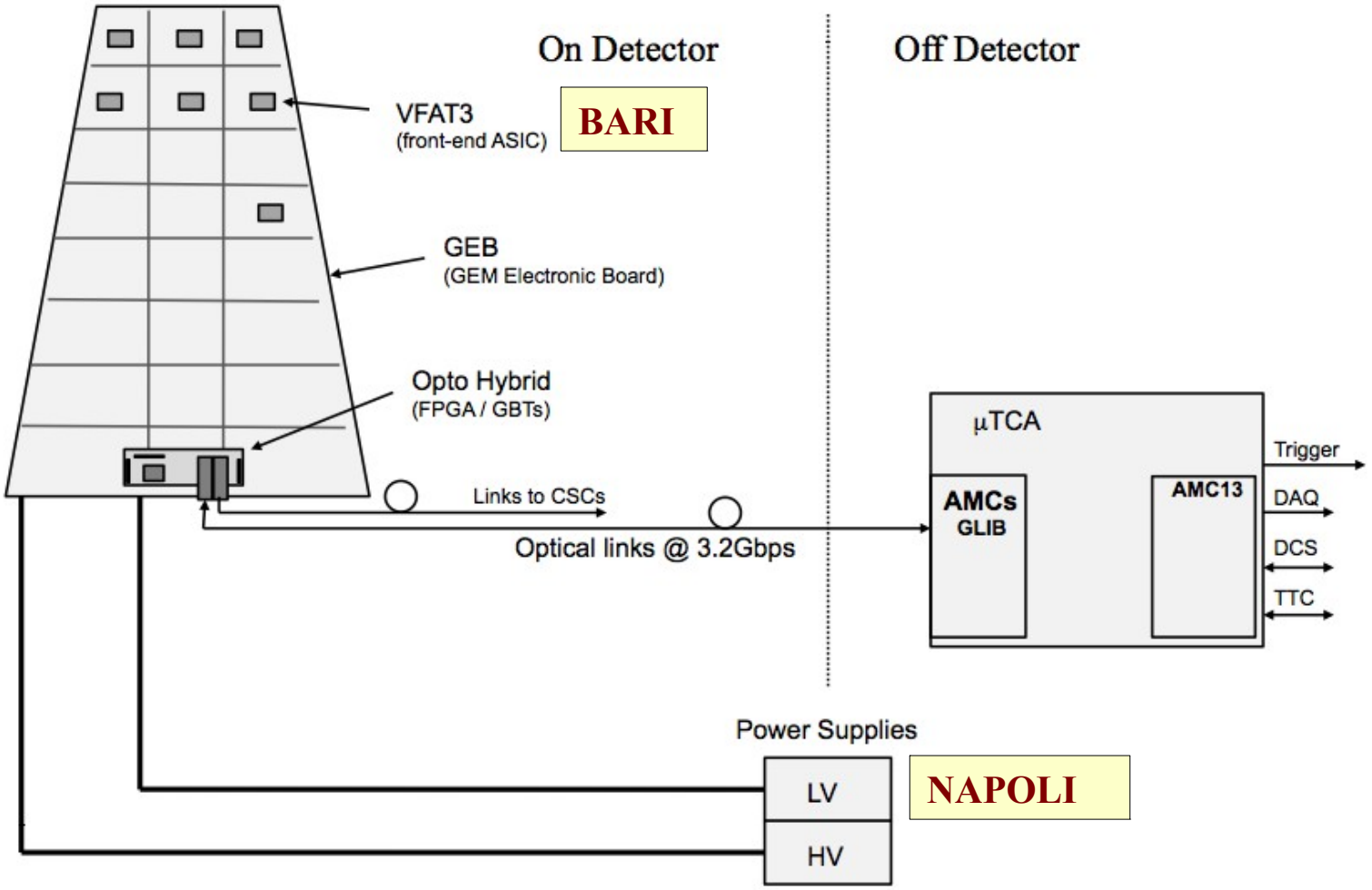


Installation
in CMS

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

Electronics system

Provide Trigger & Tracking informations from all GE1/1 chambers.



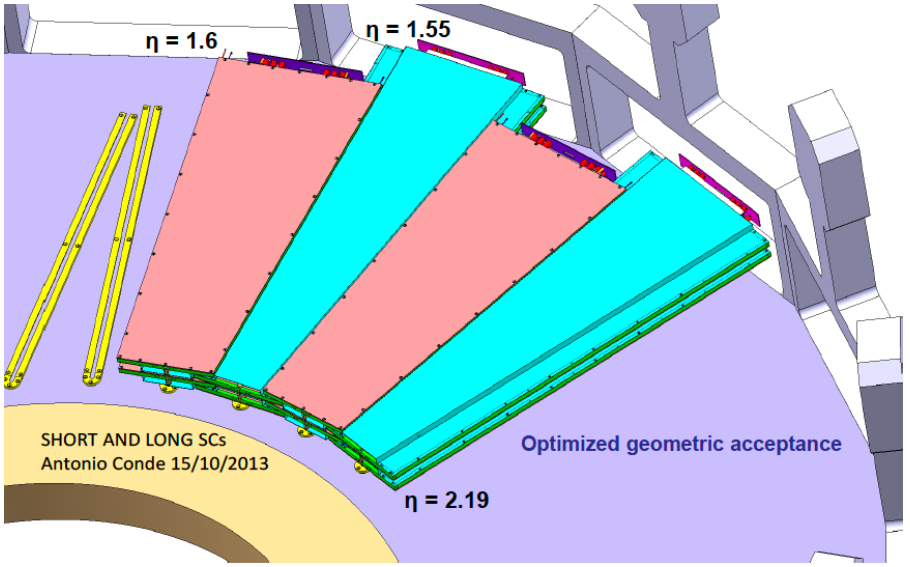
Slice test

Installation of two long SC and one short SC.

- DAQ system will be integrated in CMS DAQ (M. Maggi -Ba);
- combined CSC+GEM trigger (USA-Belgium);
- reconstruction included in official CMSSW;
  - validation done with standard tool (Colaleo, Calabria, Radogna) ;
- background and noise rate included in simulation.

MOTIVATION:

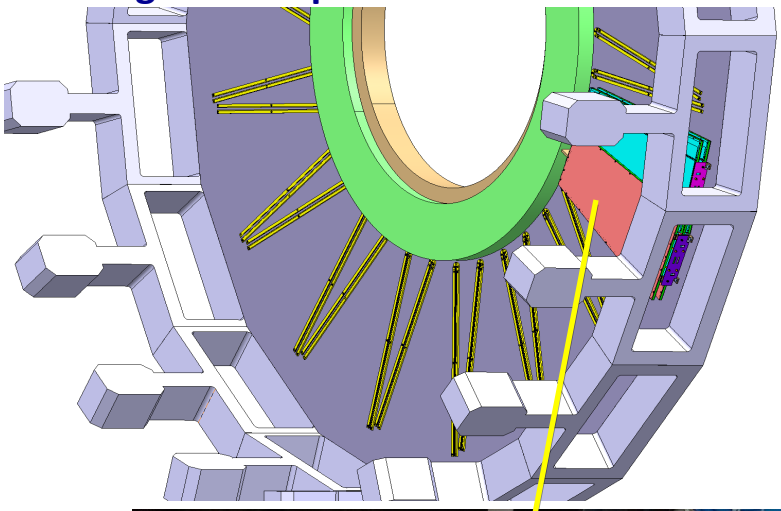
- gain integration experience with the final electronic system;
- reduce the GEM commissioning period;
- trigger commissioning and performance check;
- background measurement.
- opportunity to xcheck with data what expected by simulation.

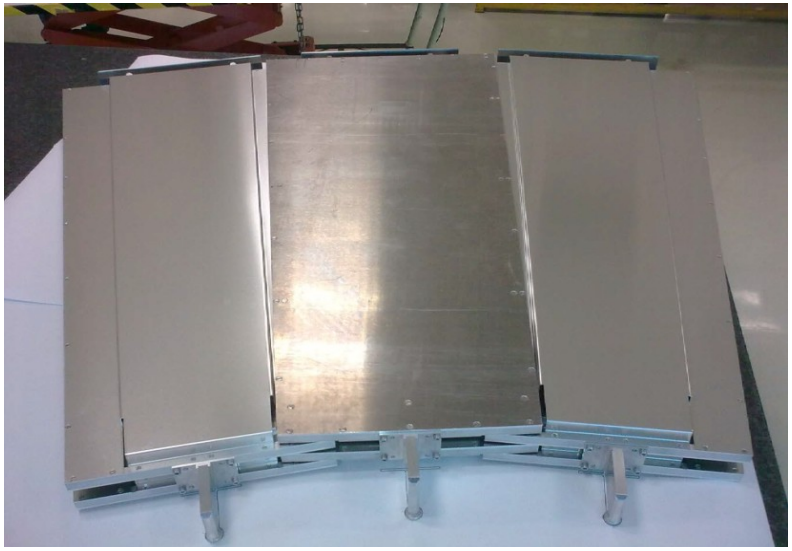


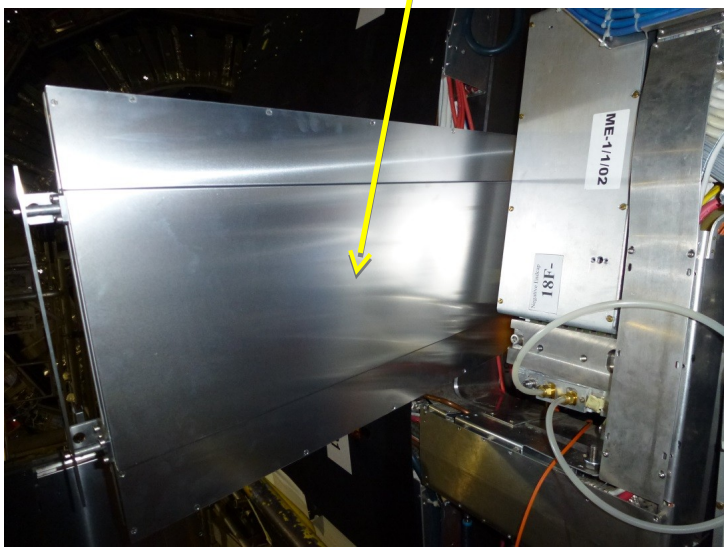
Slice test preparation:integration

3 Super Chamber dummies were produced to optimize design and to perform trial insertion into CMS:

- No detector and no electronics inside;
- All positions connections at the right place;
- Weight and dimensions as real Super Chamber.







Installation trial for Long and Short Super Chambers to be done by 2014.

Slice test preparation: FE-electronics

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

Hardware ~ Nov. 2013
We are here

Prototype 2 : (sub versions for extended eta options)
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
Could also be used for the Slice Test

Hardware ~ March 2014
TDR preparation

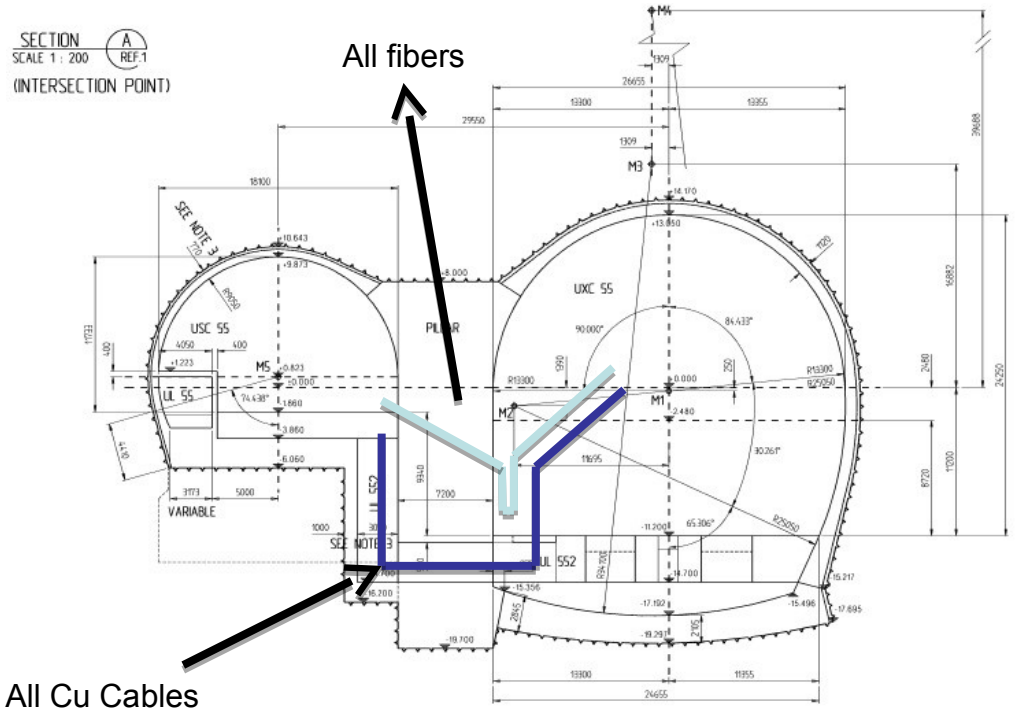
Prototype 3 :
VFAT3 (or VFAT3 emulator to start)
VFAT3 Hybrid Vx....
GEB v3
OptoHybrid V3
Readout & Programming optically via GBT from/to uTCA
Applications of Prototype 3 : Final system

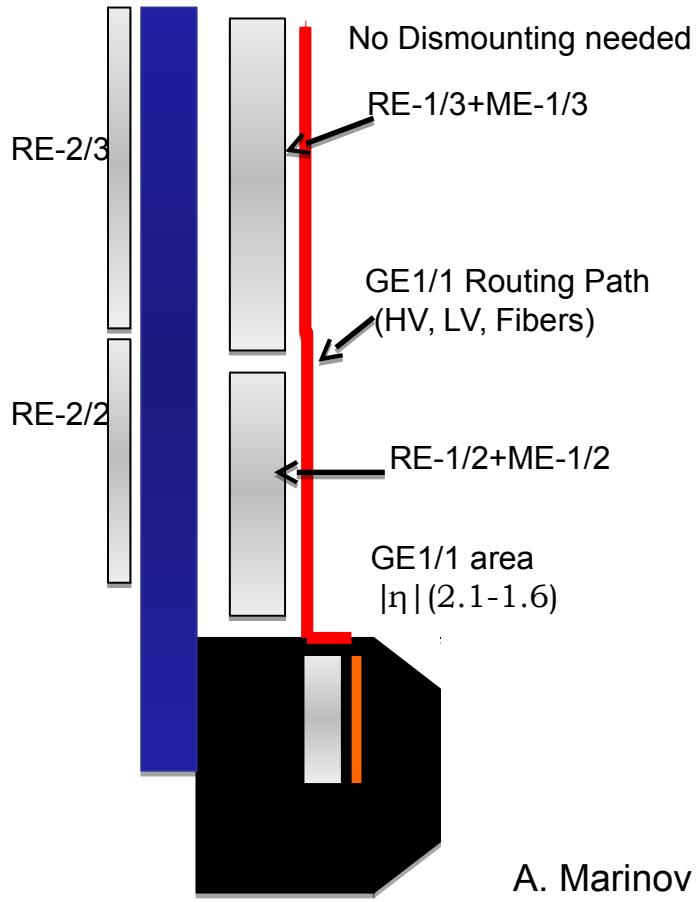
Hardware ~ 2015

Services

Ongoing work on GE1/1 integration and services at 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





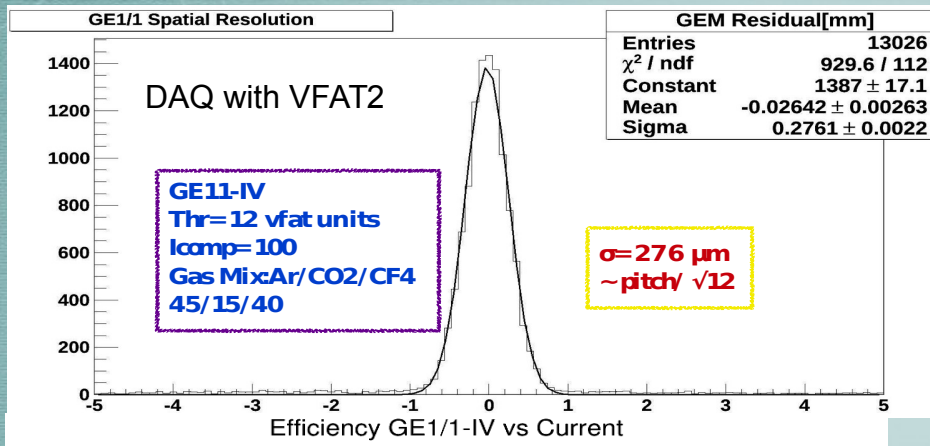
A. Marinov

For the slice test need to install the services in LS1: use available RE1/1 services (cables, pipes), gas mixer need to be installed

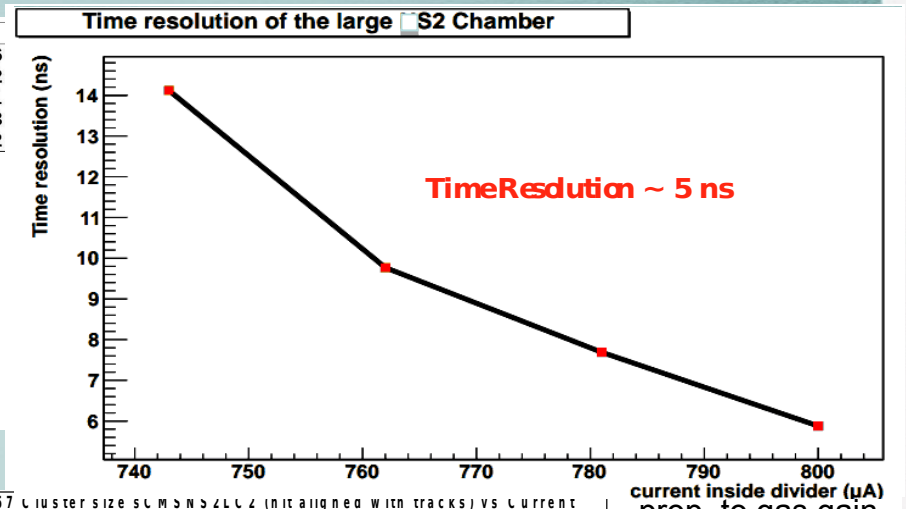
2012 GE1/1 Beam test@CERN

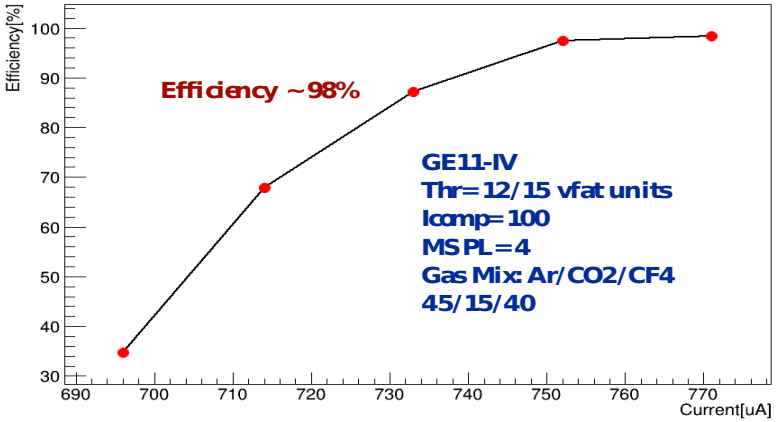
Preliminary Results for pions

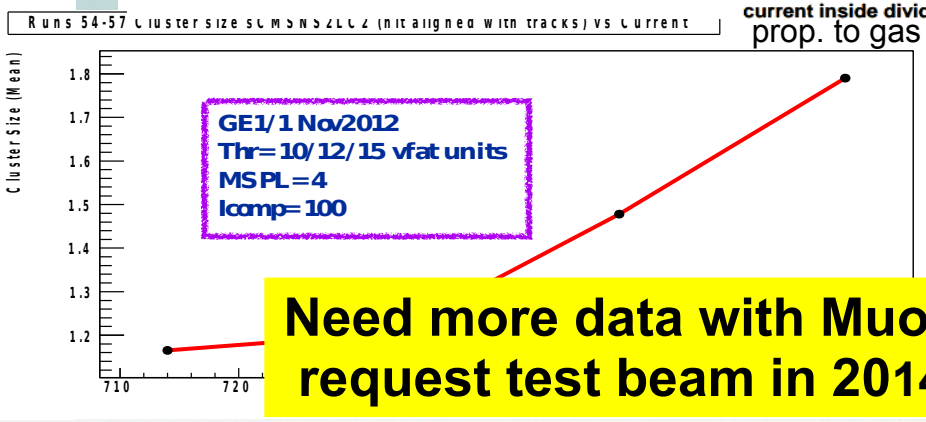
Test Beam Results



GEM Residual[mm]	
Entries	13026
χ^2 / ndf	929.6 / 112
Constant	1387 ± 17.1
Mean	-0.02642 ± 0.00263
Sigma	0.2761 ± 0.0022







Need more data with Muon: request test beam in 2014

2012 beam test@FNAL

- 120 GeV protons or 20-32 GeV pions & kaons
- > 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

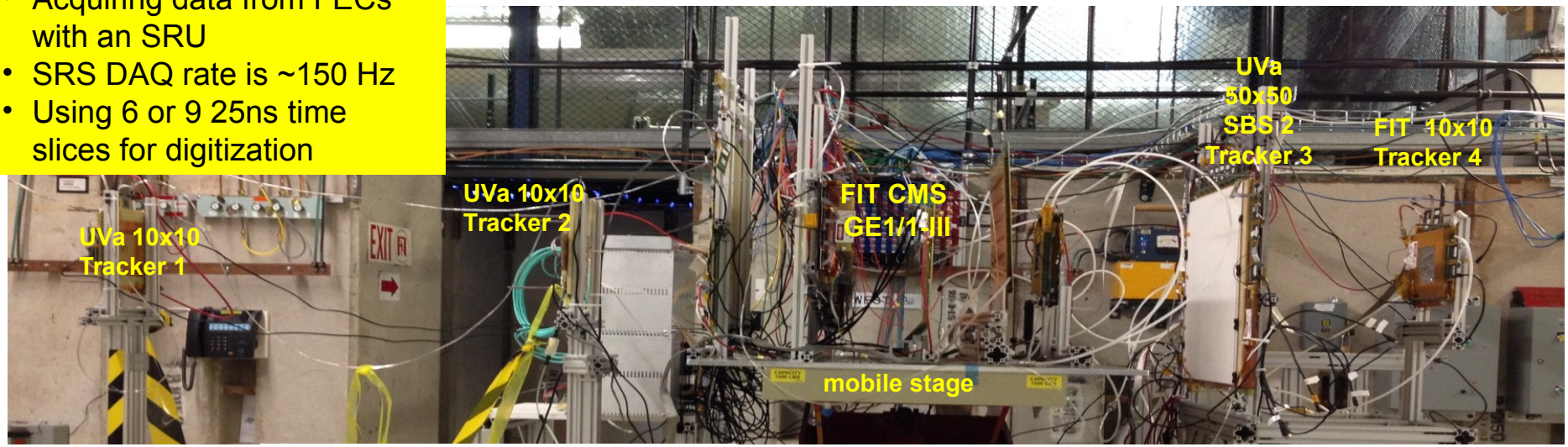
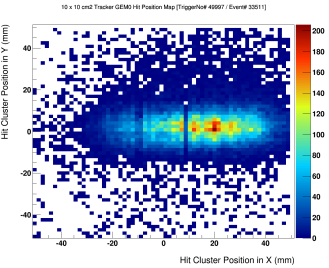
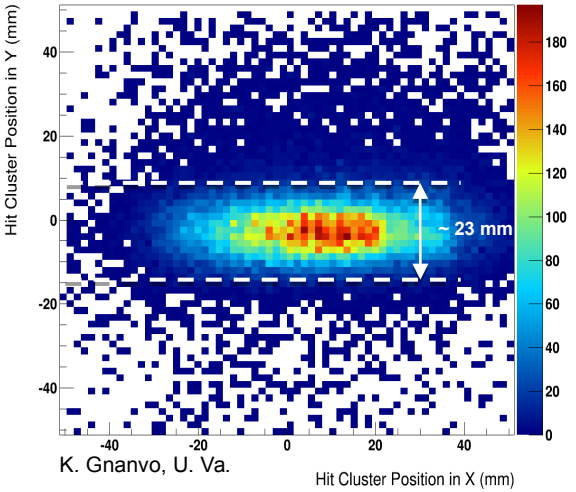


photo by VB

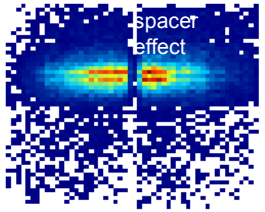
Front Tracker



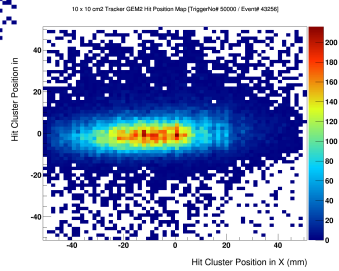


K. Gnanvo, U. Va.

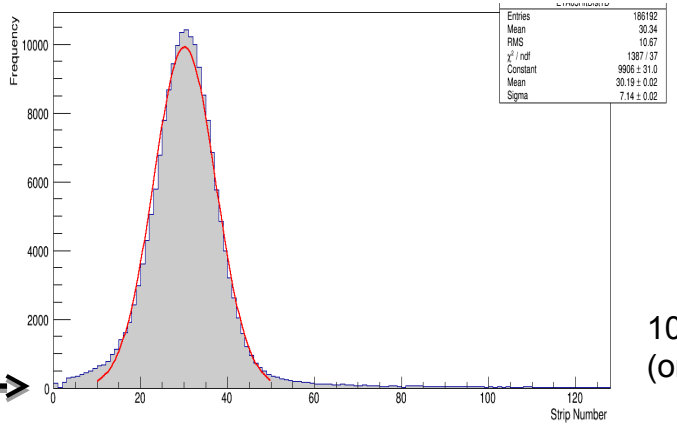
VERY PRELIMINARY



Rear Tracker



GE1/1-III Sector 5



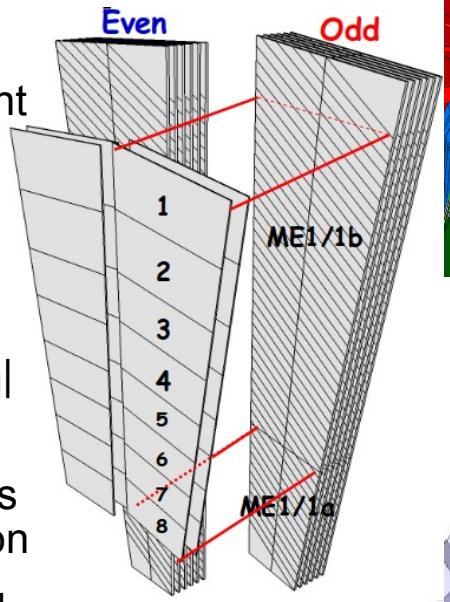
Beam width: $\sigma \approx 7$ strips $\times$ ~1 mm strip pitch ≈ 7 mm
$\Rightarrow$ Vertical beam spot diameter ~ 28 mm (over $\pm 2\sigma$ range)

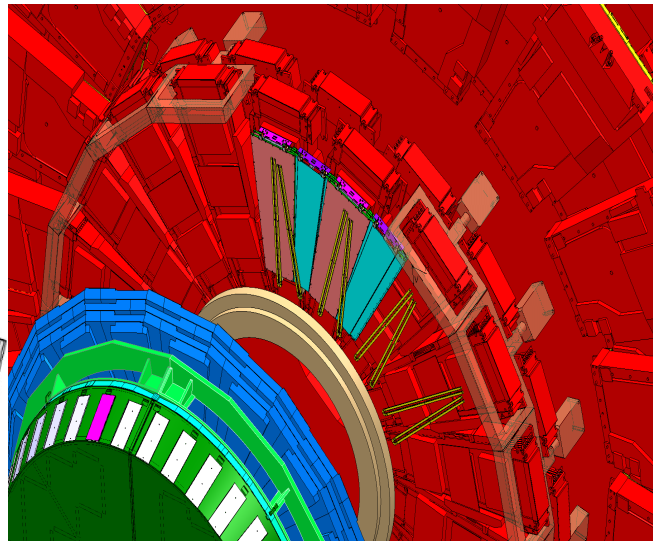
100k events
(one high-statistics run)

GE1/1 geometry

LAYOUT

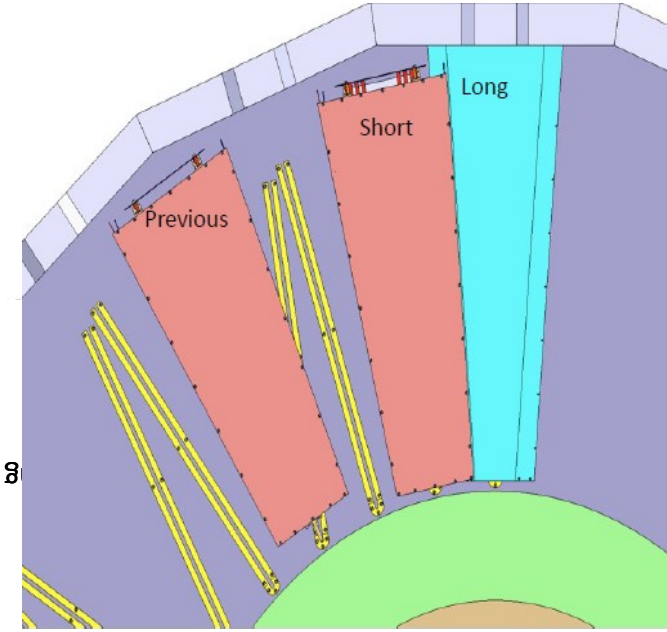
- Two 10° triple-GEM chambers to form a “super chamber”
- 144 total chambers (36 super chambers in one station per endcap)
- Each chamber is segmented into different columns and η region





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



Background simulation

The validation come in two steps:

First step: Particle Fluxes

Simulation Tool: FLUKA

CMS geometry:

- 2019 scenario for GE1/1 - Current geometry, not including any of the upgrade systems

  - *We have presented a full study for GE1/1 finalized to the TDR*

- 2023 scenario - including all upgrade systems (ME0, GE1/1, GE2/1, RE3, RE4). Need to have a realistic calorimetry upgrade description

, - *Validation: also xcheck with BRIL group*

Second step: Sensitivity

Simulation tool: GEANT

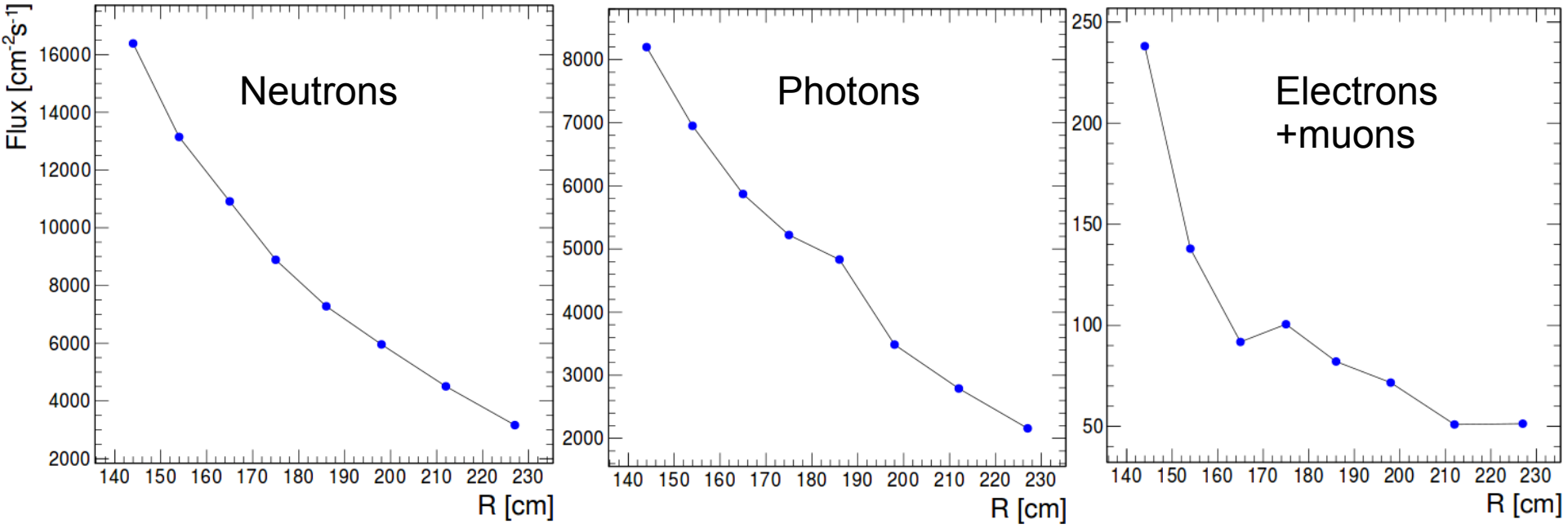
precise detector description in GEANT4 for the detector response to the photons and neutrons

Fluka: background rates GE1/1

- According to FLUKA after neutrons and photons the next most important contribution coming from electrons and muons in that order (sensitivity ~1)
- Only small percentage of them will generate a signal in the detector
- Since the sensitivities are energy dependent, need fluxes also as a function of energy

A. Castaneda

Flux of particles crossing the GE1/1 region



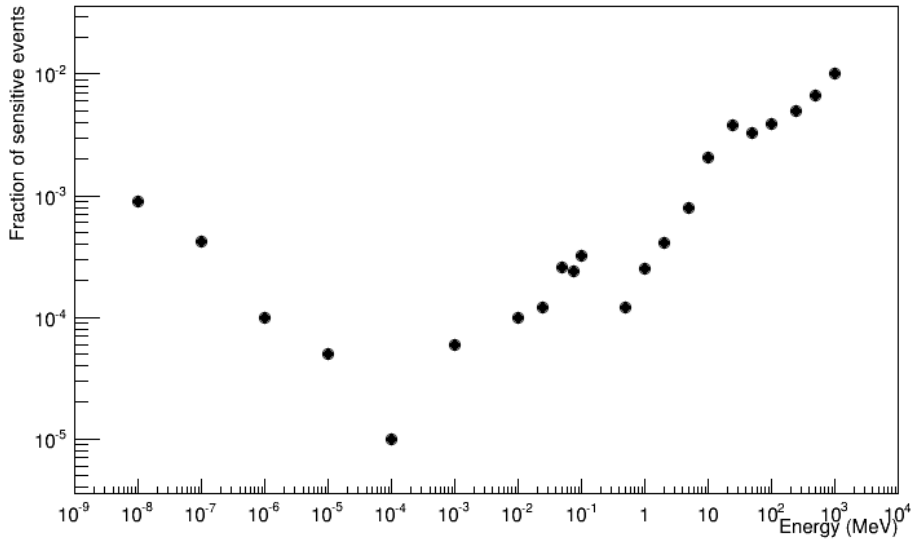
Sensitivity with GEANT 4

- Precise, energy-dependent, detector sensitivities to each particle type is needed
- Description of triple-GEM detector and gas mixture in GEANT4
- An event is considered as sensitive if there is a deposition of energy (Drift Gap) of 5 times the average potential (15.54 ev)

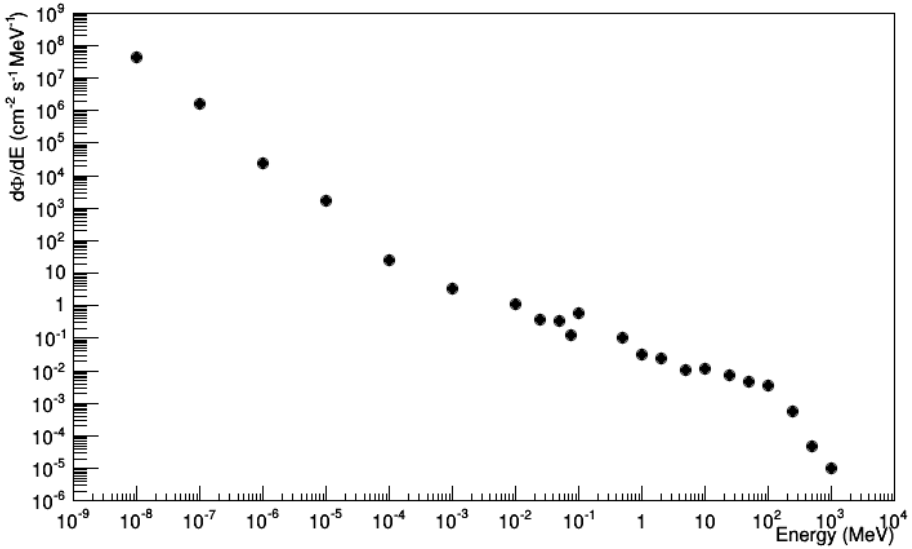
F. Zenoni

Convolution with detector sensitivity

TripleGEM Sensitivity to Neutrons



Interacting neutron flux in TripleGEM (GE1/1)

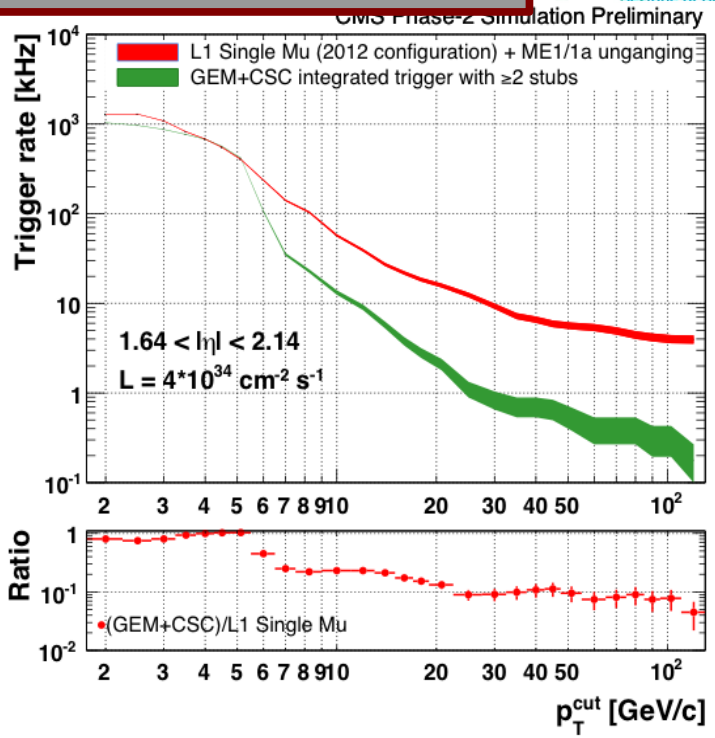


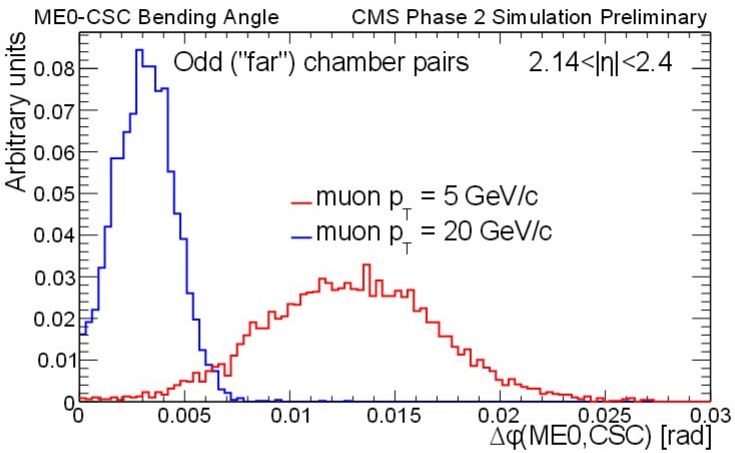
Main trigger progress

- **Trigger analysis framework is in place**
  - Constructed a trigger analysis framework
  - Working GEM simulations platform on GitHub
- **GEM-CSC integrated local trigger simulated**
  - Initial implementation done
  - First results obtained and **approved for ECFA 2013**
  - Development is ongoing, **high pileup samples** are being produced for new rate and efficiency studies
- **GEM standalone trigger**
  - Work is starting

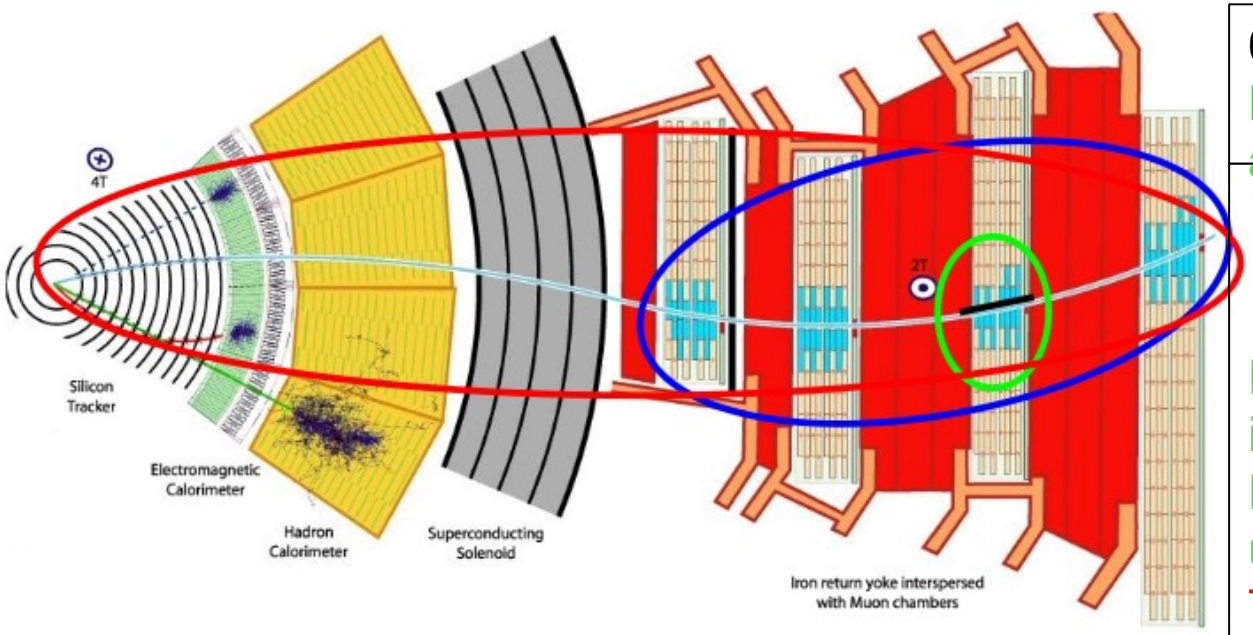
To Do:

- **High level trigger**
  - **Looking for new participants. Probably we can get some help from RECO people**
- **Future GEM studies**
  - **Implementation of a fast stub builder for GE2/1**
  - **Preliminary feasibility studies for a "ME0" and a GE2/1 system + approved for ECFA 2013**





Reconstruction status



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

1. Local reconstruction:
Reconstruction of **hits** and **track segments** inside a **chamber**

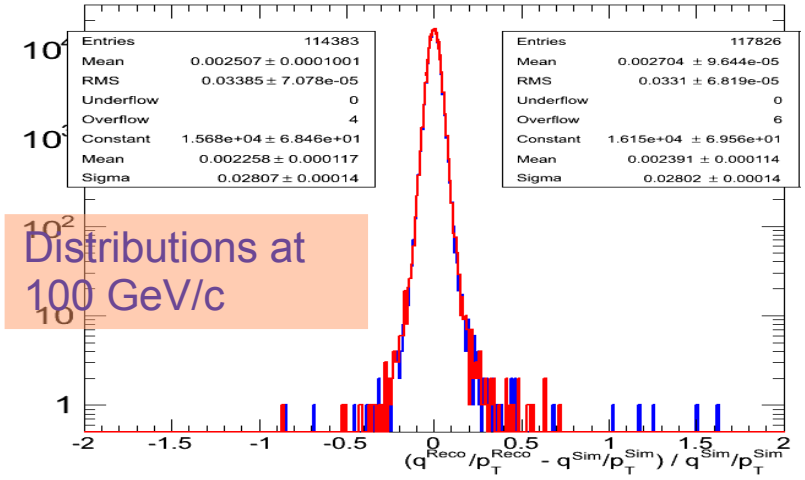
DONE: GEM RecHit implemented for Digital R/O
DONE: Correct RecHit uncertainty implemented
TO BE DONE: Seeding

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

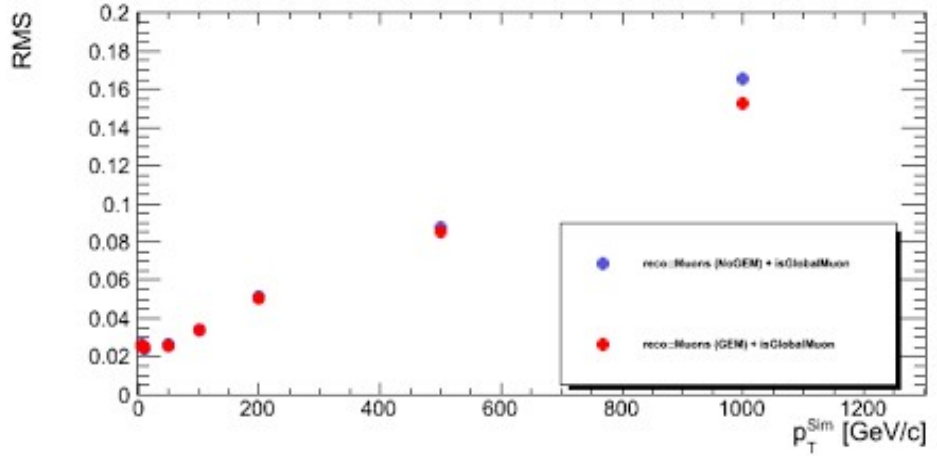
RecoMuons: charge mis-id & q/p

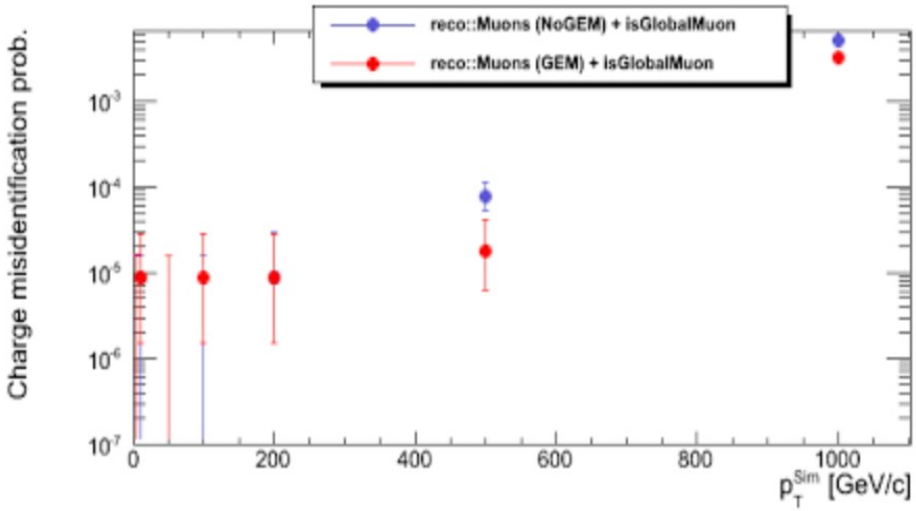
C. Calabria

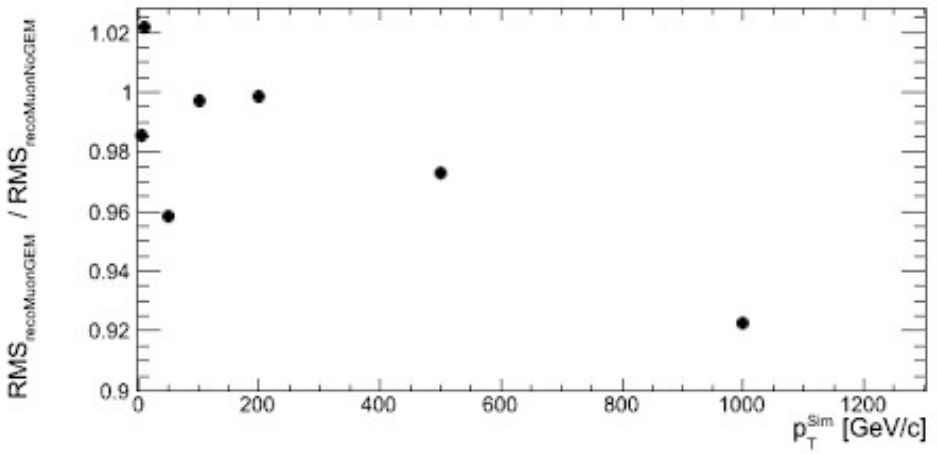
Looking at the reco::Muon for high quality muons
Tails reduced when GEM are included



Distributions at 100 GeV/c





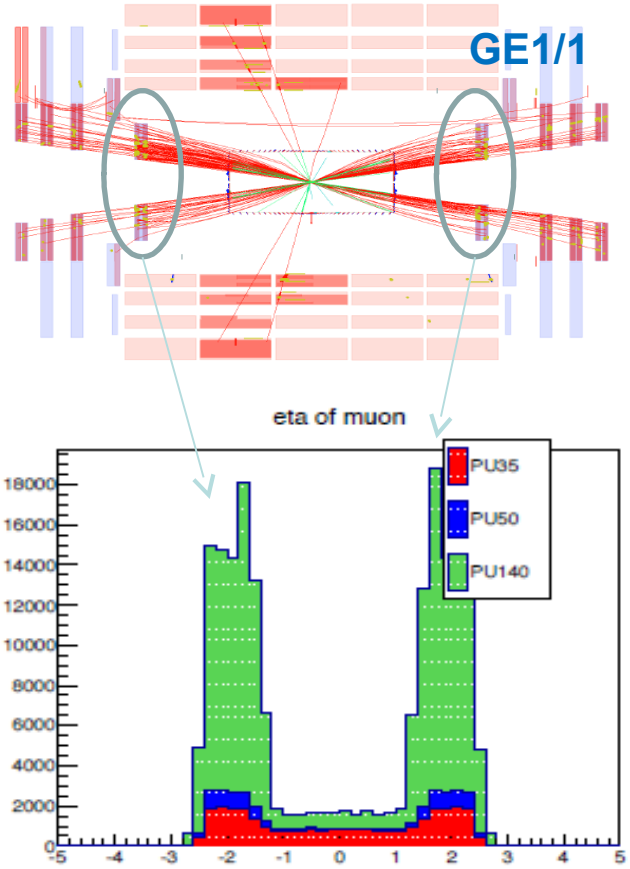


Improvement in charge-mis-id (up to 60%) and RMS for medium-high p_T
Work to be done on tracker-muon and TeV muon

Physics challenges at HL

HL affects muon system performance. Forward region |η|≥2.0 especially challenging.

- Rates up to MHz/cm2 and growing with η
- Reduced resolution and longevity issues
- Exceeds capabilities of existing electronics
- pT mis-measurements and multiple scattering in iron yoke cause rate flattening



Charged particles

Region without redundancy at present

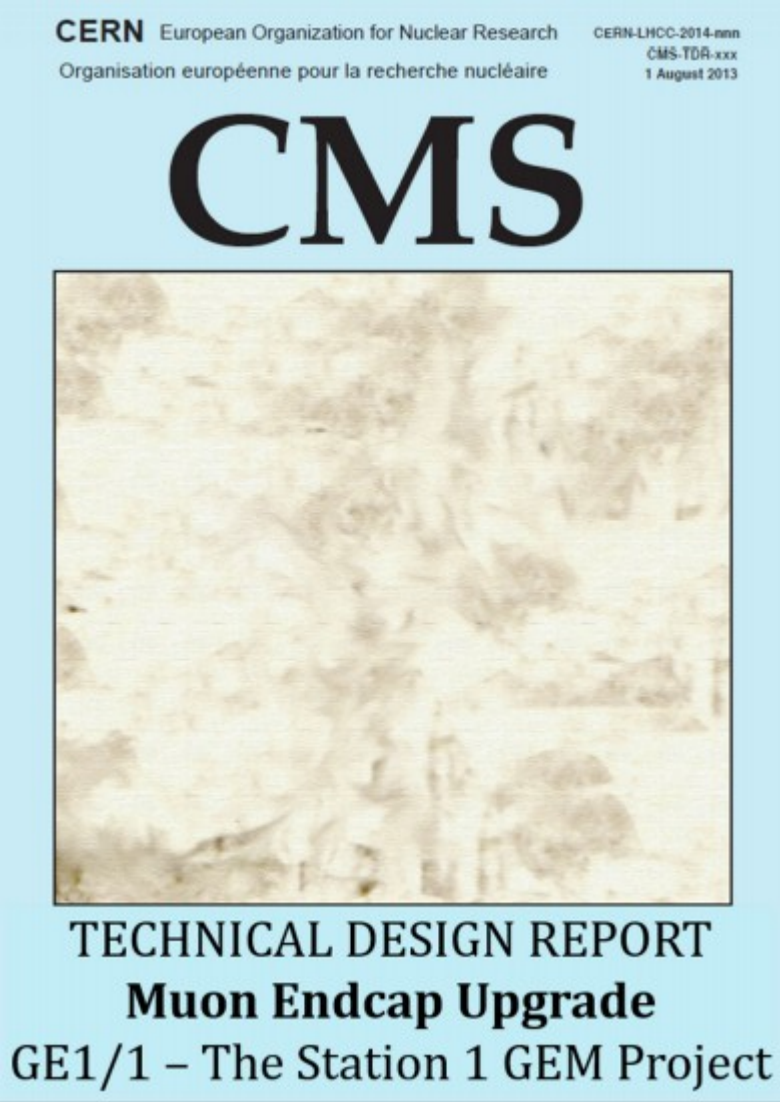
Several physics channels with **~20% of their event**s in that acceptance (1.5 – 2.2)

H4Mu (20%), H2Tau (23%), Z2Mu (16%)

Physics studies

Channel	Manpower Needed	Manpower Available	Time scale	Physics argument
H2Tau	2	1	TDR	Lowering trigger threshold
WH→W(μ/τν)H2Tau	3	3	Phase2	Extension in eta
H4Mu	3	3	TDR	Redundancy Improved pT measurement (?)
H2Mu	2	1	Phase2	Extension in eta ~20% gain
WH→WW→WWW (3mu3nu)	2	1	Phase2	
High momentum muons	2	0.5	Phase2	Do GEMs help with showering muons? See also DPG studies
Z→mumu	1	1	TDR	Performance studies
Redundancy studies	?	?	TDR	Performance studies

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)
- 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

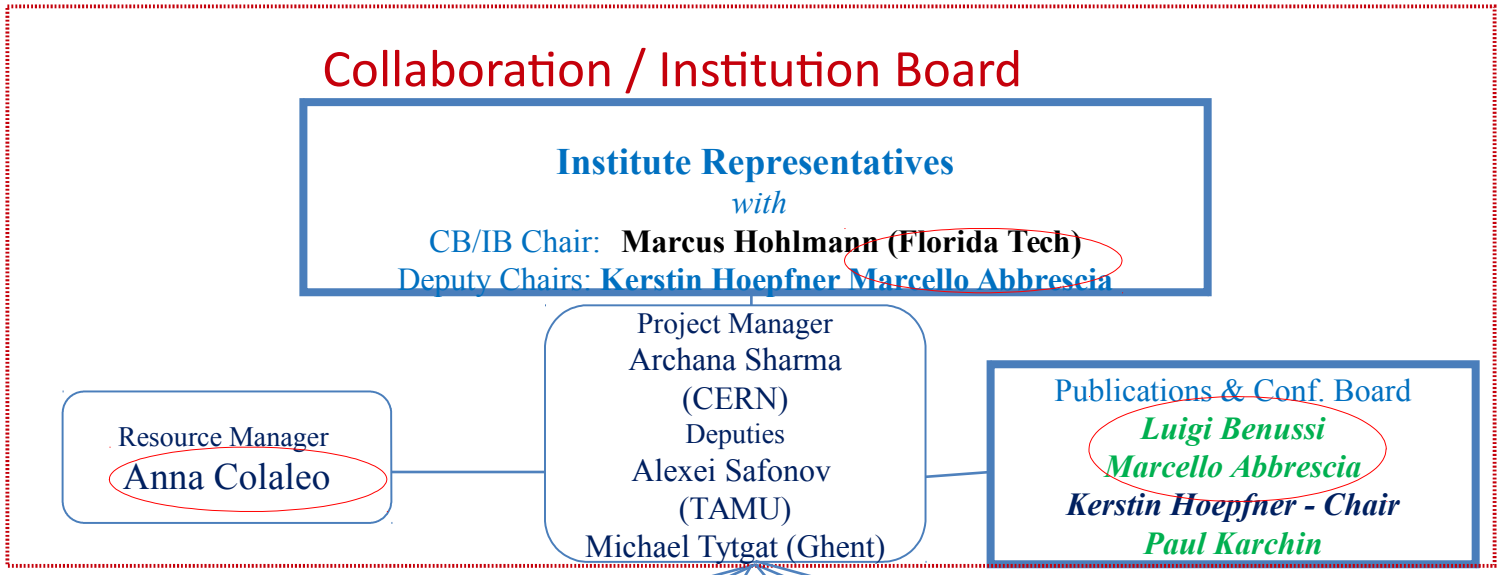
TDR schedule

- First draft for Christmas Reading 24.12.2013
- Comments to be submitted by 31.1.2014
- Corrections completed 20.2.2014
- Circulate to GEM Collaboration for comments
- Corrections implemented by 20.3.2014
- Circulate to CMS for comments 31.3.2014
- Assembled for printing – deadline 15.4.2014
- Comments implemented 15.4.2014
- Send for printing 30.4.2014
- Receive copies by July CMS week to be submitted to CMS Management

➢ Update schedule to be in sync with Muon Phase-2 Technical Proposal

INFN Responsability

NFN people have most important roles in the collaboration: several CMS LV2 positio



Approved: GEM IB CMS Week 11.7.2013

Total costs and INFN contribution

CSN1 approved a maximum INFN contribution of 850 keuro (requested 950 keuro).

Items	Cost full project (kEuro)	INFN (K Euro)
Detector Components	776	210
Electronics	2074	510
Front-end (VFAT3)	623	210
HV & LV systems (incl. Cables)	566	300
off detector electronicss	843	
DCS/DSS	42	
Services (cooling&gas)	150	
Logistic & Installation	113	
Optimization and prototype	513	130
Prototype VFAT	83	28
Proto powering system	75	45
DAQ	233	
Electronics - Cooling Proto	25	
Prototype Chambers	97	57
Total (kEURO)	3626	850

-Include 10% on detector chambers and electronics

~ 3100 Keuro: CORE cost

30 keuro INFN In-kind contribution

~ 500 Keuro: finalize TDR and slice test preparation

Funds for 2014

Requests for 2014 finalized to the system optimization for the TDR, only “CORE” have been funded.

Chamber Optimization and production		INSTIT	2014	
	Ageing	LNF	8	
	n.1GEMfulls	LNF	8	
	consumable gas/cables/connect	LNF	4	Non CORE
	n.1GEMfulls	BA	8	
	consumable gas/cables/connect	BA	4	Non CORE
Optimization (2013-2014)			32	
Powering system		INSTIT	2014	
	setup test system	NAPOLI	10	
optimization&prototype			10	
Front-end electronics		INSTIT	2014	
	prototype (design and tests)	BA	15	
	final prototype	BA		
optimization&prototype			15	
TOTAL RICHIESTA 2014			57	

Not funde

Tot
49 keuro

INFN 2014 activities

Focusing on system optimization for the TDR

Aging and long term stability (LNF)

Characterize the GE1/1 materials under 20-yr radiation dose, asses the stability of gap spacing at the required precision level via optical measuring and monitoring.
Use of optical sensors is proposed and will be optimized on a full-scale GE1/1 chamber in LNF

Time resolution studies (BA)

Study the time resolution response of full-size GE1/1 chambers as a function of mechanical tensioning of GEM foils, the different gap widths and gas mixtures (binary, ternary and quaternary gas mixtures)

Front-end electronics (BA)

Bari is participating in chip design and have the responsibility of the Control Bias Monitoring and slow control circuitry.
2014: last prototyping steps and final submission foreseen in 2015.

Design of the power system (NA)

Naples is involved in designing and production of the power system**.**
Design has to be finalize for the TDR in 2014. Test setup in Naple to be prepared. Induced noise study and the grounding schema also to be check on the chamber prototype

2023 scenario

Moving towards the software integration of all Muon subdetectors in one scenario

Task-force in place: M. Maggi. I. Osborne, C. Calabria, S. Dildick, P. Verwillingen,S. Krutelyov

Extended2023HGCalMuon

The code is in GitHub.

- 2019 detector
- BE5D tracker
- HGCal (no ES nor EE nor HE)
- ME0
- GE1/1
- GE2/1
- RE3/1 and RE4/1 (extended to 2.4)

It will be replaced soon with either Extended2023SHCal (Shashlik+Phase II (shorter) HE) or Extended2023CFCal (CFCal)– 4.0 eta coverage

Look at the Yana's page

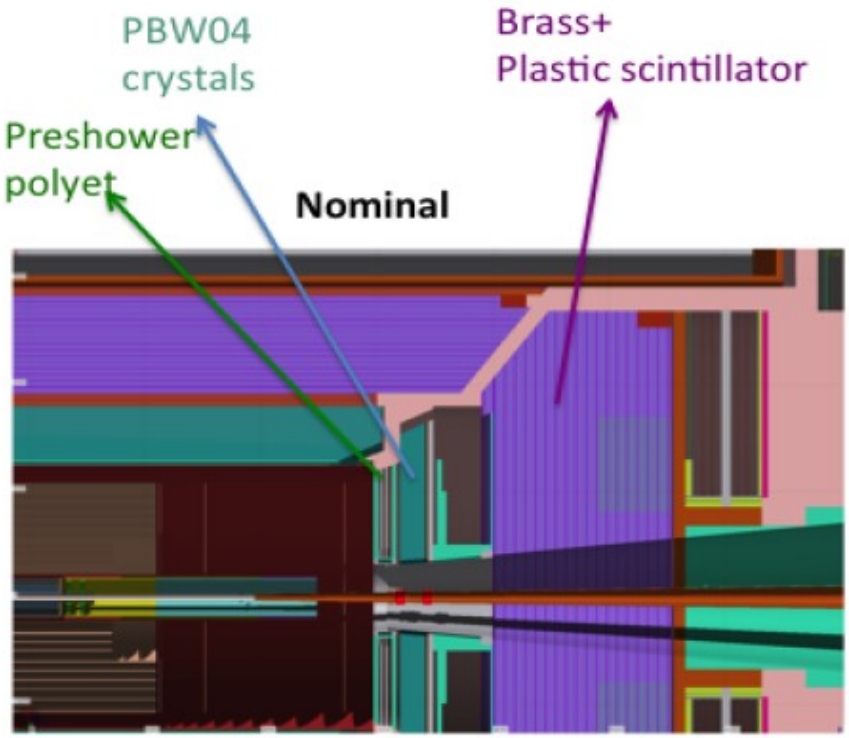
https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideUpgradeGeom

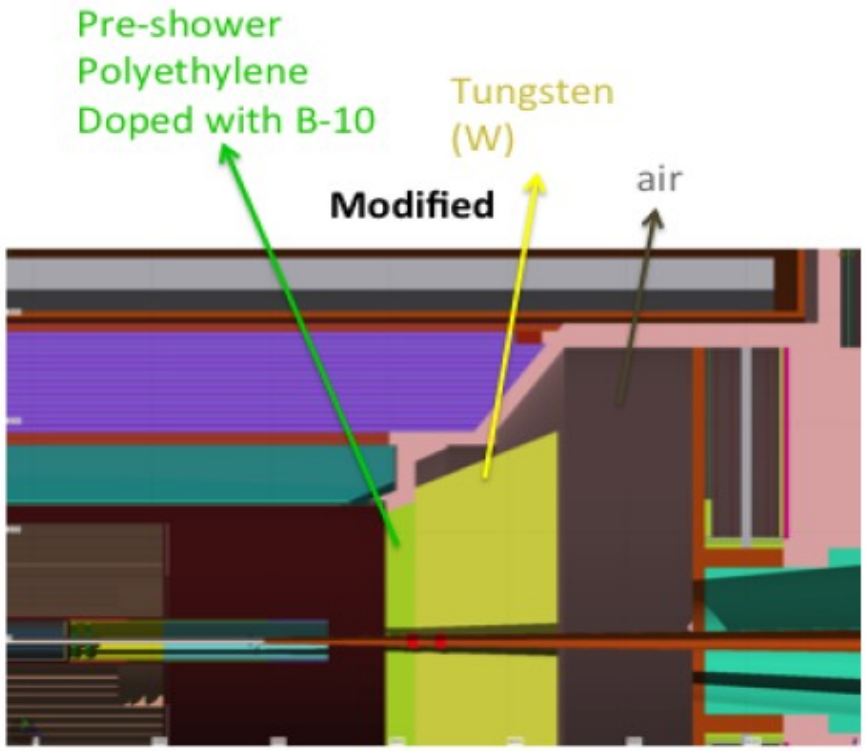
Background:2023 scenario

Two CMS geometry scenarios:
- "Nominal", old geometry (not including any of the subsystem upgrades)

- "Modfied", first attempt to modify endcap calorimetry (using Lovedeep's input file)

Add W-HF from 322-442cm, replacing current EE+HE
EE material (PBWO4) changed to tungsten (W) with 86% of density from nominal i.e 16.6 g/cm3 - two times more dense than current EE media
Present pre-shower space used for shielding design to reduce radiation impact on tracker.





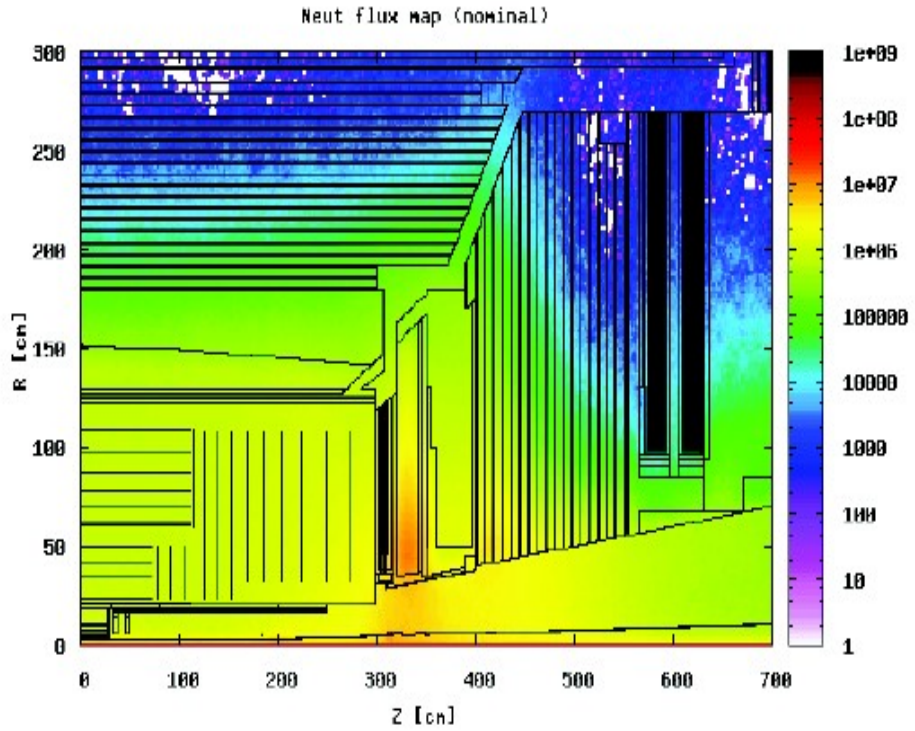
Background:very forward region

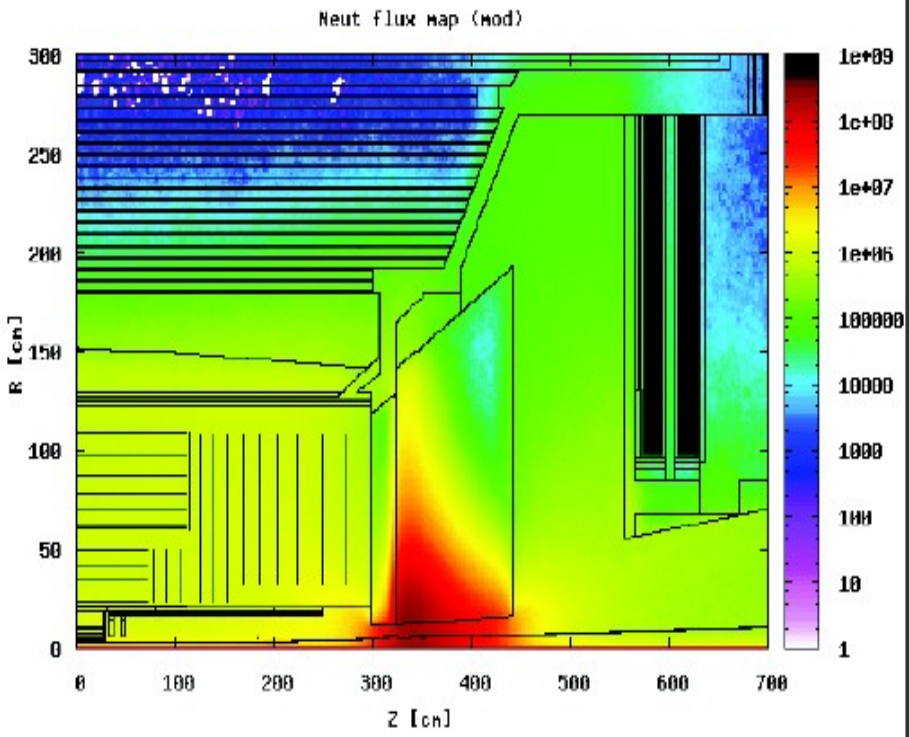
Running standalone FLUKA simulation

- 7TeV energy per beam
- Instantaneous luminosity=10E34cm-2s-1
- Flux in Hz/cm2
- Flux maps for neutrons and photons

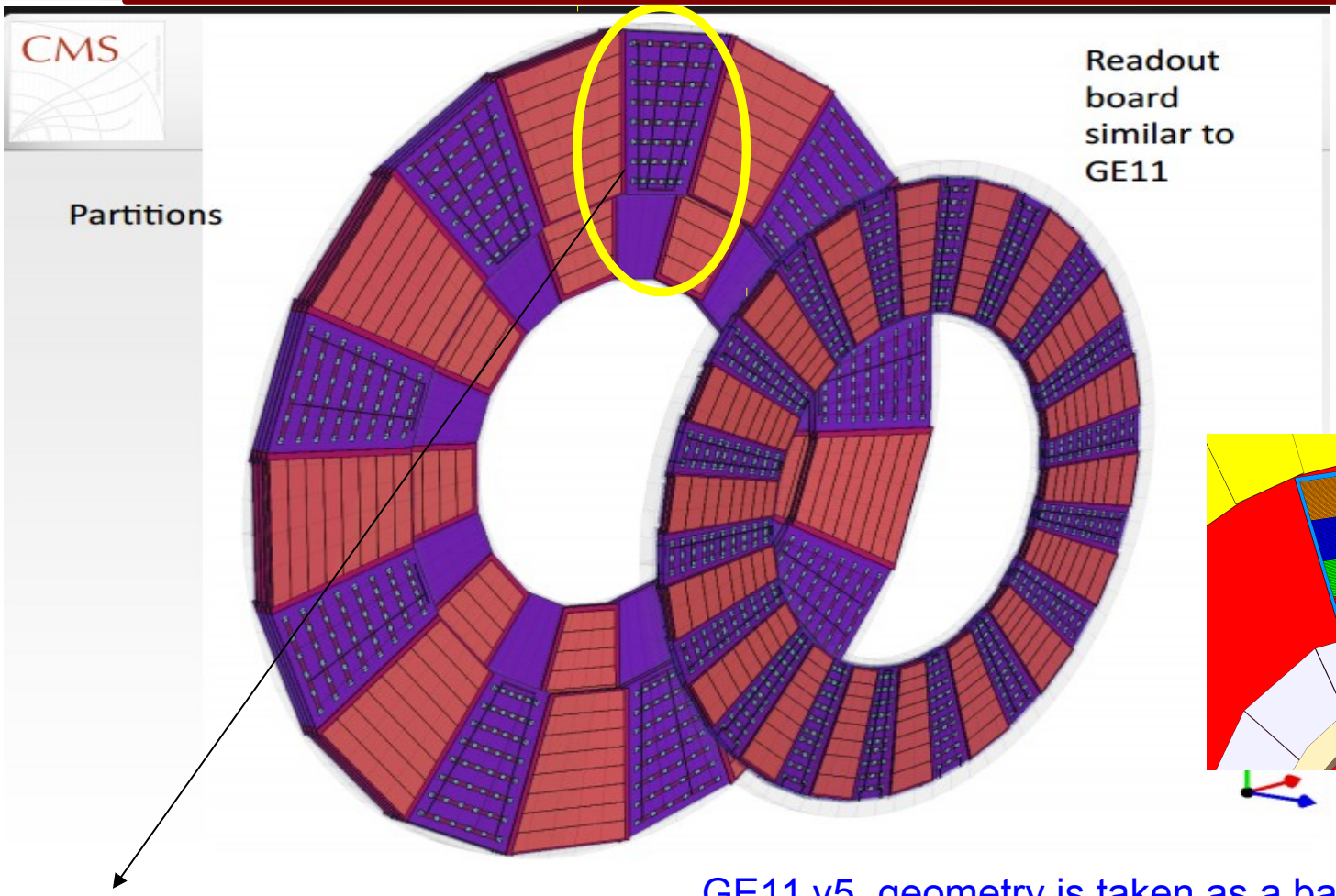
A. Castaneda

Neutrons

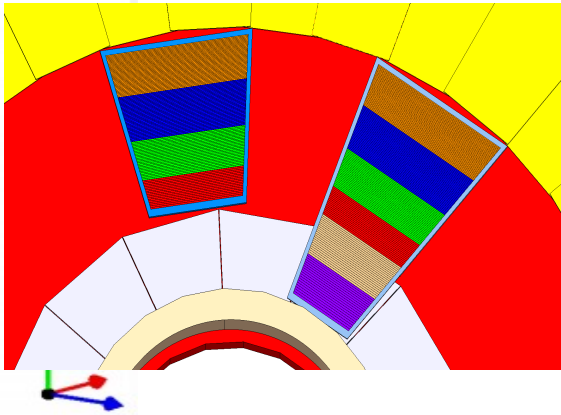




GE2/1 geometry



I. Osborne,



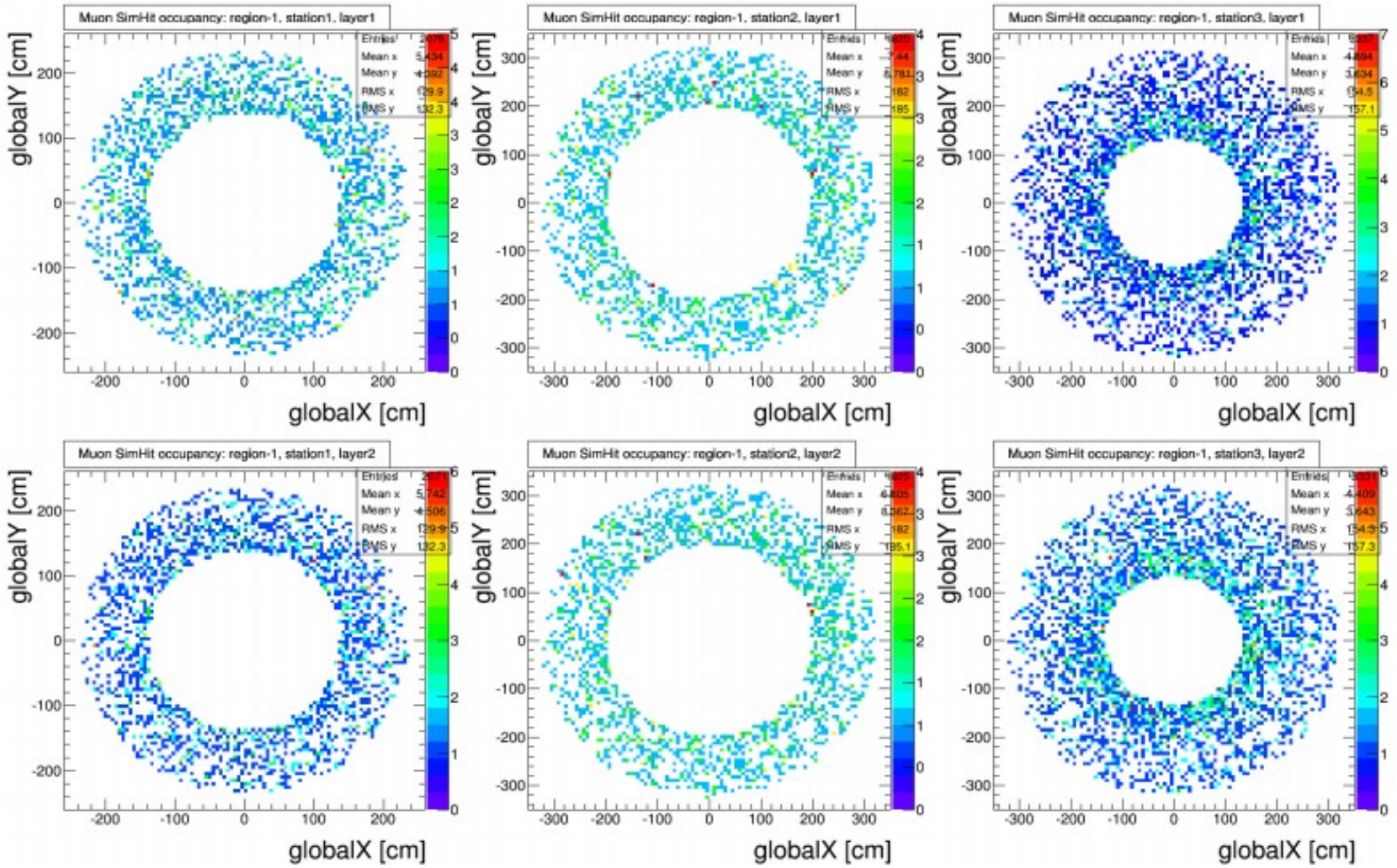
GE11 v5 geometry is taken as a baseline

- 20 degree chambers
- 8 rolls up to 2.12 (Short Double super-chamber): station 2
- 12 rolls up to 2.4 (Long super-chamber): station 3.

GE1/1 and GE2/1 integration

GE1/1 and GE2/1 simhits

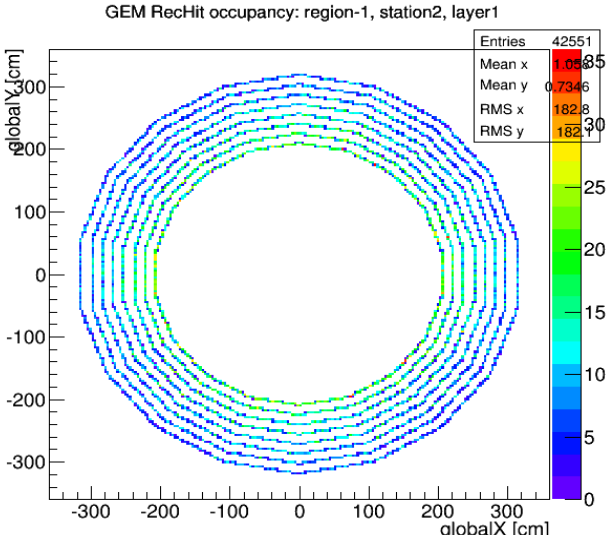
globalY vs globalX occupancy plots. Note station 2 = GE2/1s, station 3 = GE2/1l

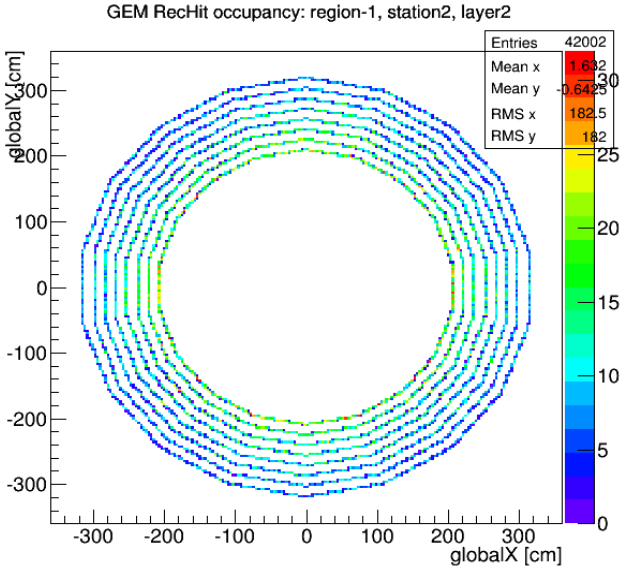


X-Y occupancy plots: GE2/1

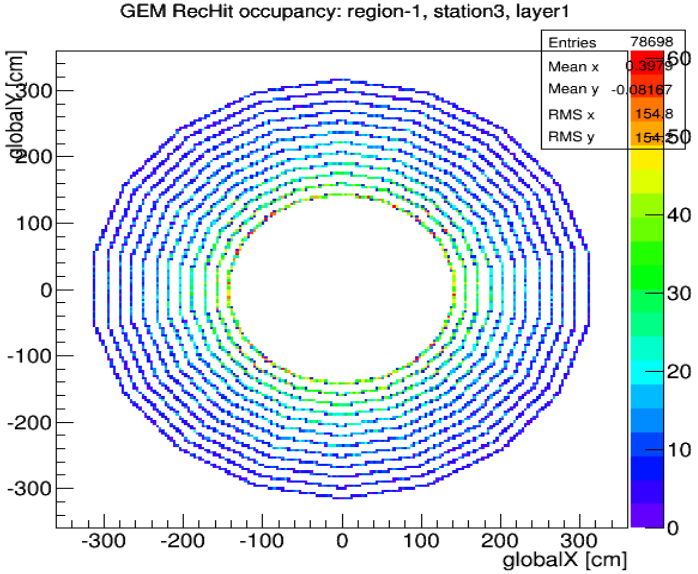
- **GEM RecHit Global x vs. global y, Region -1**

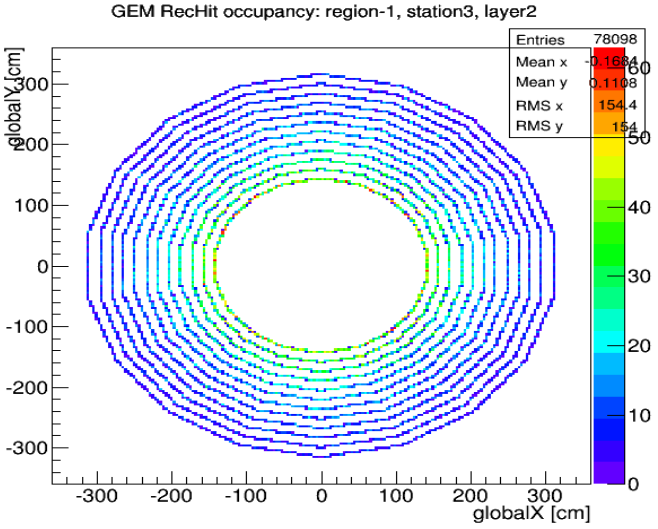
C. Calabria





Station2



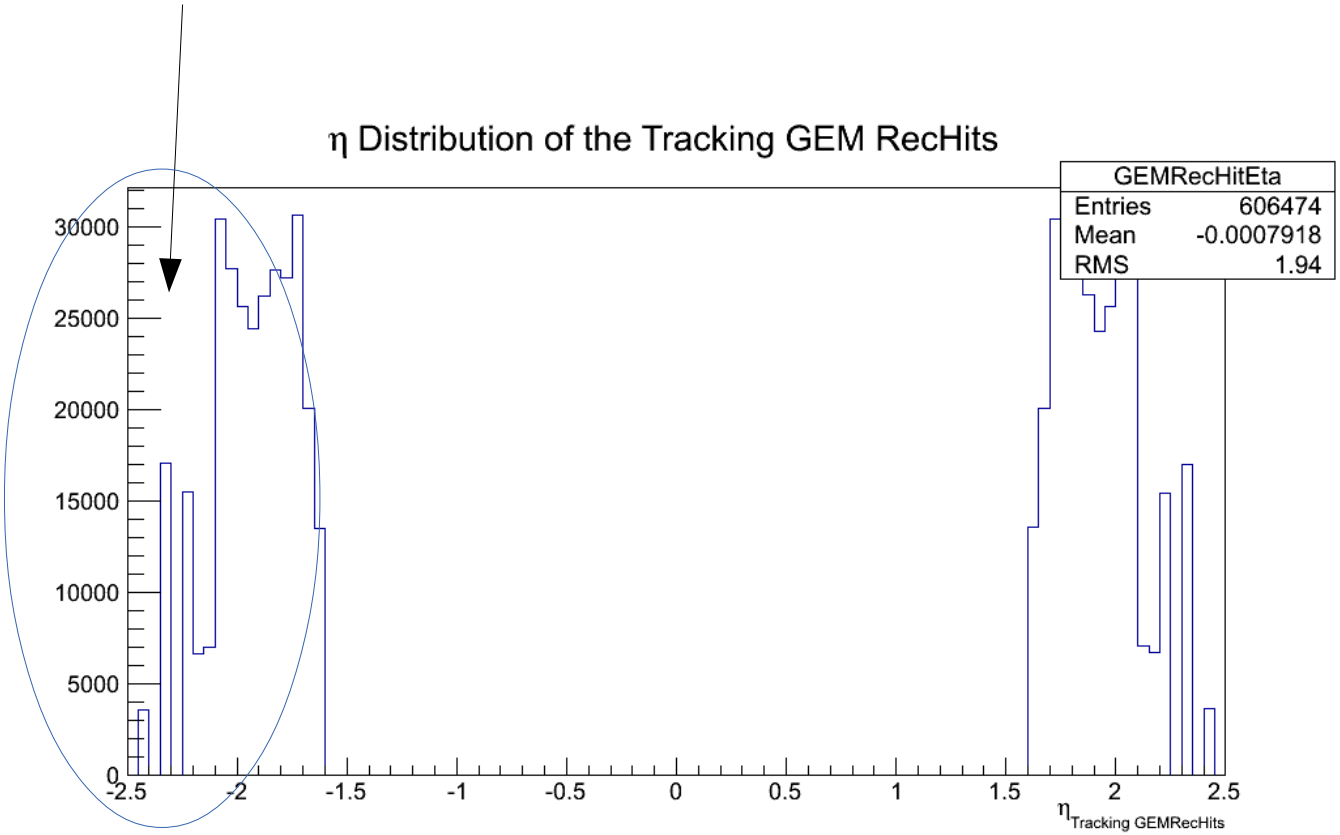


Station 3

GE2/1 Global Reco

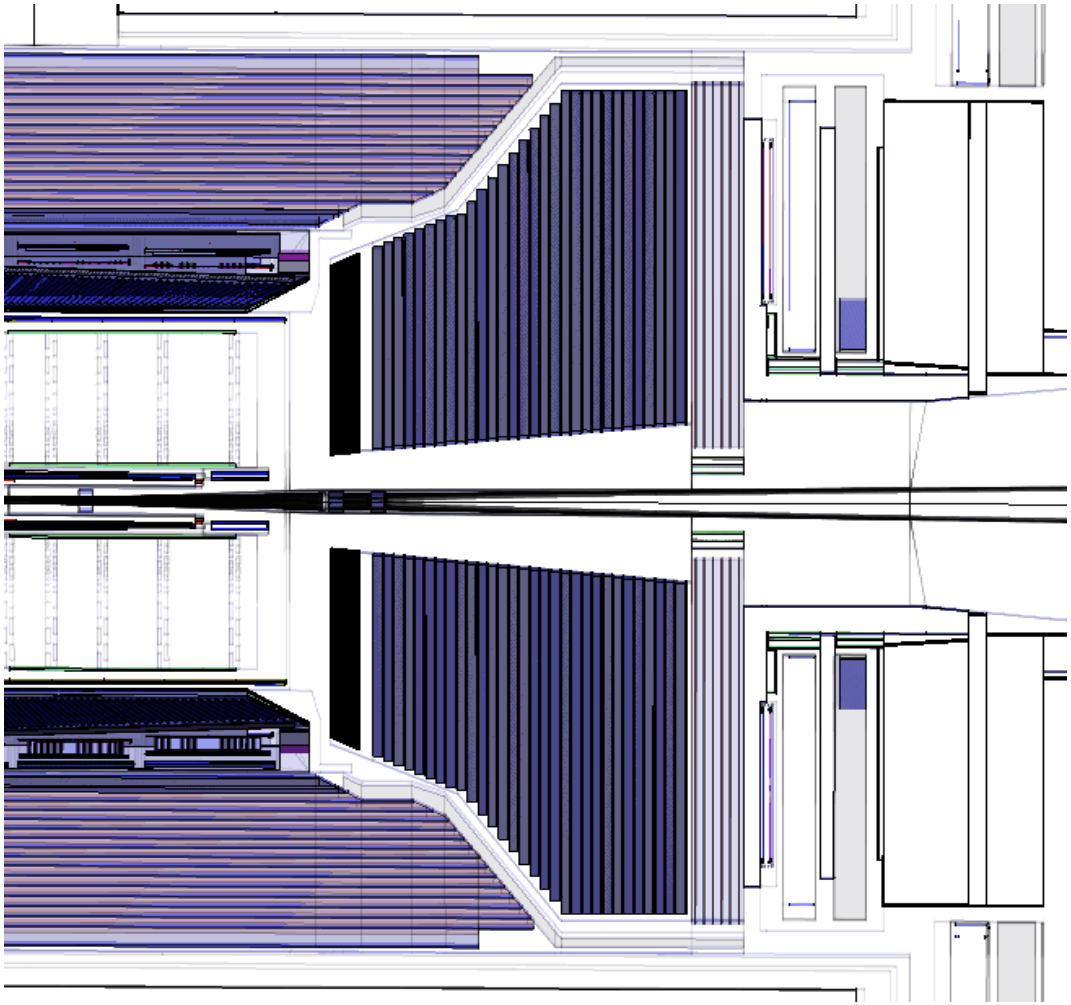
- The algorithm now include in the fit also the GEM recHits coming from GE2/1

C. Calabria



...more plots for global reconstruction in few days

ME0 geometry



I. Osborne,
M. Maggi

Total width of 30 cm

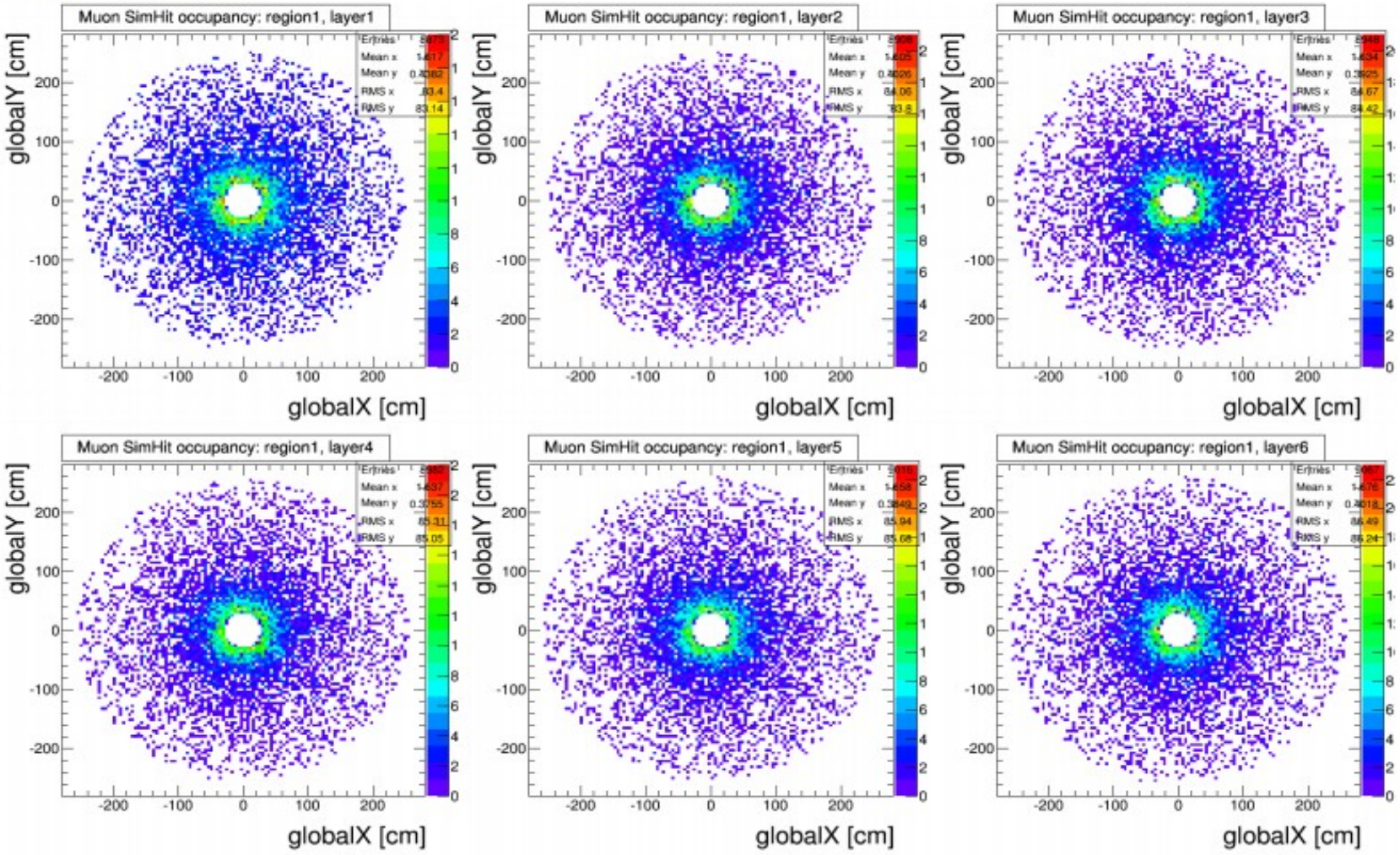
- **rMin =30.0 cm – hard limit 4 eta**
- **5 cm Poly + 5 cm Lead shielding**
- **rMax =273.0cm –limited by cables**

2 x18 chambers (6 layers each) is available in 2023HGCal scenario, 2023HGCalMuon

ME0 Sim-Hits validation

S. Dildick

Occupancy in XY

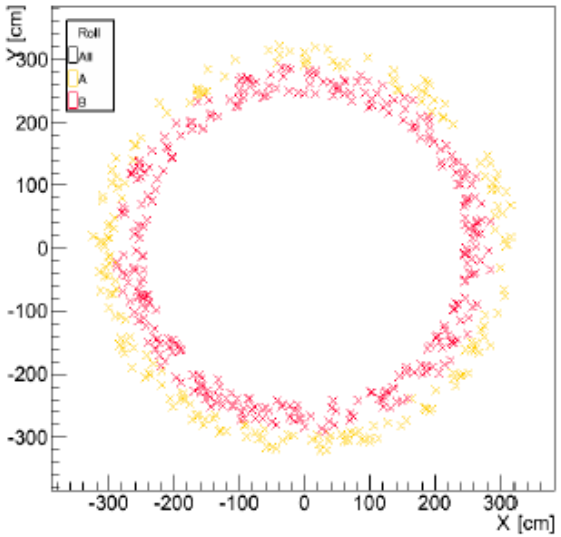


RE3/1&RE4/1: SimHits X-Y view

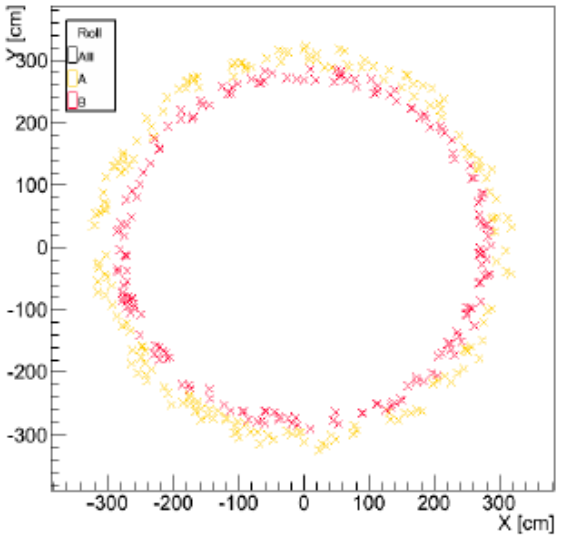
P. Verwillingen

SimHits Up to 2.1--> 2 eta partitions

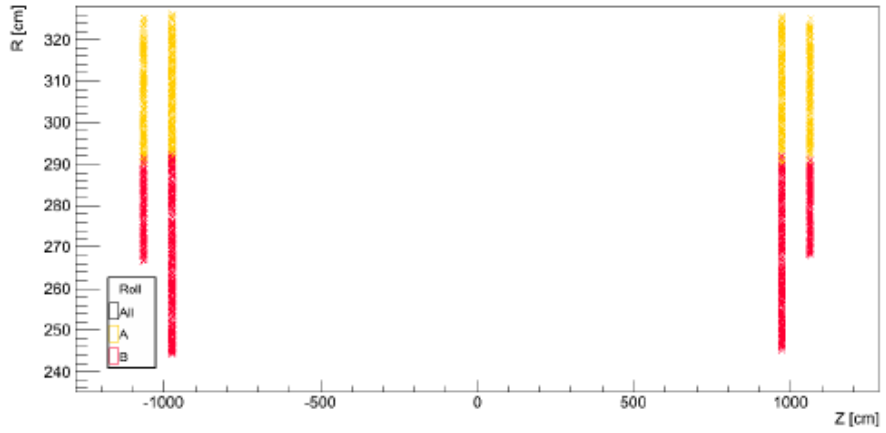
RE+3/1 simhits



RE+4/1 simhits



RE SimHits



ESP 2013-2014

In 2013 total ESP requests for approval by Upgrade manager: **42.5 months (only students)**

Preparing 2014 ...

Activity	Tasks	Fte Needed
Detector Hardware	Chamber R&D	
Detector Hardware	Test beam and test at irradiation facility	
Electronics and DAQ	Power System	
Electronics and DAQ	Electronic configuration	
Electronics and DAQ	DAQ and online DB	
Simulation	Reconstruction	
Simulation	Trigger	
Simulation	Detector simulation and background simulation	
Simulation	Physics studies	
Simulation	Sample Validation	
Software	Database	
Management	Coordinators	

Priorities and milestones 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 TIF**
  - **Installation of services for Slice Tests**

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

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

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

Person power needed

- **Hardware area**
  - **FE Electronics**
  - **Integration**
  - **Tests at neutron and gamma facilities**

- **Software**

  – Geometry implementation

  – Background studies (also for RE3, RE4)

  – test beam analysis

  – sensitivity studies

  – software development (Tracker-muon, TeV muon, cosmic muon, validation)