COMMISSIONING OF THE FIRST CHAMBERS OF THE CMS GE1/1 MUON STATION
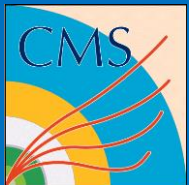
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on behalf of the CMS Muon Group

ICPPA2017 - The 3rd International Conference on Particle Physics and Astrophysics

National Research Nuclear University "MEPhI"
Moscow, Russia

2-5 October 2017

Outline

Introduction

- The CMS Muon System
- The GEM Technology
- The LHC Future Upgrades

The GE1/1 station and the Slice Test

- The GE1/1 station
- Motivation for the GE1/1 station
- The GE1/1 Slice Test

• Commissioning

- The HV system
- The Readout and LV system
- System Calibration
- Detector Performance

The CMS Muon System

Several detection technologies are employed:

- **Drift Tubes (DTs)** in the barrel and **Cathode Strip Shambers (CSCs)** in the endcaps (covering $1.0 < |\eta| < 2.4$) $\rightarrow$ precision position measurements and trigger

- **Resistive Plate Chambers (RPCs)** up to $|\eta| < 1.8$ in both barrel and endcaps $\rightarrow$ Redundant trigger and coarse position measurement
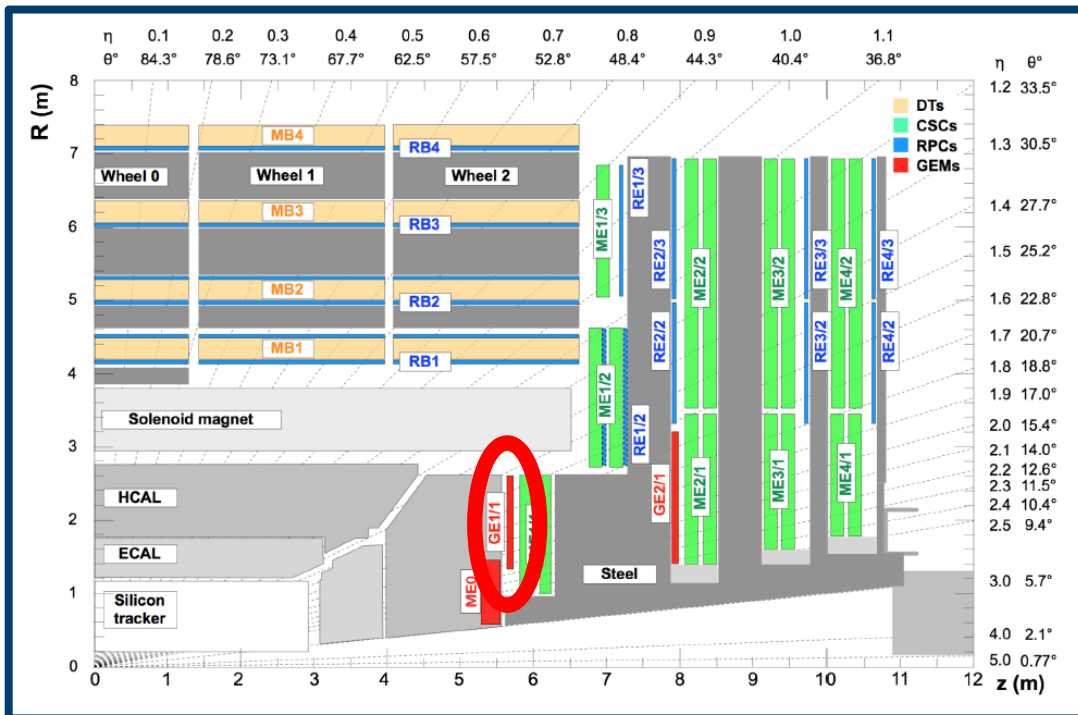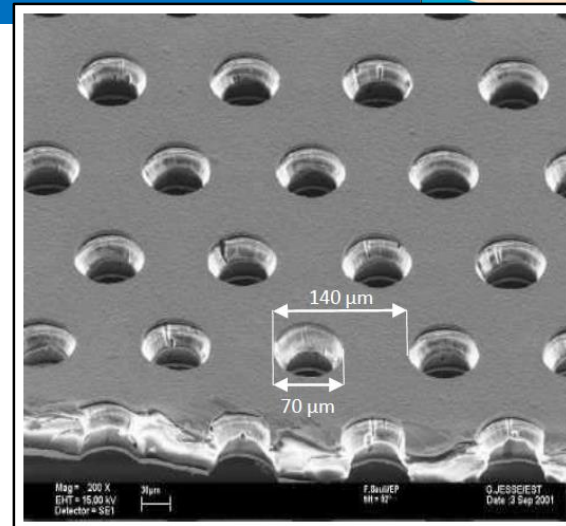

- Installation of **triple GEM detectors** in the region 1.6<|η|<2.2 is scheduled in 2019-2020

n Particle

The GEM Technology

DESIGN

- A GEM (Gas Electron Multiplier) foil is a 50 μm thick polymer foil coated with 5 μm copper on each side

- Regular (triangular) pattern of holes

- Biconical holes with maximum diameter of 70 μm, interspace 140 μm

- A triple-GEM is a stack of three GEM foils

Rate capability up to 100 MHz/cm²
Muon detection efficiency $\varepsilon > 97\%$
Gas gain $\sim 10^4$

OPERATION

- Potential difference applied on copper sides either through a divider or through independent HV channels

- Electric field between foils → drift of electrons towards the underlying foil

- High electric field inside holes → avalanche multiplication of electrons entering the holes

- Signal collected with appropriate electronics
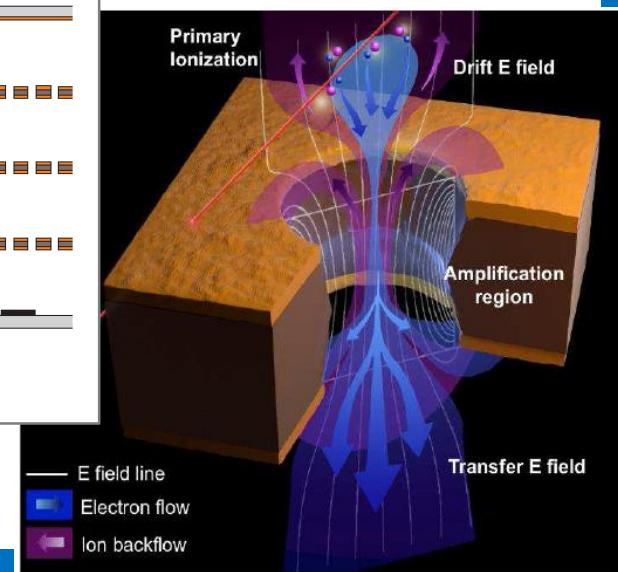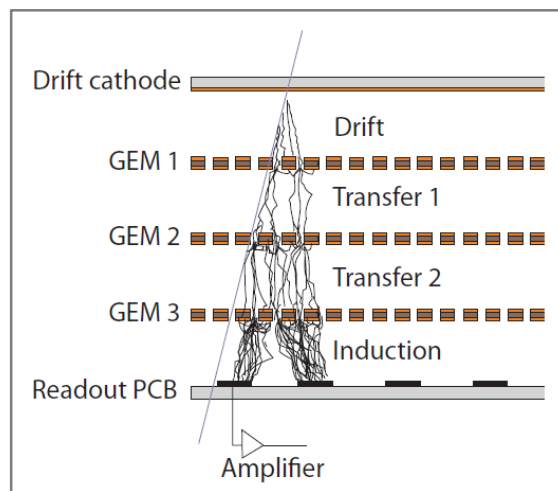
The LHC Future Upgrades

The LHC Upgrades

• The Large Hadron Collider (LHC) has scheduled some upgrades, starting in 2019 and 2024 resp., in order to gradually increase the delivered luminosity.

• In the final configuration a luminosity of about $5 \times 10^{34}\ cm^{-2}s^{-1}$ is expected

Consequences on CMS muon system

• The background rate in the $1.6 < |\eta| < 2.2$ region is expected to be $\sim 1000\ Hz/cm^2$ after the Upgrades, so that achieving an acceptable L1 trigger rate for muons with $p_T < 25\ GeV$ will not be possible without increasing the threshold on muon p_T.
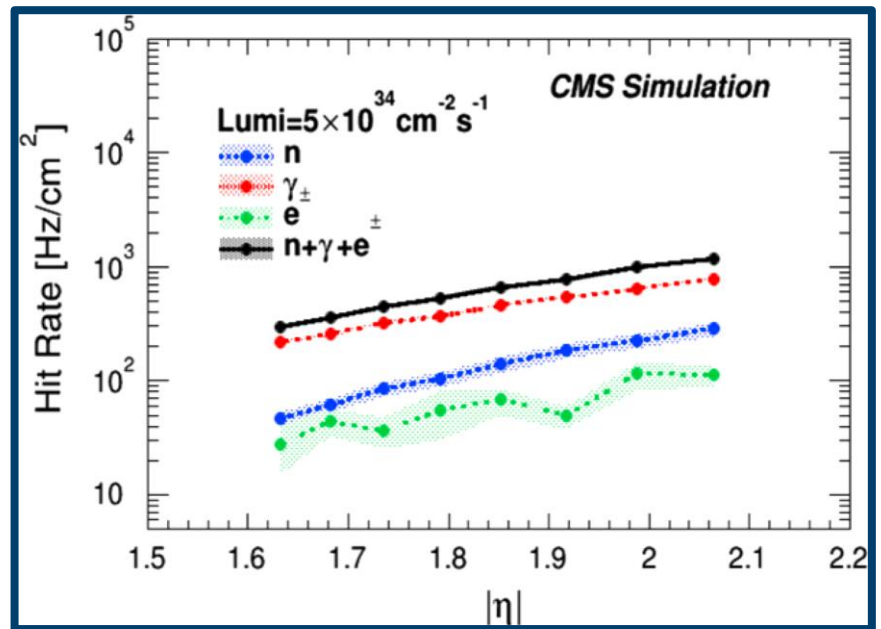
Background rate expected in the GE1/1 region.

The GE1/1 station

- Composed of 36 chambers (*«Gemini»)* per endcap, spanning 10° each

- Each chamber is made of two stacked triple-GEM detectors (*«Layers»*)

- The rate capability of the chambers is orders of magnitude above the expected background rate in that region
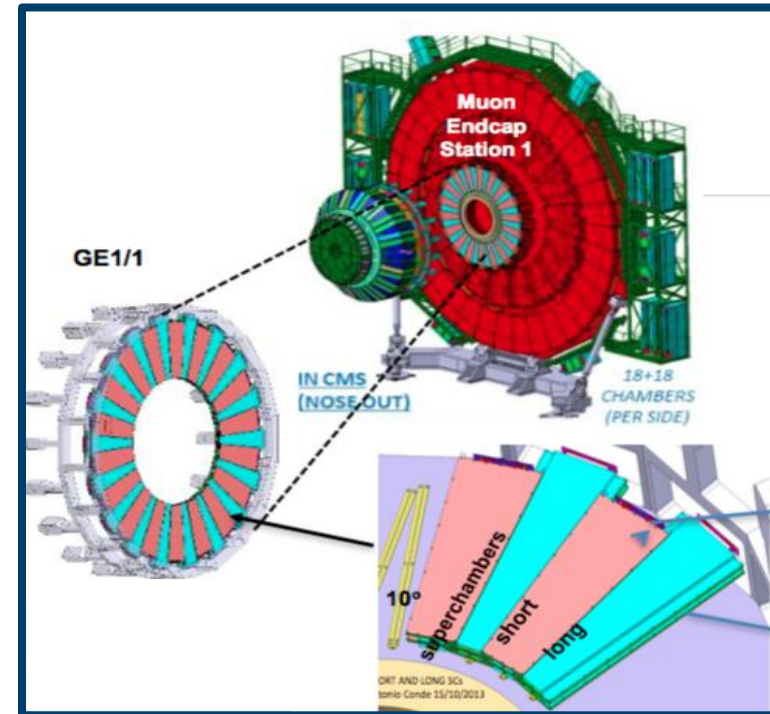
Motivation for the GE1/1 station

In view of the high luminosity:

GE1/1 will allow to keep <5 kHz trigger rate without increasing threshold on muon's momentum

- $\Delta\varphi_{strip} = 463\ \mu rad$
- Will be added in front of CSCs to measure the muon bending angle in magnetic field
- Adds redundancy
- Will work combined with CSCs
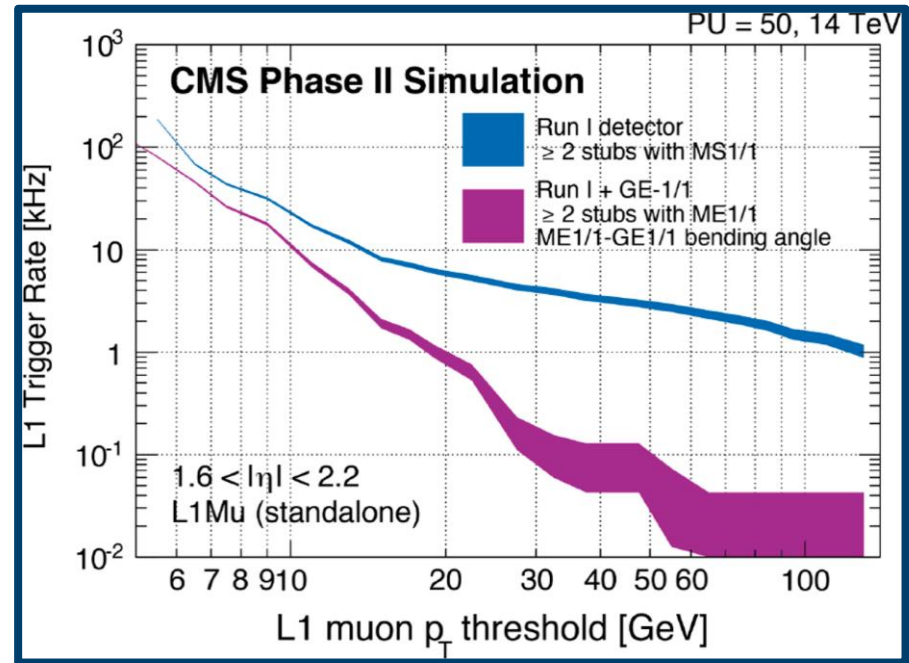
Above: Level-1 muon trigger rates before and after the GE1/1 upgrade at a luminosity of 2×10³⁴ cm⁻²s⁻¹, for constant efficiency of 94%.

Left: Measurement of the bending angle from CSC and GEM combined.
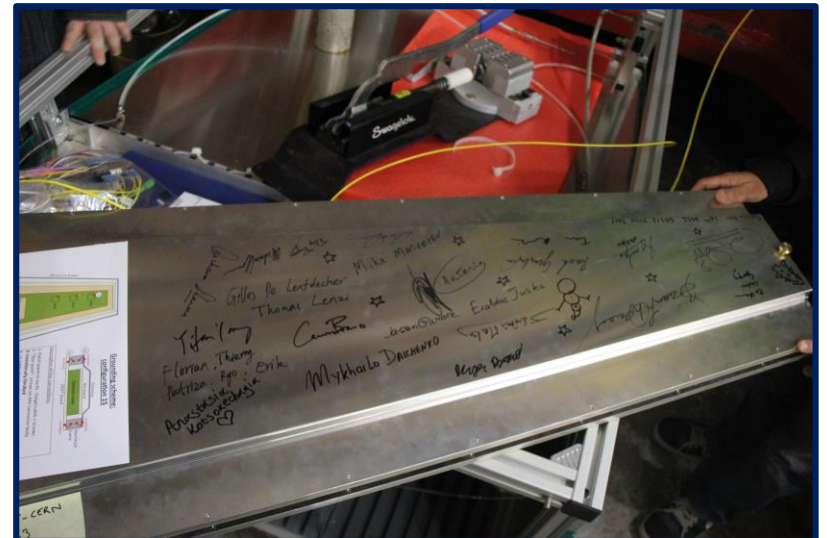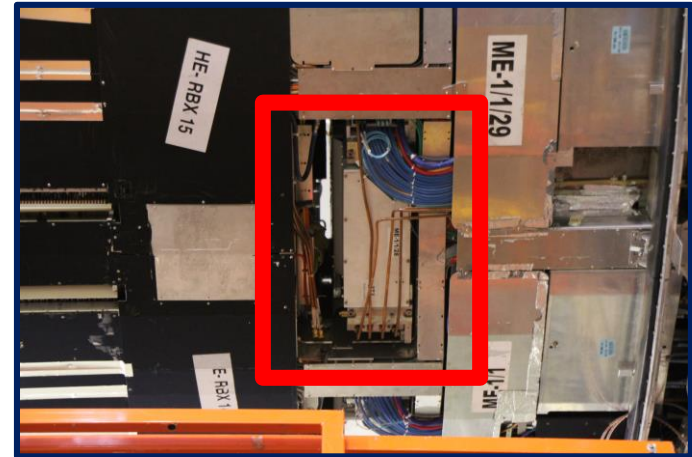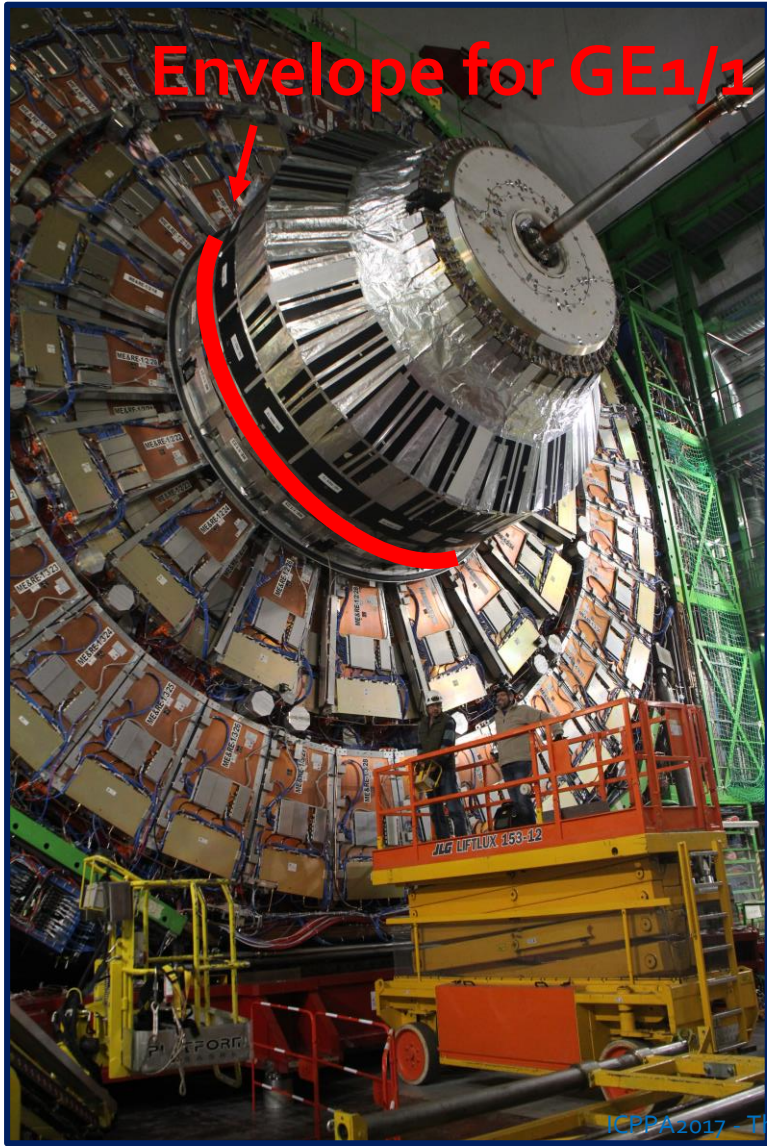
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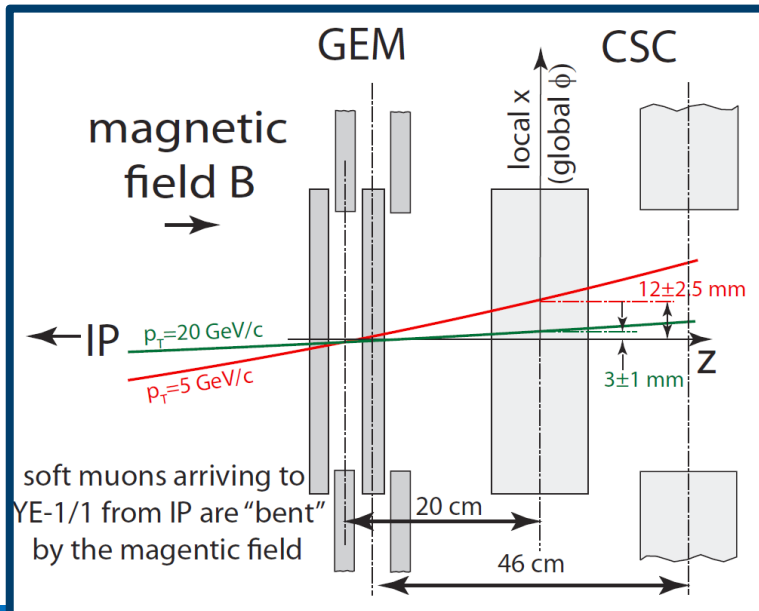
The GE1/1 Slice Test

- Five Gemini chambers (50° in total) have already been installed at the beginning of 2017

- The goals are to prove the system's operational conditions and to demonstrate the integration into the CMS online system
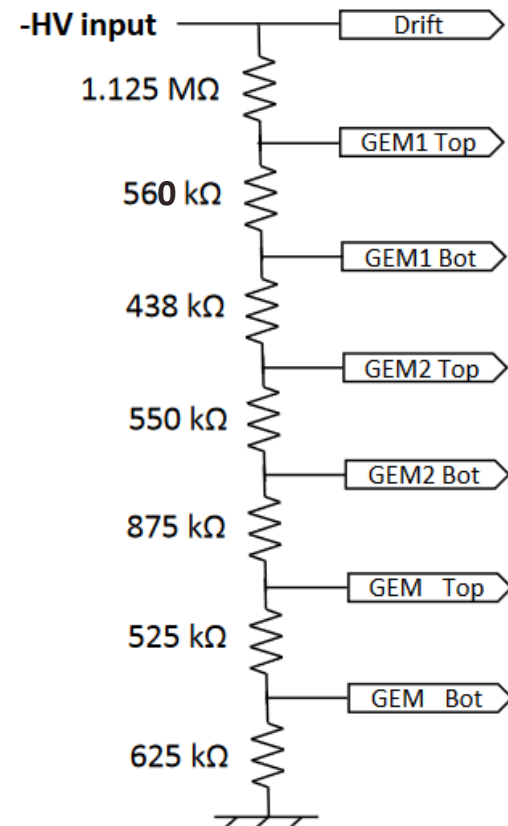
The GE1/1 Slice Test

Envelope for GE1/1
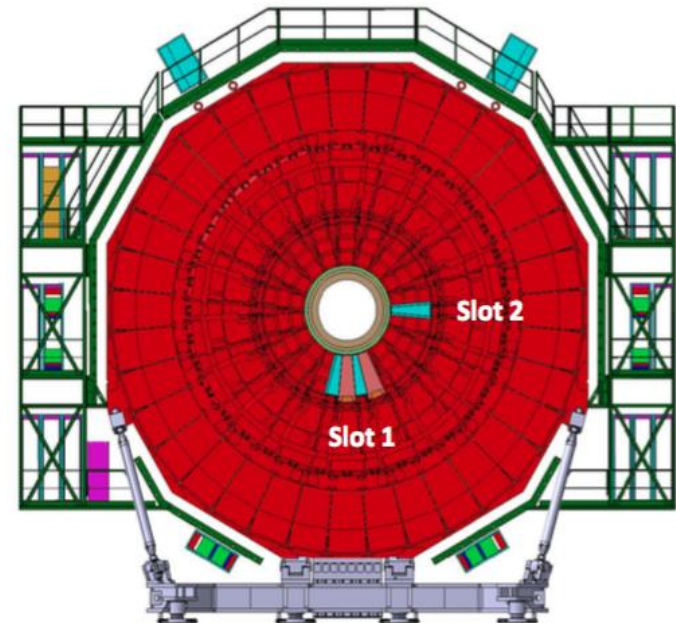
The HV system

High Voltage Supply

- 4 Gemini chambers are supplied with a CAEN A1526N:
a ceramic divider distributes the voltage to each detector's stage
→ 1 HV channel per layer

- 1 Gemini chamber is supplied with a CAEN A1515TG [*] module:
each detector's stage can be powered independently from each other
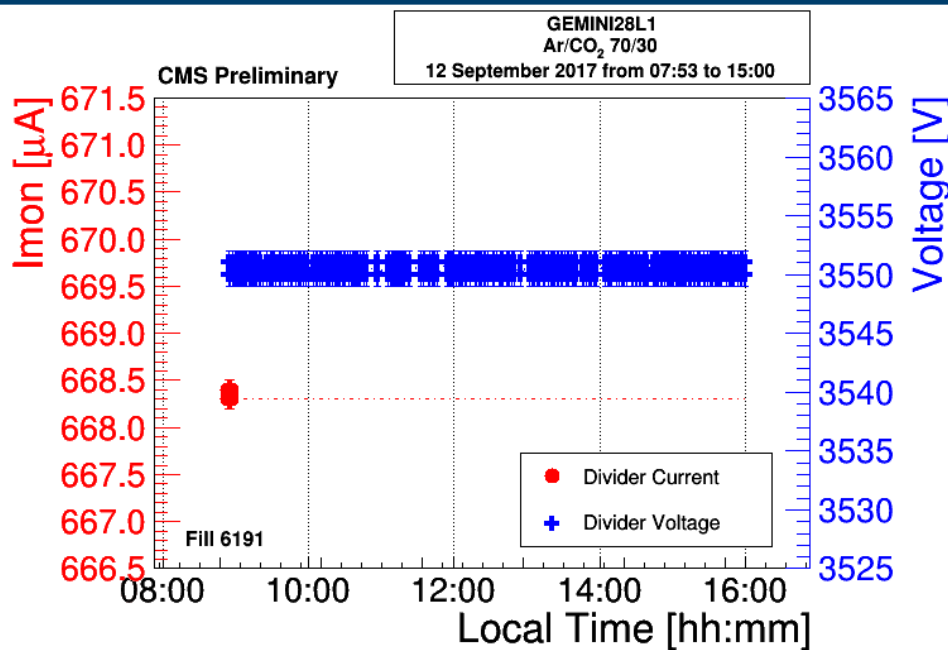→ 7 HV channels per layer

(*) to be used with production chambers.
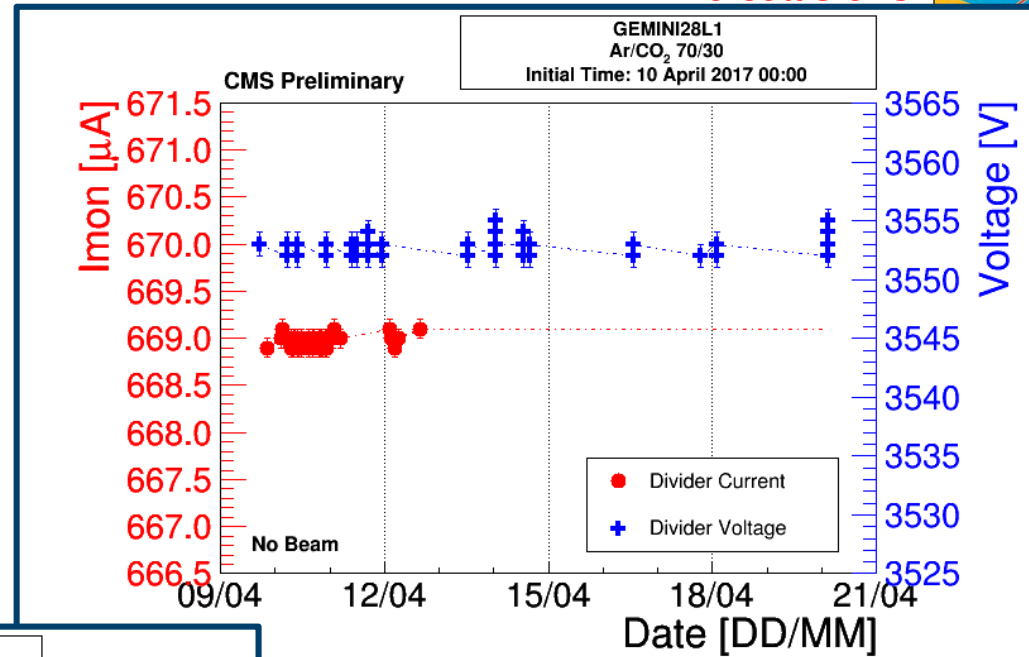
HV stability A1526 module

- An overall stability <1% is observed in a 10 days period without collisions

During collisions

An increase in current of the order of $\sim 1\ nA$ per primary electron is expected at $L = 10^{34} cm^{-2} s^{-1}$ (negligible w.r.t. the scale of the divider current)
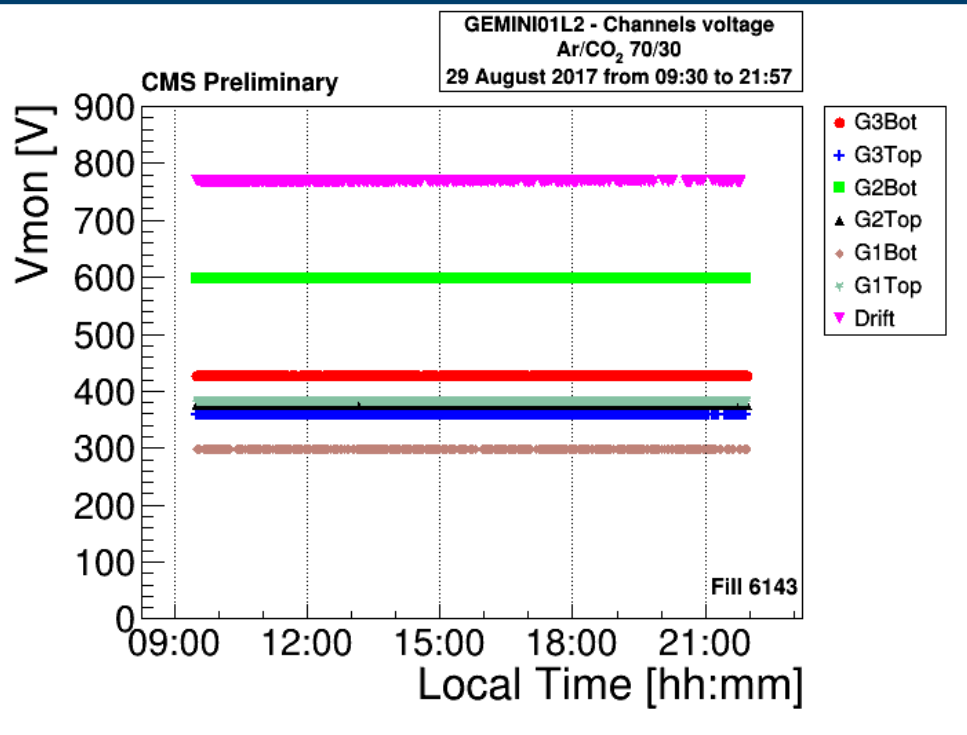
- An overall stability $< 10^{-3}$ is observed also in a 7 hours period during collisions

HV stability A1515TG module

- An overall stability $< 10^{-3}$ is observed in a 7 days period without collisions

During collisions

GEMINI01L2 - Channels voltage
Ar/CO$_2$ 70/30
Initial Time: 13 April 2017 16:34

CMS Preliminary

No Beam

GEMINI01L2 - Channels voltage
Ar/CO$_2$ 70/30
29 August 2017 from 09:30 to 21:57

CMS Preliminary

Fill 6143
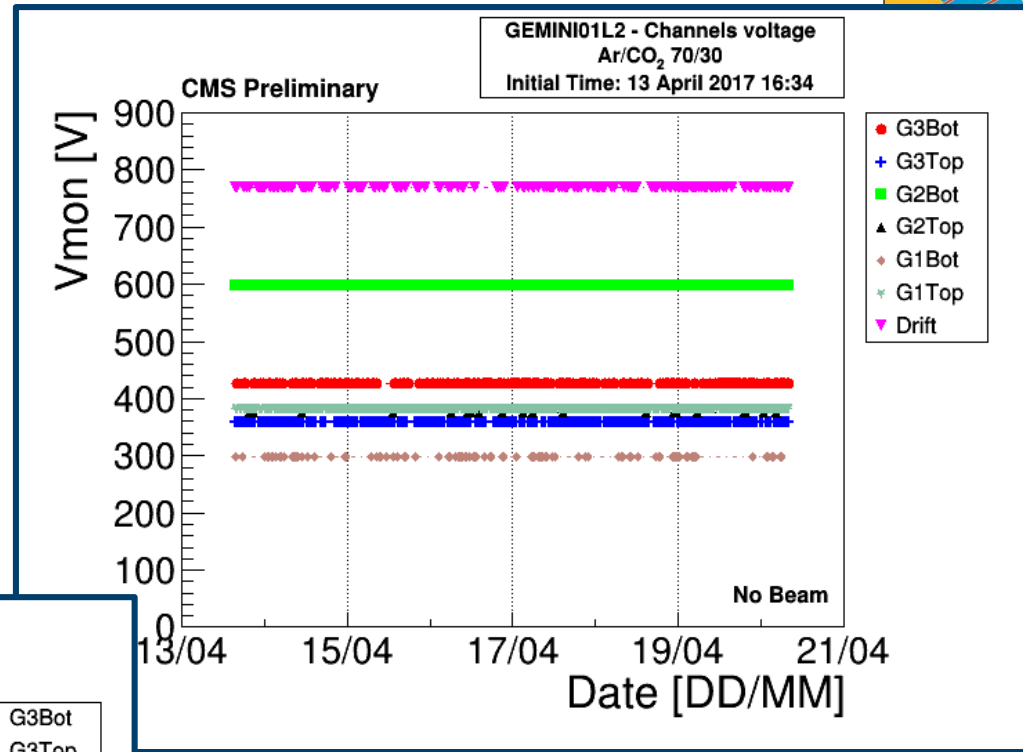
- The same $< 10^{-3}$ stability is observed also in a 12 hours period during collisions

The Readout and LV system
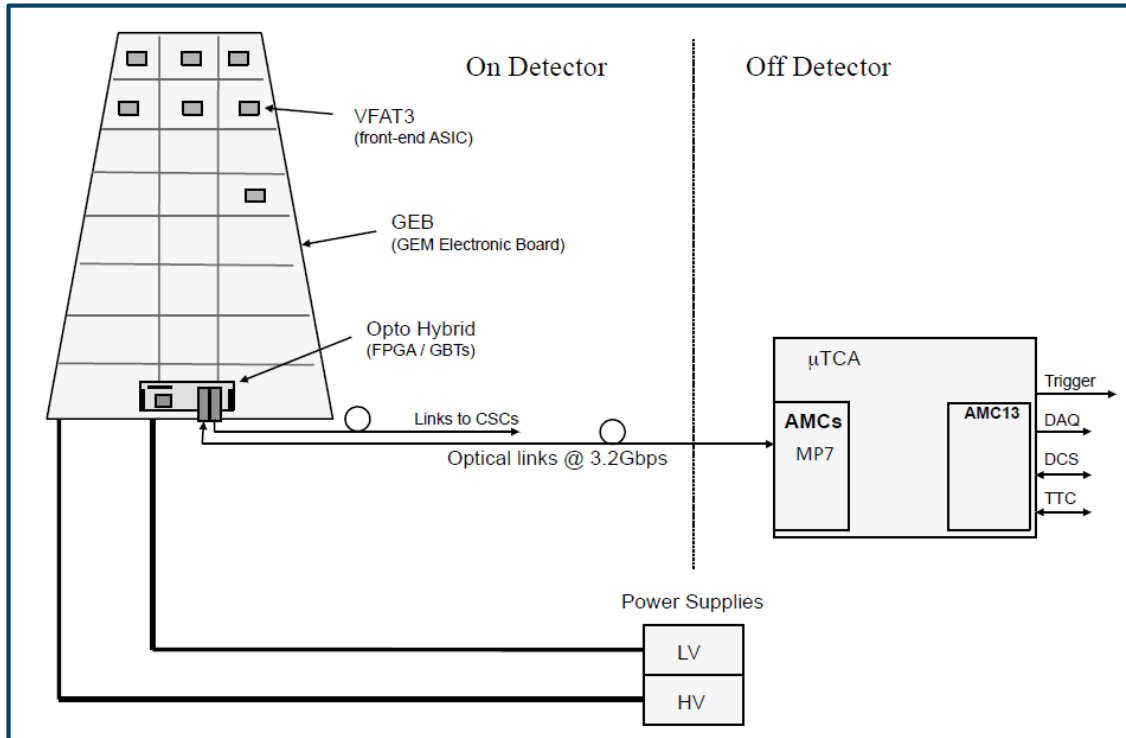
- The readout system is based on VFAT2 [*] chip and OHV2b
 - Optical fibers for data flow and control (8 fibers per layer)

- The LV power system requires **3 LV channels per layer**:
  1 to power the VFAT (approx. 3.3 V)
  2 to power optohybrids (approx. 4V and 1.7 V)

(*) VFAT3 will be used in the production chambers.

LV stability - VFATs

- Two different ranges:
  running mode → the current increases up to about 6.5 A
  sleep mode → the current is around 2 A.

- Values overall stable during a 10 days period
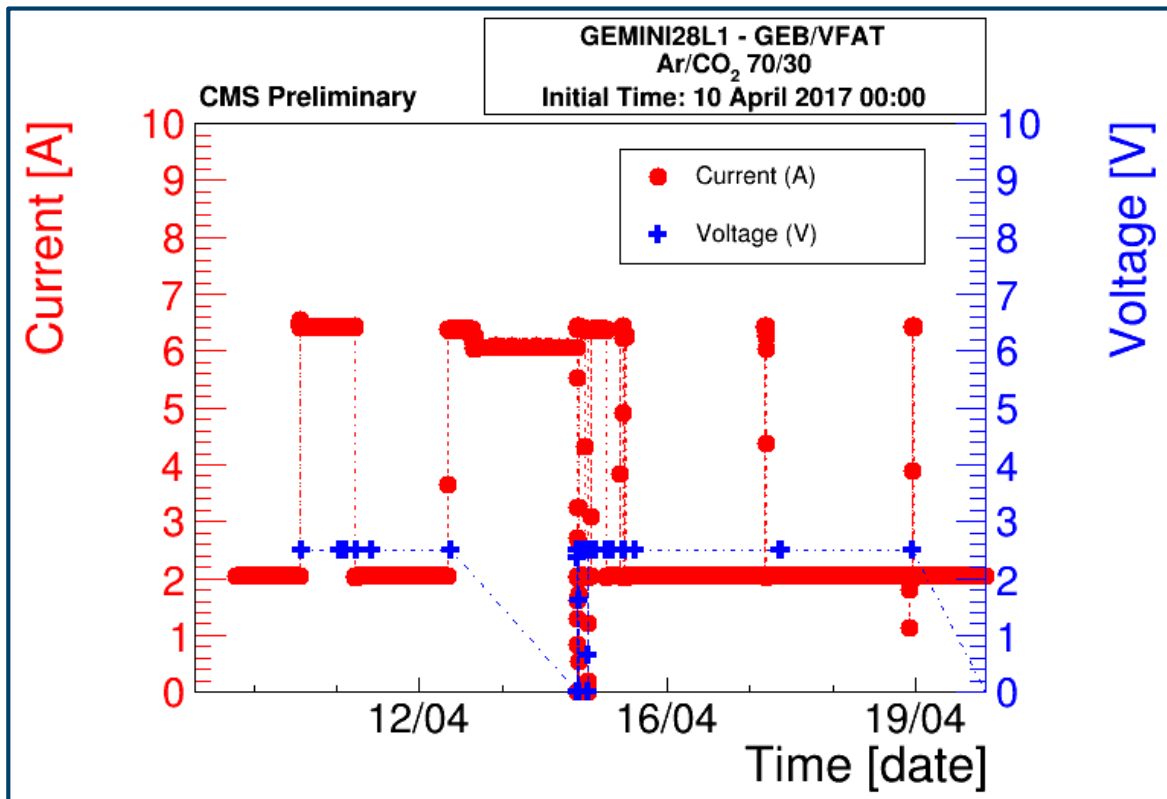
Note: on the 14th of April the data series go to zero because the LV has been off for a short period.

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System Calibration

Threshold scans	→	Scan the noise of the channels as function of applied threshold.
S-curves	→	Scan the response of the channels to an injected pulse calibrated to a given charge at a given threshold. It indicates at which amplitude of the calibration pulse a signal becomes visible, i.e. a conversion between the threshold and the charge, to evaluate the equivalent noise charge of the system.
Latency scans	→	Scan the ratio of events with detected hits over the total number of events, per different latency values. *The latency is the time difference between the time of arrival of a L1Accept (L1A) and the time at which the related event was stored.

Calibration: S-curves

## Before trimming
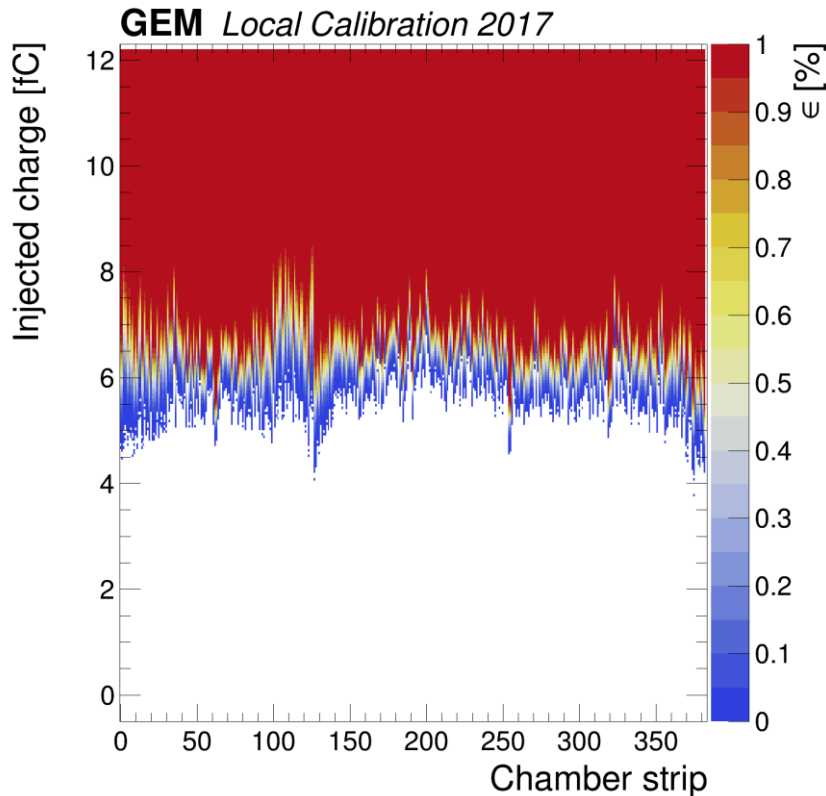
After trimming
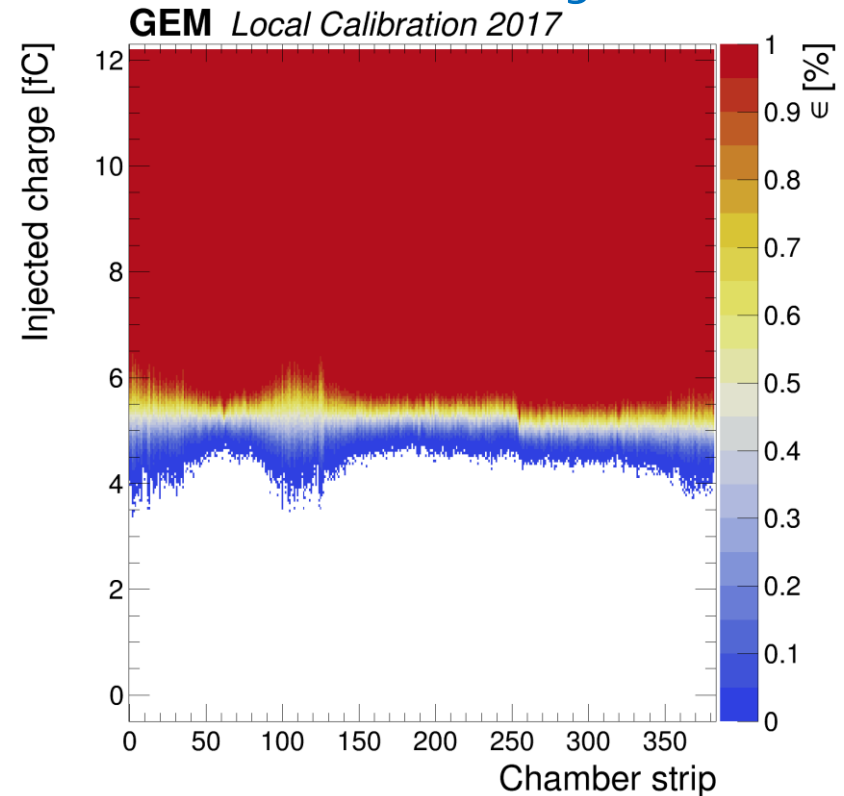
The channels display a dispersion of the 50% of hit-per-pulse ratio → the effective threshold is not constant across the chips.

The threshold value is adjustable channel by channel using programmable registers
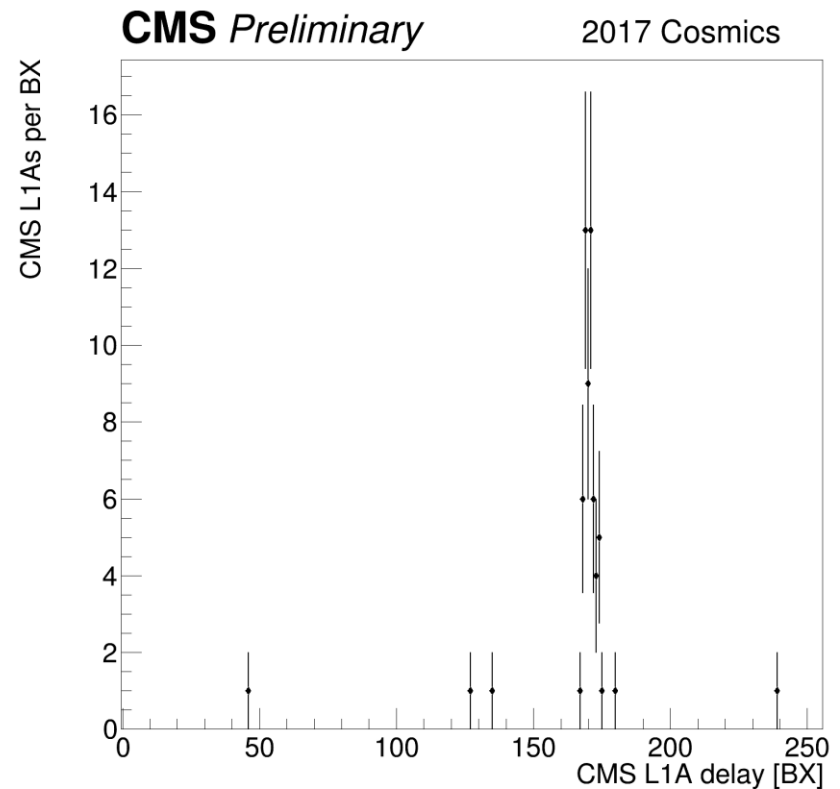
After trimming the channels display a reduced dispersion of the 50% of hit-per-pulse ratio around the average one.

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Detector Performance

Delay between seen S-bit and received L1A for cosmic ray muon data
(Expected delay = 175 BX)
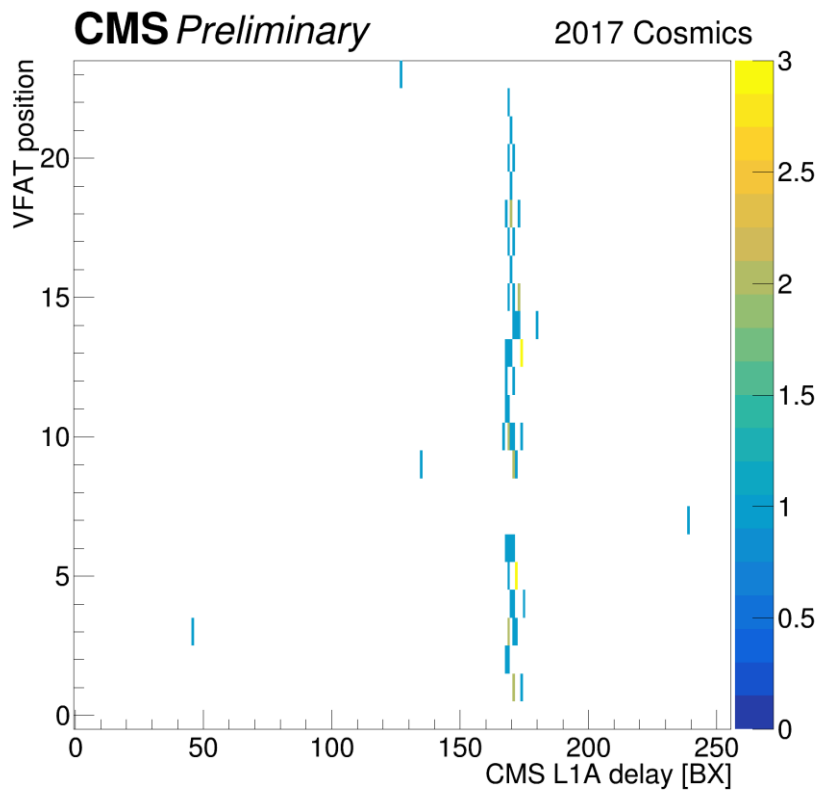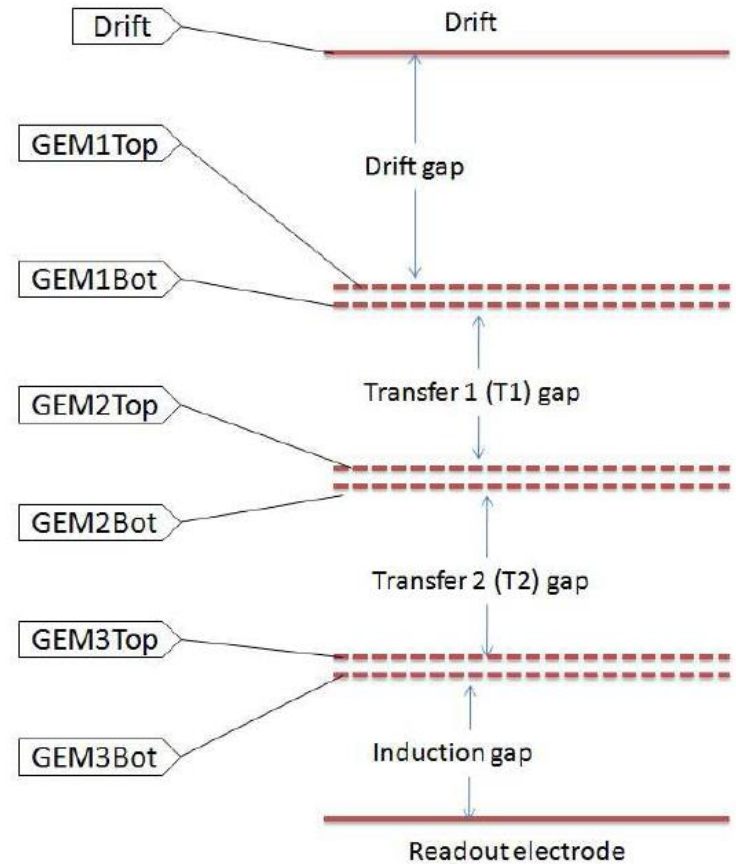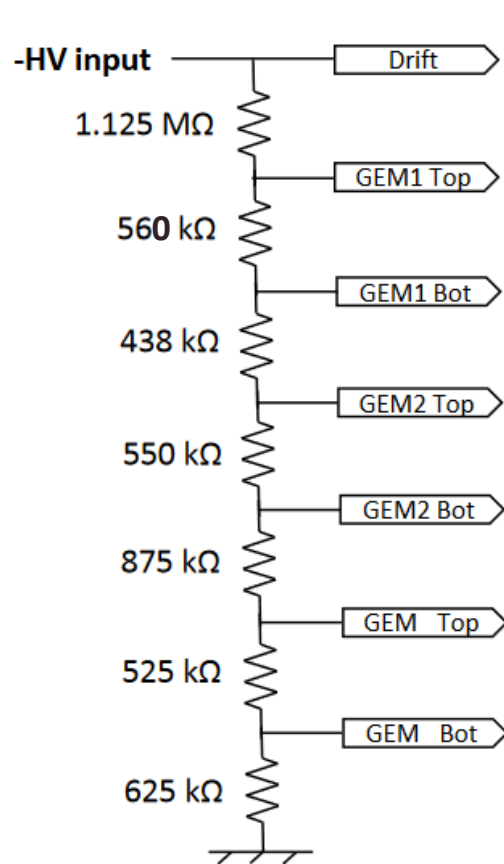

Per VFAT position

Integrated over all VFAT positions

Summary

- The installation of GE1/1 chambers based on GEM technology has been scheduled in order to allow maintaining an acceptable trigger rate after the LHC upgrades.

- A Slice Test composed of 5 Gemini chambers has been installed at beginning of 2017 and is under commissioning:
  - HV and LV systems: functional and stable.
  - DAQ system: work is progressing, not yet functionally used
  - Electronics: functional and successfully calibrated.
  - Operation: successfully detected cosmic ray muons and muons from pp collisions.
  - Other aspects not covered here: gas system, cooling system, cable routing and other necessary services have been installed/performed and working properly.

- Production of GE1/1 chambers is in a full swing.

Backup

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VFAT2

Main features:

- A 128 channel chip for charge sensitive readout of multi-channel silicon & gas particle detectors

- Trigger: Provide intelligent "FAST OR" information for the creation of a trigger.

- Tracking: Binary "hit" information for each of the 128 channels

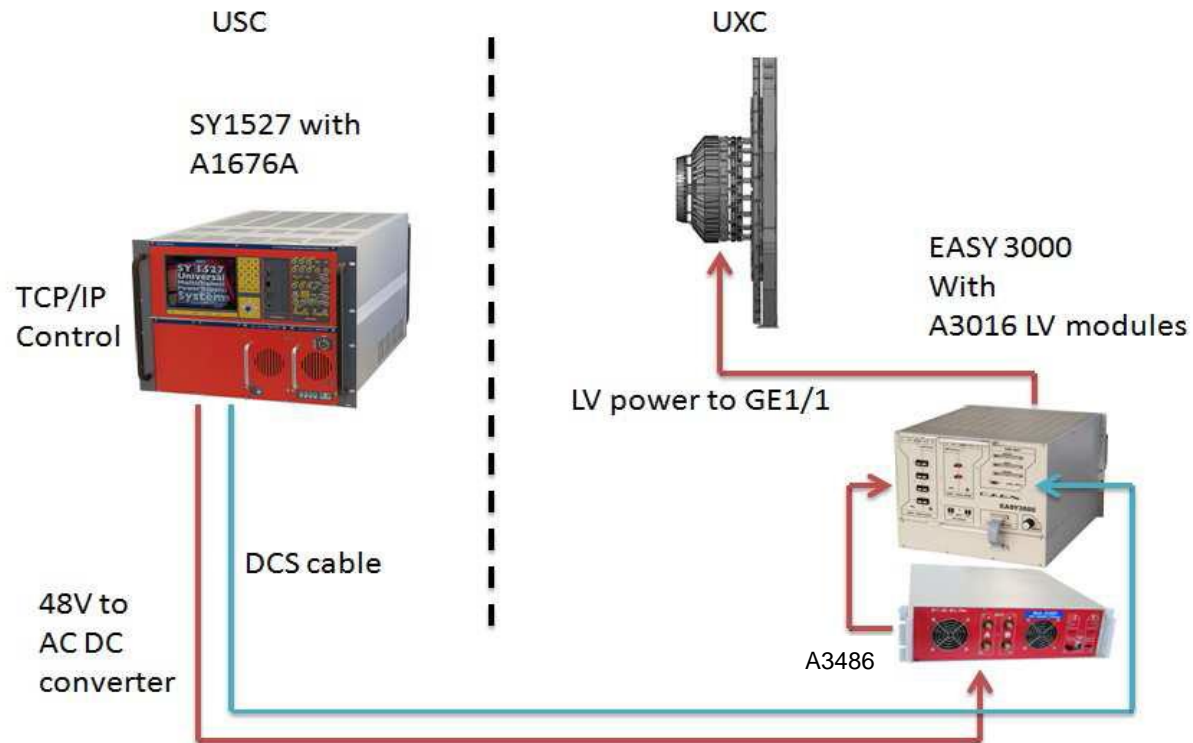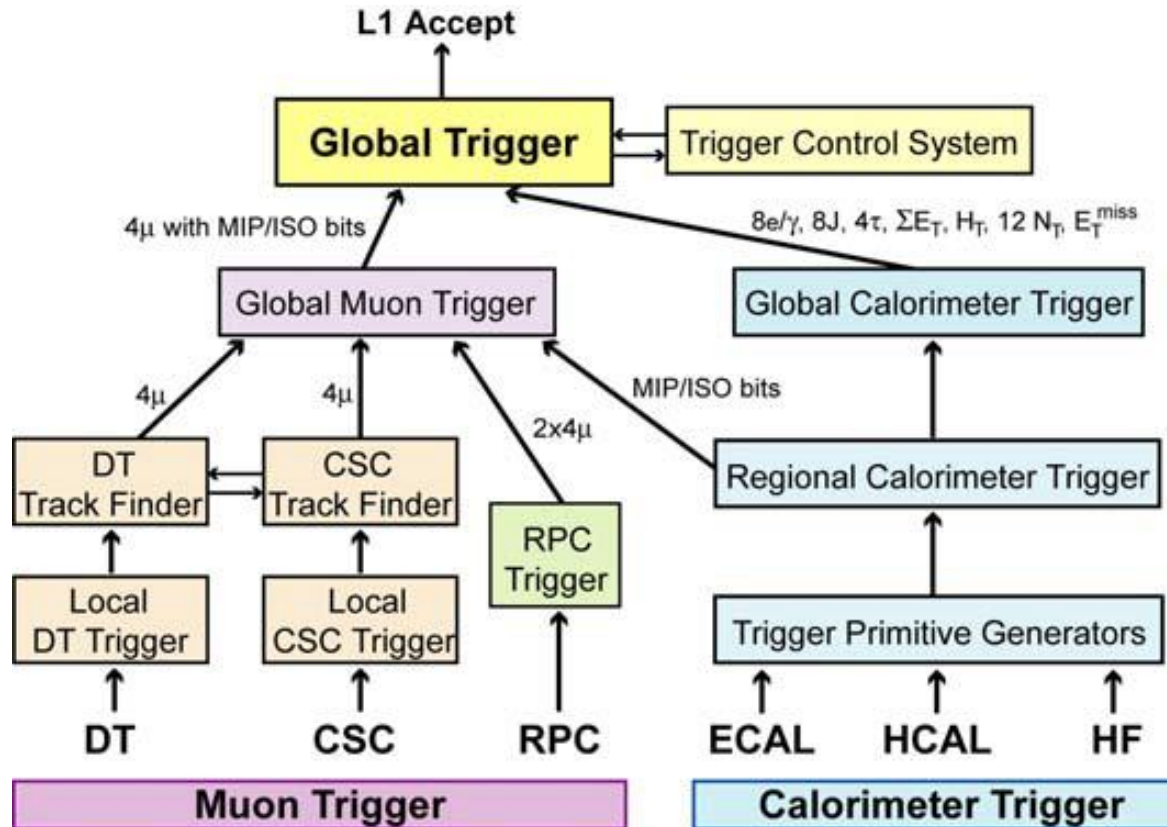- 40MHz signal sampling (dead time free)

Reference:

"VFAT2: A front-end system on chip providing fast trigger information, digitized data storage and formatting for the charge sensitive readout of multi-channel silicon and gas particle detectors", Proceedings of TWEPP Prague, Czech Republic, 3-7 September 2007, ISBN 978-92-9083-304-8, p.292

P. Aspell, CERN

LV System

USC

UXC

SY1527 with
A1676A

TCP/IP
Control

EASY 3000
With
A3016 LV modules

LV power to GE1/1

DCS cable

48V to
AC DC
converter

A3486

Architecture of the Level-1 Trigger

The CMS experiment at the CERN LHC, 2008 JINST 3 S08004

iη sectors

- Readout strips are arranged in eight iη-sectors

- Each iη sector comprises 384 strips, so that three VFATs (128 strips each) are used for the read-out of each iη-sector

- iη sectors get wider from iη sector 1 to iη sector 8

VFATs

η

iη sectors

1
2
3
4
5
6
7
8

128 strips

φ