TIPP2023 TECHNOLOGY IN INSTRUMENTATION & PARTICLE PHYSICS CONFERENCE

The Power System of GEM-Muon Sub-Detector for CMS Phase-II Upgrade

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On behalf of CMS Muon Group

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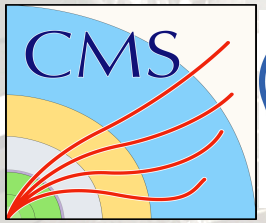


Overview of GEM* Muon Detector

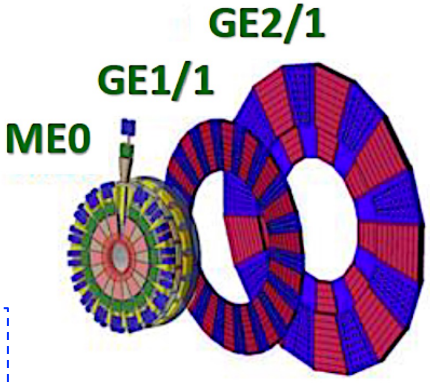
Three Triple-GEM based stations:

GE1/1 in region $1.55 < |\eta| < 2.18$,

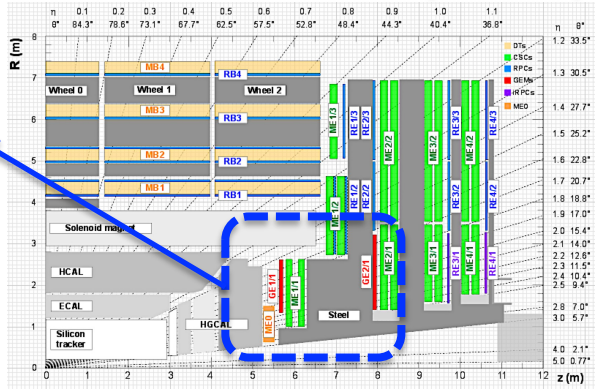
GE2/1 in region $1.62 < |\eta| < 2.43$,

ME0 in region $2.0 < |\eta| < 2.8$

They are partly overlapped in η in order to avoid gaps and increase redundancy!

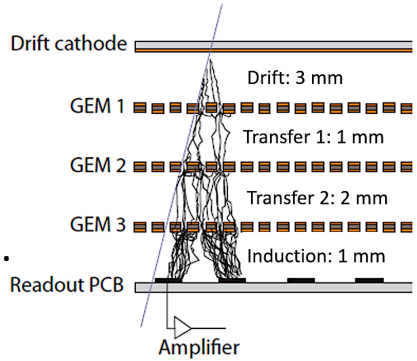


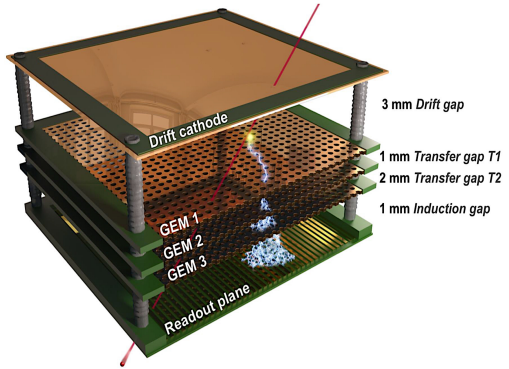
*GEM (Gas Electron Multiplications)



→ GE1/1 was installed (2019/20) & is taking Data since the beginning of Run3 (May 2022).

→ The GE2/1 and ME0 stations will be installed during the next Year-End Technical Stop (YETS) and Long shutdown-3 (LS3) (2026/29) respectively.

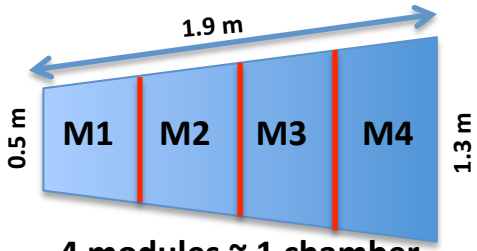




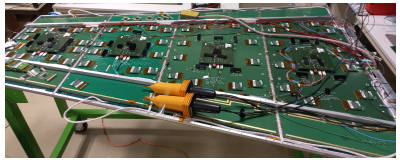
Overview of GEM Muon System

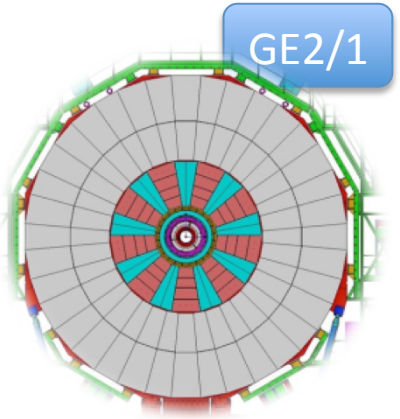
Each GE2/1 chamber consists of 4 independent triple-GEM modules.

For both Endcap: 72 chambers (36 per endcap).



4 modules ~ 1 chamber

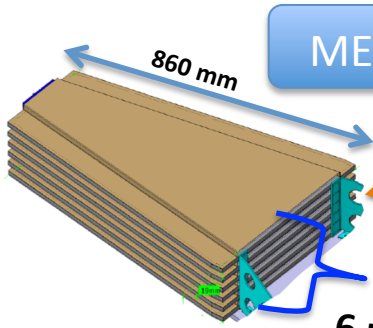


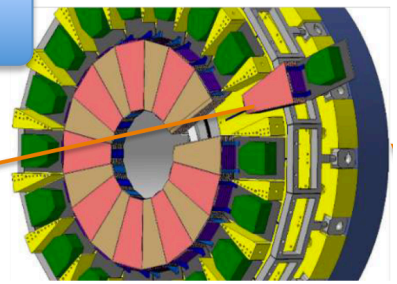


Each ME0 detector consists of 6 stacked layers of triple-GEM modules.

For both Endcaps: 36 stacks (18 per endcap)

Each module has 7 independent HV electrodes (GEM foils and gaps)



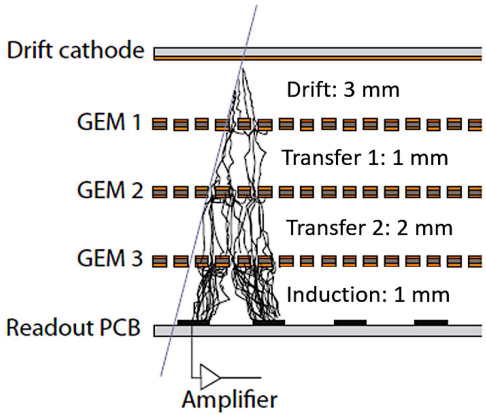


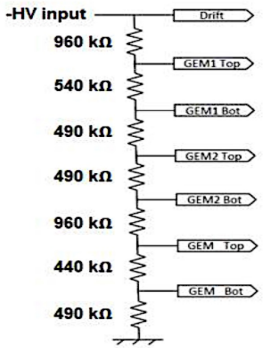
6 modules ~ 1 stack

The Power Systems for GEMs

High-Voltage Power System (HV-PS)

Used to generate the electric field needed for the multiplication of electrons inside of the GEM foils

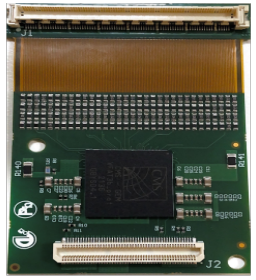




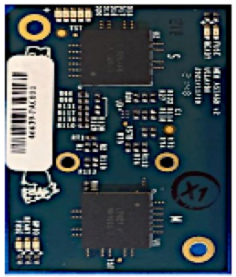
Low-Voltage Power System (LV-PS)

Is crucial for the GEM On-detector electronics (VFAT3, Opto-Hyprid (OH), ..)

Plugin card



OH



HV-Power System Requirements

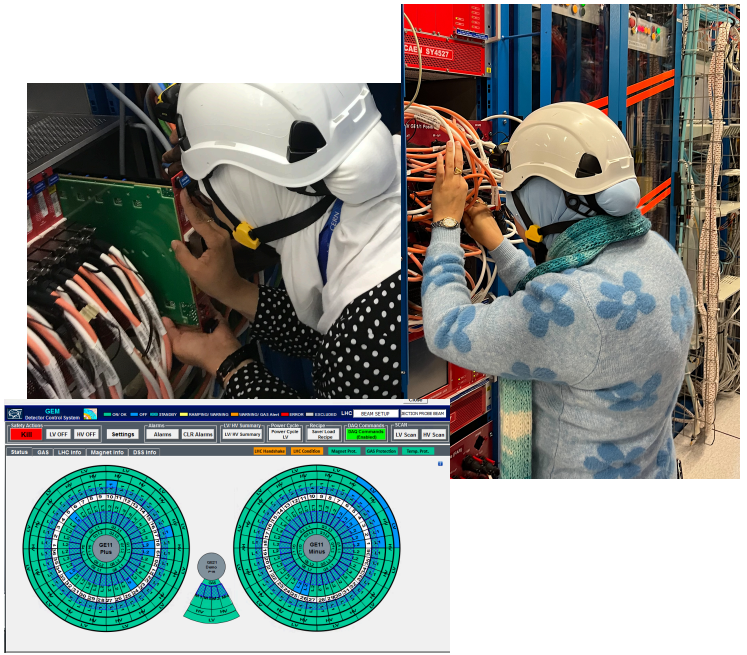
1. Very high stability:

- No over-voltage (< few Volts) during the ramping (up/down)
- Voltage stability = 0.2%/^{o}C ± 0.2 V (< 2V/^{o}C)
- Voltage stability at fixed temperature < 0.1% (1V)

2. Low noise (< 10 mV pp)
3. Fast feedback in case of local discharge
4. Hardware and software voltage limitation
5. Accessibility (during the operation):

To disconnect malfunctioning area and
replace hardware components

5. Compatibility with CMS DCS (Detector Control System) and DSS (Detector Safety System).



High-Voltage (HV-PS)

- HV-PS of each GEM station (GE1/1, GE2/1 and ME0) is independent.
- HV modules for each GEM station (SY4527 Maniframes, Power supplies, and HV-boards) are hosted in 2 racks in Underground Service Cavern (USC)
- The connections from These HV modules to different GEM chambers is done using different cables going from USC to UXC and passed through some Patch-Panels.

Racks in CMS USC
GE2/1 – GE1/1

Mainframe SY4527

Primary Power supply A4531

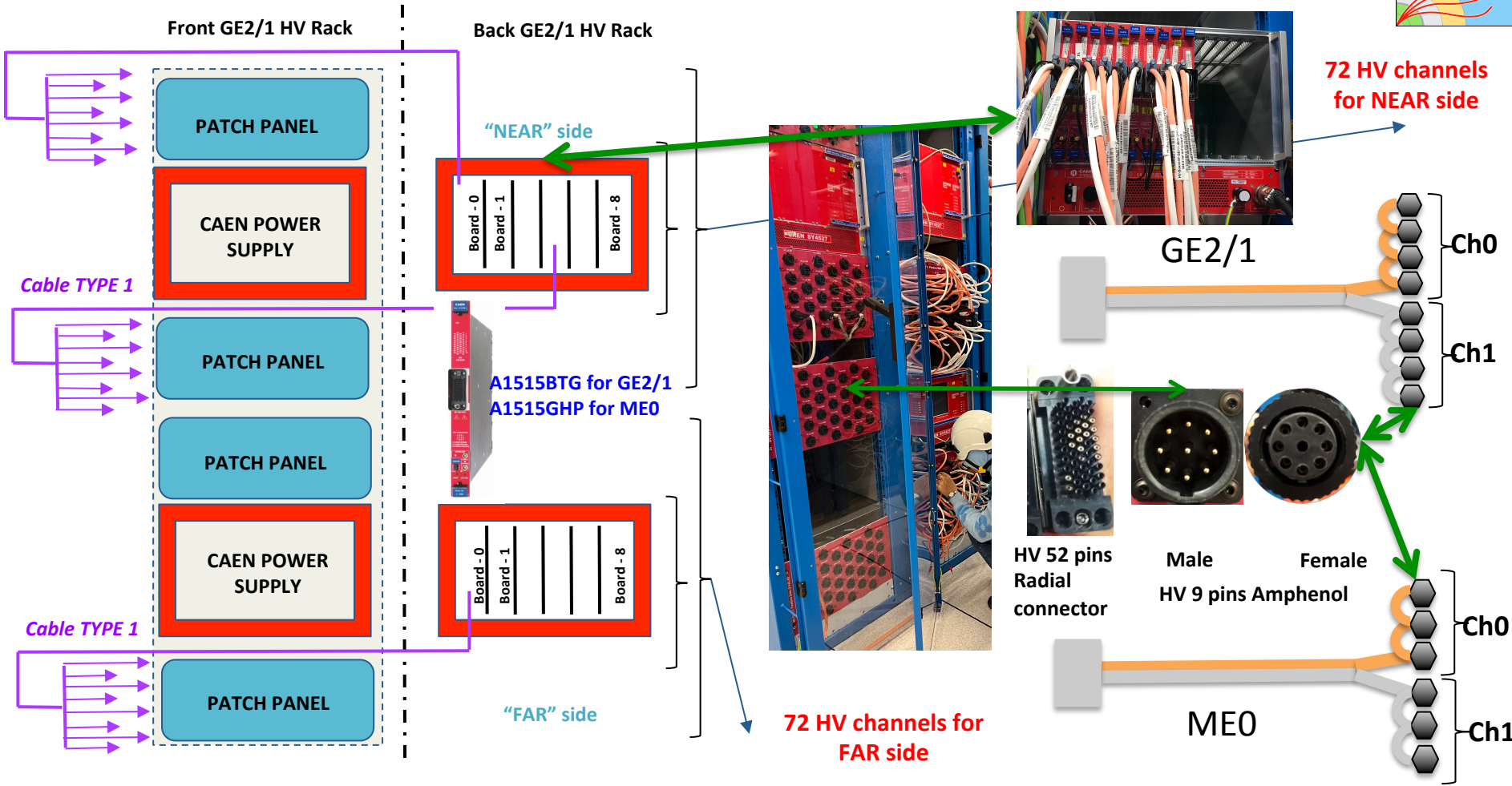
Power supply booster:
- A4532 (600W)
- A4533 (1200W)

High-Voltage (HV-PS)

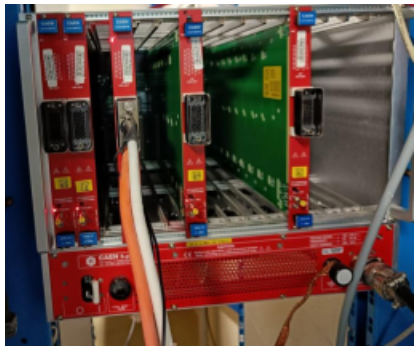
- **A1515 HV boards** are single width board (5 TE wide) that house **14** independent high voltage Individual Floating channels. All versions are equipped with Radial Multi-pin connectors.
- The 14 independent channels grouped in 2 complex channels (Ch0, Ch1) accessible via Radial 52 pin connectors.
- The CAEN A1515BTG HV-boards are used to power GE2/1 chambers, while A1515GHP will be used for ME0.
- The main difference:
  - A1515BTG can provide 1KV/1mA (0.7W) per channel, while A1515TGHP provides 500-600V/3mA (1.5W)per channel.
  - A1515TGHP board specially designed for High-Rate applications

- More details and operation of CAEN A1515B can be found
https://www.caen.it/products/a1515b/

NEGATIVE (POSITIVE) MUON ENDCAP - USC cavern



Validation of HV-boards

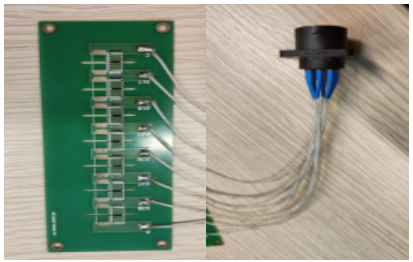


In order to confirm that every single HV-board meet the specifications, each board (A1515BTG, A1515TGHP) is tested before installation in CMS Cavern.

1. **Voltage test (open circuit):**

- During this test, the voltage stability (in open circuit configuration) should be confirmed within the limits of the specifications

1. **Current test:**



- In this test the board is connected with a load (set of resistors) with a switcher. The switcher allows the addition of parallel resistances to an electrode, to simulate a detector with a short circuit.
- The load is adjusted to obtain the maximum current on each channel, and the current and the voltages are monitored over night.

GEM LV-PS Components

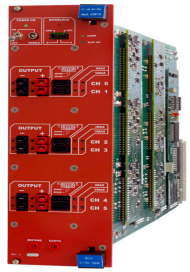
Mainframe SY4527

A1676
Branch controller

"A3486LS" MAO

"3000S" Easy-Crate

A3009HP



A3016HP

1. One Mainframe SY4527 is to host 4 CAEN A1676 Branch controllers that are used to control all the GEM stations (GE1/1, GE2/1 & ME0). *Thanks to A1676 Branch controller configuration which can host up to 6 crates (+ 6 power converters).*
2. The "A3486LS" AC/DC Power Converter (MAO) provide 4kW (2 kW per channel).
3. The efficiency of "3000S" Easy-Crate = 60%.

Taking in consideration all these inputs + experience we gained from GE1/1 operation, we could design the LV-PS for GE2/1 and ME0 stations!

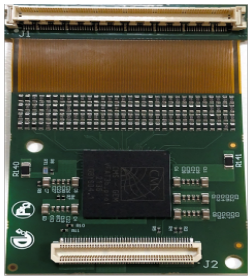
Low-Voltage (LV-PS)

- The strategy is to extent the current LV power system of GE1/1 by adding extra modules to power GE2/1 and ME0 chambers.

→ *The current measurements of GE2/1 Demonstrator (one GE2/1 chamber was installed in CMS and in operation since beginning of LHC Run3) shows that for each GE2/1 module (OH+VFATF3) the max. power consumption < 25W.*

→ *The current measurements of ME0 modules in the lab shows that a full module (plug-in cards + OH) consumes ~ 16 Watts. Taking in consideration the working conditions in CMS experiment, the expected power consumption per module should be between 20 – 25 W.*

Plugin card



~ 0.322 W
0.136 W for digital
0.186 W for analog

OH

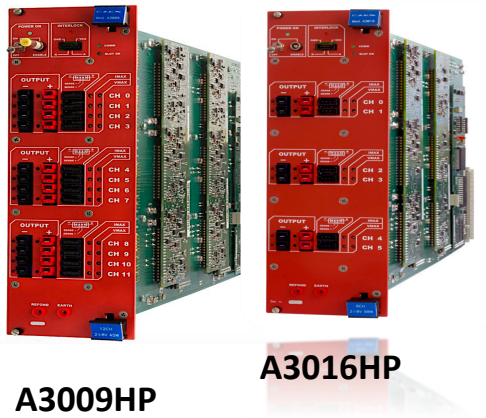
~ 0.882 W
0,648W (1,2V)
0,234W (2,5V)

In All GEM detectors, each module is powered by one independent LV channel

Facts about LV-PS Components

- The A3009HP (12 channels) /A3016HP (6 channels) board are upgraded versions of the standard A3009/ A3016 respectively:
  HP Board is modified to work between 0-14 V, while the standard A3009/A3016 work between 0-8 V.
- The difference between A3009HP & A3016HP is max. current/ power per channel, is up to 5A/45 W, and 8 A /90 W respectively.

	GE2/1	ME0
Chambers/stacks	72 chamber (36 per endcap)	36 stack (18 per endcap)
Modules	288	216
LV boards	24 A3009HP	16 A3009HP + 4 3016HP



A3009HP

A3016HP

Validation of LV-PS Components

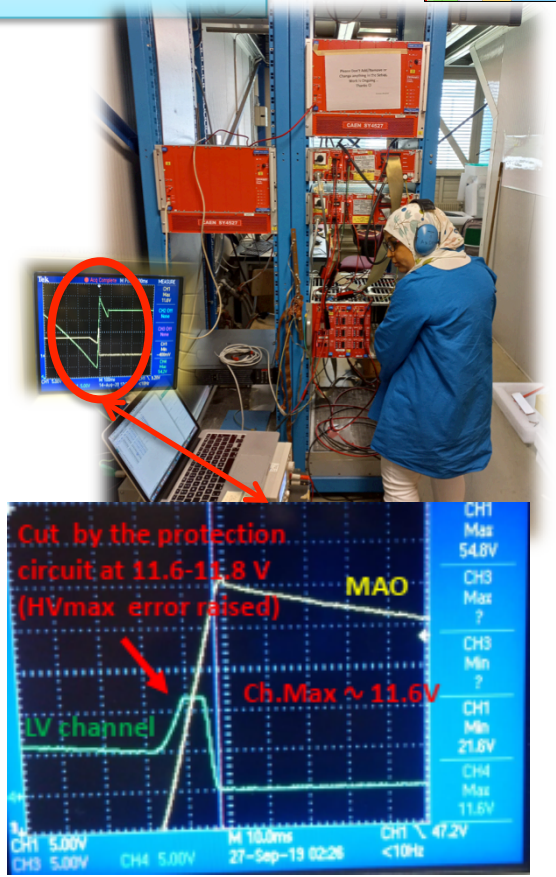
→***Special modification for GEM:***

- The output of each channel for both A3009HP & A3016HP is adjustable between 6-11.8 V (with hardware protection).

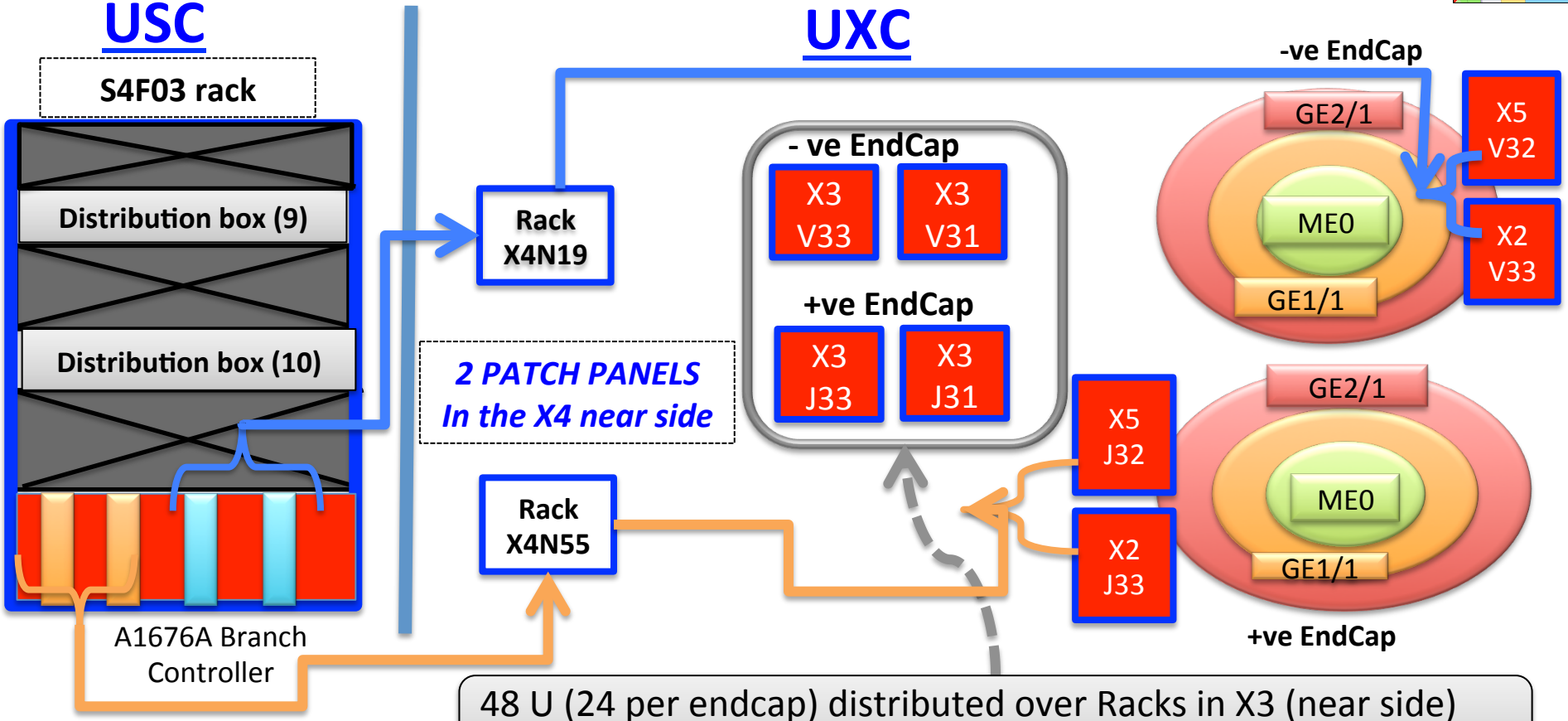
→*Before installation in CMS cavern, all LV-modules are undergoing some tests in lab to verify the required specifications.*

1. Longtime monitoring (for AC/DC power converters).
2. For LV boards :

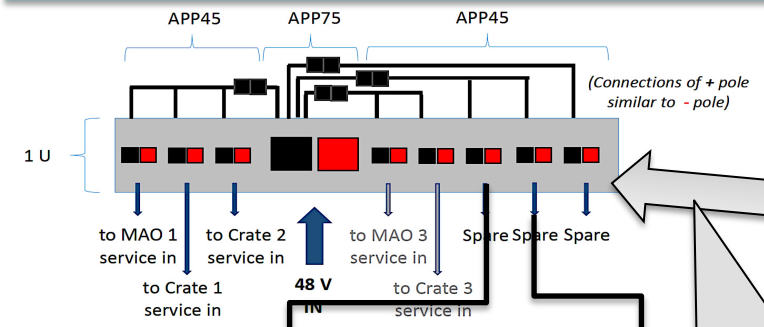
- "max. Current" test to verify that 5 A can be reached.
- "Transient" tests in the lab to ensure 11.8 V limit in case of power interruption.

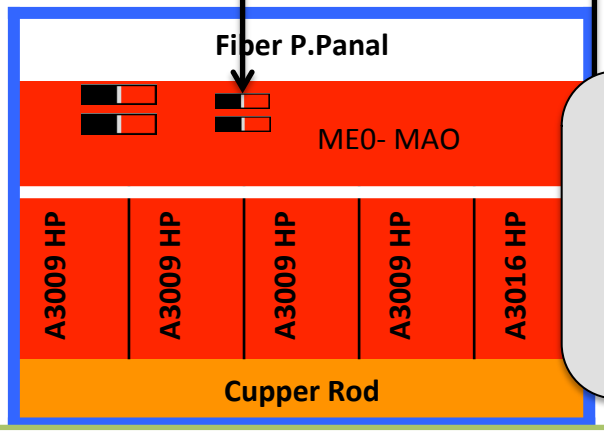


- The modules of LV system of GEM are distributed between Underground Services and Experimental Caverns (USC, UXC) of CMS experiment.



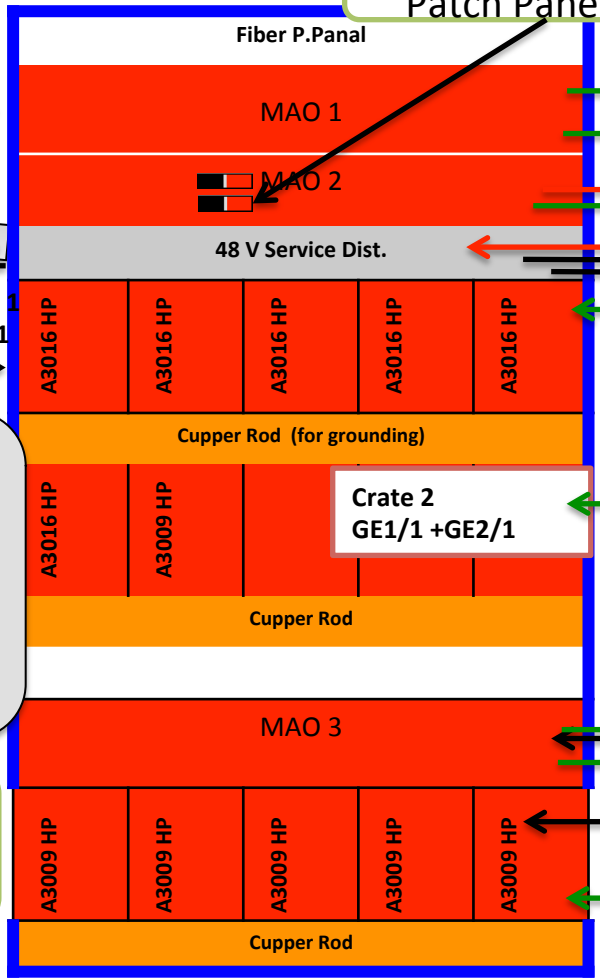
48 V Service & Power





Service

48 V service from Patch Panel (PP)



Using this distribution box helps to reduce the number of used MAOs (save space and money budgets)

- from Patch Panel (PP) to Serv. Input of MAO2.
- From CH1 of MAO2 to the input of Service Dist.
- Other MAOs and Crates take 48 Serv. From service Dist.

Summary

- The LV and HV power systems of GEM are based on CAEN commercial modules with some modifications to adapt the GEM detectors requirements.
- The Chosen HV boards full-fill the requirements: stability, operating voltage and current range.
- The Chosen LV boards (A3009HP, A3016HP) are modified with Hardware protection to ensure the safe operation in case of spikes.
- All HV/LV power systems components are being tested to validate the requirements.

Grazie

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Thanks

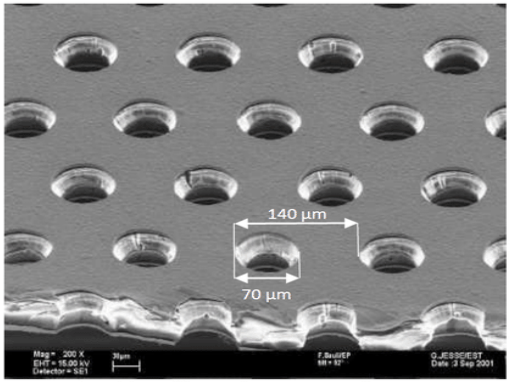
CMS GEM Muon

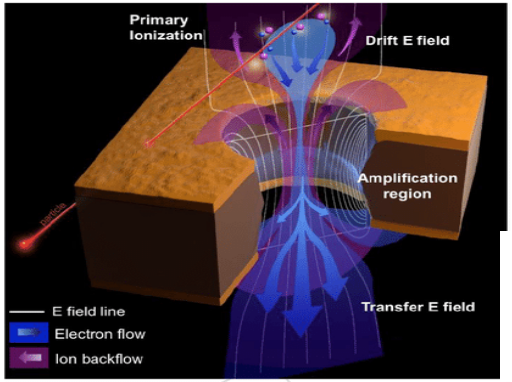
Detector

Backup

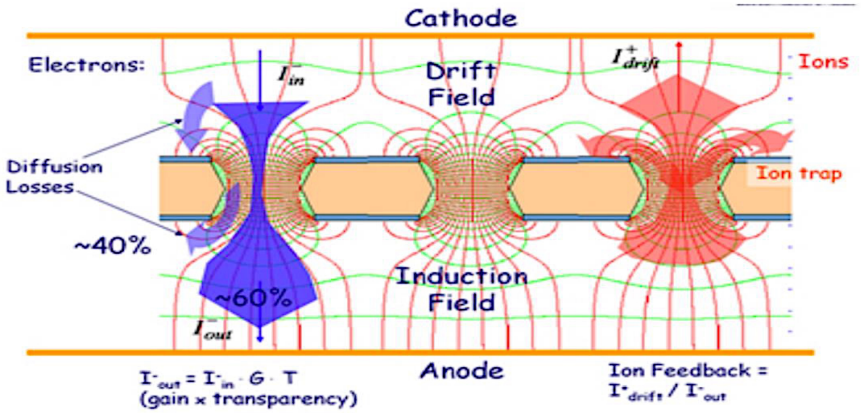
Technology of GEM detectors

- A GEM foil is a 50-µm-thick polymer foil covered with 5-µm-thin copper sheets on both sides, and chemically perforated by a high density of microscopic holes.





Each hole acts as a proportional counter with gains up to 800 at voltages between 500 and 550 V.



NEGATIVE (POSITIVE) MUON ENDCAP - UXC cavern

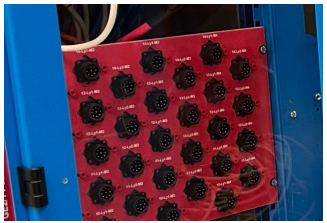
Cable Chain from USC to UXC

4 x (1to1) cables

~ 90m near /104m far AWG 22

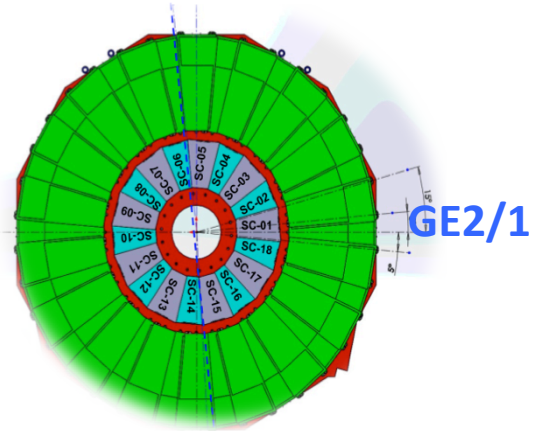
2 Rack on Balcony

GE2/1
PATCH PANELs
2 P.P in Far side
+
2 P.P near side



1 to 1 cables

~ 40m AWG 22



GE2/1

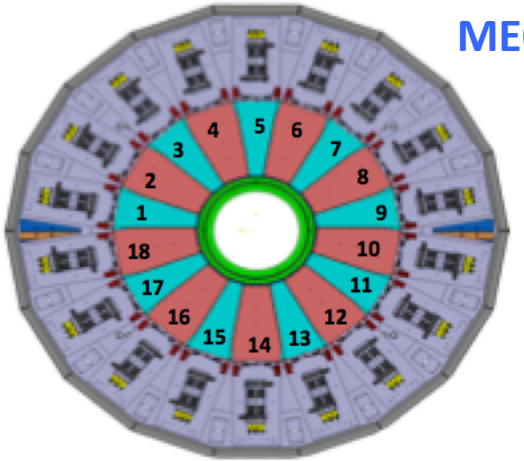
3 x (1to1) cables

~ 90m near /104m far AWG 22

ME0
PATCH PANELs
2 P.P in Far side
+
2 P.P near side

2 Rack on Balcony

1 to 1 cables



ME0

Cable Chain from USC to UXC

GE2/1 - ME0 LV Power System Components

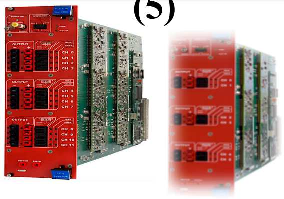
(1)

(2)

(3)

(4)

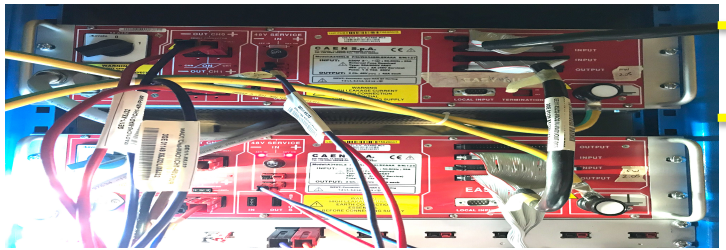
(5)



	Component	Quantities	Notes
1	Mainframe SY4527	1	The same ones for GE1/1, G2/1 & ME0
2	Easy Branch Controllers A1676	4	
3	48 V Power Modules A3486LS	8 (4GE21+4ME0)	4 for GE2/1 + 4 for ME0 Service will take from power distribution box fed by MAO2 of GE1/1
4	Easy 3000S Create	8 (4GE21+4ME0)	
5	LV Board A3009 HP , A3016HP	36 GE2/1 + 20 ME0	4 (A3009HP) + 1 (A3016HP) per rack for ME0
	Copper box	8 (4GE21+4ME0)	for grounding of LV channels

48 V Power

48 V service from Patch Panel (PP)



3

ME0 Rack

Fiber P.Panal

4

ME0- MAO

4 kW

A3009 HP | A3009 HP | A3009 HP | A3009 HP | A3016

Crate 4

Cupper Rod

DCS

GE1/1 – GE2/1 Rack

Fiber P.Panal

Service

Power

MAO 1

MAO 2

48 V Service Dist.

4 kW

A3016 HP | A3016 HP | A3016 HP | A3016 HP | A301

Crate 1

Cupper Rod

2 kW

A3016 HP | A3009 HP

Crate 2

Cupper Rod

MAO 3

Crate 3

A3009 HP | A3009 HP | A3009 HP | A3009 HP | A3009 HP

4 kW

Cupper Rod