Current state of the R&D on Micropattern Gaseous Detectors for the CMS muon system upgrade

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129° LHCC Meeting, 22-23 February 2017, CERN

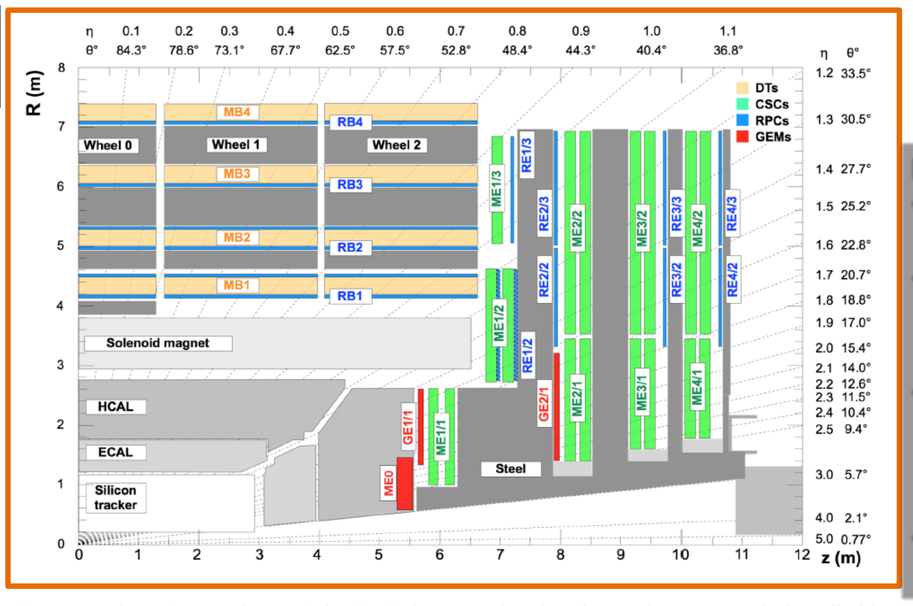
1. The CMS Muon System and Motivation for its Upgrades

The CMS muon system is composed of three different detector technologies:

- Drift Tubes (DTs)
- Cathode Strip Chamber (CSCs)
- Resistive Plate Chambers (RPCs)

In the current configuration:

- no redundancy in the region 1.6< |η|<2.2
- not instrumented at higher pseudorapidity.



Cross section of a quadrant of the CMS detector showing the stations currently installed in the muon system and the stations proposed for the upgrades with MPGDs (red).

2. Upgrades with MicroPattern Gaseous Detectors (MPGDs)

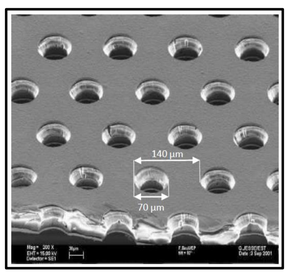
New proposed stations based on MPGDs:

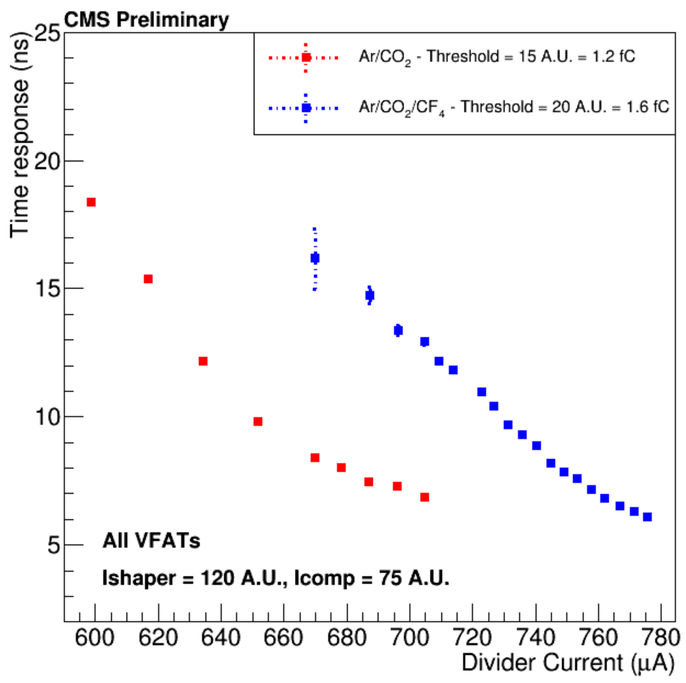
- the **GE1/1** station in the region 1.55 < |η| < 2.2 *(approved)*
  - Two layers of triple-GEM detectors [2]
- the **GE2/1** station in the region 1.55 < |η| < 2.45
  - Baseline: two rings of single-layered triple GEM detectors
  - Option: micro-Resistive WELL (μ-RWELL) detectors [section 4]
- the **ME0** station in the region 2.03 < |η| < 2.82
  - The first station at |η| > 2.2
  - Multi-layered structure
  - Baseline: 6 layers of triple-GEM detectors [section 3]
- R&D of interest:
  - Fast Timing Micropattern Detector (FTM) [section 5]

3. The Back to Back GEM detector

- Two independent triple-GEM detectors
- A triple-GEM detector is a stack of three copper-cladded kapton foils covered with holes
- In the Back to Back detector triple-GEMs are positioned with the anodes toward the outside, sharing the same cathode

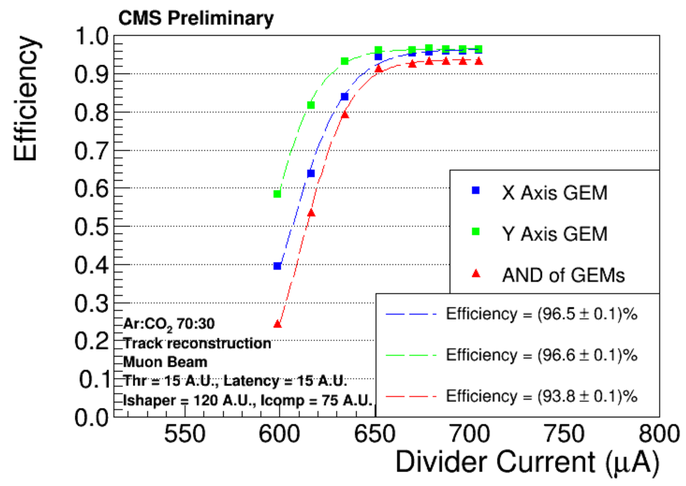
➢ Compact-size multi-layered detector

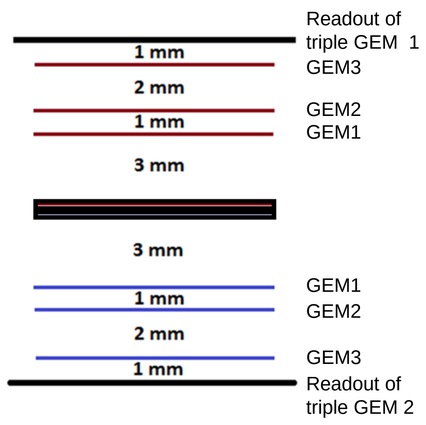




Prototype with active area 10x10 cm² has been tested:

- ➢ Gas gain: up to ~10^4
- ➢ Time resolution: up to 6 ns ($Ar/CO_2/CF_4$ 45/15/40) and 7 ns (Ar/CO_2 70/30)
- ➢ Efficiency: between 96.5% and 98.1% for a «single» triple GEM

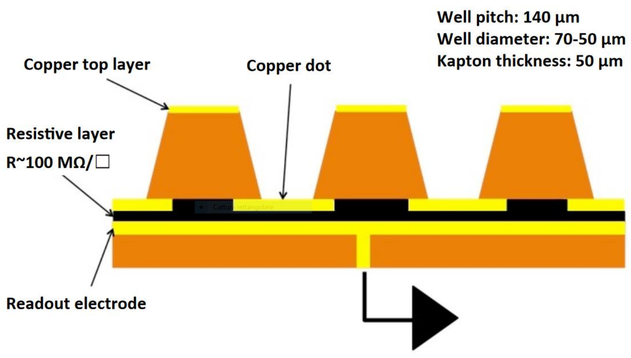




From left to right: Image of the GEM structure taken with an electron microscope, time response and efficeincy of the back to back detector operated with Ar/CO_2 70/30 and $Ar/CO_2/CF_4$ 45/15/40 gas mixtures (the dashed lines are the best fits with the equation A/(1+exp(B-x)/C)), schematic representation of the structure of the back to back detector.

4. The μ-RWELL detector

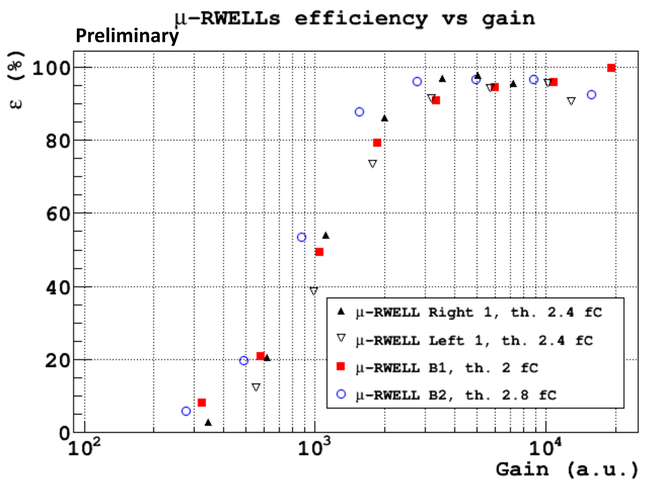
GEM foil merged with a readout PCB plane coated with a resistive deposition, with small copper dots in correspondence of each WELL structure on the bottom side of the foil.

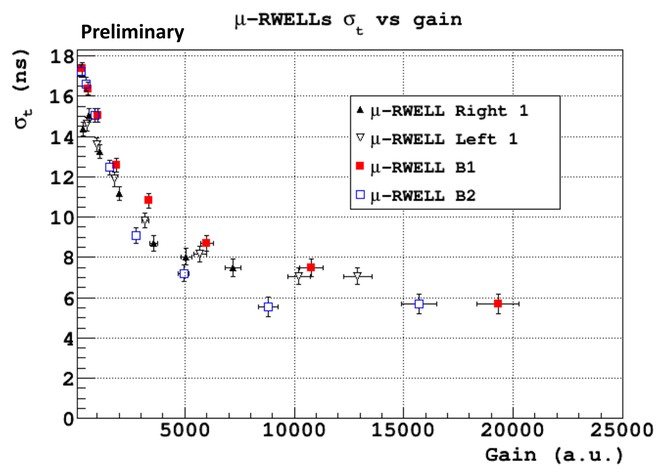


A first prototype with dimensions similar to the GE1/1 station has been realized and small active areas of the detector have been tested:

- ➢ Measured time resolution: order of 7 ns at gain of 10^4
- ➢ Measured efficiency: order of 98% at gain of 10^4

➢ The detector has easier drift vs. readout plane coupling





Above: efficiency (left) and time response (right) as a function of gain for different detector's dimensions.
(G. Morello et al., *55th International Winter Meeting on Nuclear Physics*, 23-27 January 2017, Bormio, Italy, http://www.bormiomeeting.com/)

Left: schematic representation of the amplification stage of a μ-RWELL detector.

5. The FTM detector

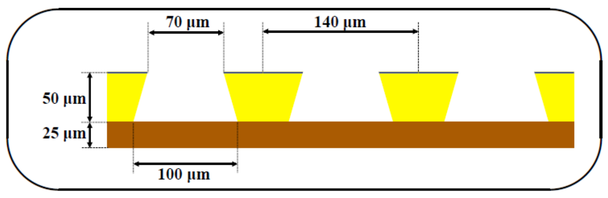
- A stack of similar layers:
  - Each one is made of a **resisitive foil with a high resistivity coating** on the top (i.e. DLC) and covered with holes, the bottom side is "closed" by an insulating material (i.e. kapton)
- At the very bottom of the detector is the readout board
- Every single layer works independently from the other ones.

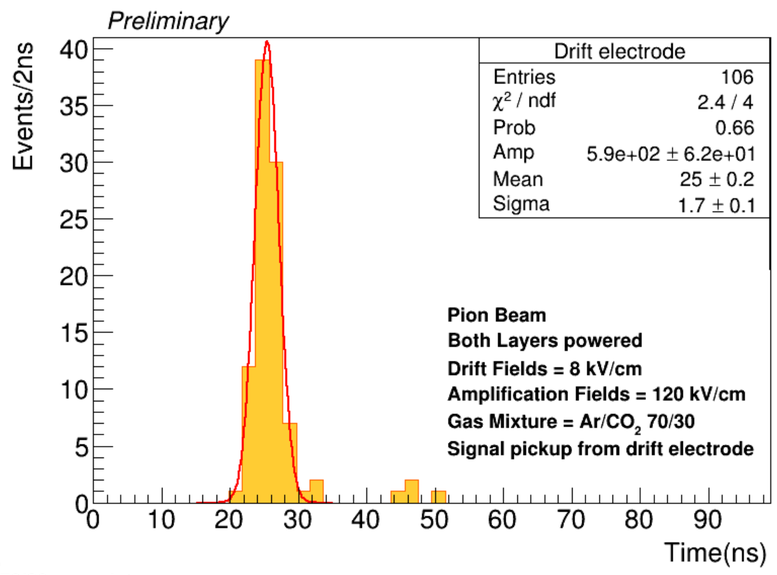
➢ Transparency: Fully resistive foils allow the signal to be inducted on readout also from further amplification layers

➢ A basic goal of FTM detector (to be verified): using the *fastest signals* produced, by increasing the number of layers time resolution should improve

Small prototype with two layers has been tested:

- ➢ Working principle and detector's transparency have been proven
- ➢ Measured time resolution: 1.7 ns with pion beam and 2.4 ns with muon beam





Above: schematic representation of the amplification stage of the FTM detector.
Right: time response of the FTM detector measured with pion beam and Ar/CO_2 70/30 gas mixture.

References

[1] The CMS Collaboration et al., (2008) JINST 3 S08004. [2] The CMS GEM Collaboration, (2015) CERN-LHCC-2015-012. [3] G. Bencivenni et al., (2015) JINST 10 P02008. [4] R. De Oliveira, M. Maggi, A. Sharma, CERN-OPEN-2015-002. [5] I. Vai on behalf of the CMS Collaboration, NIM A 845, 313, 2017.

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