First performance of triple-GEM detectors at the LHC and development of innovative micro-pattern gaseous detectors for future colliders

XXXV PhD cycle

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Overview on MPGDs in high-energy physics

State-of-the-art MPGDs

- Currently beginning to instrument large areas
- $< 100\,\mu\mathrm{m}$ space resolution
- 5-10 ns time resolution
- $100\,\mathrm{MHz/cm^2}$ rate capability

At LHC

- ATLAS Micromegas
- CMS triple-GEM

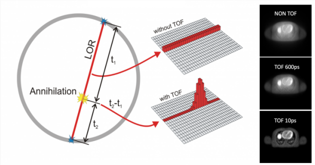
Present work directed towards discharge protection strategies

At future colliders

At FCC-ee, FCC-hh, $\mu^+\mu^-$:

- Equally large areas
- Stricter pile-up mitigation: increased time resolution needed by one order of magnitude

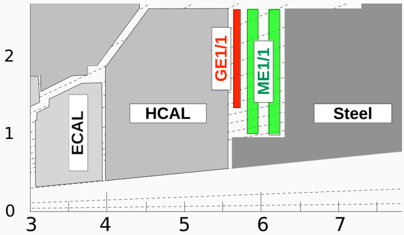
Fast timing in medical imaging



GEM detectors at the CMS upgrade for LS2

CMS upgrade

The CMS experiment is currently being upgraded to sustain the higher luminosity expected for the LHC Run 3.



GE1/1 sector in the muon system

- occupies the $1.5 < |\eta| < 2.2$ region
- made of 144 triple-GEM detectors
- 36 superchambers per endcap
- muon p_T measurement at level-1 trigger

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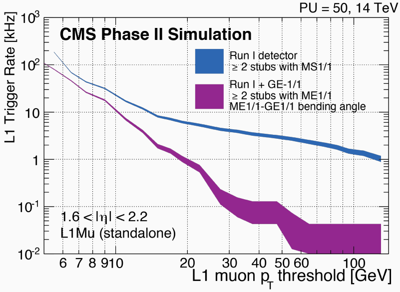

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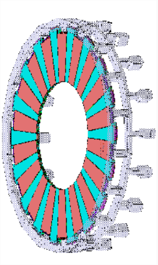
Commissioning of the GE1/1 chambers

One endcap is already installed, next one planned for early 2020.

I will take part to the various CMS cosmic runs in 2020 and 2021. Timeline:

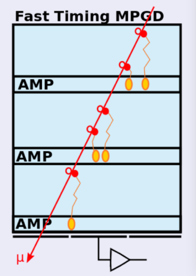


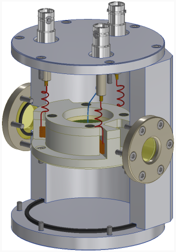
- Gaining first-hand experience on the CMS GEM detector operation (gas, HV, thresholds, DAQ)
- Ensuring GEM interoperation with CMS core
- Cosmic run at 0 and 4 Tesla and first pp collisions: chamber performance
  - Muon sample selection from CSC tracks
  - Analysis: efficiency, cluster size, noise rate, occupancy, dead areas

Overall aim: confirming the GEM viability for p_T measurement for the CMS L1 trigger.

MPGDs for fast timing at future colliders

Fast timing MPGD





Working principle and time resolution

$$\sigma_t = \lambda / N v_{\text{drift}}$$

λ = ionization mean free path

N = number of stages

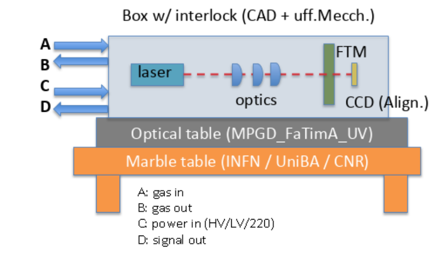
Signal pickup by external readout: **only resistive electrodes**

Tiny drift gaps (250 μm): **cannot perform gain calibration by conventional sources (X-rays)**

For 12 stages, $\boldsymbol{\sigma_t} < 500\,\text{ps}$

A 2-layer prototype was assembled in Bari and is ready for testing

The FTM laser facility



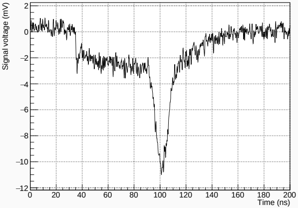
During my master thesis, I developed a **UV laser test bench** for the characterization of MPGDs.

The laser box is now **ready for the gain measurement of the FTM** and can also be used for time resolution measurements.

Plan for the FTM characterization:

- Gain measurement
- Signal transparency
- Single-layer time resolution
- Signal shape

In parallel, **complete simulation of the FTM** (`ANSYS/Elmer`, `Garfield`, `HEED`).

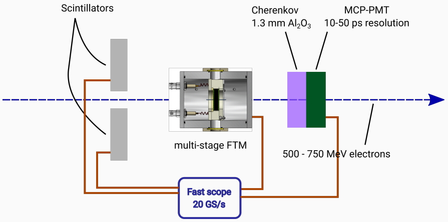


The FTM signal shape is presently not well understood.

Test beam for the FTM

A test beam for the FTM is planned for late 2020.

- Full multi-layer (4 to 16) performance
- Measure the full detector time resolution
- Time performance at alternatively powered layers



Test beam preparation

- MCP-PMT timing calibration with laser or cosmic muons
- Full test beam simulation (`GEANT4`)
  Cherenkov yield, optimization of beam parameters (beam energy loss and scattering, required intensity)
- Test setup assembly
- Feedback for improvement in future test beams

Total expected duration: 1st yr + 1/2 2nd year

Meanwhile

- A large-area FTM ($10 \times 10\,\mathrm{cm}^2$) is planned with an eventual test beam in 2022
- Investigate on the origin of discrepancies in finite-element-method software used in MPGD simulations (`ANSYS`/`Elmer`) with respect to gain measurements
- Study the requirements for the muon system at future collider experiments to determine the required gaseous detector technology. Possibly, propose the FTM solution

Backup slides

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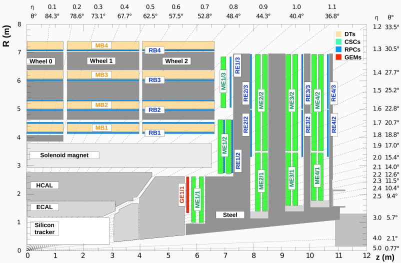

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