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DEGLI STUDI
DI PADOVA

**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

Annual report

Name and surname: Felice Nenna

Cycle and a.a.: XL cycle a.a. 2024/2025

Supervisor: Dr. Piet Verwilligen (University and INFN Bari)

Dr. Federica Simone (University and INFN Bari)

1. Research activity carried out during the year

The High-Luminosity LHC (HL-LHC) will deliver proton-proton collisions at 5 to 7.5 times the nominal LHC luminosity, with 140–200 expected interactions per bunch crossing. To maintain the performance of muon triggering and reconstruction in this high background rate environment, the forward region of the CMS Muon Spectrometer will be upgraded with Gas Electron Multiplier (GEM) detectors. In particular, three stations are scheduled to be installed in CMS; GE1/1 and GE2/1, that will work in tandem with CSC station to improve bending angle measurement and reduce the trigger rate; ME0 that will, additionally, extend the coverage of the muon trigger to $|\eta| < 2.8$.

The goal of my PhD project is twofold. On one side, it consists of analyzing and optimizing the performance of the CMS GEM detectors, evaluating their spatial and time resolution as well as their efficiency both during production stages and at trigger level; on the other side, the project aims to enhance muon reconstruction algorithms that optimize muon identification at high pile-up into the newly covered regions of the muon system. These improvements will be deployed to assess the role of GEM detectors in searches of rare decays with low transverse momentum (p_T) and high pseudorapidity (η) final-state muons.

Throughout the first year, I have completed the performance analysis of the final prototype of the ME0 detector stack, tested in a test beam campaign at the Gamma Irradiation Facility (GIF++) at CERN. I developed the so-called *Road Usage* algorithm for tracking muons through the stack and evaluated its spatial resolution, time resolution, and efficiency. The results confirmed that the ME0 design meets the requirements for the Phase-2 CMS Muon System Upgrade, paving the way for the start of mass production in Fall 2024. The first stack was completed in June 2025, and quality control is now ongoing. As part of my PhD work, I am contributing to the validation of mass-produced ME0 stacks using cosmic ray data at CERN's 904 laboratory. After the validation, during my third year of PhD, I am going to participate to the commissioning of the ME0 detector and electronics.

Midway through the second year, my focus is going to shift to studying the trigger performance of the GE1/1 chambers already installed in the CMS experiment, using proton-proton collision data collected during the 2024 and 2025 runs. The goal is to check the quality of the trigger primitives provided by the GEM and their matching with CSC trigger primitives.

Finally, I have also begun studying muon reconstruction in the ME0 system at simulation level in the HL-LHC scenario, characterized by a very large (~ 200) number of Pile-Up (PU) interactions.

Currently, I am working on developing an algorithm for improving the matching between the muon segment and the track reconstructed in the Inner Tracker. This is particularly challenging due to the high multiplicity of low- p_T tracks. Once a reliable arbitration strategy is established, the next step is to implement a quality assessment algorithm that can improve the discrimination between genuine



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muons from fakes. The final goal is to have a full Phase-2 reconstruction schema for very forward muons to compute final projections on HL-LHC flagship analyses.

2. List of attended courses and passed exams

1. Big Data Analysis in Python (2.5 CFU)

Exam passed in May 2025

2. Novel Detectors for Future Colliders (2 CFU)
3. Neural Networks (4 CFU)
4. Fundamental of FPGA-based digital design (2.5 CFU)

3. List of attended conferences, workshops and schools, with mention of the presented talks

Schools:

1. DRD1 Gaseous Detector School (CERN) | 27 Nov.- 6 Dec. 2024
2. National PhD TFPA Retreat (LNGS-L'Aquila) | 17 - 21 Feb. 2025
3. Flavor Physics at LHC School (CERN) | 26 – 30 May 2025
4. (scheduled) CMS Data Analysis School (DESY) | 13 – 17 Oct. 2025

Workshops:

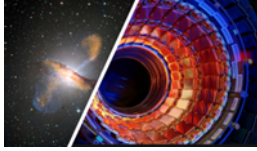
1. Talk at Incontri di Fisica delle Alte Energie (IFAE 2025)
2. Poster at the 26th International Workshop on Radiation Imaging Detectors (iWoRID)
3. Talk at the 26th International Workshop on Neutrinos from Accelerators

4. List of published papers/proceedings

1. Upgrade of the CMS Muon system with triple-GEM detectors: Performance of the GE1/1 station and detector design and testing of the ME0 station, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 1080, 2025, 170680, ISSN 0168-9002, <https://doi.org/10.1016/j.nima.2025.170680>.

5. Thesis title (even temporary)

“Development and Exploitation of MPGD detectors for the upgrade of the CMS experiment”



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Date, 12/09/2025

Signature...

Elice Muri

Seen, the supervisor

Pierluigi Jannini Verilligen

Federica Nova Stone