Contact: ktoto9785845@gmail.com
Title: CMS Level 1 trigger scouting for luminosity measurement
Abstract: In High-Luminosity LHC era the CMS 40 MHz L1 Scouting system will be used for luminosity measurements by counting multiple trigger primitives, as muon stubs, energy deposition in calorimeters, track primitives, and others. A detailed study of these primitives and their correlations is required to determine their suitability for precision luminosity measurement in the HL-LHC conditions. A prototype of the system has already been deployed as a Run3 demonstrator, and data is available for analysis. Students involved in this project will gain experience with the CMS data flow, including the use of the CMS Software Framework (CMSSW) and HTCondor for large-scale data processing.

Project description and deliverables:

The main focus of the work will be dedicated to luminosity measurement with CMS sub-detectors.
CMS stands for Compact Muon Solenoid, and is one of the experiments at LHC. It consists of a few coaxial cylindrical layers. Innermost layers are silicon detectors with 66 m of pixels, which are used for particle tracking. The outer layers are Electron calorimeter (ECAL), hadron calorimeter (HCAL) and then cryostat for superconductive magnets.
Outside the cryostat there is a steel structure, which serves a dual purpose. It propagates magnetic field from the magnet, it provides structural support, and it shields muon chambers from other non-muon particles.

In the collider, there are two parallel rings with counter-rotating beams. There is no continuous beam but rather small batches of protons. Overall there are about a few thousand bunches in the LHC ring (depends on fill). Proton bunches are grouped in so-called trains.

In four determined places equipped with detectors (one of them is a CMS detector) these beams are crossed and protons collide. As the cross section for inelastic proton-proton collisions at 7 TeV energies is about 60 mbarn, resulting in about tens of collisions per bunch crossing despite hundreds of millions of protons per batch. As data acquisition systems have limited bandwidth, the system uses triggers, which do online decision making whether to keep data or not: a Level 1 trigger. Such an approach makes the amount of data acquired from detectors manageable, even though this data is biased. There is also a limited amount of unbiased data from triggers, which could potentially contain new physics: 40 MHz scouting. The data will be used in the project to study the suitability of 40 MHz trigger primitives for luminosity measurements.

Luminosity is important to measure precisely, as it is further used to normalize any physics cross section measured with a CMS experiment.

Currently to measure luminosity there are several luminometers inside CMS: PLT, BCM1F and also CMS sub-systems used for lumi pixel detector, HF, DT. Multiple detectors are required for reliable estimation of luminosity, as detectors have dead time and different parasitic effects, which need to be corrected for.

In this project, we will investigate 40 MHz scouting data to measure luminosity. In particular, the number of muon detections in GMT(global muon tracker) was shown to increase linearly with increasing luminosity. We will investigate this variable and other available trigger primitives.
Similar to the currently used approach involving multiple detectors, we will study the correlations between various trigger primitives.

Work plan:

Week 1 onboarding, reading literature and papers regardless CMS inner structure and signal processing pipeline. Get CERN computing account, get access to the data, and run the codes to open and plot the data.

Week 2-5 dive deep into a project, MC modeling, search for linear parameters with respect to luminosity. Compare vs. other detectors (ratio plots).

Week 6-8 Using data-driven methods to filter useful signals from background. Plotting all basic parameters for signal bunches and empty bunches to find which parameters can be used to filter out noise (out-of-time hits).

Week 8-12 Based on the findings from Weeks 2–8, develop a refined filtering algorithm or model. Validate its performance on independent datasets. Quantify its impact on luminosity estimation precision.