First semester report

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Ph.D. Thesis title:

**Challenging the Standard Model and searching for new physics at the LHC with the CMS experiment**

## *Introduction*

Precision measurement of the luminosity delivered to the CMS experiment [1] by the LHC is important for a variety of reasons. Online, the luminosity measurement provides real time feedback on the LHC performance and operation, as well as to CMS operations for tasks such as measurements of trigger rates. Offline, the luminosity measurement is a crucial component of nearly every physics analysis, either for measuring the cross section of standard model processes or for setting upper limits in searches for processes beyond the standard model, including the measurement I will perform during my PhD studies.

A total of five systems are used for measuring luminosity at CMS. The Pixel Luminosity Telescope (PLT) [2] , the Fast Beam Conditions Monitor (BCM1F) [3], and the hadronic forward calorimeter (HF) use a separate data acquisition (DAQ) system, called BRILDAQ, and thus provide online luminosity measurement even when CMS globally is not switched on, while the drift tube luminosity (DT) and pixel cluster counting (PCC) use the main CMS DAQ system.

Each luminometer reads out a rate of the specific quantities observed in the detector (hits, tracks, clusters, etc.). This rate, **R**, should be proportional to the instantaneous luminosity, $\mathcal{L}_{inst}$ , with the constant of proportionality given by the visible cross section $\boldsymbol{\sigma_{vis}}$ :

$$R = \mathcal{L}_{inst}\, \sigma_{vis} . \quad (1)$$

In practice, the luminometers usually exhibit some nonlinear dependence on the instantaneous luminosity or on external factors such as the LHC filling scheme; these nonlinearities need to be corrected to obtain an accurate measurement. Having independent measurements gives a handle on detector related uncertainties.

The **calibration constant $\boldsymbol{\sigma_{vis}}$** is determined at hadron colliders using van der Meer (VdM) scans that measure the beam overlap width that appear in the luminosity formula

$$\mathcal{L}_{inst} = \frac{N1i\,N2i\,f}{2\pi\Sigma x\,\Sigma y}, \ (2)$$

where $\mathbf{N_{1i}}$ and $\mathbf{N_{2i}}$ are the number of protons in the two individual beams for the colliding bunch i, **f** is the orbit frequency and $\mathbf{\Sigma_x}$, $\mathbf{\Sigma_y}$ are the overlap widths in x and y direction.

## *Description of research work carried out in current semester*

During the 1st year I need to fulfill the CMS Collaboration's requirements to become a full member (an author). This requires significant contribution to a central technical task of the experiment which I started to perform within its Luminosity Physics Object Group. I had the following tasks this semester:

- In preparation for the CMS physics analysis to be started in the 2nd year, study particle physics.
- Increase my knowledge on the existing luminosity calibration methods and results [4]. Understand the main sources of systematic uncertainties and their measurements which affect the beam overlap width measurement (x-y correlations, length scale calibration, orbit drift correction, beam-beam effects and bunch current normalization).
- Learn C++ and the CERN ROOT analysis framework.
- Learn to use the tools developed within CMS for luminosity measurements.

## *Publication plan*

Contribute to the final luminosity calibration paper of the CMS experiment for the Run 2 data taking (2015-2018) that aims to achieve a precision <2%. Expected date: end of 2019 / early 2020

## *Studies in current semester*

I followed 3 lectures this semester:

- Particle Physics (4 credits) by Dr.Giordano Matteo
    - Elementary particles and their interactions. Parity and CP violation in weak interactions. Isospin symmetry in strong interactions. Quark model and SU(3) symmetry. Scattering cross-section and S-matrix. Basics of QFT. Feynman diagrams and scattering matrix element.
- Intensive Neutrino Course (6 credits) by Prof. Kai Zuber
    - Discovery of the neutrino. Parity violation in weak interactions. Neutrino helicity measurement. Neutrinos in the Standard Model. Dirac and Majoranna mass terms. Solar neutrinos. Neutrino oscillation experiments. Future of neutrino physics.
- High-energy Heavy Ion Physics and the Perfect Quark Fluid (6 Credits) by Prof. Csanád Máté

- Project based course. Analysis of the heavy ion collision data collected by the PHENIX experiment at the RHIC accelerator using the C++ based CERN ROOT analysis framework.

### *Participation on conferences and seminars*

- CMS Physics and Upgrade Week, 1-5 October 2018, Budapest
- Intensive course in Neutrino Physics by Prof. Kai Zuber (Technische Universität Dresden, MTA ATOMKI), 5-9 November 2019, ATOMKI, Debrecen
- CMS Induction Course, 30 January / 1 February 2019, CERN, Geneva, Switzerland – participant (introduction to the CMS experiment and hands-on course to use CMS software)
- CMS Week, 4-8 February, 2019, CERN, Geneva, Switzerland

### *Attendance on regular seminars, meetings*

ELTE Ortvay seminars, ELTE Particle Physics seminars, Hungarian CMS Group seminars, ELTE CMS meetings, CMS Luminosity Working Group meetings

### *References*

[1] CMS Collaboration, "The CMS experiment at the CERN LHC", JINST 3 (2008) S08004,doi:10.1088/1748-0221/3/08/S08004.

[2] P. Lujan, "Performance of the Pixel Luminosity Telescope for luminosity measurement at CMS during Run 2", PoS 314 (2017) 504, doi:10.22323/1.314.0504.

[3] M. Hempel, "Development of a Novel Diamond Based Detector for Machine Induced Background and Luminosity Measurements". PhD thesis, DESY, Hamburg, 2017.doi:10.3204/PUBDB-2017-06875.

[4] CMS Collaboration, CMS luminosity measurement for the 2017 data-taking period at sqrt(*s*)=13 TeV, CMS-PAS-LUM-17-004 (2018)