Second 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

The CMS Collaboration expects all of its collaborators to take an experimental physics responsibility, a central task that is beneficial for the whole collaboration, in order to become a full member, a signing author of the collaboration.

I chose to participate in the luminosity calibration as the precise knowledge of the luminosity is essential for almost all measurements at the Large Hadron Collider (LHC) and it is the dominant source of systematic uncertainty for various Standard Model cross-section measurements of W, Z and top quark production.

A total of six systems are used for measuring luminosity at CMS. The Pixel Luminosity Telescope (PLT), the Fast Beam Conditions Monitor (BCM1F), the hadronic forward calorimeter (HF), the drift tube luminosity (DT), pixel cluster counting (PCC) and a radiation monitor (RAMSES).

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, L_{inst}, with the constant of proportionality given by the visible cross section σ_{vis}:

$$R = L_{\mathrm{inst}}\, \sigma_{\mathrm{vis}}.$$

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.

The **calibration constant** σ_{vis} is determined using Van der Meer (vdM) scans that measure the beam overlap width that appear in the luminosity formula

$$L_{\mathrm{inst}} = \frac{N_{1i} N_{2i} f}{2\pi \Sigma_x \Sigma_y},$$

where N_{1i} and N_{2i} are the number of protons in the two individual beams for the colliding bunch i, f is the orbit frequency and Σ_x, Σ_y are the overlap widths in x and y direction.

There are several systematic effects which affect the beam overlap width measurement, and hence the σ_{vis} extracted from the vdM scan procedure, one of these main effects is the length scale calibration (LSC) which corrects the possible differences between the actual and nominal LHC beam separations during the scans. It is determined by exploiting the high precision of the CMS inner tracker using the reconstructed vertex positions during a special beam separation scan for LSC. There are two different kinds of LSC scans, the constant separation scan and the variable separation scan.

Description of research work carried out in current semester

During this semester I analysed the constant separation scan data in order to fulfill the CMS authorship requirements.

In the constant separation scan, the beams are separated by about 1.4 σ_{beam} and moved together first in the *x* direction forward and backward and then the same procedure is repeated in the *y* direction. The CMS tracker is used to reconstruct the position of the luminous region and the resulting position is plotted against the nominal beam separation; a linear fit is then applied to extract the slope which gives the LSC correction factor and its uncertainty.

Previous work on the analysis of the constant separation scan in the 2018 proton-proton vdM scan data taken at $\sqrt{s}$ = 13 TeV showed several problems with the measurement stability. Therefore I studied the calibration both for the prompt reconstruction and the more precise re-reconstructed vertex data. I compared results using per scan step fits and averages to find the sources of inconsistency.

Publication plan

The final luminosity calibration for the 2017-18 data is planned to be completed by late 2019, with the publication expected in 2020. The goal is to achieve a precision well below 2%. My work on luminosity calibration will be part of this peer-reviewed CMS publication.

Studies in current semester

I followed 4 lectures this semester:

- Quantum electrodynamics (6 credits)
- Selected chapters from experimental high energy physics (6 credits)
- Experimental Methods in Particle Physics (2 credits)
- Strong Interaction at Low Energies (3 credits)

Participation on conferences, workshops and seminars

- LHC Lumi Days, 4-5 June 2019, CERN, Geneva, Switzerland – Workshop dedicated to luminosity calibration and LHC beam optimisation and beam parameter measurements in Run 2 and discussions on improvements for Run 3.

Attendance on regular seminars, meetings

ELTE Ortvay Colloquiums, ELTE Particle Physics Seminars, Hungarian CMS Group Seminars, ELTE CMS groop meetings, CMS Luminosity Physics Object Group meetings.