PROCEEDINGS OF SCIENCE

Run 3 luminosity measurements with the Pixel Luminosity Telescope

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For Run-3 of the LHC, the CMS experiment has installed the pixel luminosity telescope (PLT) which is made of three layers of pixel sensors that count charged particles from each bunch crossing of the LHC beam. The rate of triple-coincidences between layers is translated into a luminosity value that is published about every 1.4 seconds. In addition, at a lower rate, particle trajectories are reconstructed for systematic studies of beam backgrounds and efficiencies. The paper discussed the working principles of luminosity calibrations and results from systematic studies.

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1. Introduction

The Pixel Luminosity Telescope is a dedicated detector built for luminosity measurements [1]. It was installed in 2015 for Run 2 and it has been rebuilt for Run 3. The PLT has sixteen different channels (telescopes) and each has 3 silicon sensor planes. The telescopes are arranged around the beam pipe on either side of the interaction point. The distance from the interaction point to each telescope is 172.5 cm. In the new version, one of the sixteen telescopes was upgraded with phase-2 silicon sensor prototypes.

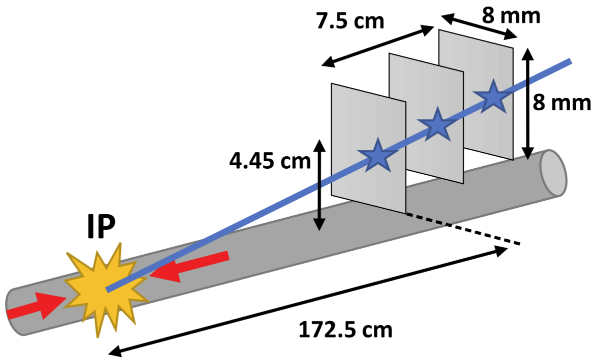

Figure 1: The position of a single telescope with respect to the beam pipe and the interaction point. Individual sensor planes of the telescope are shown

The PLT has two independent readout modes, Fast-OR, and Full Pixel Readout. In Fast-OR mode, hits over threshold in all three sensors in a telescope are histogrammed with respect to the bunch-crossing ID. In this mode, PLT can provide luminosity measurements at the full LHC rate of 40 MHz. Zero-counting method (Equation 1) is used to avoid under-counting due to two or more tracks passing through a telescope at the same time. In full pixel readout mode, per-pixel information is gathered at a lower rate of around 3 kHz. These pixel data are used to provide track reconstruction in diagnostic studies, such as beam background corrections and collision point calculations [2].

2. Absolute luminosity calibrations

The measured triple-coincidence rates need to be scaled by the visible-cross section (σ_{vis}) to determine absolute luminosity. Van der Meer (VdM) scans are used to determine this scale factor. The beam is separated in steps in both X and Y planes individually while the rate of triple-coincidences are recorded.

The rate vs. beam separation plot for the X (Y) plane is then fitted with a Gaussian fit as shown in figure 2 to obtain the two fit parameters, peak rate, R_x (R_y) and the effective width, Σ_x (Σ_y). The averaged peak rate from both planes, R_0, and the effective widths are then used in equation 2 to determine the visible cross-section. Finally the single bunch instantaneous luminosity (SBIL), L_b is calculated using equation 3 [3].

$$\mu = -ln(< f_0 >) \tag{1}$$

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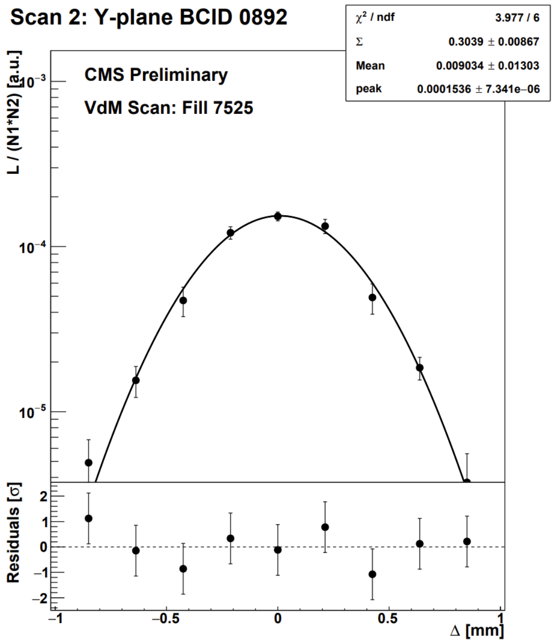

Figure 2: Normalized rate observed by luminomter vs. beam separation in Y-plane.

$$\sigma_{vis} = \frac{2\pi\Sigma_x\Sigma_y R_0}{N_1 N_2 f} \tag{2}$$

$$L_b = \mu\frac{f}{\sigma_{vis}} \tag{3}$$

where;

N_i - Beam current (measured by LHC Beam Current Transformers)

f - LHC revolution frequency (11245.6 Hz)

f_0 - Fraction of bunch crossings with no triple-coincidences

μ - Number of triple-coincidences

3. Accidental Analysis

Triple coincidences from background tracks (not originating from the interaction point) are called accidentals. Beam-induced background, from particles travelling parallel to the beam, can contribute to accidental tracks. The fraction of accidental tracks needs to be taken into account to provide an accurate triple-coincidence rate. Two main methods have been investigated to remove accidental tracks.

In the first method, the hits in the three planes are fitted with a straight line to reconstruct the track. If the fit residuals at each point are larger than a threshold value, the track can be considered an accidental hit. A similar cut can be applied to the y-slope of the track which filters out the tracks based on the angle between the track and the beam pipe.

The second method is based on the maximum likelihood fit to the y-slope distribution. The shape of the y-slope distribution at VdM luminosity is modeled using a double Gaussian model

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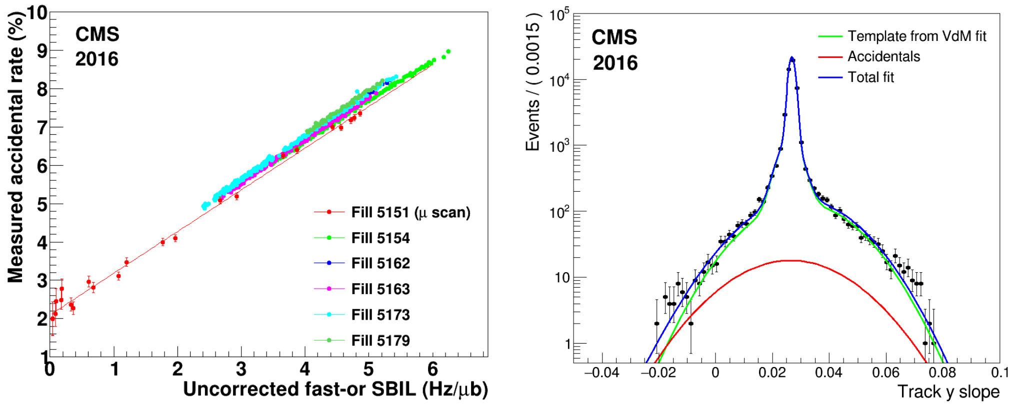

Figure 3: Left: Fraction of accidentals vs. Fast-OR SBIL. **Right**: The total fit to the y-slope distribution(blue) measured at 2.95 Hz/μb, double Gaussian template(green) measured at VdM luminosity and the extra contribution due to the increase of accidentals(red)

(template). The accidental contribution at this VdM SBIL is assumed to be zero. Thus, at zero SBIL, the proportion of accidental tracks is exactly zero by design. For nominal SBIL values, the shape of the y-slope distribution is compared with the template and the excess contributions are considered background tracks.

4. Summary

The PLT was able to provide luminosity continuously and reliably during Run-2. The rebuilt version has been successfully commissioned for Run-3 and performed as expected during 2022 data-taking. Access to track information provides a unique chance to do systematic studies with the luminosity data from the PLT and pave the way to provide precision luminosity measurements for the CMS experiment during Run-3.

5. Acknowledgment

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References

[1] A. Kornmayer on behalf of the CMS Collaboration, *The CMS pixel luminosity telescope*, Nucl. Instrum. Meth. A 824 (2016) 304

[2] The CMS BRIL Collaboration *The Pixel Luminosity Telescope: A detector for luminosity measurement at CMS using silicon pixel sensors*, CERN-CMS-NOTE-2022-007

[3] Sirunyan, A.M., Tumasyan, A., Adam, W. et al. *Precision luminosity measurement in proton–proton collisions at* $s=\sqrt{13}$ *TeV in 2015 and 2016 at CMS*, Eur. Phys. J. C 81, 800 (2021)

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