Commissioning Experience and Upgrade Plans of the Pixel Luminosity Telescope for Luminosity Measurement at CMS

Andrés G. Delannoy, on behalf of the CMS BRIL Collaboration

TWEPP 2017: Topical Workshop on Electronics for Particle Physics 2017
11-14 Sep 2017, SCIPP, UC Santa Cruz , Santa Cruz, CA (United States)

delannoy@cern.ch

Introduction

- The Pixel Luminosity Telescope (PLT) is a dedicated instrument for measuring luminosity delivered to the CMS detector at the LHC
- The same sensors and PSI46v2 readout chips (ROCs) developed for the CMS phase-0 Pixel detector are used

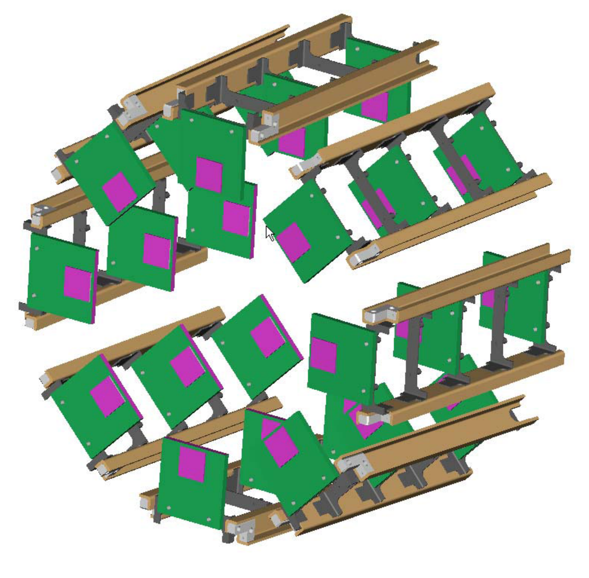

Fig. 1: The PLT is made up of 48 silicon sensor planes arranged in 16 “telescopes" (8 on either side of CMS, each made up of three sensor planes) located outside the pixel endcaps $\sim$ 1.75m from the interaction point ($|\eta| \approx 4.2$)

Online Luminosity

- The “fast-or" readout mode of the ROCs generates a signal when any pixel hit in the sensor is over threshold in a given 25ns bunch crossing (BX) window and its signal height is proportional to the number of double columns hit
- A dedicated “fast-or" Front End Driver (FED) histograms events in a BX where all three planes in a telescope register a hit (“threefold coincidence")
- The published instantaneous luminosity is proportional to the “zero-counting" rate, i.e. the fraction of events with no registered threefold coincidences, $\mathcal{L} \sim -\ln(f_0)$

Offline Luminosity

- A hit is registered when a pixel in the sensor is ionized and the charge collected by the ROC is greater than a programmable threshold
- The timestamp, pixel ID, and pulse height are buffered and read out by a dedicated trigger at $\sim$ 3kHz
- The pixel data allows for track reconstruction and multiple precision studies

Control and Readout

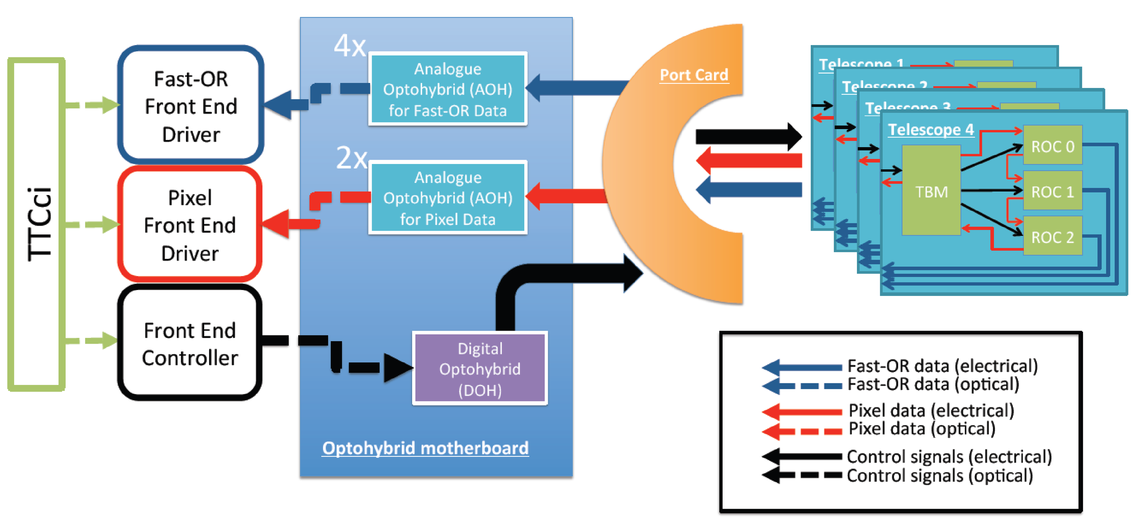

Fig. 2: Control and readout logic of a PLT quarter

- The three ROCs in a telescope are controlled and read out by the Token Bit Manager (TBM)
- The Opto-Hybrid Motherboard digitizes optical control signals and optically encodes data signals from the telescopes

Calibration

- In order to determine the absolute luminosity, a Van der Meer (VdM) scan is performed, where the beam separation is gradually varied and the observed rate curve is fit to determine the beam size

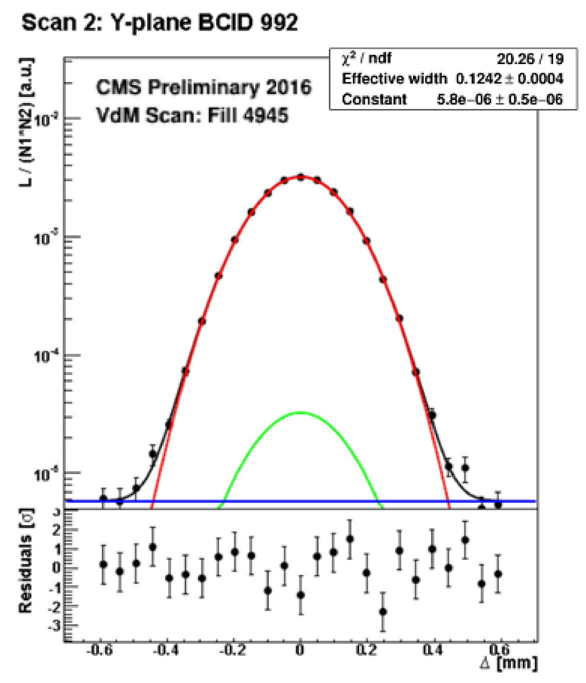

Fig. 3: Example fit for a single bunch in a single VdM scan. The resulting luminosity curve is fit with a double Gaussian (green and red) and a constant term (blue). The effective width is extracted and used to find the overall calibration constant.

- The visible cross-section of the detector can also be determined from emittance scans, where the beam separation is varied under nominal collisions and more quickly than in VdM scans

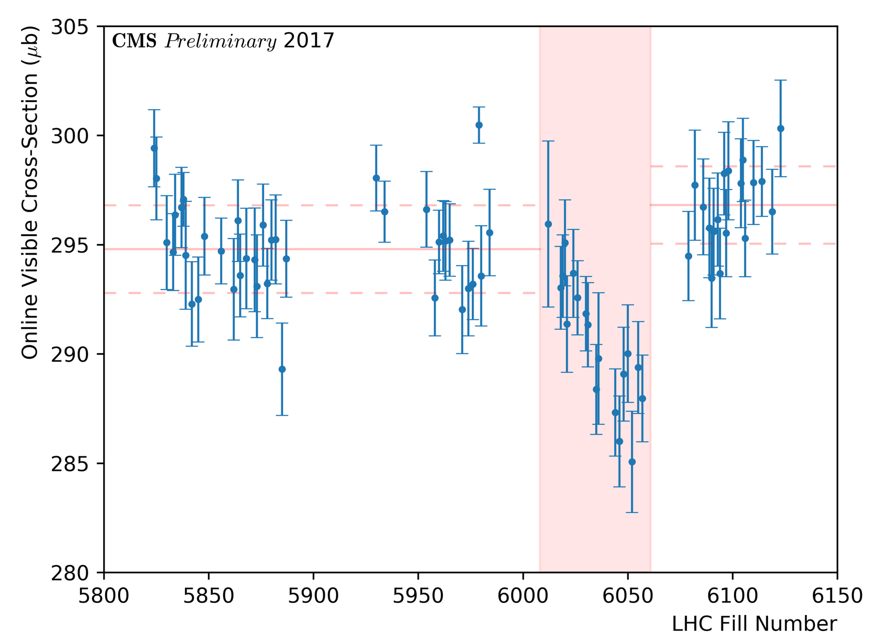

Fig. 4: Measured uncorrected visible cross-section (SigmaVis) calculated as the mean for all colliding bunch-crossings (BX) during 2017 LHC emittance scans. The error bars are calculated from the standard deviation of the SigmaVis values for each colliding BX. The horizontal red line corresponds to the mean SigmaVis and the dashed red lines correspond to one standard deviation from this mean. The downward trend highlighted in red coincides with a drop in efficiency which was mitigated by an increase of the operational high-voltage.

Alignment

- The center plane has an active area of 3.6 $\times$ 3.6mm and slightly larger for the outer planes to allow for alignment and accidental calculations
- The telescope alignment can then be determined from the detector occupancy in order to maximize tracks that originate from the interaction point and reduce accidental tracks

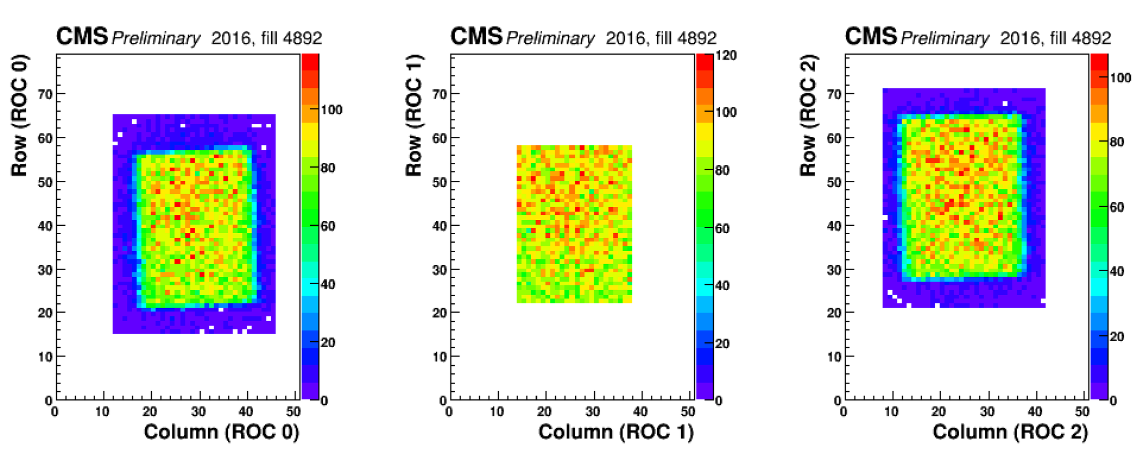

Fig. 5: Events which can be reconstructed from a single track registered in all three planes using the full pixel readout

Offline Corrections

- The pixel data is analyzed offline to correct for accidentals (i.e. triple coincidences observed in the PLT which are not caused by a track originating from the interaction point) by looking at the distribution of tracks in reconstructed slopes, measuring the mean slope, and rejecting any track more than 5σ away from the mean
- The pixel data is also used to calculate efficiency corrections by looking for events with two hits in two planes consistent with a track, and seeing how often the expected hit in the third plane was registered

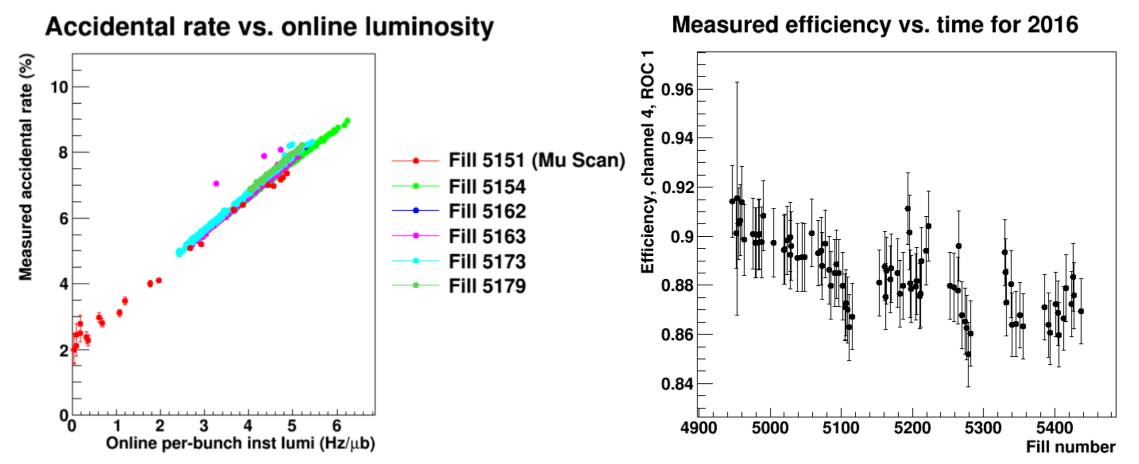

Fig. 6: PLT accidental rate for several LHC fills (left) and efficiencies for Channel 4, ROC 1 during 2016 (right)

Upgrade Plans

- The PLT is scheduled for repairs and upgrades during Long Shutdown 2 (LS2) at the end of 2018
- The ROCs, sensors, and other components will be close to their expected end-of-life mainly due to radiation damage
- All components in proximity to the interaction point are scheduled to be replaced with unirradiated spares
- The necessary sensor planes bump-bonded to the PSI46v2 ROC are available and are in the process of being retested
- Since port cards, which route all electrical signals to and from the detector, have proven to be unreliable, spares have been subjected to multiple thermal cycles in order to ensure consistent operation
- Spare optohybrid-motherboards are also being prepared from available digital and analog optohybrid modules and slow hub chips

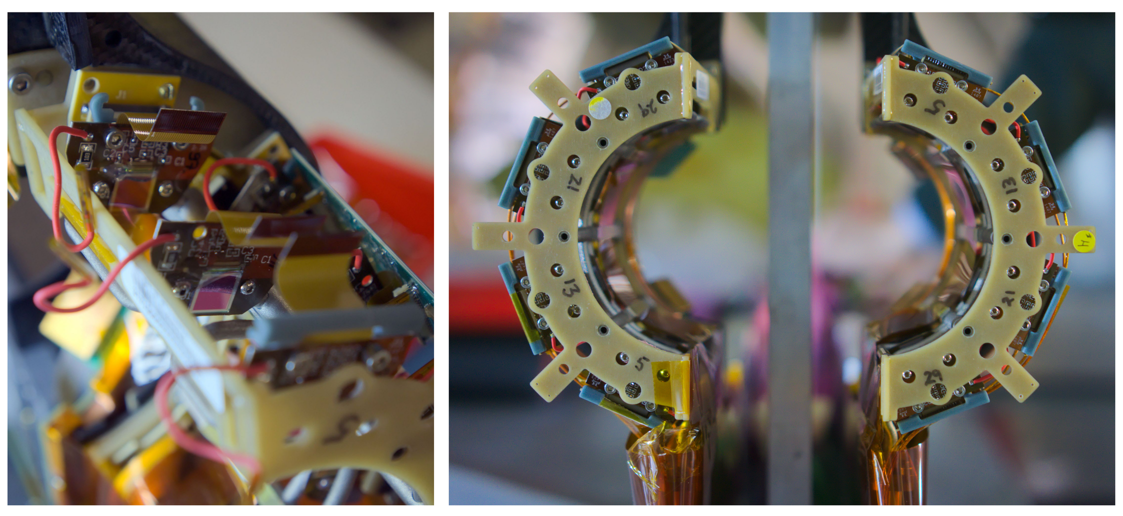

Fig. 7: PLT telescope with visible sensors (left) and front view of a PLT quadrant (right)

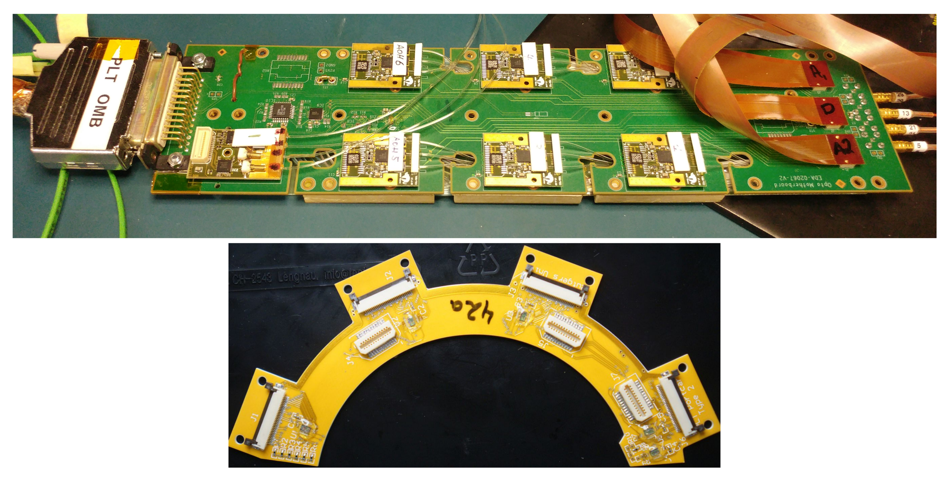

Fig. 8: Spare port card (top) and fully assembled PLT optohybrid-motherboard (bottom)