Run 3 luminosity measurements with the Pixel Luminosity Telescope

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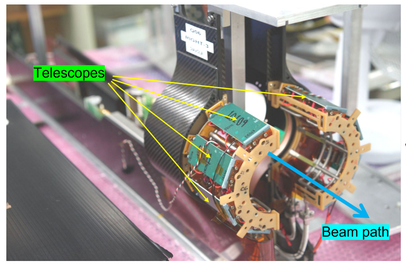
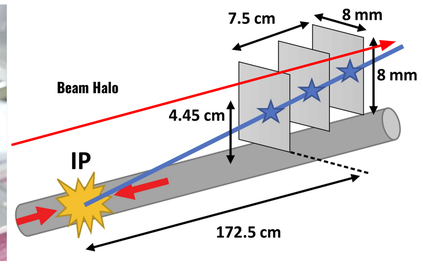
Pixel Luminosity Telescope (PLT)

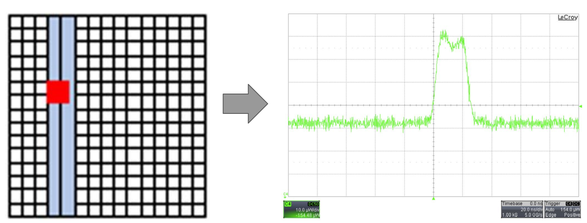
- Silicon pixel detector dedicated to luminosity measurement
  - Installed in CMS in 2015 for LHC Run 2 and rebuilt for LHC Run 3
  - New version implements three CMS Phase-2 silicon sensor prototypes
  - Sensors are actively cooled using C_6F_{14} at -20 ºC
- Arranged into 16 channels or "telescopes"
  - 8 telescopes located on either side the CMS pixel detector endcaps, at z ≈ ±172.5 cm from the interaction point and |η|≈4.2
  - Three sensor planes per telescope



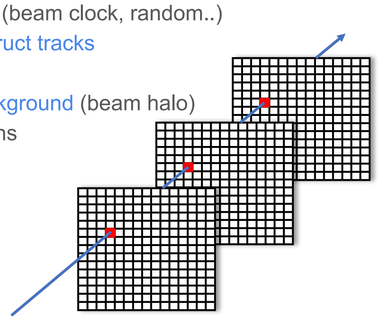


Readout Modes

- Fast-OR readout (40 MHz)
  - Register hits in pixel double columns
  - 3-layer fast coincidence at each bunch crossing
  - Record signal at full bunch crossing rate
  - Uses two data buffers to avoid down time
  - Cannot detect simultaneous two hits in the same column
    - Uses zero-counting to avoid undercounting

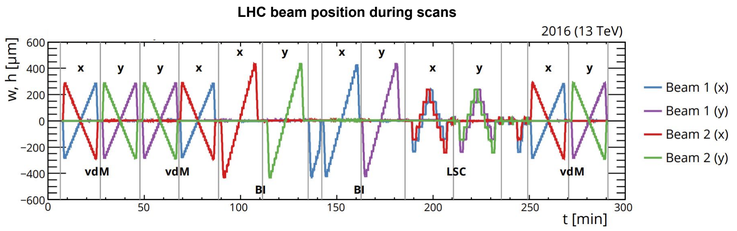


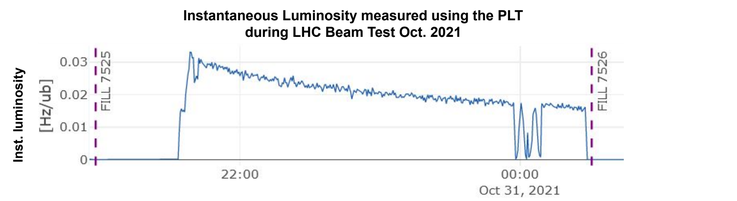
- Full pixel readout (1-10 kHz)
  - Read charge deposit and position of the hit
  - Triggered by external trigger (beam clock, random..)
  - Data can be used to reconstruct tracks
  - Used for diagnostics:
    - Correction for beam background (beam halo)
    - Collision point calculations



Absolute luminosity calibrations

- Van der Meer (vdM) Method
  - Displace the beam with respect to each other observing resulting rates
  - Determines the calibration constant for the detector (σ_{vis})





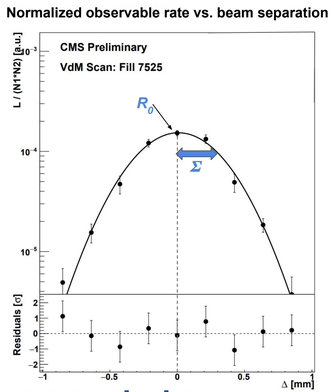
- The normalized rates measured during the separation is fitted with Gaussian function to obtain fit parameters and the Instantaneous Luminosity(L_b)

$$\sigma_{vis} = \frac{2\pi \sum_x \sum_y R_0}{N_1 N_2 f}$$

$$\mu = -\ln(\langle f_0 \rangle)$$

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

N_i : Beam current
f : LHC revolution frequency (11245.6 Hz)
f_0 : Fraction of BXs with no triple coincidences
μ : Number of triple coincidences

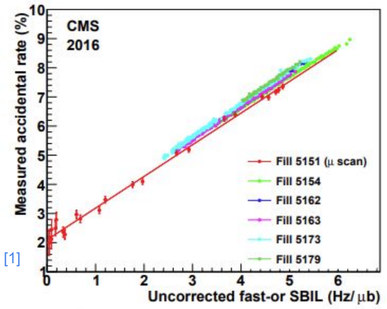


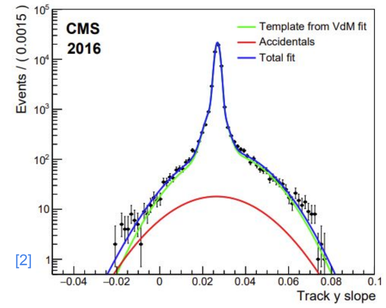
Corrections to vdM scan data

- Beam current calibration
  - Measured by two dedicated devices
    - FBCT - per 25 ns, less accurate
    - DCCT - per orbit, more precise
- Beam position monitoring
  - Corrections to beam positions
- Beam-beam effects
  - Corrections to the deflections caused by electromagnetic repulsions of the two bunches
- Length scale calibrations
  - Correction to the beam separation

Accidental Analysis

- Accidentals: Triple coincidences that do not come from actual tracks originating from IP
- One of the most significant contributions to the systematic uncertainty
- Two methods were employed to identify the background
  - A 5-sigma residual cut based [1] on track residuals histogram or track slope histogram
  - Maximum likelihood fit based [2] background subtraction Monitors the change in shape of the track slope y distribution for different luminosities





Improvements for Run-3

- New components
  - New OMB version (new SlowHub chip) produced at CERN
  - High-density interconnects and port cards produced at Rutgers University
- Sensor production and characterization with Sr-90
  - Batch of ≈180 sensor planes produced at the Paul Scherrer Institute
  - Source testing at CERN with special Digital Testboard (PSI46dig) adapter
- Assembly and integration
  - New cooling structure fabricated from titanium powder using a selective laser melting process
- Stress-tested under thermal cycles
  - Extensive break-in period with -20ºC < temperature < 5ºC every 2 hours
  - Troubleshooting, investigation, and repairs

Summary

- PLT published online luminosity continuously during Run-2
- The rebuilt version of the PLT has been successfully installed
  - Hardware commissioning has been completed and software in progress
- PLT will provide luminosity for LHC Run-3