Luminosity measurements at the CMS experiment

Oleksii Turkot for the CMS Collaboration

Luminosity detectors at CMS

At CMS up to 8 luminosity measurement techniques are exploited:

Pixel Luminosity Telescope:

✧ **PLT** - 8 three-layer "telescopes" at 1.8m from the IP in both directions.

Fast Beam Condition Monitor:

✧ **BCM1F** - silicon and diamond sensors with 6.25 ns time resolution, located near PLT.

Hadron forward (HF) calorimeter:

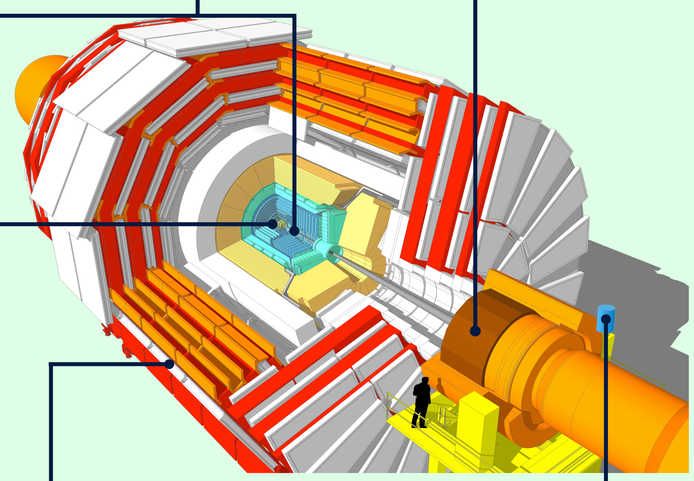
✧ **HFOC** - channels occupancy

✧ **HFET** - based on the sum of the E_T

Tracking detectors:

✧ **PCC** - counting of clusters in the Pixel detector.

✧ **PVC** - counting of primary-interaction (PV) vertices with stringent track selection requirements.



10.1088/1742-6596/513/2/022032

Muon Drift Tubes:

✧ **DT** - rate of the muon trigger primitives in drift tubes.

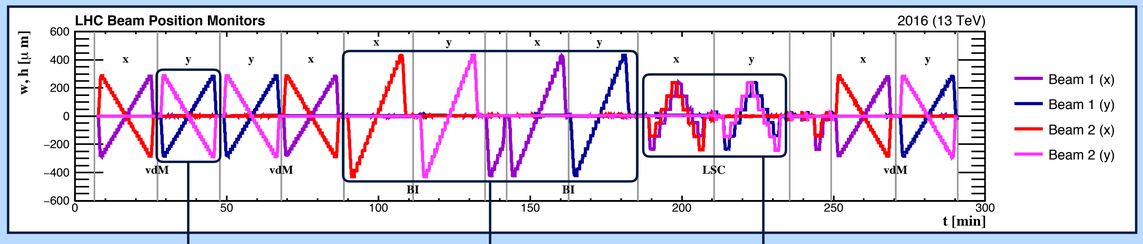
CERN radiation and environmental monitoring subsystem:

✧ **RAMSES** - rate in ionisation chambers (principally from high-energy photons).

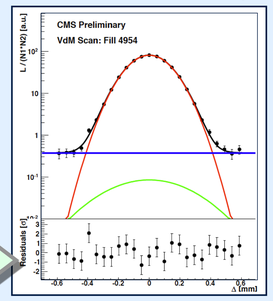
$$R(t) = \sigma_{\text{vis}} \cdot \mathcal{L}(t)$$

Luminosity calibration

Dedicated fills with beam separation scans allow the estimation of σ_{vis}:

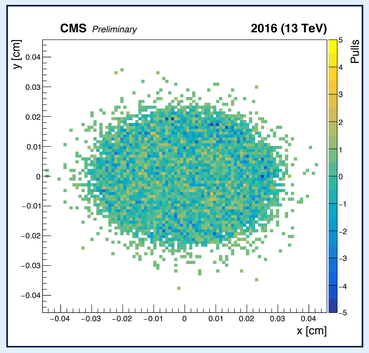


Beam densities are assumed to be factorizable in x and y:



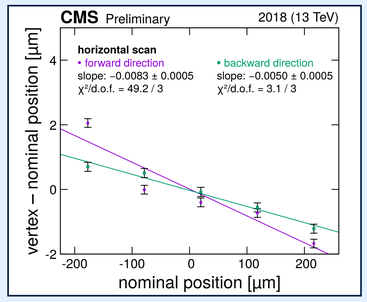
$$\sigma_{\text{vis}} = \frac{2\pi\Sigma_x\Sigma_y R(\Delta x_0, \Delta y_0)}{N_1 N_2 f}$$

x-y nonfactorization:



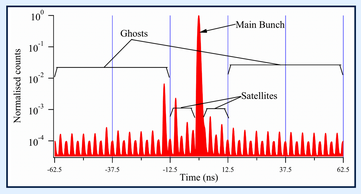
$$\sigma_{\text{vis}} \longrightarrow \sigma_{\text{vis}} \times \left(1 + \frac{\mathcal{O}_{\text{vdM}} - \mathcal{O}_{\text{fit}}}{\mathcal{O}_{\text{fit}}}\right)$$

Length scale calibration:



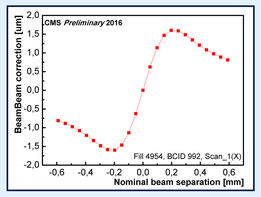
Beam separation calibrated with the PV data.

Beam current correction:



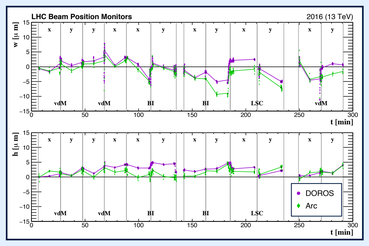
CERN-ATS-Note-2012-029 PERF

Beam-beam effects:



Electrostatic deflection and defocusing.

Orbit drift correction:



Correction of the beam positions during the scans.

Systematic uncertainties

	Uncertainty (%)		
	2016 [1]	2017 [2]	2018 [3]
x-y nonfactorization	0.9	0.8	2.0
Length scale	0.8	0.3	0.2
Beam-beam effects	0.4 ⊕ 0.5	0.4 ⊕ 0.5	0.2
Beam current normalization	0.3	0.3	0.2
Orbit drift	0.4	0.2	0.1
Ghost and satellite charges	0.4	0.1	0.1
Background subtraction	–	<0.1	0.1
Scan to scan variation	–	0.9	0.3
Bunch to bunch variation	0.3	0.1	0.1
Cross-detector consistency	–	0.6	0.5
Cross-detector stability	1.5	0.5	0.6
Linearity	0.6	1.5	1.1
Out-of-time pileup	0.7 ⊕ 0.5	0.2 ⊕ 0.3	0.1 ⊕ 0.4
Internal stability	0.5	–	–
Dynamic inefficiency	0.3	–	–
CMS deadtime	0.5	0.5	<0.1
Total uncertainty	**2.5**	**2.3**	**2.5**

http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/LUM/

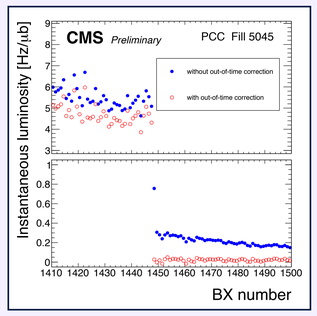
[1] CMS-PAS-LUM-17-001 [2] CMS-PAS-LUM-17-004 [3] CMS-PAS-LUM-18-002

Detector stability and linearity

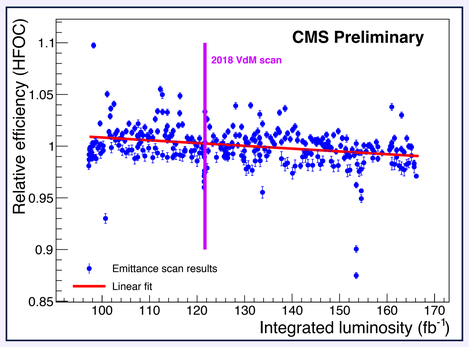
Luminosity integration over the whole data-taking period.

Out-of-time pileup:

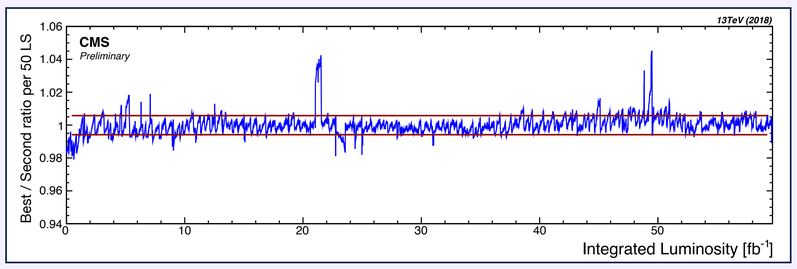
- Type 1 - electronic signal spillover into next bunch crossing
- Type 2 - additional response from material activation



Detector ageing:



Cross-detector stability:



Linearity: