PM2018: La Biodola, May 27th-June2nd 2018

The LUCID-2 Detector

LUCID-2 (***LU****minosity* ***C****herenkov* ***I****ntegrating* ***D****etector*) is the upgrade of the main detector dedicated to luminosity measurements in ATLAS. Most changes were motivated by the **number of interactions per bunch-crossing** and the **25 ns bunch-spacing** expected in LHC RUN II (2015-2018). Both fast online information used by LHC for luminosity optimisation and levelling in ATLAS, and per-bunch data to be used offline, come from LUCID-2

Detector

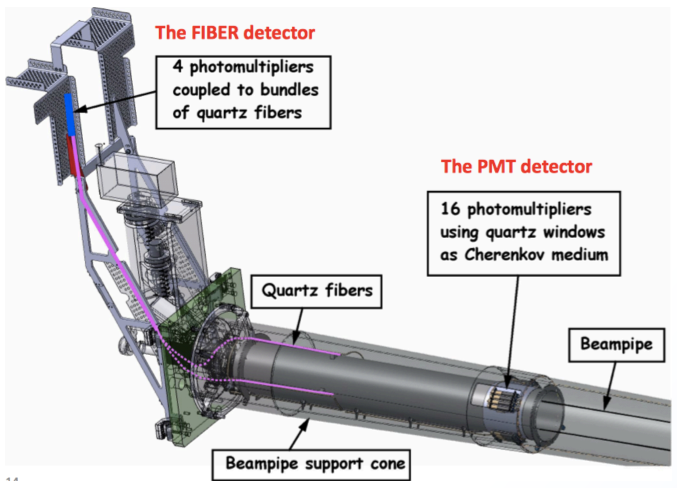

Fig.1: View of the LUCID detector

Two identical modules (Fig.1) are placed around the LHC beam-pipe at 17 m from the ATLAS interaction point. Each module hosts four groups of four photomultipliers (PMTs), and four quartz fibre-bundles coupled to PMTs located at about 1.5 m. All PMTs are model R760 by Hamamatsu. Both the quartz fibre-bundles and the ∅=10 (or 7) mm quartz window of the PMTs are used as Cherenkov radiators to detect charged particles. This peculiar use of PMTs is one of the novelties of LUCID-2.

Electronics

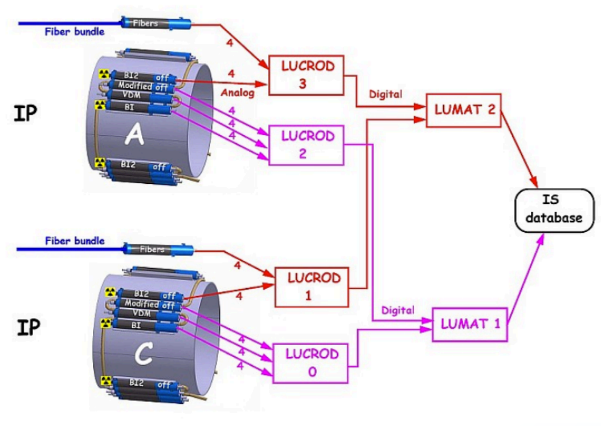

Fig 2: Schematics of the electronics

Custom VME boards (**LUCROD**) sit at only 15 m from the PMTs for **early** signal **digitisation**, **discrimination** and **integration.** Signals above threshold (hits) are sent to other custom VME boards (**LUMAT**) located ~100 m away which combine hits from both detector modules (Fig 2).

Hit-patterns, as well as hits and charges referring to each bunch-crossing and sensor, are accumulated in the FPGAs of each board over periods known as luminosity-blocks and represent the main luminosity raw-data.

Digitised PMT-signals are readout for calibration and monitoring.

Calibration Systems

Long-term stability of PMT gain (Fig 3) is ensured by ^{207}Bi radioactive sources deposited on each PMT window and decaying into 1 MeV electrons via internal conversion (example of a digitised signal in Fig 4). Gain losses occurring during beam collisions are recovered by calibration sessions started after the beams are dumped and followed by automatic re-adjusting of the PMT's high-voltage. The HV evolution as a function of integrated luminosity, radiation dose and charge produced by the PMTs is shown in Fig 5.

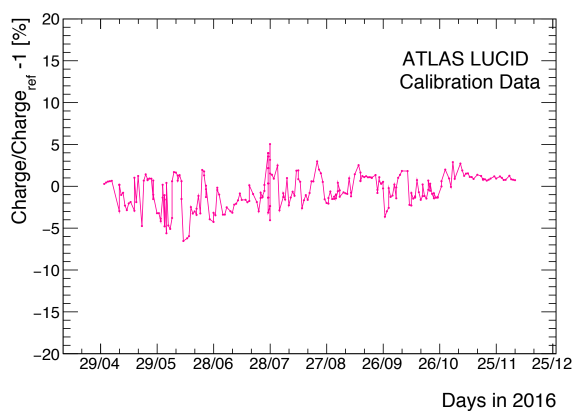

Fig 3: % variation of mean-charge deposited by ^{207}Bi decay in one of the PMTs over 1-year period

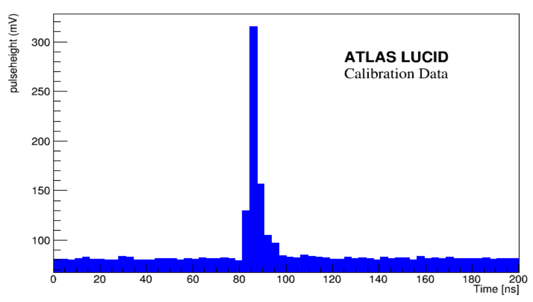

Fig 4: ^{207}Bi digitised signal

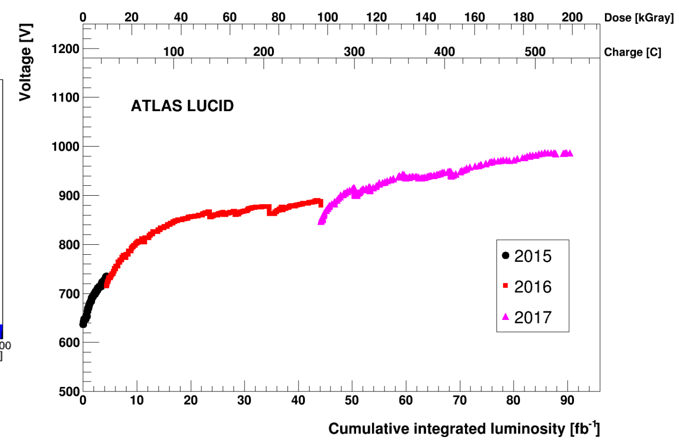

Fig 5: Average HV applied to each ^{207}Bi-calibrated PMT as a function of integrated luminosity

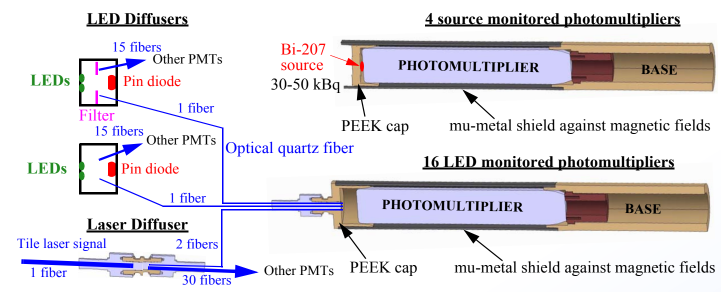

Fig 6: Schematics of calibration system

In 2015 a calibration system using LED light monitored by PIN diodes was also used (Fig 6), but it was less successful than the ^{207}Bi system. Since 2017 only PMTs connected to fibre-bundles have been monitored by LED light.

Luminosity determination

Luminosity is defined as the ratio between the rate of any process and its cross section. LUCID-2 estimates the rate of inelastic pp interactions in each bunch crossing with various algorithms:

- **Hit and Event counting:** Poisson statistics relates the observed rates to the number of *visible* (without efficiency/acceptance corrections) pp interactions per bunch crossing (μ^{vis}). Hit and event counting are affected by pileup of several below-threshold signals which combine into fake hits and events. Events also suffer from saturation.
- **Charge (or pulse) integration:** the total charge is directly proportional to luminosity - as well as to the PMT-gain. Does not saturate.

The visible pp inelastic cross-section (without corrections for efficiency and acceptance) is measured for each algorithm in LHC fills known as *Van der Meer* scans: beams are separated both horizontally and vertically while rates are measured (Fig 7). The visible cross section is obtained from scan widths, the peak μ^{vis}, and the beam currents.

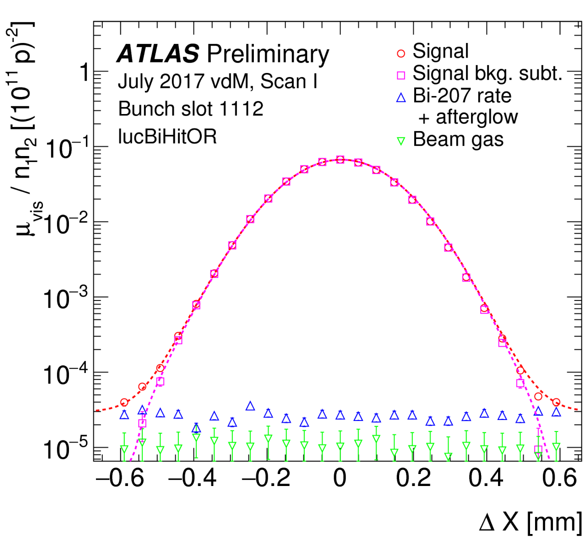

Fig 7: normalised number of interactions per bunch crossing during a beam scan

Results

LUCID-2 has provided luminosity to ATLAS since 2015. By comparing measurements with different algorithms and detectors, systematics are assessed and the robustness of results is reinforced.

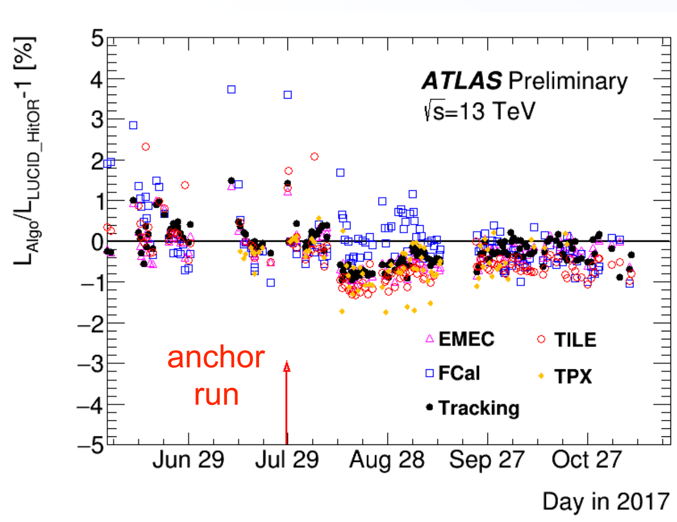

Fig 8: comparison between Lucid and other detectors

Fig. 8 shows the fractional difference in run-integrated luminosity between the preferred LUCID algorithm and other detectors in 2017. The LUCID luminosity is corrected with offline tracking luminosity since the latter is the only other detector that can measure luminosity for individual bunch crossings.

The final precision on integrated luminosity is dominated by uncertainties in the absolute calibration and long term stability. Systematics used for pp data analysis are shown in Table 1 per each year of running.

* preliminary

Year	Precision (%)
2015	2.1
2016	2.2
2017	2.4*

Table 1: systematic uncertainties on pp integrated luminosity

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