The LUCID detector

First 13 TeV collisions with new ATLAS luminosity monitor

Oleksandr Viazlo on behalf of the ATLAS collaboration

The LUCID detector

LUCID is a luminosity monitor with two detectors placed around the beam-pipe on both forward ends of ATLAS. Each detector consists of 16 photomultipliers (PMT) and 4 quartz fiber bundles. The PMTs detect charged particles that traverse their quartz windows, where Cherenkov light is produced. Cherenkov light is produced in the fiber bundles as well and carried to PMTs that are protected by shielding some 2 meters away (see Fig. 1). To increase the detector lifetime, only a subset of the PMTs is used at a given time, the others being available as spares. In additions, 4 PMTs have a reduced window to decrease their acceptance and thus avoid saturation of some luminosity algorithms.

New readout electronics have been built that consists of VME boards that digitize the PMT signals with FADCs. The electronics records hits if the pulseheight is above a threshold and integrate the pulses in each 25 ns interval that correspond to a LHC bunch crossing.

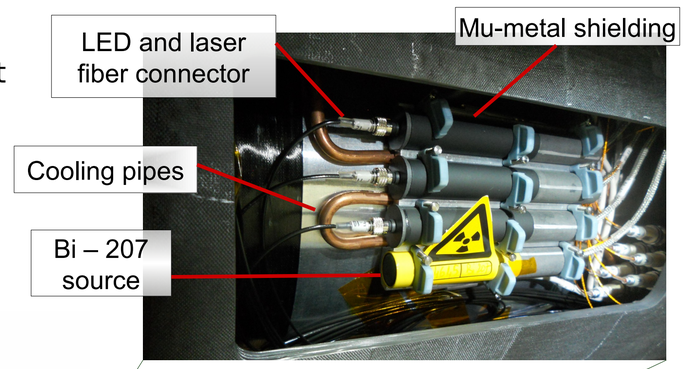

Fig. 2: A quarter of one of the detectors.

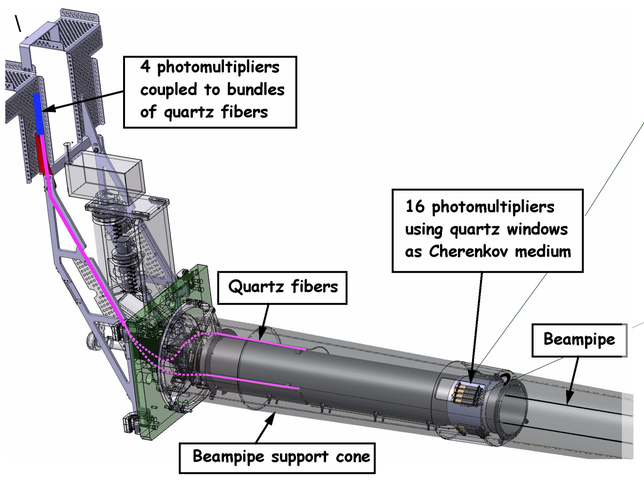

Fig. 1: Drawing of one of the two detectors.

With respect to the detector used in phase I, the new LUCID has a reduced material budget, an increased dynamic range, and will measure luminosity with additional algorithms based on PMT charge integration. It also has a completely new calibration system.

Luminosity measurement

Luminosity is measured by LUCID from a measurement of the number of PMT-hits, the number of bunch crossings with at least one PMT-hit and the integrated pulseheight (charge). These measurements are done over a time period called a luminosity block which are typically 1 minute long and they are done for each of the individual bunch crossings in the LHC.

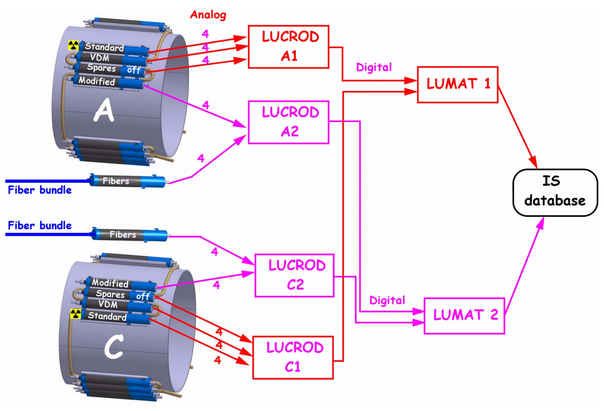

Fig. 6: Bloc diagram of the electronics.

The new electronics provides luminosity measurements using 124 different algorithms which take as input different combination of hits or charge from different tubes. Algorithms which are based on PMT hits from only one of the detector (either A or C), are calculated by the LUCROD cards, while algorithms which depends on combination of hits from both detectors are calculated by the LUMAT cards.

The luminosity is proportional to the measured charge while it is proportional to the logarithm of the measured number of PMT-hits. The two type of measurements therefore have different limitations. The main issue with the charge measurement is PMT gain stability while the hit measurements can suffer from pile-up of several signals below threshold giving a signal above threshold.

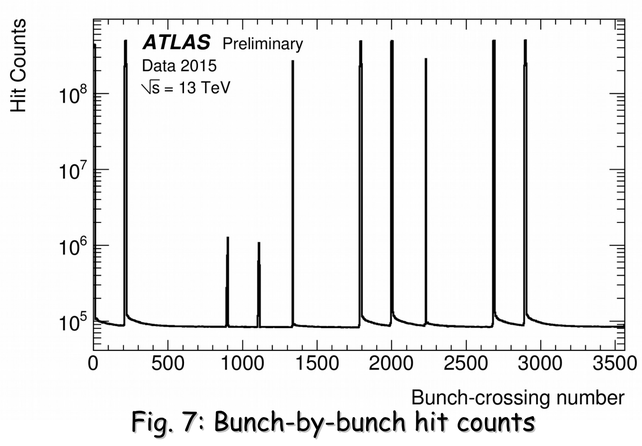

Fig. 7: Bunch-by-bunch hit counts

Figure 7 shows the number of PMT-hits from different LHC bunches. The large peaks correspond to six trains of six colliding bunches each, plus two isolated colliding bunches. Two smaller peaks that correspond to bunches with only one beam are also seen. The baseline background level is due to the Bi-207 source used for monitoring of the photomultiplier gain.

PMTs and calibration

LUCID II uses R760 Hamamatsu PMTs, a smaller version of the previously used R762 model. A smaller PMT model has been chosen to reduce acceptance which will help to cope with the increased occupancy and to avoid saturation of the luminosity algorithms.

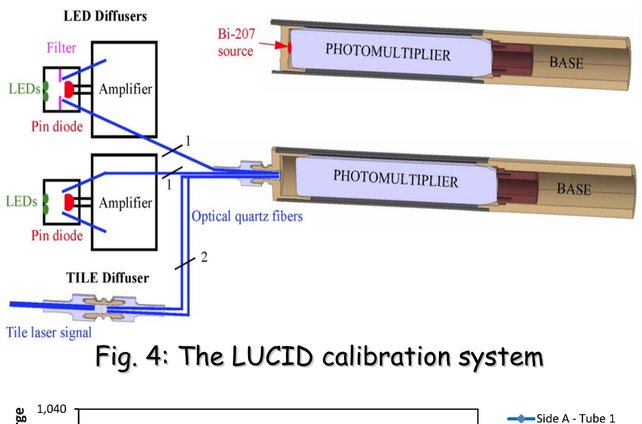

Fig. 4: The LUCID calibration system

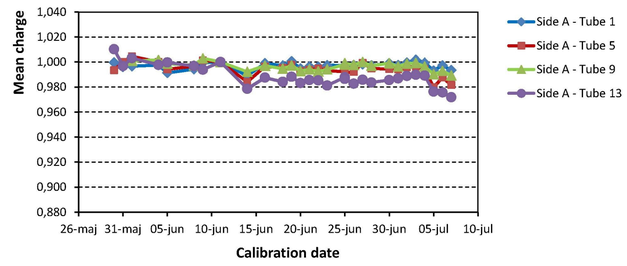

Fig. 5: Bi-207 calibration trending plot

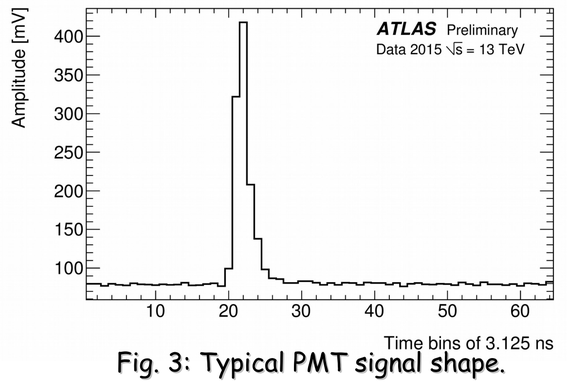

Fig. 3: Typical PMT signal shape.

The duration of the pulses is less than 25 ns, which will be important when LHC starts running with a 25ns bunch spacing.

The PMT gain calibration is monitored in 3 independent ways:
- LED/PIN-diode charge ratio
- LASER signal from the Tile Calorimeter
- Radioactive sources (Bi-207)

Figure 5 shows a trending plot of Bi-207 calibrations during a 1.5 month period. There is no significant deviation from nominal value. A 10% change of mean charge correspond to a 1% change in luminosity. In case of a decreasing gain the high voltage will be increased to keep the gain constant.

13 TeV collisions at LHC

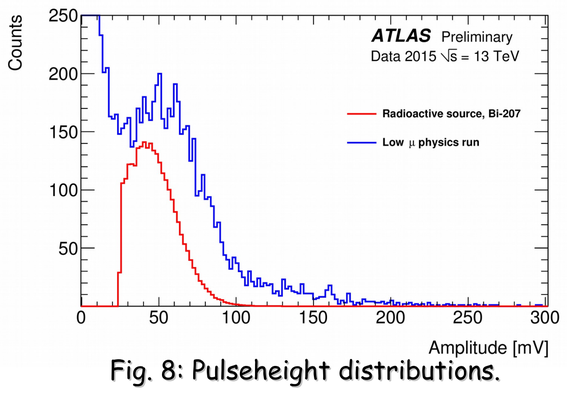

Fig. 8: Pulseheight distributions.

The PMT pulseheight distribution in a physics run is shown in Fig.8 (blue) together with the same distribution during a Bi-207 calibration run (red). In both distribution a peak due to Cherenkov photons is visible. The calibration distribution is cut due to the threshold in the electronics that define a PMT-hit.

LUCID can measure luminosity in many ways and Fig. 9 shows a comparison of the luminosity measured by an A and a C detector for different ATLAS data taking runs. The two measurements agree to better than 0.5%.

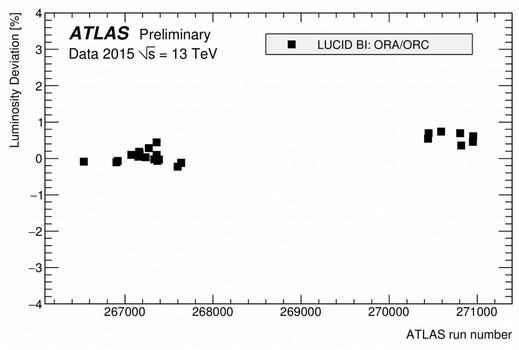

Fig. 9: Difference in luminosity measured by two LUCID detectors.

Figure 10 shows a measurement of the average number of inelastic pp collisions using different ATLAS luminometers and Figure 11 shows the ratio of this measurement with respect to a LUCID measurement. One of the detectors shows a deviation of up to 2% during this LHC fill but the other measurements are all in agreement with LUCID to better than 0.5%. The first month of data taking with the new detector therefore shows that LUCID can measure the relative luminosity with a precision of about 0.5%.

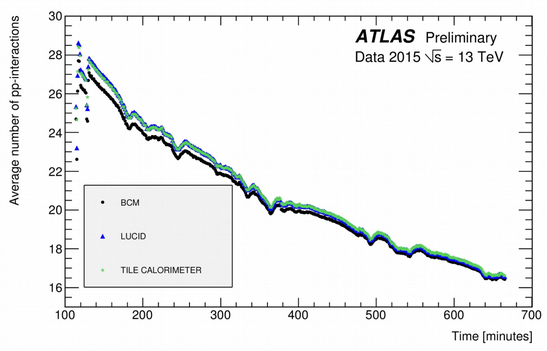

Fig. 10: Average number of inelastic pp collisions per bunch crossing during a 13 TeV fill.

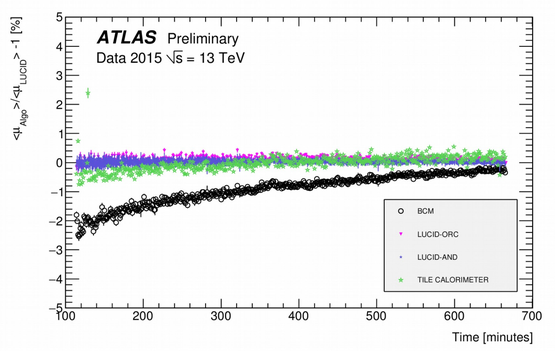

Fig. 11: Comparison of measured luminosity by different luminometers in ATLAS wrt to LUCID.