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Luminosity measurements of the ATLAS experiment in LHC Run2 with LUCID

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Summary. — After the long *shut-down*, the LHC Run2 has started with new running conditions with respect to Run1: the $\sqrt{s}$ has reached 13 TeV and the bunch-spacing is 25 ns. In order to cope with these changes, the ATLAS luminosity monitor LUCID and its electronics have been completely rebuilt. This note describes the new detector, the new luminosity algorithms and the new calibration systems, with a brief review of the preliminary results about stability of the measurement and evaluation of systematic uncertainties for the 2015 data-taking.

1. – The LUCID-2 detector and luminosity stability in 2015

An accurate determination of the luminosity is essential in any high-energy physics experiment with the aim of providing cross-section measurements. LUCID (LUminosity measurement using a Cherenkov Integrating Detector) is the dedicated luminosity monitor of the ATLAS experiment [1] at LHC. The detector is composed by two modules, symmetric with respect to the interaction point. Run 2 conditions called for a complete redesign of the detector and its electronics for three main reasons: the total integrated luminosity is expected to produce a large collected charge in photomultipliers (PMTs), resulting in a fast ageing; the 25 ns bunch-spacing requires a new electronics; the increase of particle flux would result in the saturation of the event-counting based luminosity algorithms due to the so-called *zero-starvation* if keeping the same acceptance. Hamamatsu R760 PMTs, with reduced quartz windows as Cherenkov medium, solve the problems related to the detector, while for the electronics a new board has been necessary. Each LUCID-2 module is made of 5 detectors: *Bismuth* detector with 4 PMTs ($\oslash = 10\,\text{mm}$) with Bi-207 radioactive sources deposited on their windows for calibration purpose; *VdM* detector with 4 PMTs ($\oslash = 10\,\text{mm}$); *Modified* detector with 4 PMTs with even more reduced acceptance (diameter $\oslash = 7\,\text{mm}$); *Fiber* detector with 4 quartz fiber bundles, read out by PMTs. A fifth *Spare* detector, identical to the VDM one, is not turned on, for possible replacement of broken PMTs.

To prevent signals from the PMTs from travelling over long cables and degrading to a level incompatible with 25 ns bunch spacing, a new electronic board (LUCROD)

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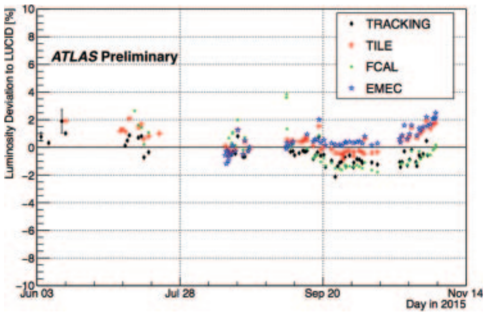

Fig. 1. – Stability of the ATLAS luminometers during the 2015 data taking.

was designed and installed close to the detectors performing a fast sampling, digitization and discrimination of the signals. Various algorithms are implemented on FPGAs to provide a redundant luminosity measurement. A second board (LUMAT) combines the information from the two sides of the detector to provide coincidence algorithms.

An accurate measurement of the luminosity requires an efficient calibration system. The ageing of PMTs, subjected to large current during the LHC fills, produces a gain decrease that must be corrected daily, after the end of each physics run by applying a high-voltage correction to compensate and keep the luminosity measurement stable to the % level. There are two different calibration strategies. The *VdM*, the *Modified* PMTs and the *Fiber* are calibrated using LED and LASER light, while the *Bismuth* PMTs exploit the signal from monochromatic electrons produced by a small amount of radioactive Bi-207 sources deposited on the quartz windows, through internal conversion.

Additional to the traditional hit-counting algorithms, new charge-integration ones are implemented in the LUCROD, based on the measurement of the charge collected by the PMTs which is proportional to the luminosity. These algorithms are free from non-linearities with the interaction rate, although more sensitive to PMT gain variations.

ATLAS uses a redundant luminosity measurement [2], based on various detectors, to keep the systematic uncertainties under control. In fig. 1, the stability of the ATLAS luminometers during 2015 is shown, in terms of percentage deviation of Inner Detector, TileCAL, FCAL and EMEC measurements with respect to LUCID, showing a long-term stability of 1.5% (RMS). In this preliminary stage of the analysis, the main systematic uncertainties on the ATLAS luminosity measurement are: Van der Meer and lenght-scale calibration (3.2%), calibration transfer (1.0%) and run-to-run consistency (1.5%), corresponding to a total uncertainty of 3.7%.

2. – Conclusions

The change of LHC running conditions has required a complete LUCID redesign for both detector and electronics. Currently, LUCID is the reference luminosity provider for ATLAS. Preliminary results of the analysis shows a long-term stability of the LUCID at the level of 1.5% and a total systematic uncertainty on luminosity measurement of 3.7%.

REFERENCES

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