# The LUCID detector

## ATLAS luminosity monitor and its electronic system

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## The LUCID detector

LUCID is a 2-modules luminosity monitor placed around the beam-pipe on both forward ends of ATLAS.

Each module is made of 16 photomultipliers and 4 quartz fiber bundles. The PMTs detect charged particles crossing their quartz window, where Cherenkov light is produced. Light is produced in the fibers as well and carried to PMTs located 2 meters away and protected by shielding

To increase the detector lifetime, only a subset of the PMTs close to the beam pipe 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 avoid saturation of some luminosity algorithms

The readout is compatible with the system used in phase I, which will be maintained in the commissioning phase, and complemented with new VME boards digitizing the PMT signals close to the detector and evaluating the charge generated in the PMTs in each 25-ns slot defining the LHC bunches.

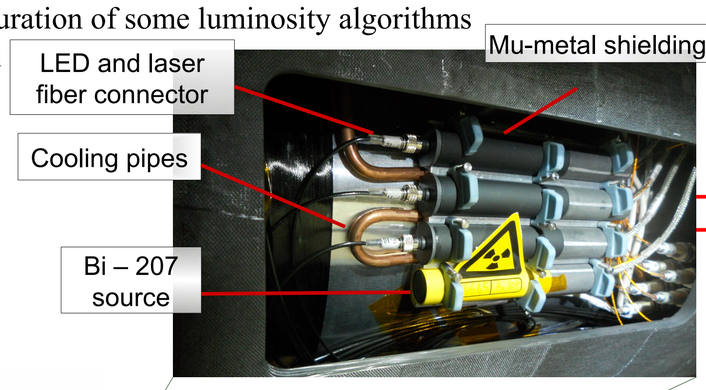
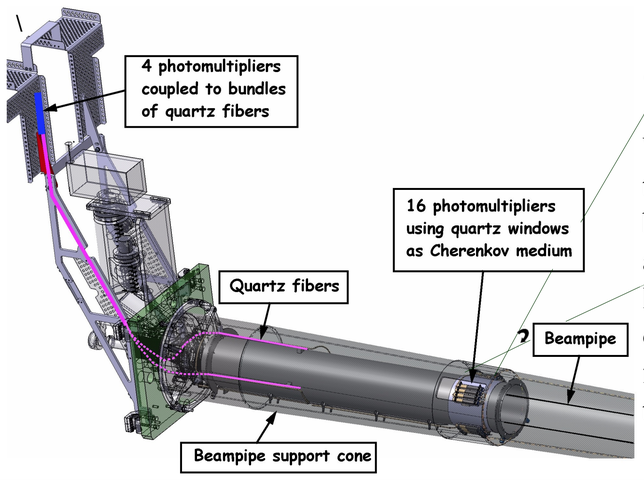



Fig. 1: A quarter of one of the two LUCID detectors, installed around the beam-pipe




With respect to the detector used in phase I, the new LUCID has a reduced material budget (no gas vessel and aluminum tubes), an increased dynamic range, and will measure luminosity with additional algorithms, based on PMT charge integration, expected to be free from the main systematics affecting the the old algorithms.

## Motivation for upgrade

Three main reasons called for a LUCID upgrade: 1) the PMT lifetime; 2) the increased luminosity; 3) the 25 ns bunch-spacing expected in phase II.

The charge collected by the PMT used in phase I is close to their expected limit, requiring a replacement. A smaller PMT model has been chosen to limit the overall current. The reduced acceptance will also help LUCID cope with the increased occupancy due to the higher √s energy and number of interactions per bunch crossing, so as to avoid saturation of the luminosity algorithms. Early signal digitization performed by new electronics will avoid broadening of analog signals, in the old set-up traveling over more than 100 m, without the need for amplification and shaping.

## PMTs and calibration

LUCID II uses R760 Hamamatsu PMTs, a smaller version of the previously used R762 model. The new PMTs have been tested for gamma and neutron radiation hardness, and calibrated with both cosmic muons and monochromatic electrons from a Bi-207 radioactive source. Shown in the figures are the amplitude spectrum of the Bi-207 source and a typical signal, as recorded by the new PMT.

These show a clear separation between signal and noise.

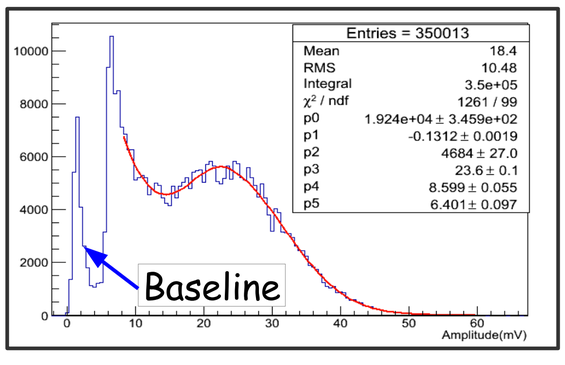



Fig. 2: amplitude spectrum

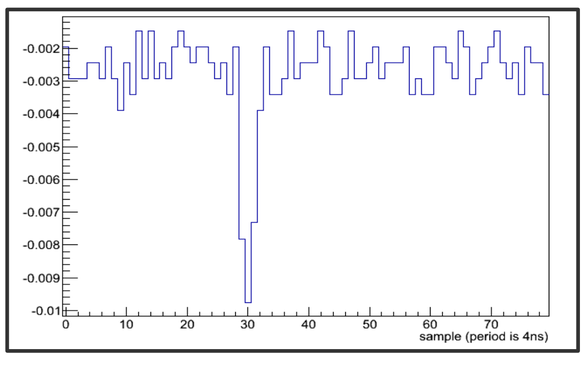



Fig. 3: typical PMT signal from bismuth source.

During operation, the PMT gain calibration is monitored by a redundant system made of;

1)Optical fibers carrying LED signals

2)Optical fibers carrying LASER signal provided by TileCal

3)Radioactive sources (Bi - 207)

## LUCID Electronics

In LUCID luminosity is measured by integrating its measurements (charge or *hits*) over an ATLAS Lumi-Block, for each individual bunch crossing. This is accomplished by its electronics, detailed in Fig. 4.

A new VME board (LUCROD), placed close to the detector, performs early signal digitization as well as PMT-charge integration over each bunch crossing time (25 ns), Fig. 5. Digital filtering is under study in order to improve the signal reconstruction for optimal charge measurement.

Each board is provided with 16 input channels, each connected to a different PMT. The main components of the LUCROD board are:

1) a low noise amplifier and a 480 MHz FADC, also serving as discriminator, for each input channel;
2) an FPGA for each pair of inputs, integrating the input signal over each bunch crossing;
3) an additional FPGA implementing luminosity algorithms and sending event fragments to the ATLAS stream after receiving an ATLAS level-1 trigger
4) an optical link to dispatch discriminated signals (*hits*) to a modified LUMAT board, which implements luminosity algorithms correlating the two detector modules.
5) an analog amplified output for each input, to be used for backward compatibility with the old readout system.
6) a possibility to readout samples of the input signals for monitoring purposes.

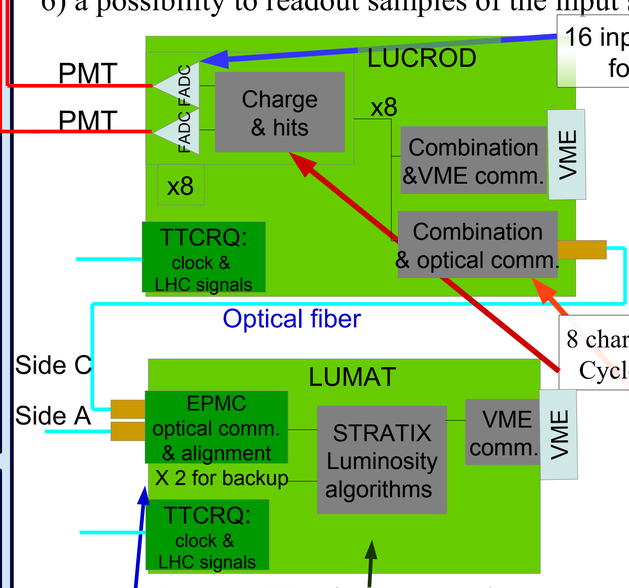



Fig. 4: LUCID electronics scheme

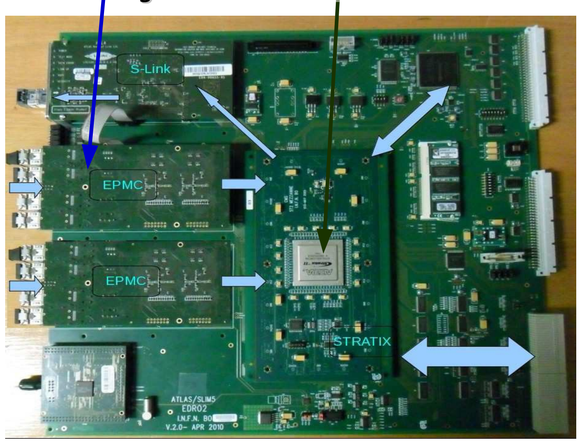



Fig. 6: the LUMAT board

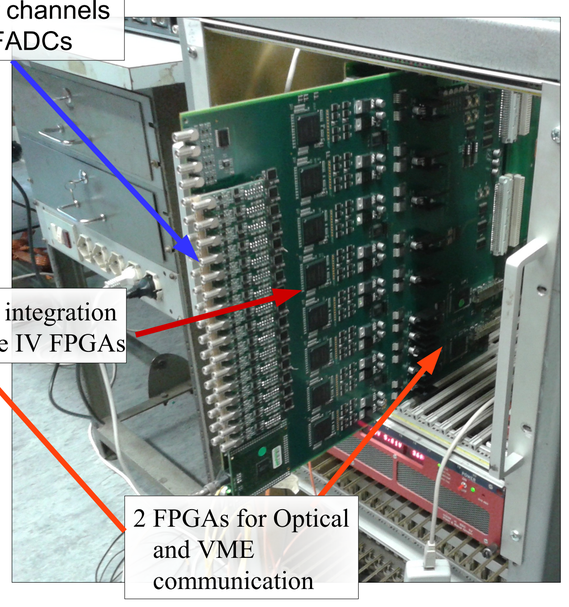



Fig. 5: Picture of the LUCROD board

Fig. 6 shows the LUMAT board with the 2 EPCM mezzanines mounted, connecting it to the LUCROD boards. It aligns side A and C inputs and performs 12 Luminosity algorithms. These are based on *hit* counting at the same time.

Default algorithms combine information from both boards, but alternative sets of algorithms provide single-PMT hit counting.

## First collisions at LHC

In April LHC was turned on for the first time after the Shutdown period (Fig. 7) and LUCID successfully registered the first beam collisions in May, as shown in Fig. 8 with the Event-OR algorithm, that counts any event registered in a tube in side A or C.

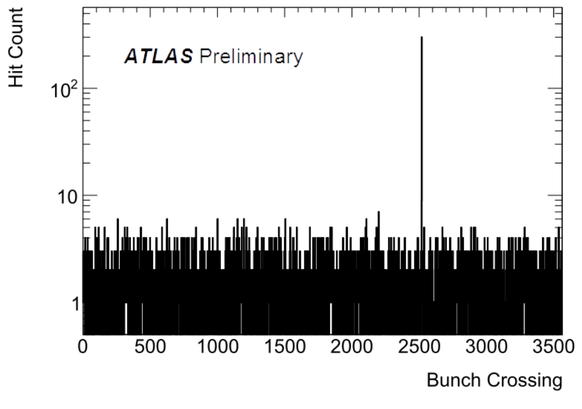



Fig. 7: LUCROD PMT-1 hit counts as a function of bunch crossing number in the second LHC beam splashes. The constant background is given by the calibration Bi-207 source.

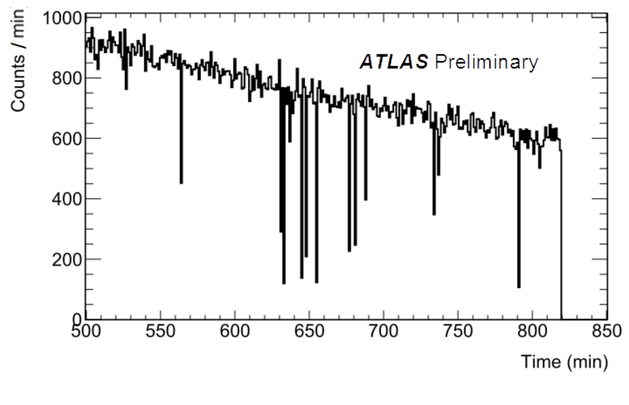



Fig. 8: LUMAT Event-OR counts acquired at √s=900 GeV, showing beam decay in time.