The upgrade of the ATLAS Luminosity detector (LUCID) for HL-HLC

Federico Lasagni Manghi on behalf of the ATLAS Collaboration

Istituto Nazionale di Fisica Nucleare

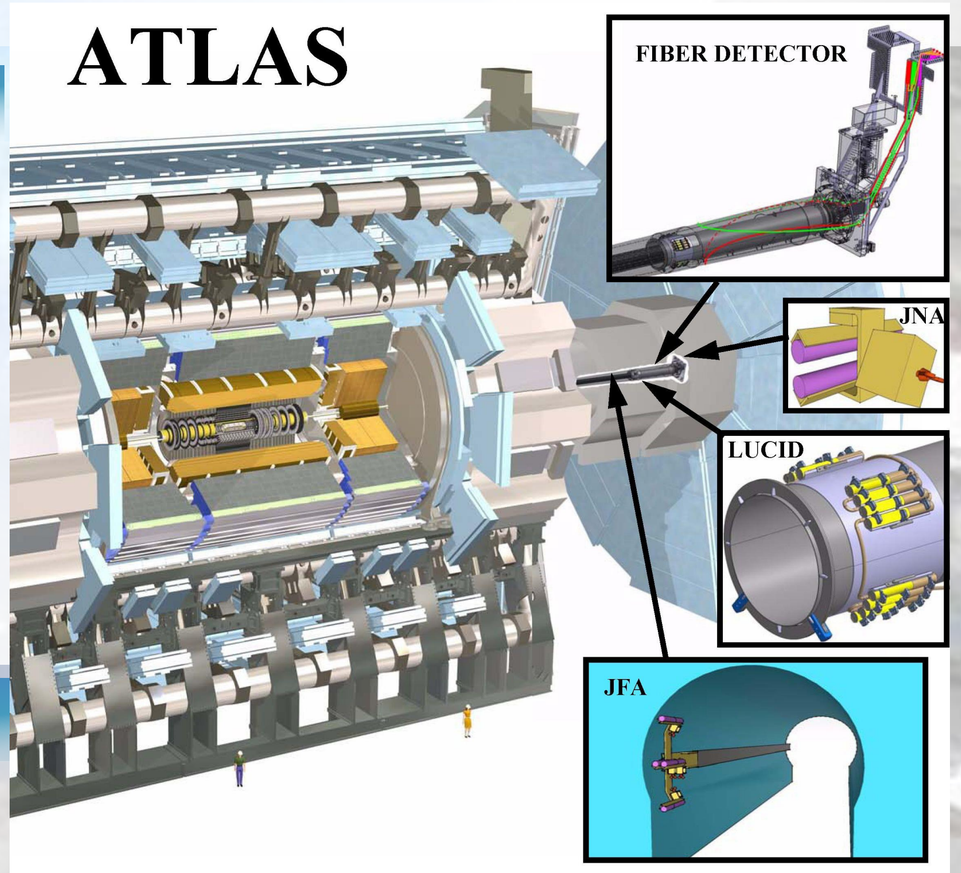
LUCID in Run 2 (and 3)

LUCID is and has been the main ATLAS Luminosity monitor: the only detector that can measure luminosity for individual bunch crossings, online, in any LHC L range.

- *Total Run 2 offline luminosity measured with a 1.7% uncertainty and a better than 1% stability over time.*
- *Main systematic:* ***VDM calibration***

Design strategies:

- a fast, low-background and rad-hard PMT-based Cherenkov detector
- fast electronics handling hit and charge algorithms
- stable, flexible and redundant operation, thanks to the gain calibration system and the layout



HL-LHC challenges

Luminosity requirements:

- Offline precision ~ 1%
- Online stability and precision (~3%) in 2s-long periods
- ➢ Operate far from saturation

Challanging conditions: μ = 200 and L = 4000 fb^{-1}

- Leading to potential saturation of the PMT acceptance and high total dose and current
- Large (and not-predictable) non-linearity in the larger μ-range

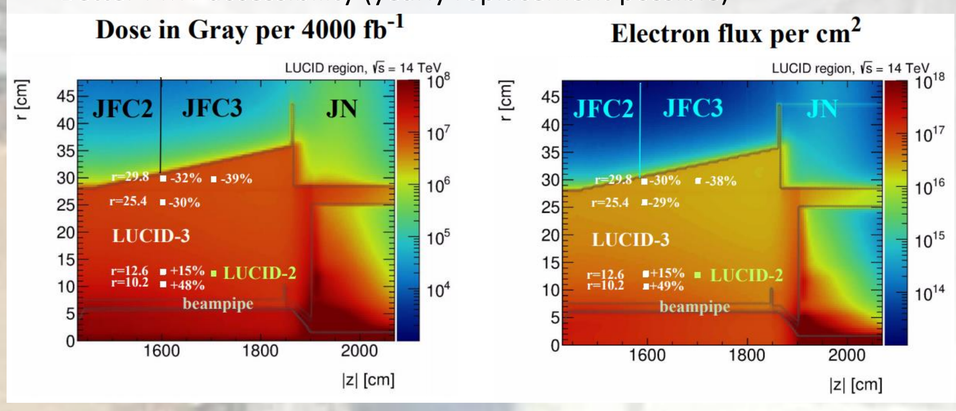
Different ATLAS TDAQ infrastructure:

- New electronic infrastructure required

Solution: New PMT locations

Moving the PMT's away from the beam-pipe attains:

- Lower dose absorbed by bases and PMT's
  - 30% lower than around the beam-pipe
- Attenuation of HIT algorithms saturation
- Better PMT accessibility (yearly replacement possible)



Solution: Smaller PMT's

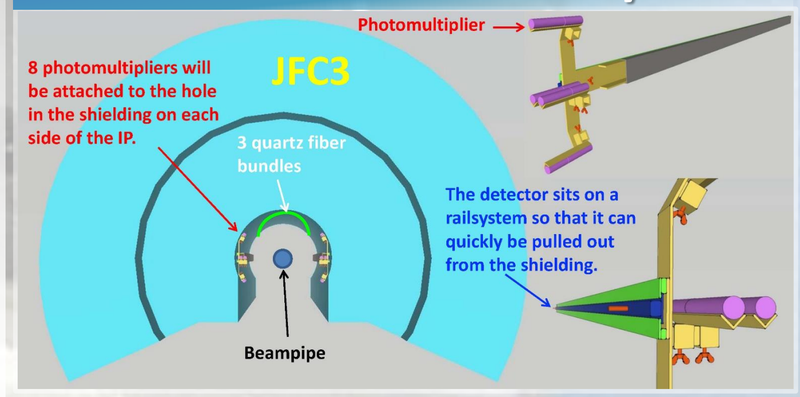
Modified R760 PMT's with an Al layer deposited to reduce the active window used in Run 2:

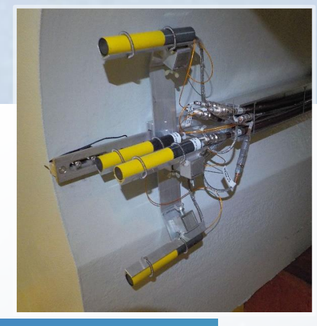
- Better saturation but a larger μ-dependence
- Light produced in the outer ring?

New small PMT's (R1635) could replace them

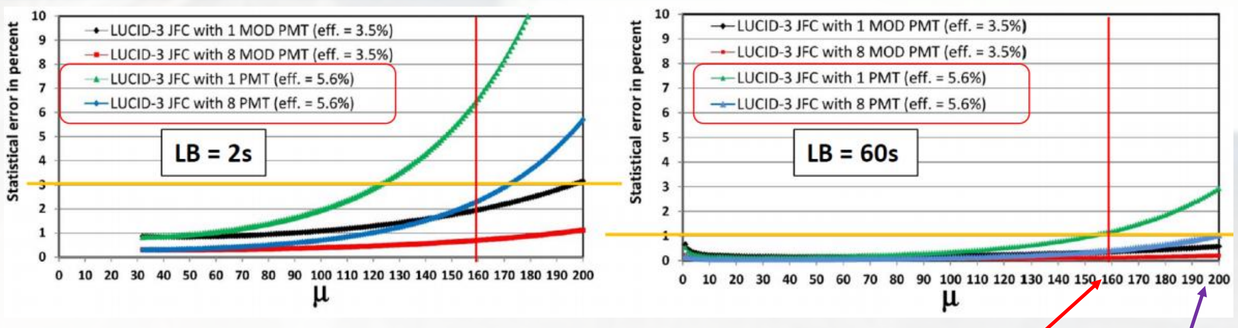
- Modified radiation-hard quartz
- Similar saturation properties
- Under test in lab and in ATLAS

New main detector: JFA/C-3





Saturation in the JF-3 position



OFFLINE requirement: 8 working standard R760 PMT's
ONLINE requirement: small R1635 PMT's

The Run 3 PMT prototypes

JFA/C-3 Prototypes with standard R760 and smaller R1635 PMT's

- To study possible shielding surface effects
- To evaluate possible crossing-angle dependences
- To validate the dose and flux simultaions in this location

JN-A prototype: two new R760 PMTs installed behind the forward JFA3 shielding.

- ➢ Low-rate measurement that is expected to be free from μ-dependence and hit-saturation.
- ➢ Predicted occupancy 10-30% wrt the LUCID-2 location
- Not sensitive in VdM scans

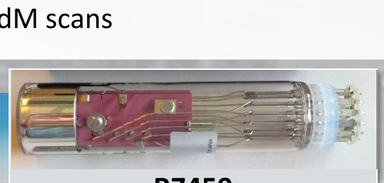
Solution 2: Improved fiber detector

Fiber detector intrduced in Run 1, improved in Run 2, upgraded prototype in Run 3:

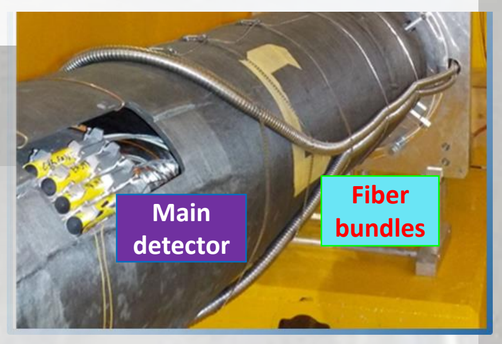
- New calibration system
- New quartz fibers with better radiation hardness
- New techiniques to overcome the shortcomings of charge measurements

Two possible layouts for HL-LHC:

- Attached below the top of the JFC-3 shielding
- Around the beampipe -> **Prototype** installed around the VJ cone in a similar fashion.

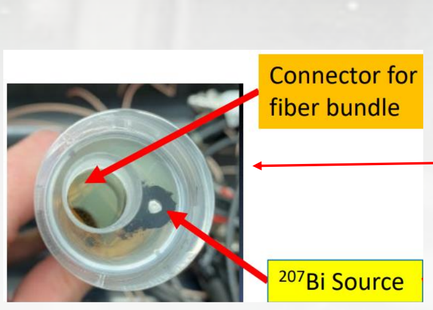


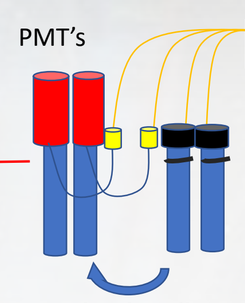
R7459

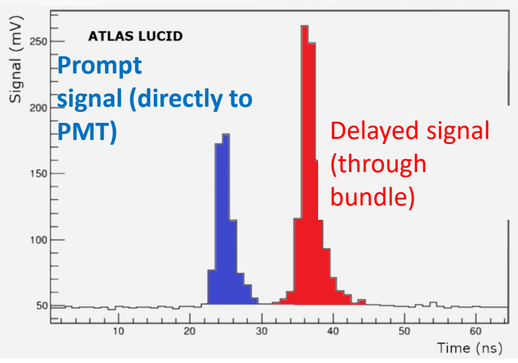


Innovative calibration system:

- New R7459 large PMT's hosting ^{207}Bi source and a bundle connector
- Connector with ^{207}Bi source, bundle plug and short calibration fiber
- 6 different LED wavelength pulsed into the bundles AND short fibers
  - Ratio variation ∝ total degradation
- UV filter in **one** of the bundles for stability







PMT gain monitored and adjusted using the ^{207}Bi source
Fiber degradation measured using pulsed LED light:

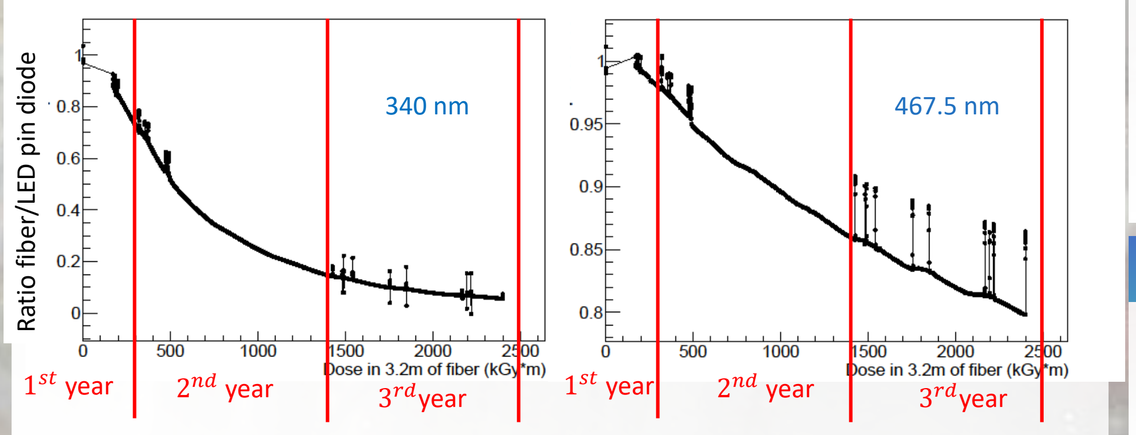
- 310, 360, 410, 467.5, 525, 627.5 nm
- Charge ratio used for L correction
- Combination of simulation and calibration data

μ = averge number of interactions per bunch-crossing
BC = bunch crossing
VDM = Van der Meer scan (absolute L calibration)

Fiber radiaton hardness

Fibers tested in gamma irradiation facility:

- 6 wavelengths (285-627 nm) cycled
- Transmission loss measured over 6 m rescaled to effective 3.2m exposed length
- Large losses observed in UV -> filter inserted in one of the prototype bundles



References

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"The new LUCID-2 detector for luminosity measurement and monitoring in ATLAS" 2018 JINST 13 P07017
"Choice and characterization of photomultipliers for the new ATLAS LUCID detector" 2016 JINST 11 P05014