Upgrade of the ATLAS Hadronic Tile Calorimeter for the High Luminosity LHC

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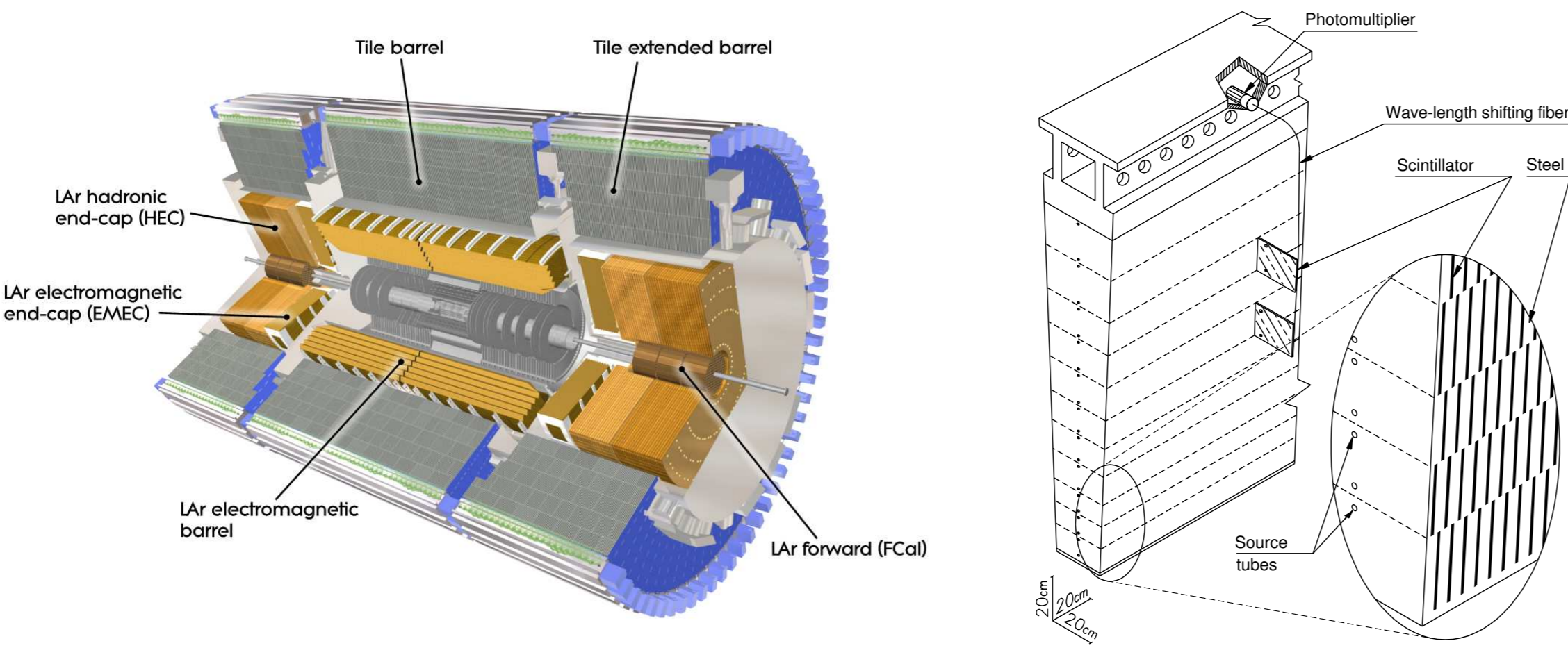Charles University, Prague, Czech Republic
No. 166

ATLAS Tile Calorimeter

- Sampling hadronic calorimeter made of alternating steel plates and scintillating tiles
- Scintillating tiles are read out by 2 photomultiplier tubes (PMTs) via wave length shifting fibers
- Divided into long barrel and two extended barrels along the beam line and segmented azimuthally into 64 modules
- Energy reconstruction of hadrons, jets, τ particles and missing transverse momentum; identification of electrons and muons

High Luminosity LHC (HL-LHC)

- The Upgraded LHC for HL-LHC will deliver five times the LHC nominal instantaneous luminosity.
- The ATLAS upgrade, in 2024, will adjust the detector and data acquisition system for the HL-LHC.
- Tile Calorimeter will undergo a major replacement of its on- and off-detector electronics. All PMT signals will be digitized and send off the detector at the full collision rate of 40 MHz. The off-detector pre-processor (PPR) will buffer the data and calculate the cell energies and trigger primitives. This will provide better precision of the calorimeter signals used by the trigger system. The upgrade will also improve reliability and redundancy of the system.

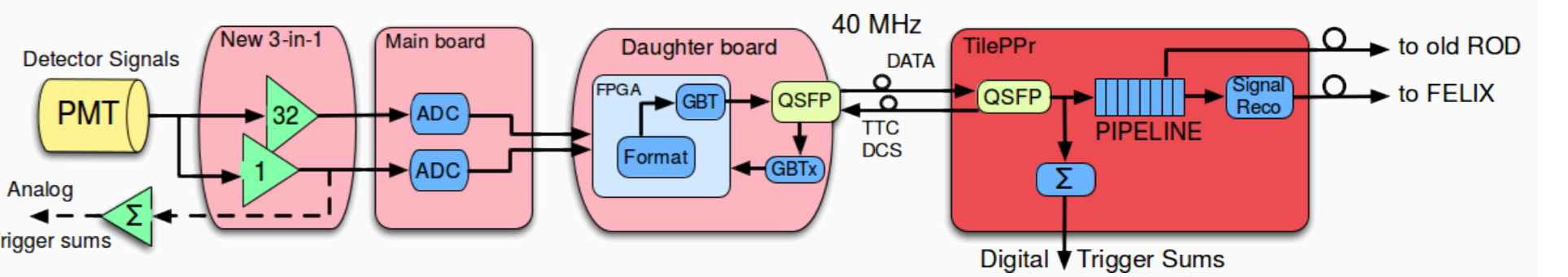## Phase II Tile Calorimeter Upgrade

	CURRENT SYSTEM	UPGRADED SYSTEM	
Level I Trigger Signals:	Low-granularity Analog Sum	Fully Digitized	→ Flexible trigger logic, lower noise and higher granularity
Pipeline Memory:	On Detector	Off Detector	→ Performance and flexibility
Readout Modularity:	1+1 Links, 48 PMTs	16+16 Links, 6 PMTs	→ Reliability
LVPS Modularity:	1 Unit, 48 PMTs	4+4 Units, 12 PMTs	→ Reliability
HV Modularity:	2 Units, 24 PMTs	4+4 Units, 12 PMTs	→ Reliability

Hybrid Demonstrator

- TileCal Demonstrator is a prototype of the upgraded readout system and it is compatible with the current system.
- The Demonstrator has been interfaced with legacy control, monitoring and calibration infrastructure and with the new off-detector electronics.
- It was extensively tested during three test beam campaigns in 2015 and 2016 and testing will continue during two test beam periods in 2017.
- Insertion of one Demonstrator module in the current system is planned during one of the short LHC shutdowns during Run 2.

Tile Calorimeter Upgrade Design

Front End Board (FEB) A

- Process PMT signals
- Slow integration for Cs calibration
- Charge injection calibration (CIS)

Front End Strategies

Upgraded 3-in-1 : Discrete elements
- Improves current design
- Passive pulse shaping
- Bi-gain amplification (1x, 32x)

QIE : Charge Integrator in an ASIC chip
- No pulse shaping
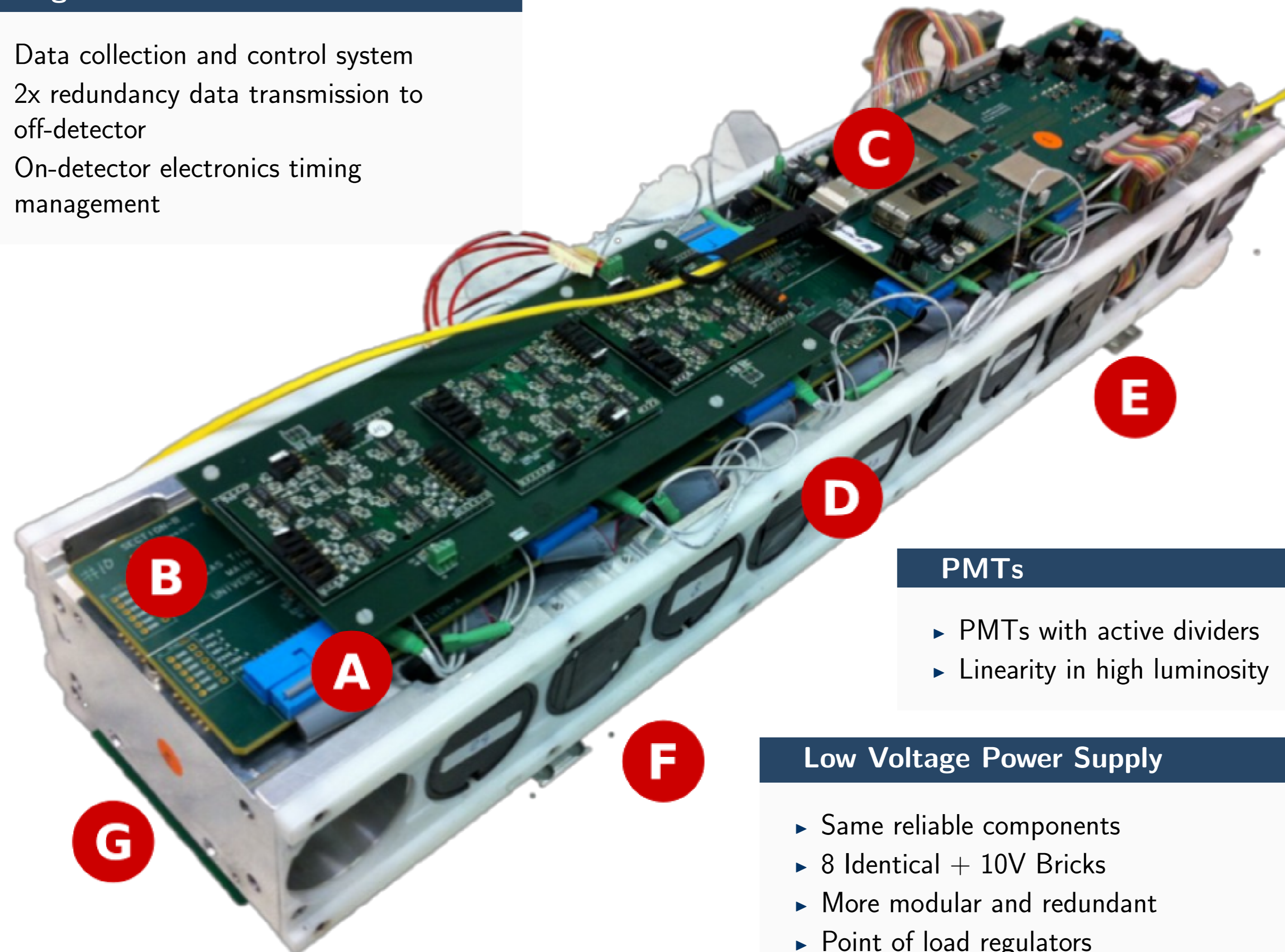- Signal digitization

FATALIC : Implemented as ASIC
- Active pulse shaping
- Tri-gain (1x, 8x, 64x)
- Signal digitization

Mainboard: Specific for each FEB B

- Interface between FEB and Daughter board
- Low Voltage control
- Signal digitization for 3-in-1 FEB option
- Control of CIS and Cesium calibrations

Daughterboard C

- Data collection and control system
- 2x redundancy data transmission to off-detector
- On-detector electronics timing management

PMTs D

- PMTs with active dividers
- Linearity in high luminosity

Low Voltage Power Supply E

- Same reliable components
- 8 Identical + 10V Bricks
- More modular and redundant
- Point of load regulators

Redesigned Chassis and Cable Carriers

- Modular design (1 Tile Module = 4 Mini-drawers)
- Easier installation, extraction and repair

High voltage (HV) regulation F

Individual PMT control (2 options studied):
Remote HV
- Off-detector
- HV to each PMT separately
Local HV/HV Opto
- Improved monitoring and radiation hardness
- HV supplied to 6 PMTs

Tile Preprocessor G

- Receives high-speed data from on-detector electronics
- 40 MHz digital inputs for the L0 Triggers
- Keeps data in pipelines pending trigger decision
- Signal reconstruction
- Trigger, timing and control signals to FEB
- Monitoring, data control system
- Interface with ATLAS data acquisition system
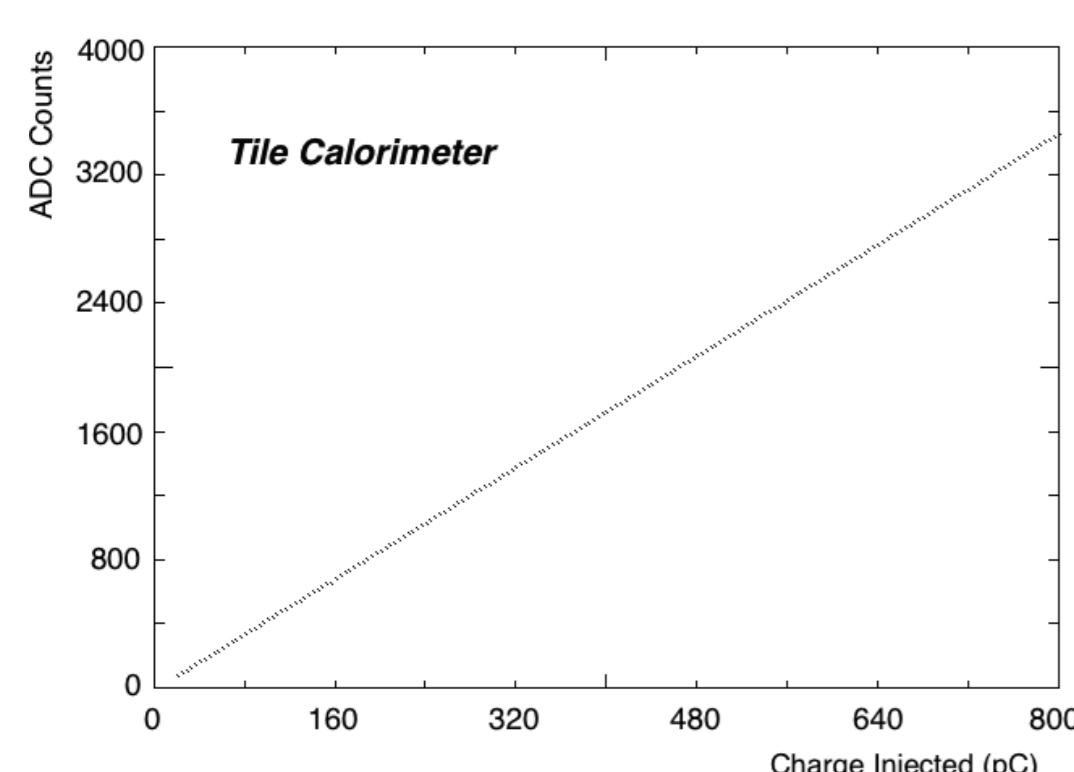
Status of Control and Calibration Tests

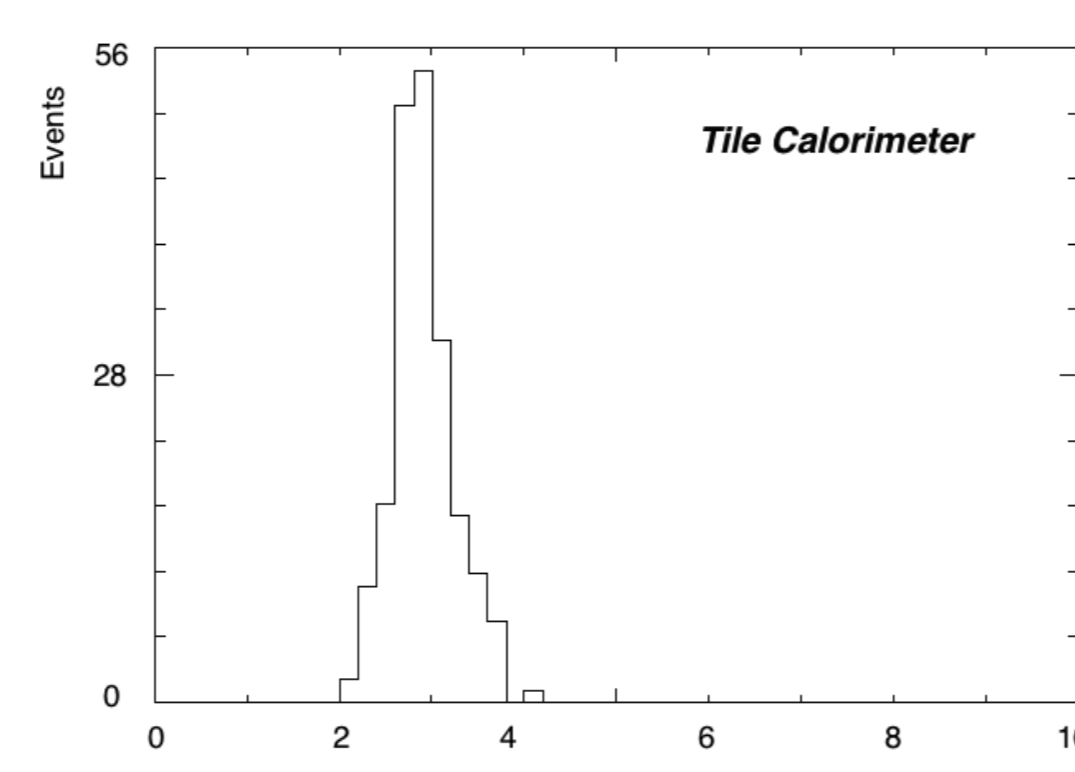- Plots for Demonstrator (3-in-1) – QIE and FATALIC provide comparable results
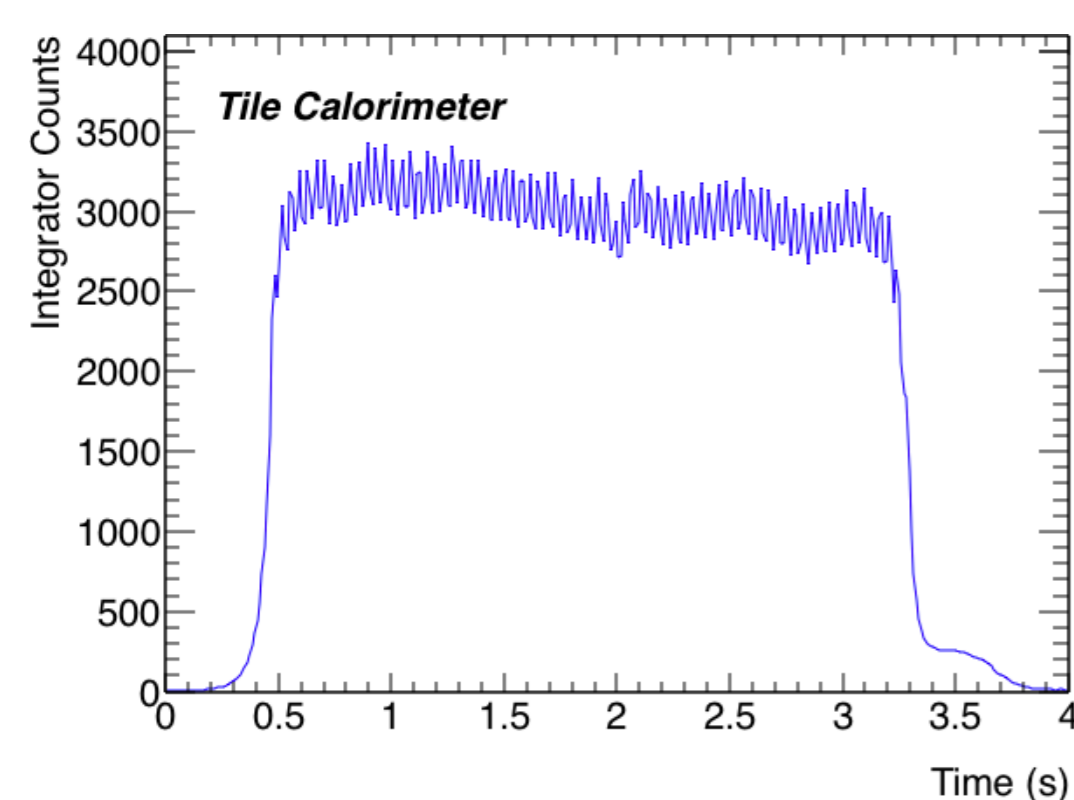
Demonstrator integrator response for Extended Barrel Cell D-6 to a passing Cesium source
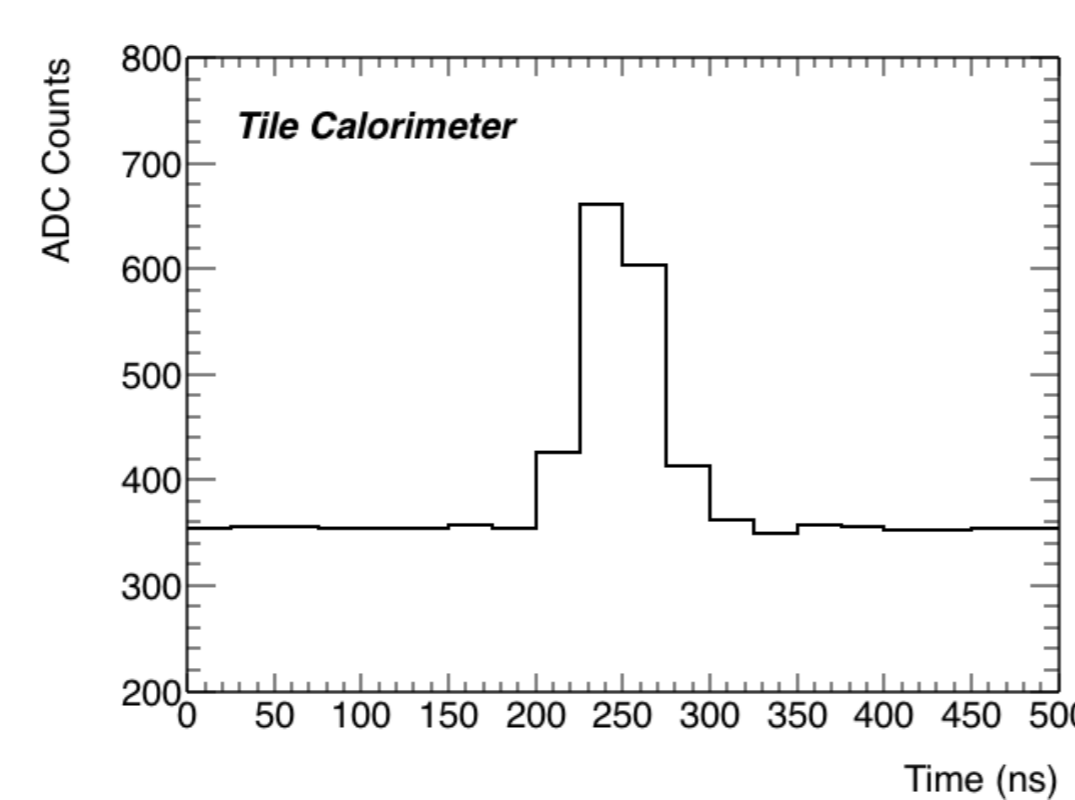
Demonstrator Low Gain response to a Laser pulse in the hundreds of GeV, sampled at 40 MHz
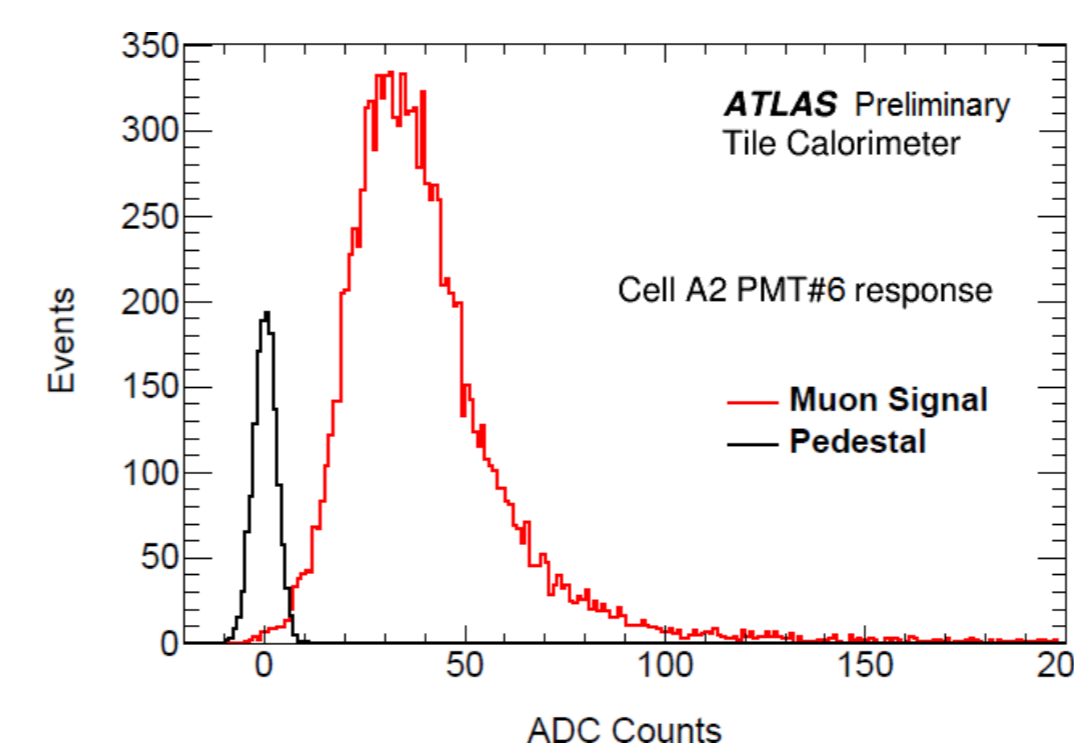

A CIS scan using Demonstrator, each charge injection step is sampled 50 times and the average is plotted for that step
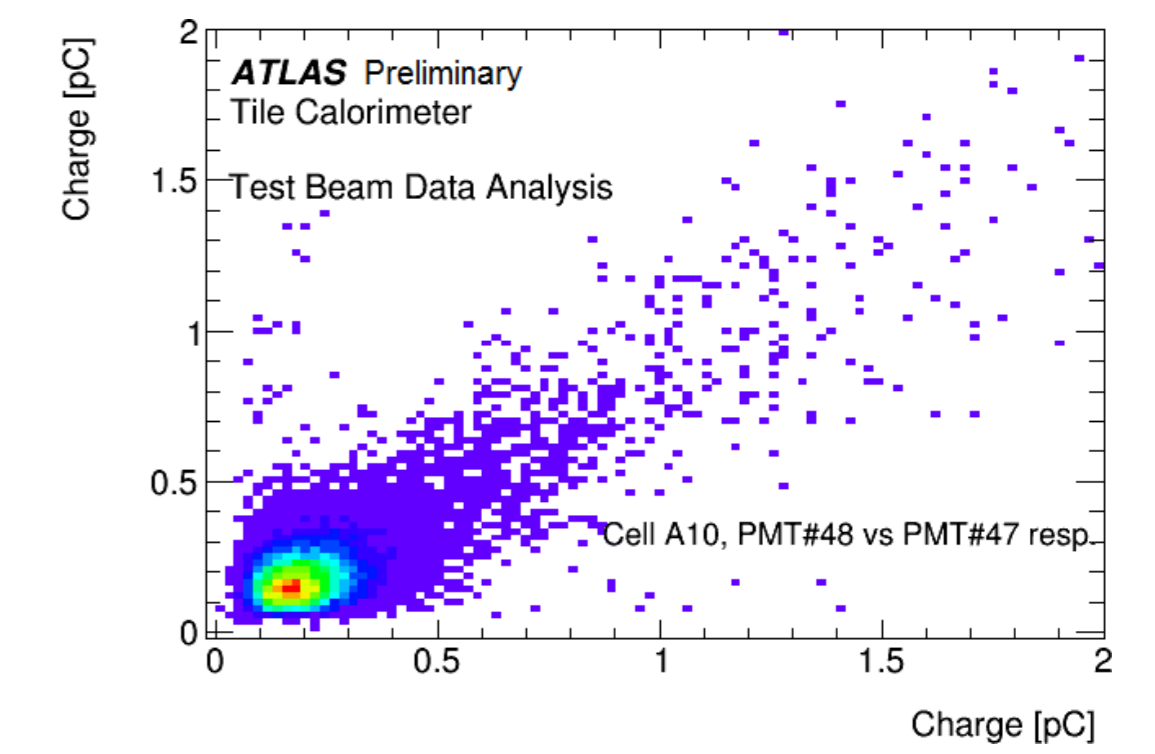

The RMS of a CIS scan using Demonstrator, each charge injection step is sampled 50 times and the RMS of these 50 samples is plotted for each step

Test Beam Results

- Good performance for Demonstrator (3-in-1), QIE and FATALIC

Muon signal in cell A2 using 100 GeV muons hitting Demonstrator at 20°

Muon signal in cell A10, PMT48 vs PMT47 using 150 GeV muons hitting Demonstrator at −90°

Summary

- The upgraded Tile calorimeter architecture was designed to meet ATLAS requirements for the HL-LHC.
- Control and calibrations tests proved successful in the Demonstrator, QIE and FATALIC.
- Three test beam campaigns conducted in 2015 and 2016 and two test beam periods are planned in 2017.
- 3-in-1, QIE and FATALIC front-end technologies were successfully evaluated at the testbeam.
- Three different front-end and two HV options are being investigated for the upgrade and a final solution will be chosen after test-beam studies.

References

- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileUpgrade
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileUpgrades
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileTestBeamResults