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

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ATLAS Tile Calorimeter

- Consists of a central barrel and two extended barrels, each made up of 64 modules, each covering the azimuthal angle 2π/64 = 1°
- Modules are made of alternating layers of iron plates and scintillating tiles
- Modules are divided up into cells
- The scintillating tiles in each cell are readout by wave-length shifting fibers on both sides of the module.
- The fibers deliver the light to photomultiplier tubes (PMTs)
- Each cell is readout by 2 PMTs, one for each side of the module
- Drawers containing the Front-End electronics are inserted in each module

Front End Designs

- 3 separate designs were designed and tested at test beams
- Upgraded 3-in-1: Discrete Elements
  - Improves current design
  - Passive pulse shaping
  - Bi-gain amplification (1x,32x)
  - GIE: ASIC chip
  - Charge Integration
  - PATALIC: ASIC chip
  - Active pulse shaping
  - Tri-gain (1x,8x,64x)

Upgrade of the ATLAS Hadronic Tile Calorimeter

- High Luminosity LHC (HL-LHC)
  - The LHC will undergo a series of upgrades towards a High Luminosity LHC (HL-LHC) that will deliver five times the LHC nominal instantaneous luminosity
  - The ATLAS Phase II upgrade, in 2024, will accommodate the upgrade of the detector and data acquisition system for the HL-LHC
  - TileCal detector components (steel absorbers, scintillating tiles, and fibers) will not be replaced
  - TileCal on- and off-detector electronics must be replaced to meet new trigger requirements and improve reliability

Current System in ATLAS

- Sends Low-granularity Analog Sum to Level 1 Trigger
- 1 LVPS Unit supplies LV to entire drawer
- 1 Cable supplies HV for the entire drawer, HV Opto Boards in the drawer then regulate and monitor HV for each PMT
- Off-detector electronics receives signal from 48 PMTs through 1 on-board Interface Board
- 3-in-1 card shapes PMT pulse which are then digitized at 40 MHz using 10-bit ADCs (1 ADC per gain).
- 2 Gains, Hi (12.5 pC dynamic range) and Lo (800 pC dynamic range)

Tile Calorimeter Upgrade Design

- The Demonstrator is a hybrid drawer of the upgraded 3-in-1 design that is also compatible with the current system in ATLAS
- It has been tested in 4 test beams and is currently being tested in a 5th test beam
- The Demonstrator could be inserted in the current system during one of the short LHC shutdowns during Run2

Signal Reconstruction

- Most studies and analysis of the upgraded 3-in-1 design use the legacy readout of the demonstrator (10-bit ADC signal of 7 samples)
- This makes energy reconstruction and simulation simple because the framework already exists
- So results here will improve by developing optimal filter using the full 12-bit ADC signal of 16 samples

Demonstrator Test Beam Results

- Each drawer is made up of 4 independent mini-drawers
- Sends full digital signal to Level 1 Trigger
- Each mini-drawer has 2 LVPSs which supply LV to each side. If one side LVPS fails the other is capable of supplying LV to both sides
- 2 HV options being considered

Remote HV:
- (option selected, awaiting clearance)
  - HV supplied to each PMT separately
  - Off-detector monitoring and setting of HV

HV Opto:
- HV supplied by single cable to the module where it is distributed to individual PMTs and monitored by on-detector electronics
- Each mini-drawer has 2 FPGAs, 1 for reading and controlling each side of the drawer. If one fails the other is able to take over for both FPGAs
- 3-in-1 card shapes PMT pulse which are then digitized at 40 MHz using 12-bit ADCs (1 ADC per gain).
- 2 Gains, Hi (25 pC dynamic range) and Lo (800 pC dynamic range)