There are currently on average 32 proton–proton collisions per bunch crossing at the Large Hadron Collider (LHC). After the high-luminosity (HL) upgrade (2024–26), this number is planned to increase up to 200. The current readout of the ATLAS Liquid Argon (LAr) calorimeters does not have the necessary buffering, bandwidth, and radiation tolerance for HL-LHC conditions. For this reason, a replacement of the readout electronics for all 182,500 channels is planned.

**Motivation**

- **Upgrade of Readout Electronics**
  - **Front-End**
    - installed directly on the detector
    - radiation tolerance
  - **Back-End**
    - LAr Signal Processor (LASP)
    - 35,000 optical links from the front-end boards
    - 250 Tbit/s input data rate
    - 372 high-performance FPGAs

- **Detector Pulses**
  - **Pulse shape**: triangular
  - **Amplitude**: up to 10 mA
  - **Length**: 450 ns
  - **Shaper baseline design**: 1× high-pass, 2× low-pass with τ = 13 ns

- **Preamplifier and Shaper**
  - **Dynamic range**: 35 MeV–3 TeV
  - **Linearity**: 0.1% in the lower 10% of the range
  - **Two R&D paths ongoing**
    - 130-nm CMOS design: line termination amplifier with electronically cooled resistor and Super Common Base amplifier
    - 65-nm CMOS design: fully differential amplifier with passive feedback
  - **Common analog front-end test stand has been developed**
  - **Results from chip submissions are expected in Fall 2017**

- **Analog-to-Digital Converter**
  - **Required width**: 16 bit/channel
  - **Sampling rate**: 40 MHz
  - **Noise**: below intrinsic calorimeter noise
  - **65-nm CMOS design**
    - Dynamic range enhancer (DRE) followed by 12-bit successive approximation register ADC
    - Test chips expected in Fall 2017
  - **COTS candidate**
    - AD76394, 14-bit ADC
    - Mitigation of single-event effects (SEE) and single-event functional interrupts (SEFI) needed
  - **Custom interface to serializer required**

- **AREUS – ATLAS Readout Electronics Upgrade Simulation**
  - **Program to simulate digitization, electronics noise, and digital filtering**
  - **Highly configurable ADC settings**
  - **Electronics noise scale and spectral density; filtering algorithms;**
  - **Used for comparing and evaluating digital filters**

**References**