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# Irradiation Tests and Expected Performance of Readout Electronics of the ATLAS Hadronic Endcap Calorimeter for the HL-LHC

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The readout electronics of the ATLAS Hadronic Endcap Calorimeter (HEC) will have to withstand an about 10 times larger radiation environment at the future high-luminosity LHC (HL-LHC) compared to the LHC design values. The radiation damages of the front-end electronics made in GaAs technology could significantly affect the HEC performance. Recent measurements of neutron and proton irradiation tests performed at LAr temperatures are reported, which allow an improved assessment of the expected degradation in HL-LHC conditions. These measurements are furthermore applied to simulations of the calorimeter performance. Results from replacement technologies, like Si CMOS, are also presented.

## Summary

The Hadronic End-cap Calorimeter (HEC) of the ATLAS experiment at the CERN Large Hadron Collider (LHC) is a copper-liquid argon sampling calorimeter in a flat plate design. The pre-amplifier and summing (PAS) systems is the heart of the HEC read-out electronics and is realized in GaAs ASIC technology. The PAS devices are installed inside the LAr cryostat directly on the detector. They have been proven to operate reliably in LHC conditions, within safety factors. At the future high-luminosity LHC (HL-LHC), however, the front-end electronics will have to withstand an about 10 times larger radiation environment compared to the design values for LHC. Radiation damages in HL-LHC conditions could therefore significantly affect the HEC performance.

The GaAs ASIC has been exposed to neutron and proton radiation with fluences corresponding to ten years of running of the HL-LHC. Neutron tests were performed at the NPI in Rež, Czech Republic, where a 36 MeV proton beam is directed on a thick heavy water target to produce neutrons, delivering an integrated fluence of about 4x10ˆ15 n/cmˆ2 (in terms of 1 MeV-equivalent NIEL in GaAs at ATLAS). The proton irradiation was done with 200 MeV protons at the PROSCAN area of the Proton Irradiation Facility at the PSI in Villigen, Switzerland, up to an integrated fluence of 2.6 x 10ˆ14 p/cmˆ2. In-situ measurements of S-parameters in both tests allow the evaluation of frequency dependent performance parameters, like gain and input impedance, as a function of fluence. The non-linearity of the ASIC response has been measured directly in the neutron tests at warm. The signal response of the irradiated samples was analyzed furthermore at cold, i.e. at LAr temperatures. In particular these results allow an improved estimation of the expected performance degradation of the HEC.

The measured gain parameters and non-linearity of the ASIC response were applied to Monte-Carlo simulations of the HEC detector in order to extract the expected energy resolution and performance of jet measurements.
For a possible replacement of the PAS chips, alternative technologies are investigated and exposed to similar neutron radiation levels. In particular, IHP 250 nm Si CMOS technology has turned out to show good performance and match the specifications required. The corresponding results will also be presented.

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