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Multi-Gsps ADC radiation qualification for the LHC BPM system consolidation

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The consolidation of the Large Hadron Collider (LHC) Beam Position Monitor (BPM) requires digitising analogue signals from more than 1000 dual-plane BPMs using radiation-tolerant analogue-to-digital converters (ADCs). To this end, two commercial off-the-shelf (COTS) quad-channel, 12-bit ADCs operating at up to 1.6 Gsps were tested. Both ADCs were evaluated for cumulative radiation effects and single event effects (SEE) with a 200 MeV proton beam at Paul Scherrer Institute (PSI). This paper presents the radiation test results, assessing ADC performance and reliability under realistic operating conditions.

Summary (500 words)

The Beam Position Monitors (BPMs) are instrumental for the safe and efficient operation of the Large Hadron Collider (LHC), providing precise beam-position measurements from more than 500 locations, each equipped with two dual-plane BPMs. Due to aging electronics and increased radiation levels anticipated during the High-Luminosity LHC (HL-LHC) operation, a consolidation project has been initiated to replace the current BPM system during Long Shutdown 4 (2034–2035).

A critical component in the new digital front-end (DFE) architecture of the BPM is the analogue-to-digital converter (ADC), responsible for digitising analogue signals from the BPM pickups and forwarding digital data via high-speed electro-optical transmitters to the back-end electronics in surface buildings. Given the 250 Gy and 1.4x10^11 HEH/cm^2 fluence expected in the LHC tunnel in 10 years, the selected ADCs and other DFE components must be qualified to withstand at least twice these levels to ensure reliable operation over their intended lifetime.

While custom radiation-hardened solutions exist, commercial off-the-shelf (COTS) alternatives offer potential advantages in availability, cost-effectiveness and performance. Two COTS quad-channel 12-bit ADCs, each capable of a maximum sampling rate of 1.6 Gsps, were selected as devices under test (DUTs) and subjected to respective radiation test campaigns. Both DUTs belong to ADC product families known for their radiation tolerance.

Radiation test campaigns were conducted at the Proton Irradiation Facility (PIF) at Paul Scherrer Institute (PSI), utilizing a 200 MeV proton beam as part of the Radiation Hardness Assurance (RHA) process for CERN application.

Both ADCs were evaluated for cumulative radiation effects via offline analysis by comparing pre- and post-irradiation measurements. The tests assessed the impact of cumulative effects on component lifetime and critical performance parameters such as noise floor, linearity, and gain stability.

Additionally, susceptibility to single event effects (SEE), including Single Event Latch-up (SEL), Single Event Upset (SEU), Single Event Transient (SET), and Single Event Functional Interrupt (SEFI), was assessed through real-time online analysis. These tests evaluated SEE impacts on data integrity, device stability, and control register functionality during irradiation, with resulting measurements used to calculate SEE cross-sections.

This paper presents the radiation test results of the evaluated ADCs, describes the radiation test setup implementation and discusses their suitability and reliability for the LHC BPM consolidation project.

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