Contribution ID: **76** Type: **Poster**

High dynamic range diamond detector acquisition system for beam wire scanner applications

Wednesday 30 September 2015 17:57 (1 minute)

A secondary particle shower acquisition system is under design for the CERN beam wire scanners upgrade. The new acquisition system is based on a polycrystalline diamond detector. Beam synchronous digitization will be performed in the tunnel, near the detector to fully exploit its large dynamic range and fast response. Two integrator ASICs (ICECAL and QIE10) are being characterized and compared for detector readout with the complete acquisition chain prototype, including the optical digital data transmission, at 4.8Gbps, with the GBT protocol and versatile link components (VTRx).

Summary

As part of a new wire scanner design being pursued by CERN, there will be an upgrade of the secondary shower acquisition system.

The current secondary particle acquisition system consists of a scintillator, optical filters and photo-multiplier tube (PMT) with a nearby pre-amplifier. The analogue signal is directly sent through long coaxial cables (up to 250m) to the surface, where the digitization is performed. The dynamic range required is covered by selecting a combination of optical filter values and PMT gains.

The new electronic design aims to cover the whole dynamic range required for all CERN wire scanners with a single configuration without tuneable parameters, and be capable of bunch-by-bunch measurements with an integration time of 25ns. To be fully independent of the scanner location and beam parameters, a dynamic range of 10e6 is required.

The upgraded electronics will use polycrystalline chemical vapour deposition (pCVD) diamond detectors for secondary particle shower measurements, with low noise measurements near the detector followed by digital data transmission through an optical link. For this architecture a custom front-end has been designed to resist a total ionising radiation dose of up to 1kGy in 10 years. The VME FMC Carrier Board (VFC) designed by CERN's beam instrumentation group will be used as the back-end system to receive and process this digital data.

In order to study the diamond detector response to secondary particles produced by the beam wire scanners, an analogue front-end installation is being installed in the CERN-SPS. Measurements with this set-up will be compared to simulation-based estimations to verify the achievable dynamic range.

The radiation-tolerant front-end prototype has been developed as a modular design. The Igloo2 UMd Mezzanine board from CMS is used to drive the gigabit optical link, while a couple of independent boards connected to it will be used for testing the potential pCVD diamond detector readout ASICs (ICECAL and QIE10). Both ASICs will be characterized in terms of linearity, noise and dynamic range for this specific application by using the complete acquisition chain in a laboratory set-up. The results of these tests will be used to determine the readout ASIC selected for the final system. For high dynamic range coverage, the detector signal is split and acquired simultaneously on parallel channels with different gain/attenuation levels.

Data transmission, slow control and synchronization are provided through the 4.8Gbps optical link. The GBT protocol and Versatile Link transceivers (VTRx), being developed for the LHC experiments, are used for this purpose.

This contribution presents the project status, the front-end performance, the first measurements with the complete acquisition chain, and the characterization of both integrator ASIC candidates under test for diamond detector readout. In addition, the diamond detector signals from particle showers generated by an operational beam wire scanner will be analysed.

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Session Classification: Poster

Track Classification: Production