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Application Of Multiple Use SiPM Integrated Circuit (eMUSIC) For Readout Based Time-Of-Flight Detectors

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This work describes several applications where an 8-channel enhanced Multiple Use SiPM Integrated Circuit (eMUSIC) ASIC for SiPM readout can be used to replace PMTs. Several SHiP (Search For Hidden Particles) Experiment Detectors at CERN SPS (Super Proton Synchrotron) are studying the employment of eMUSIC for the ToF (Time-of-Flight) Timing Detector with timing resolution around 100 ps. Moreover, eMUSIC is being used as a Beam loss Loss Monitor (BLM) for ALBA Synchrotron using scintillator fibers in order to capture variations in rate during the operation of the accelerator with 20 cm spacing resolution.

Summary

Many radiation detectors in astrophysics, particle physics, medical imaging and other fields utilize multi-anode PMTs (Photomultiplier Tubes) with a large photo-cathode area. Silicon Photomultipliers (SiPMs) sensors have become candidates to substitute PMTs due to its competitiveness, insensitiveness to magnetic field, lower voltage (tens of volts instead of hundreds) and more robust than PMTs.

An 8-channel ASIC based on a patented low input impedance current conveyor is employed for SiPM anode readout. It presents low series noise, high bandwidth, high dynamic range and allows operating SiPMs at high overvoltage. The control of each SiPM channel overvoltage allows higher gain and PDE uniformity. Combining these characteristics, it is possible to achieve excellent time resolution (single photon output pulse width between 5ns to 10ns and Single Photon Time Resolution around 100ps) and Signal to Noise Ratio. The integrated circuit offers three main features: (1) SiPM pixel summing in differential mode; (2) individual analog single ended output channels; and (3) binary output using a non-linear Time-over-Threshold (ToT) technique. Lastly, it has a power consumption of ≈30mW/ch for individual readout and ≈200mW for summation.

The SHiP Experiment is a new general-purpose fixed target facility at the CERN SPS (Super Proton Synchrotron) to search for hidden particles. A feasibility study of using eMUSIC to readout an array of SiPMs for photon detection of plastic scintillators has been carried out in SHIP experiment for the timing detector and thus a large SiPM surface area is readout in parts. More specifically, an array of 8 SiPMs was coupled directly to the end of each long plastic scintillator counter. In this study, a dedicated board (eMUSIC MiniBoard, 5x5cm2 dimension) was designed with a microcontroller to configure the ASIC and to integrate it into the data acquisition system (wavecatcher). The summation capability of the MiniBoard is used to add the signal of 8 LCT5 MPPC SiPMs (6x6mm2, 50μm cell) achieving a time resolution around 100ps.

In the Surrounding Background Tagger (SBT), which is a part of SHiP Experiment, a liquid scintillator vessel is deployed with Wavelength-shifting Optical Modules (WOM) which guide photons to the SiPM array. Measurements of charge and ToF are carried out using the eMUSIC MiniBoard with single-ended and summation outputs to determine light direction.

eMUSIC is also employed as a Beam loss Loss Monitor (Scintillator Fiber + SiPM + readout eMUSIC) to compute the rate of radiation losses in the whole ring or by regions at the ALBA synchrotron facility. The Beam Loss Deposition is absorbed by scintillation fibers and the light generated is collected by SiPMs. Then, sensor outputs are processed by a dedicated front-end board which integrates the eMUSIC ASIC and 40ps RMS FPGA-based time-digital-converters (TDC) to determine the arrival time of each photon. The ToT technique is used

to capture the events between both ends of scintillation fibers and experiments have shown 20cm spacing resolution using a 4m scintillation fiber.
Lastly, eMUSIC functionalities can be exploited in high speed applications (100-ps time resolution) like Gamma Cherenkov Telescope (GCT), CTA, IACTs, Ring Imaging Cherenkov (RICH).

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