Using Cherenkov Radiation for Vertex Detection in a Compton Camera Setup for Nuclear Imaging

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***Abstract*—Conventional detectors for nuclear therapy and imaging are inefficient for high energy Gamma radiation (1-10MeV), limiting the range of usable radioactive isotopes. A Compton Camera setup can be used to detect high energy Gamma radiation, but is inefficient for these energies. By exploiting the well defined characteristics of Cherenkov Radiation (CR) generated by a Compton scattered electron *e*, its vertex can be determined allowing to calculate the origin of the generating photon. In this contribution a concept and frontend for using CR for vertex detection in a Compton Camera for medical applications is presented.**

I. Concept

CR is emitted when a charged particle moves through a dielectric faster than the local speed of light. CR is used directly in Cherenkov Luminesence Imaging, where CR generated by a tracer in the tissue of the patient is registered by a sensitive camera setup [1]. Ref. [2] proposes a different use of CR: it can be used to determine vertex information of an electron *e* generated by Compton scattering in a Compton Camera. The well defined directional characteristics of CR – it mainly depends on material properties for Gamma radiation above ~1MeV – is exploited to determine the vertex of *e*. A photon generates in the scatter material an electron *e* that moves through the material and generates CR along its path (Fig. 1). The CR forms an ellipsoid on a Silicon Photo Multiplier (SiPM) whose output signal is adapted to digital voltage levels and fed into an FPGA. Here each event is tagged with a time stamp and coincidental events are stored and transmitted to a PC for image reconstruction.

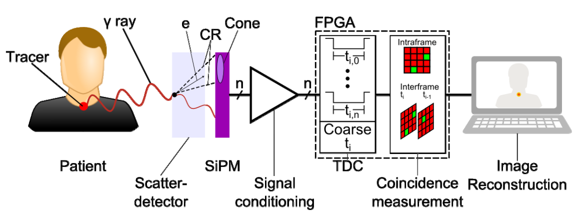

Figure 1. Concept of detector system.

II. Design of the Frontend

Since the CR production is low, a sensitive detector is necessary, for which a SiPM is used here. Even though SiPMs have several favorable advantages they also have a high dark count rate, i.e. impulses generated by internal processes (e.g. thermal) and not by photons [3]. Such an impulse has the same characteristics as a signal generated by a single photon. An approach to filter the noise is to process only signals with higher amplitudes which are generated by multiple photons that hit the sensor. However, [2] calculated a small number Cherenkov photons, so that also single photon events must be detected. To distinguish between the photons and noise, the time and spatial coincidence of the Cherenkov radiation photons has to be exploited. Our concept makes use of an FPGA based digital frontend (Fig. 2) that processes the events of the SiPM and checks for coincidence. Each event is tagged with a time stamp and processed by a coincidence filter for later processing. The front end consists of 16 Time to Digital Converters (TDC) that receive the signal of the signal conditioning circuit. A TDC generates a time stamp consisting of a coarse time value given by a 32-bit value of a counter clocked at 500MHz identifying the frame and a fine time value generated by a delay line with ~15ps resolution. A hierarchical approach is used for filtering. First, the encoder checks if a voltage level change is present in the delay line and discards a measurement if none is found. Second, when multiple events are present in a single Frame (Intraframe) and/or spread over consecutive frames (Interframe) the frame(s) are stored for further processing. Additionally to time stamp generation and filtering, functionality for calibrating the TDCs are implemented in the FPGA.

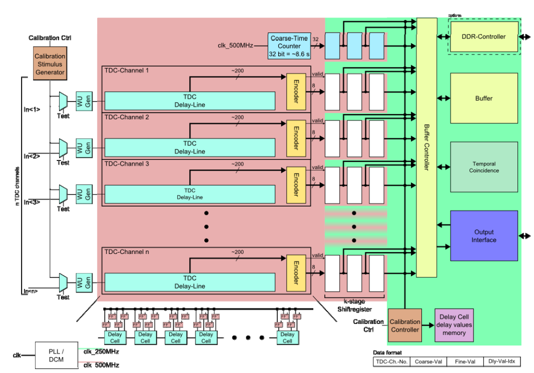

Figure 2. Blockdiagram of the frontend design.

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