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Readout Electronics for High Intensity Range Particle Beam Monitoring

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For readout electronics capable of exploiting the characteristics of 4H–SiC, we are in testing and optimization phase of a single channel circuit to continuously detect single particles up to GHz rates, including statistical pile-up detection by ToT measurements of shaped pulse signals.
Furthermore, we are evaluating an IC with 128 input channels, originally intended for X-ray imaging, which individually integrates the DC coupled electric currents delivered by sensor strips over some time into capacitors in order to monitor the particle beam at even higher luminosities. Shown are first results of a test beam at MedAustron.

Summary (500 words)

MedAustron in Wiener Neustadt, Austria, is a center for research and cancer therapy. A synchrotron accelerates protons to up to 800MeV and carbon ions to up to 400MeV/u. The beam intensity needs to cover a wide range from low flux (˜kHz) for non-clinical applications like HEP detector tests up to the clinical values of 10ˆ10 particles per each so-called spill, which lasts about a few seconds. For cancer treatment, where energy is deposited inside the human body mostly at the Bragg peak to treat tumors while minimizing the damage of healthy tissue around it, the total number of particles in each spill is very essential. Promising candidates for future beam monitors to observe the shape, position and intensity of the particle streams are segmented planar silicon, silicon-carbide, diamond and Low Gain Avalanche Detectors (LGAD).

Shown in this paper are the idea, the concept and first results of a prototype of a single channel readout electronics for such detectors. This prototype is designed to count starting from single particles up to GHz rates, while also being able to statistically detect pile-ups of multiple (depending on the sensor and the amplifier parameters, e.g., up to 20) particles.
In the pauses between spills, the zero level of the filtered sensor signal is determined by a minimum detector. A regulation circuit biases the amplifiers using this value to compensate any drifts in the detector current and in the amplifier attributes. The whole amplifier chain - from the sensor over the transimpedance amplifier to intermediate amplifiers up to a time-over-threshold comparator - is fully DC coupled, there is not a single capacitor in the signal path. The output of this comparator is a signal in the digital time domain. After some frequency division and signal line doubling in order to lower the bandwidth of the digital time domain signal, the signal then is sent into an FPGA. It is planned to implement a vernier TDC inside the FPGA to measure the length of the time-over-threshold pulses of the comparator to sum up the times, calculate the probable number of particles, make histograms, and send the results to the DAQ. For now the FPGA only counts the pulses, but the proper function of the front end electronics has been verified by data analysis of the recordings of a 16GHz oscilloscope. The next steps planned are the implementation of multiple channels onto one PCB, and, further on, the integration into an ASIC.

In addition, we developed a PCB to evaluate an IC with 128 input channels, originally intended for X-ray imaging, in order to monitor the particle beam at even higher luminosities. It individually integrates the DC coupled electric currents delivered by sensor strips over some time into capacitors. Their voltages then are read out and digitized sequentially, and the data is sent to an FPGA and further to a DAQ PC. Shown are first results of a test beam at MedAustron.

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