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A MAPS-based readout for Tera-Pixel electromagnetic calorimeter at the ILC

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For the ILC physics program, the detectors will need an unprecedented jet energy resolution. For the electromagnetic calorimeter, the use of a highly granular silicon-tungsten calorimeter has been proposed. The status of a silicon readout option, which uses Monolithic Active Pixel Sensors (MAPS), will be presented. This novel design provides extremely fine granularity with integrated binary readout. This leads to a "Tera-Pixel" electromagnetic calorimeter system. A overview of the MAPS concept will be given along with the advantages of this design. We present first results of the prototype sensor together with simulation results showing the expected detector performance.

Summary

For the readout of such a highly granular Silicon-Tungsten calorimeter, there are several options available. From detailed simulation of the Tera-Pixel ECAL we know, that most pixels are only hit once per event, if one chooses a pixel size of 50 x 50 µm. We can employ a simple binary readout using a comparator instead of an analog readout, which simplifies the pixel layout. We have then designed and fabricated a CMOS Monolithic Active Pixel Sensor (MAPS) in the novel INMAPS process. The INMAPS process is a standard 0.18 micron CMOS image-sensor technology with a high energy "deep-Pwell"implant located beneath the active circuits. A conventional MAPS design will experience charge sharing between the sense-node(s) and any PMOS active devices in the pixel which can dramatically reduce the efficiency of the pixel. By implanting the "deep-Pwell"in the pixel regions containing active circuits, charge deposited in the epitaxial layer is reflected and conserved for collection at only the exposed collection diode nodes. The pixels contain four N-well diodes for charge-collection; analog front-end circuits for signal pulse shaping; comparator for threshold discrimination; digital logic for threshold trim adjustment and pixel masking. Pixels are served by shared row-logic which stores the location and time-stamp of pixel hits in local SRAM, at the target 150ns beam bunch crossing rate of the ILC. The sparse hit data is read out from the columns of logic in the quiet time between bunch trains. A prototype sensor consisting of 8 units of 42x84 pixels with 6 million transistors in total has been produced. The data acquisition requirements for such a system with 10ˆ12 readout channels are driven by the noise. Even with a noise level of 10ˆ-6, there will be 1 million hits per event and the occupancy is entirely noise driven. Therefore the required DAQ bandwidth is around 500 Gbit/s. Another system issue is the power consumption. For a MAPS detector with a 1 % duty cycle we obtain a power consumption of 40 µW/mmˆ2. The test sensor will allow us to explore options to further reduce this. A clear advantage of the MAPS approach is the fact, that it can be manufactured in a industry standard process and will be cheaper to produce than the combination of high resistivity silicon sensor and a readout chip. Parallel to the design work on the sensor itself, we have worked extensively on the physics simulation of a MAPS-based ECAL. For an accurate sensor simulation the Sentaurus package was used for optimizing the design layout and to study the charge spread within the MAPS pixels. To study the physics performance, the MAPS based calorimeter was implemented in the MOKKA detector simulation, which is based on GEANT4. The simulation output has been used to test Particle Flow Algorithms and some first results of using Particle Flow with a highly granular MAPS-based ECAL are presented.

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