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# Chronopixel Detector Development for Vertex Detectors for future e+e- Colliders

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Studies carried out in the U.S., Europe, and Asia, have demonstrated the power of a pixel vertex detector in physics investigations at a future high energy linear collider. At one time, silicon CCD's (Charged Coupled Devices) seemed like the detector elements of choice for vertex detectors for future Linear e+ e- Colliders. However, with the decision for a cold TESLA-like superconducting technology for the future International Linear Collider (ILC), the usefulness of CCD's for vertex detection has become problematical. The time structure of this cold technology is such that it necessitates an extremely fast readout of the vertex detector elements and thus CCD's as we know them will not be useful. New CCD architectures are under development but have yet to achieve the required performance. For these reasons there is an increased importance on the development of Monolithic CMOS pixel detectors that allow extremely fast non sequential readout of only those pixels that have hits in them. This feature significantly decreases the readout time required. Recognizing the potential of a Monolithic CMOS detector, we initiated an R&D effort to develop such devices3. Another important feature of our present conceptual design for these CMOS detectors is the possibility of putting a time stamp on each hit with sufficient precision to assign each hit to a particular bunch crossing. This significantly reduces the effective backgrounds in that in the reconstruction of any particular event of interest we only need to consider those hits in the vertex detectors that come from the same bunch crossing.

The current Chronopixel design is for chips up to 12.5 cm x 2.0 cm in size with a single layer of 10 μ m x 10 μ m charge sensitive pixels. Each pixel has its own electronics under it, but both the sensitive layer and the electronics are made of one piece of silicon (monolithic CMOS) which can be thinned to a total thickness of 50 to 100 μ m, with no need for indium bump bonds. The electronics for each pixel will detect hits above an adjustable threshold. For each hit the time of the hit is stored in each pixel, up to a total of four different hit times per pixel, with sufficient precision to assign each hit to a particular beam crossing (thus the name "chronopixels"for this device). Hits will be accumulated for the 2820 beam crossing of a bunch train and the chip is read out during the 200 millisec gap between bunch trains. There is sufficient intelligence in each pixel so that only pixels with one or more hits are read out, with the x,y coordinates and the time t for each hit. With 10 micron size pixels we do not need analog information to reach a 3 to 4 micron precision so at the present we plan on digital read out, considerably simplifying the read out electronics.

We have developed a design, in collaboration with SARNOFF Research Labs of Princeton,N.J., of the Chronopixel devices that satisfy the requirements of the proposed ILC. The detailed design has been completed and SARNOFF has fabricated the first set of prototype devices. We have designed and built, with the help of SLAC, the electronics to test these prototypes. We have completed the test of the first prototypes. We found that they mostly work as designed but have some design flaws. In consultation with SARNOFF we defined the parameters for the second set of prototypes, correcting the flaws of the first prototype and further improving the design,The detailed design of the second prototype is now in progress at SARNOFF and we expect the fabrication of the second prototype to be completed later this year.

The design of these Chronopixel detectors, the results of the tests of the first prototypes, and the design of the second prototype, will be presented.

## Summary

The University of Oregon and Yale University are carrying out an R&D program to develop the Chronopixel sensor, a CMOS pixel device, for Vertex Detectors for future high energy colliders. The unique feature of these sensors is the ability to record the time of each hit with sufficient precision to assign each hit to a specific bunch crossing of the collider (hence the name Chronopixel). This reduces the backgrounds due to integration over many beam crossings to a virtually negligible level at the linear collider.

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