

**Expression of Interest**  
**For**  
**A Proposal for R&D on CCD Vertex Detectors for Future Linear  $e^+ e^-$  Colliders**

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1. Overview of the Proposed Project

Many studies and designs carried out in the U.S., Europe, and Asia, indicate that the most attractive technology for the high precision vertex detectors for future  $e^+ e^-$  colliders are silicon charge coupled devices (CCD's). Alternate technologies being considered are CMOS pixels and hybrid pixels under development for LHC detectors. CCD's have the advantage of smaller pixels for superior spatial resolution and the possibility of thinner detector layers to minimize multiple scattering which is the factor limiting the resolution of the interesting lower momenta. There are, however, significant questions about the feasibility of using CCD's for the next generation of  $e^+ e^-$  colliders. We consider the following to be the key long lead time R&D issues in resolving these questions:

a) Increasing the Radiation Hardness of CCD's

The expected radiation dose at the SLC was less than 1 krad for the lifetime of the SLD vertex detector and the CCD's were tested to operate at a dose of 10 krad. The detailed background calculations for the next generation  $e^+ e^-$  colliders indicate an upper limit of 100 krad/10 years, a factor of 100 to 1000 higher than at the SLC. The neutron backgrounds are estimated to be  $\sim 3 \times 10^8$  neutrons/cm<sup>2</sup>/year, larger than at the SLC by a similar factor. We believe that this increase in radiation tolerance can be achieved by various strategies. Reducing the thickness of the surface silicon dioxide layer will reduce the surface damage to ionizing radiation, and reducing the well size in the pixels will reduce the amount of bulk damage due to neutrons. Furthermore, the use of the sacrificial charge technique will reduce the effect of bulk damage on the charge transfer efficiency. To test the success of these strategies will require the design of new CCD's, the fabrication of these devices by commercial silicon fabrication houses, and radiation testing the resulting CCD's.

## b) Decreasing the Readout Time

For the NLC the CCDs have to be read out in the 8.3 msec interval between trains of 190 bunches spaced at 1.4 ns. For TESLA occupancy from a full 2820 bunch train is too large, requiring that partial read out to occur between the 337 ns interval between bunches in the train. For NLC we imagine increasing the readout rates to 25-50 MHz (the SLD vertex detector was read out at 5 MHz) and increasing the number of readout nodes to 20 to 40 per CCDs. We believe that this scheme is achievable, but it will require a new CCD design and a prototype CCD fabrication run to test the new design. To achieve the same performance at TESLA, another factor of about 100 would be needed in the product of readout nodes and readout rate.

## c) Reducing the CCD and the Support Structure Thickness

The physics and detector simulation studies carried out over the last several years indicate that the heavy flavor quark tagging ability, which will be so important in the physics of the future  $e^+ e^-$  colliders, would be improved if the multiple scattering in the layers of the vertex detector could be reduced to 0.1 to 0.2% of a radiation length. This requires reducing the thickness of the CCD detectors to 50 to 100 microns and designing a more optimum support structure. At the present time, we envision two strategies to achieve such reductions. The first is to locate the output amplifiers and all of the input and output contact pads on one end of each CCD. The connections can thus be made on the outside ends of each two CCD ladder and there is no need for traces to run the full length of the ladders. The second is to eliminate the beryllium support layer and support each CCD ladder by stretching the CCD's from supports at each end of the ladder.

## 2. Work Plan and Deliverables

Last year we submitted a proposal to the DOE Advanced Detector Research Program, and this proposal was recently approved with modest funding, allowing us to start this R&D. We plan to remove the vertex detector VXD3 from SLD and study the effects of three years worth of radiation dose on the performance of the CCD's.

We are proposing here an additional three-year R&D program to address the issues discussed above. We foresee the following activities:

### a) Work Plan Year 1

- Complete study of effects of radiation damage
- Mechanical Engineering study of support scheme
- Continue discussions with CCD designers and silicon fabrication houses
- Start detailed design of CCD's for NLC

b) Work Plan for Year 2

- Complete detailed design for CCD's
- Buy masks for CCD fabrication
- Place order and start fabrication of CCD prototypes
- Continue support structure engineering design

c) Work Plan for Year 3

- Complete prototype CCD fabrication
- Test performance of prototype CCD's
- Radiation test of prototype CCD's
- Complete preliminary support structure design

d) Deliverables after the 3 Year R&D Program

- Preliminary support structure design
- First prototype CCD devices
- Performance and radiation tests of prototype CCD devices

3. Budget Estimates

Item	Request in Units of \$1000		
	Year 1	Year 2	Year 3
Engineering, Technician, Shop Support and Supplies			
At Oregon	25	25	25
At Yale	25	25	25
Subcontracts			
CCD Design	0	25	0
Masks	0	25	0
CCD Fabrication	<u>0</u>	<u>50</u>	<u>100</u>
Yearly Totals	50	150	150