No.

TEST REQUEST

Title: LC Beam 3 **Date:** July 14, 2004

Linear Collider - 3D and Thin Planar Silicon for Beam Profile and Luminosity Monitors

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Purpose of Test: Development of silicon-based detectors for a beam profile monitor and a luminosity monitor for the Linear Collider

Description of Apparatus: see attachment

Beam Requirements: single bunch mode with electron spray configuration
Momentum: 28.5 GeV primary beam in Linac; 2-10 GeV "spray" beam to ESA from Be target
Particles: 10^{10} per primary bunch, $10^3 - 10^4$ per secondary spray bunch to ESA
Rep Rate: 10 Hz
$\Delta p/p$: 1.5% for spray beam

Space Requirements (include sketch): 1 meter in z

Special Power Requirements: none

Duration of Test and Shift Utilization: 4 days

Desired Calendar dates: June, 2005

Test Beam Coordinator ______________________________ Date: __________
Radiation Physicist ______________________________ Date: __________
Chairman, SOC ______________________________ Date: __________
Area Manager ______________________________ Date: __________
Accelerator Dept. Physicist ______________________________ Date: __________
Program Coordinator
Action: Approve/Disapprove/Defer Signature ______________ Date: __________
Remarks:

Test Beam Request - 3D and Thin-Planar Silicon Detectors for use in a Beam Profile Monitor and a Luminosity Monitor for the Linear Collider

Chris Kenney

July 13, 2004

Background

Achieving the desired luminosity at the Linear Collider will be critically dependent on the beam shape and dimensions. Providing real-time feedback will be necessary to optimize the machine parameters. The degree to which the science program is successful will be a sensitive function of the effective beam diameter. It has been proposed to measure the beam profile using the distribution of background e^+e^- pairs (1,2). One possible detector scheme involves using 3D silicon sensors (3,4) for their speed and radiation hardness.

Another important metric for optimizing the machine performance is a continuous, direct measurement of the luminosity.(5) Ideally this would be on a pulse-by-pulse basis, which in the warm design would require a time resolution on the order of one nanosecond. This detector would be a calorimeter and hence would see a large signal and would not need to resolve individual minimum-ionizing tracks. Both speed and radiation hardness are required. Either 3D silicon sensors (6,7) or thin planar sensors should be suitable for this application.

The proposed running of SLAC End Station A in a spray mode (8) to mimic the conditions expected at the Linear Collider in the far forward region presents a unique opportunity to explore the performance of proposed technologies for the luminosity monitor and beam profiler.

Purpose

The main goal of this test would be to demonstrate a signal charge collection time of less than 1.4 nanoseconds in a silicon sensor under conditions similar to those expected for a beam profile monitor or luminosity monitor at the Linear Collider. We plan to make measurements using both 3D sensors and thin, planar silicon sensors. Calculations indicate that for drift distances under 100 microns, it should be possible to collect all the signal charge in less than the required 1.4 nanoseconds.

There are several secondary goals.

One is the testing of a fast preamplifier circuit designed at CERN. The existing, 0.25-micron-technology chip has 32 channels and has a rise time of about 4 nanoseconds.(9) A new 0.13 micron-CMOS chip is expected to be about twice as fast and should be ready by next June.

Ideally, some of these silicon sensors would be irradiated to fluences comparable to those expected at the Linear Collider. Our group will make an effort to have irradiated samples ready for these tests.

Description of Apparatus

For the primary timing measurement a fast oscilloscope with a bandwidth of at least 1 GHz will be connected directly to the silicon sensors via a coaxial cable of as short a length as feasible. This cable should be optimized for high frequencies. This can be read out to a PC. Beam timing information or a local scintillator can be used to provide an absolute beam timing reference.

Since most of the silicon sensors are subdivided in to strips, we can vary the area read out per channel. This will allow studying the performance of the system with different load capacitances and interactions between sensor elements.

If enough sensors and electronics are available, it would be very interesting to interleave a few layers of tungsten or other dense, high-z material with a couple layers of sensors. We envision at least having an insertable pre-radiator available for a single sensor layer. This would provide considerable information on the performance of these technologies as a calorimeter.

The 32-channel amplifier can be read out in a similar manner as above, since data from a few channels should be sufficient for these studies.

Appropriate 3D and thin planar silicon sensors exist now. We have several 3D geometries, which should be fast enough and radiation hard. There are also planar strip sensors around 100 microns thick. An image of such a thin planar sensor with active edges is shown below in Figure 1; the sensor area is 1.2mm x 3mm.

The detector will be mounted on a (SLAC-provided) stand. A tentative location for this in ESA is shown in Figure 2. It will be located at the upstream end of ESA just after the alcove region, and upstream of the hardware proposed for T-474 and T-475. The detector will be located in air, not vacuum. To perform the beam test, a spool section of beampipe needs to be removed and the beampipe terminated in a thin (10-mil) stainless window.

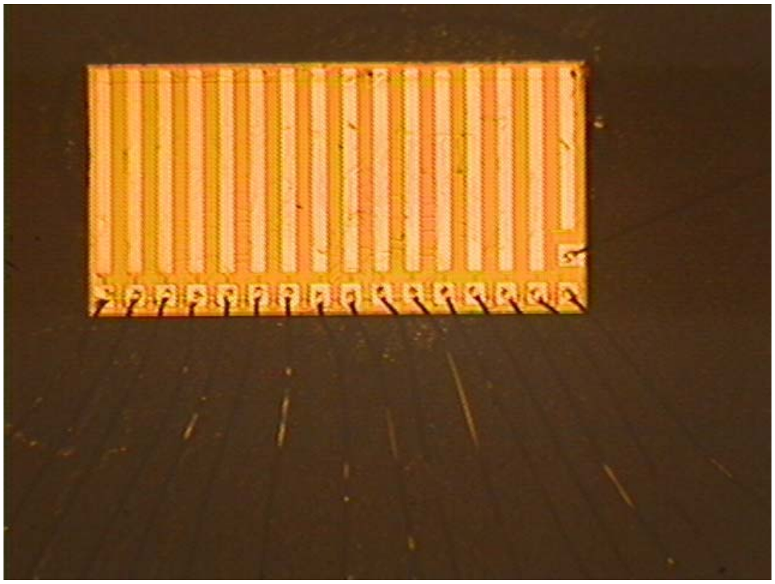

Figure 1: Planar Si Strip detector

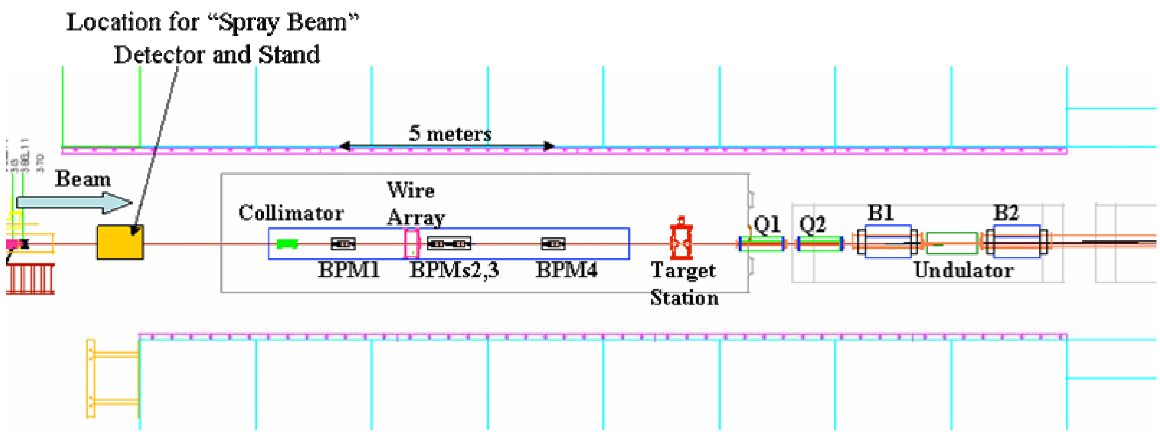

Figure 2: Proposed location for this test beam experiment in ESA. It would be after the alcove and upstream of hardware proposed for T-474 and T-475.

Beam Requirements

For these tests to be made requires the beamline to be operated as described in the spray electron mode as described by Arnold and Fieguth (8). The desired particle density is variable up to 50/mm^2; with the high density the detector signal will be readily measurable without amplification. We desire to run for four days in single bunch spray mode: 2 days set up and 2 days data taking. Single bunch mode will make the timing measurements easier to perform and interpret. A beam repetition rate of 10 Hz is fine. For initial tests, the spray beam energy is not critical, and any spray beam energy in the 2-10 GeV range is acceptable.

When doing the primary timing measurements fluxes near 10^4 per bunch are desirable. Lower fluxes might be better for testing the pixel electronics and perhaps the fast 0.13-micron-CMOS amplifiers.

Multi-bunch or two–bunch mode with bunch separations as close to the 1.4 ns of the LC warm design would be very interesting as well.

Collaborators

Tohoku University (Hitoshi Yamamoto, Peter Schoenmeier)
- Fast pixel electronics

CERN (Giovanni Anelli)
- Fast ASIC electronics

University of Hawaii (Sherwood Parker)
- Mechanical structures and simulations

Brunel University (Cinzia Da Via, Angela Kok, Jasmine Hasi)
- Supply fast electronics, data analysis

Molecular Biology Consortium (Chris Kenney)
- Supply special silicon sensors, DAQ, scintillator/PMTs

References

1) T.Tauchi and K.Yokoya, "Nanometer beam size measurement during collisions at linear colliders", Phys. Rev. E51 (1995) 6119 – 6126.

2) G.Alimonti, "Pair monitor for Linear Colliders", LCWS2000 proceedings, Fermilab October 24-28, 2000.

3) Manabu Saigo, "Pair Monitor for Beam Profile," LCWS 2002, Jeju Island, Korea, http://lcws2002.korea.ac.kr/slides/parallel/K/ManabuSaigo_Beam**profile**.pdf

4) University Program of Accelerator and Detector Research for the Linear Collider (vol. II), December 2003; http://www.hep.uiuc.edu/LCRD/pdf_docs/LCRD_UCLC_Big_Doc/ See DOE Proposal 3.9 in this document, *Development of thin, fast, radiation hard, 3d-electrode array, silicon radiation sensors*.

5) O.Napoly, "LUMINOSITY STABILITY, POSSIBLE FEEDBACK, AND BACKGROUND AT FUTURE LINEAR COLLIDERS," Proceedings of EPAC 2000, Vienna, Austria, http://accelconf.web.cern.ch/AccelConf/e00/PAPERS/TUYF101.pdf

6) Sherwood Parker and Christopher Kenney, "Performance of 3D architecture, silicon sensors after intense proton irradiation", IEEE Trans. Nucl. Sci.48 (2001) 1 – 10.

7) Cinzia DaVia, "Radiation hard silicon detectors lead the way," CERN Courier, vol. 43, No. 1, http://www.cerncourier.com/main/article/43/1/16 .

8) R. Arnold and T. Fieguth, "Spray Electron Beam for Tests of Linear Collider Forward Calorimeter Detectors in SLAC End Station A," IPBI-TN-2004-5, http://www.slac.stanford.edu/xorg/lcd/ipbi/notes/tn_beamcalspray.pdf

9) G. Anelli, K. Borer, L. Casagrande, M. Despeisse, P. Jarron, N. Pelloux, S. Saramad, "A high-speed low-noise transimpedance amplifier in a 0.25 μm CMOS technology", Nucl. Instr. and Meth. A (2002).