Project name

Radiation damage studies of materials and electronic devices using hadrons

Classification

Accelerator

Institutions and personnel

University of California Davis: Maxwell Chertok, David E. Pellett (professors)
SLAC: James E. Spencer (staff scientist)
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Project Overview

Many materials and electronic devices must be tested for their abilities to survive in the radiation environment expected at the proposed linear collider (LC). Radiation-sensitive components of the accelerator and detectors will be subjected to large fluences of hadrons as well as electrons and gammas during the lifetime of the accelerator. Examples are Nd-Fe-B permanent magnets which are being considered for the damping rings and final focus, electronic and electro-optical devices which will be utilized in the detector readout and accelerator control systems and CCDs which will be required for the vertex detector.

UC Davis has two major facilities which can be used to provide needed information on hadron radiation damage, the McClellan Nuclear Reactor Center (MNRC), located in Sacramento (approximately 50 mi. round trip from the Davis campus), and the radiation test beam at the UC Davis Crocker Nuclear Laboratory (CNL) cyclotron (on campus).

The MNRC reactor has a number of areas for irradiating samples with neutron fluxes up to 4.5×10^{13} n/cm^{2}s. A specialized area allows irradiation with 1 MeV-equivalent neutrons in a flux of 4.2×10^{10} n/cm^{2}s while suppressing thermal neutrons and gammas by large factors. Other areas allow irradiating very large objects at lower fluxes. In conjunction with physicists from the University of Oregon, we have used MNRC to irradiate CCDs.

The CNL radiation test beam consists of protons of up to 63.3 MeV kinetic energy spread over a rather uniform beam spot 7 cm in diameter. A typical central flux is 4.2×10^9 protons/cm^{2}s (0.56 kRad/s (Si)). A secondary emission monitor calibrated with a Faraday cup is used to measure the beam fluence to an accuracy of better than 5%. The beam profile has been established by a variety of means, showing the dose to have fallen by only 2% at a radius of 2 cm. We have used the CNL facility for a wide variety of tests on electronic devices and detector components.

Description of first year project activities

In the first year, we plan to study radiation damage in Nd-Fe-B permanent magnet materials using the MNRC facilities.

Permanent magnet beam optical elements have been in use in the SLC damping rings at SLAC since 1985. For the LC, it would be advantageous to use Nd-Fe-B for such magnets due to its low cost and its high energy product, $(BH)_{max}$, relative to Sm-Co. Its Curie temperature, T_C, is lower than that of Sm-Co, however, so one must evaluate the degradation of its magnetic properties due to radiation damage. Some studies have been done (see, for example, Ito *et al.,* Nucl. Instr. and Meth. B 183 (2001) 323) but more need to be carried out using specific materials available for constructing the LC damping ring magnets with fluences up to that expected during the lifetime of the LC.

SLAC has already tested samples of Nd-Fe-B to a dose of 277 kGy (Si) using gamma rays. MNRC is ideally suited to continue these studies using a sequence of tests on the existing samples from SLAC at increasing doses with 1 MeV-equivalent neutrons as well as thermal neutrons. After each dose, the samples will be returned to SLAC to evaluate changes in magnetic properties. Magnetic measurements will be made in an existing two-block, matched magnet that is easily changed to allow dipole or quadrupole or measurements of the magnetization vectors of the individual blocks. As a quad, it yields a null field at the mechanical center when the two blocks are undamaged. In this manner, small changes in the magnetic properties of the irradiated block can be observed. The quadrupole's field will be measured precisely by means of a taut wire system and a Bell micro Hall-probe. The required maximum dose will be determined by extrapolating ongoing background and damage measurements at the SLC damping rings to the much higher radiation levels expected at the LC.

We will do additional neutron irradiation studies using Nd-Fe-B material in dipole magnets supplied by Fermilab. The purpose is to test the material in a loaded condition and to test different grades of magnet materials from different manufacturers.

The magnets will be measured at the Fermilab Magnet Test Facility using a rotating coil and a GMW Associates model 133-DS Digital Teslameter hall probe. This instrument has sufficient precision to adequately determine the change in magnetization as a function of radiation dose. The magnets will then be shipped to UC Davis for neutron irradiation and field measurements using the Hall probe. Fermilab will retain a dipole magnet to use as a standard reference and to measure the time decay of the Nd-Fe-B material.

In this grant period, we expect that two magnets will be irradiated. The magnets will be returned to Fermilab after the measurements are completed.

Future Plans

In addition to continuation of magnet material tests, future plans include testing of CCDs and other electronic and electro-optical devices and materials for LC accelerator and detector applications using neutrons at MNRC or in the 63 MeV proton radiation test beam at CNL.

Budget

This EOI includes the UC Davis budget for the first year to pay for a Hall probe for making measurements on the Fermilab magnets, an undergraduate student assistant to help in performing the irradiations and measurements and travel costs for frequent trips between UC Davis and MNRC.

Item	**Cost**
GMW Assoc. Model 133 Digital Teslameter + MPT 132-2s Hall Probe	$ 3040
Student Assistant (undergraduate) (academic year + summer + benefits)	$ 16,700
Travel	$ 1848
Indirect costs	$ 4823
Total	**$ 26,411**