Planning for Electromagnetic Irradiation Studies of Silicon Strip Sensors at SLAC/SCIPP

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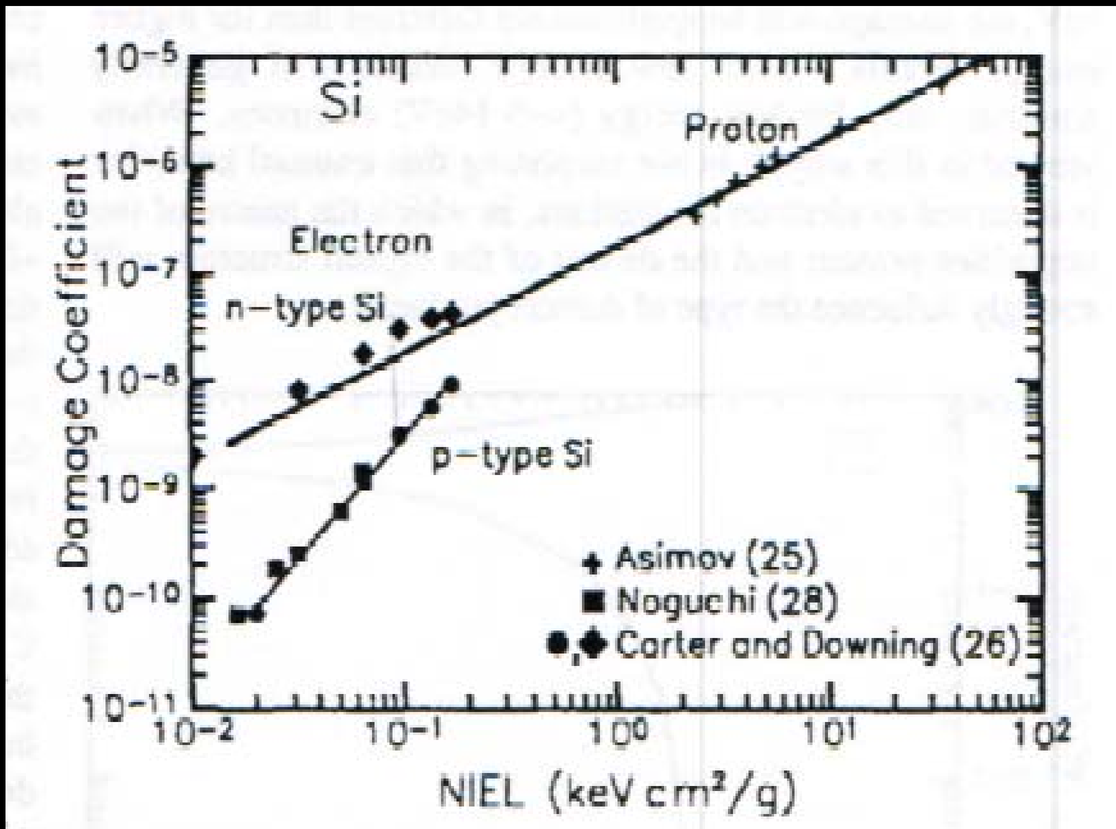
Initial thoughts; feedback welcome

Some notes:

- Beam Calorimeter is a sizable project, ~2 m^2 of sensors.
- Sensors are in unusual regime: ~ 1 GRad of e^+/e^-; 10^{14} n/cm^2 after several years.
- There are on-going studies with GaAs, Diamond, Sapphire materials (FCAL report, Nov 2009).
- We'll concentrate on mainstream Si technology proven by decades of technical development.
- There is some evidence that p-type Si may be particularly resilient:

G.P. Summers et al., IEEE Trans Nucl Sci **40**, 1372 (1993)



NIEL	e^- Energy
2×10^{-2}	0.5 MeV
5×10^{-2}	2 MeV
1×10^{-1}	10 MeV
2×10^{-1}	200 MeV

Damage coefficients less for p-type for E_{e-} < ~1GeV (two groups); note **critical energy** in W is **~10 MeV**

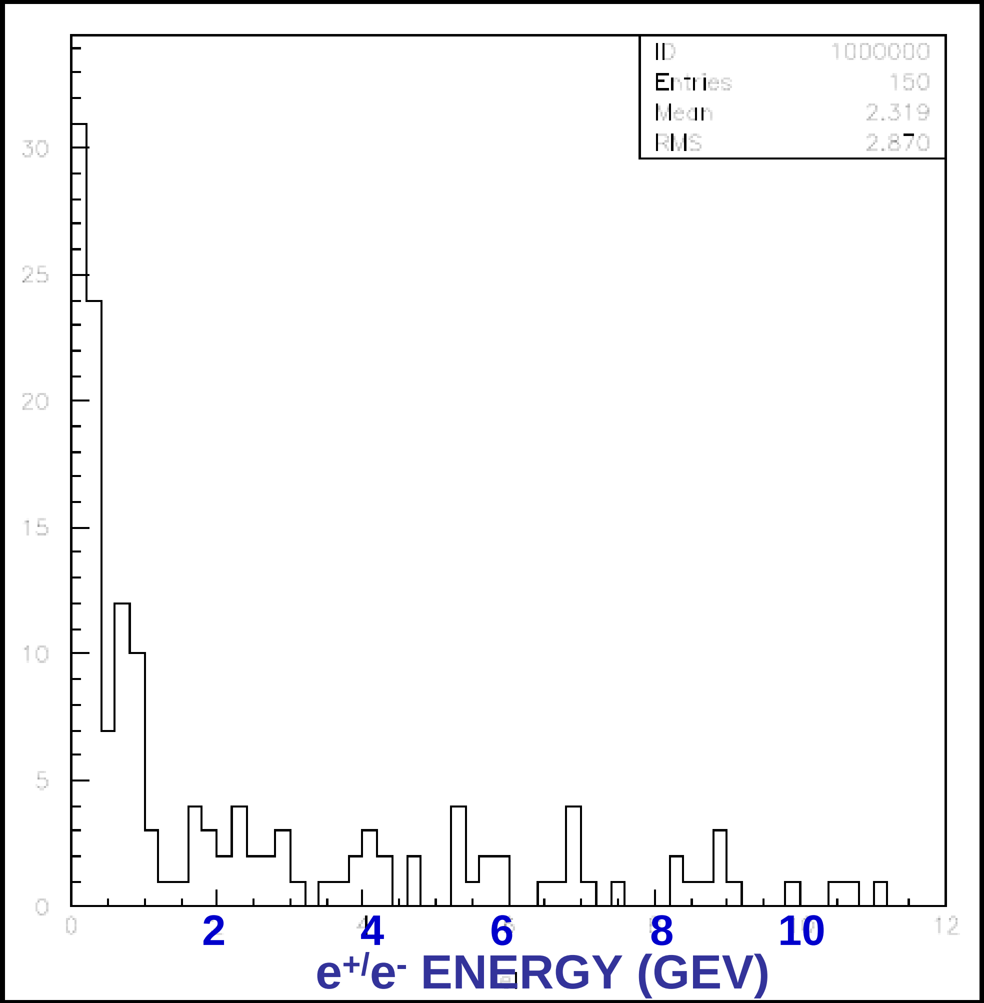
More notes:

- Neutron flux does not seem to be a problem for Si (RD50 findings).

- There are very few e^+/e^- radiation hardness studies:
    - S. Dittongo et al (2005); n/p-type Si;160 MRad of 900 MeV e^-
    - J.M. Rafi et al (2009); n-type Si; 1.7 GRad of 2 MeV e^-

- Our region of interest is 100 MeV – 10 GeV (incidence) and lower (shower max), and 1 GRad

BeamCal Incident Energy Distribution



BUT: Most fluence is at shower max, dominated by ~10 MeV e^-, e^+ and γ. Why might (?) incident energy matter?

NIEL (Non-Ionizing Energy Loss)

Conventional wisdom: Damage proportional to Non-Ionizing Energy Loss (**NIEL**) of traversing particle

NIEL can be calculated (e.g. G.P. Summers et al., IEEE Trans Nucl Sci **40**, 1372 [1993])

At $E_c^{Tungsten}$ ~ 10 MeV, **NIEL** is 80 times worse for protons than electrons and

- **NIEL** scaling may break down (even less damage from electrons/psistrons)
- **NIEL** rises quickly with decreasing (proton) energy, and fragments would likely be low energy

➔ Might small hadronic fractions dominate damage?

Hadronic Processes in EM Showers

There seem to be three main processes for generating hadrons in EM showers:

• Nuclear ("giant dipole") resonances
 Resonance at 10-20 MeV ($\sim E_{critical}$)

• Photoproduction
 Threshold seems to be about 200 MeV

• Nuclear Compton scattering
 Threshold at about 10 MeV; Δ resonance at 340 MeV

➔ Flux through silicon sensor should be ~10 MeV e/γ, but also must appropriately represent hadronic component

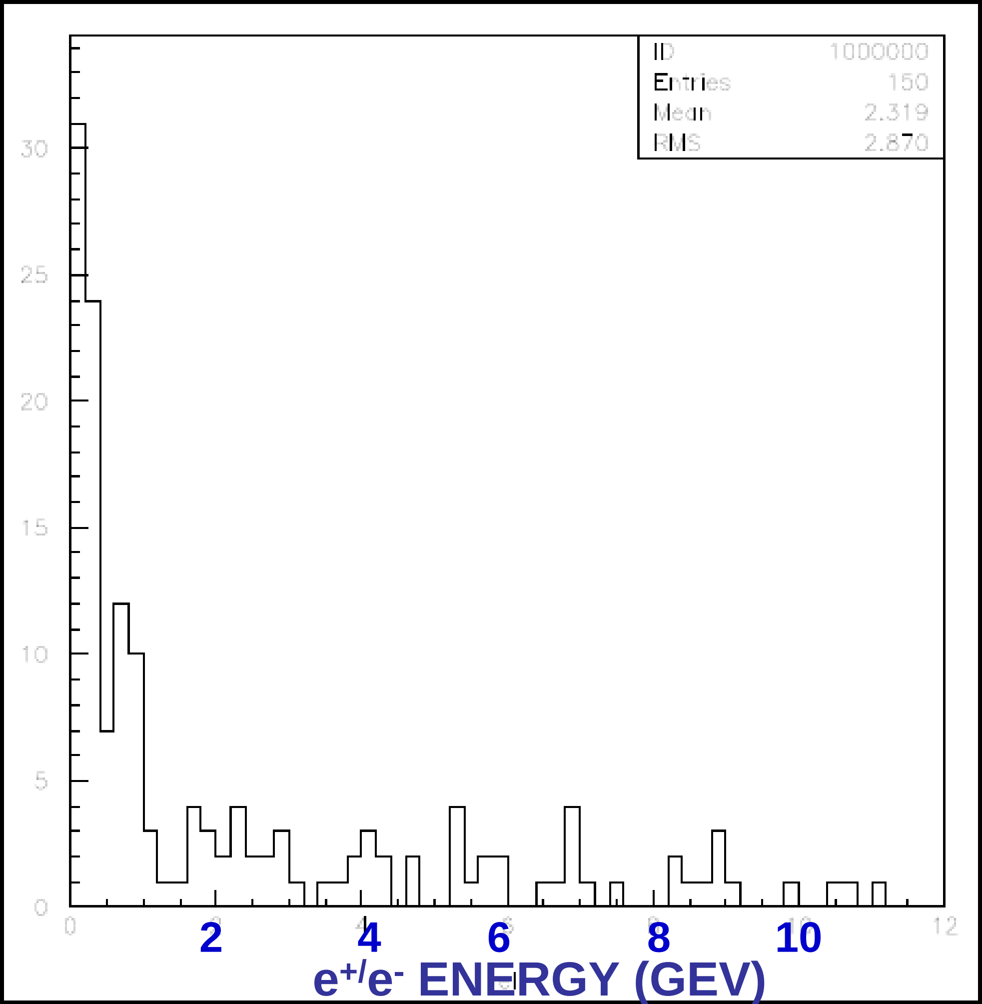
Rates (Current) and Energy

Basic Idea:

Direct electron beam of moderate energy on Tungsten radiator; follow with silicon sensor at shower max

For Si, 1 GRad is about $3 \times 10^{16}/\mathrm{cm}^2$, or about 5 mili-Coulomb

➔ Current scale is μA, which points to the **1-5 GeV beam at CBAF** (Jefferson Lab, Virginia, USA)



Recall spectrum: most beamcal incident e^+e^- below photoproduction and nuclear Compton ranges

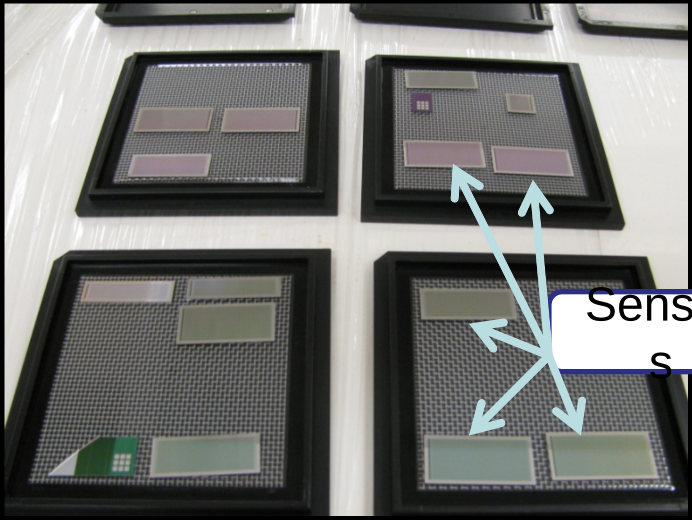
➔ having all incident flux above these thresholds should be conservative.

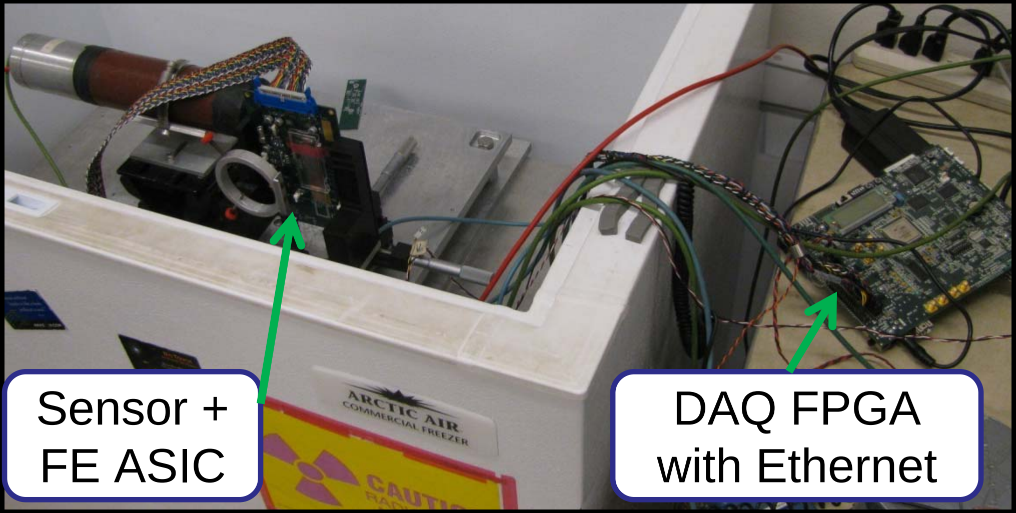
On the other hand, all incident flux above Giant Dipole Resonance (GDR) in Tungsten ➔ Beam must be at least ~100 MeV to incorporate GDR (γ from ^{60}CO would not generate hadronic component)

Irradiation Plan

- Intend to use existing sensors from ATLAS R&D (made at Micron). Both n- and p- type, Magnetic Czochralski and Oxygenated Float Zone.

- Plan to assess the bulk damage effects, charge collection efficiency. This will further assess the breakdown on NIEL scaling (x50 at 2 MeV and x4 at 900 MeV) in the energy range of interest.





Next Steps

Need to use EGS/GEANT to design appropriate Tungsten/Silicon geometry to achieve relative uniform 1 cm^2 illumination for “pencil” beam.

Need to quantify degree of shower multiplication to determine what 1-5 GeV flux will generate 1 Grad at shower max; will impact feasibility of CBAF run

Need to do pre-characterization of a number of different detectors; prepare instrumentation for evaluation of irradiated sensors (mostly in place from ATLAS RD50 studies).

CBAF test at end of calendar year?