EPI-Hi Detector Peer Review
29 October 2014

Addenda

Geometrical Factor and Angular Sensitivity (1/2)

EPI-Hi geometrical factor evaluation at the time the ISIS Space Science Reviews article was written

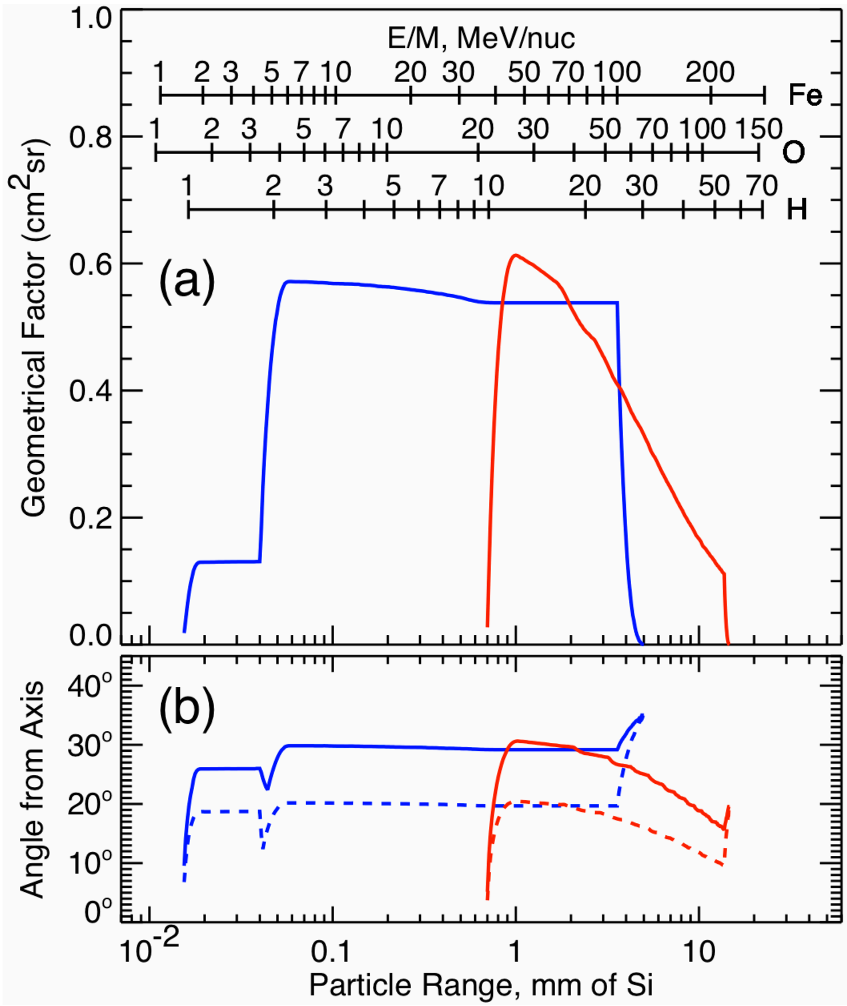
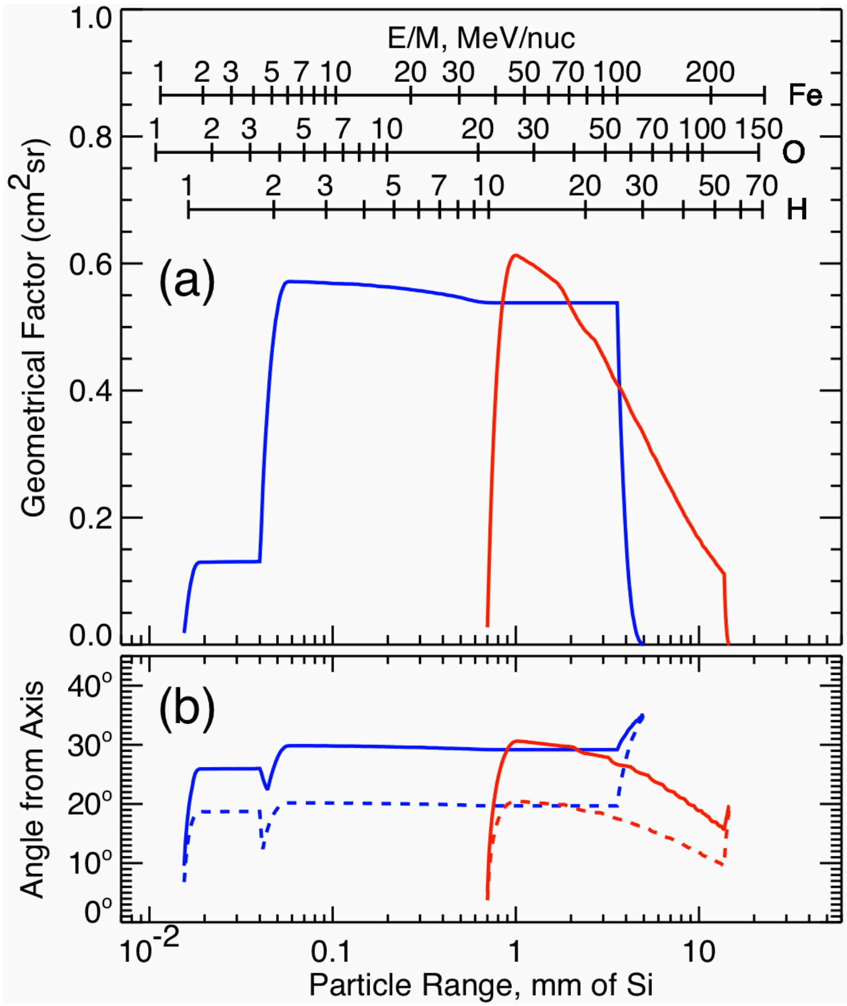


Fig. 36 (**a**) LET and HET geometrical factors as a function of the particle range in silicon. Energy scales for H, O, and Fe are also shown. *Blue curves* are used for LET, *red curves* for HET. Protons above ~25 MeV have energy losses in the L1 detector that fall below threshold and thus do not produce a coincidence in LET. Geometrical factors are shown for one end of each telescope. Plot is based on stopping particles; penetrating particle analysis will allow modest extensions to higher energies. (**b**) *Solid* (*dashed*) *curves* show the angles inside which 90 % (50 %) of the trajectories from an isotropic particle distribution fall as a function of the particle range in silicon

Geometrical Factor and Angular Sensitivity (2/2)

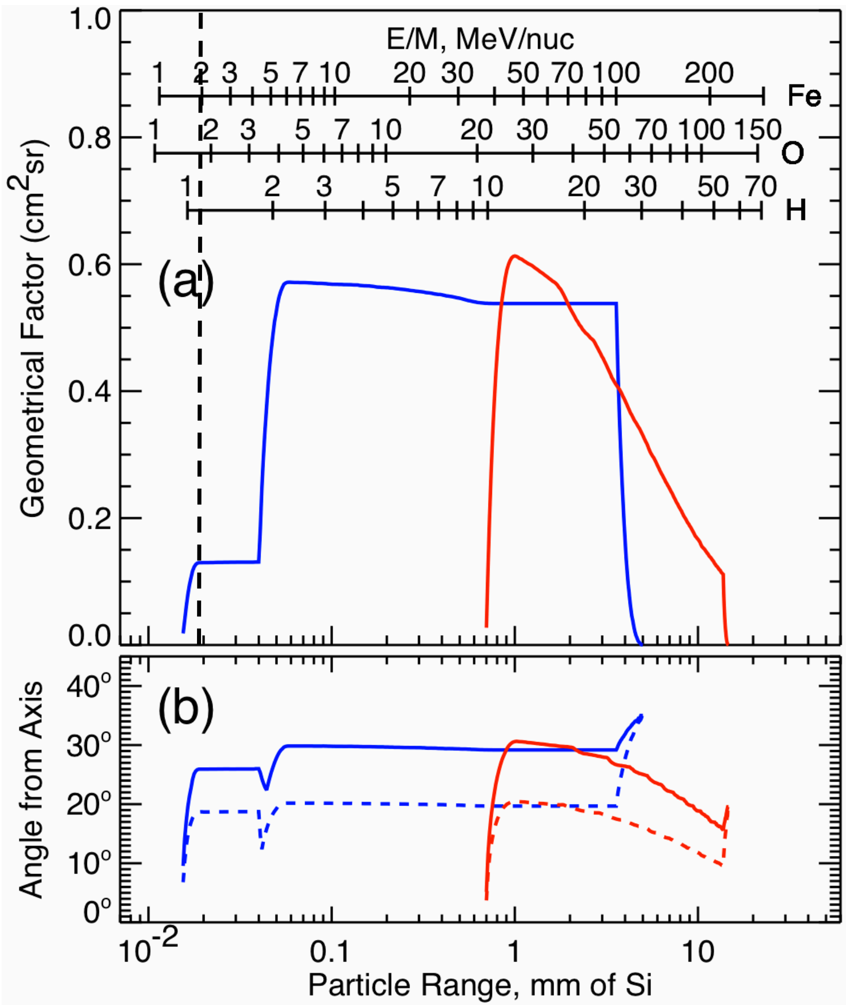
EPI-Hi geometrical factor evaluation at the time the ISIS Space Science Reviews article was written



- the low AΩ for ranges <0.04 mm of Si was due to allowing only the central bull's eye segment of L1 in the L0•L1 coincidence
- this was done to avoid penetrating particle trajectories that could miss L2 and appear to be due to stopping particles
- orientations of L0 and L1 detectors have now been arranged such that quadrants are aligned, not offset by 45° (L2 still is offset from L0 and L1 by 45°)
- this allows the use of aligned segment combinations such as L0Ab•L1Ab in addition to L0A•L1Aa
- these aligned segment trajectories provide good He isotope separation
- a very small fraction of aligned segment trajectories may miss L2, so flight software will need to pick out the stopping branch of these tracks

Geometrical Factor and Energy Coverage

EPI-Hi geometrical factor evaluation at the time the ISIS Space Science Reviews article was written



- with the present thickness of the L0 detector (12 μm of Si) and the three polyimide windows in front of it (total of 3 μm silicon-equivalent), the LET energy threshold (defined as the energy at which the geometrical factor defined by the L0•L1 coincidence reaches a plateau, as indicated by the dashed vertical line) is not quite low enough to measure 1 MeV protons
- for heavier nuclei the threshold is closer to 2 MeV/nuc
- the inclusion all of the aligned L0 and L1 sector combinations in the LET coincidence effectively lowers the energy threshold—to penetrate 15 μm of Si at 0° requires ~0.95 MeV for protons, ~1.4 MeV/nuc for O, and ~1.5 MeV/nuc for Fe)
- level 3 requirements call for an EPI-Hi proton and heavy ion energy range "of 1 MeV/nuc (TBR) to ≥50 MeV/nuc"
- present plans are to include some measurement of L0 singles pulse heights, which would push the LET energy threshold lower, but with minimal information about composition or incidence directions
- if it is necessary to increase the LET window thicknesses or L0 thickness to improve chances of surviving the high-speed dust environment, that would push the energy threshold higher yet—however such a window thickness increase would probably not be made on all three LET telescopes

Thin Silicon Detector Problems Encountered—General

On the first set of detector mounts, traces on the flex strips cracked causing an open circuit

- the problem was caused by the tendency for flex strip to bend with too sharp a radius
- added reinforcement "comb" to prevent further breakage and jumper wire to make connection around open circuit
- incorporated strain-relief combs on subsequently fabricated mounts

During preparations for the second thermal-vacuum life test a corroded piece of tubing allowed some of the cooling fluid (FC77) to leak into the vacuum chamber.

- one of the two LBNL detectors in the chamber experienced a large and apparently permanent leakage current increase
- the second LBNL detector and the four Micron detectors that were in the chamber did not have problems
- after repair and bake-out of the chamber the thermal-vacuum run was resumed and was run to completion without further changes in the characteristics of the five unaffected detectors

Thin Silicon Detector Problems Encountered—Micron Detectors

Micron found that one detector in the first set of prototypes did not have glue under a small portion of the periphery

- Micron reported the problem and supplied a replacement detector

Inspection of one Micron detector found that all the wire bonds to one segment had been detached at the detector end

- detector segment had been connected during testing in October 2013
- this was the same detector that had the gluing problem (see above)—no clear association however
- suspect a handling problem since early detectors were sandwiched between sheet metal squares before enough test holders were available; moving detectors into and out of holders for testing led to more handling than desirable

Thin Silicon Detector Problems Encountered—LBNL Detectors (1/2)

After displacement damage test using proton fluence of $10^{13}/cm^2$ in December 2013 found that the rise time of the signal from the LBNL L1 detector was significantly slowed compared to a non-irradiated detector.

- L0 and L1 detectors from Micron did not exhibit this problem
- on LBNL detectors the contact to ohmic surface is made with a wirebond to undepleted silicon on the junction surface and relies on conductivity of the undepleted silicon
- displacement damage in n-type silicon causes an increase in the material's resistivity
- increased resistance of the bias connection to ohmic surface combined with the large detector capacitance introduced a long (microseconds) time constant for the bias supply to deliver charge to the detector after a particle was detected, thereby slowing the collection of the charge signal
- explanation was confirmed by aluminizing the ohmic surface of the affected LBNL detector and making a wire bond directly to that surface, which corrected the problem

Thin Silicon Detector Problems Encountered—LBNL Detectors (2/2)

Inspection of the one LBNL detector that had been included in the first thermal-vacuum life test at Goddard showed that the wirebonds were missing and the silicon chip was completely unglued from the detector mount

- the adhesive used by LBNL is less compliant that that used by Micron
- during mounting of detectors at LBNL the epoxy adhesive had not been pumped on to remove air bubbles
- LBNL suggested that not enough attention had been paid to getting a uniform distribution of glue of a suitable thickness all along the mounting ledge
- we suspected that non-ideal gluing of the detector into the mount combined with stresses that occurred during the thermal vacuum run could have caused the chip to come loose from mount, with wire bonds subsequently being broken as chip moved around during handling and shipping back to Caltech
- two LBNL detectors were in second thermal-vacuum life test at Goddard
- to date one of them has been inspected and it was found that the chip is still attached to mount

Detector Mount Inspections

- Coupon testing is carried out at Goddard for circuit boards that are the basis for the detector mounts
- mechanical inspections of the mounts is also carried out at Goddard after post-machining
- Micron also does their own mechanical inspections
- Micron installs a dummy detector chip in a mount makes test wirebonds and performs pull tests

Detector Photographic Inspections

- after detectors are received a set of detailed photographs are made for inspection purposes and to aid in tracking down any changes that may have occurred if it is necessary to investigate some problem in the future