Galactic Cosmic Ray Simulator at the NASA Space Radiation Laboratory

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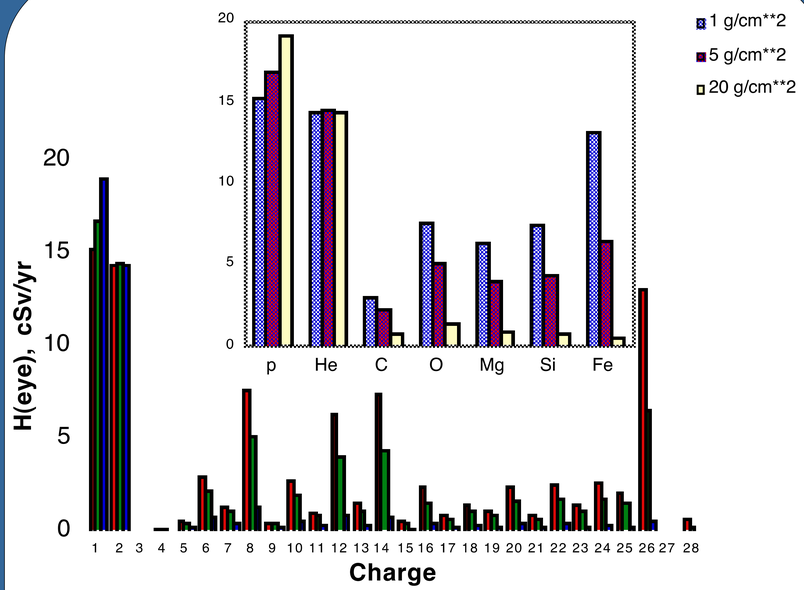
Abstract

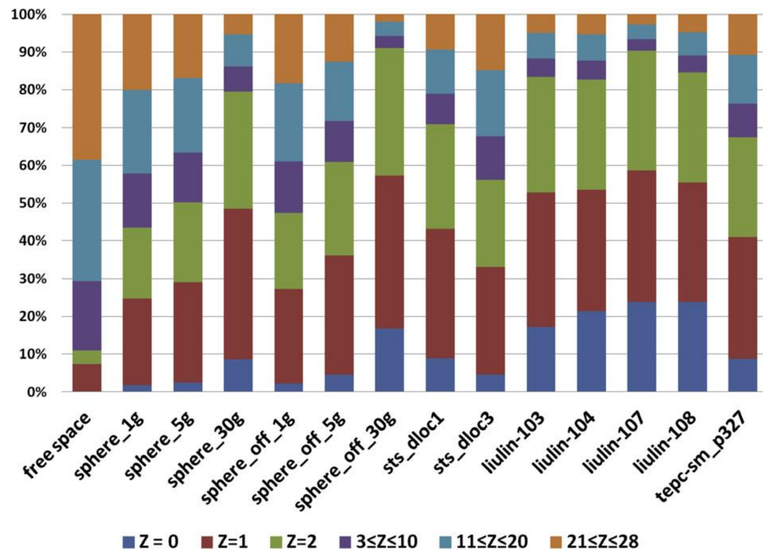
The external Galactic Cosmic Ray (GCR) spectrum is significantly modified when it passes through spacecraft shielding and astronauts. One approach for simulating the GCR space radiation environment is to attempt to reproduce the unmodified, external GCR spectrum at a ground based accelerator. A possibly better approach would use the modified, shielded tissue spectrum, to select accelerator beams impinging on biological targets. NASA plans for implementation of a GCR simulator at the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory will be discussed.

Heavy vs. Light Ion contributions to Dose Equivalent

- Heavy ions dominate dose equivalent only for thin shielding
- For realistic thick shielding, neutrons & light ions contribute significantly [Norbury & Slaba, 2015]
- Fe at 1 GeV/n does *not* represent galactic cosmic ray (GCR) spectrum
- Need to define a set of beams to represent GCR

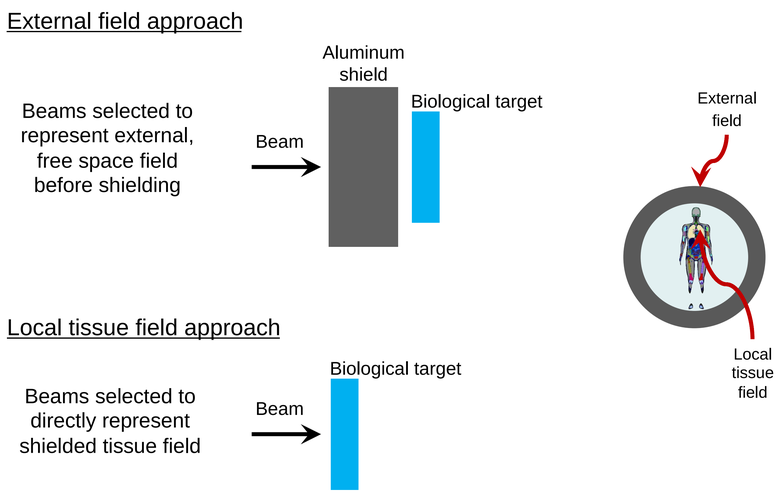


Average dose equivalent rate (H) from exposure of the eye behind various thicknesses (1, 5, 20 g/cm^2) of polyethylene slab shielding at solar minimum. Red, green and blue bars in the lower portion of the figure represent 1, 5 and 20 g/cm^2 respectively. The most significant components are shown in the inset. Reprinted from [Schimmerling et al., 1999].



Calculations of percent contribution to blood forming organ (BFO) dose equivalent by charge group for free space (far left), simple spherical geometries in free space, and various detector locations inside the space shuttle (STS) and the International Space Station (ISS) in free space. This figure does not show data, but only calculations at detector locations. Reprinted from [Walker, Townsend & Norbury, 2013].

Two approaches to GCR simulation



Langley Workshop

- Identify advantages & limitations of GCR simulation
- Concluded that local tissue field approach was best for NASA Space Radiation Lab (NSRL) [Slaba et al., 2015]
- Quality factor (Q) known for cancer, not central nervous system (CNS). Dose better quantity for CNS
- Pick beams based on linear energy transfer (LET) spectra
- NSRL beam switching capabilities allow for GCR simulation

Issues

- Neutron beams
- Pion & electromagnetic cascade
- Mechanisms difficult to unravel with mixed beams – need to compare to single beams
- Dose rate effects
- Multi-track effects
- Multiplicity effects
- Timing and ordering of beam exposures
- Several issues common to both GCR simulation and single beams
- GCR simulation should address both animals & cells

Conclusions

- Neutrons & light ions contribute significantly to dose equivalent for realistic shielding
- NSRL energy constraints limit feasibility of external field method
- Local tissue field method most suitable for NSRL
- A single reference field is within uncertainties
- Several issues to be resolved in future

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W. Schimmerling, J. Wilson, F. Cucinotta, M. Kim, 1999. *Requirements for simulating space radiation with particle accelerators.* http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.30.732. Also available at NASA Technical Reports Server http://ntrs.nasa.gov. Available in the Public Domain.

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