Overview of the Graphical User Interface for the GERM code (GCR Event-based Risk Model)

Myung-Hee Y. Kim[1] and Francis A. Cucinotta[2]

[1]USRA, Division of Space Life Sciences, SK/SRPE/B37, 2101 NASA Parkway, Houston, TX 77058, USA, myung-hee.y.kim@nasa.gov

[2]NASA Johnson Space Center, SK, 2101 NASA Parkway, Houston, TX 77058, USA, francis.a.cucinotta@nasa.gov

Abstract

The descriptions of biophysical events from heavy ions are of interest in radiobiology, cancer therapy, and space exploration. The biophysical description of the passage of heavy ions in tissue and shielding materials is best described by a stochastic approach that includes both ion track structure and nuclear interactions. A new computer model called the GCR Event-based Risk Model (GERM) code was developed for the description of biophysical events from heavy ion beams at the NASA Space Radiation Laboratory (NSRL) [1]. The GERM code calculates basic physical and biophysical quantities of high-energy protons and heavy ions that have been studied at NSRL for the purpose of simulating space radiobiological effects. For mono-energetic beams, the code evaluates the linear-energy transfer (LET), range (R), and absorption in tissue equivalent material for a given Charge (Z), Mass Number (A) and kinetic energy (E) of an ion[2]. In addition, a set of biophysical properties are evaluated such as the Poisson distribution of ion or delta-ray hits for a specified cellular area, cell survival curves, and mutation and tumor probabilities[3-5].

The GERM code also calculates the radiation transport of the beam line for either a fixed number of user-specified depths or at multiple positions along the Bragg curve of the particle. The contributions from primary ion and nuclear secondaries are evaluated[6,7]. The GERMcode accounts for the major nuclear interaction processes of importance for describing heavy ion beams, including nuclear fragmentation, elastic scattering, and knockout-cascade processes by using the quantum multiple scattering fragmentation (QMSFRG) model[8,9]. The QMSFRG model has been shown to be in excellent agreement with available experimental data for nuclear fragmentation cross sections[10], and has been used by the GERM code for application to thick target experiments. The GERM code provides scientists participating in NSRL experiments with the data needed for the interpretation of their experiments[11], including the ability to model the beam line, the shielding of samples and sample holders, and the estimates of basic physical and biological outputs of the designed experiments. We present an overview of the GERMcode GUI, as well as providing training applications.

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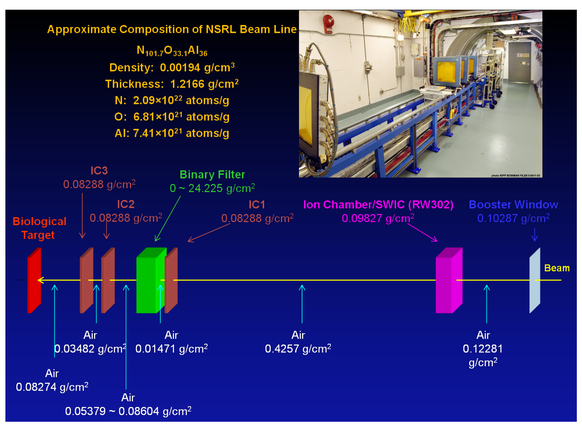
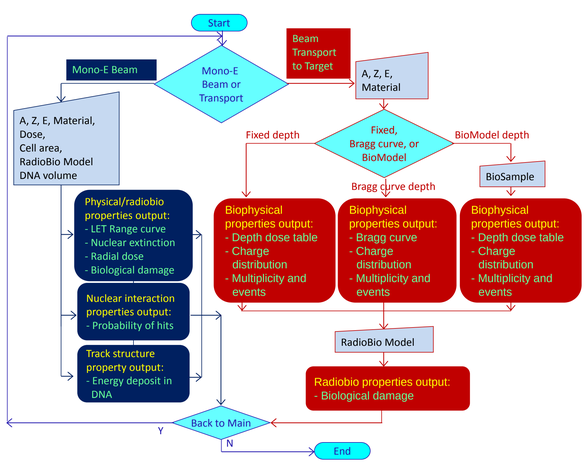


NSRL Beam Line and Approximate Atomic Composition



Flow Chart of GERM GUI

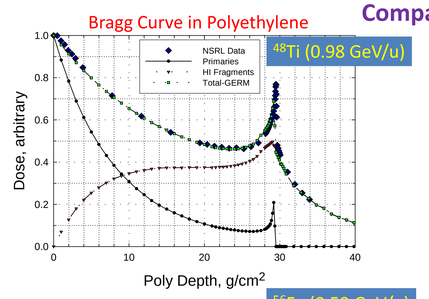
User Input Control Parameters

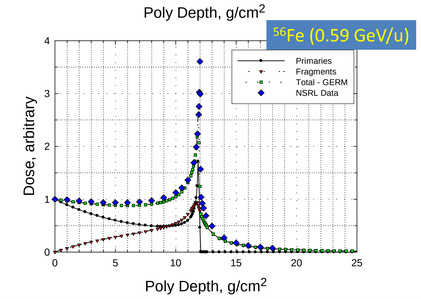
Parameter	Mono-energetic beam	Radiation transport in thick target
Mass number	1 – 58	1 – 58
Charge number	1 – 28	1 – 28
Beam energy, MeV/u	50 – 1500 MeV/u	50 – 1500 MeV/u
Material	Water Aluminum Polyethylene CO_2 Graphite Carbon	Water Aluminum Polyethylene CO_2 Graphite Carbon
Dose, Gy	0.0 - 5.0 Gy	
Cell area, μm²	0.1 – 1000 μm²	
DNA volume (*d* x *l* of cylinder volume, unit in *nm*)	DNA segment, Nucleosome, DNA fiber	
Biophysical Models		
Radiobiology model	No radiobio model Cell survival Chrom. aberration Cell mutation Mouse tumor model	No radiobio model Cell survival Chrom. aberration Cell mutation Mouse tumor model

- a) Beam transport for fixed depth
- b) Beam transport for Bragg curve depth
- c) Beam transport in biological sample
  - Mouse: Longitudinal placement along the beam
  - Mouse: Transverse placement to the beam
  - Rat: Longitudinal placement along the beam
  - Rat: Transverse placement to the beam
  - Ferret : Longitudinal placement along the beam
  - Ferret : Transverse placement to the beam
  - T-25 flask
  - T-75 flask
  - Flaskette
  - Chamber slide
  - 6-well plate

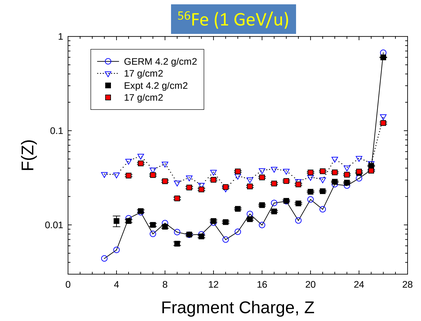
Comparisons to NSRL Data

Bragg Curve in Polyethylene



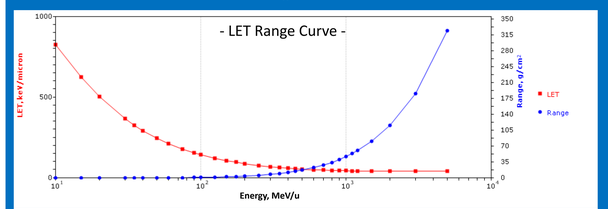


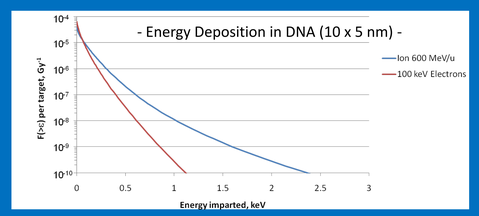
Elemental Fragment Spectra in Polyethylene
- GERM code with QMSFRG Cross Sections -

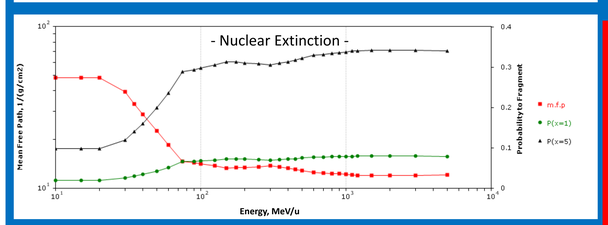


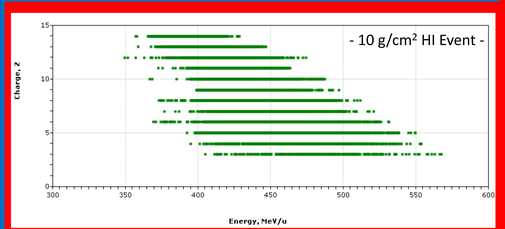
Results of ^{28}Si (600 MeV/u) on Water

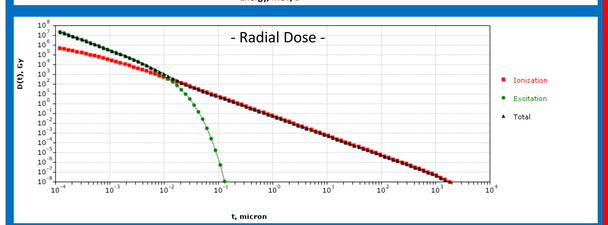
Mono –energetic Beam

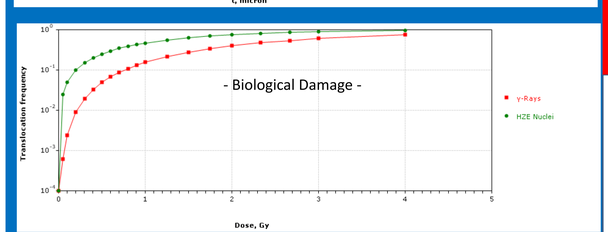


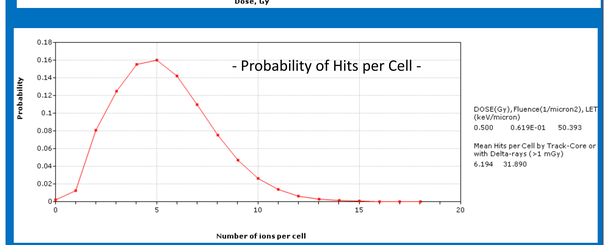




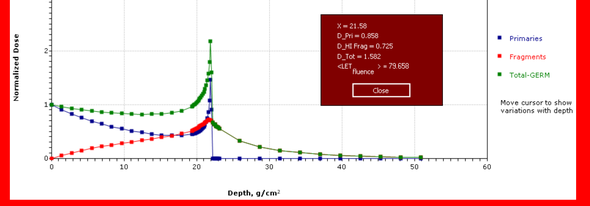


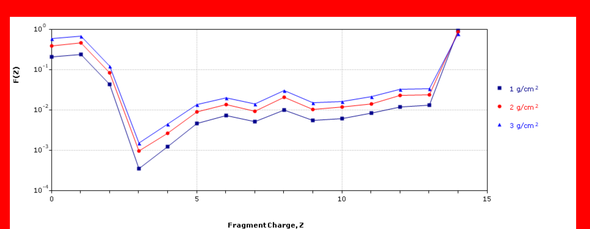


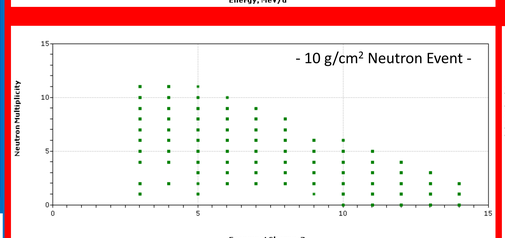


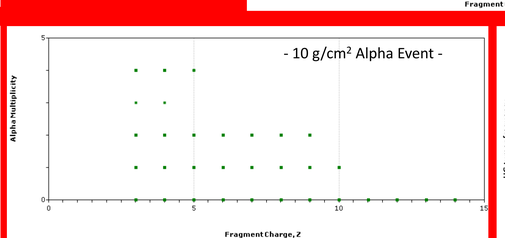


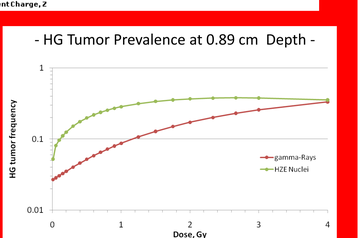
Beam Transport to Target











Progress

- Development of a stochastic simulation tool using track structure and nuclear interactions provides the description and the integration of physical and biophysical events from mono-energetic ions.
- Development of a stochastic Monte-Carlo based model of radiation transport in spacecraft shielding and tissue is made with the quantum multiple scattering model of heavy ion fragmentation (QMSFRG) and the energy loss processes.
- The scientists participating in NSRL experiments obtain the data needed for the interpretation of their experiments: Ability to model the beam line, the shielding of samples and sample holders; Estimation of basic physical and biophysical outputs of the designed experiments.

Gaps in Progress and Knowledge

- Detector composition and response functions
- Angular acceptance of detectors
- Description of time-dependent biophysical events produced from GCR within the tissue volumes → Estimate of GCR event rates to biological signaling induction and relaxation times
- Uncertainty reduction for GCR transport and risk models

Color Categories of the Research