Interpretation of TEPC Measurements in Space Flights for Radiation Monitoring

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Introduction

- The quality factor used in radiation protection is defined as a function of LET, $Q_{avg}(LET)$
- TEPCs measure the average quality factors as a function of lineal energy (*y*), $Q_{avg}(y)$
- A model of the TEPC response for charged particles:
  - energy deposition as a function of impact parameter from the ion's path to the volume
  - the escape of energy out of sensitive volume by δ-rays
  - the entry of δ-rays from the high-density wall into the low-density gas-volume
- TEPC response for broad spectrum of HZE particles:
  - the weighted function of discrete Monte-Carlo simulation data of the energy deposition

Approach to Radiation Evaluation

- Transport properties of spacecraft:
  NASA BRYNTRN/HZETRN code system
- Nuclear interaction model:
  Quantum Multiple Scattering Fragmentation (QMSFRG)
- TEPC detector response function:
  - Analytic model for frequency event spectra for trapped protons
  - Monte-Carlo track simulation for frequency event spectra for HZE particles

Analytic Model for Track Structure

Frequency Distribution for Energy Imparted by Ions

$$\frac{dF}{d\varepsilon} = 2\pi \int t\,dt\, n_{ev}(t)\left[f_{ion}(\varepsilon,t) + f_{\delta}(\varepsilon,t)\right]$$

$$n_{ev}(t) = \frac{D(t)}{\bar{z}_F(t)}$$

where $n_{ev}(t)$: the number of events as a function of impact parameter t

$f_{ion}(\varepsilon,t)$: ion events through the volume

$f_{\delta}(\varepsilon,t)$: ion events outside the volume as δ-ray events

$D(t)$: the radial dose distribution

$\bar{z}_F(t)$: the frequency average of the distribution at t

Dependence of Frequency Distribution on *t*

$$L = 2\pi \int_0^{t_M} t\,dt\left[D_{\delta}(t) + D_{exc}(t)\right]$$

where D_{δ} : the radial dose from primary or secondary electrons

D_{exc} : the radial dose from excitation

f_{ion} Mean and Variance Correction for δ-ray Diffusion

For example, the variance is

$$V(t) = \int dx' \int d\varphi \frac{d^2\bar{\varepsilon}_t}{d\varphi\, dx'} \delta_2[E_r(x,\varphi)]$$

where δ_2 : the quotient of the second by the 1st moment

$E_r(x,\varphi)$: the restricted energy

Event Spectra for an Ion of E MeV/amu

TEPC Response Function

$$f_{tot}(j,E,y) = f_{ion}(j,E,y) + f_{\delta}(j,E,y)$$

The Lineal Energy Distribution behind Shielding

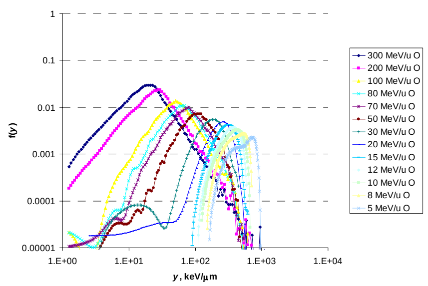
$$f(y) = \sum_s d_k c_s \sum_j \int dE\, \phi_j(x_s,E)\, f(j,E,y)$$

where c_s : the directional weighting coefficients for spacecraft shielding

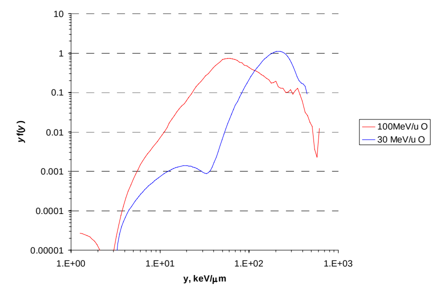
d_k : the directional weighting coefficient for instrument

ϕ_j : flux from BRYNTRN or HZETRN

Monte-Carlo Simulation of Walled TEPC in 1-μm Tissue Site for Oxygen Ions



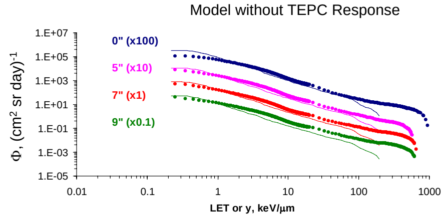
Fraction of *y*



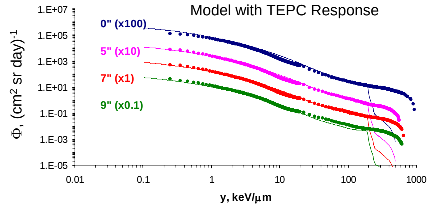
Event Distributions

Shuttle Tissue Equivalent Proportional Counter (STS-89, January 1998)

Model without TEPC Response

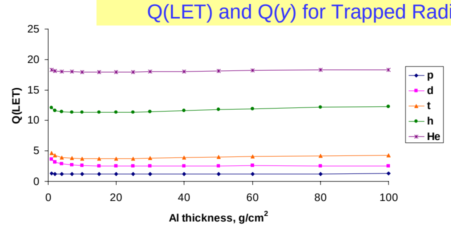


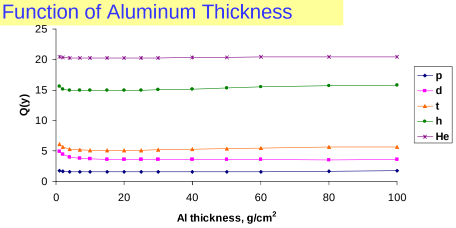
Model with TEPC Response



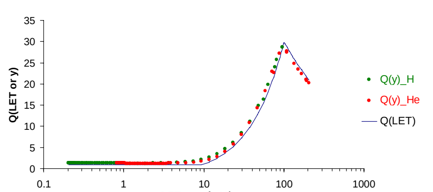
Trapped Integral Flux inside Aluminum Sphere : — Model calculation for TEPC Response; • TEPC Measurement
Experimental Setup: TEPC Aluminum Spheres Located in Payload Bay (Diameter: 0", 5", 7", and 9")
Environmental Parameters: Duration (6.894 days); Orbit Inclination (51.6°); Orbit Altitude (296 km);
Solar $F_{10.7}$ (94.6×10-22 Joule/sec/m2/Hz); FBAR (92.4×10-22 Joule/sec/m2/Hz); Sunspot Number (50.3);
Average Ø (493 MV)

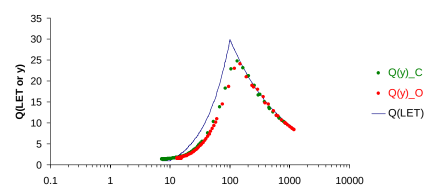
Q(LET) and Q(*y*) for Trapped Radiation as a Function of Aluminum Thickness





Quality Factors of LET and Lineal Energy for Various Ions





Q_{avg} of Trapped Radiation inside Aluminum Sphere (STS-89)

Sphere Thickness g/cm²	Q_{avg}(L)	Q_{avg}(y)	Measured Q_{avg}(y)	$Q_{avg}(y)/Q_{avg}(L)$
0"	1.50	2.07	2.06	1.38
5"	1.57	2.18	1.99	1.39
7"	1.61	2.25	2.26	1.40
9"	1.65	2.32	2.58	1.41

Concluding Remarks and Future Works

Trapped protons:

- The model calculation of integral flux is very close to the TEPC measured data except above 100 keV/μm
  ⇒ Target fragmentation to be included in the model
- $1.99 \le Q_{avg}(y) \le 2.58$ as measured by the TEPC
- $1.5 \le Q_{avg}(LET) \le 1.65$ as calculated from LET distribution using BRYNTRN
- $2.07 \le Q_{avg}(y) \le 2.32$ as calculated from *y* distribution determined from TEPC response function and BRYNTRN
  ⇒ TEPCs overestimate the average quality factor about 40% for trapped protons

HZE particles of GCR:

- Q(*y*) < Q(LET) for HZE particles in the major interval of y or LET
  ⇒ TEPCs underestimate the average quality factor for GCR
- Monte-Carlo simulation to be made for broad spectrum of ion types and energies extended to 1000's MeV/u, and low *y* components with better statistic
- Radiation transport calculation of TEPC response will be compared with the TEPC measured data of GCR for the code validation effort and interpretation of radiation monitoring