

# Interpretation of TEPC Measurements in Space Flights for Radiation Monitoring

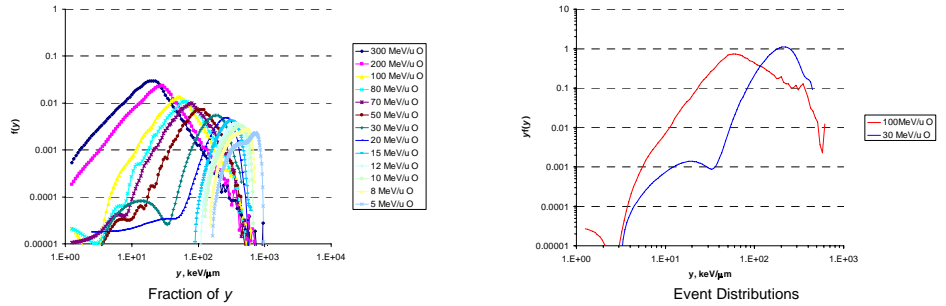


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## Introduction

- 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  $\delta$ -rays
  - the entry of  $\delta$ -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

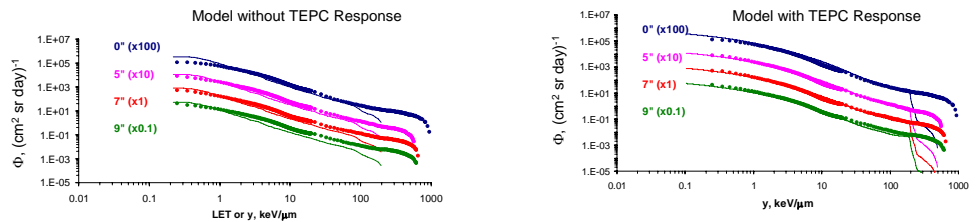
## Monte-Carlo Simulation of Walled TEPC in 1- $\mu$ m Tissue Site for Oxygen Ions



## 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

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



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  $F_{10.7}$  (94.6x10<sup>-22</sup> Joule/sec/m<sup>2</sup>/Hz); FBAR (92.4x10<sup>-22</sup> Joule/sec/m<sup>2</sup>/Hz); Sunspot Number (50.3);  
 Average  $\Phi$  (493 MV)

## Analytic Model for Track Structure

### Frequency Distribution for Energy Imparted by Ions

$$\frac{dF}{d\epsilon} = 2\pi \int dt n_{\sigma}(t) [f_{in}(\epsilon, t) + f_{\delta}(\epsilon, t)]$$

$$n_{\sigma}(t) = \frac{D(t)}{\bar{z}_{\sigma}(t)}$$

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

$f_{in}(\epsilon, t)$ : ion events through the volume  
 $f_{\delta}(\epsilon, t)$ : ion events outside the volume as  $\delta$ -ray events

$D(t)$ : the radial dose distribution  
 $\bar{z}_{\sigma}(t)$ : the frequency average of the distribution at  $t$

### Dependence of Frequency Distribution on $t$

$$L = 2\pi \int_0^{t_{max}} t dt [D_{\delta}(t) + D_{exc}(t)]$$

where  $D_{\delta}$ : the radial dose from primary or secondary electrons  
 $D_{exc}$ : the radial dose from excitation

### $f_{ion}$ Mean and Variance Correction for $\delta$ -ray Diffusion

For example, the variance is

$$V(t) = \int dx' \int d\phi' \frac{d^2 \bar{z}_{\sigma}}{d\phi' dx'} \delta_2[E_r(x, \phi)]$$

where  $\delta_2$ : the quotient of the second by the 1<sup>st</sup> moment  
 $E_r(x, \phi)$ : the restricted energy

### Event Spectra for an Ion of E MeV/amu

#### TEPC Response Function

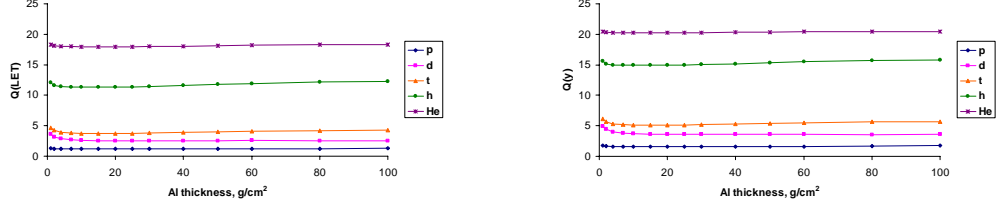
$$f_{in}(j, E, y) = f_{in}(j, E, y) + f_{\delta}(j, E, y)$$

#### The Lineal Energy Distribution behind Shielding

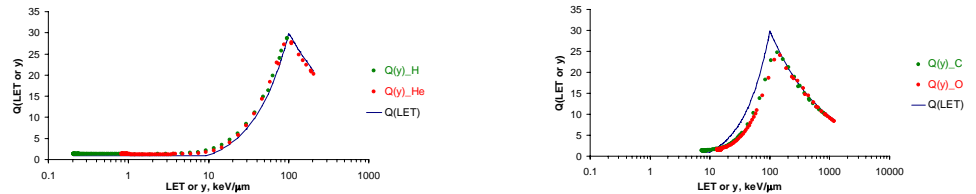
$$f(y) = \sum_i d_i c_i \int dE \phi_i(x, E) f(j, E, y)$$

where  $c_i$ : the directional weighting coefficients for spacecraft shielding  
 $d_i$ : the directional weighting coefficient for instrument  
 $\phi_j$ : flux from BRYNTRN or HZETRN

## 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/cm <sup>2</sup>	$Q_{avg}(L)$	$Q_{avg}(y)$	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
- $1.99 \leq Q_{avg}(y) \leq 2.58$  as measured by the TEPC
- $1.5 \leq Q_{avg}(LET) \leq 1.65$  as calculated from LET distribution using BRYNTRN
- $2.07 \leq Q_{avg}(y) \leq 2.32$  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