The Average Quality Factors by TEPC for Charged Particles

Myung-Hee Y. Kim[1], Hooshang Nikjoo[2], and Francis A. Cucinotta[3]

[1]Wyle Laboratories, Houston, TX
[2]USRA Division of Space Life Sciences, Houston, TX
[3]NASA Johnson Space Center, Houston, TX

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

- The quality factor used in radiation protection is defined as a function of LET, $Q_{ave}(LET)$
- TEPCs measure the average quality factors as a function of lineal energy (y), $Q_{ave}(y)$
- 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.

- Experimental Setup:
  - TEPC Aluminum Spheres Located in Payload Bay
  - Diameter: 0”, 5”, 7”, and 9”
  - Duration: 6.894 days
- Environmental Parameters:
  - Orbit Inclination: 51.6°
  - Orbit Altitude: 296 km
  - Solar F10.7: 94.6×10^{-22} Joule/sec/m^2/Hz
  - FBAR: 92.4×10^{-22} Joule/sec/m^2/Hz
  - Sunspot Number: 50.3
  - Average Ø: 493 MV

Frequency Distribution for Energy Imparted by Ions

$$\frac{dF}{de} = 2p \int t \, dt \, n_{ev}(t) \left[f_{ion}(e,t) + f_d(e,t) \right]$$

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

where $n_{ev}(t)$: the number of events

as a function of impact parameter t

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

$f_d(e,t)$: ion events outside the volume

as d -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*

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

where D_d : 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

$$V(t) = \int dx' \int dj \, \frac{d^2 \bar{e}_t}{dj \, dx'} d_2 \left[E_r(x, j) \right]$$

where d_2 : the quotient of the 2^{nd} by the 1^{st} moment

$E_r(x, j)$: the restricted energy

Event Spectra for an Ion of E MeV/amu

TEPC Response Function

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

The Lineal Energy Distribution behind Shielding

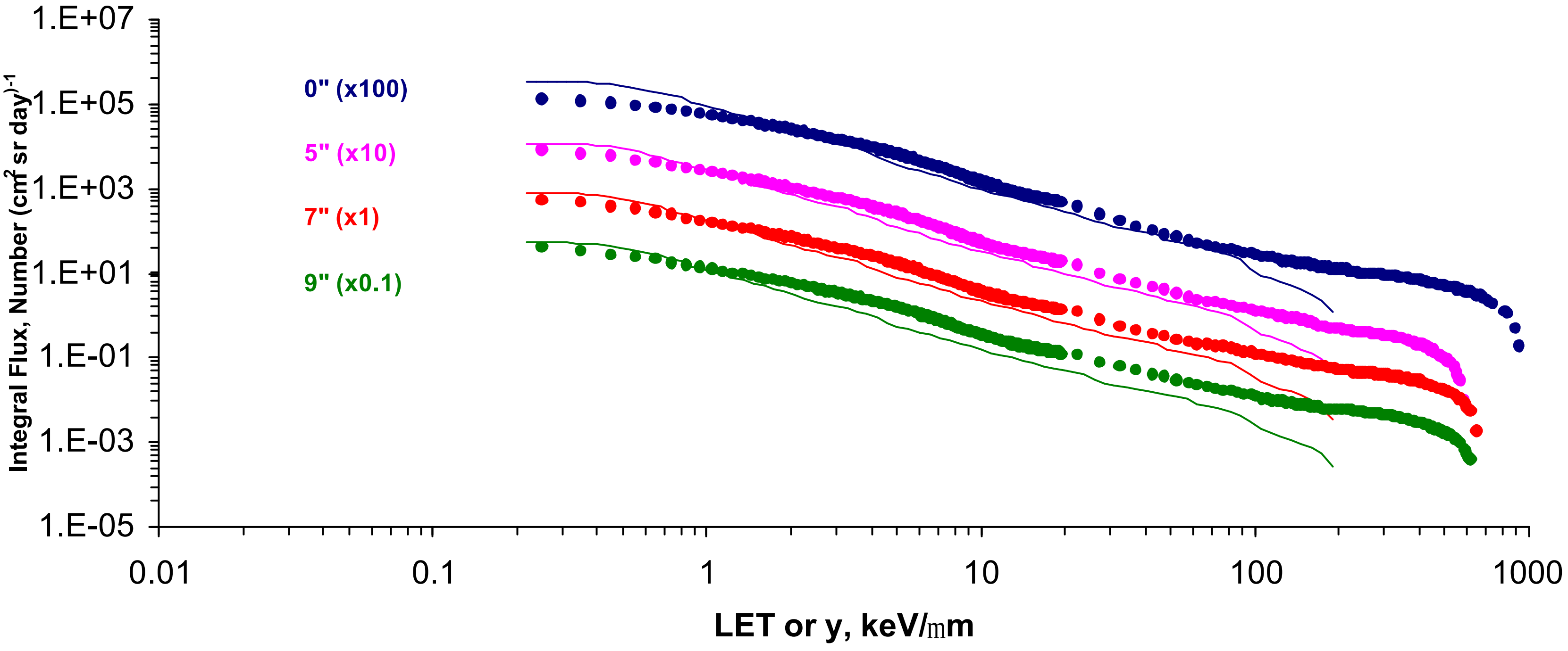
$$f(y) = \sum_s d_k c_s \sum_j \int dE\, f_j(x_s, E) f(j,E,y)$$

where c_s : the directional weighting coefficients for spacecraft shielding

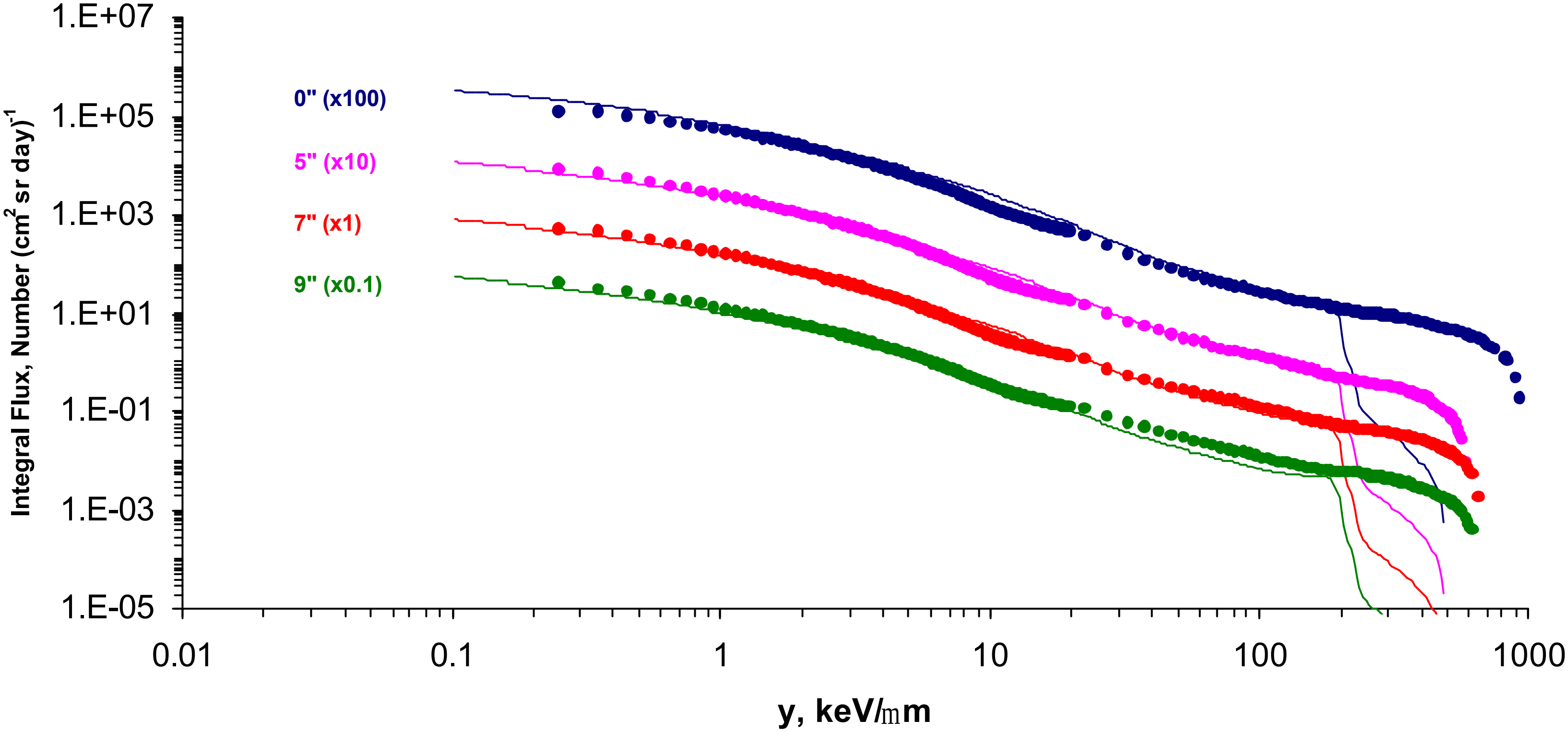
d_k : the directional weighting coefficient for instrument

f_j : flux from BRYNTRN or HZETRN

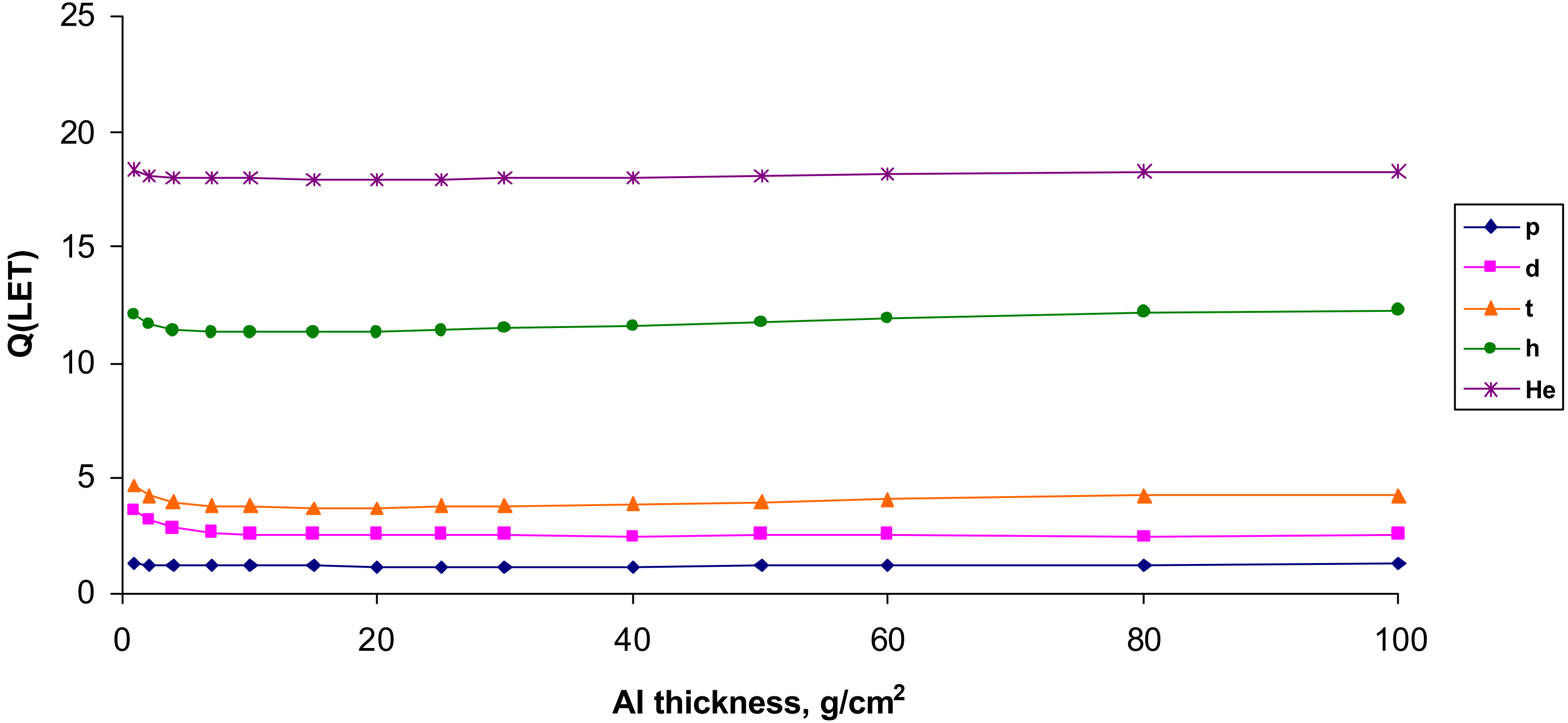
Trapped Integral Flux inside Aluminum Sphere Model without TEPC Response (STS-89)



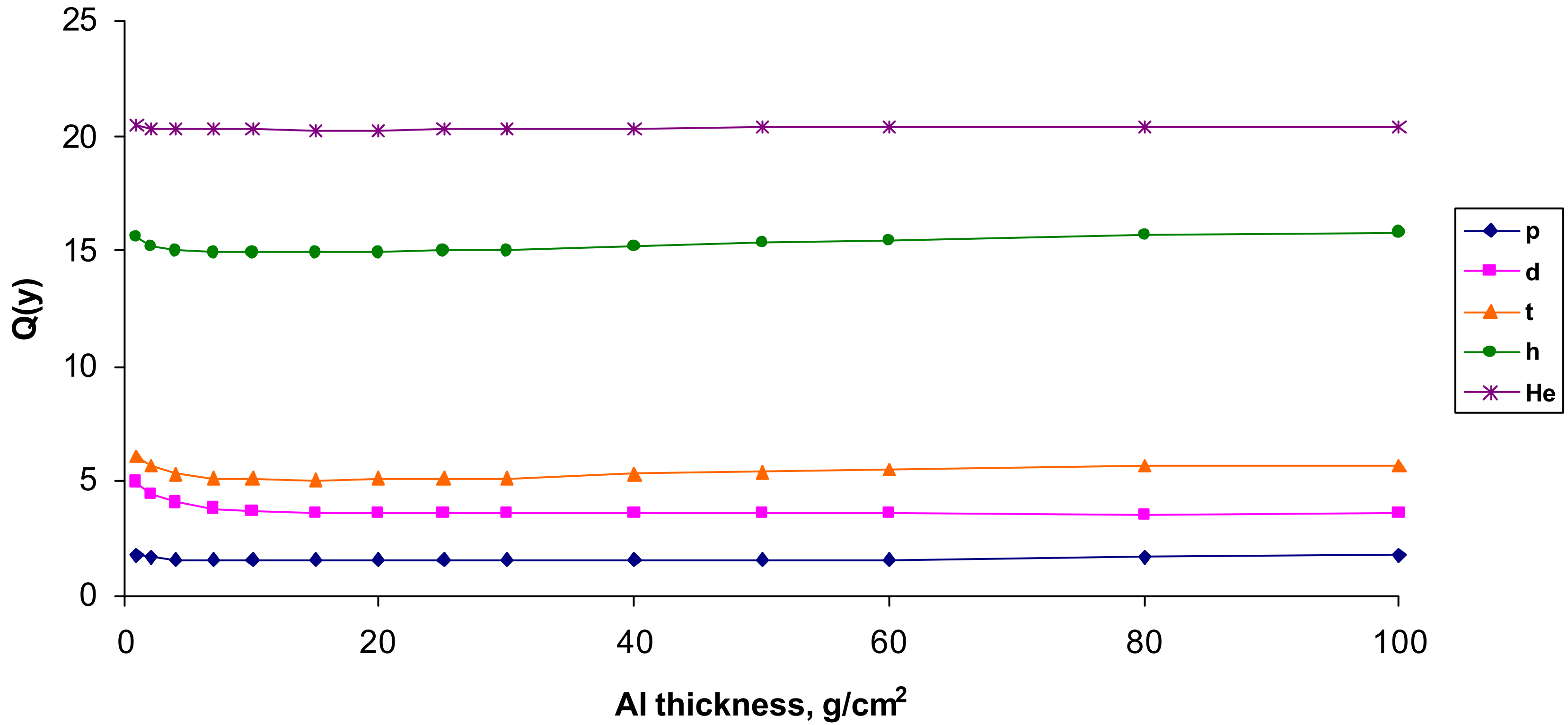
Trapped Integral Flux inside Aluminum Sphere Model with TEPC Response (STS-89)



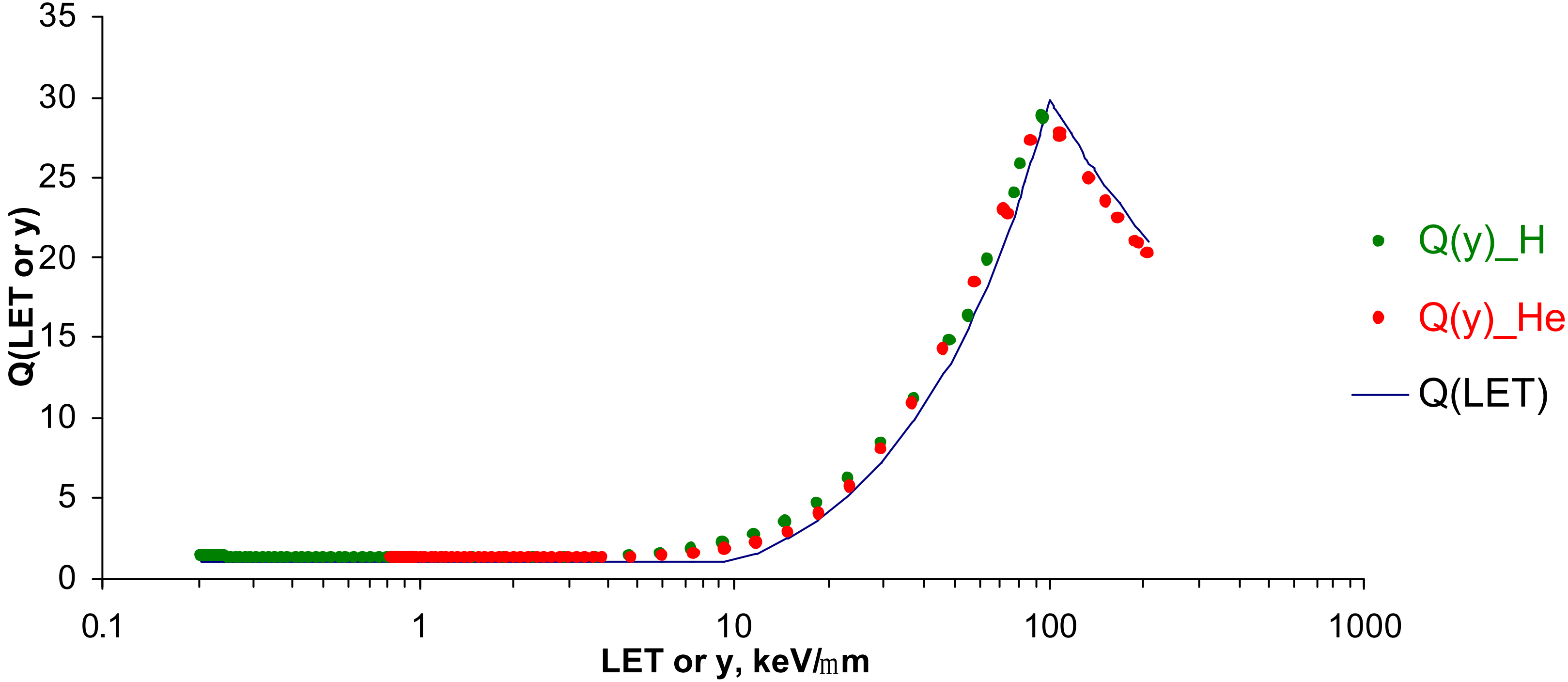
Q(LET) for Trapped Radiation as a Function of Aluminum Thickness



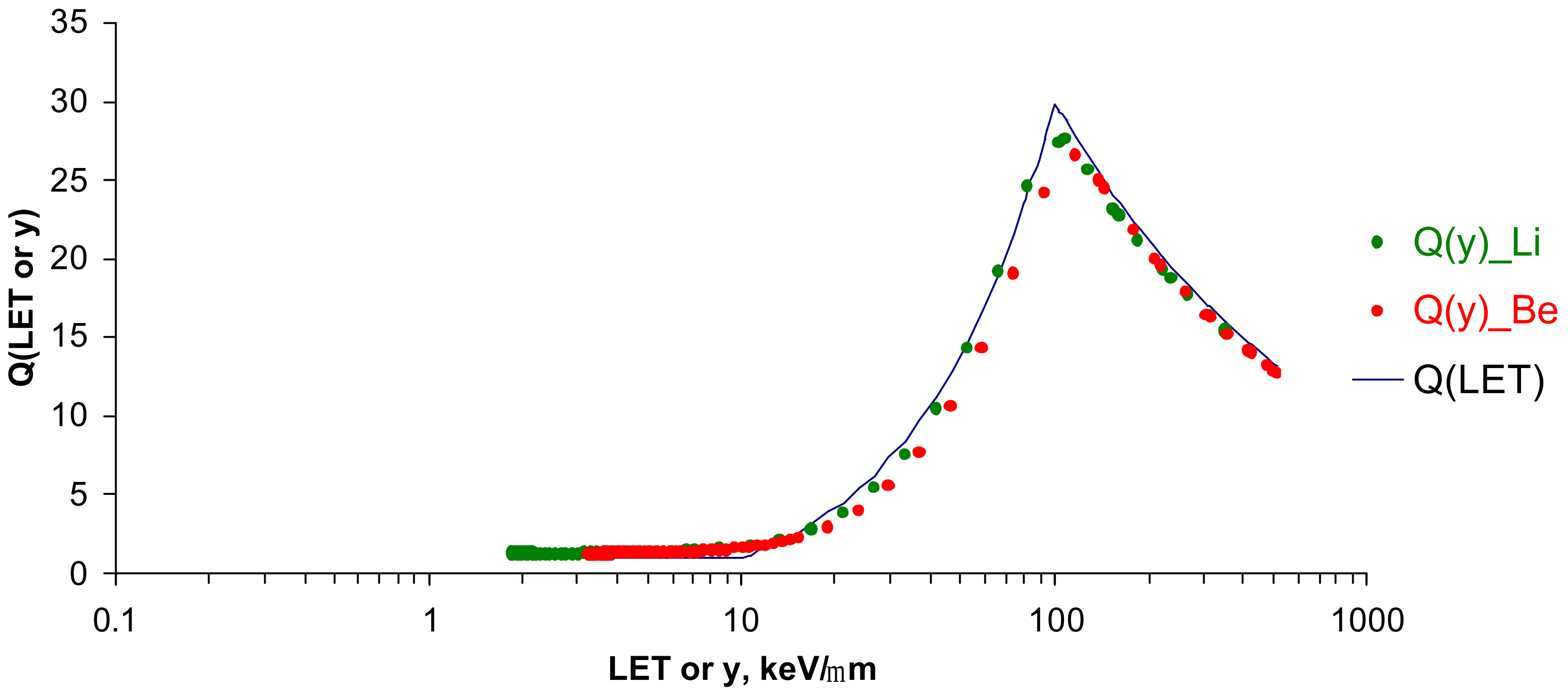
Q(y) for Trapped Radiation as a Function of Aluminum Thickness



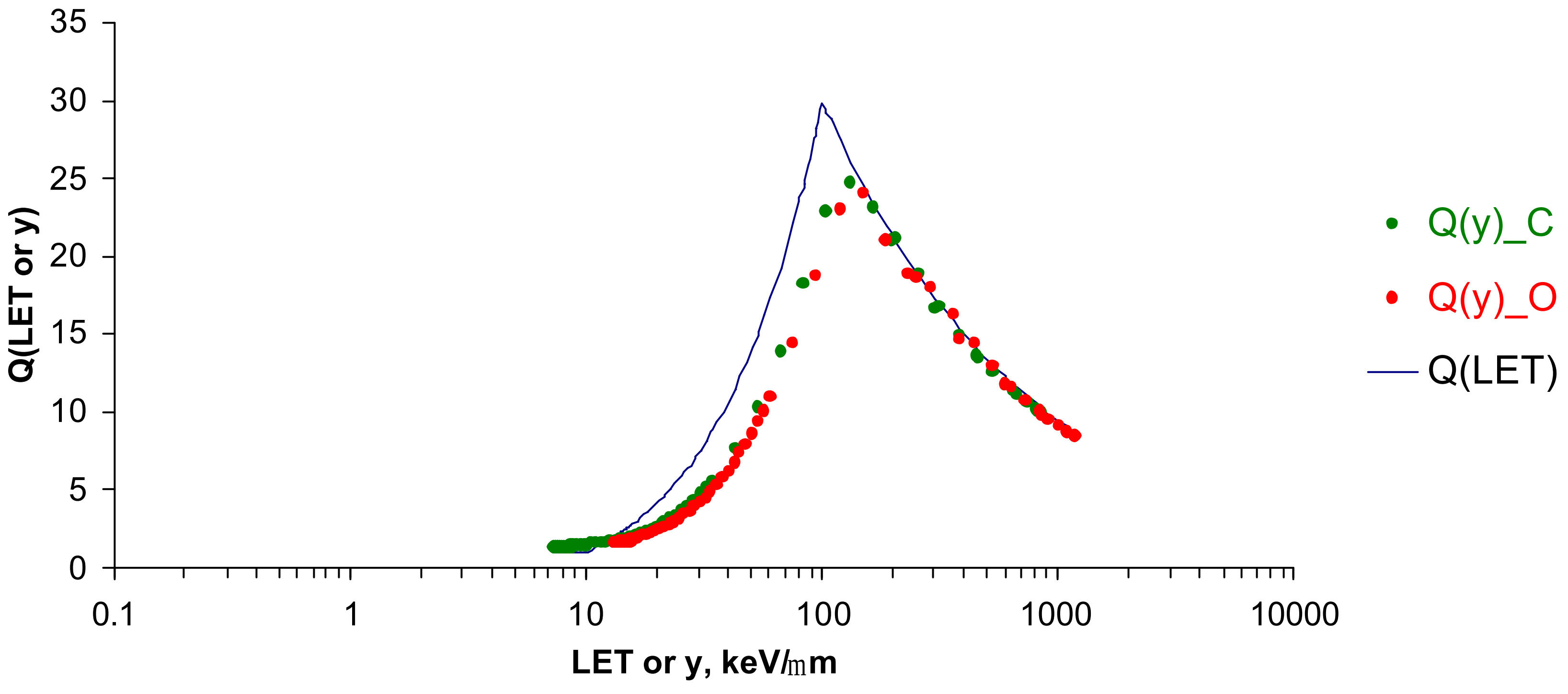
Quality Factors of LET and Lineal Energy (Proton and Alpha)



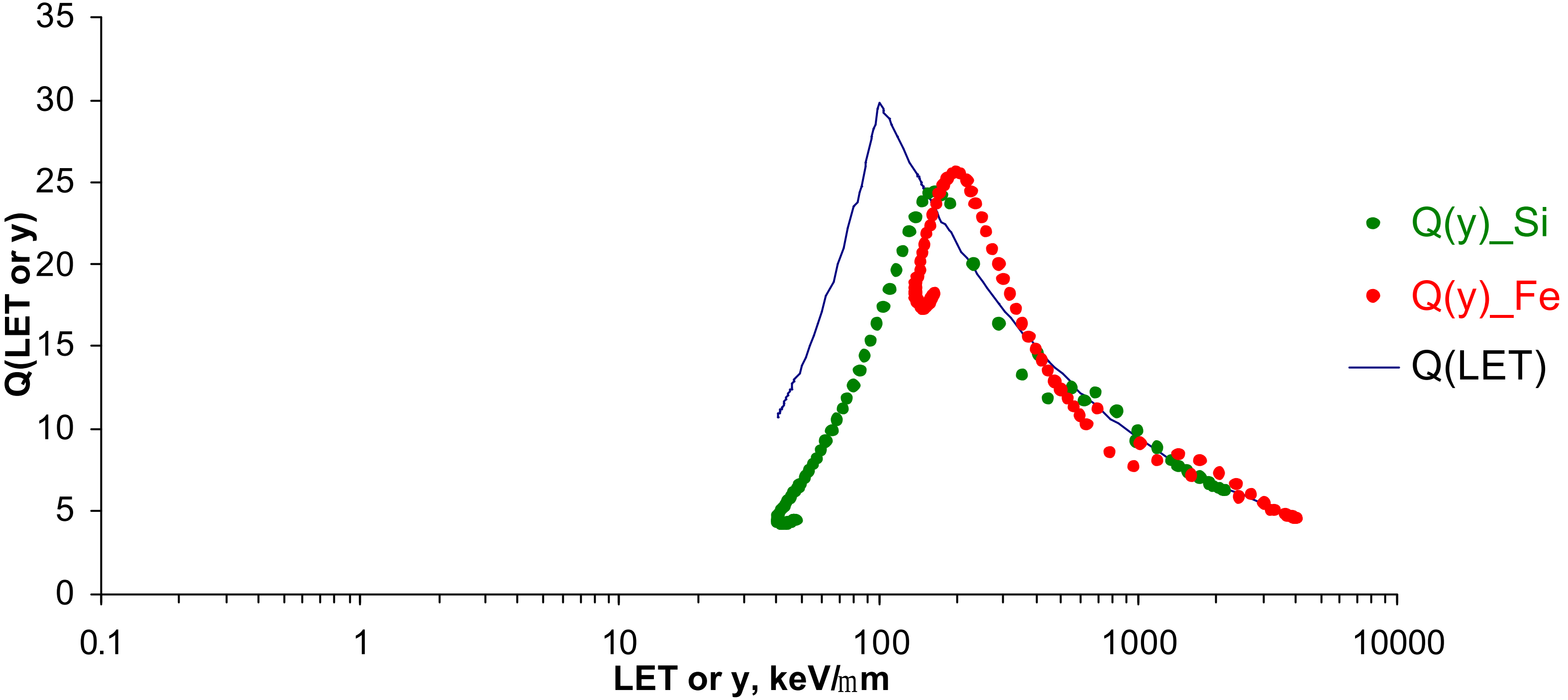
Quality Factors of LET and Lineal Energy (Li and Be)



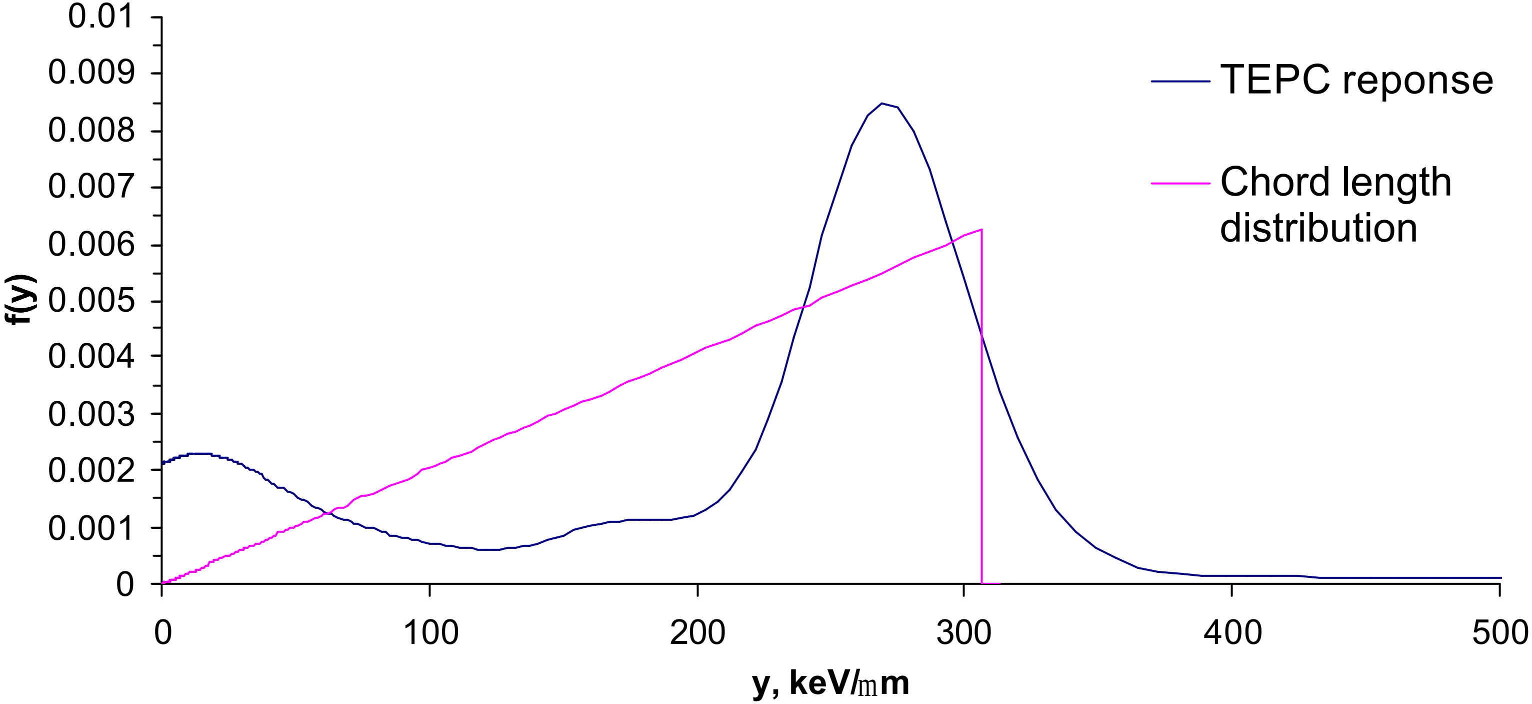
Quality Factors of LET and Lineal Energy (C and O)



Quality Factors of LET and Lineal Energy (Si and Fe)

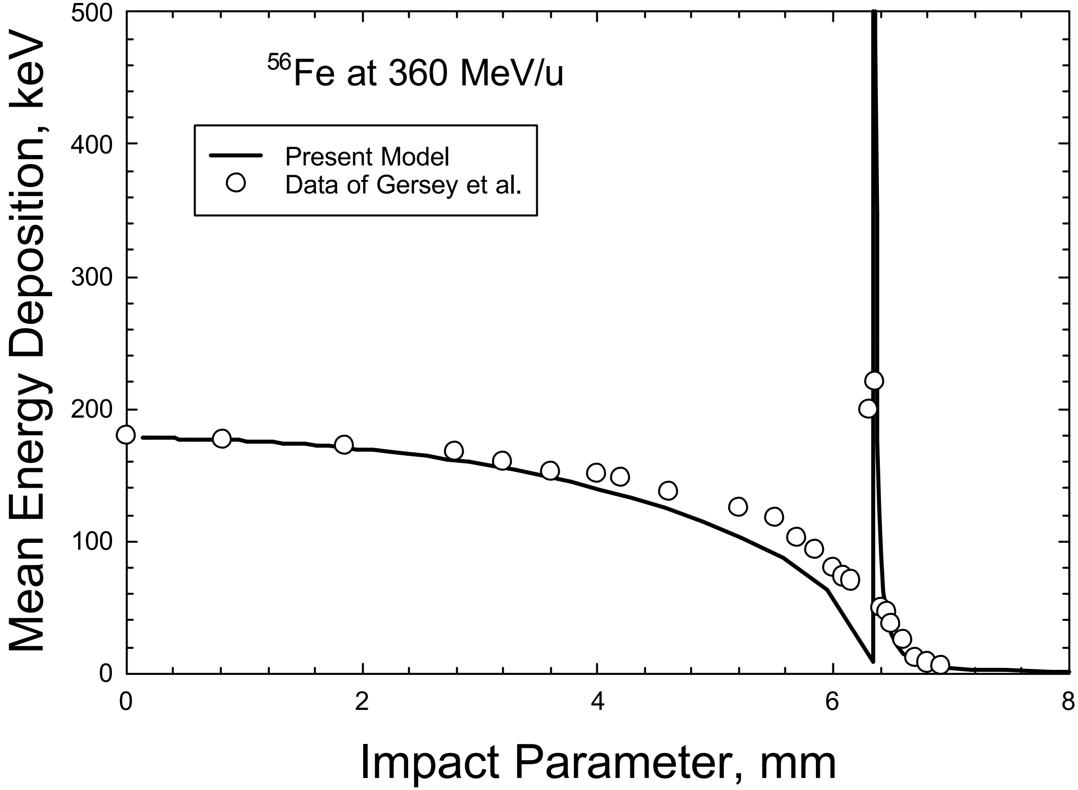


Distribution of y for a Uniform Fluence of ^{56}Fe at 390 MeV/n in a Walled TEPC

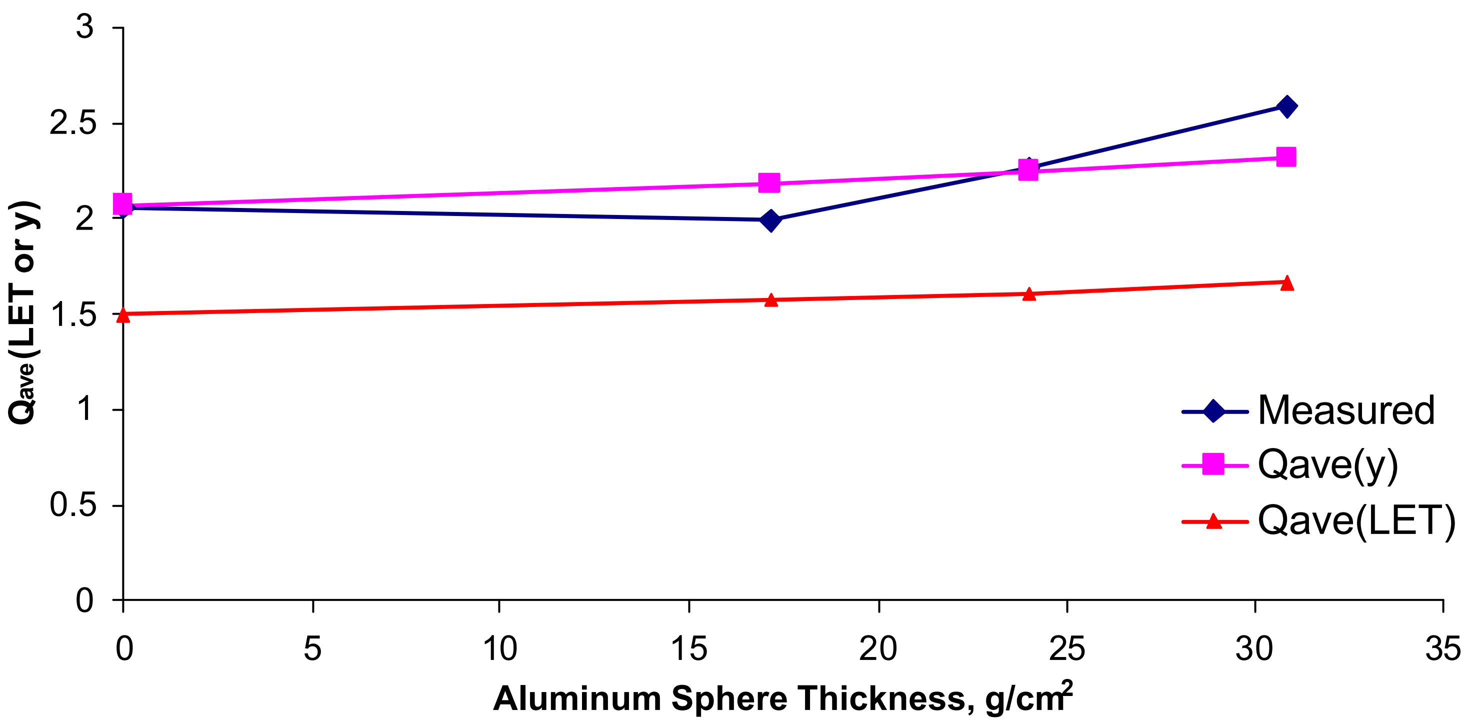


Comparison of Deterministic TEPC Model to Measurement

(Gersey *et al.*, *Radiation Research*, **157**, 350-360, 2002)



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



Average Quality Factors inside Aluminum Sphere for Trapped Radiation (STS-89)

Sphere Thickness g/cm^2	$Q_{ave}(L)$	$Q_{ave}(y)$	Measured $Q_{ave}(y)$	$Q_{ave}(y)/Q_{ave}(L)$
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

Conclusions

For trapped protons we find:

- $1.5 \leq Q_{ave}(LET) \leq 1.65$ as calculated from LET distribution using BRYNTRN
- $1.99 \leq Q_{ave}(y) \leq 2.58$ as measured by the TEPC
- $2.07 \leq Q_{ave}(y) \leq 2.32$ as calculated from y distribution determined from TEPC response function and BRYNTRN
- TEPC response model agrees well with flight TEPC data for trapped radiation in terms of $Q_{ave}(y)$.

$\Rightarrow$ TEPCs overestimate the average quality factor about 40% for trapped protons; underestimate the average quality factor for GCR