A Possible New Generation Personal Dosimeter TEPSC (Tissue Equivalent Plastic Scintillator Counter)

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1. Motivation and Purpose

Present personal passive dosimeters for astronauts: TLDs/OSLDs (low LET) + CR-39 PNTDs (high LET)

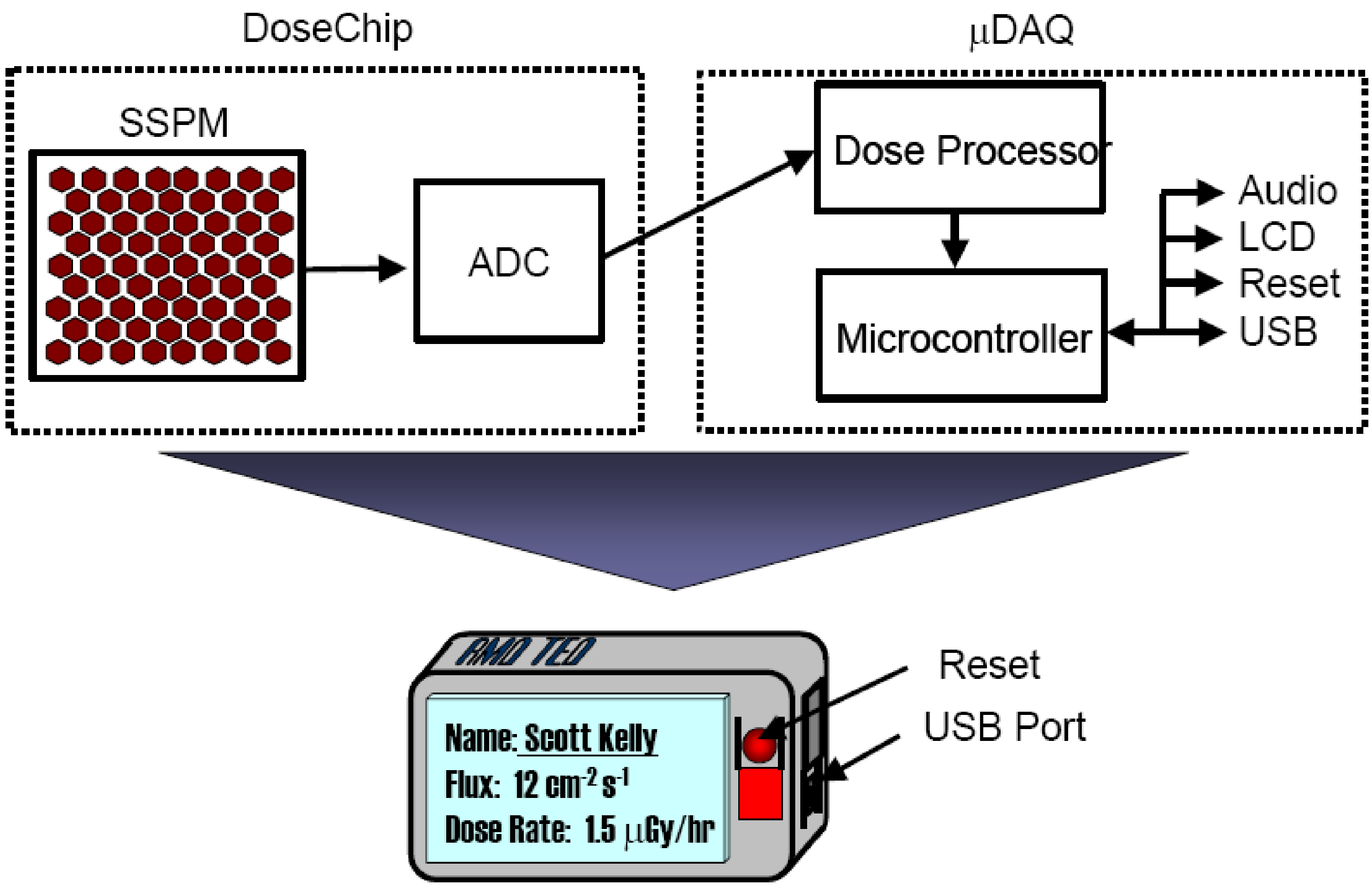
This approach may not satisfy the future NASA's requirements for long term lunar missions.

TEPSC (Tissue Equivalent Plastic Scintillator Counter) is the new generation active personal dosimeter being developed by RMD (Radiation Monitoring Devices, Inc., Boston, MA)

TEPSC integrated in a chip with PS and SSPM (Solid-State Photon Multiplier) [1].

This paper presents light response of plastic scintillator to relativistic GCR and data analysis method for TEPSC .

RMD Concept


DoseChip
μDAQ
SSPM
ADC
Dose Processor
Microcontroller
Audio
LCD
Reset
USB
RMD TED
Name: Scott Kelly
Flux: 12 cm-2 s-1
Dose Rate: 1.5 μGy/hr
Reset
USB Port

RMD SSPM

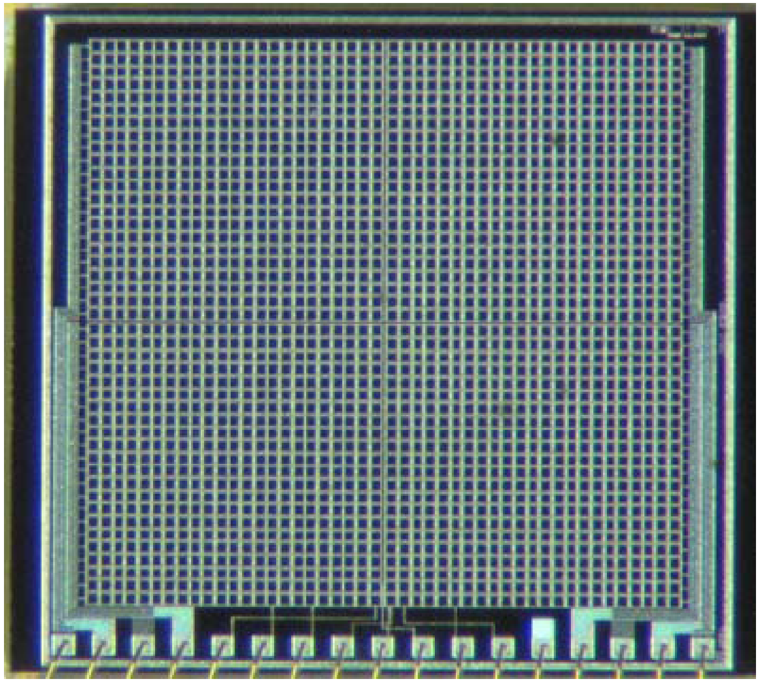
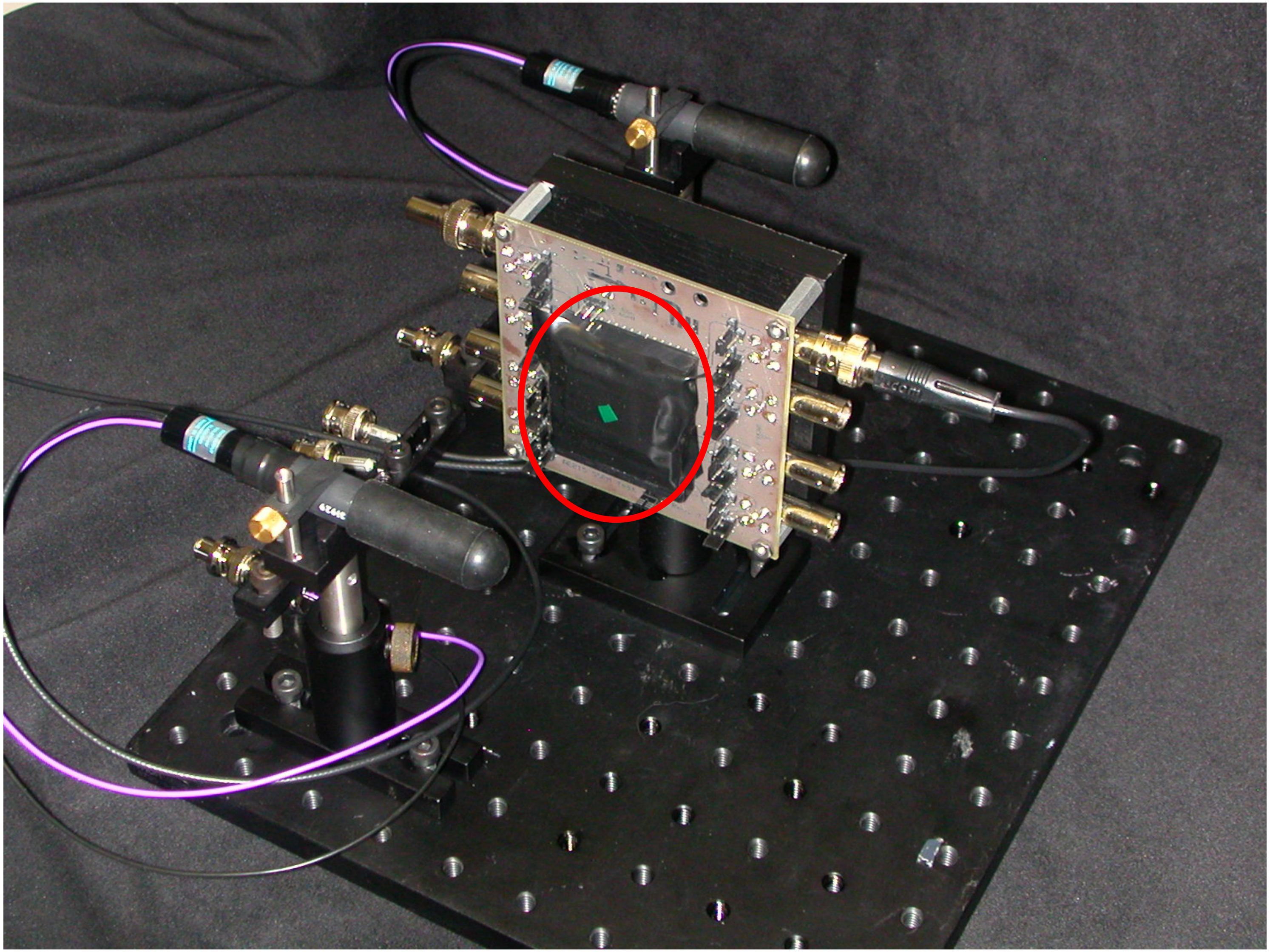


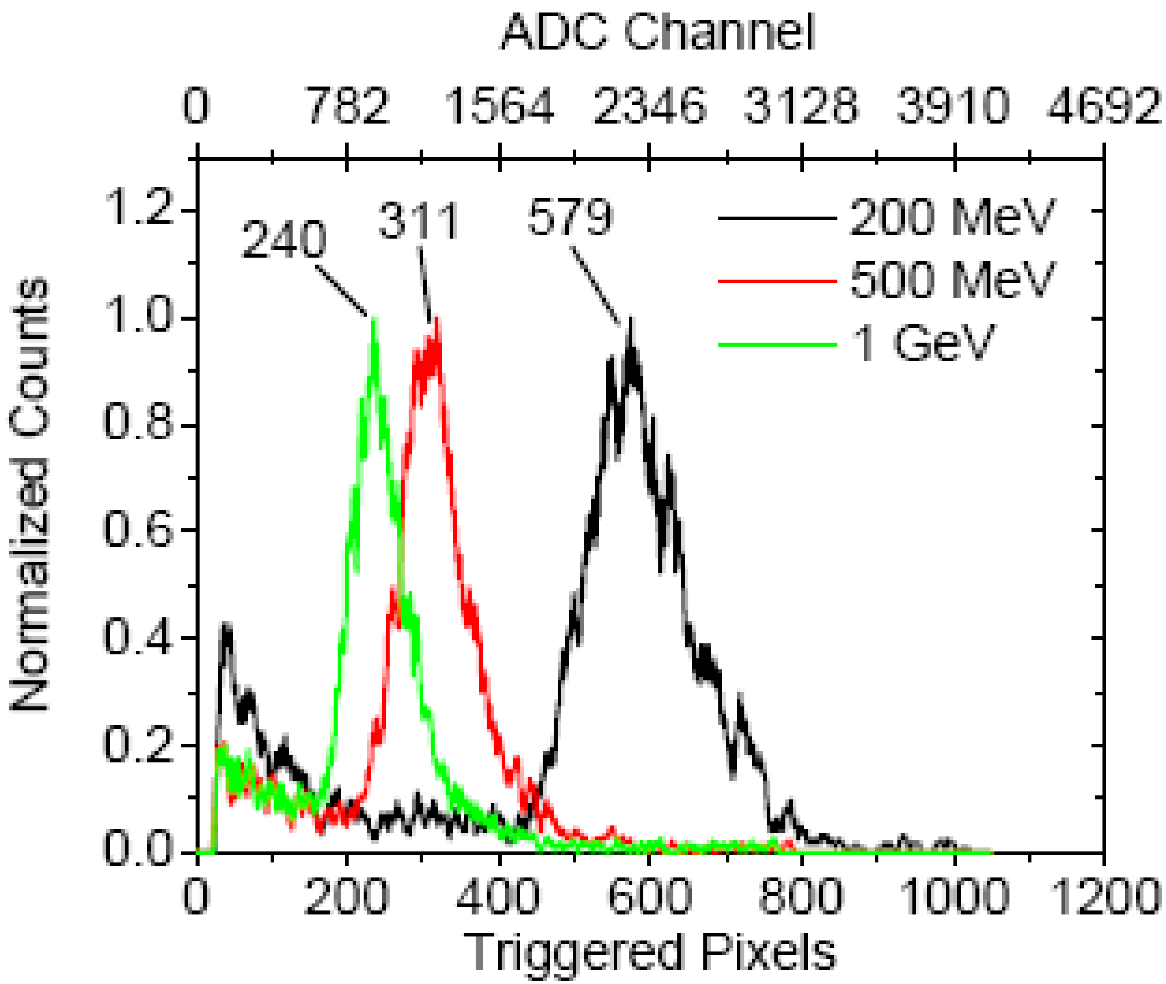
Figure 3: Picture of the new SSPM (AE217). The new design consists of a uniform distribution of pixels over the entire 3 mm x 3 mm silicon die. The fill factor for the device is 61%, and the number of pixels is 2024.

Pixel Size: 50 microns x 50 microns

NSRL Setup



RMD Data from NSRL



2. Physical Model of Light Response

A recent physical model for light response of plastic scintillator is the BTV (Birks-Tarle-Voltz) core-halo model [2-5]:

$$\frac{dL}{dx} = \frac{A(1-F_h)dE/dx}{1+B_s(1-F_h)dE/dx} + AF_h\frac{dE}{dx}$$

where A is the gain factor of the detector;

B_s (g/MeV.cm^2), the parameter of the quenching;

F_h, the ratio of energy deposited in halo;

dE/dx is calculated by Bethe-Bloch formula.

The above parameters were obtained by UC (University of Chicago) researchers [6] in the 1980s based on the results from high energy cosmic ray experiments. In the formula, the first term represents the core and the second term represents the halo.

Table 1 is the collect of the parameters. In the table values of A are derived through the normalization to the experimental results for protons obtained by RMD.

Table 1: Parameters determined for BTV formula

Energy Bin	F_h	B_s	A
(GeV/n)		($g/MeV.cm^2$)	
< 1.0	0.3644 ± 0.0029	0.0085 ± 0.0002	0.0598 ± 0.0003
1.0 - 1.2	0.3683 ± 0.0026	0.0085 ± 0.0002	0.0609 ± 0.0003
1.2 - 1.5	0.3792 ± 0.0027	0.0080 ± 0.0002	0.0597 ± 0.0003
1.5 - 2.0	0.3908 ± 0.0033	0.0080 ± 0.0003	0.0601 ± 0.0004
2.0 - 3.1	0.4018 ± 0.0036	0.0073 ± 0.0003	0.0595 ± 0.0004
> 3.1	0.4073 ± 0.0044	0.0059 ± 0.0002	0.0600 ± 0.0004

Figure 1 shows that the light response of plastic scintillator to the relativistic GCR if the response to protons is normalized to the values for BC - 430 obtained by RMD from data taken at NSRL.

The figure shows: light is contributed by the core (saturated) and halo (non-saturated linear response); light contribution of halo increases as the charges of the nuclei increases and for $Z \geq 8$ the light contribution from halo is higher than that from the core and the bigger the charge, the greater the halo contribution.

At high charges the light contribution from halo is dominated, for Iron the contribution is ~ 16% and 84% of total for core and halo respectively.

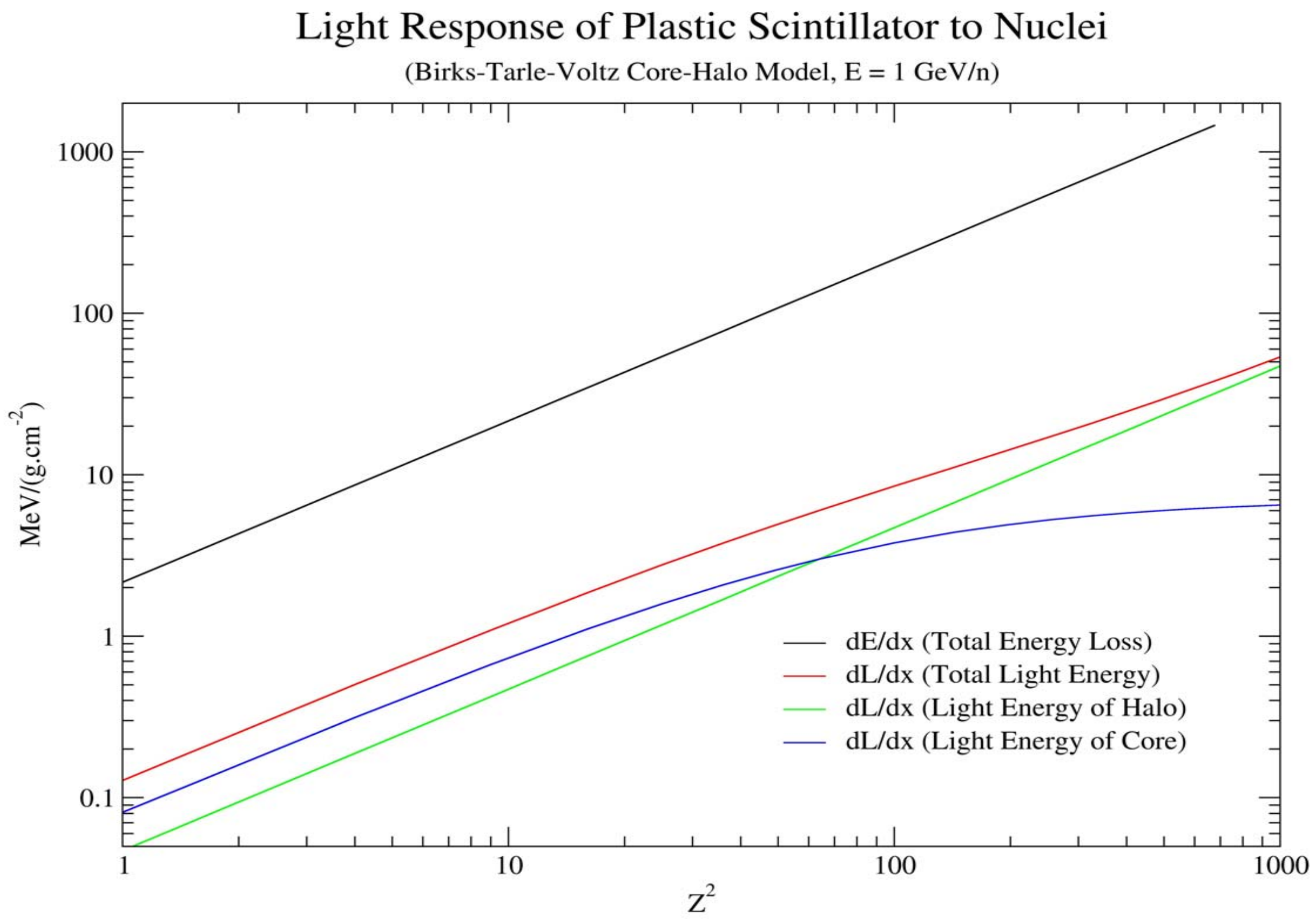


Figure 1: Light response of plastic scintillator to relativistic nuclei.

3. Data Analysis Method for TEPSC

1) dL/dx Calculation

dL/dx can be calculated on the pulse height measured with SSPM and the energy loss – pulse height calibration.

2) Calculation of Total Energy Loss dE/dx Using dL/dx

A key work for data analysis for the TEPSC is to find out the formula to convert the light energy measured by TEPSC to the total energy loss.

Figure 2 shows the relationship between dL/dx and dE/dx for relativistic GCR. In the Figure, the lower left part of the curve is for protons with low energy loss and the main part of the curve is for particles with higher charges (Z≥2) and higher energy loss. The conversion formula can be expressed as

$$dE/dx = a_0 + a_1 dL/dx + a_2(dL/dx)^2 + a_3(dL/dx)^3 + a_4(dL/dx)^4$$

The coefficients in the formula are collected in Table 2.

Table 2: Best Data Fit to Convert dL/dx to dE/dx

dL/dx (MeV/g.cm^{-2})	a_0	a_1	a_2	a_3	a_4
< 0.36	0.15678	14.597	7.4017		
≥ 0.36	0.42927	16.256	0.7482	-1.1213×10^{-2}	6.5359×10^{-5}

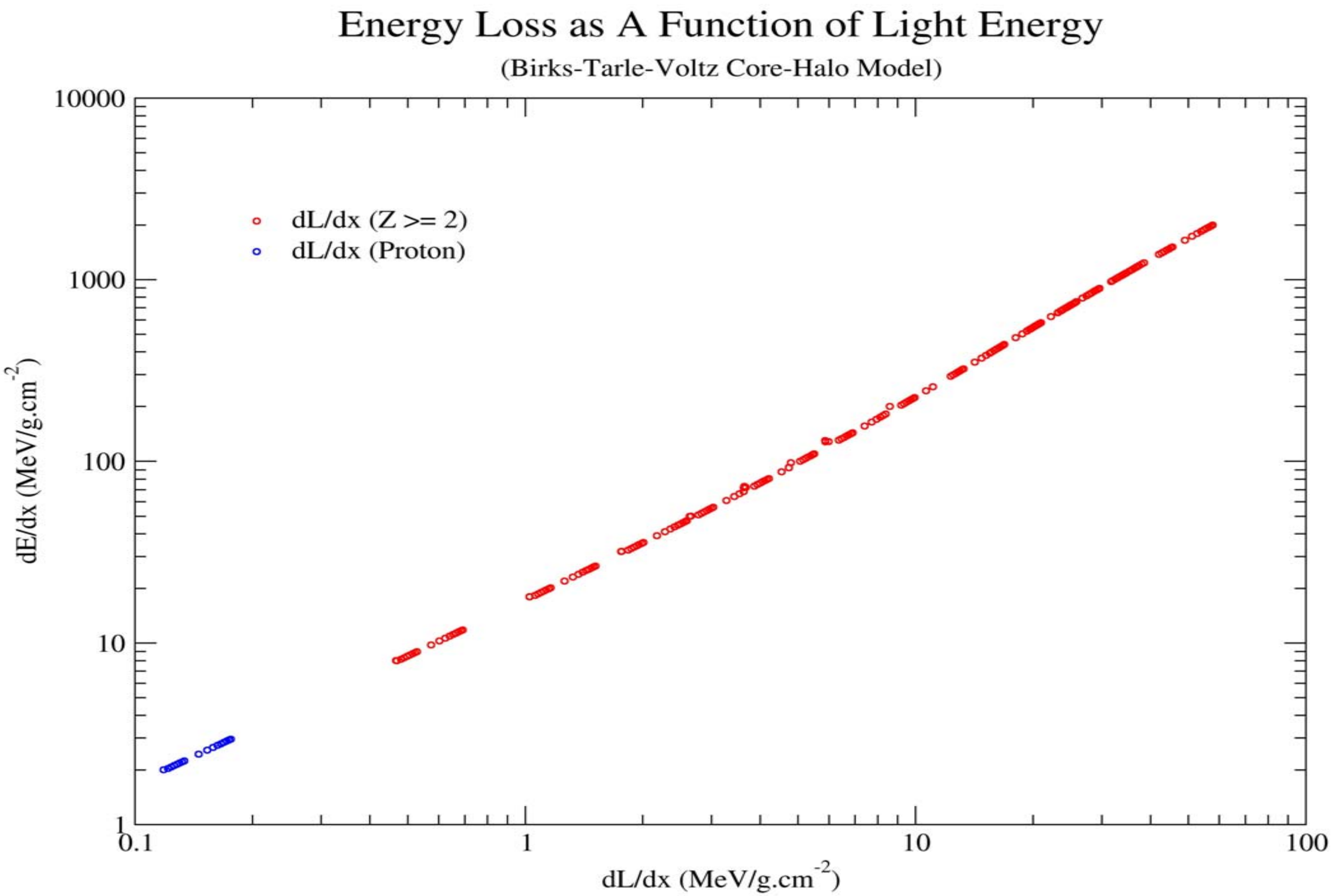


Figure 2: Relationship between dL/dx and dE/dx.

Table 3 collects some typical data calculated for dL/dx and dE/dx. Data indicate that TEPSC has good multiplication power (dE/dx)/(dL/dx), i.e., **TEPSC measures small dL/dx to realize big dE/dx.**

Table 3: Calculated data for dL/dx and dE/dx

dL/dx	dE/dx	(dE/dx)/(dL/dx)
(MeV/g.cm^{-2})	(MeV/g.cm^{-2})	
0.15	2.5129	16.753
0.25	4.2684	17.074
1.0	17.442	17.442
10.0	227.25	22.725
50.0	1690.6	33.812

LET spectrum

The LET spectrum (differential and integral fluence, dose, dose equivalent and quality factor) can be obtained with the similar formulae used for the LET spectrum method of CR-39 detectors.

Conclusions

TPESC using TEPS and SSPM is a possible next generation active personal dosimeter; the light response of PS to relativistic GCR was obtained using the BTV core-halo model. A key formula to convert the measured light energy dL/dx to the total energy loss dE/dx was found by this work.

References

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