A new TEPC for monitoring the space radiation environment

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INTRODUCTION

A new tissue-equivalent proportional counter to assess the radiation quality at the International Space Station was designed and constructed at the Legnaro laboratories of INFN, in the framework of the ESA project EUCPAD. The detector geometry is spherical, to guarantee an isotropic response, and the cathode is segmented in several rings which are properly biased to produce an almost uniform electric field along the anode wire. The detector has been delivered to ESA and successfully passed the tests in standard exposure facilities for photons, neutrons and heavy ions. A similar TEPC, based on the same design, is still at LNL and was used last year to develop a calibration procedure based on the use of an external gamma-ray source.

THE DETECTOR

The peculiarity of this TEPC, having an internal diameter of 50 mm, is the segmented cathode, which is made of 9 rings separated by 0.5 mm thick Rexolite spacers (figure 1). The 9 rings are biased at 5 different voltages to achieve parallel-to-anode equipotential lines, like in a cylindrical detector, for good energy resolution.

The cathode, 3 mm thick, is made of a tissue-equivalent plastic (A-150). Two Rexolite® half-sphere insulator-shells of 3 mm thickness keep the cathode segments in place without glue need. The anode is a 100 μm gold-plated tungsten wire. The detector is sealed and enclosed in a stainless steel vacuum housing of 0.375 mm thickness. The electronic front-end and the divider, kept at atmospheric pressure, are just below the stainless steel vacuum housing. The whole system is enclosed in an aluminium housing of 0.35 mm thickness that shields from the electromagnetic environmental noise. A block design of the TEPC and its housing is given in figure 2.

All the TEPC components, included the anode wire, are easily removable for maintenance or substitution.

METHODS AND RESULTS

The calibration procedure based on the electron-edge technique has been described in detail by Conte et al.¹, and applied for the calibration of cylindrical TEPCs. As the track length distribution of a cylindrical counter is a bit...
different from that of a sphere, significant (more than 1%) differences could be expected, in particular in the position of the electron edge. The experimental study was therefore repeated for the spherical TEPC. The detector was filled with the propane-based tissue-equivalent gas mixture. The mass per area of the cavity diameter $D \rho$ was varied between 0.05 mg cm$^{-2}$ and 0.3 mg cm$^{-2}$ by changing the gas density. The microdosimetric spectrum of a $^{137}$Cs gamma-ray source was measured at each gas density.

The first step was to determine a marker point in the electron edge region of the measured distribution of pulse-height $h$. By fitting this region with a Fermi-like function, the intercept of the tangent through the inflexion point with the $h$-axis, $h_{TC}^{(e)}$, can be determined with high precision.

Figure 3 shows, as an example, a measured $^{137}$Cs-gamma spectrum and the fitted Fermi-like function at the electron edge region.

![Fig. 3: $^{137}$Cs pulse-height spectrum measured at site size $D = 1 \mu$m. The grey area indicates the electron-edge region. The thick line represents the Fermi-like function fitted to the measured data.](image)

Afterwards, a precise value of lineal energy $y_{e\text{-edge}}$ must be assigned to this marker. The values of $y_{e\text{-edge}}$ were determined by calibrating the $^{137}$Cs microdosimetric spectra with the proton edge, at each simulated site size. To have a clear and sharp p-edge, the microdosimetric spectrum of 0.58 MeV neutrons from the p(Be,n)-reaction at 3 MeV was measured at the CN Van de Graaff accelerators at LNL. Afterwards, a fit with a Fermi-like function was done in the p-edge region, and the position of the intercept of the tangent through the inflexion point $h_{TC}^{(p)}$ was used for calibration. The lineal energies at the p-edge $y_{p\text{-edge}}$ were calculated by using the energy-range table published by ICRU. In order to transfer the calibrations for protons to photons, the ratio $W_{d}/W_{p} = 0.981$ was applied\(^{(5)}\). Therefore the calibration factor $0.981 y_{p\text{-edge}}/h_{TC}^{(p)}$ was used to calibrate also the gamma spectra at the same site size. More details on the procedure are given in reference (2).

![Experimental results for the measured $y_{e\text{-edge}}$ at the intercept marker, $y_{TC}$, are presented in Figure 4, in dependence of site size $D$.](image)

To give a physical interpretation of the results, Figure 4 shows also the lineal energy $y_{(R)}$ (dashed line) obtained by application of the following formula for the practical range of electrons\(^{(1)}\):

$$\frac{(R)_p}{\mu g/cm^2} = 0.844 \left( \frac{T}{keV} \right)^{0.00059} + 0.129 \left( \frac{T}{keV} \right)^{1.738} + 0.00059 \left( \frac{T}{keV} \right) + 0.0788$$

The calculated data, $y_{(R)}$, are in an almost perfect agreement with the scaled data within the uncertainties.

From fitting experimental data of Figure 4 with a simple power function, the dependence of $y_{e\text{-edge}}$ on $D$ can be described by the following equation:

$$y_{e\text{-edge}} = 13.9 \left( \frac{D}{\mu m} \right)^{-0.42}$$

The procedure allows the calibration of TEPCs with an overall uncertainty comparable to that of the p-edge calibration.

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