

空间应用像素 CdZnTe 探测器的质子诱导辐射损伤研究

摘要

高性能 3 维位置灵敏的像素 CZT 探测器在康普顿成像望远镜中具有很大应用前景。我们提出在 MeV 天体物理光谱仪 (MASS) 中使用像素 CZT 探测器, 这是一个大面积的康普顿望远镜。然而, 空间中高能质子会导致像素 CZT 探测器的辐射损伤, 导致探测器性能逐渐下降。利用非电离能量损失 (NIEL) 方法, 提出了一种定量评估空间探测器辐射损伤的方法。为了验证该方法, 本研究用 100 MeV 质子辐照了两个 $2 \times 2 \times 1 \text{ cm}^3$ 像素 CZT 探测器两种不同的偏压条件下。辐照累计通量范围为 $3 \times 10^7 \text{ p+}/\text{cm}^2$ 到 $3 \times 10^9 \text{ p+}/\text{cm}^2$ 。当质子累计通量为 $3 \times 10^9 \text{ p+}/\text{cm}^2$ 时, 探测器的能量分辨率在 511keV (FWHM/E) 时显著下降至 3.8%。最后, 本研究为其在空间的应用提供了工程考虑。

关键词

辐照损伤, 像素 CZT, 能量分辨率, 空间伽马探测

Abstract

High-performance pixelated CZT detectors that achieve 3D position sensitivity are promising candidates for use in Compton imaging telescopes. We proposed to use pixelated CZT detectors in the MeV Astrophysical Spectroscopic Surveyor(MASS), which is a large area Compton telescope. Nevertheless, the presence of high-energy protons in space can lead to radiation damage in pixelated CZT detectors, causing their performance to degrade gradually. Using non-ionizing energy loss (NIEL), this study develops a method that quantitatively evaluates the radiation damage of detectors in space. To verify the method, this study irradiated two $2 \times 2 \times 1 \text{ cm}^3$ pixelated CZT detectors with 100 MeV protons at fluences ranging from $3 \times 10^7 \text{ p+}/\text{cm}^2$ to $3 \times 10^9 \text{ p+}/\text{cm}^2$ under two bias sets. When the proton fluence reaches $3 \times 10^9 \text{ p+}/\text{cm}^2$, the energy resolution of the detectors significantly deteriorates to 3.8% at 511 keV (FWHM/E), even after post-correction. Finally, this study provides engineering considerations for their application in space.

Keywords

Radiation damage, pixelated CZT, energy resolution, space gamma detection

Authors: 常, 昊 (清华大学); Dr 郑, 煦韬; 李, 玉兰 (Tsinghua university); 曾, 鸣

Presenter: 常, 昊 (清华大学)

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