Radiation Hardness of 4H-SiC Detectors for the CEPC Fast Luminosity monitor detector

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Motivation

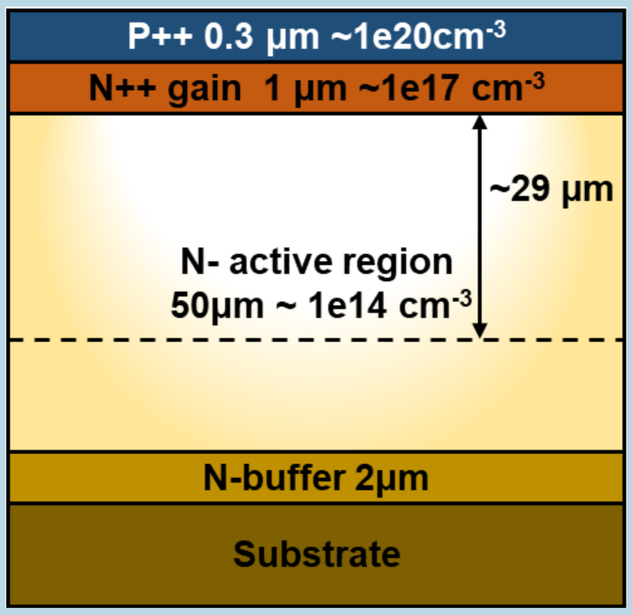
Silicon carbide (SiC) is an ideal material for radiation monitoring in harsh environments due to its excellent properties, including low dark current, high breakdown voltage, high thermal conductivity, and strong radiation hardness. To systematically evaluate the performance of SiC-based detectors under realistic high-energy physics conditions, this study conducted irradiation experiments on two typical SiC detector structures:

- SiC Low-Gain Avalanche Detectors (LGADs) were irradiated with 80 MeV protons
- SiC PIN diodes were irradiated with 160 keV X-rays

By comparing the electrical characteristics , charge collection efficiency (CCE), and degradation mechanisms before and after irradiation, this work aims to validate the stability and durability of SiC detectors in high-radiation environments. The results will assess whether SiC-based detectors meet the stringent radiation hardness requirements for the Fast Luminosity Detector at the CEPC (Circular Electron-Positron Collider), providing critical experimental support for future detector selection in high-luminosity collider experiments.

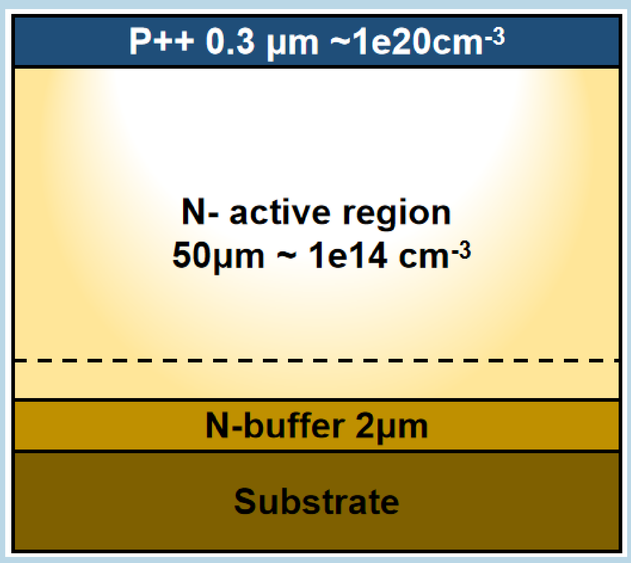
Device Profile

SiC LGAD



- **Irradiation conditions**: 80 MeV proton irradiation up to 7.0×10^{13} p/cm^2 in China Spallation Neutron Source (CSNS, Dongguan).

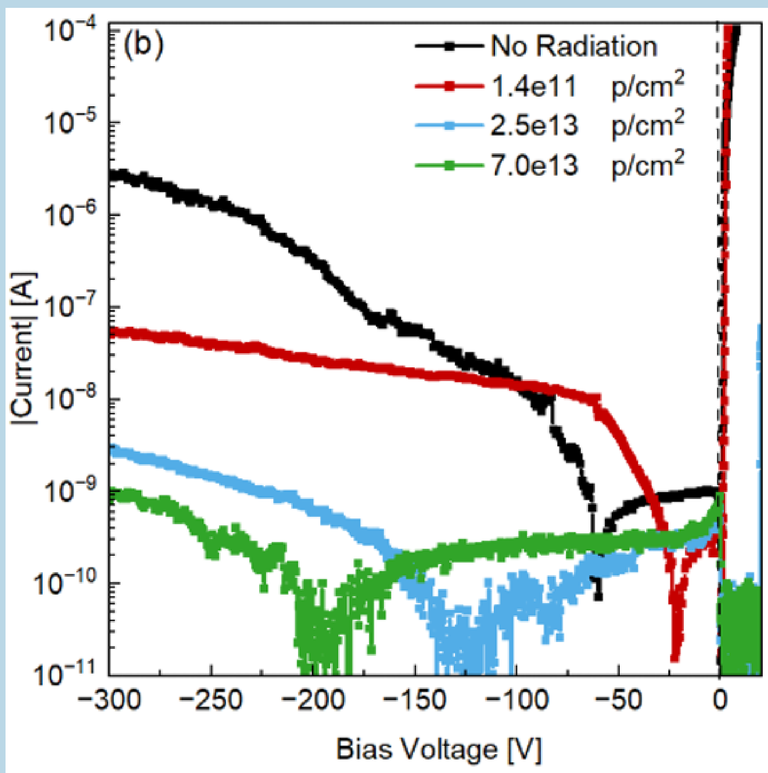
SiC PIN



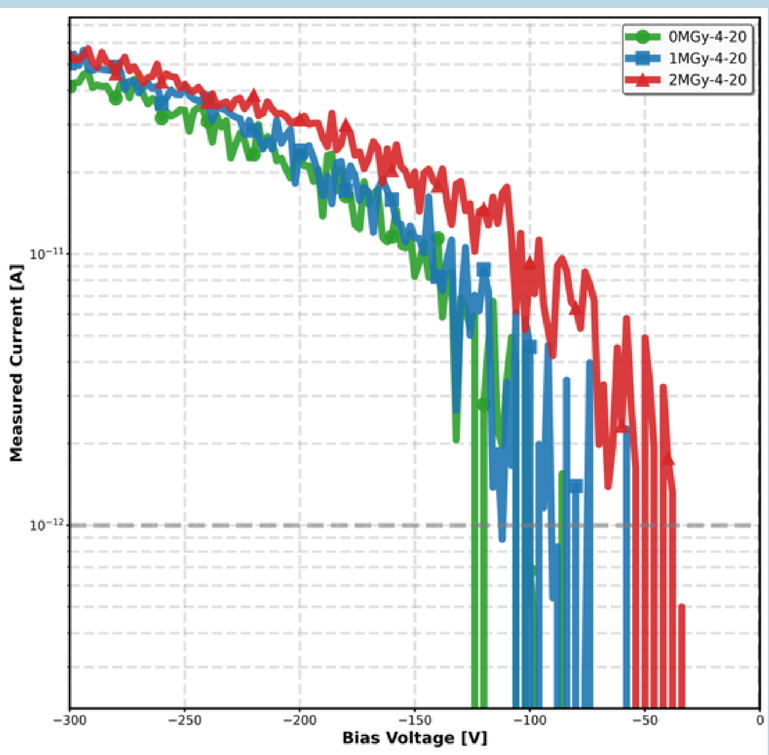
- **Irradiation conditions**: 160 keV X-rays up to 3.0×10^{21} p/cm^2 by Multi-Rad 160.

Test results for SiC LGAD and PIN

- **Leakage current and vs. bias voltage curve of SiC LGAD and PIN with radiation**:

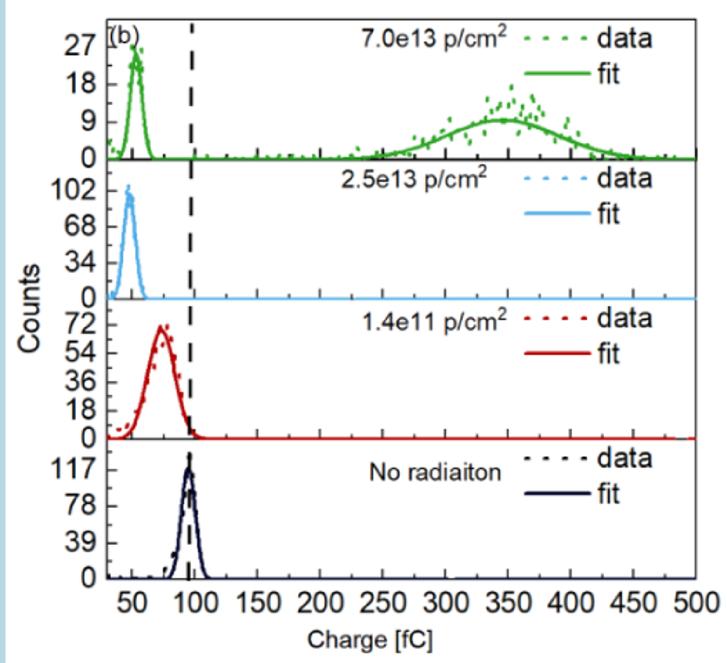


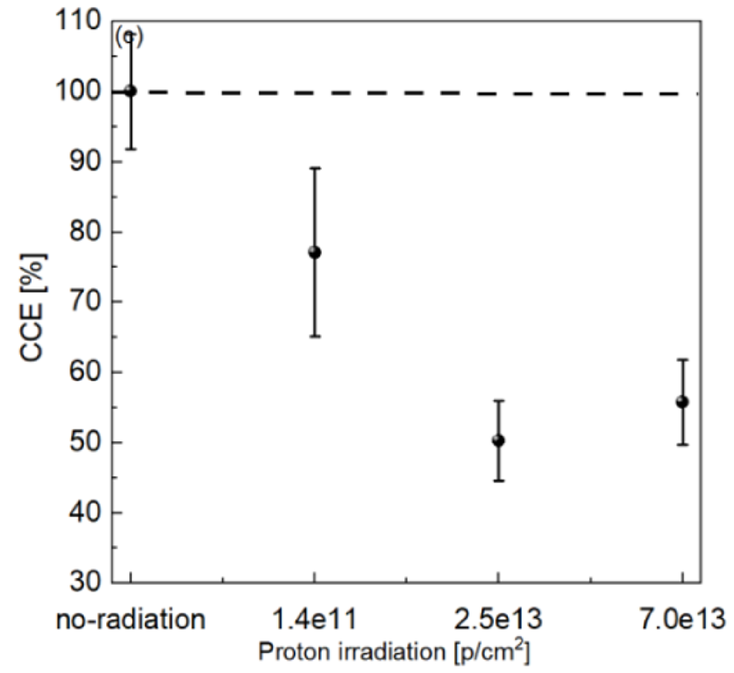
- IV curves of SiC LGAD under different proton irradiation fluences, showing a decrease in current with increasing fluence



- IV curves of SiC PIN under different X-ray irradiation doses, showing almost no change in current even with increasing dose

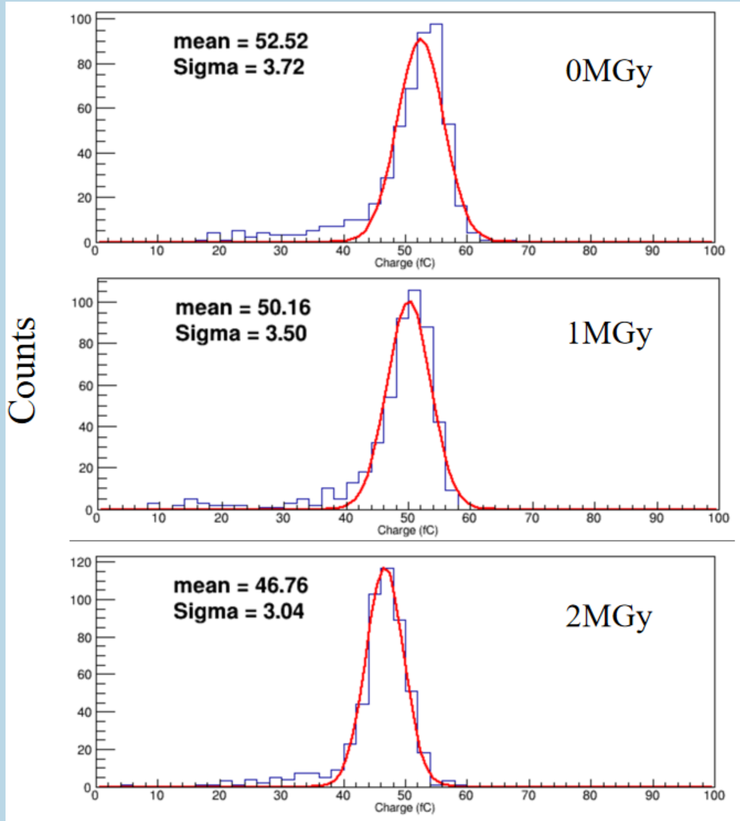
- **The LGAD charge collect efficiency vs. proton radiation fluence**:

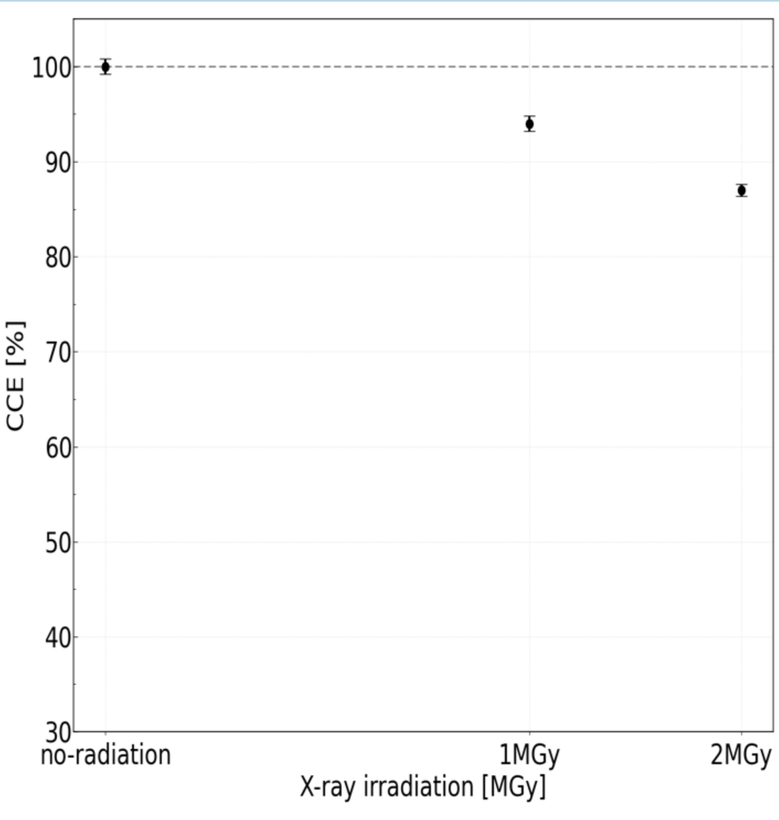




Under 7e13 proton fluence, the charge collection efficiency of SiC LGAD has decreased to 50%

- **The PIN charge collect efficiency vs. X-ray radiation dose**:





SiC PIN diodes maintain over 85% charge collection efficiency even after 2 MGy X-ray irradiation

References

Zhao, S. et al. The study of 4H-SiC LGAD after proton radiation. *arXiv:2507.12238* (2025).