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Neutron Radiation Damage in HPGe Detectors

The effect of fast neutrons on the performance of germanium detectors is described in detail in the literature (see Ref. 1).

A summary of the results of greatest practical interest follows:

(1) HPGe coaxial and planar detectors show energy resolution degradation when bombarded with fast neutrons. The approximate threshold fluences are:

2×10^8 cm^{-2} for GEM detectors up to 20% in efficiency
1×10^7 cm^{-2} for GEM detectors up to 70% in efficiency
4×10^9 cm^{-2} for GMX detectors up to 30% in efficiency
1×10^9 cm^{-2} for GMX detectors up to 70% in efficiency
1×10^9 cm^{-2} for GLP (planar) detectors

(2) Evidence (Ref. 2) suggests that in order to achieve the highest possible resistance to neutron damage, the detector should operate at a temperature as close to 77 K as possible. Detectors in PopTop capsules typically operate at a temperature ~10 K higher than detectors in "streamline" non-PopTop cryostats. We recommend that detectors that may be exposed to significant fast neutron fluences be **ordered in streamline cryostats** that may be equipped with an internal heater and companion hardware (596A Temperature Controller) to allow in-cryostat neutron damage repair at the place of detector use.

(3) Larger detectors start showing energy resolution degradation at lower fluences than smaller detectors.

(4) The increase in resistance to neutron damage of GAMMA-X detectors vs. GEM detectors can be as high as a factor of 20 (Ref. 1). However, this increase depends on a variety of factors including detector size, configuration of electric field internal to the detector, energy spectrum of the neutrons, and probably other variables.

(5) Both GEM and GAMMA-X detectors can be repaired for neutron damage by heating for a period of time at sufficiently high temperatures. However, GAMMA-X detectors are easier to repair (lower temperatures, shorter "annealing" time). Typical annealing temperatures and duration of the annealing cycle for 30% relative efficiency detectors with severe damage are given below:

Detector	Temperature	Time
GEM	120˚C	168 hours
GMX	100˚C	24 hours

(6) Moreover, when GEM detectors are annealed, there is a significant loss in relative efficiency because of inward diffusion from the lithium outer contact. Such loss is negligible for GAMMA-X detectors because the lithium diffusion is at the inner contact where an increase of the lithium diffusion depth has little effect on the detector's active volume.

(7) There is no known limit to the number of times that a neutron-damaged detector can be annealed if proper precautions are taken. There is no evidence of a radiation hardening effect.

(8) Slightly neutron-damaged GAMMA-X detectors show some improvement in energy resolution when cycled to room temperature. However, severely neutron-damaged GAMMA-X detectors show a catastrophic deterioration of energy resolution when cycled to room temperature. As a general rule, it is best to maintain neutron-damaged detectors at LN_2 temperature until they are annealed.

ORTEC routinely installs a heating resistor in GMX detectors which are to be used in fast neutron fields. The annealing temperature is controlled with a 596A Temperature Controller.

References

1. T.W. Raudorf, R.C. Trammell, S. Wagner, and R.H. Pehl, "Performance of Reverse Electrode HPGe Coaxial Detector After Light Damage by Fast Neutrons," *IEEE Trans. on Nucl. Sci.* **NS**-31, No. 1 (1984) 253.
2. R.H. Pehl, Private Communication, 1990.

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