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Authors
Pehl, Richard H.
Landis, Donald A.
Goulding, Fred S.
et al.

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Ernest O. Lawrence Radiation Laboratory

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Since the use of Li-drifted silicon counters for the detection of charged particles having a range greater than ≈3 mm is severely hampered by the inability to collect all the charge within a reasonable period of time, it is of considerable interest to evaluate the ability of Li-drifted germanium counters for detecting long-range charged particles. Recent developments in producing thin-window Li-drifted germanium counters[1)] have enabled us to investigate the response of such counters to 30- and 40-MeV protons. Although an accurate measurement of the effective window thickness has not been made, the window is certainly less than 5μ, and is probably about 0.5μ.

The depletion region of the detector, pictured in fig. 1, is about 1 × 1 × 0.5 cm. This small size was chosen to reduce the gamma-ray background. To further reduce the background the beam was stopped about 4.5 m behind the target, and the counter was shielded by lead from the Faraday cup and beam pipe. The Berkeley 88-in. variable-energy cyclotron was used for these experiments. After energy analysis, the protons were scattered from either a gold or carbon foil—both of which were about 200 μg/cm^2 thick. All measurements were made at a fixed scattering angle of 19.7°, and with the detector, preceded by a 2.5-by-5-mm collimator, approximately 65 cm from the target. To protect the germanium detector from the relatively dirty scattering-chamber vacuum system, a 2.5μ

Havar window separated the counter holder from the system. The counter was operated at 77°K in a vacuum of 10^{-5} mm Hg, in a holder that has been described previously[2].

Resolutions of 41 and 52 keV (FWHM) were obtained when 30- and 40-MeV protons, respectively, were scattered off gold. To determine the contribution from the germanium counter itself one must correct for the energy spread introduced by: (a) the spread of the beam energy, assumed to be 0.08%, and thus 24 and 32 keV for the two energies used; (b) the thin window, calculated[3] to cause a FWHM of 12.3 and 9.5 keV for 30- and 40-MeV protons, respectively; (c) electronic noise, determined by observation of many pulser peaks to be 23 and 26 keV for the system adjusted for 30 and 40 MeV, respectively. (No correction for the angular resolution contribution is necessary because with the geometry used such a correction is less than 1 keV.) After subtracting these contributions the remaining spread is 21 keV for 30-MeV protons and 30 keV for 40-MeV protons.

Knowledge of the Fano factor F and the average energy-per-hole-electron pair ϵ enables one to determine the theoretical limitation of the energy resolution. Figure 2 presents this limitation as a function of the energy deposited in a germanium crystal for different nondetector contributions. This calculation was based on $F = 0.30$ and $\epsilon = 2.98$ eV[4]. For 30 and 40 MeV the theoretical limit is 12.2 and 14.0 keV, respectively. Thus our results are somewhat worse than the theoretical limit. However, the detector used was rather poor—it would not operate at more than 400 V bias, and exhibited a relatively broad satellite peak of slightly lower energy than the main peak. Nevertheless, the use of Li-drifted germanium counters for the detection of long-range charged particles appears very promising.

References

1) F. S. Goulding and B. V. Jarrett, A Method of Making Thin-Window Germanium Detectors, Lawrence Radiation Laboratory Report UCRL-16480, Nov. 1965

2) C. E. Miner, Mountings and Housings for Li-Drifted Si and Ge Detectors, Lawrence Radiation Laboratory Report UCRL-11946, Feb. 1965 (unpublished)

3) B. Rossi, High-Energy Particles (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1952) chap. 2

4) S. O. W. Antman, D. A. Landis, and R. H. Pehl, Measurements of the Fano Factor and the Energy per Hole-Electron Pair in Germanium, Nucl. Instr. Methods (to be published)

Figure Captions

Fig. 1. A thin-window lithium-drifted germanium detector.

Fig. 2. Energy resolution as a function of the energy loss in the detector for different nondetector contributions.

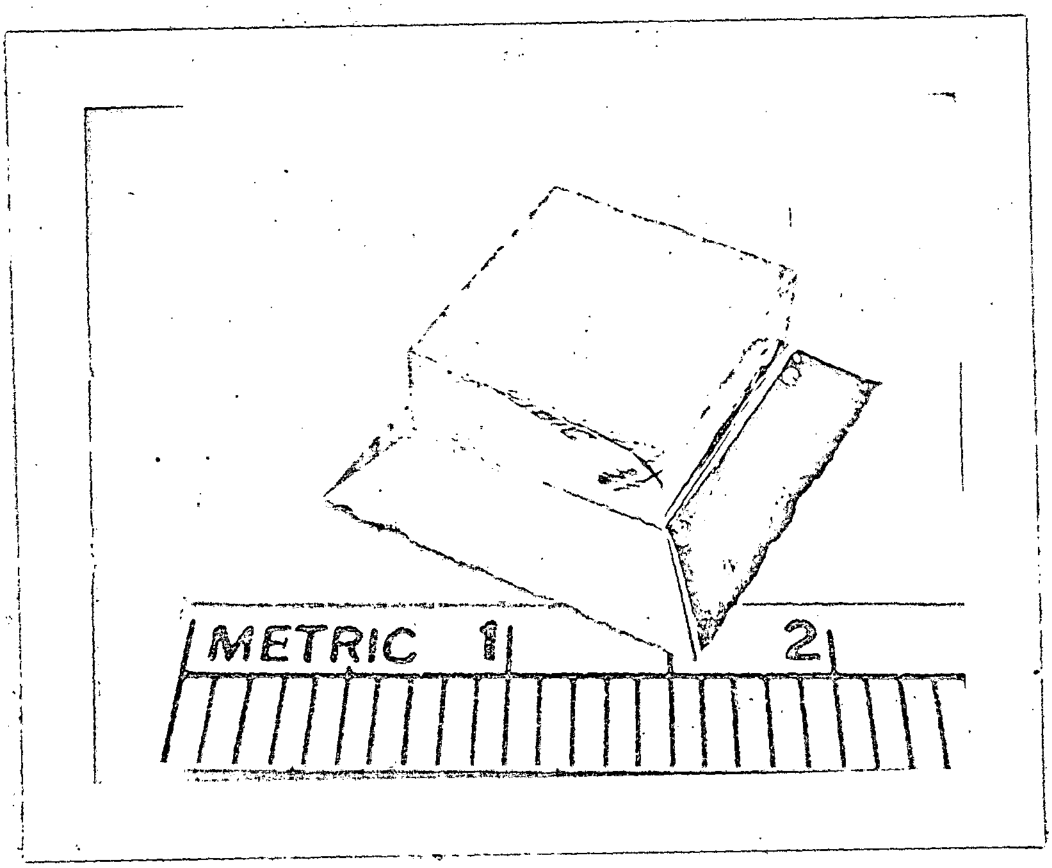

Fig. 1

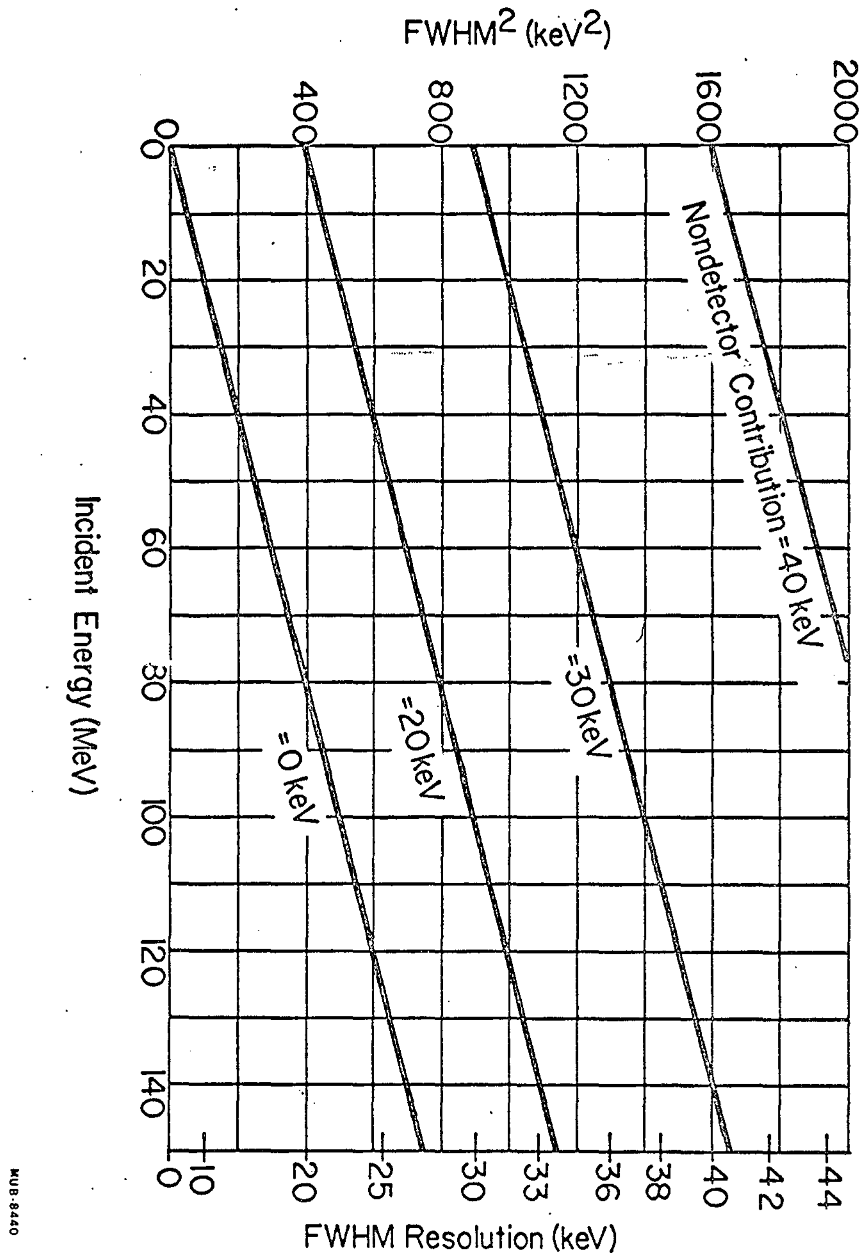
FWHM^2 (keV^2)
0
400
800
1200
1600
2000
Nondetector Contribution = 40 keV
= 30 keV
= 20 keV
= 0 keV
0
20
40
60
80
100
120
140
Incident Energy (MeV)
0
10
20
25
30
33
36
38
40
42
44
FWHM Resolution (keV)
MUB-8440

Fig. 2