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State of the art on epitaxial GaAs detectors

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Motivation

Decrease the dose (more than a factor of 10 compared to scintillator flat panels) in X-ray imaging

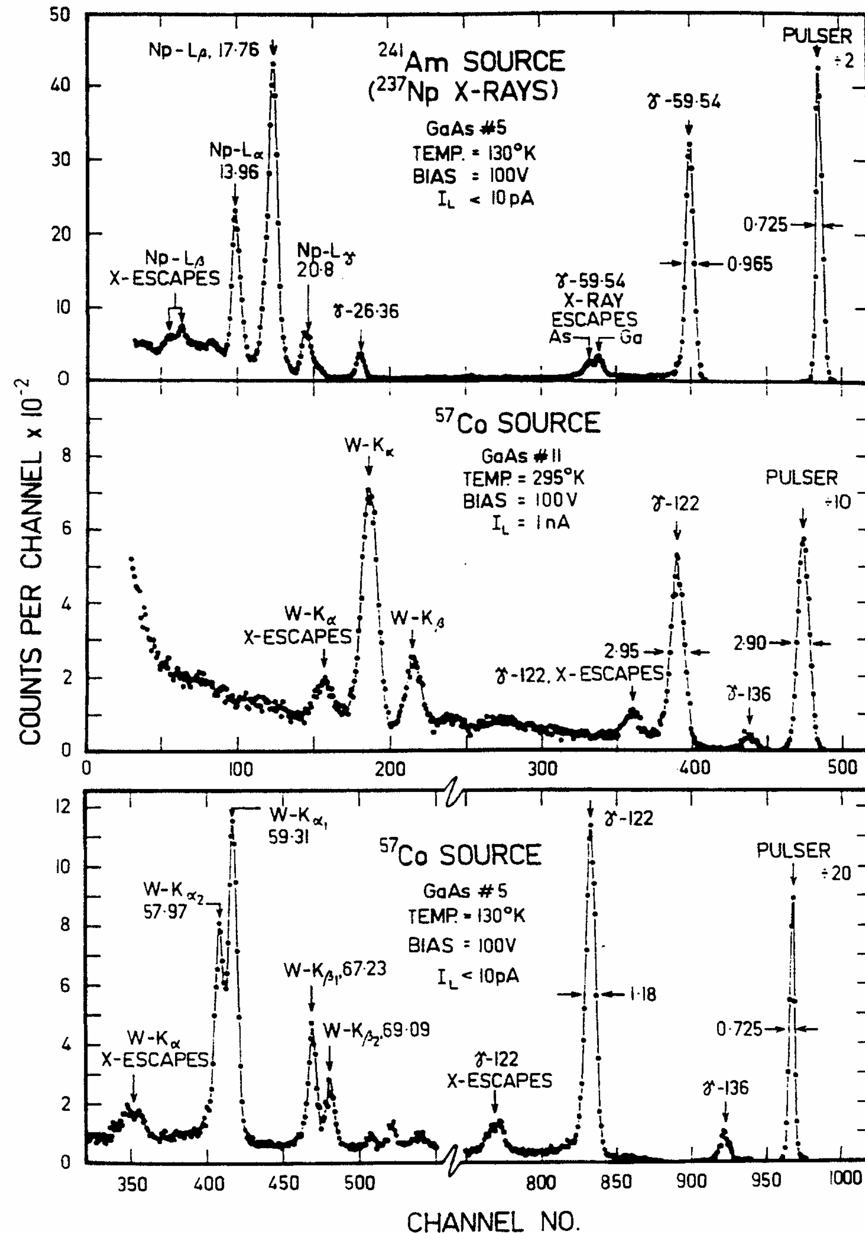
Outline

- Review of X-ray detection with GaAs
- Development of epi-growth of GaAs
- Device processing
- Device electrical characteristics
- Performance of radiation detectors
- Limitations of current devices and ways to overcome

History of GaAs radiation detectors (1)

Early work with LPE GaAs

(by Tavendale group, 1970)

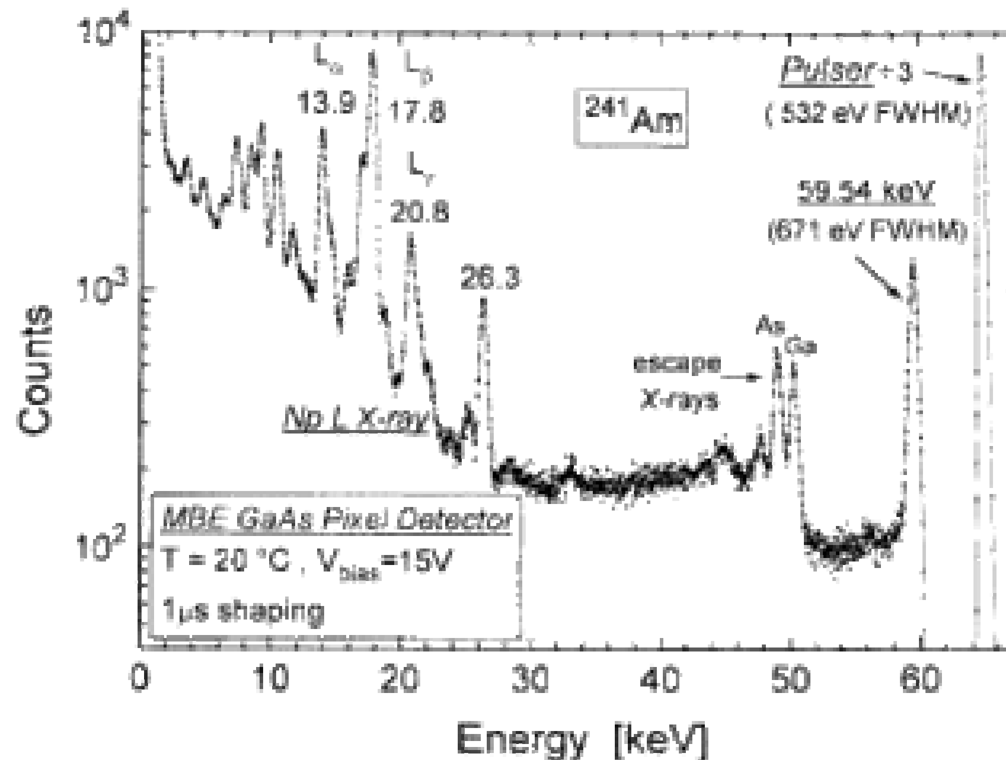


Three typical ^{241}Am and ^{57}Co γ-ray spectra, at 100V bias and 130°K, from 1.5mm diameter, 80μm thick LPE GaAs surface barrier detectors, (carrier concentration ~ 6 x 10^{13} cm^{-3}), fabricated on tin-doped substrates.

History of GaAs radiation detectors (2)

MBE epi-GaAs

(Bertuccio et al., 1996/97)

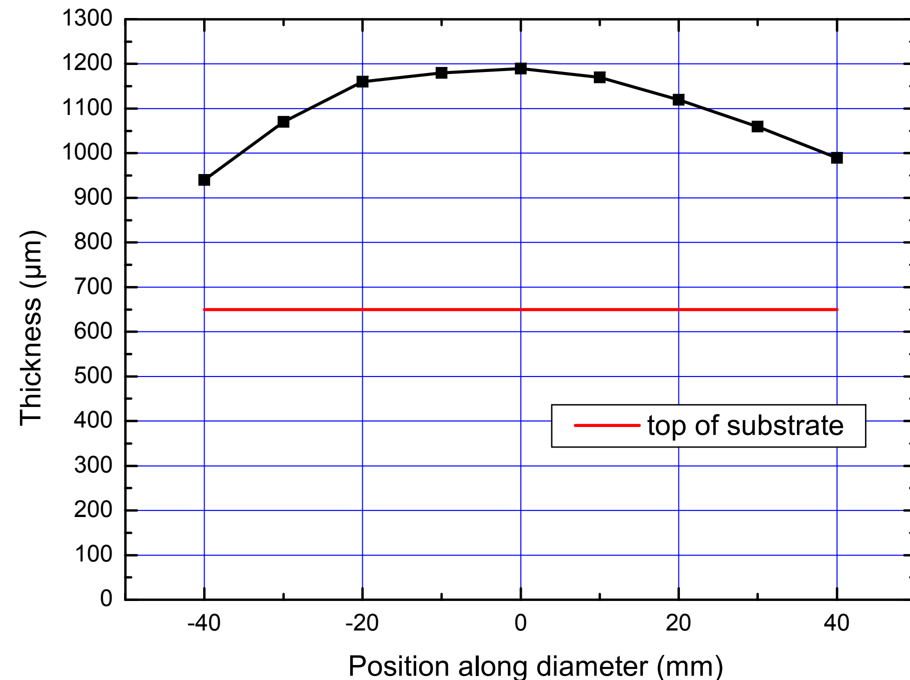


Pulse height spectrum of photons from an ^{241}Am source detected in a 170 x 320μm^2 , 5 micron thick MBE undoped GaAs diode detector at 15V reverse bias

Progress in the growth of epitaxial GaAs

- **One 4 inch, 550 µm layer**

- **Thickness profile of epi-GaAs grown on four inch substrate**



<table>
<tr><td rowspan="2">Source: SI GaAs</td><td>n^+ substrate: n type (<10^{14} cm^{-3})</td></tr>
<tr><td>SI substrate: p type (<10^{14} cm^{-3})</td></tr>
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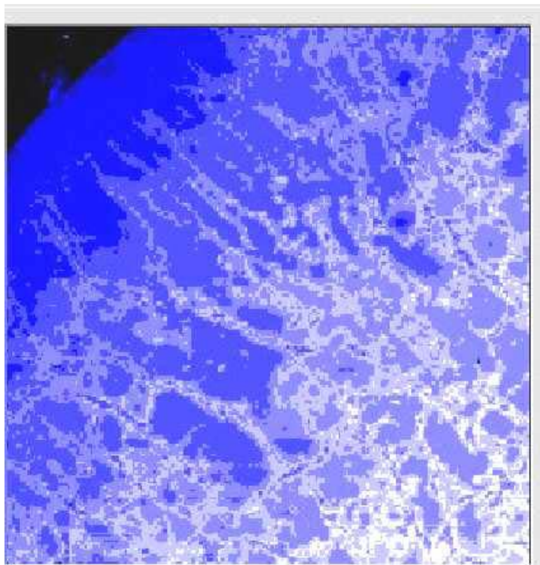
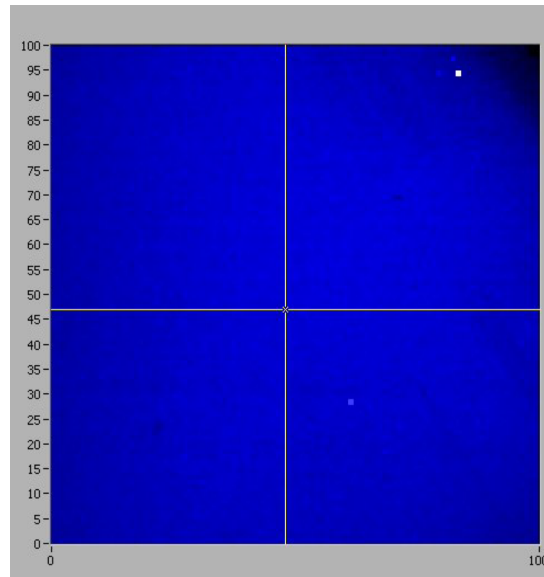
Electronic properties of epitaxial GaAs

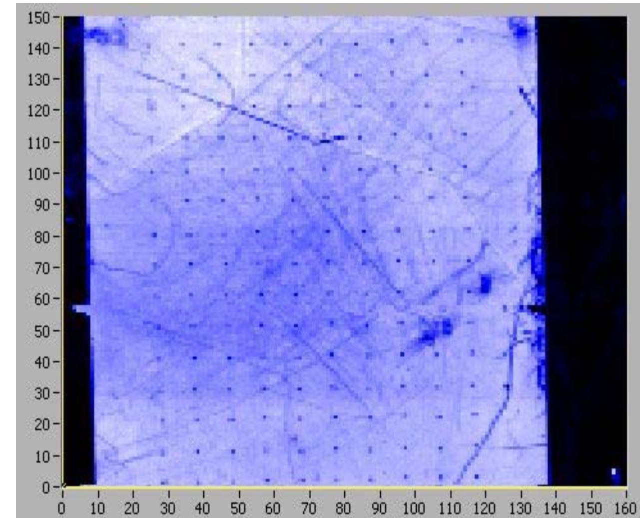
- Photoluminescence mapping



SI GaAs

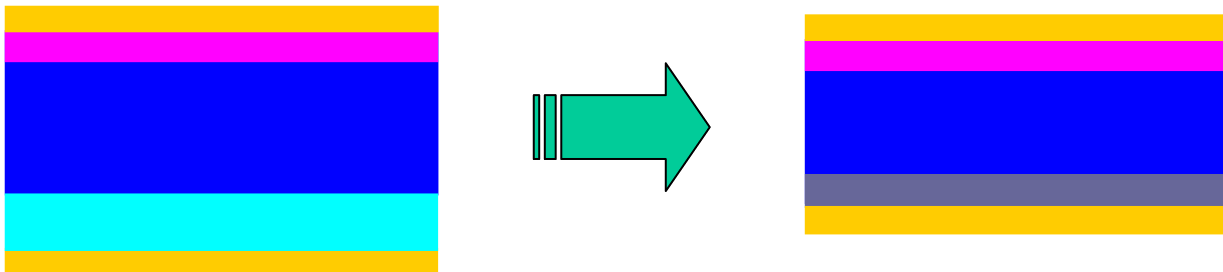


Epitaxial GaAs layer



CdTe

Technique to fabricate detectors



ohmic contact

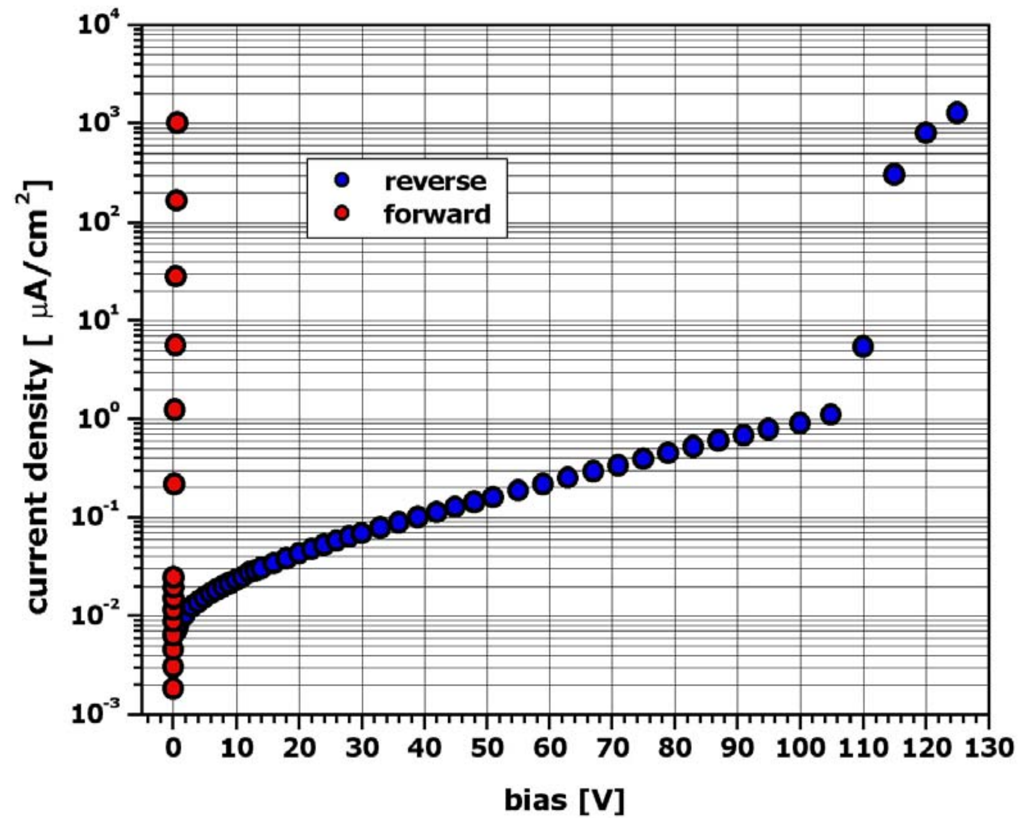
p^+ ion implantation (35 nm)

GaAs epilayer

n^+ substrate (Cz GaAs)

n^+ ion implantation (35 nm)

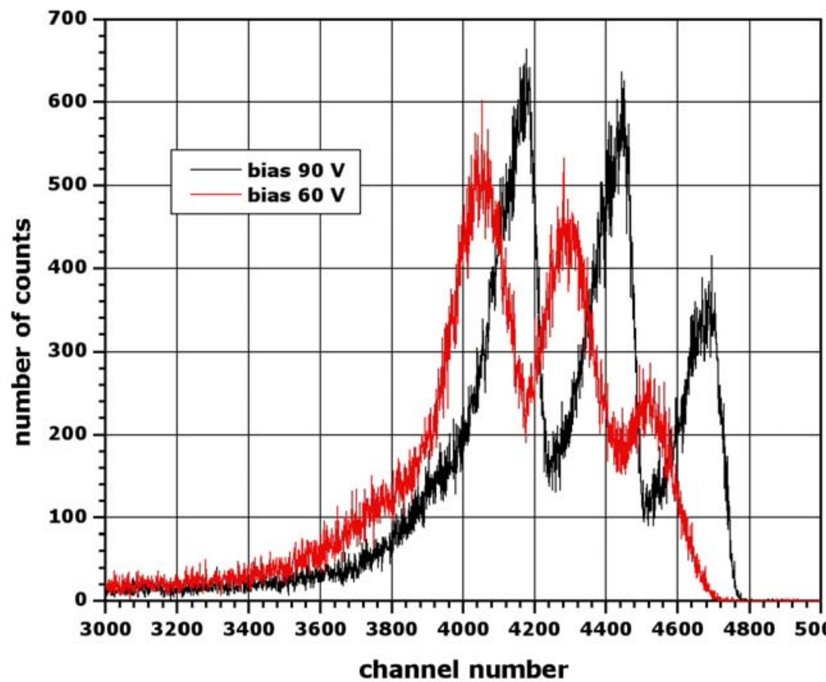
Current-Voltage characteristic of a small pad diode

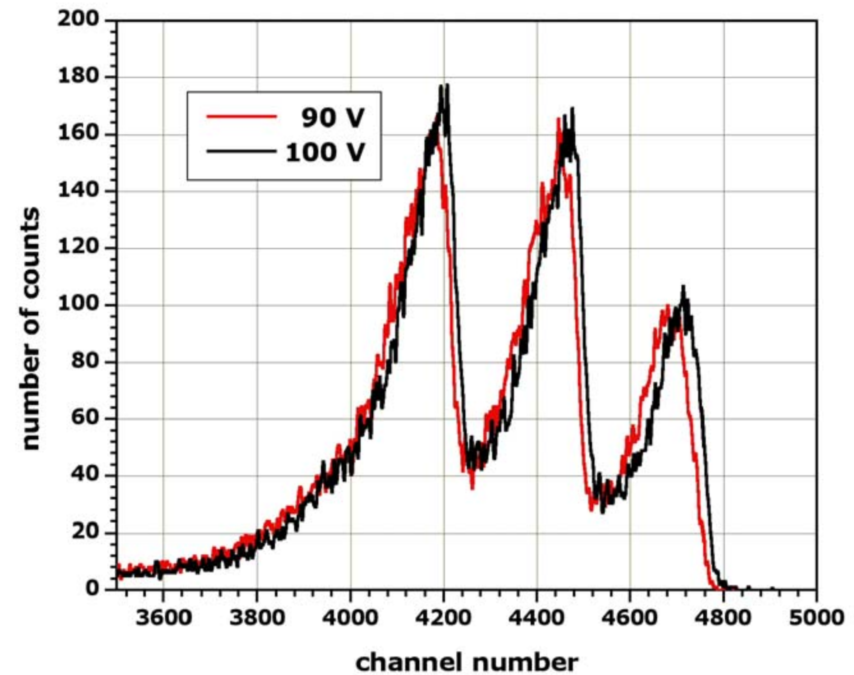


2 nA/mm^2 at 50 V

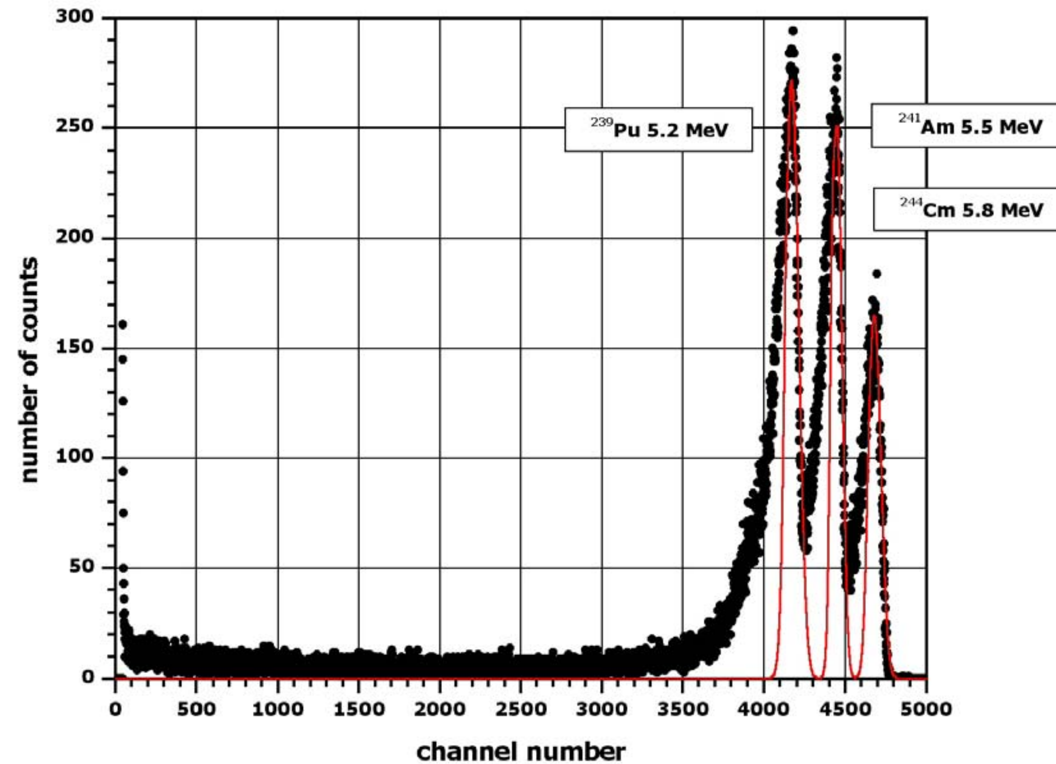
Alpha particle pulse height spectra

- **Combined source ^{241}Am(5.5 MeV), ^{244}Cm (5.8 MeV) and ^{239}Pu (5.2 MeV)**





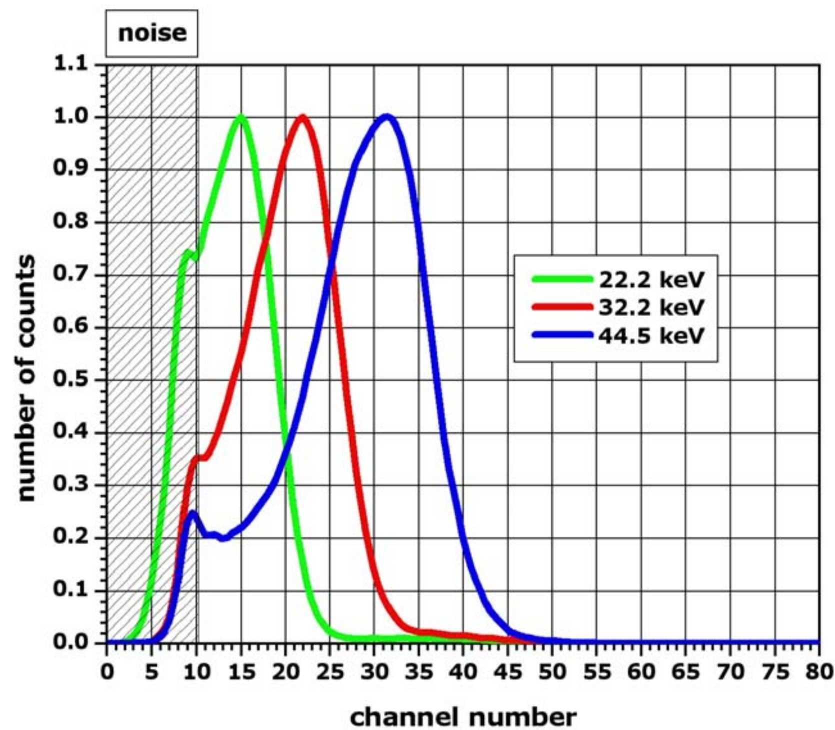
Charge collection efficiency

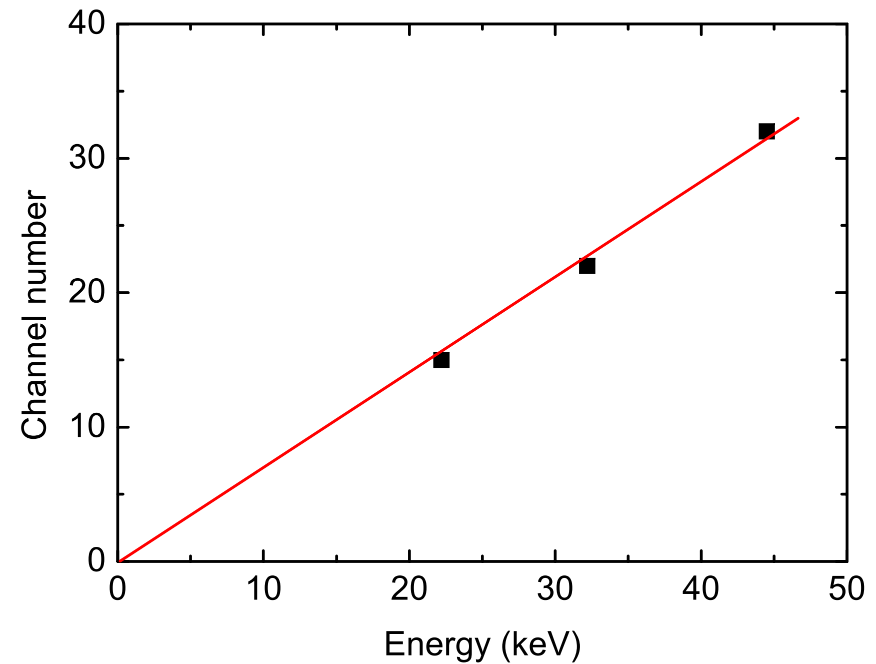


Fitted values at 100 V, giving charge collection efficiency of 85%.

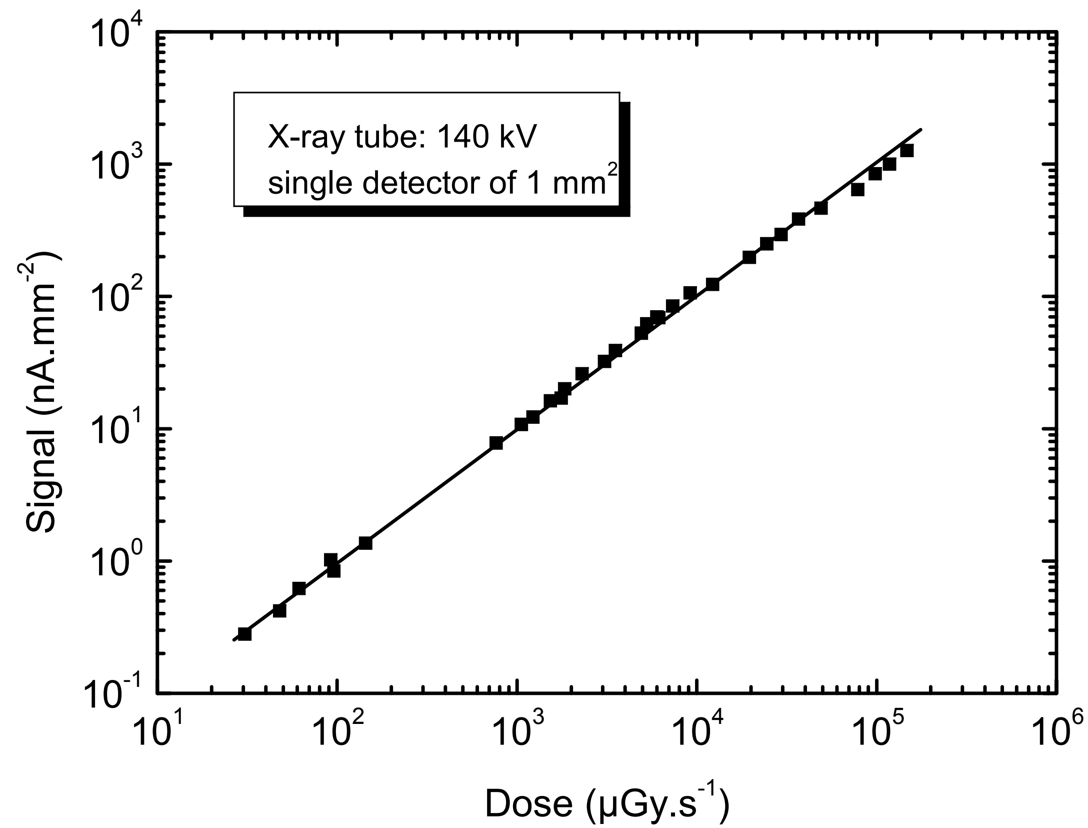
Pulse height spectra of monoenergetic X-rays

- **Characteristic K-series X-rays of Ag, Ba and Nb.**





Photocurrent versus radiation dose



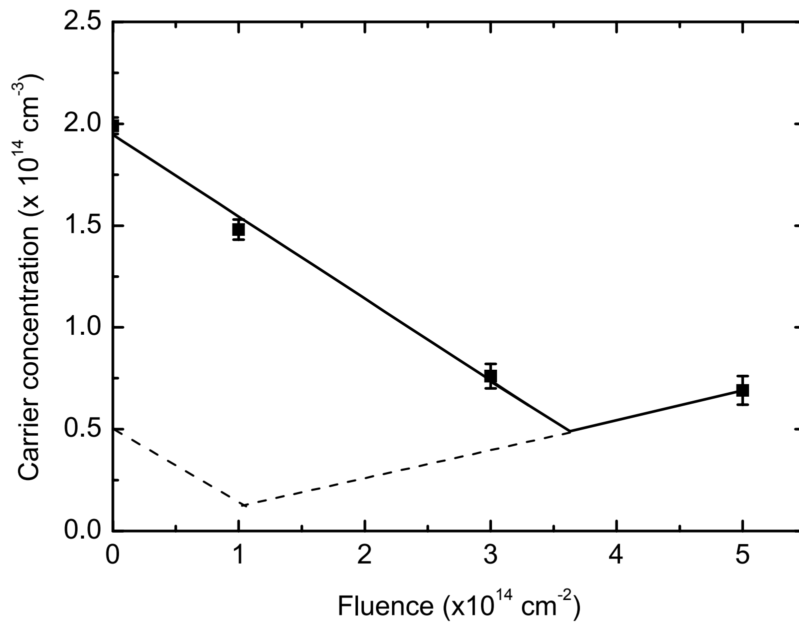
1mm² epitaxial GaAs diode detector

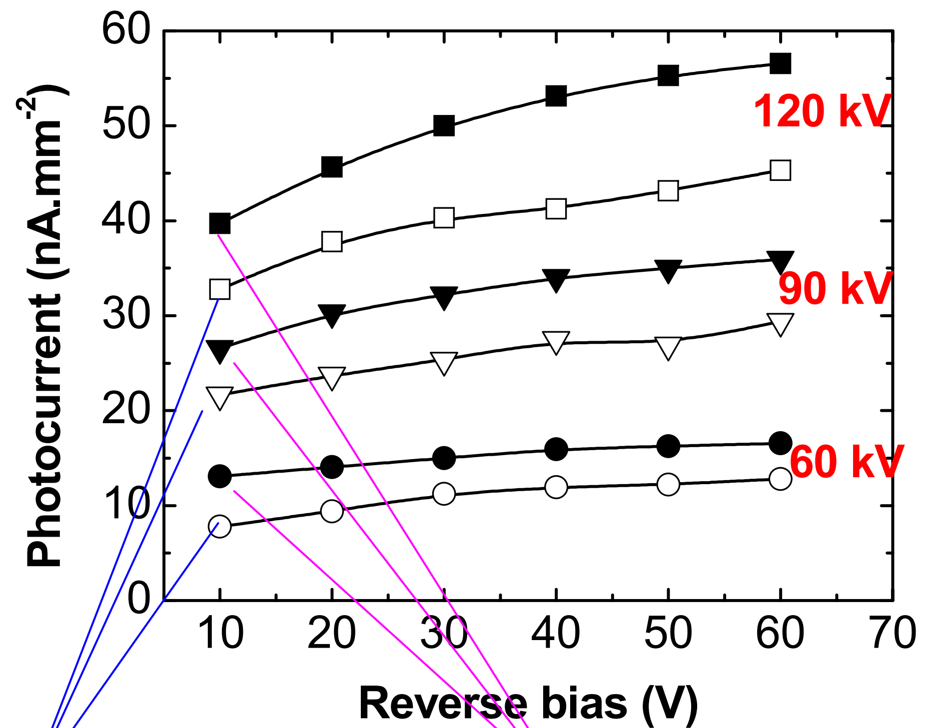
Limitation: width of depleted zone

Three ways to overcome it:

1. growth conditions
2. electron irradiation
3. use of 3D detectors

1 MeV electron irradiation





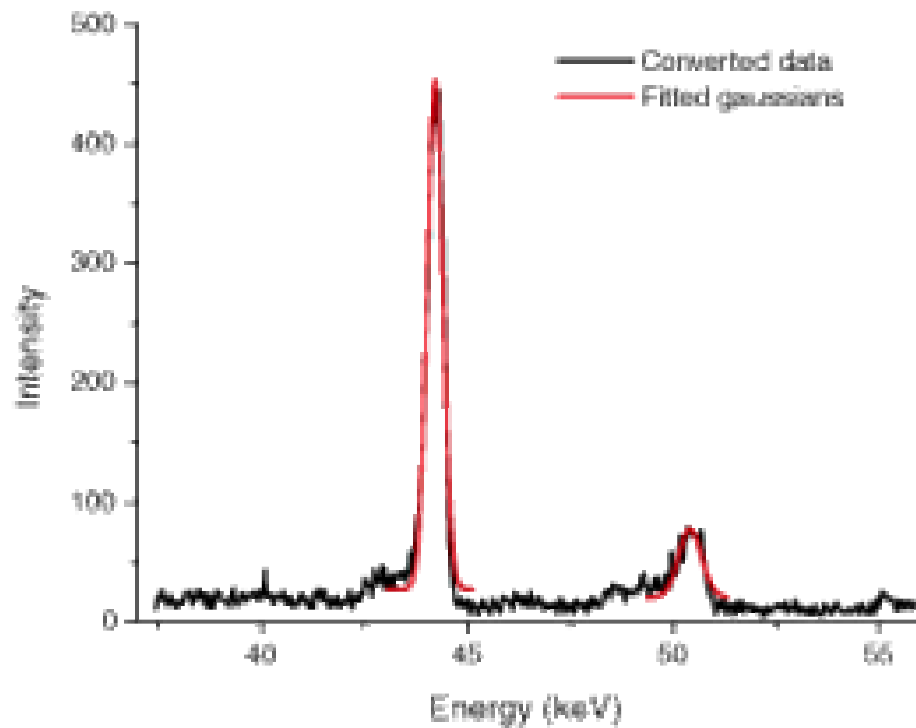
Low defects not enough to compensate free carriers.
Irradiation introduces defects →increase depleted depth

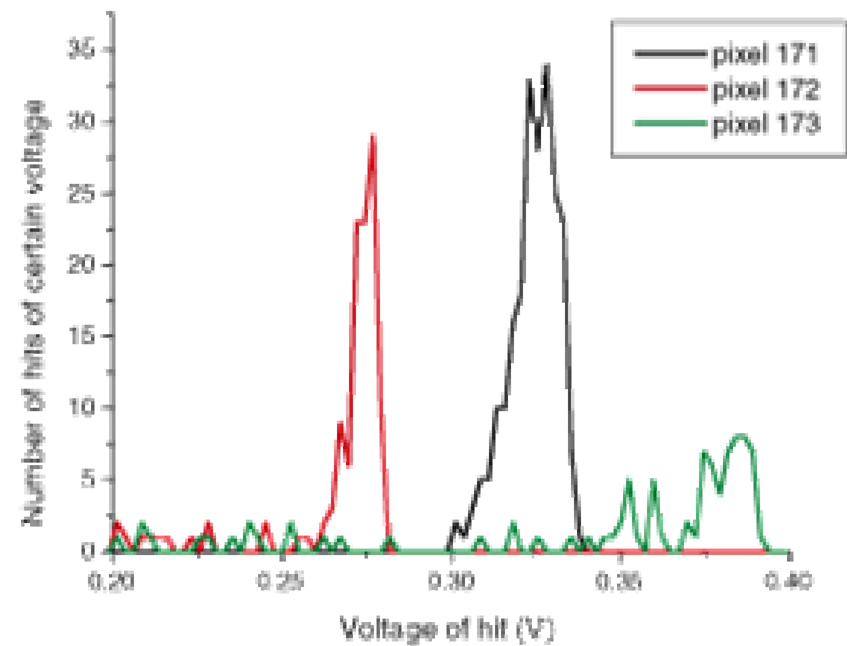
Before irradiation

After irradiation

3D detectors

‘3D’ SI-LEC GaAs pixel detector bonded to DASH-E ROIC





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