

# **Semi-direct thermal neutron detection via the $^{10}\text{B}$ -neutron reaction using a solid state heterodiode**

**Robert Venn  
Cambridge Microfab Ltd  
October 2008**

## The 10B – neutron reaction

- The isotope 10B has a high thermal neutron cross section ( 3840 barns)
- 10B & 11B occur naturally in the ratio 1:4
- Essentially the 10B(n,α)7Li reaction can be written:



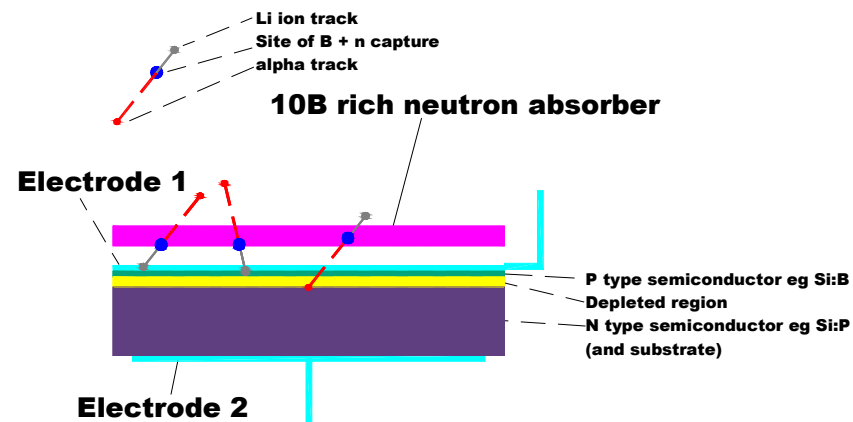
*The two possible capture reactions have probabilities of 6 and 94 % respectively  
An alpha particle and a lithium ion result from either reaction path*

- These neutron capture products can be detected either:
  - Directly – in the absorber film through application of an electric field
  - Indirectly – the capture products can be detected in a separate device
  - Semi-directly – the capture products are detected in an active extension of the absorber
- Our device works by using the third approach

# Conventional diode as a neutron detector – Indirect detection

## Indirect detection

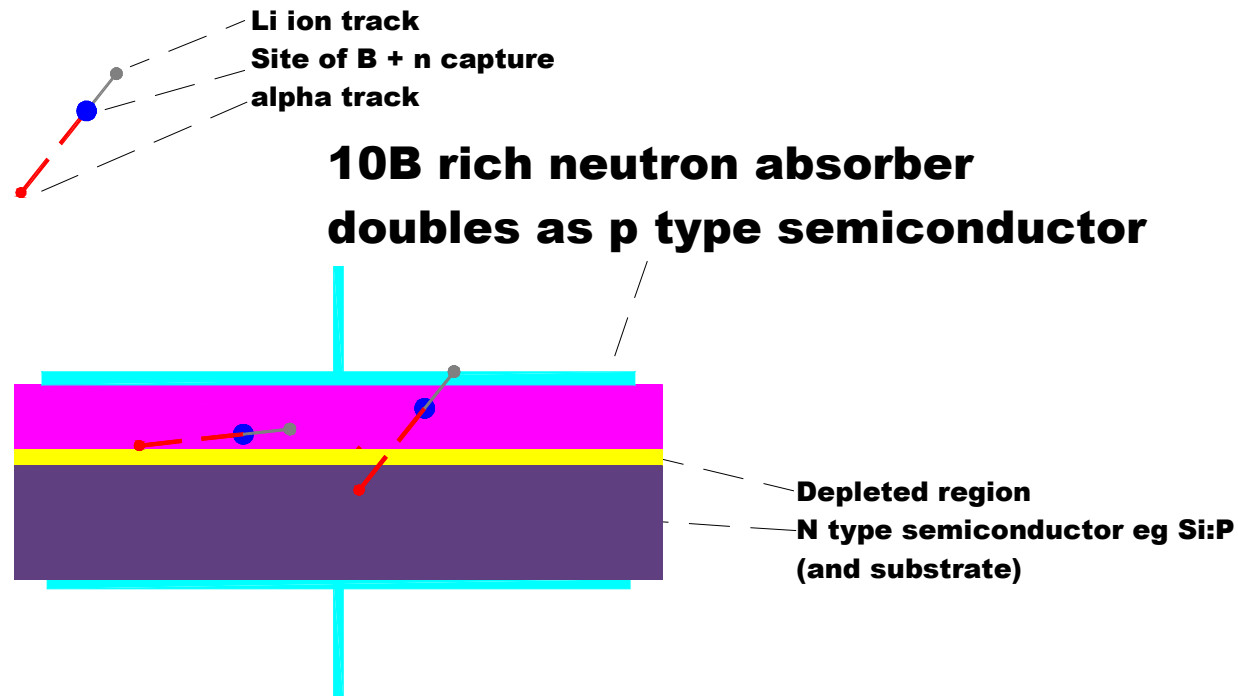
- Capture products penetrate the diode from above the electrode**
- Attenuation of the product energy occurs within the absorber within the electrode**
- and within the top semiconductor layer**
- The residual energy is registered in the depleted region**



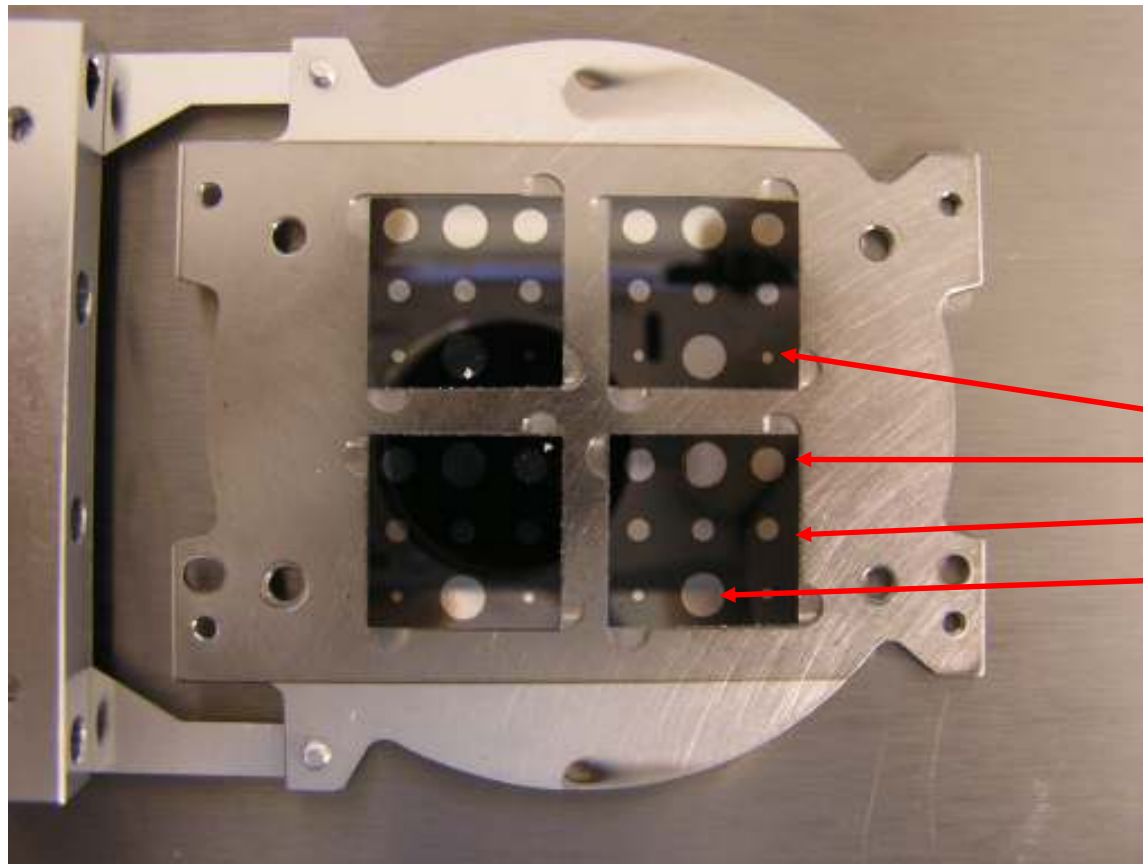
## Conventional diode as a neutron detector – Indirect detection

- **Good example of the indirect approach is (eg Douglas Macgregor) using GaAs based p-i-n diode**
- **Problem:**
- **Only the depleted (insulating) region of the diode is sensitive to the alpha/Li ion and to get there the ion loses energy:**
  - **via the neutron absorber layer itself**
  - **via the top electrode**
  - **and then via the upper semiconductor layer**
- **before it can deposit its residual energy in the depleted region**

# A heterodiode – the p and n type materials are made from different semiconductors but still form a diode junction



# 18mm x 18mm heterodiode tiles with 9 electrode areas each

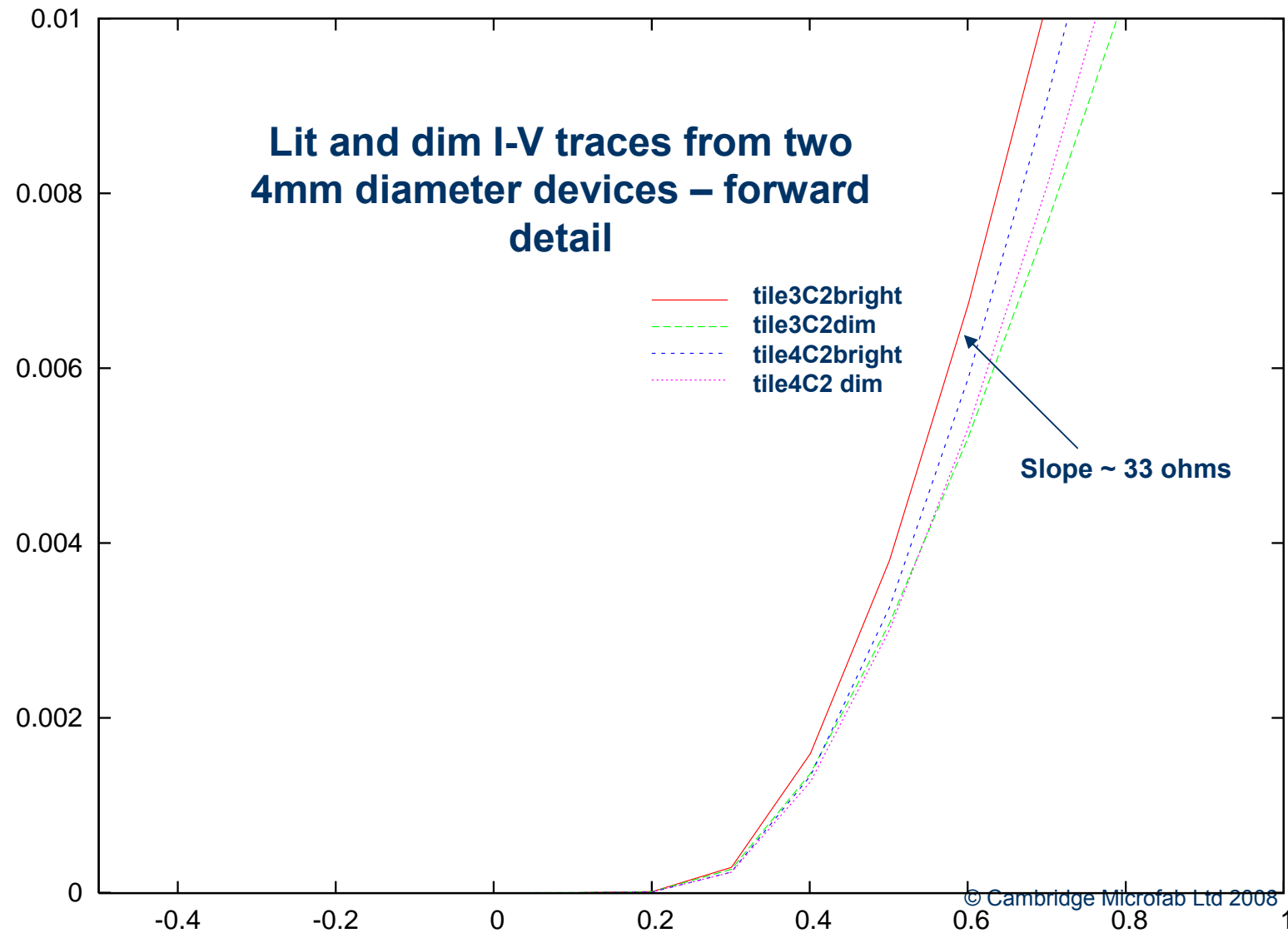


## Electrode Diameters

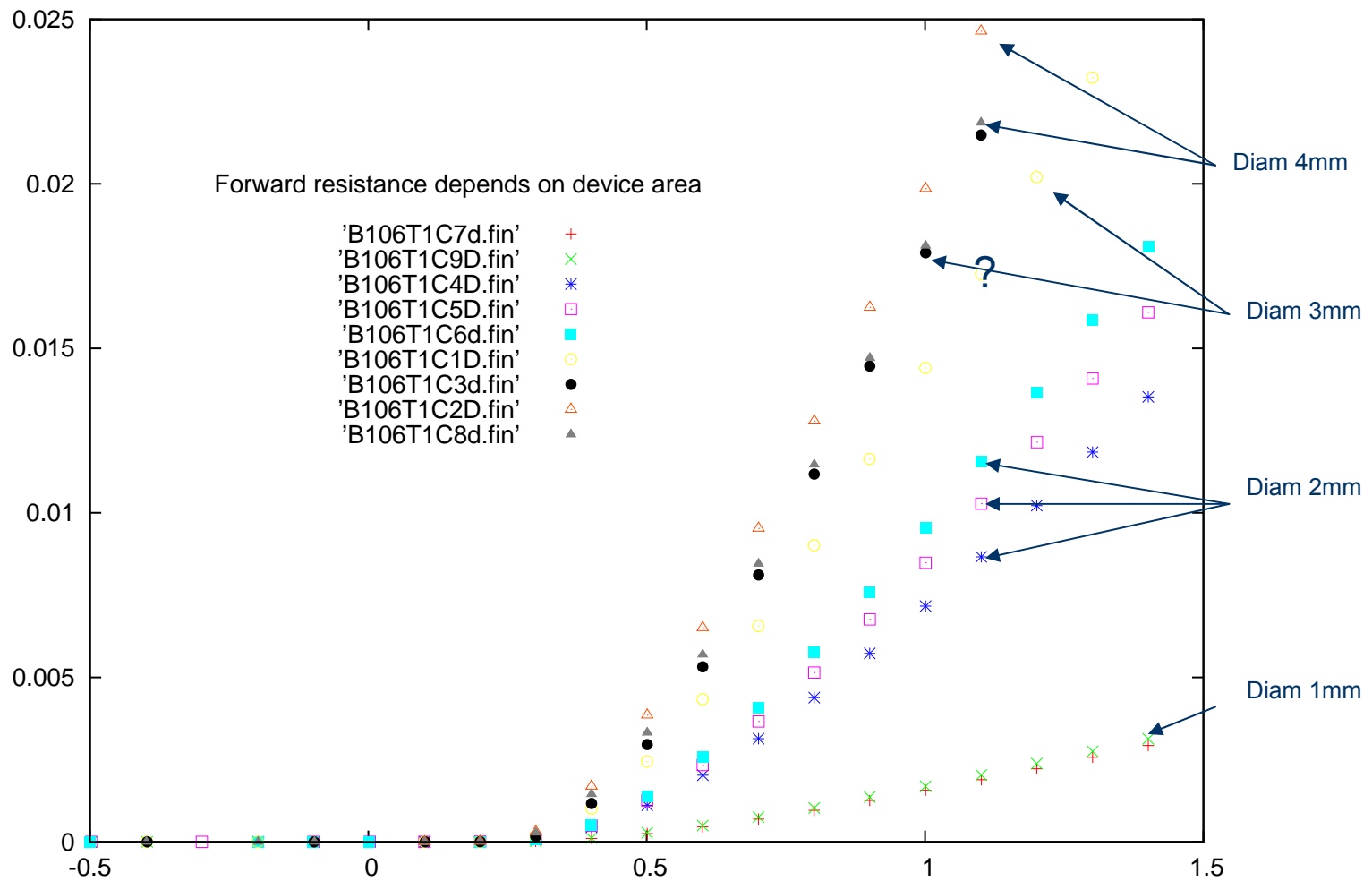
- 1 mm  $\Rightarrow 0.785\text{mm}^2$
- 3 mm ....
- 2 mm
- 4mm  $12.56\text{mm}^2$

## Active areas

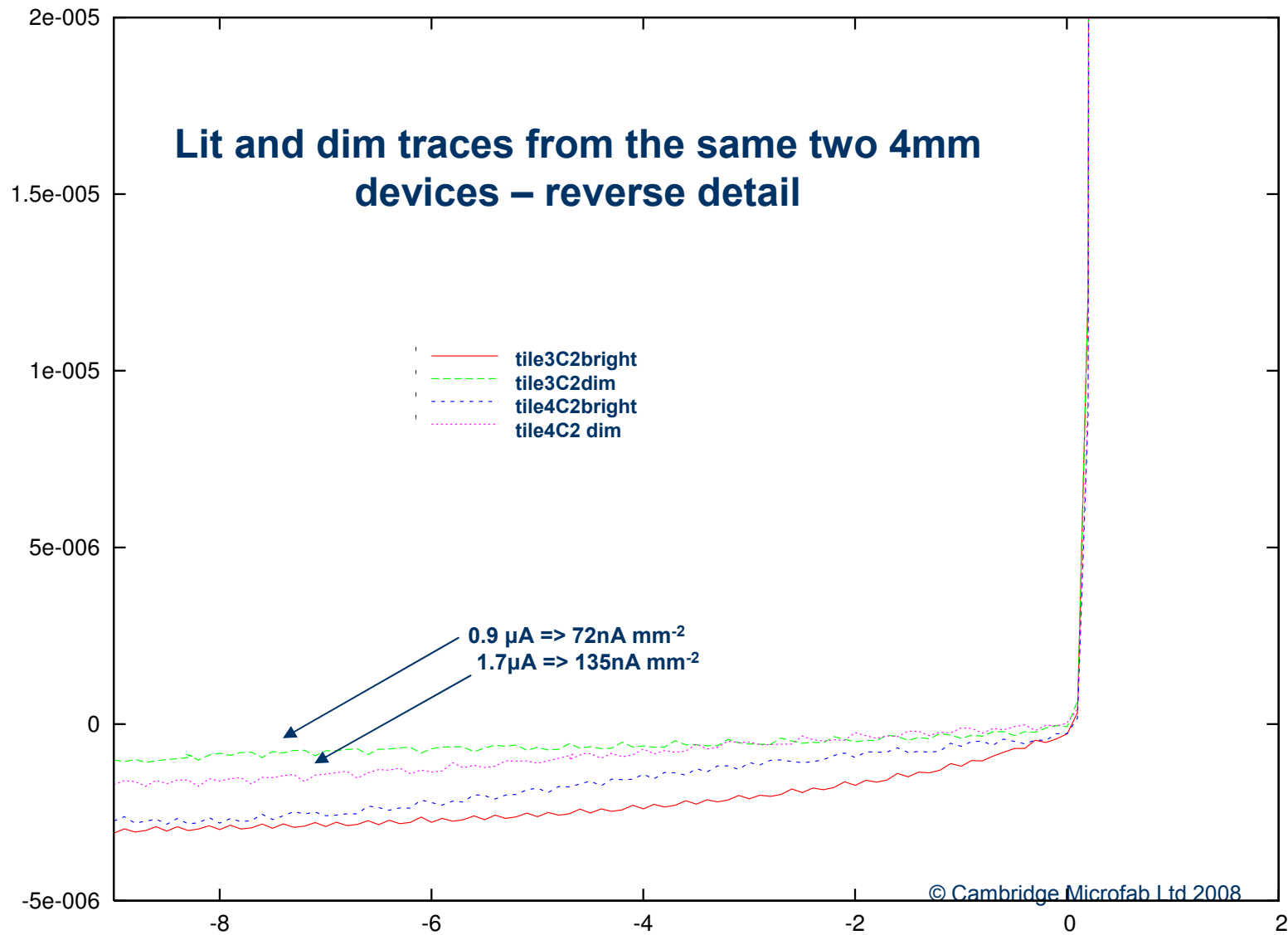
## Electrical characteristics of the neutron heterodiodes



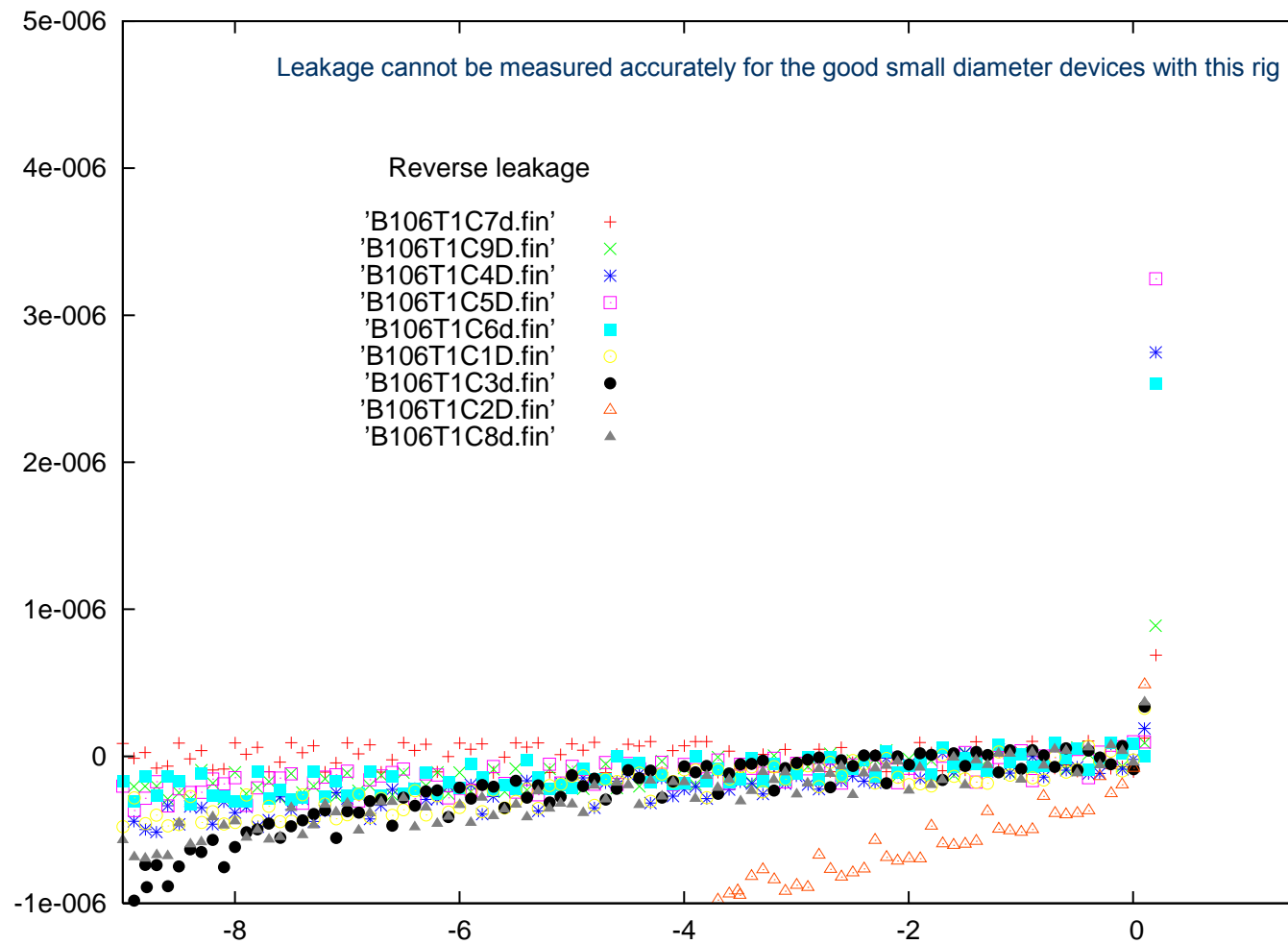
# Electrical characteristics of the neutron heterodiodes



# Electrical characteristics of the heterodiodes



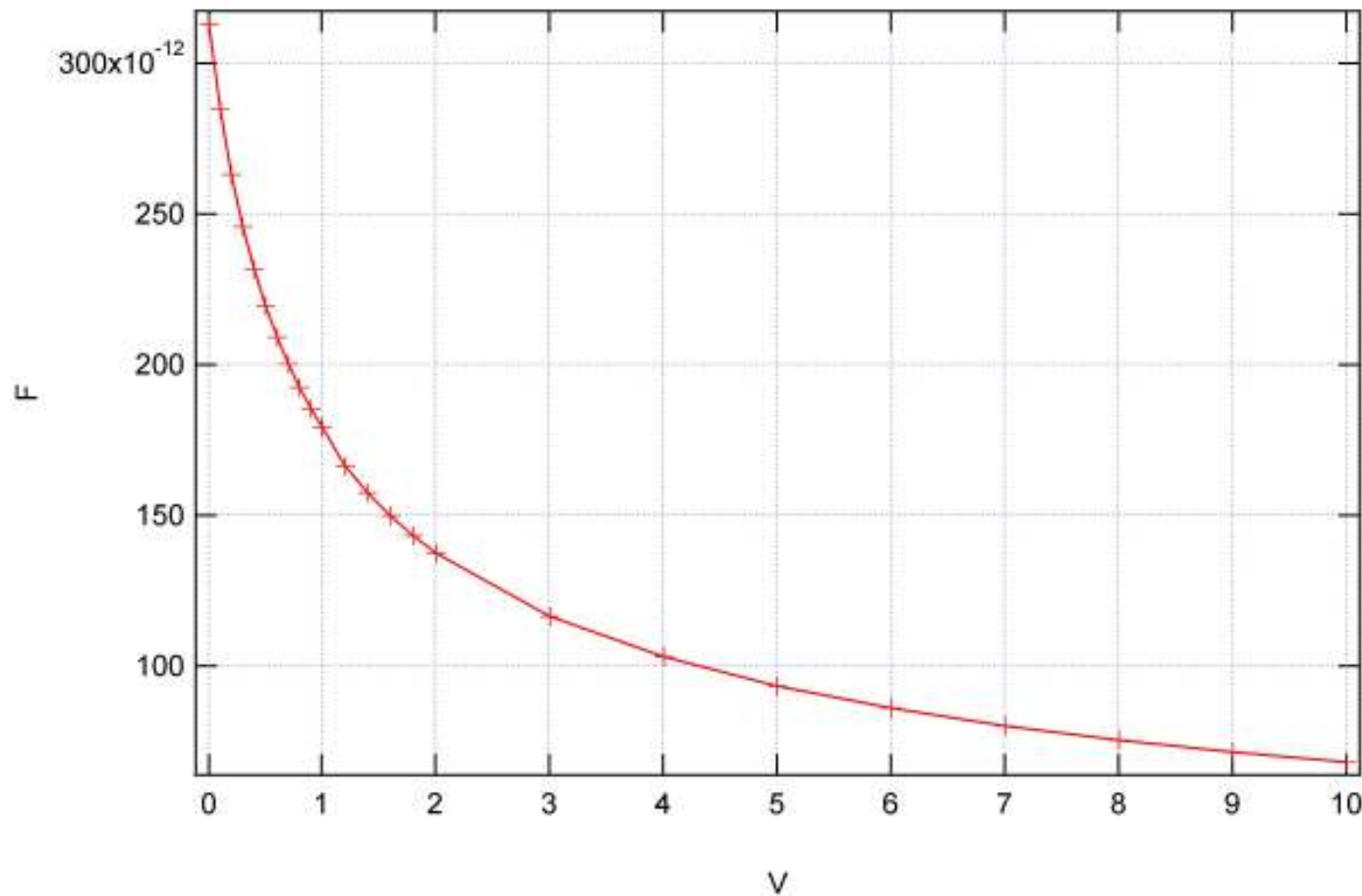
# Electrical characteristics of the heterodiodes



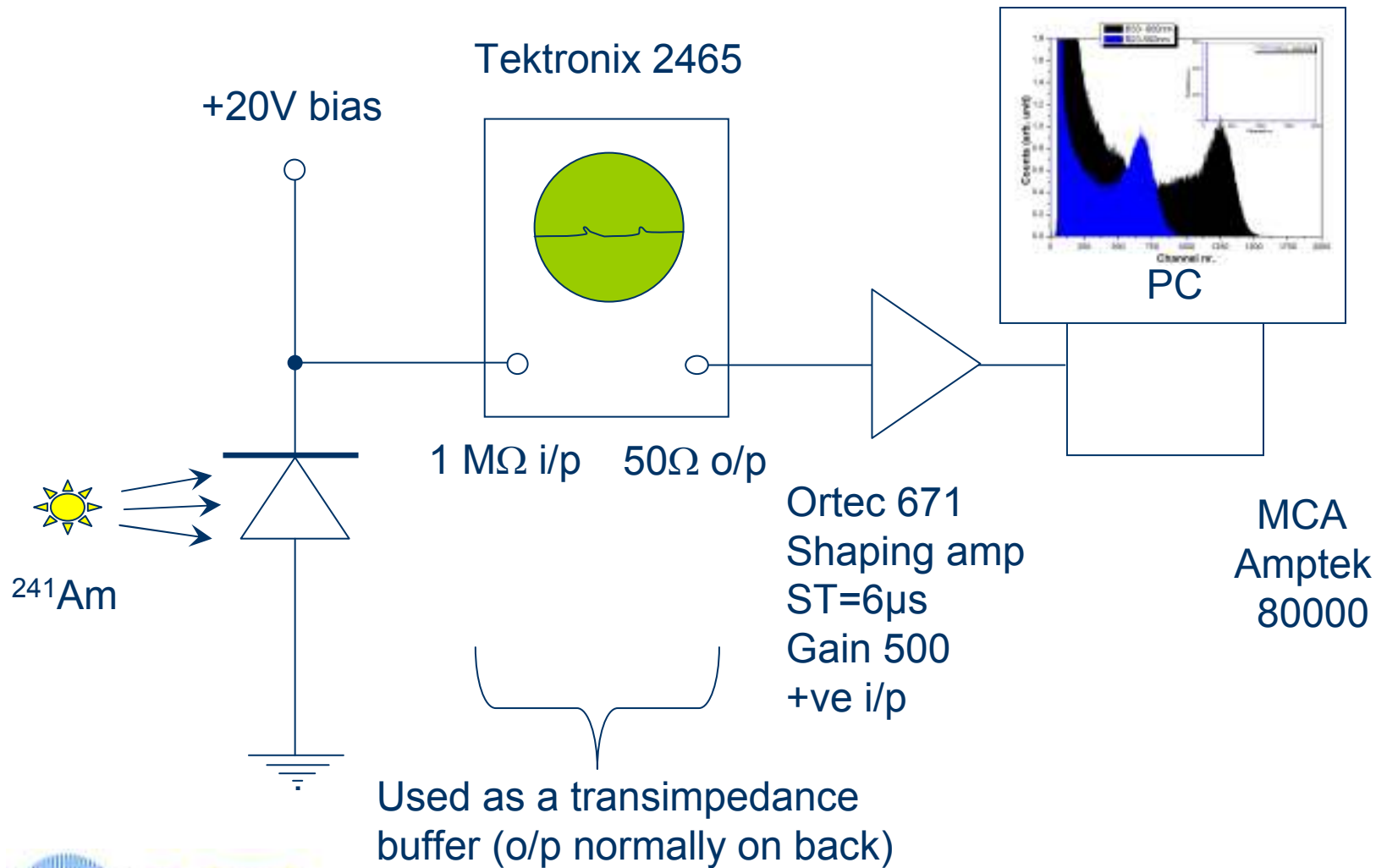
# Electrical characteristics of the heterodiodes



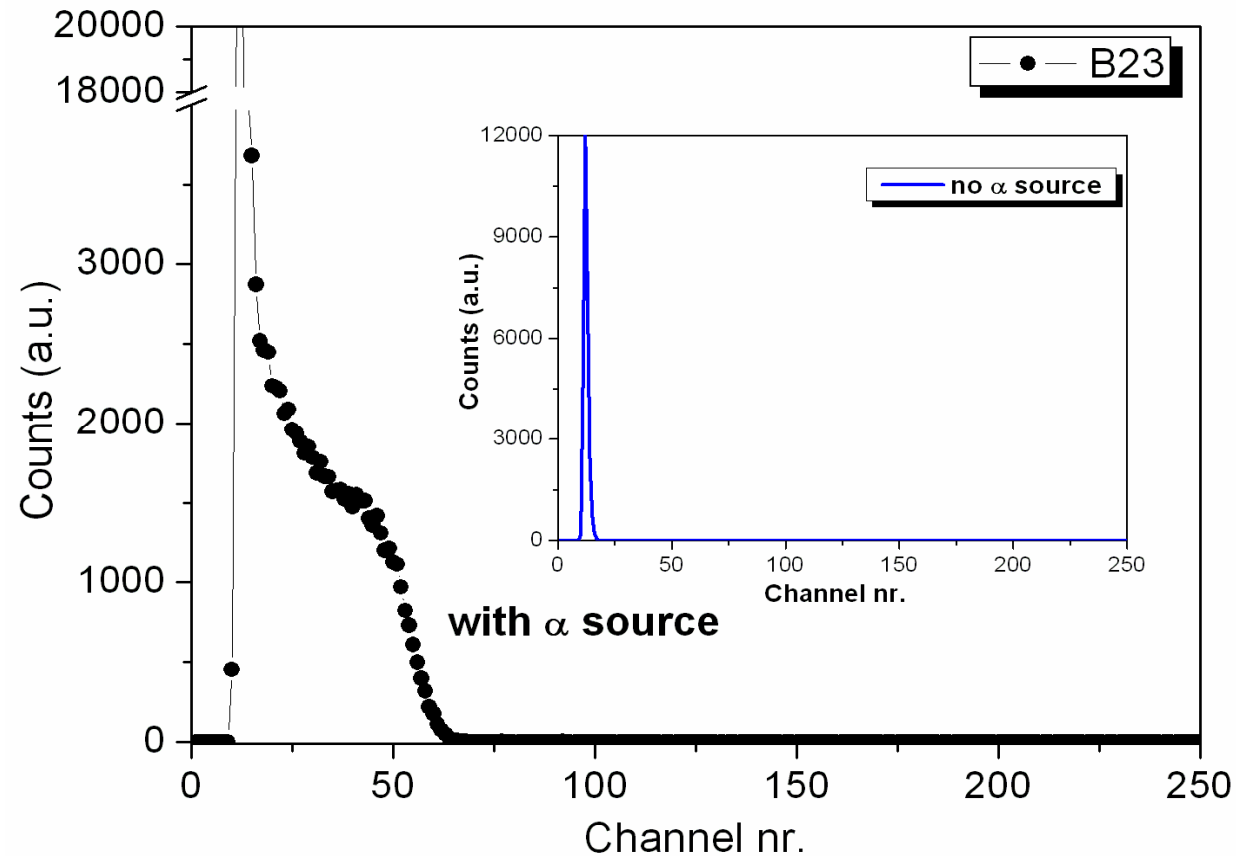
## Capacitance – Voltage characteristic of a 3mm diameter device



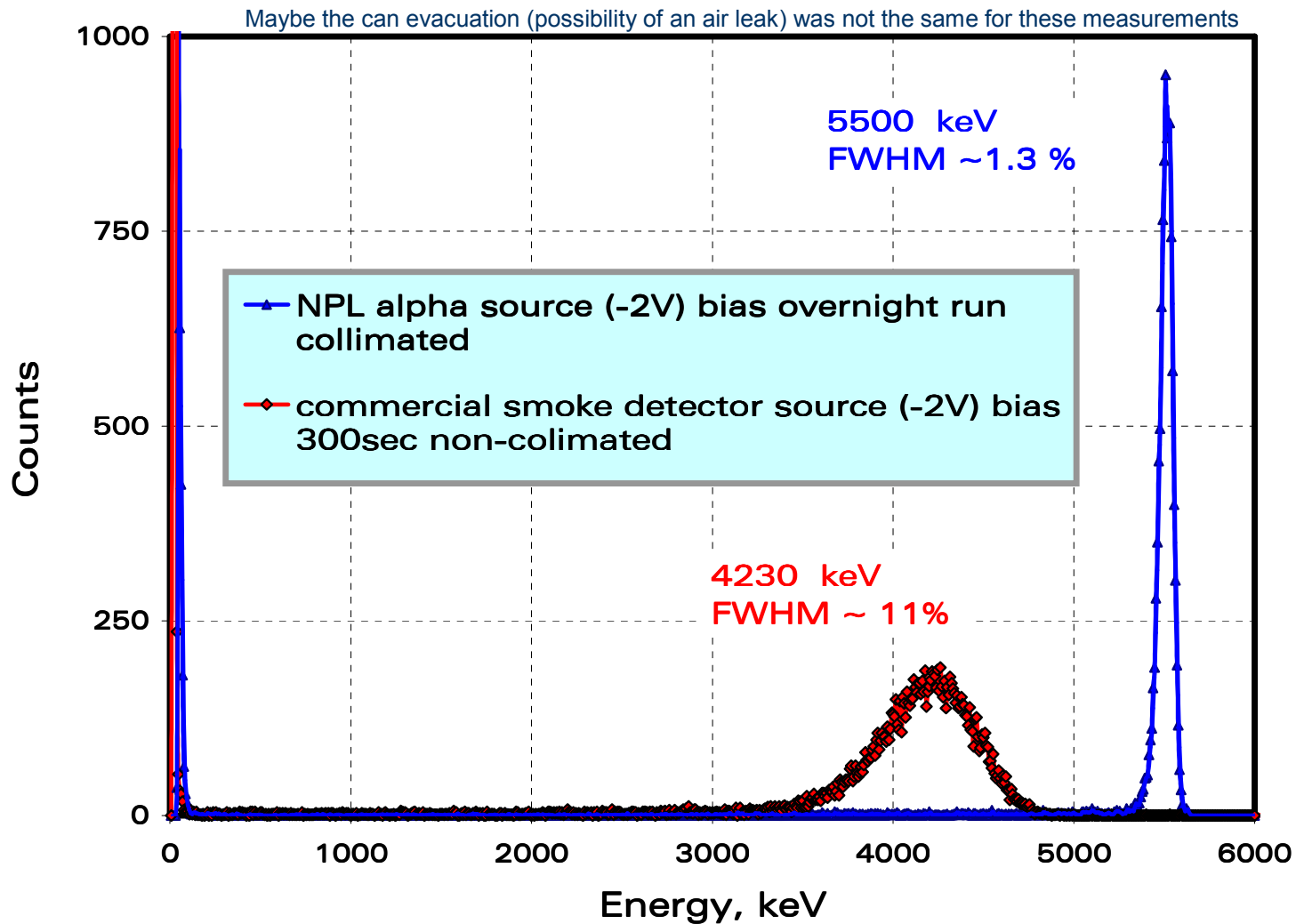
# How might one detect radiation with one of these devices ? Alpha particle detection in the first instance ~ Sep 2007



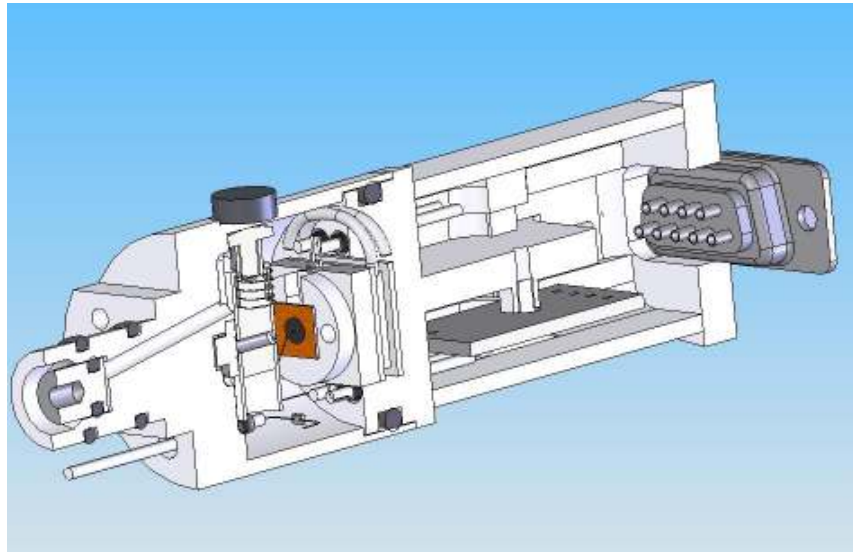
# Earliest Americium spectrum from a Microfab heterodiode



# And by July 2008 – dramatically improved device leakage – new electronics and new packaging – recognisable spectra



## What about neutron testing?



- **Solidworks model of a test & characterisation enclosure**
- **Design incorporates an alpha source with magnetic shutter**
- **Test space can be plugged under vacuum**
- **Peltier heater/cooler**
- **Temperature sensing via a Pt 100 chip**

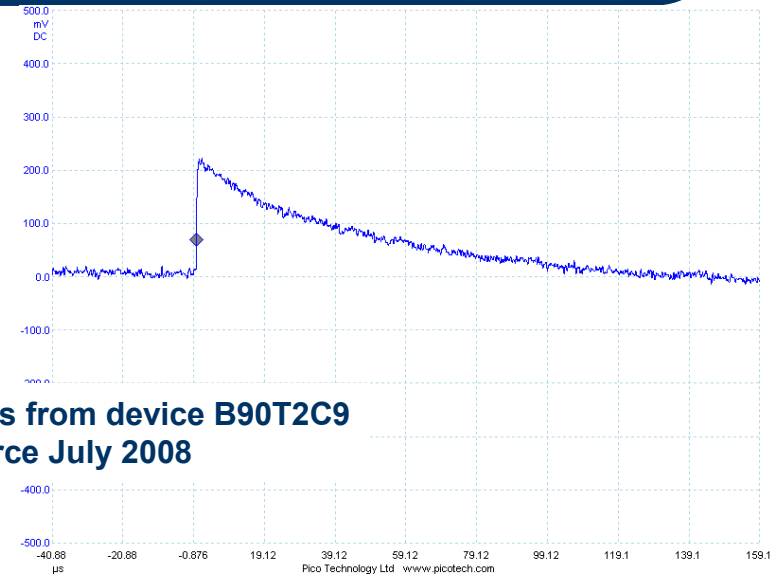
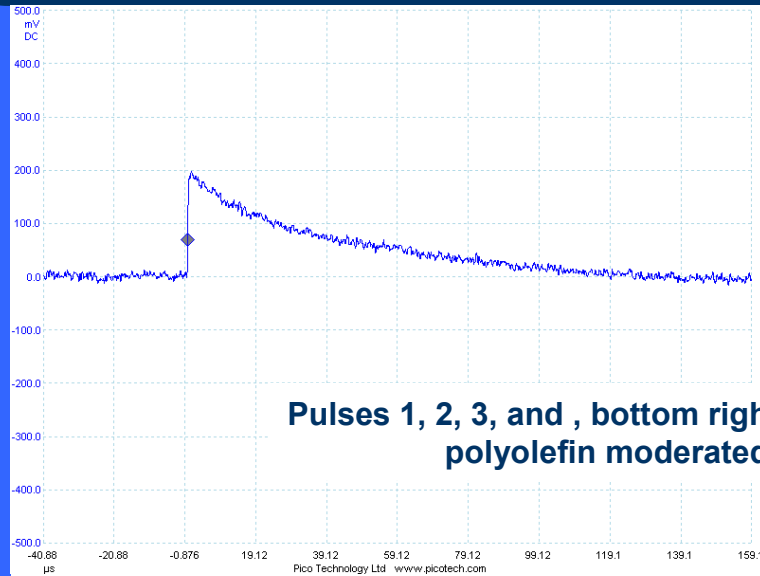
- **The real thing with a test amplifier in place**
- **The design - to be compatible with a 30mm bore in a polyolefin neutron moderator block at NPL**



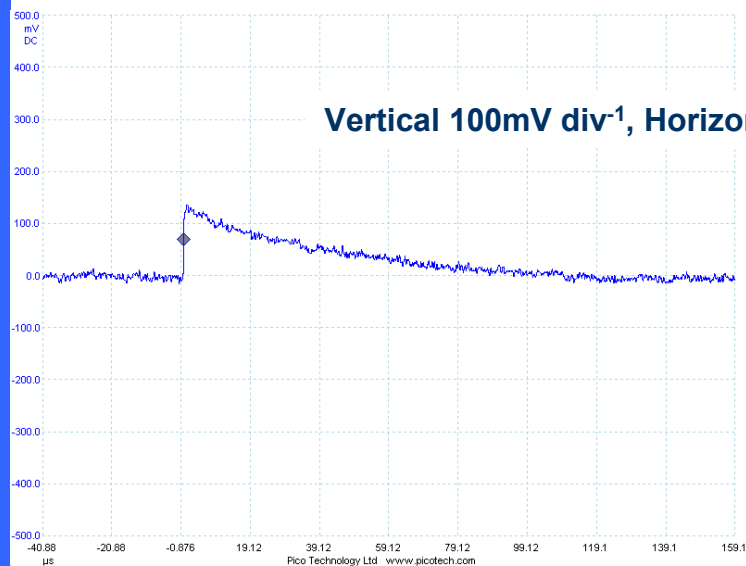
**35000 n cm<sup>2</sup> sec<sup>-1</sup> courtesy of NPL – can we see them?**



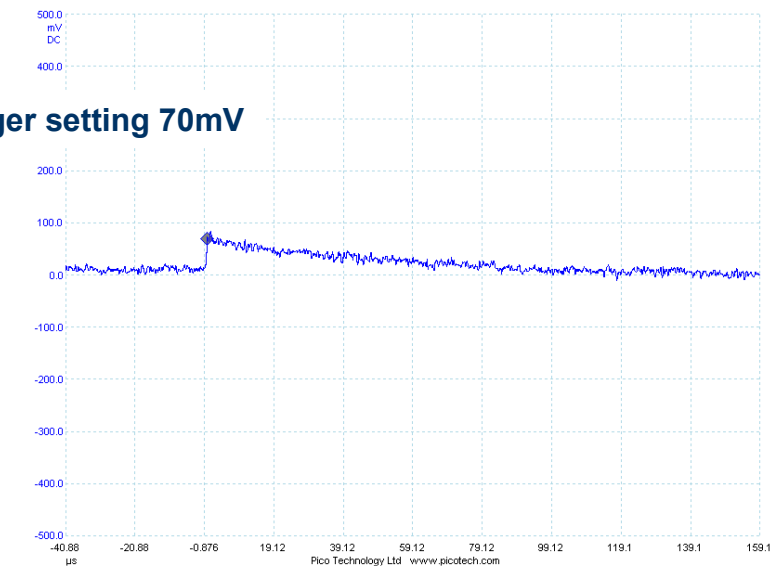
# Typical raw output pulses – no processing – no shaping stage



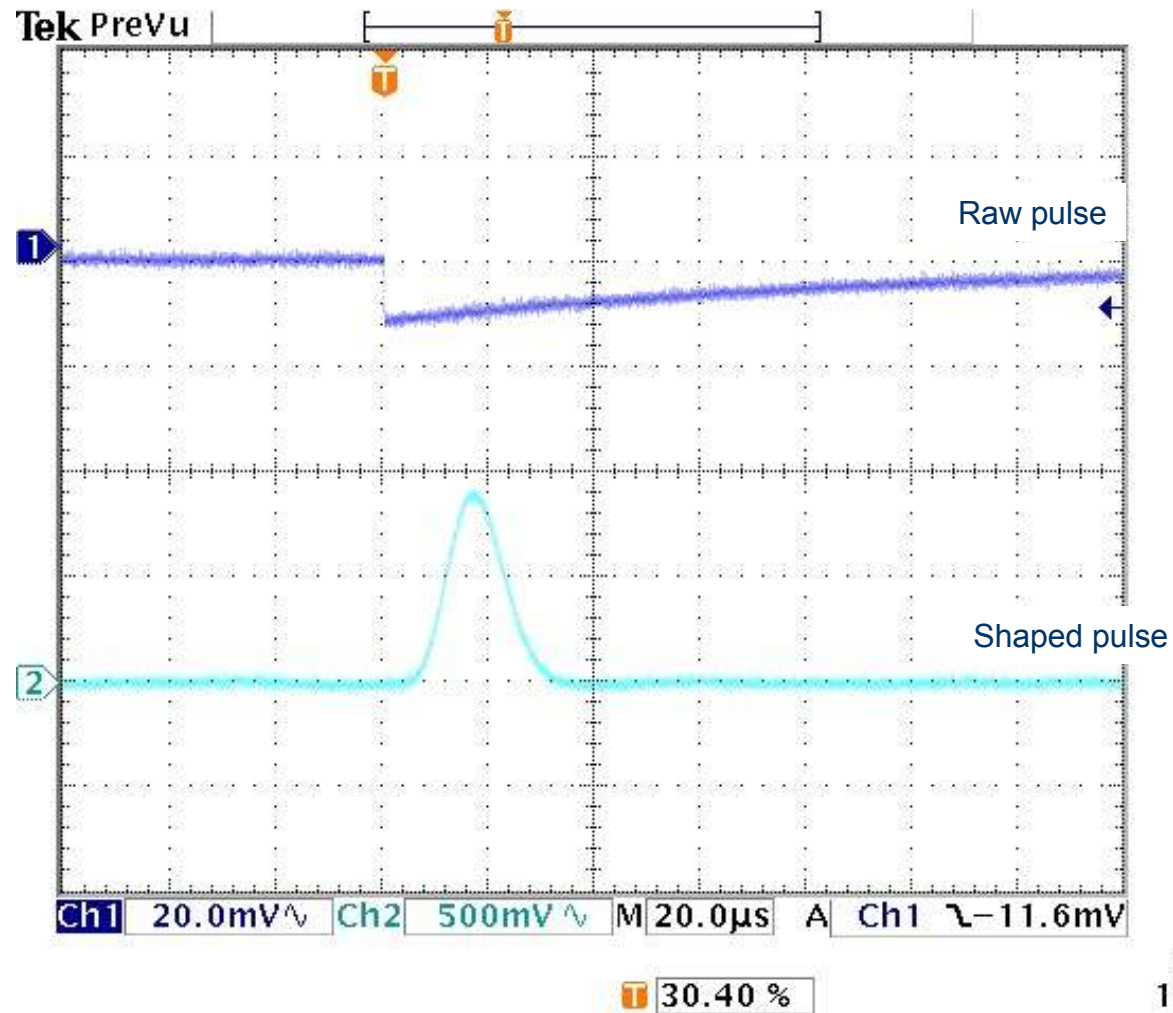
Pulses 1, 2, 3, and , bottom right, 9 of 1000 pulses from device B90T2C9 polyolefin moderated NPL Am-Be source July 2008



Vertical 100mV div<sup>-1</sup>, Horizontal 20μs div<sup>-1</sup> trigger setting 70mV



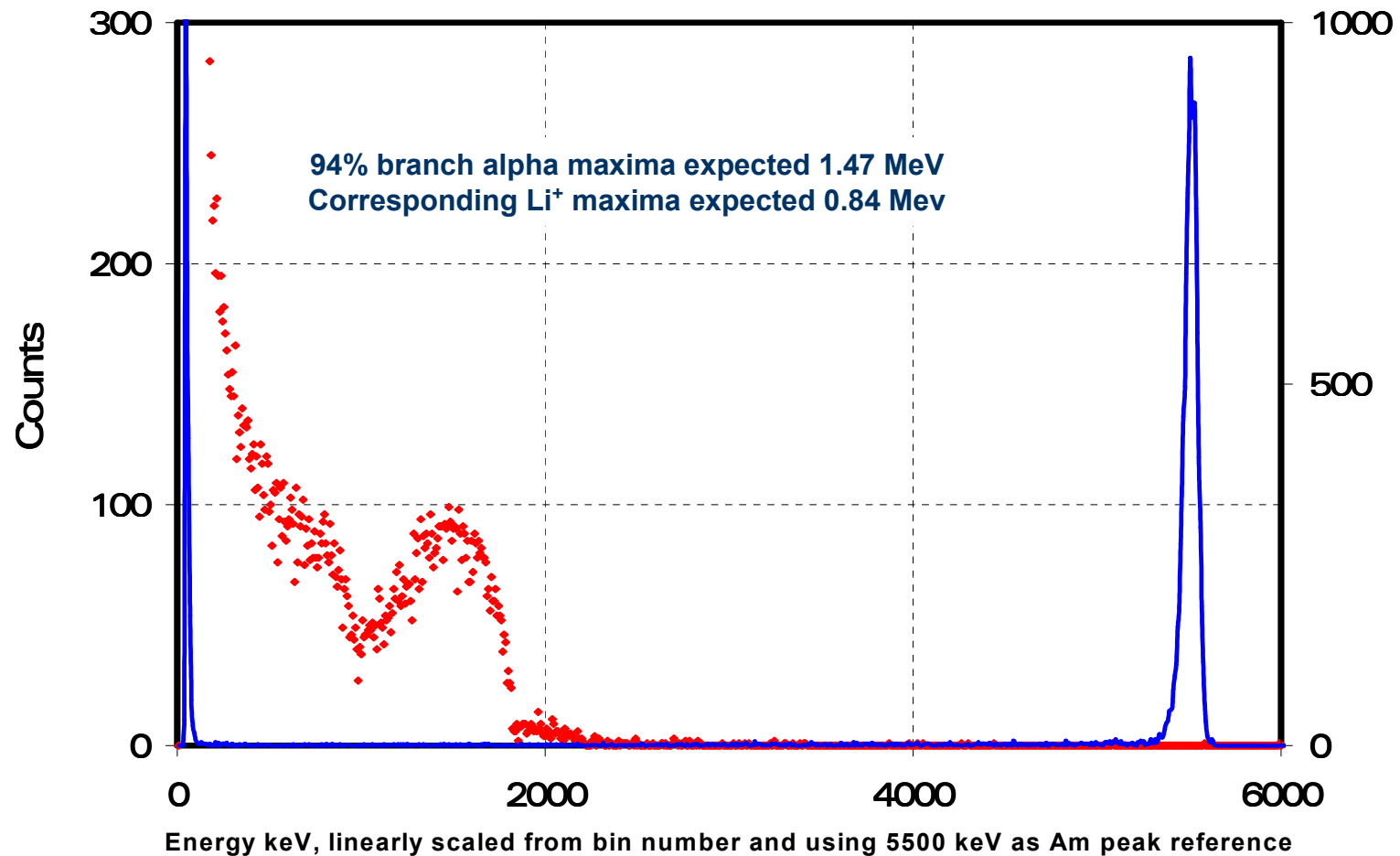
# Classical approach – pulse shaping followed by pulse height analysis



3 Jun 2008  
11:13:44

# Leading to reaction product spectra which show the neutron capture product energy maximum edges

Also showing the pulse height distribution from the same device arising from illumination with an NPL 241-Am source. The NPL source gives lower fwhm values than can be obtained from smoke detector sources. Device B90T2C9 – NPL visit July 2008



## Grateful acknowledgements

Work originally funded under ESA contract

“Technical Assistance in the Development of a Solid-State Neutron detector  
for Planetary Missions”  
(SCI-A/2003-274/AO/TIP)

Alan Owens, Solve Andersson, Tone Peacock and others at ESA

Danny Palmer, Lukasz Jankowski, Jeannie Venn, Rumen Tomov, Martin Brennan, Alan  
Briggs and Pierre Yves Baccou at or with Cambridge Microfab

Graeme Taylor and David Thomas at NPL Teddington