Source Tests of a Germanium Strip Detector

The MARK III Detector:
136Xe + 12C @ 595 MeV \( \beta \sim 8.7\% \)

**Raw spectrum**

**Doppler corrected single-pixel spectrum**

Counts per channel

Gamma-Ray Energy (keV)
Construction

back face
horizontal strips
600 μm deep
lithium

separated by 1mm
depth, 0.5 mm wide
saw cuts

front face
vertical strips
ion-implanted boron
< 1 μm deep

Ge sandwiched
between two 1mm
thick sheets of boron
nitride
surrounded and cooled
by an Al ring fixed to
a Cu cooling rod
leading to large
bucket style dewar
$V_{bias} = 1300 \text{ V}$

$V_{dep} = 100-450 \text{ V}$

Electrons $v \sim 6 \times 10^6 \text{ cm/s}$

Holes $v \sim 6 \times 10^6 \text{ cm/s}$

B p+ contact

Li n+ rectifying contact

Impurity concentration

$2 \times 10^9 \text{ cm}^{-3}$

$5 \times 10^8 \text{ cm}^{-3}$
Boron-Vertical-Front

Lithium-Horizontal-Back

10.35 cm

\[ E_\gamma = 88 \text{ keV to } 1.8 \text{ MeV} \]

Calibrated strength

\(^{109}\text{Cd}, \, ^{57}\text{Co}, \, ^{139}\text{Ce}, \, ^{113}\text{Sn}, \, ^{137}\text{Cs}, \, ^{88}\text{Y} \text{ and } ^{60}\text{Co}\]
events associated with different multiplicity of strip hits in offline sorting using ROOT

Single pixel events: \( n_h = 1 \), \( n_v = 1 \) dominant below \(~400\) keV

Two pixel events: \( n_h = 2 \), \( n_v = 1 \) and visa versa \( n_h = 2 \), \( n_v = 2 \) important above \(800\) keV nearest neighbours dominate
Pulses in regular planar

induced signals at each electrode due to both charge carriers

- electrons reach Li
- holes reach B
- signal from B
- signal from Li
Small Electrode Effect:
induced signal in an electrode is small, until the charge that it
will later collect arrives in its vicinity

![Diagram showing induced charge and signal from B and Li]

Signal from B is mainly due to holes
time

Signal from Li is mainly due to electrons

Uses:  
(i) improvement in performance if one charge carrier
subject to large trapping and not the other
(ii) allows measurement of the interaction position
by time difference between B and Li signals
Detector Resolution

Regular Ge:

\[ W_T^2 = W_X^2 + W_E^2 + W_D^2 \]

fluctuations in charge collection

electronic noise

statistics of e-h pairs

Charge collection efficiency:

bulk charge trapping
edge effects
low field regions
charge collection away from electrodes
Differences between front and back illustrate losses in charge which vary with position.

Bulk Trapping Effects

Edge Effects

Counts per channel

Energy Difference Front-Back

Counts per channel

88 keV $\lambda = 1.9$ mm
surface deposition near B face
electron collection path large
more electron trapping

122 keV $\lambda = 3.4$ mm
penetrates further
less of a difference in trapping

B Signal

Li Signal
Spectra as a function of bias voltage at 1408 keV

Li signal

B signal
Resolution as a function of bias:

- **Boron**
  - 1408 keV
  - 2.7(6) keV contribution from electronic plus statistics
- **Lithium**
  - 121 keV
  - @122 keV resolution dominated by electronic plus statistics

Estimate contributions by letting V get large:

@1408 keV
2.7(6) keV contribution from electronic plus statistics

@122 keV
resolution dominated by electronic plus statistics
Drift velocity as a function of applied field:
lithium illumination from "front"
- 40 keV
- 0.3 mm

boration illumination from "rear"
- 122 keV
- 3.4 mm

lithium "back" 0.6 mm depth

boron "front" <0.010 mm depth

No measurable resolution difference between front and back illumination............suggests not bulk trapping
Two-Strip Cross Talk

Reconstruct Compton scattered events by summing energies of two-strip events

1 to 3% shift in the gain from one-pixel to adjacent two-pixel events

Non-adjacent strips do not show significant shifts
Schematic Model

capacitive coupling between neighbouring strips

for single strip event
charge amplified is \( Q - 2q \)
net charge collected
charge stored in coupling

for two strip sum
adjacent
\( \sim (Q/2 - q/2) + (Q/2 - q/2) = Q - q \)
non-adjacent
\( \sim(Q/2 - q) + (Q/2 - q) = Q - 2q \)
Single-pixel events

Two-pixel diagonal scatters:

Two-pixel HV scatters:
@121 absolute efficiencies 2.19(4)%, similar to Monte Carlo
And Next?

For now: improve multiparameter system to reduce noise
understand efficiency (?)

MARK IV Detector is on its way to Argonne.....

5 mm wide guard ring
boron side DC coupled
lithium side AC coupled
cold initial preamp FET stages
no boron nitride sandwich

Ultimate goal: MARK V

include improvements to MARK IV
streamlined cryostat for use in arrays,
close geometries etc.