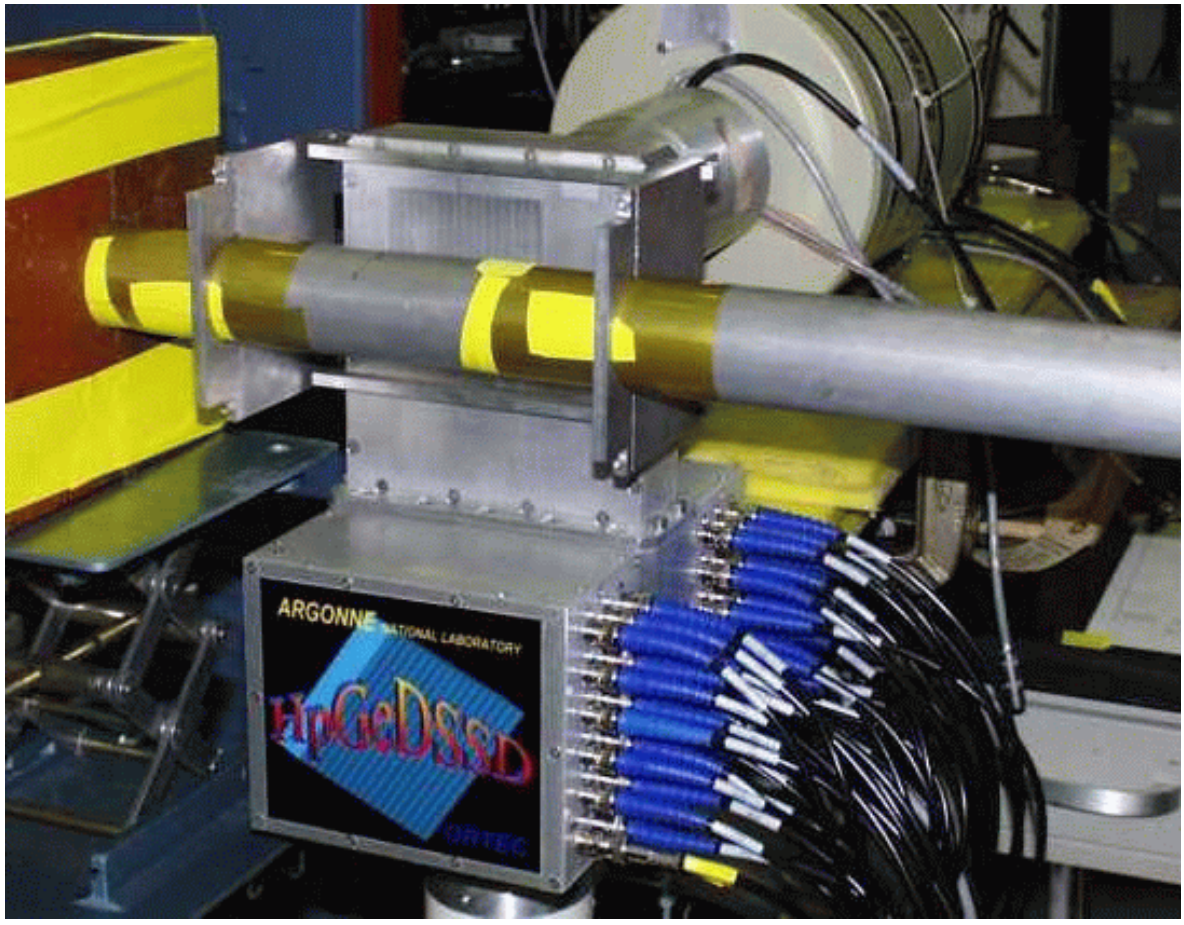
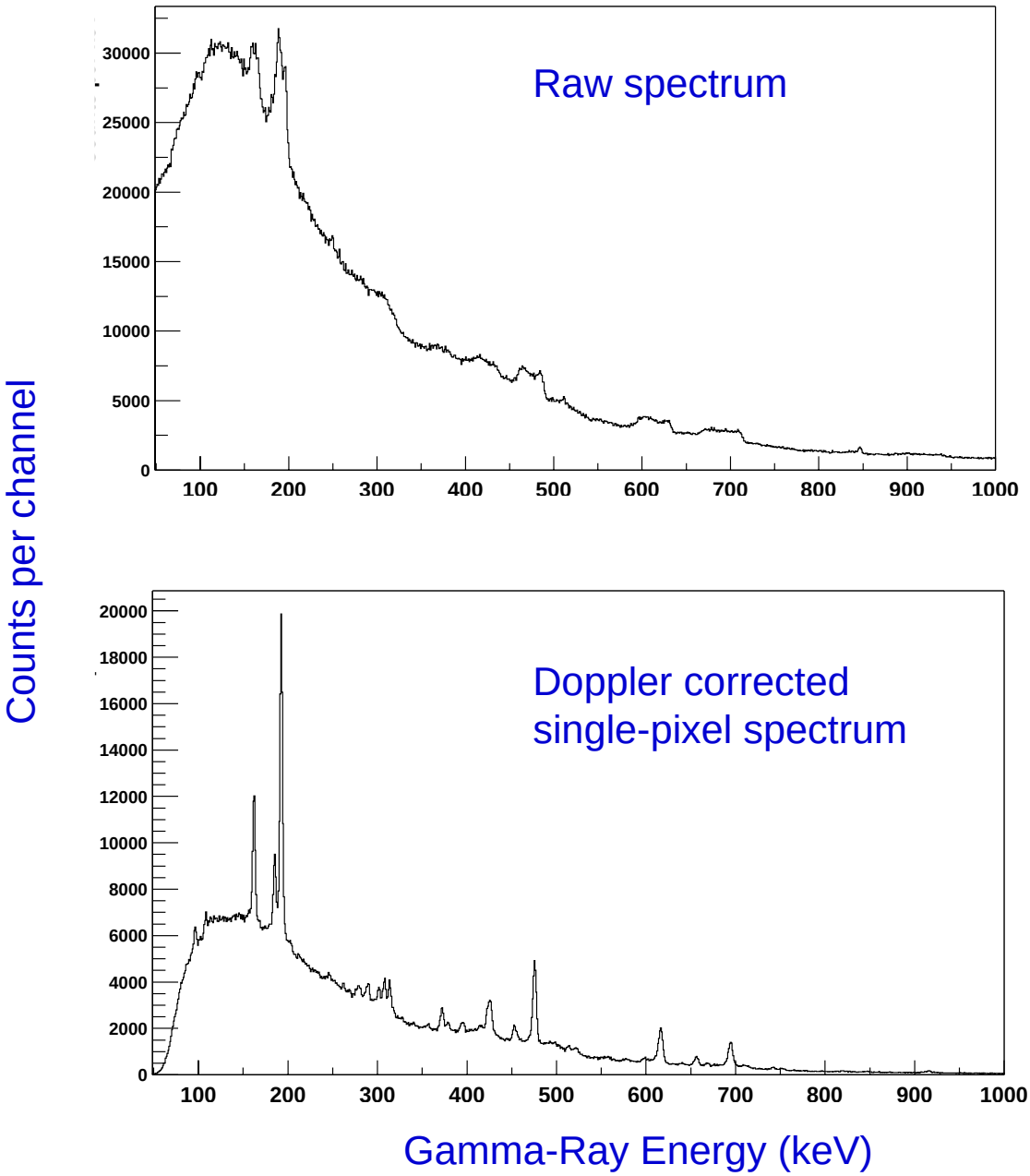
Source Tests of a Germanium Strip Detector

The MARK III Detector:



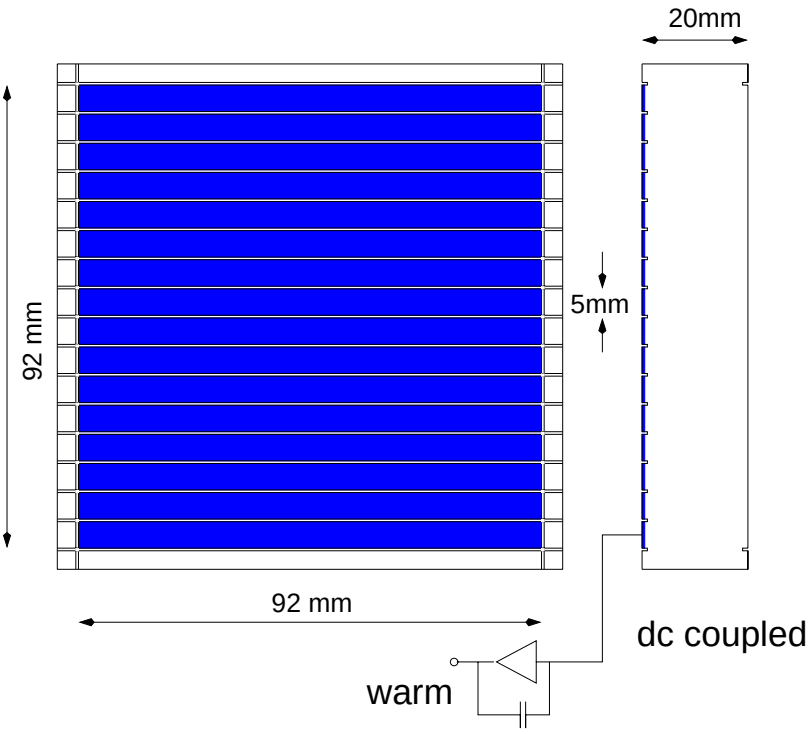
136Xe + 12C @ 595 MeV β~8.7%



Construction

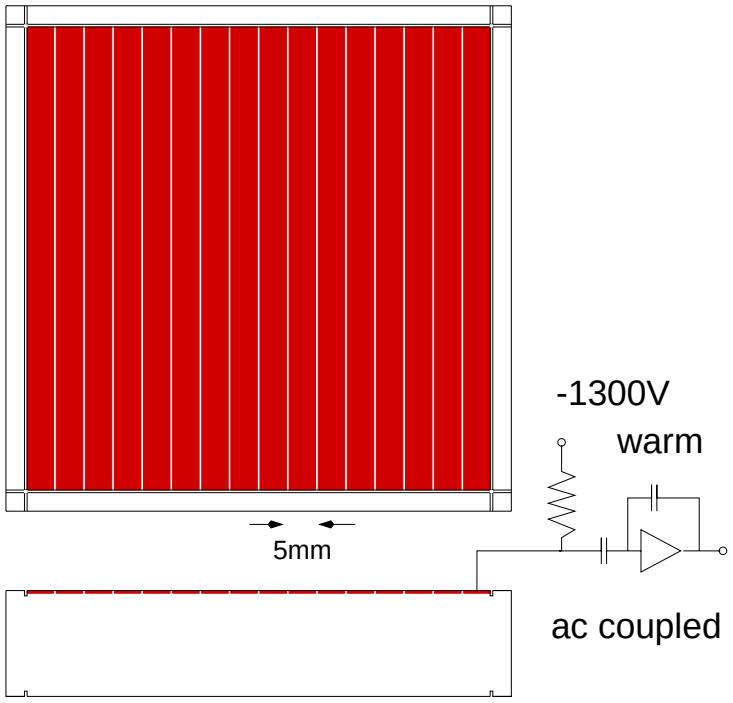
back face
horizontal strips
600 μm deep
lithium

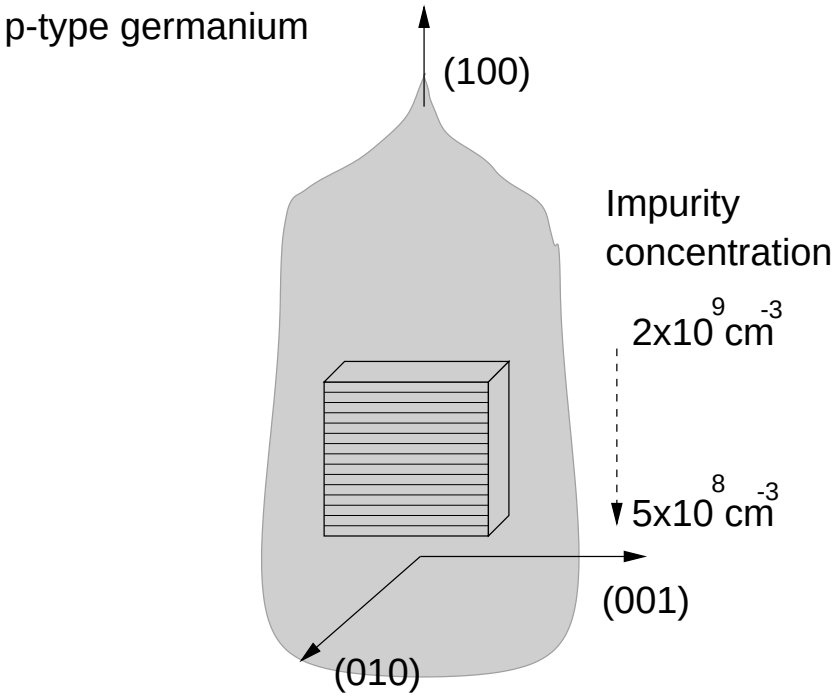
separated by 1mm
deep, 0.5 mm wide
saw cuts

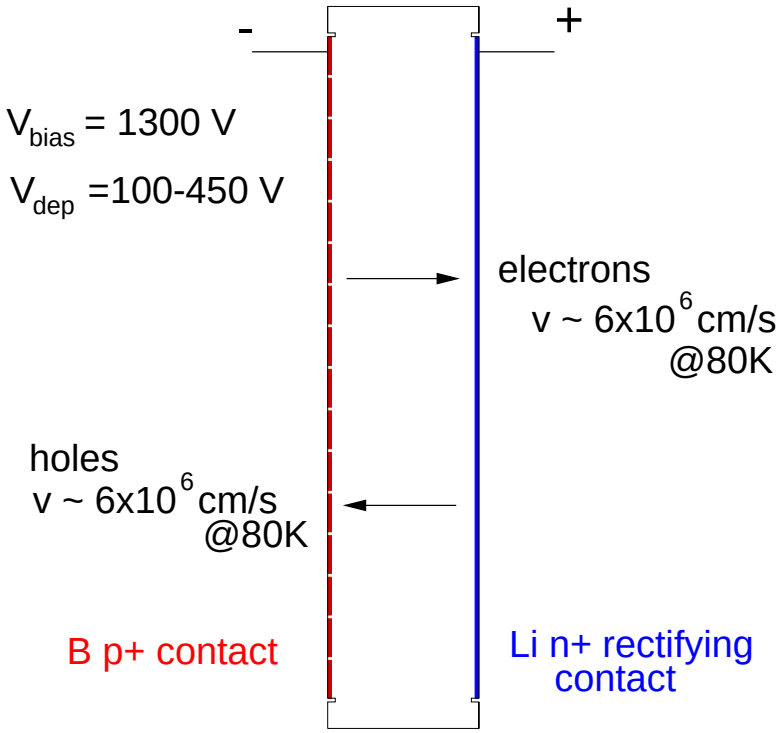


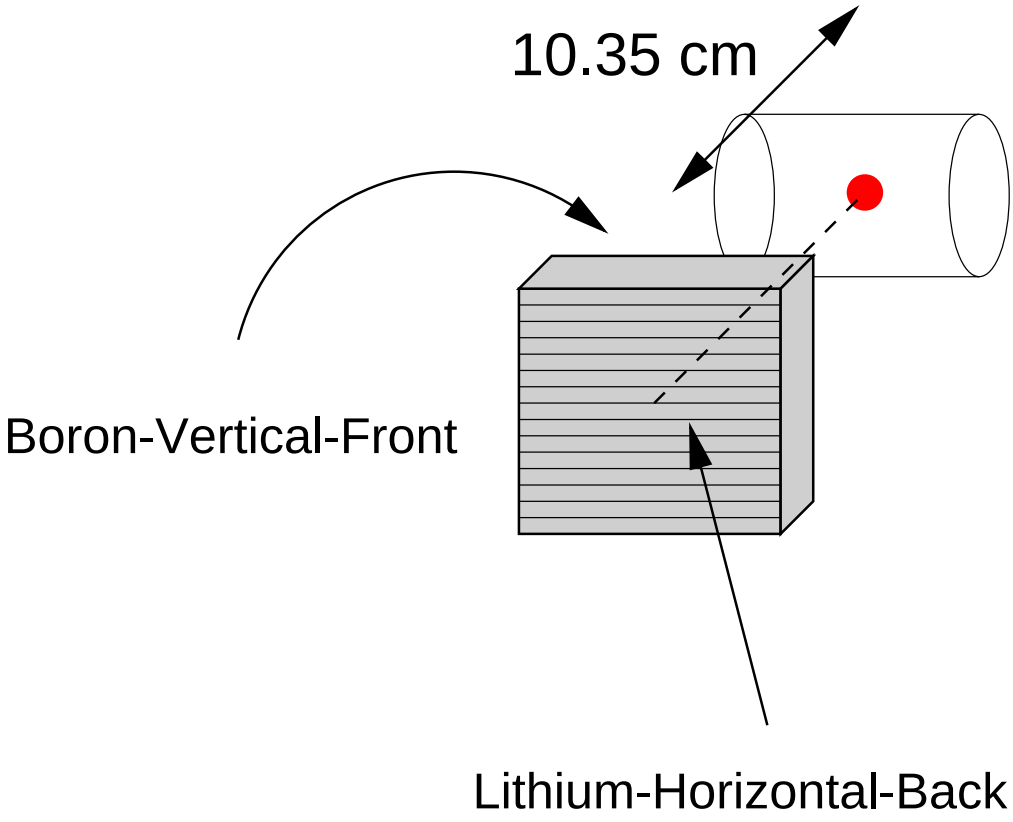
front face
vertical strips
ion-implanted boron
< 1μm deep

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




p-type germanium
(100)
Impurity
concentration
2x10^9 cm^-3
5x10^8 cm^-3
(001)
(010)


-
+
V_bias = 1300 V
V_dep =100-450 V
electrons
v ~ 6x10^6 cm/s
@80K
holes
v ~ 6x10^6 cm/s
@80K
B p+ contact
Li n+ rectifying
contact

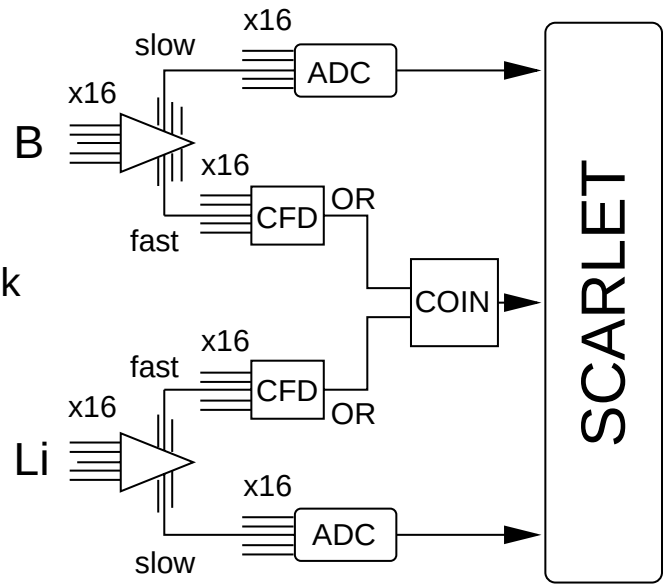


^{109}Cd, ^{57}Co, ^{139}Ce, ^{113}Sn,
^{137}Cs, ^{88}Y and ^{60}Co

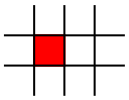
E_γ = 88 keV to 1.8 MeV

Calibrated strength

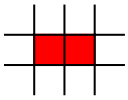
demand a front-back coincidence

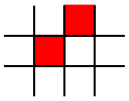


events associated with different multiplicity of strip hits in offline sorting using ROOT

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

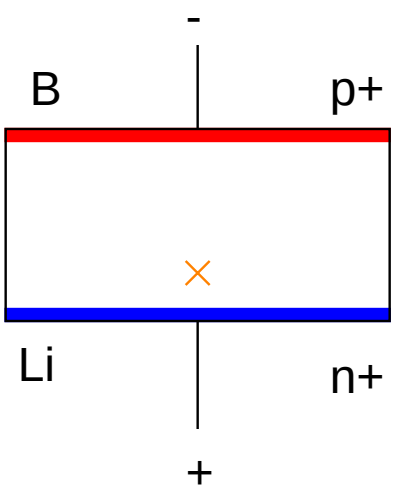
 $n_h = 2$, $n_v = 2$

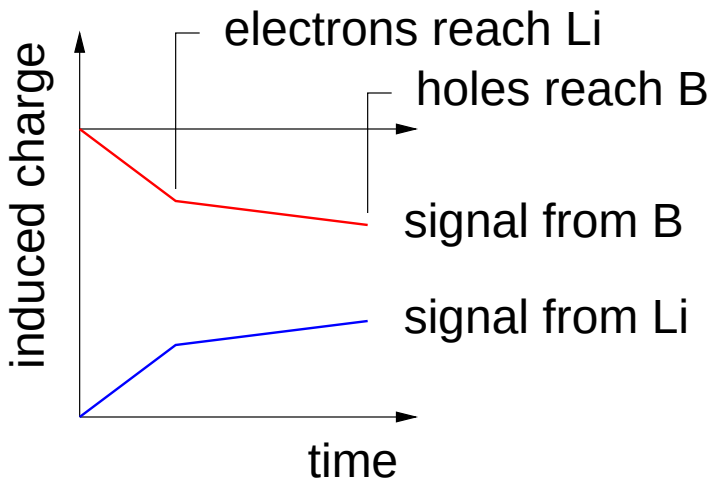
important above 800 keV

nearest neighbours dominate

Pulses in regular planar

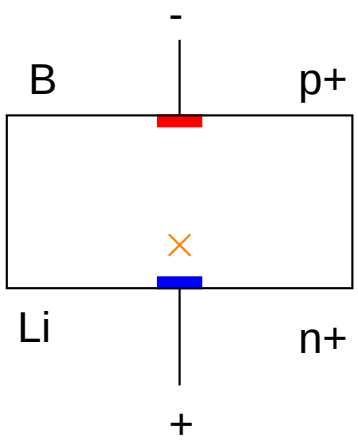
induced signals at each electrode due to both charge carriers

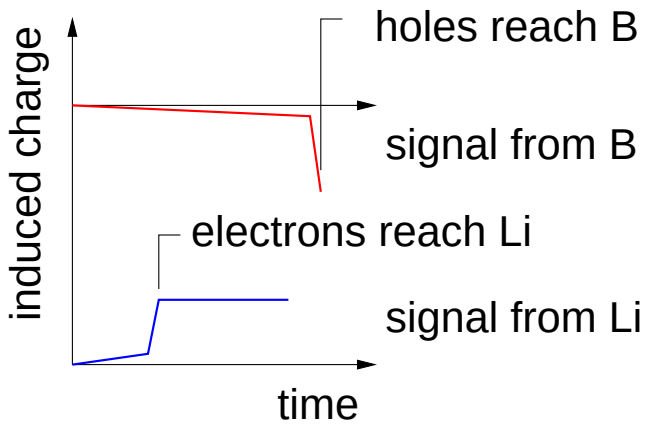




Small Electrode Effect:

induced signal in an electrode is small, until the charge that it will later collect arrives in its vicinity





Single-polarity charge sensing:

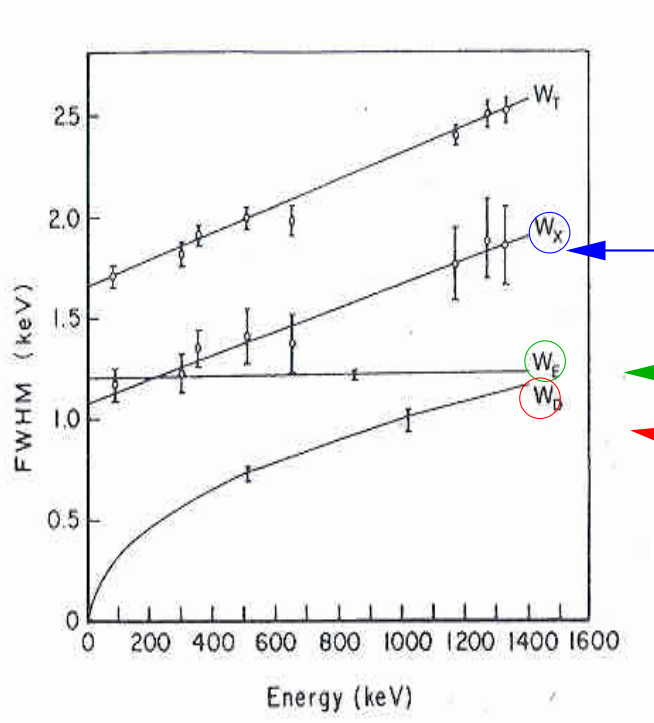
signal from Li is mainly due to electrons
signal from B is mainly due to holes

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:

typical planar:
800 eV @ 122 keV
1.7 keV @ 1.3 MeV

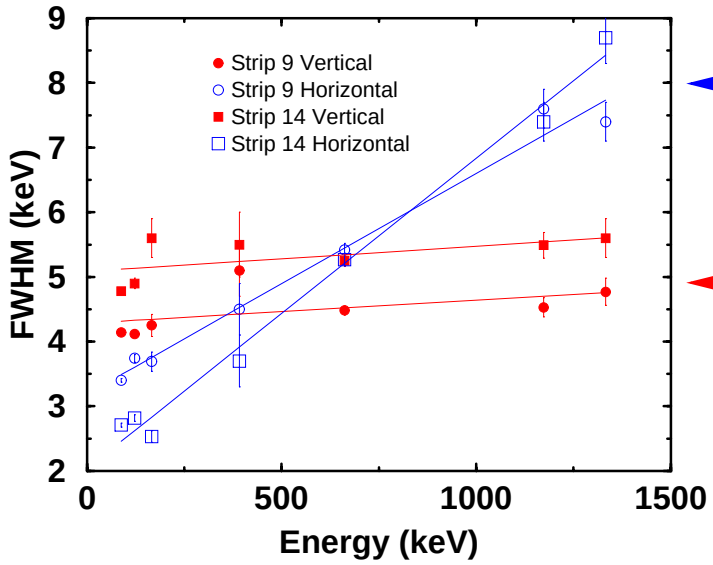


$$W_T^2 = W_X^2 + W_E^2 + W_D^2$$

fluctuations in charge collection

electronic noise

statistics of e-h pairs



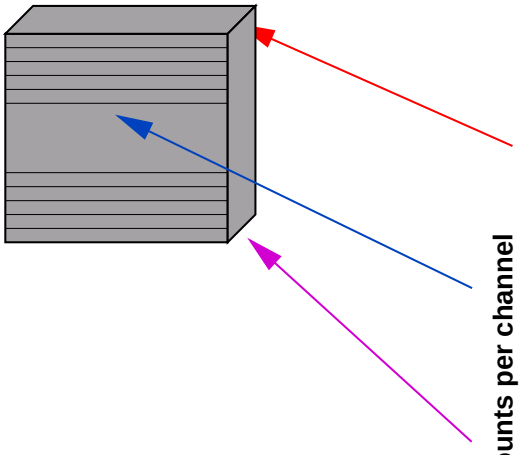
lithium strips

boron strips

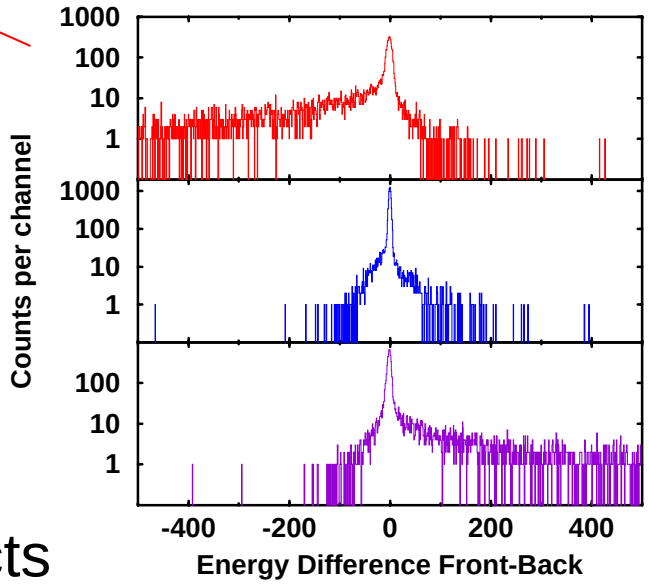
Charge collection efficiency:

bulk charge trapping
edge effects
low field regions
charge collection away from electrodes

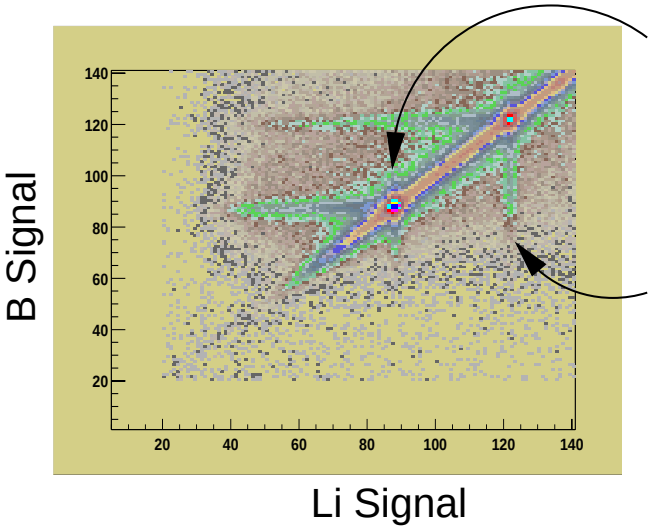
Edge Effects



Differences between front and back illustrate losses in charge which vary with position



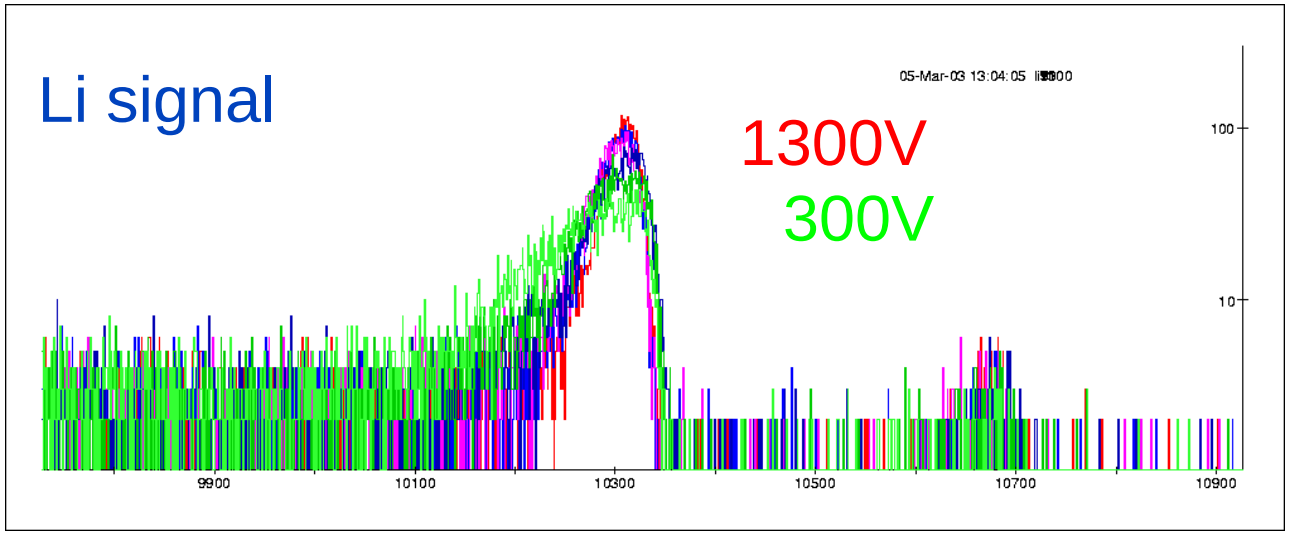
Bulk Trapping Effects

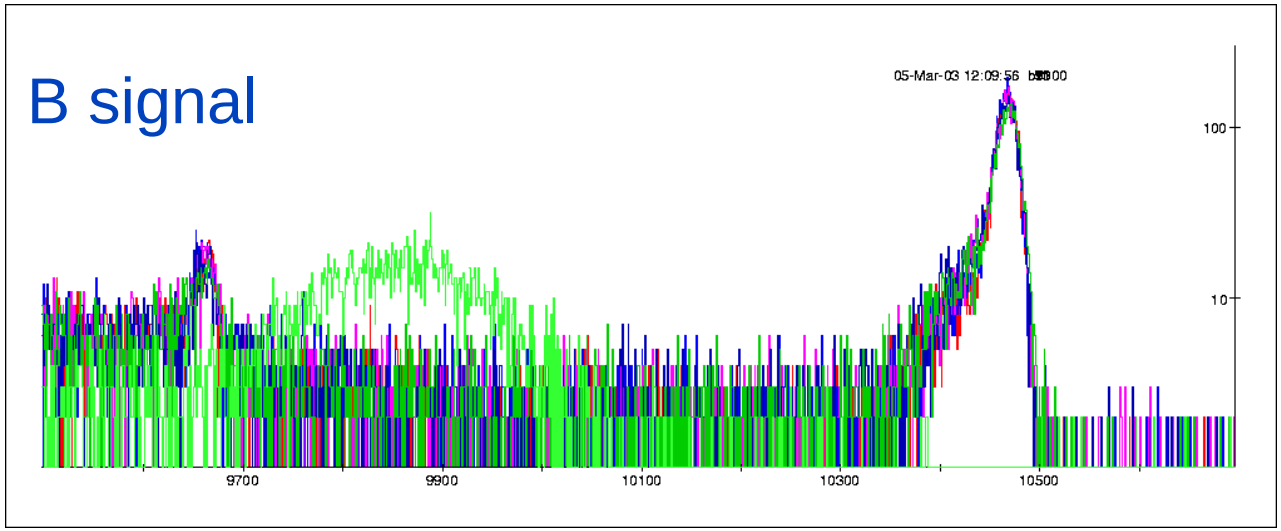


88 keV λ = 1.9 mm
surface deposition near B face
electron collection path large
more electron trapping

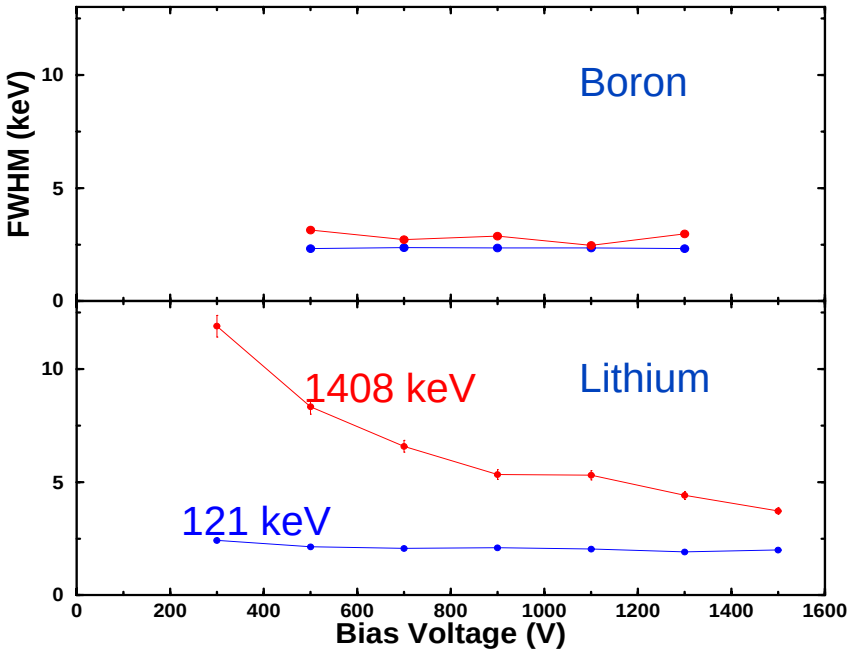
122 keV λ = 3.4 mm
penetrates further
less of a difference in trapping

Spectra as a function of bias voltage at 1408 keV





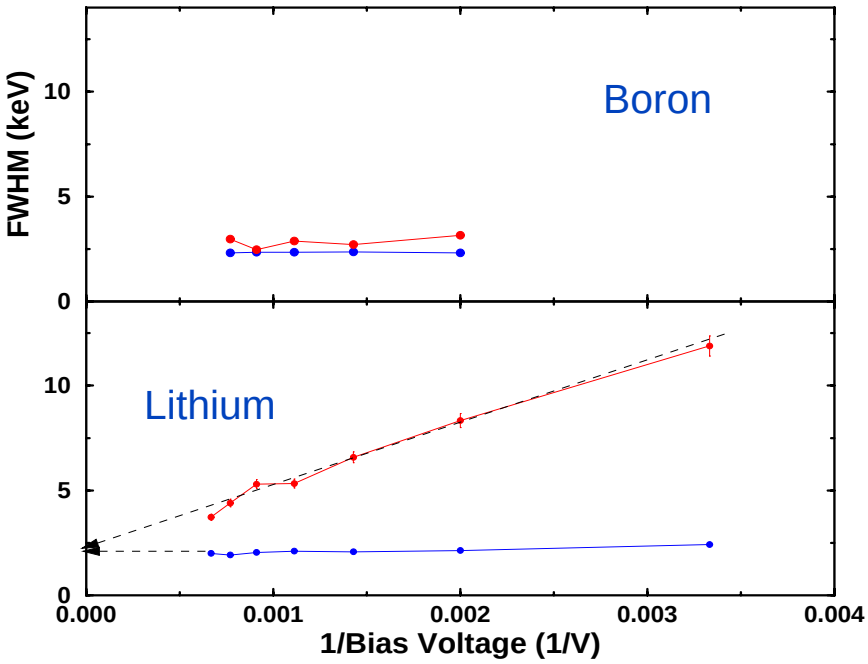
Resolution as a function of bias:



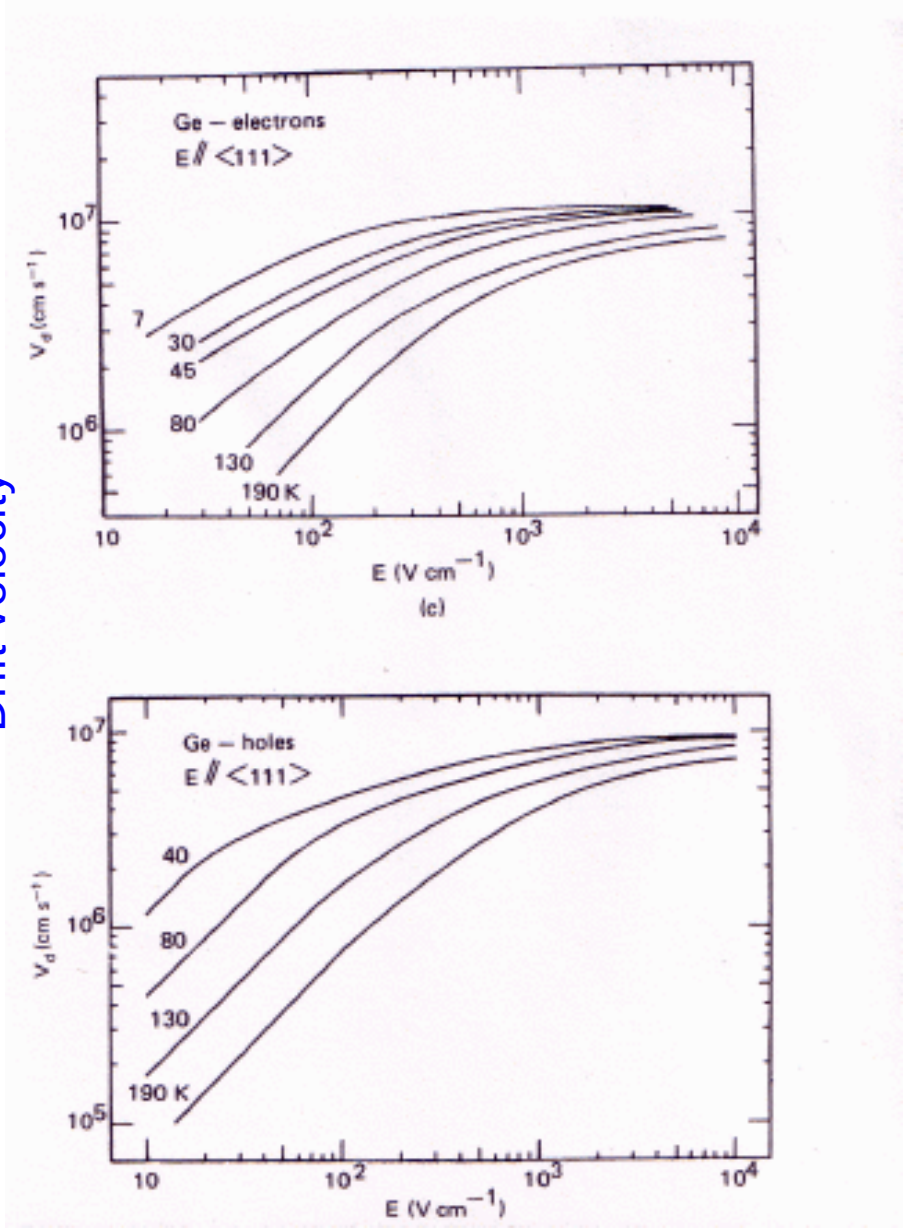
Estimate contributions by letting V get large:

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

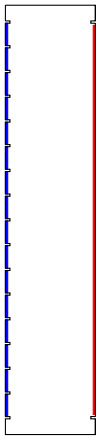
@122 keV
resolution dominated by electronic plus statistics



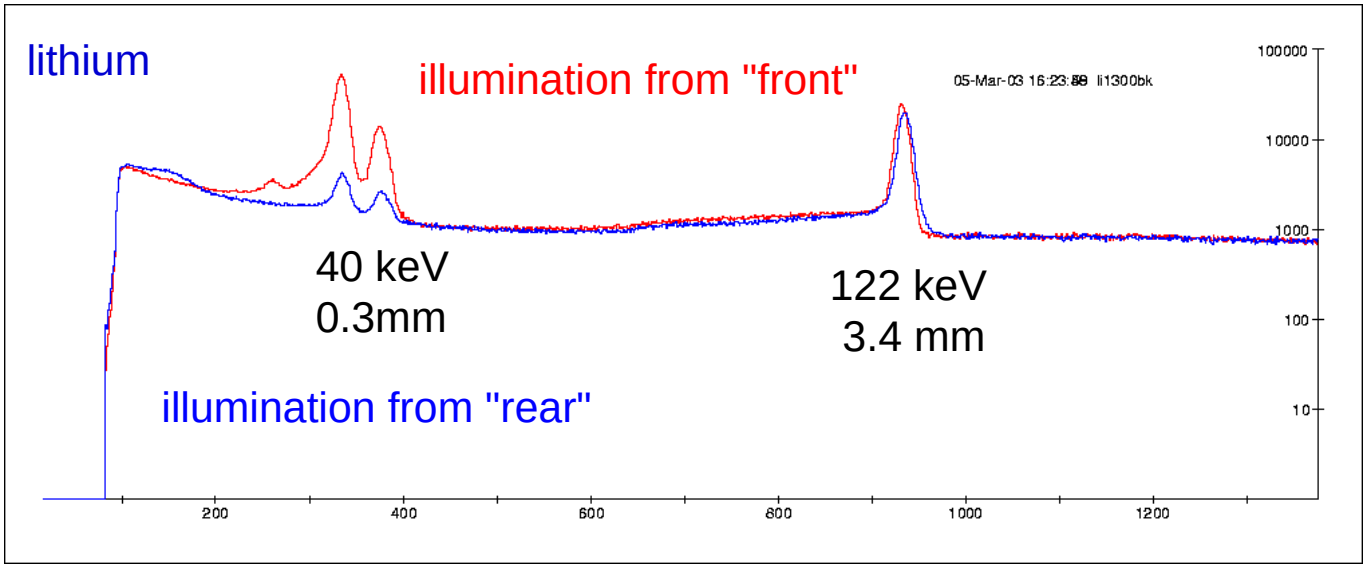
Drift velocity as a function of applied field:



lithium
"back"
0.6 mm depth



boron
"front"
<0.010 mm depth



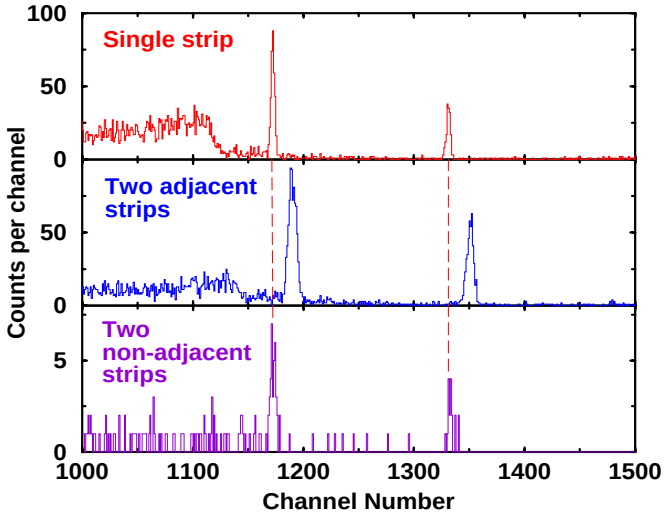
No measurable resolution difference between front and back illumination.....suggests not bulk trapping

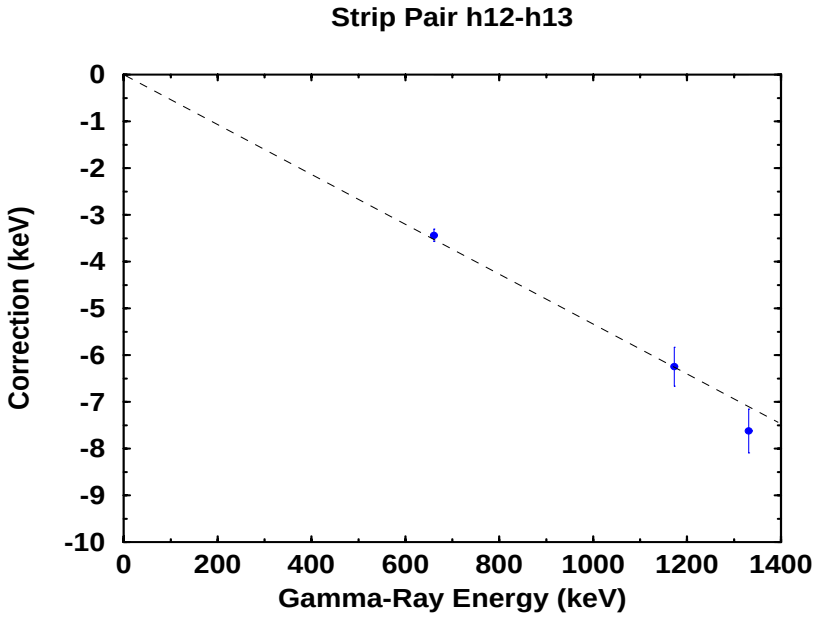
Two-Strip Cross Talk

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

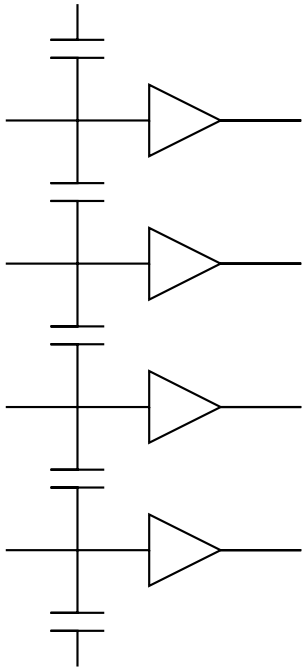
1 to 3% shift in the gain from one-pixel to adjacent two-pixel events

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

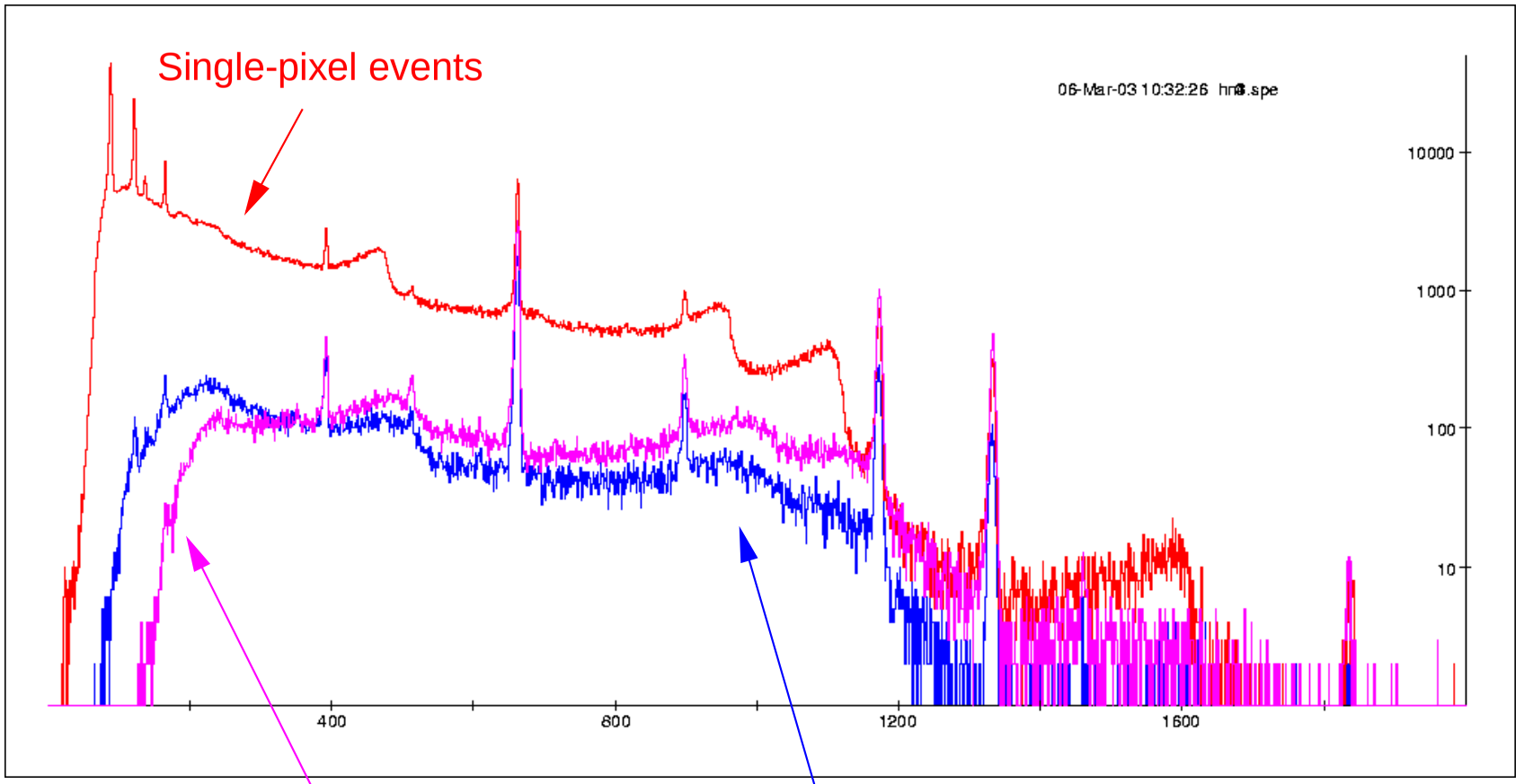
for two strip sum

adjacent

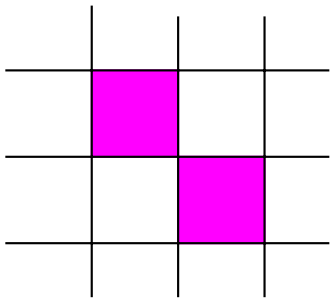
~ (Q/2 - q/2) + (Q/2 - q/2) = Q - q

non-adjacent

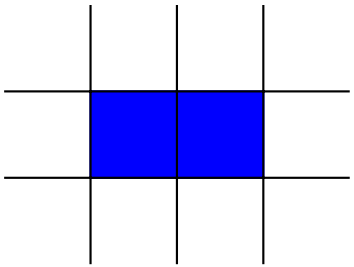
~(Q/2 - q) + (Q/2 -q) = Q - 2q



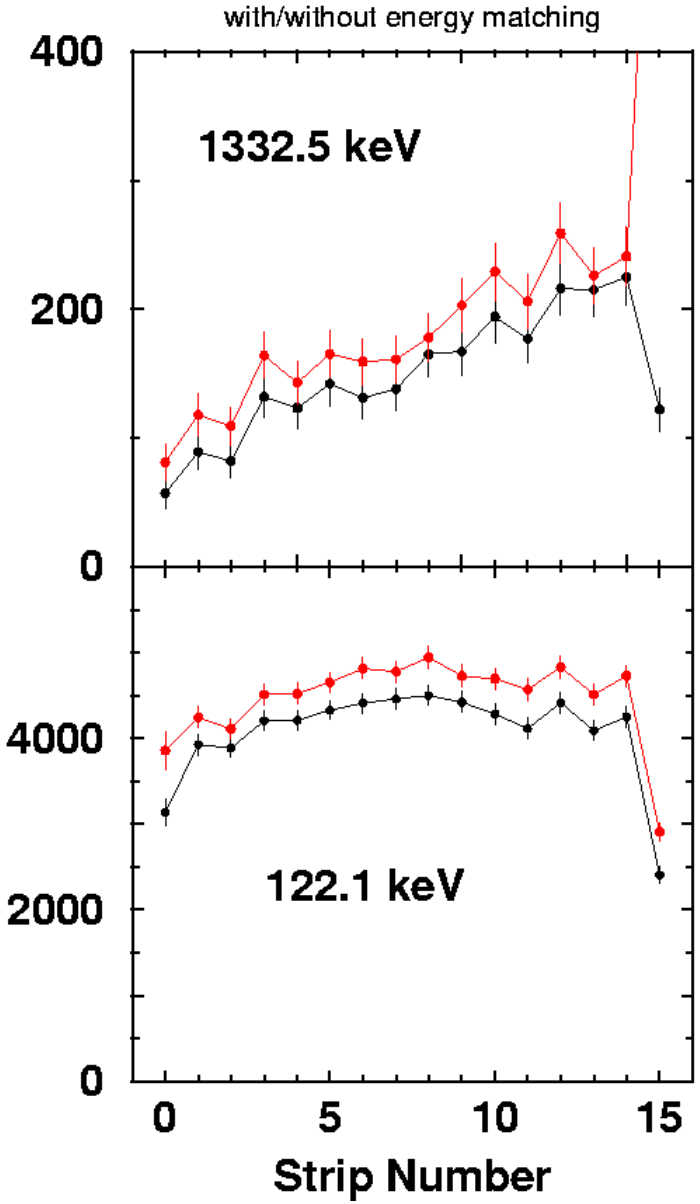
Two-pixel diagonal scatters:



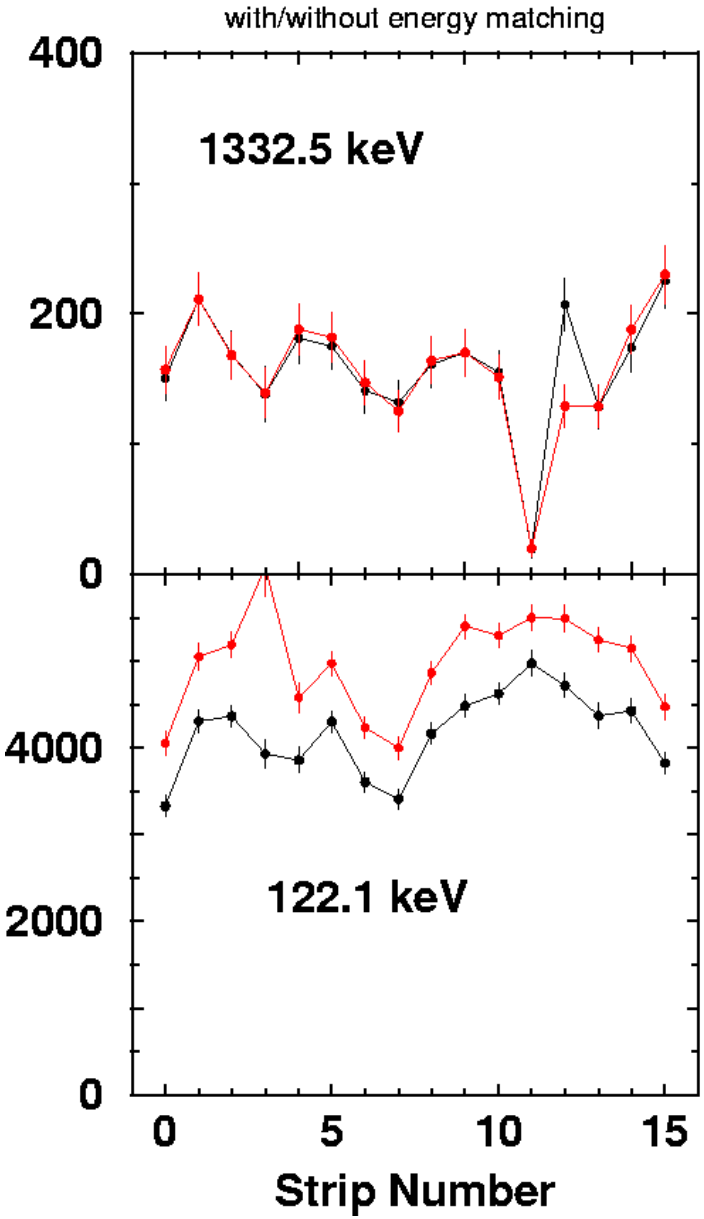
Two-pixel HV scatters:

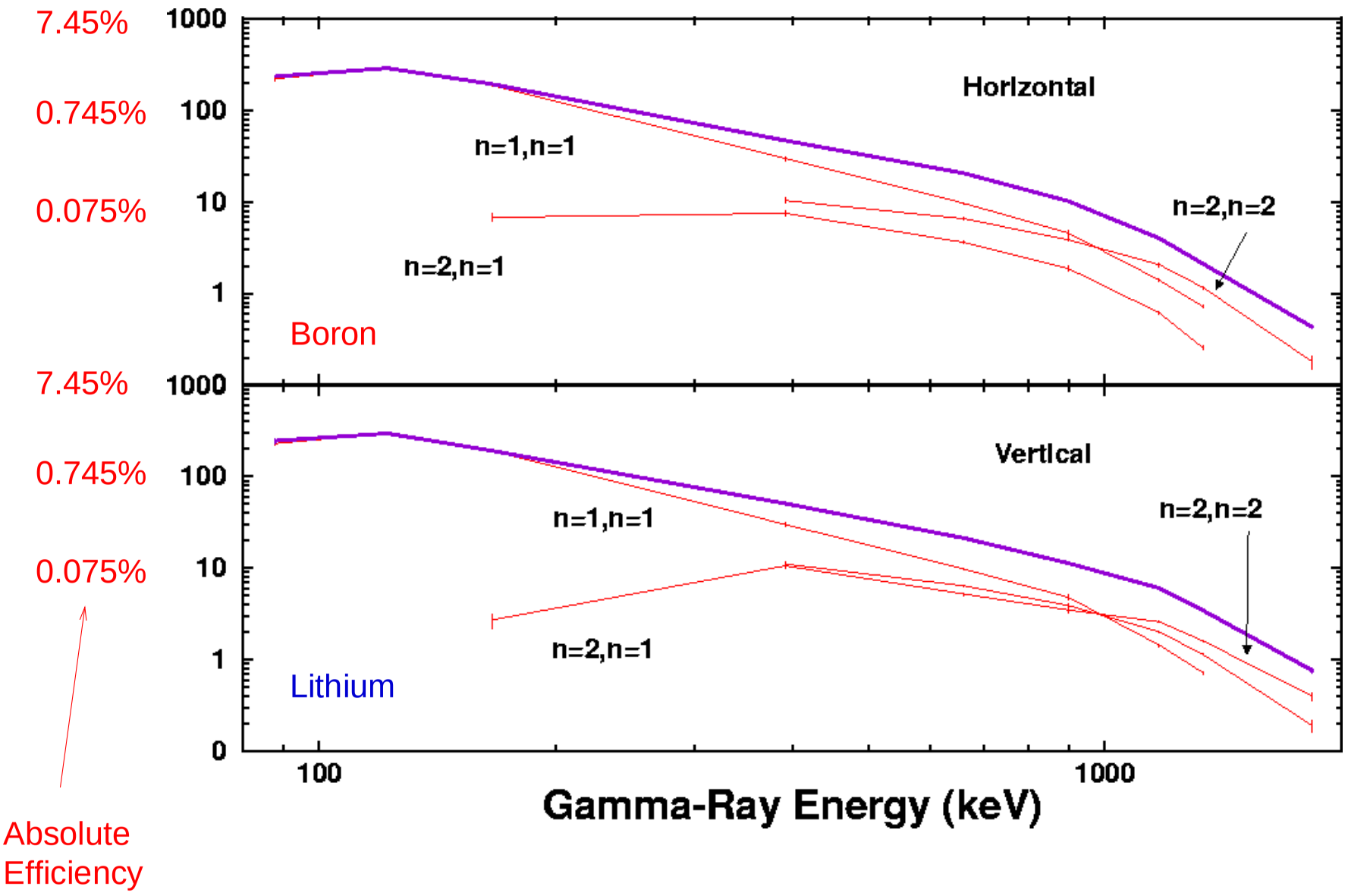


Horizontal Single Strip Relative Efficiency



Vertical Single Strip Relative Efficiency





@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.