Extracting information from partially depleted Si detectors with digital sampling electronics

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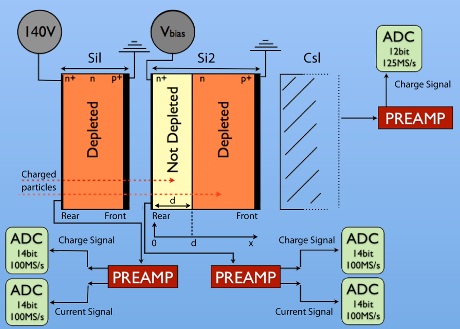
AIM:

Study of the performances (identification and energy measurement) of an underdepleted silicon detector. Five different bias voltages have been used, one corresponding to full depletion (used as a reference for comparison), the other ones associated with a depleted layer from 90% to 60% of the total detector thickness. [1]

MEASUREMENT SETUP

- Si1 310μm thickness, Si2 511μm thickness and CsI(Tl) ~10cm thickness
- Si detectors reverse mounted to improve PSA identification [2]
- Current and charge signals separately digitized by dedicated ADC [3]
- Si detector cut at 7° with respect to crystalline planes or axes to avoid channeling [4]



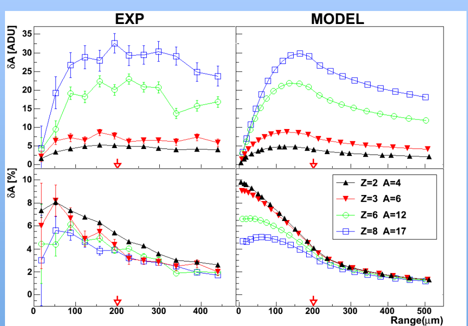
Si1 bias voltage: fixed at 140V (slightly above depletion)
Si2 bias voltage: five different values have been tested (105, 130, 200, 235, 290 V)

Vbias (V)	d (μm)	Max RiseTime (20-70%)(μs)
105	200	13
130	170	10
200	90	3
235	50	1.5
290	0	0.45

Underbiased detector requires long collection time

Our results were achieved using relatively long acquired signals (~70μs) and shaping time (~50μs)

CHARGE COLLECTION EFFICIENCY

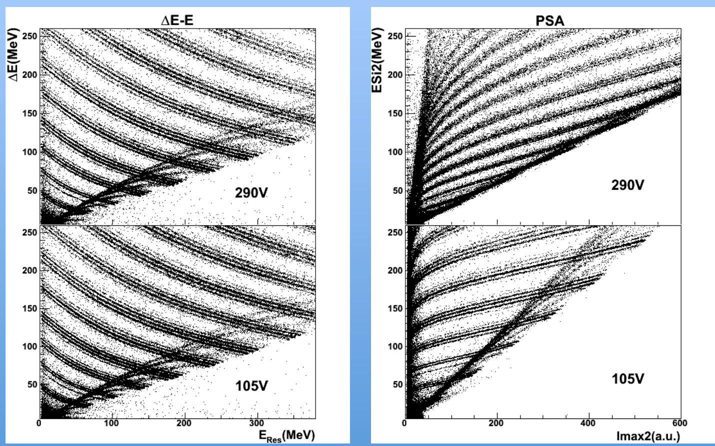


Left panels: difference between charge signal amplitude at 105V and 290V (full depletion) as a function of particle range. Right panels: results from a simple model assuming variable collection efficiency depending on penetration depth and Stopping Power

$$\eta(x) = \begin{cases} \eta(0) + (1-\eta(0))\frac{x}{d} + \alpha \left|\frac{dE}{dx}\right| \frac{d-x}{d}, & \text{if } x < d. \\ 1, & \text{if } x \geq d. \end{cases}$$

- Collected charge (even at 105V) only few % < than at full depletion
- Efficiency increases as fragments penetrate the depleted region
- Using a polynomial calibration it is possible to correct for efficiency variation

CHARGED FRAGMENTS IDENTIFICATION



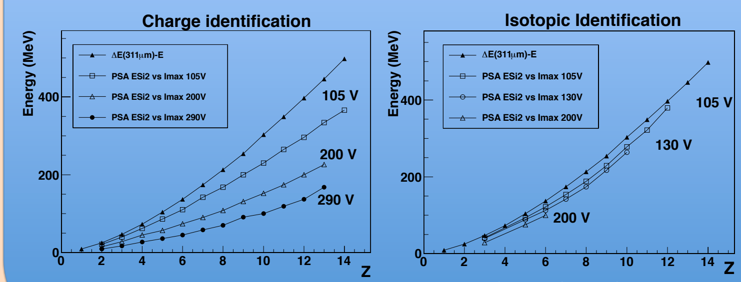
Isotopic resolution not changed by underbiasing (even at 105 V)

A much better isotopic separation (albeit with somewhat higher energy thresholds) is obtained using an underbiased detector

ENERGY THRESHOLD FOR IDENTIFICATION

ΔE-E: threshold is defined as the energy necessary to punch through Si1.
PSA:

- charge identification threshold was obtained from visual inspection of the left end of the correlation
- Isotopic identification threshold is the energy for which the FoM (Figure of Merit) relative to adjacent isotopes becomes >0.7 [3]



The lower the applied voltage, the higher the energy threshold for identification for a given Z
The lower the applied voltage, the larger the maximum Z for wich isotopic identification is achieved

CONCLUSIONS

High charge collection efficiency:

- For 60% depletion, less than 10% of the total charge is lost for short range fragments
- Collection efficiency for punching through fragments ~97-98%

ΔE-E identification not affected by underbias, even for 60% depletion
PSA identification:

- Isotopic identification improves with underbias (identification not even possible at full depletion due to doping non-uniformity of about ~6% [5])
- Energy thresholds for Z identification via PSA increase with underbias

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