

# Charge Collection in Single-Column 3D Detectors

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# Analysis of CCE - V on 3D sensors

## Sensors

P-type strip-like Sensors  $\sim 500\mu\text{m}$  thick,  $\sim 150\mu\text{m}$  single columns (n+/p)

## Depletion Pattern on 3D:

C-V and Cint-V

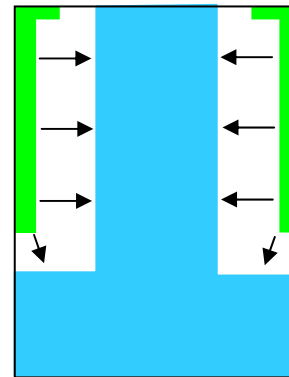
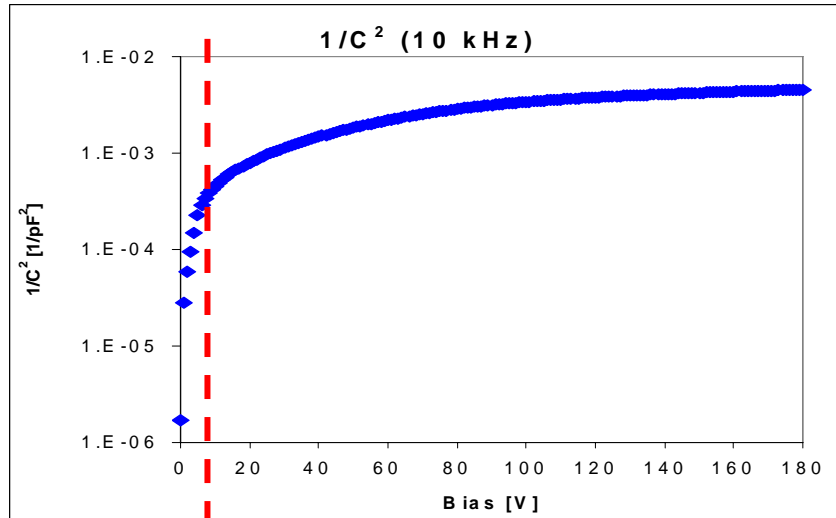
Consequences for CCE

## 2 CCE systems:

Beta source  $^{90}\text{Sr}$  with scintillator trigger

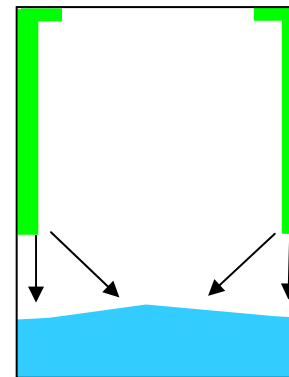
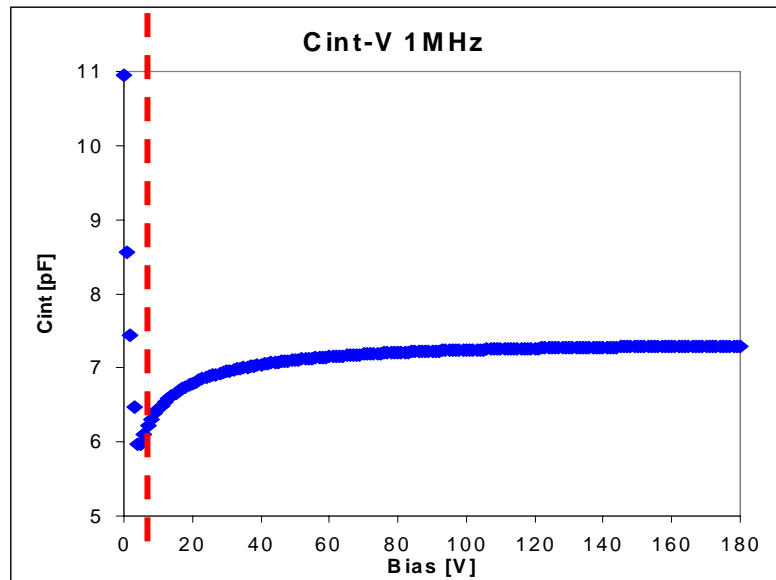
- Analog DAQ (Firenze)  
2  $\mu\text{sec}$  shaping time, pad sensor
- Binary DAQ (Santa Cruz)  
100 ns shaping time: strip sensor

# Depletion Pattern on 3D SSD: C-V and C<sub>int</sub>-V



Voltage Range 1:  
region between col.  
is not fully depleted  
⇒ large capacitance

**full dep. between columns  
~ 7V**

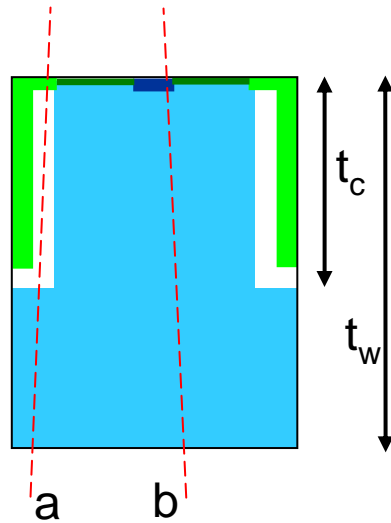


Voltage Range 2:  
region between col.  
is fully depleted  
⇒ depletion proceeds  
only towards the back  
(almost like a planar diode)

full depletion ~200V  
depletion width of  
~150+350μm

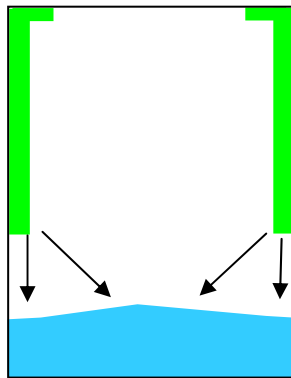
# Depletion Pattern → CCE Pattern

## Mean collected charge & Inefficiency



Voltage Range 1 (bias <  $\sim 7V$ ):  
 there are lateral depleted regions near each column which are  $t_c$  in depth.  
 Charges generated by traces like b are not collected.

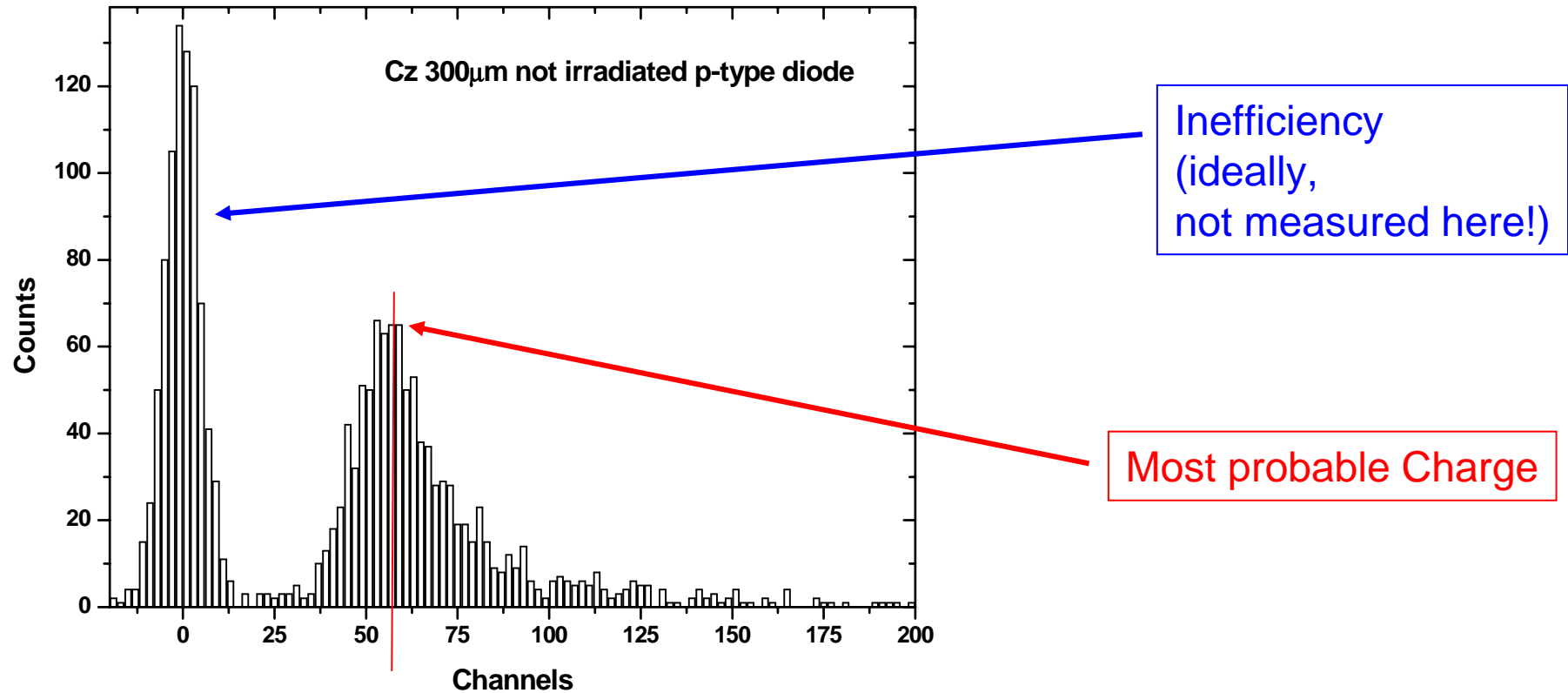
-> Charge collected =  $4fC \cdot (t_c/300\mu m) \sim 2fC$   
 -> Inefficiency = fraction of un-depleted area between columns



Voltage Range 2 (bias >  $\sim 7 V$ ):  
 region between columns is fully depleted

Depletion depth =  $t_w$   
 -> Charge collected =  $4fC \cdot (t_w/300\mu m)$   
 -> No Inefficiency

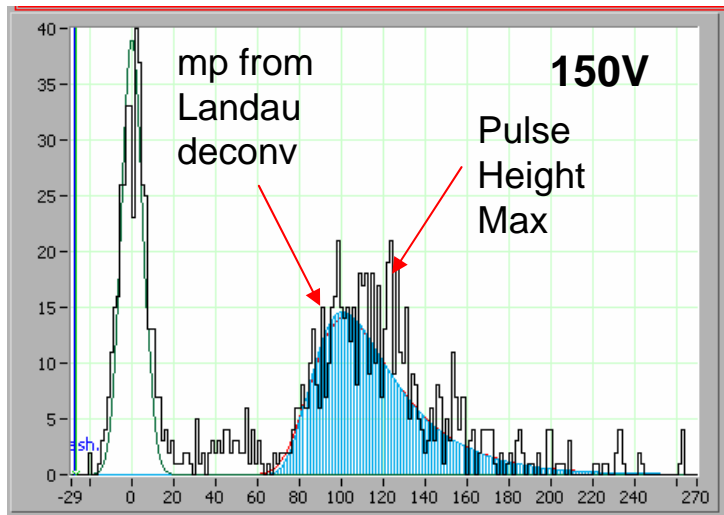
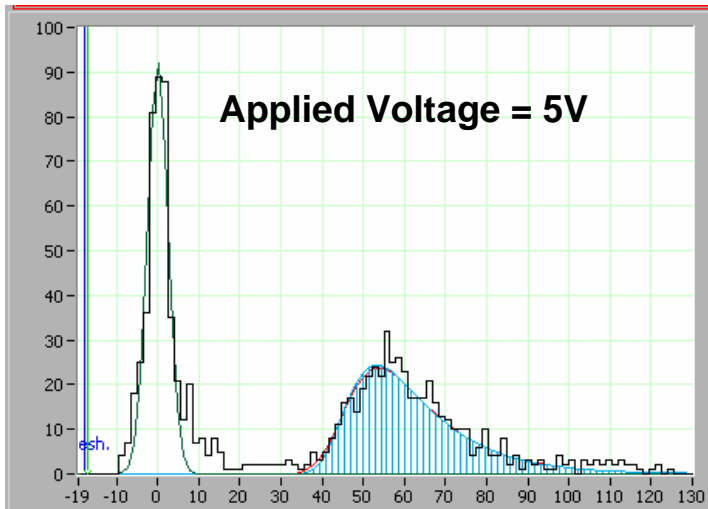
# Analog DAQ (Firenze) : Pad Sensor



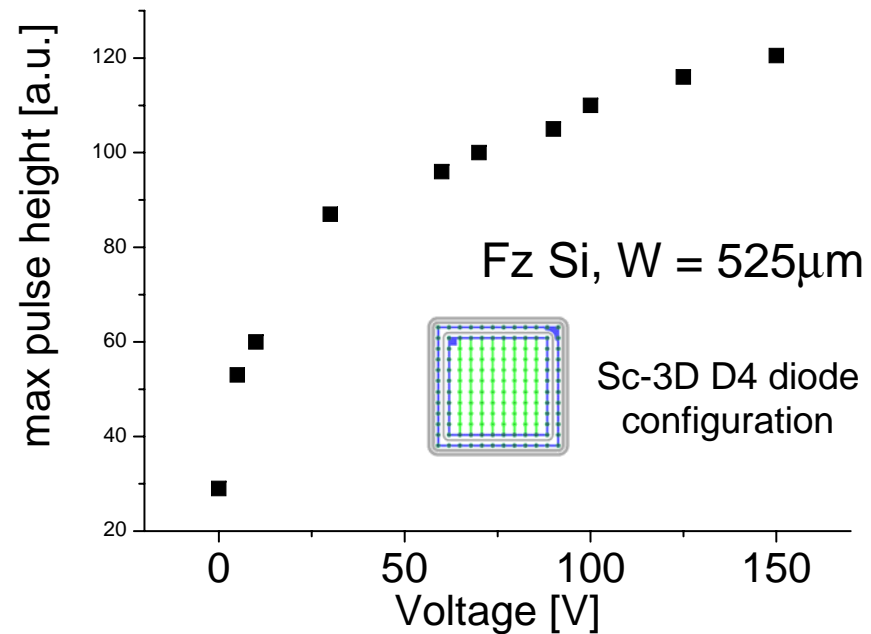
Inefficiency = fraction of undepleted area  
Mean charge  $\sim$  depleted thickness

# Pad Sensor Analysis

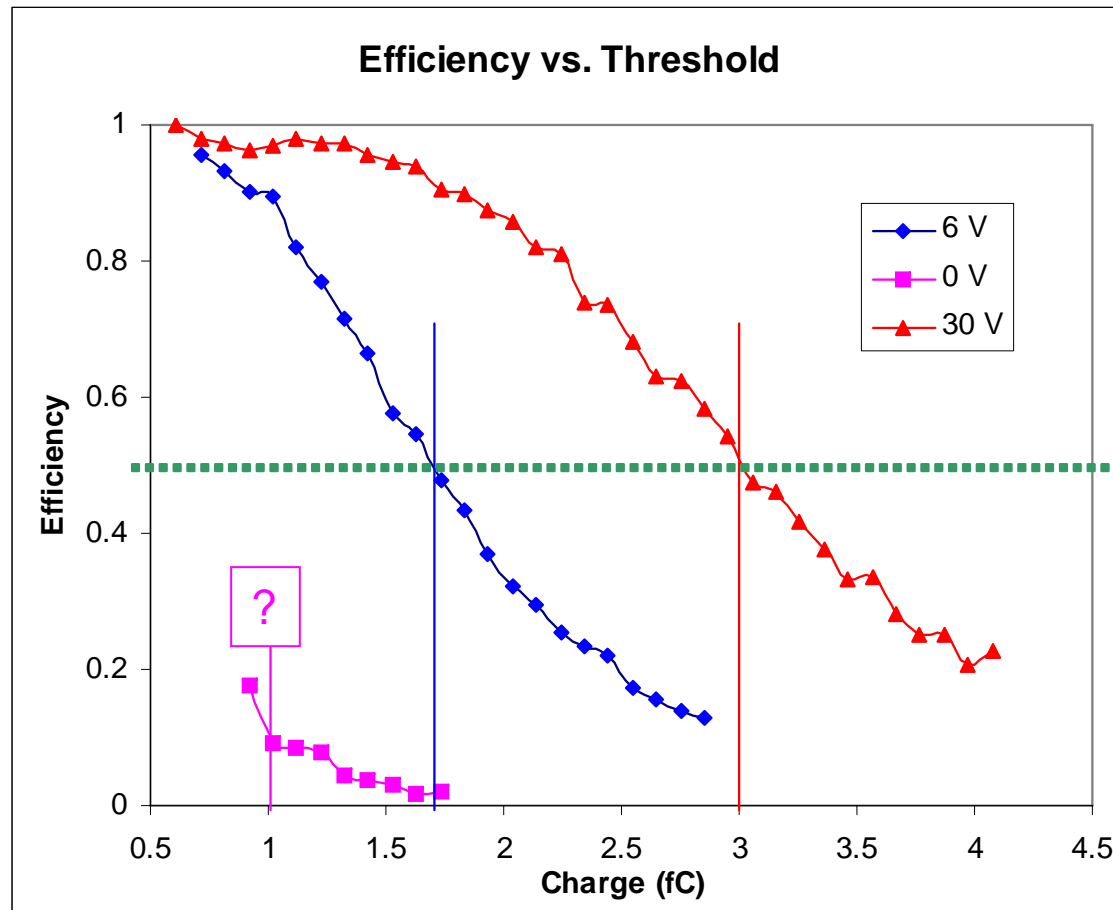
Analog DAQ (Firenze) with deconvolution software (NIKHEF)



Discrepancy between pulse height and simulated Landau is observed at high voltage. Most probable value of pulse height is determined by Landau deconvolution only in the range 0-60V. At 70-150V the most probable value taken is max of pulse height spectrum.



# Binary DAQ (Santa Cruz) Strip Sensor



(We define the median as the collected charge)

At 6V:

Collected charge = 1.7 fC

As expected from 140  $\mu\text{m}$

Inefficiency = 0

i.e. un-depleted area = 0

At 0V:

Collected charge  $\sim$  1fC

Inefficiency > 80%?

At 30V:

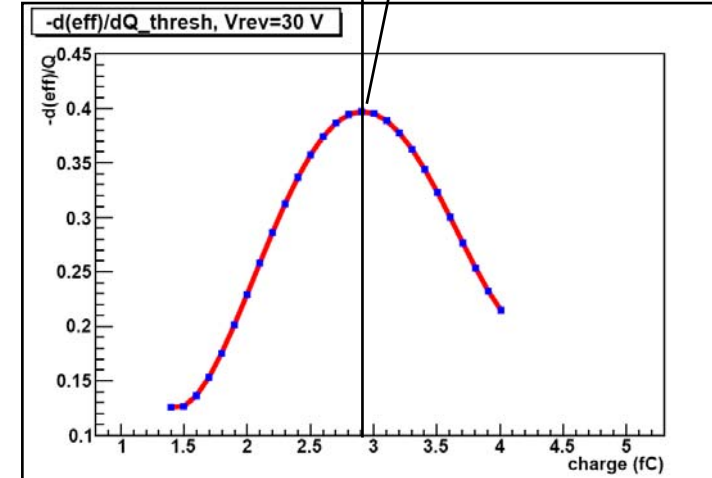
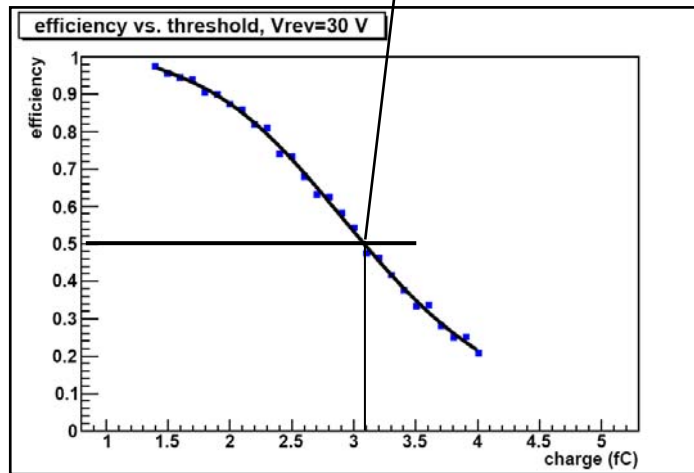
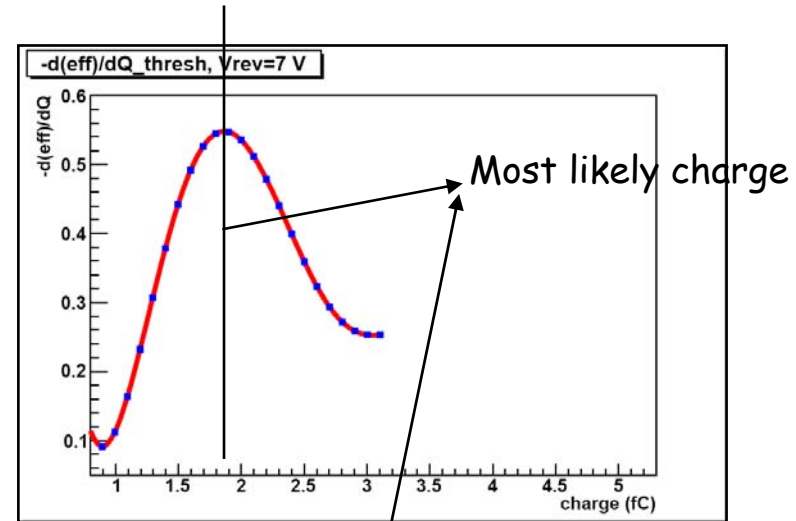
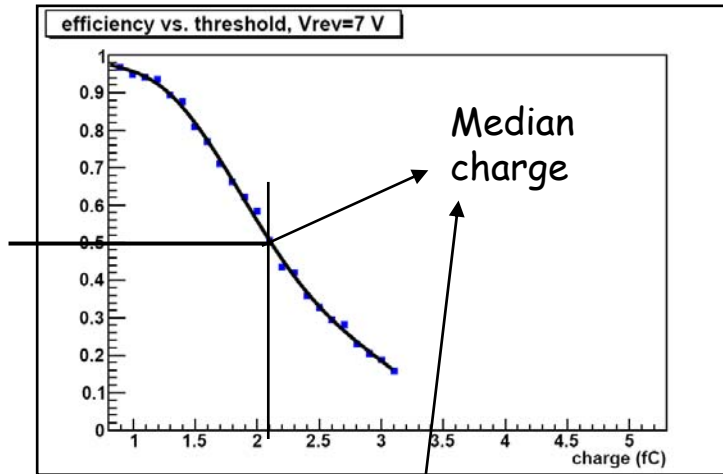
Collected charge = 3.0 fC

As expected from 280  $\mu\text{m}$

Inefficiency = 0

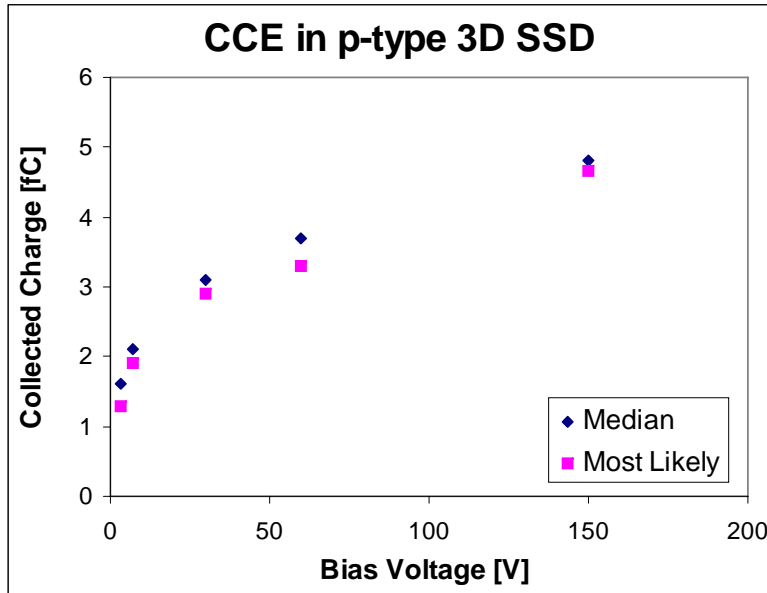
i.e. un-depleted area = 0

# Reconstruction of Pulse Height Spectrum

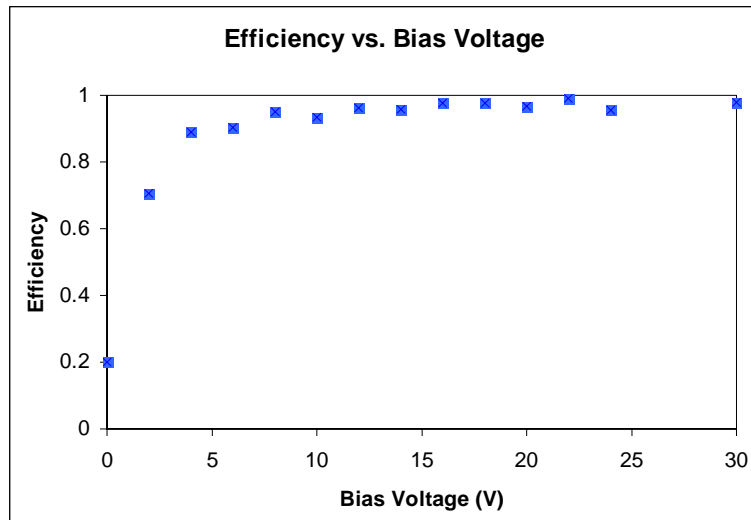




# Mean Charge and Inefficiency

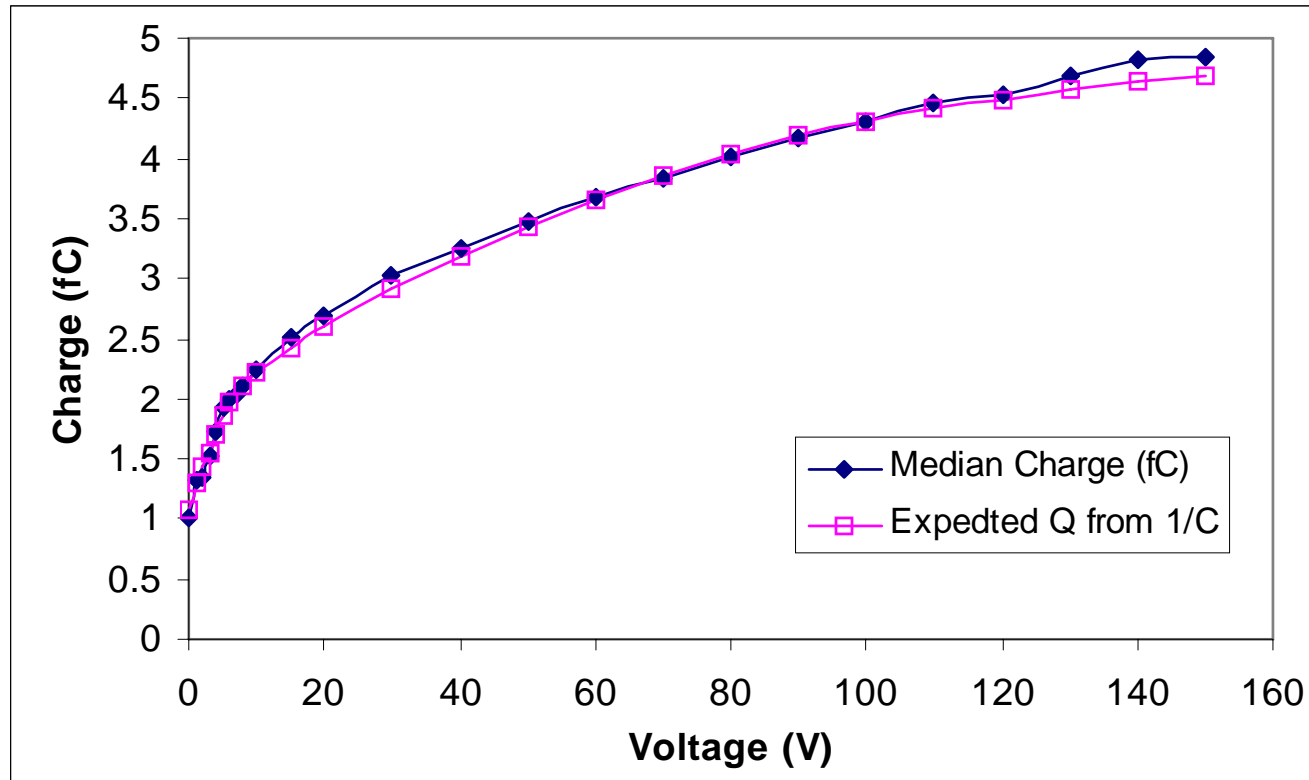


Collected charge:  
Increases with bias voltage  
(Square root behavior beyond  $\sim 7V$ ?  
Not yet saturated at 150 V)



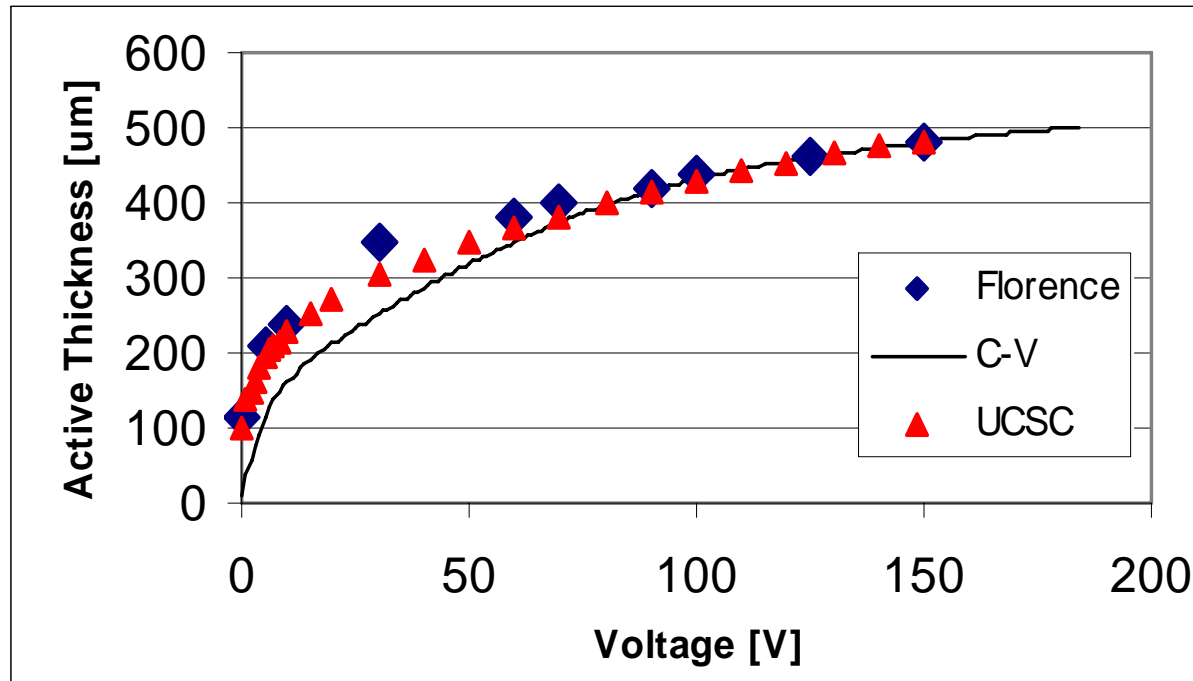
Efficiency varies only below  $\sim 7V$ ,  
 $\sim 100\%$  beyond.

# Binary DAQ (Santa Cruz)



Collected charge: compares well with Ansatz  $Q = 1\text{fC} + \text{const}/C$

# Charge Collection Comparison: Pads vs. SSD, 100 ns vs. 2.4 $\mu$ s



All data normalized  
at 150 V bias.

Good agreement  
between UCSC (100ns)  
and FI (2.4 $\mu$ s).

Higher active thickness  
than from C-V i.e.  $d \sim$   
 $1/C$  (diffusion?)

# Conclusions

## Charge Collection vs. voltage confirms simple picture of depletion in single-column 3D sensors:

- Rapid depletion between columns ( $< 10$  V)
- Slow, planar-diode like depletion beyond that
- Voltage dependence of charge collection about same for SSD (100 ns) and pads (2.4  $\mu$ s)
- Collected charge larger than predicted from  $1/C$  at lower voltages

### Acknowledgments:

IITC-irst team for production of 3D detectors

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