Surface Warfare Center Division

Assessing Alpha Particle and Neutron Induced Single Event Transient Vulnerability in a 90-nm CMOS Technology

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MURI Review Meeting
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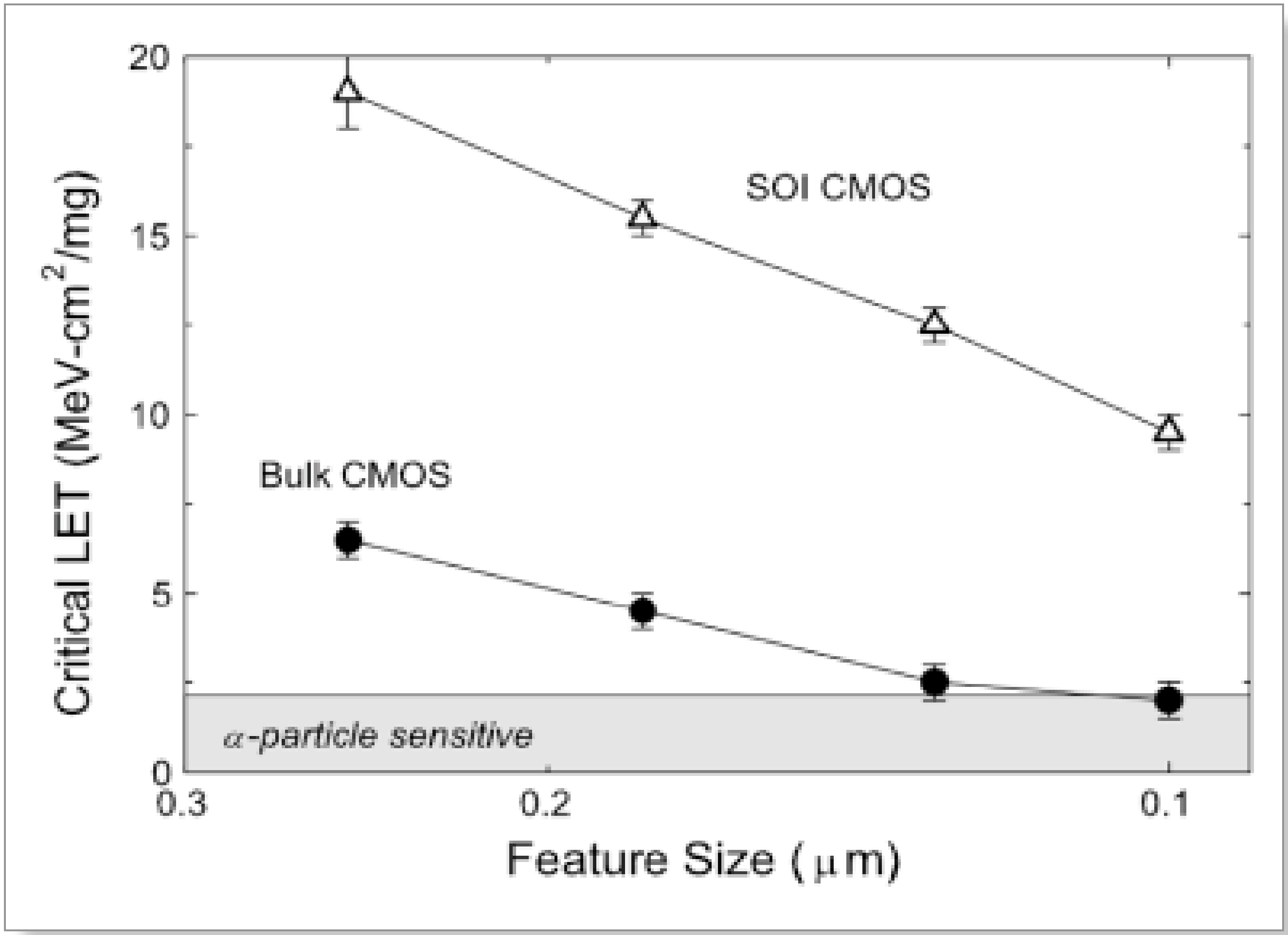
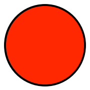
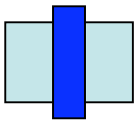
Background



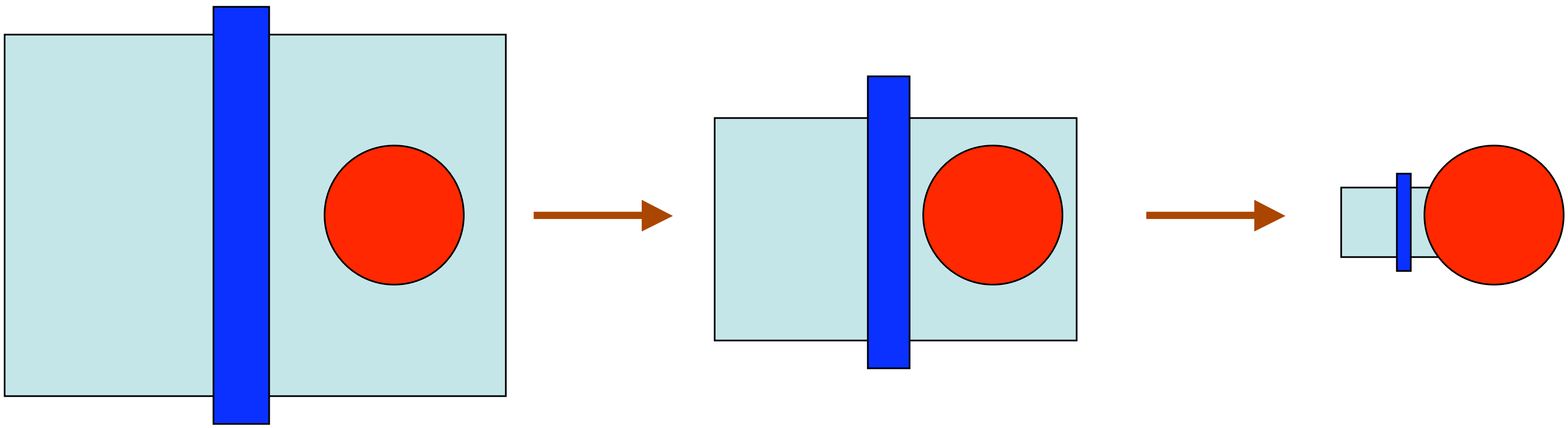
Critical LET for Unattenuated SET Propagation
(Dodd et al. 2004 TNS)

Perspective

 = radius of influence[1] of an ionizing particle

 = top view of an MOS transistor

[1] Sibley et. al. (2008 HEART Conference)

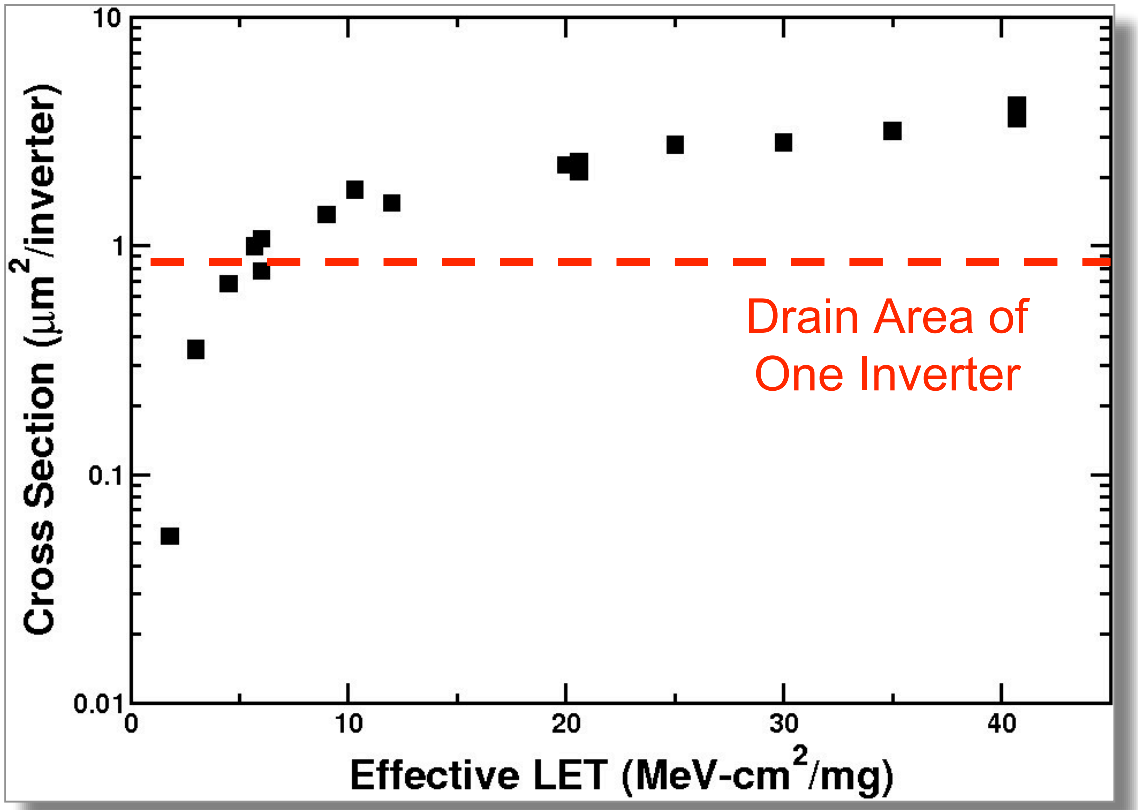


In older technologies, the radius of influence was much smaller than the size of a transistor

In newer technologies, the radius of influence can be larger the size of the transistor

Heavy-ion SET data

- Heavy ion data taken at Texas A&M
- Cross section plotted is the number of SETs divided by the fluence
- Saturated cross section was much larger than the area of the drain of one inverter – sensitive volume larger than drain area



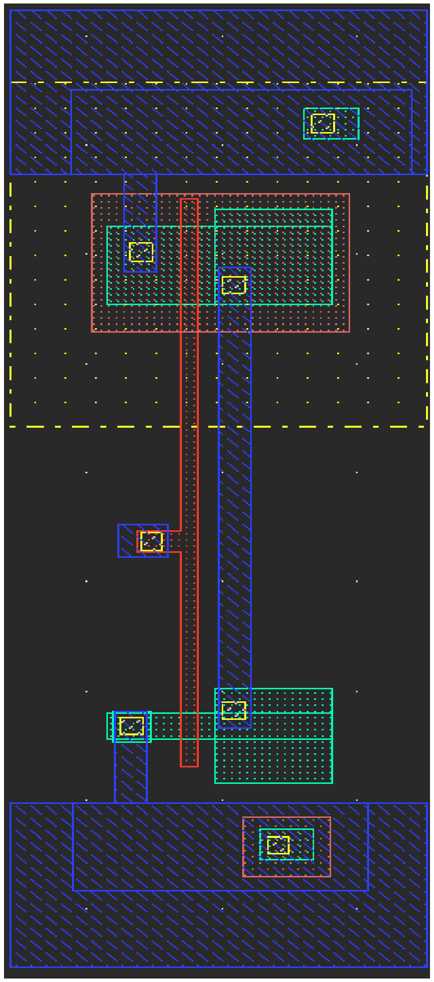
<u>5.5 MeV Alpha Cross Section</u>

6.74×10^{-4} μm²/inverter
(two orders lower than low LET heavy-ion data)

Only a small fraction of alpha particles are creating an SET

Test Chip Details

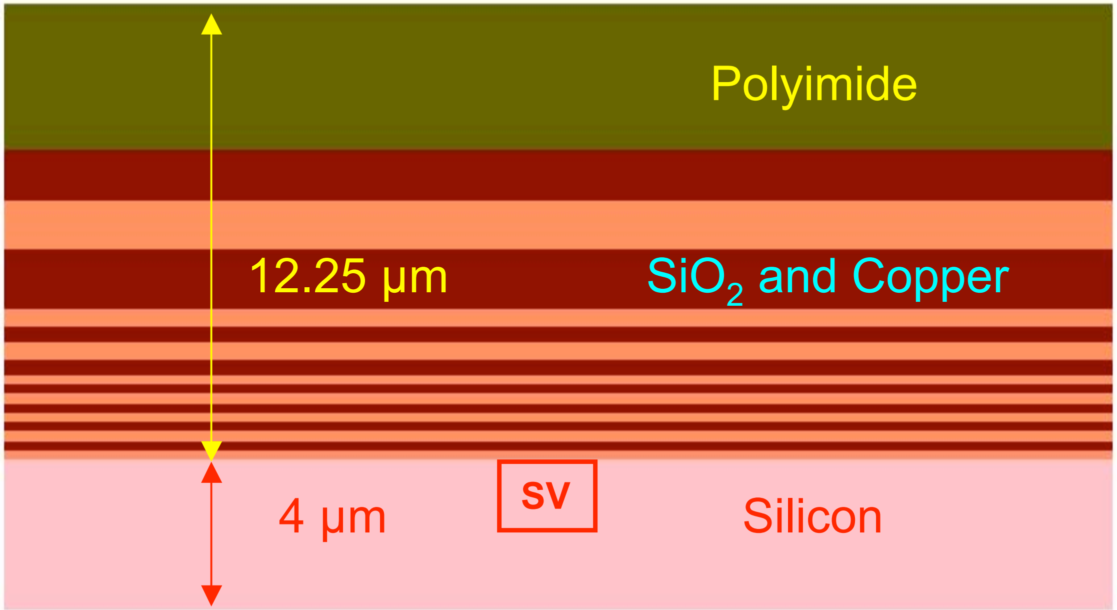
- SET pulse width measurement test chip (Narasimham et al., TDMR, 2006)
- Fabricated in IBM 90-nm process
- SET cross section and pulse width data obtained with different energetic particles
- MRED simulations to understand SET cross sections
  - Layout and overlayer info – critical inputs for MRED



Layout of an inverter in the SET test chip

MRED Device Setup

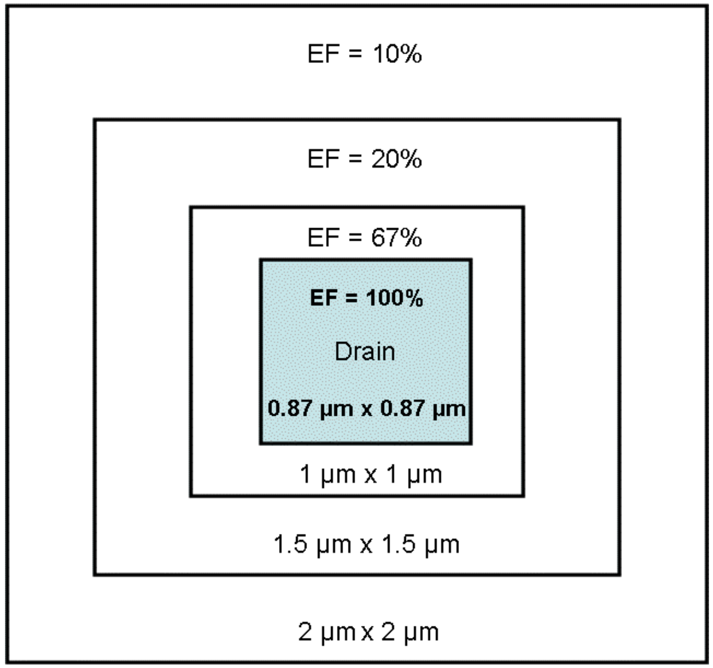
- Simulated structure was a 50 µm × 50 µm × 16.25 µm cube
- Overlayers in this process are 12.25 µm thick
- Multi-weighted sensitive volume placed in the center and top of the silicon block



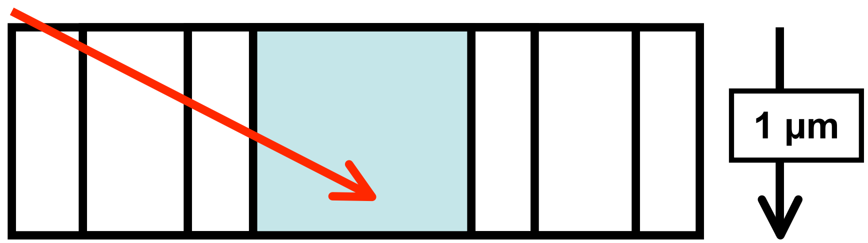
Side view of the structure used for MRED simulations

Sensitive Volume Setup

- Sensitive volumes were fitted to the heavy ion data
- Multiple regions within the sensitive volume were defined
- Each region has a different efficiency factor (EF)
- Contributions from all regions are summed to obtain the total charge in the sensitive volume

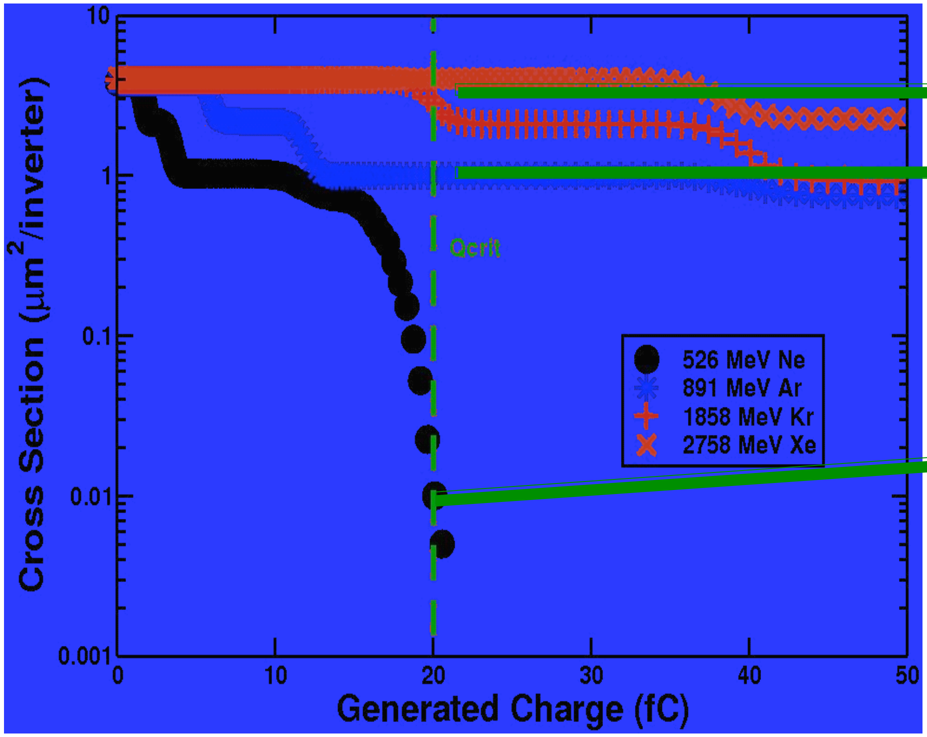


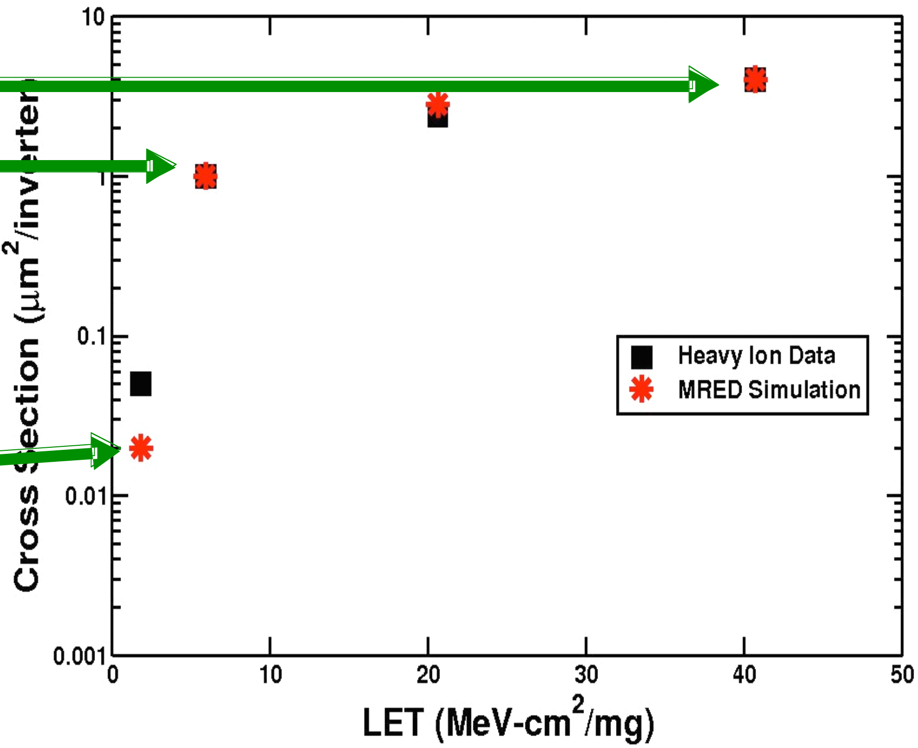
Top view of the sensitive volume used for MRED simulations.



Side view of the sensitive volume used for MRED simulations.

Calibrating the Simulation Model

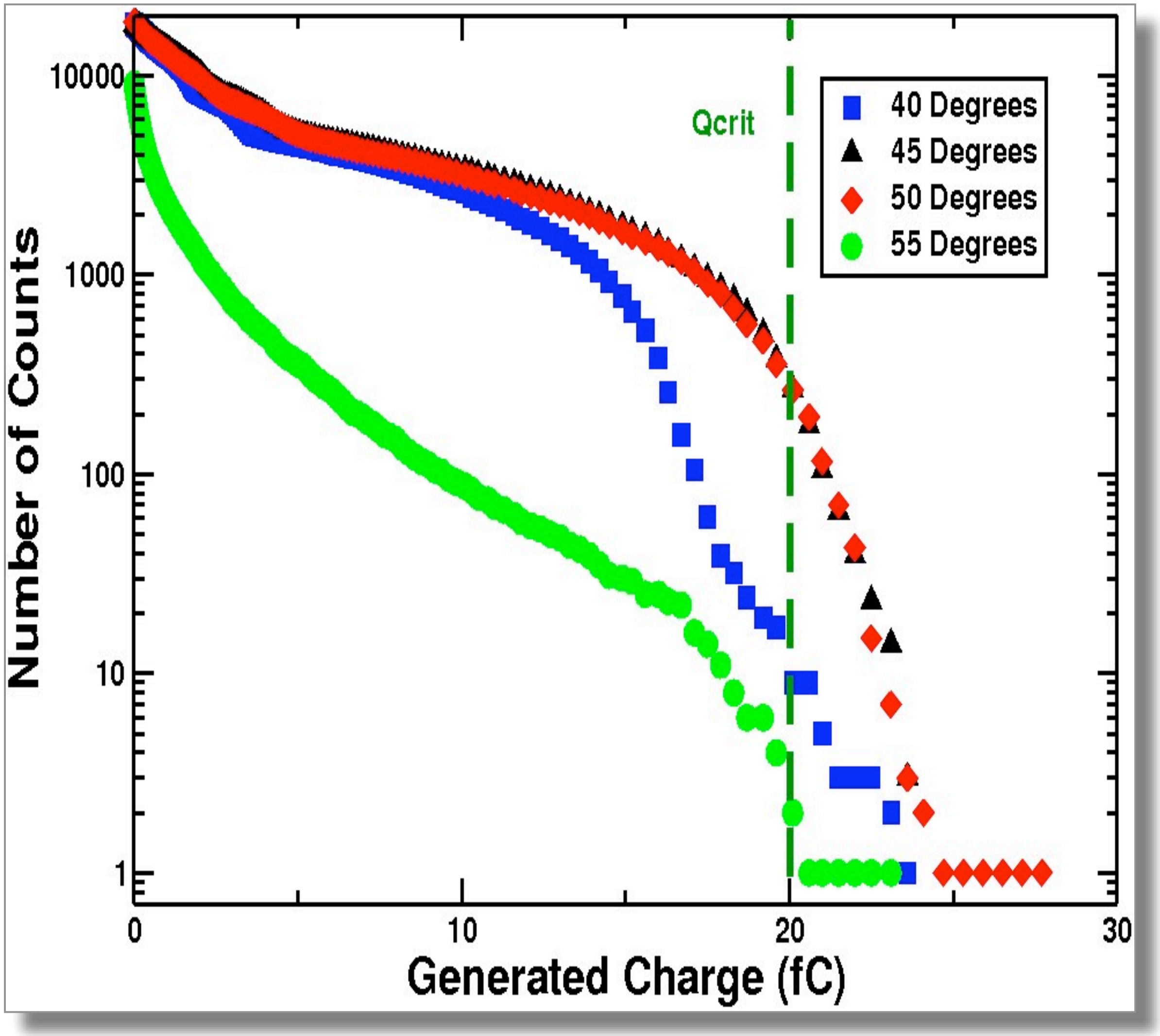




- Simulations were run using the heavy ions and energies used at Texas A&M
- A critical charge of 20 fC was found to fit the experimental data well

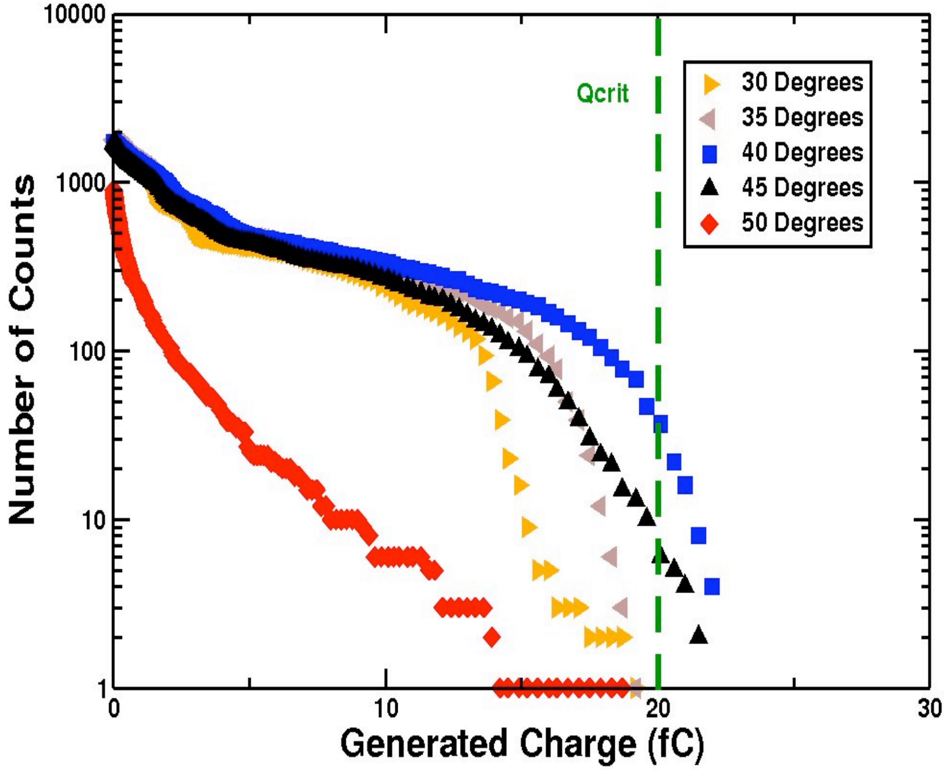
Alpha Particle Simulations

- Can a 5.5 MeV alpha particle deposit 20 fC in our sensitive volume?
- Yes…but only over a small range of incident angles
- The maximum dE/dx of the particle must occur in the sensitive volume

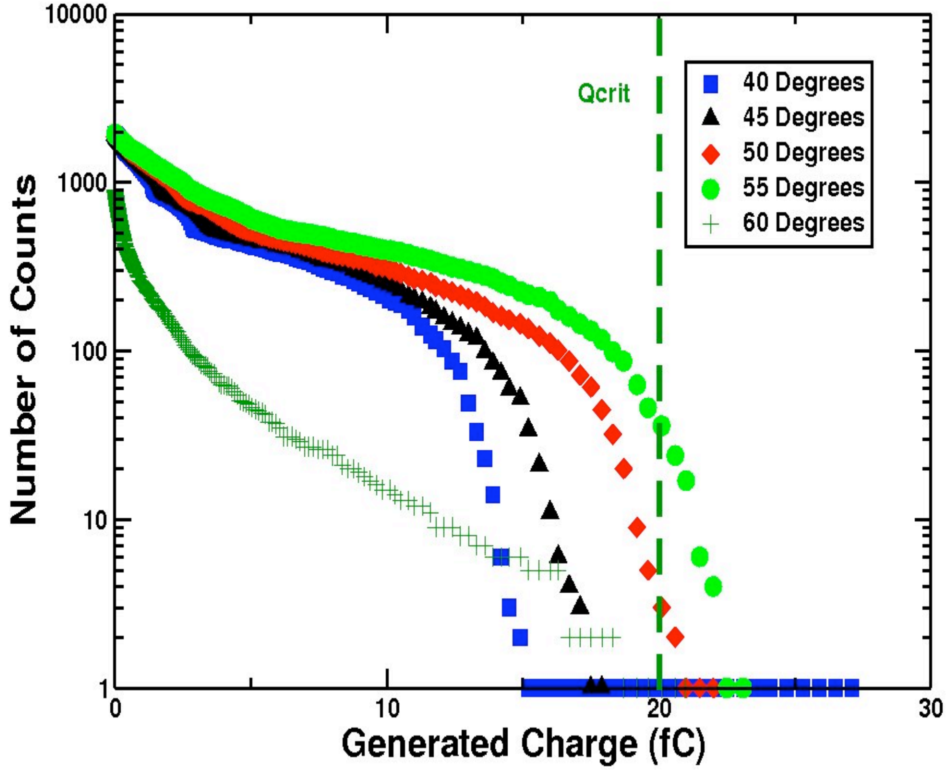


Effect of Overlayer Thickness

14.25 µm Overlayer



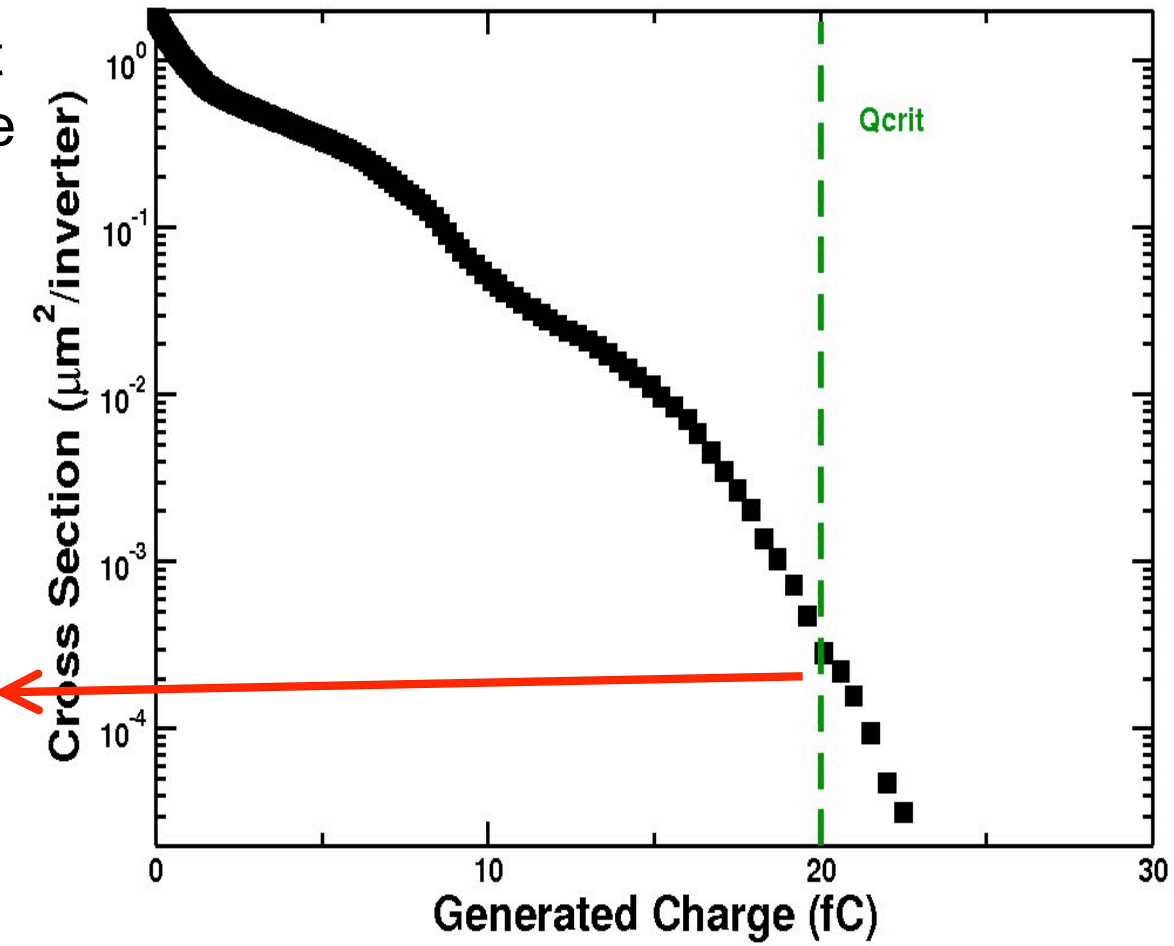
10.25 µm Overlayer



The critical angles change if the overlayer thickness changes

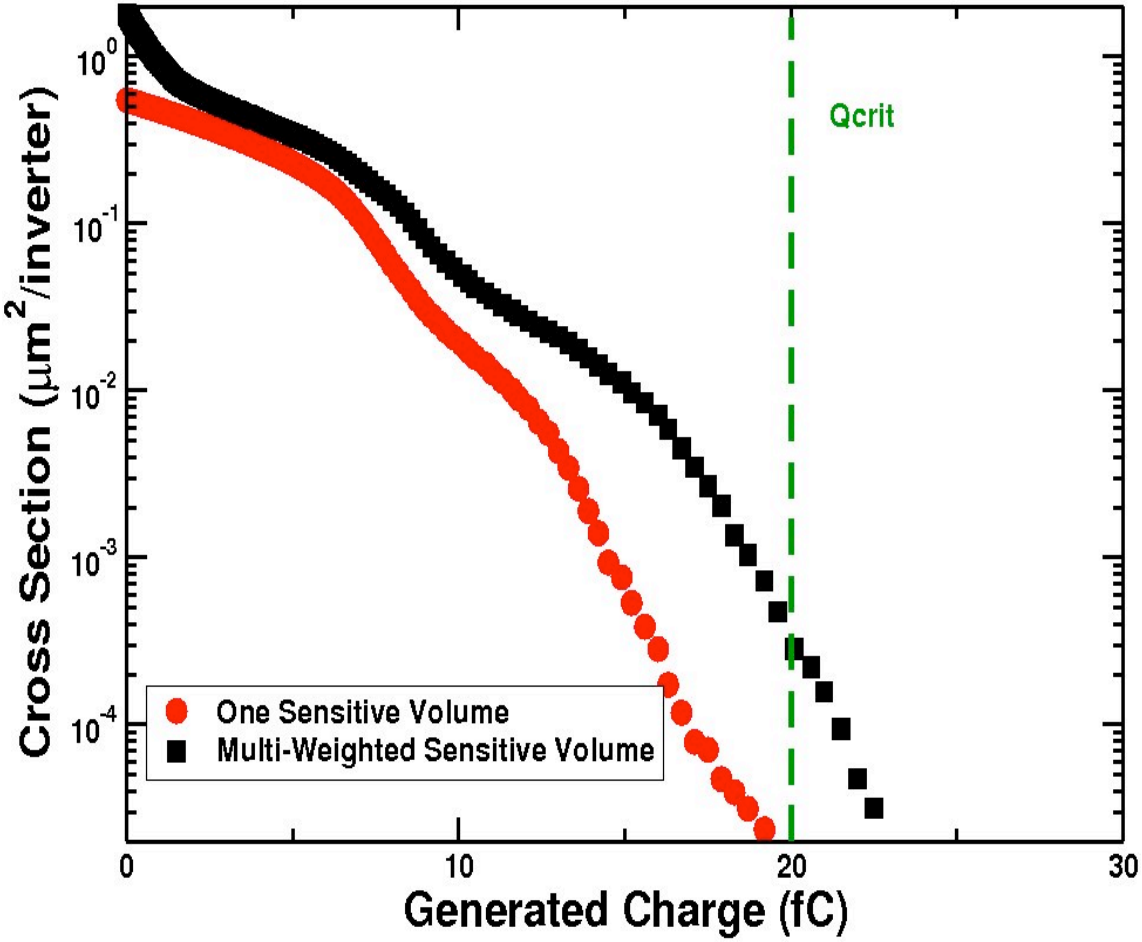
Simulations at All Angles

- Simulation with 5.5 MeV alpha particles incident at random angles across the top of the structure
- Rough approximation of the experimental conditions
- Estimated cross section from simulations – **3×10^{-4} μm^2/inverter**
- Experimental results – **6.74×10^{-4} μm^2/inverter**



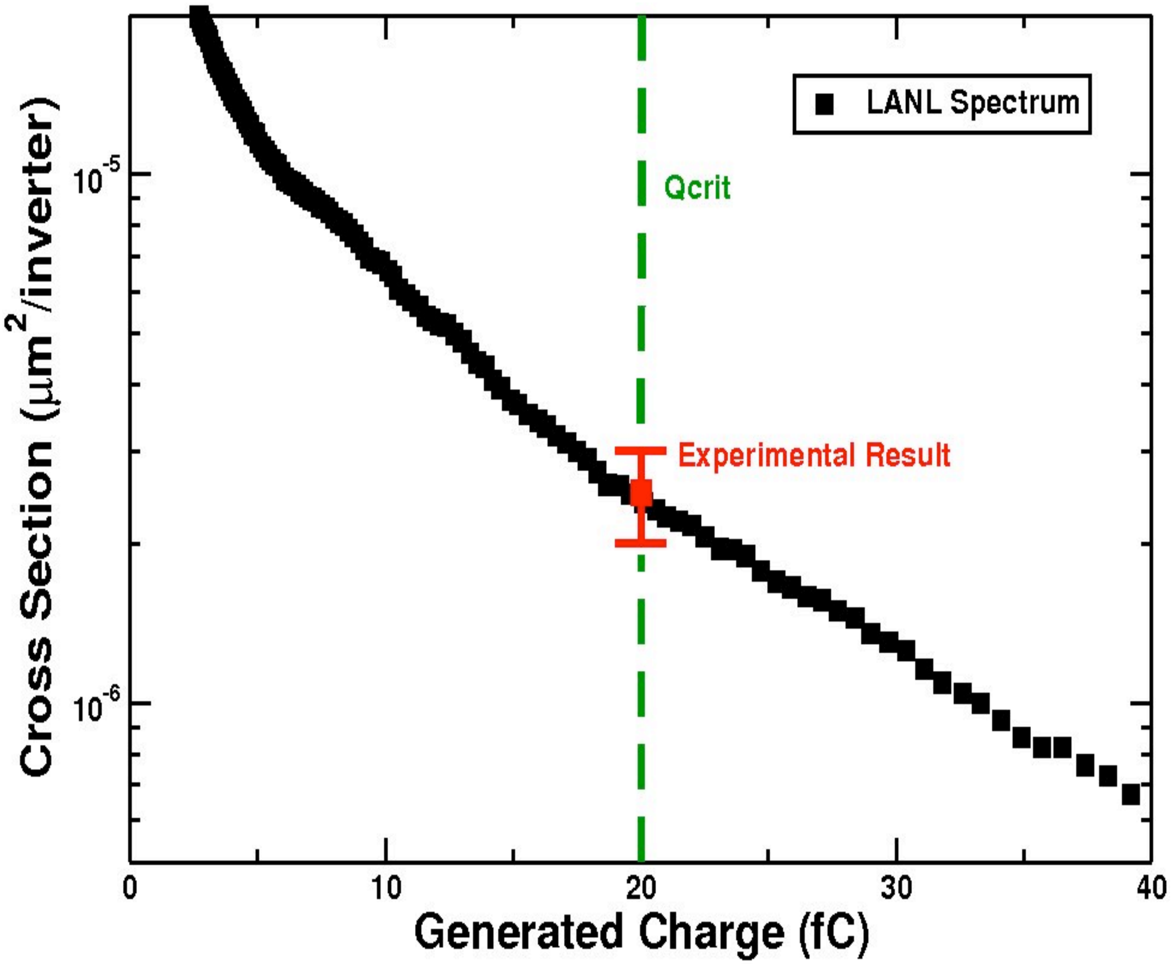
Simulations at All Angles

- Without taking into account charge collection from an area larger than the drain, the simulated alpha particle induced cross section is at least an order of magnitude too low.



Neutron Simulations

- Neutron simulations were performed using the same model that was calibrated to the heavy-ion results
- No other parameters were adjusted
- Excellent agreement obtained with the experimental results



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Shrinking Feature Sizes

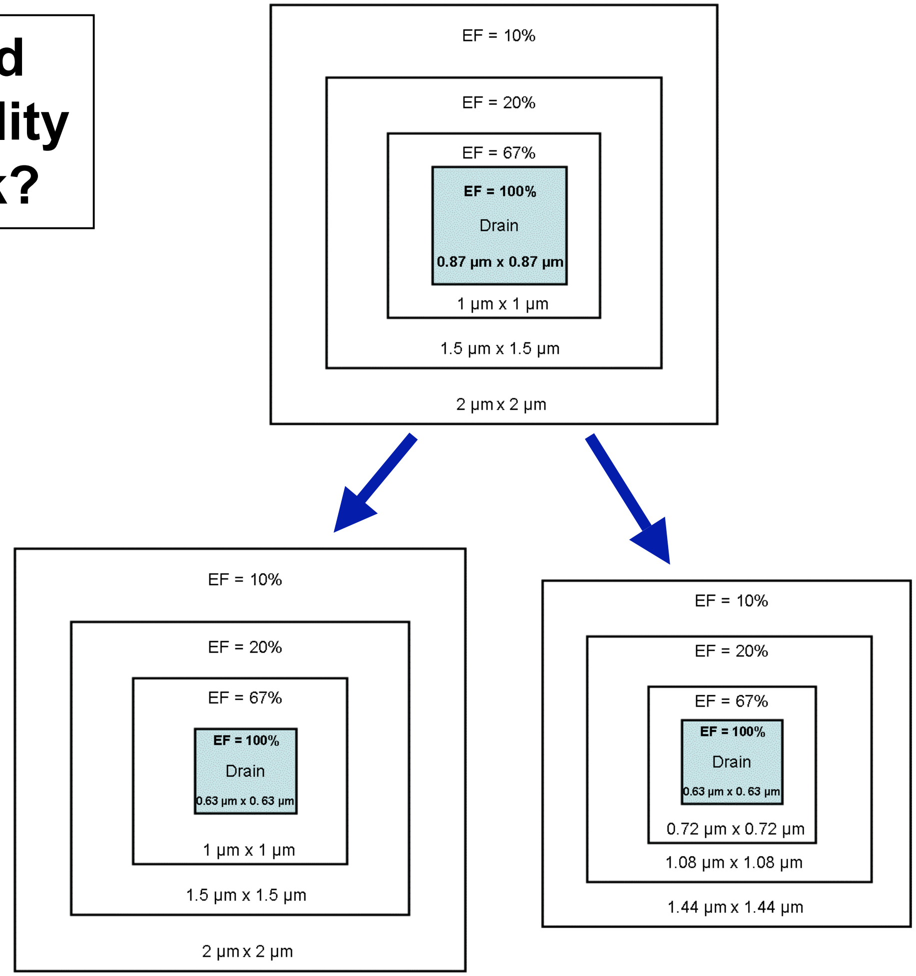
How will the alpha particle and neutron induced SET vulnerability change as feature sizes shrink?

To answer that question, you need to know (or make a reasonable estimate):

(1) By how much will the critical charge shrink.

(2) How the sensitive area will scale.

(3) How the charge collection efficiency changes.



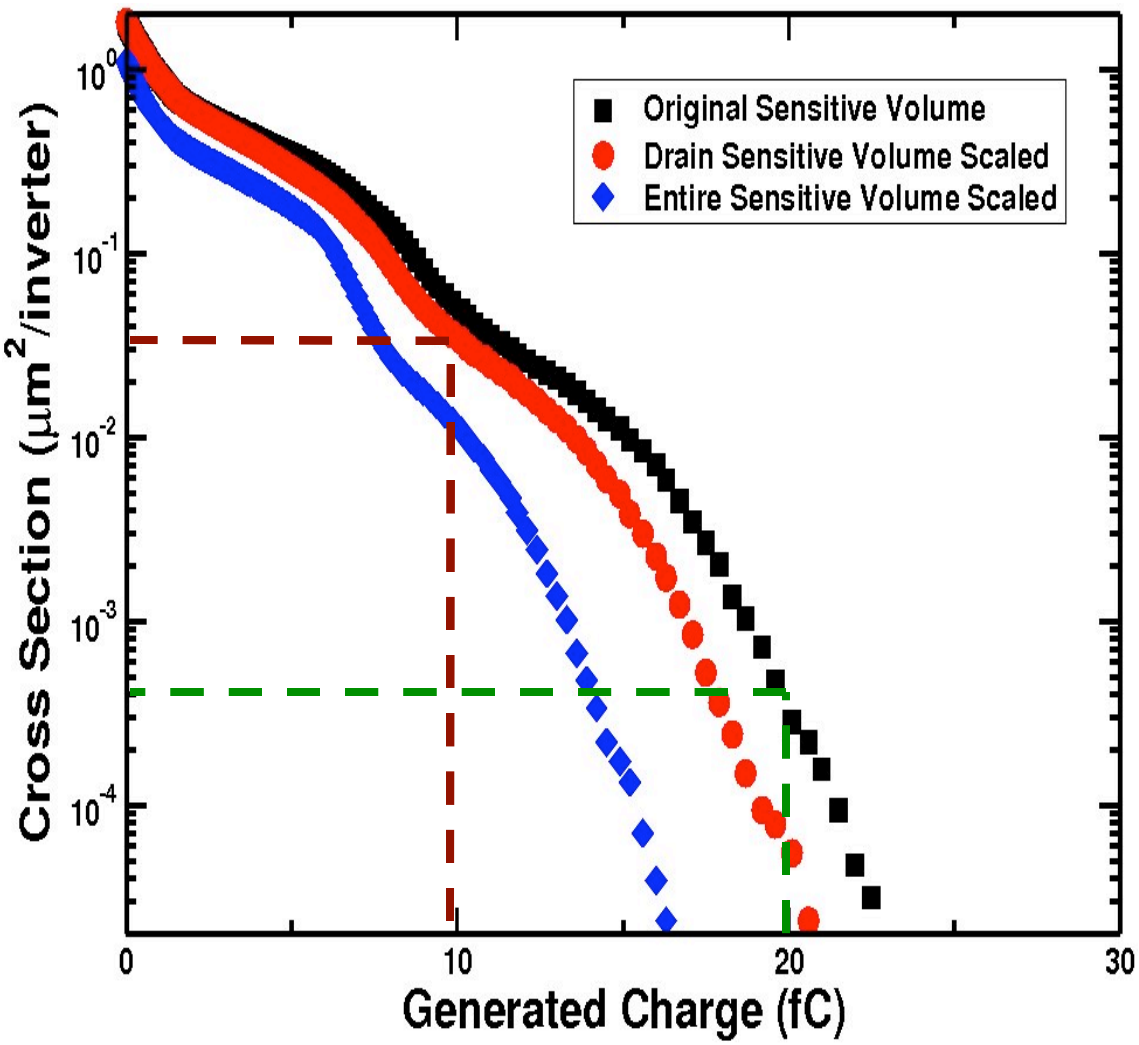
Does only the drain scale?

Or does the entire sensitive volume scale?

Alpha Scaling Simulations

- If one assumes the critical charge decreases by a factor of two, the alpha particle induced SET cross section will increase by over an order of magnitude

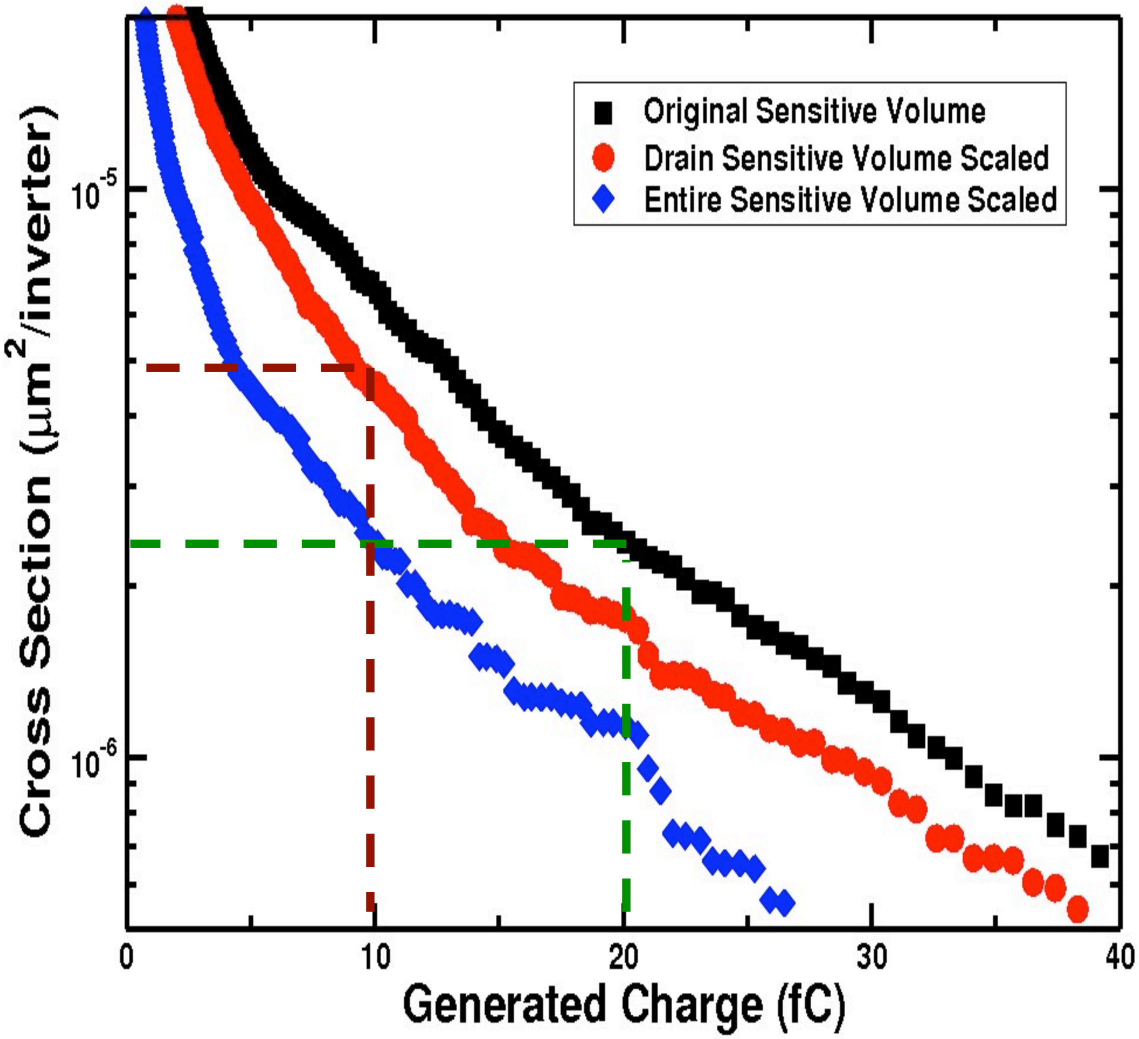
- As the critical charge decreases, the range of angles at which an alpha particle can generate that charge increases



Neutron Scaling Simulations

- For neutrons, the scaled SET cross section does not increase as dramatically as with alpha particles

- The neutron cross section depends more on the probability of an event (as opposed to the condition under which the event occurs)



Conclusions

- Described conditions under which an alpha particle can create an SET in this device
- Maximum dE/dx of alpha particle must occur in the sensitive volume for it to create an SET
- MRED simulations indicate this occurs only over a small range of incident angles: between 40 and 55 degrees
- As feature sizes decrease, the range of angles over which an alpha particle can induce an SET will increase
  - This will cause a significant increase in the alpha particle induced SET cross section