Assessing Alpha Particle and Neutron Induced Single Event Transients in a 90 nm CMOS Technology

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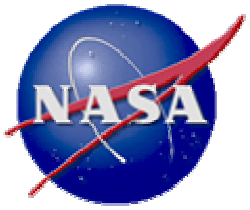


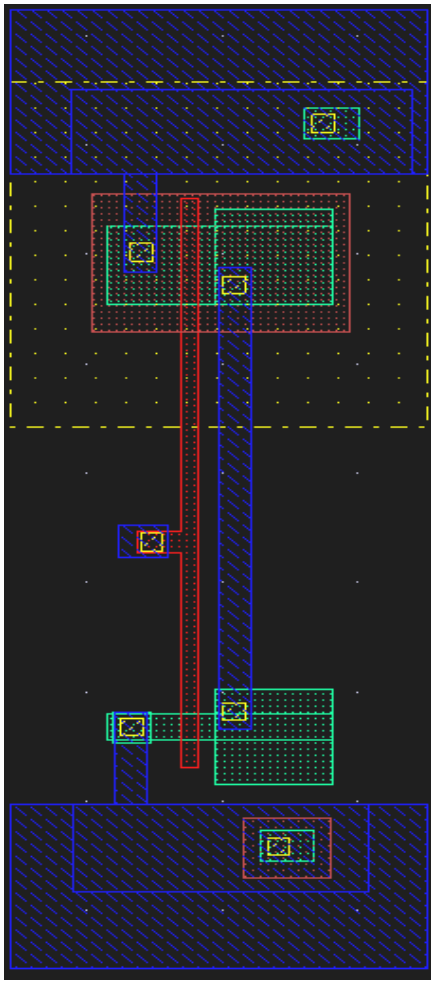
NAVSEA CRANE Surface Warfare Center Division

Background

- Heavy-ion, neutron and alpha particle induced SET data obtained on custom 90 nm SET pulse width measurement test chip
- Used MRED to help explain and gain greater insight into these results
- Using MRED:
  - Found the conditions under which an alpha particle can induce an SET in this technology
  - Were able to match the experimental neutron cross section by using a model calibrated with heavy ions

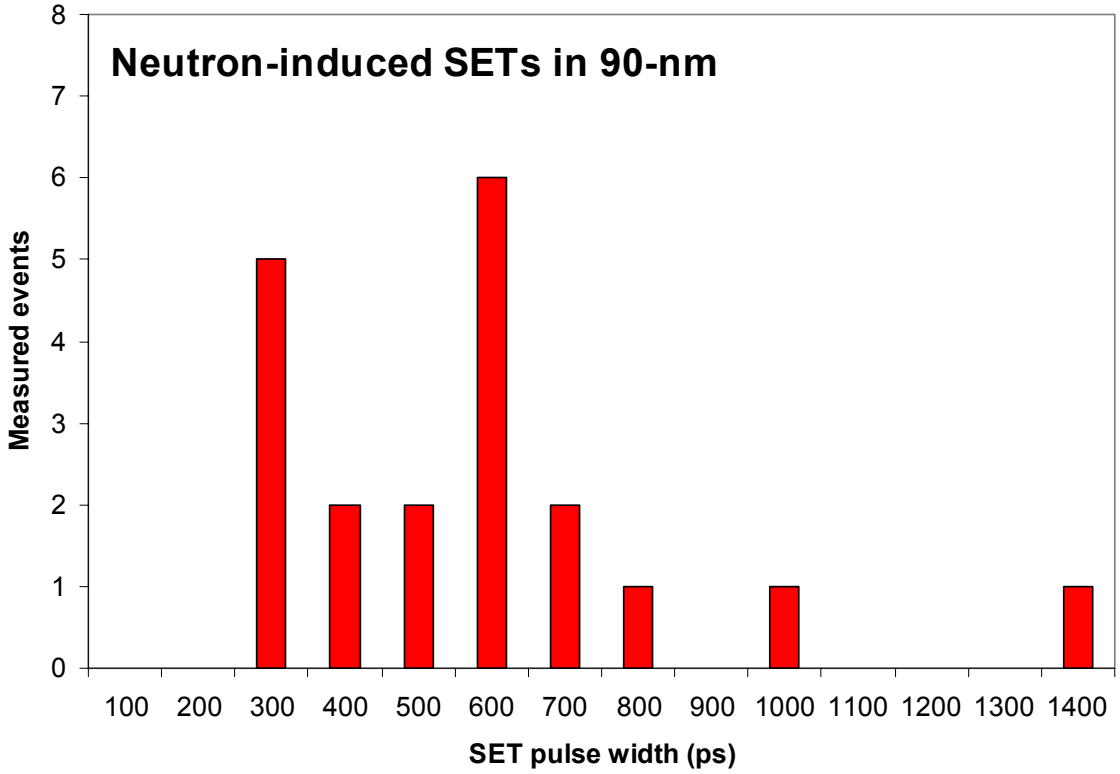
Test Chip Details

- 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

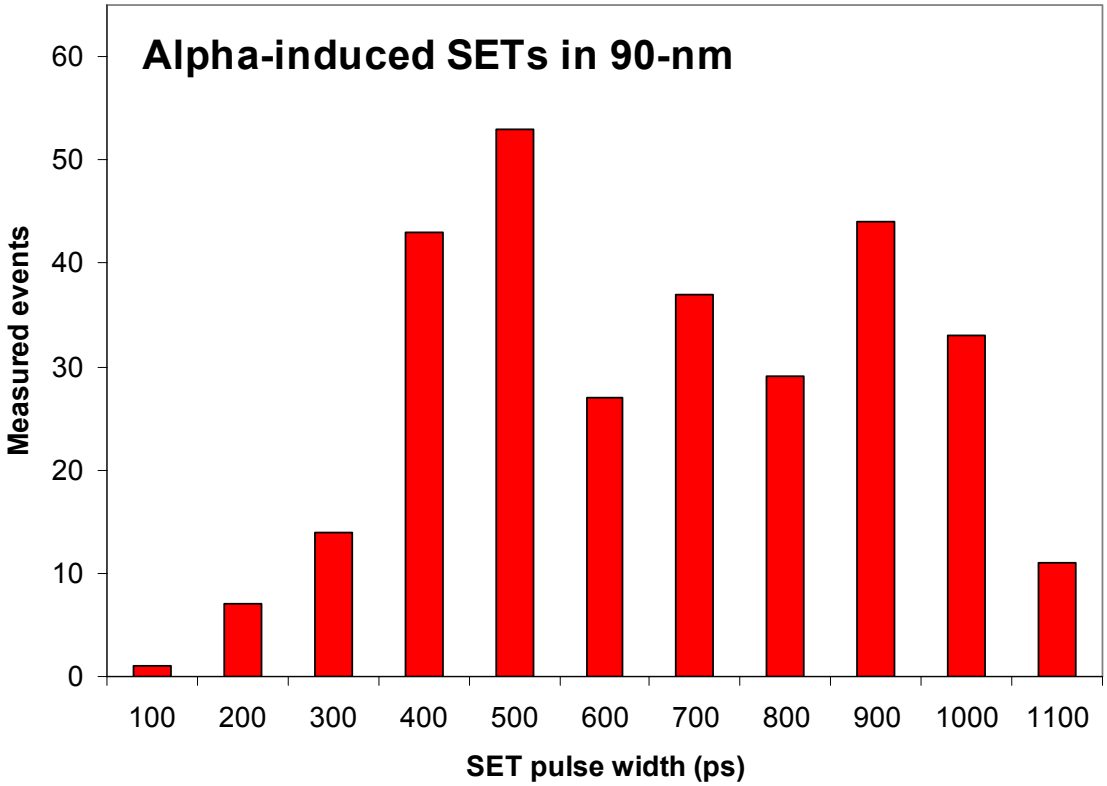
Neutron-Induced SETs



- Tested six SET test chips at WNR facility at LANL
- Energy spectrum matches sea-level spectrum for energies from 10 to 500 MeV
- Neutron fluence 1.33×10^{11} neutrons/cm^2

- Neutron SET cross section ~ **2.5×10^{-6} µm^2/inverter**

Alpha-Induced SETs

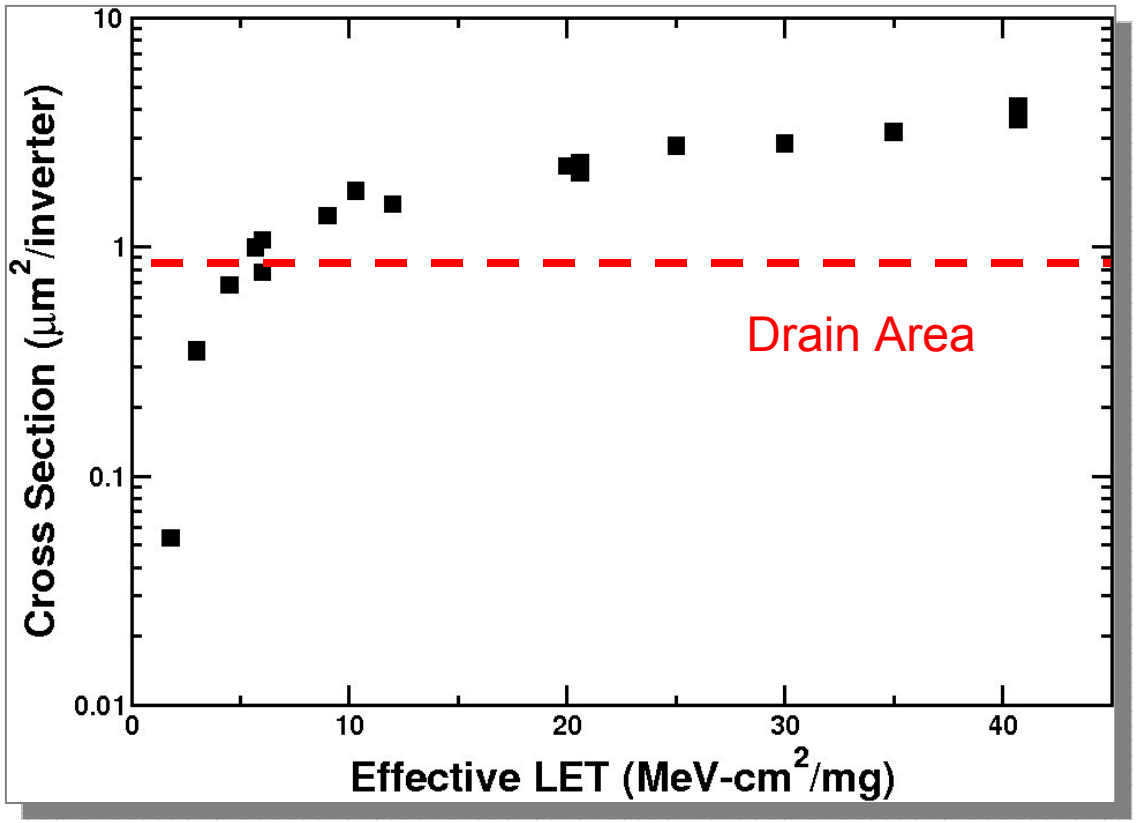


- Alpha tests at TI using foil of ^{241}Am
- Energy ~ 5.5 MeV
- Fluence ~ 4.45×10^{10} alphas/cm^2
- Total events measured ~ 300

- Alpha SET cross section ~ **6.74×10^{-4} µm^2/inverter**

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



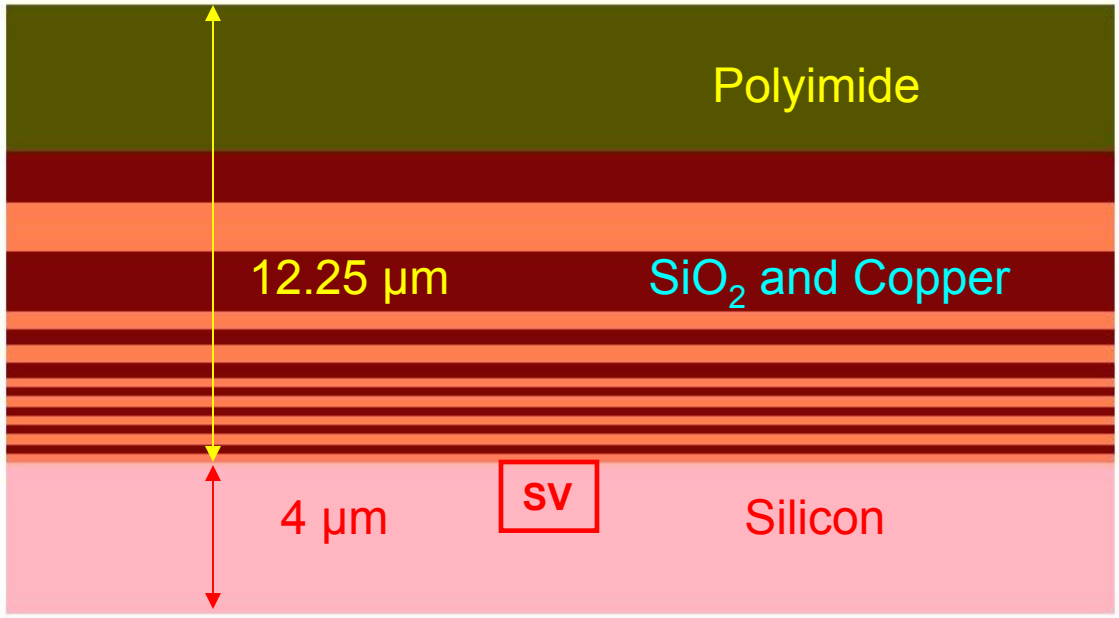
5.5 MeV Alpha Cross Section

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

MRED Device Setup

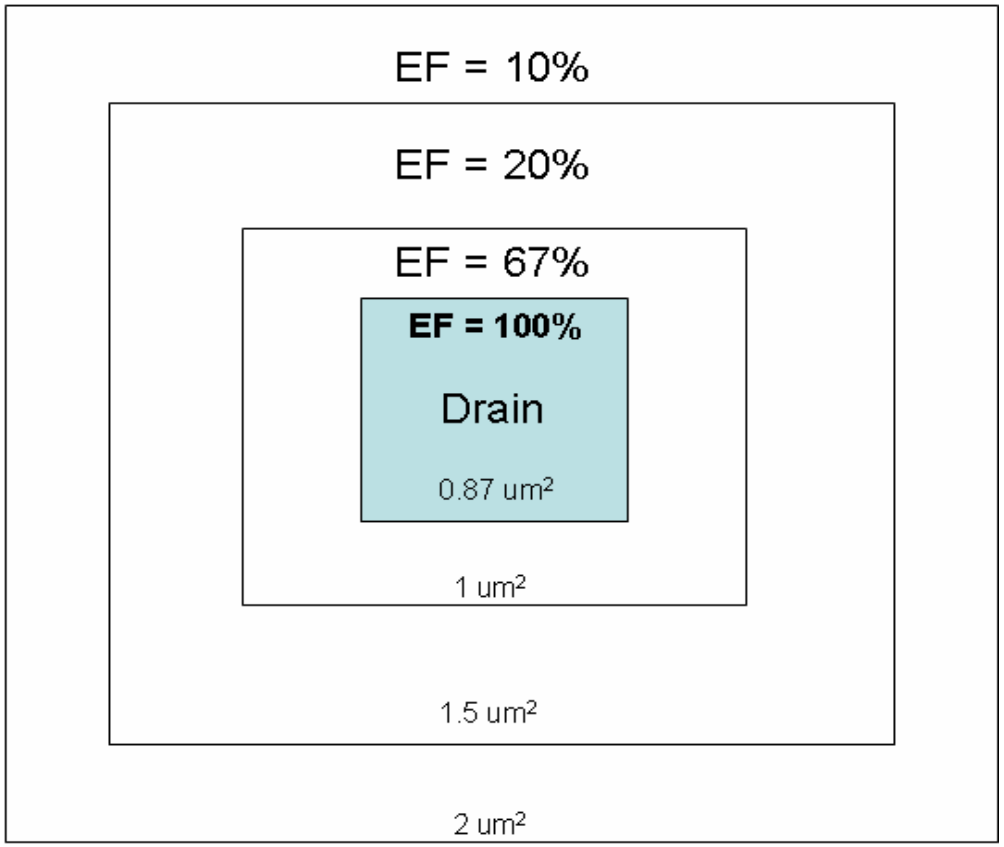
- Simulated structure was a 50 μm × 50 μm × 16.25 μm cube
- Overlayers in this process are 12.25 μm thick
- Multi-weighted sensitive volume placed in the center and top of the silicon block



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



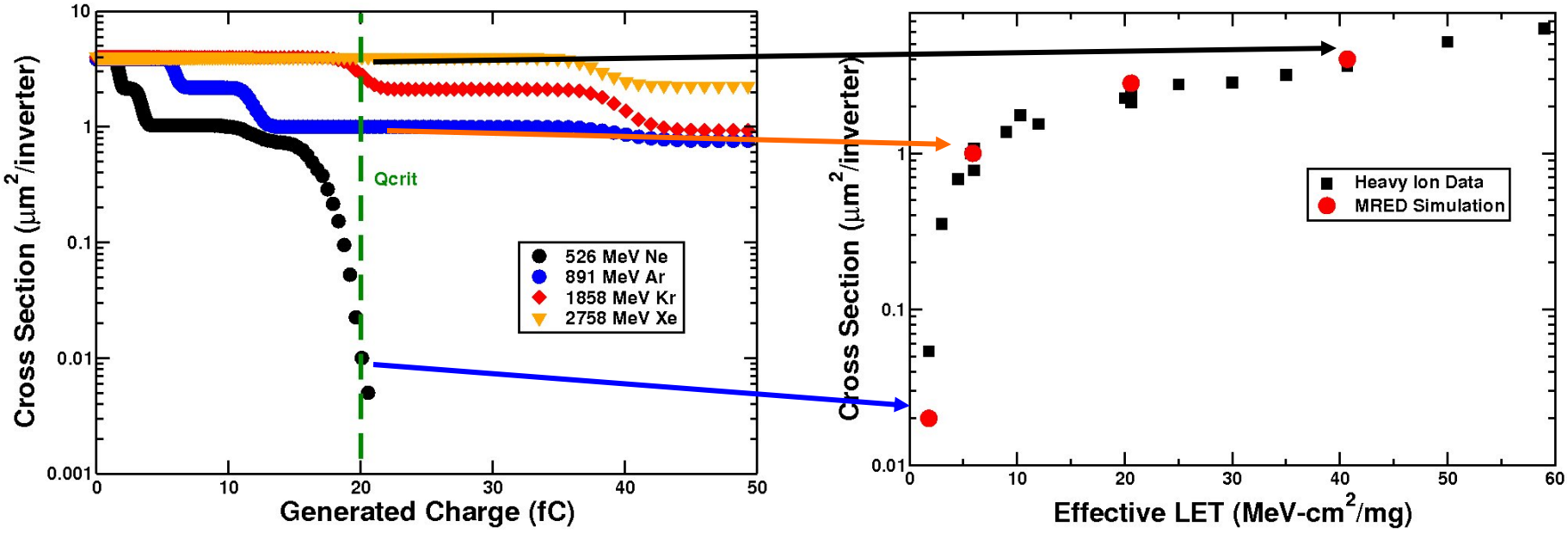
Top view of the sensitive volume used for MRED simulations. (Depth of sensitive volume is 1 μm.)

Heavy Ion Simulation Results

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

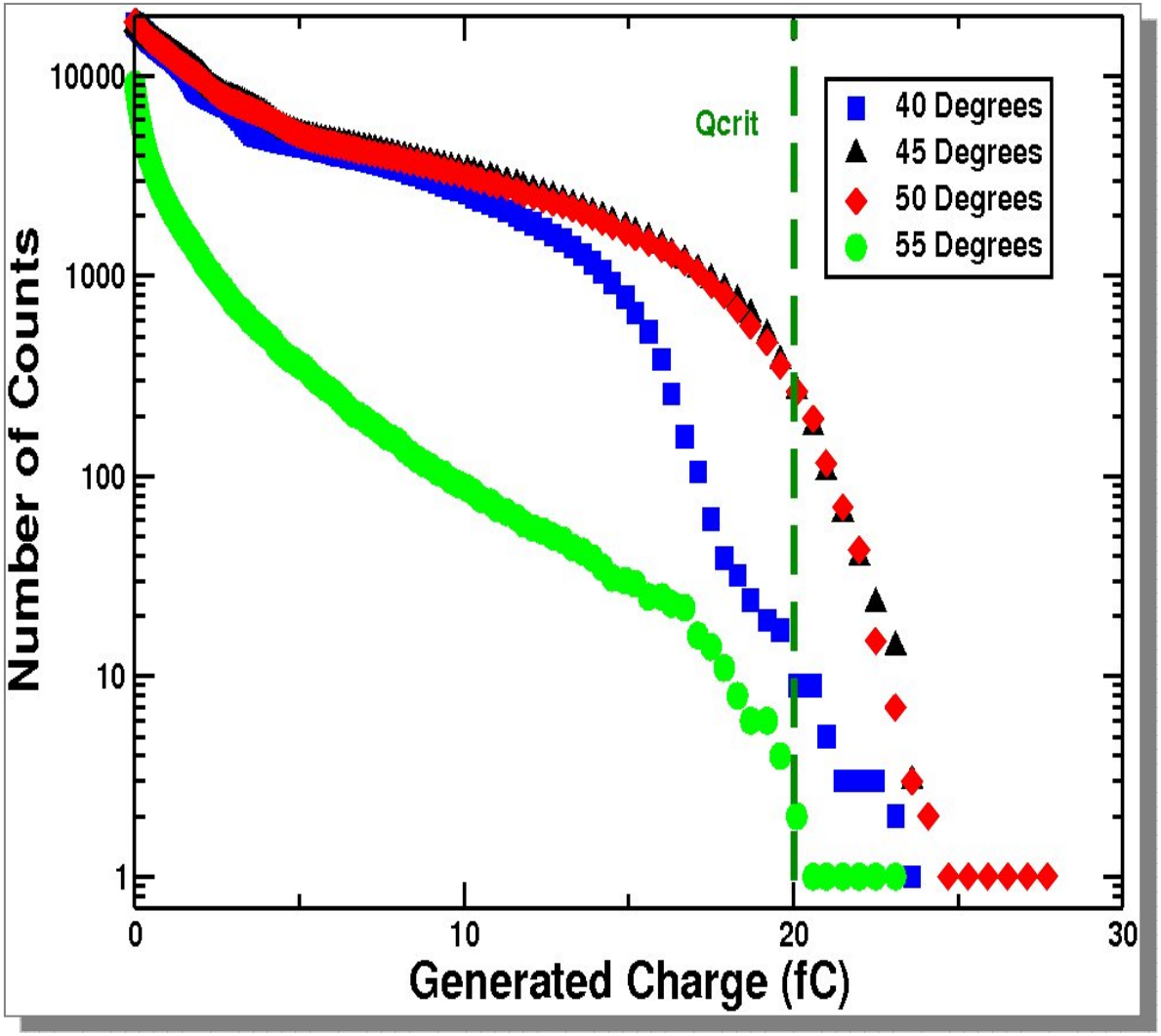
Ion	Energy (MeV)	LET (MeV-cm^2/mg)
Ne	526	1.8
Ar	891	5.9
Kr	1858	20.6
Xe	2758	40.7

Ions Used for Testing & Simulations



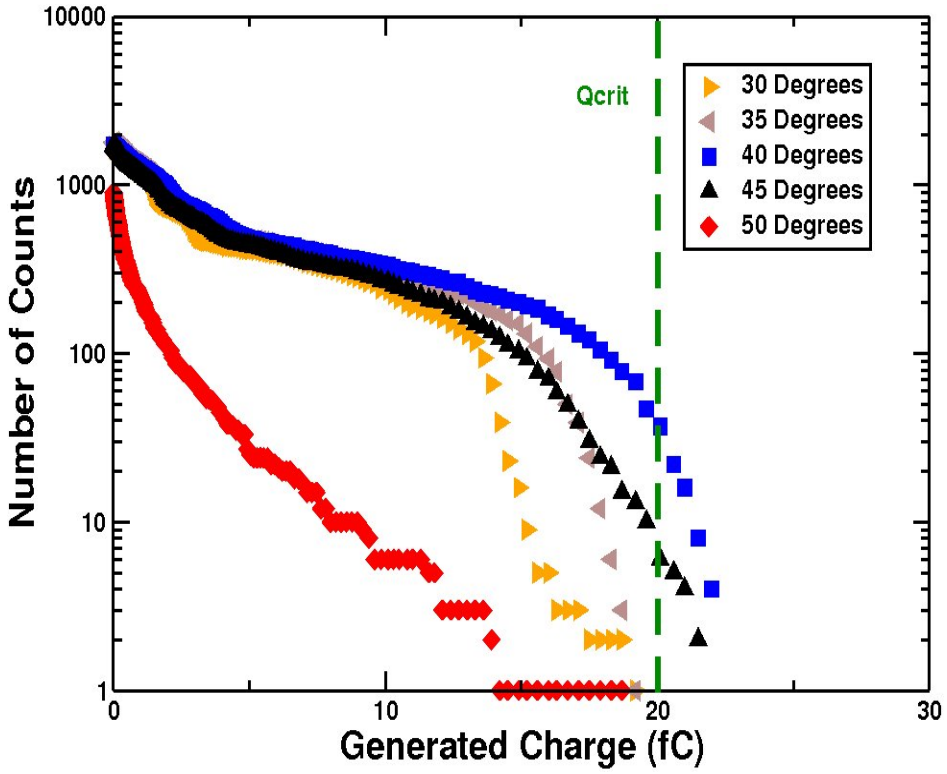
Alpha Particle Simulations

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

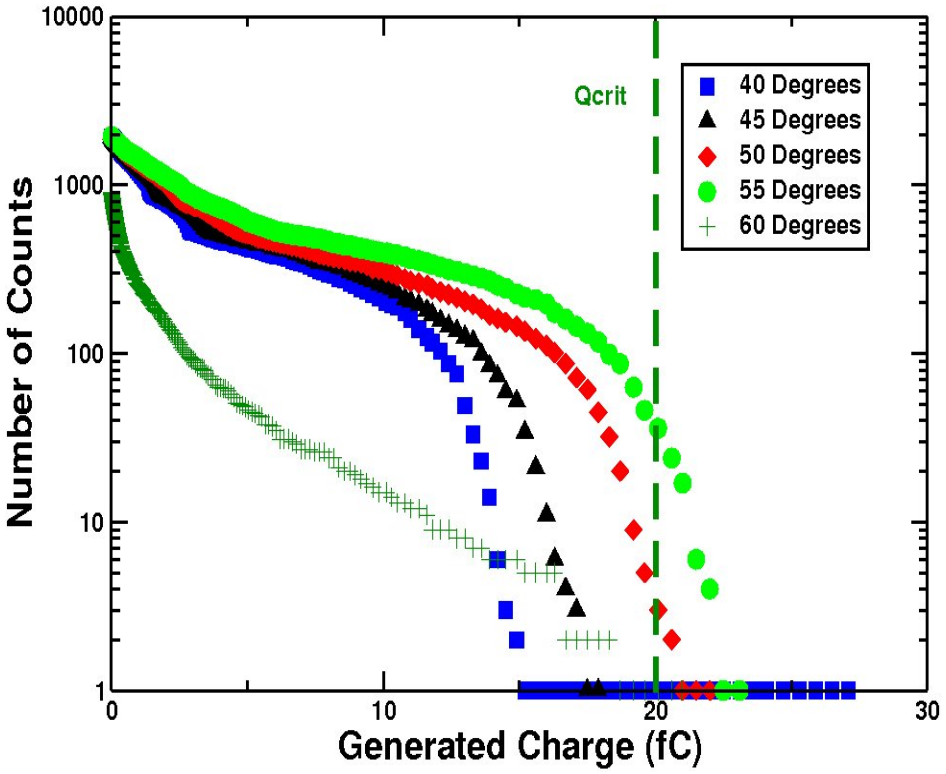


Effect of Overlayer Thickness

14.25 µm Overlayer



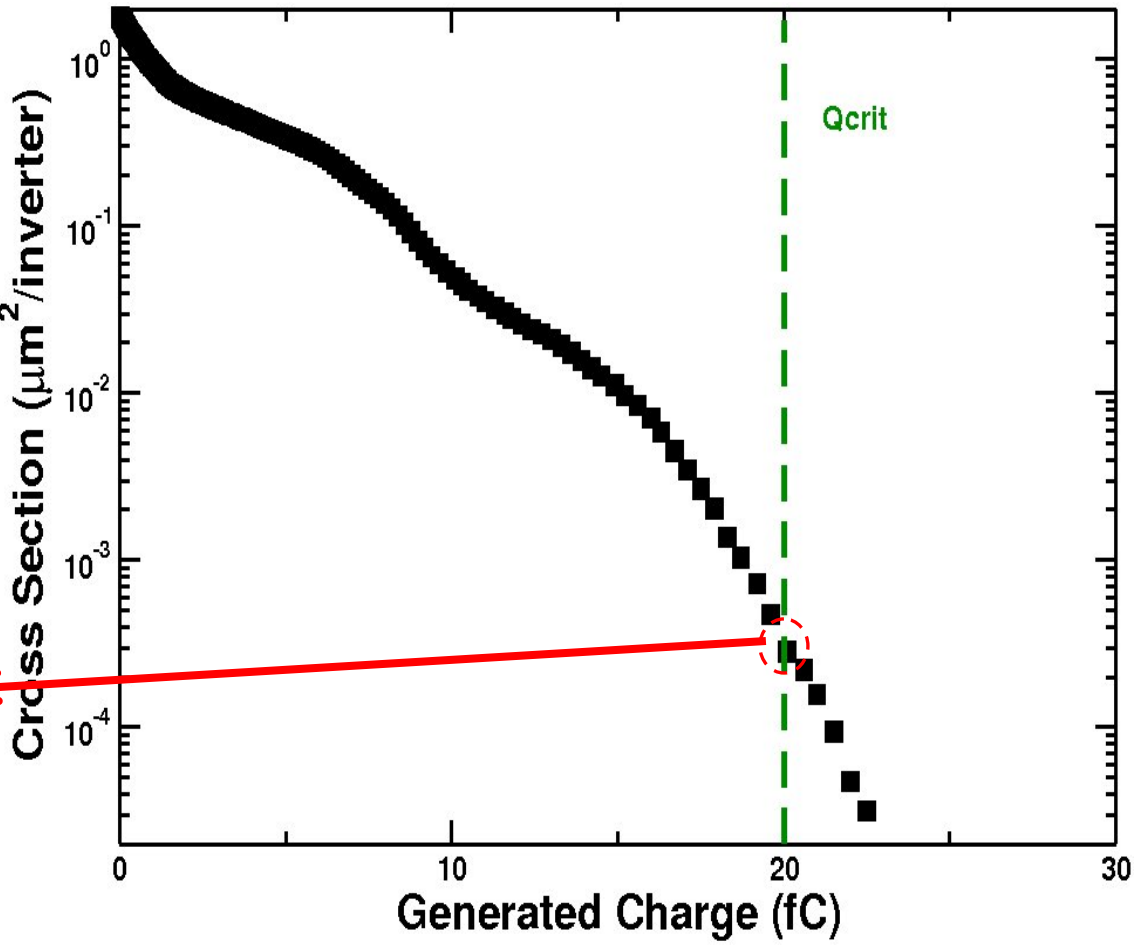
10.25 µm Overlayer



Critical angles change if the overlayer thickness changes

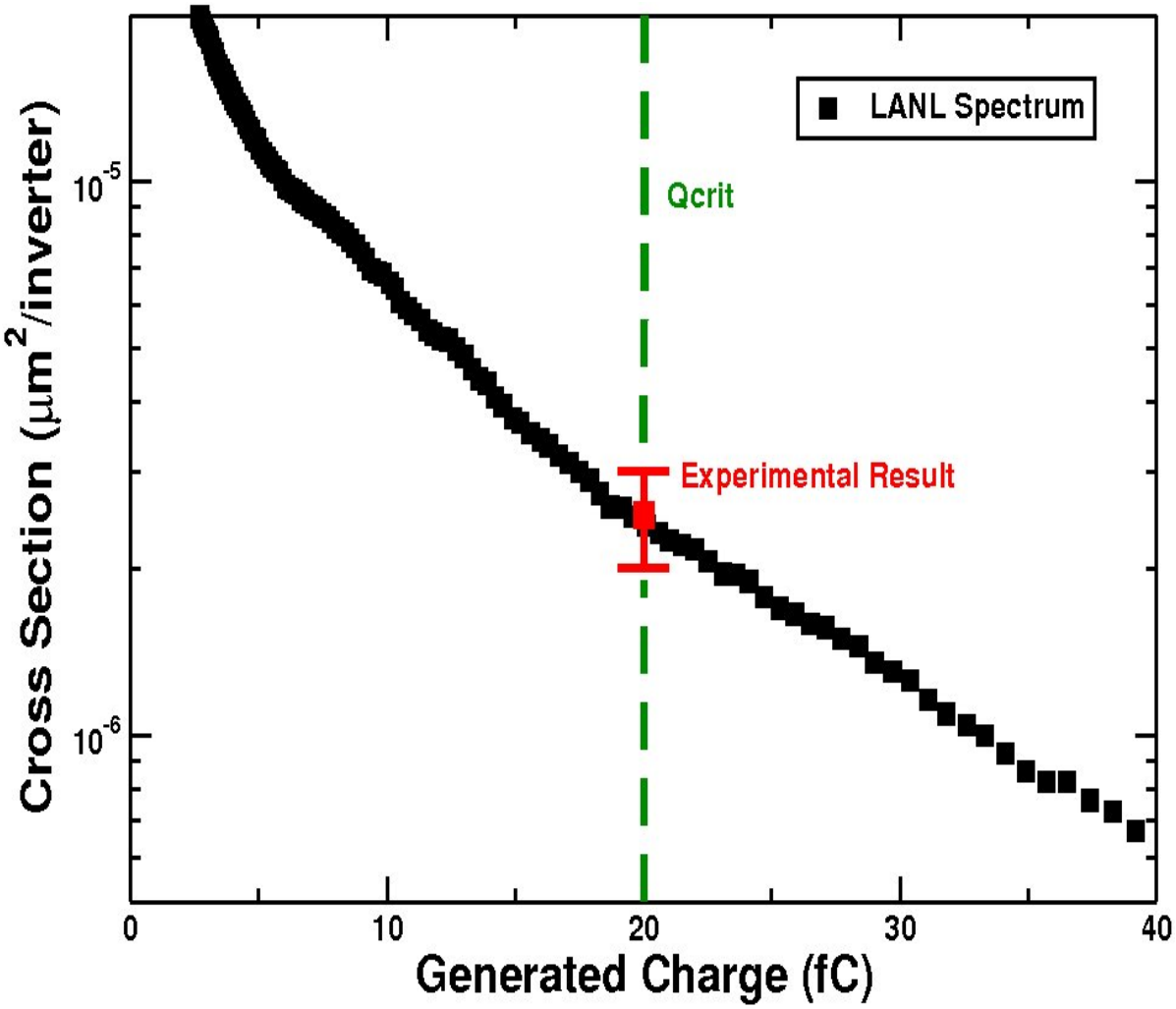
Simulations at All Angles

- 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**



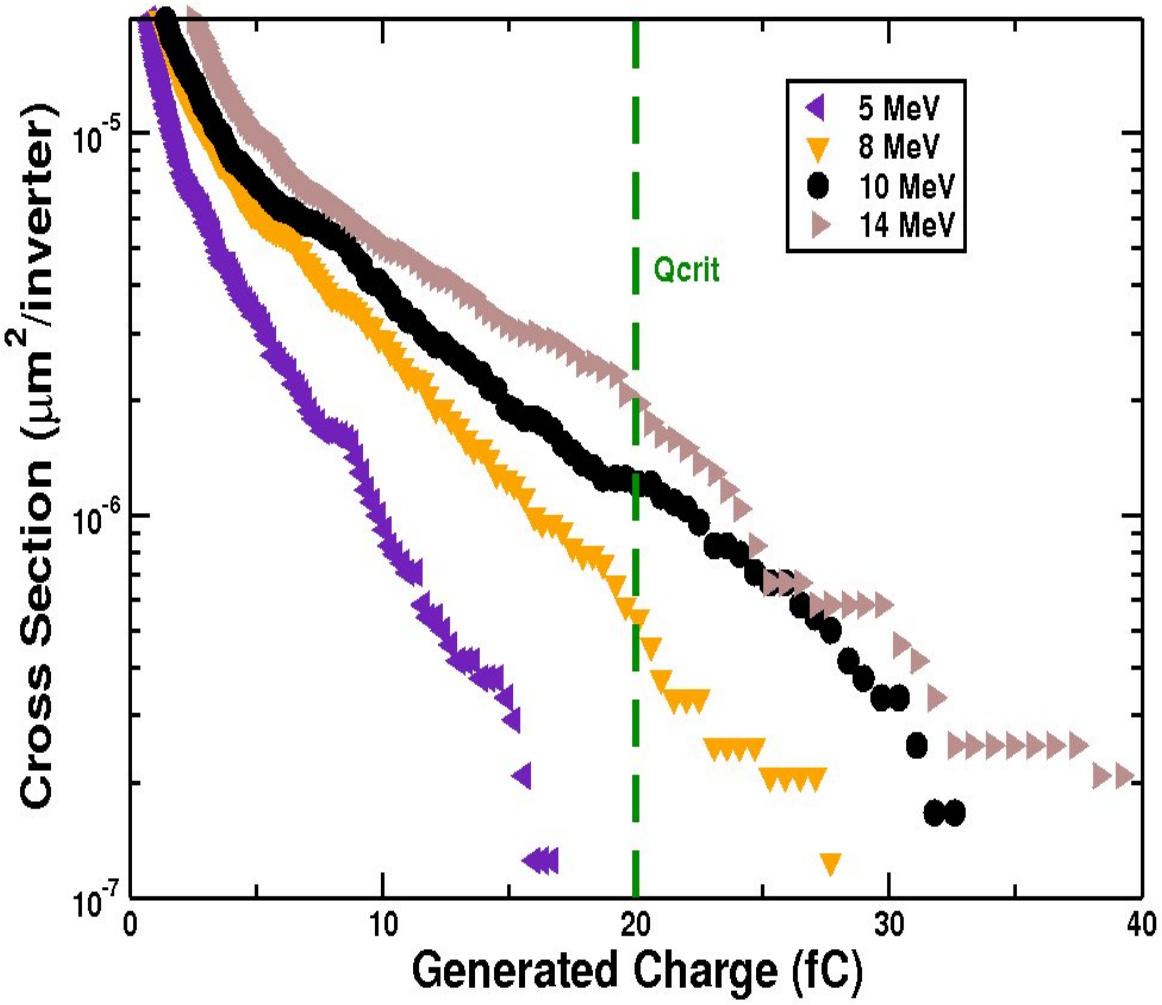
Simulations with Neutrons

- 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



Lower Energy Neutrons

- Lower energy neutrons have a higher atmospheric flux
- Simulations show that these lower energy neutrons can induce SETs
- Threshold neutron energy is ~ 8 MeV



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
- With a calibrated heavy-ion MRED model, obtained excellent agreement with experimental neutron results

Recent Papers

This work is summarized in:

- "Assessing Alpha Particle-Induced Single Event Transient Vulnerability in a 90 nm CMOS Technology"
  -- Submitted for publication to Electron Device Letters

- "Neutron Induced Single Event Transient Vulnerability of an Advanced CMOS Process in a Nuclear Burst Environment"

  -- Accepted to the 2008 HEART Conference