Increased Rate of Multiple-Bit Upset at Large Angles of Incidence

VANDERBILT

School of Engineering

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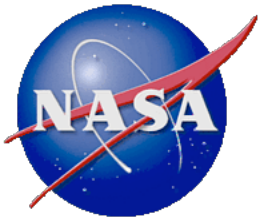
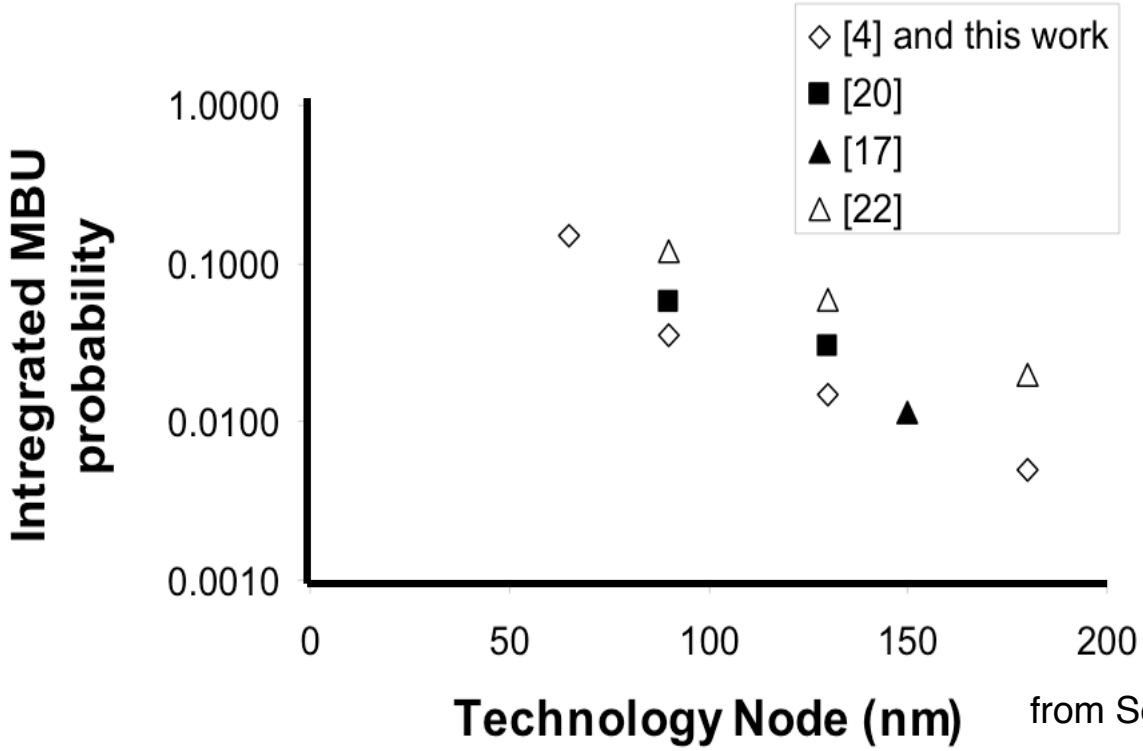
TEXAS INSTRUMENTS



Outline

- Background
  - Multiple-bit upset (MBU)
  - Neutron-induced MBU
- Experimental
  - Single-bit
  - Multiple-bit
- Modeling
  - Monte-Carlo Radiative Energy Deposition (MRED)
- Summary
  - Future work

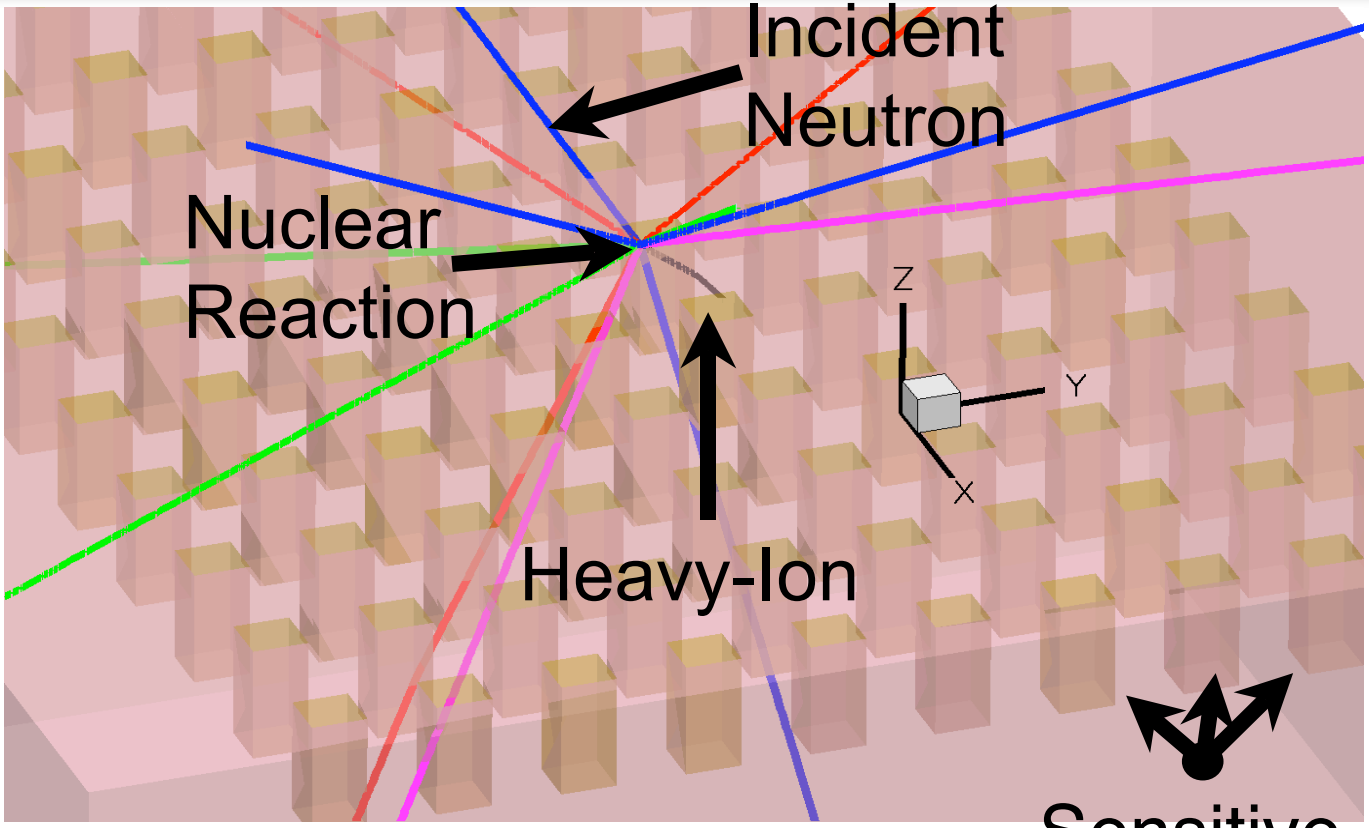
Multiple-bit upset increases with scaling



from Seifert, *et al.,* IRPS, 2006.

- Multiple-bit upset (MBU) increases for smaller technologies
- Feature size small relative to radiation events
- MBU 2 or more physically adjacent bits

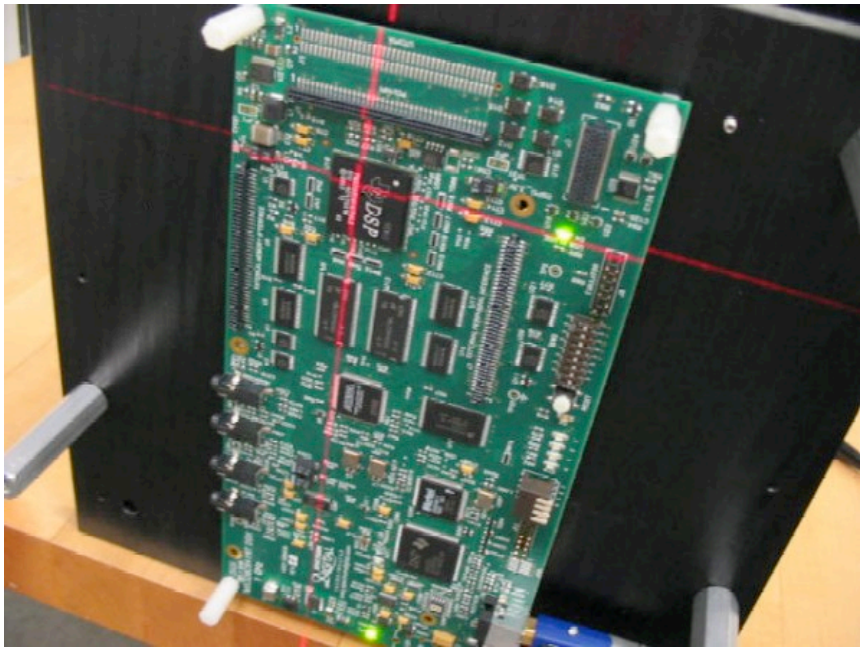
Secondary products induce soft errors



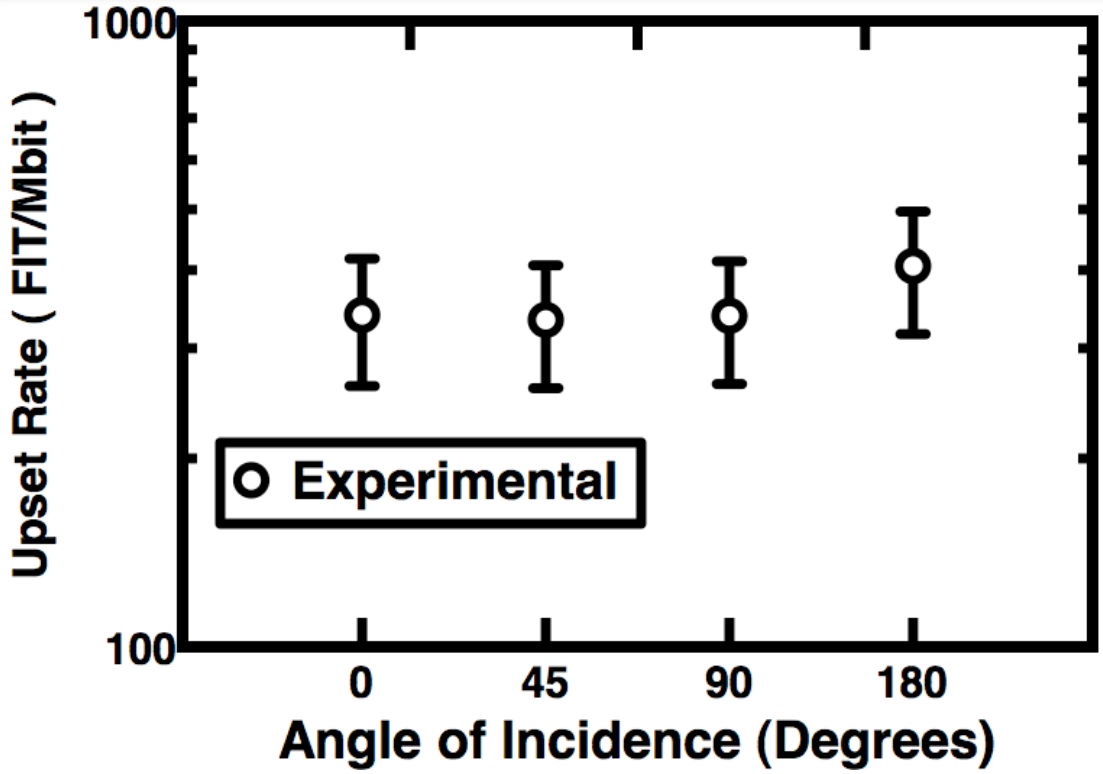
- Neutron-induced nuclear reactions

Device under test is a TI 90 nm SRAM

- TI 90nm CMOS high performance (C027)
- DSP embedded SRAM (8MEG) @ 1.2 V
- LANL WNR Neutron beam line
- Test conditions - 0°, 45°, 90°, & 180°

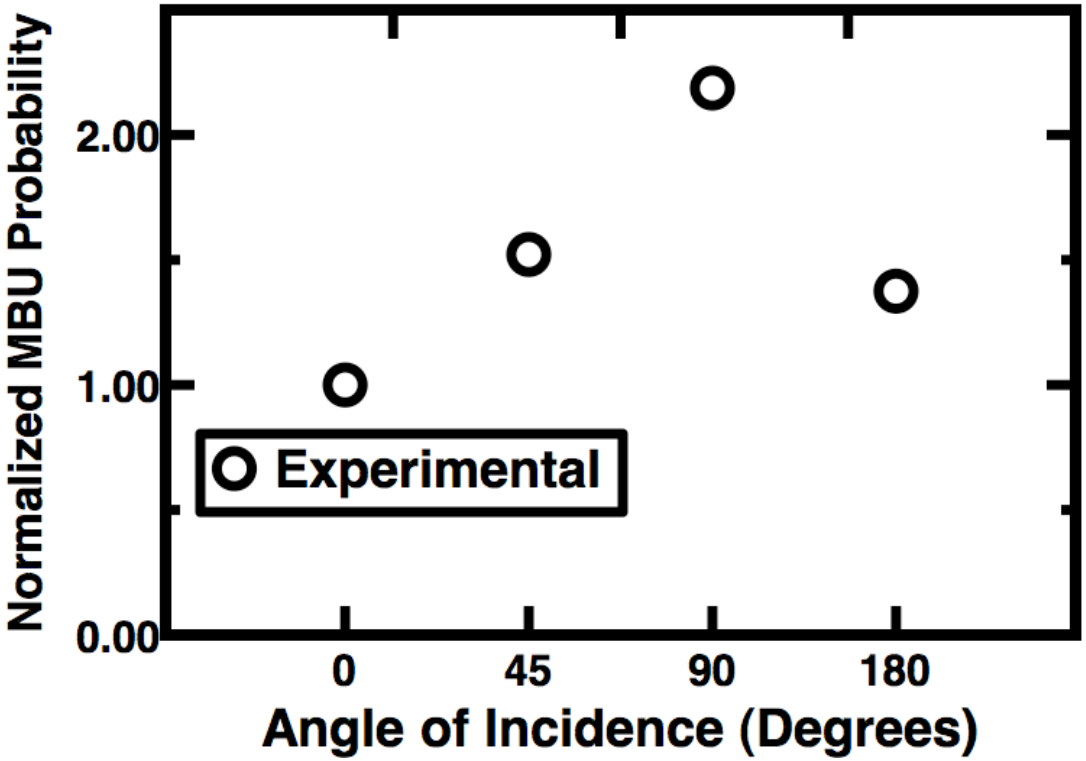


Single-bit rate is not angle dependent



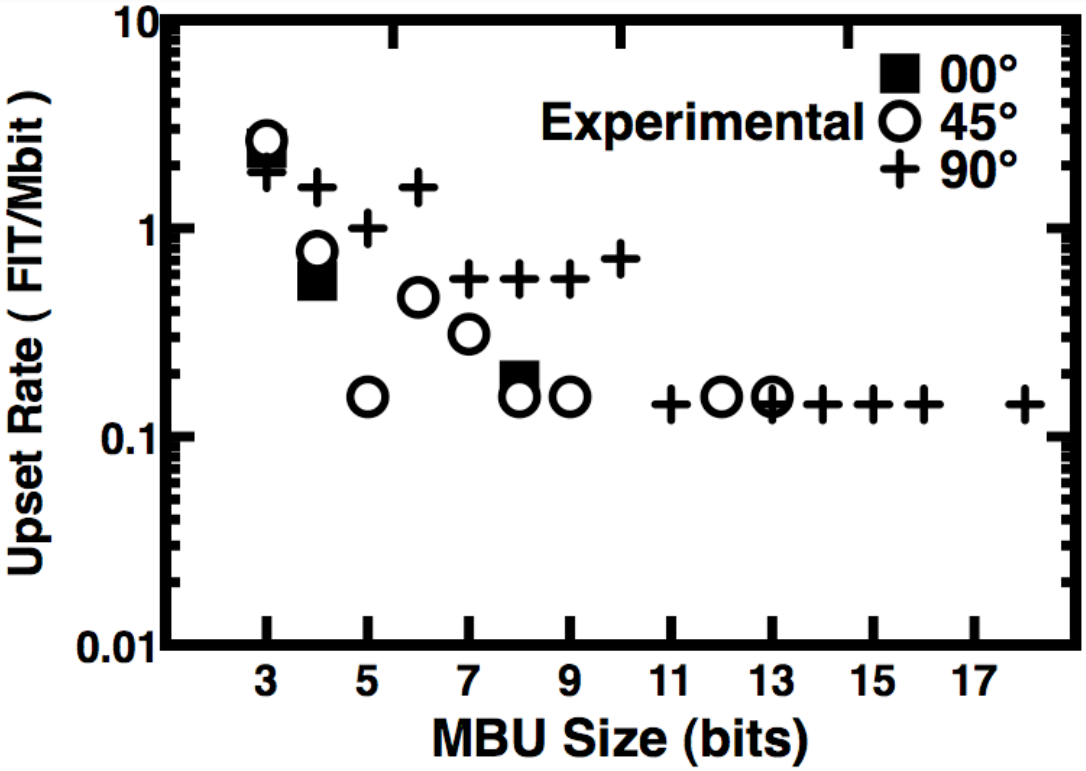
- No angular dependence

Multiple-bit probability depends on device orientation



- MBU ≡ 2 or more physically adjacent bits
- Probability of MBU ≡ (# of MBU events)/(# of total events)
- Normalized to 0°

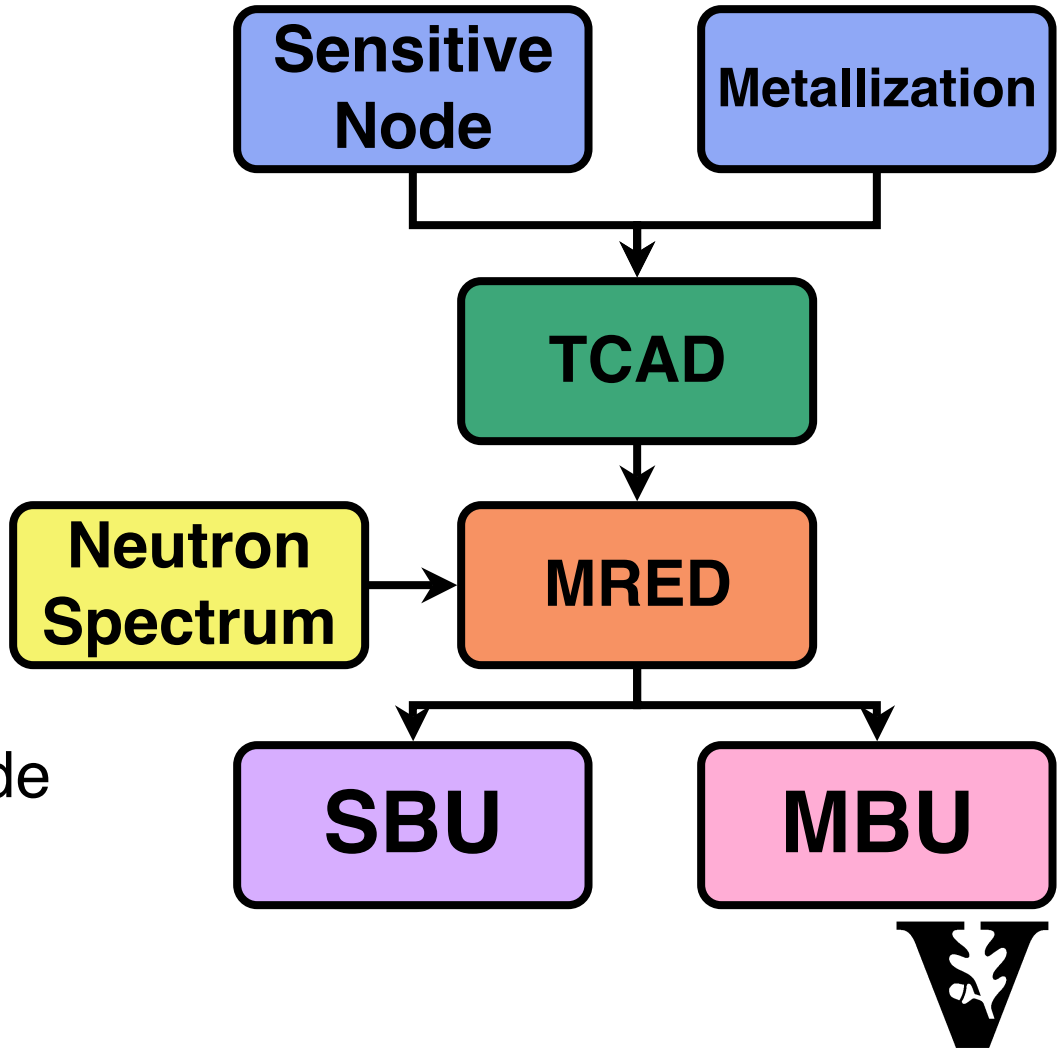
MBU multiplicity is higher at large angles



- Large angles show most number of MBU events
- Large angles show largest MBU events

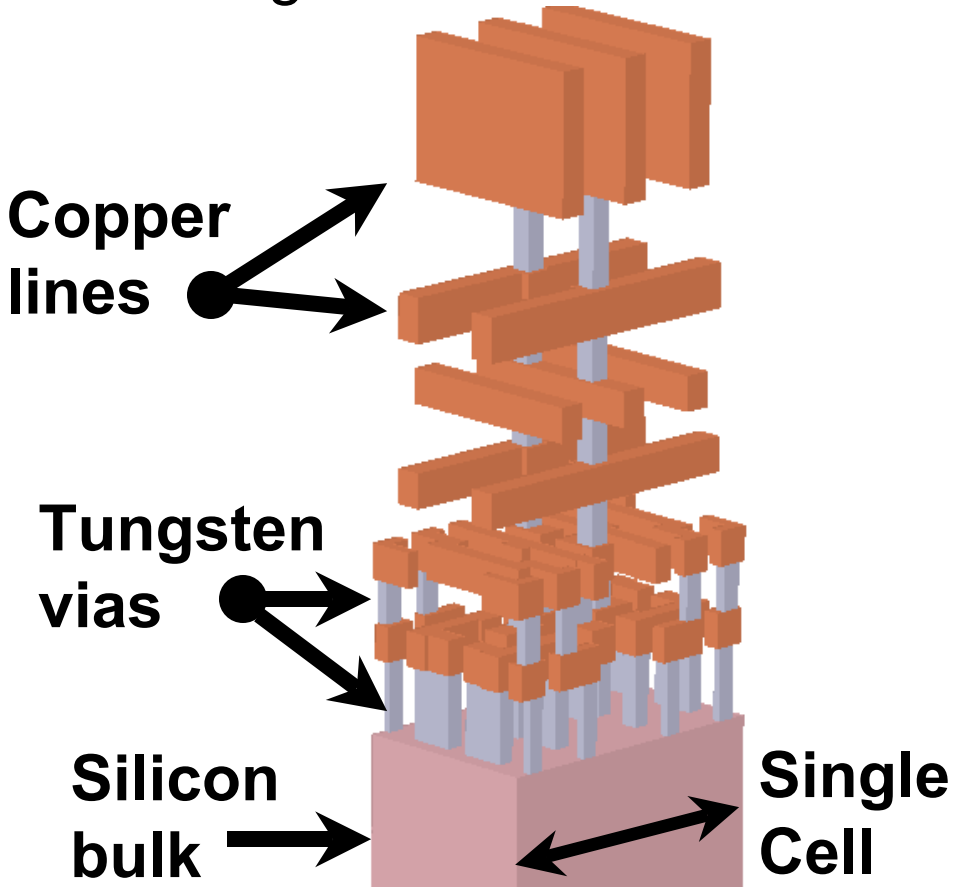
Modeling methodology

- TI 90 nm SRAM model
- Sensitive node
  - Charge collection volume
- Technology Computer Aided Design (TCAD) Model
- Simulation - MRED (Monte-Carlo Radiative Energy Deposition) Code
- Single bit
- Multiple bit

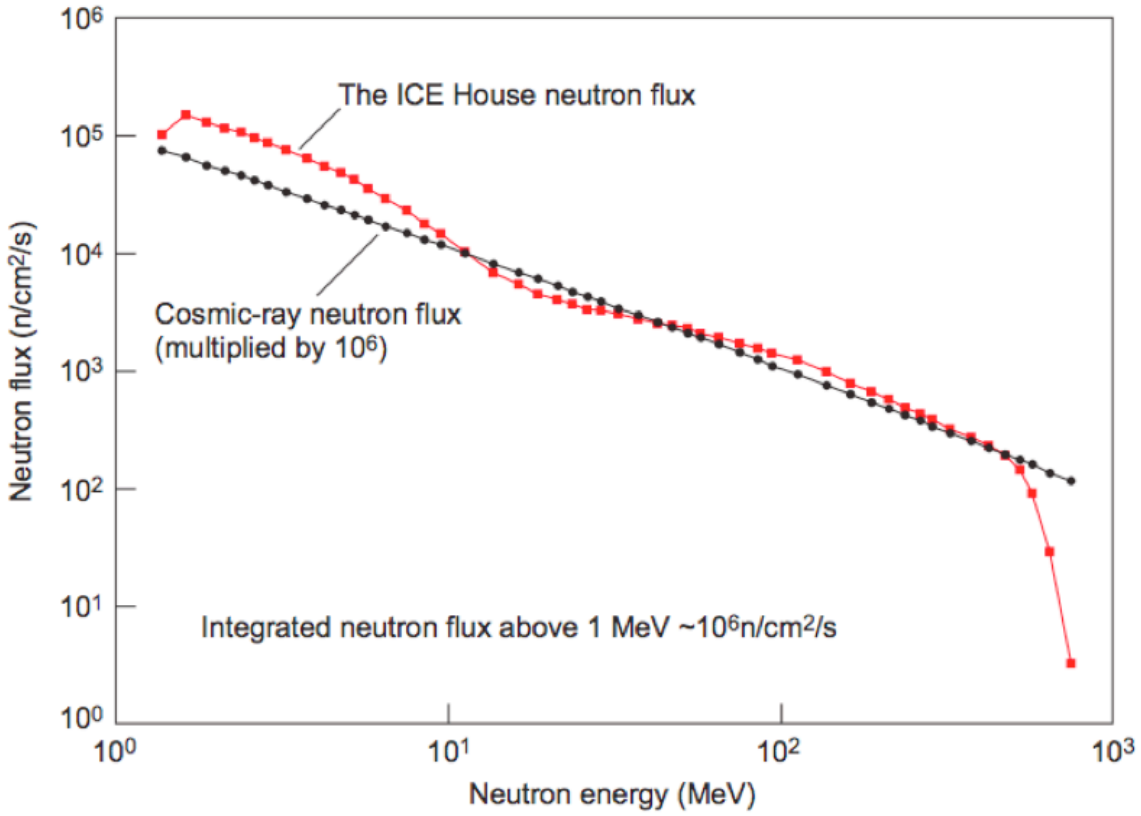


MRED simulated the TCAD device

- TCAD structure created from TI layout and process
- Device simulated using LANL beam line neutron spectrum

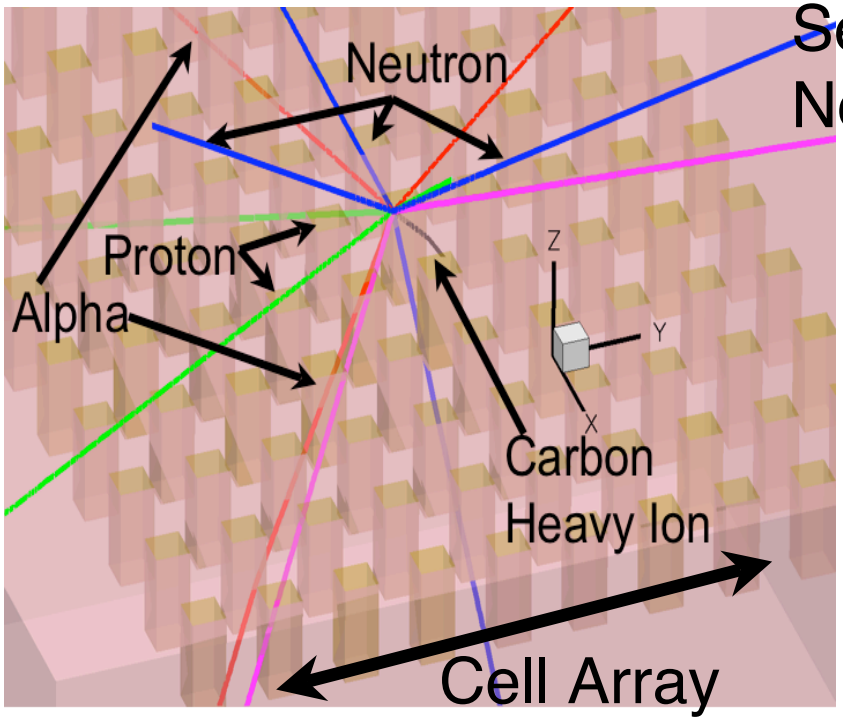


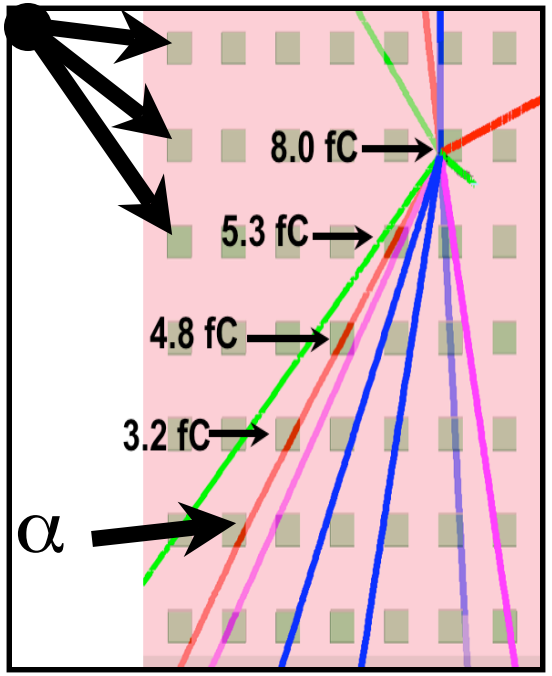
LANL neutron beam



- WNR beam spectrum imported into MRED
- Fluence comparable to cosmic-ray neutron fluence

MRED simulates ionization and nuclear processes

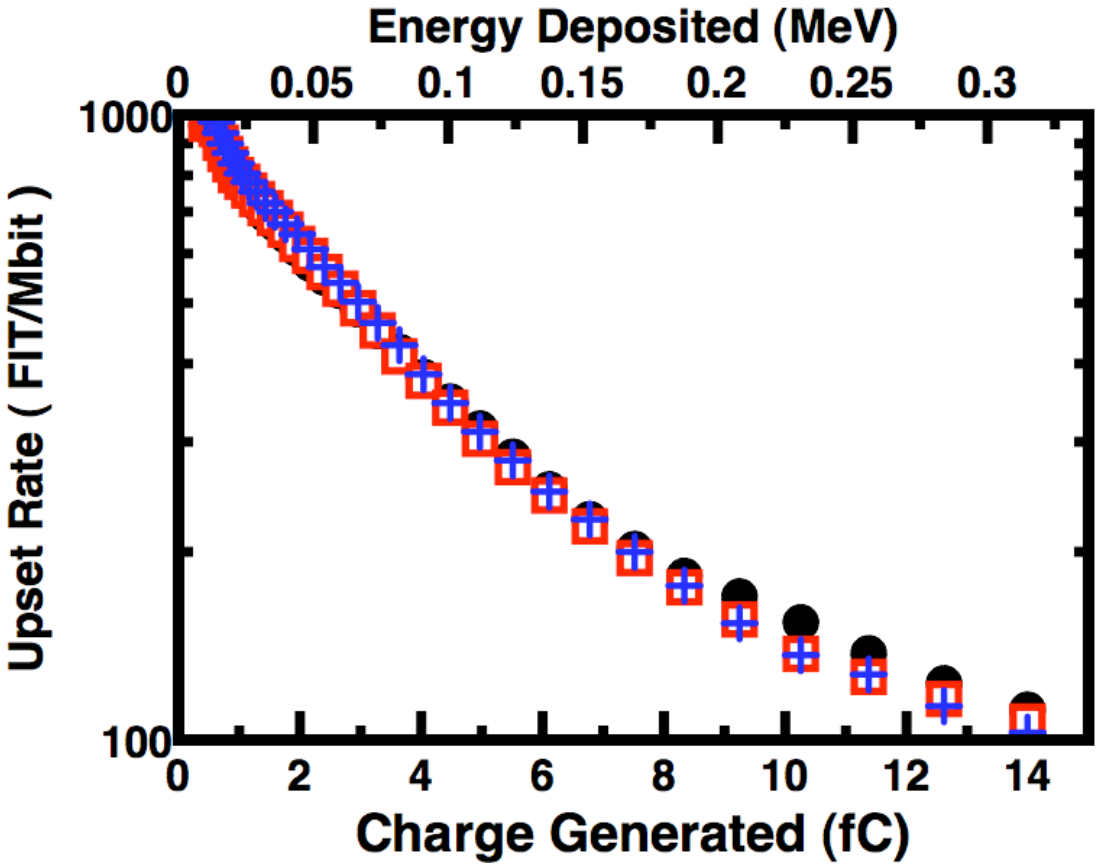


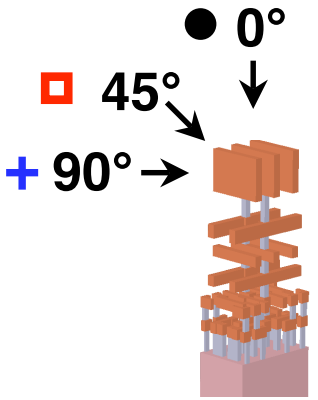


$$n+Si \rightarrow C+3n+2p^{+}+3\alpha$$

- MRED tracks energy deposition through all layers
- MRED calculates energy deposition at each node

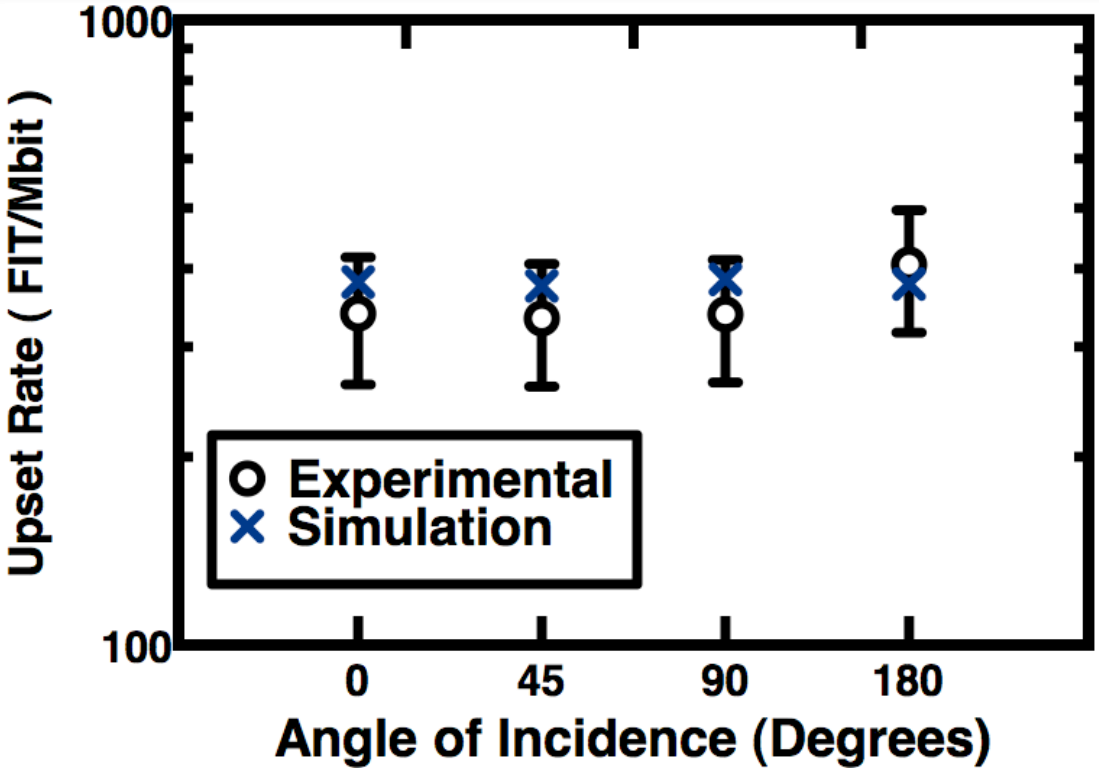
Single-bit rate does not depend on orientation





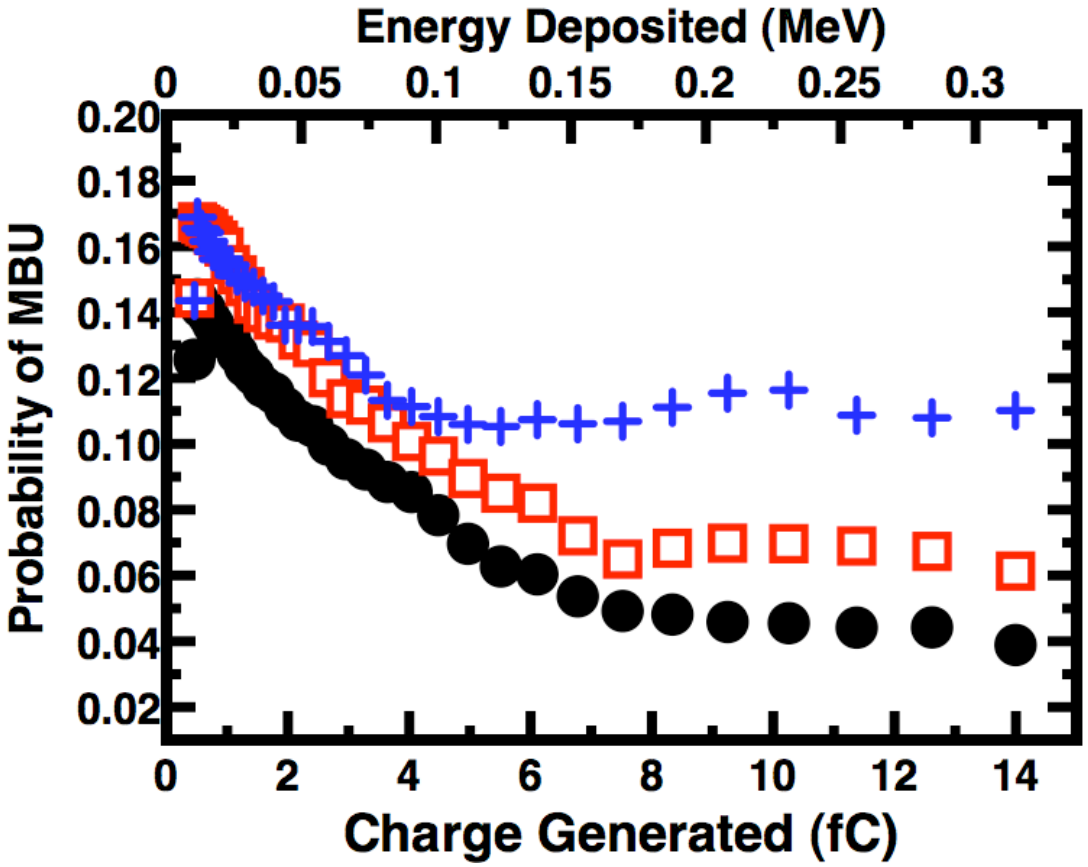
- No angle dependence
- No frontside-backside dependence

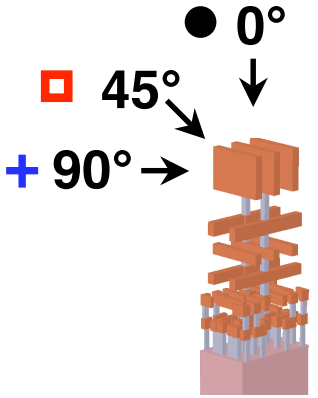
Single-bit simulation in good agreement



- Circuit simulation suggest Q_{crit} = 4 fC
- Simulation in agreement with experimental data at Q_{Crit}

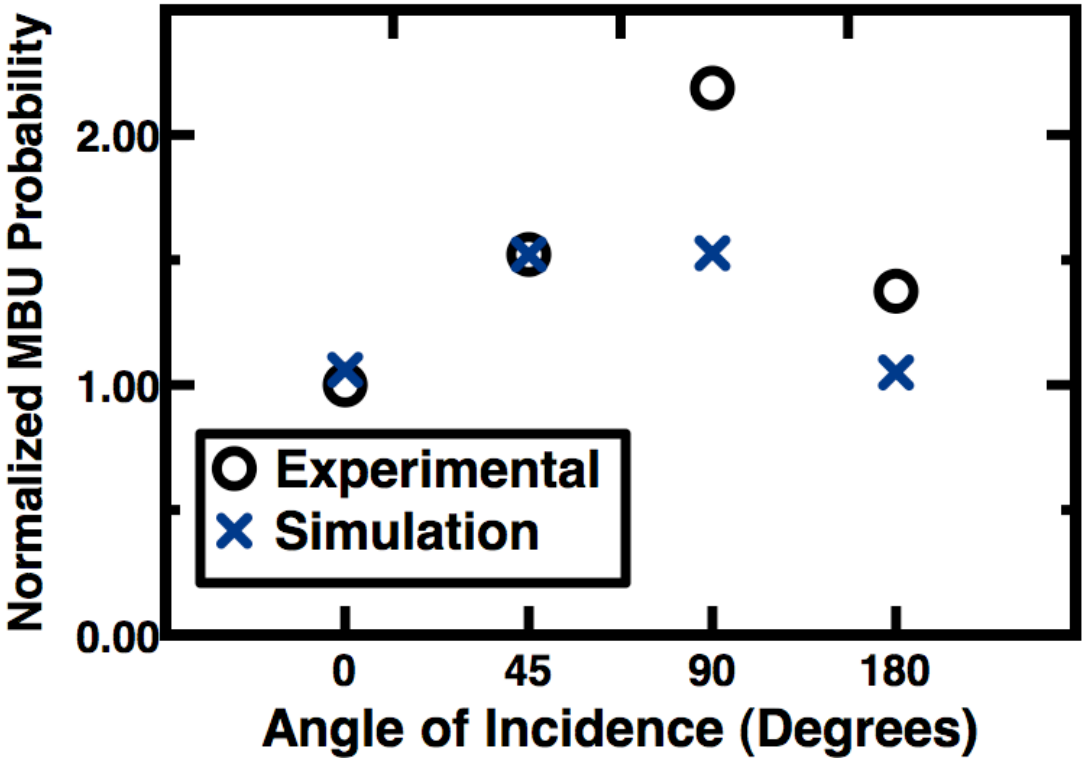
Multiple-bit probability depends on orientation





- Preferential direction from spacing and nuclear products

Multiple-bit upset probability



- Simulation shows increased probability at grazing angles
- More calibration needed at 90°

Conclusions

- Multiple-bit upset is increasing for highly-scaled devices
- Neutron irradiation has been modeled using MRED for a TI 90 nm CMOS technology
- SBU independent of device orientation
- Probability of MBU exhibits an angle dependence for neutron irradiation
  - Probability increases at grazing angles
  - Neutron testing must account for these dependencies

Publications and talks

- A. D. Tipton, J. A. Pellish, P. R. Fleming, R. D. Schrimpf, R. A. Reed, R. A. Weller, M. H. Mendenhall, and L. W. Massengill, "High-energy neutron multiple-bit upset," presented at International Conference on IC Design and Technology, Austin, TX, 2007.
- A. D. Tipton, X. Zhu, H. Weng, J. A. Pellish, P. R. Fleming, R. D. Schrimpf, R. A. Reed, R. A. Weller, and M. Mendenhall, "Increased rate of multiple-bit upset at large angles of incidence," *IEEE Trans. Dev. Mat. and Rel.*, submitted for review.

Future work

- TI 65 nm process
  - Device simulation of SRAM cell
  - NASA-GSFC/Vanderbilt proton and heavy-ion testing
  - Examine impact of angular dependence on error rate
- Proton effects
  - Proton-induce SEE
  - Proton-induced MBU
  - Possible IBM collaboration
  - Proton ionization
- Dissertation Fall ‘08