# Device-Orientation Effects on Multiple-Bit Upset in 65-nm SRAMs

VANDERBII

School of Engineeri

Alan D. Tipton[1], Jonathan A. Pellish[1], John M. Hutson[1], Robert Baumann[2], Xiaowei Deng Andrew Marshall[2], Michael A. Xapsos[3], Hak S. Kim[4], Mark R. Friendlich[4], Michael J. Cam  a[4], Christina M. Seidleck[4], Ken A. LaBel[3], Marcus H. Mendenhall[1], Robert A. Reed[1],

Ronald D. Schrimpf[1], & Robert A. Weller[1]

1. Vanderbilt University
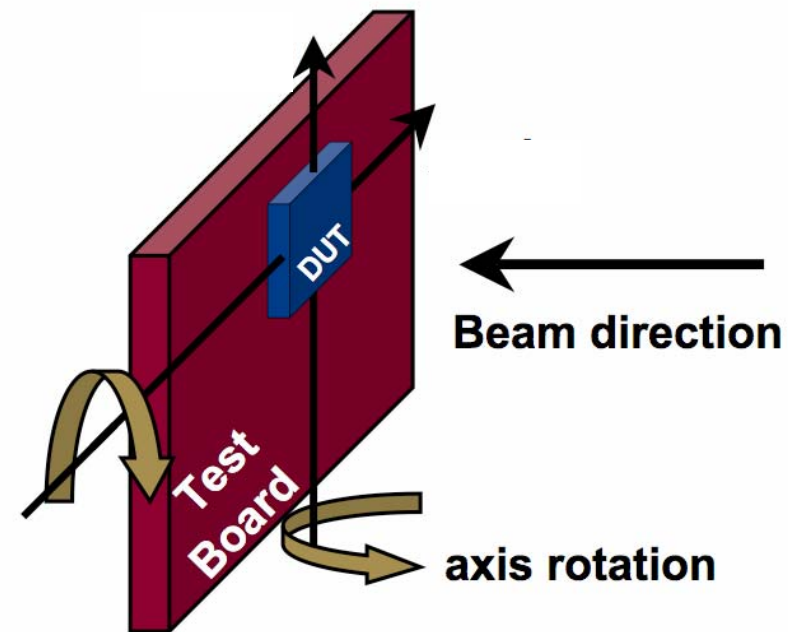2. Texas Instruments
3. NASA-GSFC
4. MEI Technology

- Device under test
- Heavy ion irradiations
  - Single event upset (SEU)
  - Multiple-bit upset (MBU)
- Monte-Carlo simulation (MRED)
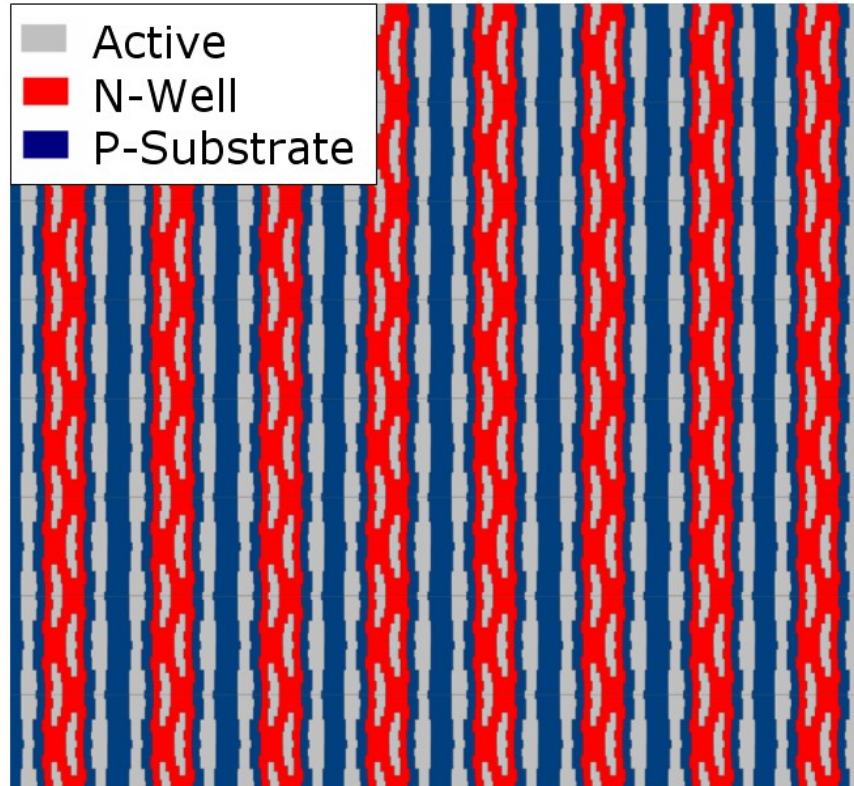  - Physical model
  - Environment
  - MBU response
- Conclusion



scale: 5 um
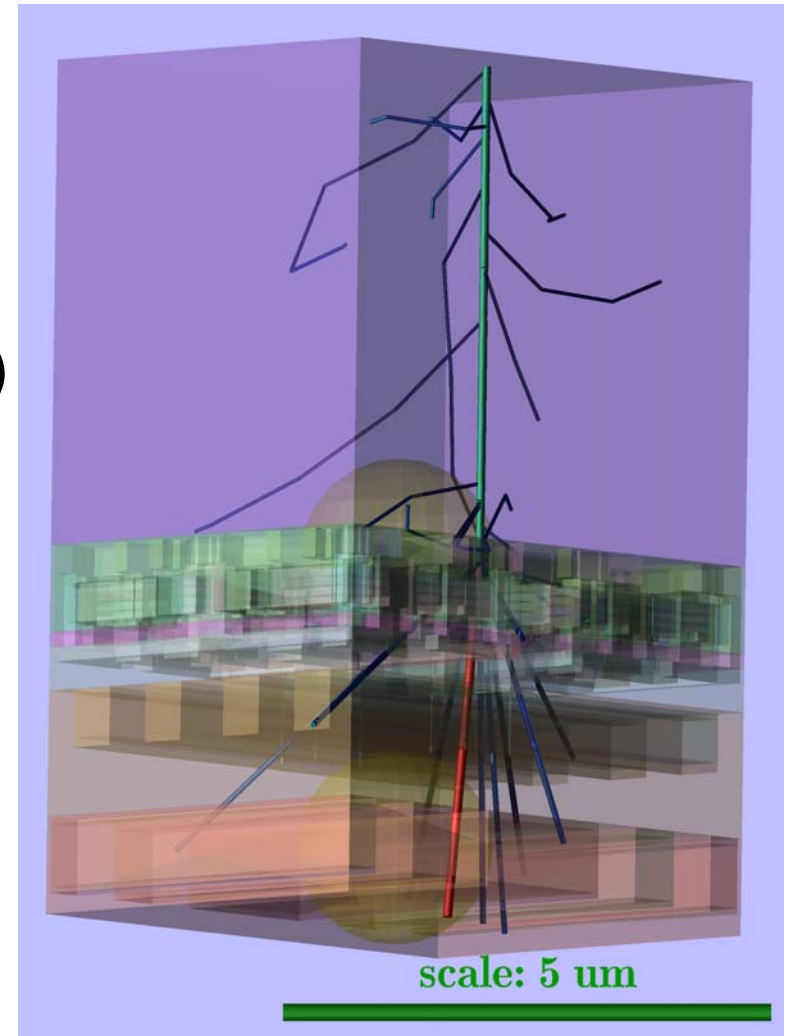
# Device under test

- Texas Instruments 65 nm CMOS SRAM

- 4 Mbit memory

- 1.2 V operating voltage
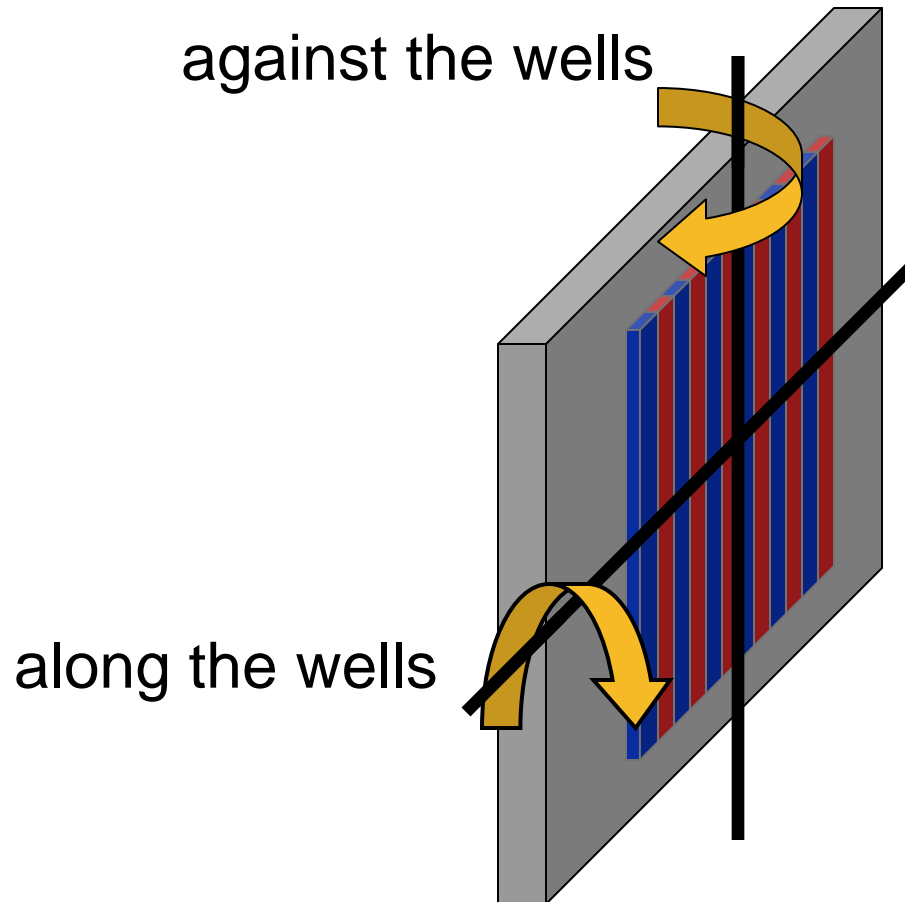
- Irradiations about two axes

- Heavy ions at TAMU



**Beam direction**

**axis rotation**

Device under test
Heavy ions
MRED simulation
Conclusion

SRAM
Orientation

VANDERBILT

# SRAM layout produces alternating columns of wells



Active
N-Well
P-Substrate

from Hutson  *et al.*

Device under test
Heavy ions
MRED simulation
Conclusion

SRAM
Orientation

VANDERBILT

# Define the device orientation by the wells

against the wells

along the wells

Device under test
Heavy ions
MRED simulation
Conclusion

SEU
MBU
MBU dimension

# SEU cross section varies little with orientation

- SEU cross section for all bit upsets
- LET values are at top of DUT
- 15 MeV/u tune

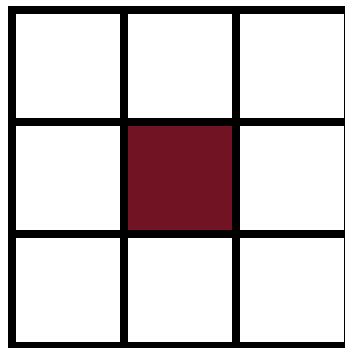Device under test    SEU
Heavy ions    MBU
MRED simulation    MBU dimension
Conclusion

VANDERBILT
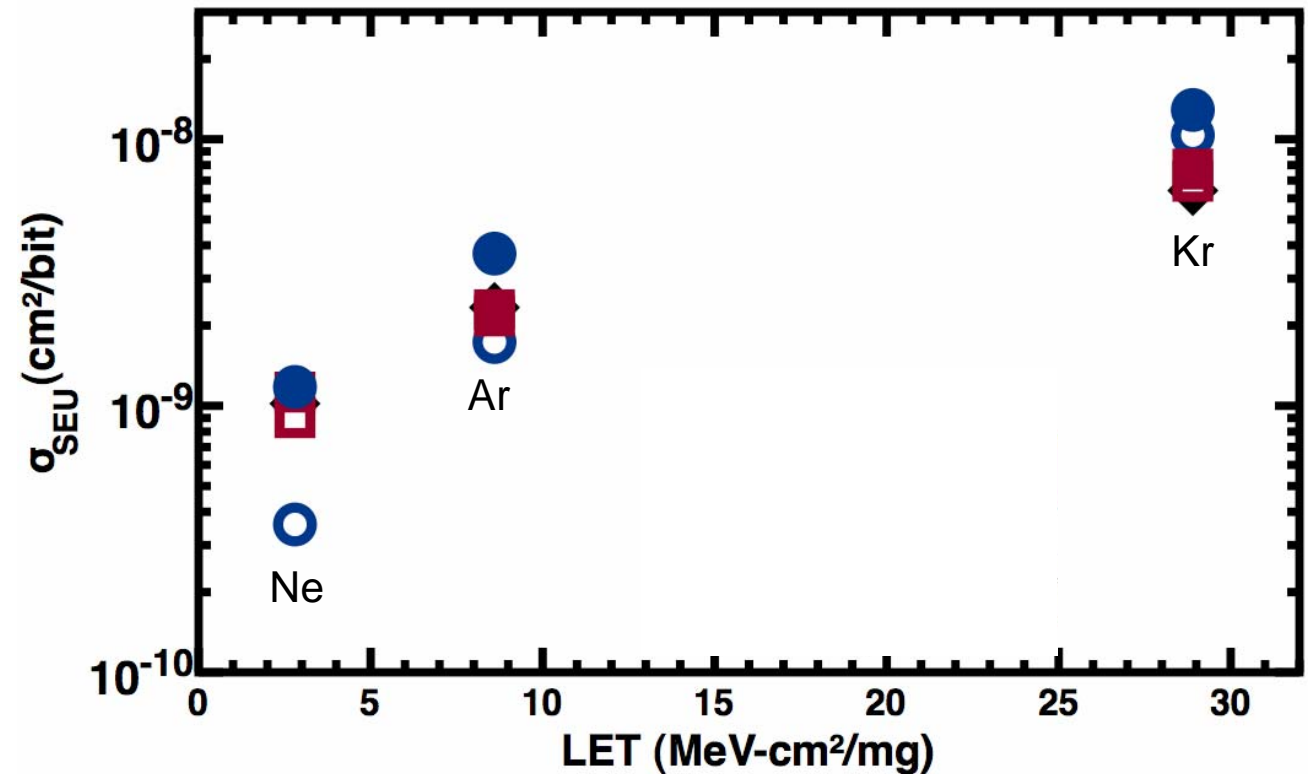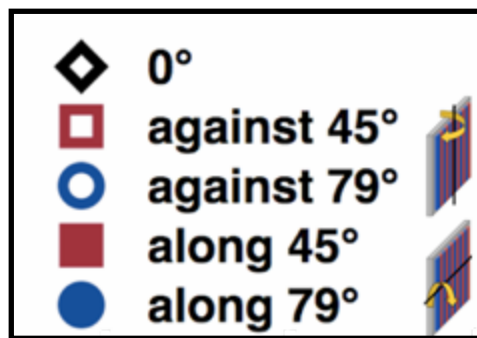
# MBU cross section changes with orientation

- MBU events are physically adjacent upsets

Device under test
Heavy ions
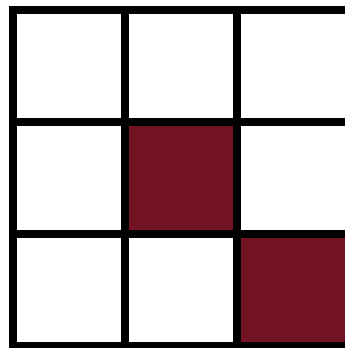MRED simulation
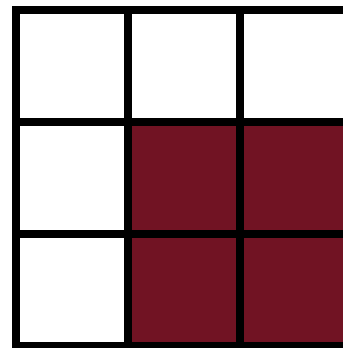Conclusion

SEU
MBU
MBU dimension

VANDERBILT
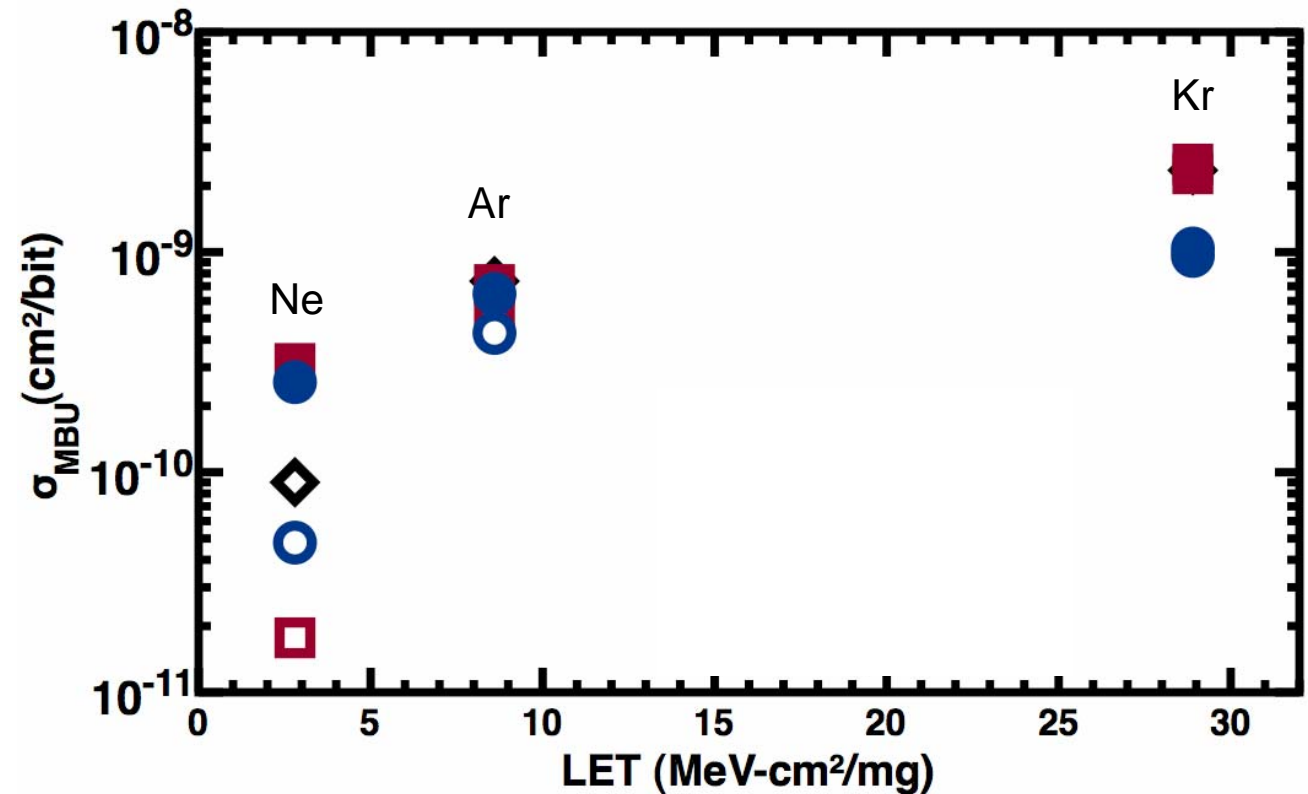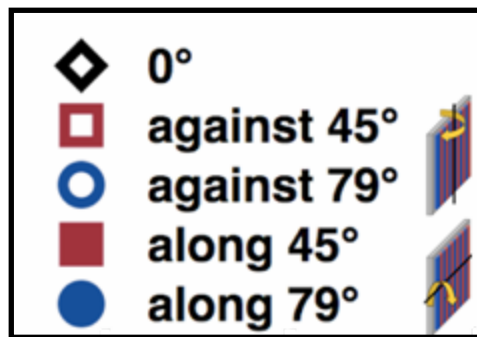
# MBU size

- Size is defined as the number of affected rows or columns
- MBU dimension $\equiv$ affected rows x affected columns
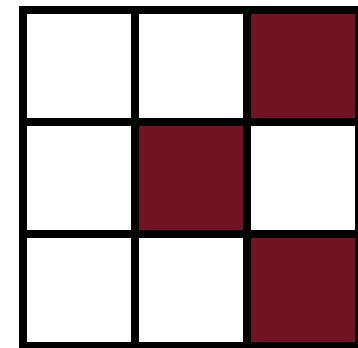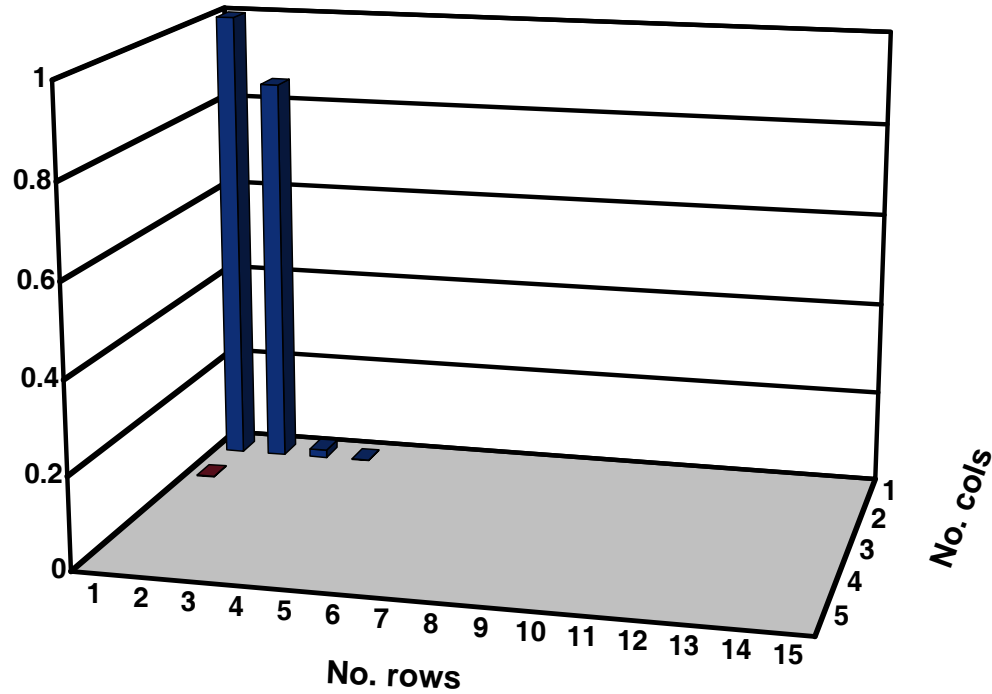- Wells run along the columns
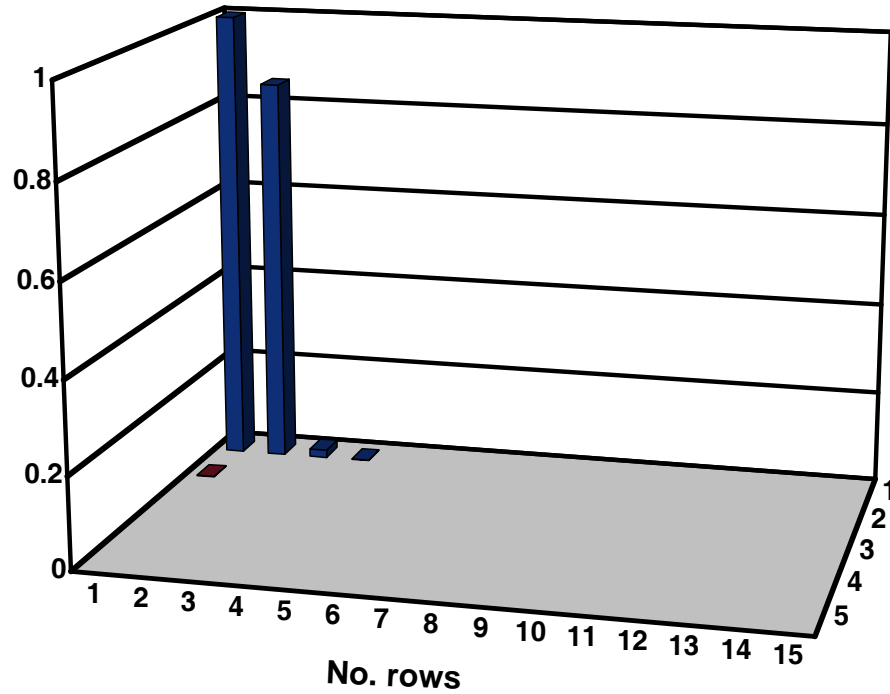- Examples



| 1x1 | 2x2 | 2x2 | 3x2 |

Device under test   SEU
Heavy ions   MBU
MRED simulation   MBU dimension
Conclusion

VANDERBILT

# MBU dimension



Ar normal incidence

Device under test · SEU
Heavy ions · MBU
MRED simulation · MBU dimension
Conclusion

VANDERBILT

# MBU dimension

**Ar normal incidence**

**Ar 79° along the wells**

Device under test SEU
Heavy ions MBU
MRED simulation MBU dimension
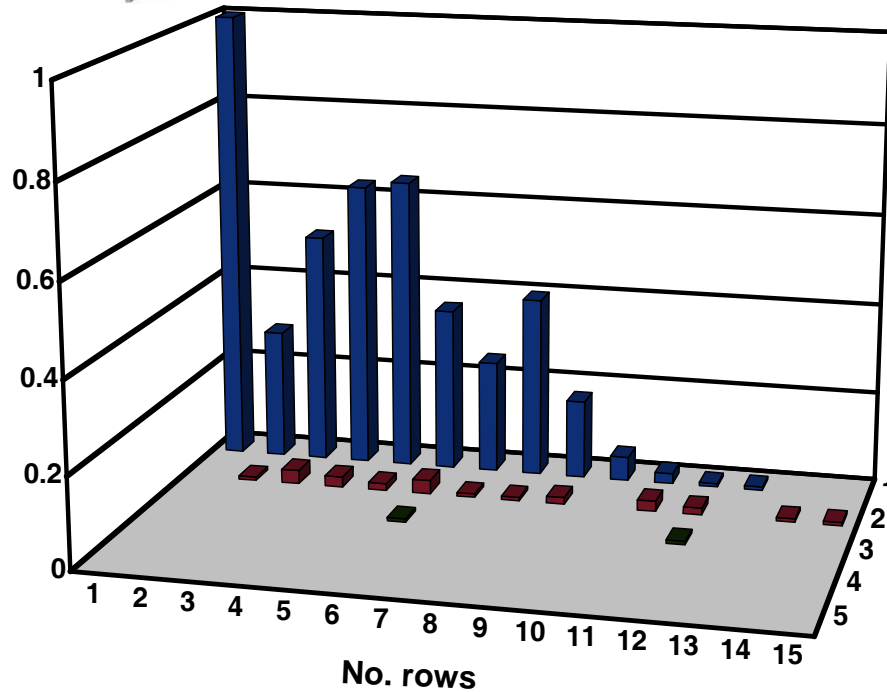Conclusion

VANDERBILT
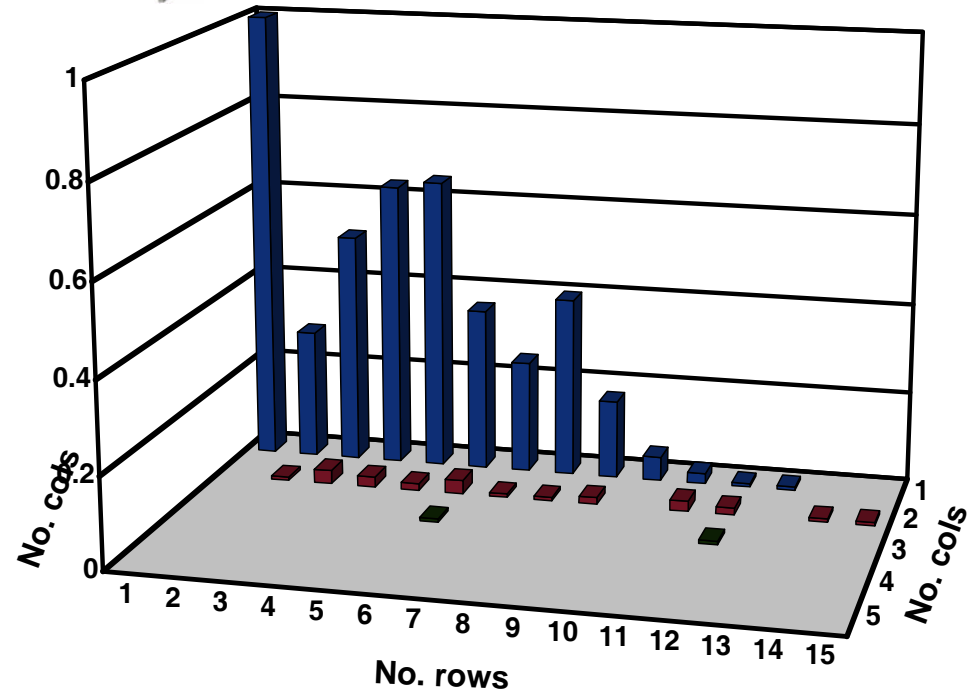
# The shape of MBU events depends on orientation



**Ar 79° along the wells**

**Ar 79° against the wells**

Device under test
Heavy ions
MRED simulation
Conclusion

Physical model
Environment
MBU response
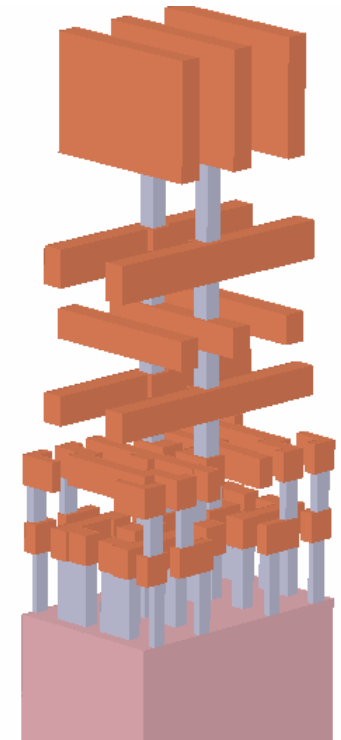
# The device was modeled in MRED

- TCAD structure
  - Layout information
  - Metallization

Device under test | Physical model
Heavy ions | Environment
MRED simulation | MBU response
Conclusion

# The device was modeled in MRED

- TCAD structure
  - Layout information
  - Metallization
- Sensitive volume
  - Layout and process boundaries
  - Calibrated using TCAD

Device under test | Physical model
Heavy ions | Environment
MRED simulation | MBU response
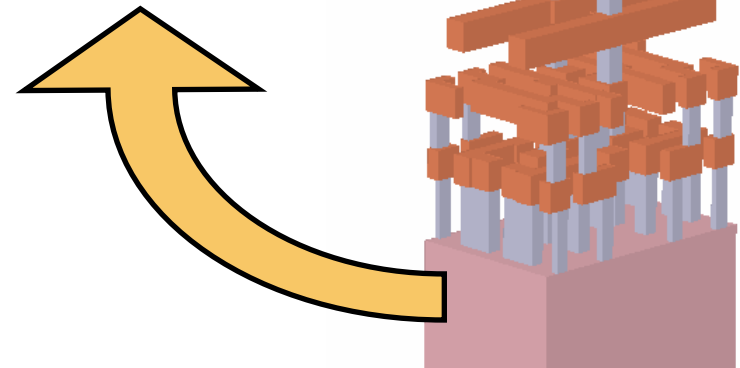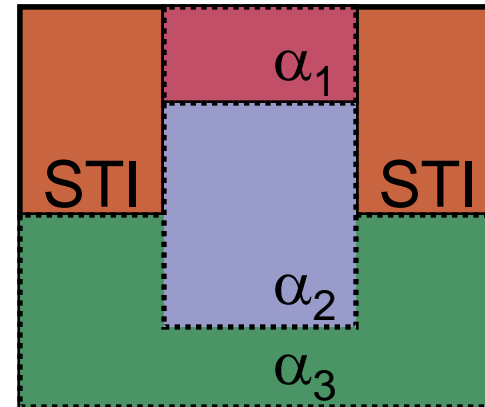Conclusion

# The device was modeled in MRED

- TCAD structure
  - Layout information
  - Metallization
- Sensitive volume
  - Layout and process boundaries
  - Calibrated using TCAD
  - Nested approach
    - Charge collection efficiency, $\alpha$

Device under test    Physical model
Heavy ions    Environment
MRED simulation    MBU response
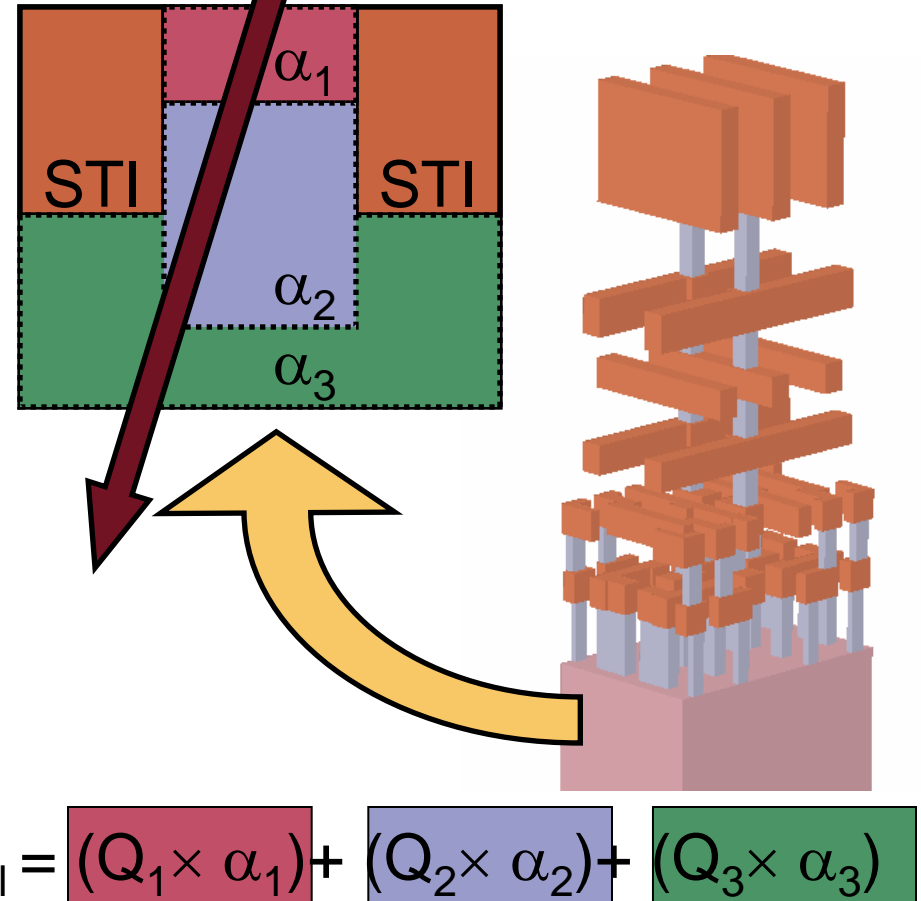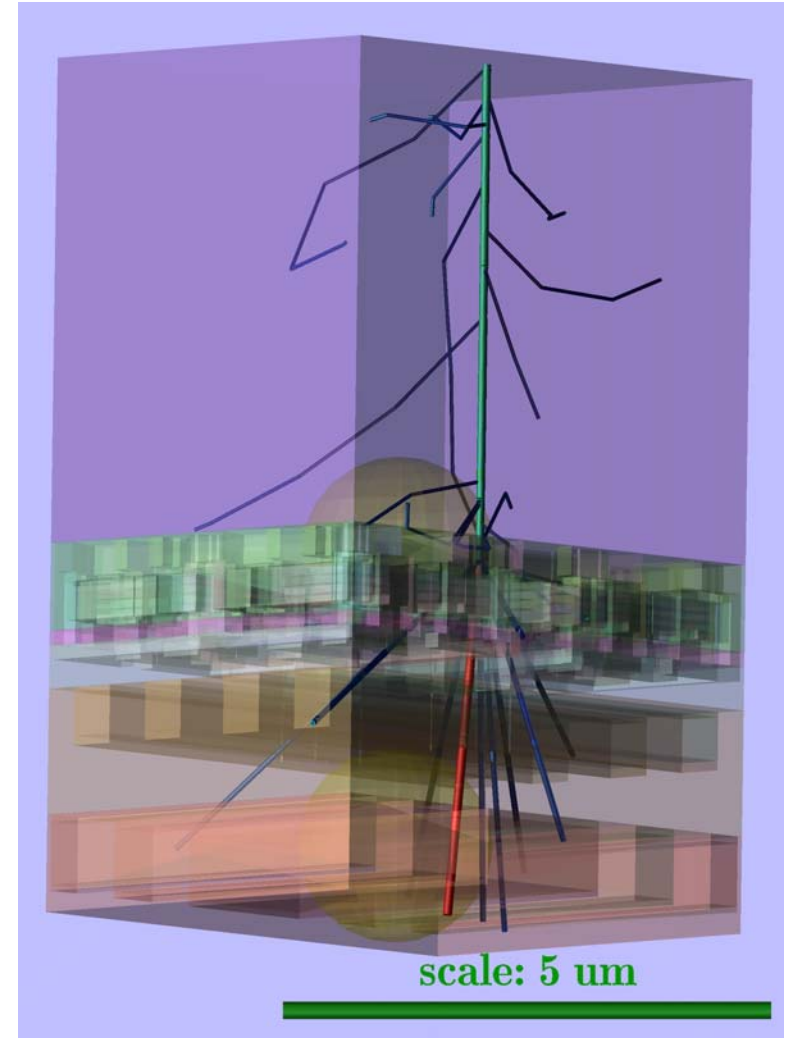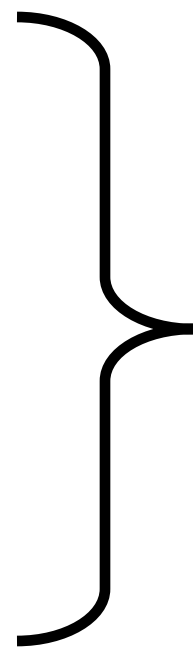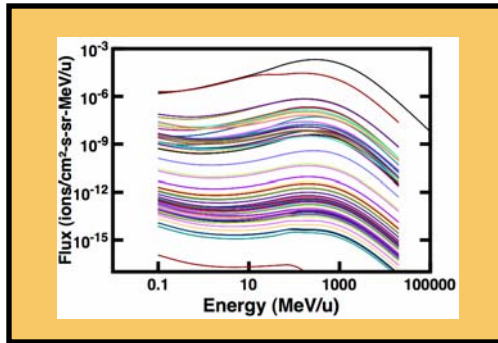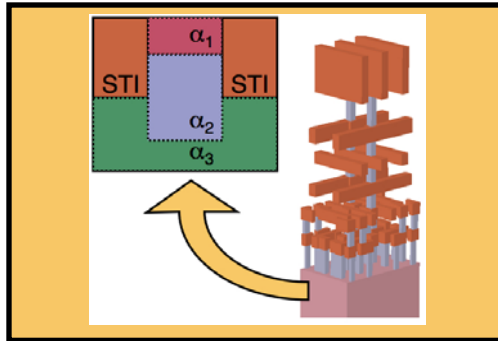Conclusion

VANDERBILT

# The device was modeled in MRED

- TCAD structure
  - Layout information
  - Metallization
- Sensitive volume
  - Layout and process boundaries
  - Calibrated using TCAD
  - Nested approach
    - Charge collection efficiency, $\alpha$



$$Q_{total} = (Q_1 \times \alpha_1) + (Q_2 \times \alpha_2) + (Q_3 \times \alpha_3)$$

Device under test
Heavy ions
MRED simulation
Conclusion

Physical model
Environment
MBU response

VANDERBILT

# MRED simulated a GEO environment



scale: 5 um

Device under test   Physical model
Heavy ions   Environment
MRED simulation   MBU response
Conclusion

VANDERBILT
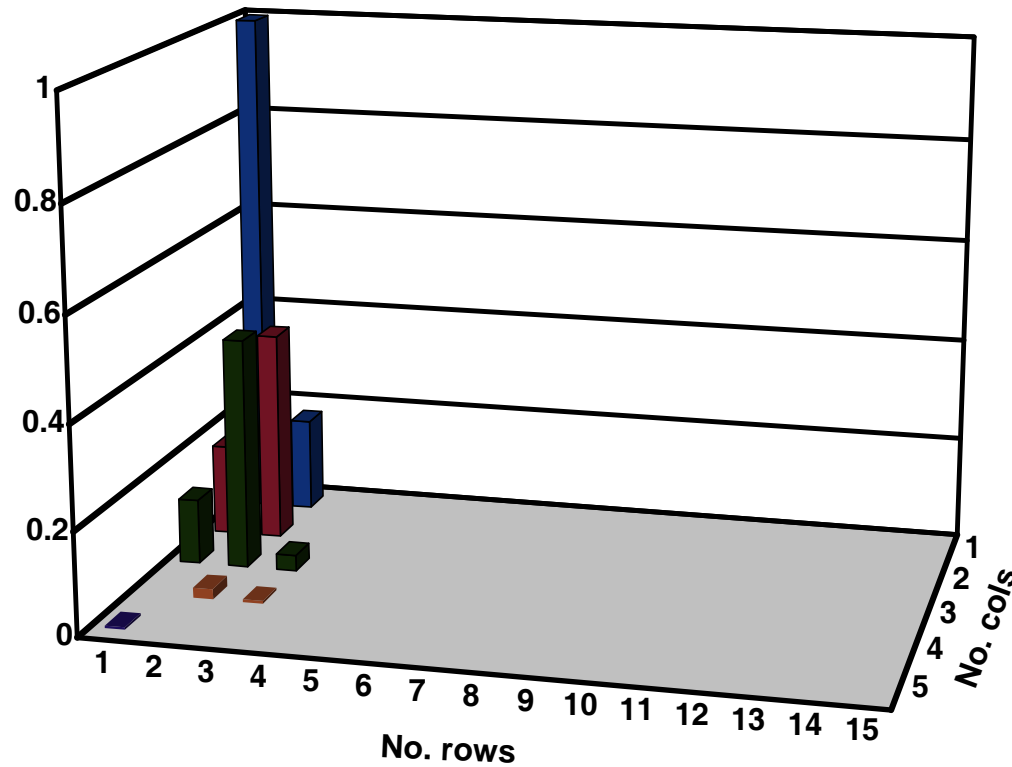
# Omni-directional simulation results



Ar 79° against the wells

# Conclusion

- Heavy ion irradiations have been performed
  - SEU varies little with angle of ion incidence
  - MBU depend on the device orientation
- The MBU response depends on the well orientation of the device
- MRED simulation of an omni-directional GEO environment shows the MBU response to be a combination of response from different orientations
- Testing and simulation must account for multiple orientations