

Multiple-Bit Upset in 130 nm CMOS Technology



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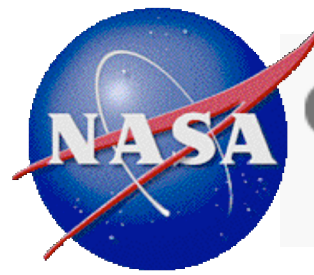
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**In conjunction with
NEPP & DTRA**

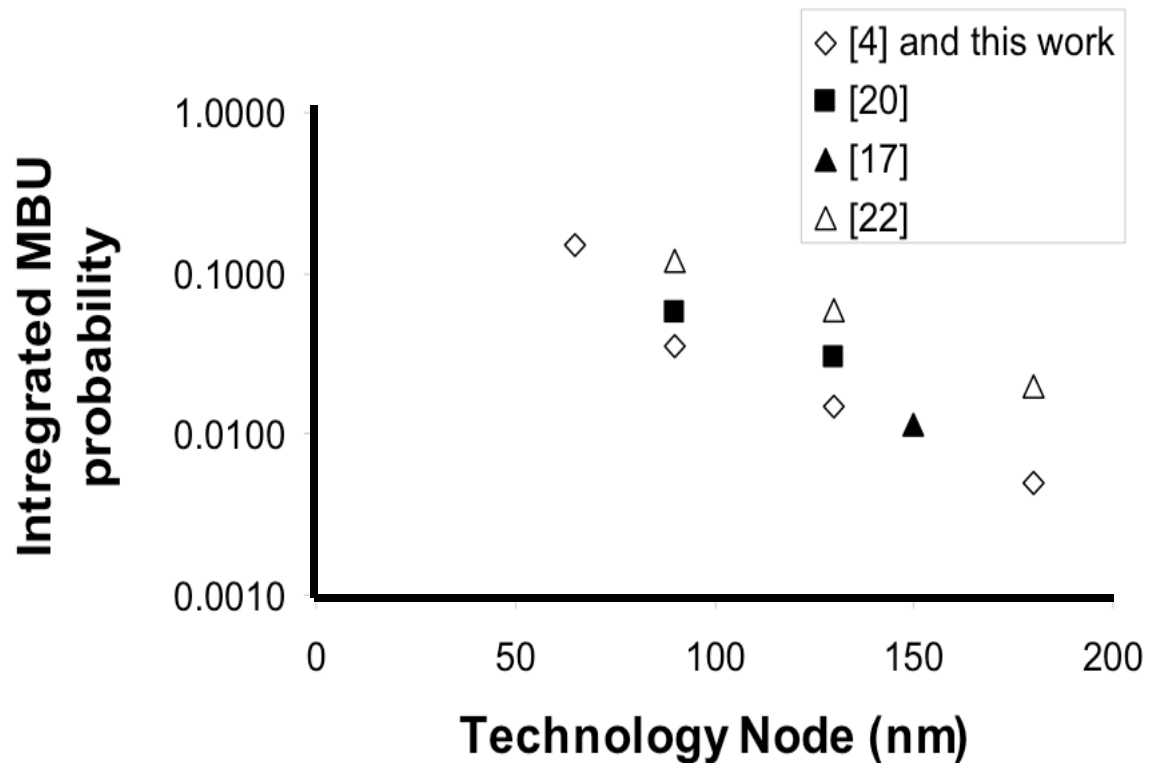


MBU increases with IC scaling



- Reliability
 - Memory design
 - Testing
- MBU has been shown to increase for smaller technologies

Proton-Induced MBU

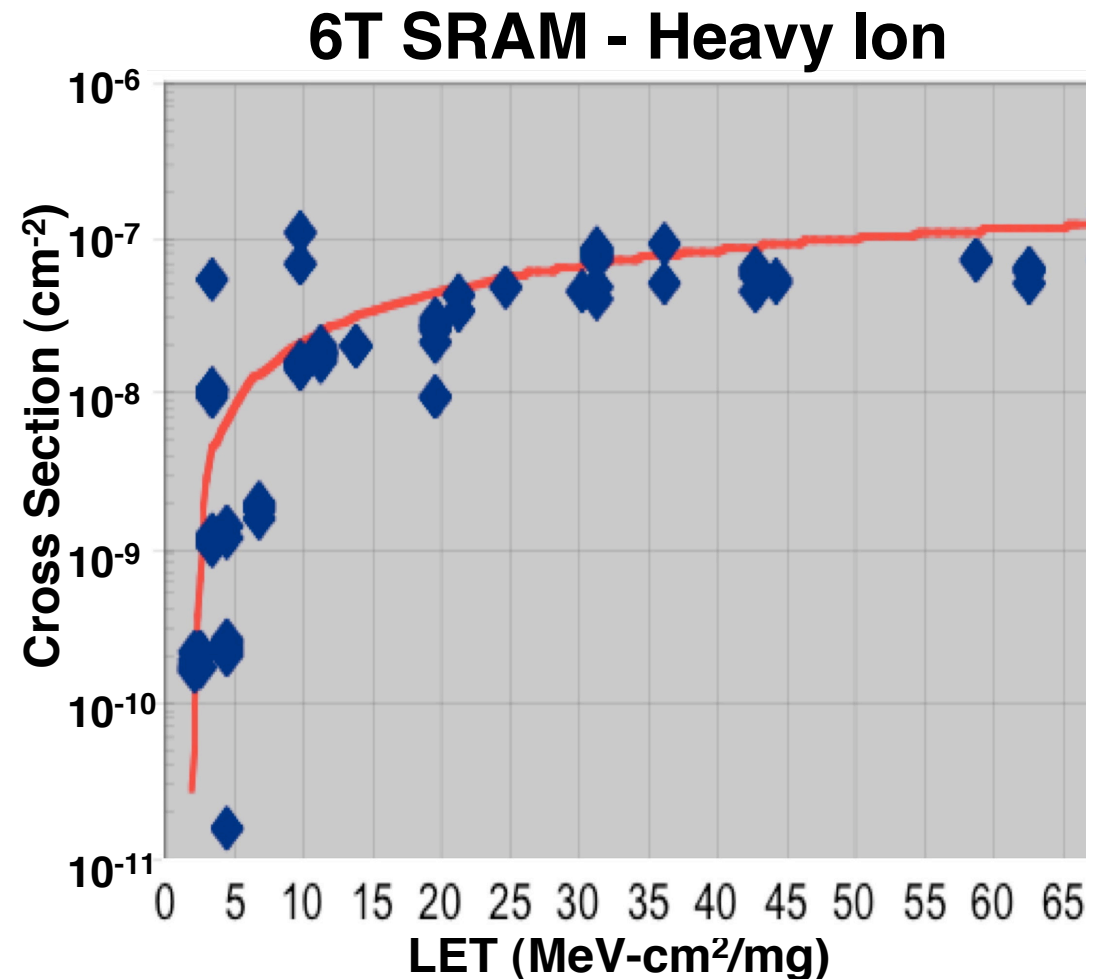


from Seifert, *et. al*, Intel. IRPS, 2006.

Soft technology



- IBM 8RF
130 nm
CMOS
- **High density**
CMOS SRAM
- Low upset
threshold
~ 2 MeV-cm²/mg



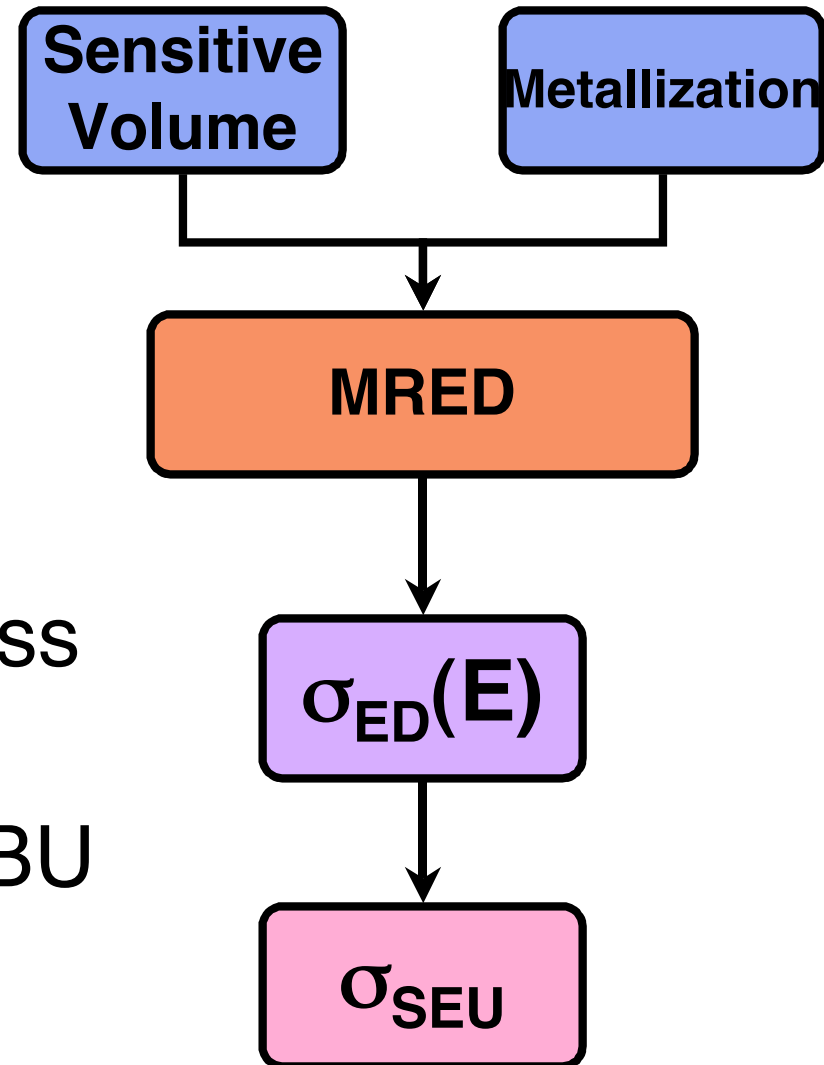
from RHBD program, BAE Systems

MURI Review



Modeling methodology

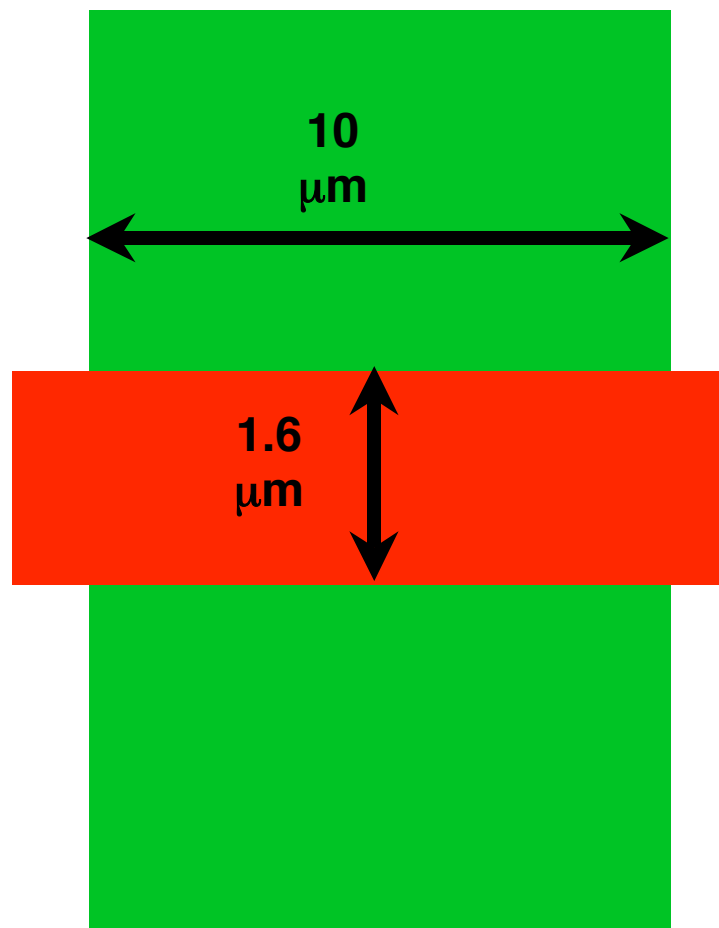
- Sensitive volume
 - Depth
 - Lateral dimensions
- Physical model
- Simulation - MRED
- Energy deposition cross section - $\sigma_{ED}(E)$
- Correlate $\sigma_{ED}(E)$ to MBU





Collection depth

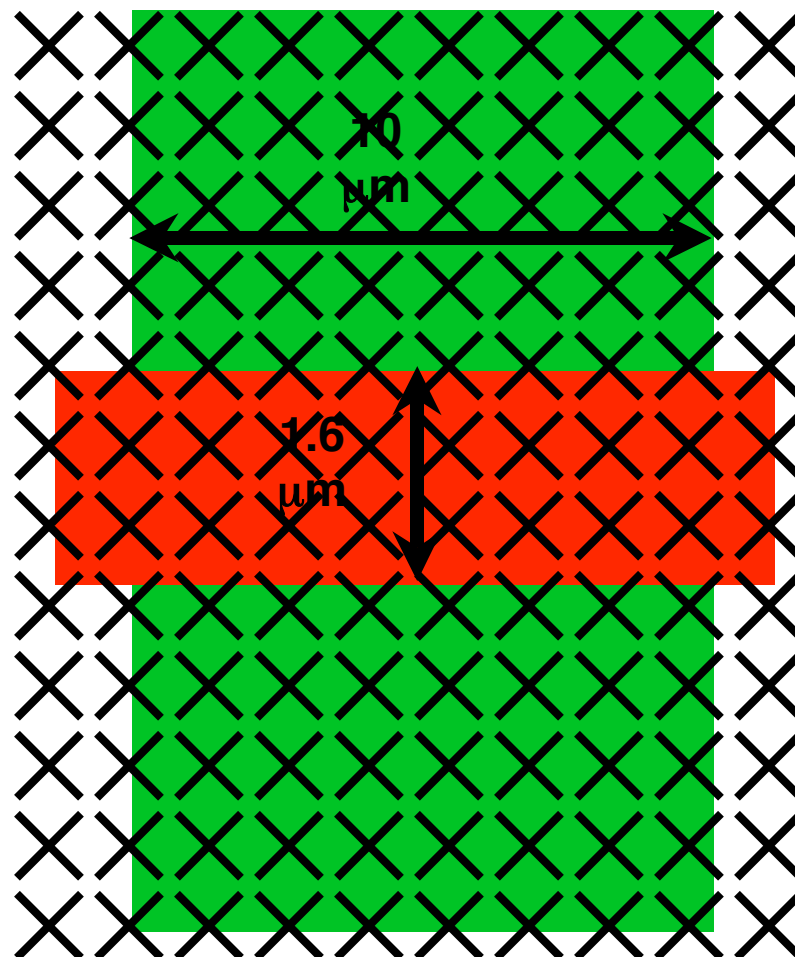
- Ion Beam Induced Charge Collection (**IBICC**)
36 MeV Oxygen
7 MeV-cm²/mg
~ 0.07 pC/ μm





Collection depth

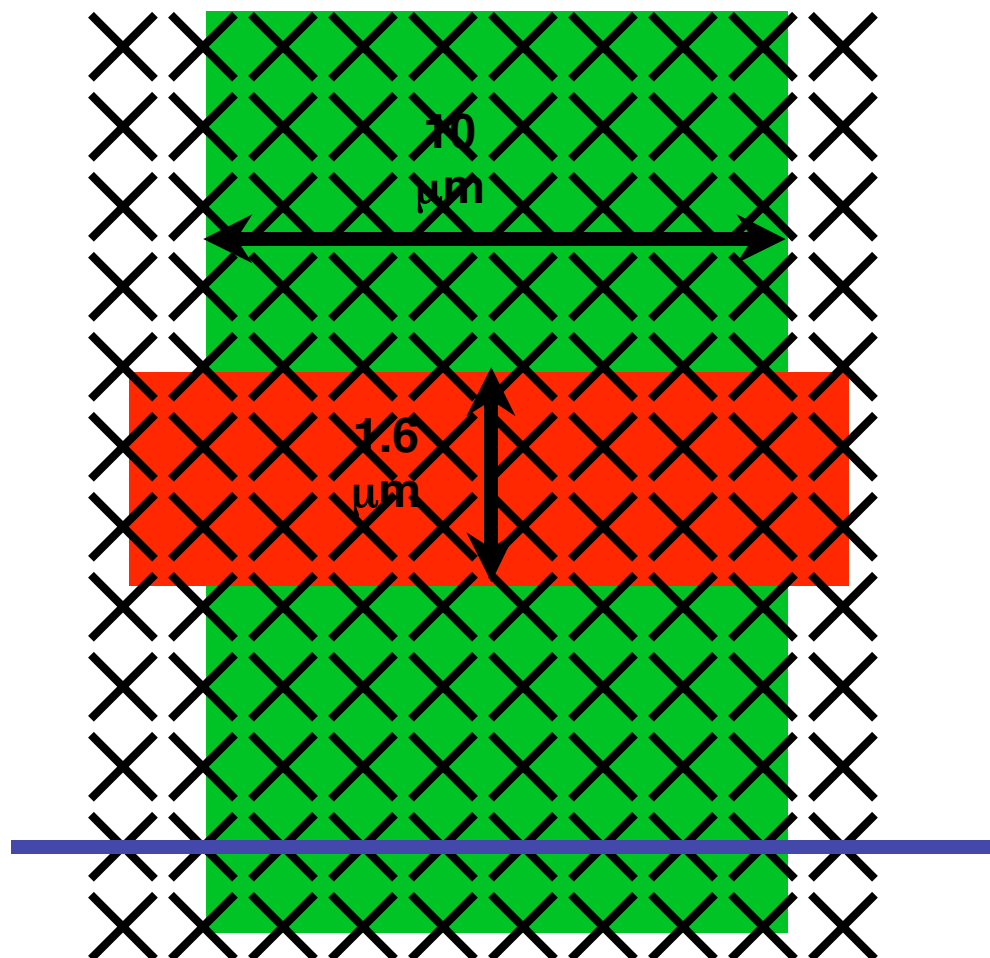
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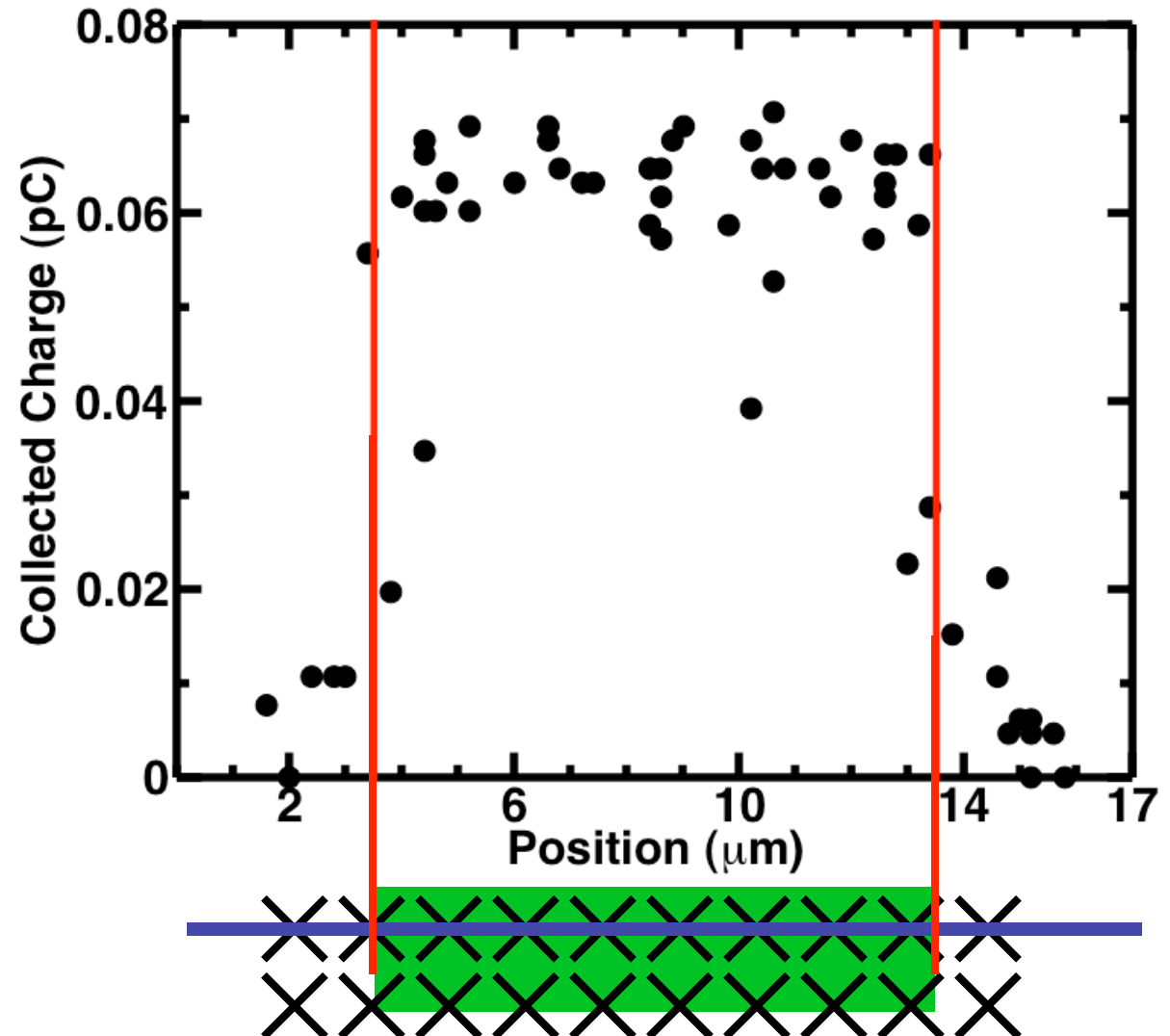
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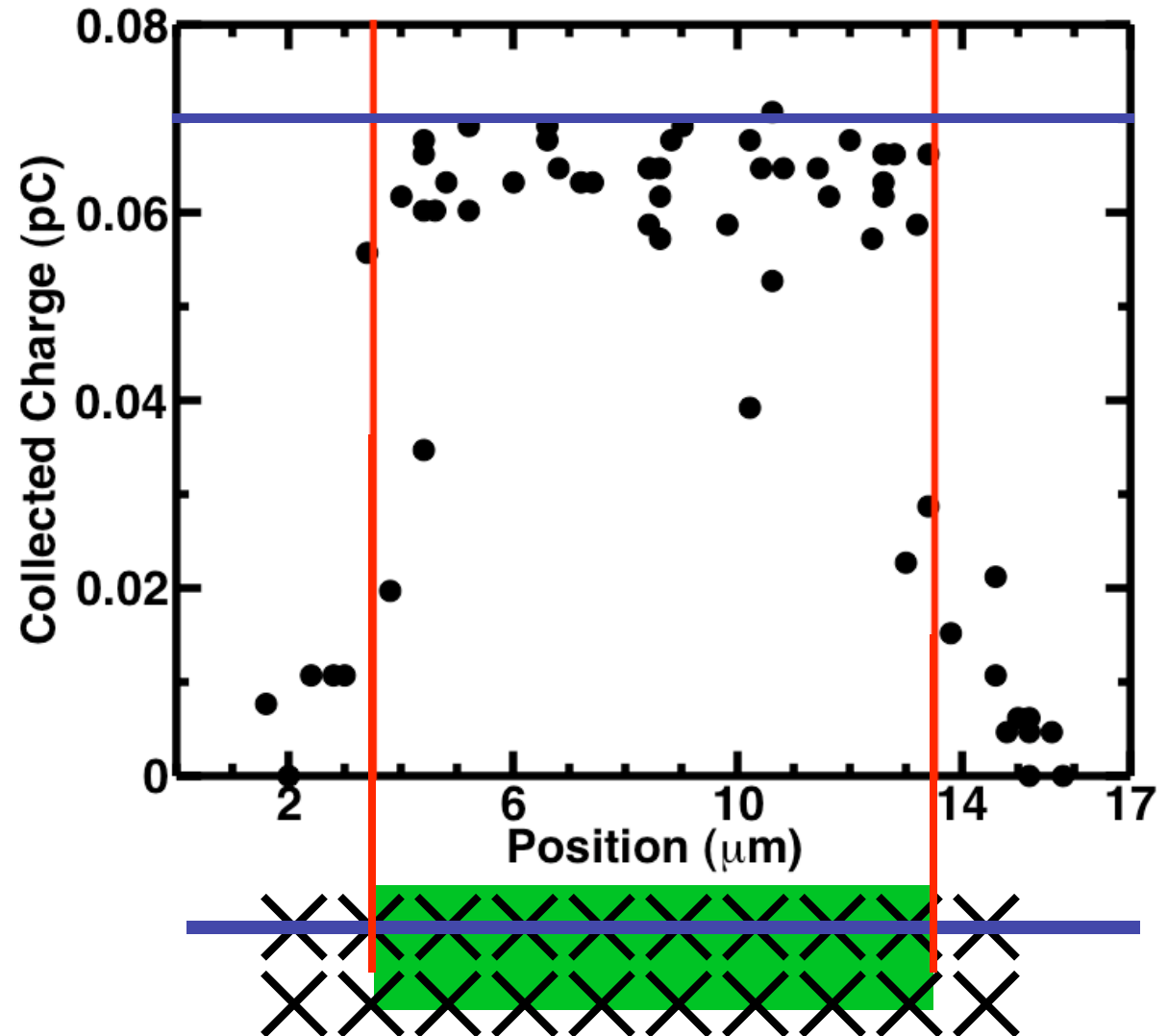
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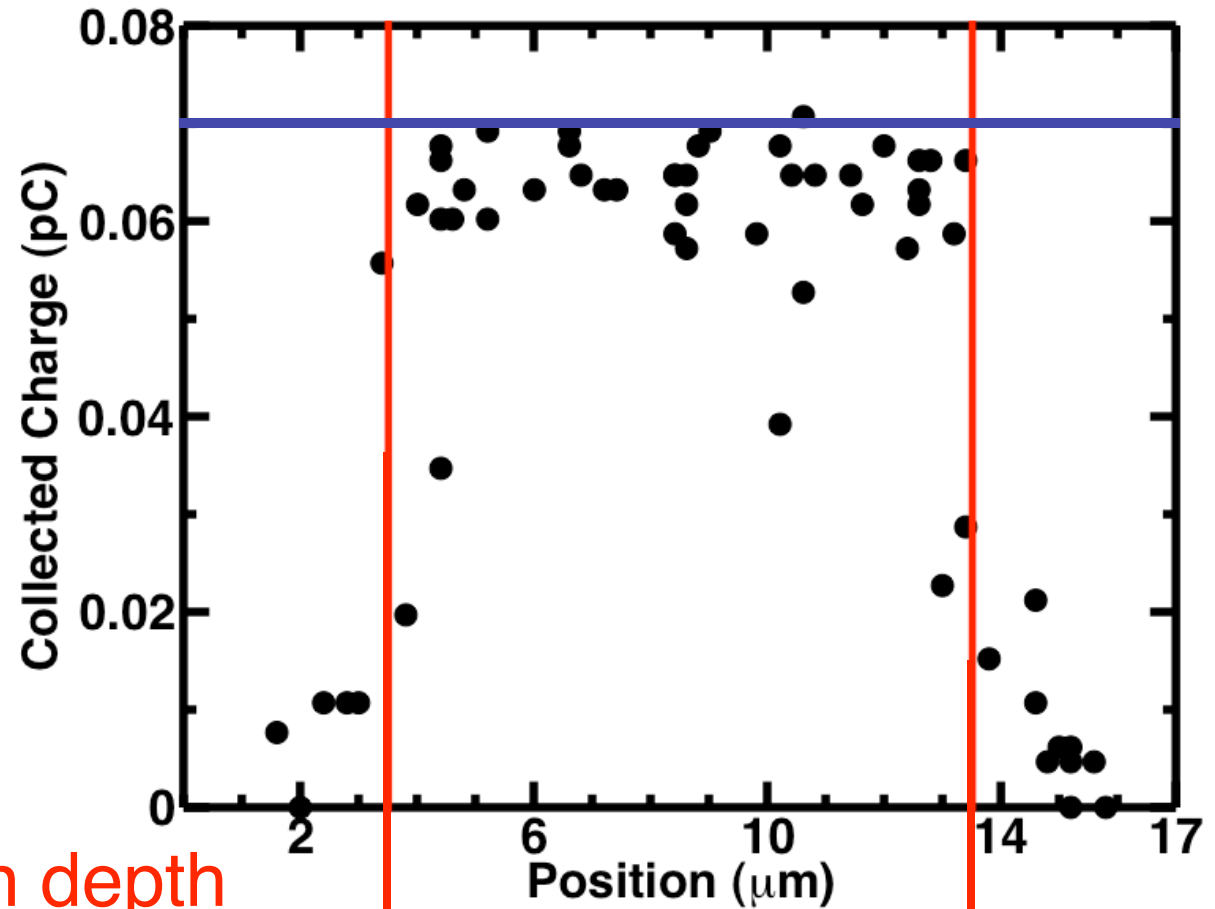
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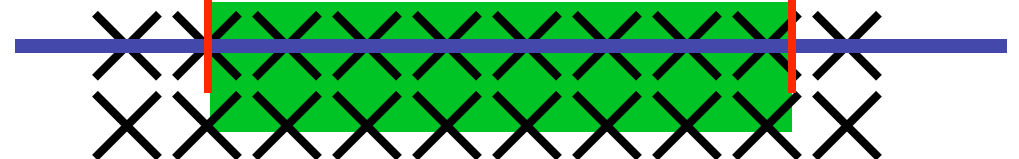
Collection depth

- Ion Beam Induced Charge Collection (**IBICC**)
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7 MeV-cm²/mg
~ 0.07 pC/ μ m



Peak 0.07 pC

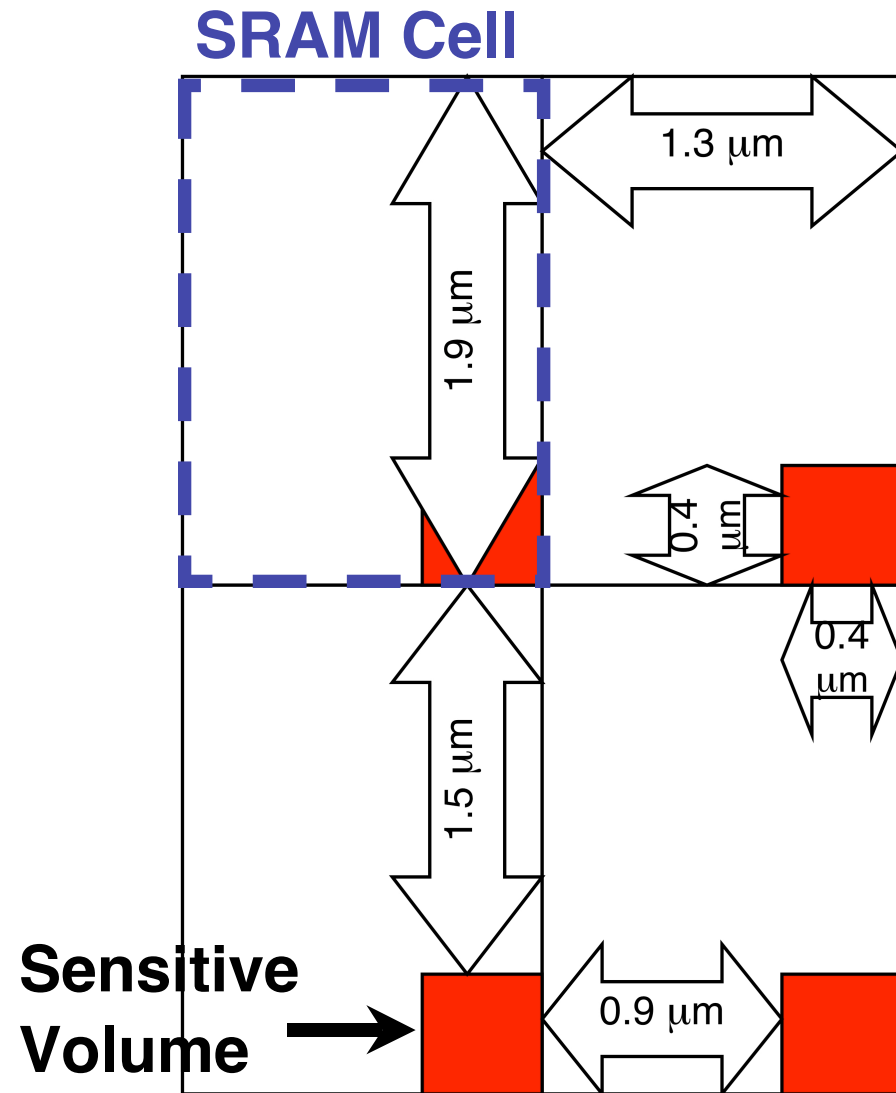
=> 1 μ m collection depth



Sensitive volume definition



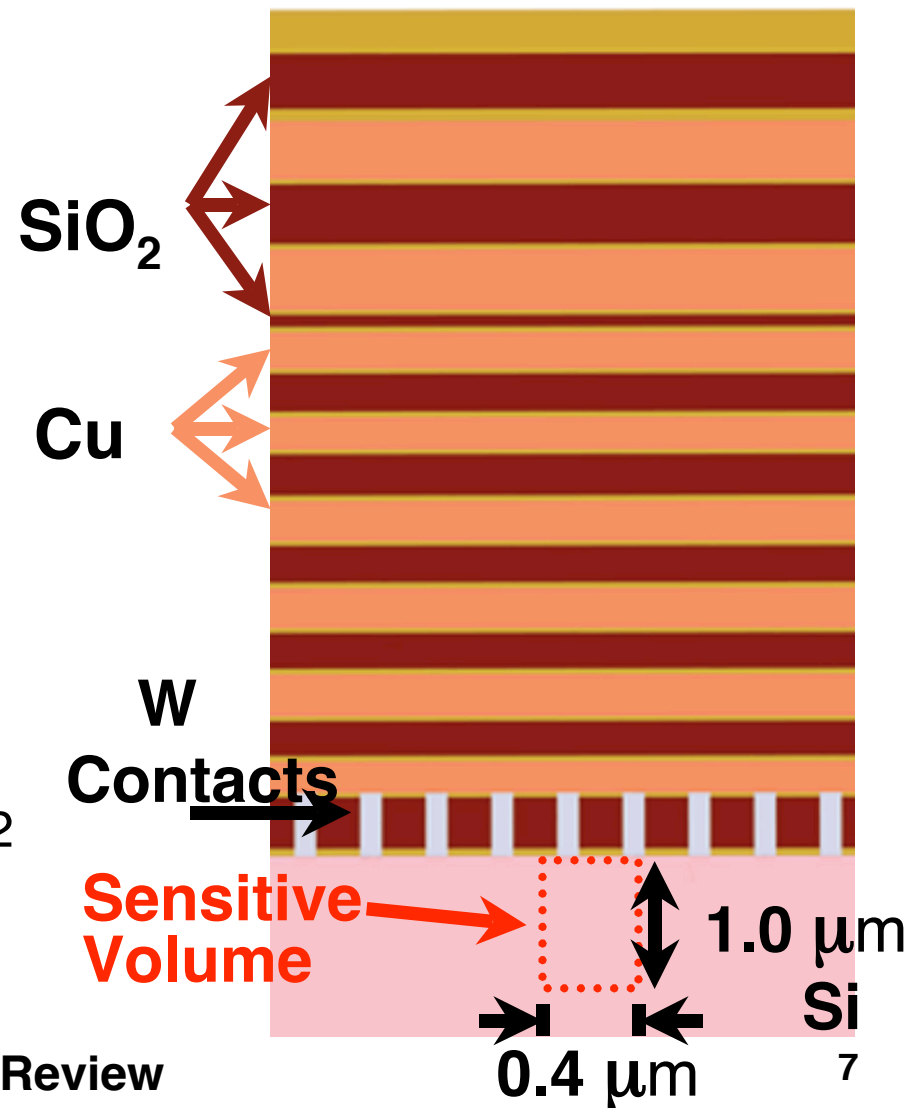
- Depth
 - From IBICC
 - $1\ \mu\text{m}$
- Lateral area
 - Process specific
 - $0.4\ \mu\text{m} \times 0.4\ \mu\text{m}$
- Spacing
 - $1.3\ \mu\text{m} \times 1.9\ \mu\text{m}$



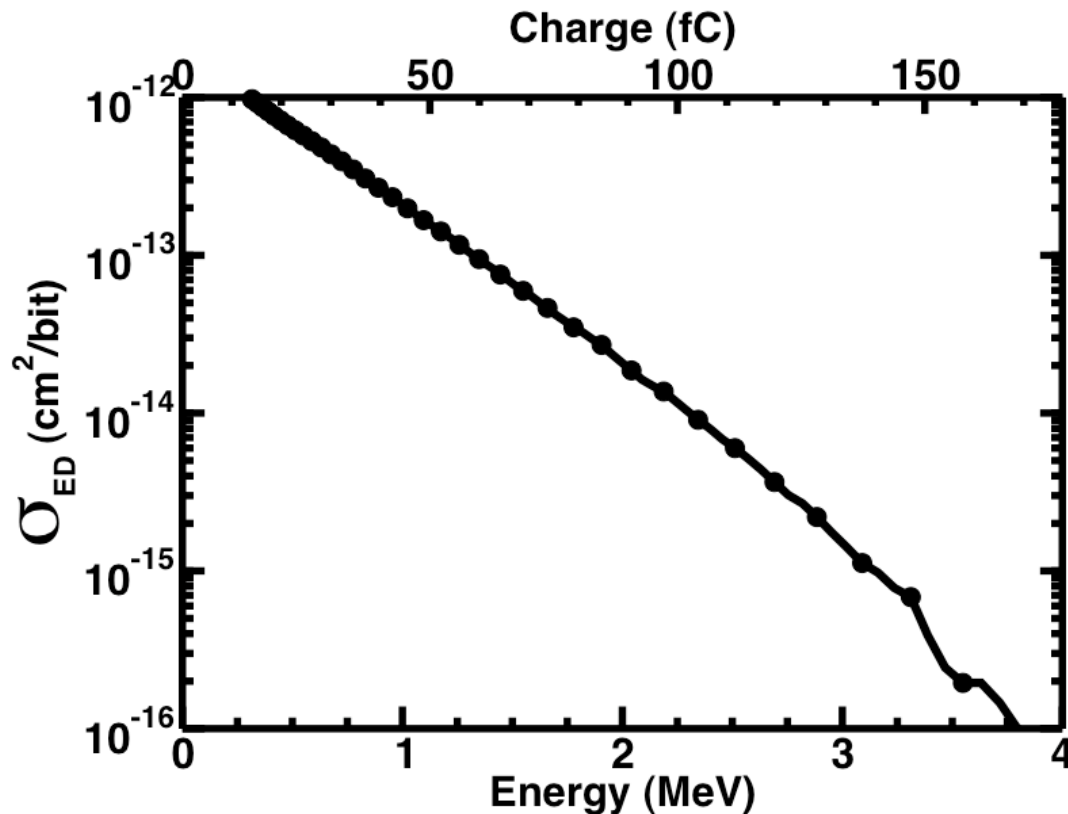


Simulation

- 204 sensitive volumes
- Monte Carlo Radiative Energy Deposition (**MRED**)
 - 63 MeV Protons
 - Fluence $1 \times 10^{14} \text{ cm}^{-2}$
 - Equivalent 2 Mbit @ $1 \times 10^{10} \text{ cm}^{-2}$



Energy deposition cross section



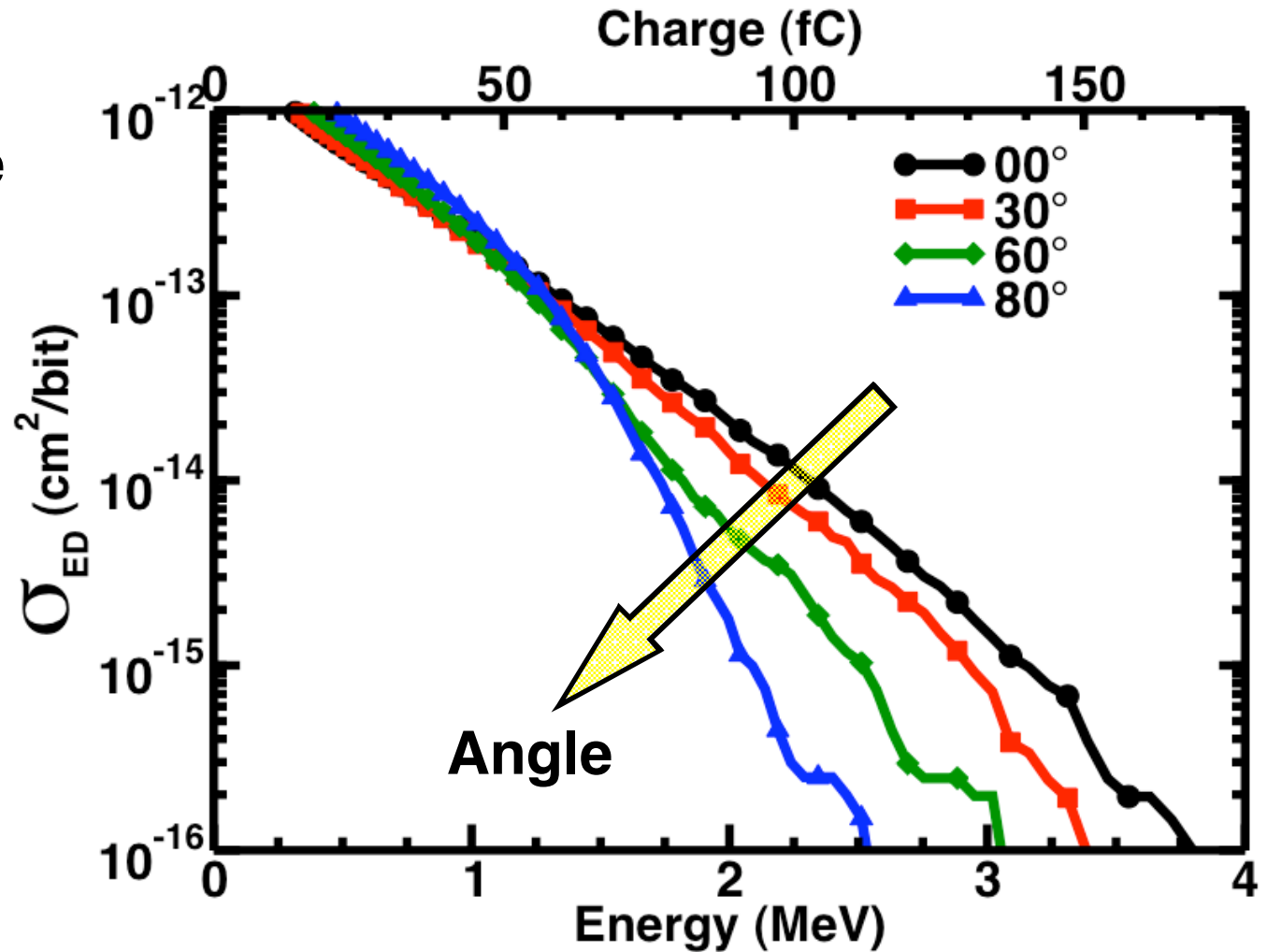
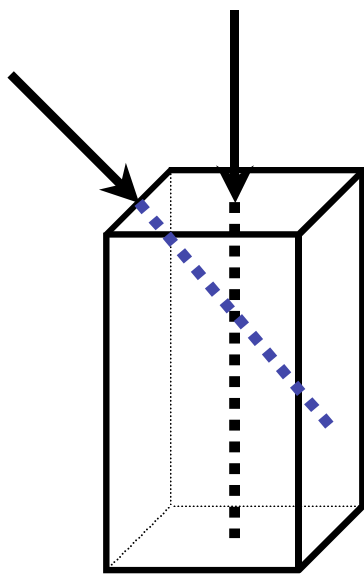
- $\sigma_{ED}(E) \equiv$ Cross section to deposit at least E in the sensitive volume
- Relationship to SEU cross section

$$\sigma_{SEU} = \sigma_{ED}(Q_{crit})$$



Single volume σ_{ED}

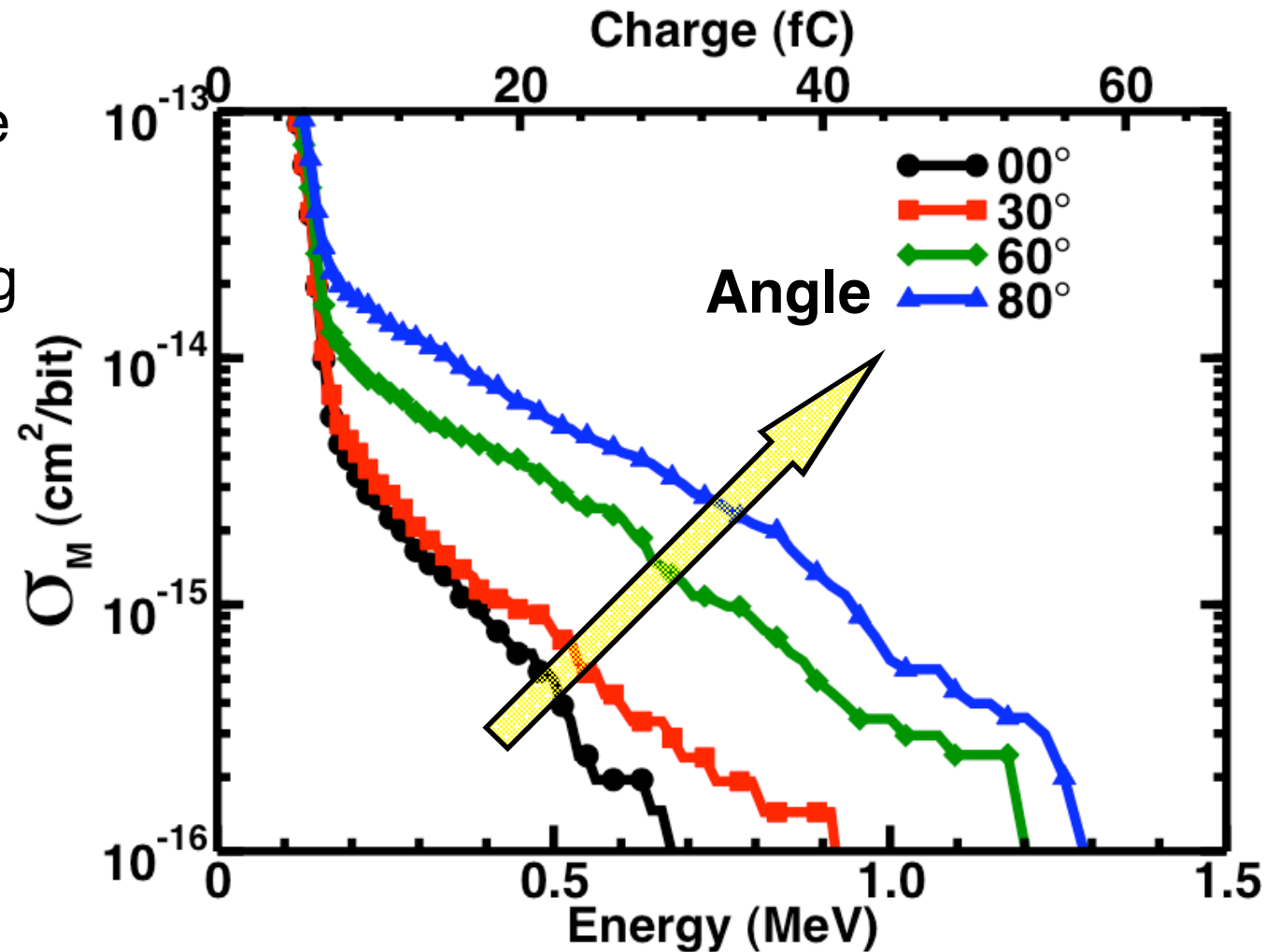
- Single volume angular dependence
 - SV aspect ratio





Multiple volume σ_M

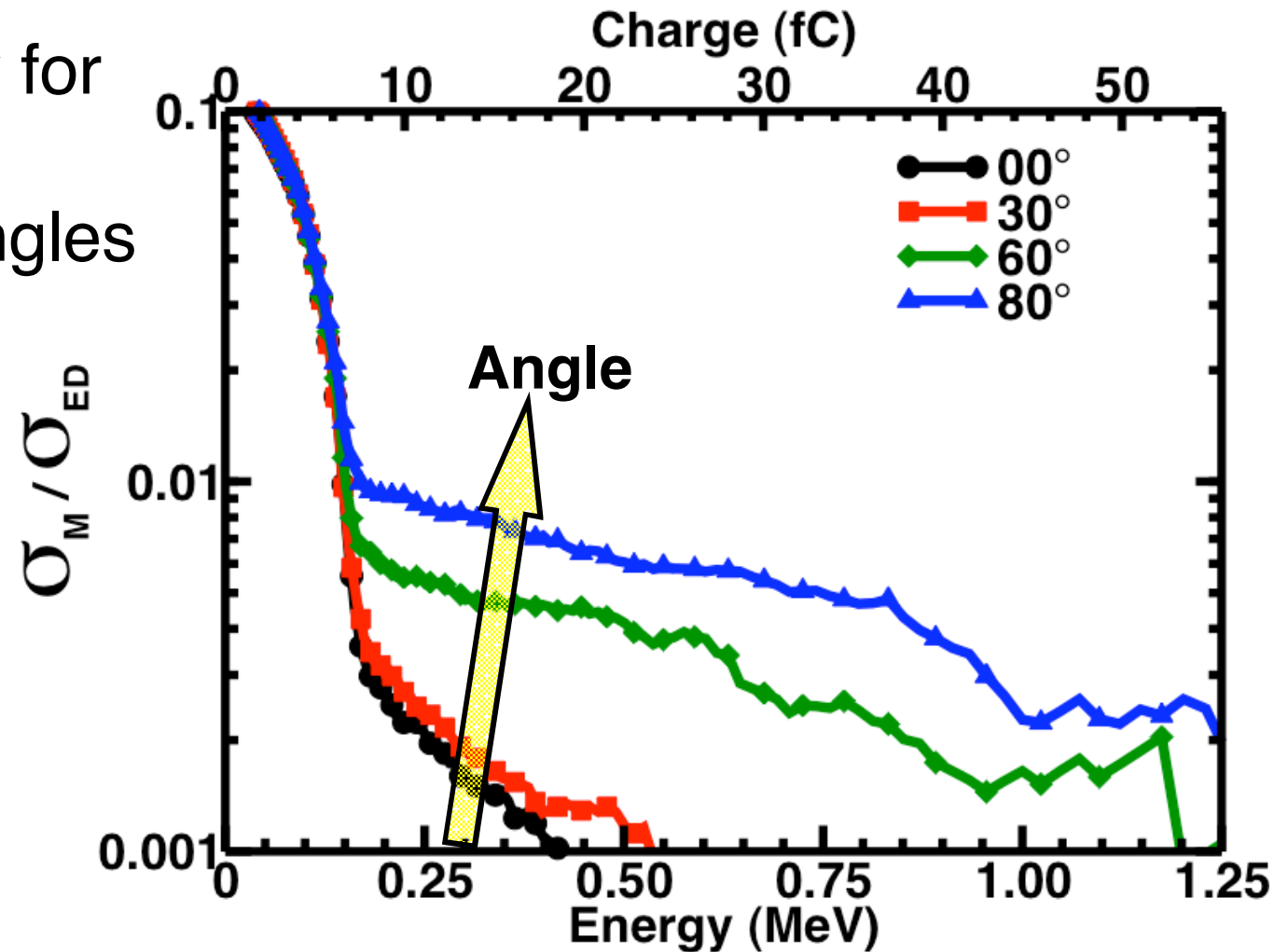
- Multiple volume angular dependence
 - Forward scattering



Multiple volume probability



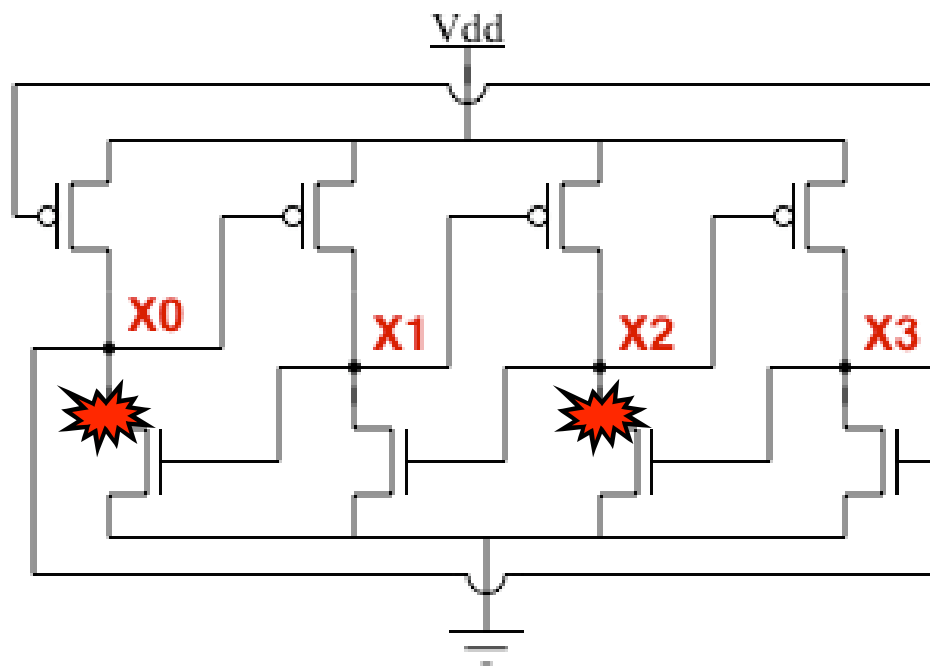
- Increased probability for protons at grazing angles





Plan

- Multiple cell
 - DRAM
 - SRAM
- Multiple node
 - DICE latch
 - CVSL logic
- Device simulation
- Rate prediction





Summary

- MBU cross section from energy deposition cross section calculation
- Single volume cross section angular dependence
 - Decreases with increasing angle
 - Aspect ratio
- Multiple volume angular dependence
 - Increases with increasing angle
 - Forward scattering
- Multiple volume probability increases with angle