SAND2019-7895C

Single Event Latchup Sensitive Volume Model for a 180-nm SRAM Test Structure

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This work was partially supported by the Defense Threat Reduction Agency through its Basic Research program and by AFOSR and AFRL through the HiREV program.

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Introduction

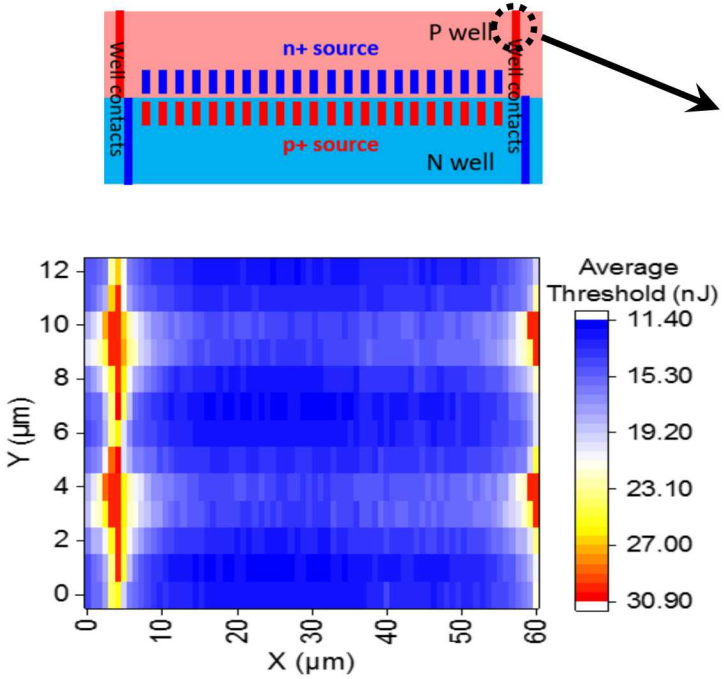
Pulsed laser testing, such as two-photon-absorption (TPA), is emerging as a powerful tool to study Single-Event-Latchup (SEL). Previous TPA data defined the location of SEL sensitive volumes.

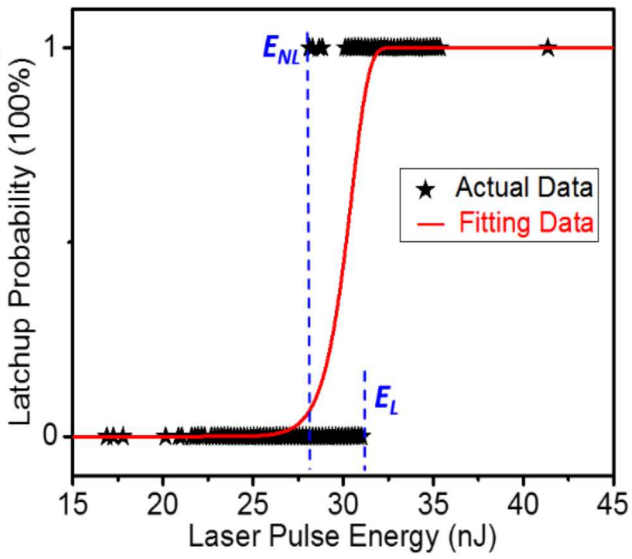
The Monte Carlo Radiative Energy Deposition (MRED) simulation tool can create a weighted multiple sensitive volume model. Normal and angular heavy-ion data can help calibrate and improve the model.

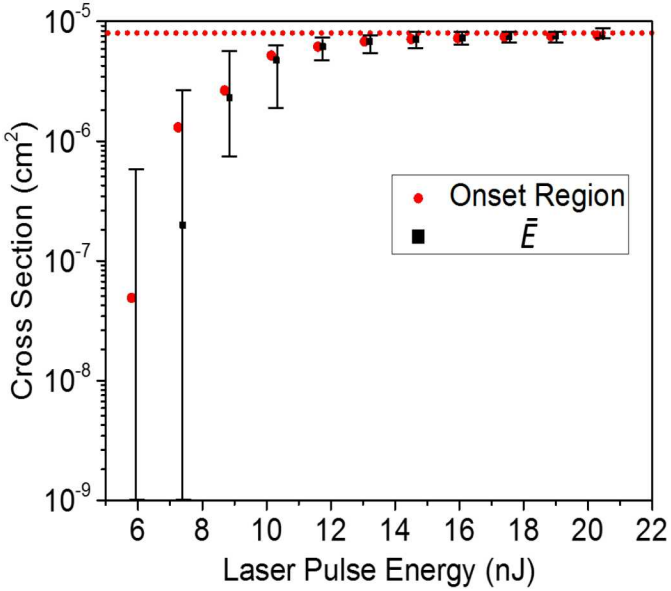
In this work, a multiple sensitive volume model for a 180-nm SRAM test structure is developed based on experimental data, including:

— Empirical match between TPA and heavy-ion tests in SEL cross section curves.
— Focused beam heavy-ion measurements.
— Calibration of the MRED model with both normal and angular data.

Application of TPA in SEL







1. P. Wang et al., *IEEE Trans. Nucl. Sci.*, vol. 65, no. 1, pp. 502-509, Jan. 2018.

MRED Multiple SV Model

--- Application in SEU analysis

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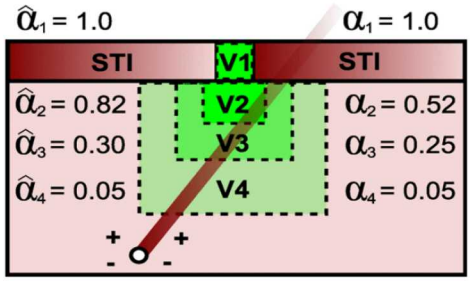
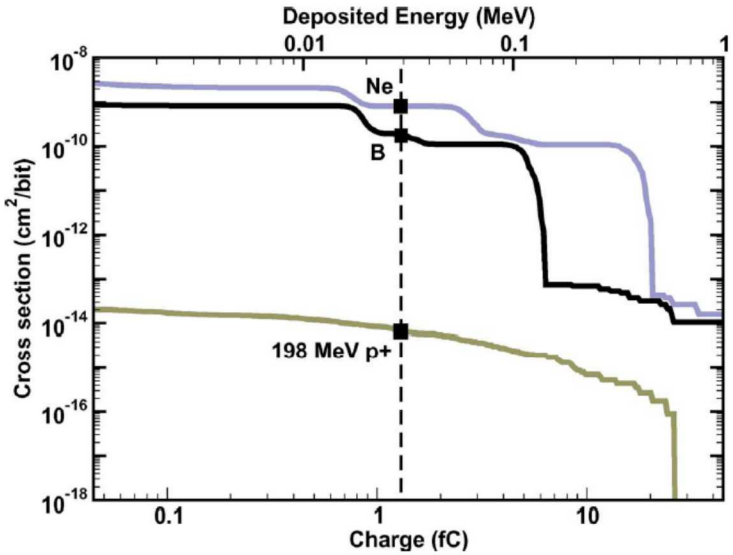
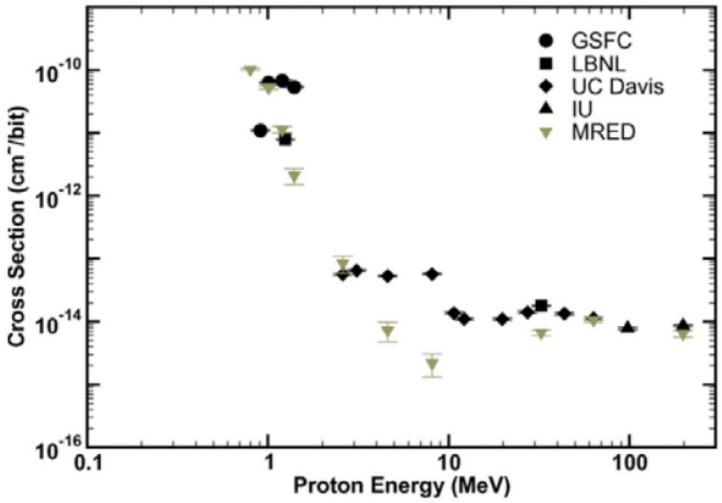


$$Q_{coll} = \frac{1\,pC}{22.5\,\mathrm{MeV}} \times \sum_{i=1}^{N} (\alpha_i \times E_{dep_i})$$





2. Brian D. Sierawski, et al., IEEE TNS, 56 (6), p3085, 2009

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Device and Measurement Setup

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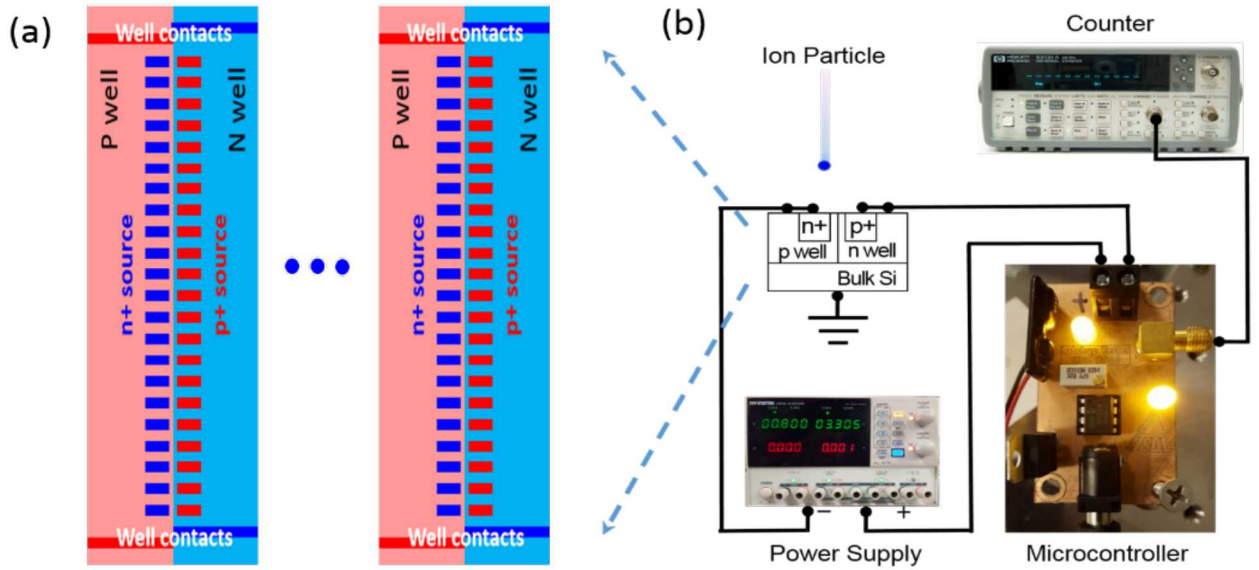

- The devices are fabricated in the Jazz Semiconductor CA18HD process, mimicking an SRAM structure.
- Thousands of arrays are bonded together (in parallel). Each array contains 22 p-n-p-n cells.
- Test Conditions:
  - Bias Voltage = 3.3 V
  - Current compliance = 50 mA

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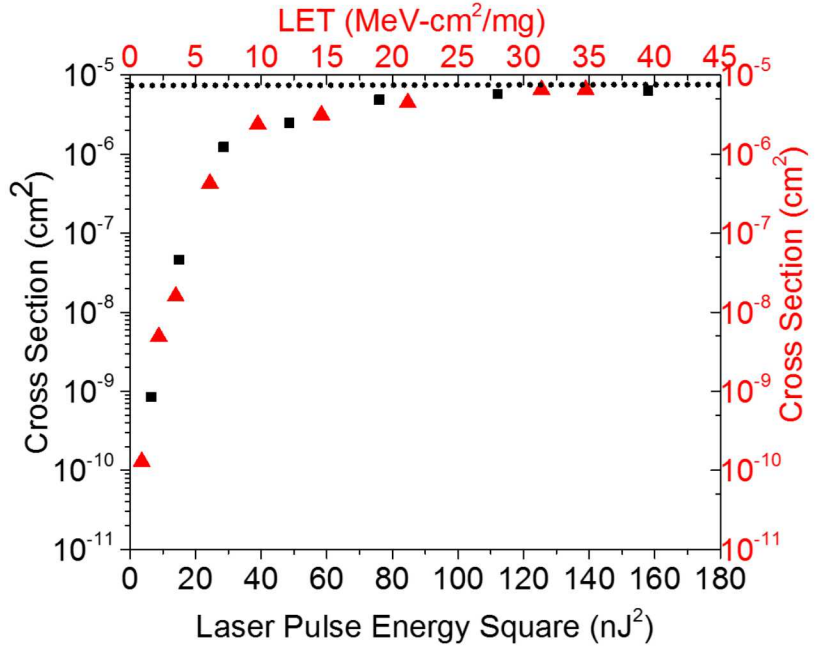
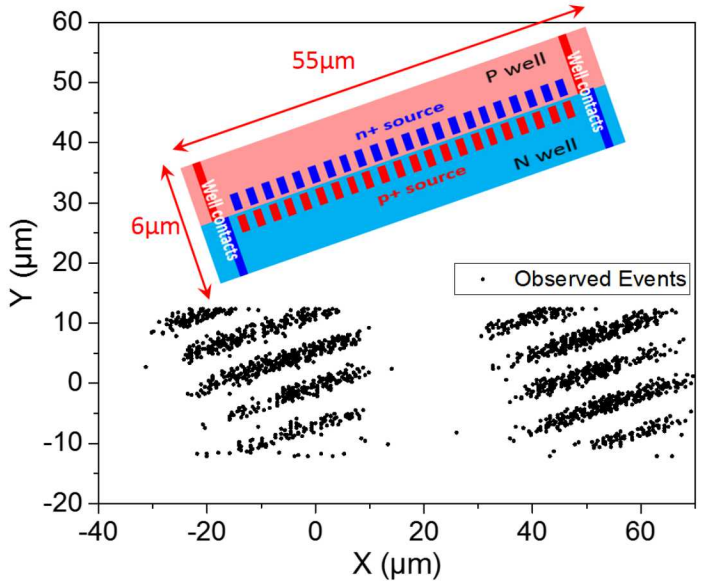
Normal Incidence Heavy-ion Test

--- Empirical match with TPA data



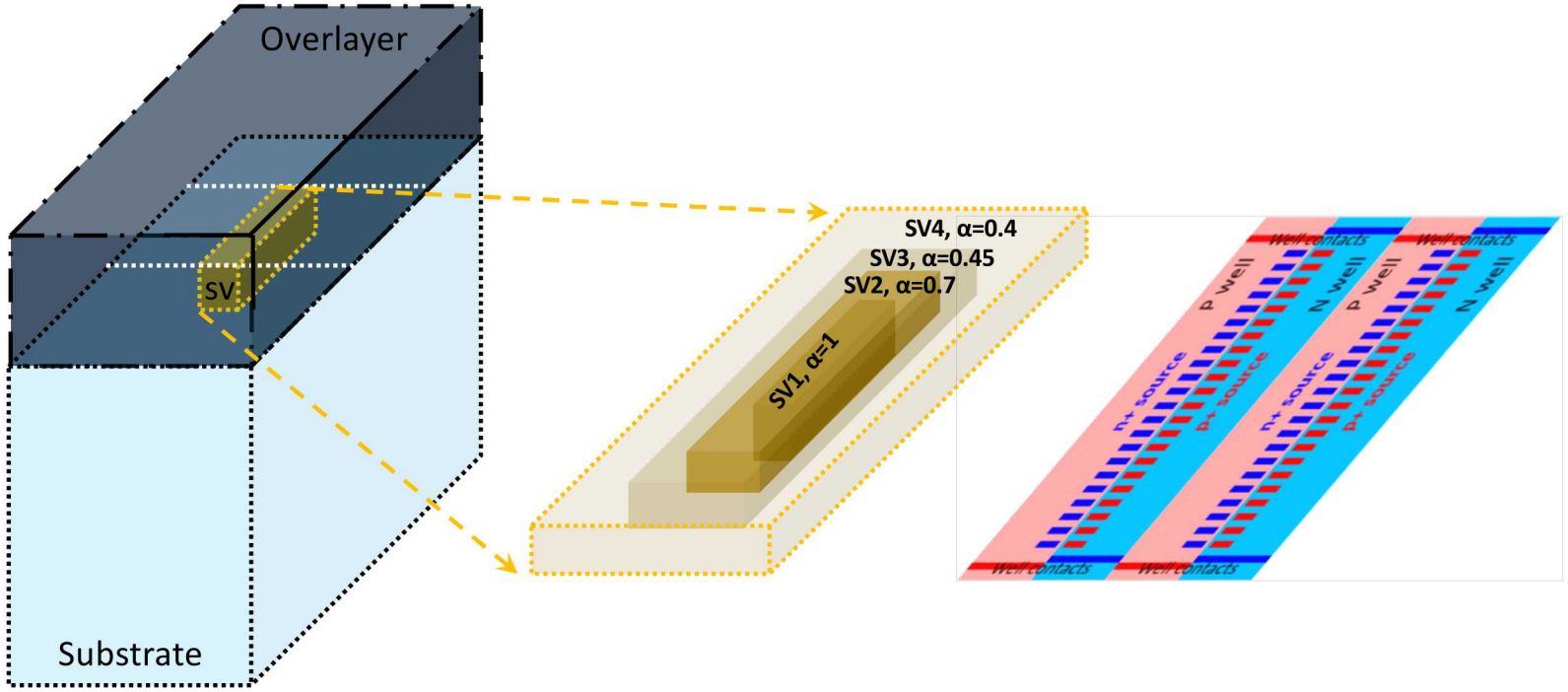
Broad beam heavy-ion data from LBNL.
E^2= 4 × LET (empirical)
with E in units of nJ and LET in units of MeV-cm²/mg.



Focused beam heavy-ion data from Sandia.
Cu^{8+} with LET = 46 MeV-cm²/mg

MRED Model

--- Model structure details



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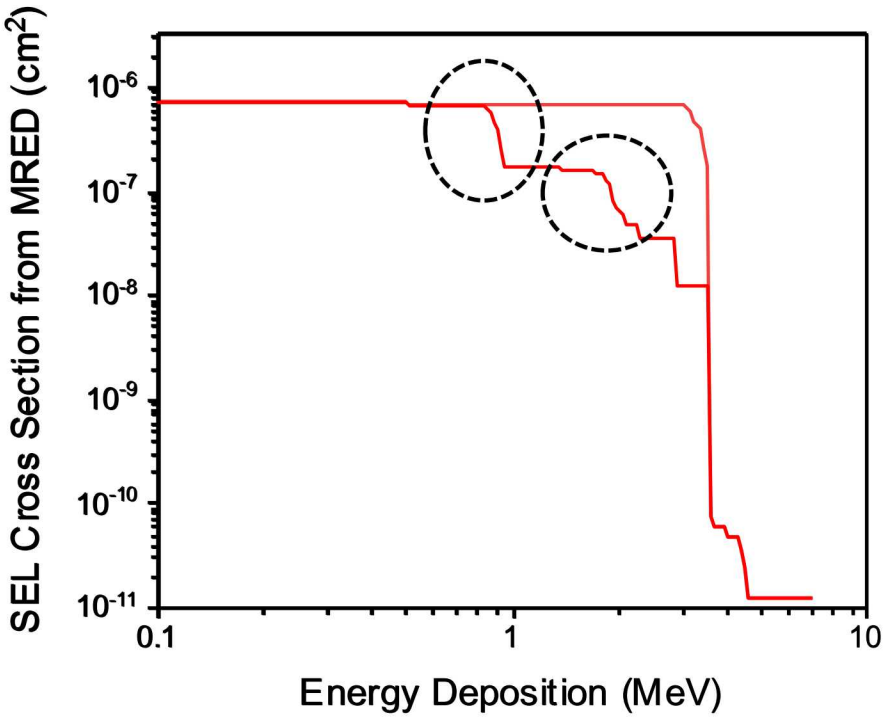
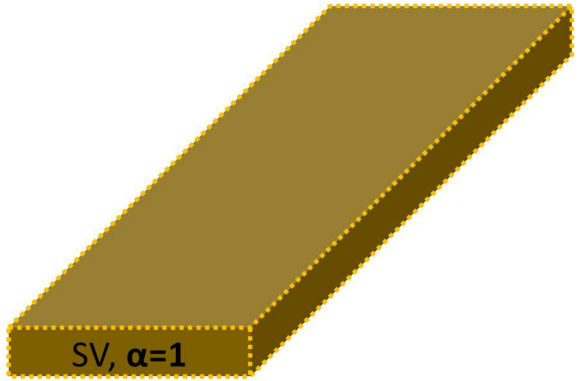
MRED Model

--- Comparison between single SV and multiple SVs





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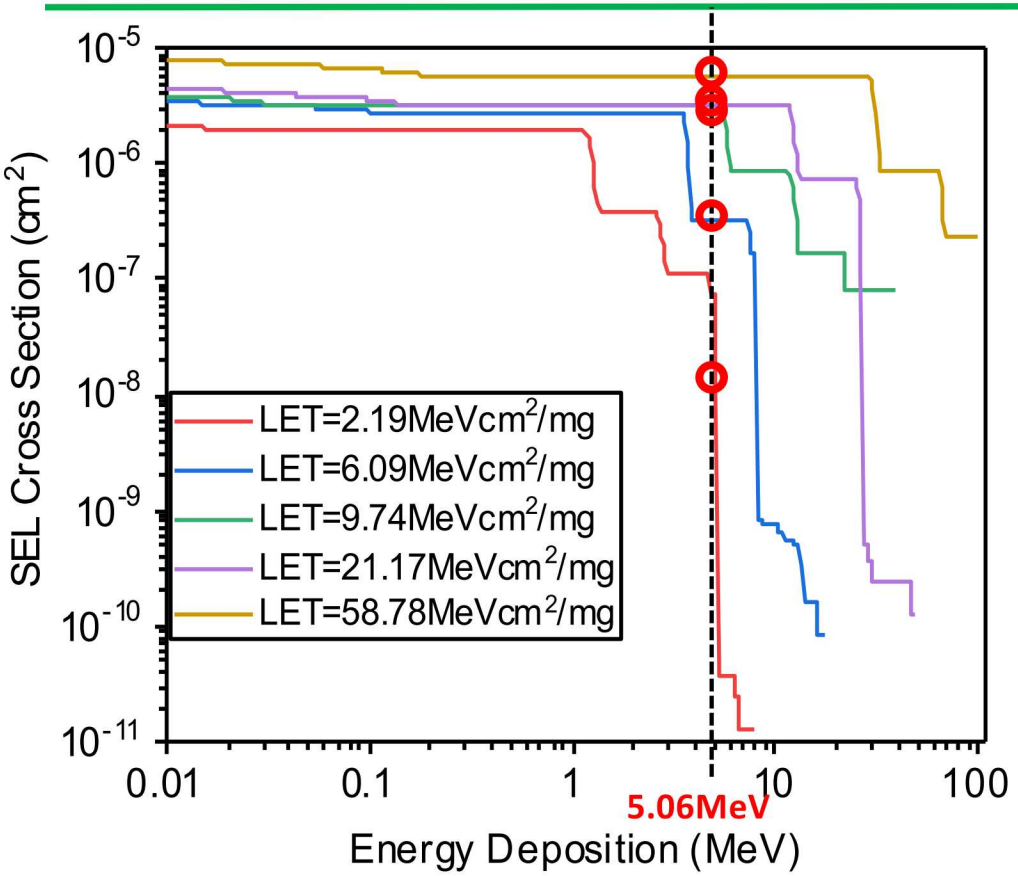
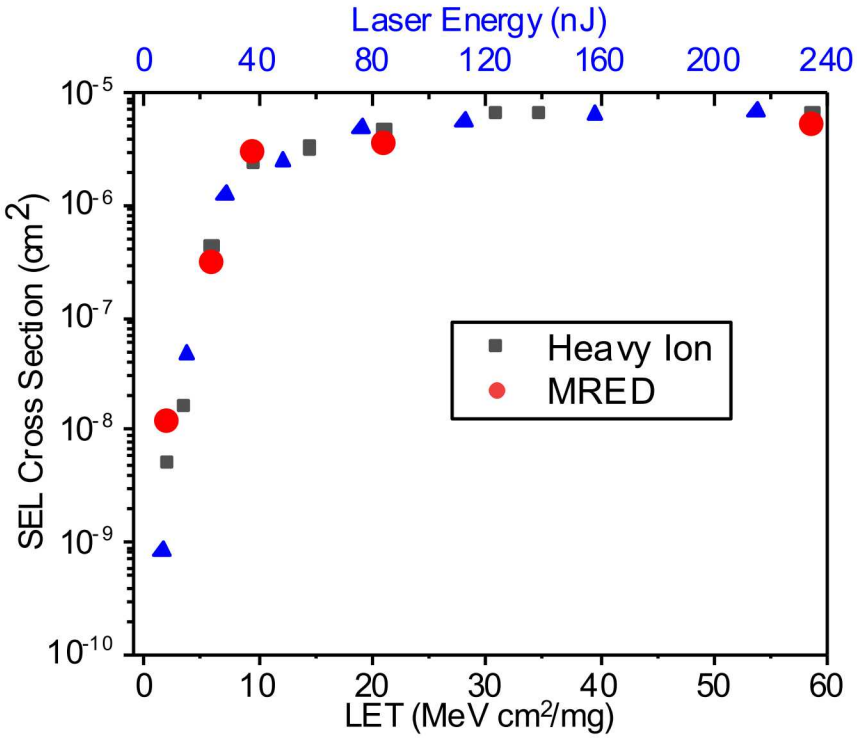
MRED Model

--- Match with heavy-ion data





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MRED Model

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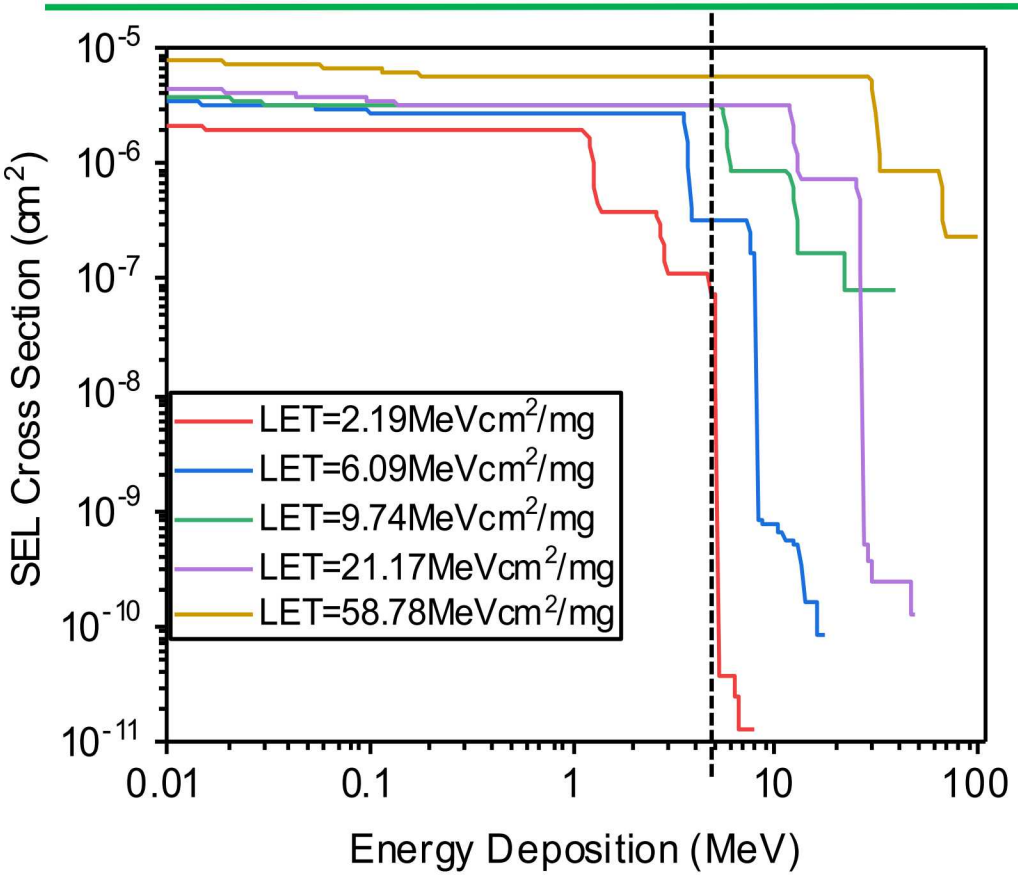

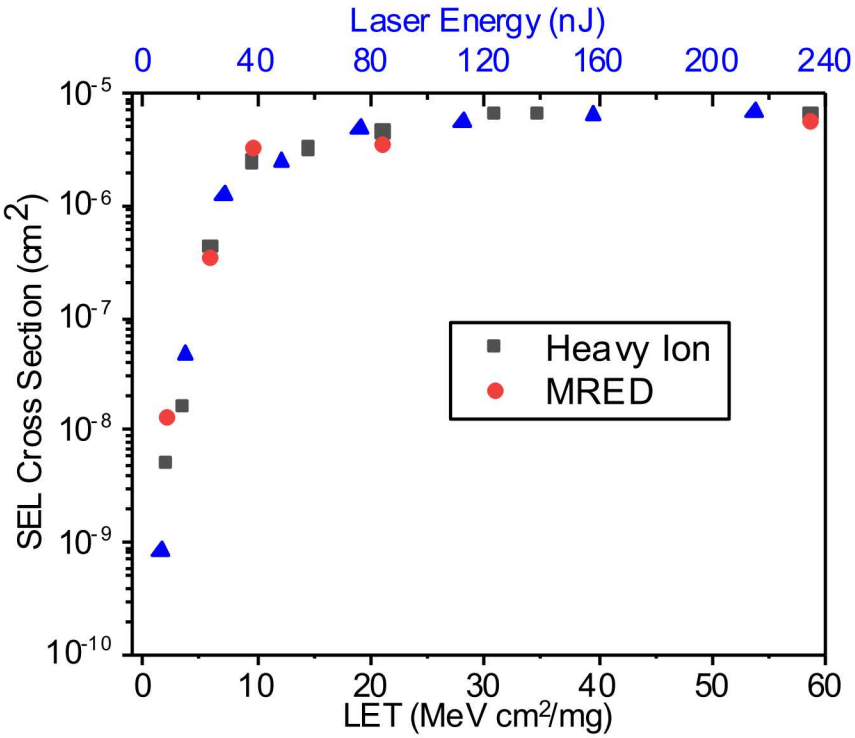

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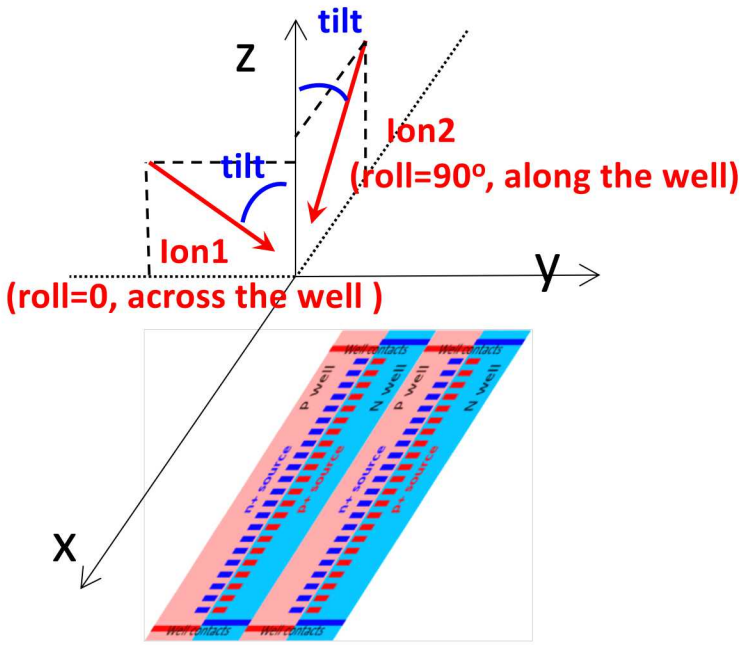
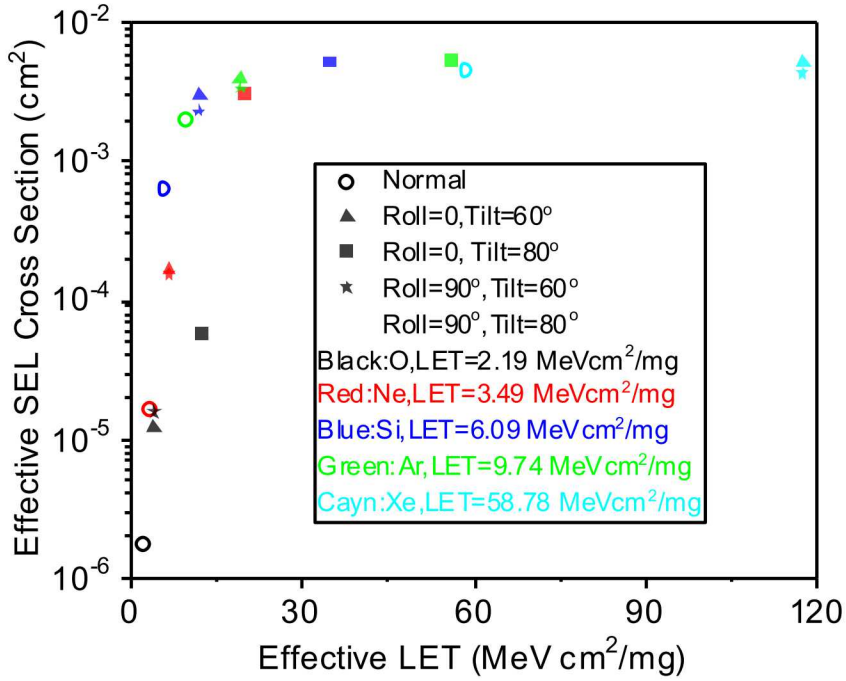
Angular heavy-ion measurements

--- Effective SEL cross section vs. effective LET





★ For high LETs, the roll = 0 direction, across the well, is more sensitive than roll = 90° direction, along the well. But for low LETs, the conclusion is reverse.

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Angular heavy-ion measurements

--- Match with MRED model

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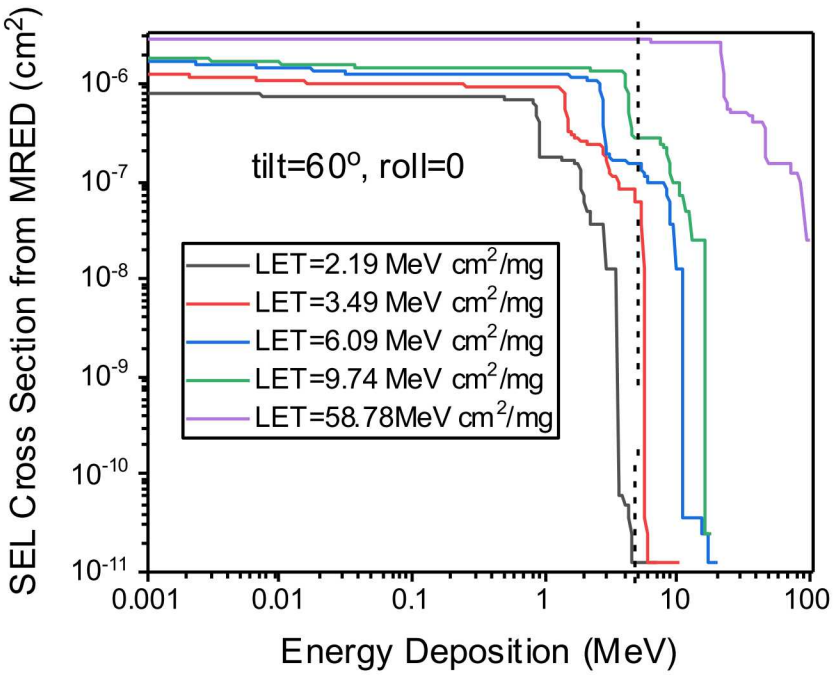

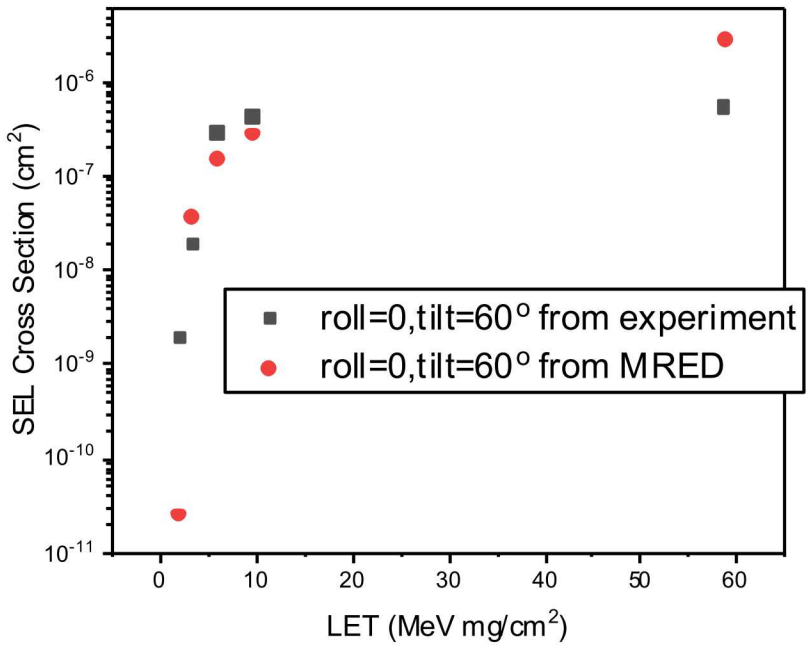

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Angular heavy-ion measurements

--- Match with MRED model

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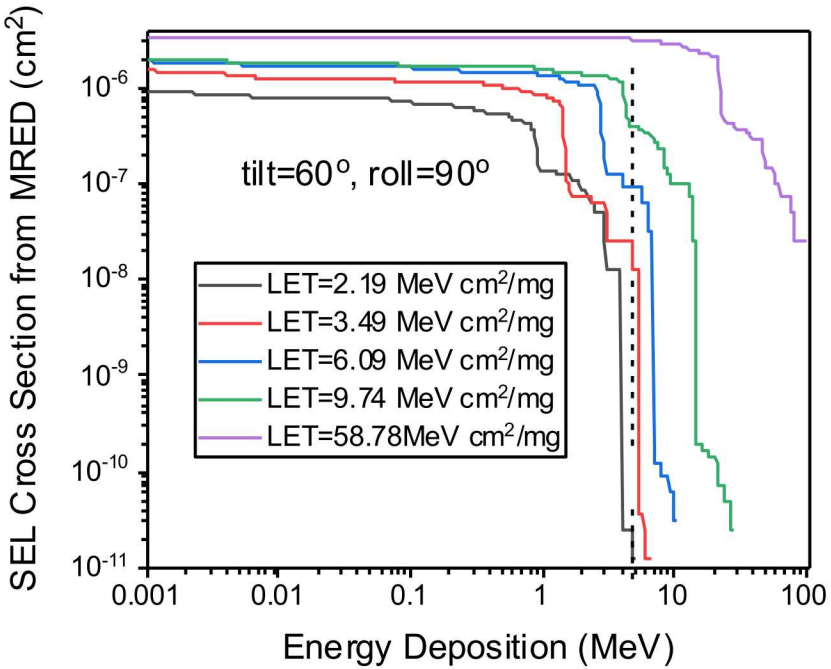

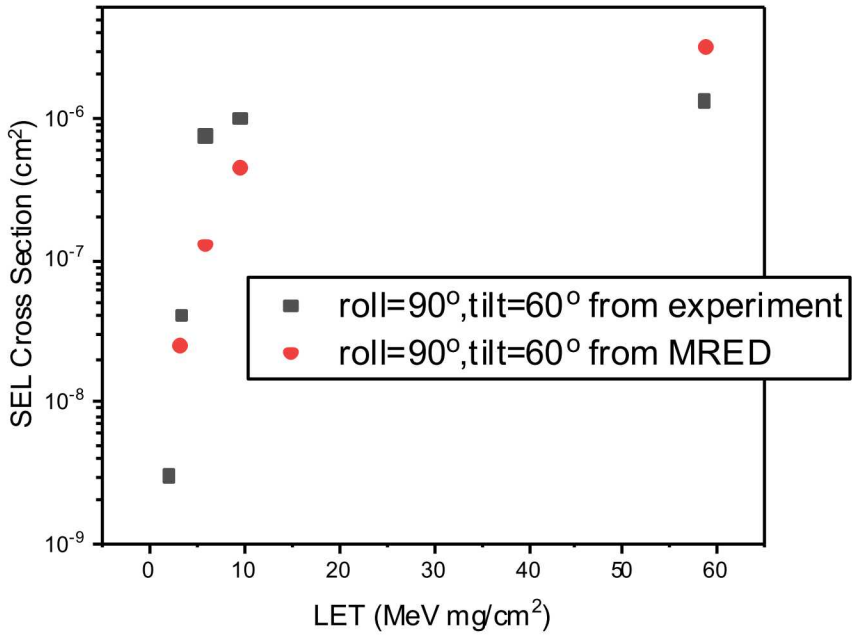

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Conclusions

We combined ion-induced latchup data and previous laser-induced latchup data to define a multiple, nested sensitive-volume model using the Monte Carlo Radiative Energy Deposition tool. A self-consistent description of the results of the full data set is obtained.

★ **Heavy-ion Test**

— A linear, empirical equation is derived to calibrate the energies from laser and heavy-ion.

— The SV location from TPA is consistent with the focused beam heavy-ion test.

— The direction across the well is more sensitive to SEL than the direction along the well.

★ **MRED Multiple SV Model**

— A simple set of concentric sensitive volumes can be used for SEL for IC well designs.

— It is possible to combine focused pulsed-laser and broad-beam ion-induced SEL data to define the sensitive-volume model for SEL. This process allows SEL to be incorporated into existing reliability assessments.