

Radiation Hardened Technologies for Microelectronics in Space

Ricardo Xie
Purdue University, xie197@purdue.edu

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***RADIATION HARDENED
TECHNOLOGIES FOR
MICROELECTRONICS IN SPACE***

Ricardo Xie, ECE

Recorded Video: <https://youtu.be/H3hKGy6fHIQ>



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School of Electrical and
Computer Engineering

Background

Fukushima Daiichi nuclear disaster



Background-2

Space also full of radiation

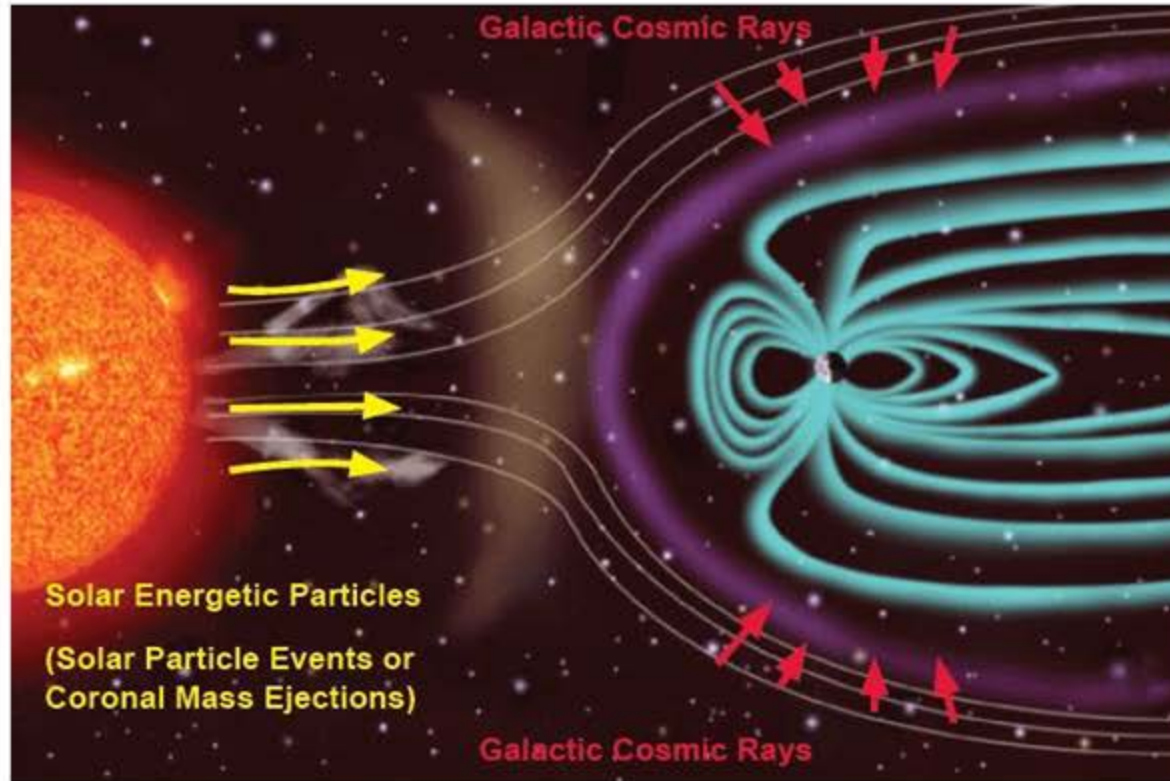


Figure 1: Sources of space radiation

Image Credit: NASA

Radiation Environment Models

- Low Earth Orbit
 - Space Station orbit (51.6 deg, 500 km apogee, 500 km perigee)

- Three parameters
 - Solar energetic particle
 - Galactic Cosmic Rays
 - Trapped Protons and Electrons

Background-4

Radiation Effects Model and Device Under Test

- Three effects
 - Total Ionizing Dose (TID) – Radiation Absorbed Dose (Rad)
 - Displacement Damage Dose (DDD)
 - Single Event Effects (SEE) – Cosmic Ray Effects on Microelectronics (CREME96)
- Devices
 - Microchip ATMX150RHA Rad-Hard CMOS 150nm cell-based ASIC
 - 16k32 for SRAM
 - 6k39 for DPRAM
 - NRB1 for D type flip-flops

Research Question

What needs to be discovered?

- SEE prediction
- TID prediction

SEE Prediction

TRP

- Space Station orbit (51.6 deg, 500 km apogee, 500 km perigee)
- AP8MIN & AP8MAX

1. Specify Orbit:

- A. 51.6 deg., 500 km (space station orbit) pre-calculated Trapped Proton Spectra
- B. 28.5 deg., 450 km (frequent shuttle orbit) pre-calculated Trapped Proton Spectra
- C. New Trapped Proton Spectra calculation with these orbital parameters:
 - a. Apogee: units: km nautical miles
 - b. Perigee: (same units as Apogee)
 - c. Inclination: degrees
 - d. Initial Longitude: degrees
 - e. Initial displacement from ascending node: degrees
 - f. Displacement of perigee from ascending node: degrees
 - g. Number of Orbits:
 - h. Calculate Trapped Proton Spectra for:
 - Whole Orbit
 - Sections of Orbits (delineated by McIlwain L)
Enter a comma-separated list of the lower limits on L:

2. Select Trapped Proton Model:

- AP8MIN
- AP8MAX

SEE Prediction-2

TRANS

- Orbit-Averaged Trapped Proton Fluxes
- Aluminum
- Shielding thickness: 0.1 ~ 180 mil
 - 100 mils = 0.254 cm
- Creme96 TRANS

CREME96/TRANS

Nuclear Transport Module User-Supplied Parameters

1. Name of flux file: min1_ave (CREME96 average trapped protons)
2. Shielding material: aluminum
3. Shield Thickness:
 - Specify single value: 100 mils
 - Use an existing distribution file:
4. Transport Code:
 - Creme96 TRANS/UPROP
 - HZETRN1995/Nucfrg2 (warning: beta code, and cannot use a .shd file)
5. Rootname for TRANS Output file: min1_100 (.tfx extension added automatically)

SEE Prediction-3

Cross-section Parameter: Weibull function

DUT	x ₀	W	S	A
SRAM 16k32	1	24	1.2	3.61E-2
DPRA M6k39	2	34	1.4	2.43E-3
DFFN RB1	3	22	1	1.08E-4

The functional form of the Weibull is:

$$F(x) = A (1 - \exp\{-[(x-x_0)/W]^s\})$$

where

- x = effective LET in MeV-cm²/milligram;
- $F(x)$ = SEE cross-section in square-microns/bit;
- A = limiting or plateau cross-section;
- x_0 = onset parameter, such that $F(x) = 0$ for $x < x_0$;
- W = width parameter;
- s = a dimensionless exponent.

SEE Prediction-4

PUP

- 10 million bits/device

CREME96/PUP

Direct-Ionization-Induced Single Event Upset (SEU) Rate User-Supplied Parameters

1. Input proton flux file:

min1_100 (CREME96 transported flux/environmen

2. Rootname for PUP Output file: min1_100see (

3. Devices:

Label:	SRAM16K3:	DPRAM6K3:	DFFNRB1		
Comment:					
Comment:					
Bits/device:	100000000	100000000	100000000	1	1

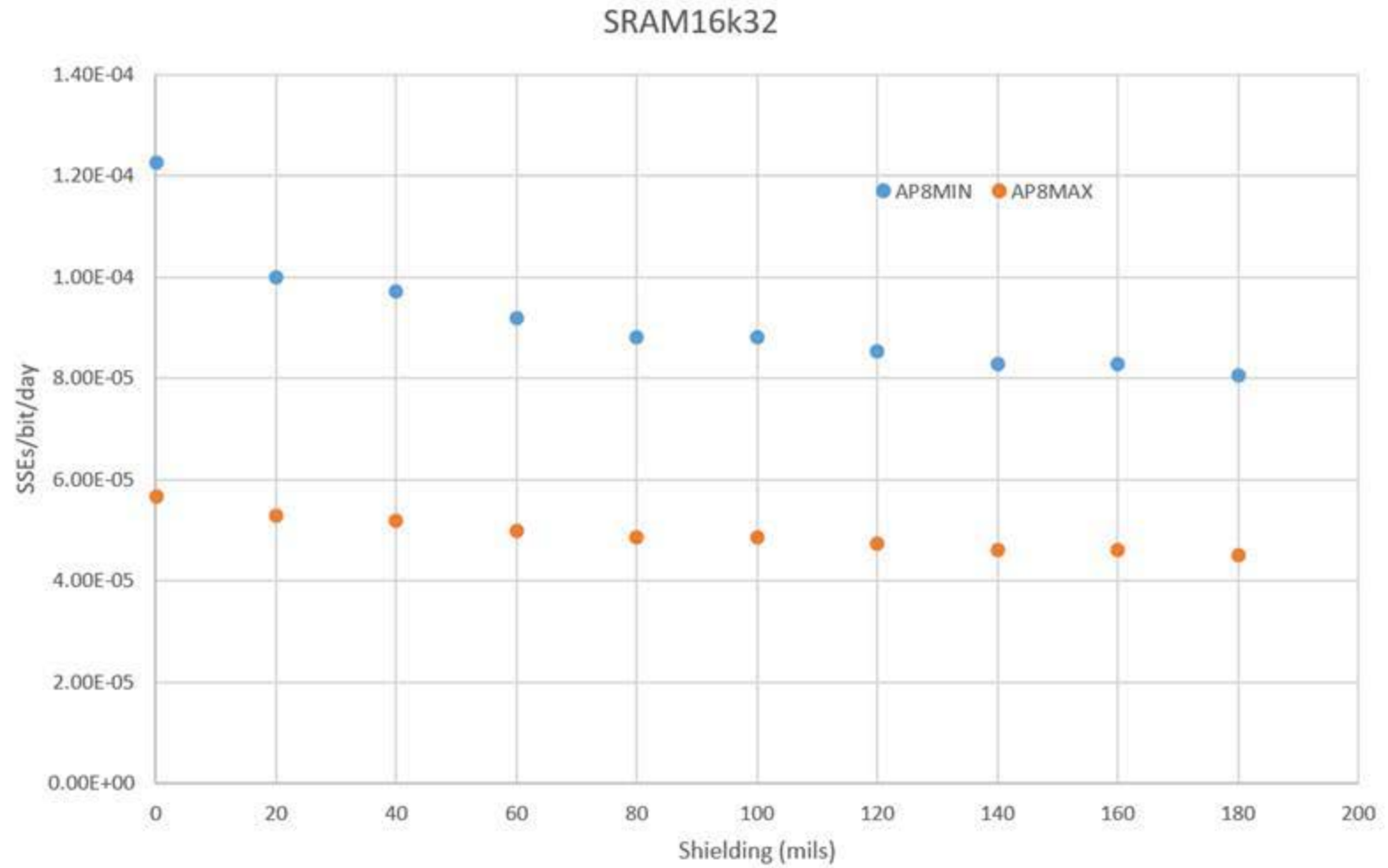
Cross-section parameters

Use buttons to choose one method in each column

Weibull:	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Onset: (MeV)	1	2	3		
Width: (MeV)	24	34	22		
Exponent:	1.2	1.4	1		
Limiting XS: (10^{-12} cm ² /bit)	36.1	2.43	0.108		

SEE Prediction-5

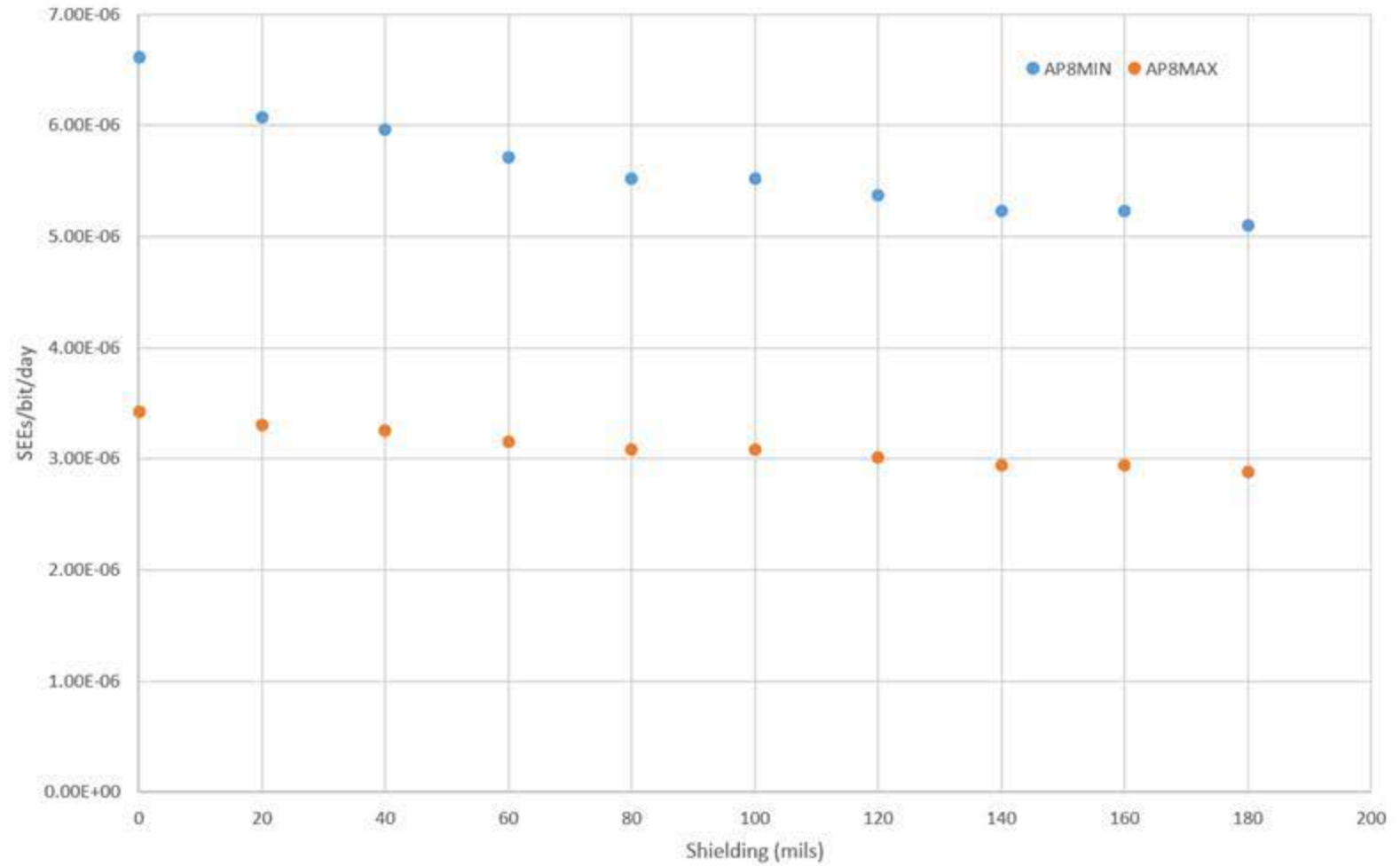
Result



SEE Prediction-6

DPRAM6K39

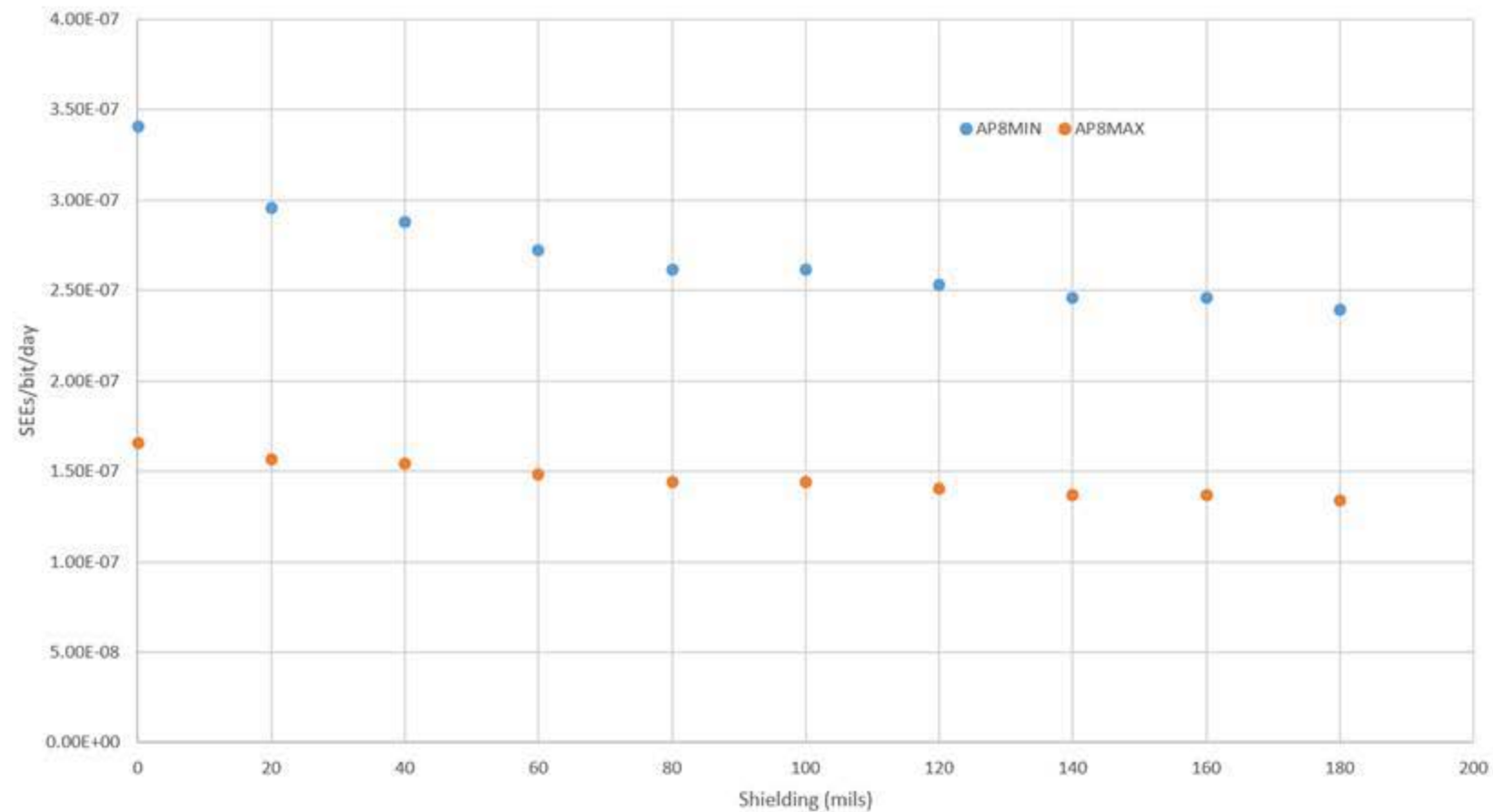
Result



SEE Prediction-7

DFFNRBI

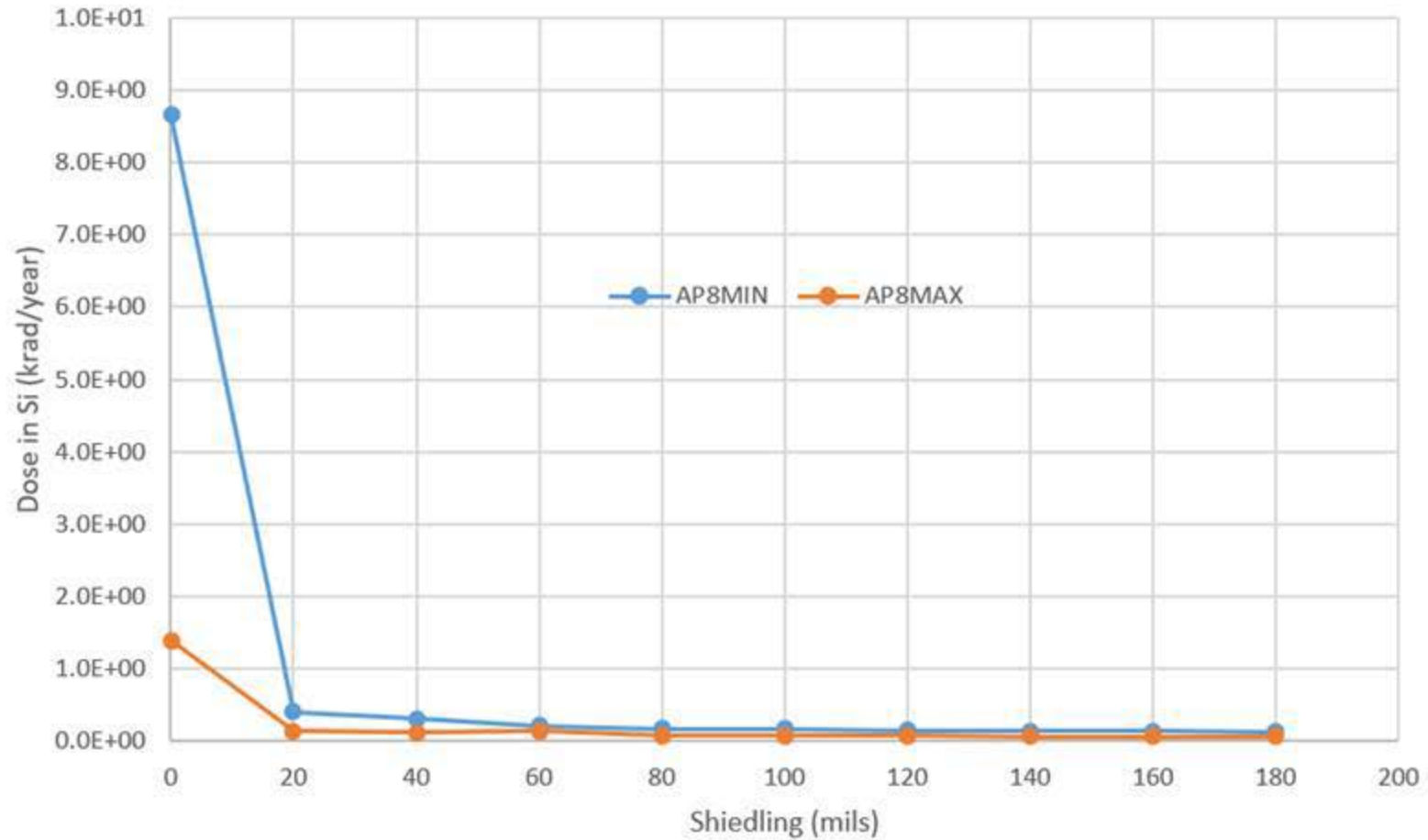
Result



TID prediction

Total Ionizing Dose

Result



FUTURE DIRECTION

More software and database

Study more about radiation hardening technology



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