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Xilinx RT20 program update:

Single Event Effect (SEE) and Total Ionizing Dose (TID) test results (to date)

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20nm UltraScale results – summary to date

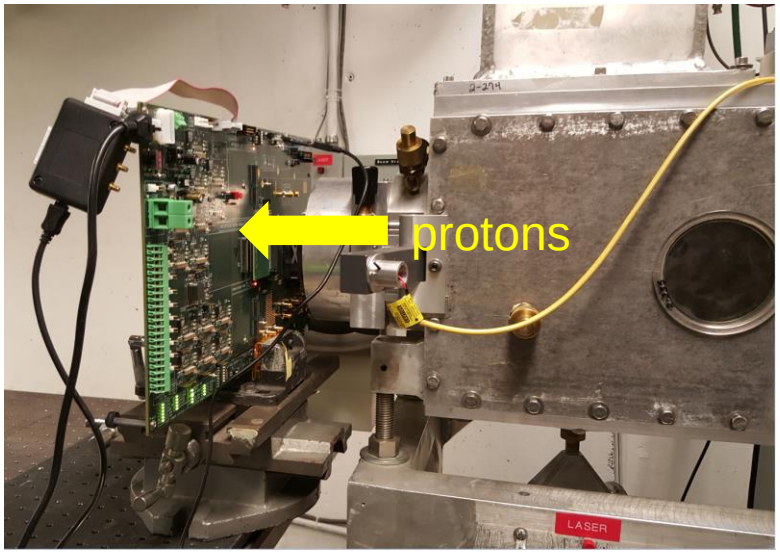
	Protons > 40 MeV	Heavy-ions	SEL	SEFI	TID
Max particle or ion energy	64 MeV / > 10MeV*	1 - 60 MeV.cm2/mg	60 MeV.cm2/mg		100 krad (Si)***
Facility	CNL / LANSCE	LBNL	LBNL	LBNL/ CNL	Vanderbilt University
Previous results (production)	2.6 x 10^{-15} cm^2/bit	1E-8 upset/bit/day	NO events @ 125C	TBD	7% increase in ICCINT No performance degradation

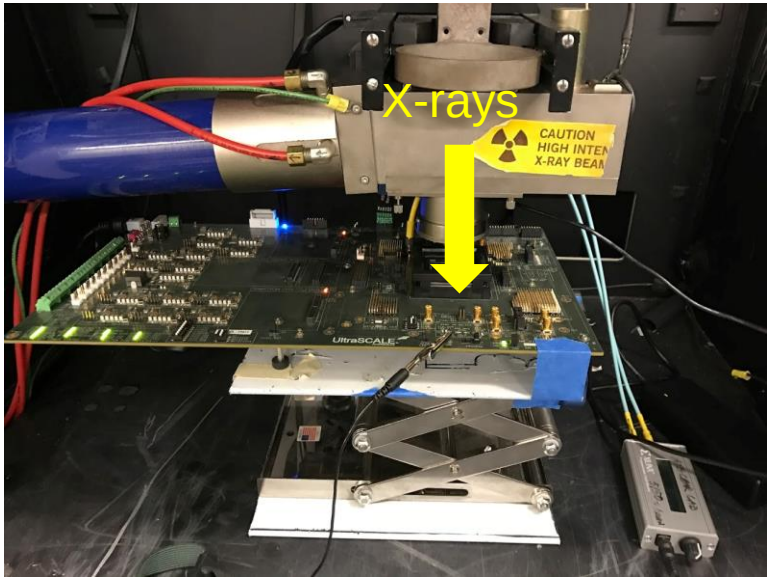
- Summary across all data points
- Suggested 4 particle tests for 20nm RT
  - Proton SEU, SEL & 1st pass heavy-ion SEU/SEL completed
  - 2st pass TID experiments at Vanderbilt University using the ARACOR® XRAY machine completed
- SEL & SEU were primarily performed on XCKU040**
  - Additional HW resources will be required for SEFI testing & uncorrectable events rate for ions > 14 MeV.cm2/mg

- * Xilinx UG116 report
- ** All Xilinx devices share the same circuit designs
- *** 100 krad is enough for most applications

Basic 20nm UltraScale test setup

- DUT: XCKU040 commercial device
  - Future plan is KU060
  - Share the same circuit designs
- DUT mounted on AFX-1156 board
  - Kapton heater tape experiments@ Temp.
- SW solution w/ Vivado:
  - Program FPGA (static patterns)
  - Monitor junction temp (SysMon)
  - Readback bitstream
- Basic XCKU040 test setup is customized based on test facility

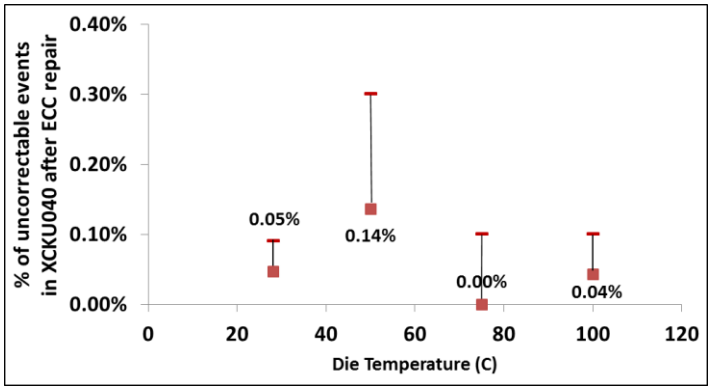




SEU & SEL results (terrestrial – NYC sea level)

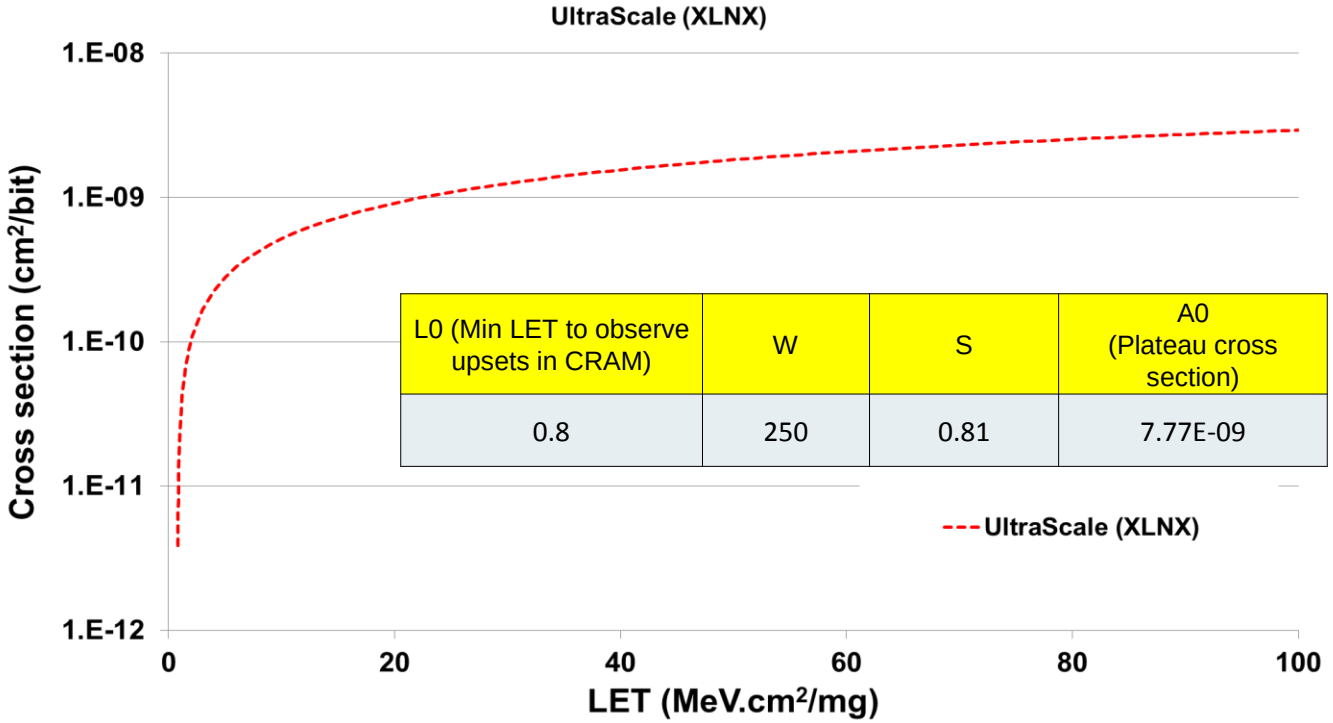
Device	Type	Neutron FIT/Mb*	Alpha FIT/Mb	Thermal neutron FIT/Mb
XCKU040	CRAM	33 (34 w/ 60% c.l.)	20 (21 w/ 60% c.l.)	0.5 (0.5 w/ 60% c.l.)
XCKU040	BRAM	58 (58 w/ 60% c.l.)	40 (Estimate from foil)	1.0 (1.1 w/ 60% c.l.)

- Same results observed for KU060
  - Same circuit elements in all UltraScale family
- > 99.9% of events are correctable in CRAM
  - Similar results @ high temperature
- 100% of events are correctable in BRAM
- No SEL observed at temp up to 125°C
  - Total fluence is ~ $2x10^{12}$ p/cm2



*For SEU cross-section please refer to UG116

Heavy-ion SEU & SEL results

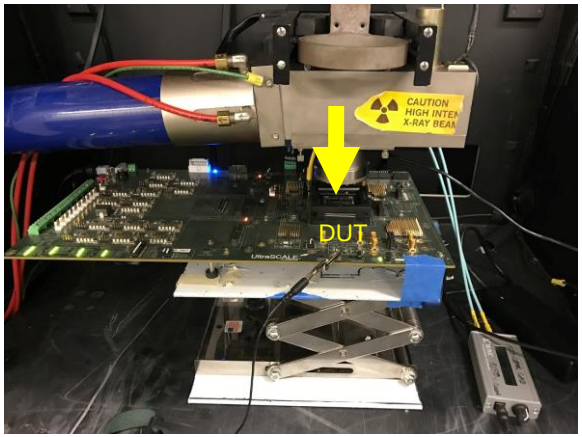


L0 (Min LET to observe upsets in CRAM)	W	S	A0 (Plateau cross section)
0.8	250	0.81	7.77E-09

- CRAM ~ 1 x 10^{-8} upset/bit/day
  - Total fluence of 1e7 ions/cm^2 per run
- NO SEL event observed @ 125°C at LET up to 60 MeV.cm^2/mg
  - Limit of LBNL test facility for 10 MeV cocktail; performed for KU060 as well
  - Total fluence of 1e7 ions/cm^2 per run
- Missing data: uncorrectable event rate @ ion LET > 14
  - No data with scrubbing (Xilinx SEM-IP) enabled

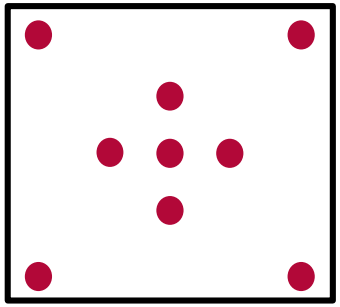
X-Ray TID test setup details

- 10 keV X-Ray test used as proxy for 60Co Gamma TID [1]
  - Aracor system @ Vanderbilt University
- Test Detail
  - Parts thinned to 40 um; exposure from die backside
  - Total exposure to 150 krad X-Ray
    - Dose rates of 5 krad /min & 10 krad /min
  - Equivalency to 60Co Si dose level
    - 140 krad (SiO2) X-Ray ≈ 100 krad (Si) 60Co gamma rays [2]
    - Hence correction factor of 0.73 used to derive 60Co Si gamma dose



- Currents monitored using Maxim power tool GUI
- Ring oscillators used to characterize live performance
  - 9 ring oscillators across die; 4 in corners & 5 in center
  - Typical RO frequency ~ 300 MHz

Ring oscillators distribution on DUT for performance characterization



  - [1]. See page 6 for complete list of references 1 - 5
  - [2]. See page 6; reference 6.

TID test results (Example: data sample for KU040)

Dose rate	Dose / step	Additional wait time btw steps (min)	Junction Temp (^{o}C)	Total dose krad (Si)	ICC-INT (pre-dose)	ICC-INT * @ Total dose	Delta ICC	ICC-INT after 1 week	Delta performance	Comments
4krad/min	4krad	5	~ 40oC	110	2.21	2.40	9%	Same as pre-dose	<< 1%	< 10% increase in leakage current; independent of dose rate Part fully recovered after 1 week at RT (unpowered)
7krad/min	7krad	0	~ 40oC	110	2.22	2.43	9%	Same as pre-dose	<< 1%	

- At 100krad Tj ~ 40^{o}C

- < 10% increase in leakage current @ 110k rad (Si)
  - Independent of dose rate
  - Leakage data corrected to same die temperature Tj @ 0krad
- Full recovery in leakage after 1 – 7 days at room temperature
  - ~31^{0}C unpowered
- Average across all data is ~ 7% increase in VCCINT leakage current

Next steps:

	Protons	Heavy-ions	SEL	SEFI	TID
Max particle or ion energy	0 - 64 MeV	1 - 80 MeV.cm2/mg	80 MeV.cm2/mg		300 krad (Si)***
Facility	CNL	LBNL	LBNL	CNL / LBNL	DMEA
Timeline / comments (production)	TBD Estimates for LEO	TBD w/ ECC (SEM IP enabled)	TBD NO events @ 125C ?	TBD	Feb./Mar/ End
Owner/funding	SEU team	A&D	SEU team	A&D	A&D