

High Energy SEE Testing Technical Interchange Meeting

System Heavy Ion Testing & Assessment
at NASA Space Radiation Laboratory (NSRL)

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13 April 2021

Agenda

- SEE Assessment Approaches: Piece Part & System
- System SEE Assessment Assumptions & Best Practices
- System Level Testing at NSRL
- Summary

SEE Assessment Approaches: Piece Part

- Piece-Part-Testing-Based (Test-Like-You-Fly)
 - Expose Devices to Range of Ion Energies & LETs
 - Record Fault Characteristics: Modes, Signatures & Counts
 - Derive Device Fault Models, LET Thresholds & Cross Sections
 - Assess Event Occurrence Rate in Mission Reference Environment
 - Utilize Fault Characteristics & Rates to Derive Reliability/Availability
 - Single Event Effects Criticality Analysis (SEECA) Typically Functional Analysis
 - Comprehend ConOps: Duty Cycles, Device Bit Loading, Operating Frequencies
 - Comprehend Mitigation Provisions: e.g. Error Detect/Correct, SET Filtering, Derating

Generate and Document the Data That Supports Underwriting Suitability for the Mission Reference Environment

SEE Assessment Approaches: System

- **System-Based (Test-Like-You-Fly)**
 - Expose **System** to Range of Ion Energies & LETs
 - Record Fault Characteristics: Modes, Signatures & Counts
 - Derive **System** Fault Models, LET Thresholds & Cross Sections
 - Assess Event Occurrence Rate in Mission Reference Environment
 - **Utilize Fault Characteristics & Rates to Derive Reliability/Availability**
 - Single Event Effects Criticality Analysis (SEECA): Embedded in System TLYF
 - Comprehend ConOps: Embedded in System TLYF
 - Comprehend Mitigation Provisions: Embedded In System TLYF

Generate and Document the Data That Supports Underwriting Suitability for the Mission Reference Environment

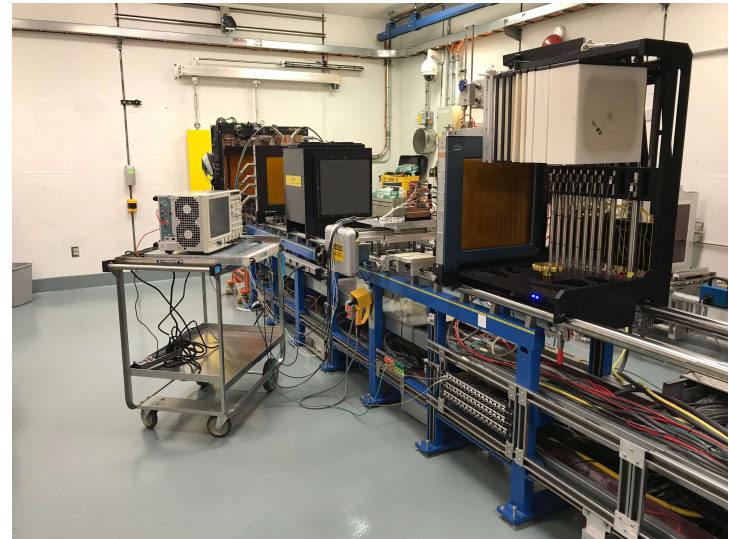
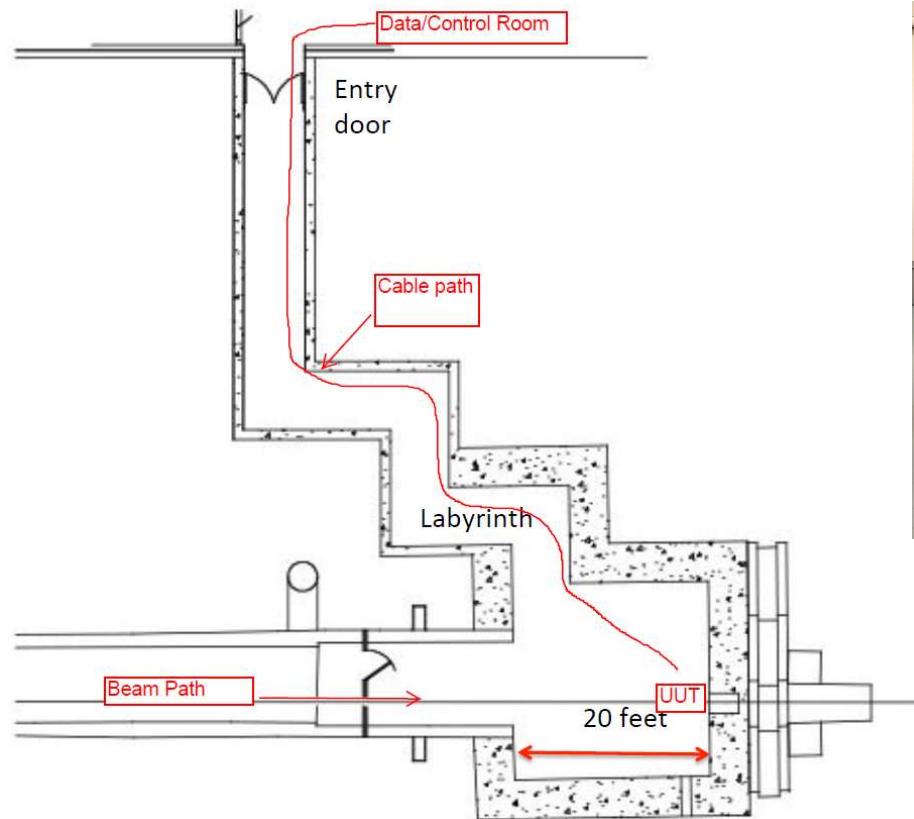
System Level Test: Assumptions and Best Practices

- Introduce a Wide Range of LETs from Low to High to Elicit Fault Modes
- LET at Every Location in System Unknown: Minimum LET Approximation
- Variation in LET Will Increase With Depth Into System Stack
- Determining Fault Source Requires System Operation Insight
- Suspected Fault Source(s) and System Responses Will Drive Subsequent Test Path – Flexibility Required
- Optimize: Beam Time vs. System Response Characteristics With Min DSEE
- Maximize Data Usefulness by Collecting and Documenting the Observed Fault Details and Demonstrated Recovery Paths for Forensic Analysis and Model Construction, Possible Mitigation Provisions
- Beware of Flux Rate Dependence and Synchrotron Duty Cycle Effects
- Beware the Consequences of Pb or W Shielding Introducing High LETs
- Beware the Consequences of Large Data Sets – Backups and Storage

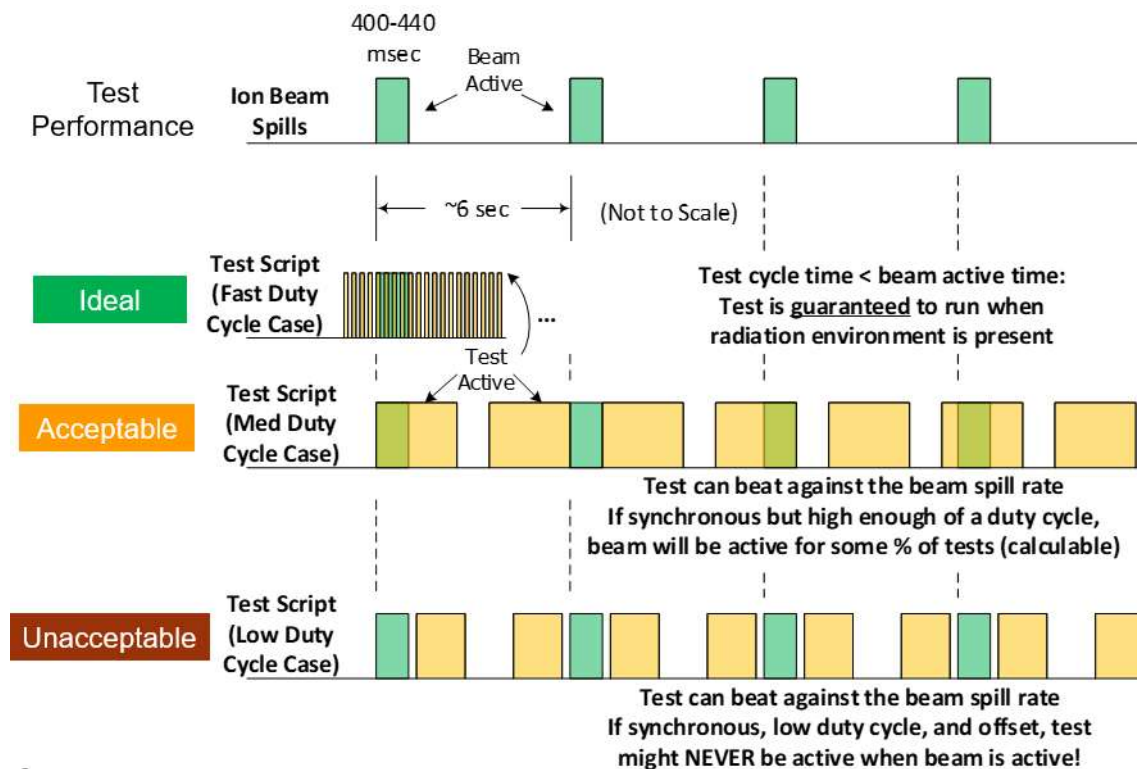
System Level Test: Assumptions and Best Practices

- Human Assets
 - Test Personnel Experienced With the Specific System Under Test – Troubleshooting and Path Selection
 - Customer/Consultant Participants for Troubleshooting/Guidance/Approval
- Test Assets
 - Ideal Configuration Is to Expose Each Card While System Operates in TLYF With Sufficient Perceptivity to Capture Relevant Fault Conditions
 - System Requires Remote Operation and Control at ~100 feet Distance from UUT & Test Set
 - Sufficient UUT Quantities to Sustain Full Test Regimen, Spares Are Good
 - Capabilities to Recover From Fault Conditions That May Derail Testing – e.g. Flash Memory Corruption, Device Replacement
 - Capability to Isolate System Elements Using Tungsten or Lead Shielding

NSRL Floor Plan and Cable Run

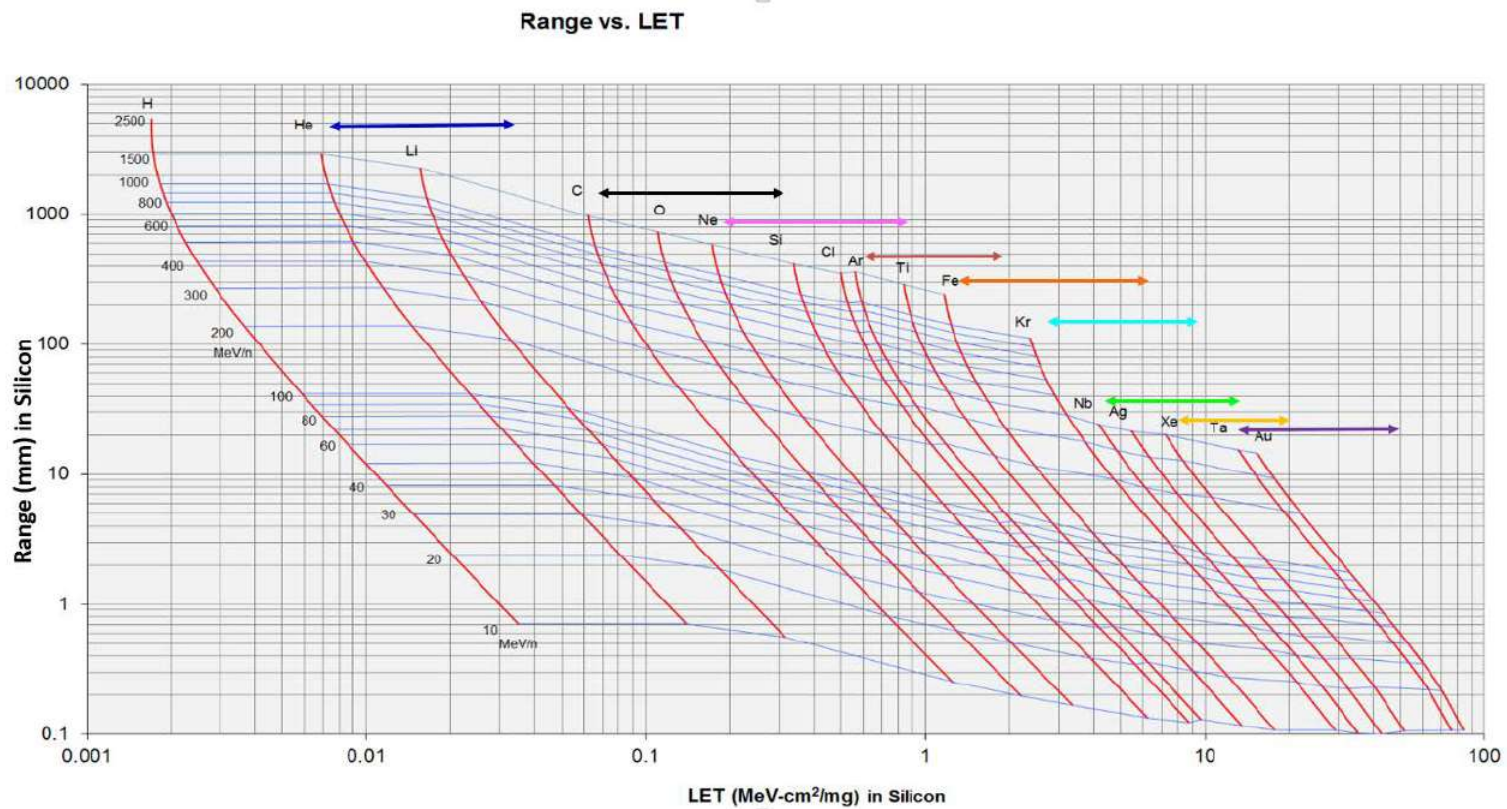


Test ConOps: Timing and Beam Synchronization Cases



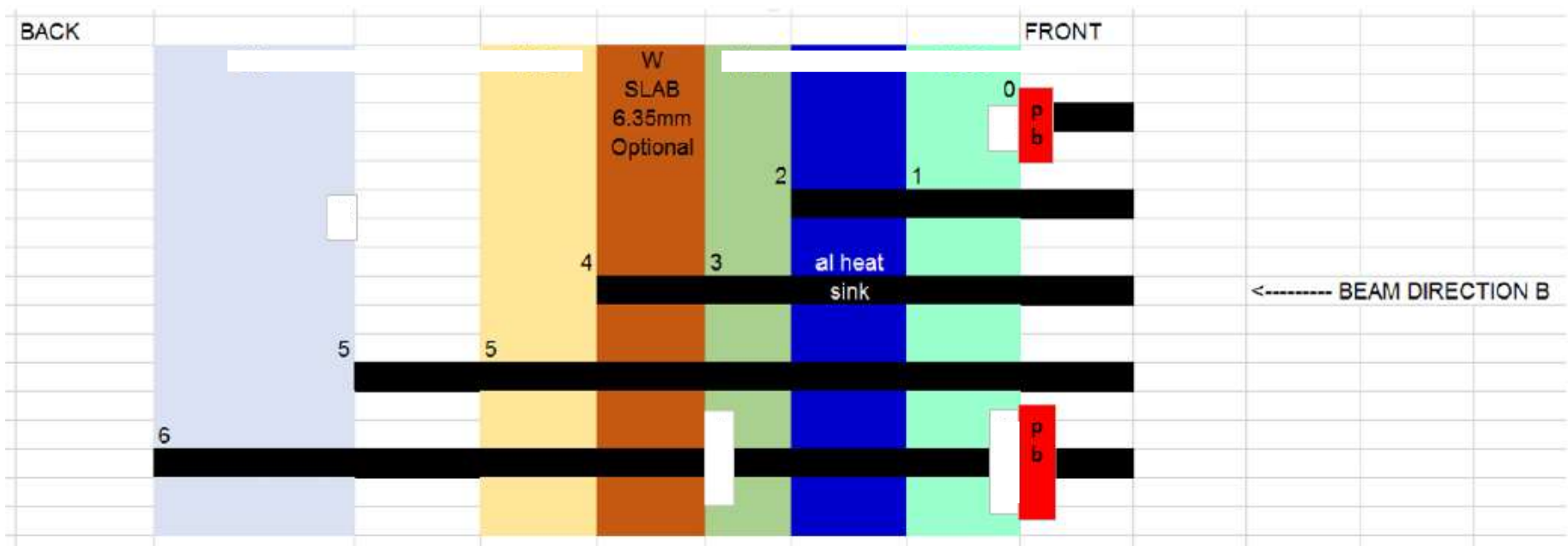
Beam Duty Cycle and System Test Script – NSRL Provides Beam Sync Signals

NSRL Range vs. LET vs. Ion Energy in Silicon



Board Stack Minimum LET Assumption: 4 Cards

Min LET at Die in Locations 0-6 Can Be Calculated With SRIM



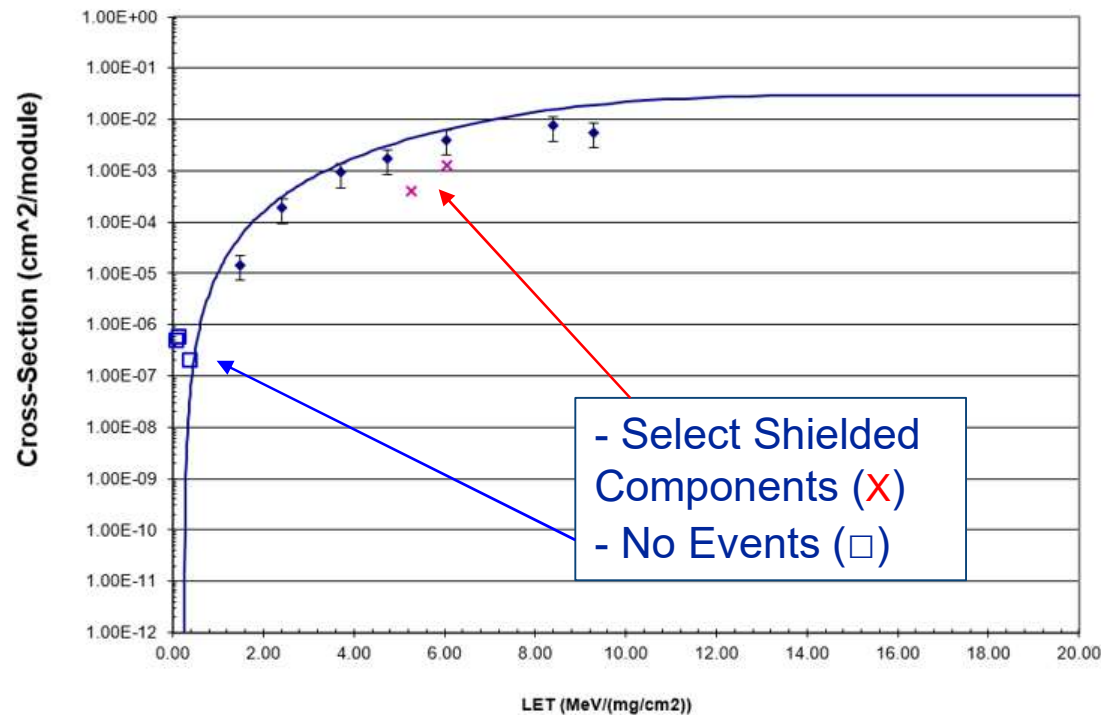
Beam Can Be Shielded For Some Ion Energies Using Lead On Piece Parts

Board Stack Minimum LET Assumption: SRIM LETs

		0	1	Al HS	2	3	W	W_STOPS?	4	5	6
Ion	E/amu (MeV)	Final LET	Final LET	mm	Final LET	Final LET	mm	6.35 mm	Final LET	Final LET	Final LET
Nb	500	3.71	3.77	1.788	3.85	3.97	0	Y	3.97	4.07	4.18
Nb	300	4.74	5.01	1.788	5.31	6.06	0	Y	6.06	6.90	8.49
Nb	250	5.27	5.72	1.788	6.28	8.11	0	Y	8.11	11.78	0.00
Nb	200	6.04	6.93	1.788	8.33	31.07	0	Y	31.07	0.00	0.00
		0	1	Al HS	2	3	W	W_STOPS?	4	5	6
Ion	E/amu (MeV)	Final LET	Final LET	mm	Final LET	Final LET	mm	6.35 mm	Final LET	Final LET	Final LET
Xe	400	7.2	7.5	1.788	7.8	8.4	0	Y	8.4	9.0	9.9
Xe	350	7.7	8.2	1.788	8.5	9.6	0	Y	9.6	10.7	12.7
Xe	300	8.4	9.0	1.788	9.7	11.8	0	Y	11.8	14.9	31.2
Xe	280	8.7	9.4	1.788	10.3	13.3	0	Y	13.3	20.0	0.0
Xe	250	9.3	10.3	1.788	11.7	18.3	0	Y	18.3	0.0	0.0
Xe	240	9.5	10.6	1.788	12.3	22.4	0	Y	22.4	0.0	0.0
Xe	230	9.7	11.0	1.788	13.0	32.6	0	Y	32.6	0.0	0.0
Xe	220	10.0	11.5	1.788	13.9	0.0	0	Y	0.0	0.0	0.0
Xe	210	10.3	12.0	1.788	15.0	0.0	0	Y	0.0	0.0	0.0
Xe	200	10.6	12.6	1.788	16.5	0.0	0	Y	0.0	0.0	0.0
Xe	190	11.0	13.3	1.788	18.7	0.0	0	Y	0.0	0.0	0.0

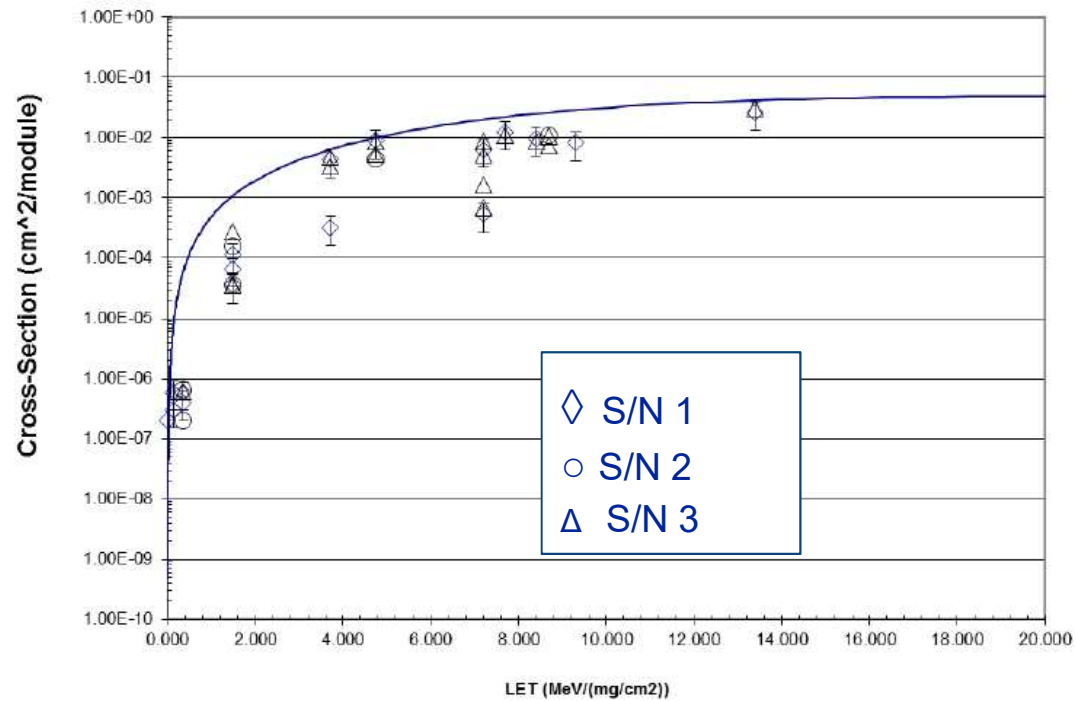
Transport Assumptions: Board FR and Cu Layers, Packages, Structures

Single Card Heavy Ion Response



Example Response of Single Card Exposure and Select Shielding (50% Error Bars)

Card Stack Heavy Ion Response



Example Response of Card Stack Exposure for Multiple S/Ns (50% Error Bars)

Summary

- System Level SEE Testing at NSRL is Feasible
- Sample Sizes Can Be Severe Limitations (Cost and Value)
- Advance Beam Planning With NSRL is Key to Success
- NSRL Can Accommodate Large Test Systems and Complex Setups
- NSRL Physicists are Engaged and Helpful in Ensuring Success
- NSRL Can Accommodate Rapid Changes in Ions, Energies, Collimation, Alignments, Beam Flux
- Challenge: Resultant Fault Mode Cross Sections at Each Ion Energy and System Configuration are Complex Sums of the Responses of Many Sensitive Volumes at Many Sensitive Locations at a Variety of Deposited LETs That are Represented at a Minimum LET Data Point