Platform Neutron Validation Testing

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June, 2024

Single Event Upset (SEU)

- Single Event Upset (SEU) occurs when sub-atomic particles collide with semiconductors
- Collision causes logic & memory element to change state
- This random event can cause system impacts: such as error flag flooding, traffic mismatch, crash, SDC…

How Cisco Validate SEU Design

Accelerated testing using a neutron or proton beam.

We test the whole system contains HW and SW

- The neutron beam is produced by a cyclotron

TRIUMF

Total magnet weight:	4000 tons
Magnet diameter:	18 m (59 ft)
Magnetic field:	up to 5.6 kilogauss
Current required by magnet:	about 18,500 amps
Electric field frequency:	23 million cycles/second (23 MHz)
Maximum spiral turns by particles:	1500 (particles travel up to 45 km - 28 miles during acceleration)
Time required for acceleration:	326 microseconds (1/3000 sec)
Speed of particles at max. Energy:	224,000 km/sec - ¾ speed of light (that would take you from earth to moon in 2 seconds)
Number of particles accelerated:	about 1000 trillion per second . TRIUMF has one of the world's most intense proton beams in this energy range.

- The two main facilities we are using:
  - **ChipIR** in UK
  - **TRIUMF** in Canada
- Few times a year

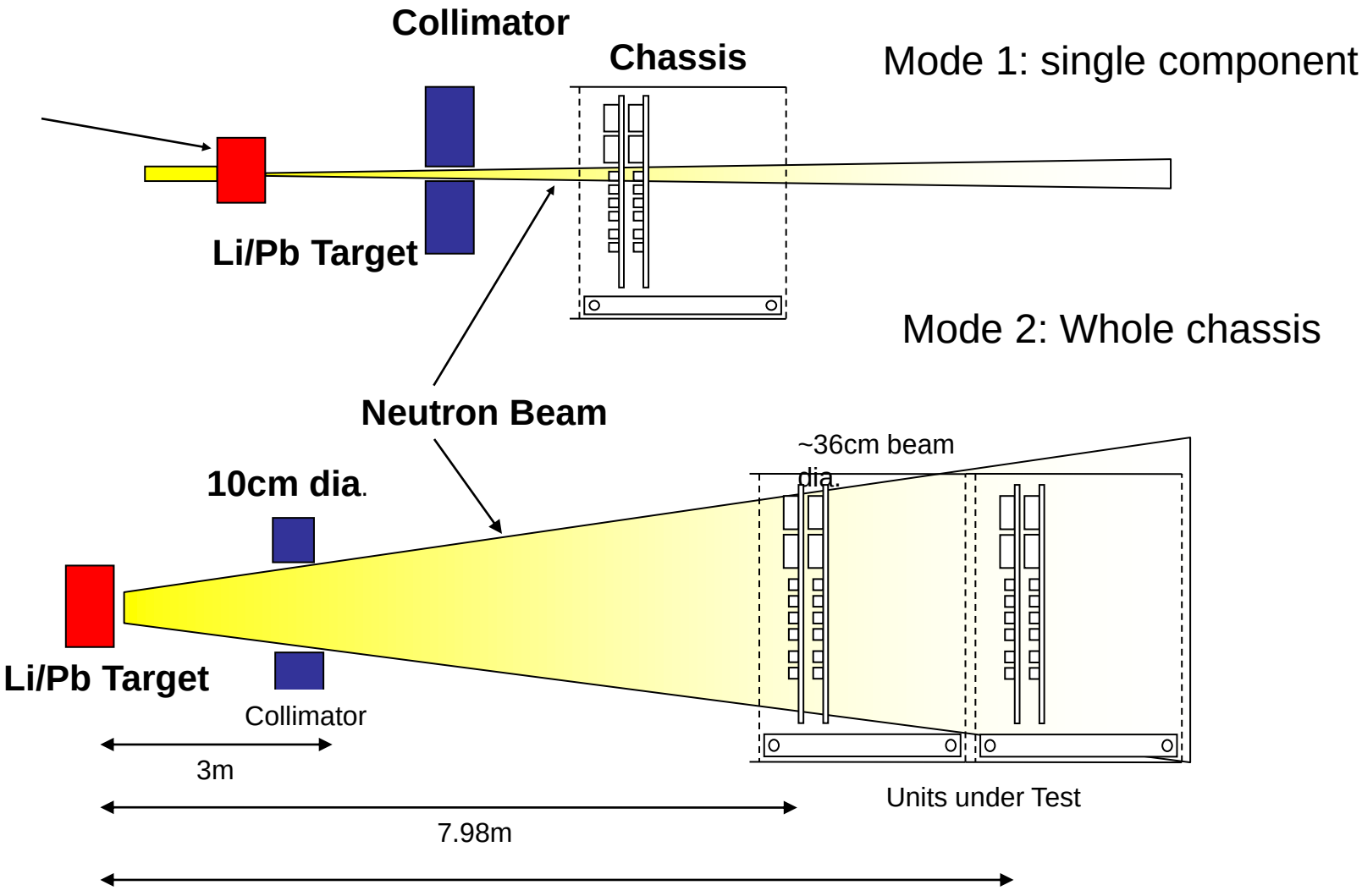
System Level Test Objectives

- Accelerates SEU errors compressing 10 years of system exposure to ~ minutes
- Similarly, equivalent to failure rates seen on thousands of systems in the field
- Avoids field surprises, improve quality
- FMEA for new design, new generation

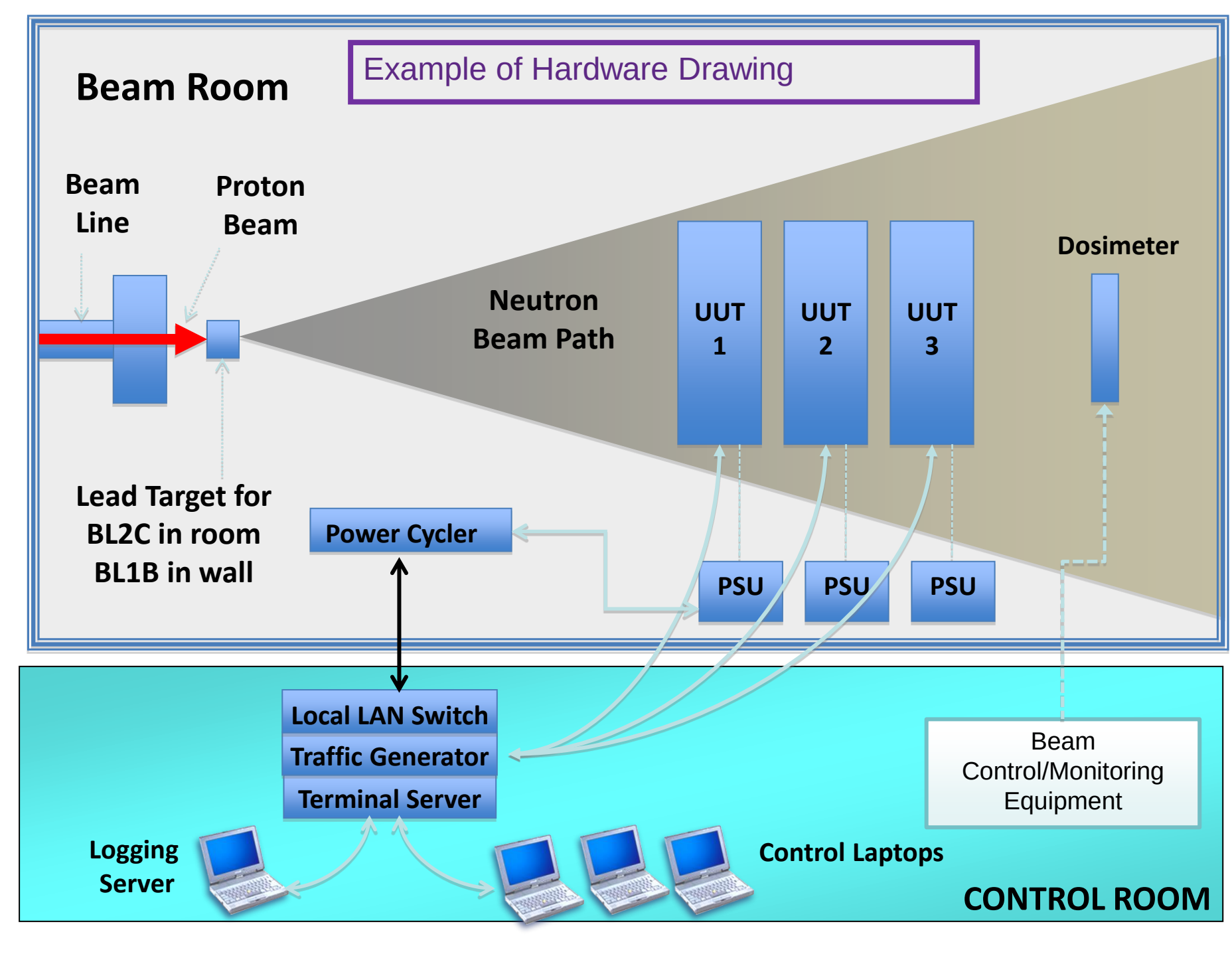
System Level Test Objectives

- Measure component and system SEU rate
- Validate the system design for SEU by testing the ability of SEU event handling
- Improve SW error recovery gracefulness
- Identify & fix component fatal SEU issues

Neutron Testing – Mode 1 and Mode 2

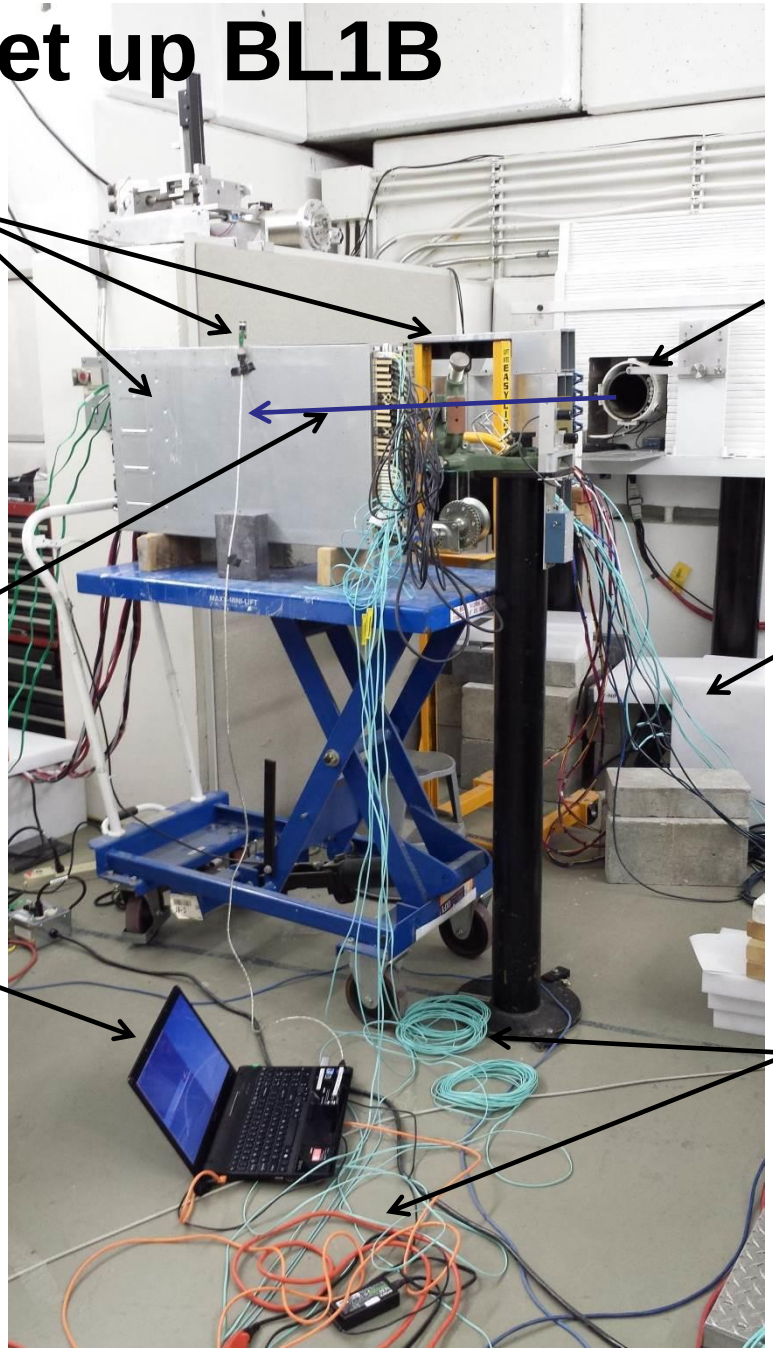


Both HW and SW focused


Beam Room
Example of Hardware Drawing
Beam Line
Proton Beam
Neutron Beam Path
UUT 1
UUT 2
UUT 3
Dosimeter
Lead Target for BL2C in room BL1B in wall
Power Cycler
PSU
PSU
PSU
Local LAN Switch
Traffic Generator
Terminal Server
Beam Control/Monitoring Equipment
Logging Server
Control Laptops
CONTROL ROOM

ChipIR Testing

Example Set up BL1B



Multiple Cisco UUTs and one chip in beam

Beam Exit to Room 1.35m from floor

Neutron Beam

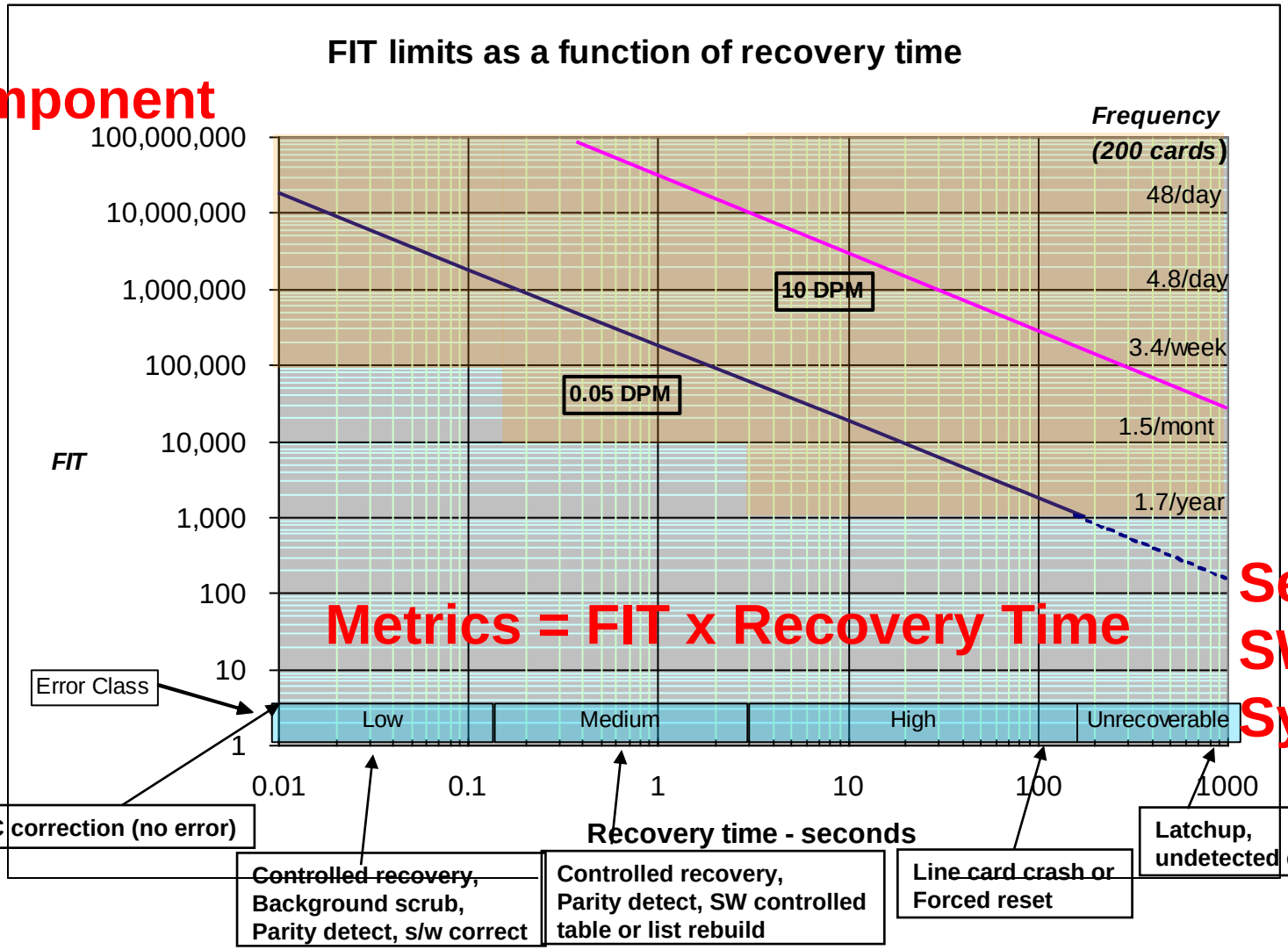
Do Not place equipment and bricks below the beam

Laptop to control chip testing, screen is facing video camera

75ft cables to connect equipment to control room

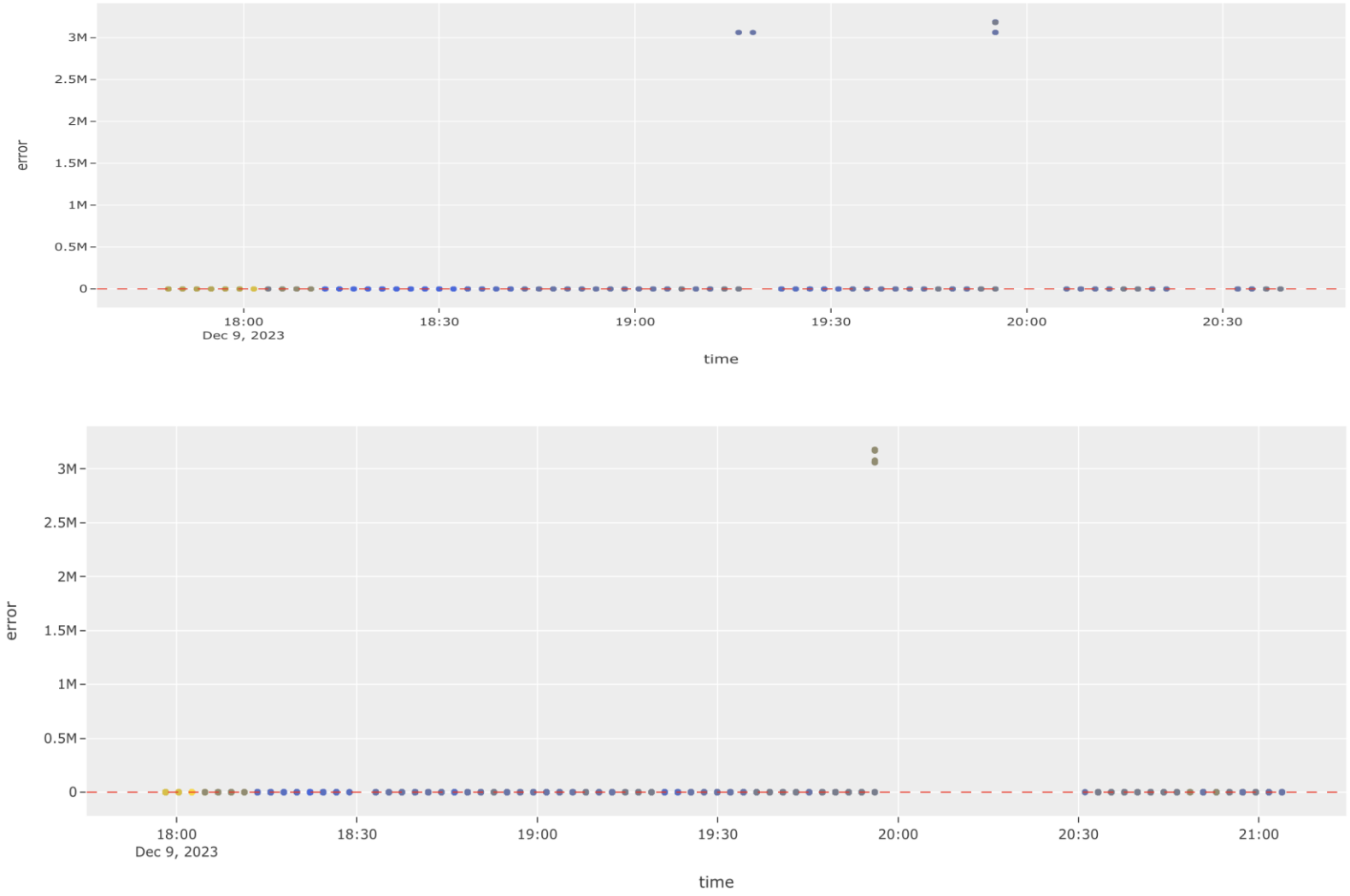
Product Level SEU Metric - illustration

Volume
HW
Component



Sensitivity
SW
System

Telemetry Based Functional Modeling



Beam Line Comparison

Beam Line	Location	Advantage	Disadvantage	Status
TRIUMF TNF	Vancouver, BC	Very high flux	Small chamber, fits small card, safety	Used for component testing only
TRIUMF BL2C	Vancouver, BC	Easy to book time	Low Flux, long cooling period for access	Not used by Cisco since BL1B opened
TRIUMF BL1B	Vancouver, BC	Med flux	Available 4x yr, wants 24 hr/day use	Opened April 2014
RAL ChipIR	Didcot, UK Near London	High flux	Shipment logistic	Opened since 2016
Los Alamos ICE House 1,2	Los Alamos, NM	High flux	9 months advance booking, cost, safety, 24 hr/day use	Not used by Cisco

TRIUMF and TSL Beam Line Comparison

- Cisco line cards are about 62cm on the diagonal
- For the 62cm beam width, fluence increased 5x from BL2C to BL1B
- For reference, max current is 5nA on both beams at TRIUMF
- ChipIR has higher flux
  - Test time reduced