

Considerations for Cryogenic Radiation Test Campaigns

Jean-Marie Lauenstein, Landen Ryder, and Jason Osherooff
Radiation Effects and Analysis Group
NASA Goddard Space Flight Center, Greenbelt, MD USA

Snapshots of a Cryogenic Test – UC Davis

Pretest Cryogenic Setup



Detector Characterization Setup

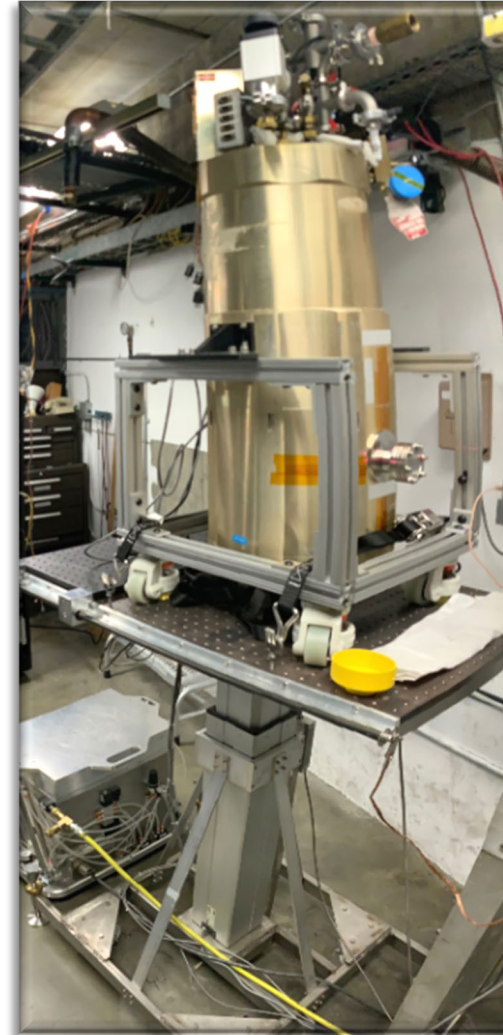
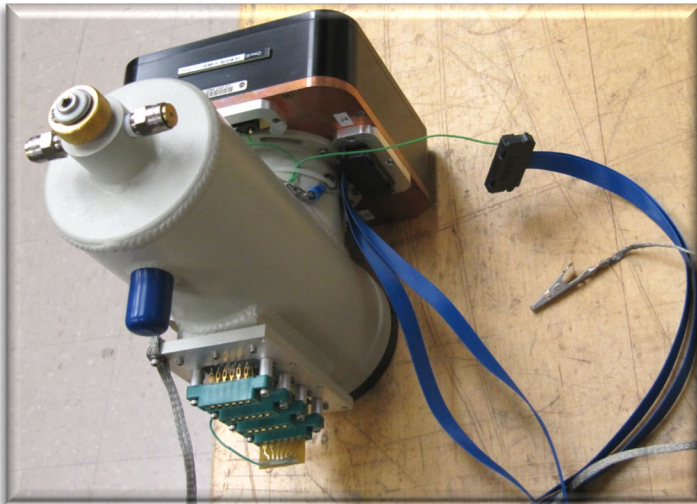
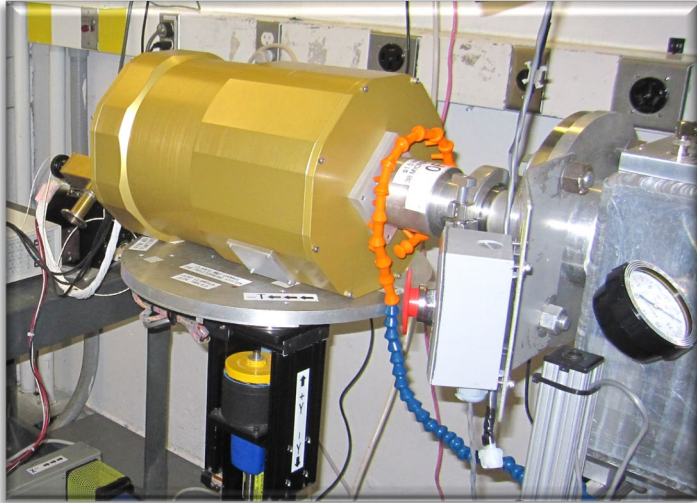


Dewar in Beam



Early collaboration with the facility operators to accommodate intricate cryo setups is key!

Dewar Considerations



Dewar Construction

- Minimize high Z materials due to nuclear activation
- Physical coupling to beam line
- Electrical feedthroughs
- Cryogen capacity

DUT Position

- Minimize fringing/masking
- Minimize beam alignment error

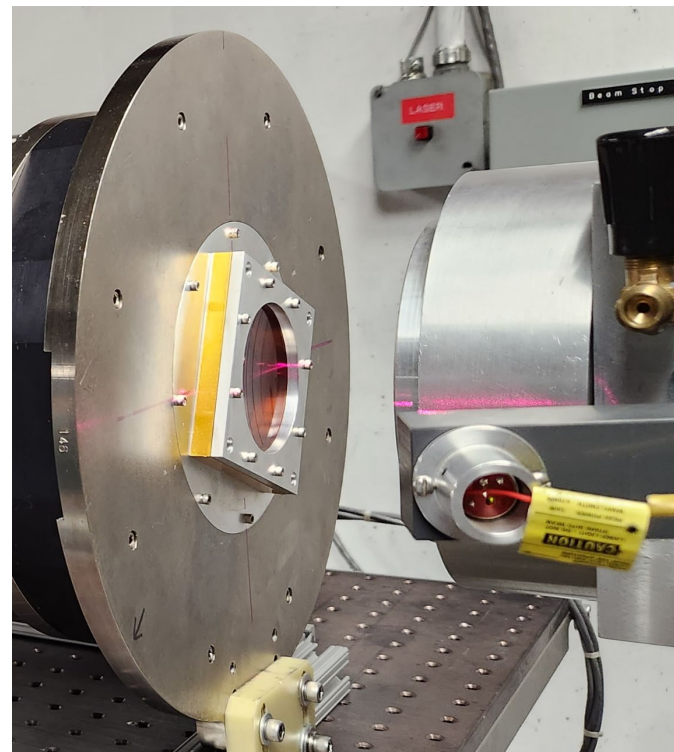
Dewar Window

- Minimize thickness while maintaining Dewar integrity
- Susceptible to condensation build-up – degrades dosimetry
- Potential darkening of window materials impacting data

Dewar Windows

Common Dewar Window Designs

- **Heavy ion tests:**
 - **As thin as possible**
 - Kapton: 2 mil for 1.5" diameter window
 - Teonex PEN: 1.5 mil for 1.75" diameter window
 - **Trade space of window size and material thickness**
- **Proton tests:**
 - **Low-Z reduces activation**
 - **Minimize secondary particles**
 - Kapton ex/ 5 mil
 - with 1-2 mil thick Al inner foil for IR imagers
 - Fused silica – good for visible light imagers
 - Thin aluminum
- **TID tests:**
 - **Most flexible**
 - Aluminum



Equipping Test Campaigns

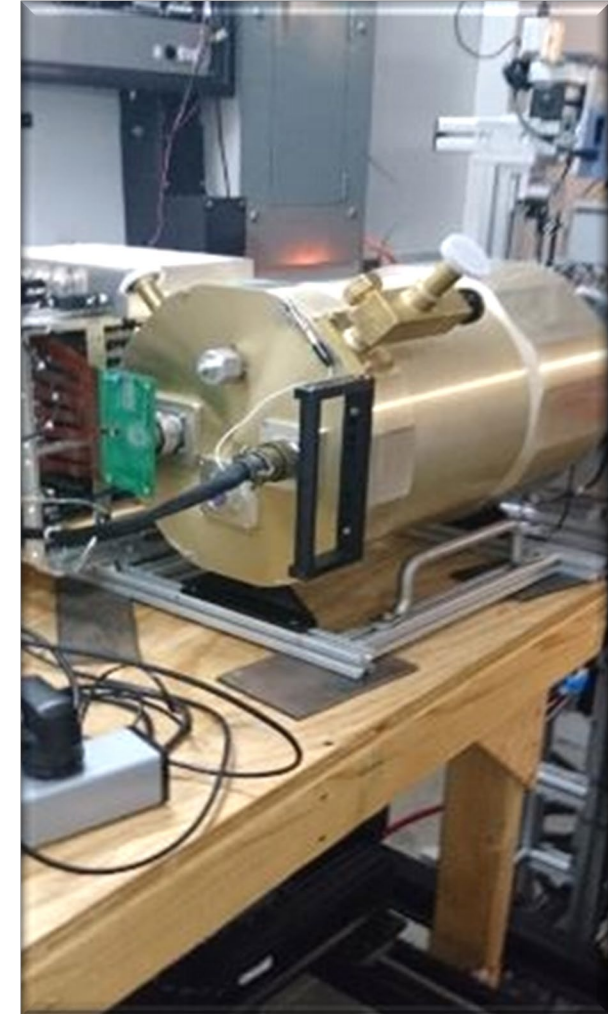
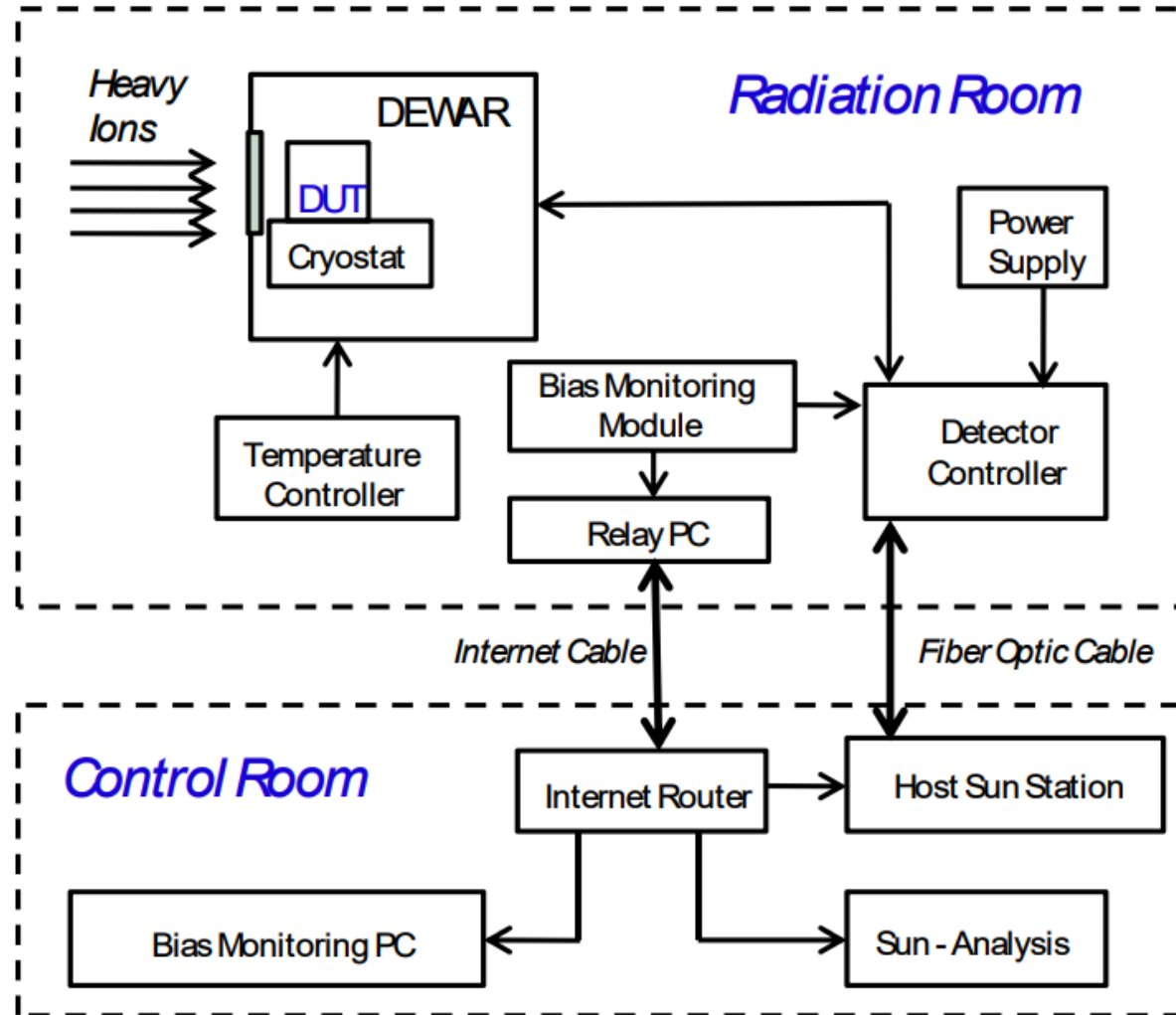
Signal Integrity Issues

- On-chip circuit traces
- Dewar patch panels
- Cable runs in the cave
- Long cable runs to users

Physical Constraints

- Weight limits for facility furnished equipment
- Dewar placement near beam
- Vibrations from pumps

Cryogenic testing tends to resist last minute adjustments more than traditional testing.



Facility Communication Check List

- **Cryogenics:**

- ☐ Proof of cryogenic safety training required?
- ☐ Notify facility when cryogenics will be delivered
 - If needed, ask for recommended local sources for cryogen procurements
- ☐ Remember to arrange for cryogen dewar pickup after testing is completed

- **Physical space logistics:**

- ☐ Is there a room or space available outside the user area for cooldown/checkout of test devices?
 - Arrive early to facility:
 - Sample cooldown and stabilization
 - Pre-rad characterization at cold temp – with enough time to rewarm and swap samples if problems
 - Identification of Dewar thermal leaks early enough for repair
- ☐ Discuss any special power needs and outlet locations

- **Beam cave logistics:**

- ☐ Maximum weight the translation stage can handle? (enough room at end of line for setup?)
- ☐ Beam port window size and material, flange information

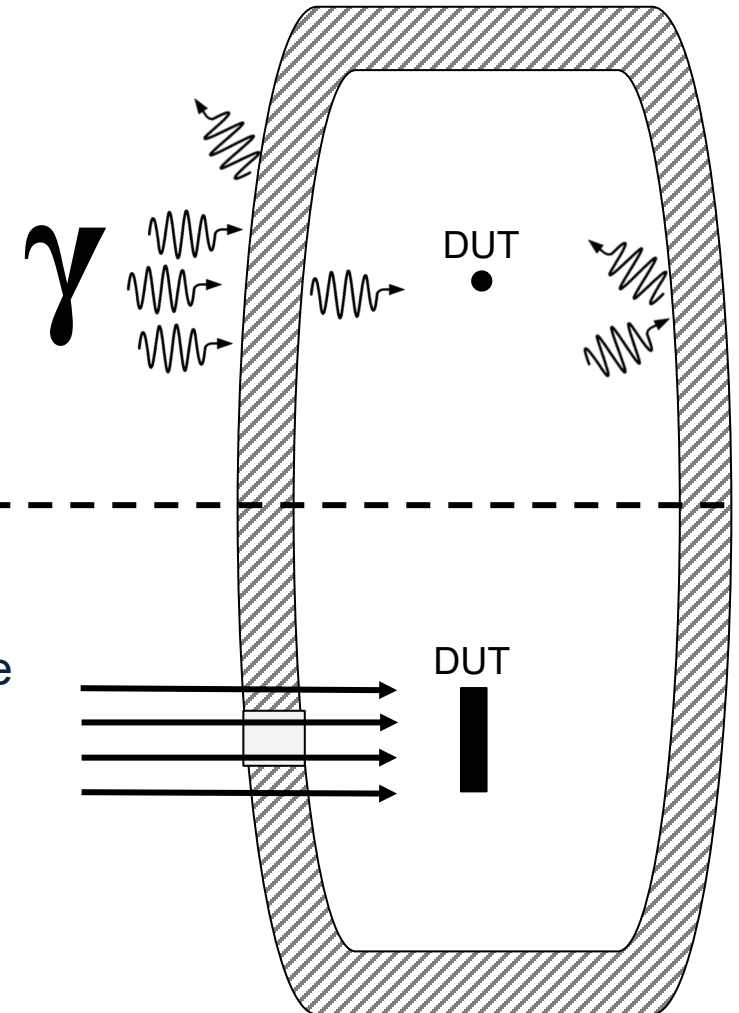
- **Scheduling:**

- ☐ Consider interleaving beam time if only 1 dewar
- ☐ Schedule extra beam time for the unexpected – and bring spare DUTs

Dosimetry Techniques

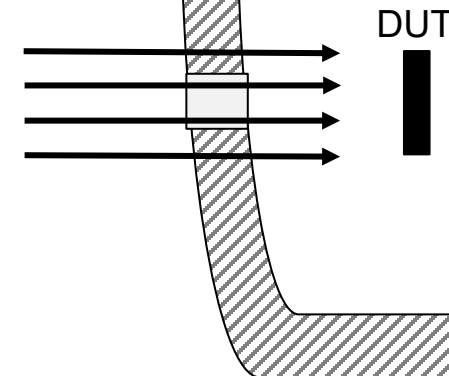
Gamma Ray

- Attenuation, scattering inhibit existing facility dosimetry practices
- Prior to irradiation campaigns:
 1. Place a dosimeter at location of the DUT in Dewar at room temp.
 2. Irradiate the Dewar with a known dose rate and a time
 3. Remove the dosimeter and use the measurements to create an effective dose rate

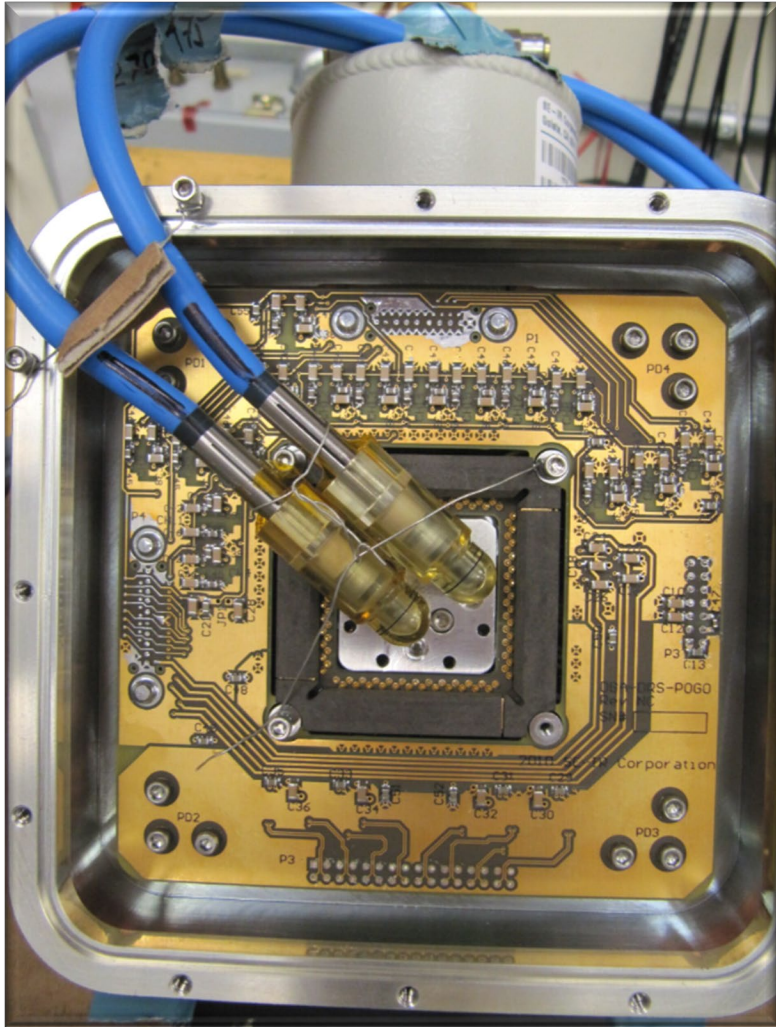


Charged Particles

- Passing through materials degrades beam energy, adds beam straggle
- Small beam aperture minimizes variation in material stack-ups
- Transport calculations (e.g. TRIM) critical for tracking LET, range
 - Air gaps from beam port window to Dewar window
 - Dewar walls and window materials
 - Overburden materials on the DUT



Gamma Dosimetry with a Small Dewar



DUT Preparation

- **Maintaining the DUT during testing**

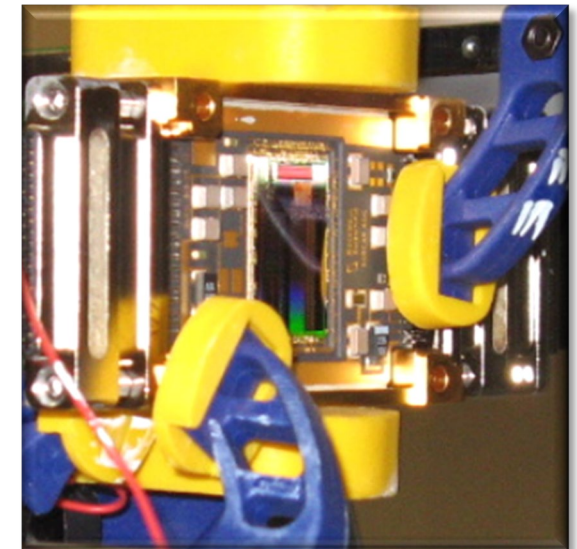
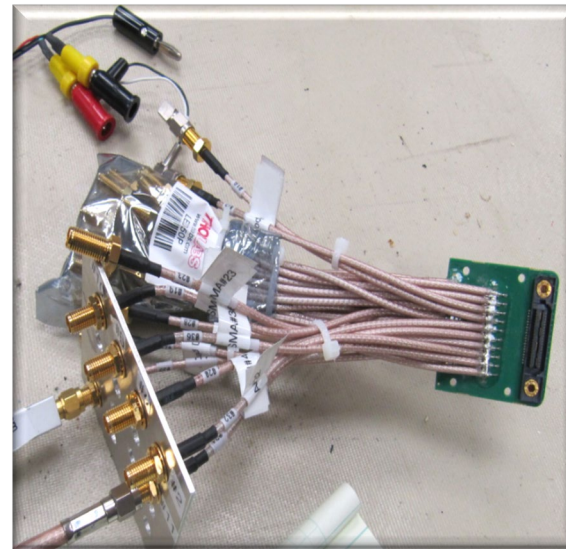
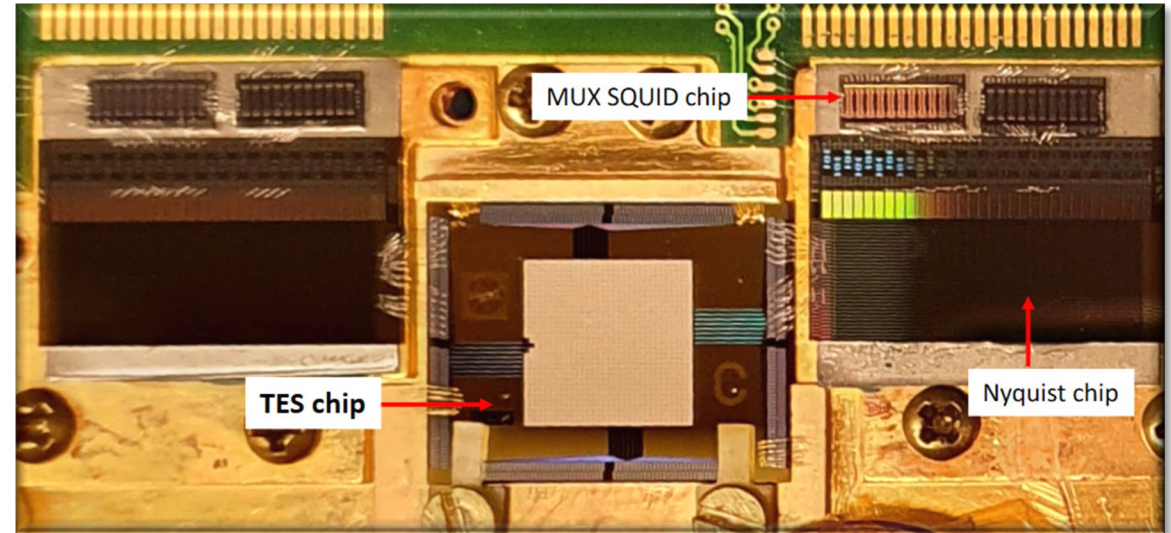
- Shielding support electronics – ROICs, amplifiers, etc.
- Heating
 - from “test like you fly” self-heating
 - from radiation-induced behavior
 - thermocoupler placement is important
- Protection circuitry for repeated SEL tests (remove for verification)

- **Potential impact of DUT package modification**

- Introduction of structural weakness
- Reduction of thermal mass impacting cooling
- Out-gassing or condensation

- **Control samples often require concessions**

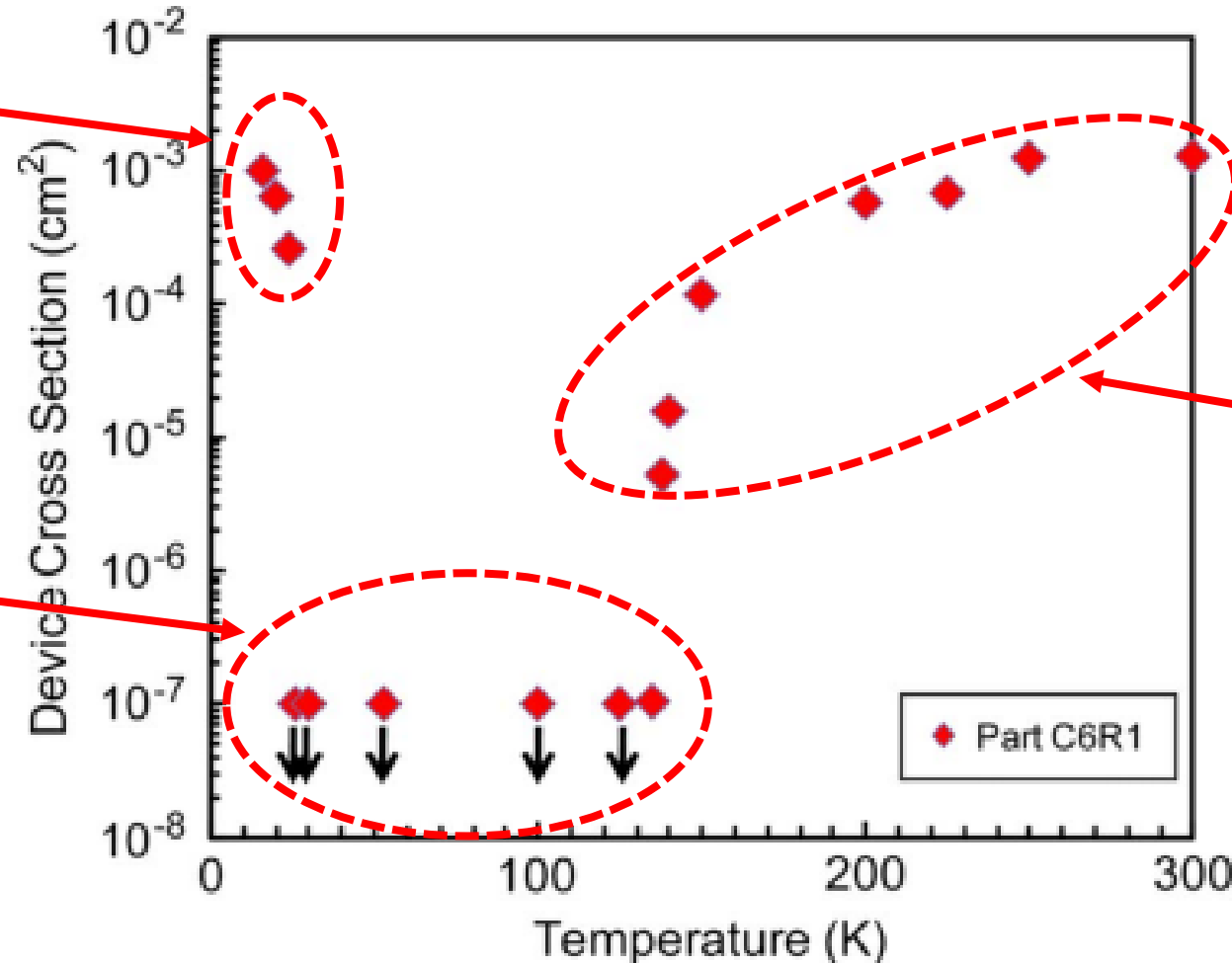
- Concurrent control samples require second Dewar, introduces variation in Dewars and support electronics
- Use of DUT as control:
 - repeated measurements for precision checks
 - alignment of beam off DUT for noise checks



Experiment Design – Temperature Range

Unanticipated behavior!

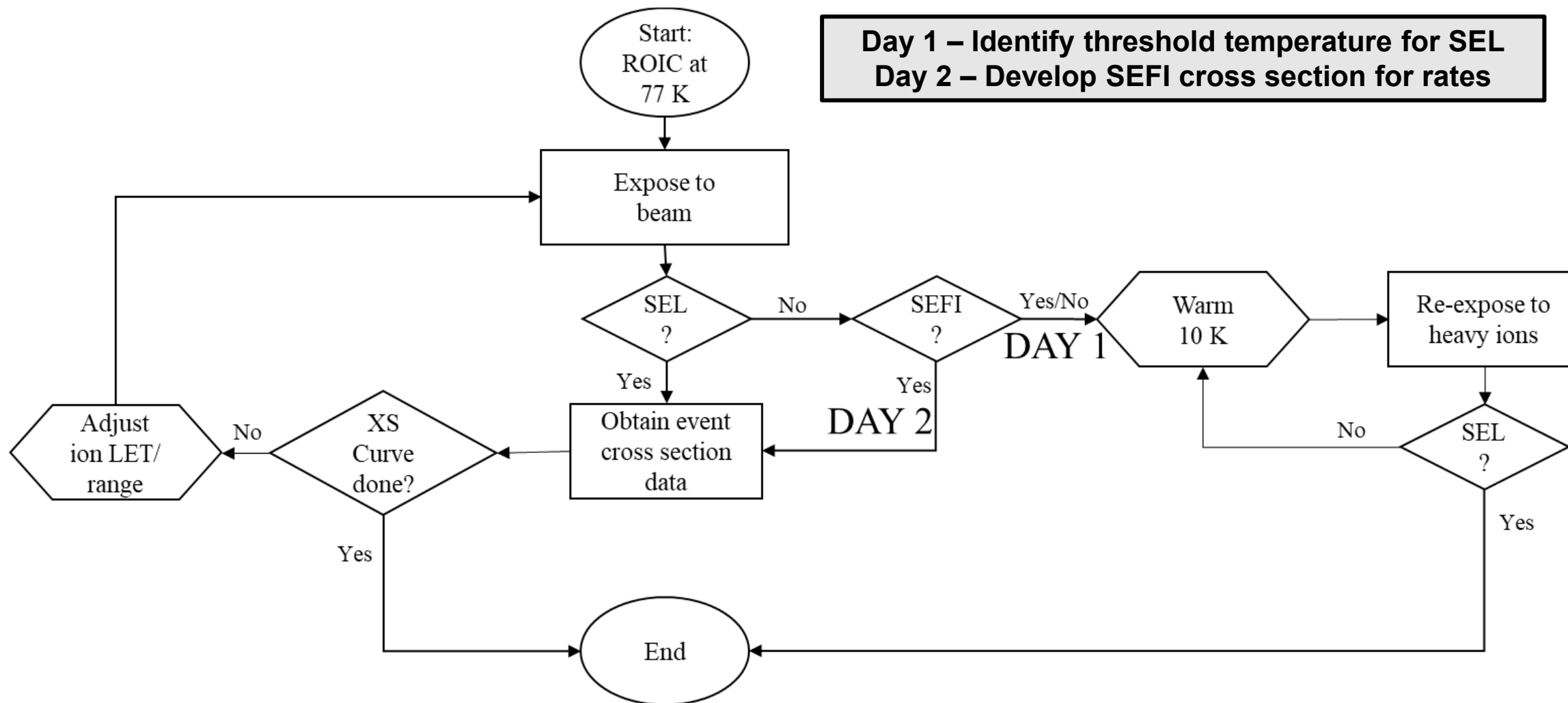
Temperature threshold for sensitivity



Temperature sensitive susceptibility

Testing over a temperature range increases confidence in dataset, informs ConOps changes

Example Test Flow for Cryogenic SEE Testing



Conclusion: Many Factors to Consider

- **Test facility communication:**
 - Interleave beam time for sample changes and problem resolution – beam time is no longer the major cost
 - Communicate early and often: physical space, cryogenics, etc.
- **Special dewar design needs:**
 - Windows, beam path materials, ease of alignment of DUT to beam, time between refills/pumping, etc.
- **Dosimetry complexities:**
 - Identify heavy ion energies and ranges BEFORE coming to the facility for testing
 - TID dosimeters are calibrated for room temperature – identify dose rate BEFORE DUT placed in dewar
- **Test temperature:**
 - Understand application temperature range
 - Identify threshold temperature for SEEs even if outside the application range
 - Check for TID/DDD annealing vs. reverse annealing; consider finding activation energies
- **Sample sizes and controls require extra planning**

Plan for the unexpected!