# EPI-Hi Technology Development

# Outline

- objective
- approach
- development strategy and status
- fidelity of test article
- test performed
- transition to flight

# Objective

Develop new approach to fabricating multi-element ion-implanted silicon solid-state detectors thinner than ~30μm with the following features:

- thicknesses in the range ~10 to 30 μm
- good control of absolute thickness and detector-to-detector variation (±1 μm)
- good thickness uniformity (~0.2% or better rms variation) to allow good species resolution (e.g., He isotope separation)
- mechanical robustness to provide good manufacturing yield and to survive launch environment without breaking

# Approach

• fabrication based on commercial silicon-on-insulator wafers (SOI)

• detector pn junctions produced on device layer of SOI using conventional ion-implantation technology

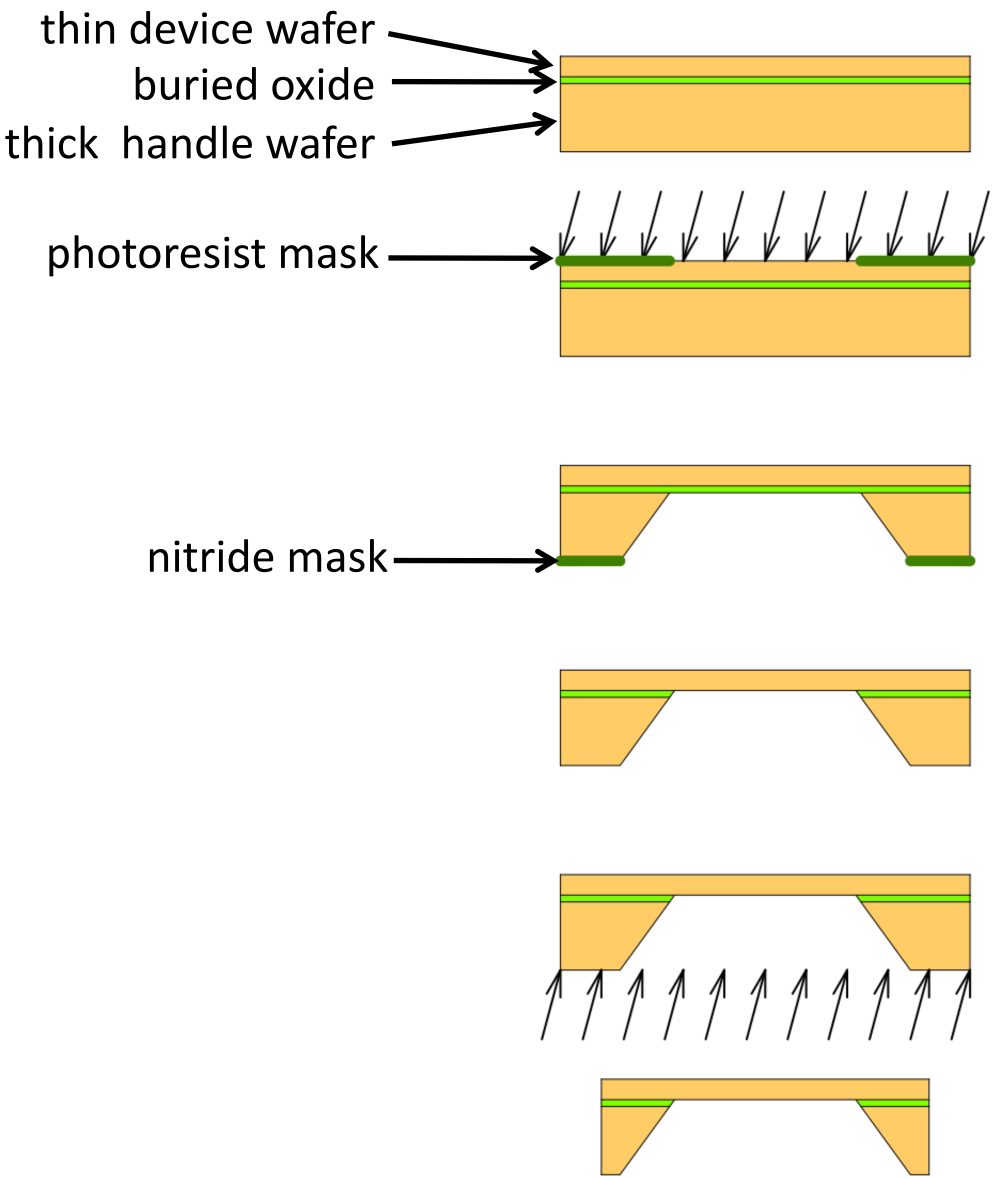
• supporting handle layer etched away under portion of the wafer containing detector active area

• thin $SiO_2$ interface between the two wafers acts as etch stop that makes thickness control and uniformity independent of etch rate variations

• remaining thick "picture frame" immediately outside the thinned region provides robust mechanical support and avoids the need to wirebond to the fragile thin membrane

• production of ohmic contact and dicing into individual detectors done after thinning

# Thin Silicon Detector Fabrication Process Summary




silicon-on-insulator (SOI) wafer, commercial product

ion implant to produce diode pn junctions on device layer

wet etch to remove handle layer under active area—oxide acts as etch stop

etch away oxide from underneath active area

ion implant from back to produce detector’s ohmic contact

dice wafer into individual thin detectors with thick supporting frames

# ***PLACE-HOLDER SLIDE***

## *SOI THICKNESS CHARACTERISTICS:*

- ***THICKNESS COMPARISON BETWEEN THINNED TEST SAMPLES OF SOI AND CONVENTIONAL (STEREO/LET) DETECTORS***

- ***MANUFACTURER DATA ON THICKNESS UNIFORMITY OF SOI PURCHASED FOR EPI-Hi THIN DETECTOR DEVELOPMENT***

- ***THICKNESSES UNIFORMITY INFERENCES FROM LBNL ACCELERATOR TEST DATA***

# Development Strategy and Status

Background

- prototyping studies carried out by a collaboration between LBNL (diode fabrication) and Caltech/JPL since 2003
- prior Caltech/JPL collaboration with Micron Semiconductor (Lancing, Sussex, England) allowed them to develop the capability for making thin, supported detectors from conventional silicon wafers; thickness control and uniformity were did not meet specifications

Phase B Activity

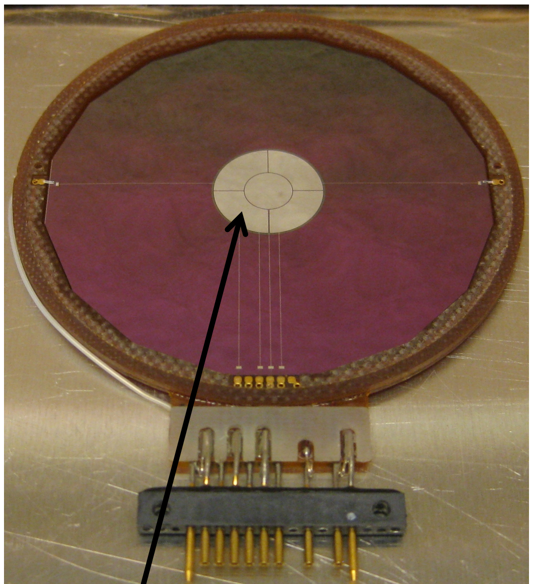
- efforts to prototype EPI-Hi thin detectors from SOI wafers has been funded during phase B both at Micron and LBNL
- testing and evaluation being carried out by the manufacturers and by Caltech/JPL and GSFC

Flight Detectors

- plan to down-select to a single source for flight detectors based on test results

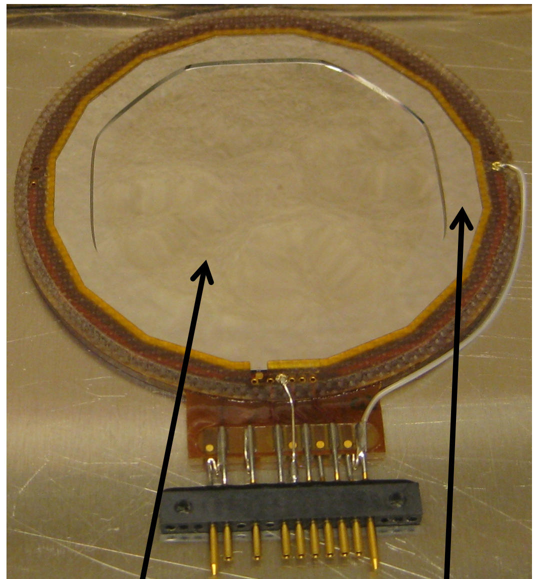
# Prototype Thin Detectors

L0 Detector from MIcron Semiconductor



front

active area
(1 $cm^2$)

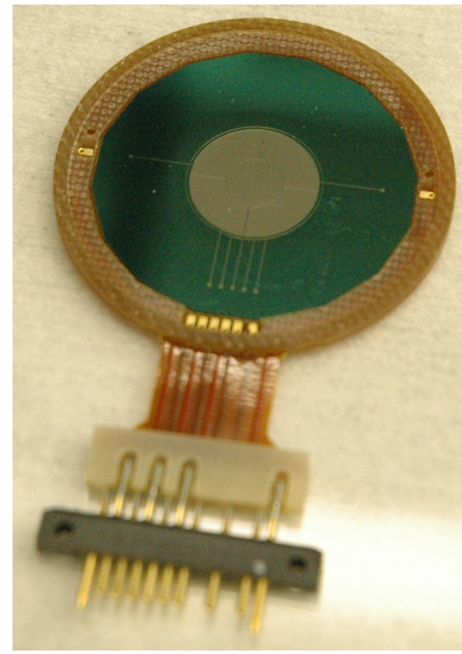


back

12 µm
membrane

thick
frame

L1 Detector from LBNL



# Fidelity of the Test Article

<u>flight detectors are expected to be identical to the prototypes</u>

• the same photolithography masks will be used

• no changes are anticipated in process parameters (ion implantation energy, annealing temperature and time, etc.)

• it presently appears that a sufficient supply of SOI wafers may be left over from the phase B work to allow fabrication of all of the flight detectors and spares

• no changes are anticipated in the detector mounts (provided by GSFC to both LBNL and Micron)

<u>possible exceptions</u>

• if expected risk from dust impacts is judged to be excessive, a modest increase in detector thickness (e.g., 12μm —> 15μm) could be considered

• if LBNL is selected to make flight detectors, adhesive used for gluing detectors into mounts may be changed to that conventionally used by Micron

# Tests Performed

electrical characteristics

- leakage current versus bias (IV) —> maximum operating voltage
- capacitance versus bias (CV) —> bias required for full depletion

particle response

- alpha particles from $^{244}$Cm source (5.8 MeV —> 1.45 MeV/nuc)
- accelerator beams of heavy ions

thickness characteristics

- thickness and thickness uniformity inferred from particle response tests checked against expectations from SOI characteristics

stability in expected environment

- thermal-vacuum life test at GSFC—our standard test for flight qualification of all silicon detectors
- total dose testing using $^{60}$Co gamma-ray source at JPL

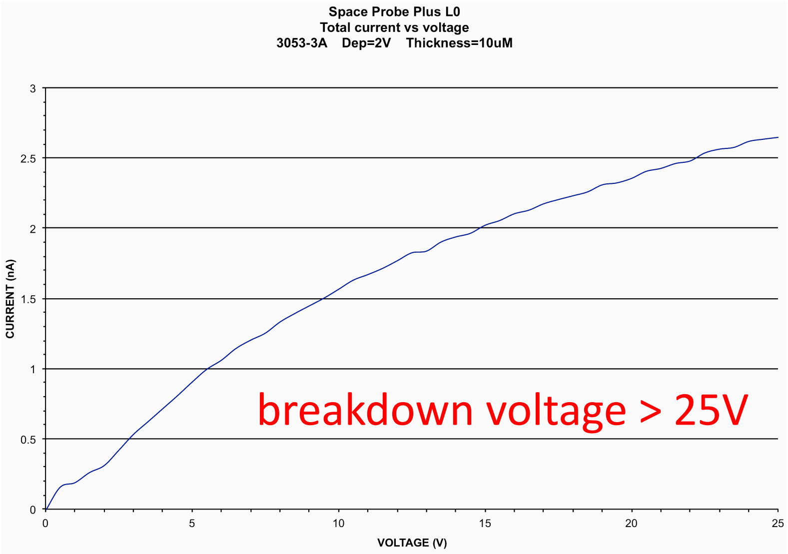
mechanical robustness

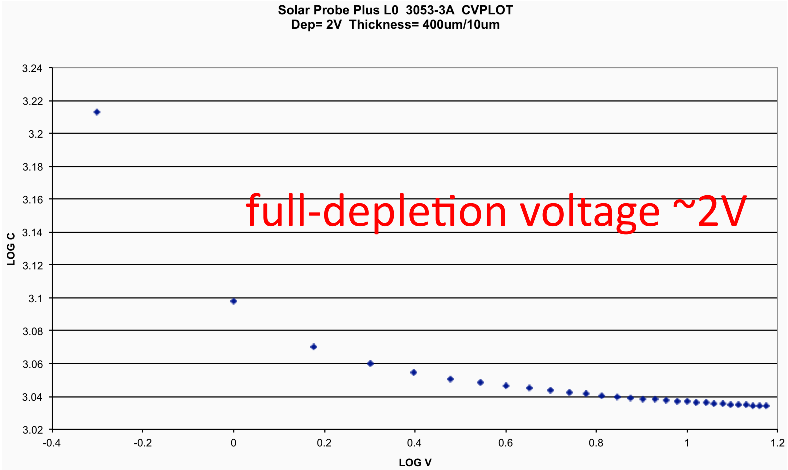
- acoustic test of mechanical model made from thinned SOI

# PLACE-HOLDER SLIDE

## Plots of electrical characteristics

- IV curve(s)
- CV curve(s)



# PLACE-HOLDER SLIDE

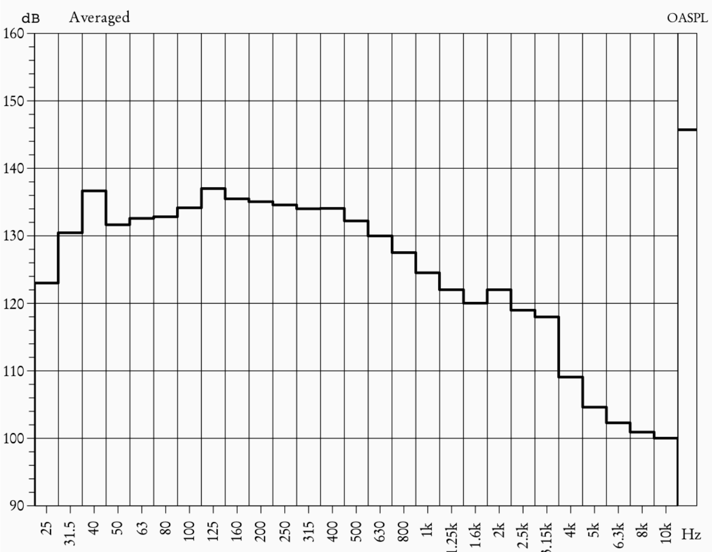
## Acoustic Test of Mechanical Sample L0

WYLE LABORATORIES

ACOUSTIC NOISE

CALTECH SPACE RADIATION LAB., TXXXXX, UTS SILICON

+8dB, Averaged | February 26, 2010

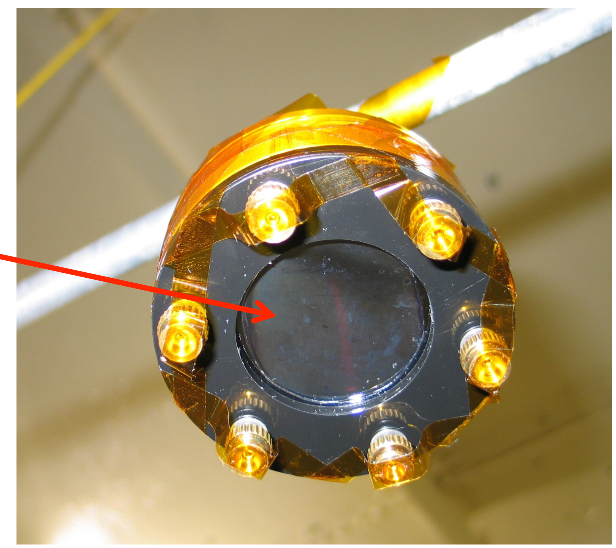



| | |
|---|---|
| 25.0 | 123.0 |
| 31.5 | 130.4 |
| 40.0 | 136.7 |
| 50.0 | 131.6 |
| 63.0 | 132.6 |
| 80.0 | 132.8 |
| 100.0 | 134.1 |
| 125.0 | 137.0 |
| 160.0 | 135.5 |
| 200.0 | 135.1 |
| 250.0 | 134.6 |
| 315.0 | 134.0 |
| 400.0 | 134.0 |
| 500.0 | 132.2 |
| 630.0 | 130.0 |
| 800.0 | 127.5 |
| 1000.0 | 124.5 |
| 1250.0 | 122.0 |
| 1600.0 | 120.0 |
| 2000.0 | 122.0 |
| 2500.0 | 119.0 |
| 3150.0 | 118.0 |
| 4000.0 | 109.1 |
| 5000.0 | 104.6 |
| 6300.0 | 102.3 |
| 8000.0 | 100.9 |
| 10000.0 Hz | 100.0 dB |

**OASPL: 145.7**

highest test level: 145 dB = SPP spec + 8 dB

silicon membrane
10 μm thick
~3.4 cm diameter



# POSSIBLE PLACE-HOLDER SLIDE

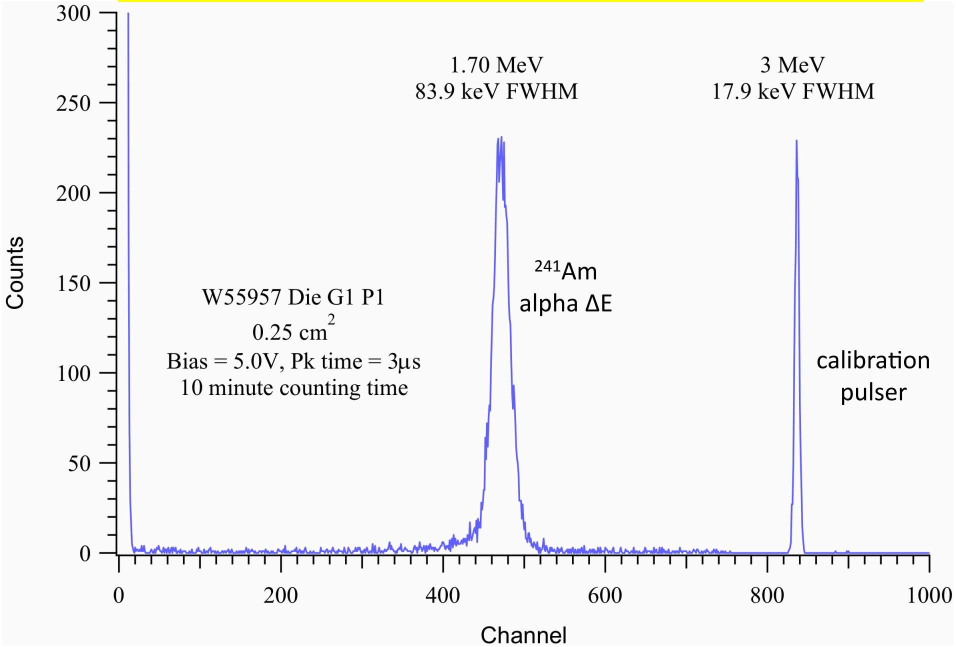
# PLOTS OF PARTICLE TEST RESULTS—ALPHAS

*He mass histogram made using alpha particles—comparison with expected resolution*

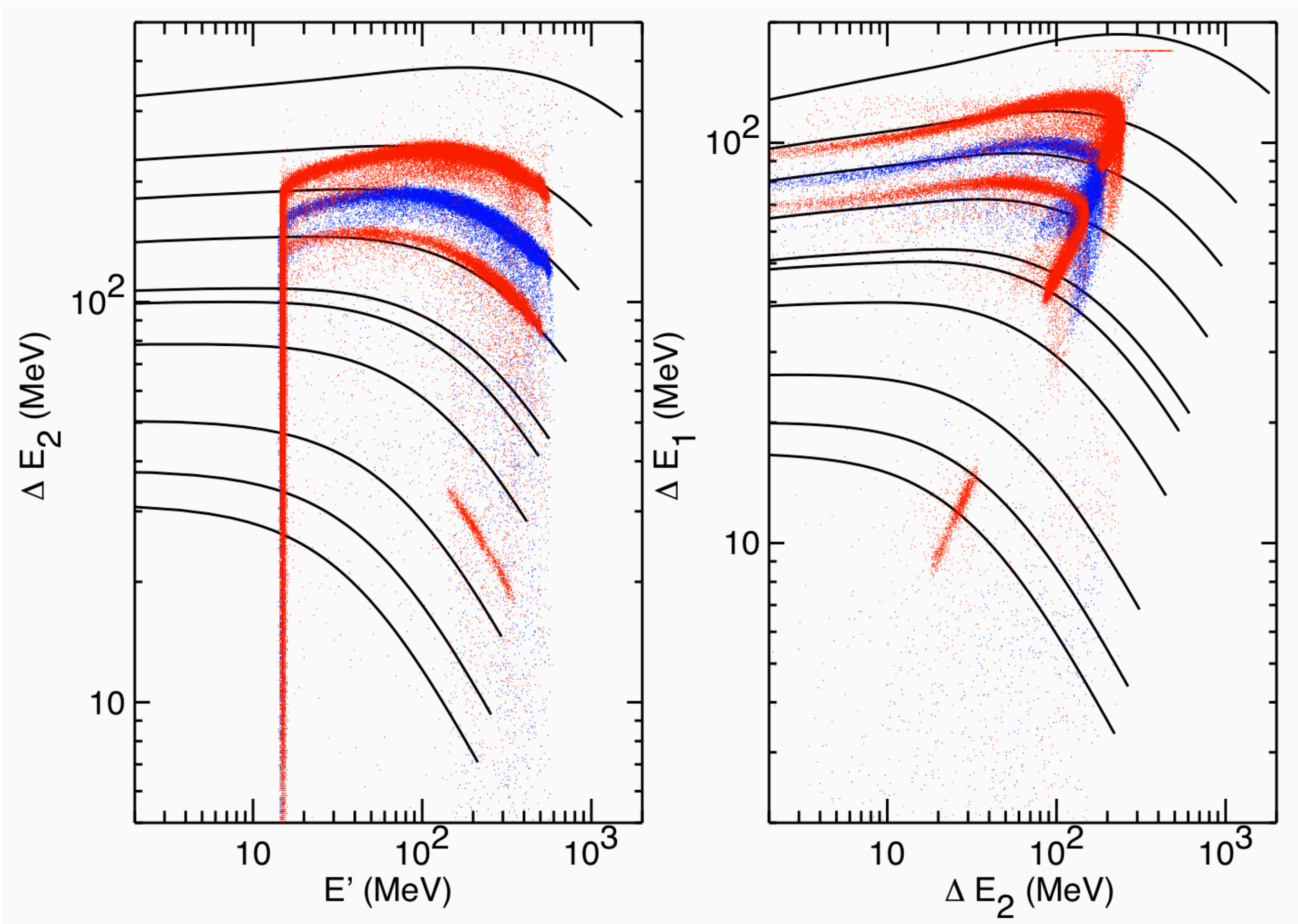
*Possibly easier alternative to consider:*

- *mono-energetic alpha particle ΔE and E' distributions compared with expectations*

NOTE: these data are not from EPI-Hi detectors; they are from a LBNL pre-prototype detector (15μm thick, 1cm$^2$ active area, 4 pixels)

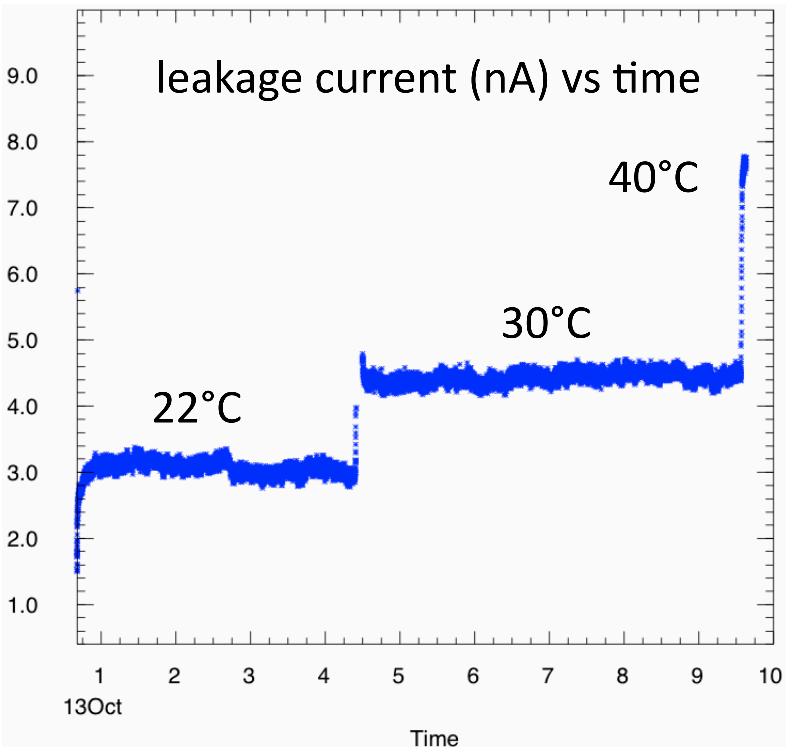


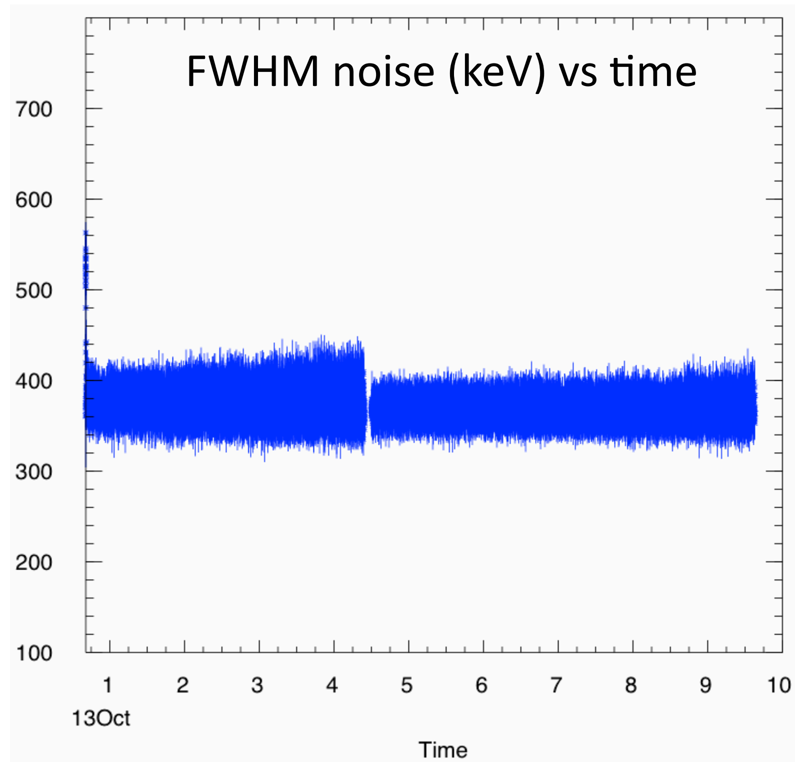
# Accelerator Test with Heavy-Ion Beams




To be replaced with version including more elements (from LBNL and from alpha-particle tests at Caltech). Use improve calibration of the energy scale that has been derived by Rick Leske. Use reasonable data cuts (the plots above use no cuts at all) and reduce quantity of points shown in regions where the plots would otherwise be saturated. Label calculated element tracks. List the beams that were used.

# Thermal-Vacuum Stability Test




To be replaced updated version including as long a time interval as possible at 40°C.

Questions for Tycho:
- why does the noise decrease going from room temperature to 30°C?
- what is the noise level with the detector not connected?

# Radiation Tolerance Testing

• thin detectors will receive high radiation dose because, of necessity, there is very little shielding in front of them

• estimated total dose to the L0 detector over the SPP mission is ... (RAM to provide value and to ask the project if they agree).

• one L1 detector from each manufacturer has been subjected to a total dose test at the JPL high-dose-rate facility ($^{60}Co$ source)

• detectors irradiated in the dark with bias applied to simulate conditions in flight

• irradiations done in a series of increasing steps with measurements of characteristics after each step

• step 1 (16 Oct 2013): 100 krads

• step 2 (17-18 Oct 2013): 1 Mrad

• step 3 ???

include plot or table summarizing measurements

# Transition to Flight

- extend selected prototype tests to cover additional detectors that have been fabricated in phase B—determine whether there are any detector-to-detector differences that might affect
    - yield
    - selection of manufacturer for flight detectors
    - test program needed for flight devices
- select manufacturer for flight detectors