Radiation-Current Effect in ABC130 Chip

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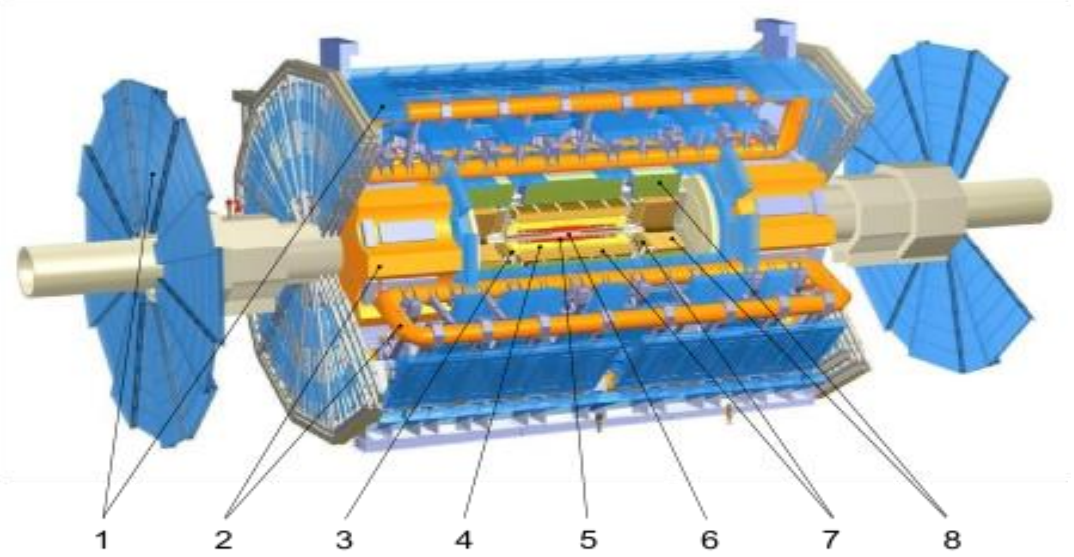
ATLAS

One of four major experiments utilizing CERN's LHC

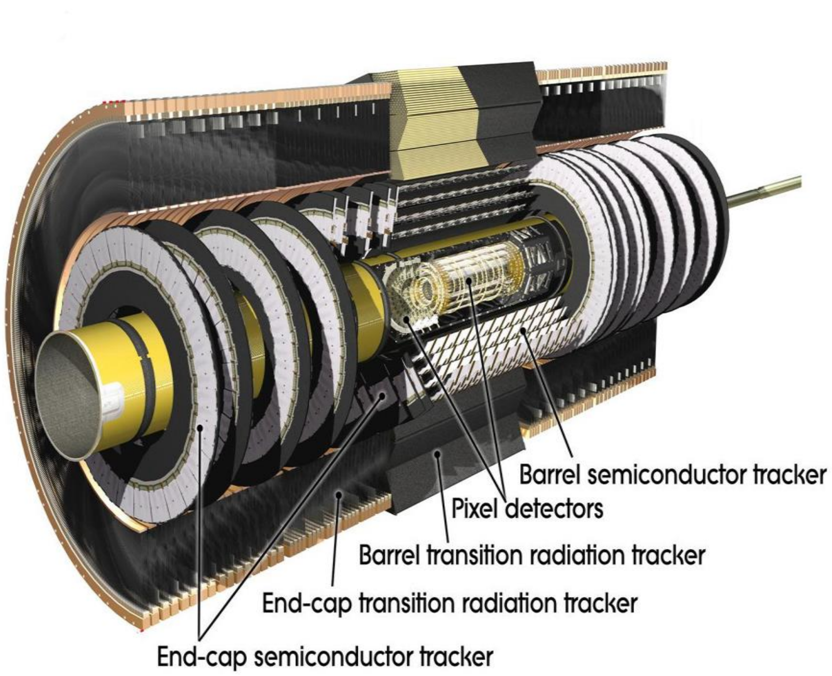
Largest particle collider detector constructed to date

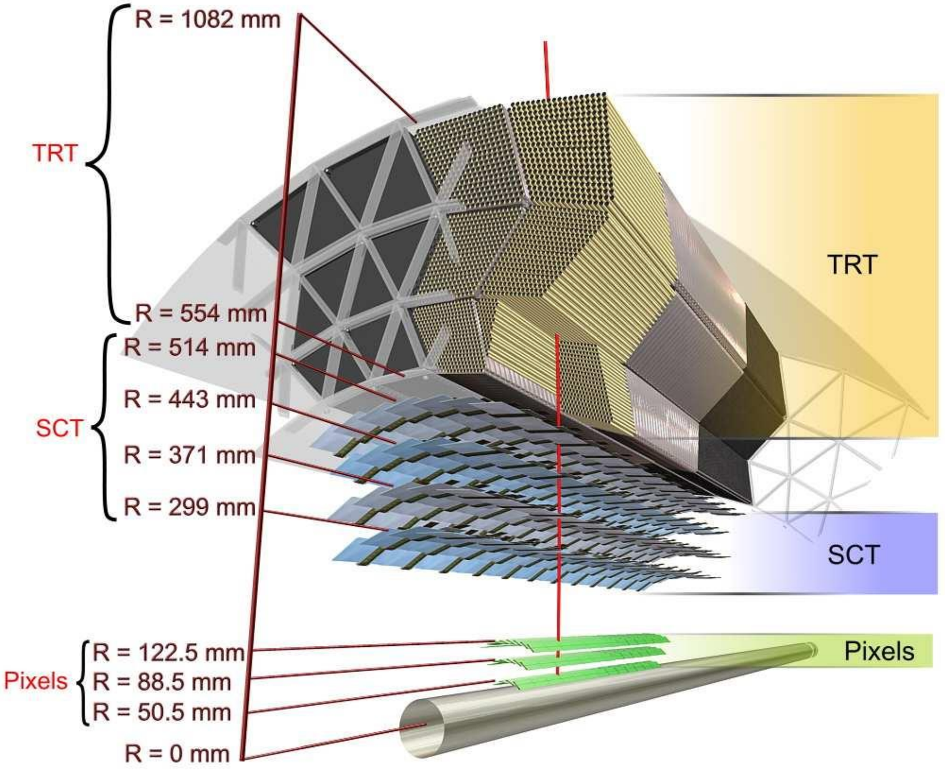
Consists of four major components

- Muon Detectors (1)
- Magnet System
  - Toroid Magnets (2)
  - Solenoid Magnet (3)
- Inner Detector
  - Transition Radiation Tracker (4)
  - Semi-Conductor Tracker (5)
  - Pixel Detector (6)
- Calorimetry
  - Liquid Argon Calorimeter (7)
  - Tile Calorimeter (8)



Inner Detector



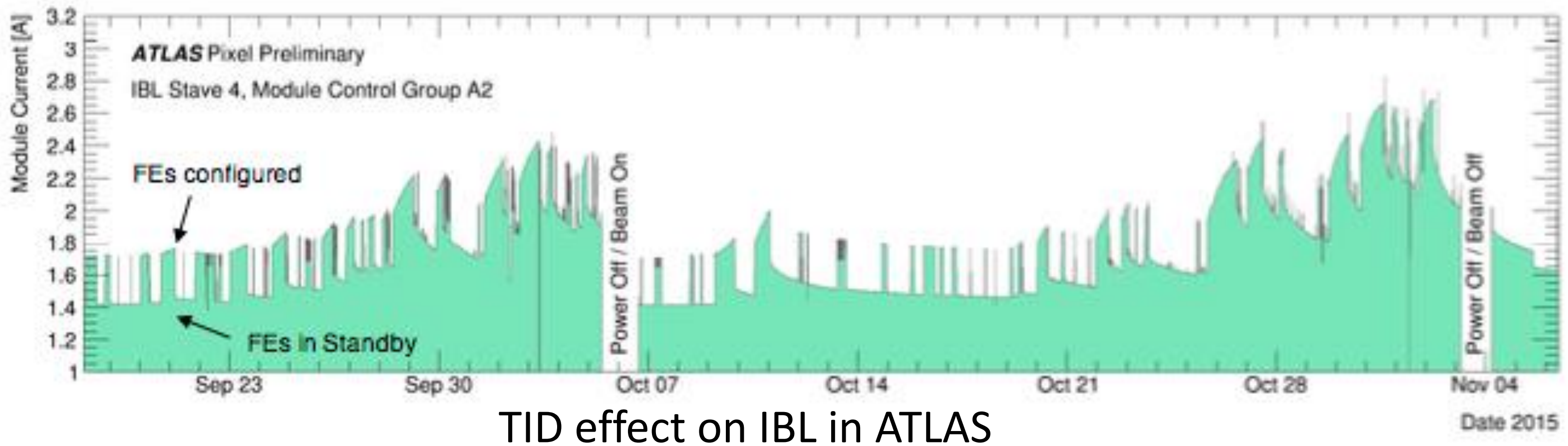


Early-life Radiation Effects

A year ago, single radiation-hardness test on proposed chip showed drastic jump in power consumption

Simultaneously, IBL power consumption jumped unexpectedly a year after installation, causing operational overhead and also temporary inactivation of IBL

Although this phenomenon was known as early as 2002, no predictive model currently exists, thus requiring experimental analysis of the individual system



TID effect on IBL in ATLAS

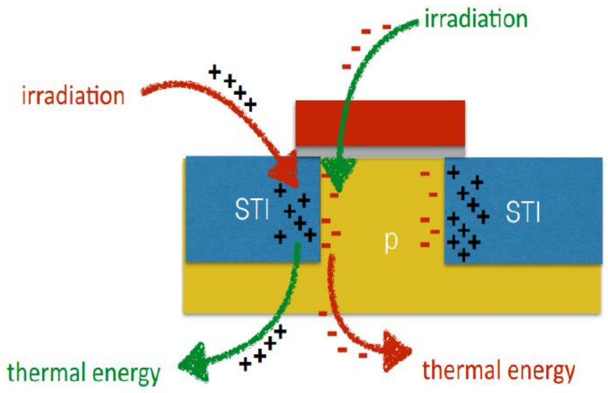
The Phenomenon – "TID Bump"

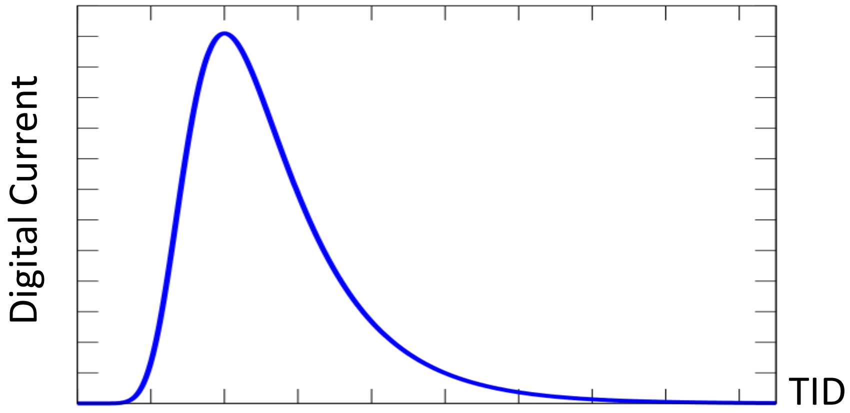
Irradiation creates in electron-hole pairs in SiO_2 in chip gate

- Electrons highly more mobile than holes, resulting in positive charge build-up
- Charge build-up increases linearly with TID but decreases exponentially with time due to diffusion

Charge build-up is counteracted by "interface traps"

- Positive charge in SiO_2 results in dangling bonds which trap electrons from p-type Si
- Since process activated by positive build-up, magnitude of effect varies linearly with SiO_2 charge
- Delay from SiO_2 charge accumulation to electron trapping results in current spike





Experiments and Analysis

Test chips irradiated under controlled conditions:

- Temperature: low temperatures inhibit annealing and trapping, thus exacerbating mid-life current bump
- Dose rate (distance from source): actual chips will be placed at different distances from collisions, thus resulting in current fluctuations at different times throughout the system.

Initial tests done locally using X-Rays

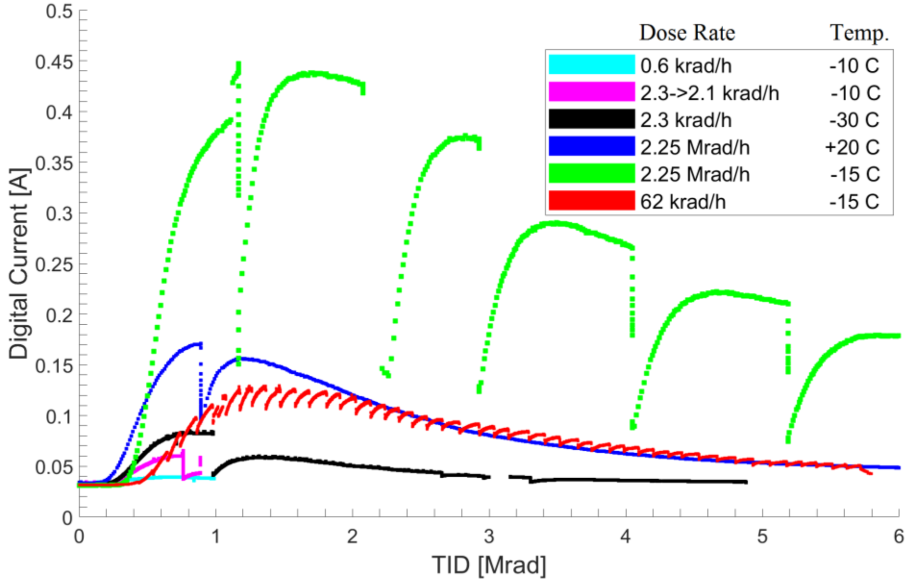
- Limited accessibility
- Excessively high dose-rate

Current tests off-site with natural cobalt source

- Occasionally power outages and computer restarts allow annealing in chip, thus interfering with representative data collection

Approaching critical point where data sufficient to attempt modeling

TID Bump in ADC130



Developing a Predictive Model

Two potential models have been suggested based on current experimental results

A purely theoretical Landau fit

- Qualitatively similar to data obtained from radiation tests
- Well established fitting methods within particle physic
- Generates four fitting-parameters, which if linked to physical conditions, could provide valuable prediction method
- No such physical significance currently established
- Trends are difficult to identify due to low data density

A “physical” model, proposed and developed by Malte Backhaus

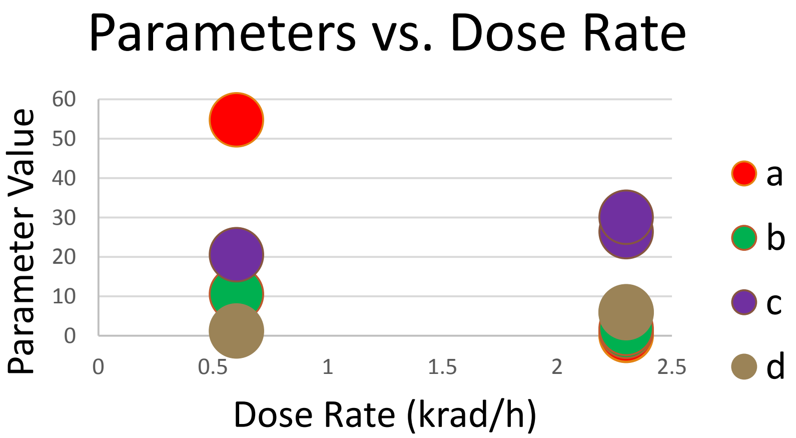
- $I_{leak} = I^0_{leak} + K \cdot \left[k_{ox} D \cdot \tau_{ox} \cdot \left(1 - e^{-\frac{t}{\tau_{ox}}}\right) - k_{if} D \cdot \tau_{if} \cdot \left(1 - e^{-\frac{t}{\tau_{if}}}\right) - N_{thr}\right]^2$
- Requires extensive parameter-fitting for each new condition-set, thus lessening use as predictive model

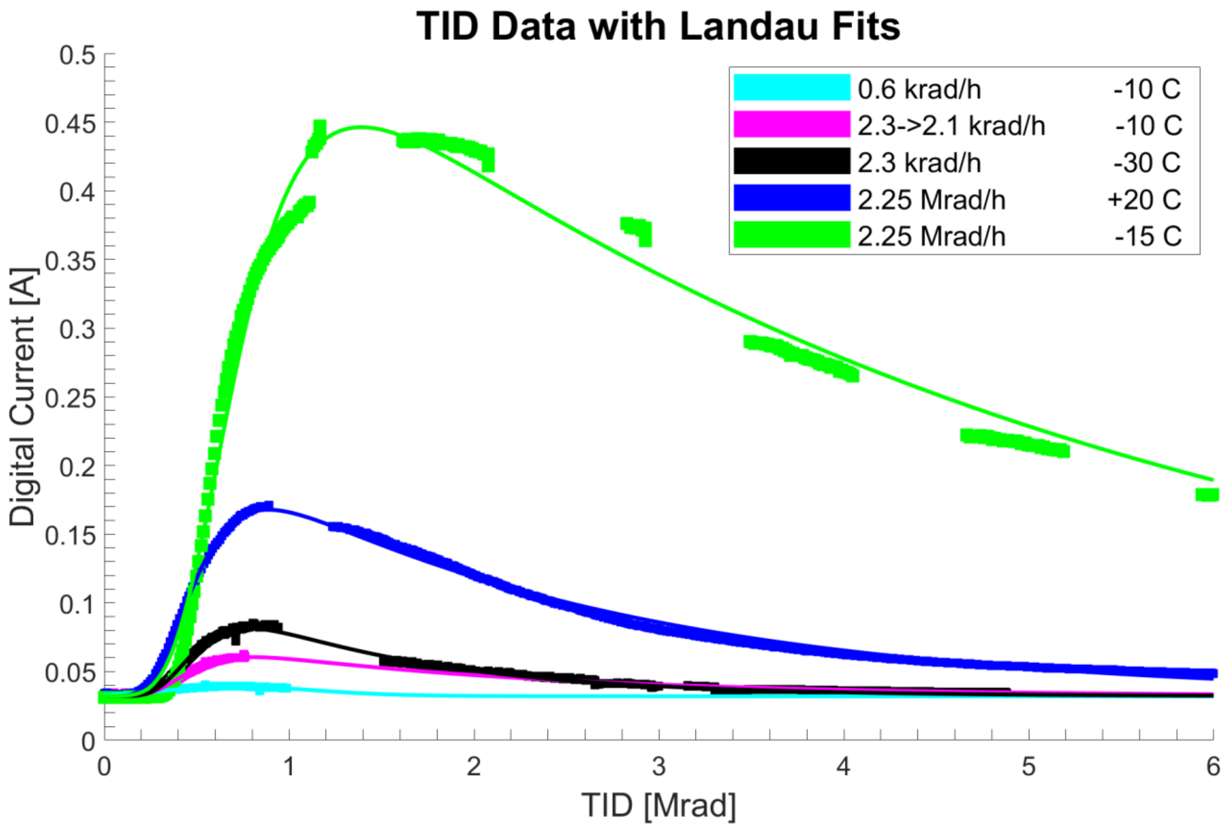
Theoretical Landau Fit

Excellent initial fitting results

Data too limited to achieve predictive model at present

Optimized parameters highly dependent on data selection and initial guess





“Physical Model” Fit

$$I_{leak} = I_{leak}^0 + K \cdot \left[k_{ox} D \cdot \tau_{ox} \cdot \left(1 - e^{-\frac{t}{\tau_{ox}}}\right) - k_{if} D \cdot \tau_{if} \cdot \left(1 - e^{-\frac{t}{\tau_{if}}}\right) - N_{thr} \right]^2$$

Substantially worse results than theoretical Landau

Accounts explicitly for dose rate but not for temperature

Some data achieves best fit with unphysical values for “physical” parameters

Conclusion: While a physical model is desirable, the current proposition is insufficient.

Improved insight into temperature dependence may help illuminate the problem.

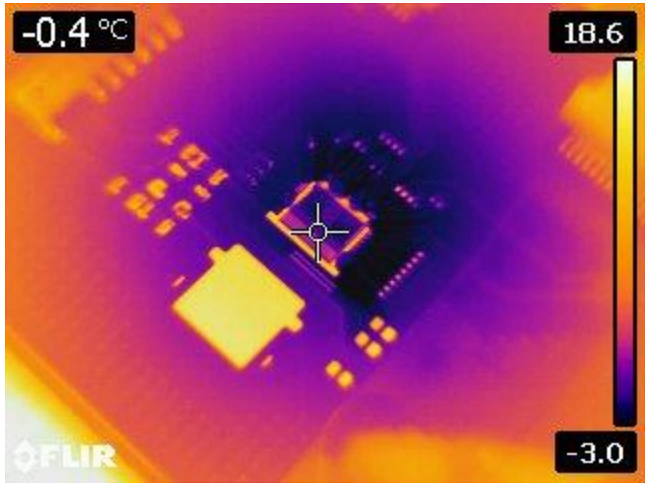
New Measurement – Temp Dependence

Backhaus's proposed fitting equation takes explicit consideration of dose rate, not temperature

To analyze temperature dependence, new test at DR = 2.3 krad/h, T = 0°C

- Will have DR = 2.3 krad/h measurements at T = -30, -10, 0°C

New testing facility at Brookhaven National Laboratory, USA, will reproduce and extend measurements at same temperatures over a range of dose rates



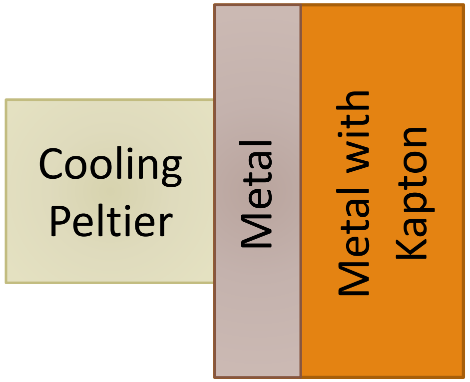
Temperature Validation

Temperature read-outs during irradiation are unreliable due to loosening of NTC connection

Previously, thermal camera used at termination of studies to confirm expected temperature, but accuracy questioned

- Dry-air flow shown to drastically alter measurements
- Possible error introduced from Kapton tape used to protect chip

Using X-Ray source, generated highly-controlled, easy-access environment in which temperature could be swept and NTC/camera measurements compared, with and without Kapton



Temperature Validation – Results

Expectations:

- Measurements may differ from setting due to physical setup, but NTC/camera measurements should agree
- Kapton should have little/no effect on NTC measurement
- NTC w/Keplar measurement may be slightly higher due to distance from cooling Peltier

Results:

- Measurements differ substantially from setting, indicate drastic effect of physical setup (likely dry air)
- NTC/camera measurements agree within +/- 2°C *with* Kapton; camera wildly inaccurate without

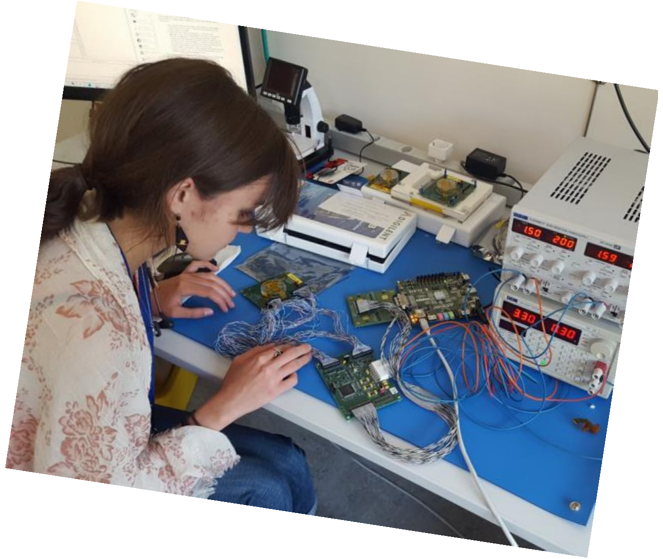
Peltier Setting	Camera Metal	NTC Metal	Camera Kapton	NTC Kapton
-02	+17.1	NA	-2.5	NA
-12	+17.5	-1.0	0.5	-0.3
-22	+16.5	-5.4	-8.5	-6.5

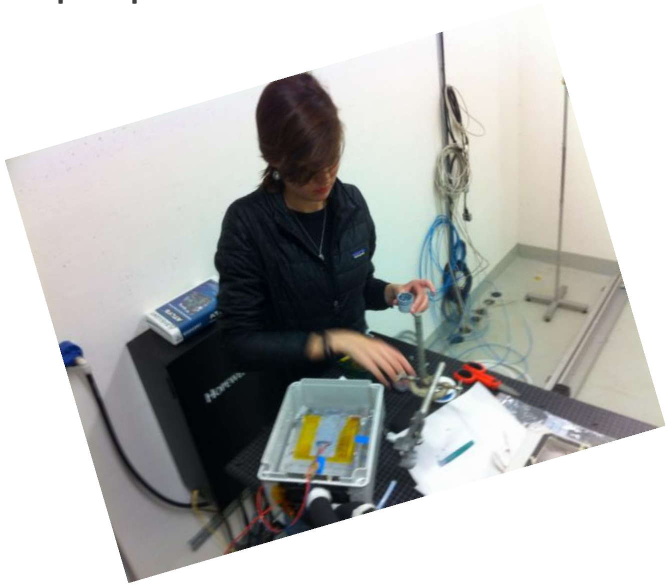
Next Steps

Upon completion of current radiation test, begin to explore possible models for temperature dependence

Use future BNL results to cross-check and extend temperature hypotheses

Continue investigating viability of proposed Landau model





People don't take trips... trips take people.

John Steinbeck

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