ABC130 Radiation Tests

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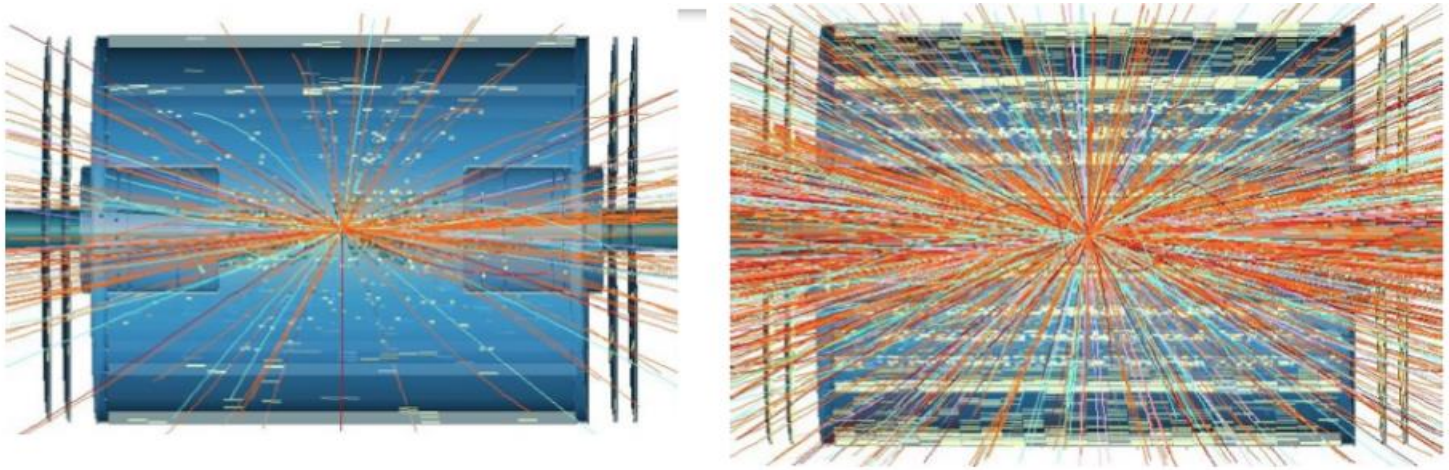
Outline

- Project overview
- Previous work
- Experiment setup
- Chip temperature studies
- Data collection and analysis
- Preliminary results
- Summary + future work

Project Overview

- Over the next 10 years, the LHC will be replaced by the HL-LHC
  - 5x the luminosity (3000 fb^{-1}) → more radiation, more pile-up (150-200 interactions per crossing)
- The ATLAS inner detector (ID) will be replaced by the ITk to prepare for this
- The new front end readout chip for the silicon strip tracker of the ITk is currently the ABC130 ASIC
- Need to map the behavior of the chip as it is exposed to radiation (threshold voltage, gain, noise, current increase)



LHC → HL-LHC (photo from Zhijun Liang)

The ABC130 ASIC front end chip

- ASIC: application-specific integrated circuit
- Reads out data from 256 silicon strips
- First step of data discrimination, then passes data down the line
- In detector, chips will be assembled on modules (left), but running tests with a single chip (right)
- Self-testing capabilities – injecting charge vs. reading a charge from silicon strip

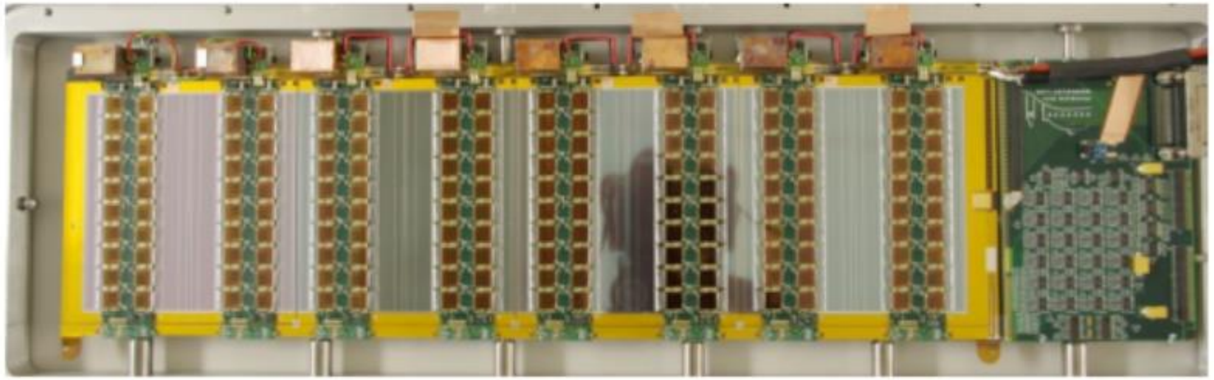
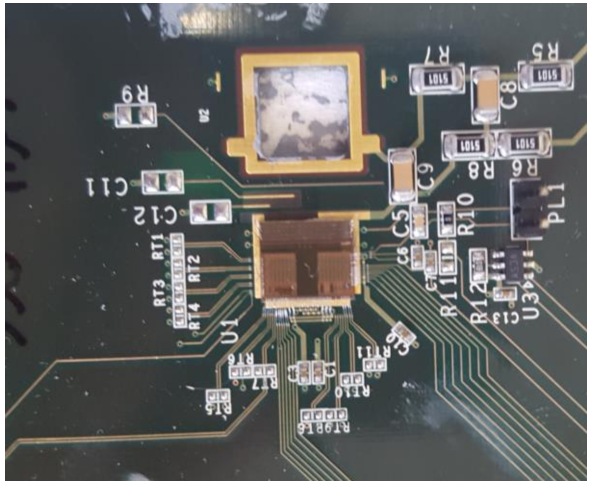
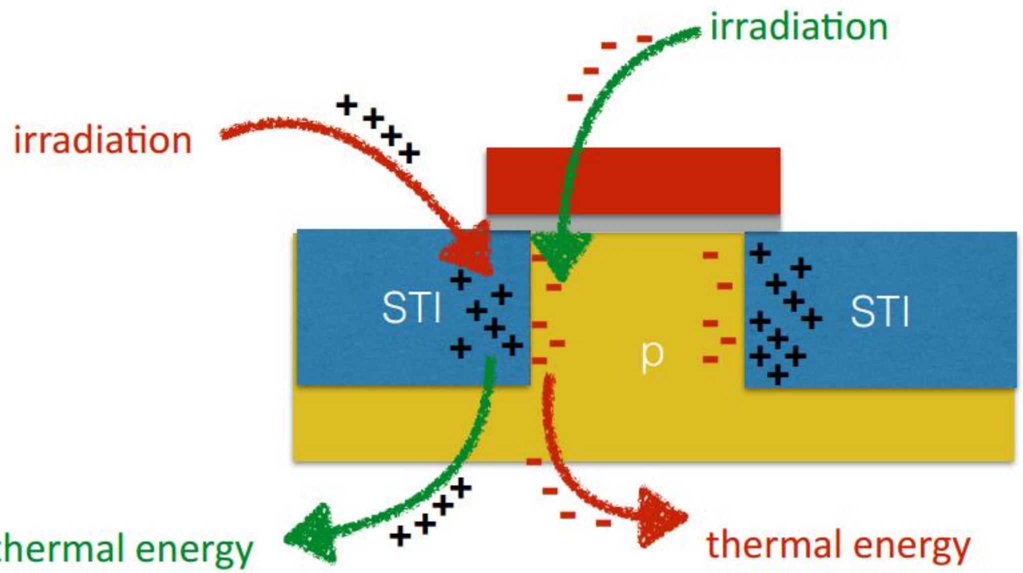


Figure 10.71. DC-DC powered stavelet with ABC250s.



How radiation affects the chip

- CMOS transistor in chip is affected by radiation
- Leakage current in transistor → creation/trapping of charge from radiation
  - Passivation/detrapping from thermal excitation
- Long term radiation studies (up to 100MRad or 1GRad) are being done by other groups – we're just looking at the effects of the first few MRad



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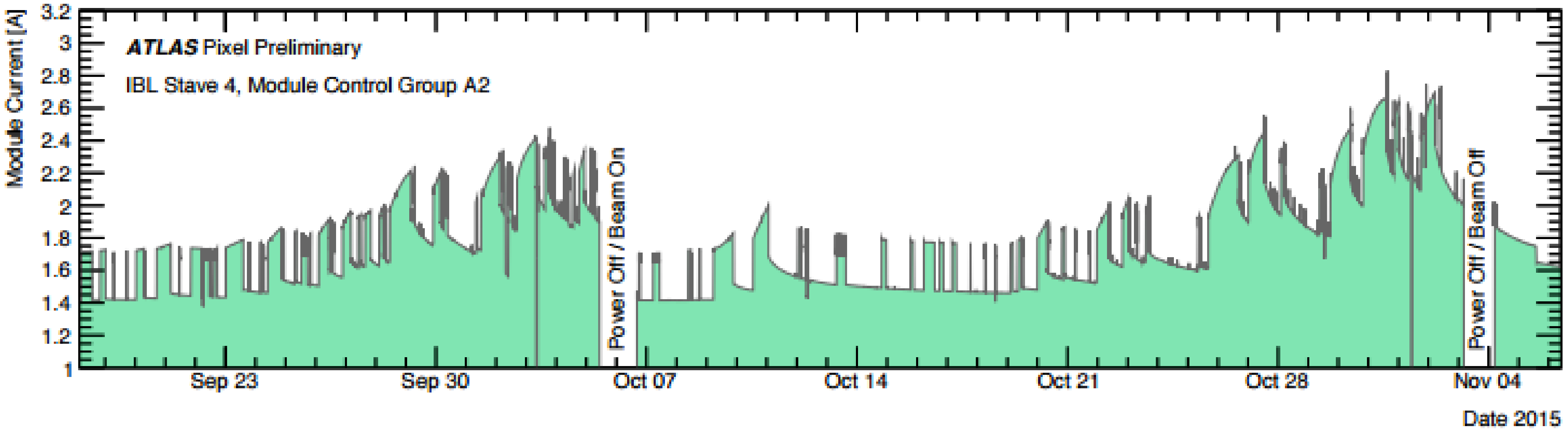
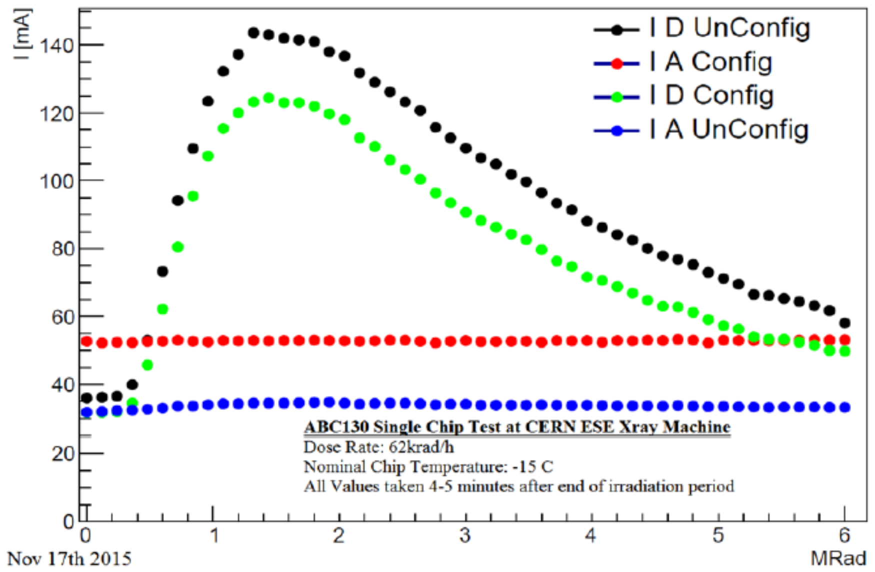
How radiation affects the chip



- ATLAS IBL group has seen this issue – large increase in power consumption from current rise
- Annealing: periods of recovery – at high temperature, trapped charges can “escape”

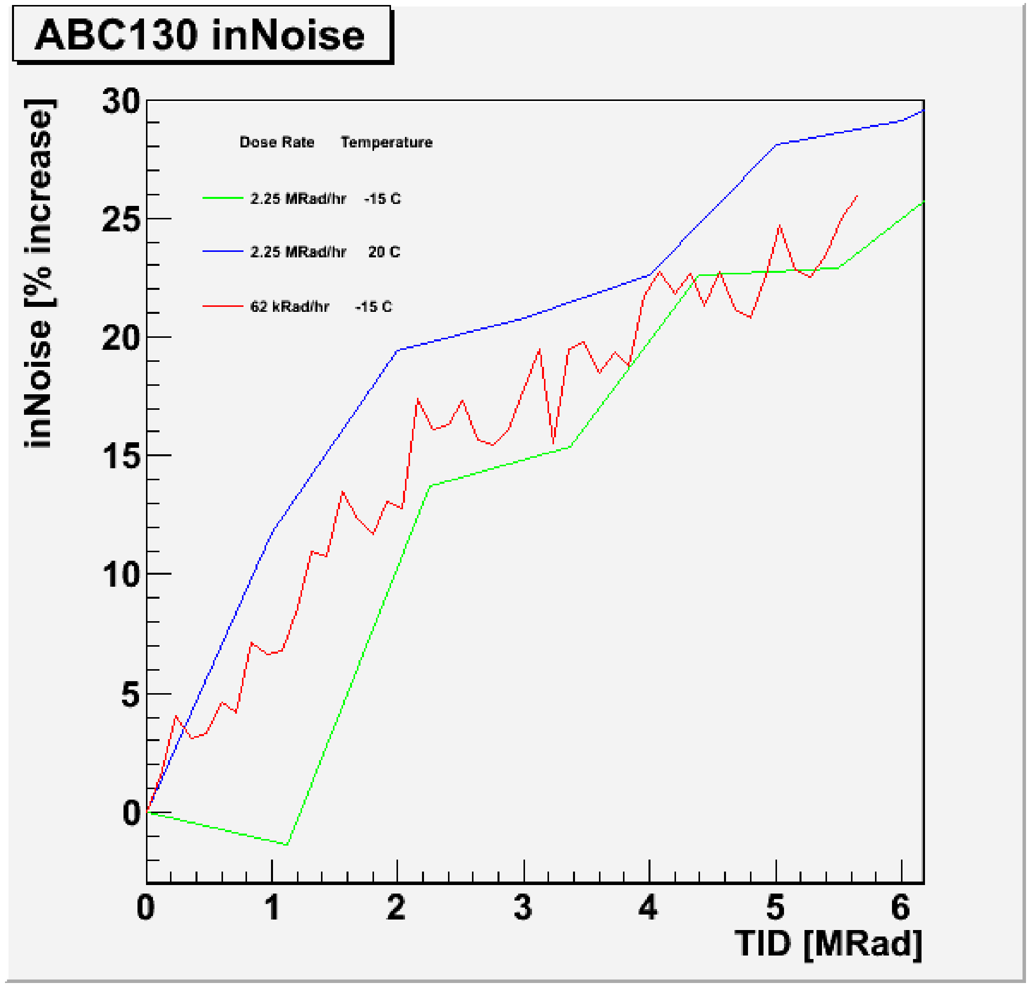
Previous work

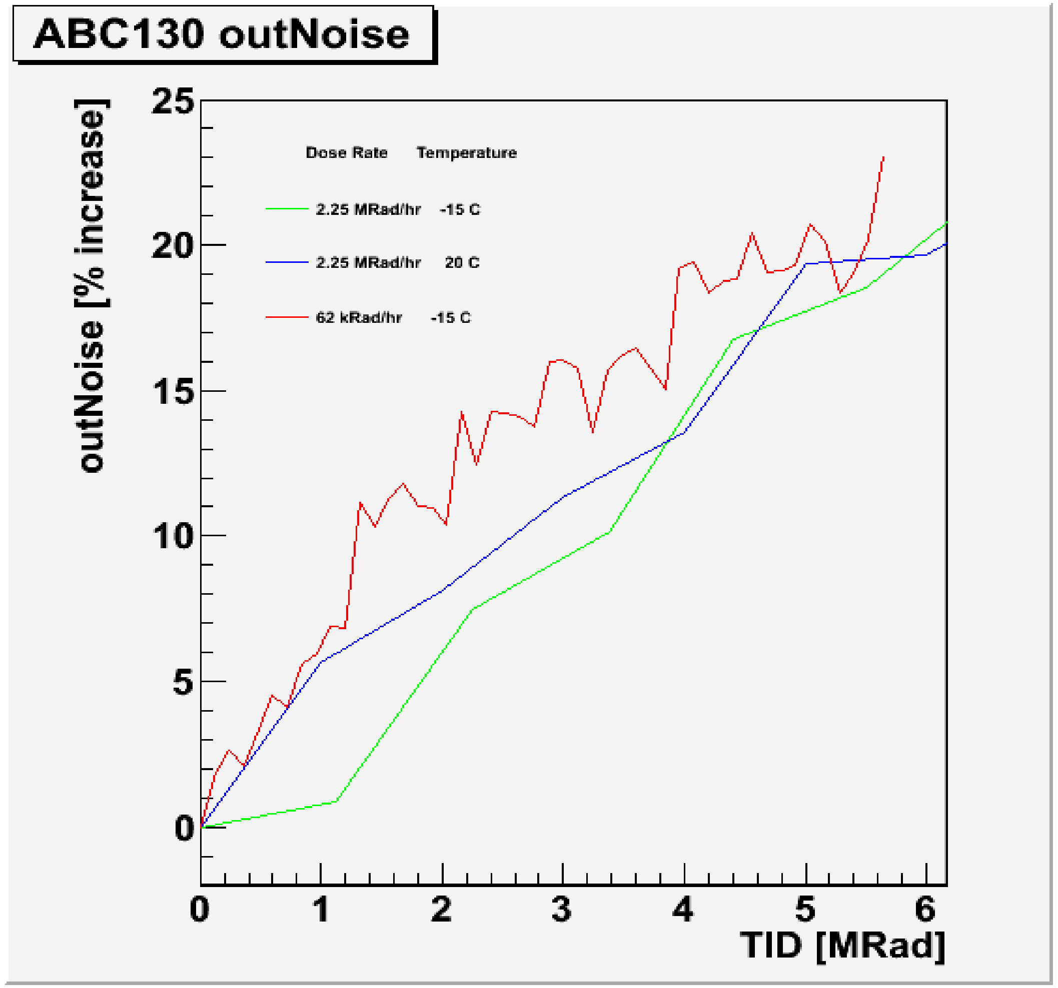
- Have seen an increase in noise and a current peak throughout radiation
- Lower temperature, higher dose rate worsen radiation effects



	Chip A8Q2Y0H_066	Chip A6Q2XKH_128	Chip A5Q2XLH_005	Chip AQQ30GH_103
Dose Rate	2.25 MRad/hr	2.25 MRad/hr	2.25 MRad/hr	62 kRad/hr
Temperature	Ambient	Ambient	-15 C	-15 C
Annealing periods	For ~30 minutes after 1 hr	Only at current peak for ~10 minutes	Every 30 minutes for ~30 minutes (first 10 MRad)	Every 2 h for ~30 minutes
Previously received dose	80 MRad	None	None	None

Previous work



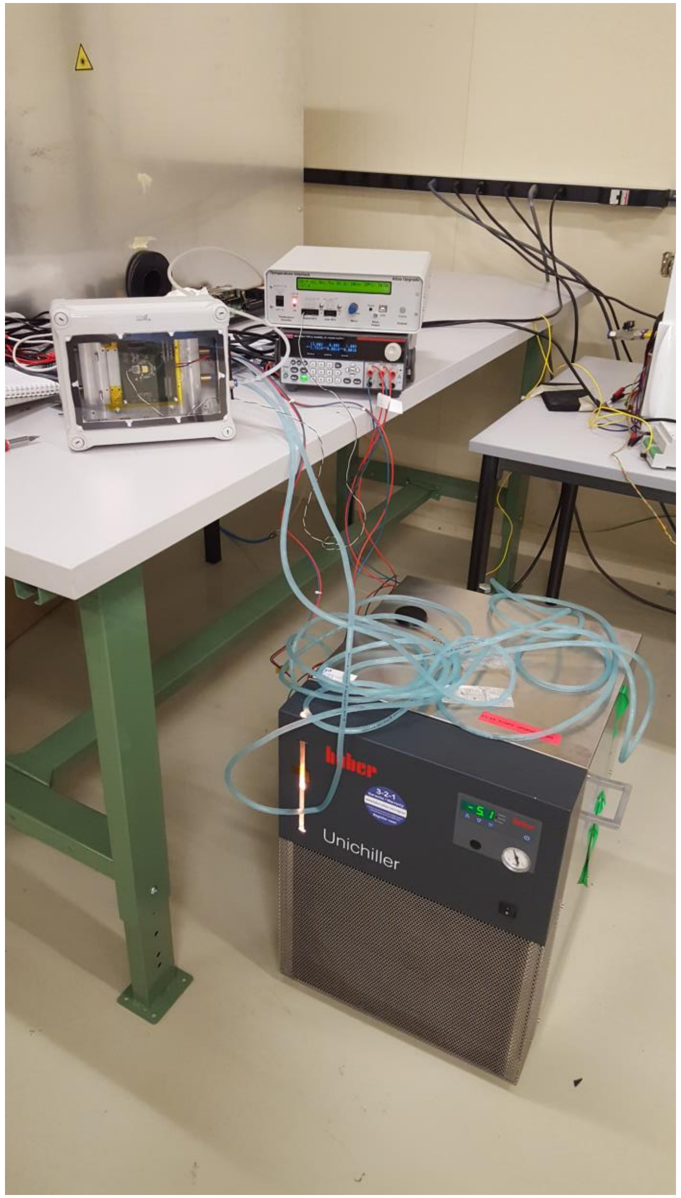


Current test

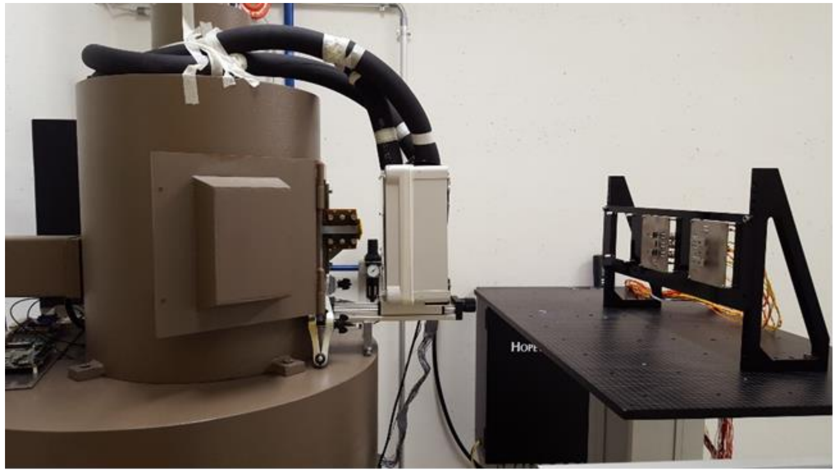
- Goal: Irradiate chip at the conditions expected when it is installed in the detector
- Test how to setup desired conditions of chip for the current experiment
- Update software to work stably over long-term tests
- Install all the equipment at our test facility
- Monitor experiment and collect data
- Data analysis- plots and interpretation
- Automate system as much as possible

Current test

- Simulate detector conditions as closely as possible:
  - Chip at -25 C; radiation dose rate around 2 kRad/hr
- Accomplished with chiller running at -5 C, Peltier module, environmental box, flushing with dry air
- NTC temperature probe taped to PCB to monitor environment inside box (stable at -11.8 ± 0.2 C)
- Tested in SR1 (see right)



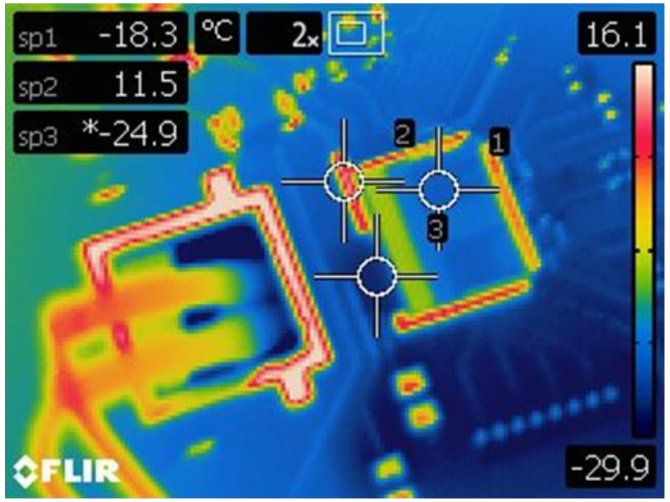
Experiment Setup

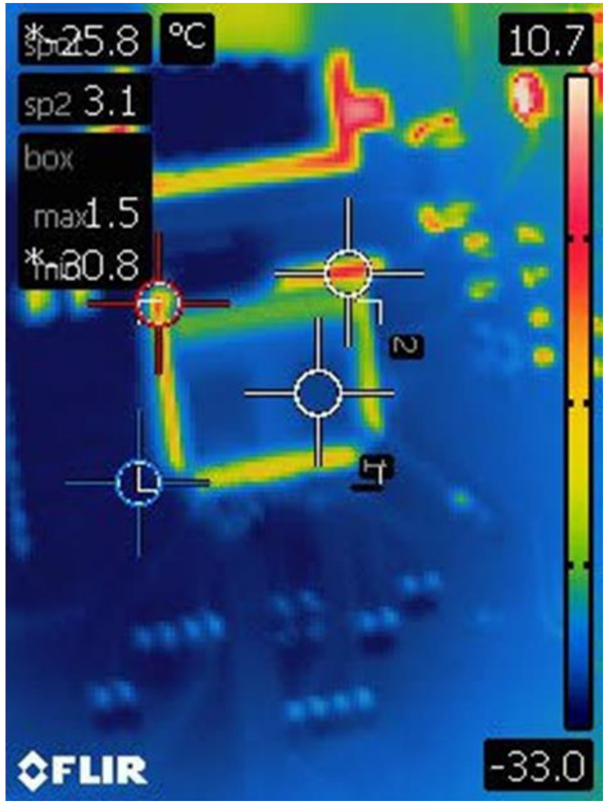


- Co60 radiation source at Prevessin site, CERN
- Supplies 2.3 kRad/hr gamma radiation
- Tests began Feb. 25th
- Have been running ~6 weeks, accumulated ~2.2 MRad

Chip temperature studies

- Goal: chip at -25 C
- NTC temperature probe beneath chip reduced thermal contact and kept it about 5 degrees warmer
- Switched to NTC next to chip on PCB → -12 C on PCB = -25 C on chip (based on thermal pics)
- Will take another picture at the end of the run

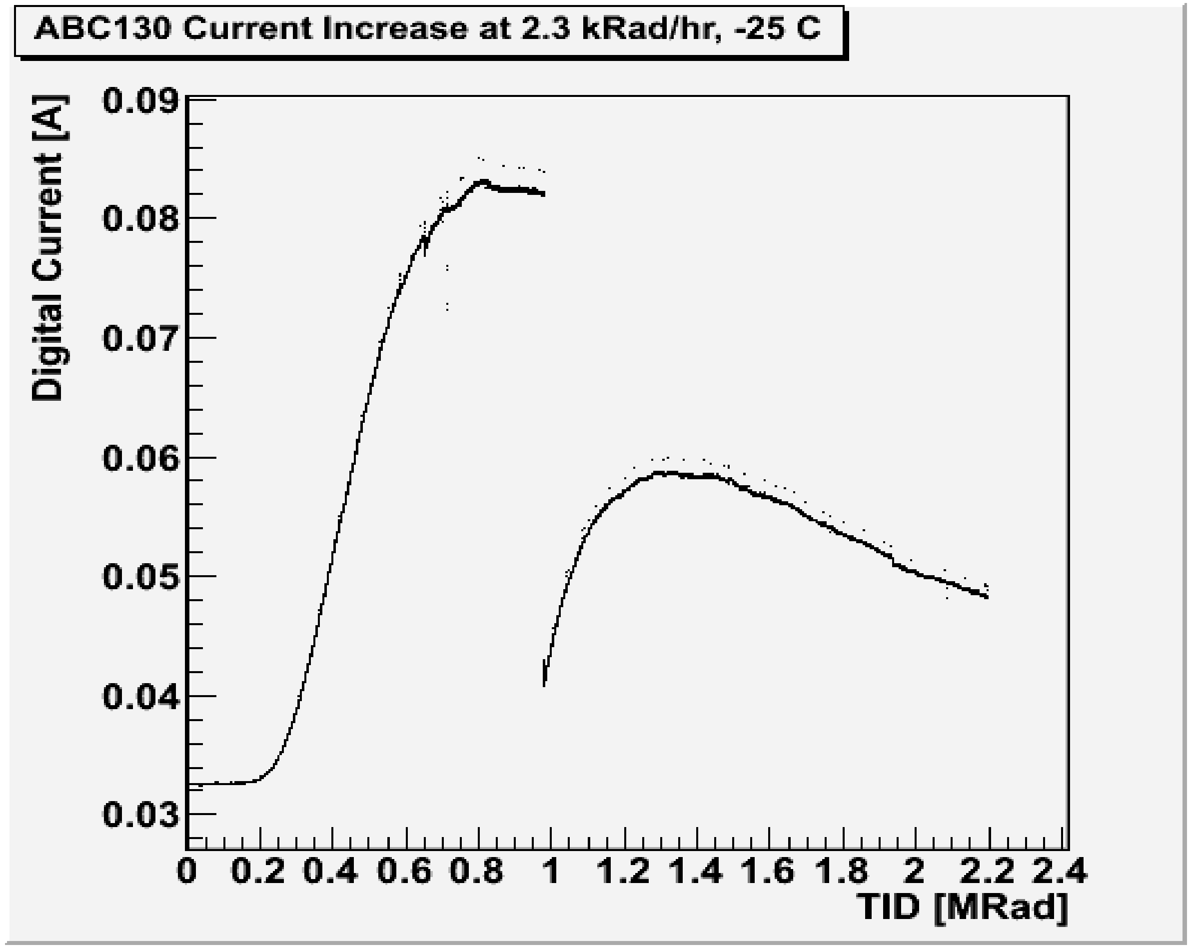




Data collection and analysis

- While the chip is being irradiated, a function is run continuously which passes information back and forth between the chip and the ATLYS board
  - Radiation effects are much worse for a chip that's working than for one that is inactive
- Every other day, ran a set of scans
  - Scan ADCs: sends commands to the chip and plots its reaction. General test to make sure we're communicating with chip properly
  - Strobe delay: calibrates time delay between charge injection and channel readout (proper discriminator timing)
  - Response curve: measures the noise, gain, and threshold voltage for 10 different input charge values

Preliminary Results- current



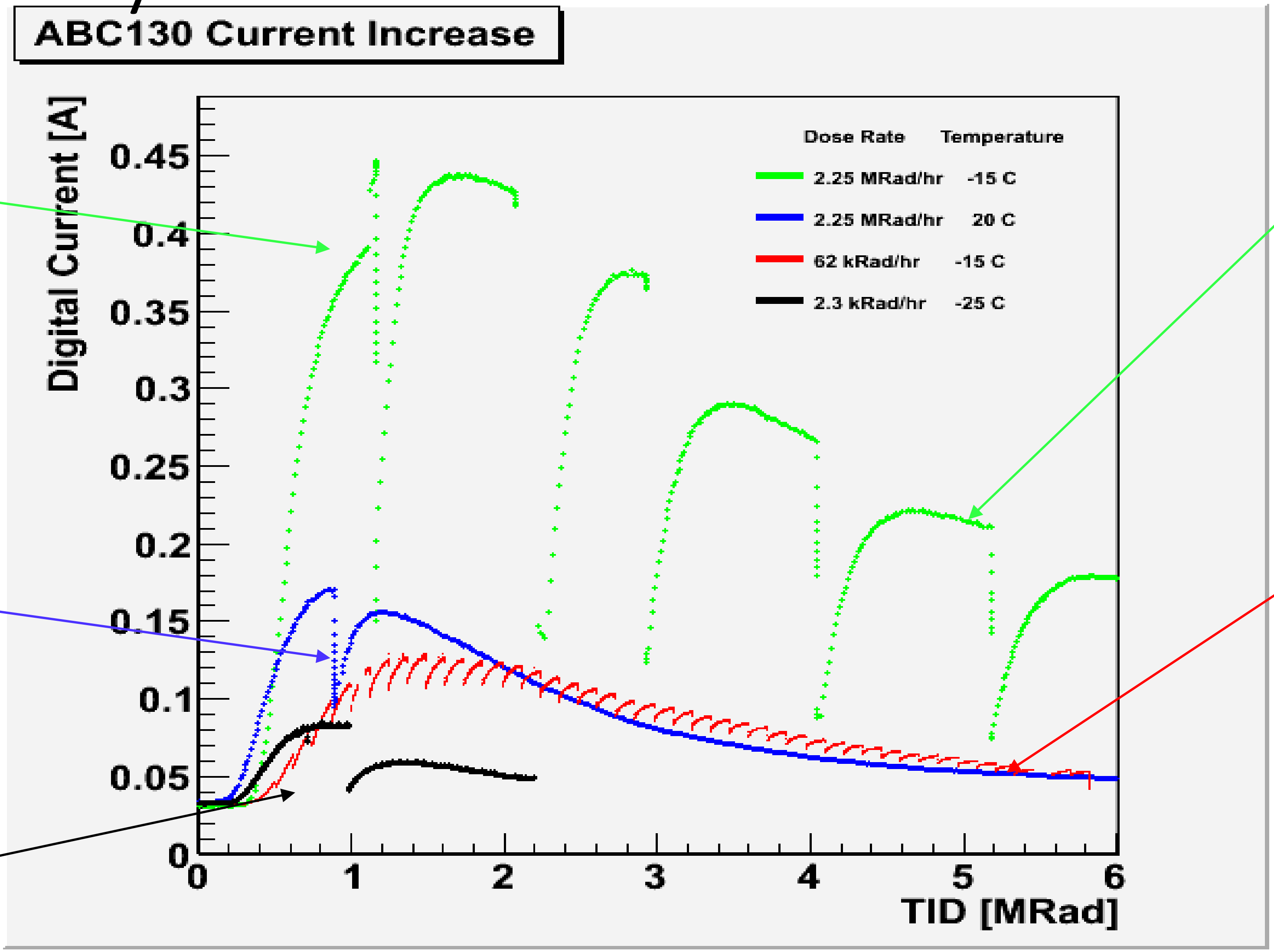
- Current peak happened around 0.9 MRad – slightly earlier than previous tests
- Power outage caused radiation to stop for ~20 hours at around 1 MRad; 5 hours without power/chiller
- Data points above general trend are from first data point of a run for the chip

Preliminary Results- current

Increase of chip digital regulated V

Short stop for thermal snapshot (no scans, same T)

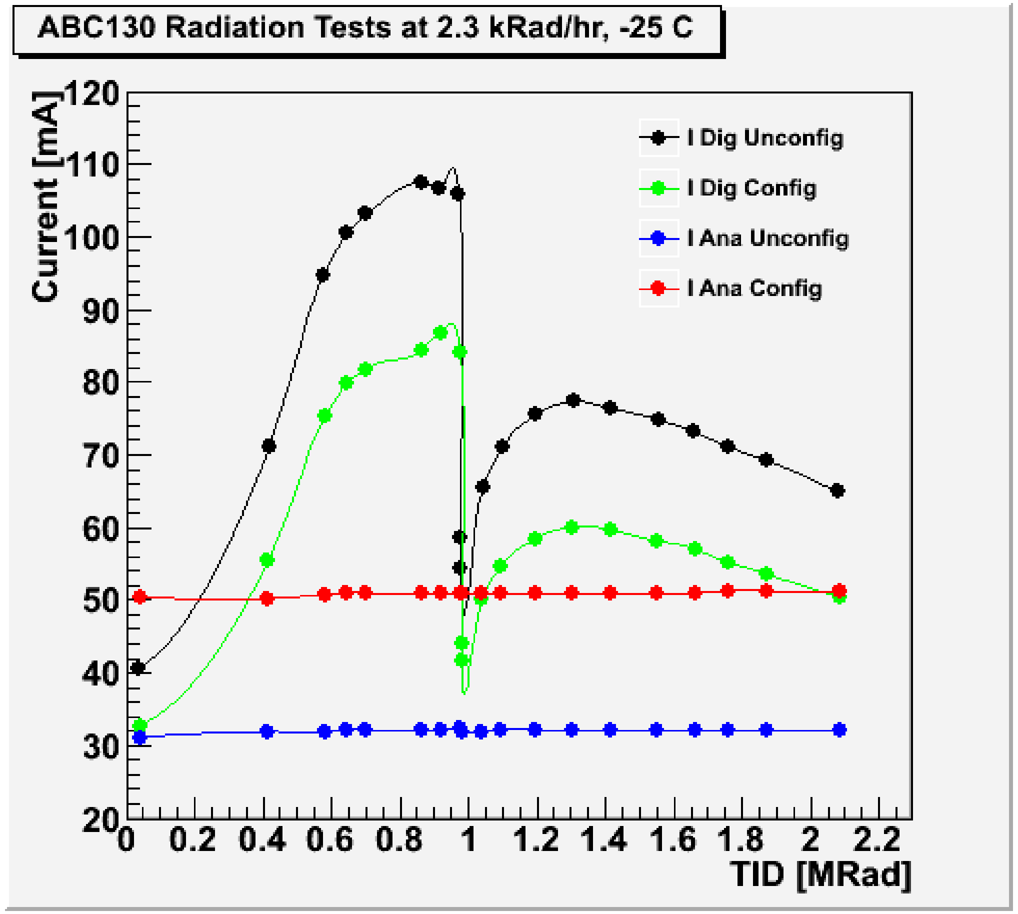
Power cut



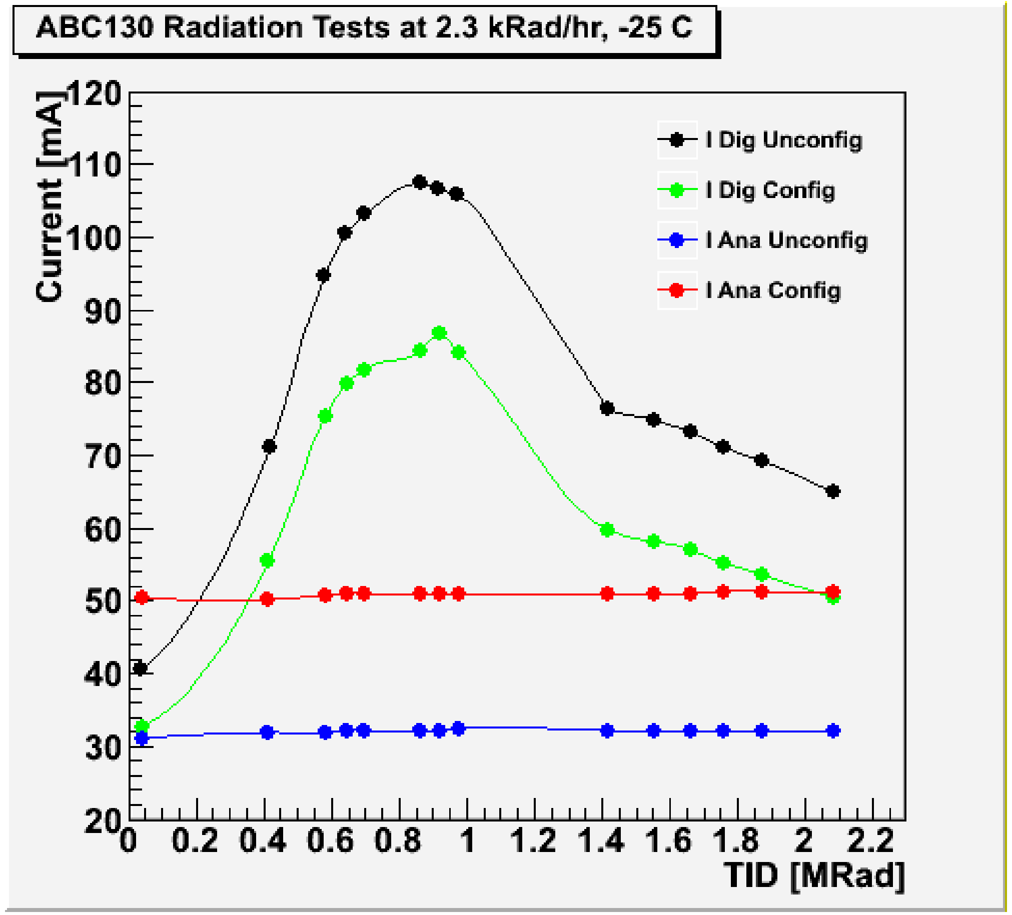
30-40 min annealing during scans (same T)

30-40 min annealing during scans (same T)

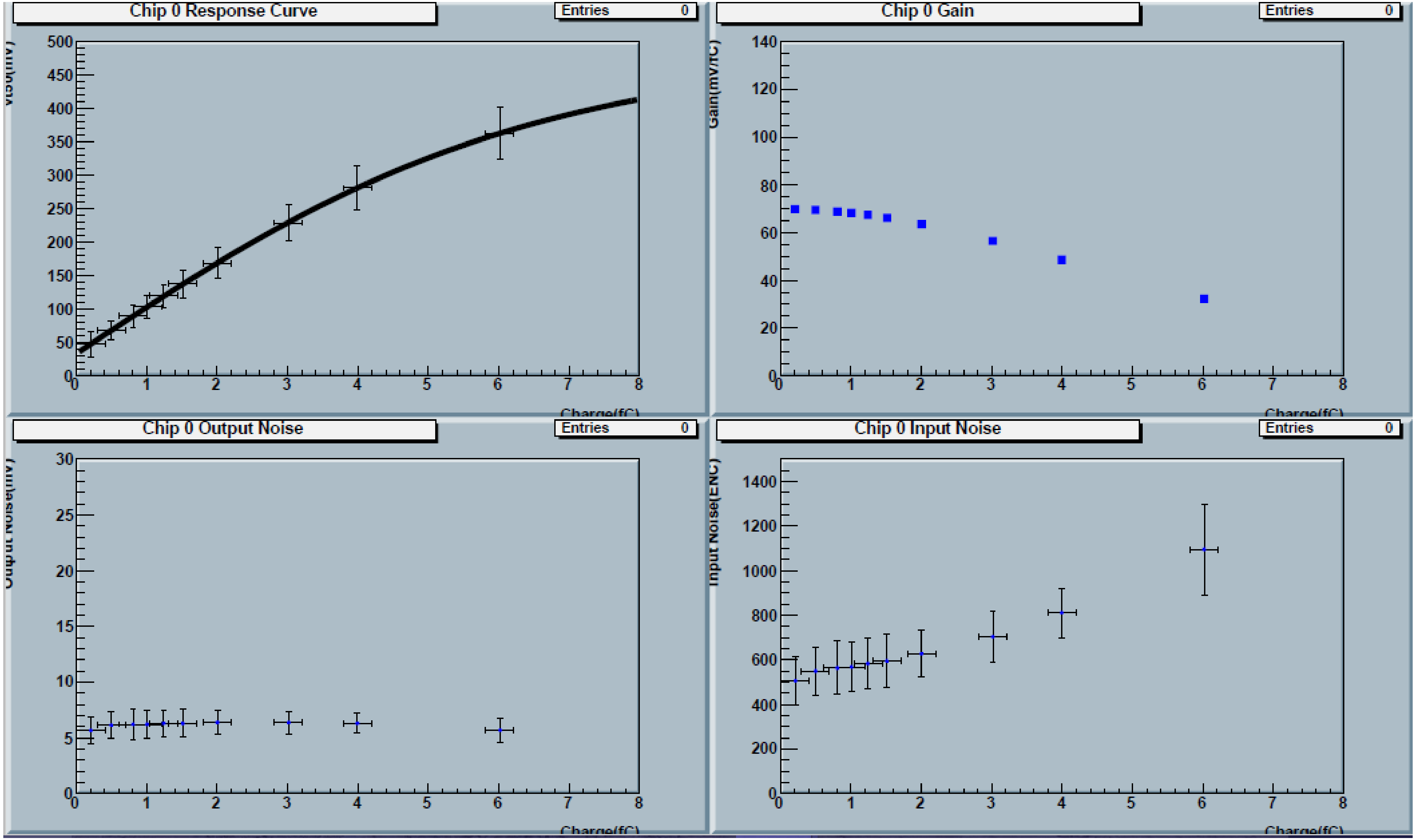
Configured and Unconfigured Currents



Including power cut

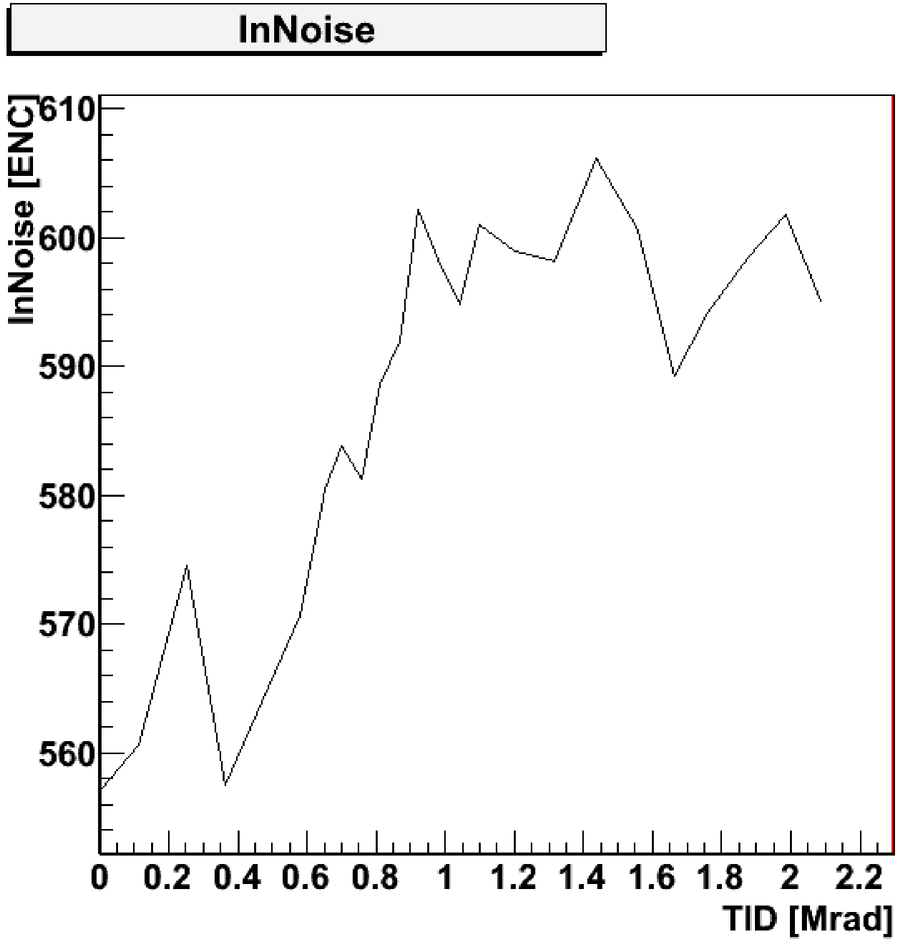


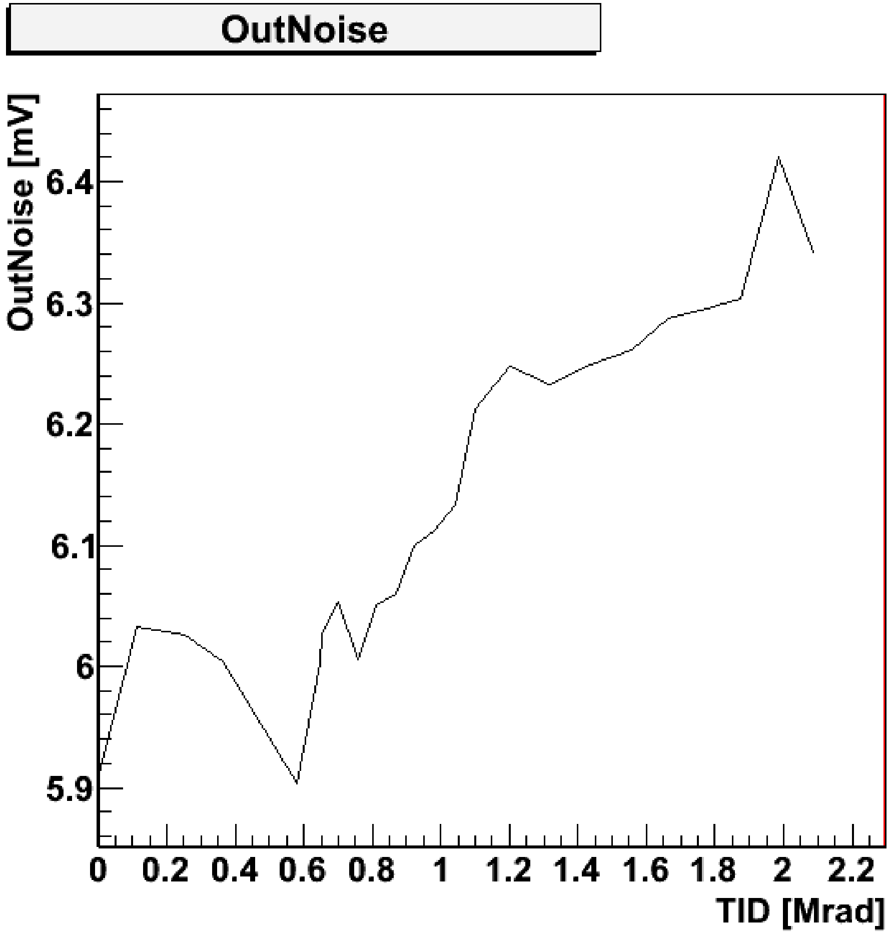
Not including power cut



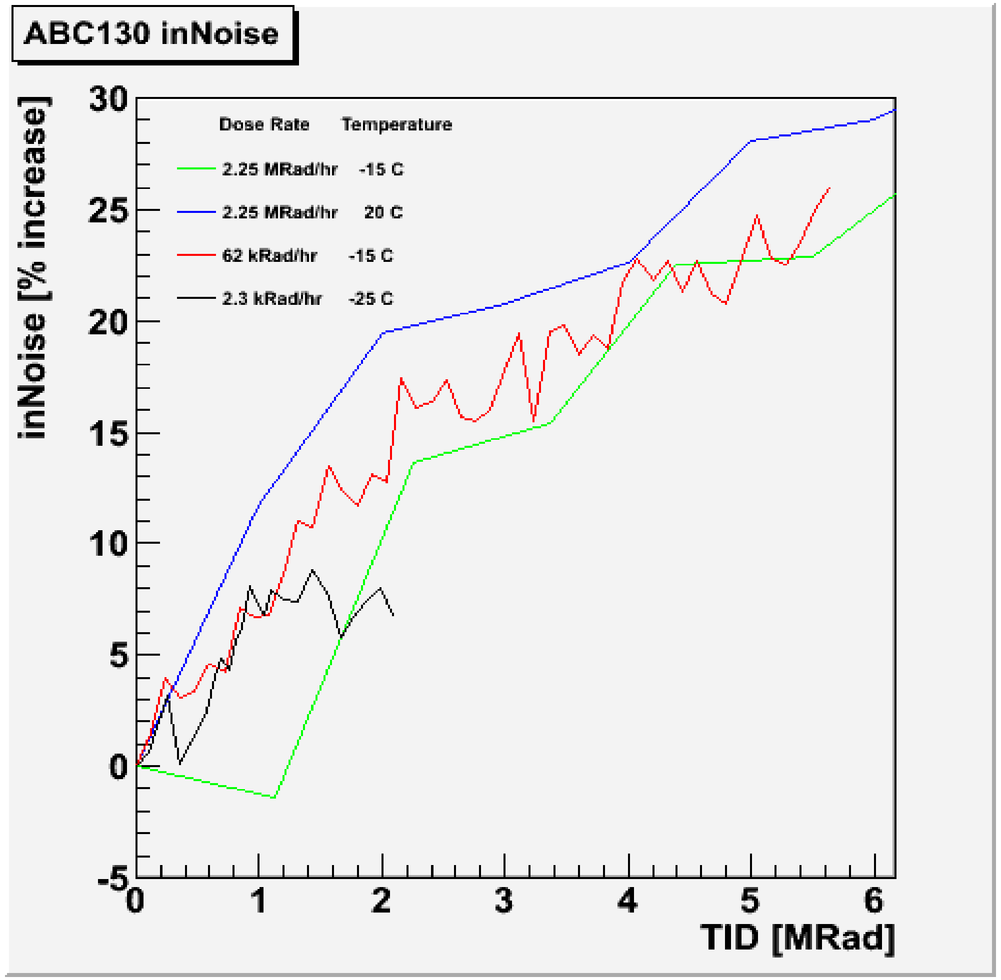
Chip 0 Response Curve
Entries 0
Charge(fC)
Chip 0 Gain
Entries 0
Gain(mV/fC)
Charge(fC)
Chip 0 Output Noise
Entries 0
Charge(fC)
Chip 0 Input Noise
Entries 0
Input Noise(ENC)
Charge(fC)

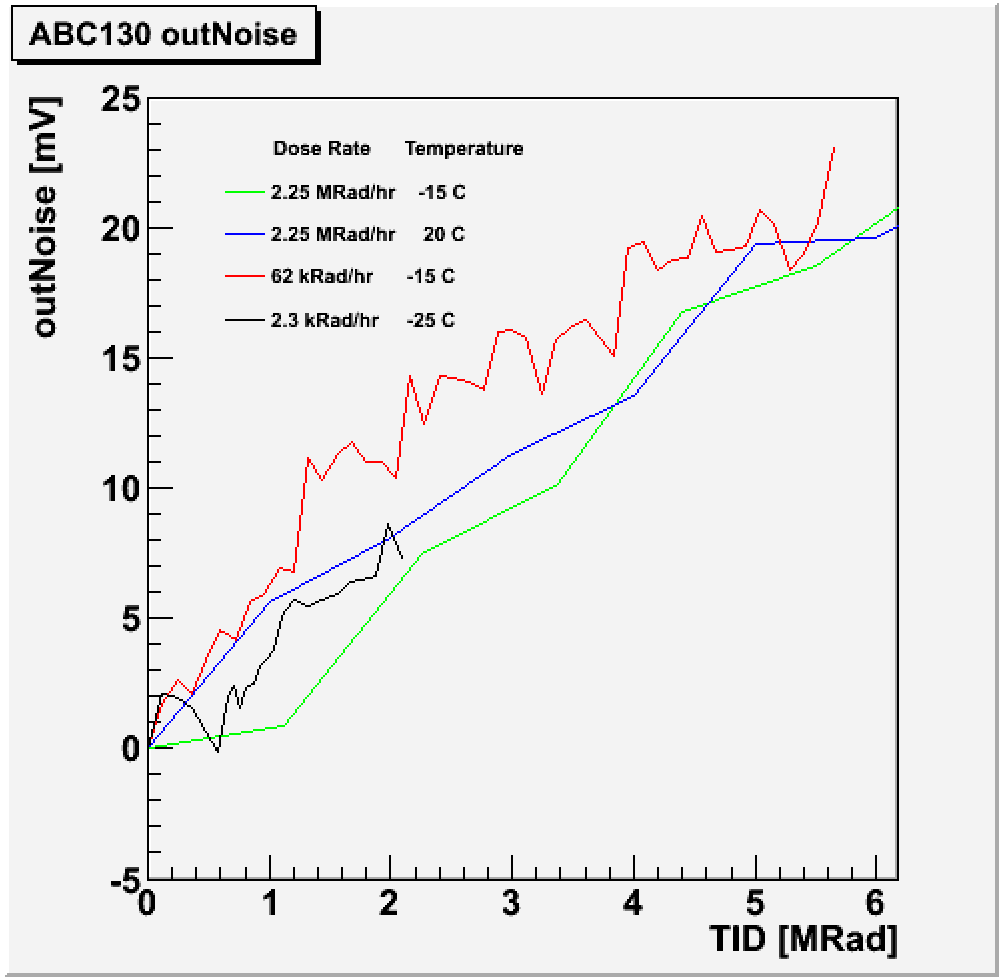
Preliminary results- noise



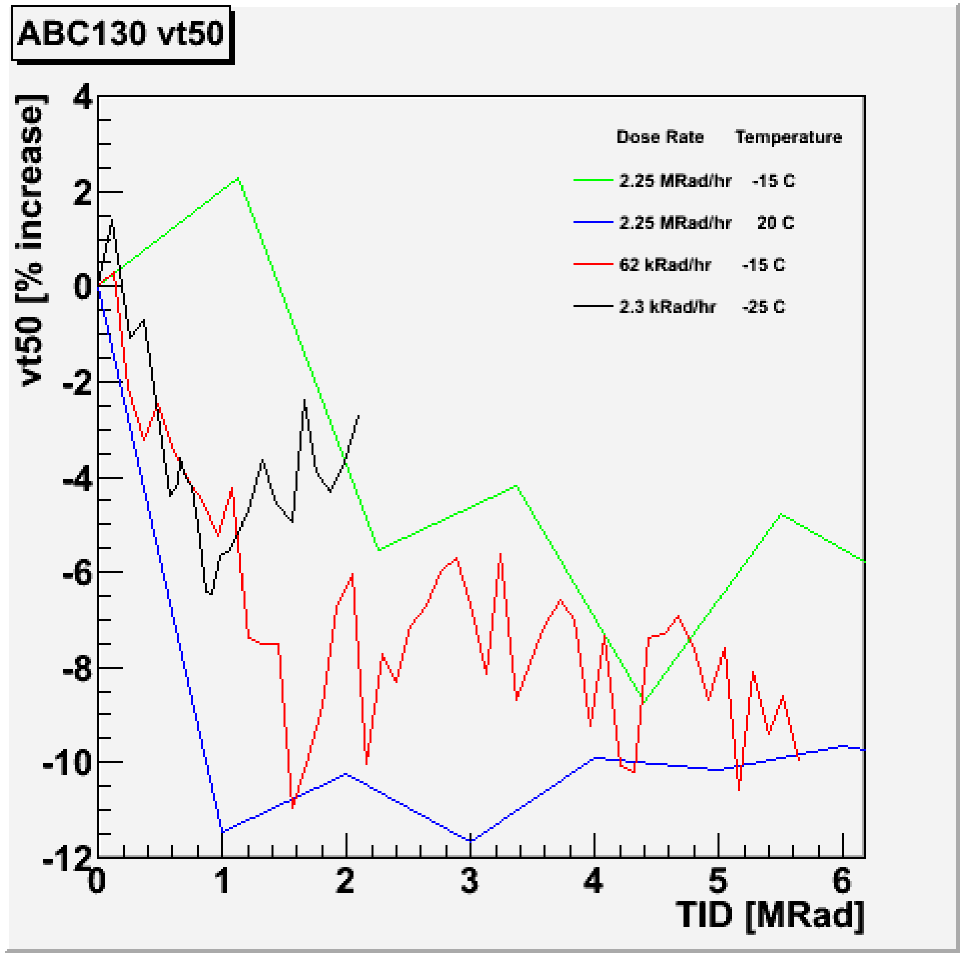


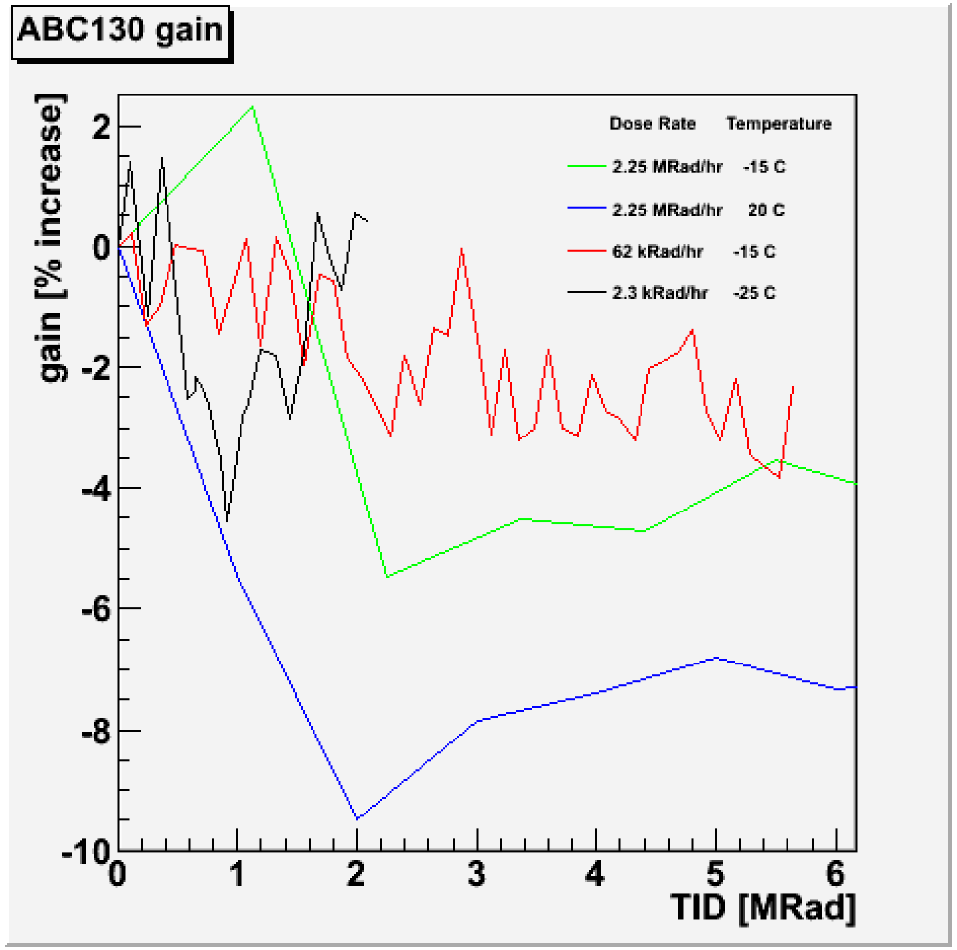
Preliminary results- noise



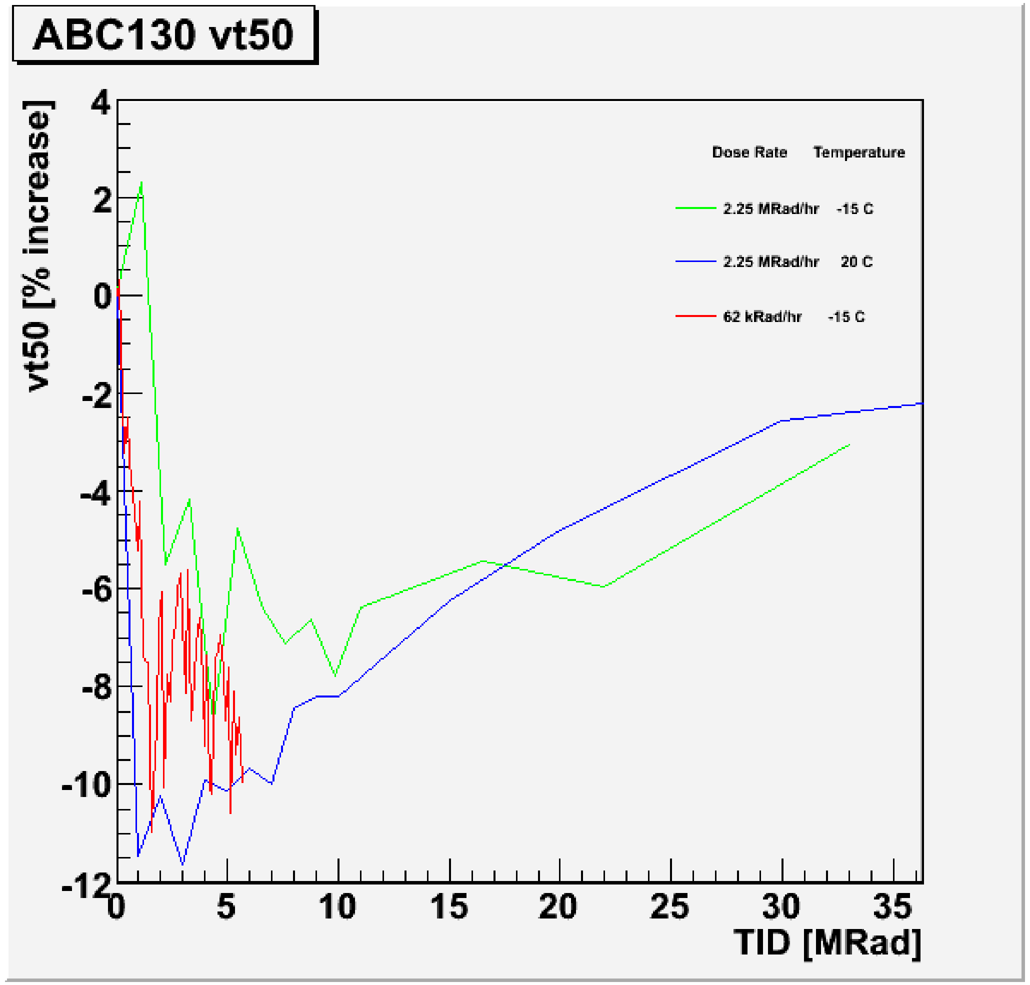


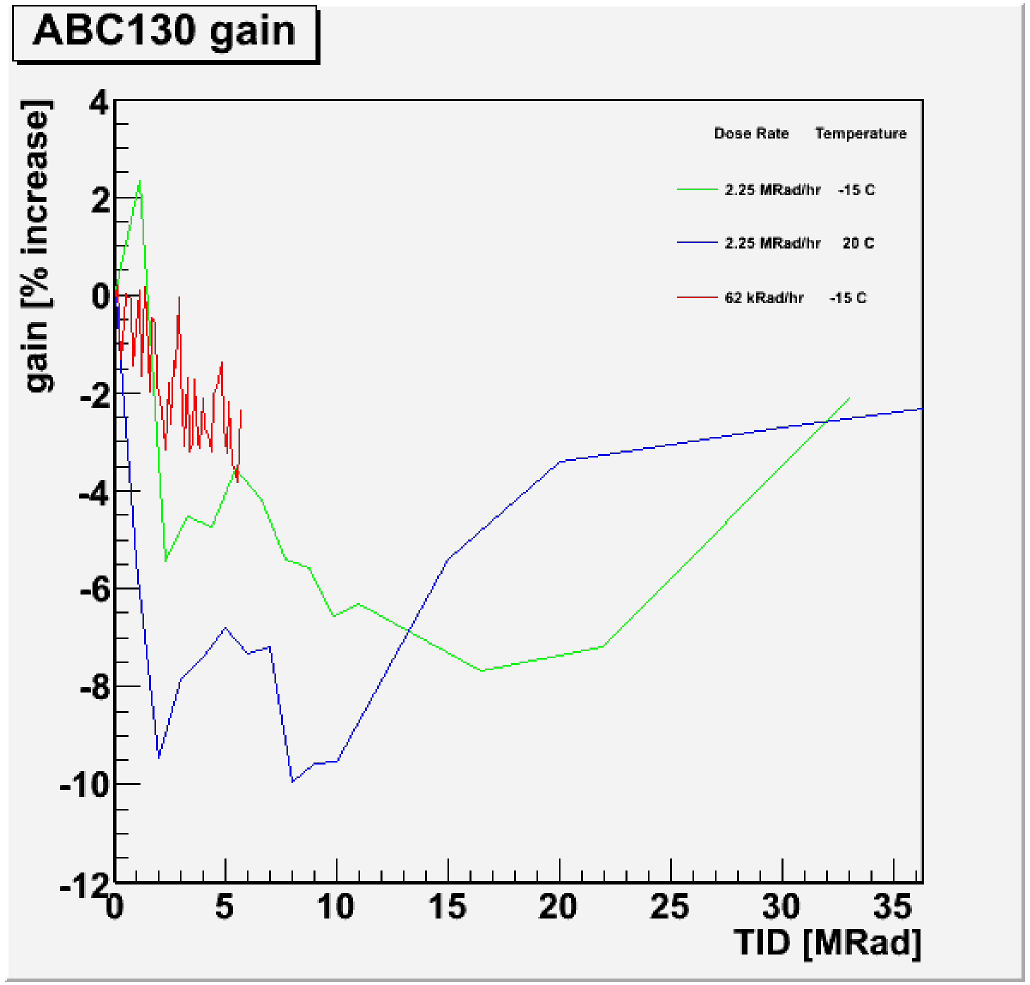
Preliminary results- voltage threshold, gain





Preliminary results- voltage threshold, gain





Future Work

- Unless something very unexpected happens, the current draw should increase with a factor of ~2.5 (33 → 82 mA)
  - Can give this value to ITk group so they can work on powering the tracker
- Have received another ABC130 chip from P. Phillips/C. Sawyer to allow for an additional test
  - At least one more test which will happen this summer
    - Maybe low dose rate and slightly higher temperature
    - Maybe looking at chip performance when current is limited

Summary

- Thank you to Jean Krisch, Thomas Schwarz, and Steve Goldfarb for allowing me this opportunity (and for allowing it to continue into the summer!)
- Thank you to my advisor, Richard Teuscher, for his trust and guidance, and to my colleagues, Nicola Venturi and Kyle Cormier