UPGRADING THE ATLAS INNER DETECTOR

CERN: University of Michigan Semester Abroad Student Talk 2

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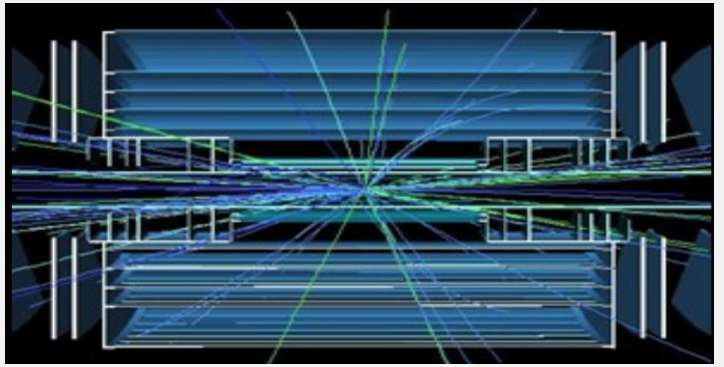
OVERVIEW

- Overall project refresher
- Radiation testing
  - Quantitative analysis of data
  - ^{60}Co testing on ABC130
  - X-ray testing on ABC130*
- Physics analysis project (Higgs)
- Major accomplishments
- What's next
- European Immersion

OVERALL PROJECT

- I am working with the University of Toronto team (Kyle and Olivier) on the upgrade of the ITkStrips for the HL-LHC upgrade
- Objective of the HL-LHC: increase the luminosity by a factor of 10 beyond current status
  - LHC produces 1.2 million Higgs Bosons/ year now
  - HL-LHC will produce 15 million Higgs Bosons/ year
    - Because of this the HL-LHC will allow for more precise Higgs measurements, and the search for smaller deviations from the standard model
- Upgrades to the inner tracker
  - Inner Detector currently is not designed for the high density or total lifetime of the HL-LHC
  - Particle sensors and readout electronics must be upgraded to be more radiation tolerant and run data at higher speeds



LHC 300 fb^{-1}

HL-LHC 3000 fb^{-1}

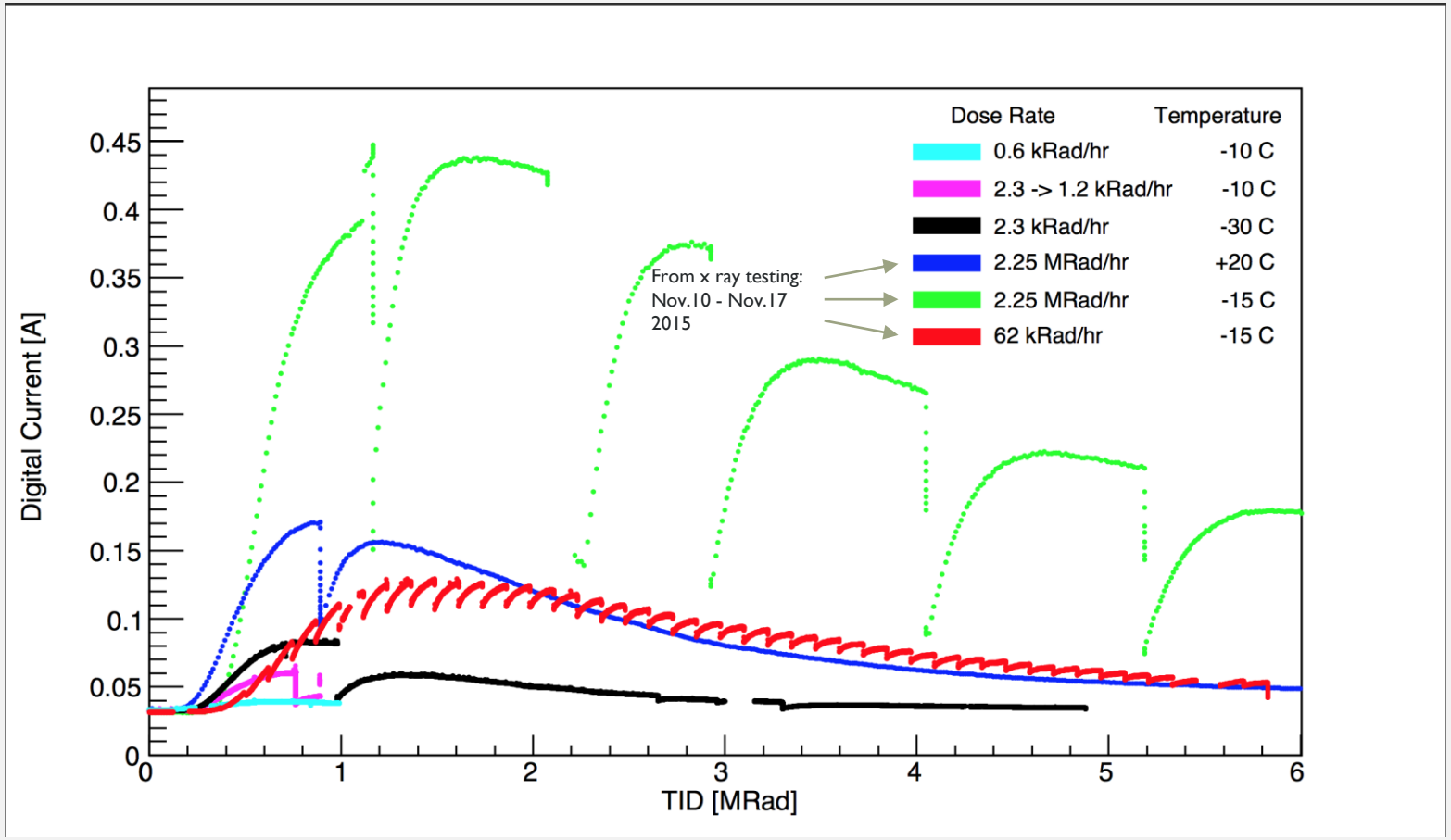
PURPOSE OF RADIATION TESTING

- We are doing radiation testing and analyzing results from past radiation tests to understand how the chips will behave in the upgraded luminosity detector
  - Looking to observe the effects of radiation dosage on leakage current
    - We know that TID causes certain defects in the chips
      1. Trapped positive charges in the bulk of the oxide
      2. Interference traps
    - These result in a varying leakage current, which we are observing
- 2 different kinds of radiation testing
  - Both are electromagnetic and representing energy based ionizing damages
    - X-ray
      - Faster way to get more radiation (higher dose rate)
    - Co-60
      - More regularly available for testing than x-ray machine (lower dose rate)

WHAT MY TEAM IS DOING

- Using Old data:
  - Fit data to the quantitative model that from "Parametrization of the radiation induced leakage current increase of NMOS transistors" by M. Backhaus in October of 2016
- Using New data (ongoing tests):
  - CO60 source at Prevessin
    - ABC130 chip at about 1.2 kRad/hour and ~0°C
    - More data to analyze for leakage current
  - X-ray tests
    - Front end of the ABC130* chip at about 870 krad/hour and room temperature ~20.5°C
    - Checking to see if noise improvements were successful
    - More data to analyze for the leakage current

PAST X-RAY TESTS (ABC130)



THE QUANTITATIVE MODEL

$$I_{leak} = k \times [N(E) - N(P_b) - N_{thr}]^2$$

- $N(E)$ the number of trapped holes at a time
- $N(P_b)$ the number of activated interface states
- k is a constant and N_{thr} is the threshold needed for leakage current

- Questions we want to answer:
  - How high is the maximum expected current and is this a problem for the detector's performance?
  - How do temperature and dose rate affect the current?

FITTING THE QUANTITATIVE MODEL

Annealing periods equation:

$$I_{t_0}(t) = I_{BC} + K \times [k_{ox} \times D \times \tau_{ox} \times (1 - e^{-t/\tau_{ox}}) - k_{if} \times D \times \tau_{if} \times (1 - e^{-t/\tau_{if}}) - N_{thr}]^2$$

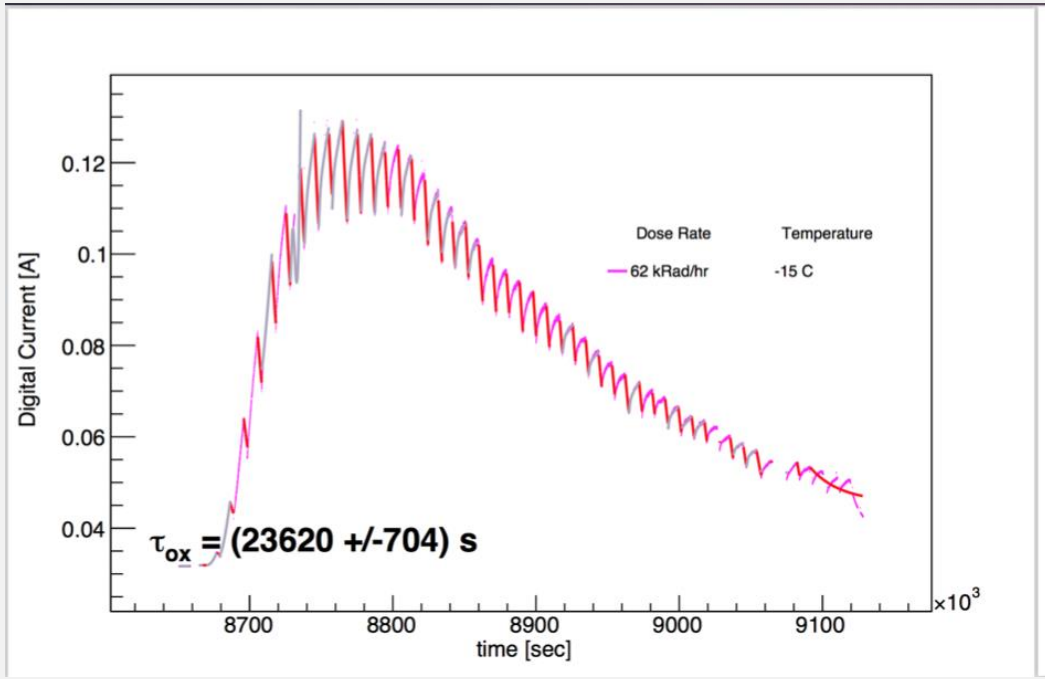
Irradiating periods equation:

$$I_{t_0}(t) = I_{BC} + K \times [N_{trap} + (N_{ox}(t_0) - N_{trap}) \times (e^{-t/\tau_{ox}}) - k_{if} \times D \times \tau_{if} \times (1 - e^{-t/\tau_{if}}) - N_{thr}]^2$$

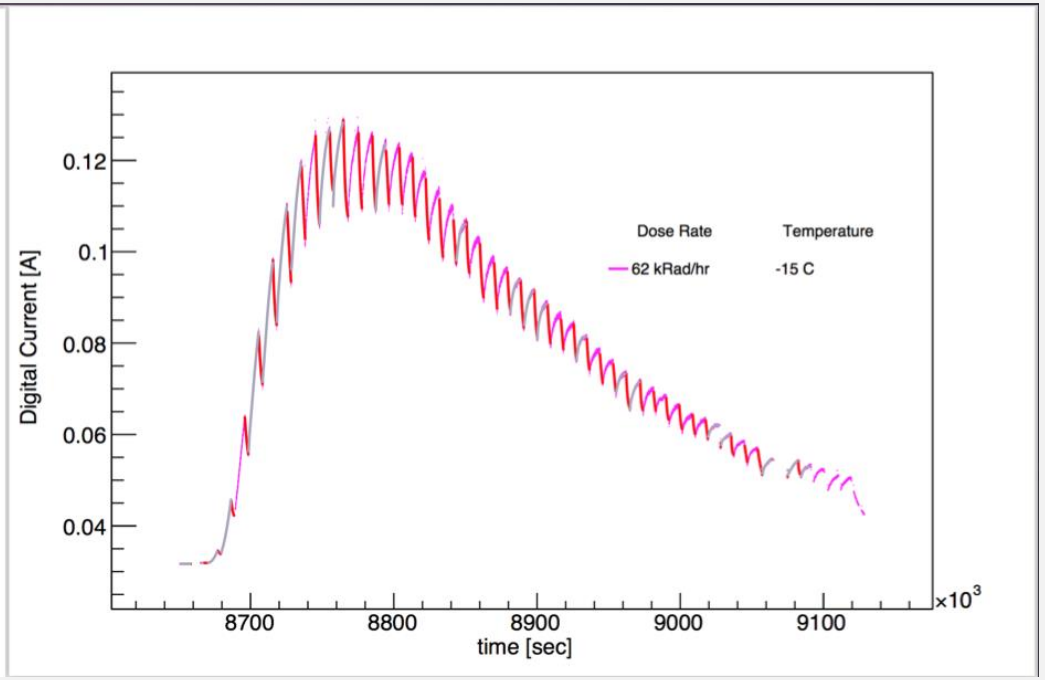
CODING THE FIT

- My team and I have worked together to write a ROOT macro that fits the data to this model
  - My contributions include:
    - Mathematical manipulation of the equations to reduce the amount of floating parameters in the fit
    - Research on the basis of the quantitative model to understand what parameters we can extract from raw data
    - Documenting the combined parameters and the relationships between parameters in annealing and irradiating fits
  - General code format
    - Fits annealing and irradiated periods separately with the different functions from the previous slide
    - Strategy to first fit the annealing curves to find a consistent value of τ_{ox} and then apply this to the irradiation fit to reduce the amount of parameters

AN EXAMPLE FIT: 62KRAD/HOUR AT -15°C



Fit all annealing periods together with a fixed τ_{ox}



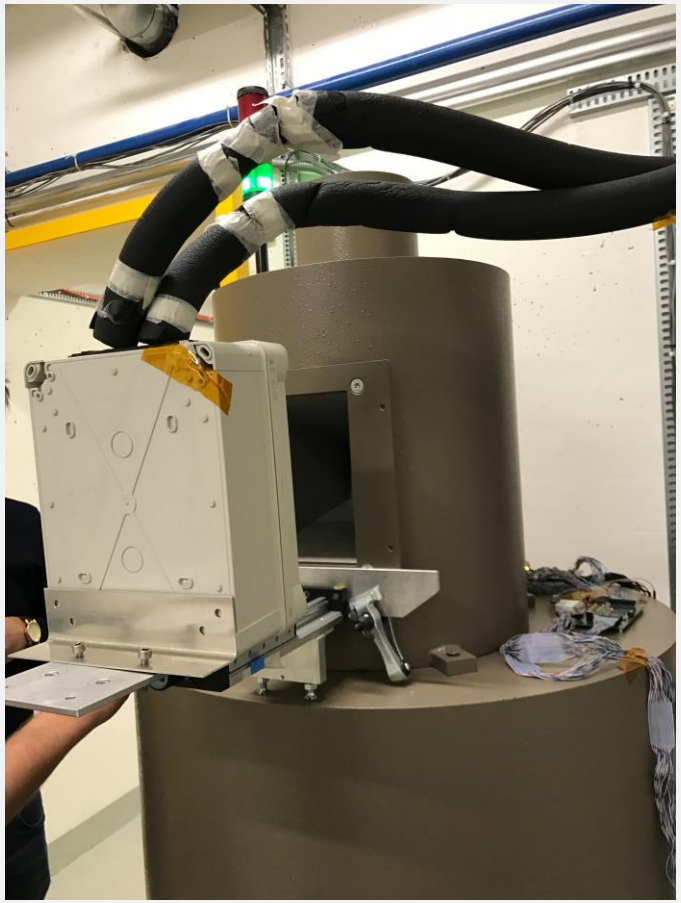
Fit all annealing periods individually

Red = annealing curves grey = irradiation curves pink = data points

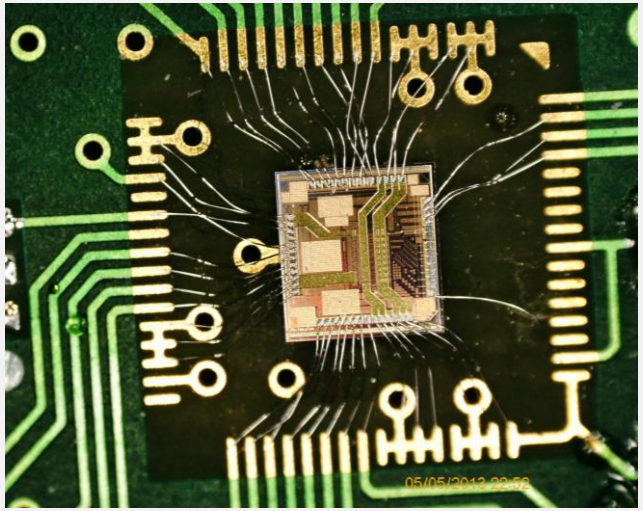
RADIATION TESTING ON THE ABC130

- Radiation started on February 21st and will run until the end of March
- Testing is taking place at Prevessin with the ^{60}Co source on the ABC130 chip
  - Running at about 1.2 kRad/hour at ~0°C
  - Goal of these tests is to gain more data for our fits
    - More data for finding relationships between
      - Current
      - Temperature
      - Dose rate

^{60}CO TESTING EXPERIMENTAL SETUP



- Experimental setup in Prevessin:
- Chip setup in front of the ^{60}Co source
- Temperature controlled with coolant liquid and fresh air pumps
- Testing to see noise and power consumption as a function of radiation



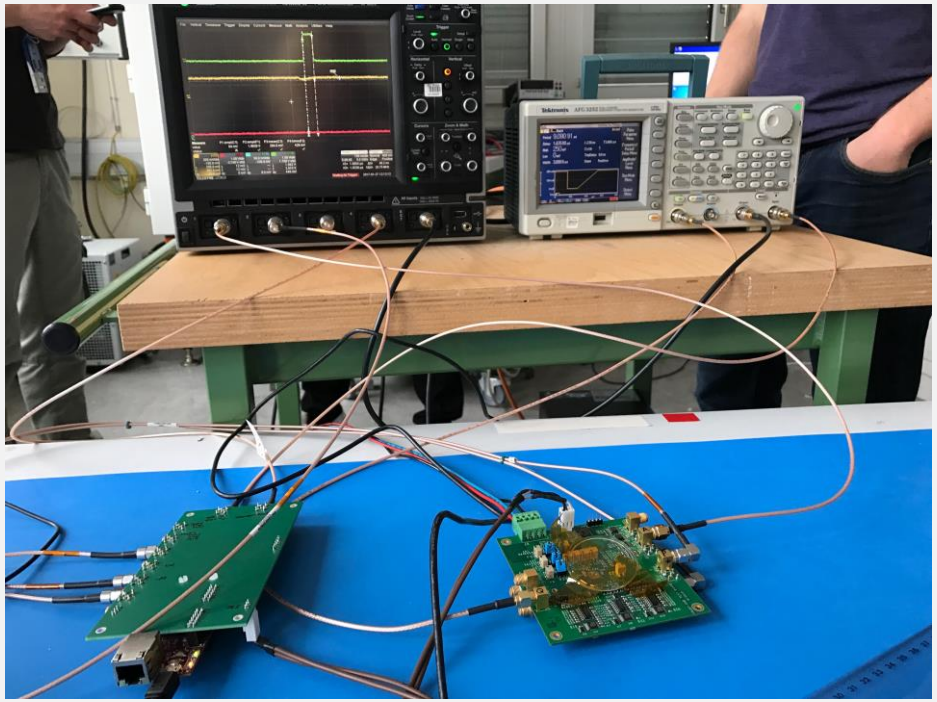
ABC130* front-end schematic

RADIATION TESTING ON THE ABC130*

- Recently started radiation testing in the x-ray lab on a prototype of the front end of the ABC130* chip
  - Weeklong runtime ending today (March 8th) around 3:00 pm.
  - Running at about 870 kRad/hour at room temperature ~20.5°C
    - Intended total irradiation does of around 70 or 80Mrad
      - This should replicate the lifetime radiation of a chip inside the detector
    - Want to see if there is less noise than the ABC130 chip
    - And how the max current consumption compares to the ABC130 chip

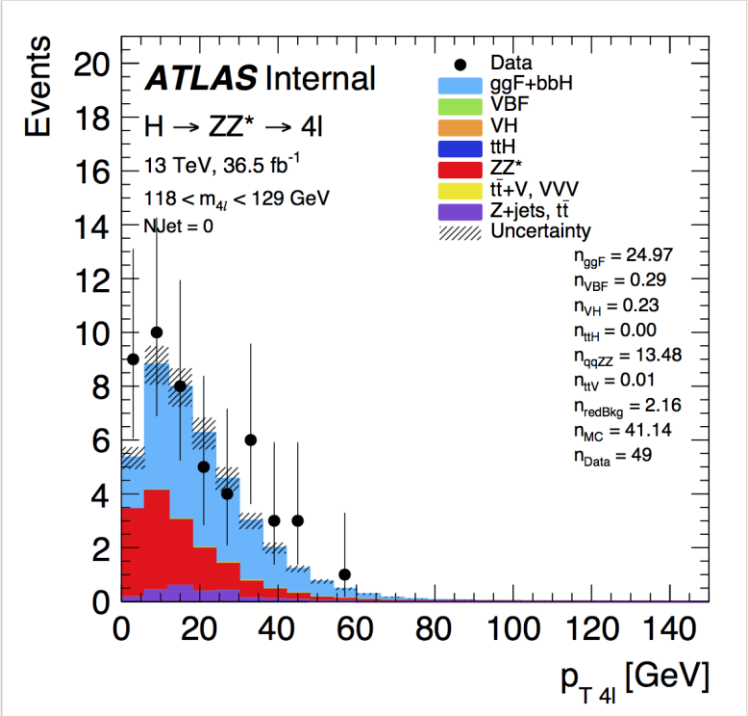
X-RAY TESTING EXPERIMENTAL SETUP

- ABC130* front end chip connected to an ATLYS board to power it
- We send fake signals to the board and see how the chip responds
- Sending set triggers to the chip that can be separated from the noise
  - Watching how radiation affects the amount of noise, which is a problem we are trying to fix from the ABC130



PHYSICS ANALYSIS PROJECT

- Separate project I am working on when things are slow with radiation projects:
- Looking at data collected in ATLAS from the most recent runs for data that have the signatures of 4 lepton Higgs decays
  - I'm comparing the Monte Carlo stimulated events to the actual data to see if there are weird peaks at masses we don't expect
- Example plot:
  - Play with different distributions, investigating potential structures in the kinematics of different populations of events



ACHIEVEMENTS THUS FAR

- Wrote a macro to create the plot on slide 6 that combines the six data files, and plots the current as a function of total ionizing dose (TID) as well as other variations of this plot
- Experimental problem solving with the physical setup of the x-ray tests
- Manipulating parameters of quantitative modeling for current vs. time to make the fit code-able
  - Learned LaTex in the process of recording it all
- Contributions to code that fits the data to the model
- Presentation for conference with BNL group to discuss similar data analysis work on radiated chips
- Work on Higgs analysis and, so far, have found no new particles in the given data and mass range I've investigated

WHAT IS NEXT?

- Meeting with BNL group in the upcoming weeks to discuss more progress with fitting parameters and introduction of new data sets
- Work on analyzing the new data as it comes in from radiation tests
  - Specifically: noise functions of the ABC130* relative to the old data from ABC130
- Writing code for Higgs physics analysis that will compare various noise functions of the Monte Carle simulated events to real data
  - Looking at large mass ranges to check that the noise is being accurately represented in sensitive areas

EUROPEAN IMMERSION

Skiing in Chamonix

Park Güell in Barcelona

Leukerbad Therme in Leukerbad

Nyhavn in Copenhagen

Mom visits ATLAS

Hungarian Parliament in Budapest

Széchenyi Bath in Budapest

PICTURE CITATIONS

- *Slide 3* http://slideplayer.com/slide/5108830/
- All other photographs and plots were taken by me and my team