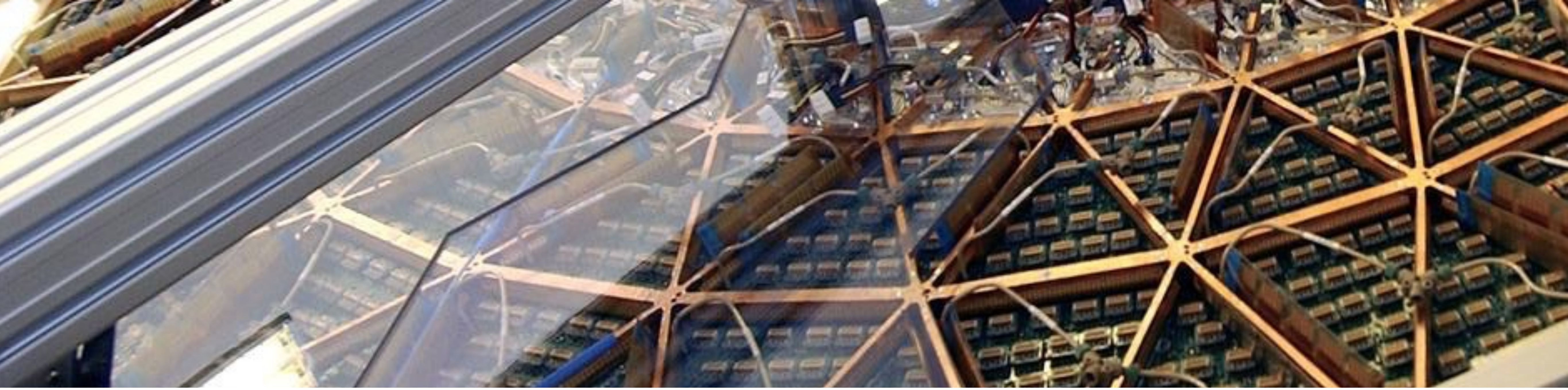

# Irradiation aging of the electronics of the ATLAS Transition Radiation Tracker

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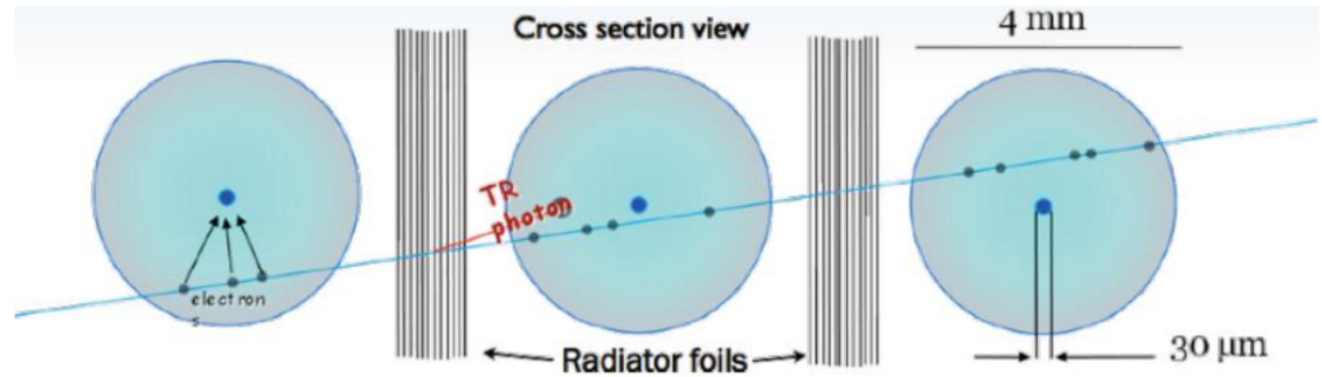
Penn
University of Pennsylvania

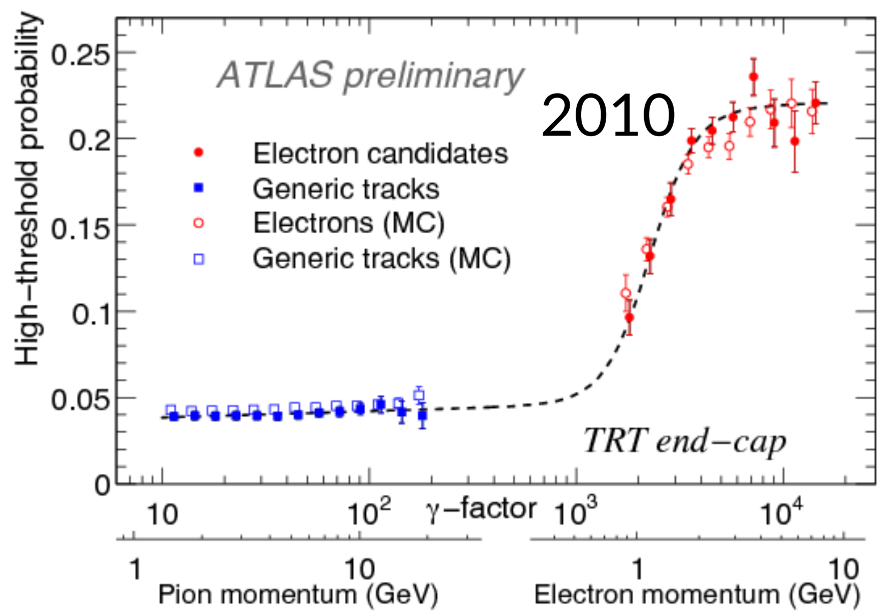
ATLAS EXPERIMENT

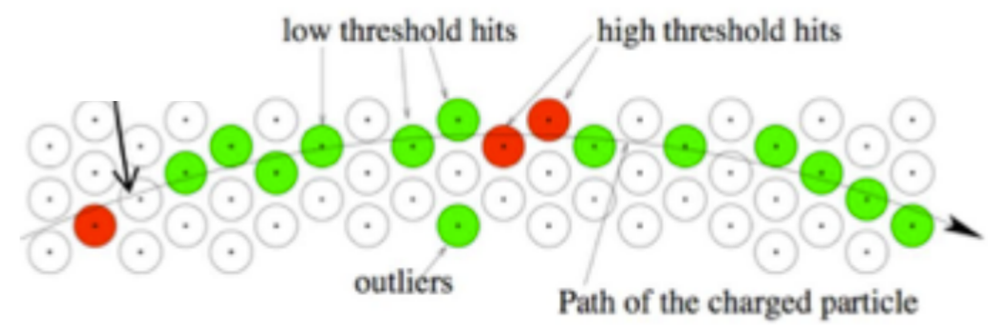
# Introduction

- The Transition Radiation Tracker is the third inner detector subsystem in ATLAS.
- Provides charged particle tracking, electron ID through transition radiation, and better momentum resolution for high $p_T$ particles.

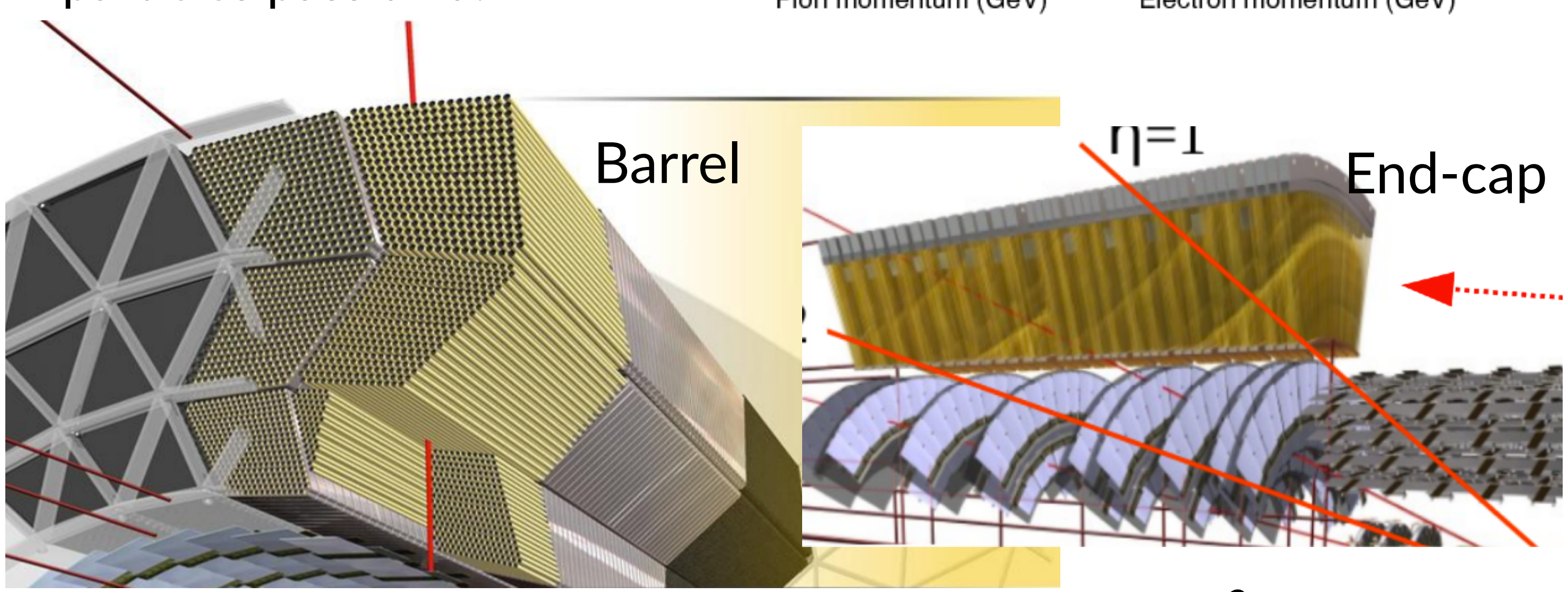


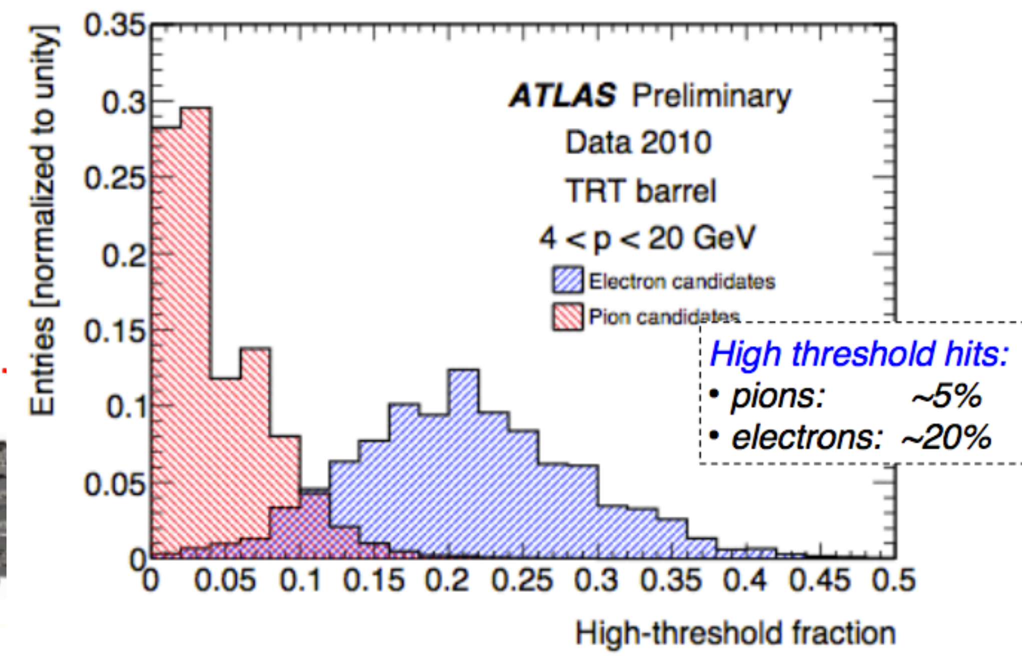

- Xe/Ar/CO2/O2 gas mixture provides active medium inside straws.
- ~30 hits per track.
- Radiator material between straws generate transition radiation when high γ particles pass thru.




- low: 300 eV : tracking
- high: 6 keV : electron identification



# Front-end electronics

- 16 straws feed their output into 2 ASDBLRs(8 straws each), the analog ASIC chips, which in turn feed their output to a DTMROC, which digitizes the signal.
- The DTMROC sets the low and high thresholds on the ASDBLR, and the ASDBLR does the discrimination between thresholds.
- The DTMROC has a test-pulse capability to inject a known charge back into the ASDBLR, which and can be used for calibration purposes.

**Amplification, Shaping, Discrimination, and Base-Line Restoration (ASDBLR)**

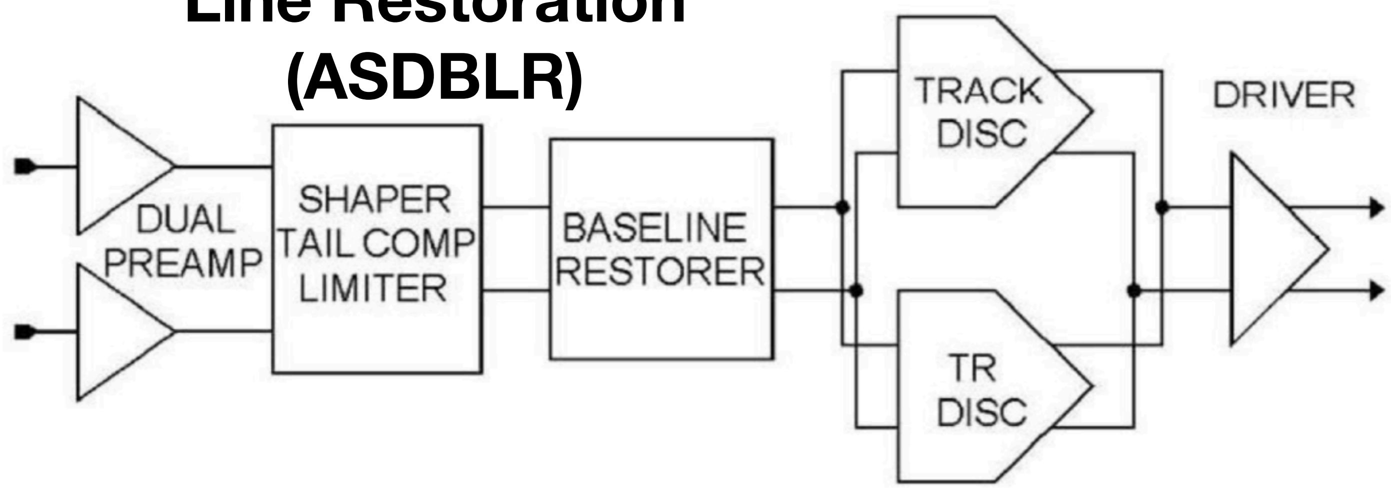
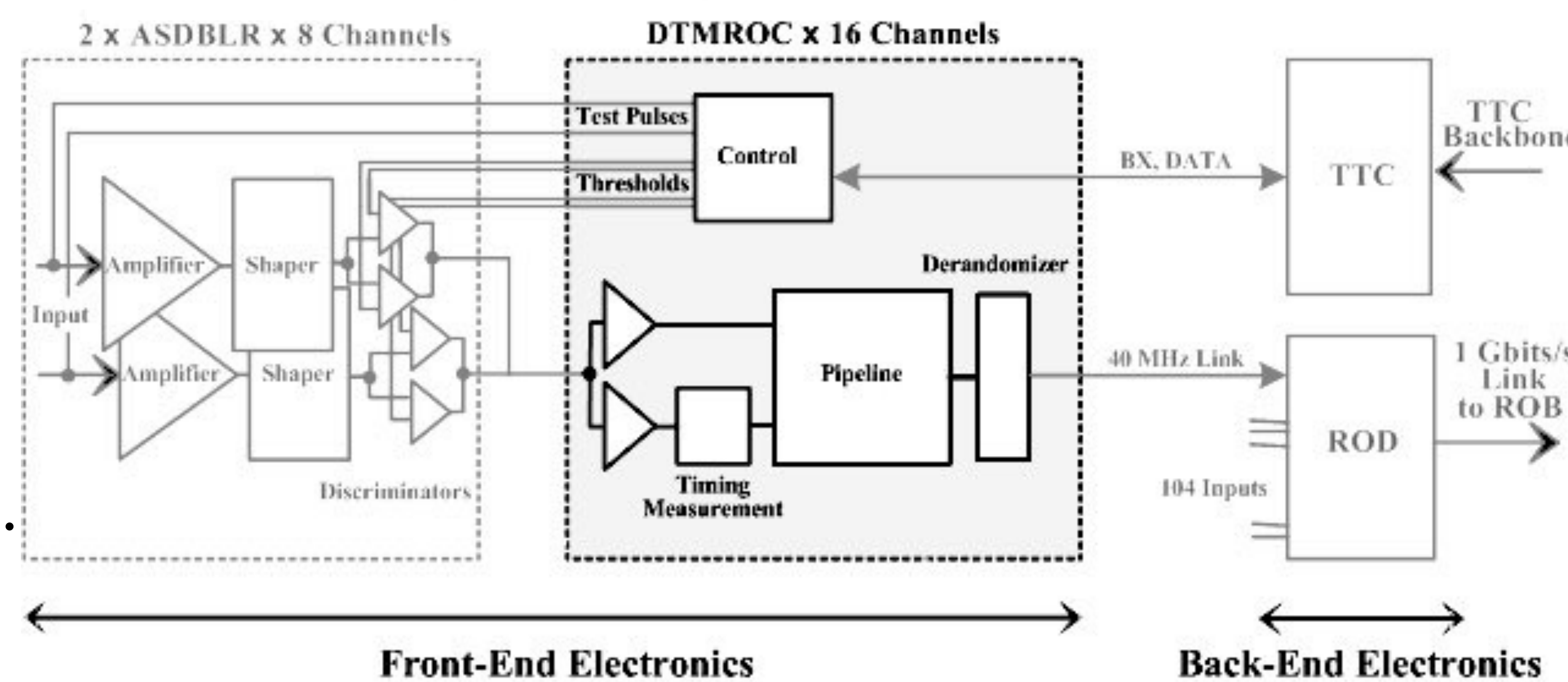



**Figure 2.** Block Diagram of one channel of the ASDBLR

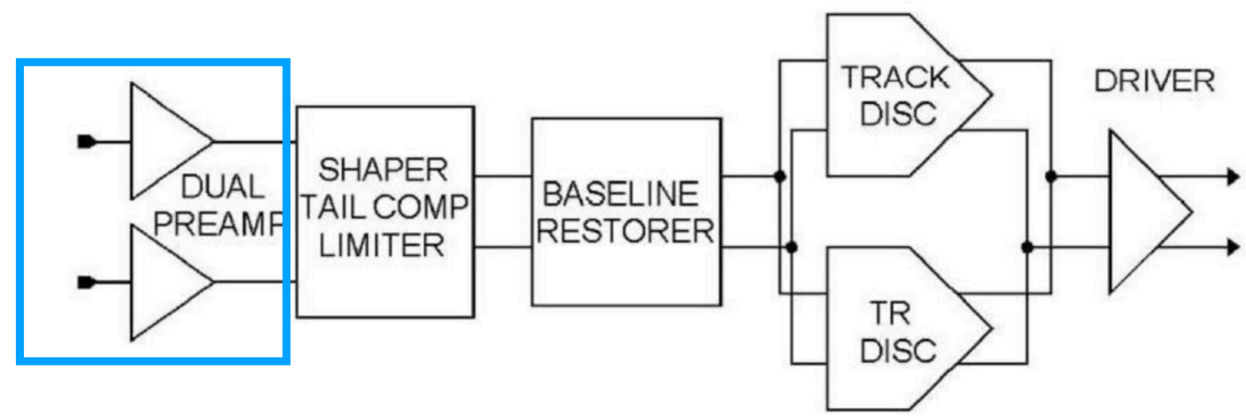


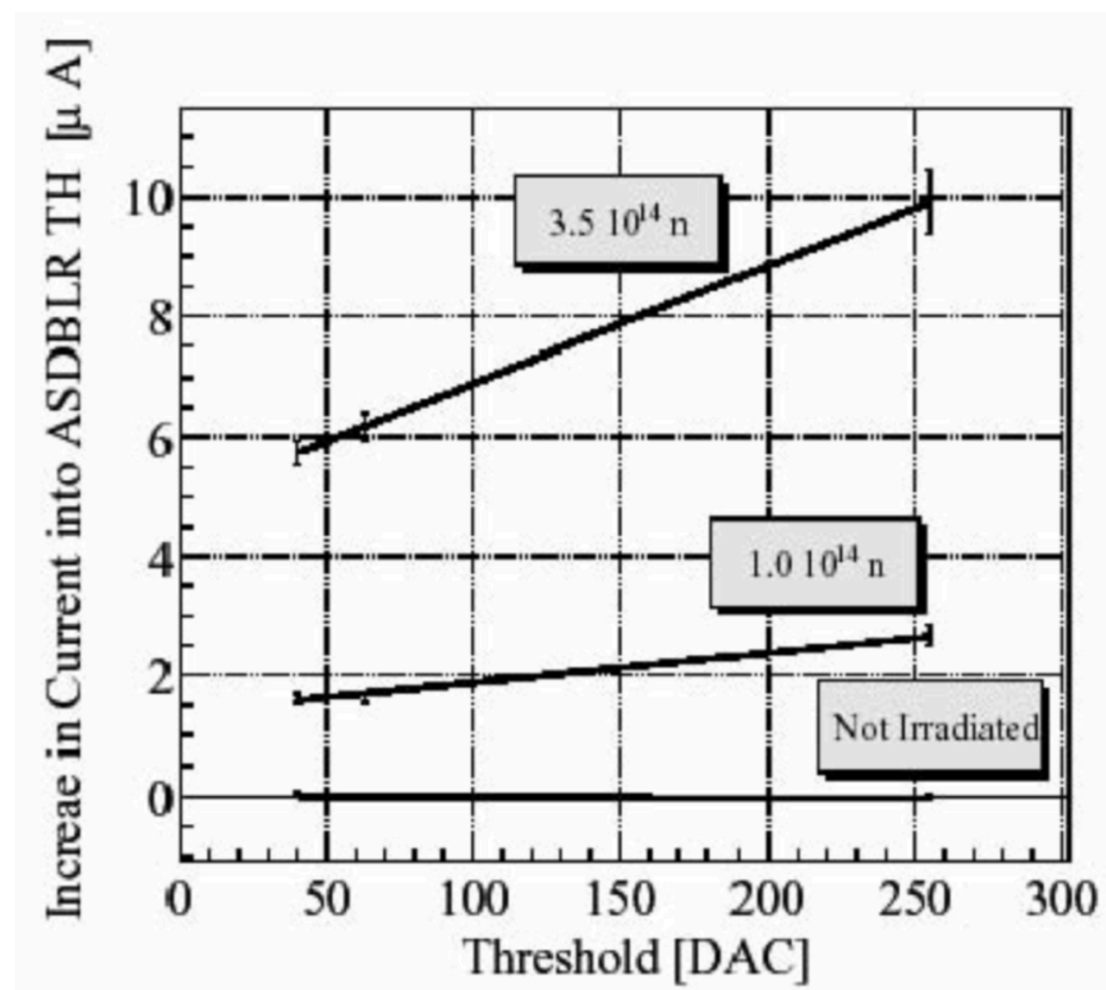

**Drift Time Measuring Read Out Chip (DTMROC)**

# Radiation damage to pre-amp

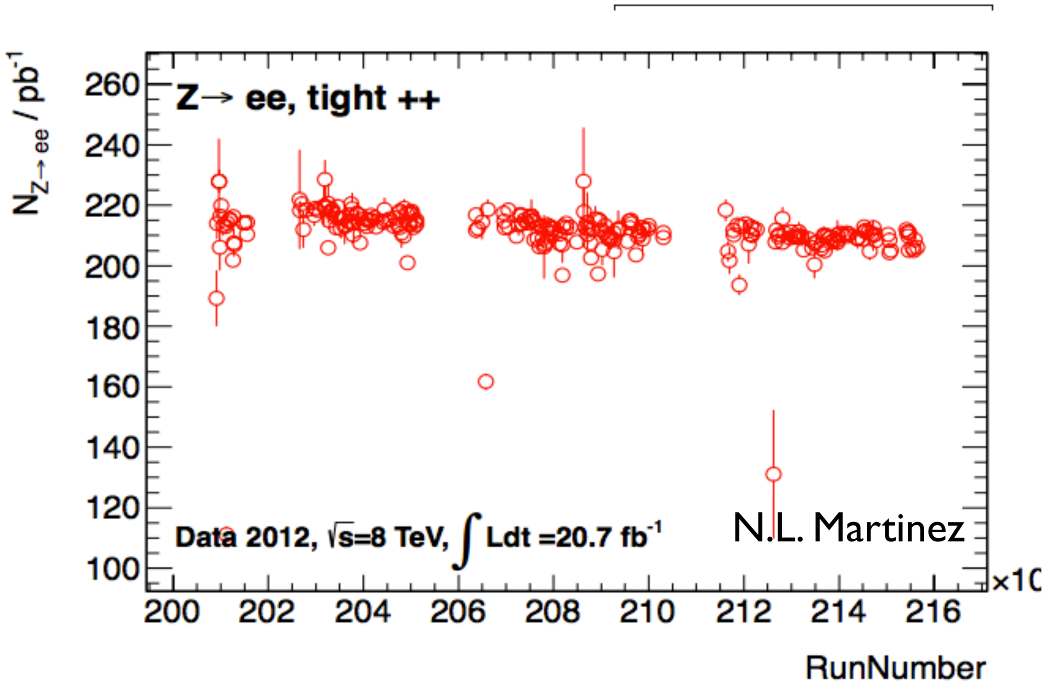
- Significant attention was given to the protection of the preamp on the ASDBLR since the input is directly attached to the straw anode wire.
- The preamp is the part of the circuit most affected by radiation damage, as the transistor is sensitive to displacement damage from neutrons and protons.
- This causes an increase in current at the base of the transistor of the preamp, which will lower the gain (β).
- Plot shows base current change as a function of different neutron irradiation levels. The threshold input (x-axis) is wired directly to the base of the transistor.

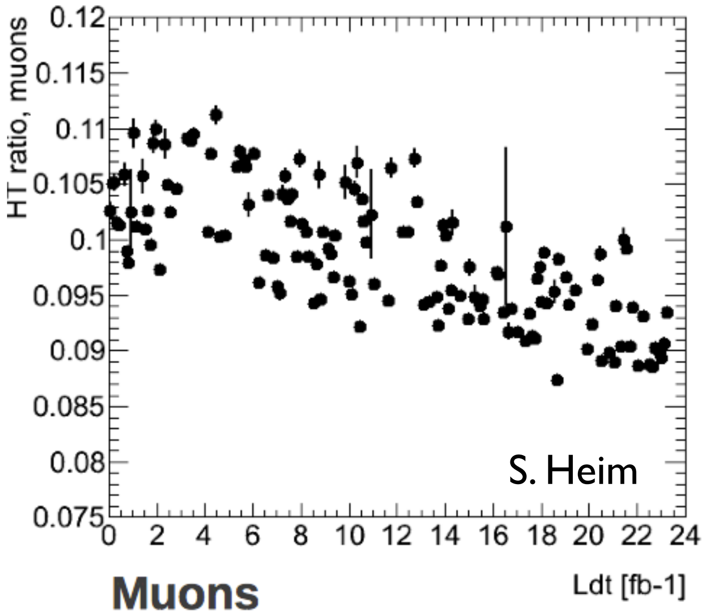
**Amplification, Shaping, Discrimination, and Base-Line Restoration (ASDBLR)**



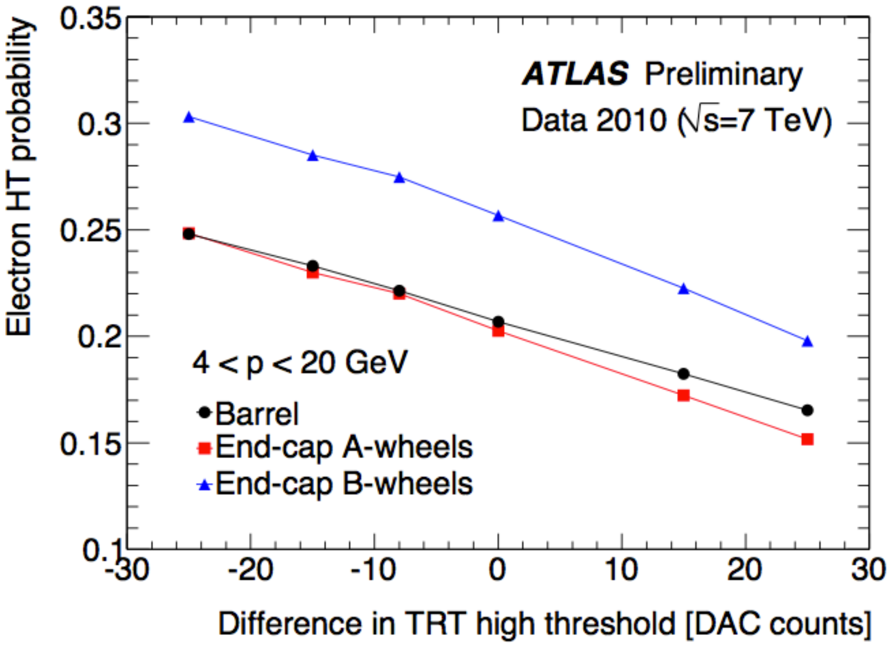



# Electron Efficiency in High Threshold



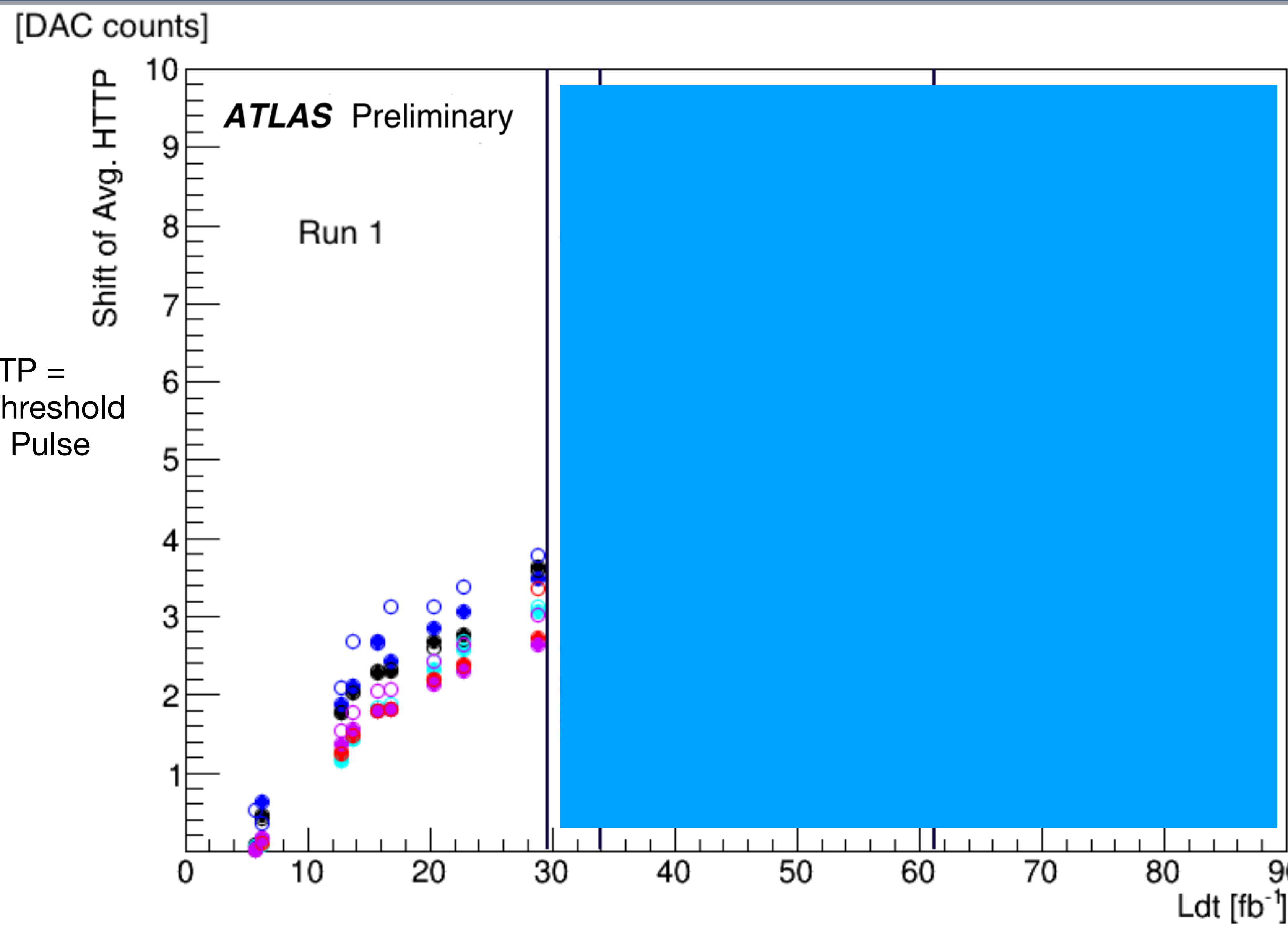

- Loss of gain caused by radiation damage to the ASDBLR will mean less tracks will pass the high threshold for electron identification.
- At the end of Run 1, we saw a decrease in the Z→ee efficiency.
- The high thresholds had not been changed since the beginning of run 1. A decrease in electron efficiency is an effective increase in the TRT high threshold.

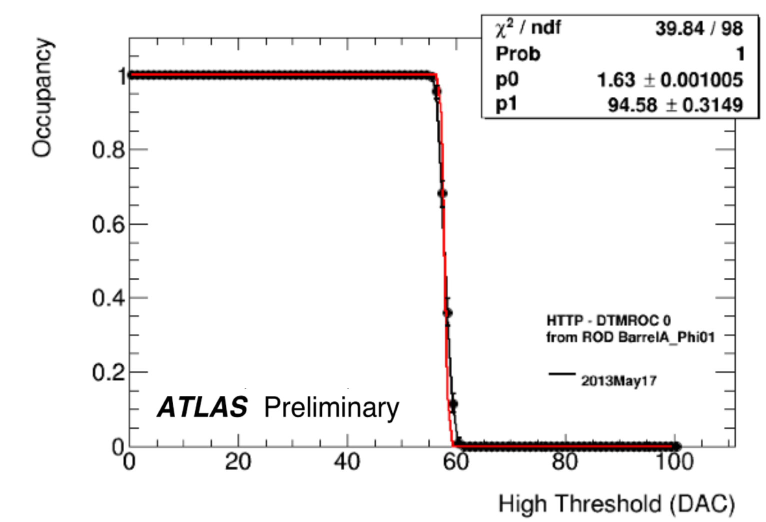



from PID paper ATLAS-CONF-2011-128

# High Threshold Drift in Run 1

HTTP =
High Threshold
Test Pulse

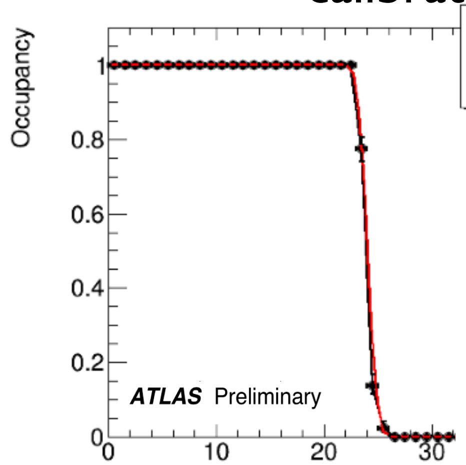


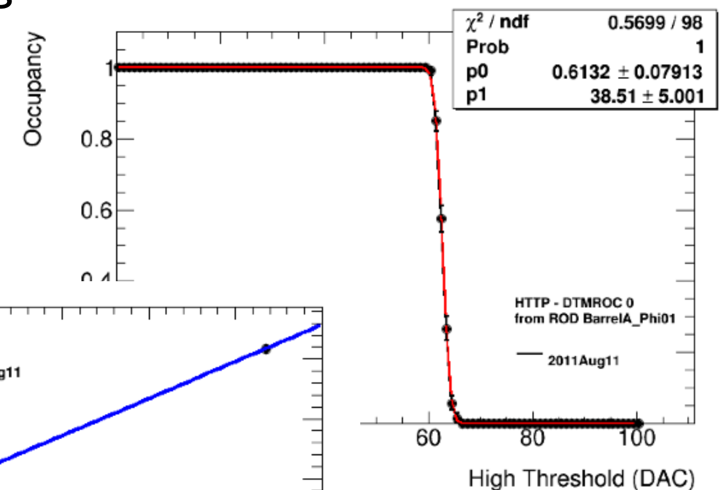



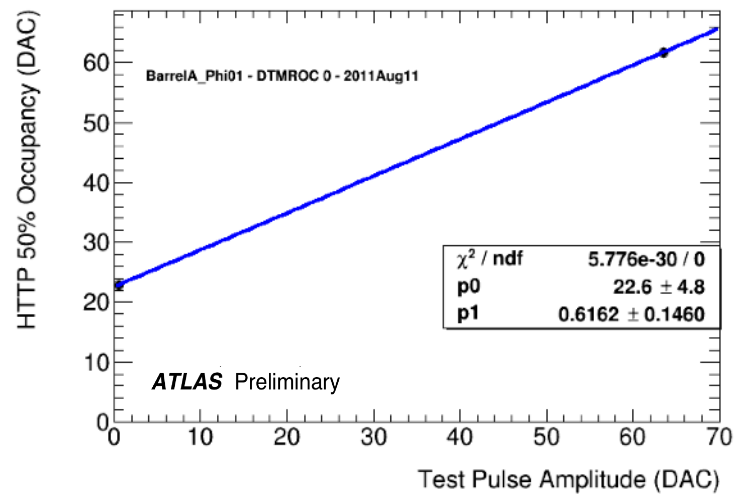

- Plot of TRT high threshold calibration scans as a function of integrated luminosity over run 1. Calibration scans inject a 63 DAC test-pulse from the DTMROC into the ASDBLR.
- The y-axis shows how the 50% occupancy threshold has drifted over time for a constant injected test pulse from the DTMROC. (change is *-1 on the plot).

# Change in Gain on TRT over Run 1

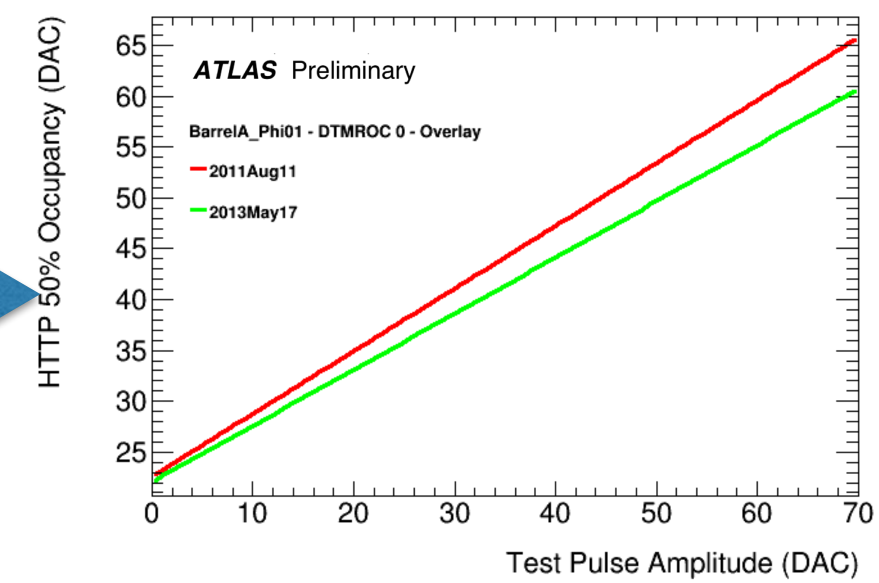
- calibration scans from Aug 2011

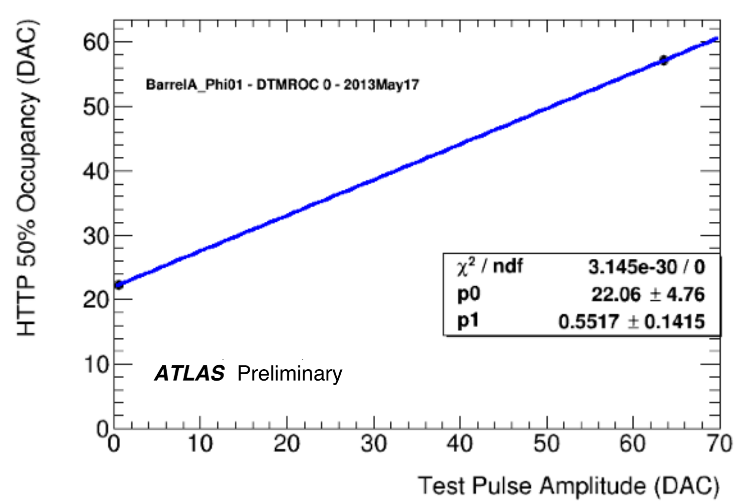


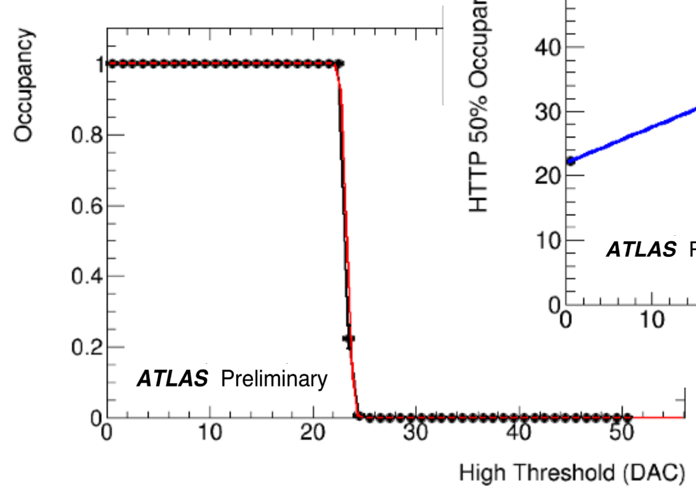



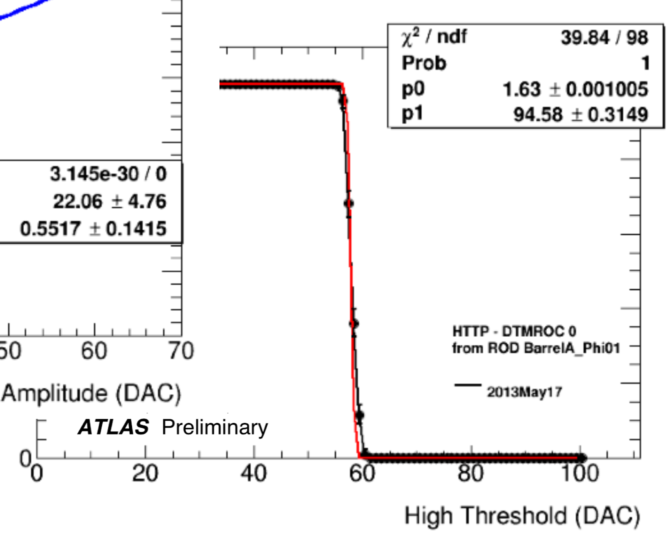




HTTP =
High Threshold
Test Pulse



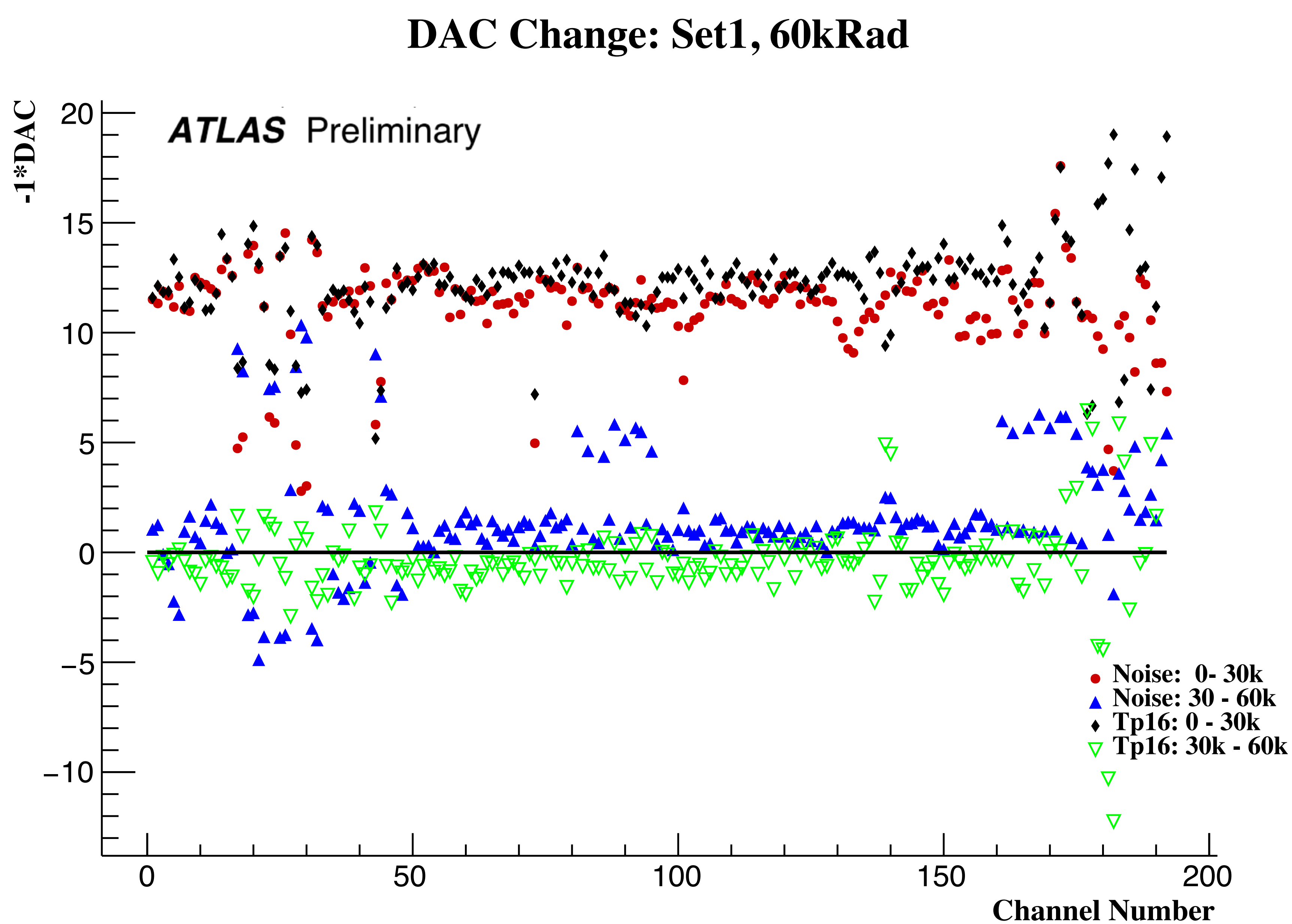




- You can see gain change in threshold response from the calibrations scans using a injected test-pulse into the ASDBLR over run 1.

- calibration scans from May 2013

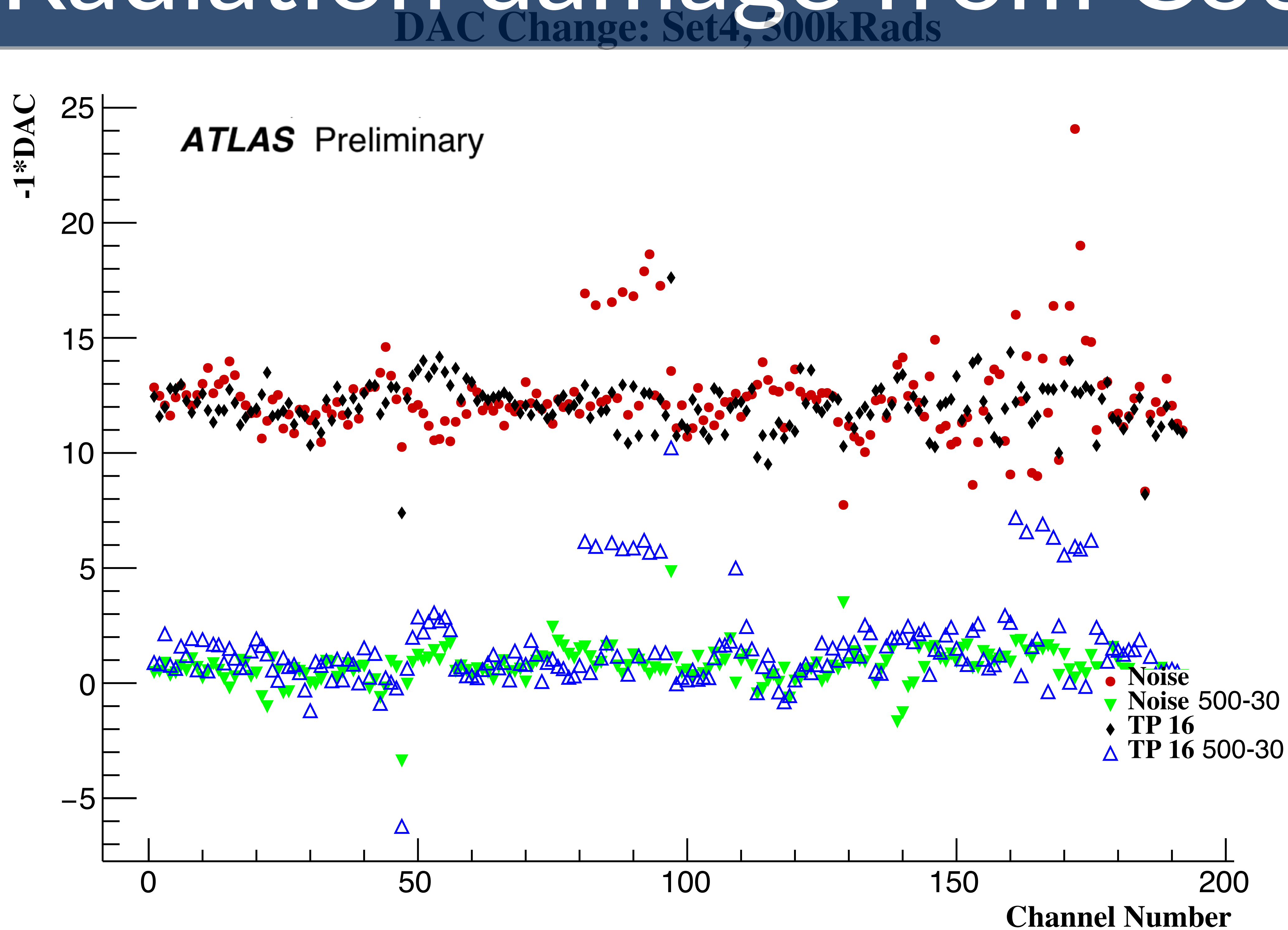
# Radiation damage from Co60

- Front-end ASDBLR boards were sent to Brookhaven lab to be irradiated by a Co60 source, first to 30 kRad, and then to 60 kRad.
- Using the test pulse on the DTMROC, a test-pulse at 63 DAC was injected into the ASDBLR at 0 kRad, 30 kRad, and 60 kRad to see shift in threshold.
- Threshold drift was observed from 0 to 30 kRad, but no drift was observed from 30 to 60.
- 30 kRad is about the amount of integrated radiation for run 1.



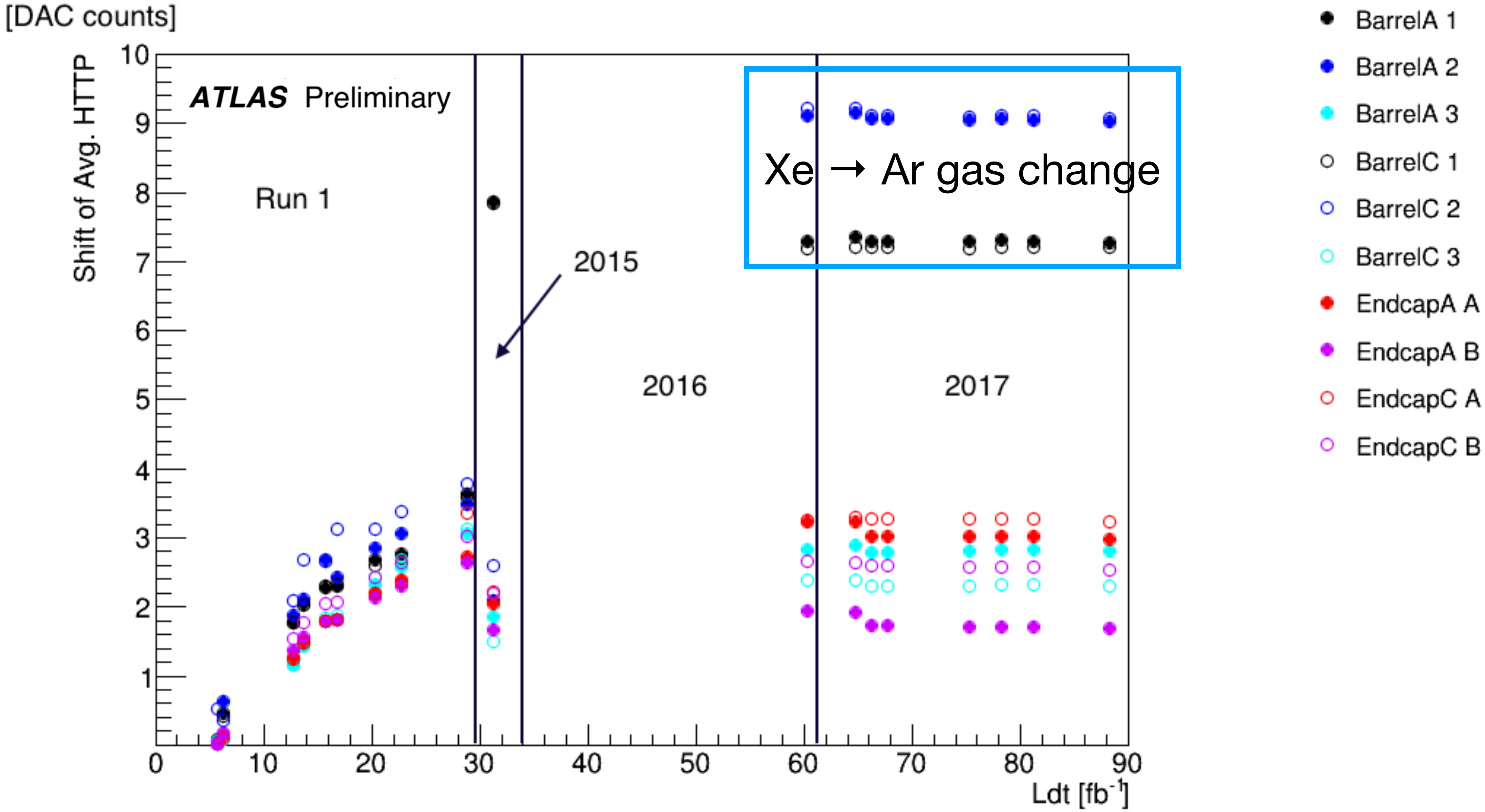

- This shows that the radiation damage saturates after 30 kRad.

# Radiation damage from Co60




- Same plot as before, but from 30 to 500 kRad.
- Threshold drift effect seems to saturate after 30 kRad.

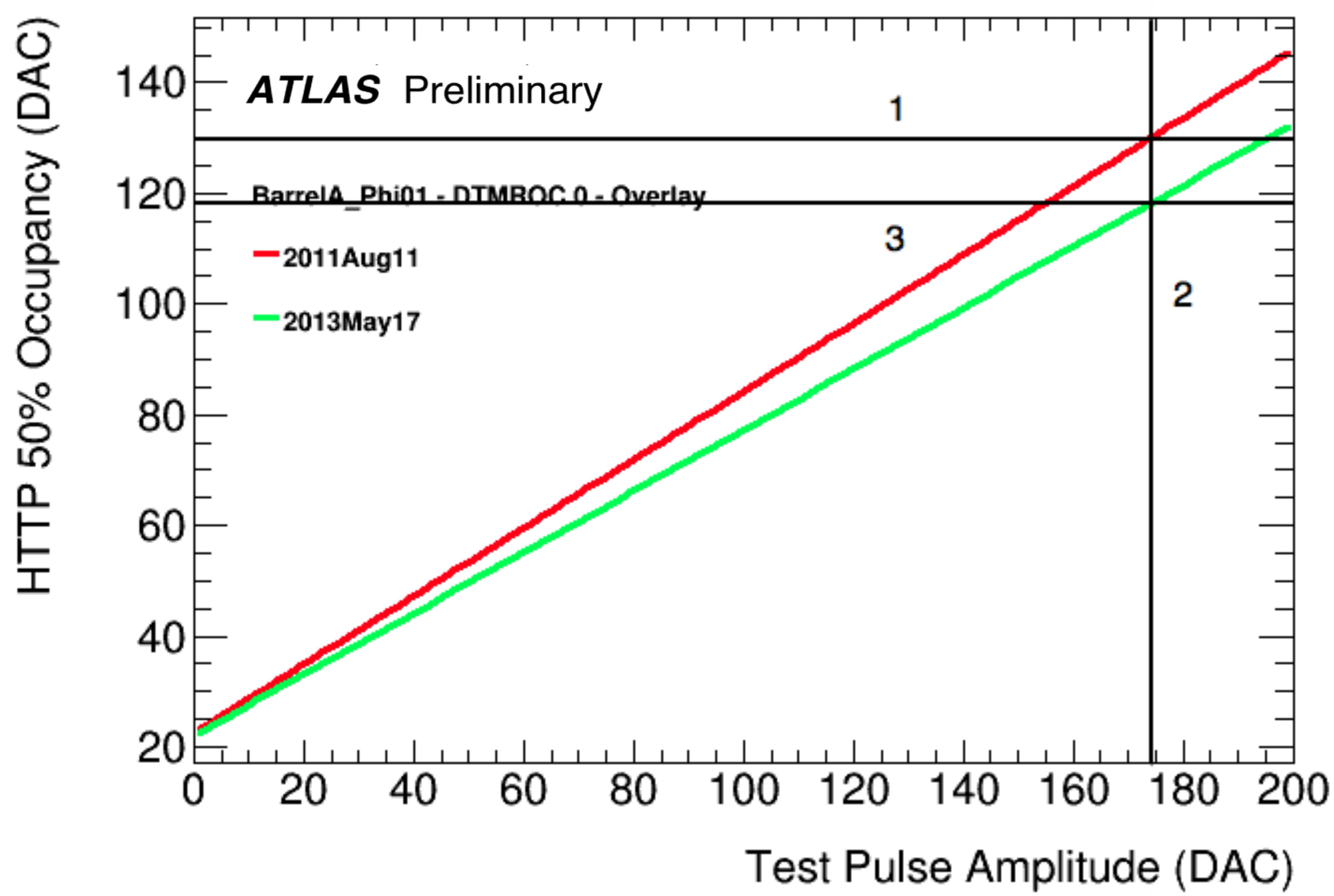
# High Threshold Drift in Run 2




- Plot of TRT high threshold calibration scans as a function of integrated luminosity over run 1 and run 2. Just as seen in the tests, threshold drift has saturated after run 1.
- Large jumps in 2016 and 2017 are caused by change of gas configuration and not radiation damage.

# Correcting the High Threshold

- A method for correcting the high thresholds was developed using the test-pulse on the DTMROC.
- Essentially, the high thresholds have to be lowered to compensate for the change in gain.
- (1) Use the original high thresholds in the TRT (e.g. 130) to find the test pulse amplitude that would create that 50% occupancy response.
- (2) Use that test-pulse amplitude to see what new threshold would be needed to create a 50% occ. response at the time after irradiation.
- (3) Use the found threshold value (e.g 119) as the new high threshold in the TRT.

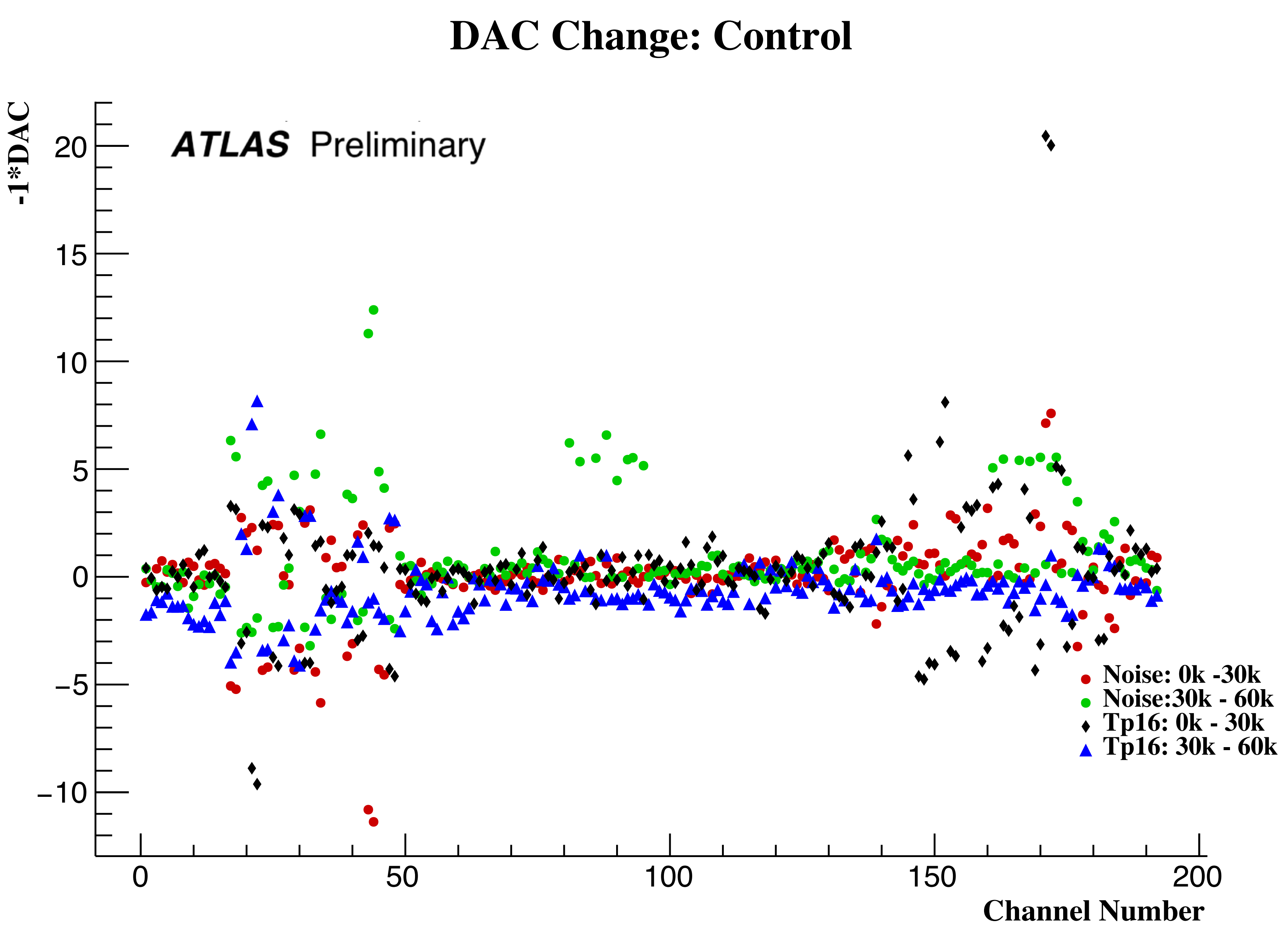


# Conclusions

- The TRT ASDBLR pre-amp was identified as the most susceptible part of the front end chips to radiation.
- The drift in gain due to irradiation was understood both at the transistor level, as well as at the higher high threshold level.
- During running, frequent calibration scans were taken with a test-pulse in order to follow the effect of radiation damage to the ASDBLR.
- Once the radiation effects were saturated, the calibration data and test-pulse were used to correct for the damage by lowering the high thresholds.

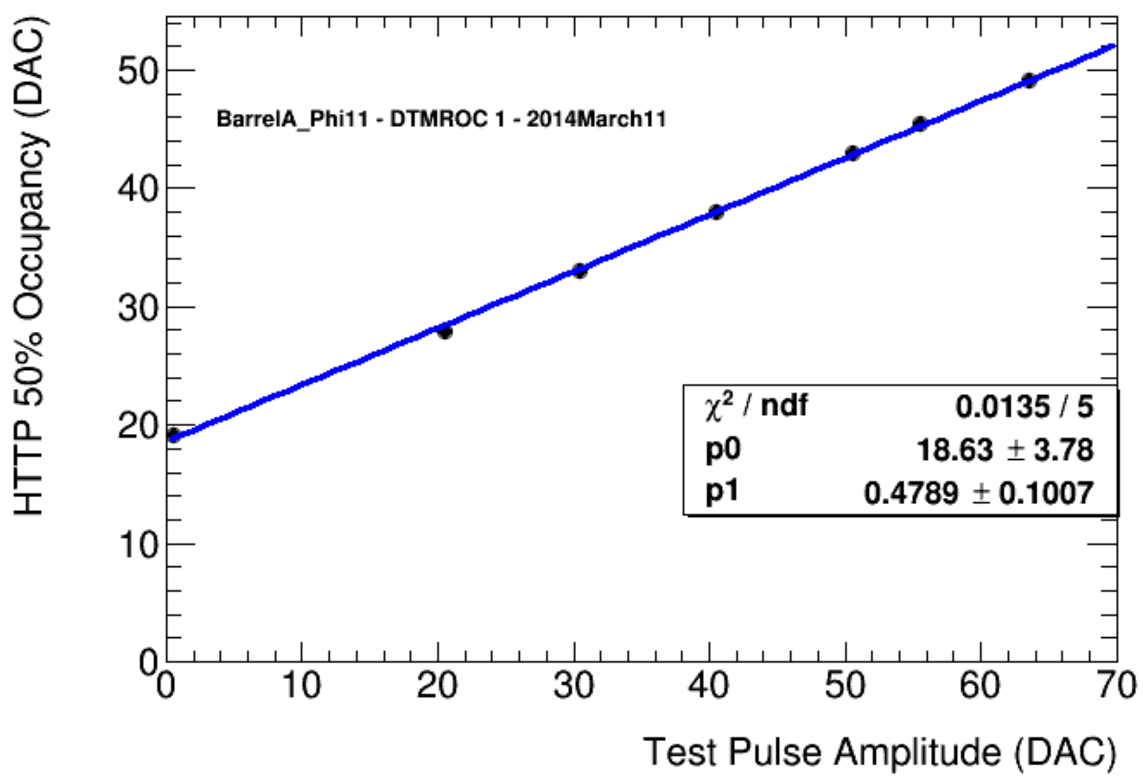
# Back up

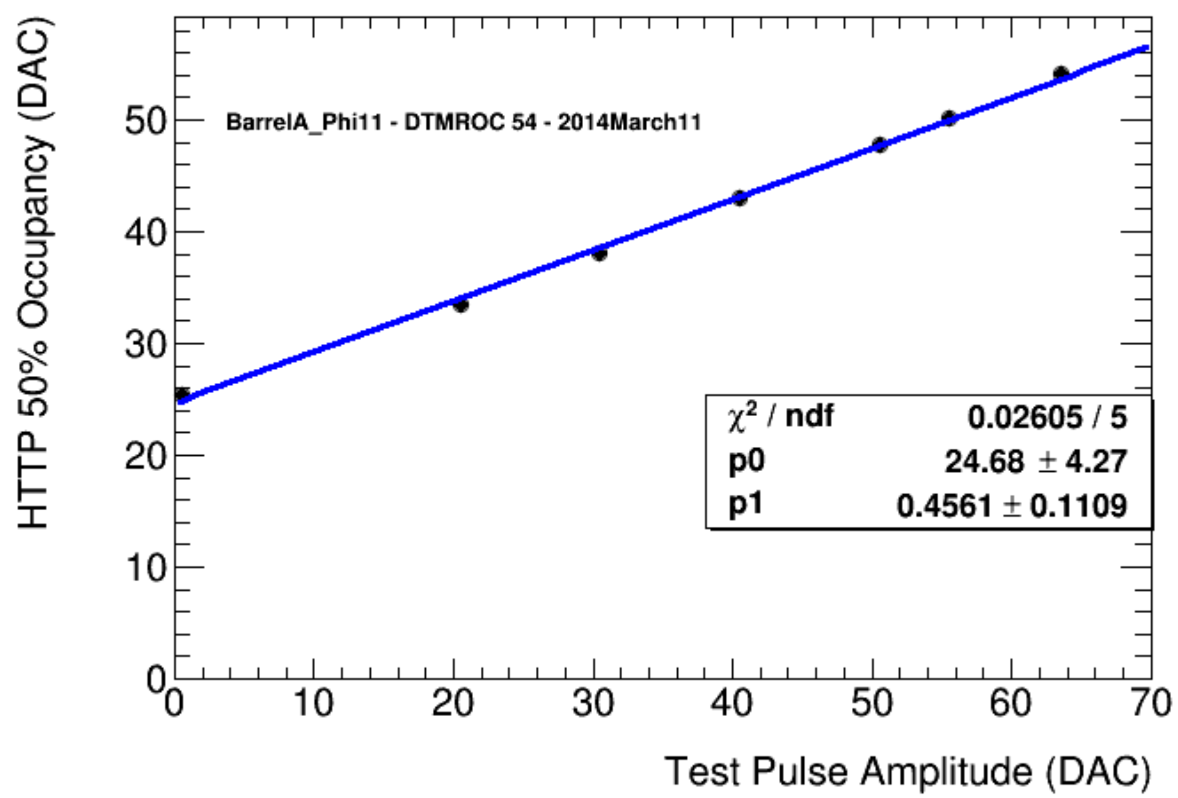
# Control sample




Unused front-end ASDBLR boards were sent to Brookhaven lab to be irradiated, first to 30 kRad, and then to 60 kRad. These boards are a control sample, that were not placed in front of the Cobalt-60 source.

# Linearity of gain of the test pulse




- The gain is linear from close to 0 DAC injected charge all the way to the maximum of 63 DAC for all DTMROCs.
- Above are two representative chips from Barrel A.