



TOB Testing Summary

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for US-CMS Tracker group

Outline

- Summary of TOB module tests
- Test results from mini-production
- Full production test results
- Conclusions



US Production in August

- Philosophy:
 - Parts available to build 35 – 45 modules. Rather than build at some arbitrary pace, we decided to build all the modules in a continuous way, day-by-day, as a test of our capability to maintain continuous production. All production and testing steps were followed.
- Mini-production run also tested our capability to maintain required testing and modules characterization rate
- Full characterization of modules is performed with ARC/LED
- All produced modules were termocycled for different periods of time



Tests Performed on TOB Modules

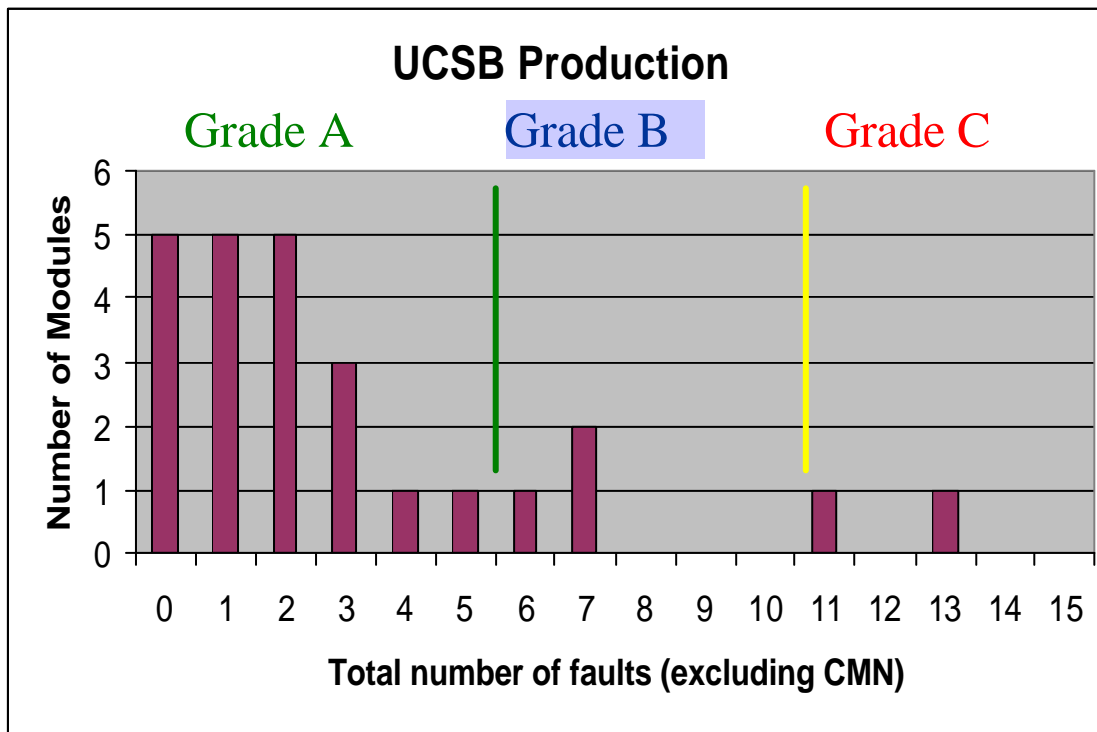
- Tests before module production
 - Sensor IV probing (for last 25 modules) (UCSB)
 - Looking for sensors with much higher current than sensor QTC
 - IV Test prior to wire bonding (for last 31 modules)
- Tests after module production
 - ARCS module tests (following Torino meeting guidelines)
 - Pedestal/Noise Test (all 4 modes at 400 V)
 - Calibration Pulse Test (all 4 modes at 400 V)
 - Pipeline Test in Peak On
 - ARC LED (pulsed test)
 - ARC Pinhole (continuous LED test)
 - IV Test (to 450 V)
 - Vienna Box Test (passive early, then active)
 - After Thermal Cycle Test
 - Pedestal/Noise Test (all 4 modes at 400 V)
 - ARC Pinhole



UCSB Module Testing

25 Modules Tested

- 17 Grade A
 - 1 has CMN/increased I_{BIAS} occasionally (not understood)
- 3 Grade A/F
 - 2 Broken Cables
 - 1 Broken Cable/CMN
- 2 Grade B
- 1 Grade B/F
 - CMN
- 2 Grade C/F
 - 2 CMN



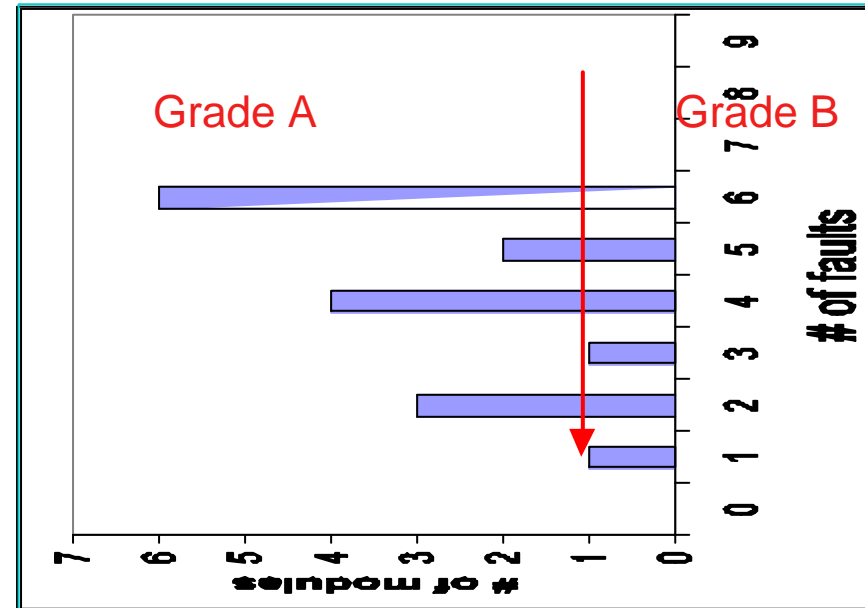
CMN = Common Mode Noise)



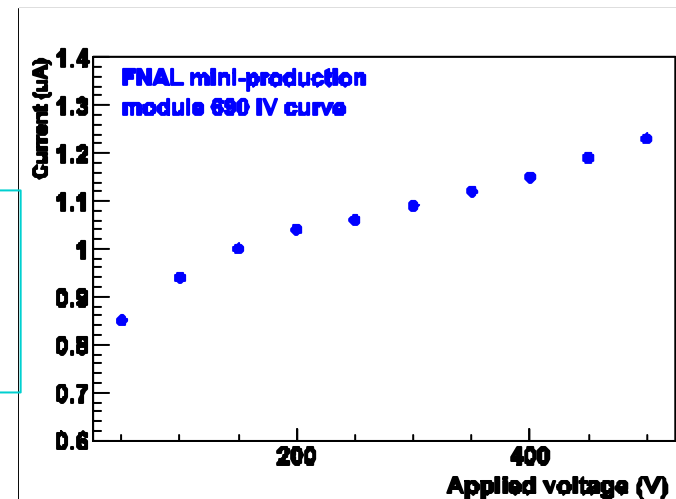
FNAL Module Testing

17 Modules Tested

- 9 Grade A
 - 1 has blown the fuse twice when tested with crow bar; shows normal behavior without current limiting
- 2 Grade A/F
 - CMN
- 5 Grade B
- 1 Grade B/F
 - CMN



IV curve
module
690



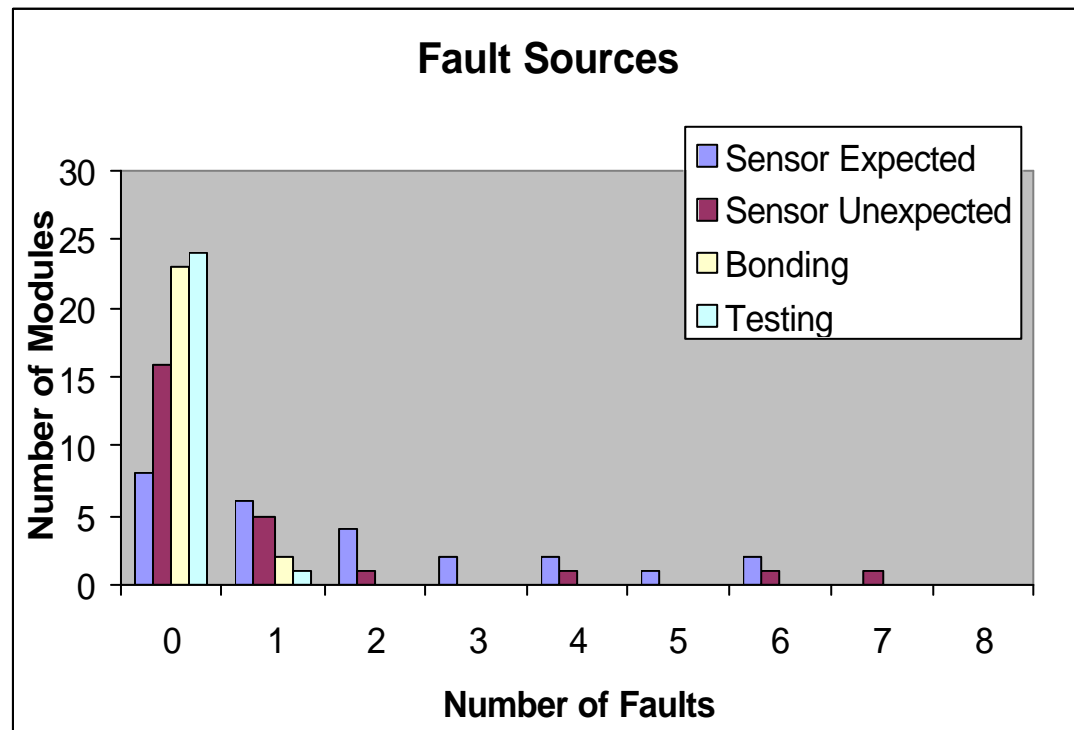


Fault sources (UCSB)

Fault Sources (based on 25 UCSB modules)

- Hybrid – 0.02%
- Sensor (in DB) – 0.38%
- Sensor (not in DB) – 0.17%
- Bonding- – 0.016%
- Testing – 0.012%

Total faults: 0.598%
cable breaks and
CMN are not
included in statistics

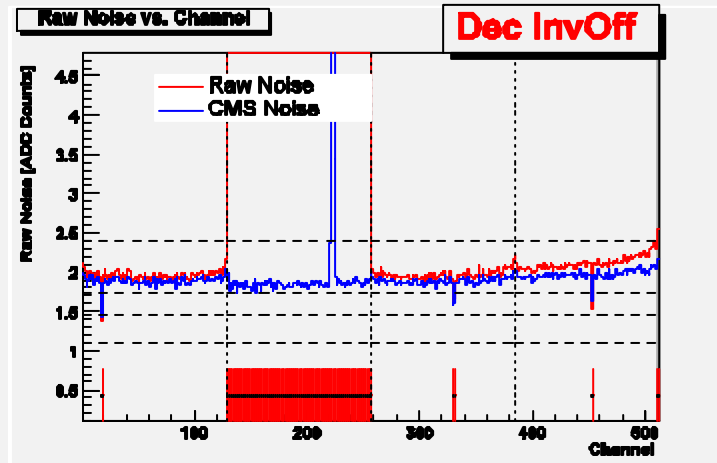
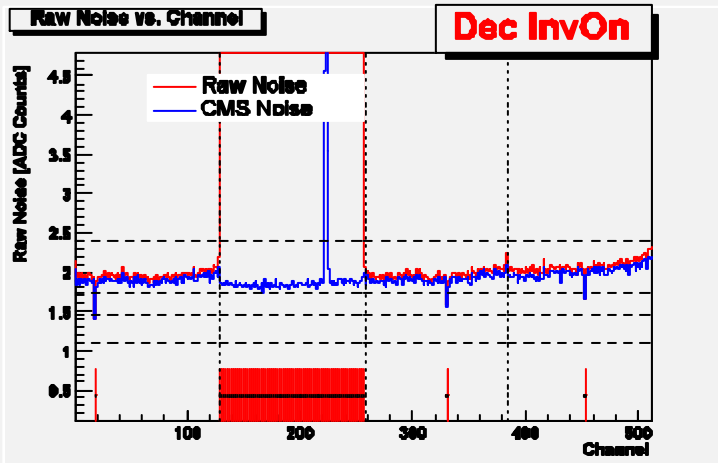
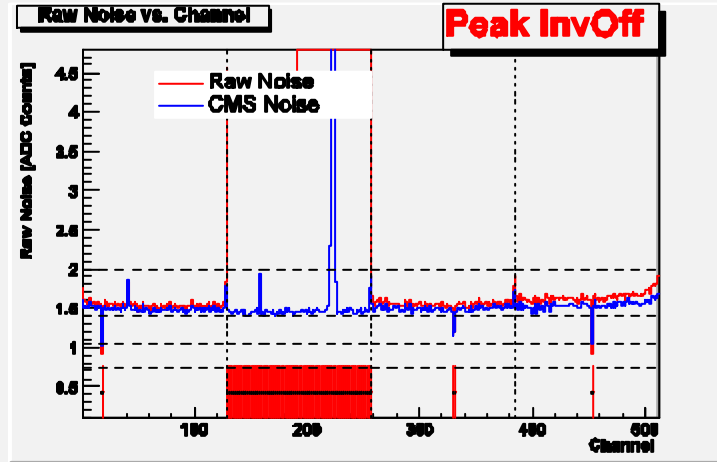
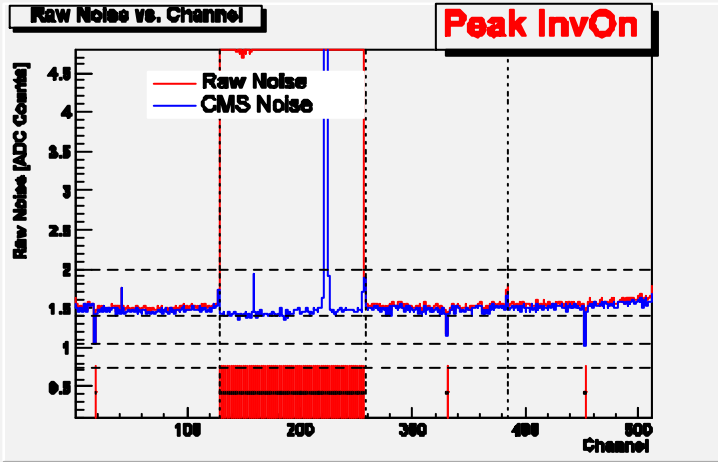




High CMN example

Module 689, 250 V

30200020000689; Record3; 2003-08-01 09:52:16



Grade
A/F



CMN source: sensor issues

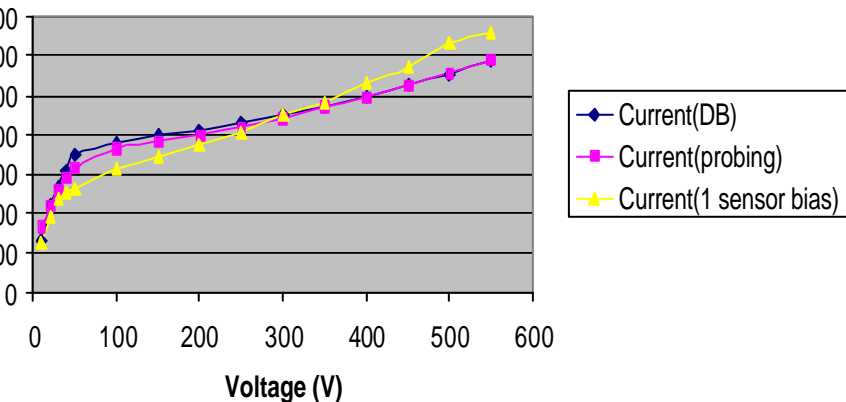
- Re-probing
 - UCSB remade IV curves for 75 sensors
 - Goal – determine whether high current strips were created prior to or during module assembly
 - Found ~10% of sensors had significantly different IV curves than indicated in DB
 - For mini-production 5 of the worst cases were selected for use in modules at UCSB.
- Module Production at UCSB
 - Found that IV curves did not change after module fabrication
 - Found that the 5 pre-selected high IV sensors resulted in 4 modules with high CMN
 - There is one module that has intermittent high CMN that was not anticipated.
- Module Production at FNAL
 - There was no pre-production IV probing
 - 4 of 10 mini-production modules which were compared to DB data showed higher IV than DB prior to strip bonding and 3 of 4 have high CMN



Example: 30200020001016

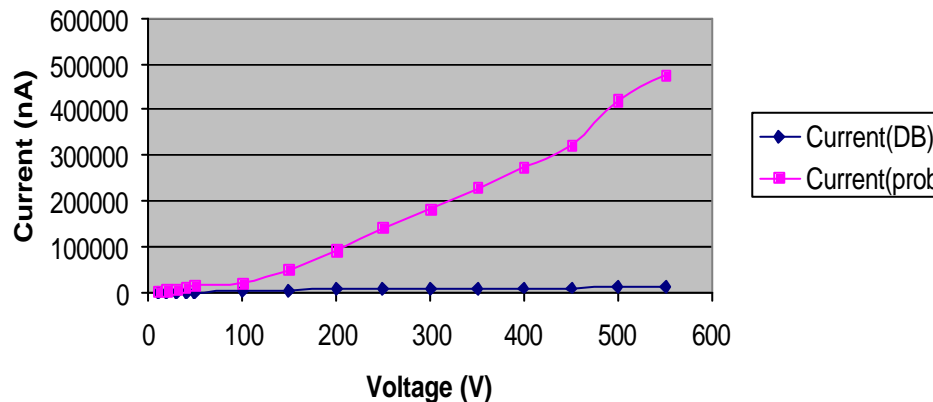
30210422067903

Sensor 1



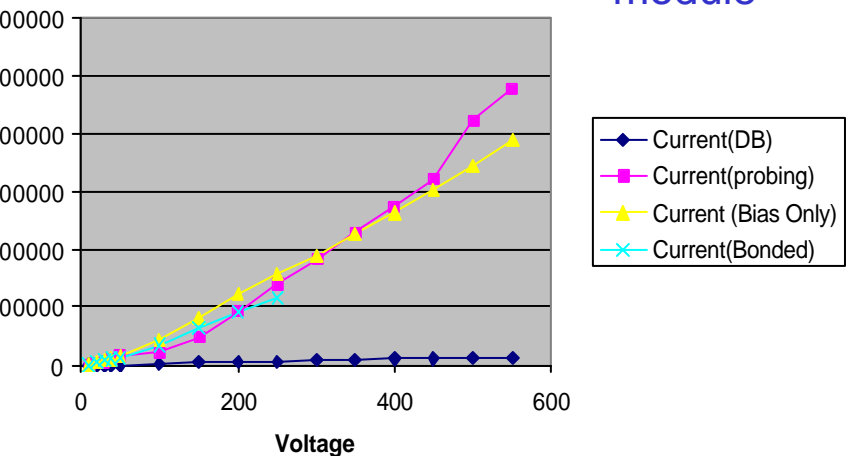
30210422066202

Sensor 2



30200020001016

module



Mid-sensor open “burn” seen in sensor 30210422067903, channel 285.

Strip defect is observed in channel 38 of sensor 30210422066202.

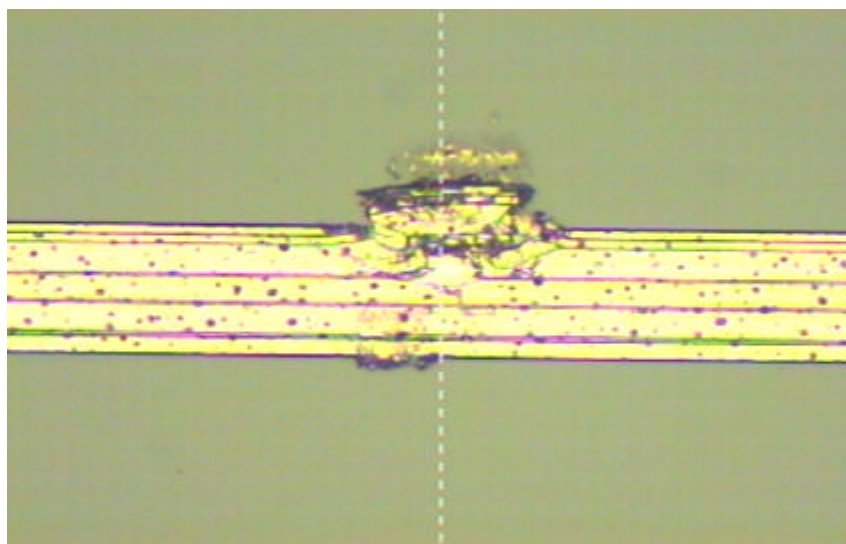
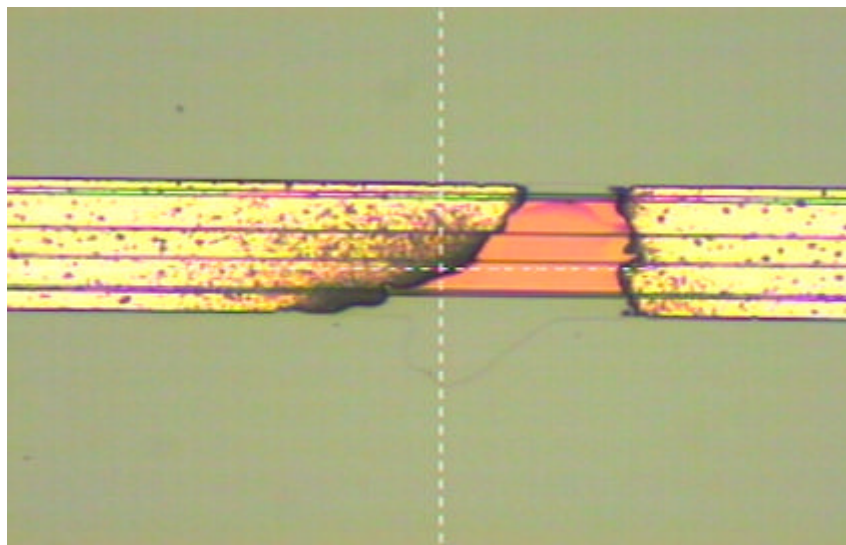
The channels referenced above were found to be the noisy channels in module testing



Pictures of 30200020001016

- Picture of mid-sensor open “burn” seen in sensor 30210422067903, channel 285.
- Picture of channel 38, sensor 30210422066202. CMN problem begins at 90 V

High CMN is observed in chip 1 of this module due to noisy strip 38 starting at 90 V





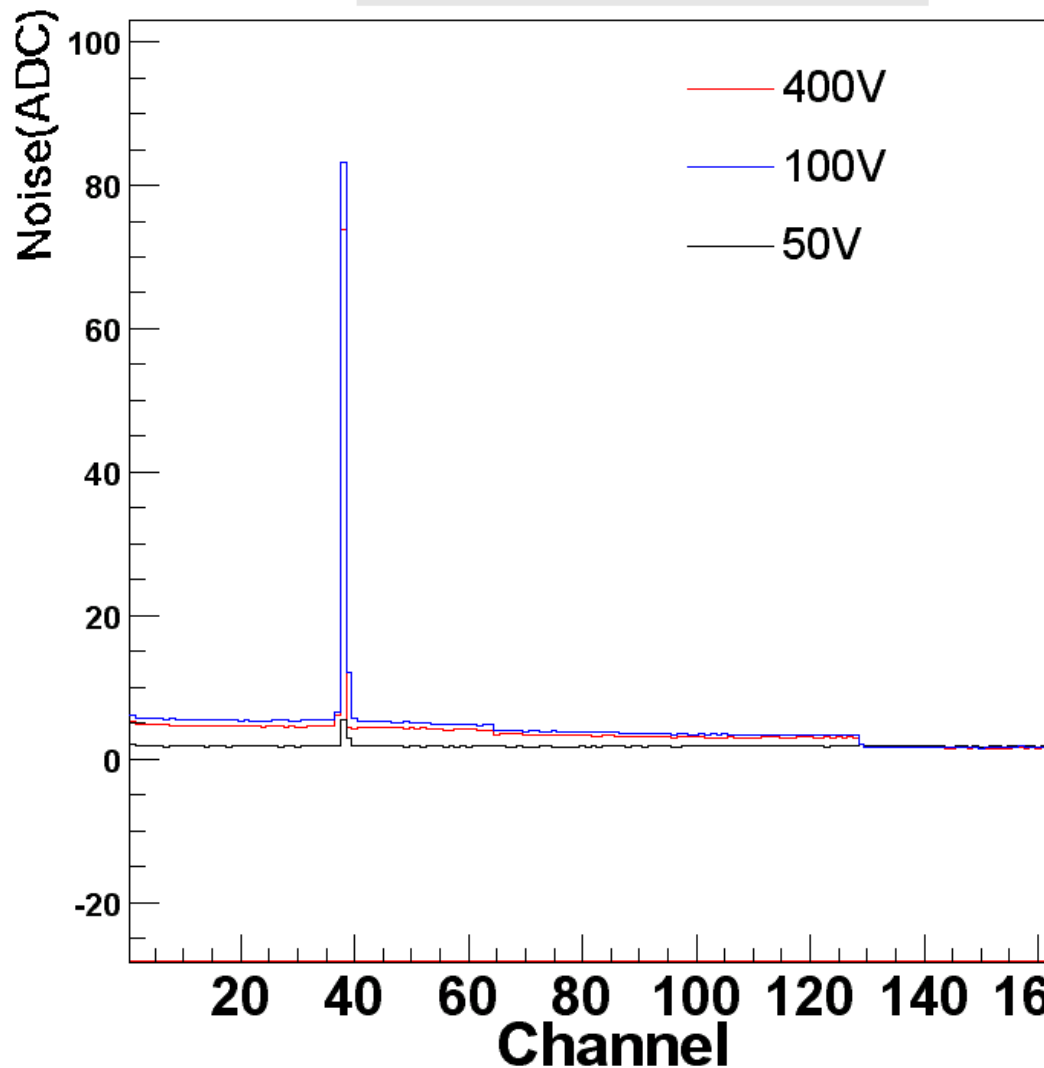
Noise of 30200020001016

Module 1016

Noise starts increasing on channel 38 with 10 V bias

- Assume micro-discharge

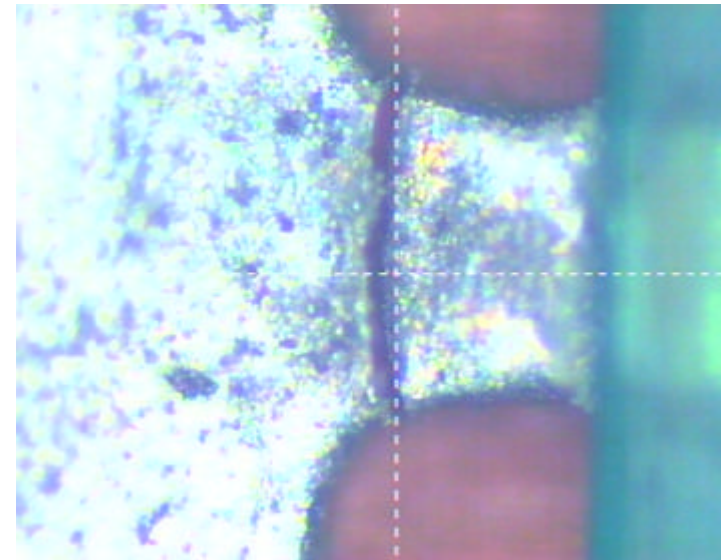
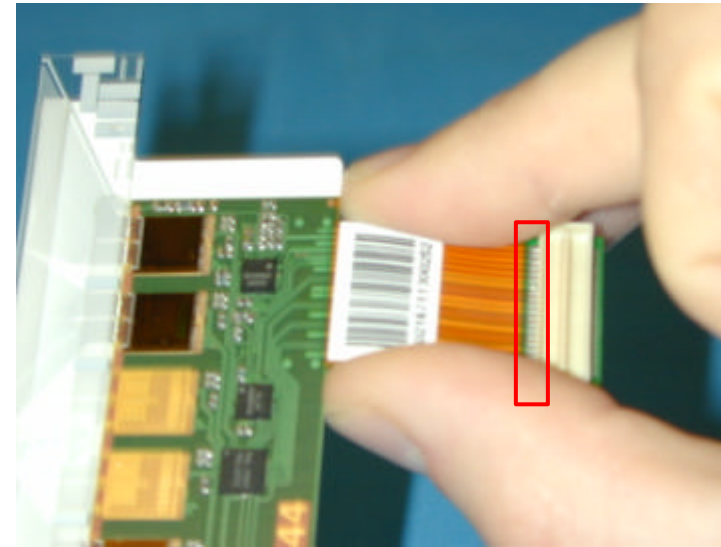
Noise on channel 38 reaches a plateau at 100 V bias and is large enough to cause 5 ADC common mode noise on chip 1.





Unforeseen Problem (Broken Cable)

- Cable extremely brittle near solder pads of connector
- In TOB SS4 connector-up hybrids, first line to break is differential data output lines
 - Causes header (with chip/column info) to have smaller height than usual (0-70%)
 - If too small, first two chips not found
 - After data, level not near zero
 - Pedestal and noise different
- Can change results by bending cable (not suggested as causes problems to get worse)
 - Bending upwards made breaks close and results normal
 - Bending downwards made breaks open even more and results look even worse





LT testing: status

- **UCSB:**
 - All 10 slots are equipped with UTRI, PAACB and adapter boards.
 - All 10 UTRI connected to multiplexer.
 - All 10 slots have HV connections with bias current monitored by electrometers.
 - 9 cold box plates available with adapter cards mounted on standoffs of correct height.
 - 4 PAACB's are connected for readout of module temperature sensors and low voltage currents.
- **Fermilab**
 - 4 slots are fully equipped (UTRI, PAACB, adapter boards, HV connections)
 - **Limited by lack of equipment**
- **Software is reading out everything that is connected**



LT Test Results

Test conditions

- applied voltage 400 V
- temperature variation from 23°C to -20°C

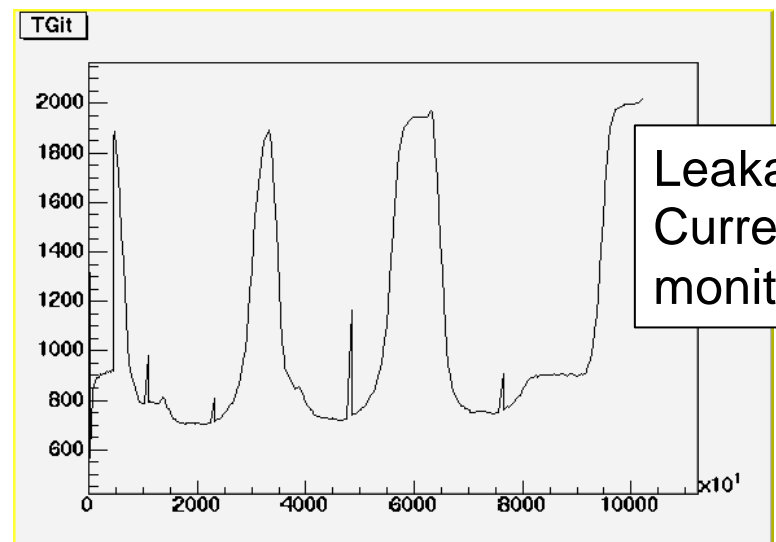
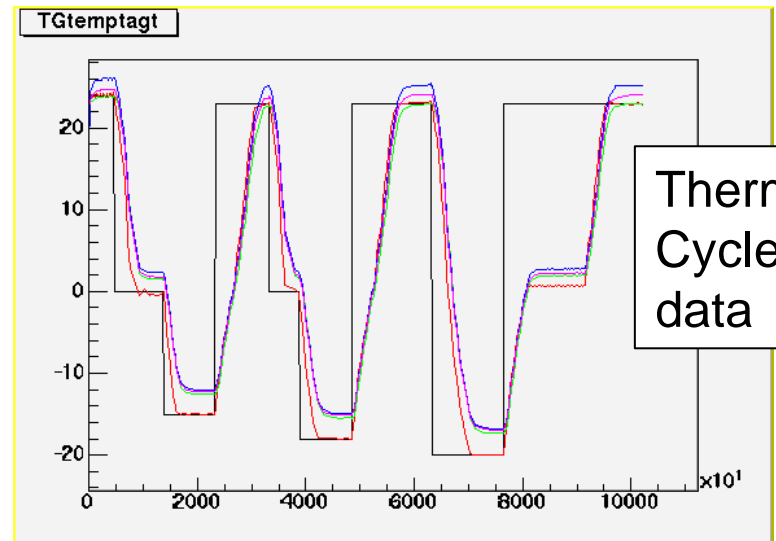
UCSB

- 21 modules had a weekday run of 21 hours with 3 cycles
- Subset of 4 modules had a weekend run of 63 hours with 9 cycles
- Subset of 5 modules had a weekend run of 80 hours with 9 cycles
- Subset of 1 module had a run of 100 hours with 12 cycles

Fermilab

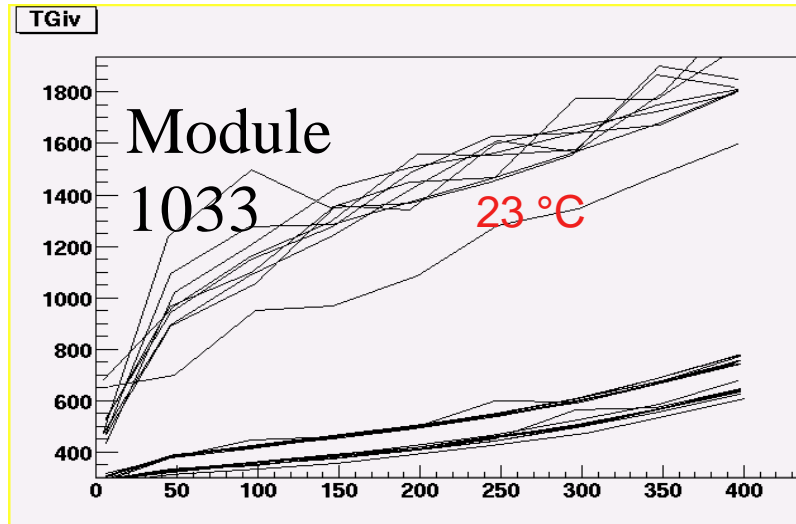
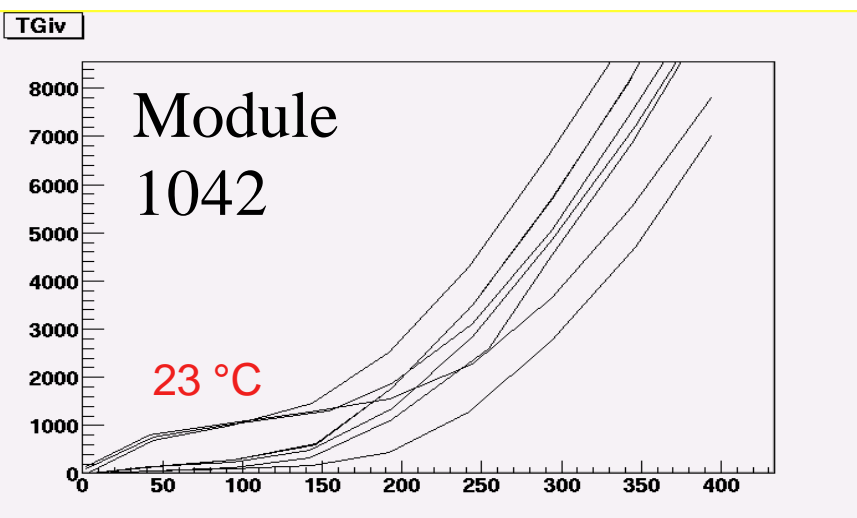
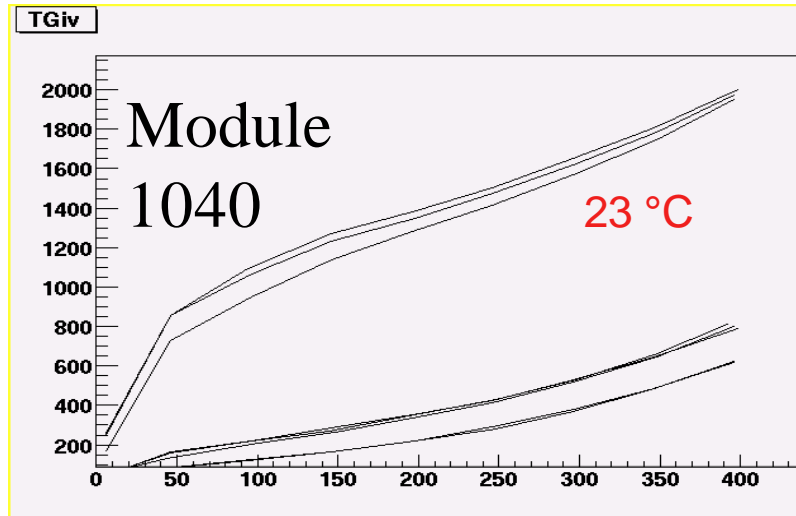
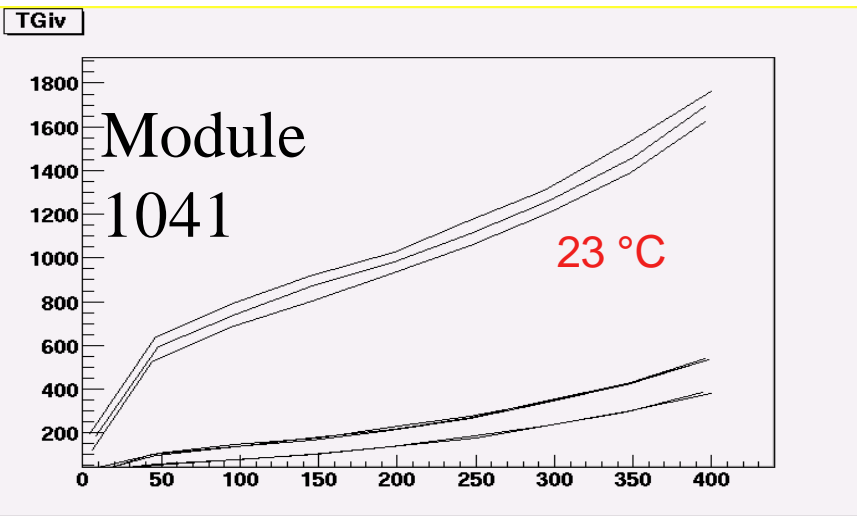
- 17 modules had a weekday run of 10 hours with 2 cycles
- Subset of 10 modules had overnight runs of 12 hours with 2 cycles

After rechecking on ARC/LED no new bad channels found





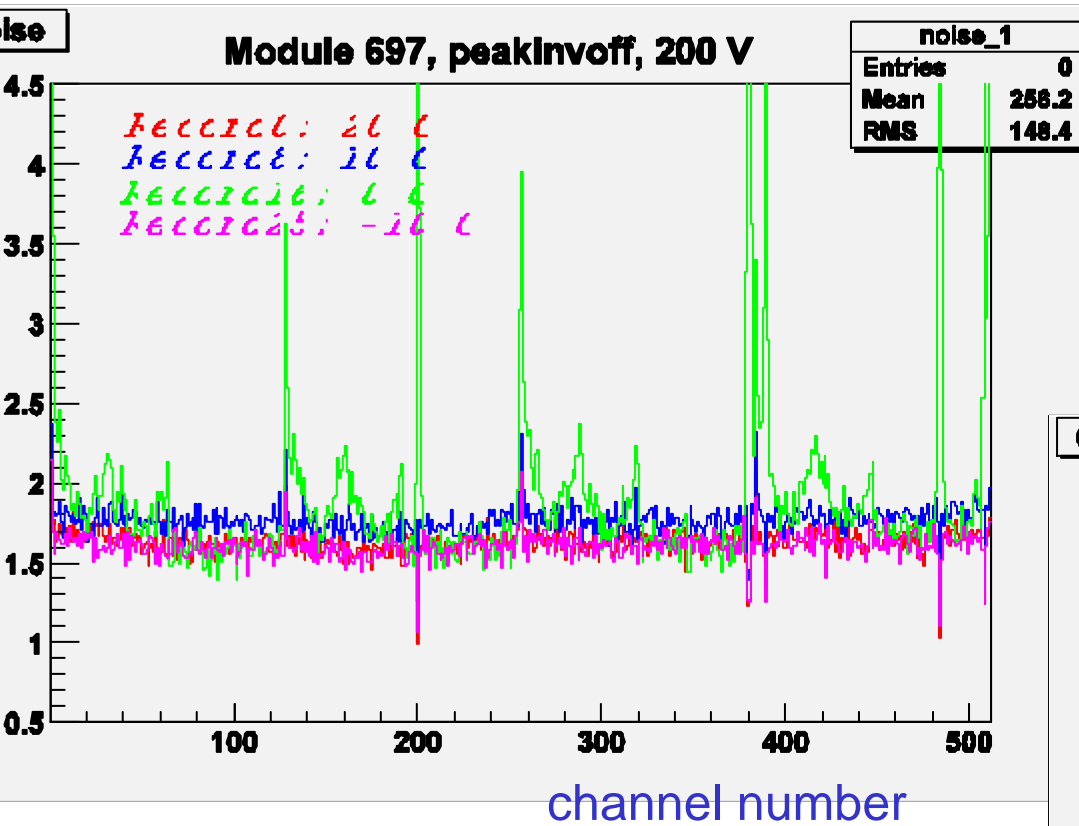
LT Test Results – IV curves



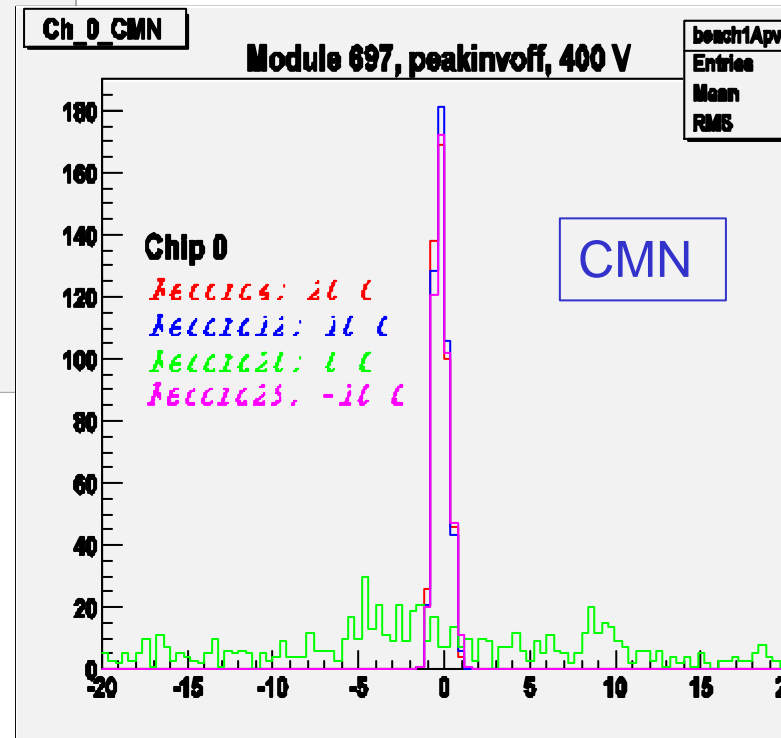
Lower IV curves at taken at $T = -15^{\circ}\text{C}, -18^{\circ}\text{C}, -20^{\circ}\text{C}$



LT test results: noise



No obvious temperature dependence of noise is observed



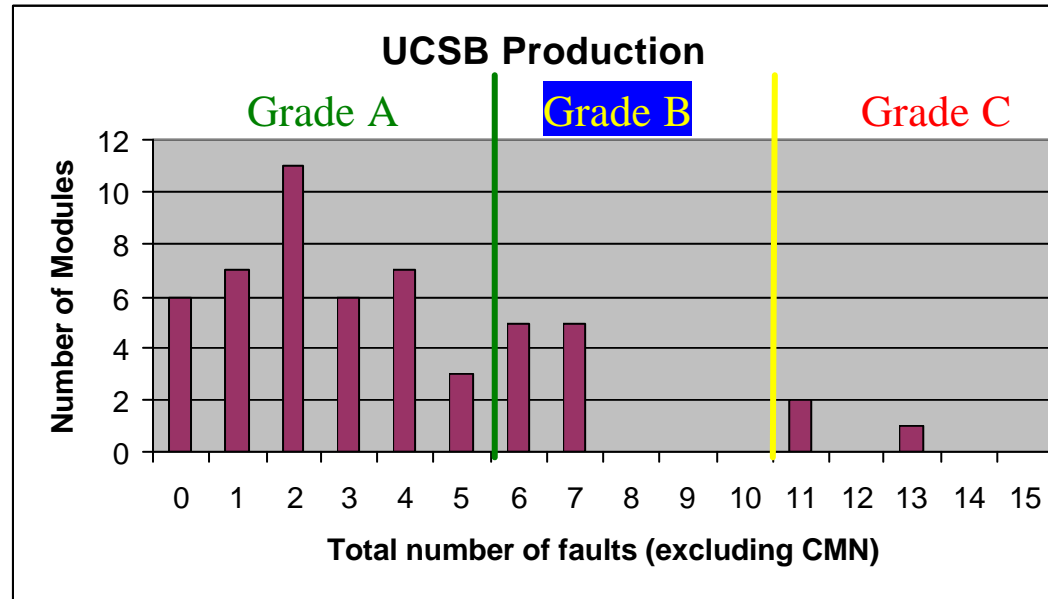
Large amount of noise is occasionally seen in LT systems at both UCSB and FNAL. The problem is under investigation



Test results for full production (UCSB)

53 Modules (out of 54)

- 28 Grade A
 - 1 has CMN/increased I_{BIAS} occasionally
- 10 Grade A/F
 - 2 Broken Cables
 - 1 Broken Cable/CMN
 - 7 CMN
- 6 Grade B
- 6 Grade B/F
 - 4 CMN
 - 2 Missing Bias Bond
- 3 Grade C/F
 - 2 CMN
 - 1 Missing Bias Bond



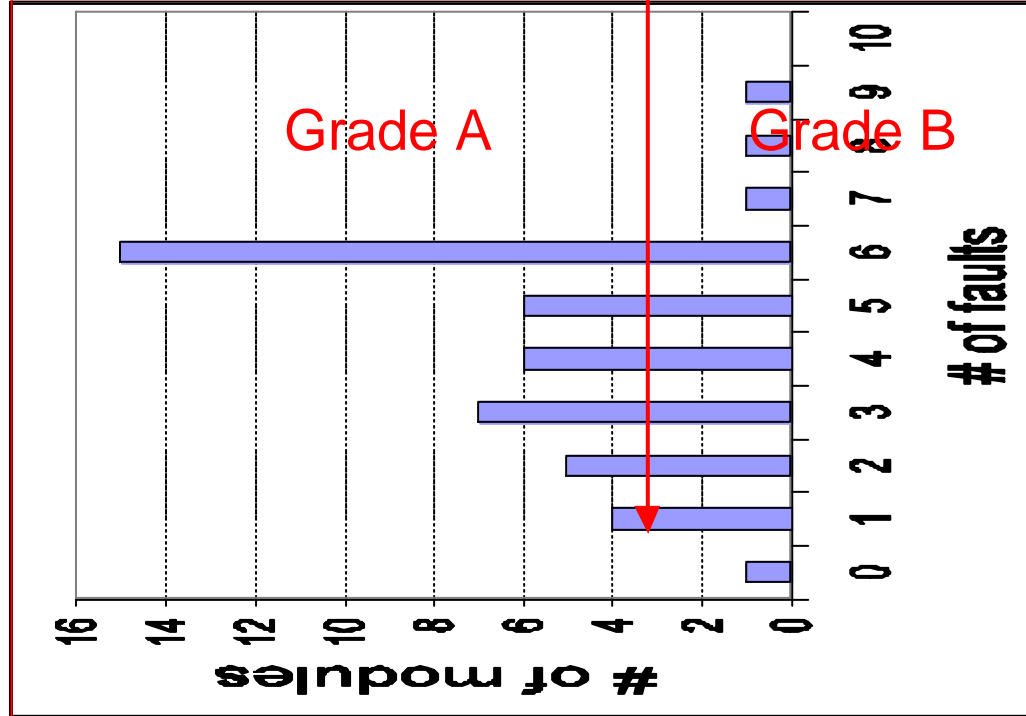
- **Catastrophic Failures**
 - 3 Missing Bias Bonds
 - Early in production missing PA-sensor wire bonds caused damage and high bias current
 - 3 Broken Cables
 - 13 micro-discharge/CMN



Test results for full production (FNAL)

47 Modules (out of 49)

- 22 Grade A
 - 7 CMN
- 7 Grade A/F
 - 7 CMN
- 17 Grade B
- 1 Grade B/F
 - 1 CMN



- **Catastrophic Failures - 8 micro-discharge/CMN**

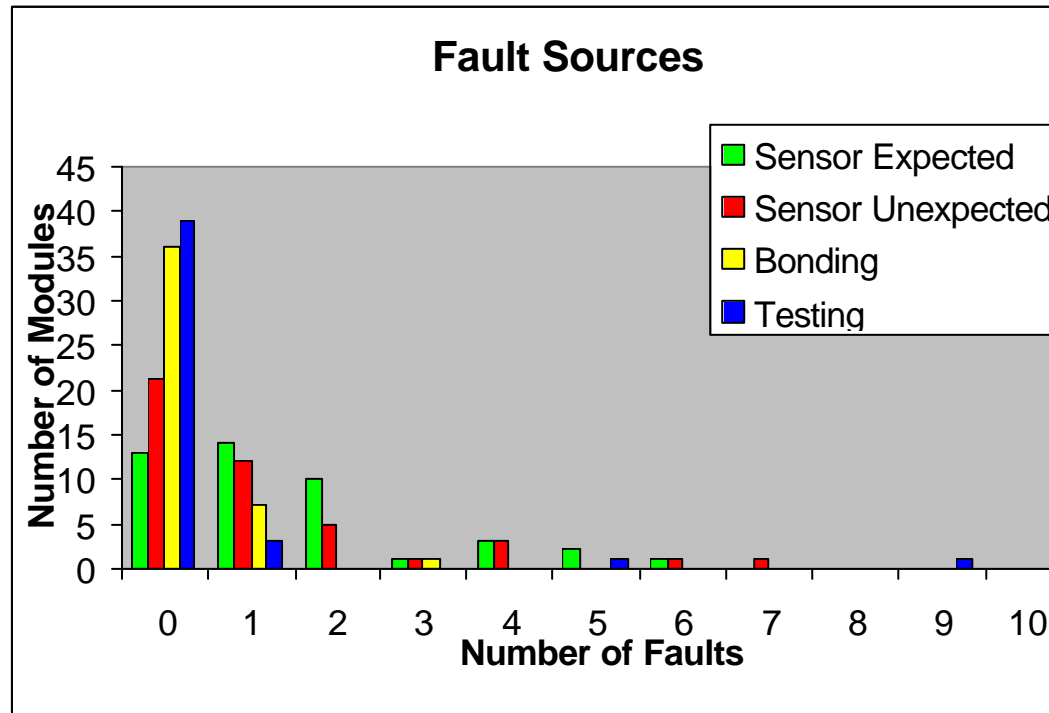


Faulty Channel Sources

Fault Sources (based on full UCSB production batch)

- Hybrid – 0.011%
- Sensor (in DB) – 0.33%
- Sensor (not in DB – 0.26%
 - Either high noise and/or visible sensor damage
- Bonding – 0.037%
 - Mostly due to hard to bond PA
- Testing – 0.074%
 - Mostly due to missing bias bond

Total faults – 0.712%
(0.598% for mini-production batch)





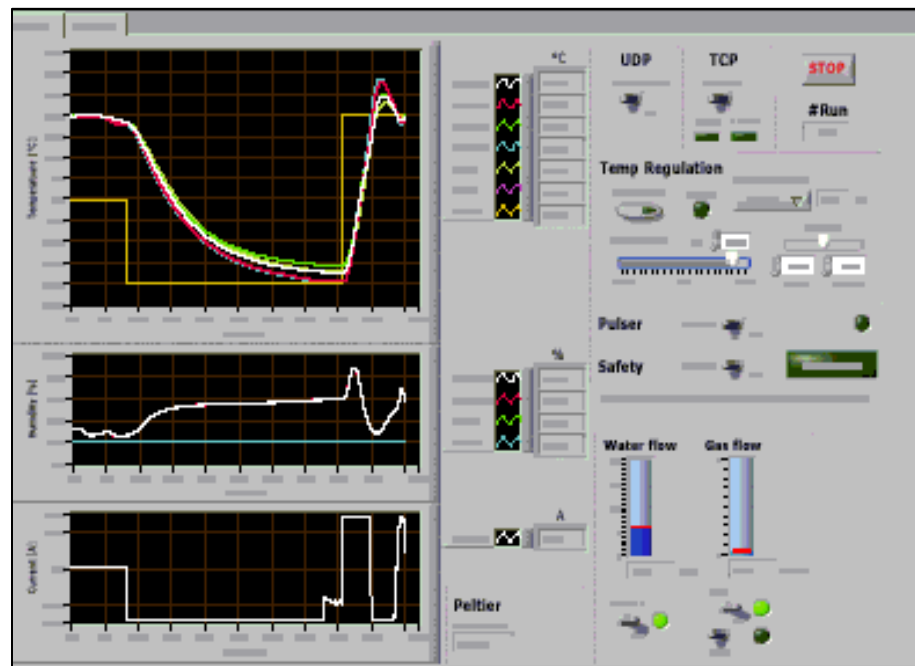
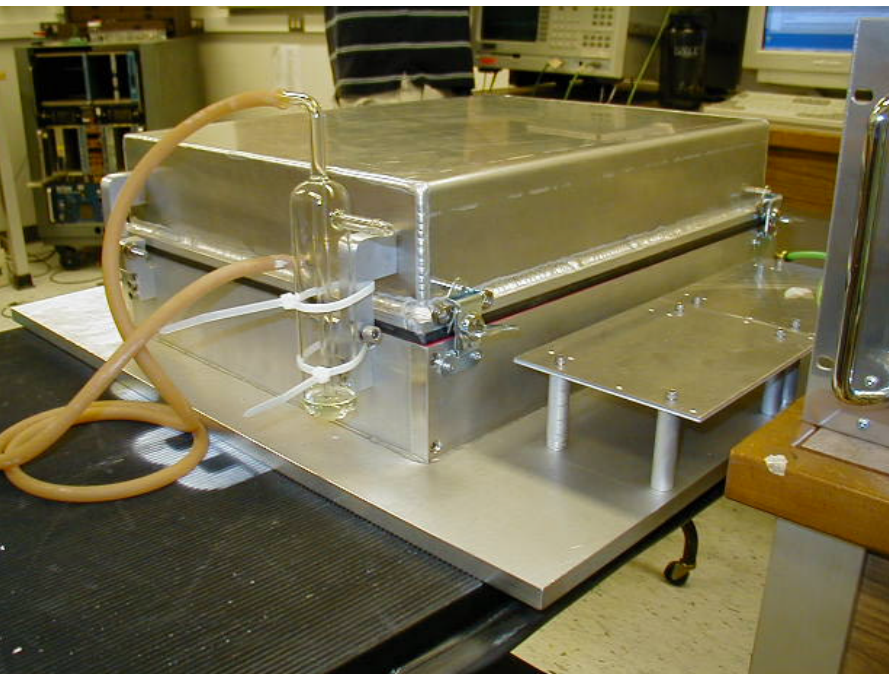
Hardware Failures

- UCSB - 4 (of 7) ARC control boards, FNAL - 1
 - 4 had tantalum capacitors blow
 - Causes failure of DCU or MUX self-test on all modules
 - 1 started to fail all modules on MUX self-test
 - No discernable cause
 - All UCSB boards were fixed by Aachen (thanks!!), FNAL is expecting the board back from Aachen
- 2 (of 6) ARCS FE
 - 1 blown fuse
 - Fixed
 - 1 unknown problem as of now
- 1 TSC-to-FED cable
 - 1 of 4 lines from differential signals open
 - Causes flaky DAQ response



New: hybrid testing at UCSB

- Hybrid testing includes:
 - Quick Test before Wirebond PA's
 - Thermal cycle with continuous ARC test and pitch adapter pulsing
 - UCSB has completed the 4 hybrid test box.





Rod testing

- Rods
 - Rods can be read out at UCSB
 - Rod test box is nearly complete
 - Rod shipment from CERN is expected. Plan to assemble and test first rod this month (this is in fact a major milestone).
- 1st Rod burn-in stand is expected to be complete in October for FNAL production line
- 2nd Rod burn-in stand completion is November for UCSB production line



Conclusions

- 103 TOB modules were produced and fully tested in US since April
- Currently TOB module production rate in US is limited by LT (Wien box) testing capabilities
 - UCSB Capacity is 10 modules per day
 - With weekend Wien box operation, the capacity of 12 modules per day is achievable
 - FNAL capacity is 6 modules per day
- Issue of noisy strips inducing serious CMN problems is real but early (low statistics) indications are that it can be mostly avoided with IV checks of sensors
- Issue of cable damage also needs to be addressed