

TOB Testing Status and CMN Issues

Claudio Campagnari - UCSB

On behalf of the US module testing groups



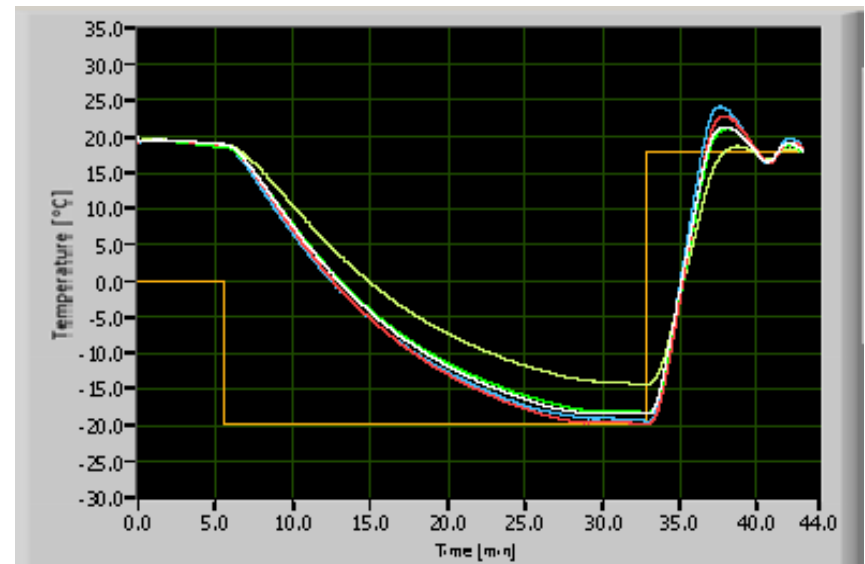
Outline

- Status Update
 - 4 Hybrid Thermal Cyclers
 - Stereo and 6 chip module production
 - Dead pipeline column fault
 - Module Burn-in (Wien Cold Box) Status
 - Grounding improvements
 - Backplane pulsing
 - First US Rod
- CMN (Micro-discharge) Problem
 - Description of problem and concerns
 - Studies performed
 - Some conclusions



Hybrid Thermal Cycler-Pulser

- Now fully commissioned
 - Many thanks to CERN group for their constant aid
 - ~40 minutes to thermal cycle 4 hybrids
- 6 hybrids had APV-PA bonded at UCSB
 - 4 6-chip hybrids
 - 1 4-chip R- Φ hybrid
 - 1 4-chip stereo hybrid
- No opens or shorts caused by bonding
- **Ready for Production**

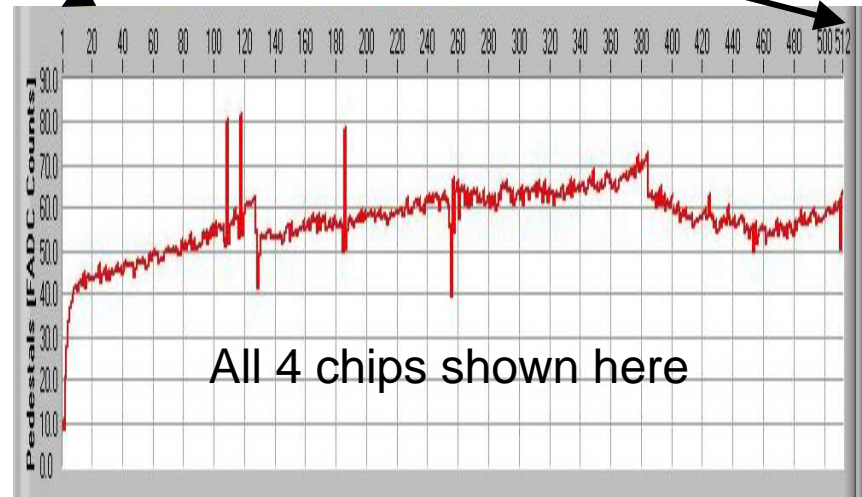
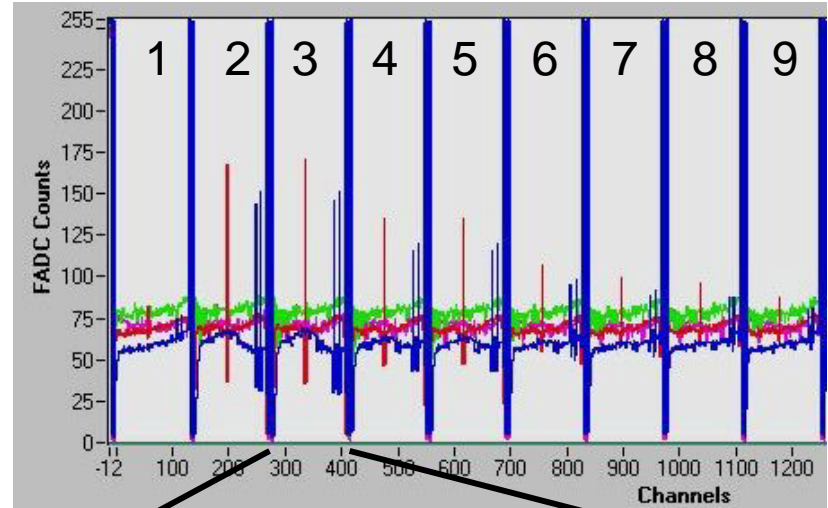




Hybrid Thermal Cycler Validation

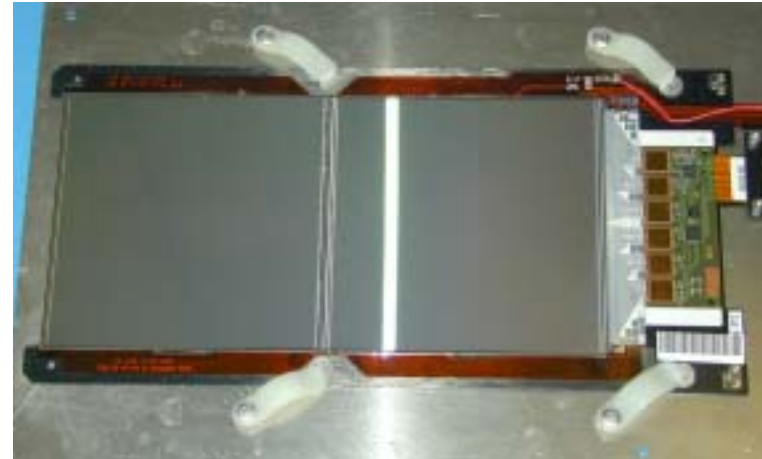
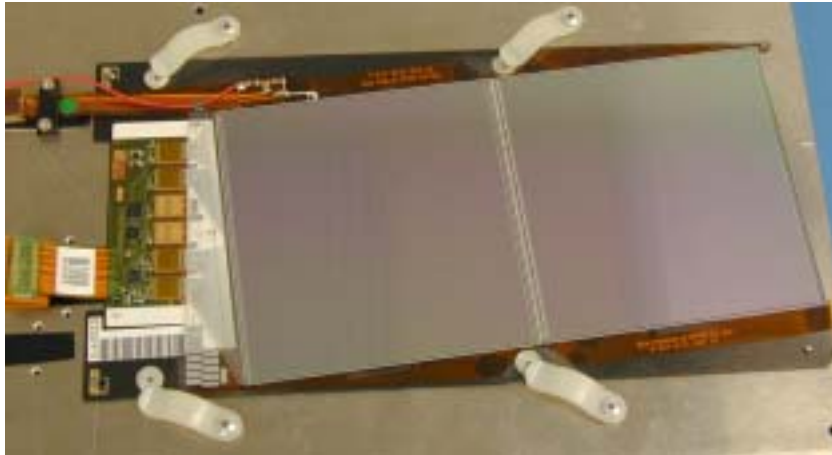
- Opens added to a test hybrid to validate PA pulser
 - Opens clearly seen in both scope mode (above) and pedestal tests (below)
- Should have no problems detecting problems in hybrid bonding

Scope mode (25 ns between each acquisition)





Modules Produced with Final Hybrids

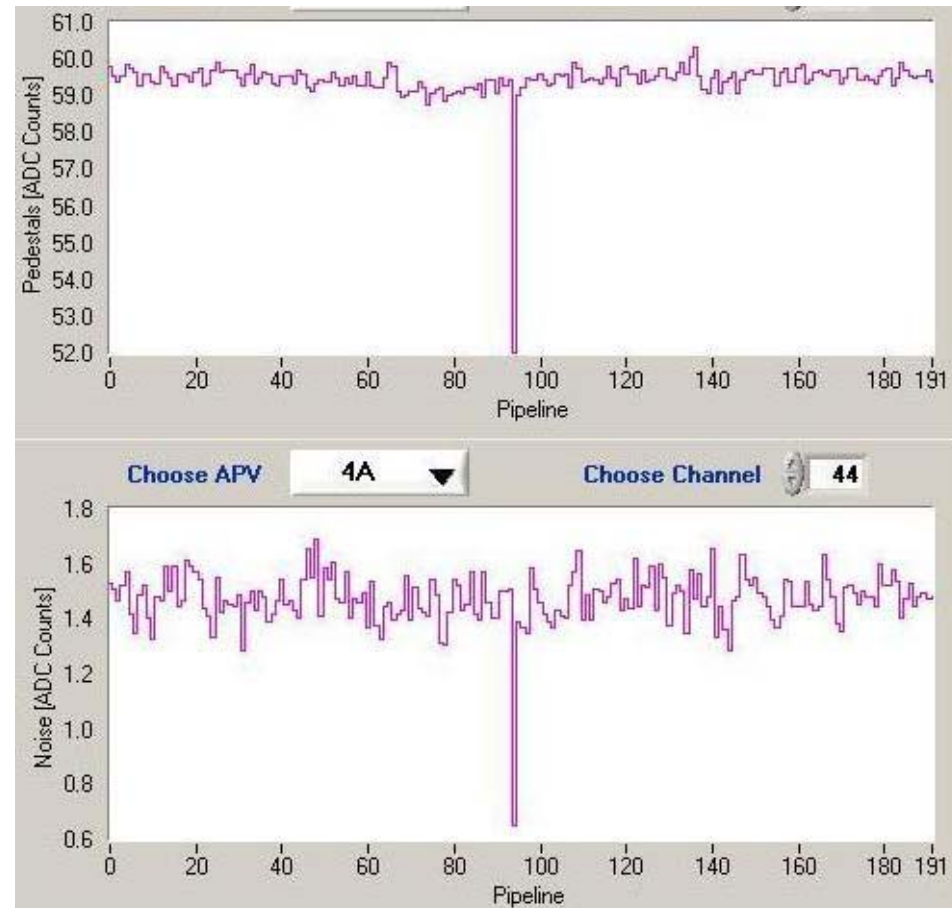


- First Stereo TOB module made!!!
 - 3 TOB stereo module produced in total
 - All well within specs mechanically and all Grade A
 - Kapton circuit was missing a trace for bias. We made it by hand with Ag Epoxy.
 - One chip has dead pipeline column
 - Found to be dead prior to module production
- 2 TOB 6-chip R- Φ module produced (first module of this kind produced!!!)
 - Both Grade A
- 1 TOB 4-chip R- Φ module with final hybrid built
 - Grade B due to known sensor faults



Dead Pipeline Column (1)

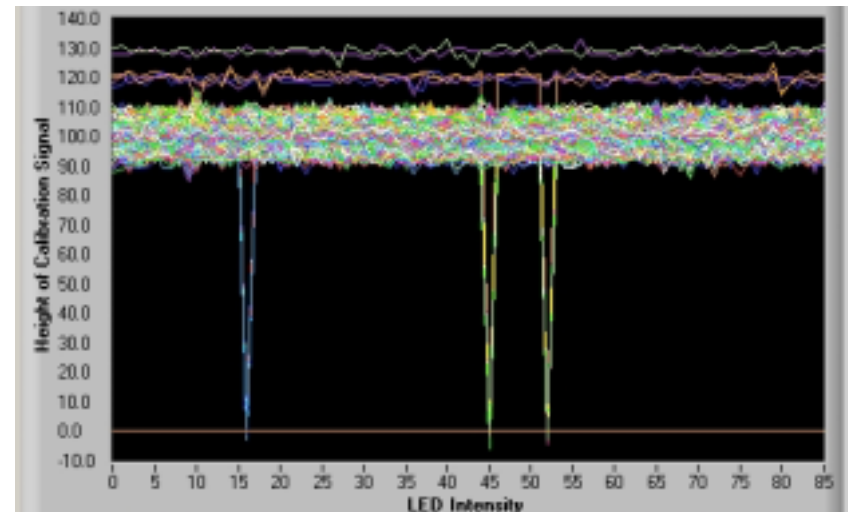
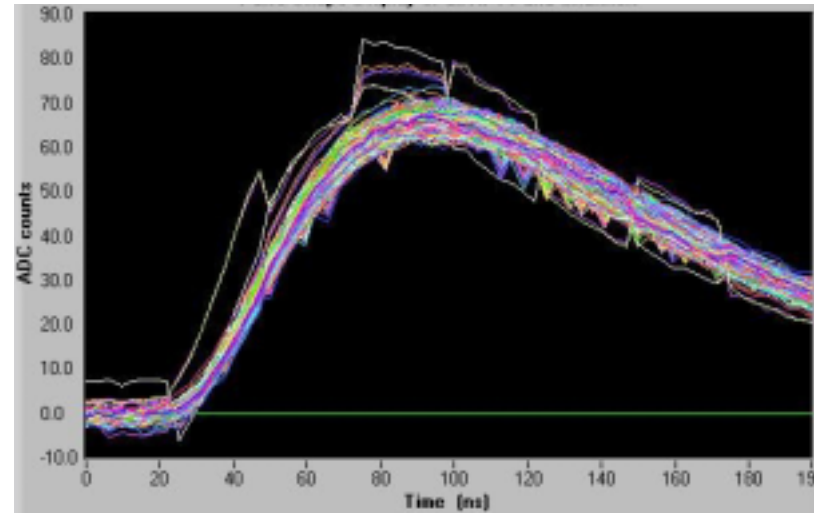
- Chip with unusual pulse shape and pinhole tests found (see next slide)
 - After conferring with Aachen and CERN, problem appears to be confined to one pipeline column
- After taking a pipeline test with many events, it became clear that the noise of a pipeline column was too low to be active (Dead pipeline column)
 - Noise is lower than APV in bare hybrid
- First time we've seen this in US
- We recommend to routinely calibrate on each column





Dead Pipeline Column (2)

- Other symptoms of dead pipeline columns
 - Pulse Shape Test
 - No calibration injection 0.5% of events
 - Causes dips in pulse shapes
 - Pinhole Test
 - 1 in 192 chance of having no calibration injection, causing channels to be marked as pinholes
- Need to modify hybrid testing procedure to find dead column prior to module assembly
 - Measuring pulse height in pipeline-like test with calibration injection would find this problem 100% of time
- Problem is not serious enough to cause rejection of module
 - ~ Equivalent to dead channel



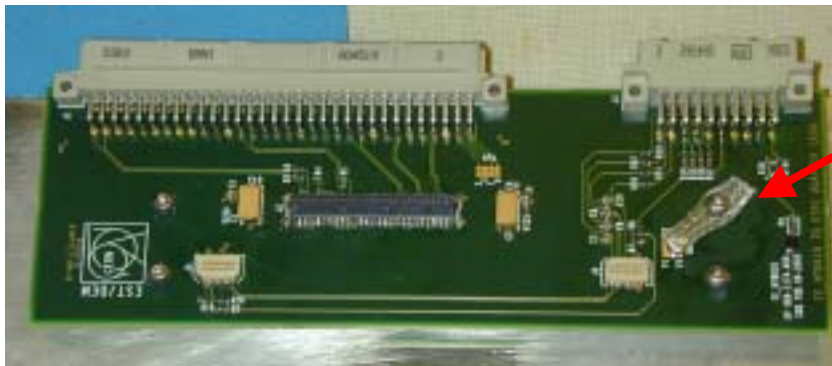
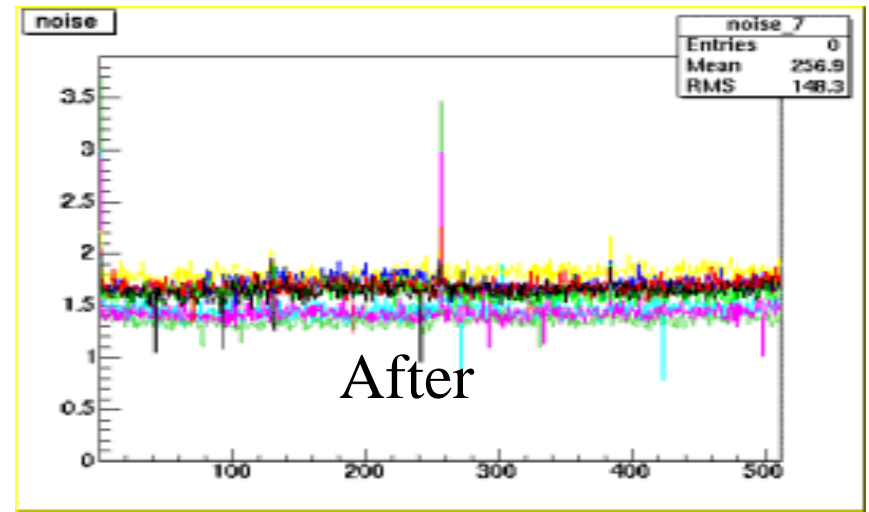
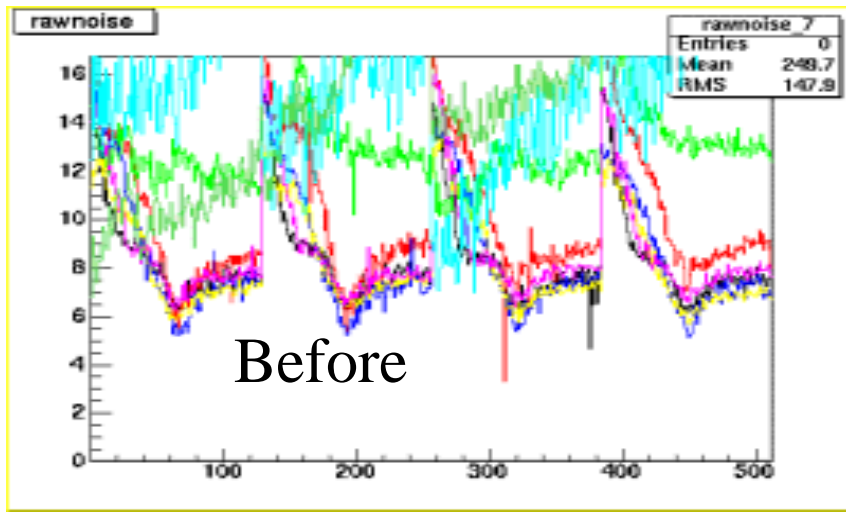


Wien Module Cold Box Status

- All functionalities demonstrated
 - Cold box fully instrumented
 - 10 UTRI, 10 PAACB, FED multiplexer, 2nd CCU and electrometers
 - Works with multiplexer, electrometers and PAACBs
 - Performed long term module tests during production run with full readout of temperatures and currents
- Since September CMS week
 - Implemented grounding scheme to reduce noise greatly with multiple modules
 - Conducted first backplane pulse tests



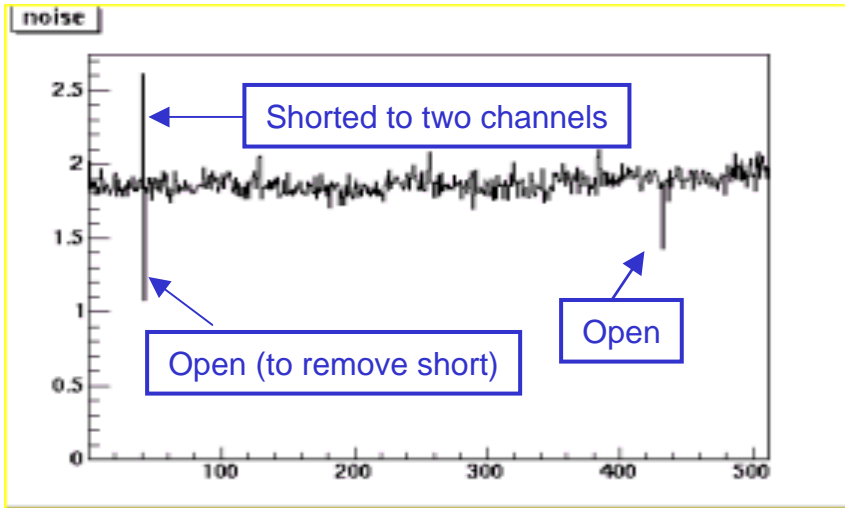
Wien Module Cold Box Noise



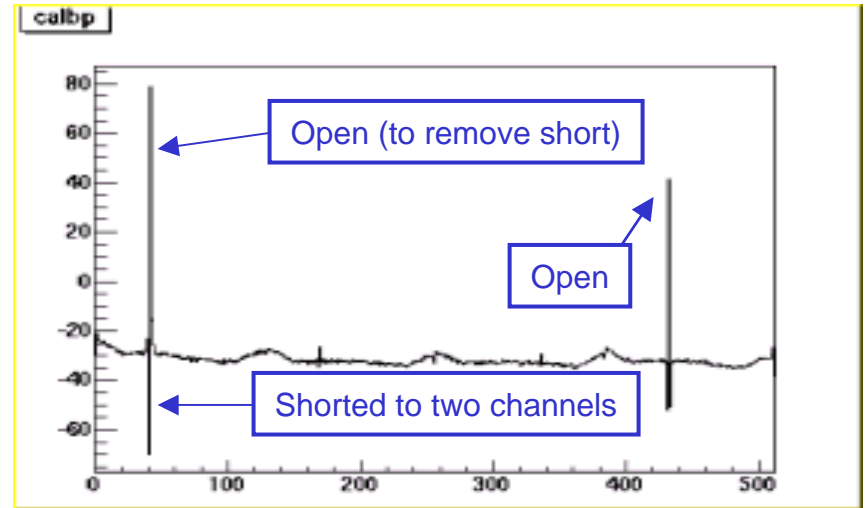
- High noise on all 8 slots tested
- Grounded hybrid-to-UTRI adapters to cold box plates.
- Noise reduced on all slots enough for defects to be seen.
 - Both at UCSB and FNAL



Backplane Pulse Test in Cold Box



Module 1025 noise with 100V bias

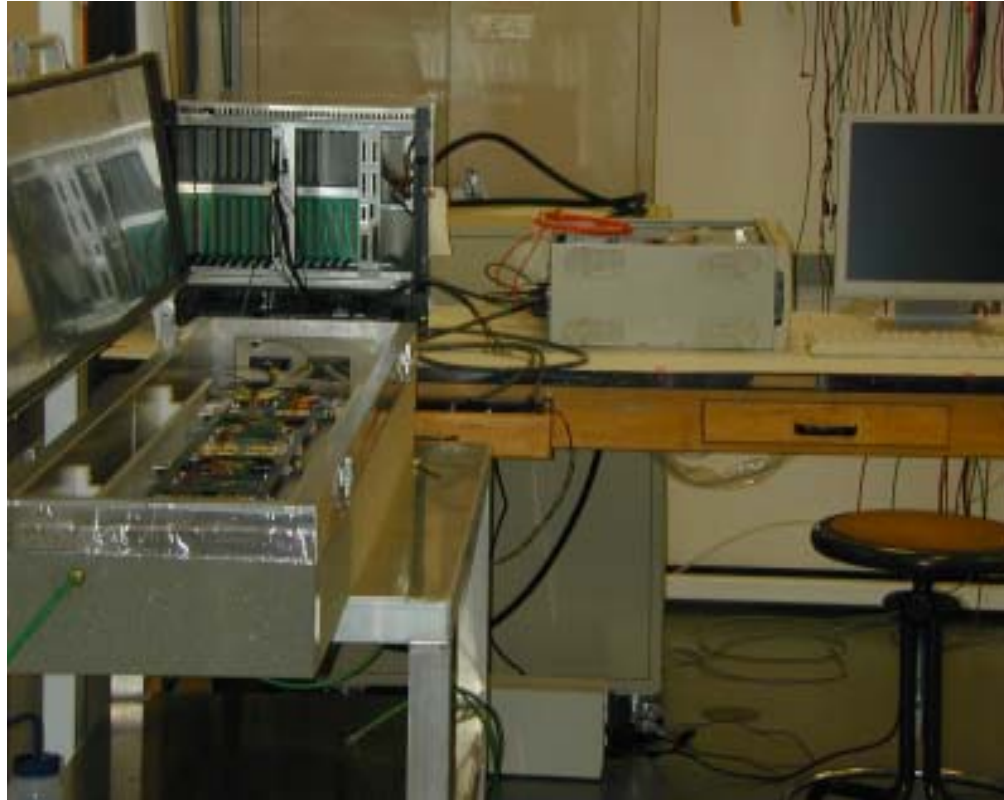


Module 1025 backplane pulse response with 100V bias

- Channel with marginally low noise shows up clearly in backplane pulse response
- Successfully tested in LT version 1.15 (needed upgrade from 1.10)



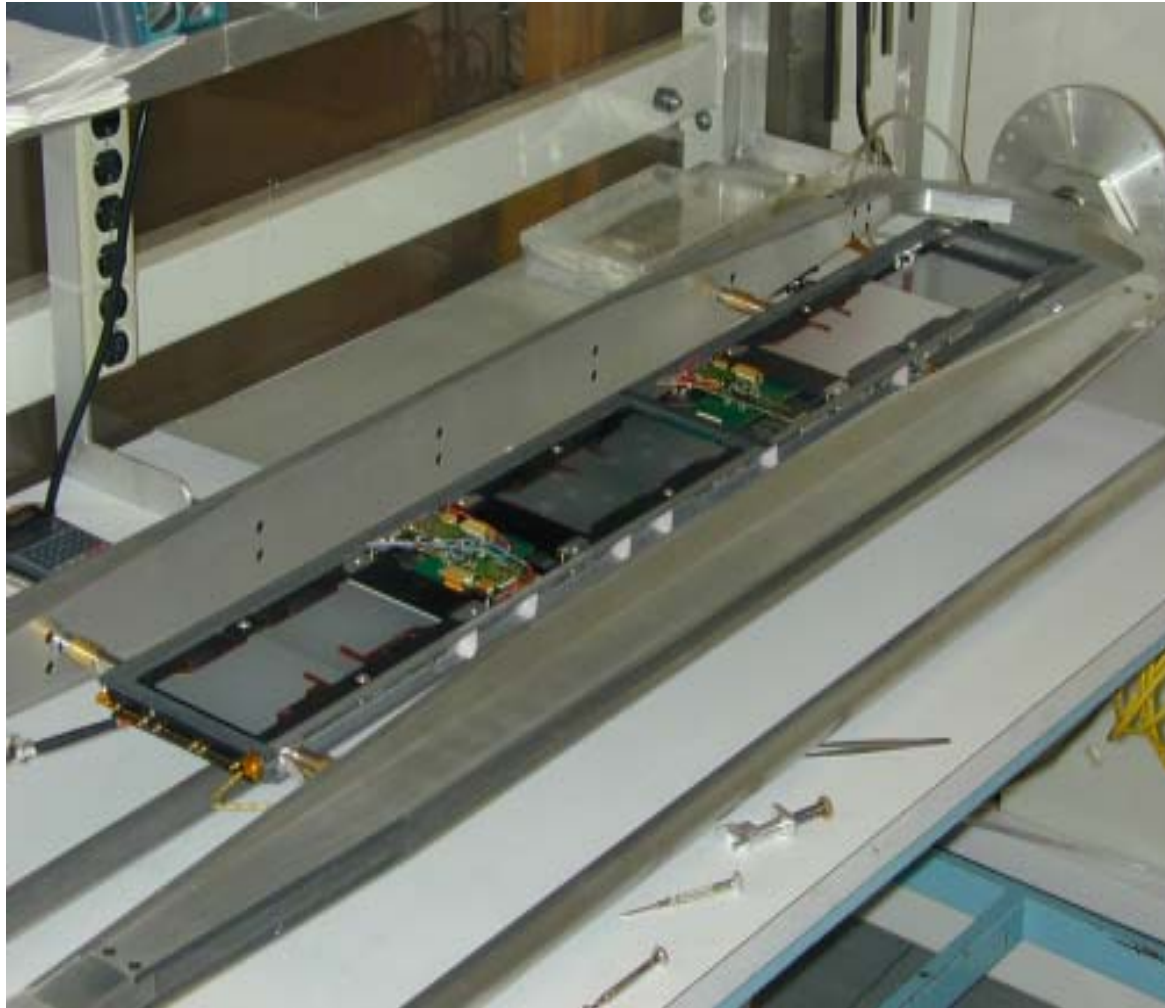
Single Rod Test Stand at UCSB



- Complete set of electronic ready to test single rods
 - Test box provides dry, dark, and electrical isolated environment
 - Connects to Rod burn-in chiller for cooling
- Prototype rod with 3 biased modules tested on stand



First Assembled Rod in US



- First rod in US fully assembled
 - Took approximately 2 hours for assembly
- Initial electric tests OK, noise under control



CMN Problem (Overview)

- 14 of 60 modules produced at UCSB exhibit large common mode noise (one chip only)
- Correlated with increase in bias current w.r.t. QTC probing
 - Initially, based on current measurement after module assembly/bonding only (in these cases, current was not measured in US before bonding)
 - Later, also with measurements made on wafers before assembly
 - Rules out hypothesis that problems due to mishandling in US
- Extremely high noise on 1-4 channels suggests that the excess current is localized to these channels
 - No obvious associated damage in visual inspection
- At UCSB, problem always appeared at first test after bonding
 - 1 module at FNAL developed problem during Wien box module burn-in after a full ARCS module characterization (more on this later)

The sampling of sensors was slightly biased toward high-fault rate sensors. Almost all from old OB2 batch.



Are the faults caused by assembly?

Extensive program of sensor probing and additional module IV measurement undertaken

- Sensors probed prior to assembly in modules
 - Sensors with $>5 \mu\text{A}$ extra current relative to sensor QTC measurement separated from others
- Module then assembled and bias bonded to first sensor
 - IV measured
- Bias is bonded to second sensor
 - IV remeasured
- Module is then fully bonded and tested



IV Correlation with CMN problems

- Significant differences from QTC sensor probing have been found
 - ~5% of sensors have current increases $>20 \mu\text{A}$ from QTC prior to module assembly
 - Roughly consistent with the rate of occurrence of the CMN problem (aka micro-discharge) observed at various production sites
 - August Production Tests of IV Pre-Screening
 - Of the 20 modules with sensors whose IV curves in the QTC database matched those obtained in UCSB re-probing, only one showed any change in current and CMN problem
 - This module showed regular current in some tests afterwards so the problem appears to be intermittent
 - Of the 5 modules with sensors whose IV curves in the QTC database were very different from those obtained in UCSB re-probing, 4 had serious CMN problems
- Rules out hypothesis that problems due to mishandling in US



Summary of IV tests of sensors in US

- Three Sets of Sensors Probed
 - Old OB2 (Week 47 2001 to Week 21 2002)
 - 75 Sensors
 - Old OB1 (Week 43 2001 to Week 2 2002)
 - 31 Sensors
 - Newer OB2 (Week 38-41 2002)
 - 97 Sensors
- Environmental conditions tightly controlled
 - Temperature 23.1-23.8 C
 - RH < 30% at all times

Includes sensors built into modules (as discussed earlier)
and sensors from more recent batches



IV Test Results

Probed Current @ UCSB (400 V) – QTC Measurement (400 V)

Sensors	> 2 μA	> 5 μA	>10 μA	>20 μA	>100 μA	< -2 μA	<-5 μA	<-10 μA
Old OB2	15%	9%	8%	5%	1%	8%	3%	1%
Old OB1	6%	3%	3%	3%	3%	3%	0%	0%
New OB2	3%	3%	0%	0%	0%	2%	2%	0%

- An increase greater than 5 μA can cause common mode noise
 - Rate of CMN problem consistent with percentage of old OB2 sensors with a 5 μA increase
- **Agreement much better with newer OB2 sensors**
 - *(Produced Week 38-41 of 2002)*
 - Factor of ~4 decrease in the rate of higher (and lower) current measurement at UCSB relative to old OB2 sensors
- **We would like to also study the 2003 batches**

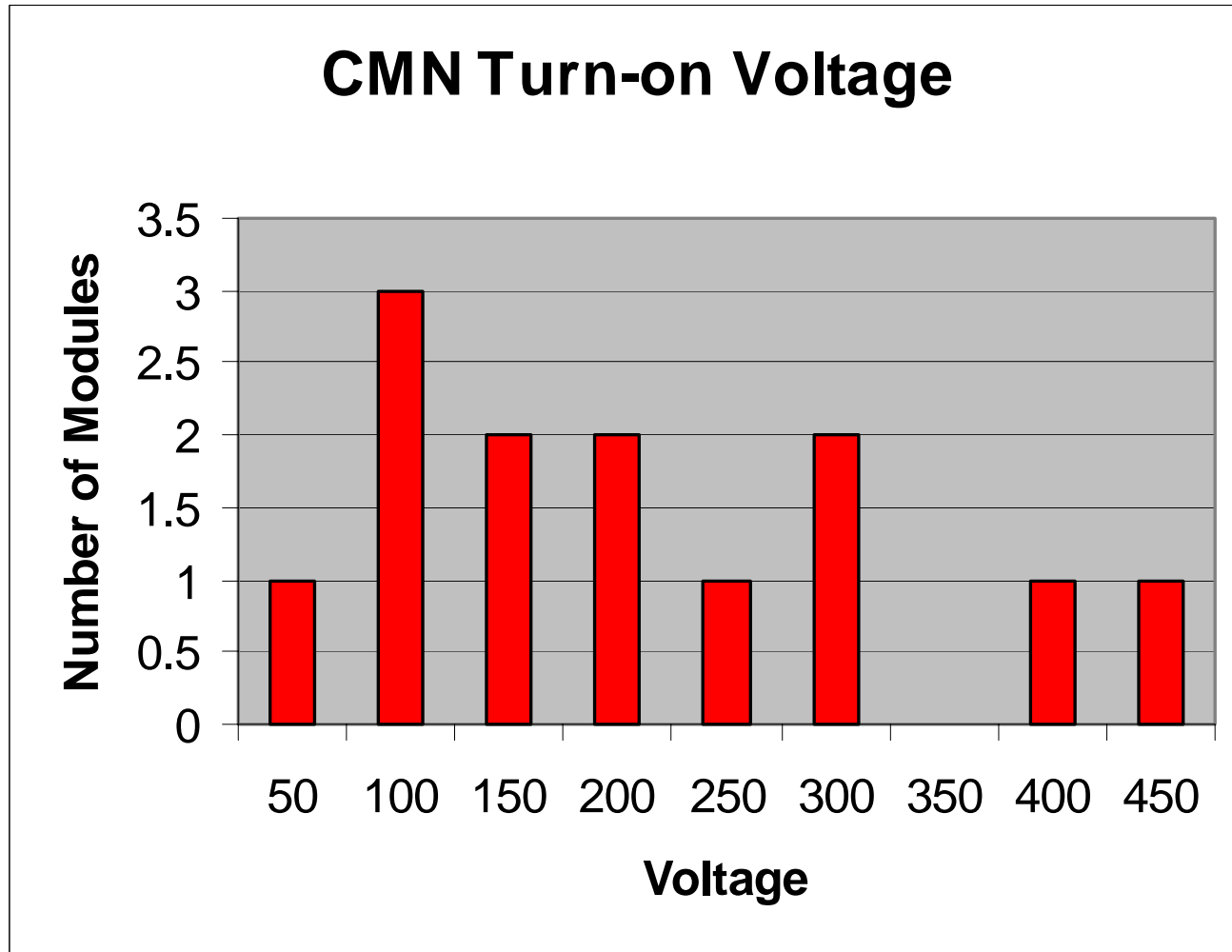


Observations on CMN problem

1. It can have an onset at any bias voltages
2. It can cause serious levels of Common Mode Noise (CMN)
3. CMN subtraction in the FED does not always eliminate it
 - More sophisticated algorithm may work ?
4. Has been seen to develop “spontaneously”
 - One FNAL module started showing during LT test
5. Newer sensors seem better



CMN Turn-on Voltage

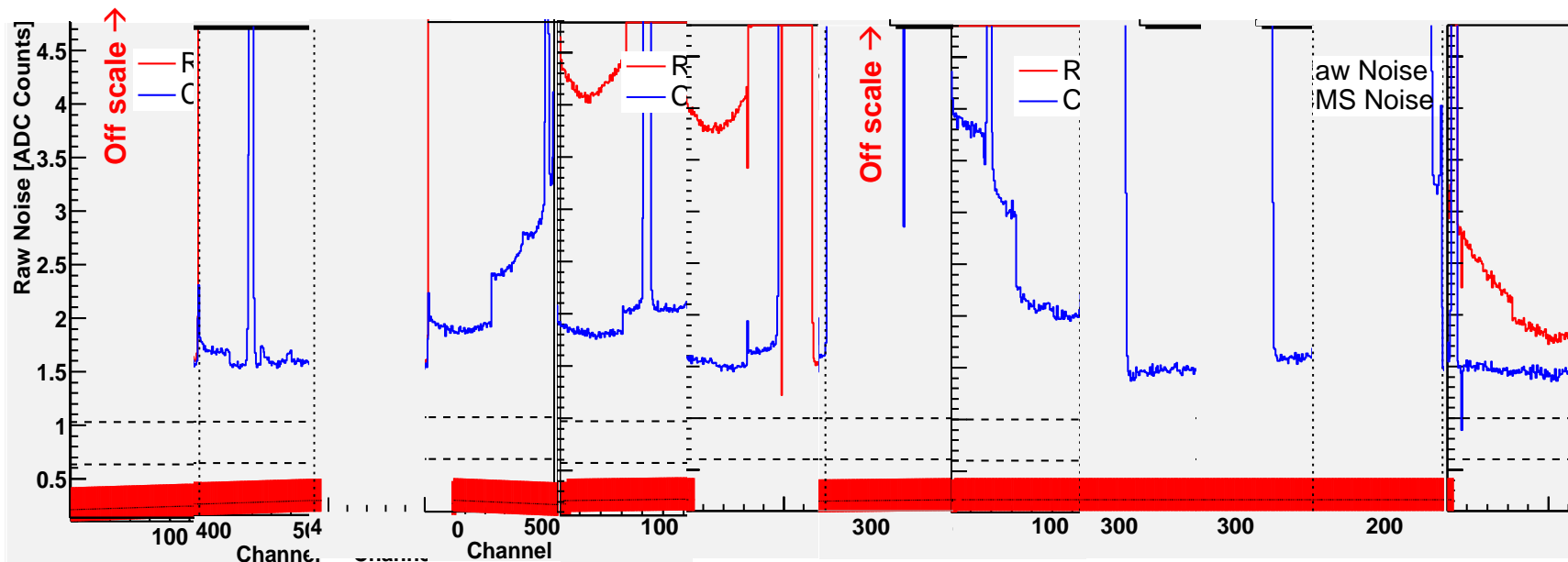




Common Mode Subtracted Noise

25 ADC

6.5 ADC



Module #: 869 881 1010 1011 1013 1014 1015 1016 1030 1031 1038 1042

Chips with CMN (micro-discharge problem)

Common mode subtracted noise in blue

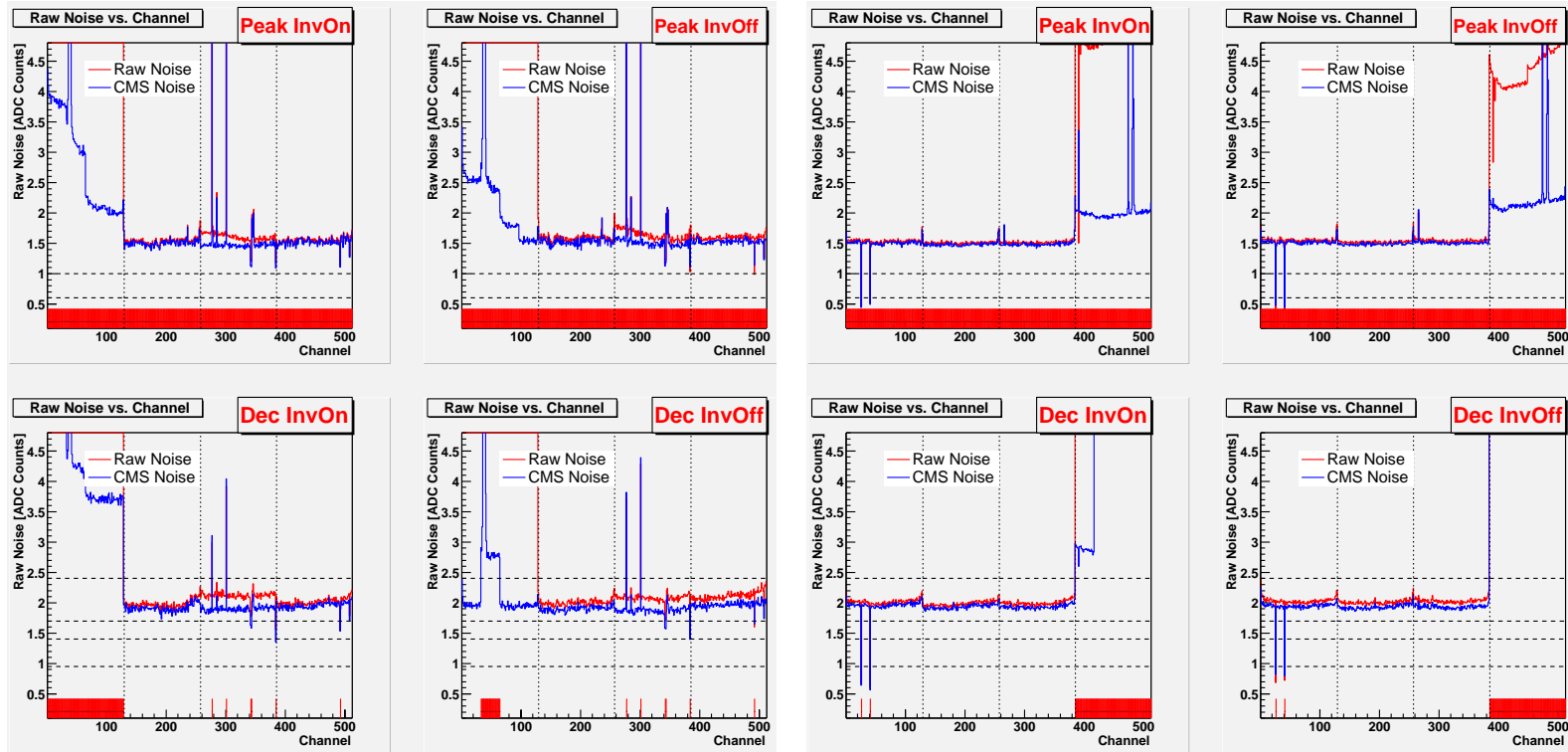
**For majority of modules with problems, the CM subtraction is imperfect.
7 of 12 have >2.0 ADC noise
3 of 12 have more than twice the usual noise**



Common Mode Subtraction Variation

Module 1016

Module 1010

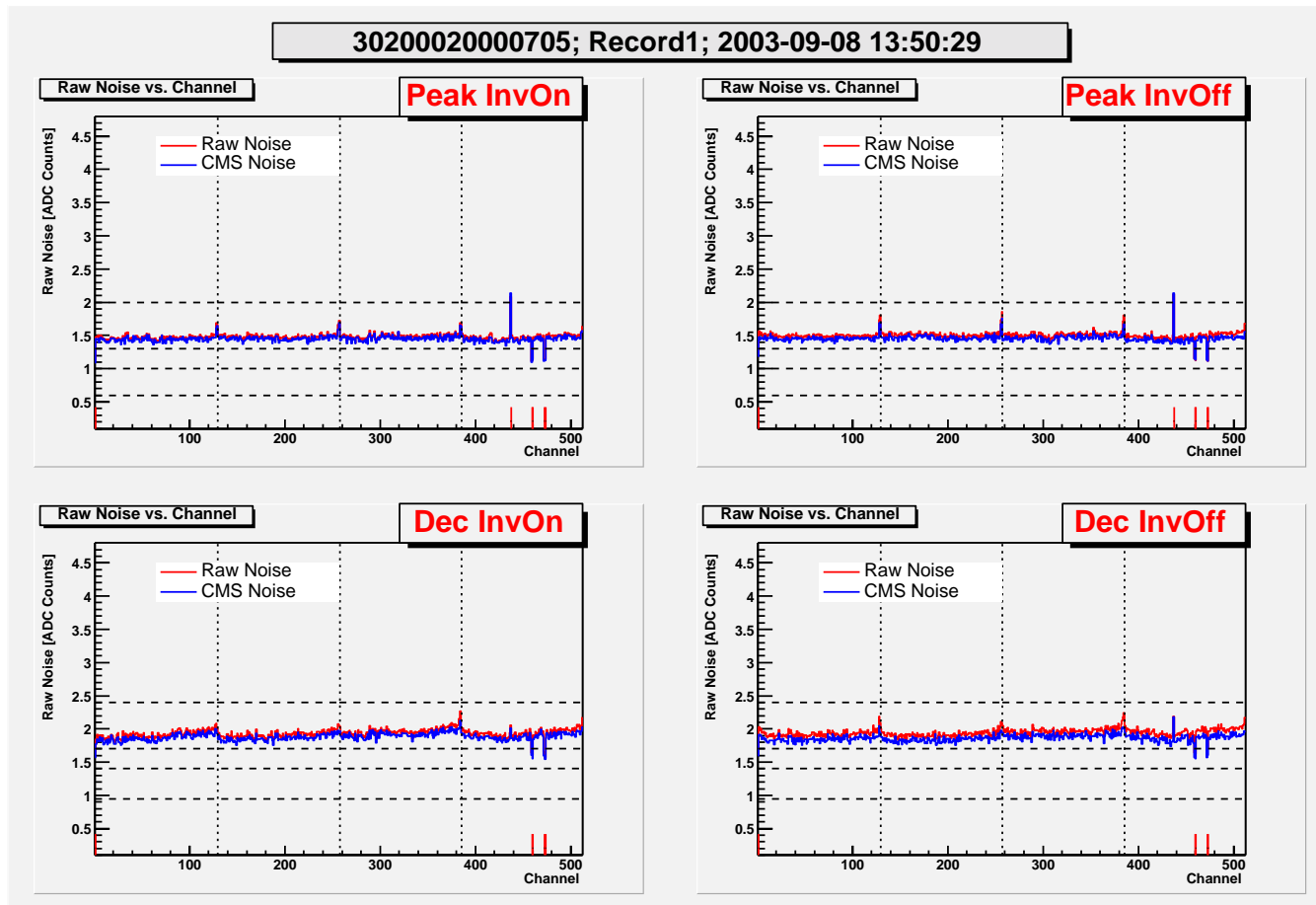


- Common mode subtraction results clearly vary
 - Answer differs mode-to-mode or test-to-test
 - **Would yield varying signal efficiency/noise during data taking**
 - **Not clear how this will evolve with time/radiation**



Module 705 before LT (FNAL)

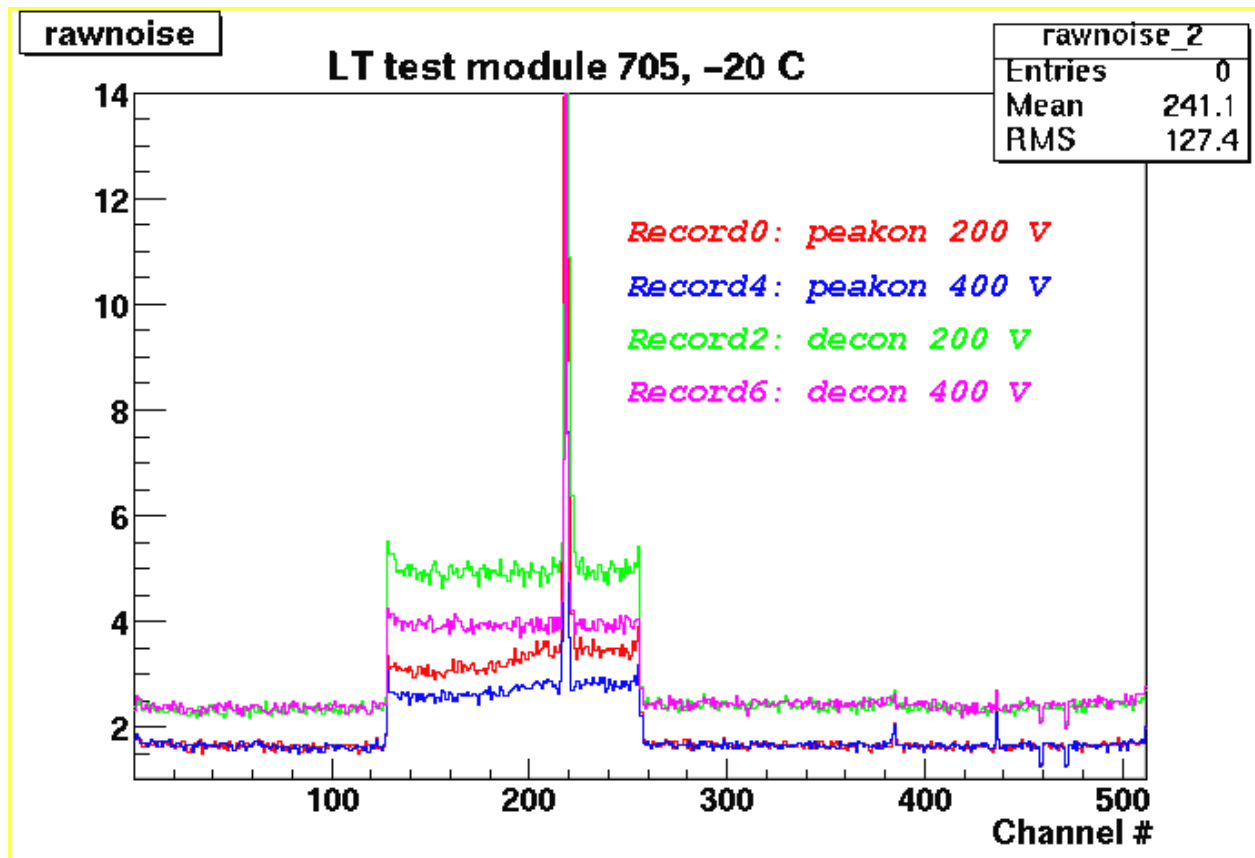
- After assembly module was tested (09/08) on ARCS at 400 V and graded “B” (6 faulty channels). No problems observed.





Module 705: LT data (FNAL)

- Data taken at -20°C on Sept.19 (10 days after the first test). A group of high noise channels is seen around channel 219 and increased CMN is seen in chip #2

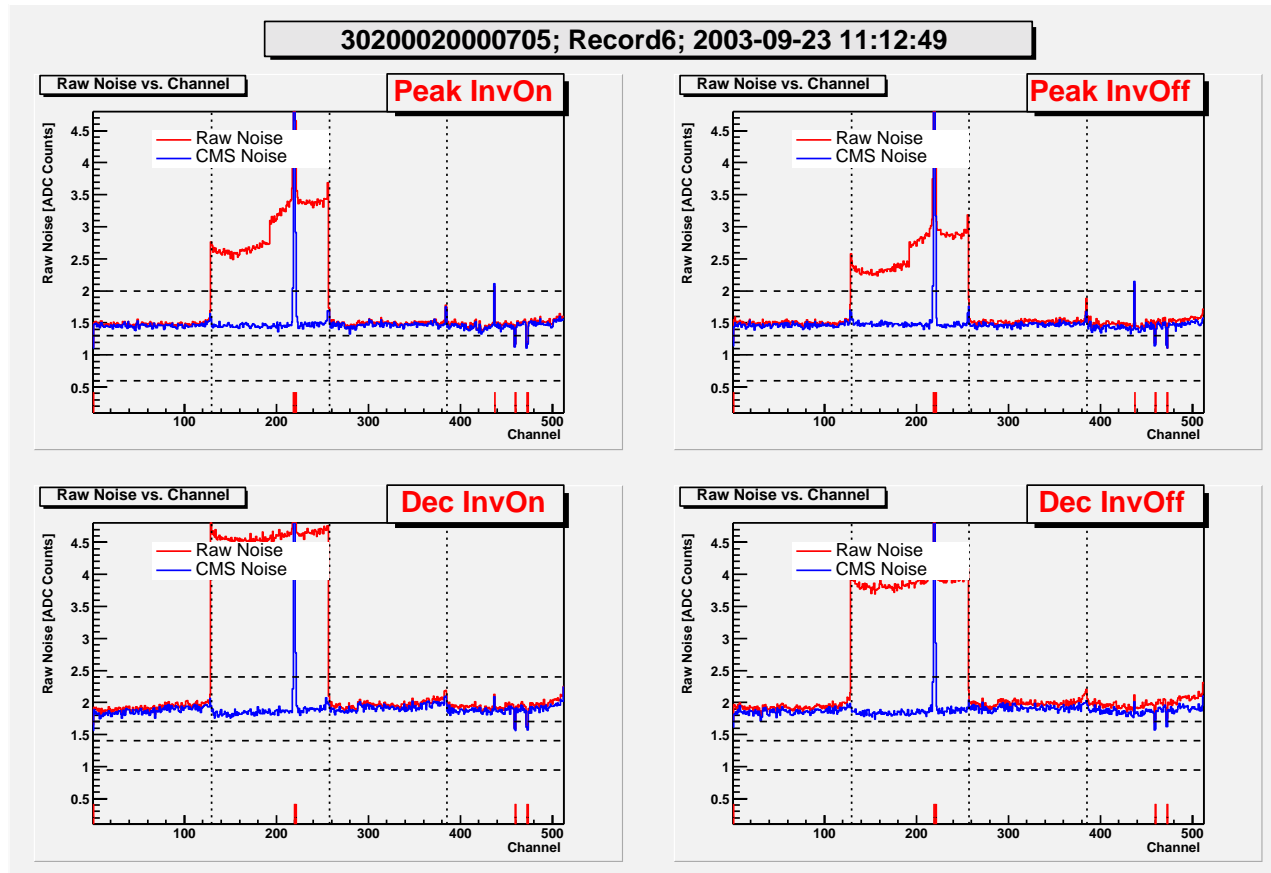




Module 705 after LT – I (FNAL)

- Module was re-tested on ARCS on 09/23. High noise in channel #219 and high CMN is observed at 400 V. At 200 V channel #219 has only slightly higher noise than the rest of the channels

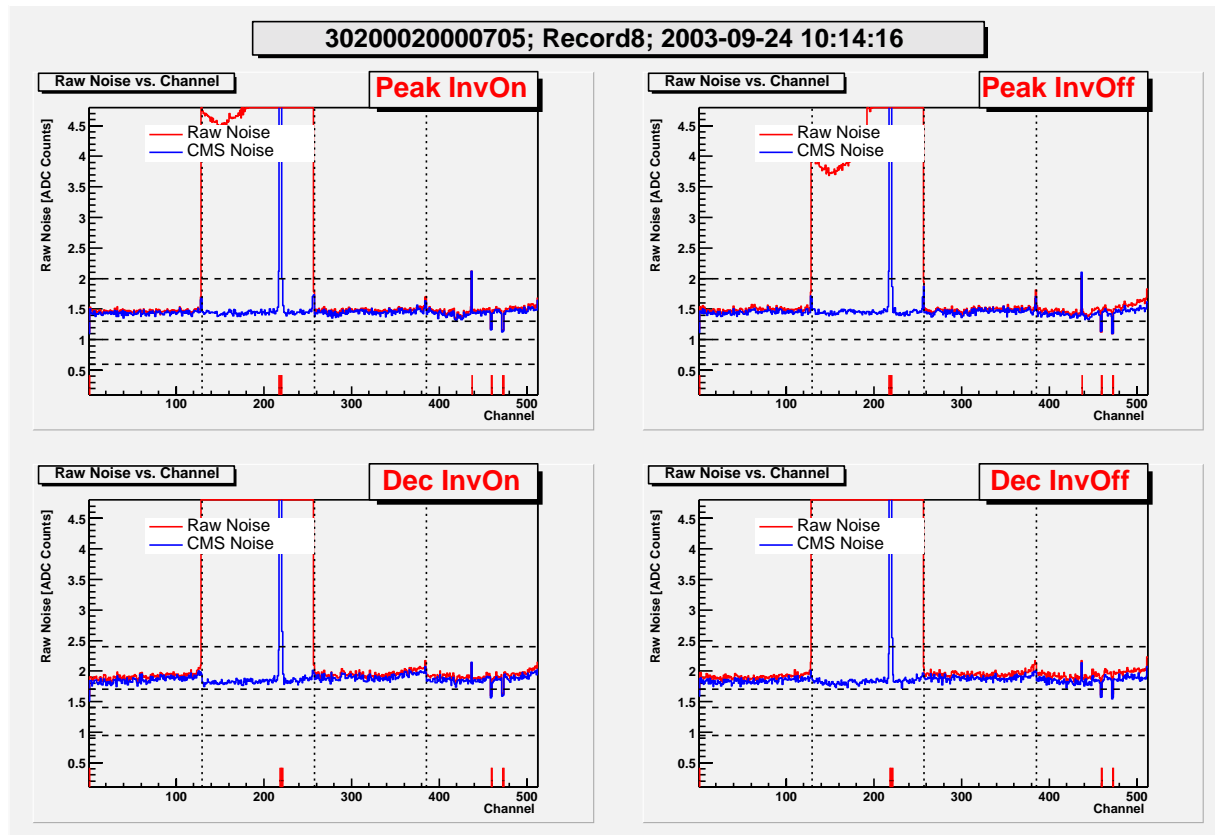
400V





Module 705 after LT – II (FNAL)

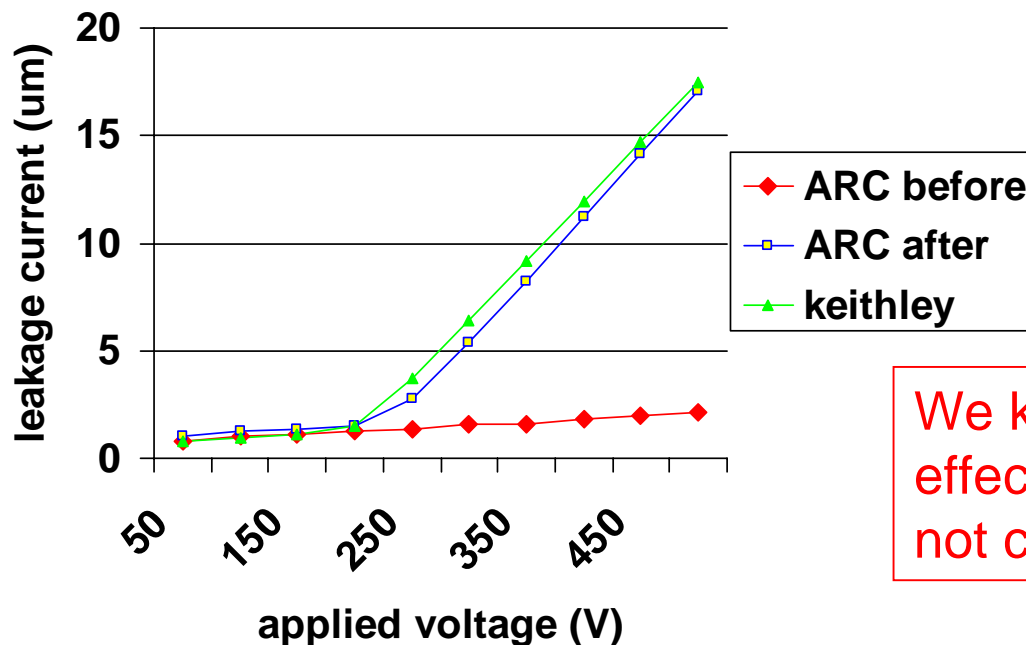
- On ARCS kept module at 400 V for 30 minutes before testing (to allow current settle down)
- CMN did not go away, it became even higher





Comparison of IV curves (FNAL)

- “before” measurement is taken on 09/08 on ARCS before LT
- “after” measurement is taken on 09/23 on ARCS after LT
- green curve is a measurement done using Keithley on 09/24 with 1 minute interval between steps



No visual defects are observed on the sensors around noisy channel #219

We know it is not a humidity effect: 3 weeks in dry air did not cure it



Conclusions (1)

- The CMN problem appears to be a sensor problem
 - Not created during module assembly or bonding
 - No visible damage or indication of defects from sensor QTC
- Pre-screening sensors (measuring IV) in US appears to improve situation greatly but:
 - We do not know how the problem will evolve
 - Rate of appearance vs. time, power cycles, etc.
 - Changes with radiation damage
 - How problem parts will act in sub-structures with final electronics and power supplies
 - Do not currently have provisions to pre-screen in US production centers



Conclusions (2)

- It is encouraging that newer batches of sensors seem to be better
 - But not perfect
- We hope that the sensor group can pursue this issue further, establish some understanding of the mechanism, and hopefully, find a fix