X-Calibration Common Testing Issues:

Grounding, Environmental Noise, and Coding

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Outline

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- Results
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  - Pulse Height Measurements
  - Pinhole Test
  - Gain Measurements
- Suggestions for bad channel description
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- Differences between ARCS/LT software
  - Algorithmic
  - Common mode subtraction (CMS) Input Parameters
  - Bad Channel Definition

Motivation

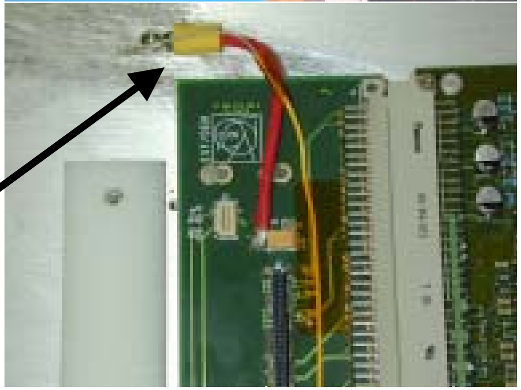
- Modules produced/tested at a large number of sites worldwide
- Uniformity in testing results is necessary in such a distributed system
  - X-calibration important step in achieving uniformity
- To achieve uniformity
  - Common algorithms
  - Common set of tests
  - Common requirements
  - Control over testing environment
- To initiate this process:
  - Investigate testing issues relevant for x-calibration
    - Grounding, environmental effects, etc.
  - Look for differences in the ARCS and LT code
    - Algorithms
    - Common mode input parameters
    - Requirements

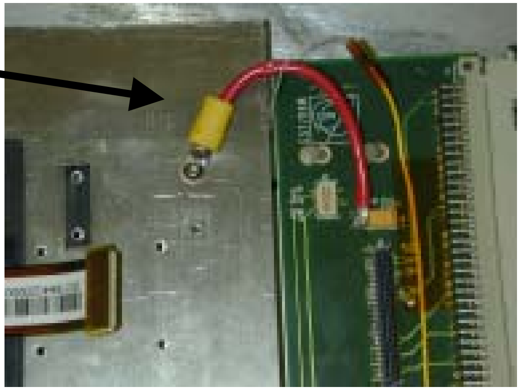
X-Calibration Testing Study

- Attempt to derive “minimal” set of tests to find faulty channels as precursor to x-calibration
  - Efficient, descriptive, redundant
- Tried to qualitatively describe effects of grounding and environmental noise sources
  - How much common mode noise acceptable?
  - How stable will testing be over 2 year period?
- Used first UCSB pre-production TOB module
  - Examples of PA-sensor opens, sensor-sensor opens, pinholes, and high current channels
    - Shorts have not yet been introduced
- Write-up available at hep.ucsb.edu/cms/xcalibration.ps

Test Setup

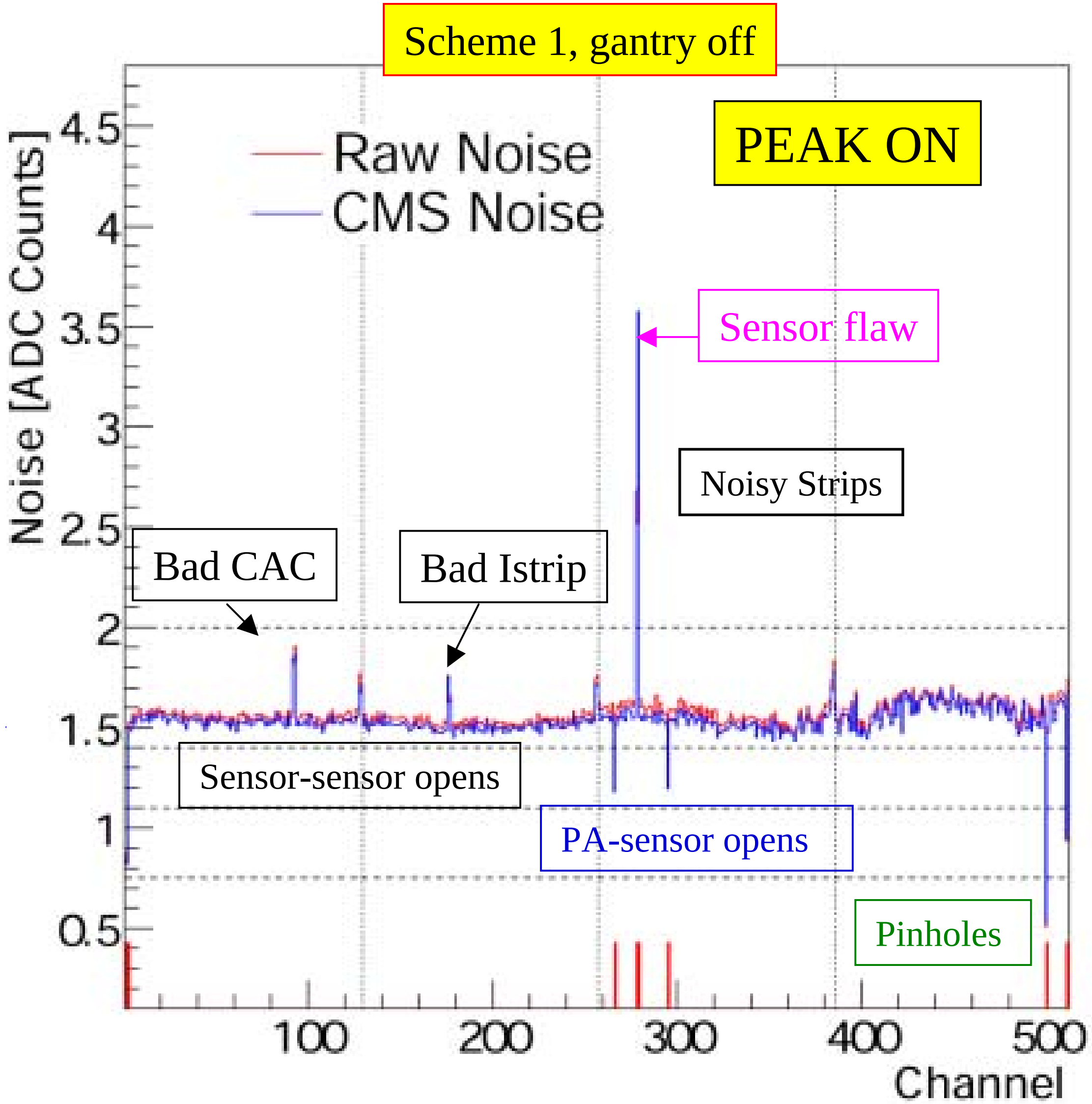
- ARCS system with new FE, LED system and 6.0β software
- Floating LV and HV supplies
- Clamshell
  - Module holding plate in clamshell but isolated
    - > 1cm from metal shell
  - Grounding achieved with large gauge wire to hybrid-to-utri adaptors
- Four grounding schemes studied
  - Both module holder and clamshell floating (Scheme 0)
  - Module holder floating, clamshell grounded (Scheme 1)
  - Module holder grounded, clamshell floating (Scheme 2)
  - Both module holder and clamshell grounded (Scheme 3)
- Nearby gantry used as source for broadcast noise
  - Test taken with/without gantry in operation





Noise Measurements (1)

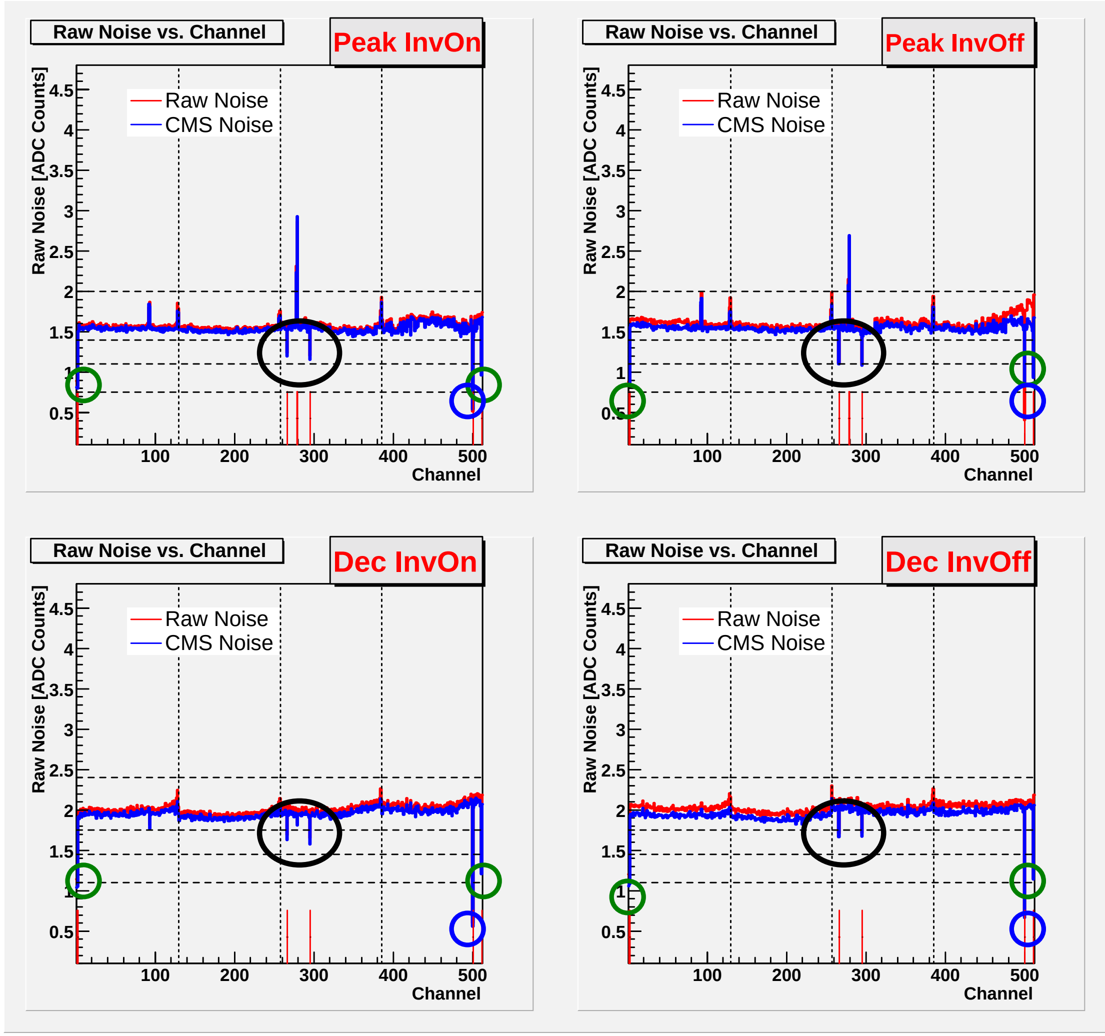
- Grounding schemes 1 & 3 give least amount of common mode noise
  - Prefer scheme 1 as closer to ideal Faraday cage
- With low common mode noise (< 0.5 ADC) distinct noise levels for sensor-sensor and PA-sensor opens and pinholes
  - Consistent levels in 8 modules tested at UCSB and 3 at FNAL with these grounding schemes



Noise Measurements (2)

Scheme 1, gantry off

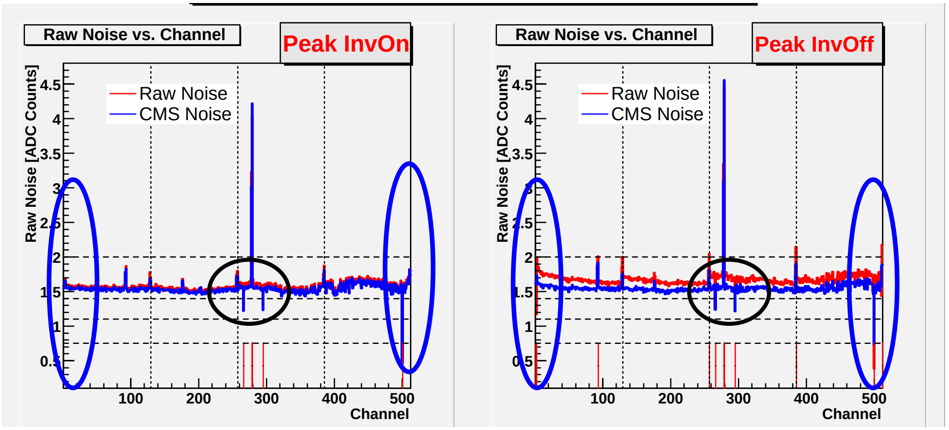
- Using grounding schemes 1 & 3, the distinct noise levels are also visible in all modes and inverter states tested



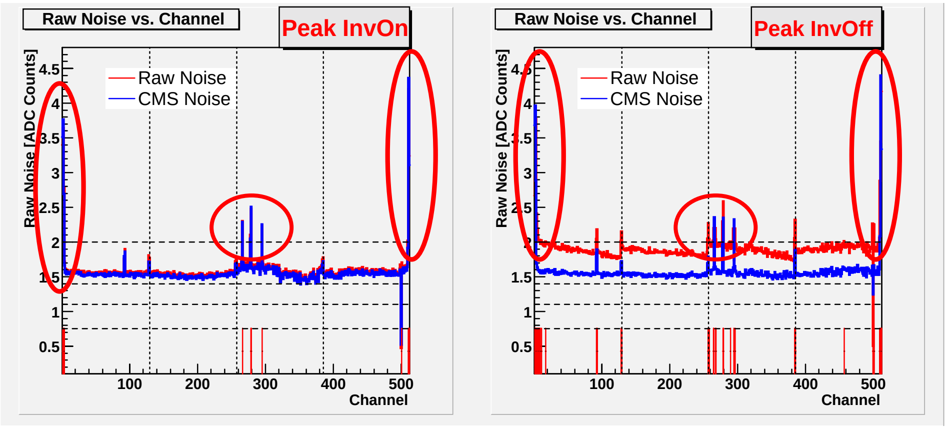
Noise Measurements (3)

- Even relatively low amounts of common mode noise makes noise levels of opens unpredictable
  - Schemes 0 & 2 have higher common mode noise
    - Presence of common mode noise indicated by difference in Raw Noise and CMS Noise in Peak Off mode
  - Noise can be lower than, equal to, or higher than good channels
- Common mode noise also indicator of sensitivity to environmental noise sources
- ***<u>Strongly suggest common mode noise in peak off mode required to be less than ~0.5 for testing</u>***
  - Use multiple bad noise levels for the different faults

Scheme 2, nearby gantry off



Scheme 2, nearby gantry on

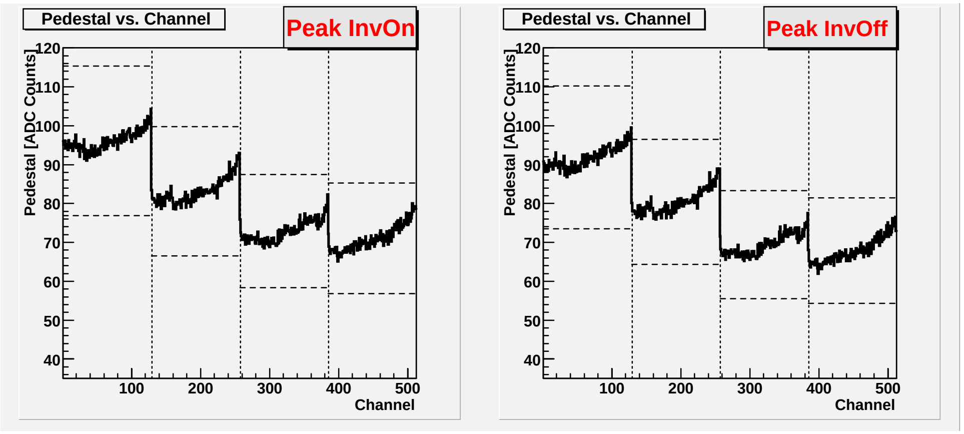


Pedestal Measurements

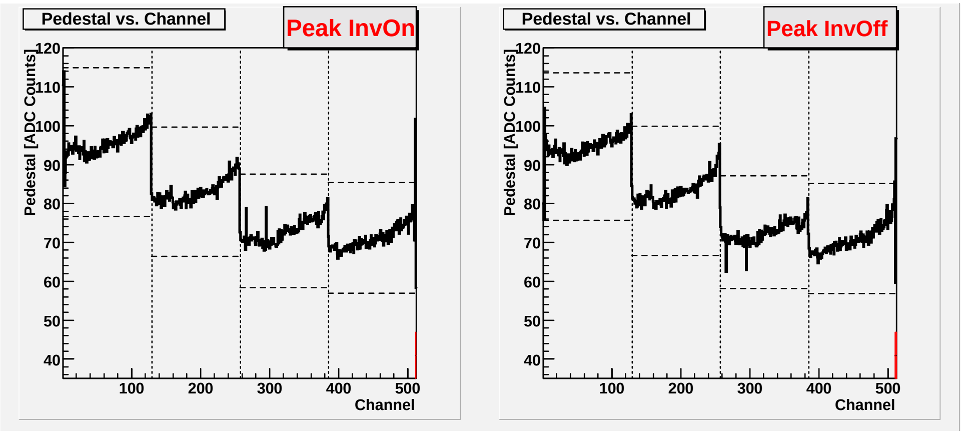
- Pedestal measurements are not very sensitive to grounding/local noise sources
  - But opens, shorts, pinholes, etc. not very different than good channels

[Pedestal test not useful for finding bad channels]()

Scheme 1, gantry off



Scheme 0, gantry on



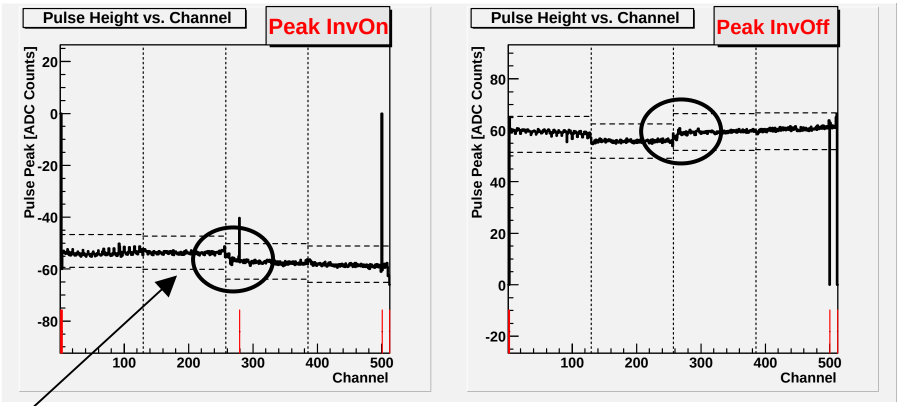
Pulse Height Measurement

- Open channels differ from normal channels at same level as the non-uniformity of the calibration response

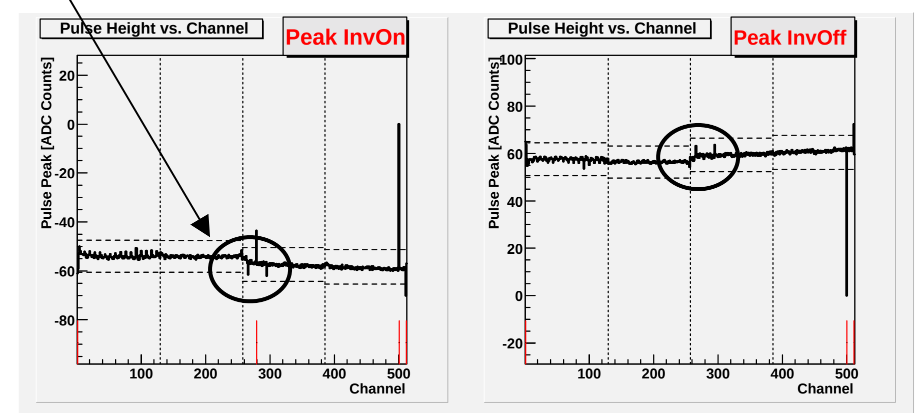
<u>Opens can easily be missed by the pulse height test</u>

- Plots shows tighter ±12% bands

Scheme 2, gantry off



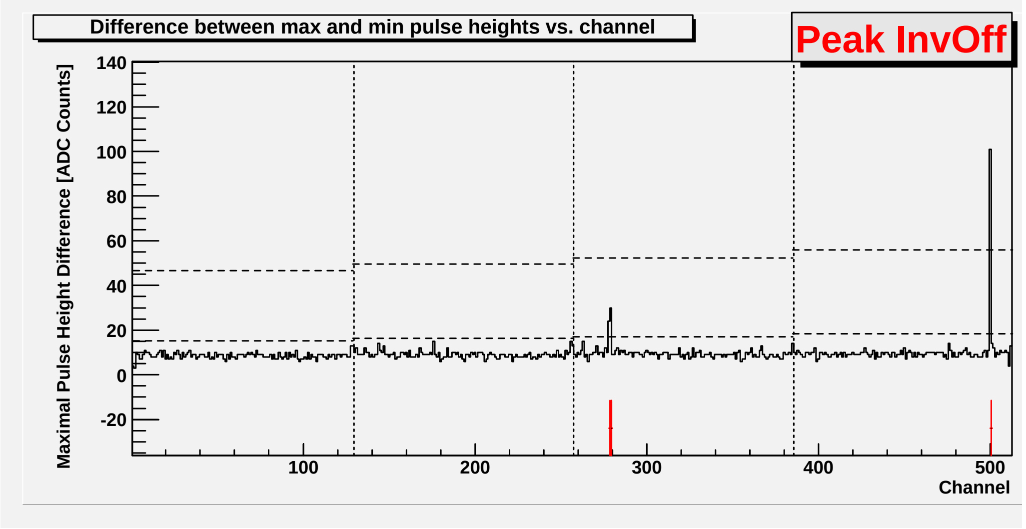
Scheme 1, gantry off



Pinhole Test (Continuous LED)

- Pinhole test works exactly as designed
  - Insensitive to grounding or local noise sources
- Two levels marked for bad channels
  - Pinholes
  - Noisy Strips

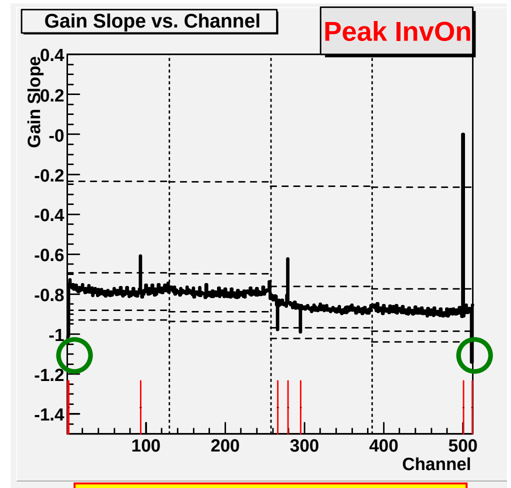
Scheme 1, gantry off



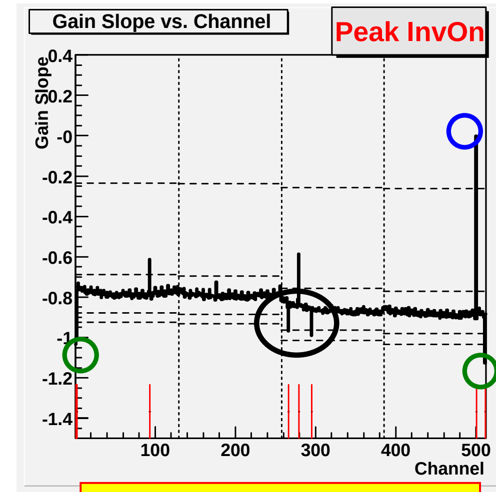
Gain Measurements

- *Gain measurements are insensitive to common mode noise and local noise sources*
  - Thanks goes to Aachen's work in coding test
- Distinct gains for sensor-sensor and PA-sensor opens and pinholes
  - Consistent levels in 8 modules tested at UCSB and 3 at FNAL

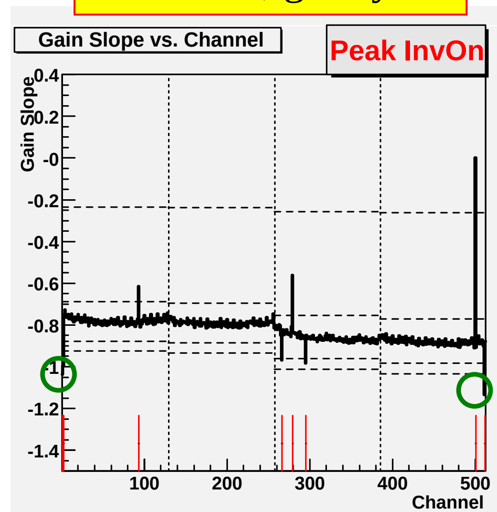
Scheme 0, gantry off



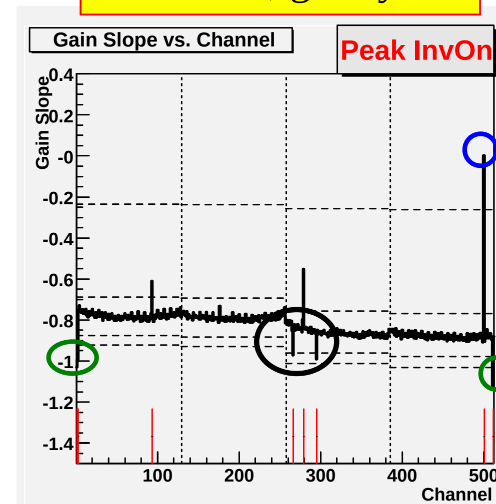
Scheme 1, gantry on



Scheme 2, gantry on



Scheme 3, gantry off



Analysis Macro

- Analysis root macro under development which correlates testing results to determine type of channel defects
  - Ultimately will output list of bad channels with suggested repairs/rework necessary for module
  - Additionally, the macro generates all plots necessary for module QA
- The macro (with directions and examples) is available at hep.ucsb.edu/cms/arcs_macro.html

```
              0000010000000200000200002200
              0000071112222622222733337733
              1234567890123656789812348978
Ped Stat      ............................
Noise Stat    TT...........O..........NN..
Gain Stat     TT...........O...........G..
Pinhole Stat  ......X.................XX..
PulseH Stat   K........................J..
              ----------------------------
Summary Stat  TT    ?      O          ?S
```

```
              000000111111141111111111111151
              999999000001115111111222222212
              123456567890120456789012345618
Ped Stat      ..............................
Noise Stat    ..............P.............T.
Gain Stat     ..G...........P.............T.
Pinhole Stat  ..............P...............
PulseH Stat   ..............J.............K.
              ------------------------------
Summary Stat    ?           P             T
```

Conclusions of Study

- Gain scan and pinhole tests least sensitive to grounding scheme and external noise sources
  - Can be used to find sensor-sensor and PA-sensor opens, pinholes, noisy channels, and most likely shorts
- Noise measurement with "optimal" grounding is also insensitive to external noise sources
  - Finds all the above faults
- These three tests can have results correlated to give great confidence to failure analysis
  - *Would like to propose the use of this set of tests for bad channel finding*
- Other tests are less optimal, but are included as they are the standard as of now
  - Pedestal test does not find common faults
  - Pulse shape measurement much less sensitive than gain measurement
- Backplane pulsing tests and shorts still need to be included

ARCS/LT Differences (Algorithms)

- Pedestal and noise calculation (including common mode subtraction) algorithms are identical
- Pulse shape tests use common mode algorithms differently
  - LT does not subtract common mode
  - ARCS subtracts common mode excluding the charge injected channels
- Pipeline scans also treat the common mode differently
  - LT applies common mode subtraction to both pedestal and noise
    - Potential for missing bad columns of capacitors in APV
  - ARCS applies common mode subtraction only to noise calculation

ARCS/LT Differences (CMS inputs)

Parameters used for skipping bad channels in the common mode algorithm are different at different sites. Since skipped channels are marked as bad in ARCS setup , these parameters are very important. X-calibration work at Karlsruhe should find optimal set of parameters .

	HYBRID TESTS		MODULE TESTS	
	FHIT	CERN	ARCS	LT
Tskip	4.9	54	4.0	3.0
Tbad	3.0	55	5.0	5.0
RMS (low)	0.3	0.3	0.5	0.0
RMS (high)	10.0	1.2	5.0	10.0
Pskip	0.2	0.2	0.2	0.3

ARCS/LT Differences (Bad Channel Definitions)

Partial listing of bad channel definitions used currently

	Guide	ARCS	LT	US TOB
Pedestal	±20%	±30%	$0>P_i>500$	±20% (not applied)
Noise	±20%	CMS skipped channels	$0>N_i>5$ $\|N_i-<N>\|>5\sigma_N$	Multiple fixed cuts
Pulse height	±20%	±20%	$\|PH_i-<PH>\|>3\sigma_{PH}$	±12% (not applied)
Gain slope	N/A	±20% (Not sure if applied)	N/A	Multiple percentage cuts
Pinhole	±20%	±100%	$\|Pin_i-<Pin>\|>3\sigma_{Pin}$	Multiple percentage cuts
Backplane pulsing	±20%	??????	$\|B_i-<B>\|>3\sigma_B$	??????

Every site has different bad channel selection criteria. Now that a relatively large number of modules produced, it is time to try to converge on a set of bad channel definitions. Gain slope, pinhole, and backplane pulsing tests need systematic studies to determine optimal bad channel definitions, etc.

Code Comparison Conclusion

- The testing algorithms are very similar between ARCS/LT software
  - Only slight differences in how common mode subtraction handled in pulse shape and pipeline test
  - Parameters used in marking bad channels for common mode subtraction differ between stands
    - X-calibration work at Karlsruhe should finalize these parameters
- Bad channel criteria differ for almost each testing site
  - Now is the time to come to a "final" uniform set of criteria
    - ***A common language/convention is needed to describe problem channels***
  - How to use test information to determine fault type should also be investigated more