Module Quality Control & Assurance

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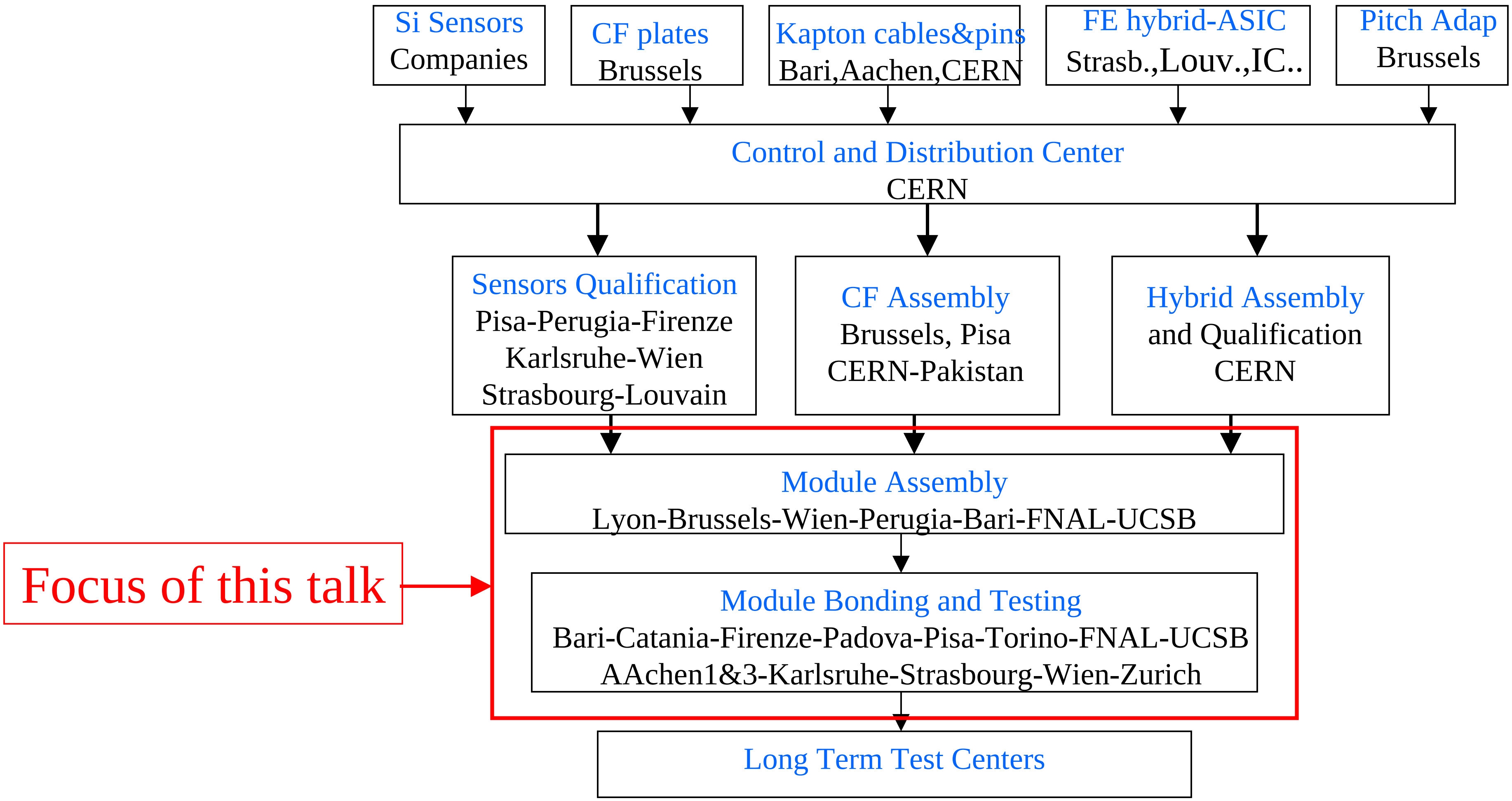
Outline

- Mechanical Quality Control & Assurance
  - → Gantry calibration & qualification
  - → Module quality
- Wire Bonding Qualification & Testing
  - → Qualification of pitch adaptors
  - → Wire bond pull tests
- Electrical Qualification & Testing
  - → Test stand types & part flow
  - → Test stand qualification & cross-calibration
  - → Module test & grading

Review of Production Network

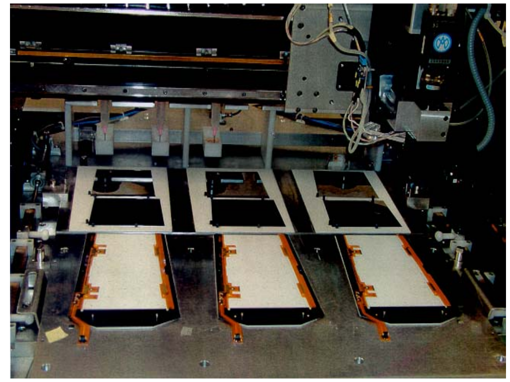


General QC&A Philosophy

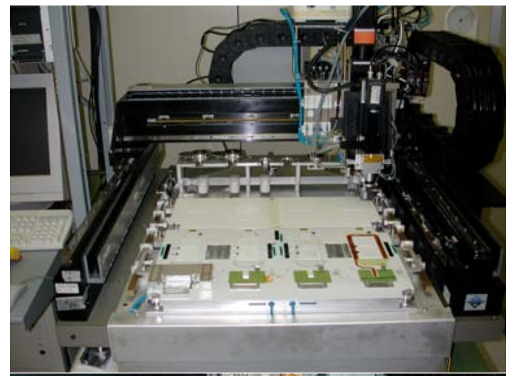
- How can process quality and uniformity be guaranteed in such a distributed system?
  - → 7 module assembly centers
  - → 13 module bonding and testing centers
  - → 9 sub-detector assembly and testing centers
- Require that equipment, software, and procedures used are as identical as possible
  - → Cross-calibrations are performed between sites in which standard candles (glass plates, hybrids, modules, etc.) are exchanged
- Require a high level of traceability of component/module flow and of testing results at all stages (Database)
  - → Global quality of production can be monitored
  - → Quick feed-back to production center, improving process quality and uniformity

Gantry centers

- Identical gantry systems assemble modules from components
  - → Bari and Perugia => TIB/TID Modules
  - → Brussels, Lyon and Wien => TEC Modules
  - → FNAL and UCSB =>TOB Modules
- Identical software used at all seven gantry cites



TEC

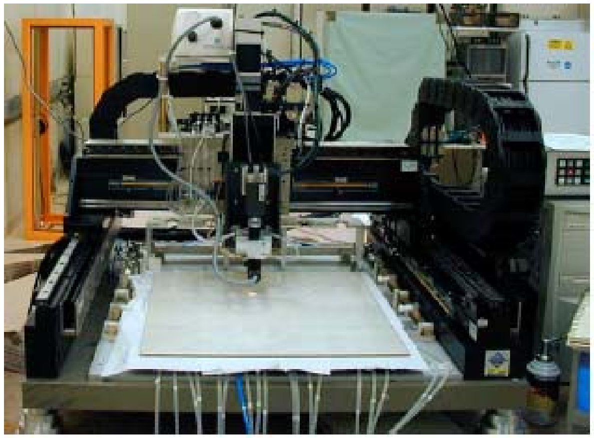


TIB

TOB

Gantry Qualification

All centers have qualified gantries through measurement of standard glass plates and production of multiple dummy modules



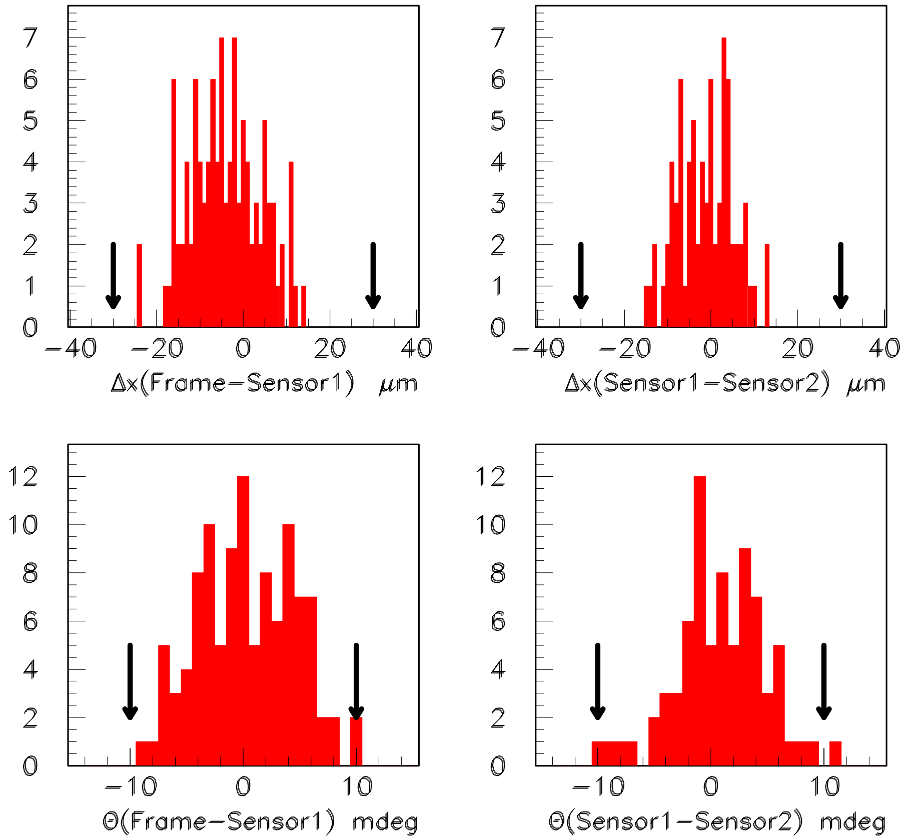
	BARI				BRUXELLES				FNAL			
	<X>	x	<Y>	Y	<X>	x	<Y>	Y	<X>	x	<Y>	Y
MANUAL POSITION REPETIBILITY		0,9		1,1								
PR INTRINSIC REPEATIBILITY		0,05		0,06	0,016	0,18	0,03	0.07		0,08		0,05
PR GLOBAL REPEATIBILITY		1,2		1,6	1,26	1,97	-0,3	2,198		0,3		0,3
PICK AND PLACE	1,05	1,04	0,9	1,28	0,007	0,7	-0,01	0,94		1,5		1,6
CORRECTION FOR ROTATION	SINUSOIDAL BEHAVIOUR				NON PARTICULAR BEHAVIOU				SINUSOIDAL BEHAVIOUR			
	LARGE CORRECTIONS				VERY SMALL CORRECTIONS				SMALL CORRECTIONS			

	LYON				PERUGIA				UCSB			
	<X>	x	<Y>	Y	<X>	x	<Y>	Y	<X>	x	<Y>	Y
MANUAL POSITION REPETIBILITY						0,5	0,6			0,9	0,6	
PR INTRINSIC REPEATIBILITY		0,27		0,1		0,5				0.06		0,06
PR GLOBAL REPEATIBILITY		0,2		0,31		0,5				0,3		0,6
PICK AND PLACE		0,22		0,41			-0,3	1,4		1		1
CORRECTION FOR ROTATION	SINUSOIDAL BEHAVIOUR				SINUSOIDAL BEHAVIOUR				SINUSOIDAL BEHAVIOUR			
	SMALL CORRECTIONS				SMALL CORRECTIONS				VERY SMALL CORRECTION!			

The precision obtained is within our requirements

Module Mechanical Precision

- Before/after glue curing, fiducials of sensors, hybrid, and carbon fiber frame are measured
  - → Requirements on relative positions and angles between the sensors, the hybrid and the frame are made
  - → Δx and relative angle between sensors and between the frame and the sensors are most critical
- All modules (but 1) have passed these requirements
- On some modules, the measurements are repeated on an independent precision measuring machine
  - → All measurement are consistent in these cross checks.



Bonding Centers

- All centers are equipped with good bonding machines (mainly Delvotec and K&S) and are fully operational
  - → Bari,Catania, Firenze, Padova, Pisa, Torino → TIB/TID Modules
  - → Aachen, Hamburg, Karlsruhe, Strasbourg, Wien, Zurich → TEC Modules
  - → FNAL, UCSB → TOB Modules
- Most of the centers have prior experience from other experiments
- Pitch adaptors and other test structures have been distributed between centers for bond quality testing

Bonding Qualification

- Each bonding center has been sent multiple bonding test pieces
- Wire bonds have their pull strengths, shapes, and break location studied at the center and at CERN
- All bonding centers have passed qualification with pull strengths greater than 9 grams

Result of 1st bond test

ID#	Centre	CERN bond	Self test§	CERN test	comments
1	Torino	10.7 ± 0.6	12.5 ± 1.5	13.9 ± 0.9	Slight under deformation
2	Bari	11.6 ± 0.4	8.5 ± 1.0	10.7 ± 0.6	good
3	Catania	10.2 ± 0.4	7.1 ± 0.8	7.1 ± 0.4	Slight over deformation
4	Florence	11.1 ± 0.4	8.4 ± 0.9	8.3 ± 0.9	good
5	Karlsruhe	11.4 ± 0.4	10.7 ± 0.5	~10 ± 0.5	Very low loop:400µm
6	Strasbourg	11.6 ± 0.5	10.6 ± 0.5	11.2 ± 0.6	good, low loop:600µm
7	Vienna	10.3 ± 0.5	7.3 ± 1.7	10.0 ± 1.8	Lift-offs, large spread
8	Aachen	9.2 ± 0.4	11.0 ± 1.7	8.4 ± 2.0	Lift-offs, large spread
9	Padova 1	8.7 ± 0.4	10.3 ± 1.5	12.1 ± 1.5	On Hughes, large spread
10	Padova 2	8.7 ± 0.4	8.5 ± 1.2	9.8 ± 1.6	K&S, lift-offs, spread
11	Pisa 1	11.4 ± 0.5	6.5 ND	11.8 ± 0.7	Do destructive test
12	Pisa 2	9.1 ± 0.4	?		Test new K&S
13	Zurich 1	9.9 ± 0.4	9.9 ± 1.1?	8.5 ± 0.8	Very high loop
14	Zurich 2	8.9 ± 0.4	10.3 ± ?	14.6 ± 0.9	Amazing!
15	FNAL 1	9.0 ± 0.4	10.6 ± 1.1	10.4 ± 1.1	Good but some lift-offs
16	UCSB	-	9.6 ± 0.3	9.9 ± 0.4	good
17	FNAL 2	10.3 ± 1.0	10.8 ± 0.9	10.7 ± 1.9	1 bad bond in CERN test, some lift-offs

§= corrected value based on CERN measured height and length   in purple = some areas of improvement to work on

1   Alan Honma, CERN

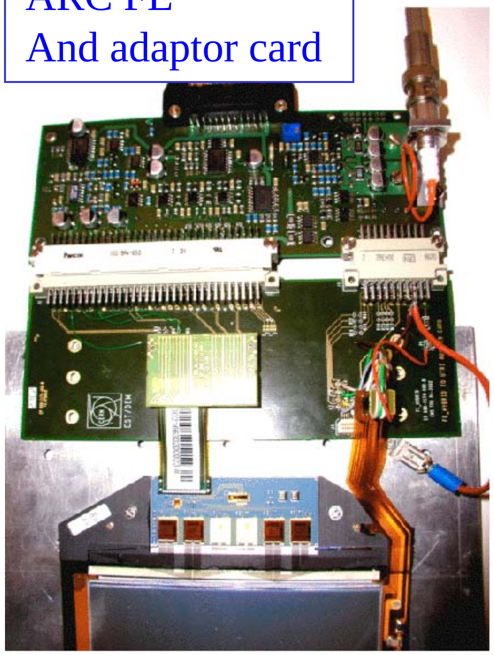
Bonding QC&A During Production

- Pull strengths, bond deformation, and lift-off measurements are made on the test pad of pitch adaptor
- Every 50th wire bond will be destructively pull tested and replaced on first ~20 module of each type at each test center
- Bond heads are regularly inspections and replaced when necessary
- A large number (>100) of hybrids and modules have been thermal cycled between –20 and 20 C with no wire bond breakage seen

Hybrid & Module Electrical Testing

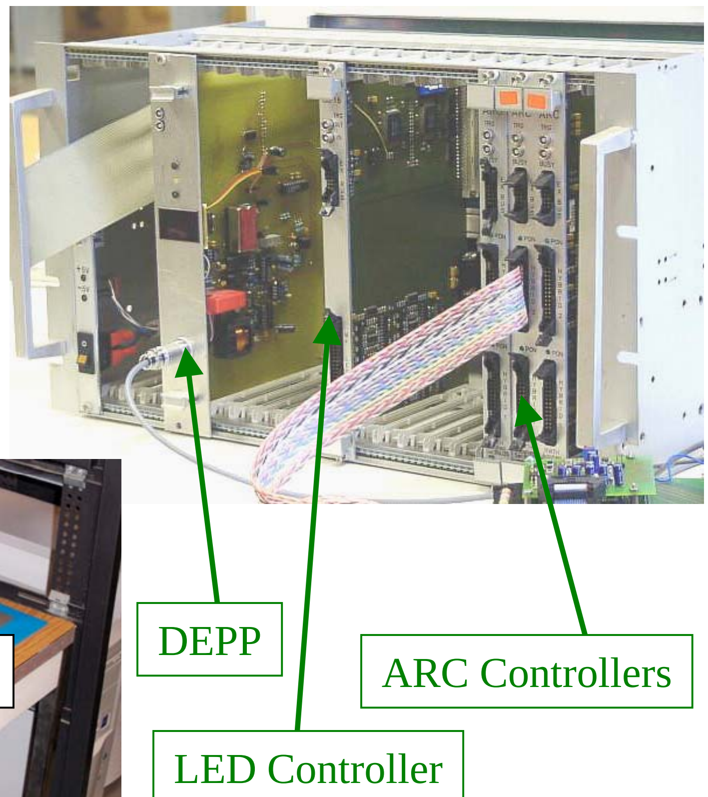
- Hybrids and modules are tested during the various stages of module production
  - → Ensure that the performed operations do not introduce any or very few defects
    - – Currently require <2% faulty channels per module
  - → CERN, Louvain, Strasbourg, UCSB -> Hybrid Tests
  - → Bari/Catania, Firenze, Padova, Perugia, Pisa, Torino -> TIB/TID Modules
  - → Aachen, Brussels/Antwerper, Karlsruhe, Lyon, Louvain,
  - → Strasbourg, Wien, Zurich -> TEC Modules
  - → FNAL, UCSB -> TOB Modules
- A big effort of standardization in the hardware and software setups has been accomplished.
  - → Only ARCS and DAQ-based testing stand are foreseen to be used
  - → Both systems use the same data analysis and fault finding algorithms
    - – Data file and database outputs of the two systems are being standardized

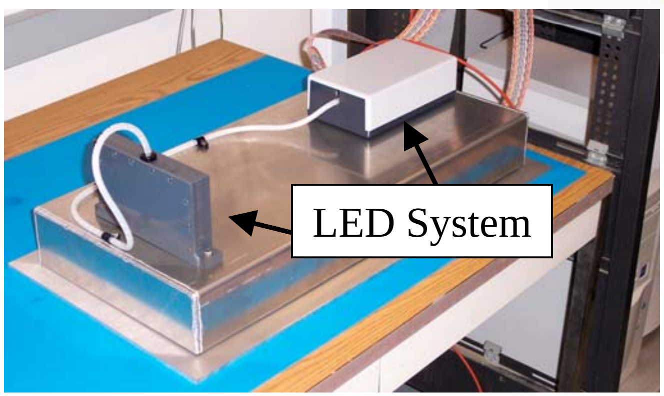
ARCS Based Test Stands



ARCS - APV Readout Controller Software

Purpose - Fast testing of hybrids and modules



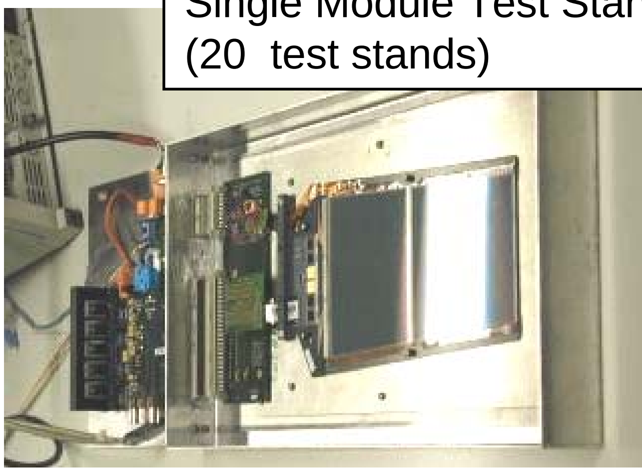


- Hybrid testing
  - → 28 test stands
- Module testing
  - → LED systems
    - – Pinhole/Open Tests
  - → DEPP HV supply
    - – Automated IV curves
  - → Pre-bonding Test (19 test stands)
  - → Post-bonding Test (15 test stands)

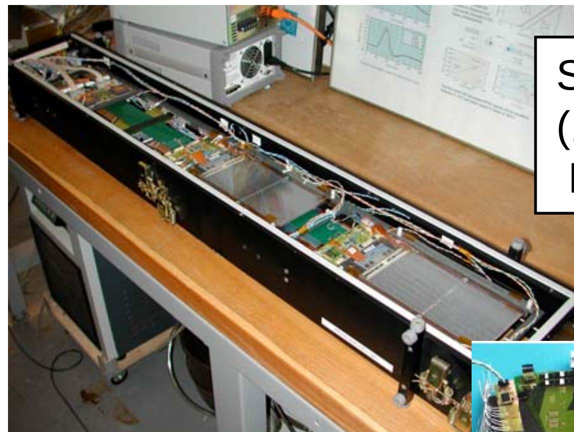
DAQ Based Test Stands

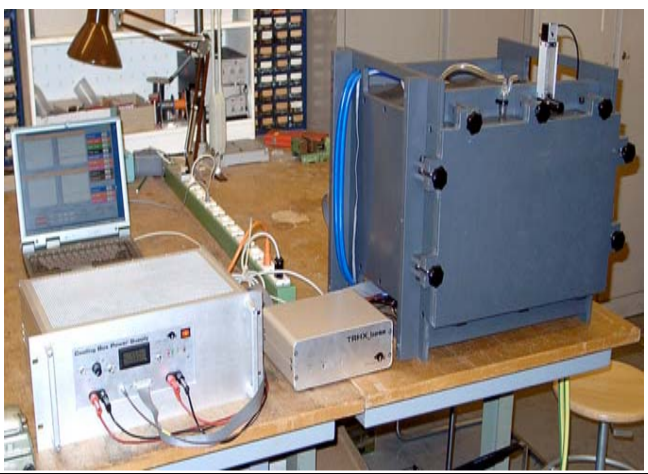
DAQ system – a PC based prototype of the real CMS tracker readout chain
Purpose – fast and burn-in testing of modules and sub-structures

Single Module Test Stand
(20 test stands)



Substructure Assembly
(10 test stands) and
Burn-in (9 test stands)





Module Burn-in (Wien box)
(7 test stands)

Electronic Testing Cycle

Quick test hybrid

Gantry makes modules

Quick test unbonded module

Wirebond

Bonded module test

Thermal cycle module

Final pinhole test

TEC/TOB

Assemble petals/rods

Petal/rod burn-in

Hybrid Quick Tests

- Hybrids are tested prior to module assembly and bonding
  - → Ensure no damage has occurred during process
  - → Hybrids have had extensive QC & A prior to module assembly
    - – See F. Hartmann's talk
- The hybrid quick tests use the same systems (ARCS), algorithms, and fault finding requirements as the hybrid QC & A

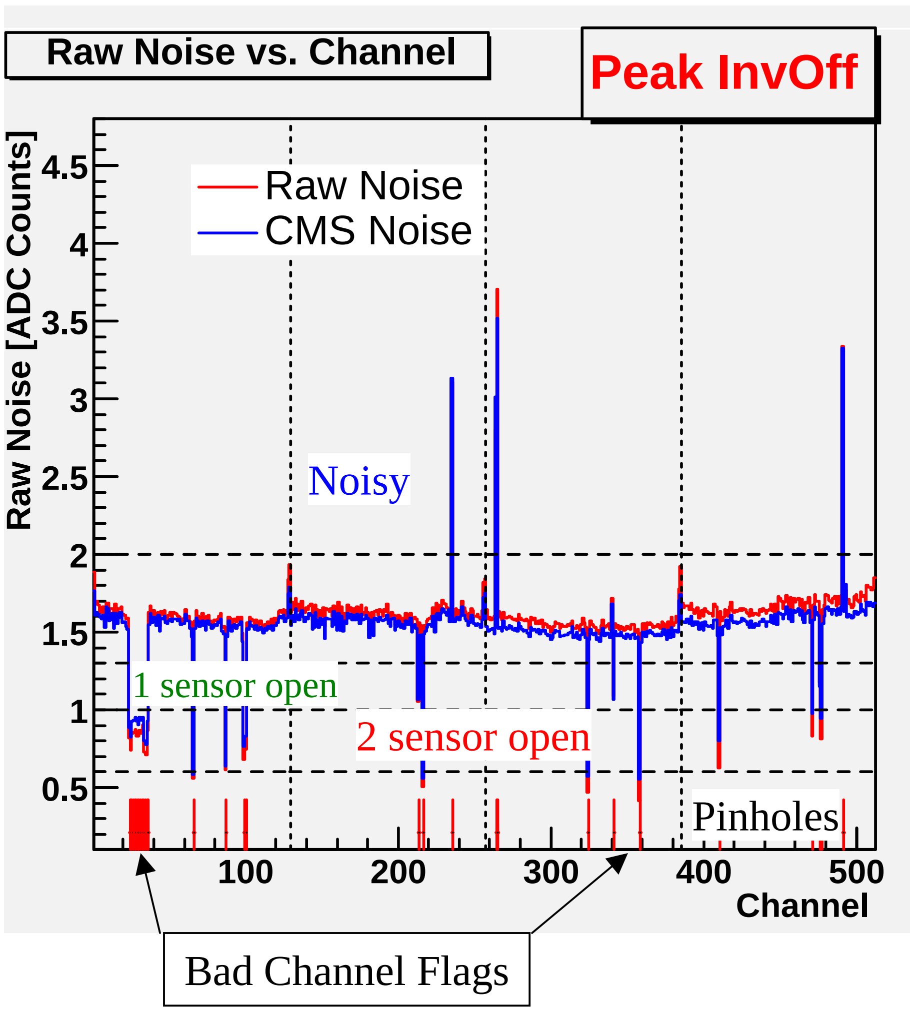
Module Tests

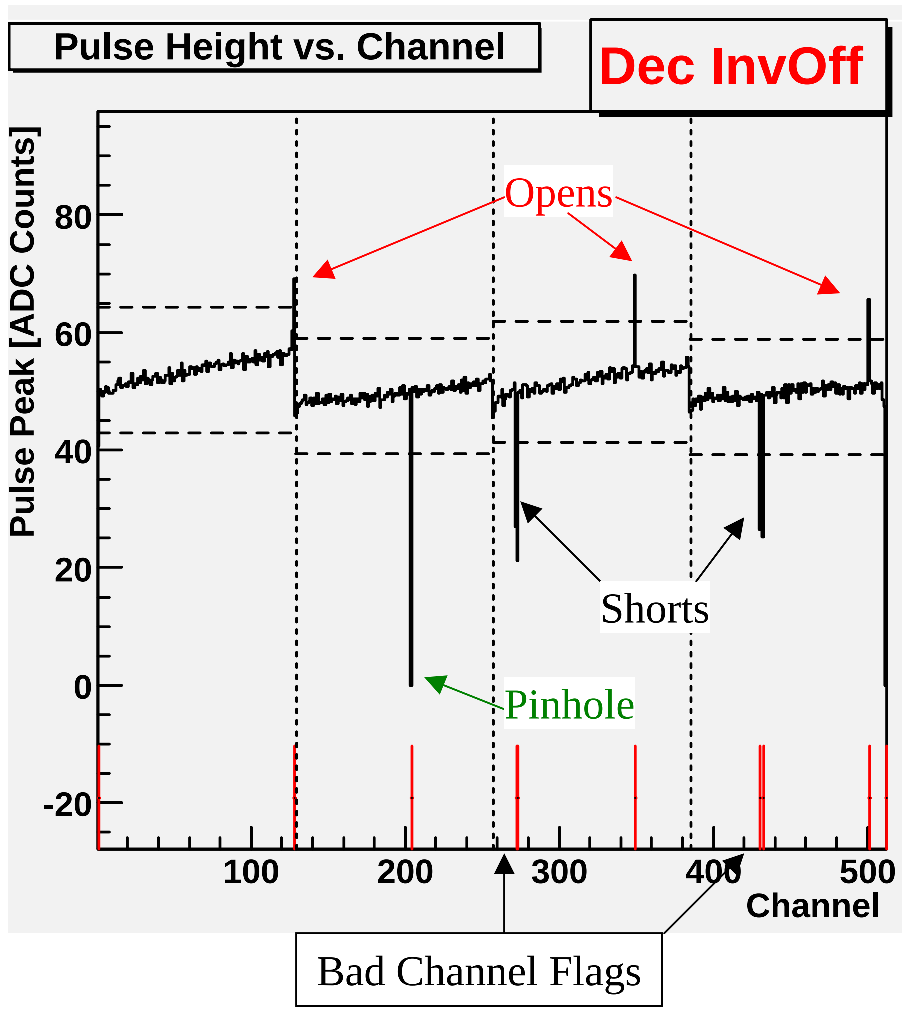
- Module testing has matured greatly recently with the production of >50 modules of a given type.
  - → Minimum set of tests defined
  - → Fault finding algorithms are now tuned to maximize fault finding and fault type identification while minimizing false bad channel flagging
- Noise performance and shielding standardization has allowed for the same fault finding algorithms to work on the TIB, TEC & TOB
  - → Minimize the effects of external noise sources
  - → Results can be combined for the same module type measured at different sites in order to further refine testing
- Testing procedures are now almost automated
  - → Work to automate testing → fault finding → module grading → database entry underway

Fault Finding Using ARCS (1)

Noise Measurement

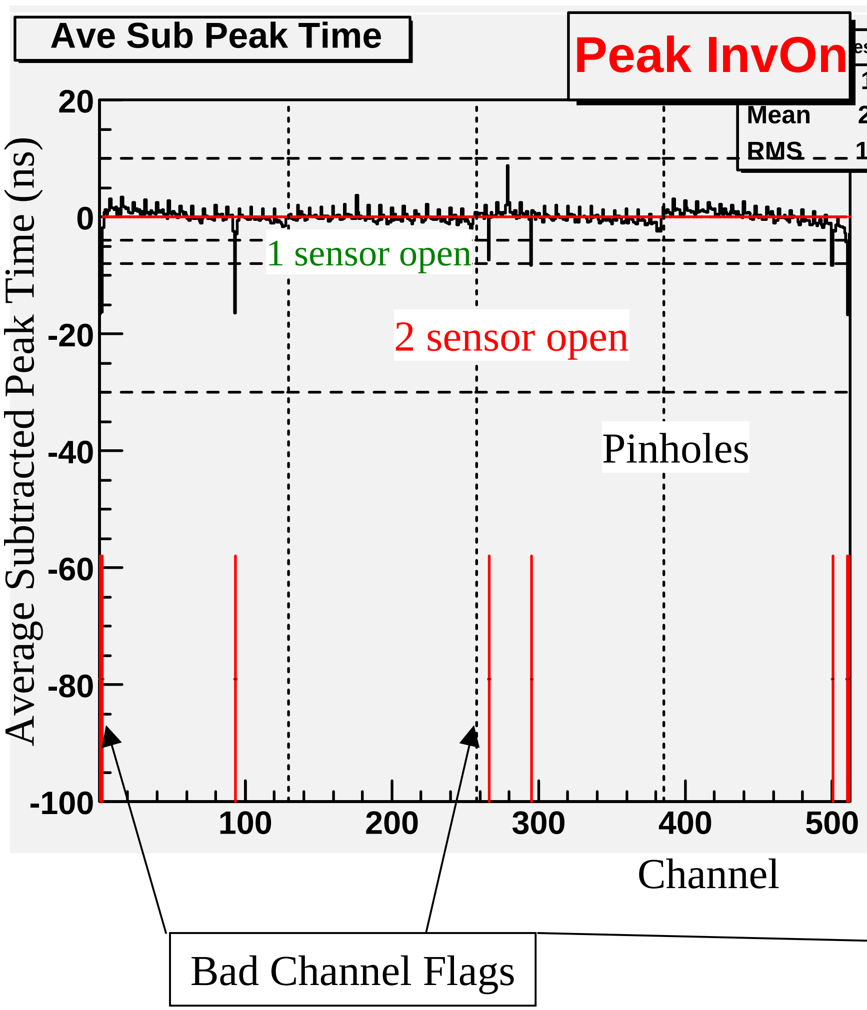
Pulse Height Measurement (Using Calibration Pulse)



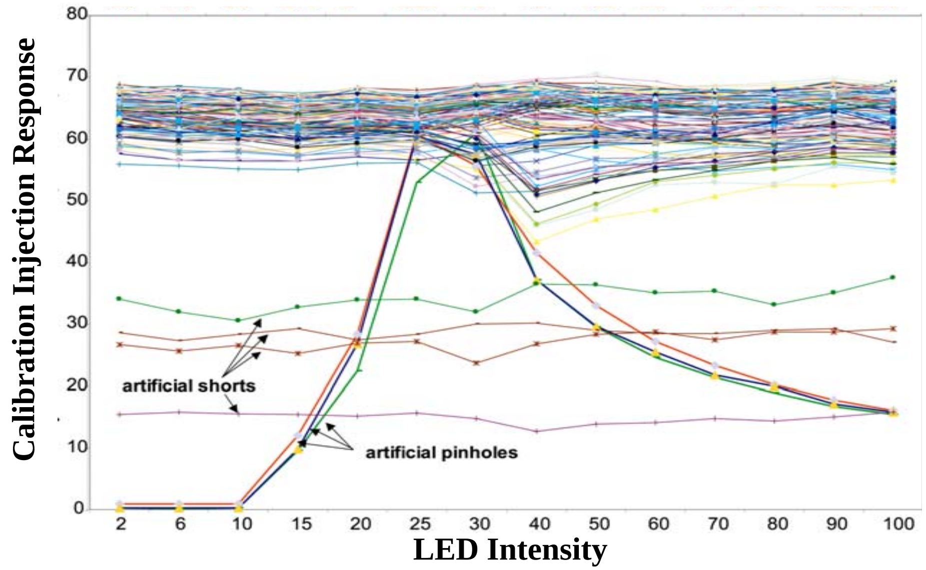


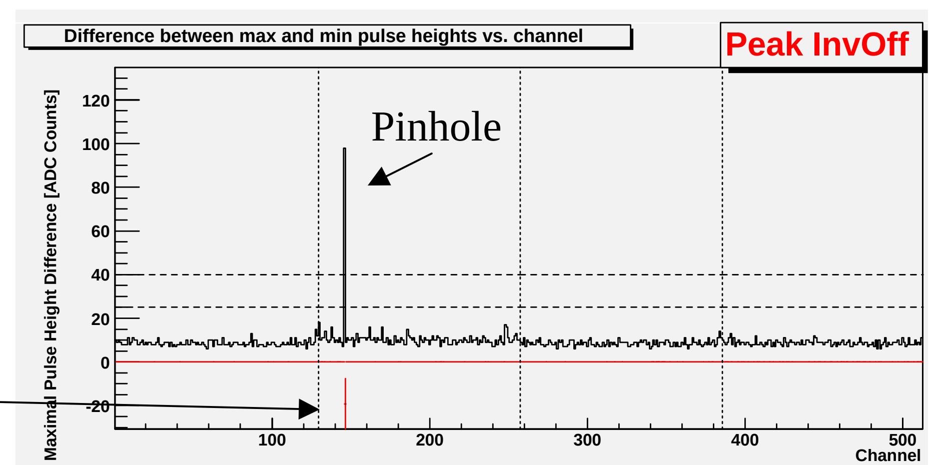
Fault Finding Using ARCS (2)

Average Subtracted Peak Time (Calibration Pulse)



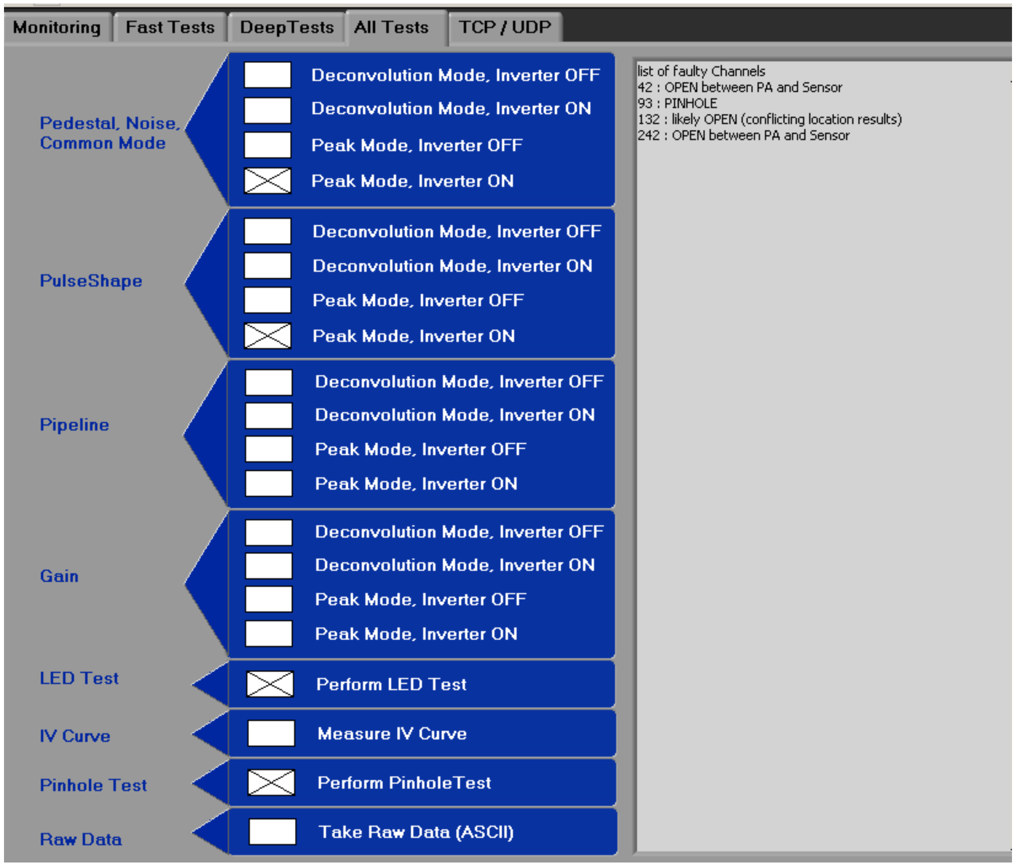
Pinhole Test (Using LED System)





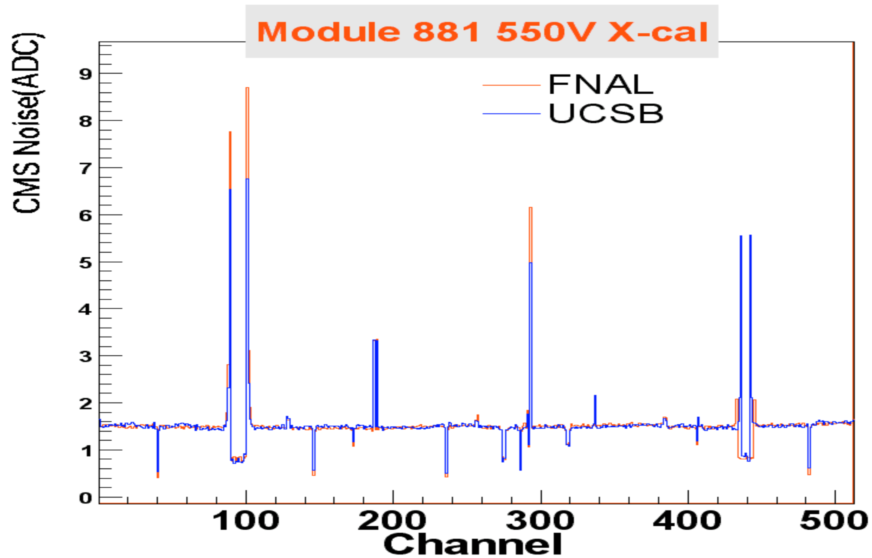
Fault Finding Using ARCS (3)

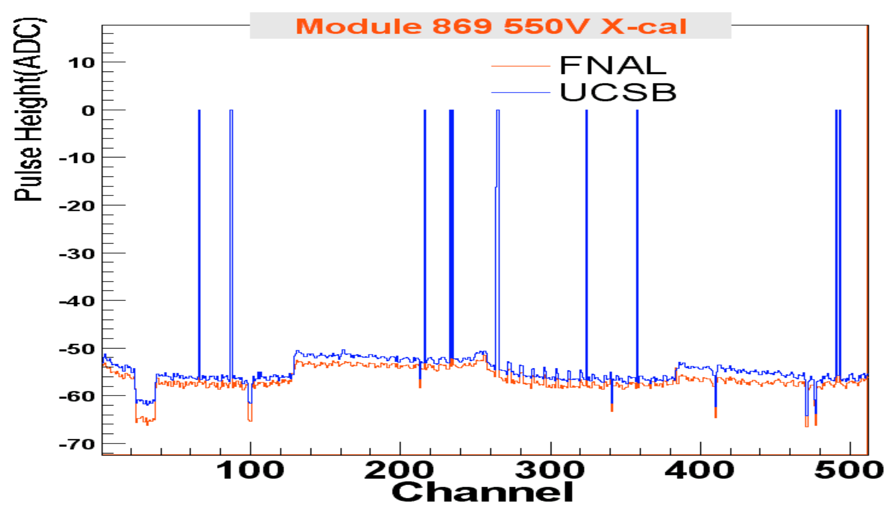
- Test failures are correlated in order to diagnose fault type
  - → Open (1 or 2 sensor)
  - → Short
  - → Pinhole/Saturated Channel
  - → Mid-sensor opens
  - → Noisy Channels
- Faults are found >95% with correct fault type identified ~90% of the time
  - → Less than .1% of good channel flagged as faulty
  - → As more modules are built, fault finding criteria will be re-tuned to improve performance
- Database output of module testing is being finalized
  - → Similar tuning of fault finding underway for DAQ-based systems



Test Stand Cross-calibration

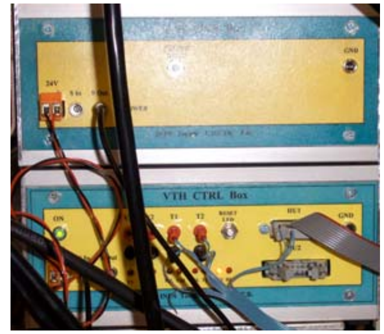
- All ARCS systems have had first iteration of cross-calibrations
- Modules are circulated between testing centers
  - → Multiple examples of common problems are added to each module
    - – Shorts (neighbors & next-to-neighbors)
    - – Opens (sensor-sensor & PA-sensor)
    - – Pinholes
- With new qualification standards, results nearly identical
  - → Final iteration of cross-calibrations are currently underway
  - → DAQ cross-calibration is forth-coming



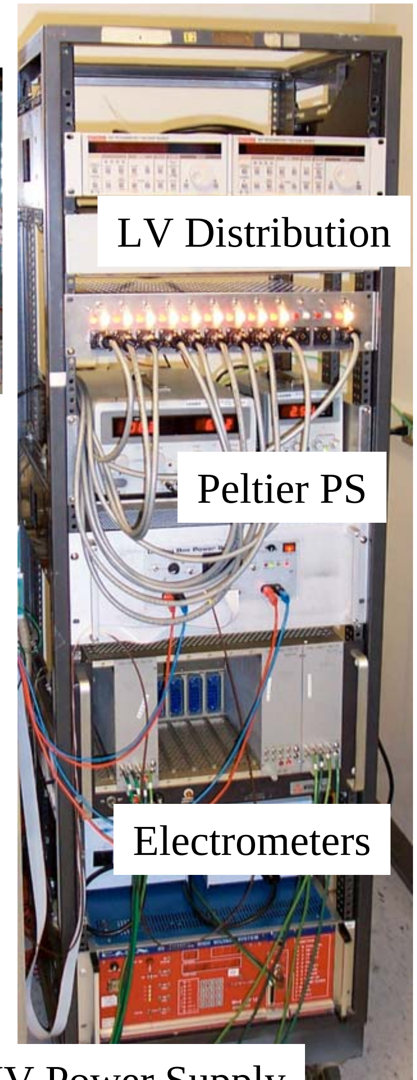


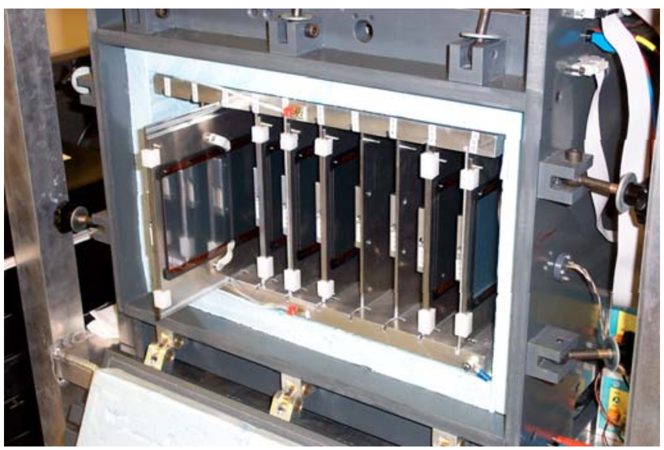
Wien cold box

- Wien cold box cycles modules from –20 C to 20 C while reading out up to 10 modules
  - → DAQ Based System
  - → Modules cycled 1-3 days with ~4 cycles per day.
  - → TIB will cycle all modules
  - → TEC/TOB will cycle all modules until sub-structure burn-in available

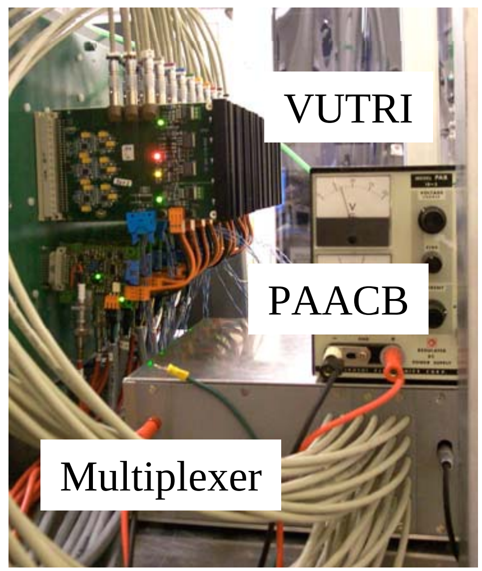


Torino Interlock Box





Inside Wien Cold Box

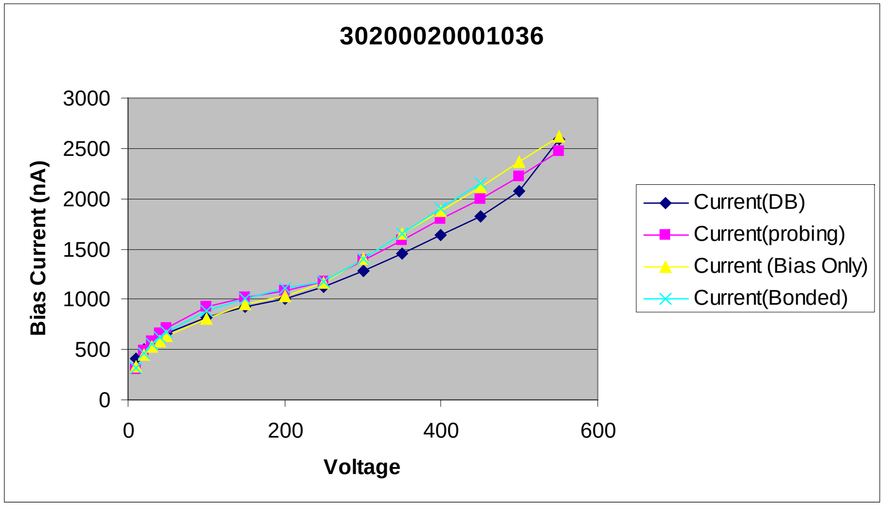


Backplane of Wien Cold Box

HV Power Supply

Database

- Lyon Database
  - → Complete description of all parts and assembly
  - → Traces all movements of the parts between centres & keeps inventories
  - → Includes all test results performed at any centre
  - → Allows extract data for
    - – Controlling the production
    - – Tracing the anomalies
    - – Later calibration or slow control purposes



For example, I-V curve of a TOB module at various stages of production

Conclusions

- Module assembly is underway
  - → Assembled modules are very uniform and all meet specifications
  - → Wire bond strengths and shapes have been excellent
  - → Module electrical testing is semi-automatically finding the vast majority of faults with a very small false fault finding rate
- With the uniformity of results, the database allows for the tracking of global module quality
  - → Any systematic problems can be quickly identified and addressed at the production centers