DUNE 35t
TPC Readout Electronics

May 19th, 2015
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Outline

- **Introduction**
- **35t Electronics Overview**
  - Front end readout boards
  - Interface to DAQ
  - Calibration
- **Electronics Validation**
  - Testing procedure
 - Results
- **Status and Summary**

Reminder: 35t FEMBs

- 35t FrontEnd Mother Boards (FEMBs) contain analog, FPGA and ERNI interface boards
  - Analog board: 8 pairs of amplifier ASICs and digitizing ADC ASICs, 128 channels
  - FPGA board: Coordinates ASIC readout, streams data to backend
  - ERNI connector board: GB cable connector board
- 35t detector contains 16 FEMBs, 2048 channels
- **35t is the first large scale test of digitizing cold electronics**
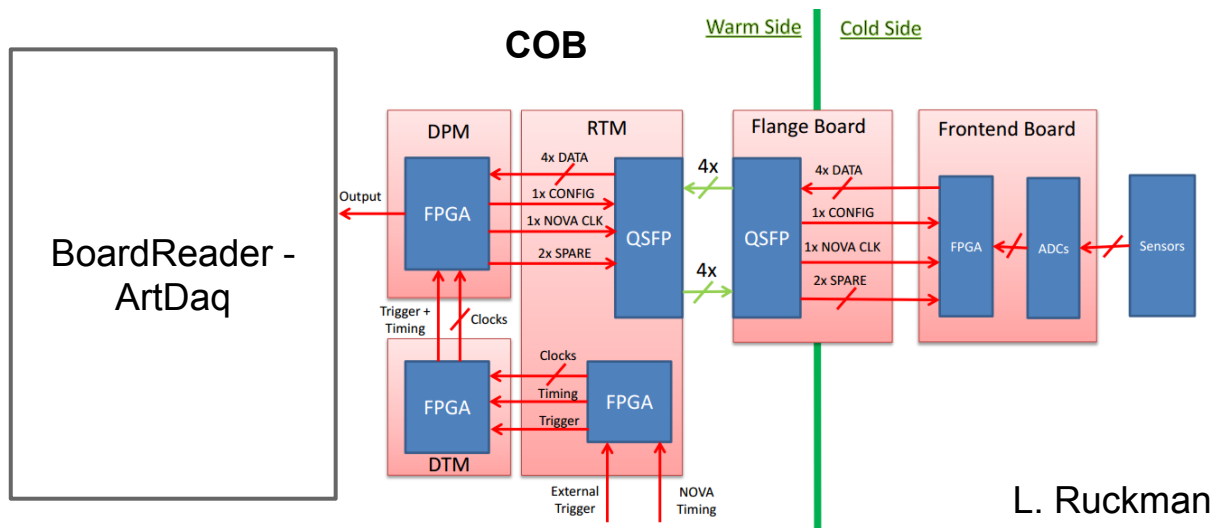 - **128 ADC ASICs and 16 FPGAs operate at cryogenic temperature**

Front End Mezzanine Board (FEMB)
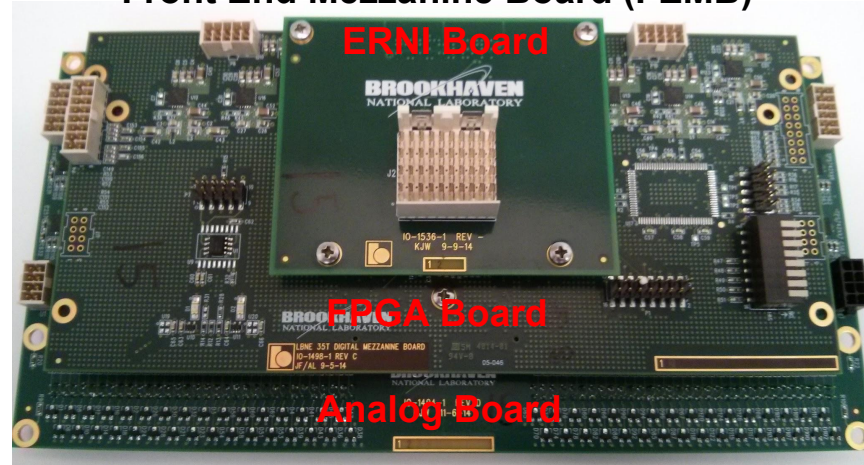
Cold Electronics Interfaces
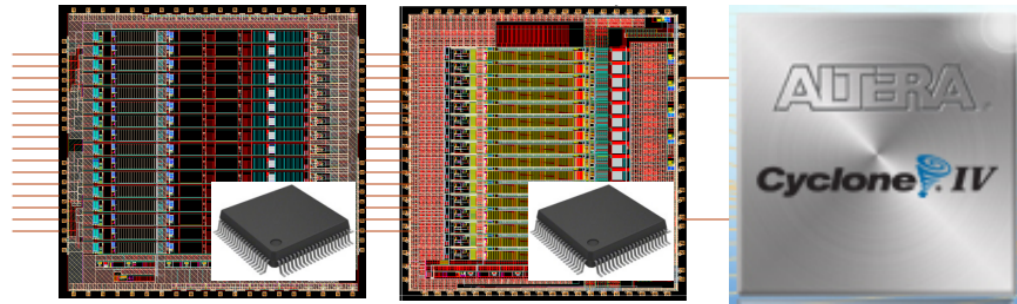
35t FEMBs in the DAQ

- 35t TPC electronics stream data via PGP protocol to COB + ArtDAQ backend
  - See talks by G. Barr and M. Graham
- FEMBs fully integrated into DAQ as of March 20:
  - FEMBs configured and ADC data streamed using artDAQ interface
- Have PGP-card readout working at BNL, emulates COB readout
  - Crucial for debugging readout

Calibration System Requirements

Internal Pulser - Example Waveform

Get diagram for external pulser signal injection system
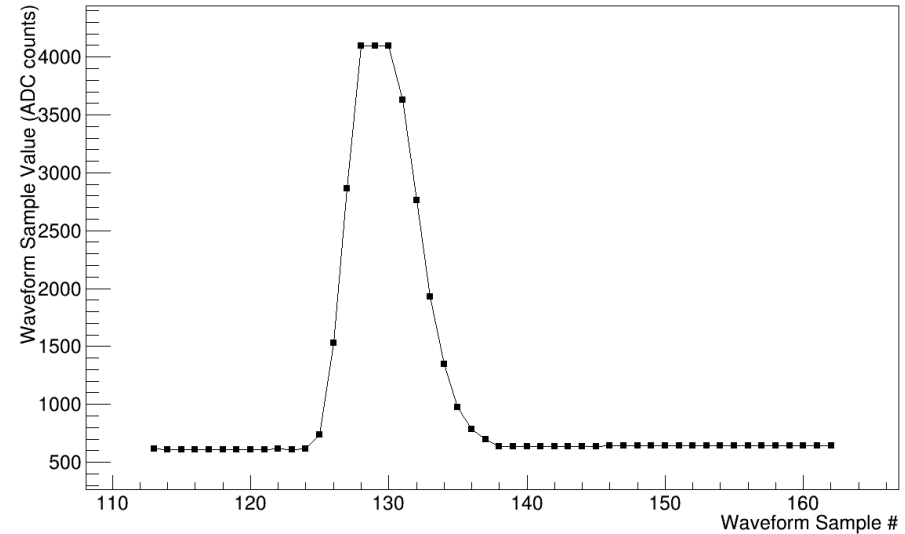
- Two calibration systems available for 35t electronics
  - External signal injection system
  - Internal pulser - redundant system, limited number of amplitude settings
- Calibration system measures and monitors noise, gain, shaping time, cross-talk, zero suppression thresholds
  - Plan to monitor noise and gain throughout cryostat cooldown and filling

35t Production Board Validation Procedure

- Boards validated in several steps:
  a. Oscillator pre-tests
     - Verify on-board oscillators work in liquid nitrogen
  b. Basic functionality tests
     - Verify assembled FEMBs work at room temperature, can be calibrated
  c. Cryogenic testing:
     - Verify boards continue to work in liquid nitrogen, can be programmed, take data etc
  d. Final validation data-taking
     - Evaluate board performance after cryogenic testing

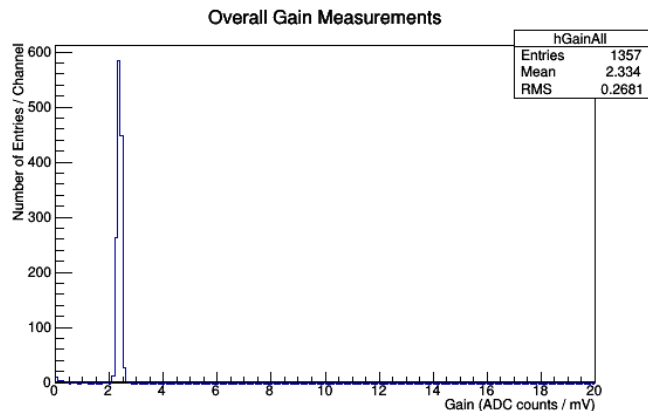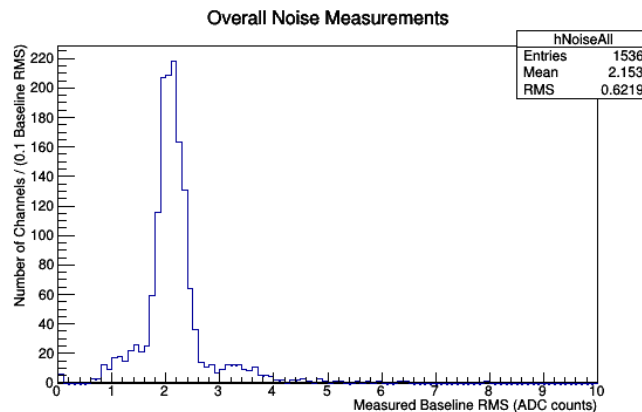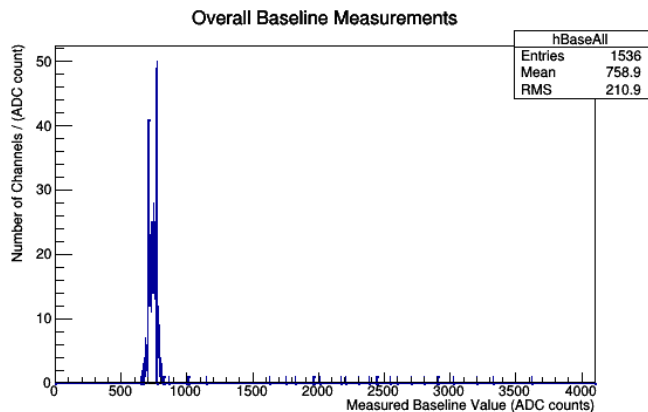**35t FEMB Tested in Liquid Nitrogen**
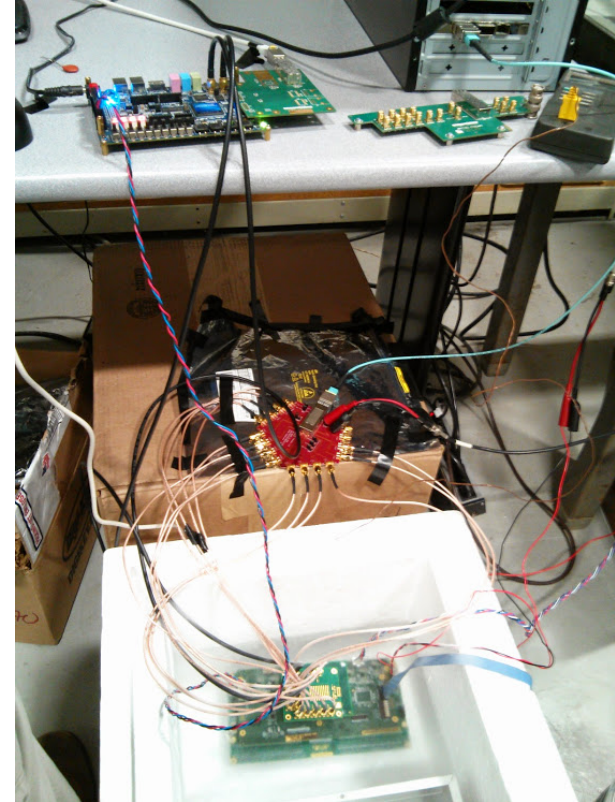
Electronics Testing Results

Overall FEMB Testing Summary				
FEMB#	Identifier	Basic Test	Cryogenic Test	Validation Data Analyzed?
		Test Log	Cryo Test Log	
1	F1A1E1	PASS	FAIL	-
2	F2A2E2	PASS	FAIL	-
3	F3A3E3	PASS	PASS	PASS
4	F4A4E4	PASS	PASS	PASS
5	F5A5E5	PASS	FAIL	-
6	F6A6E6	PASS	PASS	PASS
7	F7A7E7	PASS	FAIL	-
8	F8A8E8	PASS	PASS	PASS
9	F9A9E9	PASS	PASS	PASS
10	F10A10E10	PASS	PASS	PASS
11	F11A11E11	PASS	PASS	PASS
12	F12A12E12	PASS	PASS	PASS
13	F13A13E13	PASS	PASS	PASS
14	F14A14E14	PASS	FAIL	-
15	F15A15E15	PASS	PASS	PASS
16	F16A16E16	PASS	PASS	PASS
17	F17A17E17	PASS	PASS	PASS
19	F19A0E19	PASS	FAIL	-
20	F18A14E20	PASS	PASS	PASS
21	F2A1E2	PASS	PASS	PASS
22	F5A7E5	PASS	PASS	PASS
23	F20A0E7	PASS	PASS	PASS

- Identified 18 FEMBs that work correctly at room temperature
- Identified 16 FEMBs that work correctly in liquid nitrogen
  - 2 FPGA boards do not configure correctly in liquid nitrogen
  - 4 ASICs had decreased performance in liquid nitrogren, replacing the ASICs resolved the issue

35t Production FEMBs Performance

Overall Baseline Measurements

hBaseAll	
Entries	1536
Mean	758.9
RMS	210.9

Overall Noise Measurements

hNoiseAll	
Entries	1536
Mean	2.153
RMS	0.6219

Overall Gain Measurements

hGainAll	
Entries	1357
Mean	2.334
RMS	0.2681

- 18 FEMBs validated at room temperature with acceptable performance:
  - Mean Baseline = 759 ADC
  - Mean RMS (Noise) = 2.1 ADC
  - Mean Gain = 2.15 ADC/mV
                =11.7 ADC/fC

Summary

- 35t FEMB validation complete and installation is underway
- Production boards validated in several steps
  - Tests at cryogenic temperature crucial to identifying electronic and mechanical issues
- 16 fully validated 35t readout electronics boards will be installed on APAs in the next few weeks

BACKUP

Oscillator Pre-Tests

- Immersed on-board oscillators in liquid nitrogen, power cycle 10 times and monitored output signal on scope, measured frequence
  - Reject oscillator if output doesn't lock at correct frequency
  - Accepted oscillators installed onto production boards
- Found ~20% of 125MHz oscillators failed in liquid nitrogen
  - Failure modes varied significantly: some oscillators never work in LN, others have low <10% failure rates

Oscillator Ouput in LN2