Overview of KLM Electronics

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Belle II Summer School at PNNL

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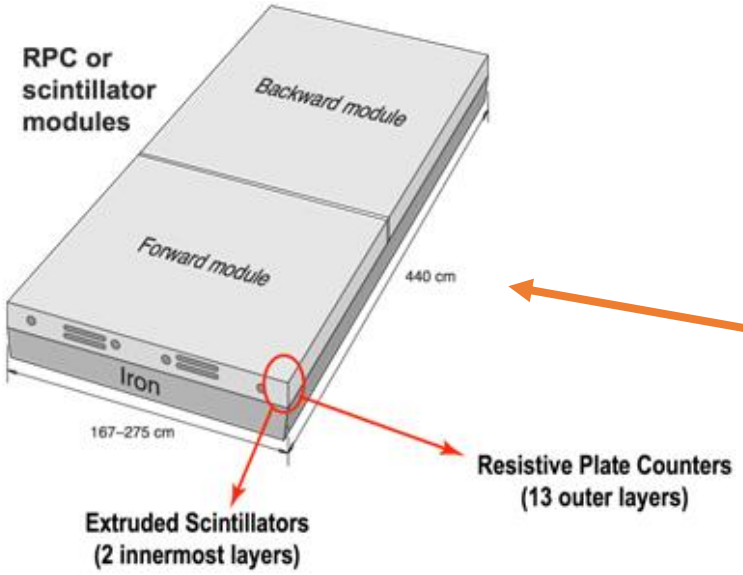
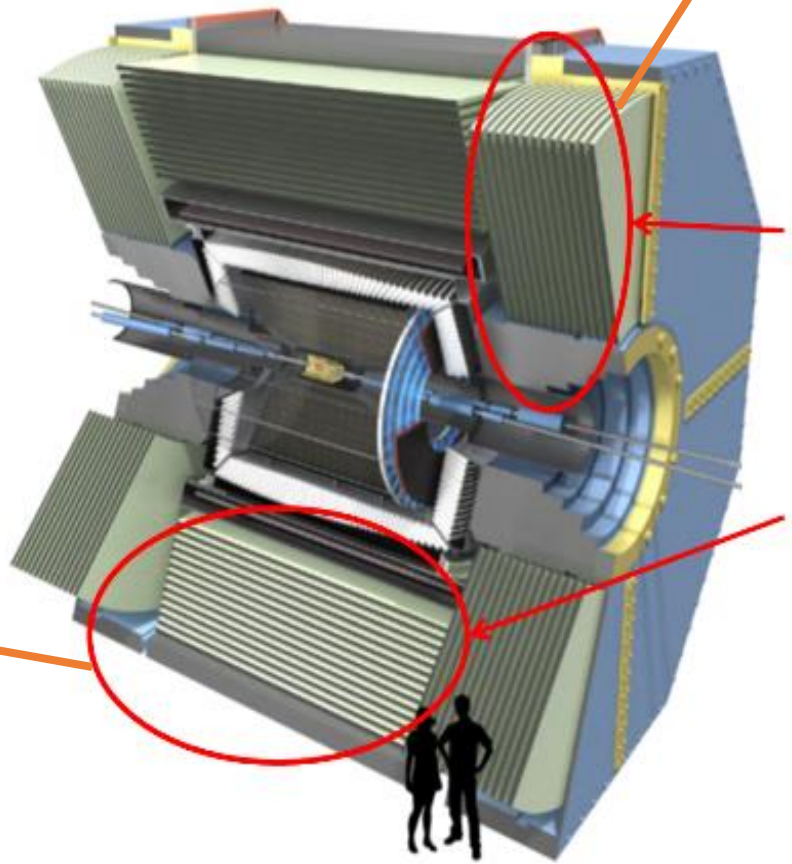
Overview of the Talk

1. KLM Scintillator Readout Electronics Development at UH Manoa
2. HW/FW/SW Overview
3. Production Testing and Calibration
4. Commissioning
5. Summary and Continued Efforts

Belle II: KLM Scintillator Upgrade

- KLM detectors:
  - Endcap: scintillators
  - Barrel: scintillators +RPCs
- Located outside the magnet
- ITEP



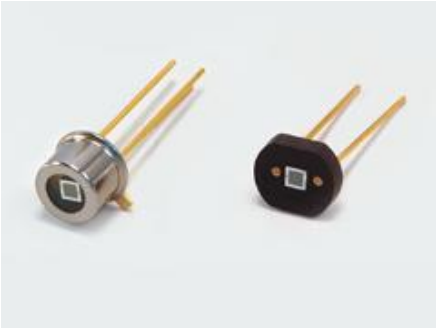


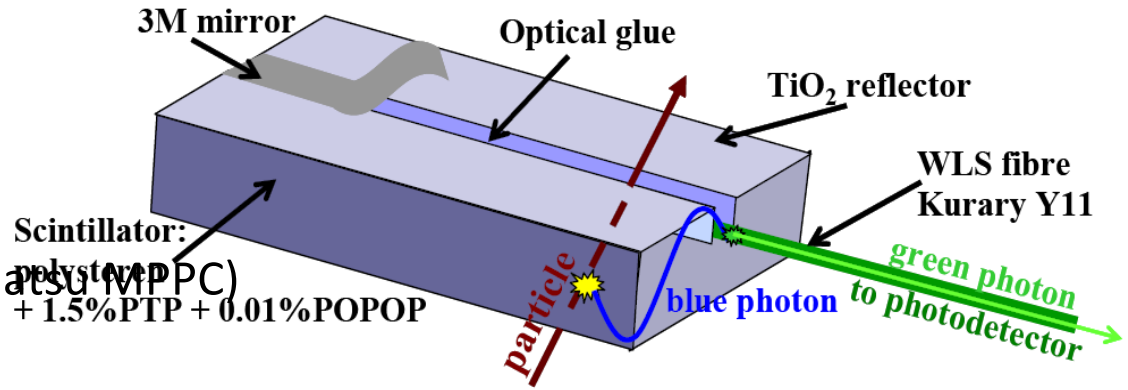
ENDCAP
14 layers, 4 sectors
WLS fiber scintillators
(75 *x*, 75 y)

BARREL
15 layers, 8 sectors

KLM scintillator upgrade

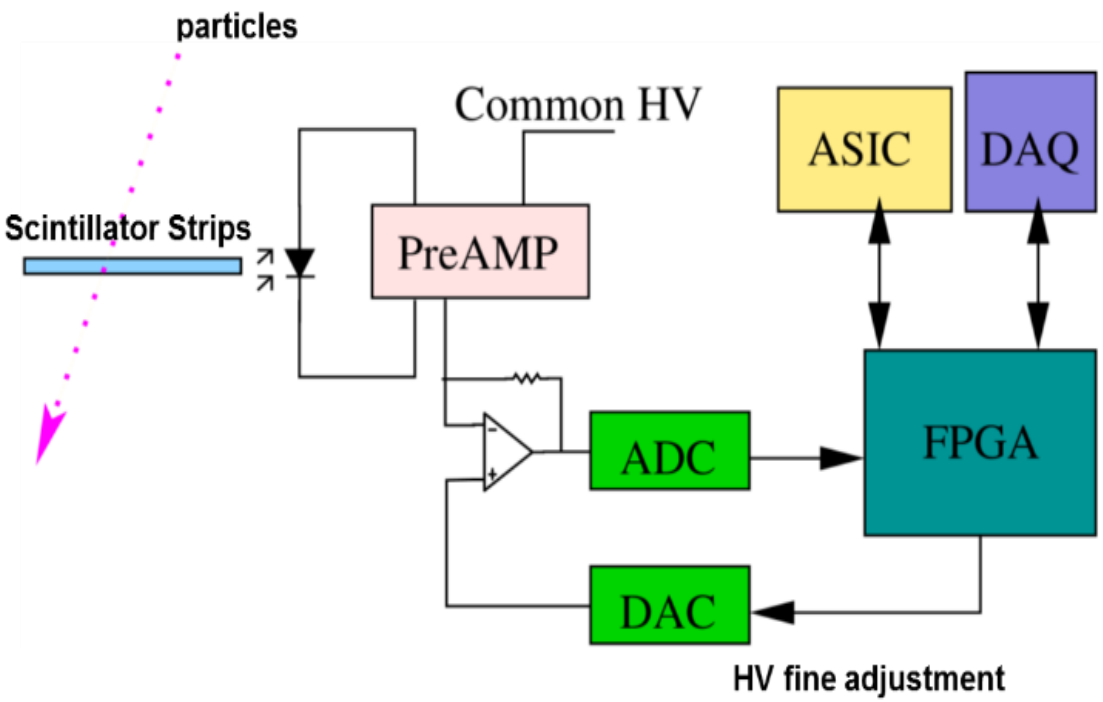
- RPC-based KLM demonstrated good performance at Belle (efficiency endcap > 90%, barrel ~ 99%, stable operation, low bg)
- With SuperKEKB luminosity, it is still possible to use RPC in the outer barrel, however the efficiency of endcap KLM becomes unacceptably low due to high neutron background and large RPC dead time.
- Requirements to maintain KLM performance:
  - Low dead time: <<us for a typical channel (strip) area of 1000 cm2
  - Large acceptance: > 95%
  - High efficiency: ~99% for MIP
  - Low bg (neutron bg + electronic noise)
- Solution:
  - Scintillator based detector with WLS readout
  - Fast photodetector: Si photo diode in Geiger mode (Hamamatsu MPPC)
  - Independent operation of x-y layers





KLM Readout module specifications

Scintillator channels	~20k
TARGETX ASICs (& daughtercards)	1250
Channels/ASIC	16
9U VME Motherboards	132
Endcap layers	14
Endcap segments	4
Modules per endcap	56
Barrel segments	8
Barrel layers	15
Modules in barrel	32
Sample rate (GSa/s)	1.0
Single sample resolution (bits)	10-12



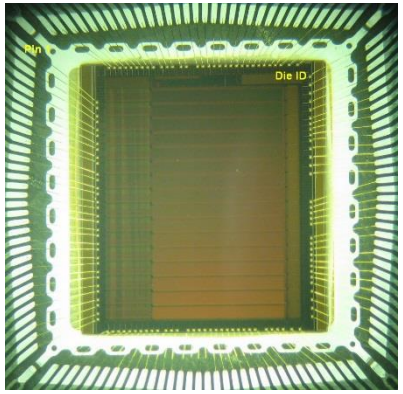
ASIC: TARGETX developed at UH Manoa, TSMC 0.25
DAQ: USB, or PocketDAQ, or Ethernet

Requirements: Low cost, high performance

Exercise:
Original number was 144 modules
Why not 144?

The **TARGET-X** ASIC: TeV Array Readout GSa/s Electronics with Trigger

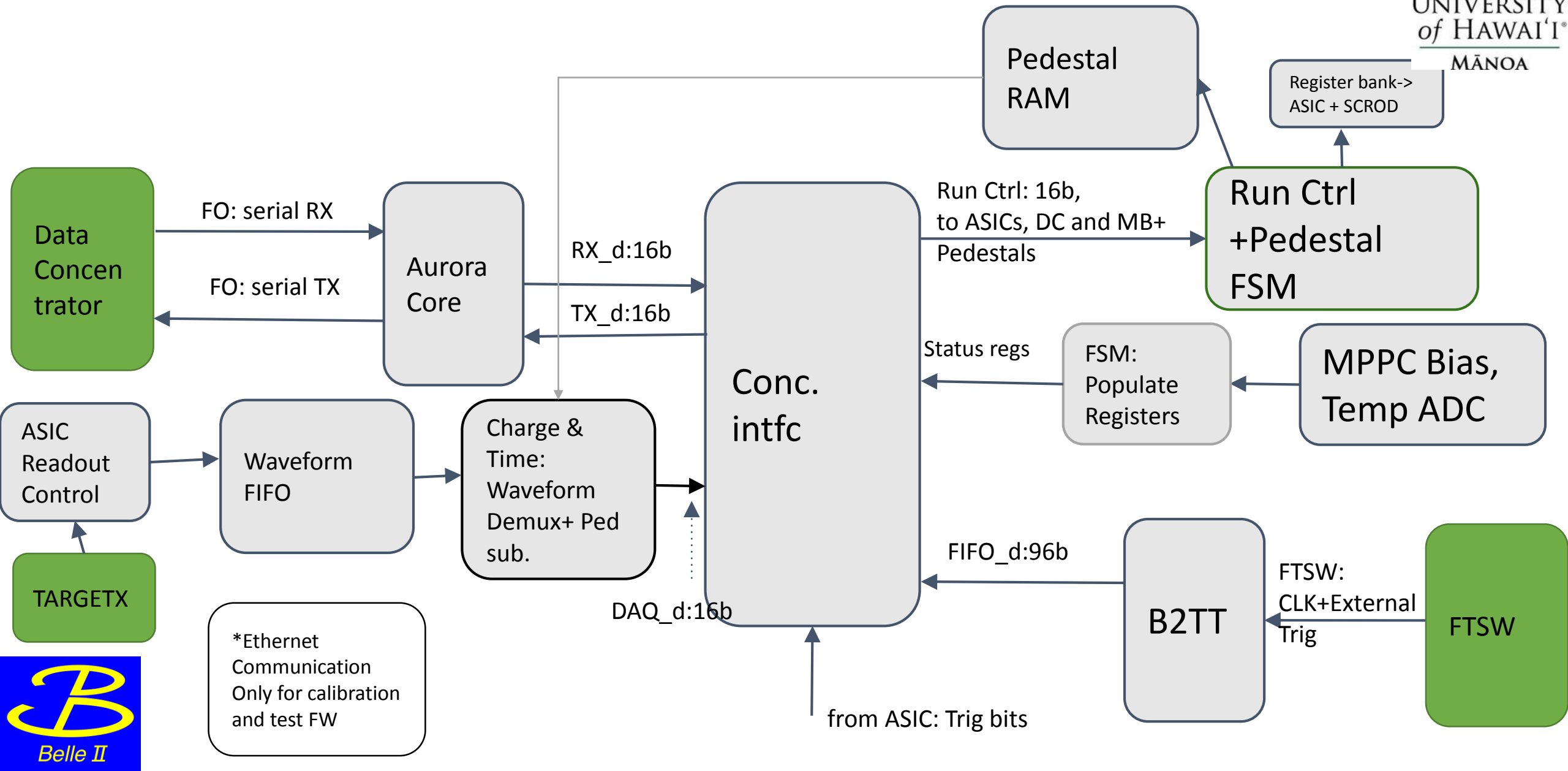
- 16 Channel ADC at 1 GSa/s
- ~16 MHz LVDS sampling clock
- ~64 MHz LVDS digitization & readout clock (16 channels at once)
- 2x32 sampling array
- 512x32 storage array (~16.3 us depth)
- ~1mV input noise
- 11 bit effective, 1.9V range
- Trigger encoding for reducing # of pins
- TSMC 250nm
- Designed at UH Manoa ID Lab.



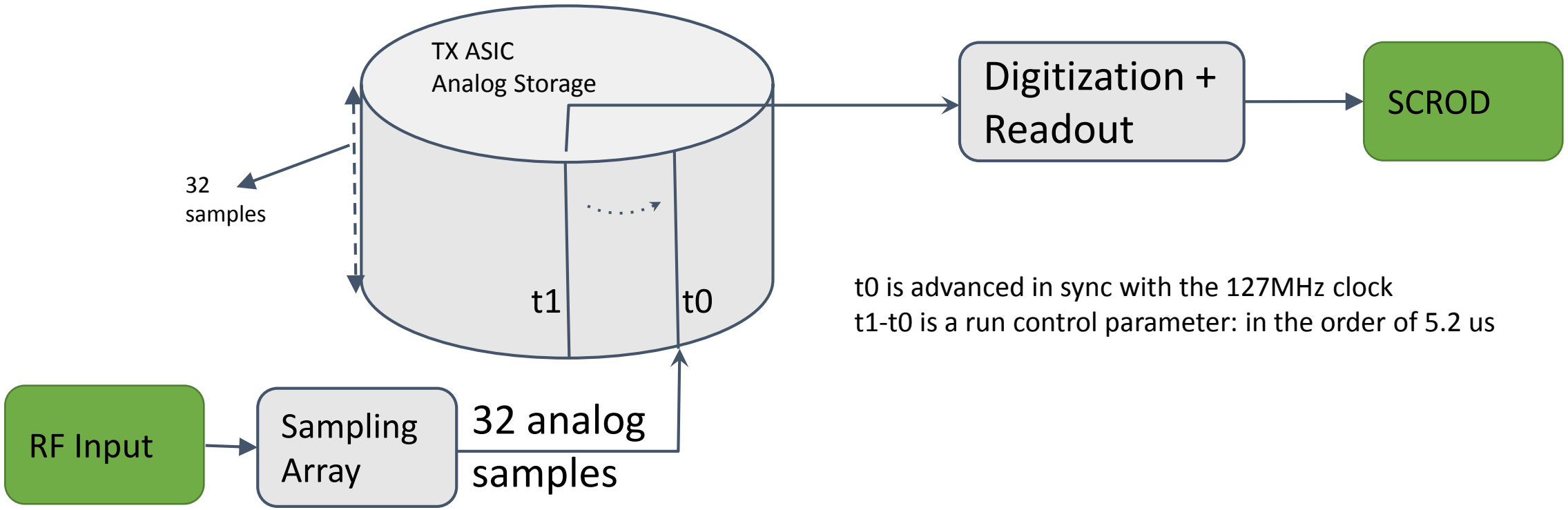
Scintillator FW Overview I

- 1 Xilinx Spartan-6 FPGA controls 10 TARGETX ASICs
  - Provide sampling and digitization clocks
  - Programs ASICs' slow control bias and timing registers
  - Programs HV trim DACs on the RHIC
  - Perform ASIC readout, calibration, pedestal subtraction and Q & T calculation
  - Routes ASIC trigger bits and readout data to Data Concentrator
- Code developed in VHDL within Xilinx ISE
  - Supports USB, PocketDAQ and Ethernet (WIP) communication

Scintillator FW Overview II



TARGETX ASIC Readout



t0 is advanced in sync with the 127MHz clock
t1-t0 is a run control parameter: in the order of 5.2 us

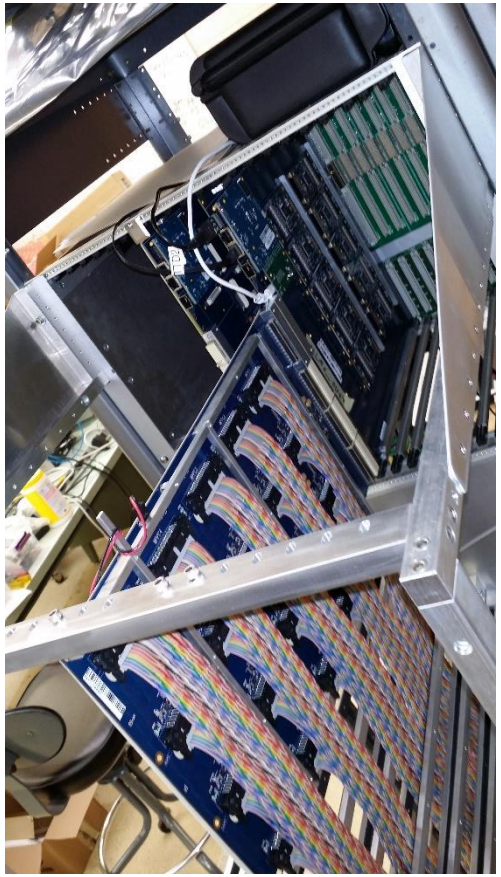
Benchtop and Crate Testing

1) KLM Motherboard

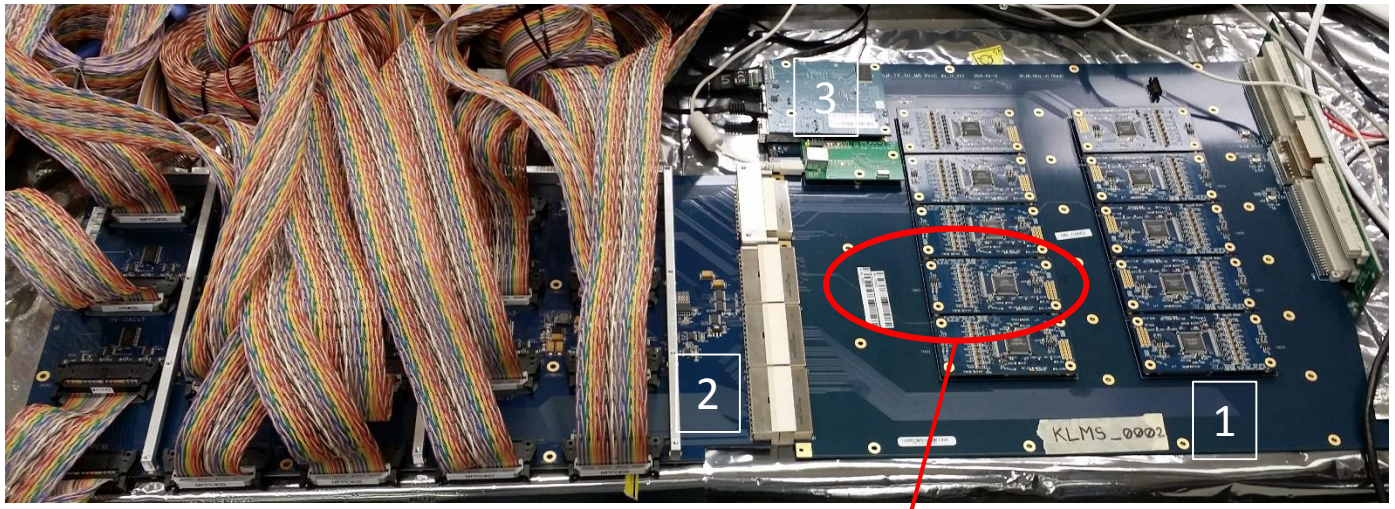
2) KLM Ribbon Header Interface Card (RHIC)

3) KLM SCROD Rev A

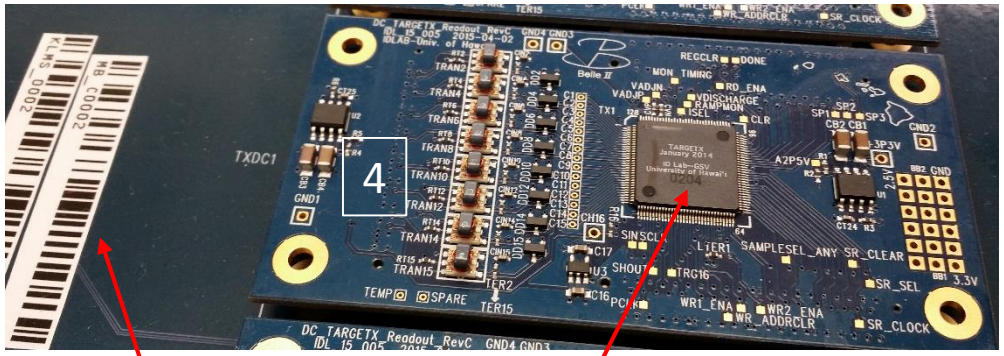
4) TARGETX Daughtercards



Crate testing at UH



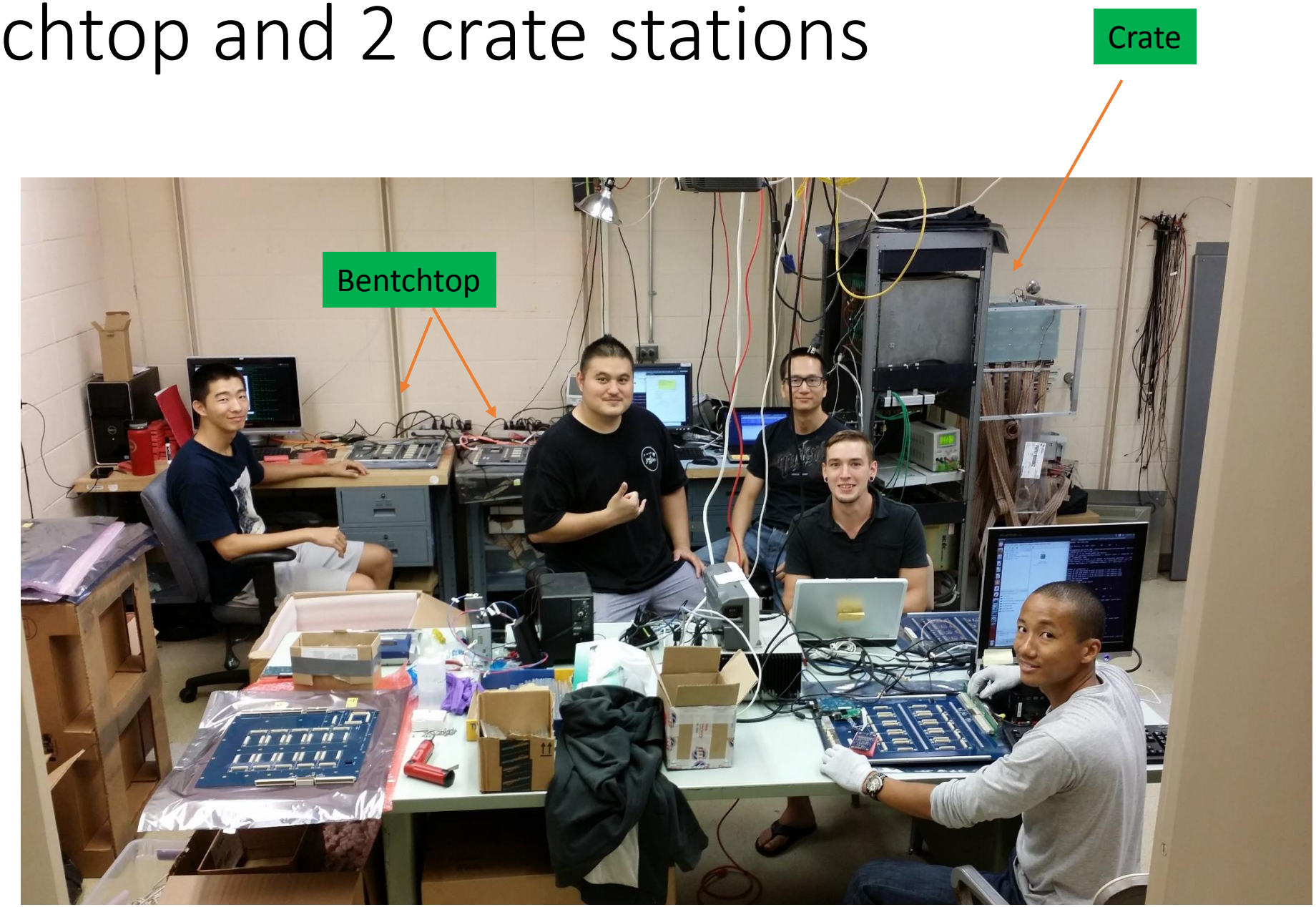
Benchtop testing



Barcode

Laser engraving

4 Benchtop and 2 crate stations



Panoramic

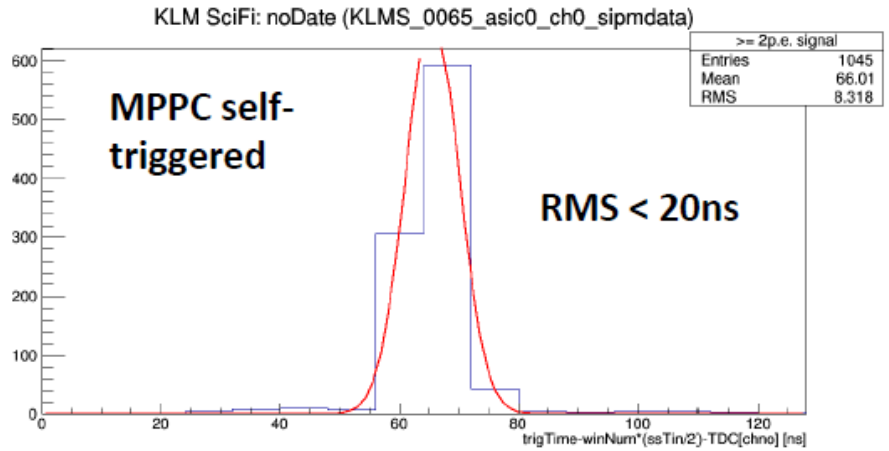
KLM final packaging:
111 modules in 4 large crates ~16k channels

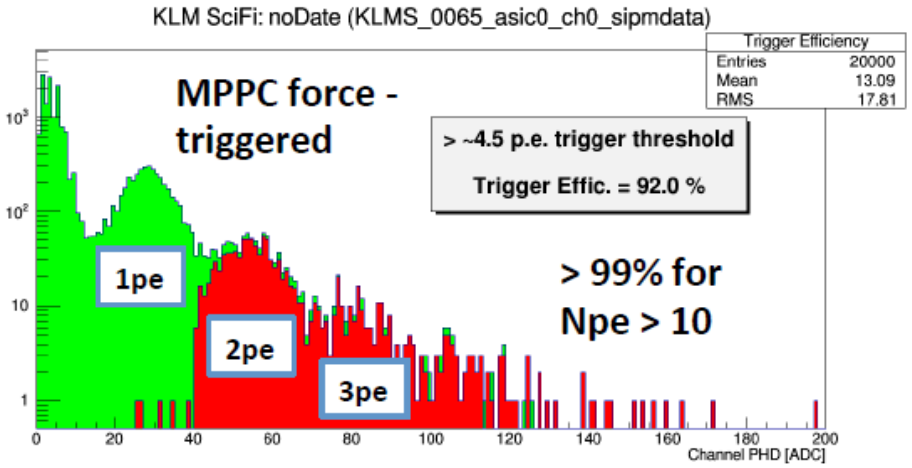
Motherboards and
RHICs staged in minicrates

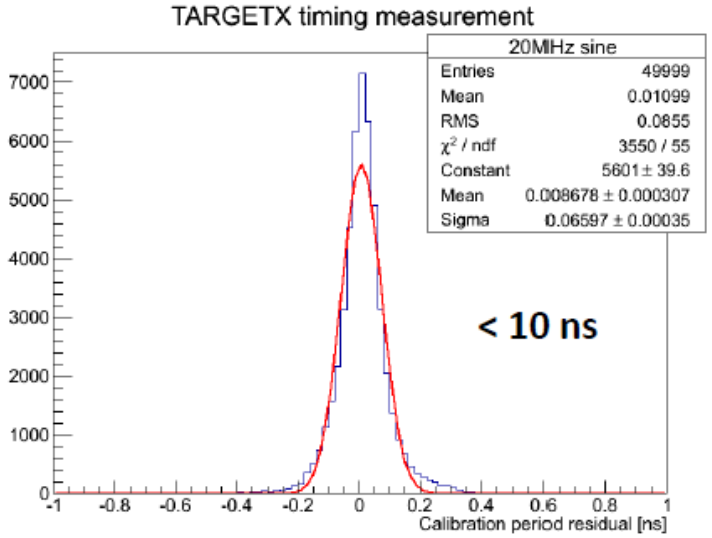
Minicrates inserted in large crates

Crates closed and ready for truck

KLM: Acceptance Tests Exceed Thresholds







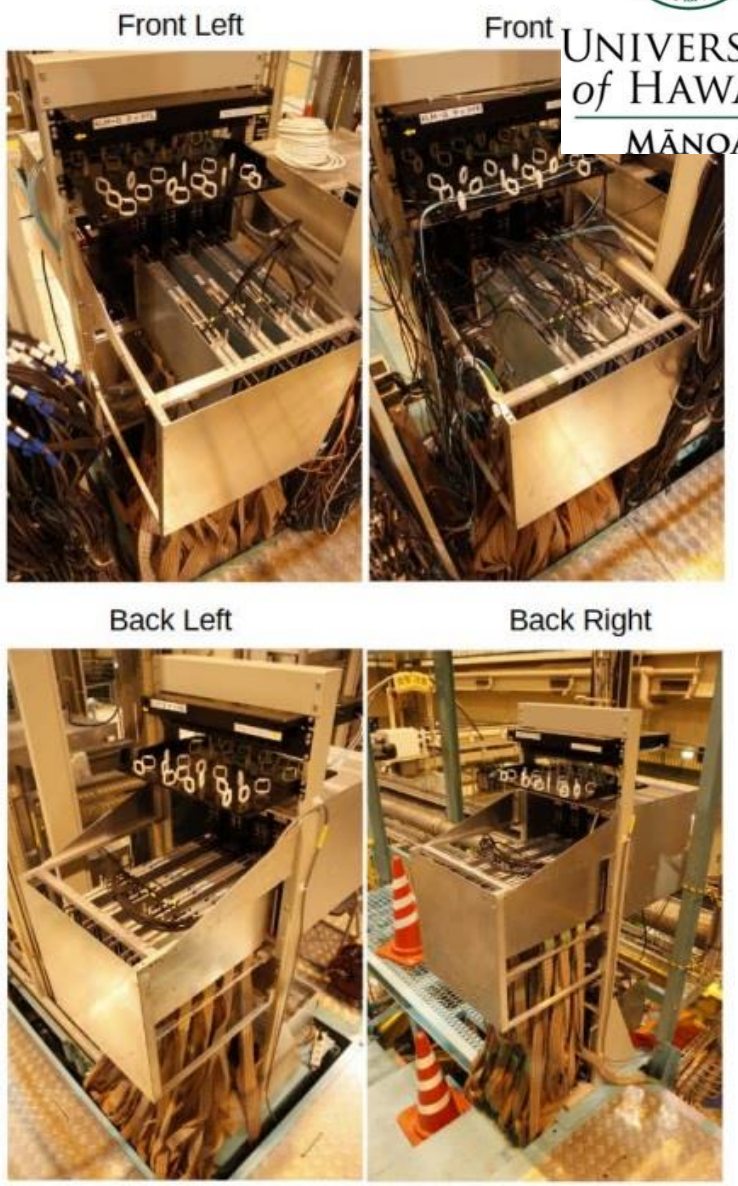
Sine scan data (zero crossing)

KLM Readout System Performance

Tolerance	Threshold	Objective
Good Channels	90%	98%
Deadtimeless Occupancy	0.5%	1%
99% minimum ionizing particle efficiency	10p.e.	7p.e.
Event Timing	10ns	5ns
Event Trigger timing	20ns	10ns

KLM: June 2016 B2GM update

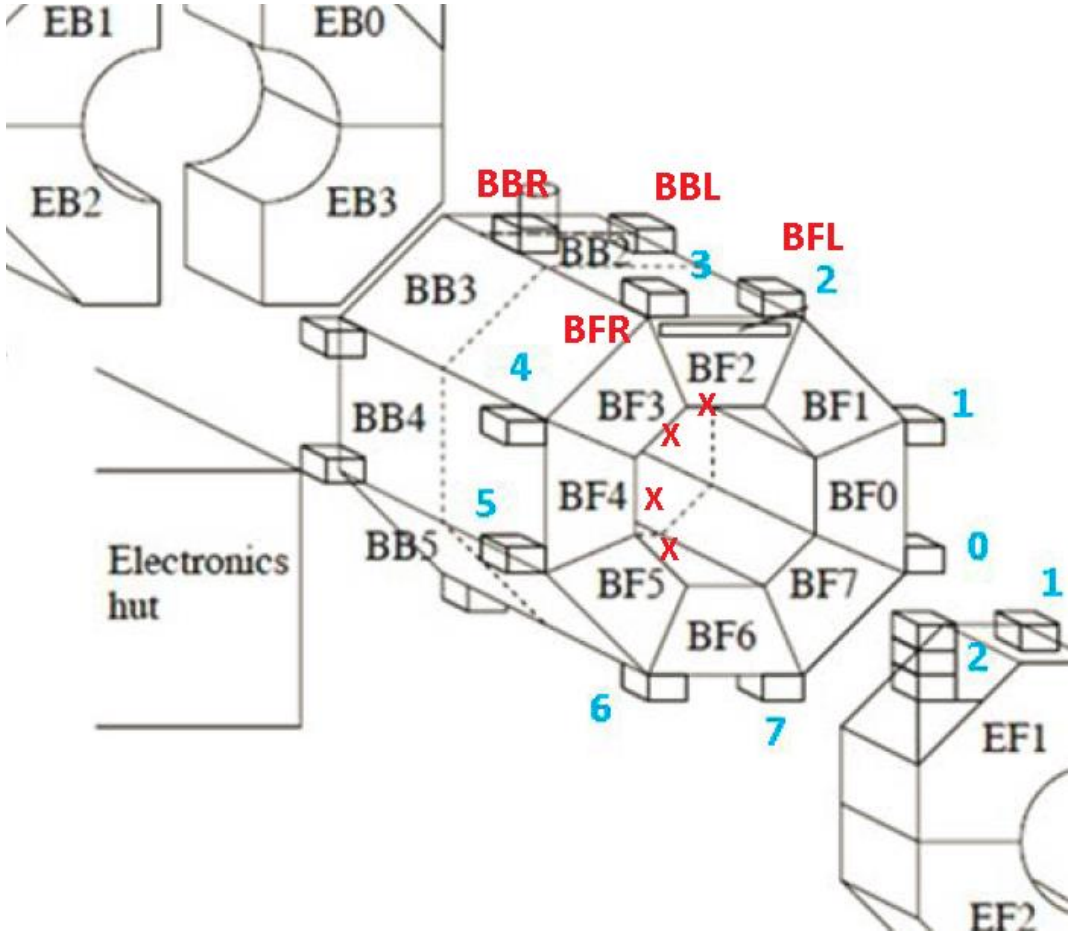
- All barrel scintillator readout modules are installed and tested (UH)
- Scintillator HV cables installed (KEK)
- Trigger, readout and FTSW Fiber trunks have been installed from ehut to crates (KEK)
- 33 Dataconcentrators arrived at KEK (IU)
- Tech transfer to INFN to build RPC readout modules (IU)
- Readout FW updated (IU, UH)
- UT3 can now read RPC and scint. trig packets
- 17x KLM spare modules are under test at UH
- **Aug 2016: More endcap modules installed by ITEP**
- **Rest of barrel fibers installed right before shutdown**



Barrel scint. readout modules-Chris Ketter, UH

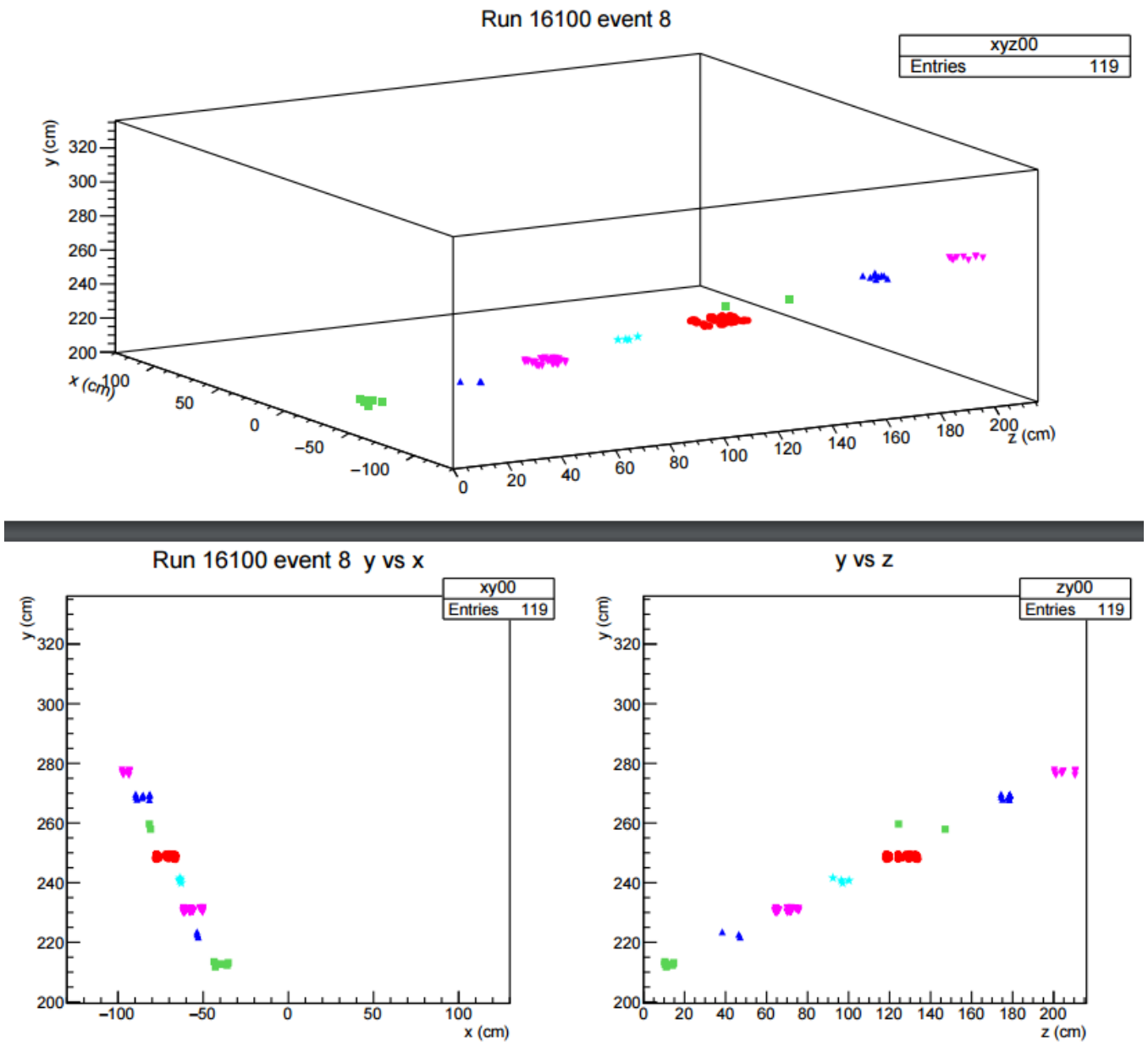
Current Barrel Connections

- Sectors marked with X show instrumented and connected sectors to DAQ:
  - BF2: Scintillator+ RPC
  - BF3,4,5: Scintillators only
- Other BFx: Scint. Modules installed only



Recent Update on CRT 6/22/16

- Fixed RPC look back window
- CRT tracks seen in RPC and Scint. Layers
  - Debugging some anomalies
- Trigger data for instrumented sectors now flowing to UT3
  - Debugging rates and anmalies



Next steps

- Recovering from annual KEK shutdown
- Ensure trigger stream quality
- Firmware updates
- Install the data concentrators and TTD system
- Take CRT data from fully instrumented barrel scintillators

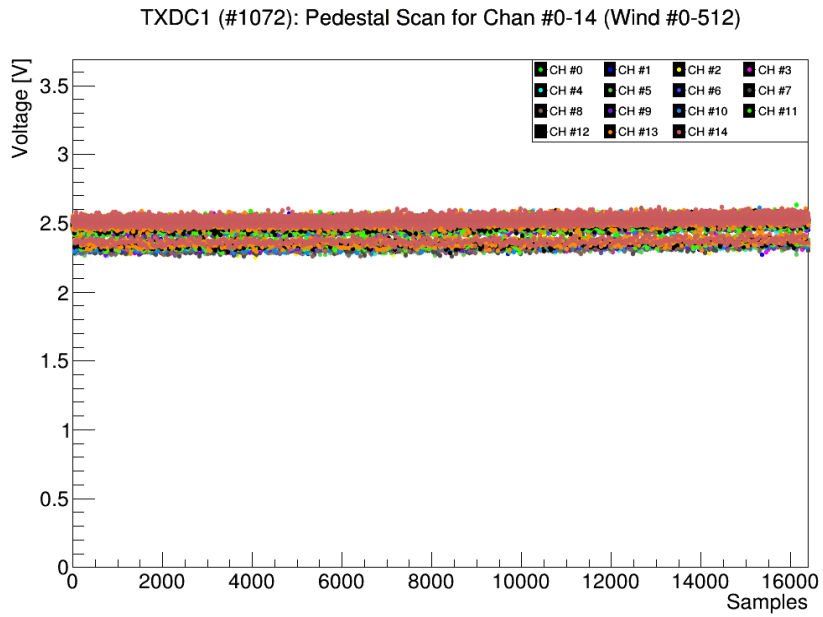
Back up slides from here on

Production Testing and Calibration

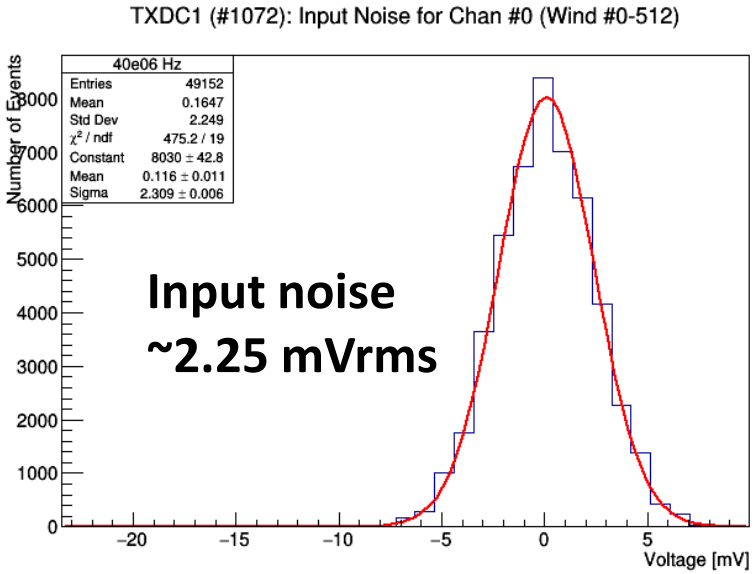
- TargetX
  - Noise test, pedestal test
  - All channels operational, all readout windows operational
  - Timing calibration for best performance
    - 40MHz sine input @ 600mVpp
    - Per chip scan of timing register
- Analog Front-end
  - MPPC bias test
  - Preamplifier carrier temperature readout
  - Trigger threshold scan
  - Full dark count waveform sampling triggered by MPPCs
- USB based readout (slow) on four concurrent stations

TARGETX ASIC Production Testing:

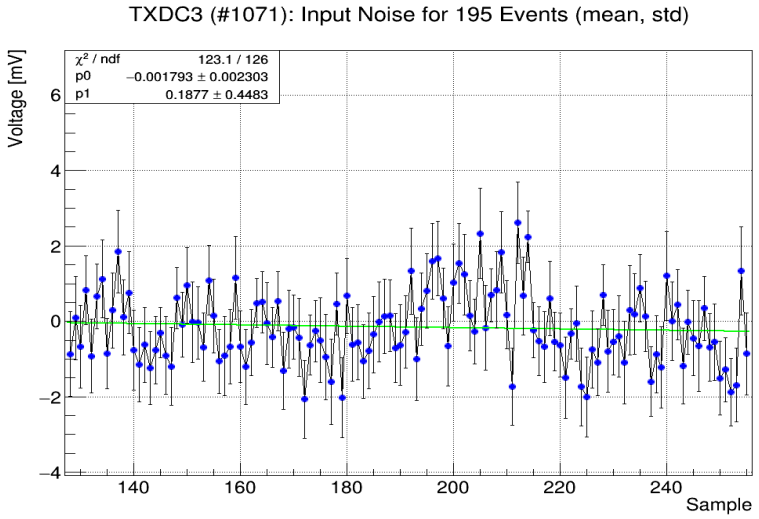
Pedestals and input noise



Look for shorts and unexpected pedestal offsets



Input Noise Histogram
for Single Channel



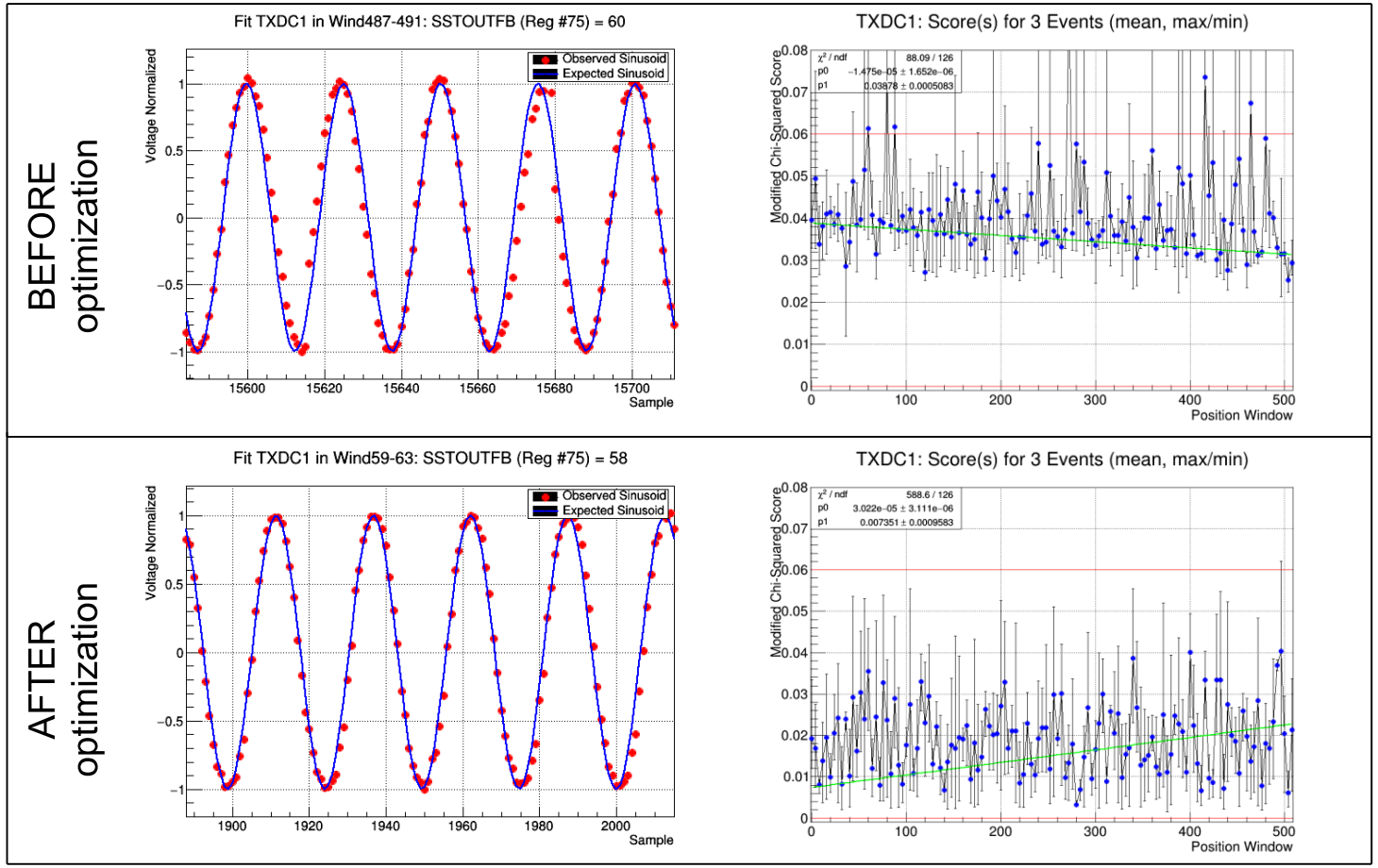
Input Noise
for Single Channel

TARGETX ASIC Production Testing

Parameter Optimization

Each ASIC went though parameter sweeps to optimize timing and create the best waveform sampling.

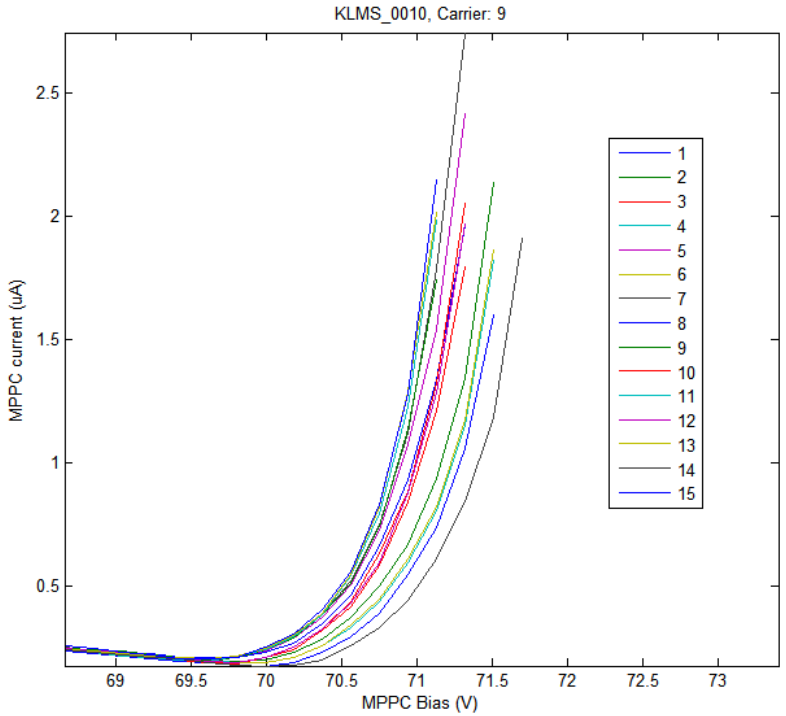
Enhanced Sampling Performance by Optimizing SSToutFB



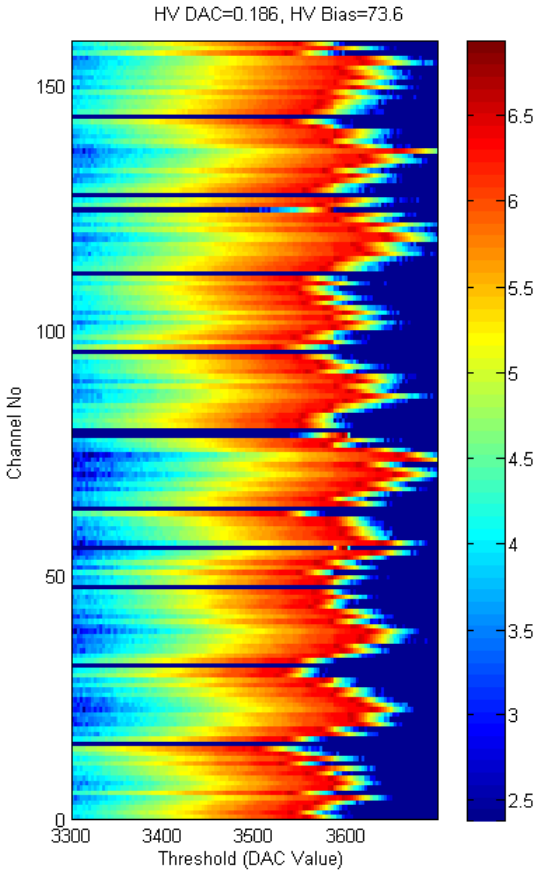
All values below red line indicate that an optimized SSToutFB was chosen

Analog front end:

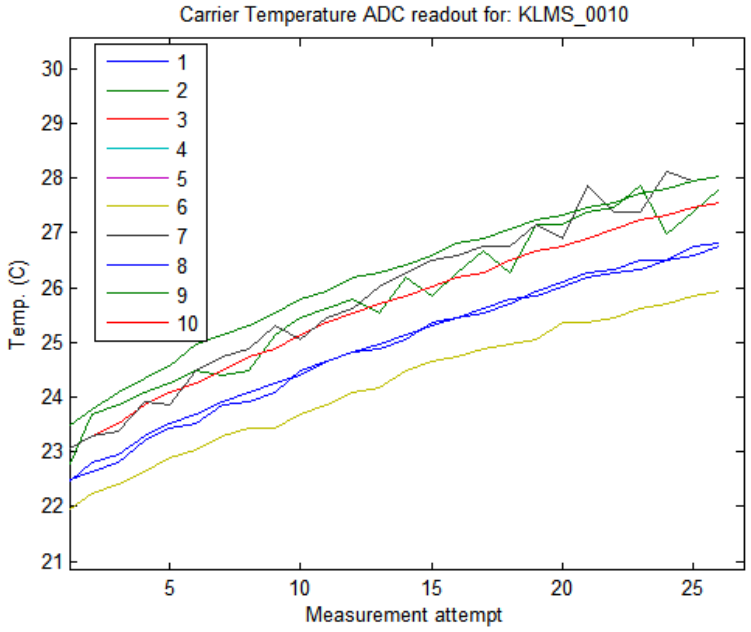
MPPC Bias, Trigger Scan and Temperature



MPPC current vs. voltage and operable region:
All channels work well



Trigger threshold scan:
All channels work well

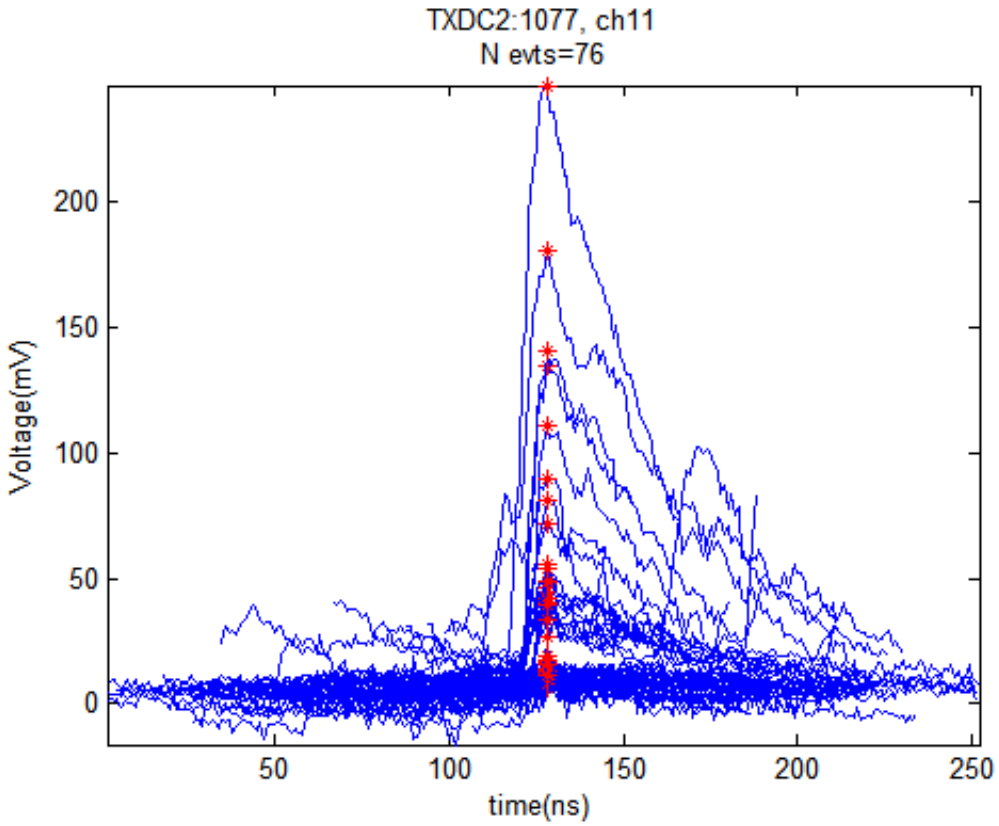


Carrier Temperature

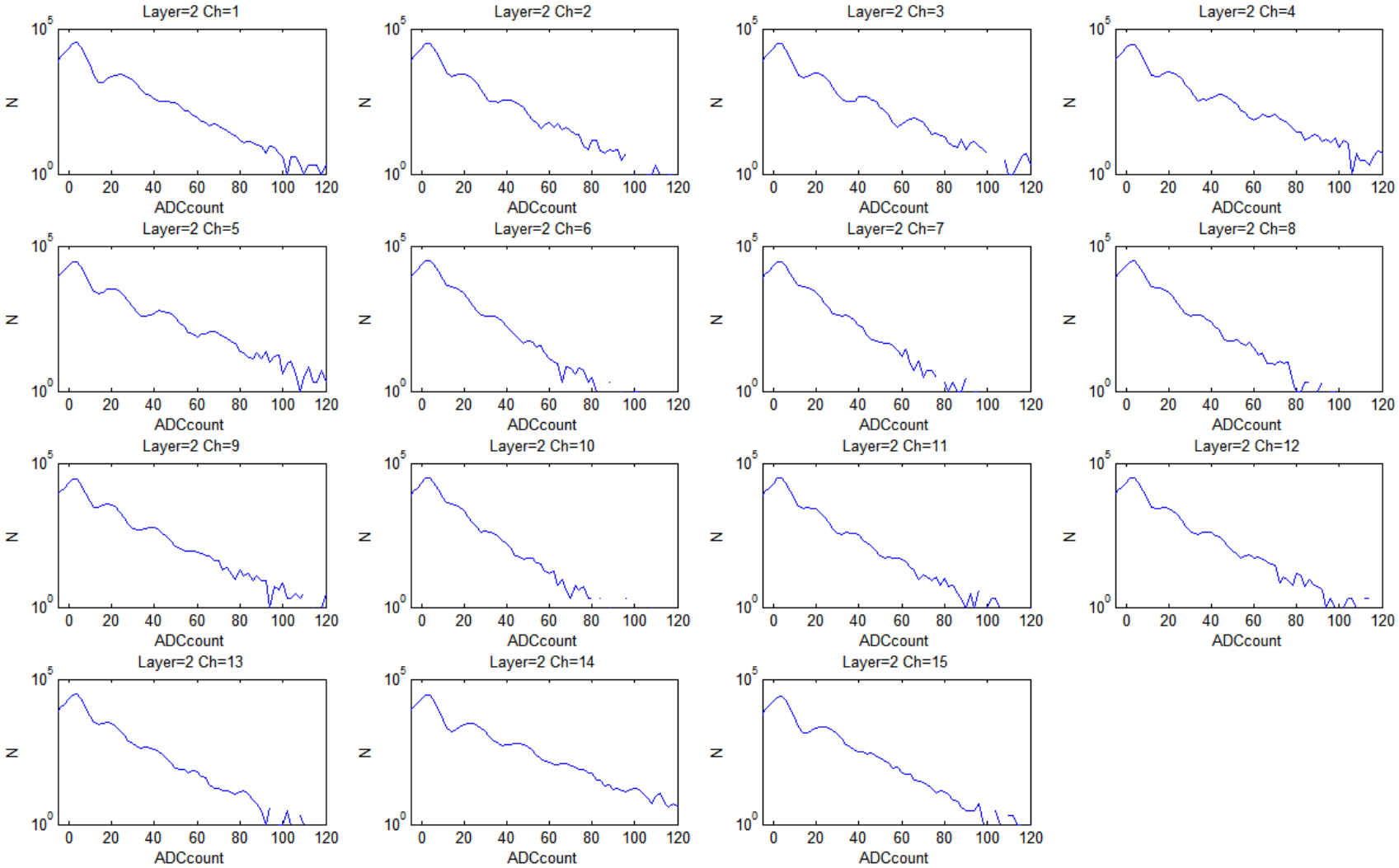
MPPC Waveform Sampling

Overlay plot of 76 MPPC events recorded on a single channel one TARGETX ASIC.

Indicates health of analog path all the way to through sampling



SW trigger Q and T



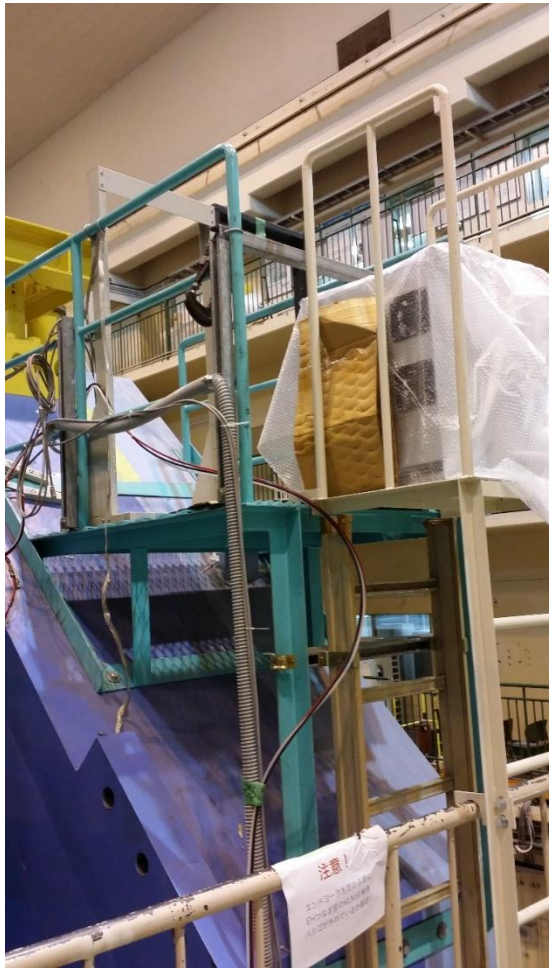
Full KLM barrel crate

- 8 RevC modules were installed in the barrel crate
- Due to only one RPC crate being fully commissioned, the data concentrators were positioned within the same RPC and VME crate for ease of access.
- Each sector (motherboard pair) is serviced by 1 data concentrator and HSLB in the e-hut.
- New RHIC framing and HV connector functionality were tested.
- Additional temporary fiber cables were routed to e-hut. Unfortunately due to lack of time and resources there were no conduits used.
- A slow control and PocketDAQ readout was performed on all sectors.

Fully populated KLM barrel crate. Ribbon cables enter from the bottom

Endcap crate

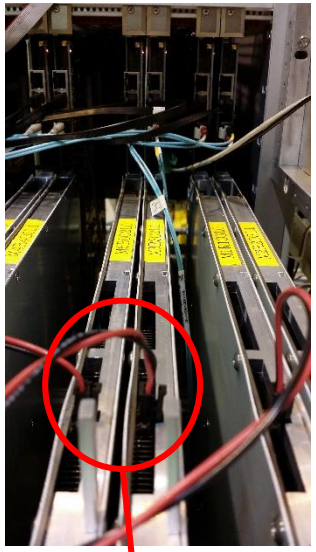
- UH crew secured the endcap racks to the rails and the floor and installed the VME crate. (Chris K.)
- Two KLM RevB readout motherboards were installed in the crate.
- FTSW and data concentrator were installed
- The scintillator ribbon cables are awaiting a jig to be manufactured.



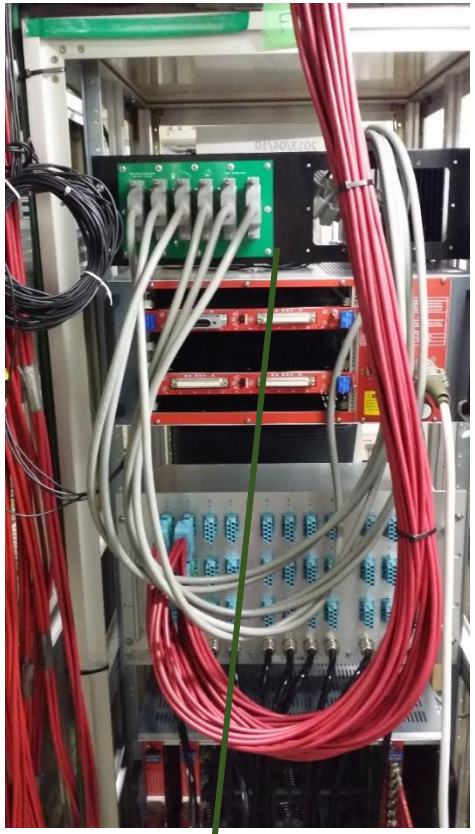
Bubble wrapped endcap crate and two endcap racks on endcap door before installation

New HV patch panel and associated cabling

- KLM HV patch panel was installed
- A temporary DB25 connector was soldered to bring HV lines to the crates.
- The HV connectors on the RHIC on the crate were tested mechanically and electrically.
- Due to an unpopulated 0 Ohm resistor, this did not work in last minute. We will try again.
- The long production HV cables and breakouts were ordered by VT and should arrive at UH.



Crate: HV line entering the RHIC



E-hut: HV Patch panel

KLM DAQ cabling plan

- Exact cable lengths were measured.
- Work in progress: coming up with a cabling plan to minimize routing while connecting the VME and RPC crates together and to the e-hut.
- These lengths will be used buy KEK to place orders for trunk fiber cables for DAQ, trigger and FTSW clocks and patch panels.

Continuing efforts

- UH, IU: Remote debugging of the sector which has both RPC and scintillator layers in order to achieve a joint RPC/Scint event readout
  - New slow control HV trim DAC values and trigger thresholds has been uploaded.
- UH: Gathering scintillator waveforms for analysis at ITEP
- UH: Troubleshooting the powering scheme to avoid future issues at next round of commissioning
- KEK: Installation of the endcap ribbon cables for endcap readout
- KEK: Installation of the rest of the barrel and endcap racks and crates; ordering and installation of fiber trunks and panels; providing the required FTSW and COPPER hardware;
- Next commissioning effort to populate the entire KLM scintillator readout electronics is scheduled for early October 2015. (2 weeks prior to 22nd B2GM: Oct 19-22, 2015)

Summary

- Overview of KLM scintillator readout and brief history
- HW design and production
- FW structure and development
- SW development and testing
- Production test results and CRT efforts
- Trigger and DAQ routing and interface
- Lot 1 commissioning summary
- Next steps

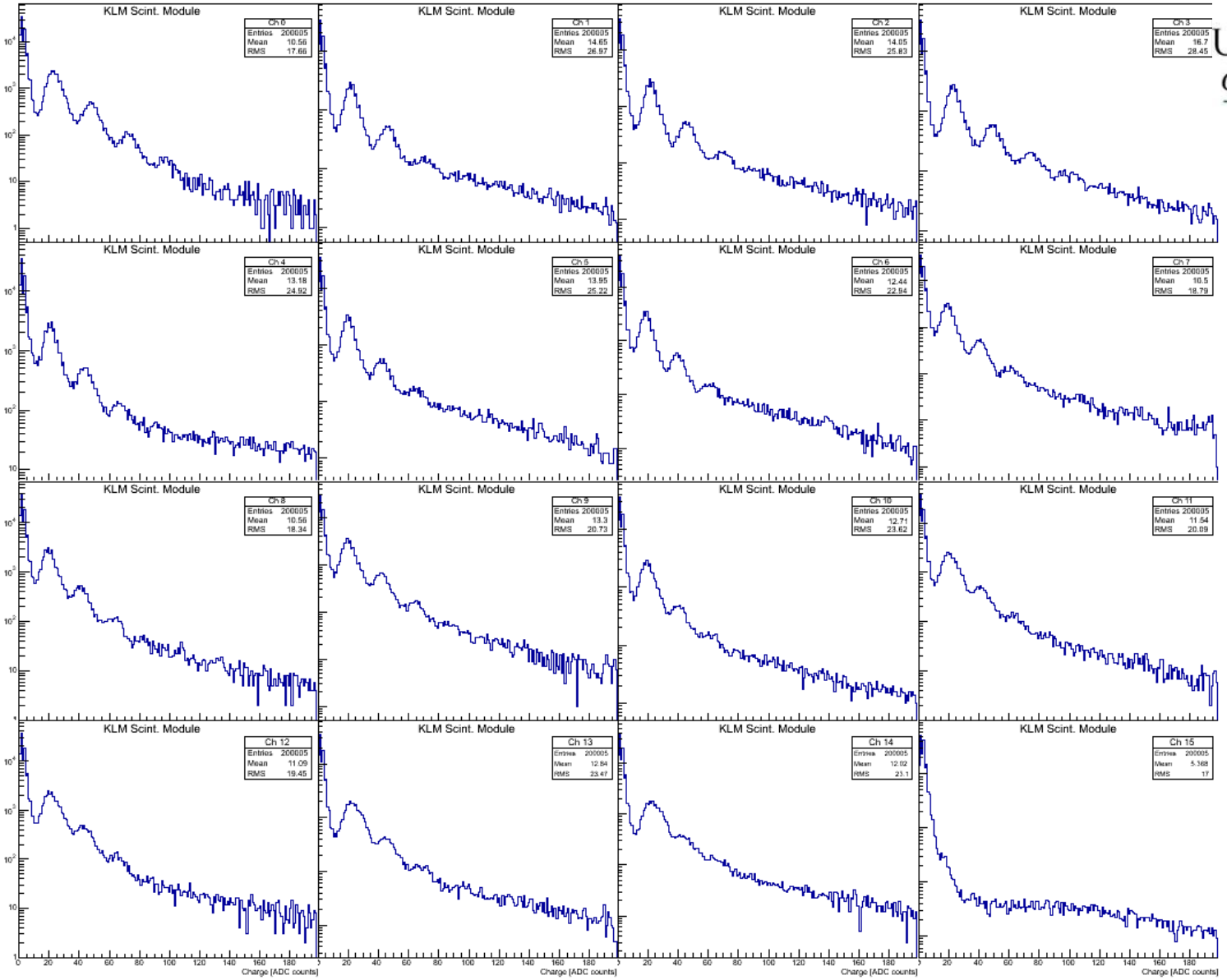
Acknowledgements and Q&A

- Credits:
  - PNNL
  - KEK
  - IDLAB
  - IU
  - VT
- Questions?

BACKUP

BACKUP

KEK: 200K events run, V=72.0
Trig Threshold=3200



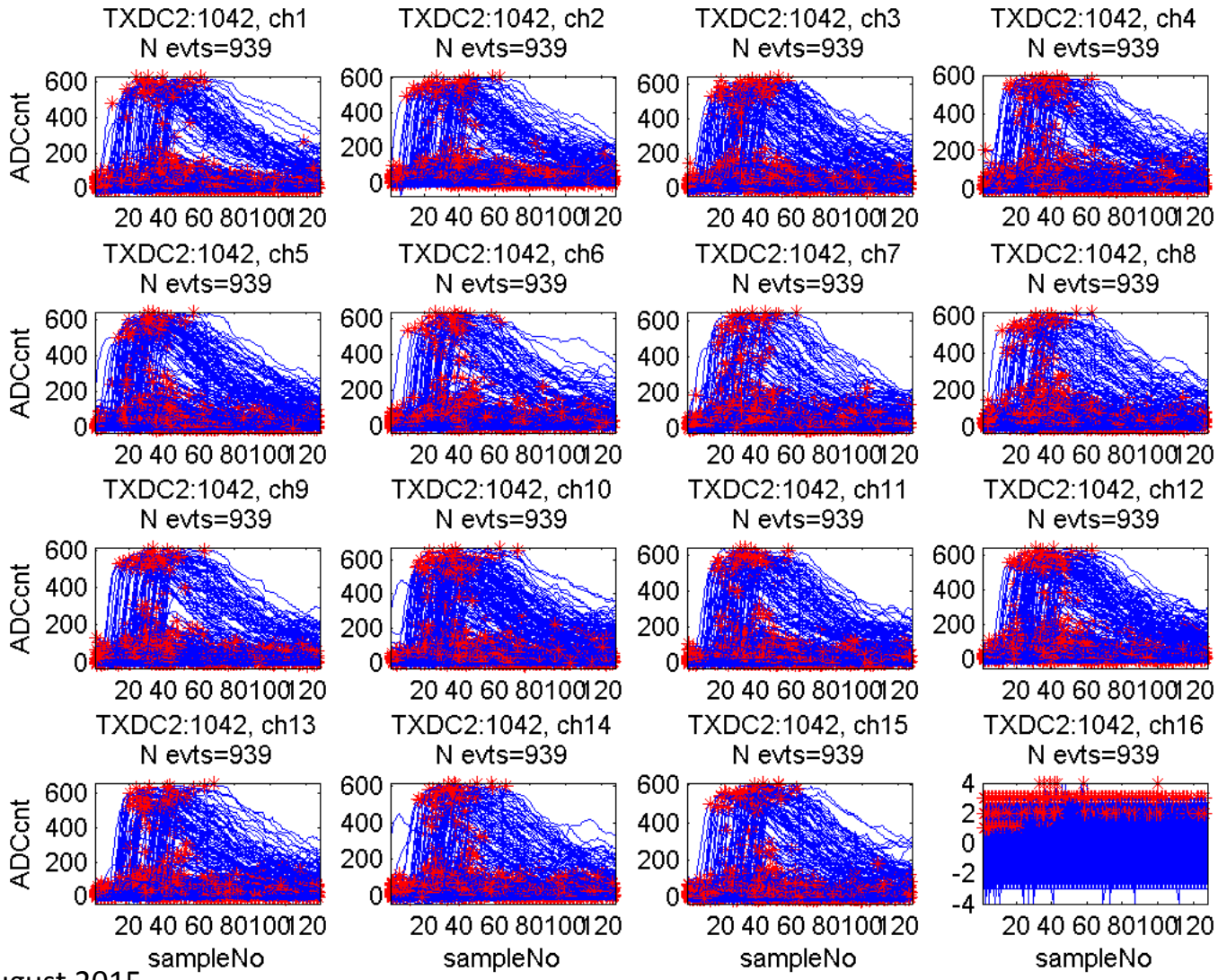
Next:

Run more large events and scan V to calculate MPPC gain

MPPC Waveform Sampling

Plot of 15K MPPC events recorded on 16 channels of a single TARGETX ASIC.

Indicates health of analog path,



Calibration channel
Not connected to MPPC