The Nevis TPC Readout Hardware for MicroBooNE and SBND

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for the Nevis electronics Group:

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Joint DUNE-SBN DAQ meeting

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Our task

- For 8256 wires in MicroBooNE and 11,264 wires in SBND:
- Readout **Neutrino** data upon appropriate trigger, compress it, format it and send it on to storage.
- Readout **SuperNova** data continuously and store it temporarily awaiting for external SNEWS network alert.

Plan of talk

- The MicroBooNE warm readout system and data flow.
- How it is modified for SBND. Clearly advantages:
  - Building on an existing system.
  - Potentially identical DAQ and data format as MicroBooNE.
- The Trigger module.

The MicroBooNE Electronics Functionality

TPC: (2 MHz)

- Neutrino events: Read them and compress them (factor of ~5) losslessly (Huffman coding) following a beam trigger.
- SuperNova: Readout Data continuously compress (~80, some loss) and store for several hours awaiting a SNEWS alert (< 1 hour delay)

PMT's: (64MHz) MicroBooNE only

- *Readout for both beam and SuperNova data*
- *Use PMT Information to provide a trigger for beam events and for cosmic rays, based on amplitude and multiplicity of all, or groups of, PMT's.*

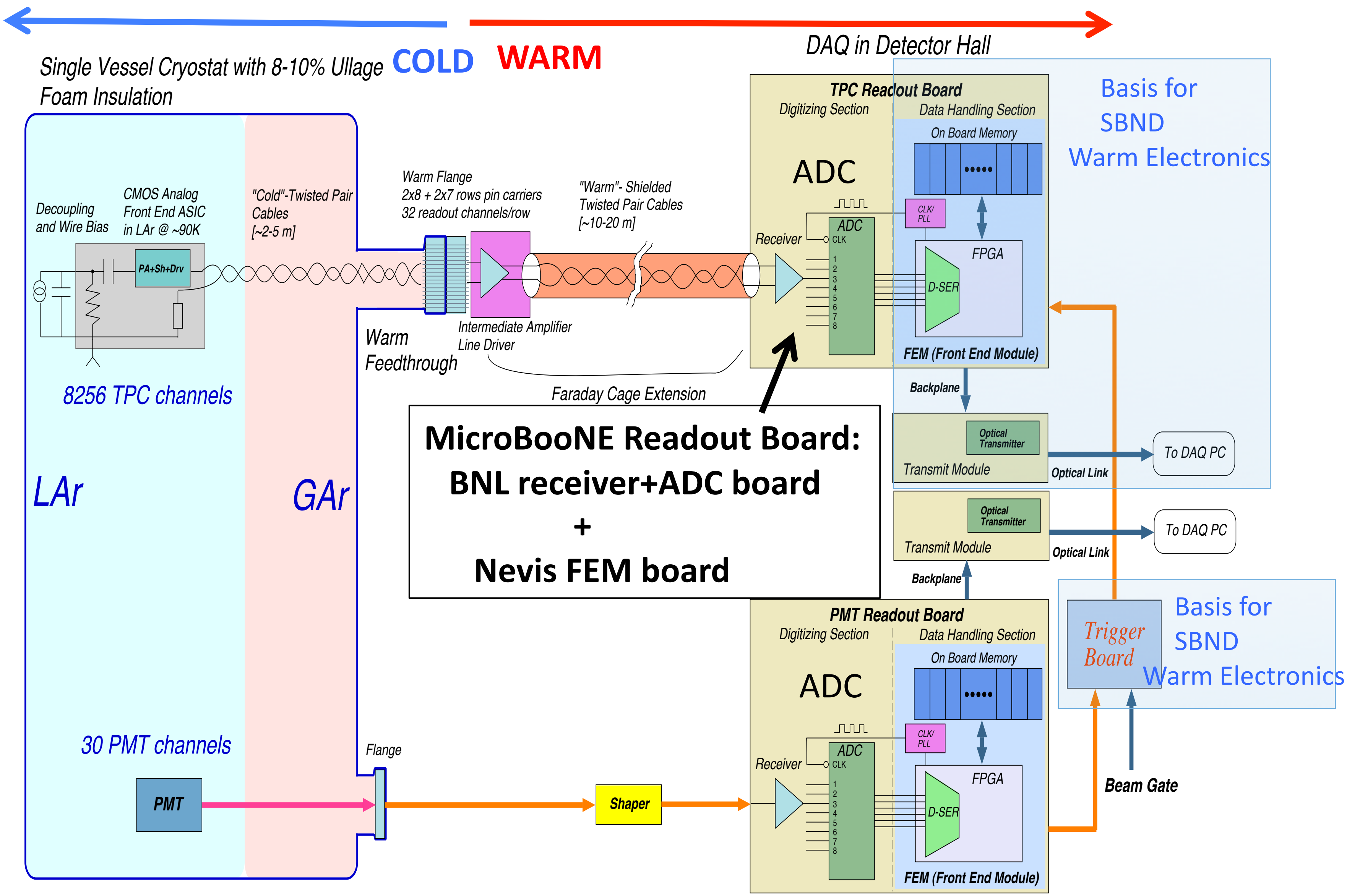
Additional readouts/triggers:

- LED's for PMT calibration
- Cold electronics ASIC calibrations
- Cosmic paddles
- Laser TPC field calibration
- Randoms

Master Trigger board

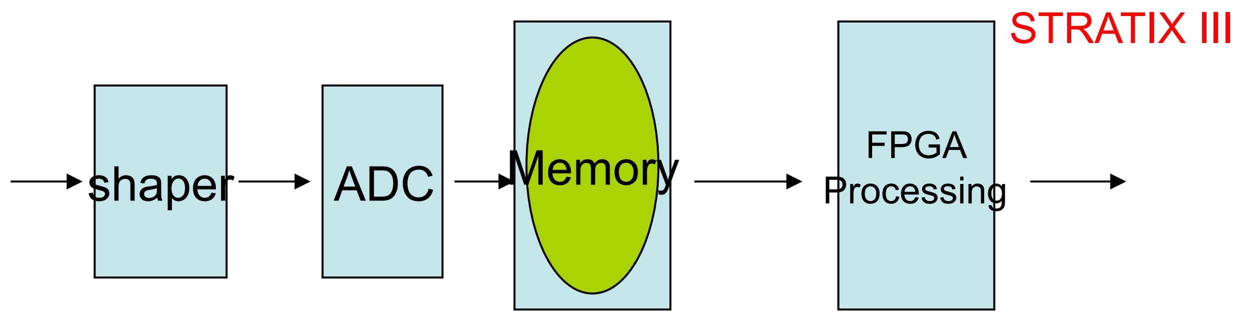
- Allows/inhibits various triggers

The MicroBooNE Electronics Scheme



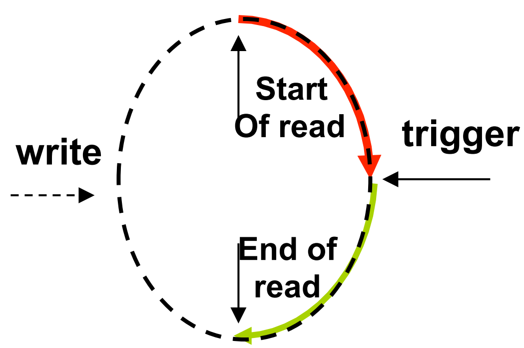
Generic FEM signal flow

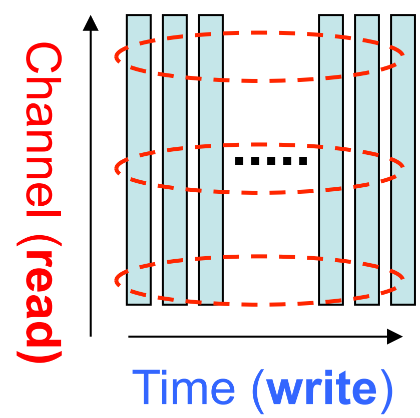
64 wires per board



Processed header is arranged for signal transport

(frame header, trigger type, event length etc)





Organized as a circular ring buffer.
Hold the data for the trigger decision.
Buffer the incoming data
for the deadtime less readout.

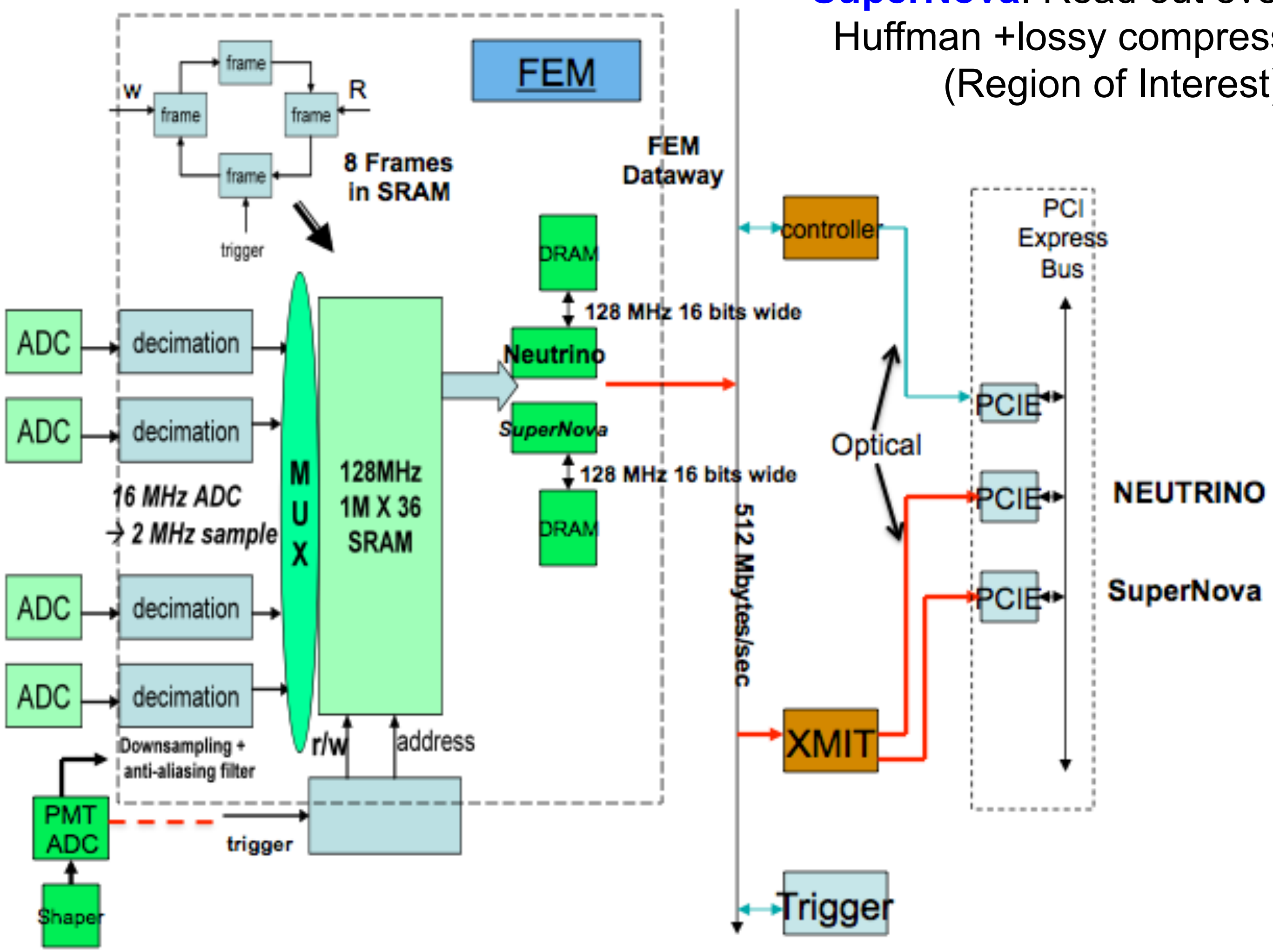
Signal is recorded in
time order
Readout in
order of wire number
For compression
(and decimation)
On alternate memory
cycles
Address field (wire number + time sequence)

System Diagram for Triggered beam events and Continuous supernova data.

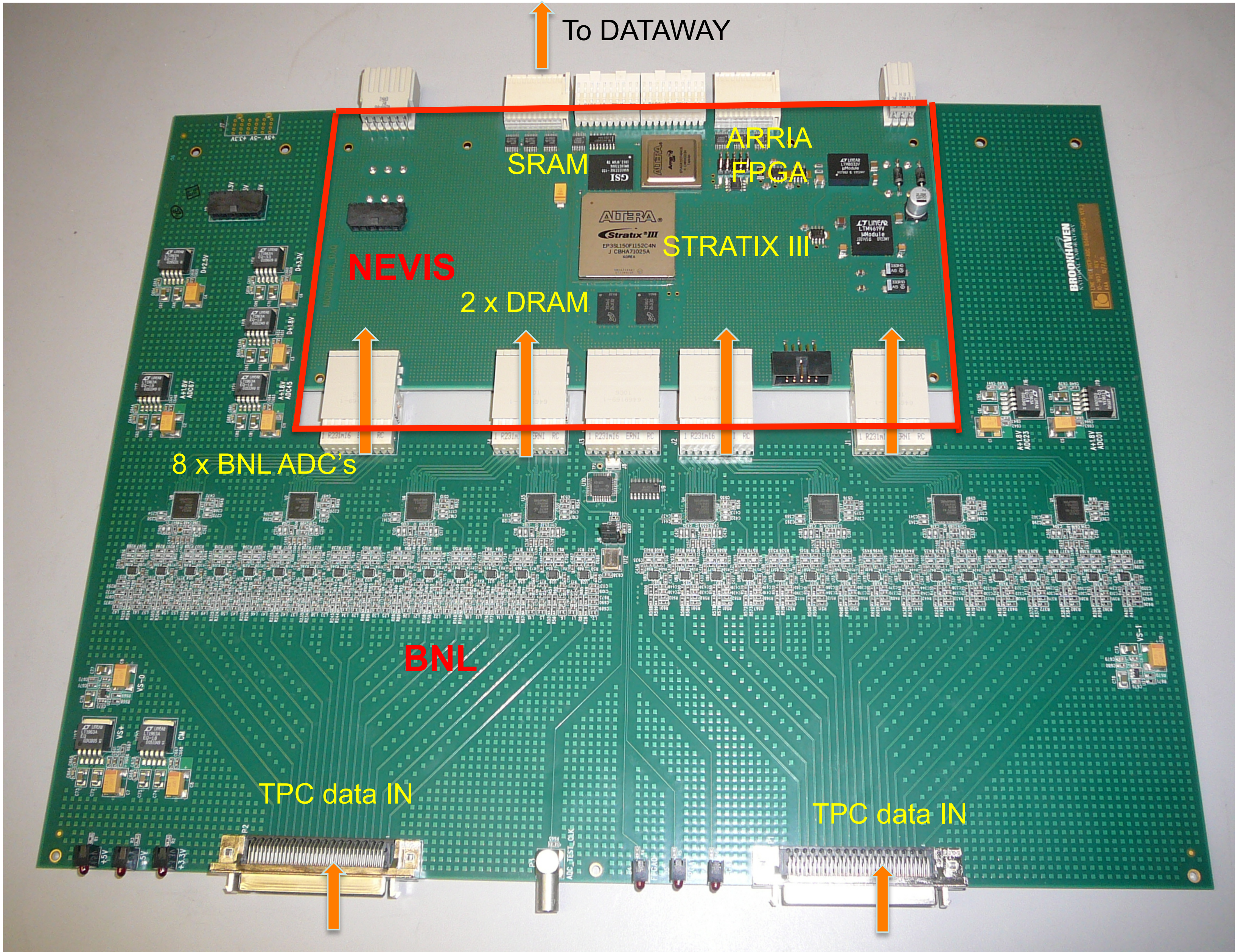
Frame size: 1.6ms = drift time

Beam Neutrino trigger: Read out 3 frames
Lossless Huffman coding ~ **factor 5 reduction**

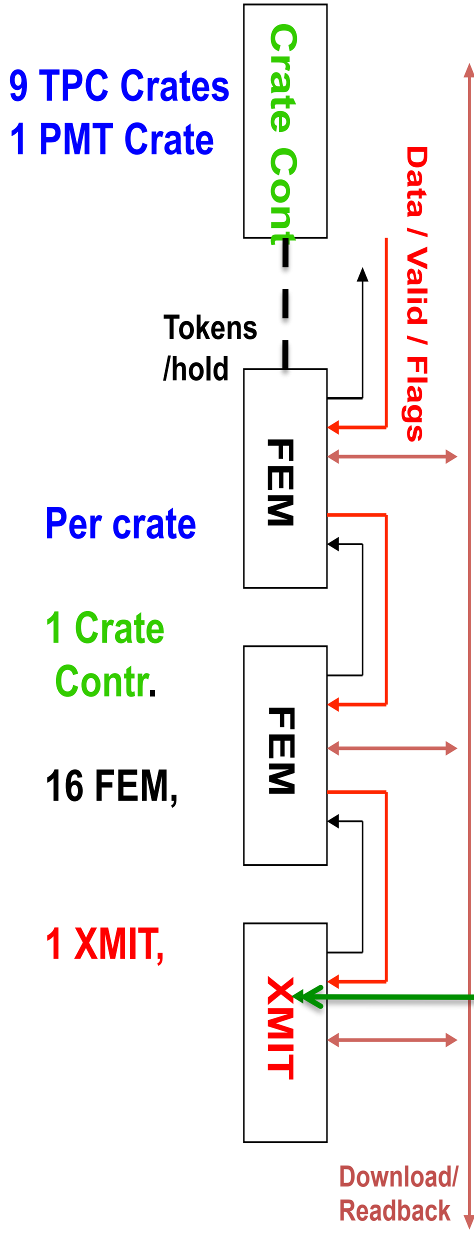
SuperNova: Read out every frame:
Huffman +lossy compression
(Region of Interest) ~ **factor 10 reduction**



The MicroBooNE Front End Module



Crate dataway recording Scheme



9 TPC crates + 1 PMT crate
Up to 16 FEM's per crate.
Token passing scheme from one FEM to other.
Initiated by XMIT
512MB/sec dataway capability.
50MByte/sec rate expected → Deadtime-less readout.

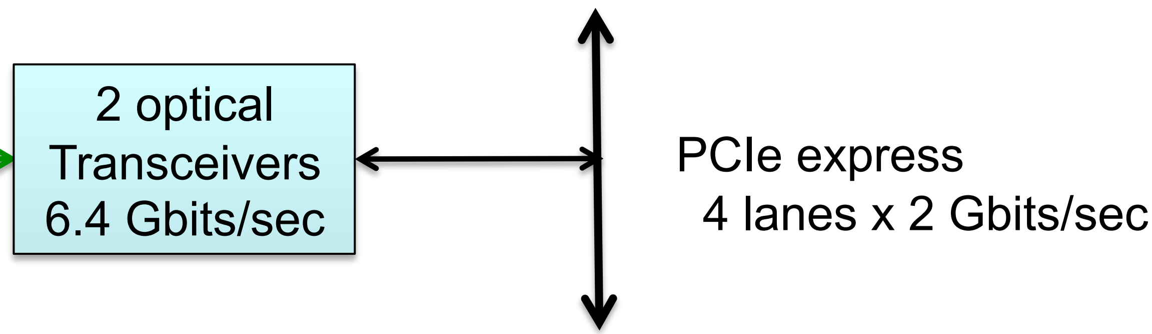
↓

One PC/crate.

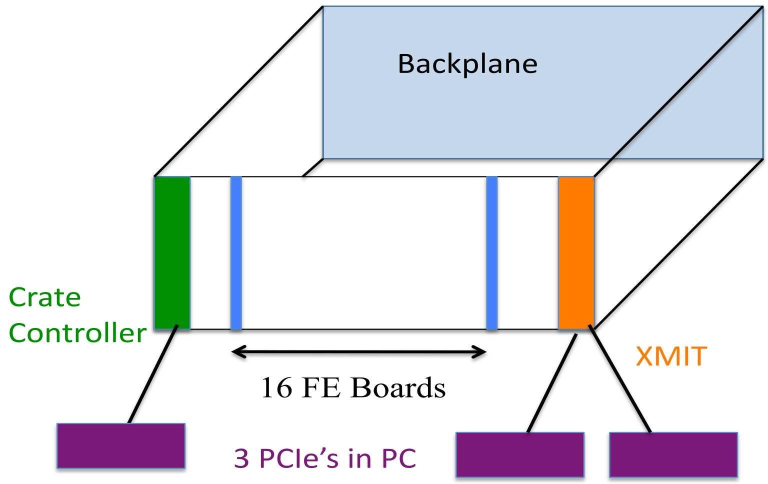
Via 2 PCIe cards in each PC: 1 for ν data, 1 for SuperNova

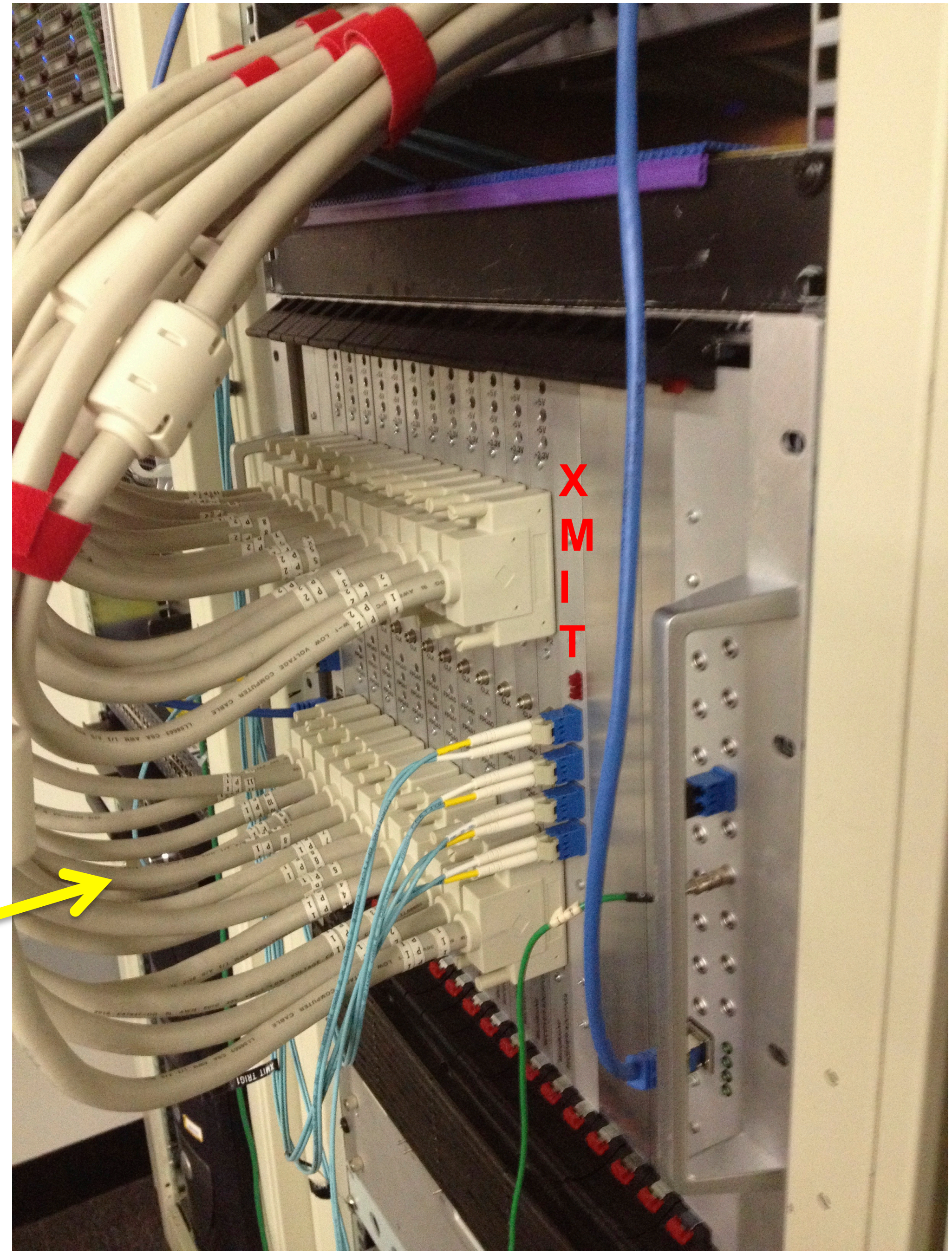
The 10 PC's send ν data to an additional event builder PC.

SuperNova data stored locally in each PC in a circular buffer resident on disks for several hours.



Crate





Cables from Feedthroughs

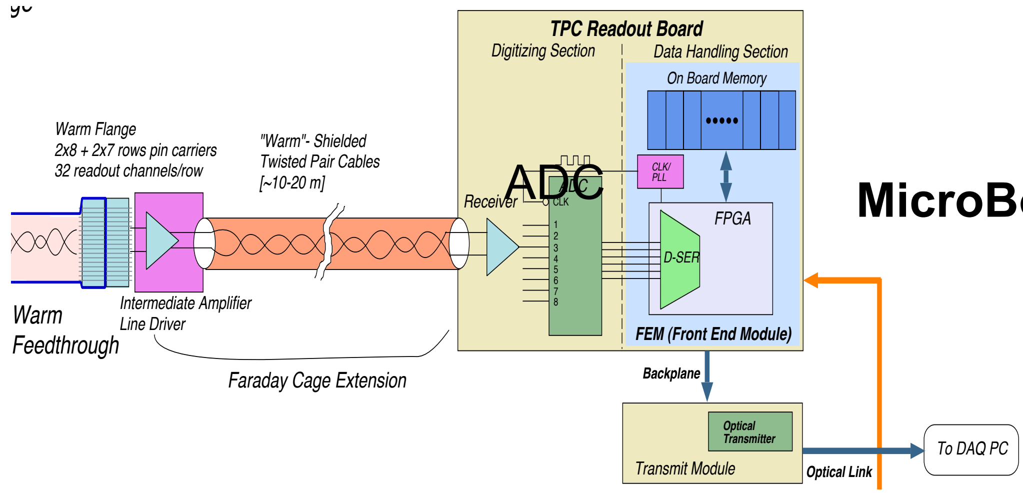
MicroBooNE data rates and Experience

- Currently getting 5Hz neutrino batches from BNB.
- Studying our on-line PMT trigger.
- Reading out all 5Hz beam spill TPC data at 2 MHz.

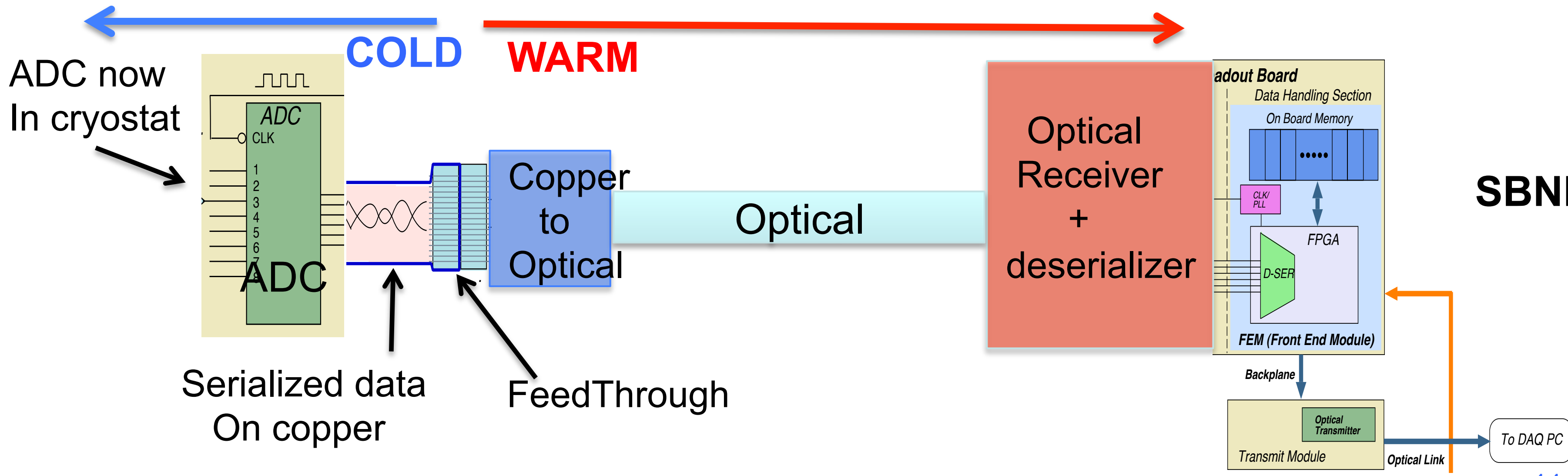
- Per crate:
  - Per beam spill we readout 4.8 ms of data
  - $(4.8 \times 10^{-3}) \times (2 \times 10^{+6}) \times$ (16 boards x 64 ch/board) x 2B/word
  - = 20MB/event
  - =100MB/sec at 5Hz.

- Huffman compression (factor of 5) = 20MB/sec on each crate dataway
- (512 MB/sec capability)
- 9 TPC + 1 PMT crates at event builder stage

Adapting the MicroBooNE electronics



Replace: BNL Receiver/ADC by Optical Receiver and deserializer
Functionality of Nevis FEM board would remain the same.



SBND electronics

- The ADC's are inside the vessel. The digitized data are sent through the feed throughs via high speed serialized copper cable.
  - The high speed serialized data is translated to optical data to go some distance.
  - Goes into optical receiver and deserialized on FEM boards.

- Adapted MicroBoone digital electronics to achieve this.

1) Increase the FEM board depth
   6U size and **160mm depth.**

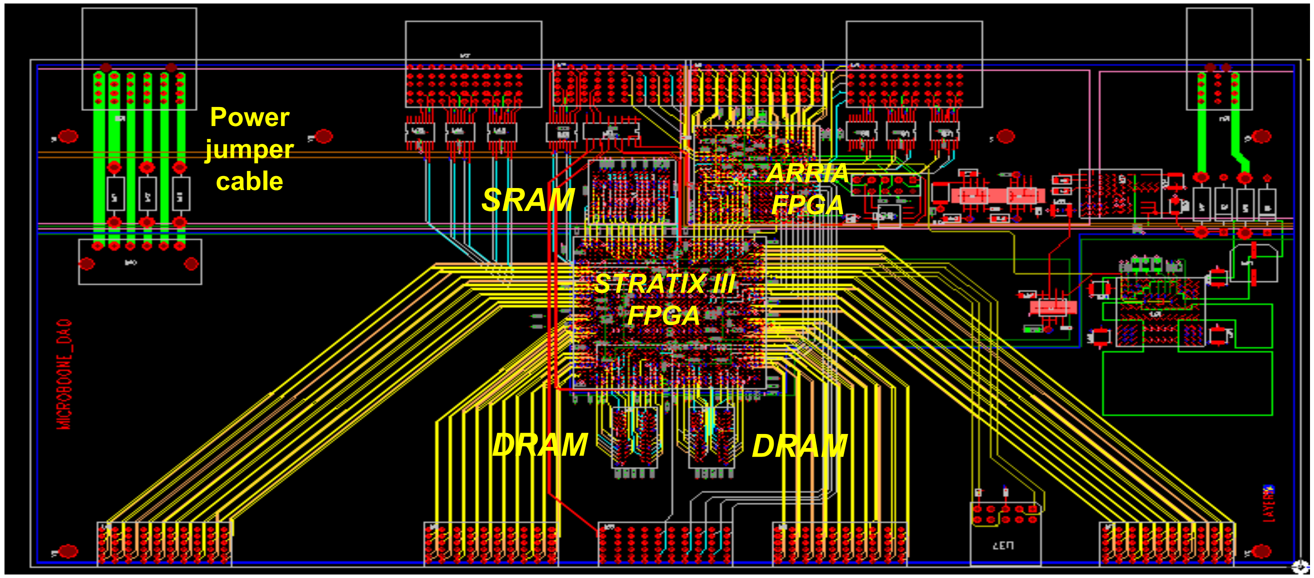
2) Add **optical transceiver** ~ 2 Gbits/sec bandwidth

3) Add **deserializer** to convert optical serial data to parallel data.

4) Remove power inputs and regulators needed for MicroBooNE BNL ADC.

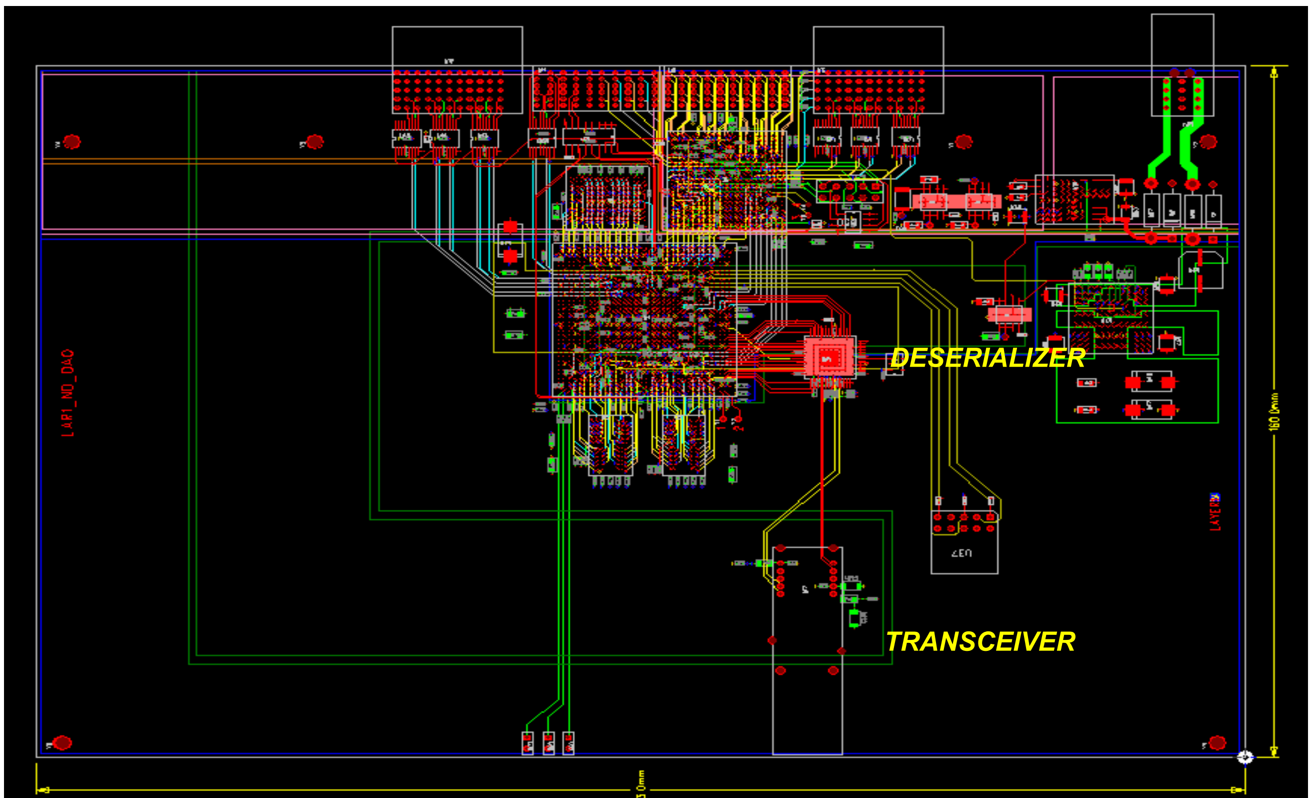
PCB

Analog power
+3V, -5V, +5V



Digital power
+12V
(4.5V – 24V)

MicroBooNE
14 Layers
233 X 118 mm

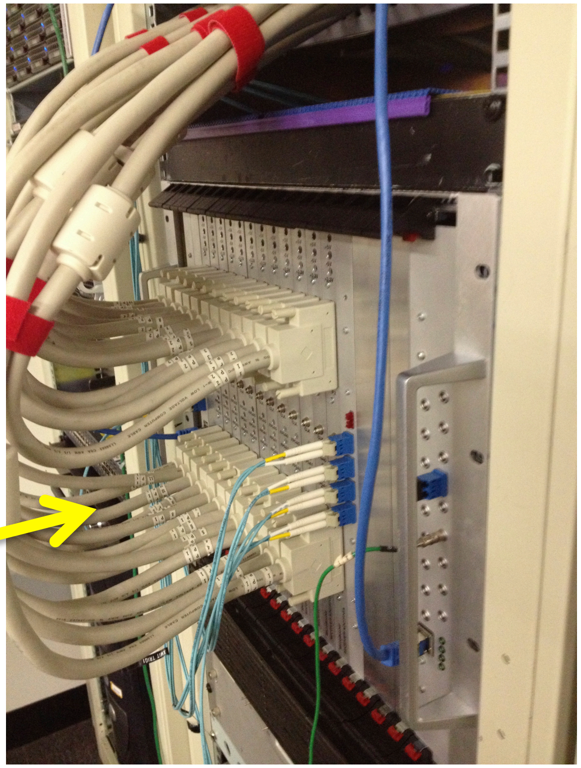


SBND
14 Layers
233 X 160 mm

Some numbers

- **11264** wires:
- → **176** 64-channel boards
- → **11** crates at 16 boards/crate. (9 TPC crates in MicroBooNE)
- Crates will be reduced from 9U to 6U as 9U was only required for BNL Receiver/ADC, and will be shallower.
- Backplane will remain the same as only the 6U Nevis FEM part "talked" to it.
- All other support modules would remain the same.
  - Controller: 1 per crate
  - XMIT: 1 per crate
  - PCIe: 3 per crate
  - Clock module: 1 per crate
  - Fanouts: 1
  - (Trigger module): 1

Cables replaced by fibers



Triggering

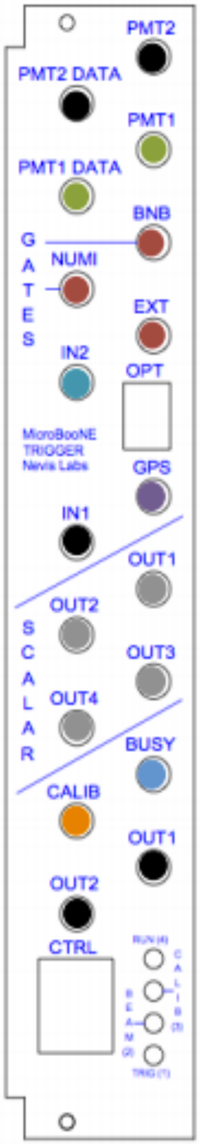
Beam neutrinos would be triggered on using

- Signals generated by the Light System (SiPMT/PMT) readout system.
- In coincidence with the BNB and/or NUMI beam gates.
- Expected to be dominated by neutrinos over cosmic rays (unlike MicroBooNE) : 1 ν every 18 spills and 1 CR every 220 spills.

- **Additional readouts/triggers:**
  - LED's for PMT calibration
  - Cold electronics ASIC calibrations
  - Cosmic paddles
  - Laser TPC field calibration
  - Randoms

- **We will provide a Trigger board with this functionality. It will be based on the MicroBooNE trigger board, modified as necessary.**

MicroBooNE Trigger Board



2 SPARE Inputs: PMT FEM *(can be implemented as LG PMT trigger input in the future)*

2 Inputs for PMT HG FEM *(PMT cosmic/PMT gate trigger: marker plus trigger type)*

3 Inputs for BNB ($1D.$1F), NuMI ($AE.$A9), and Strobe (fake beam)

Various PMT trigger configurations In coincidence with beam/random gates → Neutrino beam event

1 Input for LASER calib

1 Input for GPS marker (not a trigger)

1 Input for cosmic paddles (during commissioning)

4 Scalar outputs: TBD (not triggers)

Information as to which trigger fired and, If a PMT trigger, which configuration fired is read out from the trigger board.

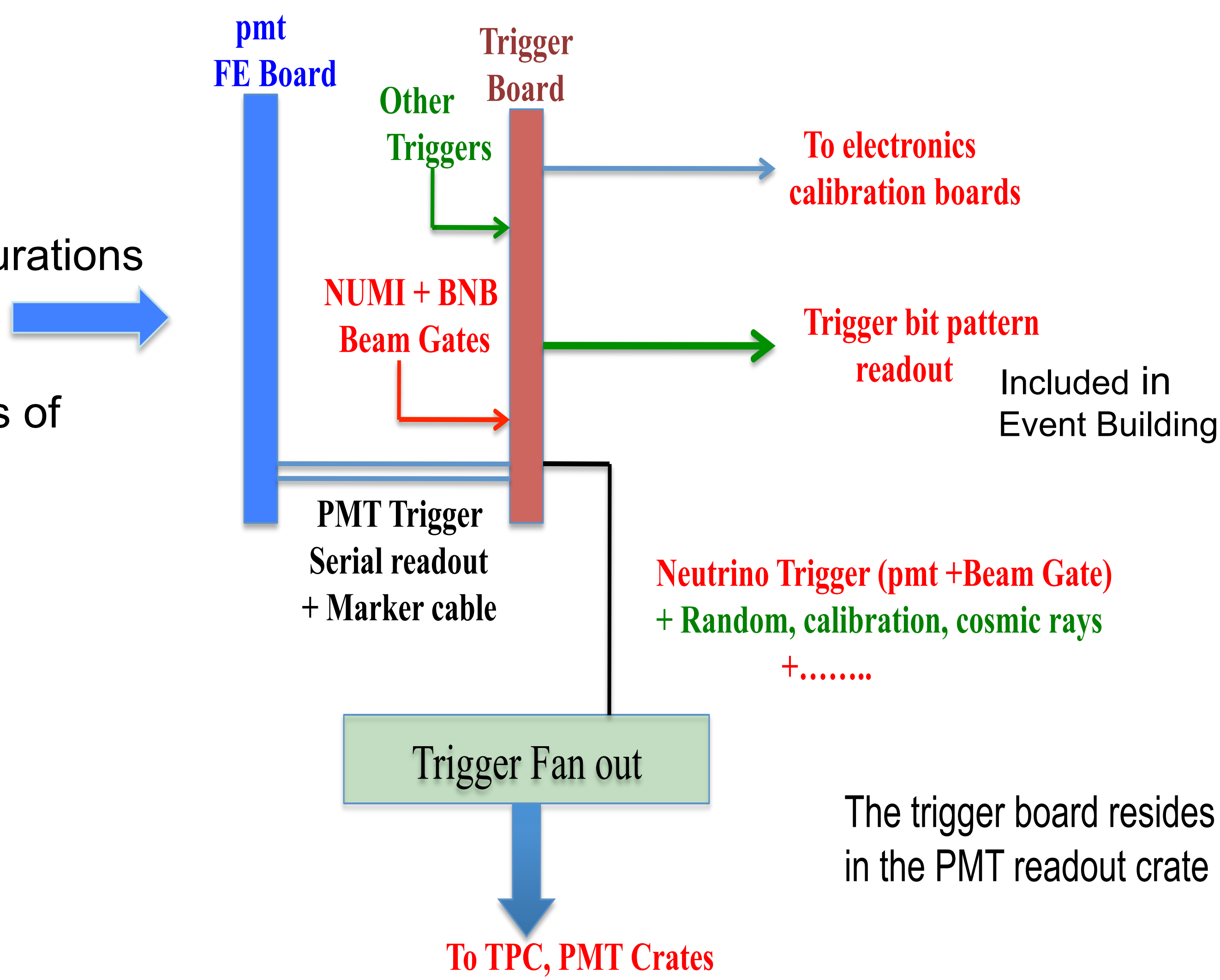
1 Trigger BUSY output (not a trigger)

1 Output for ASIC or PMT LED calibration

2 SPARE Outputs: DAQ-driven triggers *(one to be used as sync for muon paddles?)*

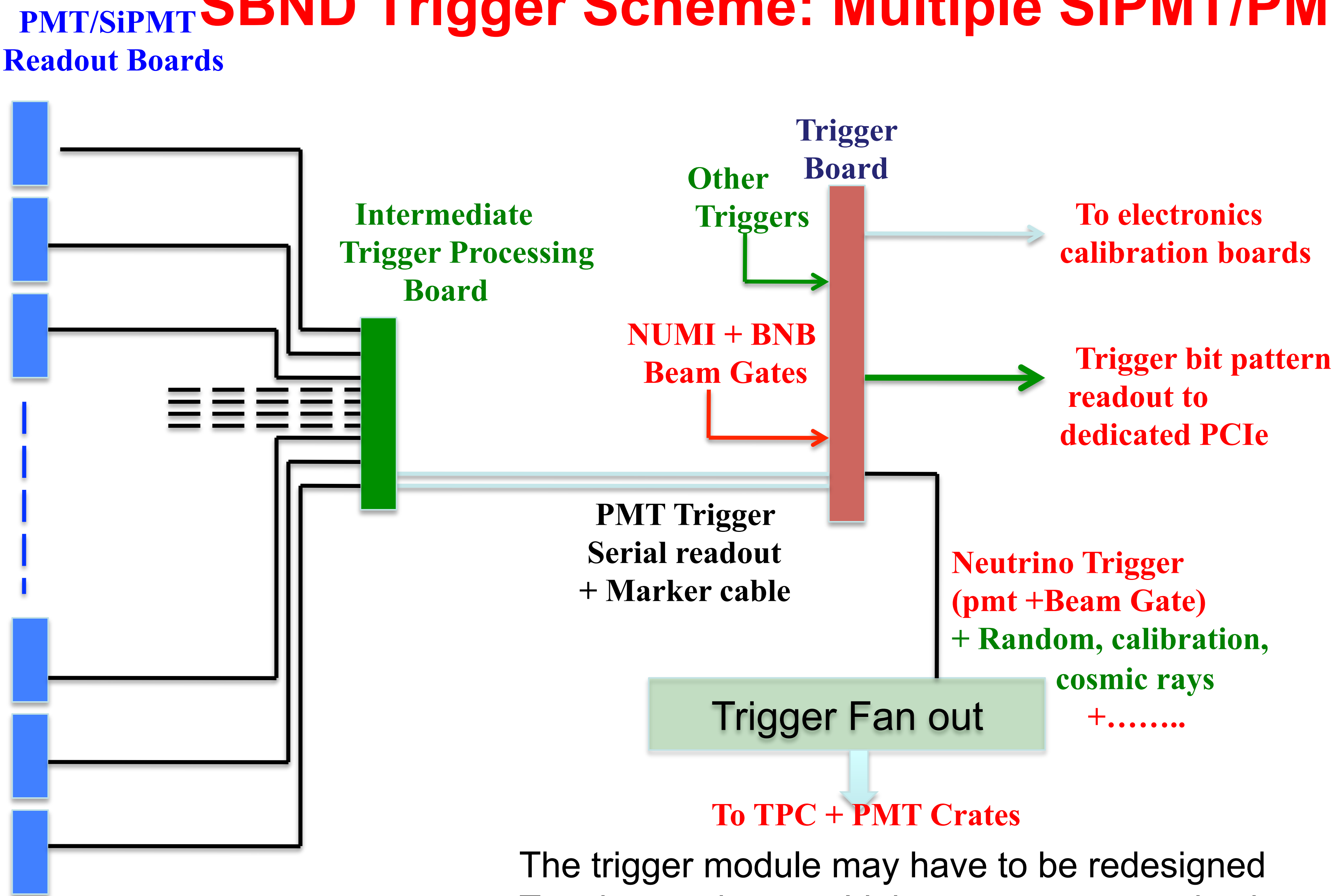
MicroBooNE Trigger Scheme

In PMT FEM FPGA,
Several trigger configurations can be implemented:
Multiplicities and/or summed pulse heights of All or groups of pmt's.



The trigger board resides in the PMT readout crate

SBND Trigger Scheme: Multiple SiPMT/PMT



The trigger module may have to be redesigned
To adapt to the new Light system communication.

Schedule

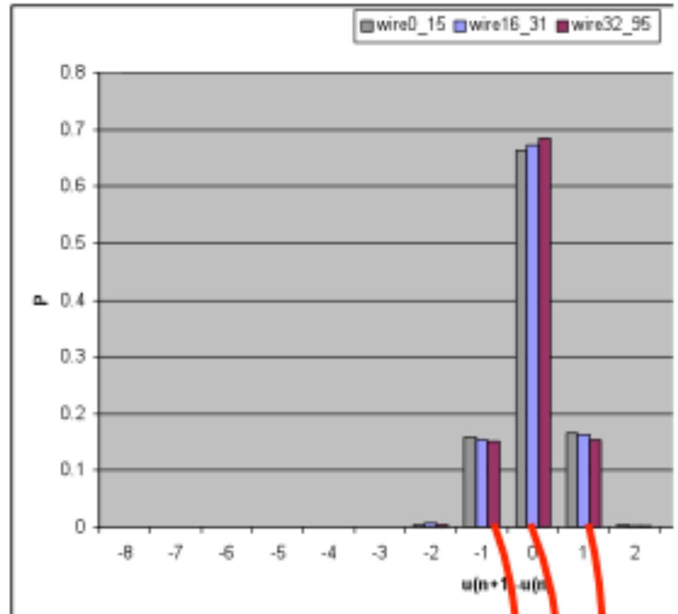
- Prototype → 6/30/2016
- Final design → 12/01/2016
- Production and Testing → 10/27/2017

Back up

Beam data compression (slow variation of signal)

Huffman Coding

- The U(n+1)-U(n) value with highest probability is assigned to shortest code, i.e., single bit 1.
- Values with lower probabilities are assigned with longer codes, e.g., 01, 001, 0001 etc.
- Huffman coded words and regular words are distinguished by bit-15.



Regular ADC data for first point or when U(n+1)-U(n) is outside +-3

0	0		ADC value (13-bit)

Huffman Coded

1	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0

-1 0 0 0 +1 +2

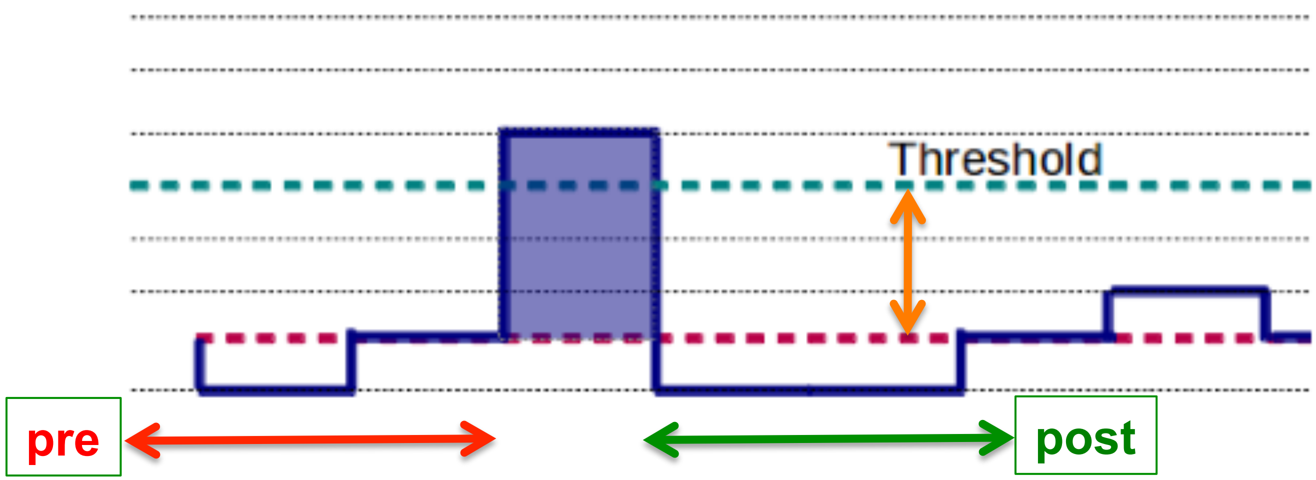
Padding or Continue to Next Word

U(n+1)-U(n)	Code
-4 and others	Full 16 bits word
-3	000001
-2	0001
-1	01
0	1
+1	001
+2	00001
+3	0000001

In this example, 6 differences of the data samples are packed in the 16-bit data word.

Achieve Factor 10 reduction

Supernova (continuous) data compression



– The current method will only keep data above threshold (per channel) + pre and post samples. Data will be Huffman compression coded.
  - The shaping time is slow then sampling frequency limits the changes in the ADC data.

– The baseline will be adjusted based on 64 samples average.
  - This is to deal with possible slow baseline variation.
  - To update a new baseline 3 adjacent 64 sample average and variance have to be within downloadable limits.