Protodune Muon Tagger

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Outer Veto (OV)

System will be positioned in the front and back of the TPC
- identify muon present in beam aloe
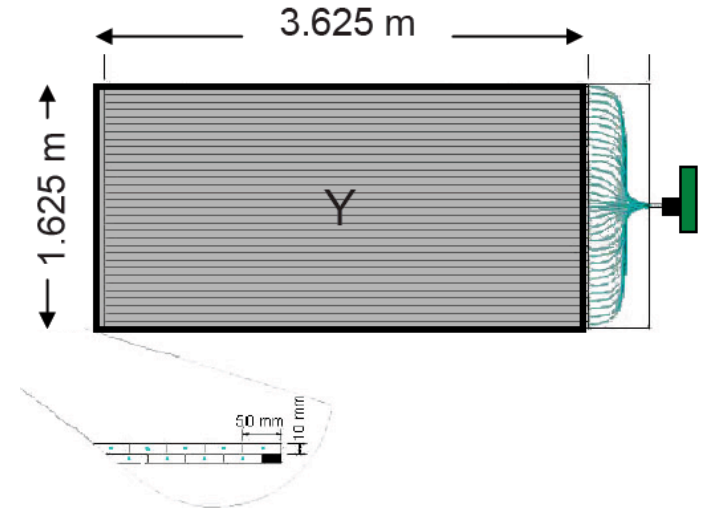- tag this muon send trigger info to TPC

System will also have some panel on top of the TPC
- Muon veto, send trigger info to TPC

Trigger will be generated as an OR of the X and Y panels
Send to the TPC trigger board within 500 ns.

Hit info or ADC info in separate data stream.

OV modules consist of two layers of 64 scintillator strips with WLS fibers connected to a multi-anode PMT

OV Readout Electronics

- Multi-anode PMT (Hamamatsu M64)
- Multi-anode readout chip (Maroc2)
- Multi-anode front-end readout board (custom-made at Columbia / Nevis labs)
- USB board (custom-made at Columbia / Nevis labs)
- Fan-out / trigger boxes (custom-made at Columbia / Nevis labs)
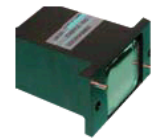
System overview and trigger signals
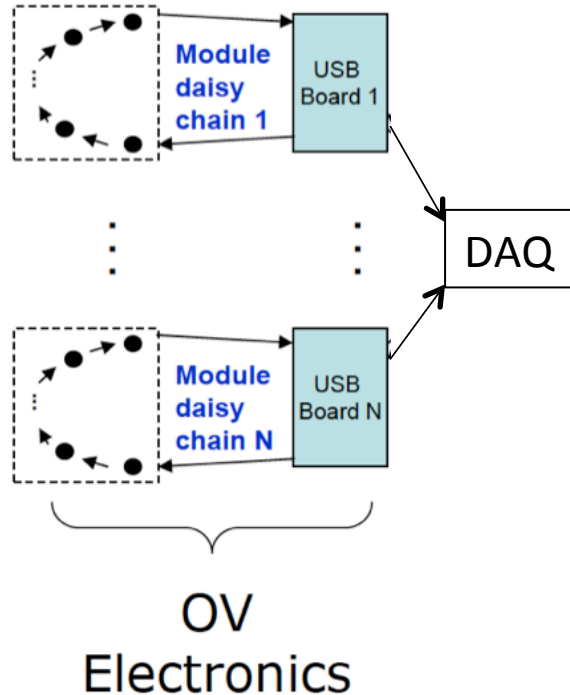
Each PMT board:
- Readout 64 channels - provide hits or ADC info
  - Hits processing require 120 ns
  - ADC processing require 32 μs
- Board trigger does not know about other boards

**Trigger board:**
- Collect info from all PMT boards
- Provide hit info pattern (through DAQ)
- Form a trigger signal (based on single board info)
  - 2 trigger out available
    - Geometrical overlapping modules in < 500 ns
    - OR of all modules in < 500 ns
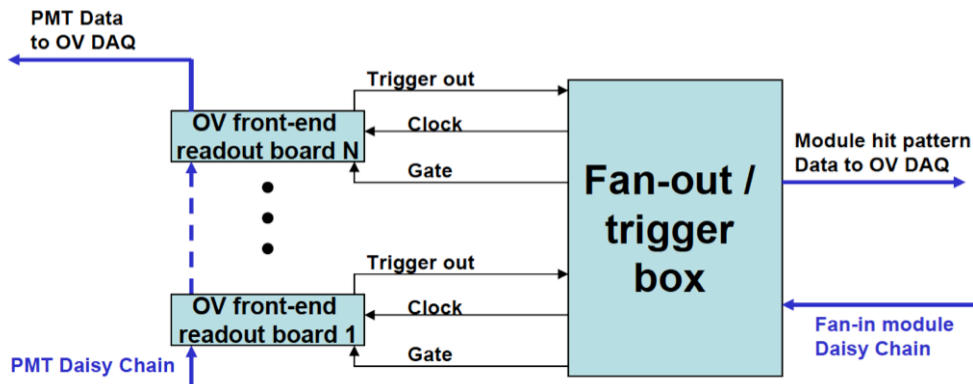
Data stream contains 32 bit timestamp can be used for data merging offline, only when a proper bit is asserted in the main data stream.

OV Readout

- Launches independent threads (C++) to manage each USB board
  - USB communication using libusb

- Separate OV run control process (perl) connects to DC run control via TCP/IP sockets
  - OV run control sends internal commands using message queues

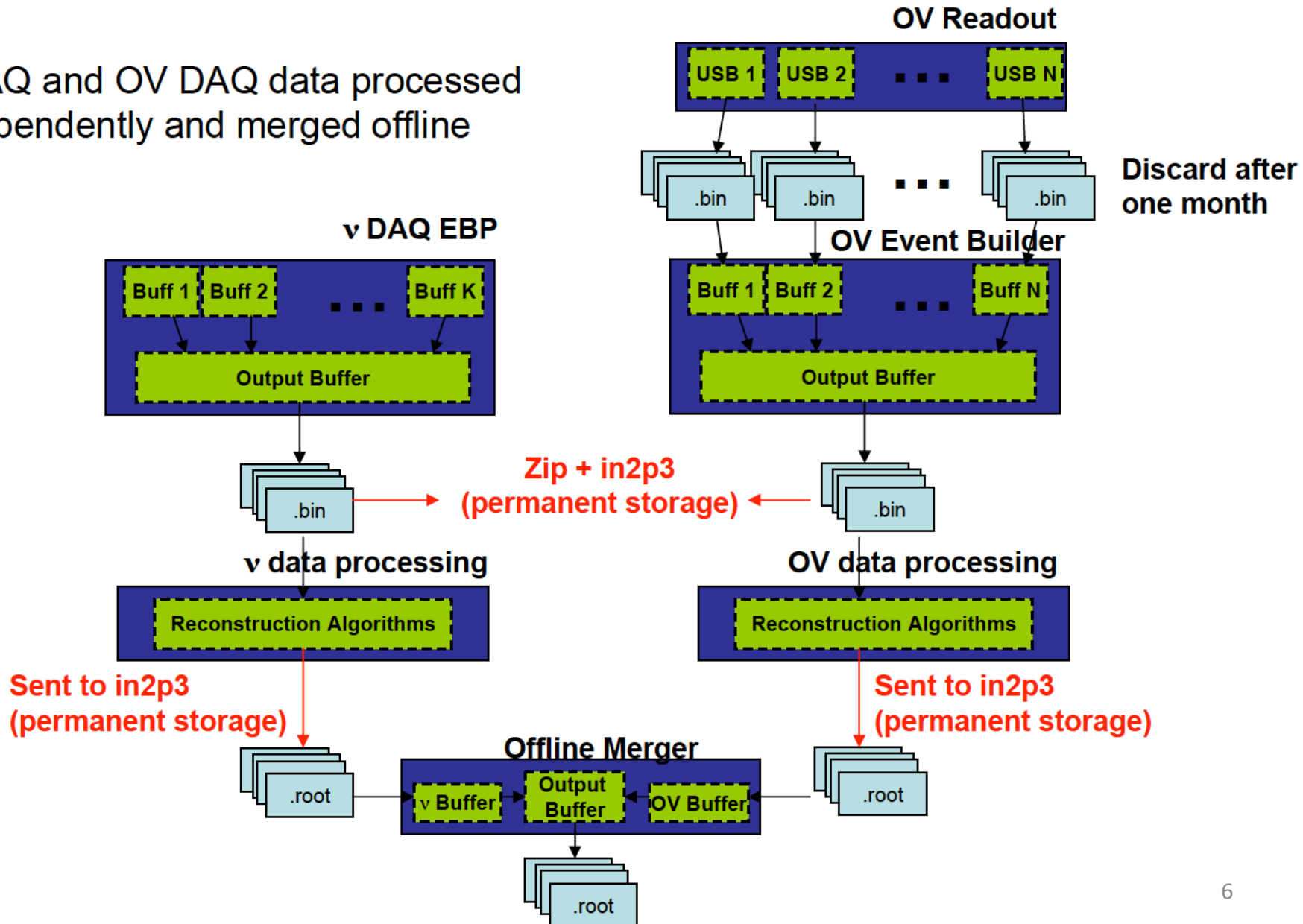- Binary data written to disk independently for each USB data stream
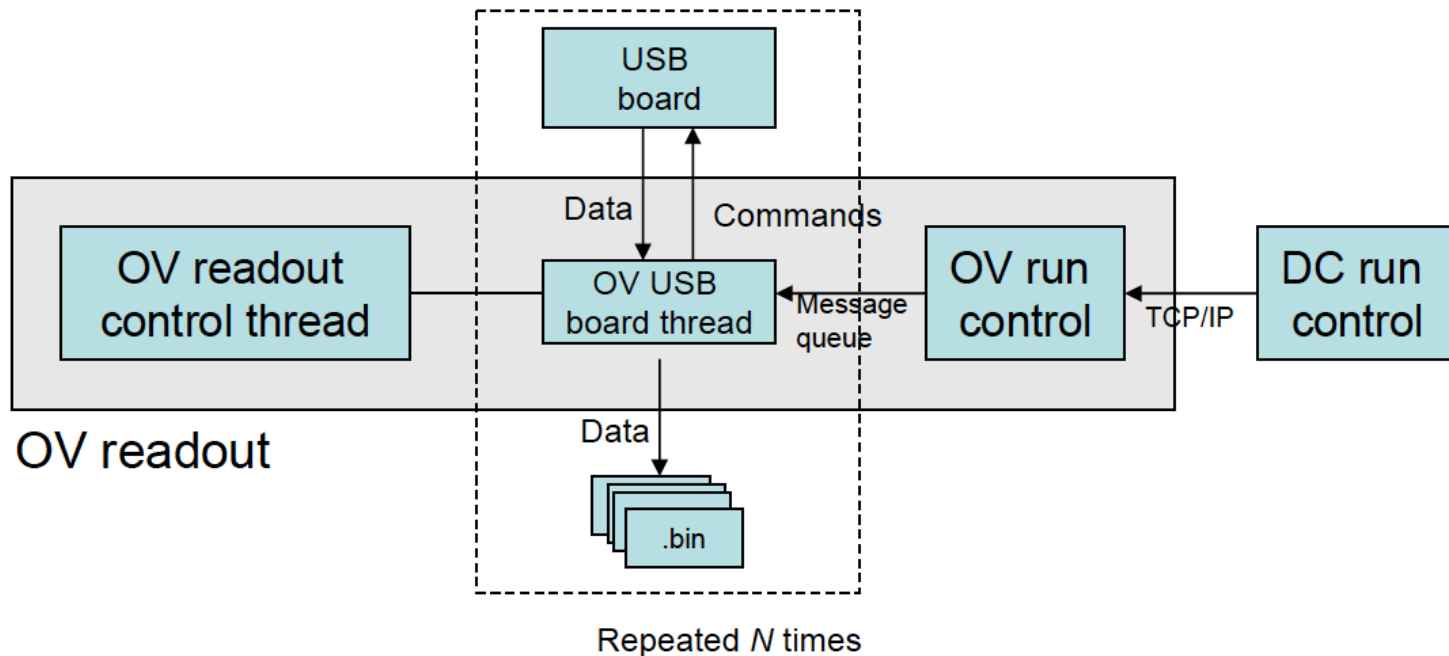
OV Event Builder

- OV Event Builder written in C++ and designed to:
  - **Read in raw data from OV DAQ**
    - Independent, unsorted data streams for each USB, consisting of data packets from individual OV modules
  - **Compute and subtract baselines**
  - **Apply offline thresholds**
    - Event rejected unless both hits in "µ-like" double > 1.5 PE
  - **Time-order hits within individual USB data streams**
  - **Merge all USB data streams in time-order, grouping hits into OV events**
    - Hits separated by ≤ 3 clock cycles added to same event

Data Flow and Merging

ν DAQ and OV DAQ data processed independently and merged offline

OV Readout

USB 1 | USB 2 | ... | USB N

.bin | .bin | ... | .bin

Discard after one month

ν **DAQ EBP**

Buff 1 | Buff 2 | ... | Buff K

Output Buffer

OV Event Builder

Buff 1 | Buff 2 | ... | Buff N

Output Buffer

.bin

Zip + in2p3 (permanent storage)

.bin

ν **data processing**

Reconstruction Algorithms

OV data processing

Reconstruction Algorithms

Sent to in2p3 (permanent storage)

Sent to in2p3 (permanent storage)

.root

Offline Merger

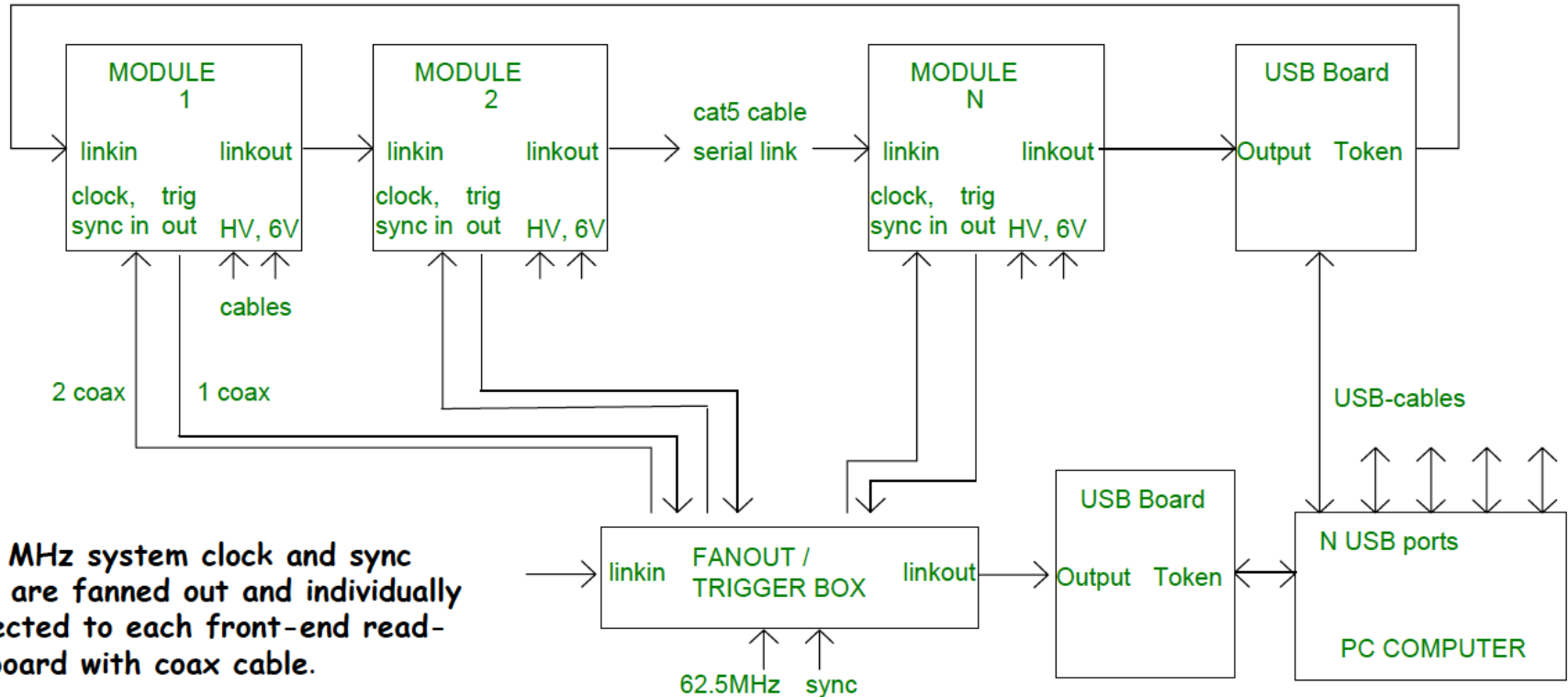ν Buffer | Output Buffer | OV Buffer

.root

.root

Backup

Specs

- MAPMT - 800-900V, 300-400μA
- PMT board - 6 V, 0.28A
- Trigger Board - 6 V, 1.0A

- USB board - 5V, decoupled from PC, 0.4A

OV Readout Scheme

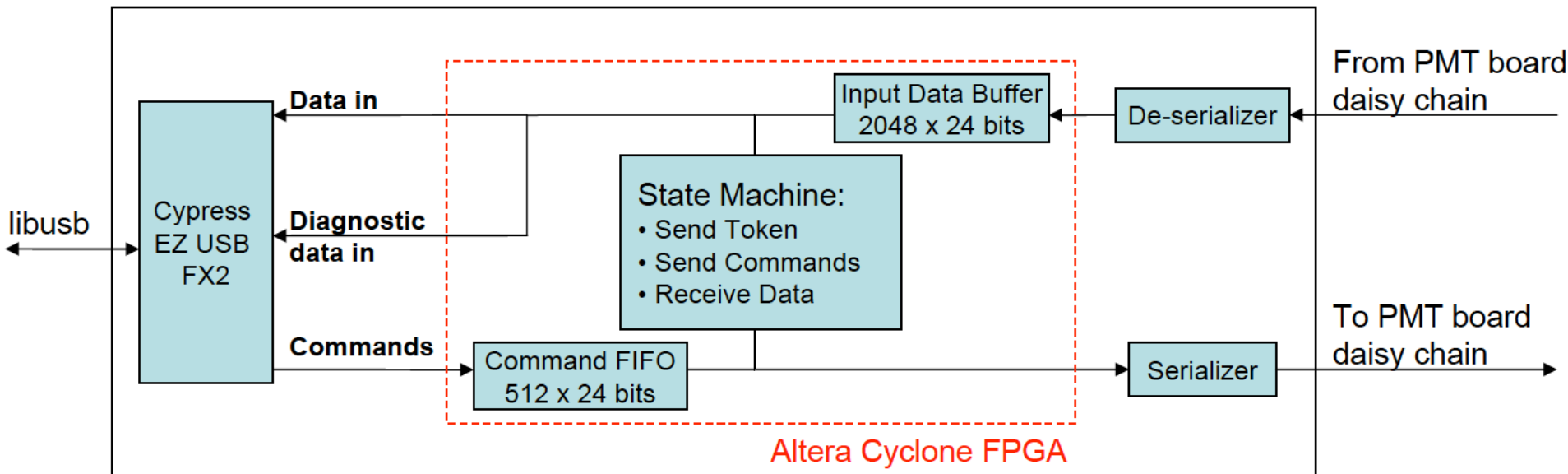OV modules common to a veto plane are linked together with Cat5e cable.

A token passing scheme is used to read out serial data to a USB hub-module:

- If OV module has no data, the token is passed forward.
- If OV module has data, it reads-out the next triggered event from the ADC FIFO, and then passes the token to next OV module.
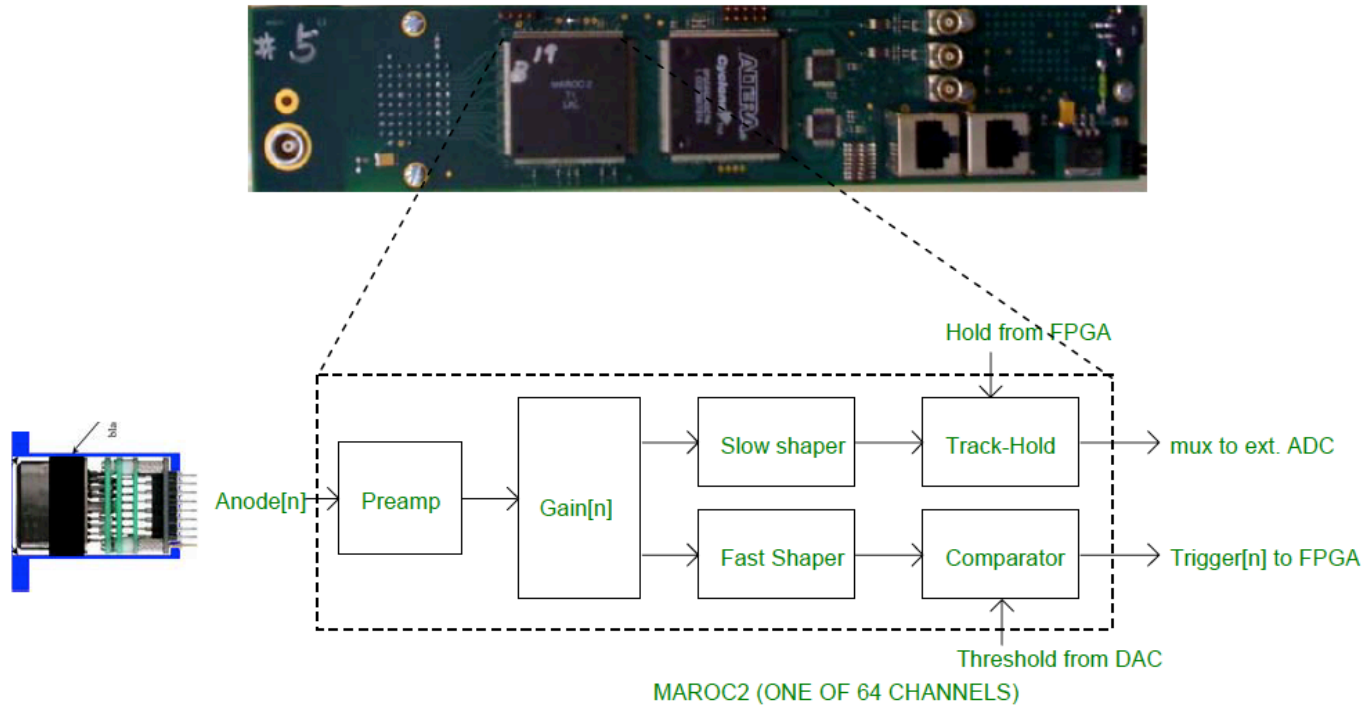
The USB board transfers the data packets to the PC and re-circulates token.

USB Board Architecture

- Cypress EZ USB FX2 micro-controller
- Three USB endpoints:
  - Data in
  - Diagnostic data in
  - Commands out
- Altera Cyclone FPGA for serial link I/O

OV Front-end Readout Board (I)

Hold from FPGA

Anode[n] → Preamp → Gain[n] → Slow shaper → Track-Hold → mux to ext. ADC

Gain[n] → Fast Shaper → Comparator → Trigger[n] to FPGA

Threshold from DAC

MAROC2 (ONE OF 64 CHANNELS)

- Maroc2 architecture allows individual 6-bit gain correction for each channel
- Comparator input threshold from DAC common to all channels
- The outputs of the 64 comparators go to the FPGA to form a trigger
- Slow shaper provides trigger delay to track and hold

Expected data rate = 25 kHz (0.9Mb/s)
DAQ rate @ VT = 35.5kHz (1.2Mb/s);

Total acquisition time = 1000 h
LV on: = 1392 h
HV on: = 1290 h

Consecutive acquisition time (stress test) = 192 h
(typical DC run = 10h);

Data written to disk in total (1000h) ~ 3.1 Tb;
Data written to disk for the 192 h ~ 0.6 Tb

DAQ performance (measured injecting pulse):
        pulser stability ~ 5 %, DAQ stable.

Analysis of the 192 h run:
Data error   - none
DAQ crash   - none
Evt builder crash - none
Online monitor   - none
Problems/warnings   - none

All the operations on the system were done remotely

No board fail;
No PMT fail.

System is operating in France for 6 years now in the DC far and 2 years in the DC near.

LV power module failure.
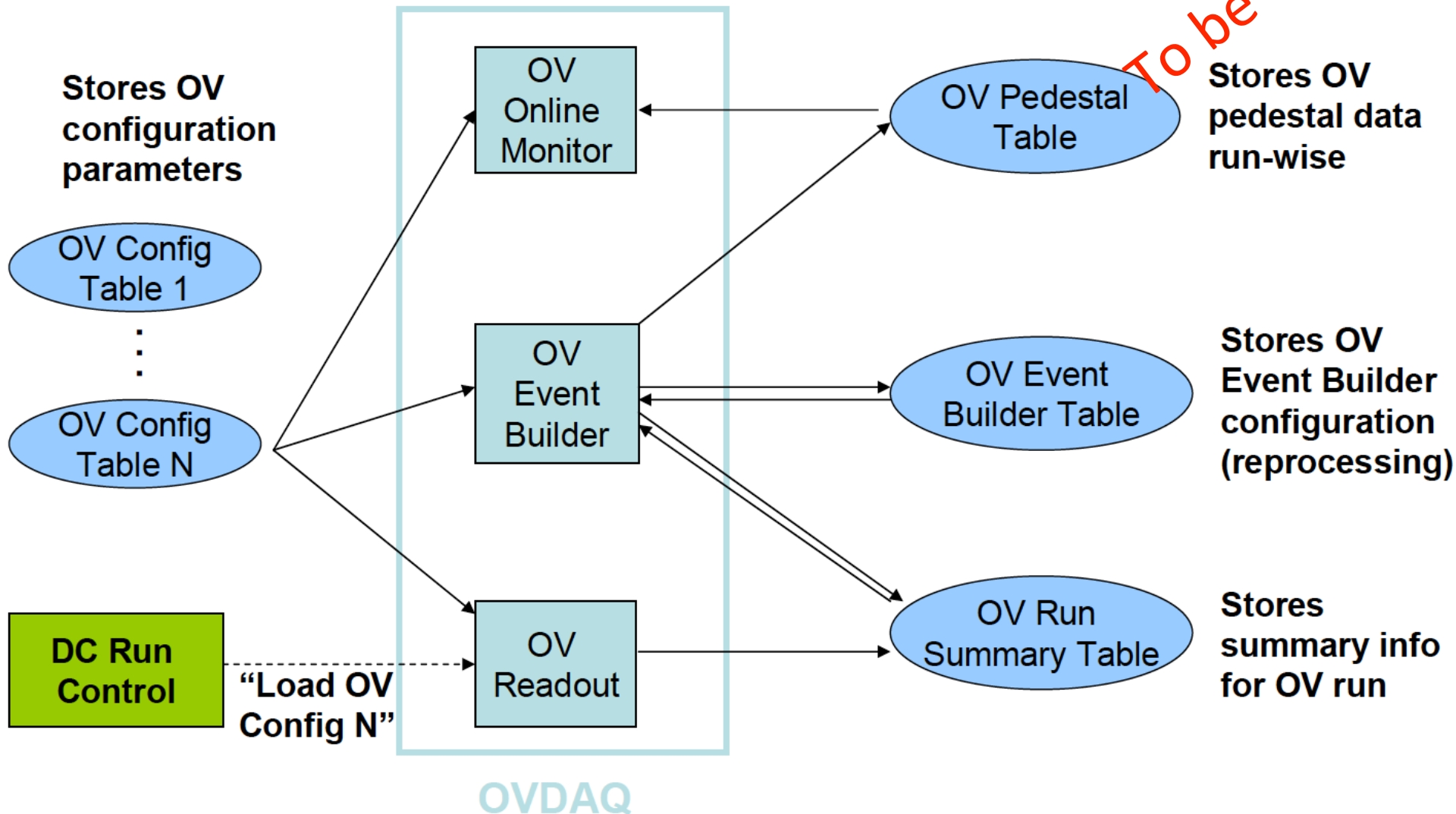1 daisy chain failure. Power failure for one board.

OV Front-end Readout Board (II)
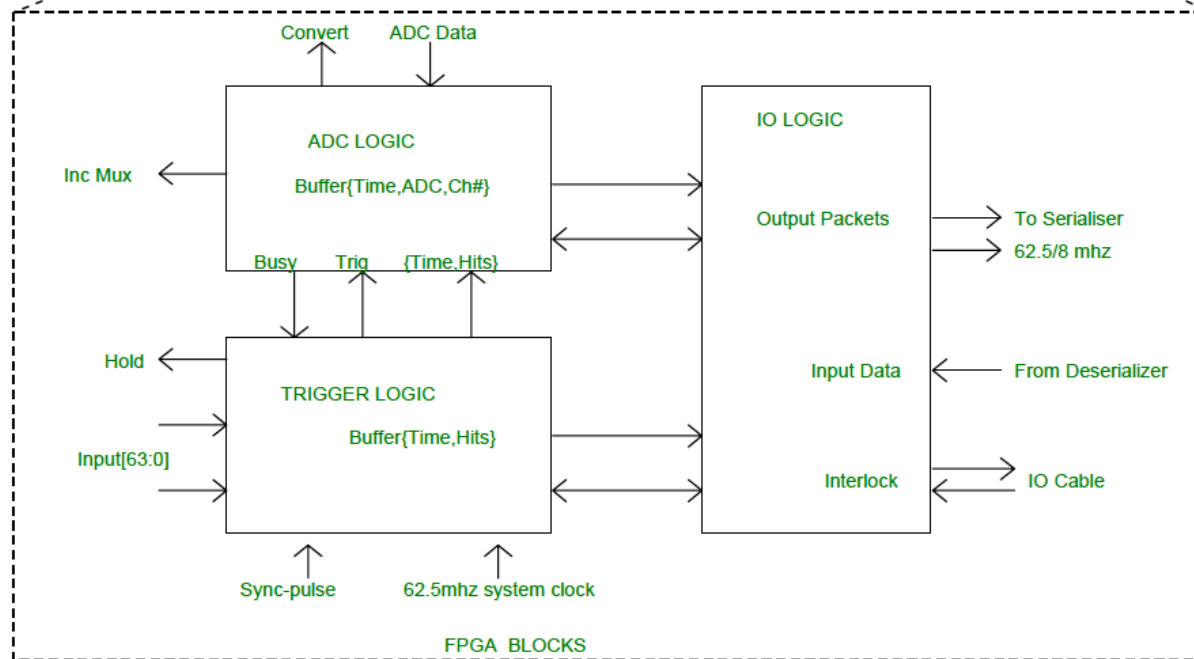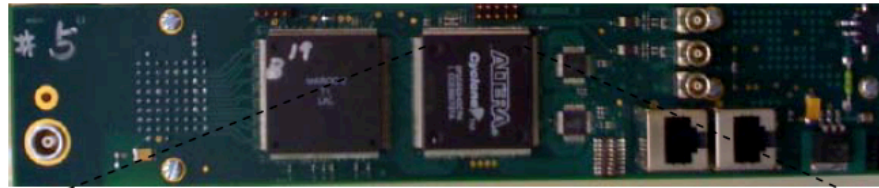
- **Trigger logic formed from Maroc2 comparator outputs generates hold signal**
- **ADC control logic reads out the track and hold data to an external 12-bit ADC**
- **ADC data and channel number output for each channel above threshold**
- **Output packets also include word count, memory address, and 32-bit clock counter**

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OV DAQ MySQL Dependencies

To be updated

Stores OV configuration parameters

OV Config Table 1

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OV Config Table N

OV Online Monitor

OV Event Builder

OV Readout

DC Run Control

"Load OV Config N"

OV Pedestal Table

Stores OV pedestal data run-wise

OV Event Builder Table

Stores OV Event Builder configuration (reprocessing)

OV Run Summary Table

Stores summary info for OV run

OVDAQ

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OV Online Monitor To be updated

- **Written in C++ (object-oriented design)**
- **Communicates with DC online monitor server via TCP/IP socket**
  - Java-based DC online monitor GUI
- **Designed to monitor:**
  - Front-end readout board hit rates and mean ADC values
    - By channel, module, and USB (time history)
  - Trigger box hit rates
    - By front-end readout board and trigger box
  - Raw data quality and online data processing status
  - OV High Voltage
- **Sends warnings/alarms (DC message server, syslog, emails)**