nEXO Data Acquisition

MIDAS Workshop

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- About nEXO
- A high-level view of the DAQ
- Requirements
- Modes of operation
- Hardware choices
- Hardware structure
- Software structure
- Thoughts on where MIDAS fits in

About nEXO

- nEXO is a rare-event search experiment for $0\nu\beta\beta$ using a single-phase liquid xenon time projection chamber (TPC) with five tonnes of xenon enriched to 90% in ^{136}Xe
- nEXO project officially started, preparations for DOE's CD-1 (conceptual review) ongoing
- Worldwide effort of 9 countries, 33 institutions, ~2000 collaborators
- Location SNOLAB

Three detectors: photon, charge, and veto

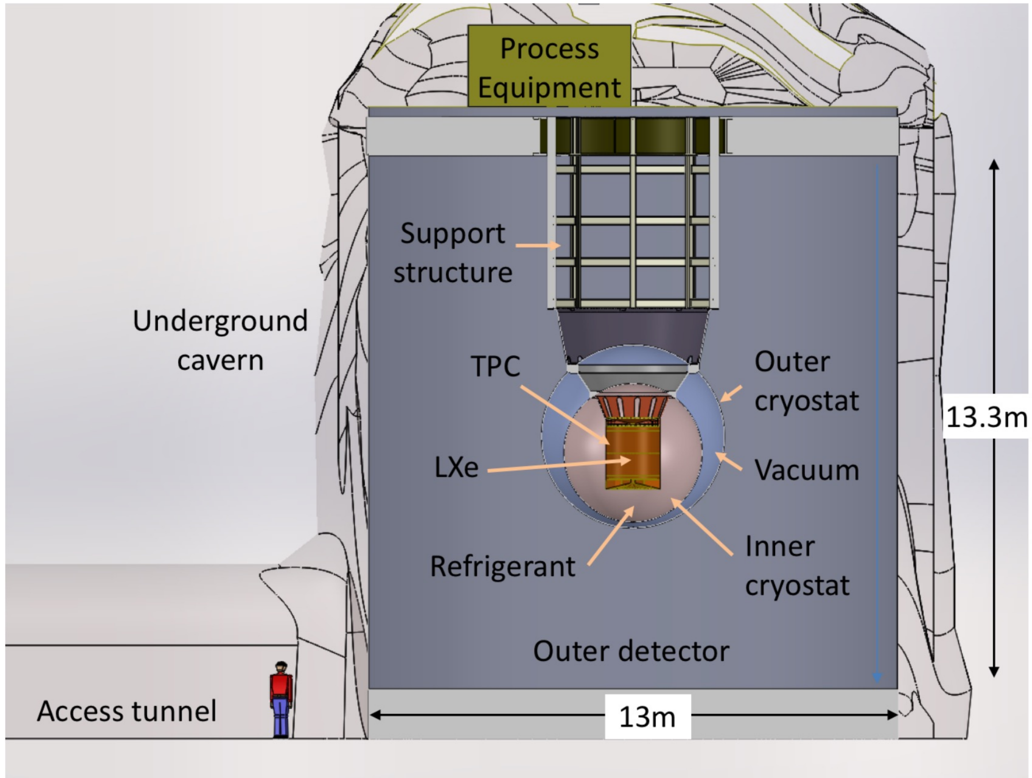
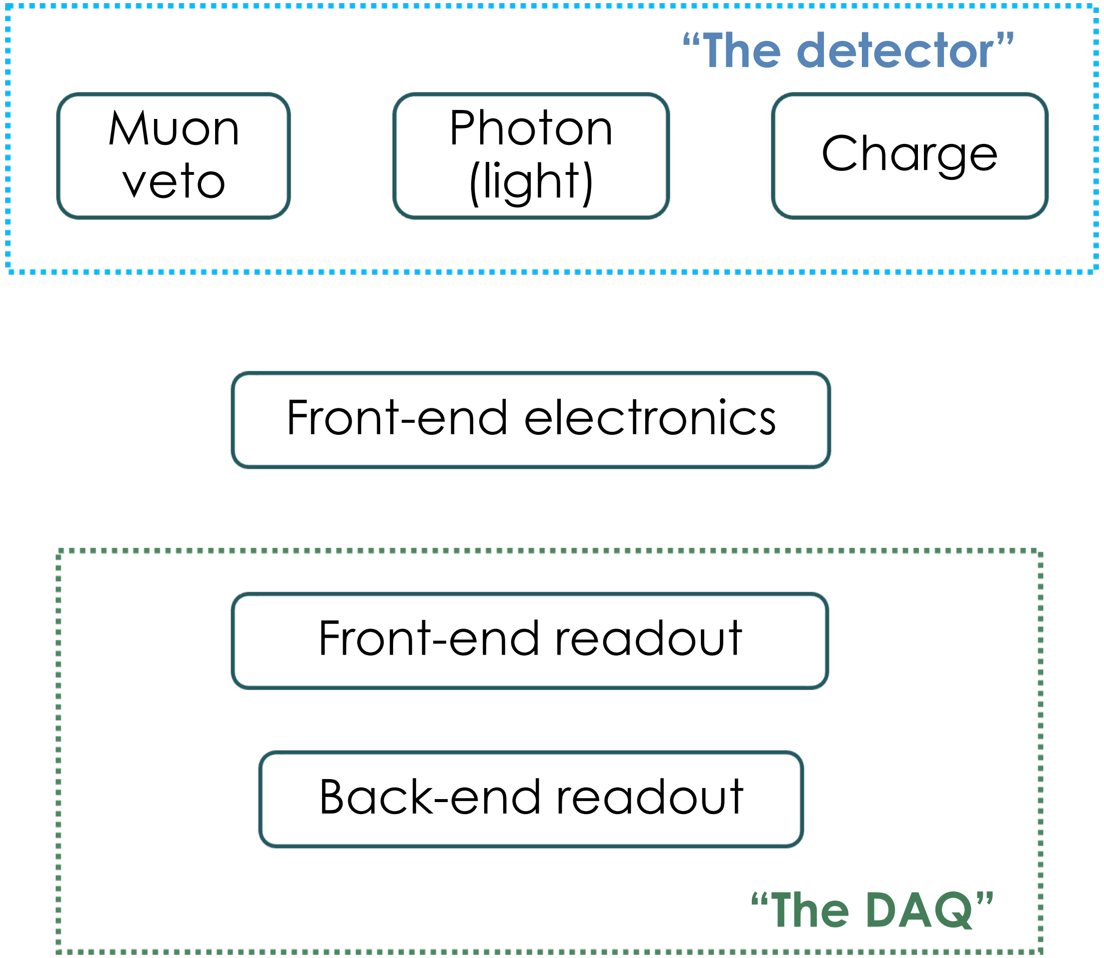


Image from nEXO Pre-Conceptual Design Report

High-level view



Muon veto

- 125 channels
- PMTs from the Daya Bay Experiment
- 16-bit ADC data at 125 MHz sampling

Photon

- 7680 channels
- CRYO ASIC
- 12-bit ADC data at 2 MHz sampling that are processed locally at the ASIC

Charge

- 3840 channels
- CRYO ASIC
- 12-bit ADC data continuously received at 2 MHz

Front-end readout

- 1 to 2 BittWare FPGA PCIe card to handle the light and charge data, buffer data locally, and form the readout trigger
- 2 CAEN VX2740 digitizers to handle the veto data

Back-end readout

- Semi-custom / MIDAS software (C++)

Requirements

- The DAQ must absorb feature extraction data of up to 12 Gb/s from the photon detector system
- The DAQ must absorb sustained raw input data rates up to 185 Gb/s from the charge ASICs and <1 Gb/s from muon veto electronics.
- Synchronize timing between channels (0.5 microseconds)
- Configure readouts for charge, light, and veto detector electronics
- Log subsystem configuration changes
- Provide zero dead-time for signals from the TPC during physics data-taking
- The DAQ system must operate in a calibration mode and a physics mode

Modes of operation and data rate

Calibration

- Data continuously received and stored (i.e., triggerless) for up to ~2 hours
- 4 kHz event rate (up to 197 Gb/s*)
- This mode drives the DAQ design

Physics

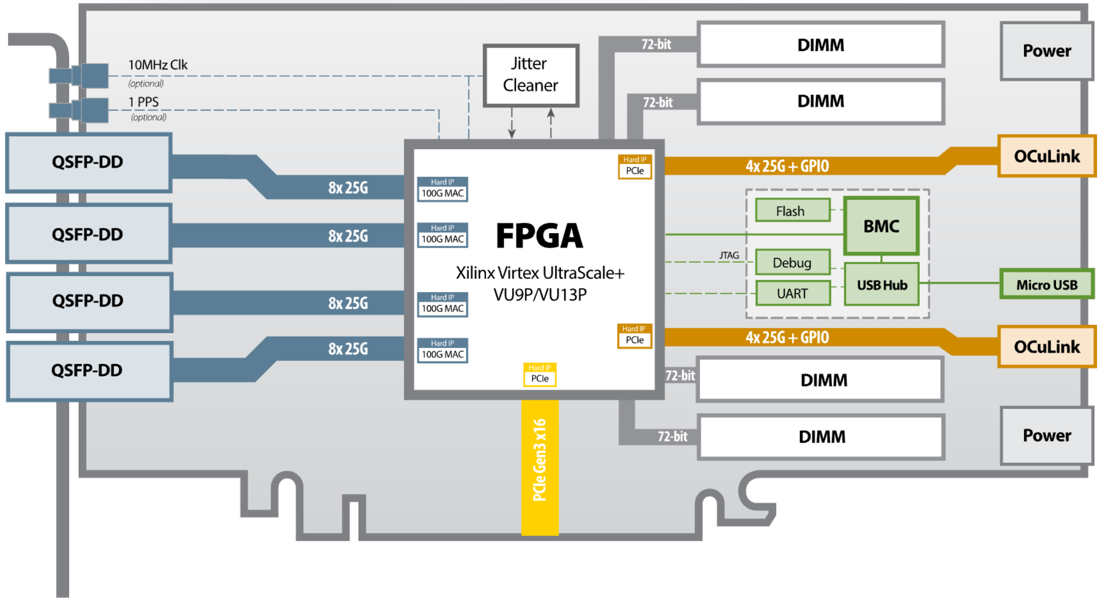
- In physics mode the DAQ system must record all data needed to determine event properties such as energy and topology when the energy deposited in the liquid-Xe of the TPC is greater than 700 keV
- 1-2 Hz event rate
- Calibration is King

* This is the maximum data rate. Photon system up to 12 Gb/s (max) with charge held constant at 185 Gb/s.

COTS FPGA PCIe DAQ Card

XUP-VV8

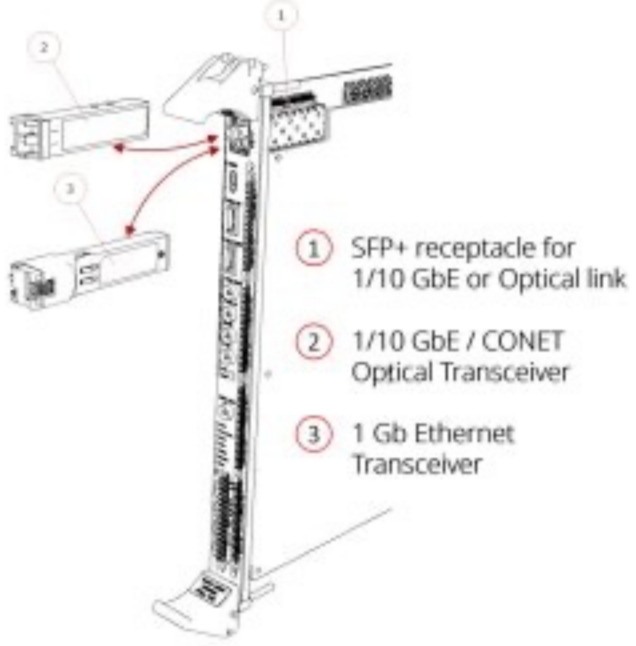
- Four QSFP-DD for up to 8x 100 GbE
- Up to 512 Gbytes DDR4 SDRAM
- VU9P/13P FPGA providing large logic and memory resources
- 1 PCIe Gen3x16 interface



https://www.bittware.com/products/xup-vv8/

COTS 64 Channel 16 bit 125 MS/s Digitizer

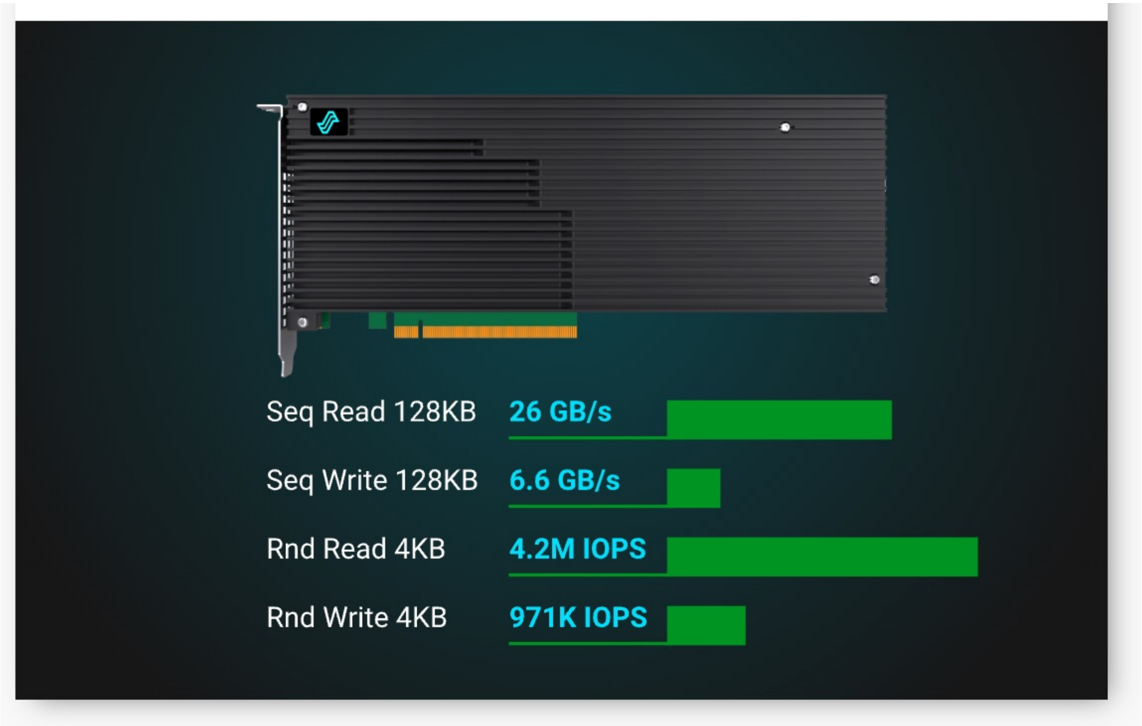
VX2740
- 64 analog inputs
- 16-bit resolution
- Xilinx Zynq UltraScale+ Multiprocessor System-on-Chip mod. XCZU19E
- “Open” FPGA



Calibration data sent to "Honey Badger" SSD

LQD4500 IO Accelerator

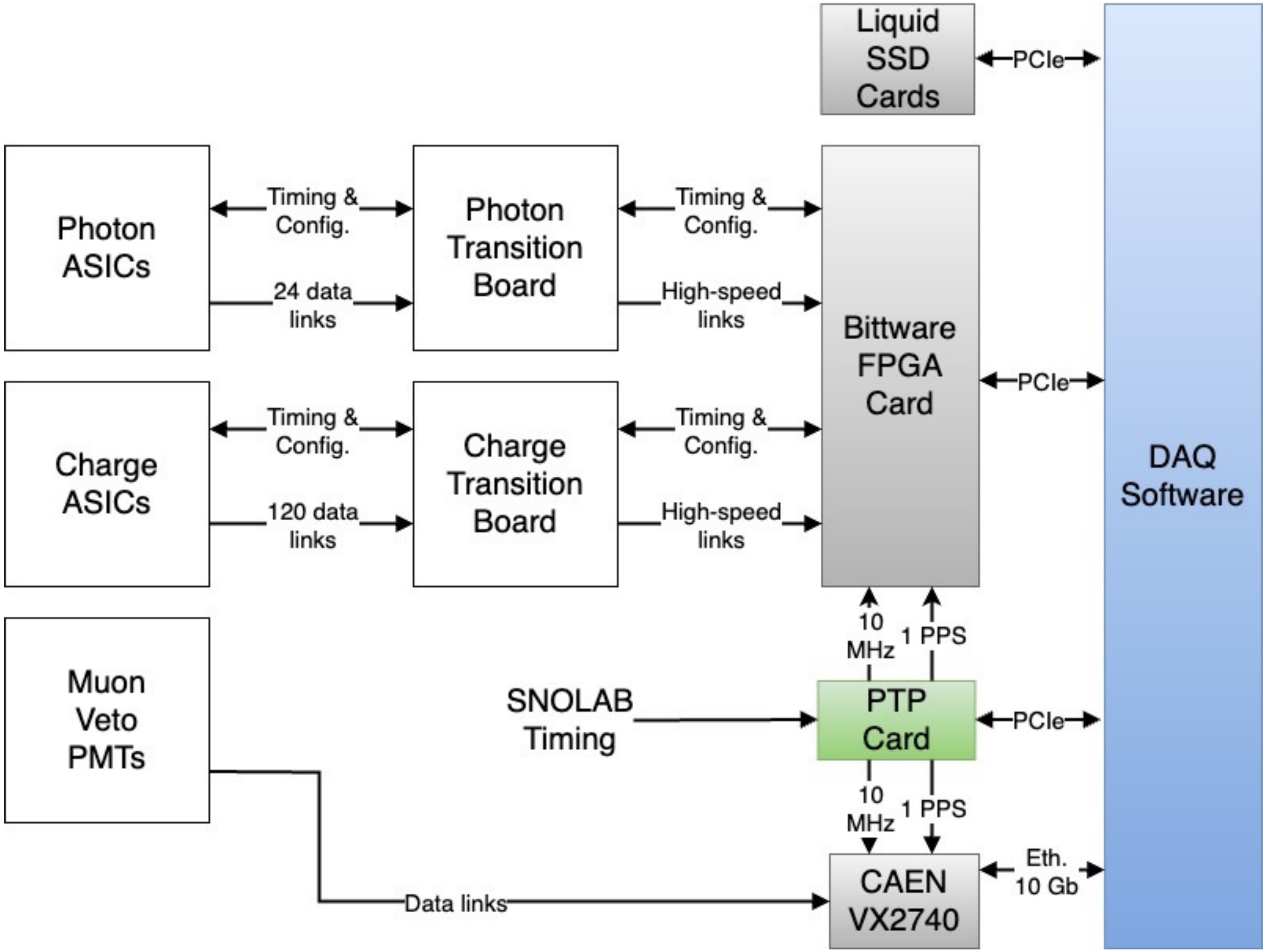
- PCIe x 16 Gen-4 (~15 GB/s)
- Raw capacity 32 TB
- 2 SSDs should be adequate for the calibration runs
  - Assume a compression (lossless) factor of 3
  - 197 Gb/s / (3*8) = 8 GB/s
  - 2 hours is 57.6 TB



https://www.liqid.com/products/io-accelerators

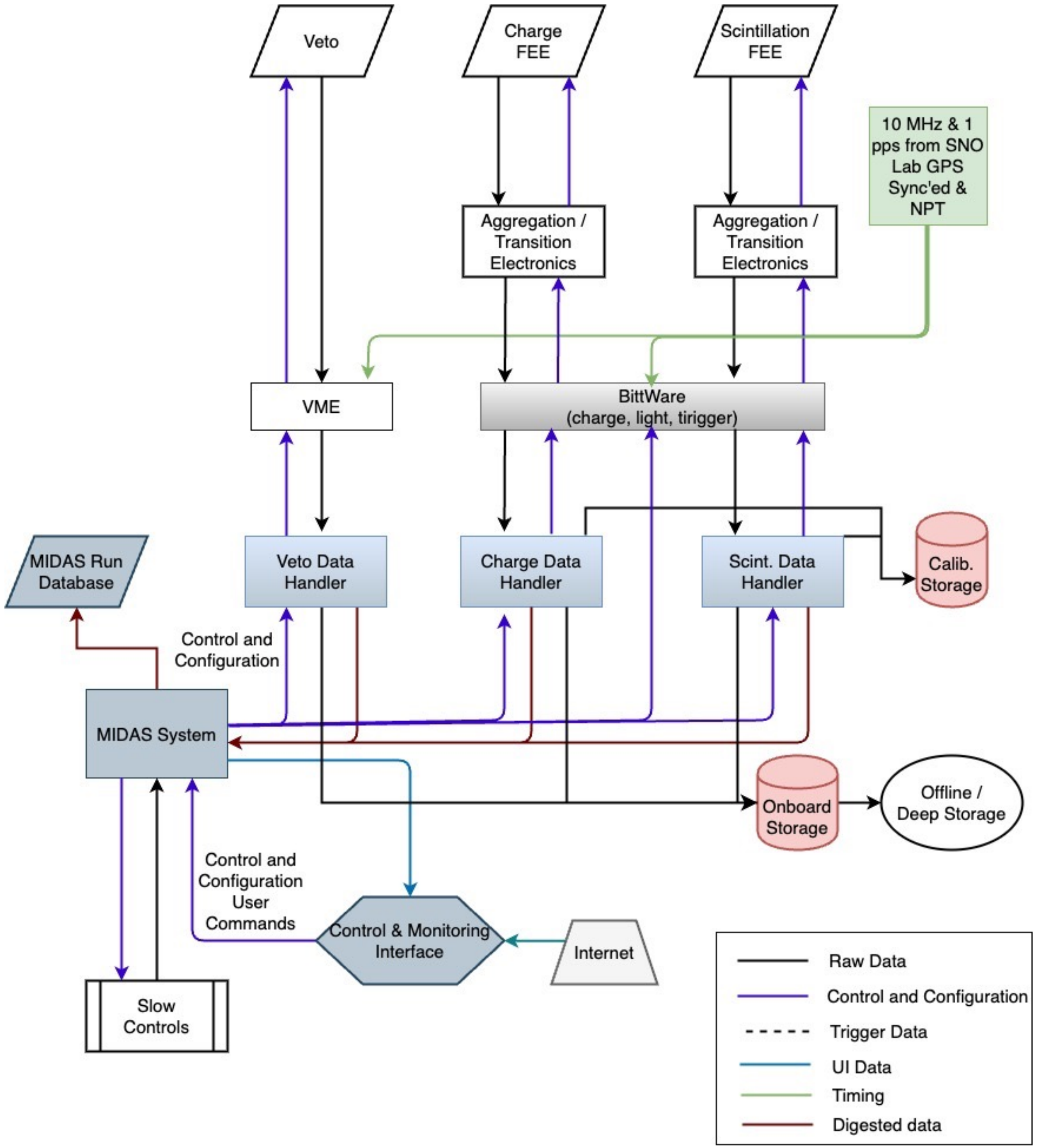
DAQ hardware structure (SLAC)

- Concept based on Commercial-Off-The-Shelf (COTS) PCIe board
  - Integrated photon and charge readout
  - Lower cost
  - Sustainable
- Initial assessment performed at SLAC last year
- We are looking at a one- or two-card solution based on the final required data rates
  - Photon system possible waveform snippets, which will reduce the data rate
- 1 PTP PCIe Card to receive the SNOLAB timing and output 10MHz/1PPS to the BittWare card
- ~$70K hardware cost



DAQ software structure

- Semi-custom approach using Maximum Integrated Data Acquisition System (MIDAS) as the workhorse for control/configuration, user interface, and online data monitoring
- This general-purpose system has been used in several experiments (DEEP, SuperCDMS, Darkside, and T2K) to deliver a semi-customized event-based DAQ tailored for the experiment
- Custom data handler software will be developed to accommodate the large data rates during calibration runs
- These data handlers will run individual instances of MIDAS to receive command signals based on a run's configuration
- The use of MIDAS for auxiliary DAQ functions helps leverage experience within the collaboration while the custom piece allows us to fully meet all requirements



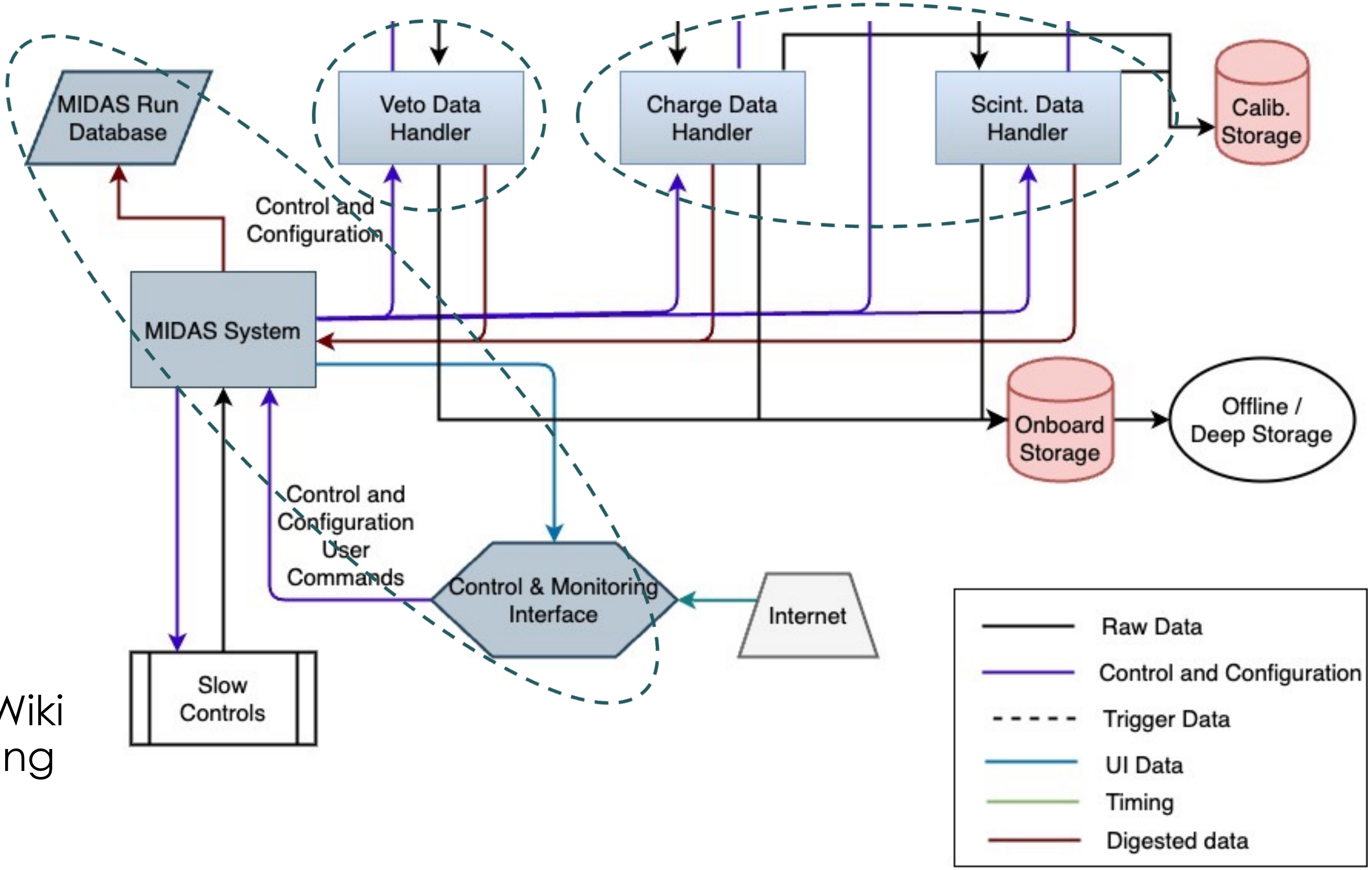
More on the MIDAS part… input welcome

MIDAS - Experiment

Applicable Interfaces

- Web interface
- Frontends – for CAEN
- odbedit - run control
- mdump - event dump
- mlogger - run database
- mChart - chart server
- mserver - remote server
- mhttpd - web server
- mstat - status display

https://daq00.triumf.ca/MidasWiki/images/1/1e/Midas_intro-04.png



Much a work in progress

- We will need online event building for real-time data visualization
  - We will most likely take a subsample of events
- What meta data does MIDAS already inherently gather?
  - Darkside?
- What configuration information do we need to start a run?
- Calibration mode and how MIDAS will interact with the custom data handlers?

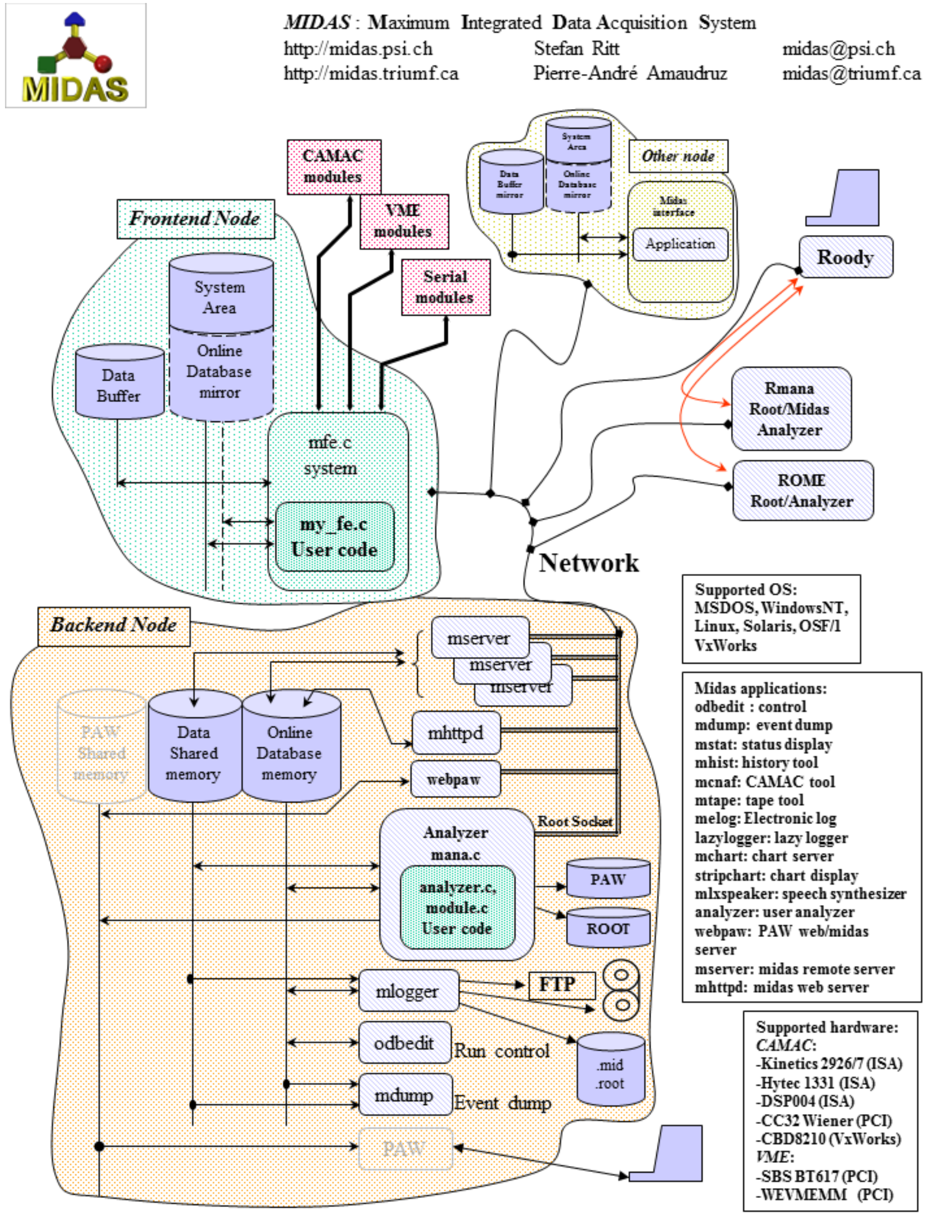


Chart from https://daq00.triumf.ca/MidasWiki/index.php/Main_Page

OAK RIDGE National Laboratory

Summary

- The current hardware design uses the Bittware FPGA PCIe DAQ Card for charge and light and a CAEN digitizer for the muon veto
- The software design will use MIDAS to orchestrate the data and control flow and perform other auxiliary DAQ functions
- The two different data-taking modes present a challenge that our hardware can withstand
- nEXO project officially started, preparations for DOE's CD-1 (conceptual design) review ongoing
- **We are making our MIDAS list and checking it twice**

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