Fermilab

Trigger & DAQ

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TDAQ Scope

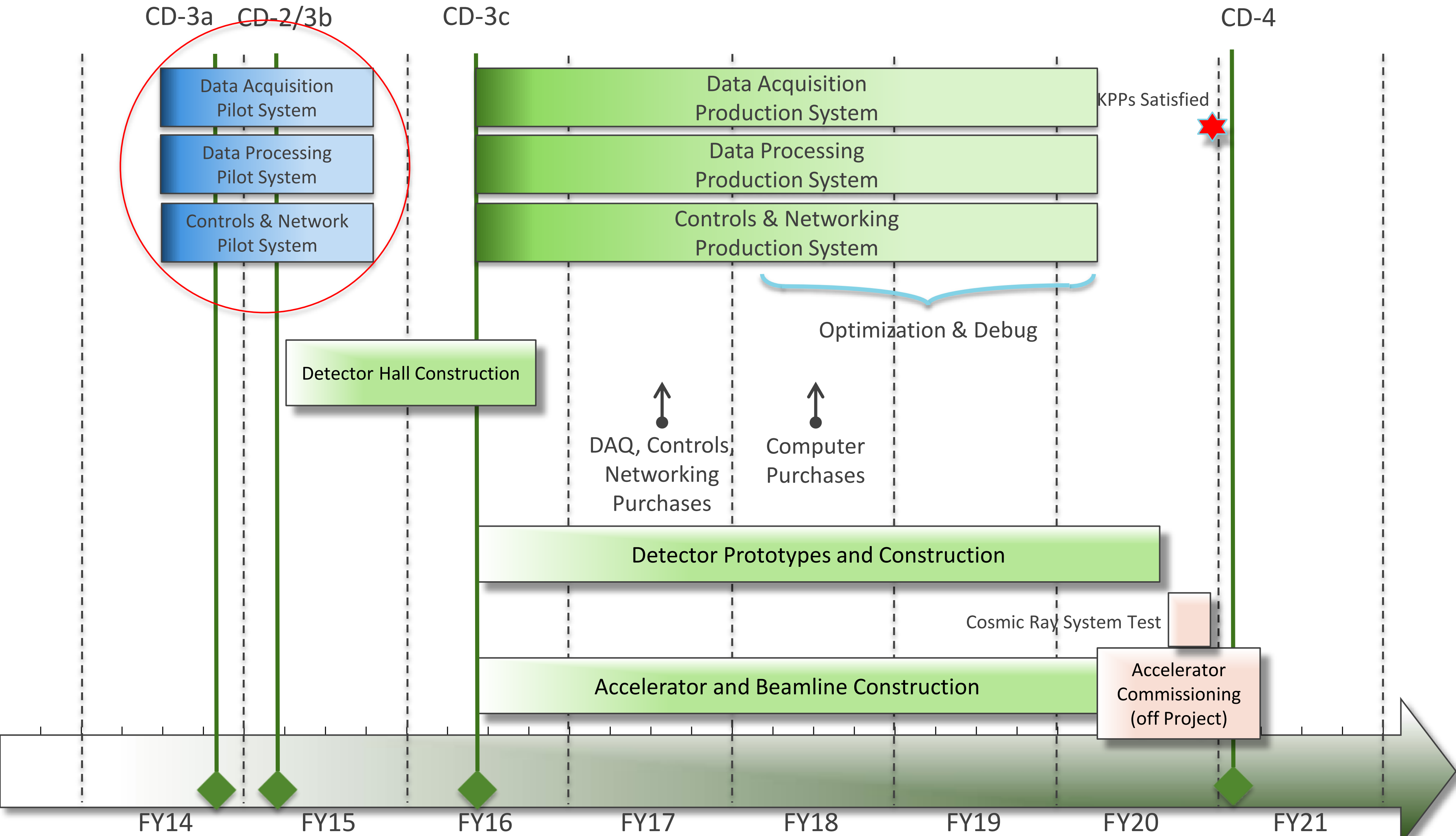
- Includes
  - Optical links between detector and DAQ (bi-directional, control and data)
  - DAQ Servers (detector interface, event building, online processing)
  - Timing System
  - Detector Control System (slow controls)
  - Control room
  - All associated software

- Doesn't include
  - Detector electronics (digitizers and readout controllers)

L3 Tasks

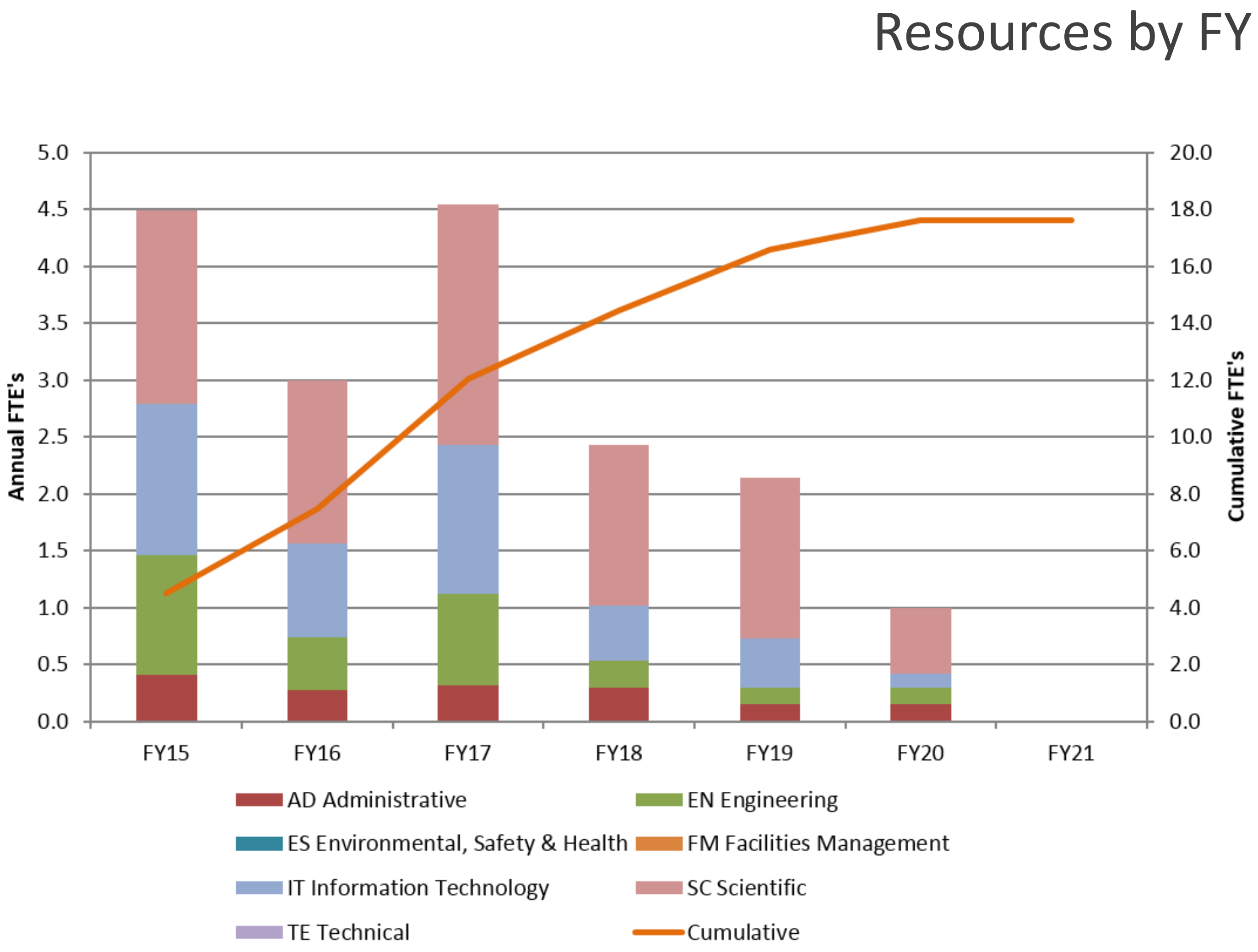
- 475.9.1 Management
  Organization, Schedule, Cost Estimates, QA, Risks, ES&H
- 475.9.2 System Design & Test
  Requirements, System Architecture, System Test
- 475.9.3 Data Acquisition
  Data Readout, Timing System
- 475.9.4 Data Processing
  Online Computing and Data Filters
- 475.9.5 Controls & Networking
  General-purpose Networking, Slow Controls, Control Room

Schedule



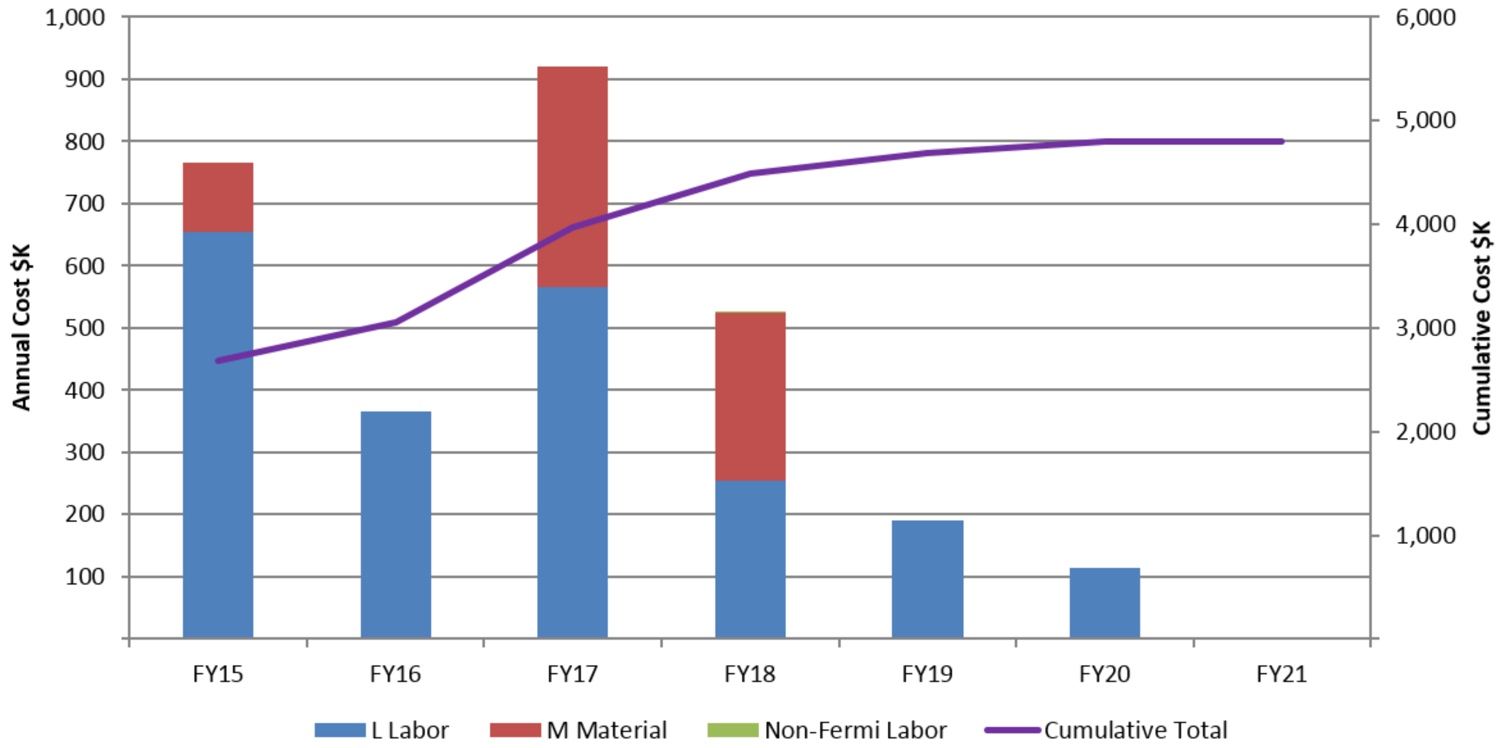
CD-3a
CD-2/3b
CD-3c
CD-4
Data Acquisition
Pilot System
Data Processing
Pilot System
Controls & Network
Pilot System
Data Acquisition
Production System
Data Processing
Production System
Controls & Networking
Production System
KPPs Satisfied
Optimization & Debug
Detector Hall Construction
DAQ, Controls,
Networking
Purchases
Computer
Purchases
Detector Prototypes and Construction
Cosmic Ray System Test
Accelerator and Beamline Construction
Accelerator
Commissioning
(off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Effort Breakdown



Cost Breakdown

Resources by FY



System Design

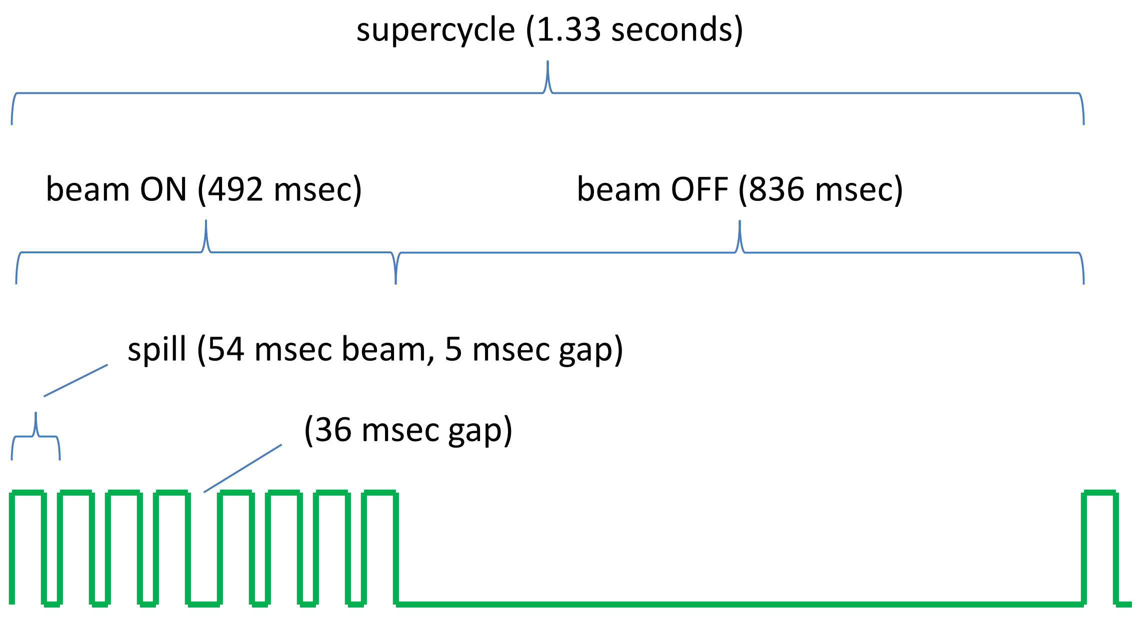
Features

- Data is zero-suppressed in detector readout controllers
  - readout controllers have large buffers (~1 second) to reduce DAQ bandwidth requirement (30% accelerator duty cycle)

- Tracker and Calorimeter readout is triggerless
  - data is transmitted for all events (~20 GBytes/sec)
  - all filtering is done in software (~1% acceptance)

- Cosmic Ray Veto readout is triggered
  - data is transmitted only for events accepted by the Tracker/Calorimeter filters
  - CRV data is not used in the online filter

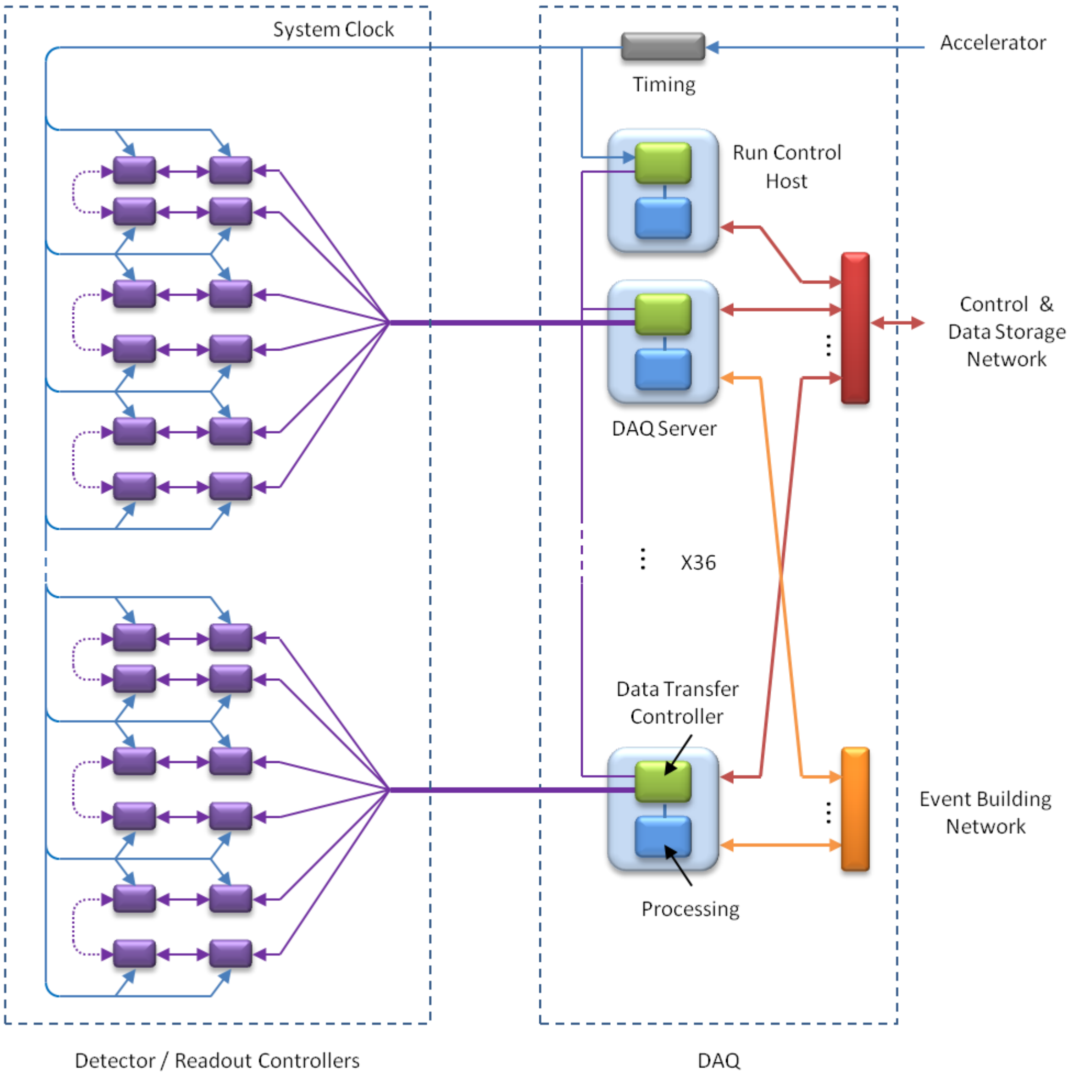
System Design



Readout Controllers capture data during the 492 msec beam ON period and transmit data to the DAQ over the full 1.33 second supercycle.

Beam Structure

System Design



- architecture supports both streaming (Tracker, Calorimeter) and triggered (CRV) readout

- DAQ Servers handle data readout, event building and processing

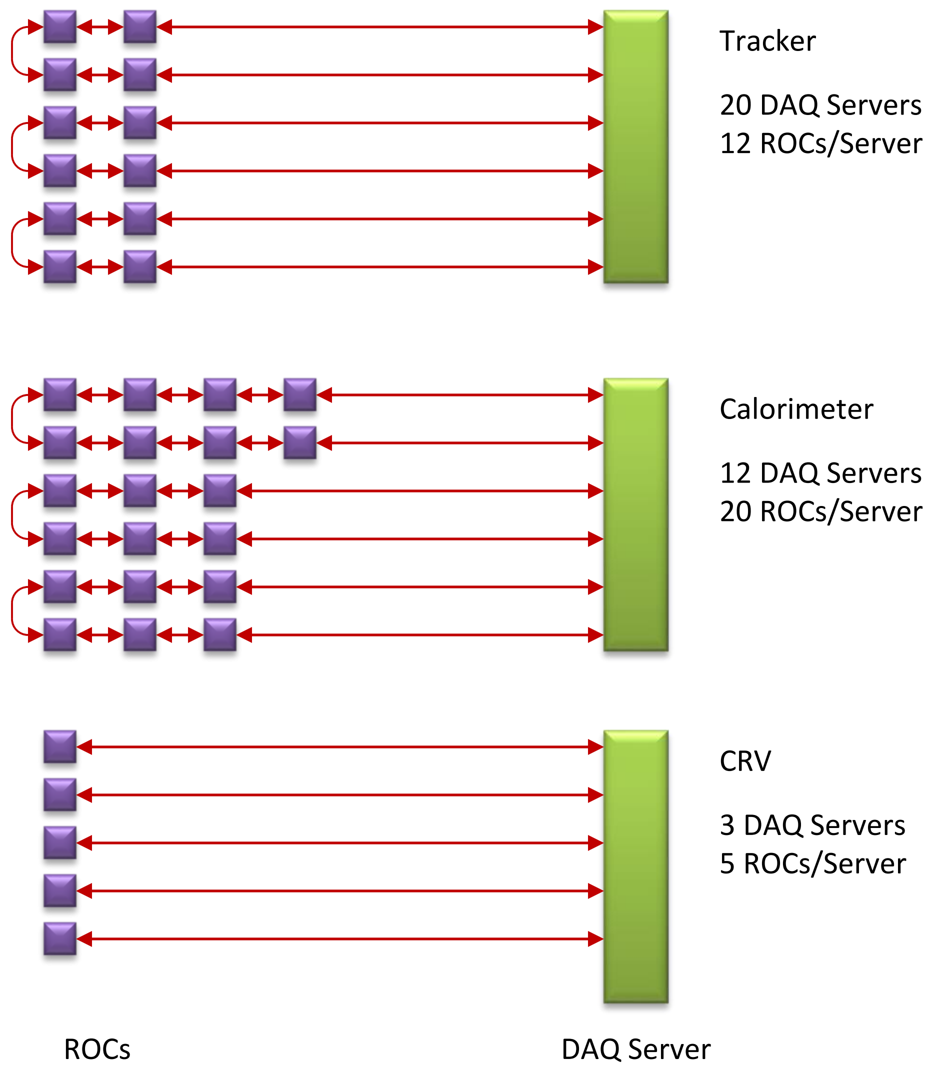
- bidirectional front-end interface for fast control and readout

- large front-end buffers for uniform data transfer

- all commercial DAQ hardware

- scalable… 1 GByte/sec per DAQ server

System Design

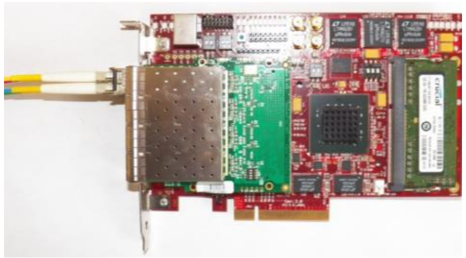


System Design

Implementation

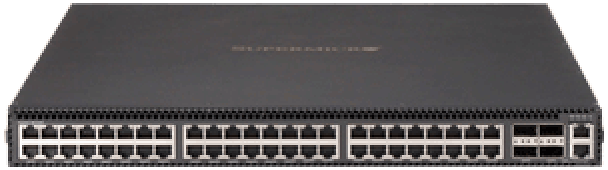
- Simple, scalable architecture... a single “DAQ Server” can function as a standalone 1 GByte/sec DAQ system, or many servers can be connected together via 10Gbps Ethernet.
- All commercial hardware
- Development effort is mainly firmware/software

System Design

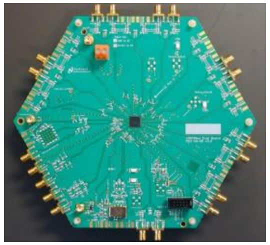


Data Transfer Controller
(FPGA card with 8 SFP
optical links)

DAQ Server

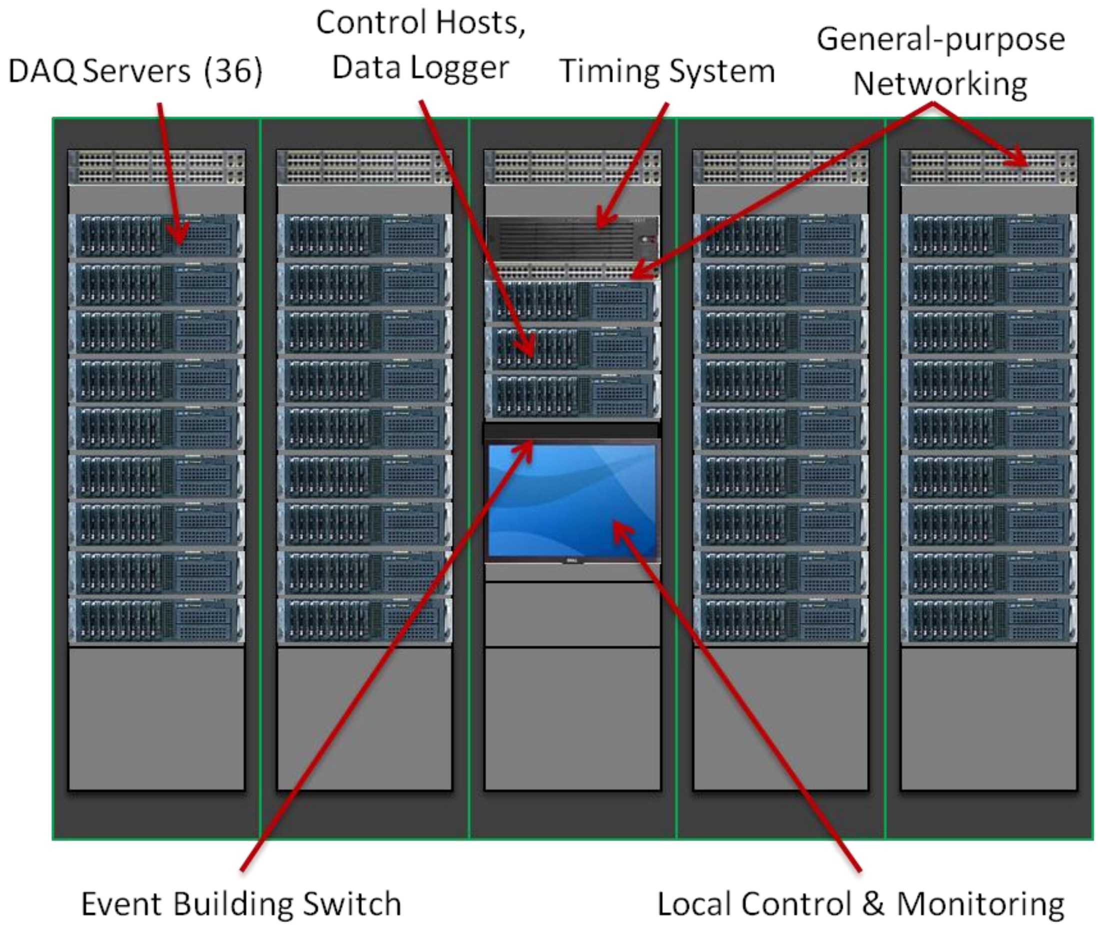


Event Building Network
(48 port, 10G Ethernet switch)



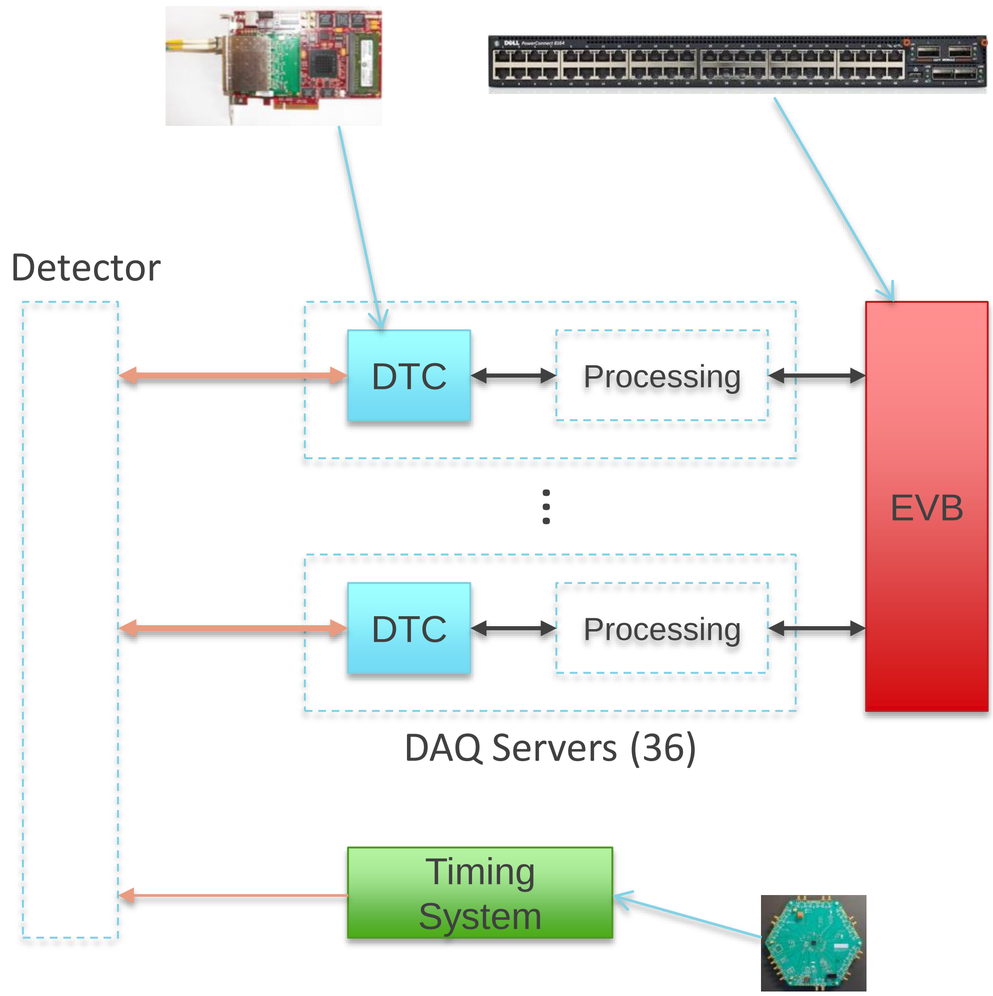
Clock Fanout

System Design



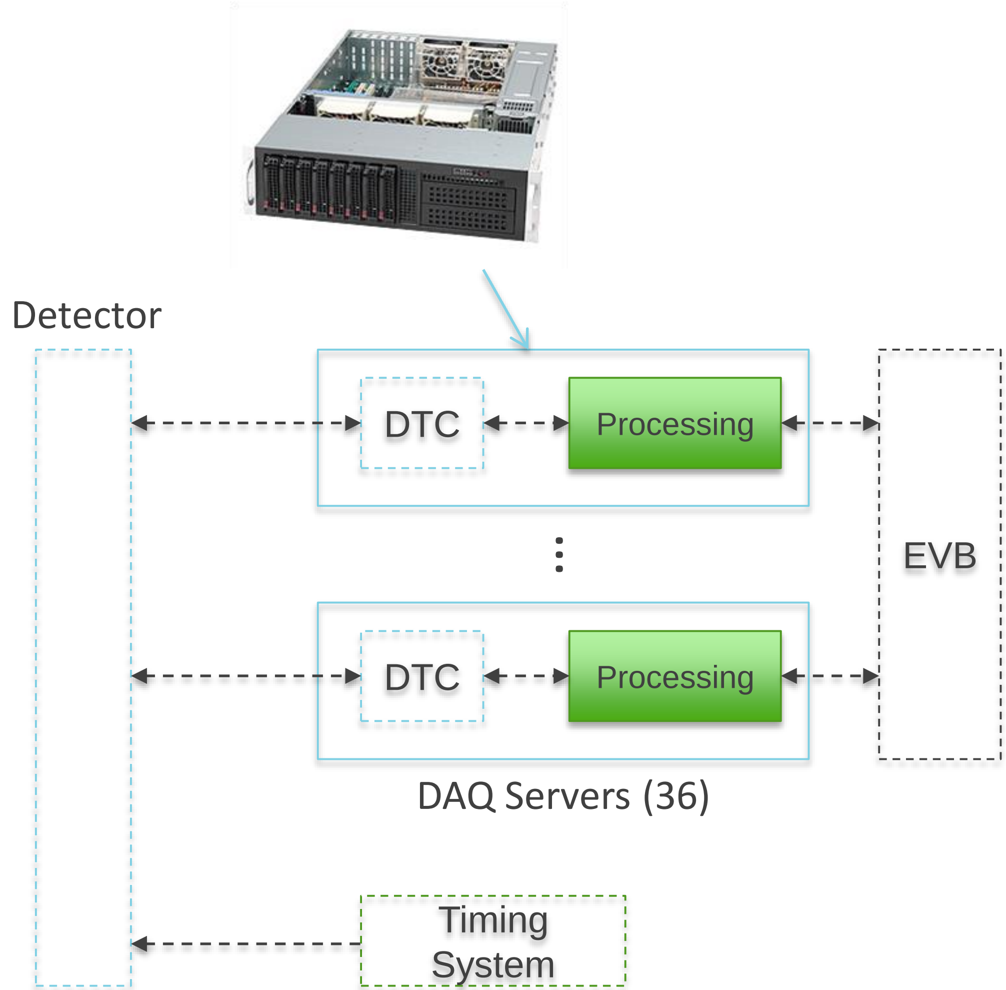
Data Acquisition

- Data Transfer Controllers (DTCs) and firmware
- Optical Links connecting DTCs to Detector
- Event Building Network (EVB)
- Timing System
- Data Acquisition software running on DAQ Servers and Run Control Host
- Infrastructure (racks, cable trays)

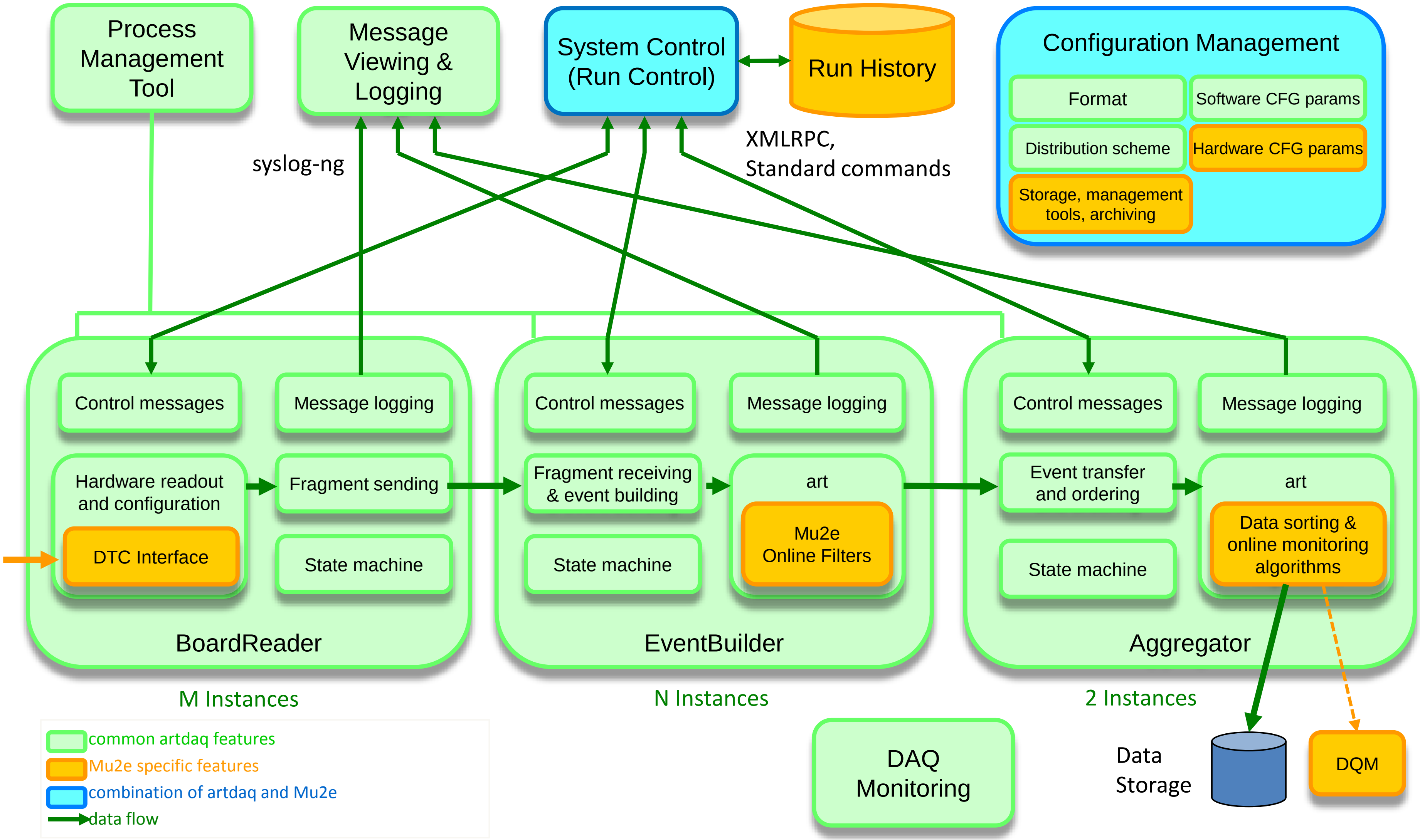


Data Processing

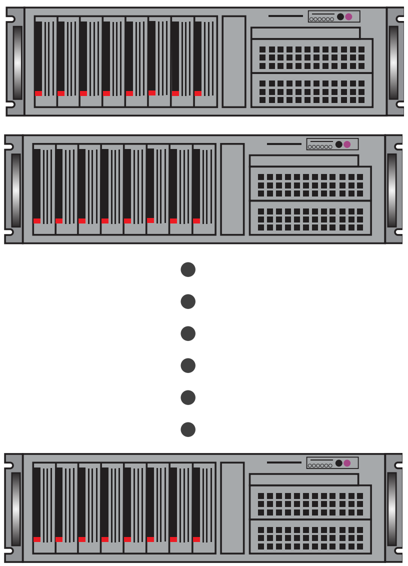
- DAQ Servers
- Data Logger, DCS Host & Run Control Host
- Data Processing software running on DAQ Servers
- Online data filters and analysis



artdaq Software Framework



Data Processing



DAQ Servers

- 36 DAQ Servers
- 192k events/sec
- using XEON-PHI processor
  64 cores X 36 servers → 2,304 total cores
  Available processing time/event: 12 ms
- using dual XEON processors
  20 cores X 36 servers → 720 total cores
  Available processing time/event: 3.75 ms

Processing Requirements

Controls & Networking

Mu2e Remote Control Room - Wilson Hall, 1st floor West

(shared use - LBNF, MicroBooNE, MINERvA, MiniBooNE, MINOS, Muon g-2, Mu2e, NOvA)

University Participation

- Approx half of labor effort is scientific (mostly software)
- Costed labor averages 2 FTE/yr

- Hardware – not much (all commercial components)
- Firmware – self-test, diagnostics, accelerator interface, timing
- Software – *artdaq*, *art*, slow controls, networking, data storage, diagnostics
- Testing – detector Readout Controller integrations tests, Cosmic Ray system test

University Participation

Control Room Operator Interface – create graphical operator interfaces for the Data Acquisition and Detector Control Systems, using web-based technologies.

Detector Control System (slow controls) – develop a good understanding of EPICS and begin writing code to exchange control and status information between servers in the Mu2e building (DCS Host, DAQ Servers, Data Logger, Run Control Host) and servers in the remote control room.

artdaq – help implement artdaq software framework on the DAQ servers and the Run Control Host.

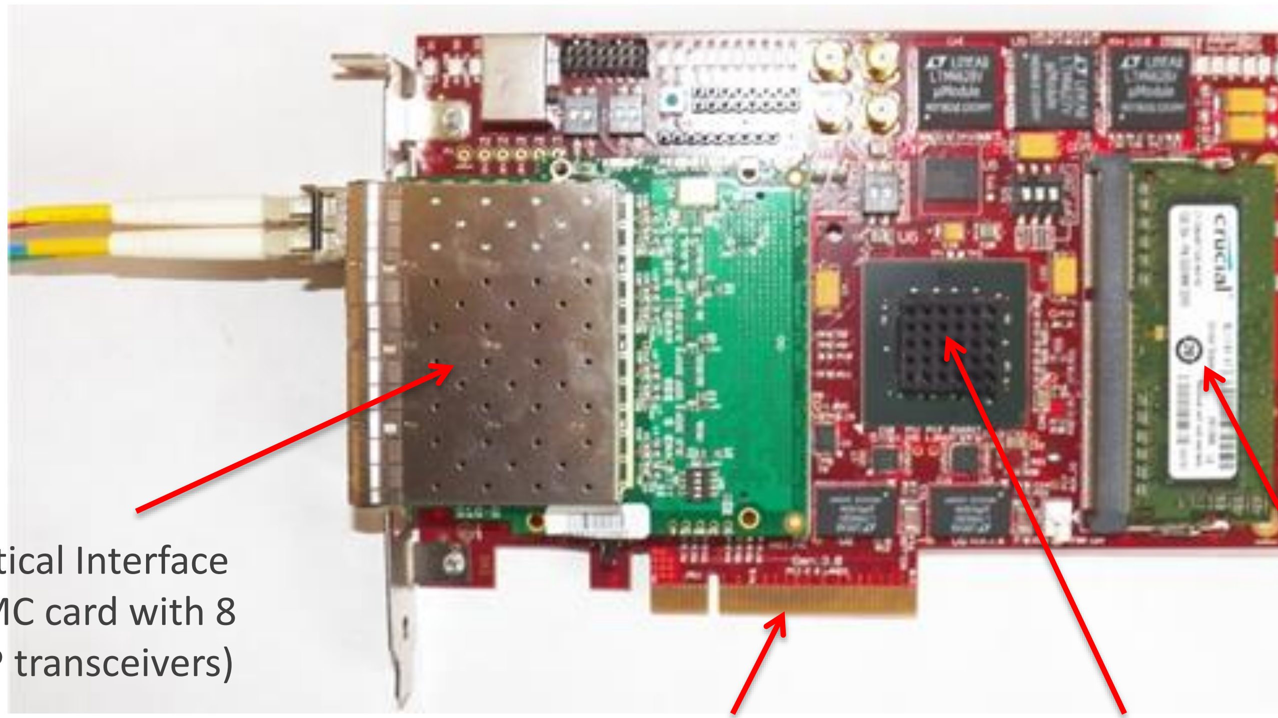
Timing System – define the interface between the accelerator RF controls and the Mu2e timing system. Design accelerator interface and timing system fanout.

Data Logger – evaluate centralized vs distributed storage architecture.

Diagnostics – define a set of diagnostics to use in isolating faults in optical links, DAQ servers, readout controllers, etc. Propose a series of Failure Modes and Effects Analysis tests to help operators identify and localize problems.

Backup

Data Acquisition



Optical Interface
(FMC card with 8
SFP transceivers)

PCIe Interface

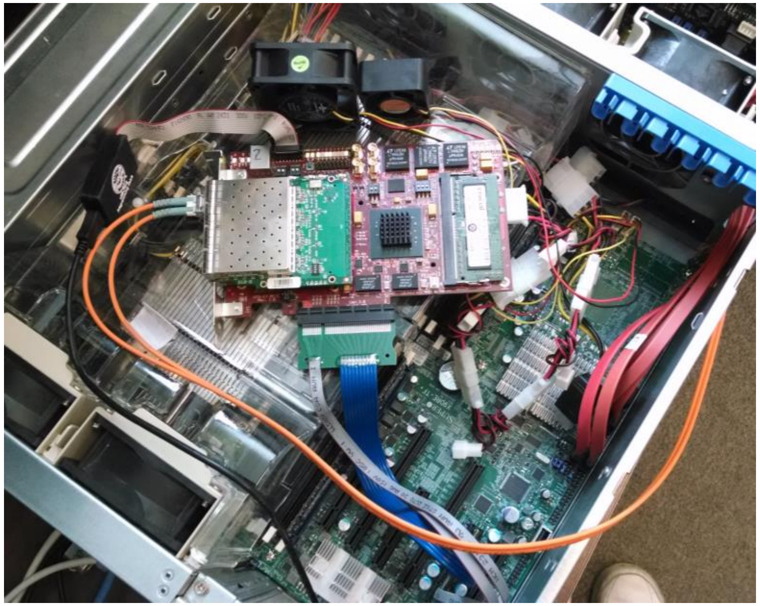
FPGA

Memory

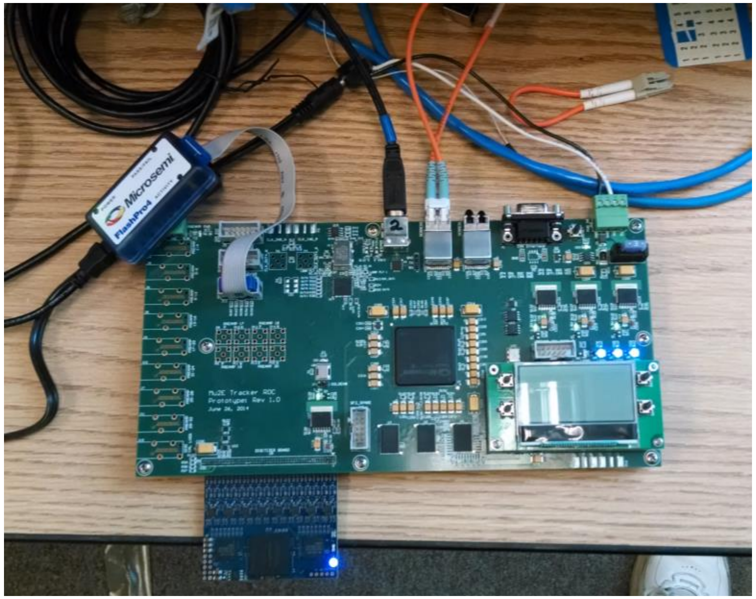
Data Transfer Controller (DTC)

Data Acquisition

Interface Tests

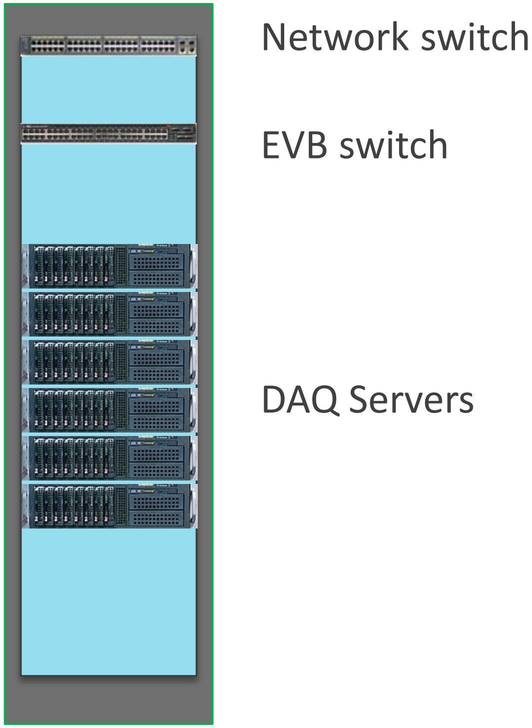


Data Transfer Controller (DTC)



Tracker Digitizer and Readout Controller (ROC) Prototypes

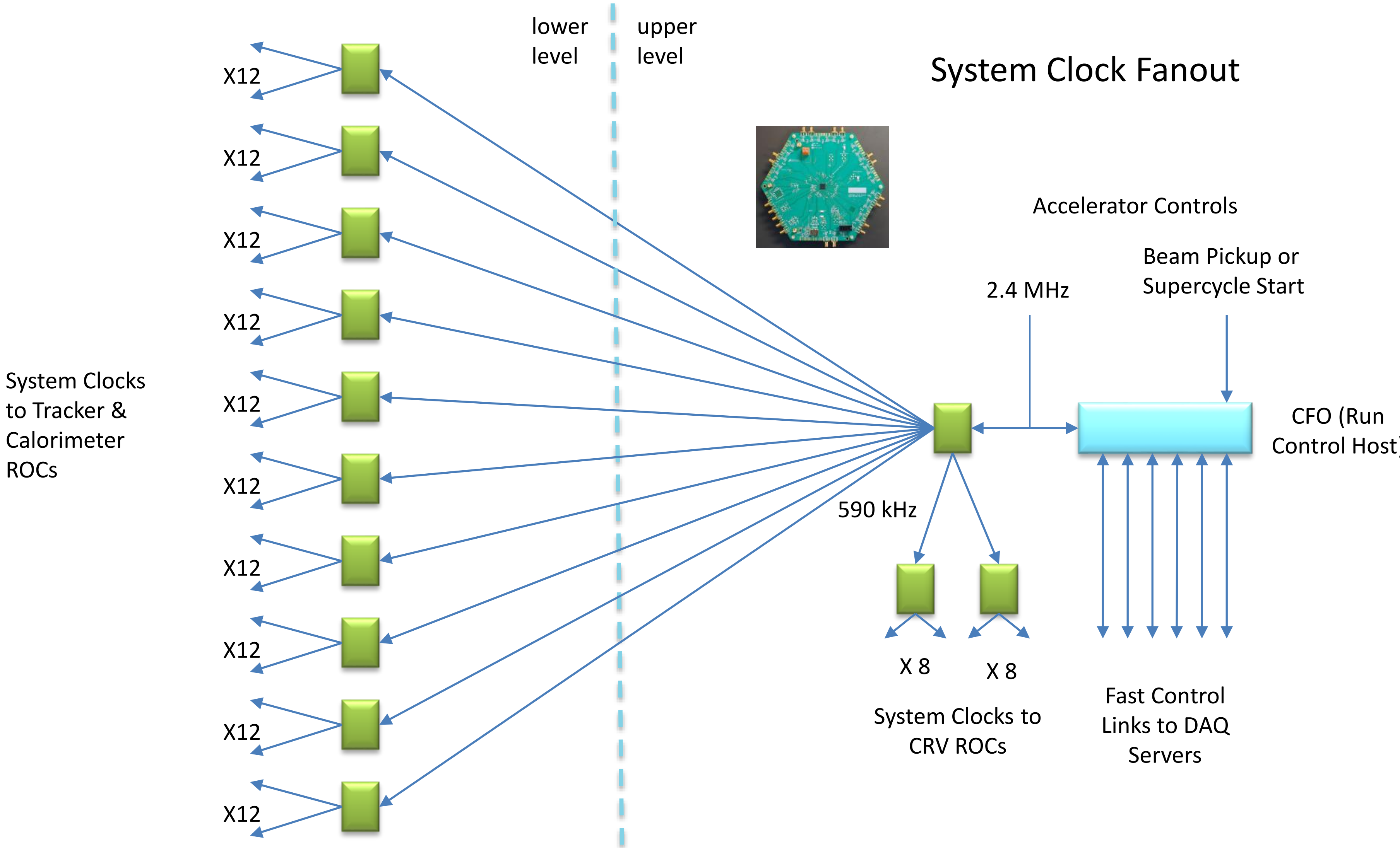
Data Acquisition



Pilot System

- 6 DAQ Servers
- 6 Data Transfer Controllers (DTCs)
- Loopback Optical Links (emulated ROCs in DTCs)
- Event Building Network (EVB)
- General-purpose Networking
- Data Acquisition/Data Processing software running on DAQ Servers

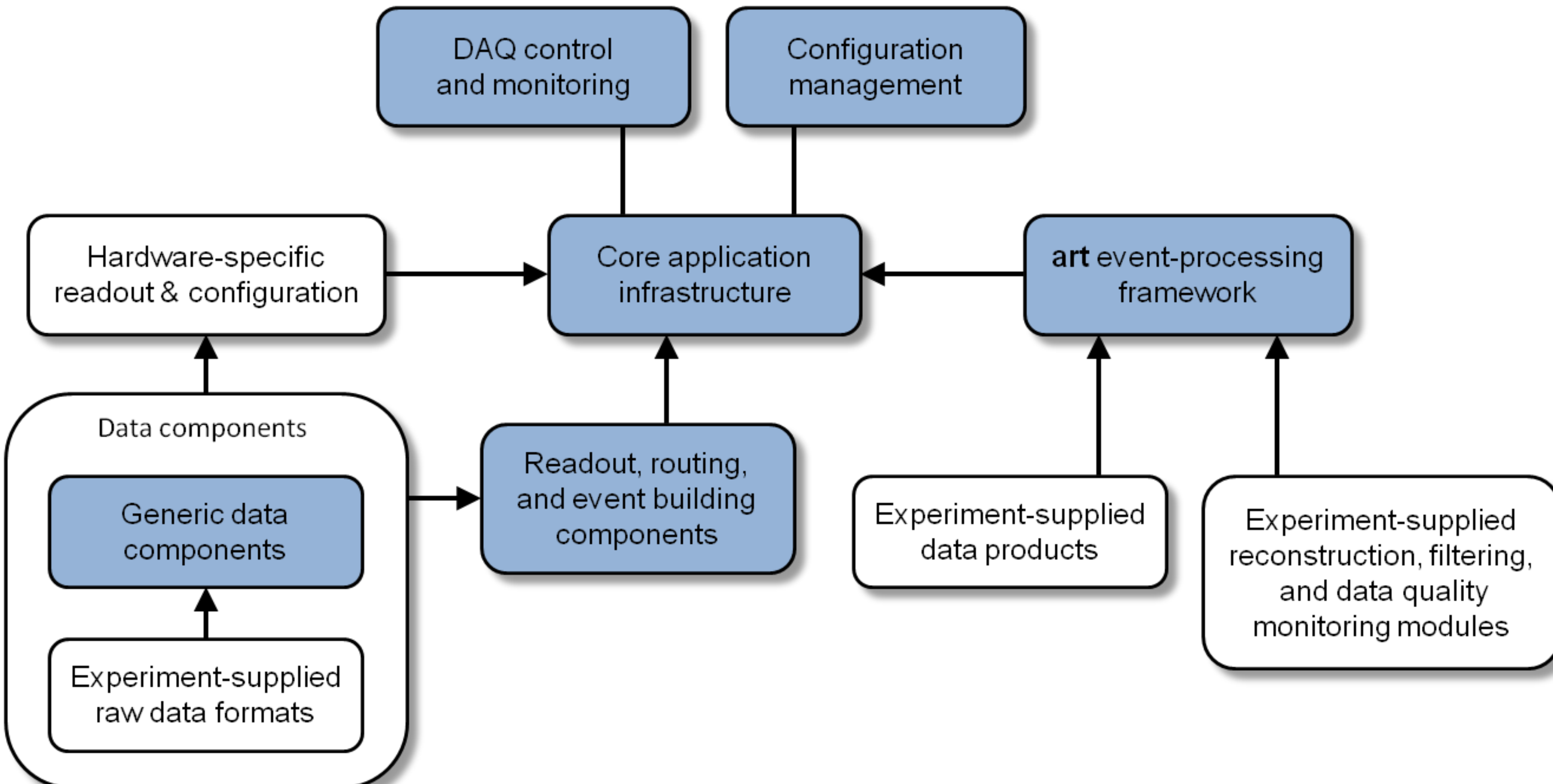
Data Acquisition



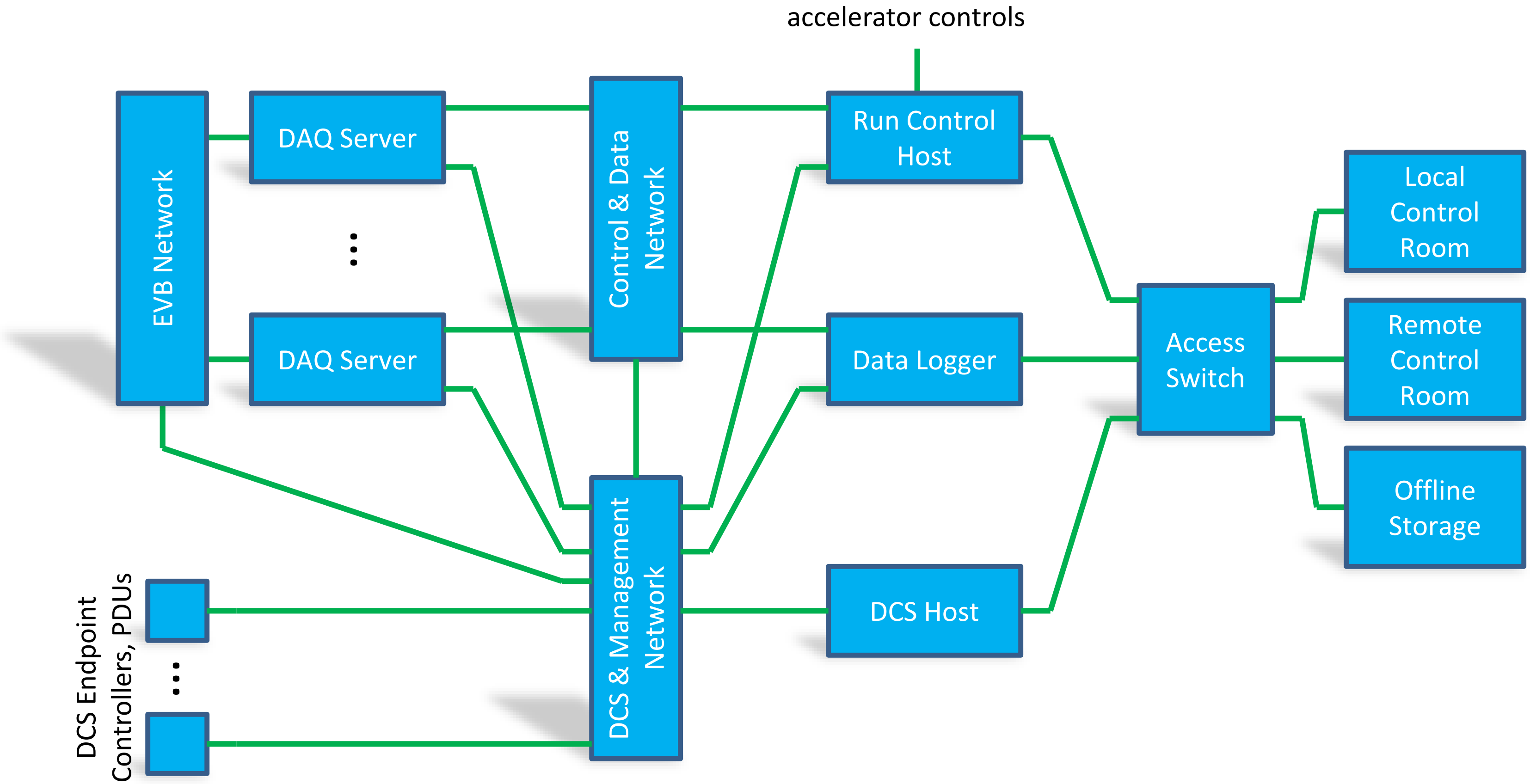
Data Acquisition

Software based on *art* and *artdaq*

(a common DAQ & Online Processing framework developed for Mu2e and other current/future experiments)



Controls & Networking



System Architecture - Networking Perspective

Controls & Networking

Slow Controls

Baseline is standard commercial DAQ hardware (~$60/channel).

As part of a separate project we will also test lower-cost solutions. Example: 2” X 2” X 2” quad-core 1 GHz Linux computer & USB DAQ modules (~$15/channel).