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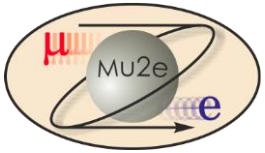


CD-3c Review: Mu2e Trigger & DAQ

R. Rivera
Trigger & DAQ L2 Manager
4/19/16

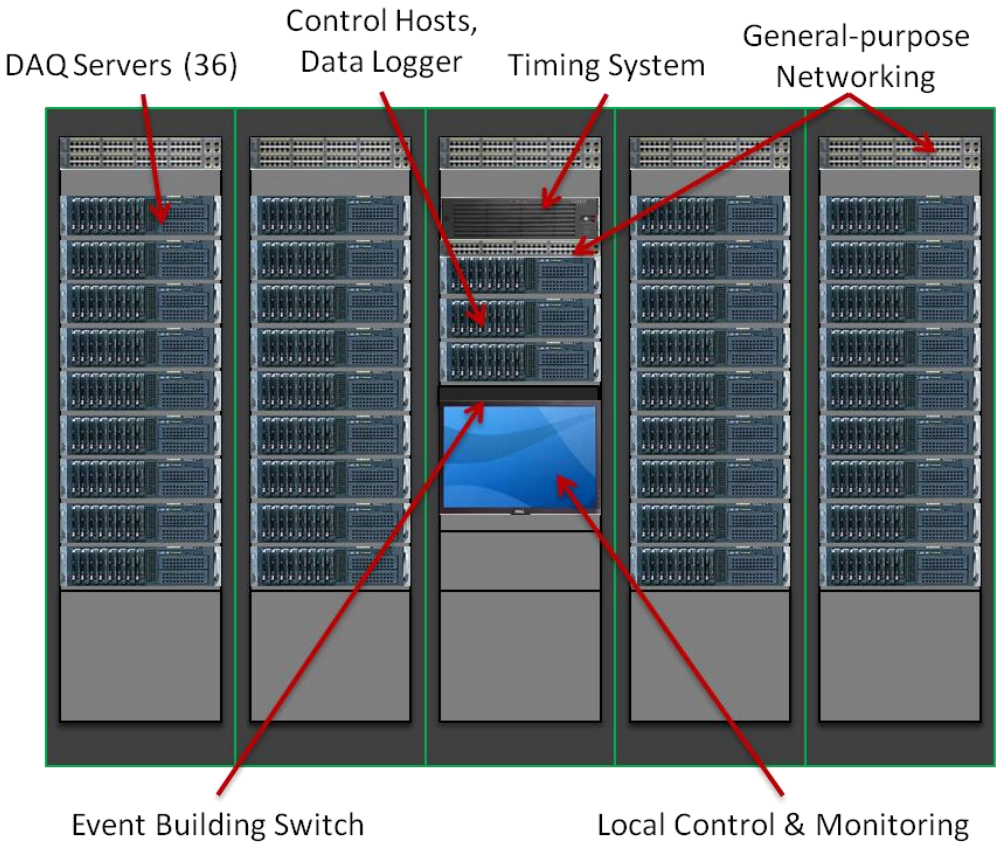
TDAQ Team Leaders

- Ryan Rivera – L2 Manager, L3 Manager (System Design & Test)
  - Group Leader - Real-time Systems Engineering, Detector Electronics Group
  - 13 years experience
- Kurt Biery – L3 Manager (Data Processing, Control & Networking),
  - Department Head - Scientific Computing Division, Real-time Systems Engineering Department
  - 18 years experience
- Rick Kwarciany – L3 Manager (Data Acquisition)
  - Electrical Engineer – Real-time Systems Engineering
  - 33 years experience

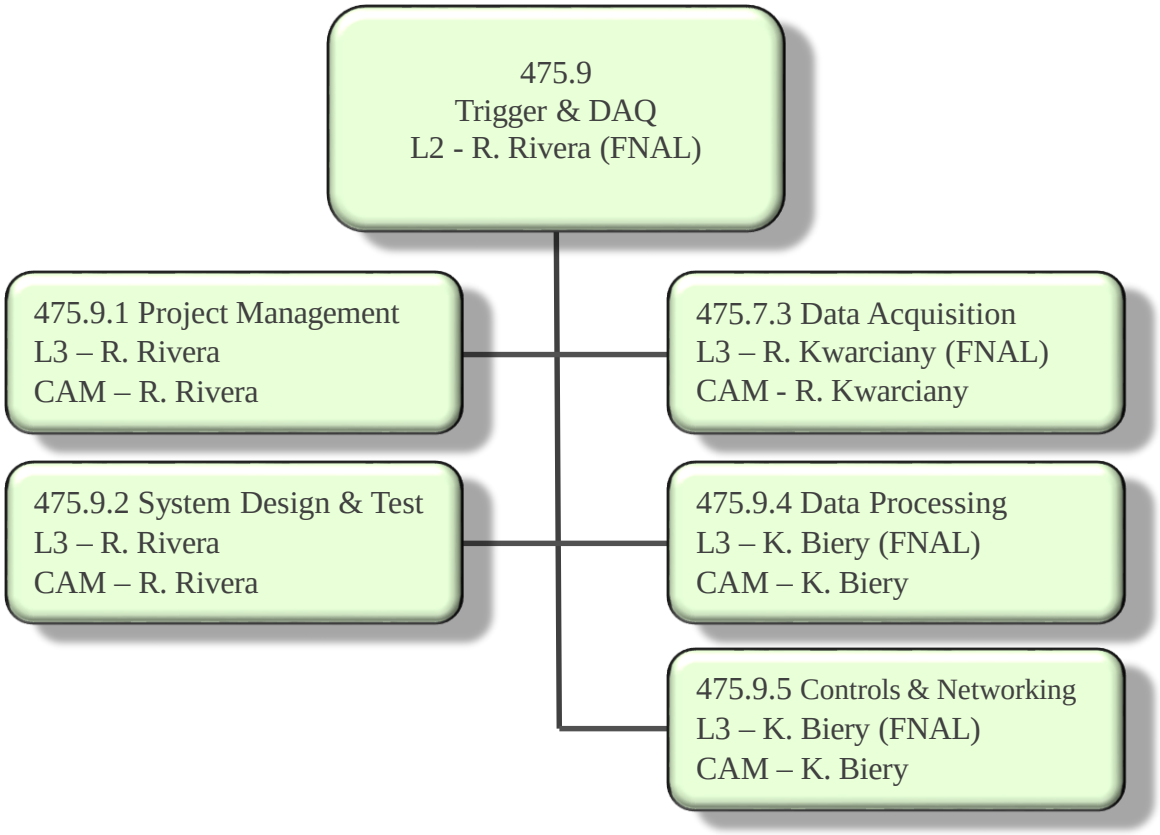
Introduction and Scope

Trigger and Data Acquisition (TDAQ)

- Provides necessary components for the collection of digitized data from the Tracker, Calorimeter, CRV, Stopping Target Monitor, and Extinction Monitor.
- Delivers data to online and offline processing for analysis.
- Is responsible for detector synchronization, control, monitoring, and operator interfaces.
- Sub-detectors are responsible for front-end Readout Controllers and signal fanout inside the vacuum.



TDAQ Organization



Institutional Responsibilities

- Fermilab
  - Management, Hardware, Firmware, and Software
- Kansas State University
  - Detector Control System
- Caltech
  - Communication Protocol, Online Filter

- Institutions funded through annual SOWs

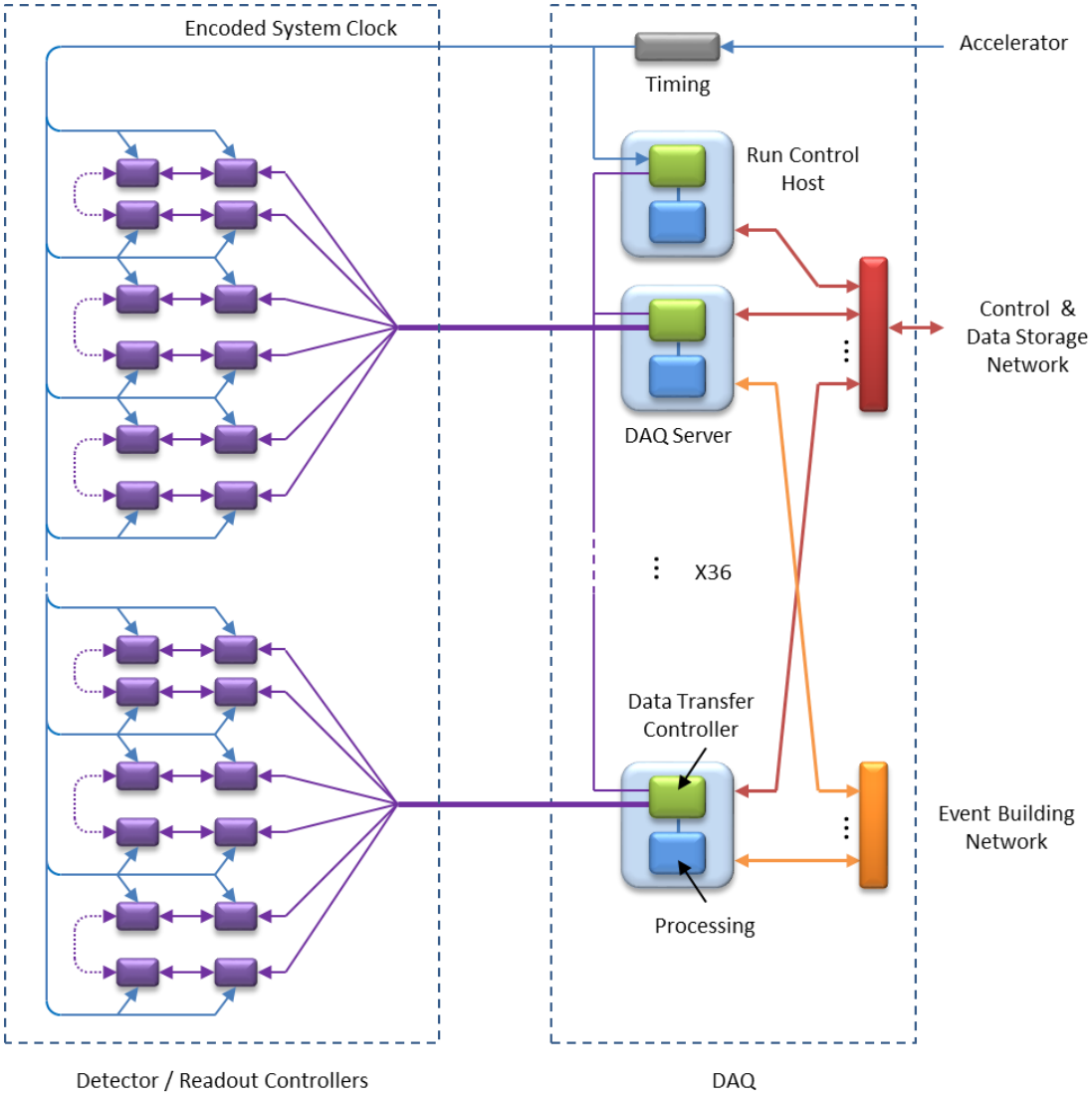
TDAQ Requirements

- Requirements for TDAQ are described in mu2e-docdb 1150.
- Collect and assemble data from the Tracker (~18 GBytes/sec) and Calorimeter (~8 GBytes/sec) for online filtering.
- Facilitate online filtering to reduce Tracker & Calorimeter data volume by ≥ 99%.
- Combine with data from CRV, Extinction Monitor, and Stopping Target Monitor for transfer to offline storage.

TDAQ Requirements

- Provide global timing synchronization
- Provide mechanism for detector partitioning and calibration
- Provide fast and slow control networks
- Provide connections to offline storage and site networking
- Provide control room operator interfaces

TDAQ Design



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

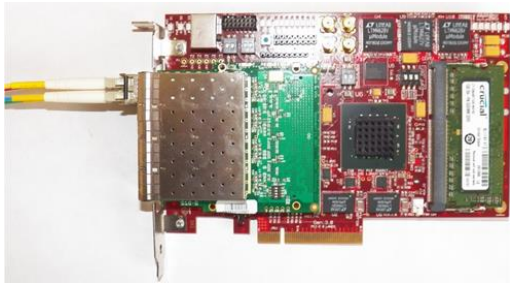
- DAQ Servers handle data readout, event building and processing

- large front-end buffers for uniform data transfer

- scalable architecture… 1 GByte/sec per DAQ server

- expected 39 GB/s in with 68 GB/s available and 7 PB/yr offline storage

Design – Commercial Hardware

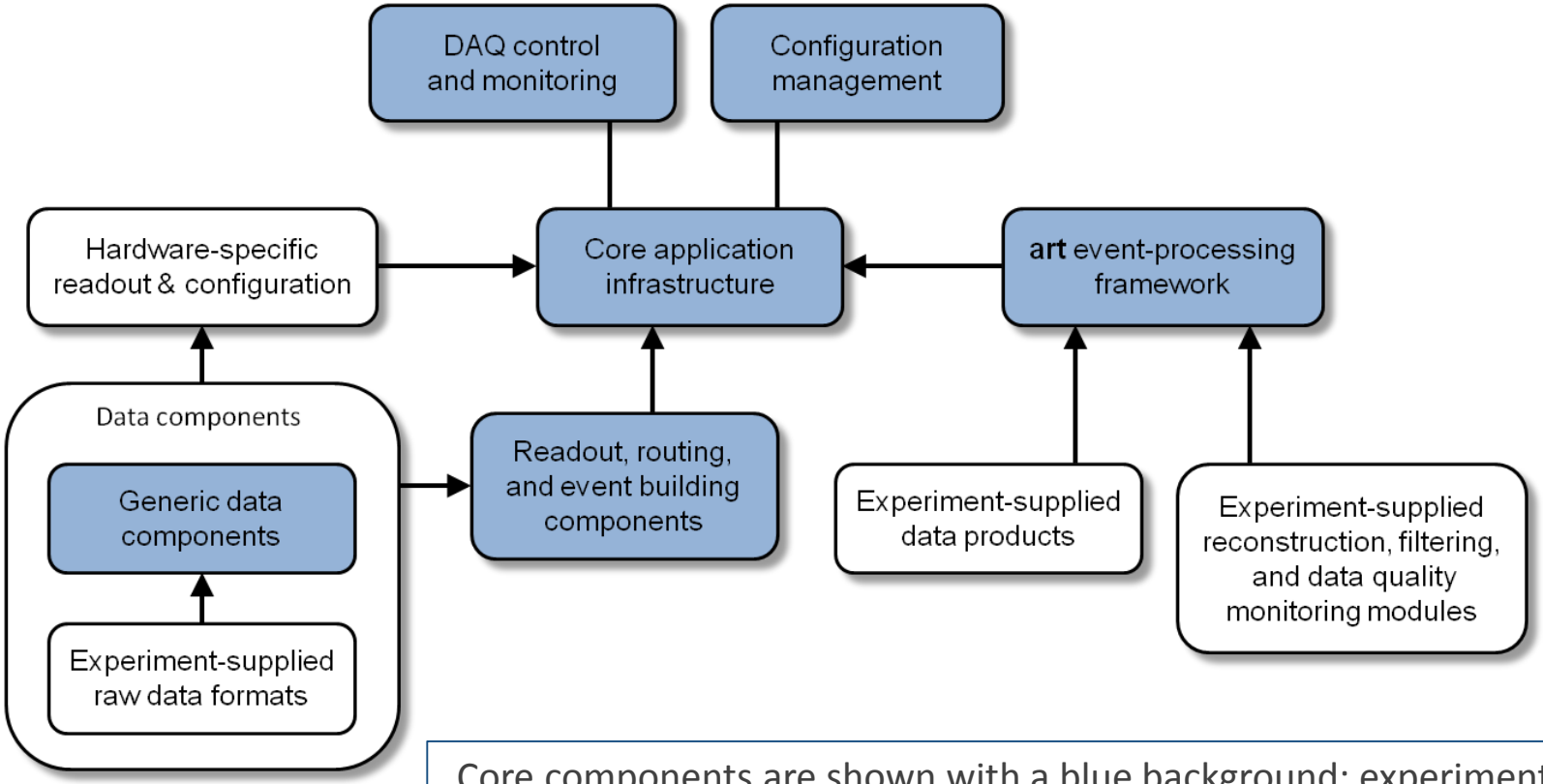


- DAQ Server
  - 3U rack-mount computer
  - integrated DAQ and online processing
- Data Transfer Controller (DTC)
  - PCIe card with FPGA, memory, and 8-port SFP+ optical interface (links at 3.125 Gbps)
  - 1 GByte/sec readout bandwidth
  - Firmware development
- Event Building network
  - 48 port 10G Ethernet switch

Design - Software

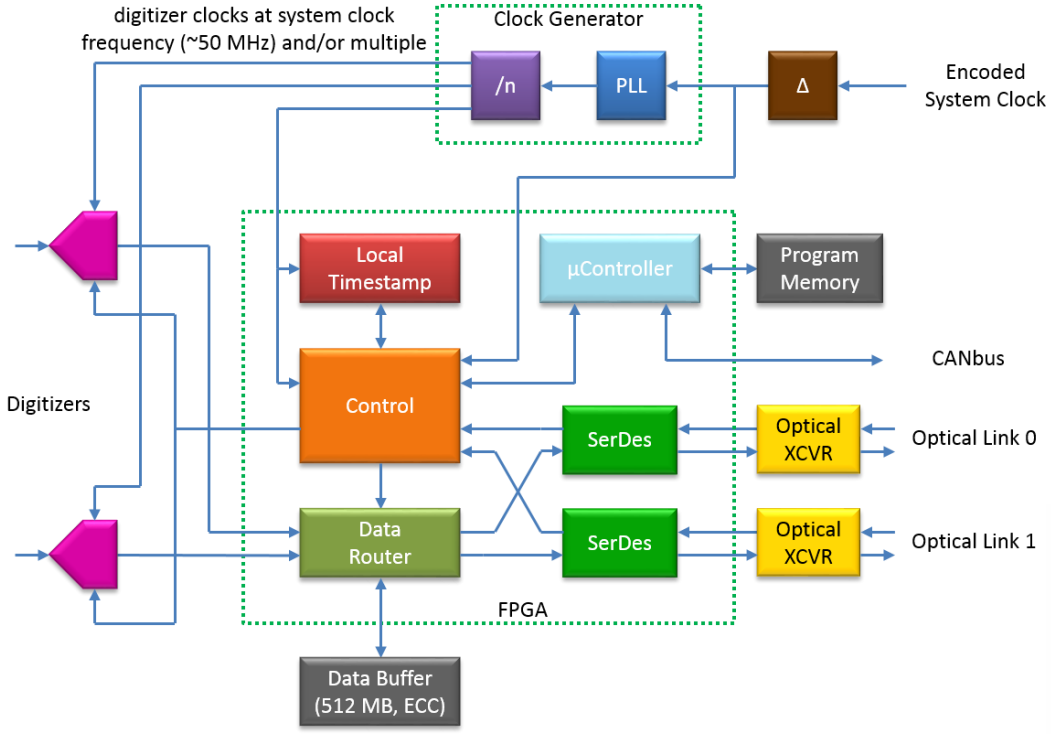
Software based on *art* and *artdaq*

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

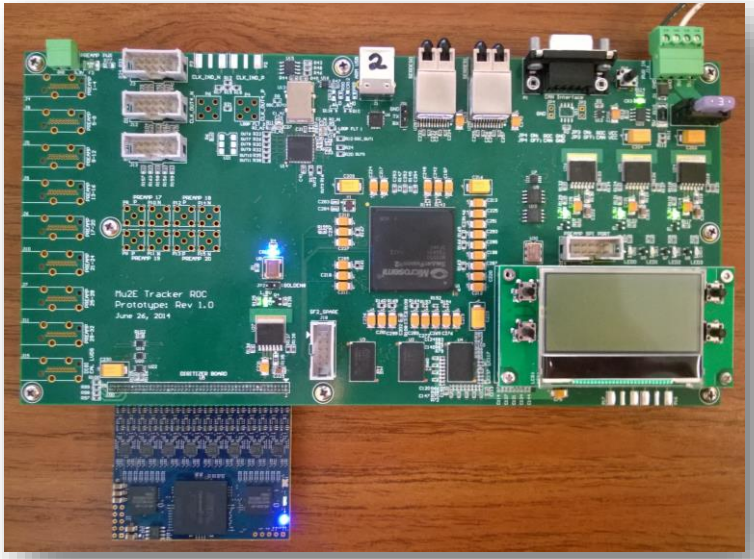


Core components are shown with a blue background; experiment-supplied components are shown with a white background

Design - ROCs

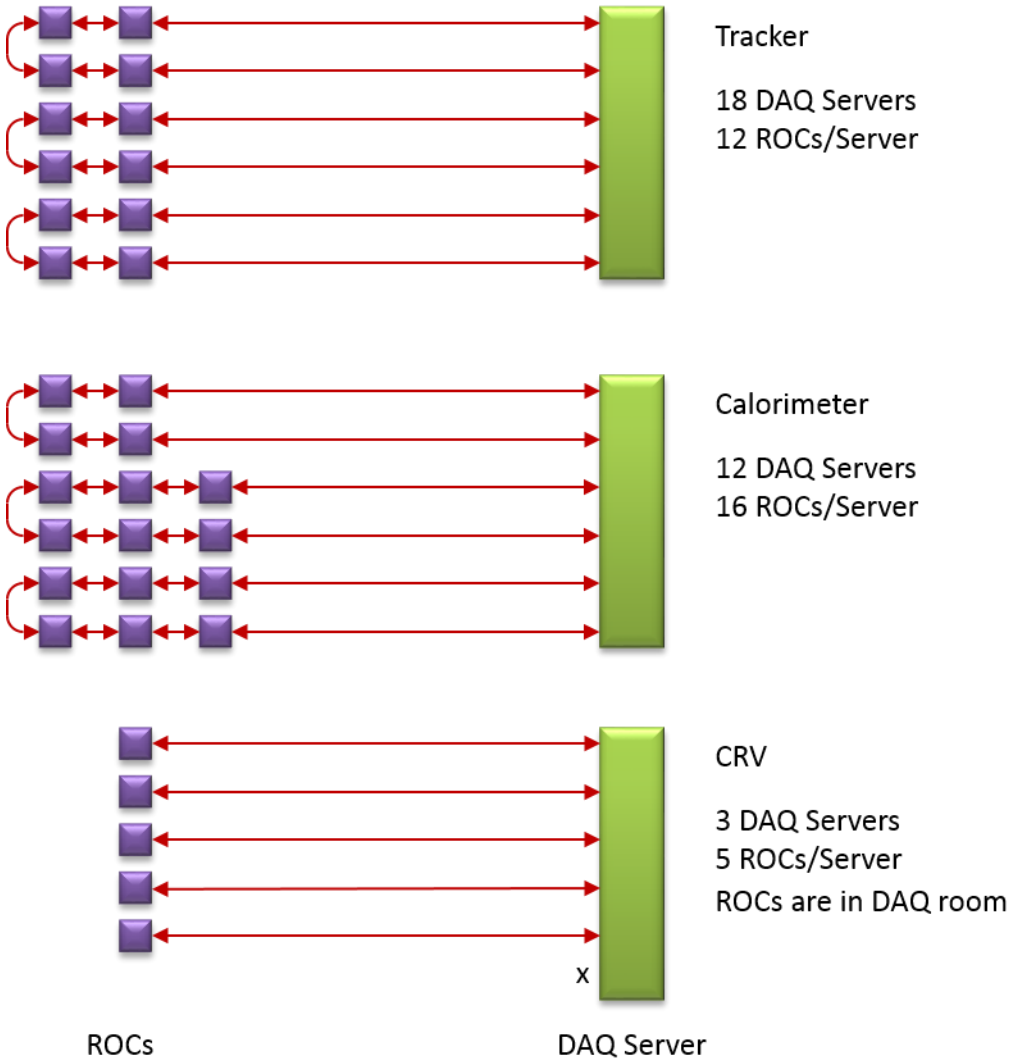


Detector Readout Controllers



- interface firmware & protocols
- prototype development

Design – ROC Distribution



Tracker = 216 ROCs

Calorimeter = 192 ROCs

CRV = 14 ROCs

STM = 1 ROC

ExtMon = 1 ROC

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Design – Data Processing Benchmark

Several algorithmic and compiler optimizations were applied to the reference Tracking filter to achieve a speedup of almost 30X. Target is 200K per second.

	XEON E5-2687v2	XEON PHI 5510P
Stereo Hits		
0) reference code (gcc compiler)	83.6 msec	-
1) algorithmic improvements (gcc compiler)	4.3 msec	-
2) Intel compiler, loop vectorization	1.4 msec	4.8 msec
Background Hits		
0) reference code (gcc compiler)	9.0 msec	-
1) Intel compiler	5.1 msec	123.0 msec
2) refactoring	3.4 msec	38.1 msec
3) double → single precision	2.1 msec	23.9 msec
Overhead		
0) reference code (gcc compiler)	0.9 msec	-
1) Intel compiler (estimated)	0.3 msec	2.0 msec
total processing time	3.8 msec	30.7 msec
events/sec (single core)	260	32
number of cores (36 servers)	720	4,320
events/sec (36 servers)	187,000	138,000

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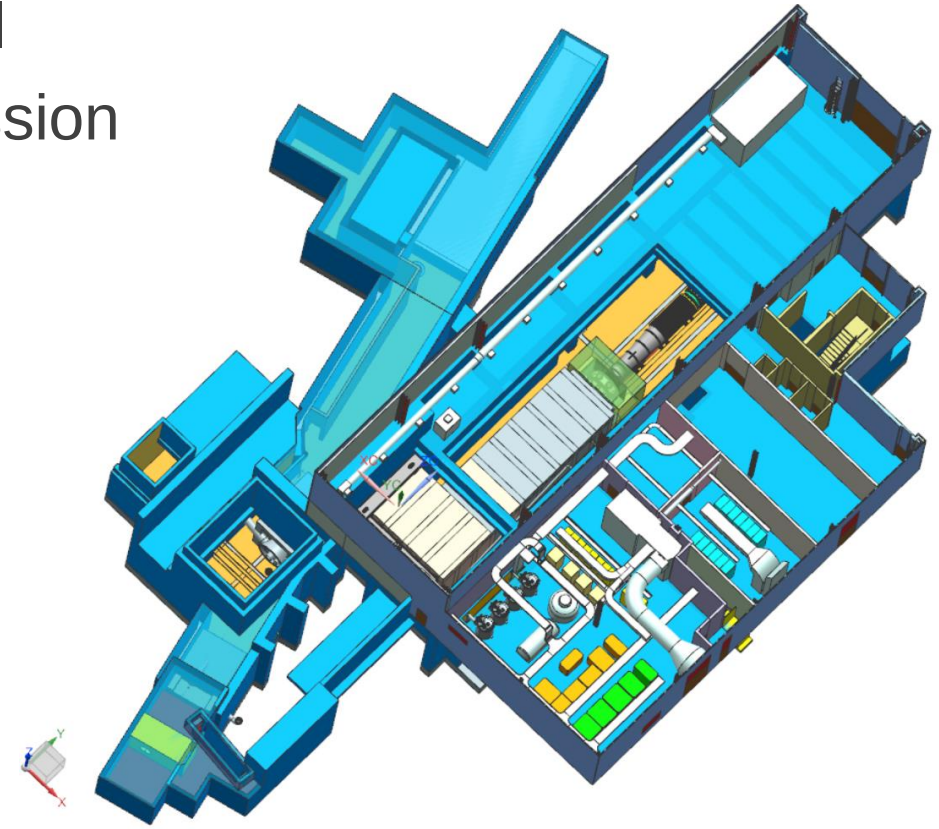
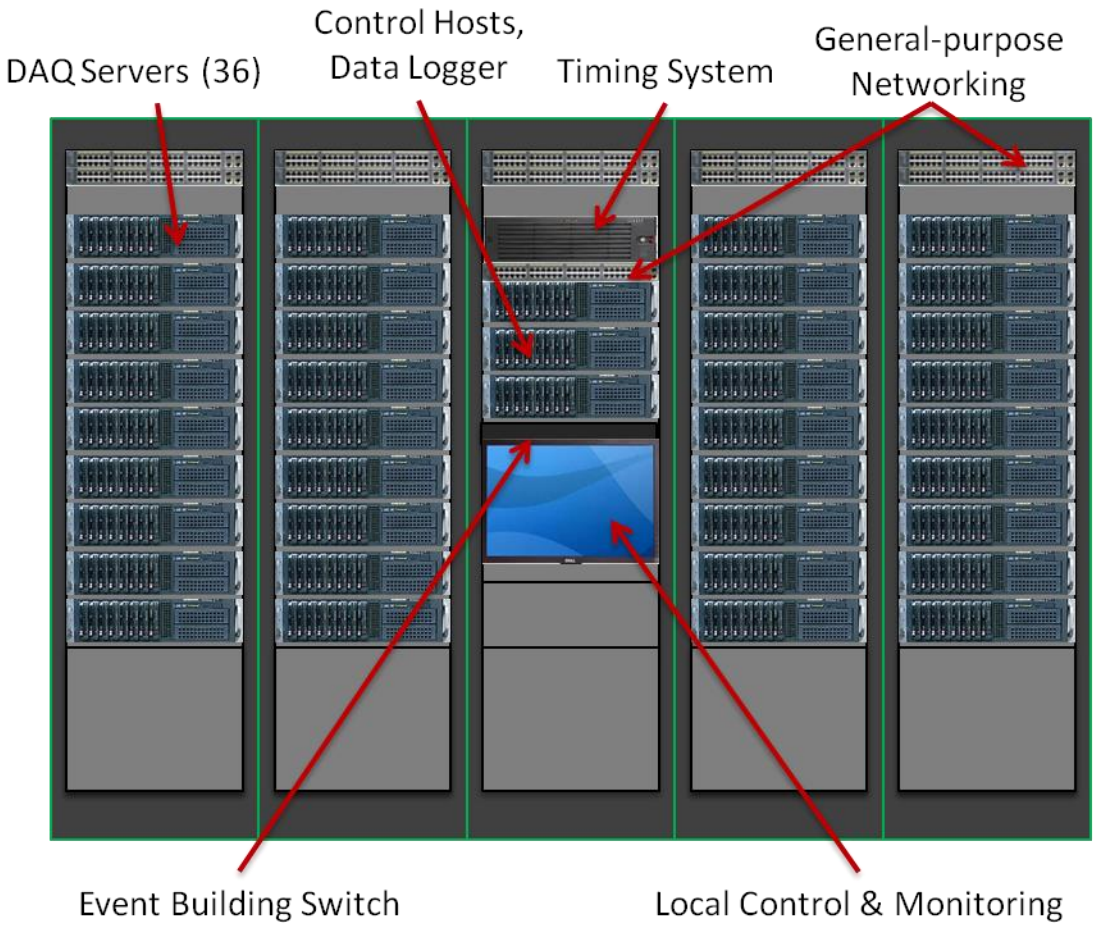
Design – Timing Distribution

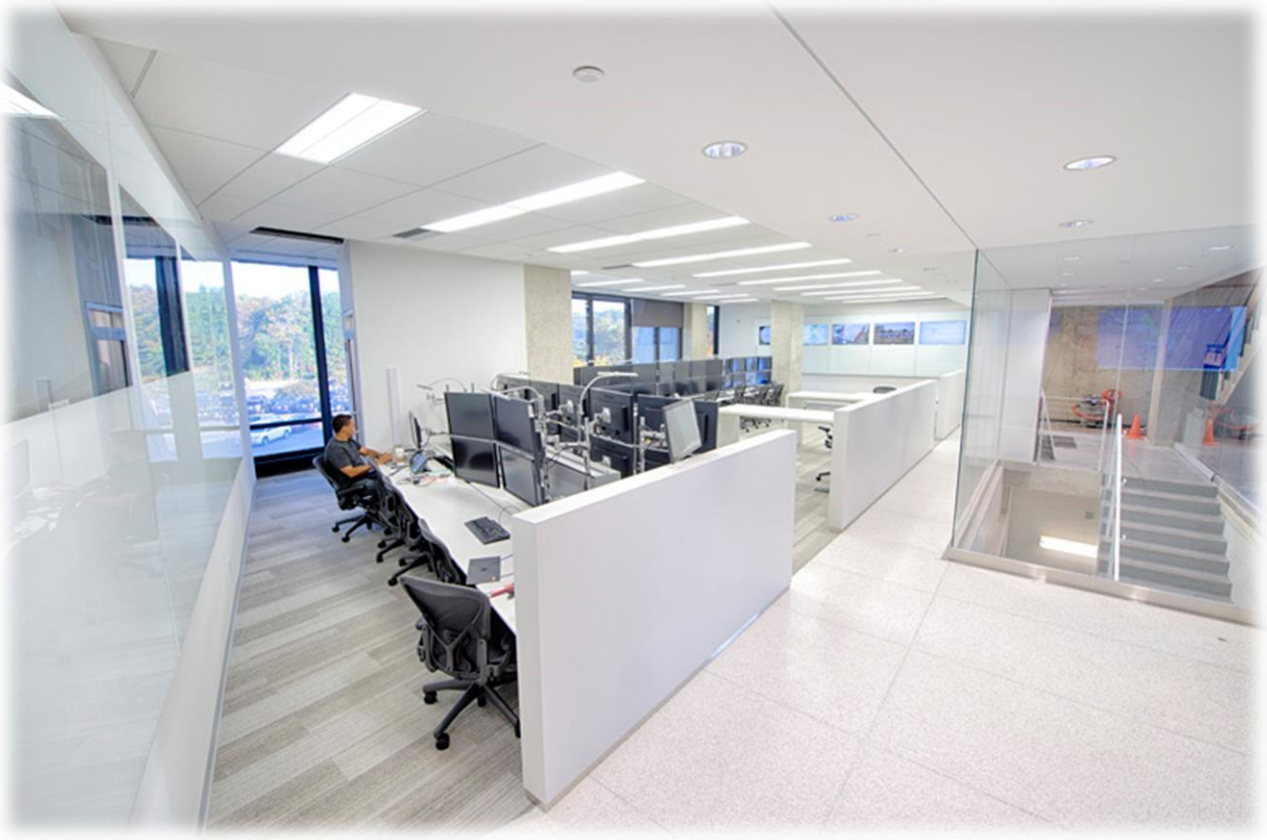
- Timing distribution system is specified in docdb 7047
- TDAQ synchronizes all front-end ROCs by distributing a free running System Clock and “Start of Event Window” marker encoded on a single signal
- Details in the breakout session



Design – Rack Plan



Design – Control Room



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

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

DAQ Design Review and Status

- A DAQ Design Review was held on Jan 26, 2016
  - John T. Anderson (ANL – Chair)
  - Jon Paley (FNAL)
  - Jamieson Olsen (FNAL)
  - Mark Paterno (FNAL)
  - Alan Prosser (FNAL)
- Committee answered yes to all charge questions
- Design is 90% complete.
- Primary risk to DAQ is an underestimation of detector rates
  - DAQ has been designed to be flexible, scalable and with significant headroom to mitigate this risk.
- Final report is in mu2e-docdb 6377

Design Review Charge Questions

- Does the TDAQ meet the requirements of the Mu2e experiment? Yes
- Are the interfaces between TDAQ and the detector subsystems well defined? Yes
- Is the TDAQ commissioning plan well defined and documented? Yes
- Has the technical risk of having higher data rates than expected in the experiment been properly evaluated and mitigated? Yes
- Is the design on track to satisfy the requirements for a DOE CD-3c review in late spring 2016? Yes

Design Review Recommendations

- We received 19 recommendations from the review committee.
- We have responded to all recommendations.
- Recommendations and responses can be found in docdb 6377.
  - Will discuss in detail in breakout session.

TDAQ Interfaces

- DAQ has external interfaces to Conventional Construction (space, power, cooling, cable paths), Muon Beamline, Tracker, Calorimeter, and CRV (monitoring, control/timing, data), Accelerator (monitoring, timing), Solenoids (monitoring), and site networking.
- Internal interfaces between servers, timing system and general-purpose networking.
- Internal and external interfaces identified and described in DAQ Interface document (docdb #1520).
- Participation in Electronics and Detector integration meetings.
- Participation in Software and Simulations meetings.

Interfaces are understood and under control

TDAQ Risks

- 6 TDAQ risks in Risk Register
  - 3 Threats
    - 0 High
    - 3 Moderate
  - 3 Opportunities
- Detailed mitigation plans for all risks, documented in risk forms on docdb and linked from Risk Register (docdb 4320)

Risks are understood and incorporated into Project Planning

Environmental, Safety, & Health

- ESH is integrated into all phases of the Project
  - Design, Construction, Installation
- ESH requirements are clearly defined within the Project
  - FESHM, FRCM
- TDAQ hazards & mitigations are captured in the Project HAR and are standard:
  - High voltage (208 VAC, no exposed connections)
  - Electronic racks
  - Class 1 lasers (eye safe)
- Design & installation review process includes an ESH component
- Utilize Fermilab's work planning requirements & processes
  - Hazard analysis

Major TDAQ Procurements

Construction Readiness Review scheduled for August 2016

- 38 FPGA PCIe Boards ($250K)
  - Commodity hardware
  - Purchase in December 2017
  - QA/Test and Acceptance Plan in docdb 6005
  - Detailed discussion during breakout session
- 40 Servers ($200K)
  - Commodity hardware
  - Purchase in December 2018
  - QA/Test and Acceptance Plan in docdb 6005
  - Detailed discussion during breakout session

Quality

- TDAQ Quality plans included in Mu2e Quality Planning Document
  - Developed in conjunction with the QA manager
  - Available on web page (docdb 6005)

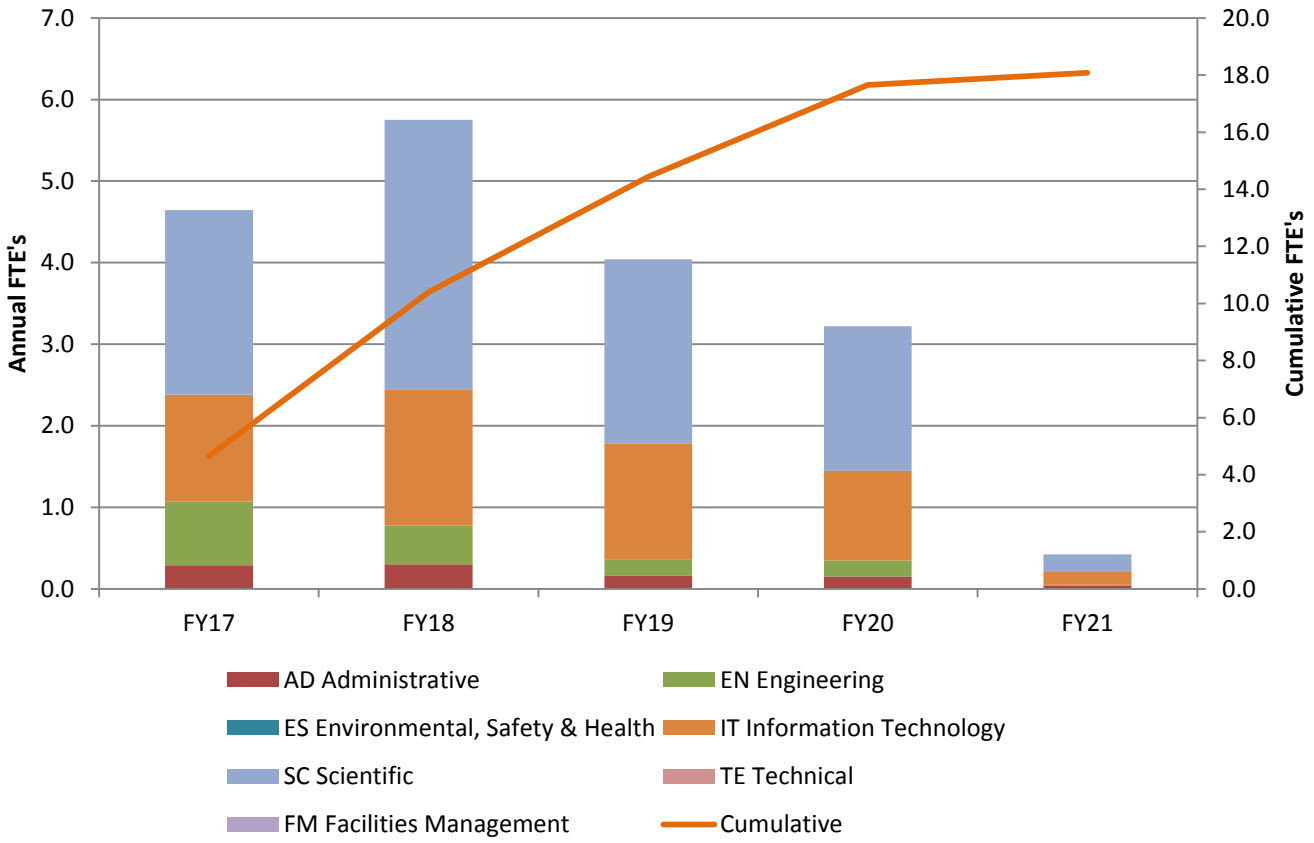
Sub-Project	Deliverable	QA or QC Step?	QA or QC Process Documentation (DocDB #)	Inspection or Acceptance Criteria/Plan	Verification	Records (DocDB# or Database Reference)
TDAQ L2	System Software/Firmware	Version Control	FNAL Engineering Manual	NA	All software/firmware development	NA
TDAQ L2	System Software/Firmware	Code Verification/Profiling	FNAL Engineering Manual	NA	All software/firmware development	NA
TDAQ L2	System Software Databases	Integrity Checks	FNAL Engineering Manual	NA	All software/firmware development	NA
System Design & Test	System	Design Reviews	Mu2e Design Review DocDB #5061	DAQ Requirements DocDB #1150	Independent review of requirements, data rate assumptions	Design Review Docs (Final Design Review DocDB #6377)
System Design & Test	Readout Controller Integration Tests (Tracker, Calorimeter, CRV)	Verify external detector interfaces	Final Design Report Chapter DocDB #6377	Trigger and DAQ Interfaces DocDB #1520	Sub-detector interface tests	Test Results
System Design & Test	Cosmic Ray Readout Test (full system test)	Verify internal and external interfaces, timing synchronization, data rates, end-to-end data transfer, Data acquisition and Data Processing software, Controls and Networking	Final Design Report Chapter DocDB #6377	NA	Full system test at maximum throughput using simulated data	Test Results & sign-off

Cost Table

(AY K$)	Budget at Completion			Forecast (Estimate at Completion)		
	M&S *	Labor	Total	Estimate Uncertainty (on remaining work)	% Contingency (on remaining work)	Estimate at Completion
475.09 TDAQ	876	4,250	5,126	714	28%	5,218
475.09.01 TDAQ Project Management	3	1,219	1,222	90	22%	1,230
475.09.02 TDAQ System Design and Test		368	368	26	35%	368
475.09.03 Data Acquisition	401	1,622	2,023	318	30%	2,089
475.09.04 Data Processing	317	557	874	160	27%	866
475.09.05 Controls and Networking	154	485	639	120	30%	664
Grand Total	876	4,250	5,126	714	28%	5,218

- Bottoms up ETC completed in March is $200k more than base cost at CD-2.
- BOEs posted on web page

Labor Resources

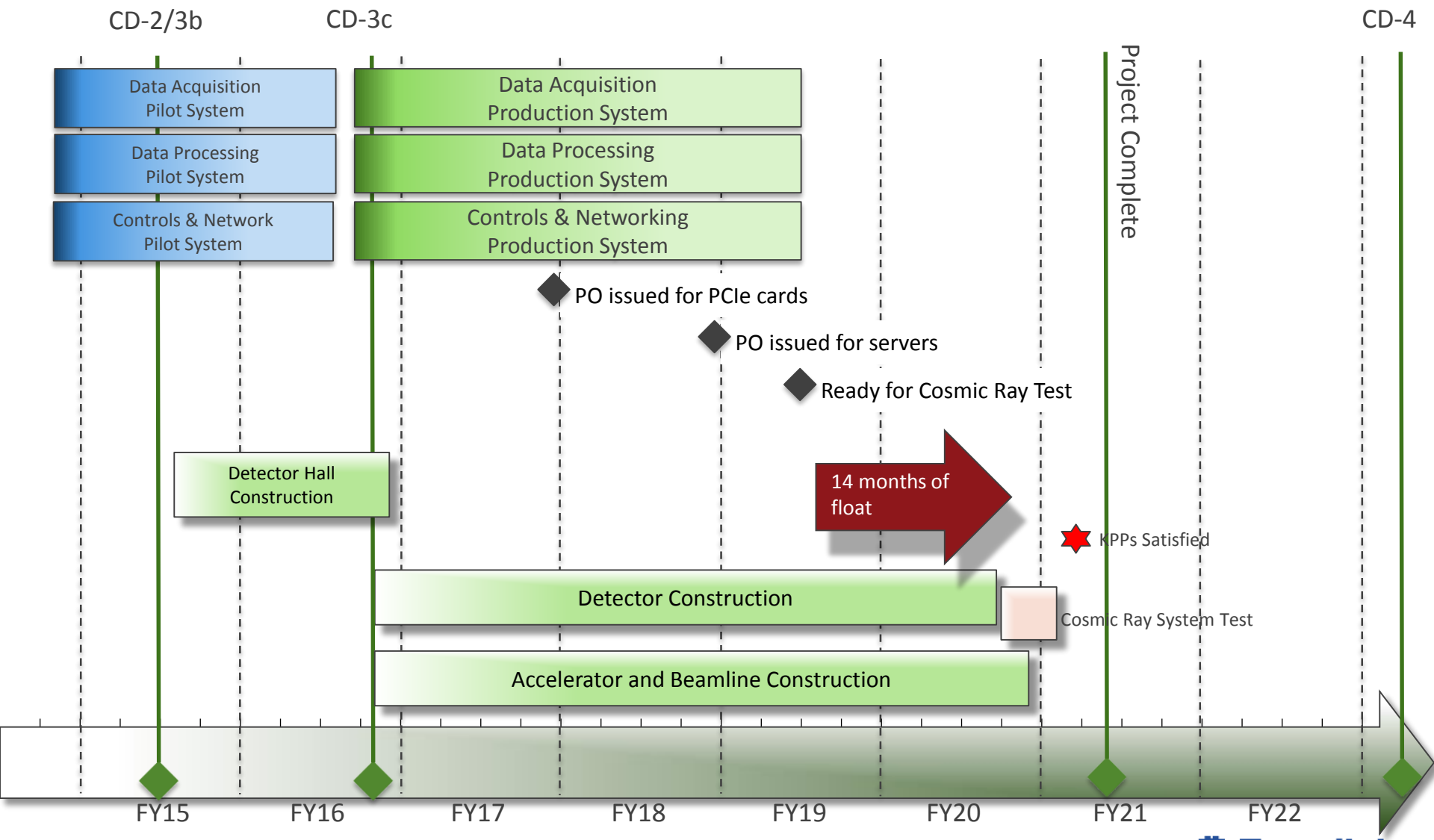


- Agreements in place with Fermilab for FY16.
- Confident that resources in the out years will be available.

Major TDAQ Milestones

T5 - PO issued for Controls & Networking Production Components	12/26/2017
T5 - PO issued for Data Acquisition Production Components	12/26/2017
T5 - Production System Data Cabling, Equipment racks, Networking and Controls Installed	6/19/2018
T5 - PO issued for Data Processing Production System Components	12/7/2018
T5 - Production DAQ Servers Installed	2/12/2019
T5 - Ready for Cosmic Ray Test	6/18/2019
T5 - Cosmic Ray System Test Complete	11/9/2020

TDAQ Schedule



Summary

- TDAQ design is 90% complete. The risks associated with the remaining design are understood and small. Clear path to a final design.
  - Recommendations from design review addressed
  - Interfaces, risks, ES&H issues identified and under control
  - QA/QC plans in place
  - Procurement plans in place
- TDAQ cost and schedule remain consistent with the baseline schedule approved in March 2015.
- Construction Readiness Review scheduled for August 2016
- TDAQ is ready for CD-3 approval