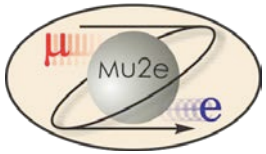
Fermilab

Mu2e CD-2 Review



Mark Bowden
TDAQ L2 Manager
10/21/2014

TDAQ Team

- Mark Bowden – L2 Manager, L3 Manager (System Design & Test)
  - 31 years
- Kurt Biery – L3 Manager (Data Acquisition), Department Head - Scientific Computing Division, Real-time Systems Engineering
  - 16 years
- Ryan Rivera – L3 Manager (Data Processing, Controls & Networking), Group Leader - Real-time Systems Engineering, Detector Electronics
  - 11 years

Greg Deuerling, Rick Kwarciany, Ron Rechenmacher, Mike Wang

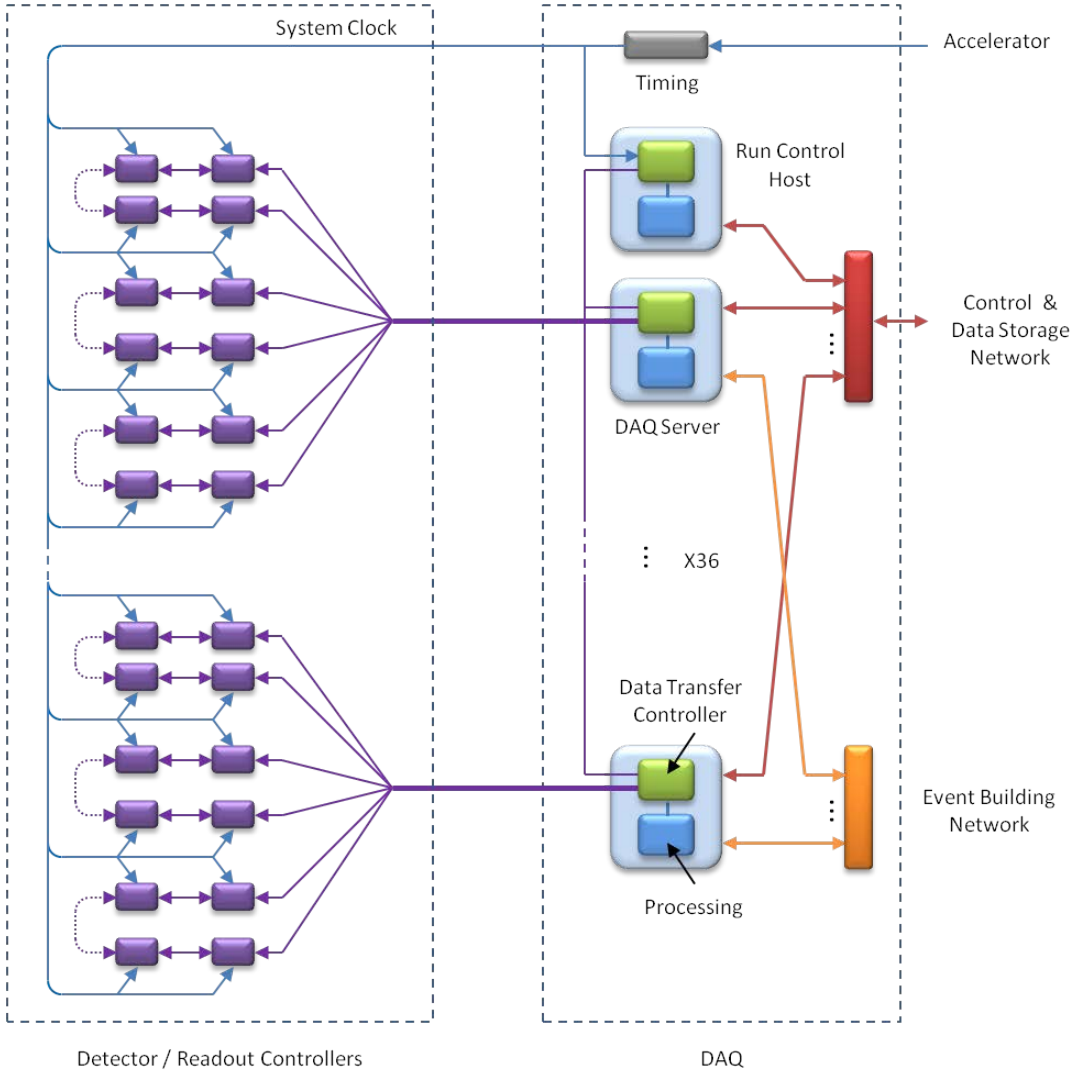
Requirements

- Requirements for the DAQ are described in mu2e-docdb 1150.
- Collect and assemble data from the Tracker (~13 GBytes/sec) and Calorimeter (~8 GBytes/sec) for online analysis.
- Provide online filtering to reduce data Tracker & Calorimeter data volume by ≥ 99%.
- Combine with data from CRV, Extinction and Target Monitors for transfer to offline storage.

Requirements

- Provide global timing synchronization
- Provide fast and slow control networks
- Provide connections to offline storage and site networking
- Provide control room/operator interfaces

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

Design

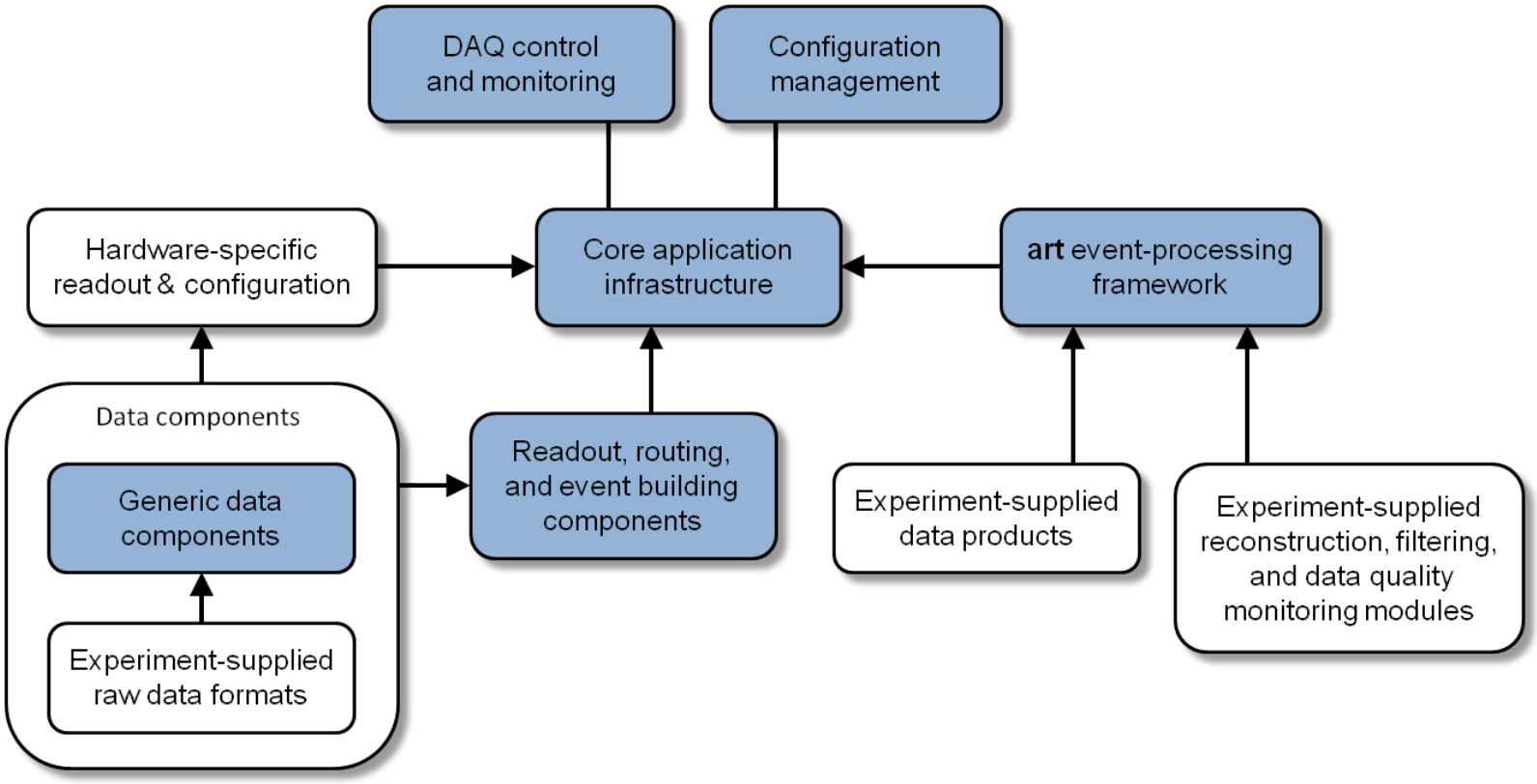
Commercial (off-the-shelf) hardware

- 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
  - 1 GByte/sec readout bandwidth
- Event Building network
  - 48 port 10G Ethernet switch

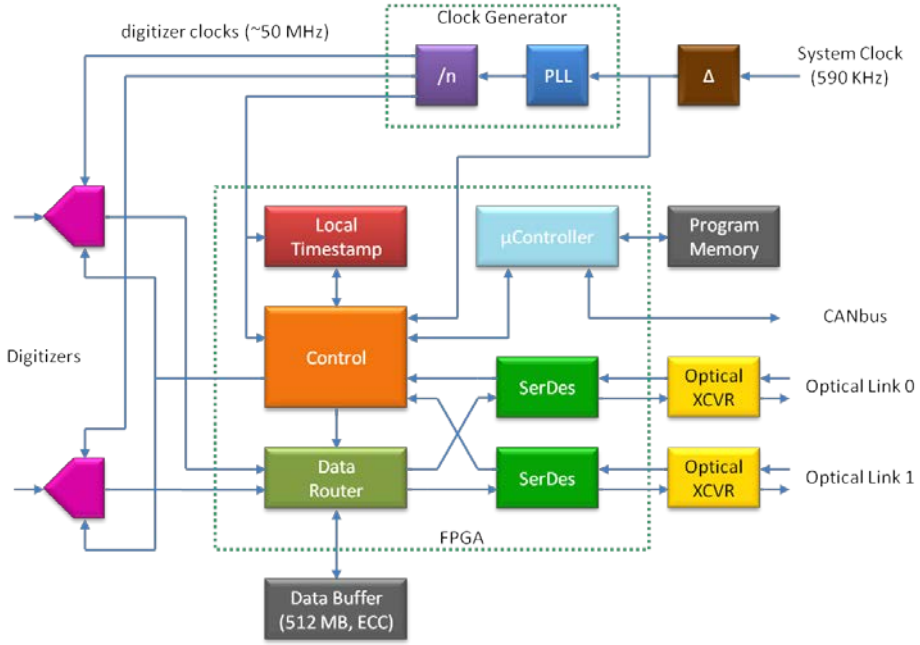
Design

Software based on *art* and *artdaq*

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

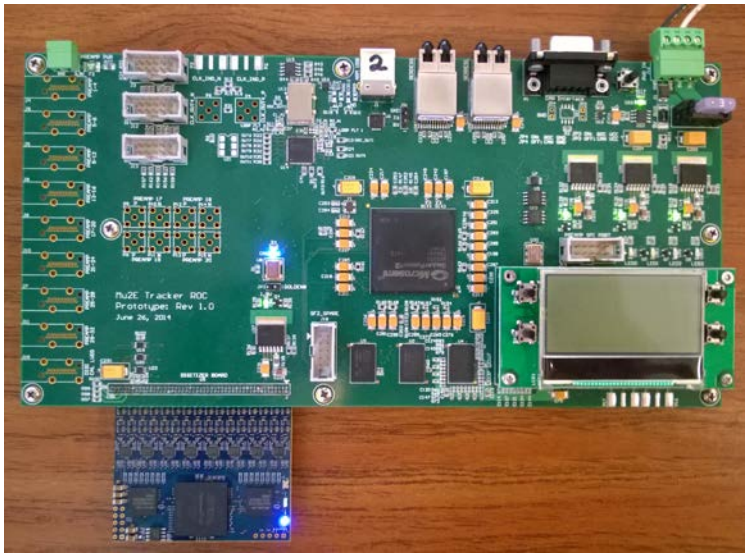


Design



Detector Readout Controllers

- interface firmware & protocols
- prototype development



Design

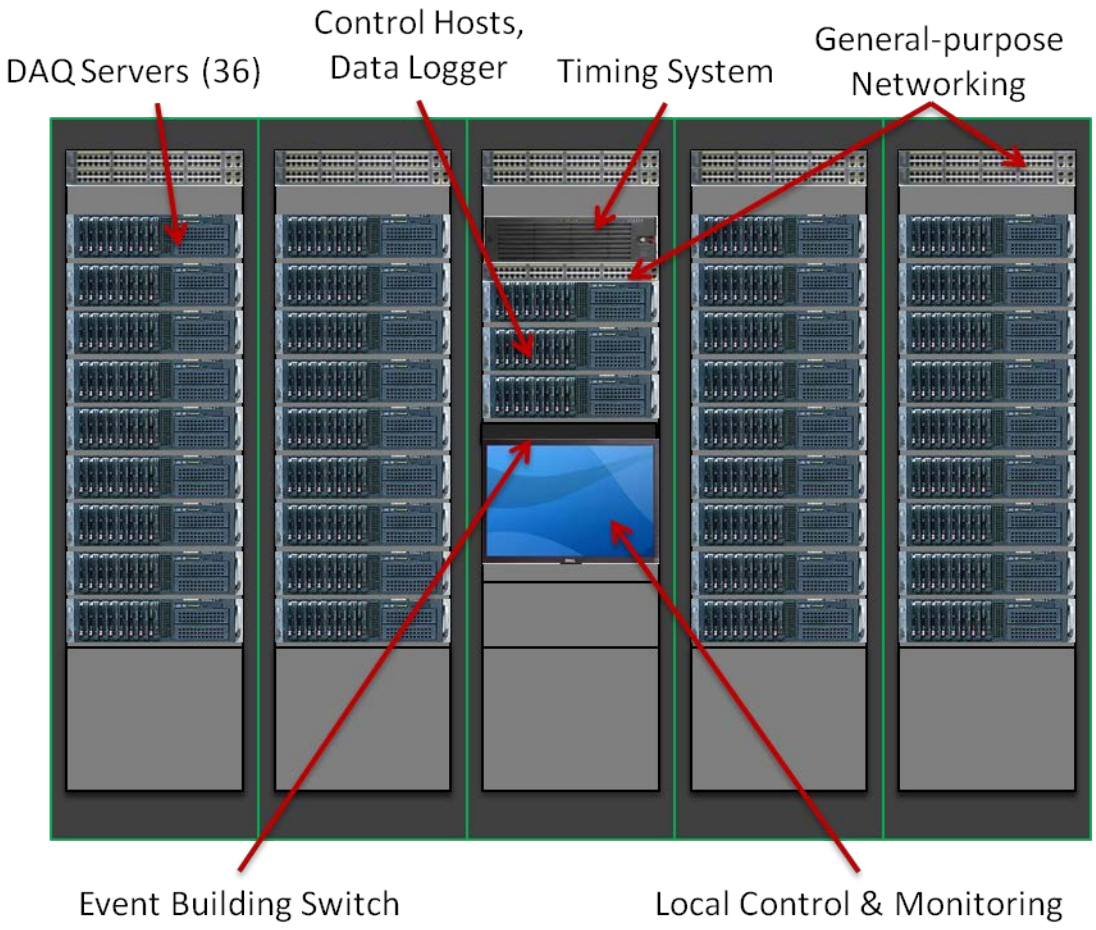
Several algorithmic and compiler optimizations were applied to the reference Tracking filter to achieve a speedup of almost 30X.

Optimization stage for MakeStereoHits	Compiler	Execution Time (ms)	
		Xeon (speedup)	Xeon Phi (speedup)
Reference	gcc 4.4.7	132	-
Modified algorithm	gcc 4.4.7	6.67 (19.8x)	-
Modified algorithm	icc 14.0.1	2.04 (3.33x)	-
Additional optimizations	icc 14.0.1	1.88 (1.08x)	30.4

Optimization stage for FlagBkgHits	Compiler	Execution Time (ms)	
		Xeon (speedup)	Xeon Phi (speedup)
Reference	gcc 4.4.7	14.2	-
Reference	icc 14.0.1	8.03 (1.77x)	123
Optimizations (mem align/layout)	icc 14.0.1	5.01 (1.60x)	37.7 (3.26x)
Optimizations (single precision)	icc 14.0.1	3.37 (1.49x)	24 (1.57x)

Note : Speedup factors in parentheses are relative to previous stage

Design


DAQ Servers (36)
Control Hosts,
Data Logger
Timing System
General-purpose
Networking
Event Building Switch
Local Control & Monitoring

Design

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

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

Integration and Interfaces

- DAQ has external interfaces to the Detectors (control/timing, data), Accelerator (timing), other subsystems (slow controls), 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.
- Formal sign-off between owners of all external interfaces as part of final design requirements.
- Interfaces understood and under control.

Improvements since CD-1

- better data rate estimates due to improved background simulations
- switch to a triggered CRV readout to accommodate higher background rates and lower thresholds (CRV data not needed for online analysis)
- rejection rate reduced from 99.8% to 99.0% to allow independent Calorimeter filters

Value Engineering since CD-1

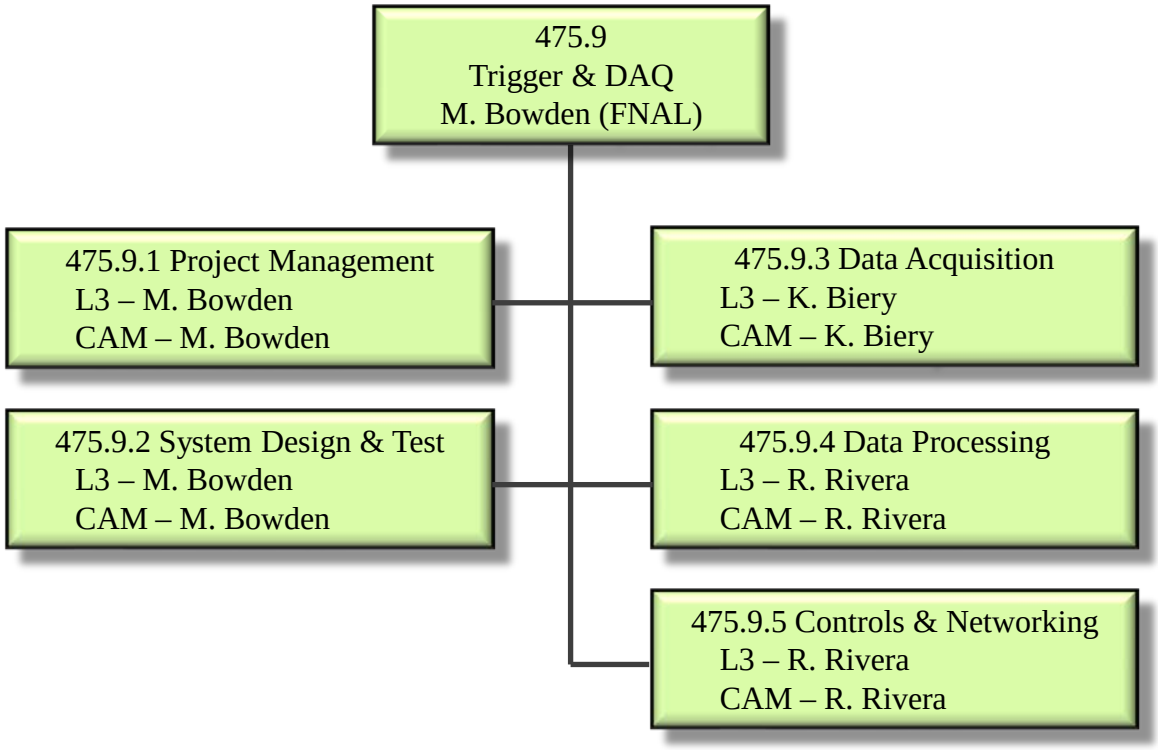
- reduction in number of DAQ servers (48 → 36) to optimize front-end configuration, use higher performance servers

Performance

- Tests have been performed on the primary DAQ interfaces - digitizer to readout controller (LVDS), readout controller to data transfer controller (optical link), and data transfer controller to DAQ server (PCIe) to verify bandwidth requirements

- Optimized version of the online Tracker filter meets processing requirement

Organizational Breakdown



Quality Assurance

- DAQ system can be tested to a high level of confidence using simulated data, prior to Cosmic Ray test
- Full DAQ system is a scaled version of the Pilot system
- In-situ testing - diagnostic features include monitoring of data link bit-error rate and optical power levels, memory and processor tests using large simulated data sets

Risks

- 7 DAQ risks in risk registry
  - All risks mitigated to the extent possible
  - 3 threats
    - 0 high
    - 3 low / medium
  - 4 opportunities
- Detailed mitigation plans for all risks, documented in risk forms on docdb and linked from Risk Register (docdb #4320)
- All risks understood and under control.
- Details in breakout session.

ES&H

- ES&H issues are minimal
  - High voltage (208 VAC, no exposed connections)
  - Class 1 lasers (eye safe)
  - no issues with radiation or magnetic field

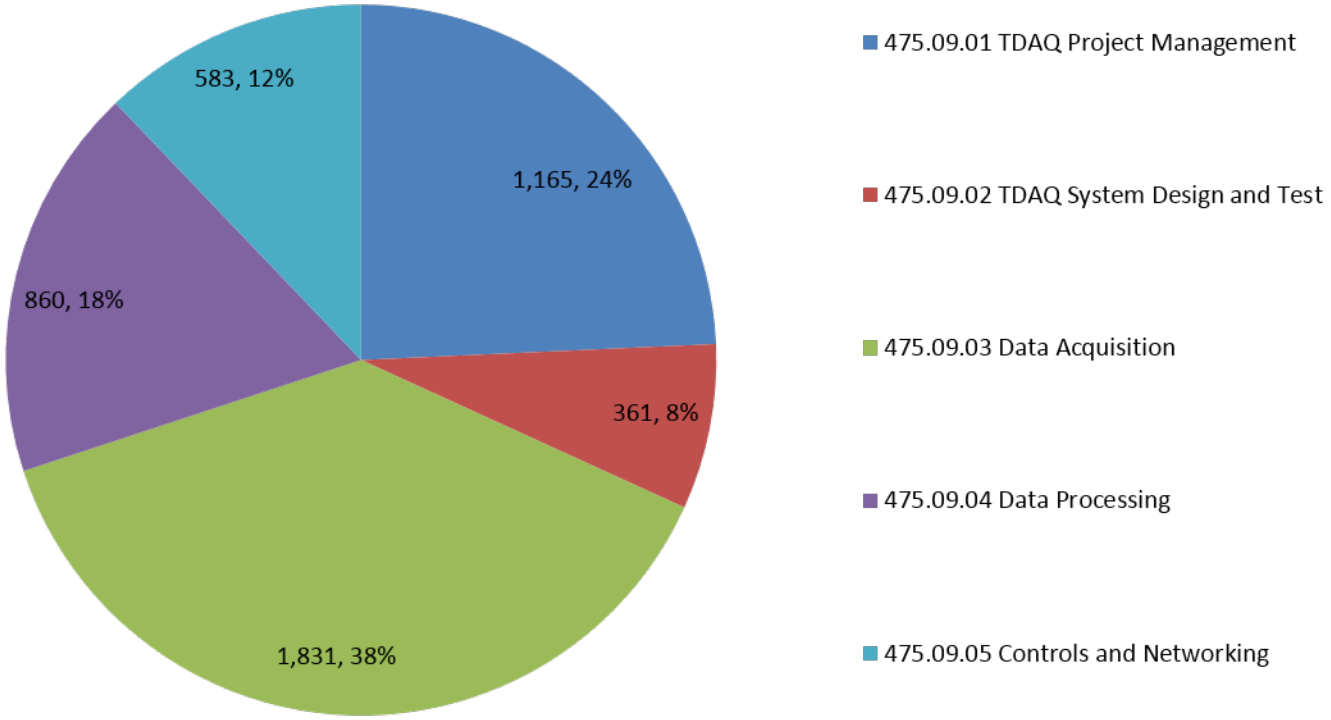
Cost Table

WBS 9 Trigger & DAQ

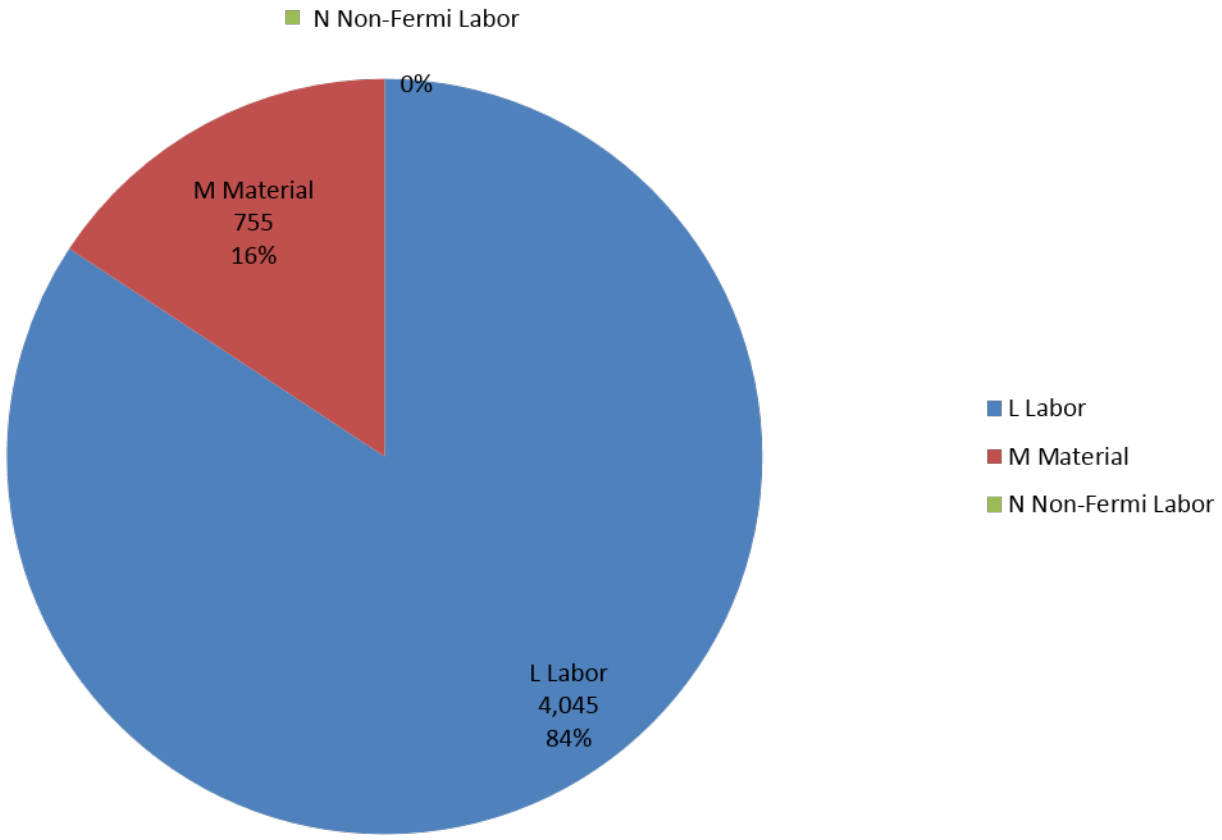
Costs are fully burdened in AY $k

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency on (on remaining budget)	Total Cost
475.09.01 TDAQ Project Management	3	1,162	1,165	118	23%	1,284
475.09.02 TDAQ System Design and Test		361	361	23	35%	385
475.09.03 Data Acquisition	317	1,513	1,831	459	37%	2,290
475.09.04 Data Processing	310	551	860	208	30%	1,068
475.09.05 Controls and Networking	125	458	583	154	34%	737
475.09.99 Risk Based Contingency				244	-	244
Grand Total	755	4,045	4,800	1,207	41%	6,007

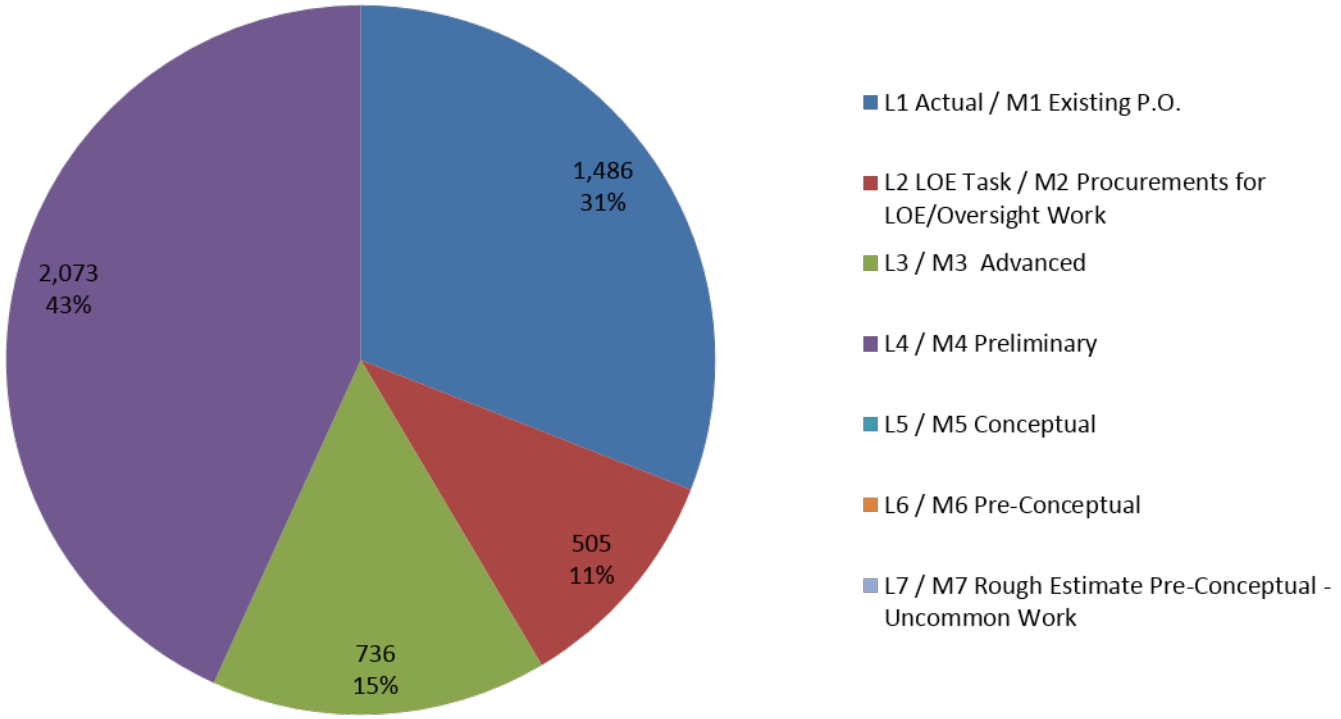
Cost Breakdown



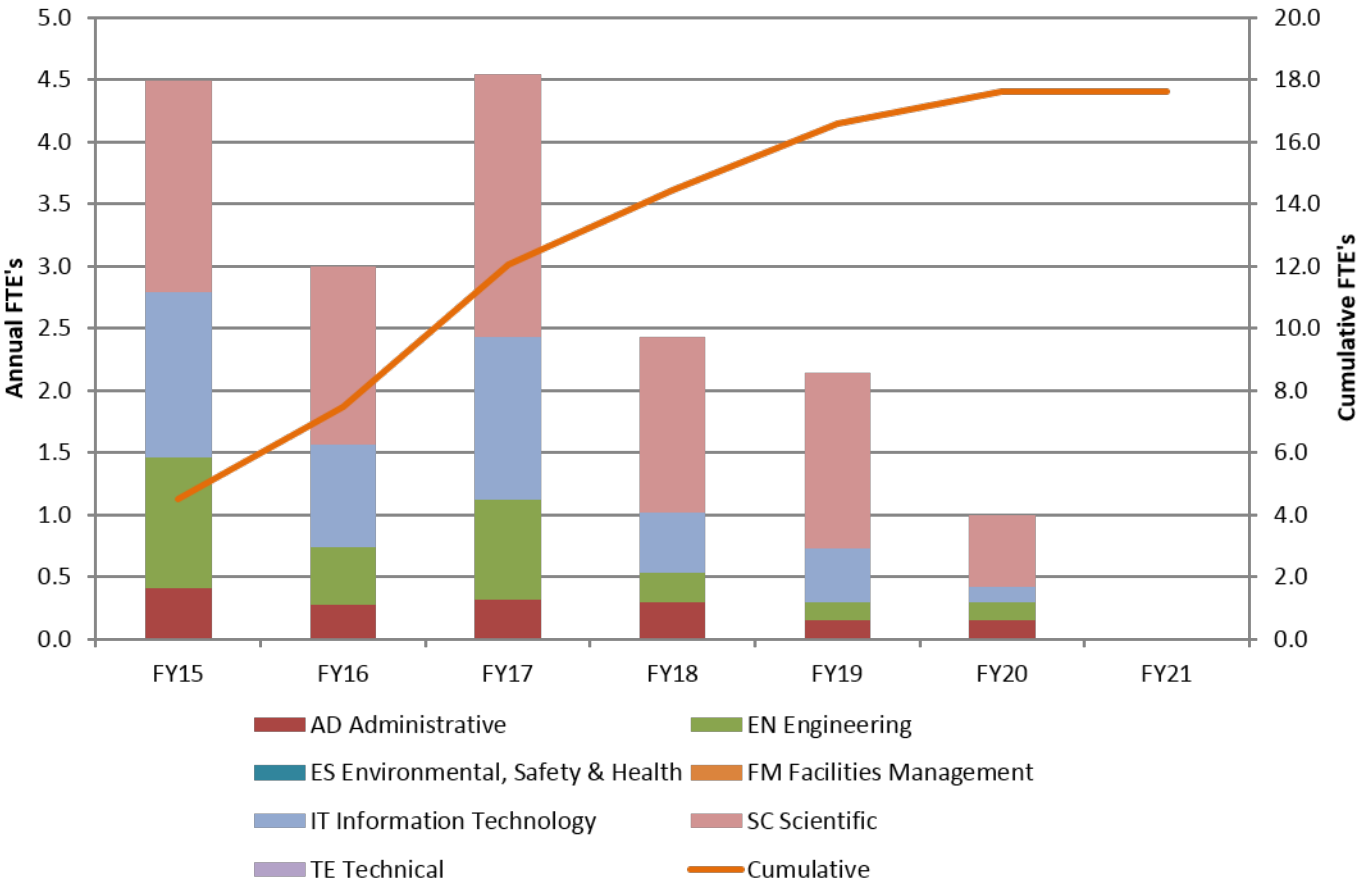
Cost Breakdown



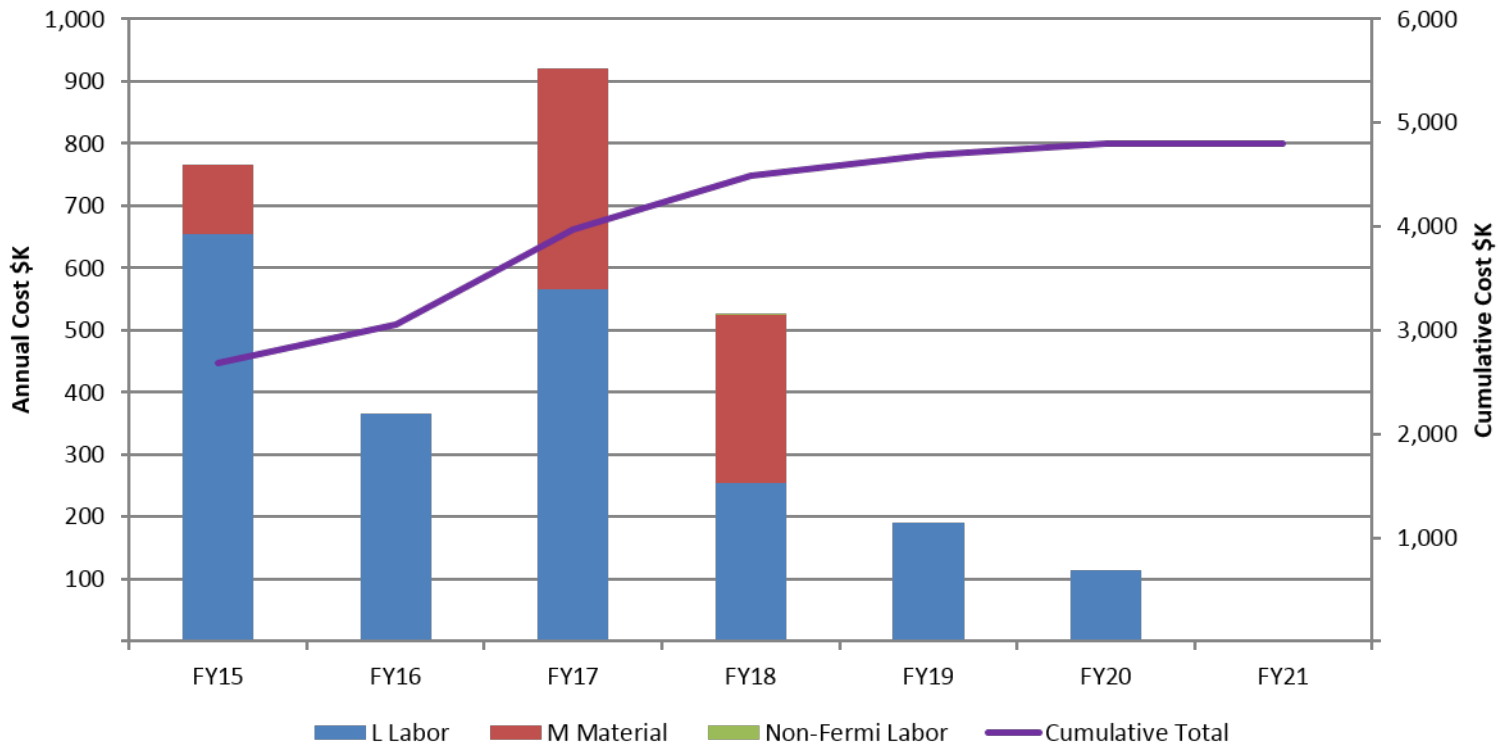
Quality of Estimate



Resources by FY



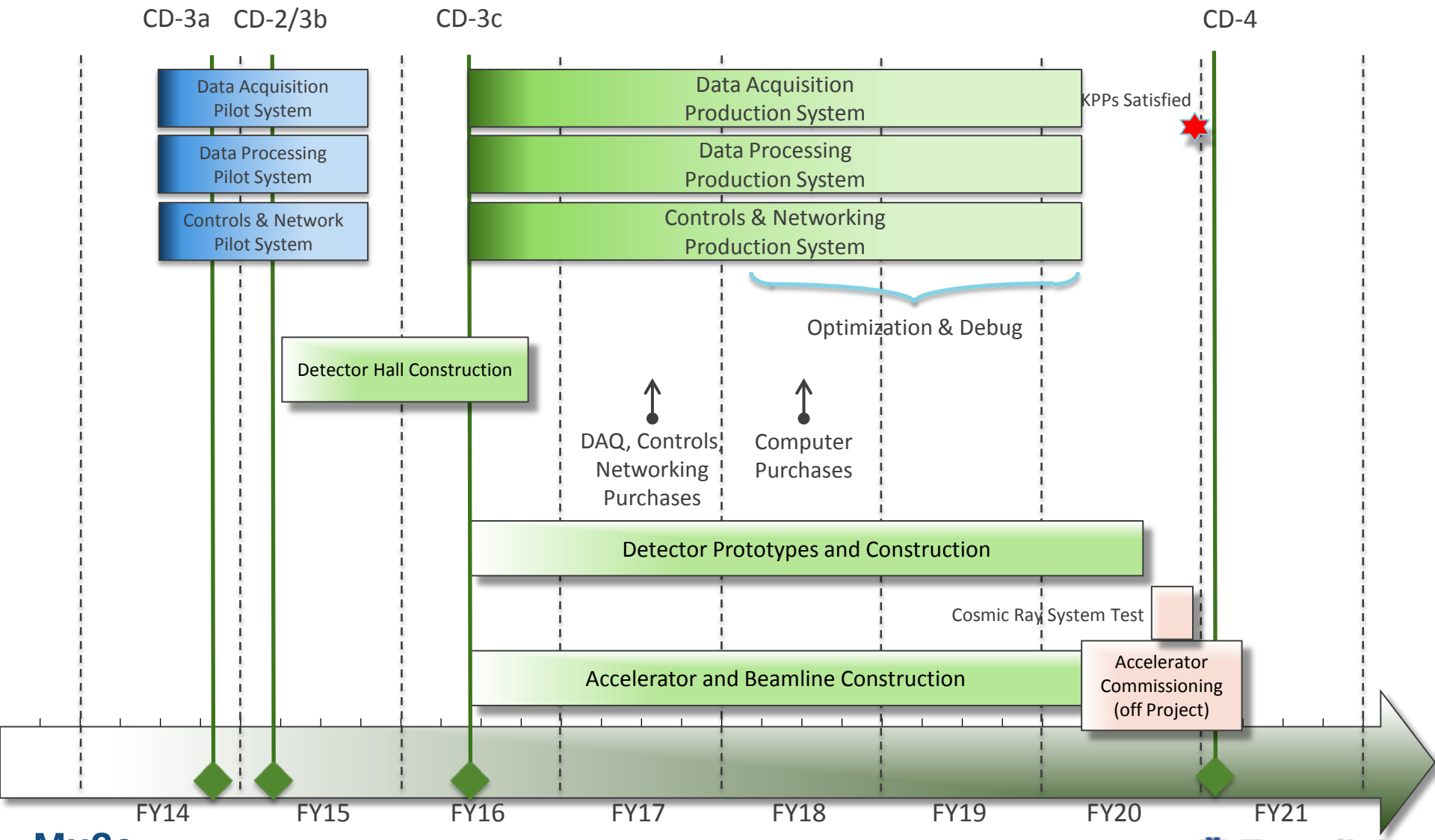
Resources by FY



Major Milestones

- Completion of Pilot System development for Data Acquisition, Data Processing, and Controls and Networking tasks (July 2015)
- Completion of Production System development for Data Acquisition, Data Processing, and Controls and Networking tasks (January 2020)
  - last two years are optimization & debug at reduced level of effort
- Cosmic Ray Test (final integration with detectors and full readout test) (June 2020)

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

Summary

- We have a design that fully satisfies the requirements
- Cost estimates for the DAQ are complete
  - 100% of the cost understood at the Preliminary Design level or higher
  - Risks are understood, mitigated to the extent possible and are under control.
- All interfaces are identified and defined
- Resource needs understood
- ES&H embedded into all aspects of the Project
- Responded to all recommendations from previous reviews
- DAQ is ready for CD-2