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**: Detector Prototypes and Construction
  - Data Acquisition Pilot System
  - Data Processing Pilot System
  - Controls & Network Pilot System

- **CD-3b**: Accelerator and Beamline Construction
  - Detector Hall Construction

- **CD-3c**: Controls & Networking Production System
  - Data Acquisition Production System
  - Data Processing Production System
  - Controls & Networking Production System

- **CD-4**: KPPs Satisfied
  - Optimization & Debug
  - Cosmic Ray System Test
  - Accelerator Commissioning (off Project)
Effort Breakdown

Resources by FY

- AD Administrative
- EN Engineering
- ES Environmental, Safety & Health
- FM Facilities Management
- IT Information Technology
- SC Scientific
- TE Technical
- Cumulative
Cost Breakdown

Resources by FY

![Bar and Line Graph showing cost breakdown by FY]

- **FY15**: $600,000 (L Labor: $500,000, M Material: $50,000, Non-Fermi Labor: $50,000, Cumulative Total: $600,000)
- **FY16**: $400,000 (L Labor: $300,000, M Material: $50,000, Non-Fermi Labor: $50,000, Cumulative Total: $1,000,000)
- **FY17**: $900,000 (L Labor: $600,000, M Material: $300,000, Non-Fermi Labor: $50,000, Cumulative Total: $1,900,000)
- **FY18**: $500,000 (L Labor: $400,000, M Material: $100,000, Non-Fermi Labor: $50,000, Cumulative Total: $2,400,000)
- **FY19**: $200,000 (L Labor: $100,000, M Material: $100,000, Non-Fermi Labor: $0, Cumulative Total: $2,600,000)
- **FY20**: $100,000 (L Labor: $70,000, M Material: $30,000, Non-Fermi Labor: $0, Cumulative Total: $2,700,000)
- **FY21**: $0 (L Labor: $0, M Material: $0, Non-Fermi Labor: $0, Cumulative Total: $2,700,000)
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

supercycle (1.33 seconds)

beam ON (492 msec)  beam OFF (836 msec)

spill (54 msec beam, 5 msec gap)

(36 msec gap)

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
- 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

Tracker
- 20 DAQ Servers
- 12 ROCs/Server

Calorimeter
- 12 DAQ Servers
- 20 ROCs/Server

CRV
- 3 DAQ Servers
- 5 ROCs/Server
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)

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

DAQ Server

Clock Fanout
System Design

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

- 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
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 – \textit{artdaq}, \textit{art}, slow controls, networking, data storage, diagnostics
- Testing – detector Readout Controller integrations tests, Cosmic Ray system test
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

Data Transfer Controller (DTC)

- Optical Interface (FMC card with 8 SFP transceivers)
- PCIe Interface
- FPGA
- Memory
Data Acquistion

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

System Clock Fanout

System Clocks to Tracker & Calorimeter ROCs

Accelerator Controls

Beam Pickup or Supercycle Start

CFO (Run Control Host)

Fast Control Links to DAQ Servers

System Clocks to CRV ROCs

2.4 MHz

590 kHz

X 8

X 8

Mu2e

Mu2e Newcomer Lunch - Ryan Rivera

8/3/2015
Data Acquisition

Software based on *art* and *artdaq*
(a common DAQ & Online Processing framework developed for Mu2e and other current/future experiments)
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).