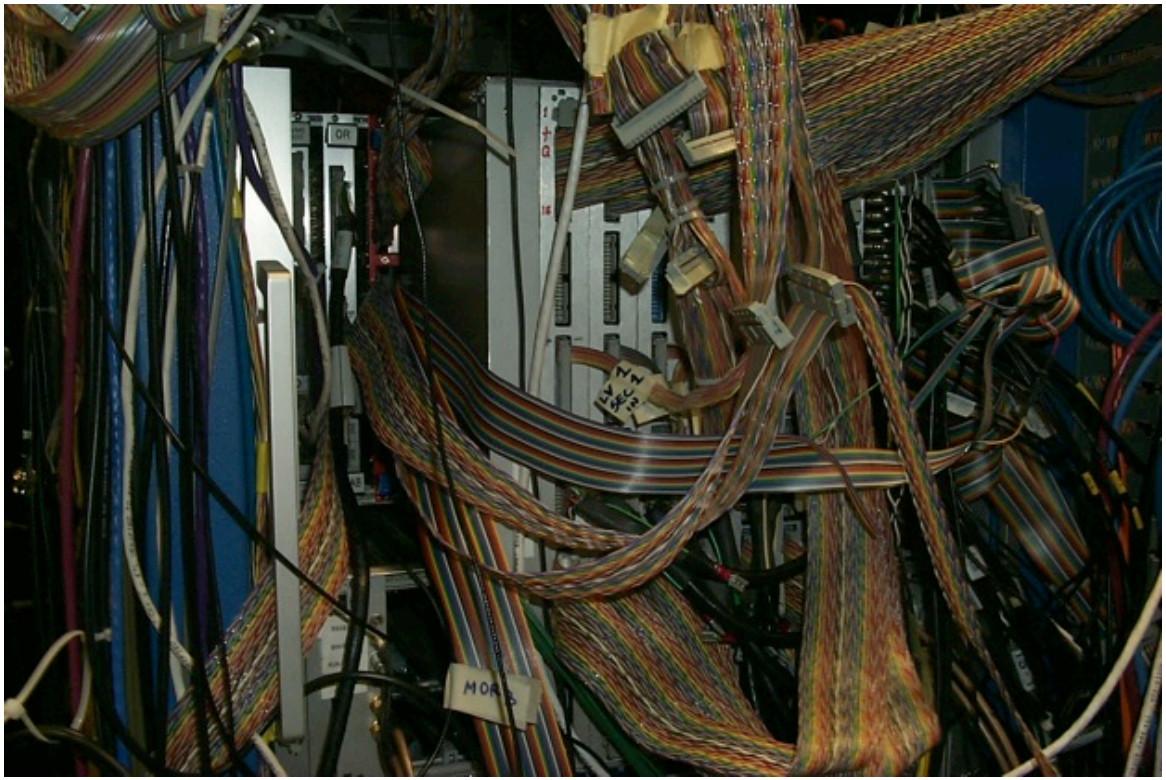
DAQ and Common Online tools



Graham Heyes - DAQ support group

Introduction

- Online organization - who is responsible for what.
- CODA and the 6 GeV program.
- 12 GeV online requirements.
- CODA and the 12 GeV program.
- Other online software and services.
- Status
- Deployment of online systems for the 12 GeV program.
- Summary.

Organization and relationships - DAQ support group

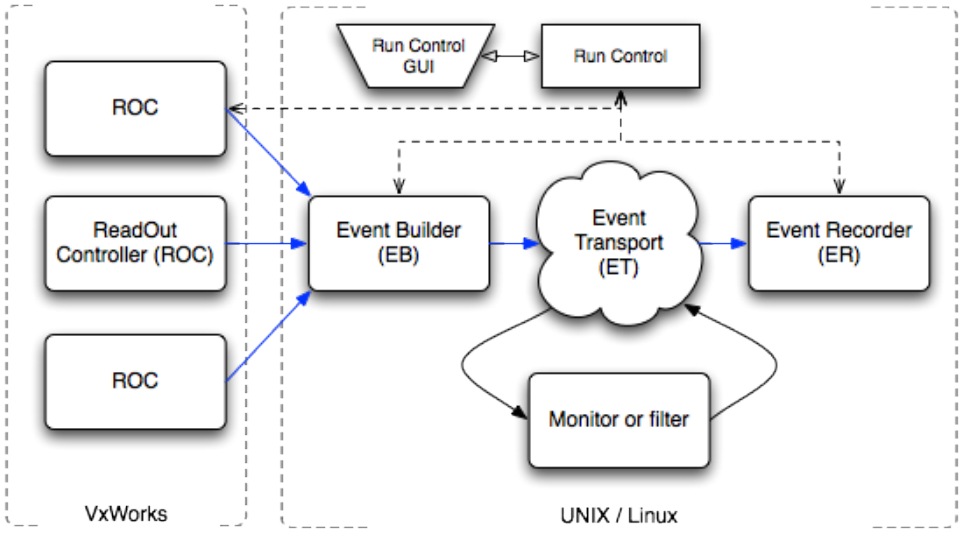
- The DAQ support group is a team of 7 physicists in NP division dedicated to online operations and R&D.
- It is a support resource for online R&D, system implementation and operation providing:
  - Generic custom software and hardware for high speed data acquisition.
  - Experiment specific custom software and hardware.
  - Evaluate and recommend commercial hardware and software.
  - On-call troubleshooting and additional manpower for installation.
- Staffing is sized for 12 GeV development, implementation and operation.
  - Manager - me
  - Six other physicists with two experts in each of the following fields:
    - Electronics - trigger and readout hardware at component and board level.
    - Front end systems - trigger and readout at crate and rack level.
    - Back end software - Data transport, event building, communication, experiment control and monitoring software at system level.
  - Total of over 75 years of JLab experience and a proven record.
- R&D lab on 1st floor of F-wing, simulation and test cluster in main data center.

Organization and relationships - hall online groups

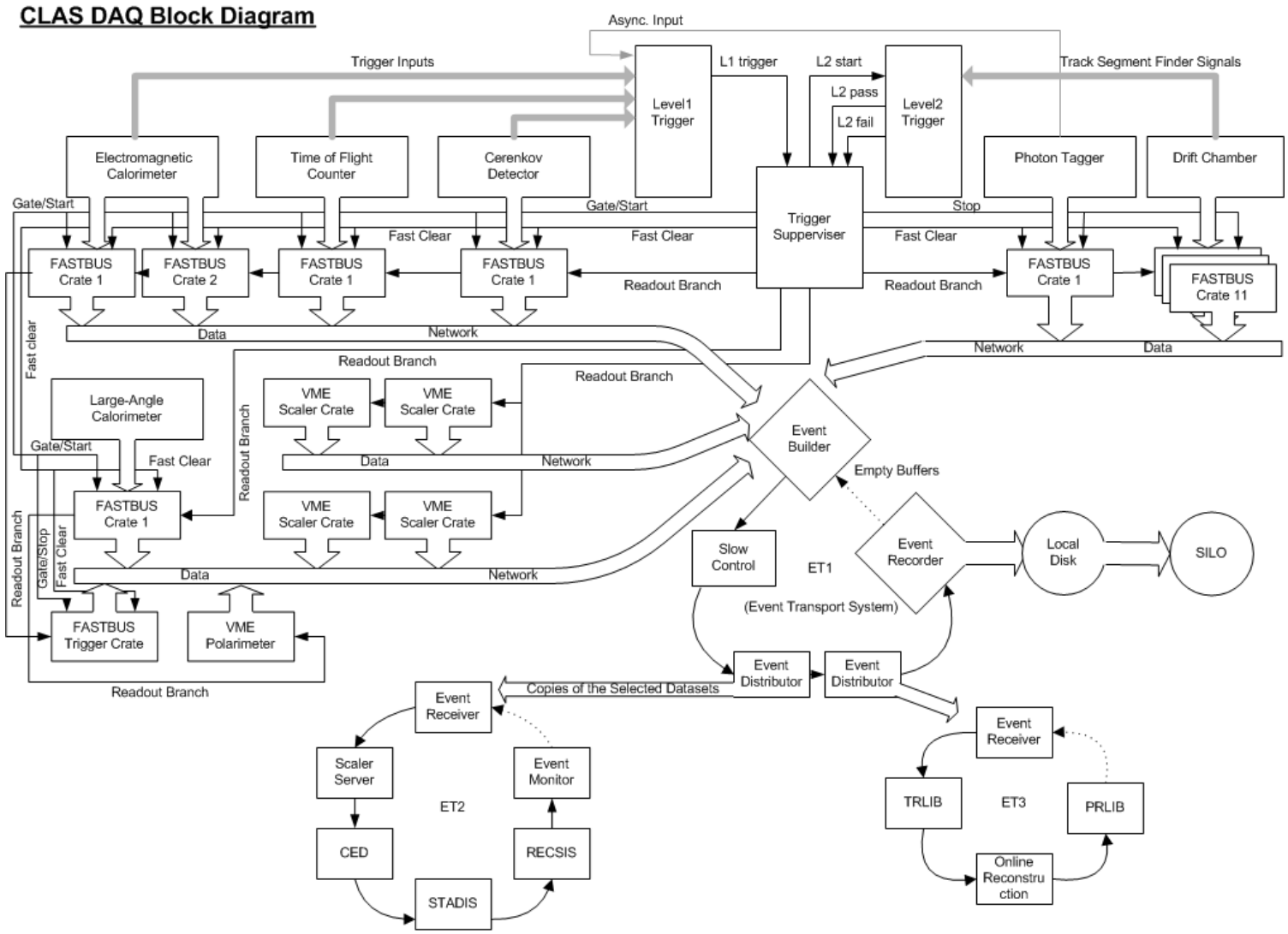
- Hall online groups
  - Responsible for the implementation and day-to-day operation of the online system in each hall. They are the experts in their hall's online.
  - Weekly to monthly online meetings for each hall. Online reports at collaboration meetings, other meetings and reviews as required.
  - Three 6 GeV halls have existing mature online groups and mature DAQ systems.
  - Although the Hall-D online group is new it is lead by a former DAQ group member and has existed for a few years now.
  - The hall-online groups are appropriately sized for operation. Additional support from the DAQ group and collaborators will provide manpower for construction.
- Fast electronics group - a physics division support group.
  - Design and fabricate custom electronics for experiments.
- Accelerator control group
  - A separate group are responsible for the software that controls the accelerator.
  - The accelerator is run using EPICS, the halls use EPICS for slow control.
  - We collaborate with the accelerator group to develop an implement slow control and other online related systems (see later in this talk).

CODA and the 6 GeV program

- CEBAF Online Data Acquisition (CODA)
- CODA is a suite of software and hardware components with which data acquisition systems can be implemented.
  - CODA 1 was used in early test beds and first beam from CEBAF.
  - CODA 2 was designed for the 6 GeV program and has been very successful.
  - Key features are that it is modular and distributed by design with data transport over commercial network hardware.
  - Readout is one trigger per event pipeline.
- All of the major experiments and many of the detector testbeds at JLab use CODA.
  - CODA is familiar to the community.
  - Allows rapid deployment of new detectors.
  - Reduces R&D costs by reuse of software and hardware components.



CODA and the 6 GeV program



12 GeV Online Requirements

- A - Various short experiments with varying rates. Highest, 100 kByte events at 1 kHz = 100 MByte/s. This high rate running is two 60 day periods.
  - An early experiment A1n plans to run at 20 kHz with smaller 2-3 kByte events.
- B - 10 kHz and 10 kByte events = 100 MByte/s.
- C - Various rates but highest is 10 kHz and 4 kByte events = 40 MByte/s
- D - The detector and hardware trigger are capable of producing rates one to two orders of magnitude larger than those seen in 6 GeV hall-B running.
  - A Level 3 software trigger is planned but is outside the initial 12 GeV scope.
  - Data spread over 50+ front end systems.
  - Design for event/data rate of 200 kHz and 15 kByte events = 3 GByte/s.
  - Rate to storage after factor of 10 Level 3 trigger reduction = 300 MByte/s.
  - Since there will be no Level 3 trigger the initial running will be at 10% of design luminosity but the same storage rate of 300 MByte/s.
- Bottom line - design for hall-D and the others should be fine.

CODA and the 12 GeV program

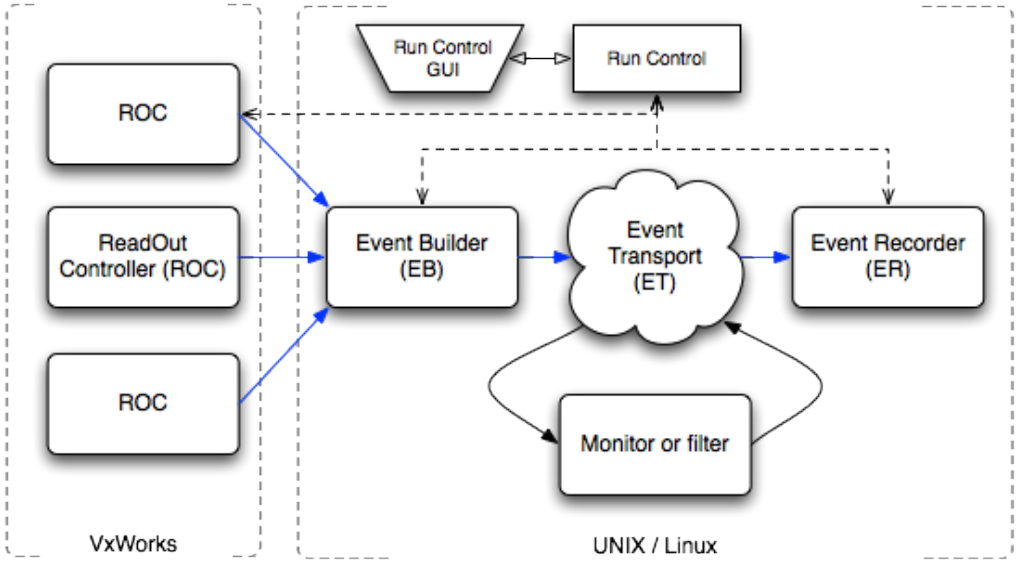
- DAQ system anatomy will be similar in each hall and based on CODA version 3, written to meet the 12 GeV requirements.
- The following bullets show how specific requirements are met.
- To handle high trigger rates:
  - Decouple hardware trigger and software trigger rates by reading blocks of events in a pipeline. Instead of one software trigger per event one trigger per block.
  - Pipelined ADC, TDC and other digitizing electronics buffer data from multiple events on-board.
  - New electronics, Trigger Supervisor (TS), Trigger Distribution (TD) and Trigger Interface (TI).
    - Manage and distribute the trigger and allow scaling to larger numbers of front end crates than CODA 2 could handle.
    - Manage the pipeline. For example, set the block size that is the ratio between hardware and software trigger rate.
  - Data format software (EVIO) updated to support pipeline readout which generates more complex trigger information.
  - Decoupling the software and hardware trigger removes the need for a Real Time OS.
    - Front-end software (ROC) runs under Linux on embedded Intel hardware.

CODA and the 12 GeV program

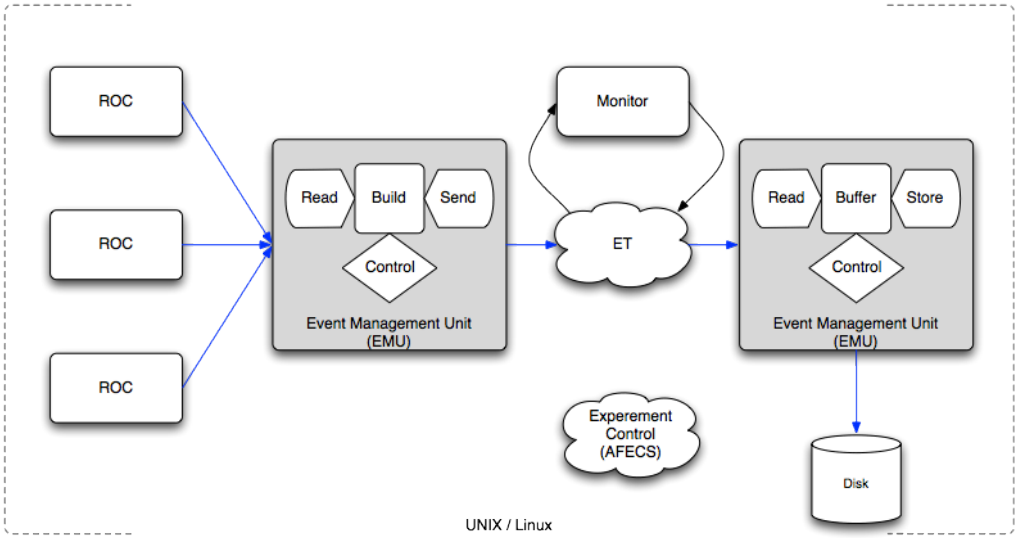
- Hall-D and CLAS12 require complex systems of 50+ crates of electronics:
  - Agent based (AFECS) experiment control system. Designed to control and monitor arbitrarily large heterogeneous systems of devices.
    - Robust, fault tolerant, platform independent system written in Java.
    - The agent model divides complex problems into a hierarchy of simpler tasks.
  - Publish and subscribe inter-process messaging system cMsg.
- High data rates and online filters
  - Distributed network based event transport (ET) to move data efficiently in a complex webs of software components.
  - ET contains software hooks for event selection algorithms and is used in the 6 GeV program for online monitoring, event selection and event display.
  - Distributed event building.
    - At this time no single (affordable) computer has the bandwidth to handle the entire data stream.
    - The Event Management Unit (EMU) is a module of CODA 3. It can be built into tiered networks to implement arbitrarily complex distributed event processing systems. For example a distributed parallel event builder.
  - The combination of AFECS, ET and EMU allows for the easy implementation of a level 3 trigger farm or an online data monitoring or calibration system.

CODA v3 and the 12 GeV program - example

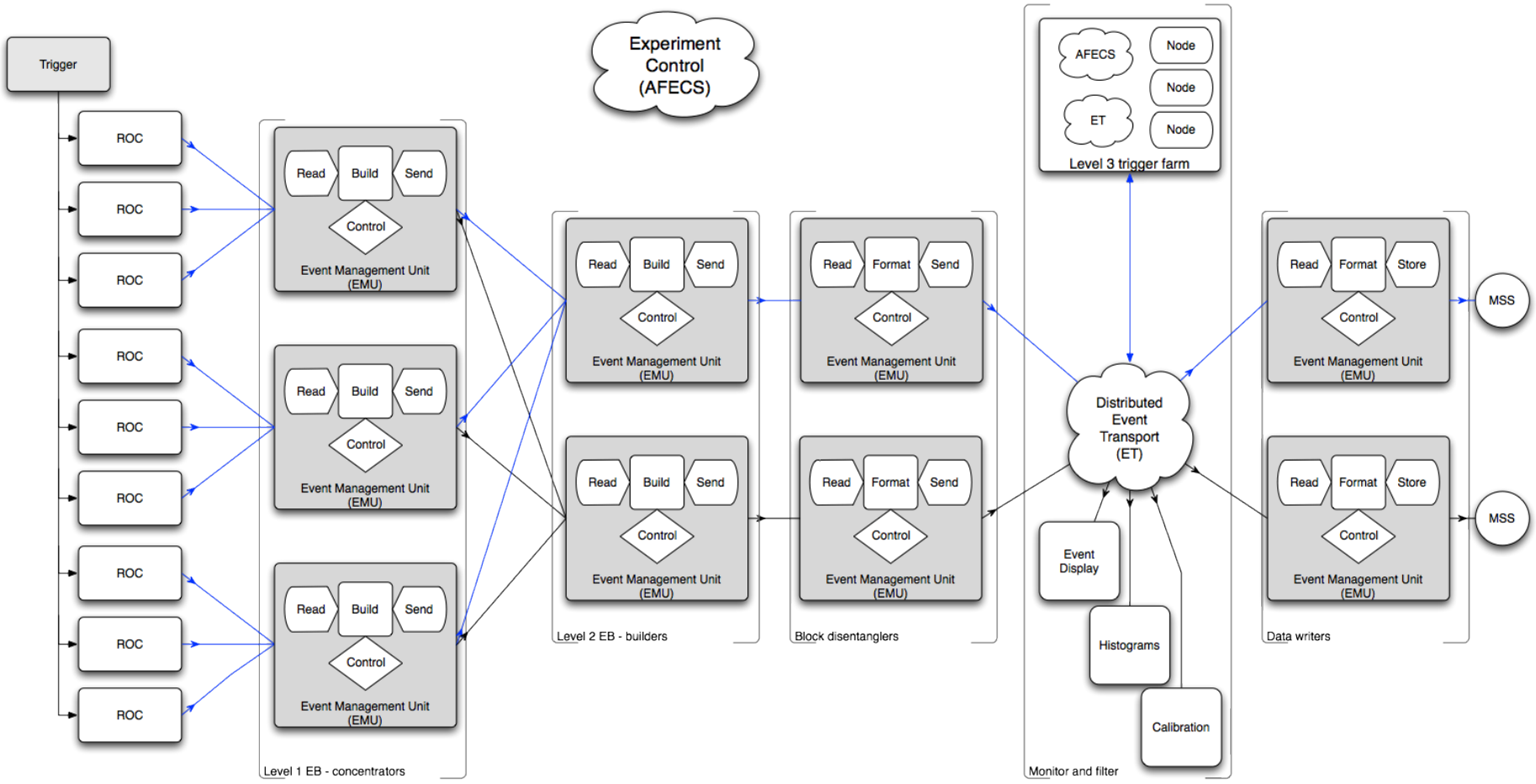
CODA v2.x



CODA v3.x



CODA v3 and the 12 GeV program - example



Other online services

- System administration support is provided by IT division (IT-CNI) for all online systems except embedded controllers.
- Network bandwidth from the halls to the data center must support at least 600 MB/s. Of this 300 is from hall-D and 300 from existing counting house. This will be implemented and operated by IT-CNI.
- Disk buffer storage for one or two days running 25 - 50 TB, owned by each hall administered by IT scientific computing (IT-SCI).
- Data is archived in the IBM tape library in the data center operated by IT-SCI. Tapes are in the hall budget. The large disk buffer reduces maintenance cost since IBM has up to two days to fix the library before data taking is impacted.
- Databases are required for calibration and other online systems. These are of comparable scope, and in some cases identical to the databases already managed for the existing 6 GeV program scaled up by the addition of hall-D. Databases will be operated by IT-MIS with system administration from IT-CNI.

Other online services

- Slow Control of magnets, beam-line components, detectors, targets and other hardware:
  - EPICS is used to control the accelerator. It was decided almost 20 years ago to use EPICS for slow in the halls.
  - The hall online groups develop the slow control systems with help from Accelerator control group (ACG). Once deployed the ACG provides operation support.
- CODA experiment control, AFECS, interfaces to EPICS and can make decisions based on slow control data. This feature was not available in the 6 GeV program.
- Some third party software will exist for commercial systems or systems developed by collaborating institutes. This will be layered under AFECS or EPICS.
- The collaborating physicists have a requirement for remote access to control systems and data. IT-CNI and ACG are working on a secure fire-walling of online systems that will still be compatible with this requirement.
- Physics is collaborating with ACG to develop a new online logbook common to all four halls. We are also looking at an ACG solution to the problem of keeping track of all of the components of a large online system. Hall-B already had a working system developed for 6 GeV the hall-D online group have collaborated with hall-B to update this system for use in both halls.

Current status

- Linux readout code and module drivers for most DAQ hardware modules have been written and tested in the 6 GeV program.
- Enough electronics has already been delivered for testing of the trigger electronics and pipeline to start.
- AFECS based experiment control has been used in halls A and C.
- Pipeline electronics and CODA 3 drivers have been used for production data taking in hall-B.
- Event format (EVIO) is stabilizing with feedback from all four halls (see offline talks).
  - Libraries to read and write EVIO format data have been implemented in C, C++ and Java.
    - Working with hall-D to generate files of simulated data that can be fed through the DAQ components. Hopefully what comes out = what goes in!
- Data transport (ET) and messaging system (cMSg) are stable and have been used in production data taking in the 6 GeV program

Current Status - continued

- The EMU event management system has been written and a prototype event builder implemented. Currently working on the interface with the front end and correct event formatting.
  - Expect to test a large hall-D scale system using simulated data sources in next six months using the DAQ group cluster.
  - Stress test using real crates as soon as we have enough hardware.
- A "proof of concept" level 3 trigger design based on AFECS, EMU and ET has been made.
  - Expect a prototype level 3 trigger on the DAQ group simulation farm in the next 12 months.
- Event *disentangler* to convert blocks of events into events. It is at design stage with a prototype in next 6 months.
- Experiment Control
  - Main framework is complete and in use in 6 GeV program.
  - Same underlying technology used in CLARA offline - in use by hall-B
  - Working on cMsg based generic user interface software to allow rapid development of GUIs for systems using cMsg.

Deployment of online systems for the 12 GeV program

- Much of the underlying software and hardware frameworks and technologies have been implemented it time to be tested in the 6 GeV program.
- We have plans for testbeds and technology tests over the next two years either on the DAQ group's simulation cluster or using real hardware as it is procured and technology choices are locked down.
- The most important of these are:
  - Full crate - full rate tests to look for bottlenecks in a single crate.
  - Tests of full scale DAQ systems to ensure that the architectures scale as expected. This is particularly important for the event builder.
- Final hardware choices will also determine the DAQ architecture for hall-D. Currently a single machine does not have the bandwidth to handle the full data stream. This mandates parallel streams now but may not be true in 2016.
- The distribution of data in the detector is based on current simulations. As the detectors and models are better understood this may change and require redistribution of the electronics to remove bottlenecks.
- As hardware and software is tested and released to the halls it will first be used for detector tests. This will provide us with valuable feedback.
- Once the detectors and accelerator are completed there will be a commissioning period with a further chance to refine the DAQ

Summary

- I think that we are in good shape!
  - Mature online groups in each hall and the new online inherits much from the old
  - Much tested in 6 GeV running.
  - A series of tests of technology, scaling and throughput test end with detector and DAQ commissioning with beam.
  - Infrastructure (power, cooling and network) to support the online hardware is already in place in three existing halls and part of 12 GeV scope for hall D.
  - Staffing and funding is adequate to meet the milestones between now and turn on.
    - We keep an eye on changing schedules.
    - We are careful to not over subscribe key people.
- A lot of hard work has been done and still needs to be done but we can see our goal and it is achievable!