Photon Systems Controls and Data-Acquisition

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Particle Physics and Astrophysics Division
Photon Control and Data Systems (PCDS) Group

12 November, 2008

Outline

- LCLS versus LUSI Responsibilities
- PPS/HPS
- XTOD Diagnostics
- AMO Instrument Controls
- LUSI Instruments and Diagnostics
- Installation
- Machine Protection System
- Laser Safety System
- EPICS Software
- Network Security
- Data Acquisition
- 2-D Detector Control and Readout
- Femto-Second Laser Timing System

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LCLS & LUSI

- Common photon-area Controls and DAQ System Design for LCLS and LUSI
  - Includes Front-End Enclosure (FEE), Near Experimental Hall (NEH), X-Ray Tunnel (XRT) and Far Experimental Hall (FEH)
  - Most of XTOD in FEE
- LCLS Controls & DAQ W.B.S 1.6.2
  - AMO experiment (NEH, hutch 1)
    - All controls and DAQ
  - Common services for all hutches
    - Examples
      - PPS/HPS/LSS
      - 120 Hz beam-quality data interface
      - Machine protection system interface
      - Network interface
      - Local science data online processing & cache
  - 2-D detector
    - Control and DAQ for detector
- LUSI Control & DAQ W.B.S
  - XPP, XCS, CXI Instruments, Diagnostics
- Examples of documents released
  - 1.1.523 XES-LUSI ICD (includes Controls and Data systems)
  - 1.1-516 XES Photon Controls to Electron Beam Controls System ICD
  - 1.1.517 XES Photon Controls to Electron Beam Controls MPS ICD

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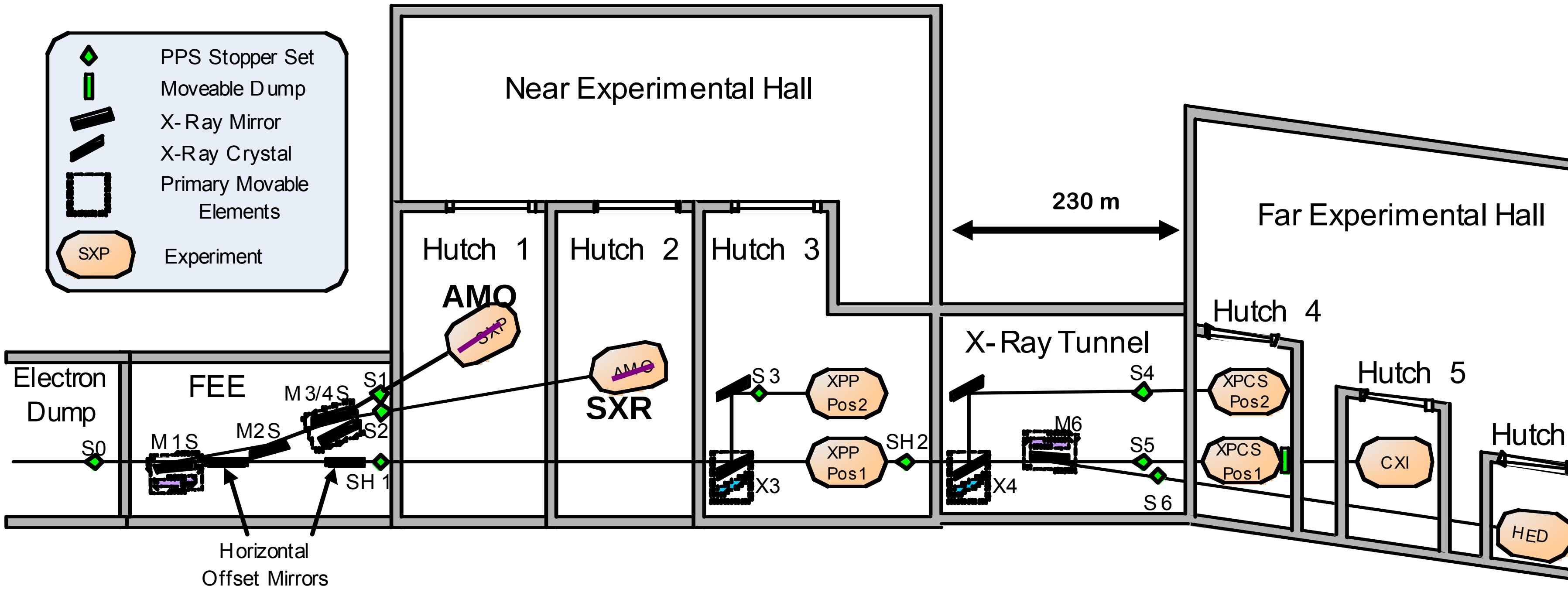
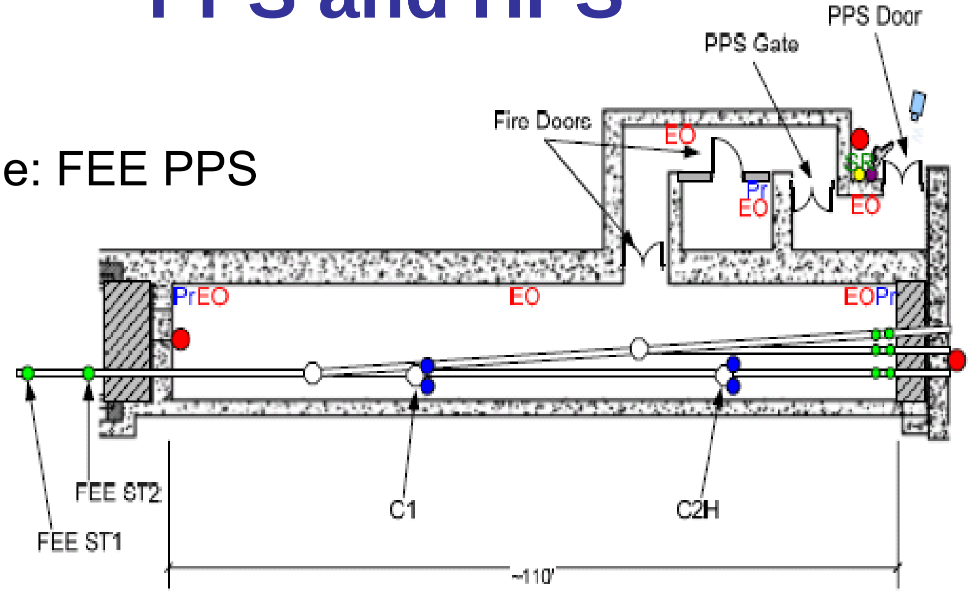
XES Near & Far Hall Hutches and Beamline Layout (not to scale)



AMO and SXR swapped hutches since last review

PPS and HPS

Example: FEE PPS



- Personnel Protection System for FEE and XRT plus Hutch Protection System for NEH and FEH
  - HPS based on SSRL model with some modifications
  - Final Design Review held 10-22-08
    - http://confluence.slac.stanford.edu/display/PCDS/XRAY-PPS
  - Hardware in house
  - FEE/NEH software being written
  - Installation early CY09

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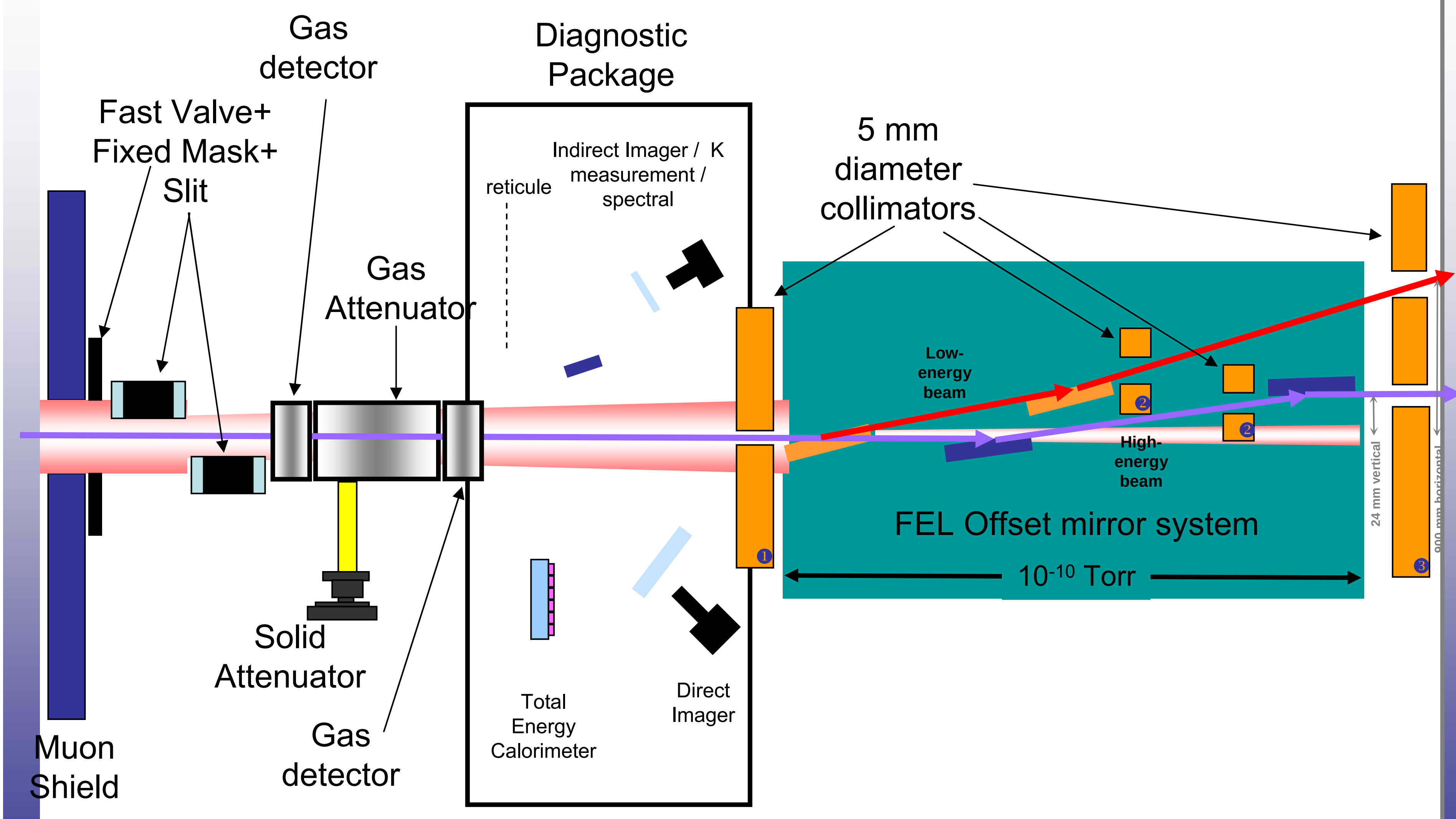
XR Diagnostics in Front End Enclosure



XTOD Instrument Racks under test in LLNL lab

- Installation Readiness Review held 11-7-08
- First racks will be moved from LLNL to SLAC Jan 5, 09

Photon Area Controls and Data Systems Devices

- Created web-pages to list supported controls and data-acquisition devices for photon area
  - For all experiments in xray area (AMO, XPP, XCS, SXR, CXI, etc)
    - SXR might have up to 8 different end-stations
  - http://confluence.slac.stanford.edu/pages/viewpage.action?pageId=9175609
  - Additional devices can be added after discussions with Photon Controls and Data Systems (PCDS, G. Haller) group

AMO Instrument Control

- Requirements listed in Engineering Specification Documents (ESD's)
  - 1.6-108 AMO Controls ESD, status: released
  - 1.6-109 AMO DAQ ESD, status: released

- Interfaces specified in Interface Control Document (ICD)
  - 1.1-515 XES AMO Controls ICD, status: released

- Held Final Design Review 11-10-08
  - http://confluence.slac.stanford.edu/display/PCDS/AMO-FDR
  - Including identification of each component to be controlled and data to be acquired
    - ~10 cameras
    - ~50 stepper motors, almost all smart motors (serial port)
    - ~ 50 channels of high-voltage bias supplies
    - ~ 8 sets of vacuum gauges, 2 valves
    - misc other controllers, but mostly straight forward serial devices
  - All controllers identified, example power supplies -> next slide
  - Submitted requisitions for most controllers to purchasing
  - Start of integration, not before summer 09 per schedule

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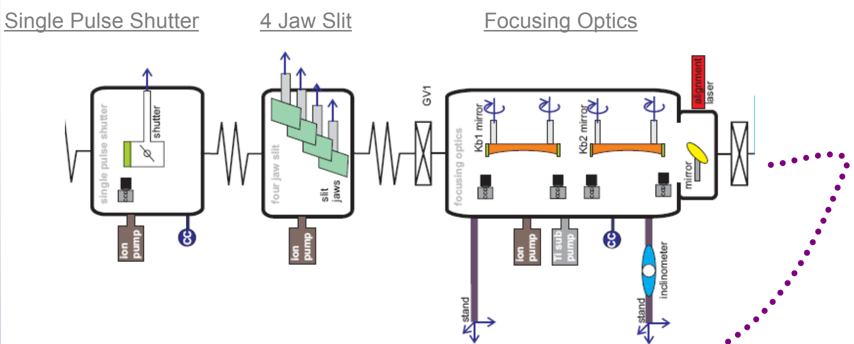
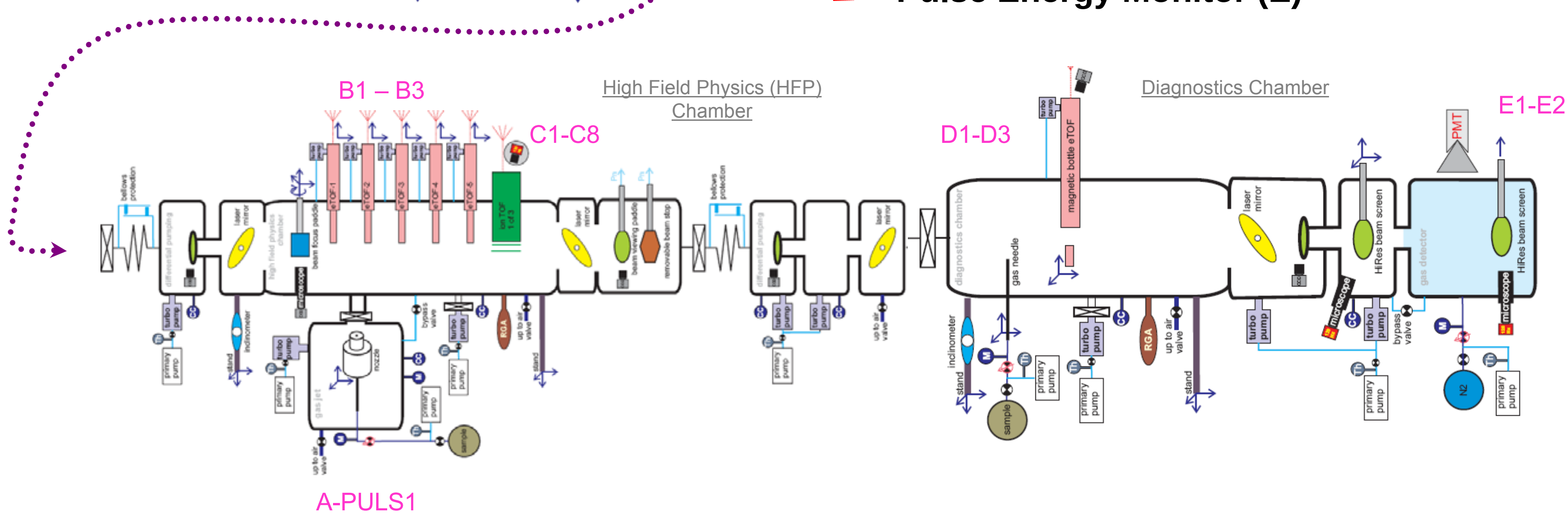
AMO Instrument Power Supplies



AMO Layout 10/2/2008

- Gas Jets (A)
- Electron Spectrometers (B)
- Ion Spectrometers (C)
- Magnetic Bottle Spectrometers (D)
- Pulse Energy Monitor (E)

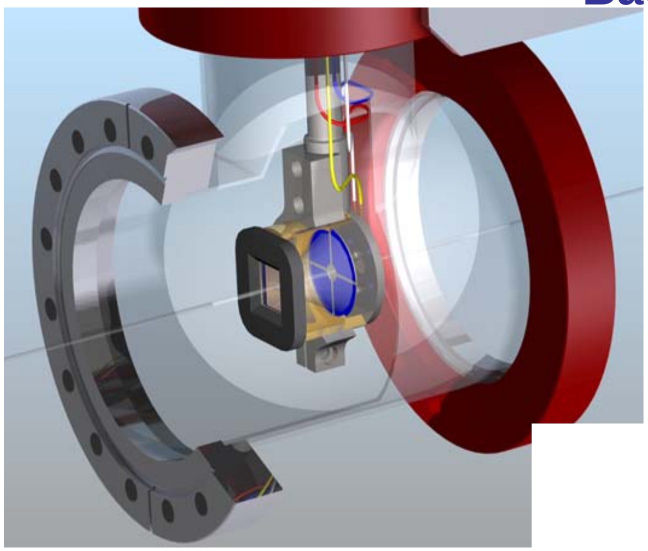


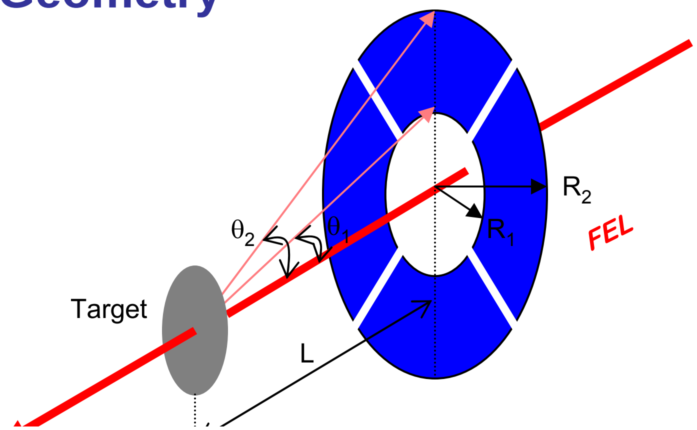
LUSI & SXR

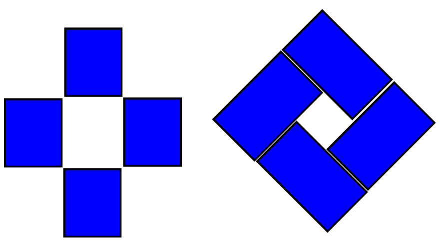
- LUSI includes the instruments
  - XPP (NEH, hutch 3)
  - XCS (FEH, hutch 4)
  - CXI (FEH, hutch 5)
  - Have written and released ESD’s and ICD’s for each instrument
  - Controls and DAQ devices from PCDS list with some additions
  - Will purchase components according to schedule (not before mid 09)
- SXR
  - Have device list for beamline
  - Held discussions with several end-stations on how to plan to make them compatible with LCLS
  - As soon as SXR beamline has been added to scope of LCLS, ready to purchase components.

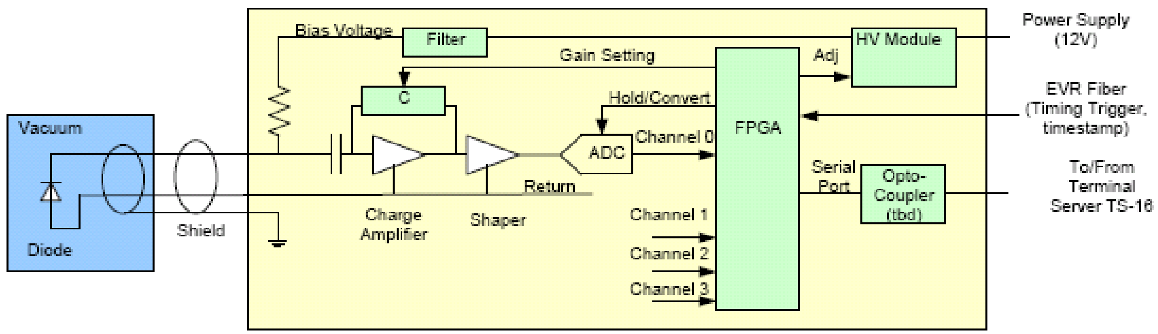
Diagnositics: e.g. Intensity-Position

- Back Scattering Geometry









- On-board calibration circuits not shown

- Four-diode design

- Status: Design complete, schematic complete, board in layout

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Installation

- Held Installation Readiness Review 11-7-08
- Already installed
  - Fibers from SCCS (Computer Center) and MCC (Main Control Center) to NEH
  - Fibers from server room to each hutch, to laser room, to FEE, and to MPS & PPS racks
  - LSS (Laser Safety Systems) cables
  - MPS cables from each hutch and FEE to MPS rack in hall
  - Some PPS cables
  - XTOD cables for upstream 2/3 of FEE

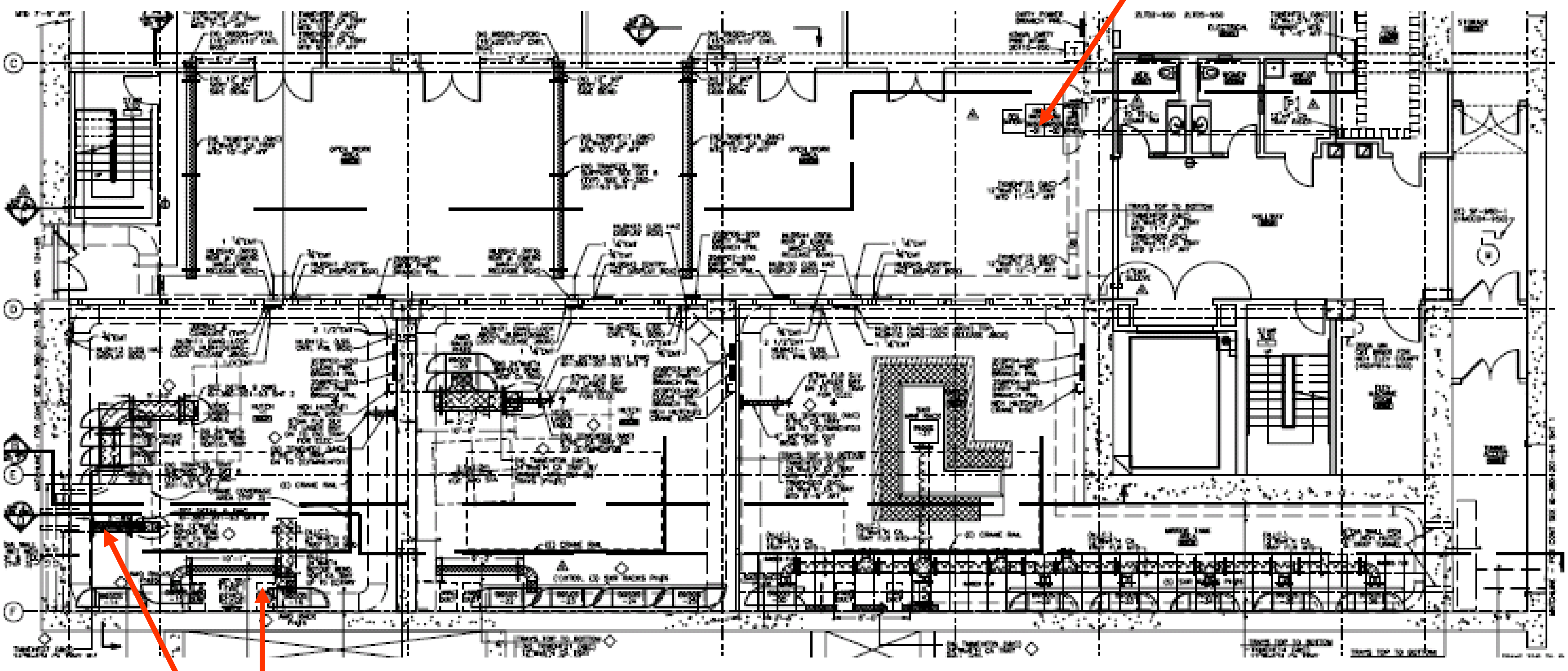
- To be installed February 09
  - Balance of PPS/HPS cables
  - XTOD cables for downstream 1/3 of FEE

- Already installed
  - NEH hall MPS racks
  - Server room racks with main network switch, fiber optics distribution
  - Hutch 1 XTOD rack
  - Laser Room Laser Safety rack

NEH Sub-Basement

PPS and MPS/LSS racks

Phase 5 and phase 6 cable and rack install

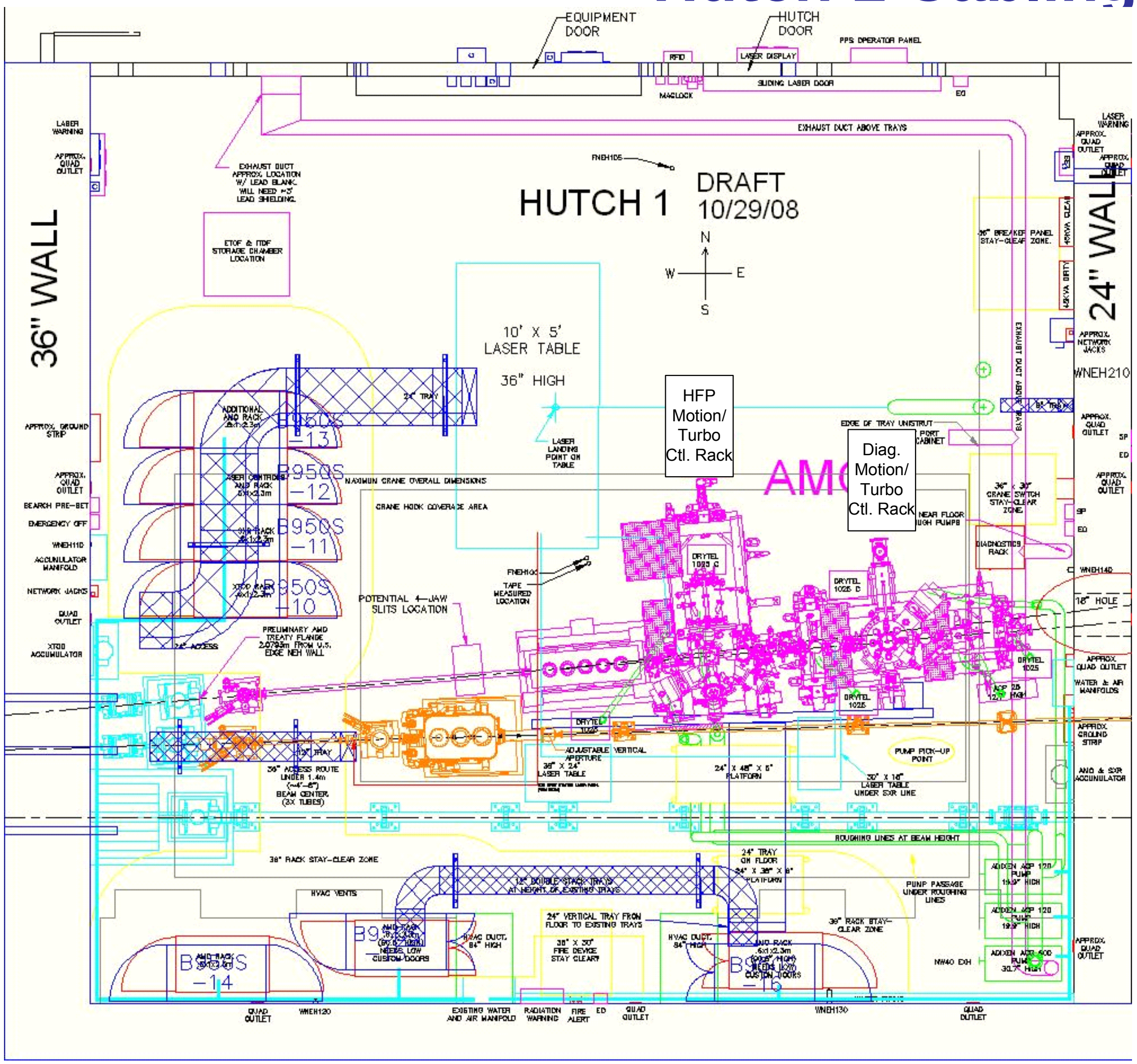


XTOD/Laser Controls/SXR/AMO racks

SXR racks

LUSI XPP racks (in CY 09)

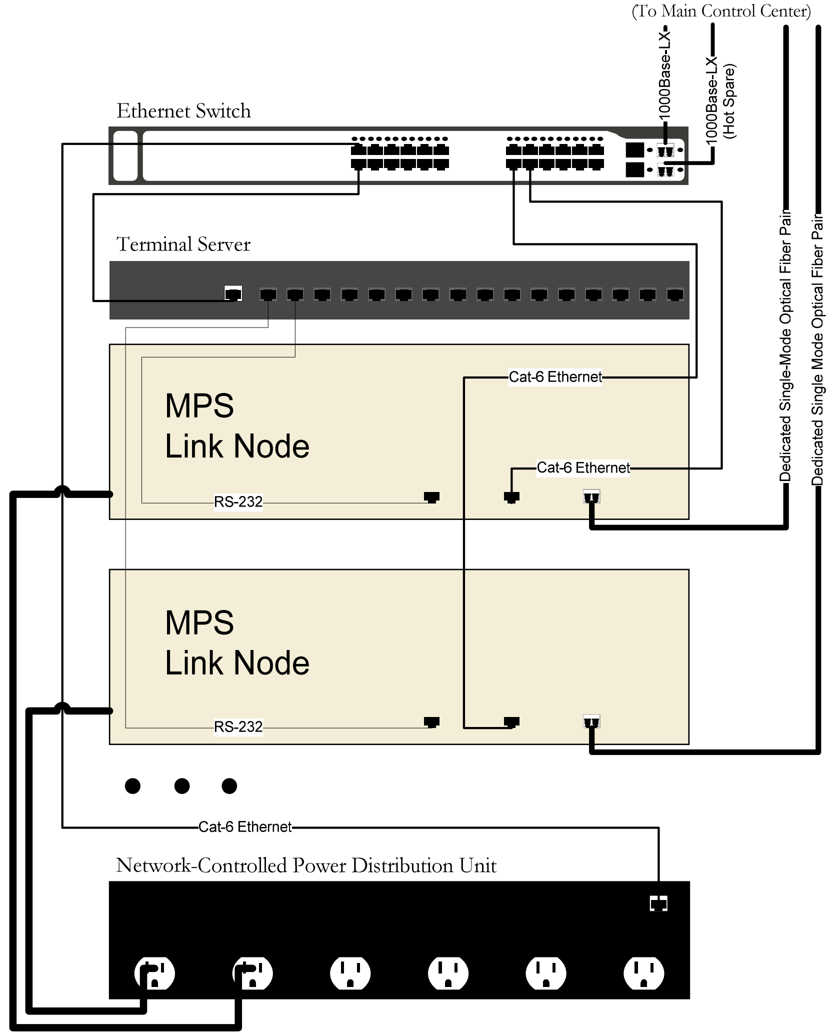
Hutch 1 Cabling



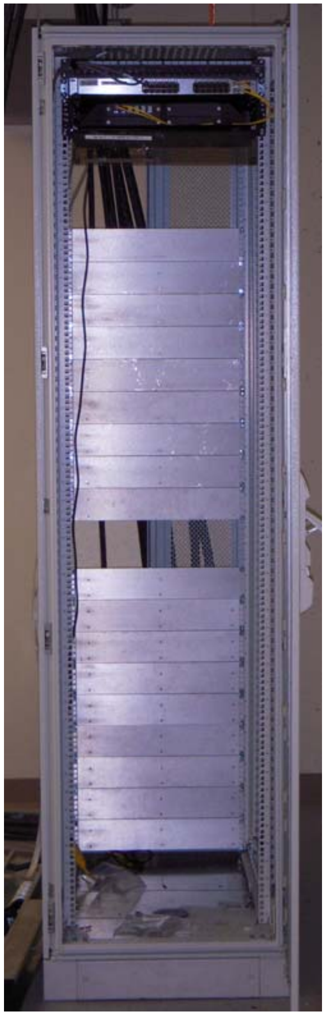
- Mix of fiber optic, Category 6, coaxial, and industrial controls cabling.
- All cables routed through trays will be Low-Smoke, Zero Halogen.
- Industrial controls cabling will follow the XES Machine Protection System's model for trunk layout, termination, and cross-connect.

MPS Rack Layout

- Dedicated Optical fiber
  - 1 single-mode pair per Link Node for custom MPS signaling protocol
- TCP/IP Networking
  - Redundant single-mode pairs for 1000Base-LX Ethernet
    - Access to EPICS process variables on MPS Link Nodes via local Ethernet switch
    - MPS Link Node console logins via Terminal Server
    - Remote power-cycling of Link Nodes via APC AP7900 Switched Rack PDU
- All optical networking paths route through experiment hall patch panels and terminate at fiber patch panel in MCC



Installation Status



- Near Experiment Hall Machine Protection Rack, (B950S-04), Installed.
- 48-strand fiber trunk pulled between B950B-42, (NEH Server Room), and B950S-04. The NEH MPS optical networking path is now complete.
- Ethernet Switch Installed in rack B950S-04, connected to fiber, and provided with temporary power.

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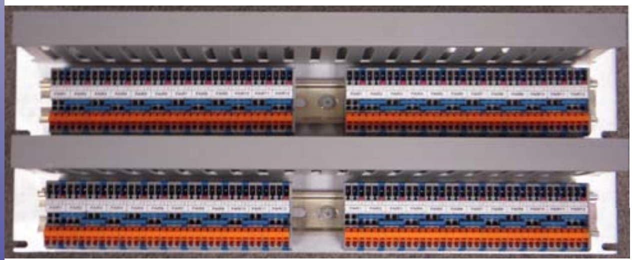
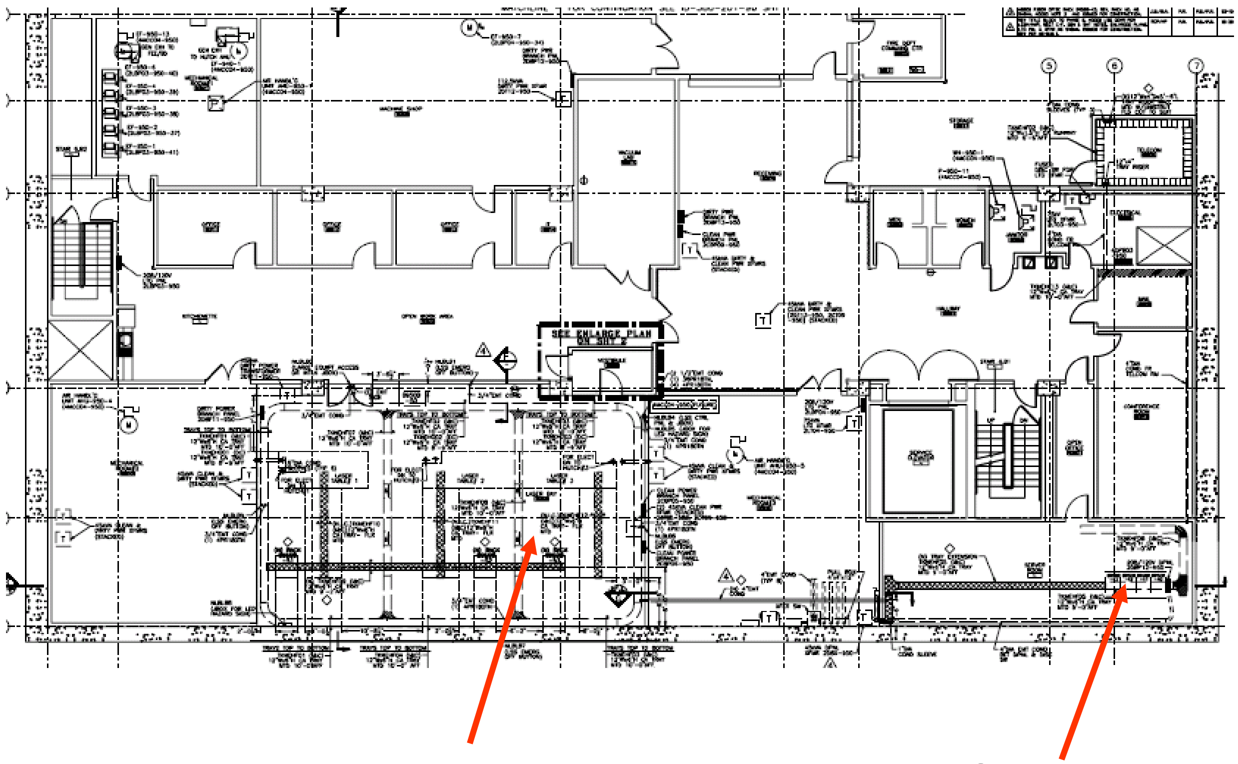
MPS Installation Status

- All DIN rails for rack B950S-04 assembled, tested, and installed
  - 12 MPS Link Node Input Aggregation Rails
  - 6 MPS Trunk Head-End Rails



- MPS Trunk Field Rails assembled
- MPS trunk cables are being pulled between the hutches, the FEE, and rack B950S-04 as we speak.

NEH Basement



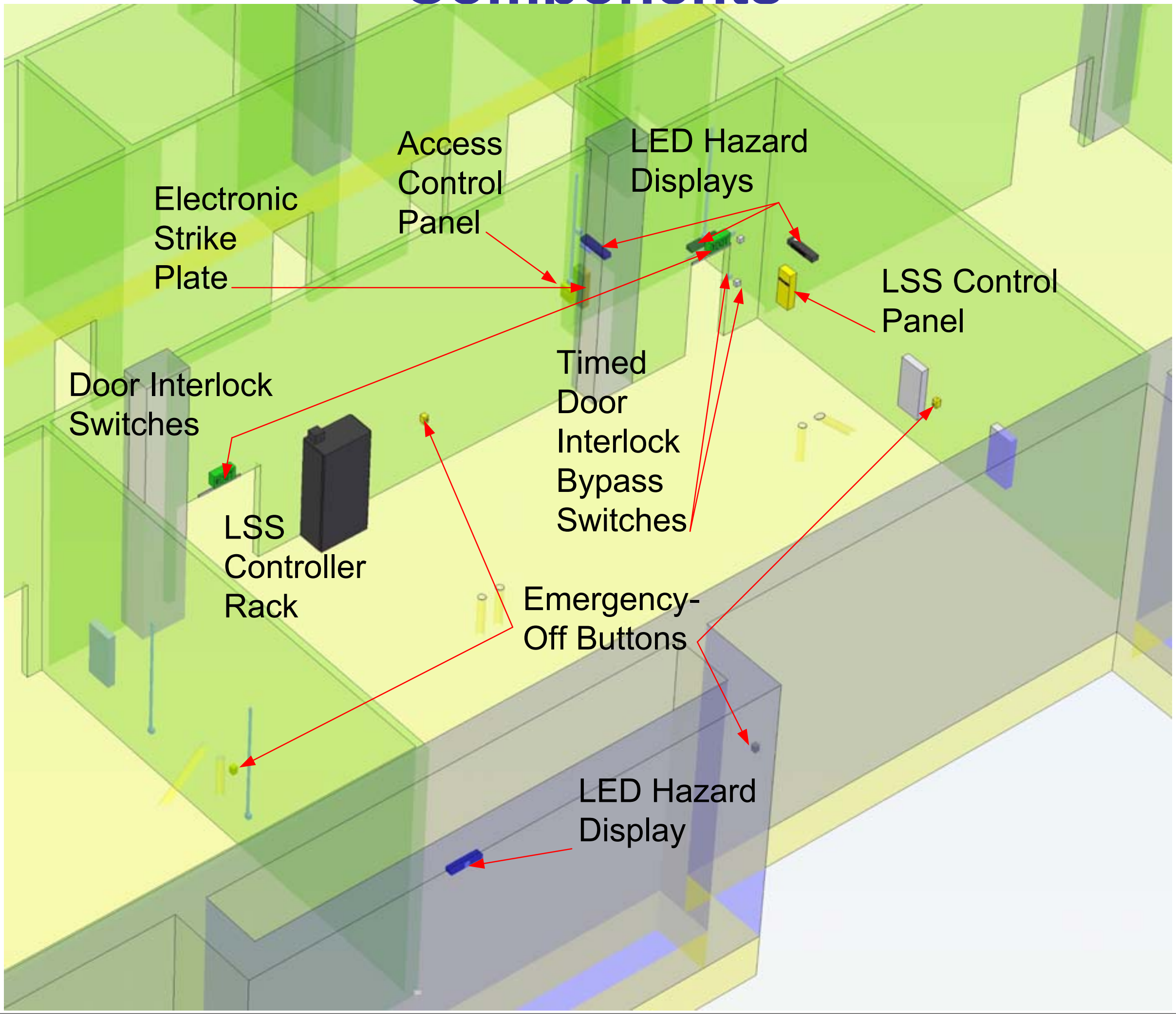
Laser room racks

Server room racks including network switch (installed)

Server Room Racks

Main
10-G
switch

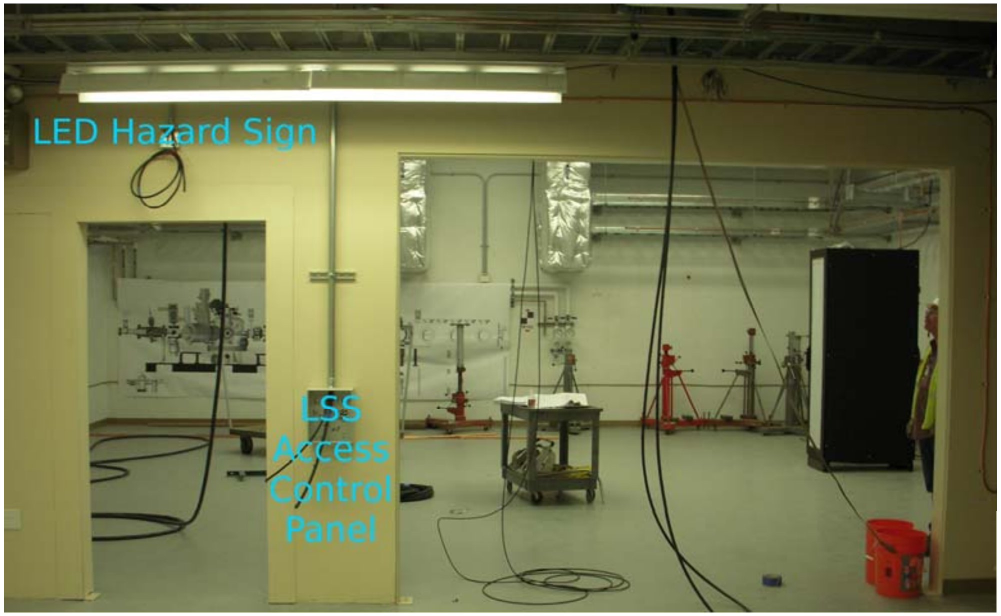
NEH Laser Bay Laser Safety System Layout and Components



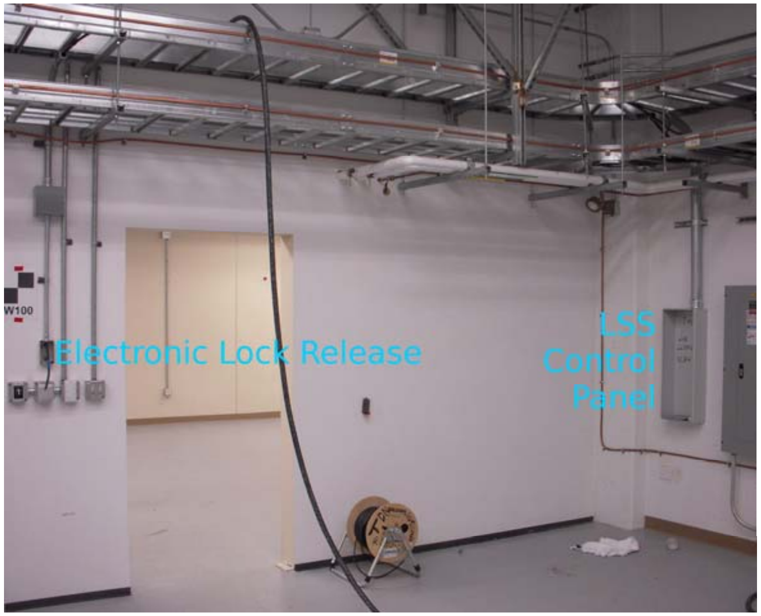
NEH Laser Bay

NEH Hutch 1

Exterior View



Interior View



AMO Installation

- Vacuum test setup running in PCDS lab (Central lab annex)
- AMO racks ready to be loaded (Central lab annex)

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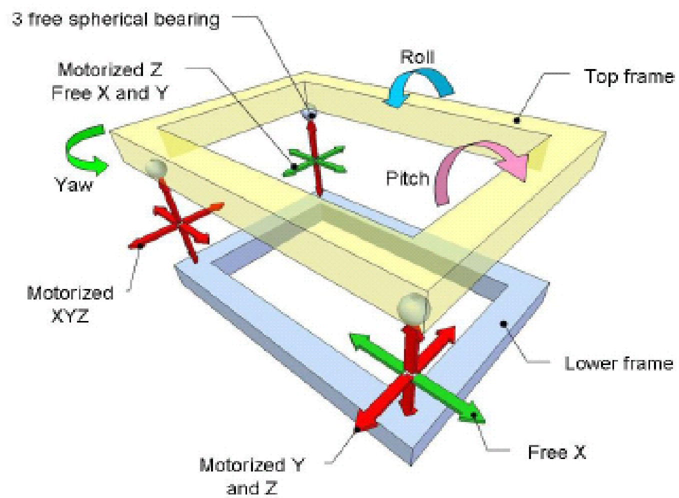
Software: AMO Example: Moving Tables

AMO contains 3 moving tables: Focusing Optics, High Field Physics Chamber and Diagnostics Chamber. It is expected that those tables will be very similar.

The driver will:

- Control movements in X, Y, Z, Pitch, Yaw and Roll
- Keep track of position at all time
- Ensure there are no damages to the bellows
- Adjust a downstream table position if needed



Operator's view:

- For each table, + and – buttons in up to 6 directions
- Display position of table
- If a sensor triggers, no movement will be allowed in the direction that caused the sensor to trigger but operator is responsible for resolving the issue

Challenges:

- Tracking position across IOC reboot
- Prevent damages when laser system is hooked-up
- Moving from position with KB mirrors to position without (large movement)

Devices controlled by this driver:

- MDI3CRL23A7: motor
- MDI3CRL23B7: motor
- Applied Geomechanics 900: inclinometer
- Balmer IFRM 05N15A3_S05L: bellow sensor
- RGH24: encoder with home position
- LIK21: encoder with home position

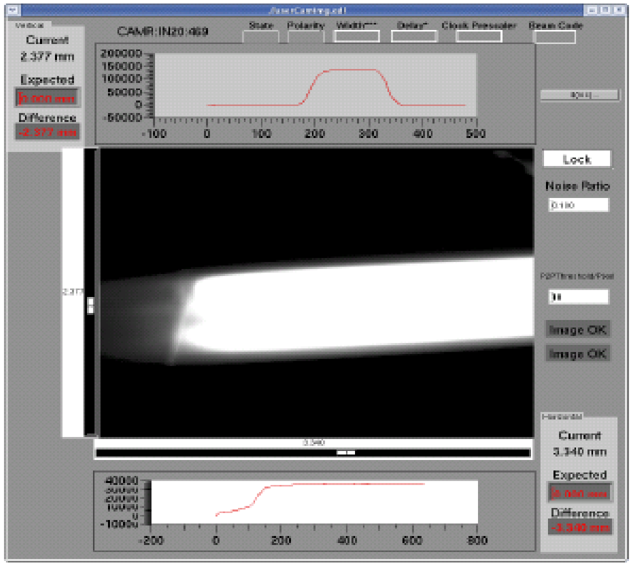
Consoles: PyQt versus EDM

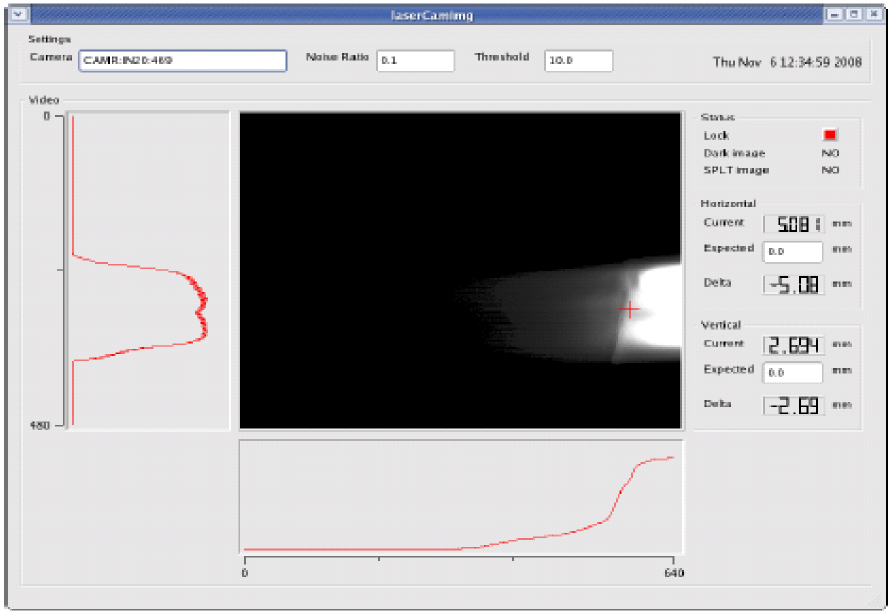
Traditionally, EPICS systems use **EDM**

- ✗ Motif based GUI
- ✗ Objects put together to create a console
- ✗ User cannot personalize GUI
- ✗ Additional processing requires the use of external tools such as LabView and MatLab
- ✗ Not well maintained any more

AMO will use **PyQt** framework instead

- ✗ Based on Python and Qt: open source, widely used and active projects
- ✗ Python provides scripting capabilities and an easy way for the user to personalize GUI
- ✗ Qt provides modern GUI and widget concept





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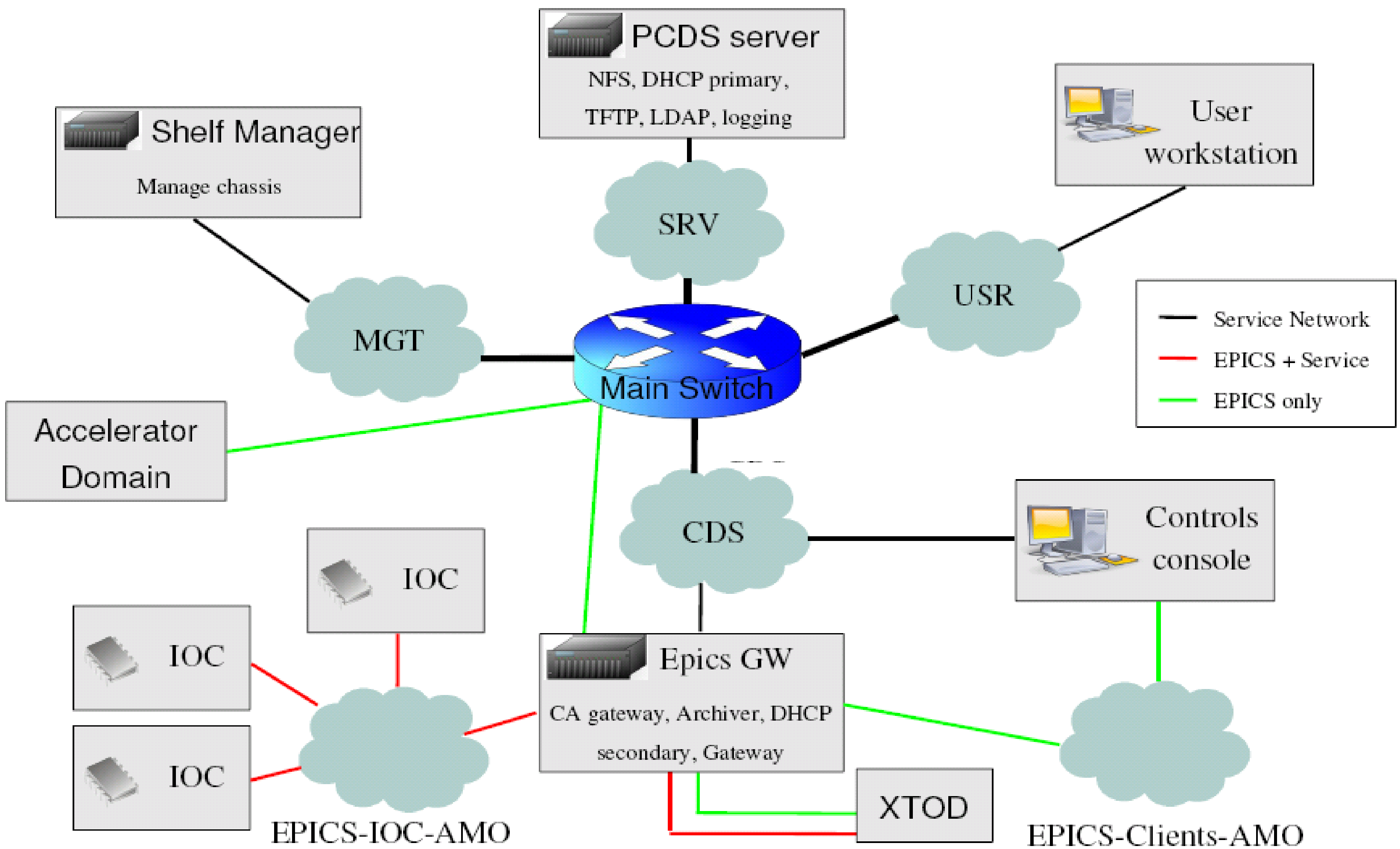
EPICS Network



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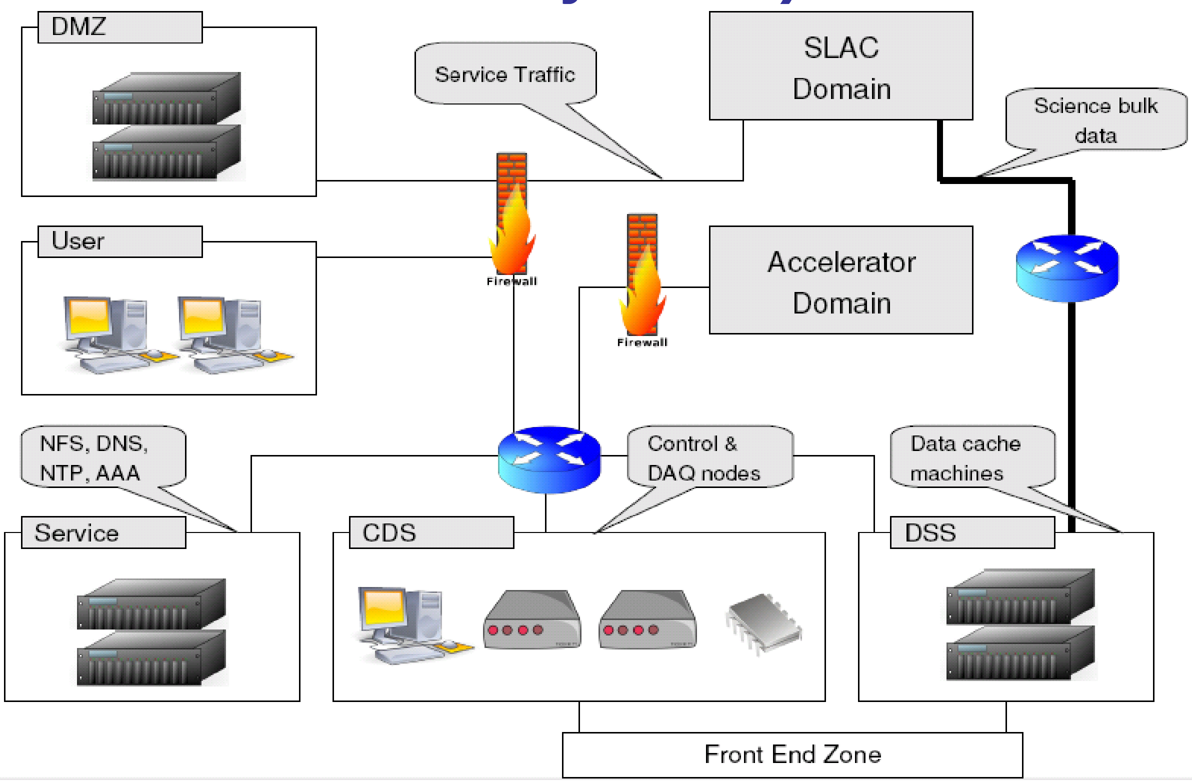
Status

- EPICS drivers for most devices are written
- Remaining drivers and consoles will take another ~ 6 months at 2 FTE effort.
  - Is according to schedule

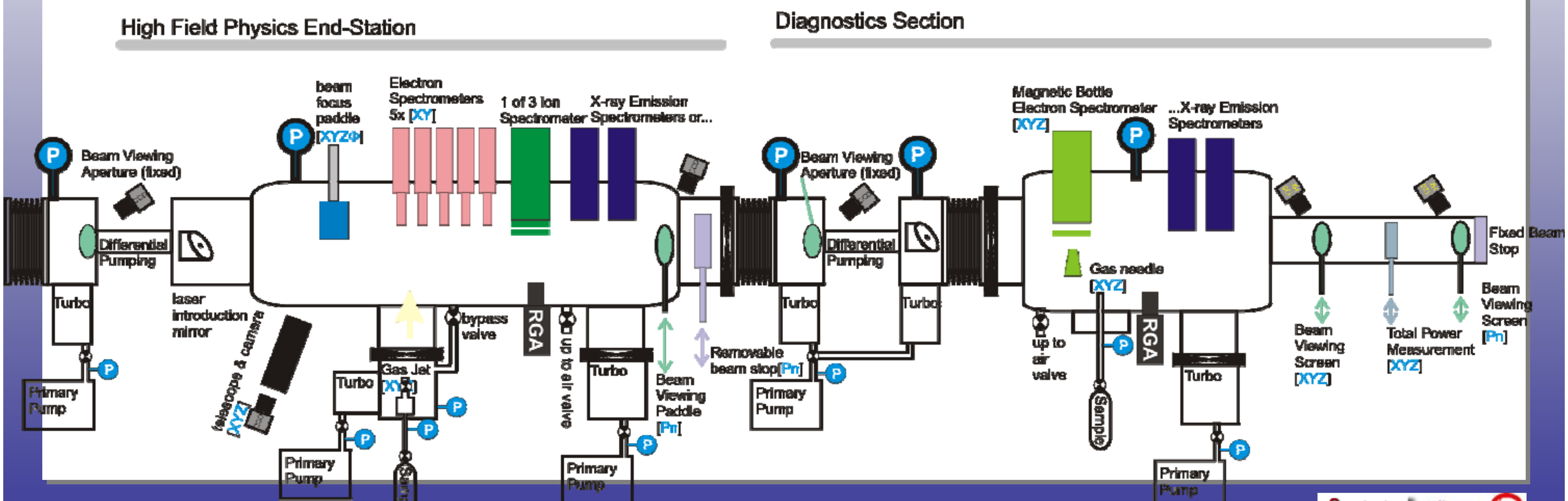
Network Security Enclave PCDS (Photon Control and Data Systems)



- Created PCDS Network Security Plan, approved by SLAC network security and DOE
  - http://confluence.slac.stanford.edu/display/PCDS/Networking
  - Can't bring "ad-hoc" instrumentation/computers with data analysis software and hook up. Need to plan ahead.
    - Completely fine for planned LCLS operation

AMO DAQ Instruments

- High Field Physics End-Station
  - electron time-of-flight spectrometers
  - ion spectrometers
    - time-of-flight, imaging, momentum
  - x-ray emission spectrometers
- **Diagnostic Section**
  - magnetic bottle electron time-of-flight spectrometer
  - x-ray emission spectrometers
  - pulse energy monitor
  - beam profile screens



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AMO DAQ Overview

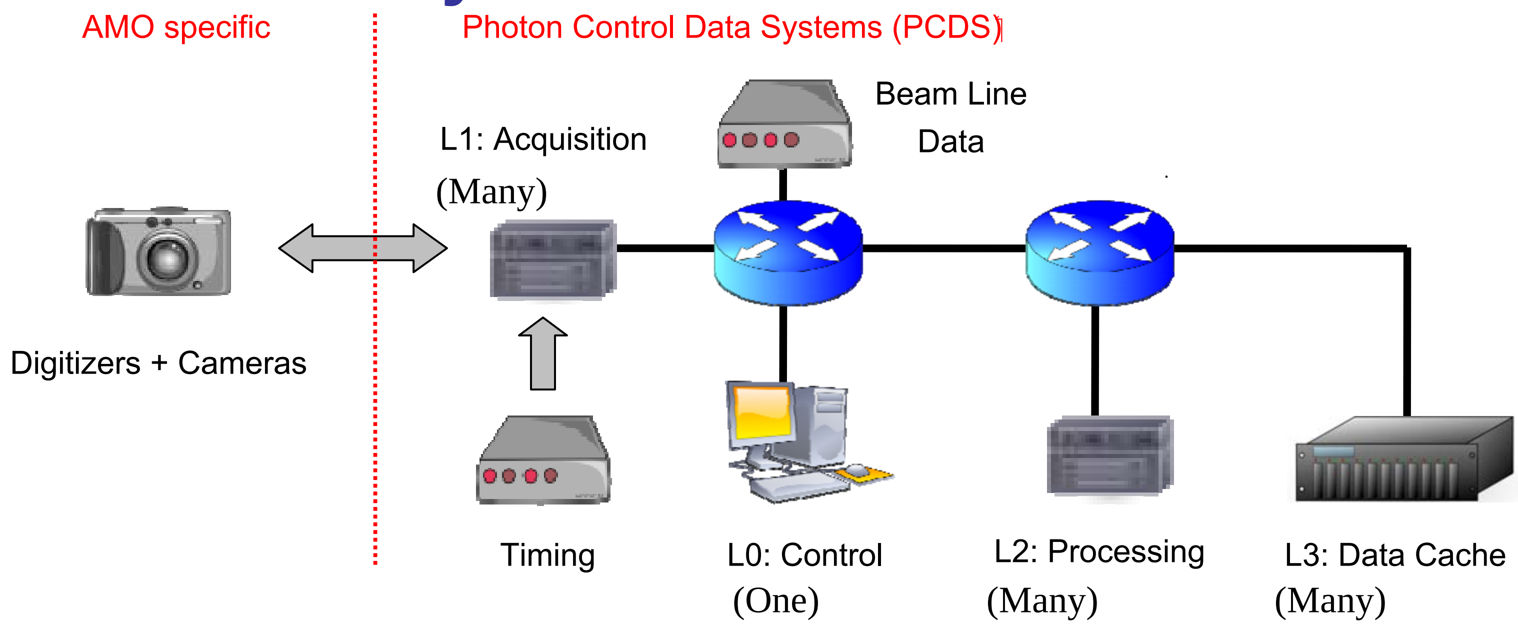
Detector	Readout Interface	Number of Devices	Number of Channels	Sample Time [ns]	Integration Time [us]	Data Rate [MB/s]
E-TOF	Acqiris	5	5	0.1-0.5	1-5	12
Ion-TOF	Acqiris	1	1	0.5-5	10-100	4.8
Ion Imaging Spectrometer	Opal1000	1	1	N/A	N/A	18 (after zero suppression)
Ion Momentum Spectrometer	Acqiris	2	7	0.5	10	34
Magnetic Bottle e-TOF	Acqiris	1	1	0.1	2	4.8
X-Ray Emission Spectrometer	Opal1000	2	2	N/A	N/A	50
Pulse Energy Monitor	Acqiris	1	2	0.5	0.5	0.48
Beam Position Monitor	Opal1000	2	2	N/A	N/A	Small (after calculation)

Babar archived ~30MB/s. Should reduce data sizes with online software.

Data System Overview

- Large data volumes compared to synchrotron light sources
- Common DAQ back-end architecture for all LCLS experiments
- AMO DAQ:
  - Linux (open source, supported by hardware vendors)
  - cPCI (driven by Acqiris)
- Must be able to associate data from different sources
  - 120Hz AMO DAQ Data
  - 120Hz Beam Line Data ("BLD")
  - Non-120Hz AMO Controls Data

Data System Architecture



- DAQ system primary features
  - Trigger and readout
  - Process and veto
  - Monitoring
  - Storage

Configuration & Calibration

- Instrument configuration saved together with science data
- Two e-TOF calibrations:
  - Take Acqiris spectra at different retarding potentials
  - Calibrate Pulse Height vs. Number of Electrons
- One Pulse Energy Monitor calibration:
  - Fire laser and measure Acqiris response
- Same software used to create the configuration profiles for data taking is able to create the configuration settings used for calibration
  - data taking: configuration remains constant during a run
  - calibration: detector configuration changes often in between cycles
- Outputs from calibration runs can be used for on-line processing of the data (e.g. gain corrections, thresholds)

Acquisition & Processing

- Each event labelled with a pulse ID for associating DAQ data with Controls/BLD
  - Controls data stream separate. Association done with Offline tools
  - BLD embedded in DAQ data stream
- Processing envisioned during data acquisition to reduce data volume:
  - Bad pulse rejection
  - Zero-suppression for Acqiris readout (peak calculation eventually?)
  - Zero-suppression for Ion Imaging Spectrometer (~5% occupancy)
  - XES: Region-of-interest and projection onto one axis
  - Centroid/Width/Tilt calculation for beam-position monitors
- Ability to send raw data on selected events (e.g. for monitoring)

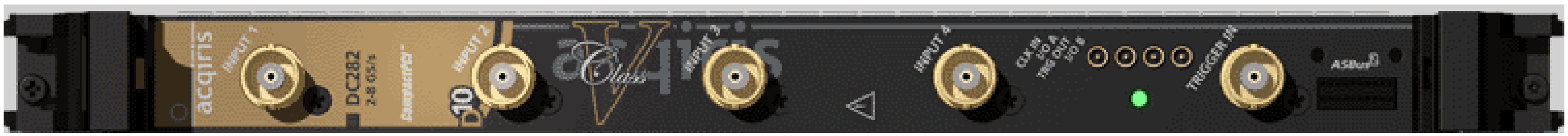
Monitoring & Storage

- Data is multicast to both DAQ CPUs and monitoring CPUs.

- Individual or summed spectra displayed in real-time
  - User selectable refresh rate of up to 10 Hz
  - Time-frame of the display user selectable
    - i.e. last n shots, cumulative data set, etc.
  - Possible to zoom on the display
    - options for auto-scaling or user defined ranges
  - Storage and printing capabilities included for the displayed data
  - All data converted from hardware format to physical units before display

- Data stored to data cache in custom object-oriented format ("XTC")

Digitizer



- Acqiris DC282 high-speed 10-bit cPCI Digitizer
  - 4 channels
  - 2-8 GS/s sampling rate
  - Acquisition memory from 1024 kpoints to 1024 Mpoints (optional)
  - Low dead time (350 ns) sequential recording with time stamps
  - 6U PXI/CompactPCI standard, 64 bit, 66 MHz PCI bus
    - Sustained transfer rate up to 400MB/s to host SBC

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Status

- Re-used significant fraction of Babar DAQ software
- Implemented “zero-copy” transmission/reception of network data (hard in Linux)
- Running full DAQ Chain (EVG/EVR/L0/L1/L2/L3): Configuring/Reading out Acqiris/Opal1000 with “zero-copy” of objects in memory (better performance)
- Generating official data files. Iterating over them.

Online and Offline

- Online data-acquisition and offline data management and data analysis
  - Covered in separate presentation

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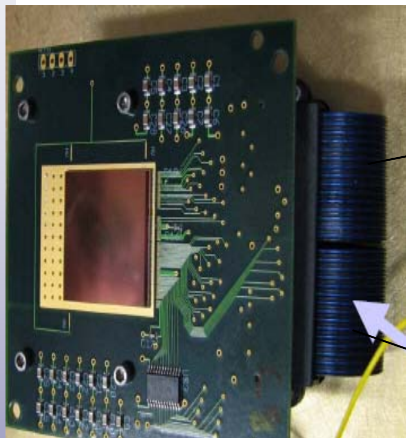
LUSI Data Acquisition

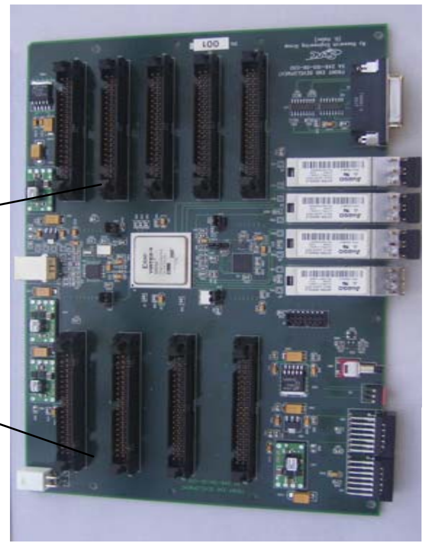
- Cornell and Brookhaven 2-D pixel detectors are configured & read out using the SLAC ATCA Reconfigurable Cluster Element modules.

2D-Detector Control and DAQ Chain

Vacuum

Ground-
isolation





Fiber

Cornell
detector/
ASIC

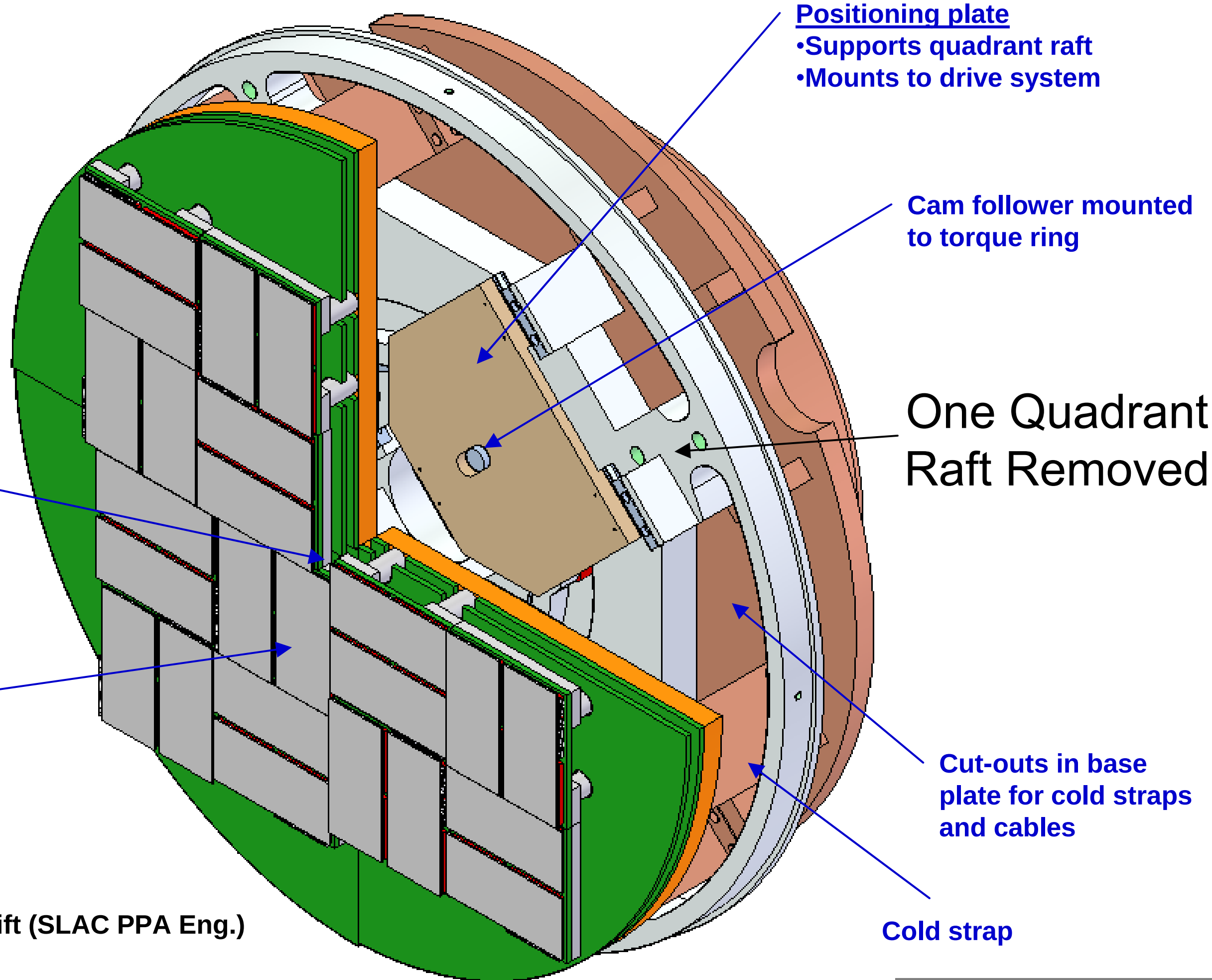
SLAC FPGA
front-end
board

ATCA crate
with SLAC
DAQ Boards

CXI 2D Detector

- 2D pixel array detector for CXI instrument
  - Collaboration with Sol Gruner Group at Cornell Univ.
  - Full-scale custom ASIC received, measurements in progress at Cornell & SLAC
  - Integration with SLAC DAQ system done at SLAC
  - Mechanical packaging done at SLAC
    - Coordinated with CXI

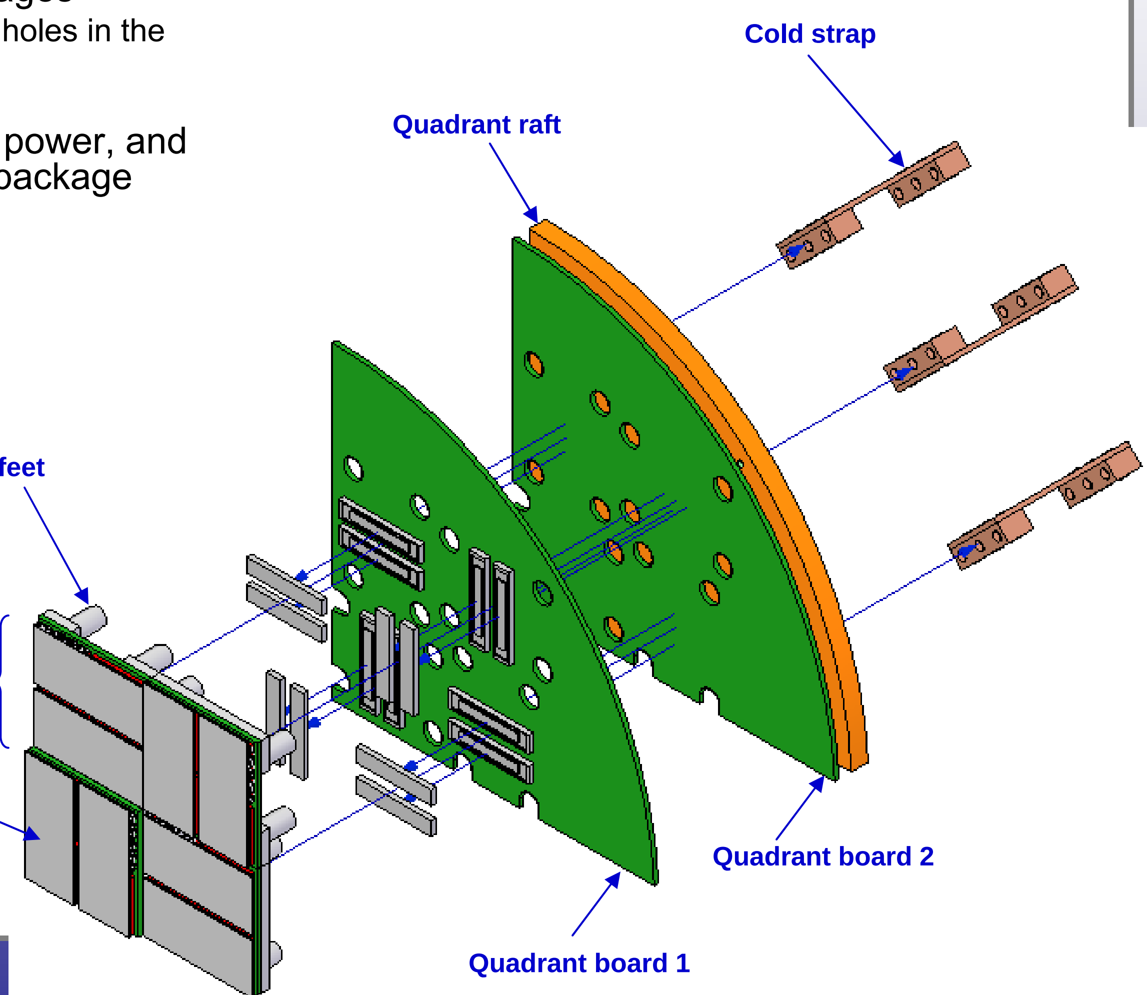
2D-Detector Mechanical/Electrical Vacuum Assembly Conceptual Design (SLAC PPA Engineering)

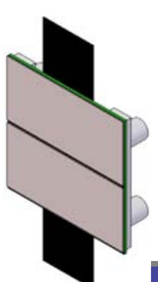


Martin Nordby, Matt Swift (SLAC PPA Eng.)

Quadrant Board and Electrical Interfaces

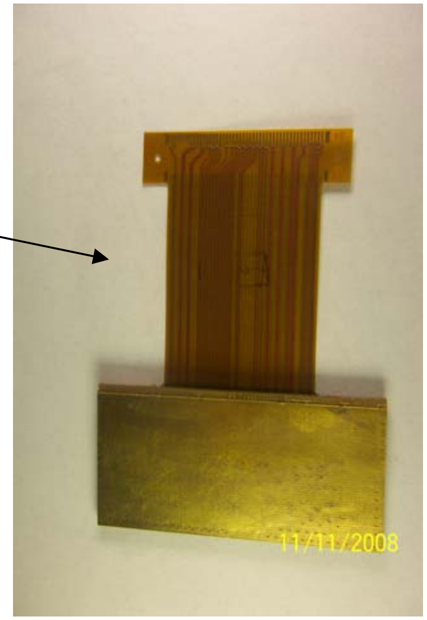
- Quadrant raft provides structural support and stability for the double-detector packages
  - Feet mount on quadrant raft through holes in the quadrant boards
  - This is also the thermal path
- Quadrant boards provide grounding, power, and signal interface to the PAD detector package
  - 1 flex cable per detector
  - 1 FPGA on each quadrant board

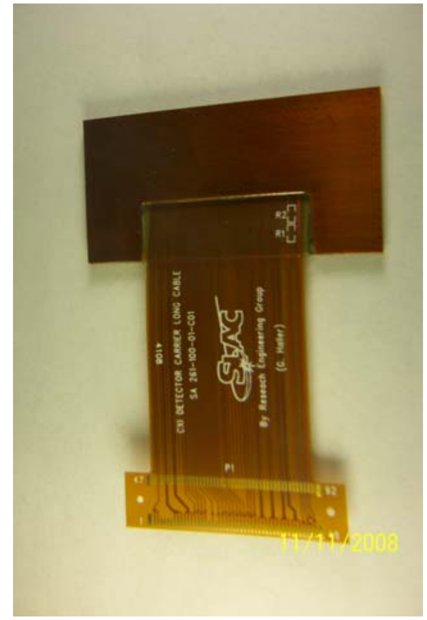




ASIC Board

- Rigid-flex ASIC board (SLAC design)
- ASIC to be loaded this month
- Analog quadrant PCB in layout





Femto-Second Laser Timing System

- Provided by LBL
- Tested performance of prototype at SLAC, better than 20 fsec drift performance (100 fsec is spec)
- Pulled fibers from Sector 20 to NEH
- Prototype will come to SLAC in Spring for initial commissioning
  - “Production” unit in late summer 09

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Summary

- XTOD
  - Instrumentation to be delivered in January well under way, installed in racks, in testing. Delivery driven by getting AC installed into FEE
- PPS, HPS, MPS, and LSS are all well on their way, most will be installed in Spring 09
- AMO Instrument Controls and Data Acquisition
  - Final Design Review held
  - Devices are being ordered
  - Test setups and software in progress
- Installation
  - Well under way
    - Most long-haul cables already installed
    - Many racks already installed

Summary con't

- Data Acquisition Challenging
  - Much more data than past xray experiments
  - However we reuse many parts of DAQ developed for BaBar at SLAC
  - See no issue acquiring data when instruments are ready
- Network Security plan approved by SLAC and DOE
- Offline infrastructure in design
  - Issue is scientific computing (not in scope of project)
    - Needs to be addressed asap

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