9. Beamline Controls

9.1 General Description

9.1.1 Hardware Configuration

NYX uses Galil DMC-4080 advanced motion controllers to control NYX the beamline photon delivery system and the experimental station. It takes care of all the motion controls, most I/Os, temperature monitoring and analog input. The Galil motor amplifiers are built into the controller. We embedded the Galil controllers in custom-built control cabinets located near each of the major beamline and endstation components. The advantage of such a configuration is that it eliminates long motor and encoder cables to the motor amplifier and controllers. The main control PC communicates to the Galil controller through ethernet.

9.1.2 Software Plan

Blu-Ice is a graphical interface to a Distributed Control System (DCS) for crystallographic data collection at synchrotrons [1]. It was designed and developed by SSRL, and it is used at crystallography beamlines worldwide. It is proven and known for being elegant and user friendly.

NYSBC used Blu-Ice at NSLS beamline X4 in the last five years of its operation. It controlled all major components of the X4 endstation. Our experience with Blu-Ice can be summarized as follows:

1. User friendly. Blu-Ice is easy to use. The GUI is self-explanatory. The user can master beamline control and data collection in a very short time. Our users love it.
2. Central control. All the beamline control and data collection is under one GUI, unlike much beamline software, where the user needs to open multiple windows. It’s less confusing.
3. Multi-user. It controls or monitors the data collection both locally and remotely. Blu-Ice can be accessed by many users at the same time to monitor their experiments. Users are able to view all processes of the experiments, but only one user is allowed to control the experiments.
4. Security. The authentication server takes care of the user login security. Each user can have their own user name and password to access the software and collect their data securely.
5. Reliability. We have had very smooth operating experience since using Blu-Ice, and there is rarely a need to reboot or restart, unlike with our previous control softwares.
6. Efficiency. The experimental processes are standardized. The user can simply use data collection number tabs to setup multiple data collections and run them continuously.
7. Many experimental procedures and scripts have already been developed for beamline control; we can easily use them or modifiy them. This saves us a lot of time in development.
8. Easy to expand and upgrade. New hardware can be easily added into the system. SSRL provides many useful templates. We also have full access to the Blu-Ice repository so that we can upgrade to the newer version of the Blu-Ice whenever it’s available.
9. Excellent support from SSRL. The people in the SSRL control group have been extremely supportive over the last five years, making themselves available for us if we need help.

Blu-Ice References

[1] T.M. McPhillips, S.E. McPhillips, H.-J. Chiu, A.E. Cohen, A.M. Deacon, P.J. Ellis, E. Garman, A. Gonzalez, N.K. Sauter, R. P. Phizackerley, S.M. Soltis and P. Kuhn Blu-Ice and the Distributed Control System: software for data acquisition and instrument control at macromolecular crystallography beamlines. J. Synchr. Rad., 2002. *J. Appl. Cryst.* **9**, 401-406 (2002).

[2] A. González, P. Moorhead, S.E. McPhillips, J. Song, K. Sharp, J. R. Taylor, P.D. Adams, N.K. Sauter and S.M. Soltis. *Web-Ice*: integrated data collection and analysis for macromolecular crystallography. *J. Appl. Cryst.* **41**, 176-184 (2008).

[3] Y. Tsai, S.E. McPhillips, A. Gonzalez, T.M. McPhillips, D. Zinn, A.E. Cohen, M.D. Feese, D. Bushnell, T. Tiefenbrunn, C. D. Stout, B. Ludaescher, B. Hedman, K.O. Hodgson and S.M. Soltis. AutoDrug: fully automated macromolecular crystallography workflows for fragment-based drug discovery. *Acta Cryst. D* **69**, 796–803 (2013).

9.2 Major Hardware Components

9.2.1 Components and Controlling Connections

End Station	Vendor
• Diffractometer	Crystal Logic
• Auto Mounter Robot	Crystal Logic
• Dual Mode detector	ADSC
• Camera Server	Axis
• BPM System	BNL/Libera
Optics	
• Monochromator	Oxford FMB
• Mirror	Irelec
Insertion Device	
• Undulator	X25-NSLS
Control Computer	
• Intel based PC	

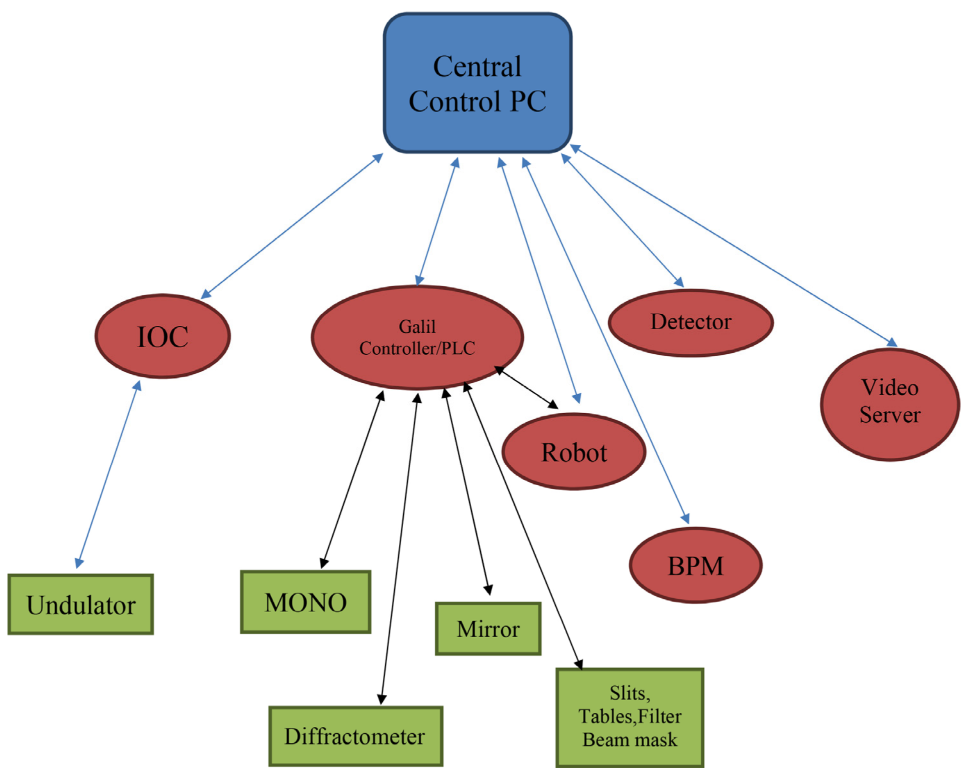

Figure 9-1. Connection schematics

9.2.2 Device and Interface List

Device Name	Function	Specification	controlled by	Interface	Protocol Name
GUI PC	User interface to control experiment	Intel Processor base PC	-	-	-
Galil Motor Controller	Control motors and encoders		GUI PC	eth	proprietary
Galil Pocket PLC	Analog Input Timer and Counter		GUI PC	eth	proprietary
Mean Well	Power Supply	24V-48V		eth	
Galil SCB 48316	K thermal card for reading motor temperature sensor	Galil	Galil	eth	analog
Renishaw	Encoder		Galil		quadrature
MicroE Mercury2000-MV	Encoder		Galil		quadrature
Phtron	Vacumm Motors		Galil		
PM170	McLennan servo driver		Galil	-	-
M543E	Mclennan Servo Motor for Phi		Galil		
Stogra SM56.2.18.J3	Steppers for Mirror		Galil		
VEXTA PK266M-03A	NSLS2 Stage		Galil		
Nanotec 2 phase	Stepper for 4 Jaw slits		Galil		
NEMA 17-4018	Stepper for Beam mask		Galil		
HaydonKerk 57H4A 3.25	Steppers for Crystal logic		Galil		

050 ENG 0716	diffractometer				
Oriental Motor AR66MA-N10-3	Stepper for Crystal logic table		Galil		
Lin WO-211-18-02D	Steppers for camera and sample stage		Galil		
FaulhaberAM15A0046	Steppers for Slits		Galil		
McLennan 23HSX206	Stepper for filter		Galil		
LS	Limit switches for motion	-	Galil	5v DIO	TRUE/FALSE
Physik Instrument P-841-30	Stain gauge for Mono Benders		Galil	0-10V	
PI E-500 Modular Piezo controller	Control Piezo		Galil	0-10V	
Infinity Strain Meter	Mirror bending force reader		Galil	0-10V	
IOC	Hosts PVs, integrates connected devices	NSLS2 compliant	GUI PC	eth	CA
PLC	Read temperature, implement Interlock logic	Allen Bradley Compact Logix	IOC	eth	EtherIP
GB	DeltaTau Geobrick IMS 2 Motion controller	BNL compliant	IOC	eth	DeltaTau proprietary

9.3 NYX Beamline Control System

The NYX control system has three components: the general user interface (GUI), the distributed control system server (DCSS) and the the distributed hardware server (DHS).

Blu-Ice provides the GUI for NYX beamline controls and it thereby interfaces with the DCSS and on to hardware elements through the DHS/EPICS Gateway (Figure 9-2).

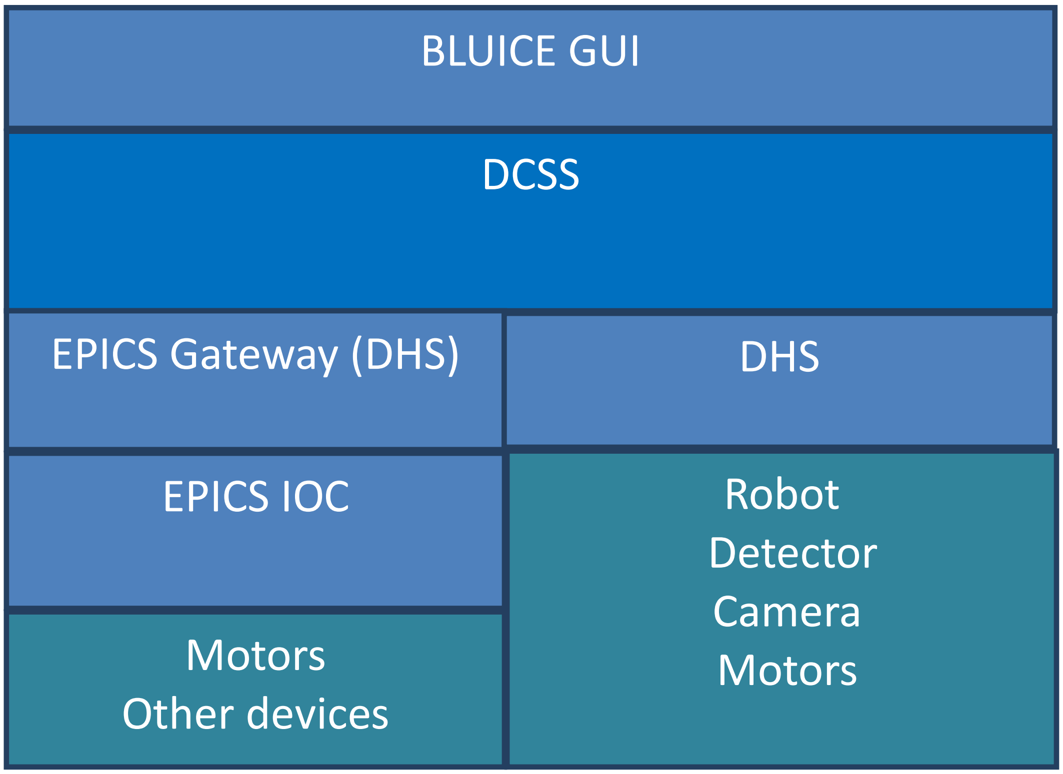

Figure 9-2. Blu-Ice Control Block Diagram

9.3.1 DCSS

Distributed Control System Server (DCSS) is a centralized sever. It handles the communications between GUI and DHS. It has two basic functions:

1. **Message handler:**

   It delivers messages from Blu-ice GUI to DHS to control the devices and broadcast messages from DHS to all the GUI

   GUI ←→ DCSS ←→ DHS ←→ Device

2. **Script Engine:**

   It also is a special Client called "self" for both DCSS and Blu-Ice GUI. It can receive all the messages from DHS and access all the DHS. It can execute the user defined scripts which controls devices.

   The DCSS is running in the Central Control PC.

9.3.2 DHS

Distributed Hardware Server is a program which talks directly to devices. It accept DCS messages and controls a piece of hardware directly. It reports the status of the device to the DCS.

9.3.3 Blu-Ice DCS Framework

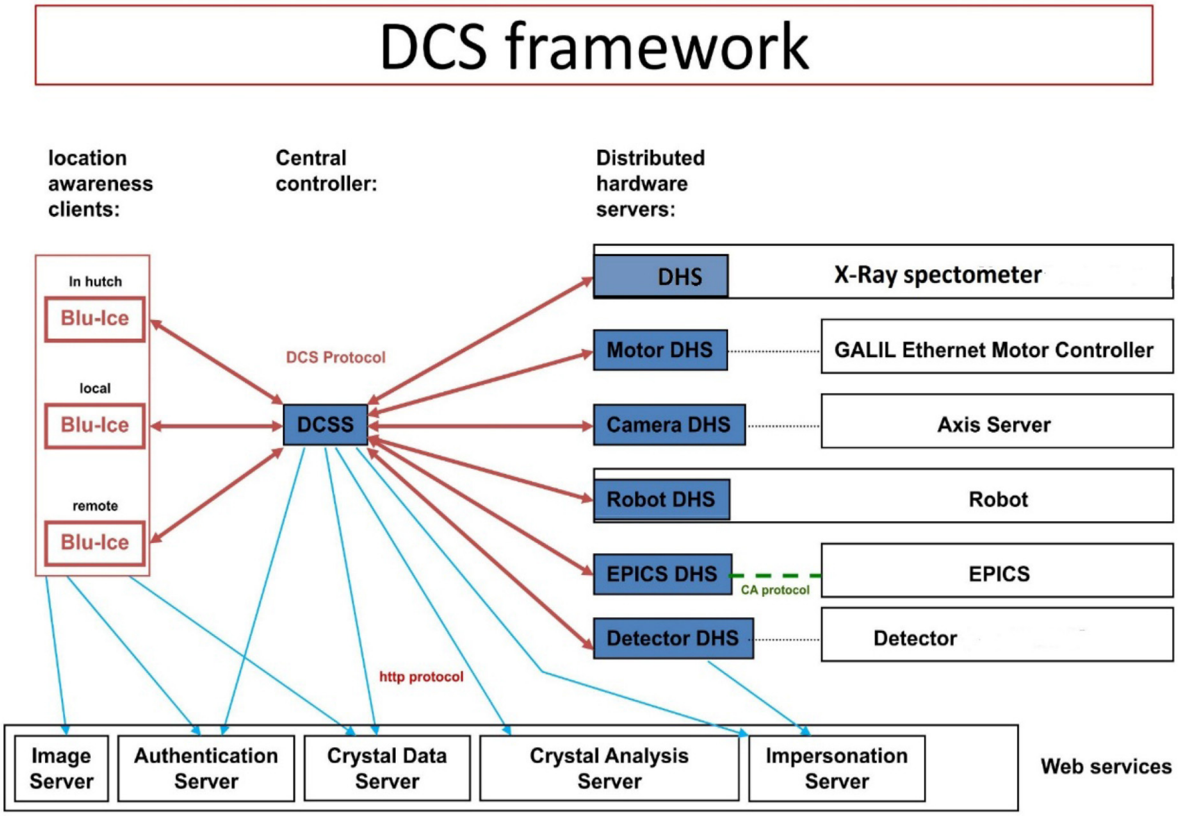

Figure 9-3. DCS Framework. This figure is courtesy of SSRL

Features of the framework include the following:

- **Central Control**
- **Security**
  - **Authentication Server**
  - **Impersonation Server**
- **Web-Ice service** [Reference 2]
  - **Crystal Information Server**
  - **Crystal Analyze Server**

9.3.4 Blu-Ice GUI

9.3.4.1 Hutch Tab

The **Hutch Tab** (Figure 9-4) allows the users to adjust various parameters for data collection.

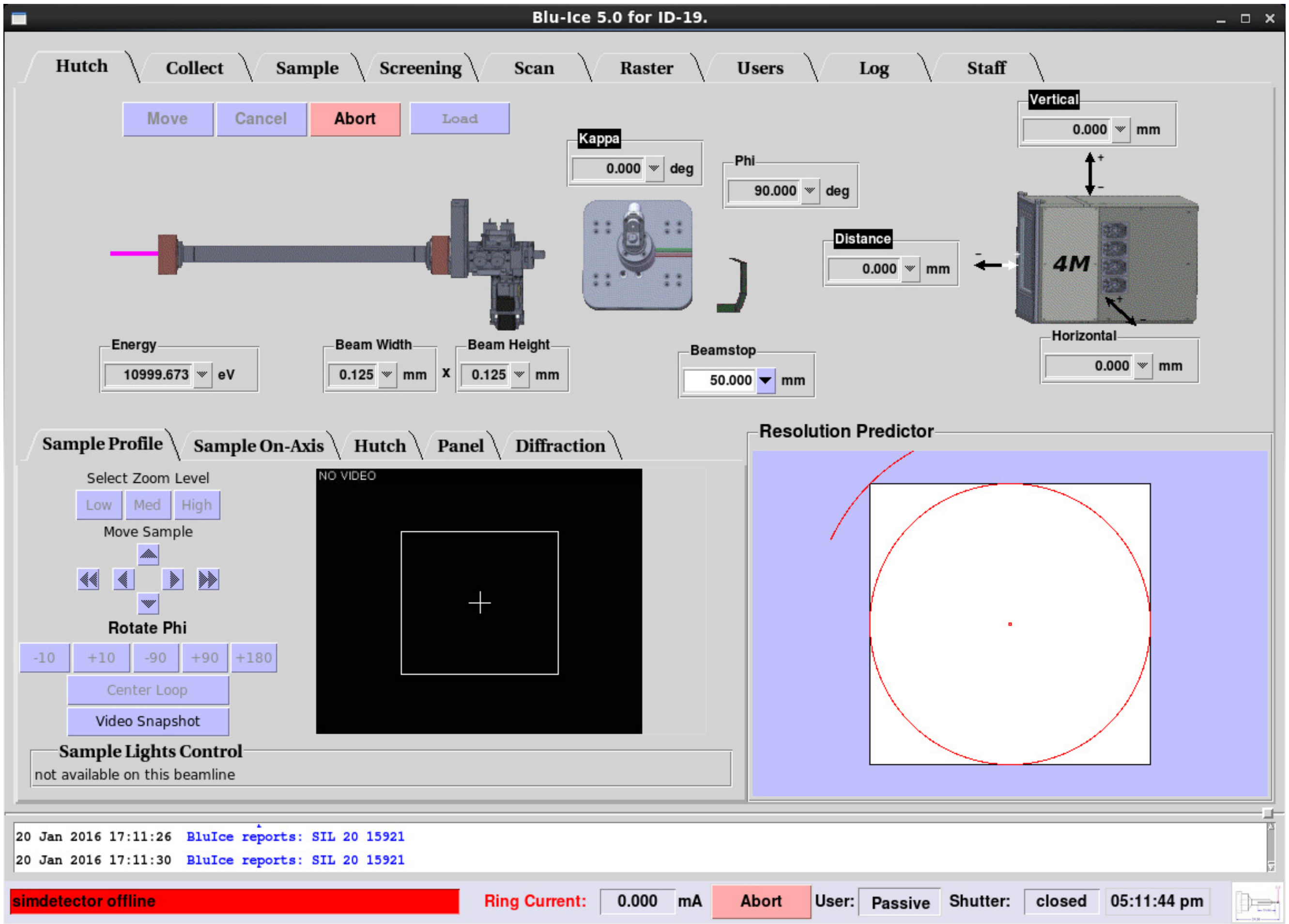

Figure 9-4. Hutch Tab

9.3.4.2 Data Collection Tab

The **Collect Tab** (Figure 9-5) is used for collecting test images and complete monochromatic, SAD and MAD data sets. Multiple run windows can be set up by creating additional Run Tabs.

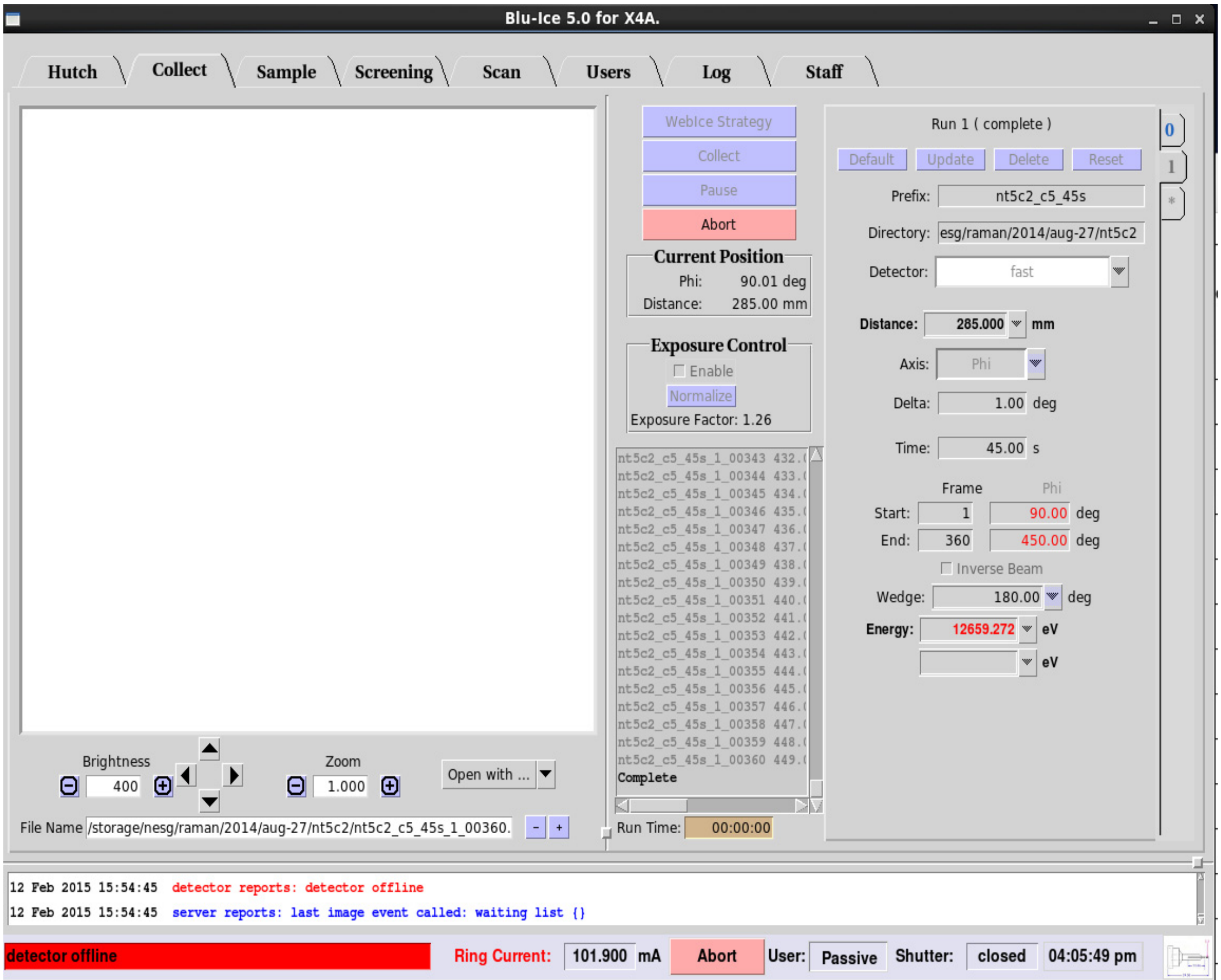

Figure 9-5. Data Collect Tab

9.3.4.3 Sample Tab

The **Sample Tab** (Figure 9-6) allows the user to prepare the sample for data collection: The user can change the sample camera zoom and adjust the sample position, change the beam size, mount and dismount additional samples with the SAM robot, remove ice, and anneal the crystal.

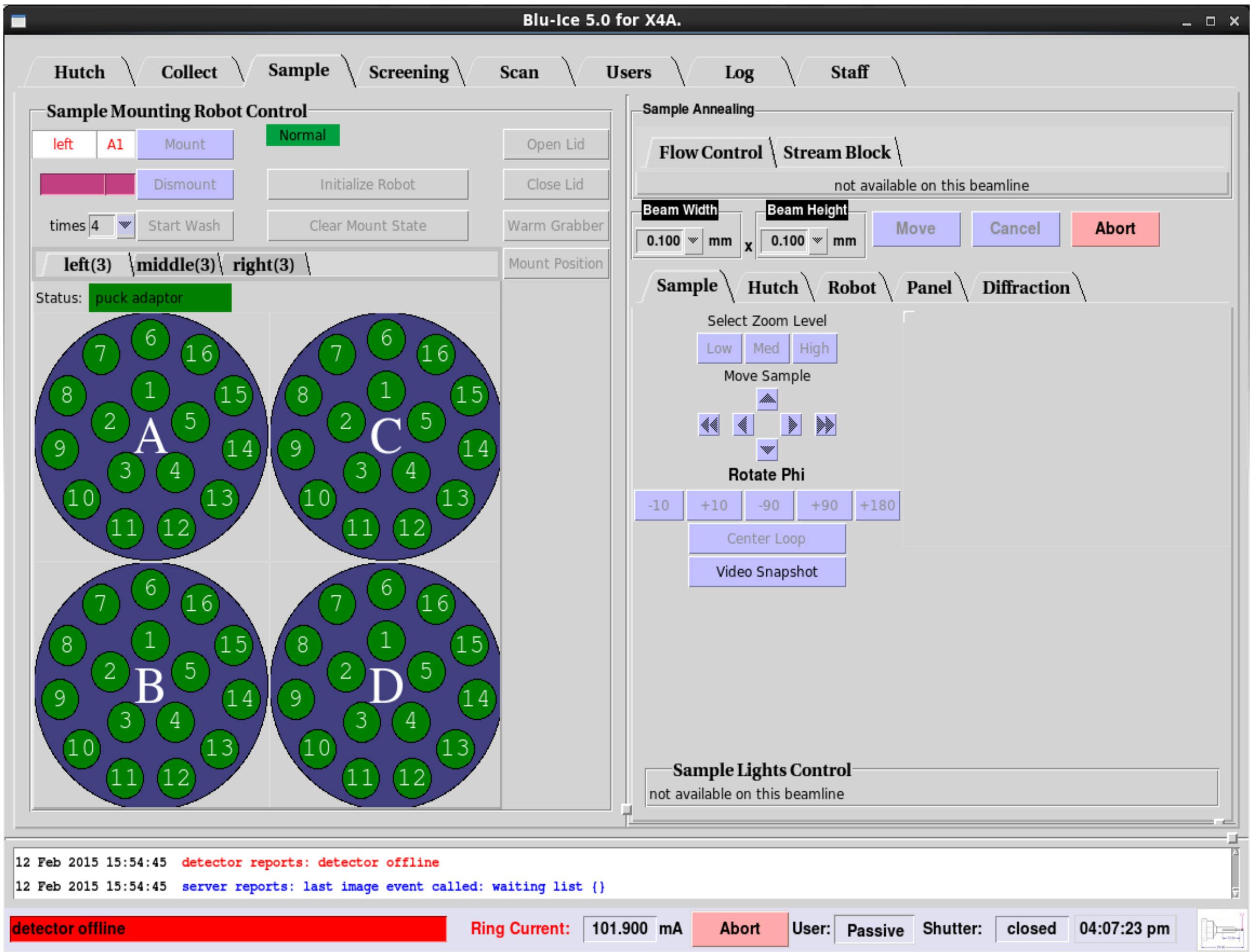

Figure 9-6. Sample Tab

9.3.4.4 Screening Tab

The **Screening Tab** (Figure 9-7) provides an interface for automatically screening samples. With this interface, the user selects multiple samples of interest from an embedded spreadsheet and defines the actions to be performed on each sample. Once started, the interface can run with minimal supervision until all of the samples have been screened identically.

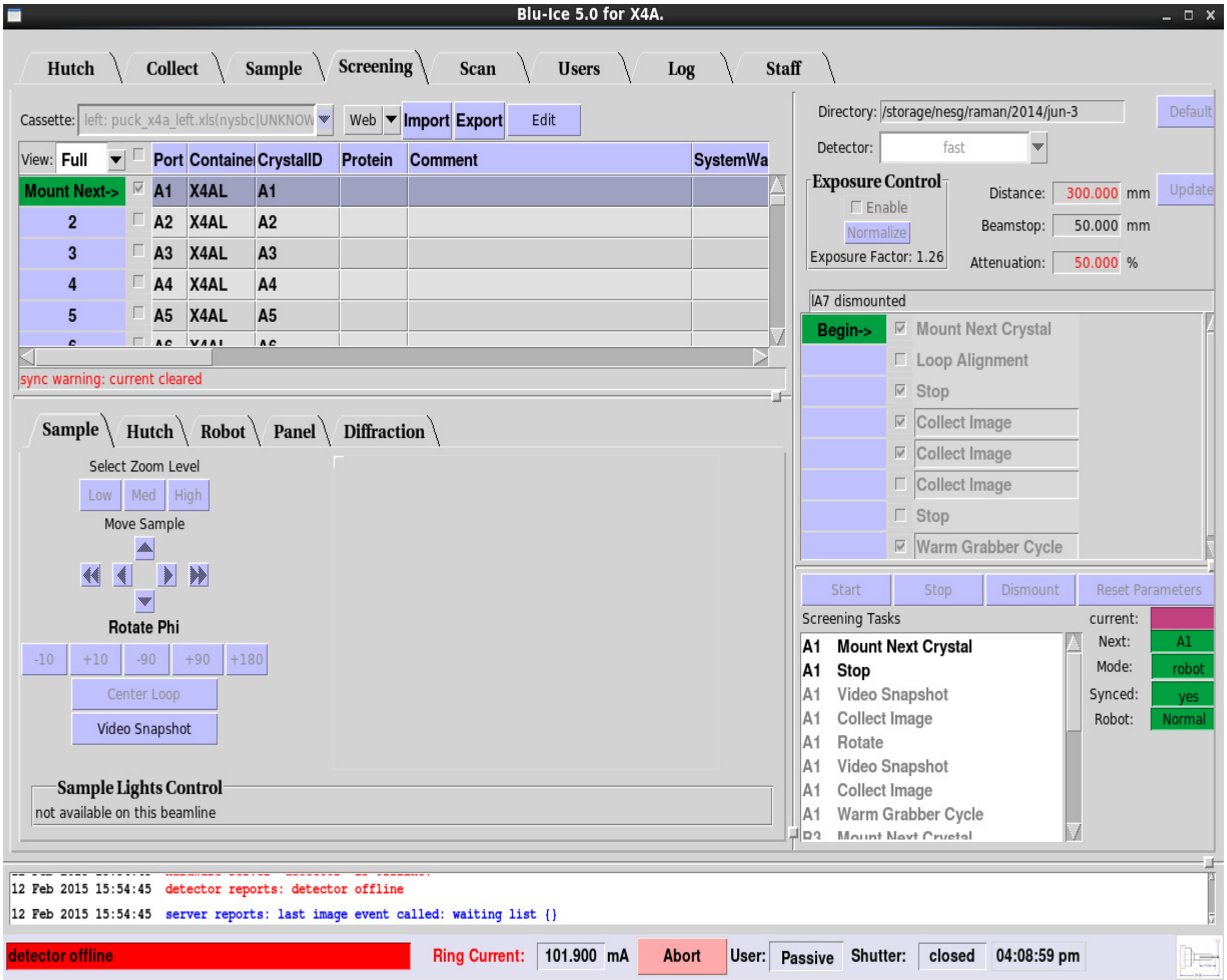

Figure 9-7. Screening Tab

9.3.4.5 Scan Tab

The **Scan Tab** (Figure 9-8) is used for energy and excitation scans. The energy (MAD) scans are used to select the appropriate wavelengths for anomalous dispersion experiments (optimized SAD and MAD). The excitation scan is useful to identify and verify the presence of anomalous scatterers in the sample.

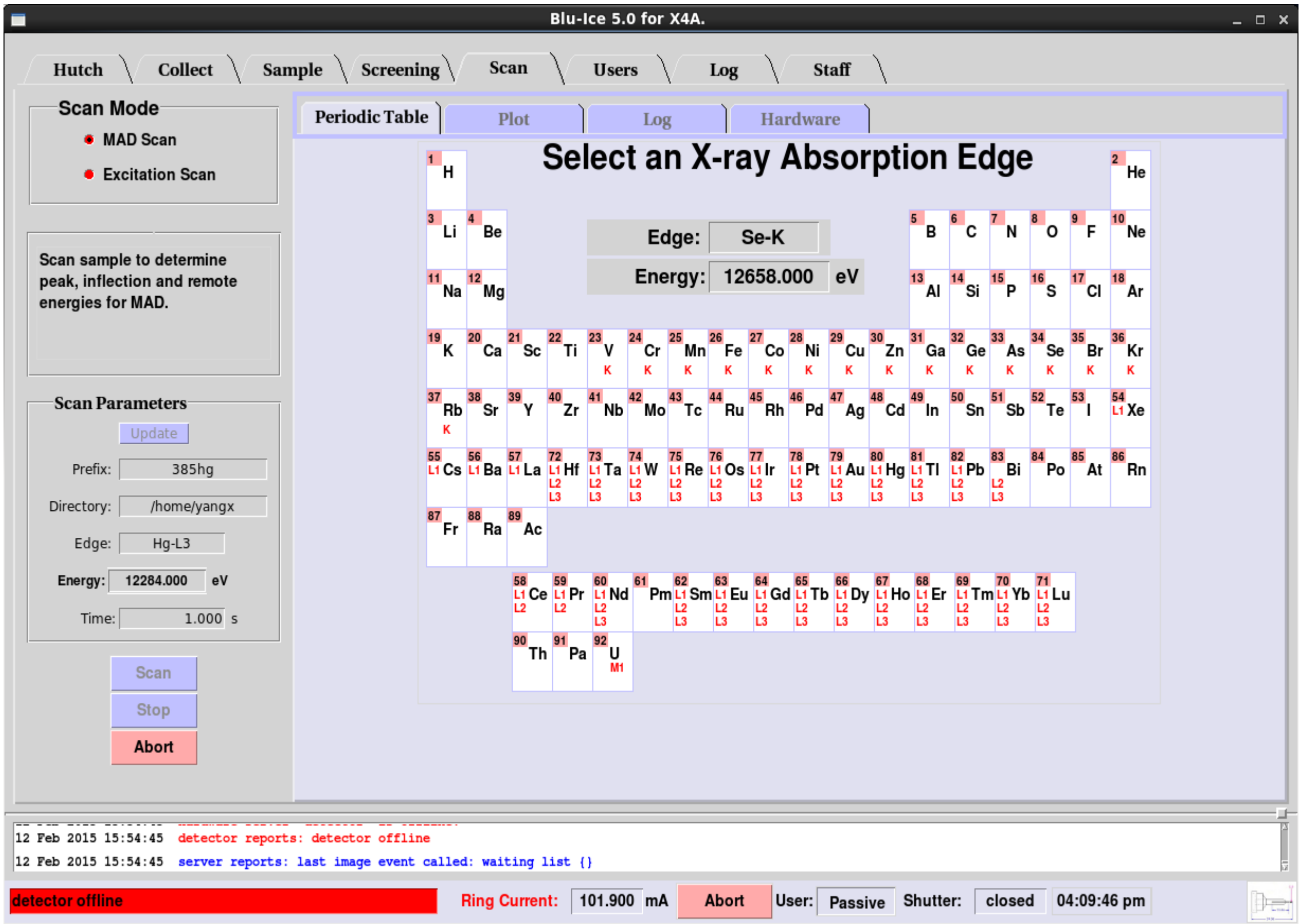

Figure 9-8. Scan Tab

9.3.4.6 Raster Tab

The **Raster Tab** (Figure 9-9) allows the user to search for and align crystals based on low level diffraction. This is carried out by defining a 3-dimensional raster, recording low level diffraction images, and then processing them with "Spotfinder" using a specialized input file tailored for weak low resolution spots and detector characteristics.

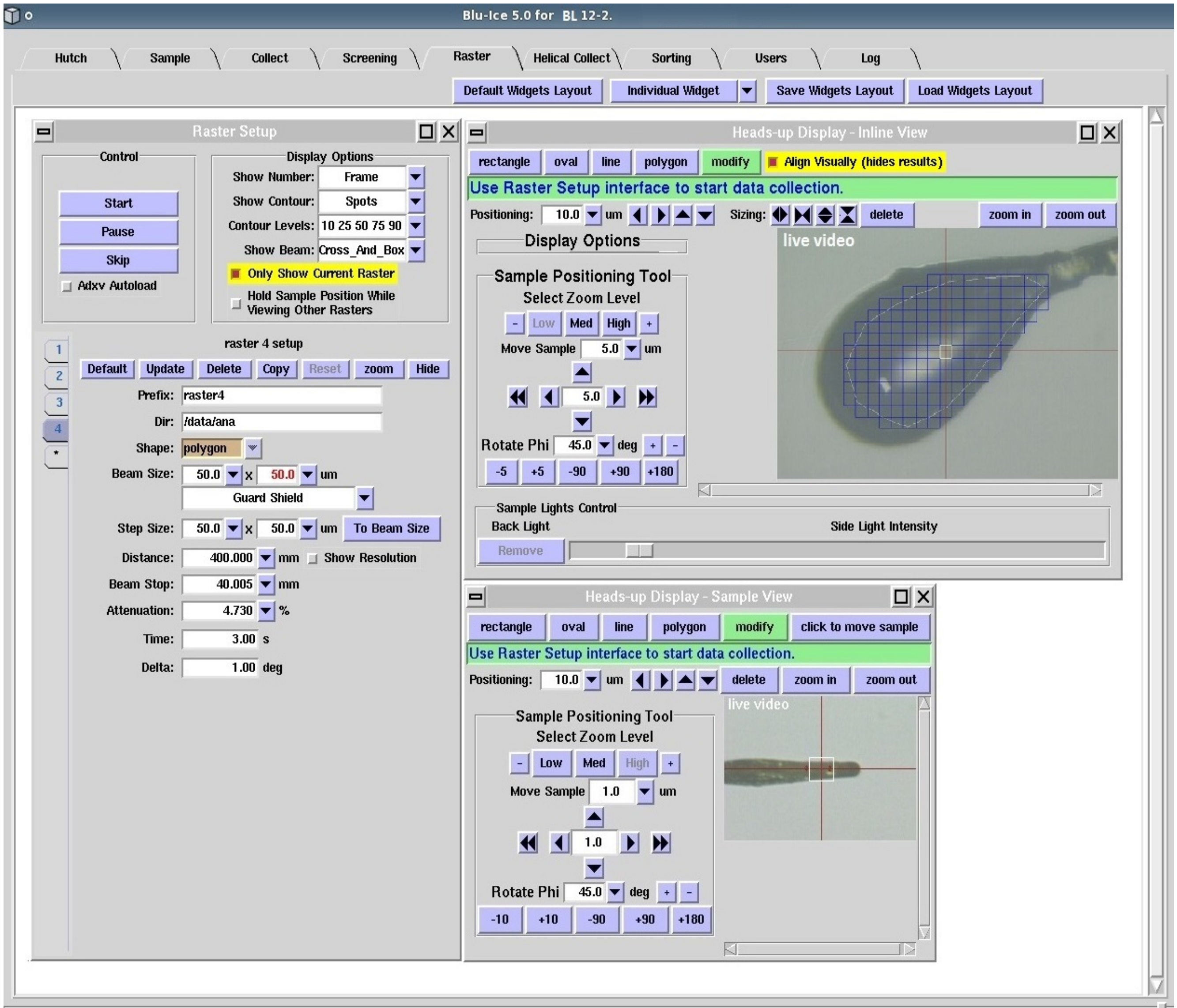

Figure 9-9. Raster Tab. This figure is courtesy of SSRL

9.3.4.7 Helical Collection Tab

The **Helical Tab** (Figure 9-10) allows collection of oscillation data while translating the crystal along the spindle axis: The software collects one oscillation image before moving the crystal to a new position and collecting a new image, with the new oscillation starting where the previous one ended.

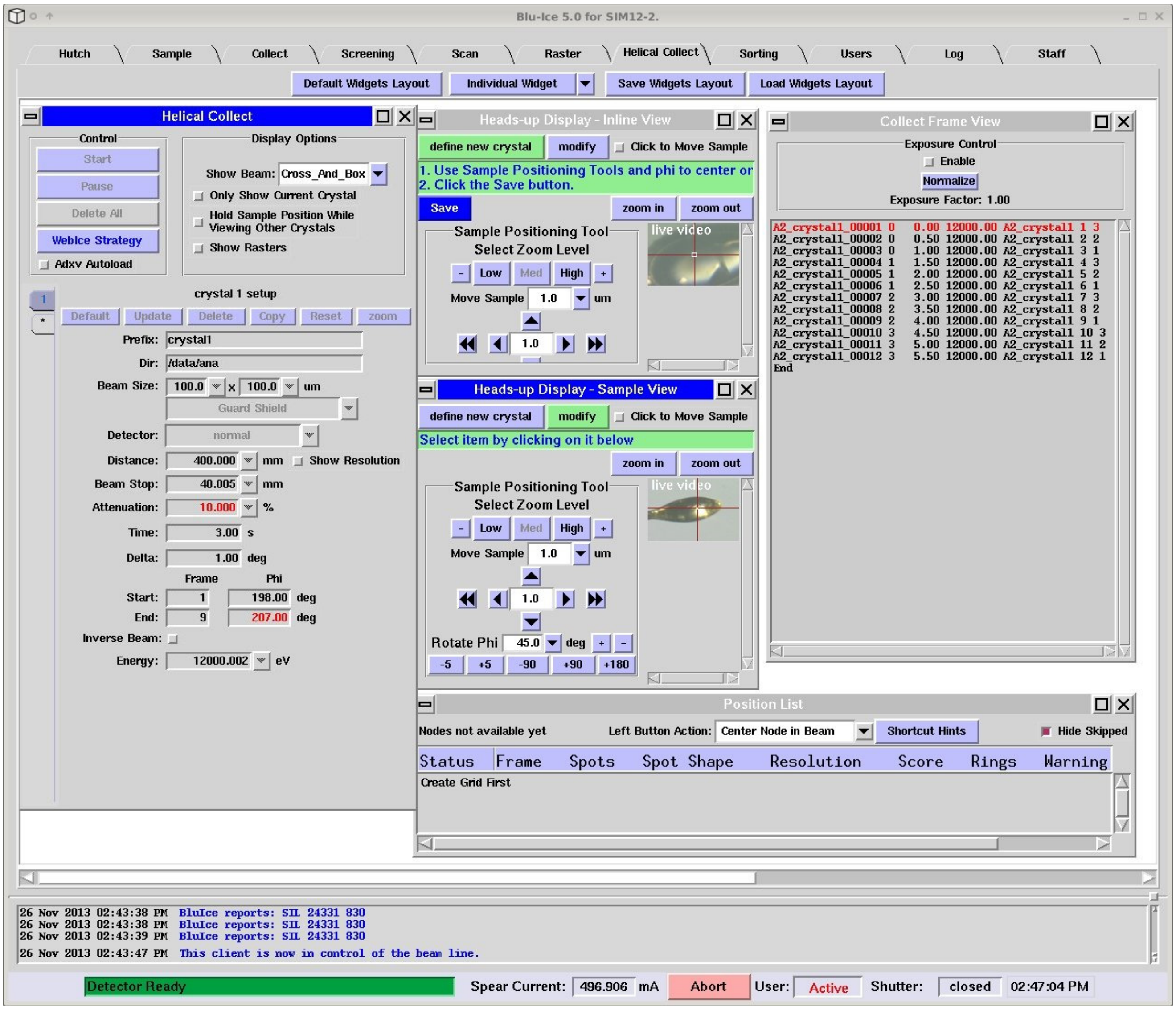

Figure 9-10. Helical Collection Tab. This figure is courtesy of SSRL

9.3.4 Summary on Blu-Ice

- Least risk (transition from X4 to NYX); Easy to manage for a small group with limited resource.
- Minimal development work required.
- Good support from SSRL.
- Takes advantages of other software associated with Blu-Ice like Web-Ice [Reference 2] and Autodrug [Reference 3].

9.3 Description and Distribution of Local Control Cabinets

There are four local control cabinets designated for the NYX beamline. There is an additional local control cabinet for the LAX line.

Each local control cabinet, as shown in Figure 9-11, contains motor controllers with drivers and ancillary components for up to 12 motions. Each cabinet will be mounted near the motors it drives, so motor and encoder cables will be kept short, as well as any other cables such as thermocouple. Each cabinet has its own internal DC power supplies, so the cabinet will need only a single AC cord for power, and an ethernet line for communications.

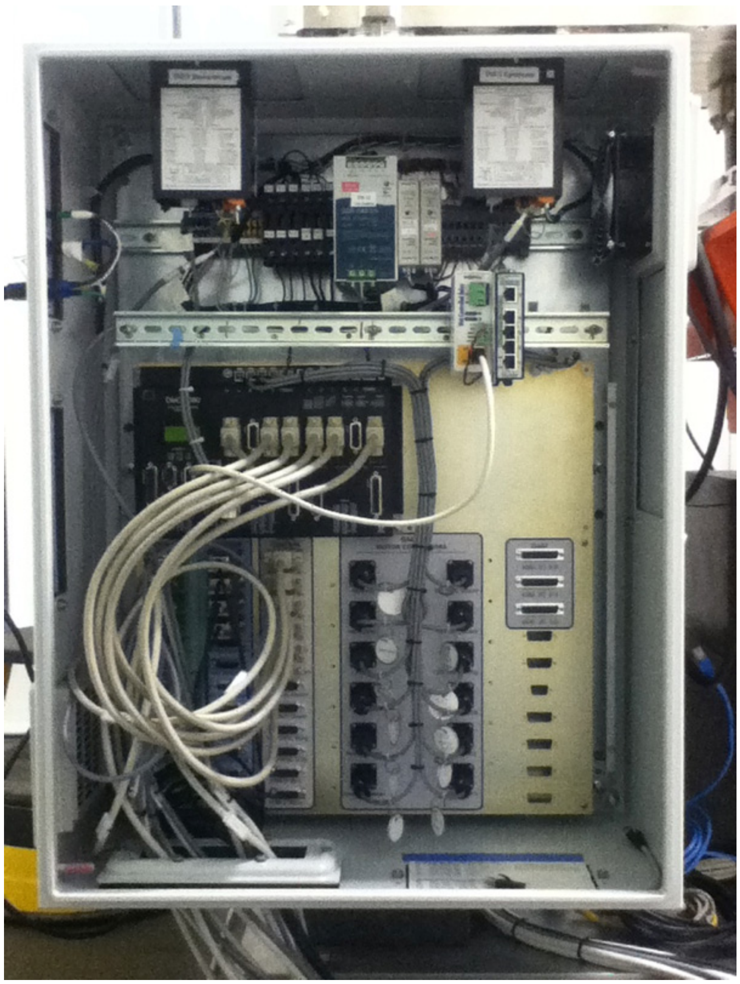

Figure 9-11. An NYX Local Control Cabinet

Locations:

For the NYX line, there are four designated cabinets: LCC2, LCC3, LCC4, and LCC5.

LCC2 will be mounted on the upstream C-hutch wall and will control beam position monitor 1, an aperture, and filters.

LCC3 will be mounted in the C-hutch on the monochromator plinth and control the monochromator motions as well as beam position monitor 2.

LCC4 will be mounted in the C-hutch on the mirror plinth, and will control the motions of the mirror as well as the 4-jaw slits and beam position monitor 3.

LCC5 will be mounted in the D-hutch on the pathway stand, and will control the four motions of the pathway.

The control cabinets are 600mm x 800mm x 300mm, and are manufactured by Hoffman. They are sealed with high-density foam gasketing on all removable panels and the door, and use Roxtec glands for cable entry. There is a fan and a passive vent.

The contents of each cabinet are arranged around a large aluminum patch panel, which serves to mount the Galil motor drivers, as well as all the connectors needed to interface the Galils with the motors. In addition, each cabinet has two DIN rails to mount DIN components.

The large aluminum panel on which the Galil drivers are mounted acts as an additional heat sink. Then, forced air cooling removes the heat from the cabinet. There is a passive vent on the lower right of the cabinet, and a five inch fan blowing air out on the upper right of the cabinet, drawing air across the Galils.

The electronic components common to every LCC are:

Galil DCM-4080 – 8-motion controller/driver

Galil DCM-4040 – 8-motion controller/driver

Meanwell SDR-240-24 - 10amp 24vdc power supply – for Galil and motor power

(2) Meanwell MDR-20-24 - 1 amp 24vdc power supplies – for Netswitch and Web-relay

Stride Netswitch SE-SW5U-WT - to distribute ethernet within the cabinet

Xytronix WebRelay X-WR-1R12-1I5-I to enable a remote shutdown function

Location-specific components:

Also, there are a few location-specific components, such as the readouts for the strain gauges on the mirror (LCC4), and the crystal heater with its power supply for the monochromator (LCC3).

Components specific to the monochromator cabinet, LCC3, are:

Jumo Ctron crystal heater and power supply

Components specific to the mirror cabinet, LCC4, are:

(2) Rockport INFS strain gauge readouts for the mirror bender

In each cabinet there is a power distribution harness for AC and DC which uses DIN terminal blocks and fuses. The cabinet has a main fuse, and each AC powered device within the cabinet has its own fuse, this includes the DC power supplies as well as the fan. In addition, each DC powered item has its own fuse, this includes each Galil drivers as well as the DIN components such as the Netswitch.

The patch panel:

In brief, the Galil groups its motor output on one connector (per motion), and its limit and encoder together on a second connector, whereas we need a different grouping: we use the motor and limit signals grouped together on one connector (per motion), and the encoder on a second connector. So, the panel’s main patch function is to provide this regrouping for twelve motions.

9.5 Description and Distribution of Racks

There are eight equipment racks distributed along the NYX beamlines. The configuration adopted by NYX consist of commercially available NEMA-12 racks integrated with industry standard pannel mounted heat exchangers (Figure 9-12). This configuration is similar to what was implemented by the NSLS-II accelerator group for more than 800 racks used to enclose accelerator power supplies and instruments. The panel mounted heat exchangers are attached to the side of each group of racks avoiding over head water connections and eliminating equipment damage due to water leaks. Conforming to NEMA-12 restricts air infiltration which provides automatic fire saftey by oxygen starvation in the event of equipment failure. To manage the loss of the cooling supply water while the equipment contained in the racks are actively rejecting heat, the electrical power will be latched with power relays activaed by passive temperture alarm in each heat exchanger. The following is the distrubution of rack on NYX. One is near the A-hutch and reserved for the LAX beamline. The remaining seven are dedicated to the NYX beamline. All the racks are identical and connected in groups of two and three. Each rack has both UPS power and unconditioned power.

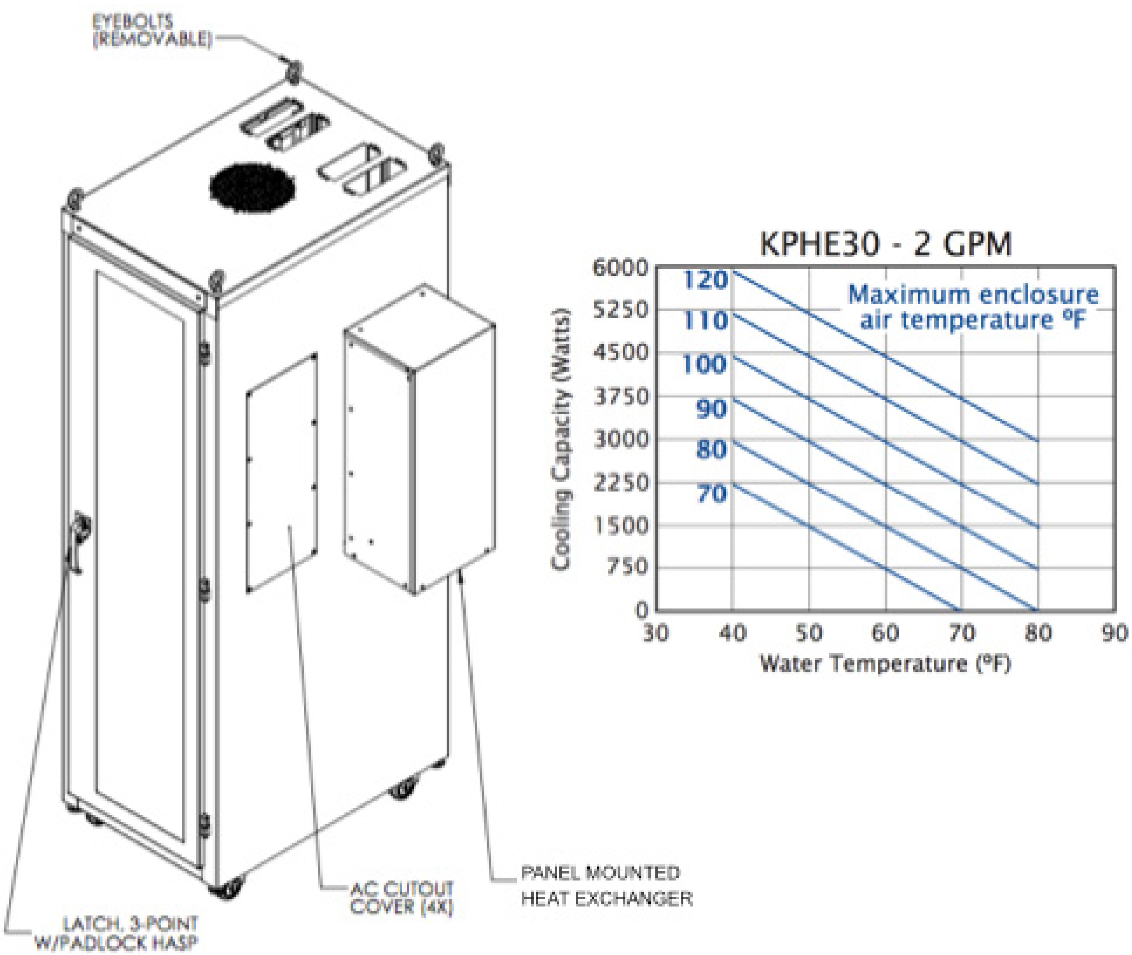

Figure 9-12. NYX Equipment Rack

NYX Rack Locations:

The racks will be distributed along the NYX beamline as shown in Figure 9-13.

There is a group of two racks on the outside end of the D-hutch that will be used for control and data collection systems and computers.

There is group of two racks on the roof of the D-hutch that will be used for Ion pump controllers, gauging controllers, and any diamond detector equipment which cannot fit inside the D-hutch.

There is a group of three racks on top of the C-hutch that will be used for Ion pump controllers, gauging controllers, and any other support equipment for the C-hutch.

There will be space available in all racks for EPS units, so they can be placed where needed.

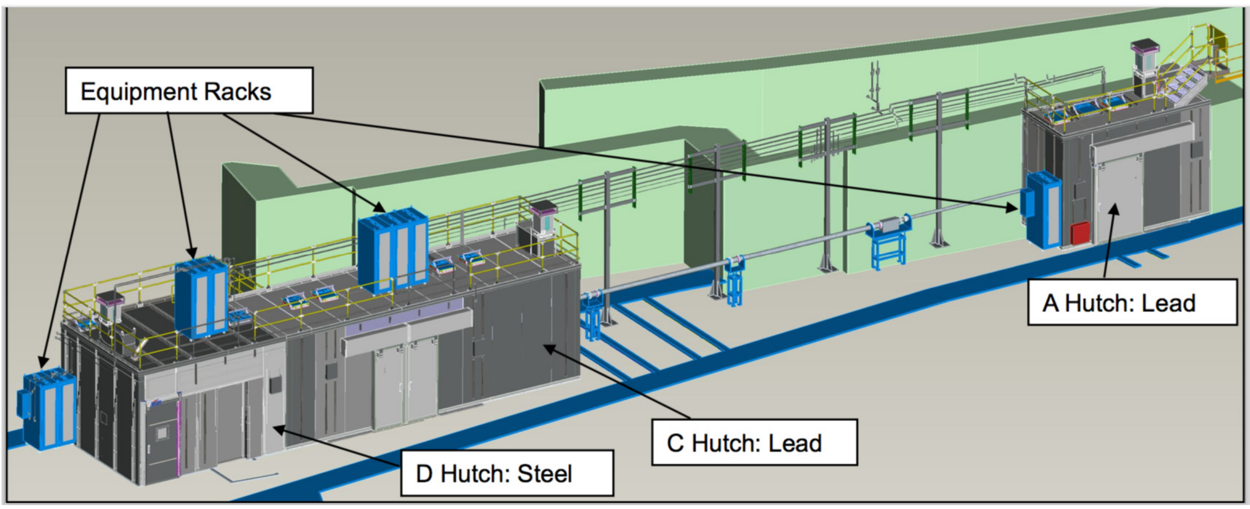

Figure 9-13. Distribution of NYX Equipment Racks

9.5 Cables and Interconnectivity

Most of the electronic control system cabling, motor, limit, and encoder, will be provided by the vendors who supply the connected equipment: Irelec for the Mirror, and Oxford for the Monochromator, Slits, Filters, and Apertures. These cables will run directly from the respective unit to the assigned local control cabinet, and will not run in cable trays.

We will be making the motor, limit, and encoder cables for the Beam Position Monitors, and for the D-hutch pathway. Cables will be constructed of PVC multi-conductor cable, with motor/limit cables being terminated at the motor side with 12 pin metal Trim-Trio connectors, and at the control cabinet/patch panel side with fifteen-pin D-sub connectors.

The local control cabinets are connected to the beamline control computer by ethernet cables. These cables will run through hutch walls and in cable trays, so will have to be LSZH.