

## NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY

The overall mission of the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University is to provide forefront research opportunities with stable and rare isotope beams. A broad research program is made possible by the large range of accelerated primary and secondary (rare isotope) beams provided by the facility. The major research thrust is to determine the nature and properties of atomic nuclei, especially those near the limits of nuclear stability. Other major activities are related to nuclear properties that influence stellar evolution, explosive phenomena in the cosmos (e.g. supernovae and x-ray bursts), and the synthesis of the heavy elements; and research and development in accelerator and instrumentation physics, including the development of superconducting radiofrequency cavities and design concepts for future accelerators for basic research and societal applications. In all activities an important part of the NSCL program is the training of the next generation of scientists. Upon completion of the DOE-funded Facility for Rare Isotope Beams (FRIB), the laboratory will transition to programs with beams from this facility.

NSCL operates two coupled cyclotrons, which accelerate stable ion beams to energies of up to 170 MeV/u. Rare isotope beams are produced by projectile fragmentation and separated in-flight in the A1900 fragment separator. For experiments with high-quality rare isotope beams at an energy of a few MeV/u, the high-energy rare isotope beams are transported to a He gas cell for thermalization, and then sent to the ReA linear post-accelerator for reacceleration. Rare isotope beams in this energy range allow nuclear physics experiments such as low-energy Coulomb excitation and transfer reaction studies as well as for the precise study of astrophysical reactions. The facility has produced over 904 rare isotope beams for experiments, and 65 new isotopes have been discovered at NSCL.

NSCL is a national user facility and has a large user community with over 800 actual, active users in a given year. Most experiments conducted at NSCL involve international collaborations with about 75% of the experiments lead by a US spokesperson.

NSCL provides beams to approximately 30 experiments per year. Experiments are short (~3-7 days) with many changes during and in between experiments. Data acquisition and analysis and simulation framework need to support fast online decision making. Experiments have increased significantly in complexity with an increase of the number of channels read out, often together with high-resolution digitized waveform data. Each experiment can generate up to 10 TB of experimental data set. Storage and backup systems must match such data sizes. Data sets are analyzed on-line during the data acquisition and later off-line either at NSCL or at the spokesperson's institution. Experiments with in-house spokespersons require long-term storage (usually a few years) of the full data set and adequate computing resources for analysis. A computing cluster in the order of 1000 cores dedicated for online analysis is foreseen. Network bandwidths of 100 Gbit/s will be required. External data transfer capabilities must continue to accommodate the needs of a large and distributed user community with increased data set sizes. Data sets are provided to experimenters via magnetic tape, though other methods are available.

NSCL CI supports and enables the Laboratory overall mission. CI includes a broad range of functional areas: business support information technology, networking, accelerator controls, experimental controls and DAQ, and offline simulation and analysis. Internally developed and commercial solutions are used. Systems are primarily managed and maintained by Laboratory

personnel. CI challenges include increasing security requirements, Laboratory growth with FRIB planning and construction, and increasing and foreseen experimental needs.

The Business IT department provides a range of enterprise IT services directly supporting business processes including an internally hosted ERP suite and other customized COTS solutions. Windows based services including Active Directory, Exchange, SharePoint are deployed. More than 500 Windows desktop PCs are maintained.

Business IT department also maintains the Lab-wide network, servers and storage used by DAQ and NSCL Controls and is responsible for overall IT security.

Internet is provided via MSU with MSU assisting with Internet security. Laboratory wired networks are managed internally with MSU supporting wireless access.

The Controls department is responsible for hardware and software controls for accelerators, beamlines, and other experimental equipment. The controls system uses EPICS protocols with graphical monitoring using CS-Studio. NSCL personnel are active in development of both projects. A number of associated systems provide alarms, access controls, archiving etc. for EPICS.

With construction of the FRIB accelerator progressing, new accelerator and cryogenic controls networks are being deployed. These are also EPICS based. The designs emphasis security with FRIB Controls network isolated from other Laboratory systems.

In house developed software forms the core of the DAQ systems. NSCLDAQ is a modular system supporting a range of experiment arrangements. SpecTcl is a compatible analysis software. DDAS is an internally developed digital-DAQ, supporting XIA Pixie-16 Digitizer and compatible with NSCLDAQ. As a user facility, NSCL provides DAQ assistance to visiting experimenters. Typical experiments produce approximately 100 GB of data per day with experiments storing digitized waveforms producing ~1 TB per day. Currently, most experiments' needs are met with 1GE networking and several DAQ computers. Data is recorded to ZFS/Linux servers. Reliability is critical as experiments' beam times are generally limited for less than one week. Visiting experimenters may make use of DAQ systems while present at NSCL.

Increasingly, flexible CPU and software systems are used for DAQ. One purpose is distinguishing overlapping waveform signals from higher rate experiments. The GRETINA experiment is active at NSCL currently utilizing a dedicated farm of approximately 100 PC nodes (1000 cores) for selecting events based on digitized waveforms.

Offline simulations and analysis systems are provided for Laboratory students, faculty and staff. Clustered interactive Linux hosts and a small (~50 node) Linux SLURM batch system are available. Approximately 1 PB of networked research storage is available using ZFS/Linux systems with NFS. Increasing detector complexity, data volumes and analysis complexity require increasing simulation and analysis capacity. Free and widely used applications such as ROOT and GEANT are the norm.