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NSLS-II INJECTOR HIGH LEVEL APPLICATION TOOLS*

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Abstract

The National Synchrotron Light Source II (NSLS-II) is a state of the art 3 GeV third generation light source at Brookhaven National Laboratory. The injection system consists of a 200 MeV linac, a 3 GeV booster synchrotron and transfer lines in connection of linac, booster and storage ring. The transfer lines, designed and built from BNL, are equipped with sufficient diagnostics to commission to characterize the beam parameters from linac and booster. In the paper, we summarized the high level applications tools, beam emittance, energy and energy spread measurement, developed during the injector commissioning.

INTRODUCTION

The NSLS-II [1] is a state of the art 3 GeV third generation synchrotron light source at Brookhaven National Laboratory. It consists of a 200 MeV linac, a booster ring accelerating beam from 200 MeV to 3 GeV, a 3 GeV Storage ring and transport lines in between them. Both transfer lines are equipped with sufficient diagnostics to commission along with linac/booster and characterize their beam parameters.

As many other facilities [2,3], NSLS II chose the Experimental Physics and Industrial Control System (EPICS) as its control system to monitor and control the accelerator hardware. It interfaces to the accelerator instruments and devices (such as Power supply, digitizer, and motor) with IOC (Input Output Controllers). Channel Access is used as the interface to the machine process variables (PVs).

The typical operation applications include two types, simple monitor/control device and complex accelerator physics application for studies and machine optimization (measurements, data analyses and applying correction). Mainly, we use cothread to access the process variables (PVs) in Python script for complex accelerator physics applications and the CSS (BOY) [4] panel for simple tasks such as monitoring, displaying and setting of the machine Process Variables (PVs). Besides, MATLAB is also available as an alternative tool and EDM panels are used for Linac control system from the linac vendor Research Instruments, GmbH. All source codes including panel configurations are controlled and managed by mercurial version in the control system.

Both Python and CSS are new environment for accelerator control. Python has a lot of libraries and strong support from scientific computing community. It has very powerful functions for scientific calculation and logic control. CSS has simple feature to display/control PVs with simultaneous data sharing environment, but with a lot of new features for operations convenience, such as create olog entry, data browser to view history, et.al, which benefits the strong support from control group. So NSLS II all the related commissioning and operation tools are developed from scratch. In fact, a lot of highly operation demanding high level applications were developed based on soft IOCs and combined python and CSS advantages together with powerful calculation and convenient display interface.

To keep the beam commissioning time efficient, we did the the subsystem integration test and extended integration test [5]. In this paper, we'll present main applications for injector commissioning and operation.

MACHINE STATUS APPLICATION

All of the monitor and control panels are created with software tools in Control System Studio [6] (CSS), which is an Eclipse-based collection of tools to monitor and operate large scale control systems. The interface allows the operators to edit the desired ramp/soak profiles and provides the option to use predefined recipes.

The NSLS-II operation panels [7] include the user panels and the expert panels. They display the device status and parameters (setpoint and readback) and show the device performance. A user panel shows only information that user is required, such as the magnet current setpoint and readback. The expert panel shows all the information that expert can fully control the device or diagnose the device, such as power supply operation mode and magnet temperature.

Figure 1 shows one example for BR current monitor, include the FCT output for each turn current and number of bunches, the DCCT beam current along ramping, which average many turns data signal.

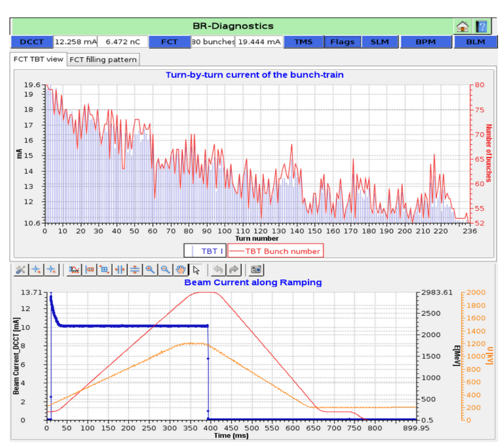

Figure 1: Booster ring current monitor along ramping.

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HIGH LEVEL APPLICATIONS

Besides the devices status and control, we also develop high level applications to realize the accelerator physics application tools. It is to translate the raw/processed data from PV to the "physics" parameters, such as from the beam size reading from flags for beam emittance or beam energy measurement. The source codes for scientific calculation are programmed with Python, but not limited, and the code operation and interesting input/output data communication are realized through IOCs. Their GUIs are implemented in the CSS, as part of operator panels, so that the operators have consistent operation interface environment and live information. The user can set parameters and monitor the progress in GUI as regular device PV set and monitor.

These are the advantages of using soft IOCs. Firstly, users do not need to know how to run different language code. Second, users simultaneously share the same information through PVs. Third, it avoids the code path dependence. CSS or user does not need to know where code is and what the script is. Finally, the related indirect hardware operation activity can be archived, which is very important for machine monitor and problem diagnoses.

But soft IOC also has limitations, including that the code depends on the soft IOC status and CSS has limited plot function feature.

In the following part, we'll show the applications that are developed in softiocs for operation purpose and general beam studies: emittance measurement, energy spectrum, BPM slicer, online model.

Emittance Measurement

In both Linac-to-Booster and Booster-to-SR transport line, there are designed with one section of dispersion free region for beam emittance measurement and Twiss parameters measurement. Figure 2 shows the screenshot of BTS emittance measurement with quads scan method. This application scans quad current with user defined range and step size while recording the beam size average value and error bar in the OTR/YAG screen. The fitted beam emittance is based on thin length quad model.

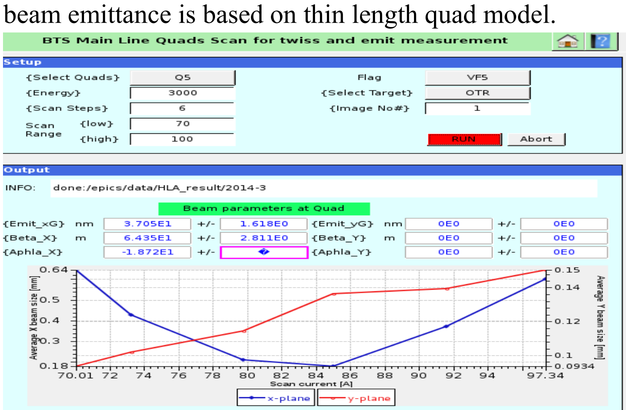

Figure 2: Beam emittance measurement with Quad scan.

The measured Twiss parameters are used in the model for optics match to determine the dispersion free region quads optimal setting. The Linac exit Twiss parameters is in a large range, but a triplet quads are there to adjust them closer to model. The Booster exit Twiss parameters are measured after a dispersion section, but pretty stable.

Energy Spectrum

In both Linac-to-Booster and Booster-to-SR transport line, there is one flag, after energy slits, located in the large dispersion region for beam energy and energy spread measurement. Figure 3 shows the screenshot of energy spectrum application. It is in continuous mode, which means whenever the beam image updates, the beam energy and energy spread application run correspondingly. The energy slit has µm precision position control and are used for image calibration. It shows the beam image, horizontal beam profile, beam energy, beam energy spread, and the charge ratio in every 0.5% energy deviation and user defined region charge ratio. As it is based on IOCs, so it can record the beam stability history into archive system for long term comparison.

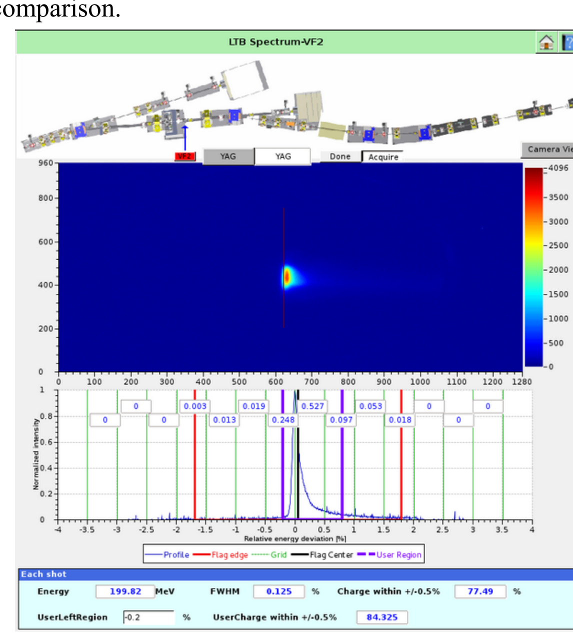

Figure 3: Screenshot of beam energy and energy spread measurement with flag VF2 in LTB transport line.

BR BPM Slicer

BPMs slicer page was initially developed to monitor the beam injection status. Later more and more featured were added. Figure 4 shows BPMs slicer application page. It reads all the BPMs TBT and FA and displays/manipulate the same turn data in waveform. It displays BPMs healthy status, sets all BPMs into different mode user defined delay, displays turn by turn data position and sum signal and compare the difference, 10 kHz data position and sum signal and compare the difference. This application is convenient to find beam loss location and loss turns, monitor the injection beam mismatched induced betatron and synchrotron oscillation, monitor the beam extraction delay. As TBT data has limited wavelength, 4k turns, but beam circulates in BR 800k turns, the TBT offset was used to see different section of ramping status. FA data is 0.9 s long to cover

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the whole ramping process status, the slicer index is user defined to select interesting energy region orbit.

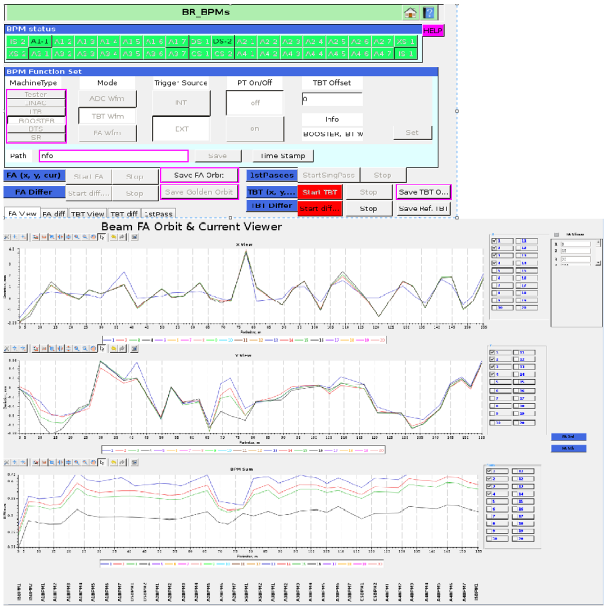

Figure 4: BR BPMs slicer application.

Online Model

Online model was developed for Booster and transport line to show live machine twiss parameters, dispersion, beam size, along with designed model. Figure 5 shows BTS live machine model.

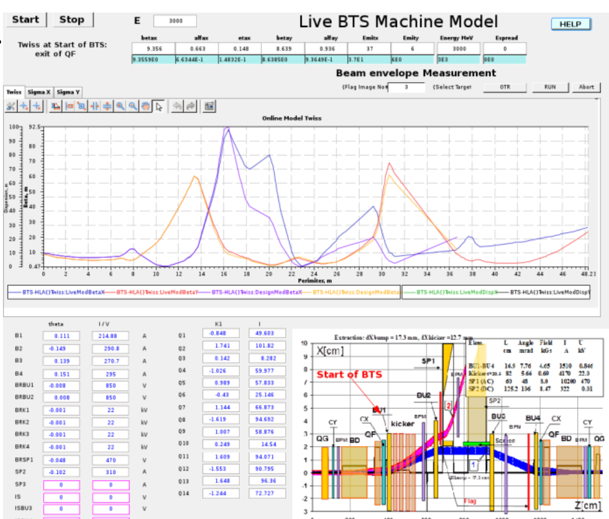

Figure 5: CSS GUI of BTS live machine model.

The program reads dipoles and quads set point, but only quads are used for online model calculation, as dipoles may introduce large trajectory and dispersion error. After converting the machine setting into the physics unit, elegant is called to calculate the live machine twiss. The twiss, beam emittance, and beam energy and energy spread at the start of BSR line is obtained from the Booster design values, or input them based the measurement result.

Besides this, there also other applications for commissioning and study, such as the BR beam orbit correction along ramping, BR emittance and energy spread measurement along ramping. The beam orbit correction along ramping selected forty orbits along ramp and correct orbit distortion at these points and the ramping table are generated with interpolation method. There are two synchrotron light monitors at BR with different dispersion source points. They can collect 10 frames image along ramping. Based on designed Twiss parameters, the beam emittance and energy spread can be measured.

CONCLUSION

A set of high level application tools had been developed for NSLS II injector commissioning and operation. Most of them are developed in softIOCs, so that it minimizes the code knowledge requirement and the operators have consistent operation interface environment and live information and the data result are saved into archive database.

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