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SUMMARY OF THE COMMISSIONING AND OPERATIONS AND PERFORMANCE WORKING GROUP FOR HB2023 WORKSHOP

N. Milas, European Spallation Source ERIC, Lund, Sweden
M. Bai, SLAC, Palo Alto, USA
S. Wang, IHEP, Beijing, People's Republic of China

Abstract

As hadron machines enter the multi-megawatt era issues such as machine activation caused by beam loss, machine protection and machine availability become more critical concerns. The operational experience of the high power, high intensity facilities in these areas is compared. In addition, upgrade plans and commissioning results are discussed and operational optimizations and routines and presented.

INTRODUCTION

In this working group, the focus was on the commissioning and operational advancements within high intensity hadron facilities. Commissioning developments included the initial results from global facilities like ESS, GANIL, Spiral 2, and LIPAc. On the operational front, a prevalent theme was high power operation, exemplified by the multi-megawatt beam operation at facilities such as SNS, FRIB, and J-PARC, along with their upcoming upgrade plans. Particularly significant was the progress at HIPA in PSI, which has seen a remarkable 24-fold increase in its original design power, alongside components reaching the impressive milestone of 60 years of operation. The presentation encompassed an overview of maintenance strategies and a roadmap for ensuring continuous, reliable operations.

Additionally, high power facilities main challenges are related to machine protection, residual activation resulting from uncontrolled beam loss, and machine reliability. Insights from major facilities such as ISIS, CSNS, IMP, and CERN AD were presented. Details of each of the session contributions are presented in the individual papers. In this summary, we concentrate rather on the common themes.

FACILITY COMMISSIONING AND STATUS

The primary objective in any commissioning stage is the integration and verification of all essential sub-systems with the beam, demonstrating the capability to transport and accelerate a nominal beam. In the case of the SPIRAL2 linac, successful commissioning has been achieved, with H^+, $^4He^{2+}$, D^+, and $^{18}O^{6+}$ ions accelerated up to nominal parameters. Additionally, $^{18}O^{7+}$ and $^{40}Ar^{14+}$ beams have been accelerated up to 7 MeV/A. Noteworthy observations during the commissioning phase include the necessity for improved matching to the linac, tuning procedures for the 3 Medium Energy Beam Transport (MEBT) rebunchers, and 26 linac Superconducting (SC) cavities.

During the ESS NCL commissioning period, a proton pulse of 50 µs and 65.2 mA was successfully transported to the end of the DTL4 tank. Various strategies for cavity tuning were tested during this period. The Linear IFMIF Prototype Accelerator, LIPAc, accomplished the acceleration and transport of a nominal beam of 5 MeV−125 mA in 1 ms/1 Hz pulsed mode in 2019. Resuming beam operation since July 2023, the focus has shifted towards the commissioning of the full configuration, emphasizing the RFQ behavior with high duty cycle and longer pulses.

In the context of the SARAF project, significant progress has been made, including the updating of the injector control system and the installation and integration of the MEBT line into the infrastructure. Recent testing and commissioning of the injector and MEBT with 5 mA continuous wave (CW) protons and 5 mA pulsed Deuterons were completed in 2022 and 2023. These tests involved multiple emittance measurements and exercises in cavity tuning.

CAFe2, an evolution of its predecessor CAFe, initially designed as a proton demonstrator linac for Accelerator-Driven Systems (ADS), has undergone substantial upgrades. Since 2021, CAFe2 has logged over 2400 hours of operation, delivering heavy beams for Superheavy Element (SHE) experiments.

The IOTA ring is now being prepared to receive its first protons and the injector, capable of delivering 20 mA pulse of 2.5 MeV is under installation. This proton source will operate concurrently with its electron counterpart and is integral to the fundamental accelerator research program conducted at the facility.

The presentations highlighted the ongoing commissioning efforts across various facilities. A common theme emphasized the critical importance of machine characterization during these early stages and throughout the commissioning process. This includes, but is not limited to, having a profound understanding of the machine dynamics, recognizing the limitations of diagnostics, assessing the fidelity of the machine model concerning reality, and understanding of longitudinal tuning, particularly in the context of linacs and low-energy machines.

FACILITY UPGRADE PLANS

In the era of multi-megawatt linacs and synchronous operation, existing facilities are on the way of expanding their capabilities and achieving higher performance levels. Facilities such as SNS, FRIB, JPARC, and HIPA are in the process of implementing upgrade plans, with a primary focus on power ramp-up while ensuring effective loss control

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and reduction. Substantial efforts have been directed toward these goals, involving:

Understanding of Transverse Dynamics: Investigating instabilities and resonances in the transverse dynamics of particle beams, a crucial aspect for maintaining stability during power ramp-up.

Addressing Space Charge and Chromaticity Tune Shifts: Studies into the effects of space charge and managing chromaticity tune shifts, ensuring particles remain contained within the beam.

Optimization of Working Points and Tuning: Achieving optimal operational conditions by fine-tuning the symmetry of lattices and tunes, essential for maximizing beam stability and performance.

Improved Model vs. Real Machine Analysis: Enhancing the accuracy of theoretical models in comparison to the real machine behavior, aiding in predictive analysis and better performance.

Reliability: Investigating strategies to improve the reliability of these high-power facilities, ensuring consistent and stable operation over extended periods.

A critical factor in these studies is interplay between in-depth machine knowledge and practical experience. Striking a delicate balance between conservative approaches and pushing the boundaries of machine performance is essential.

OPERATIONAL ASPECTS AND OPTIMIZATIONS FOR OPERATIONS

Regarding high-power accelerator facilities in steady-state operation, reliability is paramount. To ensure this, several key factors come into play:

Data Availability and Analysis: Access to relevant data, including comparisons with past performance and ongoing machine and equipment evolution, is essential. Thorough analysis provides valuable insights into the facility's operational health.

Diagnostic Capabilities: Proper diagnostics are fundamental for both performance improvement and routine operations. Advanced diagnostic tools are crucial for identifying issues promptly and optimizing facility performance.

Skilled Workforce: Having the right people with adequate training and knowledge transfer mechanisms in place is vital. Skilled personnel ensure efficient operation and maintenance of the facility.

Specific highlights from recent efforts include the work at ISIS focused on improving loss control in the Rapid Cycling Synchrotron (RCS) using geodetic survey data to develop realistic lattice models. Rigorous measures, including implementing quantitative beam loss analysis through graphical interfaces and MQTT streaming data, were employed to optimize loss control.

At CSNS, the installation of programmable trim quadrupoles in the RCS enabled rapid variation of tunes and adjustment of Twiss parameters. Additionally, a dual harmonic RF system was studied to mitigate emittance increase and beam loss due to space charge effects, optimizing the longitudinal beam distribution.

At the CERN Antiproton Decelerator (AD) ring precise knowledge of transverse beam emittances on different energy plateaus was crucial. Using the Abel transform, transverse beam profiles were reconstructed from scraper measurements, providing insights into electron cooling performances.

The use of AI, specifically swarm intelligence algorithms, demonstrated promising results at linac ALPI. These algorithms enhanced longitudinal acceptance for Radioactive Ion Beams (RIB) acceleration and enabled beam orbit correction without requiring first-order measurements, showcasing innovative approaches to machine optimization.

These efforts underscore the interdisciplinary nature of advancements in accelerator facilities, combining sophisticated data analysis, diagnostics, skilled personnel, and cutting-edge technologies to ensure reliable and optimized operations.

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