Beam Physics Note
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A Summary of my ISOLDE Workshop 2024 Visit

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Abstract: I visited CERN from 24/11/2024 to 30/11/2024 for the ISOLDE Workshop and Users meeting 2024, and to also follow-up on a potential collaboration with the ISOLDE group. This document is a summary of my findings during this visit, which should help to inform us about the status of our beam physics group relative to the wider community.

1 Introduction

I will be discussing my findings pertaining to bayesopt at CERN with a focus on the different algorithms tested and their results, including the various applications of bayesopt. More generally, the status of automated tuning and surrogate modelling at ISOLDE is also discussed.

2 Bayesian Optimization at OFFLINE2

Figure 1: Front-view of OFFLINE2, beam propagates from right to left. The mass separator magnet is preceded by the first beam instrumentation station, and followed by the second station. The full diagram can be found in the following reference [1].

My visit overlapped with that of Santiago Ramos, a colleague from SCK CEN who has been working on Bayesian optimization at the OFFLINE2 facility. OFFLINE2 is a stable isotope facility designed to be as similar to ISOLDE as possible, in order to allow for the research and development of projects relating to ISOLDE [1]. This is a test bench beamline for the ISOLDE facility. OFFLINE2 is approximately 5m long and well diagnosed with three beam instrumentation stations. Santiago used a wire-scanner to determine the beam alignment, initially a run focused on beam alignment is completed, with 7 parameters: A set of three quadrupoles (QP30, QP40, QP50) and 2 pairs of deflectors (DEH1, DEV1, DEH2, DEV2). The quadrupoles are bounded between 750-3000V, the deflectors from 0-250V. After the beam is aligned, ion-source optimizations take place (see section 2.3).

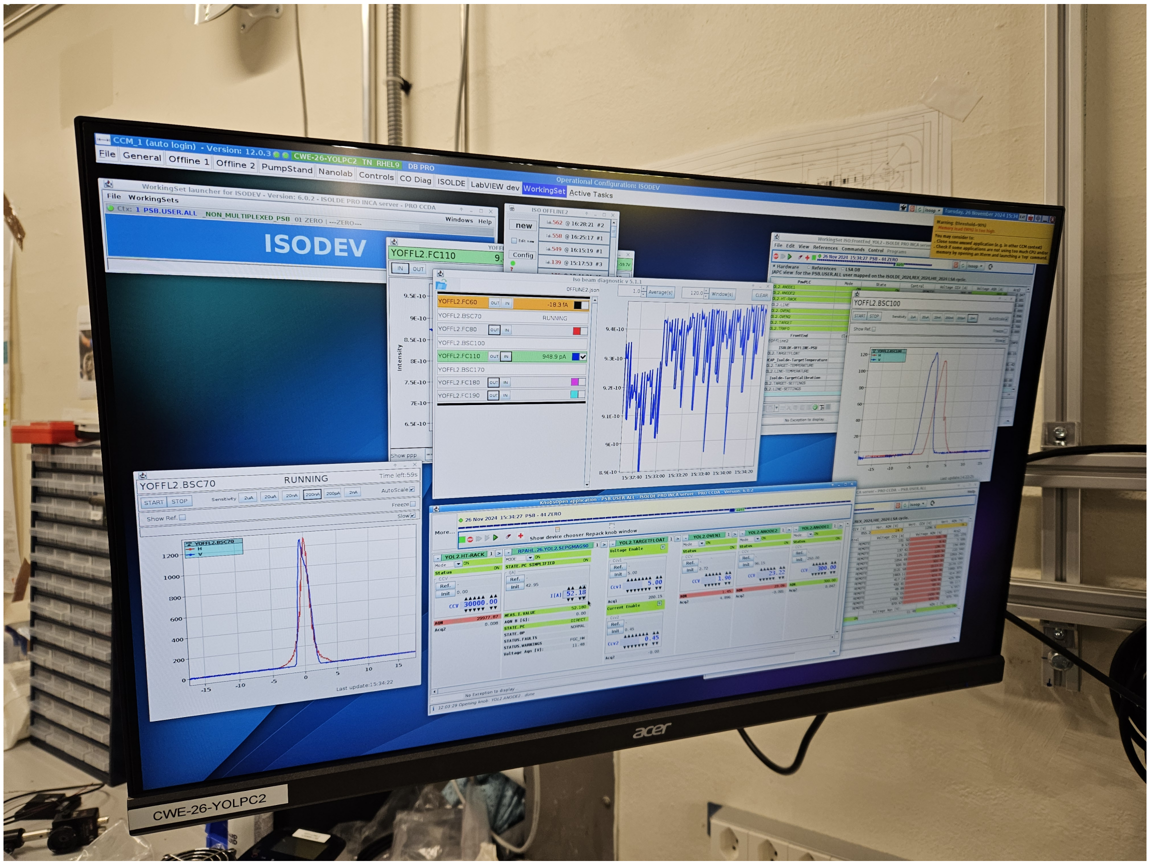

Figure 2: Bayesian optimization at OFFLINE2: Beam profiles during initial optimization (bottom left). Current at several Faraday cups (top center). Ion source parameters (bottom center)

2.1 Multi-Objective Bayesopt

Solving a multi-objective problem was something that Santiago had tested, where he attempted to center the beam and maximize transmission. The goal of multi-objective bayesopt is to determine the Pareto front: the set of non-dominated solutions that exist in the objective space. Using multi-objective bayesopt was quickly ruled out as it was determined that both of these objectives are correlated, where the improvement of one objective leads to the improvement of the second objective. It is simply not an effective technique for online use due to the excessive optimization times for the multi-objective acquisition functions. This case is further strengthened since the multi-objective problem at ISAC-1 (beam alignment and current transmission) doesn't have competing objectives.

2.2 Constrained Bayesopt

A more practical technique to addressing multiple objectives without the downsides of a full multi-objective approach is to constrain the output space such that we only allow a certain set of solutions for one objective, while solving for the other. This can be simply thought of as making a cut in objective space where all solutions of beam alignment are valid if some threshold is met, say 90% transmission, or vice versa. This method has a few advantages: 1) It yields a single solution instead of the Pareto front. 2) This is still a single-objective problem, so the used acquisition functions are far less time consuming. This technique appears to have the relevant benefits of multi-objective optimization while also being practical for online use. This is perhaps the most promising algorithm for improving beam delivery to DRAGON.

2.3 Ion-Source Optimizations

Another interesting finding was observing the use of bayesopt for ion-source optimization. A FEBIAD ion-source was optimized with two parameters: the oven current and the anode voltage. The goal is to maximize the current at the Faraday cup. Something to note: ion-source optimizations was stated as a very difficult problem to solve, possibly due to the high sensitivity of the inputs or the complexity of the objective function. It would be worthwhile to attempt ion-source optimizations at OLIS: MWIS is the most promising ion-source to test, whereas MCIS is not recommended due to it's compleity. SIS should be considered. A hindrance that exists is that some important parameters are not configured in EPICS. However, IMS is well integrated into EPICS, so applying bayesopt there instead of OLIS would be more practical. CSB is another potential avenue which can be explored.

3 Other Findings

Through talking to some of the students and staff at ISOLDE and CERN, a few things of note came up:

- ISOLDE does not use a beam transport code for the facility akin to `TRANSOPTR` for TRIUMF. This leads to the operators tuning entirely based on transmission. It should be noted that Rick Baartman visited ISOLDE in October 2001, providing a working model which is not currently in use [2].
- There are efforts to model the facility using particle-tracking codes.

- Operators are not available around the clock; experimenters are often required to tune the facility themselves.
- I was told that the operators aren't too keen on the idea of tuning with bayesopt as potential issues like hysteresis are not addressed.
- The difference between CPU vs GPU for bayesopt is negligible. This is corroborated by Ryan Roussel's findings that GPU only becomes viable at a large number of training points [3].
- The acquisition function used by Santiago was expected improvement with $\beta = 0.01$. They did not experience the issue of over-exploration that we have in certain sections.

4 Acknowledgments

I would like to acknowledge Sebastian Rothe, Asar Jaradat, and Line Le for facilitating my stay, Santiago Ramos Garces and Michael Schenk for help on more technical details regarding Bayesian optimization, and Edgar Reis for giving me a tour of ISOLDE and informing me of the current status of the facility.

References

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