ML-Driven Tuning of Beamlines: Using Bayesian Optimization

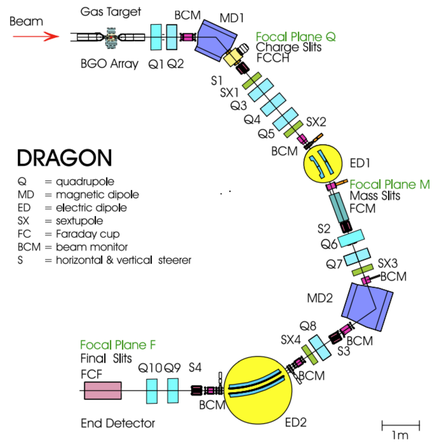
Defne Tanyer[1], Alexander Katrusiak[2], Wojtek Fedorko[3], Chris Ruiz[3], Christopher Charles[3], Paul Jung[3], David Wang[4], Hui Wen Koay[3], Olivier Shelbaya[3]
[1]University of Waterloo, Waterloo, ON [2]Queen's University, Kingston, ON [3]TRIUMF, 4004 Wesbrook Mall, Vancouver, BC [4]UBC, Vancouver

Problem Set-up

Isotope Separator and Accelerator (ISAC) facility allows for leading research in nuclear and particle physics. Off-Line Ion Source (OLIS) is the front-end of stable isotope beam creation and delivery to all R&D in the ISAC complex. The high demand calls for constant manual retuning costing hours of operator time.

We present results of modeling the beam using Bayesian optimization machine learning algorithm to model and maximize expensive black-box functions. We ran BO with the objective of maximizing current at faraday cups.

A picture of OLIS, located in the southwest corner of ISAC-I Building



Layout of DRAGON. The section used for the BO tuning is from the gas target to FCCH.

Adaptation to DRAGON

The Detector of Recoils and Gammas of Nuclear Reactions (DRAGON) is a recoil separator in the ISAC-I hall. comprised of 26 ion optical elements, the electromagnetic recoil separator of DRAGON achieves a beam suppression on the order of 10^{12}.

However, to transport the recoils of the reaction from the gas target to the end detectors these elements must

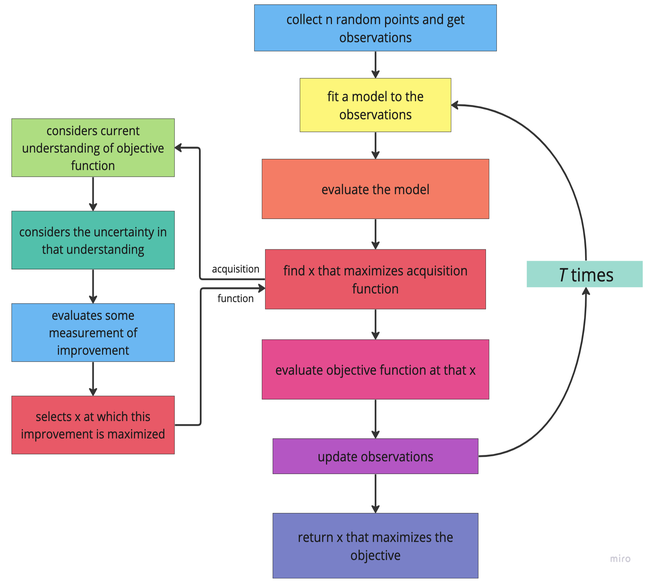
be carefully tuned to maximize the transmission of the desired species.

Building from the success of BO tuning of the MEBT and DTL, models are currently being built to tune DRAGON.

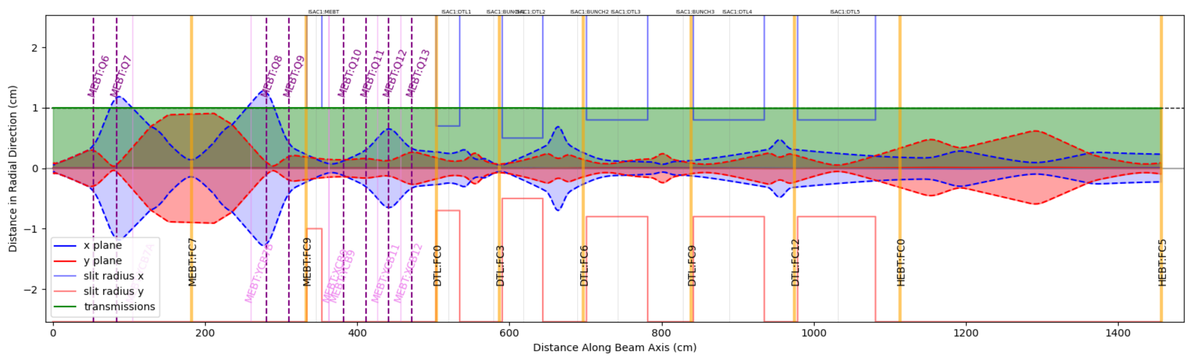
Results

Tested the optimizer on many different experimental set-ups. Here presenting three main ones. Surface Ion Source 7Li (1+), Multi-Charge Ion Source 16O (1+) and the MEBT+DTL section linear accelerator with 36Ar (7+) at 0.254 MeV/u.

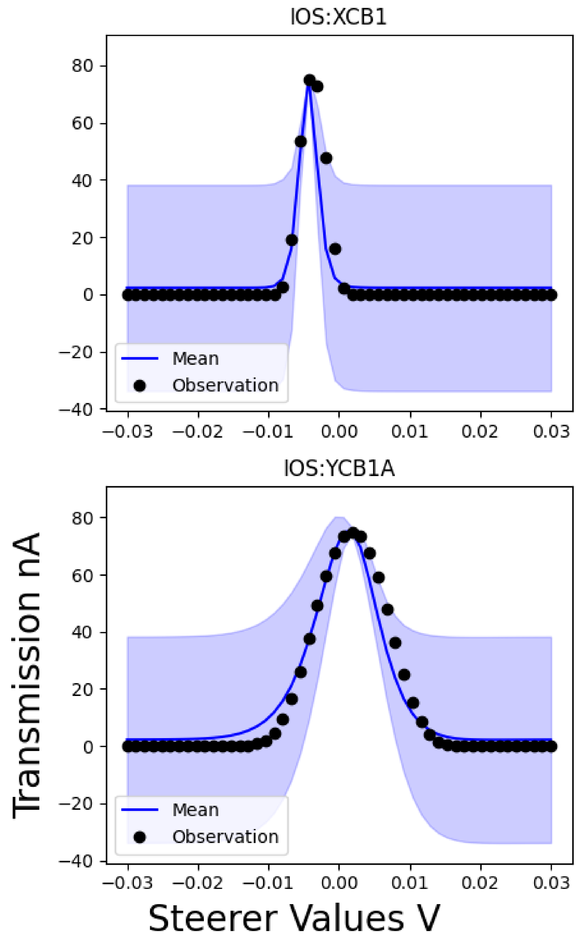
- Able to model the beamline accurately
- Reached a global maximum and effectively tuned OLIS in under 10 minutes.
- Matches operator performance
- Reached 100% transmission on MEBT corner.



Bayesian optimization algorithm



TRANSOPTR simulation of the algorithm, showing the path of beamline from a bird's eye view. Beam is taken as a 2-d Gaussian in xy-plane.
Simulation courtesy of David Wang and Hui Wen Koay



Performance on OLIS, shows the agreement between the data and the model.

Conclusion

This success has far-reaching implications for automated tuning of the entire ISAC-I/II and ARIEL beamline complexes for rare and stable isotope beam transport.

Further development is under way with the construction of models for more of the ISAC linac, ARIEL, and ISAC experimental facilities.

Discovery, accelerated