Tailored RI Beams for DRAGON with Multi-Objective Bayesian Optimization

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Abstract

The goal of this project is twofold: to use Bayesian optimization to tune beam into DRAGON, and to explore smooth energy variation for DRAGON by utilizing the HEBT bunchers. DRAGON is an experimental apparatus designed to measure the reaction rates of nuclear astrophysical processes, by measuring resonances through radiative capture. Ultimately, this project will enable experiments that will need rapid changes of beam parameters, which were not possible before.

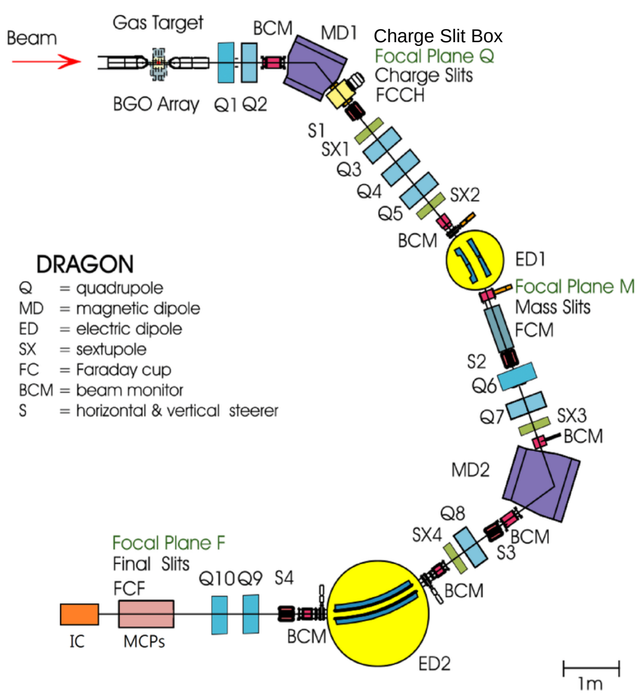

Figure 1: Layout of the DRAGON experimental setup.

Bayesian Optimization

Bayesian Optimization for Ion Steering (BOIS) has previously been developed as a single-objective tool to optimize the beam transmission. BOIS has been used in the low energy beam transport (LEBT) section replicating transmission typically attained by operators. This technique will be further developed for application to the high energy beam transport section (HEBT), namely the DRAGON experiment, with further developments for centroid correction which allows for multi-objective optimization.

HEBT Tuning Using BOIS

HEBT utilizes magnetic steerers, this presented an issue: The steerers get stuck upon switching polarity. This was mitigated using a 5 second delay during the polarity switching. Preliminary tests in HEBT were successful, tuning all the way up to DRA:FCCH.

Multi-Objective BOIS

High current transmission is not the only factor affecting the beam quality, the centeredness of the beam is currently not directly addressed by BOIS. This is then a connected problem, where optimizing on one objective impacts the other, leading to the requirement of multi-objective optimization.

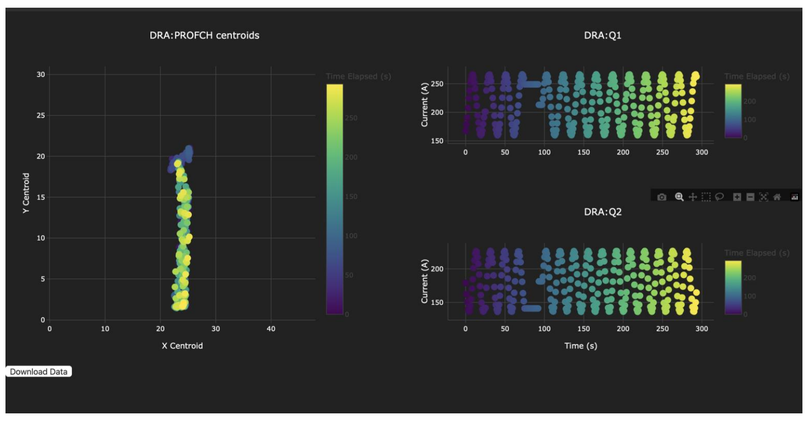

Figure 2: Web interface developed by Emma Ghelfi, on the left is the x vs y centroids, on the right are the quad values for Q1 and Q2.

Minimizing the Centroid Spread

The second objective is to center the beam, where the strongest available measure of this is the use of a quadrupole doublet and a parallel wire position-intensity monitor: The DRAGON harp (in the charge slit box in figure 1). By inducing a time-dependent current variation in the set quadrupole values by a certain amplitude and reading the x and y centroids on the harp, we use the steerers to center the beam by minimizing the centroid spread on the harp. The beam is centered once the quadrupoles no longer affect the beam centroids.

The HEBT Bunchers

DRAGON requires small energy variation to find specific nuclear resonances or to iterate through many resonances. These energy variations currently require manual re-tuning of the ISAC-DTL, which is a procedure with considerable overhead tuning. Due to the highly subscribed schedule, this is a limiting factor. A novel solution to this involves utilizing the HEBT buncher for energy stepping:

- The HEBT bunchers can be tuned with relative ease, bypassing the need for re-tuning the drift tube linac (DTL) which is a more complex task. The buncher allows for quick and small energy adjustments, allowing for the automatic stepping of the energy.
- Changing of the beam's energy requires adjustment of the DRAGON magnetic dipoles, which would require re-tuning due to the changed magnetic rigidity. Effects on the emittance are negligible.

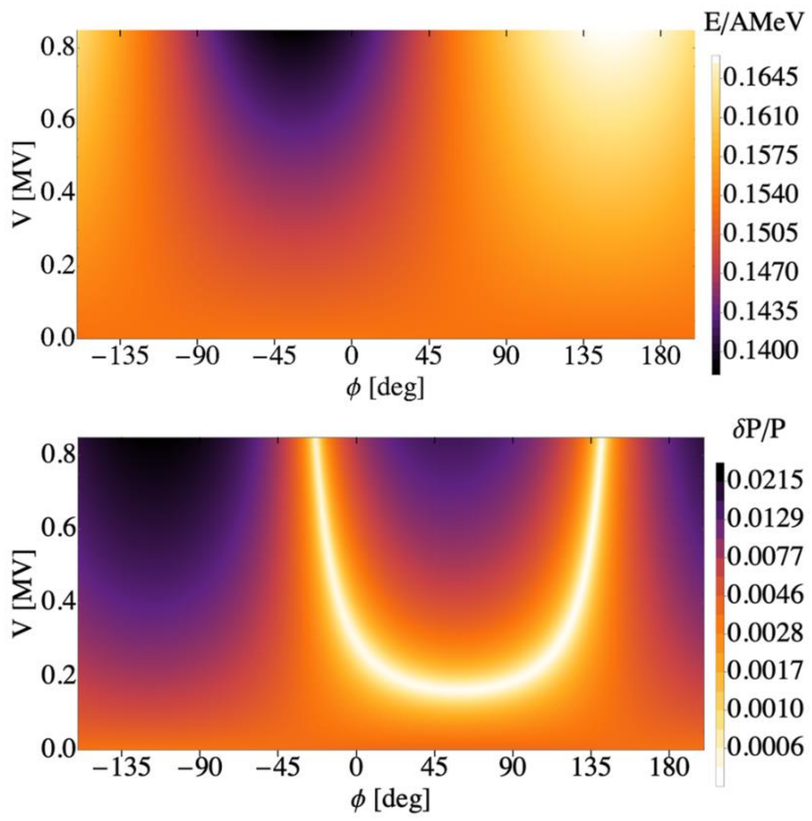

Figure 3: Optimized energy solutions (top) and momentum spread (bottom) from the HEBT buncher, as a function of the phase and amplitude [1].

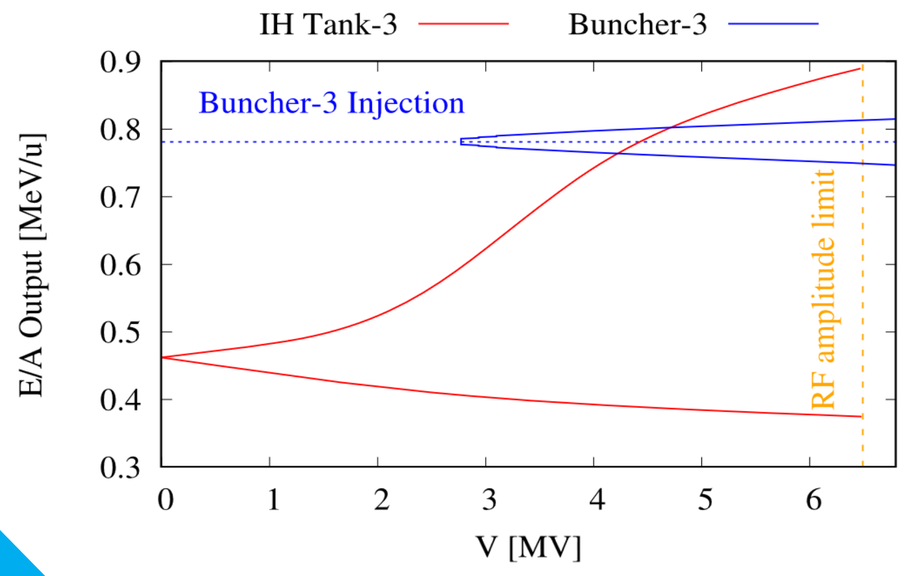

Figure 4: Comparison of a non-linear energy gain at the DTL Tank 3 and the linear response for the buncher.

Conclusion

This project will allow for the transport of tailored beams to DRAGON, with the further goal of automatic energy variation for the scanning of nuclear resonances.

References

[1] Shelbaya, O., Baartman, R., Braun, P., Jung, P. M., Kester, O., Planche, T., Podlech, H., & Rädel, S. D. (2024). Tuning methods for Multigap Drift Tube Linacs. *Review of Scientific Instruments*, *95*(3). https://doi.org/10.1063/5.0191603

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