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Multi-Objective Genetic Optimization for the High-Intensity Muon Beams Project at PSI

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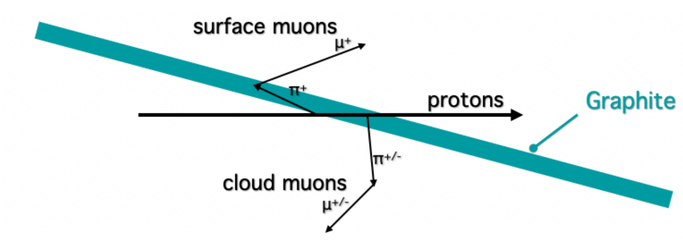
Giovanni Dal Maso on behalf of the HIMB project
Paul Scherrer Institut, 5232 Villigen PSI
Eidegenössische Technische Hochschule Zürich, 8093 Zürich
giovanni.dal-maso@psi.ch

The HIMB project[1,2]

The HIMB project aims to increase the intensity of two muon beamlines at PSI by two orders of magnitude up to 10^{10} μ^+/s.



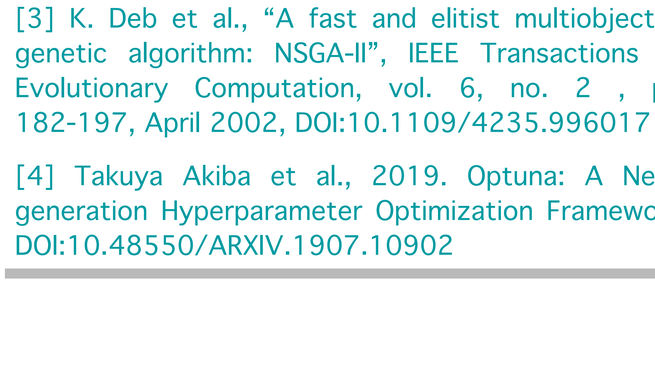
The focus is on boosting surface muon rates by:

- slanting production target → increase surface with fixed thickness as seen by protons
- employing solenoids as focusing element → increase capture and transmission

Two beamlines are going to deliver beams from the HIMB target: MUH2, particle physics oriented, and MUH3, μSR oriented. Here we present the optimization strategy of MUH2 for non-surface muon beams.

Particle zoo

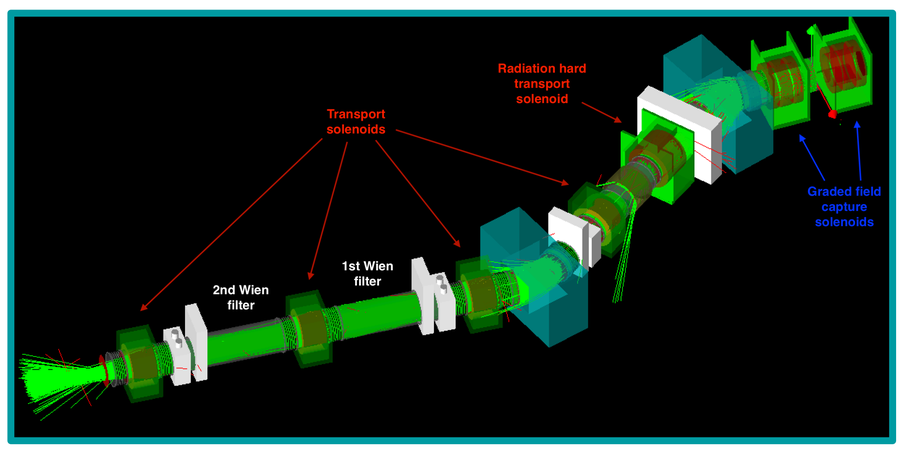
At the HIMB target (TgH), many particles are produced over a broad momentum range. We aim at delivering different particle species with momenta up to 80 MeV/c.



MUH2 beamline layout and parameters

The beamline dynamics is fully determined by 12 currents.
There are 4 values on which the beamline is optimized: rate, STD(x), STD(y) and the design average momentum |ΔPz|.

The optimization is performed per each particle species and per each selected momentum.

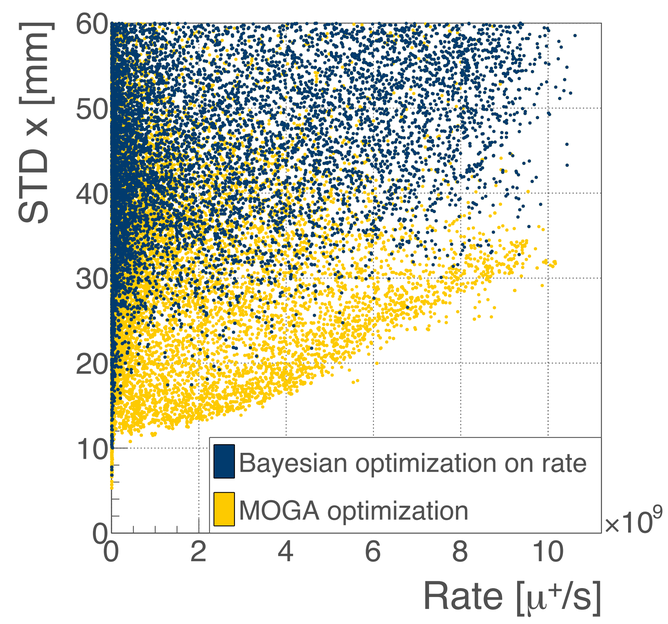


MOGA optimization

Multi-Objective Genetic Algorithms are designed to optimize complex problems by employing strategies inspired by biological evolution.

The population (set of parameters) undergoes evolution after applying random variations as mutation or breeding. The fittest individuals (based on the objective values) are selected for the next epoch.

In this work the Non-dominated Sorting GA-II[3, 4] is employed.



The parameter space is first explored with a Bayesian[4] optimization algorithm on final rate only. Then the NSGAII is applied.

Conclusions/Outlook/Preliminary results

The employment of MOGA has allowed us to automatize the optimization process with minimal adaptation for new designs.

The current design fulfills the aim of exceeding 10^{10} μ^+/s at the end of MUH2 at the surface muons momentum, but experiments will be able to benefit as well from positron and pion beams.

Rate vs momentum mup spot_ settings

Contamination vs momentum

References

[1] R. Eichler et al., “IMPACT conceptual design report”. In: PSI Bericht, Report No.: 2022-01 (2022)

[2] M. Aiba et al., "Science Case for the High-Intensity Muon Beams HIMB at PSI”. DOI:10.48550/ARXIV.2111.05788

[3] K. Deb et al., “A fast and elitist multiobjective genetic algorithm: NSGA-II”, IEEE Transactions on Evolutionary Computation, vol. 6, no. 2 , pp. 182-197, April 2002, DOI:10.1109/4235.996017

[4] Takuya Akiba et al., 2019. Optuna: A Next-generation Hyperparameter Optimization Framework. DOI:10.48550/ARXIV.1907.10902