

# State of the art BO for Accelerators

## Improvement over vanilla BO

<b>Application specific acquisition functions</b>	<ul style="list-style-type: none"><li>• Information based acquisition functions (e.g., BAX)</li><li>• Constraints (e.g., safety)</li><li>• Exploration (acq. = <math>\sigma</math>)</li><li>• Proximal biasing (avoids big steps)</li></ul>	<ul style="list-style-type: none"><li>• Minimizing emittance</li><li>• Emittance characterization</li><li>• Tuning with slow magnets</li></ul>
<b>Embed a prior/structural information into the model</b>	<ul style="list-style-type: none"><li>• Non-zero prior means (much faster <math>\rightarrow</math> scaling to high dim optimization)</li><li>• Hyperparameter priors (regularity, safety)</li></ul>	<ul style="list-style-type: none"><li>• LCLS injector tuning</li><li>• Different beams transfer / historical data</li></ul>
<b>Application specific kernel functions</b>	<ul style="list-style-type: none"><li>• Deep kernel learning (complex embeddings)</li><li>• Composite kernels, contextual/adaptive (distribution shift)</li><li>• Correlated kernels (low dimensional structure embedding)</li></ul>	<ul style="list-style-type: none"><li>• Continuous opt. with drifts</li><li>• Triplet magnets</li></ul>
<b>Techniques for efficient inference</b>	<ul style="list-style-type: none"><li>• Data subsampling (take most relevant data points)</li><li>• Approximate GP's</li></ul>	<ul style="list-style-type: none"><li>• Continuous opt.</li><li>• Large number of data points</li></ul>
<b>Parallelization for simulated optimization</b>	<ul style="list-style-type: none"><li>• Q-sampling (see botorch)</li><li>• Local penalization, etc...</li><li>• MGGPO (BO-GA hybrid, for HPC)</li></ul>	<ul style="list-style-type: none"><li>• Offline optimization</li></ul>

# What does the community need to investigate?

- Implement everything in **Botorch** + contribute new models/kernels/acquisition functions to Botorch
- **Uniform framework for generic problem optimization**
  - Xopt/GeOFF
  - OR literally anything else, just pick one!
- Advertisement of BO capabilities, not currently taken advantage of
- More benchmarking to accelerator test problems
- More development of (continuous) multi-fidelity optimization for sims
- Combine GP's with other UQ methods + differentiable simulations/surrogate models (NN's etc)
- Non-gaussian likelihoods

## How to optimize? (generally speaking)

- Complexity of the problem (dimensionality of the input space)
- Complexity of the evaluation (cost/time)
- Complexity of the decision making (which action to take)
- Overhead (cost before optimization/work)

## How can we collaborate, educate, etc?

- Review article in PRAB (Ryan will organize)
- Common channel to discuss (Slack, Mattermost)

