Notes from A. Scheinker's visit to CERN

Alex Scheinker visited CERN for two days to discuss possible applications of Machine Learning and other Advanced Algorithms on the AWAKE electron beam system. He is currently performing beam tuning and optimization experiments at the XFEL at DESY.

We met with Steffen Doebert and Simon Hirlander and decided upon some further actions.

Applications for Electron Source (w/S. Doebert):

For the electron source, we defined 3 tasks that can be addressed with Advanced Algorithms.

Simple: Optimize the energy spread of the beam after the gun and booster.

- Two parameters (gun phase and booster phase)
- One observable (spot size on BTV 430106)
- This task will establish the efficacy of various algorithms (Extremum Seeking, Powell Optimization).
- Action: Installation of a digital camera at BTV 430106. S. Gessner, I. Gorgysian.

Intermediate: The emittance measurement is carried out with a quad scan at BTV 430042. The measurement takes several minutes. Is there a fast observable that can be used to approximate the emittance measurement.

- In simulation, perform N-dimensional parameters. Which observables correlate with beam emittance? For example, the beam spot at BTV 430042.
- Action: Discuss simulations of parameter space with S-Y Kim. Who carries out simulations? What parameters do we need to cover?
- Feed results into Neural Net to establish which observables we will use in the experiment.

Advanced: Optimize beam emittance after booster with N-dimensional parameter scan. This combines the fast emittance measurement described above with optimization techniques.

- Does the emittance "landscape" from simulation match the one measured in reality?
- Use a combination of NN to provide a first estimate of where the emittance minimum is located, supplemented by optimization algorithms to find the actual minimum. That is the approach used in Alex's recent paper: https://doi.org/10.1103/PhysRevLett.121.044801

Comparison of Algorithms (w/S. Hirlander):

Simon is exploring a variety of algorithms for optimizing injection at LEIR, including Reinforcement Learning algorithms. He is in the process of creating general software tools that will be applicable for all accelerators at CERN.

- The code is in development: https://gitlab.cern.ch/PythonicOperationSoftware/LEIR-Multiparameteroptimizer
- Simon has used Powell minimization on LEIR, and supplements that with reinforcement learning algorithms in order to quickly find the optimum injection.
- Idea is to compare and contrast various algorithms at AWAKE and find which perform best.
- Action: Alex provides Extremum Seeking code in Python for testing and eventual inclusion in Simon's package.

Applications on the AWAKE Beamline:

Francesco, Verena, and Brennan were away from CERN, so we did not discuss with them potential application of these algorithms on the AWAKE beamline.

- Action: With Francesco and Brennan, develop "simple", "intermediate", and "advanced" tasks to be performed on the AWAKE electron line.
- This could mirror what we do with the source, accept that we want to optimize emittance at the end of the line (BTV 412354).

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