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Extending Reinforcement Learning for Beam Steering with Bayesian Optimization and Online System Identification in the CERN SPS North Area

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Commissioning slow extracted beams from the CERN Super Proton Synchrotron (SPS) to the North Area experimental targets requires trajectory control through multiple transfer lines using corrector magnets—a process that traditionally demands significant expert intervention. Previous work demonstrated using reinforcement learning (RL) for automated trajectory correction based on secondary emission monitor (SEM) split-foil intensity measurements, successfully centering the beam on target under nominal conditions. However, two failure modes require human intervention: complete signal loss when the beam exceeds SEM acceptance, and corrector magnet polarity changes that invalidate learned policies.

We extend this framework with a hierarchical approach comprising three sequential stages. First, when the beam lies outside SEM detection range, we employ Bayesian optimization with random exploration to recover beam visibility. Second, we perform online system identification to automatically resolve corrector polarity ambiguities. With these prerequisites satisfied, the RL agent maps SEM observations to corrector adjustments, achieving beam centering throughout the transfer line.

Student

No

Primary author: MENOR DE OÑATE, Adrián (CERN)

Co-authors: RODRIGUEZ MATEOS, Borja (CERN); SCHENK, Michael (CERN); KAIN, Verena (CERN)

Presenter: MENOR DE OÑATE, Adrián (CERN)

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