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Reinforcement Learning for Real-Time Cyclotron Tuning: Results from the PSI Injector~2 Experiment

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Achieving reliable, fast, and reproducible tuning of high-power cyclotrons remains a key operational challenge as accelerators move toward increasingly complex beam configurations and higher intensities. To address this, we conducted a two-week experimental campaign at the PSI Injector~2 cyclotron to evaluate the feasibility of applying reinforcement learning (RL) for real-time beam tuning on a live machine.

A continuous-control RL agent was integrated with the accelerator control system and operated under strict safety constraints. The agent was trained online at low beam current and evaluated across multiple turn configurations, including nominal and degraded operating regimes. We demonstrate stable convergence within hours, effective phase alignment with reduced beam losses, and robust autonomous operation during extended overnight evaluation runs without triggering interlocks.

These experiments represent an important step toward automated cyclotron tuning and provide practical insights into safe RL deployment, policy generalization, and operational robustness for future high-current HIPA and ADS-class facilities.

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