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Abstract

Studies on the nonlinear beam dynamics for future particle colliders

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Particle colliders serve as unique tools to study constituents of matter and understand their interactions. For studying rare events, the collision energy of the particle beam is key in determining which events can be observed, while the achievable collision rate gives the amount of observable events during the operation time of the machine. Naturally, current and future collider design have aimed for ever increasing collision rate to accurately study rare events with high statistical significance. Beam losses are detrimental to the performance due reducing the number of potential colliding particles. Such losses may be generated by amongst others nonlinear magnetic fields, introduced either by errors or to counteract other beam loss mechanisms. Good understanding of the impact of those fields and their interplay is thus critical as means to study mitigation measures which help increase the collider performance.

In this thesis, studies on the impact of such nonlinear fields on the beam dynamics have been conducted with focus on issues in potential future collider projects. Simulations were conducted for such a future collider design to define tolerances on the magnetic field errors. To benchmark these simulations, experiments in currently running machines were conducted where errors have been artificially introduced. A theory was developed to quantify the interplay between different effects in order to help explain observations made during the operation of the Large Hadron Collider at CERN. Further measurements have been conducted at the IOTA accelerator at Fermilab to quantify the impact of sextupole fields on the beam dynamics.