Title:

Design and validation studies of the FCC-ee positron source: from advanced simulations to proof-of-principle experiments at PSI.

Abstract:

Driven by the High-Energy Physics (HEP) community's interest in precision studies of the Standard Model (SM), CERN has proposed the Future Circular Collider electron–positron (FCC-ee) as a next-generation collider. The FCC-ee is designed to operate at multiple center-of-mass energies with unprecedented luminosity. A crucial component in reaching this luminosity is the design of a high-intensity, low-emittance positron source. Designing such a source is inherently complex, involving multiple and coupled subsystems: the electron driver beam, the production target, the downstream capture section and positron linac, and the damping ring.

This thesis focuses on designing and optimizing the FCC-ee positron source, from the production target to the end of the capture section, which are the most critical stages. The challenges associated with each subsystem are addressed. A dedicated simulation framework was developed by using the Geant4 and RF-Track codes and validated through a series of experimental measurements at the SuperKEKB positron source, and benchmarked against widely used simulation tools (EGS5, ASTRA, GPT). The framework, experimental layout, and benchmarking results are presented, establishing a solid foundation for designing and optimizing a high-intensity positron source for FCC-ee. The proposed layout and optimized design of the FCC-ee positron source are discussed.

An alternative positron source scheme based on the use of lattice coherent effects in oriented crystals is proposed and studied. A physics design for this crystal-based positron source is developed, and its application to the FCC-ee and in the PSI Positron Production (P^3) experiment is also explored.

In addition, an irradiation campaign was conducted at the MAin MIcrotron (MAMI) to study irradiation-induced damage in crystal targets and to commission a thermal diagnostics setup for measuring irradiation-induced heating. The experiment layout, as well as the measurement results, are discussed in detail.