THP35

LONGITUDINAL PHASE SPACE RECONSTRUCTION IN AN ELECTRON STORAGE RING

SSRF/SARI

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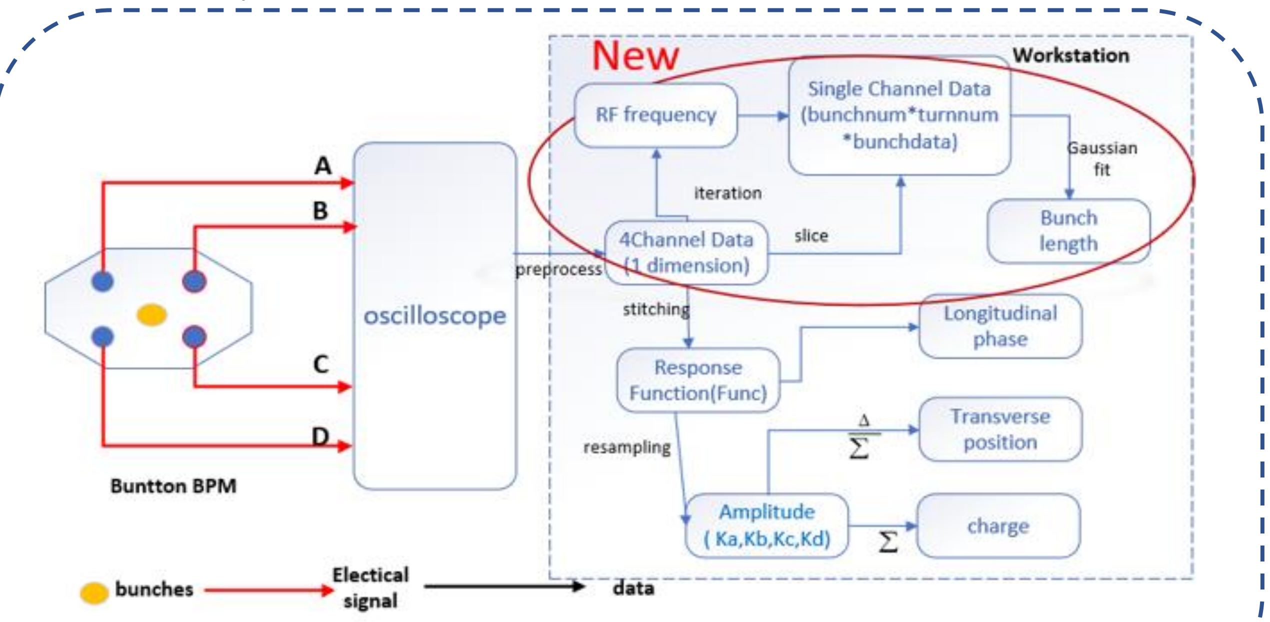
This work proposes a novel technique to reconstruct the longitudinal phase space of freshly injected bunches in an electron storage ring to determine initial parameters. It integrates single-bunch injection phase space simulation software and a bunch-by-bunch data acquisition system, enabling precise measurement of initial parameters like phase, bunch length, and energy deviation. The experiment uses a high-speed oscilloscope to collect beam injection signals, achieving phase measurement precision of 0.2 ps and bunch length precision of 1 ps. A simulation software based on the mbtrack2 package models phase space evolution under various initial conditions. A genetic algorithm optimizes initial parameters by comparing experimental and simulated data, improving injection efficiency and beam quality.

MEASUREMENT SYSTEM SETUP

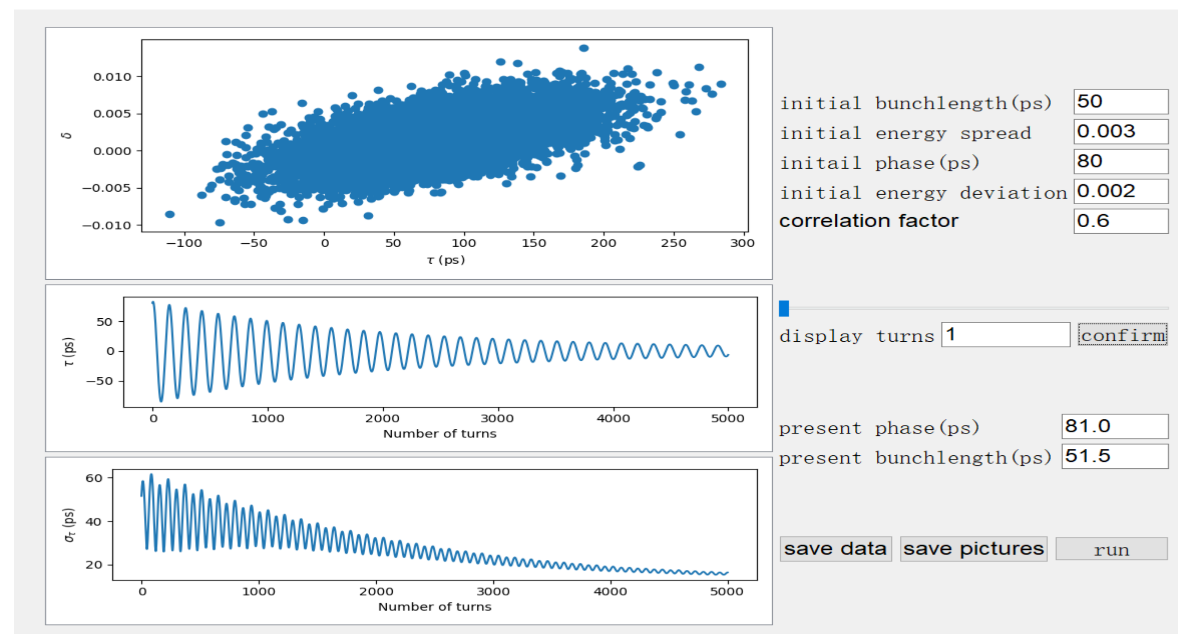
SSRF is a third-generation light source that has stable and brilliant synchrotron radiation due to its operation under top-off mode[1]. A bunch-by-bunch diagnostic system that calculates the beam's three-dimensional position, charge, and bunch length based on raw data collected from the Beam Position Monitor has been developed[2].



Structural diagram of bunch by bunch diagnostic system

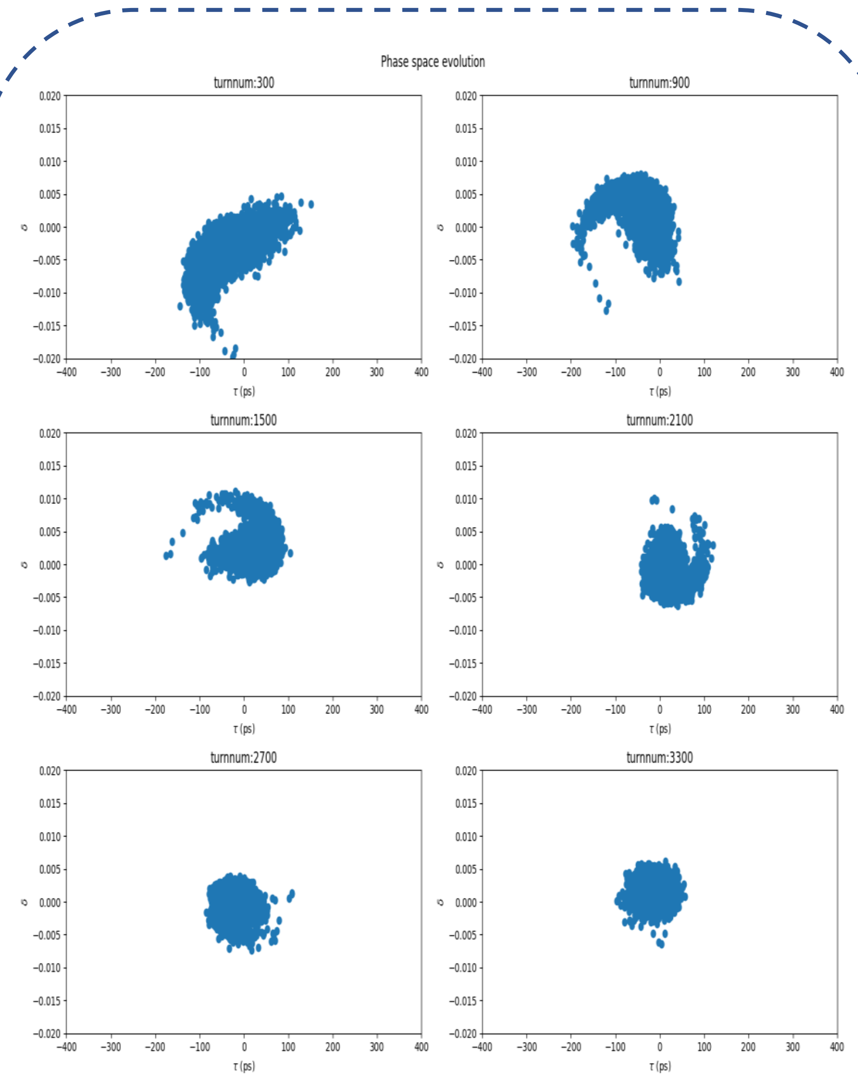
SIMULATION TOOLS

To better understand bunches' longitudinal phase space evolution during the injection process in an electron storage ring, we developed a single-bunch simulation tool based on the mbtrack2 and PyQt5 software packages. This tool is used to track the longitudinal phase space distribution of bunches after injection.

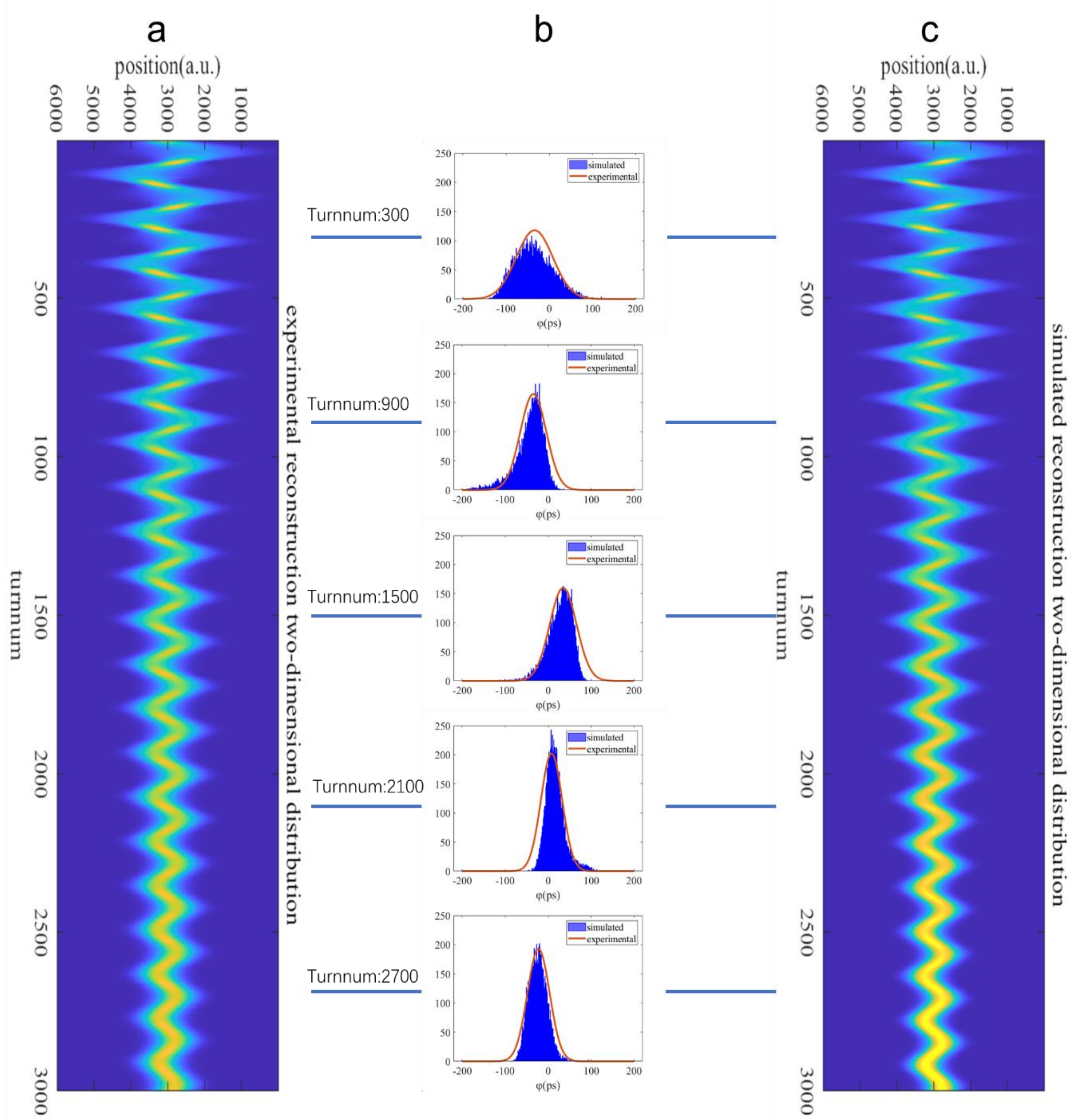


Single beam longitudinal phase space simulation software interface

BEAM EXPERIMENT RESULT



Longitudinal phase space evolution of a single bunch



a, c: Experimental and simulation reconstruction of the two-dimensional distribution map of phase and bunch length.
b: real space projection

CONCLUSIONS AND FUTURE WORK

By combining experimental data with a genetic algorithm to optimize the initial parameters, we match the simulation data with the experimental data to obtain the initial parameters of the experimental data. The acquisition of these parameters provides a powerful tool for optimizing the injection system.

Next step:

- Train a large number of simulation samples through machine learning, and combine them with experimental data to directly obtain the phase space distribution and initial injection parameters of the experimental beam cluster.

REFERENCE

[1] Zhou Y, Chen Z, Gao B, et al. Bunch-by-bunch phase study of the transient state during injection[J]. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2020, 955: 163273.
[2] Wang H S, Yang X, Leng Y B, et al. Bunch-length measurement at a bunch-by-bunch rate based on time–frequency domain joint analysis techniques and its application[J]. Nuclear Science and Techniques, 2024, 35(4): 80.

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