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# Many-objective Beam Dynamics Optimization for High-Repetition-Rate XFEL Photoinjector

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## Abstract

SHINE, as the first hard x-ray free-electron-laser (FEL) facility in China, is design to provide high-brightness FEL lasing under high-repetition-rate operation. In order to drive x-ray FEL pulses with high qualities, the photoinjector section is deployed to provide the specified electron beam with low transverse emittance and high brightness. Normally the multi-objective optimization algorithm is employed in the injector beam dynamics design. In this paper, the many-objective optimization algorithm NSGA-III is introduced to the injector physical design for optimizing the 4 detailed beam quality properties using 17 variables for the first time. The results of the optimization are presented and the correlations are analyzed. This approach can provide guidance for further physical research as well as improve the beam dynamics optimization efficiency.

## LAYOUT OF THE SHINE INJECTOR LINE

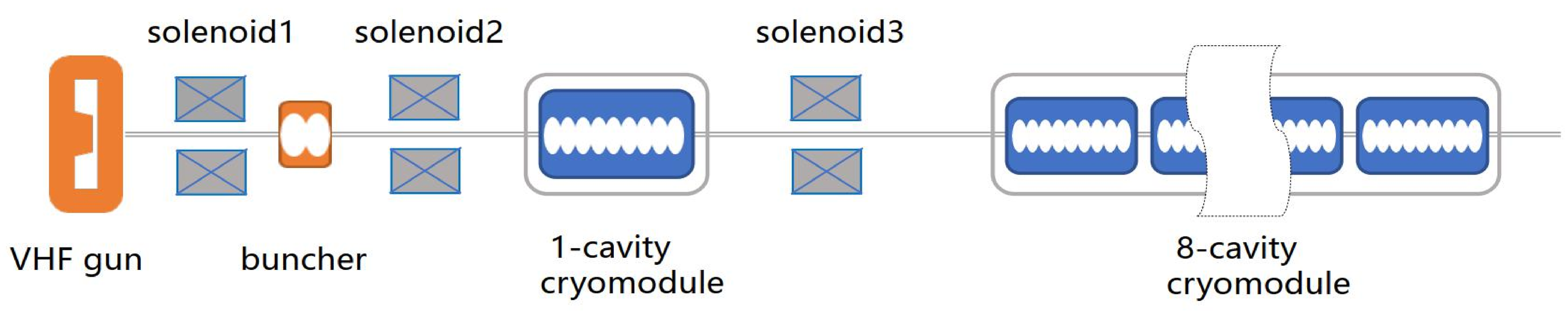



Figure 1: Schematic view of the SHINE photoinjector.

This system consists of the electron gun operating at a CW mode at the very-high-frequency band. The electron is launched from the photocathode and accelerated to about 0.8 MeV at the exit of the gun. The longer driven laser pulse is settled at the cathode for relieving the space charge effect which will dominate until the single-cavity cryomodule due to the relatively low gradient in the VHF gun. The buncher is followed by the gun exit and compresses the longitudinal distribution of the bunch utilizing the velocity difference along the bunch. The distribution modulation increases the peak current to about 10A at the entrance of the main accelerating section.

## BEAM DYNAMICS OPTIMIZATION RESULTS

### • Parallel coordinate plots

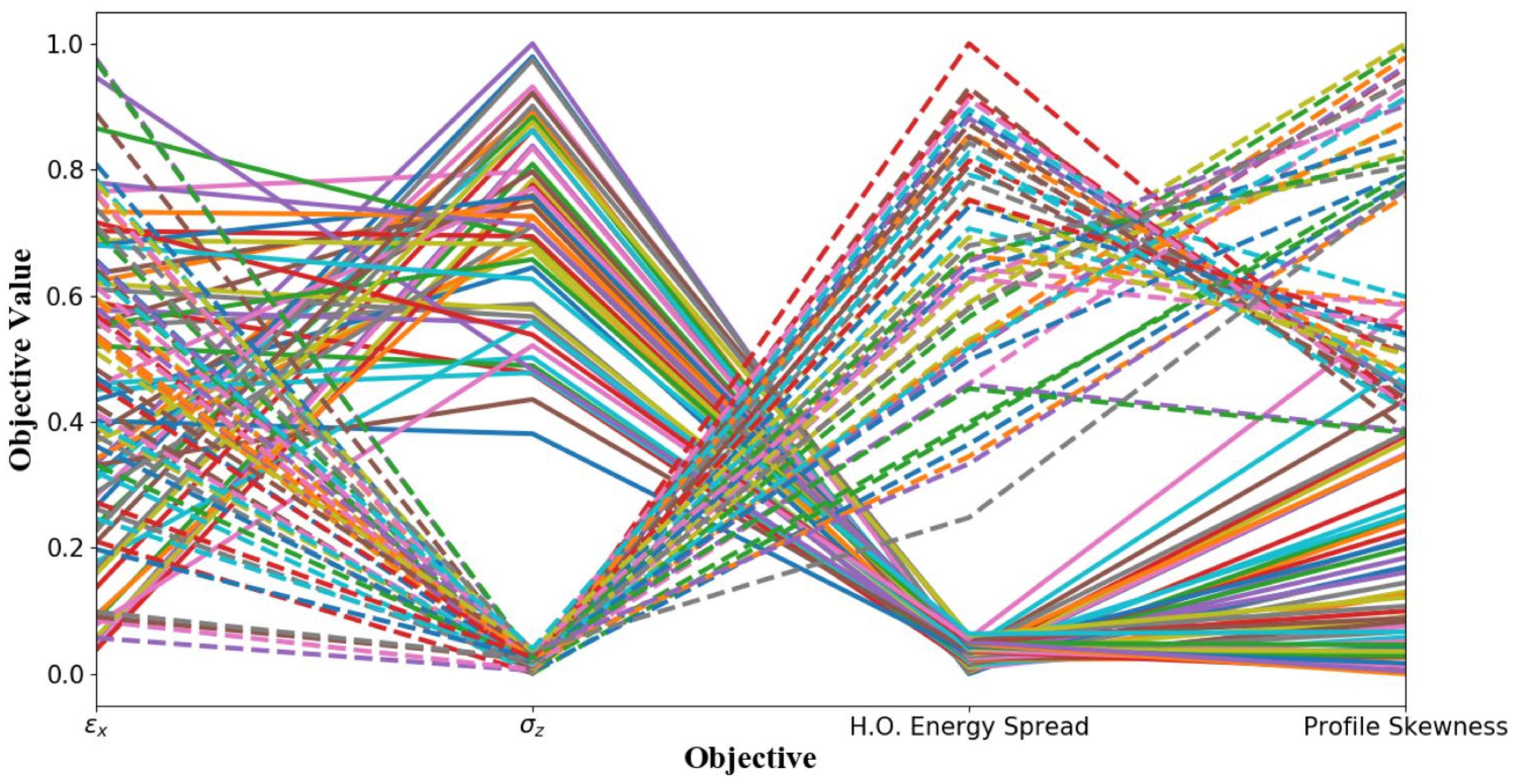



Figure 2: The parallel coordinate plots of the 100 solutions in the final population of generation showing the objectives value path. 50 of them with the shortest bunch length (dashed line) and the other 50 lines present the solutions with the smallest high-order energy spread (solid line).

### • Projections of the Pareto front

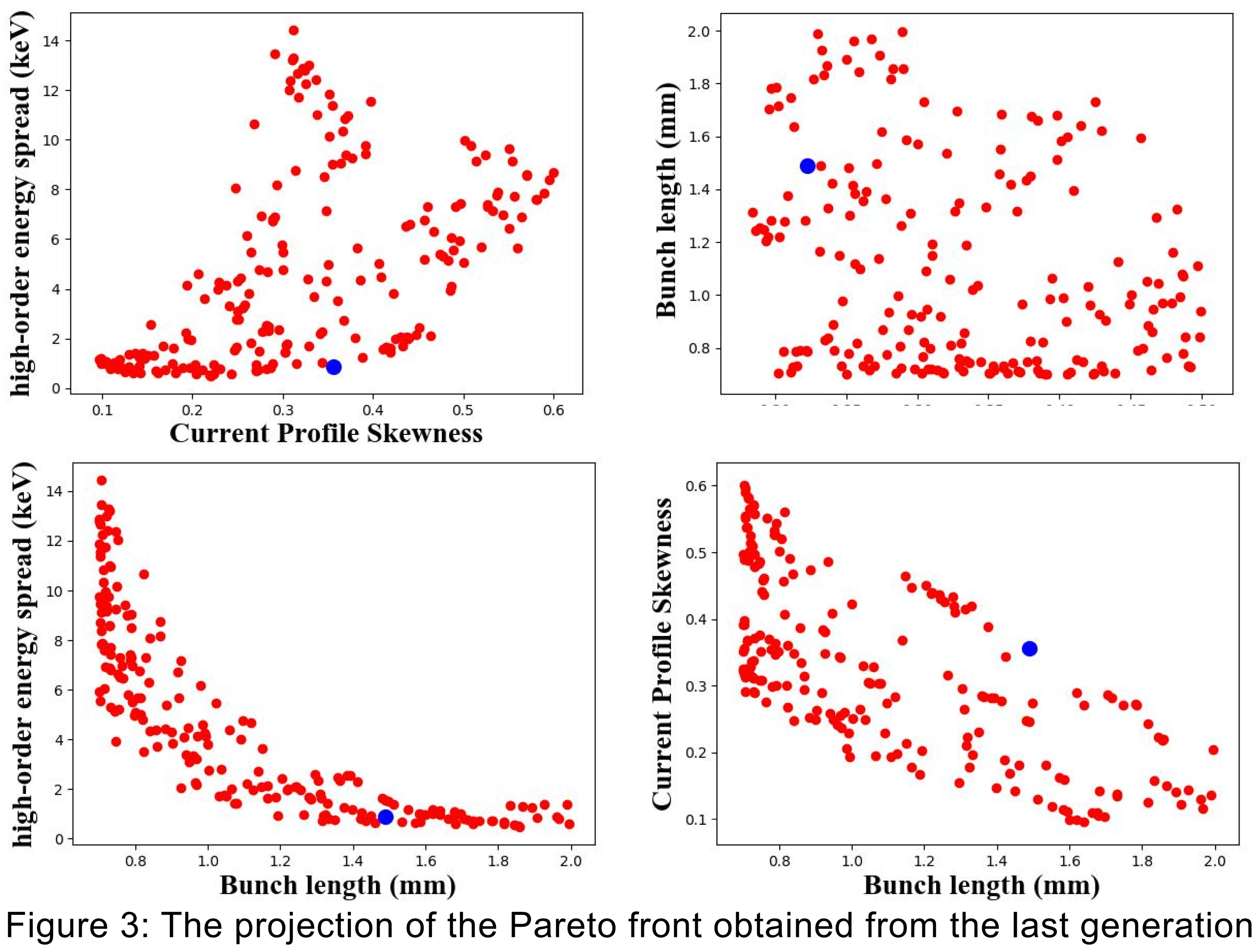
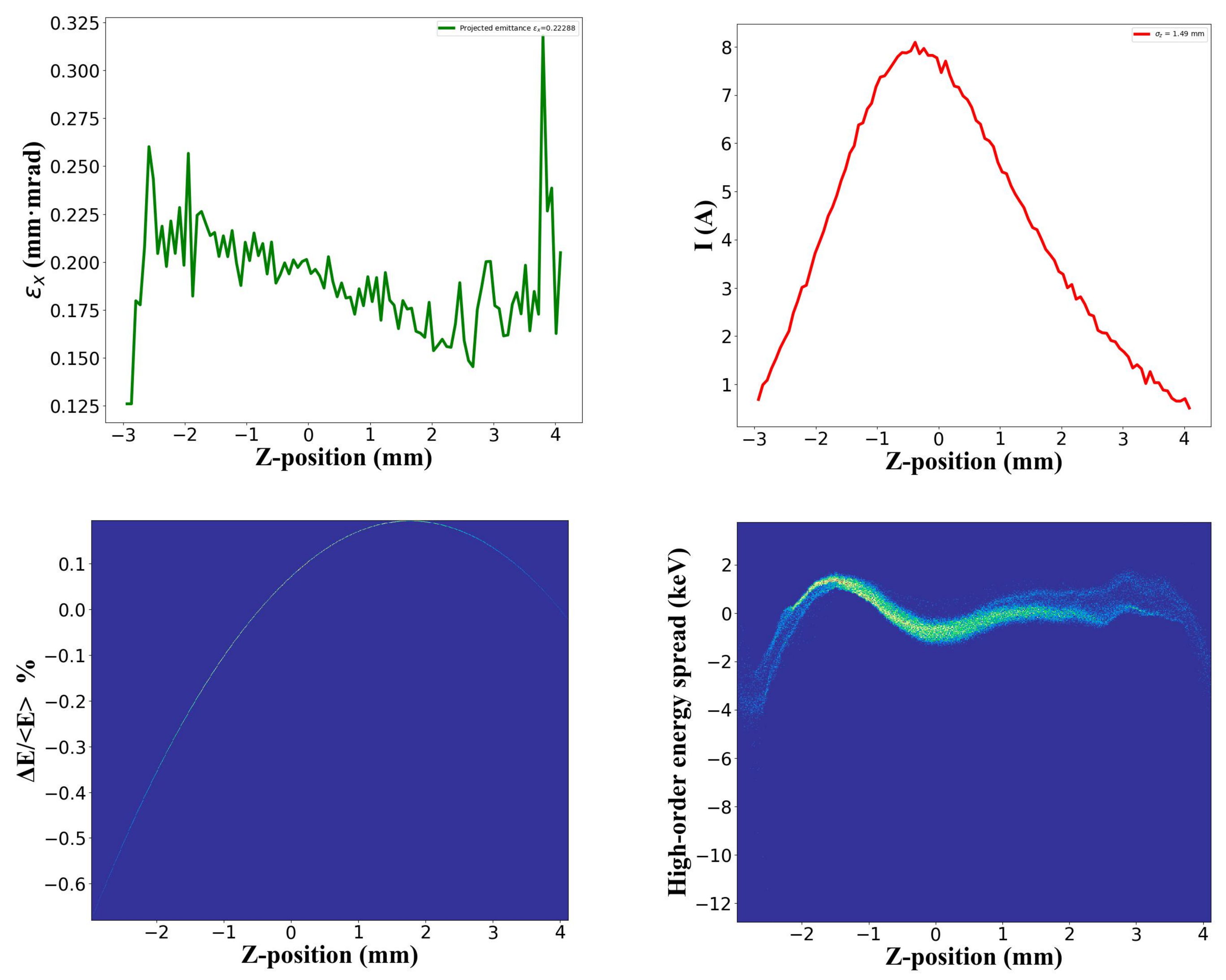



Figure 3: The projection of the Pareto front obtained from the last generation. The blue dots in each figure represent the selected solution of which the detailed beam dynamics paramters are shown in FIG.4. The four projection figures indicates the potential relationship between the detailed beam properties.

### • Optimized beam dynamics simulation results




The compromise is made and the bunch length is slightly longer (1.49 mm) compared with the previous design for mitigating the high-order terms in the correlated energy spread, which can be figured out in the last figure. This property can facilitate more linear magnetic compression in the chicane. Additionally, the slice transverse emittance, which is significant to FEL radiation performance, should be kept at an acceptable value. The optimized projected emittance is 0.23 mm·mrad.

## References

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