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Commissioning and Operation of the Transverse Collimation System at the RCS of CSNS

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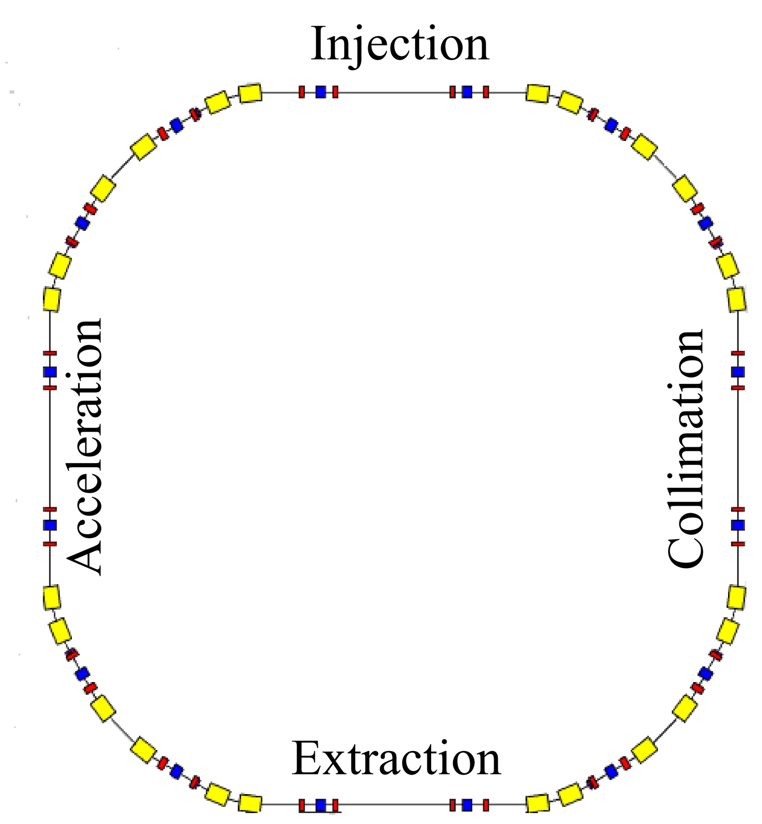
Abstract

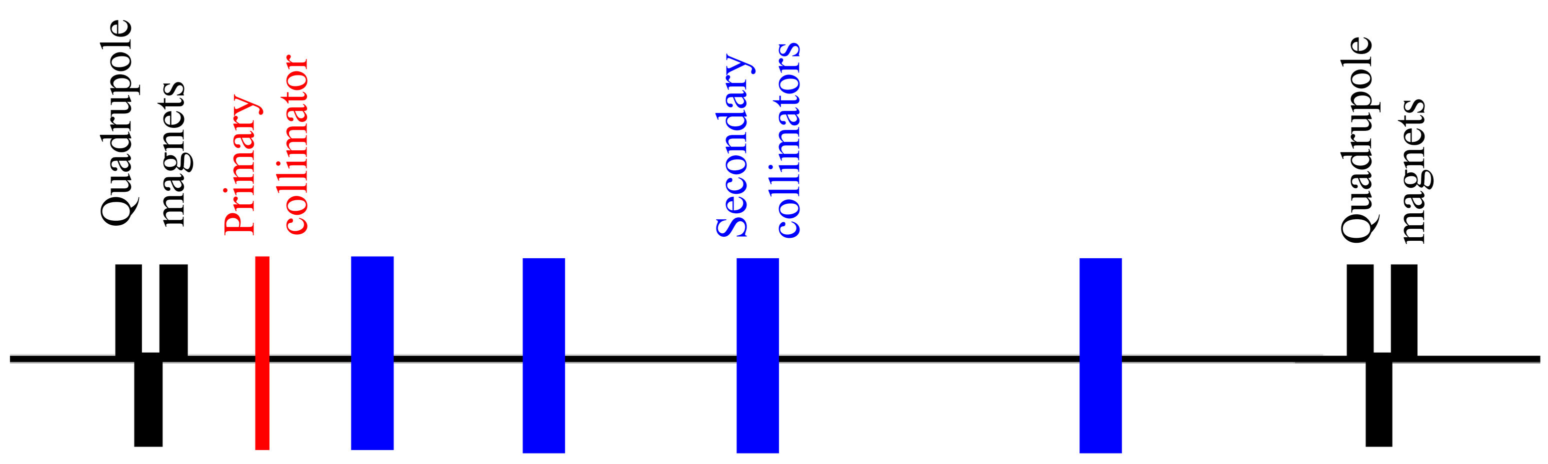
In high-intensity proton synchrotrons, minimizing particle losses during machine operation is crucial to prevent radiation damage. Uncontrolled beam loss is a major obstacle to achieve higher beam intensity and power in these synchrotrons. The beam collimation system plays a vital role in removing halo particles and localizing beam loss. It serves as a critical tool for controlling uncontrolled beam loss in high-power proton accelerators. To address the issue of uncontrolled beam loss, a transverse collimation system was designed for the RCS of CSNS. Initially, the design included a two-stage collimator. However, during the beam commissioning of CSNS, it was found that the collimation efficiency was compromised due to insufficient phase advance between the primary and secondary collimators. As a result, the designed two-stage collimator was modified to a one-stage collimator. Through optimization of the collimation system, the beam loss was effectively localized within the collimator area, resulting in a significant reduction in uncontrolled beam loss. As a result, CSNS achieved the design power of 100 kW with minimal uncontrolled beam loss.

Main parameters of CSNS/RCS



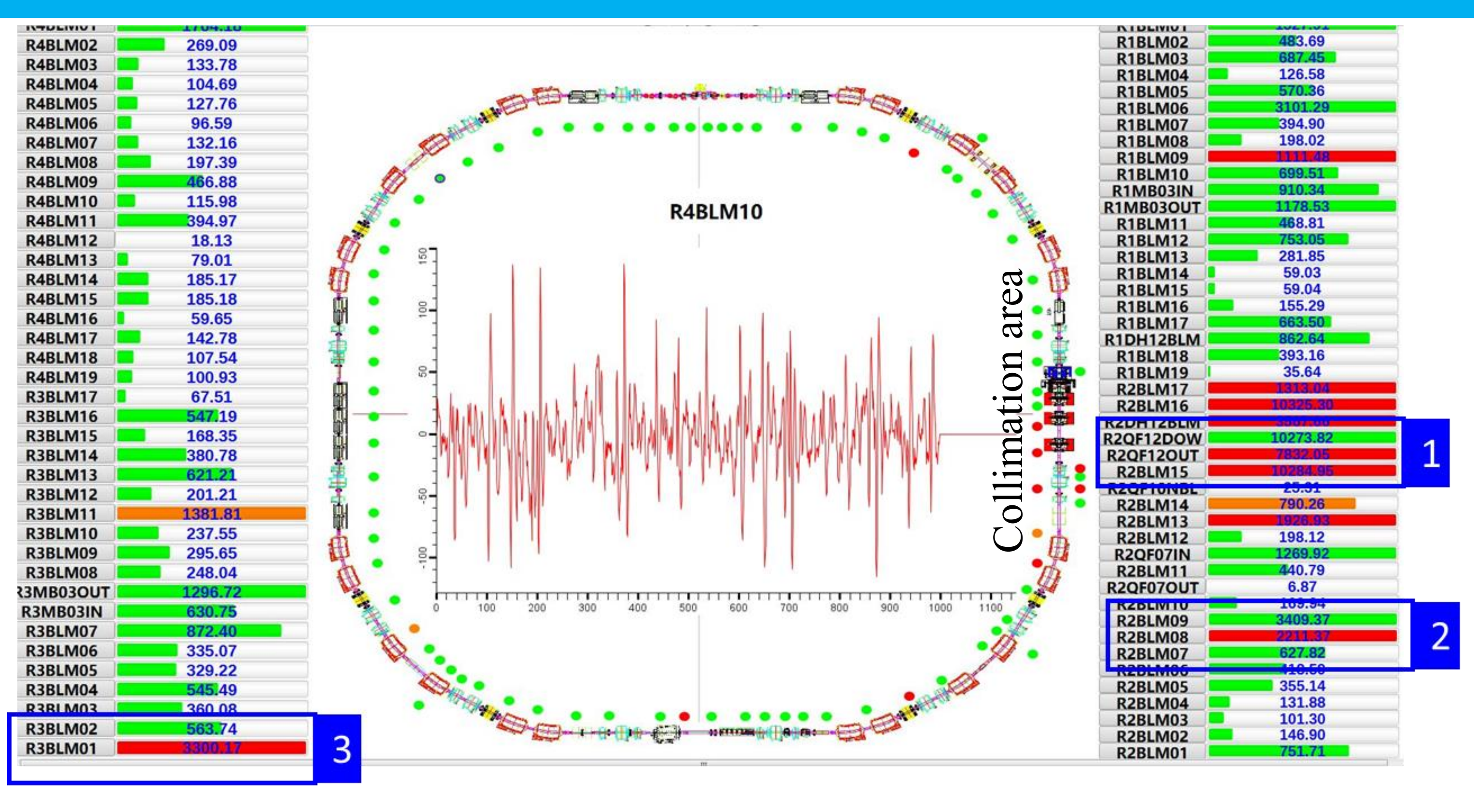
Output Beam Power [kW]	100
Injection Energy [MeV]	80
Extraction Energy [GeV]	1.6
Pulse repetition rate [Hz]	25
Ramping Pattern	Sinusoidal
Acceleration Time [ms]	20
Circumference [m]	227.92
Number of dipoles	24
Number of quadrupoles	48
Lattice Structure	Triplet
Nominal Betatron Tunes (H/V)	(4.86, 4.80)
Natural Chromaticity	-4.0/-8.2
Ring Acceptance [πmm-mrad]	540
Harmonic Number	2
Number of Particles per Pulse	1.56×10^{13}
Space-Chare Tune Shift	-0.28

Design of the transverse collimation system



I. The transverse collimation system is a two-stage collimation system, including a primary collimator and four secondary collimators.
II. Primary collimator scrapes beam halo and secondary collimators absorb the primary halo as it evolves following the phase advance.
III. The phase advances between the primary collimator and the secondary collimators are (9°, 9°), (21°, 22°), (38°, 41°) and (62°, 67°), respectively.
IV. The collimation efficiency is expected to be over 95%.

Beam commissioning results



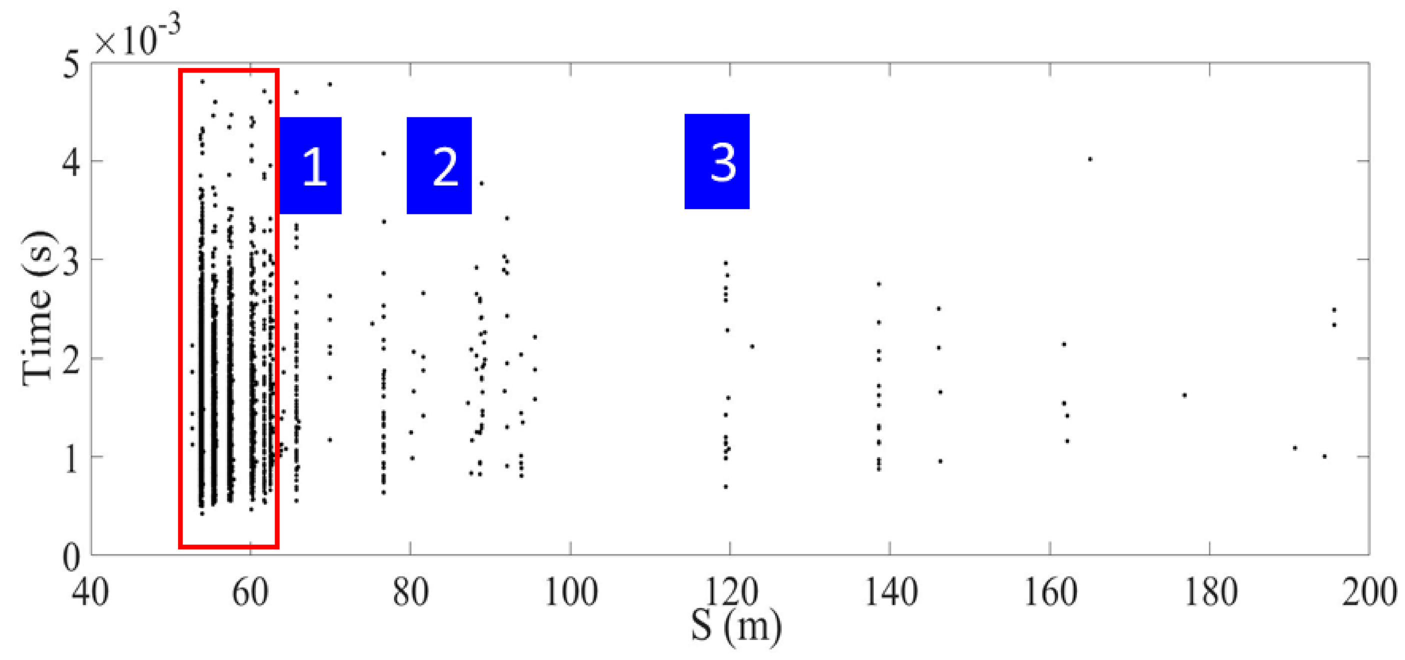
In addition to the collimation area, there are three other crucial beam loss points.

Analysis of the uncontrolled beam loss

In a two-stage collimation system, collimation efficiency is influenced by two crucial factors: the phase advance between the primary collimator and the secondary collimators, and the ratio of the physical aperture to the aperture of the primary collimator.

I. The phase advance between the primary collimator and the secondary collimator, which is less than 90°, plays a crucial limitation in enhancing collimation efficiency.

II. Due to various dynamic errors and the limited painting area, the beam emittance exceeds the design value, while the ring acceptance falls short of the intended value. The ratio of the ring acceptance to the beam emittance, which is about 1.2, is significantly lower than the intended design value of 1.8.



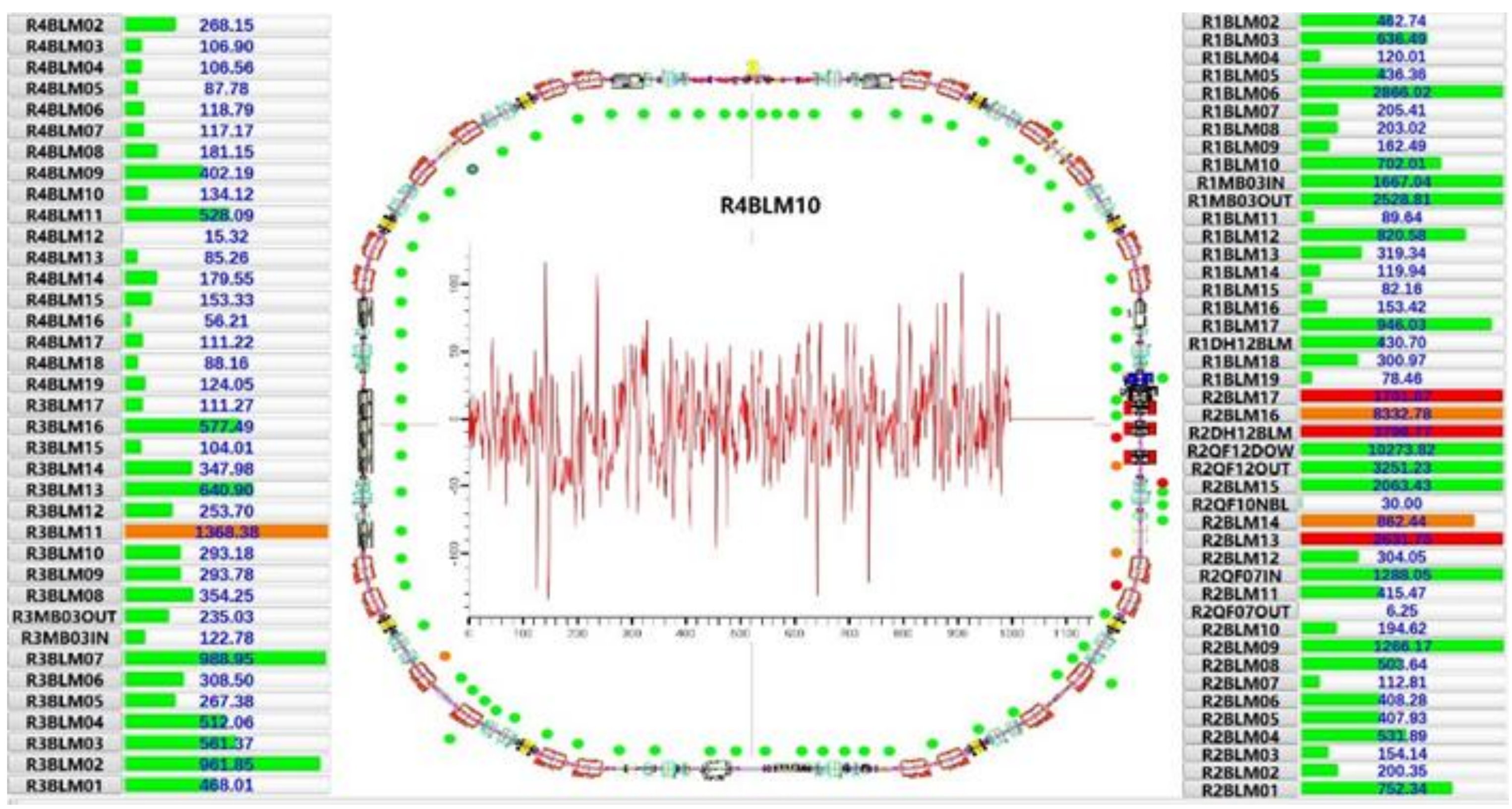
The simulated beam loss distribution obtained using the actual machine parameters matches the experimental results.

Collimation system optimization

I. After the machine is constructed, the physical aperture remains fixed.
II. The phase advance can only be adjusted within a limited range.
III. The beam emittance cannot be optimized below the design value when operating at the intended beam power of 100kW.

Transverse collimation system optimization:

I. The designed two-stage collimator is changed to one-stage collimator.
II. The beam halo passes through the main collimator without scattering and is directly absorbed by the first secondary collimator.
III. Additional instances that do scatter are further absorbed by subsequent downstream secondary collimators.



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