Proton beam dynamics in bare IOTA with intense space-charge

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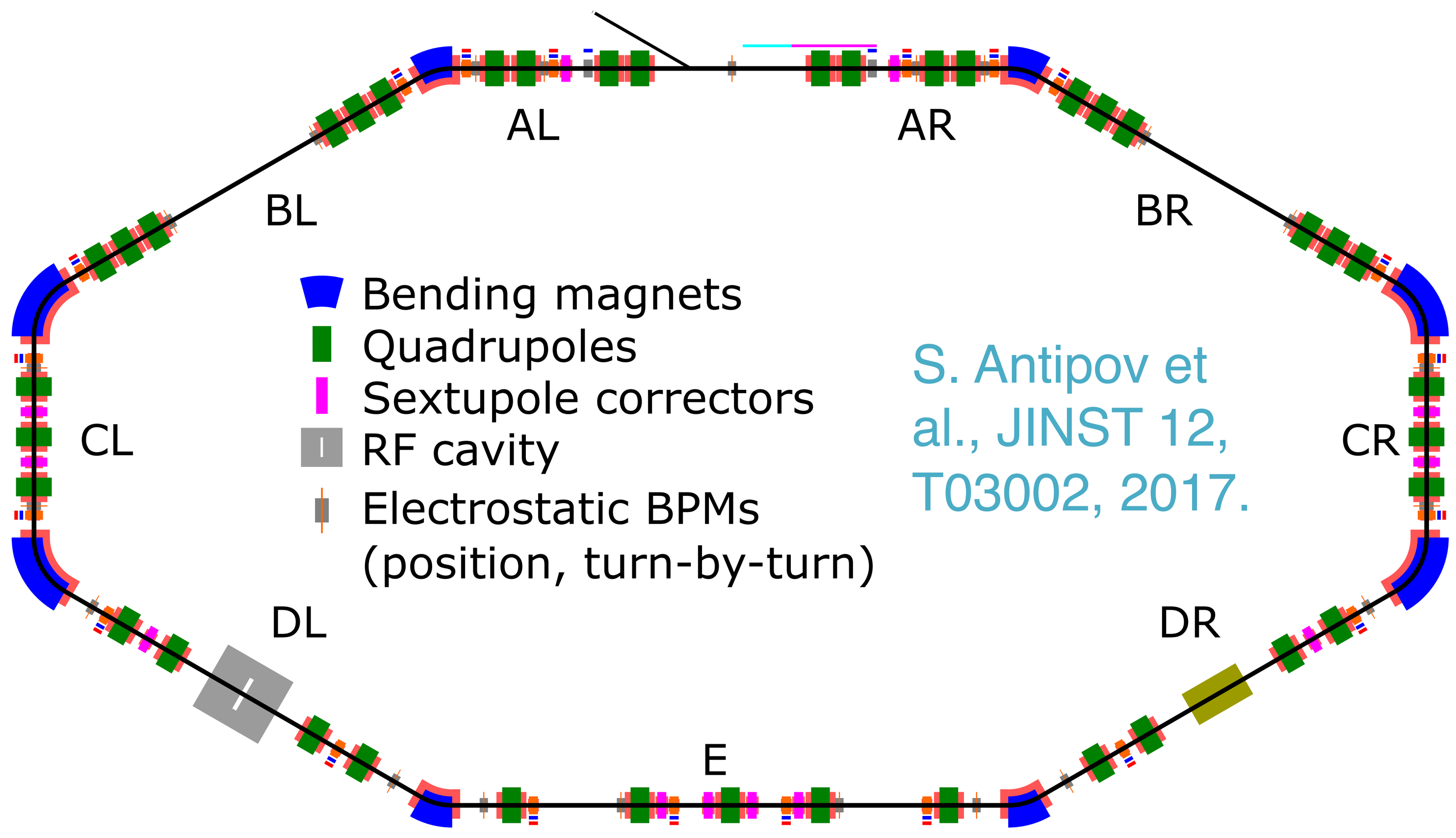
We compared anticipated emittance growth and loss of 2.5 MeV proton beams in the bare configuration of the Integrable Optics Test Accelerator at Fermilab using transverse space-charge models in Xsuite, PyORBIT, and MAD-X simulation codes.



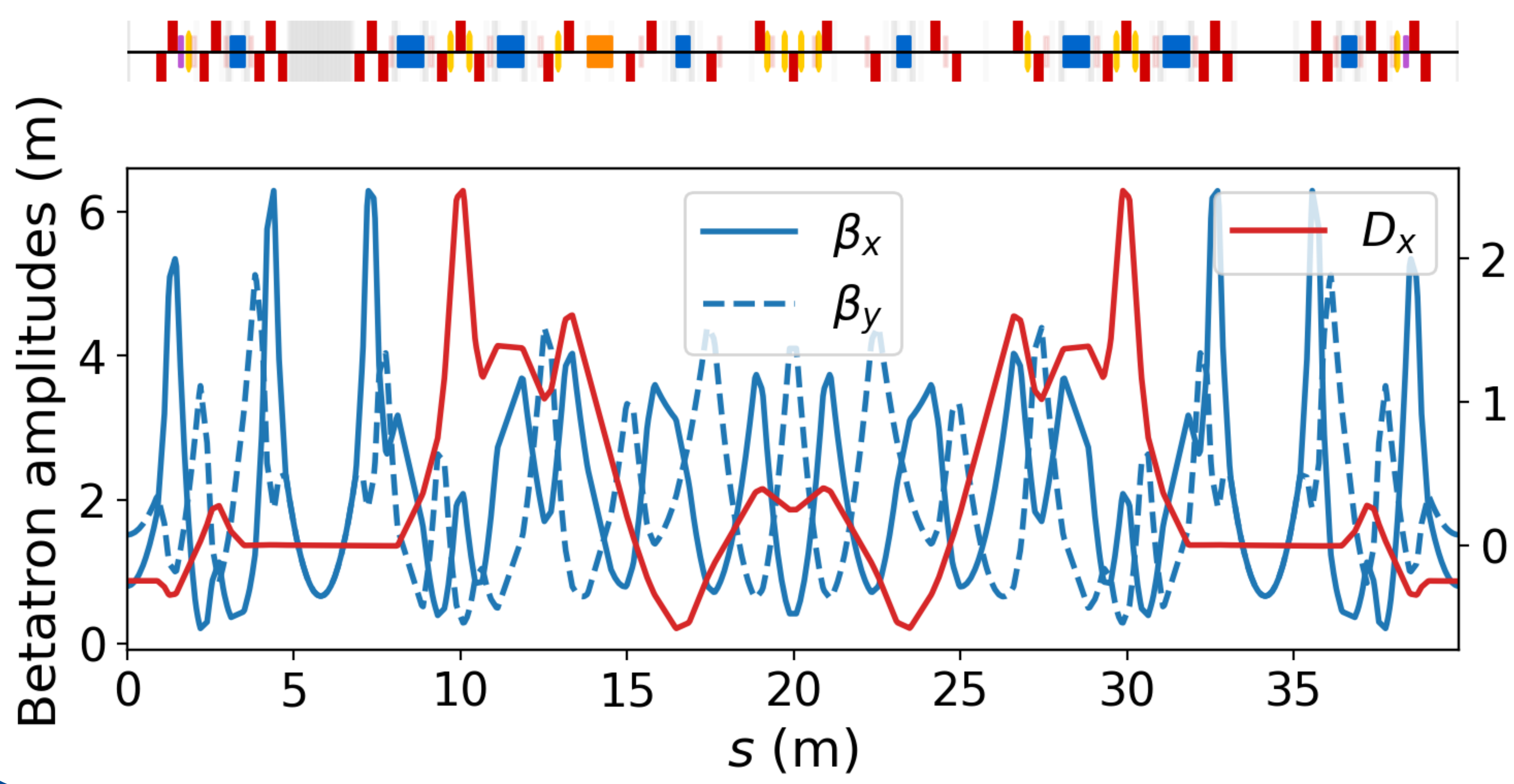
S. Antipov et al., JINST 12, T03002, 2017.

The Integrable Optics Test Accelerator is dedicated to research in beam physics. Non-linear Integrable Optics, Optical Stochastic Cooling, quantum statistics of undulator radiation, single electron studies, electron lens and many more. **See posters MOPG05, MOPG06, MOPS57, MOPS67, TUPC28, TUPR48, WEPG39, WEPR48, THPC20, THPC21, THPC68, THPR32 and talks MOZD1, WEBN1.**

Lattice configuration and beam parameters

We utilize the bare lattice configuration without non-linear elements, and with sextupoles deactivated for our benchmarking studies.

Parameter	Value	Units
Kinetic Energy (K)	2.5	MeV
Geometric rms emittances (ϵ_x, ϵ_y)	4.3, 3.0	μm
RMS momentum spread (σ_δ)	2.1	10^{-3}
RMS bunch length (σ_z)	1.24	m
Circumference (C)	40	m
RF harmonic (h)	4	
Working point (Q_x, Q_y, Q_s)	5.3, 5.3, 0.01	



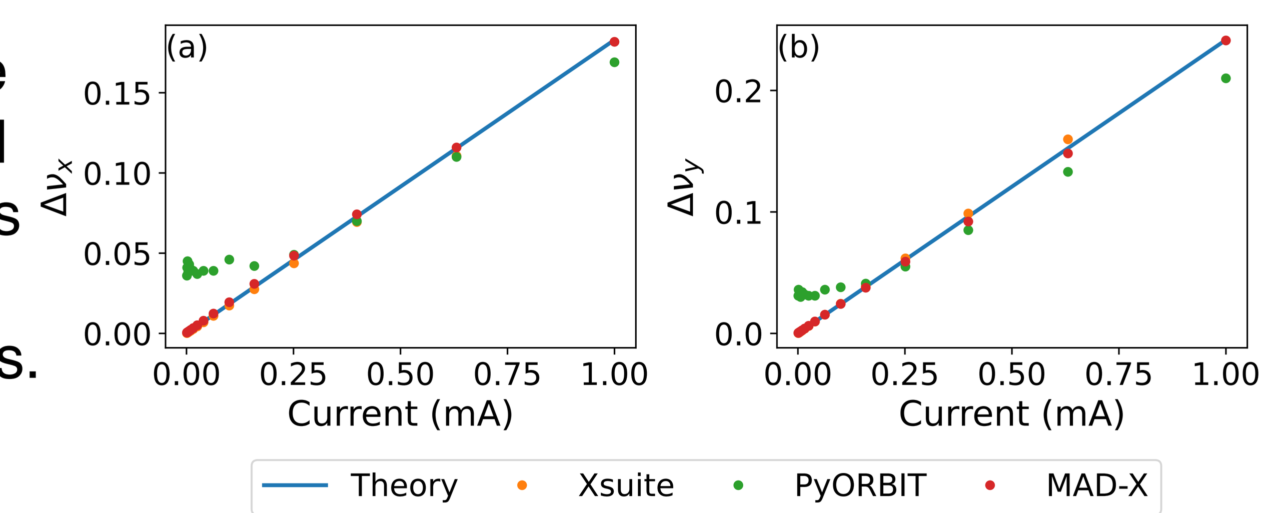
Space-charge codes and setup

Xsuite
Transverse frozen
G. Iadarola, in Proc. HB'23, Geneva, Switzerland, Oct. 2023, pp. 73-80.

PyORBIT
Transverse 2.5D Electrostatic PIC
A. Shishlo et al., Procedia Computer Science 51, pp. 1272-1281, 2015.

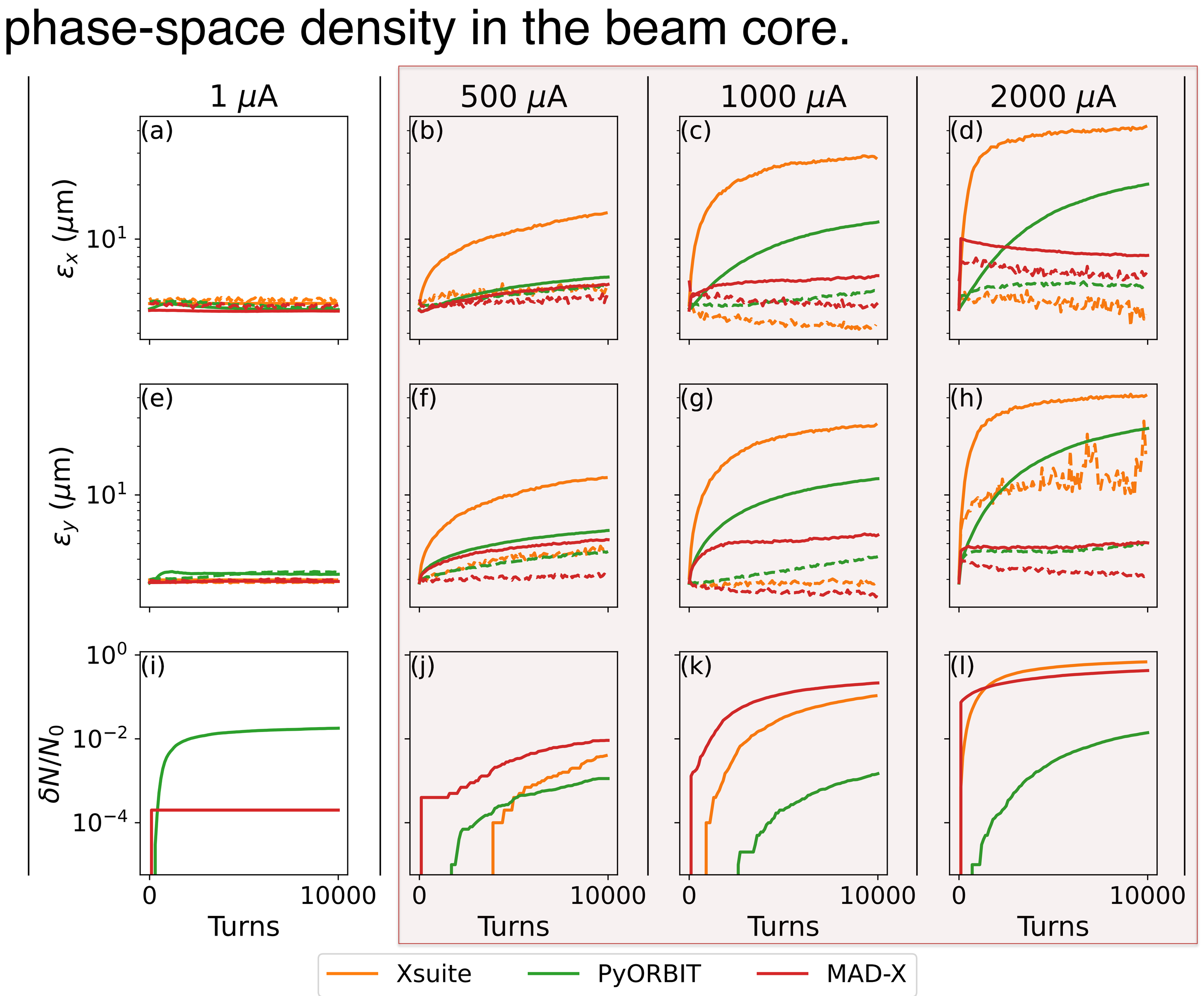
MAD-X
Transverse quasi-frozen
F. Schmidt et al., in Proc. HB'16, Malmö, Sweden, Jul. 2016, pp. 357-361.

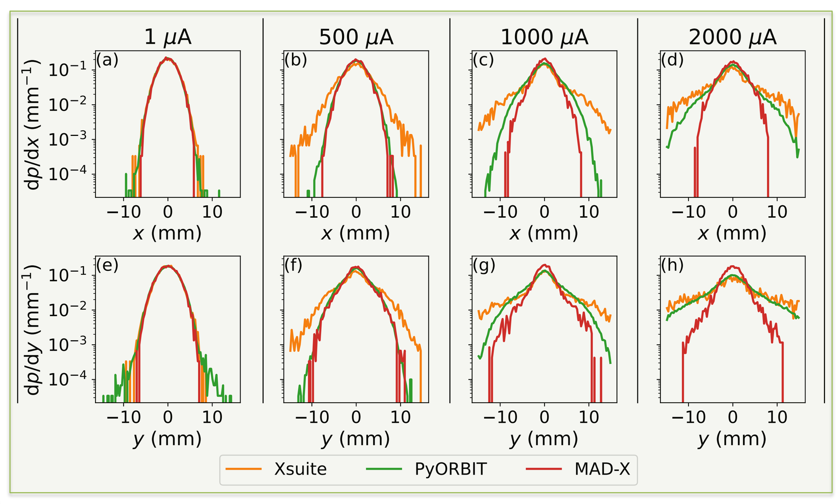
Incoherent tune shifts estimated from the models match with expected values.



Comparison of phase-space evolution

We compare the evolution of rms emittance and inverse phase-space density in the beam core.





Substantial difference in rms emittances and beam loss at moderate and high currents. Evolution of the beam core is consistent among the three codes until particles cross the integer resonance.

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