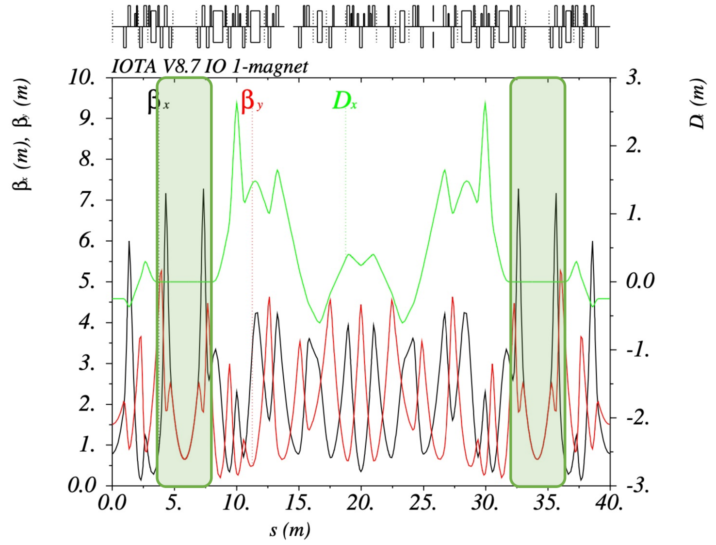
Proton parameter calculations for an ensemble of lattices

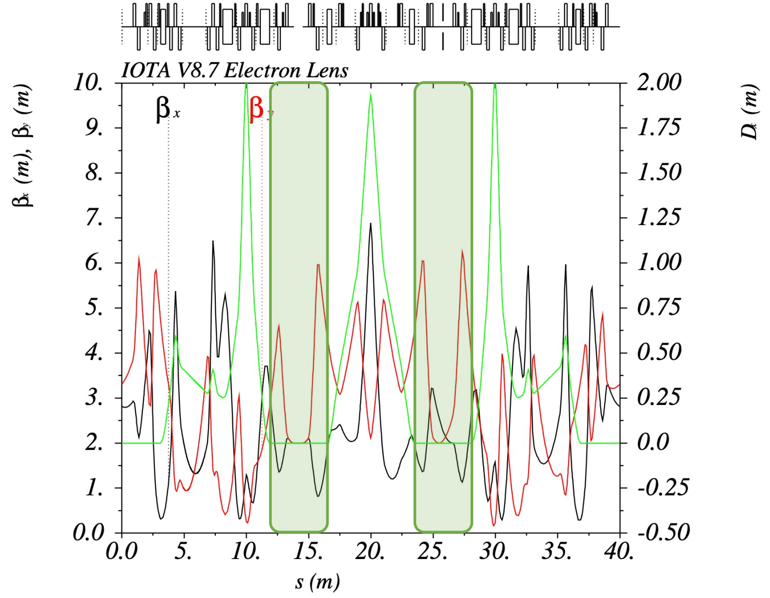
Lattices for IOTA

The standard lattice file contains 5 main lattices (some have subtypes):

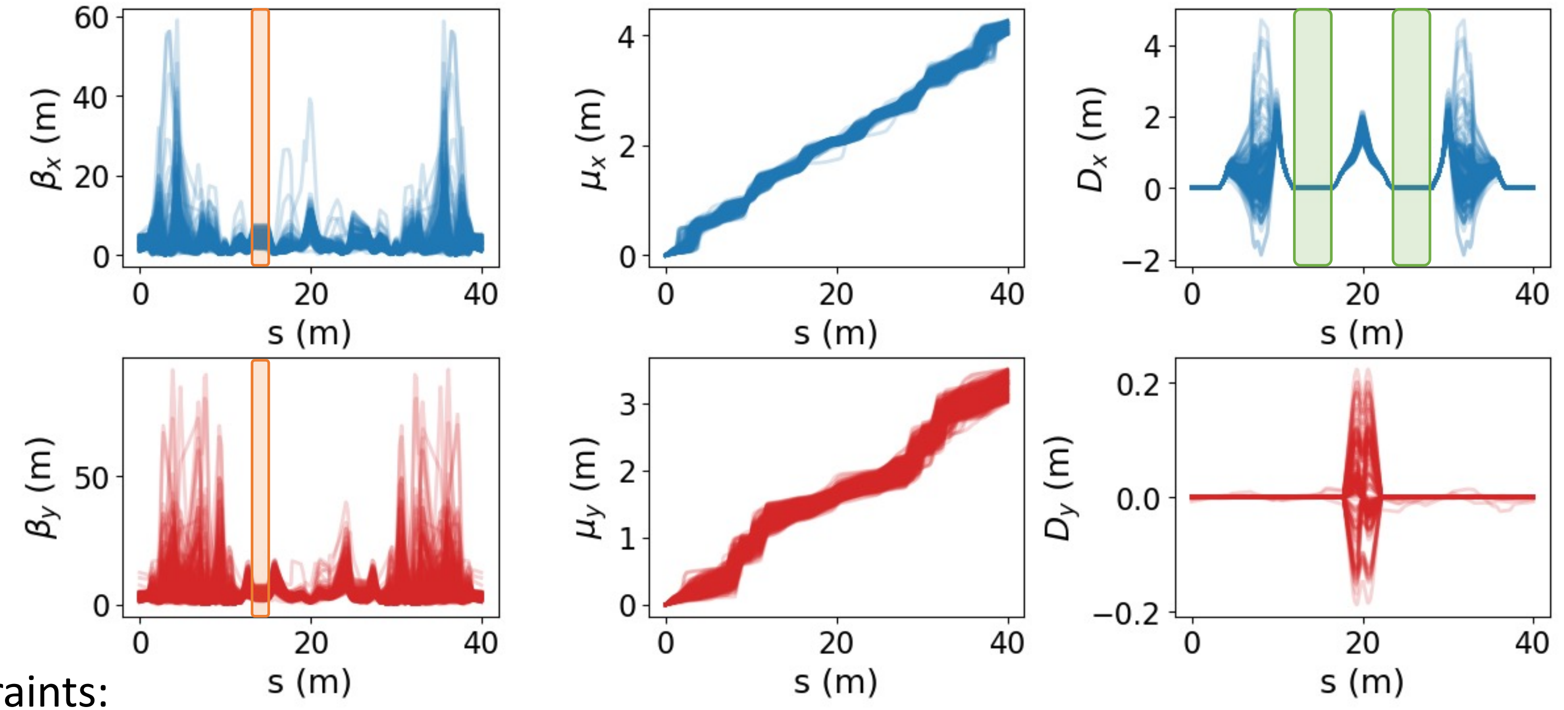
1. Danilov-Nagaitsev system
2. Octupoles channel
3. Optical Stochastic Cooling
4. McMillan Lens
5. Electron Lens

Chose the electron lens lattice as the basis for electron cooling.





Ensemble of lattices for electron cooling



The lattice design is implemented as a series of match statements in MAD-X. 258 lattices in plot.

Non-zero y dispersion generated through transverse coupling.

Constraints:

✓ Zero dispersion at cooler and rf cavity.

✓ Matched beta function at solenoid.

✓ Zero transverse coupling for one-turn matrix.

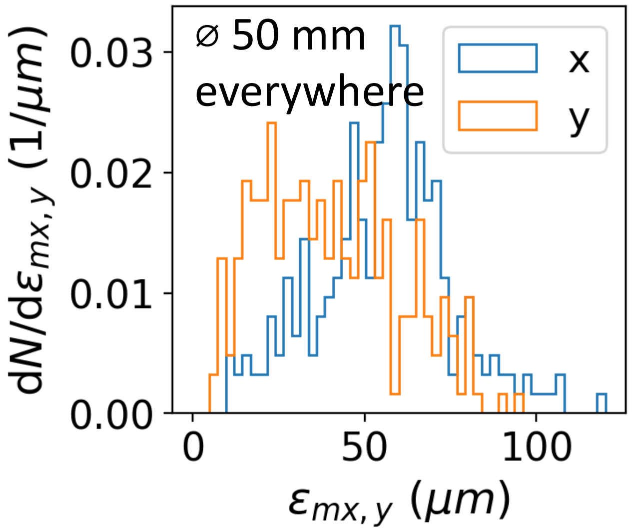
• ~~Magnet strength limits.~~

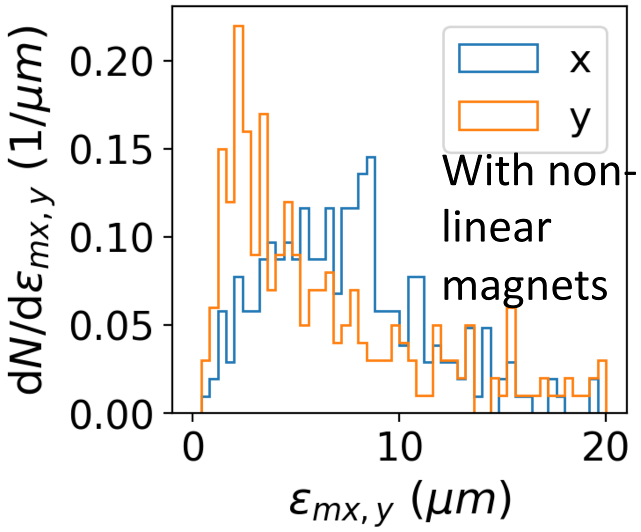
Knobs:

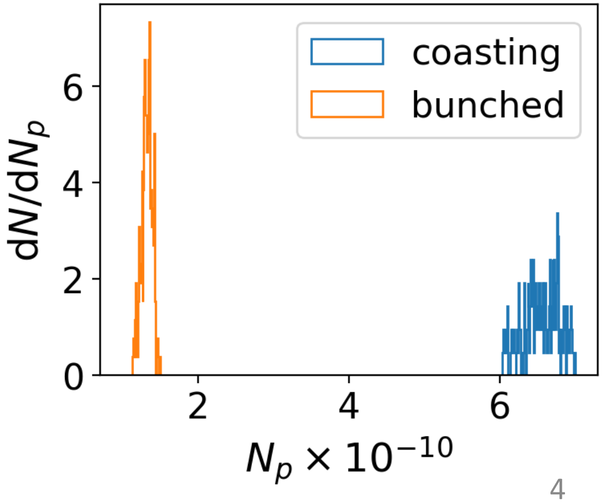
- Beta functions at injection (2)
- Beta functions at entrance of DR line (2)
- Solenoid field (1)
- Betatron tunes (2)

Acceptances and space-charge tune shift

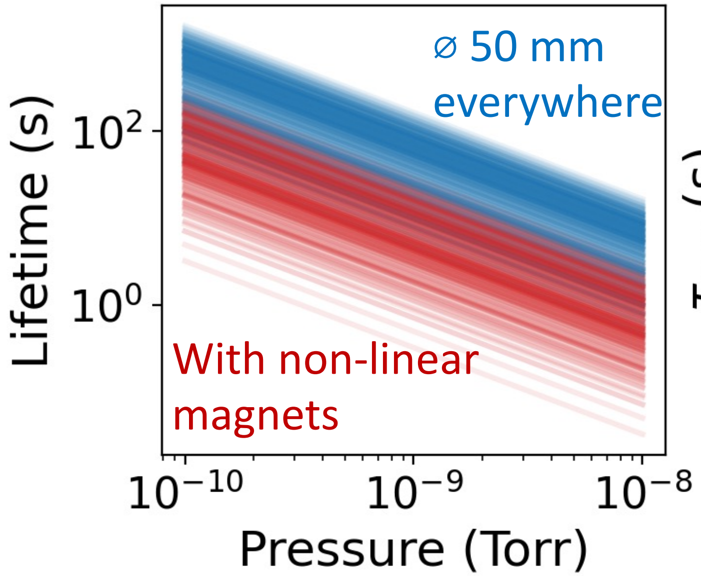
- The aperture restriction from the non-linear magnet reduces the acceptance by almost an order of magnitude.
- The total beam intensity required to reach a space-charge tune shift of 0.5 is about 10^{10} for bunched beam and 6.5×10^{10} for coasting.

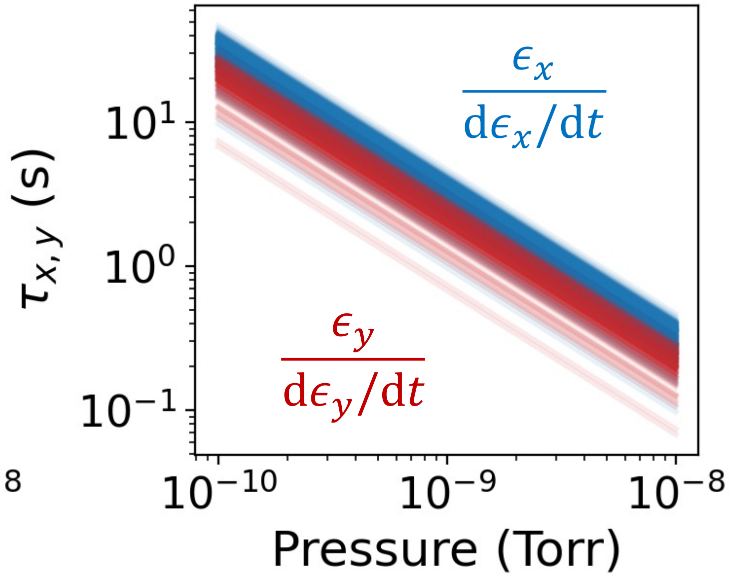






Effects of Residual Gas Scattering





Large angle scattering

$$\tau_{RGS,single}^{-1} = \frac{2\pi c r_p^2}{\beta^3\gamma^2}\left(\frac{\langle\beta_x\rangle}{\epsilon_{mx}} + \frac{\langle\beta_y\rangle}{\epsilon_{my}}\right)\sum_i n_i Z_i (Z_i + 1)$$

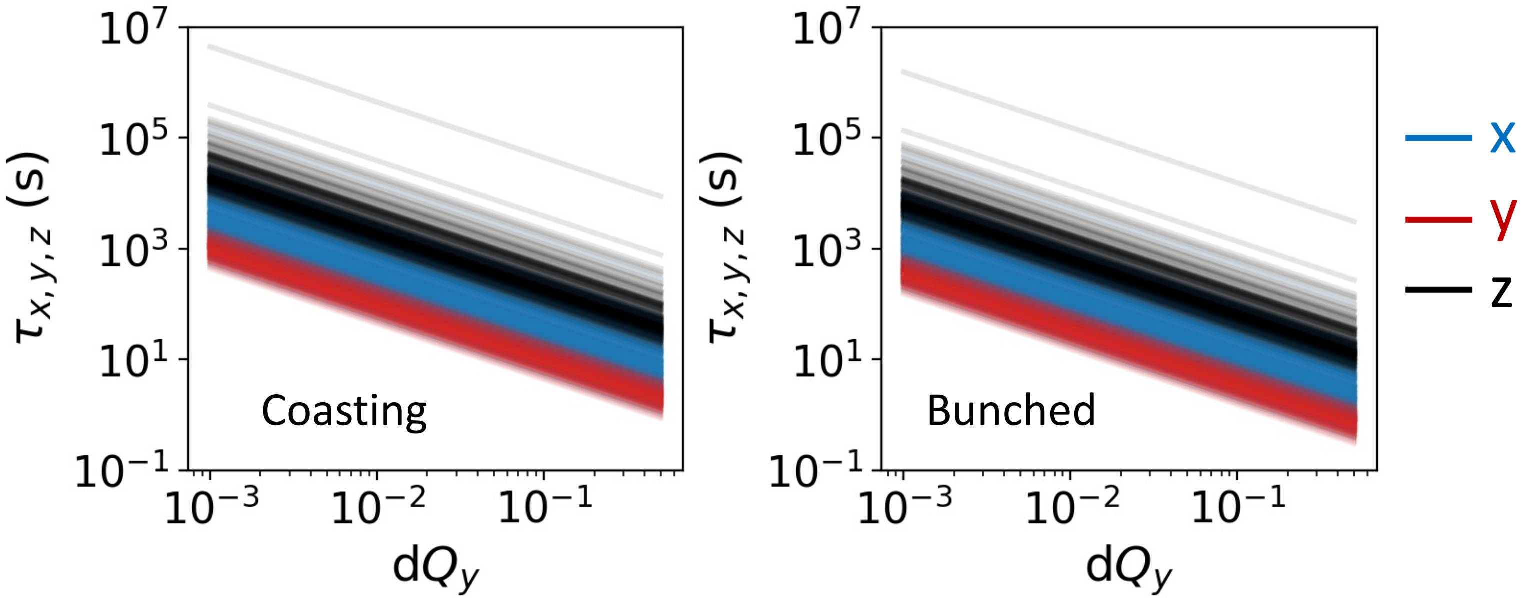
Aperture restrictions reduce lifetime by almost an order of magnitude.

Small angle scattering

$$\tau_{RGS,\epsilon_{x,y}}^{-1} = \frac{1}{\epsilon_{x,y}}\frac{d\epsilon_{x,y}}{dt} = \frac{2\pi c r_p^2}{\beta^3\gamma^2}\frac{\langle\beta_{x,y}\rangle}{\epsilon_{x,y}}\sum_i n_i Z_i (Z_i + 1)\, L_{c,i}$$

Emittance growth time scales are about 10 seconds and higher at 10^{-10} Torr.

Emittance growth from Intra-Beam Scattering



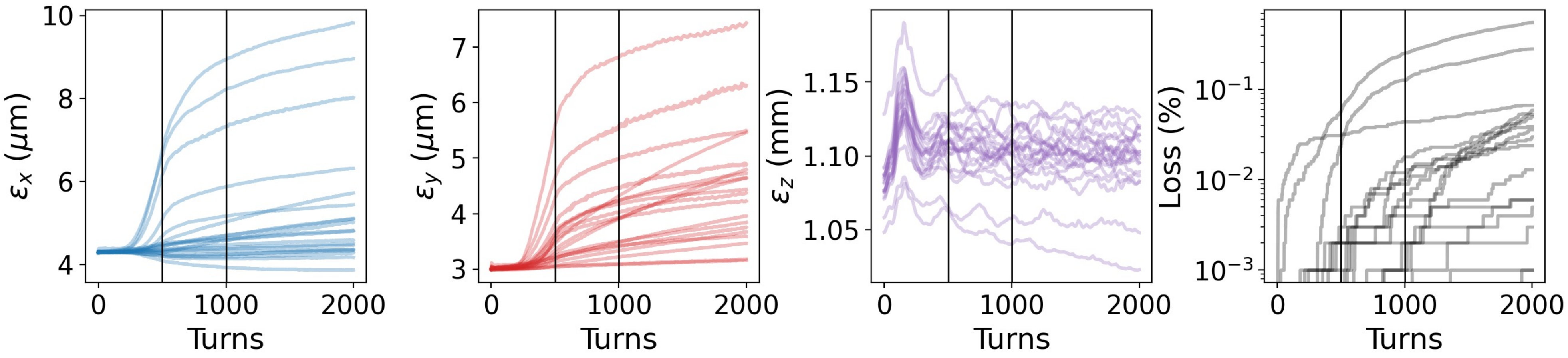
Using the extended Bjorken-Mtingwa approach implemented in MAD-X which incorporates vertical dispersion and non-relativistic corrections.

See CERN-ATS-2012-066

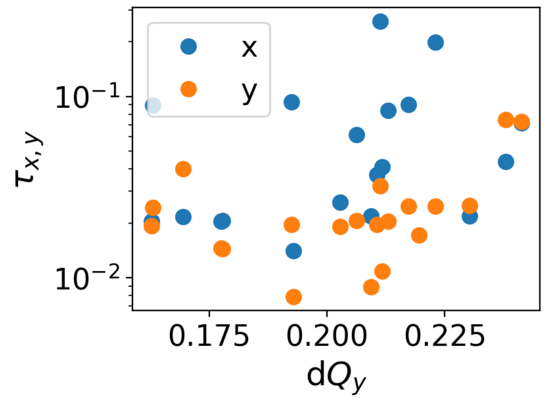
Does not support transverse coupling! I assume that the coupling is weak in DR-E-DL.

Emittance growth from space-charge

Chose 20 simulations out of 50 which ended with less than 1 % beam loss. Turns 1 – 500: Charge ramping, Turns 500 – 1000: Transient, Turns 1000- 2000: Steady state?



Emittance growth rates between 10 – 100 ms without cooling. Need more statistics!



Next Steps

- Create more statistics for the space-charge emittance growth estimation.
- Make summary table with parameter ranges based on 95% confidence intervals.
- Finish writing these results into the report.
- Upload code and data into Redmine.