



# PS Space Charge Simulations

Updates

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# Methods Explored

At each of the four sections (40, 42, 43, 44) in the PS we use:

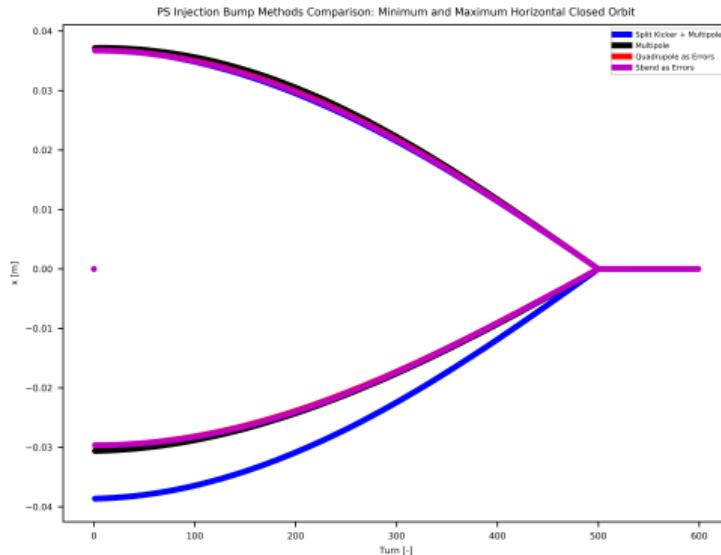
- ▶ Two 10 cm HKICKER with MULTIPOLE inbetween for the sextupole component.
- ▶ A single MULTIPOLE with dipolar and sextupolar components.
- ▶ A single (zero gradient) QUADRUPOLE with dipolar and sextupolar components added as errors.
- ▶ A single (zero angle) SBEND with dipolar and sextupolar components added as errors.

# Issues

- ▶ Make sure to update PTC and PyORBIT every turn.
- ▶ Include calls to correct PTC files (energize lattice, update twiss, read final settings etc).
- ▶ Unknown environment bug on LXPlus and HPC-Batch: causes simulation to run without updating PTC every turn - for unknown reason. Now seems to work - not satisfied with not knowing more - will keep an eye out for future weirdness.
- ▶ Dipole component was not normalised when used in QUADRUPOLE and SBEND methods.

# Horizontal Closed Orbit Maximum and Minimum

Plot the extrema of the closed orbit as a function of turn.



**Figure:** Horizontal Orbit Extrema

# Injection Bump

- ▶ All single element methods agree, only the split HKICKER method is different.
- ▶ Tunes however are not in agreement.

Note: all simulations run at the most extreme vertical working point of  $(Q_x, Q_y) = (6.21, 6.10)$ .

# Split HKICKER + MULTIPOLE

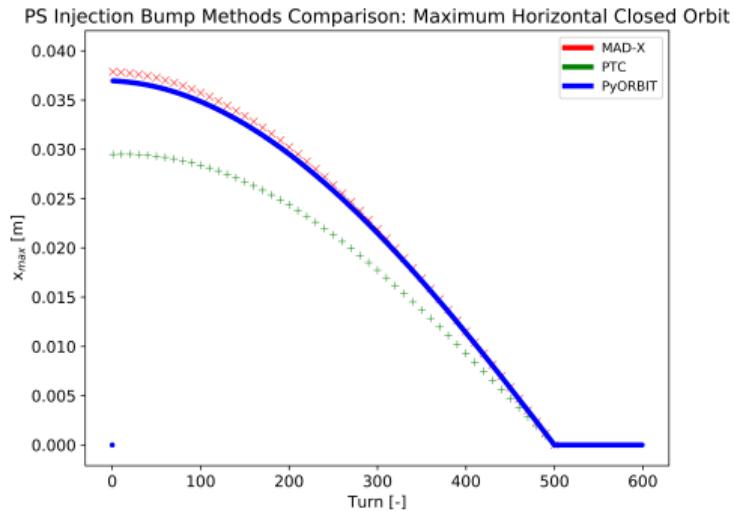
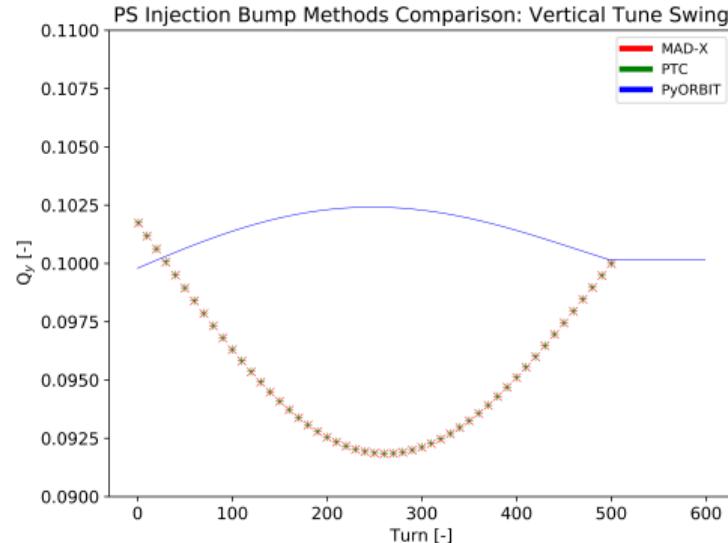
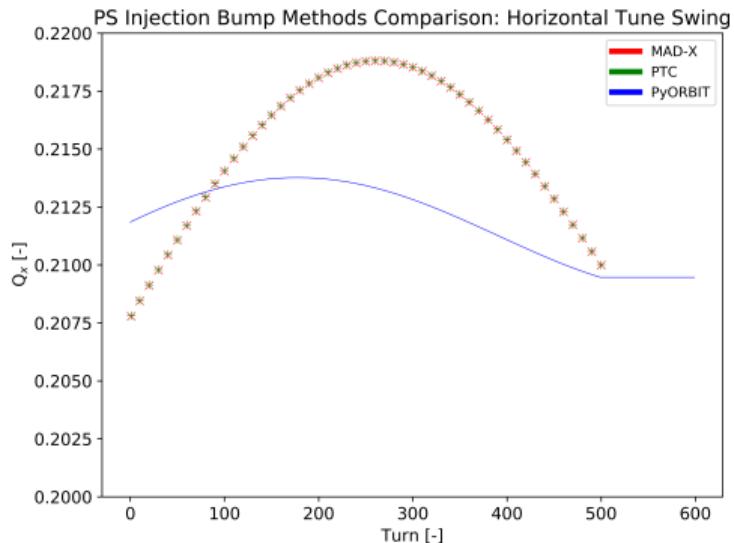
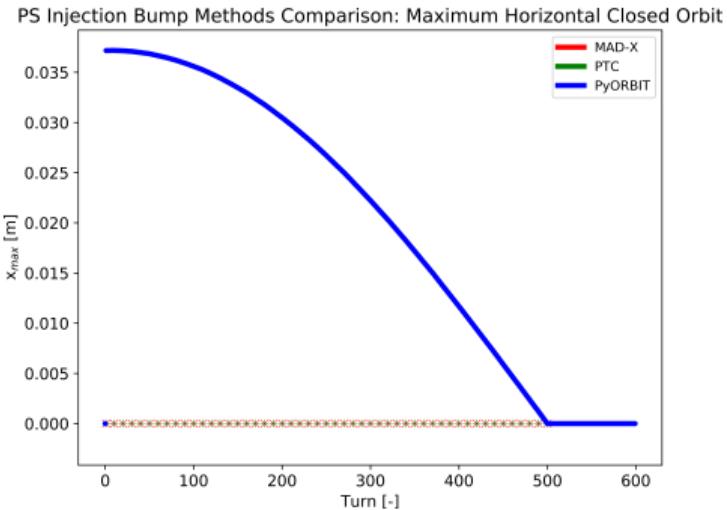


Figure: Horizontal Orbit Extrema for split HKICKER + MULTIPOLE

# Split HKICKER + MULTIPOLE

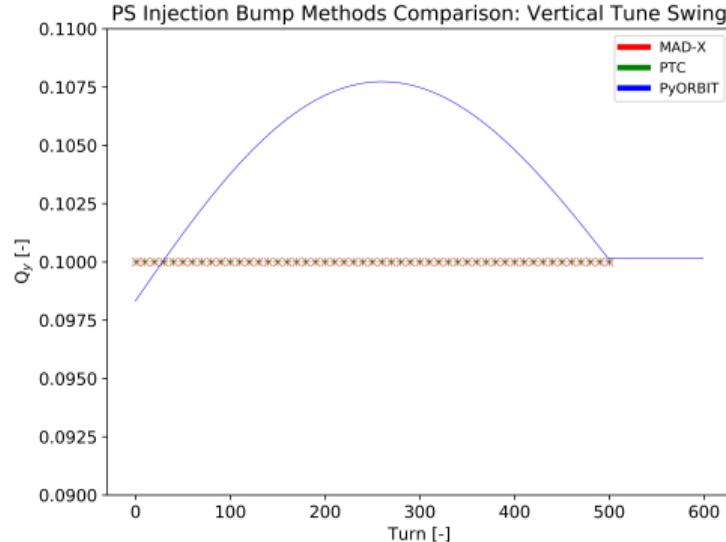
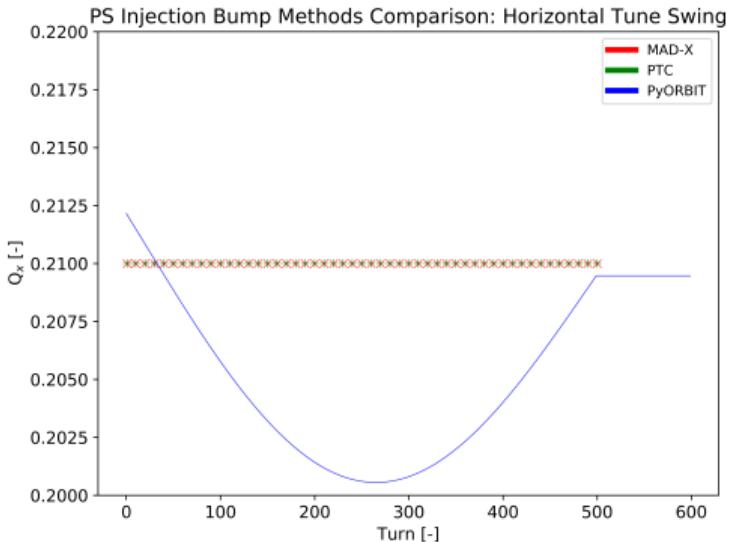


**Figure:** Tunes for split HKICKER + MULTIPOLE: magnitude and  $Q_y$  sign incorrect.



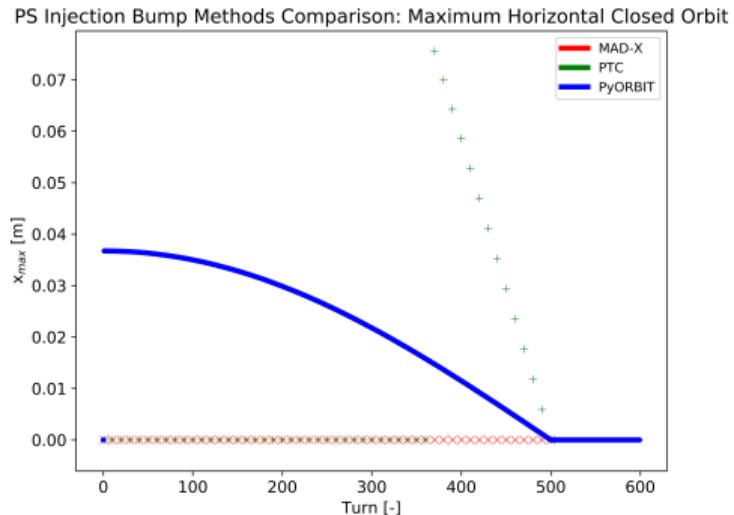
**Figure:** Horizontal Orbit Extrema for MULTIPOLE: MADX and PTC show no change, however effect is visible in PyORBIT.

# MULTIPOLE



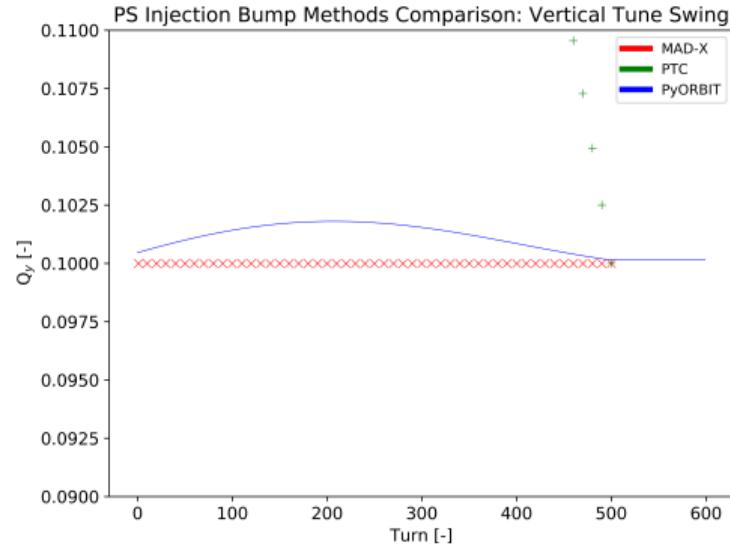
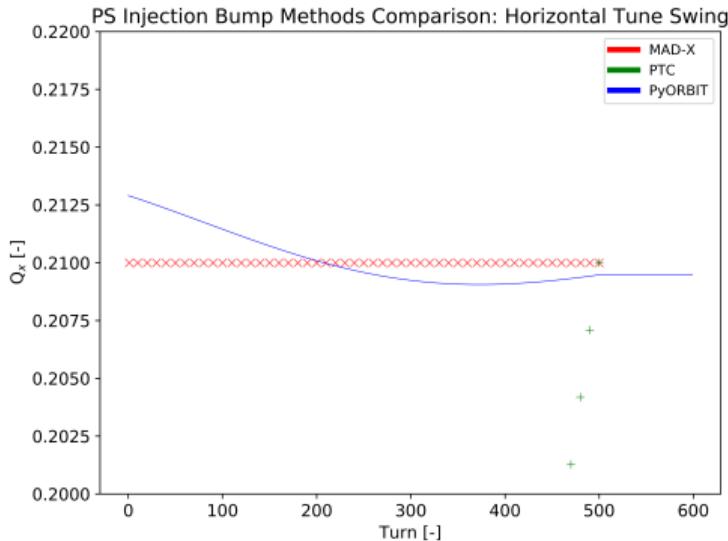
**Figure:** Tunes for MULTIPOLe: magnitude correct, sign opposite from expected.

# QUADRUPOLE

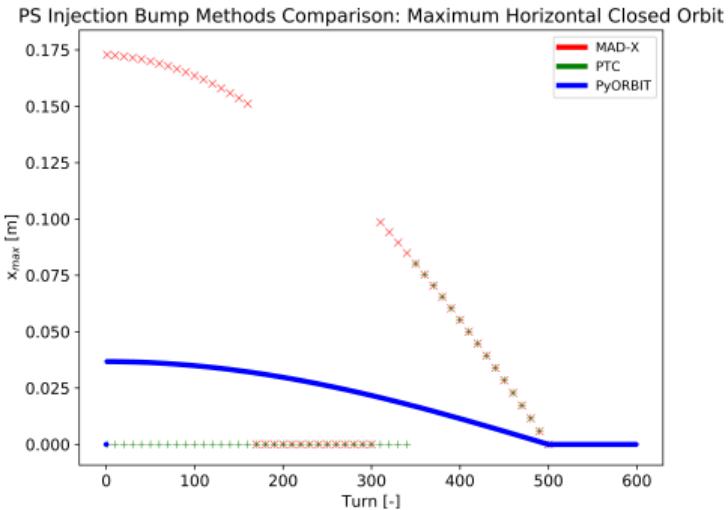


**Figure:** Horizontal Orbit Extrema for QUADRUPOLE: MADX and PTC disagree, PyORBIT as expected

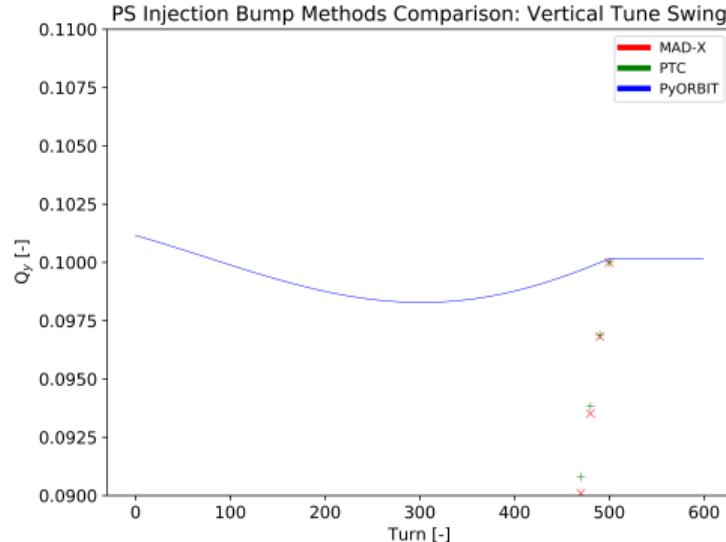
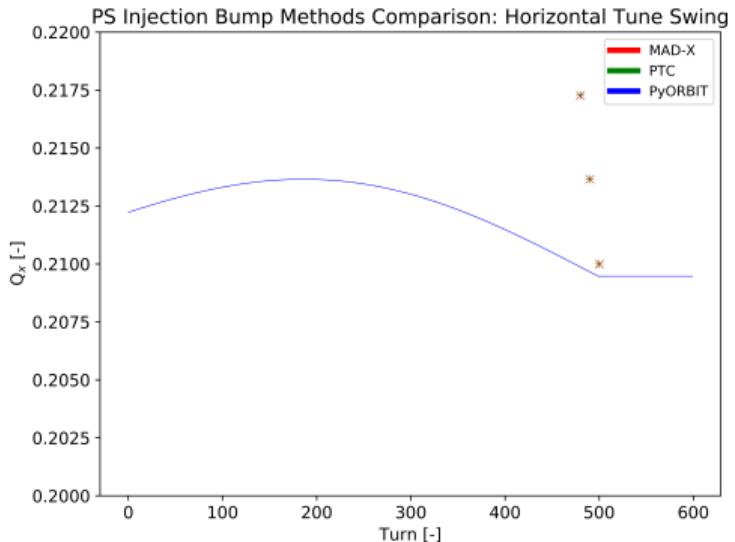
# QUADRUPOLE



**Figure:** Tunes for QUADRUPOLE: MADX and PTC disagree, PyORBIT magnitude and sign incorrect.



**Figure:** Horizontal Orbit Extrema for SBEND: unexplained behaviour in MADX and PTC, PyORBIT as expected.



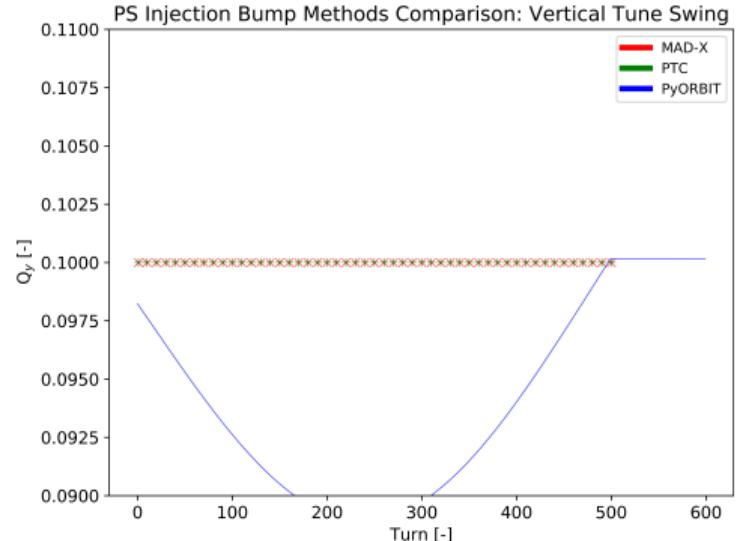
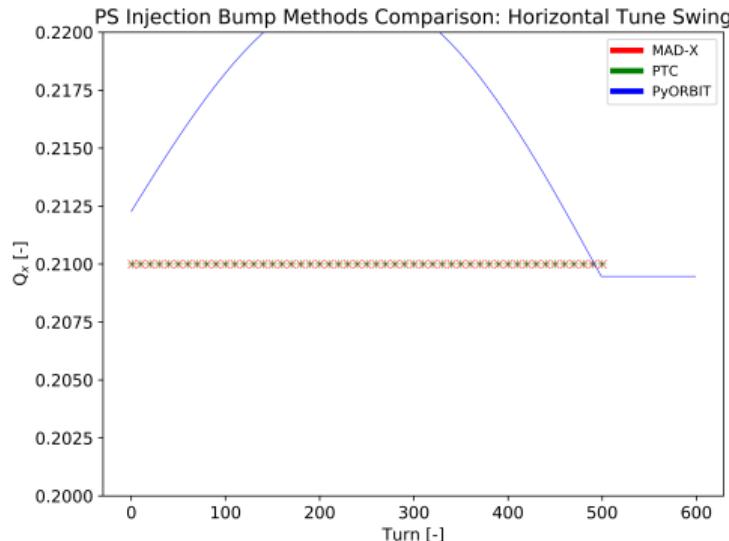
**Figure:** Tunes for SBEND: MADX and PTC agree but magnitude is large, PyORBIT magnitude incorrect but sign ok.

## Test Conversion from MADX Table to PyORBIT Table

- ▶ As MULTIPOLE method seems almost correct (tunes are incorrect sign but good magnitude) check for sign error in tables.
- ▶ As Split HKICKER + MULTIPOLE tunes both increase (expect  $Q_x$  to increase but  $Q_y$  to decrease) check for sign error in tables.
- ▶ As Split HKICKER + MULTIPOLE tunes are  $\approx$  half magnitude expected, check if factorial should not be included.
- ▶ Abandon SBEND and QUADRUPOLE methods for now due to unexpected behaviours and disagreements between PTC and MADX.

# MULTIPOLE Sign Check

Multiply all sextupole components by -1. Bump unchanged.



**Figure:** Tunes for MULTIPOLE Sign Check: Magnitudes changed unexpectedly - too large.

# Split HKICKER + MULTIPOLE Sign Check

Multiply all sextupolar components (i.e. only the MULTIPOLE) by -1. Change in bump negligible.

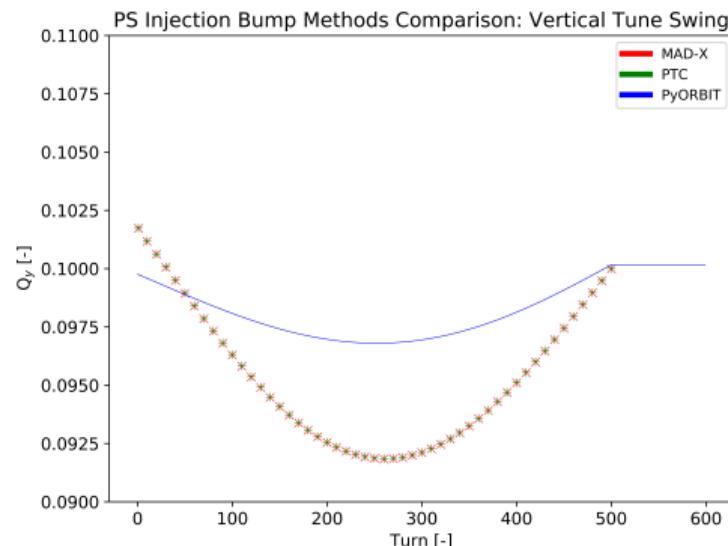
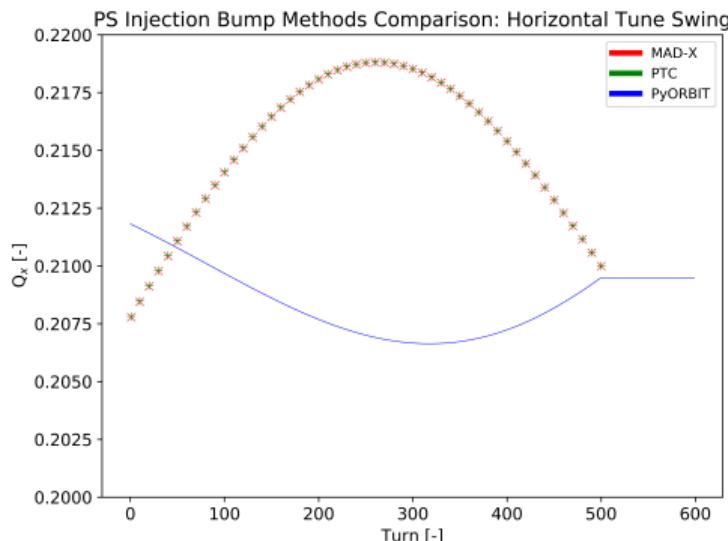
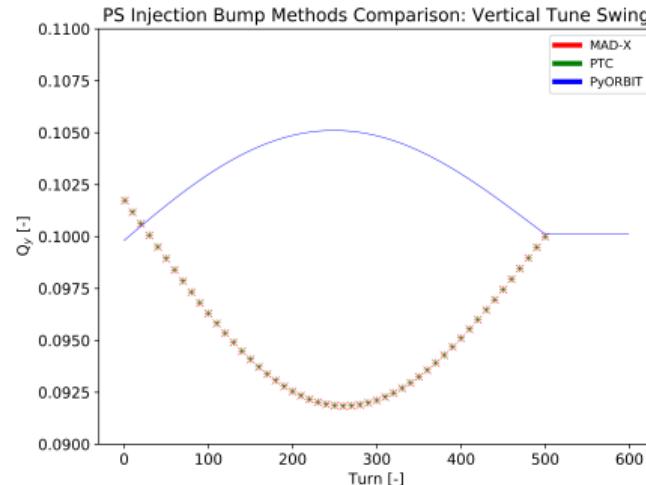
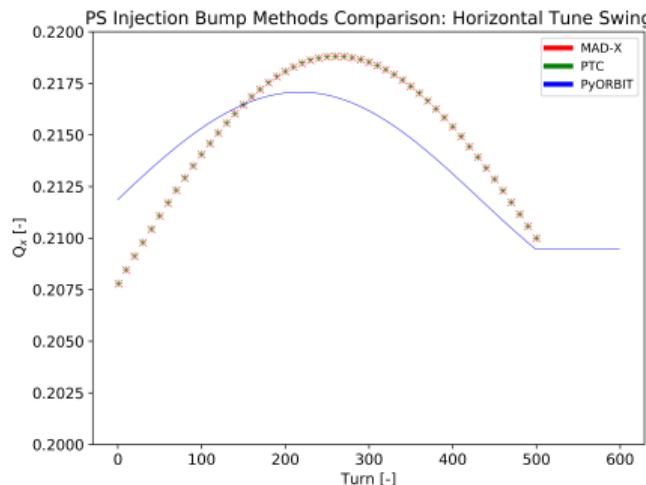


Figure: Tunes for Split HKICKER + MULTIPOLE Sign Check: both tunes flipped.



# Split HKICKER + MULTIPOLE Factorial Check

Do not include the factorial in sextupolar components (i.e. only the MULTIPOLE).  
Bump unchanged.



**Figure:** Tunes for Split HKICKER + MULTIPOLE Factorial Check: Some improvement in magnitude.

# Injection Bump Conclusions

- ▶ Split HKICKER + MULTIPOLE: Bump OK, tune swing small,  $Q_y$  incorrect sign.
- ▶ MULTIPOLE: Bump OK, tune swing correct magnitude, tunes incorrect sign.
- ▶ QUADRUPOLE: Bump OK, tune swing small, tunes incorrect sign.
- ▶ SBEND: Bump OK, tune swing small, tunes correct sign.
- ▶ Tests show that multipole method is perhaps the closest to the desired tune swing
  - only when flipping sign on sextupolar components.

MD4224 Injection Bump

**PS Transfer**

# Goals

- ▶ To investigate the space charge contribution to beam envelope oscillations observed in the PS immediately after injection.
- ▶ Reproduce measurements performed using BGI and SEM Grids in PTC-PyORBIT in order to understand the contribution of space charge.

## Current Plan

- ▶ Start with matched distribution and track without space charge.
- ▶ Add dispersion mismatch as constant factor (will obtain parameterised values from Selim/Matthew soon).
- ▶ Start with PTC TWISS to match distribution, later use end of transfer line values transported to BGI/SEM position (to be provided by Selim/Matthew).

Note: all simulations run at the nominal working point of  $(Q_x, Q_y) = (6.21, 6.24)$ .

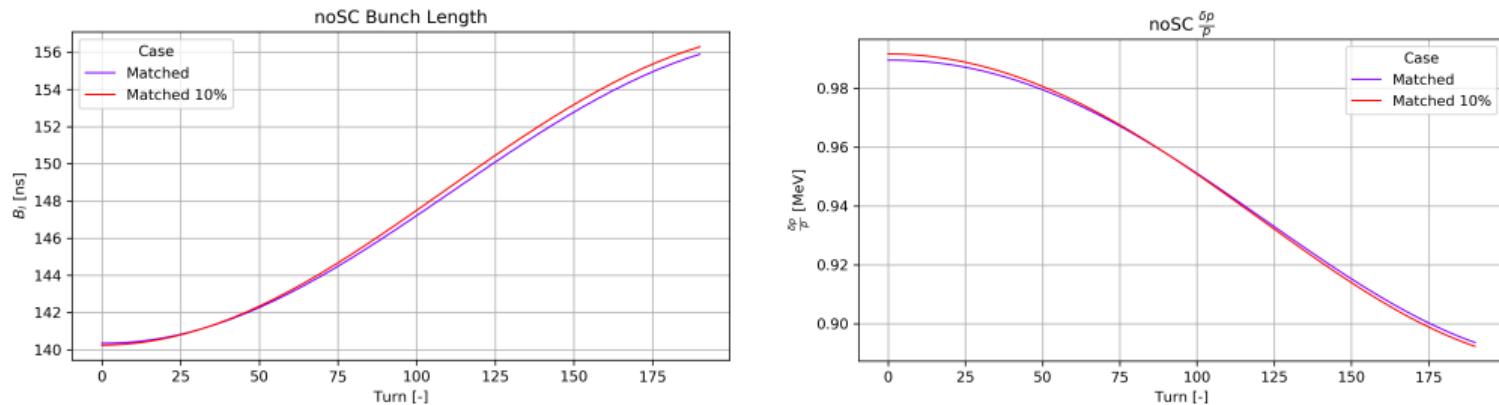
# Matched Distribution

## No Space Charge

Mismatch of factor 0% and +10%.

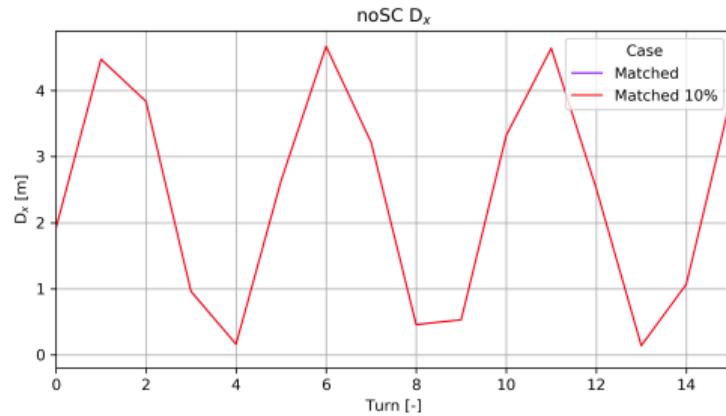
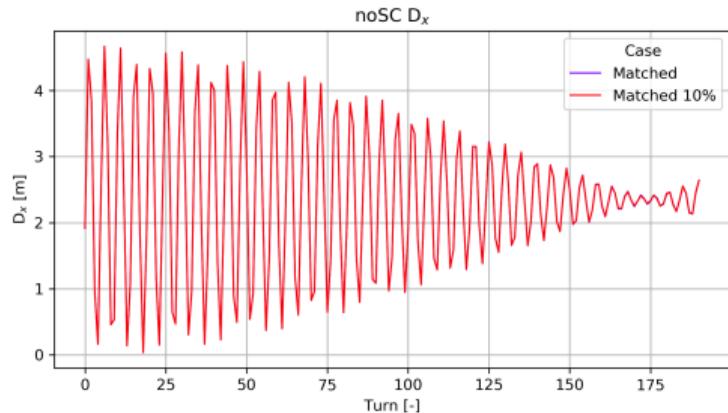
- ▶ Had to correct units of dE (factor 1E3).
- ▶ Matching not correct.
- ▶ Abandon and use tomo distribution.

# Matched Distribution Longitudinal Motion



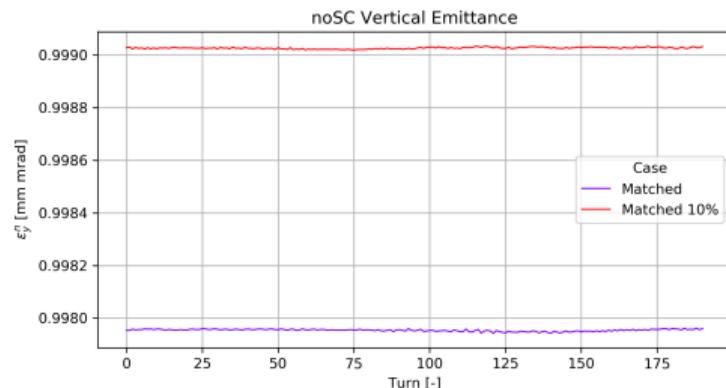
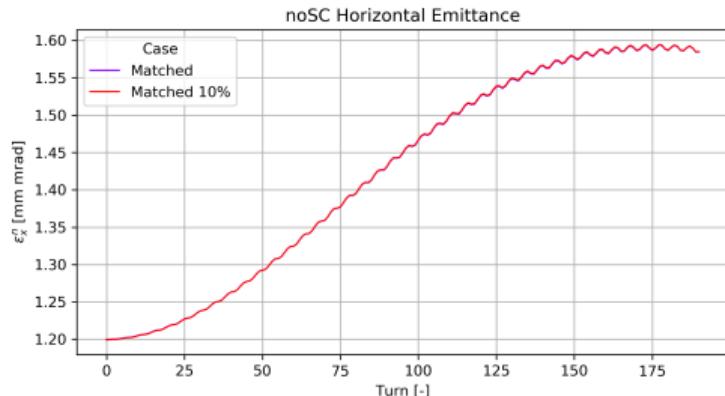
**Figure:** Longitudinal motion for matched distribution: oscillations larger than expected - indicates mismatch.

# Matched Distribution Horizontal Dispersion



**Figure:** Horizontal dispersion for matched distribution: 10% mismatch identical to 0% mismatch - indicates existing mismatch already larger than 10%.

# Matched Distribution Emittances

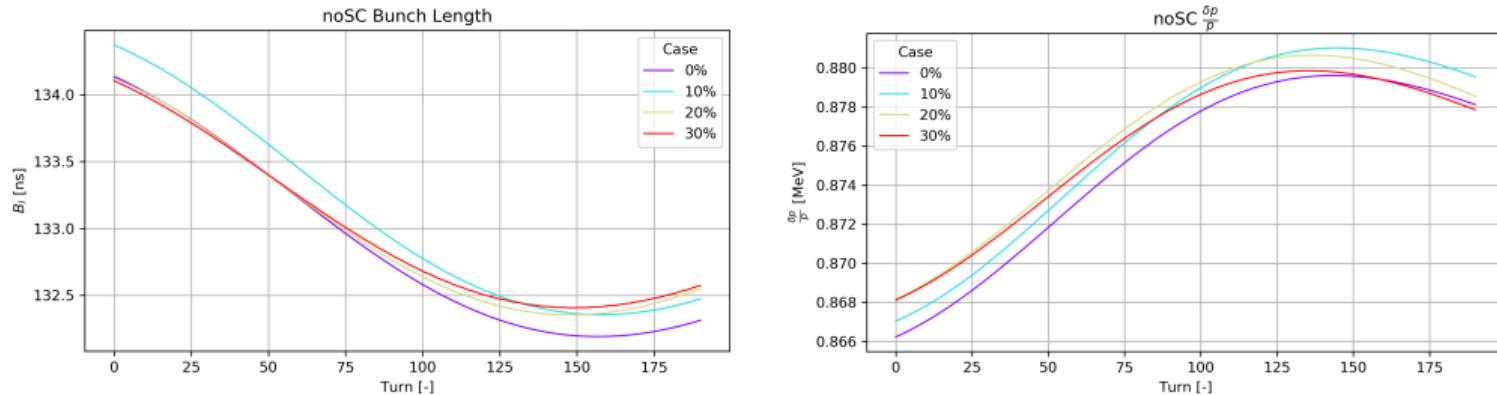


**Figure:** Emittances for matched distribution: 10% mismatch identical to 0% mismatch - indicates existing mismatch already larger than 10%.

## No Space Charge

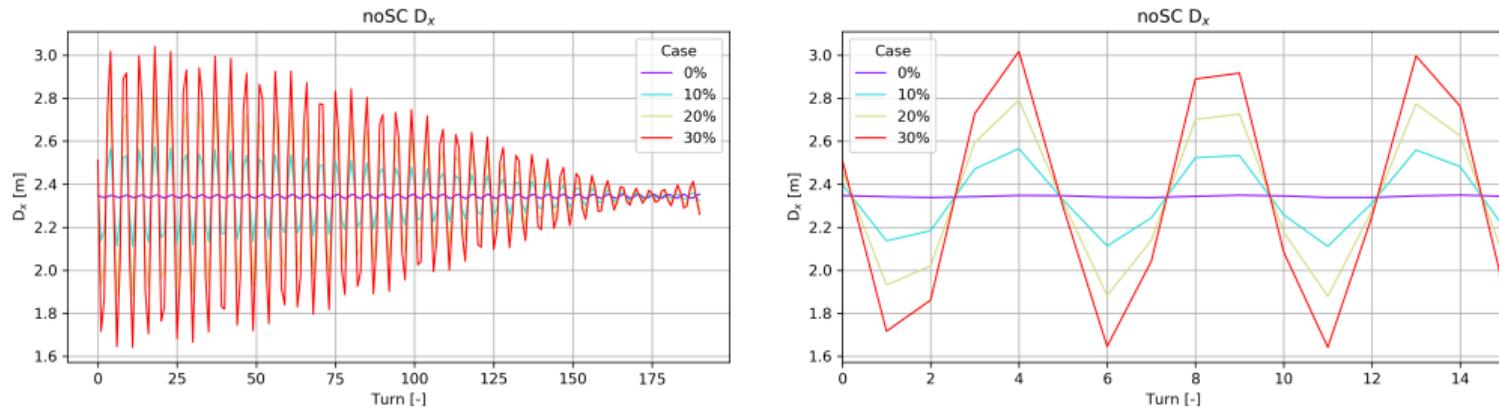
Mismatch of factor 0%, +10%, +20%, and +30%.

# Tomo Distribution Longitudinal Motion (No Space Charge)



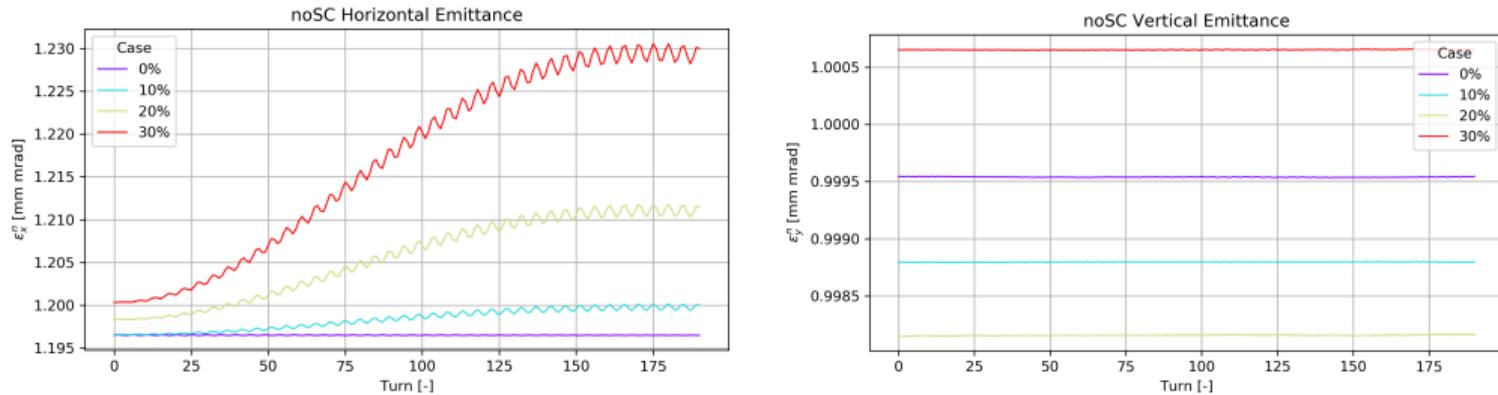
**Figure:** Longitudinal motion for `tomo` distribution: oscillation magnitude as expected.

# Tomo Distribution Horizontal Dispersion (No Space Charge)



**Figure:** Horizontal dispersion for tomo distribution: oscillation magnitude is a function of mismatch as expected.

# Tomo Distribution Emittances (No Space Charge)

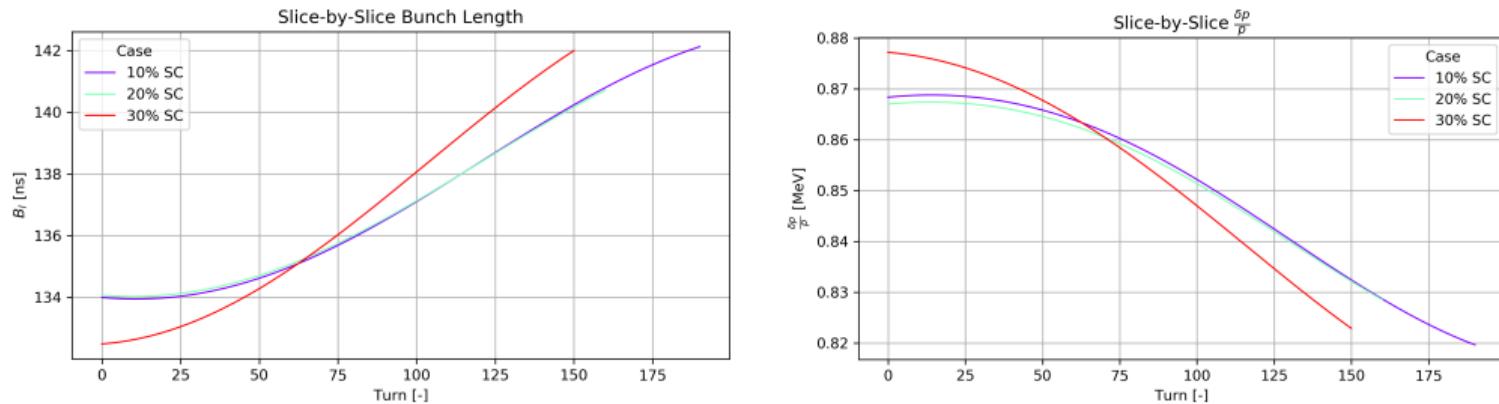


**Figure:** Emittances for tomo distribution: horizontal emittance growth is a function of dispersion mismatch.

## With Space Charge

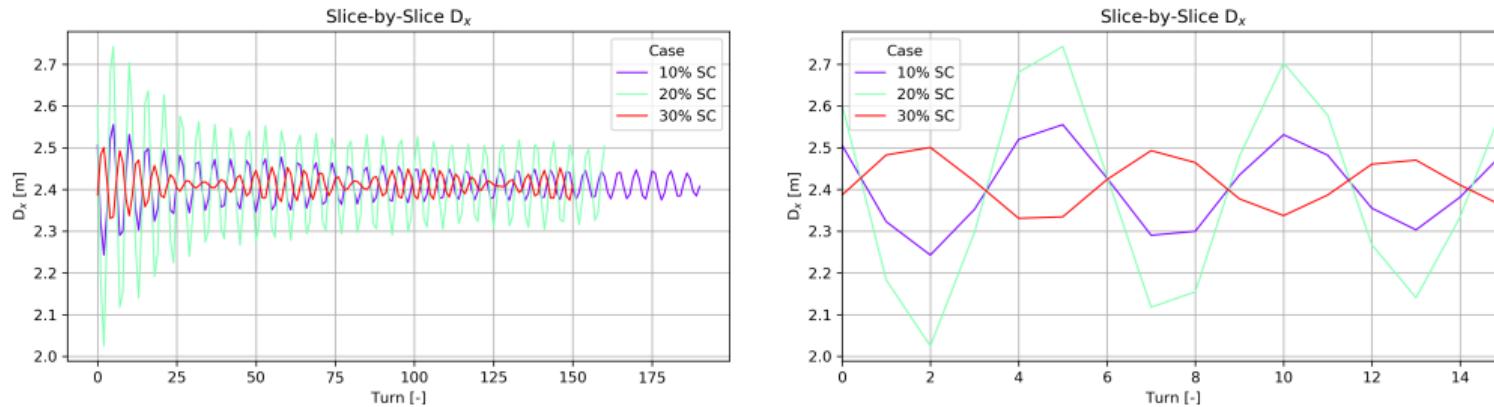
Mismatch of factor +10%, +20%, and +30%.

# Tomo Distribution Longitudinal Motion (With Space Charge)



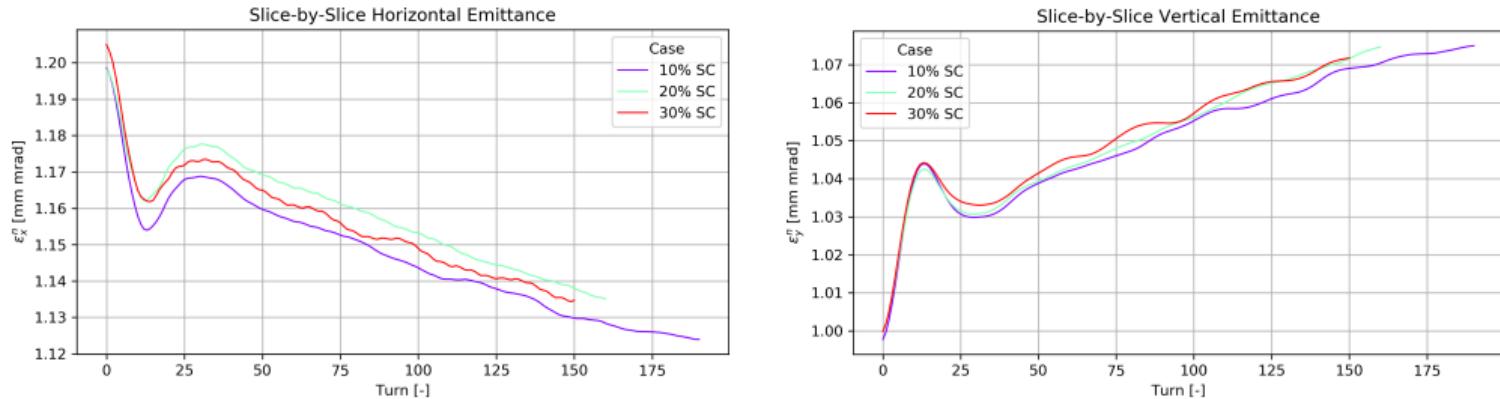
**Figure:** Longitudinal motion for tomo distribution with space charge: oscillation has opposite sign to no space charge case - SC drives bunch lengthening at the start?

# Tomo Distribution Horizontal Dispersion (With Space Charge)



**Figure:** Horizontal dispersion for tomo distribution with space charge: dispersion oscillations have longer period, highest mismatch in anti-phase rather than larger magnitude.

# Tomo Distribution Emittances (With Space Charge)



**Figure:** Emittances for tomo distribution with space charge: clear emittance exchange.



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