Simulations of Booster transverse instabilities

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Synergia codes

- Single particle propagation (full propagation, fast maps of arbitrary order)
- Apertures
- Multiple bunches
- Collective effects:
  - Space-charge (Poisson solvers for different pipe geometries)
  - Wake fields (wake functions read from files)
- Electron cloud

Booster simulations

- Full single particle propagators
- Different space charge solvers for F magnets, D magnets and straight sections
- Wake fields for F and D magnets

Wakes for pipes with parallel-planes geometry

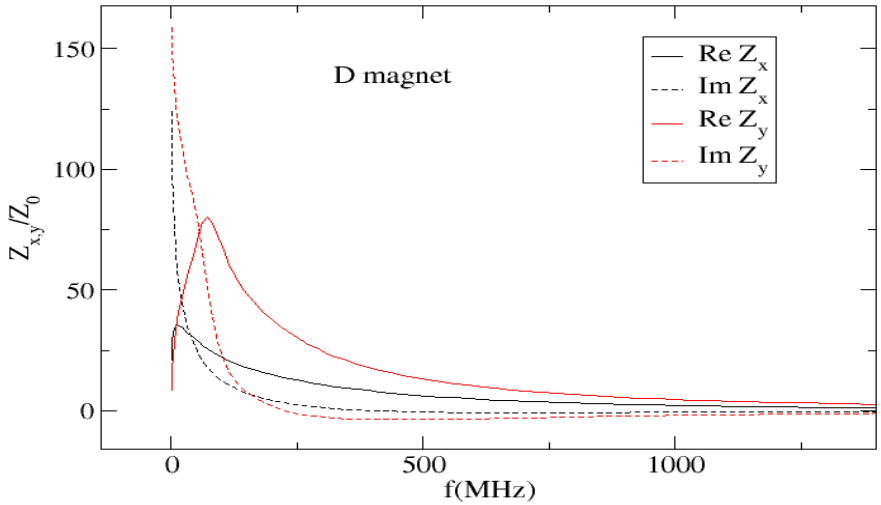
$$\beta c \Delta p_z = -qQW^{\parallel}(z)$$
$$\beta c \Delta p_x = -qQ\left(W_x^{\perp}(z)X - W_x^{\perp}(z)x\right)$$
$$\beta c \Delta p_y = -qQ\left(W_Y^{\perp}(z)Y + W_y^{\perp}(z)y\right)$$

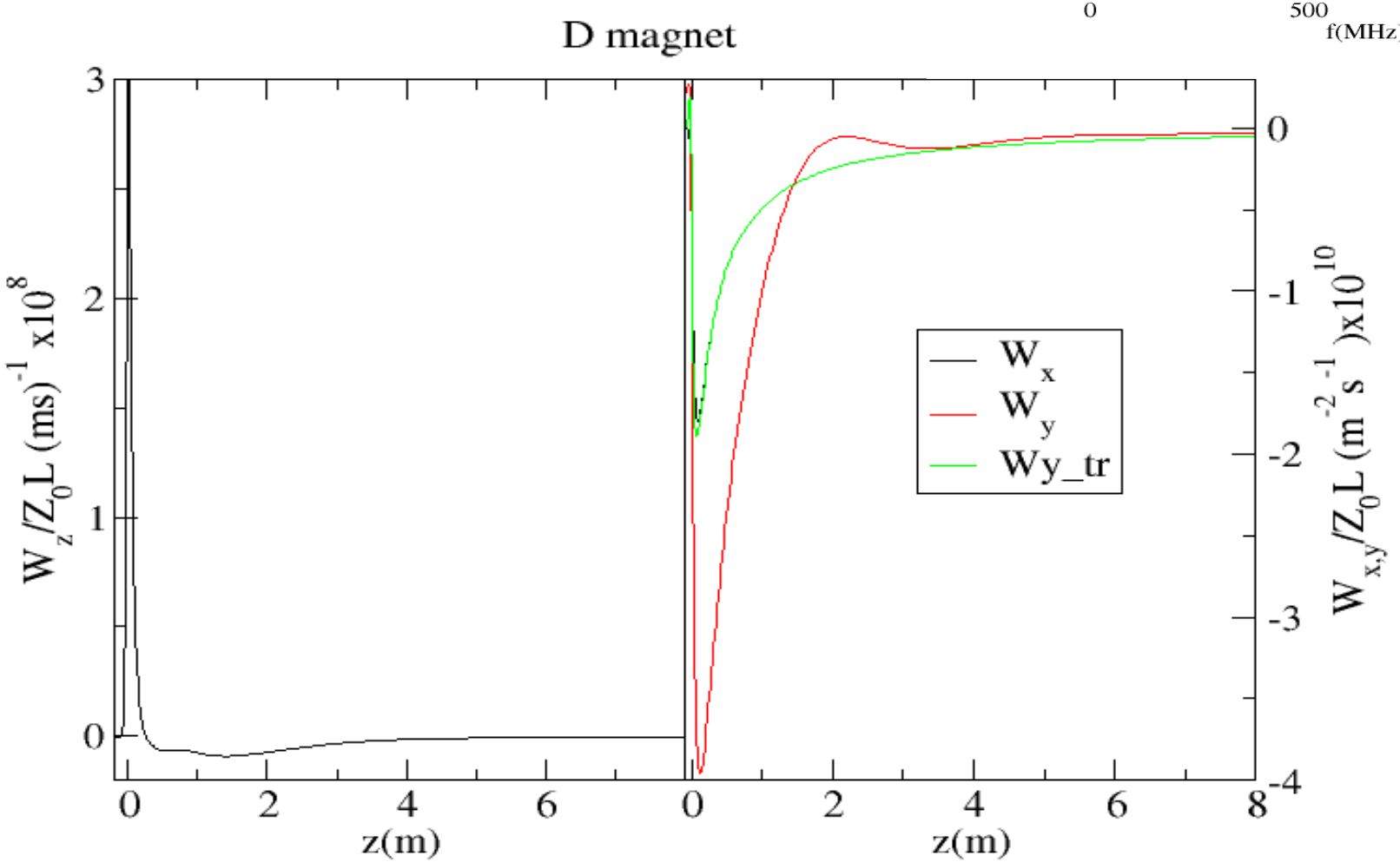
- q,Q - charge of the trailing and leading particle
- X,Y - displacements of the leading particle
- *x,y* - displacements of the trailing particle
- *z* - distance between the leading and the trailing particles

For Booster:

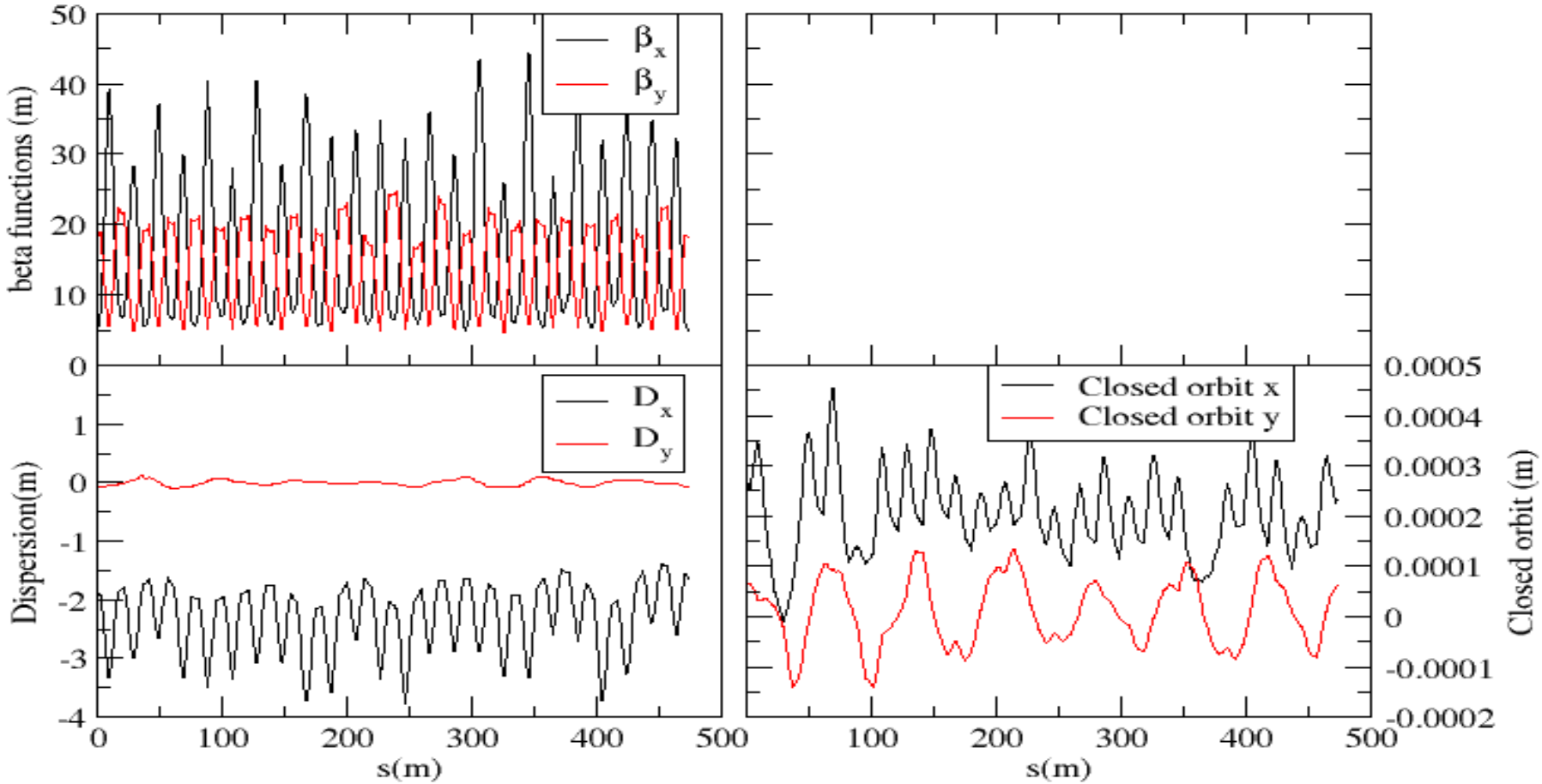
- **Laminated structures**
- **Frequency dependent magnetic permeability** (as measured by Yuri Tokpanov)
- **Nonultrarelativistic wakes, γ=1.42 at injection**

Impedance and wakes in the D magnets



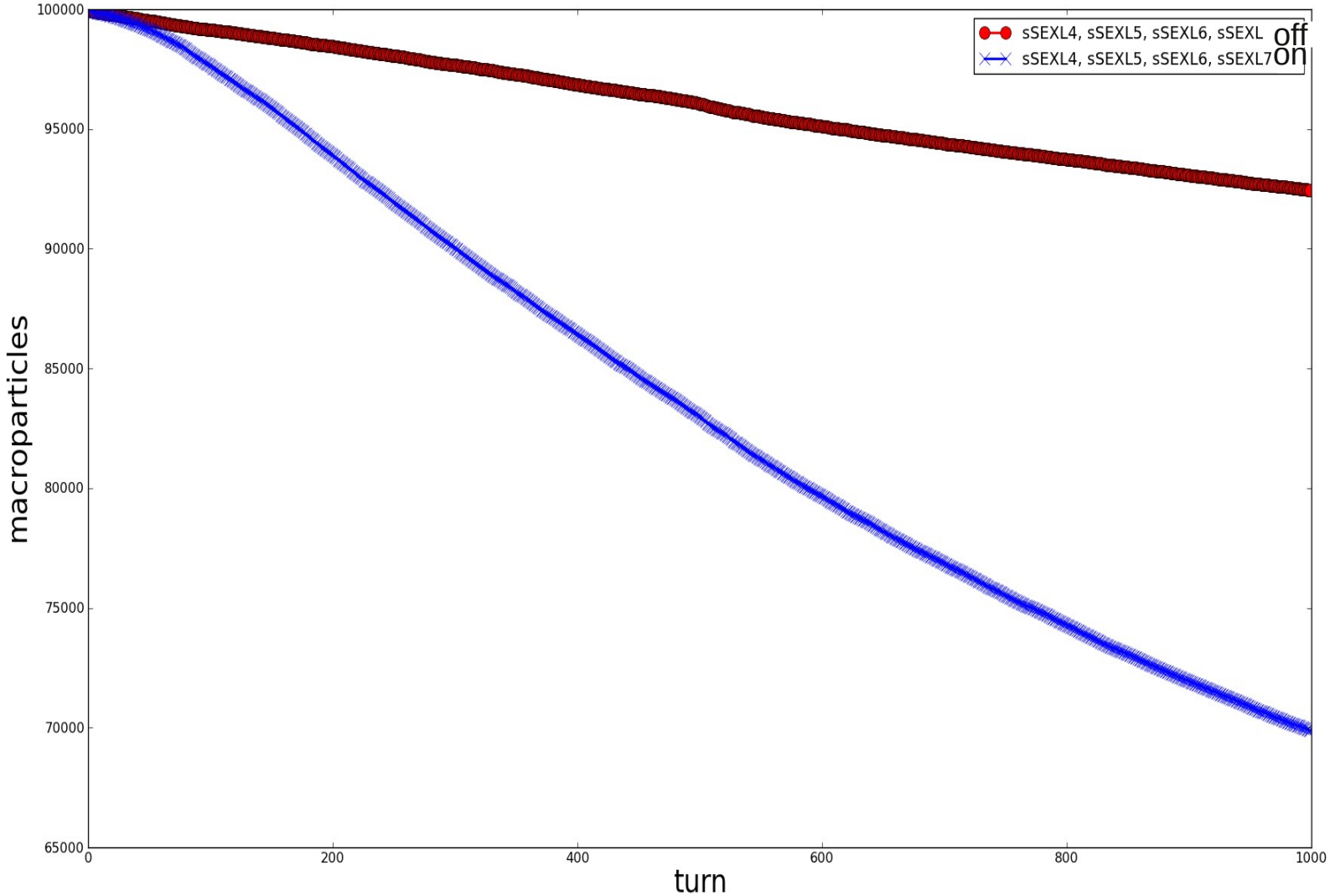


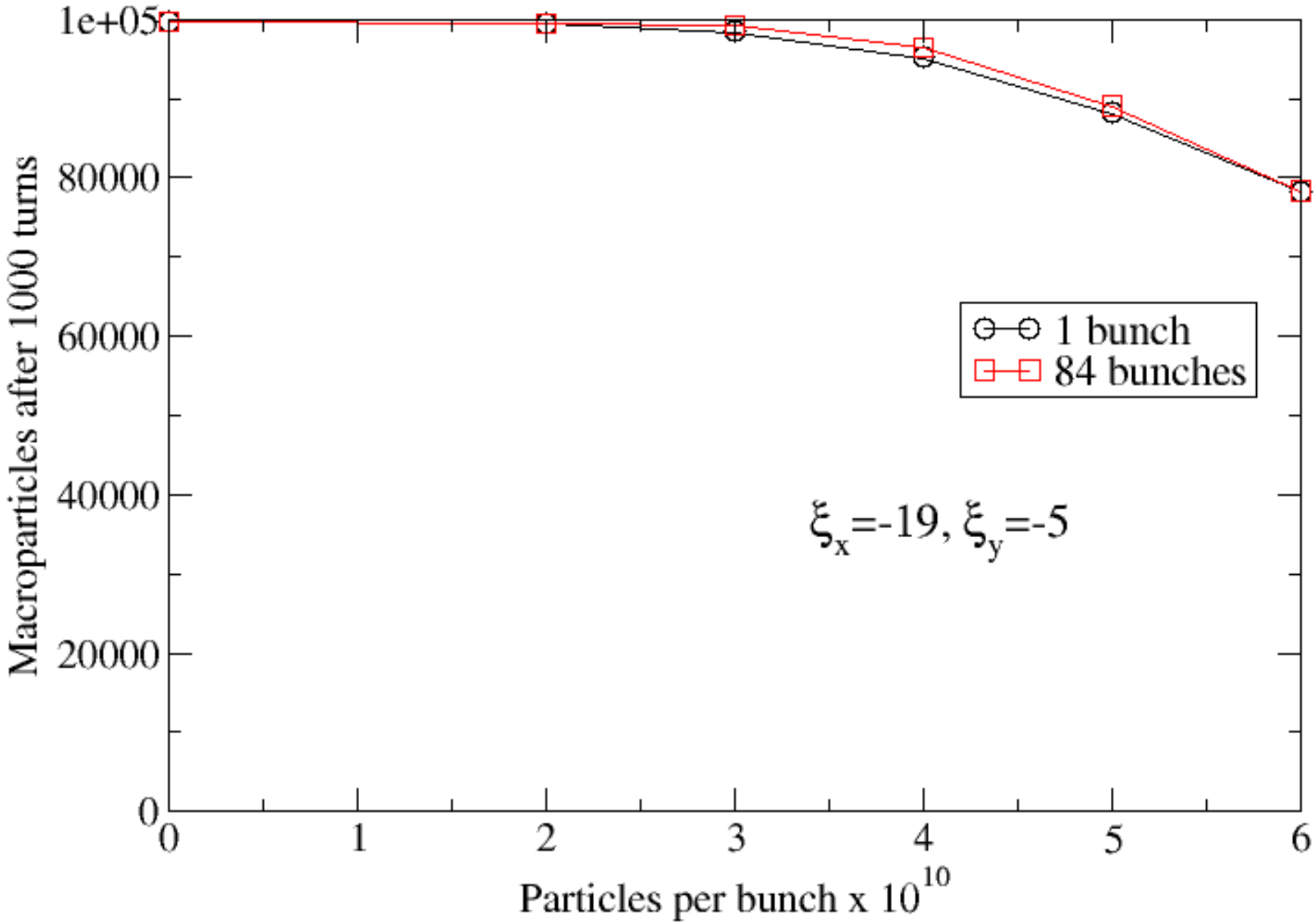
Booster lattice file (from Meghan McAteer) includes dipole and quadrupole correctors to ensure agreement with the measured lattice functions



Large particle loss with harmonic sextupoles on

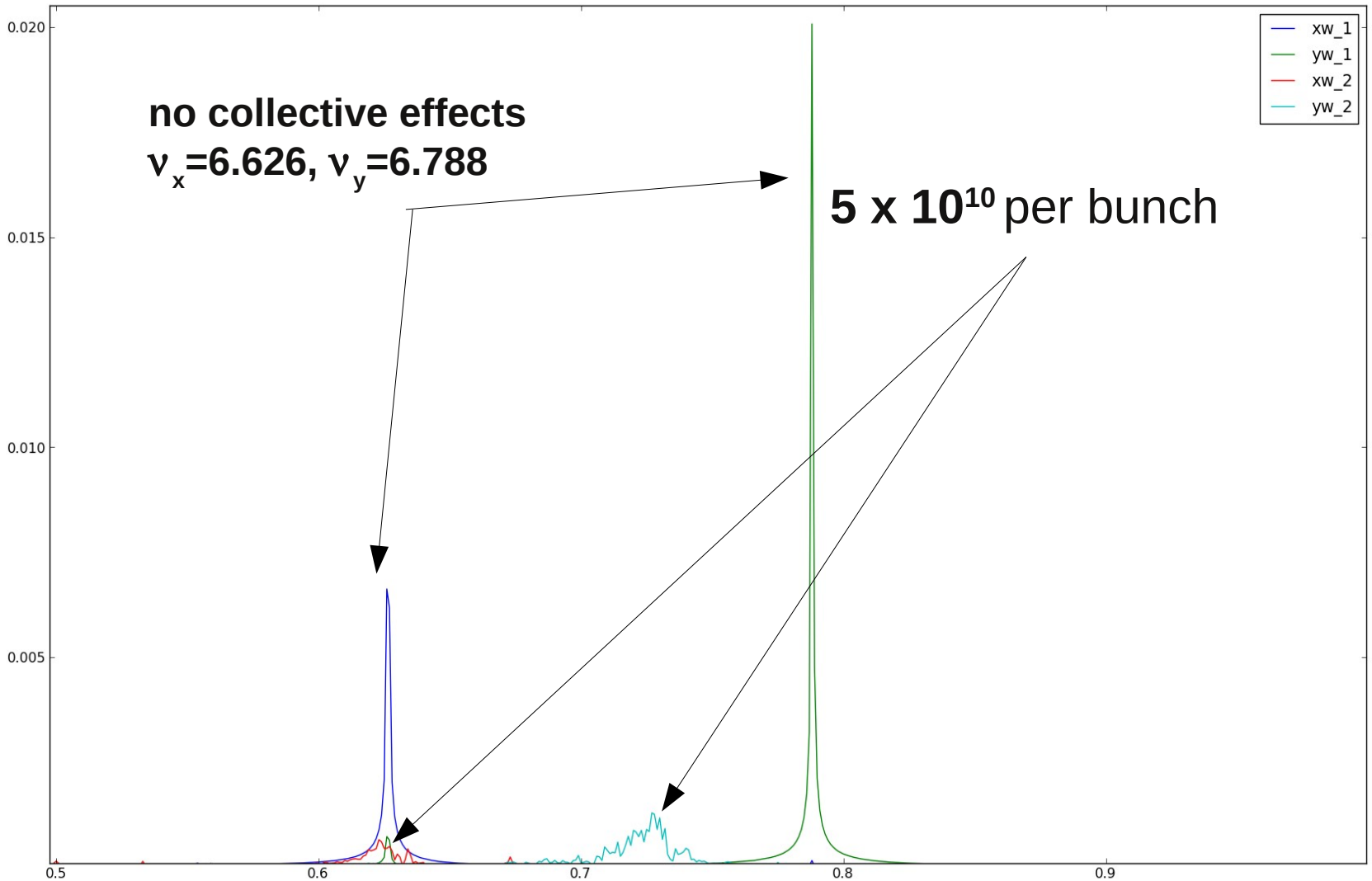
I=4.2 x10^{12} particles



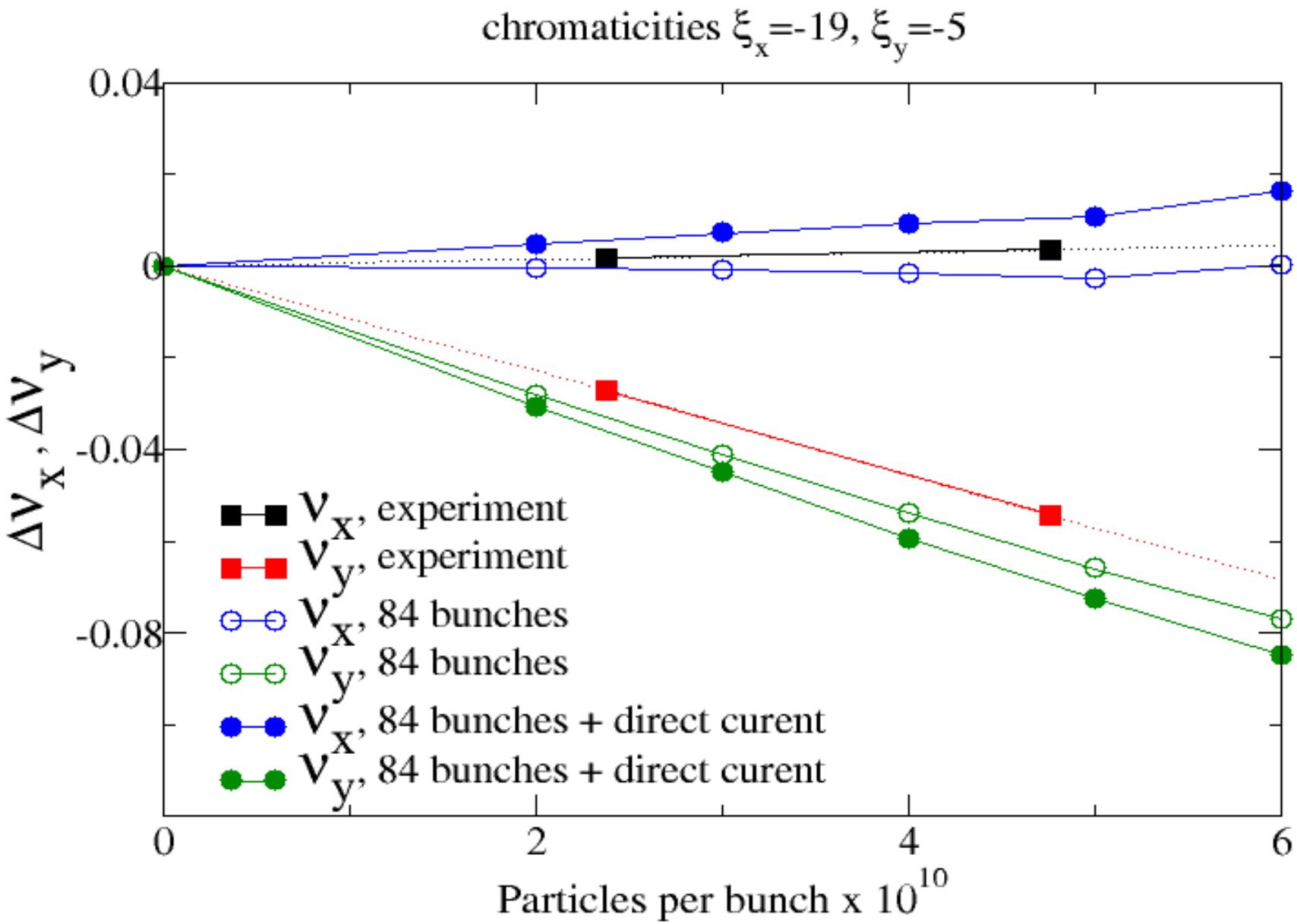

1e+05
80000
60000
40000
20000
0
Macroparticles after 1000 turns
0
1
2
3
4
5
6
Particles per bunch x 10^10
1 bunch
84 bunches
ξx=-19, ξy=-5

Coherent tune shift:

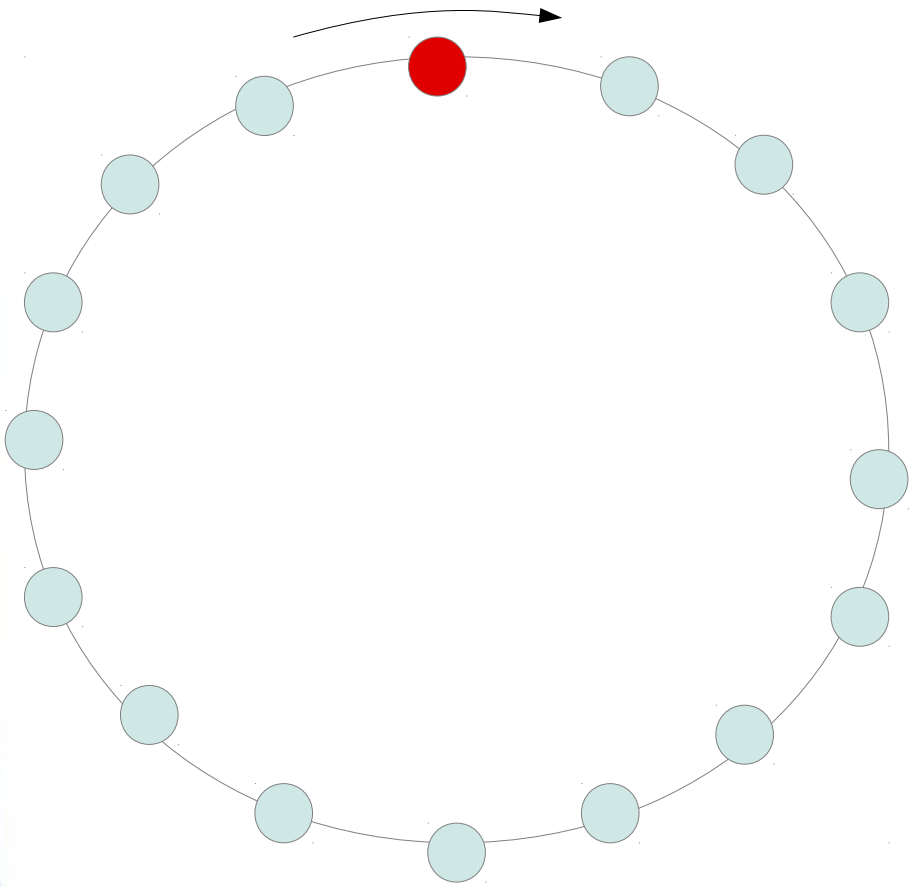
- Fourier transform of the centroid displacement

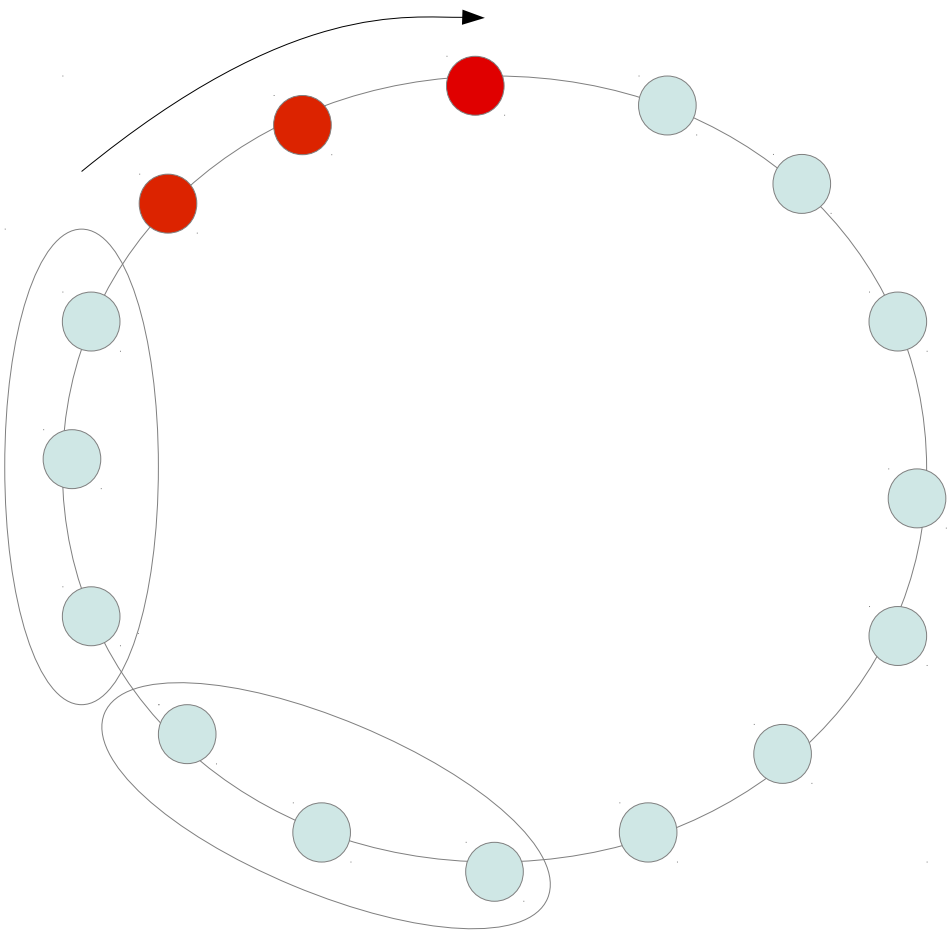


Coherent tune shift



Full machine simulation:



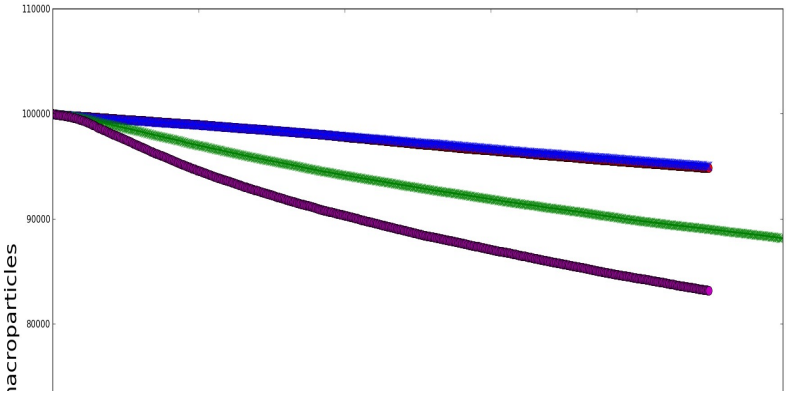


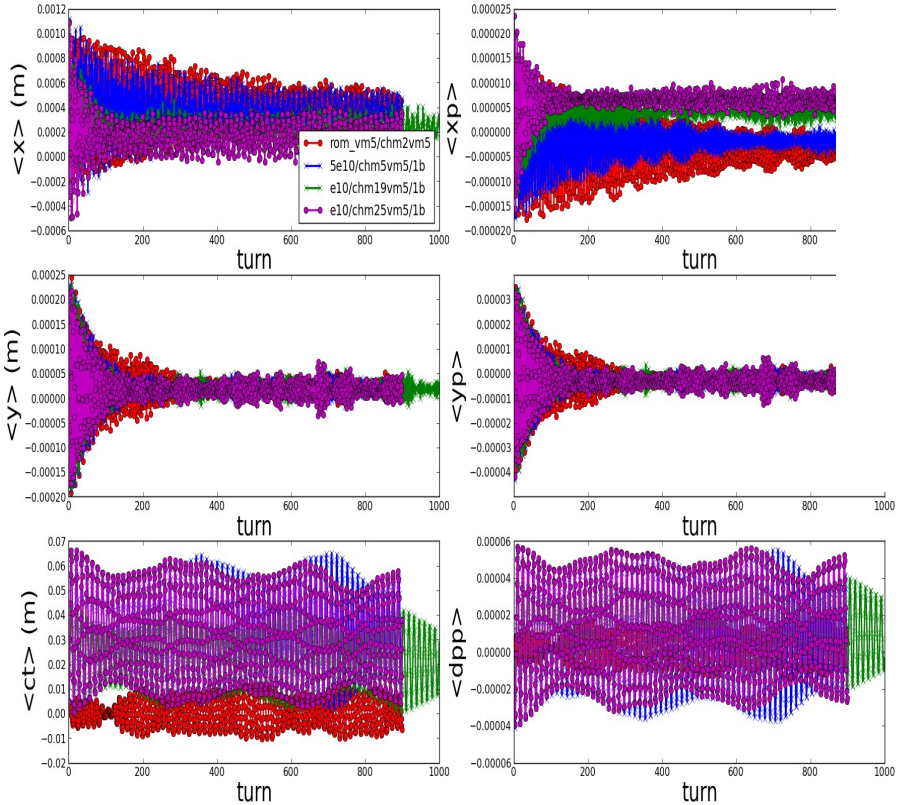
1 bunch full machine simulation

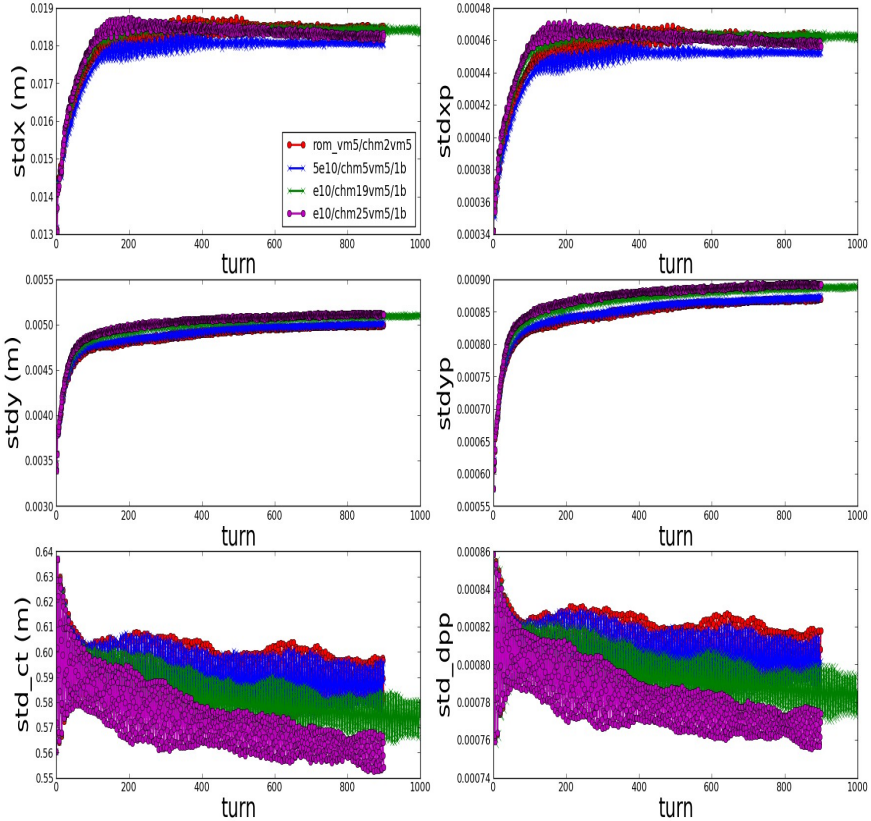
Multibunch mode m: $y_n = y_0 \, e^{i \, 2\pi/N \, m \, n}$

3 bunch full machine simulation

1 bunch simulation ξx=-2,-5,-19,-25 ξy=-5







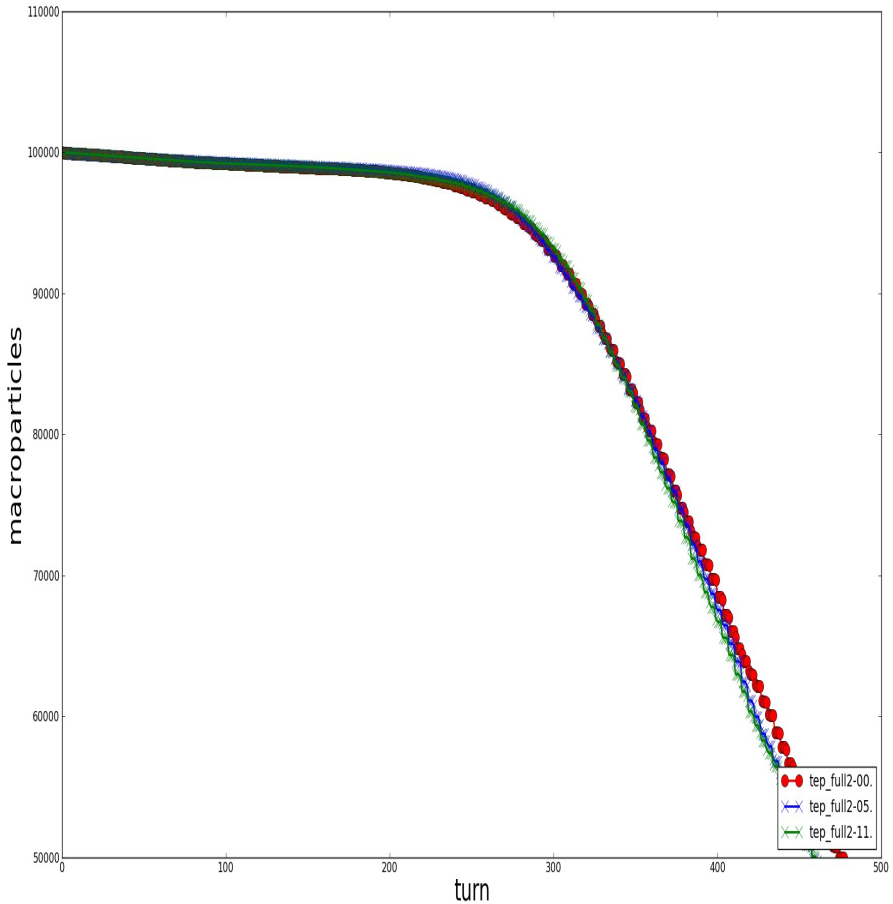
Small chromaticities like

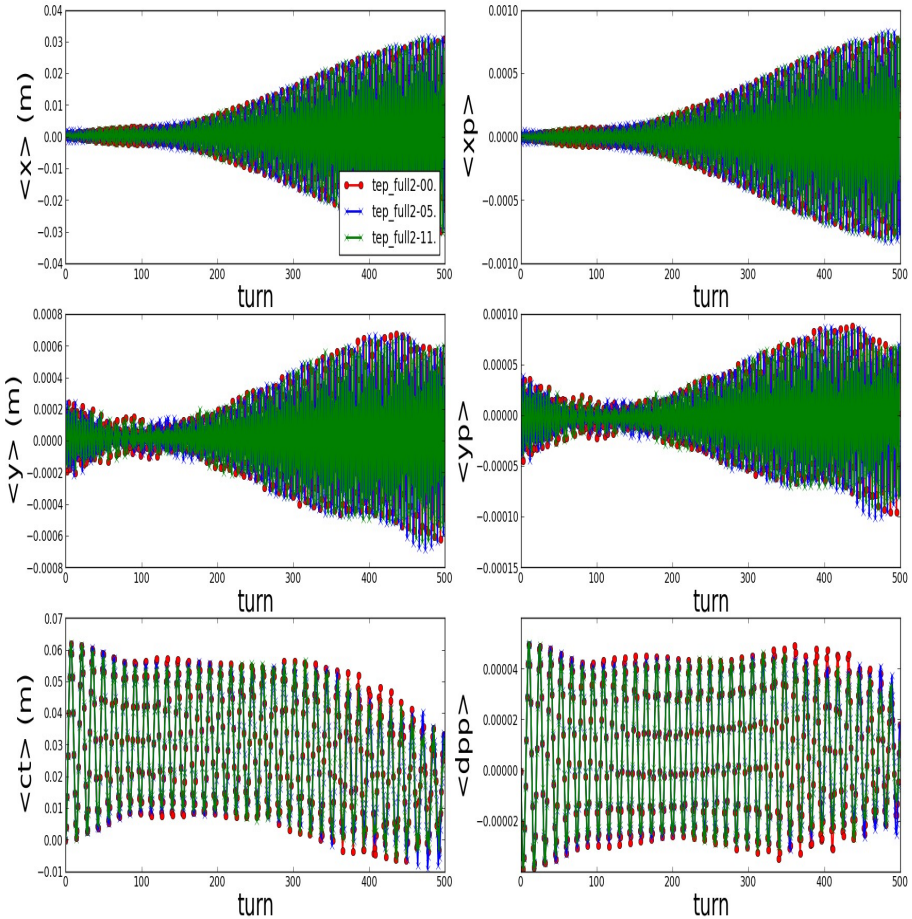
ξx=-5 ξy=-5

most favorable

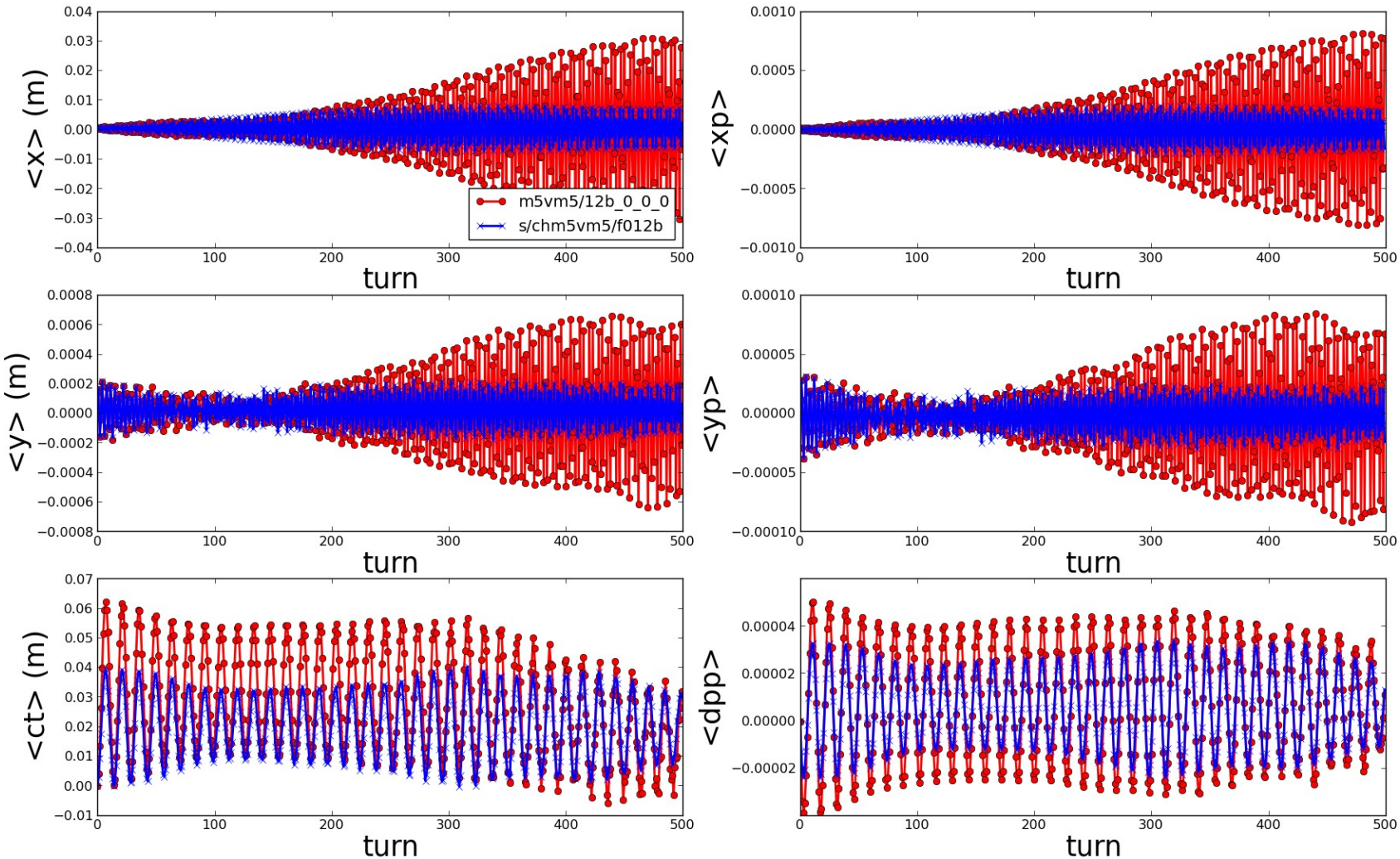
12 bunches, full machine $\xi x=-5$ $\xi y=-5$

horizontal instability





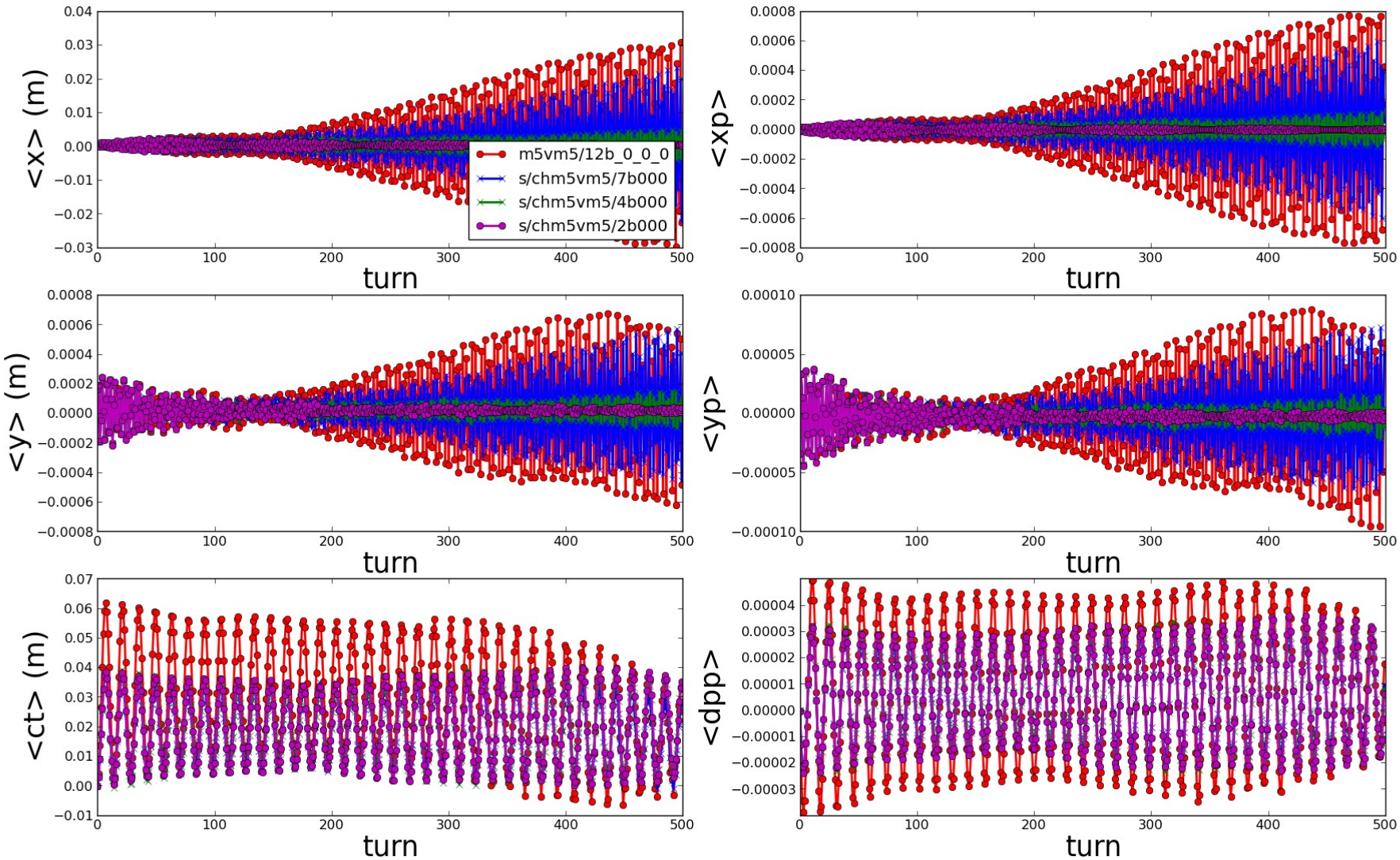
12 bunches (no full machine, blue) ξx=-5 ξy=-5
no instability observed (but looks close)



full machine $\xi x=-5$ $\xi y=-5$

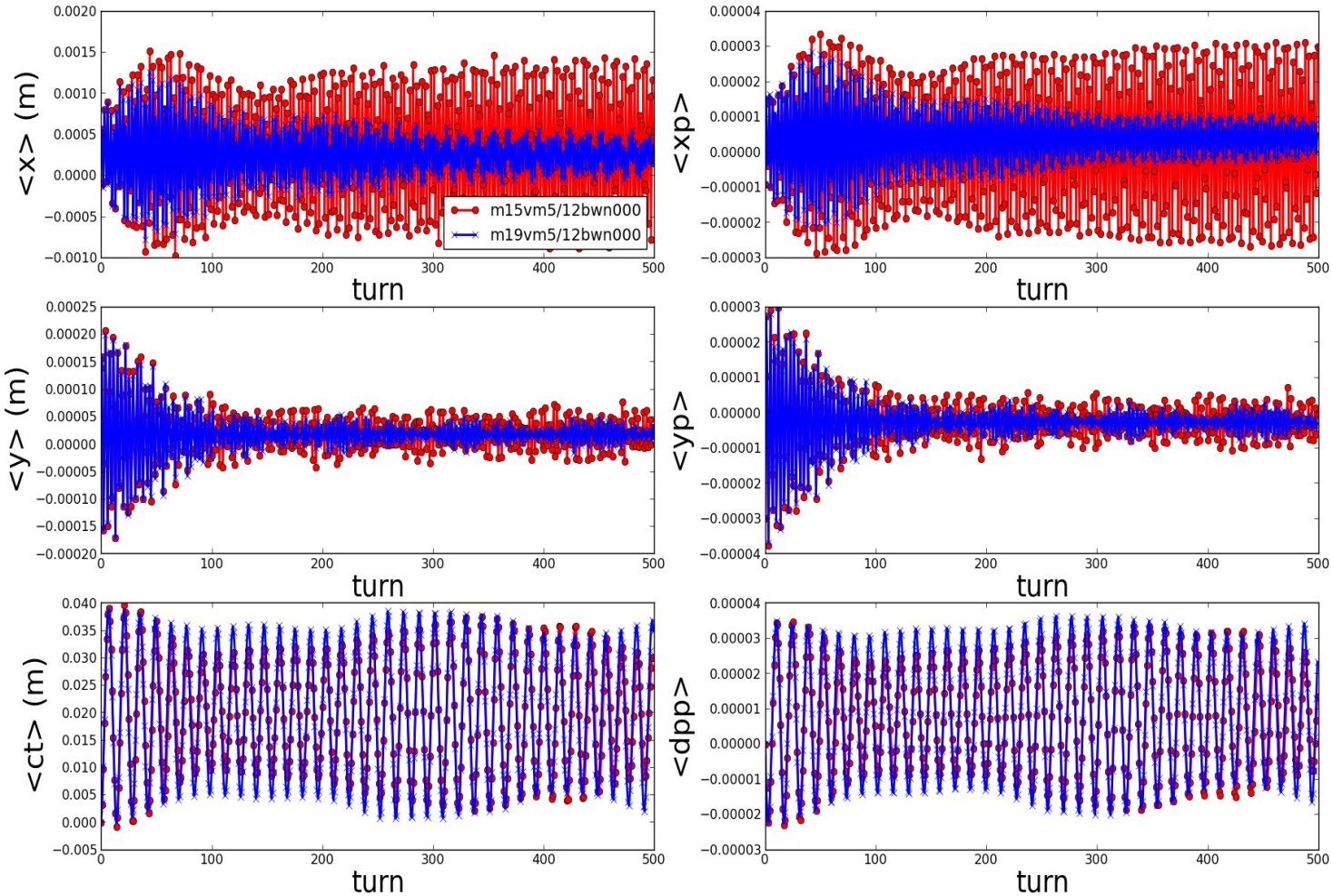
2 bunches (magenta) - no instability

4 (green), 7 (blue), 12 (red) bunches - horizontal instability



12 bunches, full machine (red), unstable ξx=-15 ξy=-5

12 bunches, full machine (blue), stable ξx=-19 ξy=-5

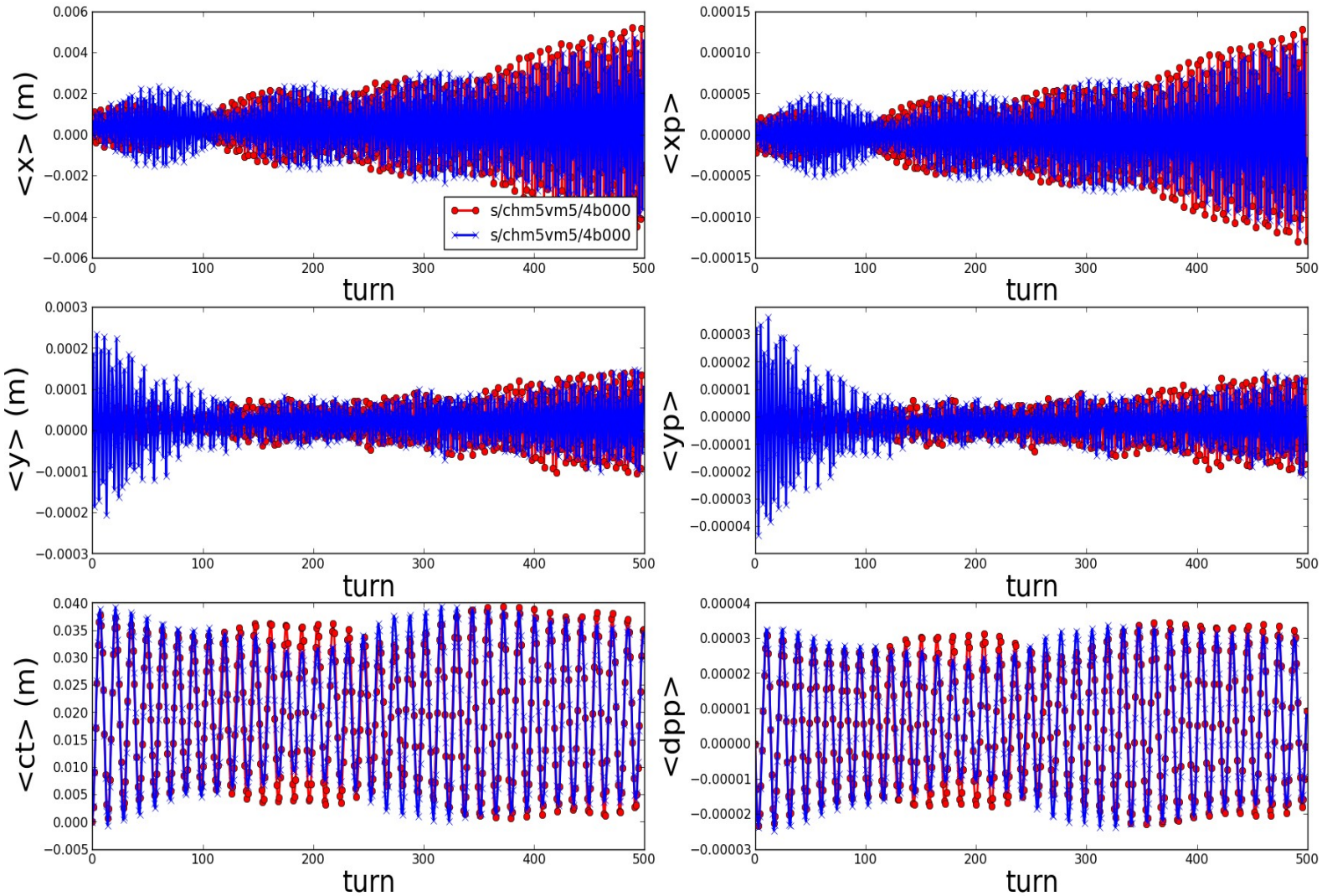


Conclusions

- Small negative chromaticities are most favorable for 1 bunch simulations
- Full machine simulation with number of bunches >4 show instability in the horizontal plane for small chromaticities
- Larger negative horizontal chromaticity needed for stabilization (ξx=-19, similar to experiment, works)
- No instability observed for 1 or 2 bunch full machine simulations, but only a few modes checked (0, π, +8, -8)

Next

- Real 84 bunches simulations check for instability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s/chm5vm5/4b000
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<xp>
<y> (m)
<yp>
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<dpp>
turn

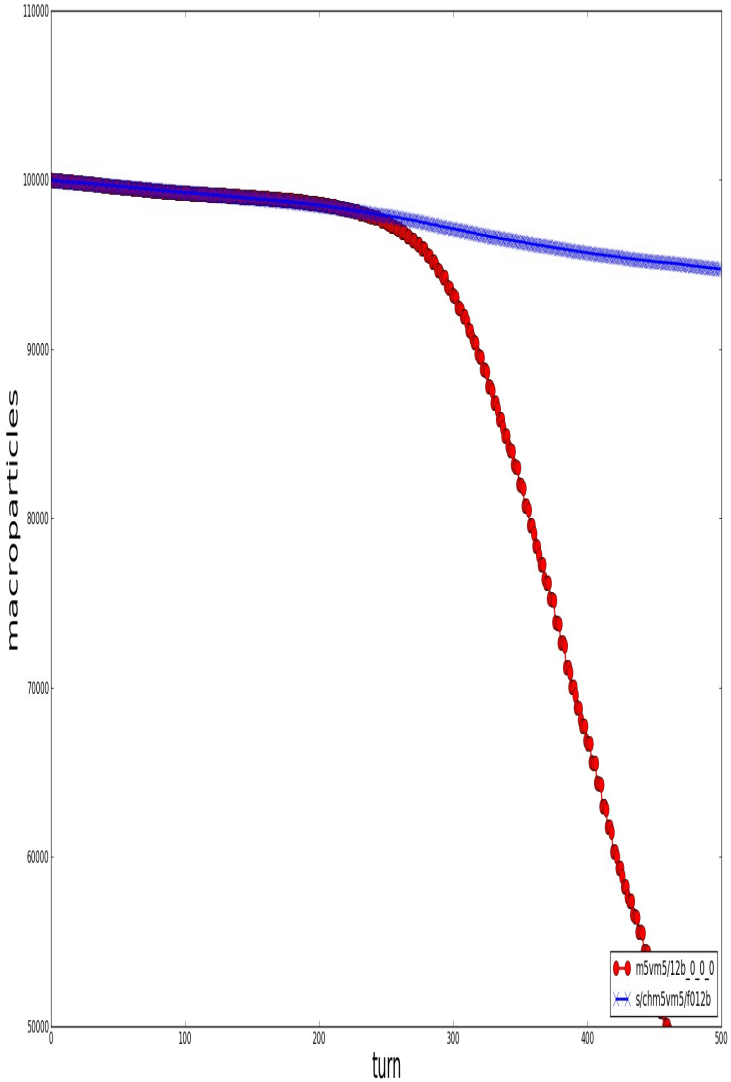
emitx= 4.54482918192e-06 meters*GeV/c = 4.7626595642e-06 meters*rad (synergia units)= 1.51600162381e-06 pi*meters*rad
emity= 1.87488822392e-06 meters*GeV/c = 1.96475026322e-06 meters*rad (synergia units)= 6.25399432664e-07 pi*meters*rad
emitz= 0.000325560118091 meters*GeV/c = 0.00108595166224 eV*s = 0.000232142587981 meters*GeV = 0.000478453292186 [cdt*dp/p] (synergia units)

* 95%emitx= 8.9639356764e-05 meters*rad = 2.85330934491e-05 pi*meters*rad
* 95%emity= 3.69791179534e-05 meters*rad = 1.17708188269e-05 pi*meters*rad
* 95%emitz= 0.0204390020255 eV*s

* Normalized emitx= 4.8438289074e-06 meters*rad = 1.54183862821e-06 pi*meters*rad
* Normalized emity= 1.99823522813e-06 meters*rad = 6.36058028036e-07 pi*meters*rad

* Normalized 95%emitx= 9.11670678286e-05 meters*rad = 2.90193789842e-05 pi*meters*rad
* Normalized 95%emity= 3.76093479071e-05 meters*rad = 1.19714272518e-05 pi*meters*rad

* xrms= 0.005 meters
* yrms= 0.006 meters
* zrms= 0.4 meters= 1.87118041835 ns
* pxrms= 0.000913323118096 GeV/c, dpx/p= 0.000957098035919
* pyrms= 0.000312583086879 GeV/c, dpy/p= 0.000327564968614
* prms= 0.000819420101319 GeV/c, dp/p= 0.000858694315327
* Erms= 0.000584292400675 GeV, deoe= 0.000436602116443
* pz= 0.954262869444 GeV/c
* total energy= 1.33827203 GeV, kinetic energy= 0.4 GeV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70000
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50000
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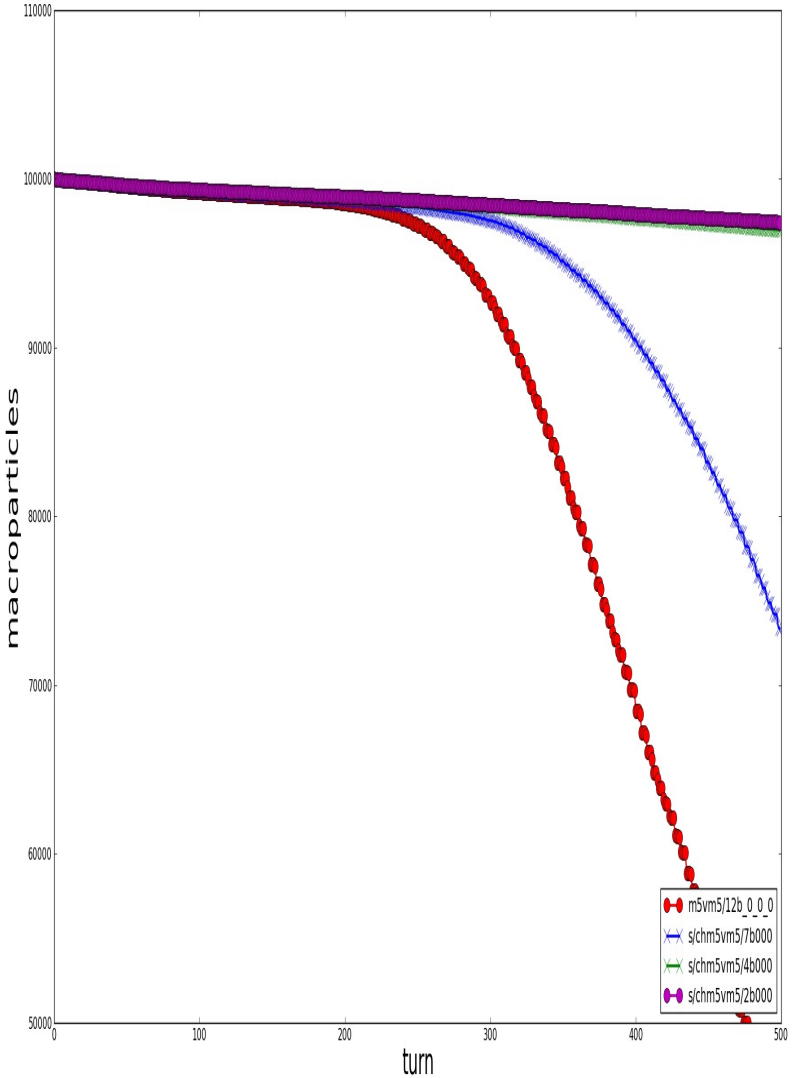
100
200
300
400
500
m5vm5/12b_0_0_0
s/chm5vm5/f012b


macroparticles
turn
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300
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500
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s/chm5vm5/4b000
s/chm5vm5/2b000