# Frequency Map Studies for the OCS6 Lattice

Ina Reichel
LBNL

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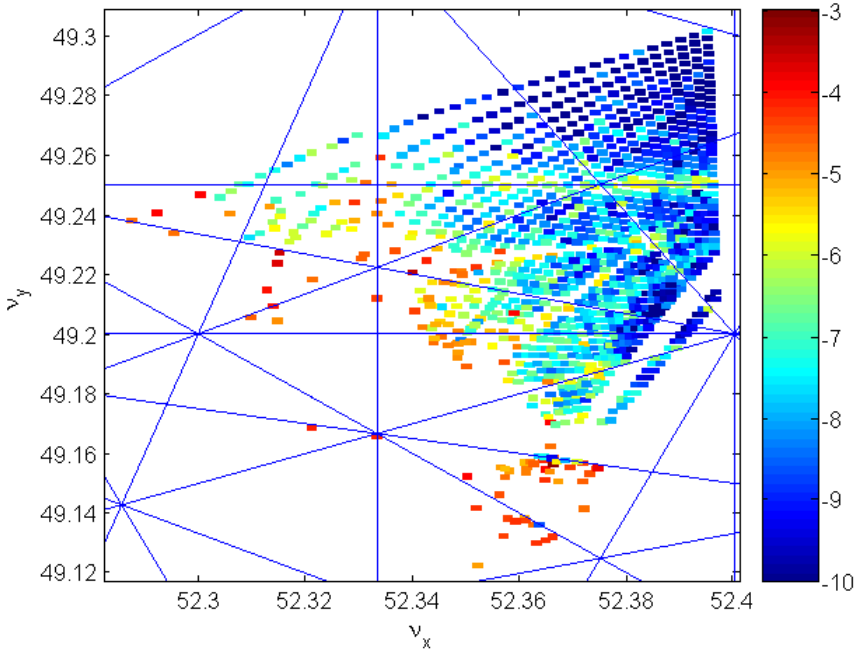
# Overview

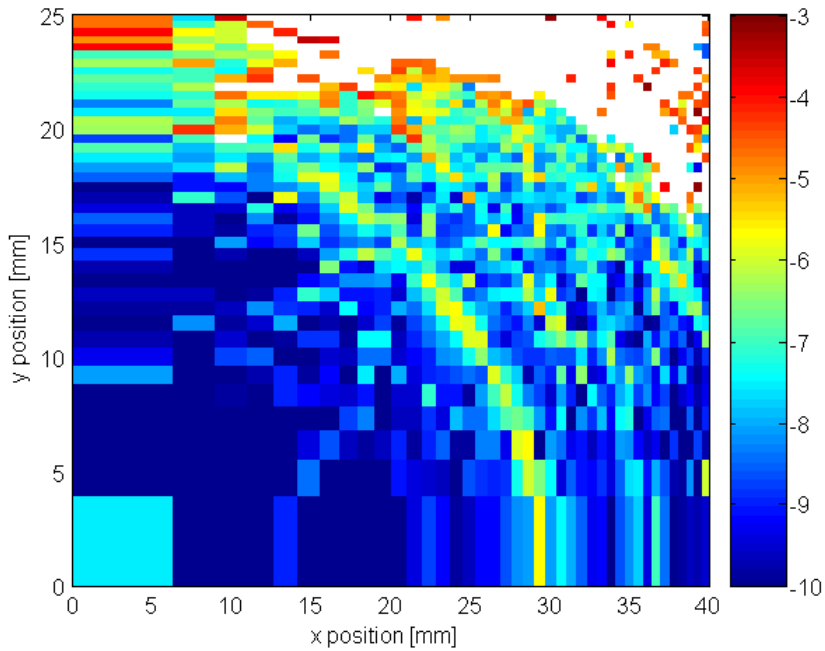
- Frequency Maps
- Results for nominal lattice
- Results for OCS5 lattice
- Results for higher chromaticity
- Results for different tunes
- Conclusion

# Frequency Maps

- track a set of particles for $N$ turns
- record position and angle every turn
- calculate tune for first $N/2$ and second $N/2$ turns
- calculate tune diffusion rate; the smaller it is, the more stable the particle
- plot diffusion rate color coded as function of amplitude and initial tune

# Results for Nominal Lattice

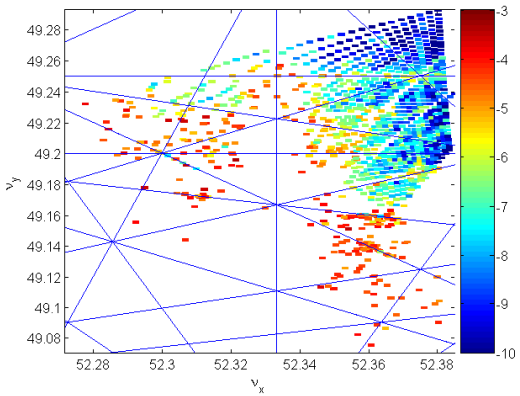


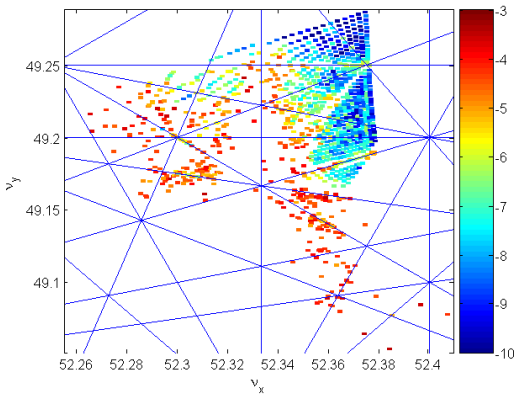

- vertical fourth order resonance clearly visible
- strong cross detuning with amplitude
- footprint frayed

# Nominal Lattice (off-momentum)

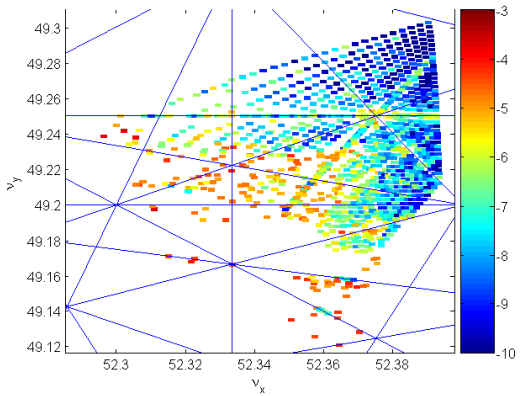
$\frac{\Delta p}{p} = -0.5\%$




$\frac{\Delta p}{p} = -1.0\%$




$\frac{\Delta p}{p} = +0.5\%$

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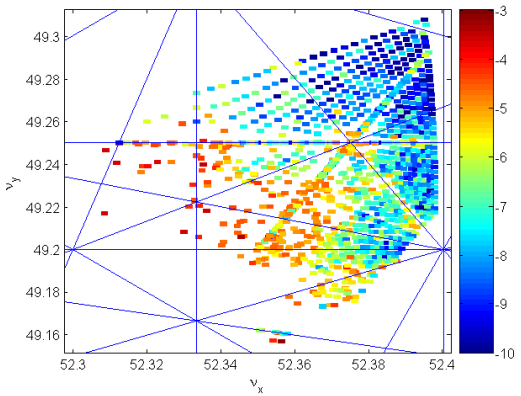


- horizontal third order resonance is strong
- footprint frayed

# Nominal Lattice (off-momentum)

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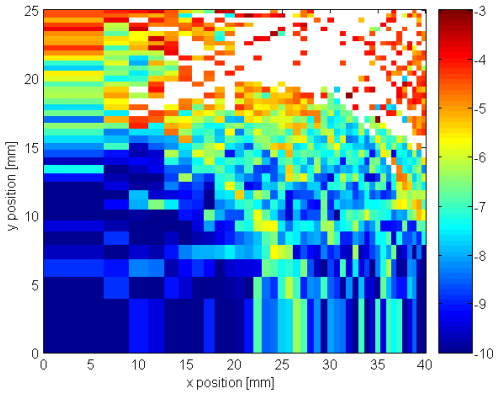


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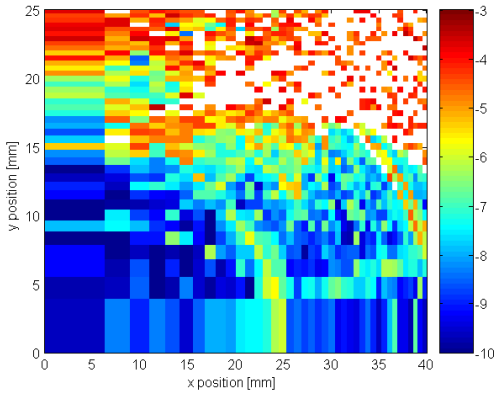


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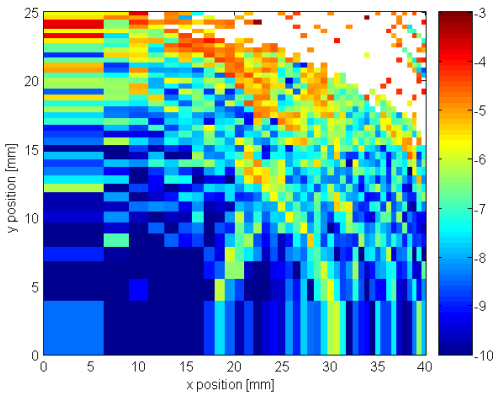


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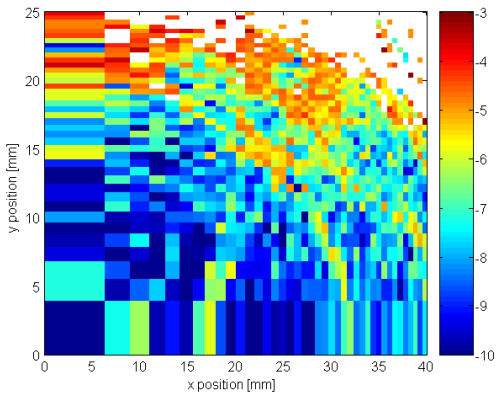
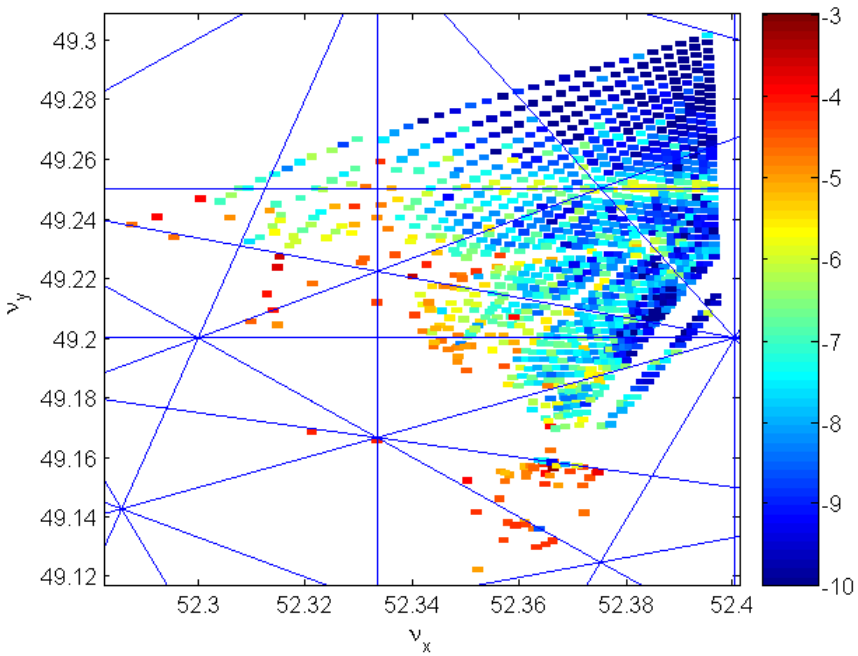


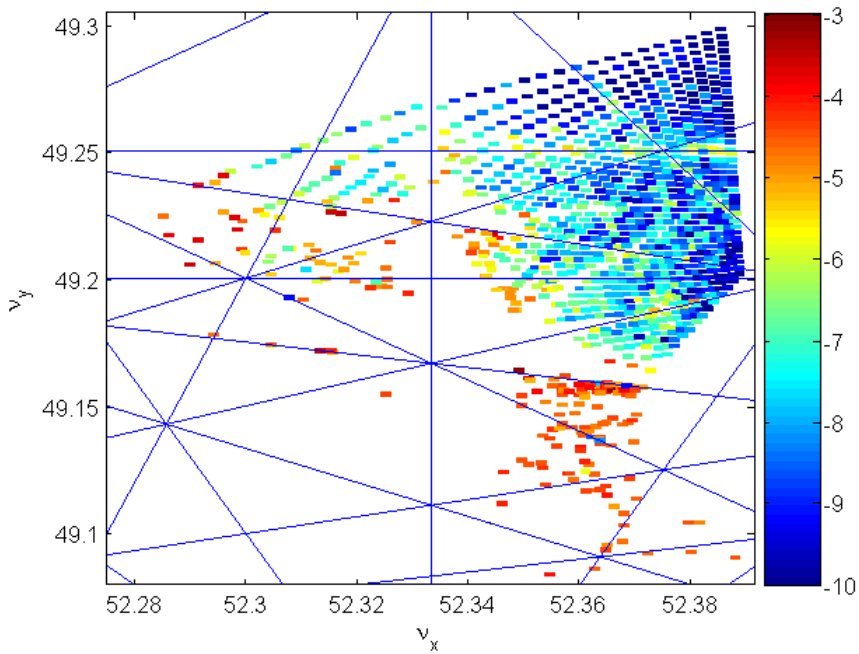

- large diffusion rates at large vertical amplitudes for negative $\frac{\Delta p}{p}$
- dynamic aperture reduced compared to on-momentum

# Results for different chromaticities

$\xi_x = \xi_y = 1$



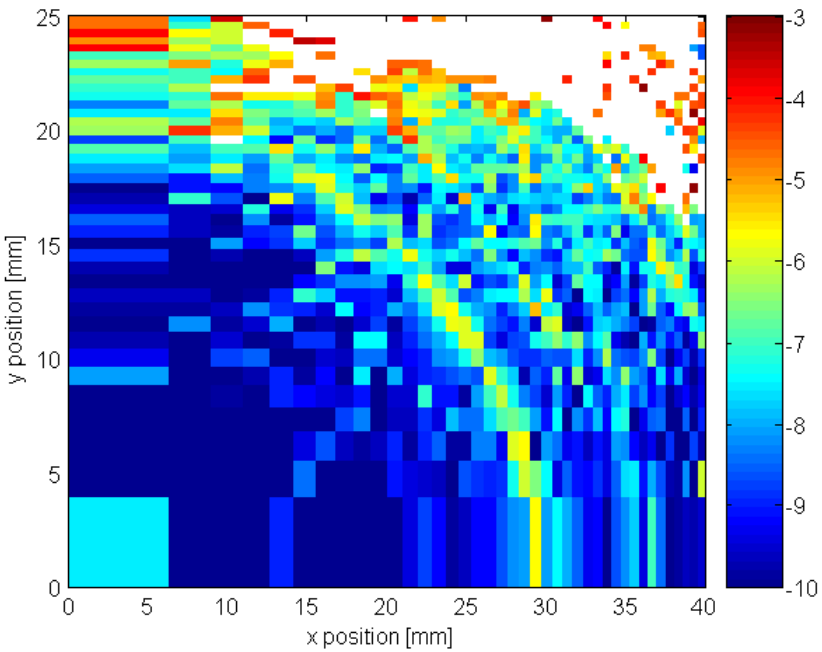

$\xi_x = \xi_y = 3$



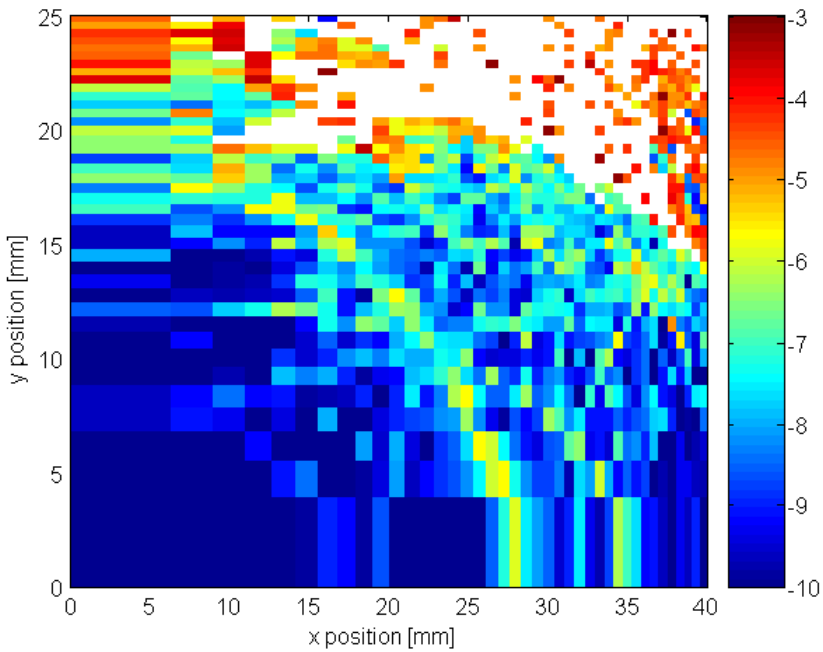

- more particles are pushed over horizontal third order resonance
- more particles with large diffusion rates

# Results for different chromaticities

$\xi_x = \xi_y = 1$



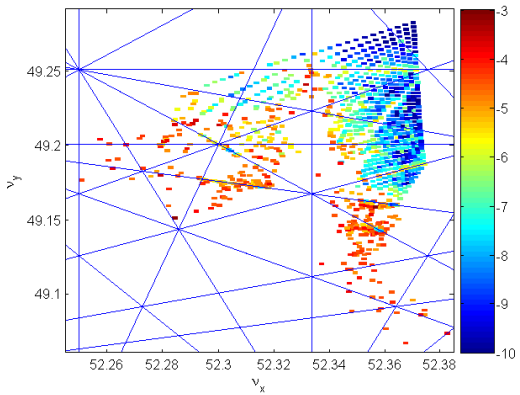

$\xi_x = \xi_y = 3$




- dynamic aperture reduced for larger chromaticity
- vertical fourth order resonance crossed at smaller amplitude

# $\xi_x = \xi_y = 3$ (off-momentum)

$\frac{\Delta p}{p} = -0.5\%$

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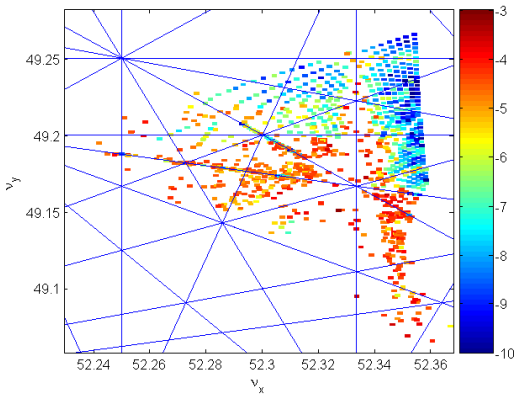


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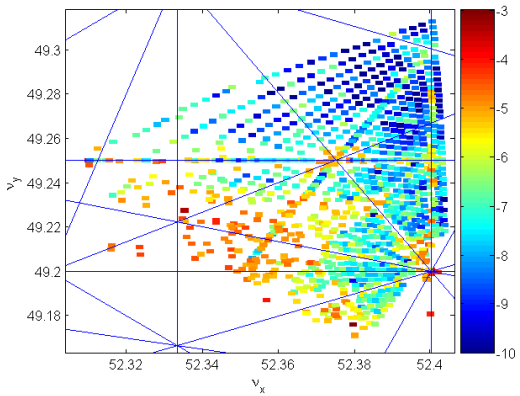


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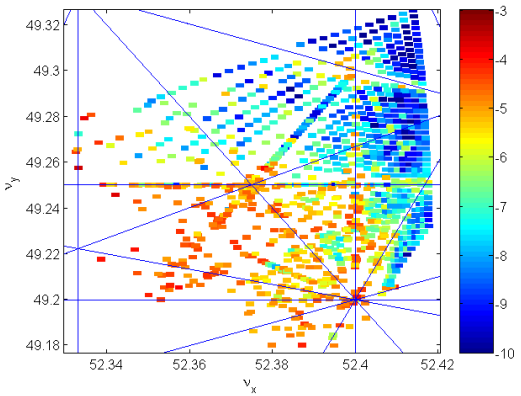
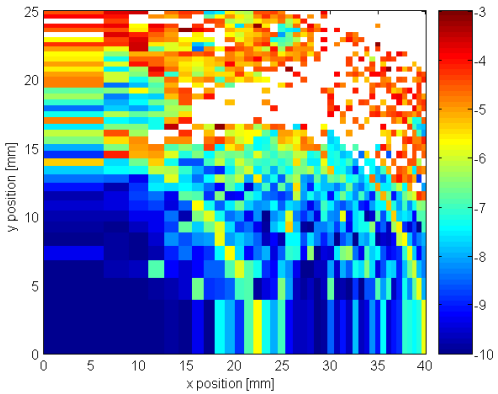



- horizontal third order resonance reduces dynamic aperture for negative $\frac{\Delta p}{p}$
- many particles have large diffusion rates

# $\xi_x = \xi_y = 3$ (off-momentum)

$\frac{\Delta p}{p} = -0.5\%$

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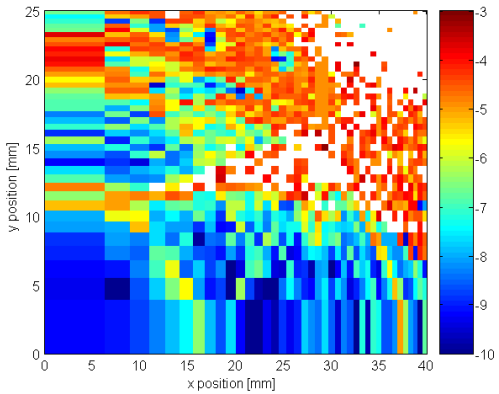


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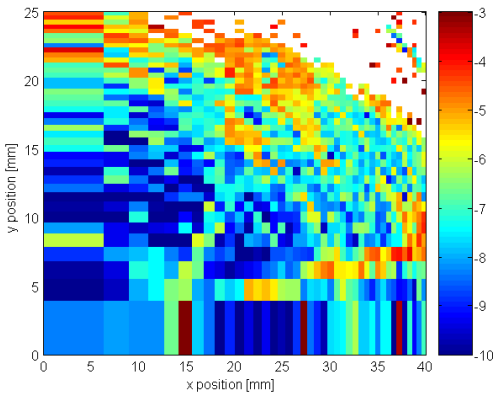


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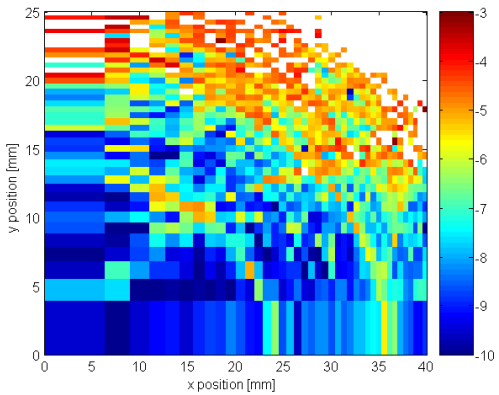
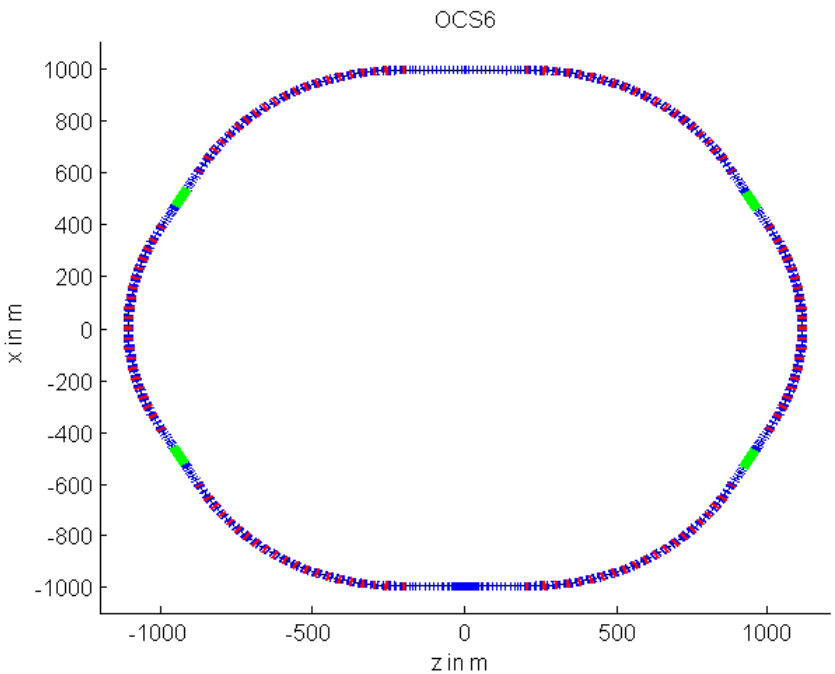
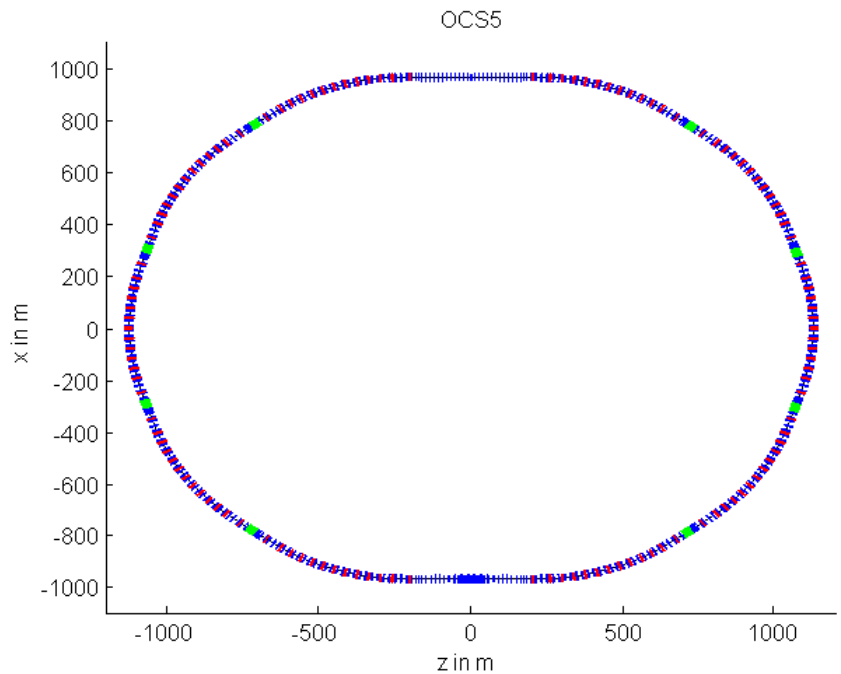



- vertical dynamic aperture clearly reduced for negative $\frac{\Delta p}{p}$
- large diffusion rates occur at small amplitudes

# Comparison between OCS5 and OCS6

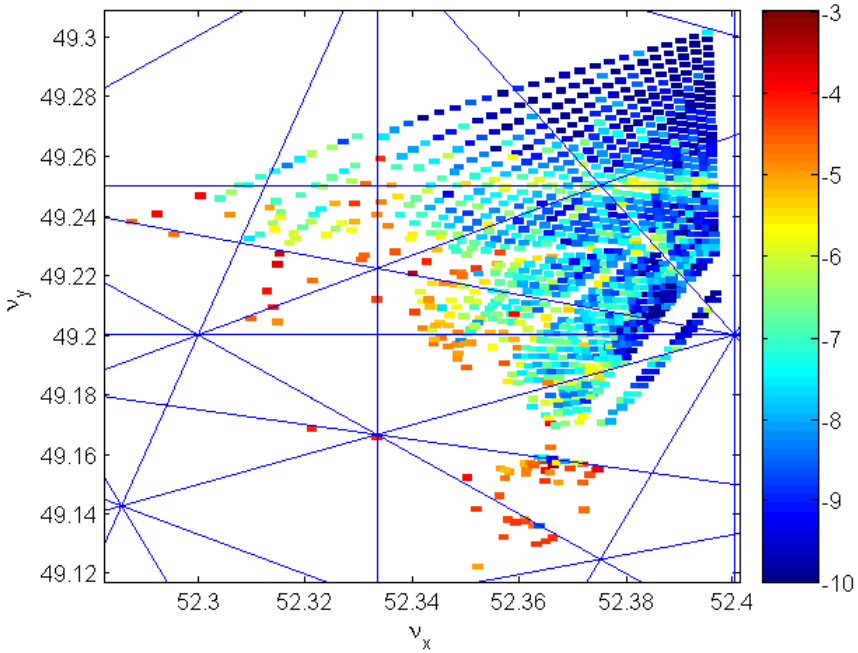


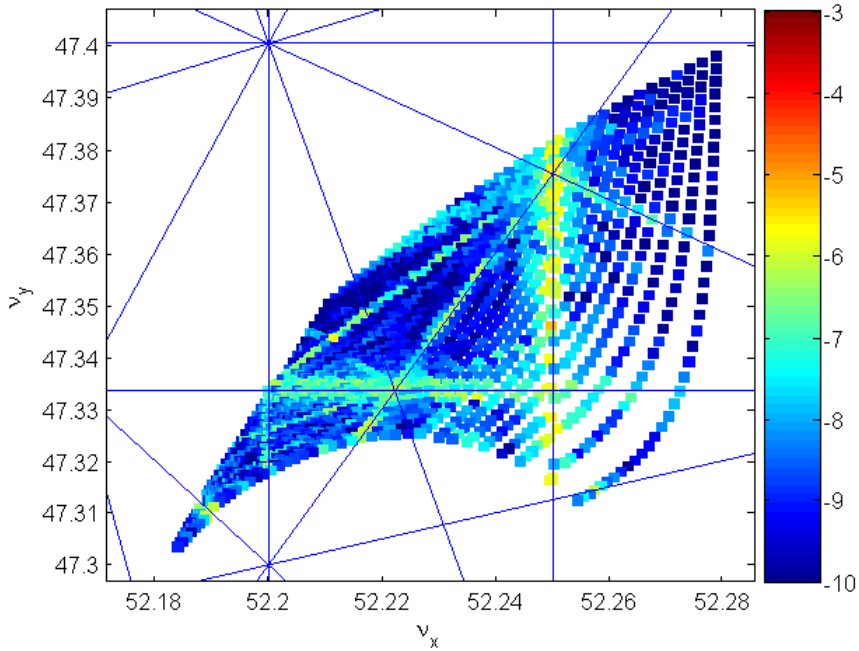

- lattices have different number of short straight sections
- arc cells are identical
- tunes are different

# Comparison between OCS5 and OCS6

OCS6



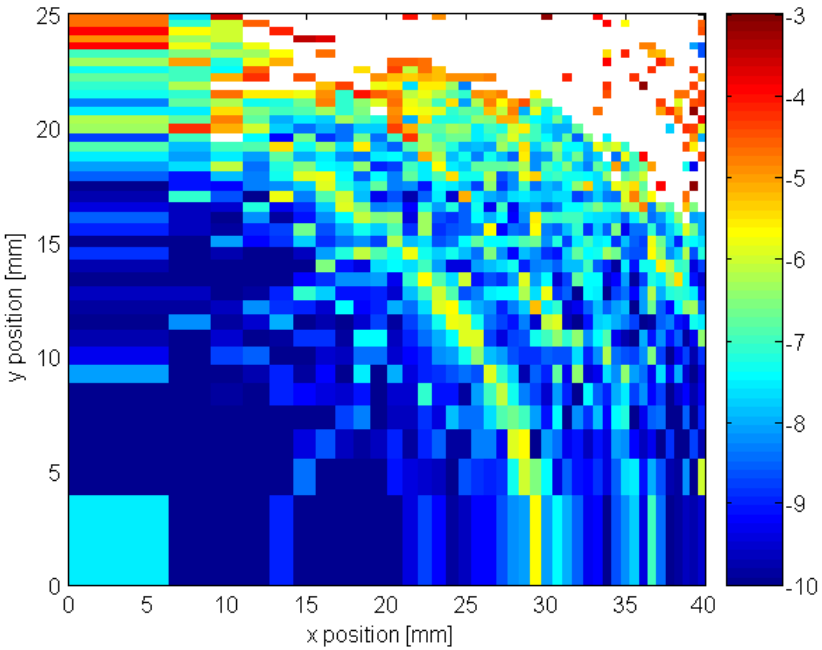

OCS5



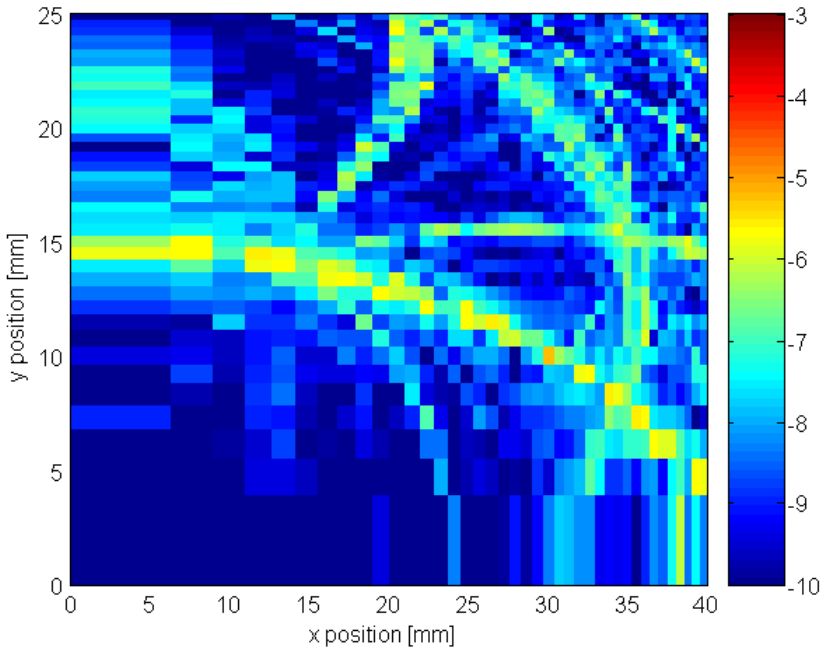

- different tunes
- cross detuning smaller for OCS5 leading to a smaller footprint

# Comparison between OCS5 and OCS6

OCS6




OCS5




- particles at large amplitude are more stable for OCS5
- dynamic aperture reduced for OCS6

# What changed from OCS5 to OCS6?

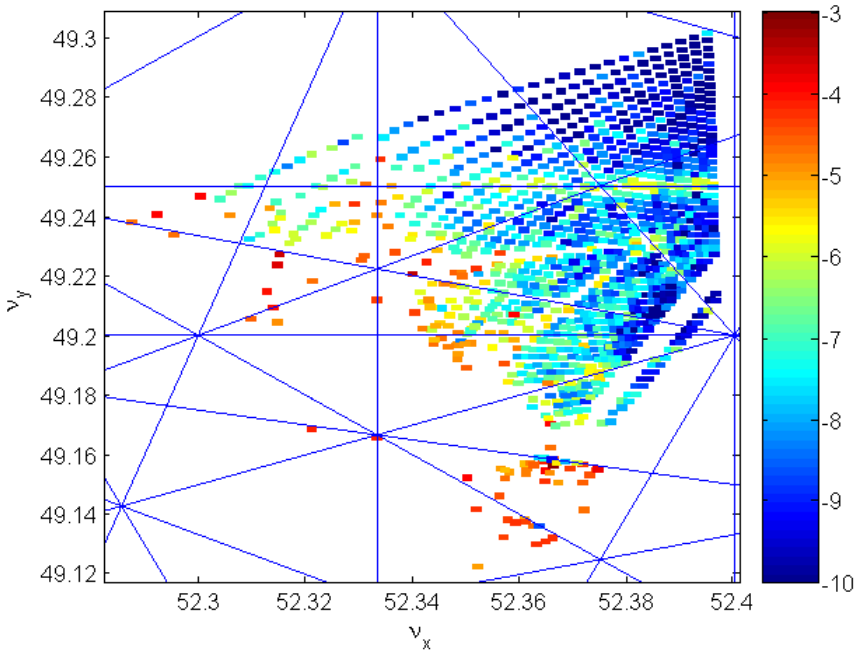
- Different number of straight sections
- Different tunes

Try to change tune of OCS6 to the values of OCS5:

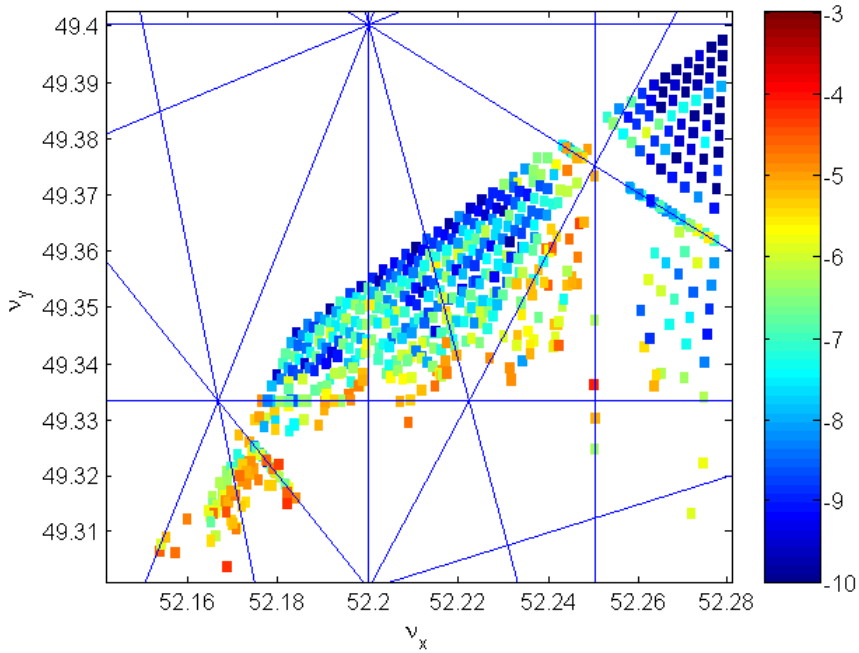
- Using one straight section as a tune trombone
- Changing the phase advance in the arc cells slightly

# Using OCS5 tunes (tune trombone)

OCS6



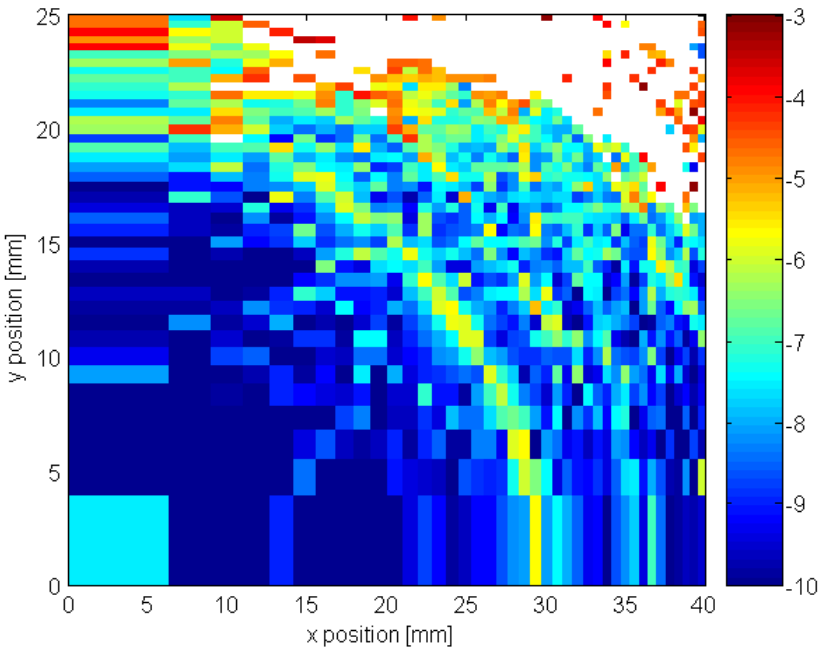

OCS6 with OCS5 tunes (tune trombone)



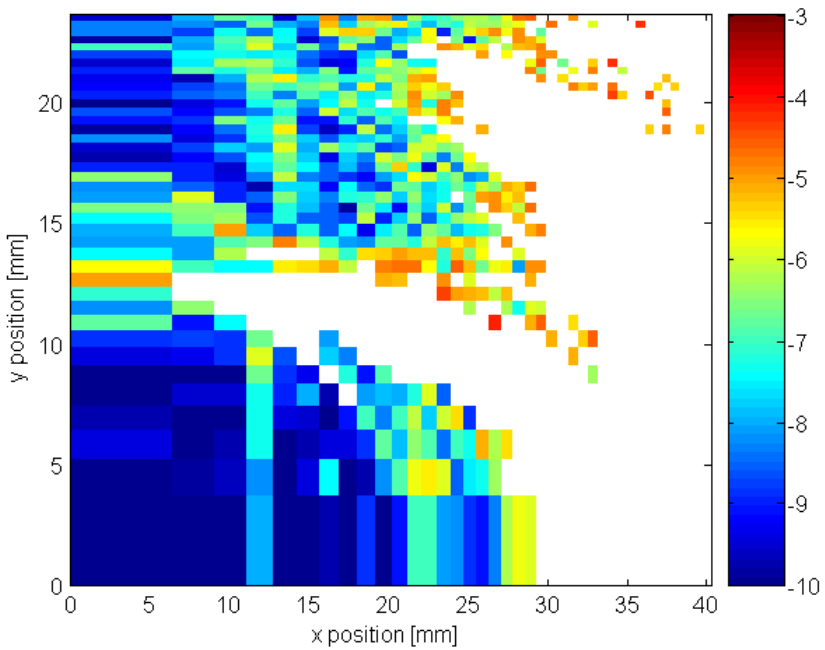

- vertical third and horizontal fourth integer resonance are strong
- footprint frayed

# Using OCS5 tunes (tune trombone)

OCS6



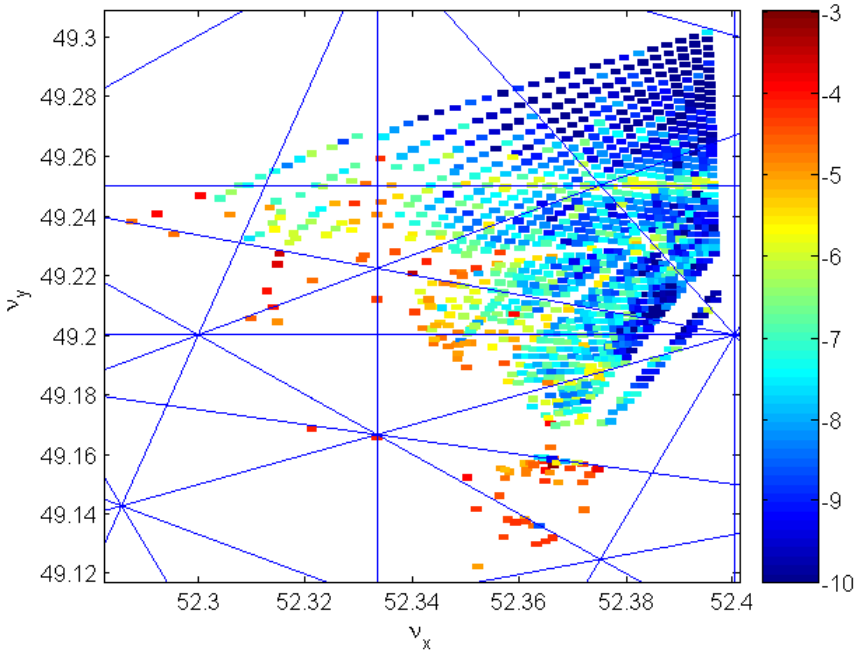

OCS6 with OCS5 tunes (tune trombone)



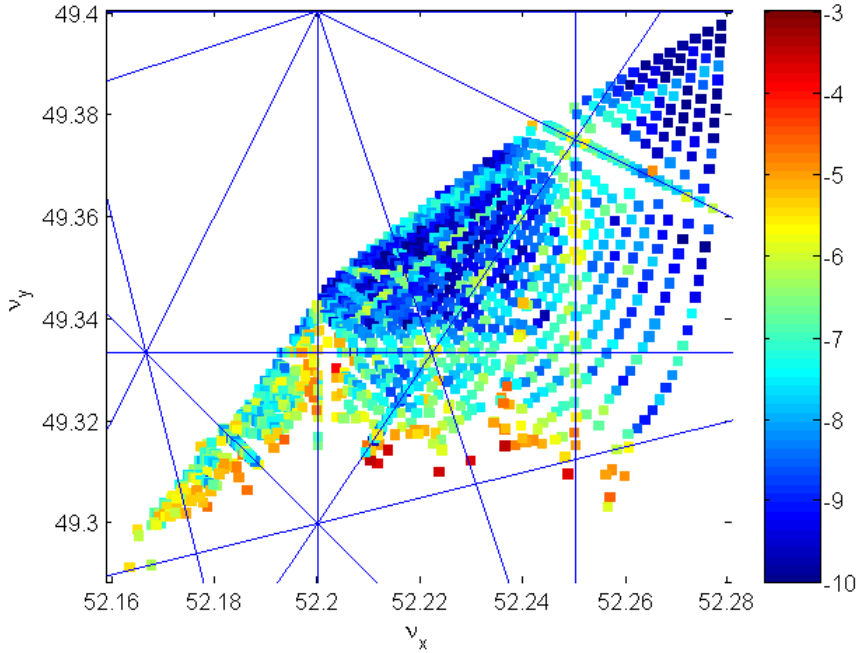

- vertical dynamic aperture reduced drastically
- horizontal fourth order resonance cutting into dynamic aperture

# Using OCS5 tunes (arc)

OCS6



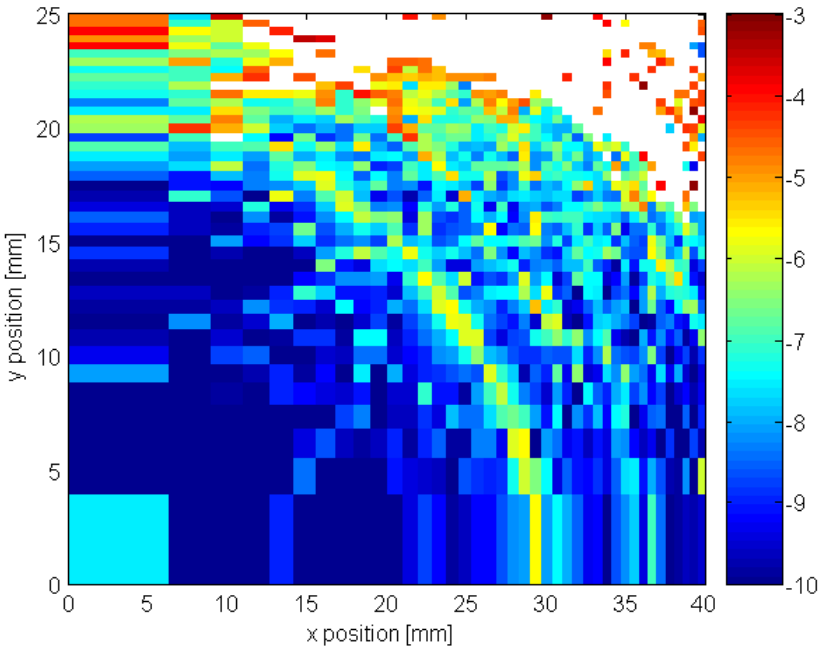

OCS6 with OCS5 tunes (arc)



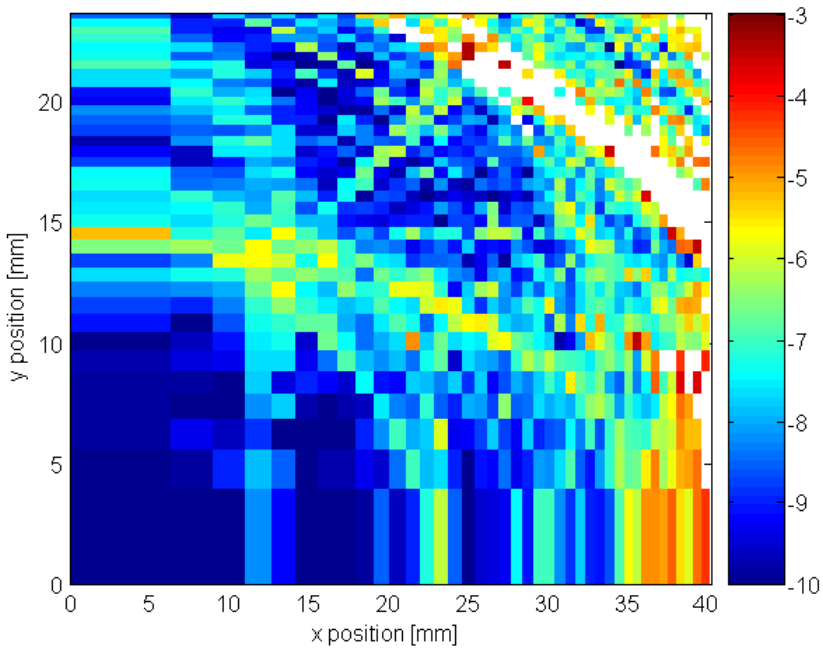

- some horizontal fourth and fifth order resonances visible
- vertical detuning reduced
- part of footprint still frayed

# Using OCS5 tunes (arc)

OCS6

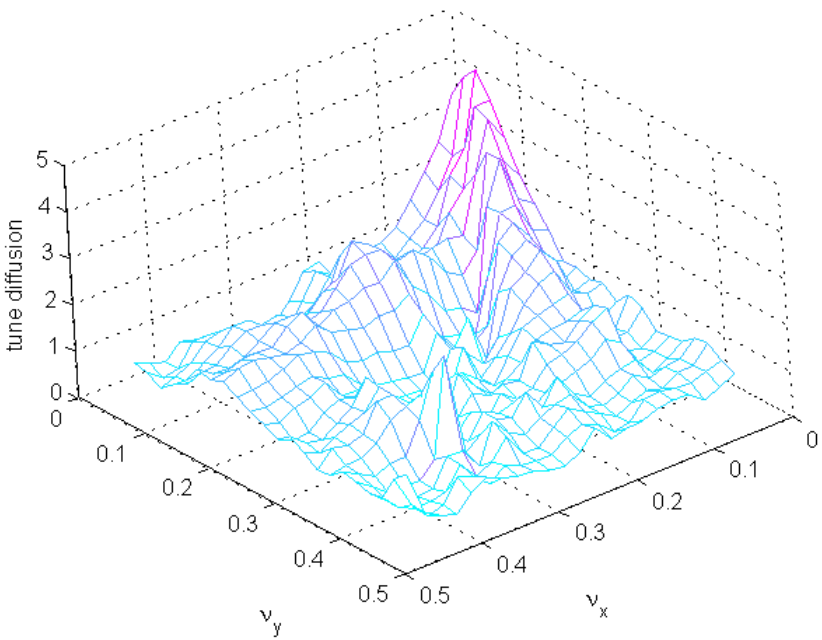


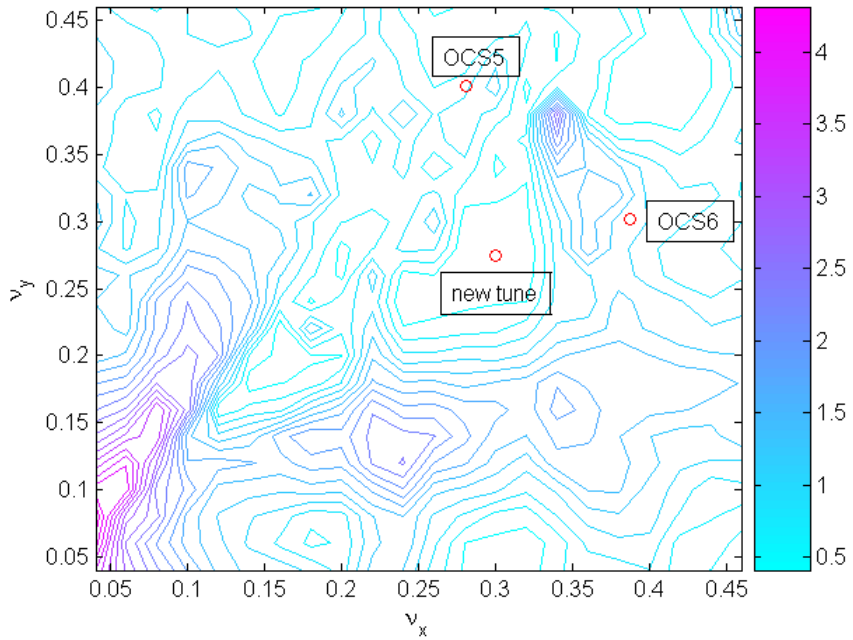

OCS6 with OCS5 tunes (arc)




- dynamic aperture about comparable, better in the vertical plane
- dynamic aperture restriction mainly caused by horizontal fifth order resonance

# Tune scan

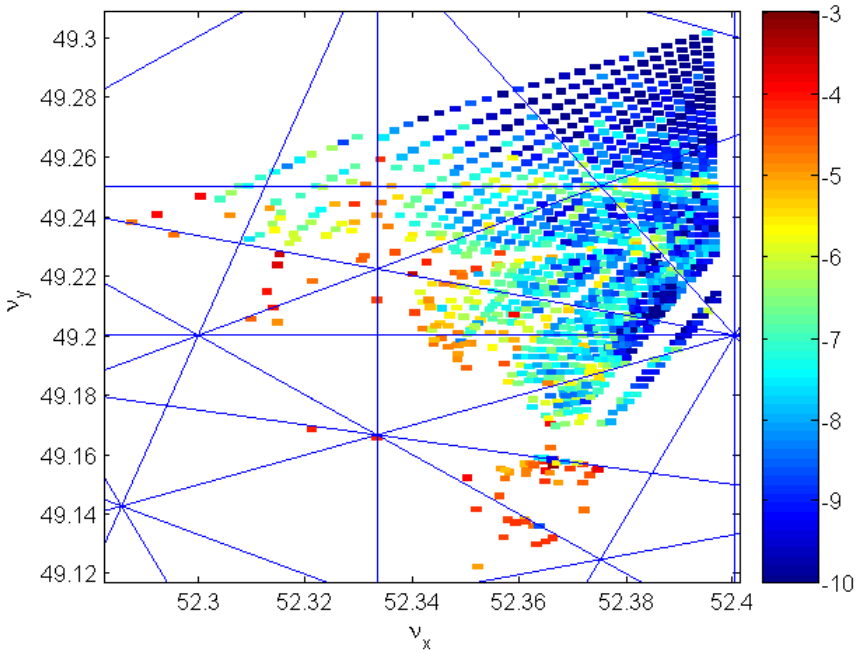


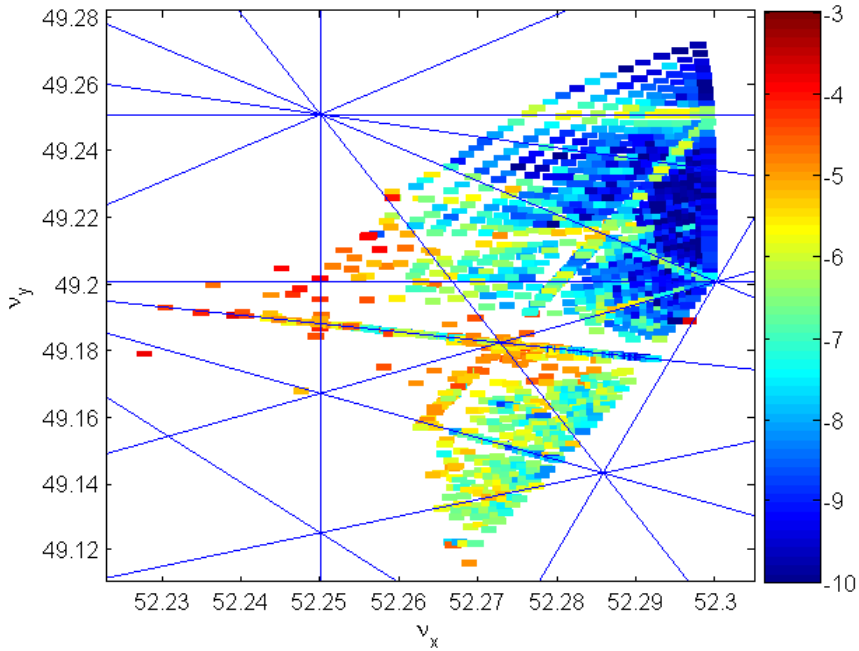

- scan tunes and calculate 10x10 frequency maps
- sum diffusion rates
- select tune at lowest diffusion rate (0.300, 0.275)

# New tune (0.300, 0.275)

OCS6



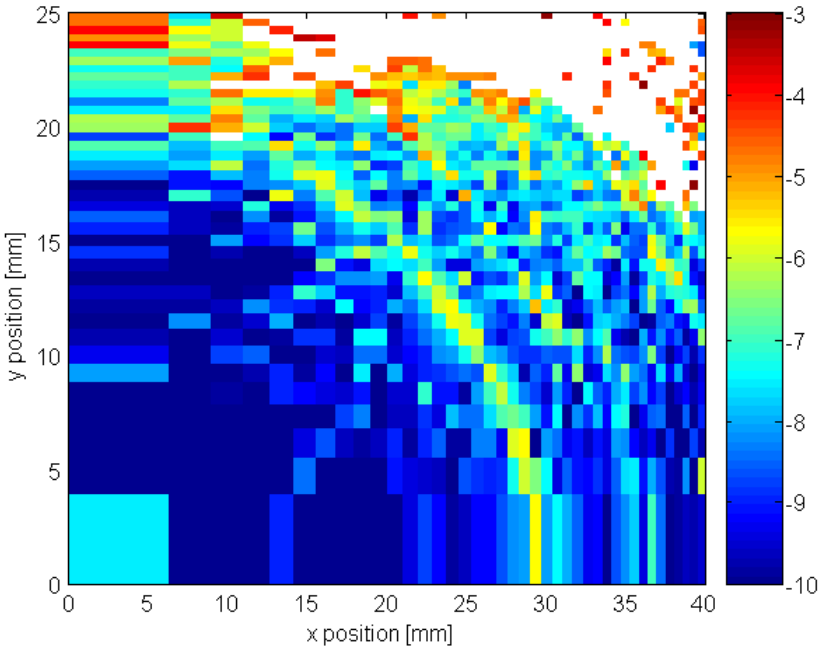

OCS6 with (0.300, 0.275)



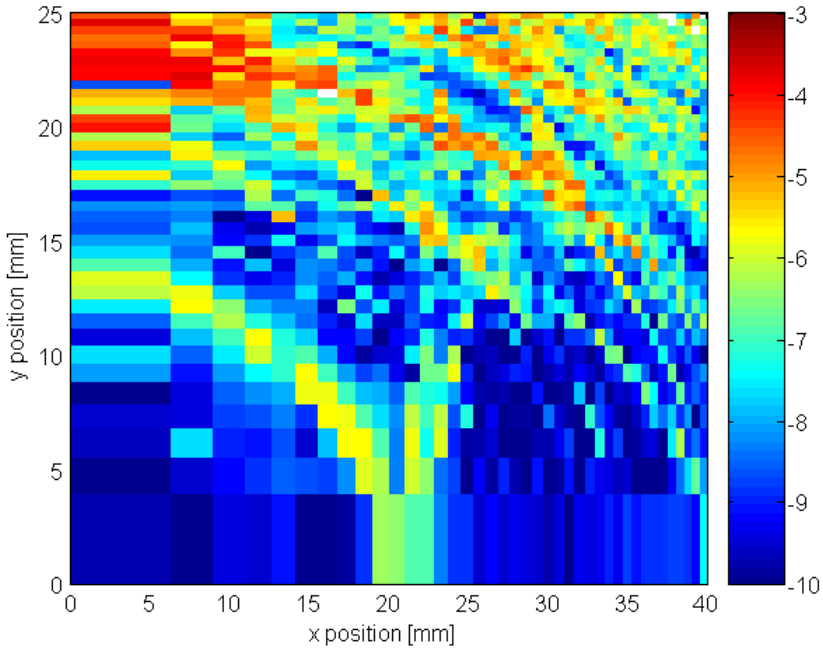

- footprint is small (i.e. detuning is reduced) but still a little bit frayed
- some resonances visible

# New tune (0.300, 0.275)

OCS6



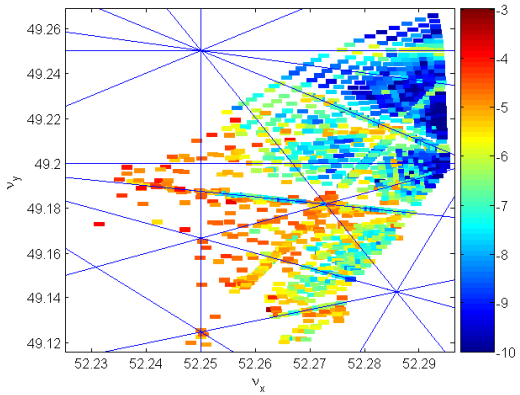

OCS6 with (0.300, 0.275)

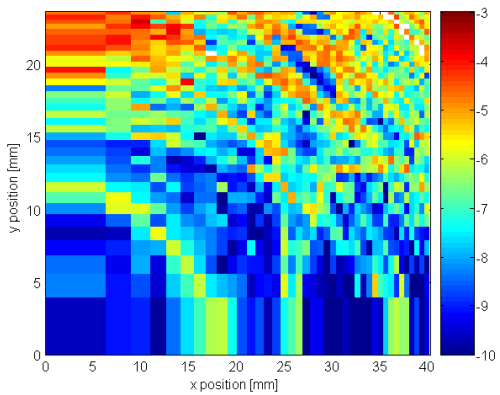



- almost no particle losses
- some resonances clearly visible at small amplitudes

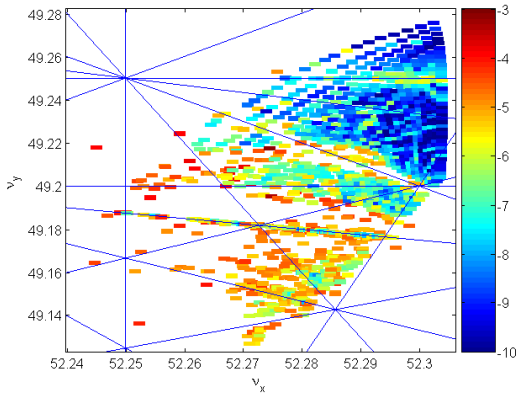
# $Q = (0.300, 0.275)$, off-momentum

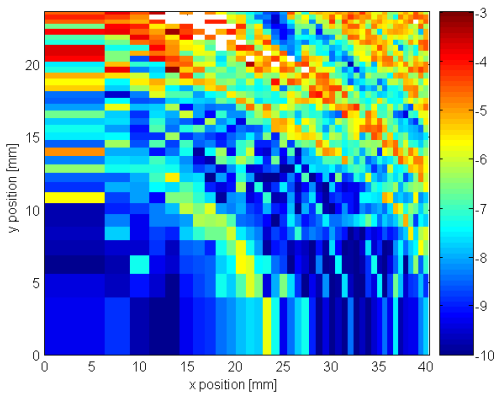
$\frac{\Delta p}{p} = -0.5\%$




$\frac{\Delta p}{p} = +0.5\%$




- footprint somewhat frayed due to some resonances
- very few particles lost
- some resonances at small amplitudes
- worse, but not significantly so, than on-momentum

# Conclusion

- Dynamic aperture problems caused by combination of tune values and large cross detuning with amplitude
- Choosing a different tune can increase the dynamic aperture significantly
- Harmonic sextupoles might increase the dynamic aperture further