Space charge effect in the ILC Damping Rings estimated by SAD

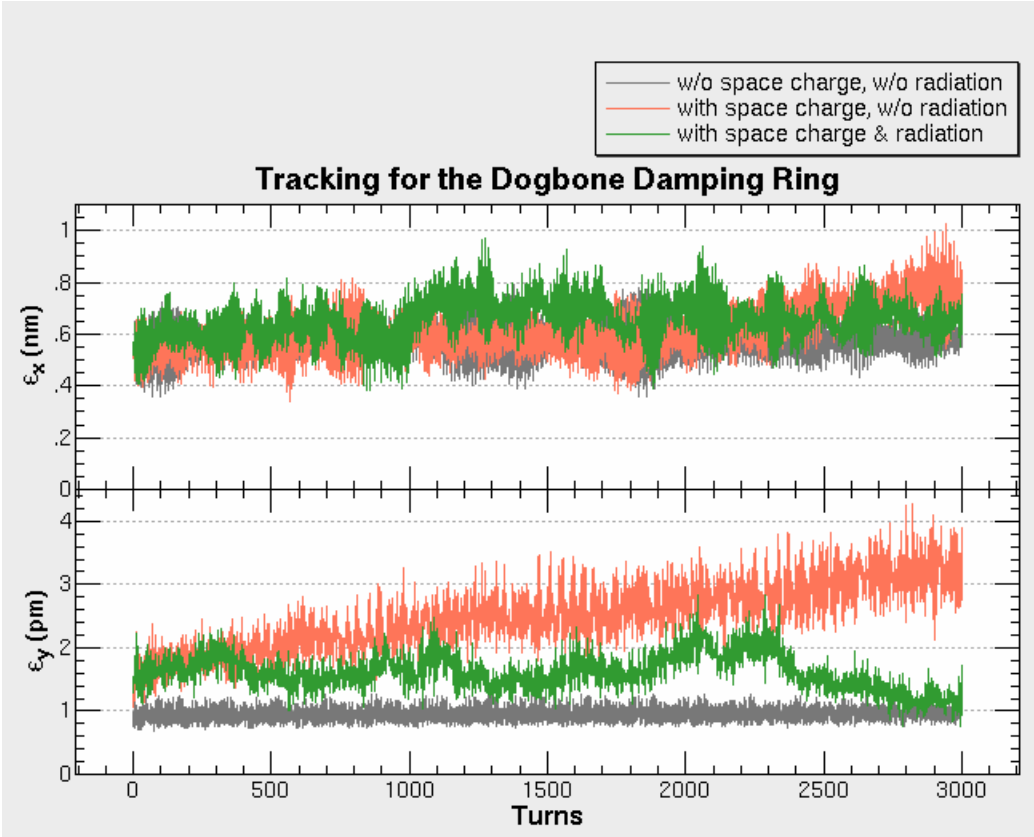
8/11/2005 K. Oide(KEK)

Presented by Y. Ohnishi @ WG3b

Many thanks to whom helped this work, eps. H. Koiso, K. Kubo, M. Kuriki, K. Ohmi, M. Venturini, A. Wolski, K. Yokoya

SAD = Strategic Accelerator Design, developed at KEK, since 1986.
http://acc-physics.kek.jp/SAD/sad.html

Tracking Simulation



$N=2\times10^{10}$

100 macro particles. Lattice tune = (76.31, 41.29)

(1) The equilibrium emittance is calculated by the equilibrium beam envelope method, including the space charge force, assuming the minimum vertical emittance 1 pm.

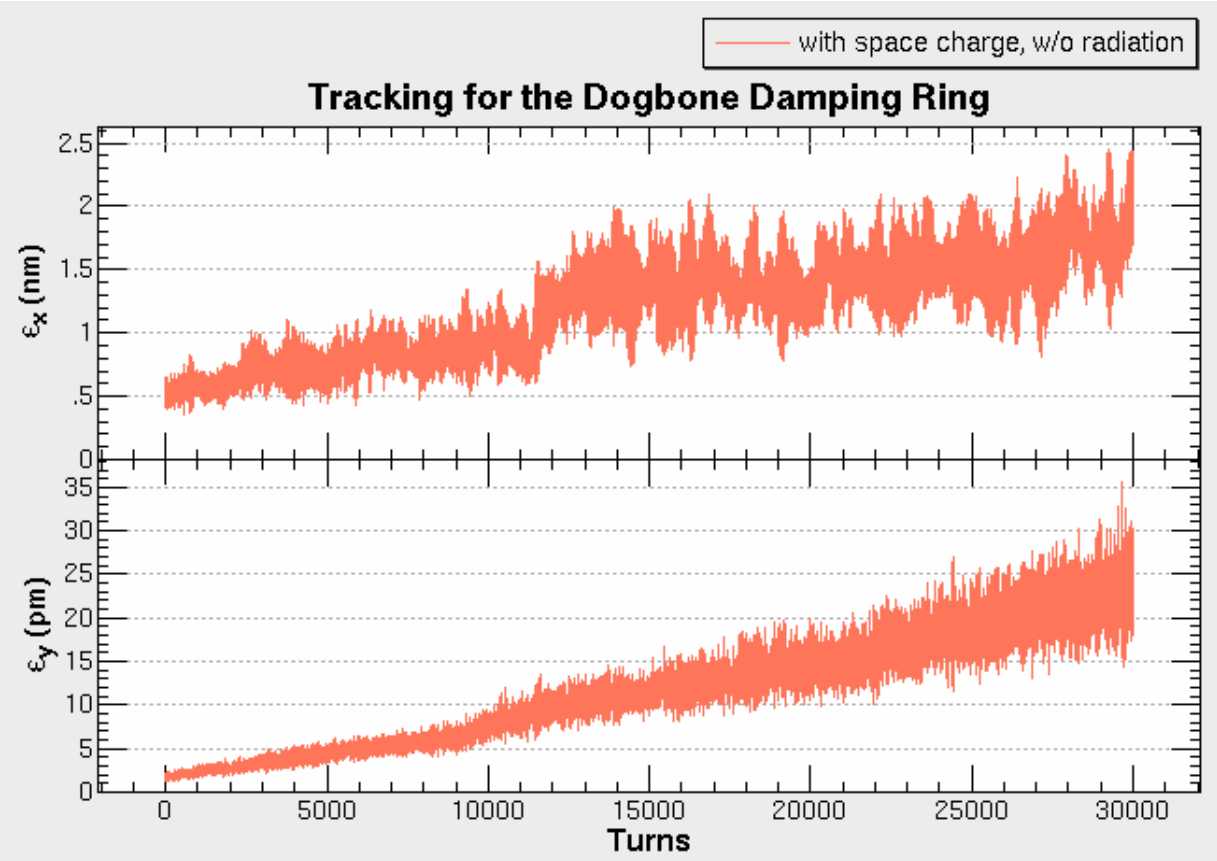
(2) Track particles with strong-weak model. Space charge kick at entrance of each element, assuming Gaussian.

3D symplectic map for the space charge, with an approximated potential $U(x,y,z) = f(x,y)\exp(-z^2/2$

• About 1-2 sec/turn by 2.5 GHz G5 Mac. Space charge takes 10% of the total cpu time.

Tracking Simulation (cont'd)

More long-range up to 30 k turns w/o radiation !

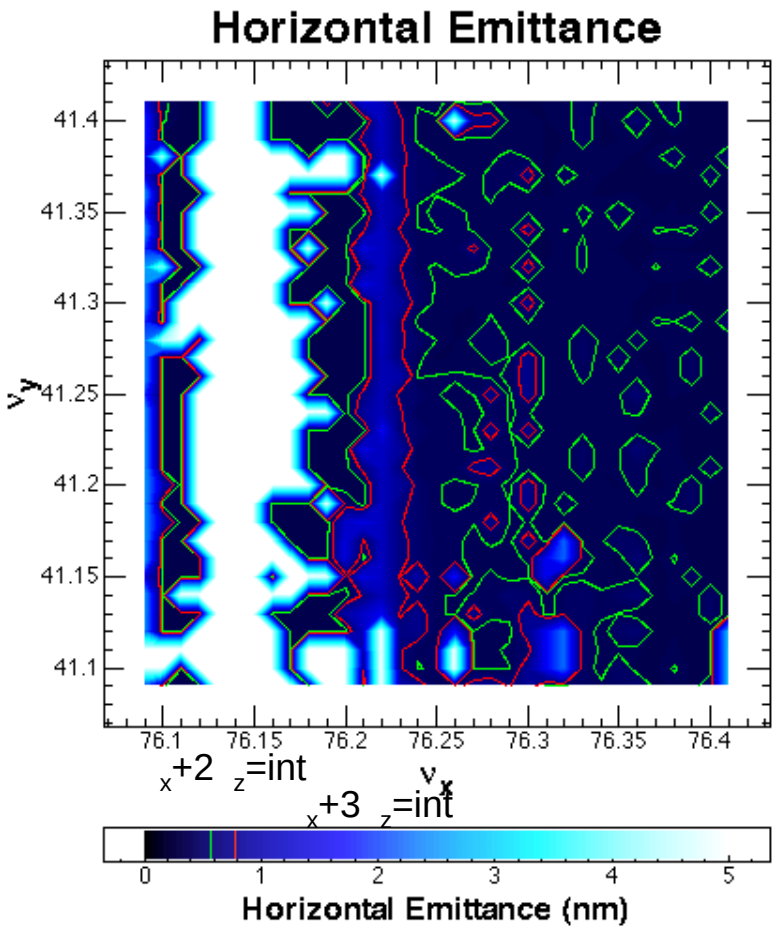


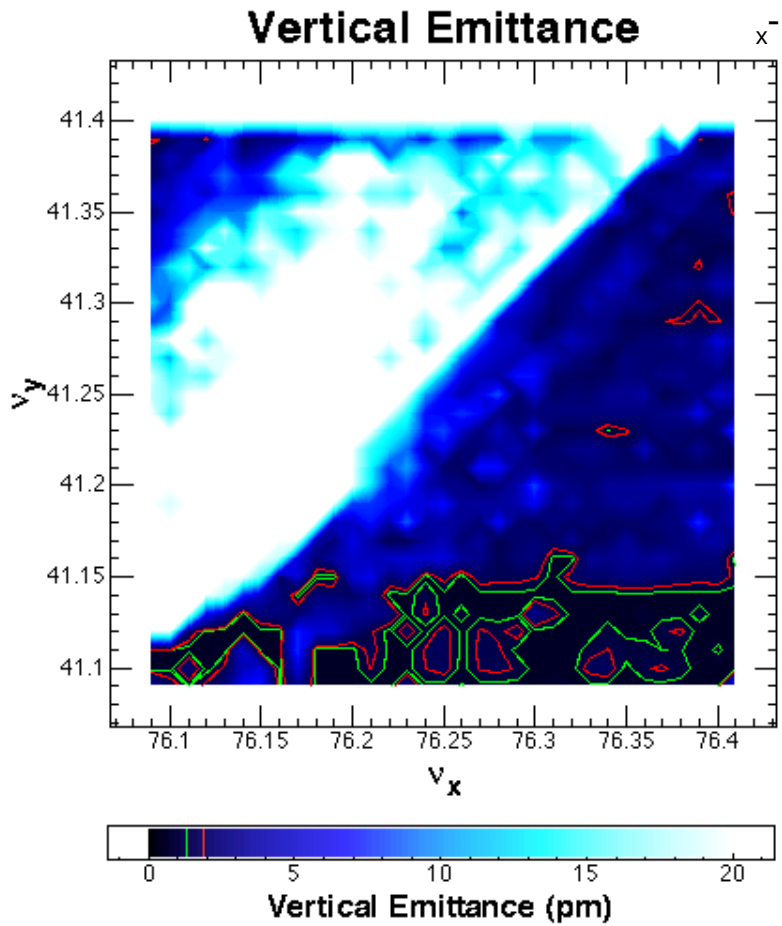
$N=2x10^{10}$

The emittance blowup (diffusion) continues if radiation is turned off.

The equilibrium emittance is estimated by $n_d \times n$ n_d: damping turns

Dogbone (S-shape, no coupling bump)



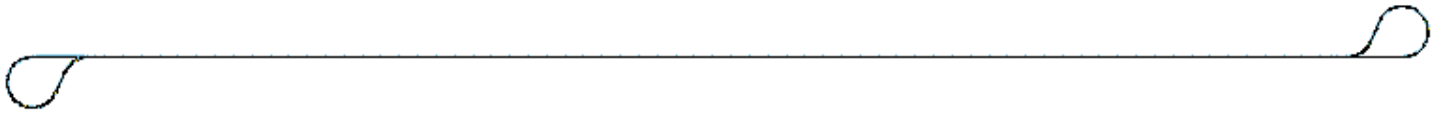


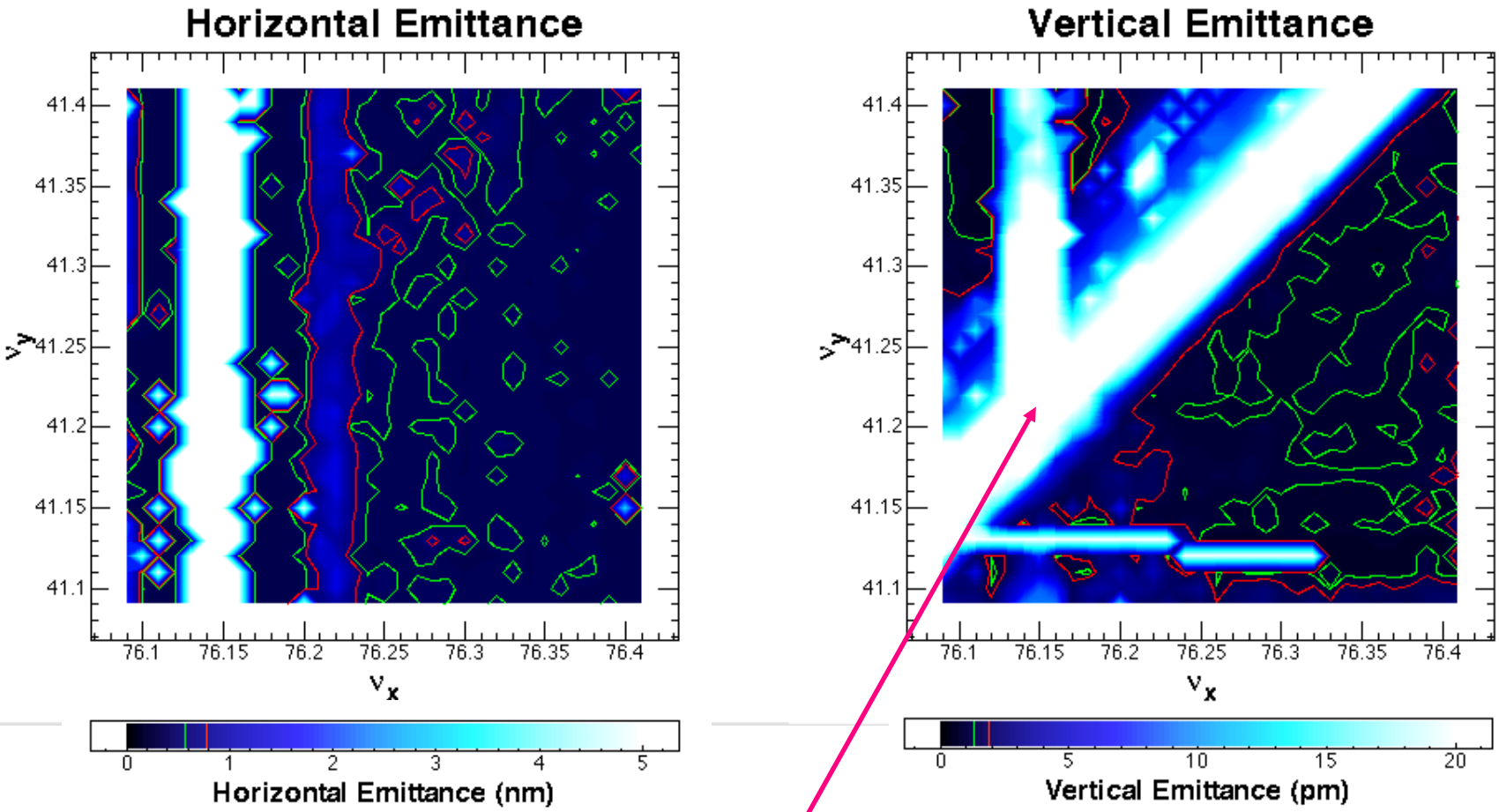
green: 0.6 nm
red: 0.8 nm

green: 1.2 pm
red: 2 pm

0.2%

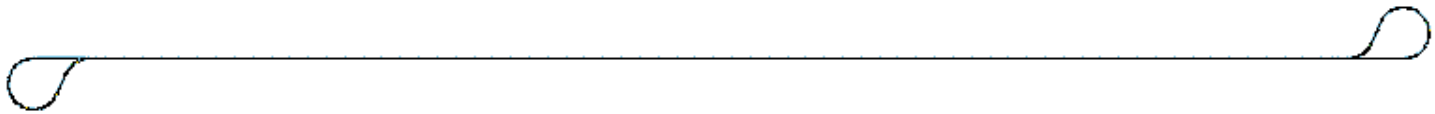
Dogbone (S-shape, original coupling bump)

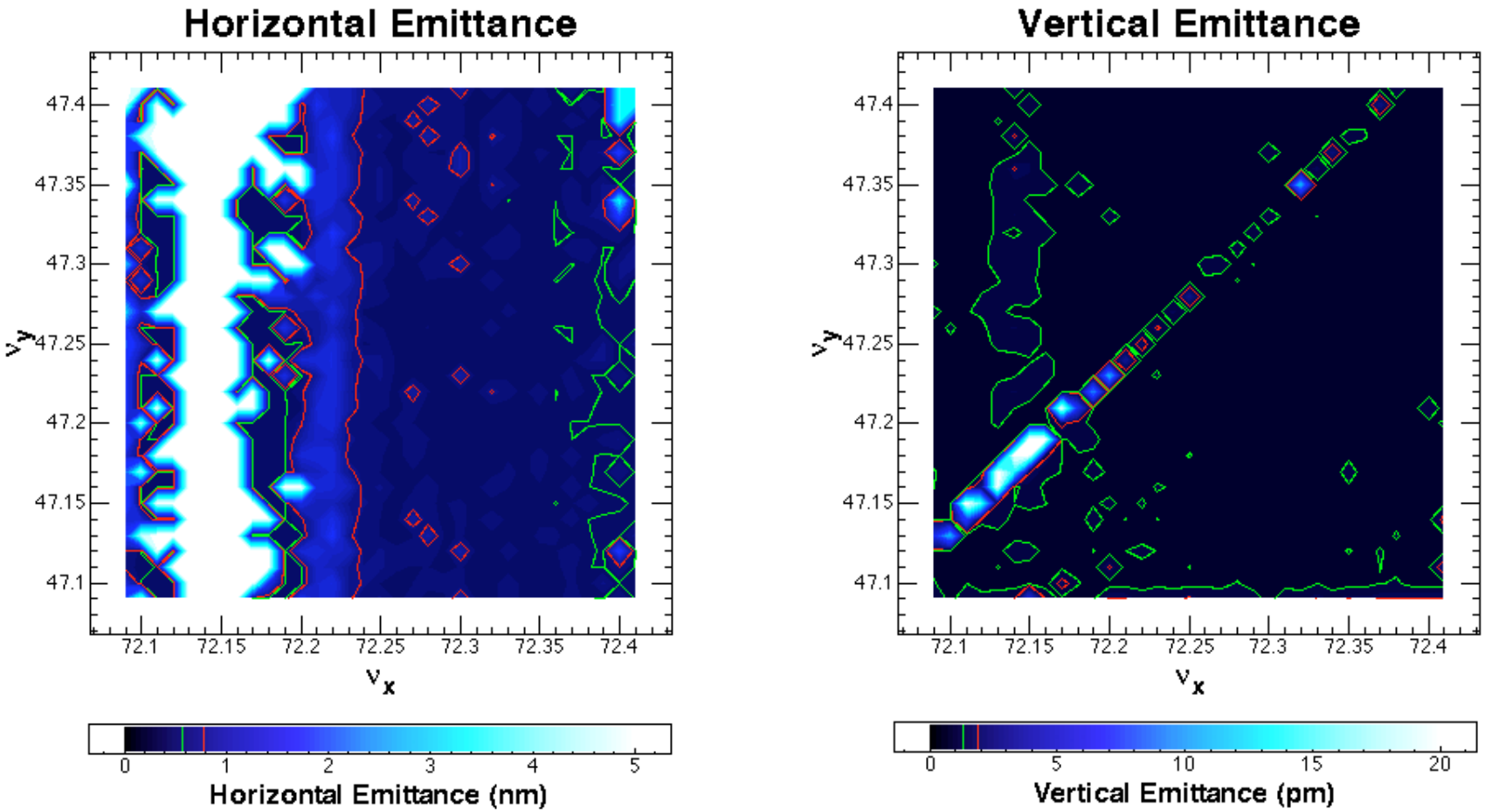




Still emittance growth

Dogbone (S-shape, round coupling bump)

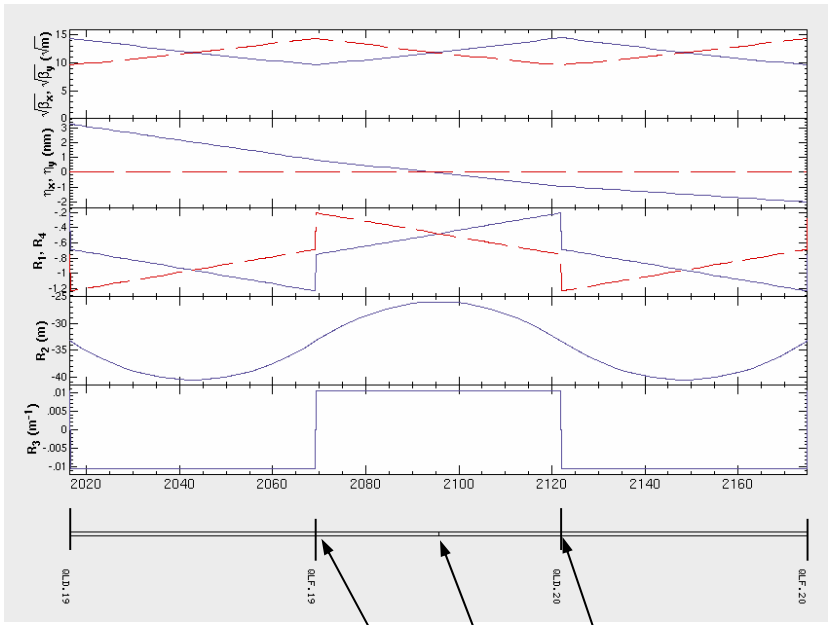


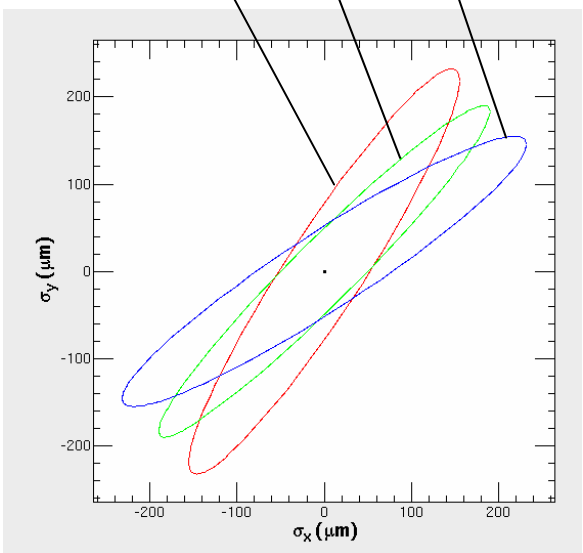


Safe region is enlarged !

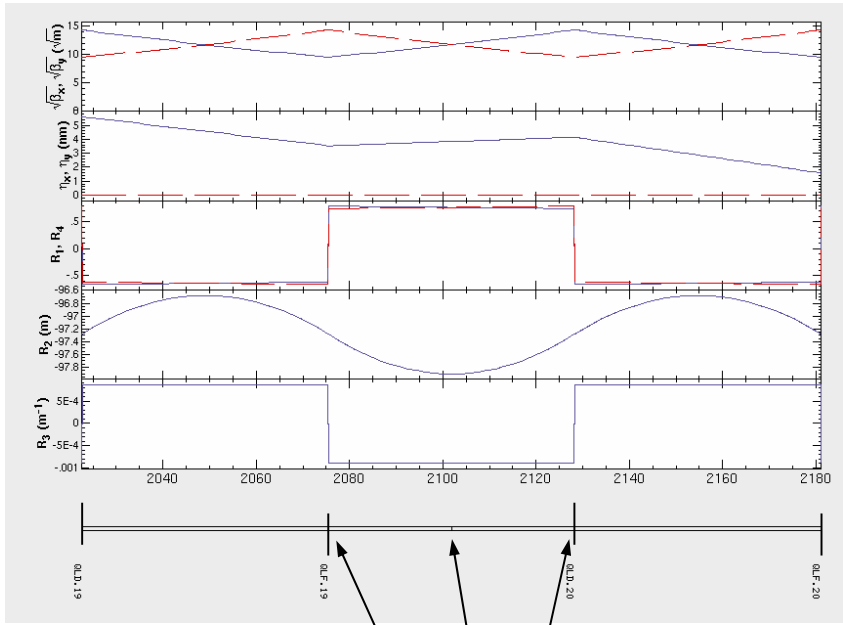
Coupling Bumps

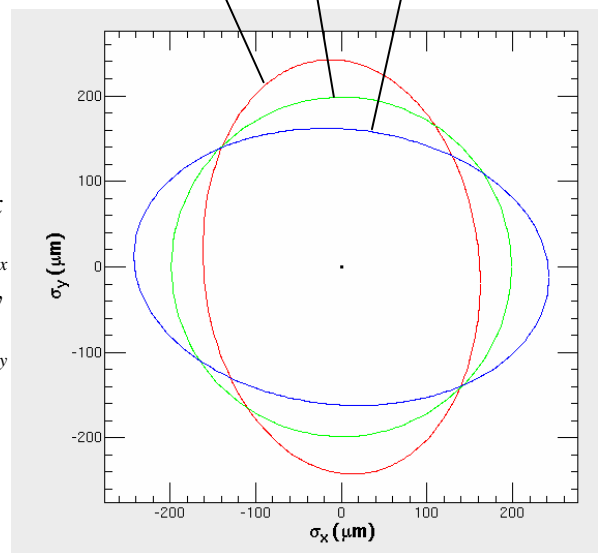
Original coupling bumps





Round coupling bumps



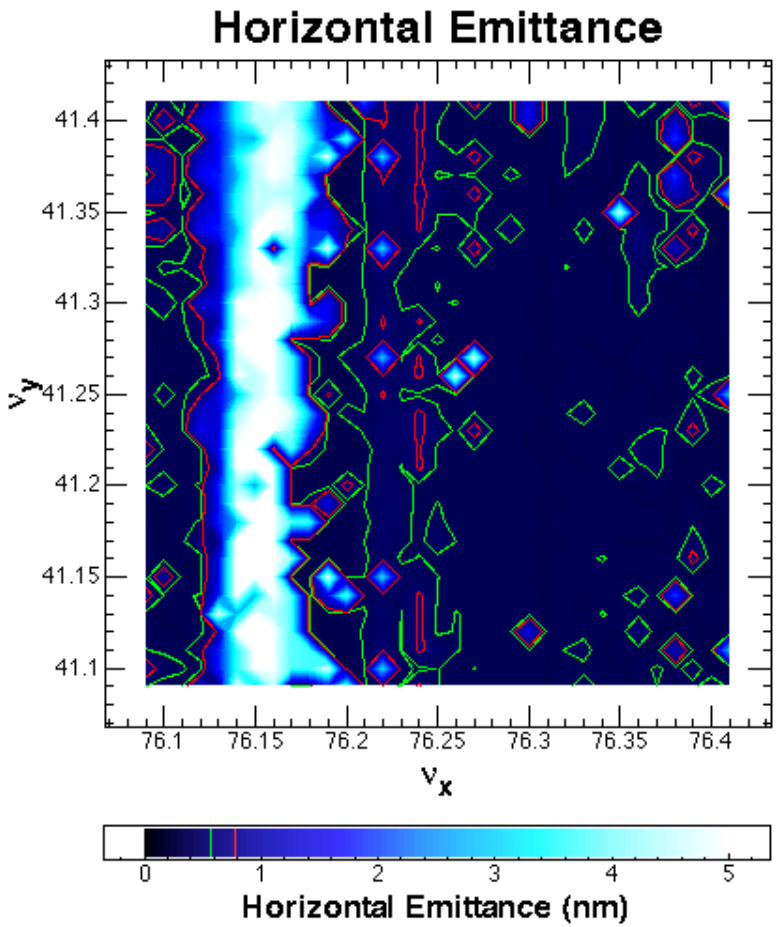


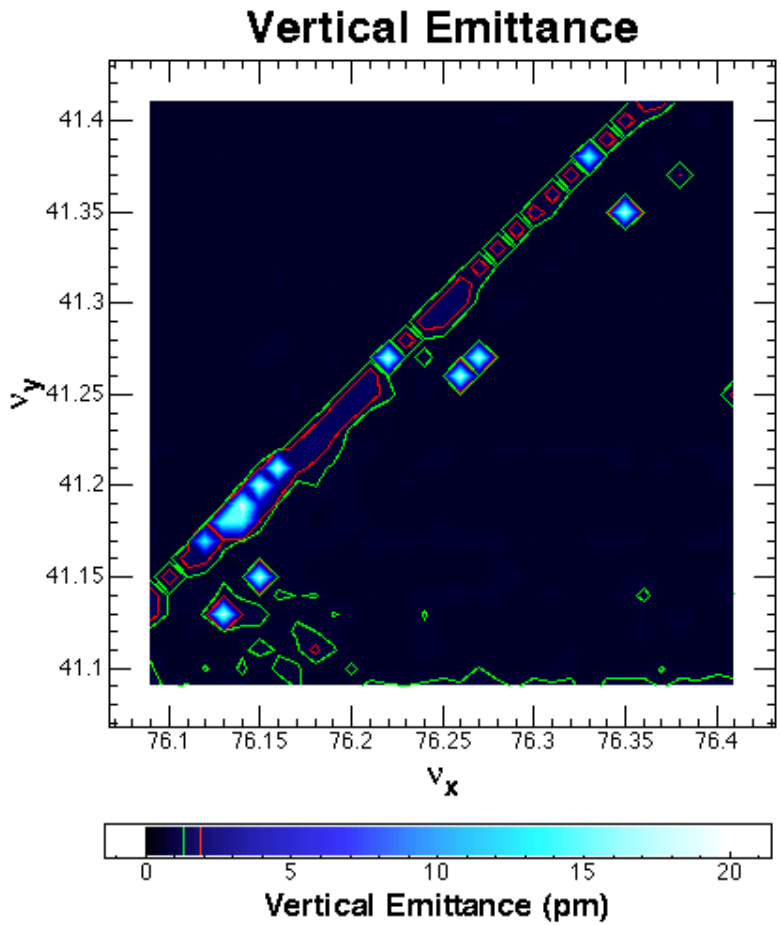
Transformation to decoupled coordinate

$$\begin{pmatrix} X \\ P_X \\ Y \\ P_Y \end{pmatrix} = \begin{pmatrix} 0 & r_4 & r_2 & x \\ 0 & r_3 & r_1 & p_x \\ r_1 & r_2 & 0 & y \\ r_3 & r_4 & 0 & p_y \end{pmatrix}$$

$$^{2} \quad (r_1 r_4 \quad r_2 r_3) \quad 1$$

Dogbone (C-shape, round coupling bump)

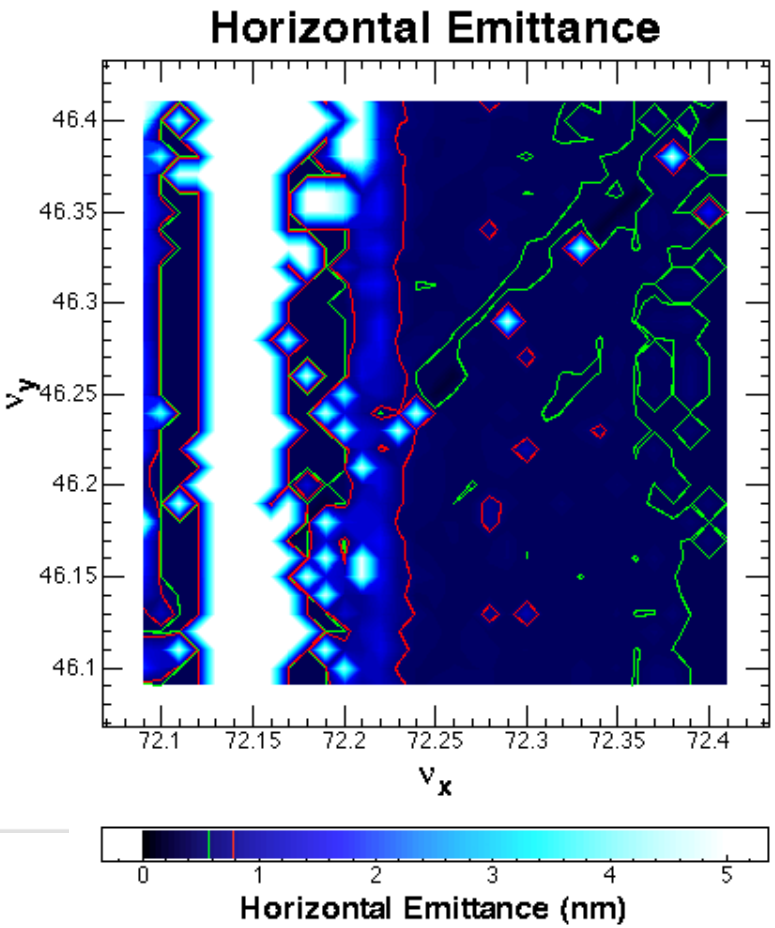


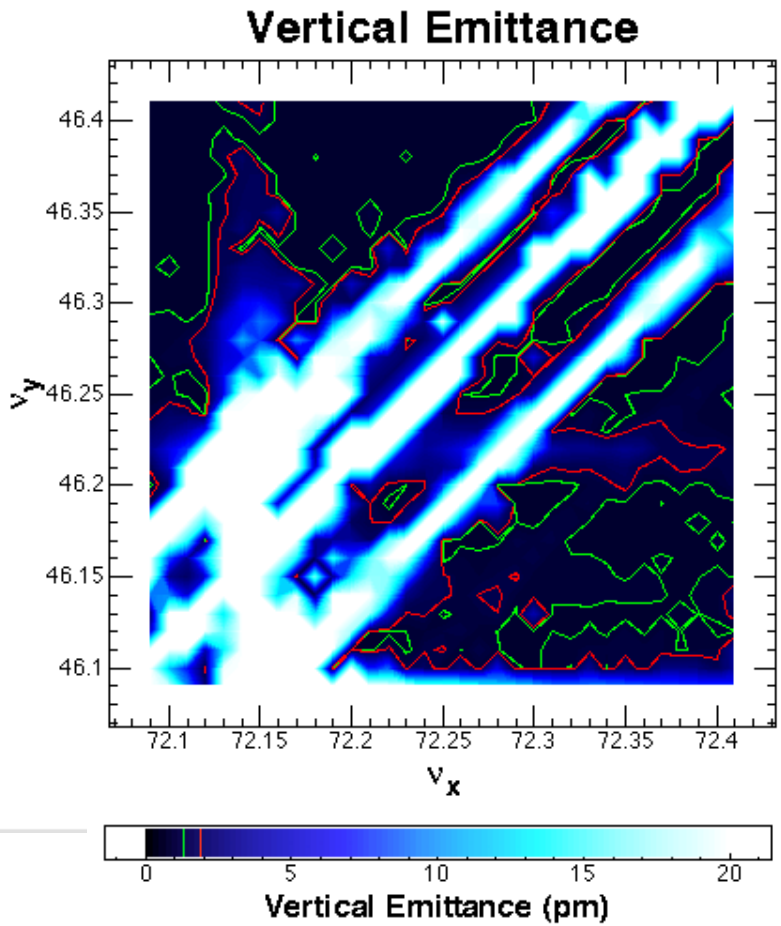


Dogbone (S-shape, round coupling bump)

Near the structure resonance

x y

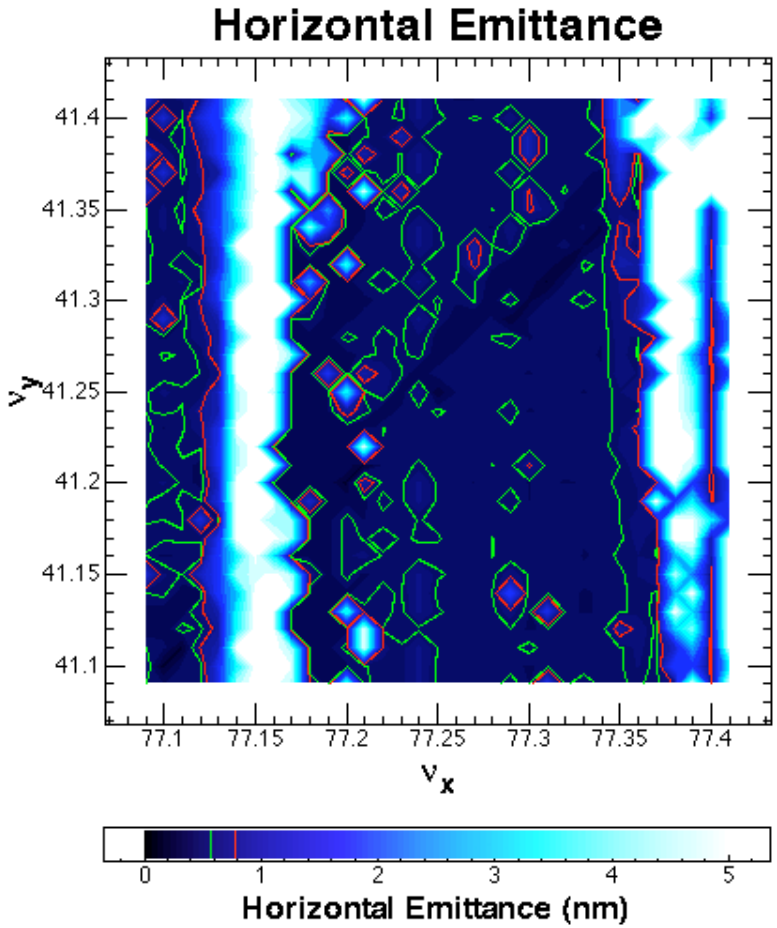


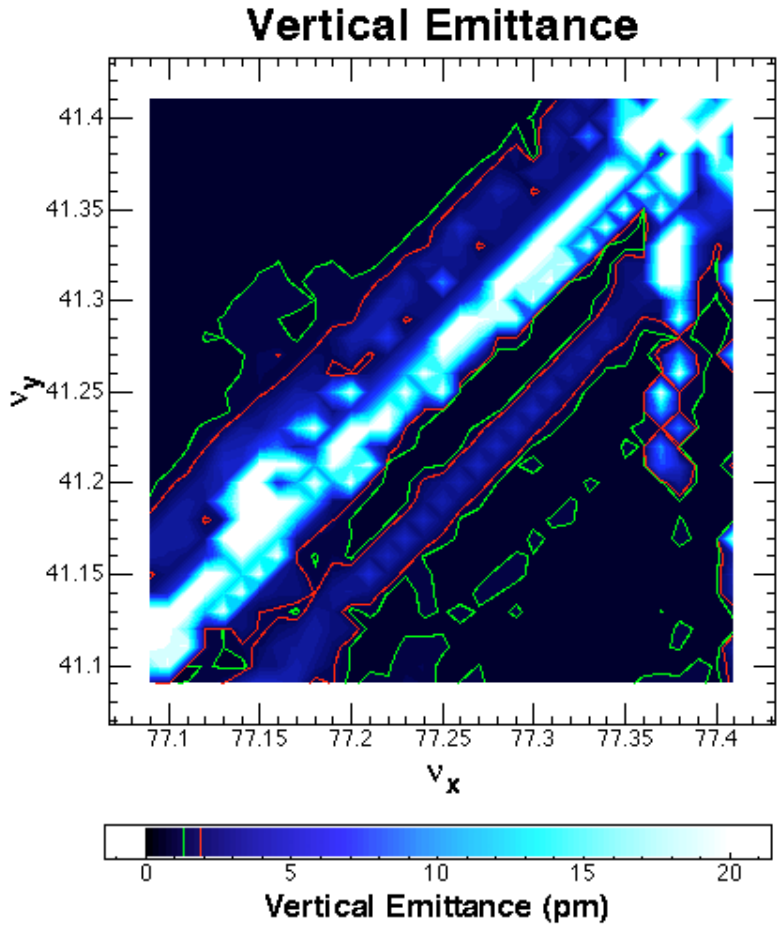


Dogbone (C-shape, round coupling bump)

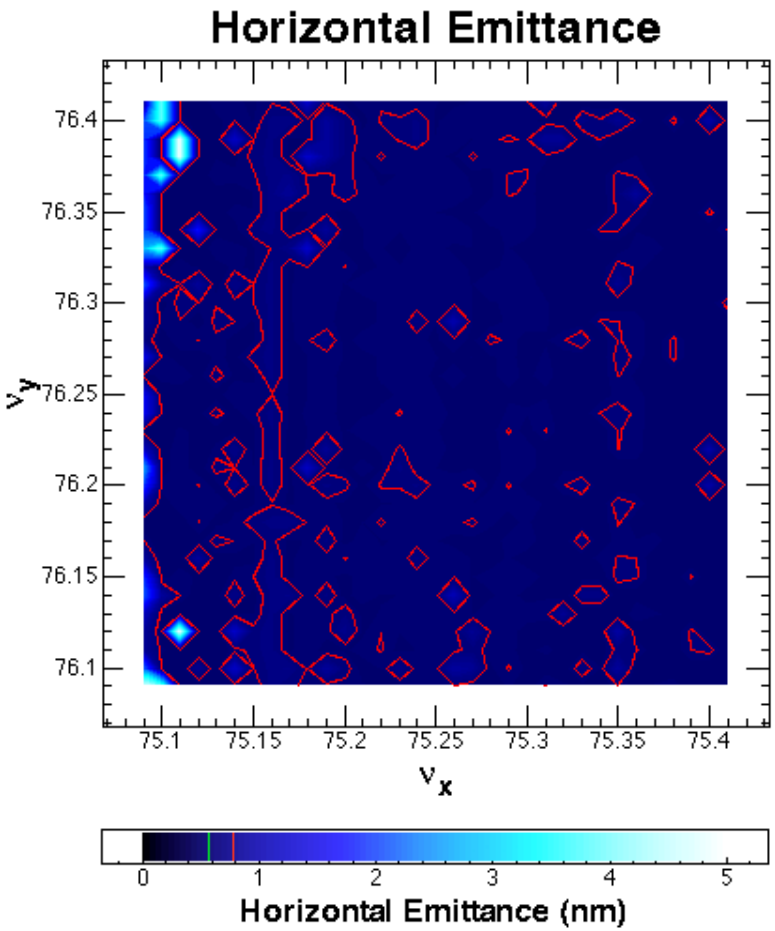
Near the other resonance

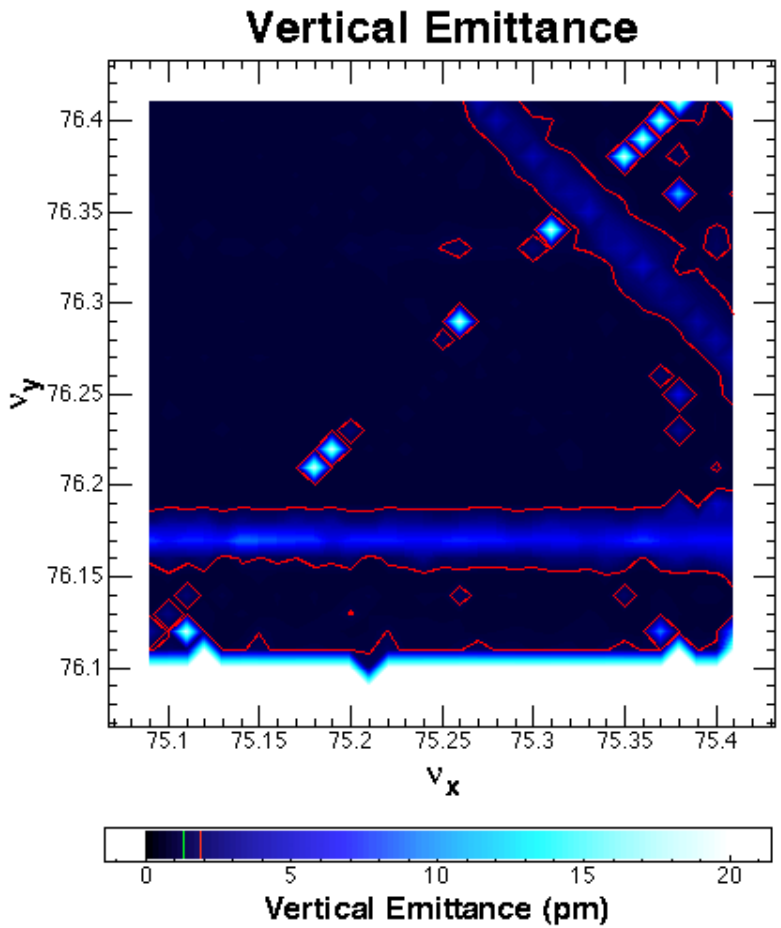
x y





MCH (16 km + round coupling bump)

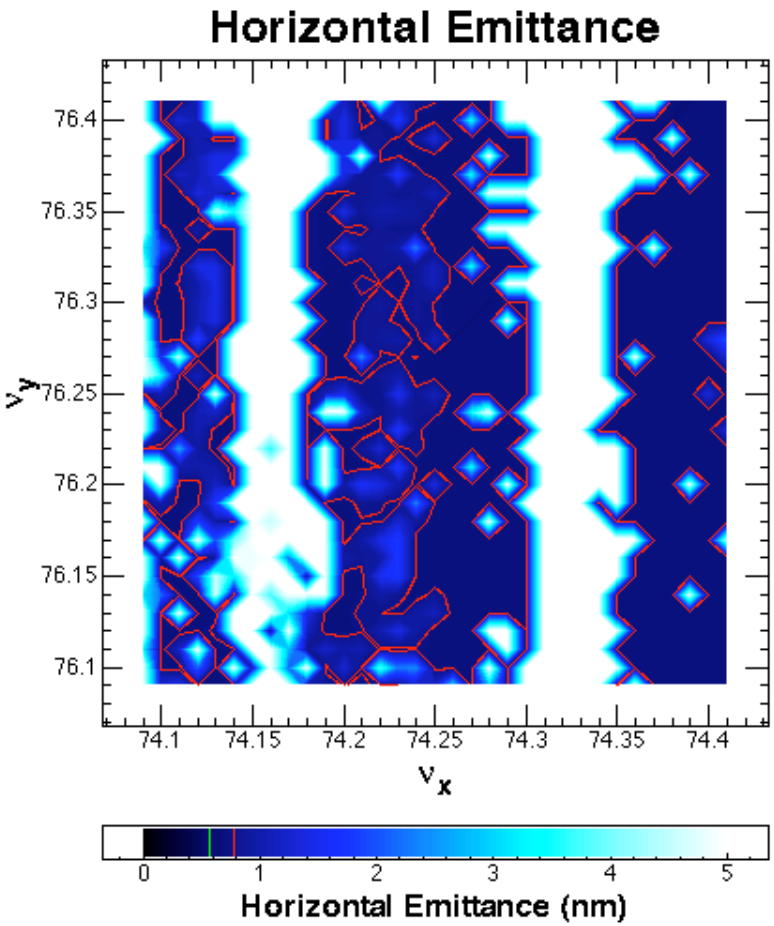


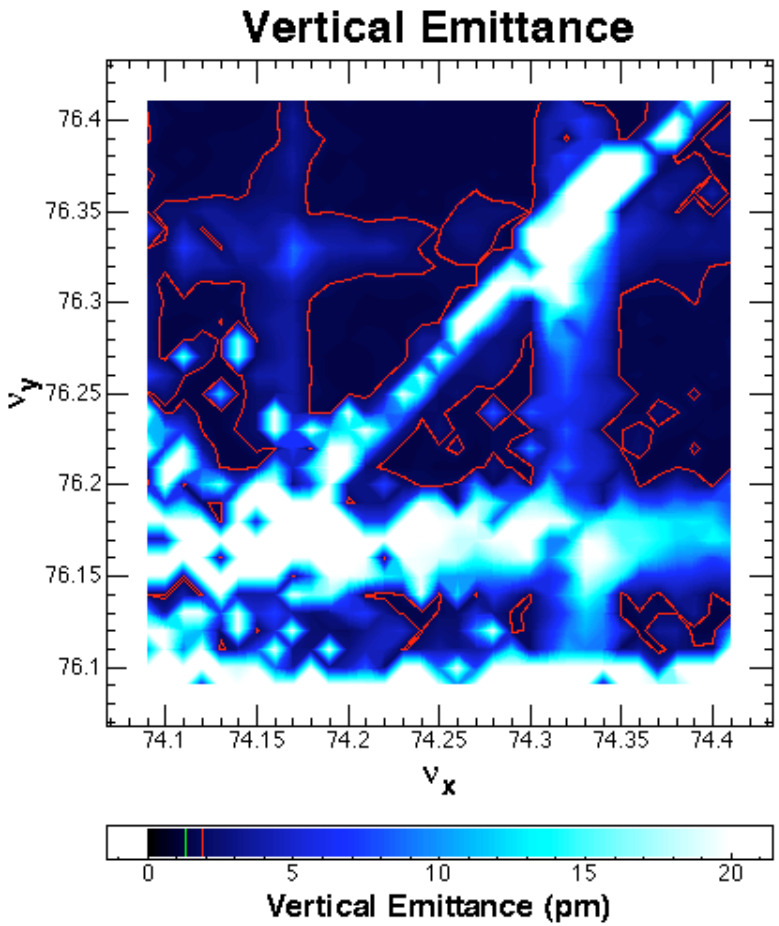


MCH (16 km + round coupling bump)

Near the structure resonance

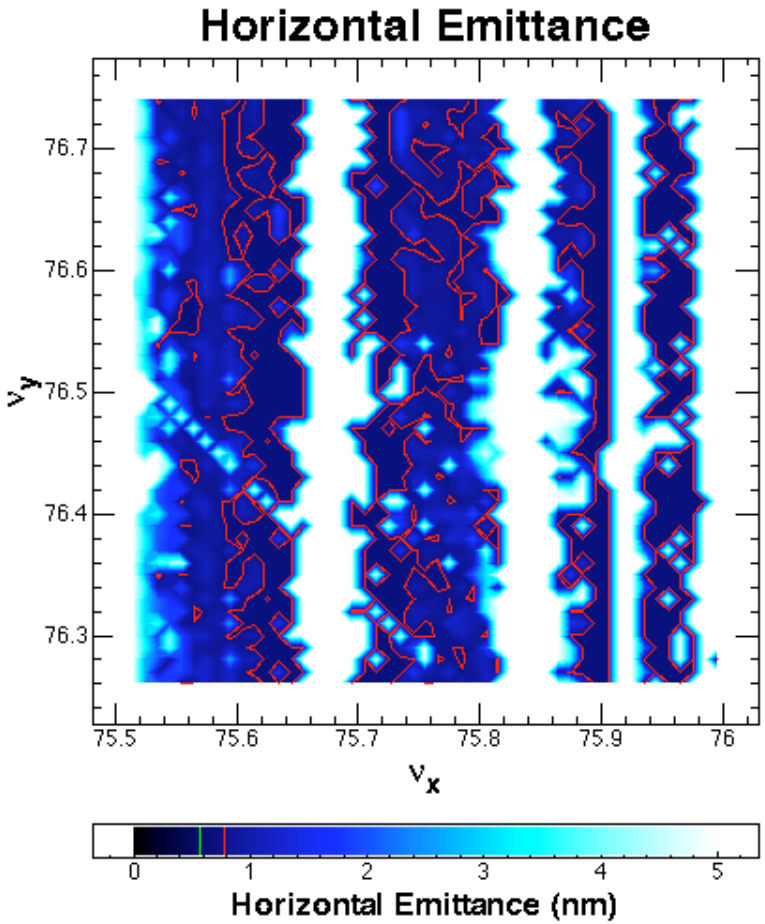
$\nu_x \approx \quad \nu_y \approx$

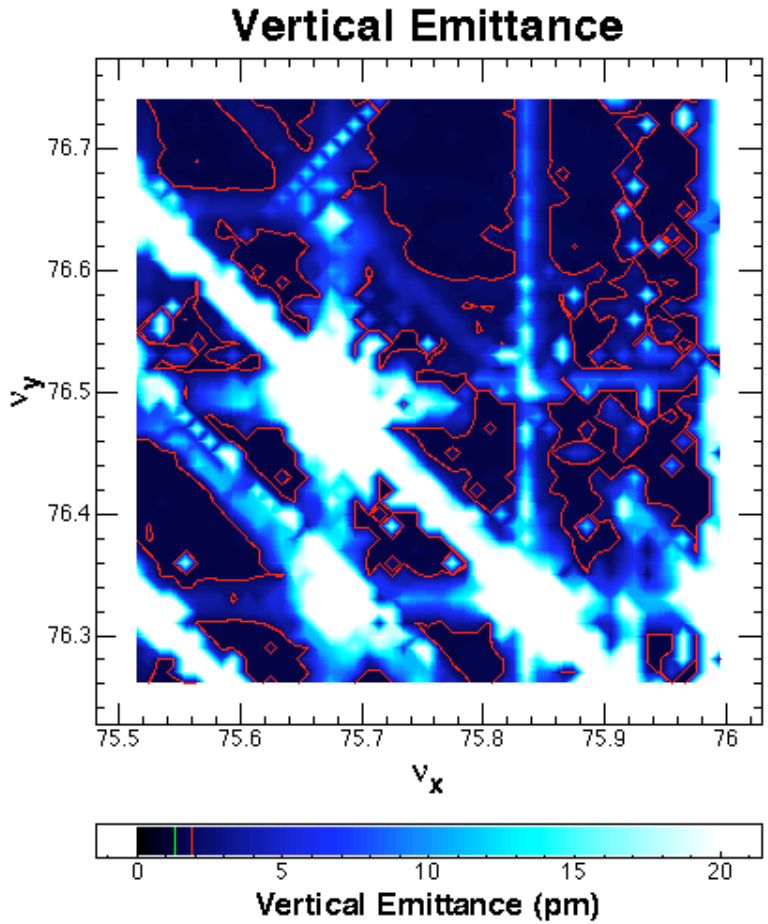




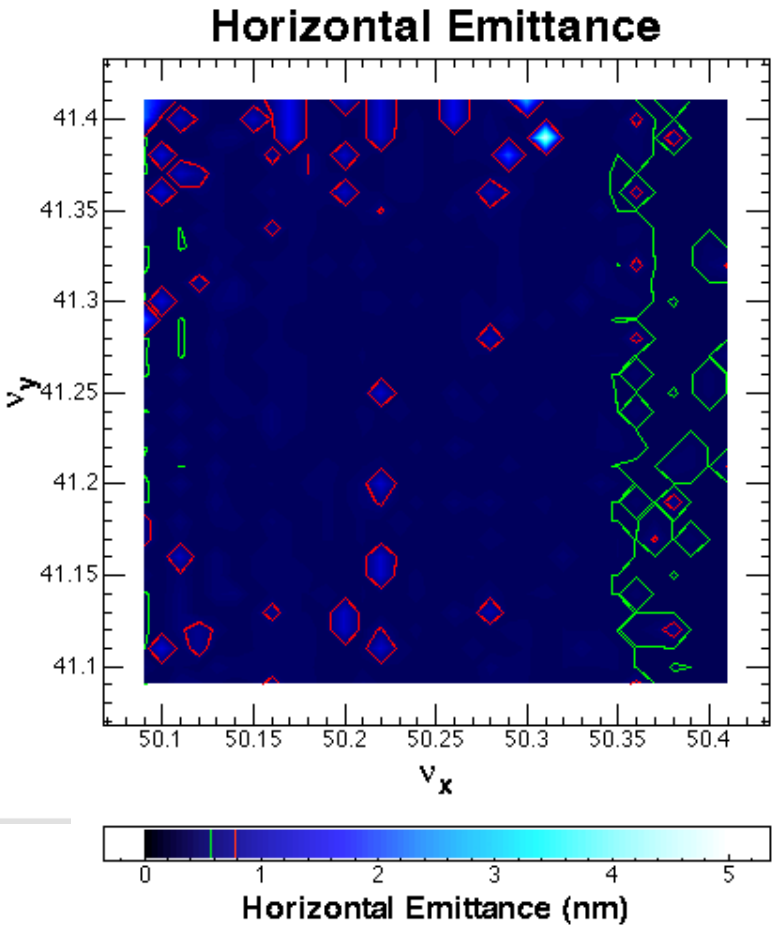
MCH (16 km + round coupling bump)

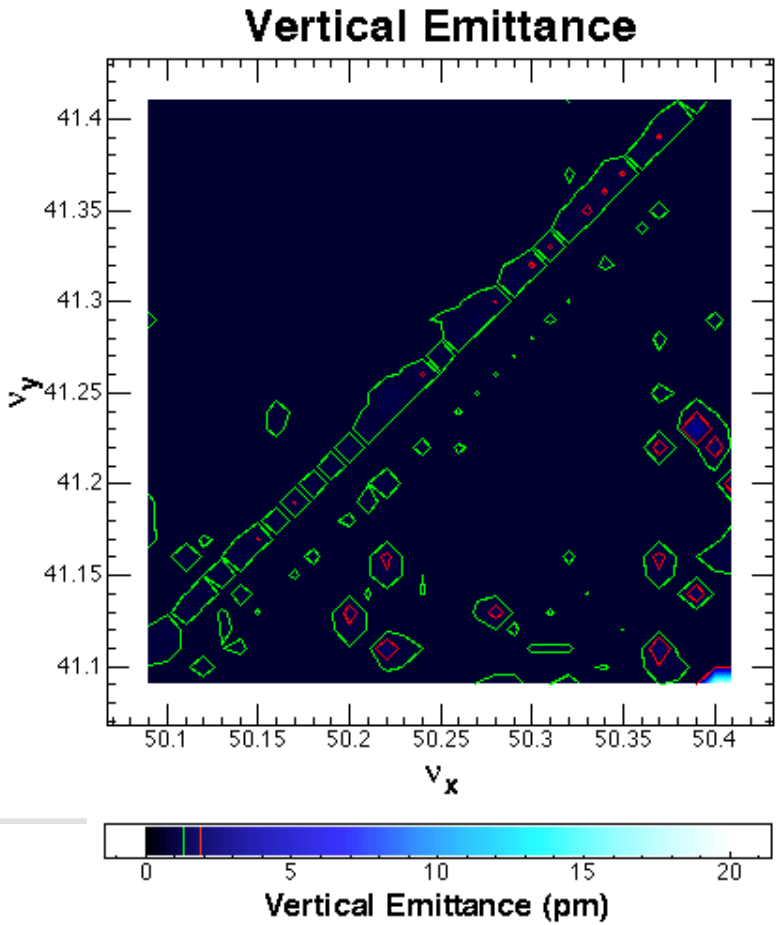
Another tune space



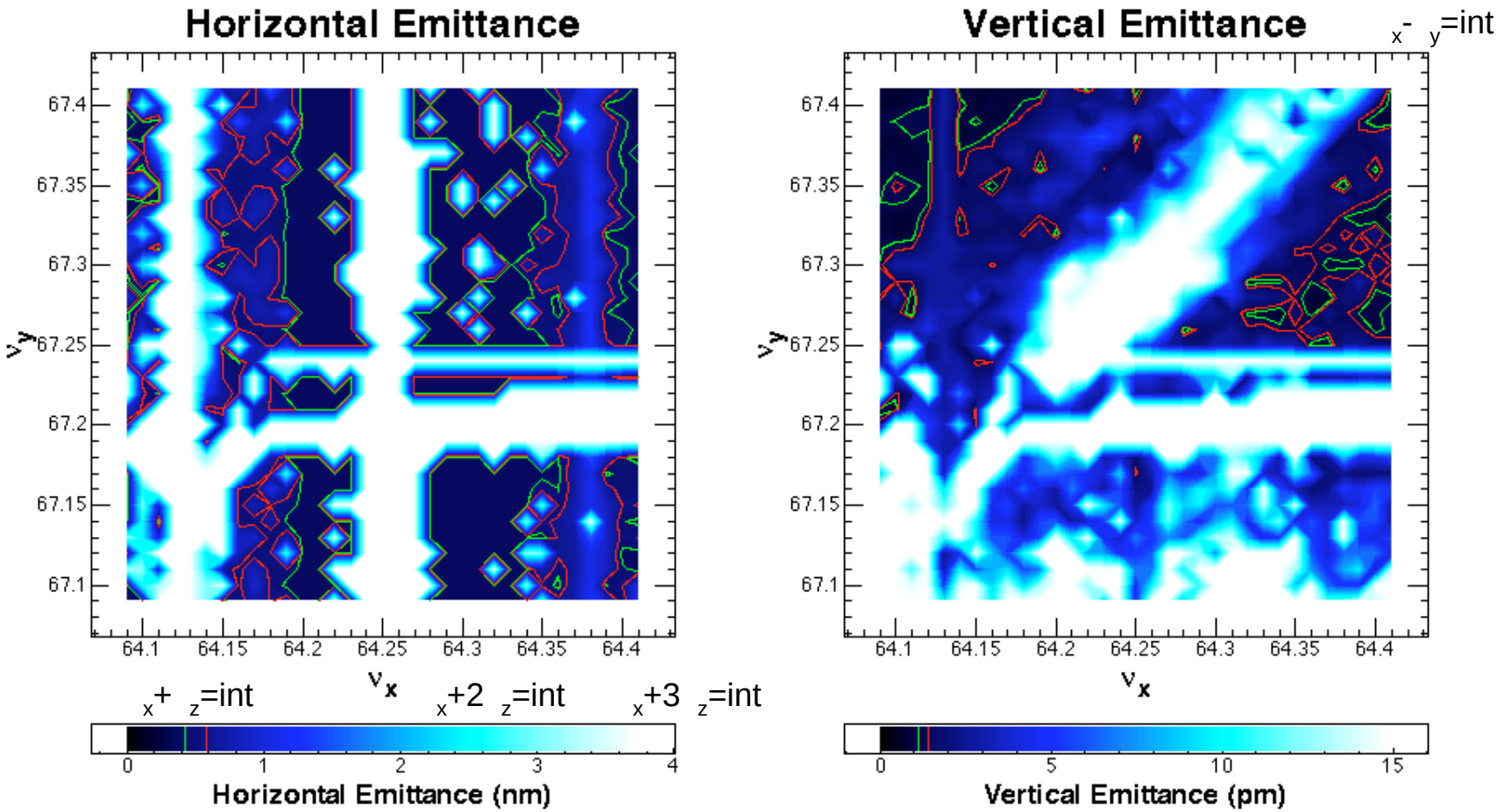


OCS (6.1 km)

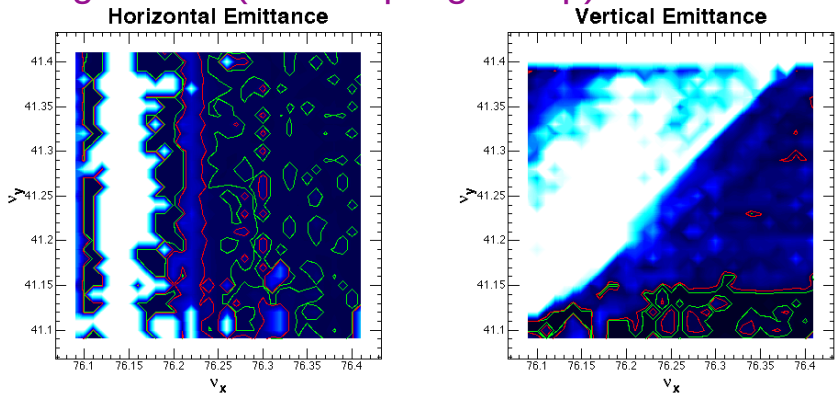

Horizontal Emittance
41.4
41.35
41.3
41.25
41.2
41.15
41.1
ν_y
50.1
50.15
50.2
50.25
50.3
50.35
50.4
ν_x
0
1
2
3
4
5
Horizontal Emittance (nm)


Vertical Emittance
41.4
41.35
41.3
41.25
41.2
41.15
41.1
ν_y
50.1
50.15
50.2
50.25
50.3
50.35
50.4
ν_x
0
5
10
15
20
Vertical Emittance (pm)

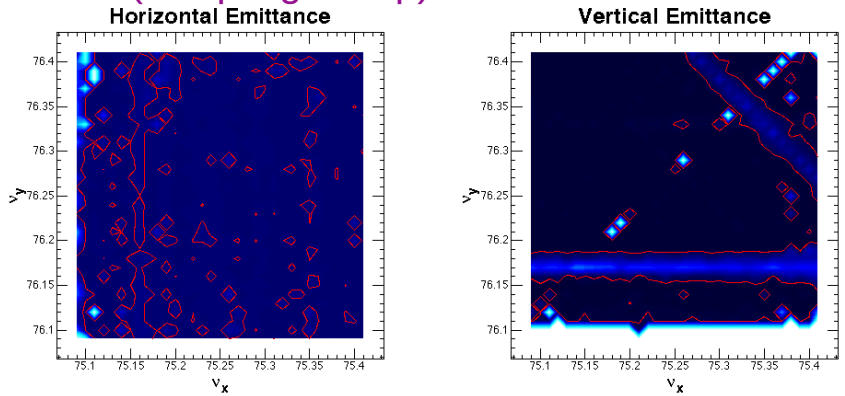
BRU (6.4 km, 3.74 GeV



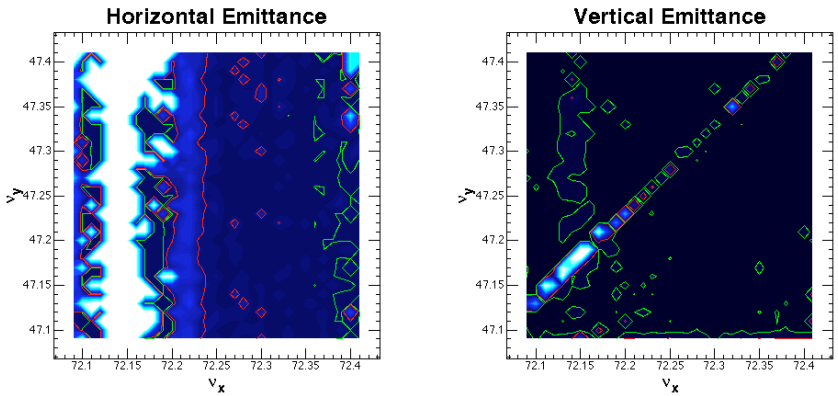
Dogbone-S (No Coupling Bump)



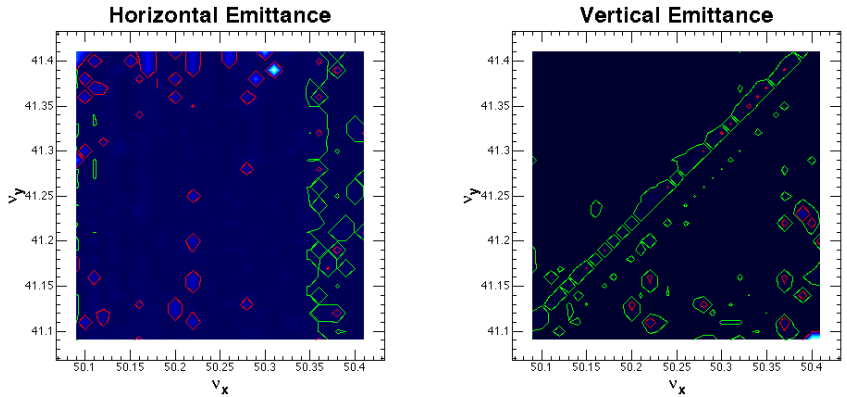
MCH (Coupling Bump)



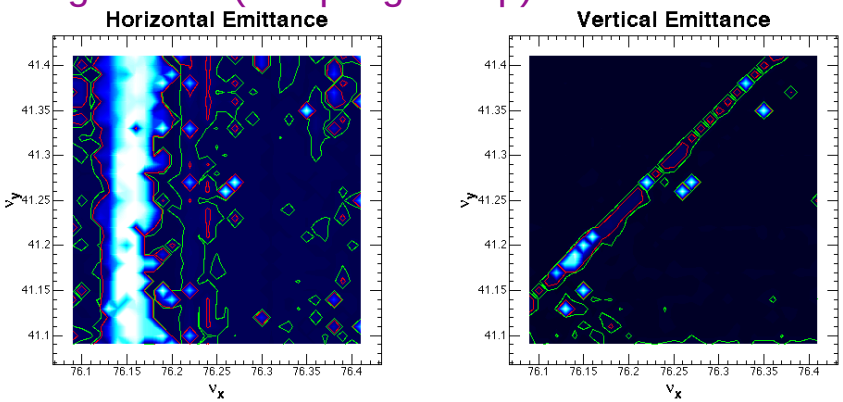
Dogbone-S (Coupling Bump)



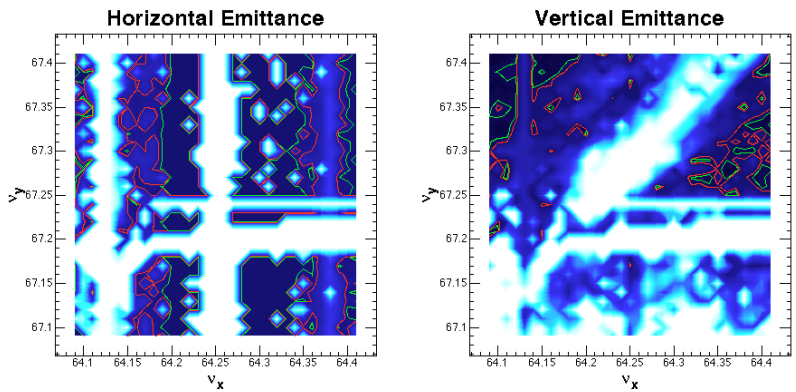
OCS (6.1 km)



Dogbone-C (Coupling Bump)



BRU (6.4 km, 3.74 GeV)



Summary

- Dogbones (17 km) and MCH (16 km) look safe for the space charge with the “round” coupling bump.
- OCS (6.1 km) is the safest.
- BRU at 3.74 GeV, the tune space with safe emittance growth is very small. Dogbone without the coupling bump too.
- The structure resonances should be avoided.
  - C or S-shape of Dogbone is not critical for space charge if good working point can be chosen, respectively.
- The detail of the lattices, such as the way how to change the tunes, may affect the strengths of the resonances.
- Need more study with lattice errors, etc.