APEX experiment on IBS with decoupling.

January 9, 2008

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Purpose of the experiment

To understand what portion of vertical emittance growth comes from x-y coupling.

Quantitative understanding of emittance growth in horizontal and vertical planes should help us to conclude whether single-plane transverse stochastic cooling will be sufficient to counteract both horizontal and vertical emittance growth.

Physics

1. For energies much higher than transition energy Intra-beam Coulomb scattering (IBS) is dominated by heating of longitudinal degree of freedom.

$$\tau_{\parallel}^{-1} = \frac{r_i^2 c N_i \Lambda}{8\beta^3\gamma^3\epsilon_x^{3/2}\langle\beta_\perp^{1/2}\rangle\sigma_s\sigma_p^2}.$$

2. At regions with non-zero dispersion, changes in longitudinal momentum change particle reference orbits, which additionally excites horizontal betatron motion.

$$\tau_{\perp}^{-1} = \frac{\sigma_p^2}{\epsilon_x}\langle\frac{D_x^2 + (D_x'\beta_x + \alpha_x D_x)^2}{\beta_x}\rangle\tau_{\parallel}^{-1},$$

3. Horizontal heating is shared between horizontal and vertical planes due to x-y coupling. For the case of full coupling, transverse heating is equally shared between x and y,

Experiment

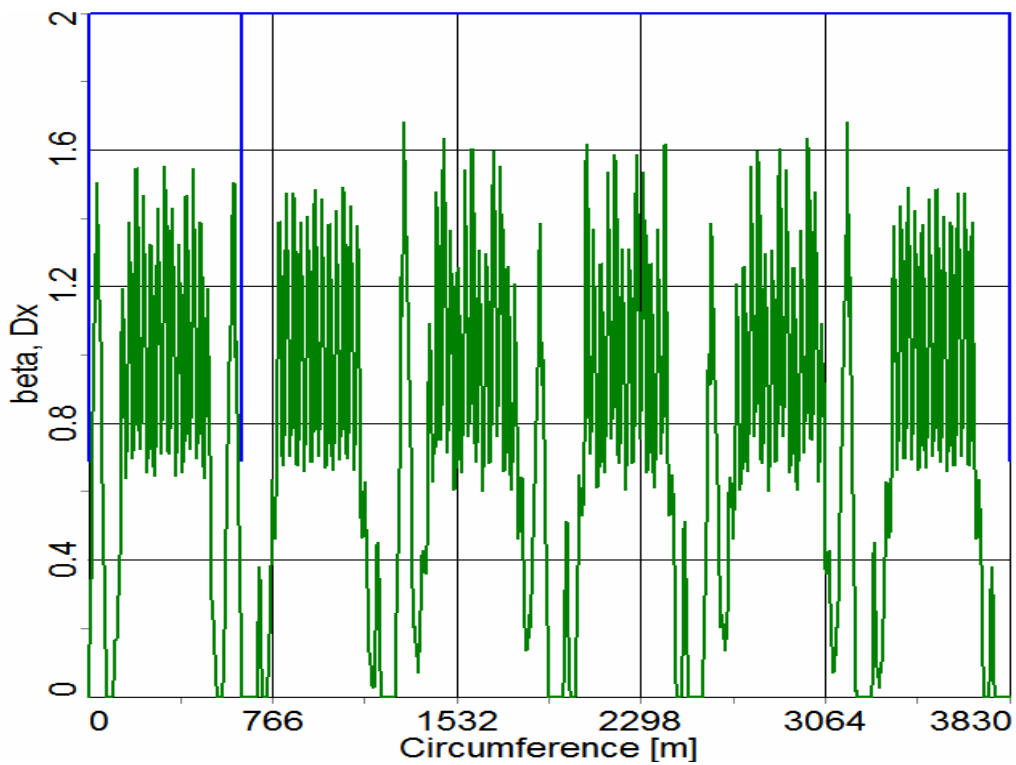
1 Create condition of clean IBS experiment (minimize contribution of all other effects: at store, h=360, RF=300kV, no collisions, no stochastic cooling).

2. Decouple machine. Measure emittance growth due to IBS.

3. For coupled machine – measure emittance growth due to IBS.

Dispersion for dAu82 lattice

RHIC run-8 lattice: "dAu82":



What one would expect – some simulations (BETACOOL) for arbitrary parameters done before the measurements

N=1e9

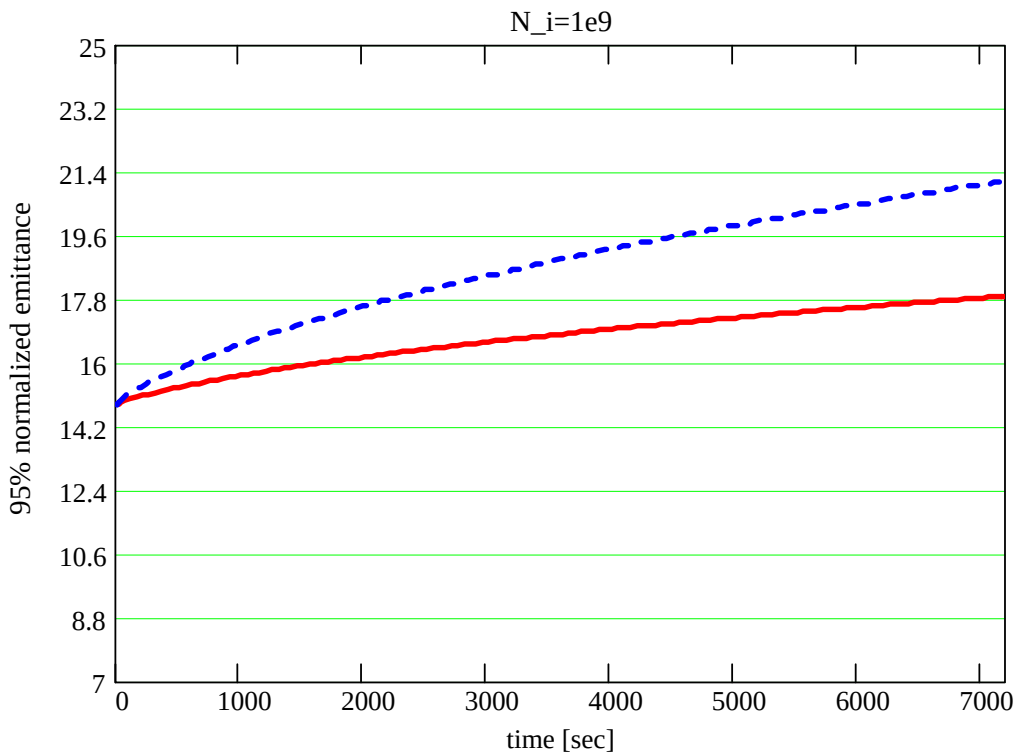
ε_x=15 π mm mrad (95% normalized), rms unnormalized=0.023 μm

ε_y=15 π mm mrad (95% normalized), rms unnormalized=0.023 μm

RF: 300kV, h=360 to avoid loss from the bucket,

rms dp/p=2.3e-4, rms length=61cm.

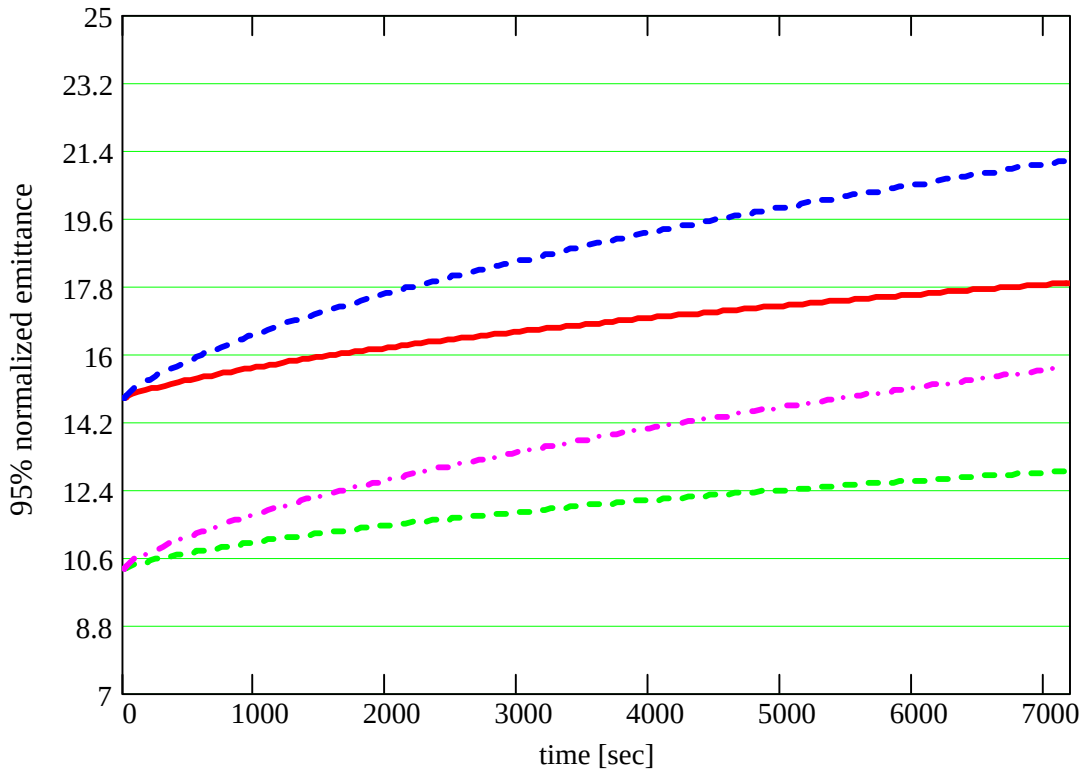
Bunch with N=1e9, initial emittance vertical and horizontal=15 μm (simulations)



red – horizontal and vertical emittance for the case of full coupling is equally shared between x and y (about 1.8 π/h).

blue – horizontal emittance for fully decoupled case (about 3.6 π/h for cosntant intensity without losses); vertical emittance stays constant at 15 μm.

Simulations: Horizontal emittance for case #1 (intensity 5e8, 10 μm initial emittance) and case #2 (intensity 1e9, 15 μm initial)



N=1e9, 15 μm:
red – coupled
blue – decoupled

N=5e8, 10 μm:
green - coupled
pink - decoupled

January 9, 2008 measurements

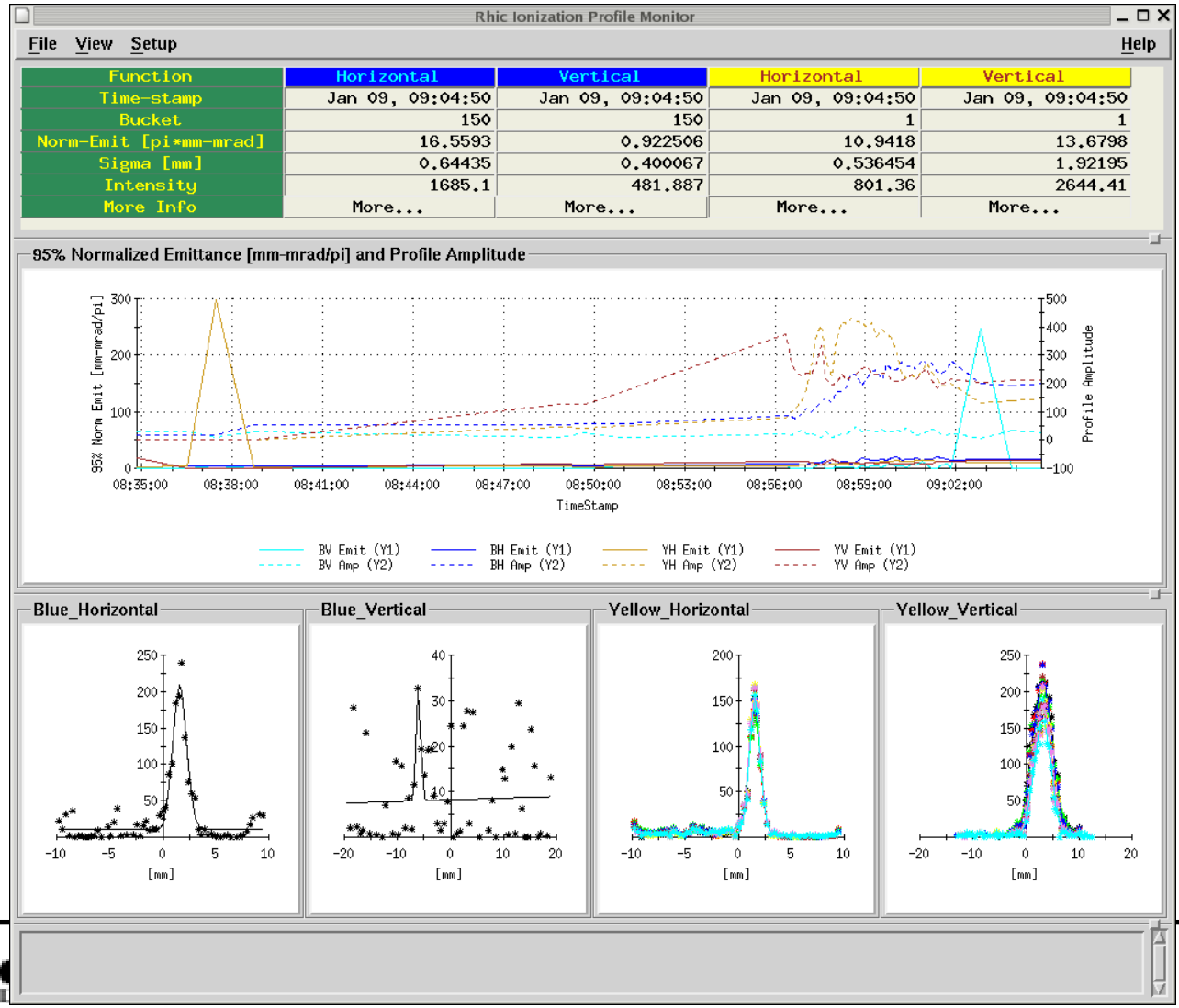
Requested overall time 3.5 hours min.

We got exactly 3.5 hours of useful beam time and were able to make measurements both with decoupling and coupling.

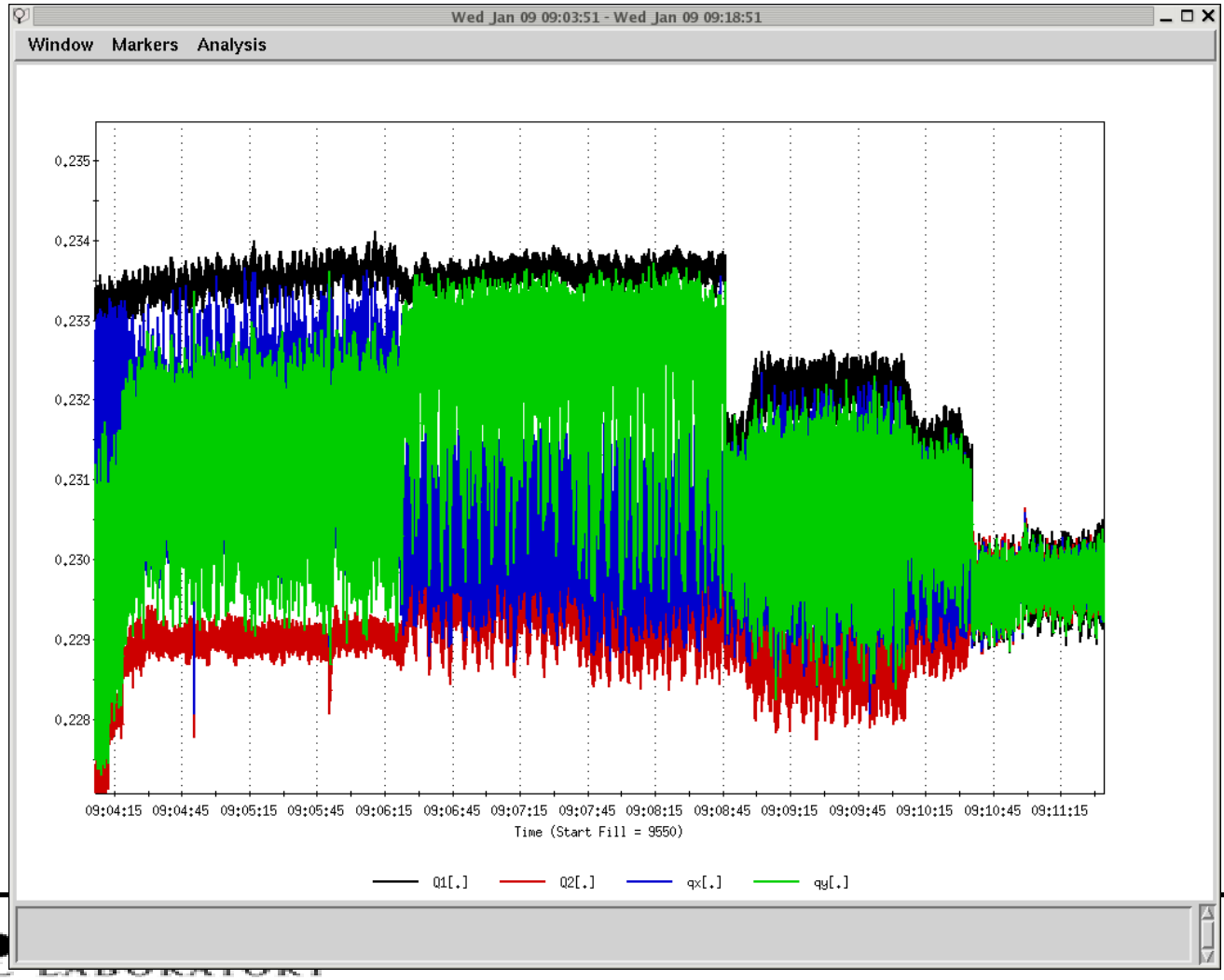
1. Decoupled case: dQmin=0.001, tunes were separated by 0.018

2. Coupled case: dQmin=0.018, tunes were separated by 0.018

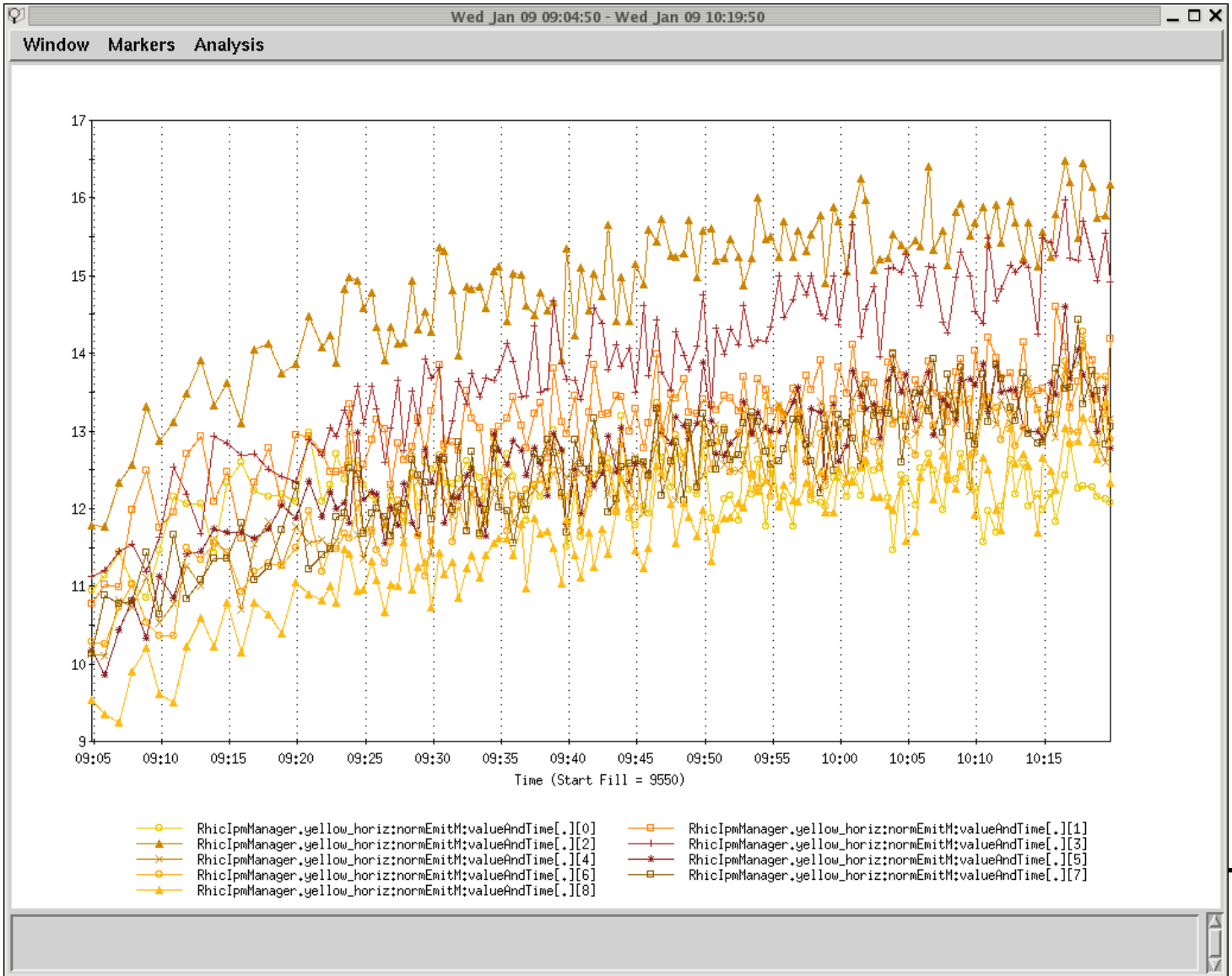
IPM – recorded 9 bunches



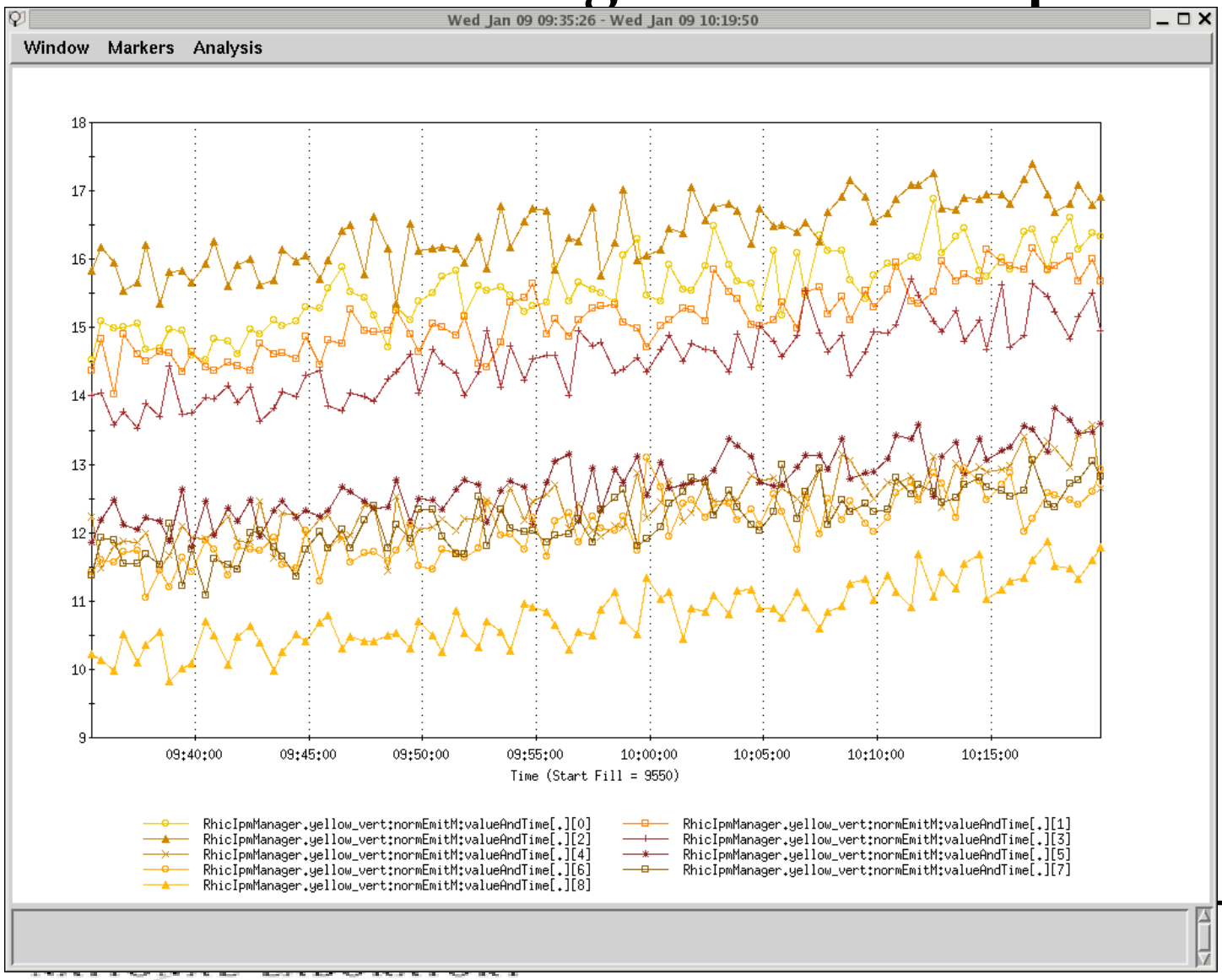
BBQ – was used to decouple machine



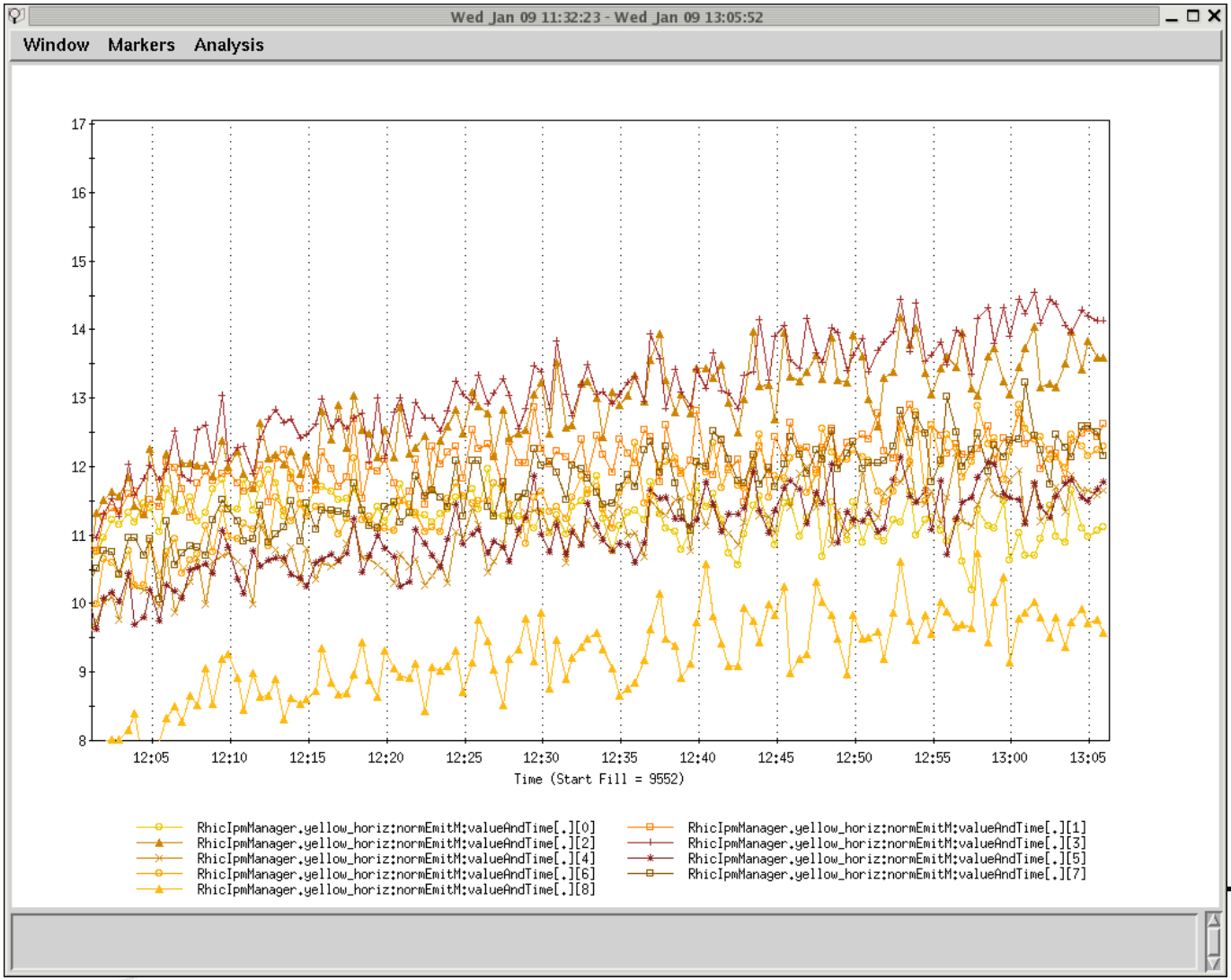
Horizontal emittance growth – decoupled case



Vertical emittance growth – decoupled case

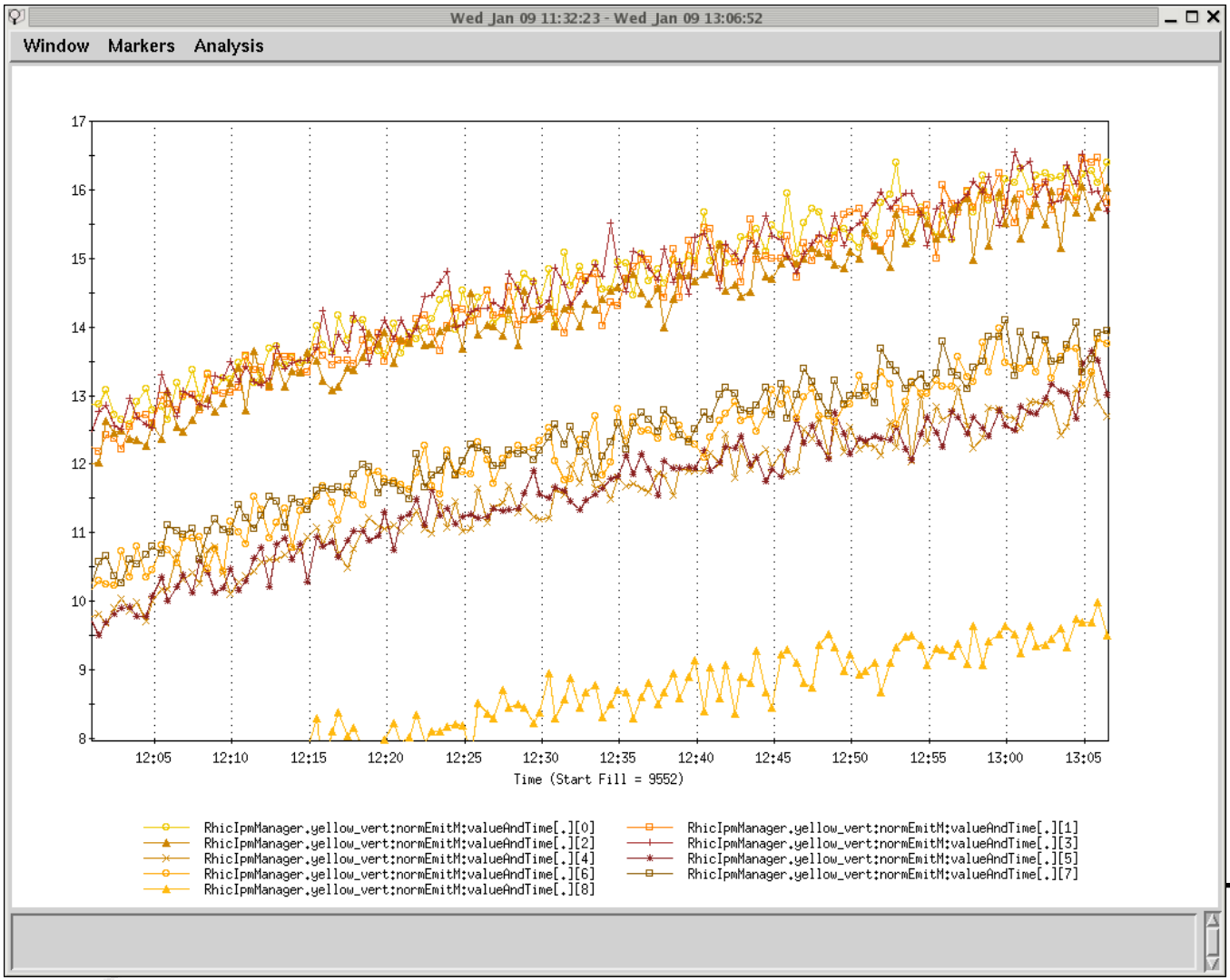


Horizontal emittance growth – coupled case



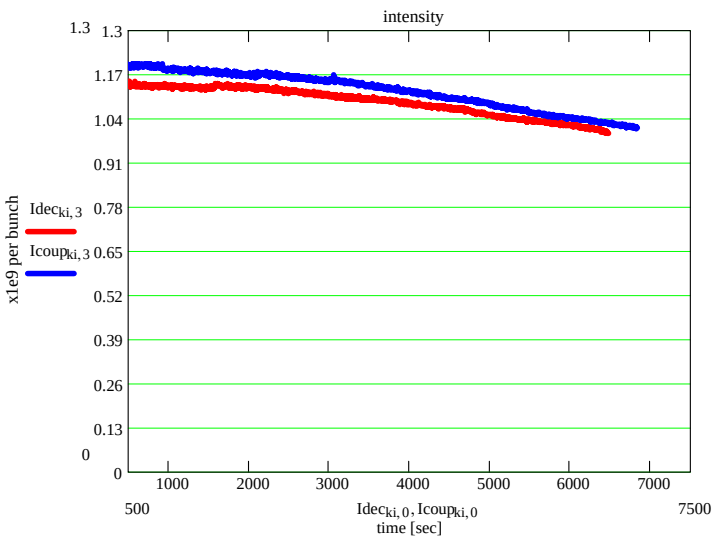
Horizontal growth rate decreased compared to decoupled case.

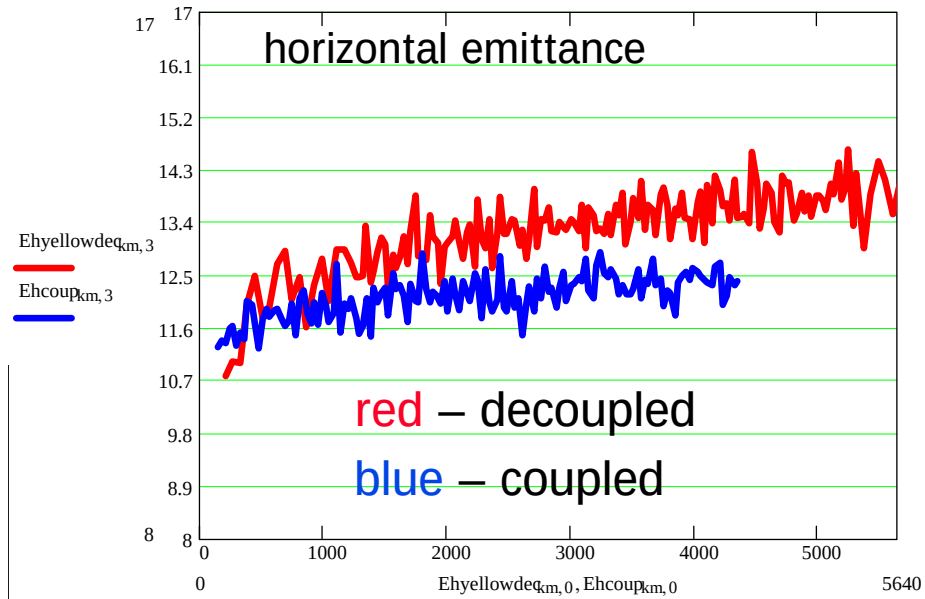
Vertical emittance growth – coupled case

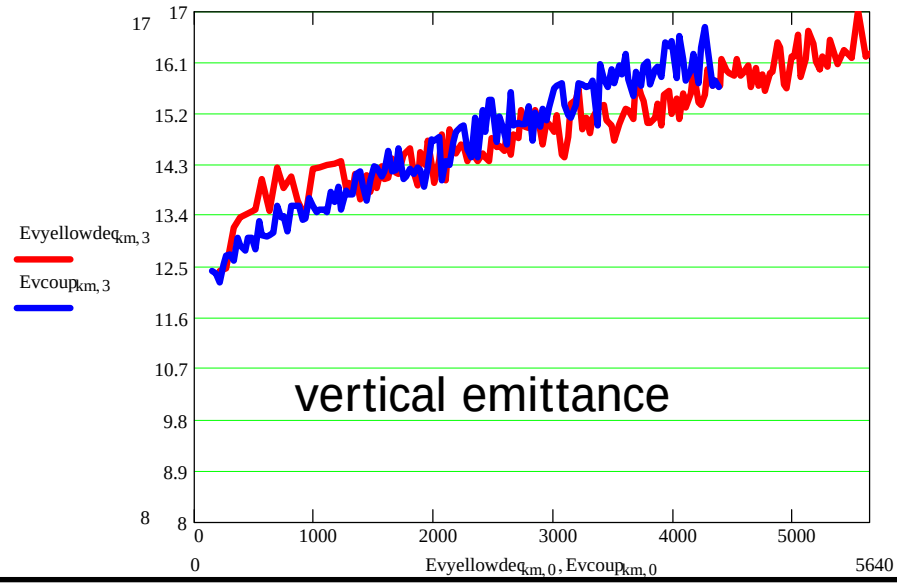


Vertical growth rate increased compared to decoupled case.

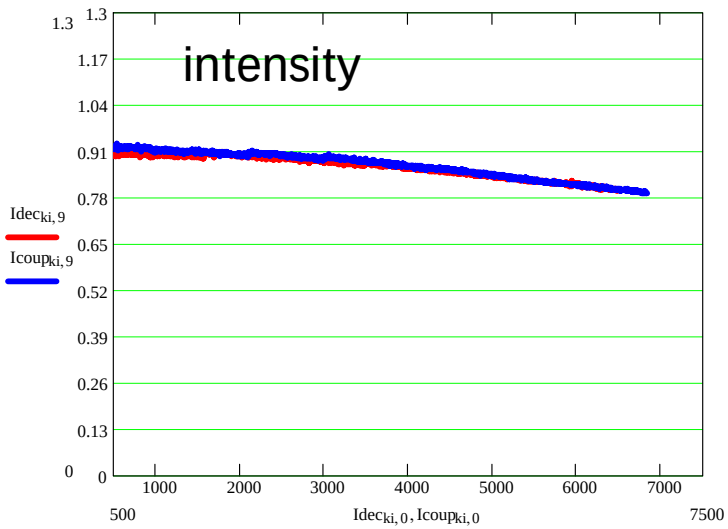
Some examples:
Bunch #2:

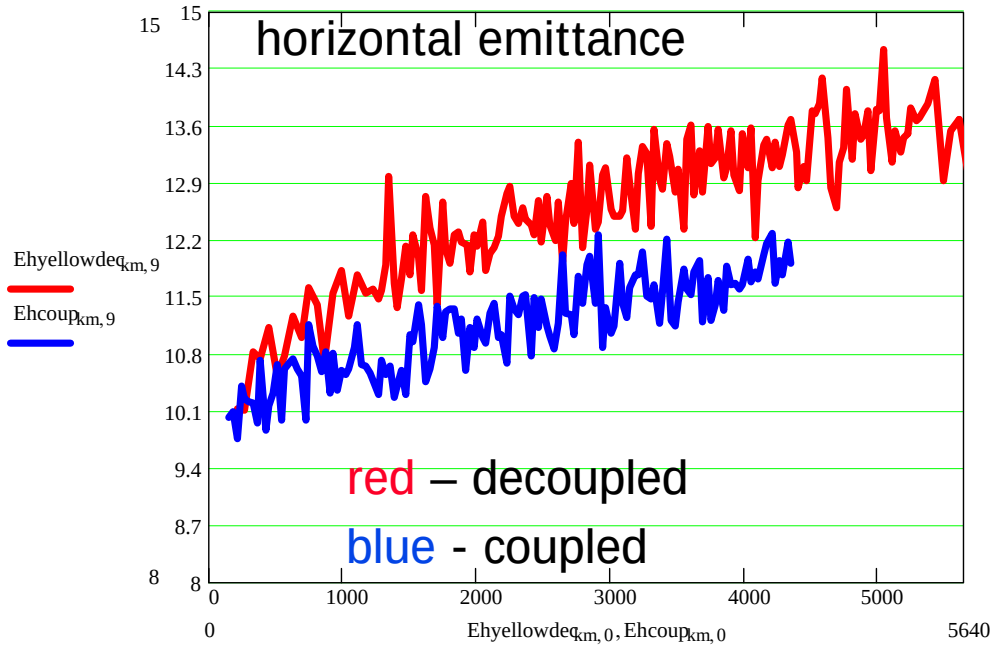


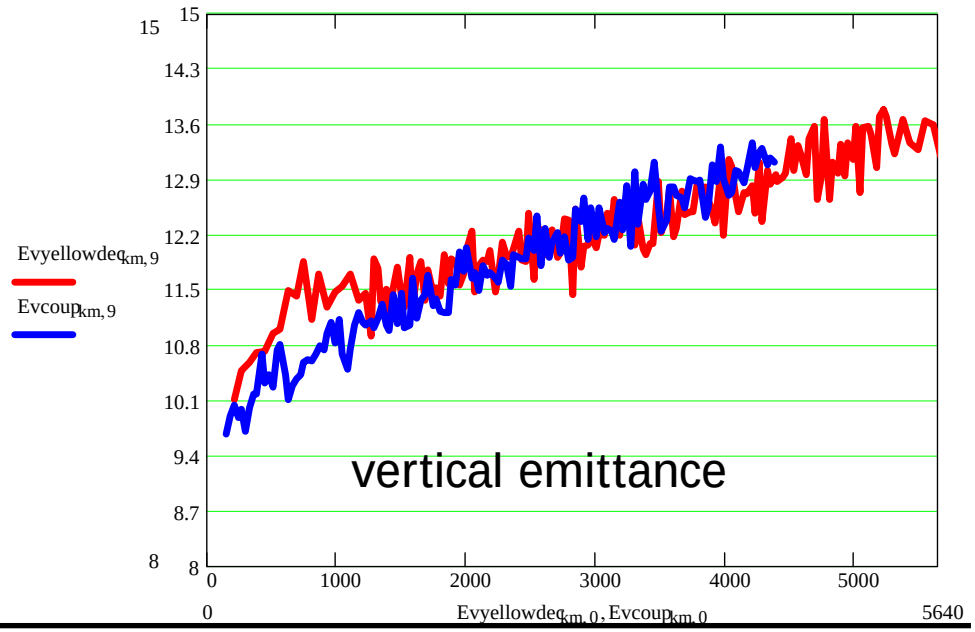




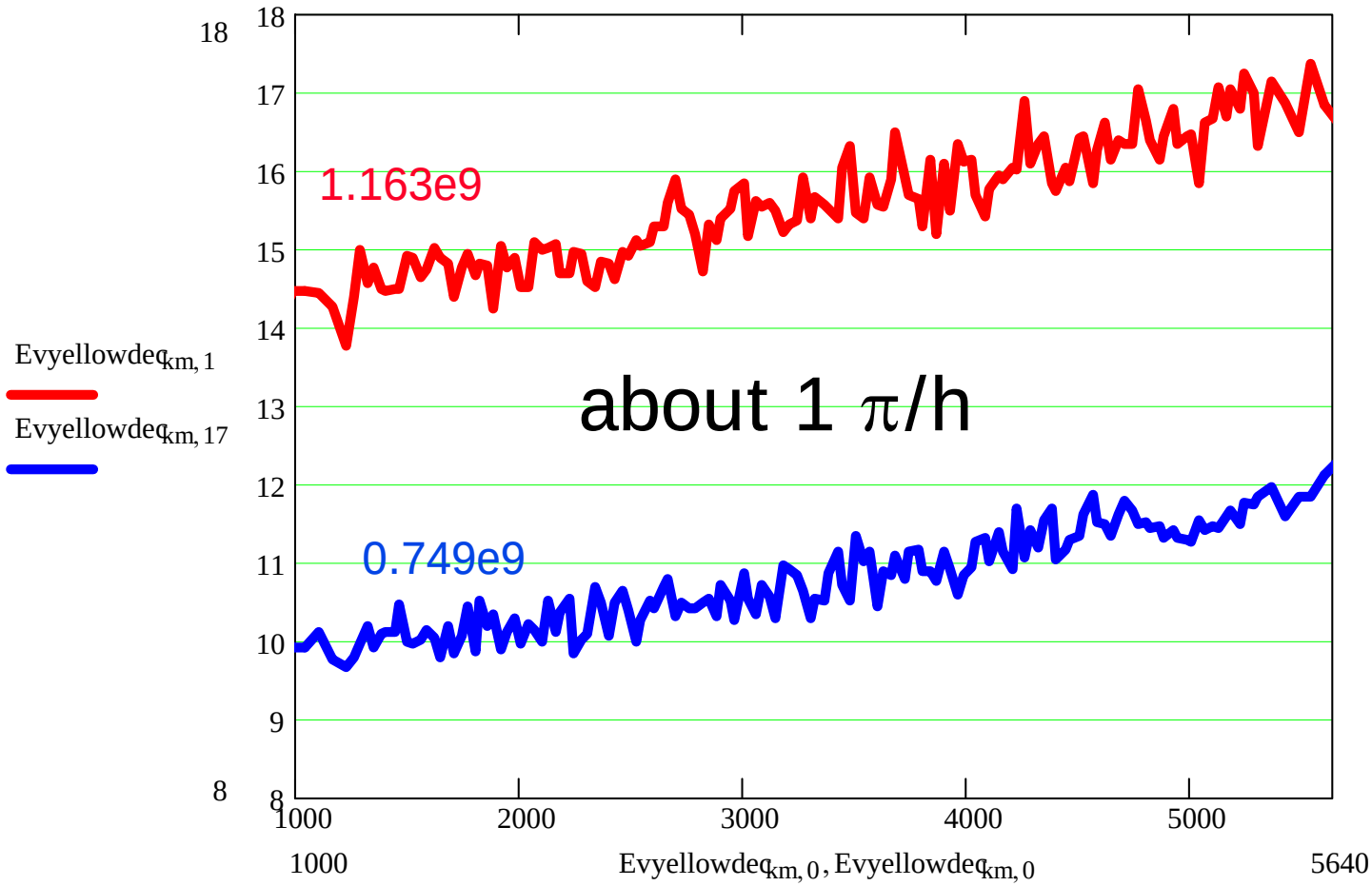
Bunch #5:


intensity
1.3
1.17
1.04
0.91
0.78
0.65
0.52
0.39
0.26
0.13
0
Idec_ki,9
Icoup_ki,9
1000
2000
3000
4000
5000
6000
7000
500
7500
Idec_ki,0 , Icoup_ki,0

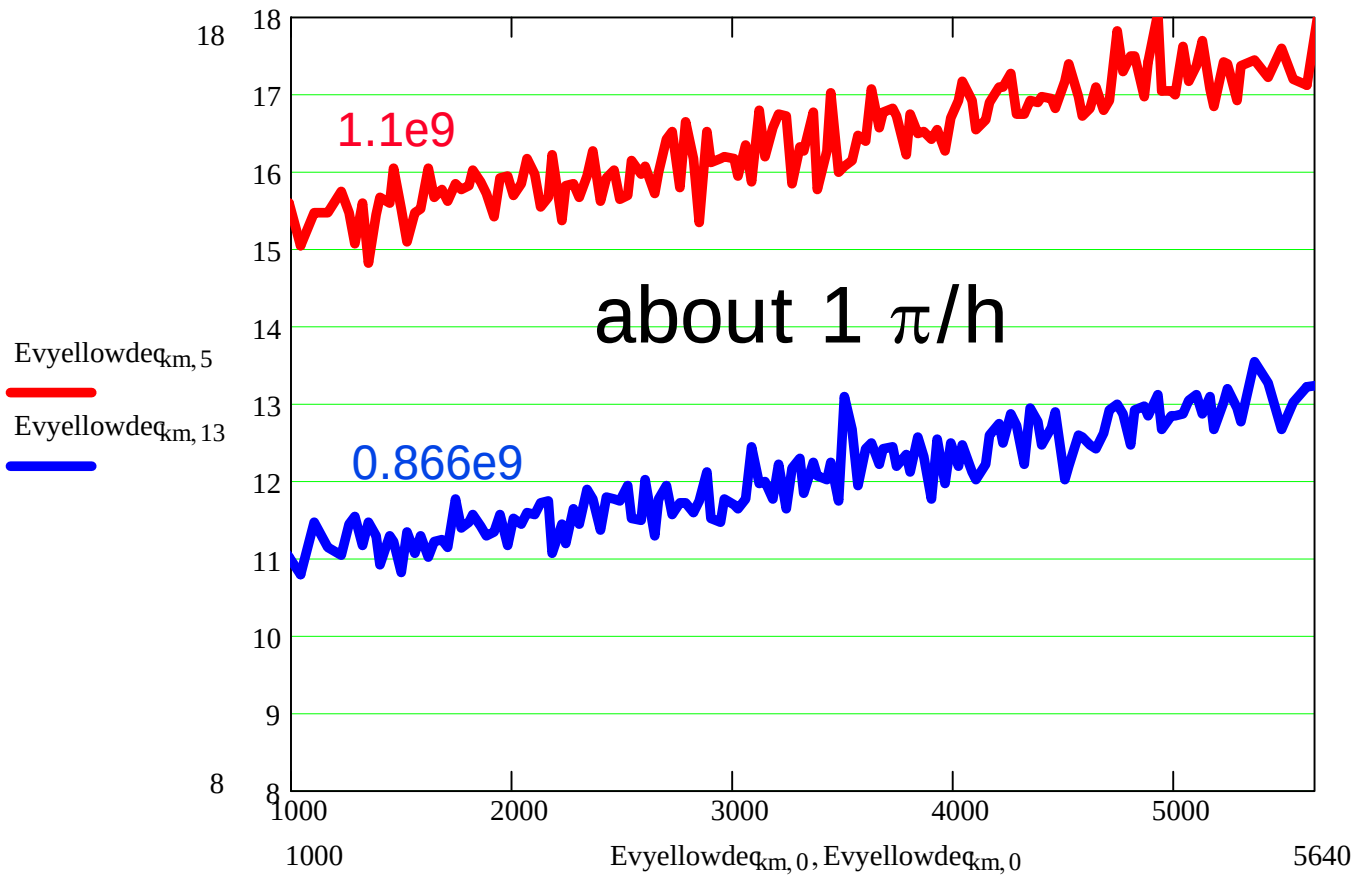

horizontal emittance
15
14.3
13.6
12.9
12.2
11.5
10.8
10.1
9.4
8.7
8
Ehyellowdeq_km,9
Ehcoup_km,9
red – decoupled
blue - coupled
0
1000
2000
3000
4000
5000
5640
Ehyellowdeq_km,0 , Ehcoup_km,0


15
14.3
13.6
12.9
12.2
11.5
10.8
10.1
9.4
8.7
8
Evyellowdeq_km,9
Evcoup_km,9
vertical emittance
0
1000
2000
3000
4000
5000
5640
Evyellowdeq_km,0 , Evcoup_km,0

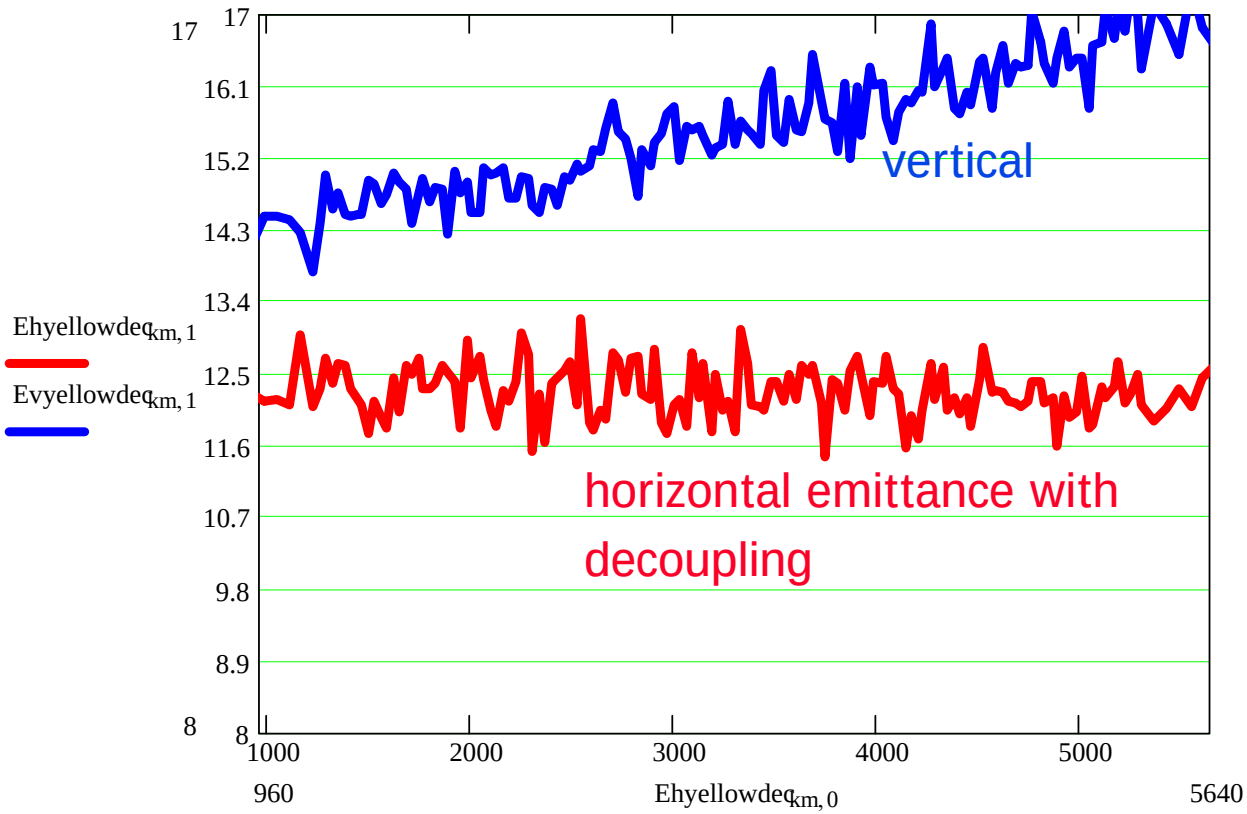
Vertical emittance growth in decoupled case



Vertical emittance growth in decoupled case



There were "odd" measurements as well. Example: bunch #1



Summary

1. We got data.
2. Going from decoupled to coupled case horizontal emittance growth should be shared between x and y. It seems that in measurements horizontal growth rate is decreased, vertical growth rate is increased. However, no conclusions yet - quantitative analysis will be performed.
3. For decoupled case: Instead of zero vertical emittance growth linear emittance growth of about 1 π/h was measured. Although decoupling was done only in a global sense.
4. Quantitative analysis and simulations will be performed.