Interplay of space-charge and beam-beam effects

APEX

April 29, 2011

Previous APEX studies in RHIC: $\Delta Q_{sc} > \xi$

- **Accelerator Physics Experiments (APEX) May and June 2009:**

p+p: at beam γ=25 (modest space-charge, large beam-beam)

- **APEX March 2010:**

Au+Au ions: γ=10.5 (modest space-charge, small beam-beam)

- **Several APEX and Low-Energy RHIC run May - June 2010:**

Au+Au ions: γ=6.1 and γ=4.1 (large space-charge, small beam-beam)

Results published in HB2010 proceedings.
Also in PAC11.

BROOKHAVEN
NATIONAL LABORATORY

RHIC

Previous APEX studies (2009-10) were motivated by Low-Energy RHIC regime of interest:

$$\Delta Q_{sc,G} = -\frac{N_b Z^2 r_p}{4\pi A \beta \gamma^2 \varepsilon_{n,rms}} \frac{C}{(2\pi)^{1/2} \sigma_z}$$

$$\Delta Q_{bb,G} = \xi = -\frac{N_b Z^2 r_p}{4\pi A \varepsilon_{n,rms}} \frac{(1+\beta^2)}{2\beta}$$

$$\frac{\Delta Q_{sc,G}}{\Delta Q_{bb,G}} = -\frac{1}{\gamma^2} \frac{C}{(2\pi)^{1/2} \sigma_z}$$

Example:

Low-E RHIC lowest energy point Au ions $\gamma=2.7$ (sqrt[s]=5 GeV/n)

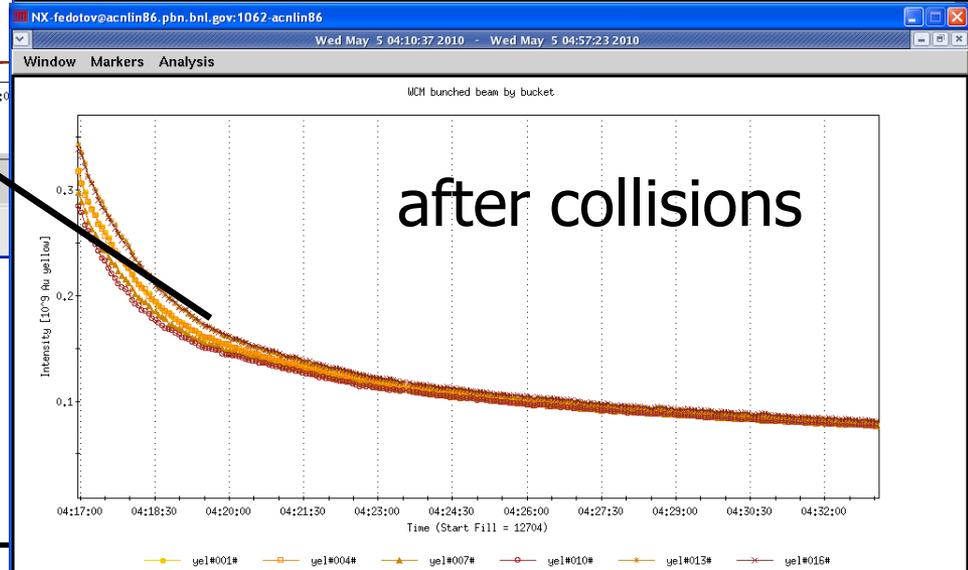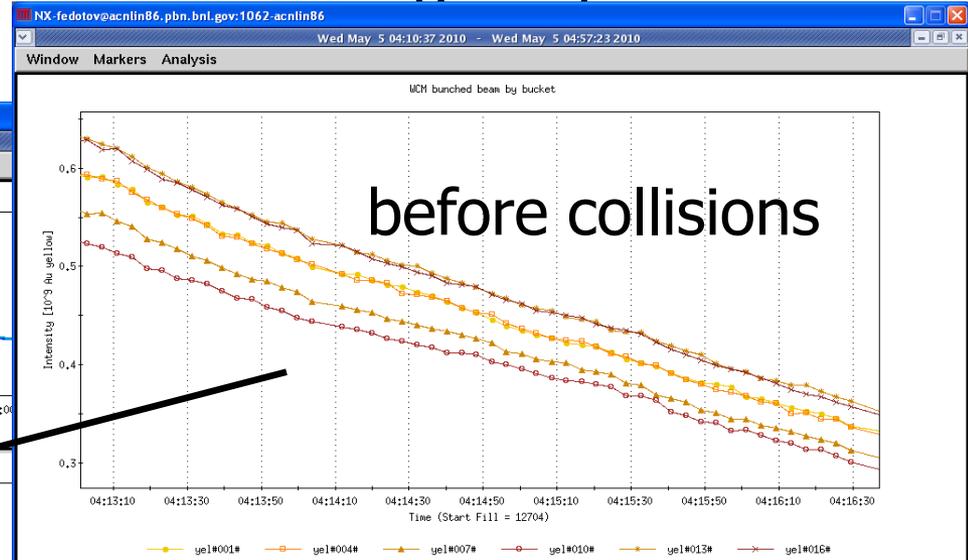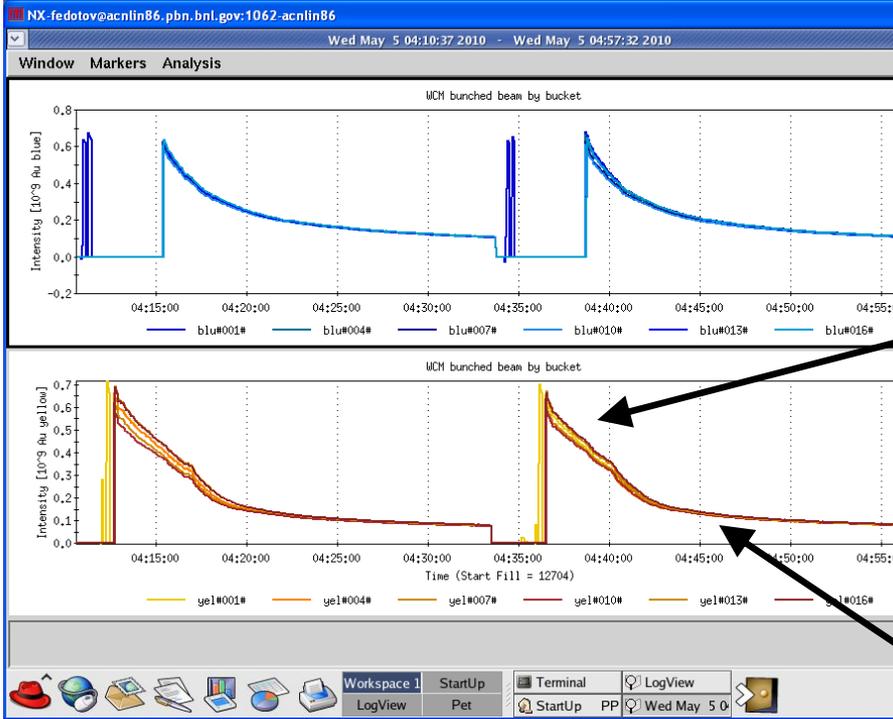when limited by space charge $\Delta Q_{sc}=0.05$
beam-beam tune shift is very small $\Delta Q_{bb}=0.00057$

$\Delta Q_{sc}/\Delta Q_{bb}=88$

For Low-E RHIC we are interested in the regime:

$\Delta Q_{sc} >> \xi$

BROOKHAVEN
NATIONAL LABORATORY

RHIC

Example of beam-beam effect on lifetime (γ=4.1)

We observed effect of beam-beam on lifetime for any space-charge tune spread (when $\Delta Q_{sc} > \xi$), even in the regime with very small ξ.

For Low-Energy RHIC:

It is hard to find working point where effect of beam-beam is minimized due to large ($\Delta Q_{sc} \sim 0.1$) tune spread.

Experimental studies in RHIC with protons:

-Mostly relevant for eRHIC parameters/luminosity

-Could help regular pp RHIC operation

First relevant studies were already done in 2009:

- **Accelerator Physics Experiments (APEX) May and June 2009:**

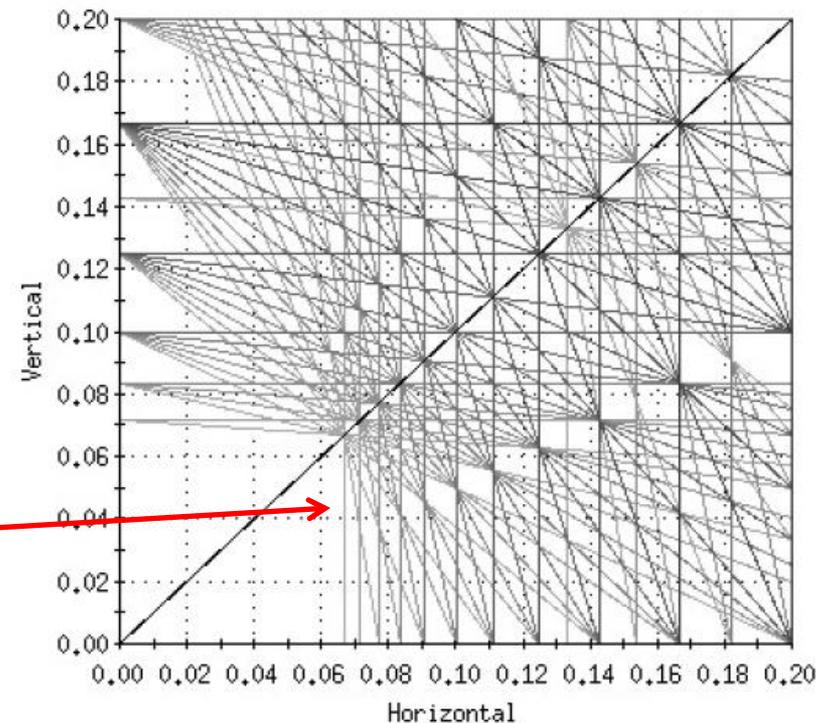**p+p: at beam γ=25 (modest space-charge, large beam-beam)**

$$\Delta Q_{sc} > \xi$$

Protons at standard injection energy (γ=25):

Finding working point where effects of beam-beam are minimized for regime ΔQ_{sc}=0.03, ξ=0.01-0.02 (this is regime of interest for eRHIC).

resonances to 15th order

For small ΔQ_{sc} (~0.03), eRHIC:

We should be able to find better working point.

• We want to start with injecting protons

for w.p. (Qx,Qy)=(0.09,0.07)

• Explore effect of beam-beam for different

bunch intensities and different working points

Did not get beam time during pp Run-11.

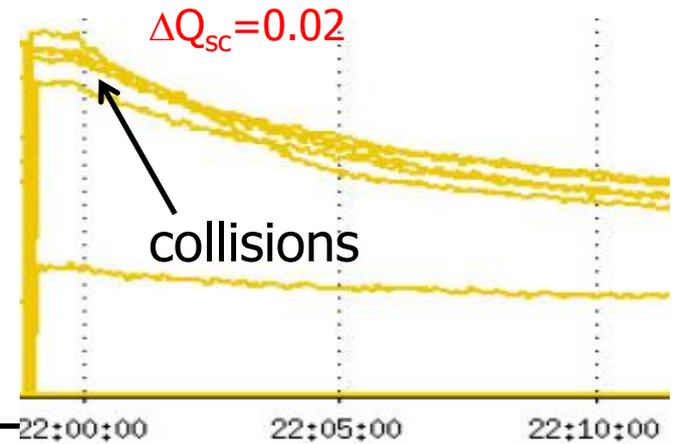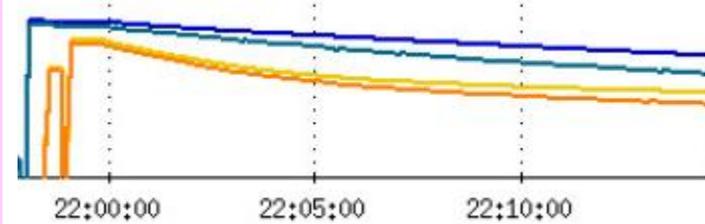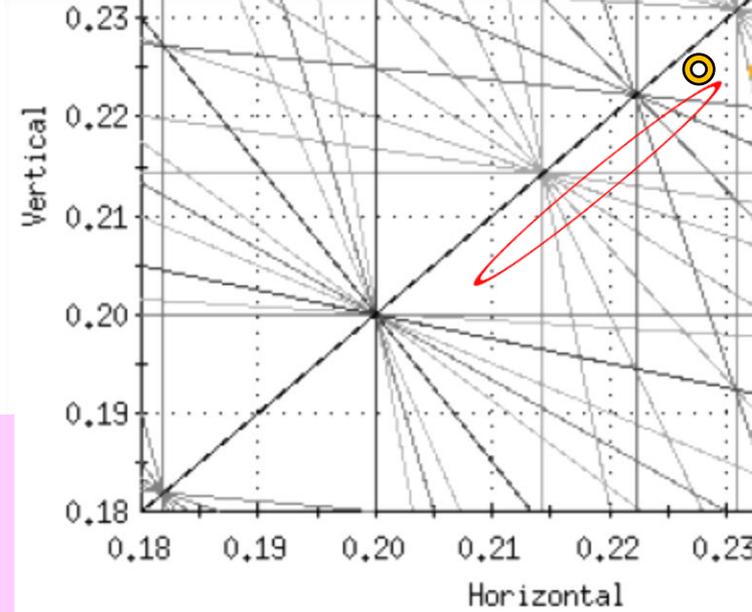Experiment can be done with Au ions BUT in a more relaxed regime "weak beam-beam".
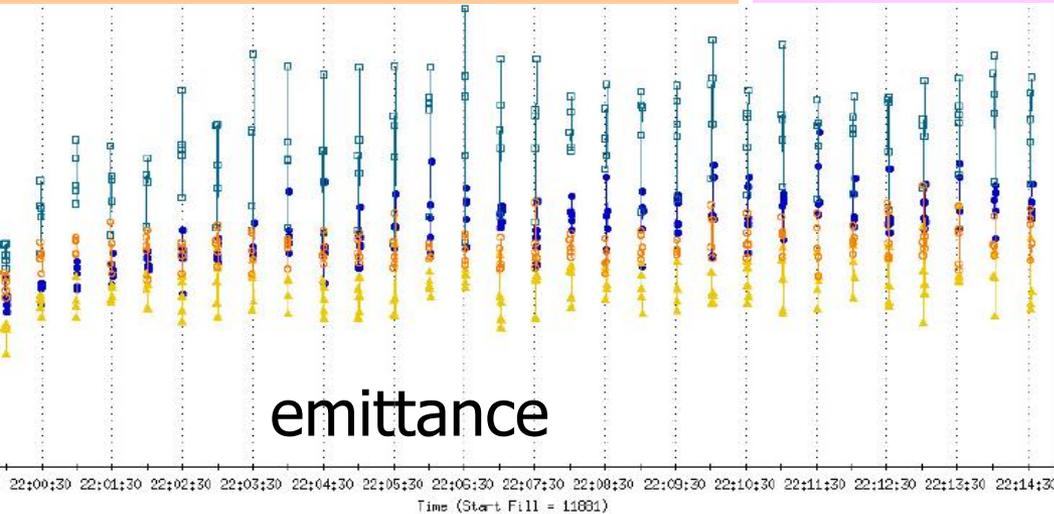
APEX Au ions at γ=10.5 (March 9, 2010)
maximum ΔQ_{sc}=0.03, ξ=0.002

$\Delta Q_{sc} >> \xi$

The goal of this APEX was to achieve large space-charge tune-shifts. We were NOT able to produce large space-charge tune spread at this energy (insufficient RF voltage).

Working point good for space-charge, is not good enough for space-charge tune spread with beam-beam.

ΔQ_{sc}=0.02

collisions

emittance

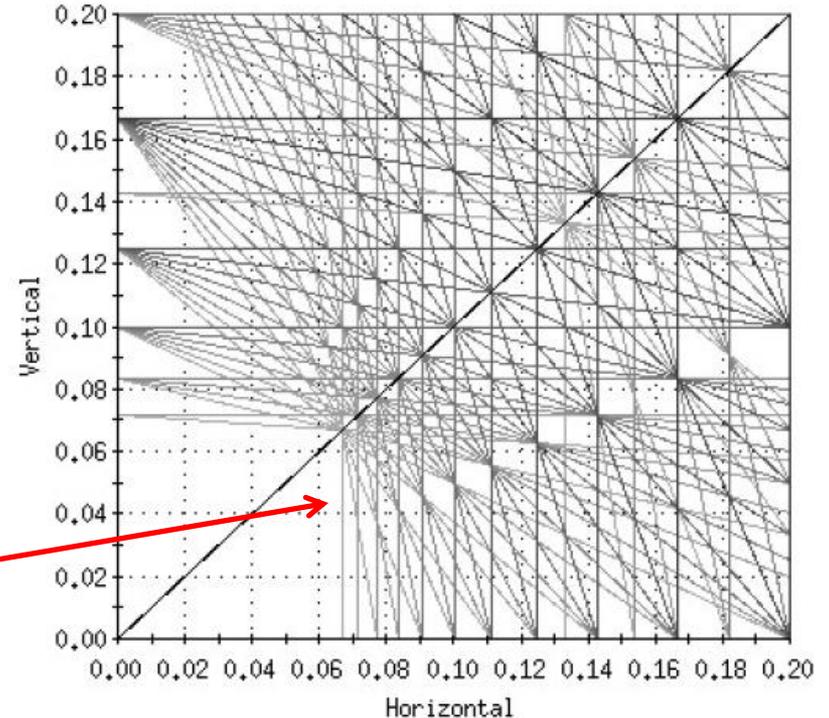Plan for APEX, May 2, 2011: Au ions at injection energy (γ=10.4):

Finding working point where effects of beam-beam are minimized at least for a very weak beam-beam for regime: ΔQ_{sc}=0.033, ξ=0.0023 (per IP), for N=1.5e9

resonances to 15th order

For small tune spread ΔQ (~0.04, even for N=1.5e9):

We should be able to find better working point.

1) Move ALL collimators out
2) set new working points in both Blue and Yellow rings: w.p. (Qx, Qy)=(0.08,0.07)
3) Inject typical bunch intensities 1.2e9; put into collisions. If no affect on beam lifetime try to get highest bunch intensity possible and repeat. If there is an effect, back-up w.p. to about 0.14.
4) Inject few bunches of different intensities and record lifetime without collisions for about 10 min.
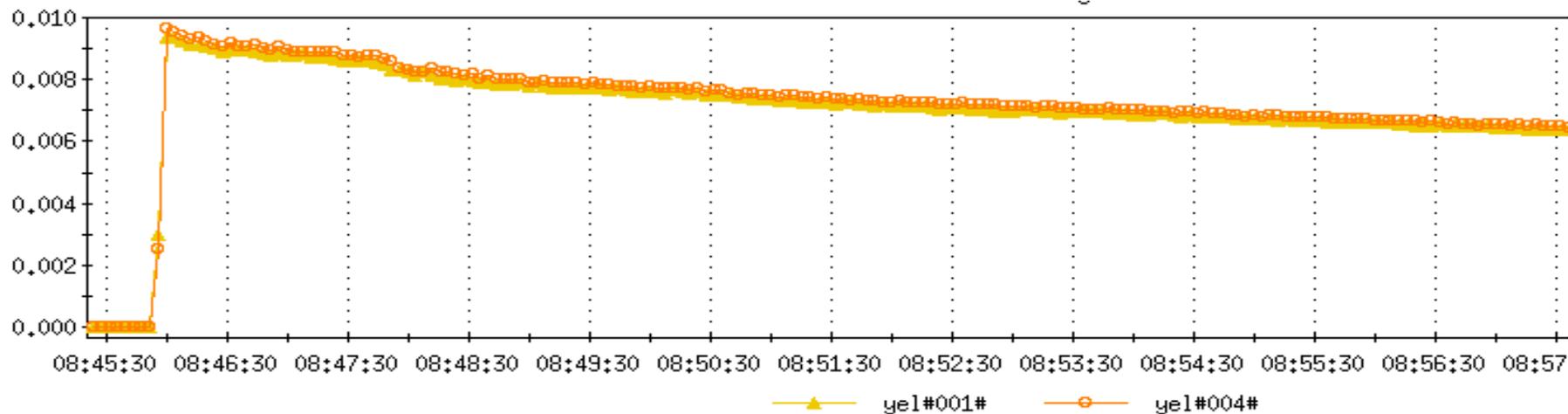
Total needed time about 2 hours.

Cons: Bunch intensity could be a problem: recent problems in Tandem; Booster RF, RHIC injection.

Perhaps, it is better to wait when we have intensities

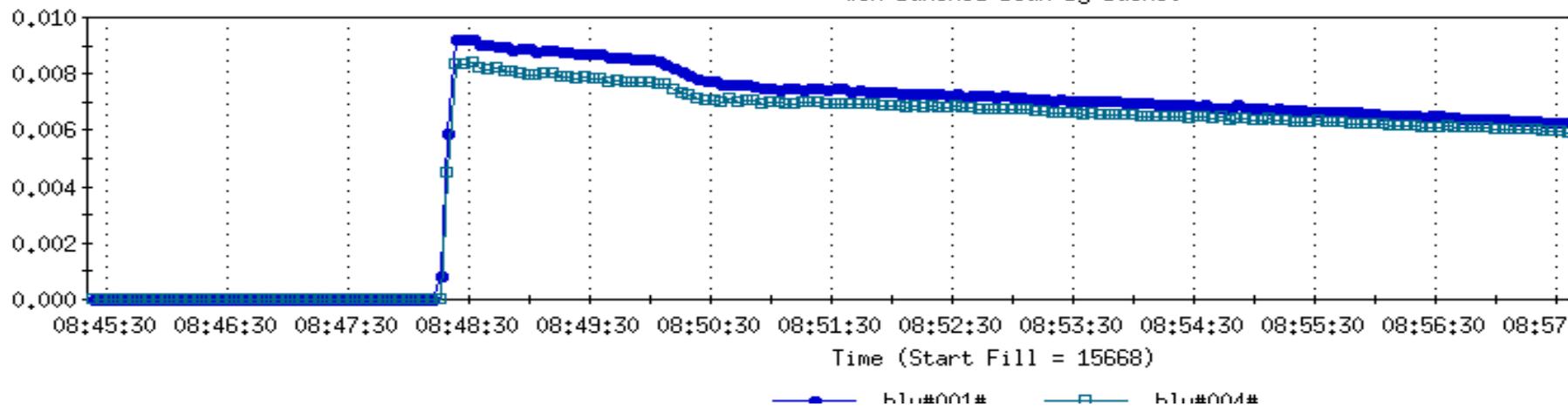back (otherwise effect is very weak – b-b (IP) 0.0013)

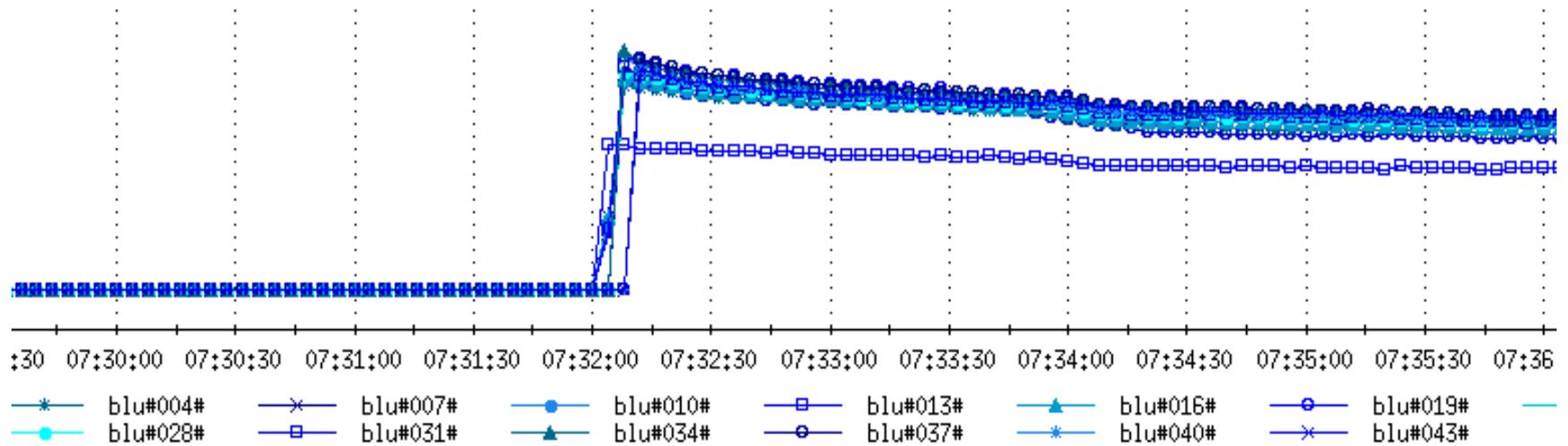# What is going on with emittance measurements?

Time (Start Fill = 15666)
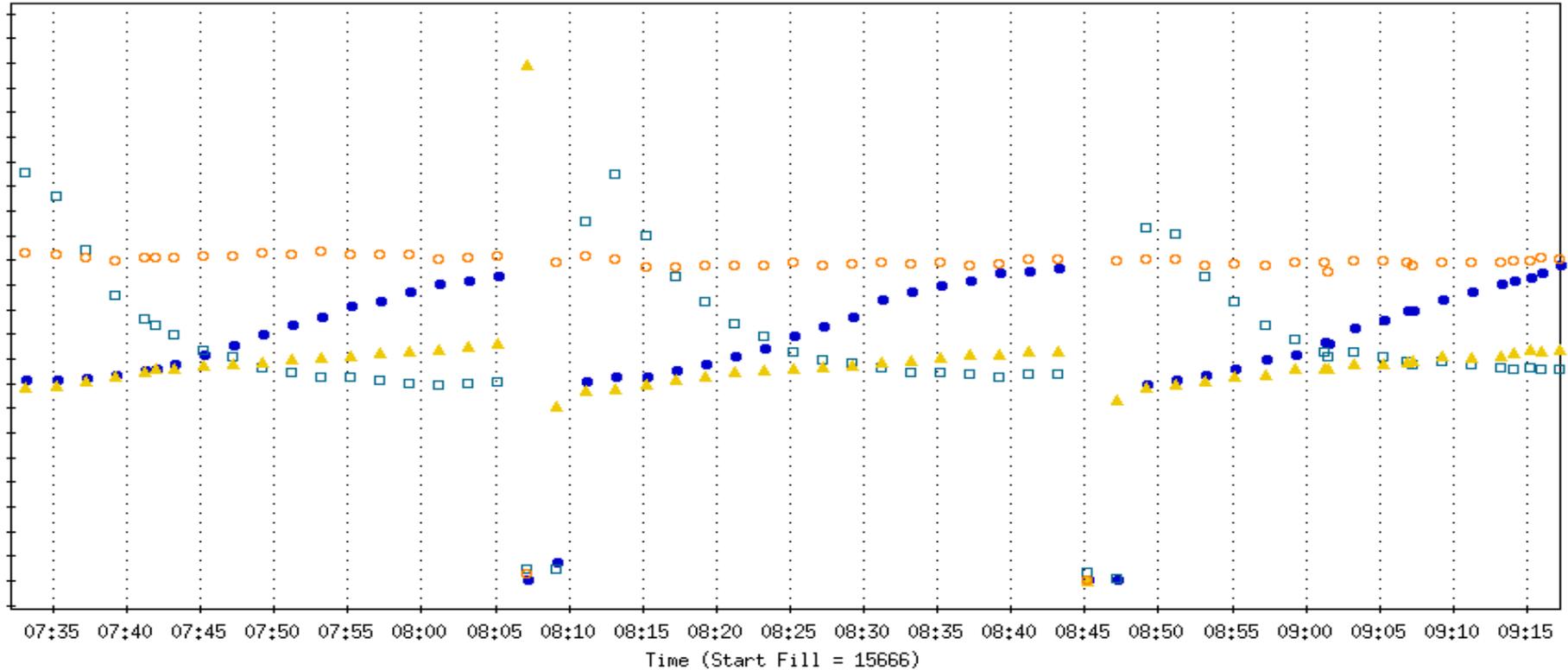
RhicIpmManager.blue_horiz:normEmitM[,]   RhicIpmManager.blue_vert:normEmitM[,]
RhicIpmManager.yellow_horiz:normEmitM[,]   RhicIpmManager.yellow_vert:normEmitM[,]

WCM bunched beam by bucket

Time (Start Fill = 15668)

WCM bunched beam by bucket

✳ blu#004#	✕ blu#007#	● blu#010#	☐ blu#013#	▲ blu#016#	⊖ blu#019#
● blu#028#	☐ blu#031#	▲ blu#034#	⊖ blu#037#	✳ blu#040#	✕ blu#043#