Studies on Head-Tail Phase Shift in RHIC

V. Ranjbar

Basic Idea

A simple model of beam motion in the presence of linear chromaticity integrated over momentum offset will give this approximation for the time sliced beam motion:

$$Z(s,\tau) = \mathrm{Re}\int_{-\infty}^{\infty} d\delta\rho(\delta)Y(s,\delta,z) = e^{-(\chi^2/2)\sigma_\tau^2\sin^2(\omega_s s/c)} \times \sin\{\omega_0 Q s/c + \chi\tau[1-\cos(\omega_s s/c)]\}, \qquad (9)$$

$$\chi = \frac{\omega_0\xi}{\eta}$$

From this we can readily see that our linear chromaticity is proportional to the phase of the time sliced turn-by-turn motion and its distance from the bucket center.

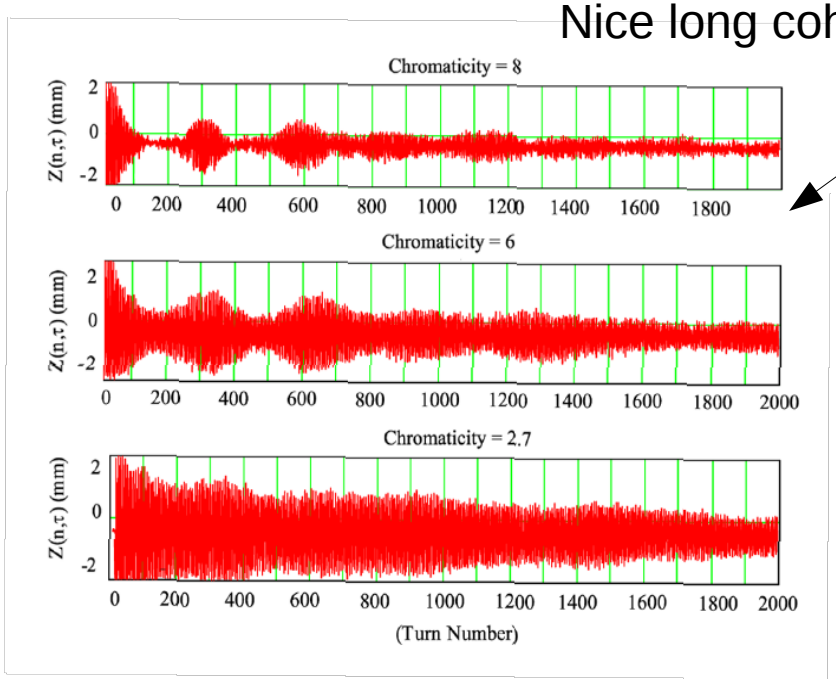
$$Q' = \frac{-\eta\Delta\Psi(n)}{\omega\Delta\tau(\cos(2\pi nQ_s)-1)}.$$

If we want to be more fancy we can also consider 2nd order Chromaticity, in which case the phase acquires and additional tau^2 dependence.

$$+\frac{\pi\omega_0^2Q_s^2\xi'}{2\eta^2}\tau^2\left(n-\frac{\sin(4n\pi Q_s)}{4\pi Q_s}\right) - \frac{1}{2}\left(\frac{\alpha^2(\tau,n)\theta(n)}{1+\theta^2(n)} - \arctan[\theta(n)]\right)$$

Experimental Set-up

Nice long coherence times in Tevatron



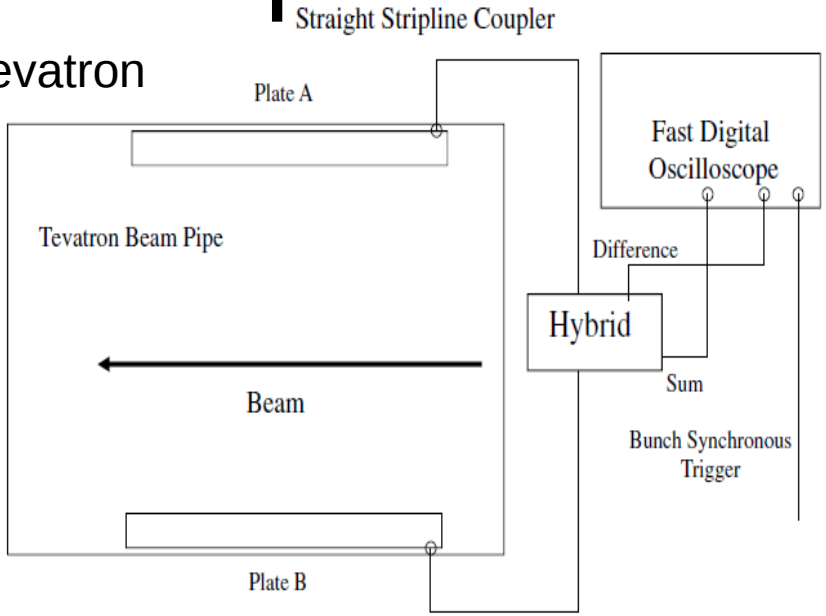


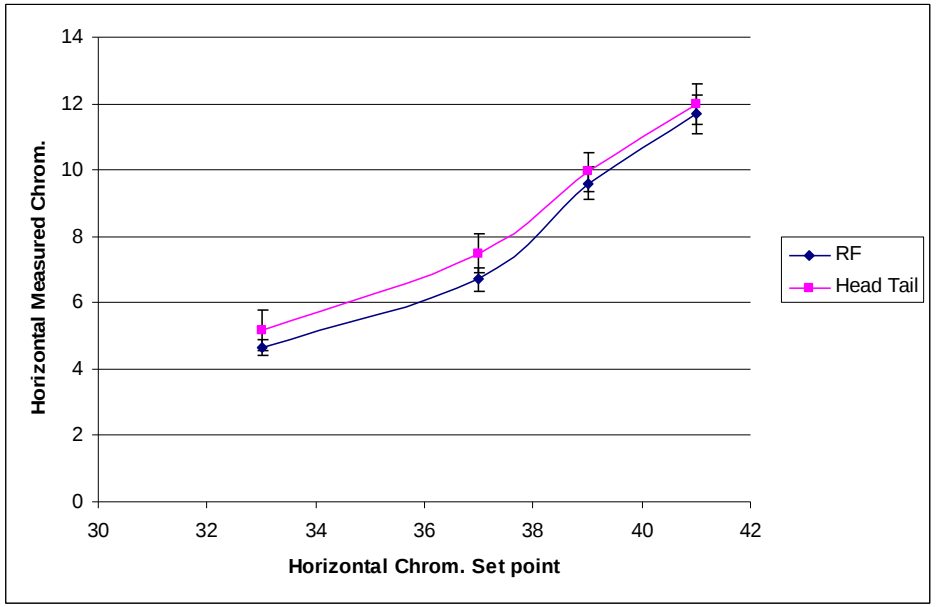
FIG. 1. Experimental setup.

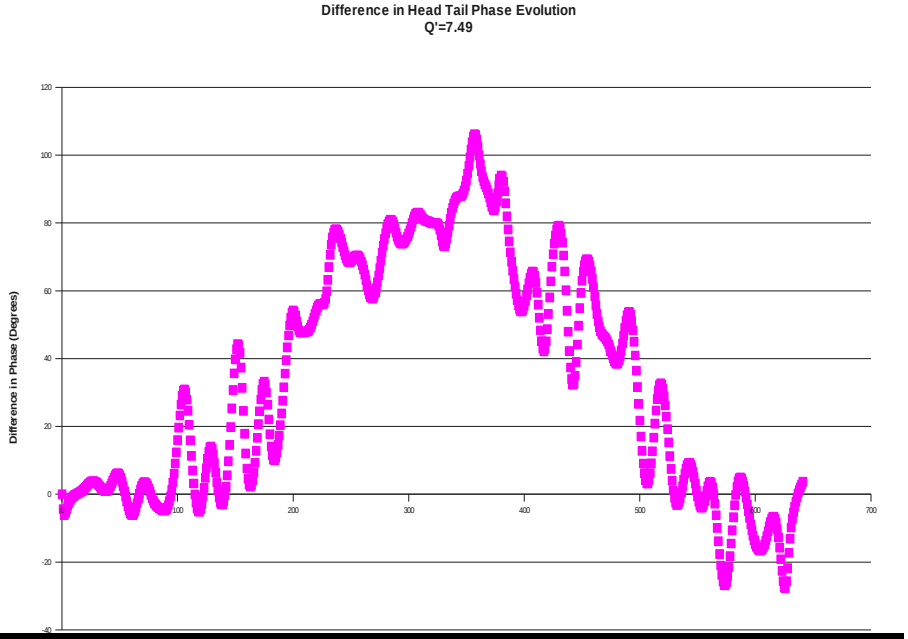
This idea was first proposed and tested at CERN by R. Jones and others but never used operationally, since it was destructive and it was challenging to make it reliable.

Later It was developed for use in the Tevatron by myself with help of E. Lorman. The performance in the Tevatron was more reliable since we had less net Landau damping at the time and thus longer coherence times for each kick (before the use of Octupoles).

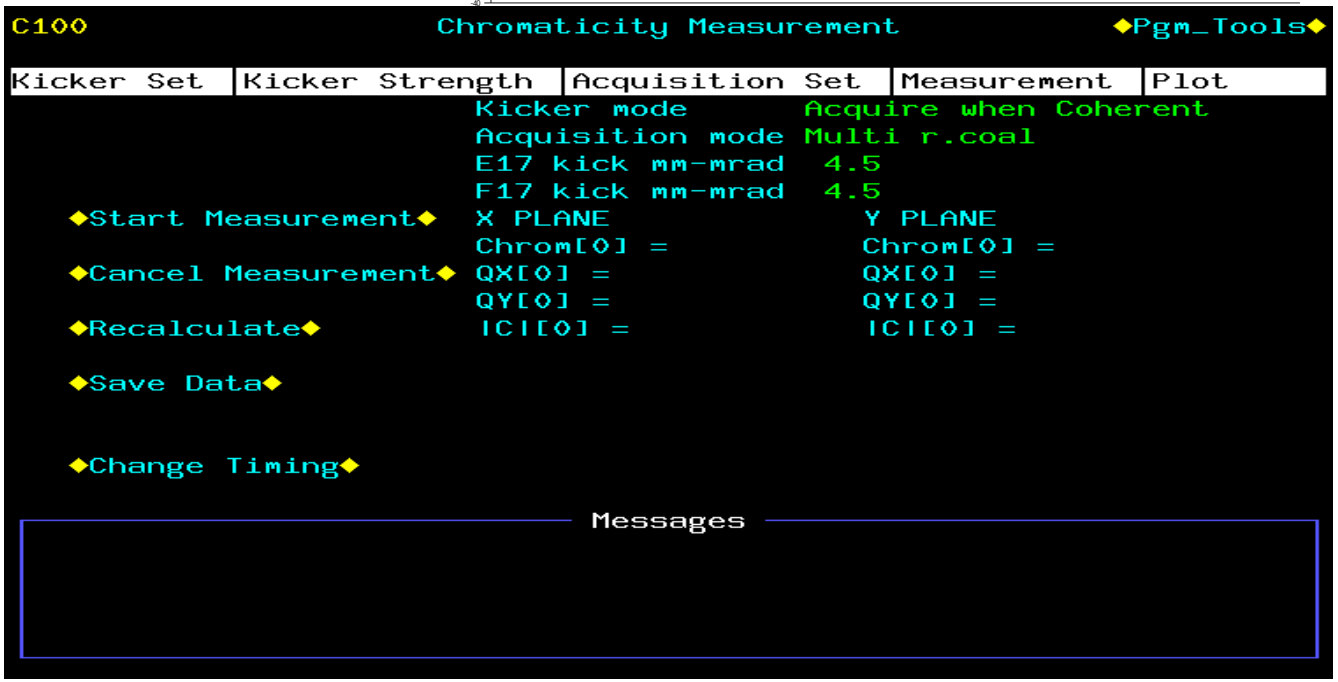
I know there was some work also done here at RHIC but I haven't seen any published papers on this yet.

Tevatron Results





Results good enough for a dedicated application used during shot setup. (never got It to work for uncoalesced bunches due to dancing bunches issues).

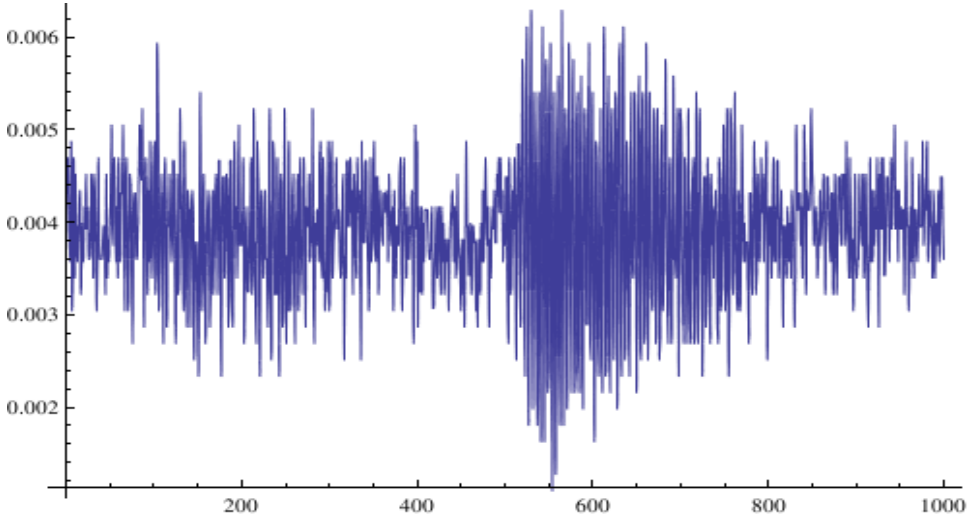


APEX tests during last run.

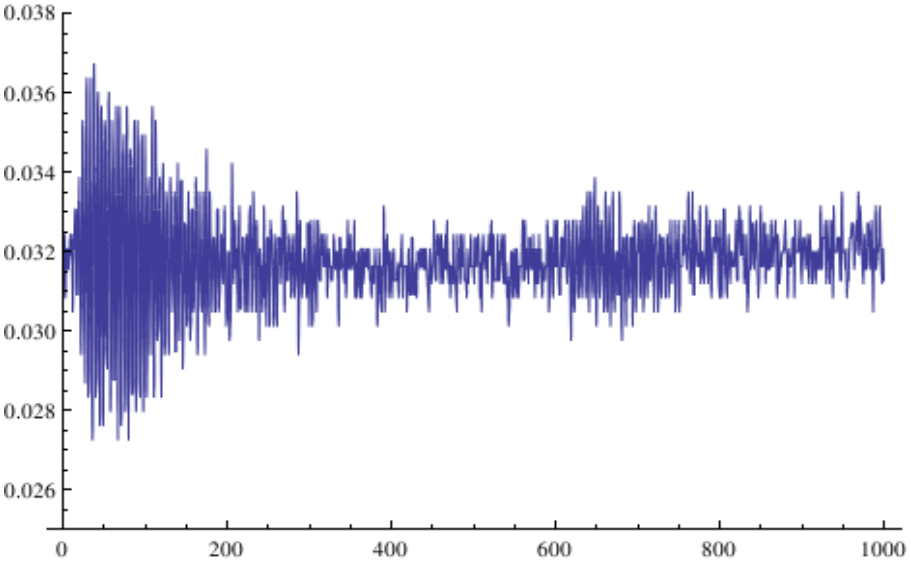
- I used a similar set-up as was done in the Tevatron connecting the button BPM scope to the yellow stripline.
- I used the Artus turn-by-turn kicker to excite the beam and acquired data in the vertical and horizontal planes.
- We performed 18 measurements at Store Energy with the Au beam scanning through different chromaticity settings.

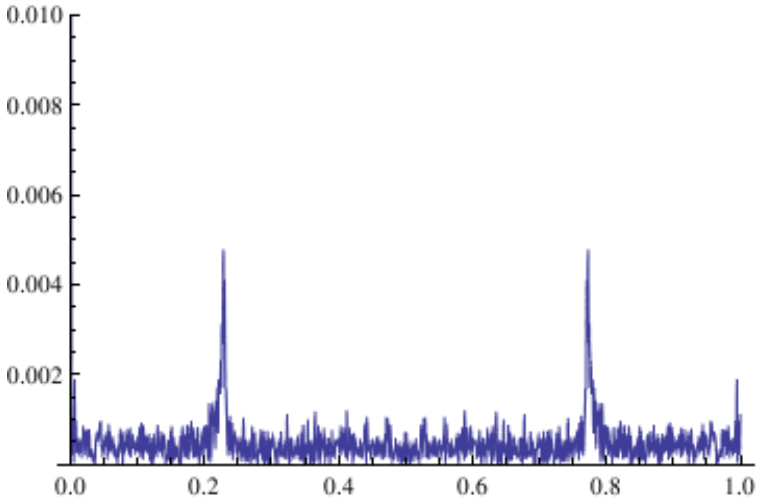
Results

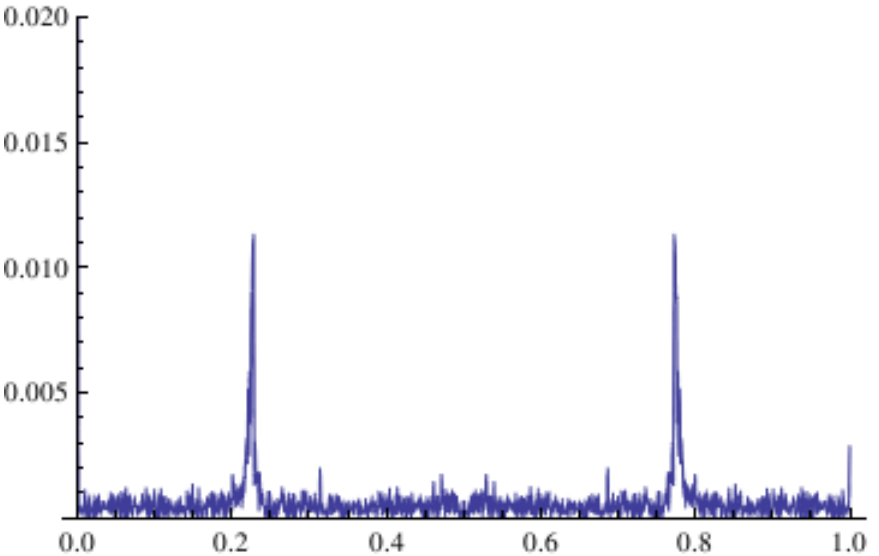
Horizontal difference signal



Vertical difference Signal

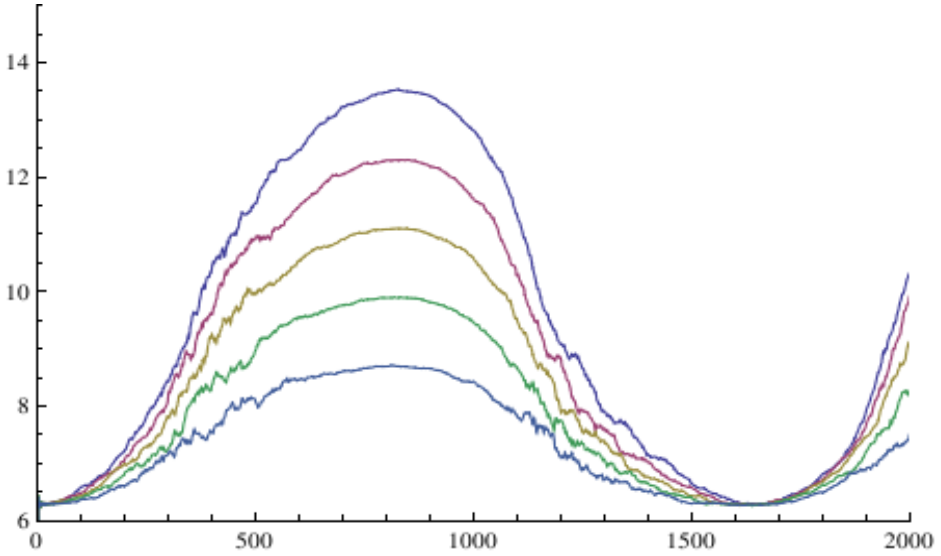






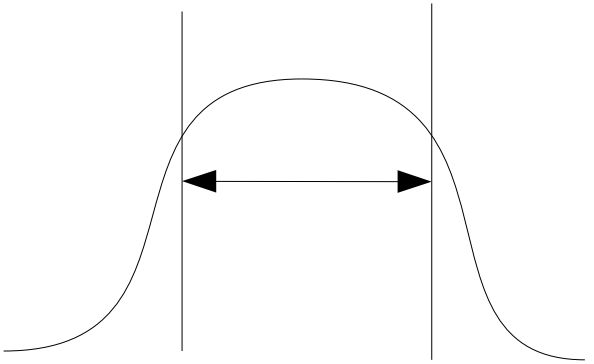
Horizontal Analysis

During this part of the ramp the synchrotron tune
Was 6.4e-4 or 1553. This means for good signal
We need to sample around turn 776. This is
When phase amplitude is the largest.



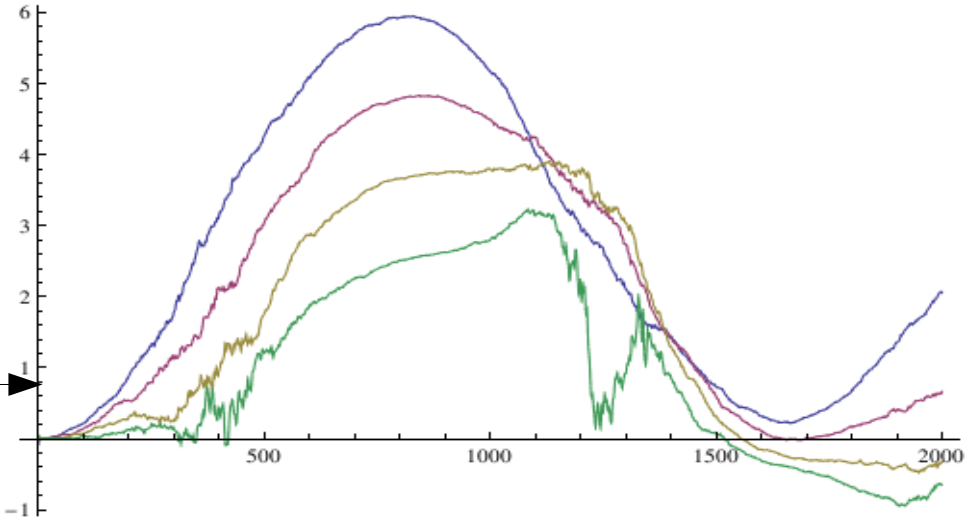
Using Mike B's Rf simulation 1 RF

Turn-by-turn evolution of phase
Difference between several slices.

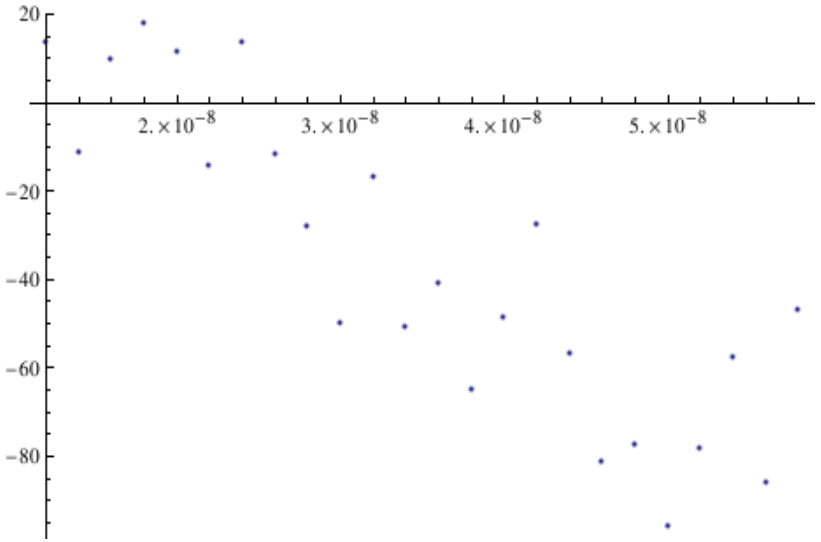


Slices taken marching inward towards
Bunch center.

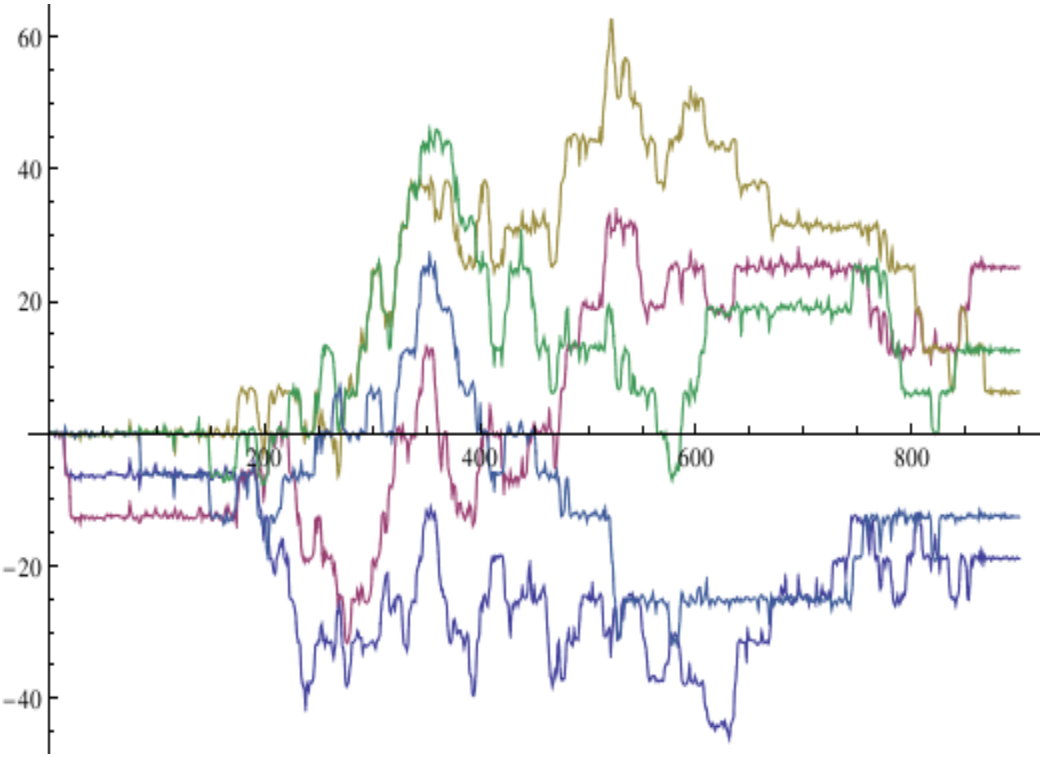
Simulation with 2 RF as we had it:



What we actually got:



Slope lets us its ~ 4 units of Chrom

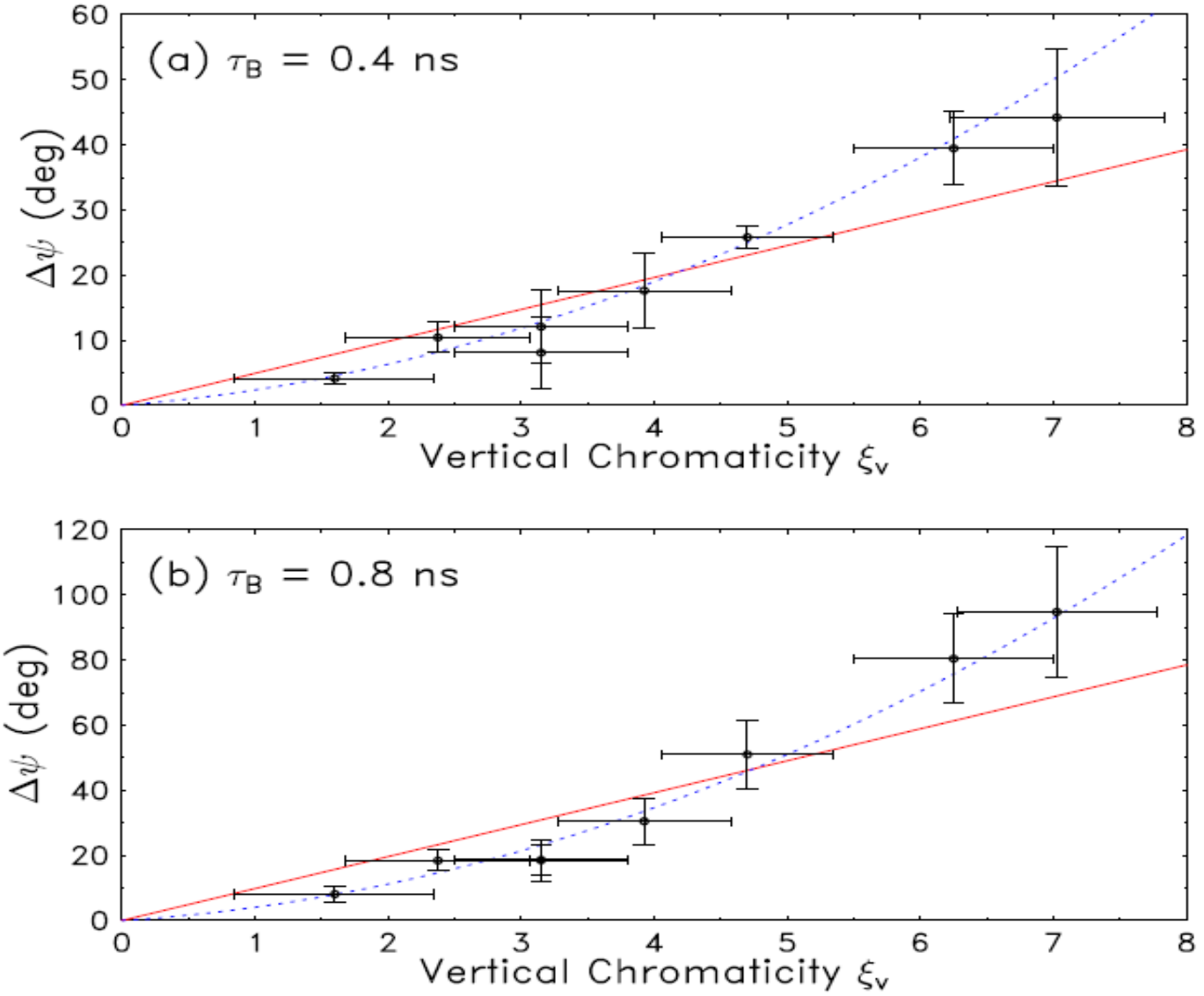


Phases are not too nice so I have a lot of doubts. I will work more on seeing if using better processing I can clean this up but I am not too hopeful

APEX proposals for 2015 run

- Since s/n due to de-coherence is our problem we can maybe use the AC dipole or spin flipper? To maintain our S/N.
  - We tested this option years back in the Tevatron and the results seem promising. Response not totally linear a per our phase equation but close enough to be accounted for maybe.

Results from Tevatron published in paper by C.Y.Tan and myself.



Along another route. Improve signal to noise in our sampling

- BBQ can get good enough signal to noise to measure tune using just bbq kicker.
- I performed tests 2 years ago to use the bbq to pick up head and tail signals using a pulse generator. Not too successful due to noise in system also since bbq integrates over many bunches to get final signal.
- We performed tests in the Tevatron to improve signal to noise using variable attenuators zero out the common mode.
- Challenge: Can we improve bit resolution of our sampling so that we can see the bbq kicker signal on a single bunch?

Thanks

- M. Bai, M. Minty, A. Marusic, J. Jamilkowski, M. Blaskiewicz,C. Liu, C. Dawson, P. Harvey, B. Van Kuik..and others.