Witness Bunch Experimental Studies at CESR-TA

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Motivation: Study the coherent tune shift caused by the electron cloud.

Experiment: Use long trains e+/e- bunches to generate a electron cloud density. Place witness bunches at varying times after the generating train and measure the coherent tune shift of the witness bunch due to the electron cloud density.

During the CESR-TA run of June 2008 experiments were made on CESR to characterize the coherent tune shift for e- and e+ generating trains at various witness bunch spacing's.

Content:

I. Single bunch tune:

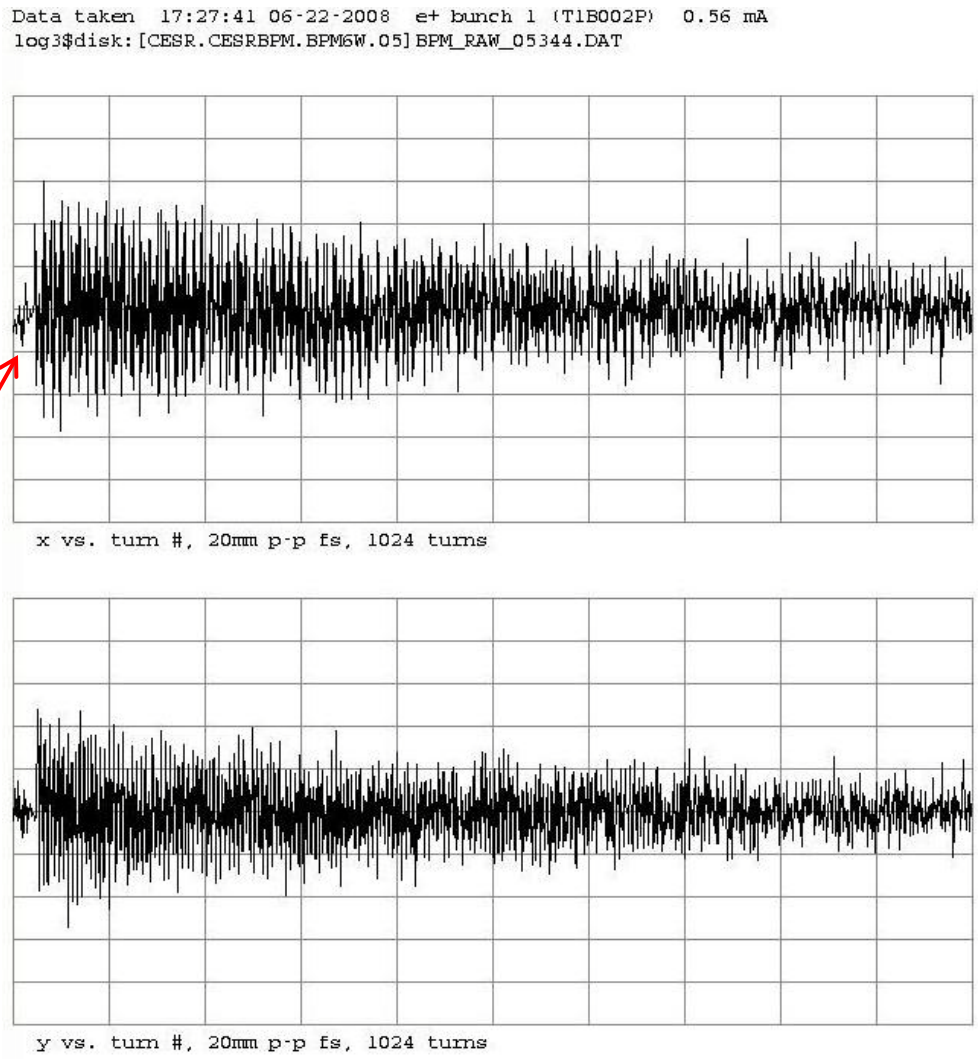
- The Cornell Beam Position Monitor (CBPM) system has the capability to measure the beam position of multiple bunches (183) in CESR on a turn-by-turn basis.

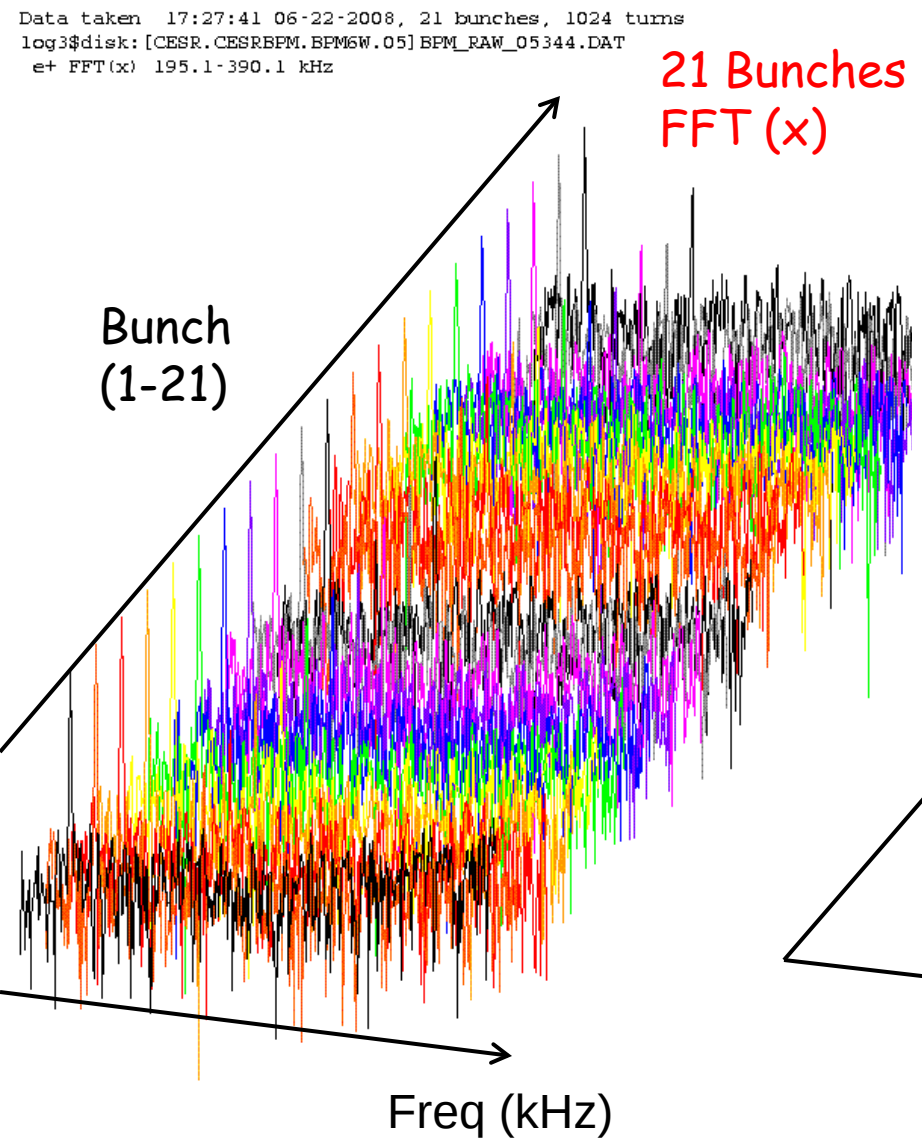
The single bunch tune is determined by:

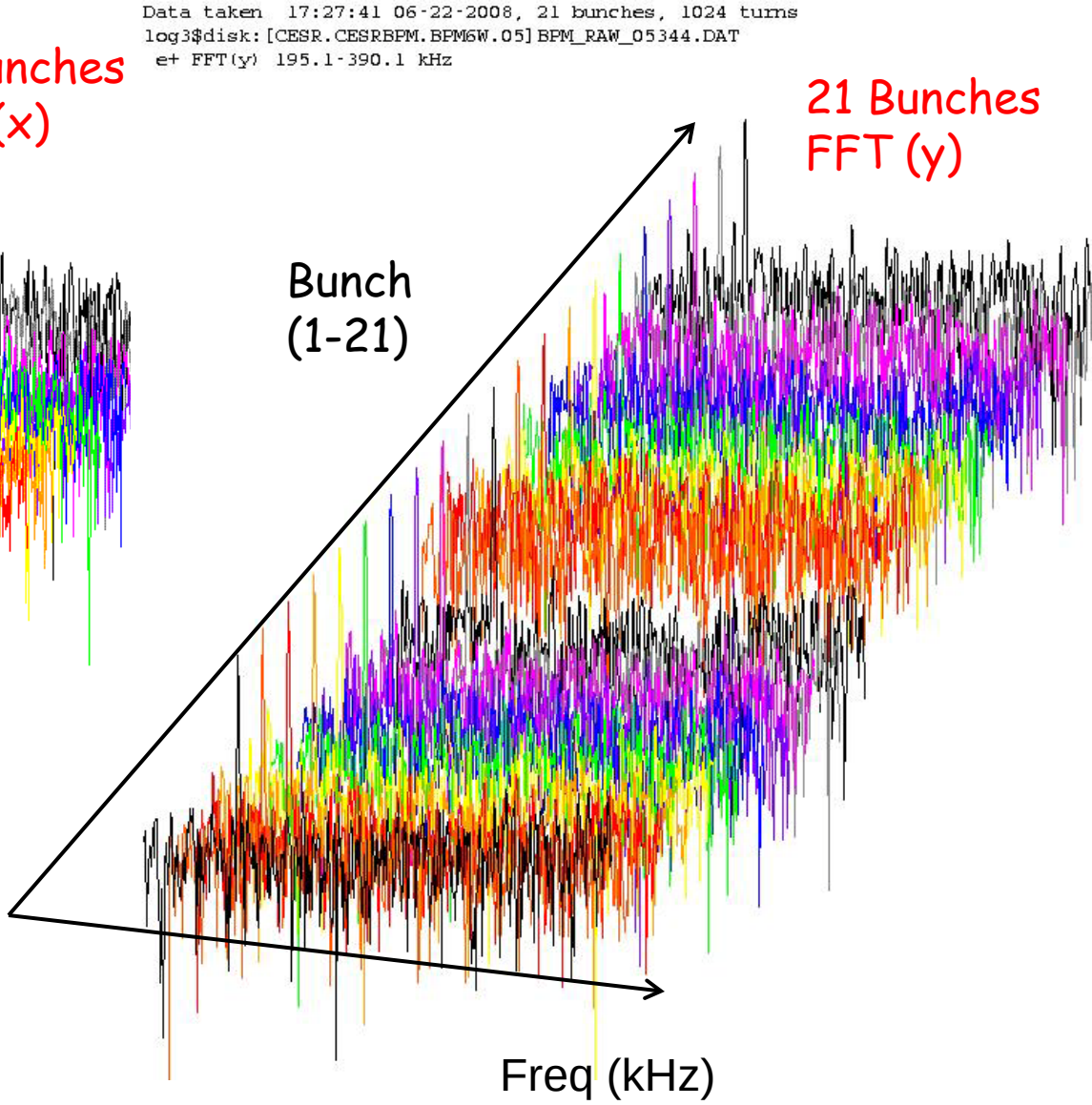
- Shock-exciting the bunches in CESR using pulsed magnetic elements. Trigger the CPBM data acquisition and pulsed magnetic elements simultaneously.

Shock excitation

- Record the position of each bunch for 1024 turns (2.6ms).

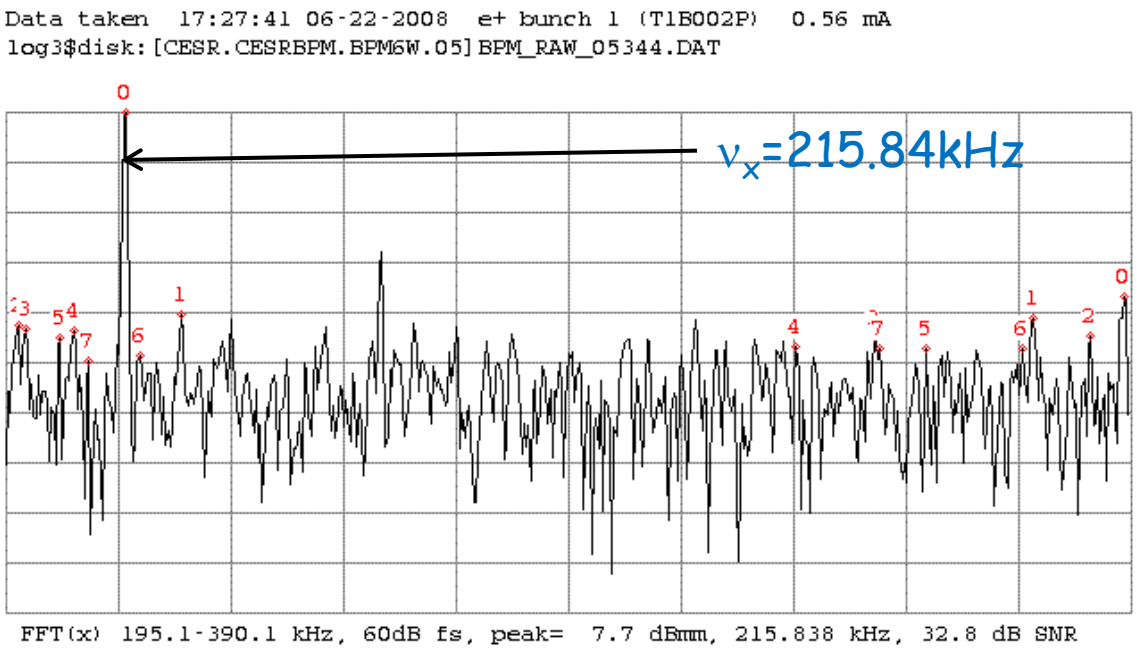




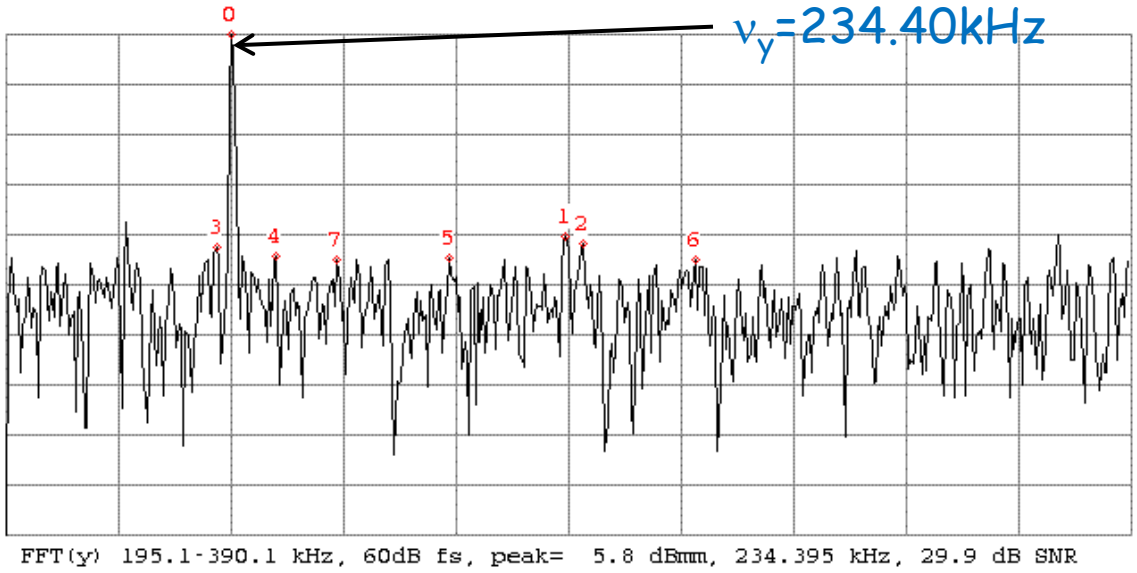


- Fast Fourier Transform the vertical/horizontal position to determine the oscillation frequency of each bunch.

Frequency spectrum of bunch 1 in the 21 bunch train.

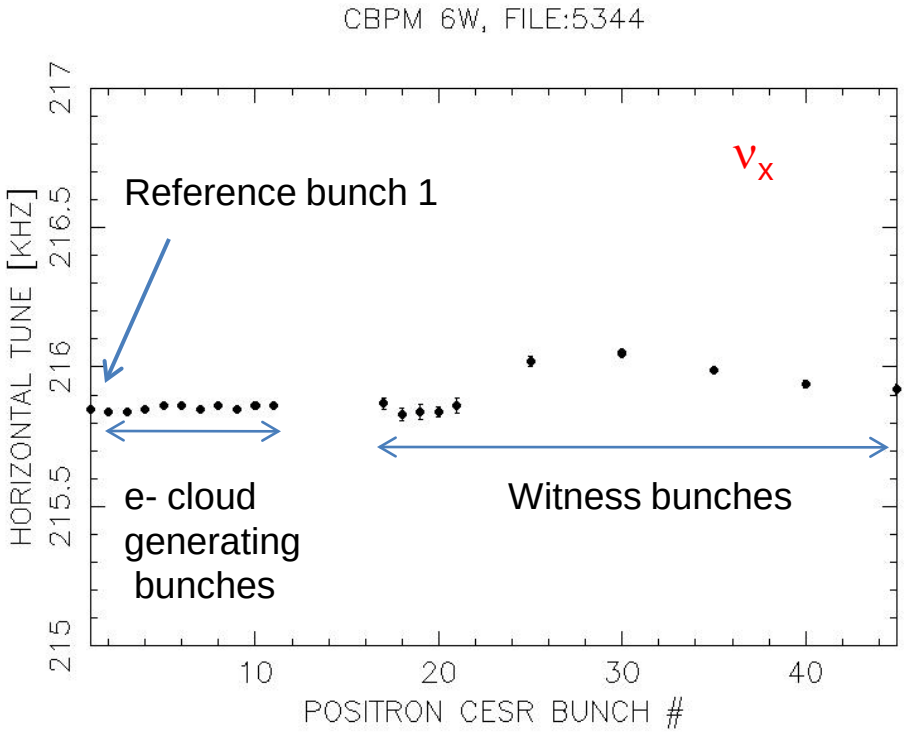


Horizontal spectra



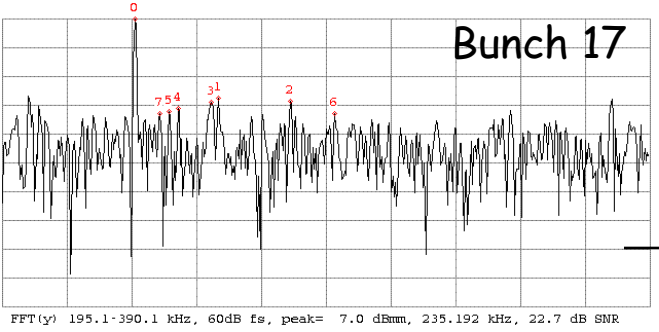
Vertical spectra

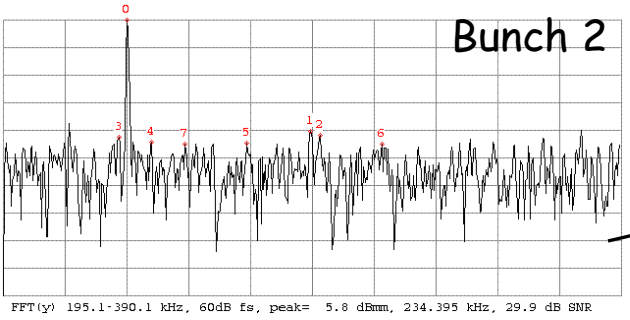
Peak in frequency spectrum is determined in both horizontal and vertical spectra for each bunch.

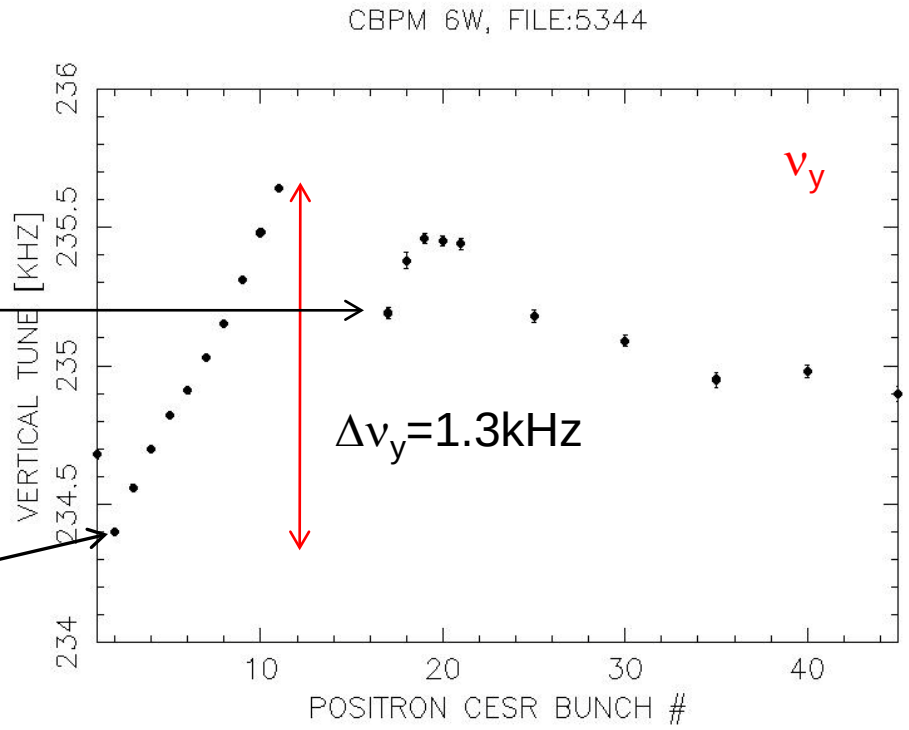


e+ horizontal/vertical tunes for 21 bunches in CESR:

- Reference bunch 1 @0.5mA.
- e- cloud generating bunches @1mA (bunches 2-11).
- Witness bunch at 0.5mA (10 bunches).







II. Machine parameters during witness bunch experiments:

-electrostatic separators off.
-Lower or zero the feedback gains to avoid pulling the tune.
-fill the evenly so the bunch current variation is a couple percent.
-operate in a clear region of tune plane to avoid resonance.
-bunch pattern: 14ns bunch spacing with lead reference bunch, followed by e- cloud generating train, followed by witness bunch.

For high beam energy (5.3GeV)-all wigglers off.

For low beam energy (~2.1GeV)-6 wigglers on.

Data Displayed:

For each witness bunch, the single bunch tune for all the bunches in CESR were measured 10 times. The mean and standard deviation of the 10 measurements was computed. To quantify the tune spread, the difference in the mean tune between the reference bunch (bunch #1) and trailing bunches are plotted.

Note: Only the witness bunch closest to the generating train is plotted.

III. Bunch Patterns measured during June 2008 CESR-TA run:

i) E=5.3 GeV

1) 10 bunch generating train@0.75mA/bunch (bunches 1-10) with 0.75mA witness bunch located at 45, 40, 35, 30, 25, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11 (e+ 6/10/2008)

2) 10 bunch generating train@1mA/bunch, change witness bunch 11 current from 0.5 to 2mA in steps of 0.5mA. (e+ 6/10/2008)

3) 3 bunch generating train@5mA/bunch (bunches 2-4), reference bunch 1@0.5mA, and witness bunch@0.5mA located at 45, 40, 35, 30, 25, 20, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5. (e+ 6/10/2008)

4) 10 bunch generating bunch@1.5mA/bunch (bunches 2-11), reference bunch 1@0.5mA, and witness bunch@0.5mA located at 45, 40, 35, 30, 25, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12. (e+/e- 7/1/2008)

5) 20 bunch generating train@0.75mA/bunch (bunches 2-21), reference bunch 1@0.5mA, and witness bunch@0.5mA located at 45, 40, 35, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22. (e+/e- 7/2/2008)

6) 20 bunch generating train at varying currents. (e+/e- 7/2/2008)

ii) E=2.1 GeV

1) 10 bunch generating train@0.75mA/bunch (bunches 1-10) with 0.75mA witness bunch located at 45, 40, 35, 30, 25, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11 (e+ 6/12, 6/14, and 6/15/2008, e- 6/13 and 6/15/2008)

2) 3 bunch generating train@3mA/bunch (bunches 2-4), reference bunch 1@0.5mA, and witness bunch@0.5mA located at 45, 40, 35, 30, 25, 20, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5. (e+ 6/22/2008)

3)10 bunch generating bunch@1mA/bunch (bunches 2-11), reference bunch 1@0.5mA, and witness bunch@0.5mA located at 45, 40, 35, 30, 25, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12. (e+/e- 6/22/2008)

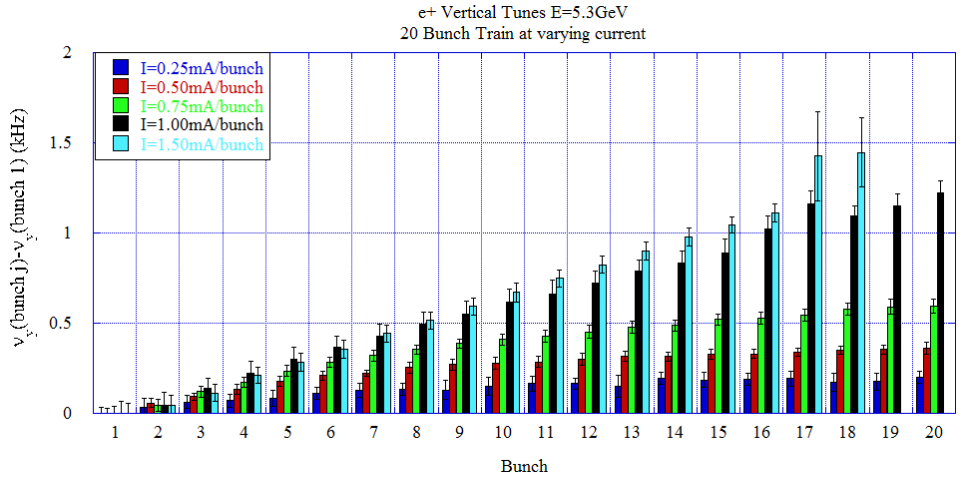
4) 20 bunch generating train@0.5mA/bunch (bunches 2-21), reference bunch 1@0.5mA, and witness bunch@0.5mA located at 45, 40, 35, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22. (e+ 6/15/2008, e+/e- 6/23/2008 100nm/8nm lattice)

5) 20 bunch generating train at varying currents. (e+ 6/12 and 6/15/2008, e- 6/13/2008, e+ 100nm/8nm lattice)

WOW! Lot's of data to show! I will present some of the data but a complete list of results can be viewed at:
https://wiki.lepp.cornell.edu/lepp/bin/view/ACC/Bunch/CESR_MS_Ecloud_2008

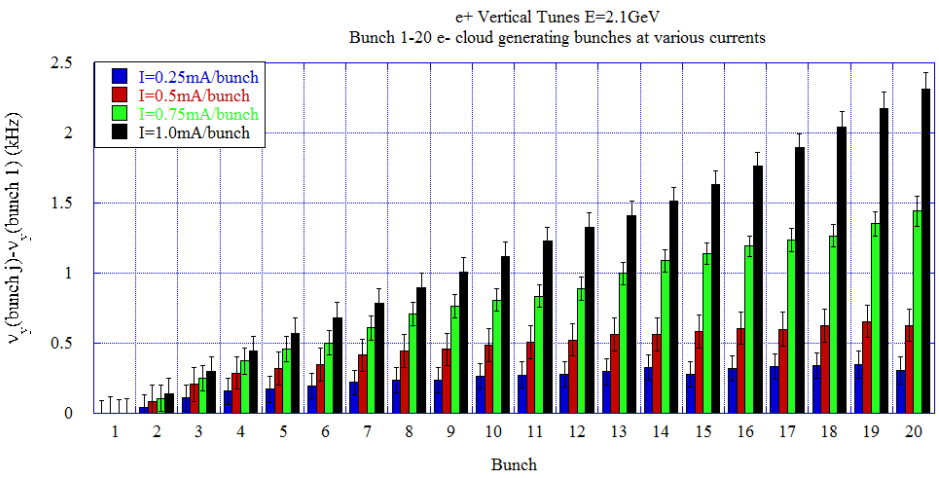
IV. Witness bunch experiments: Tune shift along 20 bunch train with vary bunch current

e+ E_{beam}=5.3GeV

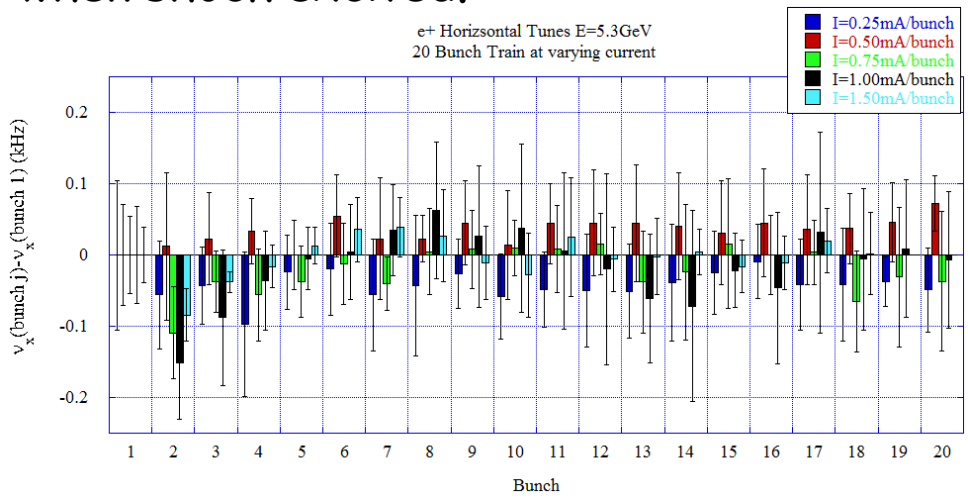


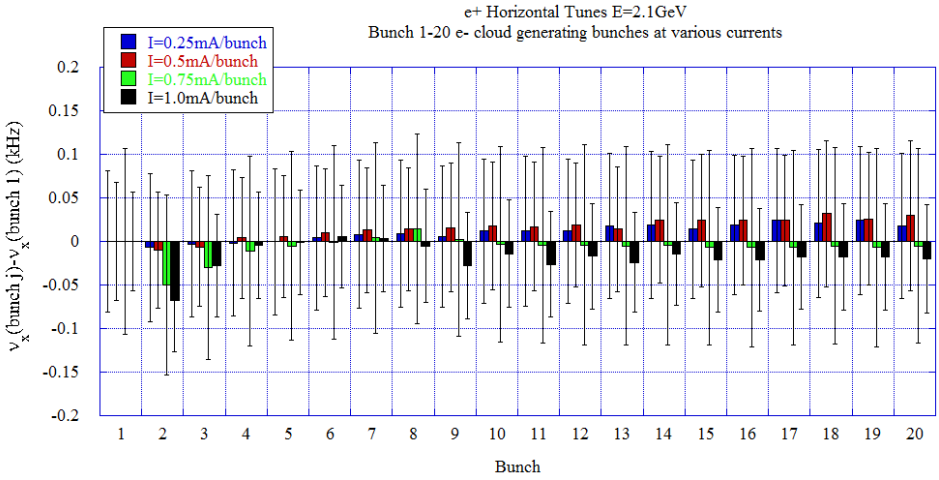
- $\Delta\nu_y$~1.3kHz@1mA/bunch-possible saturation @1.5mA/bunch.
- $\Delta\nu_x$~0.
- lost bunches 19-20@1.5mA/bunch when shock excited.

e+ E_{beam}=2.1GeV

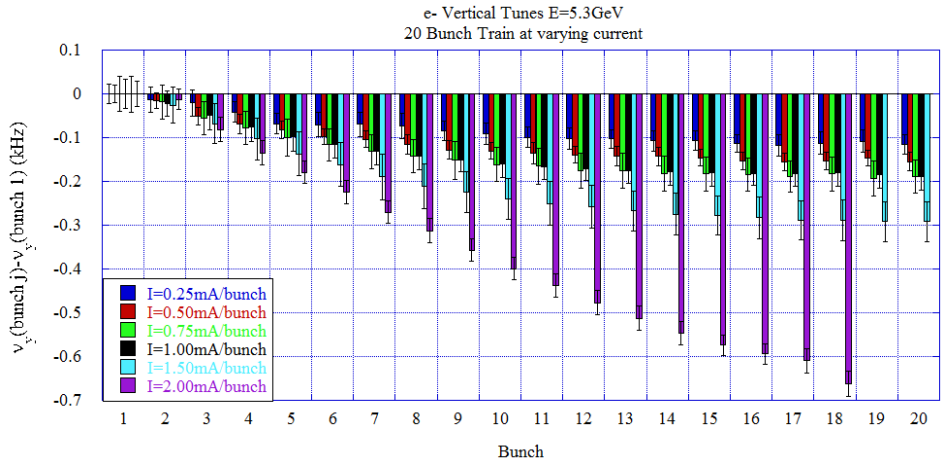


- $\Delta\nu_y$~2.4kHz@1mA/bunch, no tune shift saturation.
- $\Delta\nu_x$~0.



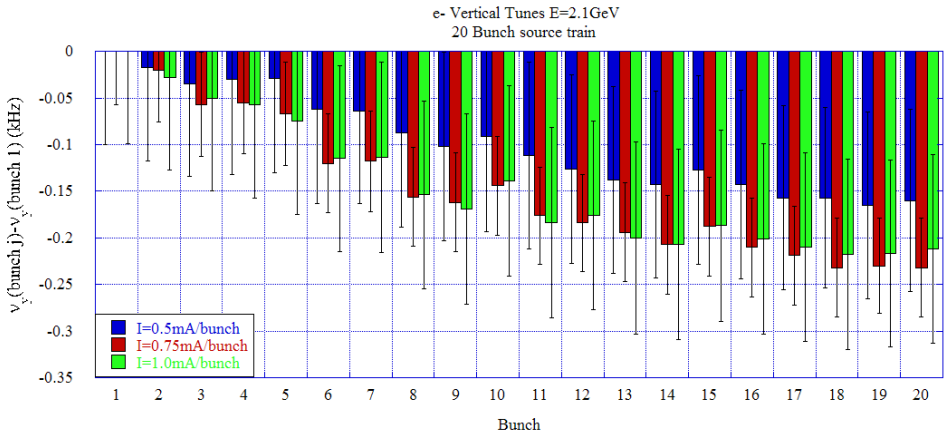


e- E_{beam}=5.3GeV

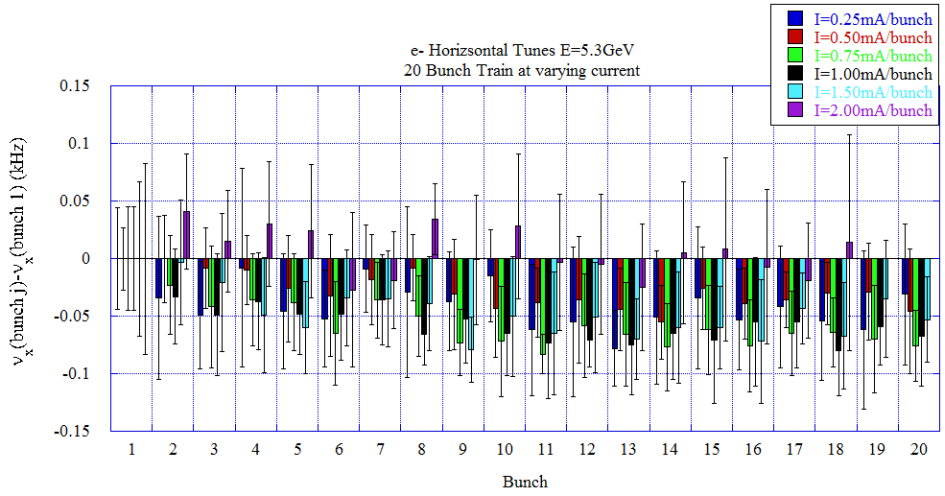


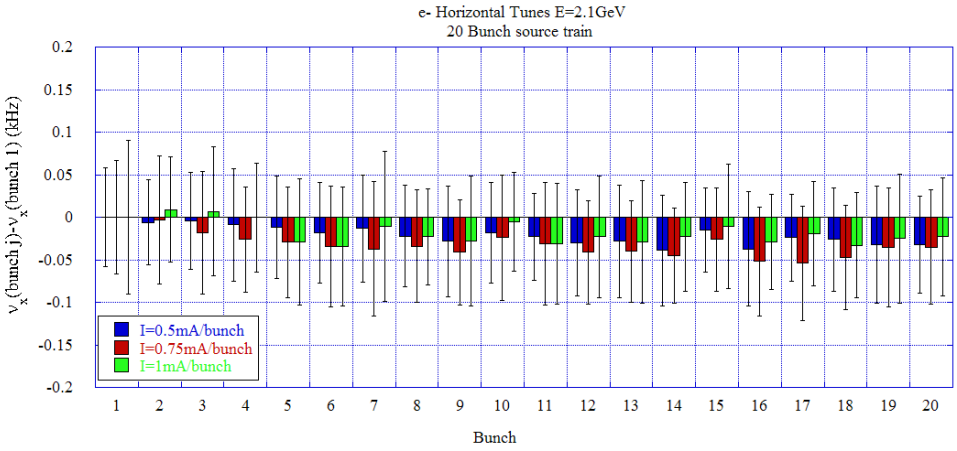
- $\Delta\nu_y$~-0.2kHz@1mA/bunch
- $\Delta\nu_x$~0.
- lost bunches 19-20@2mA/bunch when shock excited.
- large $\Delta\nu_y$ between 1.5 to 2mA/bunch

e- E_{beam}=2.1GeV

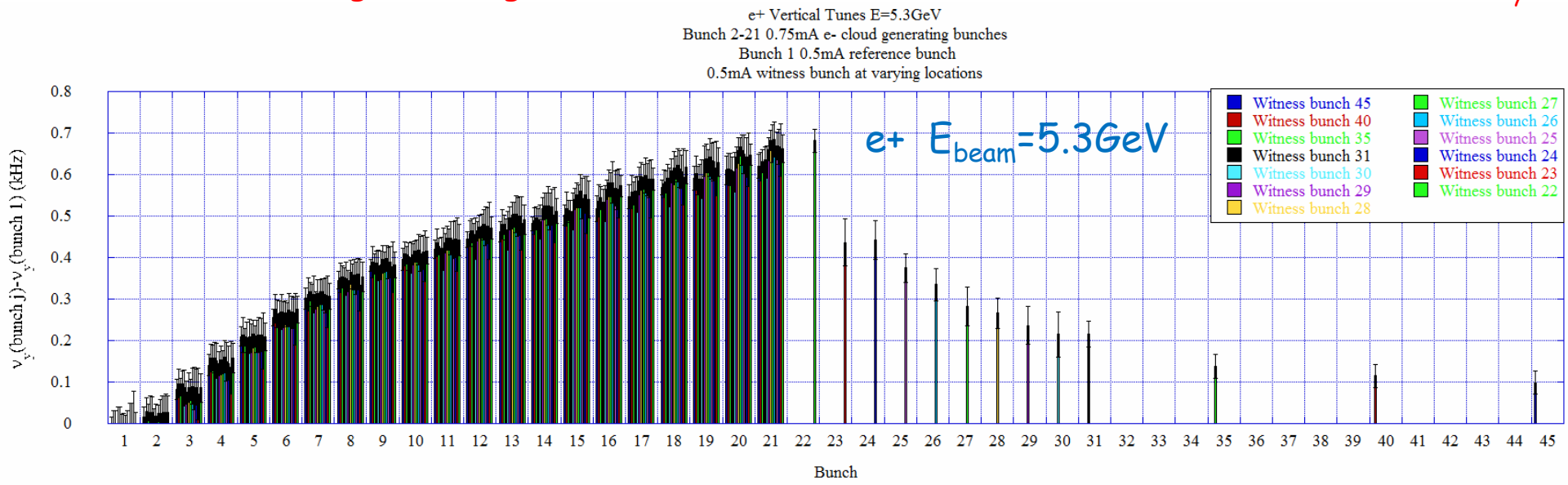


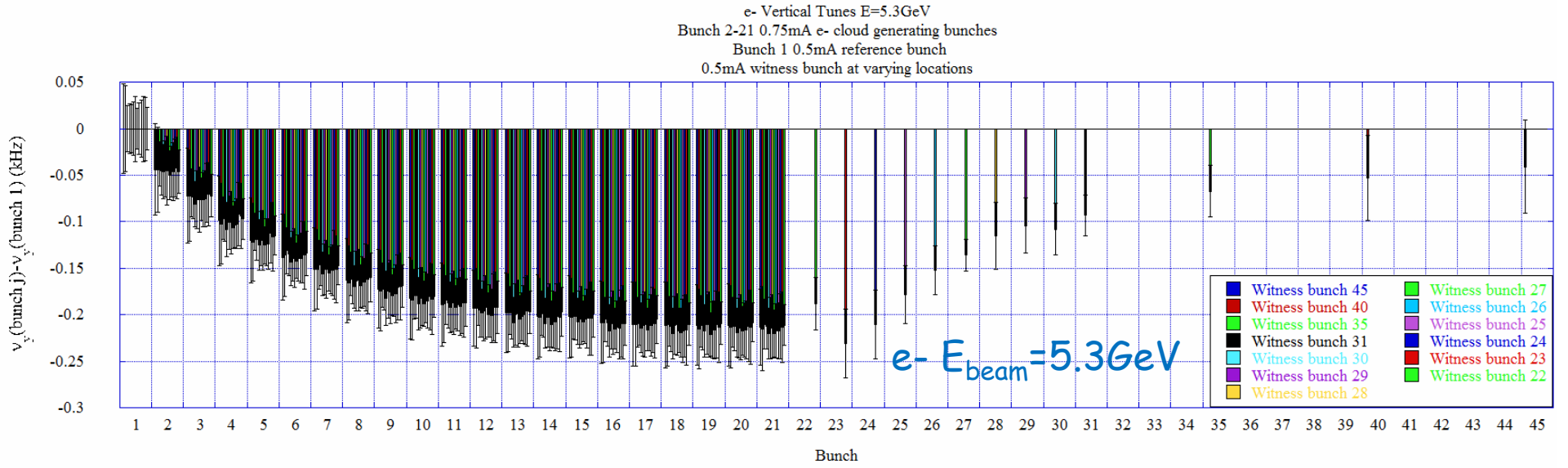
- $\Delta\nu_y$~-0.2kHz@1mA/bunch, similar to high energy tune shift. No significant change in tune shift with current.
- $\Delta\nu_x$~0.





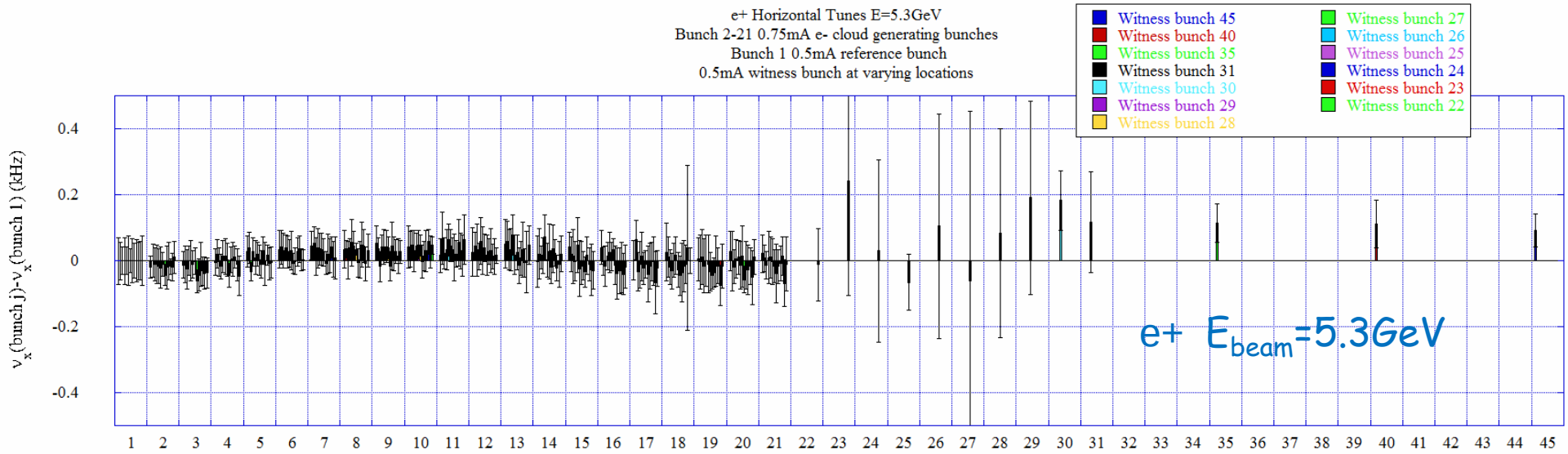
E=5.3GeV 20 bunch generating train@0.75mA/bunch, reference & witness bunch@0.5mA: ν_y

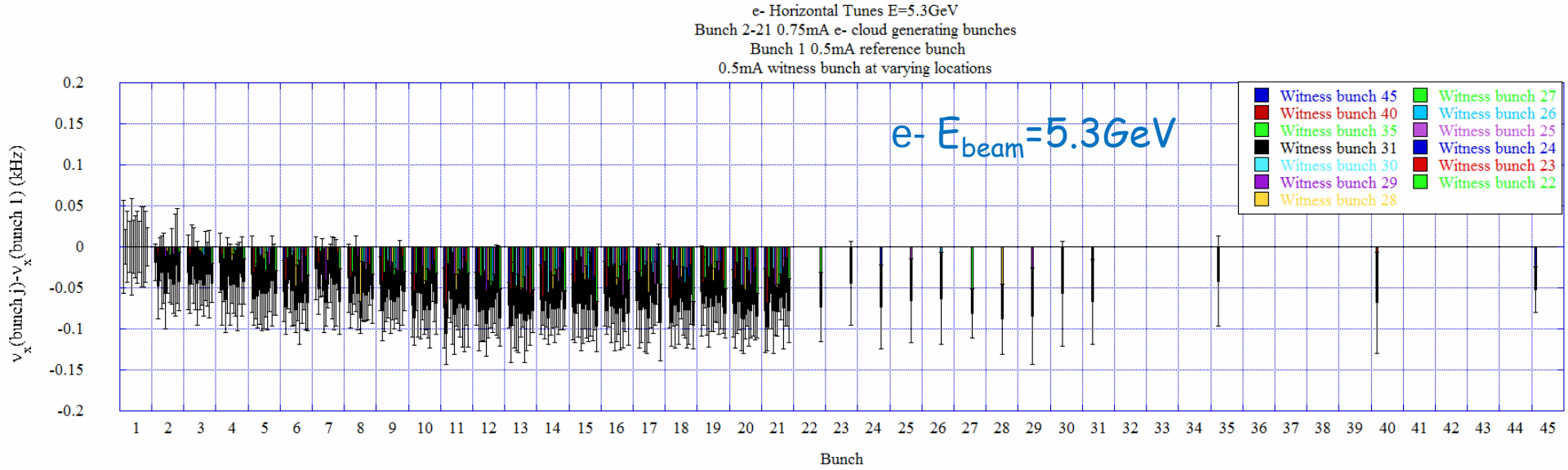




- e+ $\Delta\nu_y$~0.65kHz along generating train. The decay time of the vertical tune is ~150ns. Slope of the tune shift changes along the generating train. Tune measurement is repeatable!
- e- $\Delta\nu_y$~-0.22kHz along generating train which levels out ~bunch 16. The decay time of the vertical tune ~200ns. Note: In both cases the tune shift does not go to zero by bunch 45.

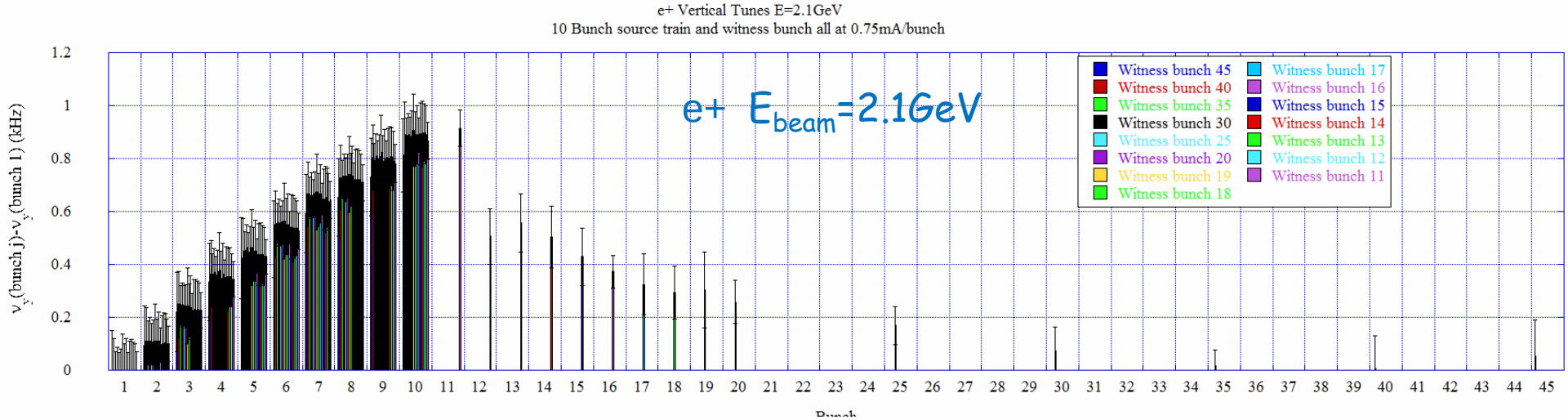
E=5.3GeV 20 bunch generating train@0.75mA/bunch, reference & witness bunch@0.5mA: ν_x

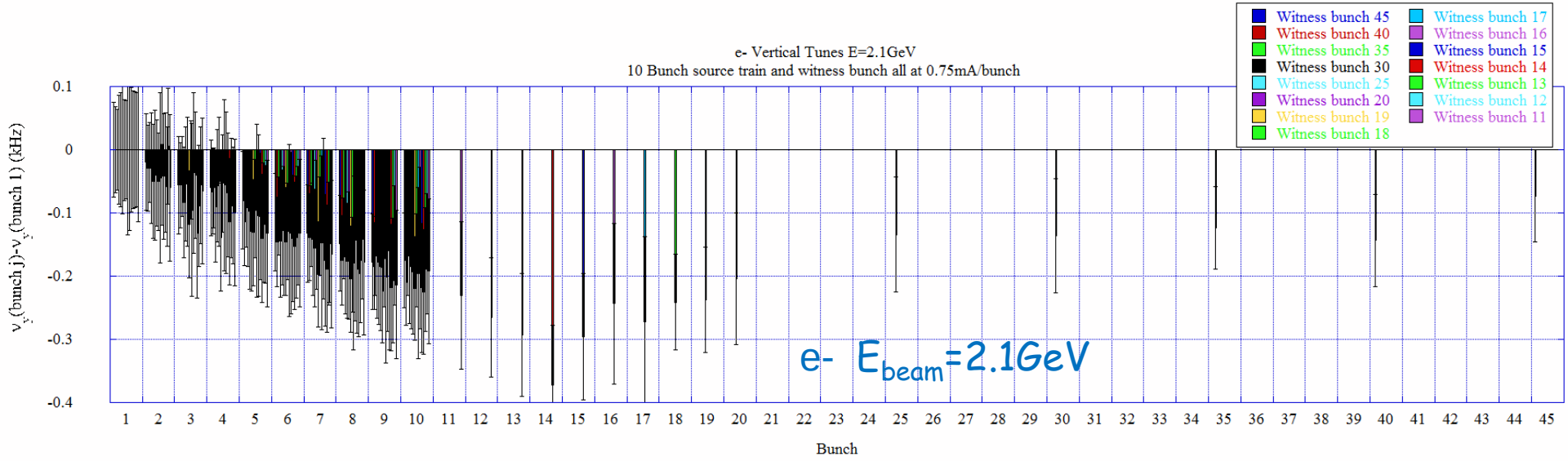




- e+ $\Delta\nu_x$~0kHz along generating train. Large scatter in the tune measurement for the witness bunches.
- e- $\Delta\nu_y$~–0.05kHz along generating train

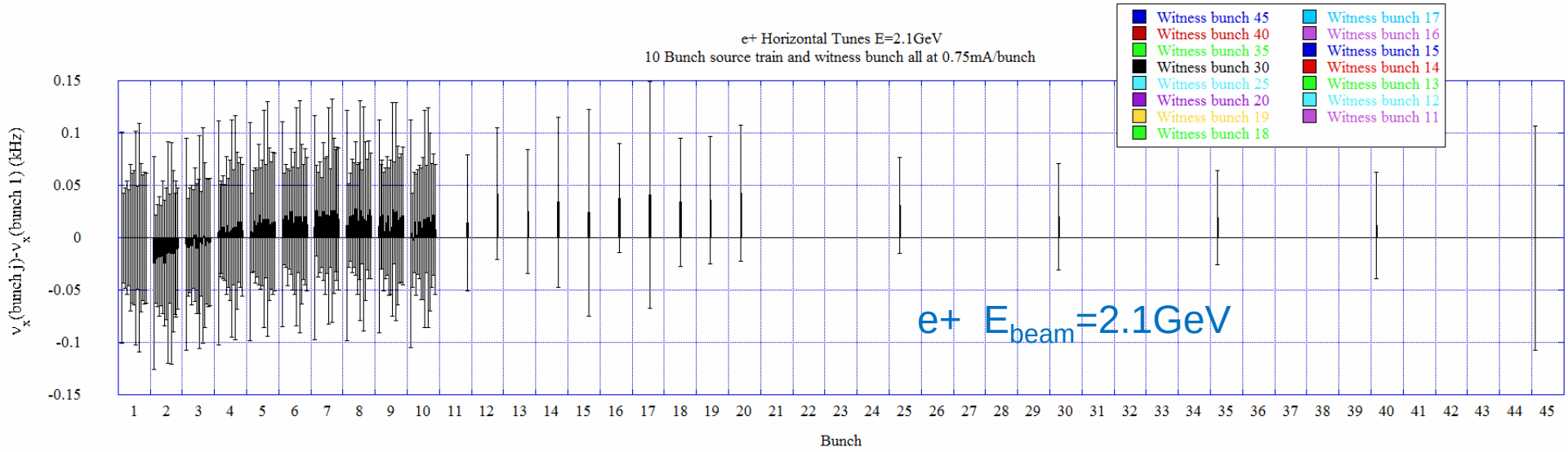
E=2.1GeV 10 bunch generating train and witness bunch@0.75mA/bunch: ν_y

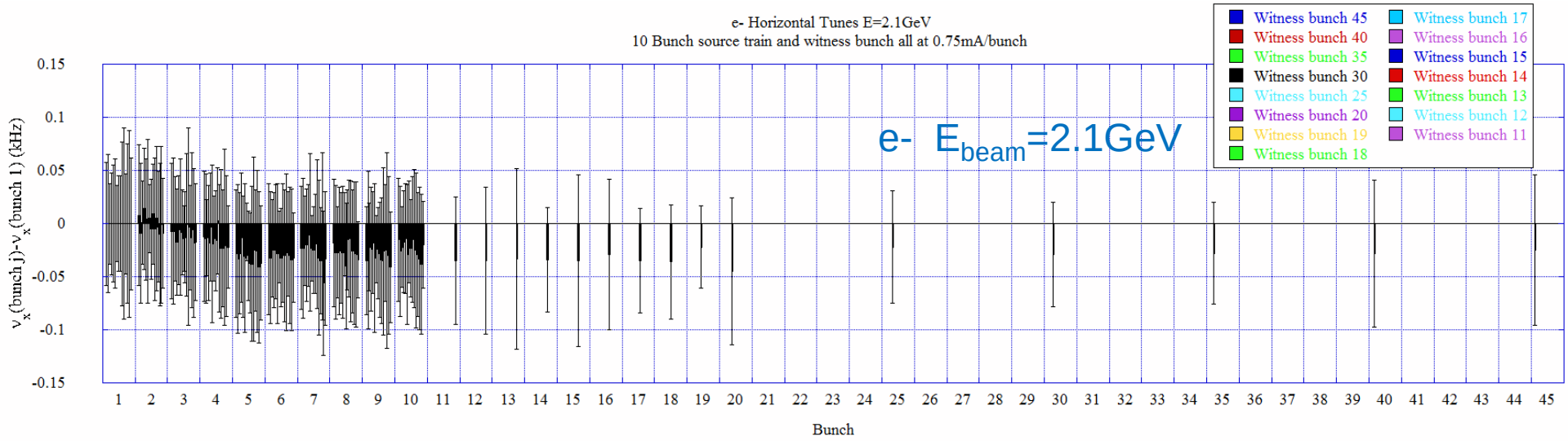




- e+ $\Delta\nu_y$~0.9kHz along generating train. The decay time tune shift is ~150ns.
- e- $\Delta\nu_y$~-0.2kHz along generating train. Tune shift continues to grow and reaches a maximum 4 bunches (56ns) later. The decay time of the tune shift ~400ns.

E=2.1GeV e+/e- 10 bunch generating train, reference, and witness bunch@0.75mA/bunch: ν_x





- e+/e- $\Delta\nu_y$~0kHz along generating train. Large scatter in the tune data.

V. Summary and Conclusions:

For e+ generating trains:

-vertical tune shift along generating train is positive and is larger at lower energy. The vertical tune shift saturation has not been observed.

-horizontal tune shift is small

For e- generating trains:

-vertical tune shift along generating train is negative and its magnitude is smaller than for e+ trains. No significant difference in vertical tune shift between low and high energy trains at low bunch current.

-horizontal tune shift is small

The decay time for the tune shift is approximately 200ns.

Next: We now have the capability to place witness bunches past bunch 45…more train patterns in the future!

I would like to acknowledge the hard work and dedication of the following people to make these experiments possible:

M. Billing, J. Calvey, CESR Operators, G. Codner, G. Dugan, M. Forster, R. Meller, M. Palmer, D. Rice (Cornell)

C.-Y. Tan, B. Zwaska (Fermilab)