

e⁺/e⁻ Vertical Beam Dynamics during CHESS Operation

- I. Introduction
- II. e⁺ turn-by-turn vertical dynamics
- III. e⁻ turn-by-turn vertical dynamics
- IV. Summary

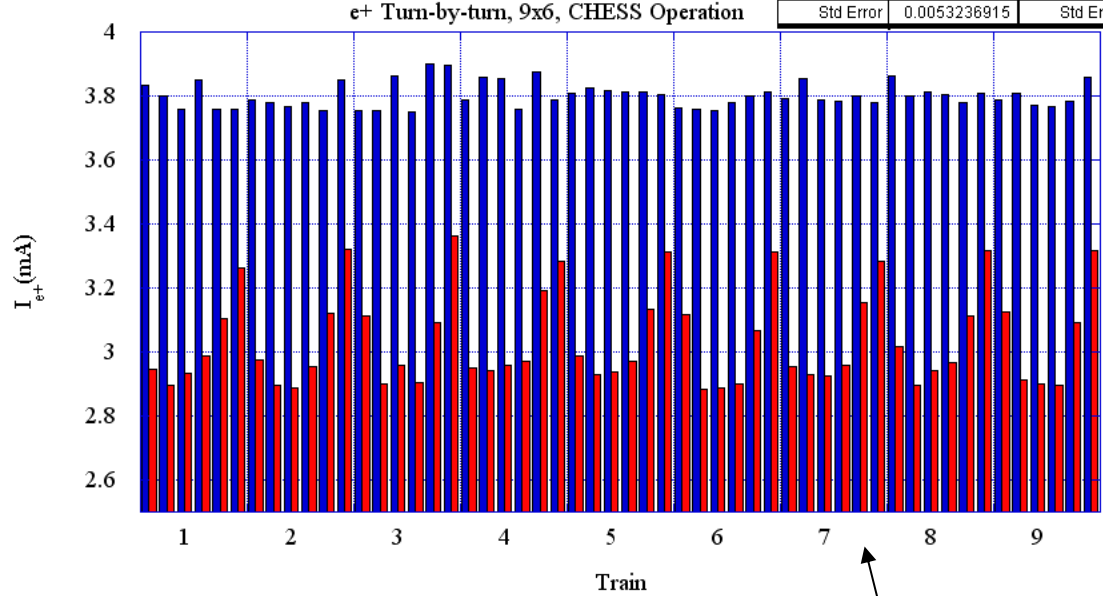
I. Introduction

e+/e- CHES
 9x6 Pattern
 Single bunch currents

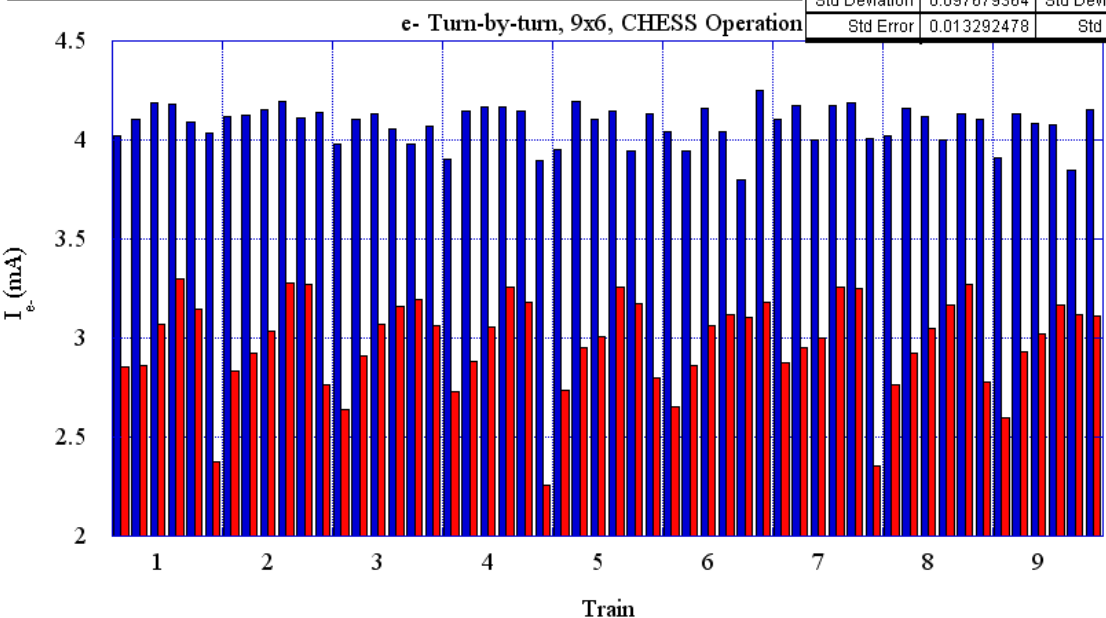
Turn-by-turn vertical beam distribution measurements made at the top and bottom of a CHES fill. $\Delta t=332$ min between measurements.

■ File:913 $I_{e^-}=220.34\text{mA}$ (4.08mA/bunch), $I_{e^+}=205.32\text{mA}$ (3.8mA/bunch)
 ■ File:915 $I_{e^-}=160.61\text{mA}$ (2.97mA/bunch), $I_{e^+}=164.05\text{mA}$ (3.04mA/bunch)

	e+ File:913	e+ File:915
I total (mA)	205.321	164.049
Mean	3.8022408	Mean 3.0379444
Std Deviation	0.039120983	Std Deviation 0.14671682
Std Error	0.0053236915	Std Error 0.01996563



	e- File:912	e- File:914
I total (mA)	220.341	I total (mA) 160.614
Mean	4.0803889	Mean 2.9743333
Std Deviation	0.097679364	Std Deviation 0.2421978
Std Error	0.013292478	Std Error 0.032958946



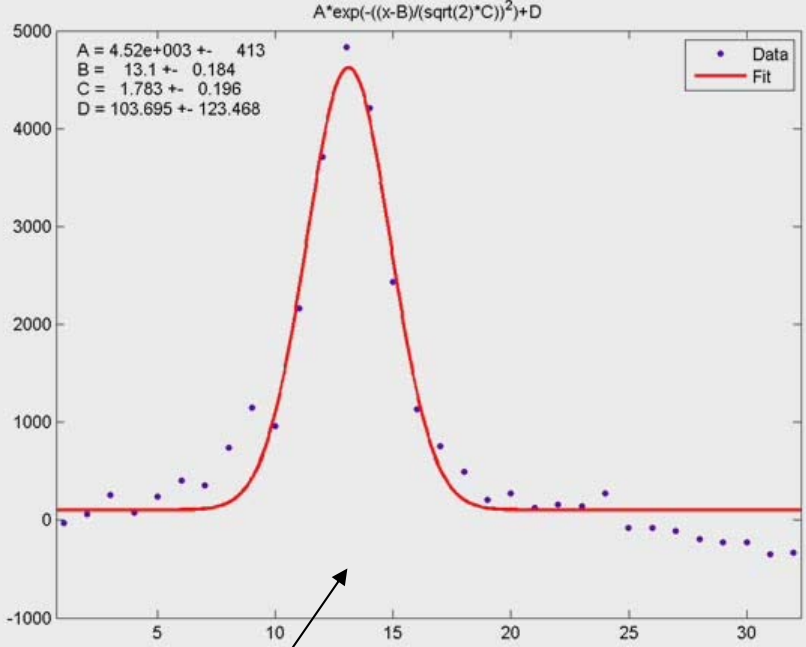
e+ current/bunch
 Lifetime grows along the train.

e- current/bunch
 Bunch 6 has a short lifetime.

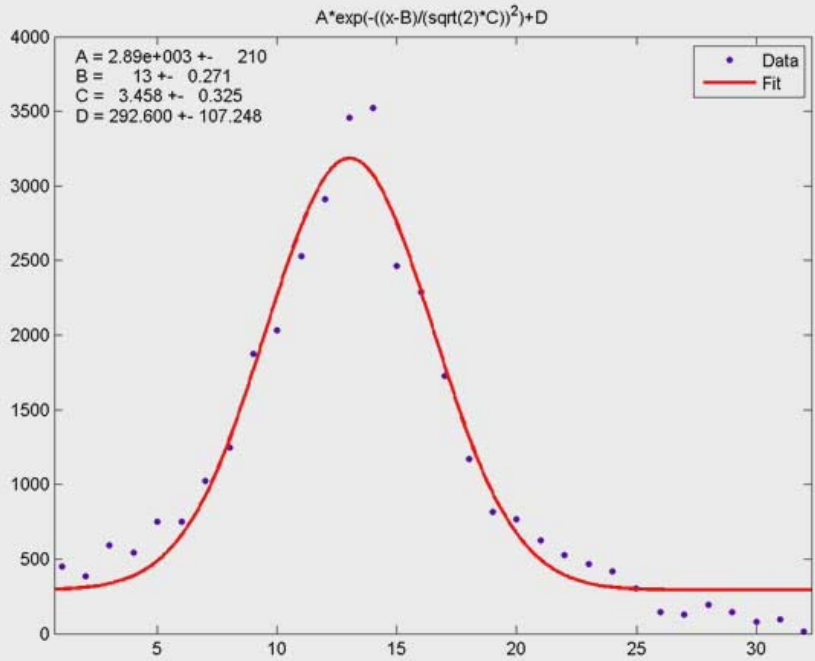
II. e+ turn-by-turn measurements

e+ single bunch vertical bunch distributions from the PMT array.

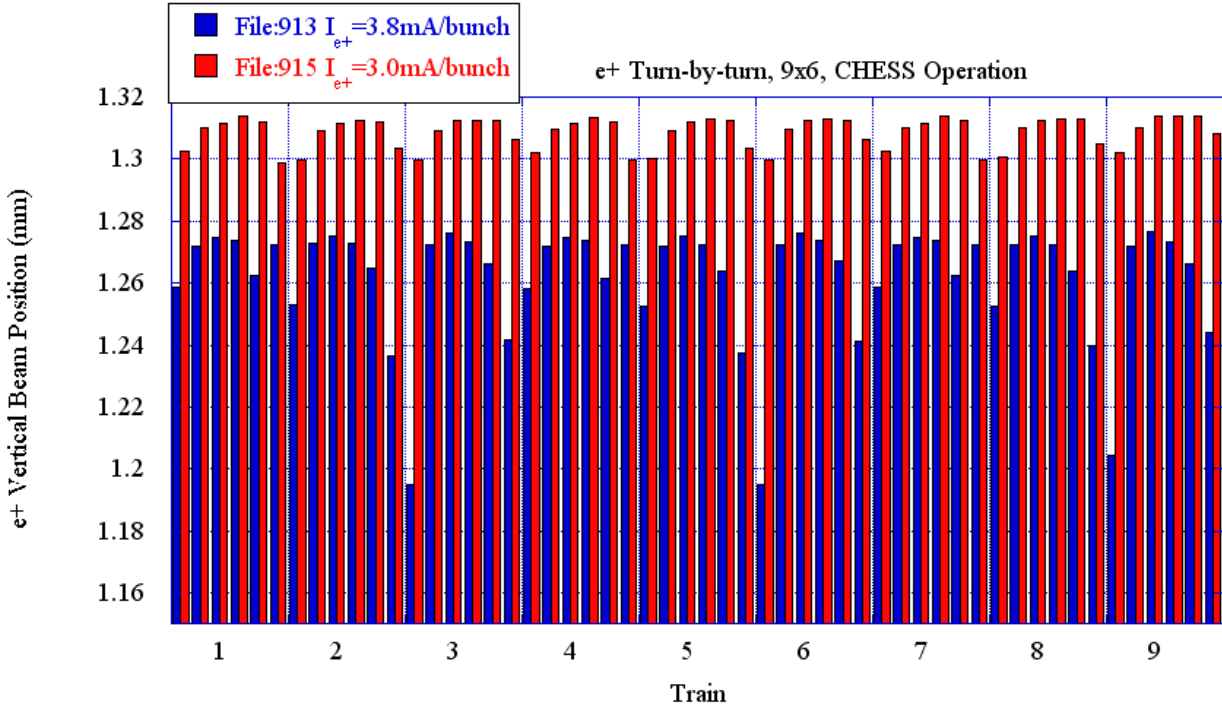
- 9,000 turns of all 54 e+/e- bunches.
- High I File:913 $I_{e+}=3.8\text{mA/bunch}$



e+ Bunch 1 Train 1
1st ten turns (movie)



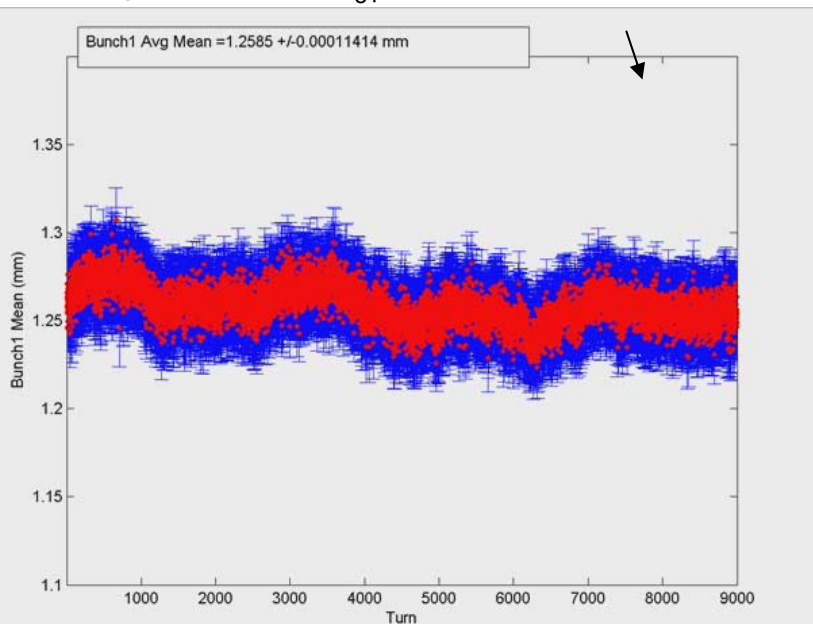
e+ Bunch 6 Train 2
1st ten turns (movie)



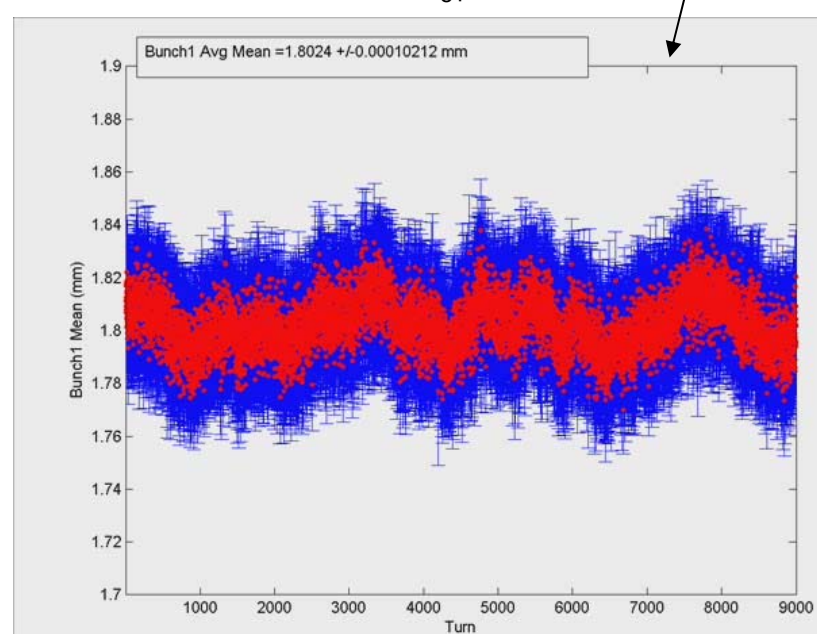
e+ Vertical Position

- e+ mean vertical position along the train-offset was included to have the plots coincide.
- Mean vertical position for 9,000 turns for 54 bunches.
- Low frequency vertical oscillation is denoted for all 54 bunches.
- At high I, a significant drop in vertical position is denoted for bunch 1 for several trains.

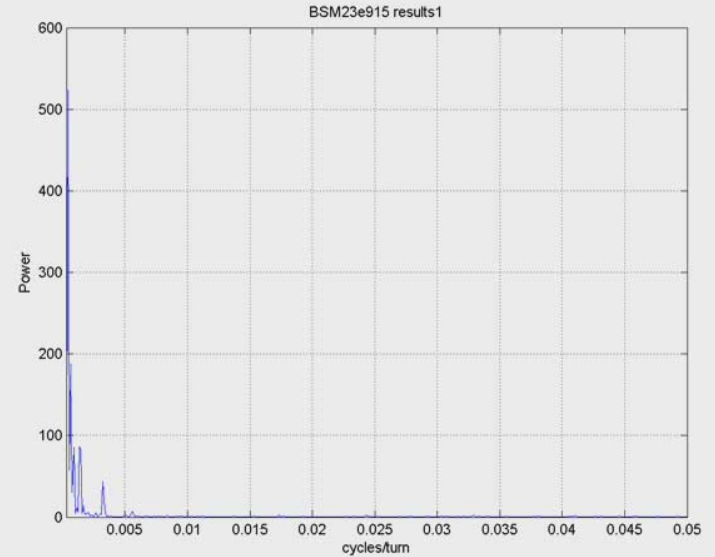
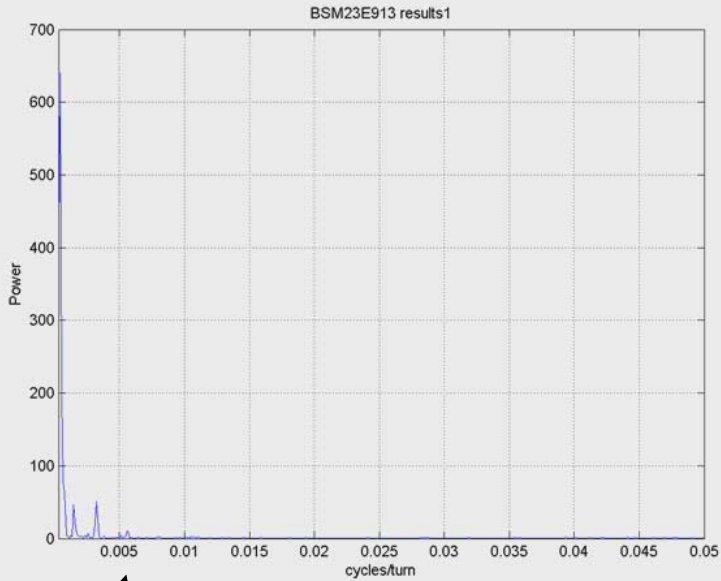
High I File:913 $I_{e^+} = 3.8 \text{ mA/bunch}$ (movie)



Low I File:915 $I_{e^+} = 3.0 \text{ mA/bunch}$ (movie)

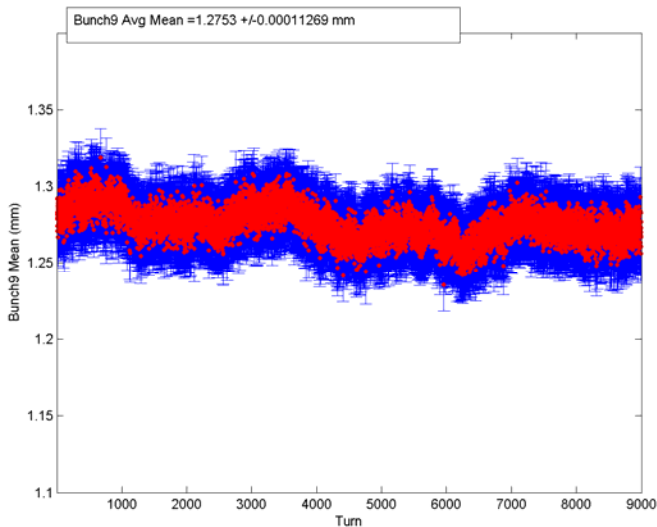


e+ low frequency vertical position oscillation- FFT of vertical position for 9,000 turns



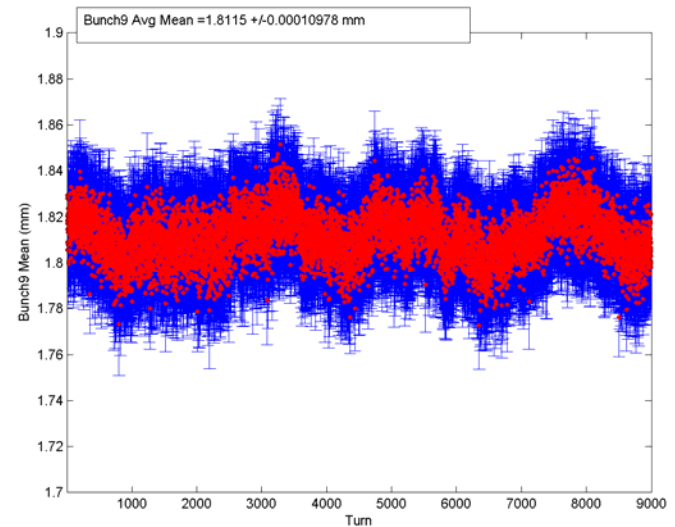
← movies →

High I File:913 $I_{e^+}=3.8\text{mA/bunch}$

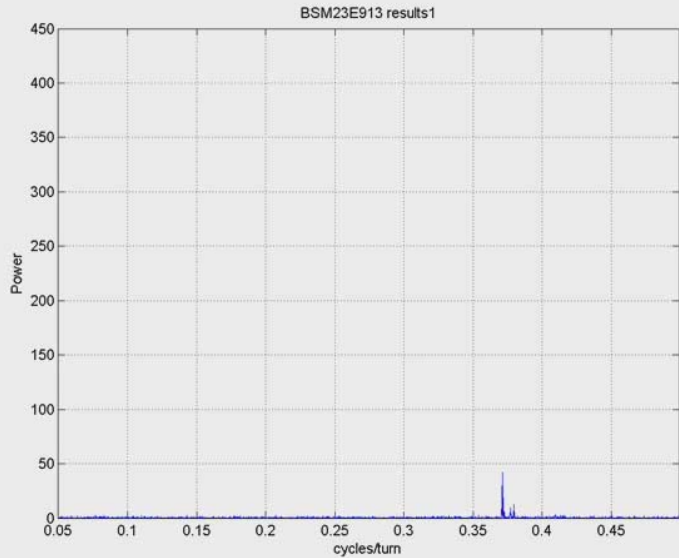


- FFT of vertical position for each bunch
- Vertical position oscillation frequency at ~ 2250 turns.
- At high I, vertical position appears occasionally at a frequency of ~ 20 turns

Low I File:915 $I_{e^+}=3.0\text{mA/bunch}$

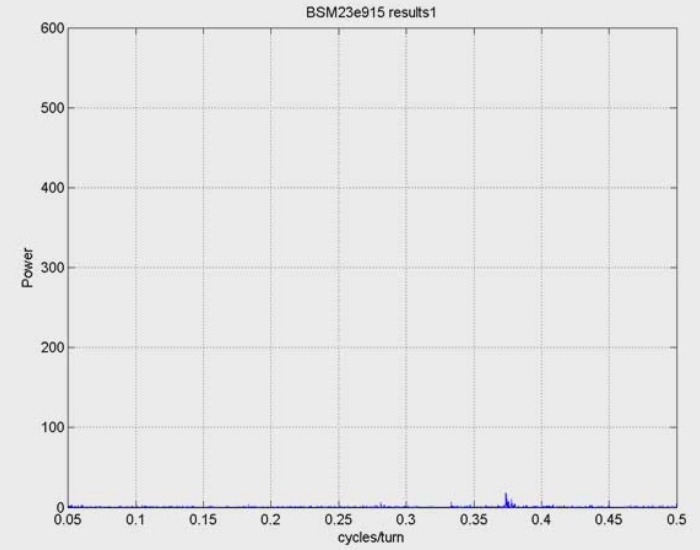


e+ high frequency vertical position oscillation-FFT of vertical position for 9,000 turns



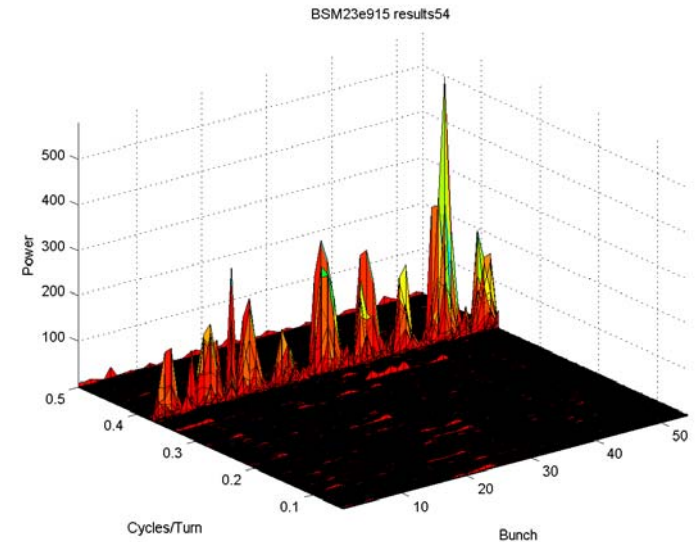
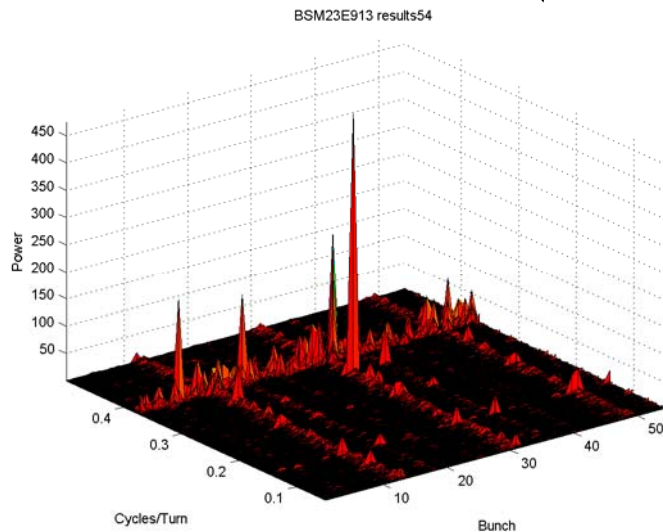
High I File:913 $I_{e^+}=3.8\text{mA/bunch}$

← movies →

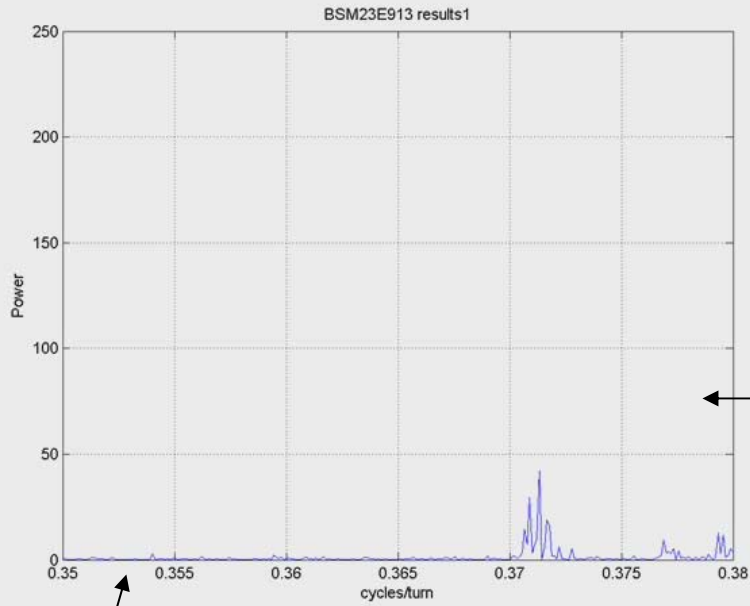


Low I File:915 $I_{e^+}=3.0\text{mA/bunch}$

- FFT of the vertical position.
- The vertical position oscillation frequency is denoted in the FFT spectrum.

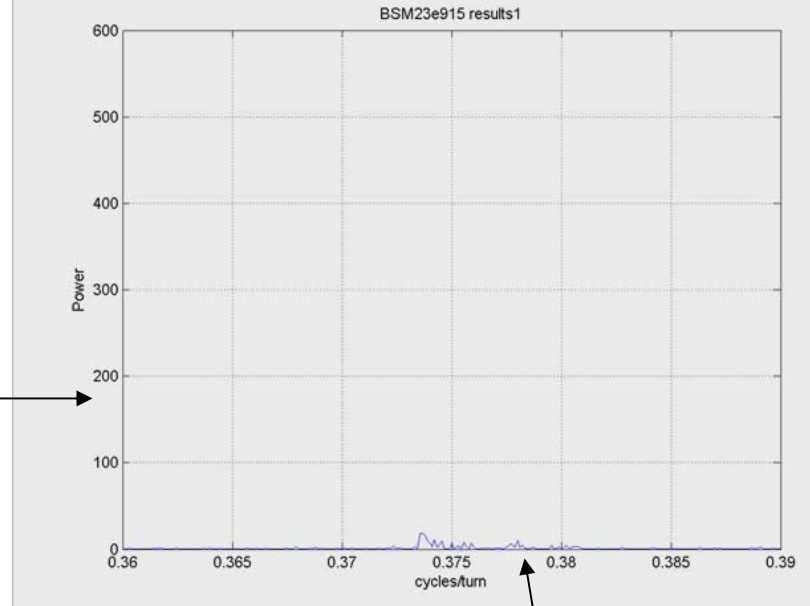


e+ high frequency position oscillation-close up of the oscillation frequency $f_{\text{oscillation}}$



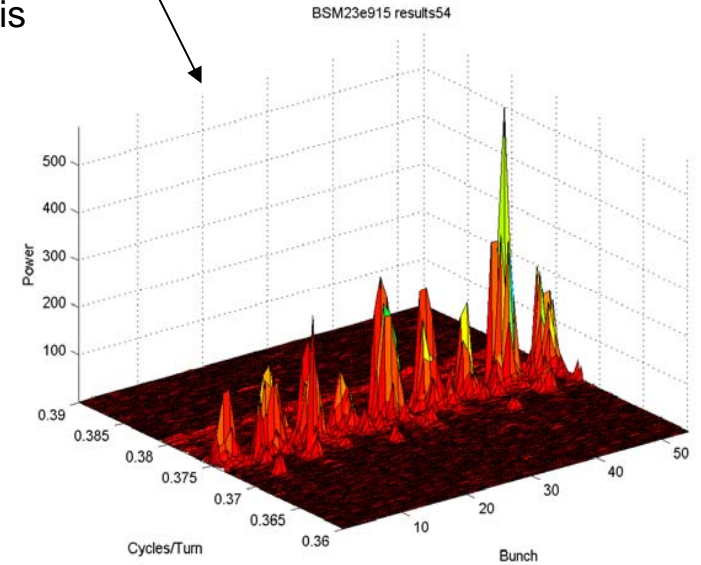
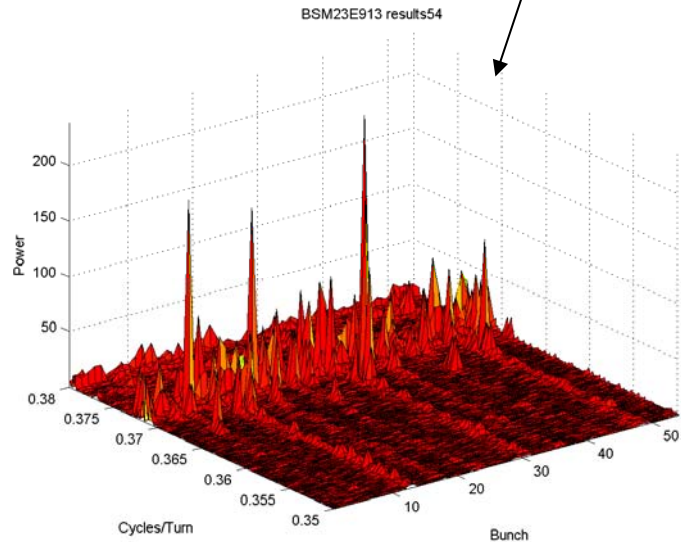
High I File:913 $I_{e^+}=3.8\text{mA/bunch}$

movies

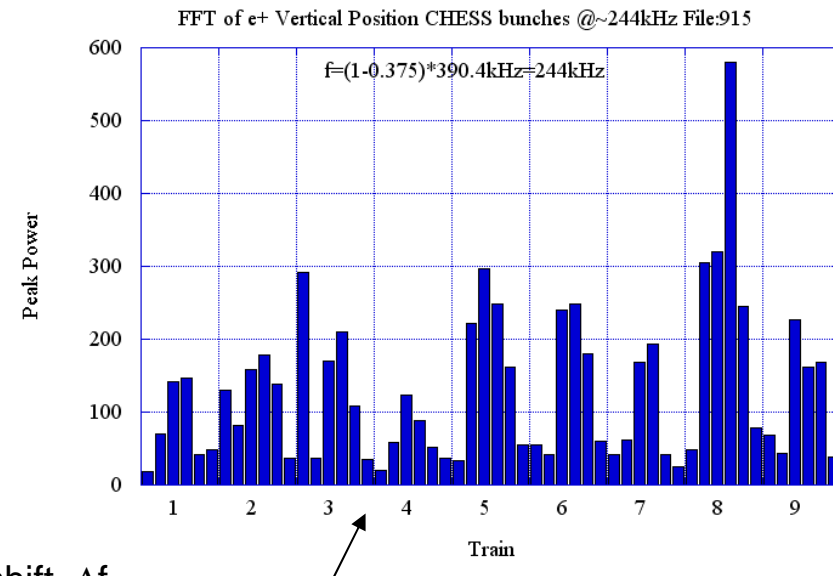
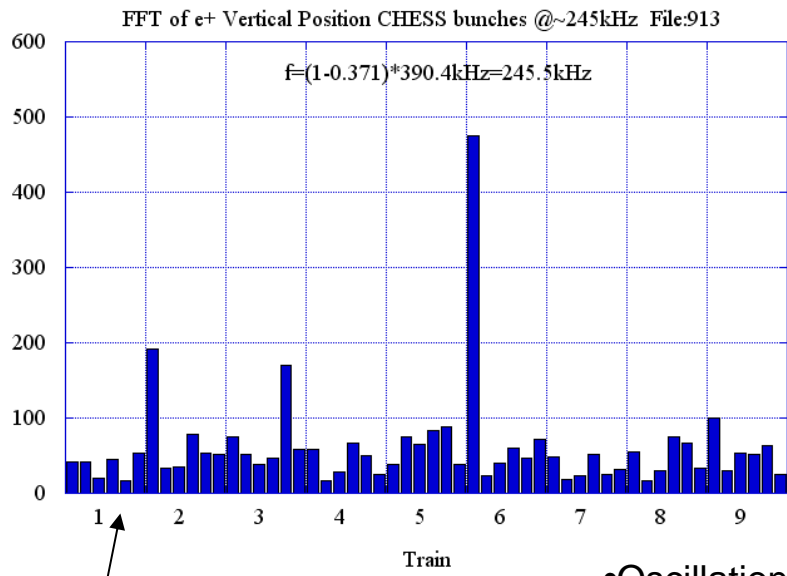


Low I File:915 $I_{e^+}=3.0\text{mA/bunch}$

•The vertical position oscillation frequency shifts slightly along the train. This shift grows larger with current.



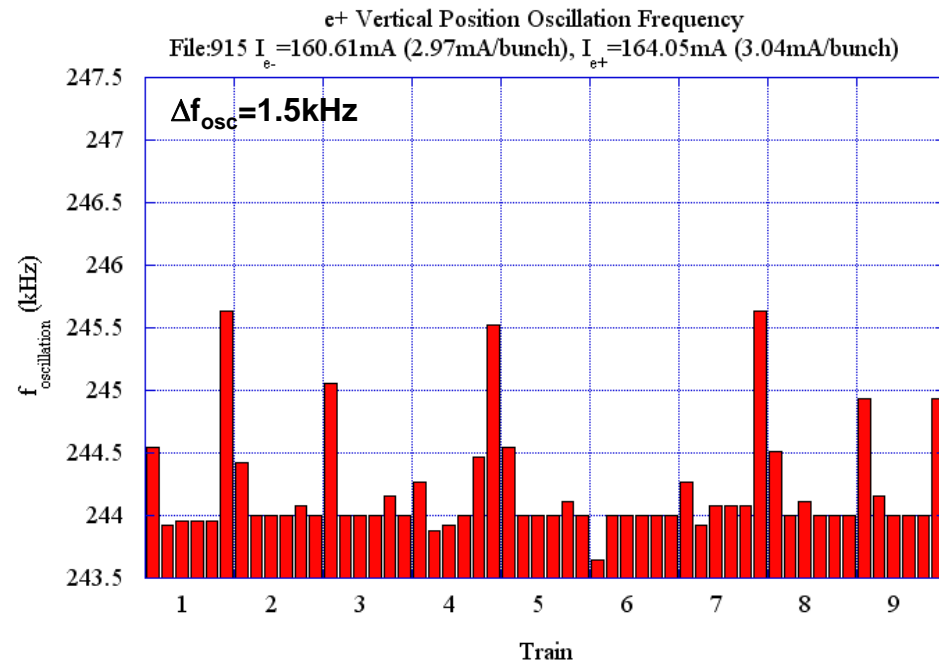
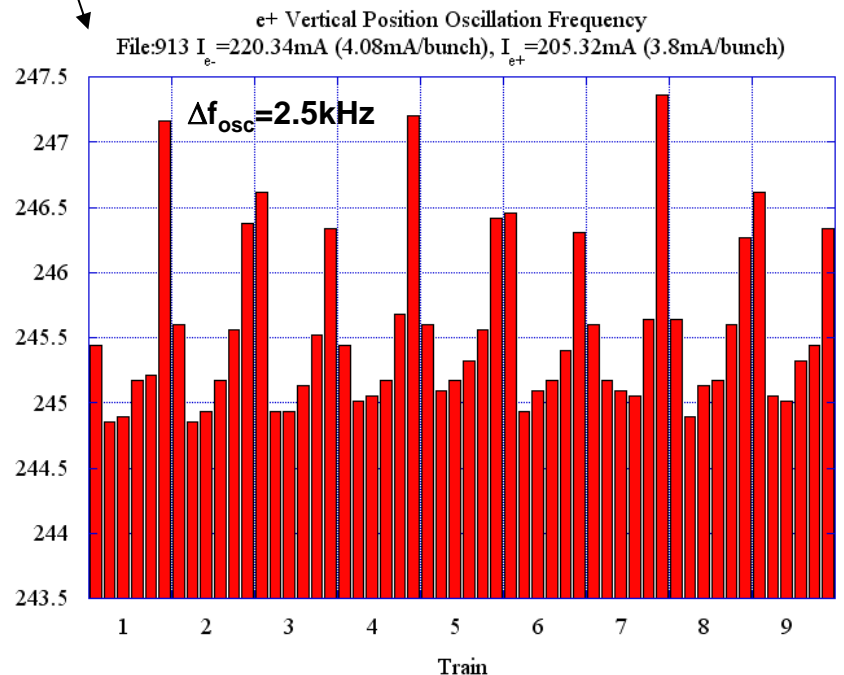
e+ high frequency vertical motion-Power and Frequency of Oscillation



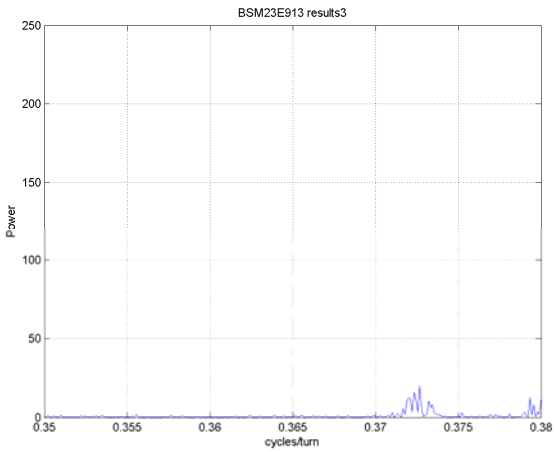
High I File:913 $I_{e^+}=3.8\text{mA/bunch}$

•Oscillation frequency shift, Δf_{osc} , along the trains is current dependent.

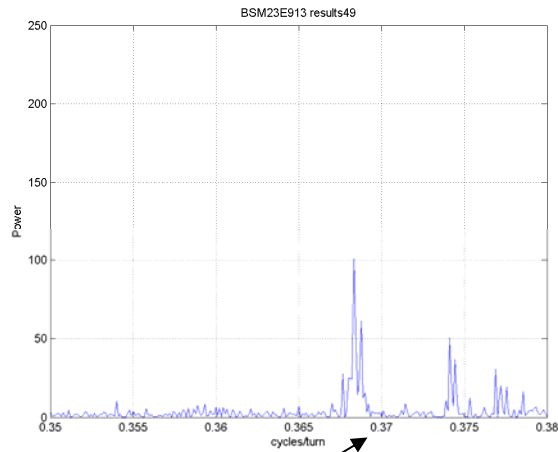
Low I File:915 $I_{e^+}=3.0\text{mA/bunch}$



e+ FFT power dependence on vertical position oscillation amplitude– High I

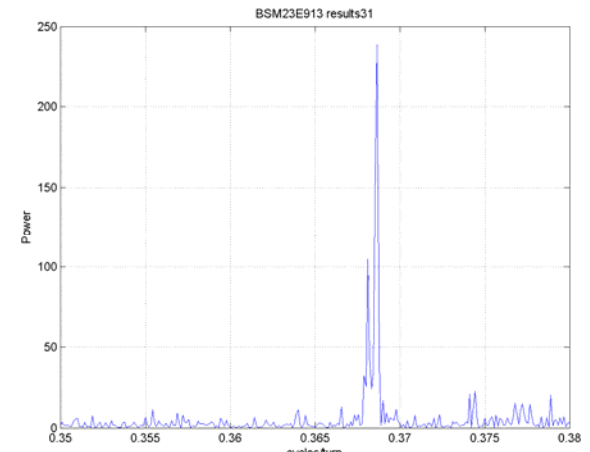


Bunch 3
Peak Power=20@244.9kHz
 $y_{avg}=1.275\text{mm}$
Std=0.011mm



Bunch 49
Peak Power=100@246.6kHz
 $y_{avg}=1.204\text{mm}$
Std=0.017mm

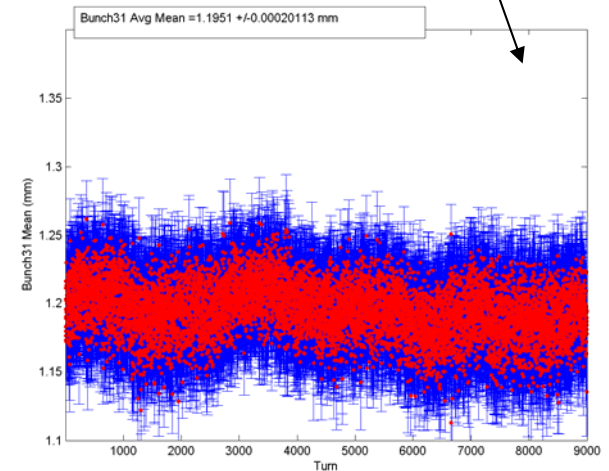
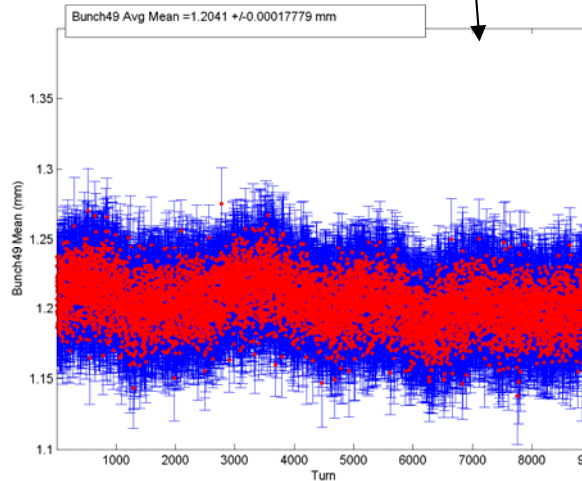
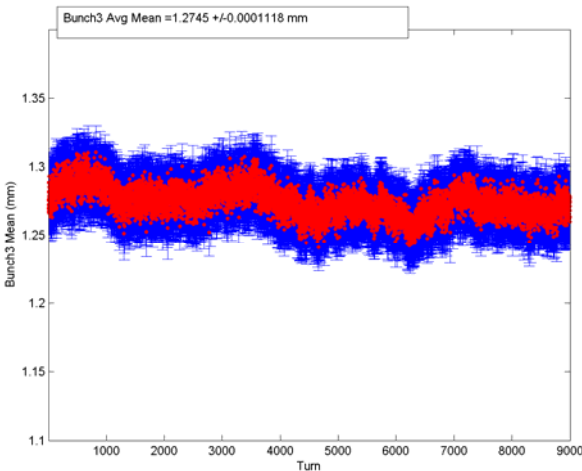
Noisy FFT spectrum background



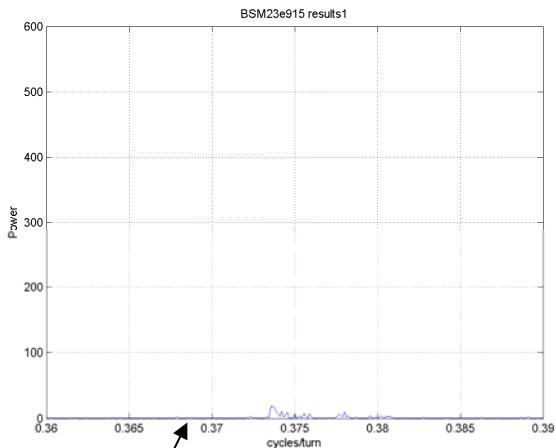
Bunch 31
Peak Power=475@260.3kHz
 $y_{avg}=1.195\text{mm}$
Std=0.0191mm

Noisy FFT spectrum background

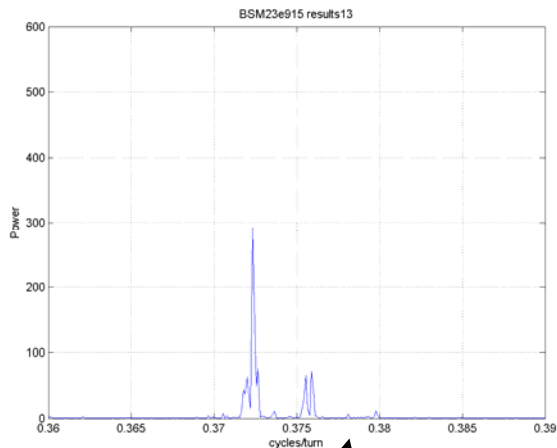
File:913 $I_{e+}=3.8\text{mA/bunch}$
•Noisy FFT spectrum correlates to increased vertical position oscillation amplitude.



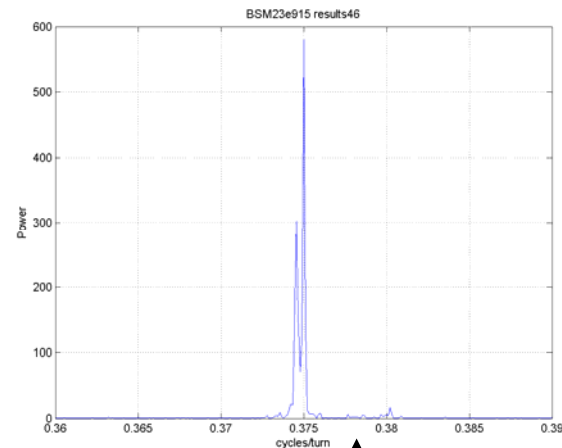
e+ FFT power dependence on vertical position oscillation amplitude– Low I



Bunch 1
Peak Power=19@244.5kHz
 $y_{avg}=1.802\text{mm}$
Std=0.009mm



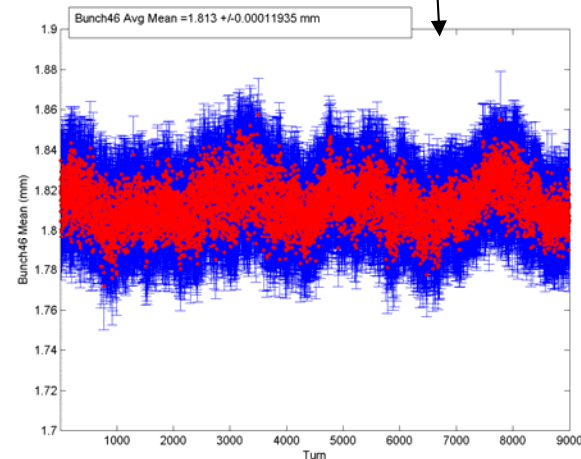
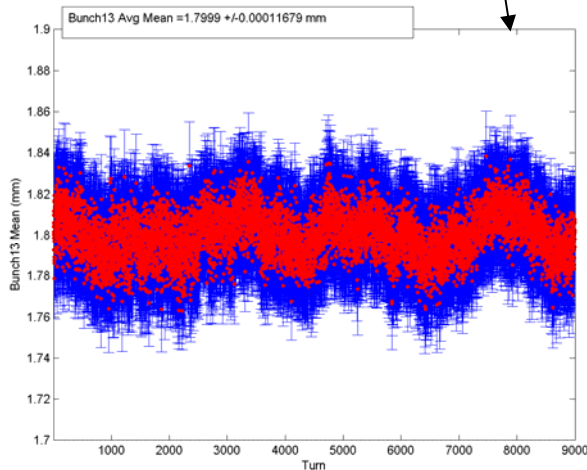
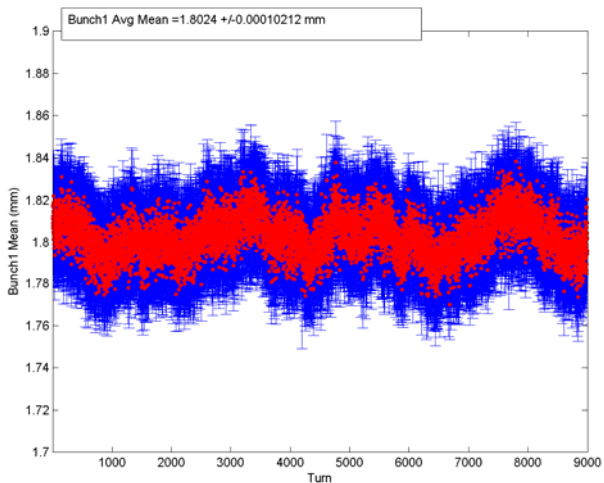
Bunch 13
Peak Power=292@245.1kHz
 $y_{avg}=1.80\text{mm}$
Std=0.011mm

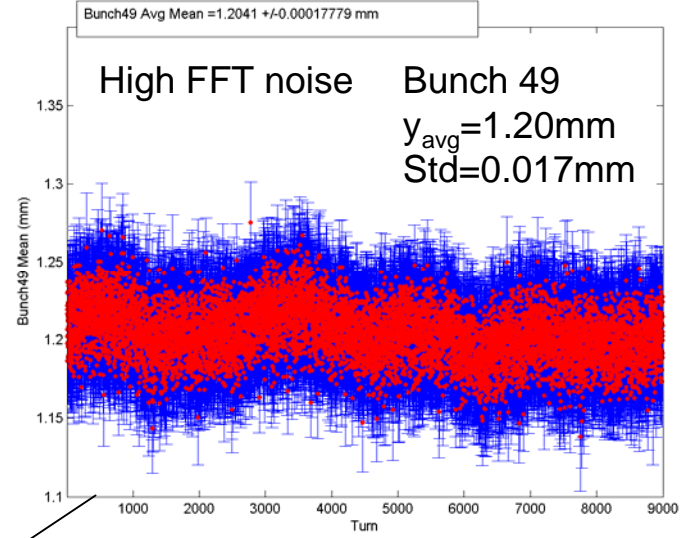
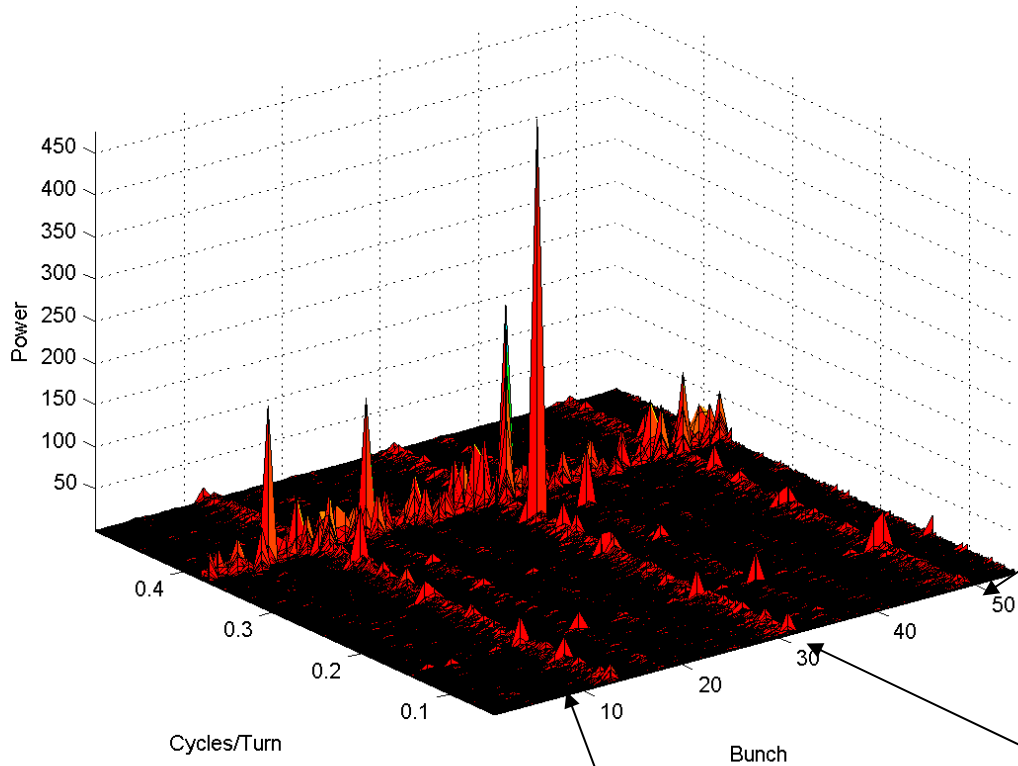


Bunch 46
Peak Power=580@244kHz
 $y_{avg}=1.813\text{mm}$
Std=0.011mm

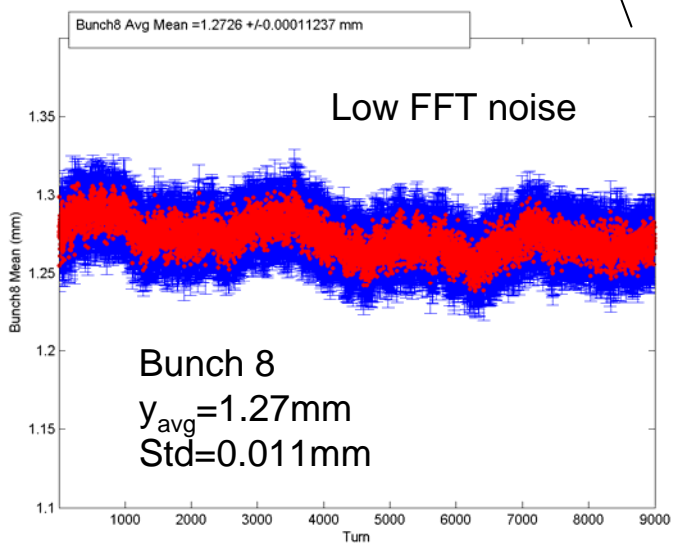
File 915 $I_{e+}=3.0\text{mA/bunch}$
•Slight increase of vertical position oscillation amplitude noted in FFT spectrum

Reduced FFT spectrum noise

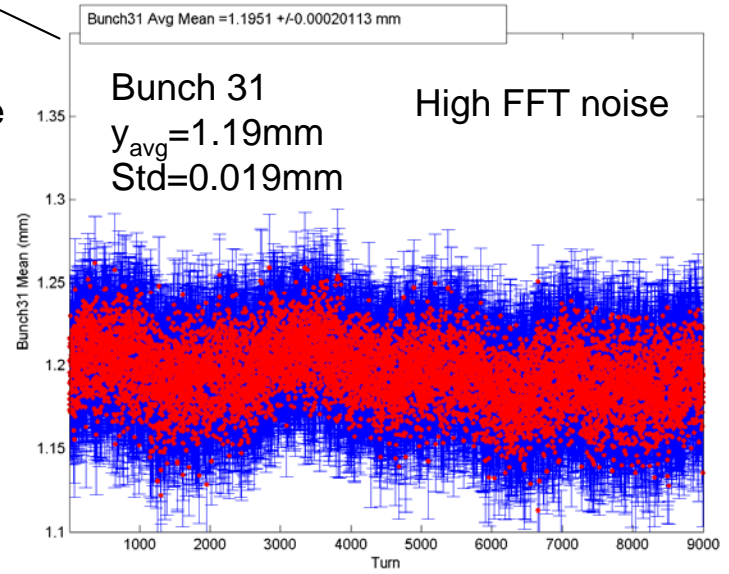




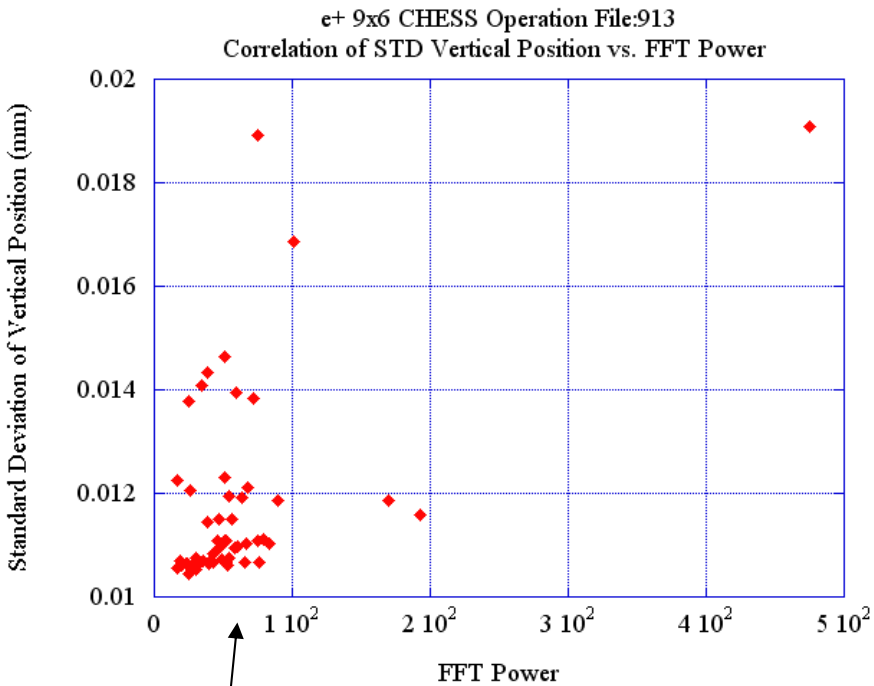
e+ high frequency vertical motion
 High I File:913 $I_{e+} = 3.8\text{mA/bunch}$



Several bunches oscillate over a wide frequency spectrum-particularly bunches 12,31,49 (noisy FFT spectrum).



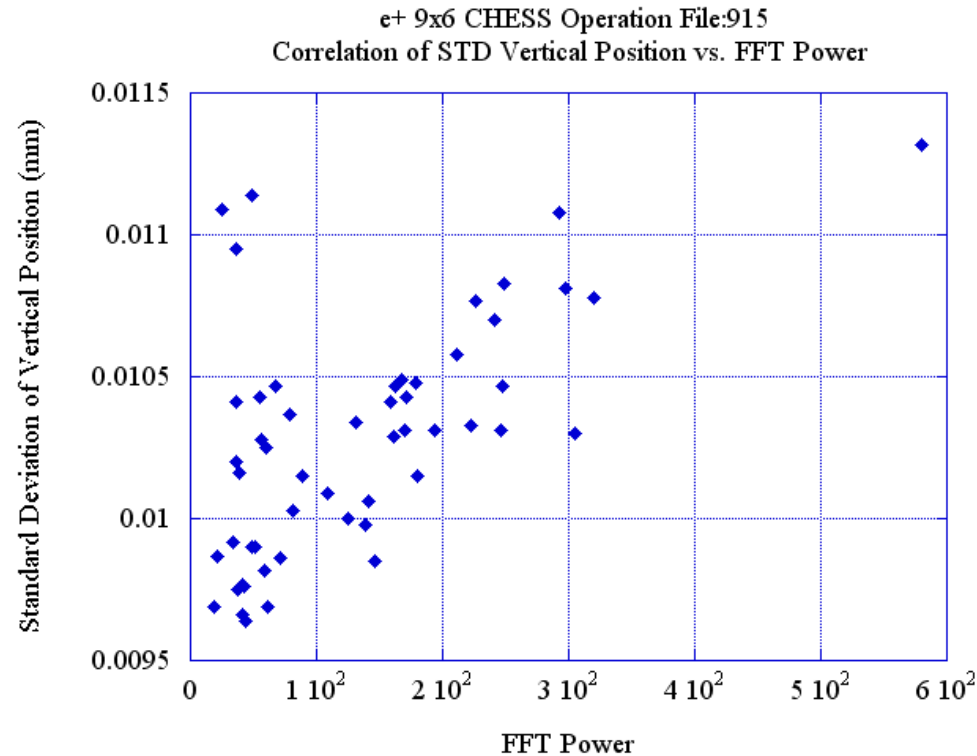
e+ vertical position oscillation amplitude

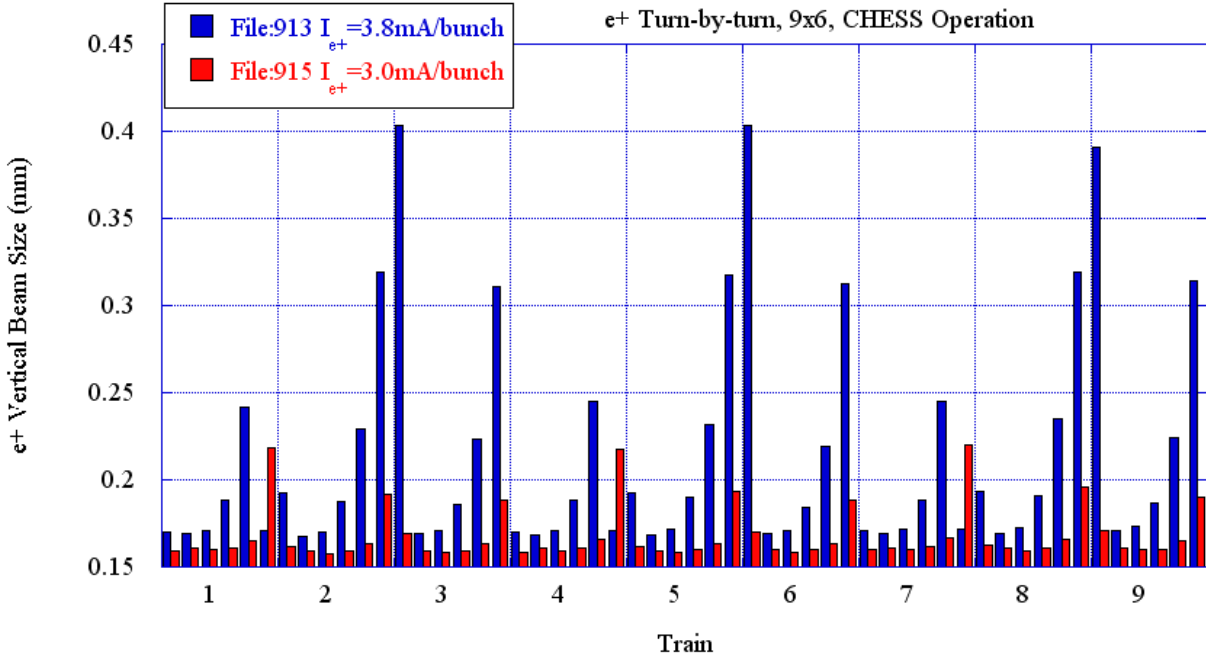


High I File:913 $I_{e^+}=3.8\text{mA/bunch}$

Low I File:915 $I_{e^+}=3.0\text{mA/bunch}$

e+ vertical position oscillation amplitude does not correlate with FFT power. Instead, the amplitude increases with FFT noise.

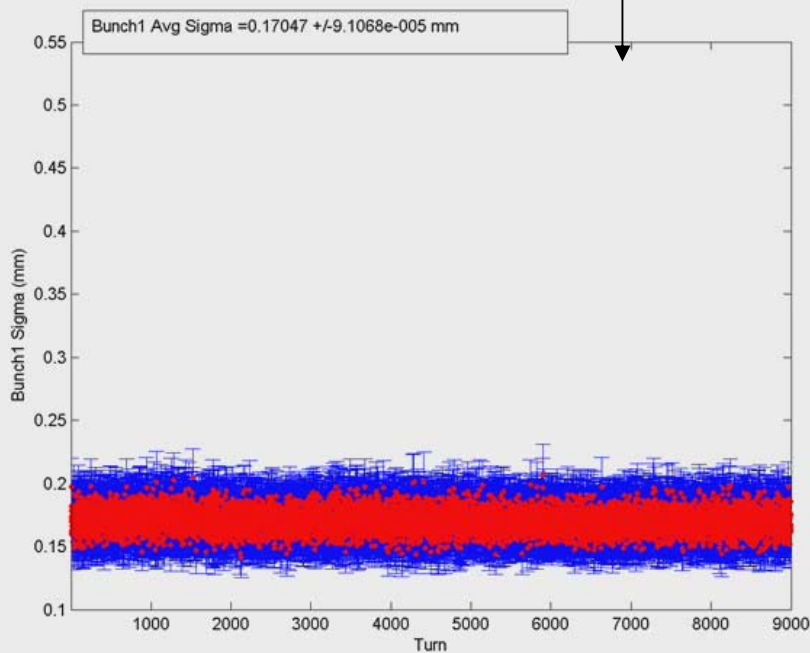




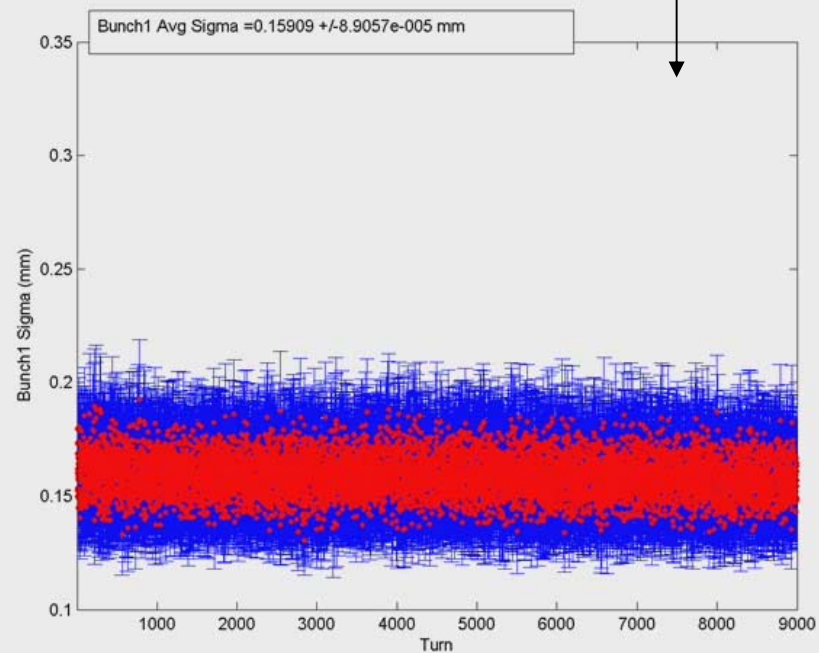
e+ σ_v along the train

- σ_v 9,000 turns for 54 bunches.
- Significant vertical beam size growth along each train-especially at high I

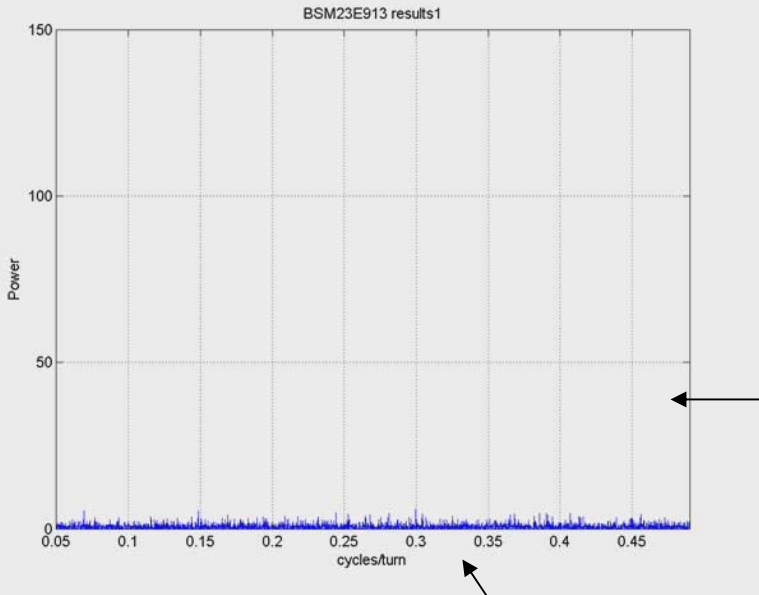
High I File:913 $I_{e^+} = 3.8\text{mA/bunch}$ (movie)



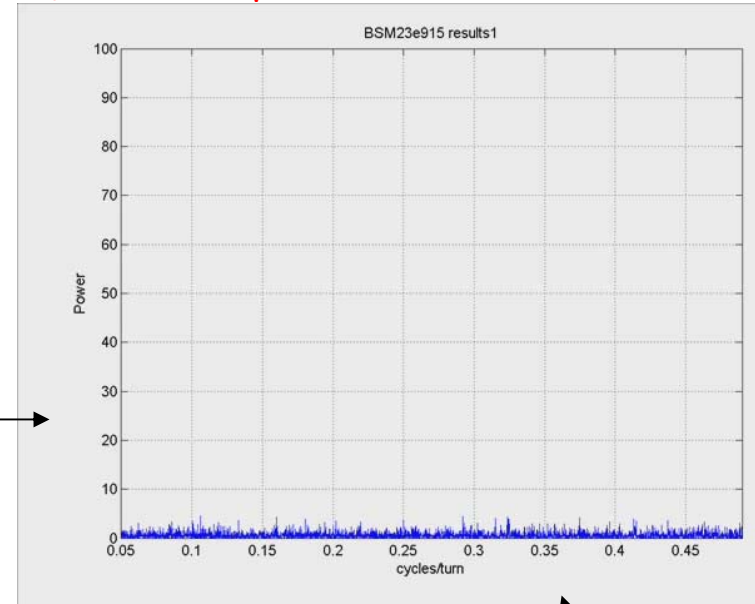
Low I File:915 $I_{e^+} = 3.0\text{mA/bunch}$ (movie)



e+ high frequency σ_v oscillation frequency-FFT of σ_v for 9,000 turns



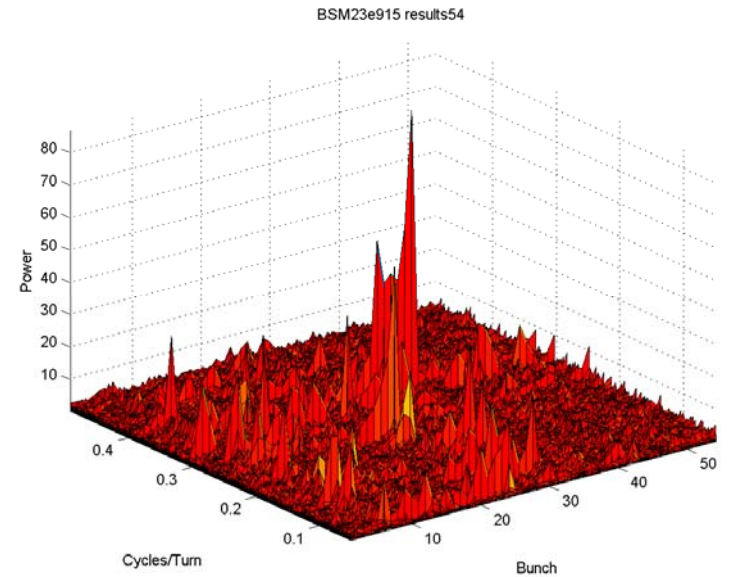
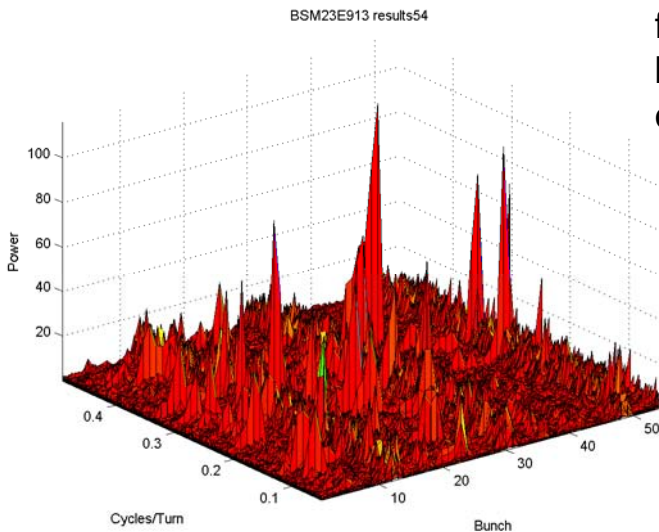
High I File:913 $I_{e^+}=3.8\text{mA/bunch}$



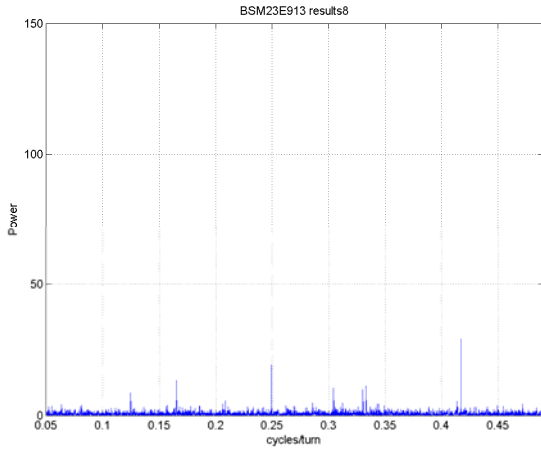
Low I File:915 $I_{e^+}=3.0\text{mA/bunch}$

movies

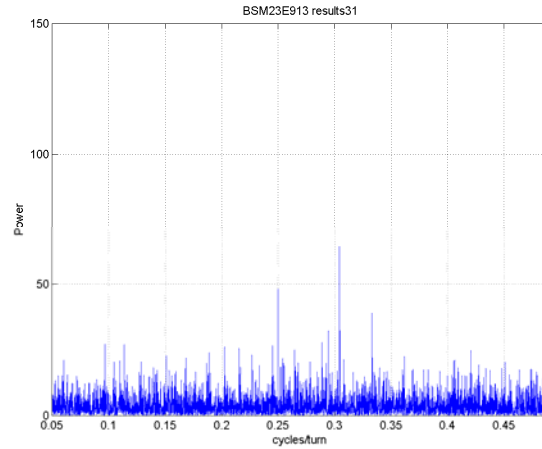
- FFT of σ_v for all 54 bunches
- No clear oscillation frequency in the vertical beam size-incoherent oscillation.



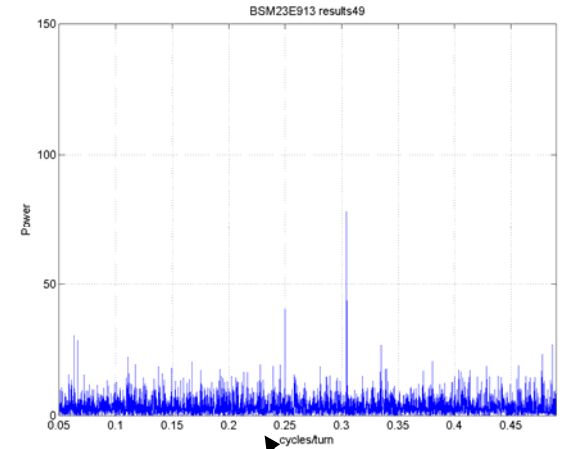
e+ high frequency σ_v oscillation frequency - FFT of σ_v - High I



Bunch 8
 Peak Power=29@227.5kHz
 $\sigma_v=0.168\text{mm}$
 Std=0.009mm

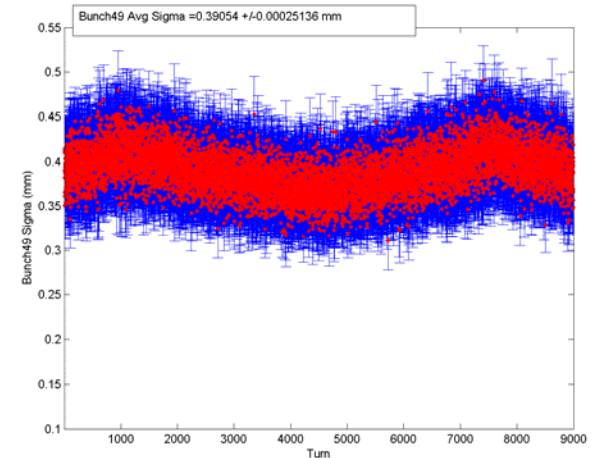
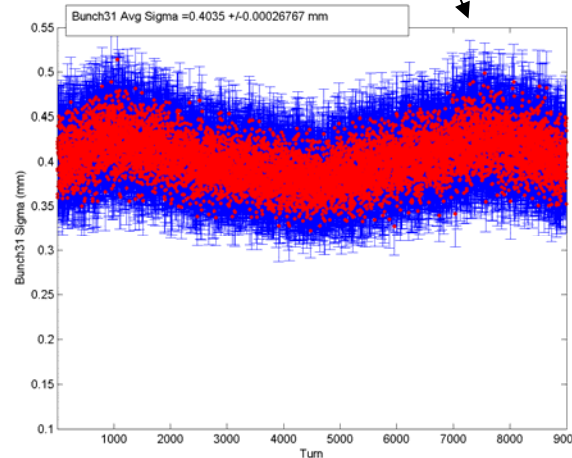
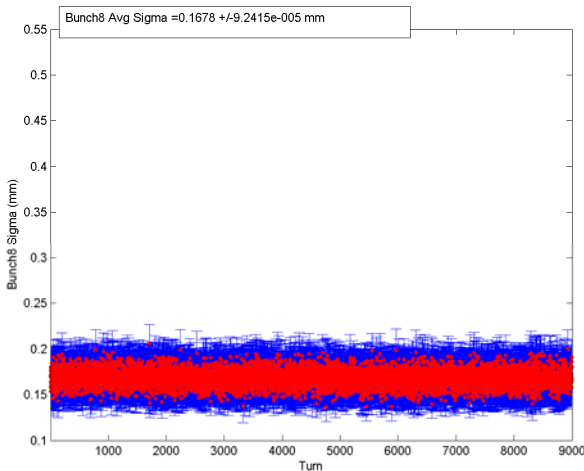


Bunch 31
 Peak Power=65@271.6kHz
 $\sigma_v=0.404\text{mm}$
 Std=0.025mm

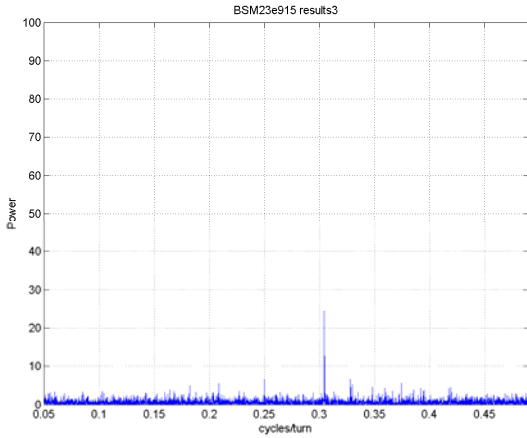


Bunch 49
 Peak Power=78@271.6kHz
 $\sigma_v=0.391\text{mm}$
 Std=0.024mm

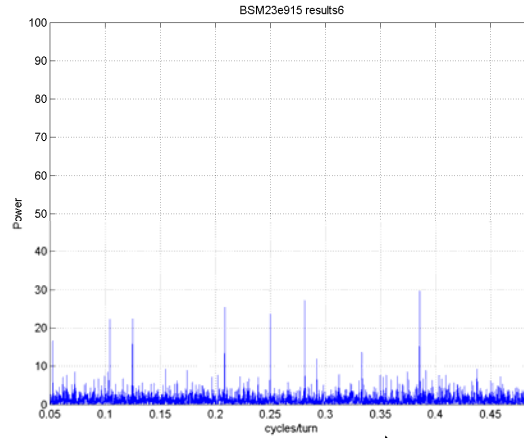
File 913 $I_{e^+}=3.8\text{mA/bunch}$
 • Noisy FFT spectrum correlates with an increased σ_v .



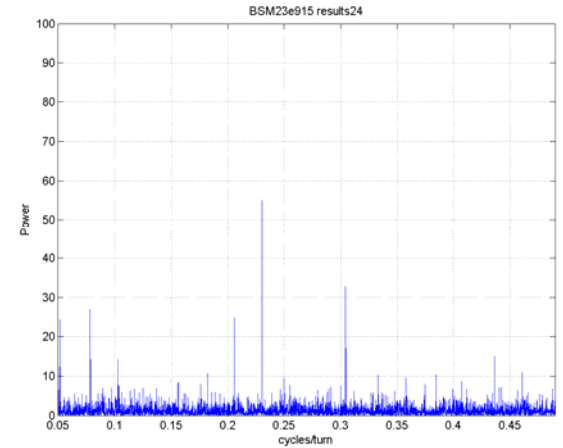
e+ high frequency σ_v oscillation frequency- FFT of σ_v - Low I



Bunch 3
 Peak Power=24@271.6kHz
 $\sigma_v=0.160\text{mm}$
 Std=0.009mm



Bunch 6
 Peak Power=30@239.9kHz
 $\sigma_v=0.219\text{mm}$
 Std=0.012mm



Bunch 24
 Peak Power=55@300.5kHz
 $\sigma_v=0.217\text{mm}$
 Std=0.012mm

File 915 $I_{e+}=3.0\text{mA/bunch}$
 • At low I the vertical beam size growth is reduced (still correlates with FFT noise).
 σ_v is largest for last bunch in each train.

