ATF Damping Ring in 2010 autumn
Multibunch instability study

2011.1.13

Measurement (S. Kuroda, T. Naito and K. Kubo) and
Calculation of ion trapping (Kubo)

Damping Ring in 2010 autumn

- For single bunch, DR Emittance and Stability are good enough for the 1st goal (small spot size at IP).
- Emittance
  - As usual, emitt_y was 10 -15 pm. (X-SR mon.)
    - Laser wire in DR did not work well. (Detector was changed for Laser-Compton study.)
  - Beta-function looks OK.
  - No important change since June 2010.
- BPM worked for COD and 1-turn. But turn-by-turn data could not be taken.
- Multi-bunch instability was studied. (2~3 shifts)

Multi-bunch instability Measurement in Nov. 2010

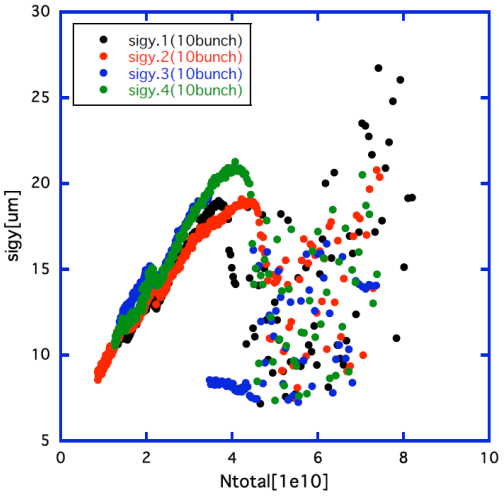
- Change number of trains, number of bunches/train and charge/bunch
- Measure beam size using X-SR profile monitor
  - Gate timing width 20 ms → Transverse oscillation is observed as beam size blow up.
- Turn-by-turn BPM did not work very well, but some oscillation could be observed.
- No time for preparation/tuning of Laser Wire Nonitor, which could have measured bunch-by-bunch projected beam size.
- Data taken on Nov. 10 (bad vacuum around kicker, large v-emittance) and 17 (better vacuum, small v-emittance)

Observation 1

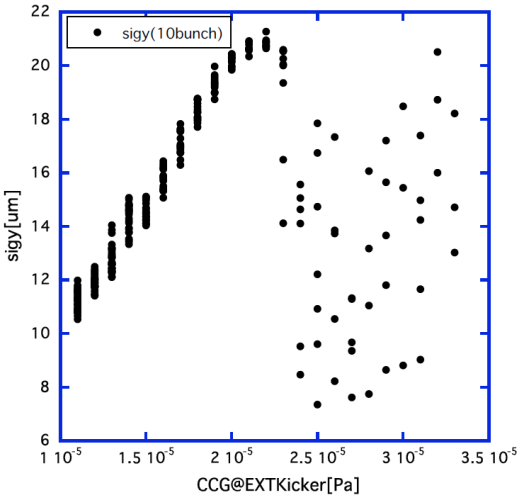
- No significant blow up (vertical oscillation) in one-train and two-train modes
  - up to 10-bunch/train and ~0.4E10 particle/bunch
- No significant blow up in three-train mode up to 3-bunch/train
  - up to ~0.4E10 particle/bunch
- Blow up (vertical oscillation) observed in three-train mode from 6-bunch to 10 bunch/train
  - Beam size (oscillation amplitude) depend on bunch intensity for each beam config.. But not monotonically.

3-train mode

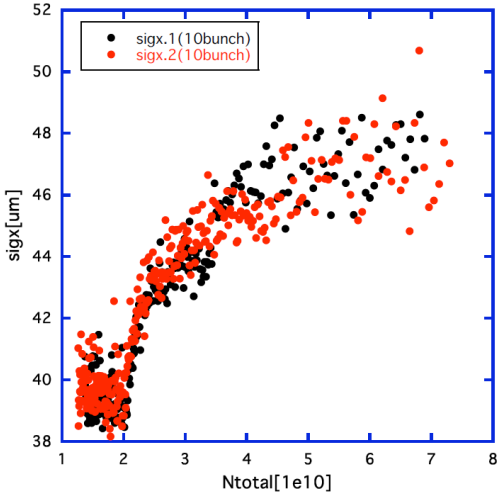
10 bunch σ_y vs I_{total}



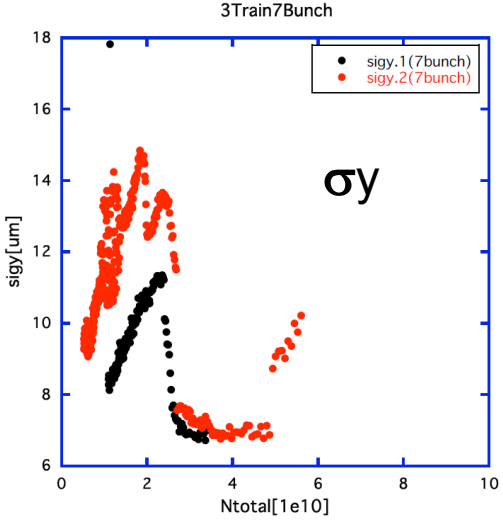
σ_y vs vac pressure$_{EXT\ Kicker}$



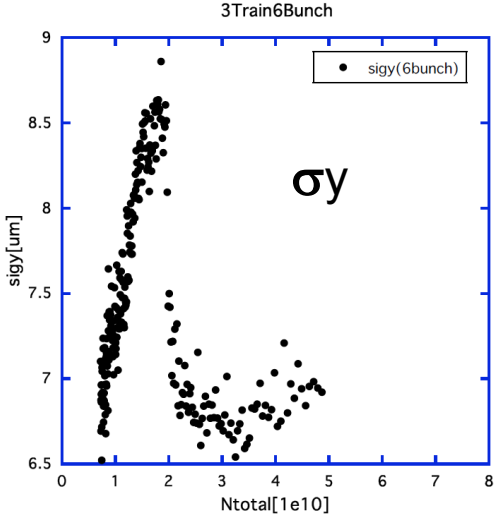
σ_x vs I_{total}



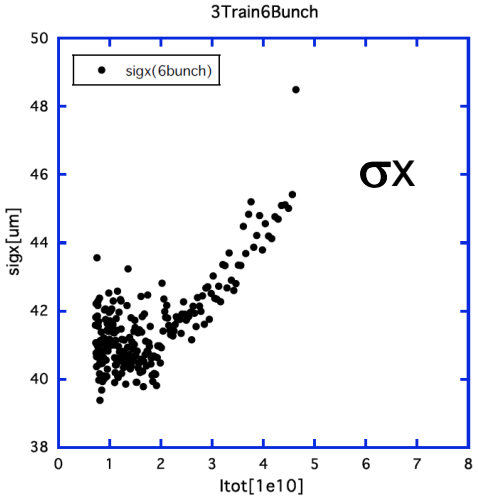
7 bunch



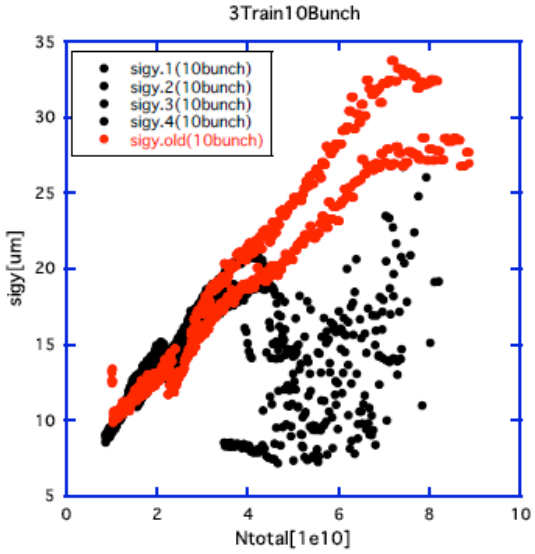
6 bunch

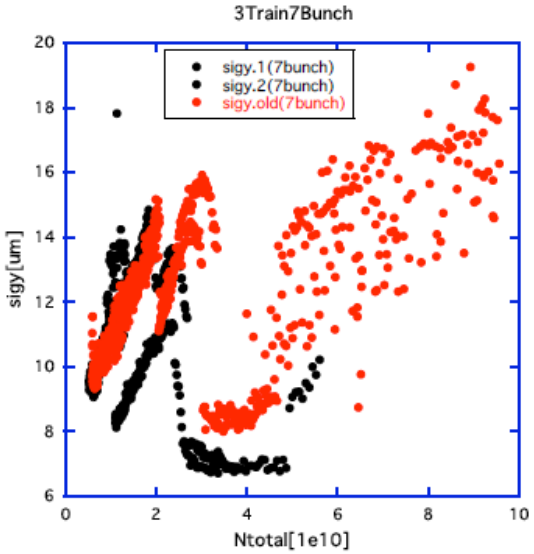


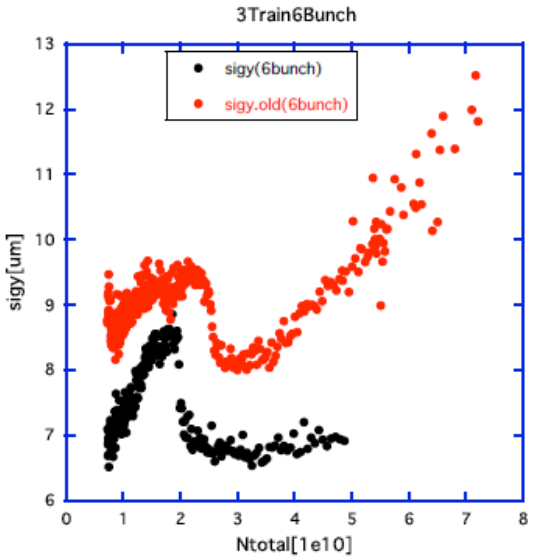
6 bunch

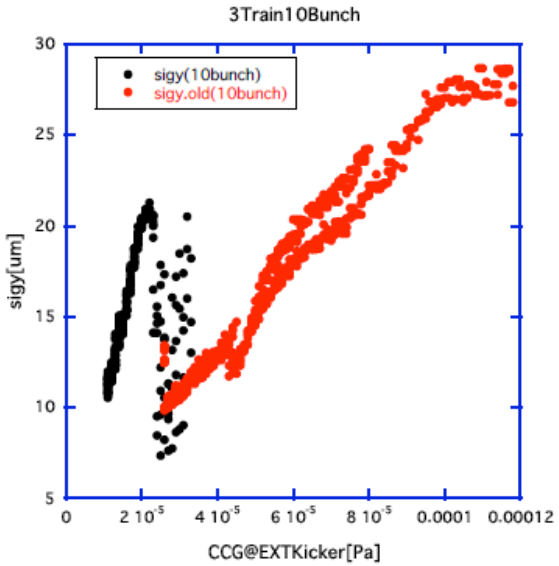


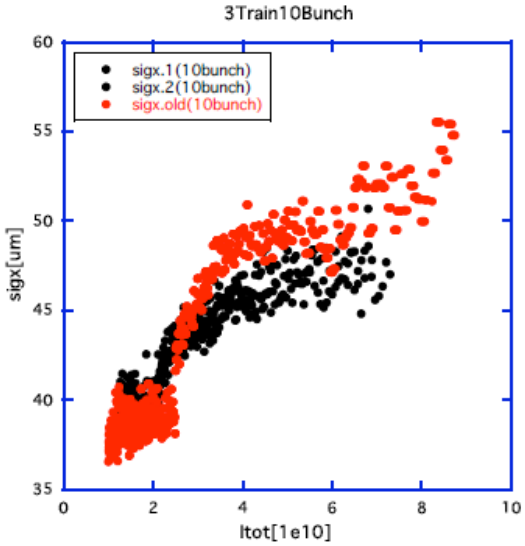
Some Comparison

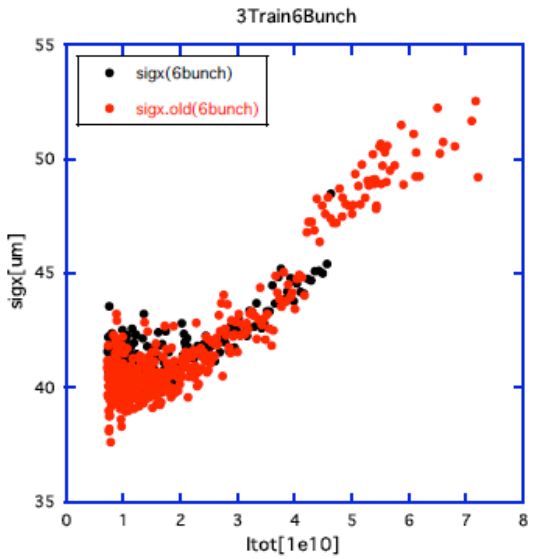




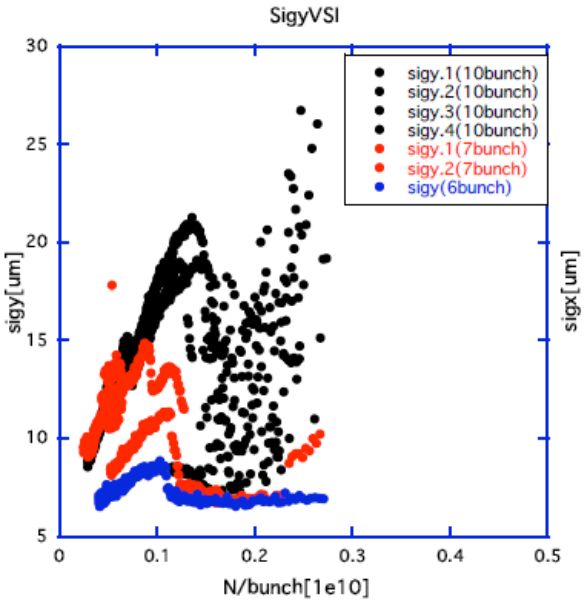


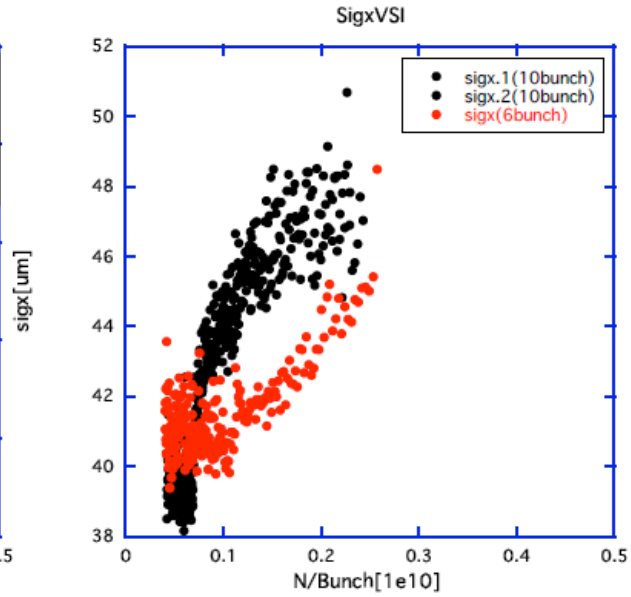






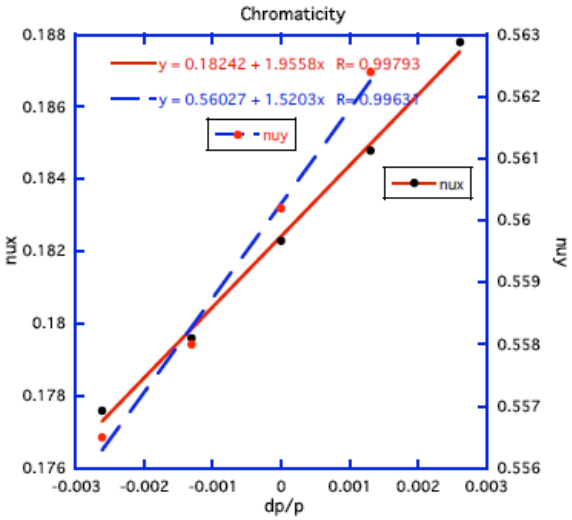
Some Comparison 2





Dependence on N/Bunch

$N/Bunch=N_{total}/(3x \# of bunch)$



Chromaticity
≈2 for x
≈1.5 for y

Observation in 3-train, 6~10-bunch/train

- Data was taken in “storage mode” (beam was stored. no injection/extraction)
- From beam size (projected) vs. intensity of each fill,
  - At very high intensity: Beam is some times stable (and sometimes unstable).
  - Lower intensity: Beam is always unstable. Beam size is monotonic function of intensity.

Possibility of ion trapping?

Simple calc. of Ion trapping condition

Motion of Ion

Bunch passage : $\begin{bmatrix} y \\ \dot{y} \end{bmatrix} \rightarrow \begin{bmatrix} 1 & 0 \\ K & 1 \end{bmatrix} \begin{bmatrix} y \\ \dot{y} \end{bmatrix}$

$$K = \frac{-2Nr_p c}{A\sigma_y(\sigma_x + \sigma_y)}$$

Gap : $\begin{bmatrix} y \\ \dot{y} \end{bmatrix} \rightarrow \begin{bmatrix} 1 & t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} y \\ \dot{y} \end{bmatrix}$

Transfer Matrix of 1 - turn

$$M = \prod_i \begin{bmatrix} 1 & t_i \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ K_i & 1 \end{bmatrix} \begin{bmatrix} y \\ \dot{y} \end{bmatrix}$$

i : index of bunces

Ion is "trapped" if $|\text{Trace } (M)| \leq 2$

depends on beam condition and atomic number of ion.

A : Atomic number of Ion

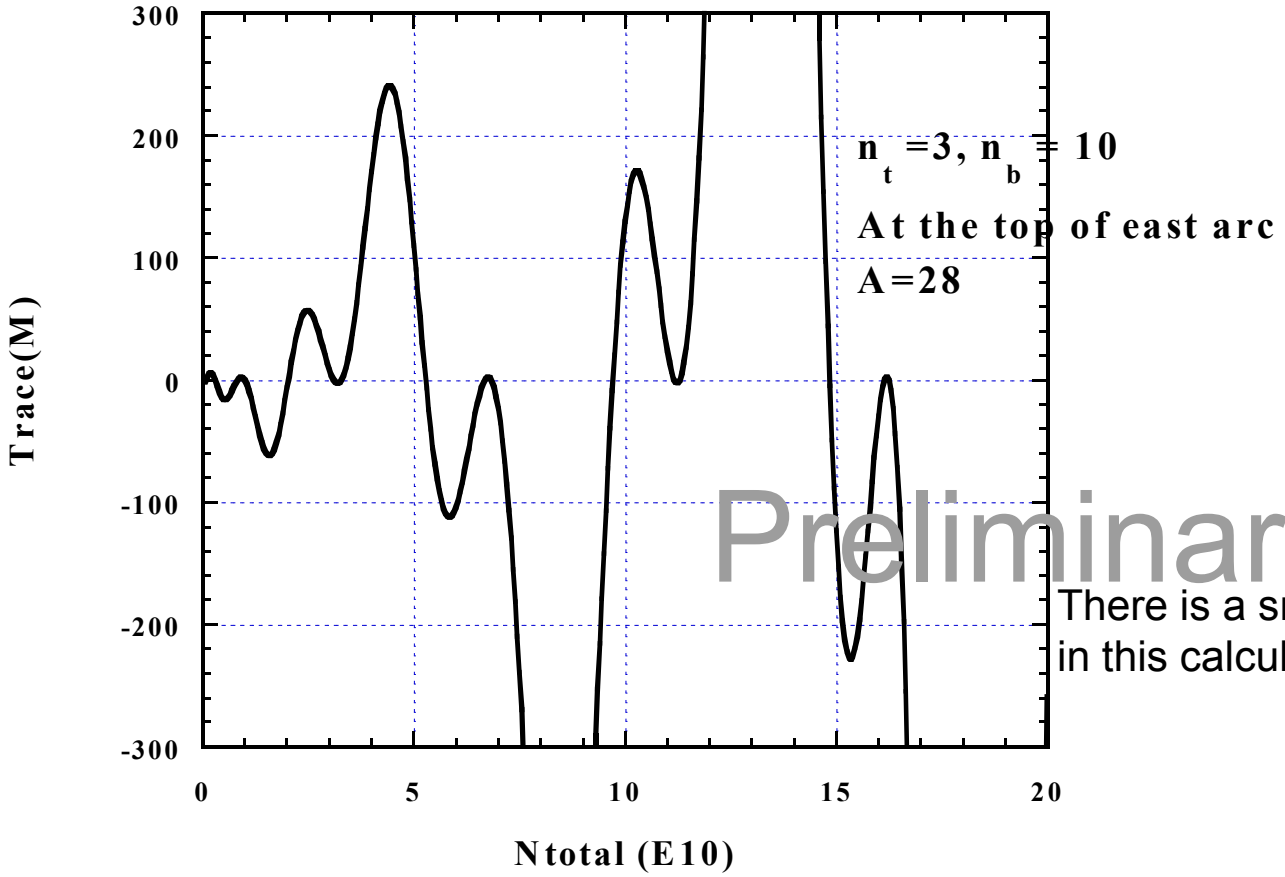
N : Bunch population

σ_x, σ_y : Beam sizes

t_i : Gap spacing after i - th bunch

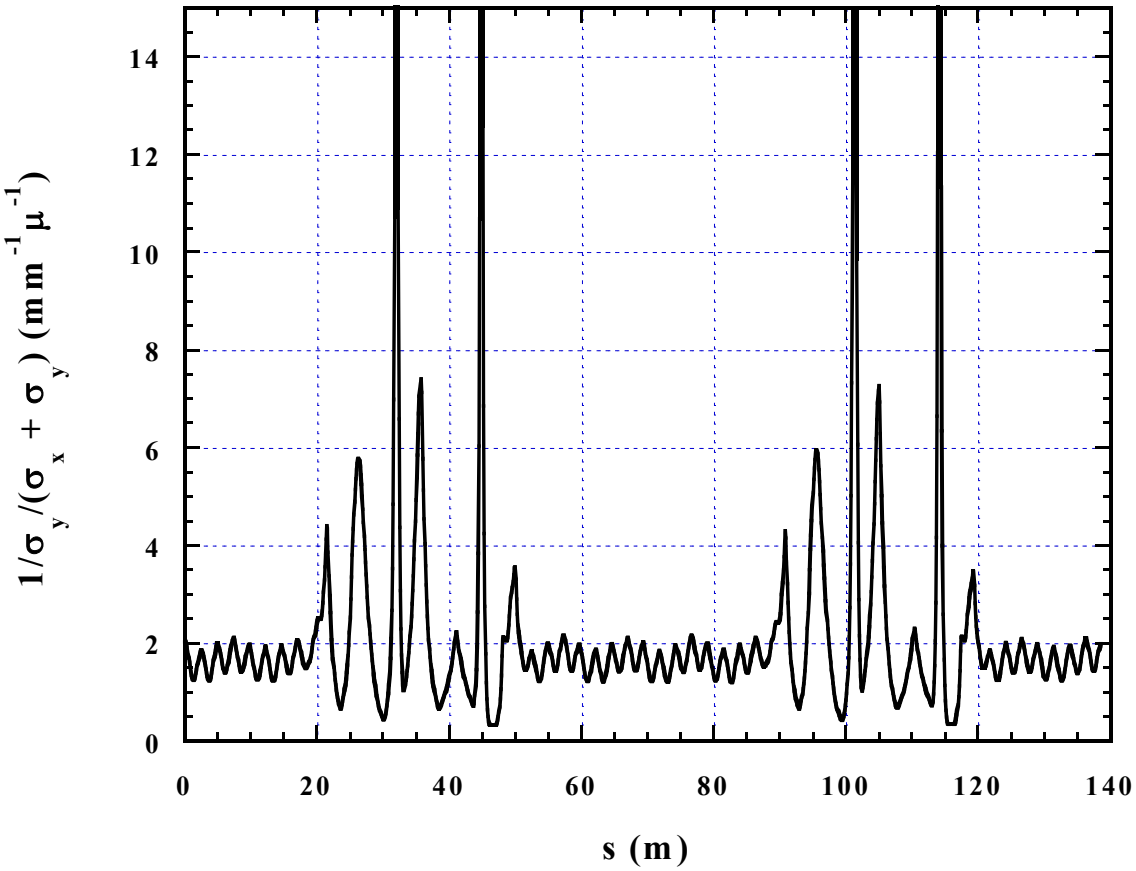
Example of Trace(M)

3 train, 10 bunch, A=28,
At the top of east arc



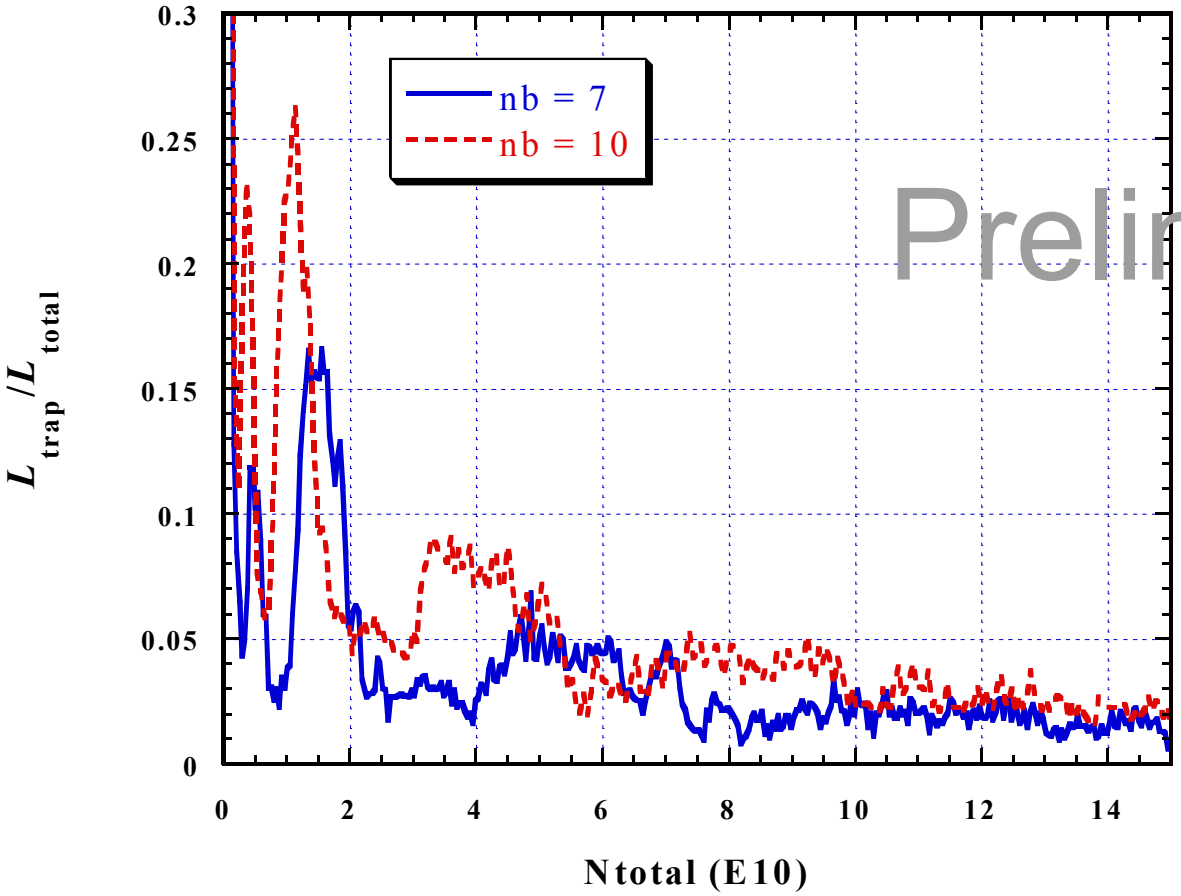
There is a small bug
in this calculation

$1/\sigma_y/(\sigma_x+\sigma_y)$



Large variation in straight sections

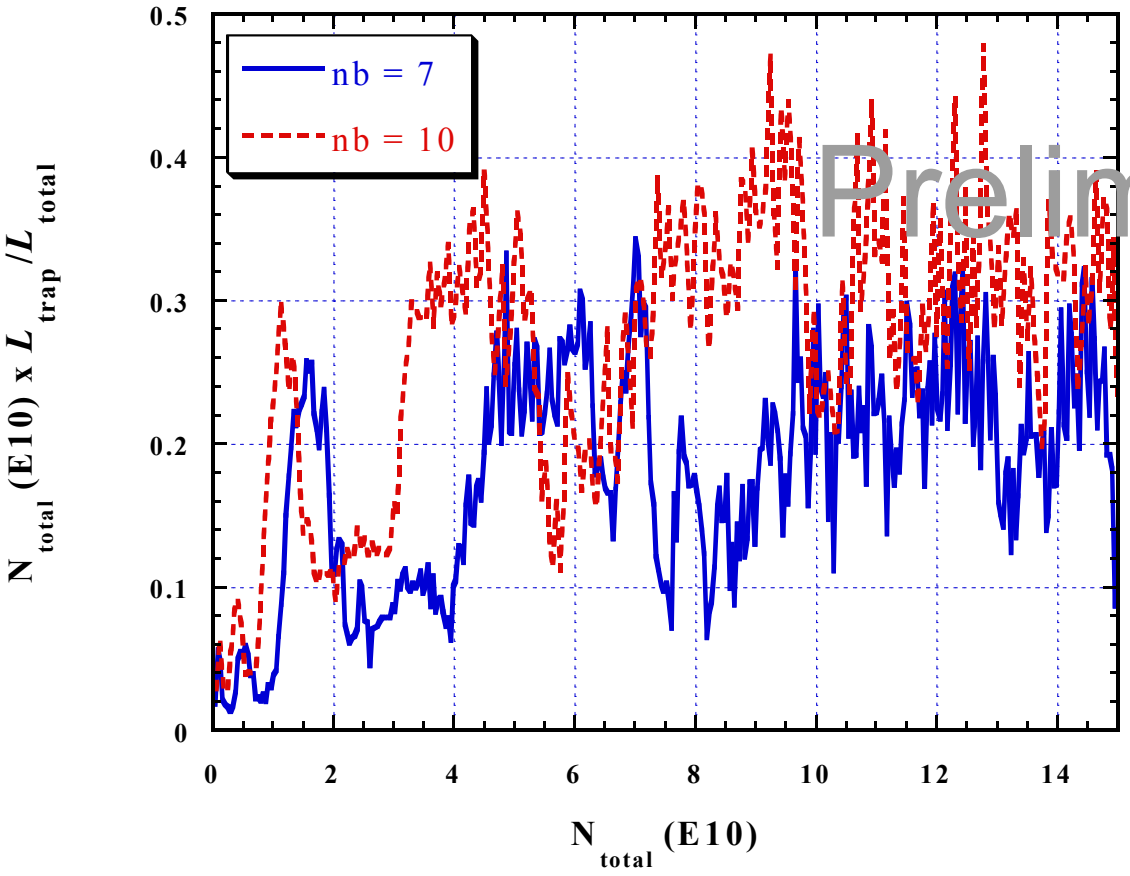
Ratio of trapped region in DR (trapped length / circumference)



Preliminary

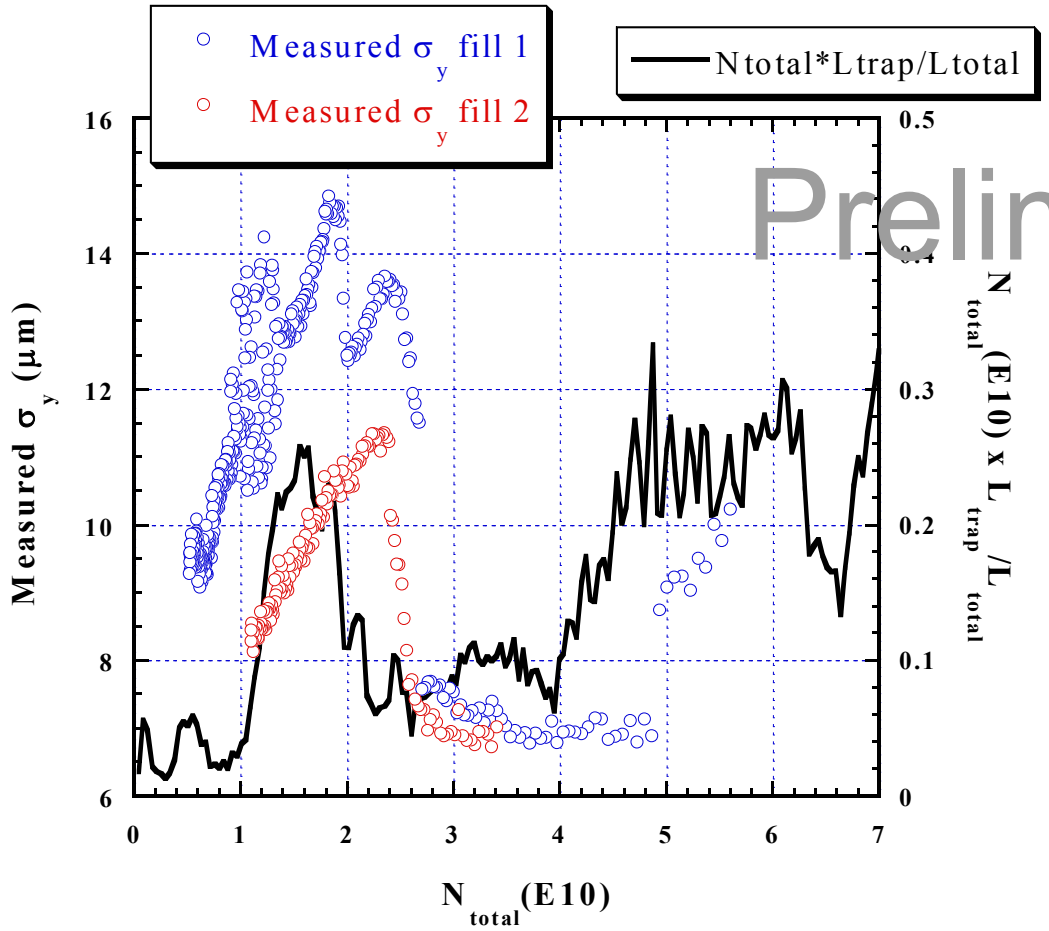
Stability Depends on Amount of Trapped Ion

$$\text{Amount of Trapped Ion} \propto N_{\text{total}} \times L_{\text{trap}} / L_{\text{total}} \ ?$$



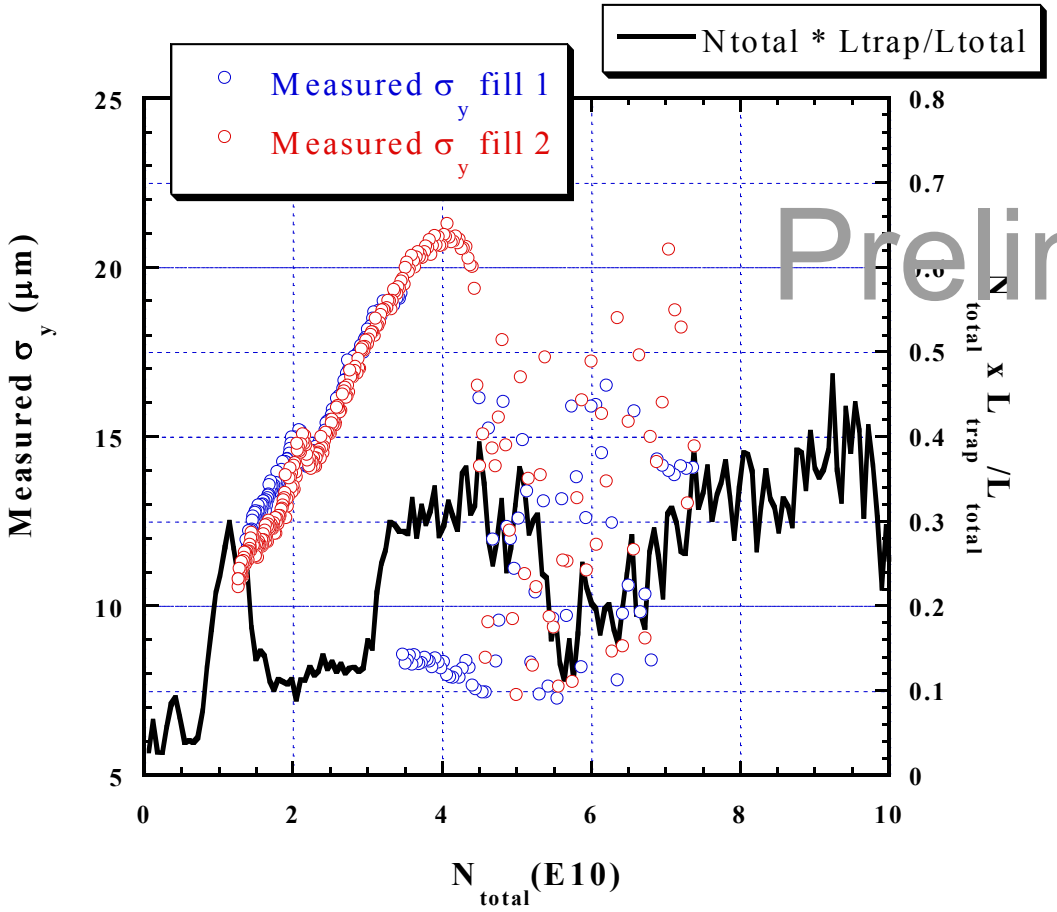
Compare measurement and ion trap calculation

3 train, 7 bunch/train



Compare measurement and ion trap calculation

3 train, 10 bunch/train



Preliminary

Summary of Multi-bunch study

- Beam size measured by X-SR mon. changing number of trains, number of bunches/train and charge/bunch, in storage mode.
  - Gate timing width 20 ms → Transverse oscillation is observed as beam size blow up.
- No significant blow up (vertical oscillation) in one-train and two-train modes
  - up to 10-bunch/train and ~0.4E10 particle/bunch
- No significant blow up in three-train mode up to 3-bunch/train
- Blow up (vertical oscillation) observed in three-train mode from 6-bunch to 10 bunch/train
  - Beam size (oscillation amplitude) depend on bunch intensity for each beam configuration. But not always monotonically.
    - At very high intensity: Beam is mostly unstable but sometimes not.
    - Lower intensity: Beam is always unstable. Beam size is monotonic function of intensity.
- Simple calculation for ion trapping
  - Should be checked if it is correct.
  - May explain the observations qualitatively ?????