Ecloud in SPS feedback

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CERN Ecloud meeting
Aug 8, 2011

Thanks F. Zimermann

Parameter

- E=26 GeV, ε=1.01x10^{-7}, β_x=33.85m, β_y=71.87m
- σ_z=0.229m, σ_E=0.19%, α=1.92x10^{-3}, ν_s=0.00564

- $\omega_e/2\pi$=355 MHz, $\omega_e\sigma_z/c$=1.7
- $\rho_{e,th}$=1.4x10^{11} m^{-3}.(use the formula)

$$\rho_{th} = \frac{2\,\gamma\,\nu_s\,\omega_e\,\sigma_z\,/\,c}{\sqrt{3}\;K\,Q\,r_e\,\beta_y\,L};$$

Formulae

- ECloud wake

$$W(z) = \frac{cR_S}{Q} e^{\omega_e z/2Qc} \sin(\omega_e z/c)$$

$$\frac{cR_S}{Q} = K \frac{\gamma \omega_p^2 \omega_e}{\lambda_p r_p c^3} L = \frac{\lambda_e}{\lambda_p} \frac{KL}{\sigma_i(\sigma_x + \sigma_y)} \frac{\omega_e}{c} \qquad \omega_e = \sqrt{\frac{\lambda_p r_e}{\sigma_y(\sigma_x + \sigma_y)}} c$$

$$\omega_p = \sqrt{\frac{\lambda_e r_p c^2}{\gamma \sigma_y(\sigma_x + \sigma_y)}} \qquad \lambda_p = N_p/2\sigma_z \qquad \lambda_e = 2\pi\sigma_x\sigma_y\rho_e$$

- Threshold of the coasting beam model

$$1 = \frac{\sqrt{3}\lambda_p r_p \beta}{\gamma \eta \sigma_\delta} \frac{Z(\omega_e)}{n Z_0} = \frac{\sqrt{3}\lambda_p r_p \beta}{\gamma \nu_s \omega_e \sigma_z/c} \frac{Z(\omega_e)}{Z_0}$$

$$2\pi\nu_s\sigma_z = \eta\sigma_\delta L \qquad n = \omega_e/\omega_0 \qquad Z(\omega_e) = \frac{cR_s}{\omega_e}$$

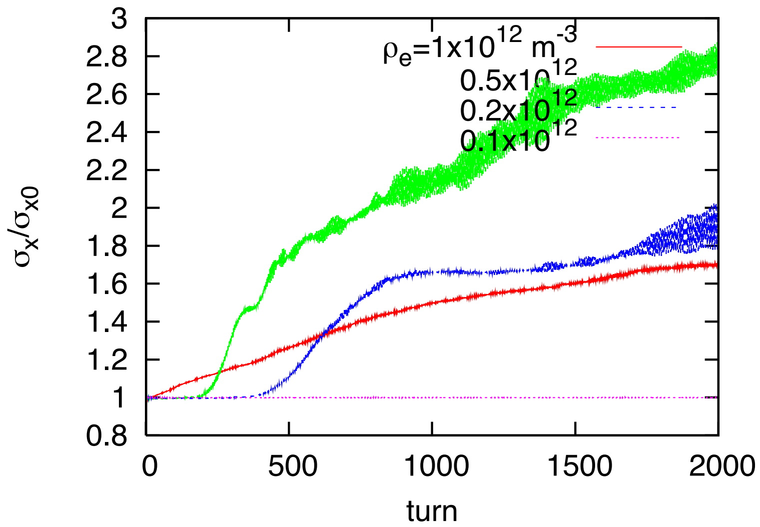
$$1 = \frac{\sqrt{3}\lambda_p r_p \beta}{\gamma \nu_s \omega_e \sigma_z/c} \frac{\lambda_e}{\lambda_p} \frac{KQL}{4\pi\sigma_y(\sigma_x + \sigma_y)} \quad \Rightarrow \quad \rho_e = \frac{2\gamma\nu_s\omega_e\sigma_z/c}{\sqrt{3} r_p \beta KQL} (\times 2)$$

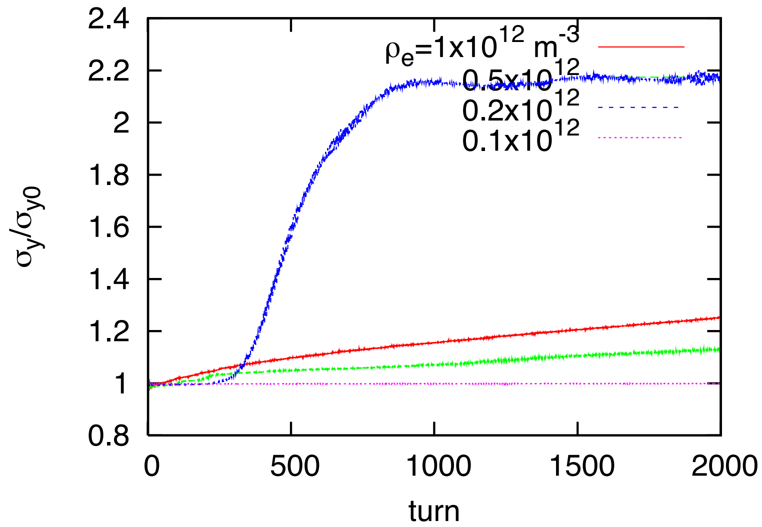
(round beam)

- $Q=\min(\omega_e\sigma_z/c, Q_{nl}\sim 10)$, $K=\omega_e\sigma_z/c$ (empirically)

Electron cloud in Free space

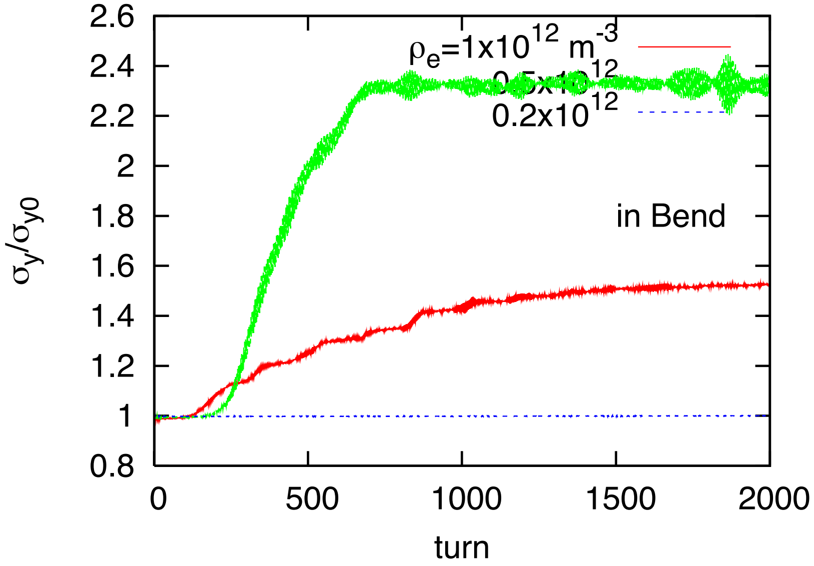
- Note $\sigma_x < \sigma_y$





- Instability signal is clear near the threshold
- Incoherent (artifact) effect is strong in high density.

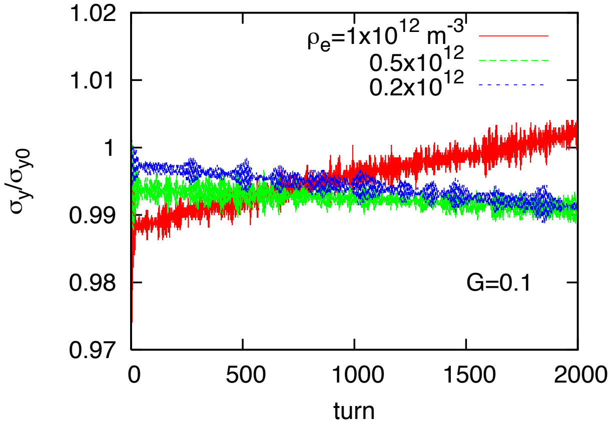
Electron cloud in bending magnet

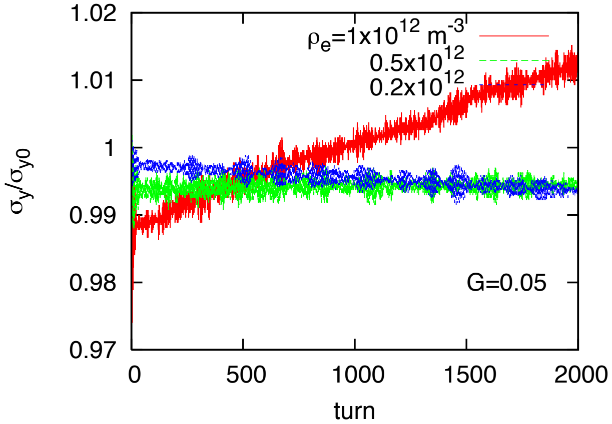


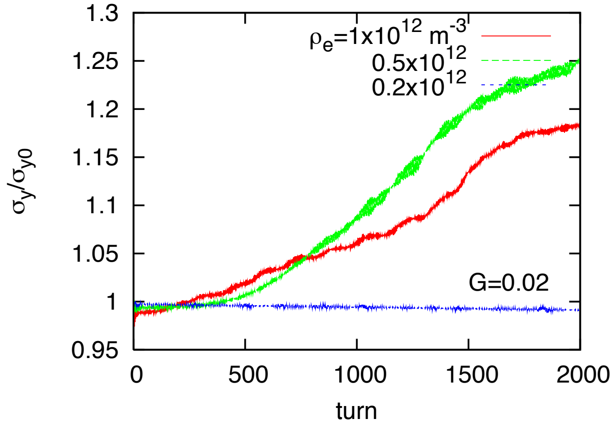
- No x instability

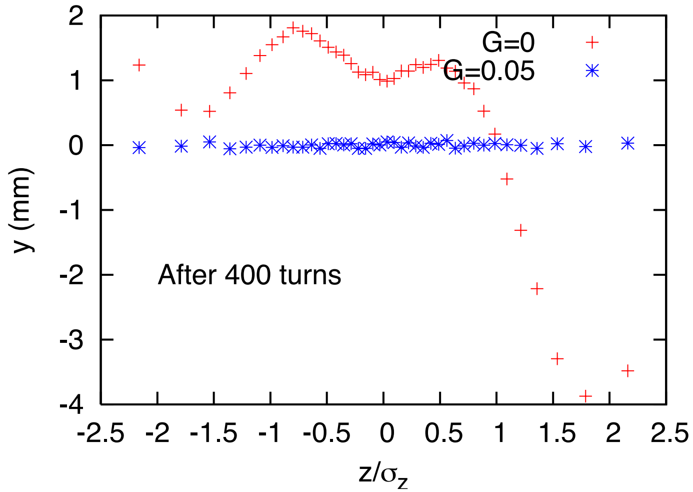
High frequency Feed back

- Feedback slice by slice, nonuniform 40 slices. Max c/Δz=22 GHz.





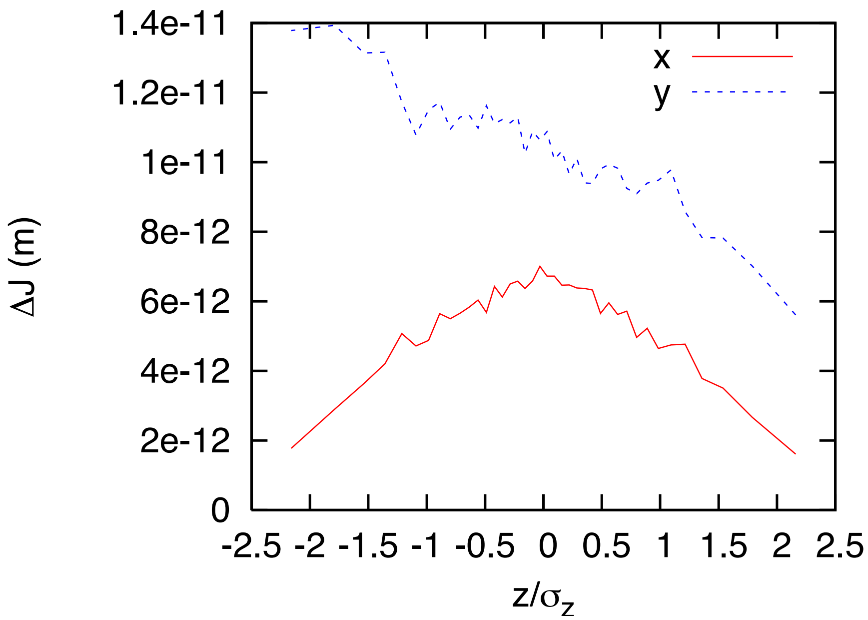




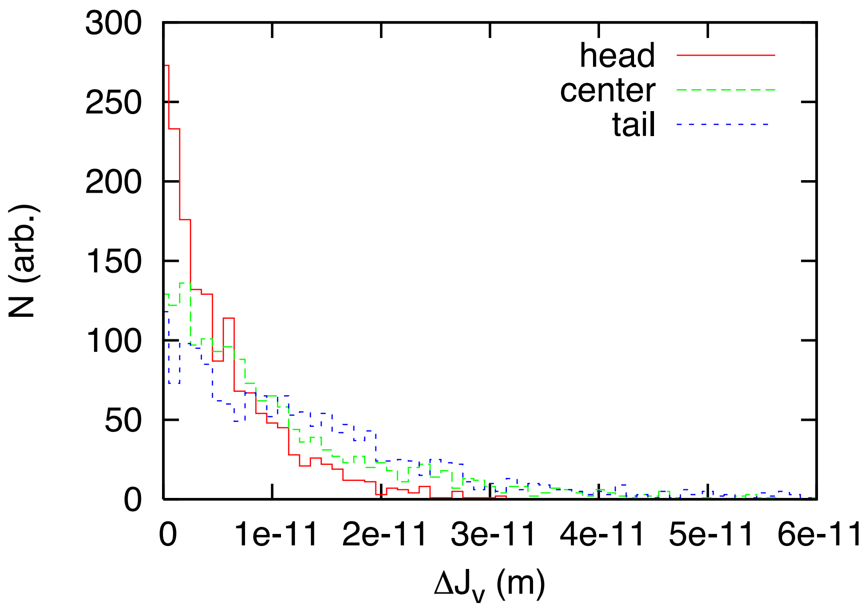
The feedback with <10GHz should give the same result, since high frequency component is not contained.

Feedback kick strength

- Plot residual J along z. $J=(\gamma y^2+2\alpha yy'+\beta y'^2)/2$
- Tail amplitude is larger than head.
- Kicker strength = $2G(\Delta J/\beta)^{1/2}$



Residual J averaged over revolutions



Hist for turn by turn ΔJ.

Feedback bandwidth

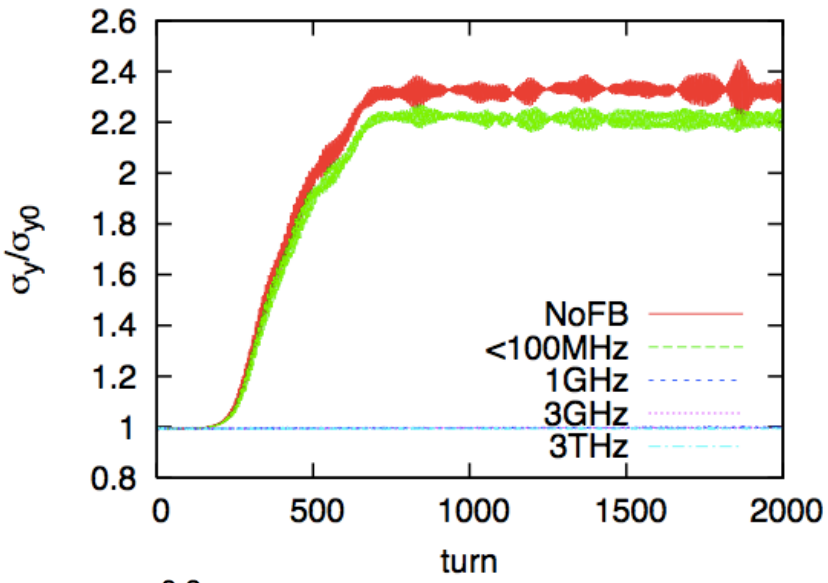
- step function filter, dz=±c/2fr

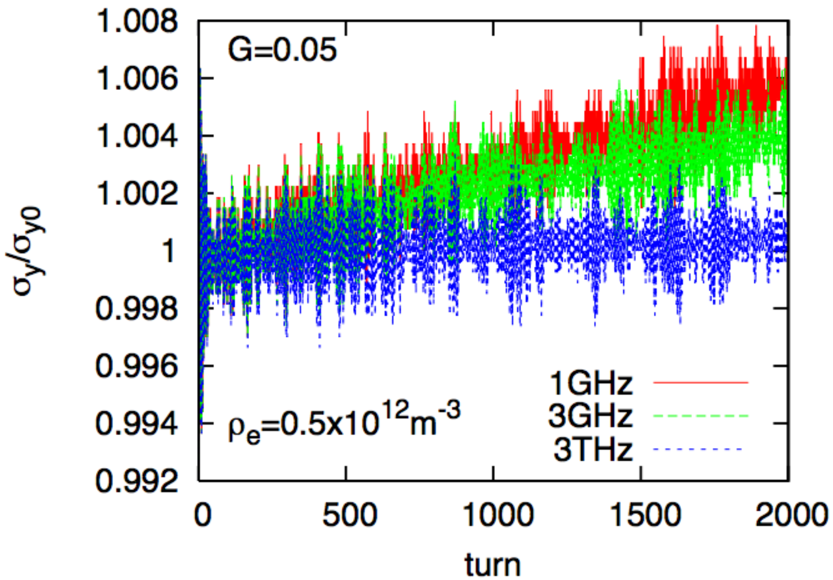
$$\Delta p_y(z) = -2G \int \theta(z - z'; f_{FB}) p'_y \rho(p'_y, z') dz' dp'_y$$

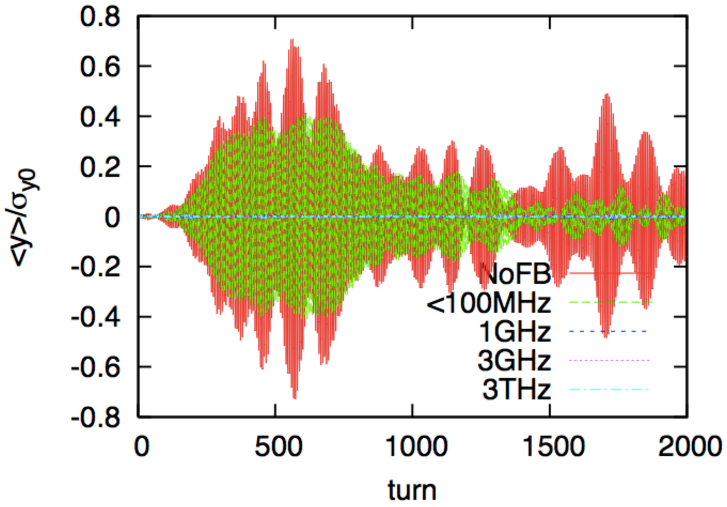
$$\theta(z; f_{FB}) = \begin{cases} = 1 & |z| \leq \frac{c}{2f_{FB}} \\ = 0 & |z| > \frac{c}{2f_{FB}} \end{cases}$$

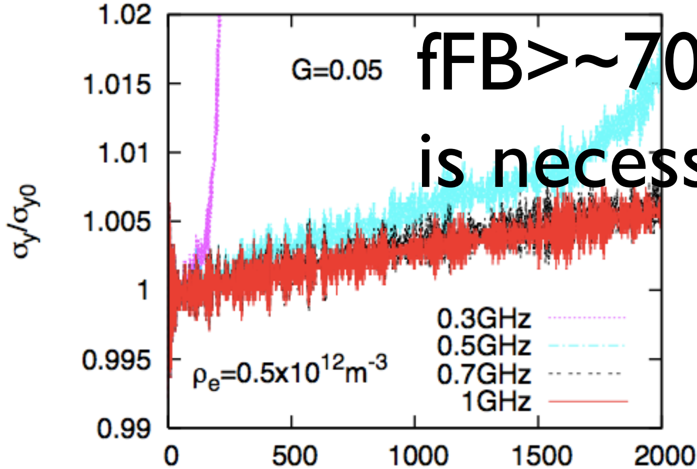
Beam size and dipole amp. for FB bandwidth

$\rho_e = 0.5 \times 10^{12}\ m^{-3}$





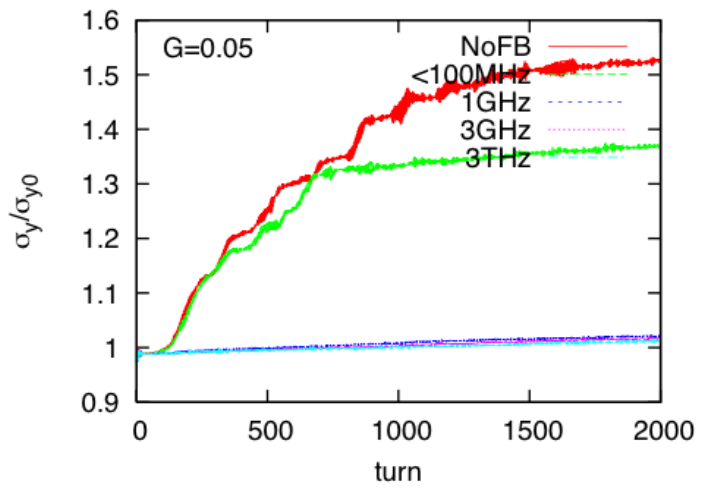


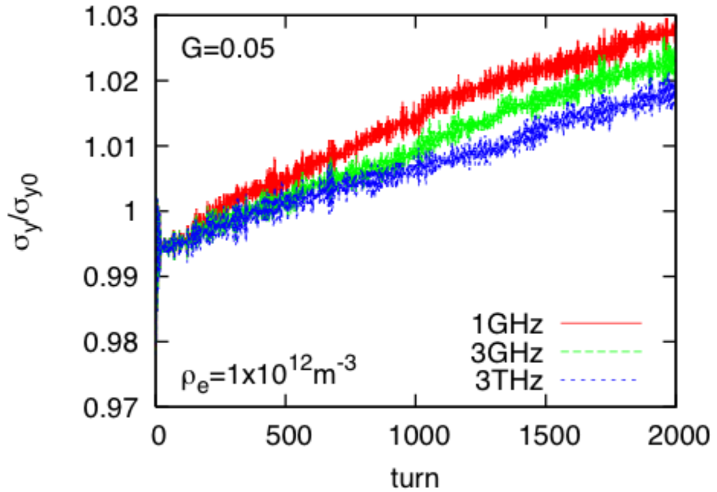


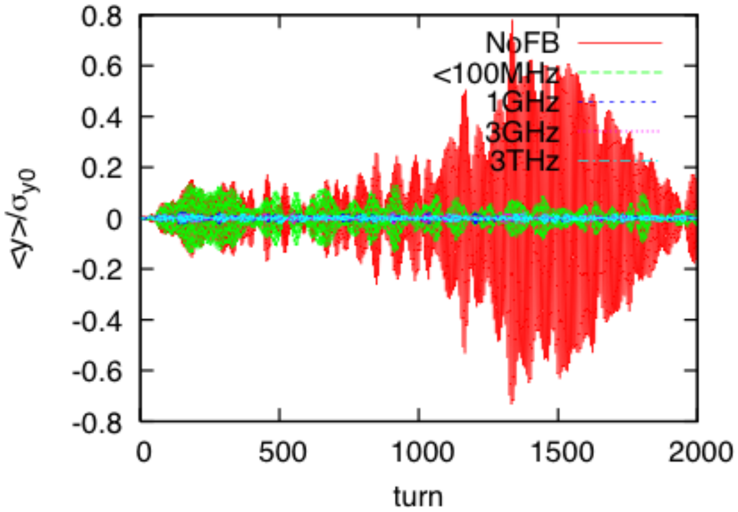
fFB>~700MHz is necessary.

Beam size and dipole amp. for FB bandwidth

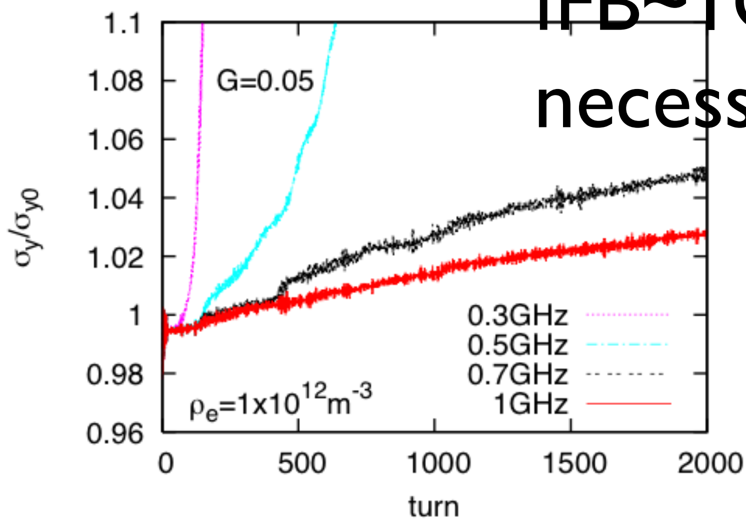
$\rho_e = 1 \times 10^{12}\ m^{-3}$





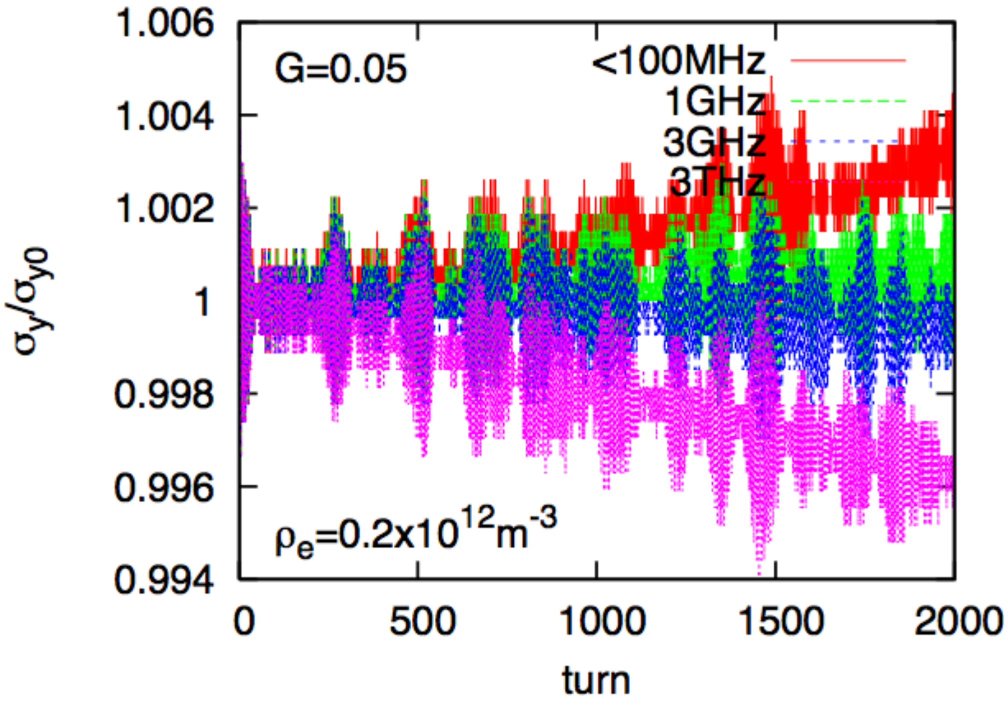


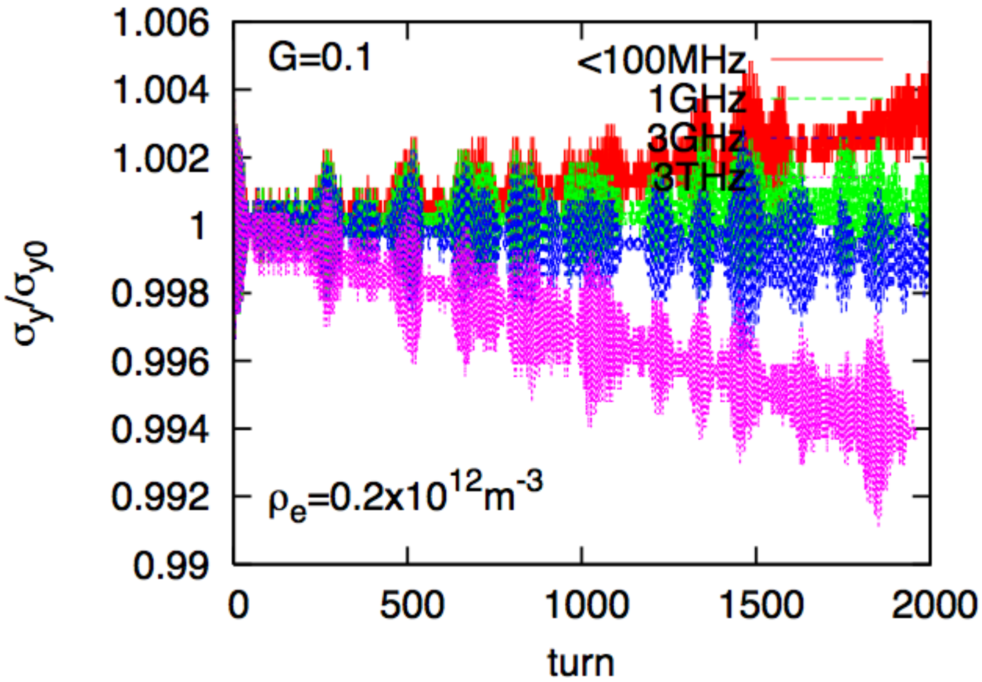
fFB~1GHz is necessary.



Check for stochastic cooling effect

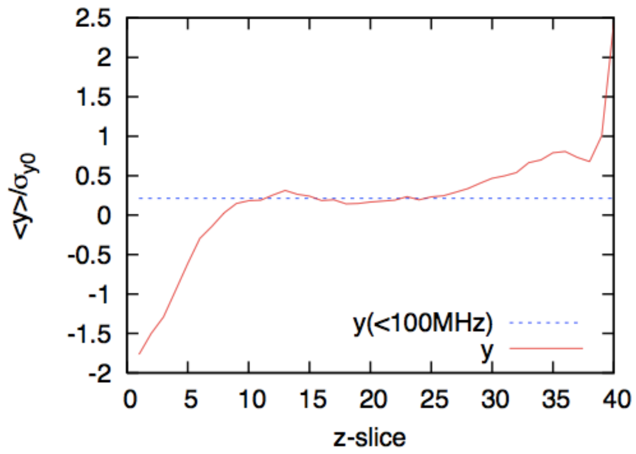
- Numerical effect , # of macro-p 10^4 /slice

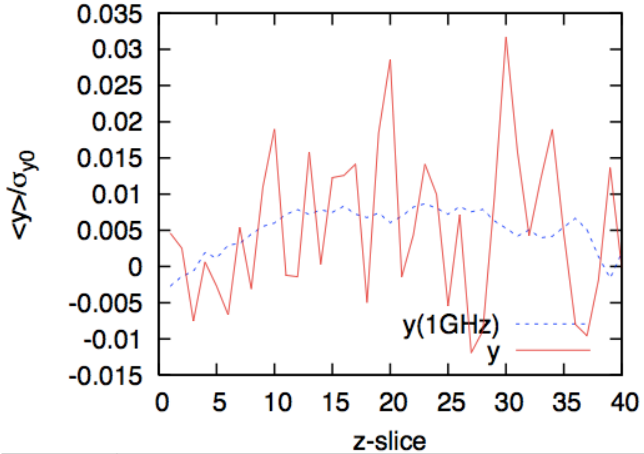


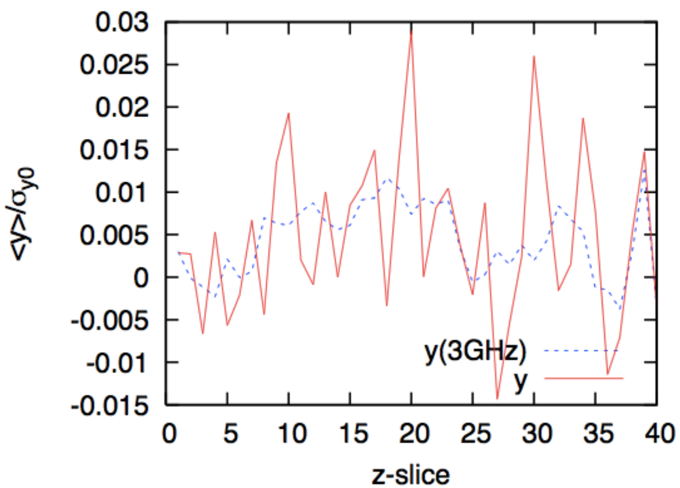


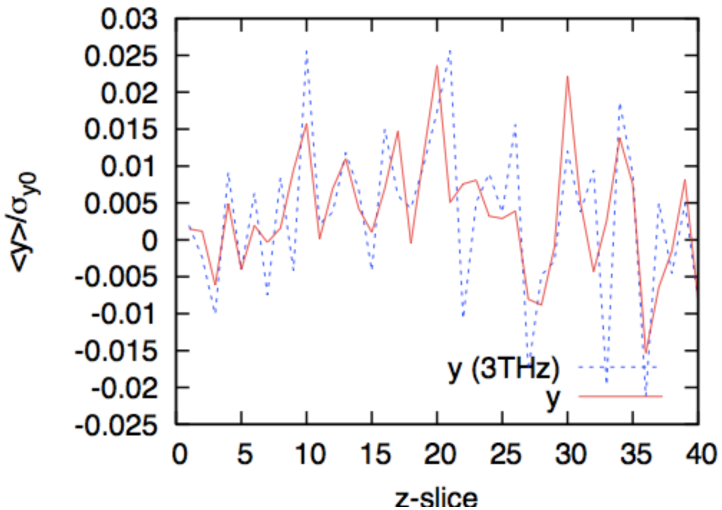
ρ_e=0.2x10^{12} m^{-3}

Bunch profile and filter signal one turn before (transferred by linear rev. matrix)





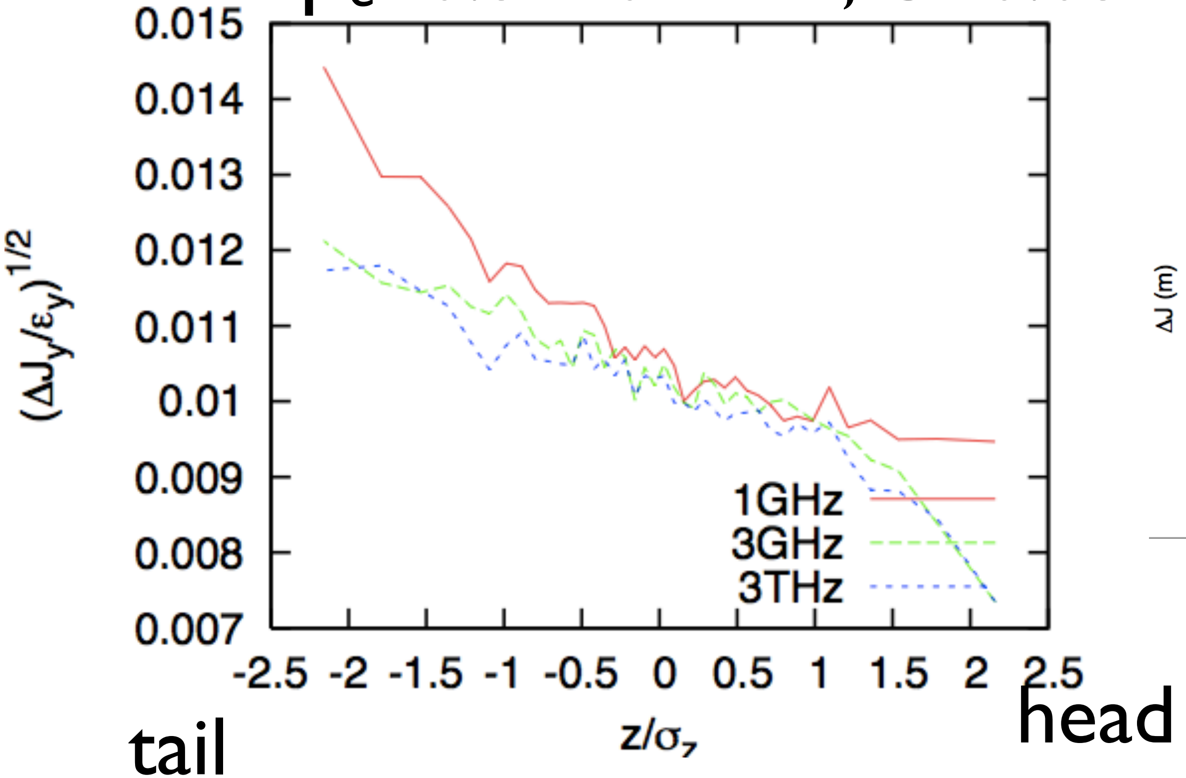


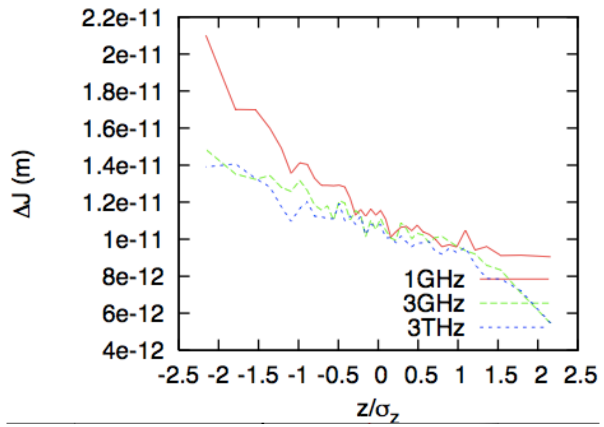


Residual J_y along z

- Residual Jy corresponds to feedback kick strength.
- The absolute values of the strength is determined by noise level.
- In this simulation, the noise level is statistical. Macro-particle in a slice is ~10,000, thus 1% error in each slice.

$\rho_e = 0.5 \times 10^{12}\ m^{-3}$, G=0.05





Feed back kicker strength

ρ_e=0.5x10^{12} m^{-3}, G=0.05

- Kicker strength $\theta = 2G(\Delta J/\beta)^{1/2}$
- G=0.05,
- $\Delta J = 2\times10^{-11}$m, $(\Delta J/\varepsilon)^{1/2}$=0.015(dynamic range)
- $\theta = 4.5\times10^{-7}\,\beta^{-1/2}$
- Wider dynamic range will be required. How wide?

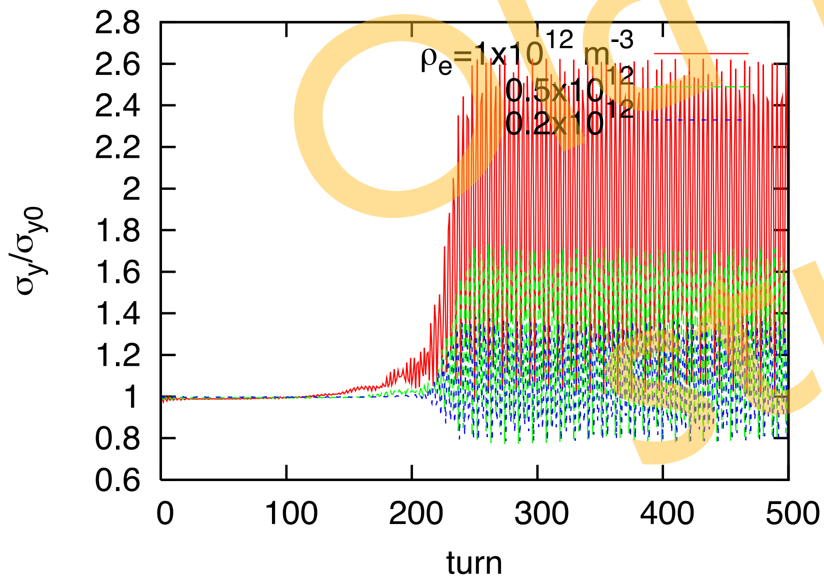
Summary

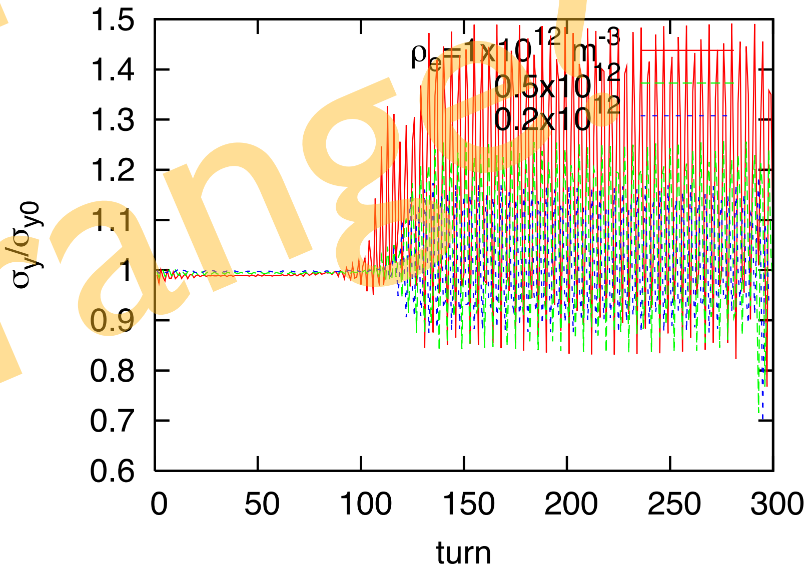
- High frequency feedback suppress the head-tail instability induced by electron cloud.
- The gain is G>0.05 (20 turn) for $\rho_e = 0.5 \times 10^{12}$ m^{-3}.
- Feedback with >~700MHz is necessary.

Feedback

- One turn delay, suppress only dipole motion

G=0.05 0.1





Old results, strange?