Ecloud effects in SuperKEKB LER

- Preliminary results

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SuperKEKB optics meeting

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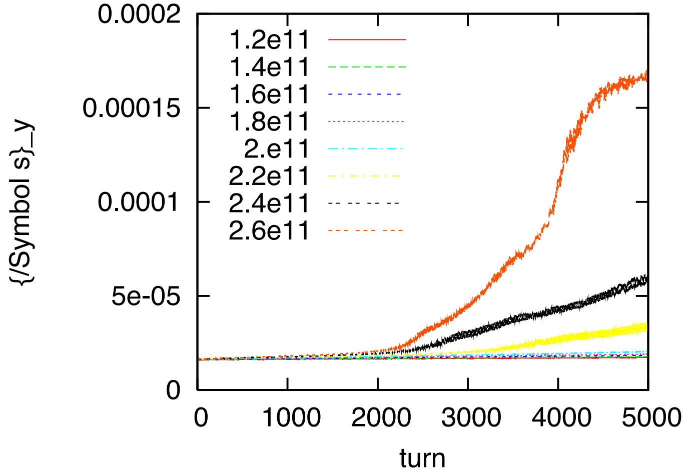
1. Introduction

- ➤ Ecloud as a concern (from LHC experience):
  - ● Three-beam instability in the LHC [A. Burov, arXiv: 1301.0443v2 [physics.acc-ph], and Talk of A. Burov at ICFA BB2013 mini-workshop]
  - ● Coherent beam instabilities
  - ● Incoherent beam emittance growth
- ➤ SuperKEKB LER
  - ● Low emittance and small beta at IP
  - ● High-beta areas near IP
  - ● Ecloud densities vary along the ring
- ➤ Collaboration effort:
  - ● K. Ohmi, D. Zhou@KEK: PEHTS2
  - ● L. Wang@SLAC: Pivi's code CMAD (Parallel computation, but uniform density along the ring) and Wang's code

1. Introduction

K. Ohmi, KEKB MAC 2011

SuperKEKB



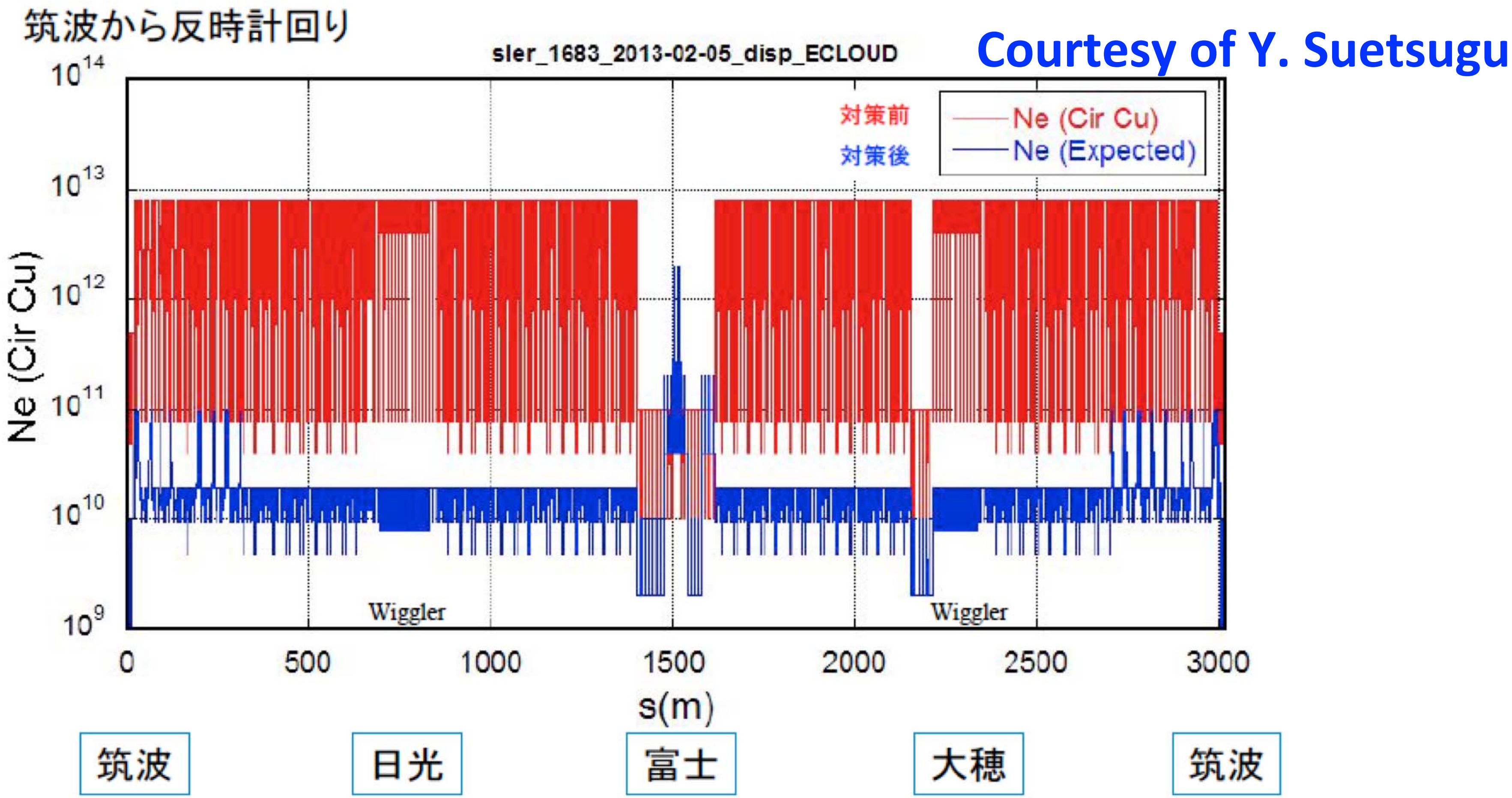
Y. Susaki, K. Ohmi, IPAC10

- Simulation ρ_{th}=2.1x10^{11} m^{-3}.(ν_s=0.012)
- Analytic ρ_{th}=2.7x10^{11} m^{-3}.
- **Target ρ_e~1x10^{11} m^{-3}**
- Take care of high β section. Effects are enhanced.

$$\oint \rho_e \beta_y ds/L = 10^{11} \times 10 \text{ m}^{-2}$$

1. Introduction

➤ SuperKEKB: Improvements in vacuum chambers => Expected low ecloud density



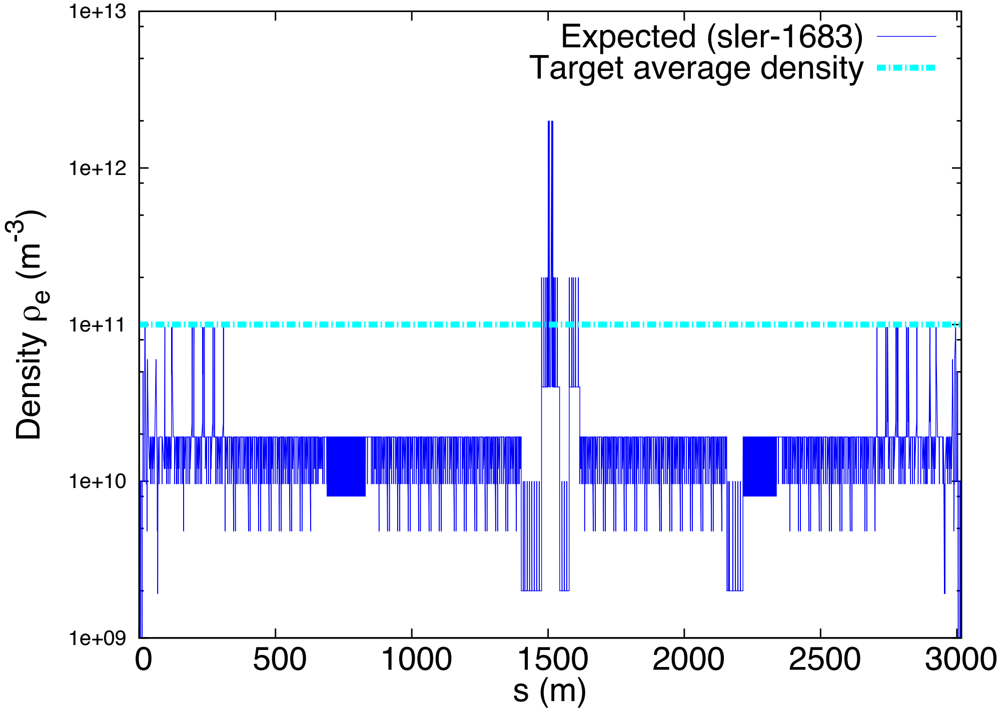
・富士はアルミ。再利用なのでコーティング無し。銅に比べて20倍。
・筑波の両側で所々高いのは回転六極部でアンテチェンバーではない。

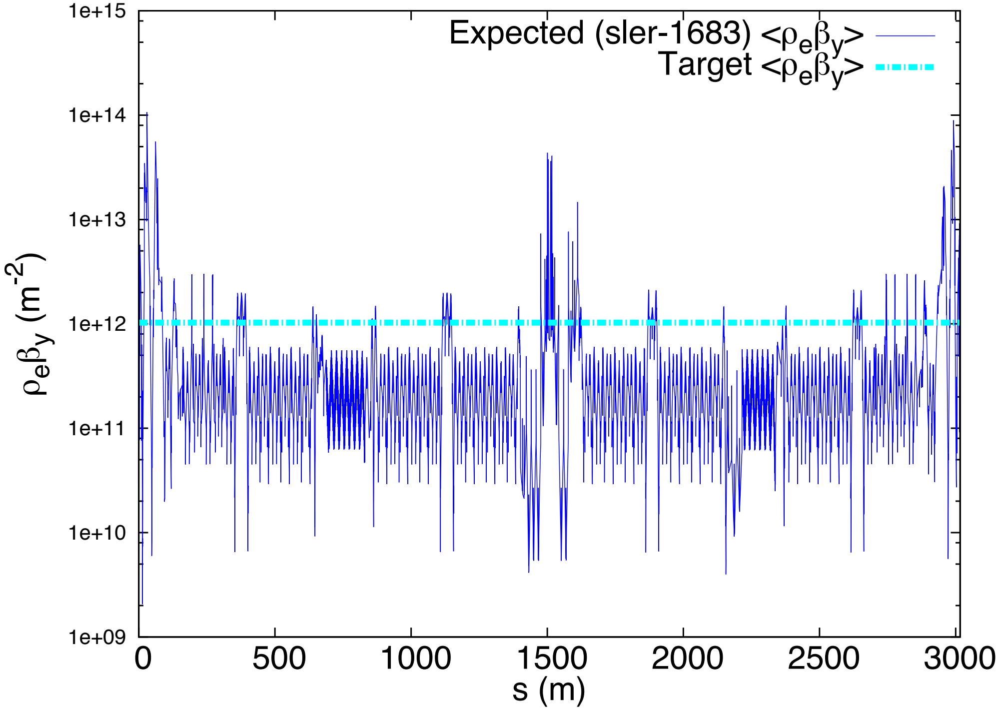
1. Introduction

- **Ecloud instability theory:**

$$\rho_{e,th} = \frac{2\gamma\nu_s \omega_e \sigma_z / c}{\sqrt{3} K Q r_0 \beta L}$$

  - **$\rho_{e,th} \propto \nu_s$** • **$\rho_{e,th} \propto 1/\beta$**
  - **$\rho_{e,th}$=4.4e11 m^{-3} for SuperKEKB LER**
- **Average ecloud density:**
  - **Expected: $<\rho_e>$=2.2e10 m^{-3}**
  - **Weighted by β_y: $<\rho_e\beta_y>/<\beta_y>$=1.1e11 m^{-3}**



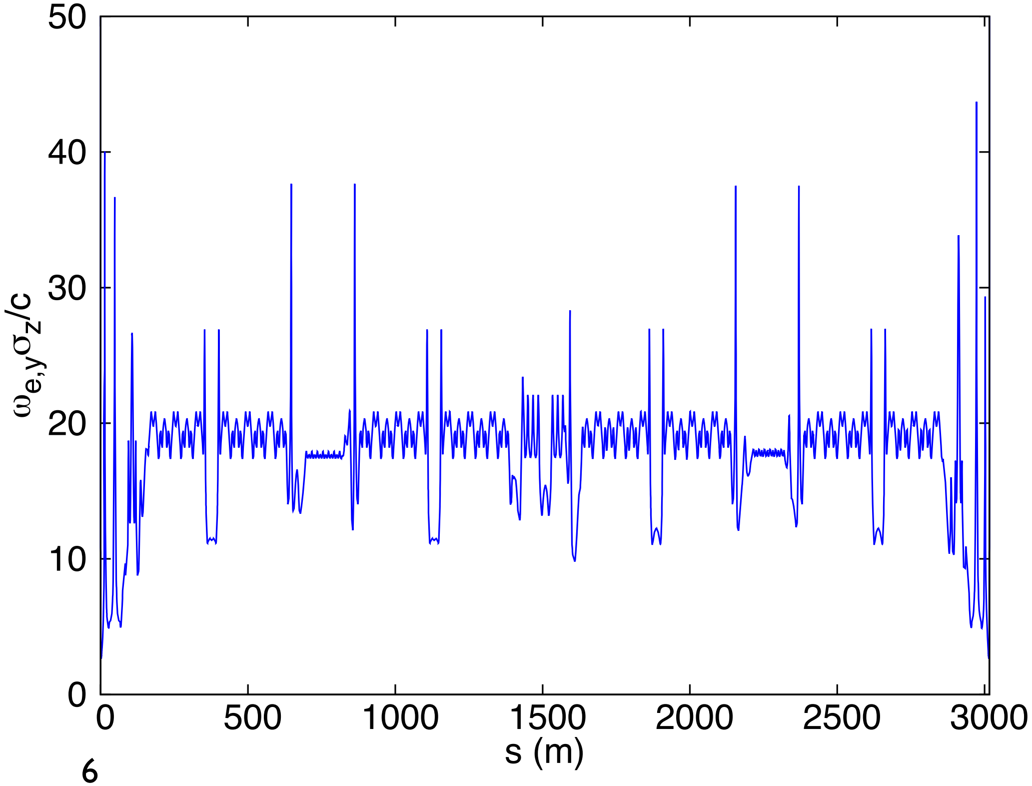


1. Introduction

➤ **Vertical single-electron angular oscillation freq.:**

$$\omega_{e,y} = \sqrt{\frac{2\lambda_p r_e c^2}{\sigma_y(\sigma_x + \sigma_y)}} \qquad \lambda_p = \frac{N_p}{2\sigma_z}$$

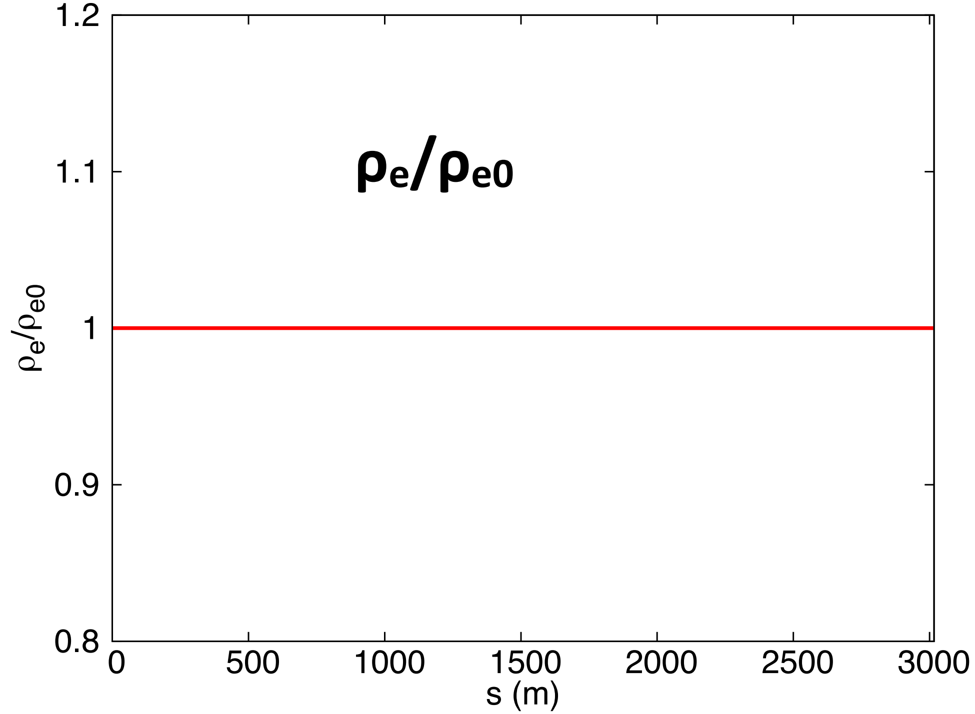
➤ **SuperKEKB: High freq. "wakefields" [similar to CSR, but transverse!]**

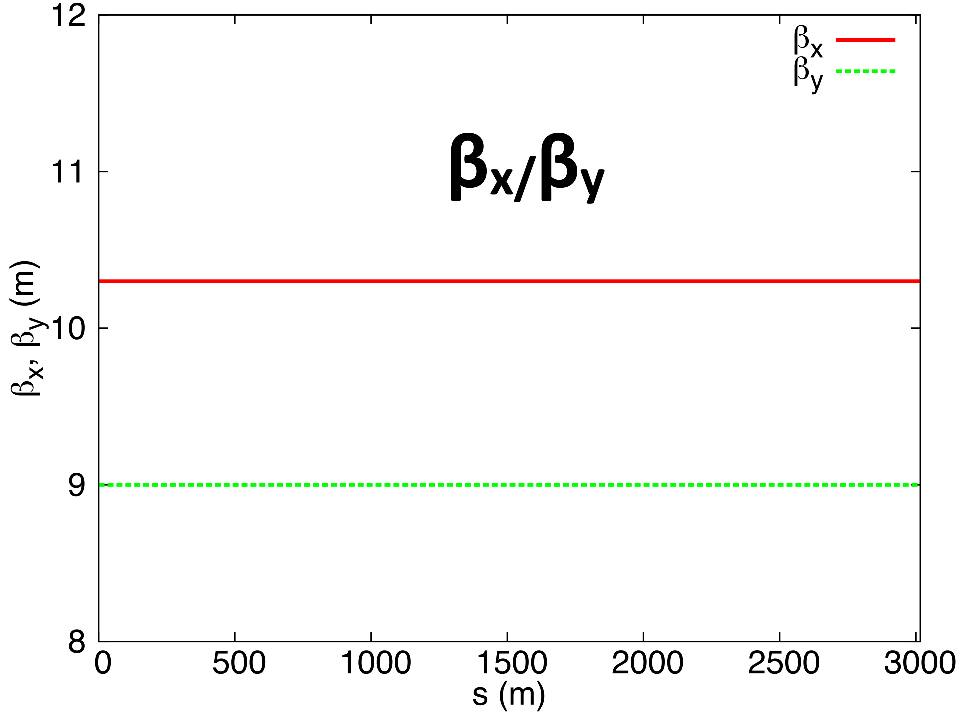


2. Results of PEHTS2

Condition 1:

- **Parameters: ν_x=44.53, ν_y=46.57, $<\beta_x>$=10.3 m, $<\beta_y>$=9 m, ν_s=0.0247, P_{BUNCH}=9.04e10, $N_{section}$=32 ρ_{e0}={3.2, ..., 6.0}e11**



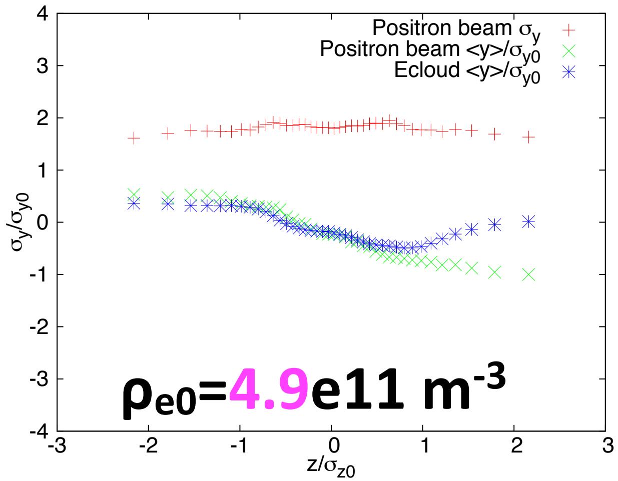


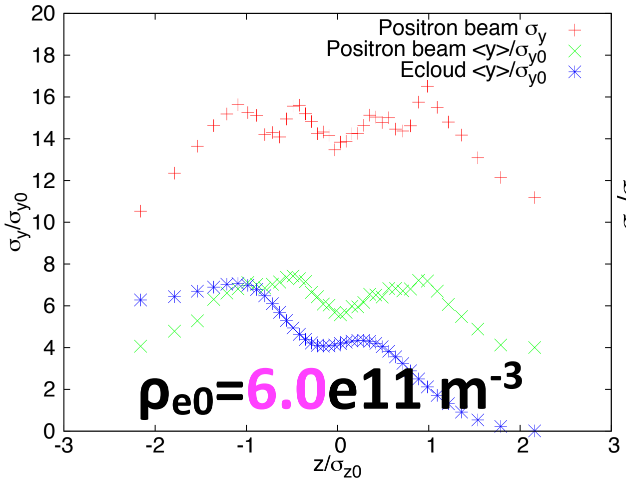
2. Results of PEHTS2

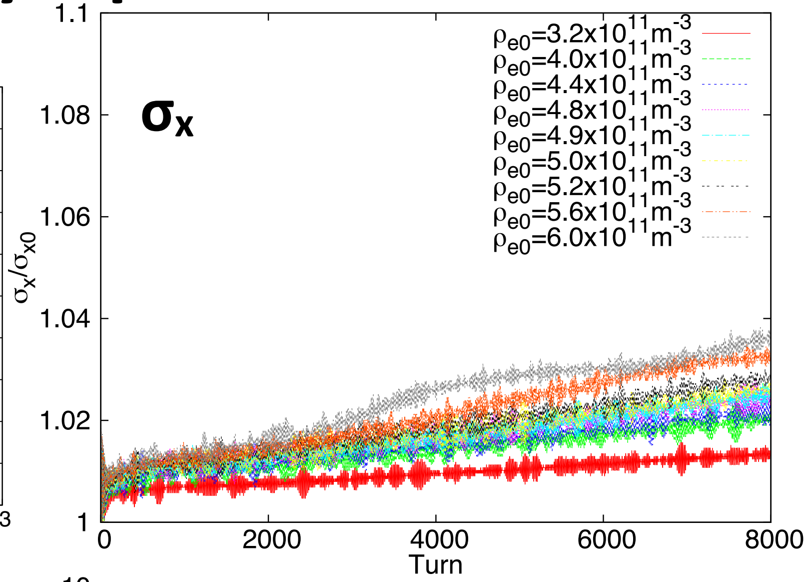
$$\rho_{e,th} = \frac{2\gamma\nu_s\,\omega_e\sigma_z/c}{\sqrt{3}KQr_0\beta L}$$

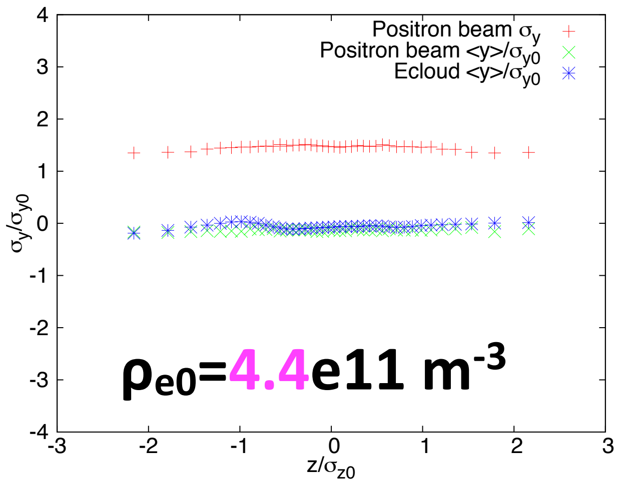
Condition 1:

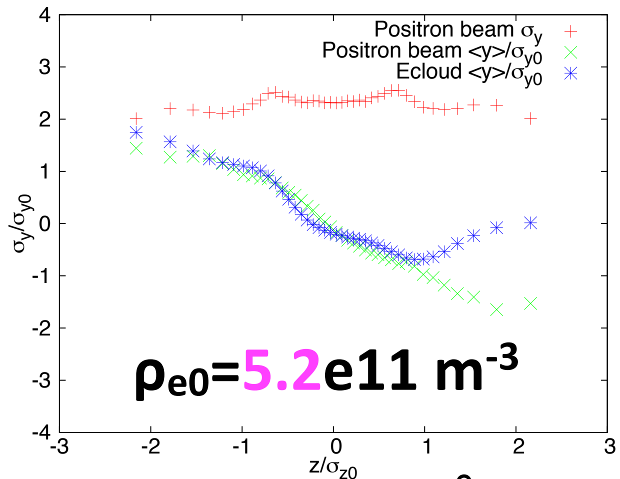
➤ **Threshold of coherent instability: $\langle\rho_e\rangle \approx 4.9e11\ m^{-3}$**

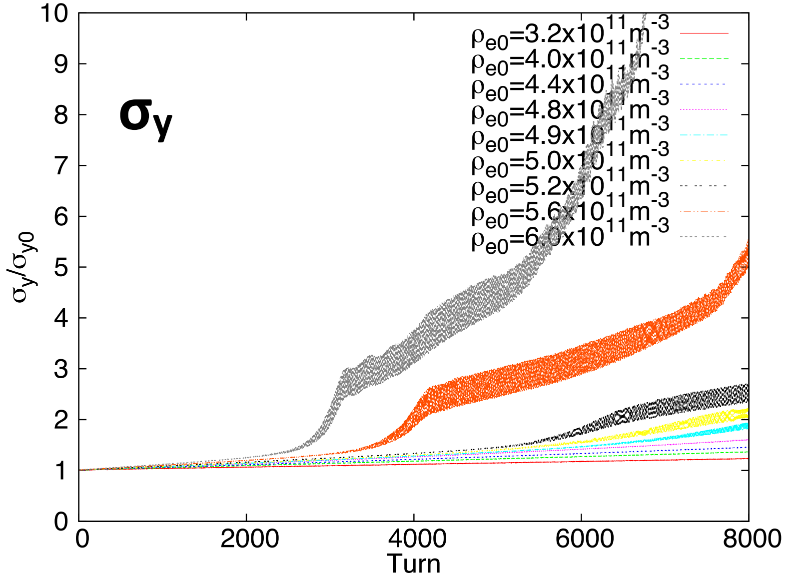










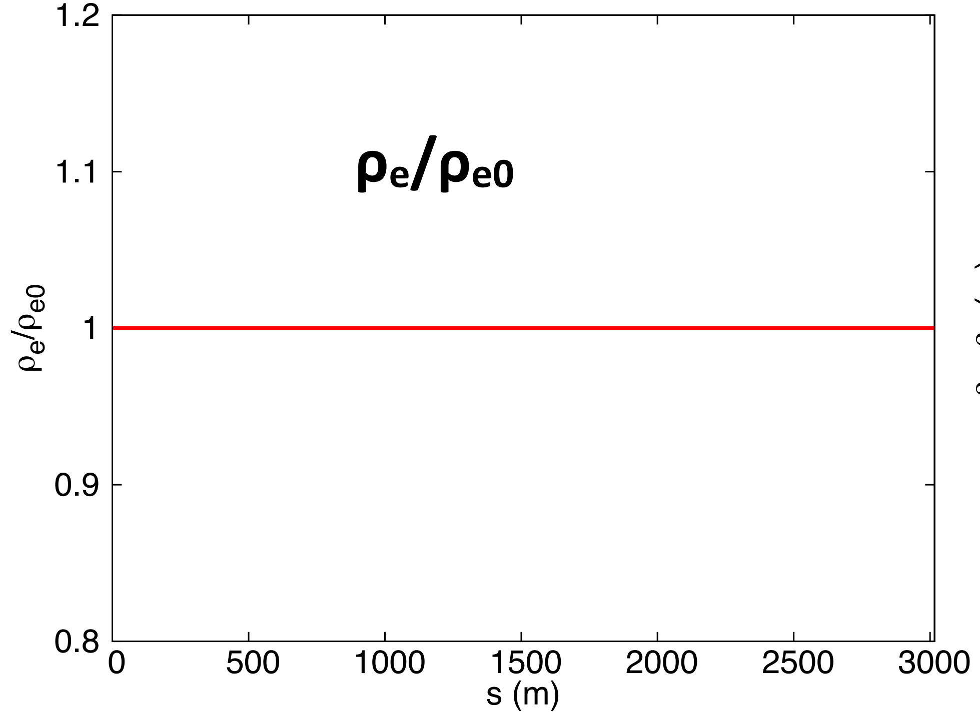


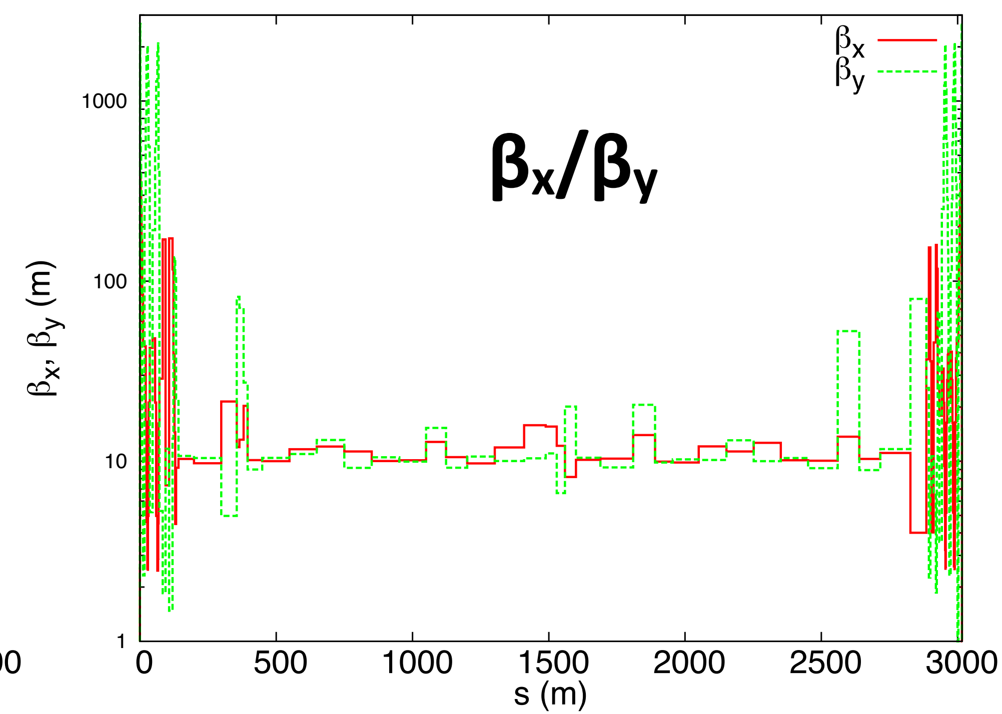
2. Results of PEHTS2

Condition 2:

➤ **Parameters: ν_x=44.53,ν_y=46.57, ν_s=0.0247, PBUNCH=9.04e10, ρ_{e0}={0.6, 1.0, ..., 5}e11 m^{-3}**

➤ **Number of sections along the ring: Nsection=129**



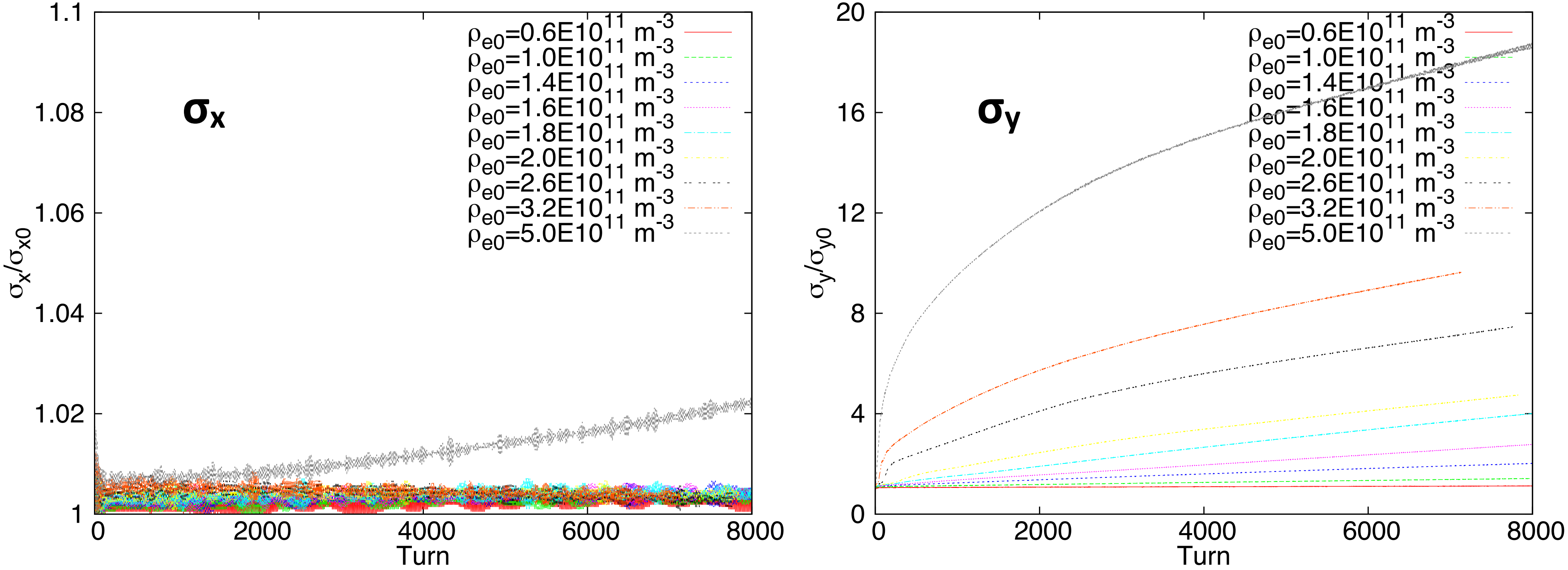


2. Results of PEHTS2

Condition 2:

➤ **Incoherent emittance growth observed with almost all simulated ρ_e**

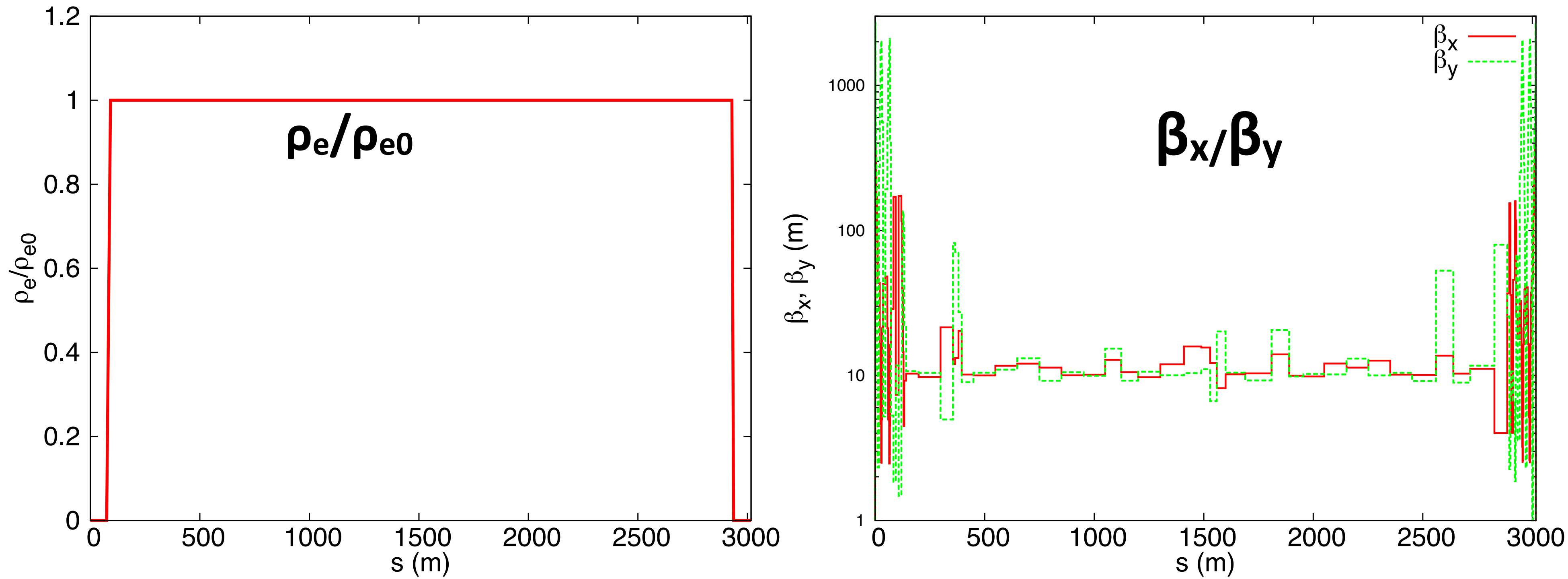
➤ **Threshold of coherent instability: $<\rho_e>\approx$1.8e11 m^{-3}(?)**



2. Results of PEHTS2

Condition 2: Without IR and LCCs

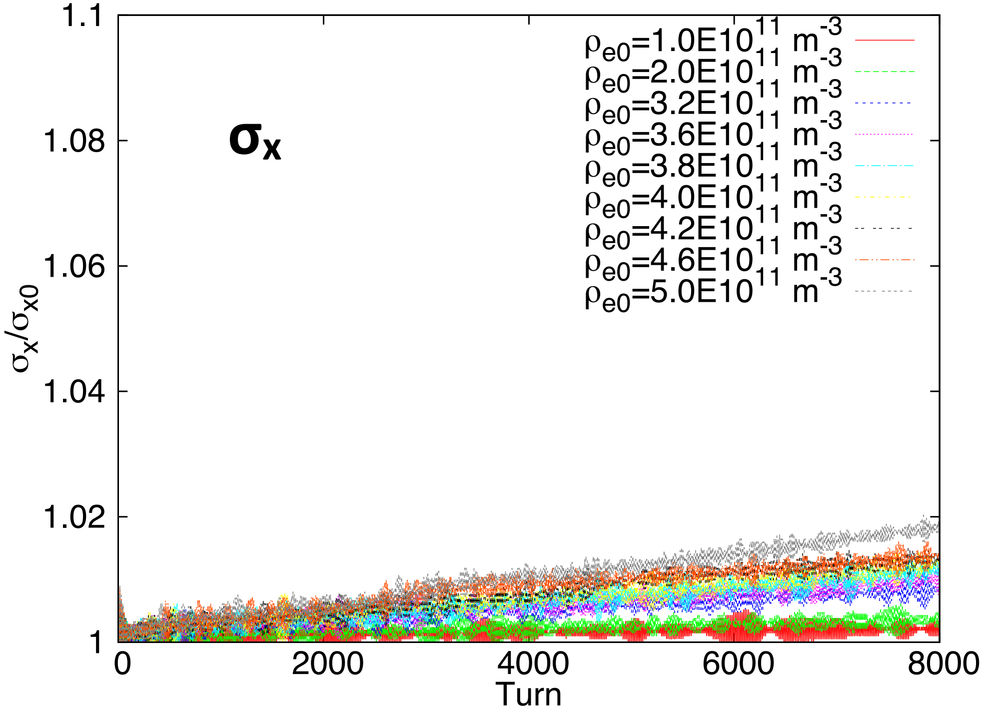
- **Parameters: ν_x=44.53, ν_y=46.57, ν_s=0.0247, P_{BUNCH}=9.04e10, ρ_{e0}={1.0, ..., 5}e11 m^{-3}**
- **Number of sections along the ring: Nsection=129**

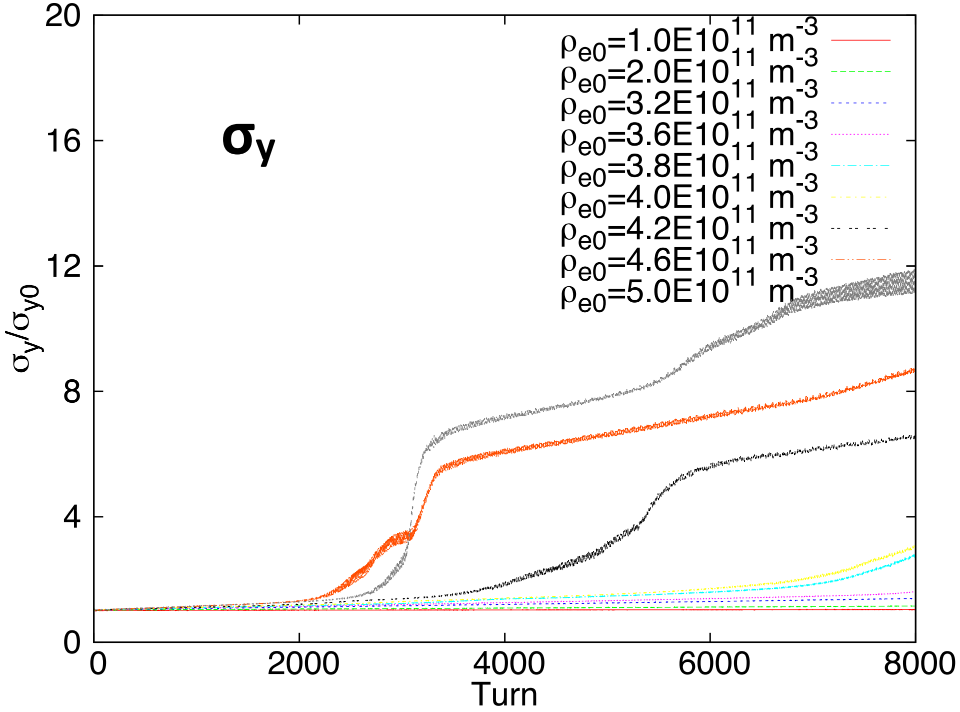


2. Results of PEHTS2

Condition 2: Without IR and LCCs

- **IR dominates the incoherent emittance growth**
- **Threshold of coherent instability: <ρ_e>≈3.6e11 m^{-3}**

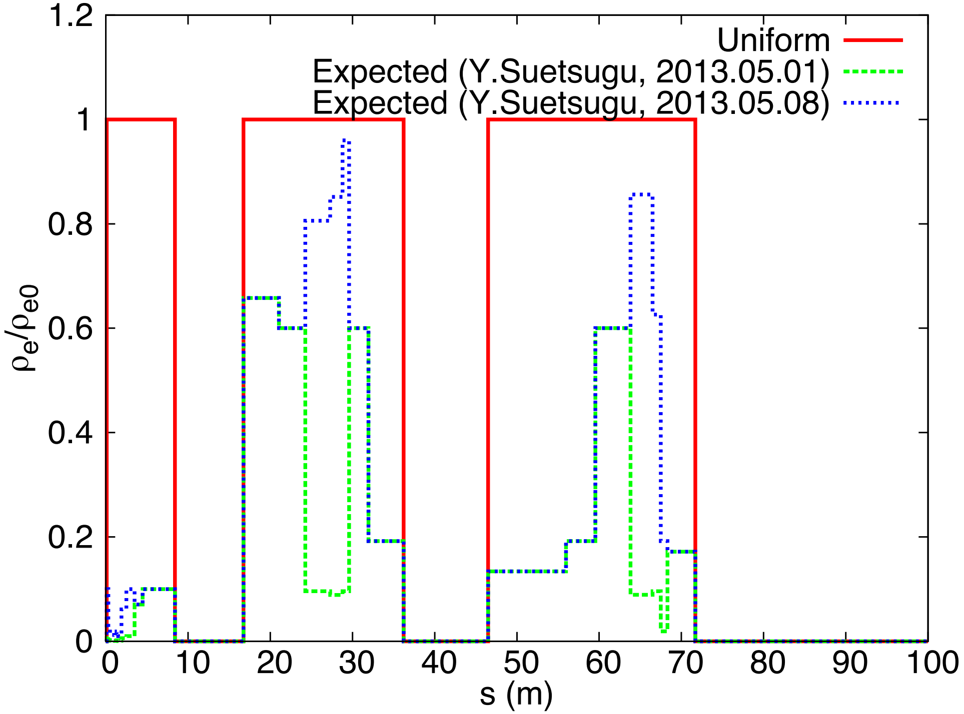


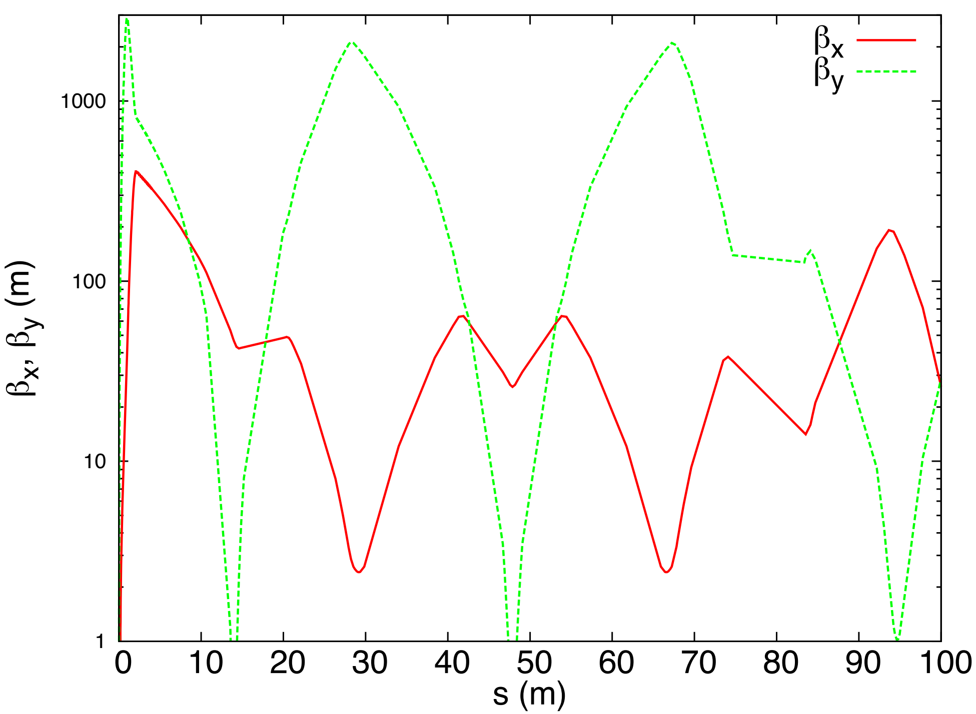


2. Results of PEHTS2

Condition 2: Only IR and β_y>50m

- Vary ρ_{e0}={1, 2, ..., 5}e11 m^{-3}
- Outside IR and LCC: ρ_e/ρ_{e0}= 0
- In IR and LCC: ρ_e/ρ_{e0}= 0 if β_y<50m





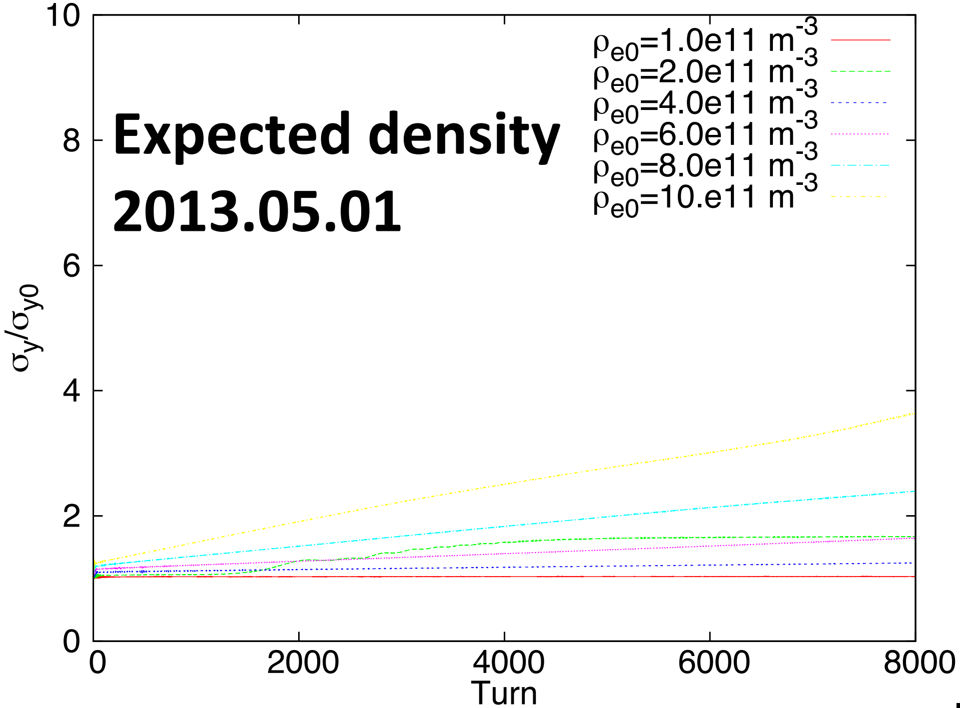
2. Results of PEHTS2

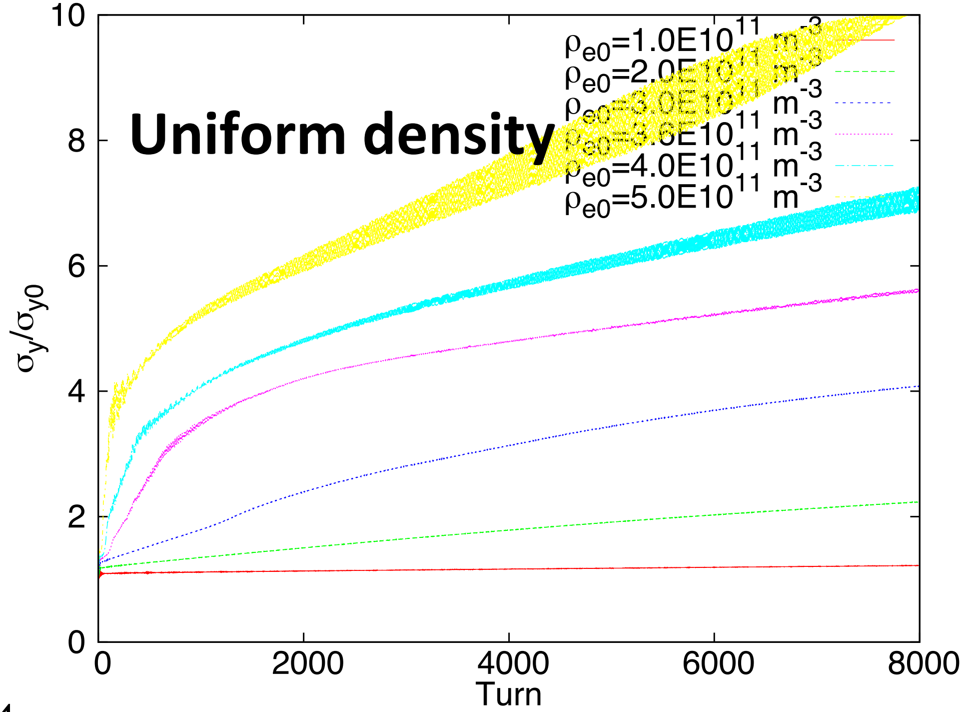
Condition 2: Only IR and β_y>50m

➤ **Vary ρ_{e0}={1, 2, ..., 5}e11 m^{-3}**

➤ **Low expected ρ_e at high beta sections**

➤ **High beta sections cause emit. growth if ρ_e high enough**

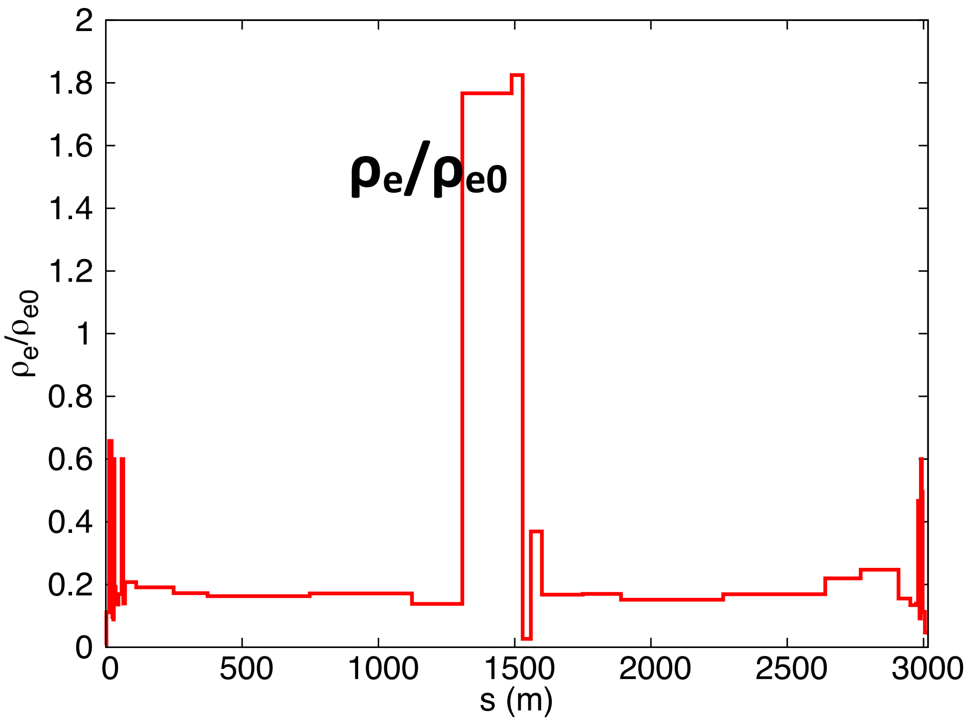


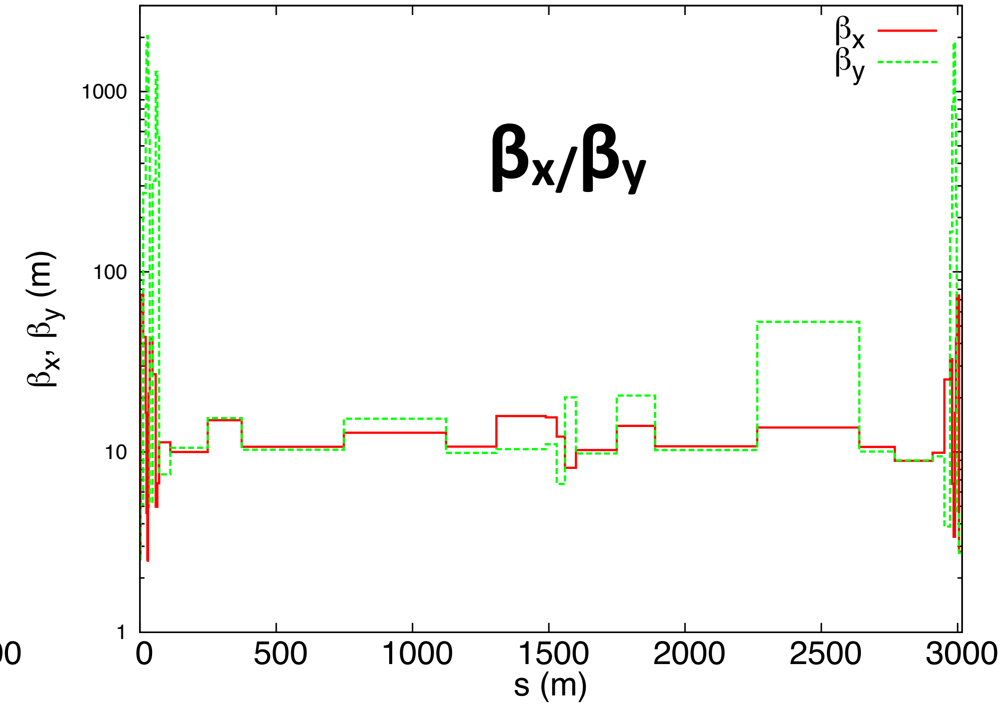


2. Results of PEHTS2

Condition 3:

- **Parameters: ν_x=44.53,ν_y=46.57, ν_s=0.0247, P_{BUNCH}=9.04e10, ρ_{e0}=1e11 m^{-3}**
- **Number of sections along the ring: Nsection=38**
- **Ecloud density data given by Y. Suetsugu**

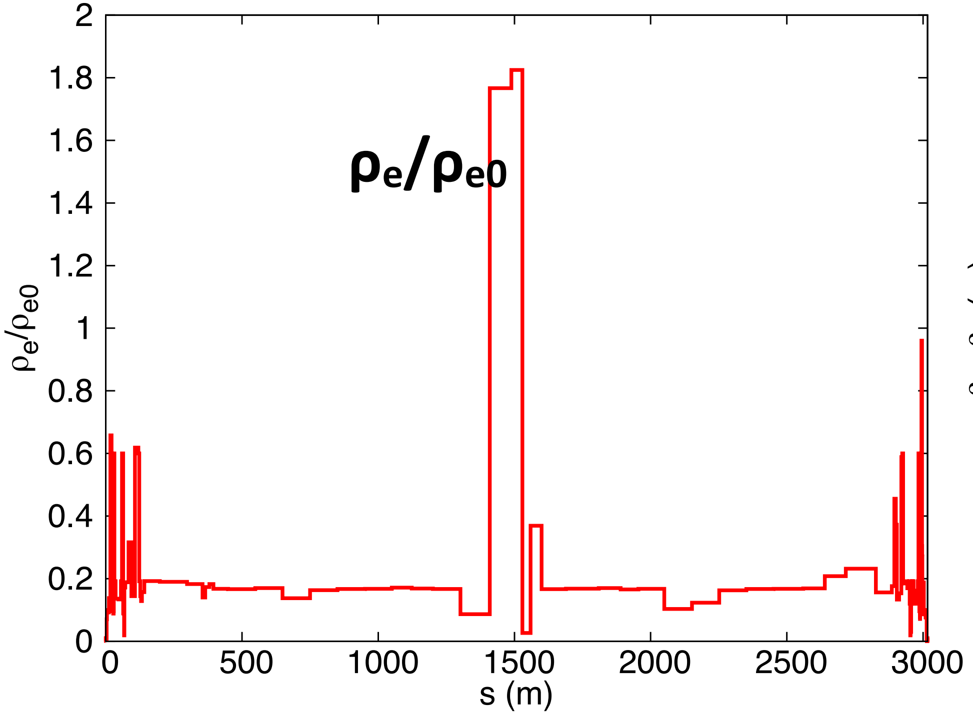


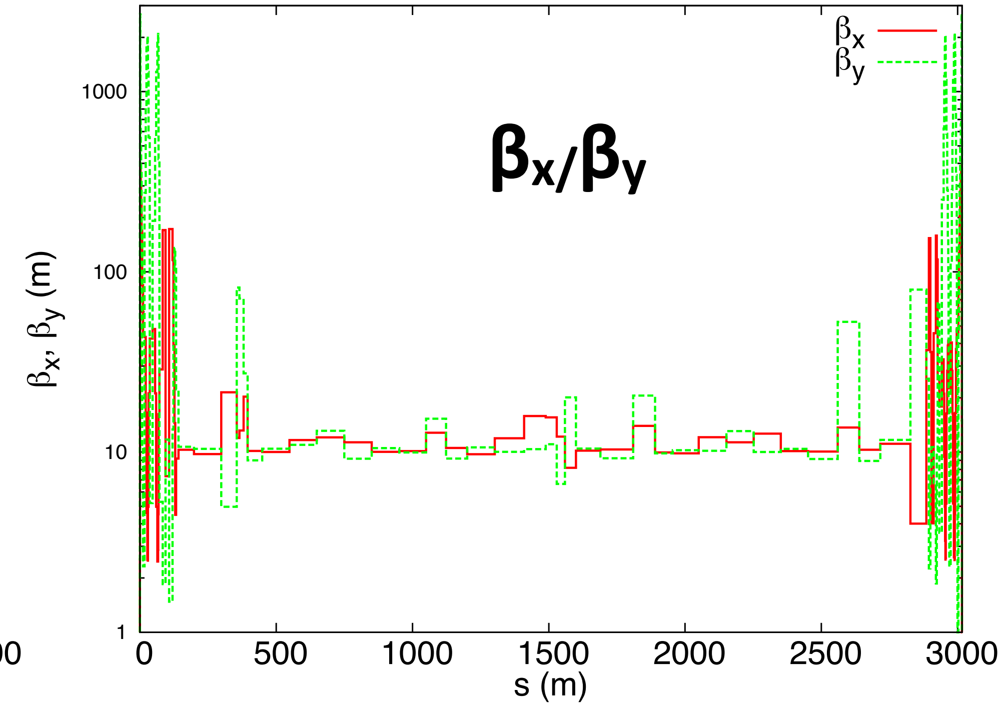


2. Results of PEHTS2

Condition 4:

- **Parameters: ν_x=44.53,ν_y=46.57, ν_s=0.0247, P_{BUNCH}=9.04e10, ρ_{e0}=1e11 m^{-3}**
- **Number of sections along the ring: Nsection=129**
- **Ecloud density data given by Y. Suetsugu**



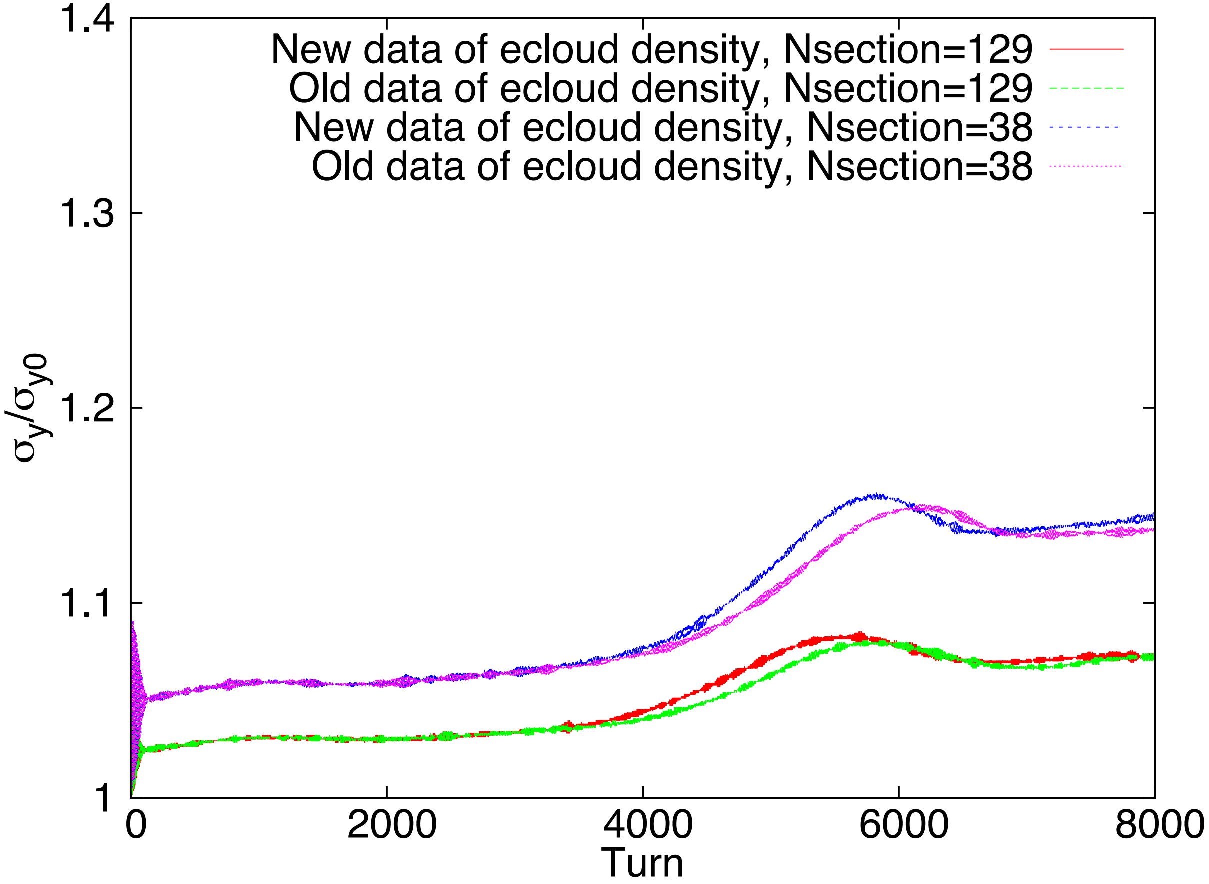


2. Results of PEHTS2

Condition 3 and 4:

➤ **Emittance growth depend on number of "wake kicks"/turn**

➤ **Vert. beam size blow-up < 10%**



2. Results of PEHTS2

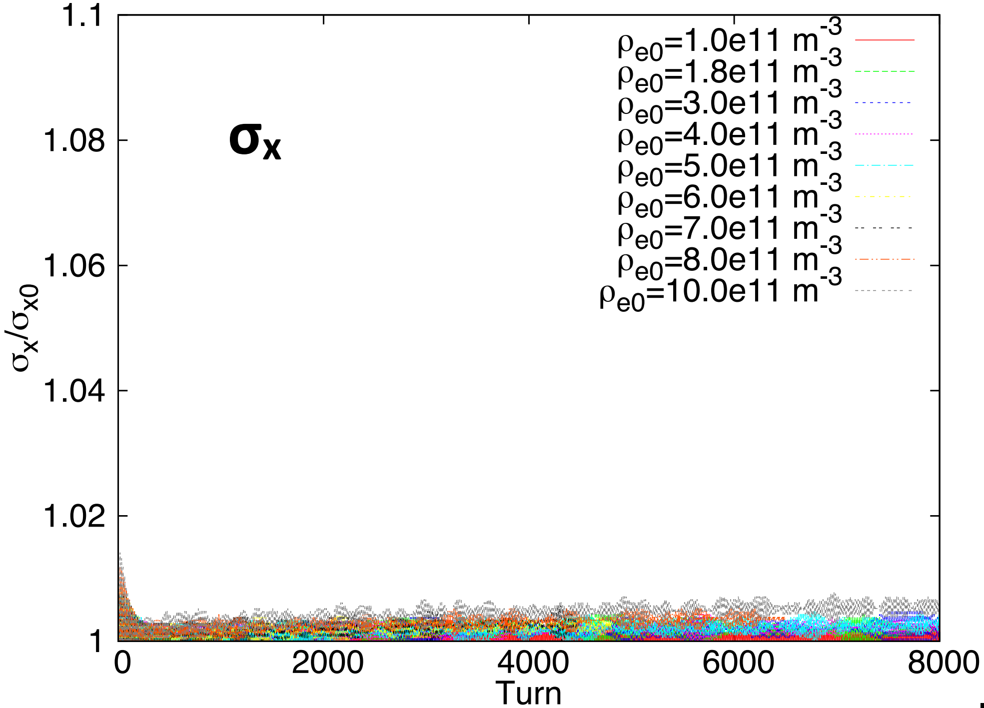
Condition 4:

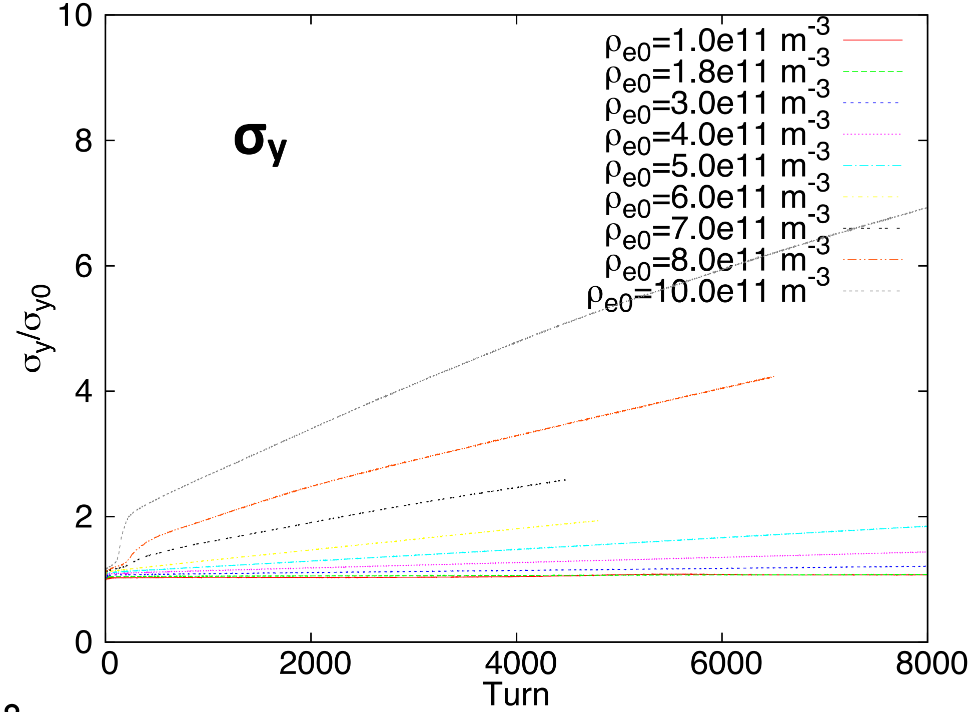
➤ **Vary ρ_{e0}={1, 2, ..., 10}e11 m^{-3}**

➤ **Seems no coherent instability up to ρ_{e0}=6e11 m^{-3}**

➤ **Safety margin for LER: factor of 6?**

➤ **Incoherent emittance growth (if true!) need to be validated via more careful simulations!**





3. Summary

- **SuperKEKB LER**
  - Varied beta functions and high-beta areas near IP
  - Ecloud densities vary along the ring
- **Uncertainties in simulations**
  - Incoherent emittance growth
  - Fixed mesh sizes and mesh area in PEHTS2 code:
    (1) Large beta function => Mesh area should hold large beam
    (2) Small beta function => Mesh sizes should resolve small beam
- **Simulation results:**
  - Given expected densities(by Y. Suetsugu) and lattice information(sler_1683) => LER looks to be safe from ecloud instability (very preliminary! safety margin to be defined!)
  - Constant ecloud density and $\beta_{x,y}$ => Reasonable results
  - Varied ecloud densities and $\beta_{x,y}$ => Threshold not easy to be detected; obtained results somehow ambiguous

3. Summary

➤ **More systematic studies:**

- **Proper set-up of PEHTS2 code (mesh sizes, mesh area, cloud sizes, number of sections, etc. depend on $\beta_{x,y}$)**
- **Understanding simulation results of PEHTS2**
- **Comment from Suetsugu-san: ecloud density expected to be high in the early stage of SuperKEKB's beam commissioning => Ecloud effects also depend on beam current**
- **Simulations and preparations of beam observations => Dedicated machine study?**
- **Benchmark study from L. Wang(SLAC)**