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Study of electron cloud at MI and slip stacking process simulation

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Purpose

1. Understand the slip stacking process which happens in the Main Injector.
2. Calculation of bunch distortion with slip stacking there is.
3. Filtering and analyze of electron cloud data from MI

Main Injector

Main Injector accelerates protons and extracts them to a target to produce antiprotons and neutrinos. In the operation cycle, 84 bunches are injected from Booster to MI, accelerated from 8 GeV to 120 GeV and extracted to hit the production target.

Main Injector

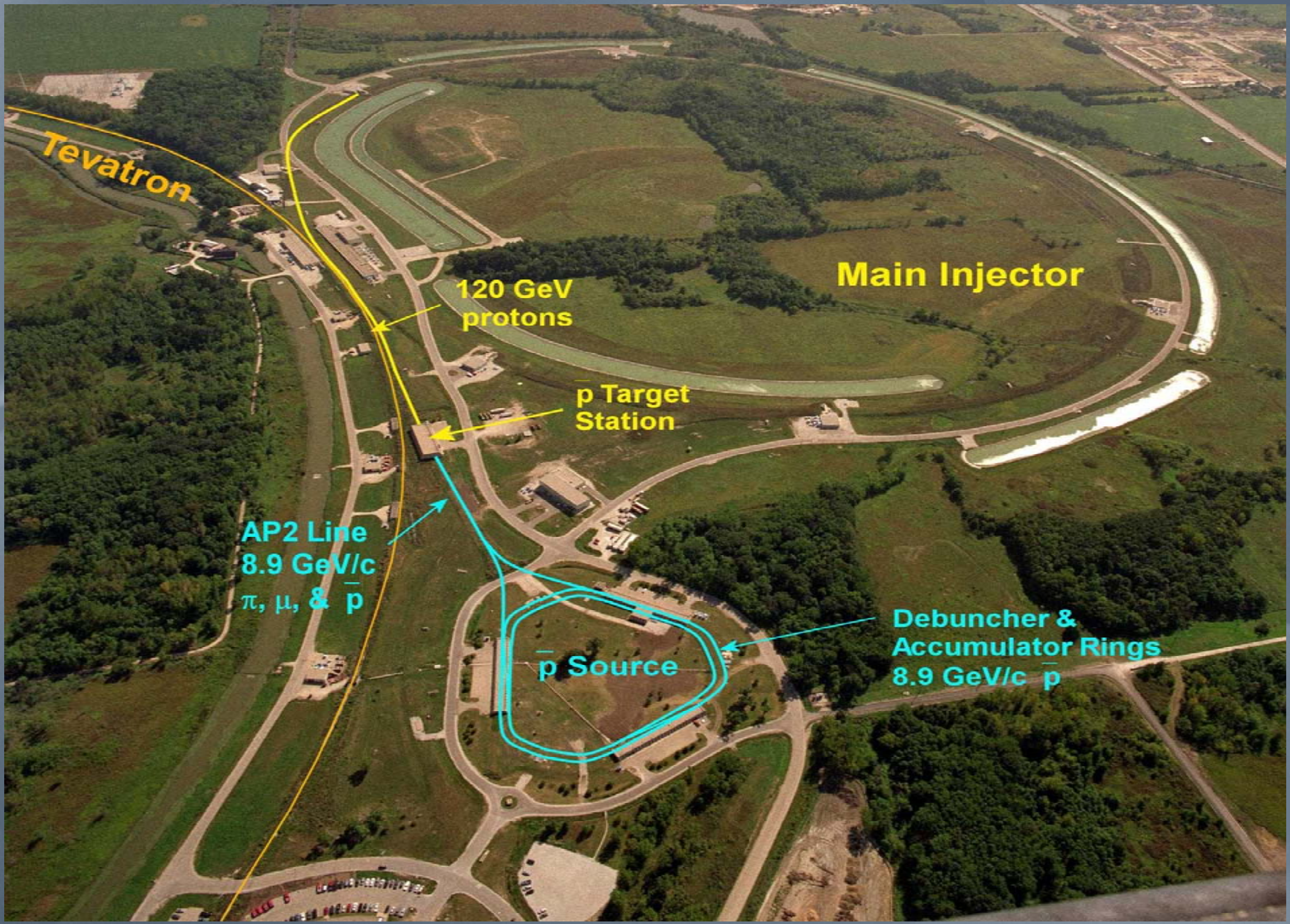

Figure 1: Fundamental Geography of the MI

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Slip Stacking Process

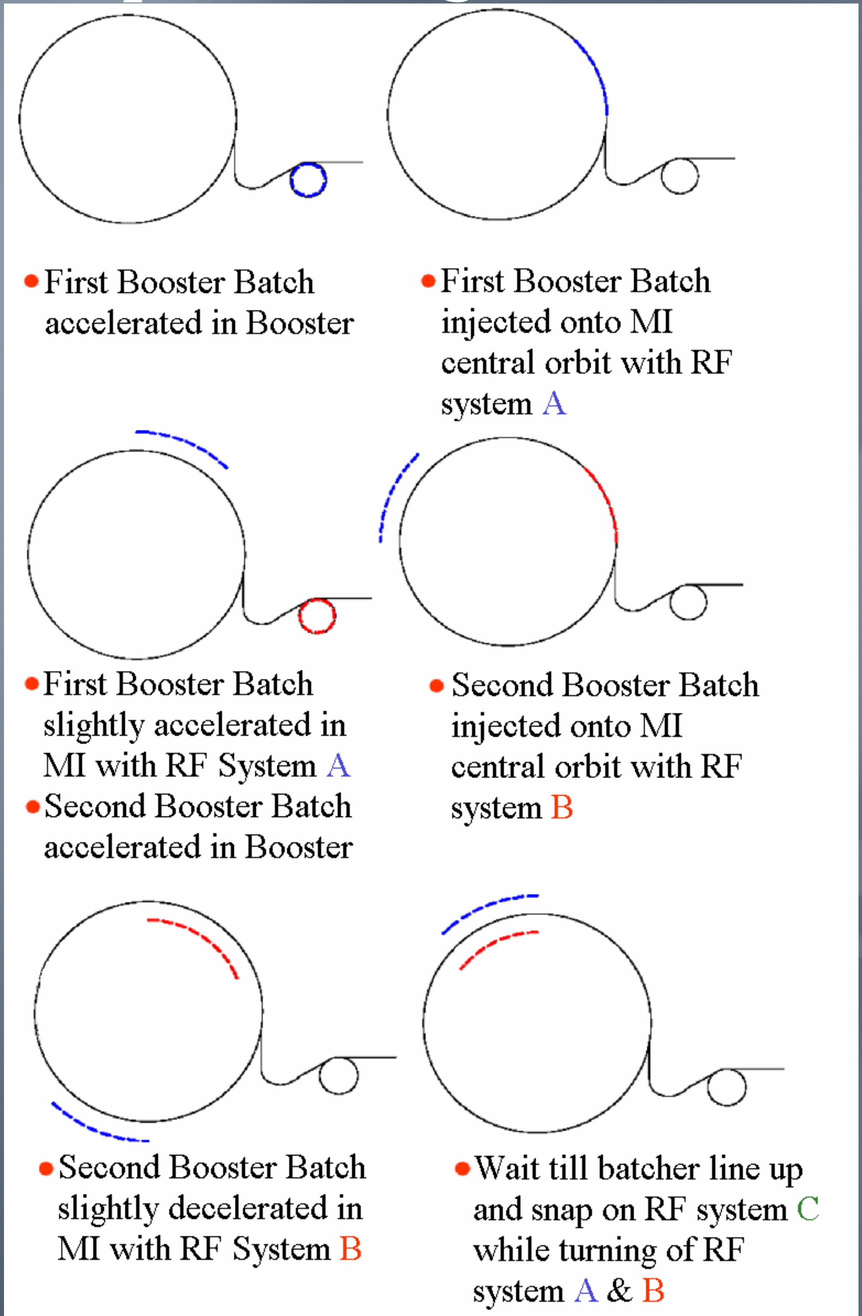

Figure 2: Slip Stacking Process

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Slip Stacking Process

With slip stacking, the intensity of the bunches can be doubled by injecting one bunch train at lightly lower energy, another train at lightly higher energy and bringing them together.

Slip Stacking Process

Since two bunch trains have different energies, MI must have an enough momentum aperture to accept both. The momentum aperture of MI is +/- 0.7% at injection, that is, the rf frequency for each bunch train can be shifted by +/- 3000Hz from the original value.

Slip Stacking Process

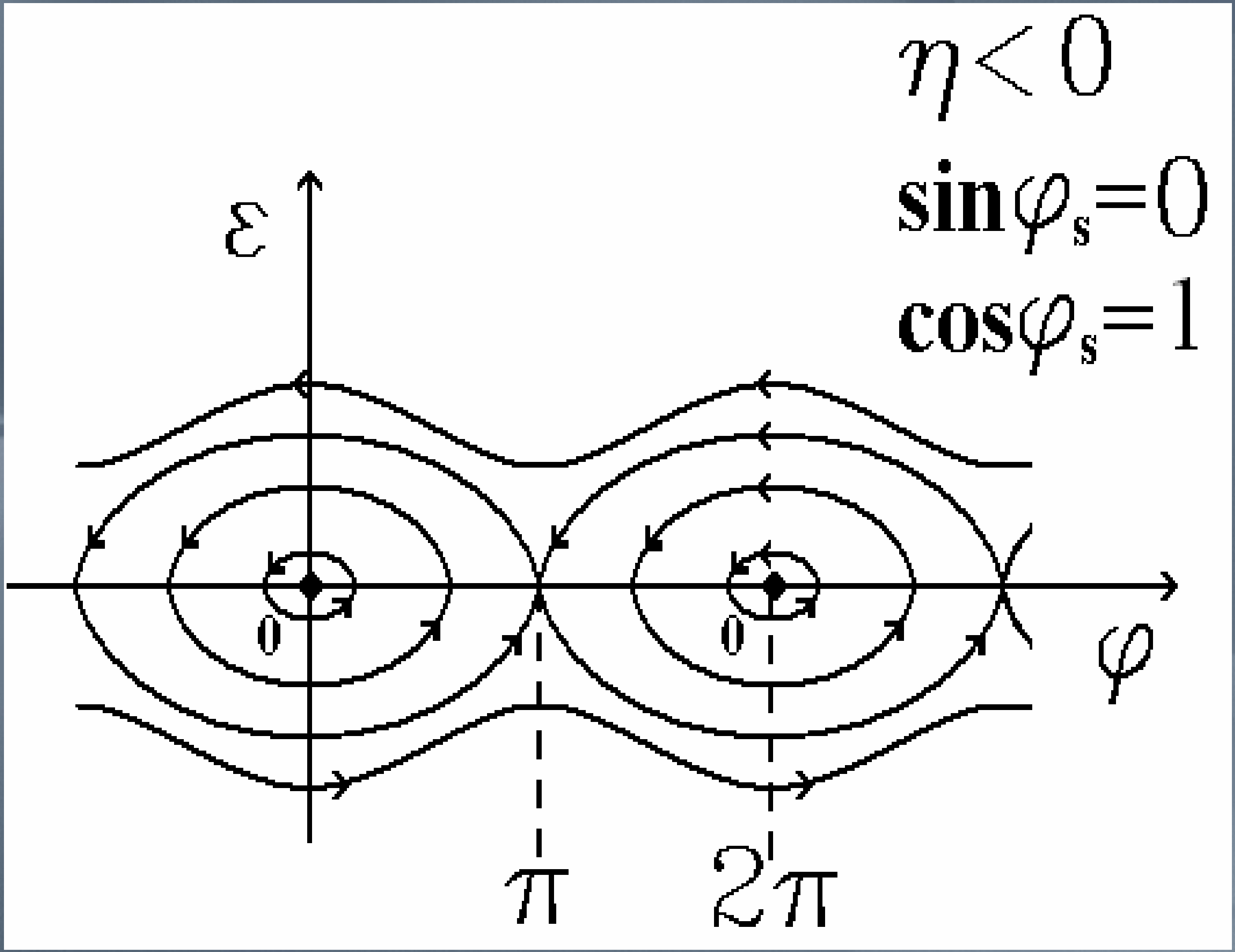

Figure 4: Stationary RF buckets

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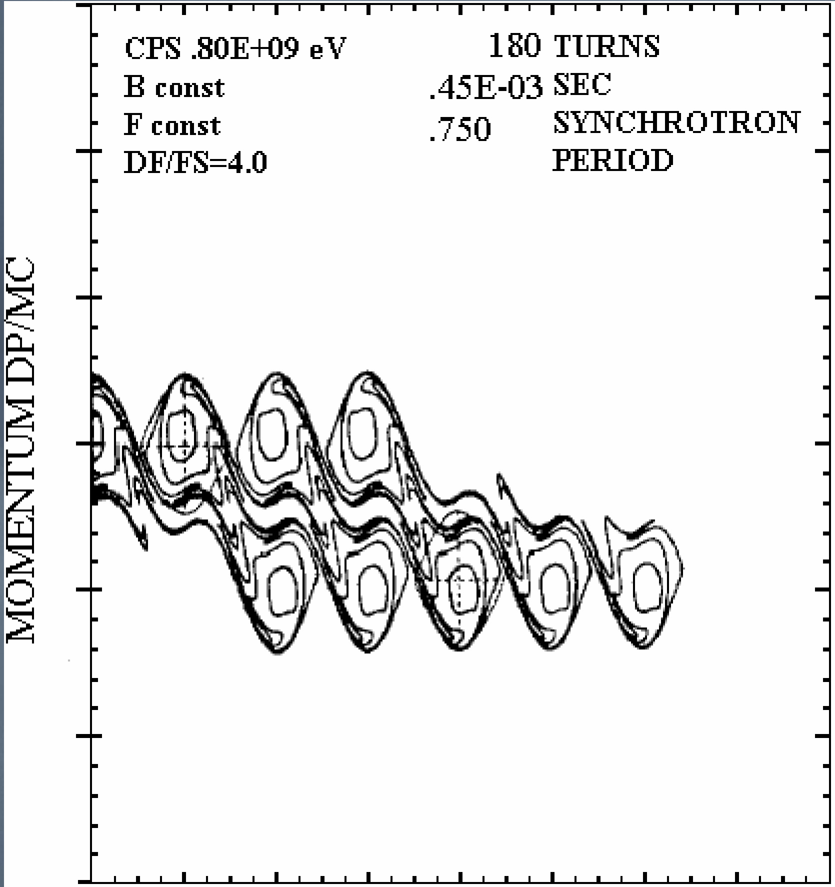
Slip Stacking Process

Both bunches train is affected by not only its own RF system.



Slip Stacking Process

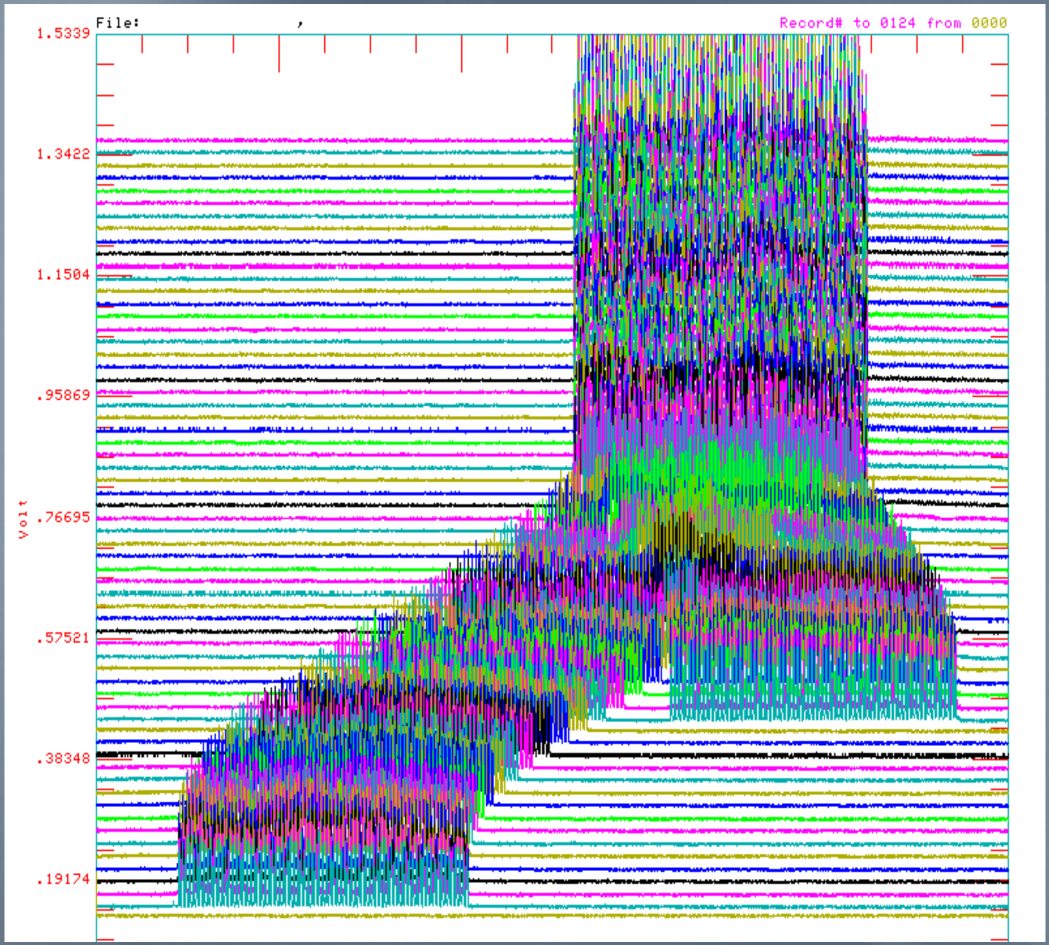


Figure 3: Mountain range plot with WCM signal

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Slip Stacking Process

Initial energy deviation for particle which is situated on the separatrix

$$\varepsilon_{max} = 2\sqrt{\frac{eU_0 E_0}{T_0 \omega_0 \eta}}$$

The bunch pairs can be combined in a single large bucket at a third RF-frequency

$$f_3 = \frac{(f_1 + f_2)}{2}$$

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Slip Stacking Process

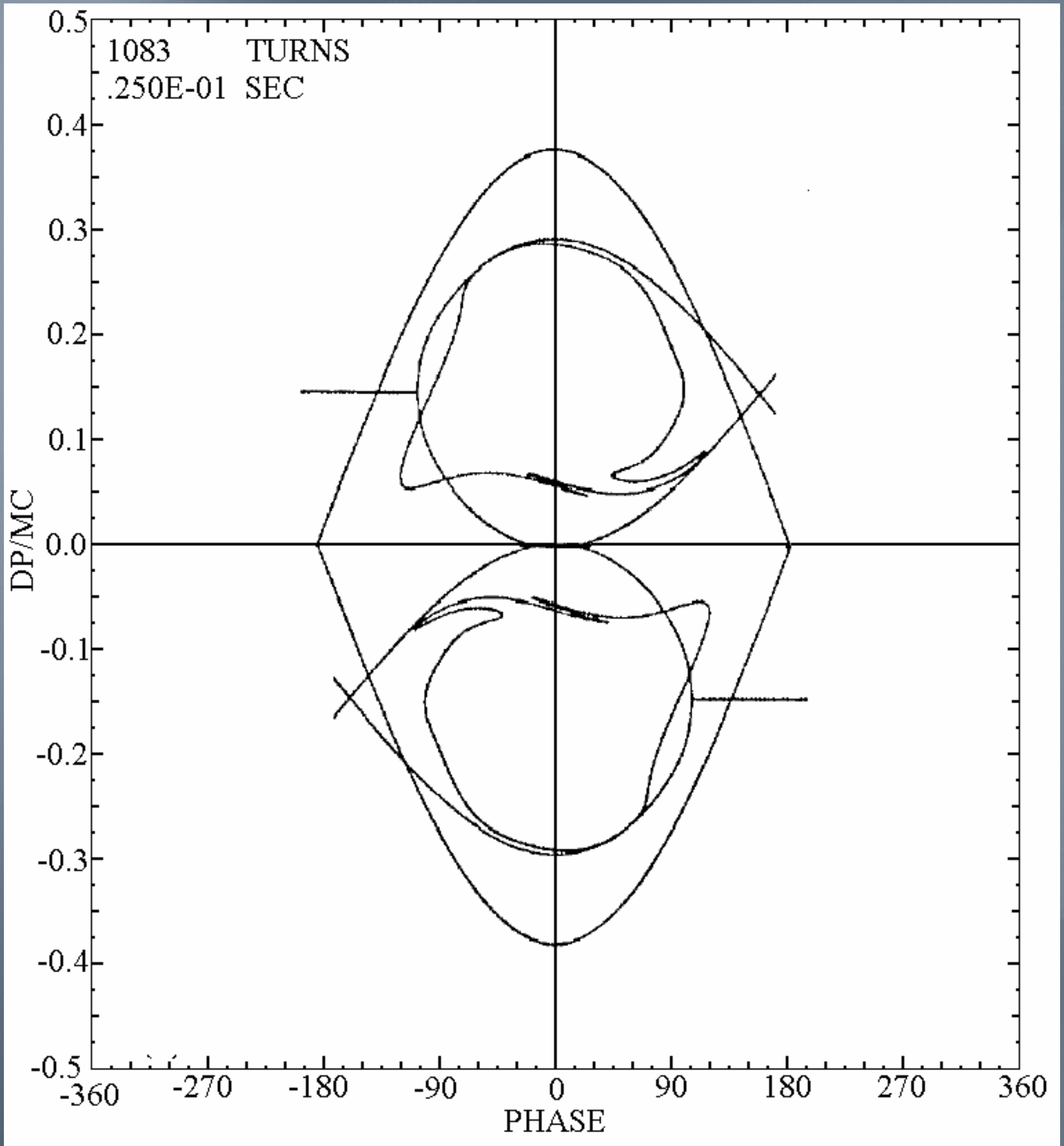

Figure 6:
Combination of two buckets under influence third RF

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Slip Stacking Process

Whether first bunches feel only the its frequency f_1?

One expects a large effect when the ratio

$\alpha = \frac{\Delta f}{f_s}$ becomes of the order of unity,

where $f_s -$ synchrotron frequency

corresponding to one wave.

Optimum frequency separation was found to be about $\alpha = 5$,which gives the minimum final emittance $(\approx 40\text{mrad})$.

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Electron Cloud Analyze

After upgrade to the MI which would increase the bunch intensity MI in a regime in which a significant electron-cloud effect has been observed at other hadron mashines.

Electron Cloud Analyze

The electron cloud is seeded by primary electron from three main sources:

1. Photoelectrons
2. Ionization of residual gas
3. Electrons produced by stray beam particles striking the chamber wall

These processes are essentially incoherent.

The contribution from residual gas ionization

Number of primary electrons produced per beam particle per unit lengh of beam traversal:

$$n'_{e(i)}\left[m^{-1}\right] = 3.3\,\sigma_i\left[\mathrm{Mbarn}\right] \times P\left[\mathrm{Torr}\right] \times \frac{294}{T\left[K\right]},$$

σ_i – ionization cross-section

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Electron Cloud Analyze

The contribution from stray protons striking the chamber walls is given by

$$n'_{e(pl)} = \eta_{eff}\, n'_{pl},$$

where n'_{pl} – number of lost protons per stored proton per unit length of beam traversal,
η_{eff} – effective electron yield per proton-wall collision.

Electron Cloud Analyze

Contribution from photoelectrons and electrons produced by stray beam particles striking the chamber wall lesser than contribution from secondary electron emission

Electron Cloud Analyze

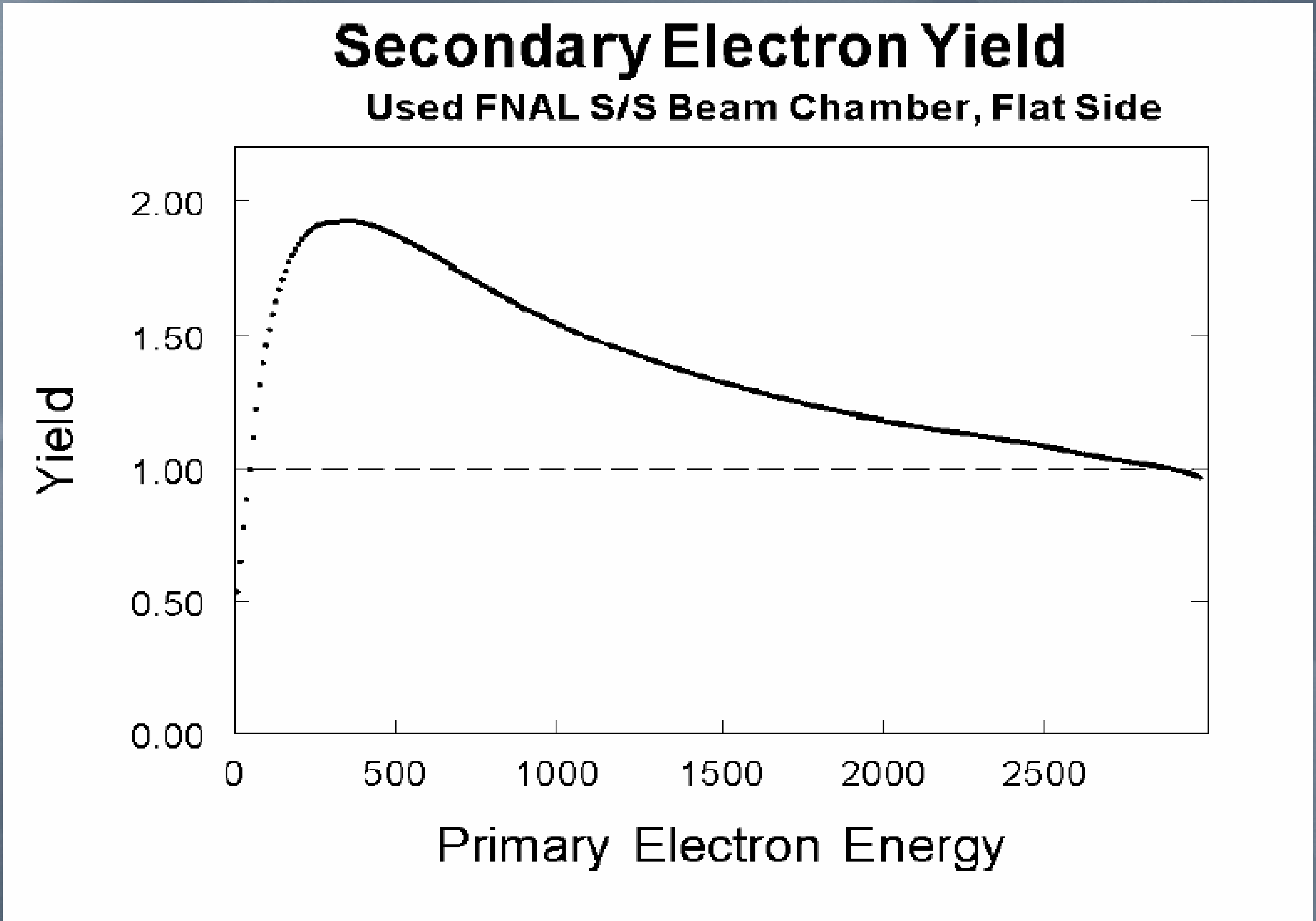

Figure 7: Secondary emission

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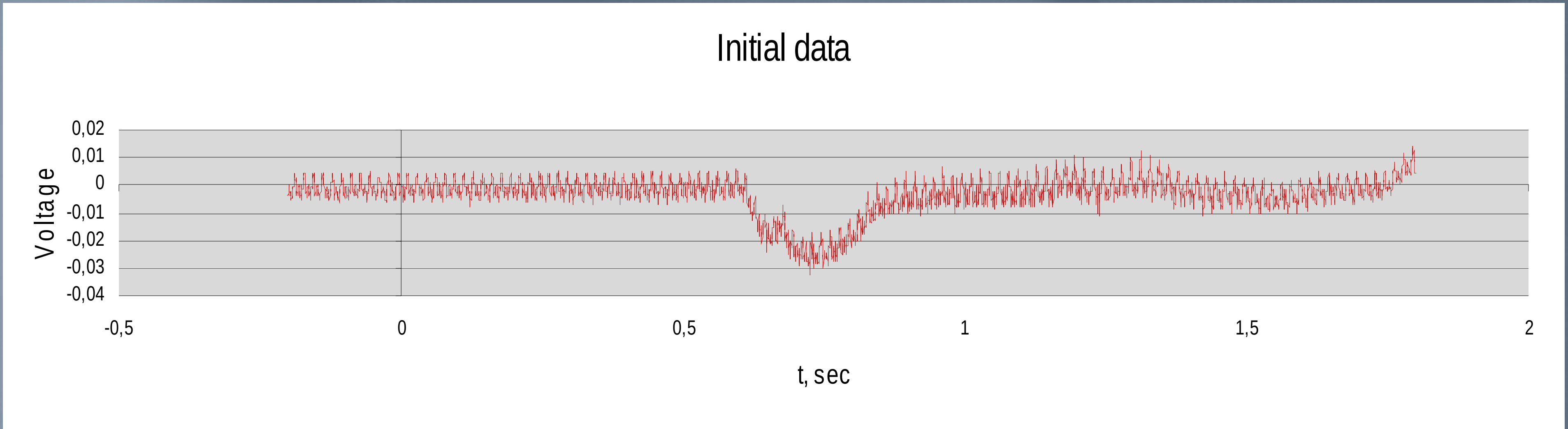
Electron Cloud Analyze

Consider case of the beam injection, since the most significant fraction of beam loss occur during this time, which lasts for $\Delta t_{inj} = 0.4\,s$

Electron Cloud Analyze



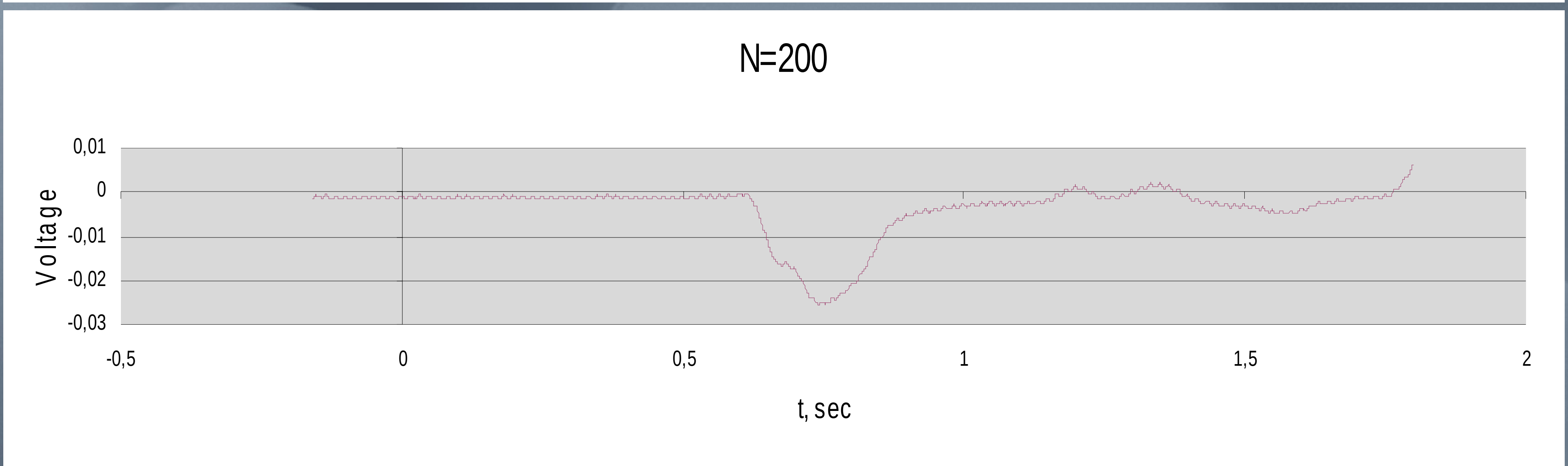


Figure 8: Electron cloud after injection (a)

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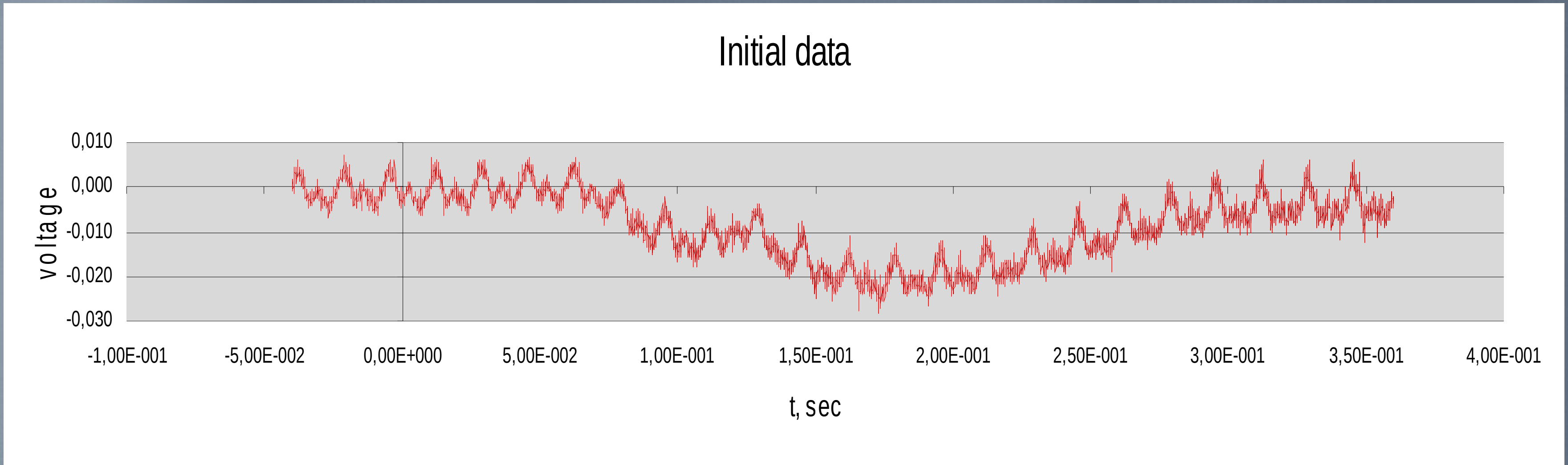
Electron Cloud Analyze



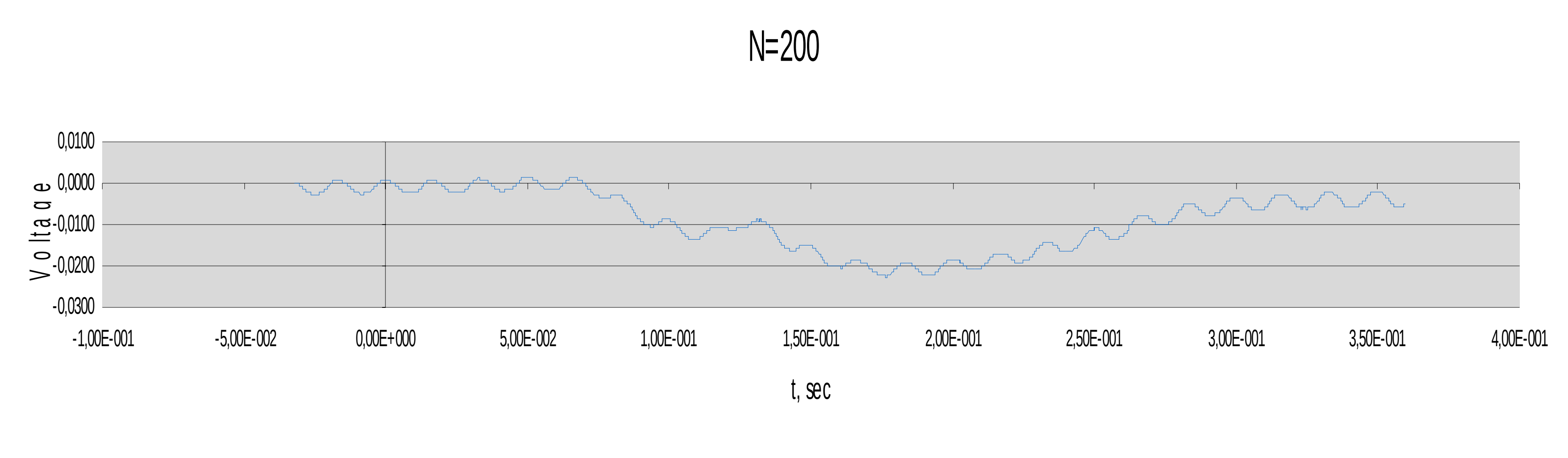


Figure 8: Electron cloud after injection (b)

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References

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Thank you, for your attention.

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