A Wideband Feedback Model for HeadTail

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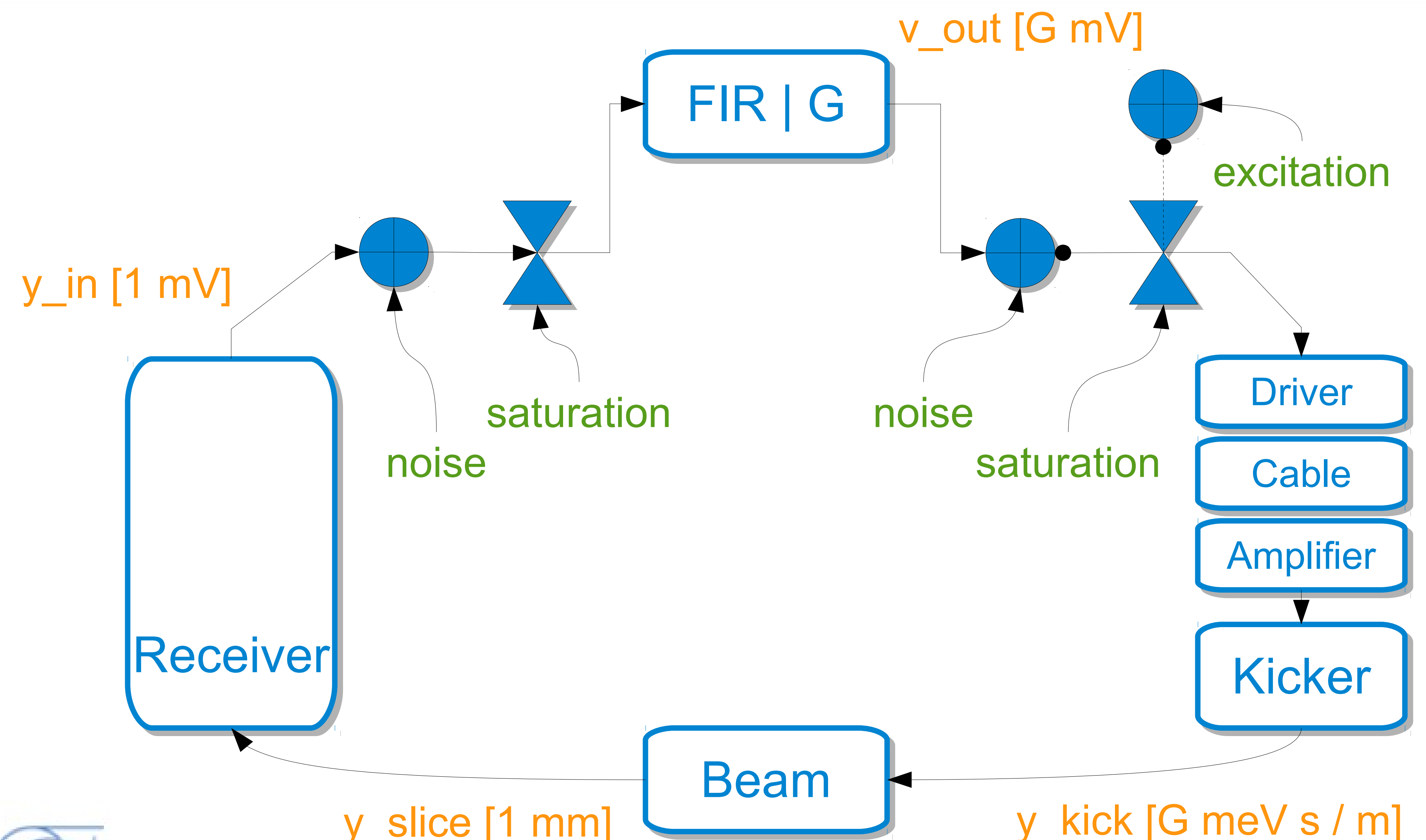
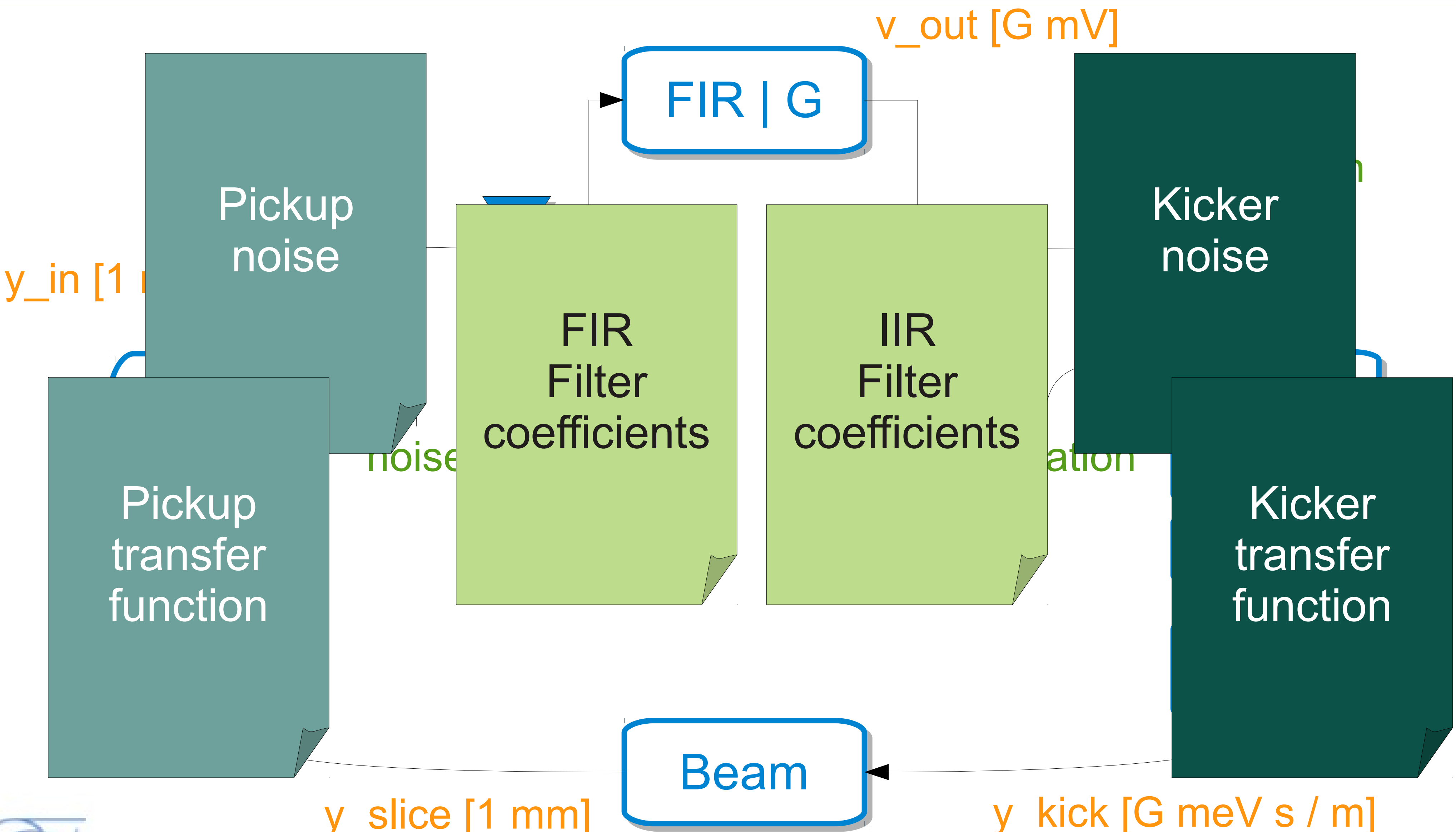
Overview

- The feedback model in HeadTail
- Model parameters
- Some applications
  - Centroid motion
  - ECI
  - TMCI
  - Noise
- Problems, open questions and future plans

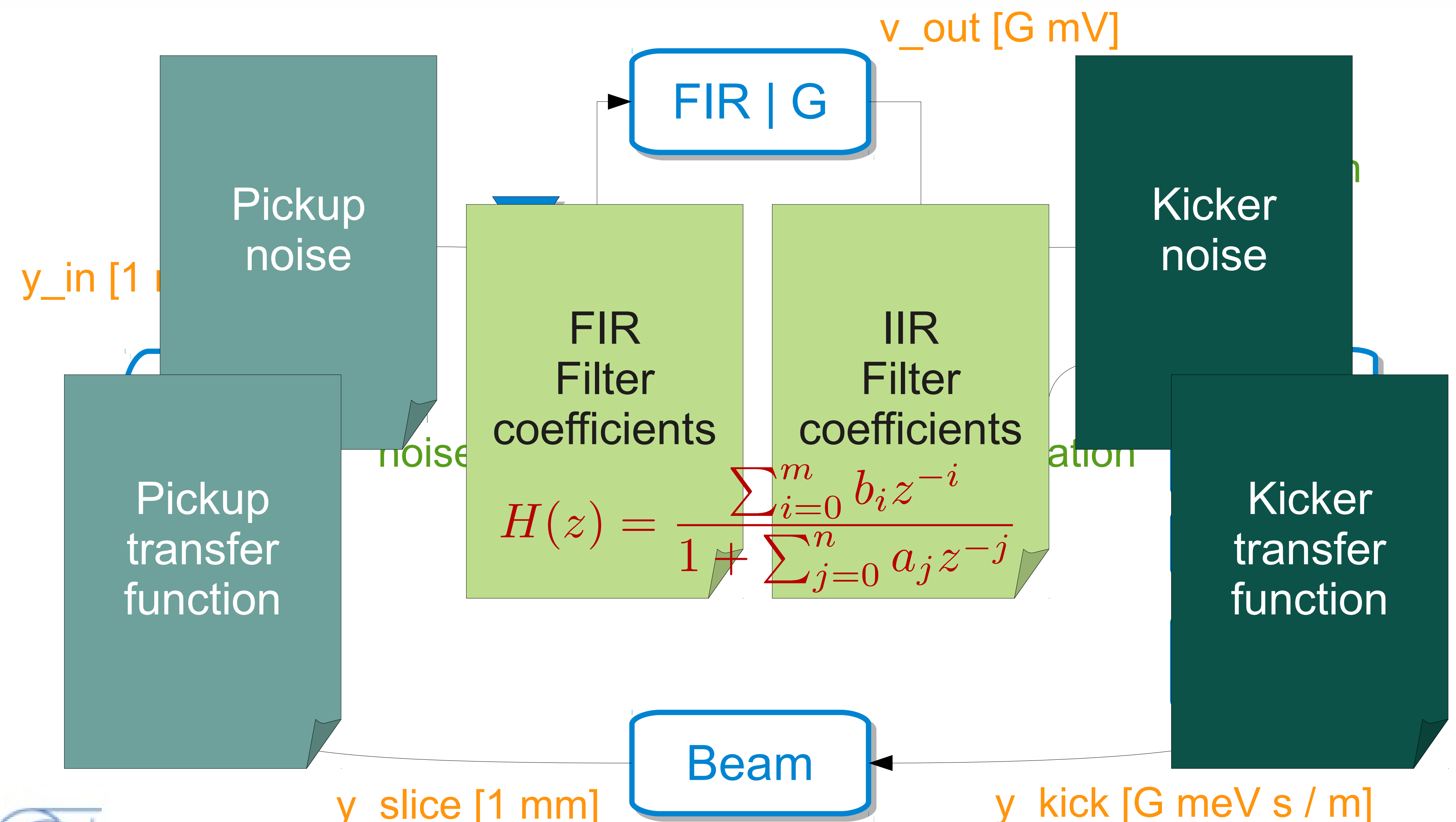
The HeadTail feedback model



The HeadTail feedback model

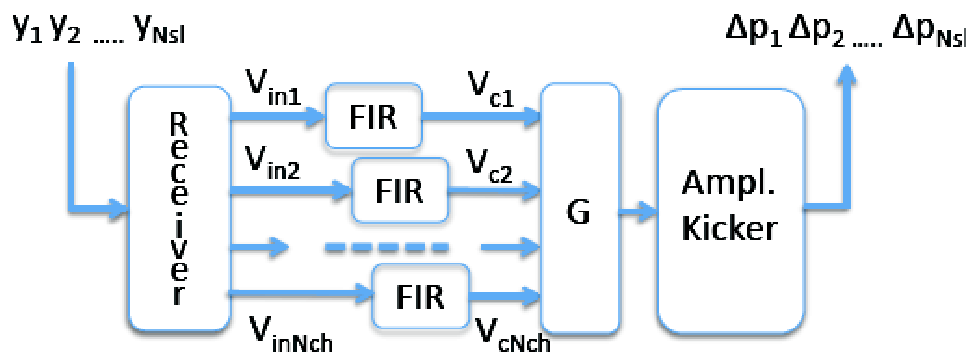


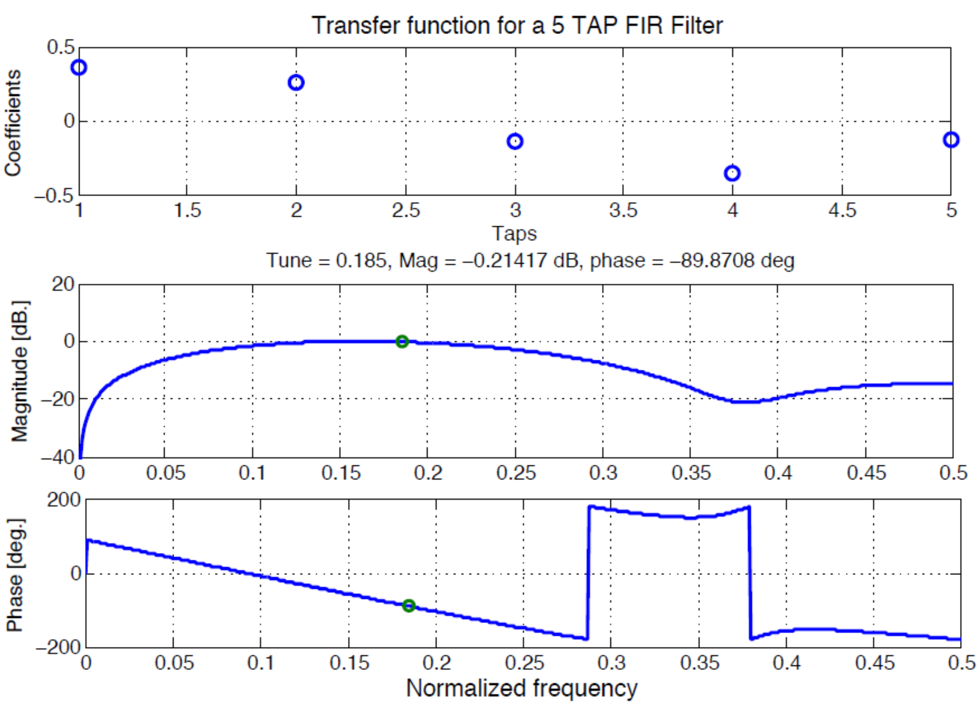
The HeadTail feedback model

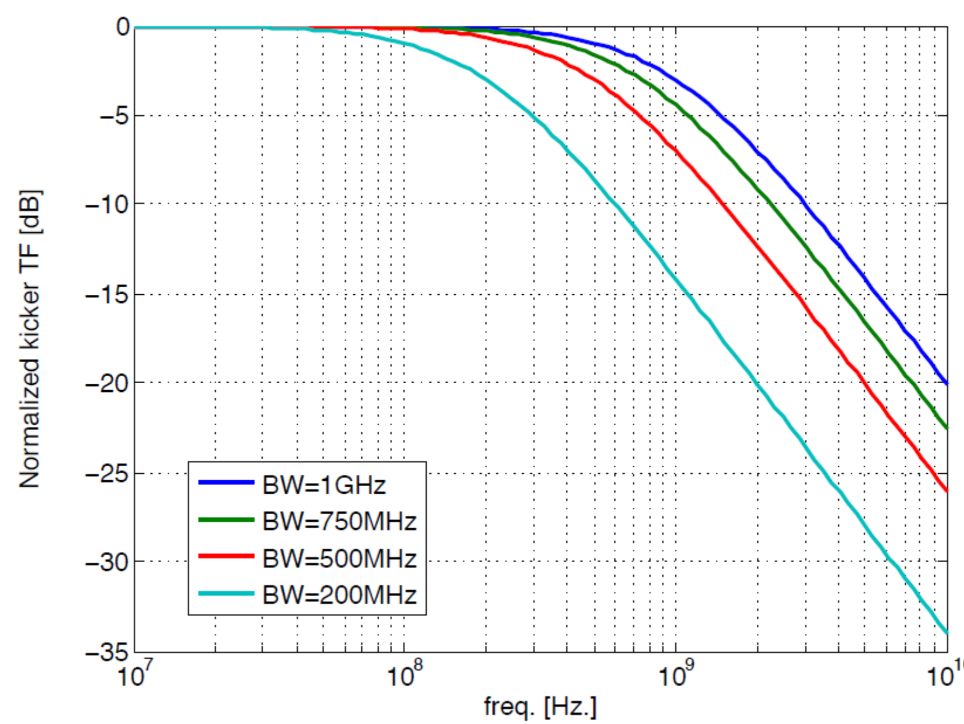


Feedback system - specifications

- 5 tap delay
- FIR transfer functions (left)
- Kicker transfer functions (right)







Model parameters

Momentum	26 GeV/c
Emittances [εx, εy, εz]	2.8, 2.8 um, 0.527 eV s
Bunch length [σz]	0.8 ns
Beta functions [βx, βy]	42, 42 m
Tunes [Qx, Qy, Qz]	26.13, 26.185, 0.00587644
Chromaticities [Q'x, Q'y]	0, 0

Shunt impedance	15 MΩ
Resonance frequency	1.3 GHz

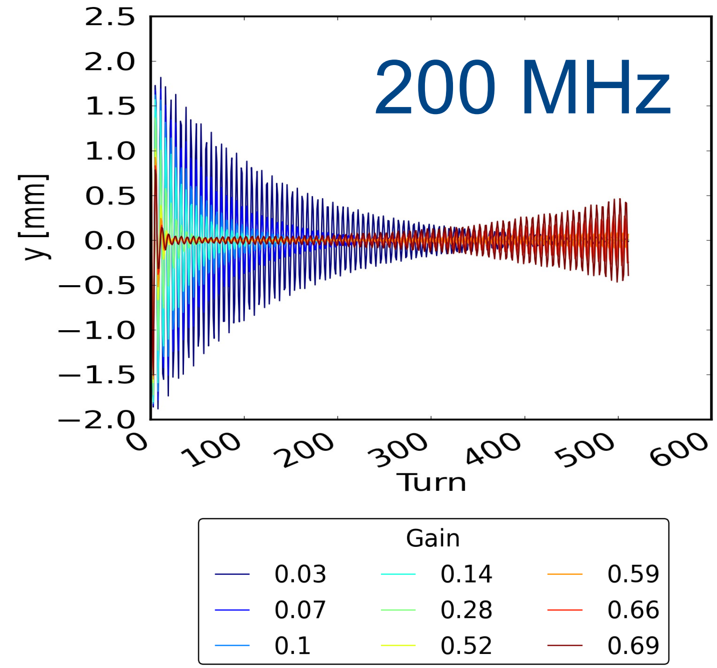
Intensity	1.15e11
Cloud density	6e11 m^{-3}

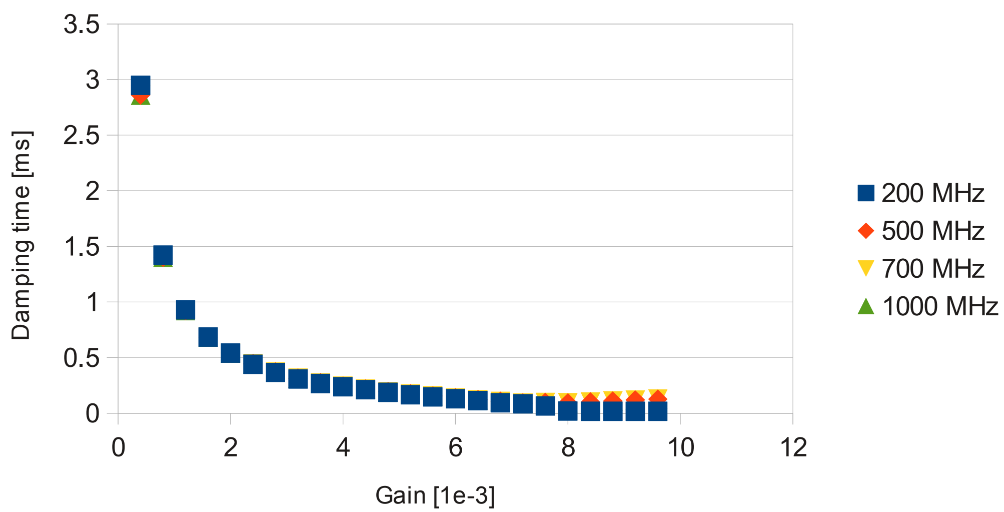
E-cloud regions	Dipole magnets

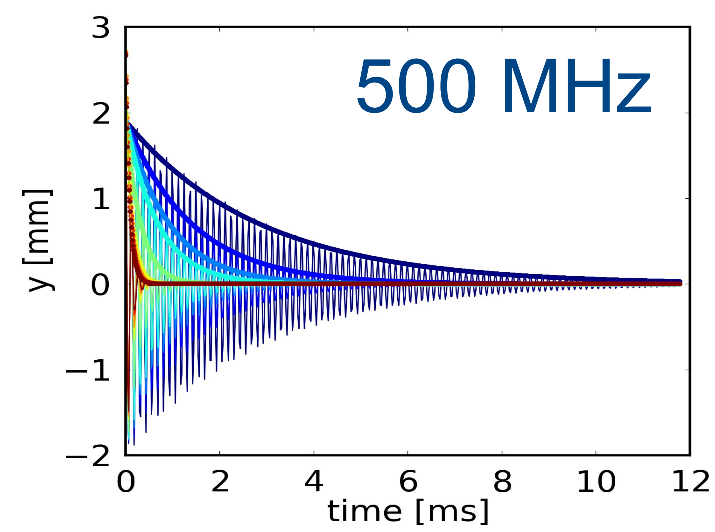
Centroid motion

Centroid motion – gain scan

- Bandwidths:
  200MHz, 500MHz, 700MHz, 1GHz
- Perturbation: 2mm initial vertical offset → monitor bunch response
- For high gains, the limited (200MHz) bandwidth makes the system become unstable
- For all cases, the bunch response (centroid motion) to the initial perturbation is similar → the systems perform equally well

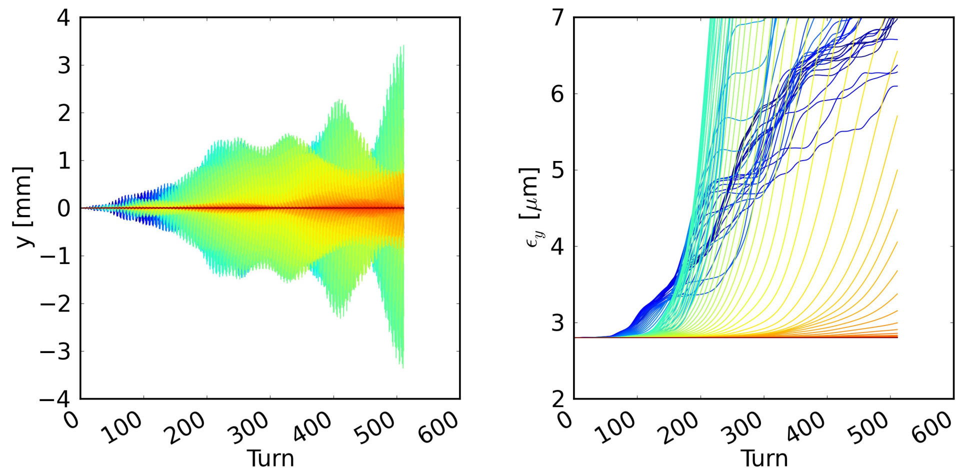




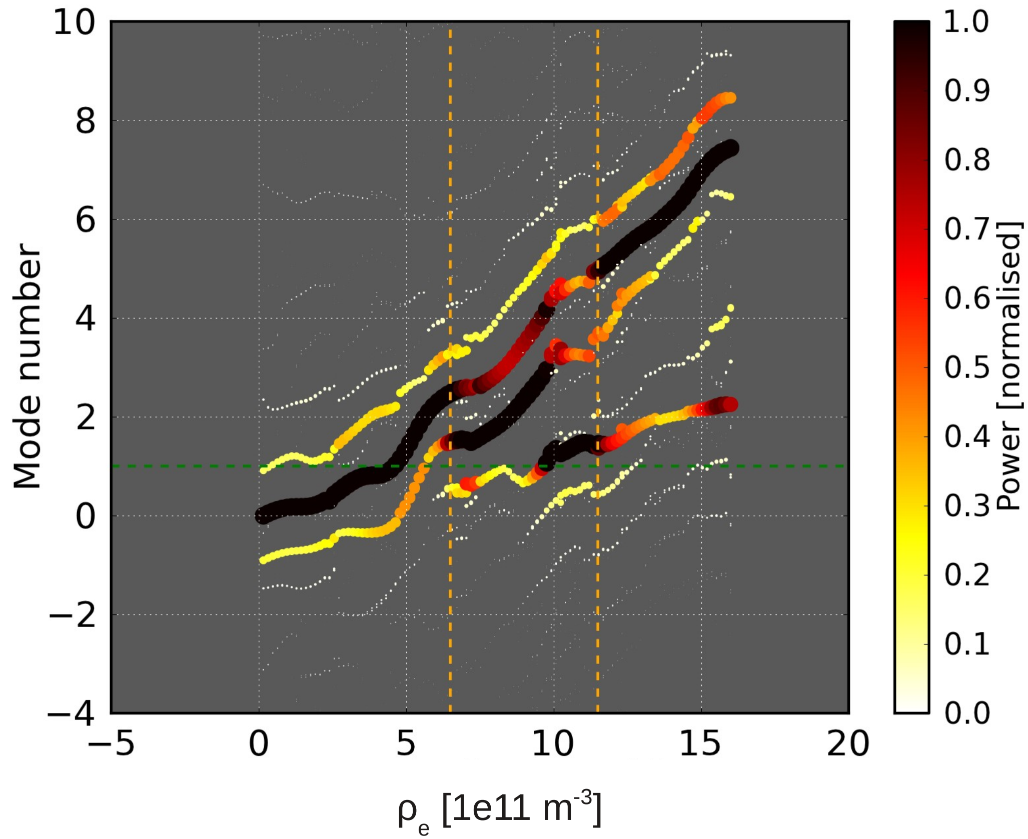


Electron cloud instabilities

ECI threshold



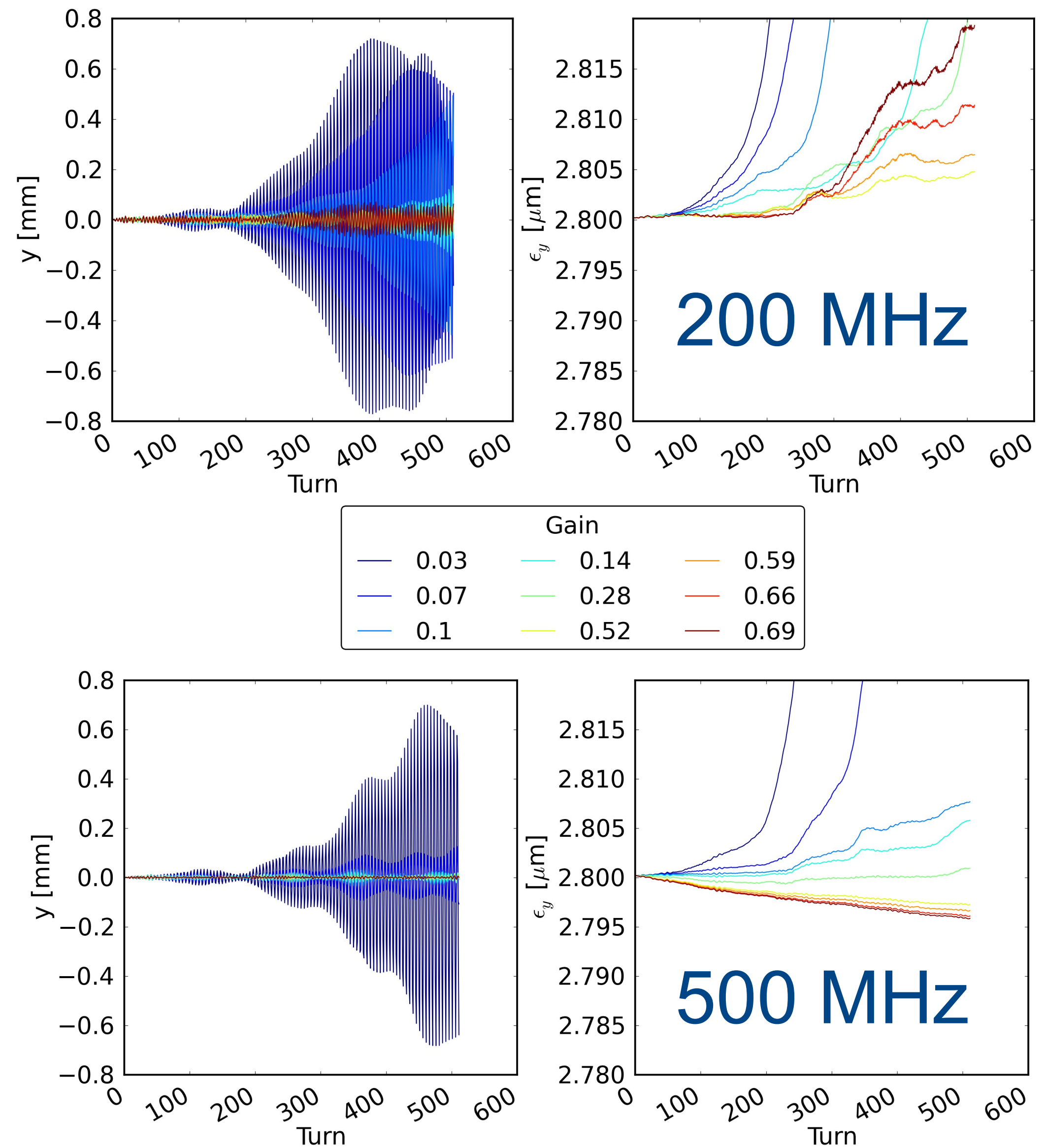
ρ_e = [1 – 16] x 1e11 m^{-3}



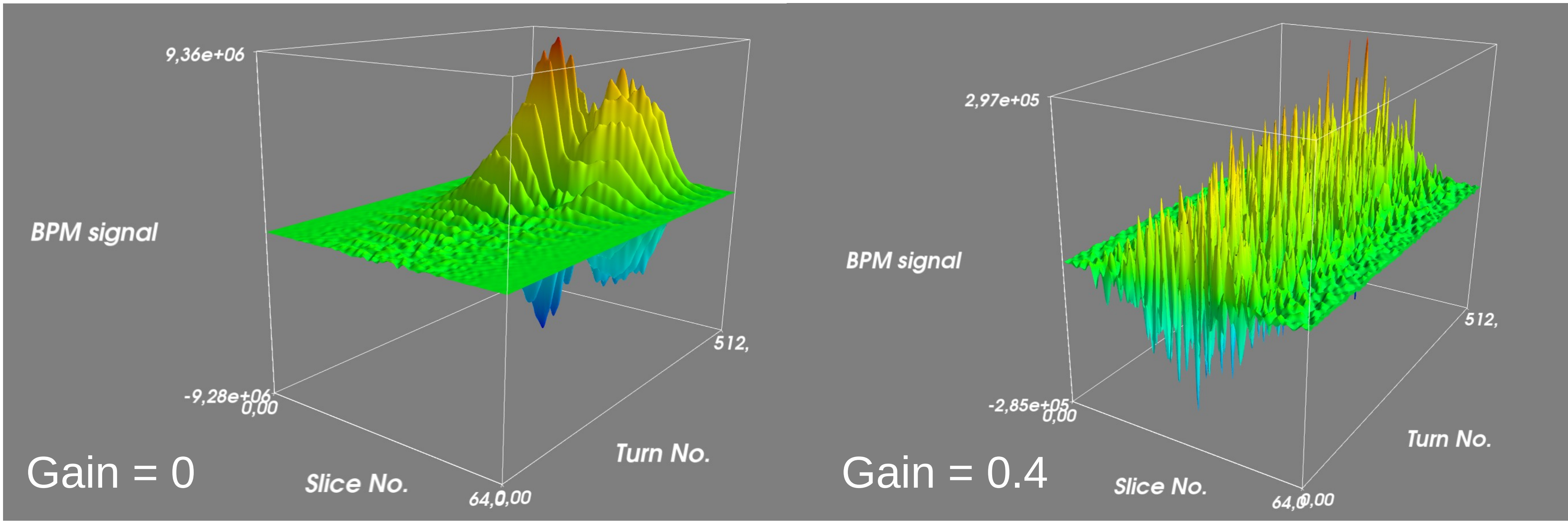
- The instability threshold is around $\rho_e \approx 4e11\ m^{-3}$
- Unstable modes are {0, -1, -2}

Intra-bunch – $\rho_e \approx$ 6e11 m^{-3} – gain scan

- Perturbation: electron cloud
- Bandwidths: 200MHz, 500MHz, 700MHz, 1GHz
- For high gains, the limited (200MHz) bandwidth makes the system become unstable
- A gain of 6e-3 appears to damp the ECI



500MHz – $\rho_e \approx 6e11\ m^{-3}$



- Clear damping of the coherent motion

Transverse mode coupling instabilities

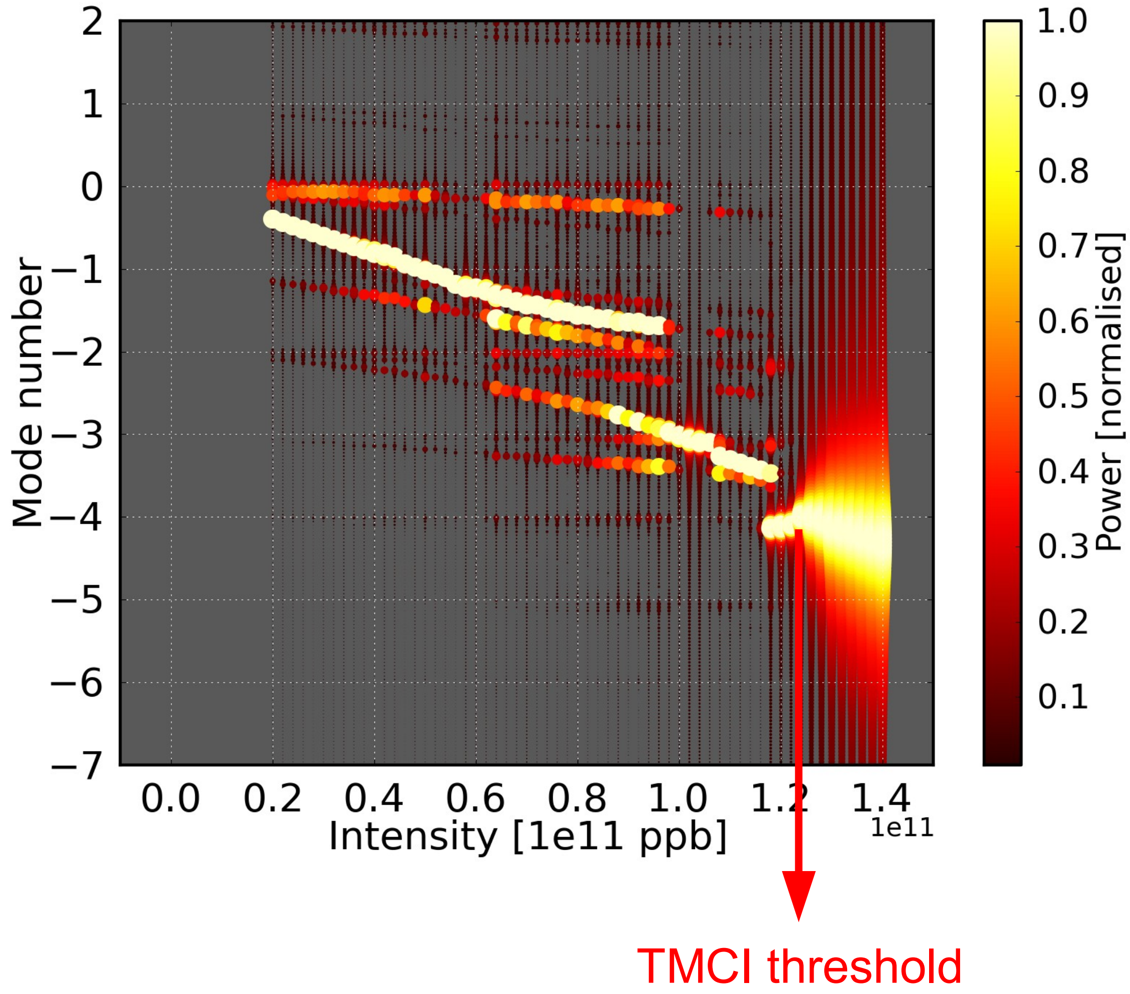
TMCI threshold

- Broad band impedance model used

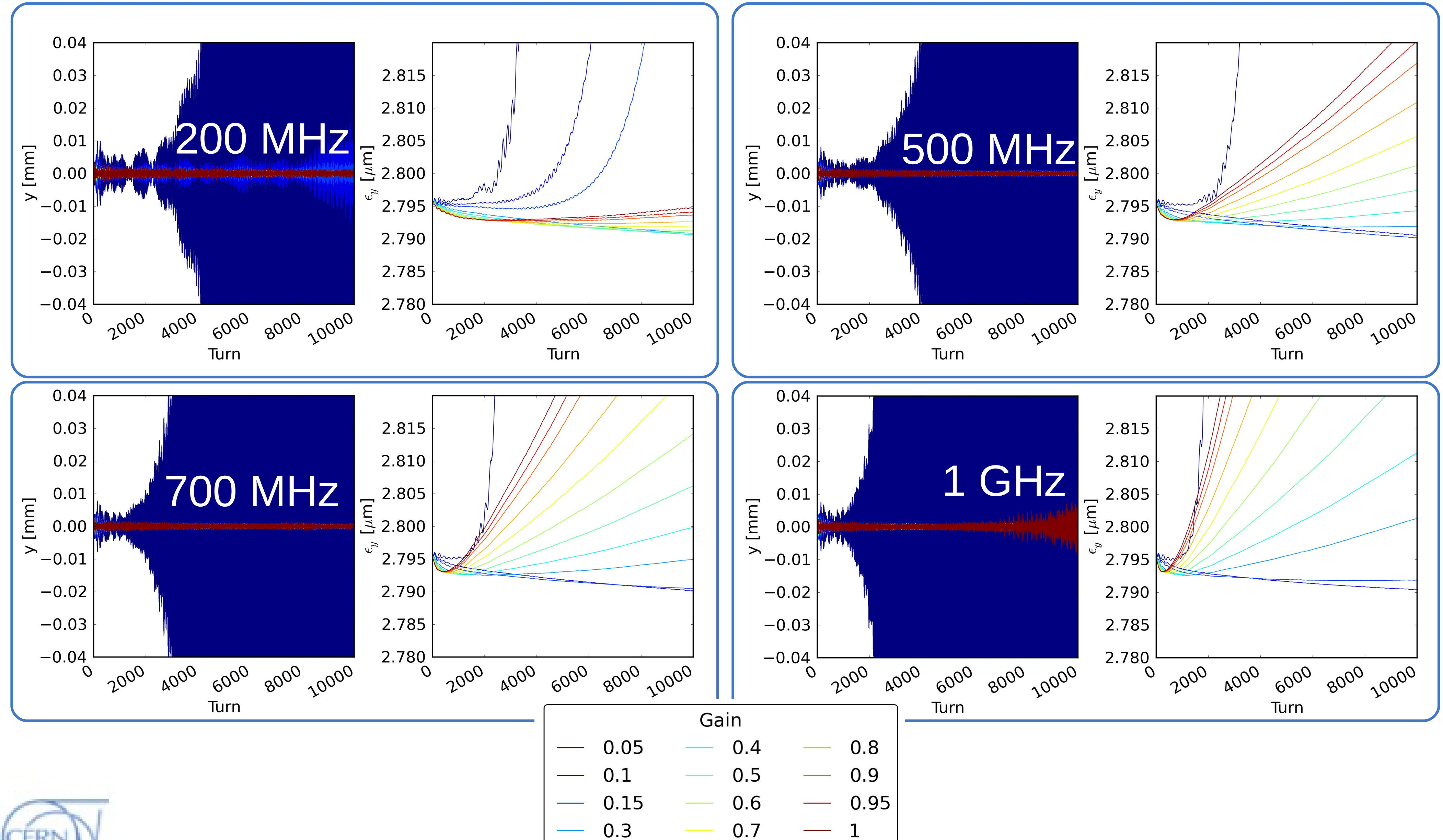
$$Z = \frac{\omega_r}{\omega} \frac{R}{1 + i\,Q\left(\frac{\omega_r}{\omega} - \frac{\omega}{\omega_r}\right)}$$

$$W = \omega_r \frac{R}{Q} \exp\left(\frac{\alpha z}{c}\right) \sin\left(\frac{\bar{\omega}\, z}{c}\right)$$

$$\alpha = \frac{\omega_r}{2\,Q} \qquad \bar{\omega} = \sqrt{\omega_r^2 - \alpha^2}$$



Scanning the gains



Scanning the gains - observations

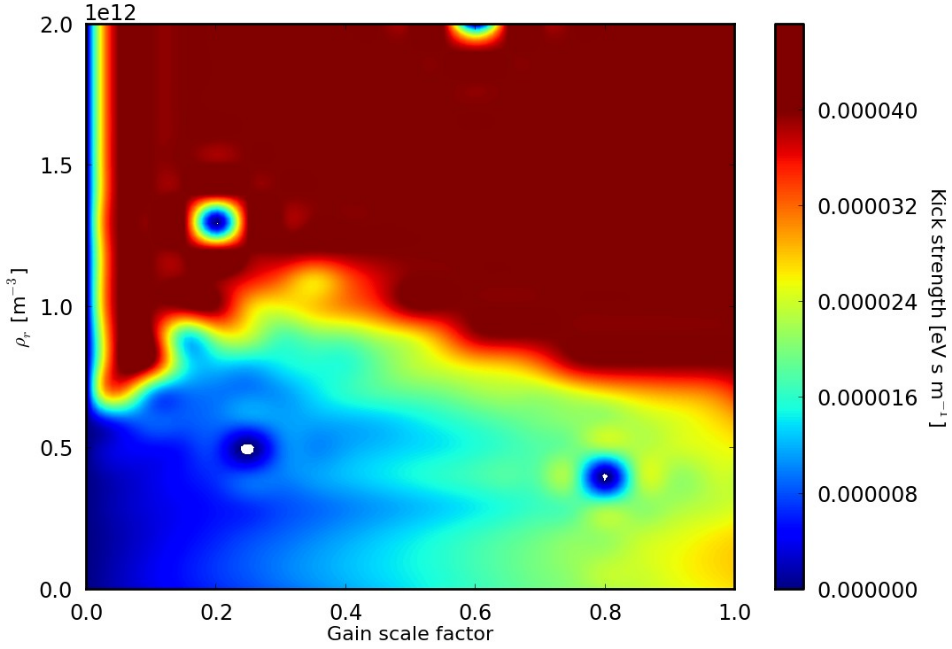
- Wider band → less gain for stabilization
- Wider band → less gain acceptance –
  seems to be in contradiction to earlier observations and to reduced model

- Perhaps an issue with the phase response?
- Further studies needed!

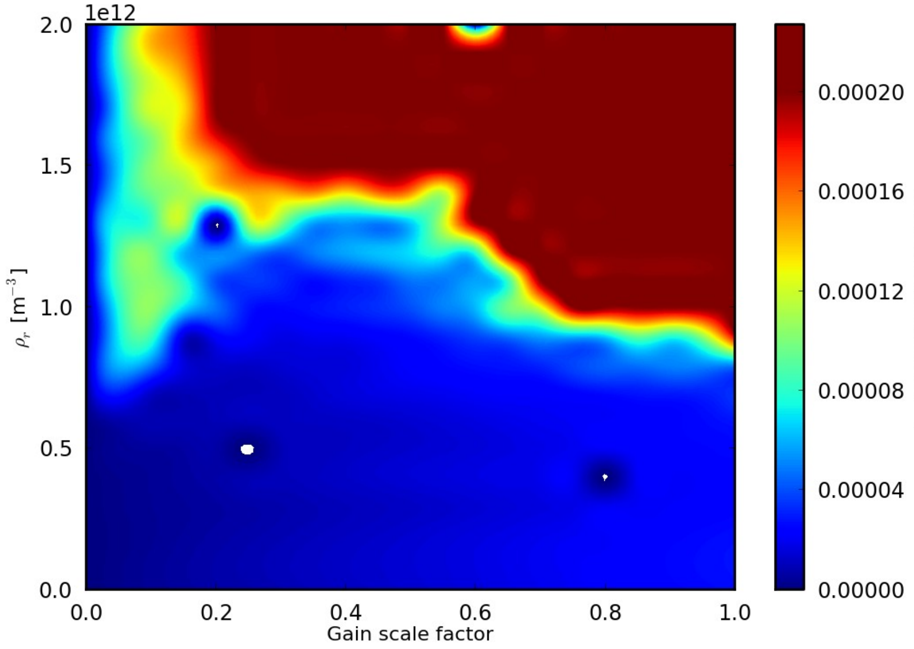
Noise and saturation

Saturation maps – 100 um – 200 MHz

Saturation level: 4e-5 eV m / s

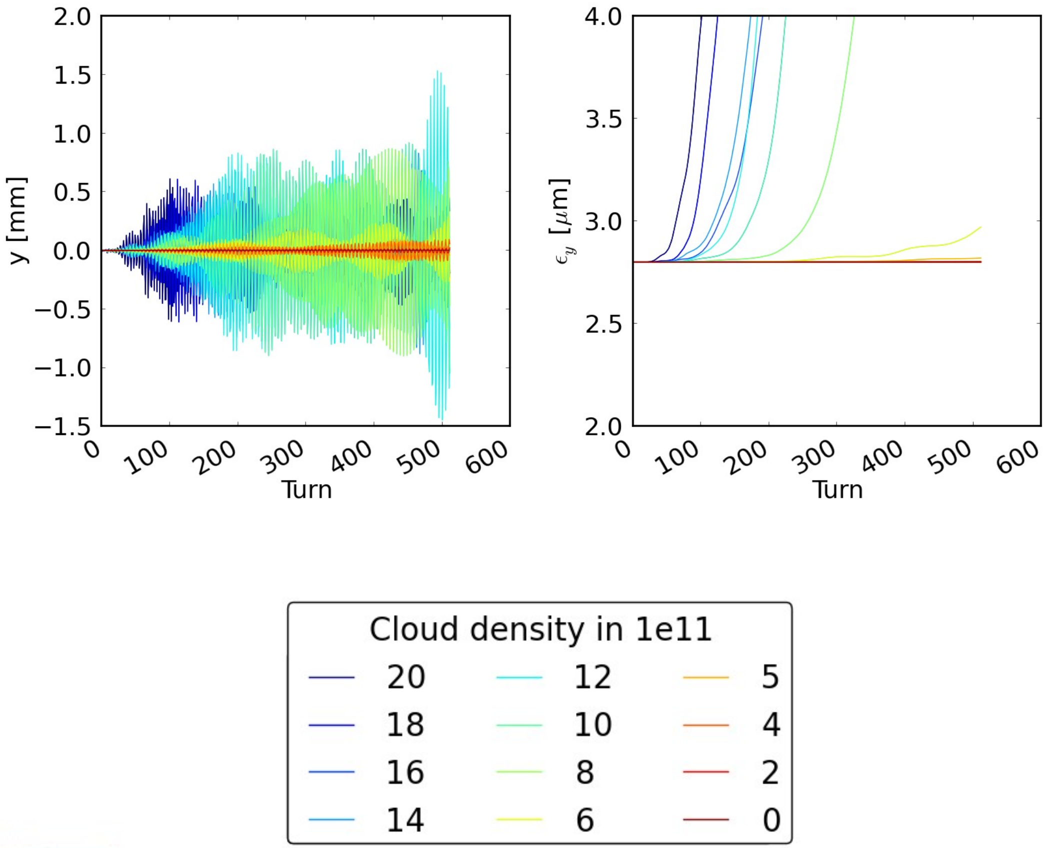


2e-4 eV m / s

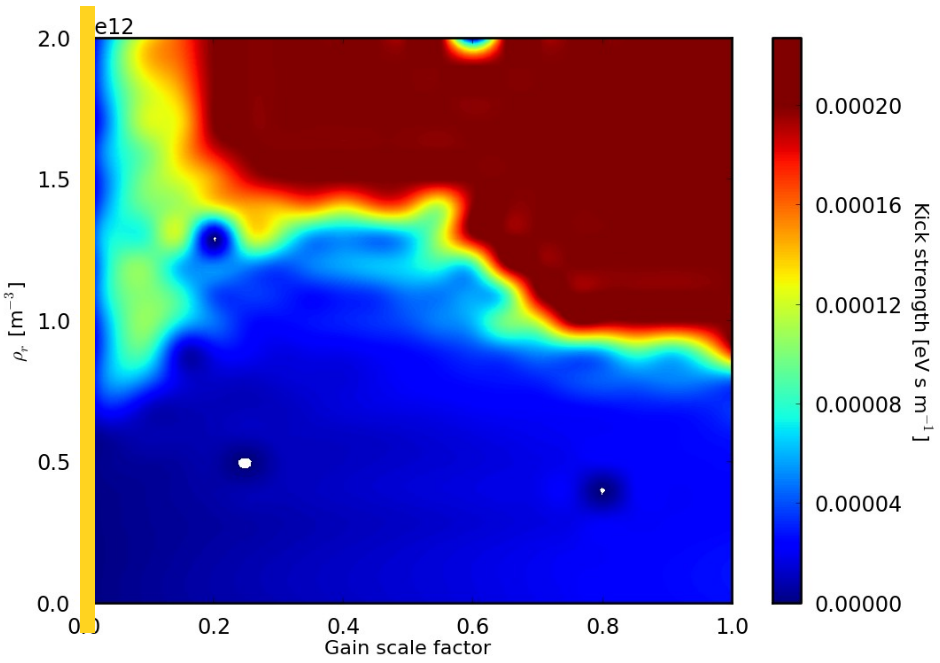


Saturation maps – 100 um – 200 MHz

Density scan at gain 0



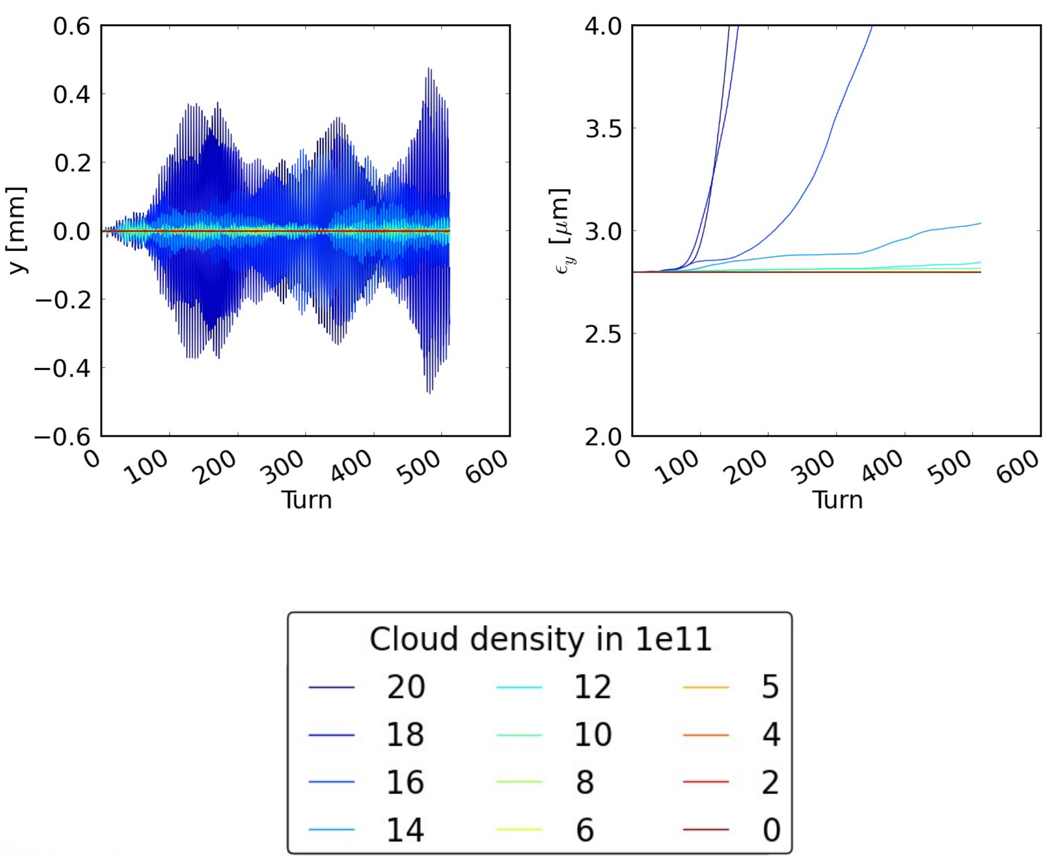
2e-4 eV m / s

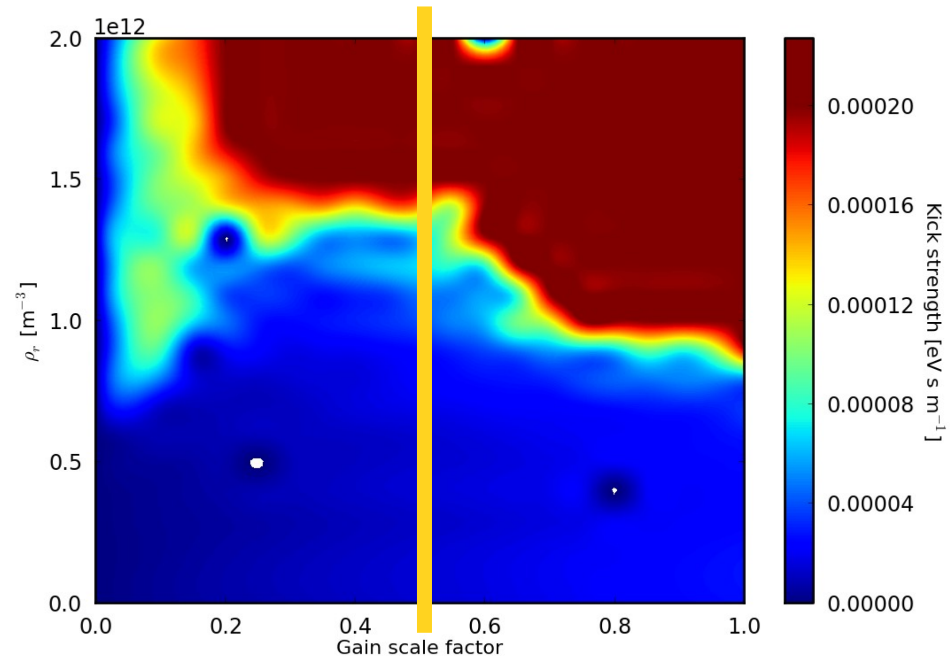


Saturation maps – 100 um – 200 MHz

Density scan at gain 0.5

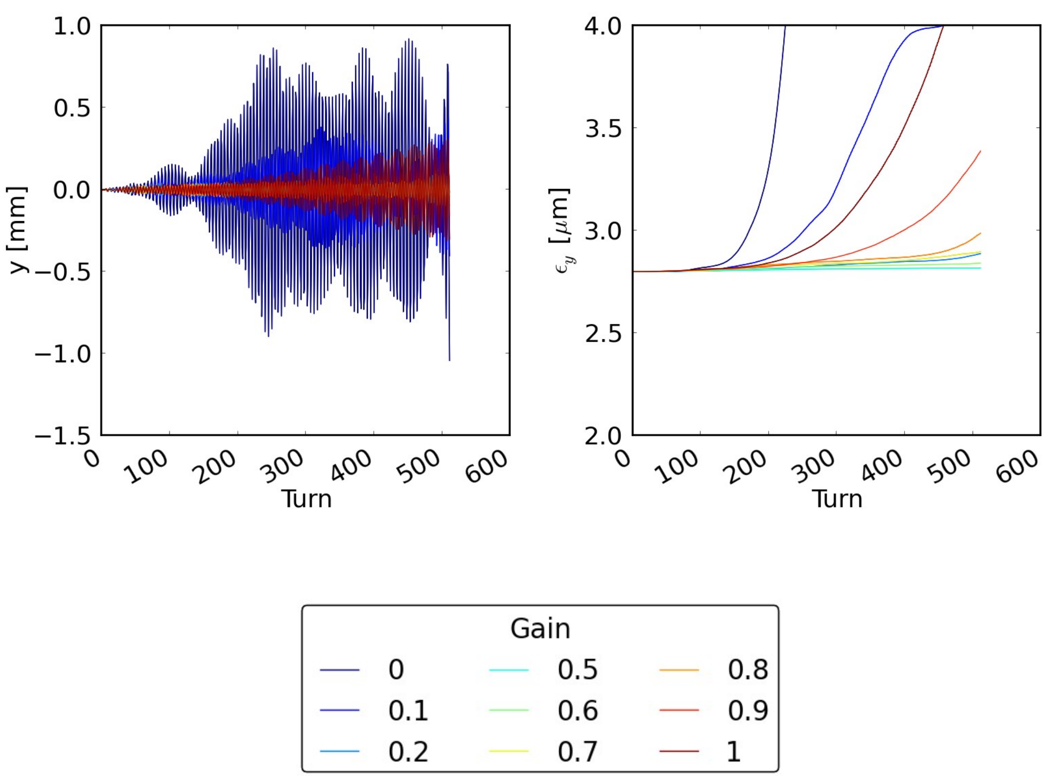
2e-4 eV m / s



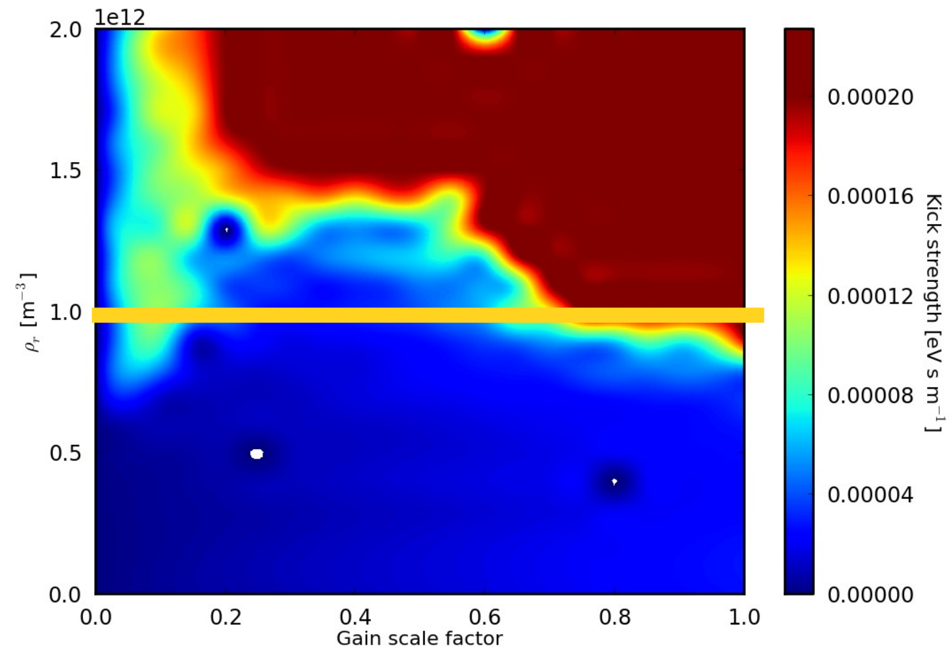


Saturation maps – 100 um – 200 MHz

Gain scan at density 1e12

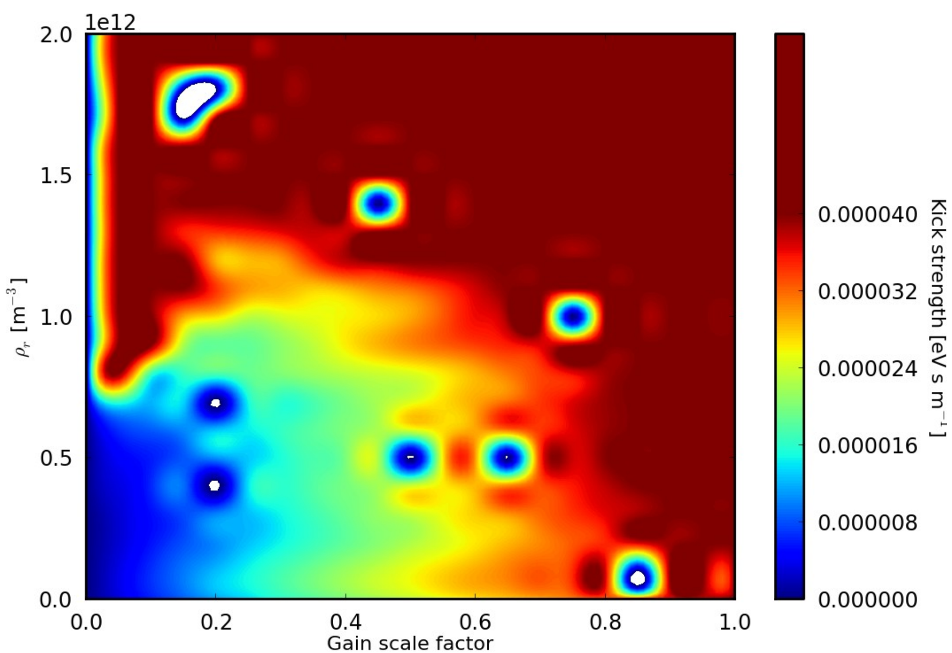


2e-4 eV m / s

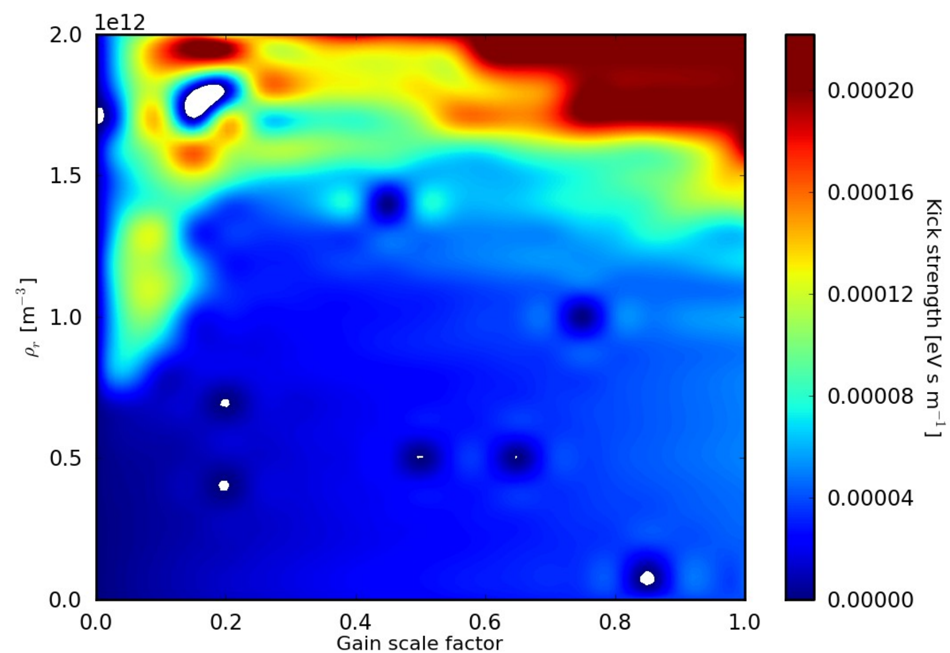


Saturation maps – 100 um – 500 MHz

Saturation level: 4e-5 eV m / s

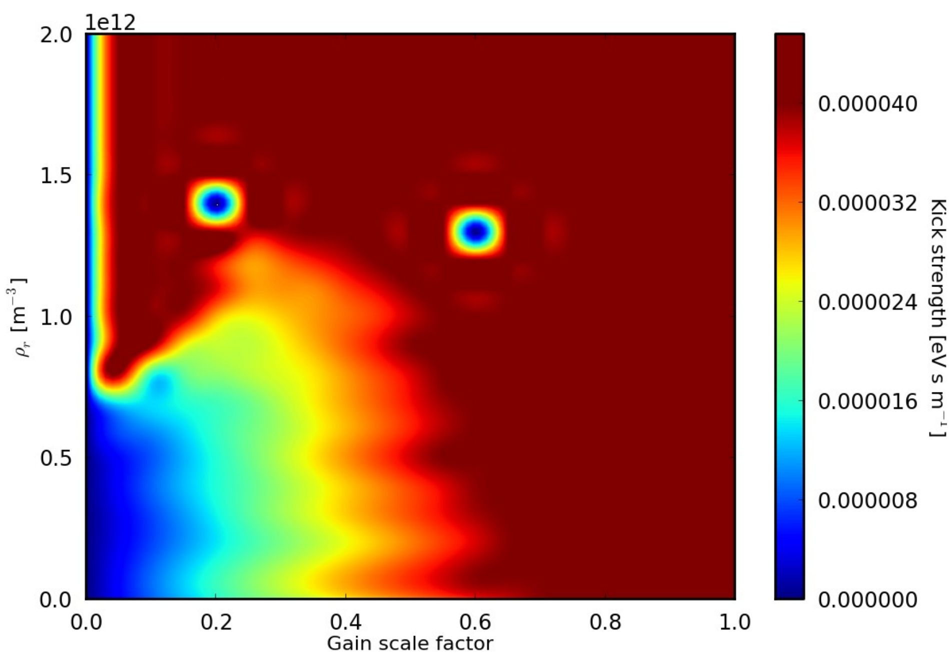


2e-4 eV m / s

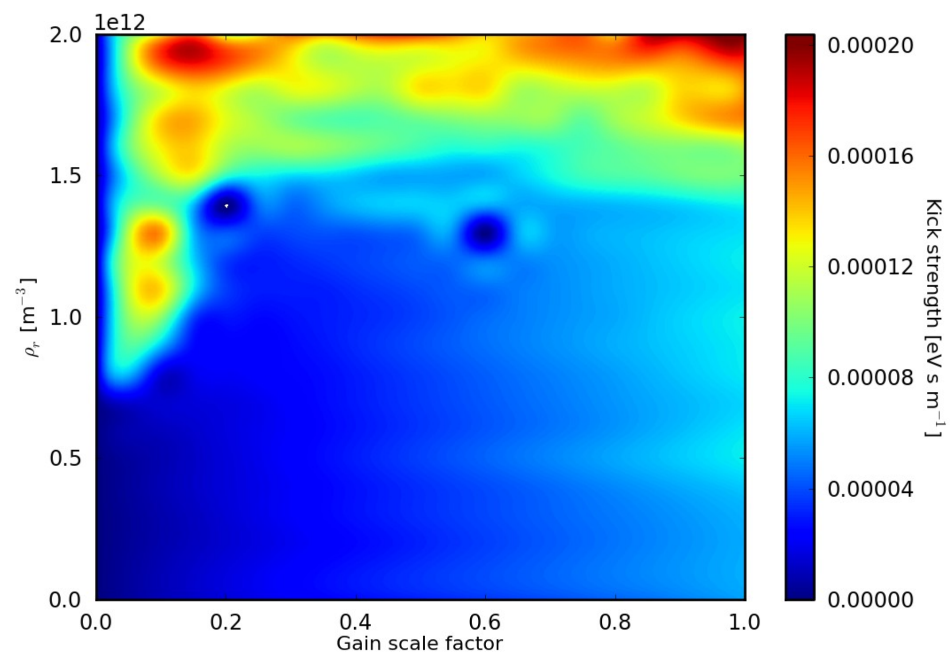


Saturation maps – 100 um – 1 GHz

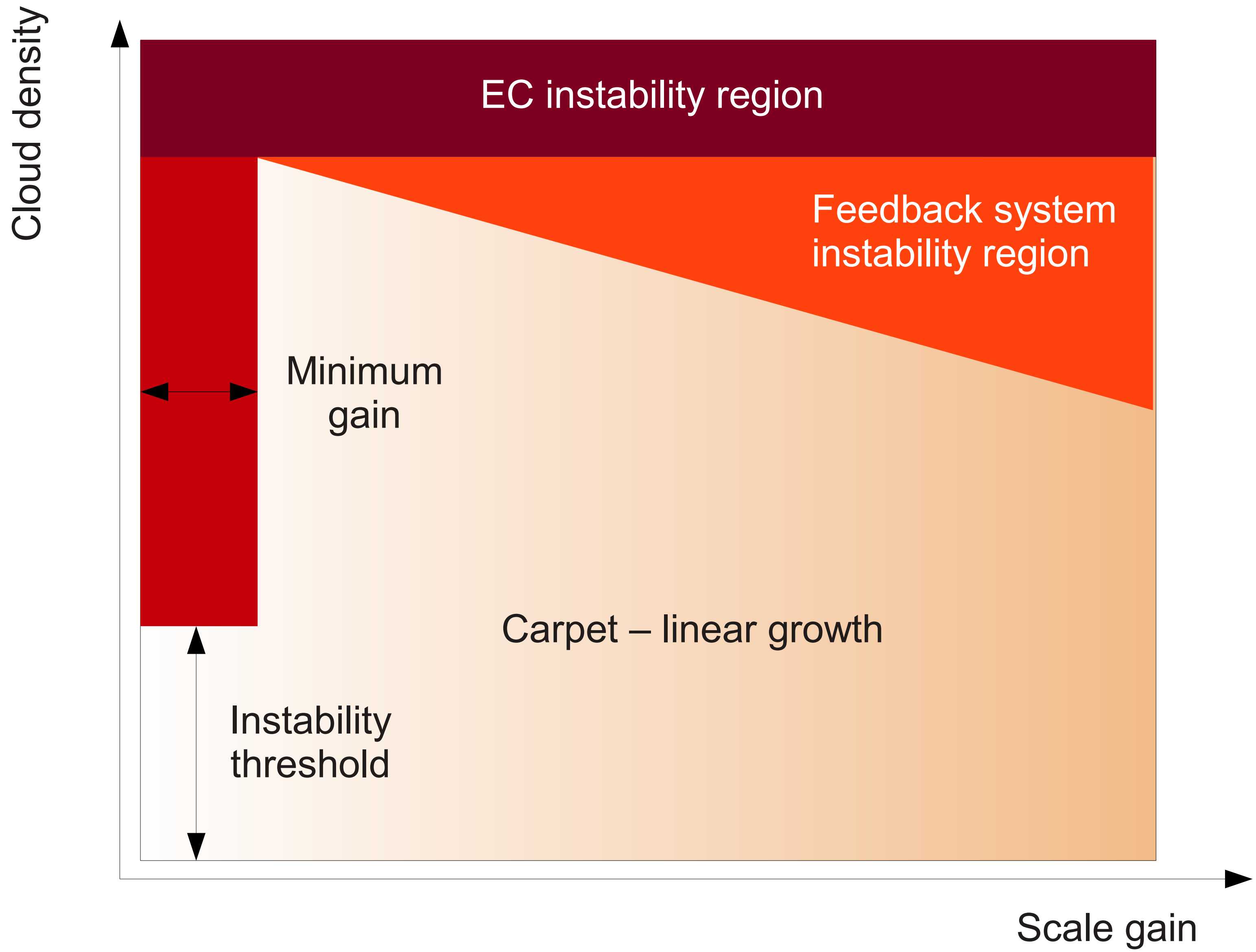
Saturation level: 4e-5 eV m / s



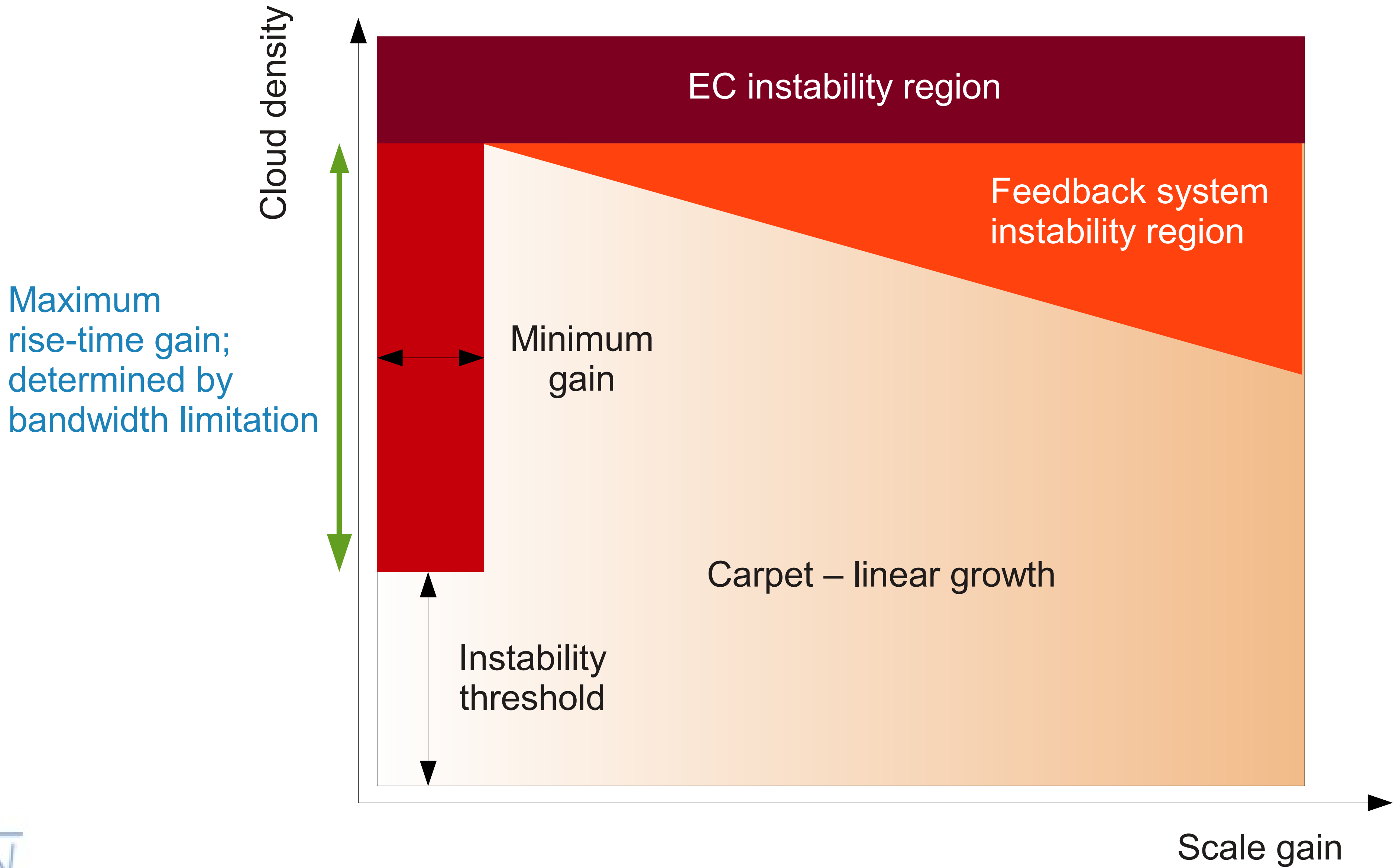
2e-4 eV m / s



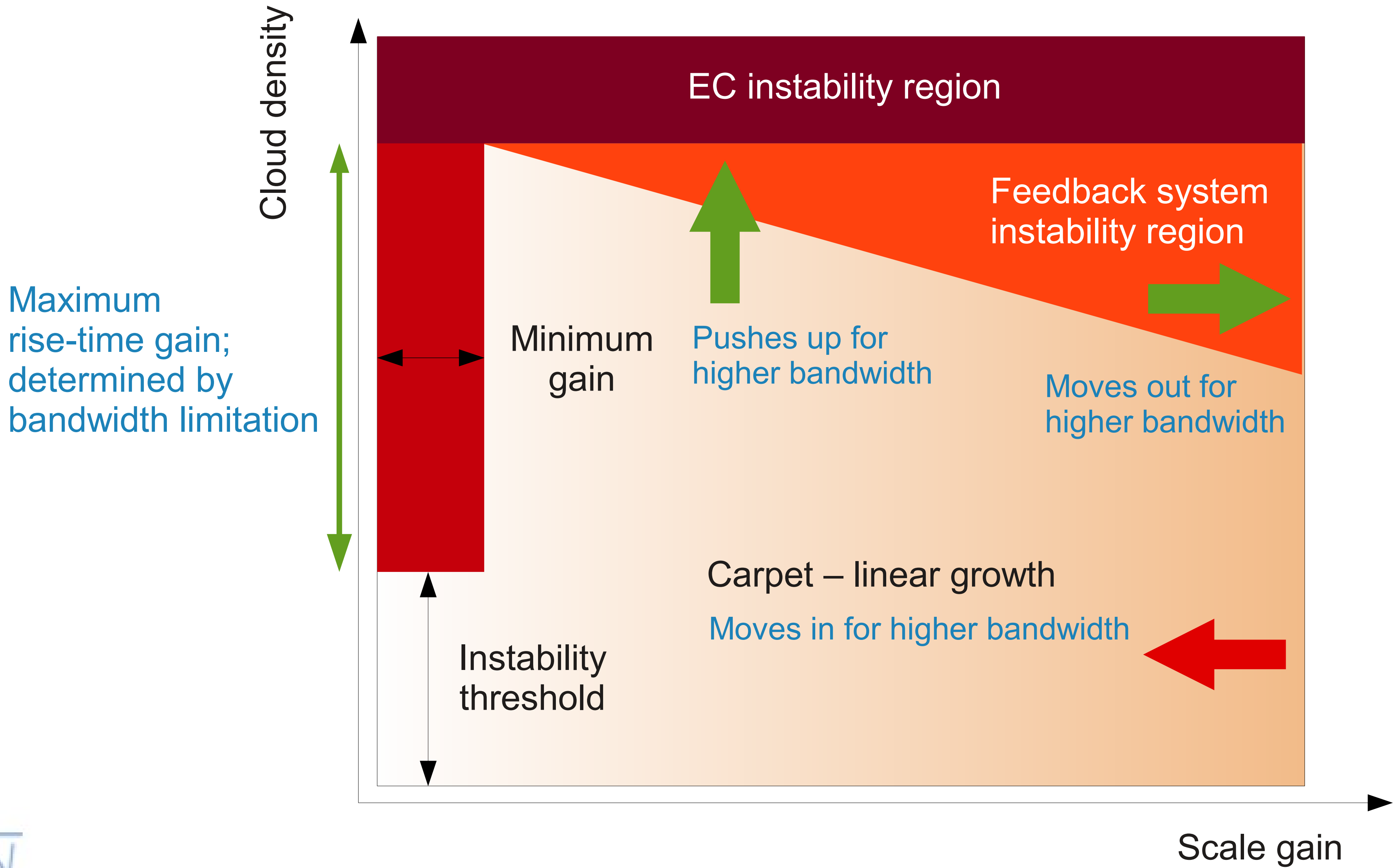
Observations



Observations



Observations



Open questions

- Q20 optics – longitudinal motion

σz	0.23975
σp	0.0020126
εz	0.527 eV s
Qs	0.00587644
V	2 MV

$$\frac{|\eta| R \sigma_\delta}{Q_s \sigma_z} = 1$$

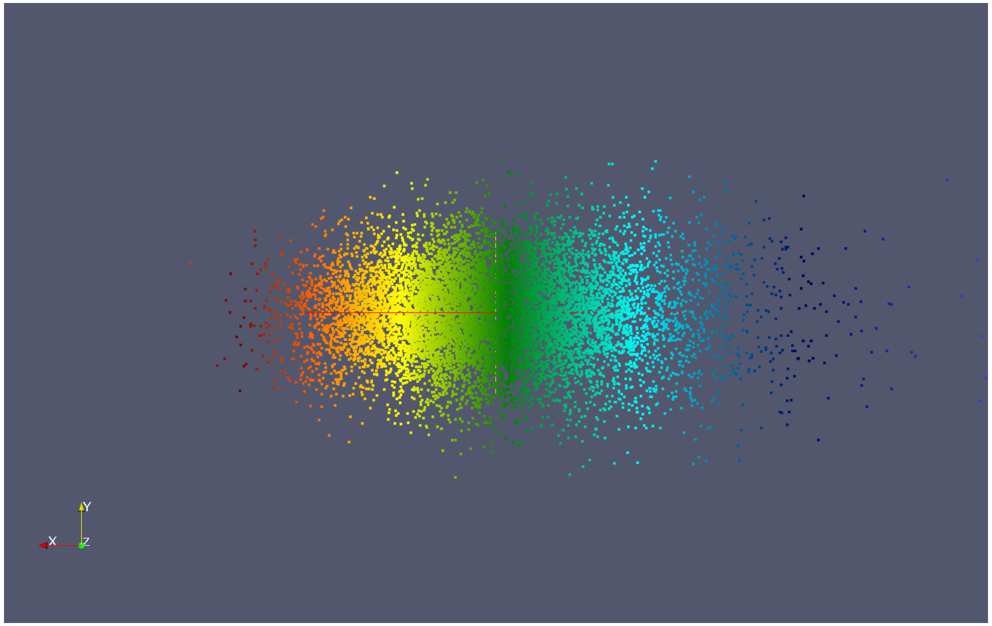
$$\varepsilon_z = 4\pi \sigma_z \sigma_p$$

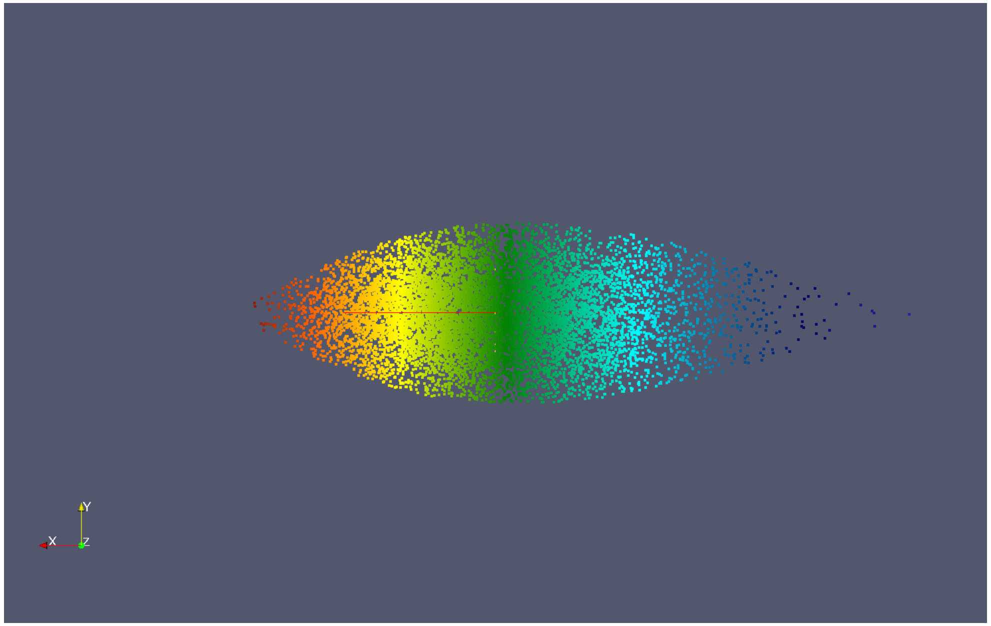
$$Qs = \sqrt{\frac{\eta V h}{2\pi E}}$$

- How do we create matched initial distributions?
- How do we treat additional harmonic RF systems?
- What are the relevant parameters?

Open questions

- Longitudinal motion





- How do we create matched initial distributions?
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Open questions

- Longitudinal motion

- How do we create matched initial distributions?
- How do we treat additional harmonic RF systems?
- What are the relevant parameters?

Outlook

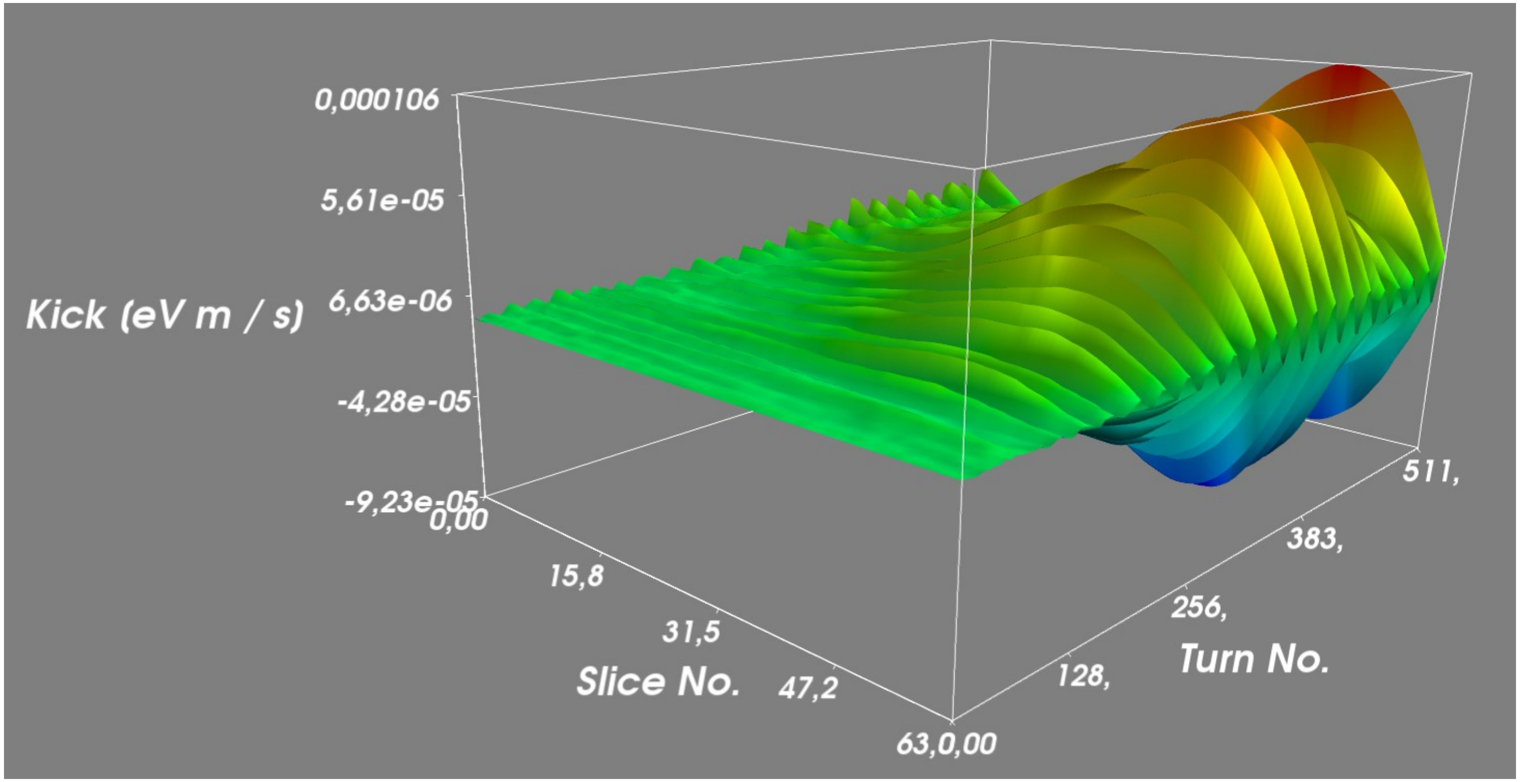
- New parameter table

Momentum	26 GeV/c
Emittances [εx, εy, εz]	2.5, 2.5 um, 0.5 eV s
Bunch length [σz]	0.77 ns
Beta functions [βx, βy]	54.6, 54.6 m
Tunes [Qx, Qy, Qz]	20.13, 20.18, 0.017
Chromaticities [Q'x, Q'y]	0, 0
Momentum compaction	0.00308642
V	5.75 MV

Conclusions

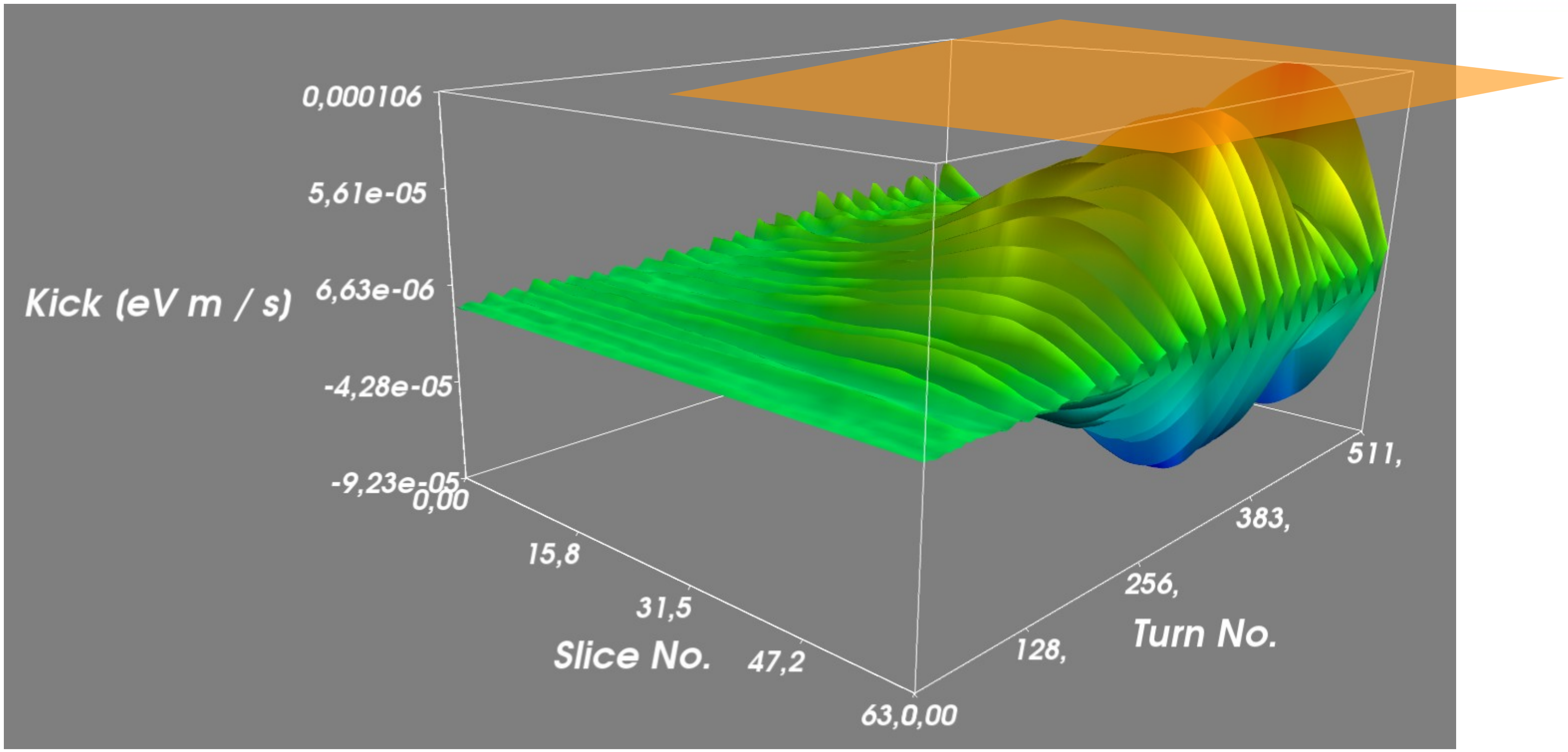
- A reduced model should help understanding the coupled dynamic systems
- ECI can be damped using feedback systems beyond 500 MHz
- TMCI seems to be easily damped using a 200 MHz feedback system
- Saturation can be investigated by means of saturation maps
- A minimum kicker strength of 4e-5 eV m / s is desired for effective damping

Saturation maps



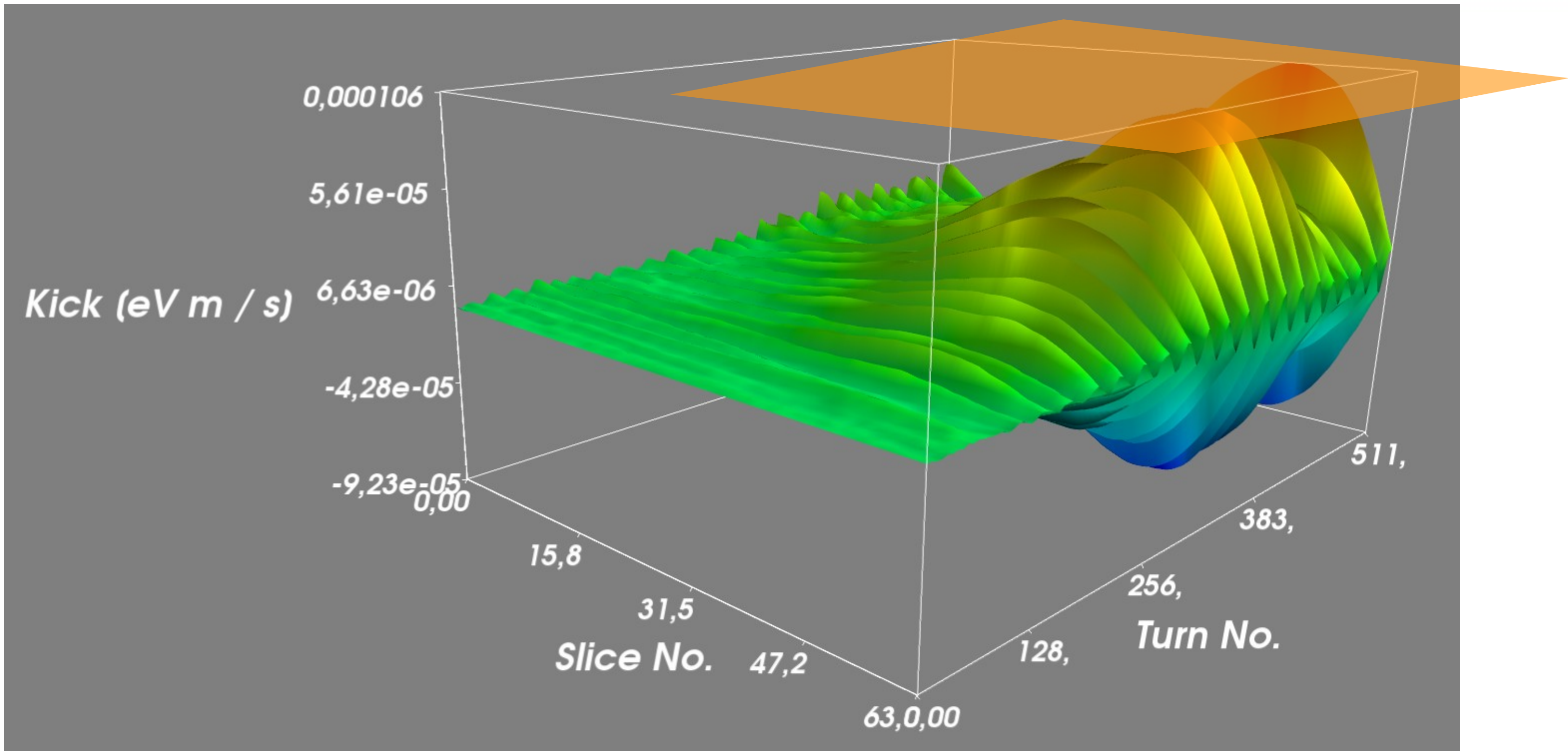
- Kicker signal (200 MHz, density 1e12, gain 0.1)

Saturation maps



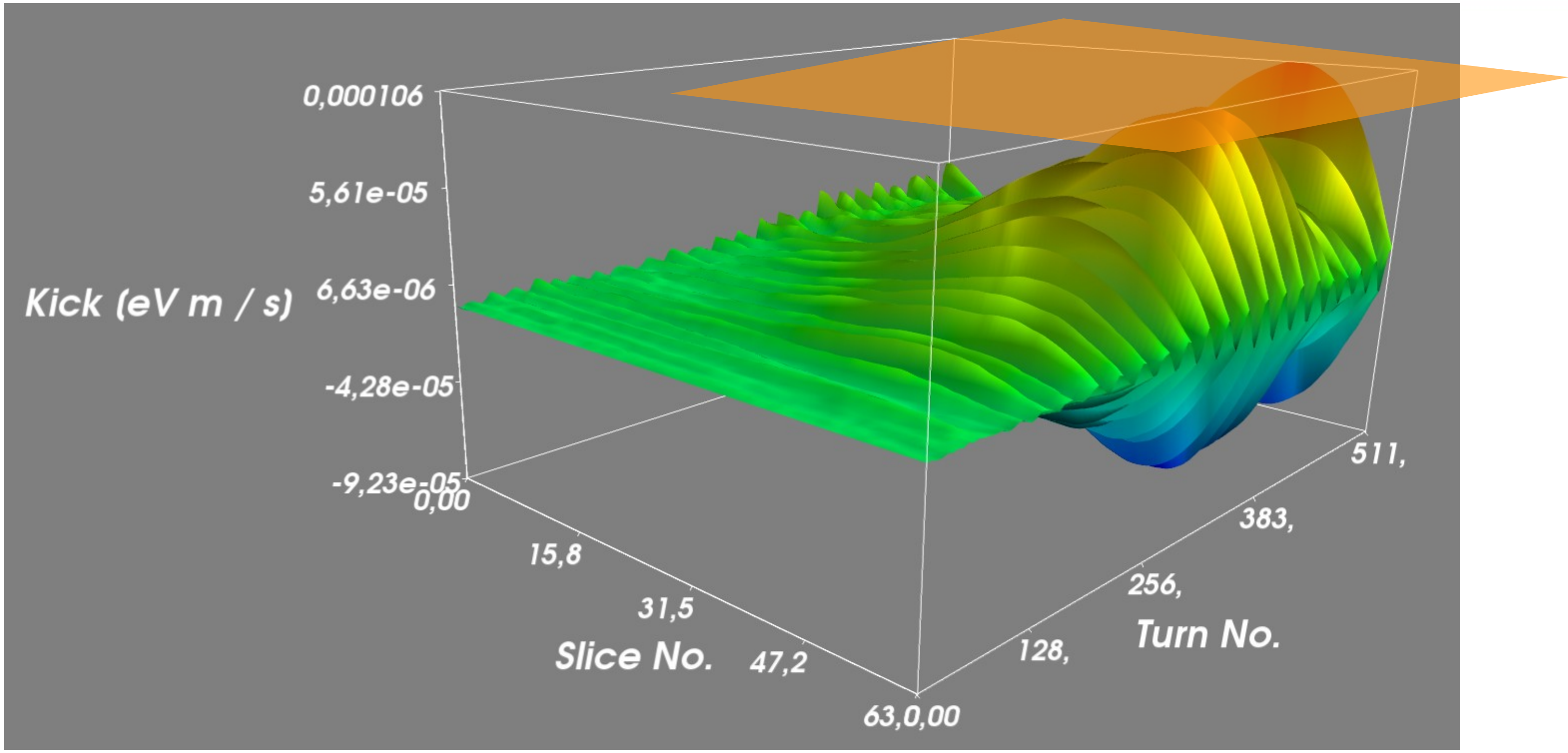
- Kicker signal
- Capture maximum kicker strength

Saturation maps



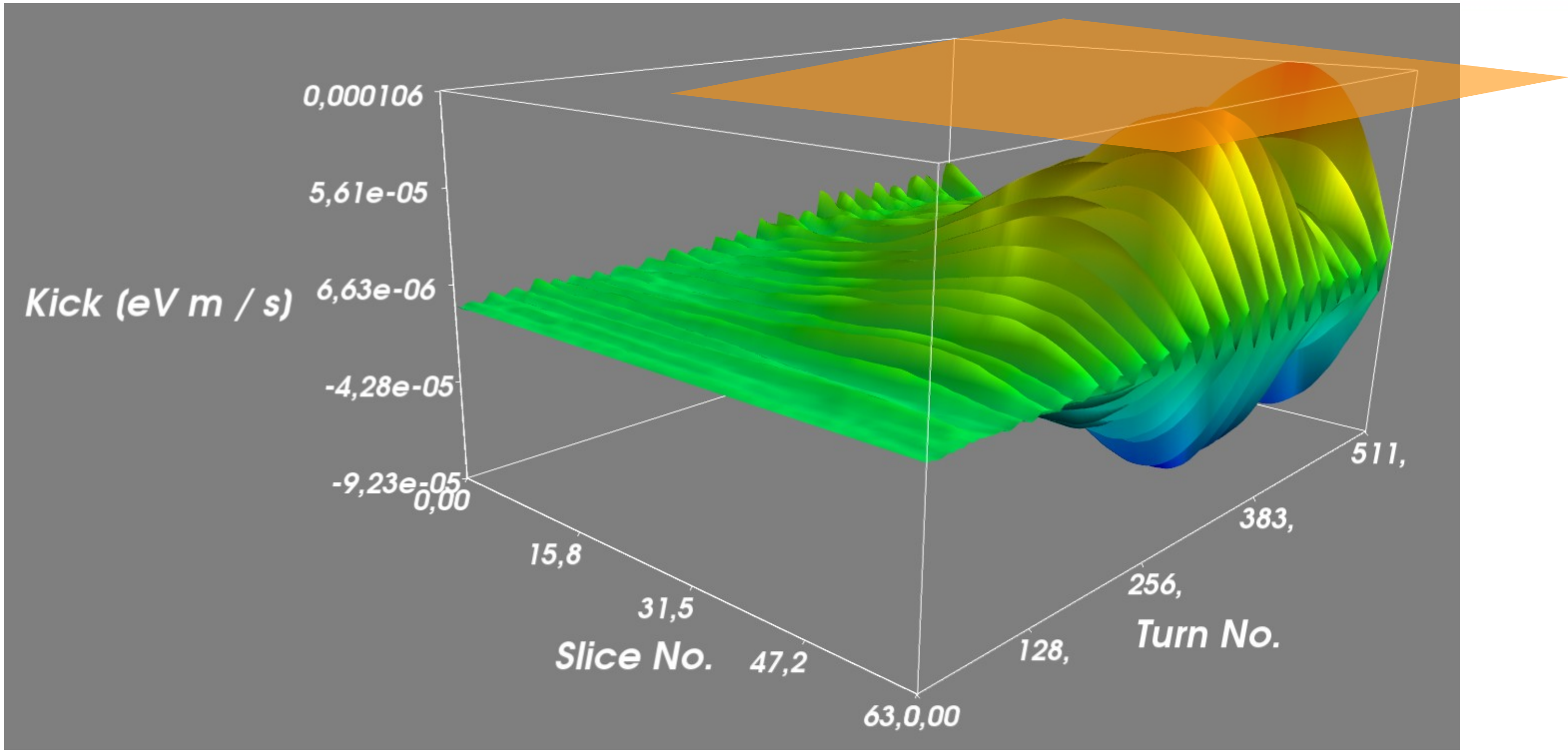
- Kicker signal
- Capture maximum kicker strength
- Repeat for a series of cloud densities, each, for a series of gains and plot each point over the cloud density – gain – plane

Saturation maps



- Capture maximum kicker strength
- Repeat for a series of cloud densities, each, for a series of gains and plot each point over the cloud density – gain – plane
- Cut resulting graph at saturation level

Saturation maps



- Repeat for a series of cloud densities, each, for a series of gains and plot each point over the cloud density – gain – plane
- Cut resulting graph at saturation level
- Conservative approach but allows for wide range parameter studies to obtain a big picture