

Simulation of CSR Instabilities

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Outline

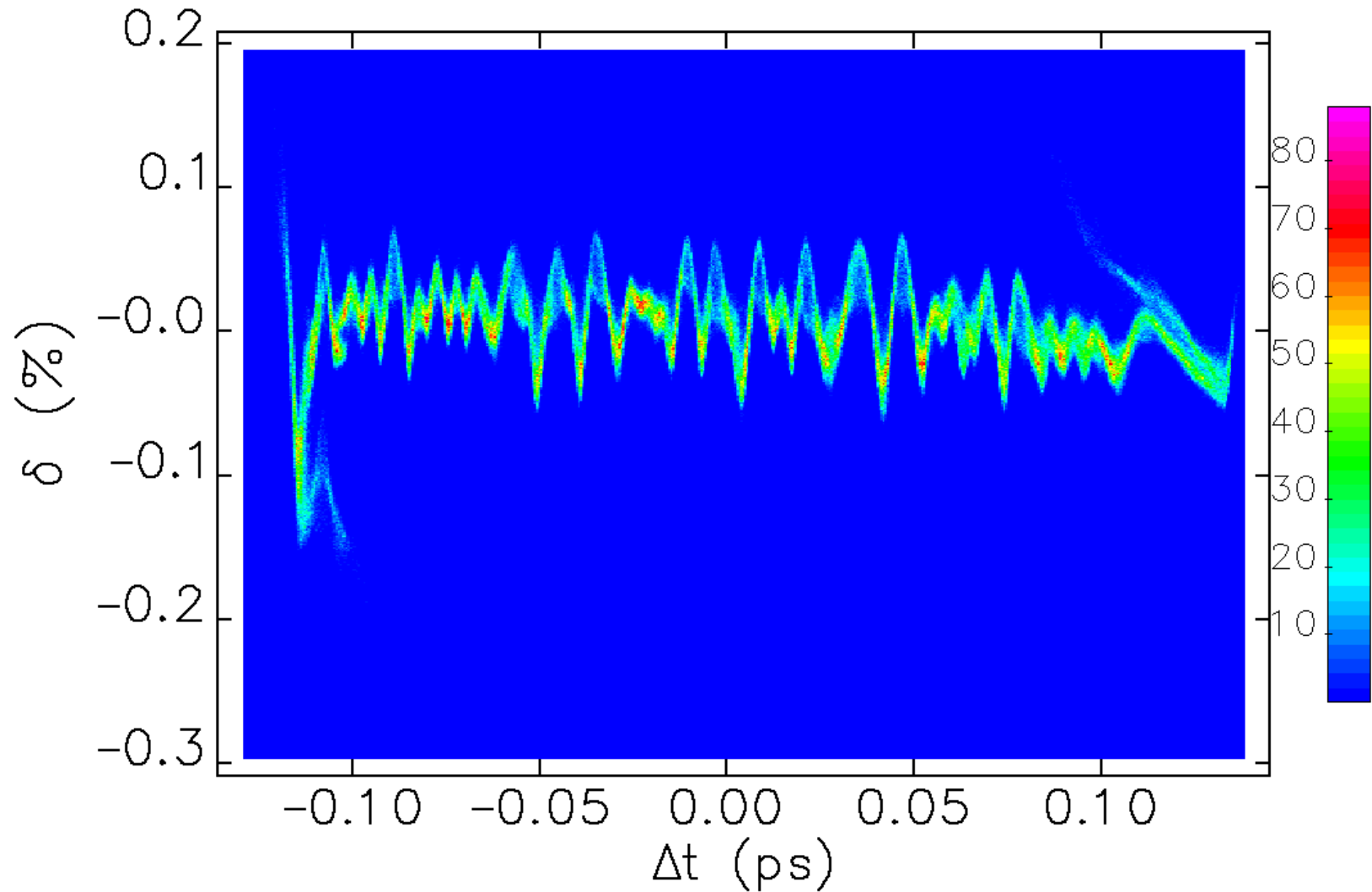
- Predicted instability in LCLS
- Reality checks
- Amplification of energy modulations

LCLS Instability

- In June 2001, **elegant** was found to predict a CSR-driven microbunching instability for the LCLS.
- This was revealed when the binning and smoothing parameters were adjusted to fully resolve the spikes in the beam.
- Subsequently, P. Emma modified the LCLS design to reduce the severity of the instability.

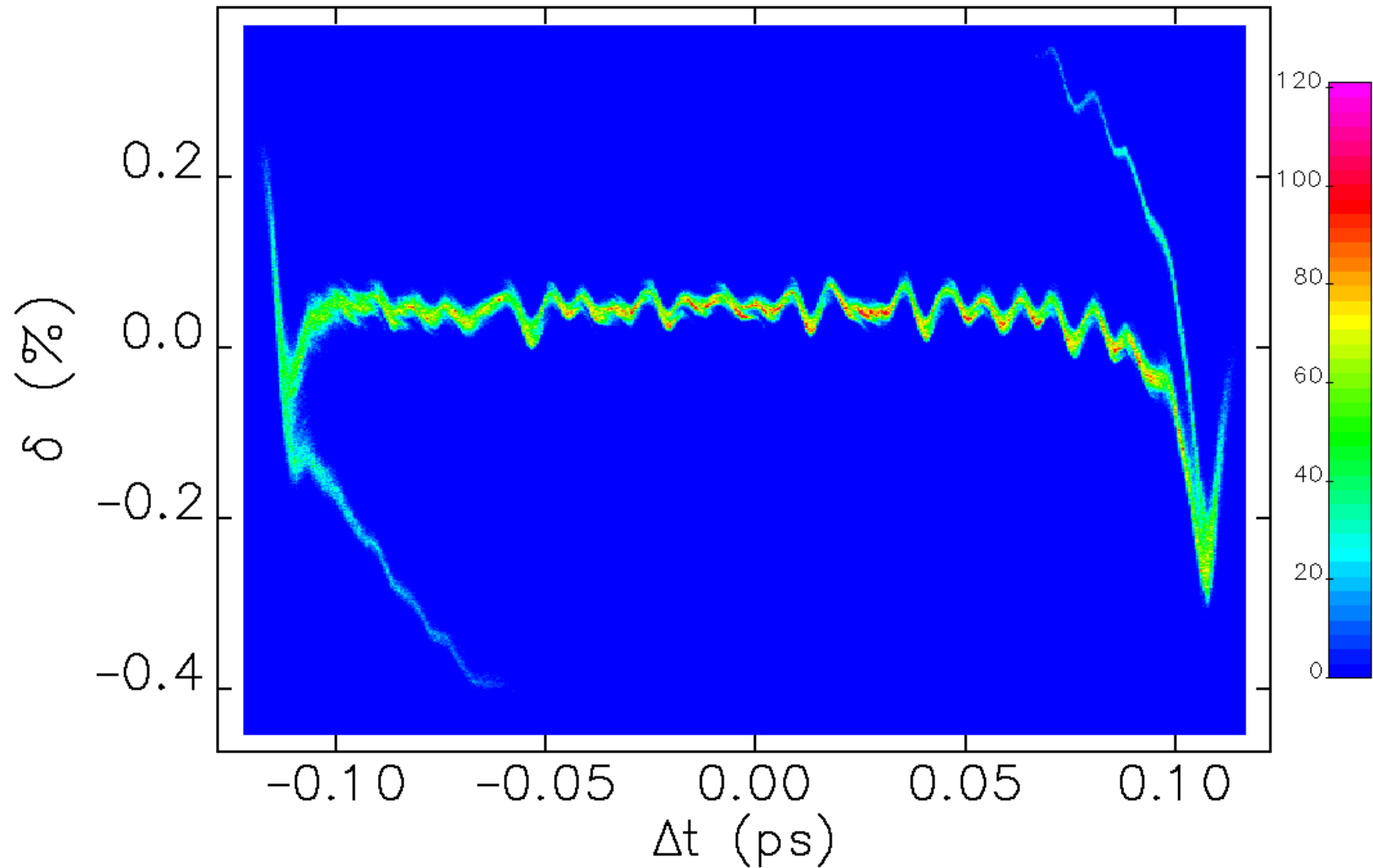
CSR Instability

—06Dec00 LCLS Design—

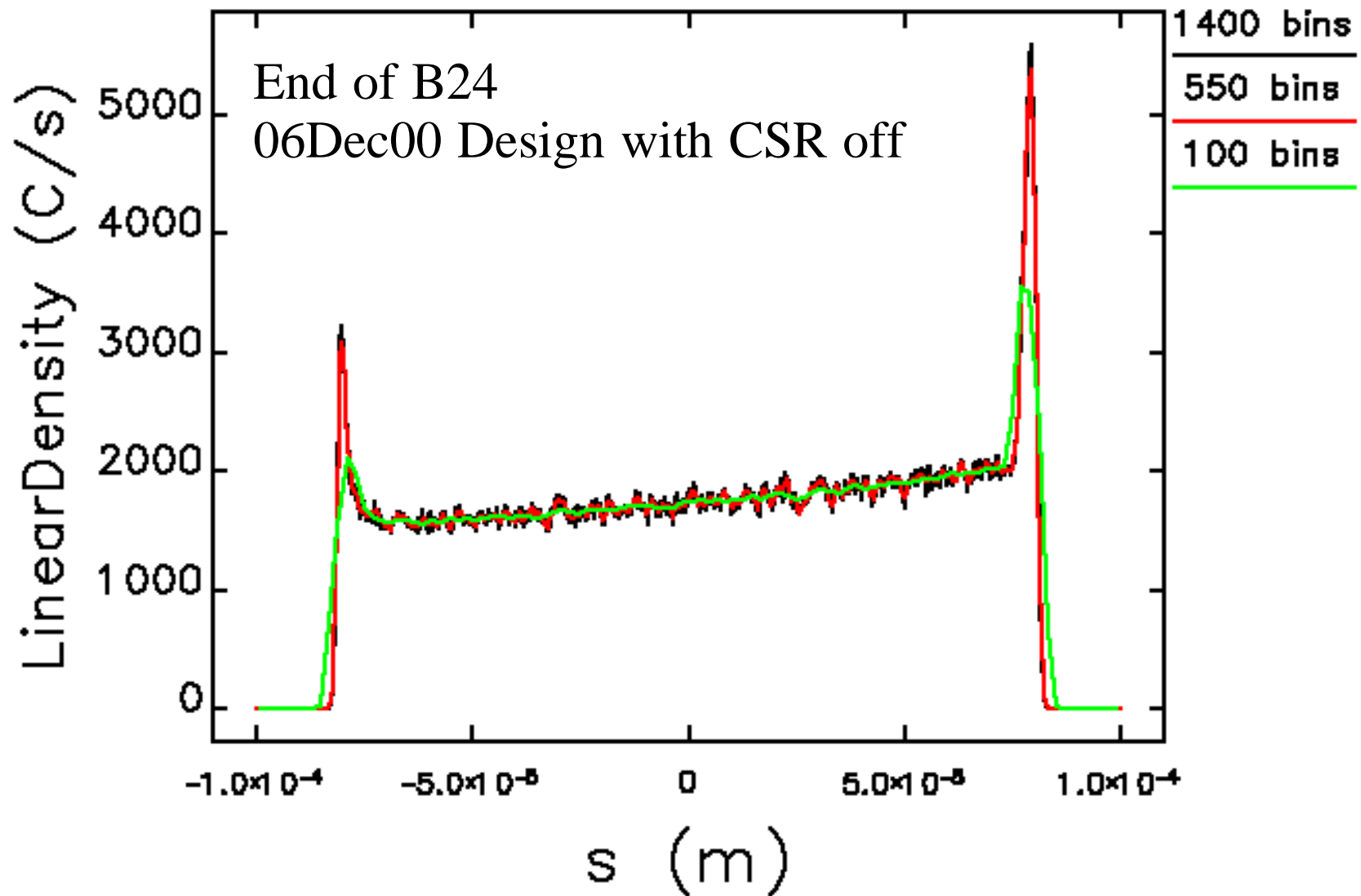


CSR Instability

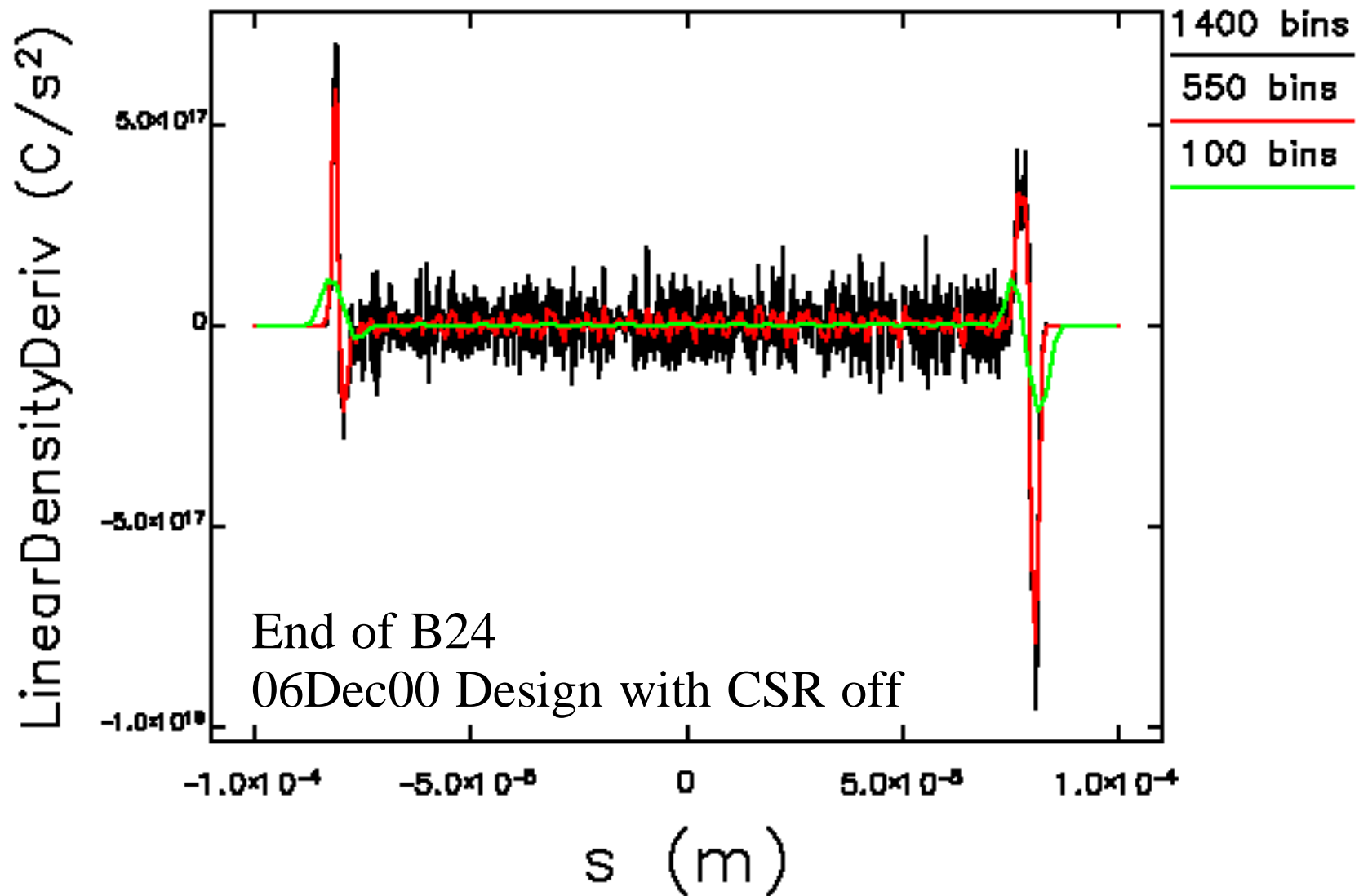
—07Nov01 LCLS Design—



Binning to Resolve Spikes ...

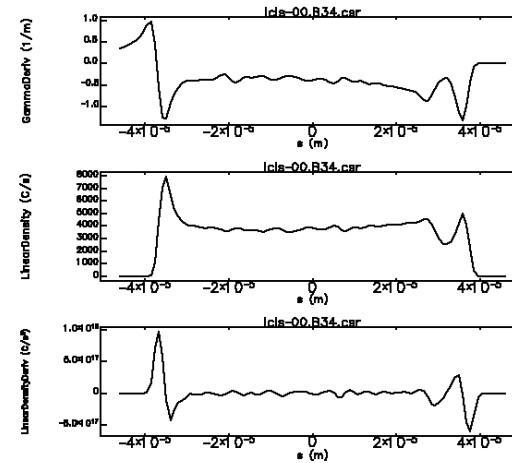


... is Essential, but Watch for Noise

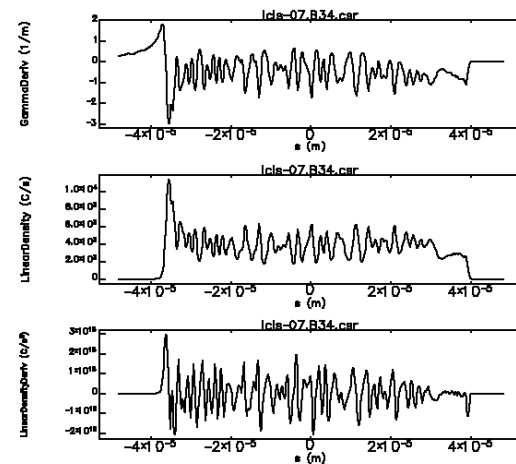


LCLS CSR Instability Movies

- 100 bin run for 06Dec00



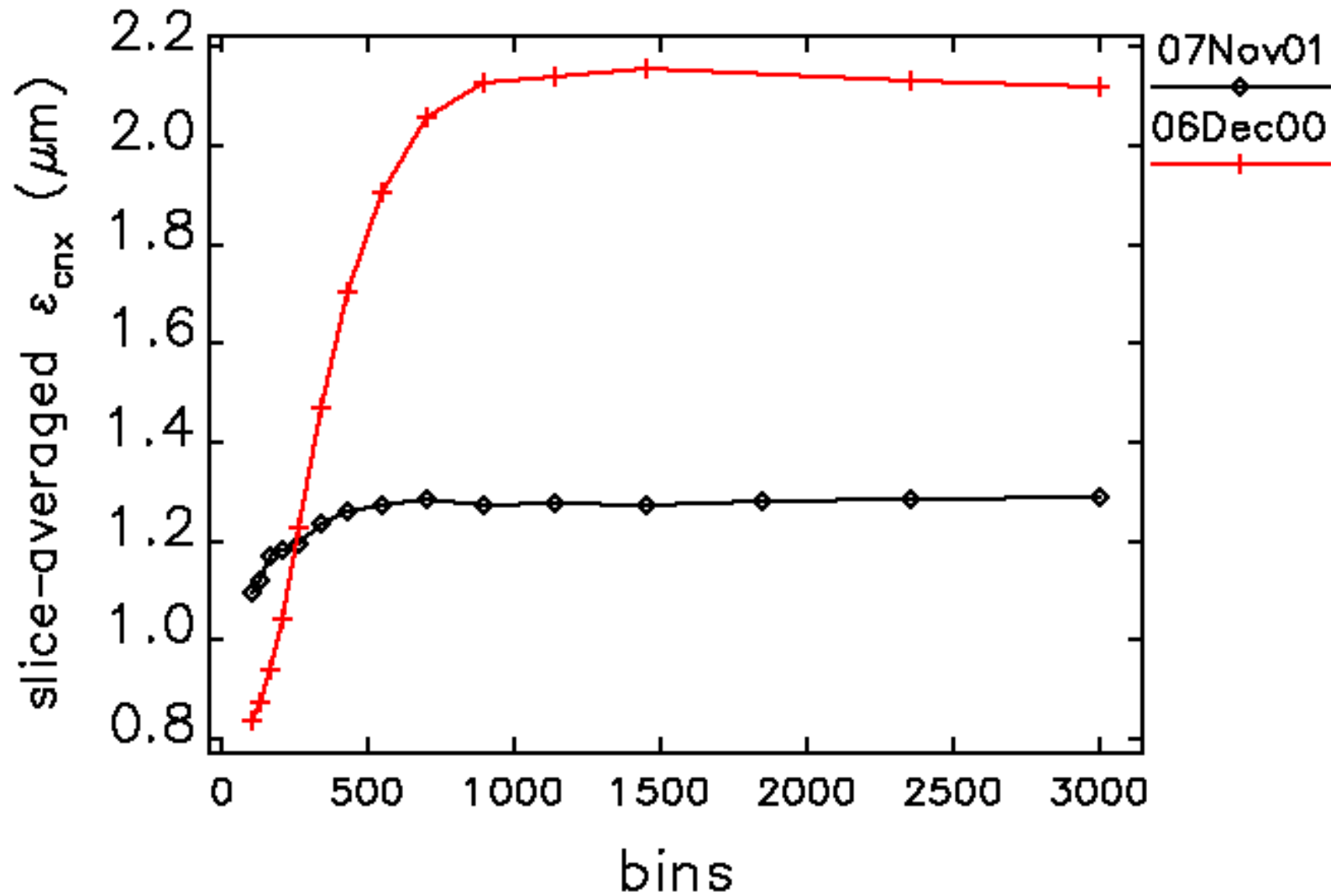
- 550 bin run for 06Dec00



Reality Checks

- To guard against numerical problems, the following checks were performed:
 - Use of a large number of particles
 - Variation of the number of bins
 - Variation of the amount of smoothing
- For example, ran the 06Dec00 and 07Nov01 designs with 0.5M particles and between 100 and 3000 bins, with smoothing of ± 1 bin.

Bin Scans for the Two Designs



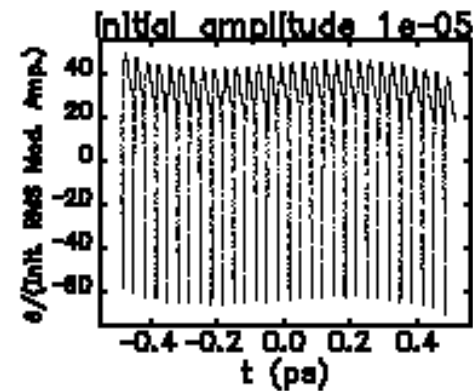
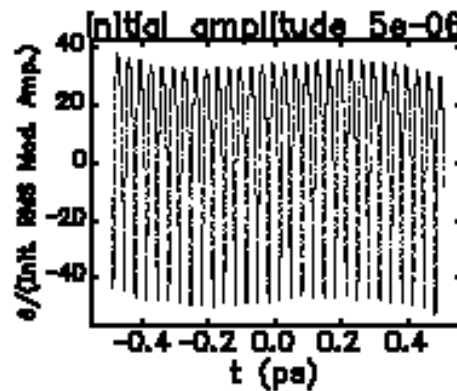
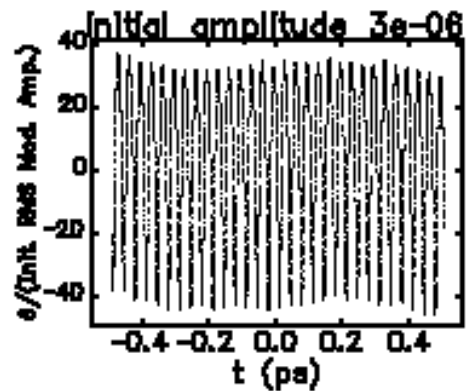
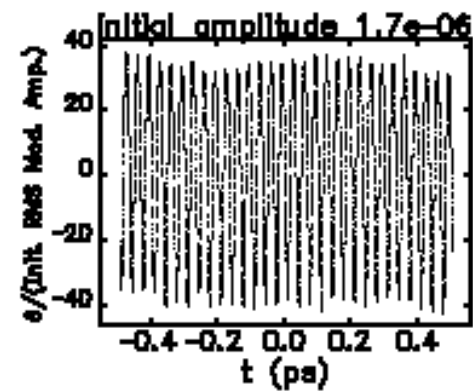
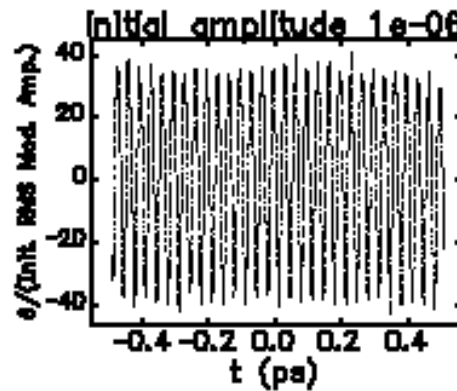
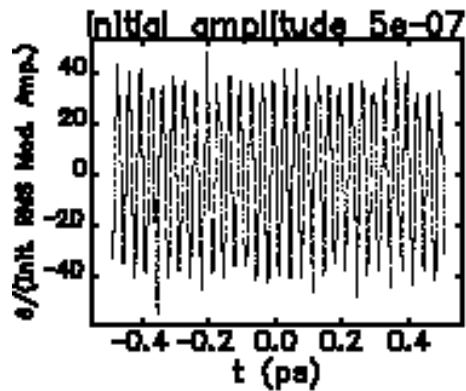
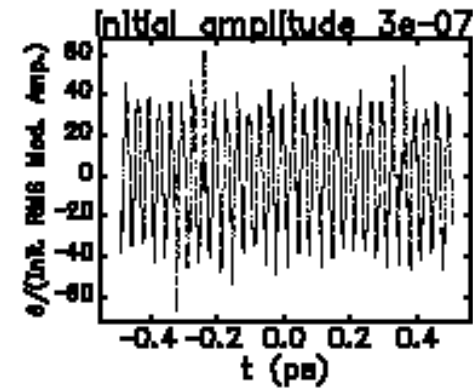
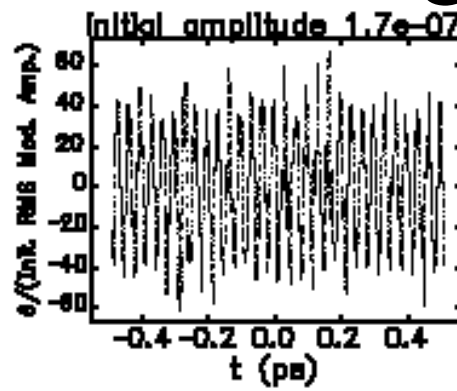
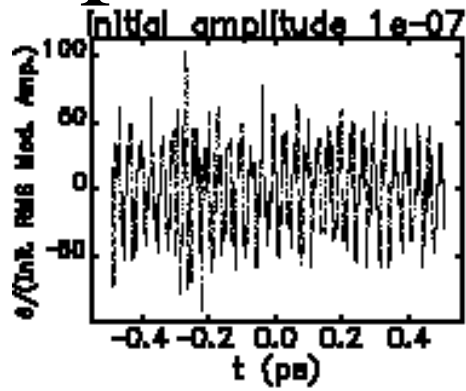
Amplification of Energy Modulations

- Simulated BC1 for 06Dec00 and 07Nov01 with a model input beam
 - uniformly distributed
 - zero emittance and zero uncorrelated energy spread
 - 90A beam current
 - 2 mm length
- Sinusoidal energy modulation added
 - peak-to-peak amplitudes from 10^{-7} to $5 \cdot 10^{-4}$
 - wavelength of $10\mu\text{m}$

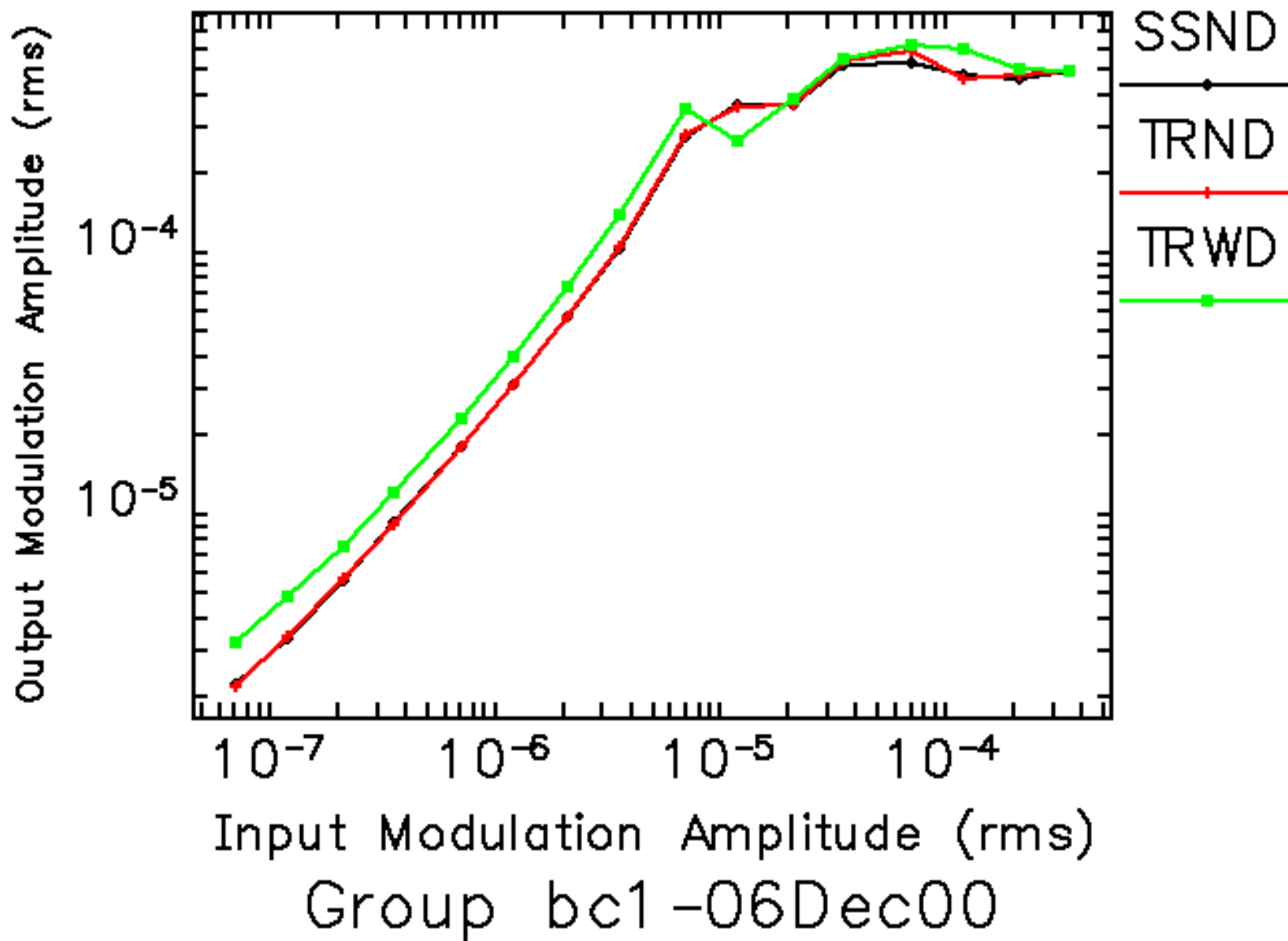
Amplification of Energy Modulations

- Per wavelength, used 25 bins and 5000 equispaced particles.
- Smoothed histograms over ± 1 bin.
- Looked at steady-state CSR, plus transient CSR with and without drift CSR.

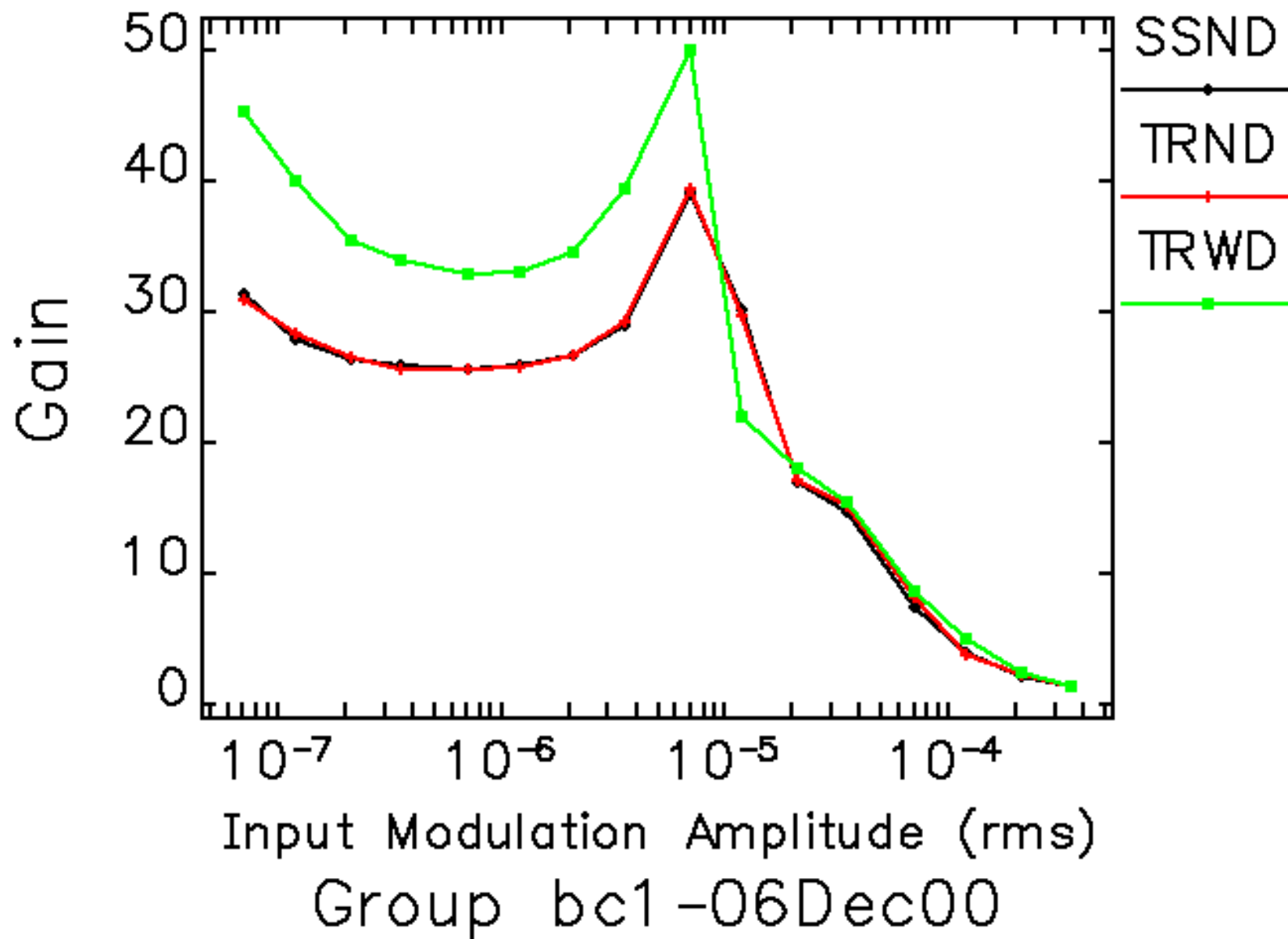
Amplification of Energy Modulations



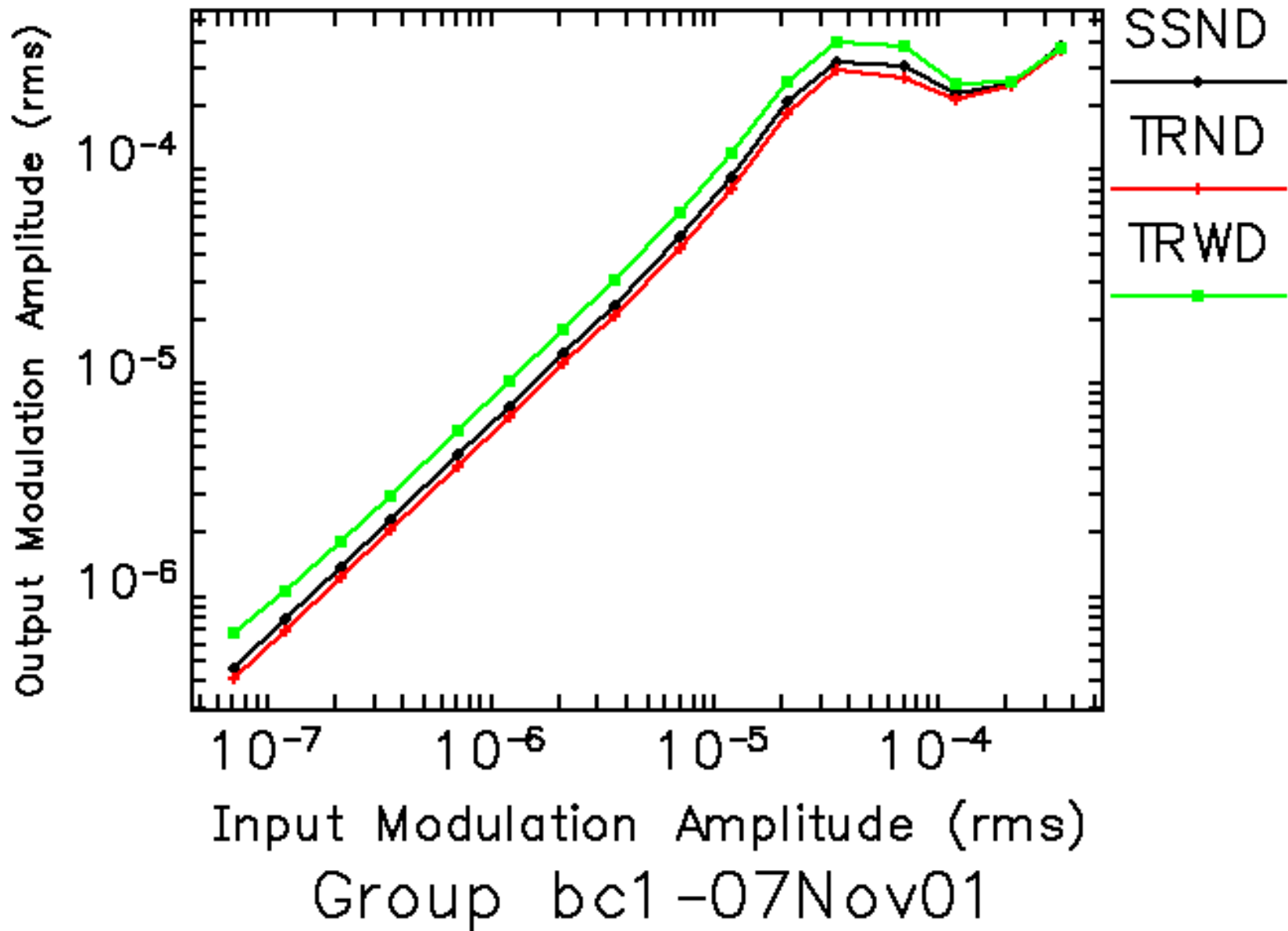
06Dec00 BC1



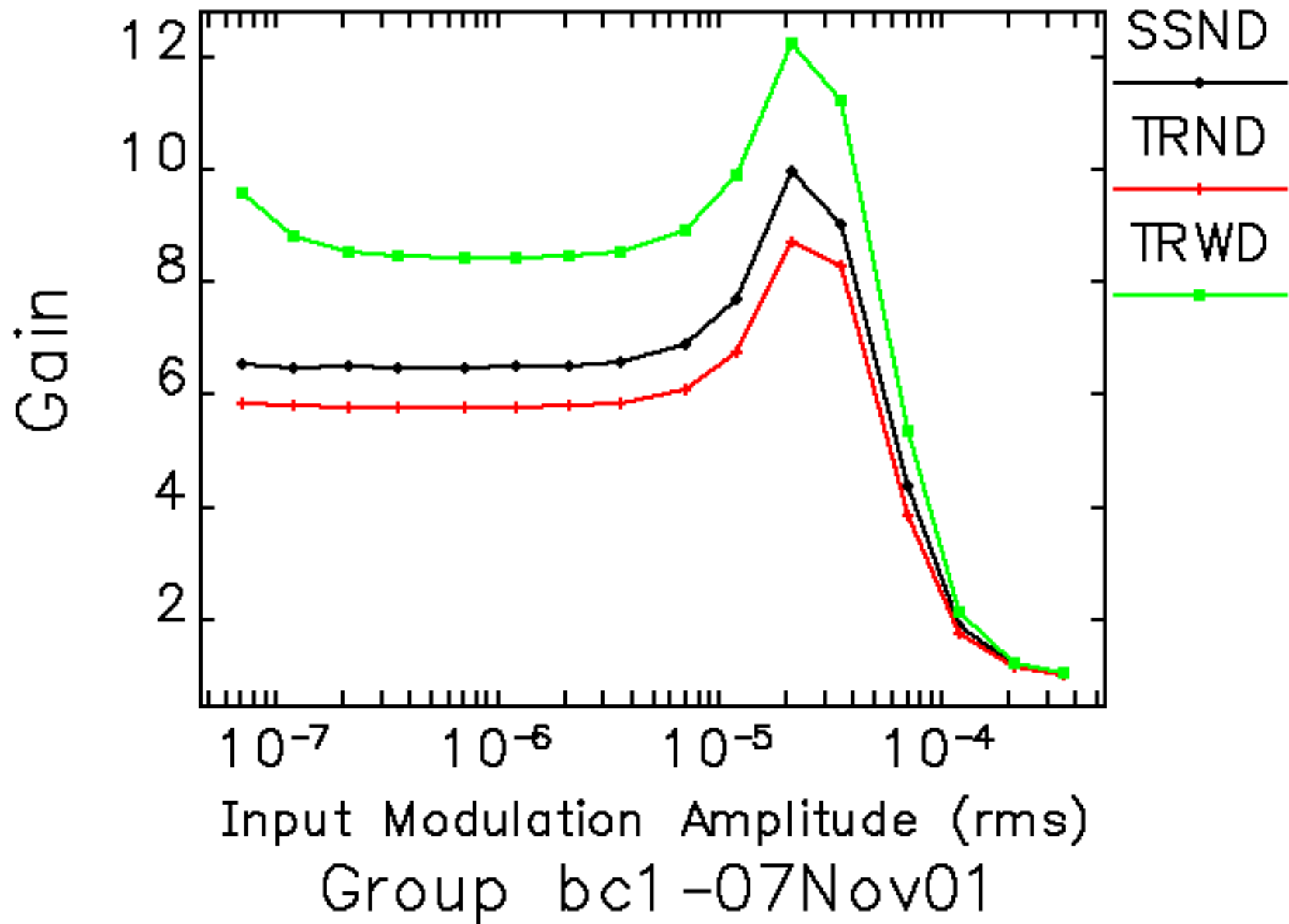
06Dec00 BC1



07Nov01 BC1

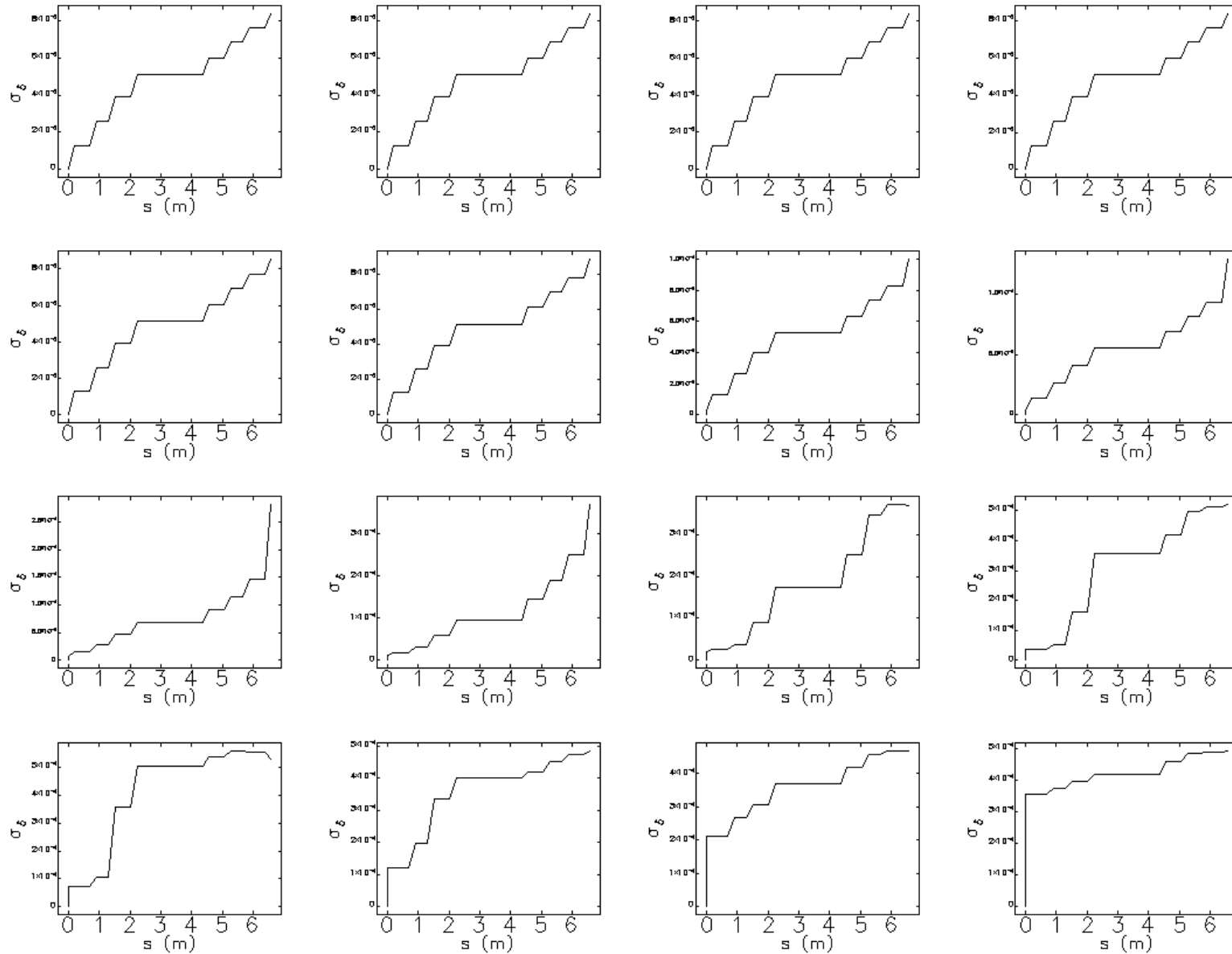


07Nov01 BC1



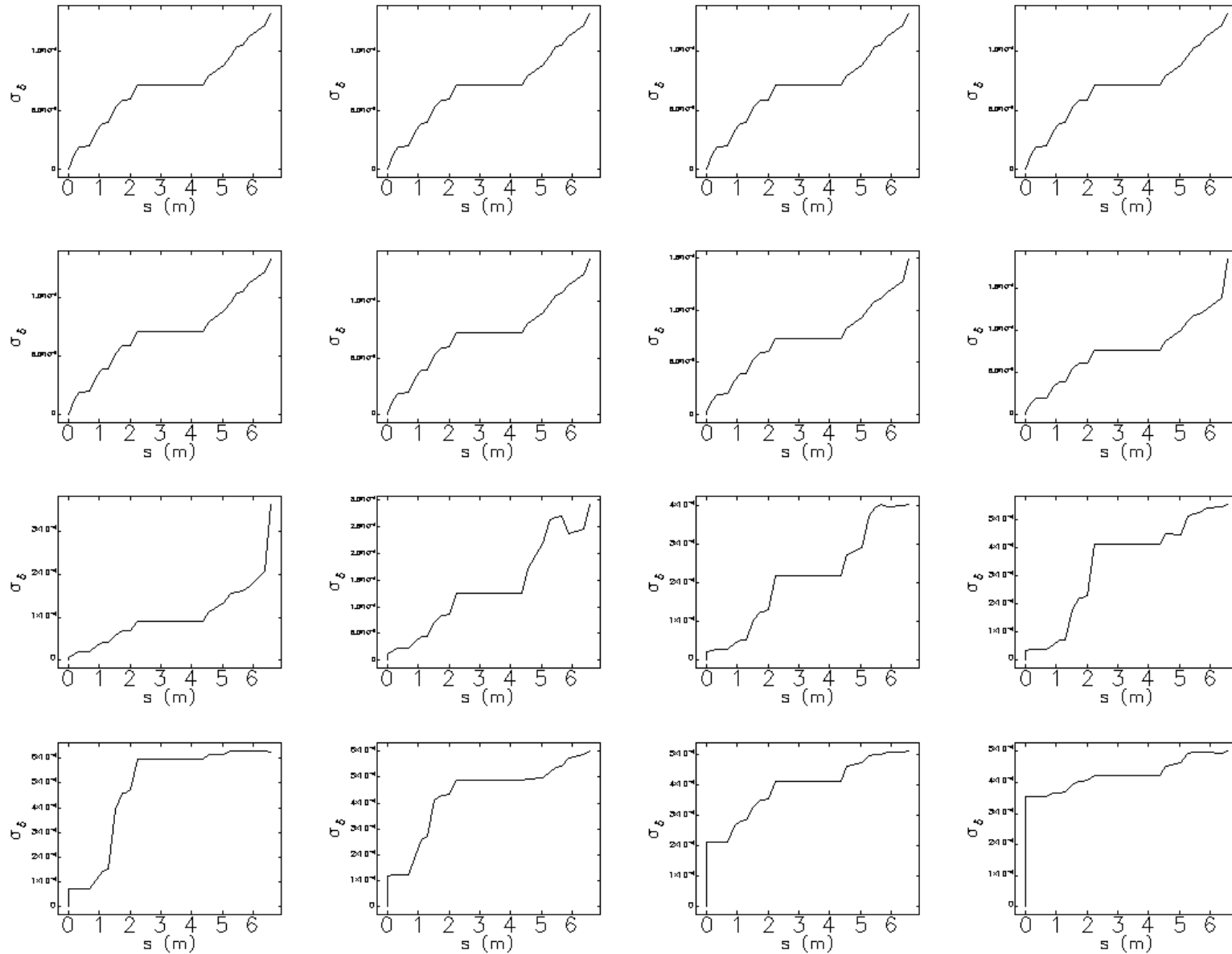
Where Does Growth Occur?

06Dec00 Steady State



Where Does Growth Occur?

06Dec00 Transient Including Drift CSR



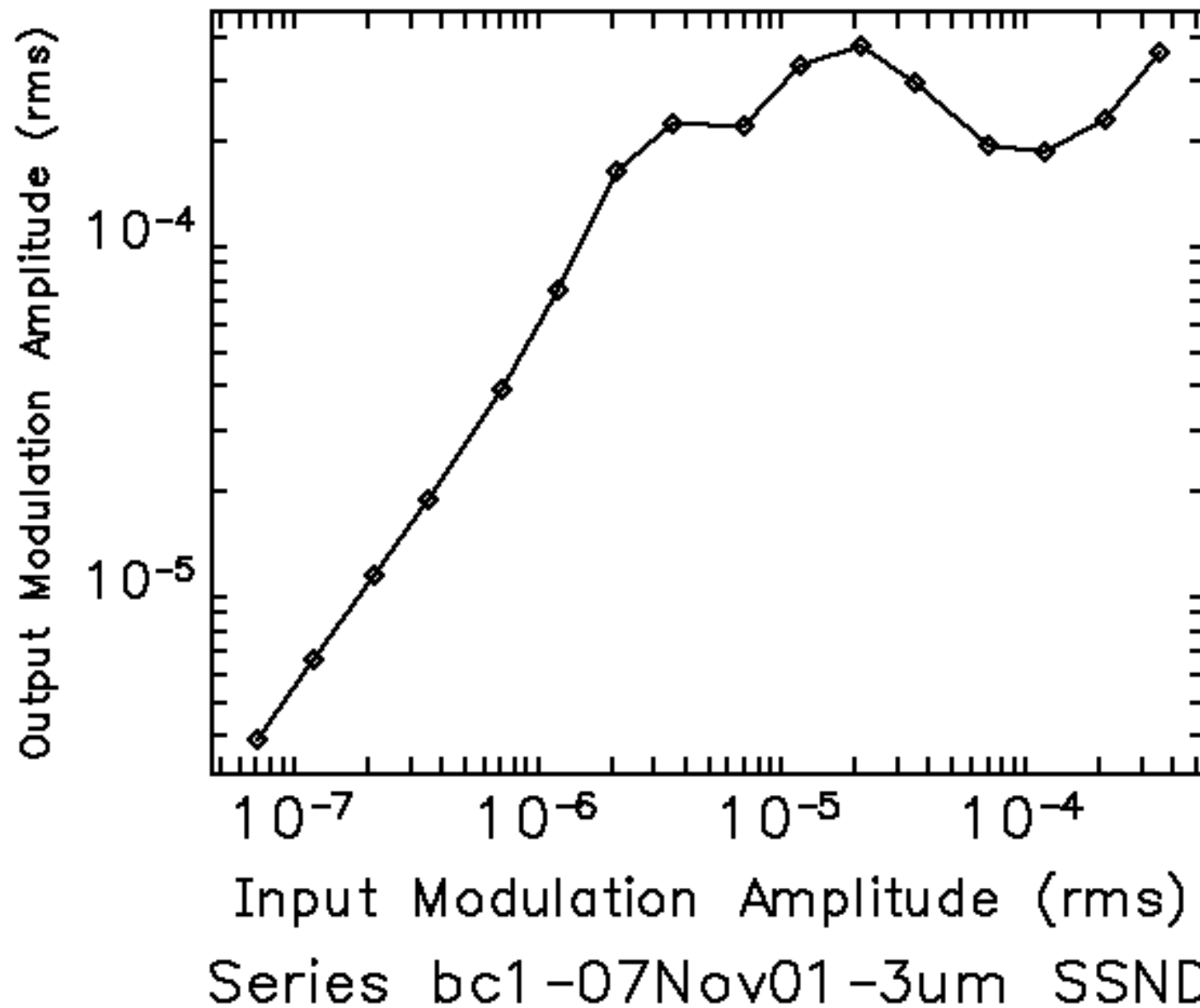
Simulation of CSR Instabilities

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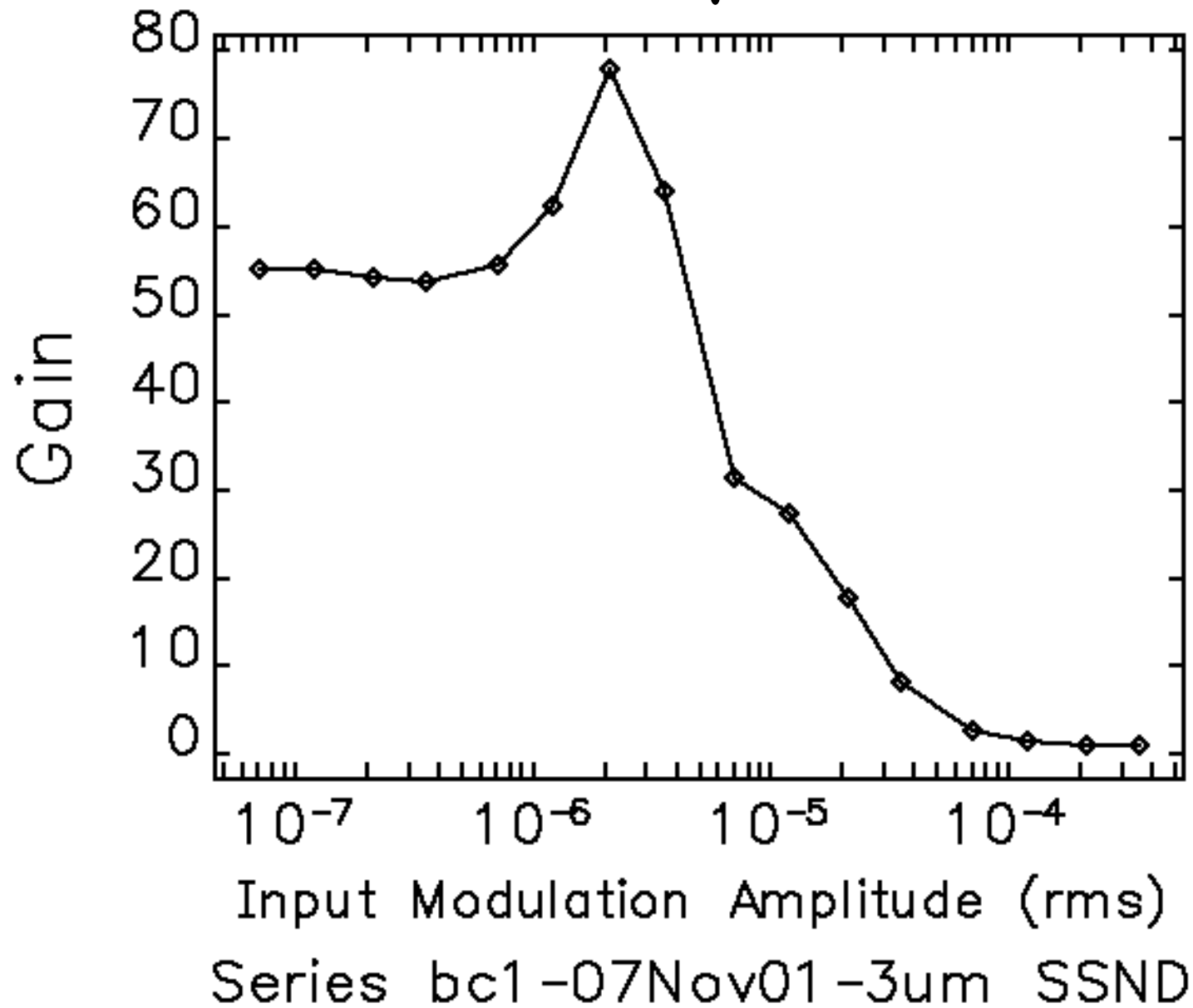
Effect of Shorter Wavelength

- Z. Huang suggested trying a shorter modulation wavelength.
- The gain is expected to be much larger.
- Parameters for 3 μm wavelength must be a little different for practical reasons
 - 1mm long bunch (instead of 2mm)
 - 3000 particles per wavelength (instead of 5000)

07Nov01 with 3 μ m Modulation



07Nov01 with 3 μ m Modulation



Summary

- Proper choice of binning and smoothing parameters is critical
- Predicted instability in LCLS does not appear to be an artifact of simulation
- Amplification of energy modulations shows
 - rough agreement with theory
 - higher gain at shorter wavelength
 - growth does not necessarily occur in any one location