17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

Analysis of a Scheme for a SASE FEL Demonstration in the 2-4 nm Range

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- APS LEUTL project will attempt to demonstrate SASE in the few 100 nm region.
- To go further, we need a more energetic electron beam.
- We want to reach the “water window” at 2-4 nm.

Options

- Adding more linac is straight-forward, except for lack of space and expense.
- Steve Milton suggested using the APS booster to accelerate the photo-injector beam to ~2-3 GeV.
- This *might* work if
  - ramp is fast enough to avoid quantum excitation and IBS
  - beam instabilities are controlled or not severe

Simulation Parameters

- Injector (mostly from S. Milton)
  - 1 nC/pulse
  - +/- 0.190 MeV energy spread
  - 2 mm-mrad normalized emittance
  - +/- 2.5 ps bunch length
  - nominal injection energy of 450 MeV.
- Booster
  - low-emittance lattice with gradient dipoles and 1/2 cell length.
  - up to 9MV rf voltage
  - ramping rate of 34 keV/turn (nominal)
  - longitudinal Q=1 resonator impedance of 1 Ohm at 1.6 GHz.

Simulation Parameters

- Undulator (S. Milton)
  - K = 1.86
  - Period = 20mm
  - Peak field is ~1T
  - Allow up to 100m length

Simulation Details

- Use the program **elegant**, a widely-used tracking code at APS.
- Simulate with 1000 particles including
  - ramping from 450 MeV to 2 GeV
  - quantum excitation (equal in both planes)
  - IBS
  - damping
  - longitudinal resonator impedance
- Use M. Xie's parameterization to estimate FEL performance.

Simulation Methods

- 6-D tracking with one-turn linear matrix.
- Linear energy ramp.
- Quantum excitation and IBS:
  - Compute the excitation rate and hence emittance growth for last turn.
  - Add gaussian random numbers with corresponding RMS parameter to particle coordinates.
- Impedance
  Directly simulate a resonance using binning and the fundamental theorem of beamloading.
- Damping
  Compute damping decrements and apply to particle coordinates once a turn.

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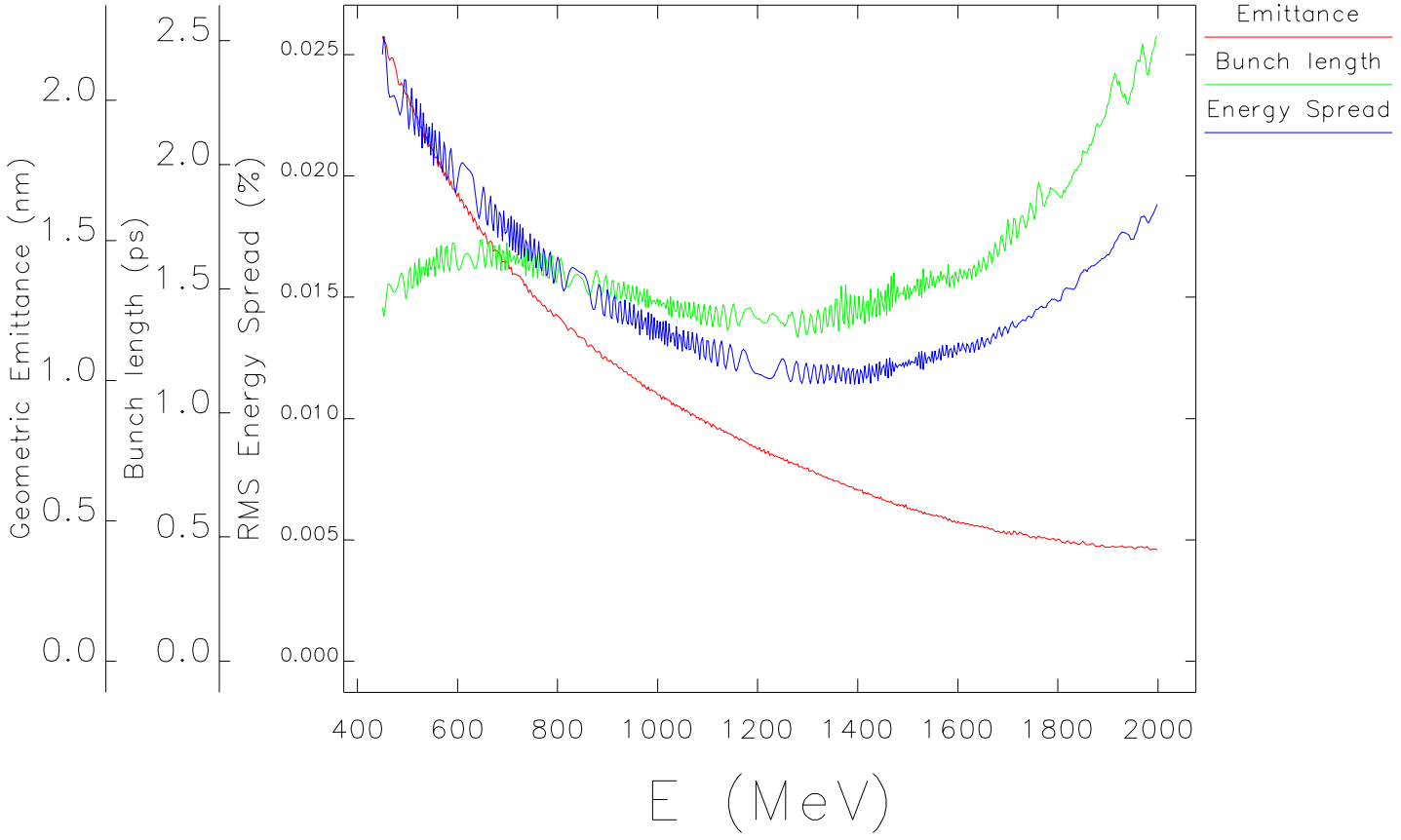
Ideal Beam Evolution without IBS or Impedance



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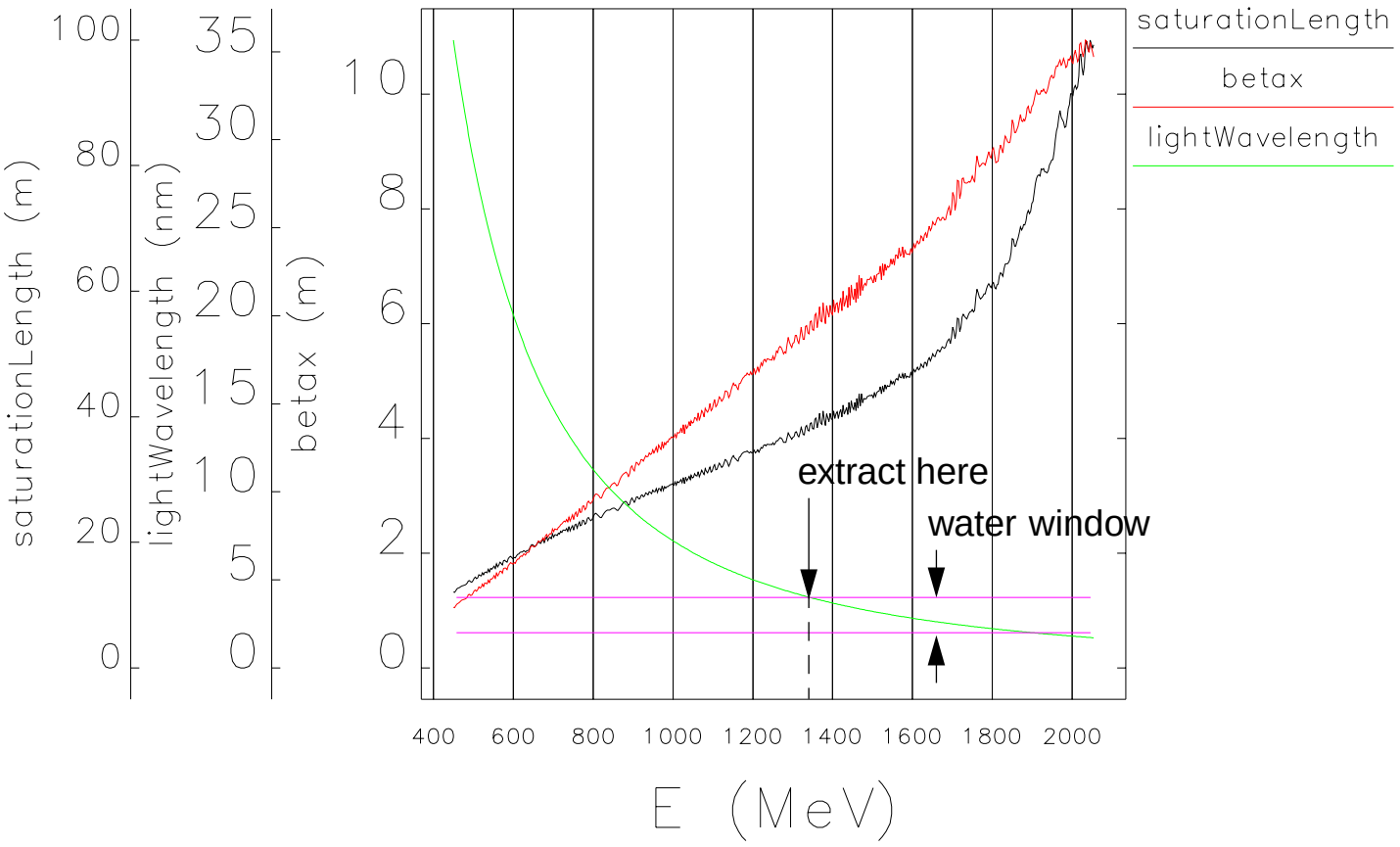
FEL Performance for Ideal Case



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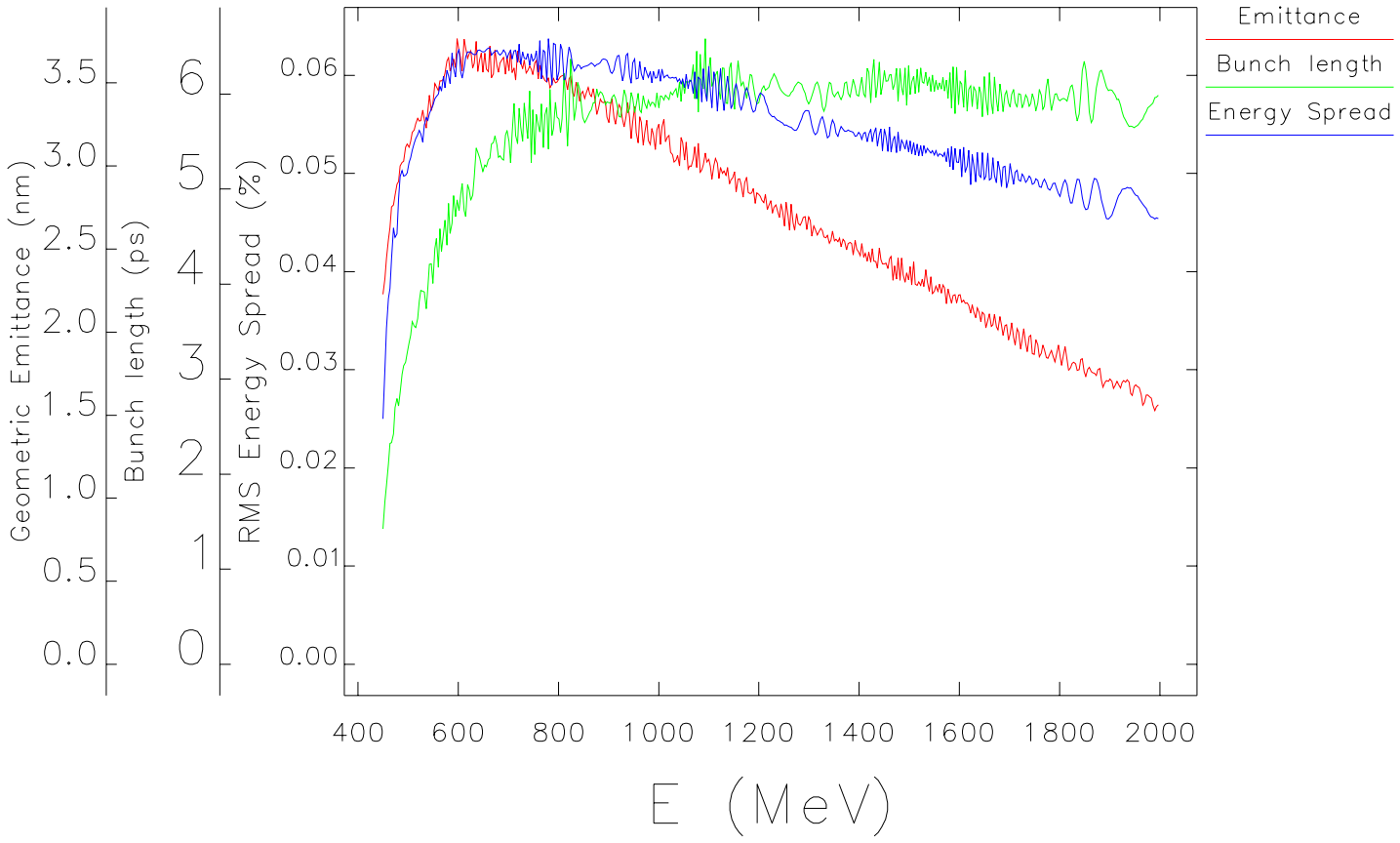
Effect of IBS and Impedance



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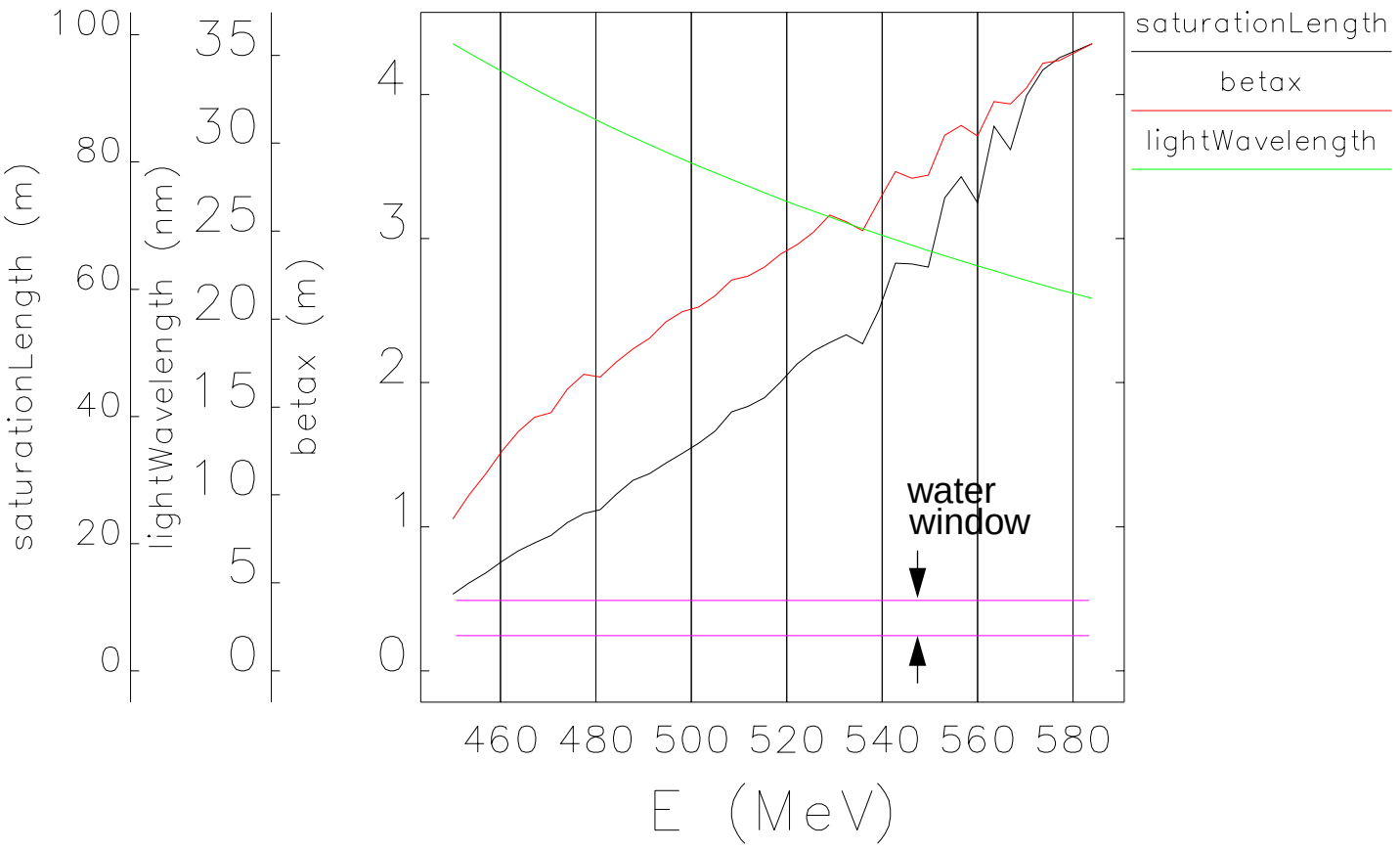
FEL Performance with IBS and Impedance



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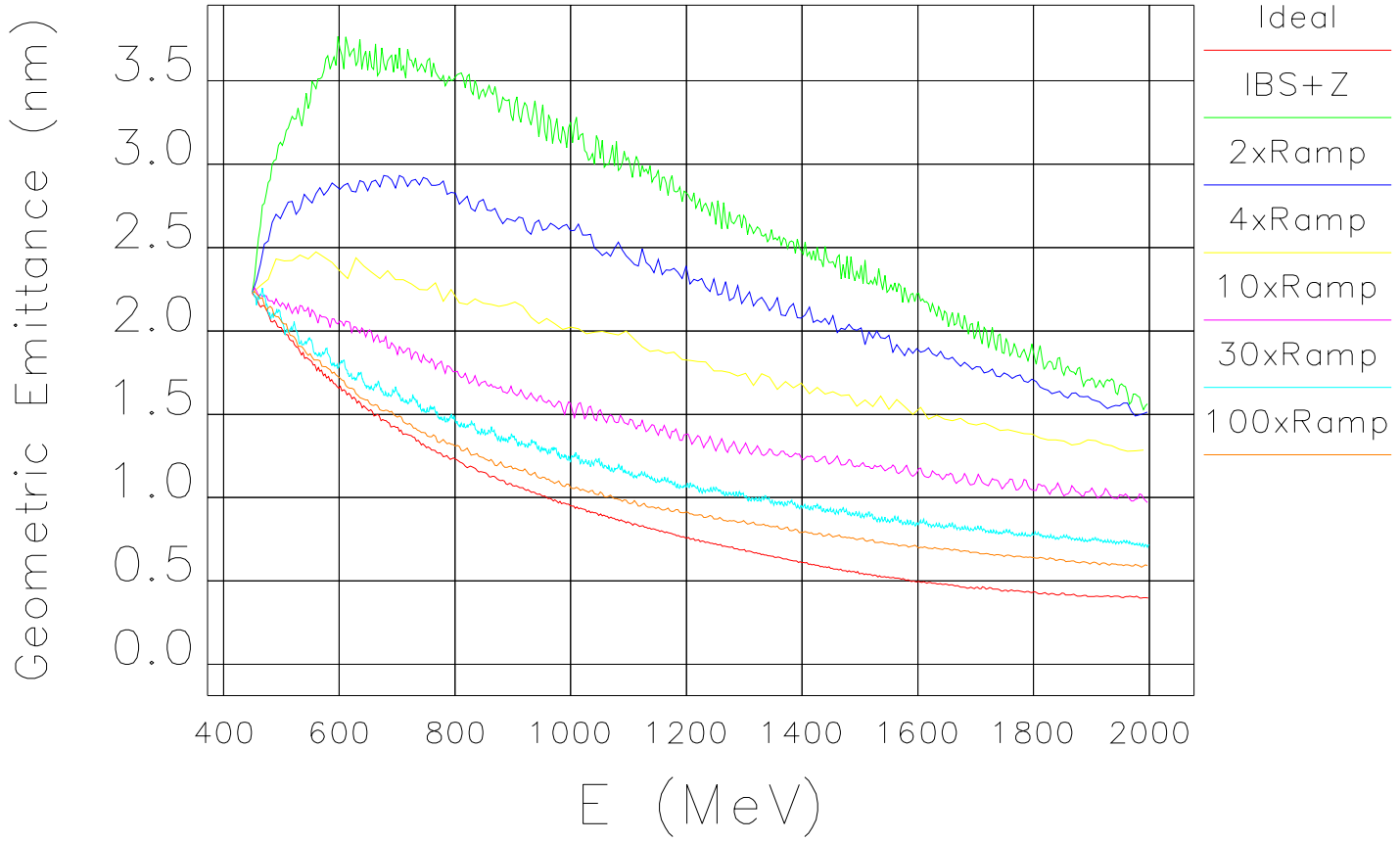
Tracking with Higher Ramp Rates



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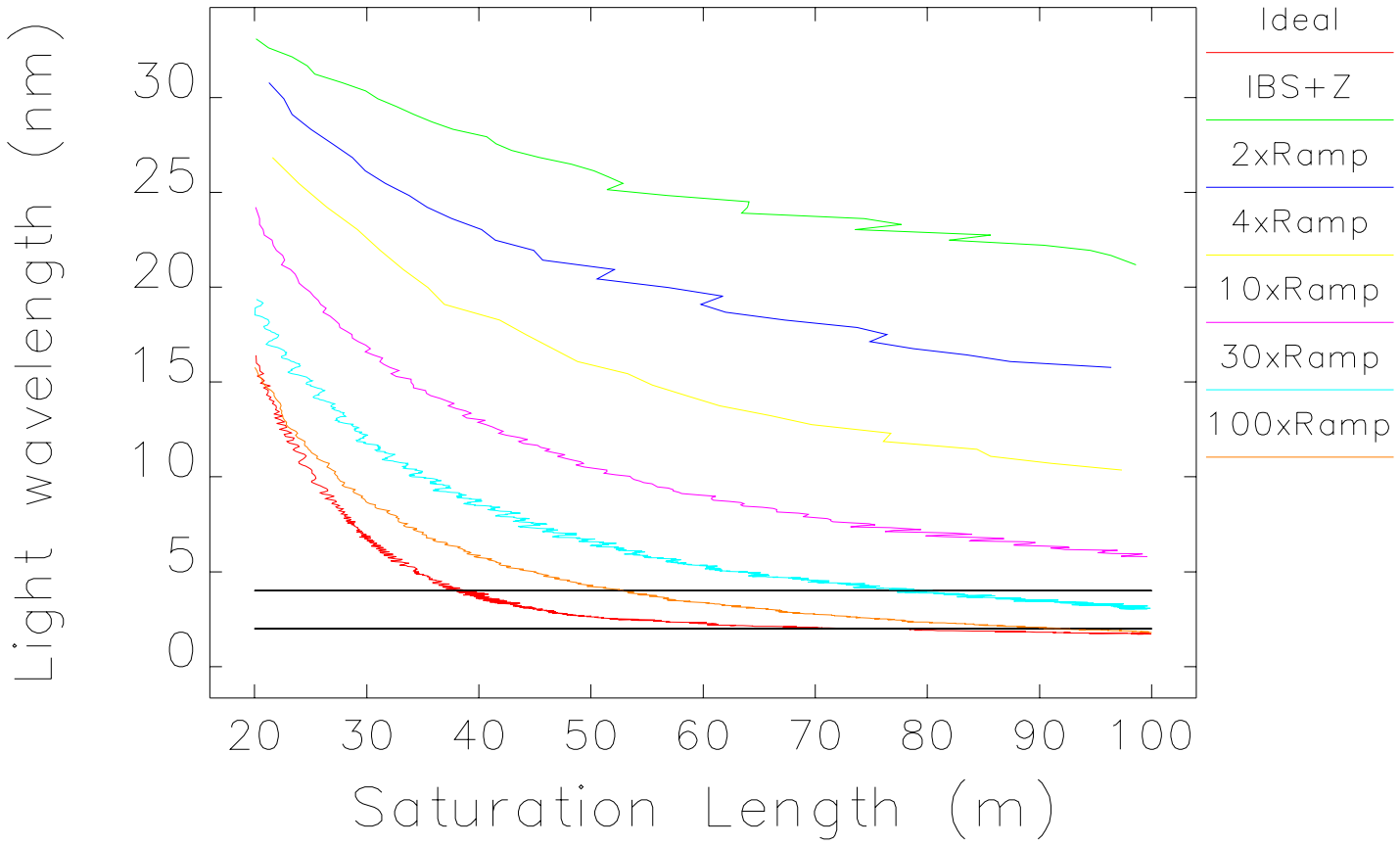
FEL Performance with Higher Ramp Rates



Conclusions

- In the absence of collective effects, a low-emittance booster can put us into the water window with a modest undulator.
- Intra-beam scattering makes our scheme unworkable with the present ramping rate.
- This scheme could work with
  - ramping rate of 1 to 3 MeV/turn.
  - 50-80m long undulator.