Commissioning Simulations using Genesis 1.3

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Foreword

- Thanks to some software from the house Microsoft, the file of my original talk was corrupted beyond repair at around 6 pm last sunday.
- The following talk is a recovery from what is left in my mind and hard disk.

Outline

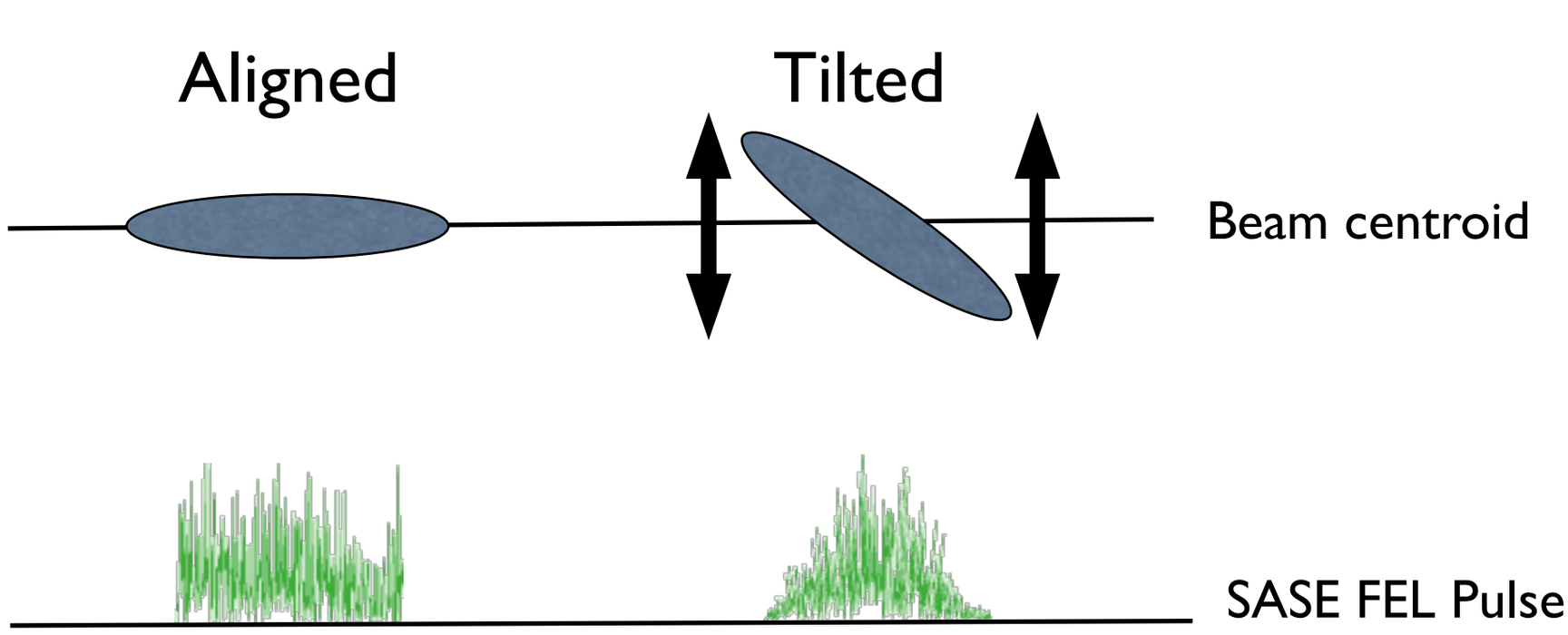
- Beam Propagation
- Beam Input for Genesis 1.3
- Undulator Modeling
- Spontaneous Radiation and Start-up regime
- The Commissioning Case at 1.5 nm
- Outlook and Conclusion

Beam Propagation

- Genesis 1.3 tracking algorithm in good agreement with Paul's BBA procedure (reproduction of the central trajectory)
- Results from BBA procedure can be directly imported in the LCLS lattice used for Genesis 1.3 run.
- Random error below BBA resolution can be added.

Beam Propagation

- The BBA algorithm works only on the beam centroid. Residual tilt might have significant effect on the FEL output power.



Strong uncertainties in detectable FEL pulse energy

Beam Input

- Input from Elegant runs or measurements.
- Slice properties essential for simulations.
  - At least 10 slices with 100-200 slices as optimum.
  - Similar to the beam tilt, the FEL pulse energy can vary (10 - 100 % from optimum performance).

Beam Energy & Spread

- Least sensitive for FEL simulations
- SASE FEL power is almost independent on the slice beam energy (reflects only in a change of the central wavelength)
- Energy spread insignificant to emittance effects and mostly determined by quantum fluctuation of the spontaneous radiation.

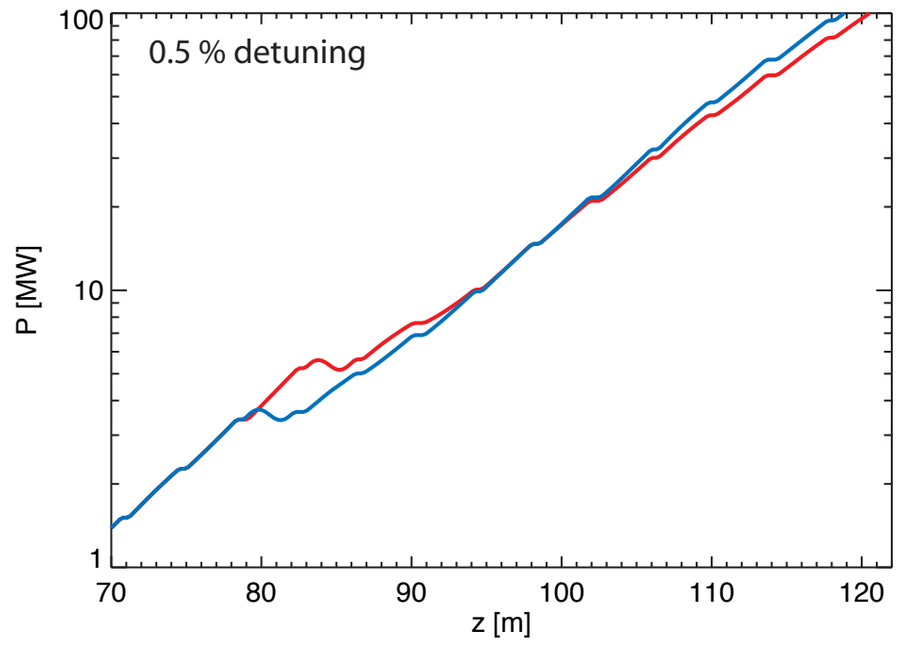
Current and Emittance

- Most critical parameters
- Ambiguous in the FEL performance, scales roughly as I/ϵ_n
- Tolerances (estimate for +/- 50% power):
  - Current: +/- 100 A
  - Emittance: +/- 0.2 mm mrad

Undulator Modeling

- Genesis 1.3 allows for arbitrary undulator profiles, module/quadrupole offsets and phase shifter.
- Field detuning and module mismatch yield local effects in FEL performance.

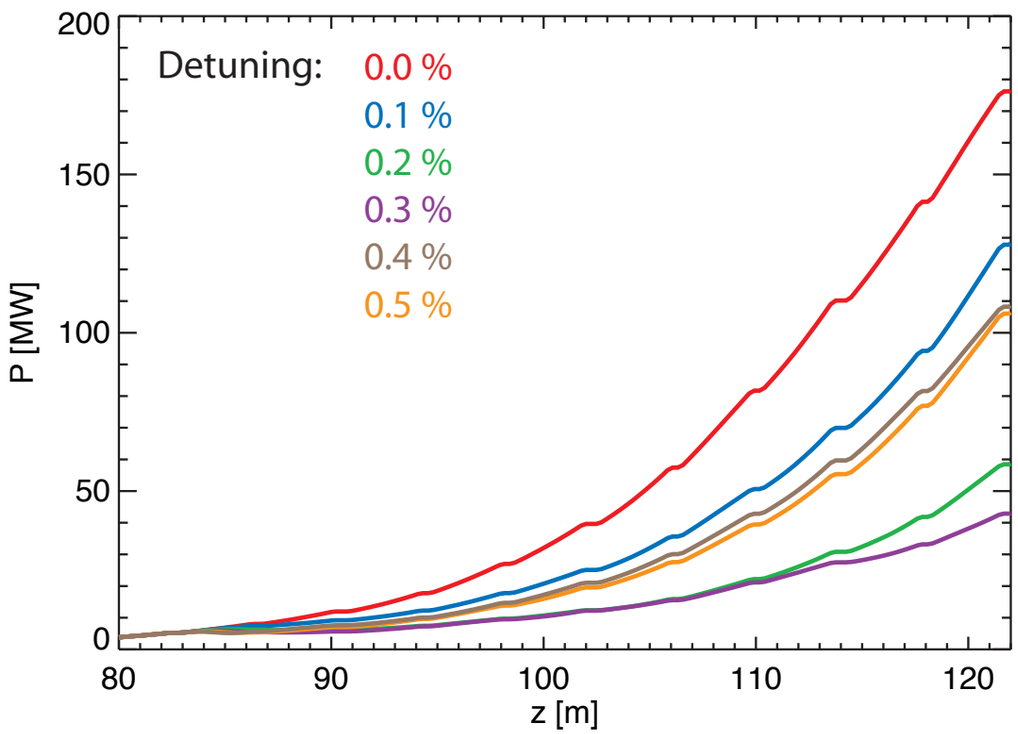
Example of field detuning by 0.5% for module 22 and 23. Requires a module by module tuning/commissioning.



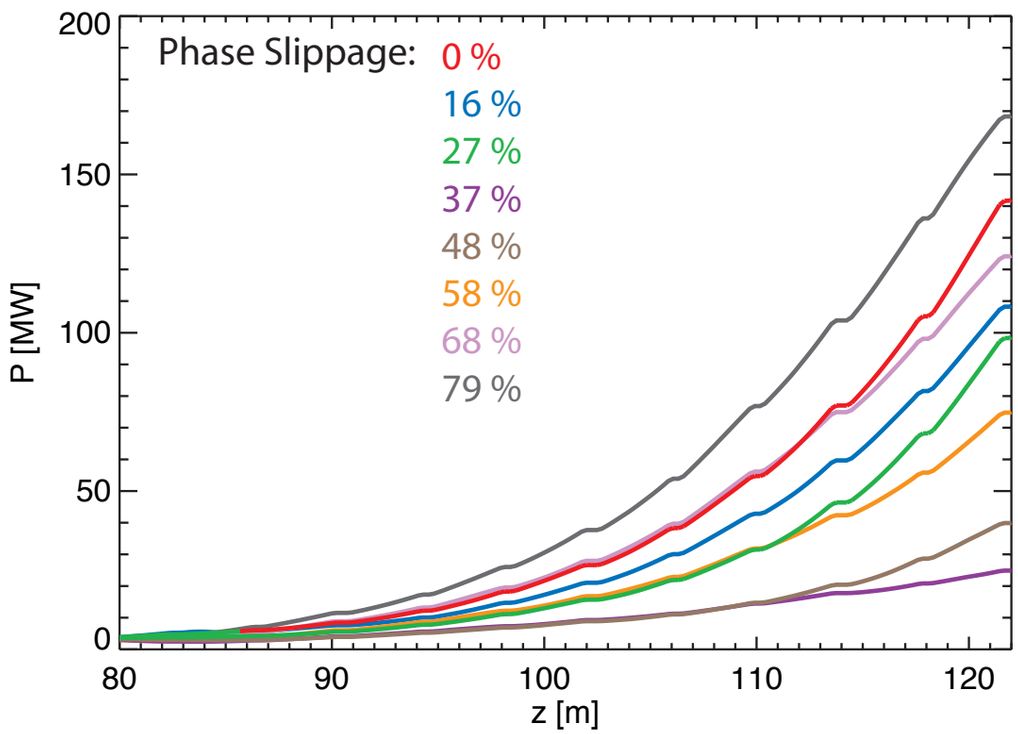
Undulator Errors

- Undulator field variation and vertical offset are indistinguishable, when only the effective K-value is measured (e.g. resonant wavelength).

Detuning of single module

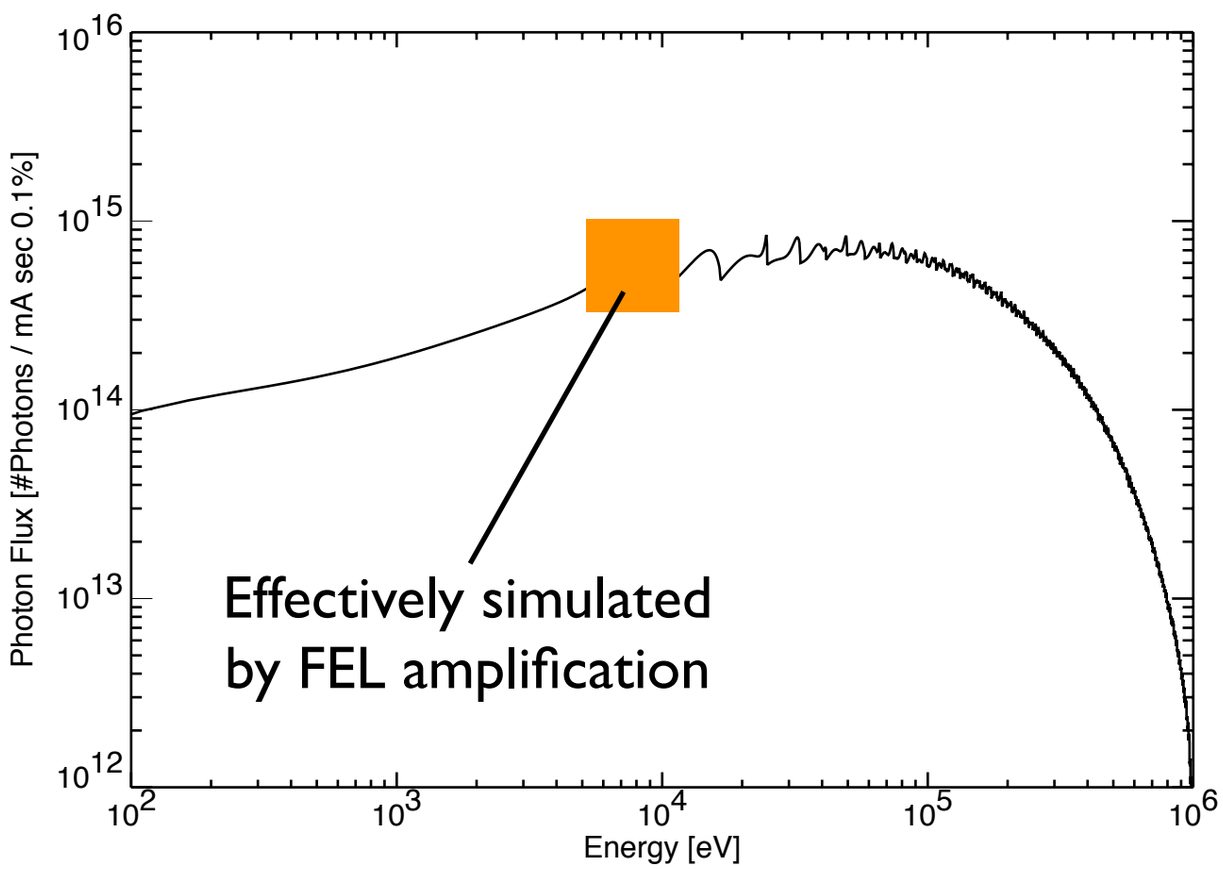


Phase slippage in a single gap



Spontaneous Radiation

- Strong background signal
- FEL uses only a small fraction as seed.

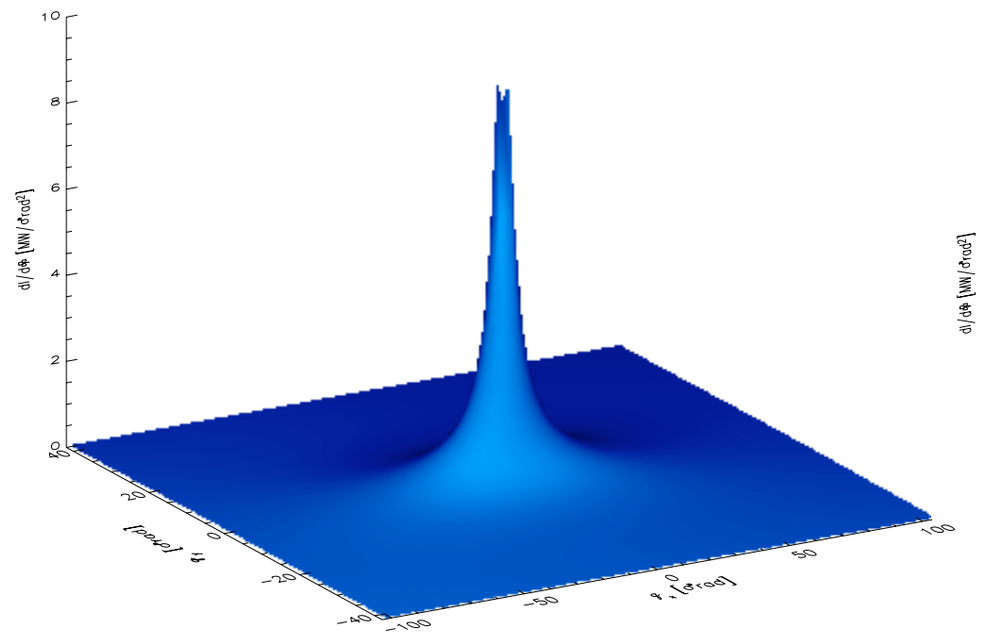


Signal Detection

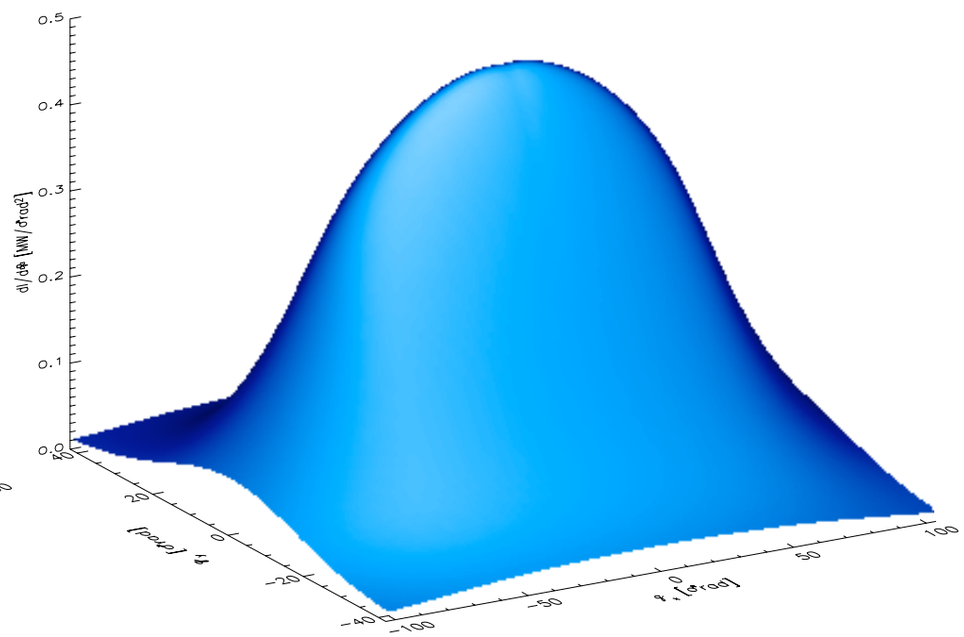
- Angular distribution depends on position of detector. Due to length of the undulator with respect of end-station, radiation source cannot be regarded point-like.

Angular distribution of SR for single module

20 cm behind undulator module



4 m behind undulator module



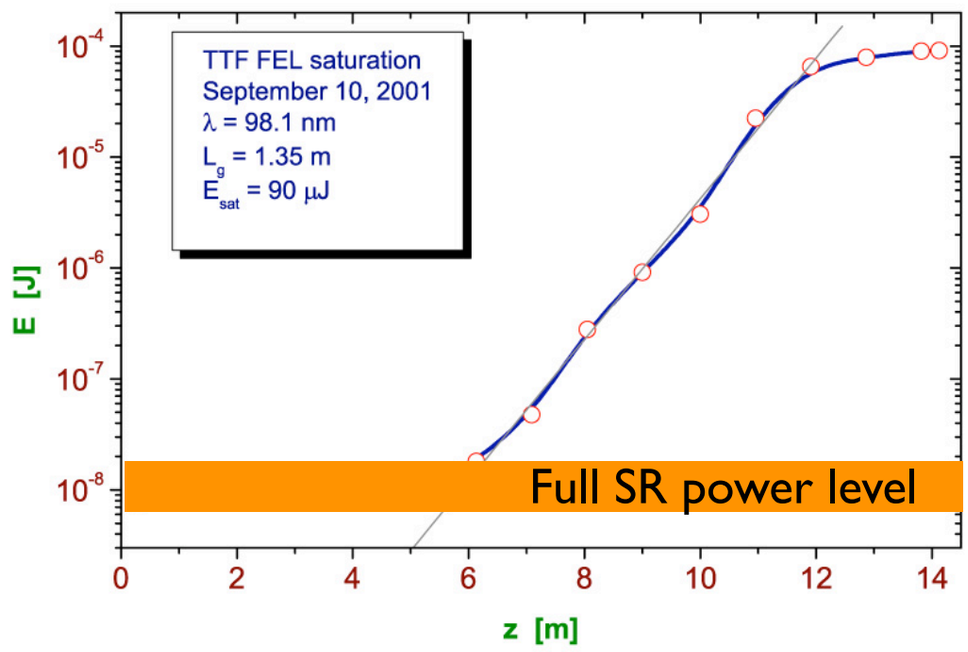
Signal Detection

- Cuts in angle (pin holes) or frequency can reduce background signal.

Case	1.5 Å	1.5 nm
FEL	9 GW	200 MW
SR	95 GW	10 GW
$\Delta f/f_0 = 0.1\%$	7 MW	800 kW
$\Delta f/f_0 = 1.0\%$	75 MW	8 MW
$\theta = 10$ μrad	3 GW	35 MW
$\theta = 20$ μrad	11 GW	135 MW

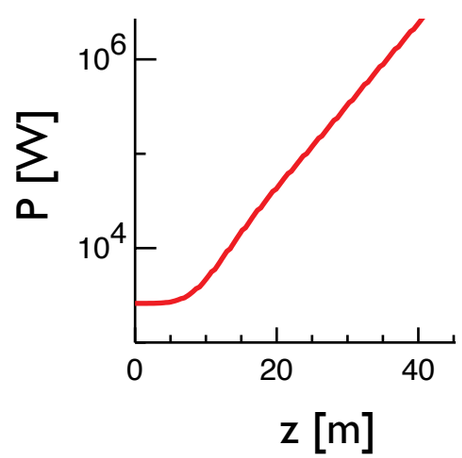
Signal Detection

- Mis-steering the beam will suppress FEL amplification, but not the spontaneous radiation.
- Detection at the end-station will detect full power of spontaneous radiation.



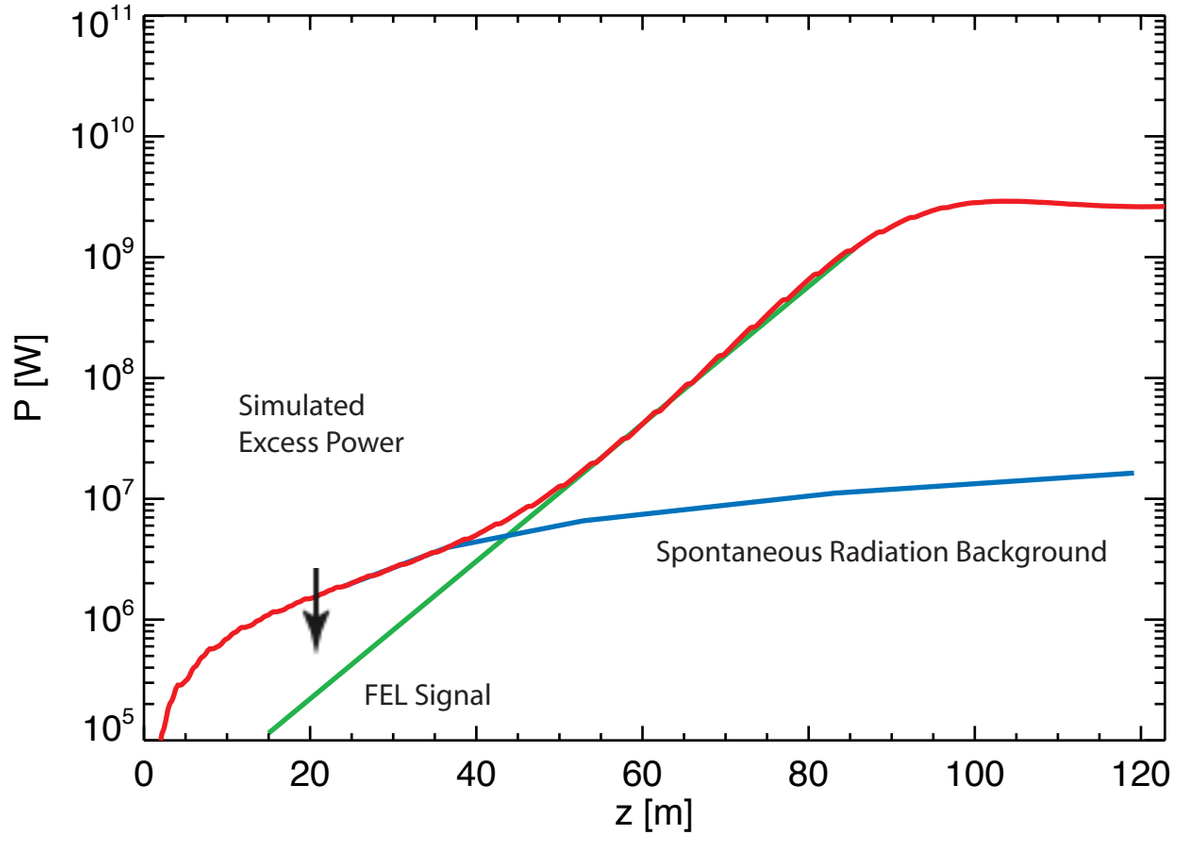
Simulating Start-up I

- Fast simulation with FEL amplifier mode of independent beam slices.
- Initial power level estimated from analytical formula (with huge error for low gain performance)
- Spontaneous radiation fully excluded



Simulating Start-up II

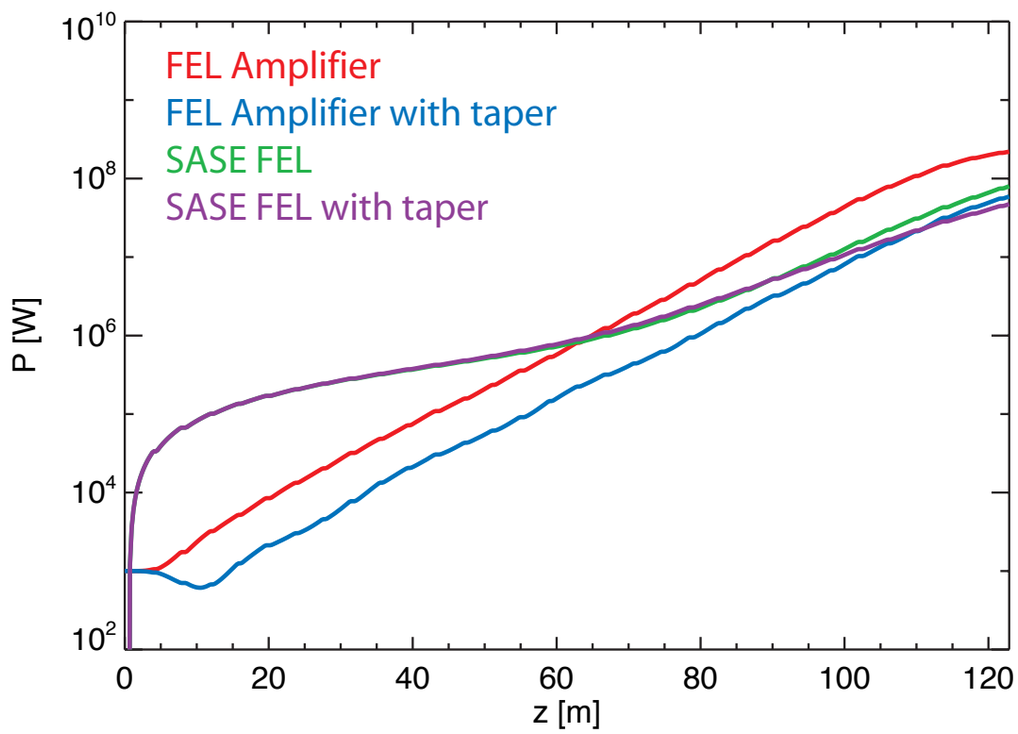
- SASE runs include spontaneous radiation, but very time-consuming.
- Complicated cut in frequency and angular aperture.
- SR power level depends on simulation parameters

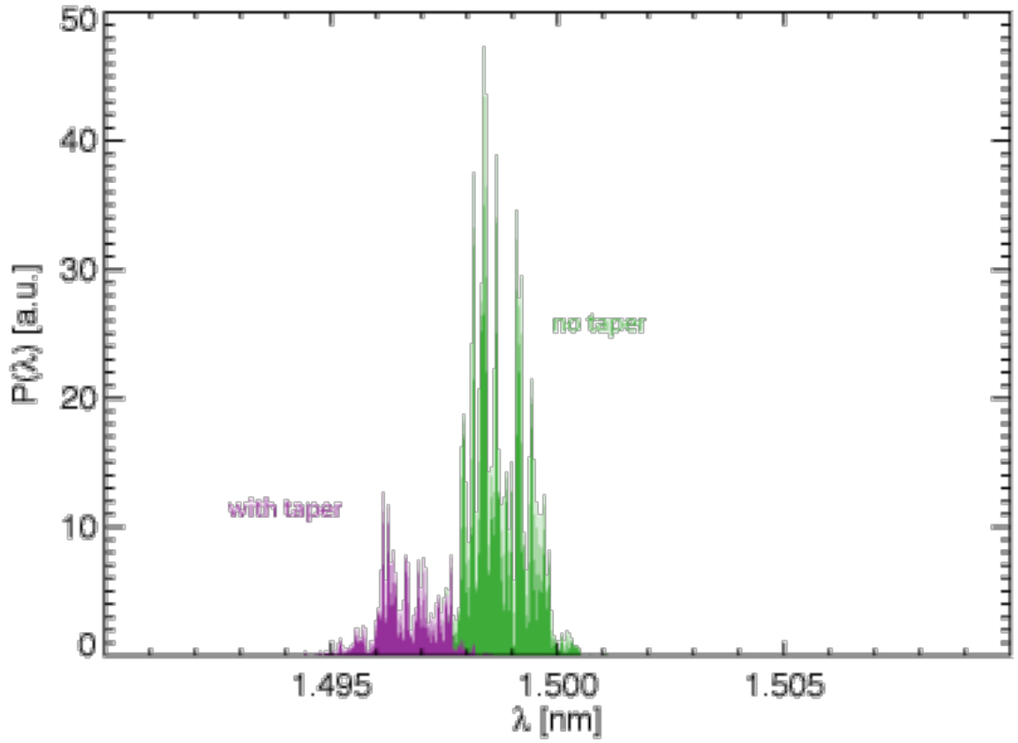


Commissioning Case

- FEL performance suffers slightly from taper for the 1.5 Å case. Power lever of 70 MW expected.

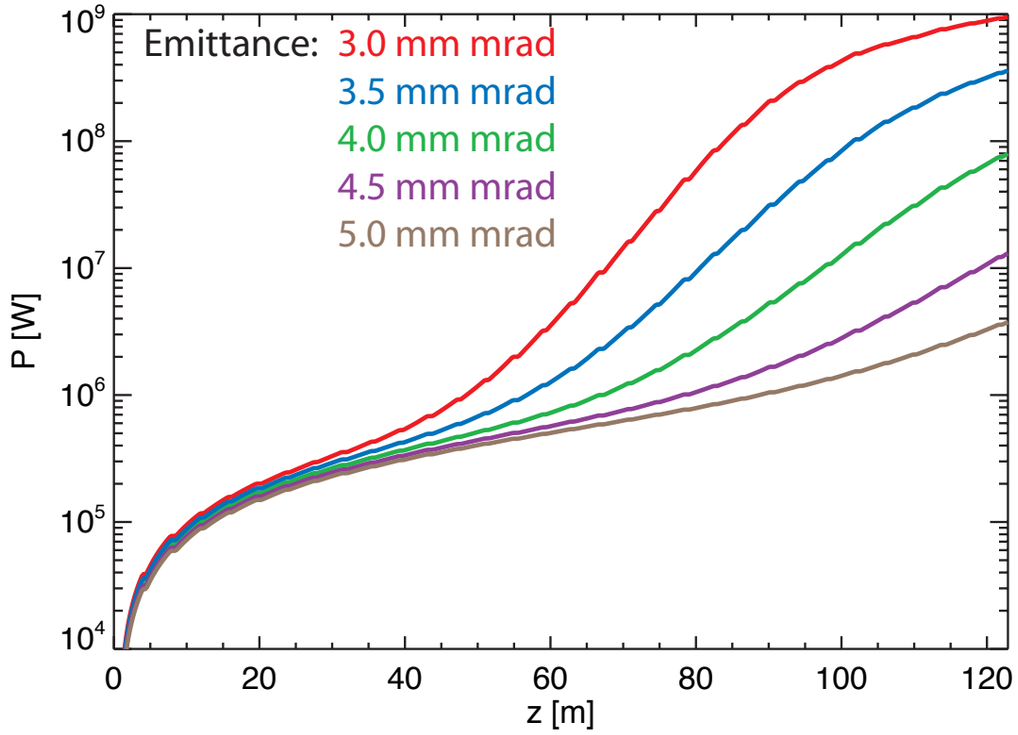
- Wavelength shift due to taper.

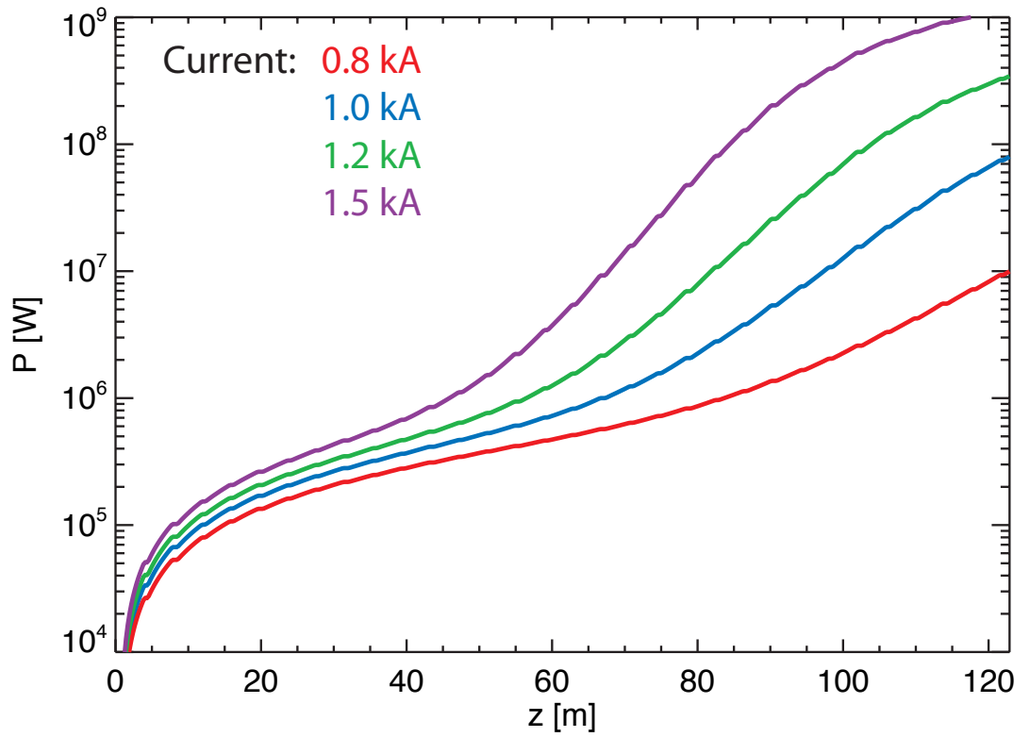


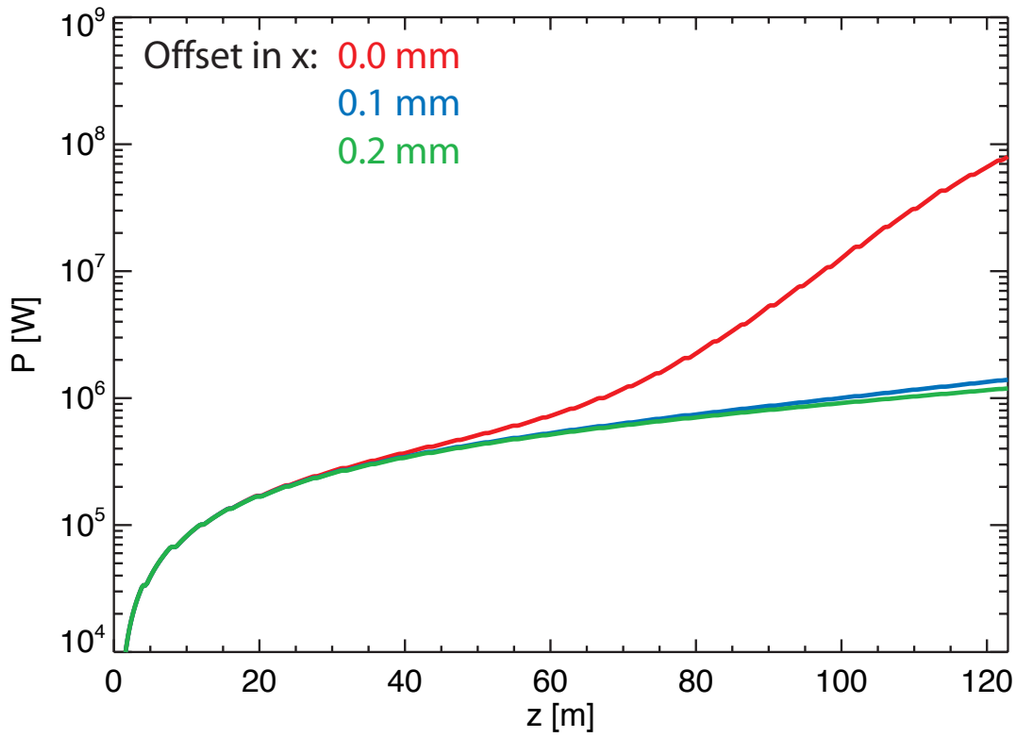


Commissioning Case

- Dependence on emittance, current and beam offsets







Genesis-Outlook

- Include Ming Xie's formula to automatically estimate shotnoise power for FEL amplifier runs.
- Porting to parallel computer (MPI interface)
- Automated interface to beam diagnostic/ Elegant runs
- Non-commissioning related improvements

Roadmap for SR Code

- Based on Lienard-Wiechert Equations
- Average over undulator period, removes for fine resolution of undulator period.
- Assume straight trajectories through undulator, allows for convolution of single particle results with angular and position distribution.
- Speed-improvement (100 x #particles)

Conclusion

- Simulation requires detailed information on beam properties (slice beam parameters, in particular emittance and current).
- Fast runs within an hour (FEL amplifier mode).
- FEL codes inadequate of calculating full spontaneous radiation, requires independent (new?) code.