Genesis Simulation with Undulator Consisting of 3 Subsections

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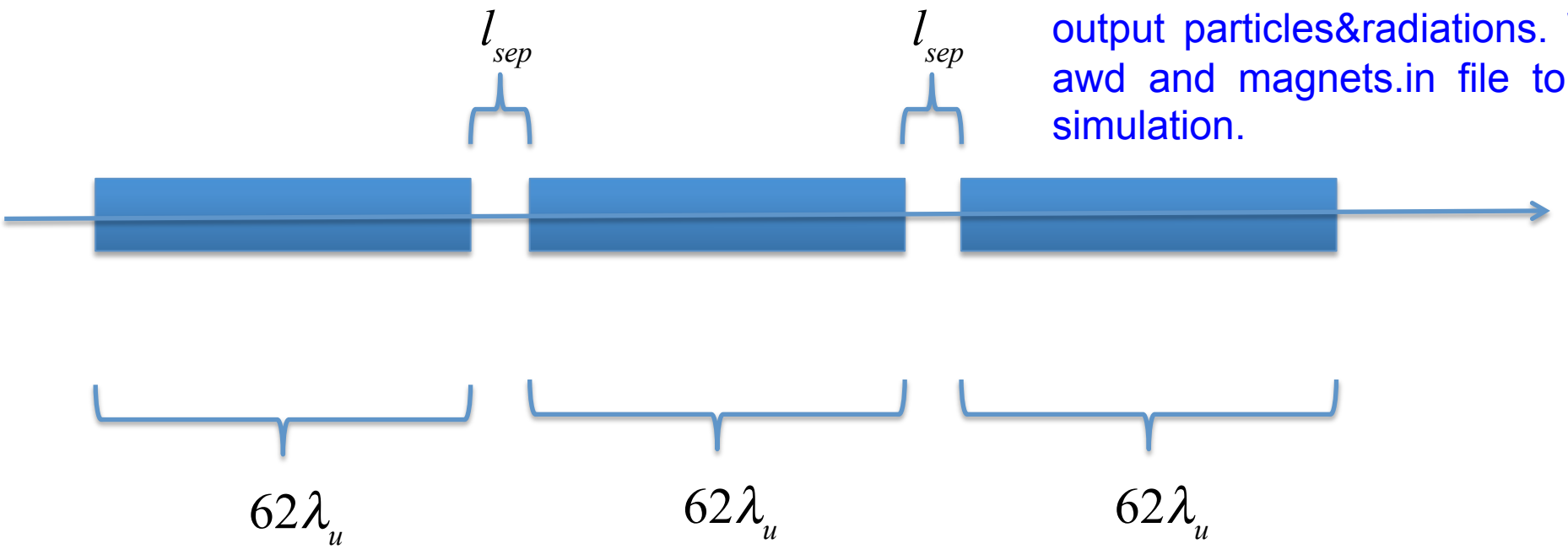
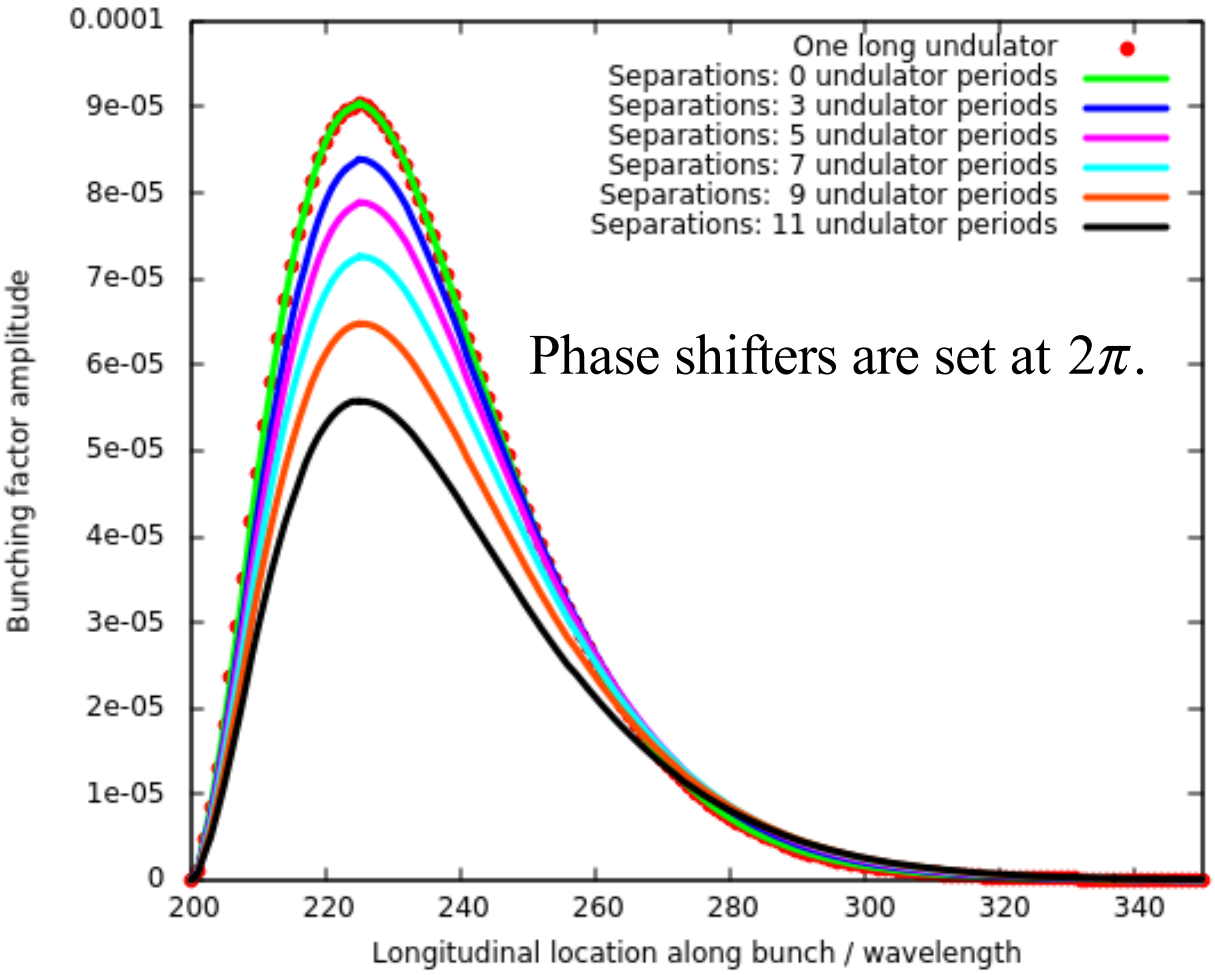
It seems possible to configure Genesis so that it simulates a multi-section undulator without input/output particles&radiations. We use awd and magnets.in file to do the simulation.

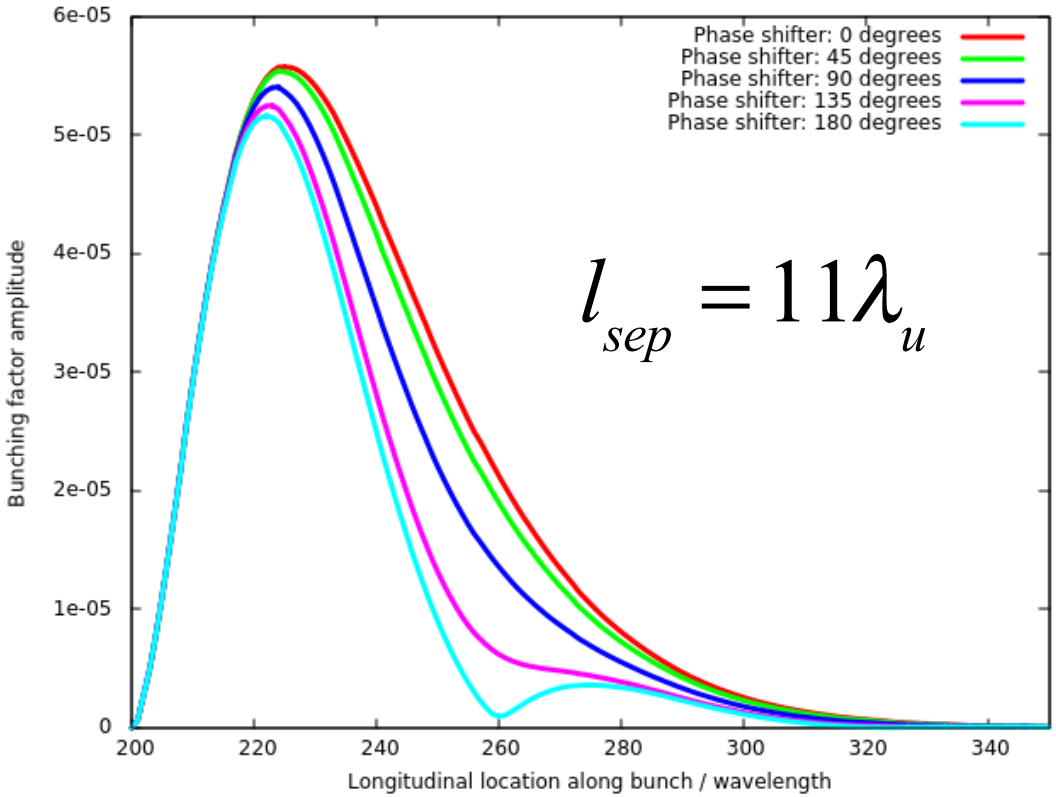


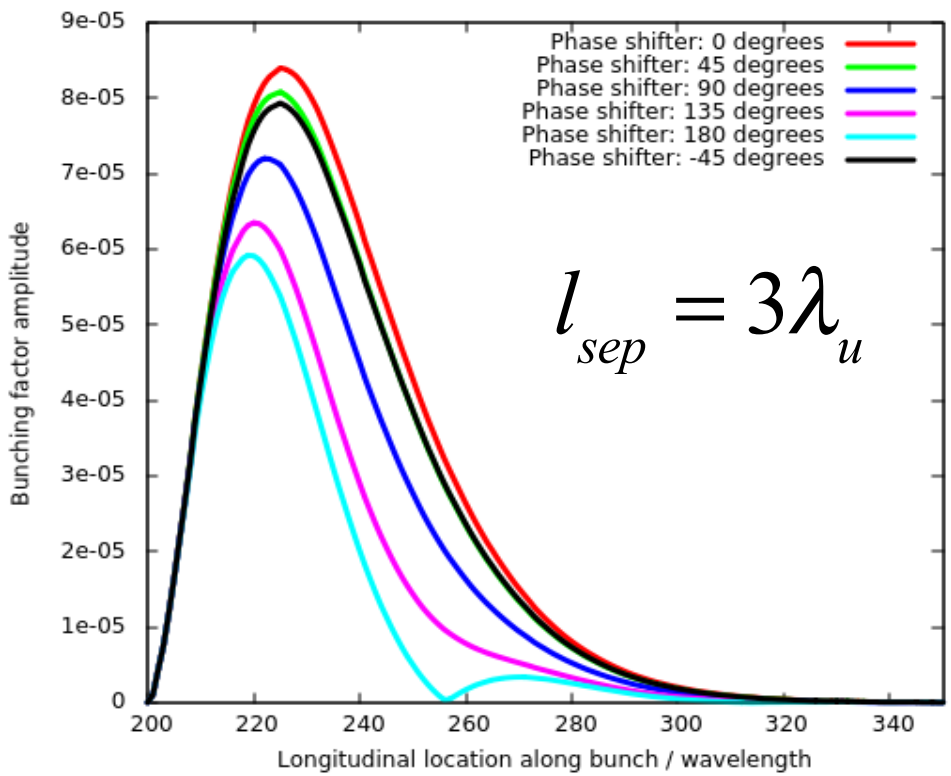
Influence of l_{sep}



- With $l_{sep} = 0$, simulation results with three subsections are identical with that obtained from one long undulator section, as expected.
- As l_{sep} increases, the FEL amplification decreases, possiblely due to loss of radiation (power density) at the gaps among undulators.
- I did not change the initial beam width at the entrance of FEL amplifier while varying l_{sep}, which may also affect gain.

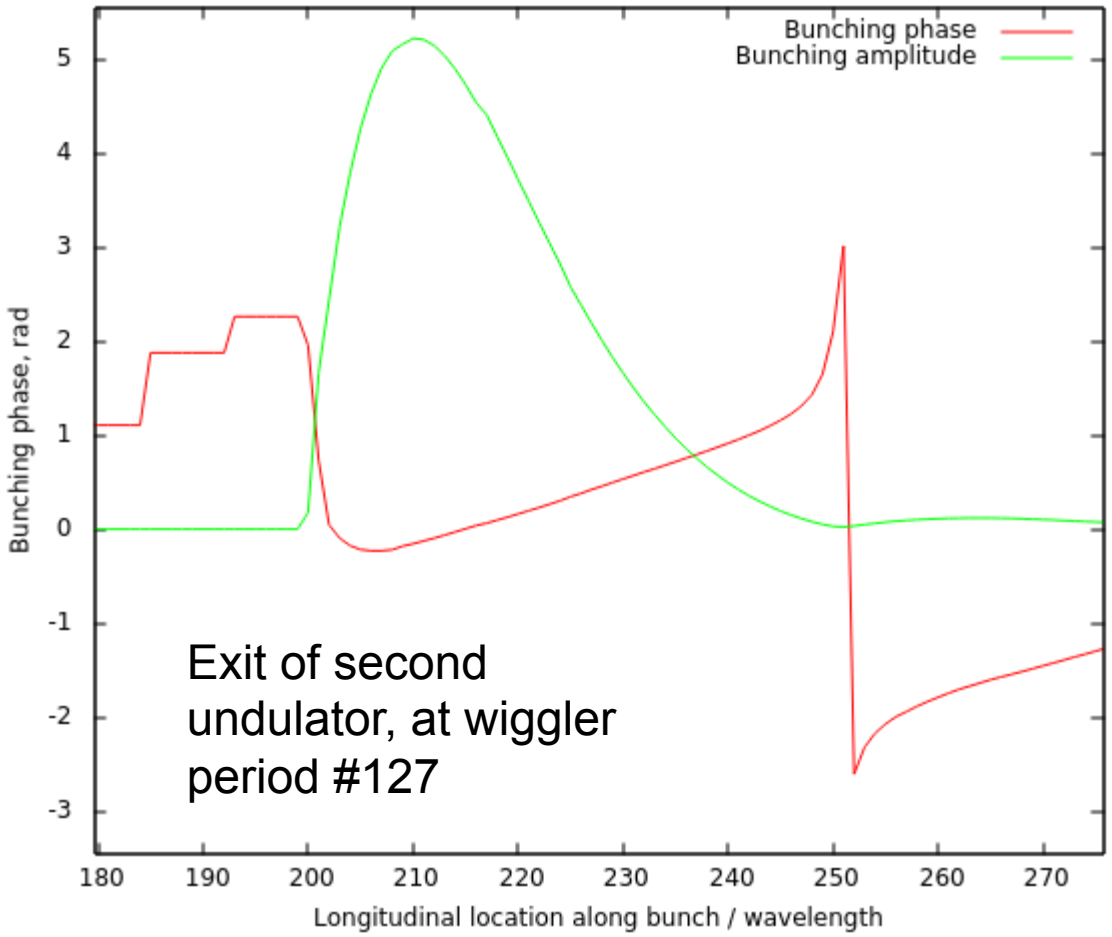
Influences of phase shifter





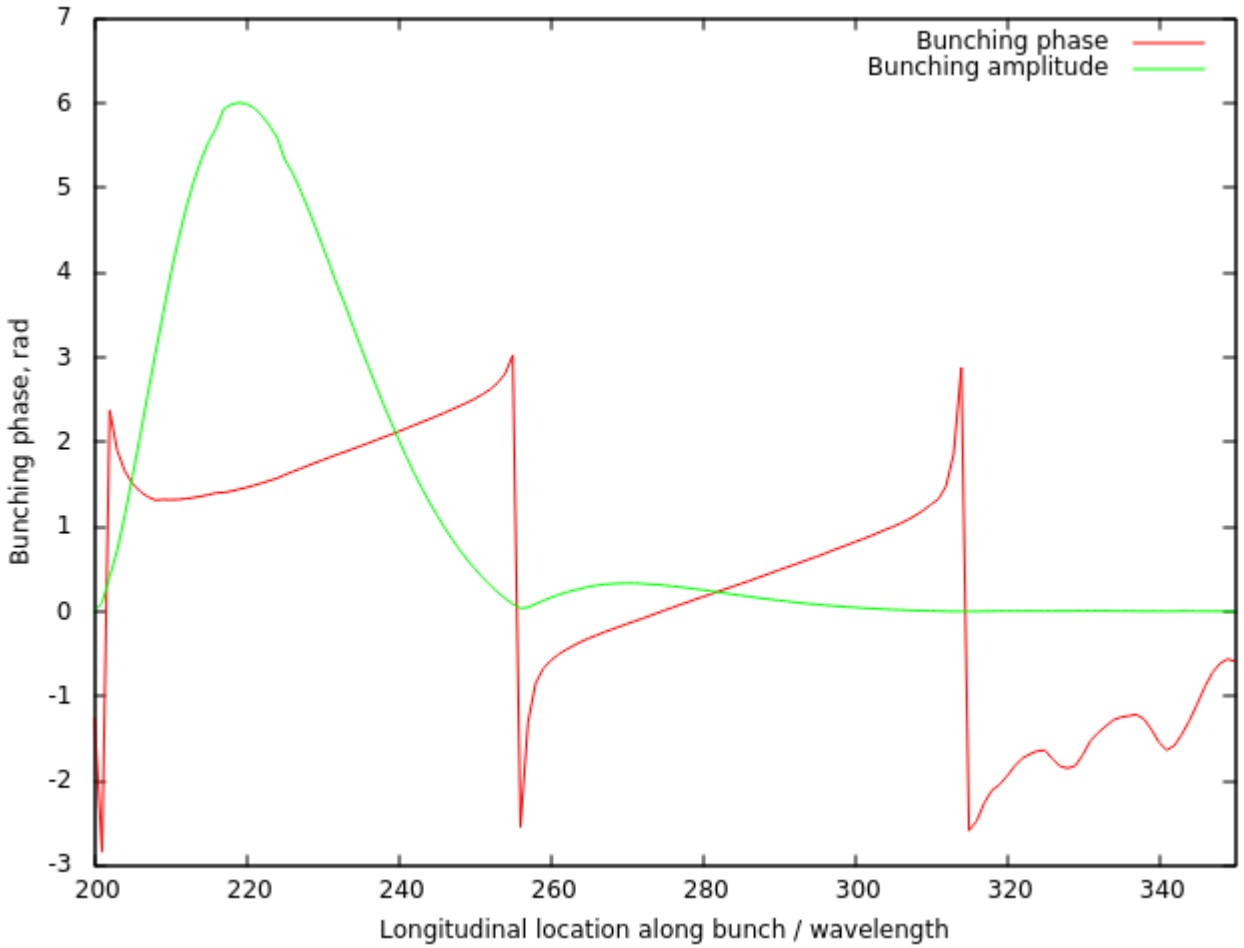
- Smooth when phase shifter are set to 0 degrees;
- Phase shifters have relatively smaller influences for larger l_{sep} ;
- The ‘left’ part of the wave-packets is not affected much by phase shifters;
- Small peak (WHY?) towards head of wave-packets when phase shifters are set to 180 degrees.

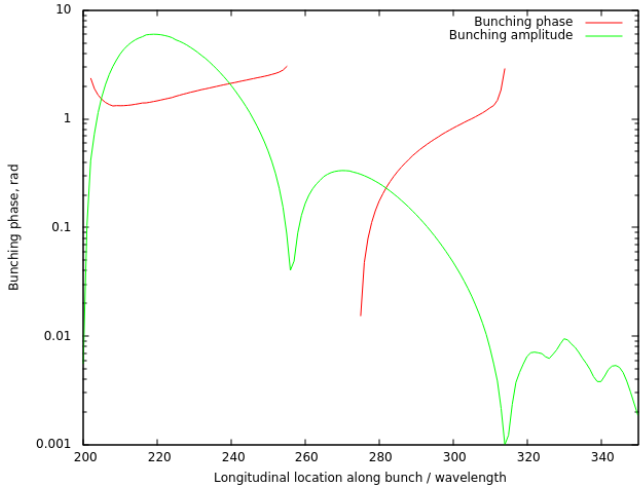
At the exit of second undulator, the small peak is already there.



Ignore the 2*pi phase jump and note that there is a pi phase jump on top of it.

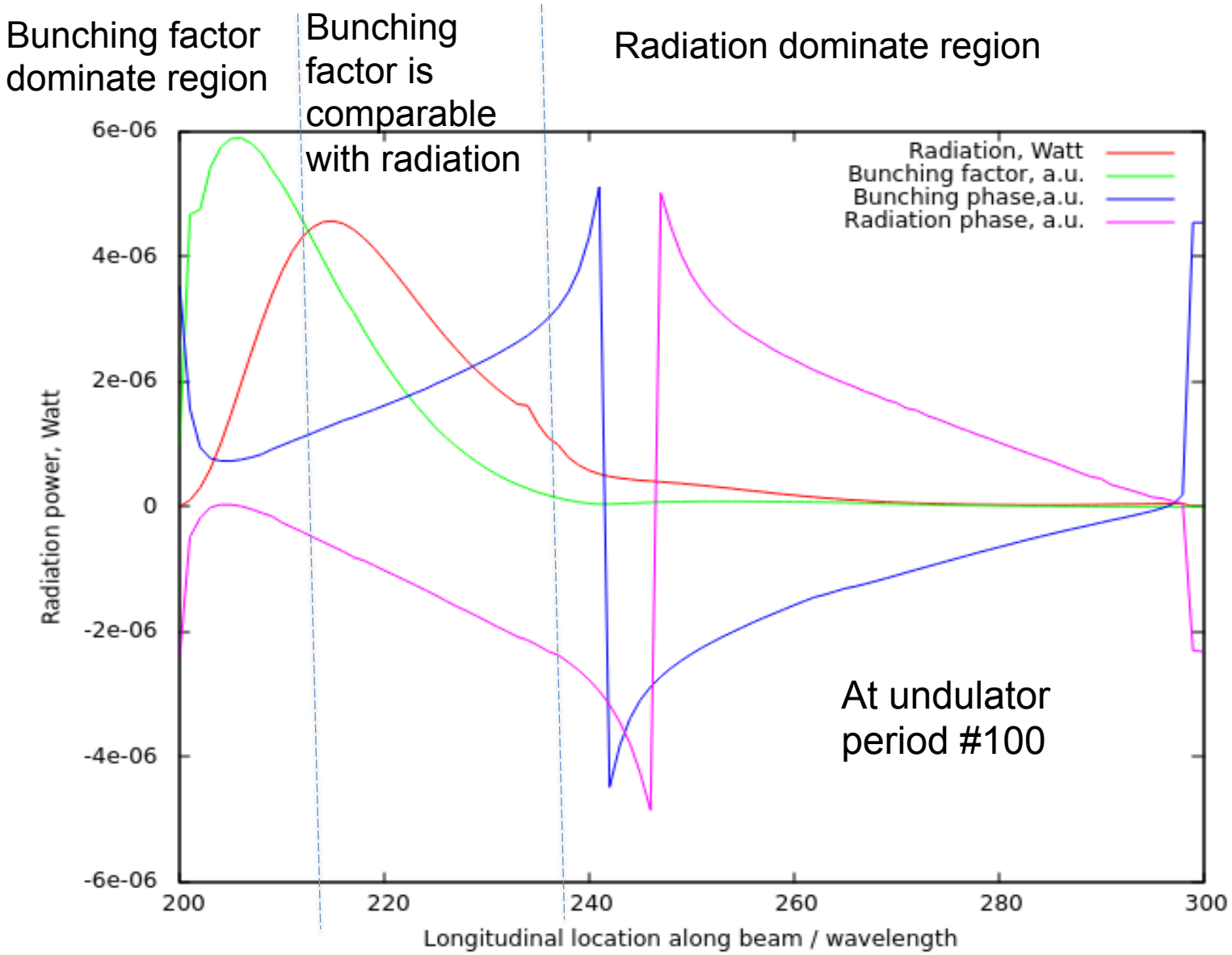
At exit of the third wiggler



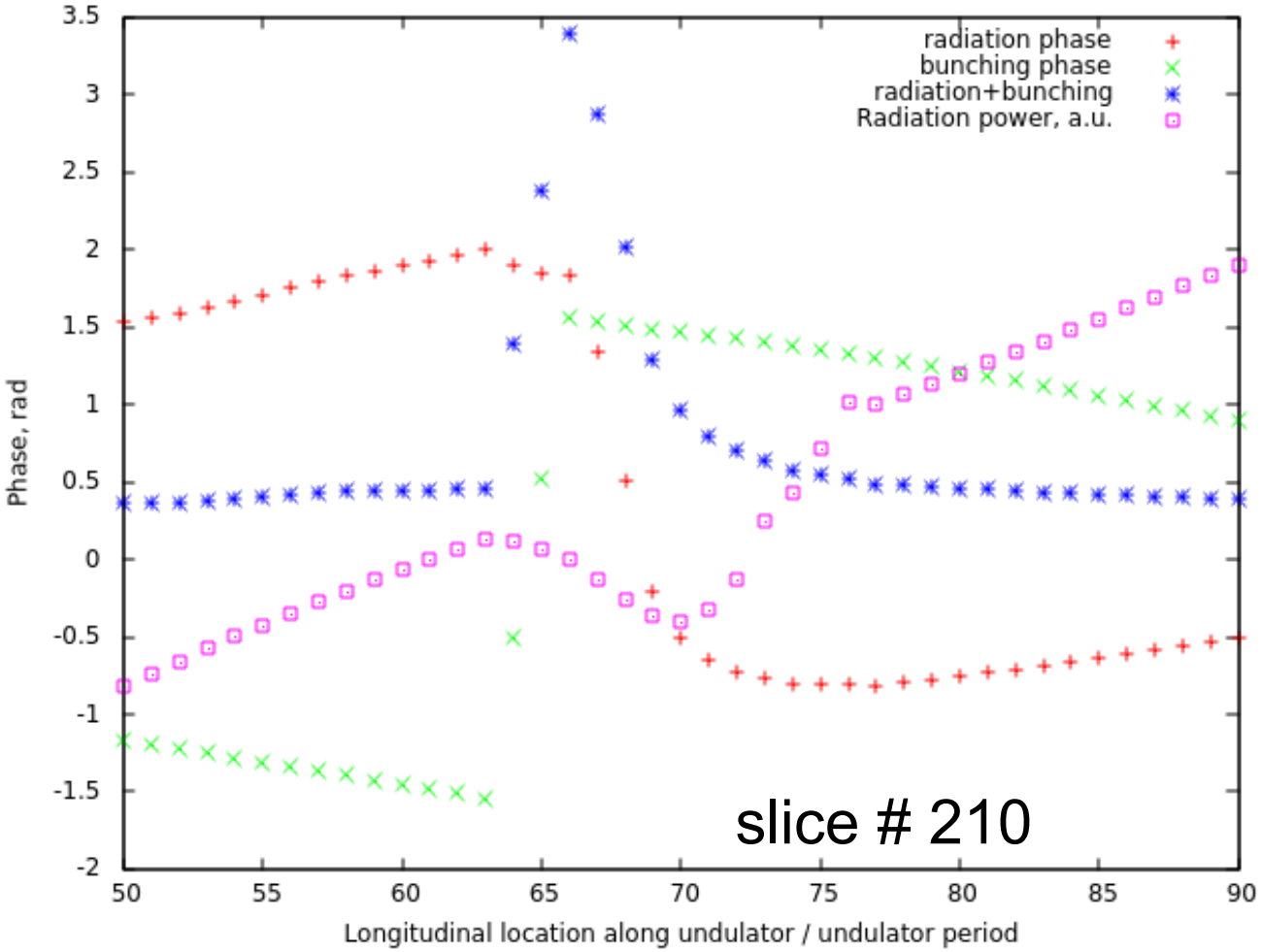


The phase jumps within the wave-packets (as well as the small bump at the tail) are due to the fact that different parts of the radiation wave-packet response to the abrupt bunching phase change differently.

Three regions of wave-packets



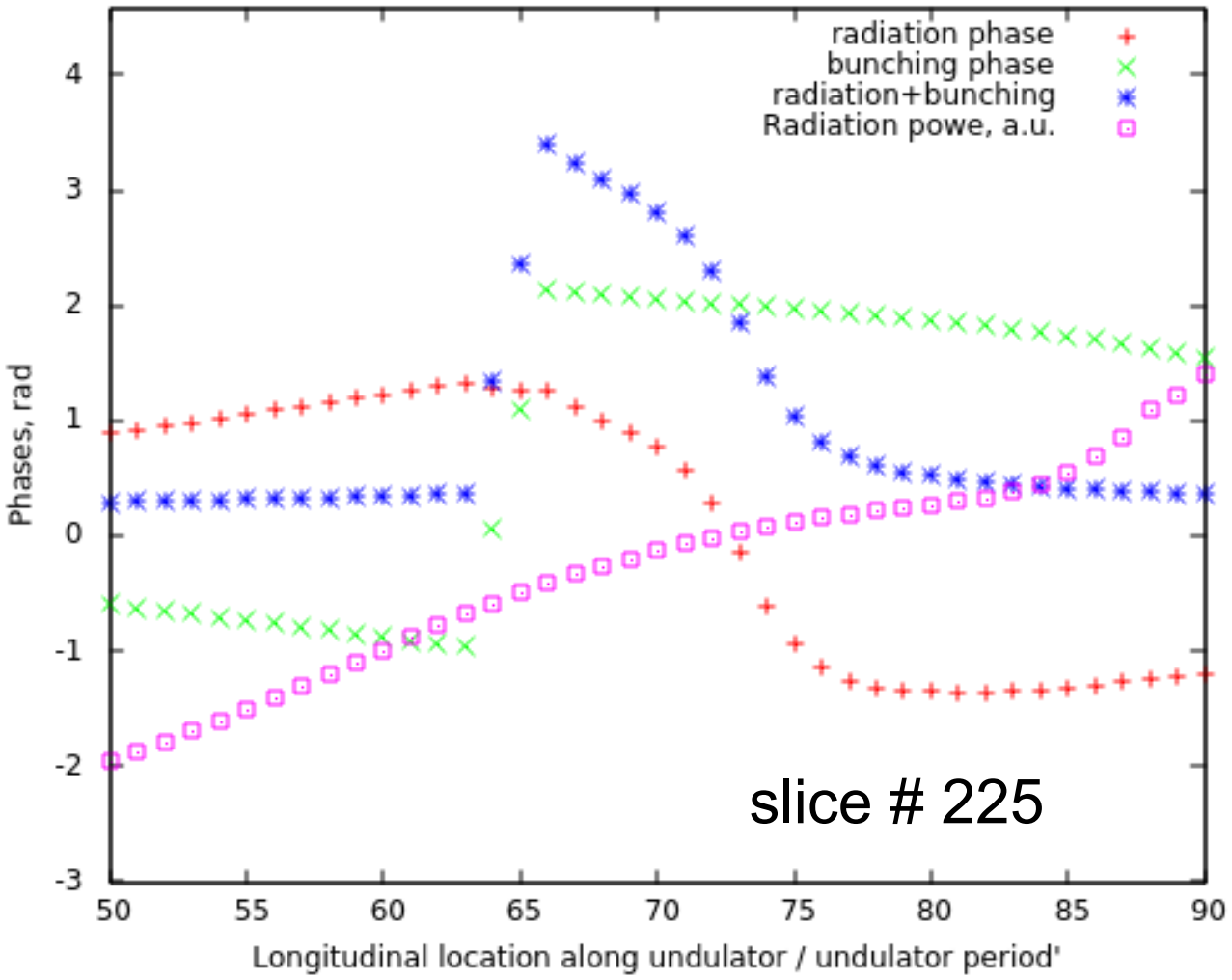
Response of radiation to bunching phase jump at bunching factor dominate region



Instant / Very fast
Radiation phase responses to bunching phase change;

Decreasing of radiation power

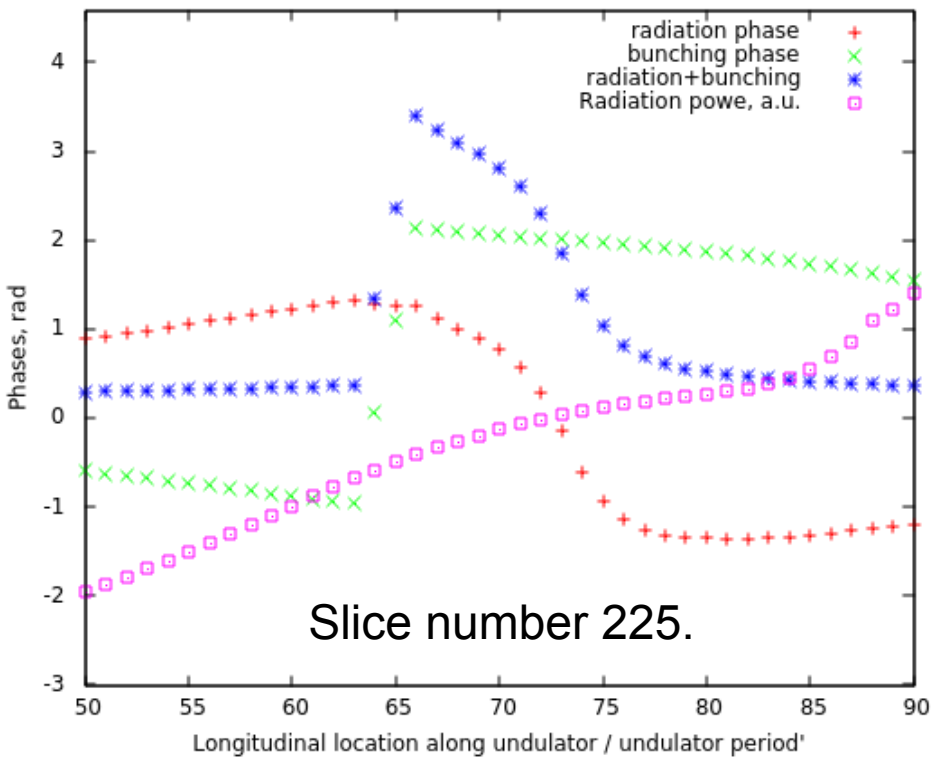
Response of radiation to bunching phase jump at the region where effects from radiation and bunching are comparable.

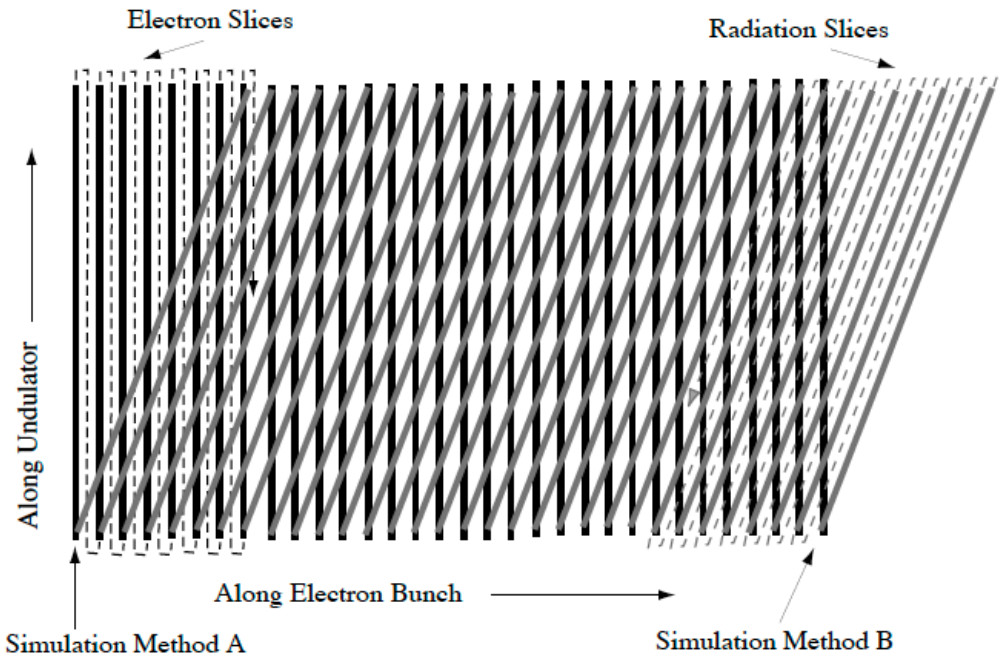


Graudual/smooth
Radiation phase responses to bunching phase change;

Radiation power stops growing, although not necessarily decreasing

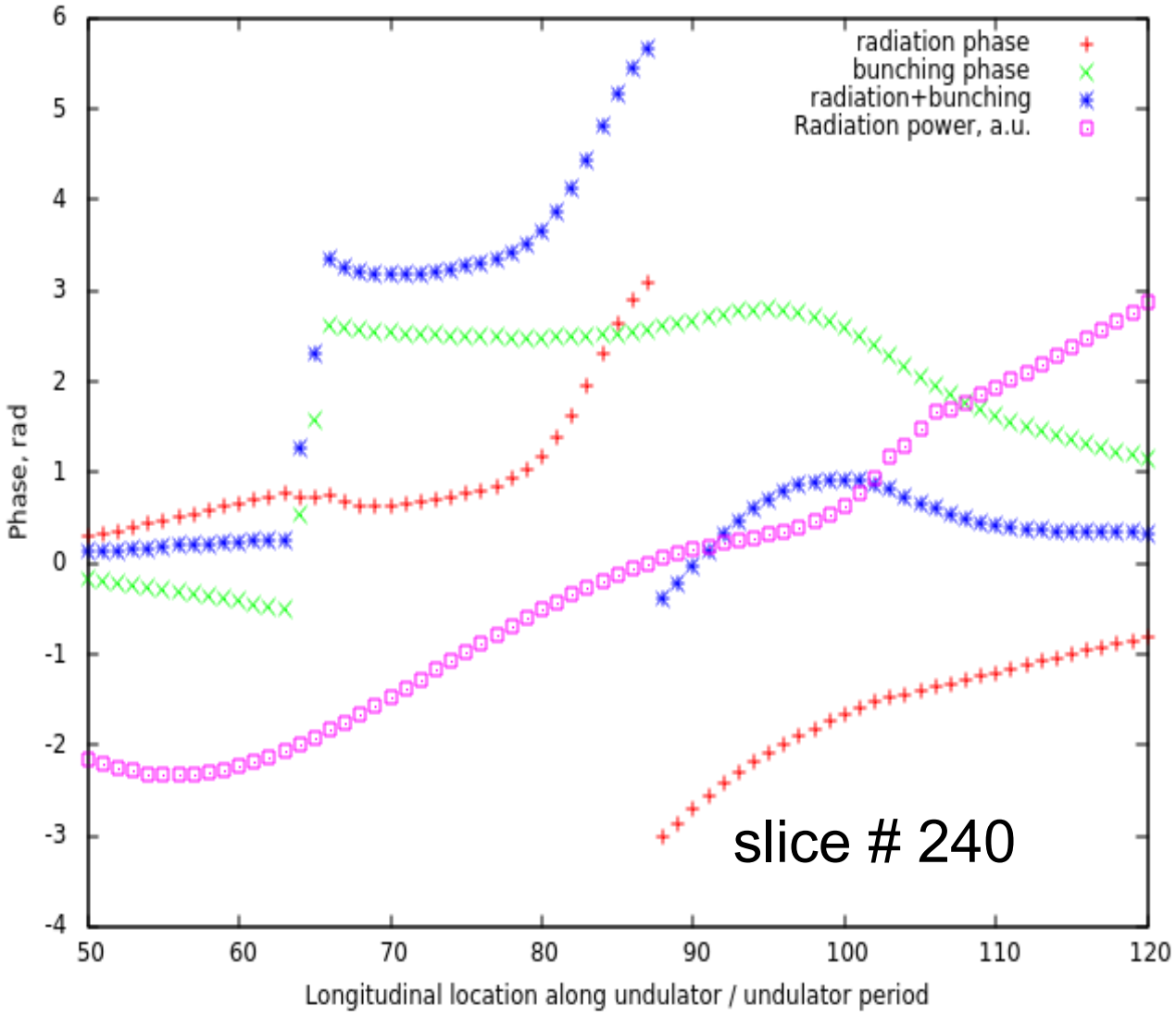
Why is there no significant reduction in radiation after phase shift?





- The radiation at every electron slice is the sum of all radiations emitted by all previous slices at earlier time.
- Contributions from different slices have slightly different phases (the slowly varying factor is coplex) but the system works in a way such that the FEL instability is supported by the net radiation at that slice (bunching phase + radiation phase does not vary).
- When the phase is flipped by pi, instead of continously reducing the amplitude of the radiation without changing phase (i.e. the case when all radiation have the same phase), the ‘new radiation’ from the given slice have an angle with respect to the radiation from all previous slices and hence we see phase rotation instead of amplitude reduction.

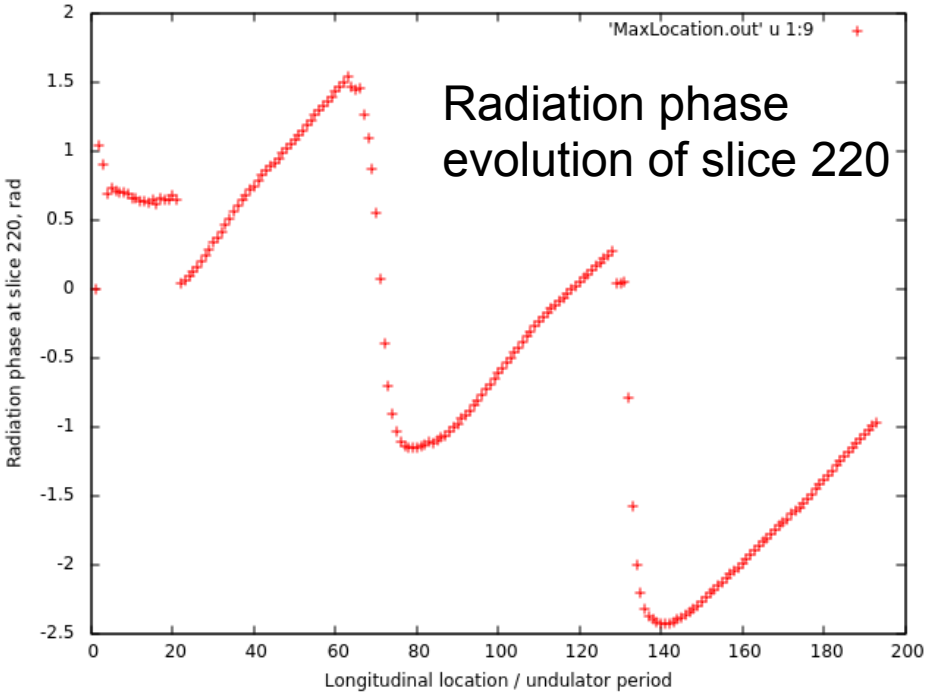
Response of radiation to bunching phase jump at radiation dominate region

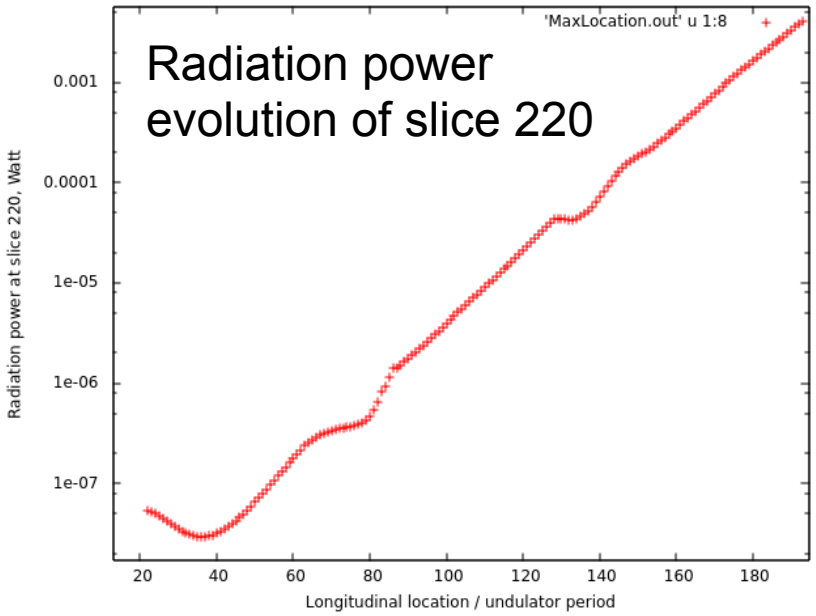


Slow / delayed
Radiation phase responses to bunching phase change;

Radiation power keeps growing after the instant bunching phase change until the radiation phase starts to jump, together with a second bunching phase jump. (The phase jump of radiation is actually carried over by radiation pulse from up-stream.).

Overall evolution of radiation at slice #220 along undulator

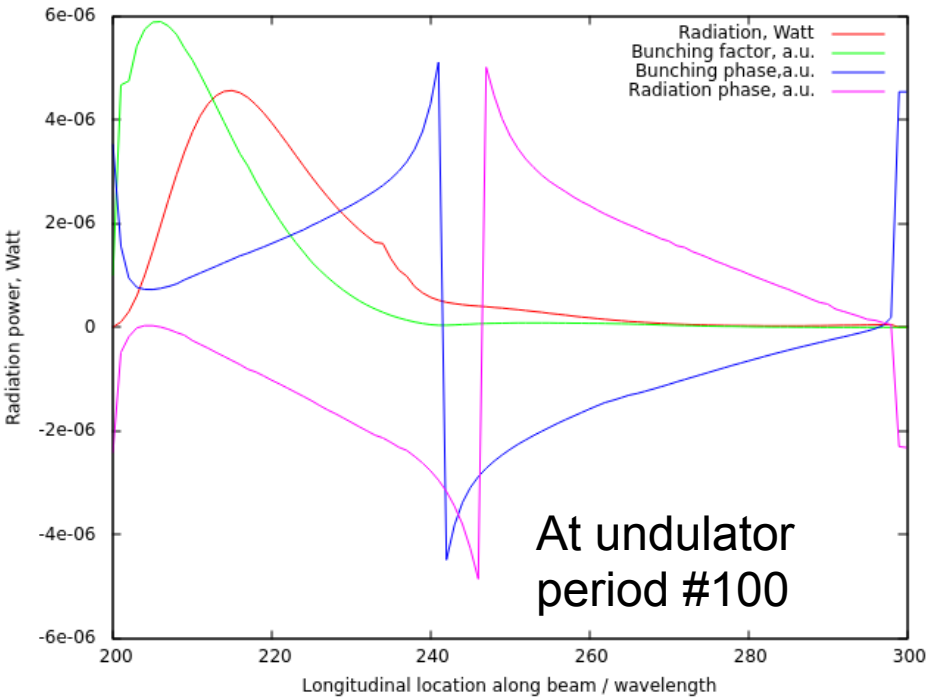


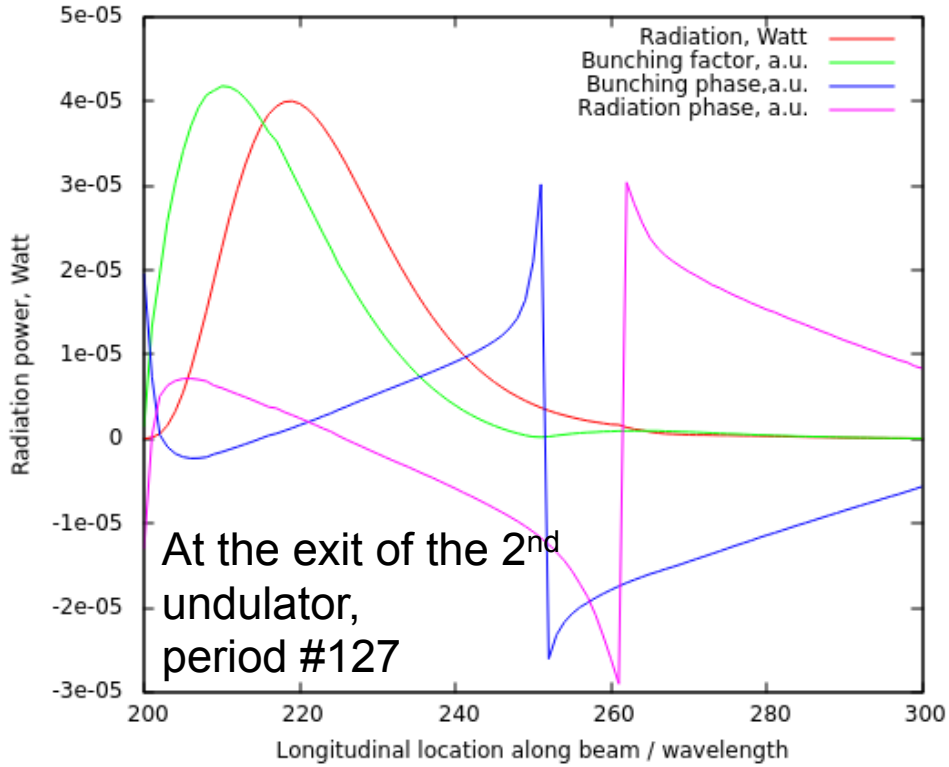


Note:

1. the radiation phase varies before the pi phase jump, possiblely due to imaginary part of eigenvalue;
2. the phase moves to the new location (variation of pi) is relatively smooth, i.e. not a one step jump.
3. no significant reduction in radiation power during the pi phase variation.

Possible explanation for the small bump





Since inside the radiation wave-packets, there is a sharp phase variation of pi, as it passing through the 'fresh electrons' which has negligibly small initial bunching, bunching induced by the two parts of the radiation (with pi phase shift) cancels out, leads to minimal net bunching at the specific slice.

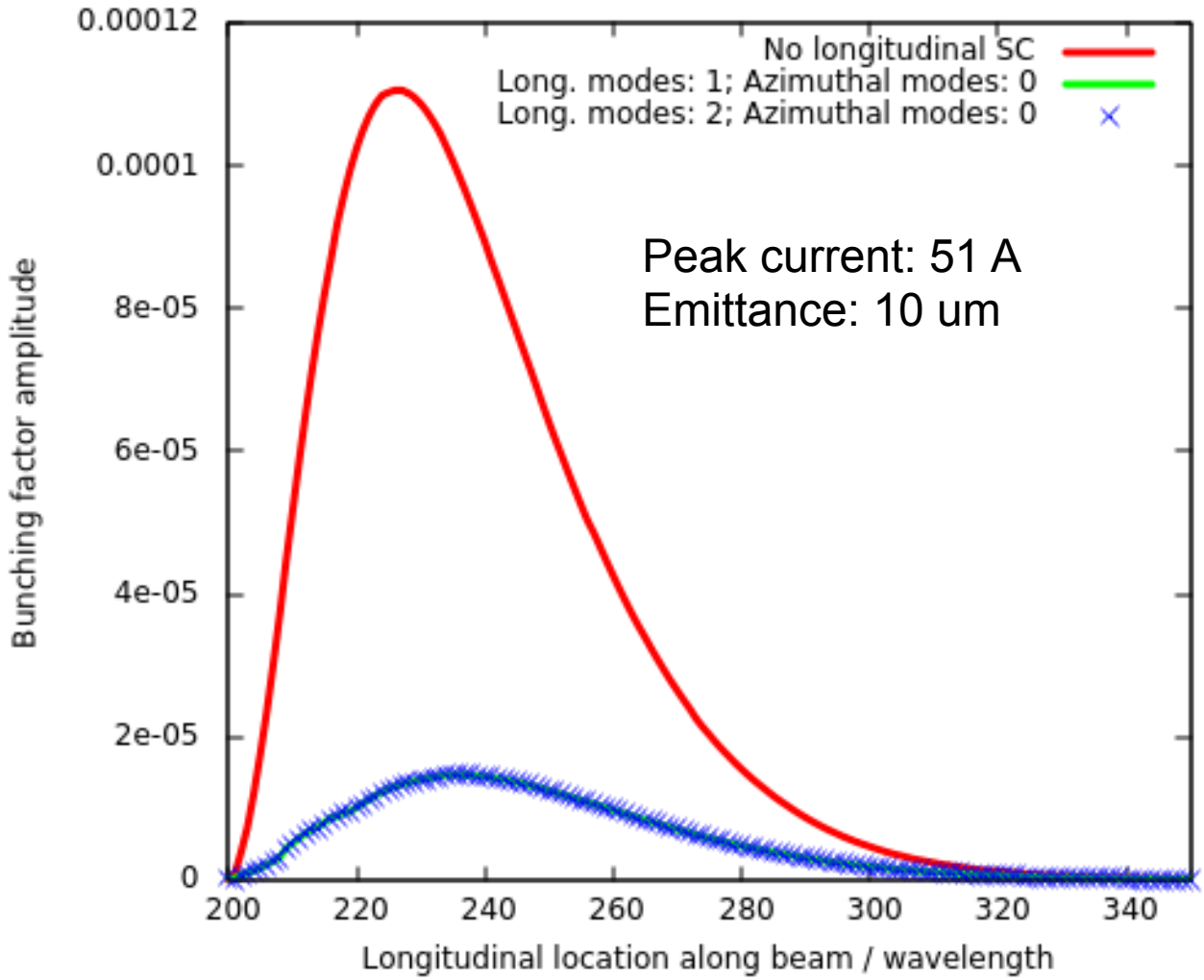
Summary

- Genesis seems having the feature of simulating FEL consisting of multiple subsections;
- We did simulations with various separations among undulator subsections (phase shifter set at zero) and observed that the FEL amplification decreases with increasing separation among sub-sections. As the separations increases from 3 undulator periods to 11 undulator periods, the peak bunching amplitude decreases by ~40%;
- We also did simulation with various phase shifter settings and observed gain reduction as the phase shift going from 0 to 180 degrees. The peak bunching amplitude varies 10% for separations among sections are 11 undulator periods. (For shorter separation, i.e. 3 undulator periods, the variation is 30%.).
- These studies did not include the longitudinal space charge effects in Genesis and we are working on repeating the simulations with LSC taken into account.

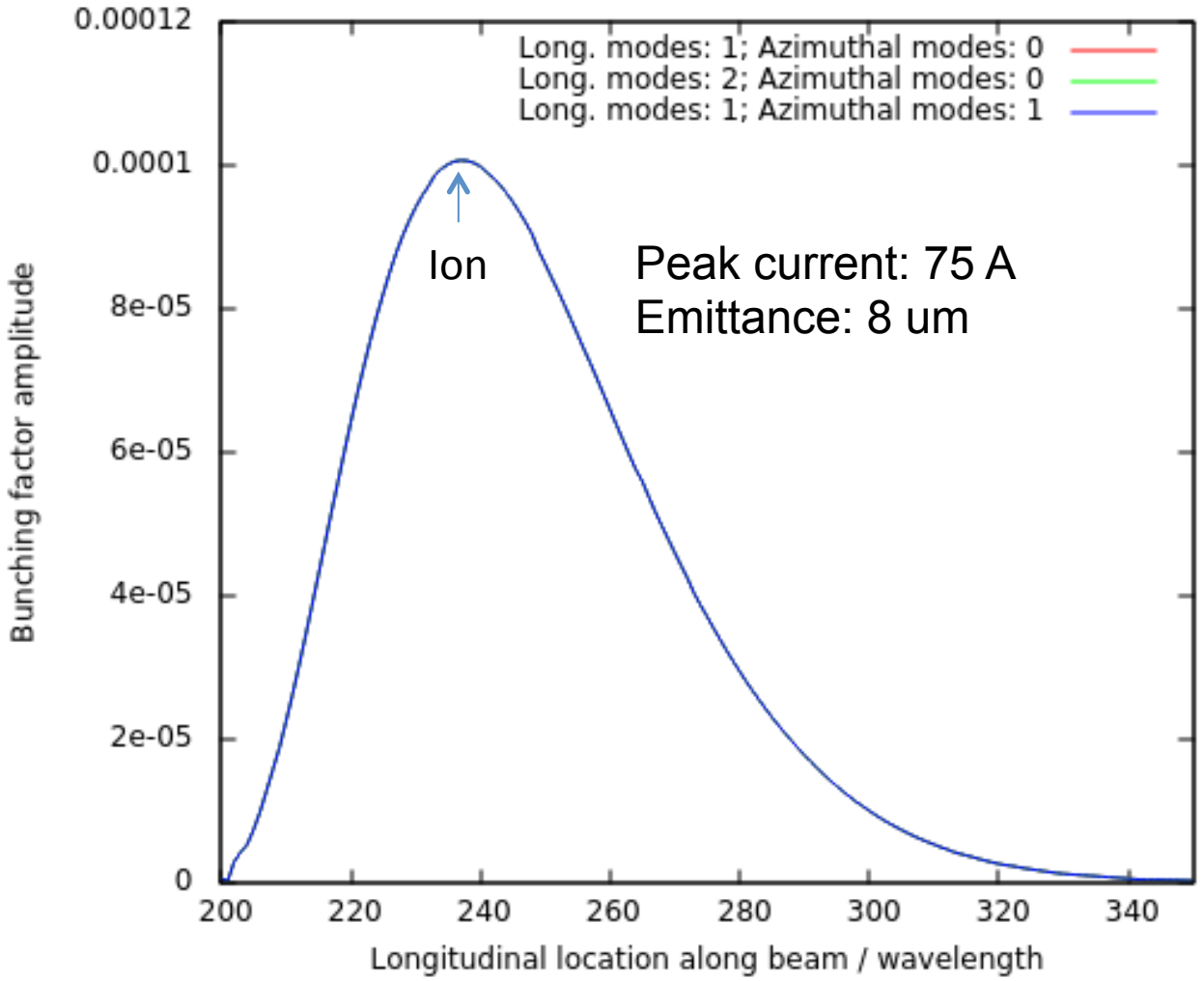
Genesis Simulation with 3-subsections and Longitudinal Space Charge

G. Wang and J. Ma

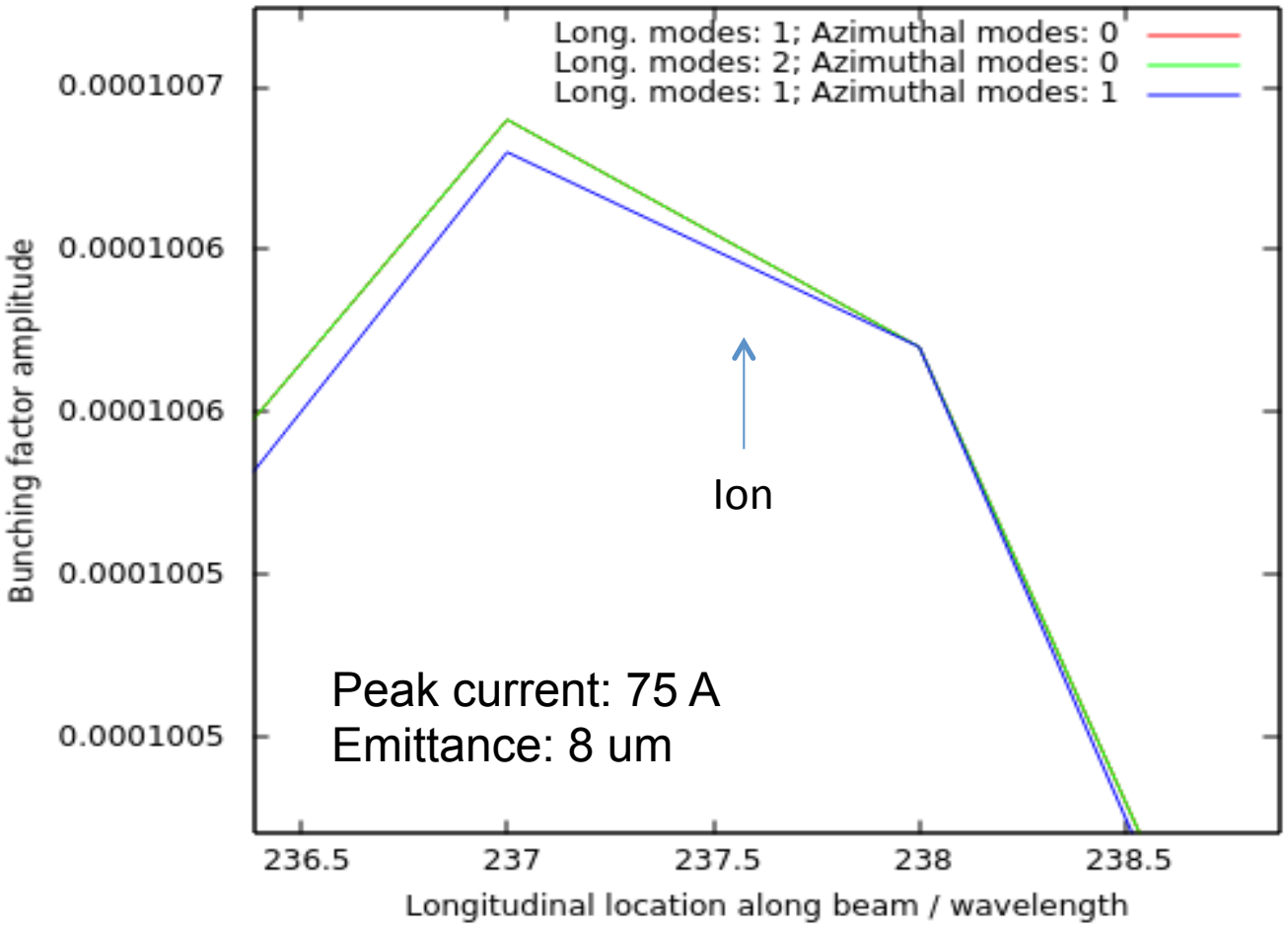
Gain Reduction After Turning on Longitudinal Space Charge in Genesis



Compensate the Gain by Increasing Peak Current to 75A



Ion Arrives on Top of the Wave-packets for the New Parameters



Summary

- With longitudinal space charge turned on in Genesis (non-zero NSCZ), FEL gain reduced by a factor of ~7.
- In order to compensate the loss of gain, I increased peak current to 75 A.
- With 75A of peak current and 8 um of normalized RMS emittance, the ion arrives right on top of the wave-packet with bunching gain of ~100.