# Cumulative Beam Breakup Study of SNS SC linac

Dong-o Jeon
SNS/ORNL

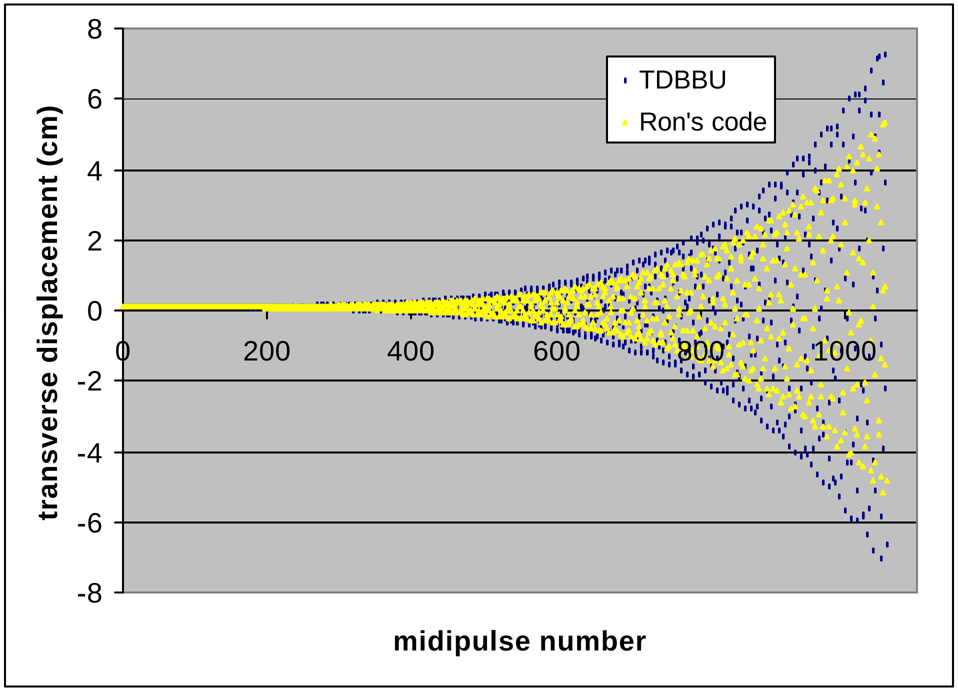
TDBBU code was modified to simulate gaps.
Simulation indicates that, transverse BBU is not a concern from the beam dynamics viewpoint with 1MHz half width half maximum Lorentzian HOM frequency spread.

Demerits of TDBBU code are:

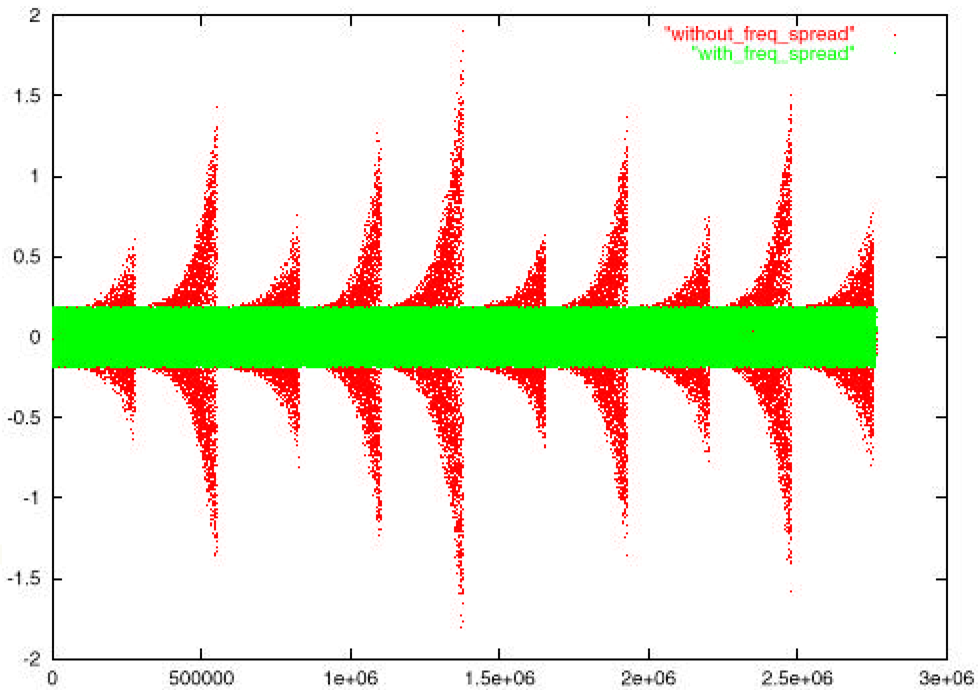
- it takes too long (2 days) to simulate even ten macropulses,
- not capable of simulating longitudinal effects.

Ron Sundelin developed two codes for transverse and longitudinal BBU study, which are very fast.

# Benchmarking




One macropulse is simulated. $f_{HOM}$=1152.14 MHz and R/Q=40Ω are assumed for all cavities. Initial transverse offset is 1mm.



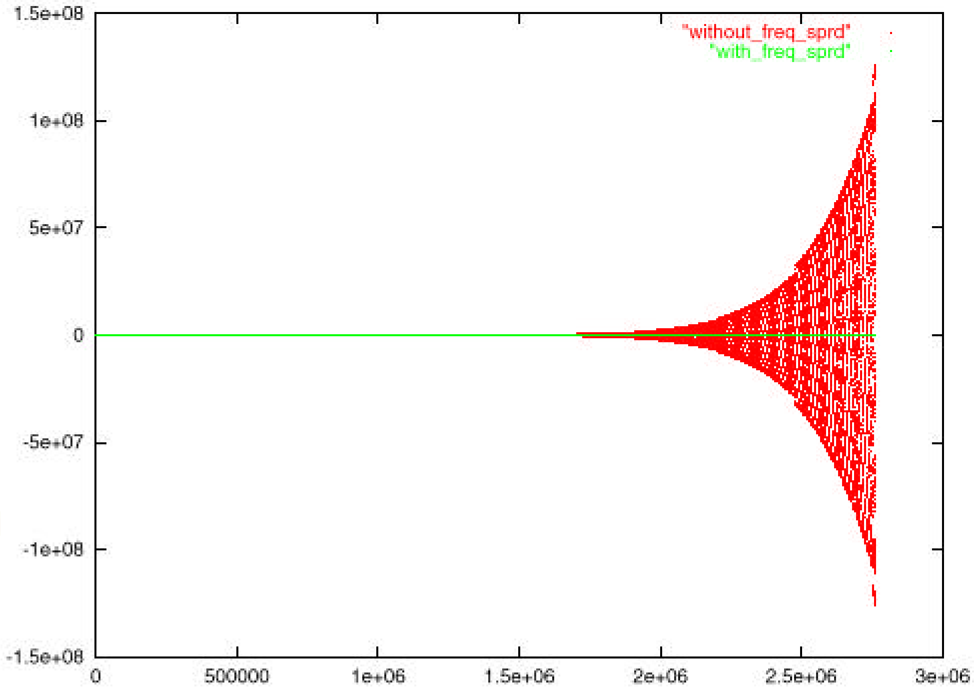

Red: without $f_{HOM}$ spread

Green: with $f_{HOM}$ spread

4 HOMs with largest R/Q are used

Simulation of 10 macropulses including relevant time structure with 4 HOMs with $Q_{HOM}=10^7$.

With 1 MHz half width half maximum Lorentzian HOM frequency spread, there is no sign of instability.

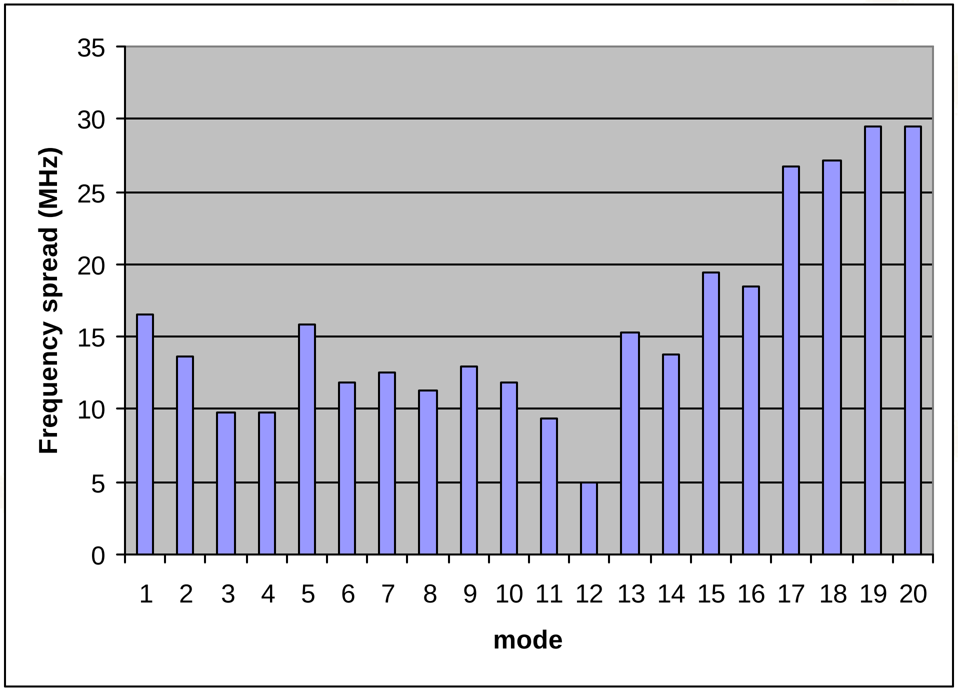



Simulation of 10 macropulses with 4 HOMs with $Q_{HOM}=10^9$.

Red: without $f_{HOM}$ spread
Green: with $f_{HOM}$ spread

With 1 MHz HWHM Lorentzian HOM frequency spread, there is no sign of instability for 10 macropulses (green line).

Even with 0.01 MHz Lorentzian HOM frequency spread, there is no sign of instability for 10 macropulses.




$f_{HOM}$ spread of JLab FEL SC cavities.
The median HOM frequency ranges from 1.7 GHz to 2.1 GHz.

In case of TTF, $f_{HOM}$ spread of 0.1% with highest measured $Q_{HOM}$=1.e6 with HOM coupler (N. Baboi).

$Q_{HOM\,eff}=f_{HOM}/2\Delta f_{HOM}=600$ when $f_{HOM}=1.2GHz$ and $\Delta f_{HOM}=1MHz$

Deflection factor D can be expressed as
$D=\exp(\mathrm{sqrt}(C\ I\ R/Q\ Q_{HOM}))$ with $C=2.48e-4$ for SNS

$D_{eff}/D=\exp[\mathrm{sqrt}(C\ I\ R/Q\ Q_{HOM\,eff}) - \mathrm{sqrt}(C\ I\ R/Q\ Q_{HOM})]$
When $Q_{HOM}=1.e6$, $Q_{HOM\,eff}=600$, $I=52mA$, $R/Q=40\Omega$,
$D_{eff}/D=\exp(-22.16)=2.38e-10$!!

$f_{HOM}$ is more effective for higher $Q_{HOM}$.

Consistent with simulation showing no sign of instability even with $f_{HOM}=0.01MHz$.

Small frequency spread is sufficient for damping.

# Conclusion and Future Plan

With $f_{HOM}$ spread, transverse BBU does not seem to be a concern from the beam dynamics viewpoint.

Benchmarking of Ron Sundelin's longitudinal BBU code is in progress (developing a code that can simulate both transverse and longitudinal BBU).

Providing relevant BBU information for Los Alamos so that multiparticle beam dynamics aspects of BBU can be studied (emittance growth, foil miss etc), if needed.