Validation of the HOM Loading Calculation in Bmad and Calculations of Orbit Distortions Induced by Cavity Offsets in the CERL 8.1 Lattice

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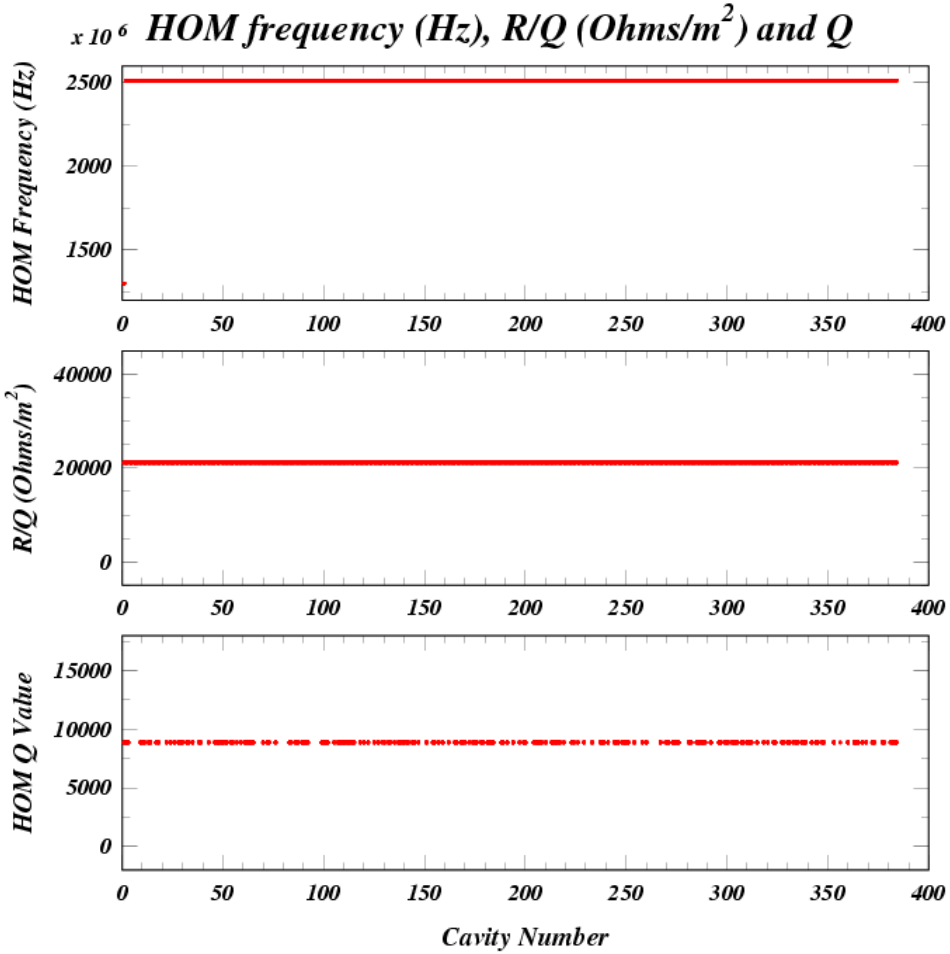
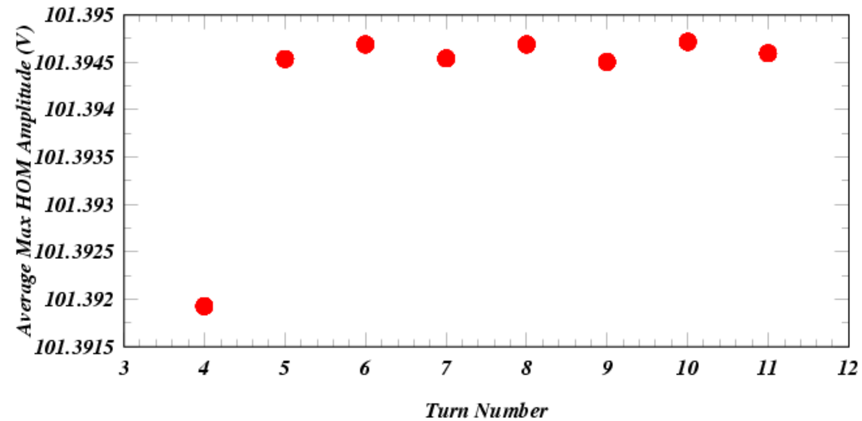
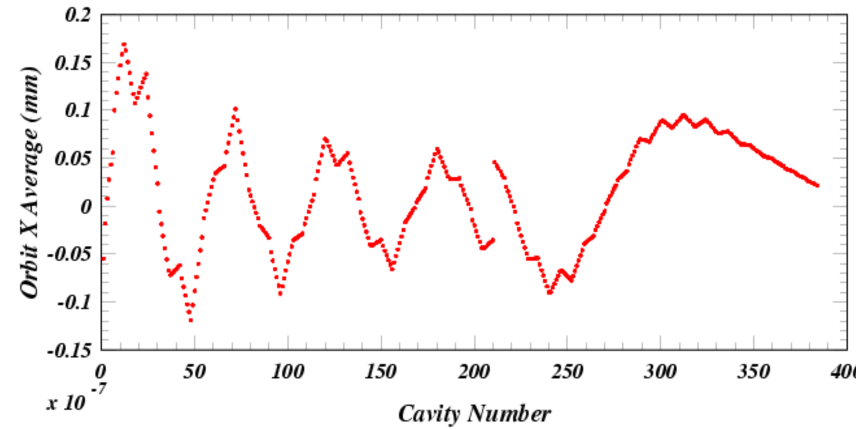
Validation Calculation
Single HOM on resonance in one cavity with fixed offset

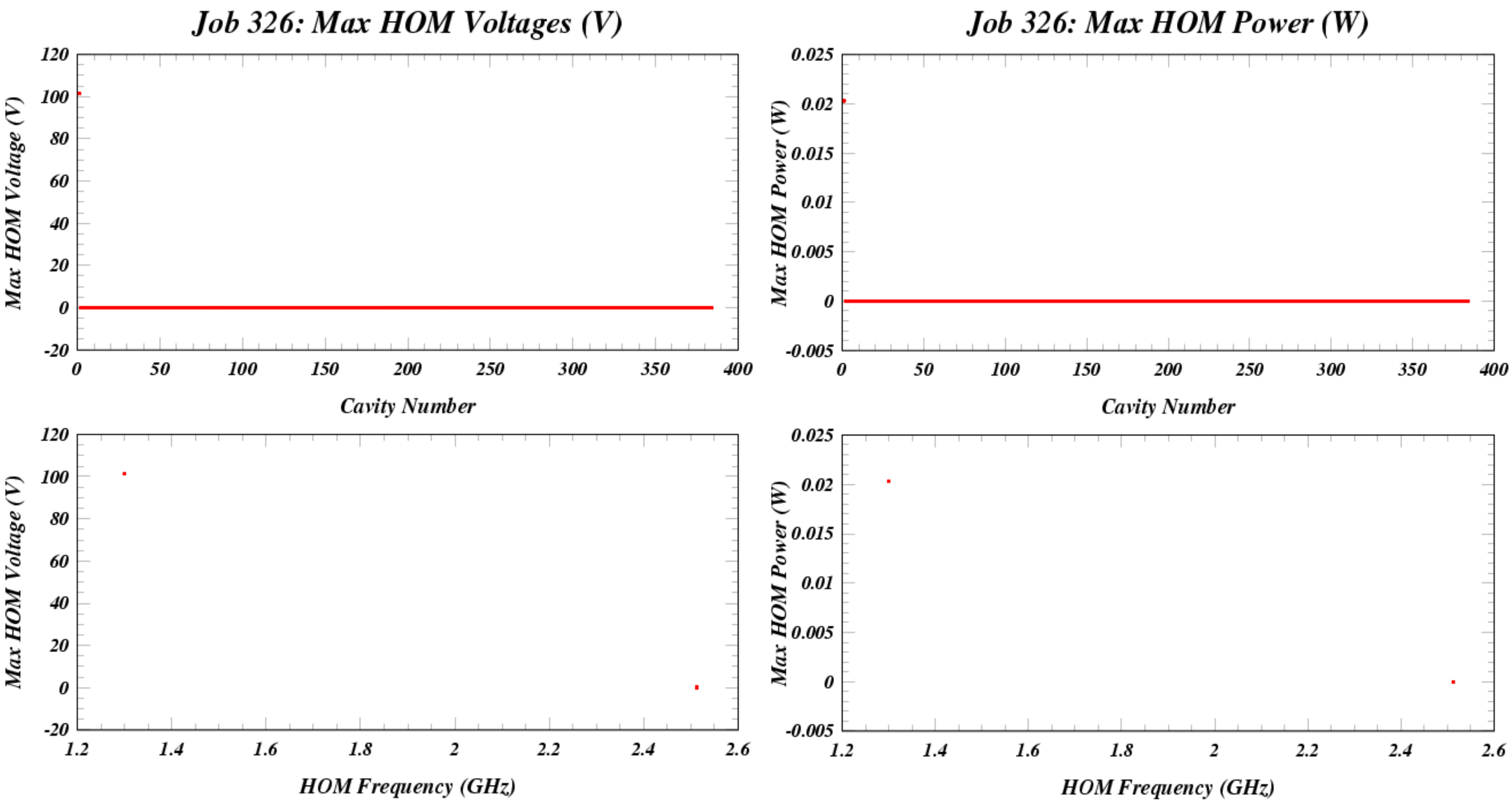






Resonant HOM in the first cavity. Equilibrium orbit reached after five turns.
Orbit offset in first cavity 55 microns, primarily due to the cavity focusing effect, not the HOM kick.
Analytic calculation of the excited HOM voltage kick: 100 V.

Validation Calculation
Single HOM on resonance in one cavity with fixed offset



Bmad calculation of HOM voltage as expected. HOM power directly related.

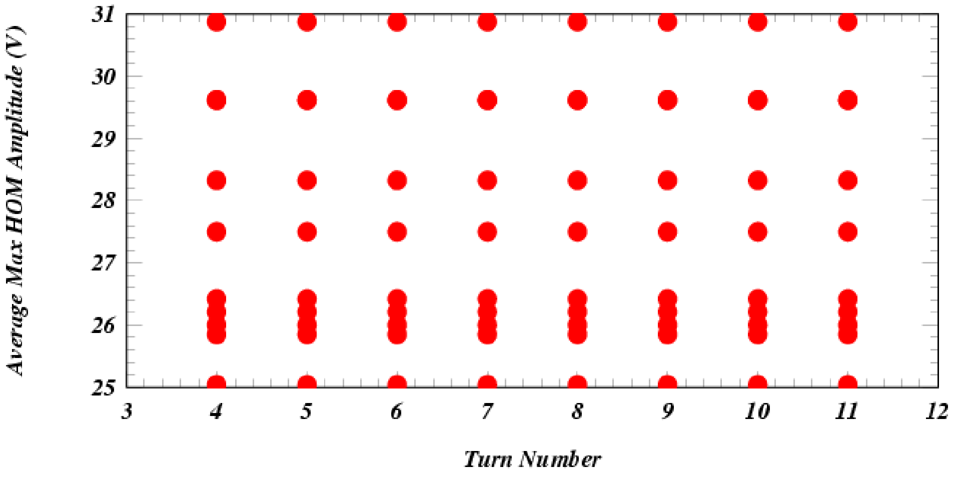
CERL 8.1 calculation with 0.1 mm randomized cavity offsets
5 HOMs (MUL 2009) in each of 384 cavities
(768 tracking elements)

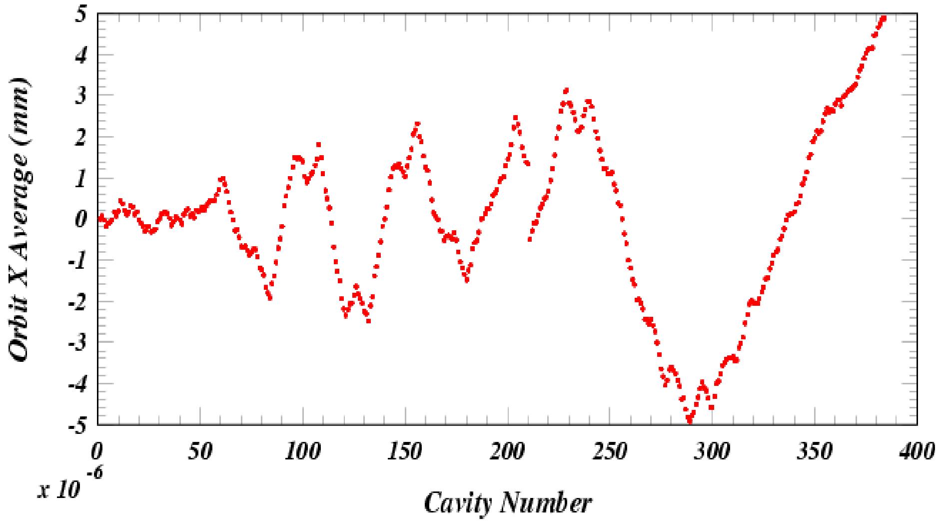
```
           Frequency          R/Q              Q           n        Polarization_Angle
            [Hz]         [Ohm/m^(2n)]                               [Radians/2pi]

&long_range_modes
lr(1) =    2.512896E+009       21180           8867         1          0.00
lr(2) =    2.513556E+009       76777           1472         1          0.00
lr(3) =    2.514671E+009       81083           8557         1          0.00
lr(4) =    3.068192E+009         632         186198         1          0.00
lr(5) =    3.073245E+009        3971          64567         1          0.00
```

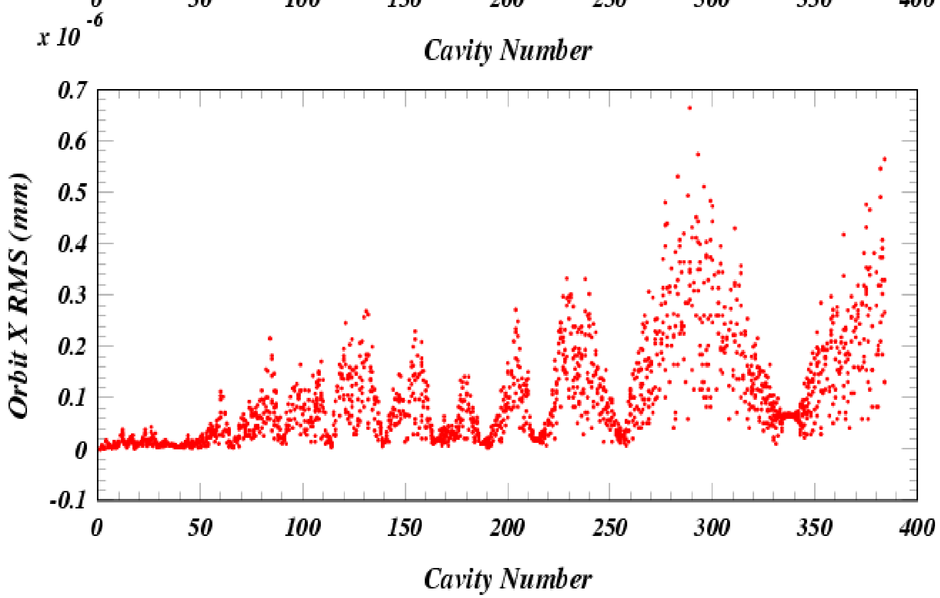
The frequency spread is 0.4%, i.e. 10-12 Mhz.

The randomization of the HOM frequencies is limited to +- 3σ_f.

CERL 8.1 calculation with 0.1 mm randomized cavity offsets
5 HOMs (MUL 2009) in each of 384 cavities
(768 tracking elements)





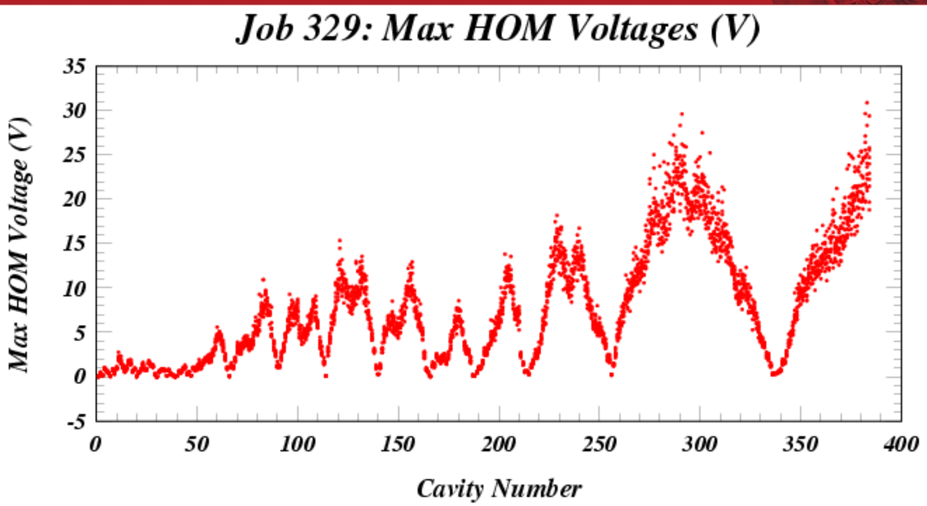


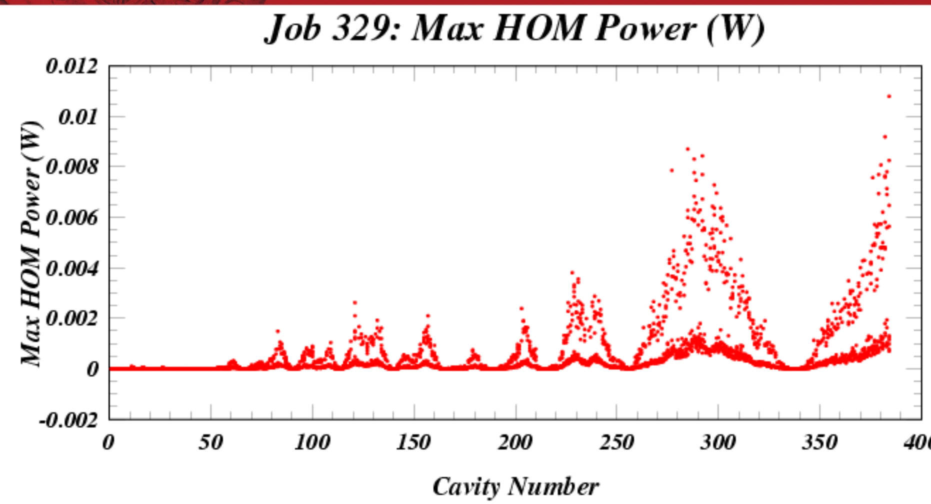
Ten re-randomizations of HOM frequency.
Equilibrium reached by 4th turn.

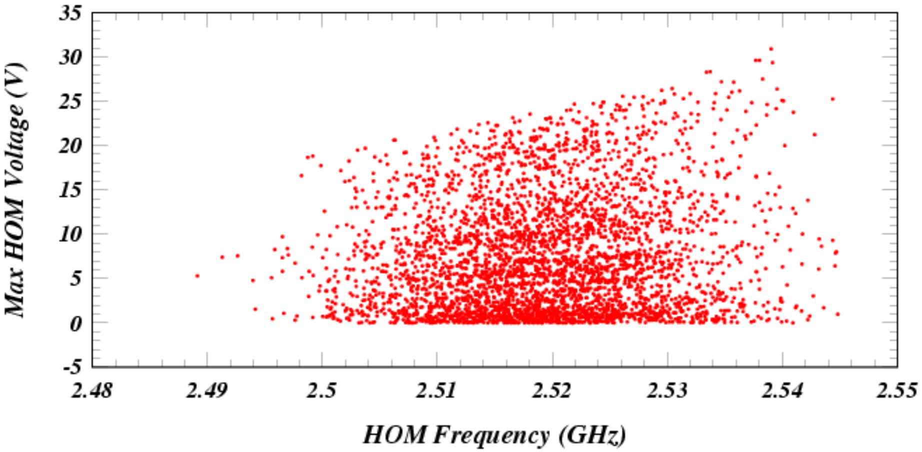
Orbit distortions up to 5mm.

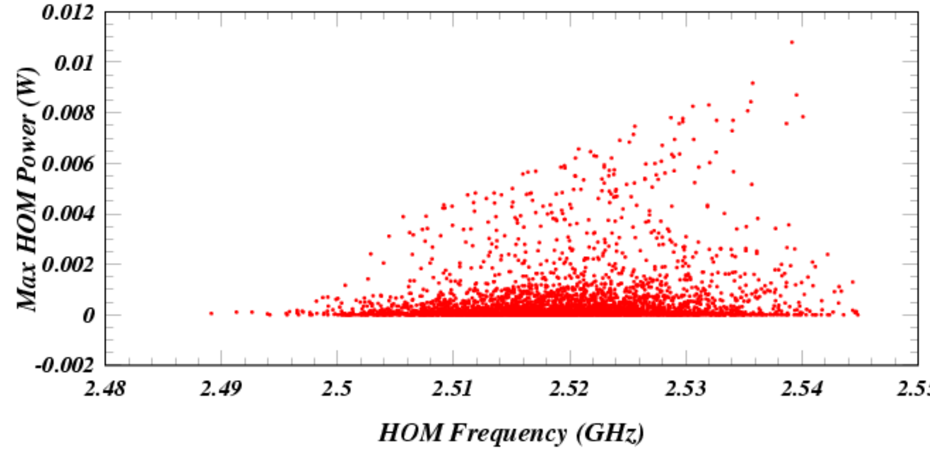
The RMS values of the orbit distortions are small. This shows that the orbit distortions due to the cavity focusing effects are much larger than those from the HOM kicks.

CERL 8.1 calculation with 0.1 mm randomized cavity offsets
5 HOMs (MUL 2009) in each of 384 cavities
(768 tracking elements)









For each cavity the HOM voltage and power are plotted for the mode with the highest excitation. Induced HOM voltages increase along linacs, reaching 30 V. HOM power less than 12 mW. The higher HOM power values correspond to the HOM with (Q,R/Q) = (1472, 76777 Ohms/m^2) HOM excitation higher for frequencies closer to twice the fundamental.

BBU_PROGRAM: Simulation of the Beam Breakup Instability

J.A. Crittenden, D. Sagan

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1 Introduction

BBU_PROGRAM is a program which simulates the beam breakup instability [1]. The beam breakup instability occurs when a particle beam is recirculated through a cavity as in an Energy Recovery Linac. The bunches of the beam are kicked by the wakefields in a cavity and this kick generates an orbit distortion so that when the bunches return to the cavity, their off-axis orbit through the cavity will create additional wake fields. Given the right conditions, this regenerative feedback can lead to instabilities. BBU_PROGRAM works by direct simulation. A train of bunches is tracked though a lattice and the wakefields and orbit can be monitored.

2 Simulation technique

In order to correctly calculate the HOM fields, bunches are tracked through a given cavity in the correct time order. That is, BBU_PROGRAM "simultaneously" tracks a sequence of bunches that fill the lattice, starting and stopping bunches as appropriate to make sure that the bunches going through a cavity are tracked in the correct order.

In BBU_PROGRAM, time (t) is measured in "turns" (Abbreviated "T"). One turn is the time it takes a bunch to travel from the start of the lattice to the end. At the start of a simulation, at time equal zero, the HOM power in the cavities is set to zero. Bunches are then started at the beginning of the lattice and tracked through to the end. To minimize computation time, a single particle is used to represent each bunch.

Bunches that are initialized at a time between 0 and 1T are given a random transverse offset. The offset distribution is Gaussian in shape and the sigma is determined by the parameter bbu_param%init_particle_offset (see below). After the zeroth turn period (which is the period ($0 \leq t \leq 1T$) , bunches will be initialized with zero transverse offset. In the second turn period ($2T \leq t \leq 3T$), the averaged "maximum field strength", $V_{max}(2)$ which is the field strength of the strongest HOM mode in all the cavities, is taken as a baseline to determine whether the fields are growing or decaying. At the end of the simulation, after a set number of turn periods n, the beam is declared stable or unstable depending upon whether the ratio $V_{max}(n-1)/V_{max}(2)$ is less than or greater than 1. Additionally, in order to shorten the

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