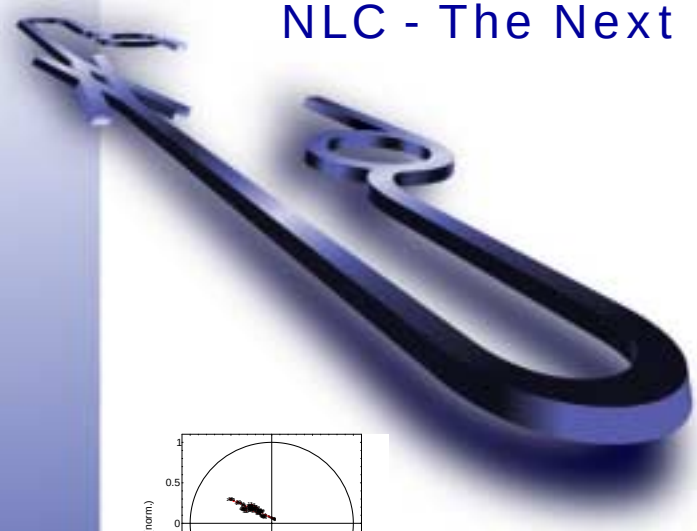
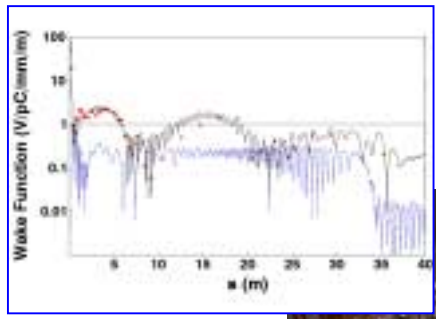
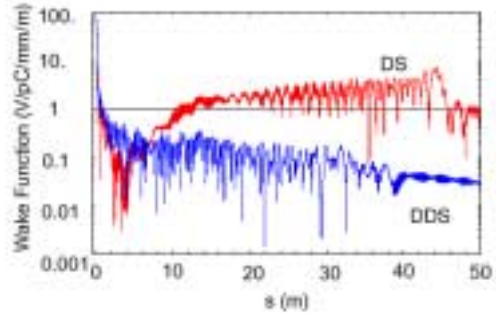
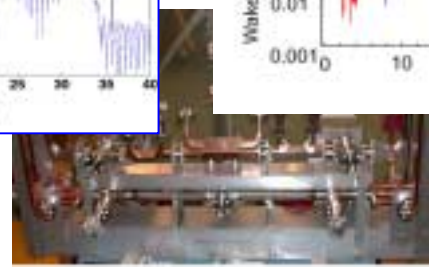
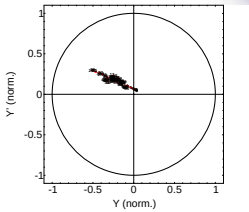
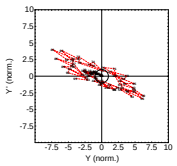




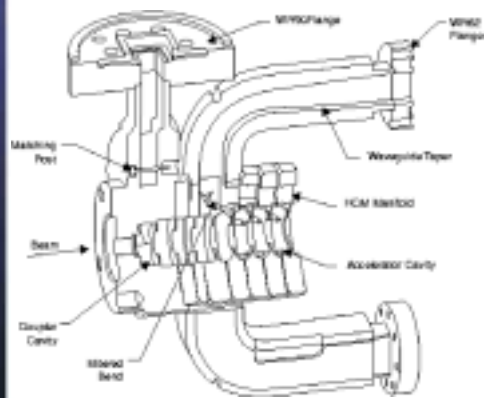


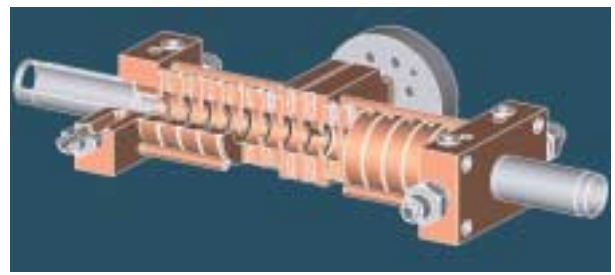






Wakefield Suppression in High Phase Advance Structures and Alignments Imposed





Overview

1. Wakefield optimization: varying the bandwidth and sigma of the Gaussian distribution.

A manifold Damped H60VG3 is illustrated. Interleaving of the frequencies of adjacent structures is necessary in order to damp the wake effectively.

This is because the shorter structures have been designed to have a similar bandwidth to the 1.8m structures and consequently the overlapping of modes within the band is not adequate to damp the wake. Increased coupling is not an option in DDS structures as pulse heating limits the coupling that can be achieved.

Cell-to-cell and structure-to-structure alignment tolerances are discussed

2. Limited local damping is applied to high phase advance traveling wave structures

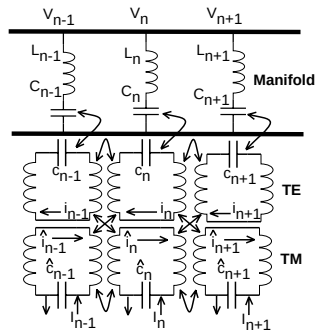
3. Damping standing structures by forming a “super-structure” and using limited heavy local damping of cells.

4. General properties concerning the band partitioning of the dipole kick factors as a function of the pha

so advance of the fundamental mode

Wakefield Optimization

- **The Spectral function calculation has been considerably optimized. *Sparse matrix techniques in a Fortran code* allows the wake to be computed in seconds rather than hours.**
- **Previously the bandwidth and σ were varied by hand in order to minimize the wake envelope function.**
- **As the *computation of the wake is now fast and efficient* we automatically optimize the wake.**
- **We chose to *optimize the sum of the squares of the RMS of the sum wake field and the standard deviation of the sum wakefield*. The method we use searches for a local minimum and so**
- **Caution needs to be observed in applying the results until a wide span in bandwidth and sigma space has been explored. We achieve this by making several runs over different parameter spaces**



Interleaved Structure Wakefield Calc.

The matrix describing two-fold interleaving of structures is obtained from the non-interleaved single structure circuit model which is reformulated in the form:

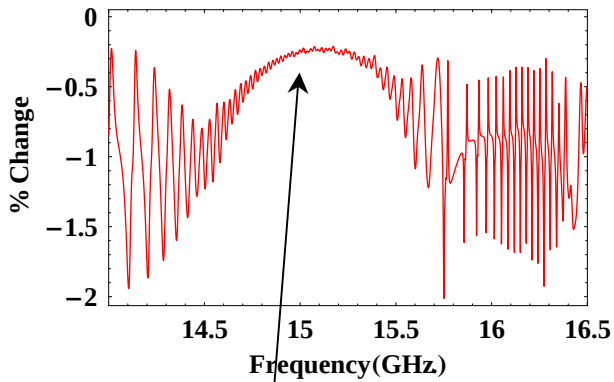
$$M\begin{pmatrix} a \\ \hat{a} \\ A \end{pmatrix} = \begin{pmatrix} 0 \\ B \\ 0 \end{pmatrix}$$

where the elements a, and A are themselves column vectors of dimension 2xN (= number of cell in a given structure) and M, is the matrix which describes the coupling of modes within the interleaved structures:

$$\begin{pmatrix} f^2H_1 - 1 & 0 & f^2H_{1x} & 0 & -f^2G_1 & 0 \\ 0 & f^2H_2 - 1 & 0 & f^2H_{2x} & 0 & -f^2G_2 \\ f^2H_{1x}^t & 0 & f^2\hat{H}_1 - 1 & 0 & 0 & 0 \\ 0 & f^2H_{2x}^t & 0 & f^2\hat{H}_2 - 1 & 0 & 0 \\ -f^2G_1 & 0 & 0 & 0 & f^2R_1 & 0 \\ 0 & -f^2G_2 & 0 & 0 & 0 & f^2R_2 \end{pmatrix}$$

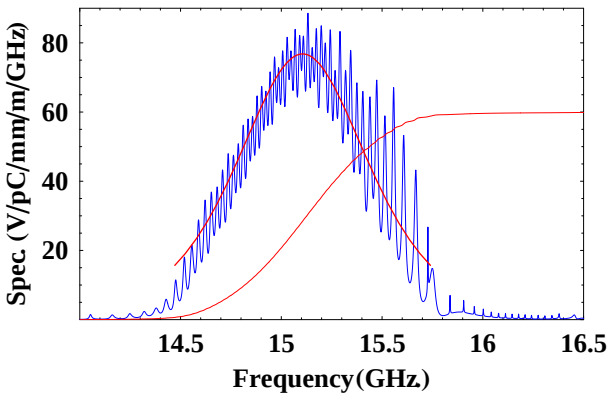
and B describes coupling to the particle beam. Here, the additional subscript refers to the particular structure, interleaved with its neighbour.

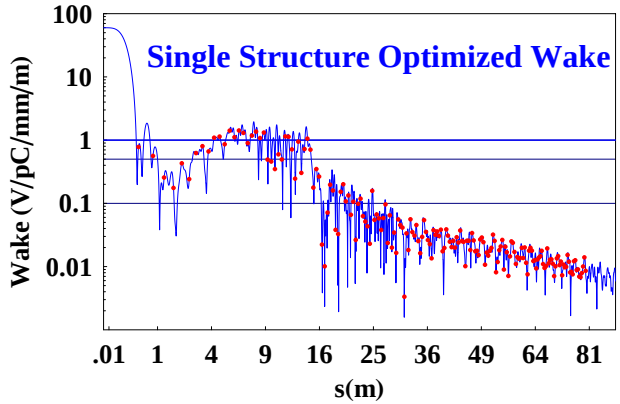
In all of our previous calculations of interleaving of the cells of the frequencies of adjacent accelerating structures we have taken the average of each spectral function and from this obtained the overall wakefield. Here, we make a calculation on the global matrix, which for 3-fold interleaving of structures is of a similar form as the above eq. (but of overall dimensions 9xN).

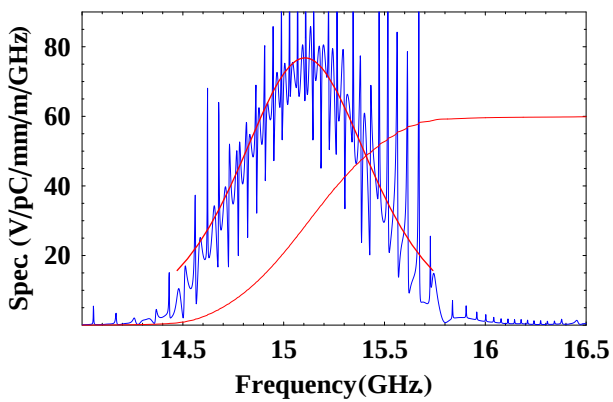


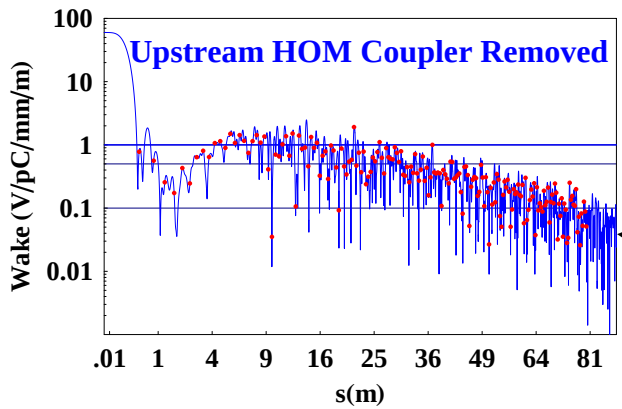
Difference in averaging method and full matrix method. In the tolerance calculation the full matrix method is used and compared with LIAR tracking simulations

1. Wake Envelope for H60VG3





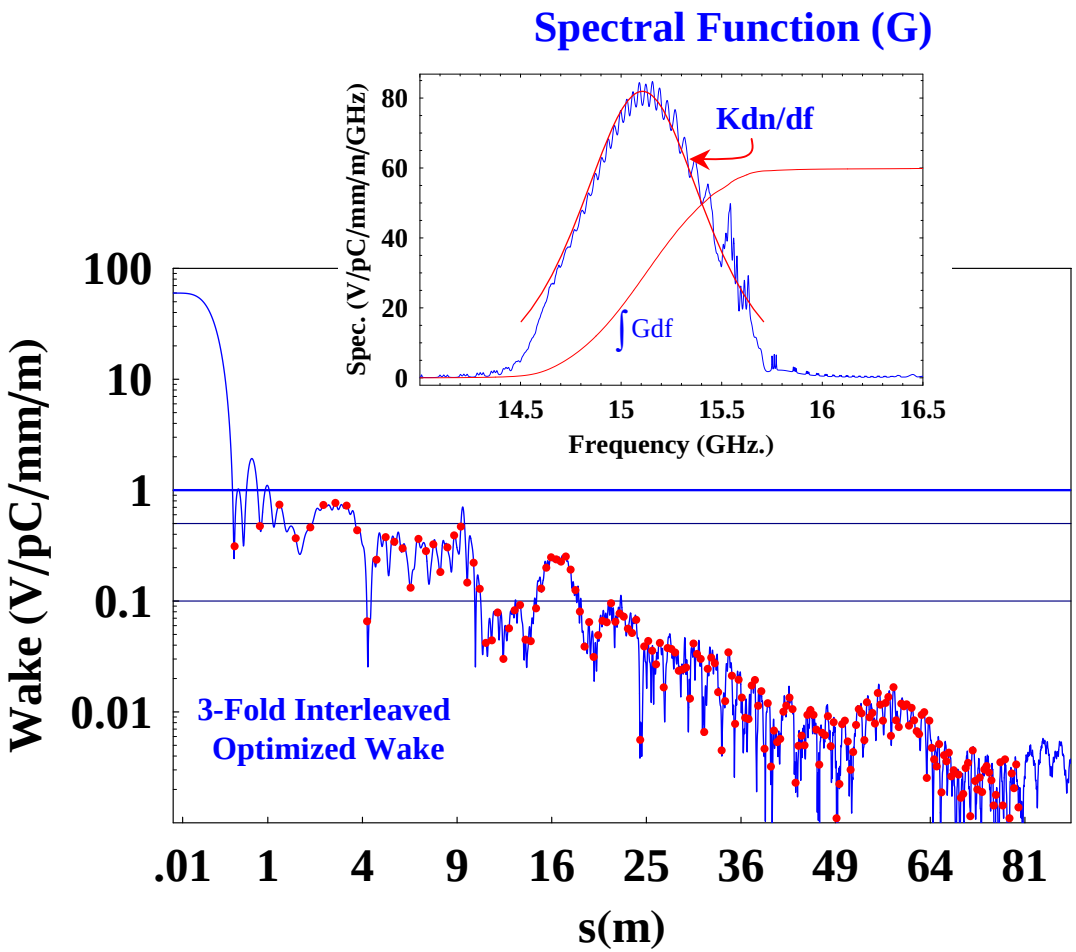




Spectral Function and Envelope of wake function for a single optimised BW=8.4% and 3.44 σ for a MANIFOLD DAMPED structure of 55 cells. The dots indicate the wake at the bunch spacing of 42 cm.

Can the I/P HOM coupler be dispensed with (as it could have in RDDS1)? No! The Wakefield is unacceptable for this situation

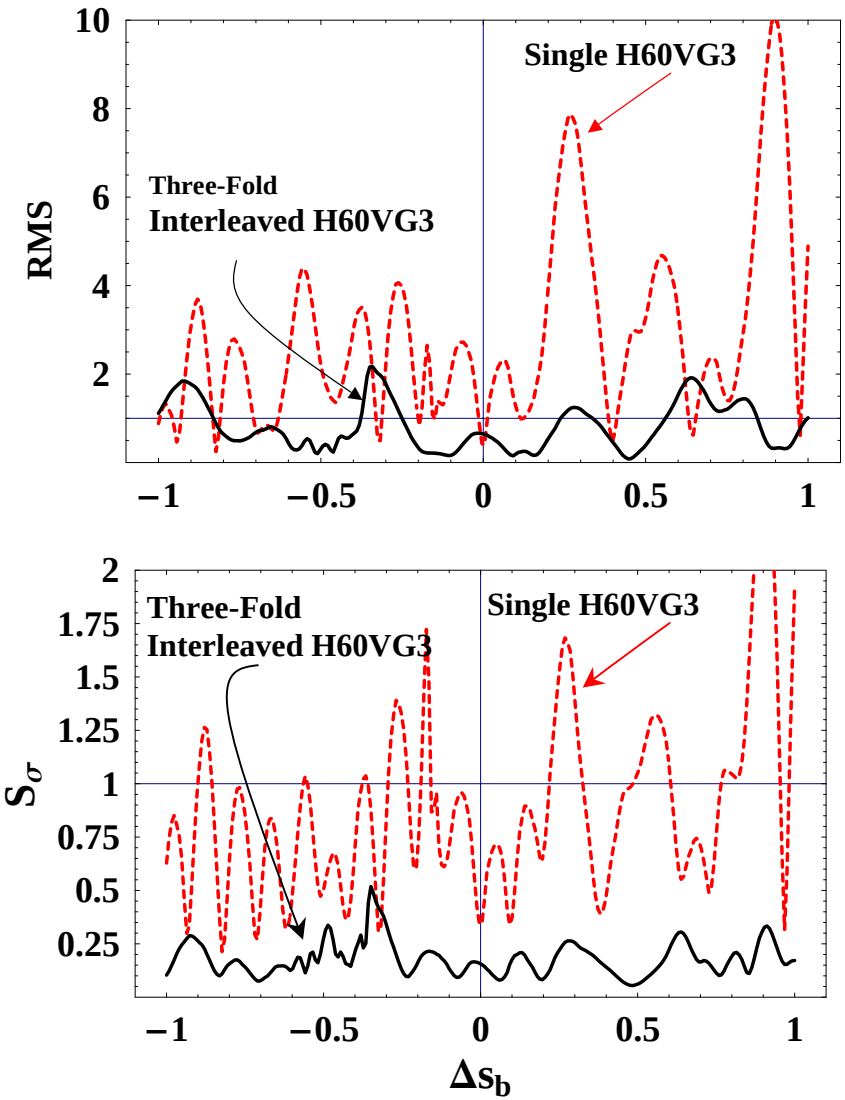
1. Wake Envelope for Interleaved H60VG3



Envelope of wake function for a MANIFOLD DAMPED structure of 55 cells *interleaved* 3-fold with neighboring structures. The dots indicate the wake at the bunch spacing of 42 cm. BW = 7.98% and 3.5 σ.

Also shown inset is the spectral function together with the original uncoupled design Kdn/df (kick factor weighted density function.)

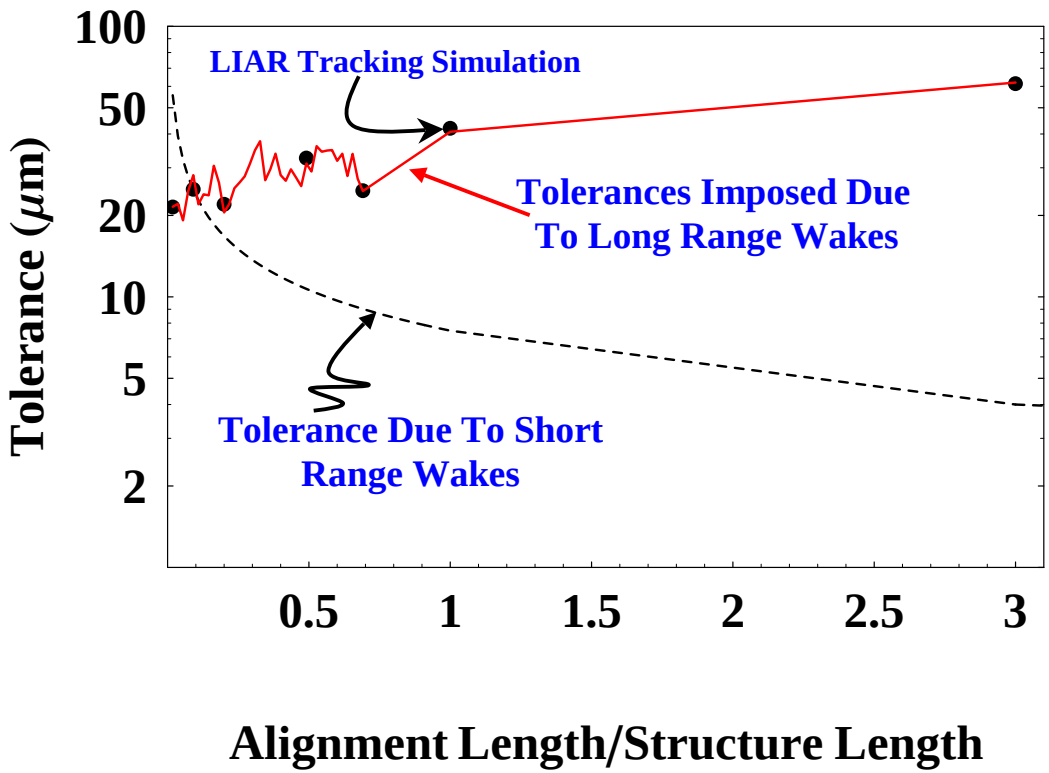
1. Beam Dynamics for H60VG3



The rms of the sum wake provides an indication as to whether or not BBU (Beam Break Up) will occur and it is shown in left-most as the bunch spacing is varied (corresponding to a systematic error in the cell frequencies). Past experience has indicated that provided the rms is less than unity then BBU does not occur. This is the case for three-fold interleaved H60VG3 to within +/-30MHz of the central dipole frequency.

The standard deviation of the the sum wake speaks to the alignment tolerances of the structure and provided it is less than 1then acceptable tolerances are obtained for an allowable emittance dilution of 10%. The single non-interleaved in marginally acceptable (providing BBU is under control of course)

1. Alignment Tolerances for H60VG3

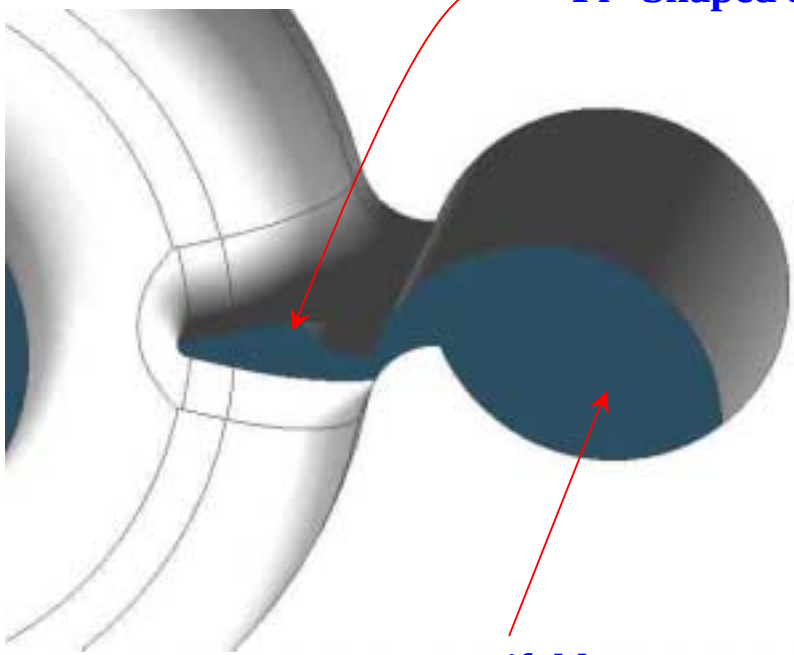


LR -> Cell-to-cell alignment ~20μm, structure-to-structure ~40 μm,
3 structures ~60μm
SR -> Controlled by beam based alignment

Cell-to-cell and structure-to-stucture alignment tolerances for a non-optimized MANIFOLD DAMPED 60 cm structure with 3-fold interleaving of adjacent structure frequencies.

The red line is obtained via a semi-analytical/statistical model. The dots are obtained with LIAR tracking simulations

1. Pulse Temp Heating in Slots of H60VG3



•Slots are necessary to couple out the wake to the manifold

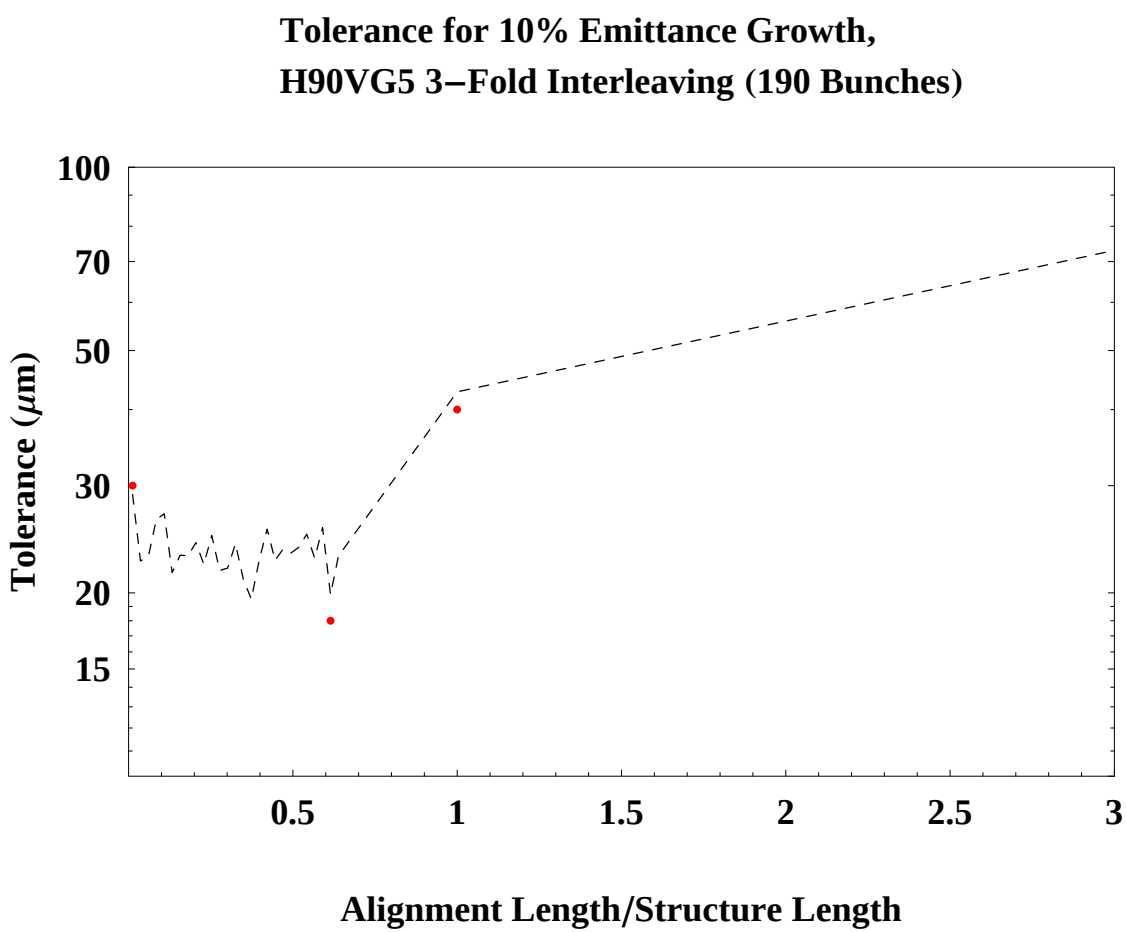
• Original design gave rise to pulse temperature heating in the slots of ~35-40C (depending on the particular design)

•New "Pi" shaped slots limit the pulse temperature rise to ~20-25.

•Analytic formula predicts the yield stressing of Cu occurs at ~37C. In practice it may be a factor of 2 or more larger than this.

•New design is in progress! Couplings, etc and final wakefield are to be calculated.

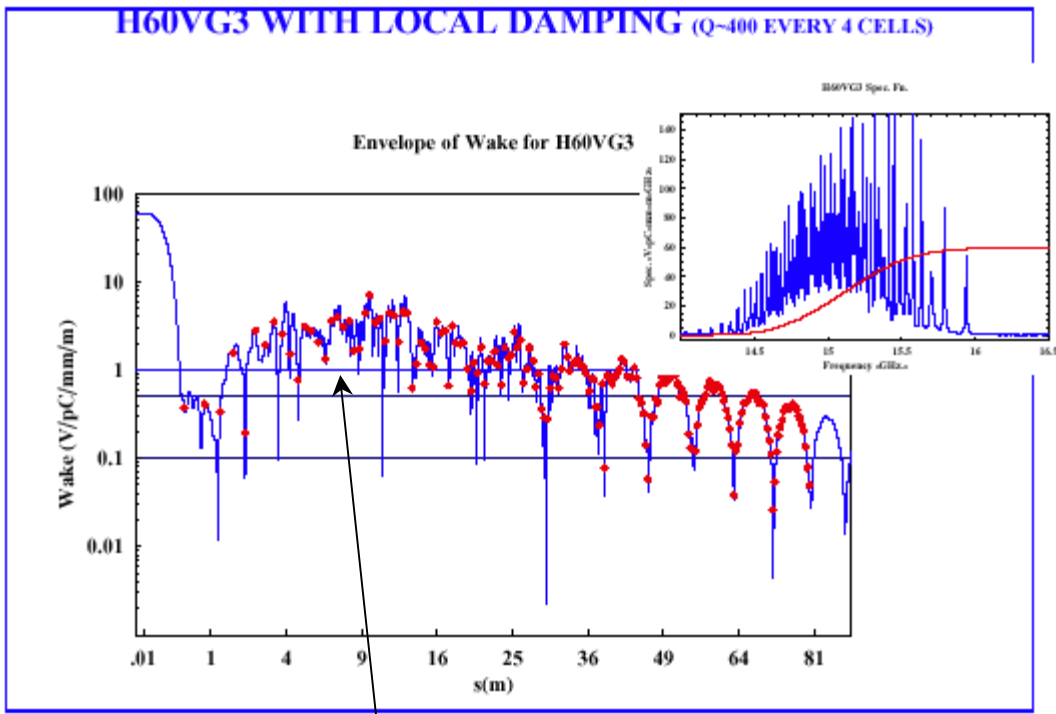
1. Alignment Tolerances for H90VG5



Cell-to-cell and structure-to-stucture alignment tolerances for a LOCALLY DAMPED 90 cm structure with 3-fold interleaving of adjacent structure frequencies.

The line is obtained via a semi-analytical/statistical model. The dots are computed by tracking through 10km of linac with the code LIAR.

2. TW High Phase Advance Structures with Limited Local Damping

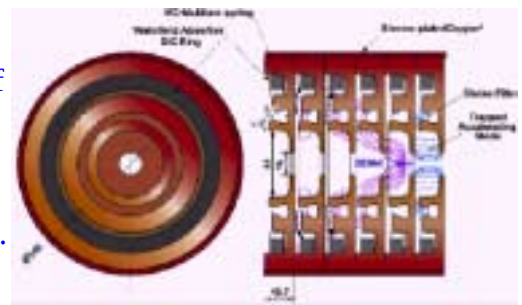


•The medium damping case shown above is H60VG3 with the dampers given a Q~400 and 3 intervening cells with purely Ohmic damping. It is clear that the damping here is not sufficient to damp the wake.

•Here we consider non-manifold damped structures. The motivation being that if the issue of pulse temperature heating at the manifold slots become insurmountable then local damping will be used.

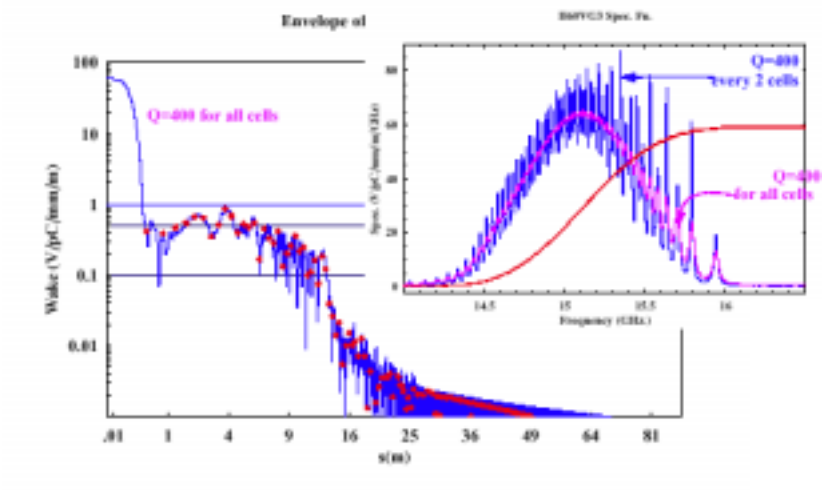
•*Is it possible to locally damp the wakefield using a limited number of dampers with medium or heavy damping*?

•Either direct local damping of each cell or a limited number of choke mode dampers are envisaged

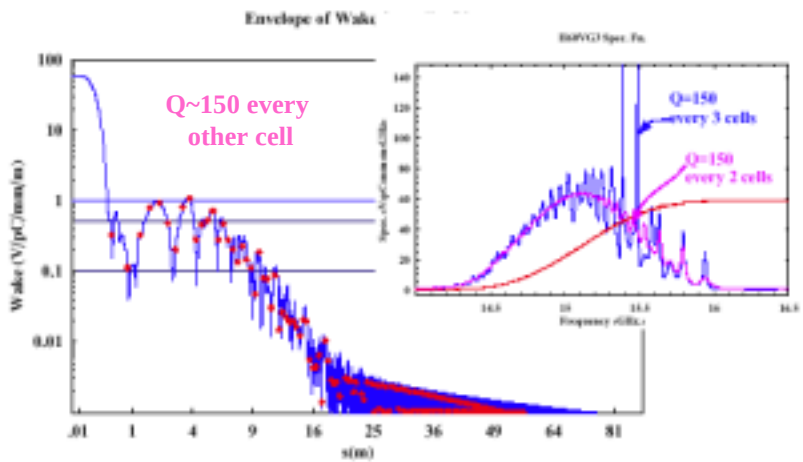


For the purpose of illustrating the principle a C-band choke structure is shown. This operates at 5.712GHz

2. TW High Phase Advance Structures with Limited Local Damping

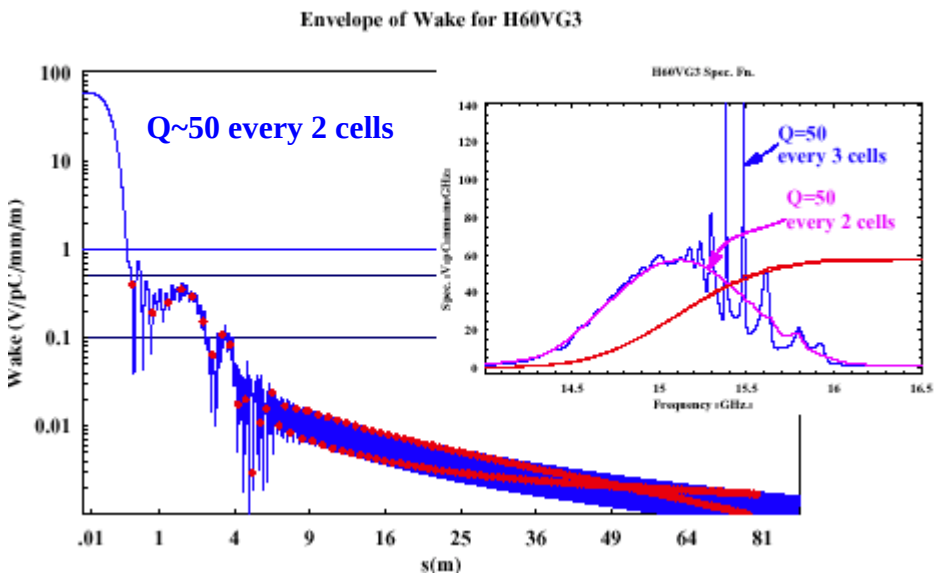


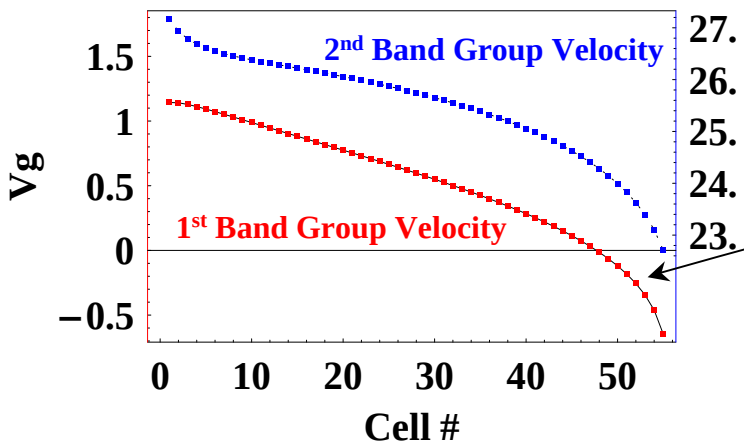
Increasing the number of dampers such that there are dampers every other cell gives rise to an unacceptable wakefield.
Every cell is required to be damped with a Q~400.



Increasing the damping to a Q~150 allows for a 2-fold reduction in the number of couplers. However, the resulting wakefield is only marginally acceptable

2. TW High Phase Advance Structures with Limited Local Damping



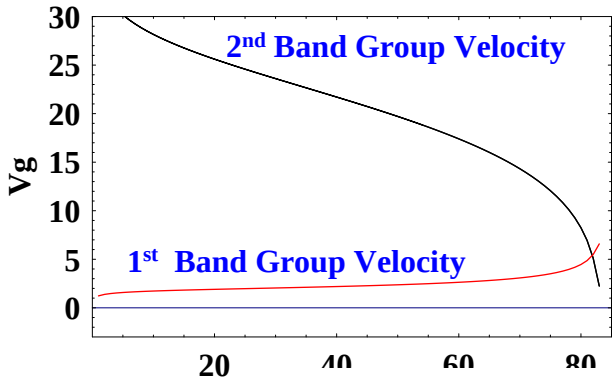


One intervening cell with a Q~50 (shown opposite) corresponding to heavy damping allows for excellent wakefield damping. Thus in this scheme, at best a factor of one half reduction in the number of the dampers is possible.

If 2 intervening cells are present between dampers then an unacceptable wakefield results. In principle the kick factors that are localized in these regions could be damped with specially targeted dampers. This would allow a further reduction in the number of dampers that are required.

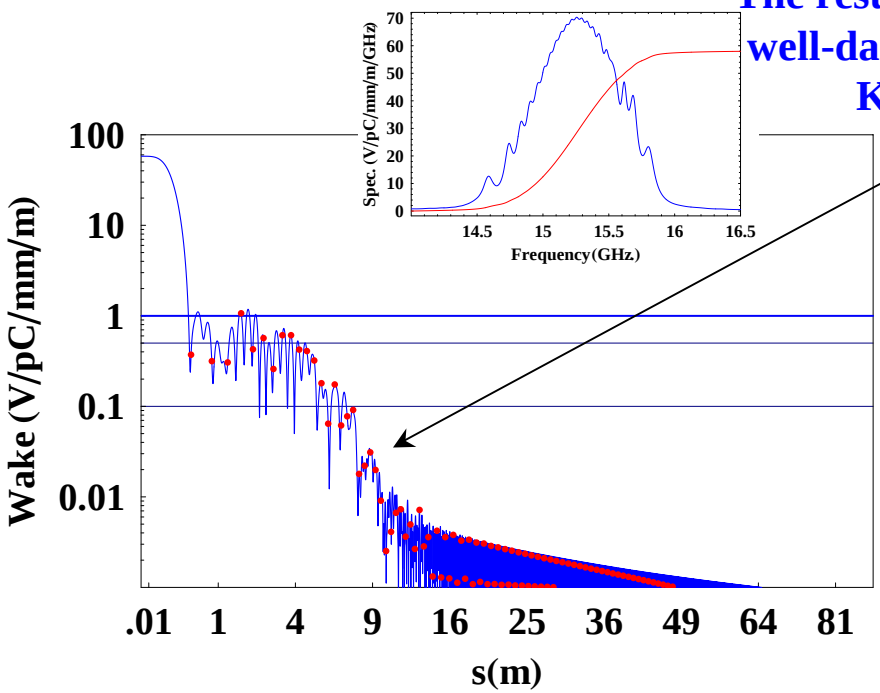
Is it possible to reduce the number of dampers without the need for targeted dampers?
Yes! H90VG3 has a different dipole mode group velocity characteristic which was unacceptable for manifold damped structures but it is desirable for locally damped structures.

2. TW High Phase Advance Structures with Limited Local Damping

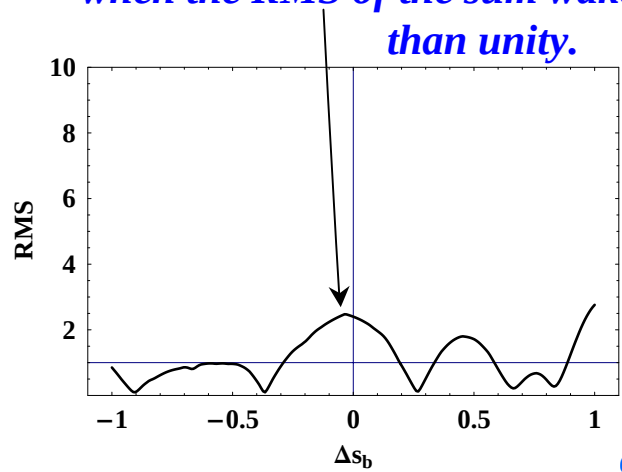


H90VG3 has the useful property that the dipole mode group velocity maintains a positive sign for all cells in the structure. This led to a characteristic pile up of kick factors in the manifold damped structure and was considered a bad feature. However, when modes are damped locally then it is a desirable to not have any trapped modes.

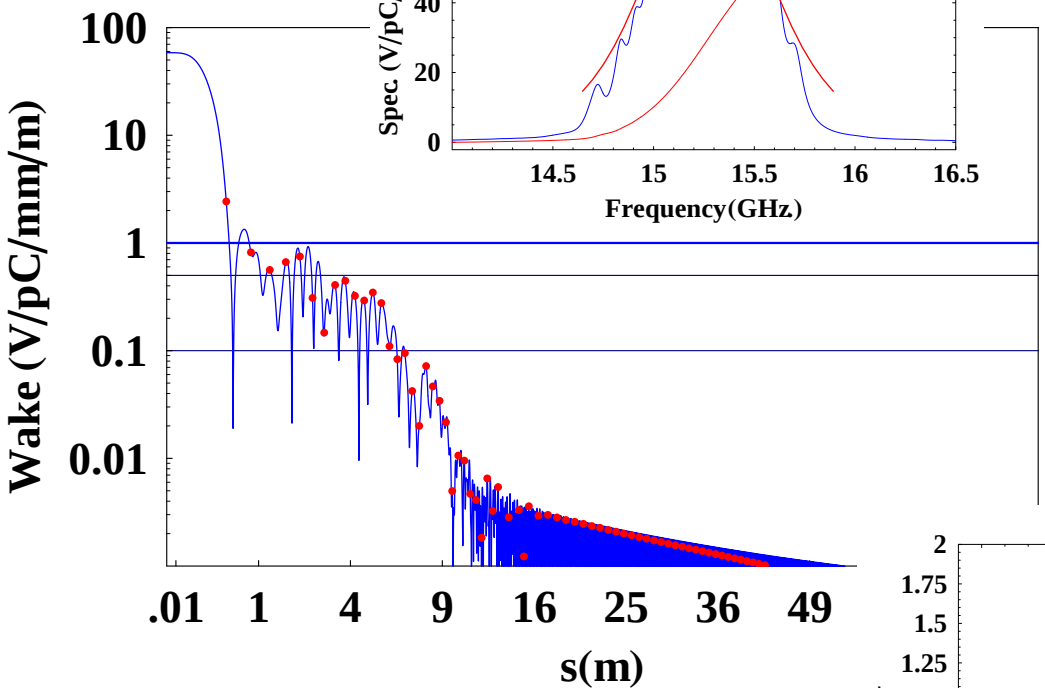
The resulting wakefield for a Q~50 every 4 cells is reasonably well-damped. The bandwidth and σ width of the Gaussian Kdn/df distribution are 10% and 4 respectively.



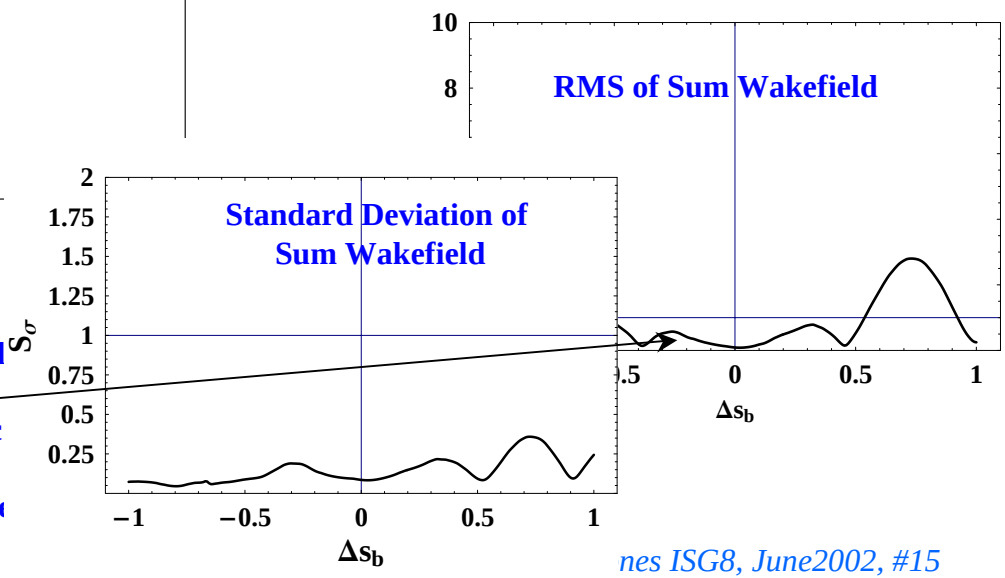
Unfortunately, the *RMS of the sum wakefield is too large. BBU has been shown to occur when the RMS of the sum wakefield is larger than unity.*



2. TW High Phase Advance Structures with Limited Local Damping

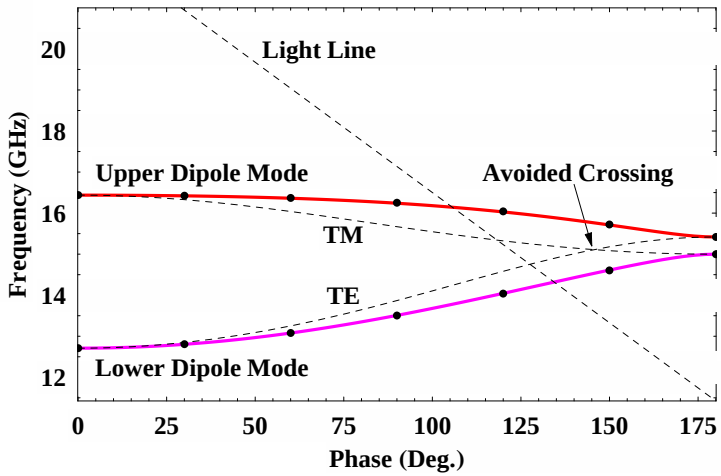


A Sech$^{1.5}$ distribution was chosen in which the cell Q ~ 50 every 4 cells. This limited damping scheme indicates allows for a rather smooth spectral function and much improved wake function. The final optimized bandwidth and σ are 8.15% and 3.64 respectively. This allows a reduced number of dampers to be used.

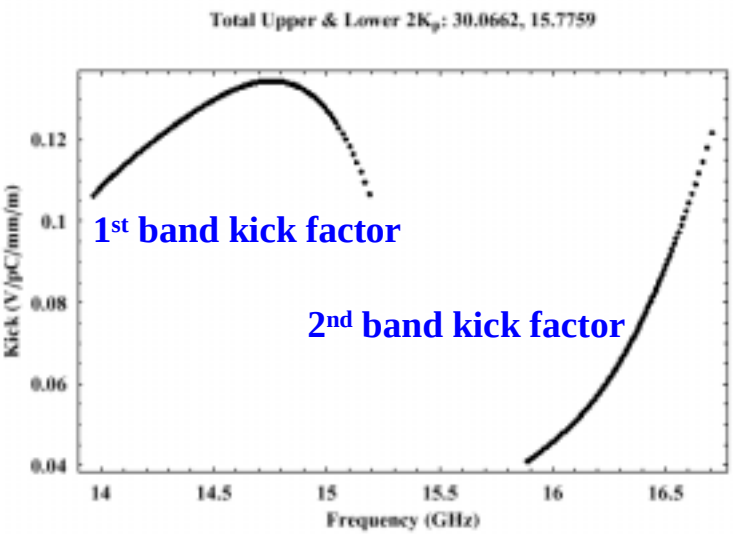


The rms of the sum wakefield as a function of the fractional deviation in the bunch spacing indicates that BBU will not occur within this structure provided the systematic errors in the cell frequencies are kept below 75MHz. Tolerances are also expected to loose as can be seen from the values of the standard deviation of the wakefield

3. Standing Wave π Structures

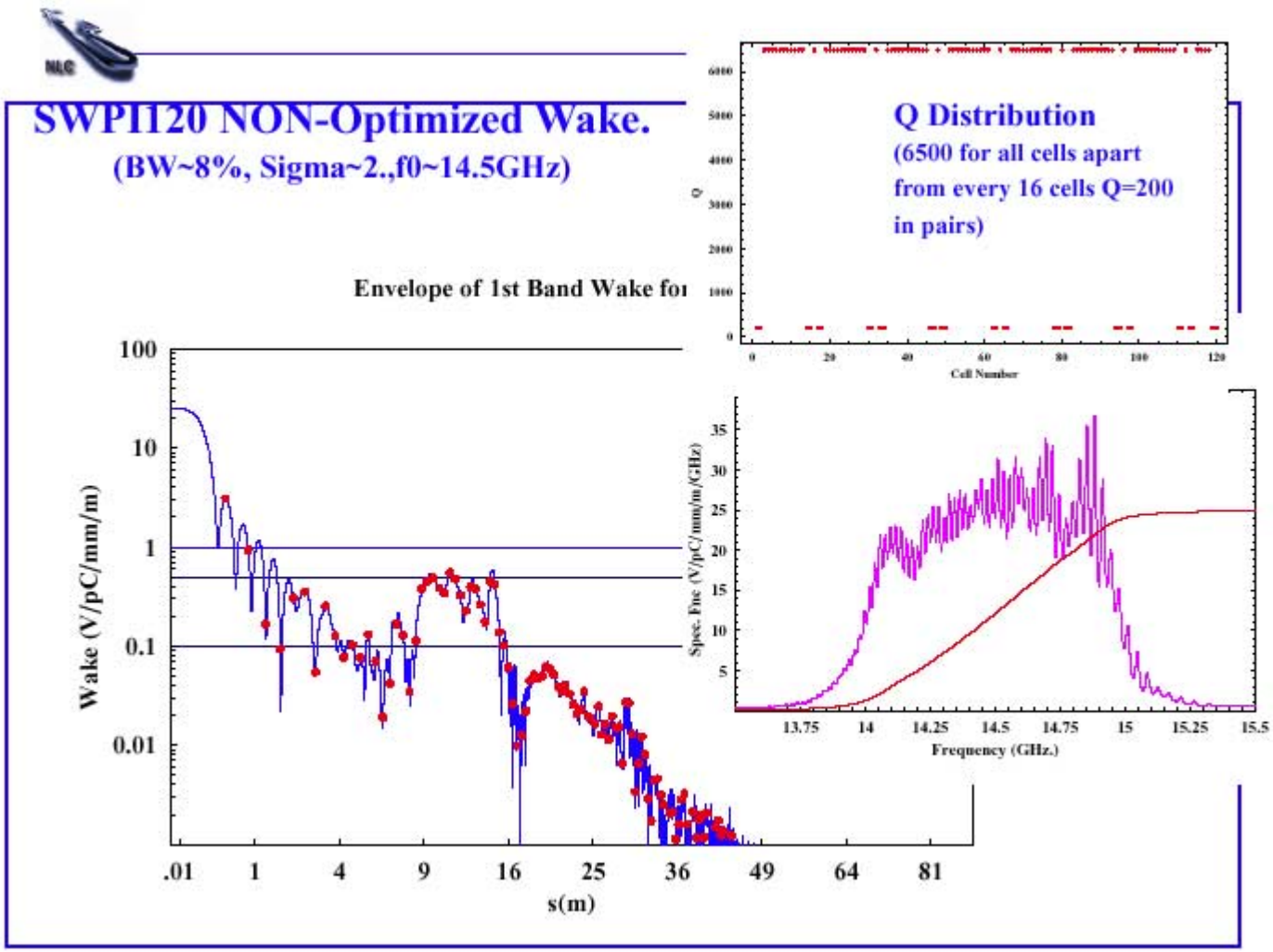


- Consider an amalgamated structure consisting of 8 separate structures (each structure consisting of 15 cells). The first two cells in each structure is damped Q ~ 200.
- Dipole dispersion curve for cell 69 of an amalgamated SW structure shown together with kick factors for the 1st two bands.



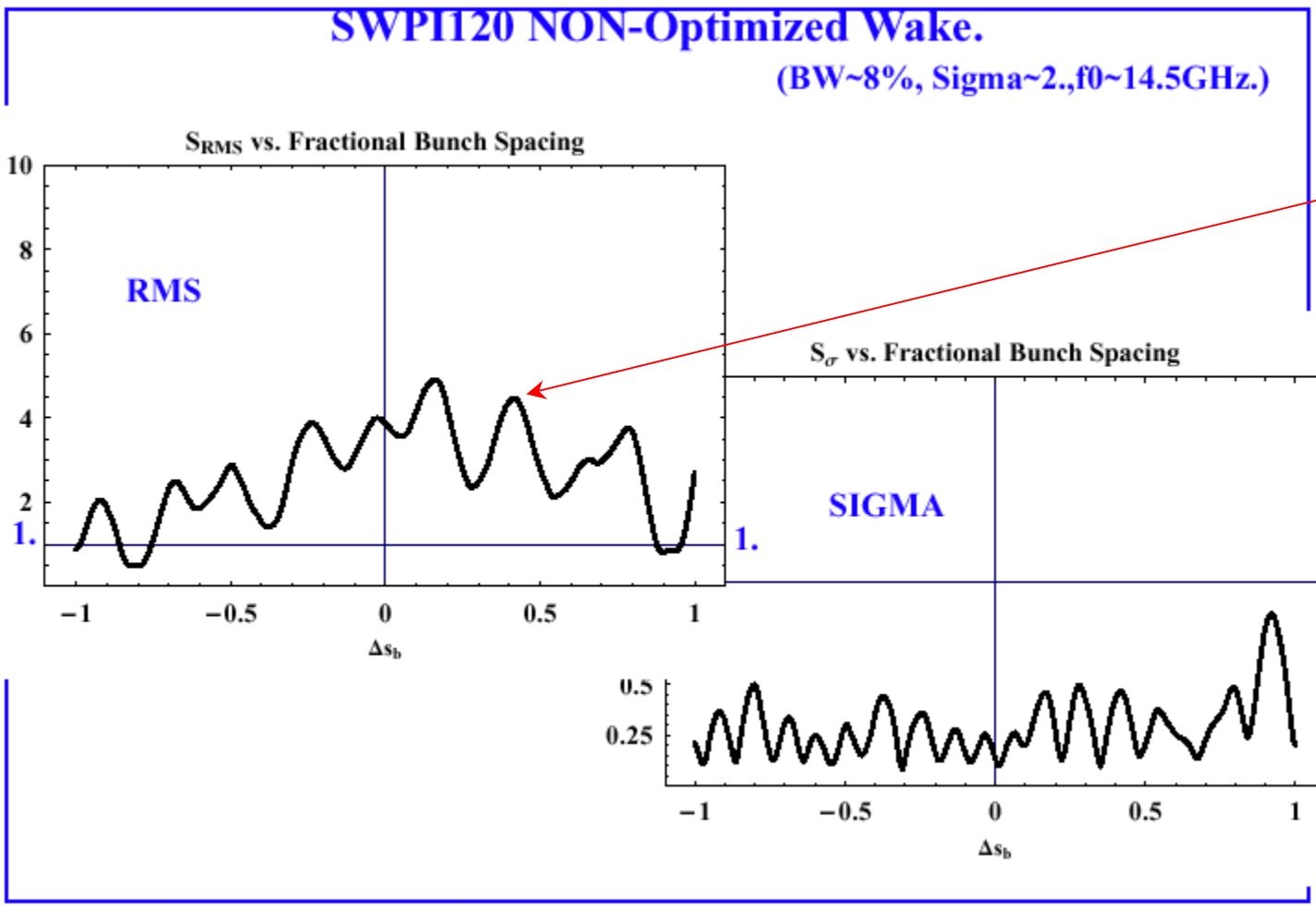
- Use a 8% bandwidth and 2σ.
- The kick factors do not increase with increasing frequency in contrast to those in the traveling wave structures

3. Standing Wave π Structures



Wake is well damped apart from the first few bunches.

3. Standing Wave π Structures



The RMS of the sum wakefield is larger than unity. On the basis of previous simulations we expect BBU to occur for this situation.

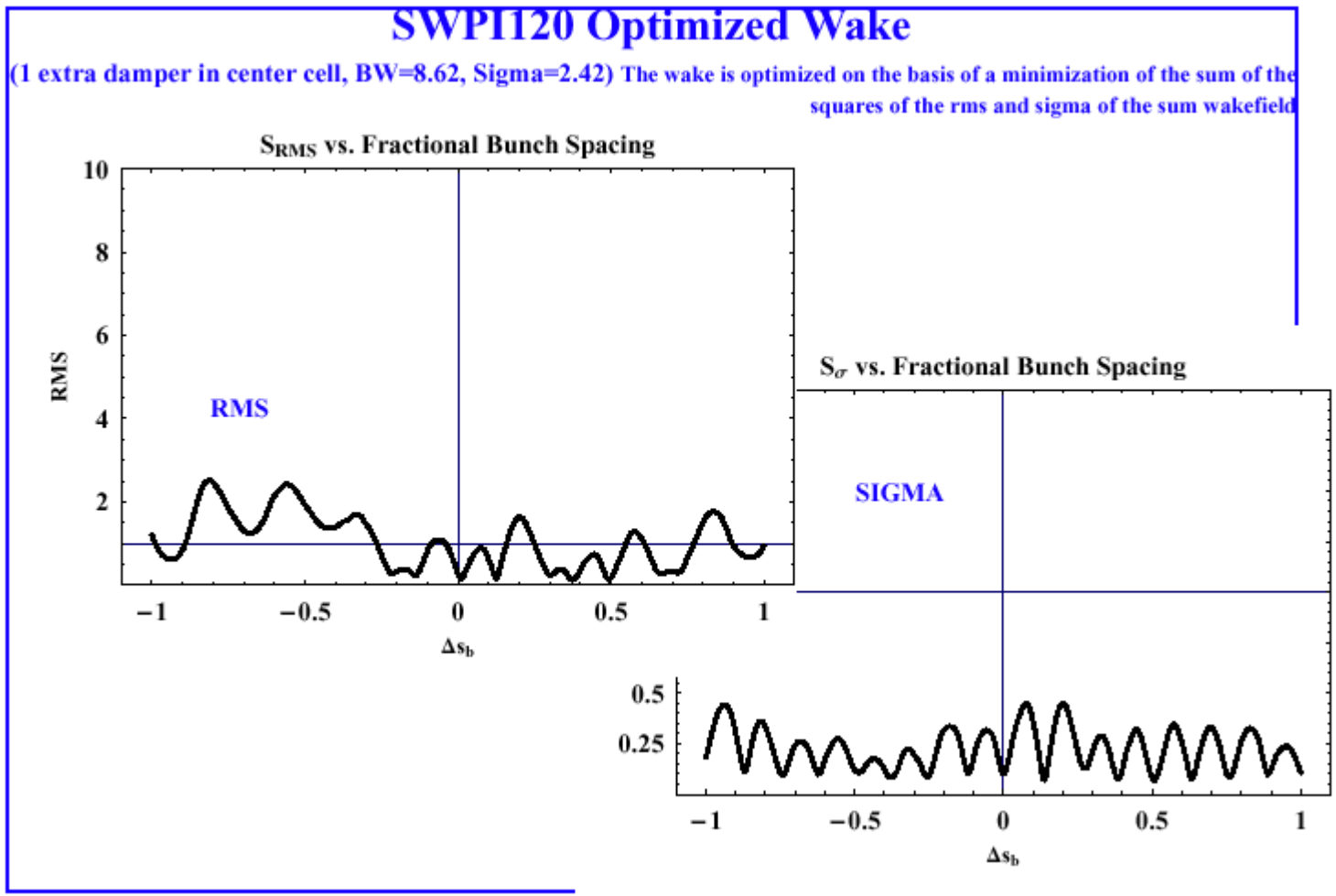
3. Standing Wave π Structures

SWPI120 Optimized Wake

(1 extra damper in center cell, BW=8.62, Sigma=2.42) The wake is optimized on the basis of a minimization of the sum of the squares of the rms and sigma of the sum wakefield

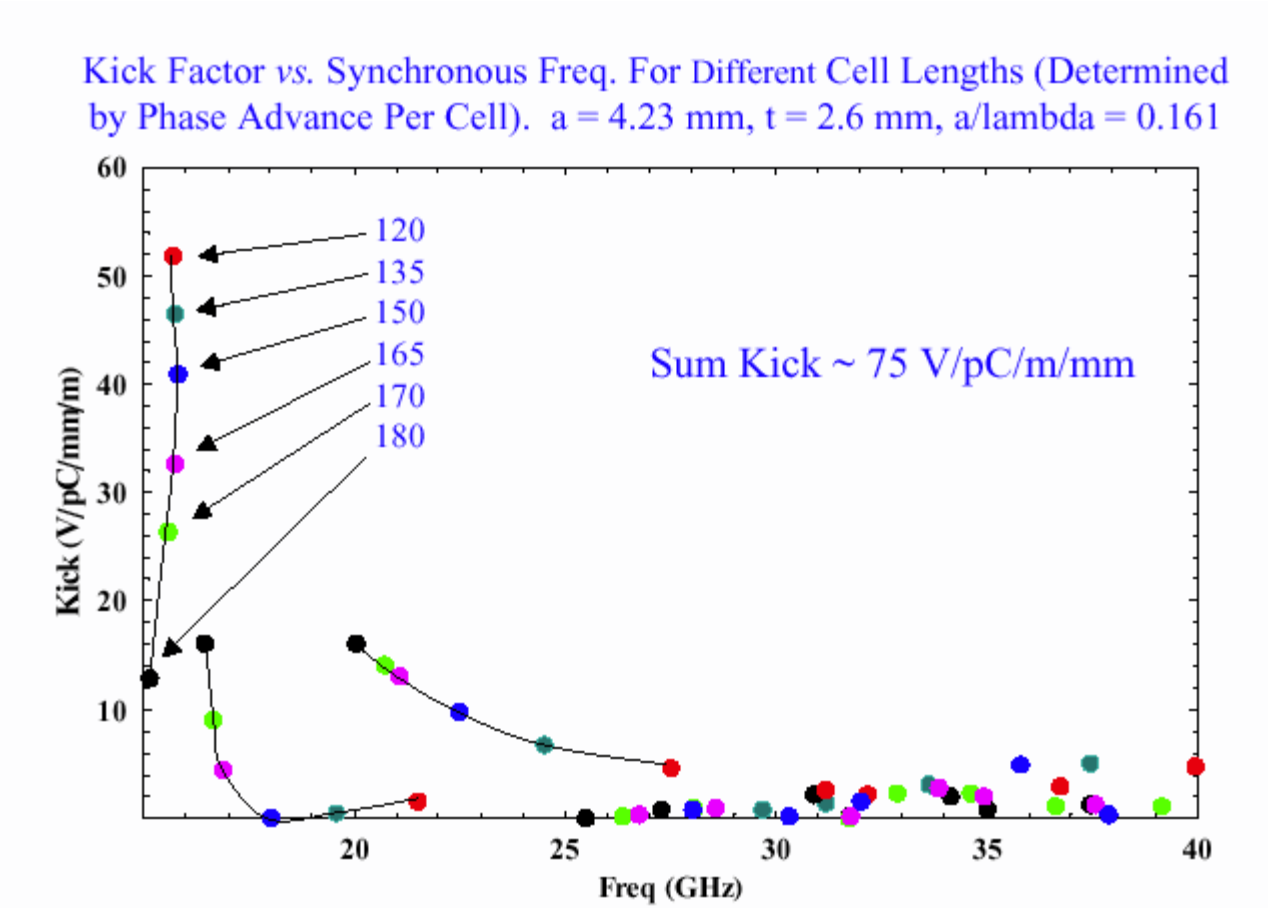
We choose to utilize the zero point crossing of the wake to minimize the wakefield that is experienced by the first bunch. This requires the central freq. be 14.28GHz
The envelope of the wake at the bunch locations are shown.
The bandwidth is automatically optimized.

3. Standing Wave π Structures

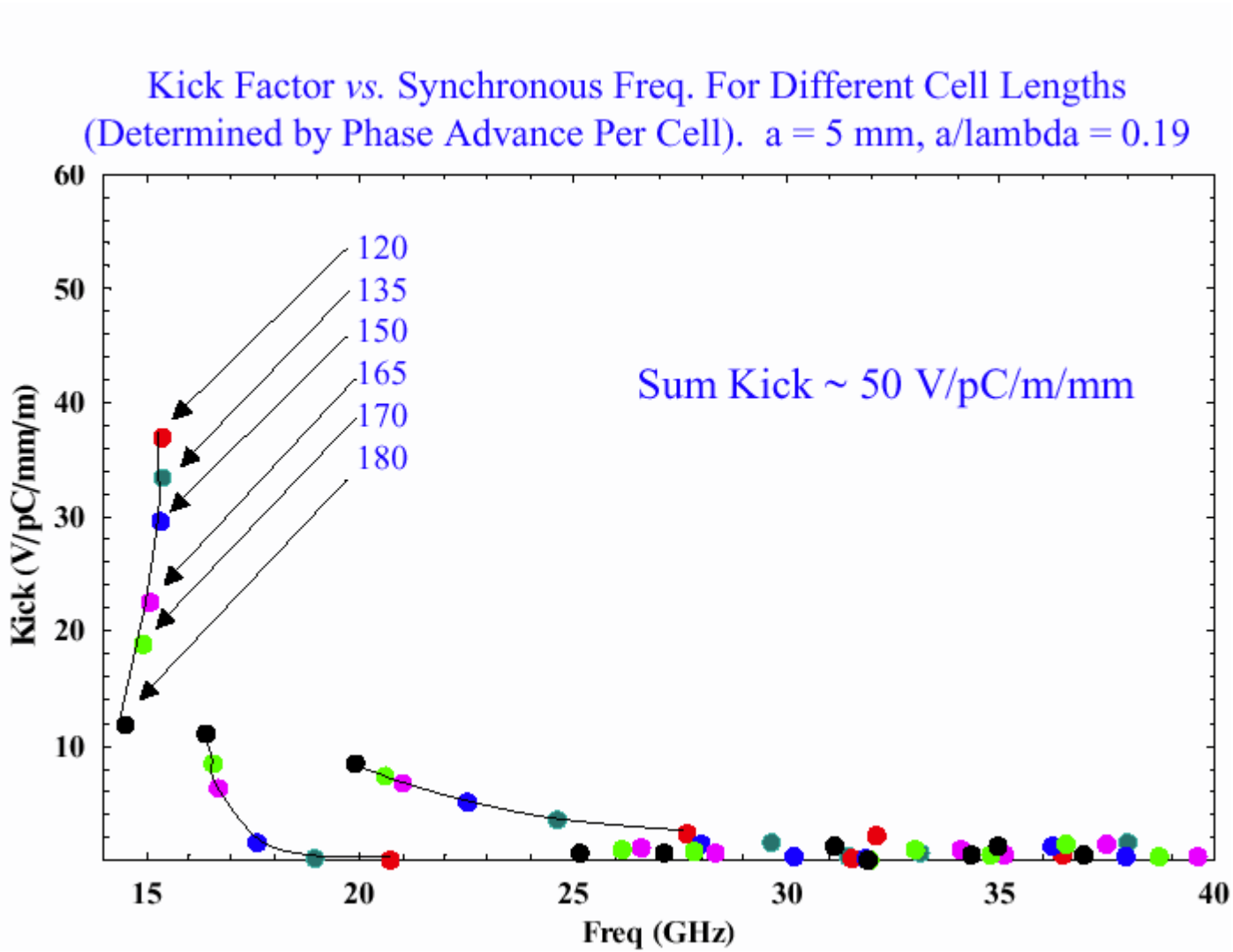


The RMS of the sum wake remains below unity to within 20 MHz of the center frequency. In this case BBU is under control. The wake is damped sufficiently that BBU is unlikely to occur.

4. Kick Factor Band Partitioning: General Properties



4. Kick Factor Band Partitioning: General Properties



5. Summary

•The highly optimized spectral function calculation allows the bandwidth to be routinely optimized.

•The wake for the DDS version of H60VG3 is well damped provided the structures are interleaved.

•The long-range wake driven tolerances for cell-to-cell alignment and structure-to-structure alignments are within acceptable limits for a 10% emittance dilution.
•Analyzing the tolerances for the optimized distribution is expected to given even looser structure-structure tolerances

•An analysis of the dipole wake for the new structure with "Pi" shaped slots is needed. This will be performed in the near future (once the design parameters have been properly chosen)

•The number of dampers in a locally damped (or choke mode) structure may be considerably reduced providing the group velocity of the dipole mode maintains the same direction throughout the structure

•The wake in standing wave structures is distributed among the bands, unlike the traveling wave 120 degree structures in which it was largely concentrated in the first band. Equal attention must be paid to damping at minimum the first three dipole bands.

Summary

- **As the central frequency is now ~14.5GHz there is not a significant loss in efficiency in reducing the freq to 14.28 GHz in order to minimize the wake at the first bunch ("zero point crossing"). This allows the bandwidth of the distribution to be optimized to minimize the wake at the 2nd dipole band.**

- **A frequency tolerance analysis of H60VG3 is required. For RDDS1 it was found that random errors from structure-to-structure improved the overall allowed the cell-to-cell frequency errors to be relaxed. A 5MHz maximum error was found to be allowable in practise from structure-to-structure.**

- **The minimum dipole frequency spacing in RDDS1 was ~7MHz. As the minimum frequency spacing in H60VG3 is ~25MHz then the frequency tolerance may be eased considerably! Detailed calculations are required to verify this.**