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MULTIBUNCH BEAM BREAK-UP CALCULATIONS FOR A SUPERCONDUCTING TEV LINEAR COLLIDER DESIGN*

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ABSTRACT

Multibunch beam break-up in an example of a next-generation (1 TeV center of mass energy) linear collider utilizing superconducting RF is calculated. The amount of damping of the transverse dipole cavity modes required to control this instability is estimated.

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1. INTRODUCTION

At the present time, designs for a next-generation linear collider, with energies in the 1/2 to 1 TeV range are being undertaken at various laboratories throughout the world.[1] In many of the extant designs, a train of bunches is to be accelerated each time the accelerating structure is filled with RF, thus there can be a blow-up of the transverse motion of a bunch due to the transverse wake fields of preceding bunches in the train. Due to the lower RF frequency and larger bunch spacing, multibunch beam breakup is expected to be less severe in a superconducting-RF linear collider than in a normal-RF linear collider. Nevertheless, it can be quite large in the superconducting case, unless measures (e.g., sufficient de-Qing via higher-order-mode couplers) are taken to control it, and it is necessary to give it serious consideration in the design. The purpose of this note is to estimate the amount of de-Qing of the transverse dipole modes that is required to keep the instability under control.

2. CALCULATIONS

The program LINACBBU[2] was used to calculate the transverse blow-up factor of each bunch in the train of bunches being accelerated on an RF fill. All bunches were assumed to start with unit offset at the beginning of the linac; no additional excitations further down the linac are included. The effect of misalignments in the linac have been examined by others and found to give comparable requirements on the Q's of the transverse modes.[3]

The parameters used are given in Table 1. A train is 200 bunches long, with about a microsecond between bunches. The energy at the end of each linac is

1/2 TeV, and the average accelerating gradient is about 20 MV/m. The bunch population of 1.4×10^{10} is similar to that considered in the TLC/JLC normal-RF designs.

The beta function is assumed to scale as

$$\beta = \beta_0 \left(\frac{\gamma}{\gamma_0} \right)^{1/2} \quad , \tag{2.1}$$

where β_0 is the beta function at the beginning of the linac. In our example, $\beta_0 = 3.2$ m. The $\gamma = \frac{E}{mc^2}$ is the usual Lorentz factor, with γ_0 its value at the beginning of the linac.

A 3.0 GHz CEBAF-TESLA design was assumed for the RF cavity; the four largest transverse modes obtained[4] for this cavity using the program URMEL[5] were used in the calculation. In addition to the 3.0 GHz case, the wake field was scaled to examine the 1.5 GHz case.

3. CONCLUSIONS AND ACKNOWLEDGMENTS

The results are shown in Table 2. The transverse mode frequencies vary from cavity to cavity due to manufacturing tolerances; a typical value is about 1 MHz frequency spread at 3.0 GHz.[6] Thus a relative frequency spread $\frac{\Delta f}{f}$ of 0.067% is assumed. For comparison, the results with $\frac{\Delta f}{f} = 0$ are also shown. The higher order modes were assumed for simplicity to all be de-Q'ed to the same value; the values $Q = 10^4, 10^5, 10^6$ are shown. The transverse blow-up factor x for the bunch with maximum blow-up is given in the right hand column. For the expected non-zero HOM frequency spread, at the higher RF frequency 3.0 GHz, the blow-up is clearly unacceptable for $Q = 10^6$ but is sufficiently well-controlled in this example for $Q \leq 10^5$. At the lower RF frequency of 1.5 GHz, again including the non-zero HOM frequency spread, $Q \leq 10^6$ may suffice.

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REFERENCES

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2. K.A. Thompson and R.D. Ruth, Phys.Rev.D, **41**, 964 (1990).
3. J. Bisognano, private communication.
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5. T. Weiland, Nucl. Instr. Meth. **216**, 329 (1983).
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Table 1: Parameters used for linacs	
Number of bunches per rf fill	200
Number of particles per bunch	1.4×10^{10}
Bunch spacing	300 m
Linac length	25 km
Initial energy	1 GeV
Final energy	500 GeV

Table 2: Maximum transverse blowup factor, x

	Q	x
f=3 GHz, $\frac{\Delta f}{f} = 0$	10^6	$> 10^7$
	10^5	28500
	10^4	1.4
f=3 GHz, $\frac{\Delta f}{f} = 0.067\%$	10^6	340
	10^5	1.2
	10^4	1.0007
f=1.5 GHz, $\frac{\Delta f}{f} = 0$	10^6	1010.
	10^5	1.5
	10^4	1.02
f=1.5 GHz, $\frac{\Delta f}{f} = 0.067\%$	10^6	1.2
	10^5	1.0015
	10^4	1.0005