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LINEAR COLLIDER ACCELERATOR PHYSICS ISSUES REGARDING ALIGNMENT

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Abstract:

The next generation of linear colliders will require more stringent alignment tolerances than those for the SLC with regard to the accelerating structures, quadrupoles, and beam position monitors. New techniques must be developed to achieve these tolerances. A combination of mechanical-electrical and beam-based methods will likely be needed.

Design of a Future Linear Colliders:

The next linear colliders require damping rings, linacs, and final focus systems which produce and deliver beams with emittances one to two orders of magnitude smaller than the SLC. The necessary placement tolerance of the components in these systems varies from system to system but range from 5 to 25 microns in the damping ring, linac, and upstream part of the final focus to well below a micron for components in the final focus near the collision point. Different alignment methods must be used in these varied geometries, adding to the complexity of the placement problem. Furthermore, the transitions between the major systems, for example the injection point of the damping ring beam into the linac, tend to have difficult beam dynamics match conditions as well as complicated alignment geometries. Special attention must be given to these transitions.

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Damping Ping:

The issues for the damping ring are to provide an adequately corrected beam orbit and to control the vacuum chamber impedance. The beam trajectory needs proper correction so that radiation damping produces the desired low beam emittance. The rolls of components must be carefully measured to minimize any residual horizontal-vertical coupling so that the required 100 to 1 emittance ratio can be achieved. The vacuum components must be carefully placed so that spurious wakefield effects do not reduce the intensity threshold of longitudinal and transverse instabilities.

Linear Accelerator:

The alignment tolerances in the linac are set to minimize the emittance enlargement of the beams during acceleration. Placement errors of the quadrupoles and position monitors introduce off-axis absolute trajectories even after correction which lead to chromatic phase space mixing. In addition, off-axis accelerating structures generate transverse wakefields which also enlarge the emittance.

Several examples of wakefield emittance enlargement are shown in Figs. 1,2, and 3. The effects of an oscillating beam in an accelerating structure are shown in Fig. 1. The head of the bunch interacts with the accelerator irises and produces a transverse force on the bunch core and tail. As the beam advances along the trajectory the effects of the wakefields become evident as an off-axis beam tail grows. The resulting increase in beam size can be quite large if not corrected. The same enlargement effects can be produced by displacements of the accelerating structure even though the beam passes through on-axis, hence the tolerances on alignment. In Fig. 2 is shown an induced beam oscillation measured in the SLC linac using the beam position monitor system. About 275 positions are measured and displayed. The amplitude of oscillation can be varied using a dipole magnet to produce (or correct) off-axis beam tails at the end of the linac. Several photographs of beam profiles with and without induced wakefield tails are shown in Fig. 3. The shapes and dimensions of these nongaussian beam profiles attest to the need for precision alignment.

The use of measured trajectories combined with knowledge of the quadrupole and correction dipole settings have been shown to provide precise alignment predictions for quadrupole and position monitor errors. This technique has been used successfully on the

SLC (see C. Adolphsen et.al., SLAC PUB 4902). This and other beam-based alignment methods will be applied to the next collider.

Final Focus:

The alignment tolerances for final focus components are tighter than for other upstream components. Since there are finite bend angles in the final focus the alignment methods are more complex. Also, the physics detector must be shielded from backgrounds requiring careful placement of the beam collimators, synchrotron radiation masking, and particle detectors near the beam. These considerations set the final focus apart from the rest of the collider. Much work needs to be done here.

Other considerations:

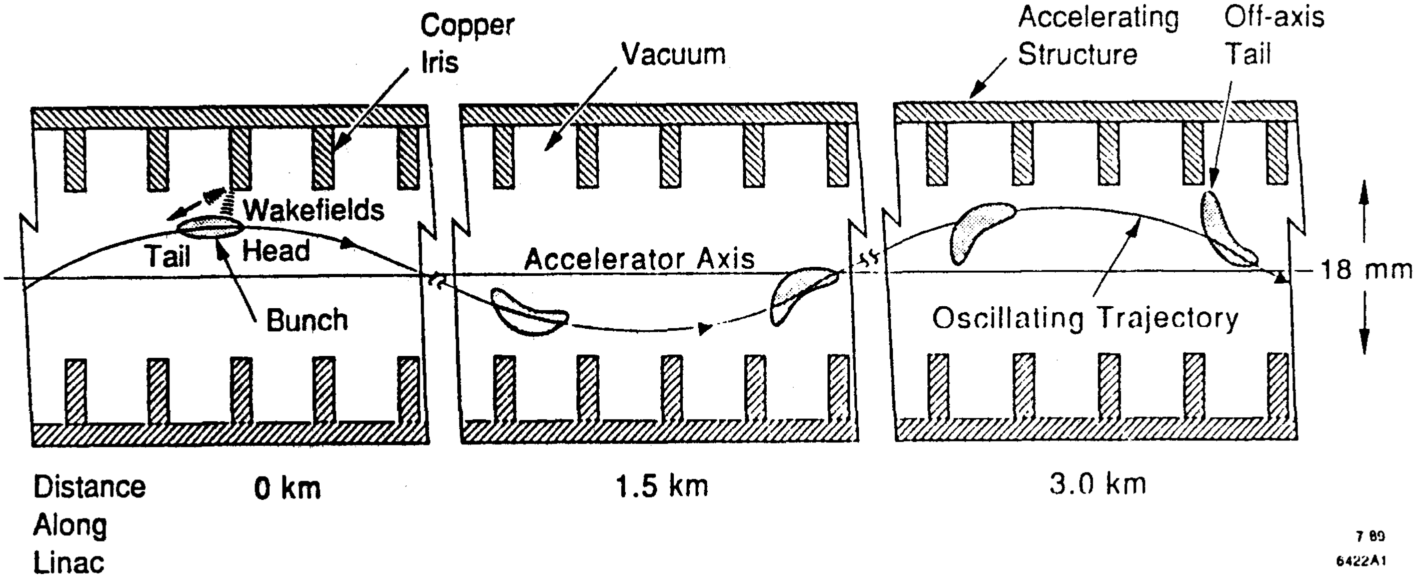
There are special circumstances in the next linear collider which make its alignment different than the SLC and other conventional colliders. (1) The beam shape will be vertically flat with about a ten to one aspect ratio. In the linac the sizes will be about one to ten microns. This ratio forces tighter roll tolerances and measurement requirements. (2) The beam oscillation frequency produced by the quadrupole lattice introduces spatial frequencies at which the beam is very sensitive. Special care must be taken, for example in the linac, that offset errors with wavelengths of 20 to 100 meters be controlled. (3) A remote alignment system is desired. The tight tolerances, the large number of effects which can misalign the accelerator (temperature, tides, ground motion, ...). and the nearly continuous operation of the collider strongly indicate that the collider be remotely alignable. (4) Finally, the connections of the accelerator to the outside world (e.g. power and control cables, cooling pipes, RF waveguides, remote alignment fixtures) must be designed so that they have minimal impact on alignment and stability.

Figure Captions:

Fig. 1 The head of an oscillating bunch in a linac produces transverse wakefields which drive the core and tail particles to ever increasing amplitudes and increase the beam emittance. Misaligned accelerating structures also produce this effect.

Fig. 2 A measured beam trajectory in the SLC linac showing an induced oscillation.

Fig. 3 Images of an electron beam on a profile monitor showing wakefield growth with increasing oscillation amplitude. The left image is for a well-steered beam and the right one for an oscillation amplitude of 1 mm. The beam intensity is 2 X 10 ** 10 electrons. The core sizes are about 120 microns.



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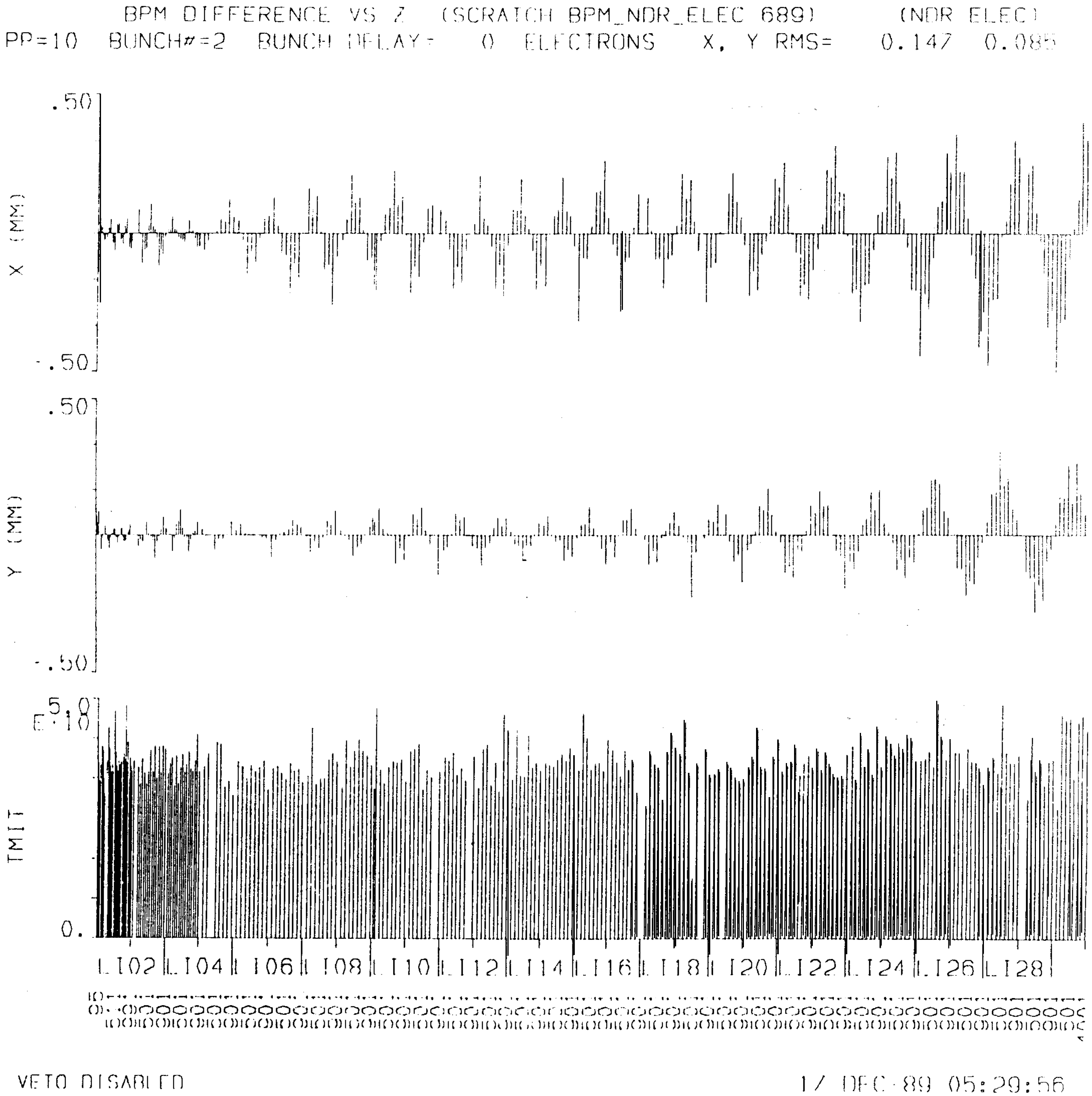

Figure 2. A measured beam trajectory in the SLC linac showing an induced oscillation.

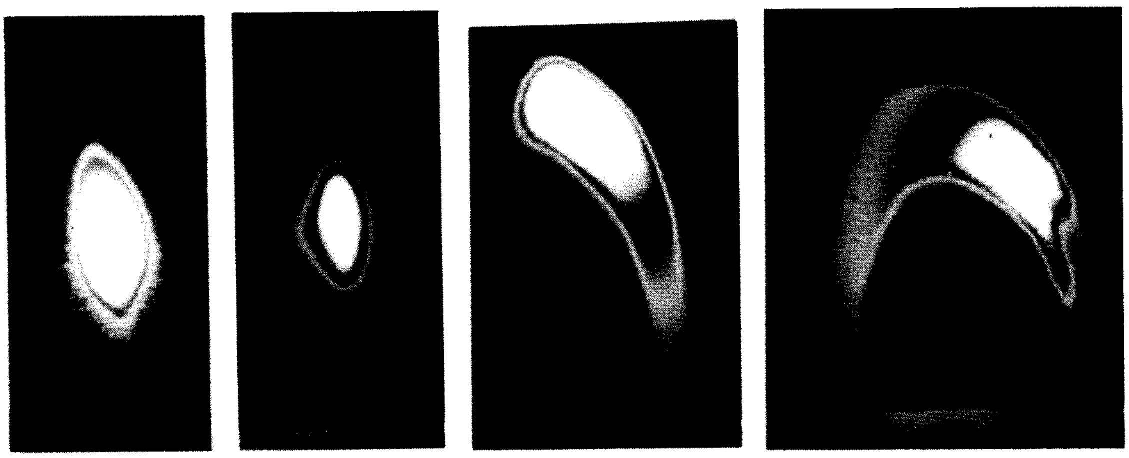

Figure 3. Images of an electron beam on a profile monitor showing wakefield growth with increasing oscillation amplitude. The left image is for a well-steered beam and the right one for an oscillation amplitude of 1 mm. The beam intensity is 2 X 10**10 electrons. The core sizes are about 120 microns.