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DIRECT MEASUREMENT OF GEOMETRIC AND RESISTIVE WAKEFIELDS IN TAPERED COLLIMATORS FOR THE INTERNATIONAL LINEAR COLLIDER

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Abstract

Precise collimation of the beam halo is required in the International Linear Collider (ILC) to prevent beam losses near the interaction region that could cause unacceptable backgrounds for the physics detector. The necessarily small apertures of the collimators lead to transverse wakefields that may result in beam deflections and increased emittance. A set of collimator wakefield measurements has previously been performed in the ASSET region of the SLAC Linac. We report on the next phase of this programme, which is carried out at the recently commissioned End Station A (ESA) test facility at SLAC. Measurements of resistive and geometric wakefields using tapered collimators are compared with model predictions from MAFIA and GdfidL and with analytic calculations.

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Precise collimation of the beam halo is required in the International Linear Collider (ILC) to prevent beam losses near the interaction region that could cause unacceptable backgrounds for the physics detector. The necessarily small apertures of the collimators lead to transverse wakefields that may result in beam deflections and increased emittance. A set of collimator wakefield measurements has previously been performed in the ASSET region of the SLAC Linac. We report on the next phase of this programme, which is carried out at the recently commissioned End Station A (ESA) test facility at SLAC. Measurements of resistive and geometric wakefields using tapered collimators are compared with model predictions from MAFIA and GdfidL and with analytic calculations.

INTRODUCTION

At the ILC, short-range transverse wakefields excited by collimators placed close to the beam may perturb beam motion and cause emittance dilution and amplification of position jitter at the interaction point. The aim of this test beam programme is the optimal design of ILC collimator jaws, specifying the geometry and material that will minimise wakefield effects while achieving the required performance for both halo removal and a range of beam damage scenarios. It is assumed that collimators will be rectangular in transverse section with a shallow longitudinal taper—long relative to the $300\ \mu$m ILC bunch length—to achieve sufficiently low impedance while having adjustable gates. To optimise reliably the design of individual collimator jaws requires tools which can accurately model wakefield effects for short bunches, including the non-linear near wall region (implications for machine protection). However, calculating the impedance using analytic methods is extremely difficult, even for an idealised design without real engineering features. Similarly, tools such as MAFIA have problems in this regime due to grid dispersive effects.

Earlier measurements have enabled significant advances in analytic calculations. New experimental data is now required to test analytic calculations and allow further development of state-of-the-art 3D electromagnetic modelling methods: typical consistency with data is within factor 2–3. The goal for ILC design capability is agreement at the 10% level.

COLLIMATORS

The underlying motivation was to study various ways of achieving a given minimum aperture which have differing implications for both fabrication and longitudinal space in the beam line. Direct comparison can be made to earlier results of varying taper angles and minimum apertures. To allow commissioning of the "wakefield box" [1] in ESA, as well as studying resistive wakes in copper and two-step tapers, measurements were made using both sets of the collimators shown in Figure 1 during a two week run in April 2006 [2]. This was possible due to the much improved access in ESA, in contrast to earlier measurements, e.g. [3], where machine scheduling excluded testing more than four collimators per year.

The eight sets of oxygen free electronic copper collimators were fabricated at CCLRC/RAL, polished to ensure surface effects did not contribute to the measured kicks (roughness average 0.4 μm), and distributed among two "sandwiches", as shown in Figure 1. Definitive specification of the collimators can be found in [4].

The rationale behind the combination of collimator taper angles and half-gaps (r, or for two-step tapers, r_1 and r_2)

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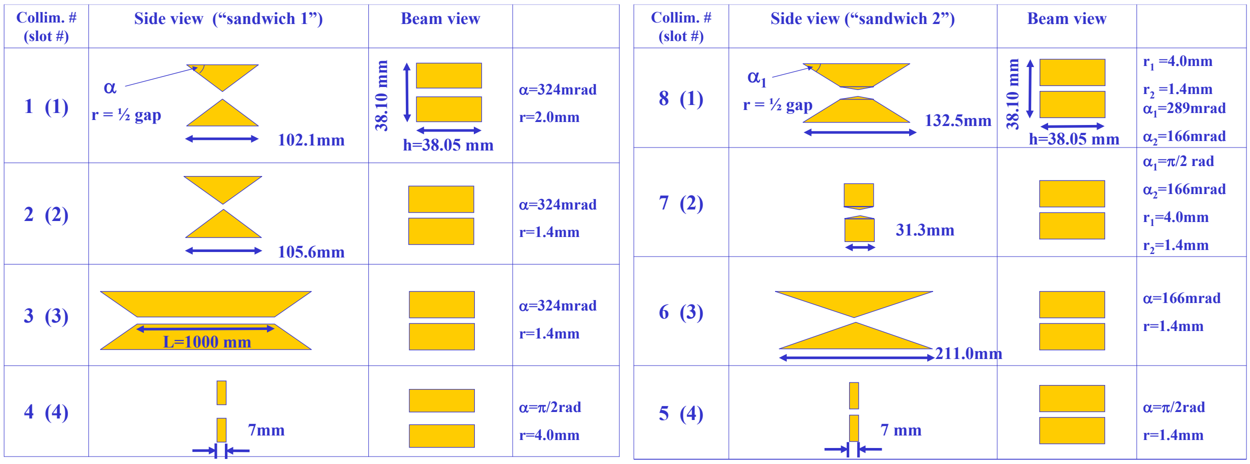

Figure 1: Collimators in sandwiches 1 and 2.

is given below for each collimator tested.

Collim. 1 Identical geometry to that of most recent measurements [3], necessary to control systematics when comparing to earlier data.

Collim. 2 Extends recent measurements [3] ($r = 2.0$ mm) to smaller half-gaps.

Collim. 3 Extends recent measurements [3] ($r = 2.0$ mm) to smaller half-gaps, where geometric wake is assumed to be measured directly by collimator 2. As the mean resistive wake kick for parallel plates is expected to vary as $1/r^3$, an increase of approx. factor 3 is expected relative to [3].

Collim. 4 Purely diffractive step, 0.5 radiation length thickness, for direct comparison with collimator 5 and also slot 4 of [5].

Collim. 5 Purely diffractive, 0.5 radiation length thickness, direct comparison with collimator 4.

Collim. 6 Gradual taper for comparison with collimator 5 of same half-gap.

Collim. 7 For comparison with collimator 3, having same change in minimum aperture (at angle $\pi/2$), and collimator 6 (at same taper angle).

Collim. 8 For comparison with a combination of [5] (same taper angle and change in aperture to $r = 3.8$ mm) and collimator 3 (same taper angle and change in aperture from r_1 to r_2).

Theoretical predictions

Predictions from earlier analytic calculations [6], numerical 3D calculations using MAFIA/GdfidL [7] and new calculations [8] have been performed for the new collimators. Results from two of these sources are summarised in Table 1, for two different bunch lengths.

It is noted that the predictions [8] for kick factors arising from geometric wakes differ significantly for collimators 2 and 3, even though they have identical taper angles and minimum apertures. Previously, it had been asserted that the geometric contribution to the measured kick would be identical for two such collimators and therefore the resistive wake could be inferred directly from their difference.

MEASUREMENTS

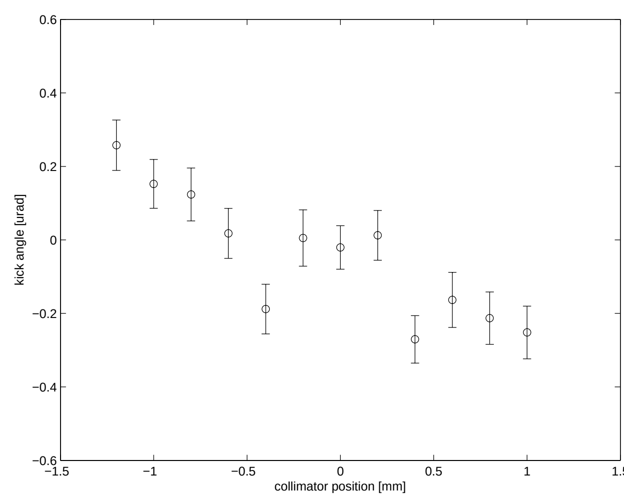

Figure 2: Example of reconstructed angular deflection with collimator 2.

The primary electron beam of 28.5 GeV was set up into ESA having a 75 μm vertical waist in the vicinity of the wakefield box. Beam position monitors (BPMs), two doublets upstream and two triplets downstream, see [2] for details, were used to reconstruct the incoming and outgoing trajectories and infer pulse-by-pulse the deflection due to transverse wakefields from each collimator in turn. The deflection was measured as a function of the vertical position of the collimator (relative to nominal symmetric placement

Table 1: Theoretical prediction of kick factors for collimators

Collim. #	**Geom. kick, V/pC/mm**			**Res. kick, V/pC/mm**	
	3D calc. [8]		**analytic calc. [6]**	**analytic calc. [6]**	
	σ_z**=300 μm**	σ_z**=500 μm**	σ_z**=300/500 μm**	σ_z**=300 μm**	σ_z**=500 μm**
1	1.9	1.7	2.2	0.005	0.004
2	3.6	3.1	4.6	0.011	0.008
3	6.1	5.1	4.6	2.5	2.0
4	0.74	0.77	0.6	0.001	0.001
5	7.1	6.8	4.6	0.018	0.014
6	2.9	2.3	4.6	0.10	0.077
7	3.1	2.7	4.6	0.021	0.016
8	3.0	2.4	4.6	0.023	0.017

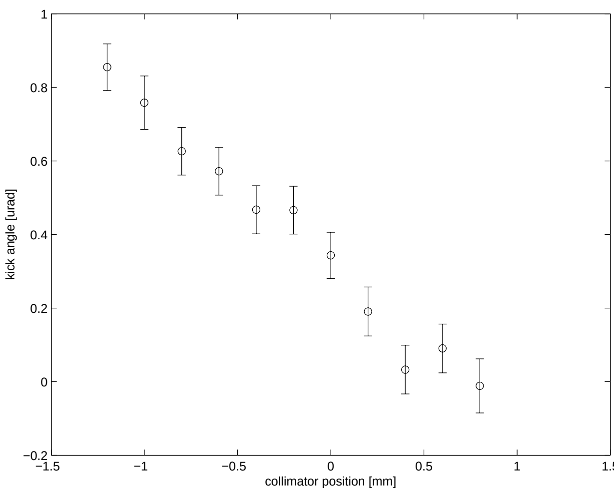

Figure 3: Example of reconstructed angular deflection with collimator 3.

around the beam) as it was stepped through the beam in 200 μm intervals. Typically 600 pulses were recorded at 10 Hz for each of 12 vertical collimator positions. Two reference orbit measurements were made immediately before and after each collimator scan to define the BPM offsets, one without any collimator engaged in the beam position, and a second with the collimator under test (nominally) symmetrically placed around the beam.

During the programme of data taking, the accelerator RF phase was varied over a range of approx. 6° to allow study of the bunch length dependence of the measurements. Similarly, measurements were also recorded at varying bunch intensities. To study possible systematic effects relating to the vertical movement of the collimators, measurements were made in a variety of ways over the full ± 1.2 mm vertical range which could be used reliably, either stepping the collimators monotonically upwards, or downwards, or in both directions in a single 12 point scan.

Examples of the measured angular deflections as a function of collimator position are shown in Figures 2 and 3 for collimators 2 and 3, respectively. Near to the extreme scan positions for collimator 3, large deflections were reconstructed which are outside the region illustrated. These figures include only part of the data accumulated for each of these collimators and, although optimal BPM calibrations are not yet used, it is encouraging that the reconstructed deflections have the expected qualitative behaviour. In the near future with improved calibrations, resolution on the reconstructed kick factors of better than 0.1 V/pC/mm is anticipated with the data from this run.

CONCLUSIONS

The apparatus used previously to measure collimator wakefields at SLAC has been successfully commissioned at End Station A. Measurements have been performed to study both geometric and resistive wakefields using eight sets of steeply tapering (“diffractive”) copper collimators, having minimum half-apertures in the range 1.4 mm–4.0 mm and with taper angles varying between 166 mrad and $\pi/2$.

New predictions from both analytic calculations and numerical models have been made to compare with data. Final calibration of BPMs used to reconstruct angular deflections is in progress, with which it is expected that kick factors will be reconstructed with a precision of better than 0.1 V/pC/mm.

REFERENCES

[1] P. Tenenbaum et al., contribution FRA29, Proc. PAC-99 (1999).

[2] M. Woods et al., contribution MOPLS067, these proceedings.

[3] P. Tenenbaum, D. Onoprienko, contribution WEPLT158, Proc. EPAC-04 (2004).

[4] See `http://hepunx.rl.ac.uk/swmd/beam/`.

[5] P. Tenenbaum et al., contribution TUP3A03, Proc. EPAC-00 (2000).

[6] See [3] and references therein.

[7] C.D. Beard, J.D.A. Smith, contribution MOPLS070, these proceedings.

[8] I. Zagorodnov, T. Weiland, PR-STAB 8 (2005) 042001; K.L.F. Bane, I.A. Zagorodnov I.A., contribution THPCH036, these proceedings.