Collimator Wakefields in the LC Context

“With the fire from the fireworks up above...”

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Statement of the Problem

- Beam off-axis thru collimator excites dipole modes
  - deflects tail of bunch relative to head
  - Increases RMS beam jitter
  - Increases emittance
  - MPS issue (nonlinear kick – very big if beam is near the wall)
Two main contributions to wakefield

- Resistive wall wakefield
  - due to finite conductivity of collimators
  - Present even for perfectly regular vacuum pipe
  - Well developed, simple theory (but maybe not correct!)

- Geometric wakefield
  - due to change in vacuum chamber x-section at collimator
  - Fairly complicated, esp. for flat (x gap >> y gap or vice versa) collimator (like spoiler)
  - Level of “benchmarking” relatively low
• Near center of collimator: kick ~ beam-coll offset ($\Delta y' = Ky$)
  – Define wakefield jitter amplification factor $A$
  – $n$ sigmas jitter incoming = $n(1+A^2)^{1/2}$ outgoing
  – Wake jitter out of phase of collimator (so collimators in FD phase cause IP phase jitter)
  – Near-center problem reduced to finding value of $A$
  – Energy collimator couples energy jitter to position jitter
    • $A_\delta \equiv \# \text{ sigmas} \times \text{jitter} / \% \text{ energy jitter}$
Finding “A”

- Assume collimators tapered in z, 20 mrad taper angle ($\theta$)
- Define $r =$ half-gap, $h =$ half-width (x width of y collimator)
- Resistive:
  - tapered: $K \sim 1/(\theta r^2) * \sqrt{1/\sigma_z}$
  - untapered: $K \sim 1/r^3 * \sqrt{1/\sigma_z}$
- Geometric: 3 regimes for “flat” collimators
  - Steep taper: $K \sim 1/r^2$
  - moderate taper: $K \sim \theta^{1/2}/(\sigma_z^{1/2}r^{3/2})$
  - Shallow taper: $K \sim \theta h/(\sigma_z r^2)$
- 2 regimes for “round” collimators
  - steep taper: $K \sim 1/r^2$
  - shallow taper: $K \sim \theta/(\sigma_z r)$
TRC Calculations

• Use values from A. Drozhdin report (last updated September 2002)

• Assumptions:
  – Spoilers must be “flat” geometry with $h = 1$ cm (adjustability)
  – Absorbers can be “flat” or “round” (depends on aspect ratio)
  – All absorbers include a flat region (short for spoilers, long for absorbers)
  – All collimators copper coated (minimize resistive wakefield contribution)

• Read all about it:
### Summary of Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TESLA</th>
<th></th>
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<th>NLC</th>
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<td>$A_x$</td>
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<td>$A_\delta$</td>
<td>$A_x$</td>
<td>$A_y$</td>
<td>$A_\delta$</td>
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<td>$A_y$</td>
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<tr>
<td>$\delta$ Spoilers</td>
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<td>0.0540</td>
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<td>$\delta$ Absorbers</td>
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<tr>
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<td>0</td>
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<td>2.3357</td>
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<td>1.2029</td>
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</table>

$x, \delta$ terms probably okay; $y$ values excessive (IP jitter dominated by FD jitter and collimator wakes) – should get $A_y < 0.5$

Fractional emittance growth = $(0.4\text{nA})^2$, so maybe okay even in vertical

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*P. Tenenbaum*
CollWake Test Facility

- Installed at 1.19 GeV point in SLAC linac
- Uses damped beam, $\sigma_z \sim 0.6$ mm
- Procedure:
  - Insert coll in beam path (x mover)
  - Move collimator vertically (y mover)
  - Measure deflection in SLAC linac
  - Fit kick angle vs coll-beam offset
First Tests

- **Tapered copper collimators**
  - study geometric kicks
- 1 “round” (square), 3 flat
  - 2 different apertures
  - 2 different taper angles
  - flat colls fairly “steep” tapers (per theory)
  - round coll more “shallow” taper
First Tests: Results

- **Round collimator:** good agreement with theory
- **Flat collimators:** not great
  - good agreement with MAFIA
  - in some cases, factor 2 disagreement between theory and experiment
  - Issues with intermediate regime
    - does it really exist?
Second Test

- 1 Cu tapered collimator
- 2 C (graphite) tapered collimators (courtesy of DESY)
  - direct check on graphite wakefields due to low conductivity
- To make a long story short: pretty good agreement with resistive wakefield theory
  - would like to do a better test with more signal from resistive wake
Third Test (coming soon!)

- 4 collimators with identical tapers
  - 2 Cu, 2 Ti (25 x resistivity of Cu)
  - 2 plain tapers, 2 with long flat section (1 m)
- Flat section of Ti should give kick of 2 V/pC/mm
  - compare to 1.5 V/pC/mm for Cu taper alone!
Future Tests

- Obvious problems with geometric wake theory
  - factor of 2 level
  - big factor for LC’s!
- Tests so far somewhat limited
  - uncertainty of TF performance
  - Alignment concerns
- Contemplating much tighter (1 mm) half-gaps
- More complex shapes
  - “two-step” taper?

![Graph showing kick factor vs. taper angle]

<table>
<thead>
<tr>
<th>Collimator</th>
<th>Geometric kick</th>
<th>Resistive kick</th>
<th>Total kick</th>
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<tr>
<td>2</td>
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<td>9.0</td>
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<tr>
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<td>0.6</td>
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