NLC - The Next Linear Collider Project

“The line between the devil’s teeth and that which cannot be repeat”

NLC Collimation

Collaboration Meeting
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Collimation Task Force


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Requirements of Collimation

- Remove particles which cause backgrounds
- Limit backgrounds from collimation muons
- Machine Protection from linac faults
  - energy
  - betatron
- Survive linac faults
- Limit Halo Regeneration
  - wakefields
  - nonlinear optics
  - scattering in BDS
- Limit wakefield luminosity loss from collimators
  - jitter amplification
  - emittance dilution
- Do not Fundamentally limit BDS energy reach!
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Collimation Locations

- **Sources**
  - at sources
  - at 250 MeV point
  - at 2 GeV point

- **Injector Linacs**
  - $\beta$: 2 GeV point
  - $\delta$: 8 GeV point

- **Post main linac**
  - before FF

- **Final Focus**
  - high $\beta$ points
Collimation Amplitude

- **Fundamental limit:** FD Quad SR → VTX
- **Acceptance:**
  - $x'^*): \pm 240 \mu\text{rad}$
  - $y'^*): \pm 1000 \mu\text{rad}$
  - rectangular in $(x'y')^*$
- $\eta_{x^*} = 5.9 \text{ mrad}$
  - Assume ±1% energy acceptance
  - uses ± 59 μrad $x'^*$ aperture
- **500 GeV CM, max $\theta'^*s$:**
  - $x: \pm 4.8 \sigma$
  - $y: \pm 17.7 \sigma$
• Limits total population of halo acceptable
  – expect \( <10^7 \) e\(\pm\) / train
• Assume use of 2 iron muon spoilers
  – “tunnel-fillers”
• Detector limits:
  – zero/train too few
  – 1000/train too many?
• 500 GeV CM: \( \sim 10^9 \) halo / train \( \rightarrow \) \( \sim 10 \) \(\mu\) / train
  – design to this number
• Also constrains transmission
  – \( < 10^{-5} \) required
Surviving Linac Faults

Damage mechanism: pulsed heating from beam-matter interaction

- Expect frequent energy faults with no warning
  - too many pulsed devices
- Expect few beta faults with some warning
- Use spoilers to protect absorbers, as in ZDR
- Energy spoilers need passive survival
- Beta spoilers do not need passive survival
  - “consumable” spoilers (more on this later)

Acceptable $\Delta T$ limits not clear
Experiments underway (more on this later)
• **Fundamental minimum**
  – Fatigue damage due to image currents on surface ("I²R" heating)

• **Limits unclear**
  – Expt: 120°C rise x 10⁷ shots = damage in Cu (single shot limit ~180°C)
  – Conservative: use 10% of approx. single-shot limit
  – Be or Cu: 60-90 µm half gap acceptable
  – Other materials: 300-500 µm half-gap indicated
The Basic Design

- Collimate energy and betatron halo separately
- Halo $< 10^9 / \text{train reduced 5 orders of magnitude}$
- $\pm 1\%$ energy acceptance
- $4.8 \, \sigma_x, \, 17.7 \, \sigma_y$ collimation at 500 GeV CM
- 2 phases, 2 planes, 2 times
- Spoilers protect absorbers
- Energy spoilers survive impact of full bunch train
- No big bend / arc -- only doglegs / chicanes
The Basic Design (2)

- **Spoiler Parameters:**
  - Energy: 1.2 mm adjustable half-gap, Be or C or Ti
  - Betatron: 150-350 µm adjustable half-gap, Be/Cu
- **Absorber Parameters:**
  - Energy: 2 mm adjustable half-gap, Ti/Cu
  - Betatron: 1 mm fixed radius, Ti/Cu, round
- **SR emittance dilution @ 1 TeV CM:**
  - 3% in energy collimation, 2% in “cleanup” dogleg
- **Pulsed Extraction Magnet in Energy Coll**
  - downstream of energy diagnostics
  - useful during linac commissioning
- **2 families of sextupoles, 2 families of octupoles**
  - all magnets reasonable
The Basic Design (3) -- Optics

\[ \frac{\delta E}{p_0 c} = 0. \]

*Table name = TWISS*
Simulation Studies

- **Optical Performance**
  - good bandwidth for beam core
  - dynamic aperture marginal
    - high-order chromogeometric aberration found
    - might be in FF or Coll system
    - More studies coming

- **Halo Transmission**
  - $\sim 4 \times 10^{-5}$ with 0.5 RL spoilers
  - $< 1 \times 10^{-5}$ with 1.0 RL spoilers
  - Some optimization still possible
Fundamental R&D Issues

- **Collimator Wakefields**
  - How bad? Geometric vs resistive vs surface finish? Near-wall wakefields?
  - Subject of significant R & D effort

- **Materials for Spoilers**
  - Damage limits? Wakefields (from resistivity)?

- **Design and engineering of spoilers**
  - consumable
  - renewable
• **Main issue is damage from pulsed heating**
  – very hard to calculate

• **A problem all over NLC**
  – main linac: single-pulse damage to structures during startup
  – Positron target: single-pulse and fatigue damage

• **Addressed by coupon “death ray” tests in FFTB**
Materials Considerations (2)

Results from “Death Ray I” Copper Coupon Tests

- Expect damage when $\rho_{\text{max}} \sim 10^5 \text{ e}^\pm / \mu\text{m}^2$

- No damage on some shots with $\rho_{\text{max}} \sim 10^7 \text{ e}^\pm / \mu\text{m}^2$

- Cu may tolerate single shots with much higher density than we plan

- Ongoing tests of other materials

\[\text{Graph showing correlation between incident electron/micron}^2 \text{ and measured impact point size (microns)}\]
“Consumable”

- Easier to design, build
  - rotating wheel spoiler

- Relies on assumptions:
  - linac fault rate
  - single-pulse damage limit
  - fatigue damage limit

- Requires minimum beam stay-clear (fatigue)

- Some materials science
  - bonding Be to Cu -- done

“Renewable”

- Hard to design, build
  - liquid metals, cooling, heating, moving parts in vacuum, liquid metal pumps

- More forgiving on assumptions

- Permits much smaller minimum stayclear
  - can be damaged on every linac pulse

- Lots of materials science
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Consumable Spoiler

- First prototype in shops
- Study
  - stability
  - placement accuracy
  - UHV performance
  - diagnostics
  - Overall mechanical viability of design
- Looks promising so far
Renewable Spoilers

- **Materials selected**
  - Liquid Tin collimation surface with Niobium wheel

- **Prototype**
  - In progress!
Conclusions

• Post-linac coll: Reasonable design exists

• Several non-simulation R & D projects

• LCC-Note-0052 now available
  – print it double-sided
Open Issues

- Spoiler Wakefields
- Damage Thresholds
- Spoiler Materials
- Spoiler Thickness
- Halo Populations
- Dynamic Aperture
- Tolerances

- Iterations of collimation
  - trades length, jitter budget against attenuation of halo

- Addition of nonlinear optics
  - improve protection but may degrade optics performance
  - May permit larger (ie, looser) coll aperture