NLC Collimation

Collaboration Meeting
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“The line between the devil’s teeth and that which cannot be repeat”
Collimation Task Force


With special thanks to:

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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!
Collimation Locations

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

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

- **Post main linac**
  - before FF

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

- **Fundamental limit:** $FD$
  - Quad SR $\rightarrow$ VTX
- **Acceptance:**
  - $x^\ast$**: $\pm 240 \mu$rad
  - $y^\ast$**: $\pm 1000 \mu$rad
  - rectangular in $(x'y')^\ast$
- $x^\ast = 5.9 \text{ mrad}$
  - Assume $\pm 1\%$ energy acceptance
  - uses $\pm 59 \mu$rad $x'^\ast$ aperture
- **500 GeV CM, max $\theta'^\ast$s:**
  - $x$: $\pm 4.8 \text{ s}$
  - $y$: $\pm 17.7 \text{ s}$
Muon Production

- 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

- 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)

Damage mechanism: pulsed heating from beam-matter interaction

Acceptable $\Delta T$ limits not clear
Experiments underway (more on this later)

P. Tenenbaum
**Spoiler Gap Size**

- **Fundamental minimum**
  - Fatigue damage due to image currents on surface ("$I^2R$" heating)

- **Limits unclear**
  - Expt: $120^\circ$C rise x $10^7$ shots = damage in Cu (single shot limit ~$180^\circ$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
- $4.8 \, s_x, 17.7 \, s_y$ 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
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?
  - Next talk!

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

• **Design and engineering of spoilers**
  - consumable
  - renewable
Spoiler Materials

• 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** \( \sqrt{E_{\text{max}}} \approx 10^5 \text{ e} \pm / \mu\text{m}^2 \)

- **No damage on some shots with** \( \sqrt{E_{\text{max}}} \approx 10^7 \text{ e} \pm / \mu\text{m}^2 \)

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

- **Ongoing tests of other materials**
Spoiler Design + Engineering

“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 stay-clear
  - can be damaged on every linac pulse

- Lots of materials science

P. Tenenbaum
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 degrade optics performance