NLC - The Next Linear Collider Project

Post-Linac Collimation

NLC Collaboration Meeting
FNAL, June 2000

P. Tenenbaum
Overview of Collimation

• A serious problem for all high-performance colliders
  – # of collimators tends to increase over machine lifetime!

• A nightmare for NLC -- must be addressed in systematic, machine-wide fashion
  – bunch length collimation in DR extraction?
  – 5-D system at end of pre-linac (8 GeV)
    • part of machine protection system
  – Post-linac 5-D system
    • part of machine protection system
  – Collimators in FF high-β points
  – Assorted detector masking
  – Possible sacrificial collimators
Properties of Post-Linac Collimation System

- Collimate large-amplitude particles which make backgrounds
  - \( x, x', y, y', \delta \)
  - Do not generate bkgds from nonlinearities
  - Do not generate bkgds from muons
  - Do not generate bkgds from collimated primary particles

- Minimize collimator wakefield effects
- Do not degrade luminosity
- Protect FF and LCD from beam core
- Collimators must survive \( \sim 1 \) year ops
- System design must be OK for CM energies from 0.1 \( \rightarrow \) 1.0 TeV
- Pulsed linac extract with diagnostics
• **Set by SR emission in final doublet**

• **CD-1**: $8 \sigma_x$ by $40 \sigma_y$ at 1 TeV CM

• **Need to follow up on:**
  - aperture at lower energies?
  - New FF optics changes aperture?
  - masking and soft bend set up ok?
Sources of Beam Halo

- **Per $10^{12}$ particles (1 train), we expect:**
  - DR/RTL/Compressor: ?
  - Main Linac Wakefields: <$10^7$ (Tor)
  - Captured Dark Current: ~$10^4$ (Brinkmann)
  - Multipoles in main linac: ?
  - Linac coulomb/compton: ~$10^4$ (Tor)
  - Linac mistuning: ?
  - BDS coulomb/compton: ~$10^3$ (ZDR)

- **SLC experience:** < 1% of beam in halo (most from DRs/RTLs?)

- Expect some improvement from pre-linac collimation

- Present design assumes $10^9$ halo particles, should try to collimate at $10^{-6}$ level (transmitted halo ~ repopulation halo)
ZDR System (1996)

- **Passive survival of 1 bunch-train impact**
  - requires spoilers/absorbers
  - requires big betatron functions, sextupoles...
- **Collimate 5 $\sigma_x$, 35 $\sigma_y$, 4% off-energy**
  - interleaved collimators and lots of them
    - Jitter amplification: $\sim 0.25 \sigma$ in quadrature
    - $x, \delta$ combined collimation (not independently tunable)
    - IP phase collimation looser
    - 2 phases x 2 planes x 2 times collimation
- **Long (2.5 km) system far from IP**
  - hard to operate but good for muon bkgds
ZDR Collimation System Optical Functions

- $\beta_x, m$
- $\beta_y, m$
- $\epsilon_x, m$

Graph showing variations in $\beta_x, \beta_y, \epsilon_x$ with respect to $z, \text{meters}$.
ZDR System Problems

- Long system with many elements
- Tight tolerances
- Micron level magnet misalignments steered beam into downstream collimators
- Energy collimation too loose
- Loose collimation in IP phase does not work
  - Off energy particles have phase migration

1999: Time for a New Approach!
Collimator Damage Options

• 4-D parameter space:
  – tolerances
  – collimator survival also
  – muon backgrounds
  – tail populations

• ZDR design pushed tolerances

• Redistribute the pain—ease tolerances with engineering design!

Single Pulse Collimator Damage

- Conventional collimators not damaged
- ‘Consumable’ collimators damaged ~1000x per year
- ‘Renewable’ collimators damaged each pulse

Optics Tolerances
Tighter

Looser

Never

Seldom

Always
Consumable Collimator

- Rotating-wheel spoiler
  - many degrees of freedom needed
  - positioning accuracy
  - prototype soon
- Can be hit by beam core 1000x per run
- Absorbers can be far from core (~mm), hard to hit
- Allows optics with smaller beams
The New Approach

• Separate energy and betatron collimation
  – energy still needs passive protection
  – maximize $\eta/\beta$ ratio
  – collimation depth to 1%?

• Equal coll depths for IP and FD phases
  – permits arbitrary phase advance to IP

• Consumable spoilers in betatron coll
  – smaller beam sizes
  – min coll aperture limited by image current heating
  – DC heating from halo also an issue
The New Optics

Energy and Betatron Collimation Plus All Matching Regions

Table name = IWJSS
Energy Collimation

- **Spoiler/Absorber system used for passive survival**
  - Be spoilers (0.5 RL), Ti/Cu absorbers (20 RL)

- **20 cm** \( \eta_{\text{max}} \)
  - 1% energy collimation possible in principle

- **Looser tolerances**
  - \( R_{34} \text{ max } \sim 200 \text{ m, not } 41 \text{ km} \)

- **Emittance dilution from SR \( \sim 5\% \) at 1 TeV CM**
  - slightly larger than old system (4%)

- **Post-linac energy diagnostic and pulsed dump**

- **Collimator wakefield cancellation**
  - 2 sets of spoilers/absorbers at -1 in betatron optics but equal dispersions -- to 1st order wake kicks cancel

- **2” OD vacuum chamber**
  - allows 10% off energy beam to be handled
  - really good pumping!
Betatron Collimation

- 2 phases x 2 planes x 2 times collimation
  - 0.5 RL spoilers (~200 µm half gap at 1 TeV CM)
  - 20 RL absorbers (1 mm half aperture @ 1TeVCM)
- $5.7 \sigma_x \times 28 \sigma_y$ collimation, 90/270 deg lattice
  - gives correct collimation depth at 45 degrees in beta phase
  - can loosen coll depth if 45/135 deg lattice is used
- Smaller beta functions, looser tolerances
- Ti/Cu absorbers -- okay as long as beam goes thru a spoiler first!
- Jitter amplification: around 46%
  - ZDR system had almost 70%
  - $(0.46) \times (0.37 \sigma$ incoming jit) = $0.17 \sigma$ added jitter
  - tolerance for entire BDS is $0.25 \sigma_y$
Performance Factors

- Halo transmission: \( \sim 10^{-5} \), goal is \( 10^{-6} \)
  - dependent on halo distribution

- Primaries in 2nd half of betatron system: \( 10^7 - 10^8 \), goal is \( 10^7 \)

- Power hitting quads is 1.3% of halo (total) -- OK

- Primary/secondary beam size on absorber: > 1.5 mm, OK

- Total bandwidth \( \sim 3\% \), goal is 4%

- Muons in LCD: too many, but can add muon spoilers (presently 2 per side)
Conclusions

• New collimation system proposed for NLC post-linac region
  – 1.2 km long
  – looser tolerances than ZDR scheme

• Looks promising

• Many detailed calcs/studies, which have just begun!