NLC IR1 and IR2 Layout, BDS Optics and Collimation

NLC MAC meeting, June 2003

Andrei Seryi
Last time the BDS optics was presented to MAC was in May of 2001

- Compact system with local chromaticity corrections
- Collimation system has been built in the Final Focus system
- Two octupole doublets are placed in NLC FF for active folding of beam tails
Contents:

- Optics, configuration, evolution of second IR requirements, performance
- Design methods
- Collimation: comparative work done for TRC
- Collimation wakes
- Magnet design
- Muons
- Material tests
- Non-static background
- Design flexibility and parameter choice
1$\text{st}$ and 2$\text{nd}$ IR layout evolution

- Some time ago, considered high and low energy IRs, which were not considered fully equivalent
- The 1$\text{st}$ IR will always have higher potential (straight tunnel, good for multi TeV)
- But now have stronger requests to make them more equivalent, at least up to 1.3 TeV CM
  - Require that Lumi of two IRs can be equal within 30%
  - Require that energy can be change often (=>$SC$ FD)
- Evolution of IR layout is driven by these requests...
  - May/03: 1400m BDS in 1$\text{st}$ IR; 970m BDS in 2$\text{nd}$ IR
  - June/03: Same in 1$\text{st}$ IR; One-way 970m BDS in 2$\text{nd}$ IR
  - Soon (July/03?): same in 1$\text{st}$ IR:
    ~1100m one-way BDS for e- in 2$\text{nd}$ IR
    ~1400m one-way BDS for e+ in 2$\text{nd}$ IR
May/03 release of NLC optics contain the following

- Put together by Mark Woodley
- 250 GeV beams
- Beam Switchyard
  - skew correction / $\epsilon$ diagnostics
- post-linac dump lines
  - continuous duty cycle, 13 MW
- Interaction Region Transport
  - low energy: $<30\% \Delta \epsilon/\epsilon$ from ISR for 650 GeV beam
- collimation / Final Focus
  - high energy: “full length” (1434 m) system
  - low energy: “2/3 length” (968 m) system
- primary dump lines
  - Yuri Nosochkov’s most recent design (March 21, 2003)
  - 100 m drift added to separate dumps from IPs
May/03 layout

1st and 2nd IR configuration and optics

Crossing angle:
IP1: 20 mrad
IP2: 30 mrad

dPath(1st IR - 2nd IR) = 299.79 m (which is DR perimeter) for timing system

1st IR BDS: “full length” (1434m) TRC era version

2nd IR BDS: “2/3 length” (968 m) 4/28/03 version

Bends in optics as shown optimized for 250GeV/beam

Less than 30% emittance growth in 2nd IR big bend at 1.3TeV CM

Δε/ε Big Bend @650 GeV (e-) = 25.1% Δε/ε Big Bend @650 GeV (e+) = 25.2%
ΔZtotal = 4135.2 m (+510.1 m wrt NLC2002)

All decks are released at NLC Tech Web:
Acc.Physics=> NLC Optical Lattices => NLC2003 Lattice
IP2 crossing angle = 30 mrad
\[ \Delta \epsilon / \epsilon \] from ISR <30% for 650 GeV beam
Yuri Nosochkov's combined function FODO Big Bend
23 cells (L_{cell} = 23 m)

Low Energy Interaction Region Transport

Beam Switchyard

full bunch train: nominal charge, \( \epsilon, \sigma_z, \sigma_{\delta} \); full rate (120 Hz)
13 MW for 750 GeV beam (\( \sigma_{x,y} = 0.5 \text{ mm} \)); \( \pm 20\% \) energy Acceptance: 8 cm bore (diameter) ; \( L = 350 \text{ m}, \Delta X = 5 \text{ m}, \Delta Y = -1 \text{ m} \) separate enclosure (vault) for dump
Collimation / Final Focus Optics

High energy:
“full length” (1434 m) compact system (TRC report version)

Low energy:
“2/3 length” (968 m) compact system (4/28/03 version)

Bends in optics as shown optimized for 250 GeV/beam

Note that both BDS have bending in E-Collimation opposite to bending in FF, to nearly cancel the total bend angle. (Either one fits in a straight tunnel).
BDS layout change in upgrade to 1TeV CM
(example for 2nd IR BDS)

For upgrade:
Reduce bending angle in FF twice, and increase bending angle in E-Collimation by ~15%.

Location of IP is fixed.

With proper rescaling of SX, OC, DEC fields aberration cancellation is preserved

BDS magnets need to be moved by ~20cm.

Outgoing angle change by ~1.6 mrad (=> the extraction line also need to be adjusted)

Bends in 1TeV optics are optimized for 650GeV/beam

\[ \Delta x^* = 0, \Delta z^* = 583.3 \text{ \mu m}, \Delta \theta^* = 1.6767 \text{ mrad} \]
Motivations for one-way BDS for 2\textsuperscript{nd} IR

- To get 30mrad X-angle, the 2\textsuperscript{nd} IR needs 25mrad of FODO
  - This takes \sim 600m (to keep SR emittance growth small)
    - \Rightarrow the 2\textsuperscript{nd} IR BDS is much shorter than the 1\textsuperscript{st} IR BDS
- Luminosity loss in BDS scales as \( \frac{dL}{L} \sim \gamma^{1.75} / L^{2.5} \). That means:
  - Required length scales only as \( L \sim \gamma^{0.7} \) (i.e. soft function of E)
  - But luminosity loss can be significant when the length is decreased
    - \Rightarrow Would like to make the 2\textsuperscript{nd} IR BDS as long as possible

- \Rightarrow Make bends in E-collimation and FF to bend in the same direction, giving \sim 8mrad, and reducing the angle required from the FODO to about 17mrad
  - This will allow to shorten the FODO about twice (as \( d\epsilon \sim \theta^3 / l^2 \))
June/03 layout
2nd IR with “one-way” bending BDS

Big Bend => from 23 cells to 10 cells for δε/ε<30% @ 650 GeV/beam

All "stretches" in high E beamlines are removed => two high E BDS systems mirror symmetric about IP1 once again

The overall "Z-length" of the entire BDS is now determined by the high energy systems

We get 125 m of "extra" space in the short low energy e- beamline => will be used to lengthen the BDS

We can make the e+ low energy BDS longer by 450 m, which makes it equal to high E system

the "Z-length" of the BDS now 3962.7 m w.r.t. 4135.2 m, so the NLC site got shorter by 172.5 m

Based on: 1st IR: TRC version of NLC BDS (~1400m);
2nd IR: May 2003 version of one-way BDS (~970m)
BDS layout change in upgrade to 1TeV CM
(example for one-way BDS for 2<sup>nd</sup> IR)

Upgrade is done in the same way as for standard BDS:

- Reduce bending angle in FF twice, and increase bending angle in E-Collimation by ~15%.
- Location of IP is fixed.
- With proper rescaling of SX, OC, DEC fields aberration cancellation is preserved.
- BDS magnets need to be moved by ~20cm.
- Outgoing angle change by ~1.6 mrad (=> the extraction line also need to be adjusted).
- Bends in 1TeV optics are optimized for 650GeV/beam.
2nd IR BDS optics

2nd IR BDS for 250GeV/beam

250GeV/beam: ff2ir52903745pm  one-way bending BDS
500GeV/beam: ff2ir66032002pm  (less bending in FF and long FD)
BDS performance (June layout)  
1st and 2nd IR

Performance of NLC BDS (optics only: include aberration and synch. radiation). Effect such as beam beam or collimator wakes (!) are not taken into account.

1st IR: ff112, ff112lfd (long FD), ~1400m; 2nd IR: ff2ir52903745pm (one way FF), ff2ir6603202pm (one way FF, long FD), ~970m. Same nominal ε Upgrade= ↓ by ~50% bend angles in FF and ↑ by ~15% in energy collimation (IP location fixed, beamline relocated)

The 2nd IR BDS will be lengthened to improve performance
Thin curves show performance if upgrade (=layout change) was not made, or if one goes back from 1TeV to Z pole.

Luminosity loss scales as $\frac{dL}{L} \sim \gamma^{7/4} / L^{5/2}$. That means that though the required FF length scales only as $L \sim \gamma^{7/10}$, the luminosity loss can be significant when the FF length is decreased.
BDS performance
in absolute units

NLC BDS, 1\textsuperscript{st} & 2\textsuperscript{nd} IRs. (Included: Batman dEE & Synch.Rad; Not included: Beam-Beam)

Performance of NLC BDS (optics only: include aberrations and synch.radiation). Beam-beam luminosity enhancement is not included.
Foreseen changes of 2nd IR beamlines

- Due to the use of one-way bending BDS, have extra 125m in e- beamline and 450m in e+ beamline
- Will increase the e- BDS to ~ 1100m and the e+ BDS to ~ 1400m (will be the same as for 1st IR BDS)
- Expect that luminosity dilution in 2nd IR will reduce considerably
- These changes will make 1st and 2nd IRs to be more equivalent
BDS design methods & examples

Example of a 2nd IR BDS optics for NLC; design history; location of design knobs

A design recipe is described in all details in PAC03 and SLAC-PUB-9895
Other (than optics) considerations and possible limitations

- Work of TRC Collimation Task Force
- Possible limiting issues
  - Collimation wakefields
- Muons
- BDS magnets
- Non-static background
- Design flexibility options / parameter choice
- For time reasons, not discussed (or in not much details):
  - Geant3 Simulations of NLC BDS (T.Maruyama, K.Moffeit)
  - Mucarlo muon simulations (e.g. tunnel filler vs. toroids) (L.Keller)
  - Consumable collimation hardware (E.Doyle, J.Frisch, K.Skarpaas VIII)
  - Further collimation wakefield tests (P.Tenenbaum, D.Onoprienko)
TRC Collimation Task Force work

- TRC attempted to verify readiness of the LC designs to deliver the Energy and Luminosity

- As part of this study, the Machine Detector Interface group of TRC, with help of the Collimation Task Force, reviewed performance of the collimation systems

Especially a lot of thanks to Sasha Drozhdin

Linear Collider Collaboration Tech Notes

Comparison of the TESLA, NLC and CLIC Beam Collimation System Performance


1. DESY, Hamburg, Germany
2. CEA-Saclay, Paris, France
3. CERN, Geneva, Switzerland
4. Fermilab, Batavia, Illinois, USA
5. SLAC, Menlo Park, CA, USA
6. University of London, London, United Kingdom

March 2003

~1/2 year study reported in 53 pages, 10 Tables, 40 Figures
LC parameters

Table 1: LC parameters for 500 GeV c.m. energy.

<table>
<thead>
<tr>
<th>parameter</th>
<th>TESLA</th>
<th>NLC</th>
<th>CLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch population, $E + 10$</td>
<td>2</td>
<td>0.75</td>
<td>0.4</td>
</tr>
<tr>
<td>Number of bunches per train</td>
<td>2820</td>
<td>192</td>
<td>154</td>
</tr>
<tr>
<td>Separation between bunches, ns</td>
<td>337</td>
<td>1.4</td>
<td>0.67</td>
</tr>
<tr>
<td>Repetition frequency, Hz</td>
<td>5</td>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>Average current (each beam), $\mu$A</td>
<td>45.1</td>
<td>27.6</td>
<td>19.7</td>
</tr>
<tr>
<td>Beam power (each beam), MW</td>
<td>11.3</td>
<td>6.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Normalized emitt. x,y, mm$\cdot$mrad</td>
<td>10, 0.03</td>
<td>3.6, 0.04</td>
<td>2.0, 0.01</td>
</tr>
<tr>
<td>Beta function at IP, x,y, mm</td>
<td>15.2, 0.41</td>
<td>8, 0.11</td>
<td>10, 0.05</td>
</tr>
<tr>
<td>Beam size at IP, x,y, ($\sigma$), nm</td>
<td>553, 5</td>
<td>243, 3</td>
<td>202, 1.5</td>
</tr>
</tbody>
</table>

- Assume (pessimistically) that we would need to collimate 0.001 of the beam
  - (despite that estimations predict much less)
NLC and CLIC use new FF with local chromaticity compensation

TESLA - traditional FF design

JLC/NLC and CLIC have crossing angle

TESLA - no crossing angle: more complications for setting the collimation system

NLC:

TESLA and CLIC:
Simulation tools

- Use STRUCT program
  - Cross check with TURTLE and Geant3
- Assume 0.001 of the beam in halo
- Distribute halo in 1/r manner surrounding the nominal collimation depth
  - Such distribution is more pessimistic than the flat one
- Gaussian in E

<table>
<thead>
<tr>
<th></th>
<th>TESLA</th>
<th>NLC</th>
<th>CLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of $A_x/\sigma_x$</td>
<td>7-18</td>
<td>6-16</td>
<td>5.7-14.2</td>
</tr>
<tr>
<td>Range of $A_y/\sigma_y$</td>
<td>40-120</td>
<td>24-73</td>
<td>54-162</td>
</tr>
<tr>
<td>Momentum spread $\sigma(dP/P)$, %</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Typical number of rays</td>
<td>$5 \cdot 10^5$</td>
<td>$5 \cdot 10^5$</td>
<td>$5 \cdot 10^5$</td>
</tr>
</tbody>
</table>

Halo parameters used in simulations and example of initial beam distributions
Methodology

- The effectiveness of the collimation system can be quantified in terms of:
  - the fraction of initial halo particles that survive (or are rescattered out of) the primary collimation system and hit secondary collimators or other aperture limitations closer to the IP
    - this is relevant when estimating muon backgrounds
  - or
    - the number of halo particles that lie outside the collimation depth when they reach the final doublet
      - this is relevant when estimating synchrotron-radiation backgrounds
Performance in terms of halo particle losses along the beamline

- NLC achieves a primary-collimation efficiency better than 1E-5
- CLIC collimation system achieves a primary-collimation efficiency of about 3E-4
  - For both in NLC and CLIC this efficiency number is a too crude figure of merit as losses vanish sharply after the collimation system. Further studies of muon reaching detector would give a better indication of performance

- In TESLA the loss rate in the secondary system amounts to about 1% of the initial halo population
  - The system, as currently designed, is not doing its job.
  - Studies of the reasons of such performance are ongoing
  - TESLA team is redesigning their FF using the new FF scheme
Performance in terms of halo size at the FD (SR on VX)

- In NLC, the edge of the collimation depth is sharply defined, and there are no particles outside collimation depth.
- In CLIC, the edge is sharp too, but one needs to iterate on desired collimation depth/gap settings.
  - For both NLC and CLIC, the photons flux hitting SR masks seem to be small enough.
- In TESLA, the boundary of the collimated halo is not visible.
  - Charged-halo losses on the SR mask ~7400 particles/bunch.
  - SR photons from the halo hitting detector masks: ~$10^5$ photons/bunch 3m downstream of IP and ~$10^7$ at 18m downstream.
Conclusions for TRC

• Comparative studies of the performance of the post-linac beam-collimation systems in the TESLA, NLC and CLIC designs have shown that the performance of the systems as currently designed is not uniform across projects, and that it does not always meet all the design goals.

• As of this writing, the CLIC and NLC collimation schemes appear the most promising.

• Improvements of the TESLA collimation system are expected to result from the ongoing overhaul of their BDS design.

• Overall, the very existence of an acceptable solution suggests that achieving the required performance in future linear colliders is feasible.
Further verifications of collimation system

- For TRC study, for the NLC system, considered only the more pessimistic case of Octupoles OFF
  - (These are tail folding octupoles which allow to increase opening of the collimation gaps ~3-4 times)

- The Oct ON case has been recently verified and shows very good performance also

- Would like to verify muon background and suppression by tunnel fillers using MARS simulations - ongoing
Controlling beam background with nonlinear elements

- Two octupole doublets give tail folding by ~ 4 times in terms of beam size in FD
- This lead to relaxing collimation requirements by ~ a factor of 4
  “Tail folding” = put particles from the halo of the beam back into the core

Tail folding by means of two octupole doublets in NLC final focus
Performance of NLC BDS looks very good both with and without octupoles. The Oct ON case allow to open the collimation gaps and reduce the collimation wake fields to an acceptable level.

With Oct ON the beam losses along the beamline behave nicely, and SR photon losses occur only on dedicated masks (gaps are ±0.6mm instead of ±0.2mm).

(So far achieved factor of 3 from ideal 4. Perhaps can do better)

Collimation gaps and wakes

Collimation settings as of end of TRC review (Octupoles OFF)

<table>
<thead>
<tr>
<th>S</th>
<th>Name</th>
<th>BetaX</th>
<th>BetaY</th>
<th>Dispers.</th>
<th>(\lambda_x)</th>
<th>(\lambda_y)</th>
<th>(\sigma_x)</th>
<th>(\sigma_y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>0.007</td>
<td>SP1</td>
<td>35.83</td>
<td>7.07</td>
<td>0.000</td>
<td>0.30</td>
<td>0.25</td>
<td>18.5</td>
<td>326</td>
</tr>
<tr>
<td>76.491</td>
<td>SP2</td>
<td>103.28</td>
<td>523.42</td>
<td>0.000</td>
<td>0.28</td>
<td>0.20</td>
<td>10.2</td>
<td>31</td>
</tr>
<tr>
<td>152.374</td>
<td>AB3</td>
<td>35.82</td>
<td>7.08</td>
<td>0.000</td>
<td>1.00</td>
<td>1.00</td>
<td>61.5</td>
<td>1304</td>
</tr>
<tr>
<td>152.491</td>
<td>SP3</td>
<td>35.82</td>
<td>7.08</td>
<td>0.000</td>
<td>0.30</td>
<td>0.25</td>
<td>18.5</td>
<td>326</td>
</tr>
<tr>
<td>228.374</td>
<td>AB4</td>
<td>103.28</td>
<td>523.42</td>
<td>0.000</td>
<td>1.00</td>
<td>1.00</td>
<td>36.3</td>
<td>153</td>
</tr>
<tr>
<td>228.491</td>
<td>SP4</td>
<td>103.28</td>
<td>523.42</td>
<td>0.000</td>
<td>0.28</td>
<td>0.20</td>
<td>10.2</td>
<td>31</td>
</tr>
<tr>
<td>288.866</td>
<td>AB5</td>
<td>59.74</td>
<td>5.36</td>
<td>0.000</td>
<td>1.40</td>
<td>1.00</td>
<td>66.8</td>
<td>1500</td>
</tr>
<tr>
<td>288.983</td>
<td>SP5</td>
<td>59.74</td>
<td>5.36</td>
<td>0.000</td>
<td>0.42</td>
<td>0.25</td>
<td>20.0</td>
<td>375</td>
</tr>
<tr>
<td>497.592</td>
<td>SPE</td>
<td>226.69</td>
<td>10058.96</td>
<td>0.213</td>
<td>3.20</td>
<td>3.20</td>
<td>78.3</td>
<td>112</td>
</tr>
<tr>
<td>662.449</td>
<td>ABEa</td>
<td>244.35</td>
<td>329.16</td>
<td>0.007</td>
<td>1.10</td>
<td>1.10</td>
<td>25.9</td>
<td>212</td>
</tr>
<tr>
<td>664.749</td>
<td>ABEb</td>
<td>240.00</td>
<td>283.52</td>
<td>0.006</td>
<td>1.10</td>
<td>1.10</td>
<td>26.2</td>
<td>228</td>
</tr>
<tr>
<td>890.421</td>
<td>AB10</td>
<td>13276.75</td>
<td>149854.87</td>
<td>0.000</td>
<td>4.40</td>
<td>4.40</td>
<td>14.1</td>
<td>40</td>
</tr>
<tr>
<td>911.000</td>
<td>AB9</td>
<td>38123.55</td>
<td>55295.79</td>
<td>0.000</td>
<td>6.50</td>
<td>3.00</td>
<td>12.3</td>
<td>45</td>
</tr>
<tr>
<td>984.952</td>
<td>AB7</td>
<td>36.63</td>
<td>82.44</td>
<td>-0.026</td>
<td>3.90</td>
<td>1.00</td>
<td>238</td>
<td>385</td>
</tr>
<tr>
<td>1384.005</td>
<td>DUMP1</td>
<td>21712.01</td>
<td>30406.34</td>
<td>-0.115</td>
<td>8.00</td>
<td>20.00</td>
<td>20</td>
<td>400</td>
</tr>
<tr>
<td>1420.795</td>
<td>DUMP2</td>
<td>33628.04</td>
<td>52550.49</td>
<td>-0.115</td>
<td>8.50</td>
<td>20.00</td>
<td>17.1</td>
<td>303</td>
</tr>
</tbody>
</table>

( N.B. At some point, increased increased
L* from 2m to 3.5m, without changing
vertex radius, making it much more
difficult for collimation wakes. )

SP1-SP5 have the tightest settings

Defined purely by optics relation to IP and the
need to shadow the vertex from SR

Collimator wakes is an issue identified by TRC
(even though NLC has less of a problem here than TESLA and CLIC)

The jitter amplification is 1.64 times (\(A_\beta = 1.3\))

![Diagram of collimation setup](image)

tilted w.r.to beam vertex decrease effective radius by 0.3mm
Collimator wakes
Transfer of $Y'$ jitter to $Y$ plane

- With present settings (Octupoles OFF), most of the effect comes from:
  - SP2: $H_y=0.2\text{mm} \quad A_\beta=0.35$
  - SP4: $H_y=0.2\text{mm} \quad A_\beta=0.35$
  - AB10: $H_y=4.4\text{mm} \quad (\text{circ}) \quad A_\beta=0.20$
  - AB9: $H_y=3.0\text{mm} \quad A_\beta=0.33$

- Giving 94% of the total $A_\beta=1.3 \quad \text{(at 500GeV CM)}$

- $A_\beta$ of 1.3 means increase of $Y$ plane jitter by $(1+1.3^2)^{0.5} = 1.64$ times, or by 64% 

  (if $\sigma$ of jitter in $Y$ and $Y'$ planes were the same and uncorrelated)
Options for Collimator Wakes reduction

- Reducing tapering angle (from 20 to 10 mrad) may give several % $A_\beta$ decrease
  - The formula for wakes is accurate nor better than factor of ~2
  => will have next round of measurements, with various gap shapes
- Using folding octupoles reduce contribution of S2,4 and reduce $A_\beta$ to at least 0.7 (that would decrease jitter enhancement from 64% to 22% which is probably acceptable at 500GeV CM)
- This would be OK at 500 GeV CM, however, if we keep the same optics going to lower E, than gaps sizes are constant with energy and wakes scales as 1/E.
  - At 90 GeV CM, we will have $A_\beta \sim 7$ without octupoles and $A_\beta \sim 3.9$ with octupoles. Both these numbers seem unacceptable.
    - Solution 0: The wake formula will be proven to give overestimate
    - Solution 1: Degrade $\beta$* and Luminosity expectations at low E
    - Solution 2: Persuade particle physics community to increase the vertex radius
      (Twice (to 20mm)? To 15mm as in TESLA ?)
Discussion with particle physicists on a possibility to increase vertex detector radius*

Agreed that VX radius is, in certain extents, a free parameter that accelerator physicists can optimize

*) This discussion took place in a context of 500GeV CM. The low energy requirements need to be discussed again.

V. Conclusions

A. I know of no study that demonstrates that either an extremely small beam pipe radius or an extremely thin vertex detector is needed to do justice to LC physics.

B. The studies cited above show very minor performance improvements when the beam pipe radius is reduced from 2 cm to 1 cm, as expected from the qualitative observations above. Radius of 1.5 to 2.5 cm is OK to my thinking.

C. Motherhood: Smaller radius is better, for vertexing resolution. We may learn new vertexing tricks that exploit very high resolution in the future, or see that particular analyses can really benefit from very high resolution.

So, beam pipe radius should be minimized, but subject to constraints imposed by operational stability of the machine, luminosity considerations, and background considerations.
One of the options is to use permanent magnet octupoles (achieved ~11kGs at 1cm radius in 1995)

SC option seem to be possible. It will provide 2-2.5 times higher field, and will give flexibility for tuning and energy change.

Brett Parker's design of SC Octupoles which avoids small radius bending of SC cables

One octupole slice (PM)
Built by Leif Eriksson in ~1995 for SLC FF
Dealing with muons

Lew Keller

Assuming 0.001 of the beam is collimated, two tunnel-filling spoilers are needed to keep the number of muon/pulse train hitting detector below 10.

Good performance achieved for both Octupoles OFF and ON.

Would like to confirm these MUCARLO simulations with MARS.

Studies at FNAL with MARS are ongoing. N. Mokhov.
Muons (Oct. OFF)

Lew Keller

**MUONS in DETECTOR per PULSE TRAIN, BOTH BEAMS**

Octupoles Off

18 m full-tunnel spoiler at Z = 1103 m and 9 m full tunnel spoiler at Z = 788 m

- X Spoilers
- □ Absorbers and Protection Collimators

Total muons in detector per pulse train = 7.0
Muons (Oct. ON)

Lew Keller

Octupoles On

18 m full-tunnel spoiler at Z = 1103 m and 9 m full tunnel spoiler at Z = 758 m

Spoilers

Absorbers and Protection Collimators

Total muons in detector per pulse train = 2.0
Studies with MARS started. So far considered only the case without magnetized tunnel fillers. Preliminary results look similar with MUCARLO simulations. Will continue studies.
Composite materials with Graphite: Al – Gr, Cu – Gr...

CERN colleagues consider use of Cu-Gr for 2nd phase of LHC collimators [R. Assmann, et al.], and would be interested in a beam test. (For the first phase would need Gr with just several % of Cu, and did not find a manufacturer for this => not considered for the 1st phase of LHC collimators).

May be useful for NLC collimators. More studies would be needed. (Beam tests, simulations, etc.)

Graphite Fiber Reinforced Aluminum Composites - MetGraf™-

Beam damage test at FFTB with Cu-Gr coupon?

Copper-graphite (Cu-Gr) surface. The graphite fiber tips appear as plateaus with rugged surfaces embedded in the copper matrix.

Example: POCO's EDM-C200 is a high density Superfine graphite infiltrated with copper. Average Apparent Density (g/cm³) 3.00 Electrical Resistivity 27.5 (micro-ohm-cm) (pure Cu : 1.7 micro-ohm-cm)

Matrix Alloy | MetGraf 7-200 | In Plane
--|--|--
Al | 200 | 200, 125 |
Thermal Conductivity (W/mK) | 6.5-9.5 | 24 |
Thermal Expansion (Avg. ppm/°C) | 13.5 | 13.5 |
Tensile Strength (KSI) | 13.5 | 5.3 |
Compression Strength (KSI) | 29.4 |
Yield Strength (KSI In Compression) | 15.9 |
Young's Modulus (KSI) | 12.870 |
Flexural Strength (KSI) | 23 |
Electrical Resistivity (µ·ohm-cm) | 6.89 |
Hardness (Rockwell C) | 60-80 |
Density (g/cc) | 2.5 |

Copper graphite brushes

Copper-graphite compositions: low contact resistance, high current-carrying capacity and high thermal conductivity for brushes in motors and generators.

http://www.kirkwood-ind.com/

Example: POCO's EDM-C200 is a high density Superfine graphite infiltrated with copper. Average Apparent Density (g/cm³) 3.00 Electrical Resistivity 27.5 (micro-ohm-cm) (pure Cu : 1.7 micro-ohm-cm)

http://www.grc.nasa.gov/WWW/RT1999/6000/6712chao2.html

http://www.yangyang-rg.com/yangyang-racket/

A. Seryi, 06/24/03, MAC mtg.
Electron cloud

- Mauro Pivi started studies of e-cloud effects in e+ BDS (lucky e-e- and γ-γ people!)
- Preliminary studies have shown that in R=3cm vacuum chamber the electron density can be small enough
- In R=1cm chamber and no coating the density level is worrisome
- Haven’t yet estimated the effect of e-cloud trapped in quads on BDS
- To be continued...
GM induced fluctuations of background?

- See about 3% (gm B) and 50% (gm C) of beam position fluctuation at BDS spoilers. Assuming the halo moves as the core does, can estimate, for example, fluctuation of muons. Perhaps small effect for background.
  - Do not really know if the halo moves with beam or its motion is amplified
- Note ~5 sigma fluctuations in FD (gm C)! Even if intra-train feedback will fix the IP offset, the halo may move significantly in FD
  - Need to continue these studies

RMS of BPM reading /(nominal beam size) over the first 256 trains for a particular seed
BDS design and parameter options

Example of BDS optics with much smaller $\beta^*$

Possible motivation: If will have to decrease current to tolerate larger wakes. Then smaller IP $\sigma_x$ would help to preserve Lumi

Optics with $\beta^*_x$ four times smaller seem to be feasible

Some implications: decreased collimation depth (collimator wakes/ larger vertex?); and Oide effect in FD at high $E$

Nominal: $121.3 \times 3 \text{ nm}^2$
Tracked: $132.56 \times 3.21 \text{ nm}^2$

$\sigma_{x0} \sigma_{y0} / (\sigma_x \sigma_y) = 85.5\%$ with $\sigma_c = 0.25\%$

$\beta^* = 2/0.11 \text{ mm}$

$1/\sigma_x \sigma_y = 85.5\%$
(should be better when 32246 would be fixed)
Conclusion

• This was the status of NLC BDS
• The NLC BDS is in good shape and we are working on improvements of its performance