Background

May 1999 - Lehman Review of NLC R&D

DOE Guidance:
  Reduce the cost
  Expand the energy/luminosity reach

Cost reduction:
  New technologies - permanent magnets, solid-state modulators
  More compact optics - Final Focus, Collimation, Bunch compressors
  New layouts to share housings

Physics capabilities:
  Discussions with physicists - ongoing and part of Snowmass preparation
  Physics & detectors meetings LBNL 3/00, FNAL 10/00, JHU 3/01
  Meeting w physicists - FNAL 1/01
Physicists asked for range of energies

Precision measurements at Z (92 Gev), Top (350 Gev), Higgs (250 Gev?)

Highest luminosity at 0.5-1.0 Tev

Future expandability to multi-Tev

FF designs can span ~ factor of 4 in Energy but not factor of 10

ZDR model:
Symmetric design included tunnel cost for 2nd IR but no beamline/detector

2001 model:
New compact FF design can support 2.5 Tev in ~ 700 m (CLIC FF @ 1.5 Tev 3 km)
High E IR beamline has minimal bending to allow for upgrades to 3-5 TeV collisions!
Low E IR with larger crossing angle for $\gamma\gamma$
Options under Study

Options offer Broader physics program (↑$)

Simultaneous operation:
  interleaved pulses to both IRs, possibly different energies
Baseline: pulses to 1 detector for months

180 Hz:
  Injector and up to 250 Gev of Linac
  @ 180 Hz shared - 60/120, 90/90, 180

Issues:
  Simultaneous operation requires separate collimators
  180 Hz requires new Damping rings, better klystron cooling

Status:
  Maintain compatible layout
  Continue to explore, understand costs
NLC design - 500 Gev tunnel, 250 Gev RF
Full tunnel allows flexibility in energy upgrade steps to match funding & physics interest
Any low E start near IP, requires 2nd BC2 180° tunnel
Low E bypass lines can facilitate staging with full tunnel

Questions:
Build full 500 Gev tunnels?
   extra tunnel ~200M$
Build only 250 Gev tunnel to start?
   lower initial $, more expensive later
1. Should there be two detectors in the baseline? **YES**

2. Should there be two IRs, one that runs with no big bend and can operate to the full machine energy at any time, and one that has a bend and a maximum energy of 500 GeV? **YES**
   (explore options to raise IR2 energy to 1 TeV)

3. Should the baseline have simultaneous running (interleaved pulse trains) to both IRs? **NO**
   (this option should be possible later)

4. Should the tunnel be sized for full 500 GeV beam energy (E_cm=1 TeV)? **YES**

5. Should the baseline be based on 70 MV/m gradient with short structures? **YES**
   (cost penalty for 50MV/m should be quoted)
NLC 2001 Configuration

Beam Delivery
2 IRs - High E 0.25-1.0 Tev (upgradable)  
   2.5 km long, 20 mrad X-angle  
Low E  90-500 Gev (? 1 Tev)  
   1.2 km long, 30 mrad angle for $\gamma\gamma$  
   Shared collimation, IR ? x=25m, ? z=440m

Main Linac
Full 500 Gev tunnel, install @low E end  
Bypass line for low E operation, staging

Injector
Compact ‘folded back’ layout  
Central injector for IL, remote for CA

Sites
Cut & cover CA, deep tunnel IL  
also have CA tunnel, IL shallow sites

180 hz and Simultaneous Operation  
NOT in baseline, keep as future options
NLC - The Next Linear Collider Project

Design Parameters

<table>
<thead>
<tr>
<th>High E IP Parameters (3/01)</th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMS Energy (GeV)</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Luminosity (10^{33})</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Repetition Rate (Hz)</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Bunch Charge (10^{10})</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Bunches/RF Pulse</td>
<td>190</td>
<td>190</td>
</tr>
<tr>
<td>Bunch Separation (ns)</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Eff. Gradient (MV/m)</td>
<td>50.2</td>
<td>50.2</td>
</tr>
<tr>
<td>Injected (\gamma\varepsilon_x / \gamma\varepsilon_y) (10^{-8})</td>
<td>300 / 2</td>
<td>300 / 2</td>
</tr>
<tr>
<td>(\gamma\varepsilon_x) at IP (10^{-8}) m-rad</td>
<td>360</td>
<td>360</td>
</tr>
<tr>
<td>(\gamma\varepsilon_y) at IP (10^{-8}) m-rad</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>(\beta_x / \beta_y) at IP (mm)</td>
<td>8 / 0.10</td>
<td>10 / 0.12</td>
</tr>
<tr>
<td>(\sigma_x / \sigma_y) at IP (nm)</td>
<td>245 / 2.7</td>
<td>190 / 2.1</td>
</tr>
<tr>
<td>(\sigma_z) at IP (\mu m)</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Yave</td>
<td>0.11</td>
<td>0.29</td>
</tr>
<tr>
<td>Pinch Enhancement</td>
<td>1.43</td>
<td>1.49</td>
</tr>
<tr>
<td>Beamstrahlung (\delta B) (%)</td>
<td>4.7</td>
<td>10.2</td>
</tr>
<tr>
<td>Photons per e+/e-</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Linac Length (km)</td>
<td>6.3</td>
<td>12.8</td>
</tr>
</tbody>
</table>

The second IR could be available for first physics, and later run simultaneously with shared luminosity.

<table>
<thead>
<tr>
<th>Low Energy IP Parameters (8/00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMS Energy (GeV)</td>
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<tr>
<td>Luminosity (10^{33})</td>
</tr>
<tr>
<td>Repetition Rate (Hz)</td>
</tr>
<tr>
<td>Bunch Charge (10^{10})</td>
</tr>
<tr>
<td>(\sigma_x / \sigma_y) at IP (nm)</td>
</tr>
<tr>
<td>L0 / Ltotal (%)</td>
</tr>
<tr>
<td>Beamstrahlung (\delta B) (%)</td>
</tr>
<tr>
<td>Photons per e+/e-</td>
</tr>
<tr>
<td>Polarization loss (%)</td>
</tr>
</tbody>
</table>
High/Low E IR Layout

Issues:
IR separation for vibration isolation  
(LIGO requirement > 100 m)
Support for 2 energies, simultaneous ops
Low E IR can tolerate more bending but  
bend angle limits maximum energy

Separate tunnels:
Cleanest solution but most $
2.5$ km line to 2nd IR from end of linac

Shared tunnel (partial):
1.2 km line to 2nd IR after collimation  
+ 300 m extra for 1st IR
Both IRs use same collimators or  
separate lines in same tunnel (later)
Bend 25 mrad to allow 1 Tev upgrade
Beam Delivery Layout

$\Delta x = 25\text{m} \quad \Delta z = 440\text{m}$

One Collimation Tunnel per Side
Main Linac Config

8-pack configuration

- Solid-State modulator
- 8 75 MW 3 μs PPM klystrons
- 4 2-mode DLDS systems
- 48 0.9m long structures (was 24 1.8m) with 70 MV/m unloaded gradient

Staging strategy

- Build full 500 Gev/beam tunnel
- Installation starting @ low E end
- Bypass line takes beam from end of installed RF to end of Linac

Low E Bypass line

- 1 line with takeoffs at 50,125,250 Gev + low E return at end of linac
- Tunnel has 150 m extra length

Linac and bypass
Central Injector

Isn’t it cheaper? NO !!

Many versions considered with rough comparative costs
No significant cost savings seen - CI has long transport lines, 270° BC2 bend
Cheapest injector is ZDR remote layout
Choice driven by other considerations e.g. surface injector on FNAL site
Selected 2 options - remote/centralized

What about future 2-Beam option?

CLIC drive beam is ~80 MW so 200 KW injector parasites off drive linac
NLC must build production injector now -> drive beam complex is future issue which does not affect injector layout

NO Impact now
Remote Injector Layouts

**e- Injector Cut and Cover, NLC2001**

- MDR
- LTR
- BSTR: 173m
- SRCS
- Pre-Coll
- BC-1: 169m
- Pre-Linac: 503m
- Main Linac

**e+ Injector NLC 2001, Cut and Cover**

- BSTR
- Targets: 186m
- PDR: 229m
- MDR
- BC-1: 229m
- Pre-Linac: 503m
- Main Linac: 1024m
- SCRS
- Drive Linac: 528m
- Pre-Coll
Central Injector Layout

Fermi Central NLC2001

Vertical Drop Line Layout
(10/31/00 Rev. 0, jcs)

Long Transport Line, Pre-Collimation & BC-2 Systems

Nan Phinney - DOE review 4/4/01
Primary issue:

Establish the physics case for a linear collider with US HEP community

NLC Role:

NLC 2001 Configuration developed in consultation with physics groups

NLC design covers wide energy range with future expandability to multi-Tev and possible 2-IR operation

NLC Collaboration will present a coherent picture of an X-band linear collider as a viable technology choice

~ 150 page Briefing on the NLC planned

NLC co-organizing the LC working group and several of the technology groups
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Briefing on the NLC

(~150 pages total)

Chapters 1-4, 9-10 for HEP physicists
Chapters 5-8 for accelerator + HEP

1. Introduction (8 pages)
2. NLC design and luminosity (6)
3. Collider layout summary (10)
4. Conventional facilities (6)
5. RF system design (30)
6. Injector systems (15)
7. Beam Delivery issues (15)
8. Beam dynamics & performance studies (15)
9. Additional options under consideration (5)
   180 hz, simultaneous operation
   e⁺ polarization, γ-γ and e⁻/e⁻
10. Route to a multi-TeV collider (4)