NLC Damping Ring

Requirements
Cost drivers
Critical technologies - Cost & Risk
Technology choices

LBL / SLAC collaboration

M. Ross
June 1, 2000
# Requirements

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MDR</th>
<th>PPDR</th>
<th>UNITS</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle types</td>
<td>e⁻/e⁺ (e⁻)</td>
<td>e⁺ (e⁻)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nominal beam energy</td>
<td>1.98 GeV</td>
<td>1.98 GeV</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beam energy range</td>
<td>5%</td>
<td>5%</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td>Particles per bunch</td>
<td>1.6x10¹⁰</td>
<td>1.9x10¹⁰</td>
<td>e⁻/e⁺</td>
<td>max</td>
</tr>
<tr>
<td>Number of trains (Nₚ)</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>max</td>
</tr>
<tr>
<td>Bunch spacing within train (τₖ)</td>
<td>2.8 ns</td>
<td>2.8 ns</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Gap for kicker rise/fall (τₖ)</td>
<td>67.2 ns</td>
<td>100 ns</td>
<td>-</td>
<td>min</td>
</tr>
<tr>
<td>Injected x/y-emittance (norm,rms) (γₑₒ)</td>
<td>&lt;150 µm</td>
<td>&lt;42,000 µm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Extracted x-emittance (norm,rms) (γₑₓ)</td>
<td>&lt;3.0 µm</td>
<td>&lt;500 µm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Extracted y-emittance (norm,rms) (γₑᵧ)</td>
<td>&lt;0.03 µm</td>
<td>&lt;100 µm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Injected energy spread (largest of bunch or train)</td>
<td>±1 1.2 rms</td>
<td>1.2 rms</td>
<td>%</td>
<td>max</td>
</tr>
<tr>
<td>Extracted energy spread</td>
<td>0.089 %</td>
<td>0.089 %</td>
<td></td>
<td>max</td>
</tr>
<tr>
<td>Extracted bunch length</td>
<td>4 mm</td>
<td>7.53 mm</td>
<td></td>
<td>max</td>
</tr>
<tr>
<td>Throughput efficiency (MDR 1.9 to 1.6, PPDR 2.8 to 1.9)</td>
<td>&gt;80 %</td>
<td>&gt;68 %</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shaded entries - special note
## NLC - The Next Linear Collider Project

### Ring Specification summary - MDR/PPDR:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MDR</th>
<th>PPDR</th>
<th>UNITS</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference</td>
<td>297</td>
<td>218</td>
<td>m</td>
<td>-</td>
</tr>
<tr>
<td>Current</td>
<td>0.75</td>
<td>0.8</td>
<td>Amp</td>
<td>max</td>
</tr>
<tr>
<td>Loss per turn</td>
<td>760</td>
<td>580</td>
<td>KeV</td>
<td>-</td>
</tr>
<tr>
<td>TME Cell</td>
<td>1B 3Q 4S</td>
<td>1B 4Q 4S</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TME Cell length</td>
<td>6</td>
<td>11</td>
<td>m</td>
<td>-</td>
</tr>
<tr>
<td>Number of TME cells</td>
<td>30</td>
<td>12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Straight length</td>
<td>58</td>
<td>43</td>
<td>m</td>
<td>-</td>
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<tr>
<td>Number of wiggler sections</td>
<td>10</td>
<td>8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Wiggler section length</td>
<td>4.5</td>
<td>TBD</td>
<td>m</td>
<td>-</td>
</tr>
<tr>
<td>Average vacuum pressure</td>
<td>1</td>
<td>10</td>
<td>nTorr</td>
<td>max</td>
</tr>
<tr>
<td>TME quad aperture (diameter)</td>
<td>40</td>
<td>100</td>
<td>mm</td>
<td>min</td>
</tr>
<tr>
<td>Wiggler magnet gap</td>
<td>20</td>
<td>50</td>
<td>mm</td>
<td>min</td>
</tr>
</tbody>
</table>

MDR dynamic aperture design will change TME cell design; require re-optimization

Shaded entries - likely to change
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Cost Summary

249M$ total + fac 59M$, glo 33M$

Cost Drivers M$:
EDI 82
Magnets 89
Vacuum 36
Install. 39
Supports 23
Facilities 59
Global? 33

Total: 341M$

Top 90% $
Cost Summary

- Total system length 1300 m
- Total combined rings 800 m
- Cost/meter 262K$/meter

SPEAR3 cost/meter 256K$
APS (1995) 135K$
MI (1993) 70K$

Example:

<table>
<thead>
<tr>
<th>VACUUM COST K$</th>
<th>NLC</th>
<th>ALS</th>
<th>APS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIRCUMFERENCE</td>
<td>800</td>
<td>197</td>
<td>1104</td>
</tr>
<tr>
<td>VACUUM COST K$</td>
<td>$30,500</td>
<td>$6,074</td>
<td>$20,967</td>
</tr>
<tr>
<td>COST / METER (K$)</td>
<td>($38)</td>
<td>($31)</td>
<td>($19)</td>
</tr>
</tbody>
</table>
Technology choices- Risk and Cost

- Permanent Magnets
- Wiggler
- Vacuum Chamber
- Girder movers
- Tunnel Electronics
- Facilities
  - Thermal control
  - Cooling / Power
- Radiation control

Cost Drivers:
- Magnets 89
- EDI 82
- Installation 39
- Vacuum 36
- Supports 23
- Facilities 59
- Global? 33
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Magnets

Magnet group recommendations

<table>
<thead>
<tr>
<th></th>
<th>edr</th>
<th>pdr</th>
<th>ppdr</th>
<th>eltr</th>
<th>pltr</th>
<th>pxfer</th>
<th>ebc1</th>
<th>pbc1</th>
<th>total</th>
<th>unit K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEND</td>
<td>36</td>
<td>36</td>
<td>18</td>
<td>10</td>
<td>13</td>
<td>2</td>
<td>26</td>
<td>26</td>
<td>167</td>
<td>54</td>
</tr>
<tr>
<td>QUAD</td>
<td>136</td>
<td>136</td>
<td>78</td>
<td>35</td>
<td>36</td>
<td>4</td>
<td>95</td>
<td>95</td>
<td>615</td>
<td>35</td>
</tr>
<tr>
<td>SEXT</td>
<td>120</td>
<td>120</td>
<td>48</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>288</td>
<td>24</td>
</tr>
<tr>
<td>CORRECTORS</td>
<td>?</td>
<td>?</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>4</td>
<td>20</td>
<td>20</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>SEPTA</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>KICKERS</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>SPIN ROTATORS</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>6</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>WIGGLERS</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

4 kinds of magnets

Main Rings  No bulk SmCo activation – only SrFeO (with SmCo tuners)
PPDR/PLTR  Electromagnets because of large size
BC-1/ PXFER  Nominal ‘linac’ style PM
MDR Wiggler  Shielded Nd-FeB

Includes:
- EDI 19%
- Mgmt 48%
- Mover 32%
- PS 19%

Swiss Light Source (SLS) quads
cost 7.1K$
Magnets (2)

Cost 73 K$/each

Cost 41 K$/each w/o Wiggler, Kicker, System EDI and girders

**Magnet costs by component**

<table>
<thead>
<tr>
<th>Component</th>
<th>Fractional cost (of 99M$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTHER MAGNET SYSTEMS</td>
<td></td>
</tr>
<tr>
<td>QUAD SYSTEMS</td>
<td></td>
</tr>
<tr>
<td>PULSED MAGNET SYSTEMS</td>
<td></td>
</tr>
<tr>
<td>MAGNET SUPPORTS/GIRDERS</td>
<td></td>
</tr>
<tr>
<td>MAGNET SYS ACTIVITIES</td>
<td></td>
</tr>
<tr>
<td>DIPOLE SYSTEMS</td>
<td></td>
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<tr>
<td>SEXTUPOLE SYSTEMS</td>
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<tr>
<td>SOLENOID SYSTEMS</td>
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<tr>
<td>CORRECTOR SYSTEMS</td>
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</table>

**TOTAL MAGNET COST INCREASE EM --> PM**

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>DIPOLES</td>
<td>1469</td>
</tr>
<tr>
<td>QUADS</td>
<td>1155</td>
</tr>
<tr>
<td>SEXTUPOLES</td>
<td>312</td>
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</table>
## Magnet Hardware BH comparison

### NLC DR's

<table>
<thead>
<tr>
<th>MAGNET TYPE</th>
<th>TOT</th>
<th>TOT K$</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEND MAGNETS</td>
<td>167</td>
<td>$7,727</td>
<td>$46</td>
</tr>
<tr>
<td>QUAD MAGNETS</td>
<td>615</td>
<td>$10,342</td>
<td>$17</td>
</tr>
<tr>
<td>Sextupoles</td>
<td>288</td>
<td>$2,985</td>
<td>$10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,070</strong></td>
<td><strong>$21,054</strong></td>
<td><strong>$20</strong></td>
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</table>

### APS MI (FNAL) ALS

<table>
<thead>
<tr>
<th>MAGNET TYPE</th>
<th>1993</th>
<th></th>
<th>1995</th>
<th></th>
<th>1989</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>TOT</td>
<td>TOT K$</td>
<td>UNIT</td>
<td>TOT</td>
<td>TOT K$</td>
<td>UNIT</td>
</tr>
<tr>
<td>BEND MAGNETS</td>
<td>80</td>
<td>$3,954</td>
<td>$49</td>
<td>344</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUAD MAGNETS</td>
<td>400</td>
<td>$7,615</td>
<td>$19</td>
<td>208</td>
<td></td>
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</tr>
<tr>
<td>Sextupoles</td>
<td>280</td>
<td>$3,967</td>
<td>$14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>760</strong></td>
<td><strong>$15,536</strong></td>
<td><strong>$20</strong></td>
<td><strong>552</strong></td>
<td><strong>$43,000</strong></td>
<td><strong>$78</strong></td>
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</table>
1999 SPEAR aperture reduction with BL11 wiggler - Very similar to planned MDR (*much* shorter)

Electromagnet field flatness is limited due to pole saturation

$\Rightarrow$ use NdFeB (*with wider poles*)

Use collimation to protect NdFeB (sensitive to few Mrad)

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June 1, 2000

NLC Damping Ring - Marc Ross/SLAC
### Movers, Tunnel Electronics and Environmental Control

#### Movers

<table>
<thead>
<tr>
<th>Cost model</th>
<th>Magnet movers</th>
<th>SLS girder (not incl movers)</th>
<th>1 M$ / ring</th>
</tr>
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<tbody>
<tr>
<td>SLS/ATF</td>
<td>Girder movers (successful)</td>
<td>NLC model movers</td>
<td>5.1 M$ / ring</td>
</tr>
</tbody>
</table>

#### Tunnel Electronics

- Tunnel radiation ~ 50 x higher than main linac (2.5x deeper holes)
- No electronics in pre-damping ring

#### Environmental Control

- SLS/ALS tunnel temperature control:
  - Design for $T_{\text{air}} = T_{\text{water}}$
  - Use weak air conditioning

#### Vertical Position stability:

- 100 µm over 10 m per year
- 10 µm over 10 m per day
- 1 µm over 10 m per hour

Permanent magnets make this easier because of low power dissipation.
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Facilities

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<tr>
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<tbody>
<tr>
<td></td>
<td>(kVA)</td>
<td>(kVA)</td>
<td>(kW)</td>
<td>(kW)</td>
<td>(kW)</td>
<td>(kW)</td>
</tr>
<tr>
<td>e-DR</td>
<td>2500</td>
<td>200</td>
<td>2530</td>
<td>2370</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>e+DR</td>
<td>2500</td>
<td>200</td>
<td>2530</td>
<td>2370</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>e+PDR</td>
<td>2500</td>
<td>4000</td>
<td>3100</td>
<td>5600</td>
<td>100</td>
<td>100</td>
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<tr>
<td>subTotal,</td>
<td>7500</td>
<td>4400</td>
<td>8160</td>
<td>10340</td>
<td>200</td>
<td>110</td>
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<tr>
<td>Totals</td>
<td>11900</td>
<td>18700</td>
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</table>

Expected Load w/o rack power:

4 primary water loops:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>RF</td>
<td>Cavity, klystron, Vacuum chamber</td>
</tr>
<tr>
<td>Magnet</td>
<td>Power magnets (PPDR, septa)</td>
</tr>
<tr>
<td>High Conductivity</td>
<td>RF loads</td>
</tr>
<tr>
<td>Radiation</td>
<td>Collimation, Dumps</td>
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</table>
RD directions

<table>
<thead>
<tr>
<th>RD Task</th>
<th>Partner</th>
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<tr>
<td>Permanent magnets</td>
<td>FNAL</td>
</tr>
<tr>
<td>Radiation control</td>
<td>SLAC/KEK</td>
</tr>
<tr>
<td>Vacuum design</td>
<td>LBNL</td>
</tr>
<tr>
<td>Wiggler design</td>
<td>LBNL</td>
</tr>
<tr>
<td>ATF performance</td>
<td>KEK</td>
</tr>
<tr>
<td>Collective effects</td>
<td>LBNL</td>
</tr>
<tr>
<td>- RF</td>
<td>LBNL</td>
</tr>
<tr>
<td>- Vacuum</td>
<td></td>
</tr>
<tr>
<td>- Feedback</td>
<td></td>
</tr>
<tr>
<td>Kicker systems</td>
<td>SSRL/SPEAR 3</td>
</tr>
<tr>
<td>Tunnel electronics</td>
<td></td>
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</tbody>
</table>