Cold - Warm Considerations for the Detectors

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Cold\textsuperscript{1} - Warm\textsuperscript{2} Considerations for the Detectors

• Politically Incorrect assessment of issues related to the LC technology choice that affects the detectors
• Mostly questions to be studied in the working groups, rather than conclusions...
• Note that US Cold and US Warm have fewer differences than NLC and TESLA. NLC and TESLA implications were discussed by J. Brau at Jeju in 2002.

• 1. US Cold. Based on TESLA linac, but more site independent.
• 2. US Warm. Similar to NLC. X Band.
• Both described in (but don’t see the ~suppressed) USLCSG LC Technology Comparison Study
## Detector Relevant Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Warm Ref</th>
<th>Cold Ref</th>
<th>Warm Upgrade</th>
<th>Cold Upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam E [GeV]</td>
<td>250</td>
<td>250</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>$L_g$ [10^{33}cm^{-2}s^{-1}]</td>
<td>14</td>
<td>14</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>$L$ [10^{33}cm^{-2}s^{-1}]</td>
<td>21</td>
<td>26</td>
<td>31</td>
<td>38</td>
</tr>
<tr>
<td>Bunches/Train</td>
<td>192</td>
<td>2820</td>
<td>192</td>
<td>2820</td>
</tr>
<tr>
<td>Rep Rate [Hz]</td>
<td>120</td>
<td>5</td>
<td>120</td>
<td>5</td>
</tr>
<tr>
<td>$e^-$/bunch [10^{10}]</td>
<td>0.75</td>
<td>2</td>
<td>0.75</td>
<td>2</td>
</tr>
<tr>
<td>$\sigma_y$ (IP) [nm]</td>
<td>3.0</td>
<td>5.7</td>
<td>2.1</td>
<td>4.0</td>
</tr>
<tr>
<td>$H_D$</td>
<td>1.46</td>
<td>1.77</td>
<td>1.41</td>
<td>1.68</td>
</tr>
<tr>
<td>$N\gamma$</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
<td>1.6</td>
</tr>
<tr>
<td>$\delta_E$ [%]</td>
<td>4.6</td>
<td>3.0</td>
<td>8.2</td>
<td>5.9</td>
</tr>
<tr>
<td>$\Theta_{crossing}$ [mrad]</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>
Classes of Issues

- Rather evident – e.g. train structure and bunch charge.
- Possibly misunderstood – e.g. crossing angle.
- Irrelevant – e.g. \(e^+\) polarization.
- Likely unknowable – e.g. Energy and Luminosity
The Trains

- **Cold:** 2820 bunches every 337 ns at 5 Hz. \( N=2.0\times10^{10} \)
  - Quite plausible to read and clear most detectors in interbunch period.
  - Quite unlikely to usefully power cycle electronics in interbunch period. Can power cycle between trains.

- **Warm:** 192 bunches every 1.4 ns at 120 Hz. \( N=0.75\times10^{10} \)
  - Read and clear between bunches probably impossible for most detectors. Some measurement of track time within train likely.
  - Power cycling same as Cold.
  - Duty Factor
  - Event pile up
  - Electronics implications
Power Cycling

• Why: Limiting power makes possible elimination of liquid cooling systems in sensitive areas of the detector, reducing multiple scattering and photon conversions. Cool electronics is also more reliable.

• Assume 10 µsec settling time. Assume “off”/“on” = 1% power. Then duty factor =
  - Warm  0.011
  - Cold   0.015

• No significant difference. Difference grows if “off”/“on” gets smaller…
Electronics Duty Factor

![Electronics Duty Factor Graph]

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Pileup

• **Vertex Detector:**
  - **Warm:** Integrate entire train, readout ~standard\(^1\) CCD’s between trains. Note that warm integrates ~1/3 luminosity (and background) during full readout cycle than cold with 50 MHz column parallel CCD’s.
  - **Cold:** Must readout in modest number (~350 @ 50 MHz) of bunches. Need column parallel CCD or other very fast technology. Doable, but complex.
  - **RF Pickup vulnerability:** If shielding inadequate to EMP - (SLD VXD3 had problems despite considerable effort) easy warm fix is to delay readout until microseconds after beam is gone; this is not a cold option.
  - 1. Need 20 readout nodes on 2x12 cm CCD. SLD VXD3 had 4.
Pileup, Continued

• TPC's

- Drift time is 5-10 µsec/cm. For a 2 m $\frac{1}{2}$ length TPC, this is 20-40 µsec, or the entire warm train, or 60-120 cold bunches. (Mike Ronan).

- By coincidence, the integrated luminosity during the drift time is ~the same. But sorting tracks to bunches will be easier with cold.
Si Strip Detectors
  - Cold should be fairly easy to separate bunches.
  - Warm unlikely to resolve within train, especially if aggressively keeping material out of tracking volume.
  - Probably not too important because of high probability of good time tag in Si-W EMCal.
Pileup, Continued

- **Si-W Calorimeters**
  - SiD is studying calorimeter with readout chip bump bonded to large area pixellated detector. Preliminary simulation indicates rather good timing tag capability for warm. (David Strom, this workshop).
  - Bunch ID should be quite easy for cold.
  - Specialized small area calorimeter for extreme forward direction should permit readout for each bunch (warm). Not easy, but doable.
Pileup, continued

- **Straws**
  - Should have full readout capability warm or cold.
# Backgrounds (Naïve Look)

<table>
<thead>
<tr>
<th></th>
<th>US SC 500</th>
<th>US SC 1000</th>
<th>US NC 500</th>
<th>US NC 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lum/bc (x10^{34})</td>
<td>1.8</td>
<td>2.7</td>
<td>0.90</td>
<td>1.4</td>
</tr>
<tr>
<td>Nγ</td>
<td>1.5</td>
<td>1.6</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Coherent Pairs/bc</td>
<td>4.6x10^{-34}</td>
<td>6.9x10^{-11}</td>
<td>4.5x10^{-11}</td>
<td>7.3x10^{-1}</td>
</tr>
<tr>
<td>Inc Pairs/bc</td>
<td>3.7x10^5</td>
<td>5.0x10^5</td>
<td>1.2x10^5</td>
<td>1.73x10^5</td>
</tr>
</tbody>
</table>

- Backgrounds are probably high risk area, but US Cold/Warm differences above are probably small compared to the errors.

- Accelerator people claim tails are at 10^{-6} of core and they can handle 10^{-3}. What have they missed? (!!)
Warm Cold Independent

- Polarized e⁺. Either design can use undulator source. US Cold and Warm both use (non-polarizing) undulators.
- Experience indicates that commissioning might be easier with a conventional e⁺ target. A design is being developed that will work for cold...(John Sheppard)
L* and Vibration Sensitivity

- \( \sigma_y (\text{IP}) = 3 \text{ nm (warm)}; 5.7 \text{ nm (cold)} \)
- Cold bunch spacing is 337 ns; intratrain feedback to correct offsets (and angles) should be straightforward. However, background in the feedback BPM’s could be a severe problem, and no relevant R&D seems plausible before commissioning. Actual luminosity (as opposed to offset) feedback may be needed.
- Warm spacing is 1.4 ns; intratrain feedback can help, but delay before correction is noticeable. Warm design expects stabilization from inertial reference or optical anchor.
- Intertrain feedback is at 120 Hz for warm; 5 Hz for cold. Cold with intertrain will not be as effective.
- Detectors for cold or warm will have to be rather careful about mechanical vibration issues, such as cooling.
- L* is a compromise among detector clearances, optical issues affecting luminosity, and “rational” beam stay clears affecting VXD radii. L* does not appear to be a cold/warm discriminator.
Crossing Angles

- **Crossing Angle**: Both warm and (U.S.) cold have crossing angles. *[End of discussion!!]*
- Required for downstream beam (LEP) diagnostics. Upgrading to a crossing angle later is ~impossible!
- A crossing angle may well be required for acceptable extraction.
  - Crossing angle does not affect acceptance except for 1 cm Radius entrance hole.
  - Crossing angle has less affect on backgrounds than choice of B field.
More on Crossing Angles

• The incoming beam line can be quite small, and should be smaller than the beam line through the VXD.
• The outgoing beam line should be set by considerations of the beam divergence and general conservatism.
• If there is no crossing angle (TESLA), than inlet and outlet radii are the same, so VXD desire for small radius implies an aggressive exit radius. A small radius VXD is a happier optimization with a crossing angle.
SiD Lum-Pair Monitor

1 cm radius

2 cm radius

14.4 cm radius

Z = 3.15 m
Pair Spatial Distribution

\[ Z = -315 \text{ cm} \]
\[ Z = +315 \text{ cm} \]

\[ Y (\text{cm}) \]

\[ e^+ \]
\[ e^- \]

5 Tesla

20 mr crossing angle

Head-on

Takashi Maruyama
Issues relating to vetos for very forward e’s - SUSY searches

- Acceptance: A crossing angle reduces the acceptance by the area of the incoming beamline - (1 cm radius).
- Pileup: One is searching for a 250 GeV e in a sea of perhaps 20 TeV of e+e- pairs. “Cold” samples one bunch easily. “Warm” might sample one or few bunches, but it will require a challenging detector. Since the detector area is tiny, it is plausible. The pair background may be sufficiently statistically stable to allow subtraction, but it probably depends on the pico-details of the bunch structure.
Energy Lego Plot

250 GeV electron

Takashi Maruyama

R
Pair Energy exiting through Beampipe

![Graph showing Pair Energy exiting through Beampipe](image)

Takashi Maruyama

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Energy Variability

- NLC was considering permanent magnet final focus quads, but
- US Warm and US Cold are configured with the same superconducting final focus, so
- There should be no difference coming from the Beam Delivery system cold/warm.
Energy and Luminosity

• U.S. Warm and U.S. Cold are both designed as 500 GeV baseline and 1 TeV upgrades.
• It is difficult to see why energy would be a problem as long as there is sufficient overhead in the design. This is not a detector or physics issue!
• The geometric luminosity of both machines is the same. With pinch, cold is higher by 23%.
• Based on SLC experience, it is difficult to see even a factor of two luminosity projections as credible. Critical question is the conservatism of the design – both in the machine physics and reliability. Extremely difficult (impossible???) for experimentalists and theorists to judge.
(My) Conclusions

• “This (the Linear Collider) ain’t LEP”  John Jaros  December, 2003
• The detector can do great physics with either machine
• The detectors will, on balance, be somewhat more challenging for warm, but not sufficiently so as to influence a choice
• I can believe the wise men are wise, but with a few important exceptions, their professional backgrounds seem surprising for what appears an accelerator physics, engineering, and political choice.