LC Background Requirements

- **Introduction:** background sources @ the LC IP

- **Detector tolerance levels**
  - naive detector model
  - pain-threshold ‘guesstimates’

- **‘Some’ open issues** *(i.e. ‘my favorite worries these days’)*
  - are the advertised tolerance levels reasonable? consistent?
  - muons
  - lost particles
  - neutrons
  - synchrotron radiation

- **Conclusions**

_W. Kozanecki, CEA-Saclay_
Acknowledgements

- ‘Somebody’ twisted my arm to give this talk, in spite of my repeated attempts at passing it on to a more competent ‘victim’...

- There are several people in this room ...
  - who have worked on / know about LC backgrounds much more than I do
  - whose talks/plots/ideas I have shamelessly exploited to put this together. In particular, I’d like to acknowledge (in order of apperance)
    - Tom Markiewicz,
    - Ron Settles, and
    - Sasha Drozhdin.
Background Sources

IP Backgrounds
- **Beam-Beam Interaction**
  - Disrupted primary beam
    - Extraction Line Losses
  - Beamstrahlung photons
  - $e^+e^-$ pairs from beamstr., $\gamma\gamma$ interactions
  - $h^{\pm}/n$ from beamstr., $\gamma\gamma$ interactions
- **Radiative Bhabhas**

Machine Backgrounds
- **Muon production at collimators**
- **Direct Beam Loss (e$^\pm$ halo) near IP**
- **Synchrotron Radiation**
- **Collimator edge scattering**
- **Beam-Gas**
- **Neutrons from dumps/extr. line**

Have been studied to death
Scale with luminosity
1. Transport them away from IP
2. Shield sensitive detectors
3. Exploit detector timing

Our topic today
1. Don’t make them
2. Keep them from IP if you do
A (very) naive detector-tolerance model

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Tolerance criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex detector</td>
<td>Rad. damage (worst-case: CCD’s) : &lt; 3 (10^9) n cm(^{-2}) y(^{-1})</td>
</tr>
<tr>
<td></td>
<td>Occupancy: &lt; 1% (hit density)</td>
</tr>
<tr>
<td>TPC</td>
<td>Occupancy: &lt; 1% (hit density)</td>
</tr>
<tr>
<td>Calorimeter</td>
<td>‘Occupancy’: &lt; 1% (MIPs)</td>
</tr>
<tr>
<td>Muon system</td>
<td>??</td>
</tr>
</tbody>
</table>

Generic LC detector

Is this conservative enough?

![Graph](image.png)

BaBar DCH

\[ N = 211.5 + 21.3 \times \text{Lum} \]

Luminosity \((10^{33})\)

% 

- 5.0
- 2.5
- 0.0

\[ * \text{1990V/FADC} \]
**Detector-response model (*)**

(*) As per R. Settles et. al., TESLA St Malo workshop

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Granularity</th>
<th>Sensitivity window</th>
<th>Fract’l sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex detector (Layer 1)</td>
<td>20 $\mu$m x 20 $\mu$m pixels</td>
<td>50 $\mu$s</td>
<td>Chgd trks: $\varepsilon = 1.0$ (4 pixels)</td>
</tr>
<tr>
<td></td>
<td>= 2500 pixels/mm$^2$</td>
<td></td>
<td>$\gamma: \varepsilon = 0.02$ (4 pixels)</td>
</tr>
<tr>
<td>TPC</td>
<td>1.5 $10^6$ pads x $10^3$ time buckets</td>
<td>(1 NLC train / 150 TESLA bunches)</td>
<td>Chgd trks: $\varepsilon = 1.0$ (3 p x 200 r x 10 tb)</td>
</tr>
<tr>
<td></td>
<td>= 1.5 $10^9$ voxels</td>
<td></td>
<td>$\gamma: \varepsilon = 0.02$ (3 p x 200 tb)</td>
</tr>
<tr>
<td>Calorimeter (excluding LAT/LCAL)</td>
<td>44,000 cells</td>
<td>$\sim 200$ ns (or less?)</td>
<td>E $&gt; 1$ MIP ($\sim 250$ MeV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1 NLC train / 1 TESLA bunch)</td>
<td>Chgd trks: 1 MIP</td>
</tr>
<tr>
<td>Muon system</td>
<td>??</td>
<td>1 NLC train / 1 TESLA bunch ?</td>
<td>Chgd trks: $\varepsilon = 1.0$ Tunnel shine: ??</td>
</tr>
</tbody>
</table>

*W. Kozanecki*  
*Collimation Task Force Workshop, SLAC, 16-17 Dec 02*
### Background tolerance levels (*)

(*) As per R. Settles et. al., TESLA St Malo workshop

Unless otherwise stated, limits are expressed in # particles per sensitivity window (SW)
(typically 150 bunches for TESLA, 1 train for NLC in VDET/TPC)

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Chrgd tks</th>
<th>γ</th>
<th>n (~ 1 MeV)</th>
<th>μ</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex detector L1</td>
<td>6 mm⁻²</td>
<td>300 mm⁻²</td>
<td>3 (10^7) mm⁻² y⁻¹</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TPC</td>
<td>2500 (!?)</td>
<td>1.25 (10^6)</td>
<td>2.5 (10^7)</td>
<td>2500 (?)</td>
<td>-</td>
</tr>
<tr>
<td>Calorimeter</td>
<td>-</td>
<td>~ 40000 ((E_γ\sim 2.5\ MeV))</td>
<td>-</td>
<td>4.4</td>
<td>400 MIPs ((100\ GeV?))</td>
</tr>
<tr>
<td>Muon system</td>
<td>leaking jets?</td>
<td>tunnel shine?</td>
<td>-</td>
<td>??</td>
<td>leaking jets?</td>
</tr>
</tbody>
</table>

**Important notes**

1. No generic answers – depend strongly on subdetector technology
2. Only guesstimates so far. Real answer needs detailed simulations, pattern recognition studies, understanding of background distribution....
3. 1% may sound overconservative...but we need ~ x 10 safety factor!
Background tolerance levels: collimation-related requirements

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Chrgd tks</th>
<th>$\gamma$</th>
<th>$n$ ($\sim 1$ MeV)</th>
<th>$\mu$</th>
<th>$E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex detector L1</td>
<td>6 mm$^{-2}$</td>
<td>300 mm$^{-2}$</td>
<td>3 $10^7$ mm$^{-2}$ y$^{-1}$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TPC</td>
<td>2500</td>
<td>1.25 $10^6$</td>
<td>2.5 $10^7$</td>
<td>2500</td>
<td>-</td>
</tr>
<tr>
<td>Calorimeter</td>
<td></td>
<td>$\sim 40000$</td>
<td>($E_\gamma \sim 2.5$ MeV)</td>
<td>-</td>
<td>4.4</td>
</tr>
<tr>
<td>Muon system</td>
<td>leaking jets?</td>
<td>tunnel shine?</td>
<td>-</td>
<td>??</td>
<td>leaking jets?</td>
</tr>
</tbody>
</table>

‘Typical’ requirements

- primary collimation efficiency $\Rightarrow$ # $\mu$’s from secondary collimation system / FFS ‘not dominant’
- no (< 1) high-energy $e^\pm$ hits beam tube /mask/SVT ‘near IP’ (i.e. within FD or closer)
- no SR photon hits beam tube /mask/SVT ‘near IP’
Some ‘personal worries’

- The ‘**typical requirements**’ above are based on experience....

  ‘At SLD/SLC SR WAS a (THE?) PROBLEM’ (*TWM et. al.*)
  - SR from triplet WOULD have directly hit beam-pipe and VXD
  - Conical masks were installed to shadow the beam pipe inner radius and geometry set so that photons needed a minimum of TWO bounces to hit a detector
  - Quantitative measurements of background rates could be fit by a “flat halo” model where it was assumed that between 0.1% and 1% (in the early days) of the beam filled the phase space allowed by the collimator setting.

- but somewhat arbitrary, and not yet supported by quantitative detector studies (to my knowledge)

- **Perhaps part of our job during the next 2 days in to put them on a more robust basis. In addition, I would like to suggest a few ‘sanity checks’...**
Open issues & ‘sanity checks’

- **Muons**
  - Comparisons of muon yields (# e\(^\pm\) lost / \(\mu\) @ IP) at low & high c.m. energy (500 GeV vs. 800, 1000 or 3000 GeV) appear inconsistent across LC designs
  - Secondary e\(^\pm\) energy cutoff (> 50 GeV in AD’s code?) may be too high to realistically model ‘harmful’ \(\mu\) production
  - Tunnel modelling: a huge job by itself....

- **Electromagnetic debris: production & transport**
  - Is the showering in ‘thin’ machine elements (vacuum pipe, magnets) modelled with enough realism to be sure we are not overlooking potential problems?
  - High energy e\(^\pm\) losses ‘near’ the IP:
    - what is reasonable tolerance level (TWM: ‘a few ten per train’?)
    - how near is ‘near’?
How far upstream of the IP do electromagnetic debris matter?

Can showers produced by full-energy $e^{\pm}$ 10-20 m from the IP on the incoming beam side cause substantial backgrounds, in view of?
Open issues & ‘sanity checks’ (continued)

- **Synchrotron radiation**
  
  - **Concerns**
    
    - backscattering from downstream aperture limitations
    - edge- & tip- scattering from upstream SR masks
    - impact of a partially-shared beam line on SR masking?
      
      - compatibility of stay-clear apertures (spent beam, pairs, beamstrahlung $\gamma$) with effective masking of incoming SR
      
        - NLC: some IP apertures had to be adjusted in the process of optimizing the collimator settings
      
        - head-on scheme: are we sure the masking works in the presence of realistic constraints (dynamic errors, thermal effects on SC quads or septum,..) ?
    
    - any hidden alligators?
      
      - is the apparent discrepancy between the TESLA TDR & Sasha’s results trying to tell us something important?
IR & Extraction-Line Layout: **SR masking**

**Tesla**

**Halo photons**

- Photon loss distributions emitted from the beam halo in IP region for TESLA (top) and NLC (bottom). 10^-5 of the beam intensity is collimated in the TESLA and NLC. IP is at 1766.383 m in the TESLA and at 1433.815 m in the NLC. Spokes of the TESLA second stage of collimation are at A_x = 132 cm and A_y = 77 cm in the horizontal and vertical plane. TESLA: Photons number per bunch = 0.147E+07 photons/bunch, Photon mean energy = 0.435E-03 GeV, Photon energy per bunch = 845 GeV/bunch.

**NLC/JLC**

**SR from core**

- Photon loss distributions generated by the core of the beam in the IP region for TESLA (top) and NLC (bottom). IP is at 1766.363 m in the TESLA and at 1433.815 m in the NLC. Photon loss in the TESLA DUMP1 is 1.48 W. Photon loss in the NLC DUMP1 is 1.52 W, in the DUMP2 is 0.11 W.
### SR masking (ct’d)

#### Background flux hitting SR masks (assuming $10^{-3}$ halo)

<table>
<thead>
<tr>
<th></th>
<th>NLC Photon halo</th>
<th>TESLA Photon halo</th>
<th>NLC SR from beam core</th>
<th>TESLA SR from beam core</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SR mask upstream</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of IP</td>
<td>$\gamma$: 14 GeV/b</td>
<td>$\gamma$: 645 GeV/b</td>
<td>$\gamma$: $3 \times 10^4$ GeV/b</td>
<td>$\gamma$: $6.4 \times 10^6$ GeV/b</td>
</tr>
<tr>
<td></td>
<td>$8.4 \times 10^7 \gamma / \text{train}$</td>
<td>$2.2 \times 10^8 \gamma / 150\text{b}$</td>
<td>$3 \times 10^{11} \gamma / \text{train}$</td>
<td>$3 \times 10^{12} \gamma / 150\text{b}$</td>
</tr>
<tr>
<td><strong>SR mask downstream</strong></td>
<td>[0]</td>
<td>1.2 $10^5$ GeV/b</td>
<td>[0]</td>
<td>~ above/15</td>
</tr>
<tr>
<td>of IP</td>
<td>[0]</td>
<td>4.2 $10^{10} \gamma / 150\text{b}$</td>
<td>[0]</td>
<td>~ above/15</td>
</tr>
</tbody>
</table>

As per A. Drozdhin, 30 Aug 02

<table>
<thead>
<tr>
<th></th>
<th>NLC $e^+$ halo</th>
<th>TESLA $e^+$ halo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SR mask upstream</strong></td>
<td>[0 $e^+$]</td>
<td>$9 \times 10^5 e^+ / 150\text{b}$</td>
</tr>
<tr>
<td>of IP</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SR mask downstream</strong></td>
<td>[0 $e^+$]</td>
<td>$3.4 \times 10^4 e^+ / 150\text{b}$</td>
</tr>
<tr>
<td>of IP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Synchrotron radiation (continued)**

**Lessons from existing detectors**

- **BELLE**: ‘fried’ their first VDET by a combination of
  - improperly masked incoming-beam SR (very soft X-rays from XYCORS)
  - hard SR backscattered from the first beam-pipe wall on outgoing side
- **BaBar design**: SR background dominated by tip-scattering
- **Zeus + H1**: SR – much of it backscattered – absorbs a large fraction of their ‘background budget’
CTD Background – Source of SR

Long positron fill 18-10mA

Drift time distribution:
• ~ 30 in-time
• ≥30% 70ns delayed absorber at SR11
• ≤30% 96 – 130ns vacuum chamber SR 19 and SR 26

Uncertainty CTD response

Proposed modifications will reduce both delayed components
Coating of absorber SR11 not
One more ‘sanity check’ (perhaps already done?)

- **Neutrons**

  - Because of dynamic errors, the outgoing-beam losses (both spent $e^\pm$ and beamstrahlung photons) will (see AS’s talk on Tue):
    - fluctuate pulse-to-pulse
    - sometimes vastly exceed the ‘ideal beam’ predictions (for the original TESLA TDR design)

  For perfect collisions, predicted charged spent-beam losses are
  - NLC $\sim 36$ W ($E_{cm} = 500$ GeV)
  - $\sim 1.6$ kW ($E_{cm} = 1000$ GeV)
  - TESLA $\sim 5$-7 kW ($E_{cm} = 500$ GeV)

- Could the rate of neutrons backscattered from the ‘nearby’ section of the extraction line ($< \sim 50$ m) be a problem under these circumstances?
Conclusions

- **Detector tolerance levels:**
  - well-understood & under control for beam-beam sources
  - still at the level of ‘guesstimates’ for incoming-beam backgrounds
    - detailed ‘physics-performance’ simulations are required to quantify what is acceptable
    - the ‘1 % occupancy limit’ is probably adequate, at this stage, in most cases

- **Some open issues**
  - µ tolerance criteria need to be consolidated
  - how do we quantify the impact of incident high-energy e± losses inboard of the FD entrance?
  - back- & edge- scattering of SR photons
    - are known to be a (serious) problem in (some) existing detectors
    - need to be modeled promptly, so we can
      - develop effective masking schemes
      - avoid overconstraining the collimation-system design
Spares
### Background Sources, quantified: TESLA example

<table>
<thead>
<tr>
<th>Source</th>
<th>$N_{\text{tot}}$ $(E_{\text{tot}})$</th>
<th>VTX (CCD) $N_{\text{hits}}$/mm$^2$</th>
<th>SIT $N_{\text{hits}}$</th>
<th>FTD $N_{\text{hits}}$</th>
<th>TPC $N_{\text{hits}}$</th>
<th>FCH $N_{\text{hits}}$</th>
<th>ECAL $N_{\text{hits}}$</th>
<th>HCAL $N_{\text{hits}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beamstr. $\gamma$</td>
<td>$6.4 \cdot 10^{10}$ $2.6 \cdot 10^{11}$ GeV</td>
<td>No direct beamstrahlung background in detector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pairs (@ 4 T)</td>
<td>129 000 $E=361$ TeV</td>
<td>L1: $36 \cdot 10^{-3}$ L2: $3.1 \cdot 10^{-3}$ L3: $0.7 \cdot 10^{-3}$ L4: $0.3 \cdot 10^{-3}$ L5: $0.2 \cdot 10^{-3}$</td>
<td>SIT1: 23 SIT2: 7</td>
<td>D1: 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadrons $p_t \geq 2.2$ GeV/c</td>
<td>0.02 events $E = 2.07$ GeV</td>
<td>L1: $34 \cdot 10^{-6}$ L2: $6.6 \cdot 10^{-6}$ L3: $4.2 \cdot 10^{-6}$ L4: $2.9 \cdot 10^{-6}$ L5: $2.3 \cdot 10^{-6}$</td>
<td>n/s n/s</td>
<td>$N_{\text{tracks}} = 0.7$ $N_{\gamma} = 7.1$ $E_{\gamma,\text{total}} = 18.5$ MeV</td>
<td>n/s</td>
<td>ECAL and HCAL: $E_{\text{tot}} = 6$ GeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rad. Bhabhas</td>
<td>$3.9 \cdot 10^4$ $1.7 \cdot 10^6$ GeV</td>
<td>$N_{\text{hits}} = 2$ (L1)</td>
<td>negligible</td>
<td>$N_{\gamma} = 3$</td>
<td>negligible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n from RB</td>
<td>$2.8 \cdot 10^5$ $1.3 \cdot 10^5$ GeV</td>
<td>(&lt; 0.5 \cdot 10^6$$n$/cm$^2$/y</td>
<td>n/s n/s</td>
<td>110 n/s</td>
<td>903160</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n from Pairs</td>
<td>70 000 $E = 322$ GeV</td>
<td>$O(10^9)$ $1$ MeV</td>
<td>n/cm$^2$/year</td>
<td>439</td>
<td>478</td>
<td>14 551 n/s</td>
<td>$N_n = 8024$ $E_{\text{tot}} = 6.1$ GeV</td>
<td></td>
</tr>
<tr>
<td>n from BS+dump</td>
<td>see text</td>
<td>see text</td>
<td>negligible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muons</td>
<td>$7 \cdot 10^4$ $\frac{N_{\mu}}{N}$</td>
<td>10$^4$ beam halo particles: Full detector: 0.3/BX; TPC: 11 Tracks / 160 BX.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sync. Rad.</td>
<td>$2.0 \cdot 10^{11}$ $2.0 \cdot 10^8$ GeV</td>
<td>$60,\text{cm}^2$/BX</td>
<td>negligible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam-Gas</td>
<td>$3 \cdot 10^9$ $0.15$ GeV</td>
<td>negligible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.1.6: Summary table of backgrounds for one BX at $\sqrt{s} = 500$ GeV. n/s: not studied.