Backgrounds

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Background related Questions

• For each of your critical sub-detectors, what is the upper limit you can tolerate on the background hit rate per unit area per unit time (or per bunch)? Which kind of background is worst for each of these sub-detectors (SR, pairs, neutrons, muons, hadrons)?

• Can the detector tolerate the background conditions for the ILC parameter sets described in the Feb. 28 2005 document at www-project.slac.stanford.edu/ilc/acceldev/beamparameters.html? Please answer for both 2-mrad and 20-mrad crossing angle geometries. If the high luminosity parameter set poses difficulties, can the detector design be modified so that the gain in luminosity offsets the reduction in detector precision?

• What do you anticipate the difference will be in the background rates at your detector for 20 mrad and for 2 mrad crossing angle? Give your estimated rates in each case.
More questions

• What are your preferred values for the microvertex inner radius and length? If predicted backgrounds were to become lower, would you consider a lower radius, or a longer inner layer? If predicted backgrounds became higher, what would be lost by going to a larger radius, shorter length?

• What is your preliminary evaluation of the impact of local solenoid compensation (see LCC note 143) inside the detector volume, as needed with 20mr crossing angle, on the performance of tracking detectors (silicon, and/or TPC, etc).
Background Sources

IP Backgrounds

- Beam-beam Interactions
  - Disrupted primary beam
  - Extraction line losses
- Beamstrahlung photons
- $e^+e^-$ pairs
- Radiative Bhabhas
- $\gamma\gamma \rightarrow \text{hadrons}/\mu^+\mu^-$

Machine backgrounds

- Muon production at collimators
- Collimator edge scattering
- Beam-gas
- Synchrotron radiations
- Neutrons from dumps/extr. line

Good; scale with luminosity

- Transport them away from IP
- Shield sensitive detectors
- Exploit detector timing
- Reliable simulations.

Bad,

- Don’t make them
- Keep them from IP if you do
- Dominated by beam halo
- Dependent on assumptions
## Three Detector Concepts

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>GLD</th>
<th>LDC</th>
<th>SiD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex detector</td>
<td>Si pixel r1 = 2.0 cm</td>
<td>Si pixel r1 = 1.5 cm</td>
<td>Si pixel r1 = 1.4 cm</td>
</tr>
<tr>
<td>Tracker</td>
<td>TPC</td>
<td>TPC</td>
<td>Si strips</td>
</tr>
<tr>
<td>EM CAL</td>
<td>Scintillator-W</td>
<td>Si-W</td>
<td>Si-W</td>
</tr>
<tr>
<td>HAD CAL</td>
<td>Scintillator-Pb</td>
<td>Scintillator-Fe</td>
<td>Si-W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPC/GEM-Fe</td>
<td></td>
</tr>
<tr>
<td>Muon system</td>
<td>Scintillator</td>
<td>RPC</td>
<td>RPC</td>
</tr>
<tr>
<td>Solenoid</td>
<td>3 Tesla R = 3.5 – 4.5 m L = 8.9 m</td>
<td>4 Tesla R = 3 – 4.45 m L = 9.2 m</td>
<td>5 Tesla R = 2.5 – 3.3 m L = 5.4 m</td>
</tr>
</tbody>
</table>
# Background tolerance levels

Three levels of criteria:
- Radiation damage
- Pile up
- Pattern recognition

Table is from W. Kozaneck (Collimation Task Force Workshop, SLAC, 2002)
GLD and SiD answers included.

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Chrgd trks</th>
<th>$\gamma$</th>
<th>$n$ ($\sim$ 1MeV)</th>
<th>$\mu$</th>
<th>$E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex detector</td>
<td>6 / mm$^2$</td>
<td>300 / mm$^2$</td>
<td>$3 \times 10^9$ cm$^{-2}$y$^{-1}$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>100/mm$^2$/tr</td>
<td></td>
<td>$1 \times 10^{10}$ cm$^{-2}$y$^{-1}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si Tracker</td>
<td>0.2/cm$^2$/BX</td>
<td>10/cm$^2$/BX</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TPC</td>
<td>2500</td>
<td>$1.25 \times 10^6$</td>
<td>$2.5 \times 10^7$</td>
<td>2500</td>
<td>-</td>
</tr>
<tr>
<td>Calorimeter</td>
<td>-</td>
<td>$\sim 40000$</td>
<td>-</td>
<td></td>
<td>1MIPS/cm$^2$/train</td>
</tr>
<tr>
<td>Muon system</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100/cm$^2$/s</td>
<td>-</td>
</tr>
</tbody>
</table>
Background simulations

- Simulations from BDS to Dump
  - EGS4, Decay TURTLE, STRUCT, MARS, FLUKA, BDSIM, GEANT3, GEANT4
- Three detectors
- 10 ILC beam parameters
- 2 crossing angles
- Many background sources

• Requires a tremendous amount of work to complete.
• A great deal of work has been done, but much more studies are needed.
Realistic geometries

MARS model of BDS

LDC model

2mrad in BDSIM
SiD in two crossing schemes

- Disrupted beam
- Beamstrahlung
- Incoming beam

QD0  SD0  QF1  SF1  QFEX1  QFEX2

- 20 mrad
- 2 mrad
- 18 m
- 60 m
• Dominant background
• Very dependent on Beam parameters
• Solenoid field strength
  - Solenoid compensation for 20 mrad
• VXD layer radius
• Far forward geometry

<table>
<thead>
<tr>
<th>Beam</th>
<th># e+/e-/BX</th>
<th>Total energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal (N)</td>
<td>98 K</td>
<td>197 TeV</td>
</tr>
<tr>
<td>Low Q (Q)</td>
<td>38</td>
<td>86</td>
</tr>
<tr>
<td>High Y (Y)</td>
<td>104</td>
<td>191</td>
</tr>
<tr>
<td>Low P (P)</td>
<td>232</td>
<td>709</td>
</tr>
<tr>
<td>High Lum (H)</td>
<td>268</td>
<td>944</td>
</tr>
<tr>
<td>Nominal</td>
<td>174</td>
<td>1042</td>
</tr>
<tr>
<td>Low Q</td>
<td>73</td>
<td>486</td>
</tr>
<tr>
<td>High Y</td>
<td>229</td>
<td>1356</td>
</tr>
<tr>
<td>Low P</td>
<td>458</td>
<td>4596</td>
</tr>
<tr>
<td>High Lum</td>
<td>620</td>
<td>7367</td>
</tr>
</tbody>
</table>
Pairs at $Z = 300$ cm

Solenoid field map is important.

SiD 5 Tesla $\rightarrow$ 3 Tesla @ $Z = 300$ cm

DID field
VXD hits GLD

- Pair background hit rate on the 1st layer of the Vertex Detector (R=24mm)
- Simulation using CAIN and JUPITER
- Hit rate of the Low Q option is ~1/3 of the nominal option, as expected

<table>
<thead>
<tr>
<th>B (tesla)</th>
<th>Nominal</th>
<th>LowQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.488</td>
<td>0.149</td>
</tr>
<tr>
<td>4</td>
<td>0.48</td>
<td>0.113</td>
</tr>
<tr>
<td>5</td>
<td>0.183</td>
<td>0.069</td>
</tr>
</tbody>
</table>
Crossing angle dependence  LDC

TESLA Beam parameters

• VXD hits
  – No difference between 0 mrad and 2 mrad
  – Higher background in 20 mrad

• TPC hits
  – Twice as much in 2 mrad than in 0 mrad
  – Twice as much in 20 mrad than in 2 mrad
DID effect on VXD and TPC hits LDC

- VXD hits
  - DID field reduces vxd hits to 2 mrad level.
- TPC hits
  - Significantly more TPC hits
Crossing angle dependence SiD

- Average and RMS from 20 BXs.
- 20 mrad and 20 mrad + DID will have more VXD hits than 2 mrad.
- But bunch-to-bunch fluctuation is larger than the crossing angle difference.
How many bunches to reach 1 hit/mm$^2$

Layer #1

Layer #2

SiD

• One readout/train does not work for 25µm×25µm pixel detector.

• 5µm×5µm fine pixel detector can allow one readout/train for some beam parameters.

• Layer #2 can take x8 more bunches.
e+/e- density in Si Tracker

SiD

- Steep radial dependence
- Innermost region is at the tolerance level (0.2/cm²/BX).

Forward Tracker Layer #1 hits

500 GeV Nominal

![Graph showing e+/e- density vs. radius](image)
Photons in Si Tracker

- Twice as many photons in 20 mrad than in 2 mrad
- More than the detector tolerance level for Low P and High Lum options
Muons are generated at collimators: $\mu / e = 5 \times 10^{-4}$

Assume collimate 0.1\% of $2 \times 10^{10} / BX$
9 & 18m Toroid Spoiler Walls

Design Constraints: Minimize gap & minimize stray field in beampipe
Muon distribution at 250 GeV/Beam

MUCARLO (Keller)

No Spoilers
130 / BX
\langle p \rangle = 63 \text{ GeV/c}

2 Spoilers
0.08 / BX
\langle p \rangle = 37 \text{ GeV/c}

7.3 /cm²/sec

At least one spoiler is required to reduce the muon rate to < 1 Hz/cm²

500 GeV Beam: 144 / BX

GEANT4-BDSIM (Blair)
Neutron Backgrounds in VXD
The closer to the IP a particle is lost, the worse

- 20 mrad
  Pairs: $3.6 \times 10^8$ n$_s$/cm$^2$/yr
  Rad. Bhabhas: $1.1 \times 10^8$ n$_s$/cm$^2$/yr
- 2 mrad
  Pairs: $2.3 \times 10^8$ n$_s$/cm$^2$/yr

Neutron background is proportional to pair total energy.
  - Reach $1 \times 10^{10}$/cm$^2$/yr for 1 TeV Low P and High Lumi options.

- Neutrons from the extraction line and beam dump
  - NLC era estimation
    ~$1 \times 10^8$/cm$^2$/yr
  - Need updating calculations using the ILC conditions.
Neutrons in TPC LDC

<table>
<thead>
<tr>
<th></th>
<th>L*=4.05 m</th>
<th>L*=3.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stahl</td>
<td>333977</td>
<td>413286</td>
</tr>
<tr>
<td>TDR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total neutrons per BX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrons reaching TPC</td>
<td>517</td>
<td>10959</td>
</tr>
<tr>
<td>Bouncing neutrons</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Total TPC hits</td>
<td>5361</td>
<td>9881</td>
</tr>
</tbody>
</table>

Only preliminary!
- simulation of one single BX – need more statistics
- how many hits are caused by neutron scattering?
Synchrotron Radiations (A. Drozhdin)

<table>
<thead>
<tr>
<th>element</th>
<th>Mean energy GeV</th>
<th>Photons number per bunch</th>
<th>Photon energy per bunch GeV/bunch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>synchrotron radiation from beam halo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lost at PDUMP</td>
<td>0.752E-04</td>
<td>0.373E+07</td>
<td>0.280E+03</td>
</tr>
<tr>
<td>lost at MSK1</td>
<td>0.155E-03</td>
<td>0.115E+07</td>
<td>0.179E+03</td>
</tr>
<tr>
<td>lost at MSK2</td>
<td>0.300E-04</td>
<td>0.768E+05</td>
<td>0.230E+01</td>
</tr>
<tr>
<td>pass through IP</td>
<td>0.320E-02</td>
<td>0.422E+07</td>
<td>0.135E+05</td>
</tr>
<tr>
<td>bremsstrahlung photons from beam halo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lost at PDUMP</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>lost at MSK1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>lost at MSK2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pass through IP</td>
<td>0.140E+00</td>
<td>0.400E+03</td>
<td>0.561E+02</td>
</tr>
<tr>
<td>synchrotron radiation from beam core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lost at PDUMP</td>
<td>0.740E-04</td>
<td>0.426E+10</td>
<td>0.315E+06</td>
</tr>
<tr>
<td>lost at MSK1</td>
<td>0.683E-04</td>
<td>0.464E+10</td>
<td>0.317E+06</td>
</tr>
<tr>
<td>lost at MSK2</td>
<td>0.305E-04</td>
<td>0.396E+09</td>
<td>0.121E+05</td>
</tr>
<tr>
<td>pass through IP</td>
<td>0.398E-03</td>
<td>0.383E+10</td>
<td>0.152E+07</td>
</tr>
</tbody>
</table>

Photon loss at PDUMP, MSK1, MSK2 and passed through the IP from beam halo for collimation at $8\sigma_x$ and $65\sigma_y$ and from beam core.
Collimation Depth
F. Jackson, J. Carter

• Limiting aperture: $r = 12 \text{ mm (20 mrad)}, 15 \text{ mm (2 mrad)}$
• Spoiler gaps $a_x = 1 \text{ mm}, a_y = 0.5 \text{ mm}$
• Tighter collimation for 2 mrad
Sync radiations can be very serious

At SLD/SLC, SR was the problem
- Conical mask completely shadowed the beam pipe and VXD.
- Mask was designed so that photons need at least TWO bounces to hit VXD.
- Two-bounce masking is not compatible with pairs.
  - Central detector is vulnerable to SR.

Require
- Complete analysis of SR from soft-bends and quads.
  - Gaussian core and beam halo
- Study
  - Repopulation of particles outside the collimation depth
  - Tip scatterings from upstream SR masks
  - Backscatterings from downstream apertures
Conclusions

• Detector tolerance levels need to be updated/expanded.
• Beam-beam pairs are dominant background
  - Very dependent on geometry, solenoid field strength, crossing angle, and beam parameters.
• Sync radiations are potentially very serious backgrounds.
  - We cannot assume beam collimation works perfectly.
  - We have to be conservative.
• Building realistic model is essential.
  - Detector geometry, magnets, tunnel, solenoid field map, magnet fringe field
• Simulation standards
  - Having many tools is good, but we need standards.
  - Repository
    • Optics
    • Detector description
    • Magnet geometries, field maps
    • Guinea-pig files, muons, beam-gas scattered particles
• Benchmarking and cross checking