Very Forward Region

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Outline

• Beamstrahlung
• BeamCal
• Bhabha
• LumCal
• Physics requirements
• Detector layout
Overview of Beamstrahlung

- Useful to have both analytic and simulations.
- Use Gauss’ law and Ampere’s law for a single flat bunch of height $a$, width $b$, and length $L$
  - $a << b << L$
- The magnetic field cancels the electric field in the Lorentz force

\[
E_V = \frac{\rho y}{\varepsilon_0}
\]

\[
B_H = \frac{\beta E_V}{c}
\]

\[
F_V = \frac{e \rho y (1 - \beta^2)}{\varepsilon_0}
\]
Two Bunches

• Electric fields cancel while magnetic fields add!
• With ILC parameters, maximum magnetic field is about 0.6KT
• Beams radiate
• Some of gammas convert to pairs when they see the oncoming electrons
• $\sigma_{\text{inc}} \approx 0.6\text{mb}$
Info from both pairs and gammas

- Beamstrahlung power = $\gamma^2 F^2 \left(\frac{2r_0}{3mc}\right)$
- Beamstrahlung energy = $P_t \propto N^2/(b^2L)$
- Pair energy $\propto N^3/(ab^3L)$
- Luminosity $\propto N^2/(ab)$
- Pairs to gamma ratio $\propto N/(ab)$
- Conclusion: measure both pairs and gammas
What happens when bunches miss each other?

- Both electric and magnetic fields add
- Beamstrahlung is much more
- Incoherent pairs are nil
Measurement of the Pairs

- Gammas and pairs created with $<\theta> \approx m_e/p$
- However, pairs are in up to 0.6KT field
- Impulse approx: $\max \Delta p_V \approx 0.1$ GeV/c
- Then undergo betatron oscillations in 5T solenoid field with maximum

$$R = \frac{c p_T}{e B} = 7 \text{ cm}$$
Pairs Betatron Oscillations

\[ x = R - R \cos \omega t \quad y = R \sin \omega t \]

\[ \omega t = (1.5 \text{ rad}) L_{IP} (m) / E (GeV) \]
LC-DET-2000-001 TESLA
Carsten Hensel Simulation

$B = 4T \quad L_{IP} = 2.1m$

Scattering?
Highest Physics Rate

- Lowest order Bhabha for $t$ channel one photon exchange
- Number per bunch crossing for polar angle coverage (mrad)

\[
\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{8E^2} \left( \frac{1 + \cos^2 \frac{\theta}{2}}{\sin^4 \frac{\theta}{2}} \right)
\]

\[
N \approx 8 \left( \frac{1}{\theta_{\text{min}}^2} - \frac{1}{\theta_{\text{max}}^2} \right)
\]
Overview of Physics Mission

• Hermeticity for SUSY searches
• Precision measurement of luminosity normalization (LumCal)
• Measurement of pairs to monitor bunch characteristics (BeamCal).
  • BeamCal: polar angles 3-20 mrad
  • LumCal: polar angles 20-140 mrad
Hermeticity

• Performance criteria for hermeticity: slepton production in the presence of two photon events

• $\chi^0$ escapes detector giving missing $P_T$

$$e^+ e^- \rightarrow \mu \mu \rightarrow \mu^+ \chi^0 \mu^- \chi^0$$

$$e^+ e^- \rightarrow e^+ e^- \mu^+ \mu^-$$
Missing $P_T$

- Maximum missing $P_T$ vs. LSP mass for different smuon masses (selectron and stau decay products are similar)
P. Bambade et al.

- $M(\text{stau}) = 217$ GeV
- $M(\text{LSP}) = 212$ GeV
- The BeamCal began at 3mrad polar angle
- Veto event if extra >200 GeV electron,
- or missing $P_T$ points to in-coming beampipe.
- They measured the masses $\pm 0.54$ GeV
- 7% uncertainty on cosmological dark matter
- Answers whether all dark matter is LSP, or whether axions are also needed.
On Mon, 28 Nov 2005, Morse, William M wrote:

Dear Prof. Bambade,

Dave Lissauer and I have been thinking about ILC physics for about one month. Dave asked an interesting question: is Bhabha events a pileup issue for the forward calorimeters. I enclose my calculation. Is there something I missed?

Best Regards,
Bill.

p.s. In your paper you say you are working on the procedure to pull a high energy electron from the low energy e+e- pairs in the forward calorimeter. Have you finished this study yet?
LumCal

• Measure luminosity normalization to $10^{-4}$ for GigaZ and several $10^{-4}$ for ILC.
• Need $10^8$ Bhabha events over $10^7$s
• LumCal 20 mrad – 140 mrad
• Far LumCal (20 - 46 mrad) contiguous with Beam Cal
• Near LumCal (42 - 140 mrad) contiguous with ECAL
The number occupancy per pixel per train from Bhabha pairs vs. polar angle.
Radiation Damage

- BeamCal: 10MGy/yr from pairs
- BNL Instrumentation looking at:
  - FZ (Float Zone) n-type Si wafers
  - MCZ (Magnetic Chocoski Zone) Si wafers
- Need to include effects from giant nuclear dipole resonance for neutron fluence:
  - ie. 7GeV e gives 1.2 neutrons on Cu,
  - 0.8n for Fe, 0.4 n for Al.
Conclusions

• Much more information in our SiD DOD
• Interesting problems
• We’ve just started