2.11 Design of the NLC Detector

Now that we have described the expected physics program of the NLC, we must discuss in more detail what experimental facilities should be necessary. In this section, we will present a sample design of an NLC detector and discuss the general issues which constrain this design. This detector takes into account the particular features of the NLC accelerator and its machine-related backgrounds. A more complete discussion of the machine/detector interaction is given at the end of Chapter 3.

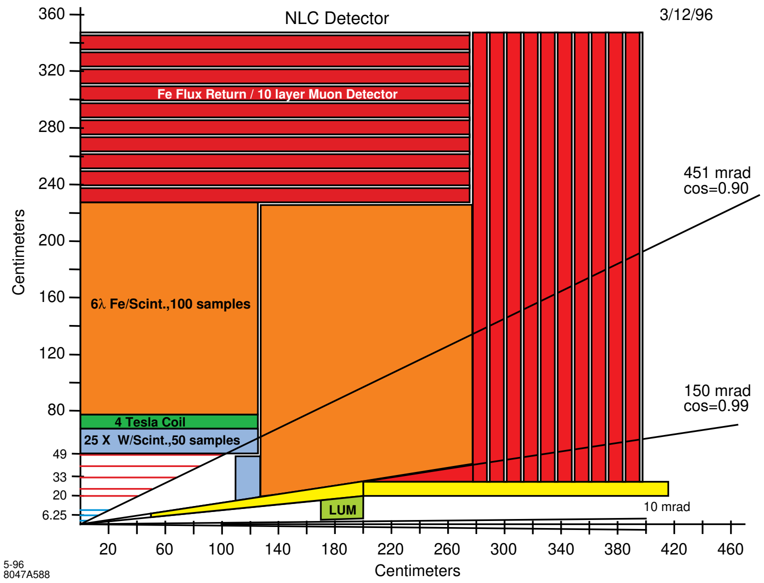

Figure 2.49: NLC Detector.

A general plan of a detector for the NLC is shown, in quadrant view, in Fig. 2.49. This detector is at a very early conceptual design stage. The architecture is a "standard" solenoid, and is just one possible approach. A 3 or 4 layer CCD vertex detector surrounds a beryllium vacuum pipe. The momentum measurement is carried out by layers of silicon microstrip detectors in a 4 Tesla field, which is produced by a superconducting solenoid outside of the electromagnetic calorimeter. A hadronic calorimeter is located outside the coil, and the structure is wrapped in laminated iron for a flux return and muon identification system. The final focus quadrupoles are located inside the detector at an L^* of 2m. A summary of the components and expected performance of the detector is given in Table 2.14.

The small volume 4 Tesla field is well matched to the expected backgrounds, cost, and technology. The small size of the tracking system eases the mechanical problem of stabilizing the final focus elements relative to one another at the required nanometer level. However, this design increases the complexity of the elements inside the detector. For example, the final quadrupoles, envisioned as permanent magnets, would have to be shielded by a small super conducting solenoid. The tracking system is modeled as 5 layers of Si microstrips

Table 2.14: Basic Components of the NLC Detector

Vertex	$3-5$ CCD Layers $2.6 \oplus (13.7/p \sin^{3/2}\theta)$
Tracking	5 Si Layers $\lvert\cos\theta\rvert \leq 0.9$ $\delta p_T/p_T = 2\times10^{-4}$ at 100 GeV at $\cos\theta = 0.9$
Coil	4T, 2–3 X_0
EM Calorimeter	$25X_0$, 50 samples $\sigma_E/E = \left(\frac{12\%}{\sqrt{E}}\right) \oplus 1\%$
Hadronic Calorimeter	Fe Scintillator 6λ, 100 samples $\sigma_E/E = \left(\frac{45\%}{\sqrt{E}}\right) \oplus 2\%$
Return Flux	6λ, 10 samples

with 5 micron spatial resolution. The expected momentum resolution, including multiple scattering, is shown in Figure 2.50. Agreement that this performance is a reasonable match to the physics goals is probably the most important question for the overall detector design. The cylindrical layers extend to $\cos\theta = 0.9$. This leaves sufficient space for the ends of the support structure, electronics, cabling, and cooling. End cap trackers could be added for improved coverage. Experience with SLC/SLD confirms the idea that backgrounds from a linear collider can be very severe for conventional wire chambers. A silicon strip system would be extremely robust.

The electromagnetic calorimeter would be inside the coil, 25 radiation lengths thick, and with angular segmentation in the range of 30 to 40 mrad^2. Possible structures include tungsten silicon-diode sampling towers and BGO or perhaps more exotic crystals. The crystals would be interesting not so much for their good resolution but for their lack of interconnections. The calorimetry is extended by endcaps to $\cos\theta = 0.99$.

The superconducting coil has an inner radius of 70 cm and a half length of 1.2 m. Since there are only weak constraints on the thickness of the coil, given that it is outside the electromagnetic calorimeter, and since it is a relatively small coil, it should be a reasonable coil to design and build. This design will be made more challenging, however, by its required integration with the quadrupole shields and supports.

The hadronic calorimeter is assumed to be an iron scintillator sampling system, 6λ thick and 100 samples. At this time, no magnetic modeling of the structure has been done. It is

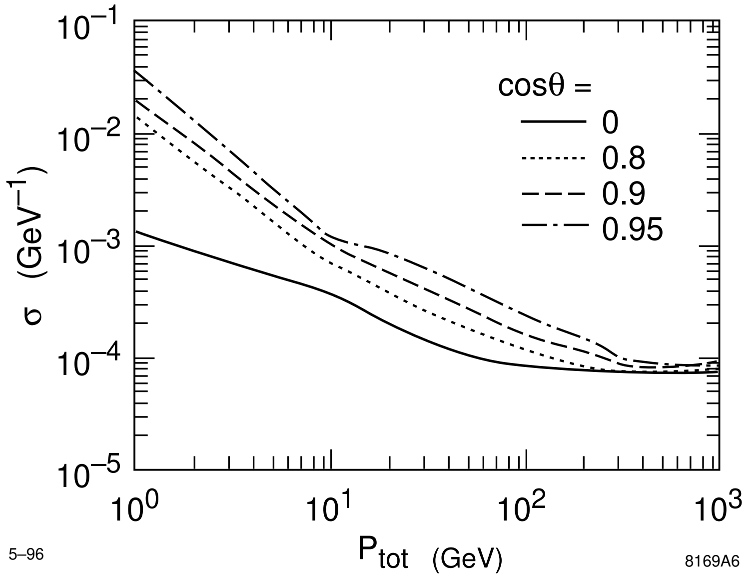

Figure 2.50: NLC Detector tracking parameters.

unclear whether the advantages of an iron based calorimeter in containing the magnetic flux would be outweighed by the structural problems.

Finally, the detector is wrapped in a flux return 6λ thick with 10 layers for muon detectors. Questions of overall geometry for internal access and vibration control are completely open.

The crossing of the two beams at the interaction point produces an irreducible e^+e^- pair background at small $p_\perp$. These particles can be kept away from a small radius vertex detector by the relatively high 4 Tesla magnetic field. A reasonable vertex detector for this environment would be a successor to the SLD vertex detector using large area CCDs with 20 micron square pixels. The CCDs could be read out in a time equivalent to a small number of beam crossings, and the beams could be suppressed subsequent to a trigger if necessary. At SLD the innermost layer of the vertex detector, at $r = 2.5$ cm with $B = 0.6$ T, sees 0.4 hits/mm^2 summed over its 19 machine pulse readout time. Vertex hits are successfully attached to tracks extrapolated from a conventional drift chamber whose closest wire is at $r = 22$ cm. Thus a conservative estimate for the tolerable background is 1 hit/mm^2. Were the NLC vertex detector to extrapolate hits from its own high resolution outer layers into an inner layer, the much smaller search area would allow a much larger (10-20 hits/mm^2) background to be tolerated.

Fig. 2.51 shows the hit density from the e^+e^- pair background, per bunch train (a series of 90 bunch collisions), at a radius of 3 cm and at 2 cm. The results are shown as a function of z for a 4 Tesla field. At $r = 3$ cm the background is nonexistant out to $z = 45$ cm. At $r = 2$ cm the background is similar to that tolerated by an existing detector out to $z = 17$ cm, a length adequate to provide vertexing coverage well beyond the $\cos\theta = 0.90$ currently used in the physics simulations.

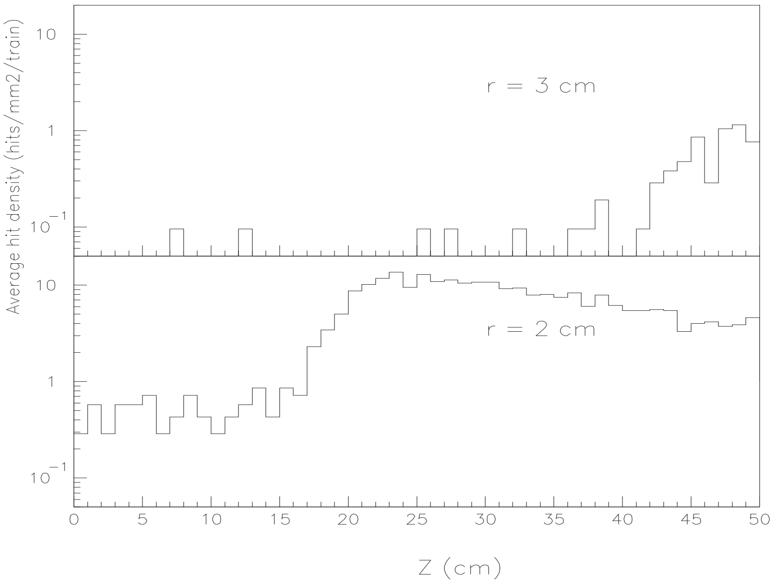

Figure 2.51: Electron pair hit density per mm^2 per train of 90 bunches, computed with the Monte Carlo program ABEL. As the pairs leave the IP in a 4 Tesla field, hits are scored (a) at $r = 3$ cm, and (b) at $r = 2$ cm.

In addition to the irreducible background of pairs emanating from the interaction point, the vertex detector will see a background of very low energy backscattered particles resulting from the interaction of the pairs that have been curled up by the field and gone forward to strike the quad faces, septum, and luminosity monitor. In the current interaction region design the calculated rate is 2.0 hits/mm^2/train at $r = 3$ cm, flat in z, and roughly constant down to $r = 2$ cm, then rising at lower radii. This background rate, already sufficiently low at $r = 2$ cm for efficient vertexing, is very sensitive to the details of the interaction region design. Efforts to reduce the flux of these soft particles, by, for instance, the use of low-Z coatings, are underway.

As experience in the collider operation is gained, one may want to consider vertex detection at smaller radii. Even at the very aggressive radius of 1 cm, in a 4 Tesla field the pair background hit rate remains below 10/mm^2/train out to $z = 3$ cm. Moreover, since the tracking system radius largely drives the scale of the entire detector, a small tracker permits consideration of relatively small L^* as a possible future upgrade of the final focus design. The small L^* is plausible because the axial extent of the tracker is small, about 1m for $\cos\theta < 0.9$. This leads to significant improvements in required tolerances in the final focus system.