NLC Final Quadrupole Support *

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ABSTRACT

High luminosity at 1 TeV in the e^+/e^- collider NLC will require collision of beams focused to 5 nanometers. Strong quadrupole magnetic lenses with short focal length will have to be mounted close to the collision point inside the physics detector. Maintaining collision of 5 nanometer beams will require close mechanical alignment. Approaches to meeting this requirement in a realistic detector are considered here.

I. MECHANICAL SUPPORT STRUCTURE

Buried deep inside the detector, beam focusing quadrupoles are difficult to support decoupled from the detector. Recent collider detectors have supported final quadrupoles in the endcaps of the detector. These large structures weighing many 100's of tons are designed to retract from the central detector for access and servicing. Such large heavy mobile structures lack adequate stiffness for support of the final quadrupoles. Being assembled from many plates of magnet steel, they act like large blocks of gelatin driven into continuous vibration by natural microseismic ground vibration and local equipment noise. Detector solenoid magnetic attraction forces are comparable to their weight and cause deflections measured in 1/10'ths of millimeters.

Interalignment of quadrupoles can be simplified by mounting them in a common support barrel which joins them across the collision point as is being done in the BaBar detector for PEP II. This simplifies the support at the cost of inserting a cylinder of scattering material into the detector's tracking volume. In a compact high field detector for NLC, it may be practical to use the detector solenoid itself as the central section of a support barrel. A support barrel built in this way introduces no additional scattering material into the detector's tracking volume. A compact high field solenoid ($R = 0.7$ meter, $B = 4$ Tesla) with final quadrupoles mounted in barrel extensions is shown in figure 1. Using the 1.5 m diameter cryostat for the central section increases barrel rigidity over the center of its length where bending moments are largest. Such a barrel would carry an all-Si tracker and vertex detector as well as electromagnetic calorimeter. Final quadrupoles with their high Z tungsten shield cones would be mounted at each end. This assembly would weigh between 15 and 20 tons and could be installed into the detector as a unit after assembly and checkout. Such a structure making use of the solenoid cryostat should be both lighter and stiffer than mounting quadrupoles independently in opposite end cap doors of the detector. The cryrostat and quadrupole module would be supported from the central section of the detector near the nodes of its fundamental vibration mode to allow free retraction of the end caps. These optimum support points for minimum deflection and highest natural frequency are also near the magnetic nodal points of the quadrupole lenses.

Support for the final quadrupoles will ultimately have to come from the ground through the detector even though they are now tied together in a common module. Much of the seismic amplification in current detectors comes from their high center of gravity and compliant foundation. If the central detector section could be grouted into the foundation of the experimental hall, it would more nearly become an extension of the floor rather than a tall heavy flexible mass rocking above it. Figure 2a below shows the built-in detector cross section with Optical Anchor.

By extending concrete aprons up to the sides of the detector, it could be rigidly coupled to the floor. Top halves of the central detector steel are retractable to the side so the solenoid module could be lifted out directly by crane. Otherwise, provision for end insertion would be needed.

II. OPTICAL ANCHOR

Magnet motion will cause beam trajectories to change from pulse to pulse along the entire length of the collider. These motions can be broken down into contributions from seismic ground motion and local vibrations and thermal distortions of the magnet and accelerator mounts themselves. Long range coherent ground motions spread over large distances along the collider will have little effect on beam collisions. Both trajectories will be distorted in similar ways and collisions will continue. But local vibrations and thermal distortions of individual magnet mounts as well as short range ground motion will cause discrepancies between the two beam trajectories. Of course trajectories need only be coincident at one point: the collision point. For most of the collider length, accelerator components are mounted close to the tunnel floor on stable mounts. But the

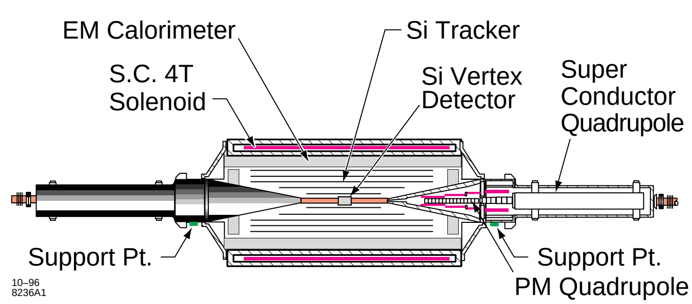

Figure 1: Central Detector Solenoid with Quadrupole End Barrels.

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collision point, up inside the detector, is the one place where stability is most difficult to achieve. It is also the place where beams are most tightly focused and tolerances are tightest (1 nanometer). For 5 nanometer beams to collide, transverse differential motion between opposing final focus quadrupoles must be held to a fraction of this beam dimension. Common-mode motions where both magnets move together shift the collision point but do not interrupt collisions. Tolerances on those motions are much looser.

How can a magnet support structure as large, heavy and flexible as the entire physics detector be made rigid and stable enough to keep beams in collision? This type of problem has been solved in the past using optical interferometry to erect a stable independent reference frame or 'metrology truss' around the equipment using Michelson interferometers. Examples are diamond turning lathes at Livermore National Laboratory [1] ,stellar interferometers at Mt. Wilson Observatory [2] ,space-borne interferometer POINTS [3] ,and geophysics earth strain interferometers [4]. Differential motion between the interferometer arms is measured and the quadrupole supports corrected by piezoelectric actuators. The simplest system with the minimum number of interferometers would monitor differential motion between support points of the quadrupole/detector cryostat itself,(figure 2). The motions most disruptive to beam collision are pitching and yawing of the quadrupole cryostat with respect to an instantaneous beam collision axis determined by combined effects of the collider's entire final focus system stretching out 1000's of meters from the experimental hall. The interferometer layout of figure 2 is sensitive to these pitching and yawing motions exclusively. Transverse displacements of the cryostat assembly simply displace the collision point but do not interrupt collisions or affect the fringe image in the equal arm interferometer. To reach 1 nanometer resolution with red light ($\lambda = 632$ nm), motion must be detected at the 1/1000 fringe level. Present commercial hetrodyne interferometers have 1-2 nm noise levels, but the POINTS project [3] is working toward 1 pico meter resolution. By configuring the interferometer in a symmetric geometry with equal arm lengths, high differential resolution is easier and many common mode sensitivities are more nearly cancelled.

Locating the motion sensing system coincident with the feedback actuators is critical for stability of feedback loops. Active isolation of the entire cryostat module will require actuators capable of supporting the 20 ton cryostat static load. The dynamic feedback forces required will be on the order of 40 micro 'g' or less than 2 lb. for 100 nanometer motions at 10 Hz. These small amplitude motions with large static loads are well suited to piezoelectric actuators. A magnet support table weighing 16 tons with 15 micron stroke piezoelectric actuators has been built and tested for the Final Focus Test Beam at SLAC [5].

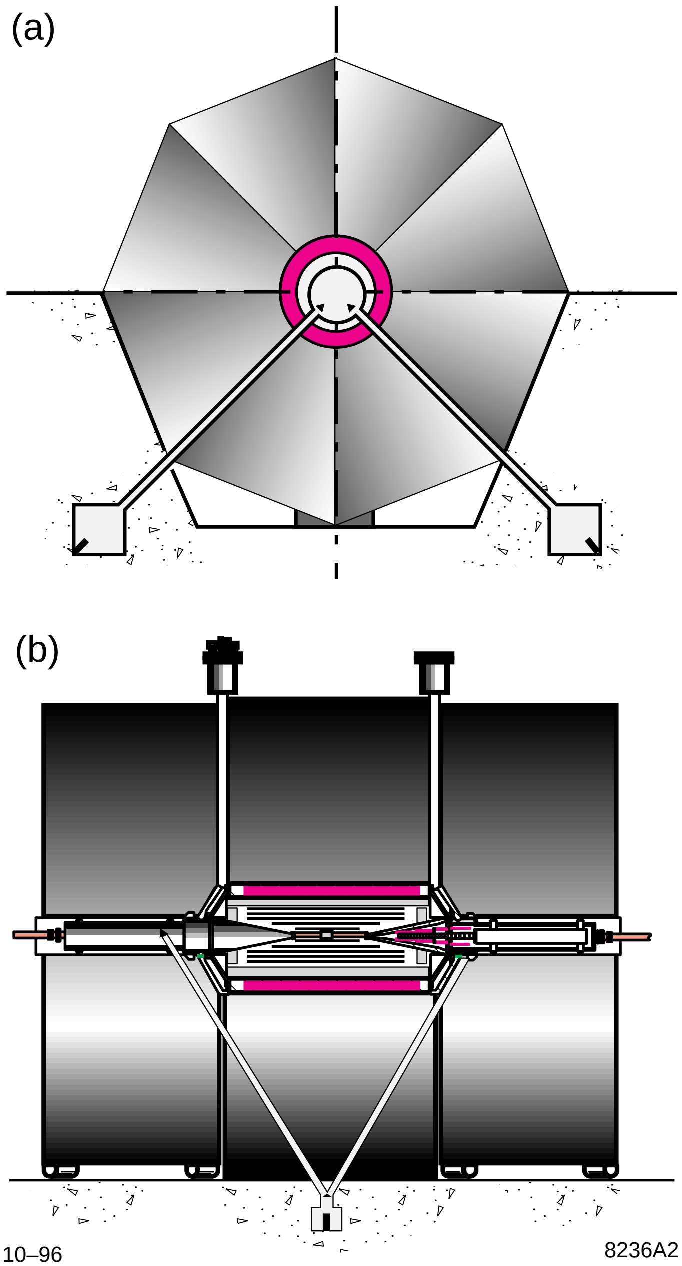

Figure 2: Detector cross section with Optical Anchor

III. REFERENCES

[1] J.B. Bryan, “Design and Construction of an Ultraprecision 84 inch Diamond Turning Machine ”, Precision Engineering , Vol.1, No.1, pg 13-17, 1979.

[2] M. Shao, et al, “The Mark III stellar interferometer”, Astron. Astrophysics, **193**, pg 357-371, 1988.

[3] R.D. Reasenberg, et al, “Microarcsecond Optical Astrometry: An Instrument and its Astrophysical Applications”, The Astronomical Journal, pg 1731-1745, 1988.

[4] F. Wyatt, K. Beckstrom, J. Berger, “The Optical Anchor - A Geophysical Strainmeter”, Bulletin of the Seismological Society of America, Vol. 72, No.5 , pg 1705-1715, 1982.

[5] N. Ishihara, et al, “XVth Int. Conf. on High Energy Accelerators”, July 20-24, pg 945-947, 1992.