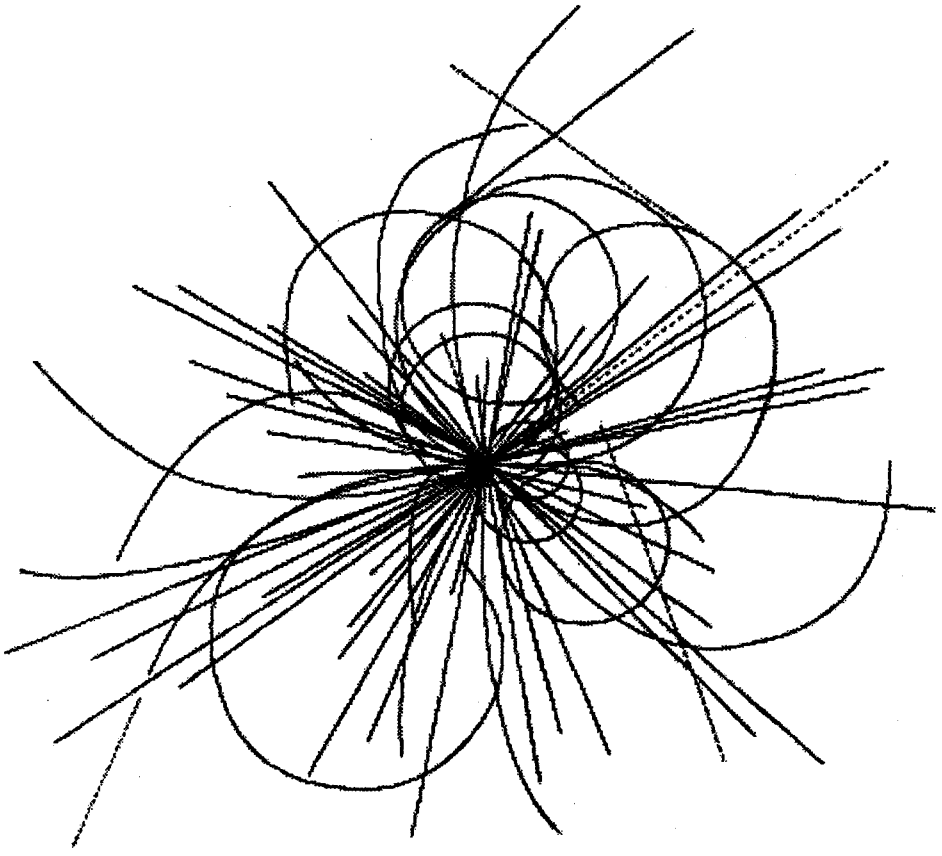
SSCL-Preprint-255

SSCL-Preprint-255
April 1993
Distribution Category: 414

R. Hovde

Measurement and Alignment Goals for the SDC Detector



Superconducting Super Collider Laboratory

To be published in *Supercollider 5*

SSCL-Preprint-255

Measurement and Alignment Goals for the SDC Detector*

R. Hovde

Superconducting Super Collider Laboratory†
2550 Beckleymeade Ave.
Dallas, TX 75237

April 1993

*Presented at the Fifth Annual International Symposium on the Super Collider, May 6–8, 1993 San Francisco, CA.
†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

MEASUREMENT AND ALIGNMENT GOALS FOR THE SDC DETECTOR

Robert J. Hovde

Physics Research Division/Solenoidal Detector Collaboration
Superconducting Super Collider Laboratory*
2550 Beckleymeade Ave, MS 2006
Dallas, TX 75237-3997

INTRODUCTION

There are two major goals driving the requirements for alignment and measurement of the detector being designed by the Solenoidal Detector Collaboration (SDC). First is each subsystem's goal of measuring its particular physics data as accurately as possible. Second is the goal of correlating the data from all subsystems in order to form a complete picture of the event. It is the ability to correlate all of the data that makes the SDC detector so powerful.

The major subsystems of the SDC detector surround the interaction point in a series of concentric layers. The tracker is at the center, surrounded by the superconducting solenoid magnet and the central calorimeter. The magnetic field of the solenoid is along the beamline, with the return path being through the steel of the calorimeter hadron section. The central systems sit within the muon system, which consists of a magnetized-iron barrel toroid, wire chamber modules and scintillation counters for muon identification and momentum measurement. At the ends of the barrel toroid are forward toroids and muon chambers, as well as a forward calorimeter.

The momentum of charged particles can be measured by the bend in their tracks as they pass through the magnetic fields (sideways bend in the solenoidal field, and towards or away from the beamline in the toroids). To complete the event description, the calorimeter system is designed to detect neutrals through the measurement of overall missing transverse energy.

The tolerances for both placement (location) and measurement (knowledge of the location) of components are very stringent. There may be several hardware and software combinations that can achieve the desired results, and the decision as to which route to take will be determined by performance, reliability and cost.

The SDC detector will be largely built on-site at the SSC Laboratory. The requirements for precise measurements, therefore, extend from basic manufacturing tolerance control to the final alignment of the entire detector. Manufacturing precisions are at the tens of microns level, while the overall alignment of the detector is at the hundreds of microns level..

* Operated by the Universities Research Association, Inc., for the U. S. Department of Energy under Contract No. DE-AC35-89ER40486.

FACTORS WHICH AFFECT ALIGNMENT

Mid-way through the detector, the two beams will cross at approximately 150 milliradians, resulting in a volume in which interactions will take place between protons of the opposing beams. Those interactions produce particles which will be measured by the detector . In order to relate all of the information, however, a trigger system must first discriminate events of interest from the massive volume of background events, passing only data from events of interest to be collected and stored for later off-line analysis.

Because of the speed of the interactions (10^8 events per second[1]), the first-level trigger must decide which data to save with very little processing time. This Level 1 trigger depends on precise placement of the detector elements, assuming that a particle that strikes a given element has traveled from the origin along a particular trajectory. If that data or combination of data from several detector elements match an expected trigger scenario, the trigger accepts the data.

The Level 2 trigger then takes the data that was accepted by the Level 1 trigger and compares the reactions of more elements before deciding that the combined group of data represents an interesting interaction event. The combined Level 1 and 2 triggers lower the accepted rate of events passed to the Level 3 processing by about five orders of magnitude.[2] Level 3 processing includes the entire saved data set, sending data from approximately 100 events per second to permanent storage.[3]

PLACEMENT ACCURACY

The requirements for positioning of the different detector components are based on the functions of the trigger, as noted above. Since there is essentially no time for computations in the Level 1 trigger, it must depend on the accuracy of a component's placement to compare its event measurement to expected values and to the measurements of other components. The accuracy of the placement is chosen so that the error in placement will not seriously degrade the component's inherent measurement capability. These decision variables are described below, in the discussion of each subsystem's position goals. Other variations, caused by the system-level environment, must also be corrected.

The collider beamline slopes down 2.16 mm per meter through the hall from North to South. This means that the entire detector must be positioned on a 0.12 degree slope, with the north end 60.5 mm higher than the south end. A system of jacks will be used to keep the detector coaxial with the beamline. The detector will be assembled and aligned several years before the beamline magnets are actually installed. The initial survey of the experimental hall, therefore, will be crucial to the interface of the detector and collider.

The 75 million pound weight of the detector will cause deflections in the floor and barrel support structure - which could be as much as 20 mm. These movements will be jacked out by the main support jacks. The weight of the barrel iron itself will cause a change in the cross section from octagonal to ellipsoidal (the top will move down as much as 4.1 mm and the sides will move out 3.6 mm[4]). There will also be movements due to removal and re-installation of the end toroids and calorimeter.

Movement of components due to changes in temperature or the force of magnetic fields must also be taken into account. The diameter change (flat-to-flat) for the barrel toroid, for example, would be approximately 0.9 mm for a 5 degree Celsius temperature rise.[5] The change in the radius of the barrel toroid when the magnet is excited will be of order 70 microns,[6] approximately the same as the measurement precision of the muon alignment system.

MEASUREMENT ACCURACY

The Level 2 trigger and the off-line reconstruction of tracks require a very closely measured location of each component. While the Level 1 trigger divides the detector into 64 bins around the circumference, the Level 2 trigger uses 1024 bins. For off-line track reconstruction, each individual silicon chip and each drift-tube wire must be located precisely in relation both to each other and to a common reference system. The

reconstruction of tracks and, therefore, the calculation of particle momenta, will only be as good as the measurement system's output.

Since it is impractical to physically measure each component's actual position on a continual basis, the alignment system will only locate fiducial markings. These locations, along with temperature measurements, inclinometer readings, and the positions calculated from previous data, will be fed into a computer model which will compute the locations of individual detector modules and wires. The computed positions will then be used in track reconstruction calculations.

ALIGNMENT/MEASUREMENT REQUIREMENTS

Central Tracker

The central tracker consists of three major components which must be in close relative alignment to act as one unit for trigger purposes. The central, silicon system must be centered within the outer barrel tracker to 150 microns and with respect to the intermediate tracker to 1 mm.[7] For off-line track reconstruction, these two values must be known to 15 microns and 40 microns, respectively.[8] Since transverse momentum is measured by changes in circumferential position with respect to radius, the rotational alignment of the silicon system vs. the barrel and intermediate systems is held to a placement of 10^{-4} radians, with measured position knowledge of 10^{-5} radians.[9] For Level 2 trigger purposes, which assume that a track starts from the orgin, the tracker needs to be centered on the interaction point to within 500 microns.[10]

Silicon Tracker. The specifications for alignment of the internal silicon tracker components are at the micron level. Manufacturing tolerances will result in a 10 micron local alignment of the silicon substructures, with a build-up of tolerances resulting in the resolution at the external fiducial markings of 135 microns.[11]

Barrel (Straw) Tracker. The barrel tracker is very sensitive to circumferential errors, with circumferential placement and measurement requirements of 140 microns and 35 microns, respectively, while the radial position requirements are only 1,200 microns.[12]

Intermediate Tracker. The intermediate tracker, presently designed as a gas-microstrip detector, has three parallel, circular planes of detectors attached to a cone-shaped support frame. The detector elements are precisely placed on each plane to a local circumferential alignment of 40 microns, while the radial position is only required to be within 1 mm.[13]

Superconducting Solenoid Magnet

The superconducting solenoid magnet will be adjusted during installation to a location precision of 500 microns,[14] with its magnetic axis aligned to within 5 microradians of the beamline.[15] Once in place, there will be no further adjustment of its position.

Calorimeter

The central calorimeter (barrel halves and end caps) rests on a wheeled support system that must transfer its 8 million pound weight through a rail structure ("picnic tables") to the muon barrel toroid steel. The forward calorimeter will be supported by a similar system. The jacks in the central calorimeter support system must be able to move through approximately 5 cm vertically and 2.5 cm horizontally to ensure that the shower maximum sections are within 3 mm of being concentric with the beamline[16] and that the tracker is within its approximately 5 mm adjustment range. Additionally, the tracker and calorimeter are divided into 1024 bins for the Level 2 trigger, and must remain within this six milliradian bin alignment for the trigger to operate properly.

Muon Measurement System

The muon barrel and intermediate modules are supported on rails which are fixed to the muon barrel steel. The rails will have an adjustment capability during assembly of approximately 10 mm with their position and alignment determined by survey. The

intermediate modules are cantilevered from the ends of the barrel, and are installed near the end of the assembly sequence, after the detector has undergone its major deformations. The forward modules are attached to the forward toroids and will have some post-installation adjustment capability.

The placement tolerances for each of the muon modules is calculated based on the movement (translation and rotation) that will cause a 10 percent degradation in the measurement resolution of the module.[17] All of the muon modules have relatively loose placement tolerances of several millimeters of translation but the forward modules have a very tight 0.41 milliradian tolerance in pitch.[18]

Since all of the detector components depend on the barrel toroid support system for basic positioning, that system has been designed to be adjustable. The jacking system will have to align the entire detector to the sloping beamline, as well as having to compensate for settling of the floor or of the detector itself. Since the muon alignment system will not have good lines-of-sight through the support structure beneath the barrel, a liquid-level system and temperature monitors will provide data for that part of the system. A combination of data from straight-line monitors, proximity sensors, a range-only measurement network, and the liquid-level, temperature sensors will be integrated via a computer model to determine actual detector element locations.[19]

SUMMARY

A combination of precise manufacturing tolerances and careful assembly will relate each detector component to a fiducial. The placement of the fiducials with respect to the primary detector coordinate system and with respect to each other will be accomplished by surveys and measurements at each successive step of assembly. The precise locations will then be continuously monitored by the alignment system, either by direct measurement or by inference through a computer model. The subsystem fiducial placement tolerances vary from 500 microns to several millimeters in translation and 0.41 milliradians to several milliradians in rotation, while the manufacturing and location measurement tolerances are very tight, at the microns and tens of microns levels. Alignment and measurement equipment and procedures continue to evolve, still remaining flexible enough to accommodate new ideas and components.

REFERENCES

1. A. Lankford et al., *Conceptual Design of the SDC Trigger from the SDC Trigger Group,* SDC-91-00098, September 30, 1991, pg. 1.
2. *Solenoidal Detector Collaboration Technical Design Report*, SDC-92-201, 1 April 1992, pg. 8-3.
3. Ibid., pg. 8-7.
4. H.J. Krebs, Ed., *Preliminary Design Report - Muon Barrel Toroid, Version 1.2*, SDC-92-342, October 7, 1992, pg. 2–8.
5. Ibid., pg. 2-8.
6. R. Bell, Committee Chairman, Ed., *SDC Muon Barrel Toroid Preliminary Design Review Committee Report*, SDT-000069, November 18, 1992, pg. 4.
7. R. J. Hovde, Ed., Minutes, *SDC Alignment Working Group, November 12, 1992*, SDT-000068, November 16, 1992, pg. 61.
8. Ibid., pg. 61.
9. Ibid., pg. 61.
10. Ibid., pg. 61.
11. Ibid., pg. 62.
12. Ibid., pg. 61.
13. Ibid., pg. 61.
14. A. Yamamoto, Telefax to R. Hovde, SSCL, with position and measurement requirements for the superconducting solenoid magnet, 28 Sep 92.
15. R. Little, *Misalignment of Solenoid Field,* PMO Memo 93 4700.52 E B, March 18, 1993.
16. *Solenoidal Detector Collaboration Technical Design Report*, SDC-92-201,1 April 1992, pg. 6-7.
17. S. Behrends, P. Hurst, J. Bensinger, *Performance-Based Tolerances For Muon Supermodule Alignment, Version 3.3*, SDC-92-376, 4 December 1992, pg. 1.
18. Ibid., pgs. 8-9.
19. R. Hovde, Ed., *Minutes, SDC Alignment Working Group, November 12, 1992*, SDT-000068, November 16, 1992, pg. 34.