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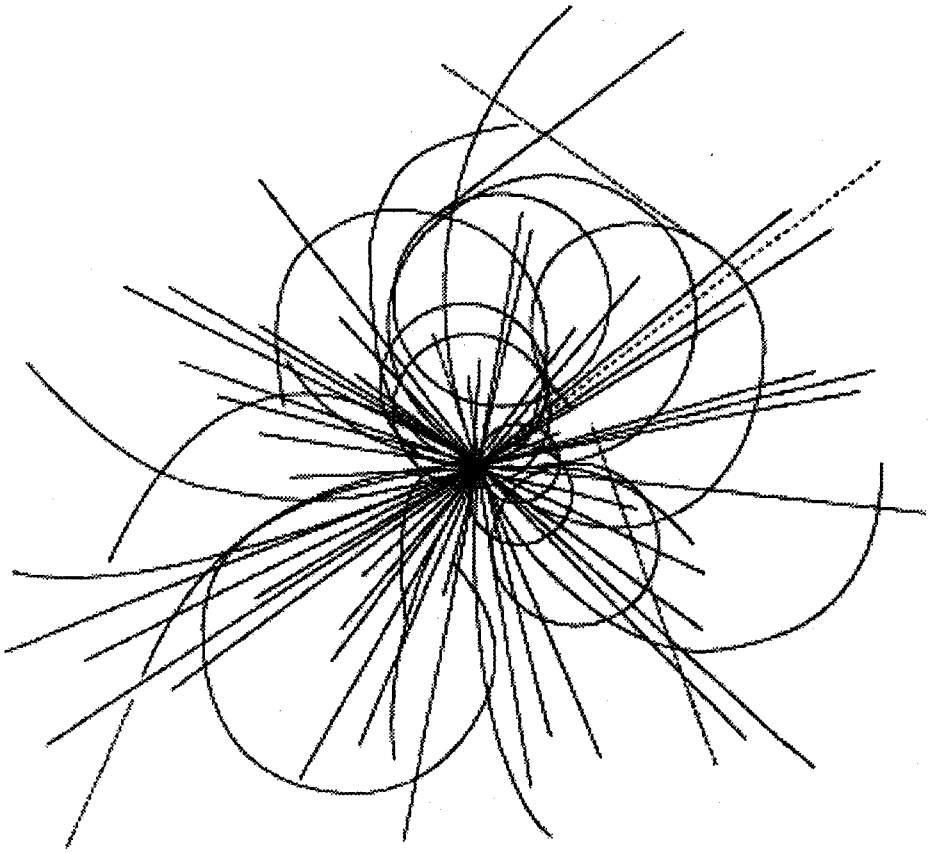

Superconducting Super Collider Laboratory

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SYSTEM-LEVEL DESCRIPTION OF THE SDC DETECTOR

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INTRODUCTION

The detector being designed by the Solenoidal Detector Collaboration (SDC) is an eight story structure with 8.5 million sensor elements[1]. The positions of these elements must be known to less than one millimeter accuracy to meet the physics requirements[2]. However, this 75-million pound experimental device could settle up to 20 millimeters and the entire detector, as well as its components, must be moveable to align with the proton beam and to accommodate detector and floor deflections.

Interesting engineering challenges are presented as the detector is designed. The management challenge of integrating the work of about 1000 physicists and engineers at institutions around the world is also significant. The coordination process is being facilitated by the publishing of a reference book for detector designers, the SDC Detector Parameters Book (Ref. 1), that contains the latest design information. It was used as the source of detector data contained in this paper (unless otherwise indicated).

This paper describes some of the systems issues that are being faced as the detector is designed. After the detector is described, the foundation requirements are reviewed and the method of keeping the detector aligned with the proton beam described. A discussion of detector operations and maintenance completes the paper.

DETECTOR DESCRIPTION

The detector is housed in a hall that is about the size of a football field and is 213 feet underground[3]. The hall is 182 feet high, including the roof structure.

Two counter-rotating beams of protons will be accelerated in a 87-kilometer beamline. A 50-meter section of the beampipe is inside of the detector. The detector beampipe subsystem consists of the beampipe and associated vacuum pumps that maintain a very high vacuum within the pipe to keep air molecules from interfering with the protons. The beampipe is approximately 80 mm in diameter and one millimeter thick. The beam is approximately 10 microns across[4] and its position can vary by up to 100 microns between daily fills of protons[5]. The beampipe position must be accurate to within one millimeter of the beam at the Interaction Point (IP)[2].

Several types of tracking subsystems surround the IP. These contain some seven million sensor elements designed to record the tracks of the particles. The tracker must be independently adjustable and be positioned to within half a millimeter of the beam in radius[2].

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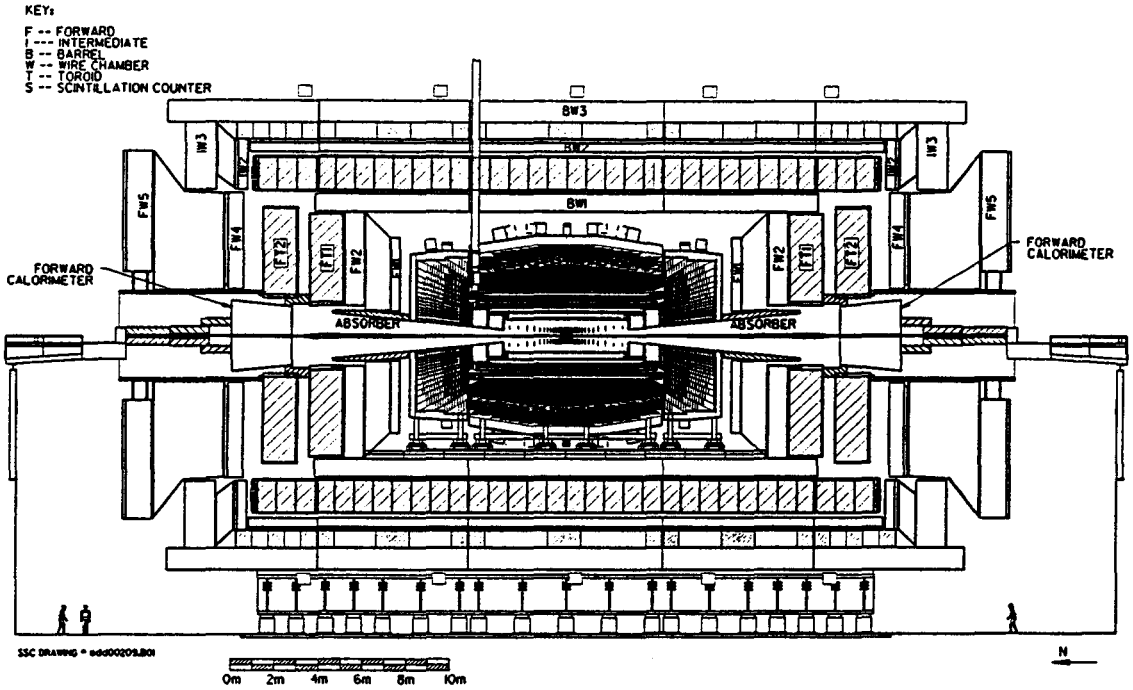

Figure 1. SDC Detector

A superconducting magnet surrounds the tracking system and provides the magnetic field that causes the charged particles to bend as they traverse the detector. The amount of bend in a track provides an indication of the momentum of the particle. A large cryogenic system on the surface provides the coolant to make the magnet superconducting.

The barrel calorimeter supports the magnet and tracker, and provides the ability to measure the energy of the particles emanating from the collisions. A forward calorimeter 12 1/2 meters from the IP provides energy measurement of particles close to the beam line. The four pieces of the 3638-metric tonne (eight million pound) central calorimeter must be rolled precisely into the center of the detector and be held in that position during operation. The 3.2 million pound endcap calorimeter pieces must have the capability to be rolled back to provide access space for maintaining the tracker and magnet. The many crates of electronic equipment that support the data acquisition from the tracker and calorimeter are mounted on the outside of the calorimeter.

The muon subsystem on the outside of the detector provides the capability to record the high-energy muon particles emanating from the IP. The measurements are done in muon chambers that are on either side of another magnet system. The 36 million-pound muon magnet system forms the outer structure of the detector and is 1.5 meter thick steel, 16.5 meters wide and high, and is 28 meters long. The design considered construction time (which favors few pieces), and transportation and handling limitations. The final design consists of 196 blocks weighing about 85 metric tonnes each. Additional muon magnets and measurement chambers are located at the ends of the detector. These must be removable to provide access to the inner components for major maintenance. The entire detector is supported by a large steel structure which rest on 76 jacks.

An extensive electronics system provides the ability to capture and record the data on the collisions. These physics interactions occur at a rate of almost 10^8 per second and each requires about a million bytes of data to record the 8.5 million data channels[6]. Such a data rate would swamp a processing system and yield more data than can be handled. A series of filters, called triggers, are used to capture only the physics events of interest and reduce the amount of data to 10-100 events per second. Even with the large reduction in data, over 10^{15} bytes of data per year are generated because the detector is scheduled to operate over 10^7 seconds per year. However, only a very few data points per year will be seen that lead to

new discoveries. An off-line computing system provides long-term storage of the data and will provide the ability for physicists around the world to analyze the results--from their home institution.

The detector is supported by utilities such as cooling systems to remove the heat generated by the electronics, electrical power supplies, safety systems and other support systems.

DETECTOR FOUNDATION

A major requirement of the SSCL was that the physics experiments be located on a foundation that provides low risk of short and long-term deflections. A study[7] in 1991 reviewed the soil/rock conditions in which the detector halls would be constructed. It was found that the East Interaction Regions provided the best foundation for the large detectors (like SDC) because the detector hall floor would be on Austin Chalk, which was the most stable rock in the area. Large detectors on the West Campus would have been on Eagle Ford Shale which is unstable and could have caused unpredictable movements of tens of centimeters. This risk was unacceptable for the large detectors and for the focusing magnets of the collider (who have even tighter positioning and stability requirements). The result of the study was that the large detectors were moved to the Austin Chalk foundations on the East Campus and the smaller detectors (which are not as deep) were located in the Austin Chalk on the West Campus. There was also a cost savings in the process.

The current SDC detector hall floor is ten-foot-thick reinforced concrete[3]. Data indicates that the floor could deflect approximately 5 mm under the load of the detector[8].

ALIGNMENT TO BEAMLINE

The proton beams will collide at a point in space called the Interaction Point (IP). This point (actually, a region about 7 cm long) is only a surveyed point in space when the detector foundation is started. The beampipe for the protons will not be installed until three years after the start of detector construction. A survey accuracy of 2 mm is expected[9] which means that the entire detector, or at least one of its subsystems, may have to move up/down and/or sideways to align with the beam.

The beamline slopes downward 2.16 mm per meter from North to South[10]. This means that the beam drops 86 mm across the detector. The entire detector must also be sloped to maintain the proper positions with respect to the beam. A study[11] was performed to determine if the detector should be assembled on the slope, or if it should be built level and jacked into position. It was found that the detector and floor will deflect during the construction process so a final alignment would be necessary in any case. The decision was made to let the muon subsystem choose the best way to assemble the muon toroid magnet (ie: build on slope, or build level and jack). The entire detector will be aligned with its final position on the slope before the muon system is complete. The inner components will be installed on the slope. This was the least-risk option because alignment of components can take place for several years with the detector in its operating position.

The detector and floor are expected to deflect up to 25 mm as the detector is constructed[12]. Additional deflection over time may also occur. The jacks supporting the detector are being specified to be able to raise and lower the detector through a range of 120 mm [13]. Differential motion between the jacks on either side will be able to translate the detector centerline sideways if necessary. Current design calls for the jacks to keep the detector positioned within 3 mm of the correct position. The calorimeter, tracker and/or beampipe may have to move independently to achieve their tighter positioning accuracies.

DETECTOR OPERATIONS AND MAINTENANCE

The detectors are planning for the proton beam to operate an average of 5631 hours per year (after the initial checkout process)[14]. The remainder of the year the beam and detectors will be scheduled to be off for planned maintenance. The collider will fill the beam with

protons about once a day and accelerate them to collision energies. The daily fill is necessary to replenish the protons that are lost to collisions. A stable beam should be available to provide physics data an average of 3754 hours per year[14].

The detector and collider organizations are working to have their systems available for operation 80% of the time. This means that they should operate 80% of the time they are scheduled to operate. During the remaining 20% of the scheduled time they would be down for unscheduled maintenance. This unscheduled maintenance time is being minimized by the use of more reliable components that fail less often (either by their intrinsic design or by designing an installation that will reduce failures), and by designs that reduce repair time.

Much of the detector electronics will be on the surface in the Detector Operations Building where they will be accessible during collider operation. No one is permitted in the detector hall during operation because of the radiation from the beam. This beam radiation is contained by the underground tunnels and halls and does not affect people on the surface. The beam radiation stops when the beam is turned off. The major utility systems that support the detector are also mostly located on the surface where they can be quickly repaired when the beam is on.

SUMMARY

The major system-level focus of the last year has been that of getting a very large steel structure to have the precise adjustability needed to meet the physics requirements. The detector halls have their foundations in the most stable rock available and the hall floor has been specified to minimize deflection. Plans have been made to align the detector and its subsystems to the proton beam when it is assembled in the hall, and to keep them aligned. Efforts are continuing that help define the reliability, availability and maintainability requirements to ensure that this large data acquisition system functions as needed to capture the data the should lead to new physics discoveries. The goal is to ensure that this huge instrument will be able to continue the advancement of science that started thousands of years ago.

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