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GEANT SIMULATIONS WITH SHELL AND MODULE GEOMETRY CODE AND SCINTILLATING FIBER CENTRAL TRACKING

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Abstract

This paper describes two GEANT geometry subroutines. One is a new geometry definition coordinating subroutine for use in GEANT simulations of the SDC, modular in design, and allows linking time replacement of subsystem geometry defintion routines. The other is a scintillating fiber central tracking geometry with four superlayers, three disk end caps, defined fiber layers, and a simple method for changing a vector position to layer number and fiber number.

Introduction

At 40 TeV center of mass energy, luminosity 10^{33}, and a bunch spacing of 16 nanoseconds, the SSC provides us with a substantial challenge: to design a 4π detector that will survive and produce accurate data, but keep costs to a minimum. To design this detector it is essential to use data from accurate simulation programs. Almost every working group has some sort of simulation program for that group's section of the proposed detector. We can get substantial results from these limited simulations, but it is time to have available more detailed detector simulations, in which a researcher studying muon detector response (for example) may take into account the effect of each internal structure on the muons, as well as coordinate the muon chamber data with that from the central tracker. This information is invaluable in creating detailed track fitting programs, accurate ideas of background radiation, etc.

Researchers at LBL and FNAL are working in conjunction with various working groups to bring together existing geometry definition routines, translate them into a format appropriate for use in GEANT, and make that package available to researchers who want an accurate detector geometry. This means the creation of a system of modular geometry subroutines, internal to GEANT, and flexible enough to use existing code in spite of its various different styles and sources. In particular, this code should have the following characteristics:

1. GEANT-based
2. Optional fast geometry
3. Accurate and up to date precision geometry
4. Useful for different approaches to the same subsystem (e.g., straw tubes versus scintillating fiber central tracking)
5. Choice of subsystem version at linking time
6. Only slight changes required of existing GEANT subsystem code for inclusion
7. Simplified GEANT volume number, material number systems for easy reference and debugging

To meet these demands, we need one geometry coordinating subroutine which then calls subsystem subroutines to collect (in common blocks) the information needed to define every volume. These subsystem subroutines can be exchanged easily, as long as the replacement routine has the same name. The internal structure of these subroutines is irrelevant as long as the common blocks are filled properly, which allows existing code to be adapted easily to the modular format. Finally, the common blocks may be useful later in tracking or digitisations.

Proposed Modular Approach

In the code written at UCLA and submitted for approval, this one geometry coordinating routine is called GEOMETRY. It is called from UGINIT, and coordinates calls to all the modular subsystem subroutines. GEOMETRY performs the following six main tasks: initialisation of the common blocks, creation of a materials table, filling the common blocks in the subsystem routines, definition and positioning of each volume, set definitions, and then calls to GSORD and GGCLOS.

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The creation of a materials table takes place in the subroutine MATERIALS. It starts with the GEANT table created by a call to GMATE. Then it adds the straw tube mixture, scintillating fiber material, and other useful materials. This table can easily be extended to include any other materials required by subsystem subroutines. There is some discussion over whether there should be a table set up such that each material is listed only once or whether each volume should have its own entry in that table. Right now there is code to do either. Magnetic fields and tracking parameters are also set (with GSTMED) at this time, so there may be several definitions for the same material, depending on the magnetic field.

Every other task that GEOMETRY performs requires use of the common block CGEOM. This common block holds all the defining information for each volume in arrays. The arrays are set up so that for each value of the pointer, I, the name of the volume is NAME(I), the position of the volume is X(I), Y(I), Z(I), the number of divisions on the volume is NDIV(I), etc. Most importantly, the assignment of the volumes is carefully set up so that the internal number that GEANT uses to identify the volume matches the pointer value, I, for that volume; something that certainly doesn't happen automatically.

These variables are initialized to default values in the subroutine INITIALIZE. Most variables are just set to zero, but not all. Two of the more interesting assignments are NMAT(I) = 16 and MOTHER(I) = 'SDCV'. NMAT is the material number from the table set up in MATERIALS. It is set up so that if the user doesn't specify otherwise, the material within a defined volume is vacuum without a magnetic field. MOTHER(I) is the volume in which volume I is to be positioned. This assignment places it in the main, overall volume, SDCV.

The next step is to fill the common blocks by calling various subsystem subroutines. The pointer, I, which keeps track of the volume number in the arrays being filled, is passed as a parameter. The first subroutine to be called is GENERAL. This routine defines SDCV, the volume which houses all other volumes. It also defines "shadow" volumes, which outline places for each subsystem. This may change, as it is difficult to reconcile such a rigid requirement–that the entire subsystem fit inside some simple but artificial shape–with the necessity of programming volumes of cables and the like, which snake between volumes and may cause problems with overlapping volumes in GEANT.

Then GEOMETRY calls a routine for each subsystem, which are at present MVTX, CENTRAL, COIL, ENDPLUGCAL, BARRELCAL, FORWARDCAL, and MUON (See Figure 1). The subsystems may change as people consider where the natural breaking points are in the structure of the SDC detector. These routines are the ones we hope to have at least two versions of, one fast but simple, and the other detailed if slow. The fast version is a block of matter with density,

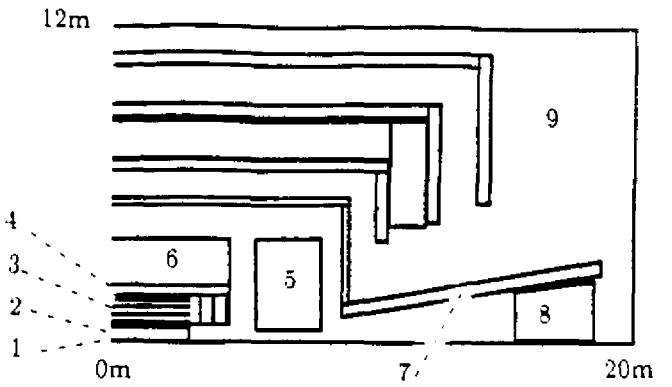

Figure 1: Full SDC geometry including scintillating fiber central tracking and muon chamber subsystems. 1: BEAM PIPE, 2: MVTX, 3: CENTRAL, 4: COIL, 5: ENDPLUGCAL, 6: BARRELCAL, 7: ABSORBER, 8: FORWARDCAL, 9: MUON

radiation length, and absorption length equal to the over-all average value within that area of the SDC detector. That is, rather than programming each layer of a calorimeter into the subroutine, the subroutine would simply define a few, or even only one, volume shapes containing a uniform material with properties an average of those of the constituent parts.

Detailed subroutines with the same names as the fast ones can replace them at compilation time. These versions don't take the shortcuts of the fast type, but define individual elements of each subsystem, with particulars such as fiber layers, support structures, readout cable bundles, etc. Rather than duplicate work that other researchers have done in this area, it is preferred to adapt existing work on these subsystem geometries to this format. The modifications required to existing GEANT code are simple: add the pointer, I, and replace the calls to GSVOLU, etc, with simple assignments to the common block variables (leaving GEOMETRY to handle all the calls to GSVOLU, etc, in a coordinated way). For code other than GEANT code, it may be easier to start from the beginning, using only the same figures that were used in the non-GEANT code. If, however, the geometrical parameters are in a CAD file, there may be more hope. Andrea Palounek (LBL) is checking into the possibility of a translation routine, capable of reading an output file from CAD and putting the information into GEANT language.

After all the common block variables are full, GEOMETRY loops through the pointer I again, calling the subroutines GSVOLU, GSPOS, and GSDVN. This defines, positions, copies and divides each volume in turn. Then GEOMETRY finished up with the requisite calls to GSORD and GGCLOS.

Scintillating Fiber Central Tracking Subsystem

The subsystem subroutine CENTRAL uses scintillating fiber technology in layers, stereo and axial, to create

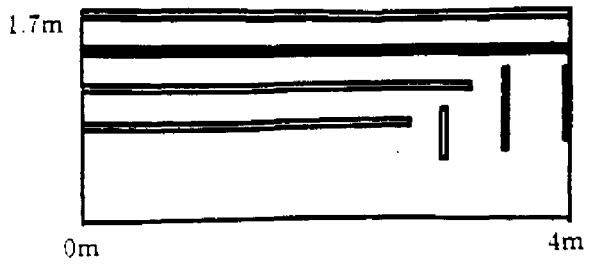

Figure 2: Central Tracker with superlayers and disks.

an effective tracking volume. The general construction of the scintillating fiber central tracker is simple, owing to the convenient properties of the fibers. The fibers are laid in parallel layers with four layers all in the same direction making a tier. These tiers fit together with the help of a tubular support structure to make a superlayer. Since fibers can be twisted and bent, they may be placed in layers such that a fiber in the layer describes a helical shape on the surface of a tube. The fibers in layers with fiber axis parallel to the beam pipe are called Z fibers, and the fibers in layers with fiber axis at a small angle to the Z axis are called stereo fibers, axial fibers, or U and V fibers.

The central tracker described here has four tubular superlayers and three disks of fibers on each end (See Figure 2). The tubular layers are each divided at the center of the tracker, and readout takes place at the outer ends. The inner two superlayers are constructed the same way. They each have a tier of four 0.5 mm Z fiber layers on the inside, a 5 cm spacer, and then another tier of Z fibers on the outside. The outer two superlayers make use of the U and V layers possible with fibers. They each have a tier of four Z fiber layers, then of U fibers, then a 5 cm spacer, V fibers, and Z fibers. The end disks each have a unique geometry that also utilizes the bending capabilities of the fibers. These layers are stacked together with more spacer material for support, and arranged as three disks on each end of the detector.

In the GEANT user code, each tier of fibers (2 mm thick) is a volume, and each single layer (0.5 mm) is a division of that tier. It is then straightforward to calculate a layer number corresponding to a hit fiber. The program simply counts through the active fiber layers, right and left, using some counting convention, and assigns the layer number for that hit. It is slightly more complicated to assign a fiber number (within the layer) to the hit. What the subroutine does is to calculate the phi angle of the hit, adjust it for the stereo angle (in the case of U or V fibers), divide by the diameter of the fibers, and truncate that answer to the next lowest integer. This effectively numbers the fibers at the Z = 0 end, starting at phi = 0 and going in the +phi direction. The process can be reversed to obtain an X, Y coordinate from a layer number, fiber number combination.

Using this set-up, the next step is to run ISAJET events through the detector to estimate an expected occupancy. The plan is to approximate data from a typical Higgs event as consisting of 16 events, one Higgs and 15 minimum bias. Then one may count the number of fiber number pairs corresponding to hits of charged particles, and calculate the occupancy. If one uses the coordinating geometry routine to include at least the solenoidal magnet and fast microvertex chamber, then we can also take into consideration the extra particles coming from decays and bounce-back.

Future Work

The most important logical step to take with the geometry coordinating routine is to finalize the module spaces. In the code described here there are seven spaces, MVTX, CENTRAL, COIL, ENDPLUGCAL, BARRELCAL, FORWARDCAL, and MUON. Using this structure places rigid constraints on the modular code: the modular geometries must fit in the spaces provided. On the other hand, the spaces are natural ones, given the working groups that we have. A scheme proposed by Dr. Kunori of FNAL[1] has only three spaces to fill (CENTRAL, CALOR, and MUON). It allows more freedom within each module, but presents problems merging different working groups' code into each module. Another option is to do away with proscribed spaces altogether. The modules could then be written and called in the most natural manner, according to the code already written. There would also be space to include cables and support structure, a major difficulty with the other two schemes. But then the burden would fall to the user to ensure that nothing overlaps. Note: errors arise in GEANT when volumes overlap. There is a portion of code written in Florida by Dr. Saul Youssef (SCRI) that checks for overlapping volumes. Perhaps this could be used here.

Future work should also include finding a continuing person to be in charge of maintaining and updating the coordinating geometry code, as well as creating and maintaining a library of modules for use by researchers. In addition, we need a naming scheme to avoid future confusion. There are several in use. Also a CAD translating subroutine is in the works, as mentioned earlier. Finally, this geometry structure needs to be incorporated into the SHELL program being developed for the SDC collaboration by Kunori et al.

Acknowlegements

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[1] SDC communication, unnumbered.