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Using the CERN Program-Library Graphics and Interactive Data Display

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Abstract

Small scale Monte Carlo programming is growing rapidly due to the ease with which complex problems may be formulated by any programmer. These programmers may choose to exploit graphics and interactive displays available in the program library developed and maintained by CERN (the Center for European Nuclear Research). This paper outlines the use of graphics and interactive data display features of the CERN program library, developed for visualizing simulated data events in particle detectors. One example uses GEANT, CERN's Monte Carlo modeling program, to simulate 300 MeV/c protons incident on a silicon slab. Display packages for GEANT are available both on-line and off-line for 3-D tracking of particles through any detector system. On-line displays provide the user a qualitative sense of the inner workings of various detector components. On-line displays may be updated for each particle track in the detector system, so any design change in detector geometry or component material may have its consequences visualized immediately. This visualization is useful for repeatedly making gross changes in the detector system. CERN has been very generous in making its program library available to any institution tied to groups working on experiments at CERN, however peripherally.

Introduction

GEANT (1994) is a powerful Monte Carlo modeling software package widely used in the high-energy physics community. It is capable of modeling sophisticated particle detectors by simulating their response to secondary events following a relativistic nuclear collision with a fixed target nucleus, or their response to central collisions of gold on gold in a colliding beam environment. GEANT is available to researchers at the University of Arkansas at Little Rock (UALR) because of the participation of our research group in experiments at CERN, the Center for European Nuclear Research in Geneva, Switzerland.

Until recently, only large institutions and national labs such as CERN used GEANT due to the complexity of the software and the extent of the computer resources required. However, with the growing availability of high-powered computing, more and more universities are beginning to use GEANT and its associated software packages. Since GEANT has traditionally been run by the sophisticated user, its complicated structure and lack of documentation is daunting to the beginner. To help fill this gap, two papers were published (Byrd et al., 1993; Roetzel et al., 1993) explaining the main features of GEANT and their uses. This paper expands on the previous two by describing the details of a simulation run by UALR students. Furthermore, the visualization capabilities of the CERN program library were not addressed previously; this paper describes the routines needed to implement the visualization of the detector and its response to particle events.

GEANT is a software package consisting of hundreds of FORTRAN subroutines. Each subroutine performs a specific task. Together these subroutines are used to model a particle detector by simulating its response to known incoming particles. A few subroutines, called user subroutines, have a special function. User subroutines are written entirely by the user for the purpose of customizing the simulation. Only CERN routines and user routines needed to implement visualization will be discussed, since non-graphic GEANT routines have been discussed extensively elsewhere (Roetzel et al., 1993).

For this simulation, a simple detector design was chosen, consisting of a silicon slab set in a vacuum. The event was chosen to be a stream of protons incident on the slab at 90°. The silicon slab represents an adequate model of a silicon drift detector (Gatti, 1989) in its interaction with charged particles. The simulation was done with the purpose of studying the energy deposition characteristics of protons while traveling through the silicon slab.

Materials and Methods

Detector Design and Event Definition.--The detector geometry consisted of a silicon slab and a mother volume. The silicon slab had dimensions of 300 m in the z (beam axis) direction and 6 by 7 cm in the x and y directions respectively. The mother volume is a large box surrounding the silicon slab. The mother volume defines the area of the vacuum.

Each proton was given an initial momentum of 300 MeV/c, entirely in the z-direction. Figure 1 shows the vertex (the proton source position) set 2 cm upstream (left) from the silicon slab with the protons incident on the silicon at 90°.

Based on the geometry defined, GEANT created a three dimensional, scaled representation of the slab of silicon and mother volume. GEANT then triggered the particles one by one and tracked them through the detector geometry in minute detail. To obtain high statistical accuracy, one million protons were triggered through the detector, requiring about one hour on a DEC 5000 workstation.

User Subroutines.--UGEOM is the routine where the user designs the specific shapes and material composition of each detector component and its spatial relation to the other components. GEANT uses this information for many purposes including drawing the detector on the screen. A call to GSVOLU defines a volume shape (for example: box, cylinder or sphere). GSPOS positions each volume with respect to the origin. GSROTM defines the viewing angle of the master coordinate system. GSATT is used to set attributes such as color and appearance.

GUKINE is the routine where the user defines the components of momentum and initial position of the event particles. For the present simulation, the protons were given an initial z-component momentum of 300 MeV/c from a source position located 2-cm upstream from the silicon detector.

GUTRAK calls the GEANT routine GTRACK. GTRACK initializes the physics processes. These processes may include electromagnetic interactions, hadron collisions, nuclear fission, bremsstrahlung, etc. GTRACK then begins with a single particle and determines the trajectory of that particle by creating a series of many small steps. Each step is determined by considering which physics processes have occurred during the previous step. The trajectory may also be influenced by bending from a magnetic field or decay of the particle into secondaries.

GUSTEP is one of the most important user subroutines for visualization of particle trajectories. It takes control after each step in GUTRAK. In GUSTEP the user can determine which physics information is to be stored, such as energy loss, secondary particles and detector hits. GUSTEP is called repeatedly for each particle at every step. GUSTEP also determines when to abandon tracking of a particular particle. To implement the visualization it is necessary to make three additional GEANT calls: 1) to store the position coordinates of the particle currently being tracked into the data structure, JXYZ, with a call to GSXYZ, 2) to store the momentum components and the time of flight information with a call to GSKING, and 3) to plot the tracks on the screen as they are created by GTRACK by calling GDCXYZ.

Results and Discussion

This simulation had several advantages over simulations done in the past and demonstrated some of GEANT's powerful visualization features. For example, while the present simulation consisted of only a simple silicon slab, much more complex designs may be made. Thus, any mistakes made when initially designing the detector geometry can be observed immediately. Without visualization, errors in detector geometry are difficult to find. These errors may only be found by carefully analyzing data taken in a batch run. The non-visual approach to error detection is difficult and time consuming and not always successful. Second, the tracking of particles can be done interactively. This allows the user to observe such features as angular distribution and back scattering.

Figure 1 shows the display of the silicon slab with the proton and secondary particle trajectories. As expected, most of the protons went through the silicon and left the mother volume on the right side. However, a few particles scattered at large angles and a few "back scattered". Also, different types of particles such as electrons and photons can be seen, represented by the dotted lines.

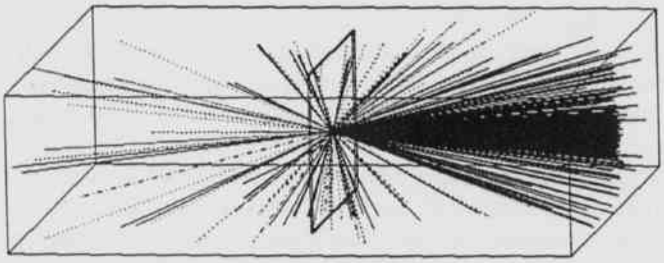

Fig. 1. Scaled diagram of the detector showing outgoing secondary particles (including protons). This figure represents 10% of this multiplicity.

Figure 2 shows the energy loss for all particles passing through the silicon. The GEANT prediction for peak energy loss is over 1000 keV. Based on predictions from other models (Williamson et al., 1966; STAR, 1992), a peak between 700 and 800 keV was expected. The value obtained was close enough to suggest that the GEANT modeling was reasonable. However, work is presently being done to determine if a more accurate value can be obtained and what the mechanisms determining the discrepancy might be.

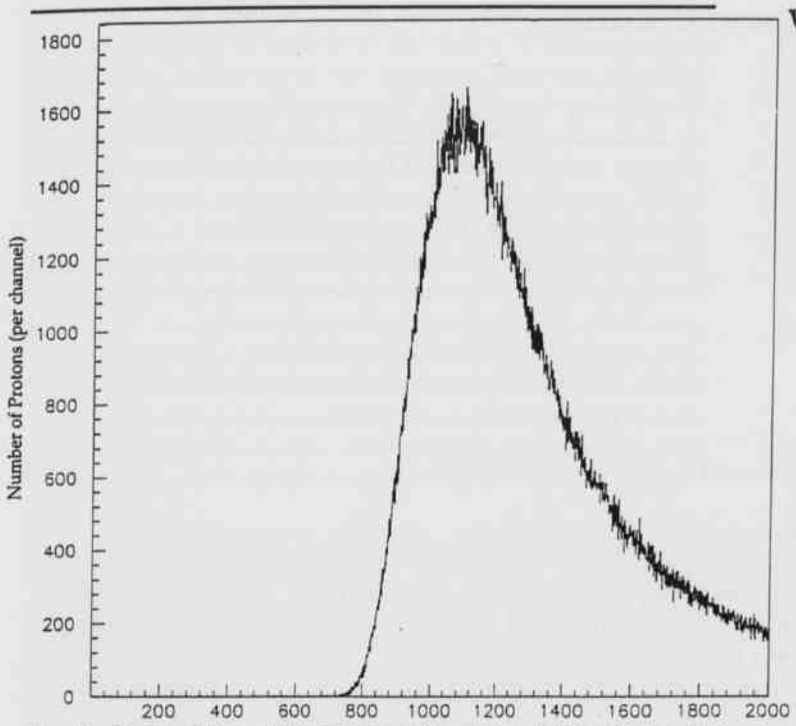

Fig. 2. Energy loss of incident protons on a 300 micron silicon slab.

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