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Abstract

A charged-particle tracking module was written and tested using pixel data generated from CERN's Monte Carlo detector-modeling program GEANT. This tracking module was customized for testing the design of a micro-strip gas time project chamber, designed by Drs. Margetis and Wieman of the Relativistic Nuclear Collisions Group at Lawrence Berkeley Laboratory. This low-mass, high-resolution, small-geometry vertex time projection chamber was designed for possible use with a larger instrument in an experiment using the relativistic heavy ion collider, RHIC, under construction at Brookhaven National Laboratory in New York. Implementing this tracking module involved generating tables and source code in a manner which is accessible to any user who is familiar with general purpose programming, using event-based data-processing. This charged-particle tracking module project was initiated in Summer-1994 as part of a 10-week, undergraduate research project at Lawrence Berkeley Laboratory, sponsored by LBL's Office of Science and Engineering Education. Further research on this project is underway at UALR.

Introduction

The Relativistic Heavy Ion Collider (RHIC) is currently under construction at Brookhaven National Lab (BNL) in Upton, New York. RHIC is scheduled to be completed in 1999. It will be used to accelerate two gold nuclei to within 1 part in 20,000 of the speed of light. At these speeds, each gold nucleus in the colliding pair has a kinetic energy over 100 times its rest mass energy and relativistic effects must be taken into account. Densities in the hot spot of the collision can reach up to 20,000 times that of a neutron star. The Standard Model predicts pairs of colliding gold nuclei will form a Quark-Gluon-Plasma (QGP), a state in which quarks and gluons are deconfined. It is believed that the QGP was the dominant form of matter in the universe during the first microsecond after the big bang (Schukraft, 1993).

To detect the QGP by examining its decay products, detectors are being built around the RHIC beam pipe. QGP is extremely short-lived, breaking up into thousands of secondary particles. The goal of the detectors at RHIC is to pick up signatures of the QGP secondary charged particles which are emitted as the QGP expands and cools. By detecting these secondary charged particles, researchers will be investigating the behavior of strongly interacting matter at high energy densities. One of the main dectors being built at RHIC is the solenoidal Tracker (STAR). STAR is comprised of a solenoidal magnet containing six sub-detectors. This magnet surrounds the beam pipe, providing a uniform magnetic field along the beam axis. Charged particles bend in this magnetic field, allowing a determination of both charge and momentum from the measurement of track curvature, using track data reconstructed in the subdetectors (Sauli, 1987).

The presence of a large amount of strange matter is one signature of a QGP. The abundance of strange quarks is observed by detecting kaons and lambda particles, which contain strange quarks.

The Vertex Tracker (VTX) is a small, low-mass, high-resolution, vertex time projection chamber (TPC) with a Micro-strip read-out. This technology is being explored to provide tracking in the forward region, close to the beam-pipe, and is the subject of a feasibility study underway as part of STAR's flavor physics program. This type of detector could potentially provide tracking at smaller polar angles, more space-point measurements per track and less material than would a silicon system placed in this region (Angellini et al., 1990).

Materials and Methods

The VTX design is fairly simplistic, consisting of a cylindrical gas-filled drift volume (of length 20-cm) with an electric field in the center parallel to the magnetic field of the detector solenoid (Wieman and Gong, 1994). The read-out endplate is a glass substrate with thin metal anode and cathode strips. When a charged particle passes through the detector it ionizes the gas. The ionization electrons drift up towards the 4 rows of pads on each end of the detectors and their signals are channeled into the data aquisition system. The measurement of the z-coordinate of the track is provided by a timing measurement. **r** and **phi** coordinates are provided by an array of crossing strips on the micro-strip endplates. This enables tracking at smaller polar angles and more space-point measurements per track.

In this study, software was created to analyze and process the data by tracking particles passing through the VTX. The particle tracking software for VTX is based upon a previously developed grouping algorithm (Prindle, 1993). This algorithm is based on the assumption of particle trajectories being nearly straight lines over small arc-lengths measured in the VTX-TPC. Reconstructed points are mapped onto a phi-z space. Each group on the phi-z map is a set of points topologically consistent with having been created by a single charged particle. The z axis is defined in the direction of the beam (which is the same direction as the solenoidal magnetic field), r is defined as the line created by the track, and phi is an angle defined in Fig. 1.

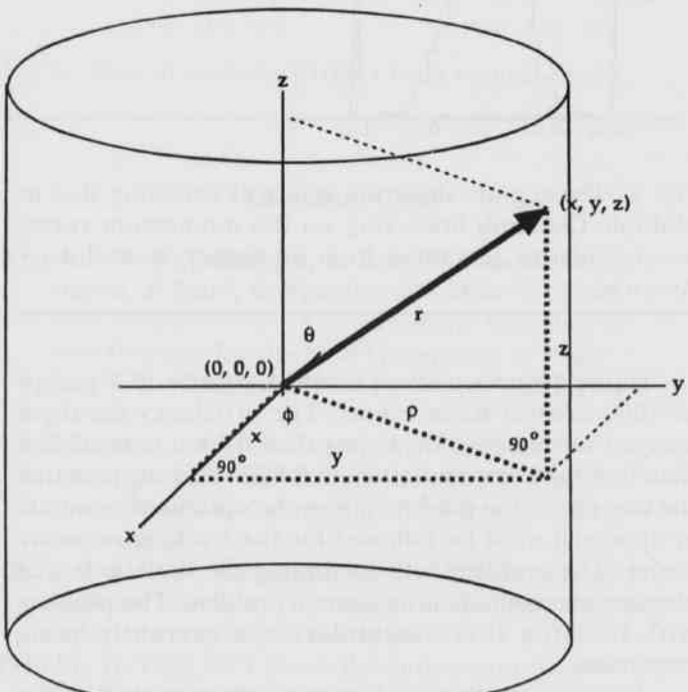

Fig. 1. Tracking geometry for the STAR TPC.

The detector software used by the STAR collaboration is run within the TPC Analysis Shell, (TAS), a general purpose analysis program for event-based data processing. TAS consists of modules containing tracking software and information about the geometry of the corresponding detector. The data is processed as a sequence of steps from raw data into physics summary data. TAS uses data structures called tables, which are 2-dimensional objects with columns and rows, which record data at any stage of event processing (Olson, 1993.).

Simulations of particle transport following central Au-Au collisions were run using the CERN (Center for European Nuclear Research) Monte Carlo detector-design package (GEANT, 1994), with properly defined geometries. A file was created in a special post-GEANT format, which was run through TAS to create tables which were filled with the results of the simulation data. The first stages of this analysis consisted of implementing and adding a new tracking module to TAS. To implement tracking, tables and source code were generated which could be accessed within TAS.

The source code input consists of TAS tables defining the TAS structures themselves (libraries, etc.) as well as vertex information, kinematics information, and table holding specific GEANT data about the particles. The output is a table which records the input data processed into data pixels.

The code first sets up a pixel map to which the hit data is transferred. The maximum number of hits per pixel is specified as well as the number of bins in phi and z-scaled. The minimum and maximum phi and z-scaled values are specified as well, and routines are called to reset the pixel map after each search, to add points to the pixel map, and to check for hits surrounding the particular hit being considered.

The code loops through all the points in the table holding the Monte Carlo data and reads the data in. Space-point data are read in cartesian coordinates, and are converted to cylindrical coordinates.

The hits in cylindrical coordinates are transferred to the phi-z pixel map. Clusters of 3 or 4 hits form on the pixel map. The code starts at the first pixel (lower left-hand corner) and searches for all the hits within it. Each hit is marked as having been recorded in pad-row one, two, three or four. The code opens its box-size (window) in four passes. In each pass the box-size is doubled. The code searches for a set of a minimum of three and maximum of four hits, consisting of one hit from each pad row. This set of three or four hits constitutes a group or track.

Another piece of software called the EVALUATOR, was written to run outside TAS. Once the tracking software has created tracks, the EVALUATOR takes the tracks and calculates the maximum distance in phi and z for each hit in every track and checks to see if the grouper's reconstructed tracks are reasonable. If a track fails this test it is marked as a wrong track. The EVALUATOR was used to determine the efficiency of the tracking algorithm.

One of the strongest features the VTX has to offer is its low mass. The tracking software was tested adding the effects of multiple coulomb scatterings, and subsequently, adding both the effects of coulomb scattering and point smearing. Point smearing accounts for the error in the electronics. This was done by writing a short code simulating these effects and adding them to the tracking software.

Results and Discussion

The grouping algorithm projects points radially in r, while phi is projected to the middle of the pad planes (Prindle, 1993). The maximum distance in phi (dphi) of the projected points in each cluster versus the transverse momentum as well as maximum distance in z (dz) versus transverse momentum are shown in Fig. 2. The first two plots are without multiple coulomb scattering, and the second two with multiple coulomb scattering. This figure shows multiple scattering effects in the detector are negligible.

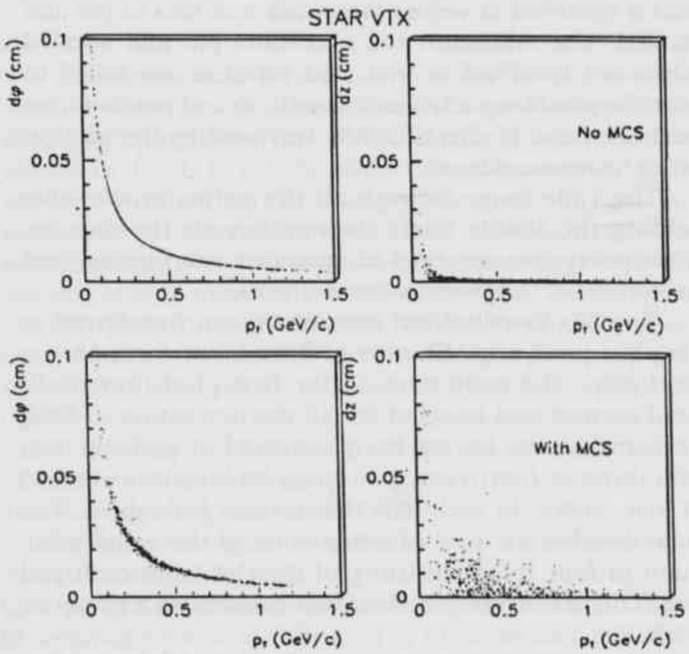

Fig. 2 Four plots from a central Zu + Au collider event. The bottom two plots include Multiple Coulomb Scattering, but the top two plots do not.

Figure 3 shows plots of the maximum distance in phi (dphi) and in z (dz) versus transverse momentum respectively with Multiple Coulomb scattering and "smeared" points. Comparing the Fig. 3 plots to the previous Fig. 2 [dphi/pt and dz/pt] plots, we see that smearing has its dominant effect on the momentum curve for primaries generated by a central Au + Au event.

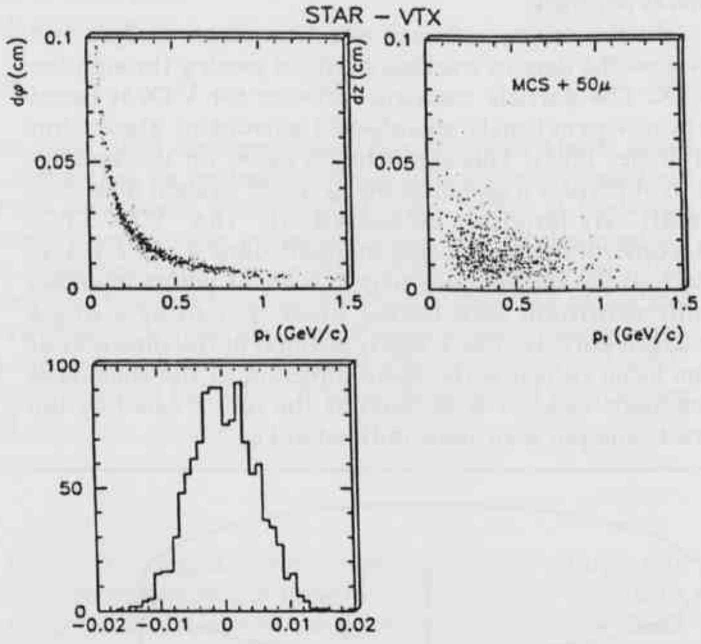

Fig. 3 These plots show the effect of smearing due to Multiple Coulomb Scattering on the momentum curve, for secondaries generated from a primary, central Au + Au event.

Figure 4 shows plots of secondary tracks of 3 groups of 1000 neutral Kaon events. The efficiency for these charged secondaries for dz less than 0.1 cm is much less than that for primaries (at about 8.5%). This suggests that the box size in the pixel map must be optimized or another approach must be followed for the tracking of secondaries. The problem with increasing the box-size is that electron contamination becomes a problem. The problem with tracking these secondaries is currently being researched.

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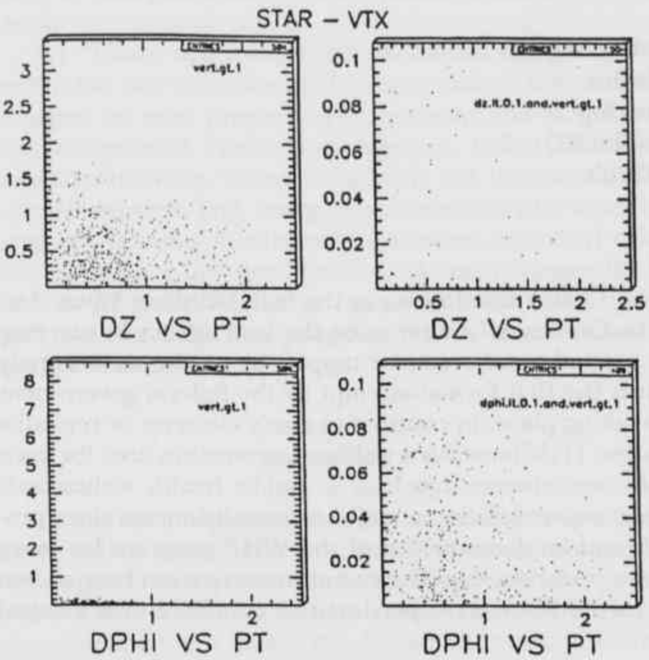

Fig. 4. Plots of secondary tracks from neutral Kaons.

Literature Cited

Angelini, F., R. Bellazzini, A. Brez, E. Focardi, M.M. Massai, F. Sauli, G. Spandre and M.R. Torquati. 1990. The Microstrip Gas Avalanche Chamber: A New Detector for the Next Generation of High-Luminosity Machines. Particle World, Vol. 1, No. 3, p. 85-90.

GEANT. 1994. GEANT user's guide: Detector Description and Simulation Tool, CERN Program Library Internal document, CERN Data Division, Geneva, CH.

Olson, D.L. 1993. TAS Applications Manual, Version 2.0. Available free from "ftp:rsgi02.rhic,bnl.gov/star/star lib/doc/www/sdd/tutorials.html".

Prindle, D. 1993. SVT Event Reconstruction Algorithms, Star Note, p. 1-16. Available free from "ftp:rsgi01.rhic.bnl.gov/star/starlib/doc/www/sno/sn0092.html".

Sauli, F. 1987. The Time Projection Chamber for Heavy-Ion Collisions: Trends and Perspectives. Reprint CERN-EP/87-233 (Invited talk given at the International Conference on Ultrarelativistic Nucleus-Nucleus Collisions, Nordkirchen, 24-28 August 1987).

Schukraft, J. 1993. Ultra-Relativistic Heavy-Ion Collisions: Searching for the Quark-Gluon Plasma. Nuclear Physics A 553:31c-44c.

Weiman, H. and W. Gong. 1994. Private Communication about a Letter of Intent for the BaBar Detector.