An Overview of Pattern Recognition in the Central Arms of the PHENIX Detector

Jeffery T. Mitchell

Brookhaven National Laboratory, Physics Dept., Bldg. 510C, P.O. Box 5000, Upton, NY 11973-5000, USA

It is predicted that a Au+Au event in the PHENIX Detector at RHIC will produce up to 800 charged particles in the PHENIX central arms. Pattern recognition algorithms are being developed to handle this hostile tracking environment. To facilitate the development of these algorithms, a suite of evaluators and event displays have been developed to calculate efficiencies and identify weaknesses in the algorithms. An overview of these algorithms and procedures will be discussed.

Key words: pattern recognition; event displays;

1 Introduction

The goal of the PHENIX detector, which is scheduled to begin taking data at the Relativistic Heavy Ion Collider in 1999, is to search for the existence of a deconfined state of nuclear matter called the Quark-Gluon Plasma. PHENIX, showed schematically in Figure 1, consists of two "central" arms designed for measurements of electrons and hadrons, and two arms designed for measurements of muons. This paper will discuss the development of charged particle tracking in the central arms only. The tracking detectors in each central arm consists of three pixel pad chambers (*PC1*, *PC2*, and *PC3*) to provide 3-dimensional coordinate information, a drift chamber (*DC*) with 12 "X" planes, 8 "U" planes and 8 "V" planes to provide accurate tracking in the magnetic field bend plane (the r-ϕ plane), and a time expansion chamber (*TEC*) with 4 wire planes to provide tracking information in the r-ϕ plane and additionally supply electron identification information.

There are many obstacles that must be overcome by the PHENIX tracking software. It is predicted that a central Au+Au central collision (with an impact parameter near zero) will produce close to 800 charged particle tracks in the central arms. In addition, the magnetic field within the central arm is designed to focus particles into the tracking detectors. This design results in a non-uniform field

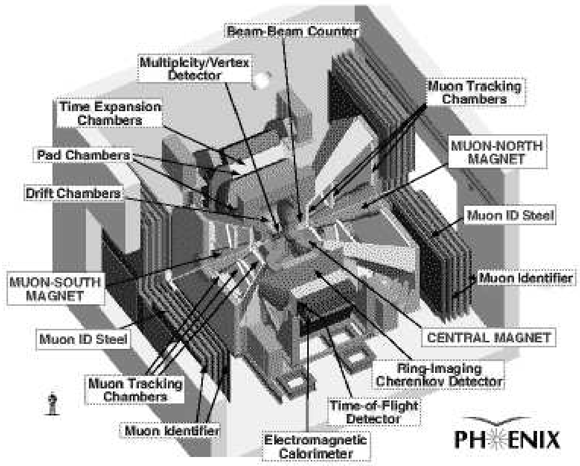

Fig. 1. Figure 1: A schematic illustration of the PHENIX detector.

that is very strong near the collision vertex and tapers off non-uniformly in the region within which the tracking detectors are located. Therefore, the PHENIX tracking algorithms cannot rely upon the behavior of the magnetic field. Finally, in order to optimize electron identification in the central arm, a Ring Imaging Cerenkov detector has been placed in between the inner tracking detectors (the drift chamber and PC1) and the outer ones (PC2, PC3, and the TEC). This results in a gap of about one meter over which tracks must be matched. The algorithms and evaluation tools being used to manage this hostile tracking environment are discussed below.

2 Track reconstruction algorithms

To optimize the processing time of the tracking algorithm in the high multiplicity environment, the first step is to sort the data in each arm in order of increasing ϕ coordinate for each detector plane. Each step of the tracking process then simply maintains a pointer to the current hit being examined on each plane. The tracking reconstructs tracks in increasing ϕ so that each pointer only needs to be incremented or decremented by a small number of steps during the sweep in ϕ. The general tracking strategy is to first reconstruct tracks in the r-ϕ plane of the drift chamber using the X wires. This reconstruction is aided by two facts: the drift field is set up to allow electron drift from only one direction on each plane, so there are very few left-right ambiguities present, and each wire is electrically isolated at z=0. The algorithm applied here is a simple road algorithm. Once an initial track segment is identified, a road is formed about that segment and allowed to stretch over all planes of the drift chamber. Hits that lie within and closest to the center of the road are associated with the track. The initial road is a straight line, which then must be corrected for the effect of the non-uniform magnetic field by applying a plane-dependent offset. The offset is determined by processing simulated events in GEANT, calculating the straight line road projections using the generated GEANT hits and then determining the offset of the projections from the hits. The offset depends strongly on the r-ϕ slope of the track segments, which is also proportional to the particle momentum, so a simple parametrization is applied once the track segment slope is calculated.

After the drift chamber track has been reconstructed in the r-ϕ plane, each PC1 hit that lies within the r-ϕ plane road is examined.. The PC1 hit supplies an initial z coordinate which is used to reduce the ambiguities present when attempting to associate UV-wire hits to the track. The ϕ coordinate of these hits must lie within the road and be consistent with the z position of the PC1 hit. The best UV-hit and PC1 combination is associated with the track once all possibilities are considered. Reconstructed tracks from the DC+PC1 combination are referred to as *inner* tracks. The road algorithm is again used to associate inner tracks with the outer detector information (PC2 and PC3 hits, TEC tracks), which will be referred to as *global* tracking. The inner track is projected to the outer detectors in the r-ϕ and r-z planes. The projections are again offset due to the residual magnetic field using the method applied in the drift chamber with different parametrizations. The best PC2+TEC+PC3 combinations are then associated with the inner track, if the projection is within the outer detectors. The outer detectors contain 30% more tracks that did not traverse the inner detectors. The remaining hits in the outer detectors are therefore associated into outer tracks with an independent application of the road algorithm without offsets.

3 Evaluation Methods

With close to 800 charged particle tracks and 19,000 hits present in the events of interest, the evaluation of the tracking algorithms become a daunting task. The most conceptual of all evaluation methods are visual event displays. A simple ntuple browser containing the elements of the data structures accessed by the various tracking modules is used in conjunction with a 3-dimensional event display for debugging purposes. Figure 2 shows the PHENIX tracking display, called *Birdseye*, which is an OpenGL-based interactive display that allows the user to rotate and fly through the event using a mouse.

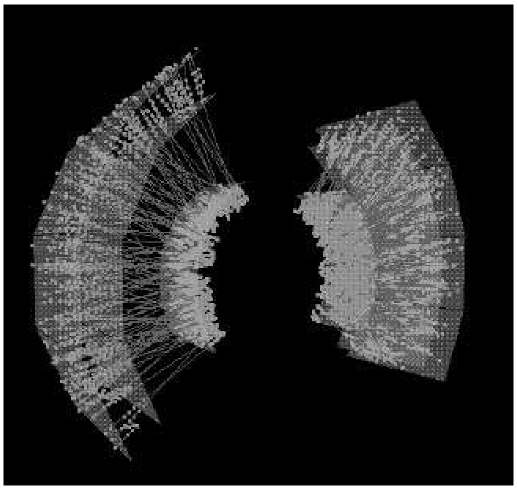

Fig. 2. Figure 2: A screen capture of the Birdseye event display showing detector hits connected by lines representing the tracks and transparent pad chambers planes.

Event displays are visually appealing, but possess limitations. They do not quantitatively calculate the efficiency of a tracking algorithm. For this purpose, evaluator modules have been written for each step of the PHENIX tracking process. Each of the evaluators provide information in the form of ntuples for each track along with event-by-event statistics that are written to a file. Activating the evaluation modules is accomplished at run-time. Each evaluator traces the information from the reconstructed track back to the simulated hits that comprise it. Because of the high track density, a method that will be called the dominant contributor method has been chosen to calculate tracking efficiencies. A dominant contributor is the simulated track which contributes the most hits to the reconstructed track. The efficiency is then quoted as the number of simulated tracks that appear as dominant contributors divided by the input number of simulated tracks traversing the detector. Another useful statistic is the number of hits that the dominant contributor donates to the reconstructed track. This quantity is stored in the track-by-track ntuple. The inner tracking efficiency is better than 85% at this time for central Au+Au events using this definition.

4 Conclusion

The algorithms used for tracking in the PHENIX detector central arms along with the methods used to determine their performance have been discussed here very briefly. More details on this software package are available at

`http://rsgi01.rhic.bnl.gov/~mitchell/tracking/luxmain.html.`

5 Acknowledgements

This work was supported by the U.S. Department of Energy.