Electron Identification in the PHENIX Experiment Using a Tracking TRD[1]

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Abstract
Measuring dielectron physics signals at RHIC will require the ability to separate electrons from pions to a level of better than 2×10^{-4} over momenta ranging from 0.1 GeV/c to 5.0 GeV/c. Particle identification over this momentum range is realized in the PHENIX detector at RHIC by a combination of detector subsystems, one of which is a tracking TRD. The PHENIX tracking TRD allows electron-pion separation utilizing both TR and dE/dx information, while simultaneously tracking charged particles with good position accuracy. The electron-pion separation of this device is better than 3x10^{-3} for particles with momenta ranging from 250 MeV/c to over 10 GeV/c.

1. Introduction

The PHENIX experiment at Relativistic Heavy Ion Collider (RHIC) will look for evidence of quark-gluon plasma formation, and determine its properties through measurements of electromagnetic and hadronic signals [1]. PHENIX places some emphasis on signals derived through the measurements of electrons. The cross sections, invariant masses and widths of the vector mesons ρ, ω, ϕ and J/ψ are measured through their dilepton decay channels. Open charm production is also studied through detection of its electron decay products.

The experimental design addresses the difficulty of extracting electrons from a much larger number of pions and kaons in high multiplicity heavy ion collisions by including a number of particle identification devices. Electrons are separated from the low mass mesons through the use of an electromagnetic calorimeter, a time-of-flight hodoscope,

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a ring imaging Cerenkov counter and a tracking transition radiation detector (TRD) (Fig. 1). These detector systems each have a maximum particle identification efficiency over different momentum ranges, but when taken together they will allow an e/π rejection of 10^{-4} or better over a range from 100 MeV/c to 5 Gev/c. The tracking TRD performs particle separation by both detecting transition radiation production and measuring the dE/dx loss of the charged particles that pass through the chambers. The dE/dx particle separation is most efficient below 2 GeV/c, while particle identification utilizing transition radiation is effective above 1.5 GeV/c. In preparation for construction of PHENIX, the collaboration has produced small detector prototypes for each subsystem and has conducted extensive test beam studies with them [2, 3].

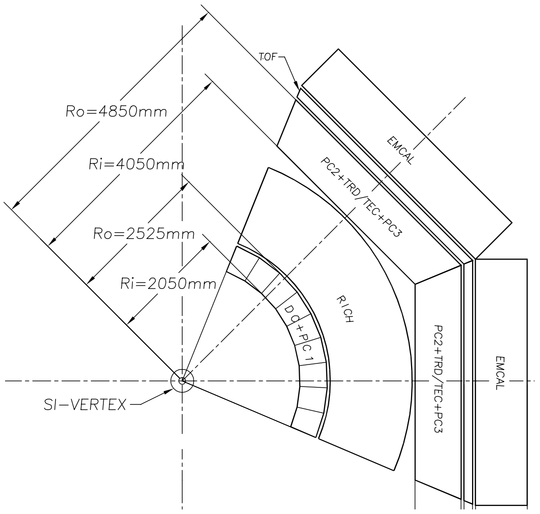

Figure 1. Cross sectional view of a central arm of the PHENIX detector.

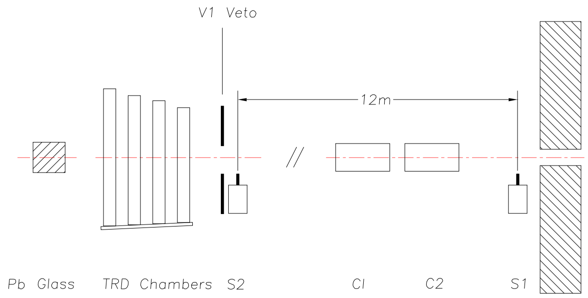

Figure 2. Diagram of the setup for the prototype tracking TRD test.

2. The Test Run

The PHENIX tracking TRD prototype was tested in the A2 beamline of the Alternating Gradient Synchrotron (AGS) at BNL using a secondary beam of e^-'s, π^-'s and K^-'s. The beamline was instrumented with two beam defining scintillation counters ($S1, S2$), two Cerenkov counters ($C1, C2$), one veto counter ($V1$) and one block of Pb-glass (Fig. 2). The TRD was composed of four wire chambers interleaved with polypropylene foil radiator packets. The wire chambers were Xe-filled time expansion chambers (TEC) with a 1-cm drift region and a proportional region of 8×2.5 mm^2. Each chamber had a 10-μm aluminized mylar front entrance window that served as the drift cathode, a plane of vertical cathode wires located at the beginning of the proportional region, a horizontal plane of 25-μm Au-W anode wires spaced 2.5 mm apart, and an aluminized exit window with cathode strips etched into it. The radiator packets were composed of 110 layers of polypropylene sheets, each 12 μm thick and spaced 800 μm apart.

Each anode wire in the chamber was instrumented with a preamplifier, a shaping amplifier with 70-ns rise time and a 6-bit Flash ADC (FADC) clocked at 41 MHz [4]. The FADCs were readout through the Nevis transport system into a DR11W module located in a VME crate. A Macintosh connected to the VME crate controlled the data acquisition system and wrote the data to 8-mm tape.

Each run was taken with either a minimum bias ($S1{\cdot}S2$) trigger or an electron trigger ($S1{\cdot}S2{\cdot}C1{\cdot}C2$). Data were taken over a momentum range of 0.7 GeV/c to 3.0 GeV/c and separate data runs were dedicated to studies of detector sensitivity to dE/dx and transition radiation signals.

3. Detector Performance

The PHENIX tracking TRD will be operated in two different configurations. The "basic" design contains four planes of TEC without the layers of radiator. This configuration will perform particle identification using dE/dx information only. The upgrade configuration is the "standard" design and contains six planes of TEC plus the TR radiator packets. The data taken during the test run was analyzed to reflect the performance of both the basic and standard detectors.

The PHENIX TRD (Fig. 3) has a 3-cm drift space, a 4-mm anode-anode spacing and a 3-mm anode-cathode spacing (Fig. 3). The FADC electronics that instrument each anode wire allows us to digitize the deposited electron cluster signals along small segments of charged particle paths. The FADC clock rate together with the TEC drift velocity results in each FADC time slice containing the charge deposit in approximately 0.5 mm of gas. For the basic design this means 240 separate dE/dx measurements for each charged track.

Multiple pion or electron events were combined during analysis until we obtained the data equivalent to a 12-cm track length. A distribution of all the FADC bins along the 12 cm track length was made and a truncated mean was taken. The distributions of the truncated means for the tracks with 1 GeV/c momentum (Fig. 4) show a clear separation

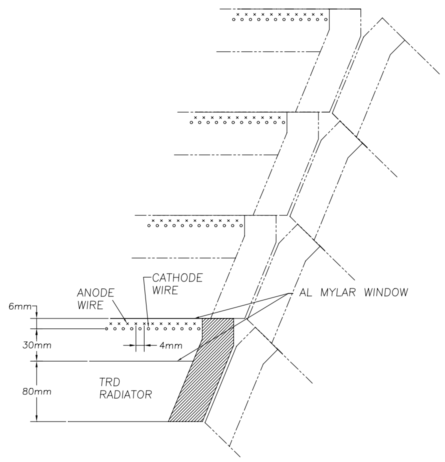

Figure 3. Diagram of the PHENIX tracking TRD.

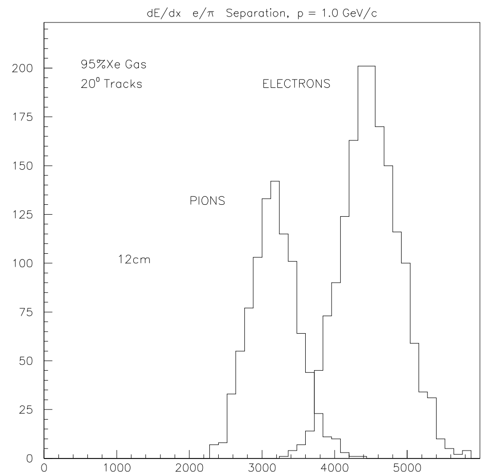

Figure 4. Truncated means distribution of dE/dx for 1 Gev/c electrons and pions measured with tracking TRD prototype.

of the electrons and pions, where the e/π rejection is 0.01 for 90% electron efficiency. This procedure was repeated for a range of momenta and both 12-cm and 18-cm track lengths (Fig. 5).

In addition to the dE/dx measurement, the Xe-filled TEC is designed to detect the transition radiation x-ray ($E \geq 3$ GeV/c) created when a charged particle with γ greater than 1000 traverses the many-layered polypropylene radiator packets. The transition radiation x-ray is absorbed in the TEC and results in a large signal spike detected on the anode wire. The data was analyzed by combining multiple electron or pion events so that one had the equivalent of six TRD planes crossed. X-ray clusters were identified in the data and the number of x-ray clusters seen in six TRD planes was plotted for both electrons and pions at each momentum. These distributions were used to calculate the e/π separations (Fig. 6). The top curve in the figure shows the measured e/π rejection while the bottom curve shows the rejection corrected for the additional layers of radiator specified in the PHENIX TRD design.

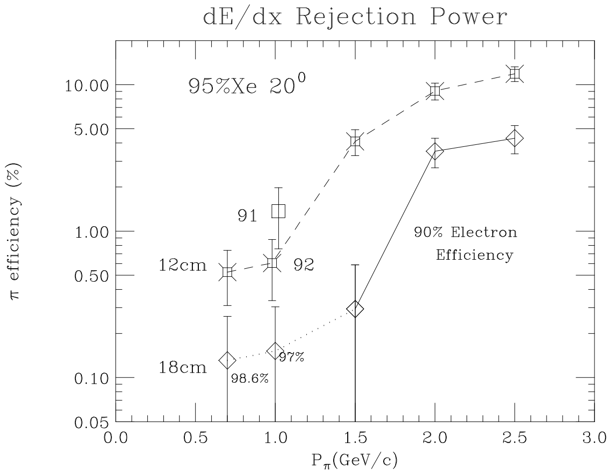

Figure 5. dE/dx e/π separation versus momentum measured with the tracking TRD. The incident beam angle was 20°.

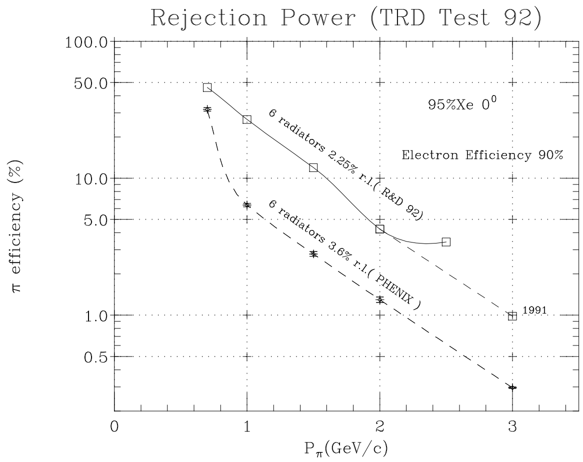

Figure 6. TRD e/π separation versus momentum measured in the tracking TRD.

4. Conclusion

A prototype of the PHENIX tracking TRD has been tested in a beam of pions and electrons at the BNL AGS. The ability of the detector to separate electrons from pions has been measured over a momentum range of 0.7 GeV/c to 3.0 GeV/c. At 1.0 GeV/c the dE/dx e/π separation was 1% using the basic PHENIX design of the tracking TRD. The transition radiation e/π separation was measured to be 0.3% at 3.0 GeV/c.

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