Proposed Detector Upgrade for Measuring Low-Mass Lepton Pairs in PHENIX

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Abstract. The measurement of low-mass lepton pairs provides a unique opportunity to study in-medium effects of vector meson production and the possibility of chiral symmetry restoration in heavy ion collisions.However, this measurement is extremely difficult experimentally due to the large combinatorial background produced by Dalitz decays and conversions.The PHENIX collaboration has proposed constructing a new detector as part of its future upgrade program that would provide a high level of rejection against the Dalitz decay and conversion backgrounds, while at the same time preserving good efficiency for measuring vector mesons and low-mass electron pairs.This device would consist of a hadron-blind detector that would identify electrons by detecting Cherenkov light produced in a gas radiator, and could also incorporate the features of a Time Projection Chamber that would serve as a tracking detector to track low-momentum particles in a low-magnetic-field region produced in the central PHENIX spectrometer.The strategy for identifying and rejecting Dalitz pairs and conversions using this technique is discussed, along with some of the ongoing R&D efforts.

INTRODUCTION

In high energy heavy ion collisions, low-mass lepton pairs provide a clean signal for studying chiral symmetry restoration and in-medium effects on low-mass vector mesons, thermal radiation from the hadron gas, and strangeness production via the leptonic decay of the ϕ. We believe that the physics program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) would be incomplete without a comprehensive measurement of low-mass electron pairs. At RHIC, the PHENIX experiment is unique in that it is the only one which has the capability of measuring the entire dilepton spectrum from the π^0 Dalitz decays up to invariant masses beyond that of the J/Ψ.

In the high-multiplicity environment of heavy ion collisions, electron pairs from Dalitz decays and photon conversions contribute to a formidable combinatorial background in the electron pair spectrum. The ability to identify and reject these pairs is essential to carrying out a measurement of this spectrum. An improvement in the signal-to-background ratio of at least two orders of magnitude is required, along with an electron detection efficiency of greater than 90%. A simulated combinatorial dilepton spectrum for central gold-gold collisions at $\sqrt{s_{NN}} = 200 GeV$ including electrons from conversions in the inner PHENIX detectors, charm decays, and meson decays is shown in Figure 1.

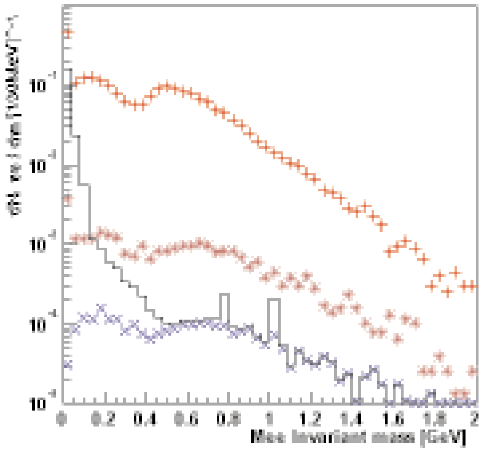

FIGURE 1. Simulated dilepton spectrum in PHENIX for 200 GeV central Au-Au collisions. The solid line represents the total of all correlated pairs; plus signs represent the total combinatorial background, including conversions, charm decays, and meson decays; asterisks represent the combinatorial background from charm decays alone; crosses represent the correlated charm signal.

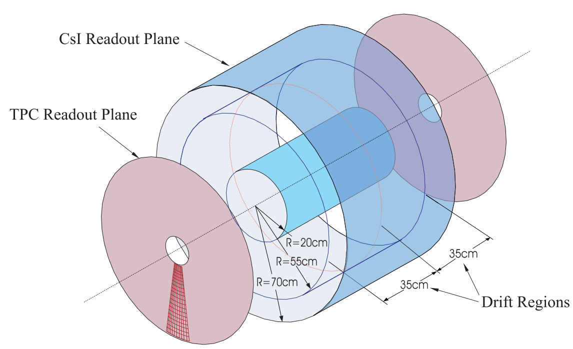

FIGURE 2. A schematic diagram of the proposed TPC/HBD.

PROPOSAL

To identify and reject Dalitz and conversion pairs, a hadron-blind detector (HBD), potentially combined with a fast, compact time projection chamber (TPC), has been proposed as an upgrade to the current PHENIX detector. A schematic diagram of the proposed TPC/HBD is shown in Figure 2. Information on the current PHENIX detector can be found in [1].

An inner magnet coil has been installed to create a low-field region in the central spectrometer, which will allow the measurement of low momentum electrons (p < 200 MeV/c) that would otherwise curl up and be lost in the normal magnetic field configuration. This lower magnetic field would also serve to better preserve pair opening angle, which would be important in the case where HBD measurements were available without any tracking information. Higher momentum electrons which pass through the stronger, outer magnetic field and reach the central spectrometer arms, such as those

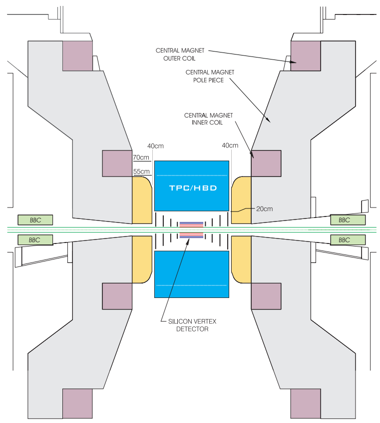

FIGURE 3. Inner region of the central spectrometer.

from the decay of low-mass vector mesons, can be identified and measured quite well via the full complement of PHENIX detector subsystems.

In Figure 3, the inner region of the central spectrometer is shown, with the inner and outer magnet coils, the TPC/HBD, and the proposed silicon tracker and vertex detector. Further information on the PHENIX silicon upgrade can be found in [2]. In this inner region, electrons would be tracked and identified by the TPC/HBD. The TPC would also provide full tracking coverage over 2π in azimuth and $|\eta| < 1.0$, while the current spectrometer arms cover π in azimuth and $|\eta| < 0.35$. Electron identification would be accomplished via detection of Cherenkov radiation by the HBD and dE/dx in the TPC. The TPC drift gas volume would double as a radiator for the HBD, and the HBD would detect the Cherenkov light from electrons using a large area photocathode such as CsI on its outer surface. The HBD would respond minimally to other particles, thus the term “hadron blind.” The TPC would have a central, high-voltage plane and would drift charge axially toward readout planes on each end of the detector, with a drift distance of approximately 35 cm. As a readout device, both the TPC and HBD would use a micropattern detector such as a gas electron multiplier (GEM). A single fast, UV-transparent gas such as CF_4 could potentially be used as the TPC drift gas, the HBD radiator, and for operation of the micropattern readout detector.

With 2π azimuthal coverage, the HBD or HBD/TPC would see both partners for a significant fraction of the electron pairs produced. A cut on pair opening angle and/or invariant mass would be used to select out and reject pairs from Dalitz decays and conversions while preserving the majority of signal electrons. In this way the combinatorial background for the dilepton spectrum would be greatly reduced.

Aside from providing rejection against the Dalitz and conversion backgrounds, the TPC would enhance the capabilities of the PHENIX detector in other ways. Currently, PHENIX has no tracking within the magnetic field, and as such, decay and conversion backgrounds limit the high-p_T charged particle measurements. 2π tracking within the magnetic field by the TPC would eliminate much of this background. In addition, the TPC alone can provide a good momentum measurement over a large solid angle, thus permitting jet measurements in both heavy ion and proton-proton collisions. The TPC would also help to identify displaced vertices from charm production in conjunction with the silicon tracker and vertex detector upgrade as well as provide additional particle identification from dE/dx.

RESEARCH AND DEVELOPMENT

Research and development is ongoing, primarily at Brookhaven National Laboratory and the Weizmann Institute of Science. Some of this work is being performed jointly with the STAR Collaboration at RHIC, and related R&D is being performed by the LEGS group at BNL and for the NLC/TESLA.

Current R&D includes prototype hardware development, gas property studies, investigaton of GEMs as readout detectors, electronics development, and simulation. More detailed information on the HBD proposal and recent R&D can be found in [3] and [4].

SUMMARY

A hadron-blind detector combined with a time projection chamber has been proposed as an upgrade to the current PHENIX detector. Research and development is currently underway in a variety of areas. The proposed detector upgrade would allow PHENIX to identify and reject Dalitz and conversion pairs, thus reducing the combinatorial background in the dilepton spectrum and greatly improving the measurement of low-mass vector mesons as well as the low-mass dilepton continuum. In addition, in both heavy ion and proton-proton collisions, the 2π tracking within the magnetic field that would be provided by the TPC would improve charged particle measurements, allow the study of jets, and in conjunction with the proposed silicon upgrade, help to identify displaced vertices from charm production.

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