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The Hadron Blind Detector Upgrade to PHENIX

J. M. Durham for the PHENIX Collaboration

Dept. of Physics and Astronomy, Stony Brook University, Stony Brook, NY, 11794-3800, USA

Abstract. A new electron identification device for the PHENIX experiment at RHIC has been designed and tested. The Hadron Blind Detector will reduce the dielectron combinatorial background by measuring the opening angle of dielectron pairs, allowing rejection of those produced from the photon conversions and pion Dalitz decays which dominate the signal in the low-mass region of the spectrum. The HBD is a windowless, unfocused Cherenkov detector utilizing triple GEM stacks, which have the upper surface of the top GEM foil coated with a CsI photocathode, to detect Cherenkov photons into the deep UV. Results from Run-7 and subsequent tests are described.

Keywords: gas electron multiplier, CsI, Cherenkov, dielectron
PACS: 29.40.-n, 29.40.Cs, 29.40.Ka, 25.75.-q

1. Introduction

Color neutral probes, such as charged leptons, have proven to be useful tools for investigating the dense partonic matter created in RHIC collisions. Measurement of the dielectron continuum in Au-Au collisions at $\sqrt{s} = 200$ GeV by the PHENIX collaboration [1] shows a clear enhancement in the low mass region of the spectrum between 150 and 750 MeV. However, this measurement is limited by the combinatorial background from randomly matched positrons and electrons that do not originate from the same pair. Dielectrons from photon conversions and pion Dalitz decays dominate at low masses, giving a signal to background of $\sim$1/300. Compounding this problem is the incomplete acceptance of the PHENIX detector [2].

The kinematics of photon conversions and Dalitz decays typically cause electron pairs from these sources to have much smaller opening angles than pairs from decays of the light vector mesons. By measuring this angle, the Hadron Blind Detector will give the correct identification of partner electrons and thereby reduce the combinatorial background.

2. HBD Design

The Hadron Blind Detector is a Cherenkov detector that uses CF_4 as both radiator and detector working gas, thus avoiding attenuation of photons that would occur by passing through a window. Triple stacks of gas electron multipliers [3] avalanche photoelectrons produced in a 350 nm CsI photocathode, which is evaporated onto the topmost GEM surface. The transparency of CF_4 and the quantum efficiency of CsI in the UV set the effective Cherenkov photon detection range from ∼120 to 200 nm. The HBD extends radially from 5 cm to 65 cm around the beampipe, in a nearly field free region. The length of the CF_4 radiator is 50 cm.

To operate in this high multiplicity environment the hadron signal must be suppressed. An SS-304 mesh situated 1.5 mm above each GEM stack provides a reverse bias that drifts ionization trails from hadrons away from the GEMs. The mesh is 92% transparent, allowing most Cherenkov photons through to produce photoelectrons which are drawn into the GEM stack and multiplied (see Fig. 1). Simulations of the electric field characteristics show that most free electrons within ∼150 microns of the GEM surface will drift into the holes, while the others will be drifted away to the mesh. The signals are collected on 2.2 cm^2 hexagonal pads underneath each GEM stack. Effective gain on the order of 10^4 has been observed for triple GEM stacks in CF_4 [4].

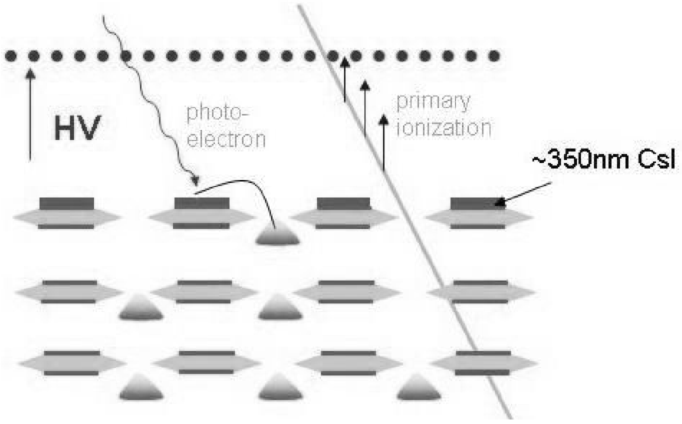

Fig. 1. Illustration of a triple GEM stack in reverse bias configuration. Cherenkov photons shine through the mesh while ionization trails are swept away.

The HBD vessel is a 19 mm thick Aramid Fiber honeycomb sandwiched on both sides by 250 micron FR4 sheets. Ten GEM stacks, each of which measure 27x22 cm^2, are in each arm of the HBD. The entire detector, including gas, body, and backplane electronics, is less than 2% of a radiation length. A more complete description of the HBD can be found in [5,6,7].

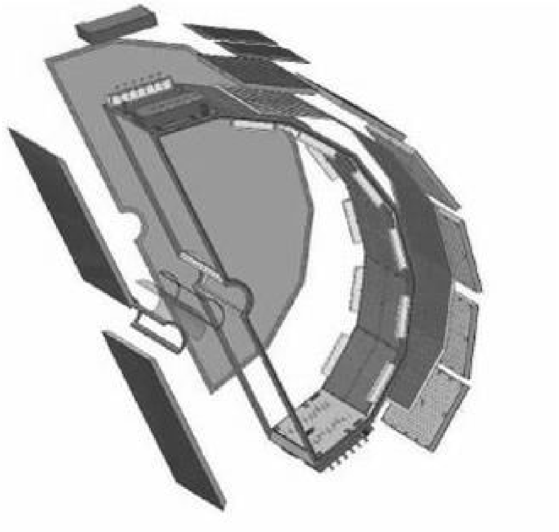

Fig. 2. Exploded drawing of an arm of the HBD. One side has been omitted for clarity.

3. Performance in Run-7

The East and West arms of the HBD were installed in PHENIX prior to RHIC's Run-7. Voltage was provided to each GEM stack by a LeCroy 1471N power supply, while the voltage on each mesh was controlled by a separate power supply to facilitate changes between forward bias (for gain calibrations) and reverse bias (for hadron rejection). Any discharges in the GEM foils caused both power supplies to trip and return to ground.

An inherent flaw in the LeCroy firmware causes voltage to be momentarily reasserted 200 ms after a trip occurs, and then return to ground. These voltage spikes led to large potential differences in the 1.5 mm gap between the top GEM surface and the mesh, which ultimately resulted in sparks that damaged many of the GEM foils. In some cases, UV light from a single discharge would induce discharges on other GEM stacks in the line of sight, resulting in several stacks tripping simultaneously. The damage resulted in non-ohmic current draw across the top GEM foils and rendered several stacks inoperable. Once the problem was identified, relays were put in place to completely disconnect and discharge the detector hardware from the power supplies after a trip, and zener diodes were put between the mesh and top GEM to remove the possibility of large voltage differences. These changes effectively eliminated the mesh-GEM spark, and the remaining undamaged stacks functioned throughout the rest of the run.

Fig. 3 shows electrons and hadrons identified by PHENIX matched back to hits in two modules of the HBD, operated in reverse bias. A strong suppression of the hadron signal is apparent, giving clear electron identification.

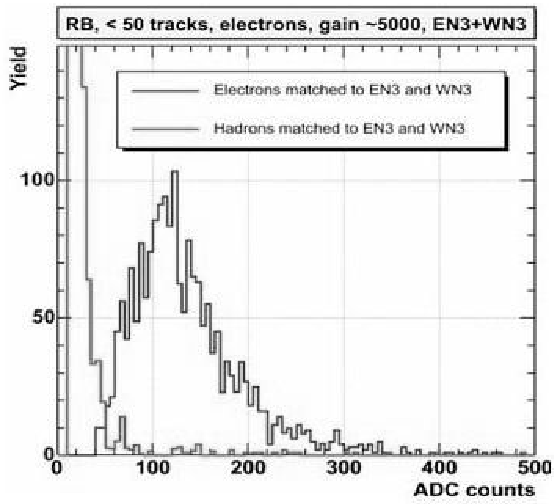

Fig. 3. A clear suppession of the hadrom signal is achieved in reverse bias operation.

An electron identification efficiency of more than 90% was demonstrated. Analysis of tracks matched back to the HBD shows a tracking resolution of $\sigma_z = \sigma_\phi = 1$ cm at the pad plane of the detector.

4. Current Work

The effectiveness of the HBD at recognizing double hits is set by the number of photoelectrons that are received from each electron. In order to maximize photon counting efficiencies, a calibrated UV light source is needed. The fact that CF_4 has an emission line at 160 nm can be exploited to provide this source.

A Lucite cube measuring 1"x 1"x 1" has been fitted with a ^{241}Am alpha source and an Ortec silicon surface barrier detector on either side of a cavity bored into the cube. Alpha particles traversing the cavity ionize CF_4 molecules and are then detected in the SSB. The cavity is coated with a thin layer of aluminum, covered with a layer of MgF_2, to reflect the CF_4 scintillation light down through an opening in the cavity. Shining this light on a GEM stack provides a low intensity photon source with a trigger from the alpha particle detection in the SSB. The cube has allowed detailed studies of the photon signal under different voltage schemes.

The drift field above each GEM stack was set at a reverse bias of 30 V in Run-7. As seen above, this heavily suppresses the hadron signal, but also reduces the photoelectron signal by $\sim$15% as compared to forward bias [5]. Studies with the cube have shown that at a smaller reverse drift voltage of 10V recovers most of the photoelectron signal while still suppressing ionization trails. An effective increase in primary photoelectrons can be achieved with this new drift field.

In CF_4, electrons begin to avalanche at a potential difference of $\sim$450V across the GEM foil. Measurements of the photon signal have shown that the extraction of photoelectrons produced in the CsI photocathode is constant as the voltage across the GEM is varied from 450V to 520V, which covers the operating range of the detector. Operating at the lowest possible voltage increases stability but does not negatively effect the photoelectron statistics.

The transfer gap between two GEMs determines the proportion of electric field lines (and thus electrons) which terminate on the bottom side of the GEM. By increasing the transfer gap voltage, some of these field lines can be turned downwards to the next GEM, giving more signal without stressing the GEMs for additional gas gain. With a constant 508V across each GEM, the effective gain can be increased by $\sim$25% by raising the transfer voltage in one gap from 500V to $\sim$800V, where the signal plateaus. This can be done for both transfer gaps and the induction gap between the bottom GEM and readout pads, giving almost twice the signal at the same gas gain.

These studies have shown that the GEM stacks can be operated at a lower gas gain than the Run-7 configuration without loss of photoelectrons. A modest voltage decrease of 10-20V will make the GEM stacks more robust against discharges, and an increase in photoelectron statistics from the lighter reverse bias will aid in identification of double hits in the detector. In addition, upgrades to the gas flow system should keep water concentration in the gas at less than 6 ppm, eliminating the $\sim$10% transparency loss experienced in Run-7.

5. Conclusions

The Hadron Blind Detector is an effective device for electron identification in a high multiplicity environment. A successful engineering run was carried out during Run-7, and problems identified during this time are being addressed and corrected. Improvements in the high voltage system give increased stability and higher photoelectron counting statistics. The HBD is currently being prepared for physics in Run-9.

Acknowledgments

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References

1. S. Afanasiev et al, *nucl-ex*/0706.3034.
2. K. Adcox et al, *NIM* **A499** (2003) 469.
3. F. Sauli, *NIM* **A386** (1997) 531.
4. A. Kozlov et al, *NIM* **A523** (2004) 345.
5. Z. Fraenkel et al, *NIM* **A546** (2005) 466.
6. A. Milov et al, arXiv:physics/0701273v1.
7. B. Azmoun et al, www.phenix.bnl.gov/WWW/TPCHBD/HBD_CDR.pdf.