Reconstruction algorithm for the PHENIX Hadron Blind Detector in heavy ion collisions

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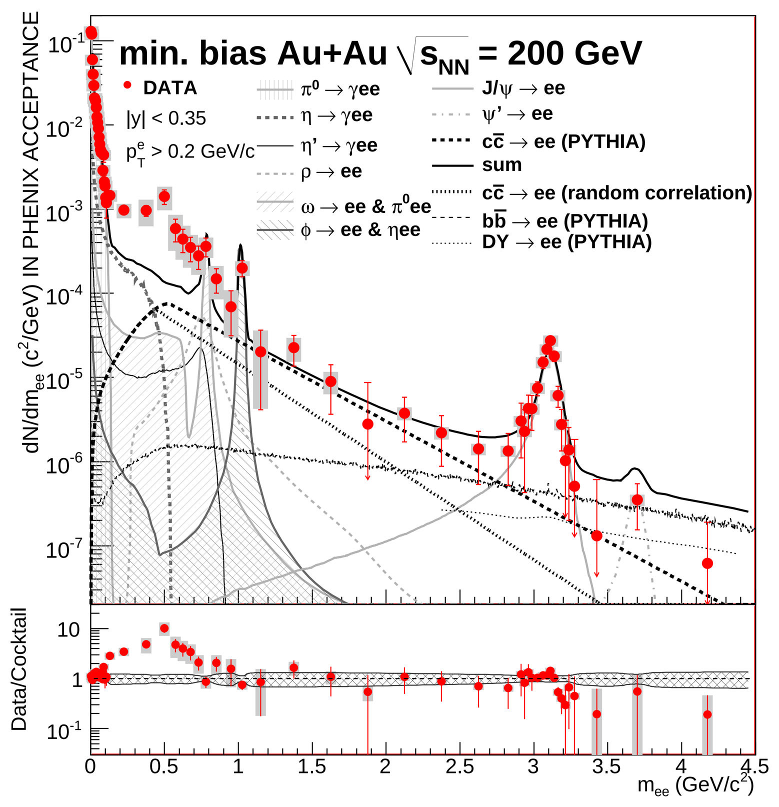
Abstract

The Hadron Blind Detector (HBD) was built, installed and operated by PHENIX with the objective of reducing the combinatorial background of the di-electron spectrum. This background comes mainly from conversions and Dalitz decay electrons. Most significantly, when one leg of the pair is swept out of the acceptance by the magnetic field, and the other pair member contributes only to the combinatorial background. Current status of the efforts in analyzing the data taken with this detector in Au+Au collisions will be shown.

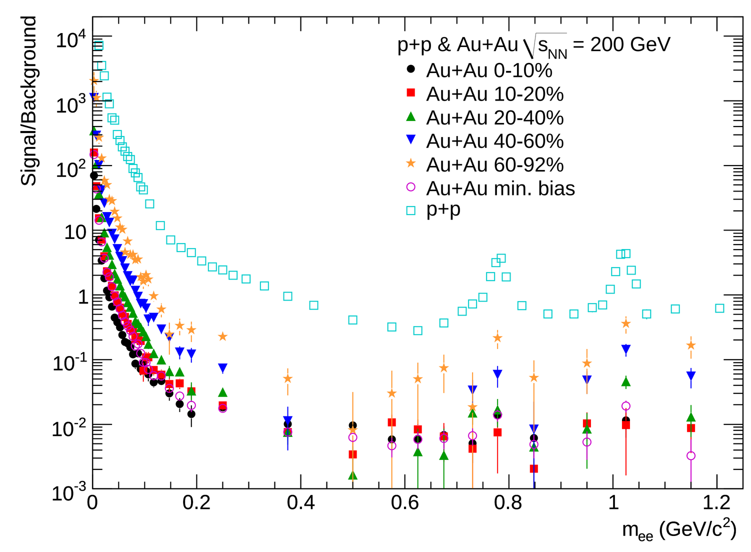
Physics Motivation

The dielectron spectrum contains a variety of signals that can be used to characterize the medium created in heavy ion collisions. In the plot on the right [1], the dielectron spectrum in Au+Au collisions at 200 GeV within the PHENIX acceptance is shown, compared to a cocktail of all known hadronic sources. The most intriguing feature is the excess at low mass (less than 1 GeV) as compared to a simulated cocktail of dielectrons from all known hadronic sources. A possible interpretation of this excess (in particular below 300 MeV) is due to virtual direct photons from the QGP phase of the nuclear collision. With this interpretation, it is possible to infer the temperature of the QGP phase as was done in [2].



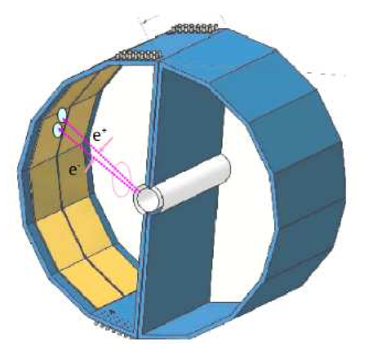
Low S/B

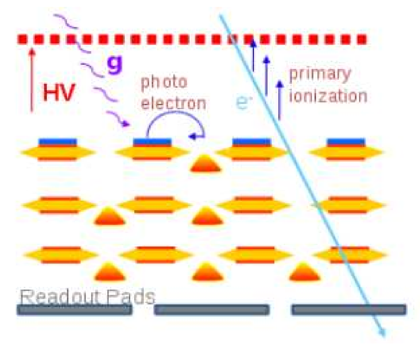
The dielectron pair spectrum sits on a significant background. The signal to background ratio is shown on the right side plot for p+p and various centralities in Au+Au. It goes to ≈1/200 at the worst point in central Au+Au collisions. The largest contributor to the background is combinatorial pairs of uncorrelated electrons. These come mostly from Dalitz decay or conversion of two independent π^0s. Less significant is the contribution from correlated background, such as electrons from Dalitz decay or conversion of π^0s within the same jet or back to back jets. The signal to background ratio is worst in the most interesting region (where the low mass excess lies), and therefore it is of very high importance to reduce the combinatorial background.



The Hadron Blind Detector (HBD)

The concept of the HBD is to tag conversion and Dalitz decay electrons by their small opening angle. To achieve that the HBD must sit in a field free region that preserves the small opening angle, in such a way that signal electrons leave only a single electron signal amplitude while background electrons leave a twice the single electron signal amplitude.

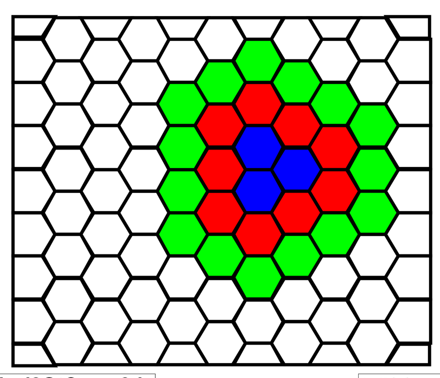


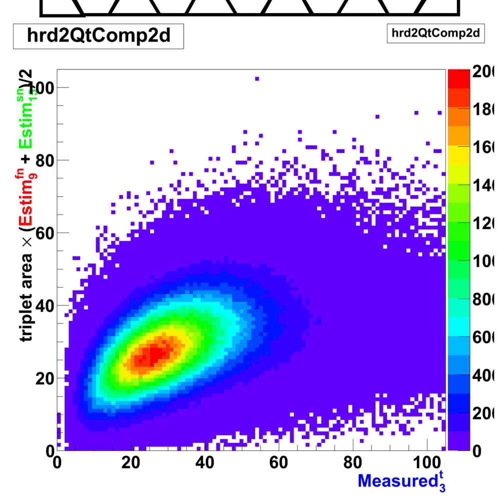


The HBD is constructed as a windowless proximity focusing Čerenkov detector operated with pure CF_4 as radiation and amplification medium within the same enclosure. The amplification is done by a triple Gas Electron Multiplier (GEM) stack. The hexagonal grid of anode readout is placed at the exit of the radiative volume. A detailed account of the construction and performance of the detector can be found in [3].

Reconstruction Algorithm

The reconstruction of the HBD information has to yield a good separation of single electrons (signal amplitude of about 20 photoelectrons) vs. double electrons (twice the single amplitude of about 40 photoelectrons). In addition, the rejection of conversion electrons from the back-plane of the HBD should be very good. This is critical since the HBD back-plane introduces an additional 1.8% of radiation length. The reconstruction should also take into account the scintillation photon background that produces a significant response. All charged particles going through the CF_4 produce scintillation photons, and in the most central events, the average scintillation yield per pad is about 12 photoelectrons (compare to 20 photoelectrons from a single electron spread over two or three pads). Any reconstruction of the HBD information thus requires some kind of estimator of the contribution of the scintillation background. PHENIX has developped two independent algorithms to deal with the subtraction of the scintillation background. In the algorithm reported here, the scintillation background is estimated from the closest neighbors of the cluster, as illustrated by the figure on the top right. The other algorithm is presented in poster [4].

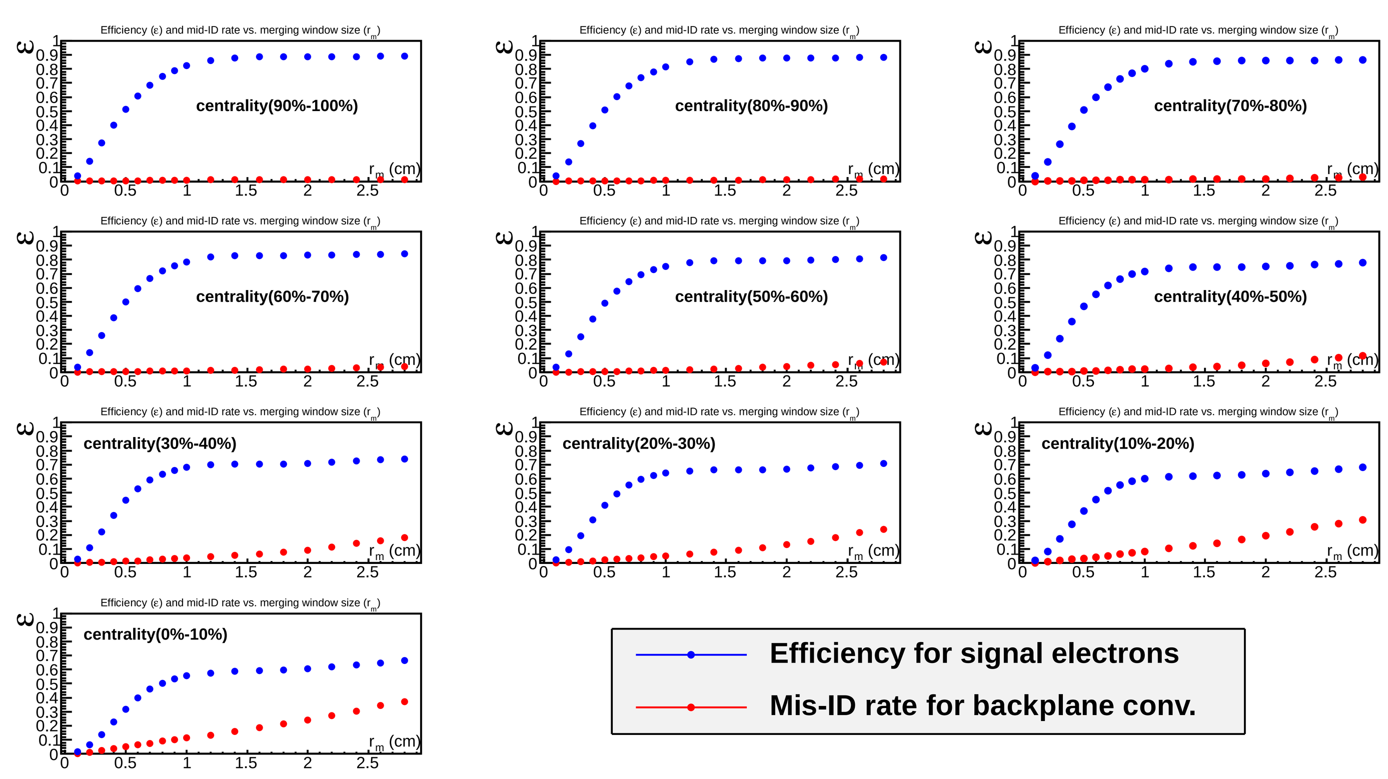




The algorithm starts with all possible compact triplets inside the HBD. This is in line with the expected size of the cluster that should be formed by single electrons. Then the estimated scintillation background from first and second neighbors is subtracted. There is a close correlation between the raw signal and the background estimator as shown in the bottom left figure to justify this. For the next step, only those triplets that fail a threshold cut on the net signal are thrown out. This is done in order to select preferentially triplets that have some Čerenkov signal thus stand out from the ambient scintillation background. Electrons are then projected on the HBD surface, and any remaining triplets within a tunable radius from the track projection position are merged, and a neighborhood based scintillation background subtraction is performed again to get the net signal of the final merged cluster. That net signal is used to identify between double and single electrons.

Efficiency and Rate of Misidentification

To benchmark the algorithm, the efficiency calculation is done through embedded simulations. The simulated response of a single isolated electron is embedded into scintillation background coming from a real data event. The two types of electrons simulated in this study are single electrons and electrons from conversion in the back-plane of the HBD. It's particularly important to reject as many of the later types of electrons as possible, because they constitute more than a fourth of the identified electrons in the central arm. Even a small contamination could result in a large amount of combinatorial background. The plot on the right shows the effectiveness of this algorithm in terms of rejecting back-plane conversions at the expense of some loss in efficiency for signal electrons in 10% wide centrality selections. For a merging radius of about 1 cm, an efficiency of about 50% is achieved for a rate of misidentification of 10%.



Conclusion

An algorithm for reconstruction of the HBD information in heavy ion collisions is shown with corresponding efficiency and rejection plots. The algorithm was developed with the objective of coping with the high rate of background from scintillation.

References

[1] A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. C **81**, 034911 (2010), "Detailed measurement of the e^+e^- pair continuum in $p+p$ and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and implications for direct photon production"

[2] A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. Lett. **104**, 132301 (2010), "Enhanced production of direct photons in $Au + Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV and implications for the inital temperature"

[3] W. Anderson, *et al.*, Nucl. Instr. and Meth. A (2011), doi:10.1016/j.nima.2011.04.015. "Design, construction, operation and performance of a Hadron Blind Detector for the PHENIX experiment"

[4] QM 2011 poster by Yosuke Watanabe