# Measuring ΔG in PHENIX using electrons to tag heavy-flavor production

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**Abstract.** Heavy flavor production can be used as a probe of the gluons contribution to the protons spin, $\Delta G$. In this paper [1] we discuss the prospects for PHENIX to tag heavy flavor production with single electron and muon/electron coincidences. We have estimated our sensitivity to $\Delta G$ using a full detector simulation which includes the effects of the trigger and dilutions due to conversions in the inner chambers and $\pi^0$ Dalitz decays.

## INTRODUCTION

Heavy flavor production, $c\bar{c}$ and $b\bar{b}$, is dominated by gluon-gluon interactions and gives rise to a double spin asymmetry

$$A_{LL} \sim \frac{\Delta G(x_A)}{G(x_A)} \otimes \frac{\Delta G(x_B)}{G(x_B)} \otimes \hat{a}_{LL}^{gg \to Q\bar{Q}} \quad , \tag{1}$$

from which $\Delta G$ can be extracted. $A_{LL}$ is the measured double longitudinally polarized asymmetry and $\hat{a}_{LL}$ is the partonic level asymmetry, or analyzing power, which is calculable within the framework of pQCD.

Below we explore tagging heavy flavor production in PHENIX using single electrons and $\mu$-$e$-coincidences. This is made possible by an electron trigger which utilizes the PHENIX electromagnetic calorimeter and ring imaging cerenkov counter. The following simulations are based on the event generator Pythia and PHENIX acceptances [2]. We have simulated the full response and reconstruction of the PHENIX Multiplicity and Vertex detector (MVD) and have used the parameterizations of the gluon polarization provided by Gehrmann and Sterling [3] and leading order calculations for the analyzing power [4]. Recently, next-to-leading order calculations have been performed [5], solidifying the theoretical framework for this measurement.

We find that a measurement using heavy flavor production extends the accessible $x_g$-range for PHENIX, and even more importantly it provides an alternative way to access the gluon polarization with different systematic and theoretical uncertainties. This will permit a cross check of the results obtained from direct photon production.

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[1] For the full PHENIX Collaboration author list and acknowledgements, see Appendex "Collaborations" of this volume.

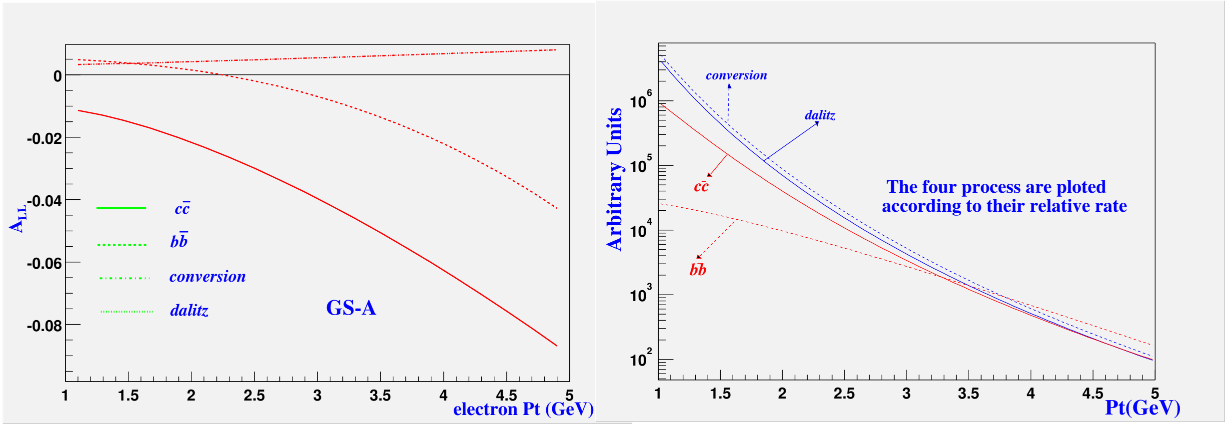


**FIGURE 1.** (left) Input asymmetries for charm and bottom production, and Dalitz and conversion decays. (right) Relative rates of single electrons from $b\bar{b}$ and $c\bar{c}$ QCD jet events and conversion and Dalitz processes from minimum bias Pythia events versus transverse momentum in GeV at $\sqrt{s} = 200\,\text{GeV}$.

## Single Electron Measurements

Single electron samples provide large numbers of charmed events with significant backgrounds from $\pi^0$-Dalitz decays and gamma conversions. The charm production cross section is not well known at RHIC center of mass energies, but will be measured soon by PHENIX and has been estimated to be between $200 < \sigma^{c\bar{c}} < 350\mu\text{b}$ at $\sqrt{s} = 200\,\text{GeV}$ [6]; the branching ratio for leptonic charm decays is about 10%. The power of PHENIX's electron identification was demonstrated in heavy-ion collisions [7]. Single electron yields come from different sources including charm decays, bottom decays, $\pi^0$ Dalitz decays, and conversion electron each of which can have different asymmetries, see Fig. 1. The difference between the charm and bottom asymmetries come about because of the mass dependence of the analyzing power and the different decay kinematics. The Dalitz and conversion ($\pi^0 \to e^+e^-\gamma$) asymmetries is the same as for $\pi^0$'s. We use Pythia coupled with a simulation of the PHENIX detector to determine the relative input rates, see Fig. 1.

PHENIX's multiplicity vertex detector (MVD) can be used to help identify electrons which have come from conversions in the beam pipe or Dalitz decay electrons. We find that a pulse height in association with a separation cut between charged particle tracks (10 degrees) rejects 68% of the Dalitz decay electrons and 75% of the beam pipe conversion electrons, while keeping 78% of the signal electrons, see Fig. 2. The values at an opening angle of 0° represents only a pulse height cut. We have estimated our sensitivity to $A_{LL}$ for heavy flavor production taking into account the diluting effect of the conversion and Dalitz electrons which are not rejected by the MVD, see Fig. 3.

The MVD cuts can be inverted to produce a sample of events which contain mostly electrons from conversions and Dalitz decays. These come from QCD jet events with $\pi^0$'s. Again, we can estimate the asymmetry from this sample, see Fig. 4. The asymmetry at low transverse momentum has flipped sign, giving us a handle on false asymmetries caused by acceptance effects. Further, the asymmetry can be used in conjunction with the direct $\pi^0$ measurement in a global analysis that will give us a handle on our systematic errors.

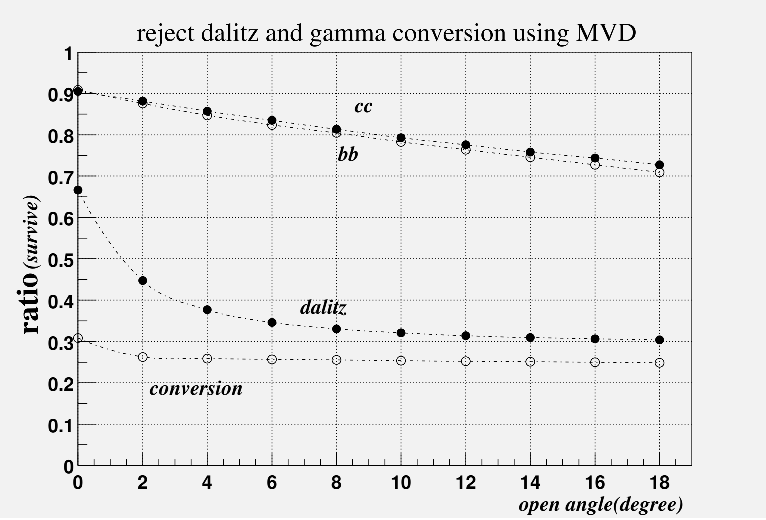


**FIGURE 2.** Rejection of Dalitz decay electrons using a pulse-height and angular minimum separation cut between charged particle tracks in the PHENIX multiplicity vertex detector. A pulse height and 10 degree separation cut rejects 68% of the Dalitz decay electrons and 75% of the beam pipe conversion electrons, while keeping 78% of the signal electrons.

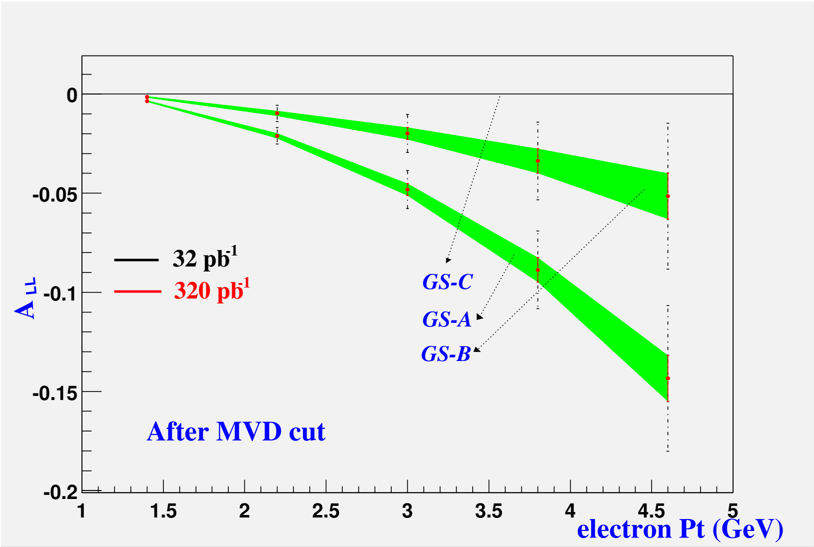


**FIGURE 3.** Projected double spin asymmetry $A_{LL}$ and statistical and background subtraction errors based on a 32 pb$^{-1}$ and 320 $^{-1}$. Events have been tagged online by an electron with $p_T$ >1 GeV in the central arm, and an offline MVD cut which rejects Dalitz and conversion electrons has been applied.

## Heavy Flavor Production tagged in $\mu$ $e$ coincidences

In addition to the electron in the central detector it is possible to require a muon detected in one of the forward muon arms in coincidence. This requirement removes all background from conversions and Dalitz decays and enhances the $b\bar{b}$ yield in the event sample. The $x_g$-distributions are shown in Fig. 5. In the $\mu$ $e$ channel the kinematic range reaches down to $x_g \approx 0.02$, and, unlike PHENIX's other measurements, can be roughly

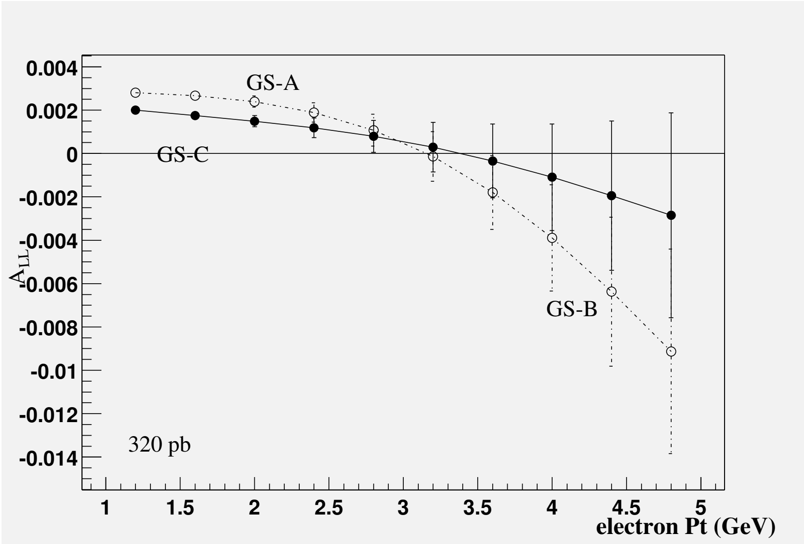


**FIGURE 4.** Projected double spin asymmetry $A_{LL}$ and statistical and background subtraction errors based on a 320 $^{-1}$. Events have been tagged online by an electron with $p_T > 1$ GeV in the central arm, and an offline MVD cut enhancing conversion and Dalitz electrons which have come from $\pi^0$ QCD jet events.

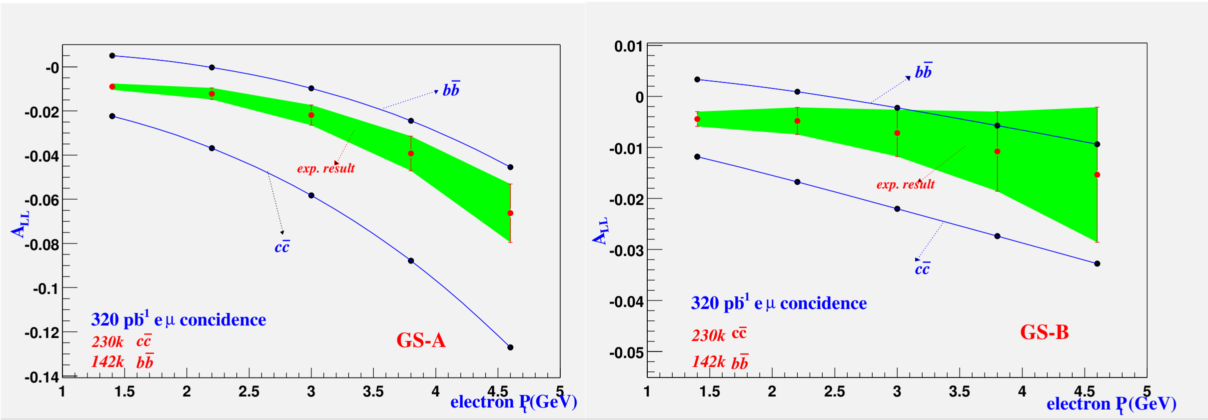


**FIGURE 5.** Projected double spin asymmetry $A_{LL}$ and statistical errors based on a 10 weeks at design luminosity. The asymmetry corresponds to parameterizations "A" and "B" of the gluon polarization from Gehrmann and Sterling. Events have been tagged online by an electron in the central arm and by an additional (offline) muon in one of the forward arms.

reconstructed.

Fig. 5 shows the expected experimental asymmetries for 10 weeks of data taking at design luminosity based on Gehrmann Stirling A and B. The pure charm and bottom asymmetries are also shown in the plots. At high transverse momentum, bottom begins to dominate. In 320pb$^{-1}$ of e$\mu$ coincidences we expect approximately 230K charm events and 142K bottom events if we require the electron to have $p_t > 1$ GeV and the muon to have a momentum $> 2$ GeV into the muon arm acceptance. The statistics allows us to differentiate between Gehrmann Sterling A and B. Further, the e-$\mu$ channel will allow us to distinguish between charm and bottom using the asymmetry at high $p_t$ and comparisons between like and unlike sign electron muon pairs.

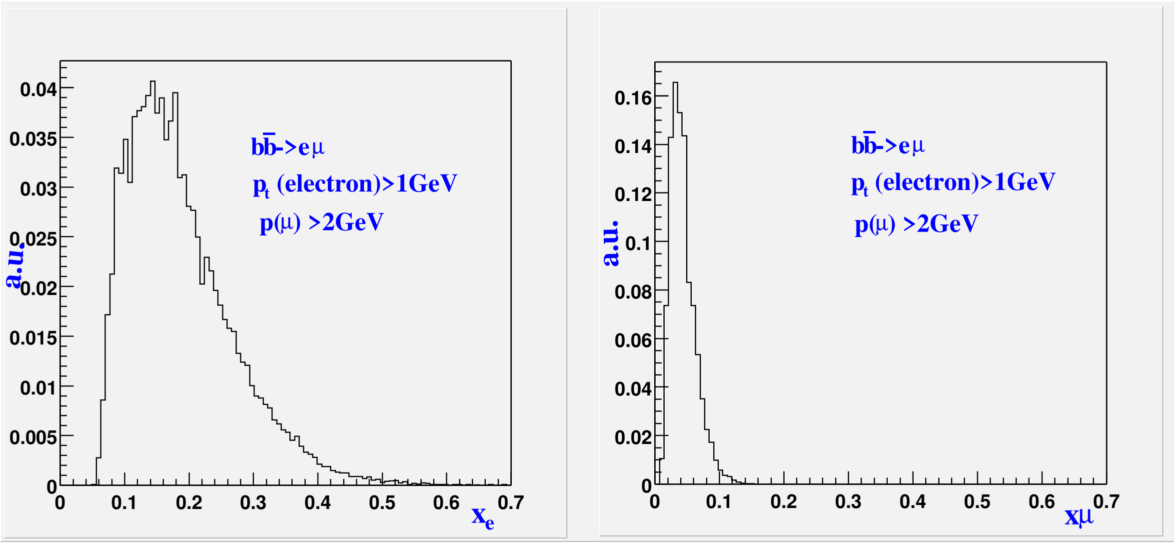


**FIGURE 6.** Parton kinematics in $\mu$-$e$-events. The difference in kinematics between $x_e$ and $x_\mu$ stem from the different acceptance for electrons and muons in the central arms and muon arms respectively.

## SUMMARY AND OUTLOOK

$\Delta G$ can be measured in PHENIX using single electrons and the quality of the measurement is improved if the background from Dalitz decays and photon conversions can be identified using an inner tracker. The additional requirement of a muon allows for an additional measurement that helps separate the charm and bottom contributions. The heavy flavor channels provide more independent measurements in PHENIX, helping to control experimental and theoretical systematic errors and the different channels cover different kinematic regions. Both of these measurements require a central arm trigger. The EMCal trigger worked in this past p+p run, and the EMCal/RICH trigger will be ready for the next run.

## ACKNOWLEDGMENTS


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## REFERENCES


1. A copy of the transparencies for this talk can be found at http://www.phenix.bnl.gov/phenix/WWW/publish/barish/talks/spin2002
2. "Sensitivity of $\Delta G$ Through Open Heavy Quark Production using Electron Decay Channels at PHENIX," DNP 2000.
3. T. Gehrmann, W.J. Stirling, Z.Phys. **C65** (1995) 461.
4. M. Karliner and R. Robinett, Phys.Lett.**B324** 1994.
5. I. Bojak and M. Stratmann, hep-ph/0112276; I. Bojak these proceedings.
6. P. L. McGaughey et. al., Int. J. Mod. Phy. A10 2999 (1995); Y. Akiba, private communication.
7. K. Adcox et al. [PHENIX] Phys.Rev.Lett.**88**:192303, 2002.