Heavy Flavor at PHENIX

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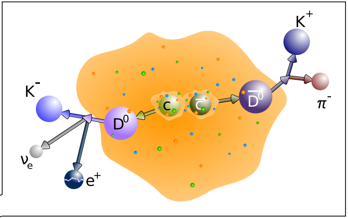
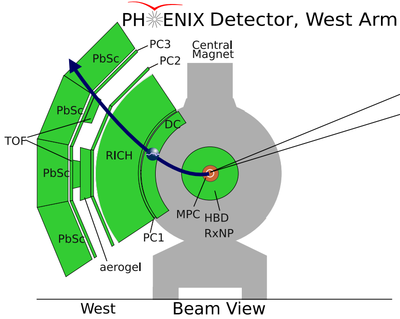
Direct Reconstruction

$D^0 \rightarrow K + \pi^-$

$D^0 \rightarrow K + \pi^- \pi^0$

Difficult without accurate vertex measurement ($c\tau \sim 123\mu$m)





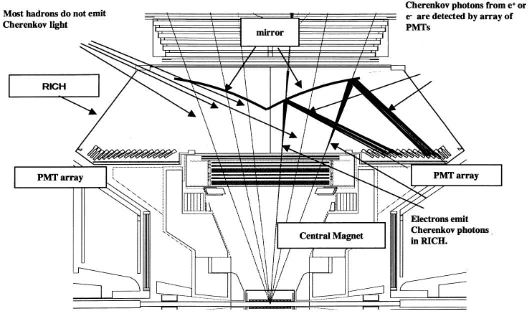
Indirect Measurement

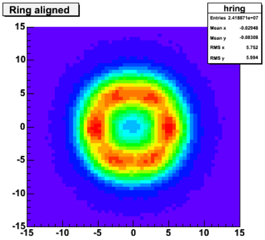
Measure contribution from semileptonic decays of heavy flavor to electron spectra.

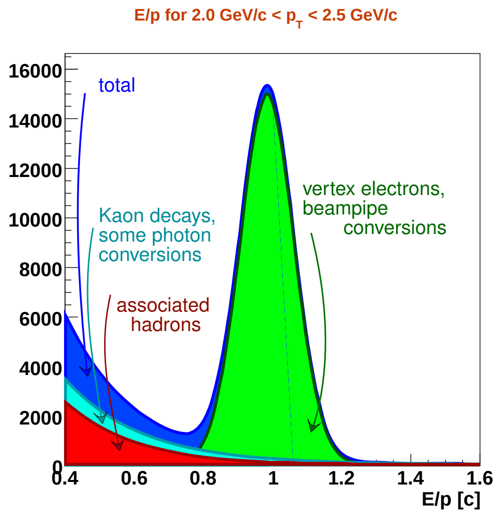
Both single and pair spectra

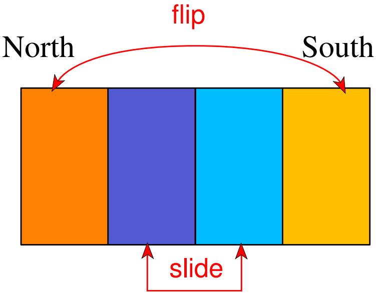
Detectors

Tracking in drift chamber. Track matching to RICH and EMC.
Ring size/shape in RICH
E/p distribution from the EMC and DC









Hadronic Background

Some hadronic tracks are randomly associated with a ring in the RICH. These are statistically subtracted by swapping the north and south sides of the RICH in software.

Energy/Momentum Distribution

The E/p distribution gives strong evidence that we understand our eID. Kaons which decay far from the collision have mis-reconstructed momentum. Most tracks passing cuts form a Gaussian centered at 0.98.

PHENIX

Method

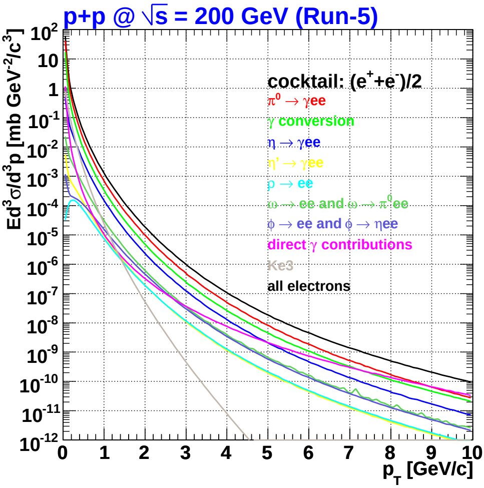
All relevant background sources are measured.

Decay kinematics and photon conversion rate are simulated.

Background cocktail is subtracted from inclusive spectrum.

Performs well at high p_T where signal/background is large.

Not limited by statistics.



Converter Method

Method

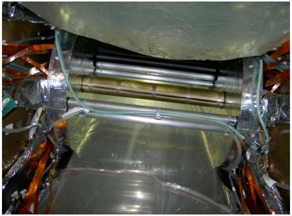
Add material of known thickness around the beampipe and compare the electron spectra with and without the material installed.

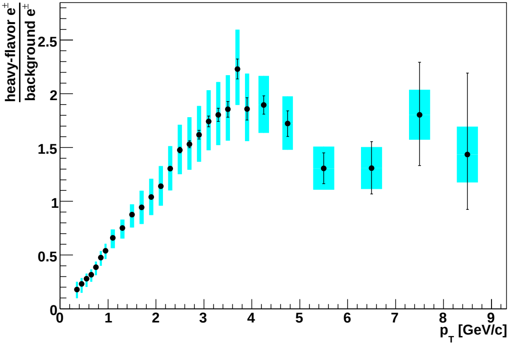
$$N_{HF} = \frac{R_\gamma N_{inc} - N_{inc}^{converter}}{R_\gamma - 1}$$

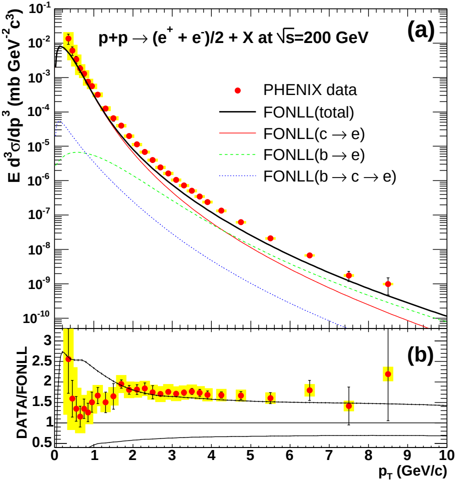
Works best at low p_T where photonic sources are significant

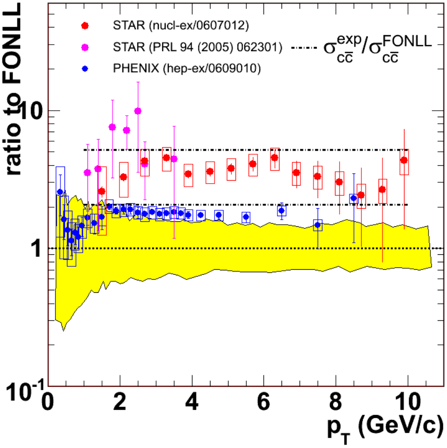
Limited by statistics of converter run

Converter method is used to normalize the cocktail method









For p_T between 4-6 GeV/c, the electron signal/background in PHENIX is about 2. Even if PHENIX subtracted no electron background, they would still be below the STAR result!

Muon Sources

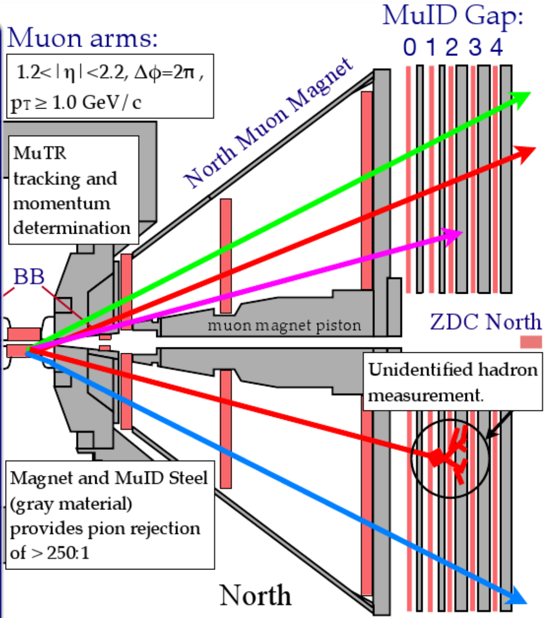
Muon from heavy flavor (the signal)

Hadron (does not interact and punches through the entire detector)

A muon from hadron decay

An interacting hadron (nuclear interaction)

A low energy muon that ranges out due to ionization energy loss (primarily hadron decay muons)



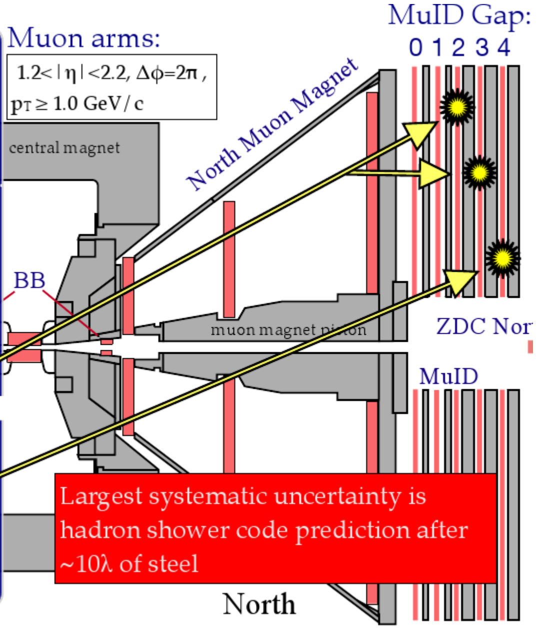
Heavy flavor single muons penetrate the entire detector (gap 4).

Simulate and subtract all known backgrounds with hadron "cocktail".

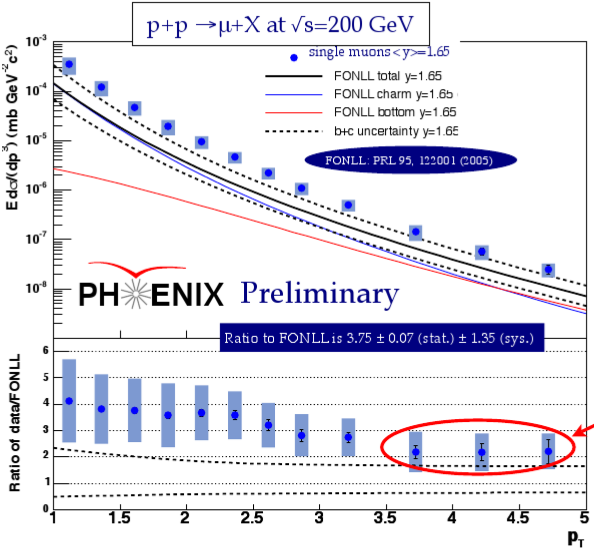
Normalize and "tune" input MC distributions by simultaneously matching data in:

1. stopped hadron distributions in gap 2 and gap 3

2. muons from hadron decay in gap 4 z-vertex distributions



Largest systematic uncertainty is hadron shower code prediction after ~10λ of steel



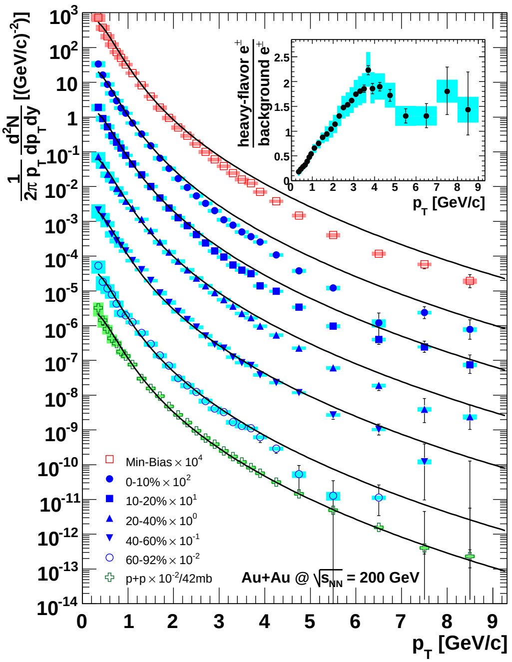
Independent forward/ backward muon arm analyses in strong agreement and combined into single spectra.

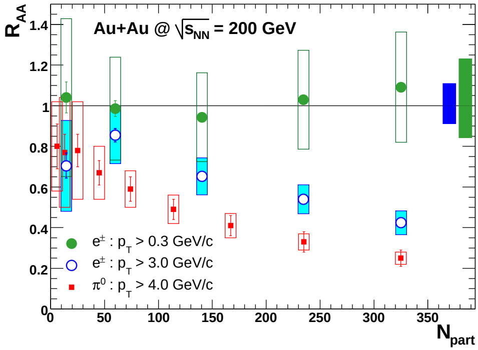
Consistent with the previous PHENIX single muon measurement. PRD 76, 092992 (2007)

Compared to FONLL c+b for <y>=1.65. At larger p_T where S/B is better, ratio to FONLL ~ 2.

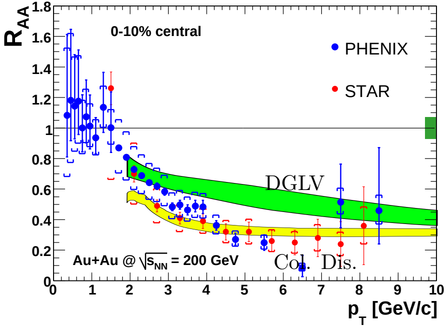
Suppression of Charm in Au+Au

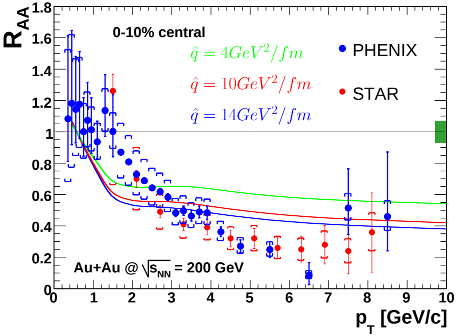
PHENIX

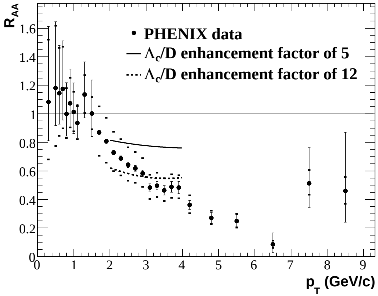




Models for Charm Suppression







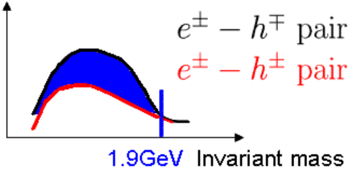
Lots of models, not much constraint from heavy flavor suppression alone.

The Idea

Look for $D^0 \rightarrow eK$ with no PID on the Kaon.

Reconstruct invariant mass for the electron hadron pair.

Subtract mass distribution from like-sign combination.



The Calculation

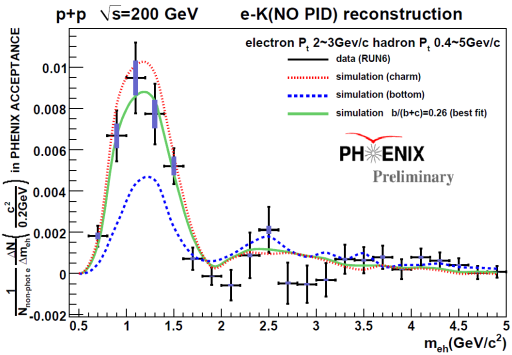
$$\epsilon_{\text{data}} \equiv \frac{N_{\text{tag}}}{N_{\text{Heavy Flavor } e^{\pm}}} = \frac{N_{c\rightarrow\text{tag}} + N_{b\rightarrow\text{tag}}}{N_{c\rightarrow e} + N_{b\rightarrow e}}$$

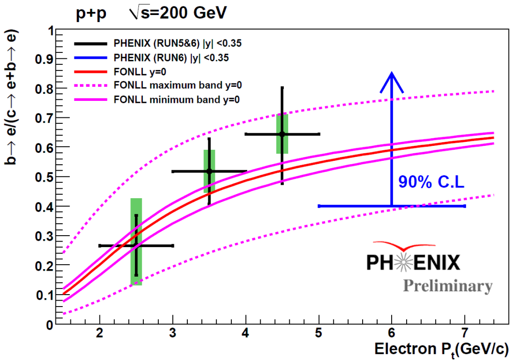
$$\epsilon_c \equiv \frac{N_{c\rightarrow\text{tag}}}{N_{c\rightarrow e}}, \; \epsilon_b \equiv \frac{N_{b\rightarrow\text{tag}}}{N_{b\rightarrow e}}$$

$$\frac{N_{b\rightarrow e}}{N_{c\rightarrow e} + N_{b\rightarrow e}} = \frac{\epsilon_c - \epsilon_{\text{data}}}{\epsilon_c - \epsilon_b}$$

Tagging efficiency determined from simulation. Production ratios of various heavy flavor mesons gives the main uncertainty.

Charm/Bottom Separation

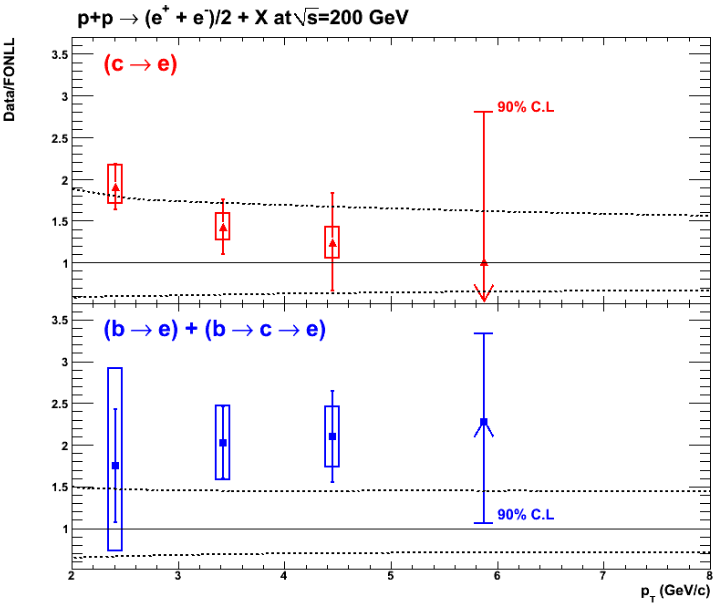


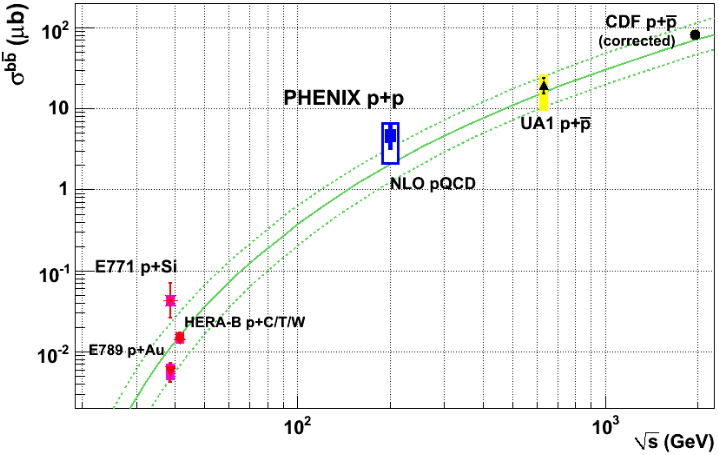


Bottom/charm ratio is in good agreement with FONLL.

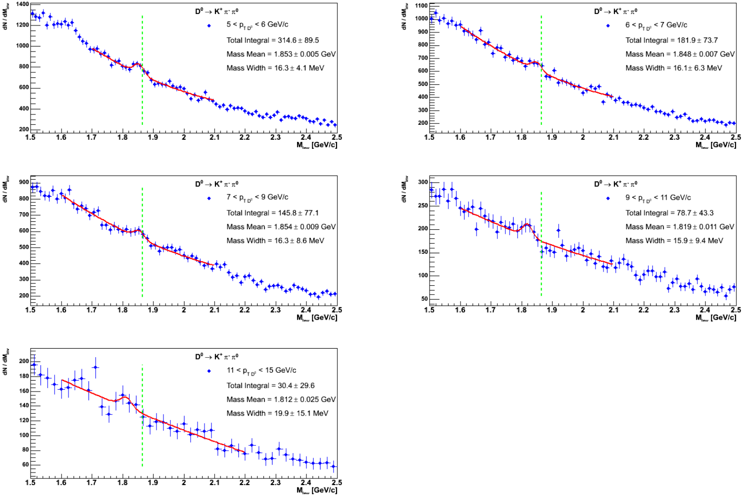
Electron Spectra from Charm and Bottom

PHENIX

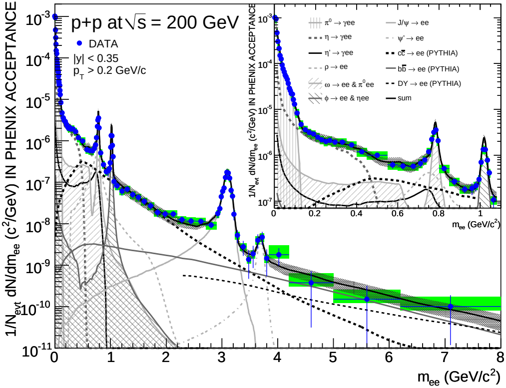


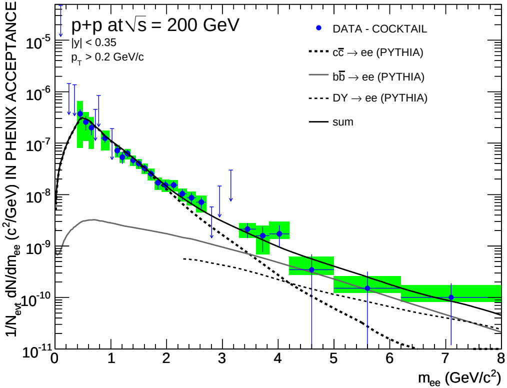


$$\sigma_{b\bar{b}} = 4.61 \pm 1.31(\text{stat})^{+2.57}_{-2.22}(\text{sys})\mu\text{b}$$



Utilize the photon trigger to enhance statistics. Low p_T is currently being worked on using electron tagging.

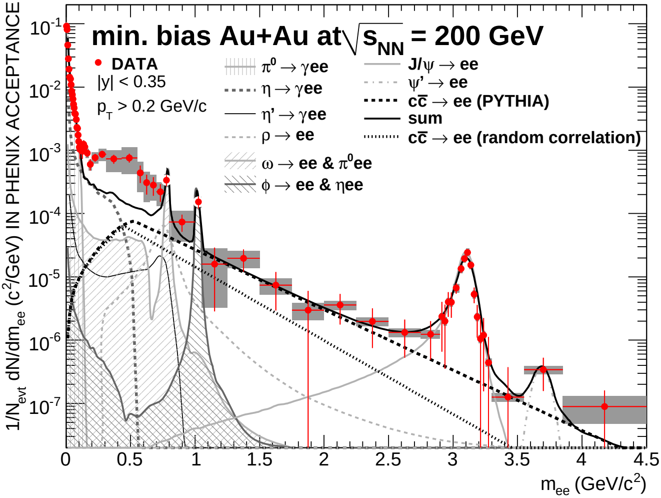




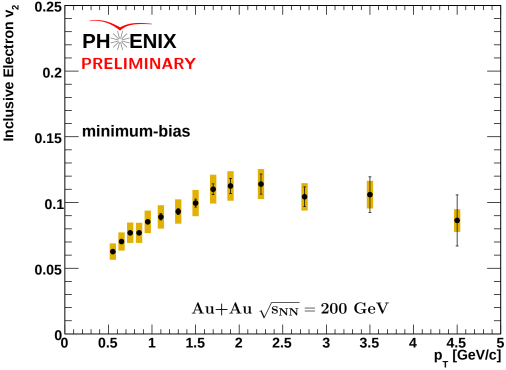
Dielectrons above and below J/ψ mass compared to charm, bottom and Drell-Yan from PYTHIA.

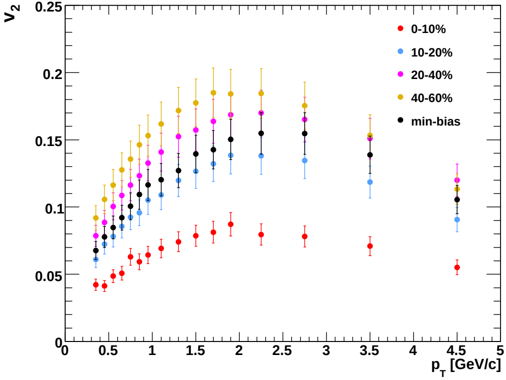
$$\sigma_{b\bar{b}} = 3.9 \pm 2.5(\text{stat})^{+3}_{-2}(\text{sys})\mu\text{b}$$

$$\sigma_{c\bar{c}} = 518 \pm 47(\text{stat}) \pm 135(\text{sys}) \pm 190(\text{model})\mu\text{b}$$



Agreement with PYTHIA in charm region. But dielectrons in charm region should be suppressed since D mesons change direction in the medium. So maybe there is room for thermal component.

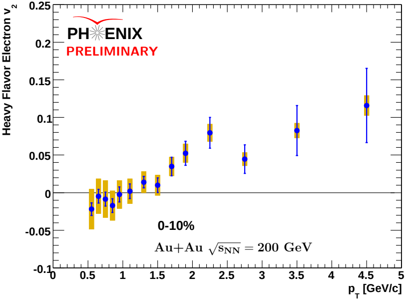


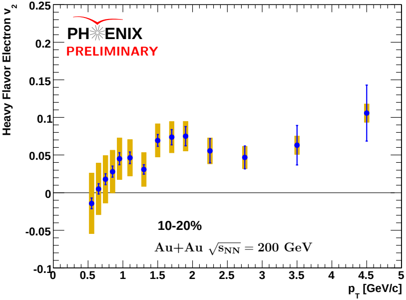


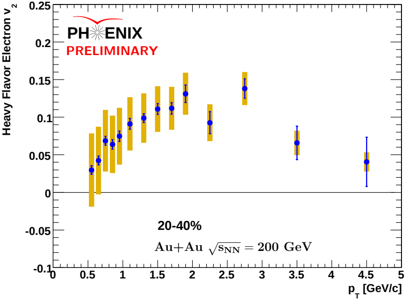
v_2 of inclusive electrons measured using the event plane from the new RXPN detector.

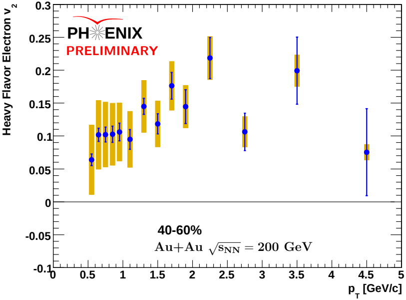
Cocktail for photonic electron v_2 takes measured hadron v_2 as input.

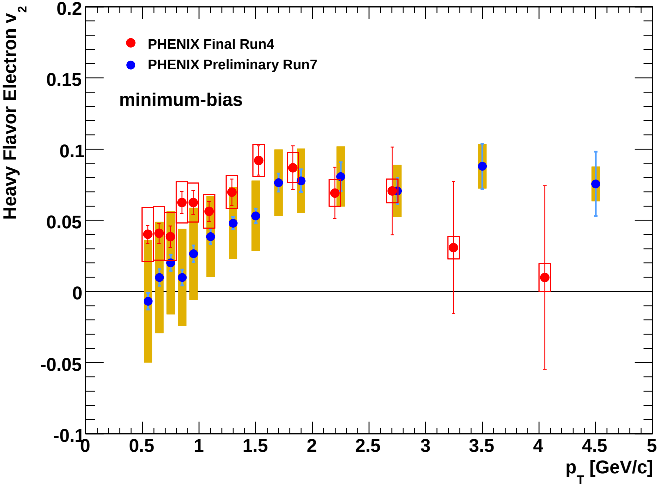
Single Electron v_2





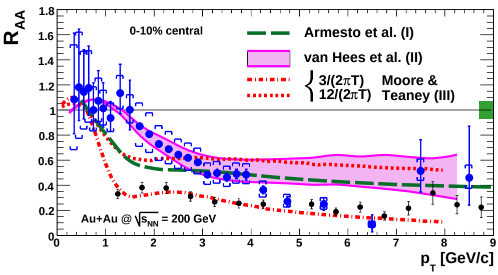


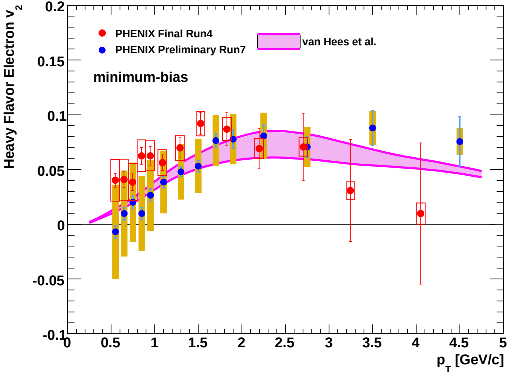




Run-7 was bad for electrons. The HBD didn't work, we used a weaker magnetic field (for the HBD), and we had no helium bag (conversions in air). The systematic errors will improve, but will stay larger than the Run4 result.

We have only analyzed half of the Run7 data so far.





The transport model from van Hess et. al. fits the data pretty well, and its resonances near the D mass gain some support from lattice calculations. It would be nice to see what effect adding gluon radiation would have.

D meson Reconstruction

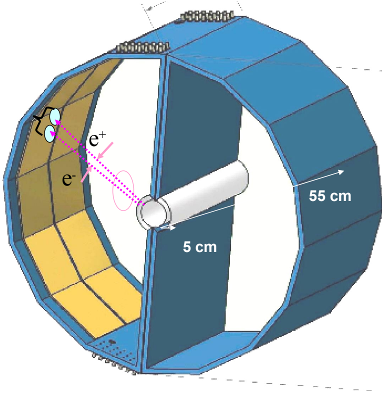
This measurement should improve in the near future. Run 6 $p+p$ and Run 8 $d+Au$ have not been looked at. But this is a very difficult measurement.

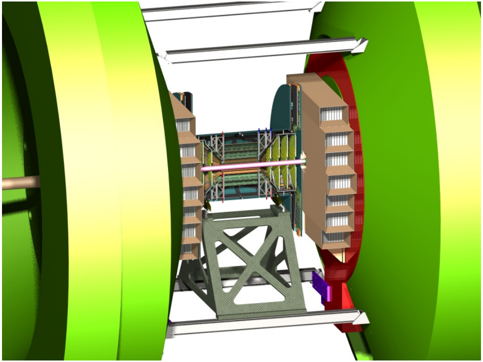
$e-\mu$ correlations

Some electron-muon correlation analyses have begun. Azimuthal opening angle distributions look promising for another heavy flavor measurement. $e-\mu$ can also be used as a trigger for the direct reconstruction.

$Cu+Cu$ Data

We still have $Cu+Cu$ data to analyze. This is simply a manpower issue.





Hadron Blind Detector

We have one more shot at getting this thing to work, and we think we know how. The dielectron measurement from Run-9 is something to look forward to.

Silicon Vertex Detector

With decay positions measured accurately, direct D and B measurement will be a breeze.