Heavy Flavor Measurements at PHENIX

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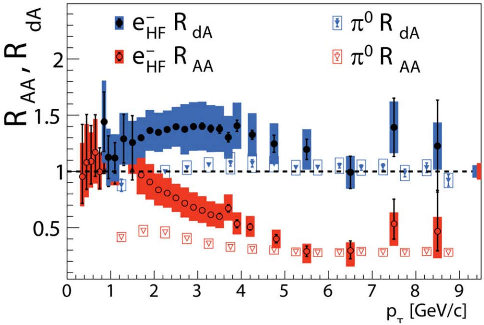
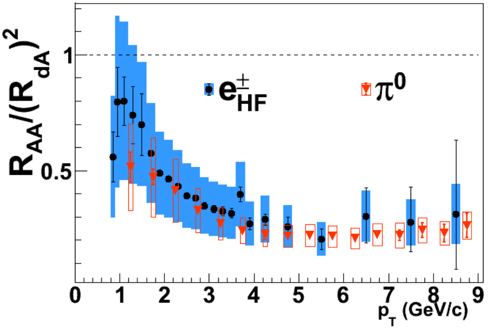
Outline

PHENIX has published recently three papers which will be the focus of this talk

- Heavy flavor decay electron spectra and anisotropy in 62.4 GeV collisions
  - arxiv:1405.3301
- Precise bottom cross section measurement via e^+e^- pairs
  - arxiv:1405.4004
- Heavy-flavor electron-muon correlations in p+p and d+Au collisions
  - Phys. Rev. C 89, 034915 (2014)

Heavy flavor decay electron spectra and anisotropy in 62.4 GeV collisions

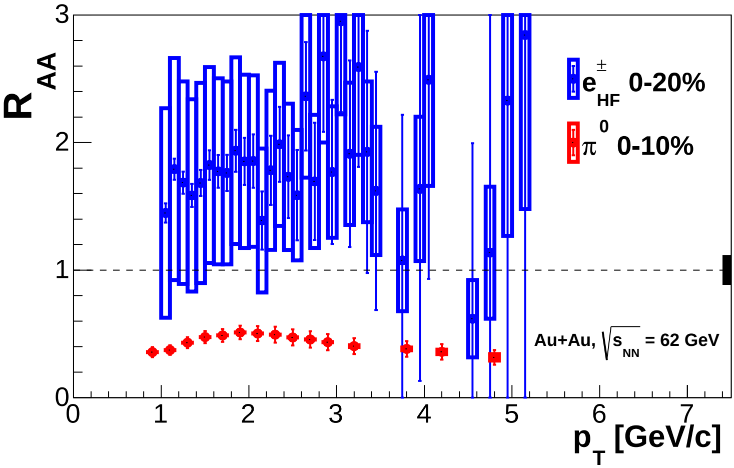




The story from 200 GeV Au+Au collisions : heavy quark suppression is similar to that of light quarks in the medium

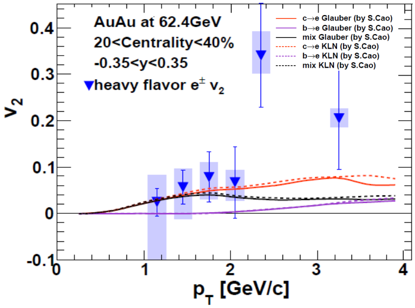
Charm quarks in 62 GeV Au+Au

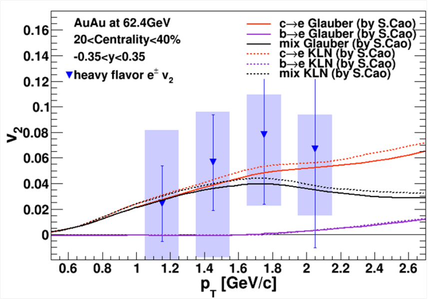
arxiv:1405.3301



Maybe not the same story in 62 GeV. But $p+p$ comes from ISR. We need more $p+p$ data at 62 GeV!

Charm quarks in 62 GeV Au+Au



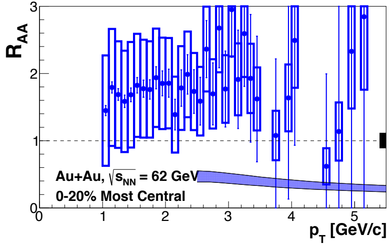


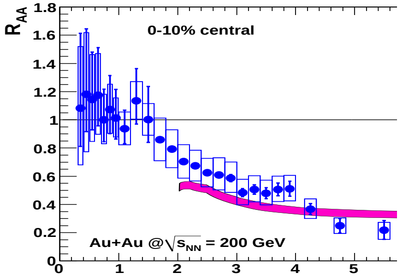
arxiv:1405.3301

Surprisingly, charm mesons still show a positive v_2 at 62 GeV even though it is not supressed

Is charm actually flowing, or is this v_2 just from recombination with a light quark?

More data will be needed to sort understand charm flow at 62 GeV





arxiv:1405.3301

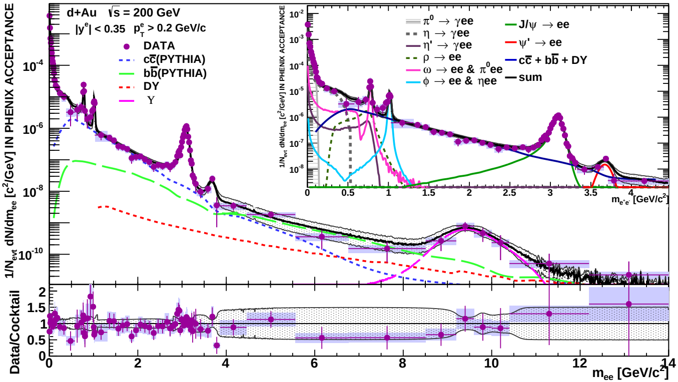
Model from Vitev including energy loss and collisional dissociation which describes the 200 GeV suppression also predicts suppression for 62 GeV

"cold" nuclear matter effects are very important!

data at 62 GeV with silicon vertex detectors could shed much light on what is happening with charm quarks as a function of beam energy

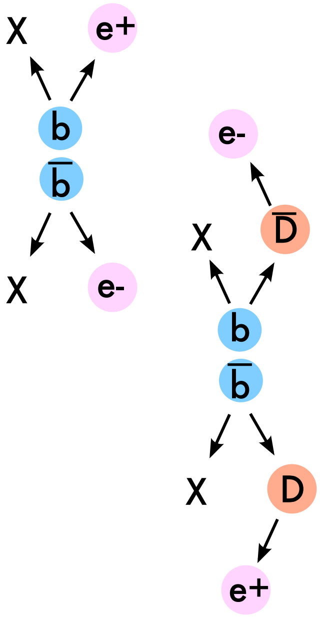
Bottom measurement in d+Au via di-electrons

Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations



High quality $e^{\pm}$ data from d+Au collisions in 2008

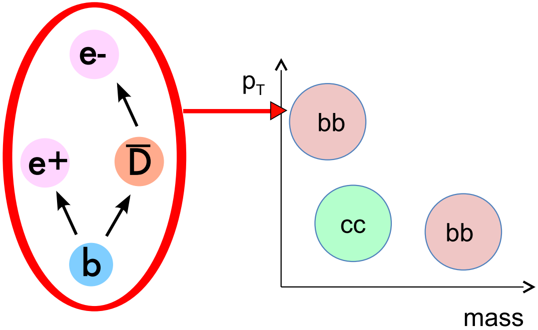
Can probe heavy flavor production as well as modification through cold (hot?) nuclear matter effects



Multiple ways to produce ee pairs

All contribute similar total pairs

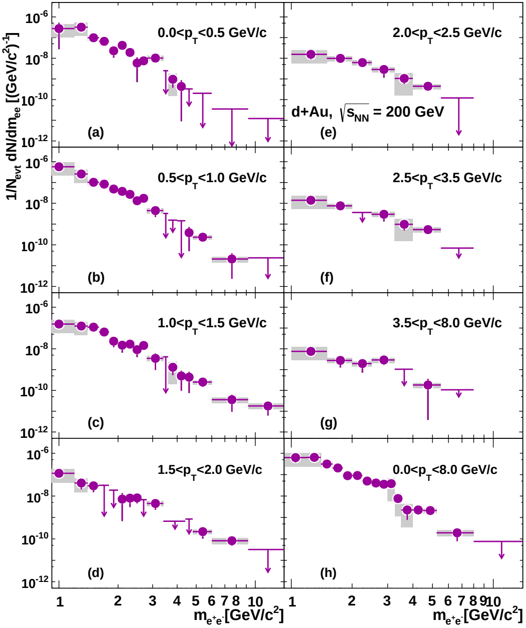
But they populate different regions of mass,pt space



Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations

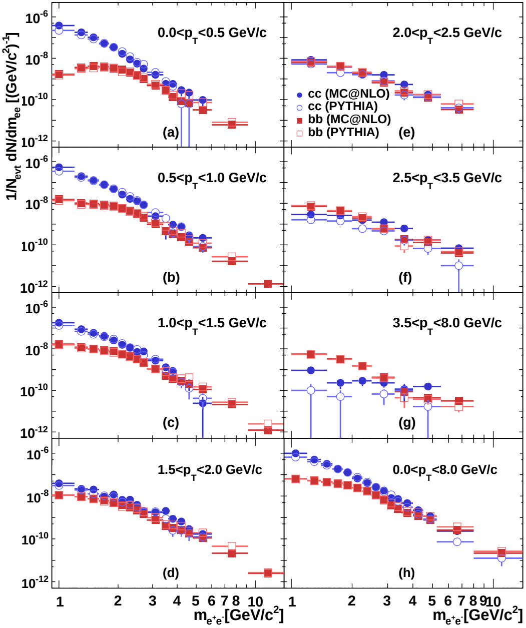
- Subtract in m, p_T
  - Vector mesons
  - Pseudoscalar mesons
  - Drell-Yan
- We are left with open heavy flavor decays
- This data is corrected for detector efficiency, but not for the PHENIX acceptance of π in ϕ and 0.35 in $|\eta|$

arxiv:1405.4004

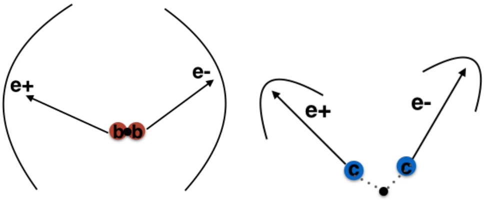


Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations

- Fit in m, p_T with
  - MCNLO
  - Pythia
- We have the following general trends
  - charm dominates at
    - low p_T,low m
  - bottom dominates at
    - low p_T,high m
    - high p_T,low m



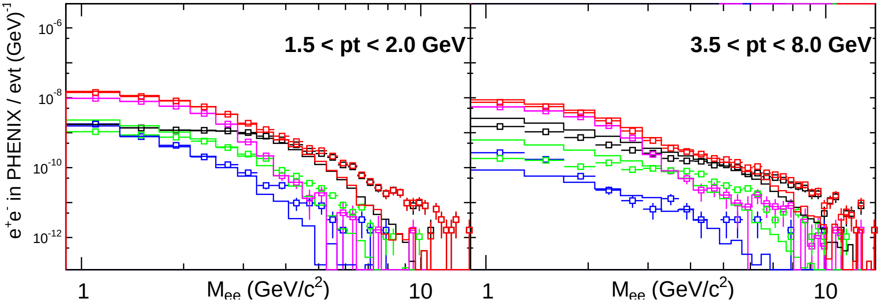
Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations



For $m_q >> p$, the $e^\pm$ decay randomizes the opening angle

Otherwise, the opening angle between electrons depends on the opening angle between the quark-antiquark pair

We thus expect more model dependence for extracted charm quark cross section than for bottom



b → ce → ee

bb → ee

bb → ce → ee

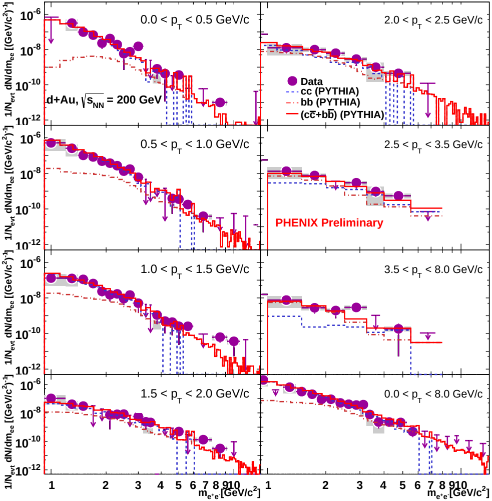
bb → cc → ee

At high p_T, decays from a single open B meson completely dominate the mass spectrum

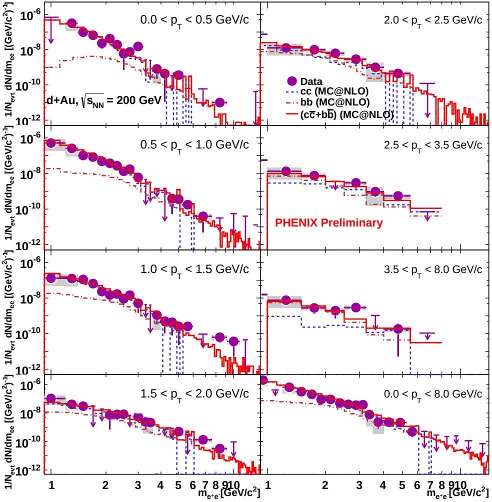
The above plot is from MCNLO, but the above statement is model-independent

Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations

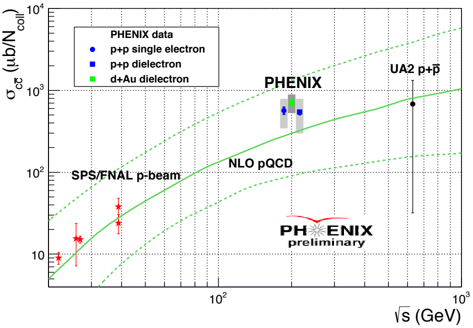
PYTHIA



MC@NLO



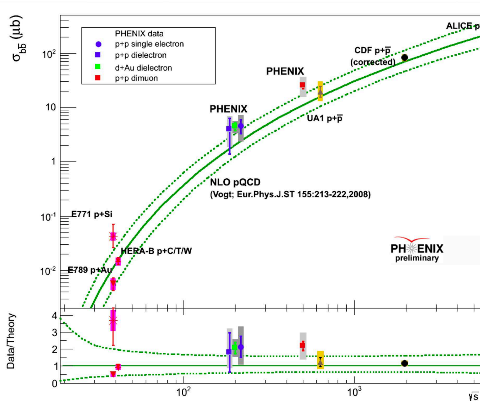
PYTHIA and MCNLO describe the data equally well



$p + p$ equivalent cross sections extracted as

- using MCNLO : $\sigma_{cc} = 958 \pm 96(stat) \pm 335(sys)\mu b$
- using PYTHIA : $\sigma_{cc} = 385 \pm 34(stat) \pm 119(sys)\mu b$

Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations



$p+p$ equivalent cross sections extracted from PYTHIA and MCNLO as

- $\sigma_{bb} = 3.4 \pm 0.28(stat) \pm 0.46(sys)\mu b$

The difference between MCNLO and PYTHIA extracted bottom cross sections are less than 2%

Separating $c\bar{c}$ from $b\bar{b}$ through e^+e^- correlations

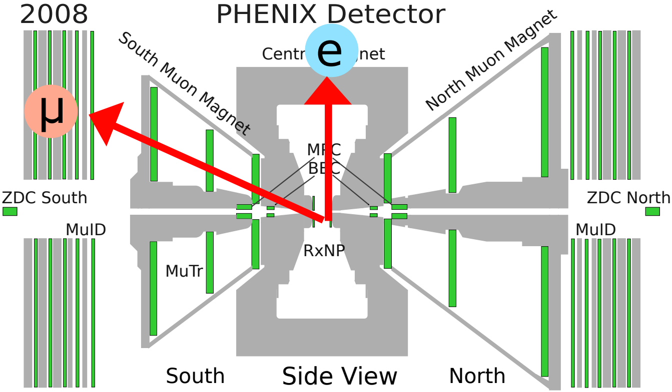
Dilepton correlations are a powerful probe of heavy flavor production

The low mass, high p_T region is dominated by the decay from a single open heavy flavor B meson

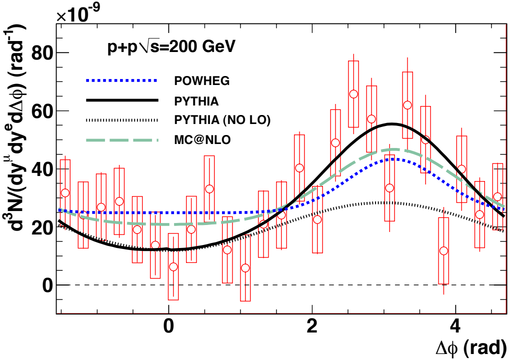
This analysis is currently being carried out for $p + p$ data as well → compare to extract cold nuclear matter effects...or are they hot effects?

What about heavy ions at RHIC/LHC? Di-muons are just as suitable as electrons at high momentum for this measurement

electron-muon correlations in d+Au



average x-range of 5×10^{-3}



Like-sign subtracted $e-\mu$ correlations should be predominantly from $c\bar{c}$ decays

$e^{\pm}$: $p_T > 0.5$ GeV/c, $|\eta| < 0.35$

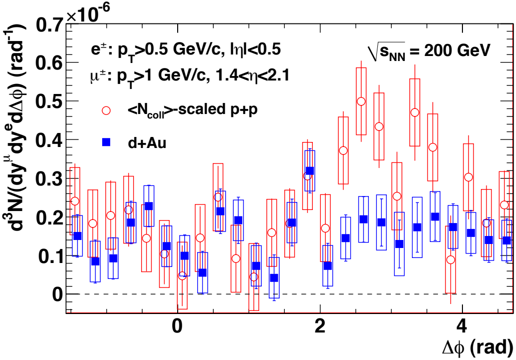
$\mu^{\pm}$: $p_T > 1$ GeV/c, $1.4 < \eta < 2.1$

pQCD-based models agree within systematics to the $p+p$ data

Combining the models :

$\sigma_{cc} = 538 \pm 46(\text{stat}) \pm 197(\text{data sys}) \pm 174(\text{model sys})\mu b$

paper can be found at Phys. Rev. C 89, 034915 (2014)

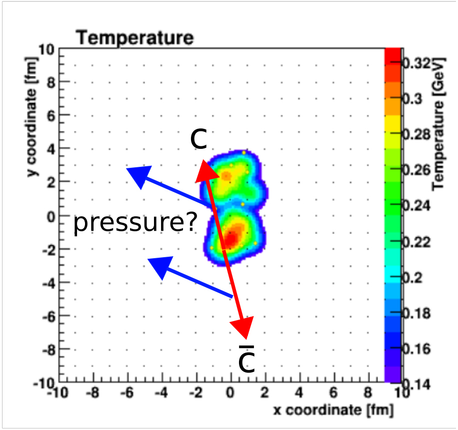


Suppression of $e-\mu$ correlations in d+Au collisions

This indicates that the $c\bar{c}$ is correlation is itself modified by nuclear effects

Is the suppression from shadowing, or gluon saturation?

Phys. Rev. C 89, 034915 (2014)



More provocatively, could hydrodynamical pressure modify the $c\bar{c}$ opening angle in a medium created in d+Au collisions?

VTX analysis

We are pushing the Run11 VTX analysis to publication very soon. We do not show a snapshot of the analysis here.

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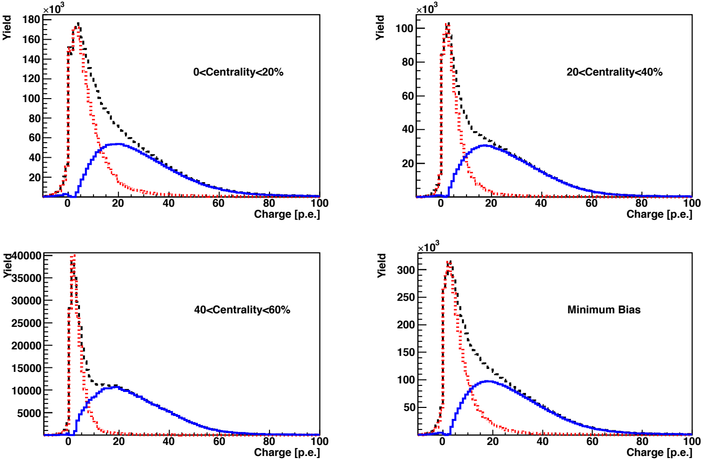
For low p_T electrons, the parent hadron momentum spectrum is needed to precisely distinguish charm decays from bottom decays

One interesting approach to take into account the lack of direct knowledge of the parent charm and bottom hadron spectra is to use Bayesian unfolding. See the poster by Andrew Adare.

Run 14 is ongoing now, and this will be the golden dataset for the VTX and FVTX!

Summary

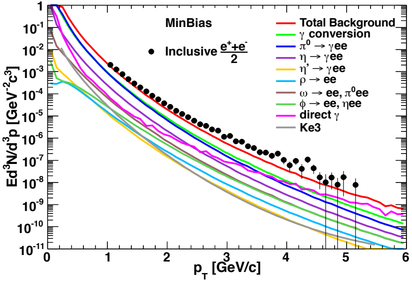
- Charm modification in Au+Au looks very different at 62 GeV and 200 GeV
- Bottom cross section measured precisely via $e^+ e^- m,p_T$ spectrum
- electron-muon correlation shows away-side suppression in d+Au
- Run 14 is going well for VTX/FVTX silicon detectors

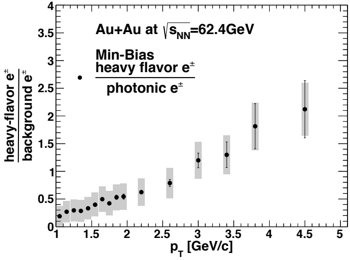


HBD in 62 GeV Run10

65% of pairs with opening angle <0.05 rejected at 75% signal efficiency

backup





After HBD cut, a large proportion of electrons are from heavy flavor decays