# PHENIX Measurements of Heavy Flavor & DY in p+p and p+Au at 200 GeV

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- Introduction
- Heavy flavor
  - Charm from p+p
  - Bottom from p+p and p+Au
- Drell Yan from p+p and p+Au
- Summary

# **Heavy Flavor Measurements in p+p and p+Au**



- Relative contributions dependent on  $\sqrt{s}$
- Study through  $q\overline{q}$  pair correlations
- In p+Au sensitive to modifications of the PDF and to initial/final state effects



# **Semi-leptonic Decays of Charm and Bottom**



c/b from single electrons in p+p 200 GeV : c/b and DY from dimuons in p+p 200 GeV : c/b correlations from  $\mu^{+}\mu^{-}$ ,  $\mu^{\pm}\mu^{\pm}$ ,  $e^{+}e^{-}$ ,  $e^{\pm}\mu^{\mp}$  in p+p at 200 GeV: b from  $\mu^{\pm}\mu^{\pm}$  in p+Au at 200 GeV: DY from  $\mu^{+}\mu^{-}$  in p+Au at 200 GeV:

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Phys. Rev. D 99 092003 (2019) Phys. Rev. D 99 072003 (2019) arXiv:1805.04075v1 Ph.D. Y.H.Leung SBU (2019) Ph.D. Y.H.Leung SBU (2019)

# **The PHENIX Experiment**



# **Single Lepton Measurement in p+p**

# Charm and Bottom life time: B<sup>±</sup> → 491 µm D<sup>±</sup> → 312 µm VTX detector 2 pixel layers 2 strip-pixel layers

• Measure DCA<sub>T</sub> with  $\sigma_{DCA_T} \sim 100 \ \mu m$ 

#### Bayesian unfolding method to separate charm and bottom

• Input:

differential cross section of HF electrons  $p_T$  dependent DCA<sub>T</sub> distributions incl. electrons Fraction of photonic electrons

- Output:
  - Charm and bottom hadron spectra
- Refolding:

Single electrons from charm and bottom







### **Charm and Bottom from Single Leptons**

PHENIX: Phys. Rev. D 99 092003 (2019)



- **D**<sup>0</sup> results compared to STAR
  - **Good agreement**



## **Charm and Bottom Electron Results**

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#### **Bottom fraction**

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- **Results consistent with previous publications**
- **FONLL** predictions consistent with measurements

#### **Differential cross section vs FONLL**

- **Data more accurate than FONLL**
- **Difference is shape and magnitude**



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# **Muon Pair Measurements in p+p and p+Au**

• Iterative simultaneous fit  $\mu^+\mu^-$  and  $\mu^+\mu^\pm$  in mass-p<sub>T</sub>:

- **Combinatorial and correlated background mostly from of**  $\mu$  from K,  $\pi$
- Decays from  $\eta, \eta' \rightarrow \mu^+ \mu^- \gamma$ ;  $\rho, \omega, \phi, J/\psi, \psi'$ , and  $Y \rightarrow \mu^+ \mu^-$
- Charm, Bottom, Drell-Yan





# **Bottom Cross Section in p+p**



# **Opening Angle of** $c\overline{c}$ and *bb* Pairs in p+p

#### Compare $\Delta \phi$ to POWHEG and PYTHIA tune A

PHENIX: Phys. Rev. D 99 072003 (2019) and arXiv:1805.04075v1

- Normalized to measured cross sections
- **Bayesian analysis fit pair creation**, flavor excitation, and gluon splitting to data



- **POWHEG predicts broader** distribution; Data favor PYTHIA
- Fit to data consistent with PYTHIA
  - $\mathbf{F}_{\mathbf{FE}} > \mathbf{F}_{\mathbf{PC}} > \mathbf{F}_{\mathbf{CS}}$ **Flavor excitation dominate**

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#### **Bottom**

- **POWHEG and PYTHIA describe** data within uncertainties
- Fit to data consistent with PYTHIA

 $\mathbf{F}_{\mathbf{PC}} > \mathbf{F}_{\mathbf{FE}} \gg \mathbf{F}_{\mathbf{GS}}$ **Pair creation dominant Gluon splitting small** 

# **Extending the** *c*<del>*c***Phase Space**</del>

#### ) Data

#### PHENIX: arXiv:1805.04075v1

- Yields of  $e^+e^-$  and  $e^\pm\mu^\mp$  dominated by charm
- Cover wide kinematic range



- **POWHEG and PYTHIA normalized to \mu^+\mu^- analysis** 
  - PYTHIA consistent with data over large kinematic range
  - Distributions from POWHEG broader for all datasets

# $b\overline{b}$ Pairs in p+Au



#### **p**<sub>T</sub> spectra

- p+Au in large-x (Au-going) small-x (p-going) consistent!
- Possible modification compared to p+p (see R<sub>pA</sub>)

#### Opening angle distribution

 p+p and p+Au (forward/ backward) no modification

#### Comparison to nuclear PDFs

- EPPS16 predicts constant R<sub>pA</sub> as function of p<sub>T</sub>
- Systematic deviation of data from prediction observed, though with limited significance

# **Drell-Yan in p+p and p+Au**

Yue Hang Leung Ph.D. SBU (2019) - https://www.phenix.bnl.gov/WWW/p/talk/theses.php

# • First Drell-Yan measurement at RHIC constrain:

- Unpolarized TMD PDFs
- Nuclear PDFs
- Nuclear initial state effects
- Drell-Yan in p+p
  - NLO calculations consistent with data
- Drell-Yan in p+Au
  - Backward x~0.1 (Au-going) R<sub>pA</sub> consistent with EPPS16
  - Forward x ~ 0.005 (p-going)
    R<sub>pA</sub> shows possible enhancement for p<sub>T</sub>>2GeV/c



# **Summary**

- Heavy flavor production in p+p at  $\sqrt{s} = 200 \text{ GeV}$ 
  - Separation of charm and bottom
    - Single electrons with vertex tracking Muon pairs
  - Data more precise than pQCD calculations
  - Measured cross sections 2x larger than pQCD central values
  - Charm production dominated by NLO Flavor Excitation
  - Bottom production dominated by LO Pair Creation
- Bottom production from p+Au at  $\sqrt{s} = 200 \text{ GeV}$ 
  - Hint of possible p<sub>T</sub> dependent modification compared to p+p
- First Drell-Yan measurements at RHIC in p+p and p+Au
  - p+p cross section well described by pQCD
  - p+Au consistent with nPDF ESSP16, with possible deviation for p<sub>T</sub>>2GeV/c at low x

# **Backup Slides**







arXiv:1805.04407

