PHENIX results on charm and bottom quark yields in p+p and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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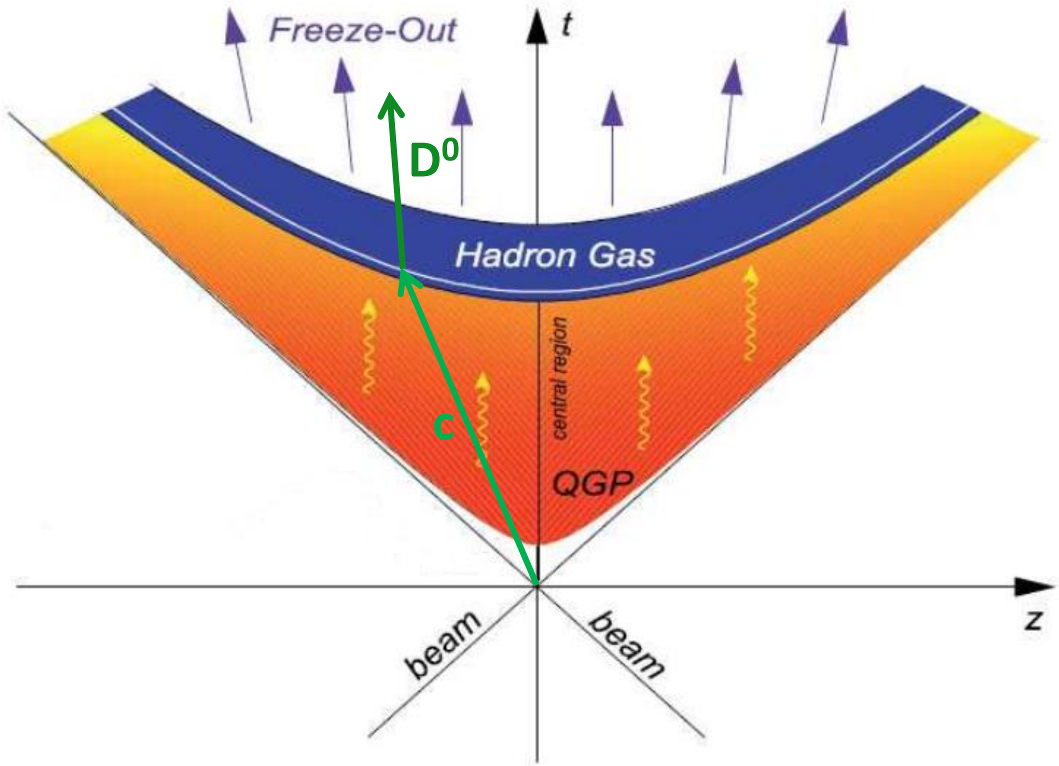
Heavy Flavor Quarks as Probe of QGP



At RHIC energies heavy flavor quarks (bottom and charm) are primarily produced in initial hard scattering collisions

Experience full evolution of the QGP

Modifications to heavy flavor quarks are a powerful way to study properties of the QGP

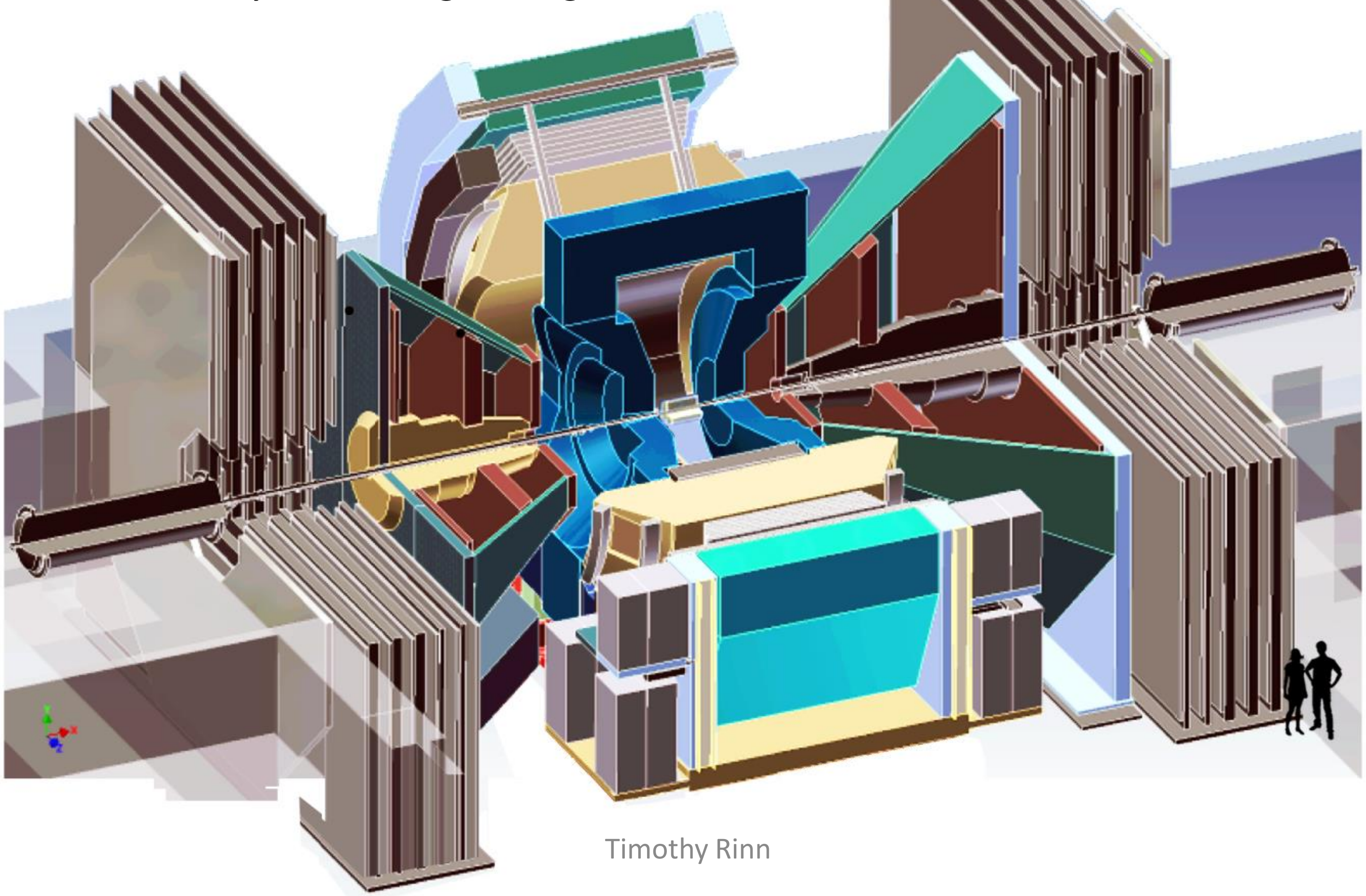
Studying Heavy Flavor in PHENIX

Central Arm: $|\eta| < 0.35$

Electrons: RICH and emcal for eid

Muon arms: $1.2 < |\eta| < 2.2$

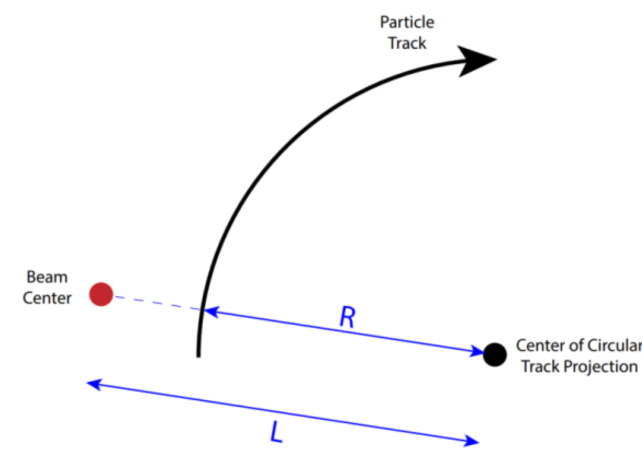
Muons: *Talk by Yue Hang Leung: Thurs 10:45*



Separating HF in PHENIX

Charm and bottom have different, non zero life times

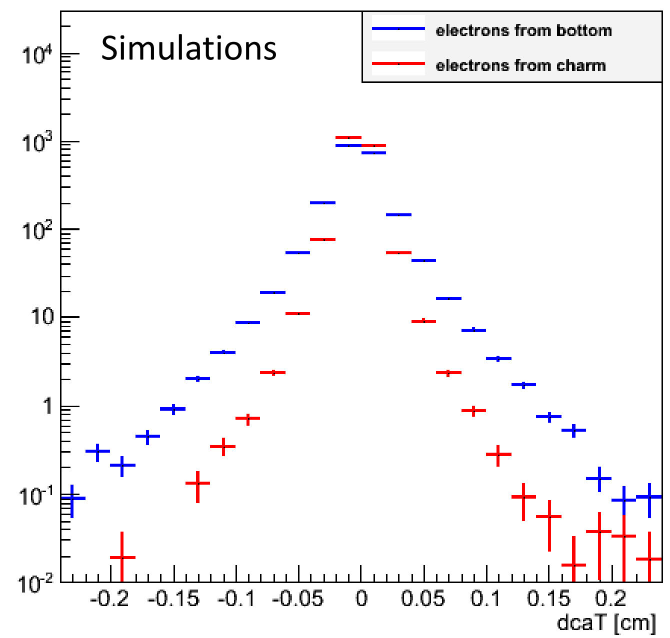
- $B^{\pm} c\tau = 491\ \mu m$
- $D^{\pm} c\tau = 312\ \mu m$

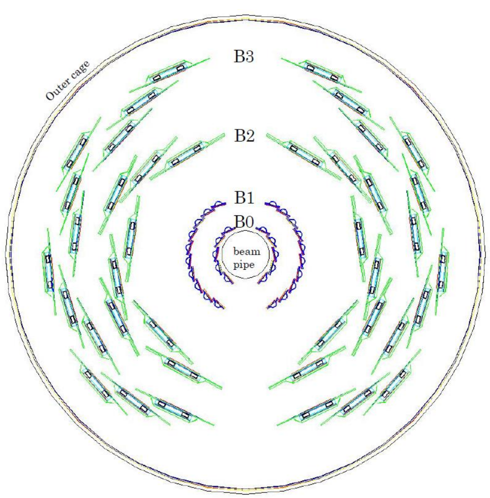


PHENIX cannot measure displaced vertexes directly.

- Using VTX can measure dca_T of electron tracks

dca_T shape of bottom and charm electrons different

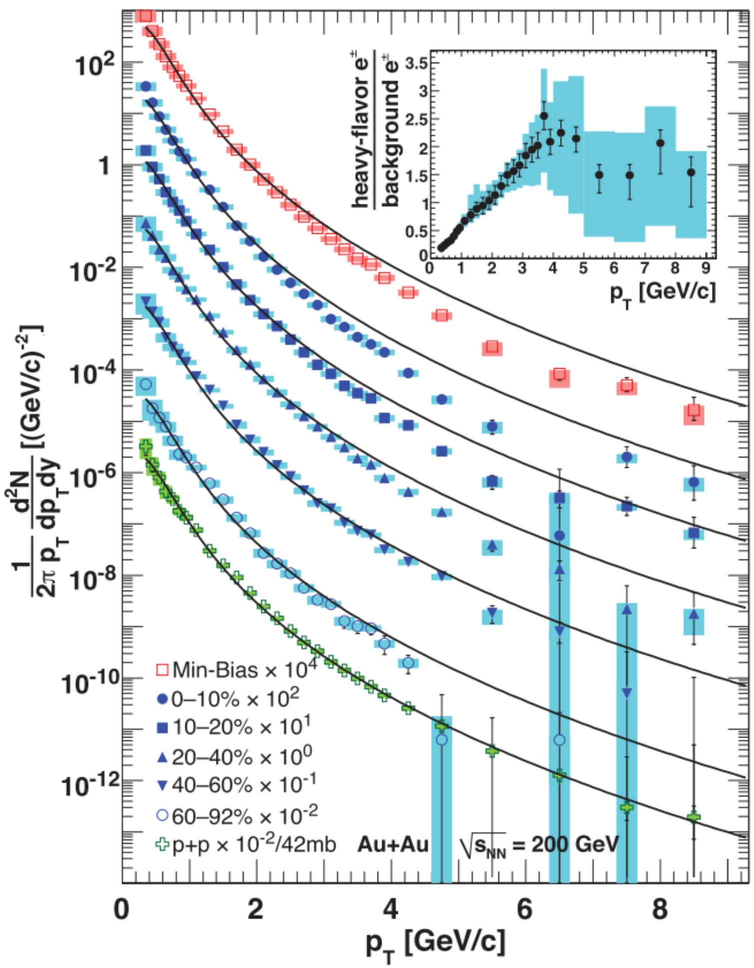




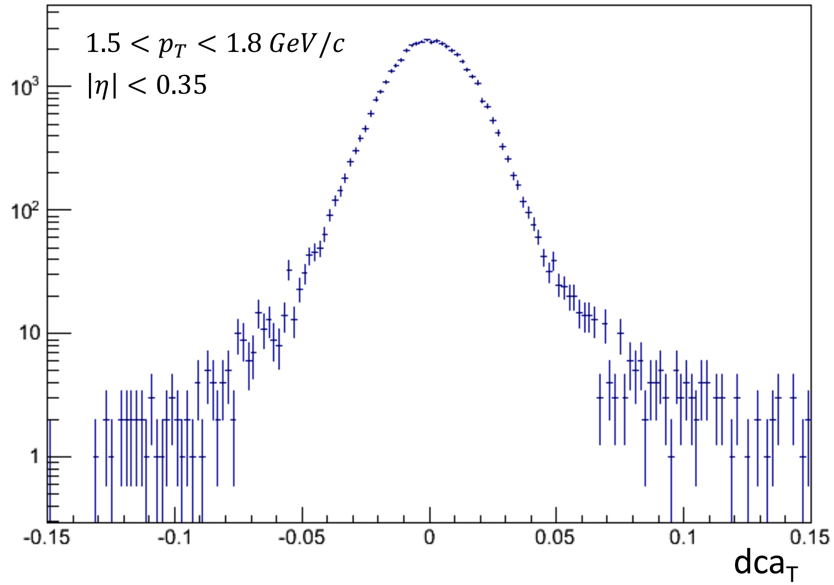
VTX: Measure track dca_T with ~100 μm resolution

Analysis Strategy

Phys. Rev. C 84, 044905 (2011)



Bayesian unfolding technique simultaneously takes into account inclusive heavy flavor differential cross sections and measured electron dca_T distributions to separate contributions from bottom and charm



Sources of Background

Photonic Electrons: π^0, η, direct γ

Shape determined using M.C.

Non-Photonic Electrons: j/ψ, *ke3*

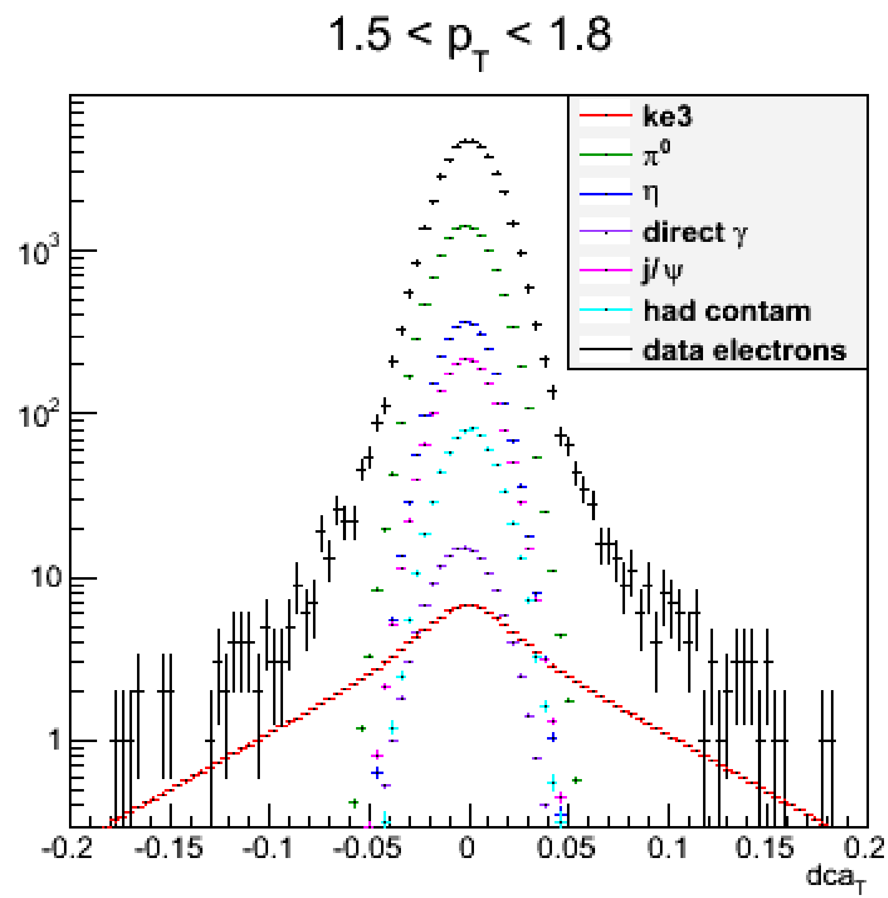
Shape determined using M.C.

Hadron Contamination:

Shape from hadrons in data

High Multiplicity Background:

Not relevant in p+p, but affects Au+Au.



Bayesian unfolding extracts b and c after fixing the background contributions

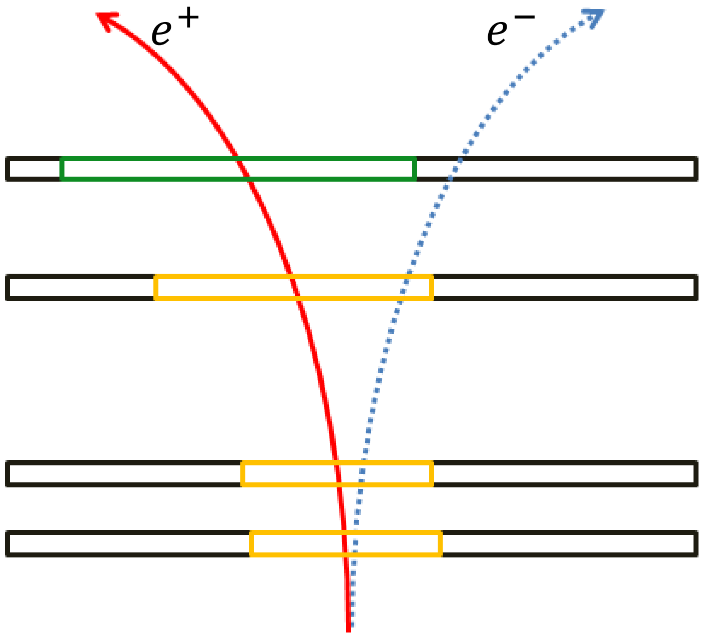
Conversion Electrons with VTX

VTX detector is approximately 13% of a radiation length

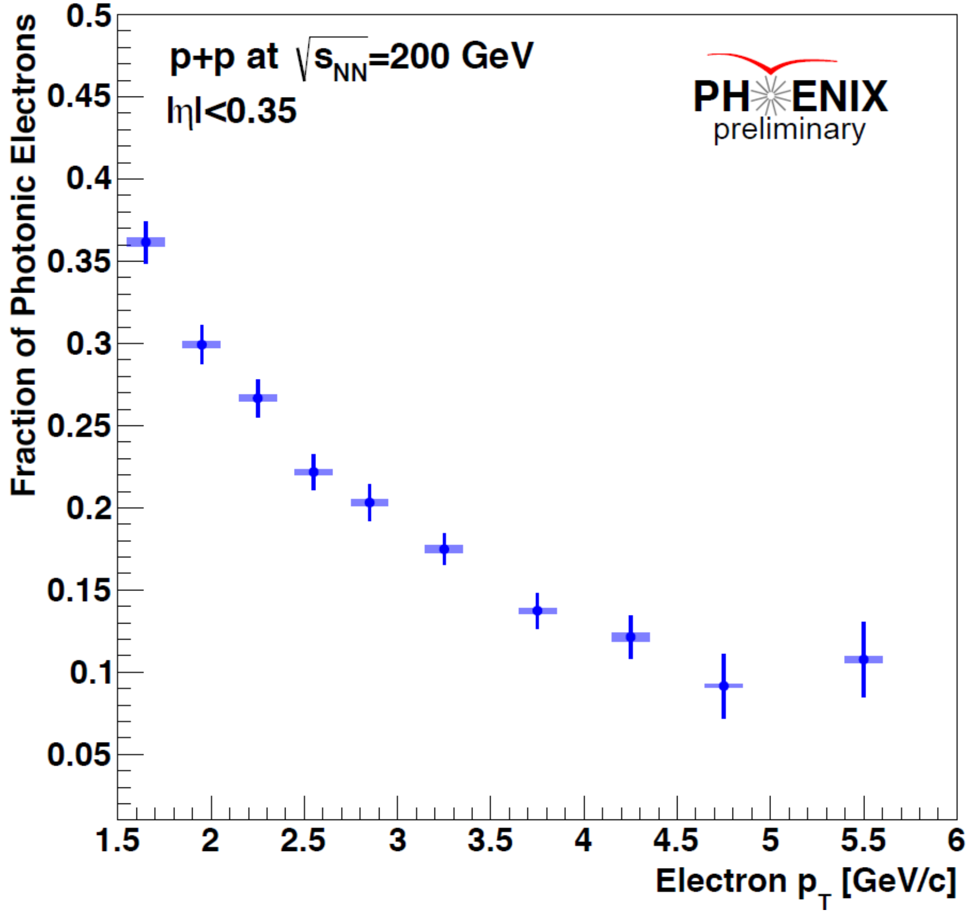
- Source of significant number of conversions

p_T dependent isolation windows in each layer of VTX can effectively flag conversion electrons

Can be used to effectively improve the signal to background ratio by reducing contributions from conversion electrons



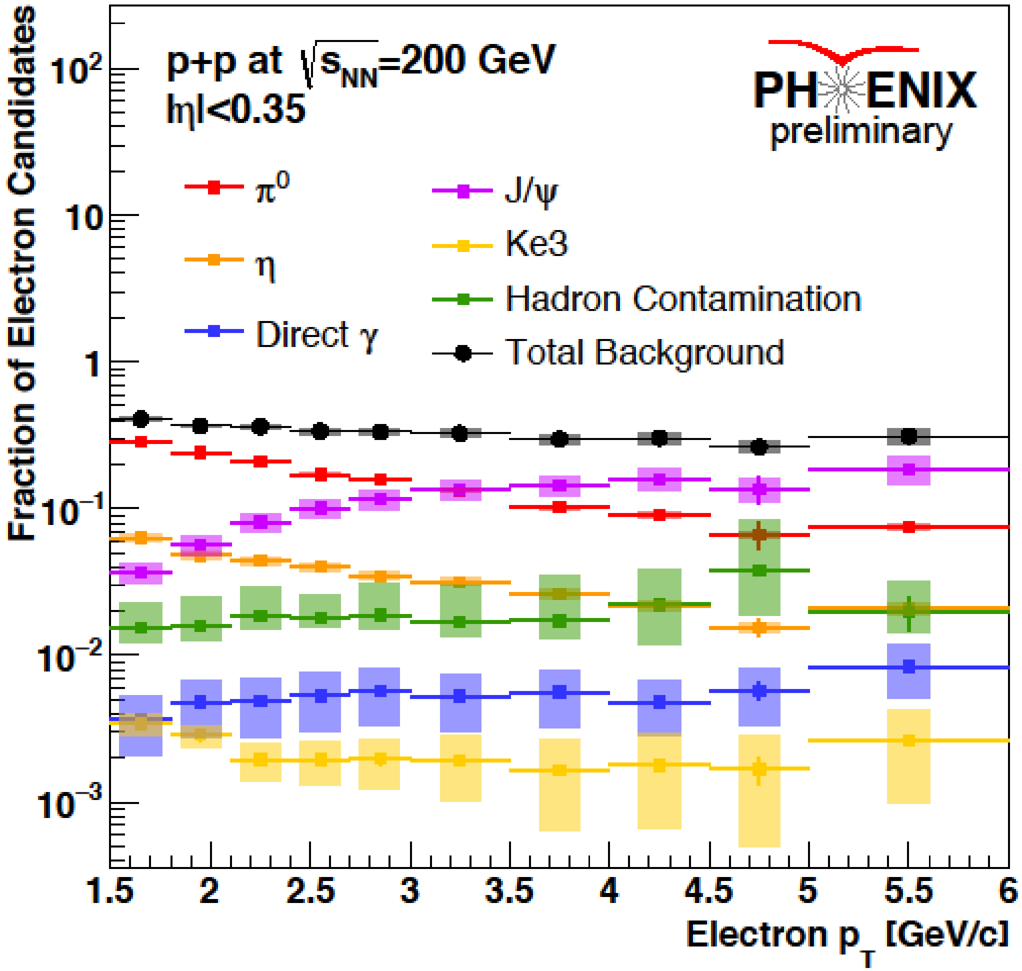
Normalizing Background Electrons



Using the survival rates of the Isolation cut the fraction of electrons from photonic sources was measured

Used to constrain background contributions

Background Normalizations



Combining the measured F_p with an electron cocktail we extracted the contribution from each background source

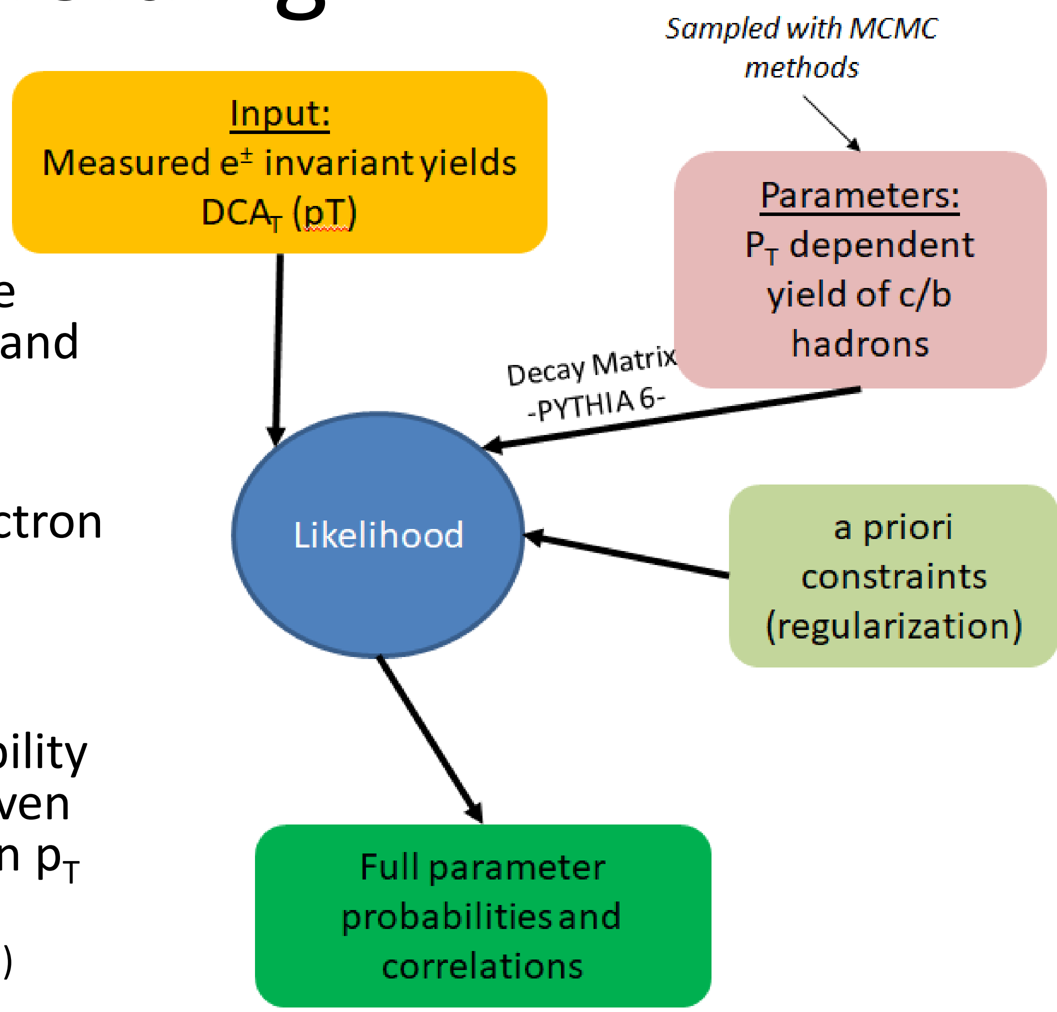
Unfolding

The unfolding uses Bayesian inference methods to determine parent charm and bottom hadron p_T distributions

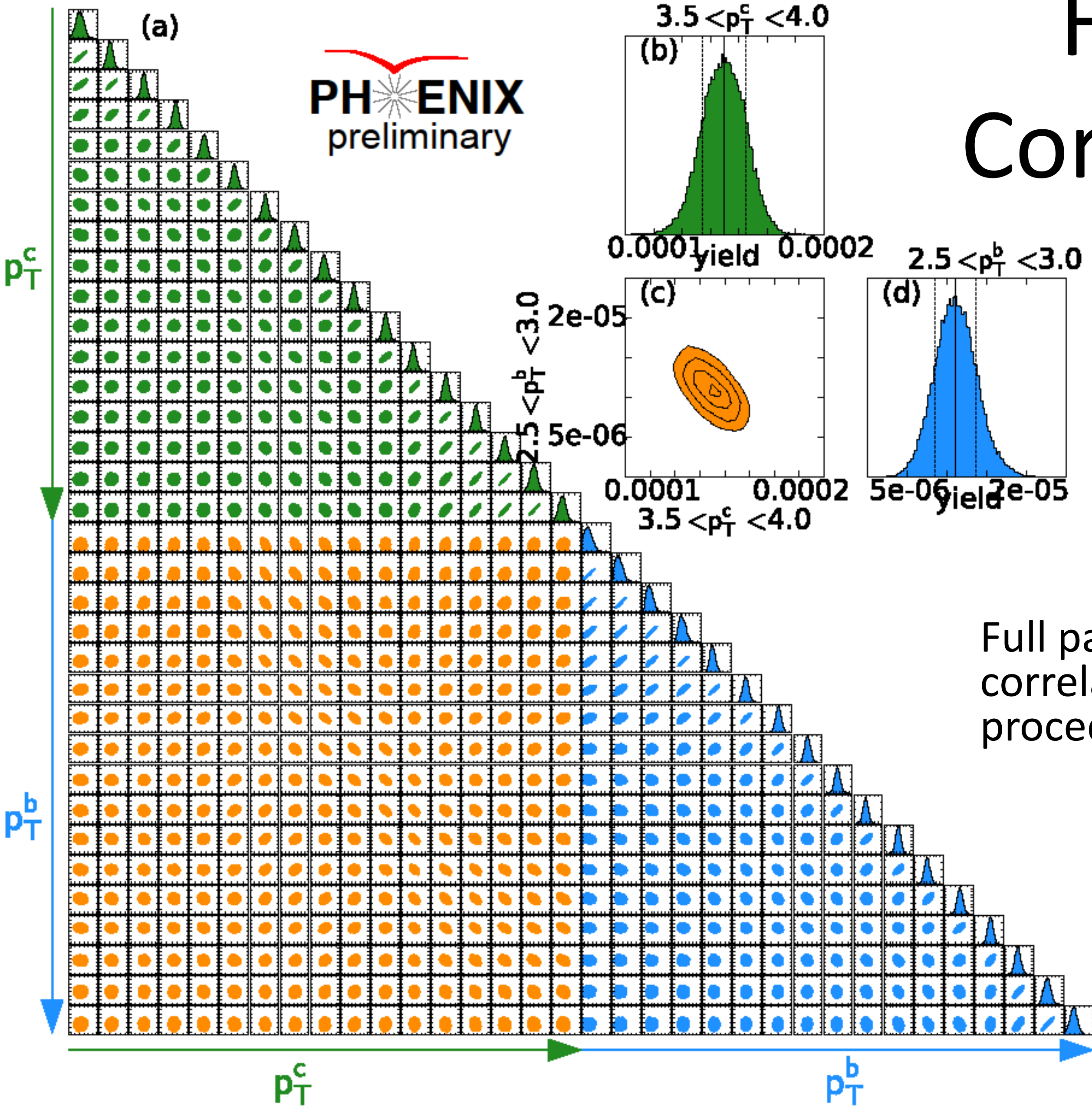
Done through simultaneous fit to electron invariant yield and electron DCA_T distributions

The decay matrix contains the probability of a bottom (charm) hadron with a given p_T to decay to an electron with a given p_T and DCA_T

- Bottom := $B^{\pm}$,B^0, B_s, Λ_b (Includes B->D->e)
- Charm := D^0, $D^{\pm}$, D_s, Λ_c
- Modeled h->e decays using PYTHIA-6

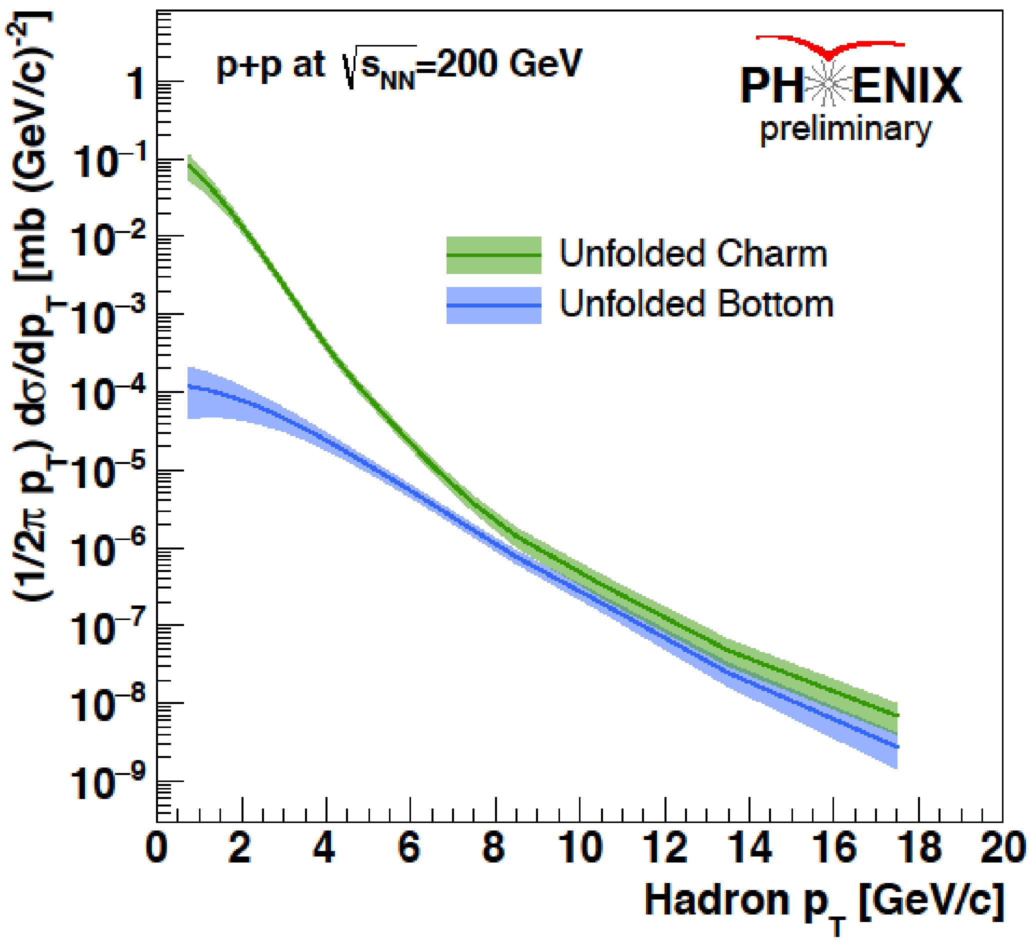


Hadron Correlations



Full parameter values and correlations from the unfolding procedure

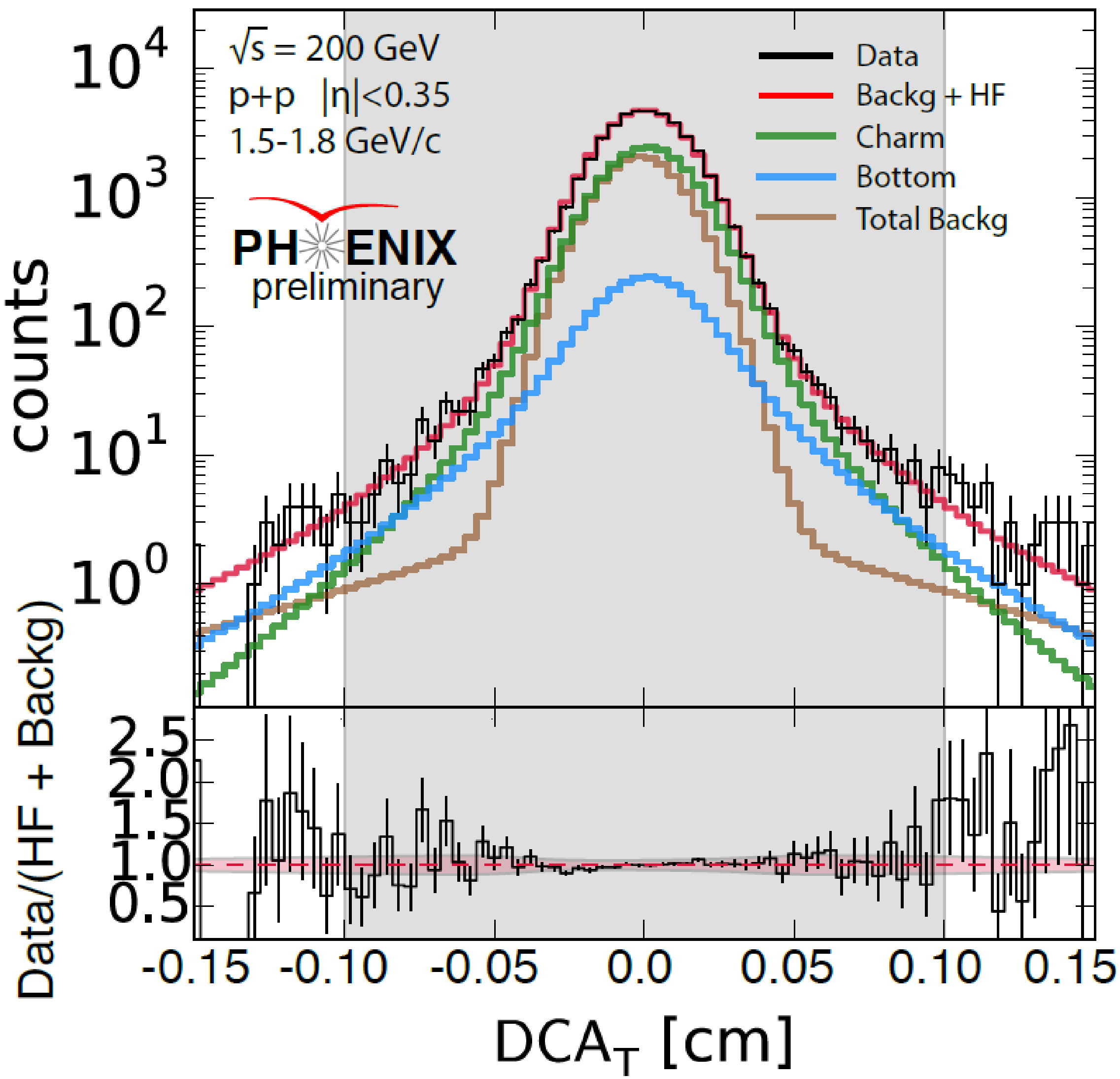
Differential Cross-Section



Hadron differential cross-sections integrated over all rapidity's were extracted.

This result is model dependent, as it relies on the PYTHIA modeling of decay probabilities and rapidity distributions

dca_T Refold p+p: Low p_T

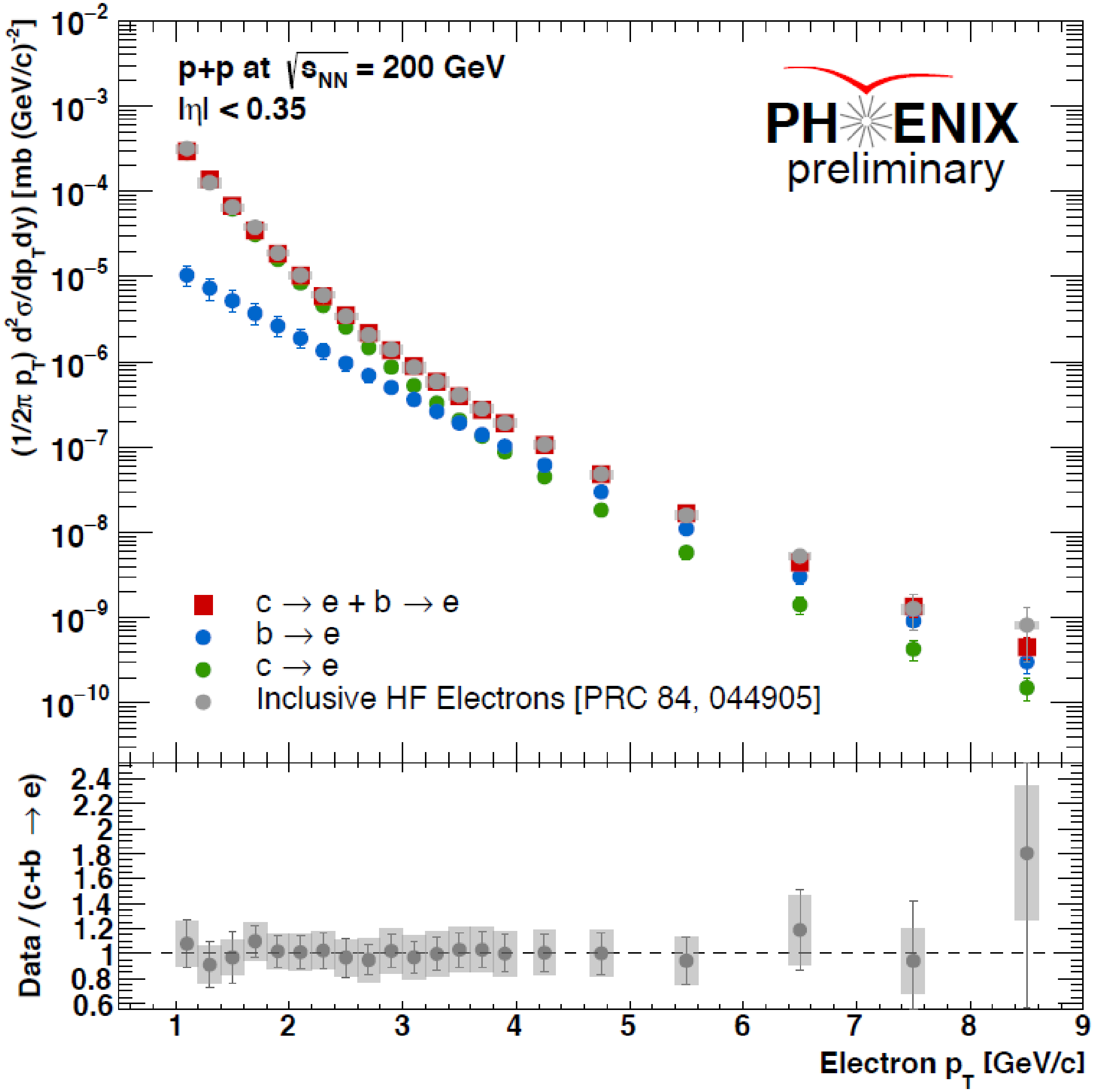


c->e:
Monte Carlo shape
Normalization from unfolding

b->e:
Monte Carlo shape
Normalization from unfolding

The charm and bottom yield predicted by the unfolding is consistent with electron measured DCA_T distributions.

Heavy Flavor Electron $\frac{d^2\sigma}{dp_T dy}$ Refold p+p

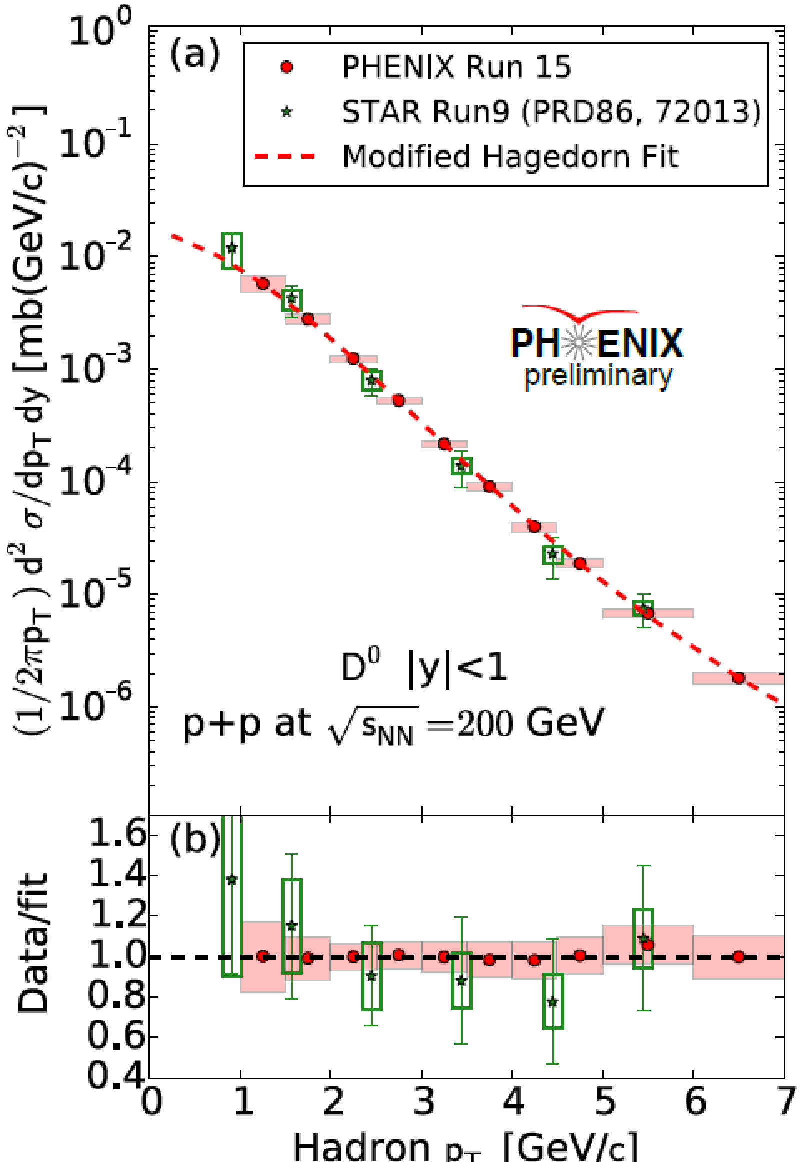


The bottom and charm electron yield measured using the unfolding agrees with the input inclusive differential cross section.

D^0 Cross-Section Measurement

Using a pythia model combined with the unfolding result can extract D^0 yield for |y| < 1

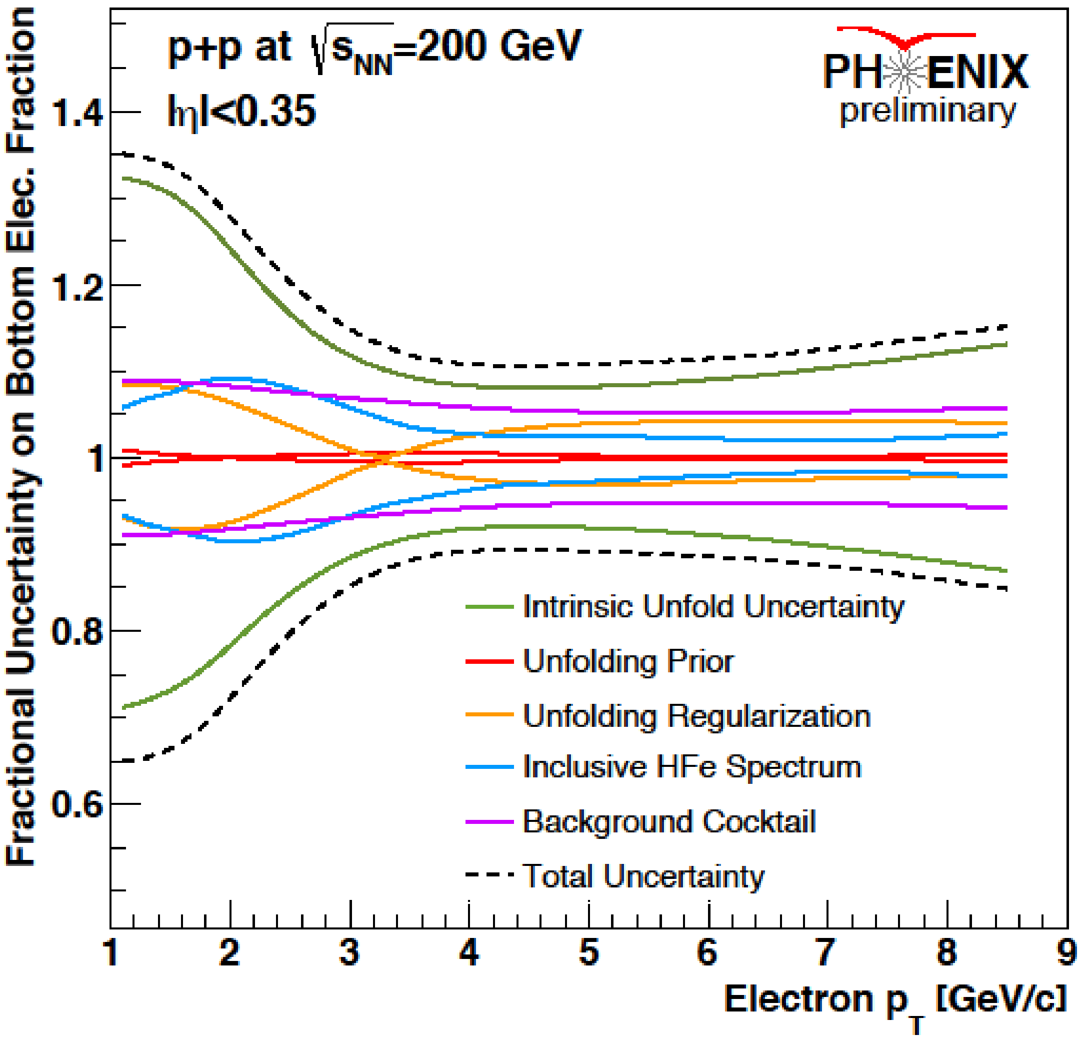
Very good agreement with STAR over comparable momentum range



Systematic Uncertainties

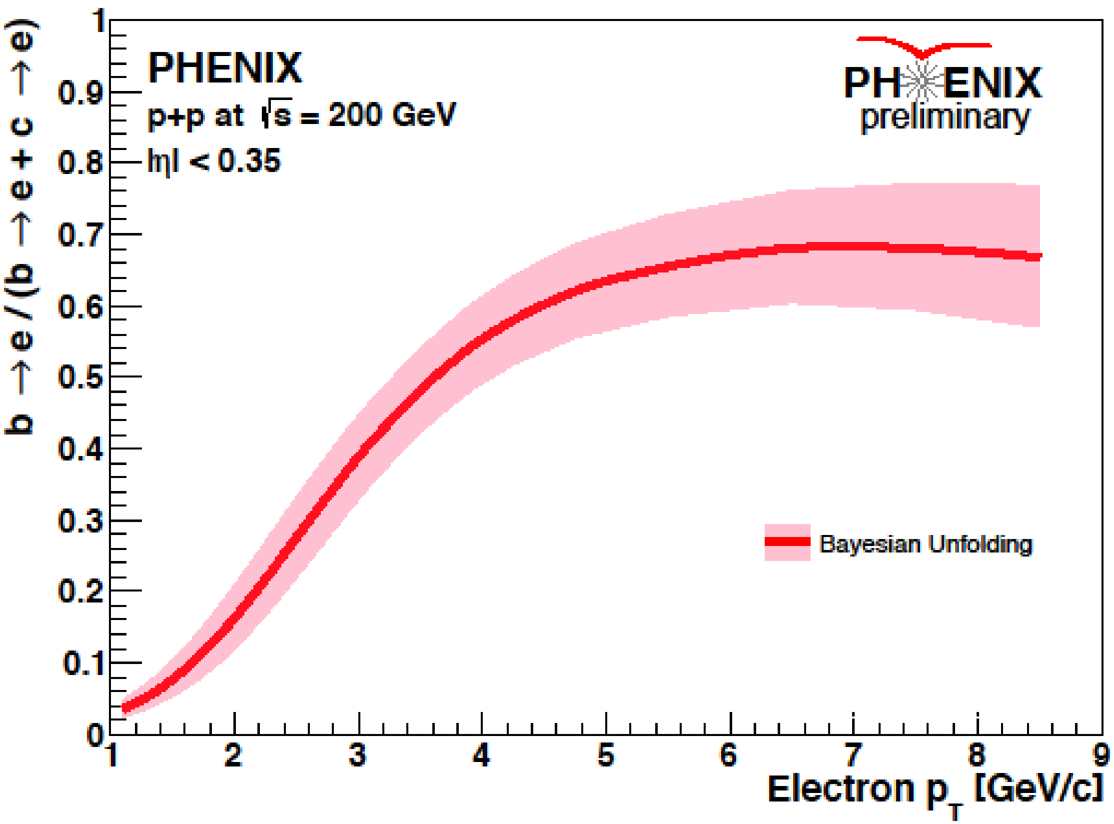
5 considered sources of uncertainty.

- Intrinsic uncertainty in the unfolding procedure
- Uncertainty to the prior
- Uncertainty due to the regularization parameter
- Uncertainty of the inclusive HF yield
- Uncertainty in the background cocktail



2015 p+p Preliminary b-Fraction

Extract continuous b-fraction result between 1 and 9 GeV



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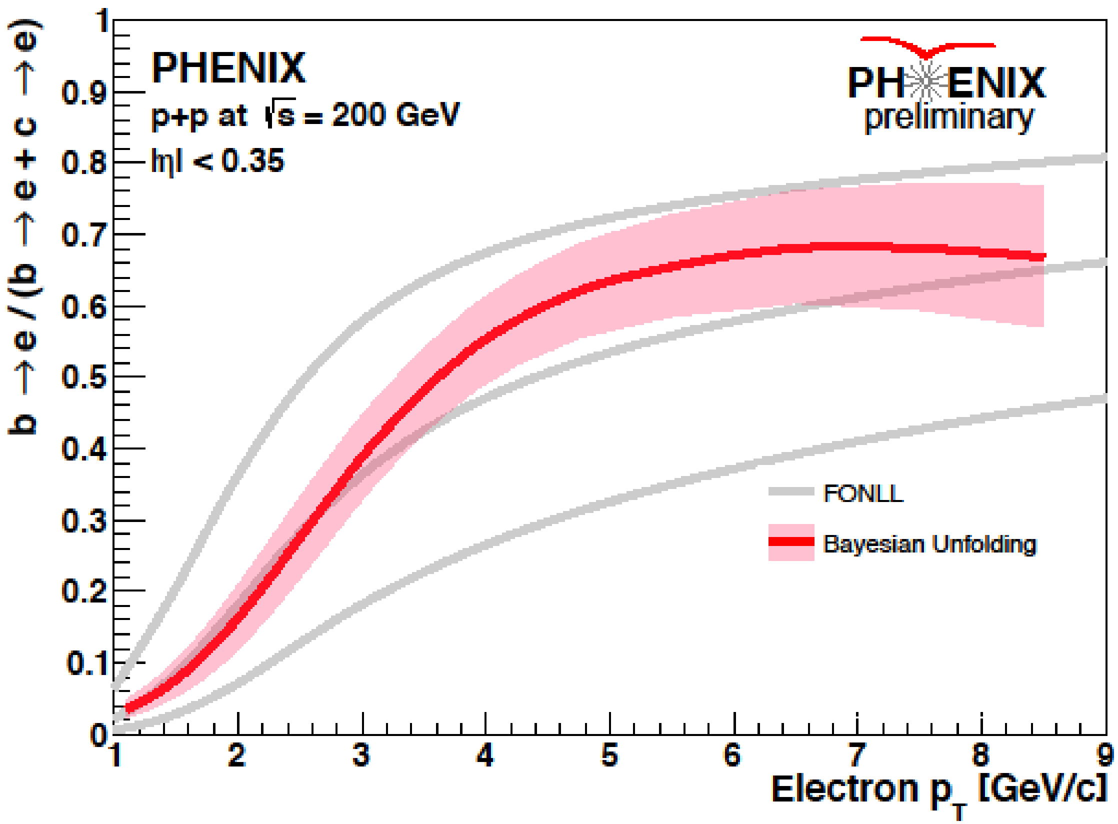
Extract continuous b-fraction result between 1 and 9 GeV

FONLL predictions are consistent with measurement



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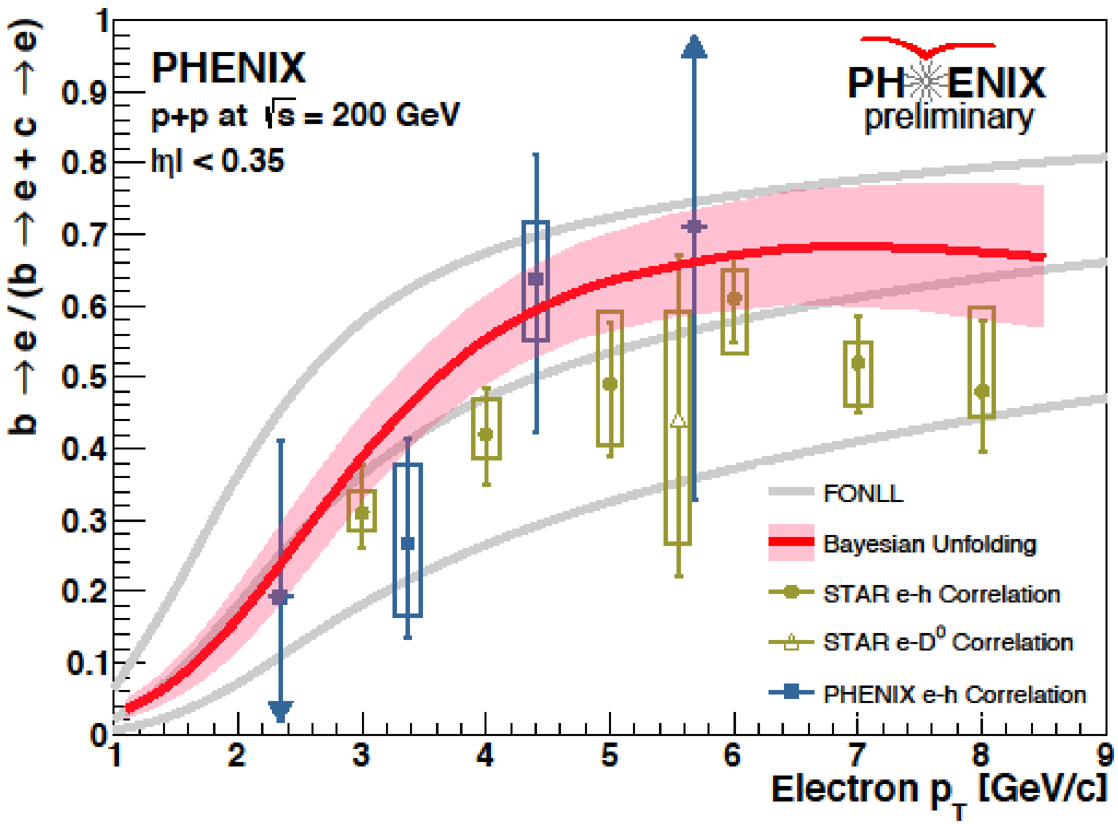
Extract continuous b-fraction result between 1 and 9 GeV

FONLL predictions are consistent with measurement

Observe consistency with previously published PHENIX measurements

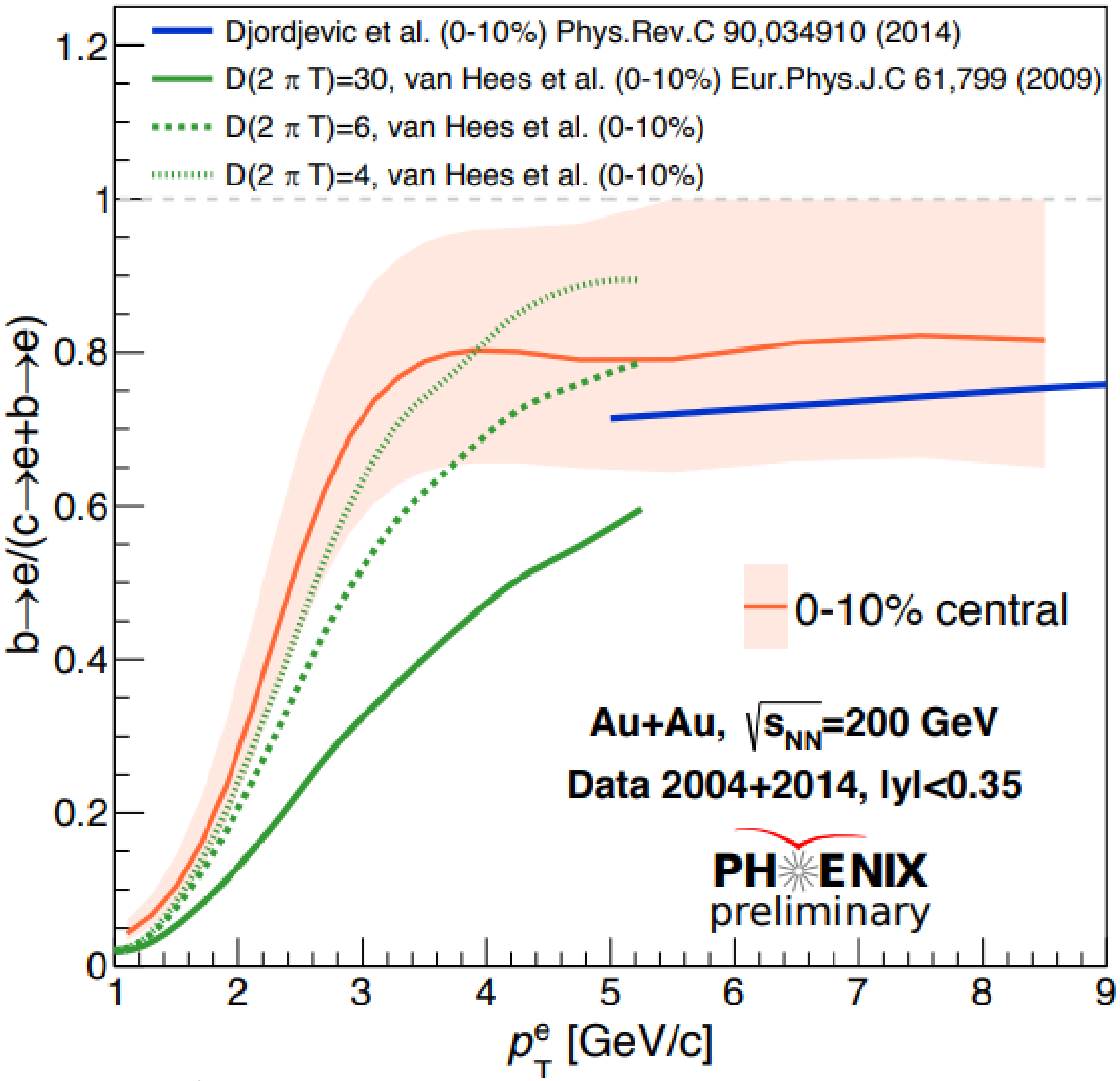


0-10% Central Au+Au b-Fraction

Parallel effort to do a similar analysis with the 2014 Au+Au data set

Observe agreement with theoretical models:

- ➢ Consistent with D(2πT) < 4, implies strong coupling in QGP
- ➢ Agreement with DGLV, contains both rad. + coll. energy loss in QGP

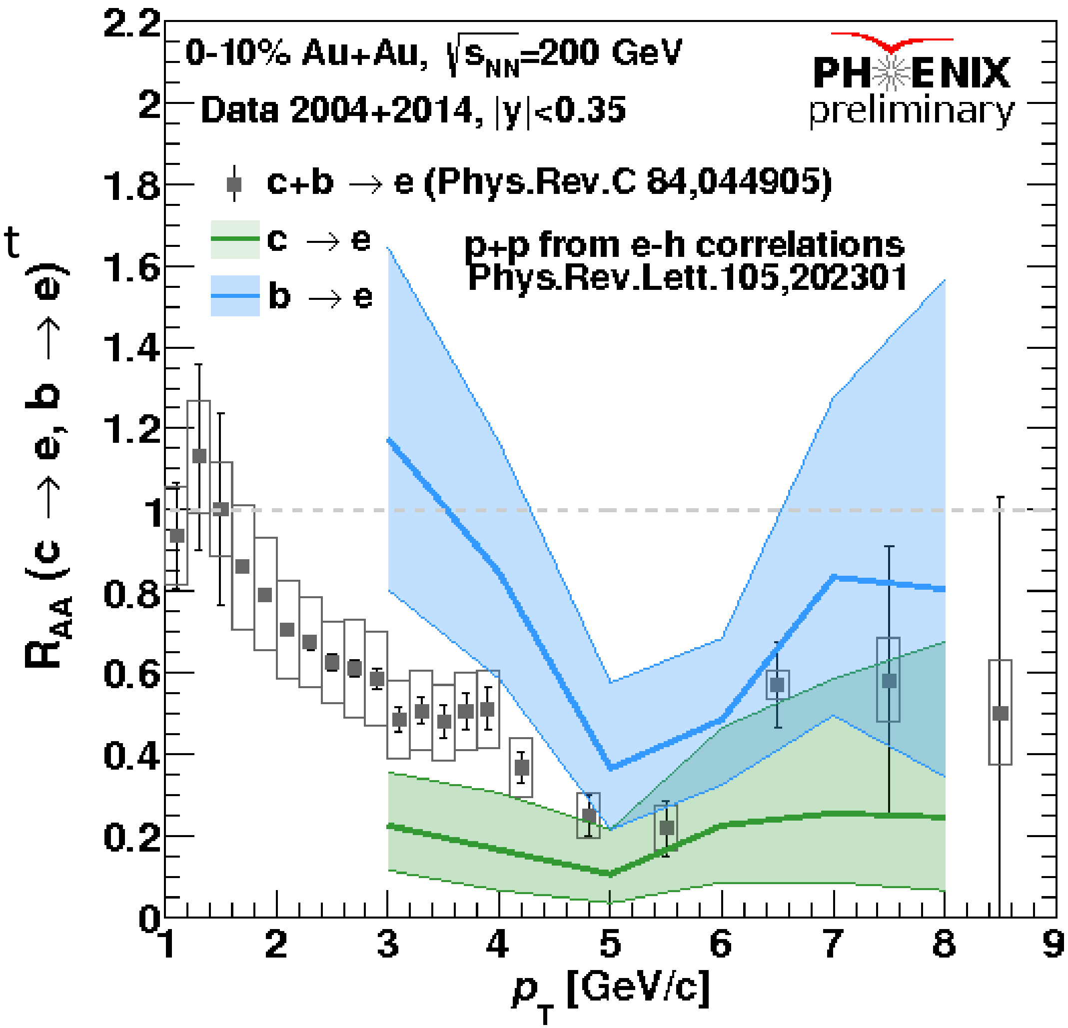


2014 Preliminary R_{AA} Central

Preliminary R_{AA} calculated using STAR e-h correlation measurement for p+p reference

Observe suppression of charm relative to bottom at ~3 GeV/c

For publication result will be updated using the new p+p baseline



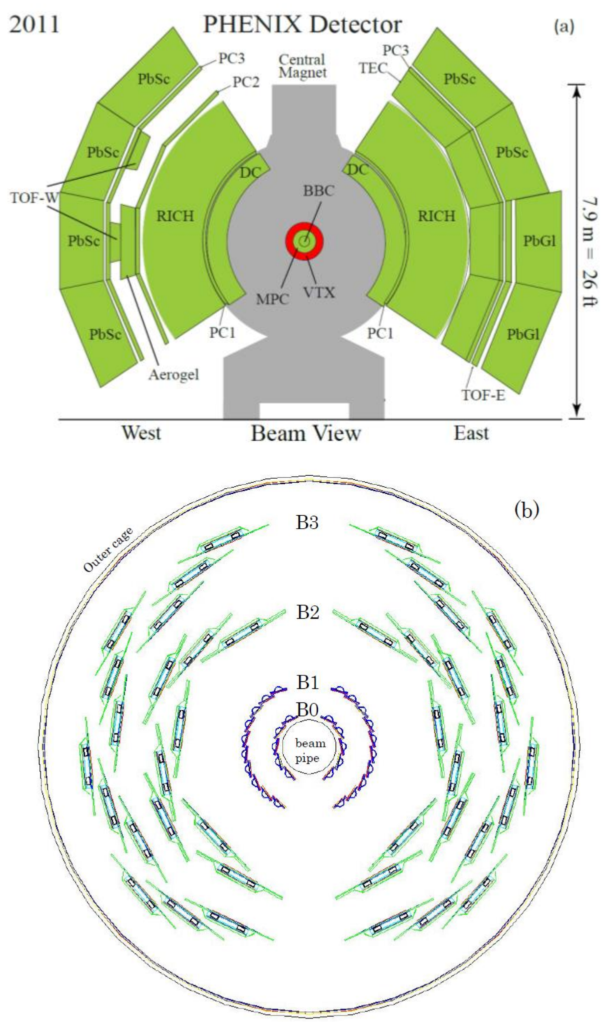
Summary and Outlook

- Using the VTX PHENIX has been able to measure separated bottom and charm in both p+p and Au+Au systems.
- Observed that in central Au+Au collisions bottom electrons are less suppressed than charm electrons at ~3 GeV/c
  - Implies mass dependence to energy loss within the QGP
- B-fraction in central Au+Au collisions implies strong coupling within the QGP, and is consistent with DGLV which has both radiative and collisional energy loss.
- B-fraction in p+p collisions are consistent with QCD production calculations, seen through comparison with FONLL

- Upon the finalization of the 2014 Au+Au result, PHENIX will now be able to calculate a full R_{AA} over the region of 1-9 GeV/c in electron p_T for separated bottom and charm.

Backups

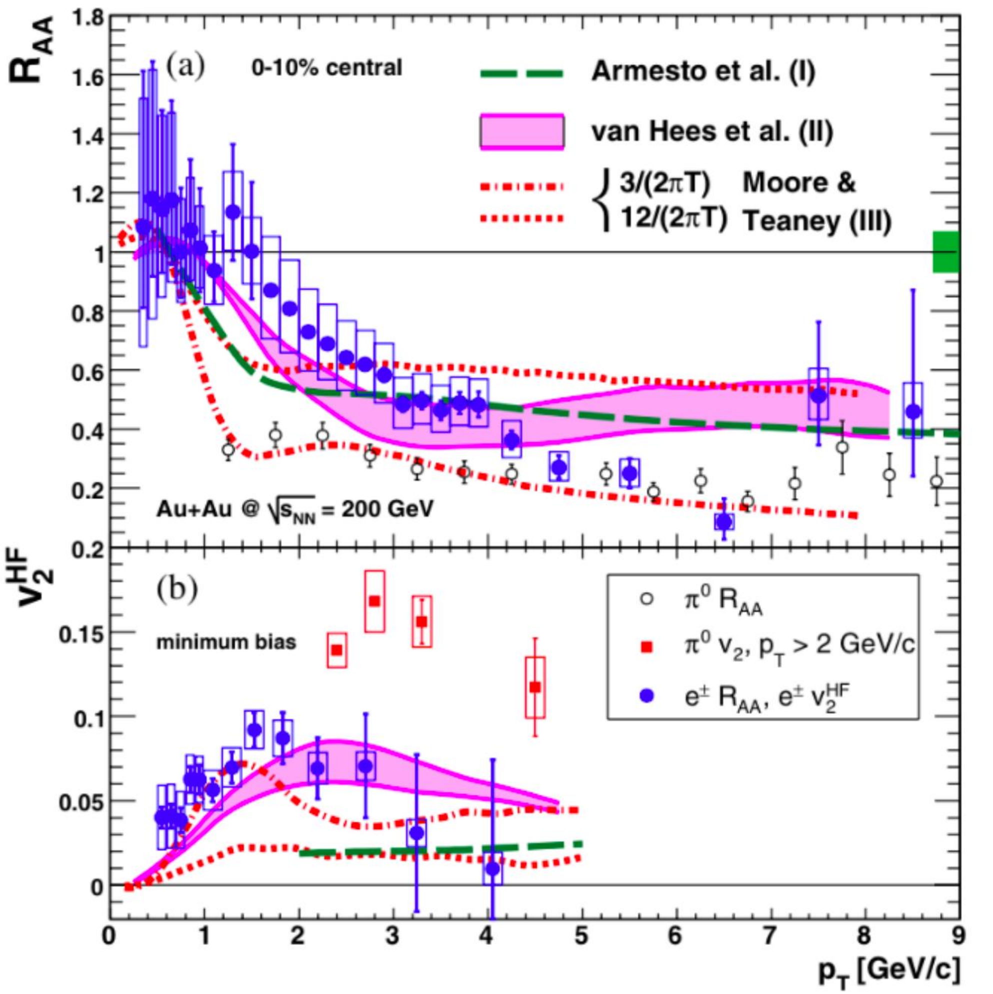
PHENIX Silicon Vertex Detector (VTX)



- For the 2011 run the VTX was added to the PHENIX Detector
  - The VTX is a silicon vertex detector, that allows for precise collision vertex determination, and particle tracking.
- VTX has 4 layers between 2.6 and 16.7 cm.
  - Inner two layers are silicon pixels with 14.4 μm resolution
  - Outer two layers are silicon strips with 23 μm resolution

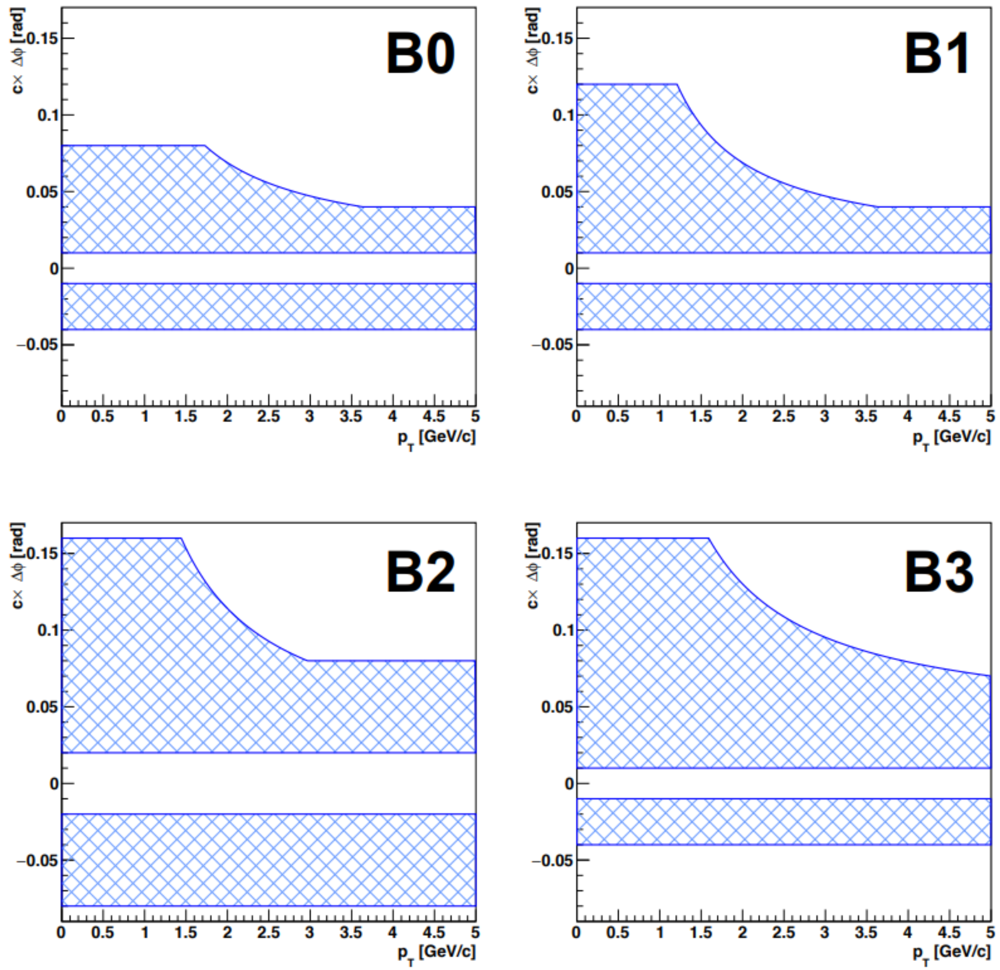
Inclusive Heavy Flavor

It was observed in PHENIX that inclusive heavy flavor experiences similar suppression to light quarks at high p_T and significant flow.



Isolation Cut Windows p+p

In order to reduce contributions from photonic background a p_T dependent isolation cut was applied in each layer of the VTX.



Reducing Photonic Background

Principle contributor to the background are photonic electrons.

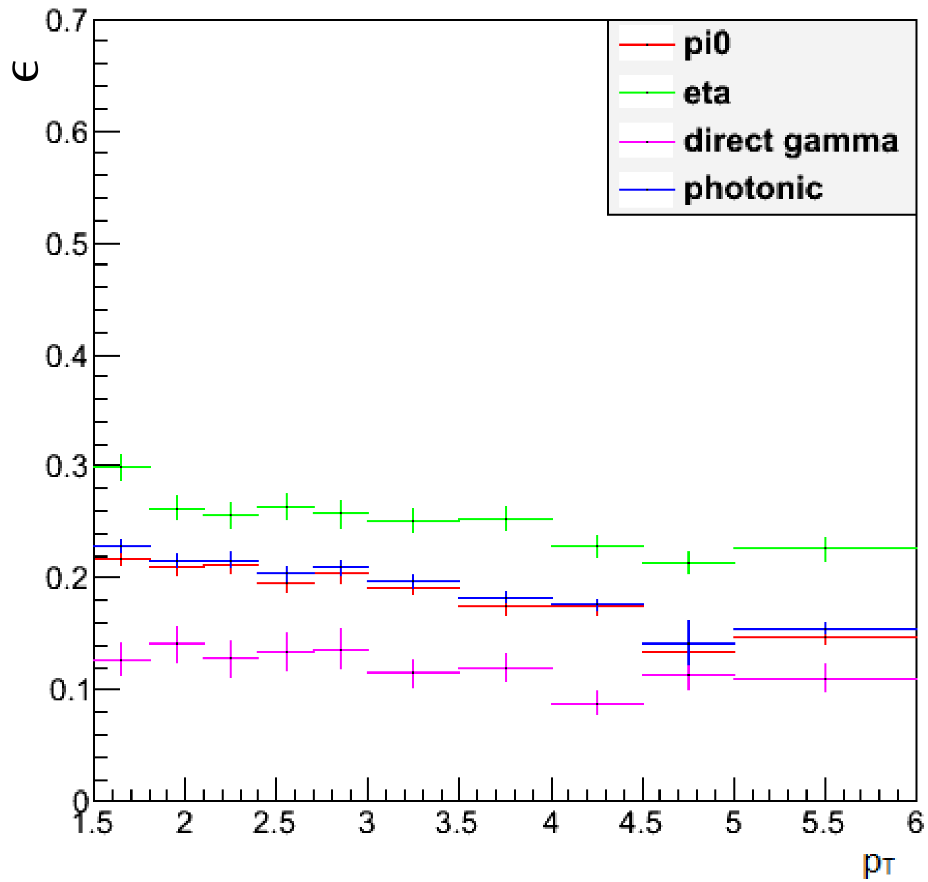
Survival rate determined in simulations

Use a p_T dependent isolation cut in the VTX to reduce Conversions and dalitz electrons

- Reduction in conversions of approximately 88% in p+p
- Total reduction in photonic background by approximately 80% in p+p

Due to random association the isolation cut reduces non-photonic electrons by approximately 9% in p+p

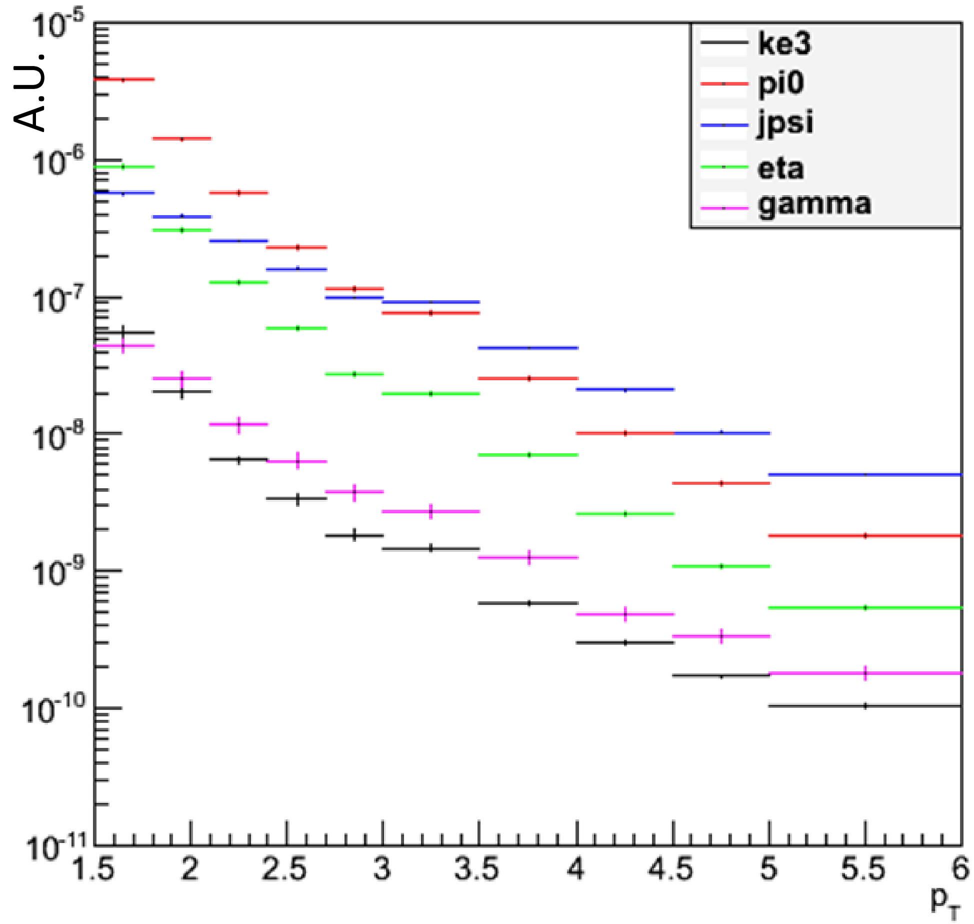
$\epsilon \equiv$ survival rate of isolation cut



Relative Contributions

Relative Contributions to background determined using electron cocktail

Generated from simulations in combination with published parent hadron yields

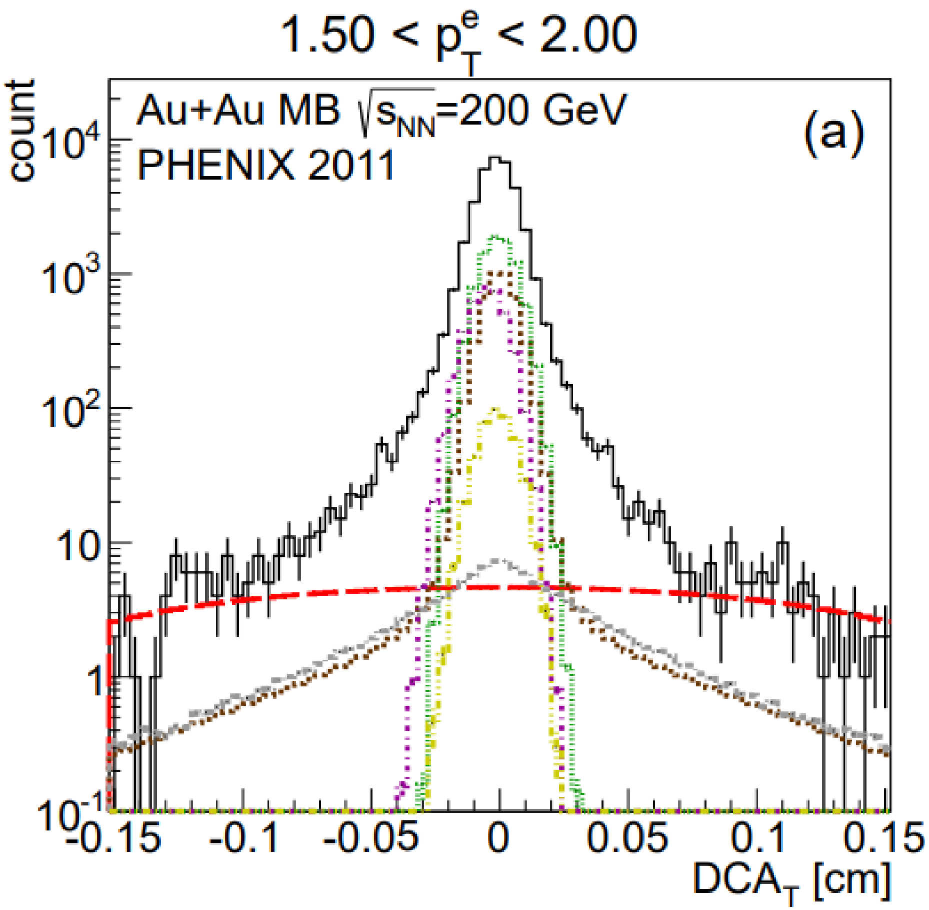


Estimating and Modeling High Multiplicity Random Background

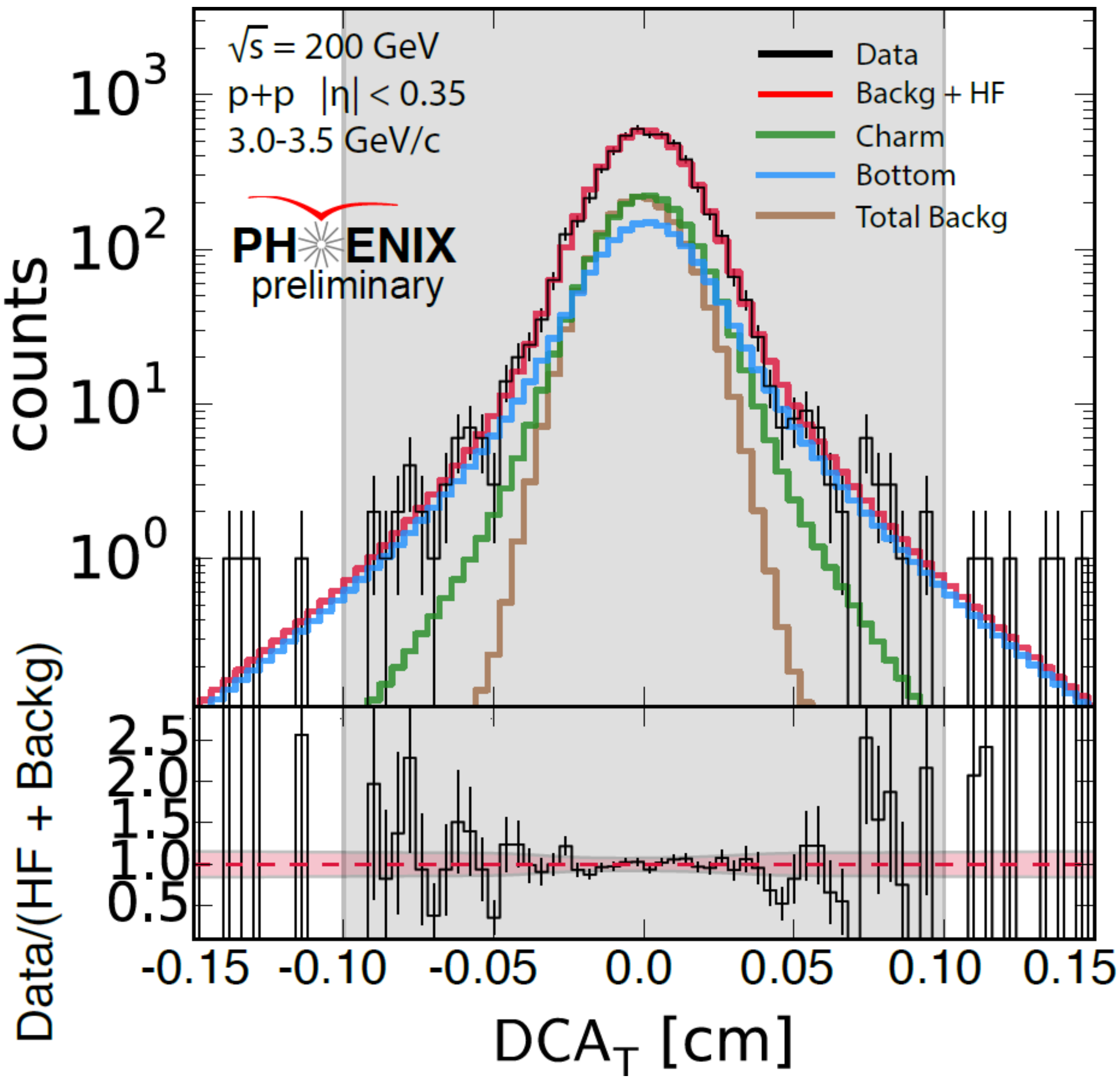
Due to high occupancy of VTX in Au+Au wrong VTX hits are occasionally picked up by tracking software

Results in distorted dca measurement.

- Modeled in 2011 Au+Au using a sideband method tuned through event embedding
- Modeled in 2014 Au+Au using track rotations



dca_T Refold p+p: intermediate p_T



c->e:
Monte Carlo shape
Normalization from unfolding

b->e:
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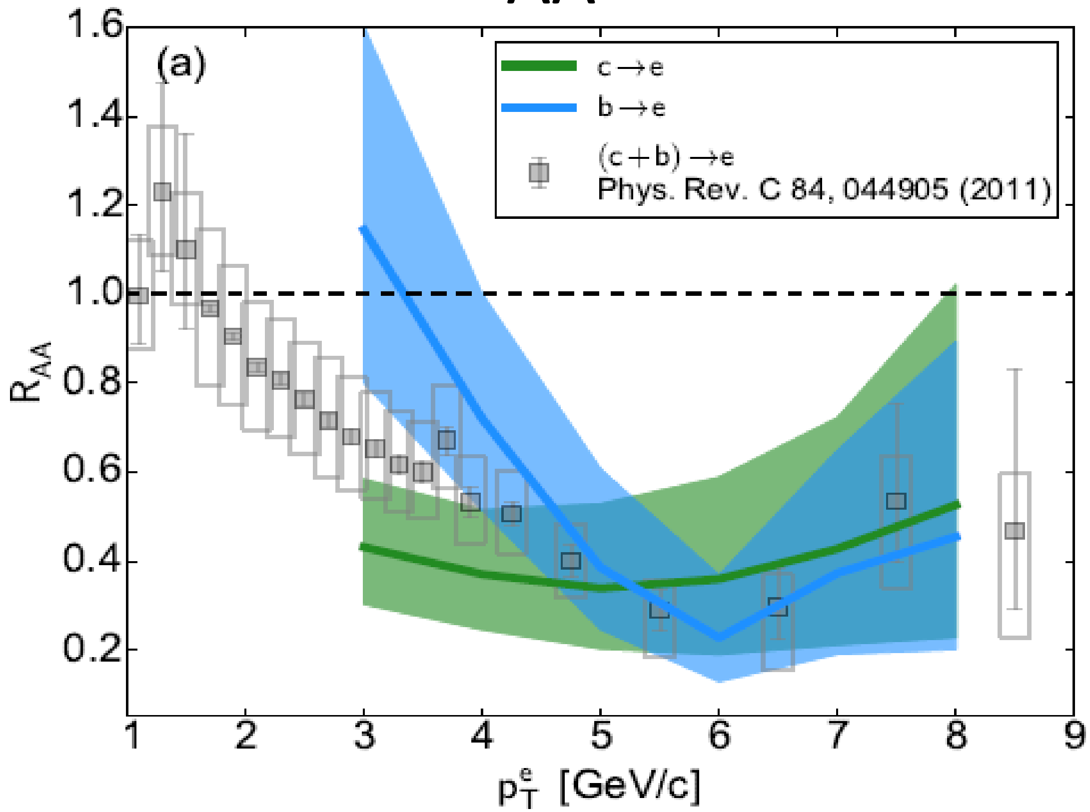
The charm and bottom yield predicted by the unfolding is consistent with electron measured DCA_T distributions.

2011 Au+Au R_{AA} Measurement



PHENIX first data set with VTX was the Au+Au collisions in 2011

Nuclear modification factor R_{AA} calculated using STAR e-h correlation measurement for p+p baseline

Indication that charm observes greater suppression at 3 GeV than bottom

2014 Au+Au b-fraction

Parallel effort to do a similar analysis with the 2014 Au+Au

Using 1/3rd of the 2014 Au+Au data set a separation analysis was done.

Observe agreement in the Minimum Bias b-fraction result with published result from the 2011 data set