Dielectron Spectrum in $d + Au$ Collsions at $\sqrt{s_{NN}}$=200 GeV

Deepali Sharma

PHENIX Collaboration

Stony Brook University

6th December, 2012

Stony Brook University

PHENIX

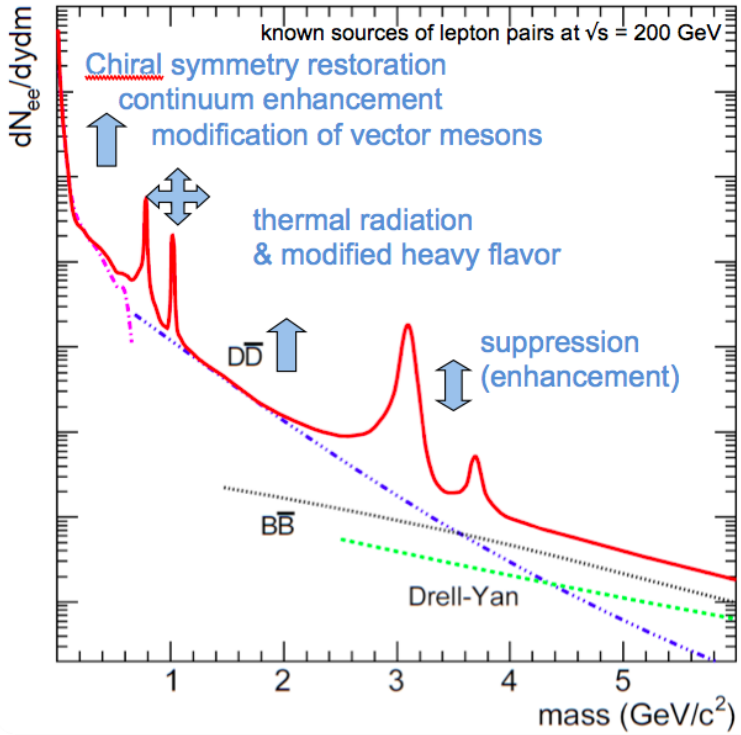
Outline

Dilepton mass spectrum

Diverse physics signal

- Sources "long" after collision:
  - π^0, η, ω Dalitz decays
  - $\rho, \omega, \phi, J/\psi, \psi'$ decays
- Early in collision (hard probes):
  - Heavy flavor production
  - Drell Yan, direct radiation
- Baseline from $p + p$
- Thermal (black body) radiation:
  - in dileptons and photons
  - temperature evolution
- Medium modifications of mesons
  - $\pi^+\pi^- \rightarrow \rho \rightarrow e^+e^-$
  - Chiral symmetry restoration
- Medium effects on hard probes
  - Heavy flavor energy loss

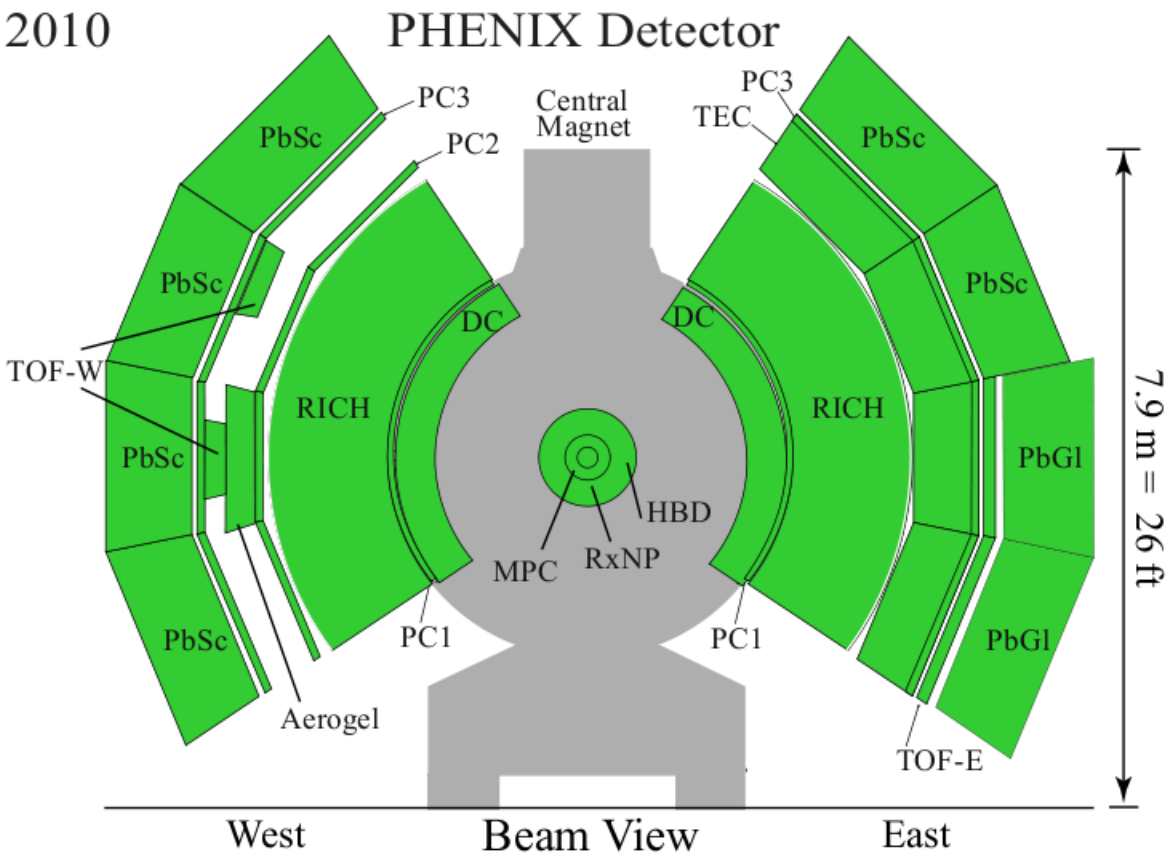
Modifications to the dilepton spectrum due to the QCD phase transition



The PHENIX Detector

PHENIX Experimental set-up

PHENIX Central arms Acceptance: -0.35$<\eta<$0.35, 2$\times$90° in φ



Measure rare probes in different collision systems: **p+p, d+Au, Cu+Cu, Au+Au**

- Vertex: **BBC**
- Tracking: **DC/PC1**
- $p_e > 0.2$ GeV/c;

Electron identification based on:

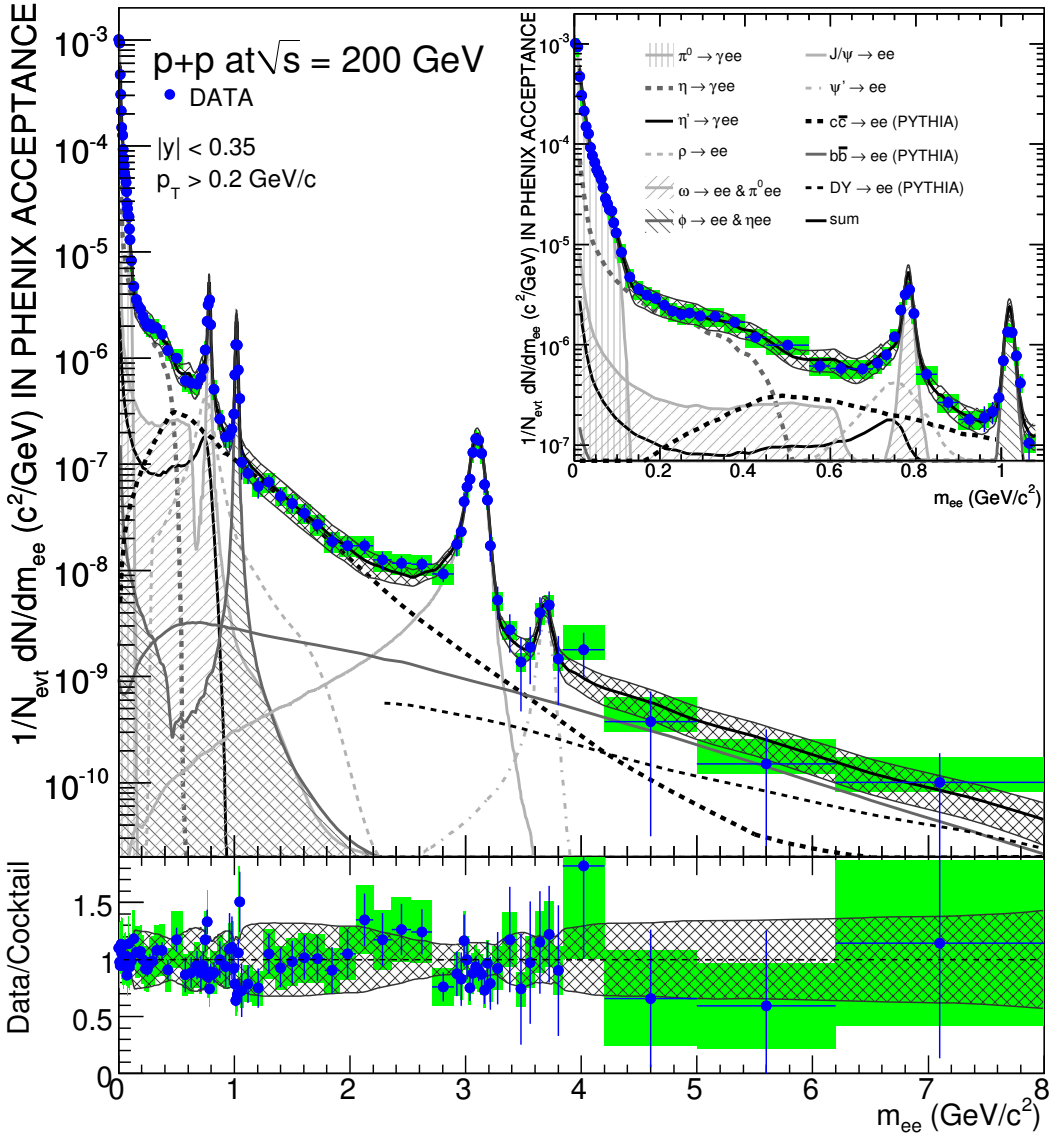
- **RICH** (Ring Imaging Čerenkov detector) (e/π rejection >1000)
- **EMCal** (Electromagnetic Calorimeter) (E-p matching, e/π rejection ~ 10)

Dielectrons in $p+p$ collisions

fundamental baseline for heavy-ion

- Inclusive mass spectrum of e^+e^- measured from $0 < m < 8$ GeV/c^2.
- Very well understood in terms of
  - hadron cocktail at low masses.
  - heavy Flavor + DY at high masses
- **Charm: integration after cocktail subtraction;**
  $\sigma_{c\bar{c}} = 544 \pm 39(stat) \pm 142(sys) \pm 200(model)\mu b$ (*consistent with PHENIX single electron measurement*)
- **Simultaneous fit of charm and bottom;**
  - $\sigma_{c\bar{c}} = 518 \pm 47(stat) \pm 135(sys) \pm 190(model)\mu b$
  - $\sigma_{b\bar{b}} = 3.9 \pm 2.4(stat) \pm^{3}_{2} (sys)\mu b$

PLB 670, 313 (2009)

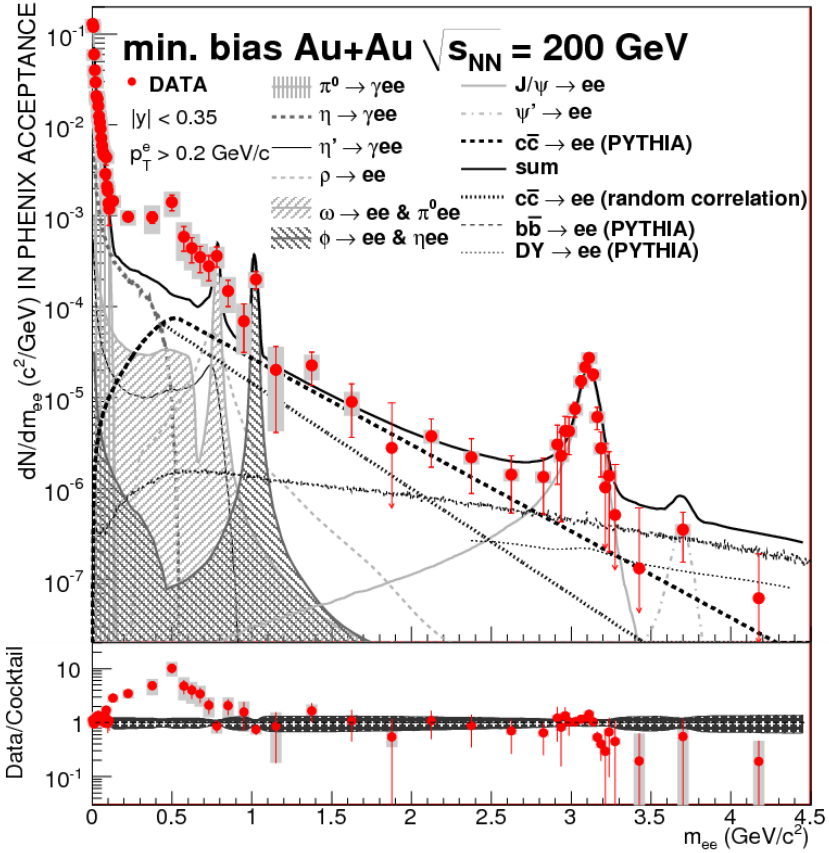


Heavy Ion Dielectrons

Au + Au and Cu + Cu

Au + Au (PRC 79, 81 034911(2010))

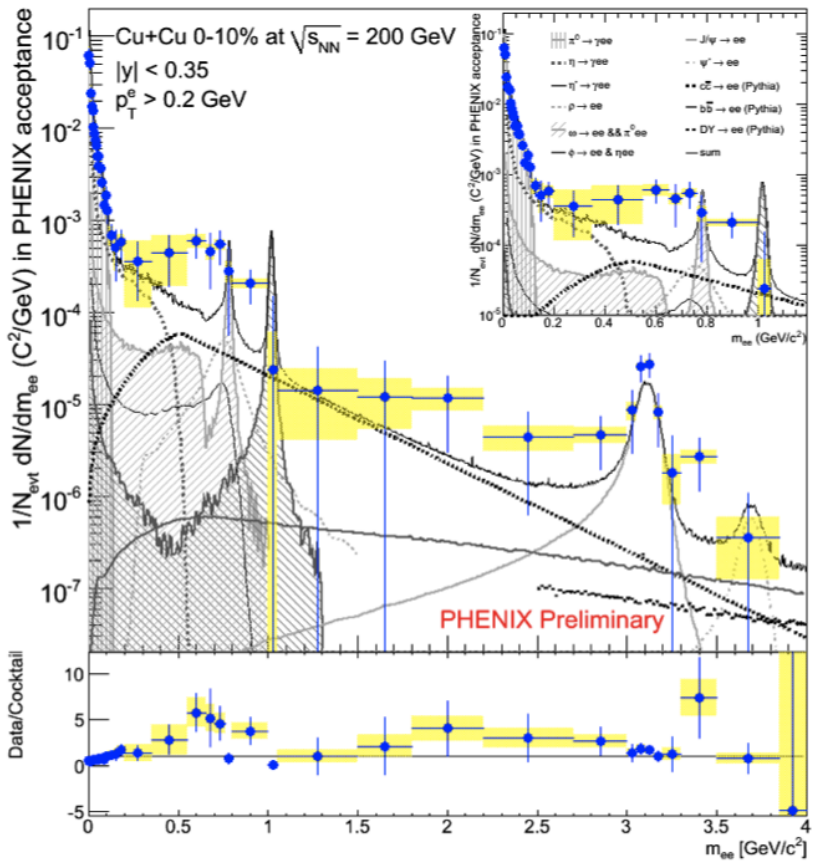
N_{part} = 109



- Minimum Bias *Au + Au* compared to Cocktail.
- Striking enhancement in LMR (150 - 750 MeV/c^2).
- No enhancement in the IMR !!

Cu + Cu (0-10%)

N_{part} = 98



- Central *Cu + Cu* compared to Cocktail.
- Some enhancement seen in LMR.
- Hints of enhancement in IMR ?

Stony Brook University

PHENIX

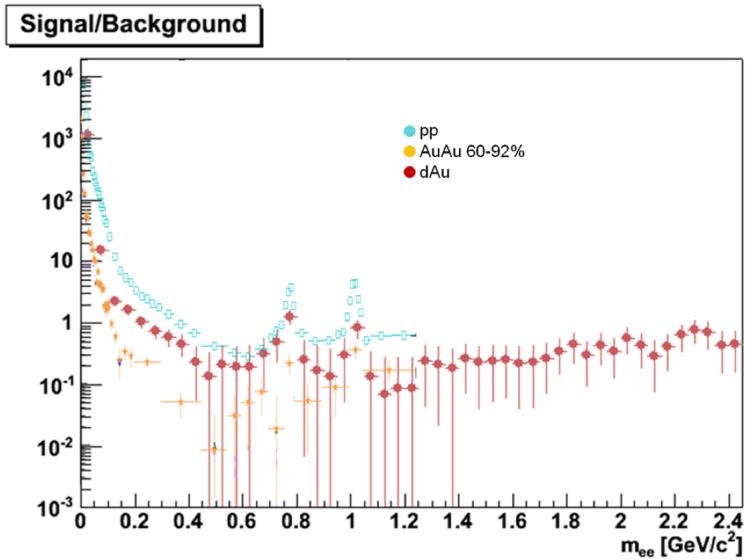
$d + Au$ Dielectron Spectrum

$d + Au$ Data Analysis Details

- Background Estimation
  - Like-sign technique is used for the signal extraction, after the like-sign pairs are corrected for the acceptance difference for $++$ and $--$ pairs. The relative accceptance correction α is derived from the mixed events and is defined as follows:

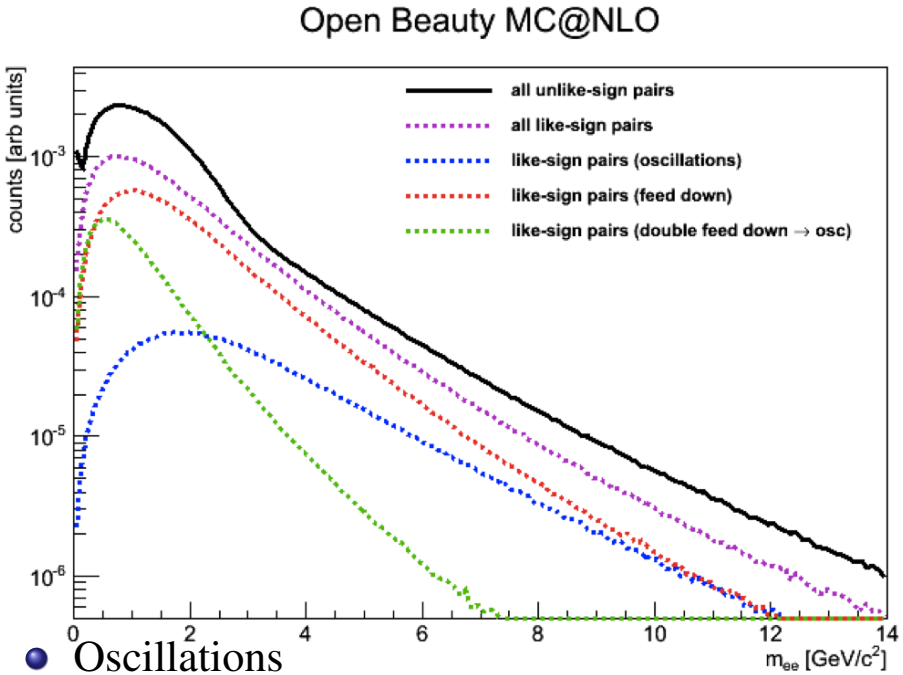
$$\alpha = \frac{BG_{+-}}{BG_{++} + BG_{--}}$$

- Signal to Background in $d + Au$

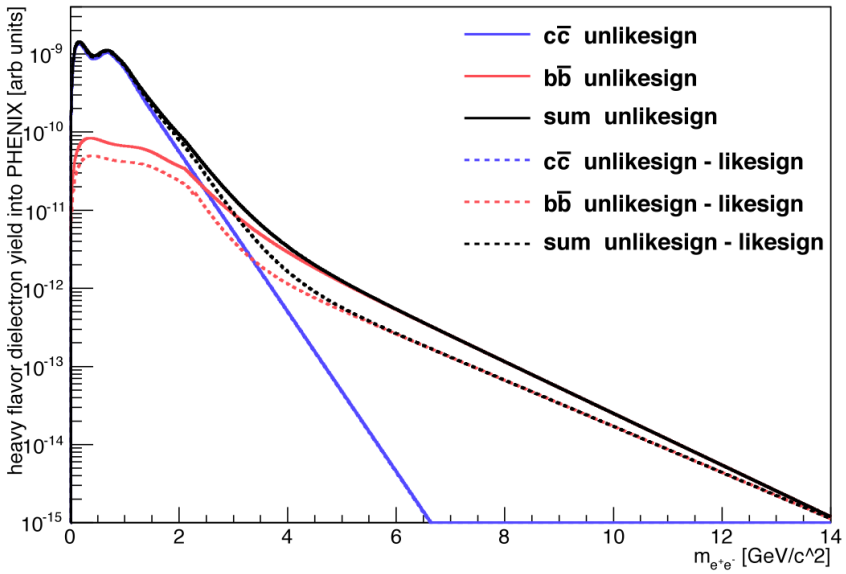


- Like-sign heavy quark correlations

Origin of Like-sign correlated pairs



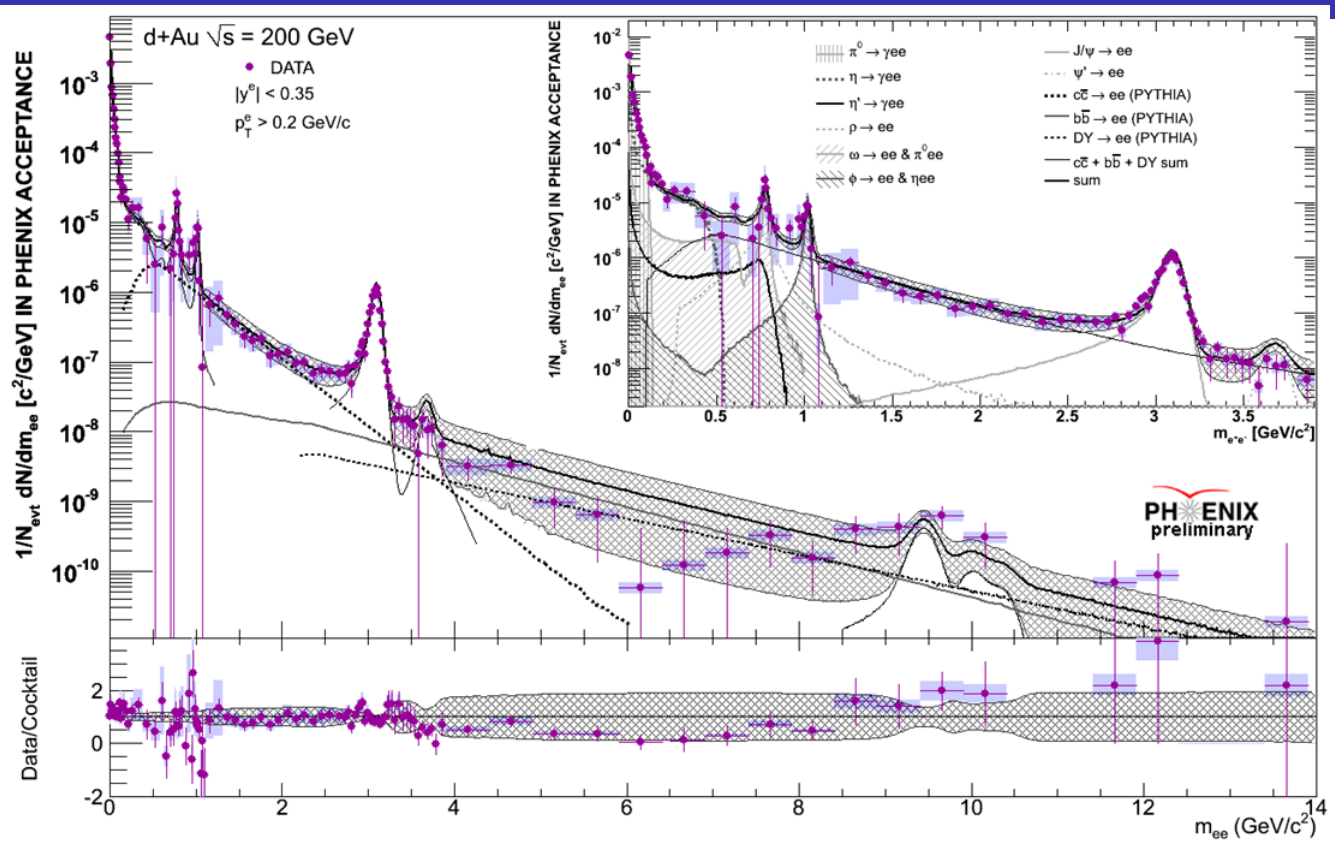
- Oscillations
  - $B^0\bar{B}^0$ mixing. This leads to $\sim 60\%$ unlike-sign pairs and $\sim 40\%$ like-sign pairs.
- Feed Down
  - BR for $B \to e \sim 10\%$, BR for $B \to D \sim 10\%$,
- Nearly half the bottom yield is like-sign!. However this is less extreme for charm ($<1\%$ within PHENIX acceptance).



- So if one uses like-sign subtraction in data, this should be accounted for in the simulations also.
- makes an appreciable difference in mass spectrum.

Minimum Bias $d + Au$ Dielectrons

PYTHIA for heavy flavor

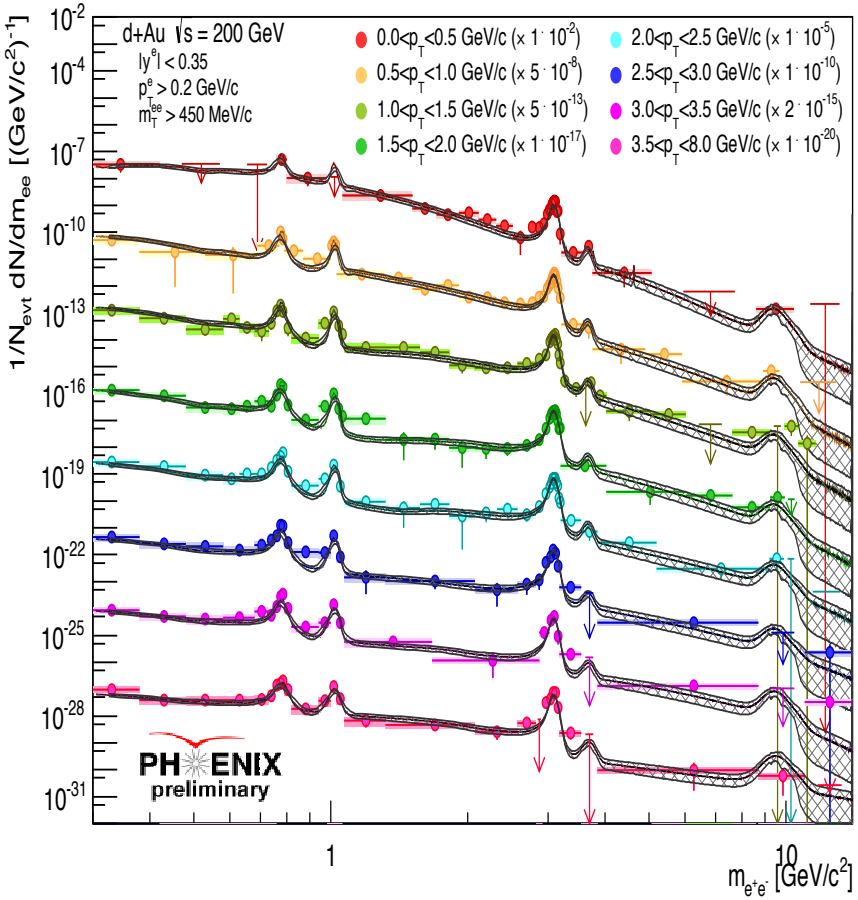


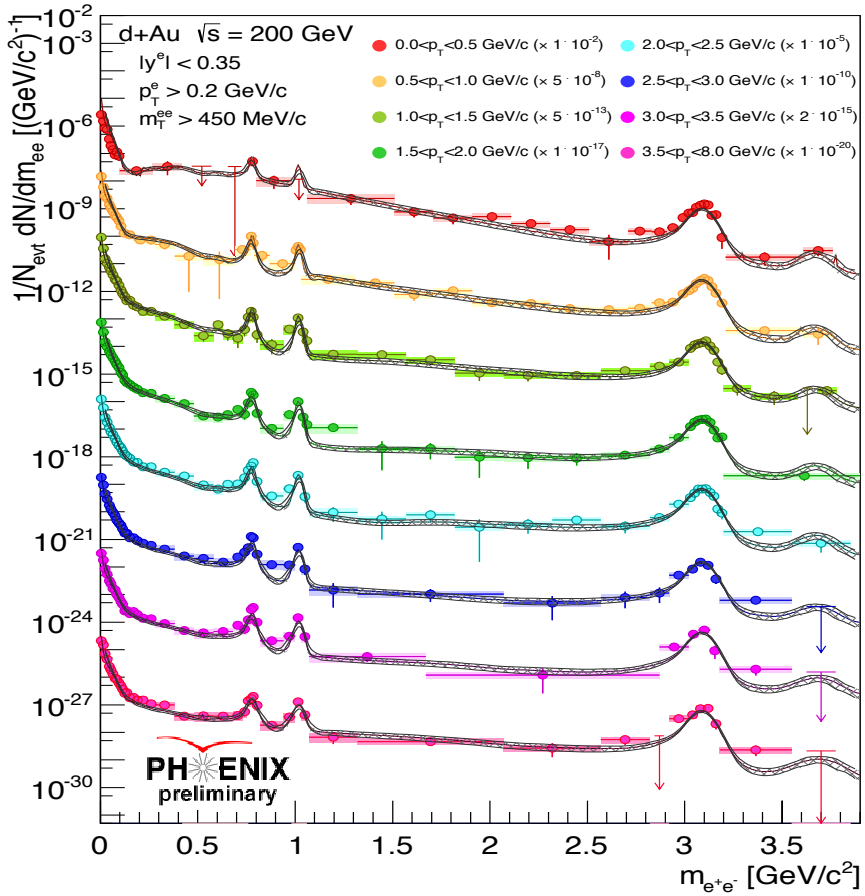
- Consistent with the expected cocktail of known sources
- Large mass range coverage $0 - 14\ GeV/c^2$.
- Open heavy flavor is N_{coll} scaled PYTHIA
- σ_{cc} and σ_{bb} consistent with $p + p$
  -like-sign heavy quark correlations not taken into account !

Stony Brook University

PHENIX

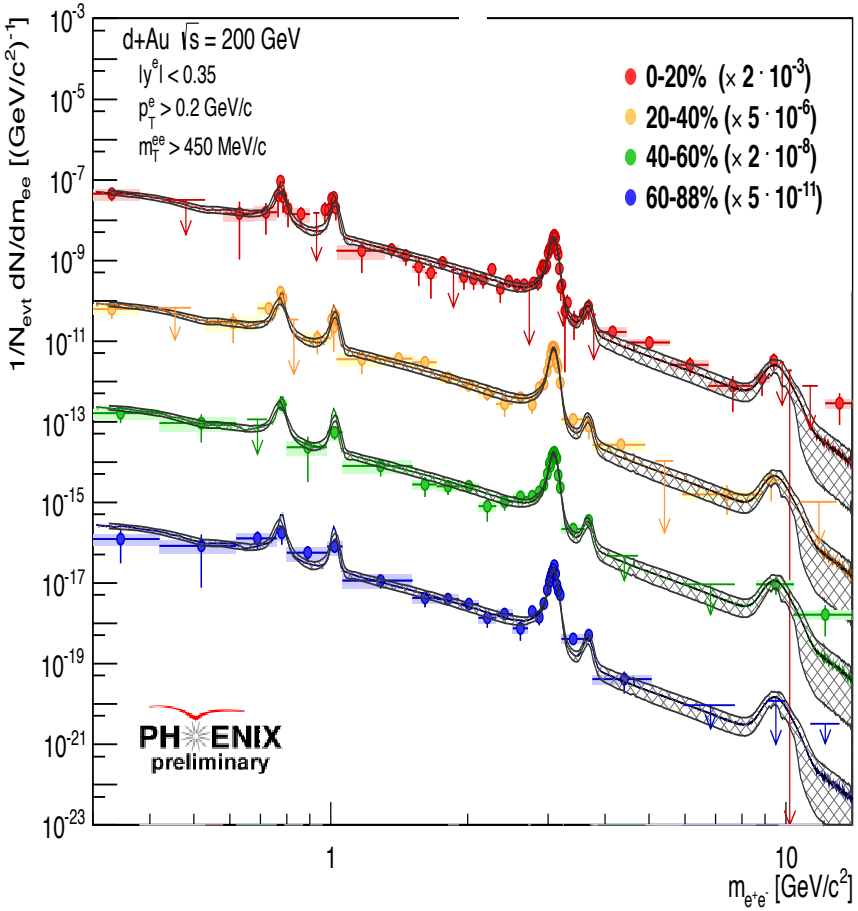
Transverse Momentum Dependence of $d + Au$ Dielectron Spectrum

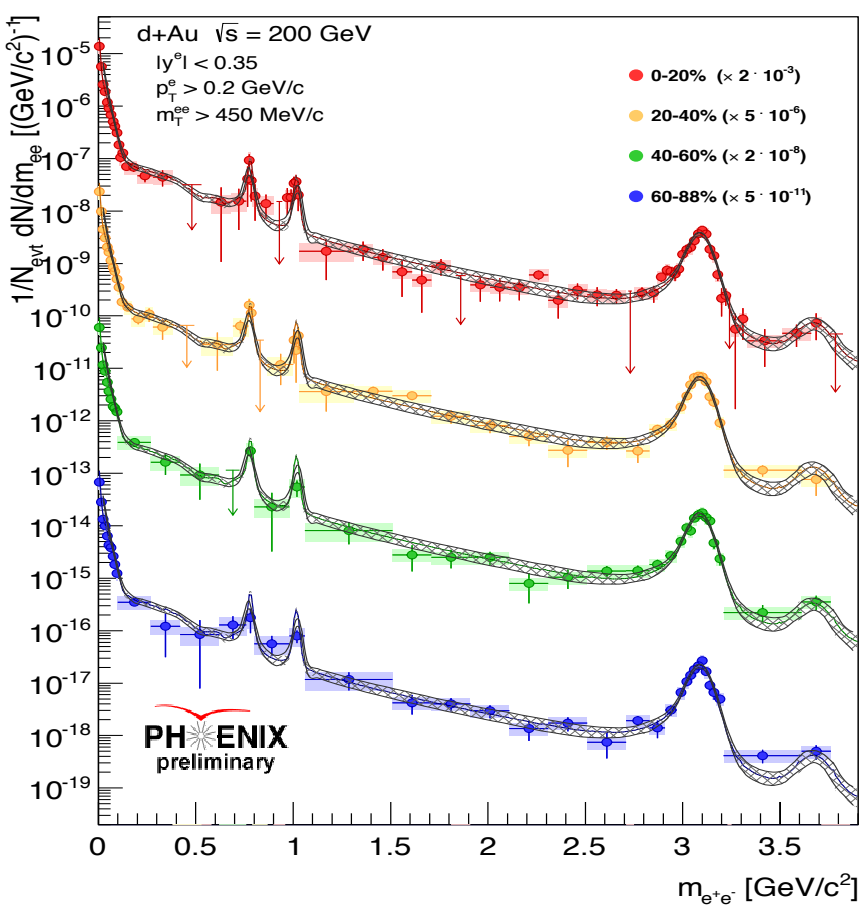




- Very good agreement with the cocktail over the entire p_T range, demonstrates a good control over the cocktail.

Centrality Dependence of $d + Au$ Dielectron Spectrum



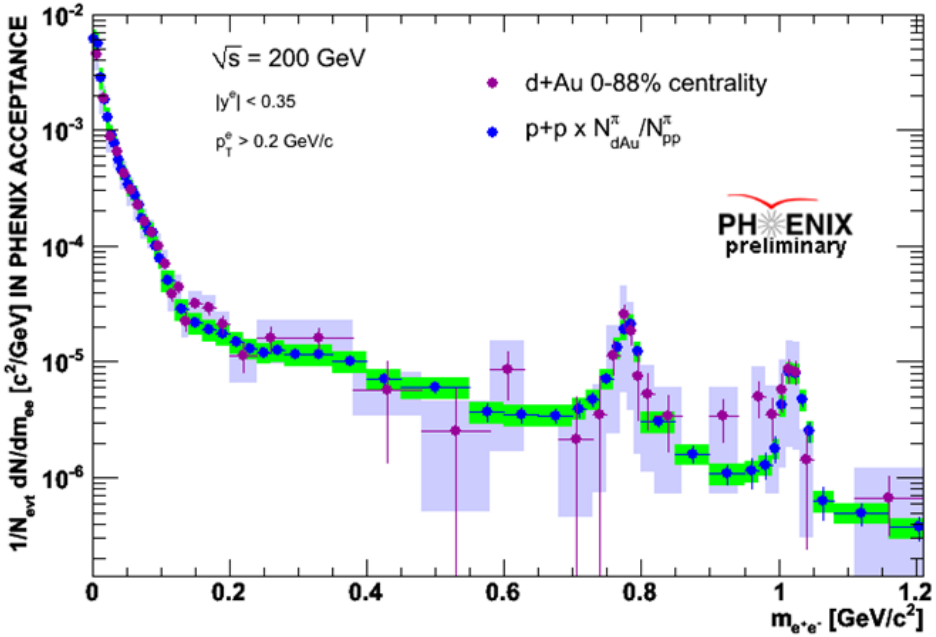


- For a given centrality the open heavy flavor is scaled by N_{coll}
- The centrality dependence is also very well described by the cocktail.

Comparison of $d + Au$ to Scaled $p + p$

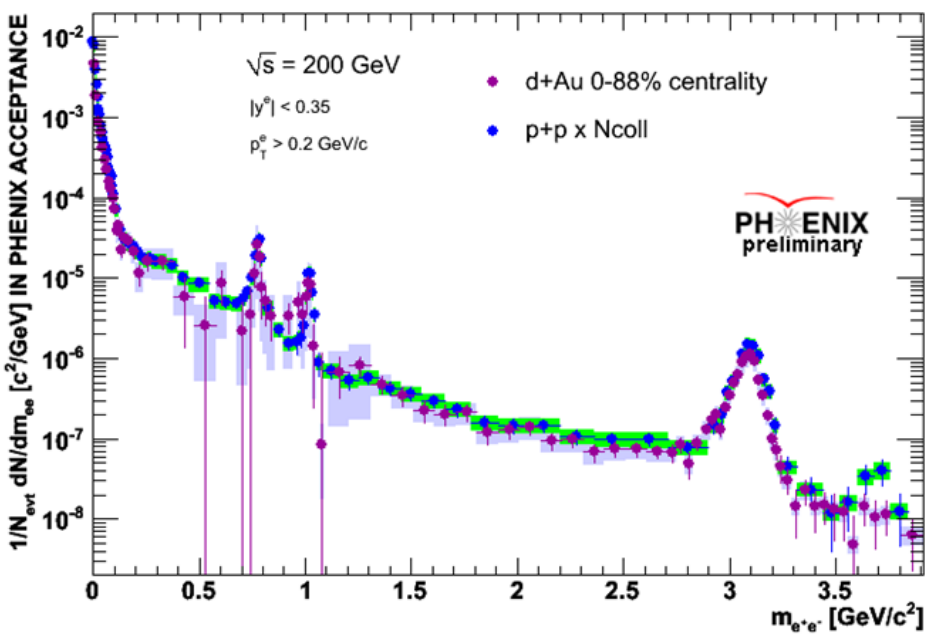
Comparison of $d + Au$ to scaled $p + p$ data

Low mass region



- No excess in LMR.
- $d + Au$ consistent with scaled $p + p$.

Intermediate mass region

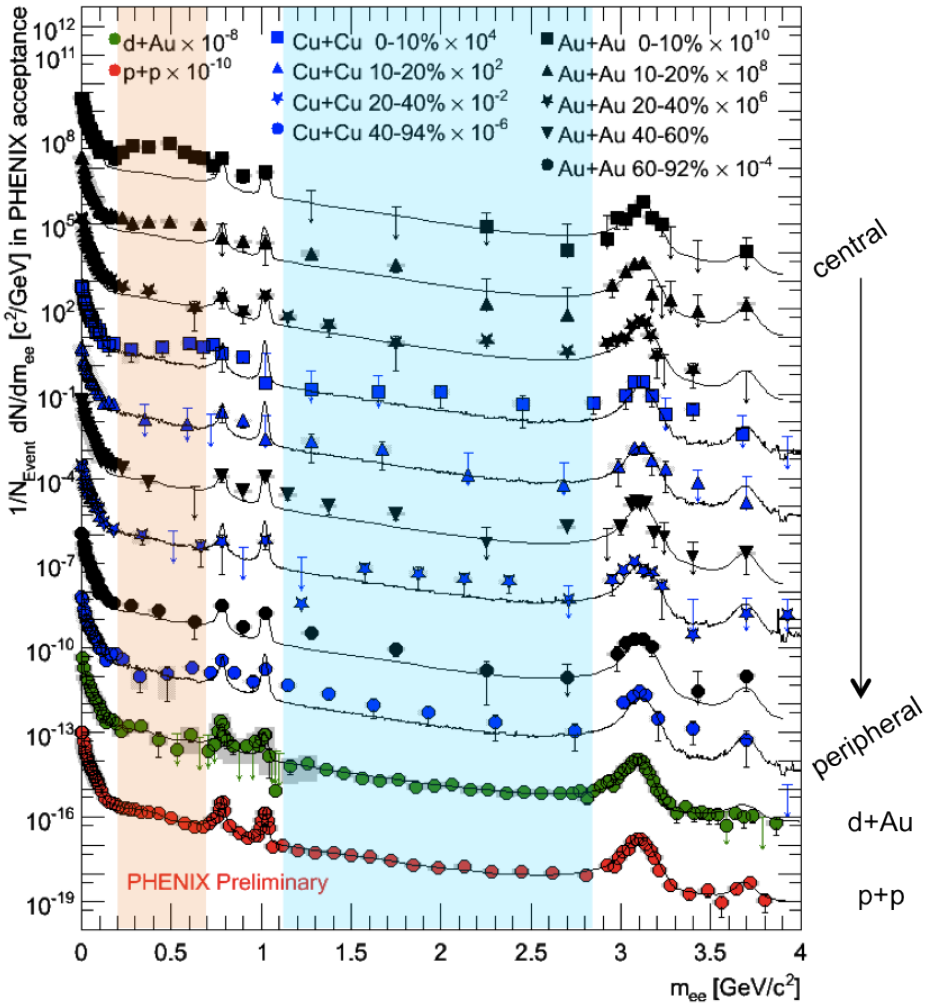


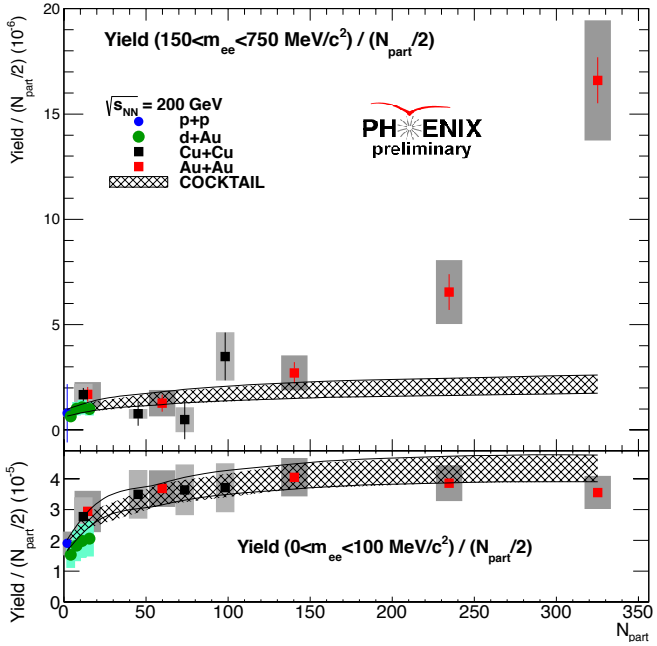
- No excess in IMR.
- $d + Au$ consistent with scaled $p + p$.
- J/ψ suprresion ~ 0.75 observed.

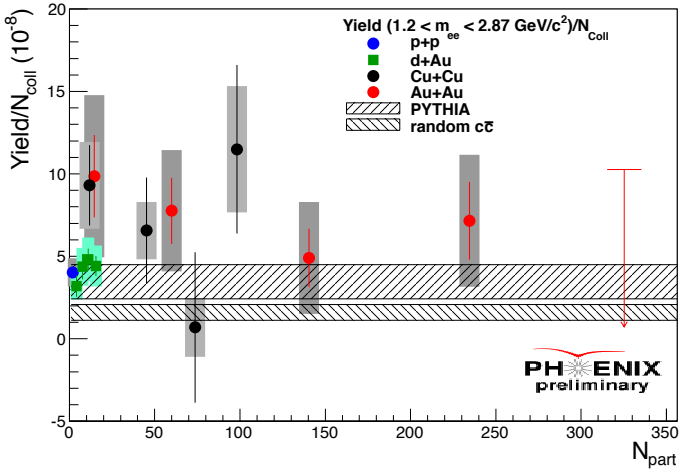
Comparison of $d + Au$ to $Au + Au$ and $Cu + Cu$

Centrality Dependence of Yields across Different Systems

ordered by N_{coll}

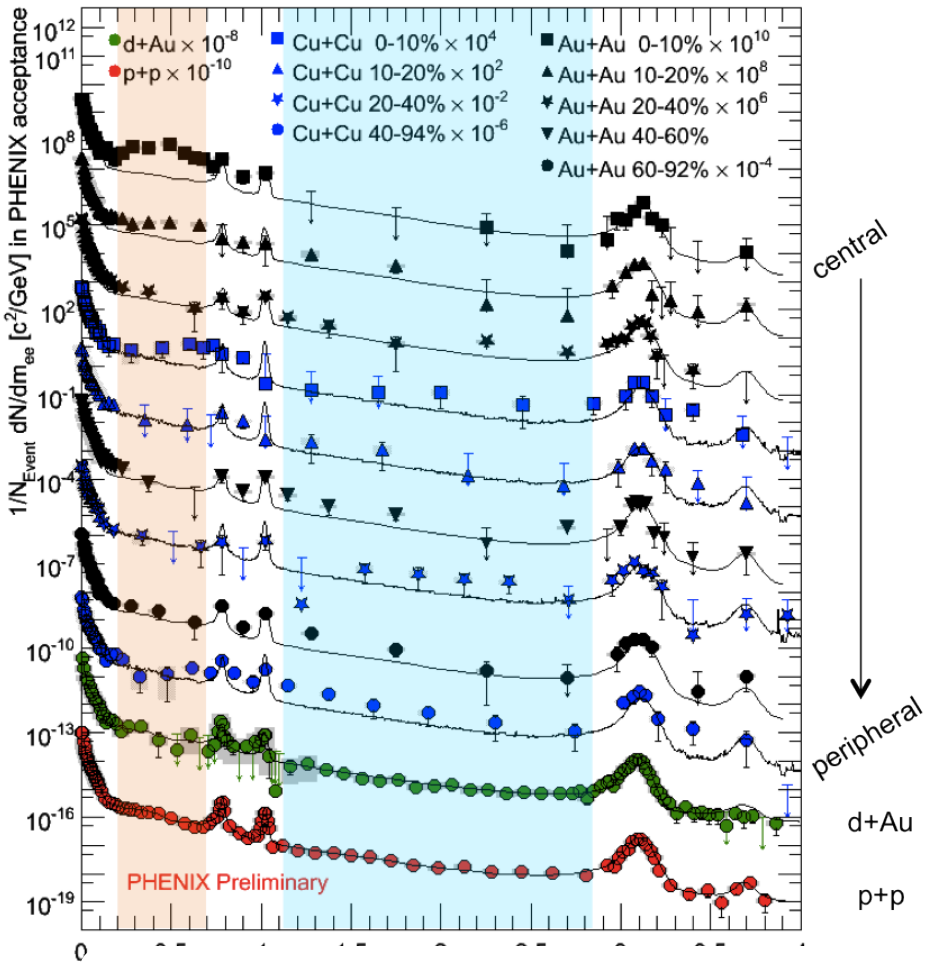


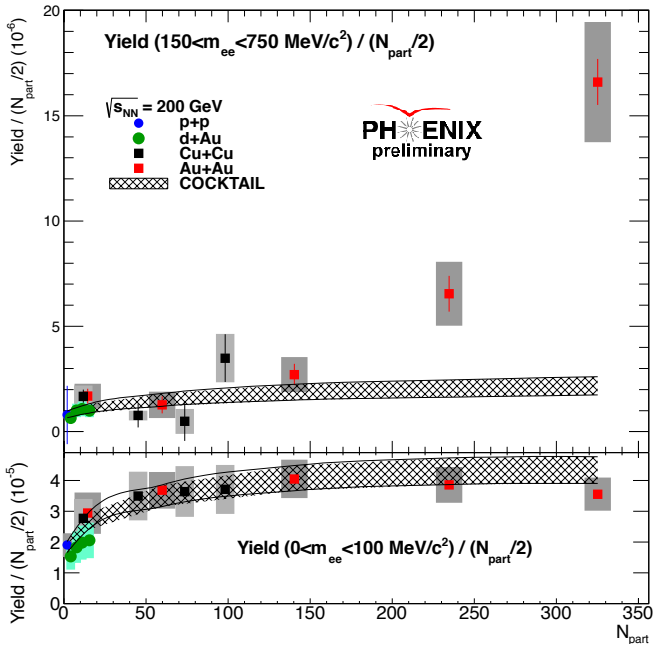


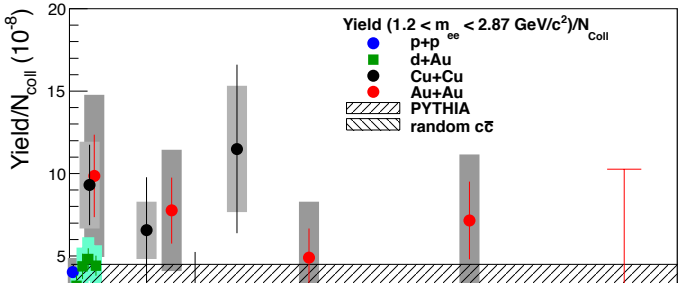


Centrality Dependence of Yields across Different Systems

ordered by N_{coll}





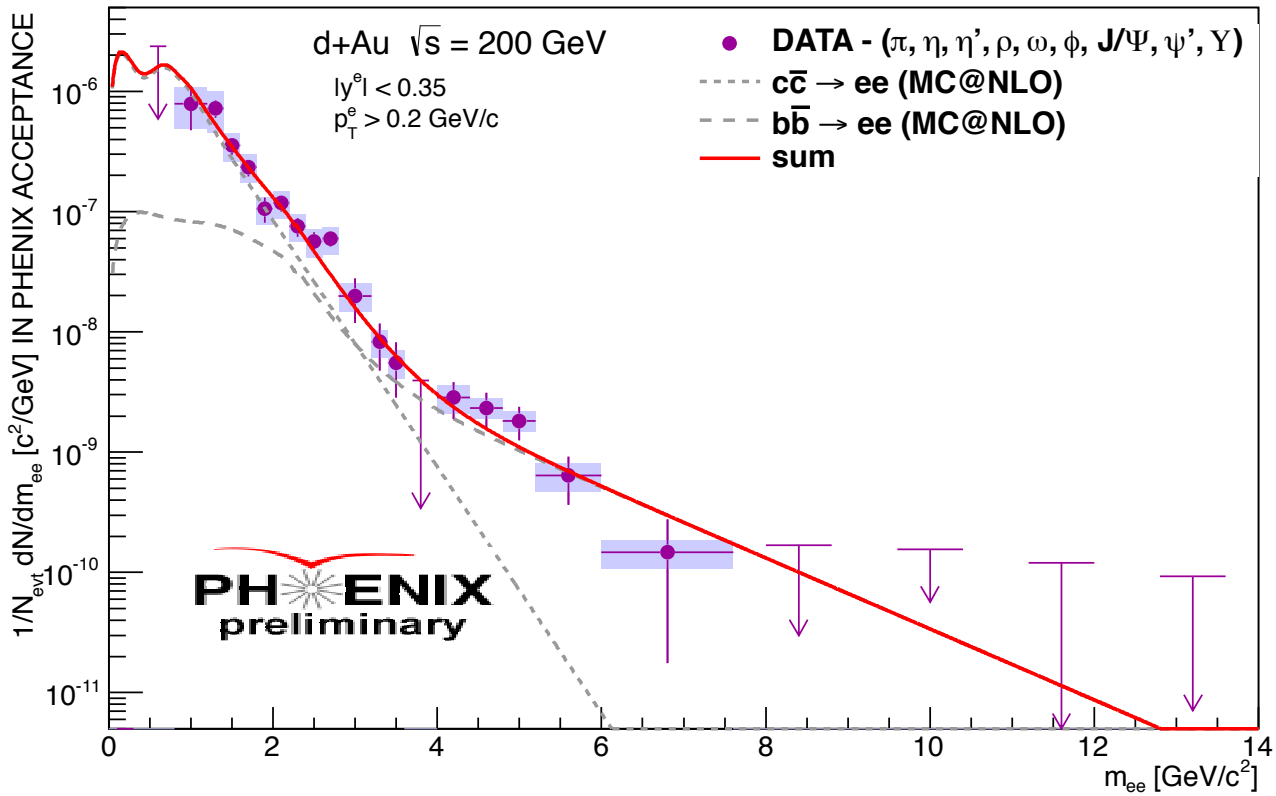


- Enhancement in low mass region is a strong function of centrality.
- Enhancement seen in both $Cu + Cu$ and $Au + Au$ systems.
- No excess is seen in $d + Au$

Heavy Flavor Extraction using the $d + Au$ data

Mass Spectrum of Heavy Flavor in $d + Au$

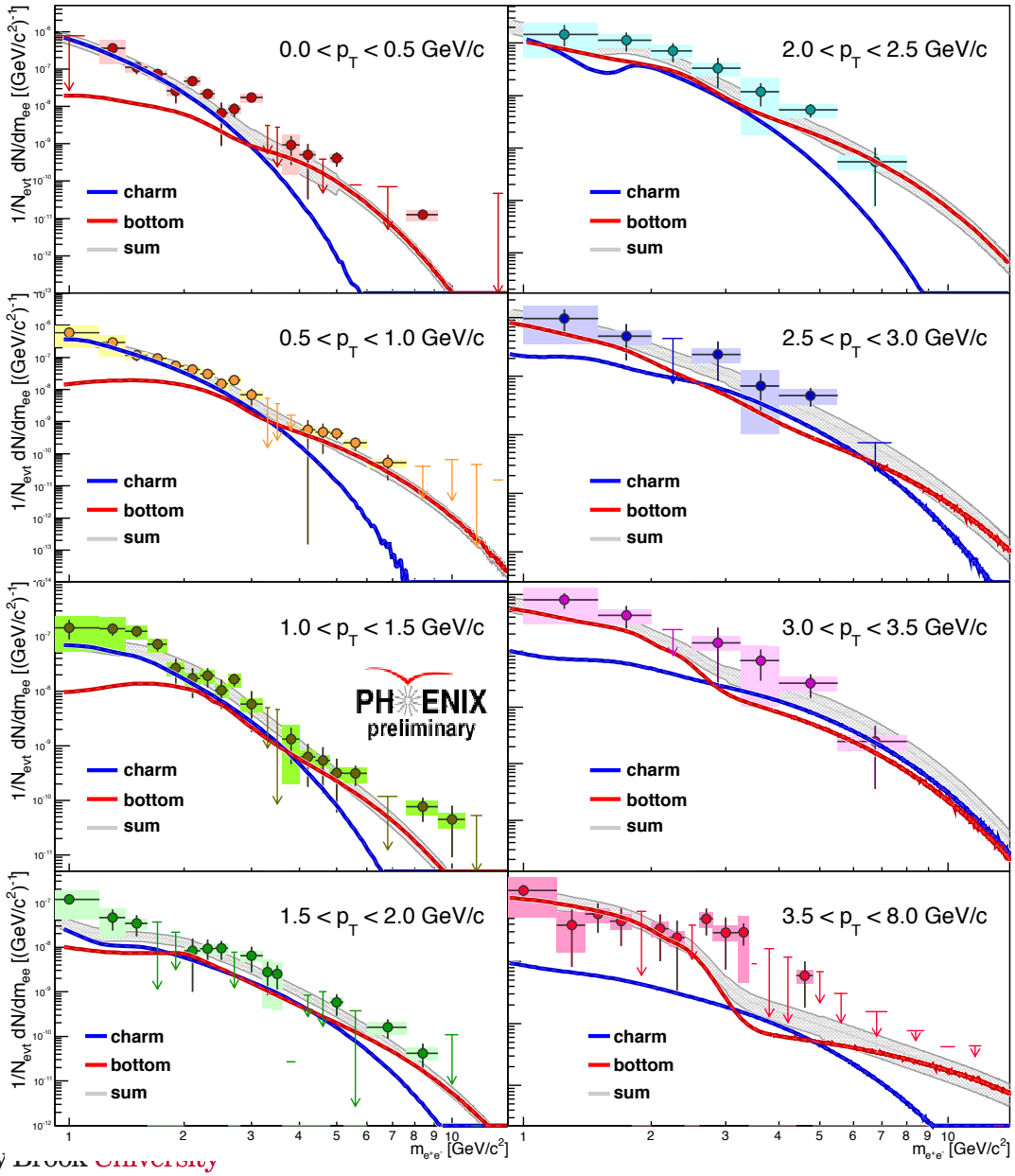
MC@NLO



- All hadronic components subtracted from the data
- Like-sign HQ correlations subtracted in simulation.
- MC@NLO normalization fit to data 2D differentially (mass vs p_T).
- Extrapolated heavy flavor cross-sections:
  - $\sigma_{cc} = 711 \pm 62$ (stat) ± 183 (syst) ± 80 (model) μb.
  - $\sigma_{bb} = 4.46 \pm 0.70$ (stat) ± 1.08 (syst) ± 0.22 (model) μb.

p_T Dependence of Heavy Flavor Spectrum

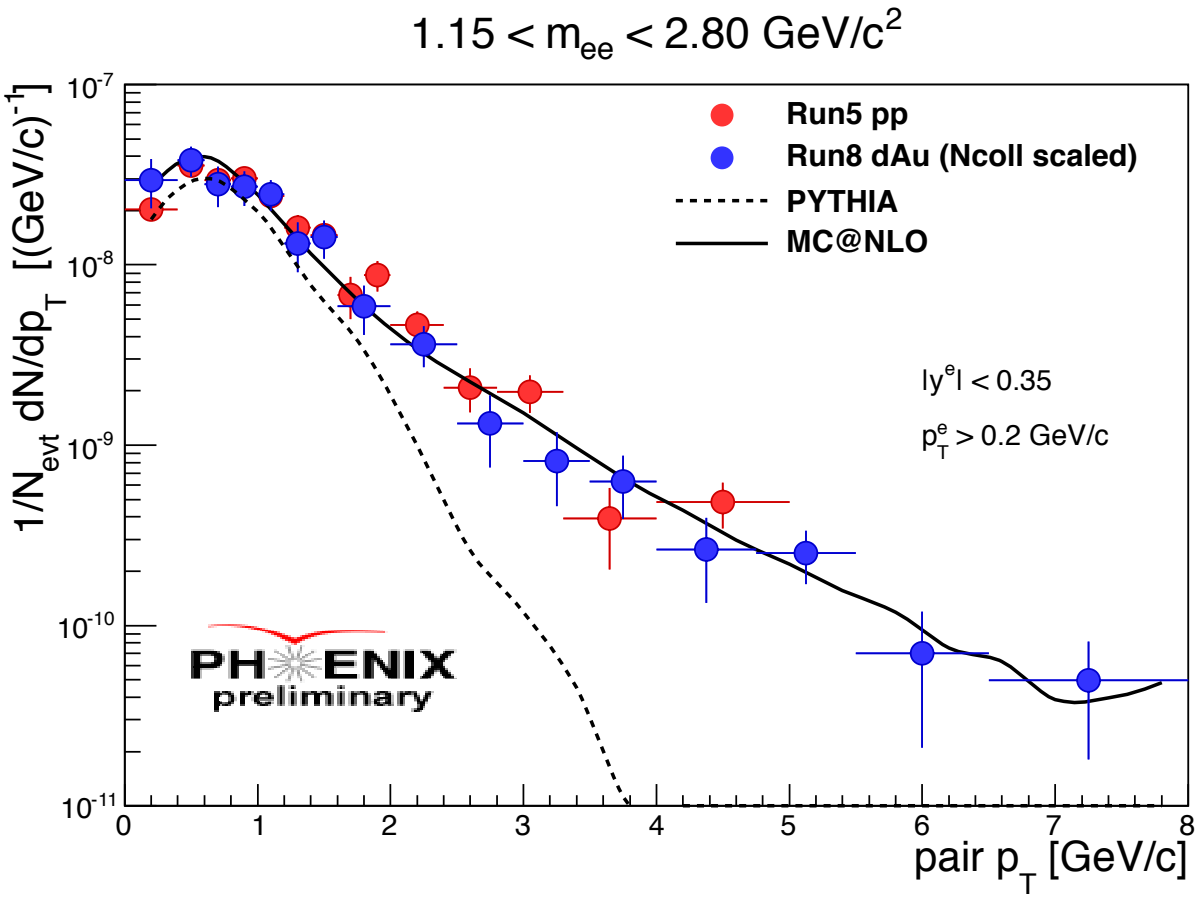
MC@NLO calculations



- MC@NLO predicts a complex interplay between charm and beauty
- Low p_T:
  - IMR -charm
  - HMR -beauty
- Intermediate p_T:
  - charm and beauty similar
- High p_T:
  - IMR -beauty
  - HMR -charm
- MC@NLO predicts the data !!
- A powerful confirmation of NLO data.

LO vs NLO

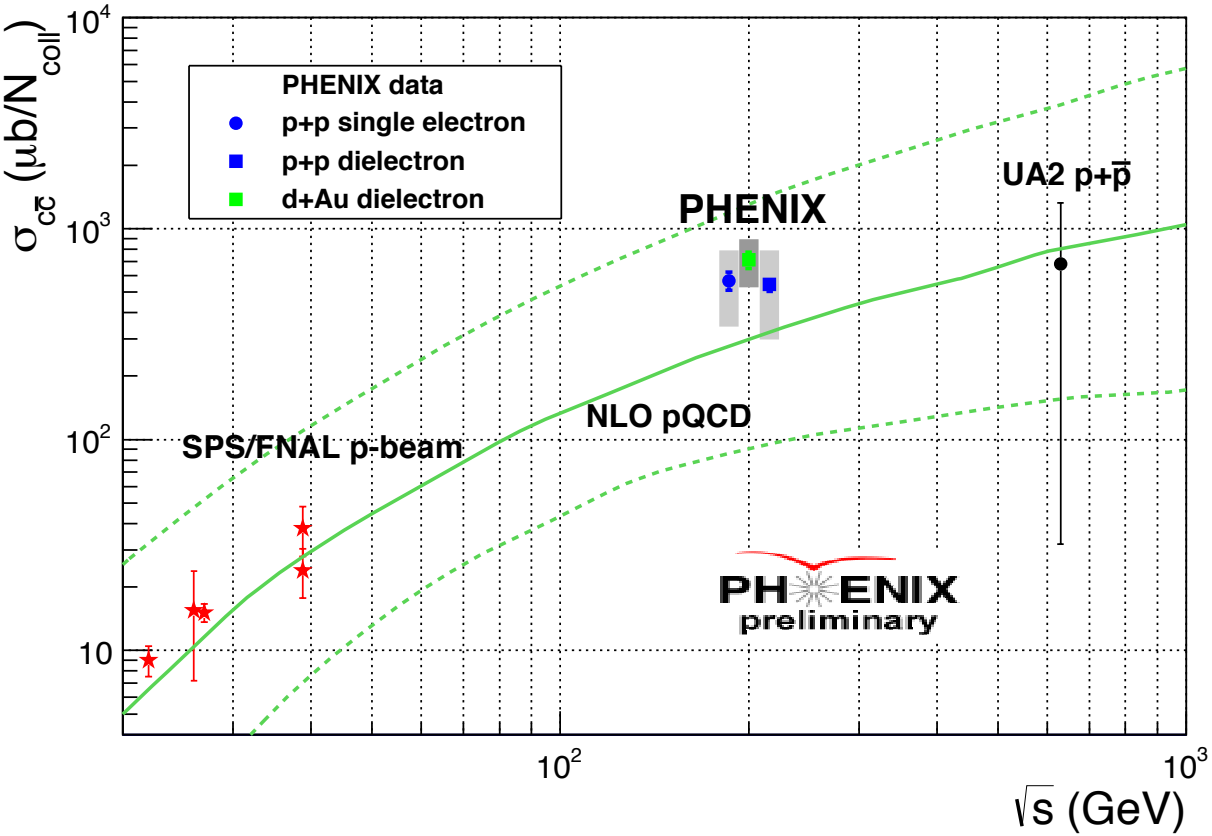
PYTHIA vs MC@NLO



- p_T dependence of integrated yield in IMR.
- PYTHIA normalized by fitting to $p + p$ data and MC@NLO normalized uding the $d + Au$ data.
- MC@NLO does a better job of describing the data while PYTHIA underestimates the data above ~ 2 GeV/c.

Global Perspective

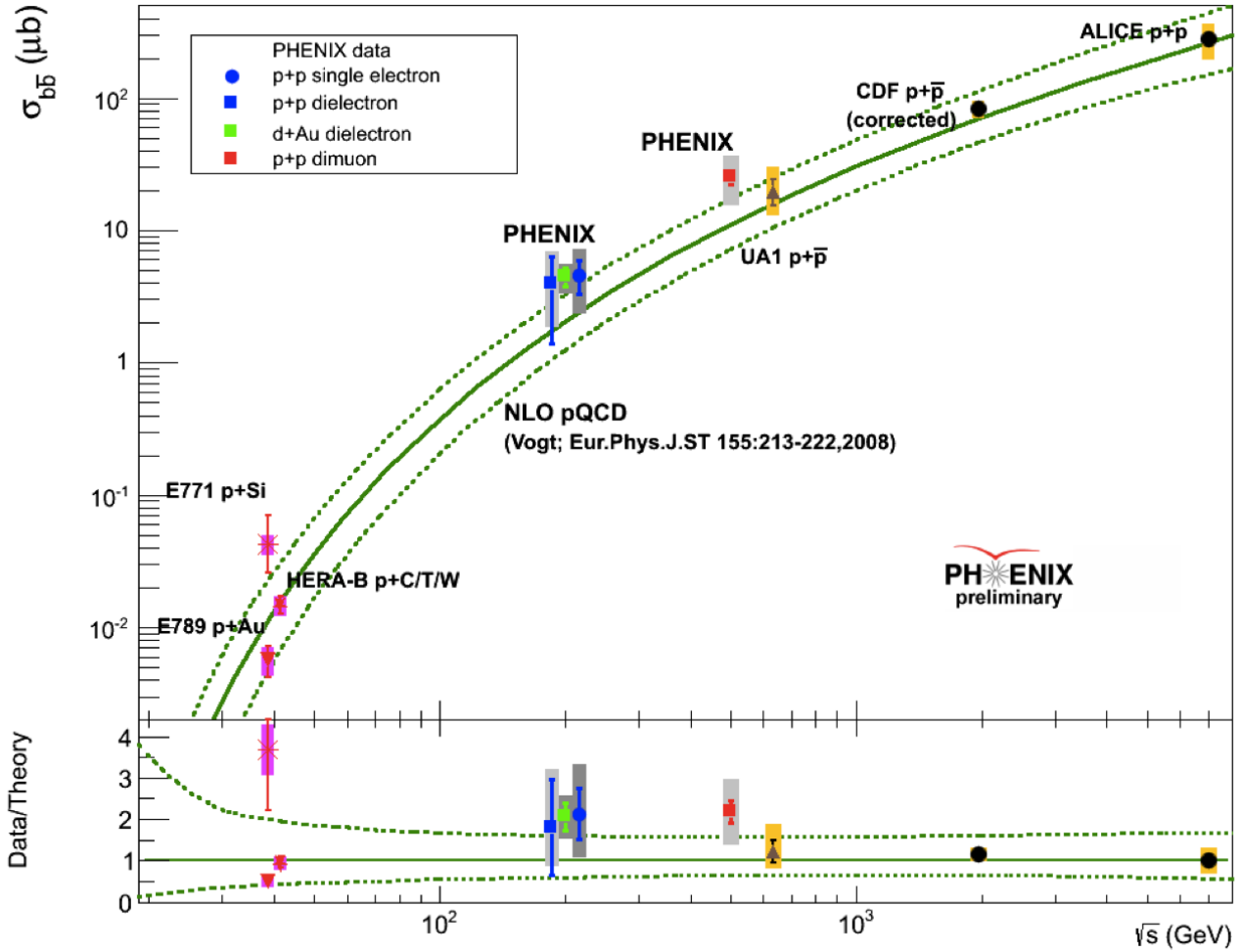
Charm X-section



- PHENIX has 3 electron measurements of extrapolated cross-setion
  - All are in agreement with each other.
  - All fall within pQCD NLO.

Global Perspective

Beauty X-section



- PHENIX has 4 lepton measurements of extrapolated cross-setion
  - All are in agreement with each other.
  - All fall within pQCD NLO.

Summary

- The d+Au data dielectron spectrum is consistent with the expected cocktail of known sources and, to the scaled $p + p$ results.
- Any enhancement seen in the HI collisions is not due to any cold nuclear matter effects.
- Dielectron like-sign correlations are useful and should be taken into account.
- The $d + Au$ dielectrons data provides a new independent measurement for the heavy flavor that are consistent with the already published results.
- The next-to-leading order calculations (MC@NLO) describe the data very nicely as compared to the leading order calculation (PYTHIA).
- PHENIX dielectron heavy flavor cross-sections are in good agreement with pQCD predictions.

Back-ups

Cocktail of Expected Sources

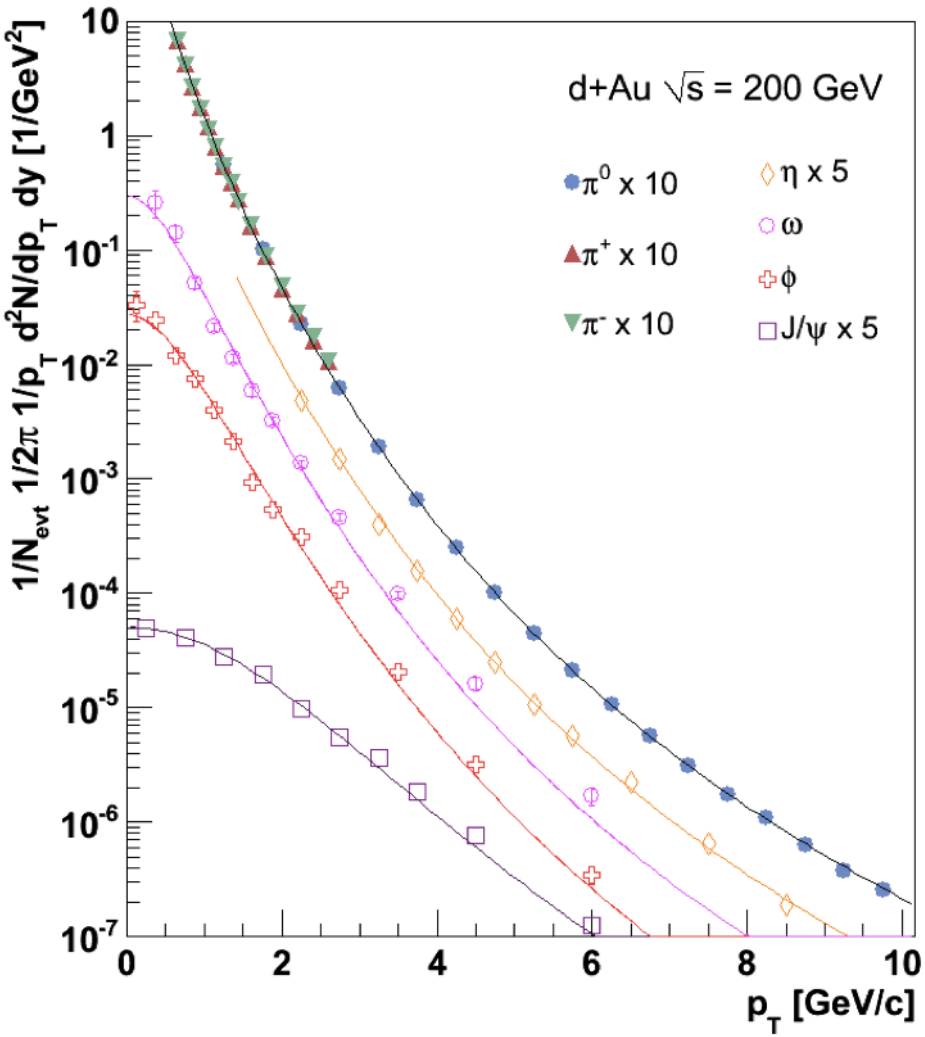
Estimate of Expected Sources

Cocktail

- Hadron decays
  - Fit the $\pi^{\pm}$ and π^0 data for a given collision system

$$E\frac{d^3\sigma}{dp^3} = \frac{A}{(e^{-(ap_T+bp_T^2)} + p_T/p_0)^n}$$

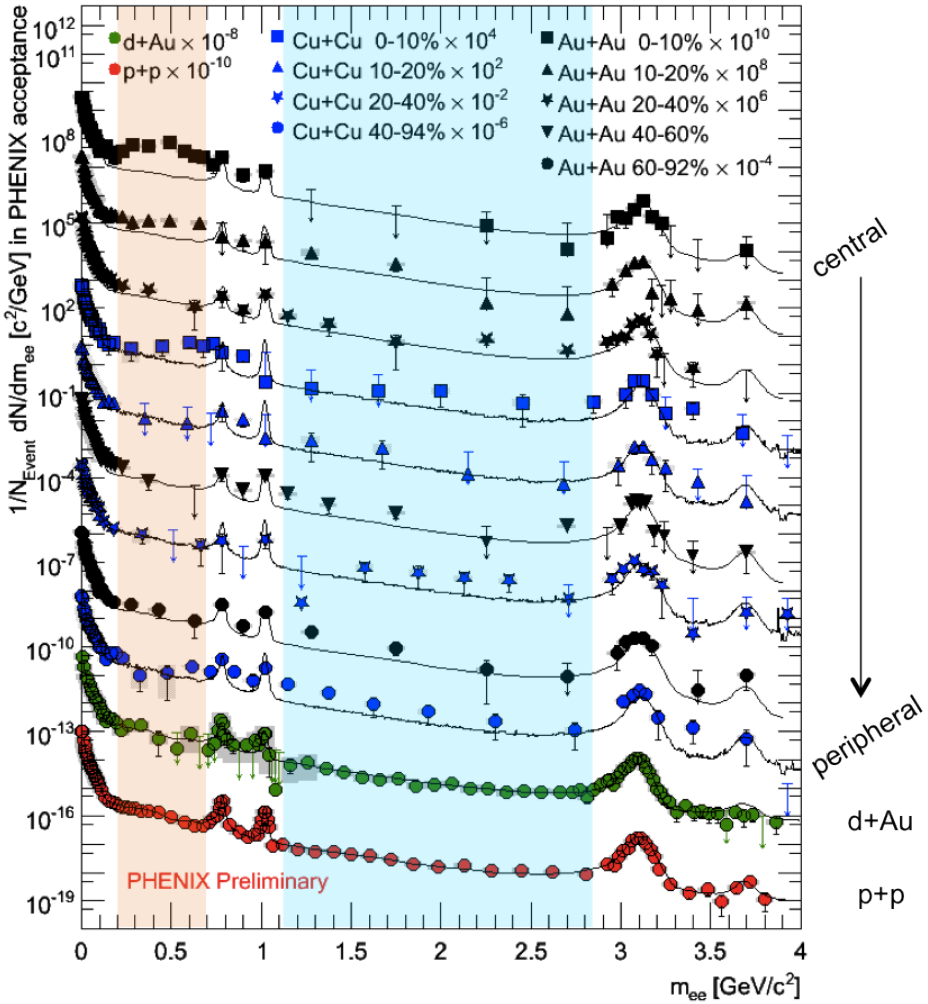
  - Use m_T scaling for shape of other hadrons: $p_T \rightarrow \sqrt{p_T^2 - m_{\pi^0}^2 + m_{hadron}^2}$ and fix normalization using the existing data where available.
  - Fits are done independently for each particle and each centrality.
- Open heavy flavor (c, b) contributions determined using MC@NLO.
  - For a given collision system use $N_{coll} \times \sigma_{cc} = 567 \pm 57 \pm 193$ measured in $p+p$ from single electrons.
- Put the ideal PHENIX acceptance filter.
- R_{dAu} of J/ψ included in the Cocktail.



Compilation of meson invariant yields in $d+Au$ collisions. The data are compared to the parameterization based on m_T scaling.

Centrality Dependence across Various Collision Systems

ordered by N_{coll}



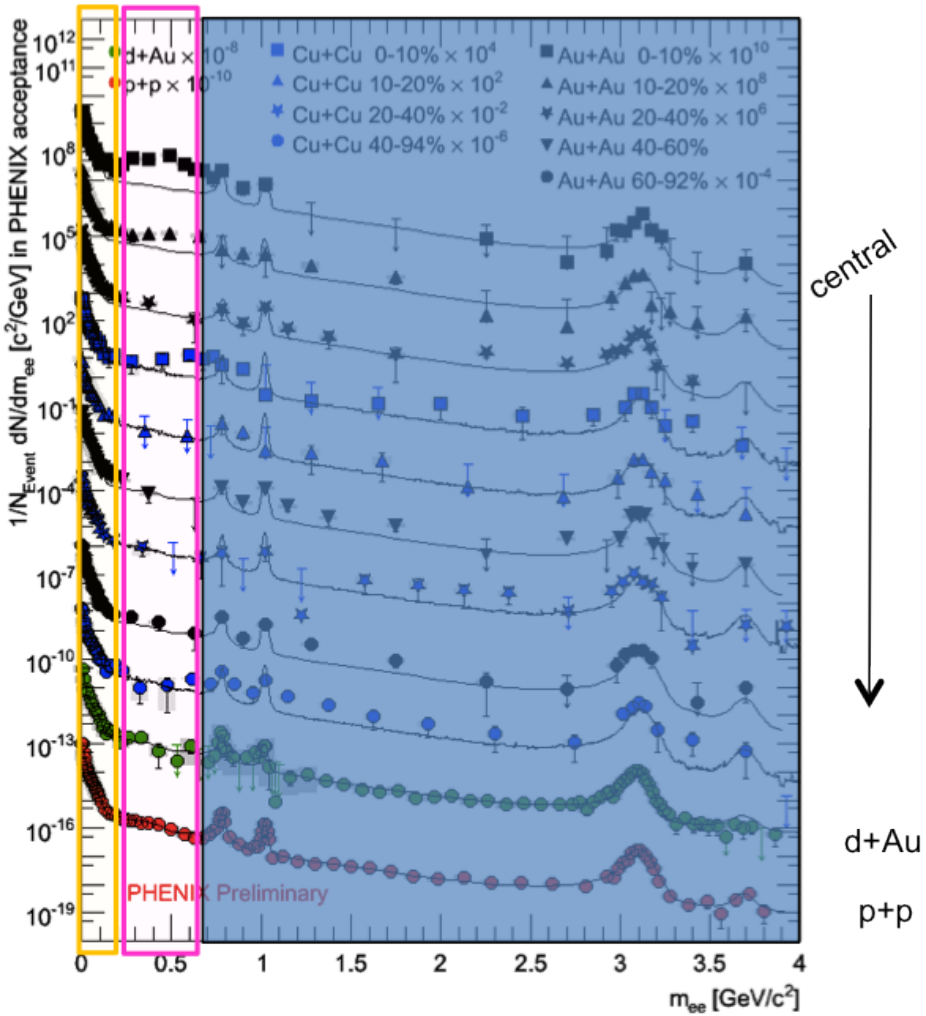
All PHENIX dielctron data

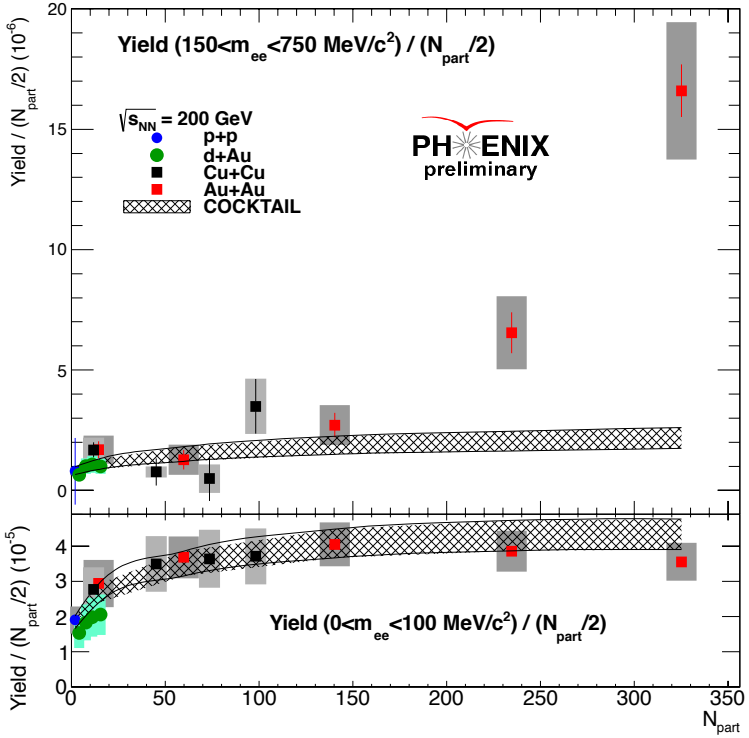
- Heavy Ions, $p+p$ and $d+Au$
  - $Au+Au$ by Centrality.
  - $Cu+Cu$ also plotted into centrality.
- $d+Au$ and $p+p$ are at the bottom
- Black line correspond to the respective cocktail for the given system.

Centrality Dependence

- LMR excess in more central.
- Slight IMR excess in peripheral heavy-ion collisions.
- $d+Au$ and $p+p$ are consistent with the Cocktail.

Low Mass Region (LMR) Scaling of Yields



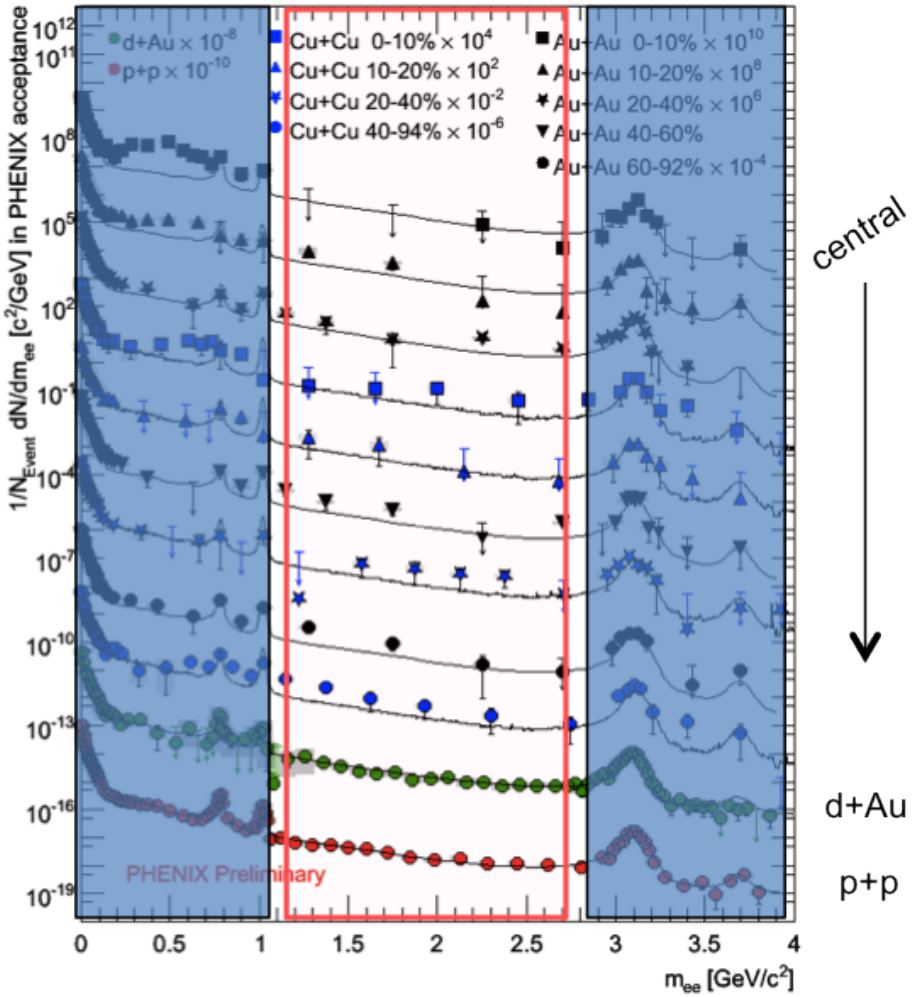


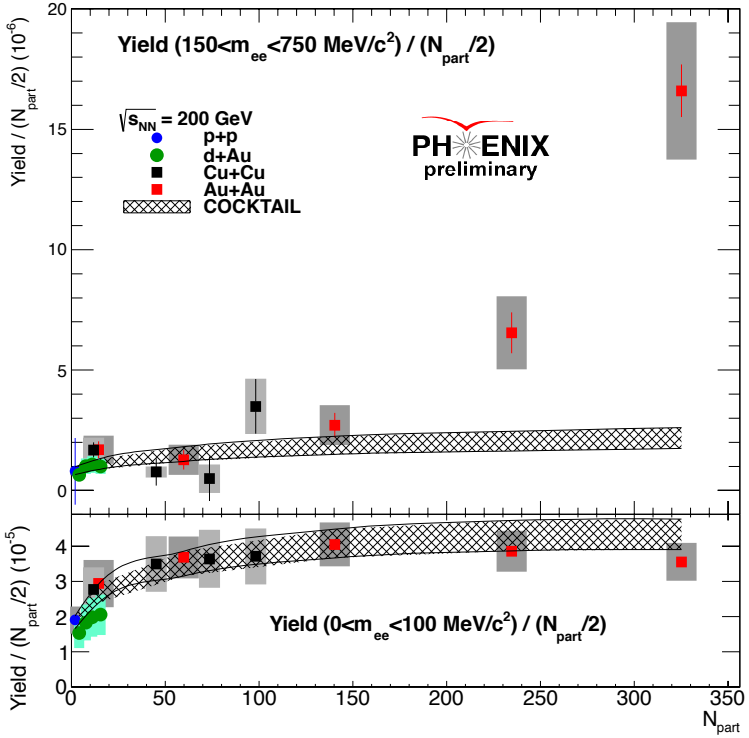
- Yield in the π^0 region scales approximately with N_{part}.
- Enhancement in the LMR (0.15 - 0.75 GeV/c^2) is a strong function of the Centrality.
- Excess seen in both $Au + Au$ and $Cu + Cu$
- No excess in $p + p$ or $d + Au$.

Stony Brook University

PHENIX

Intermediate Mass Region (IMR) Scaling of Yields





- Very little or no enhancement seen within the large systematic uncertainties of $Au + Au$ and $Cu + Cu$ as compared to the cocktail.