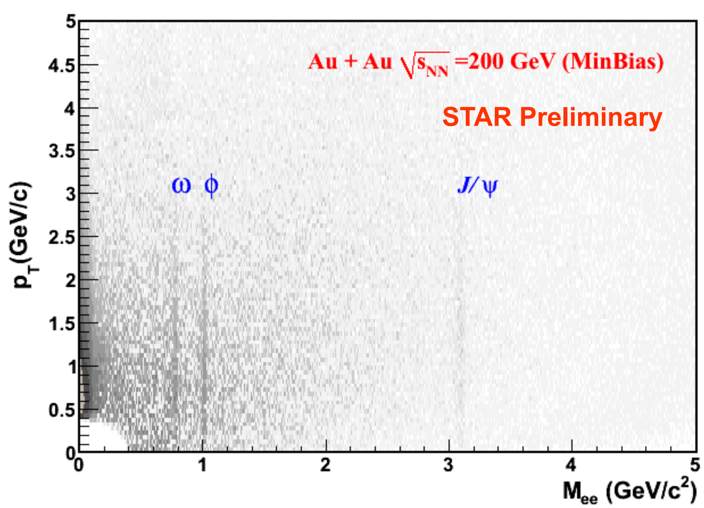
Di-electron Production from $\sqrt{s_{NN}}$=200GeV Au+Au Collisions at STAR



Jie Zhao[1,2]

for the STAR Collaboration

1, Lawrence Berkeley National Lab, USA

2, Shanghai Institution of Applied Physics, CAS, China

Outline

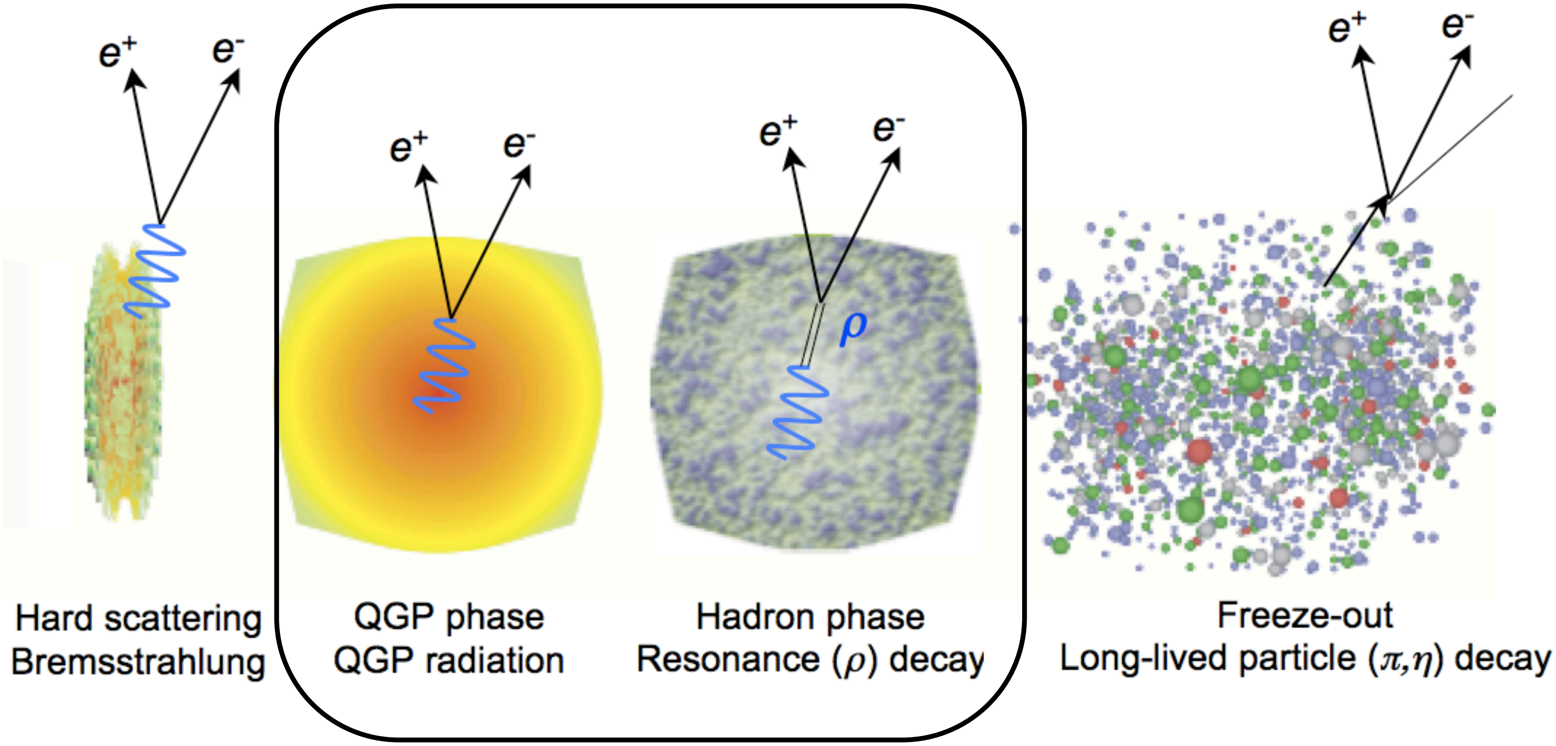
- **Motivation**
- **Electron identification**
- **Background subtraction**
- **Di-electron production in Au + Au collisions**

  comparison with theoretical calculations

  acceptance investigation
- **Transverse mass spectra**
- **Summary and outlook**

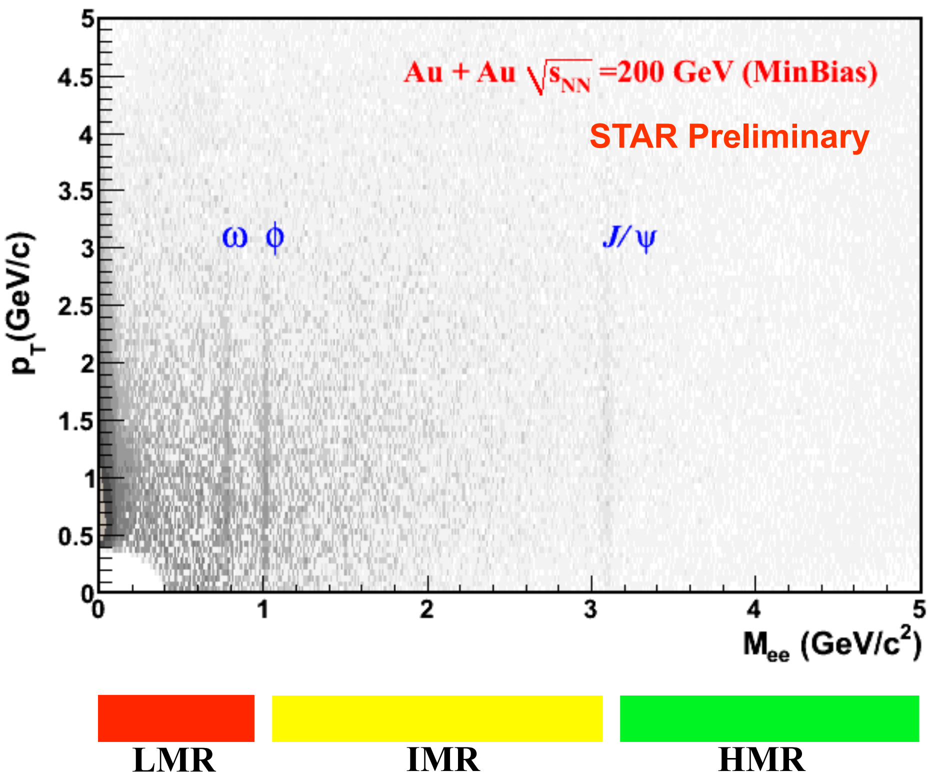
Motivation(1)

Dielectron – A Penetrating Probe of the Medium



Advantages: *EM probe / penetrating – not suffer strong interactions*
(p_T, M) – additional mass dimension, sensitive to different dynamics
Challenges: *Production rate is rare, over many background sources*
integral over time, sensitive to system evolution

Motivation(2)



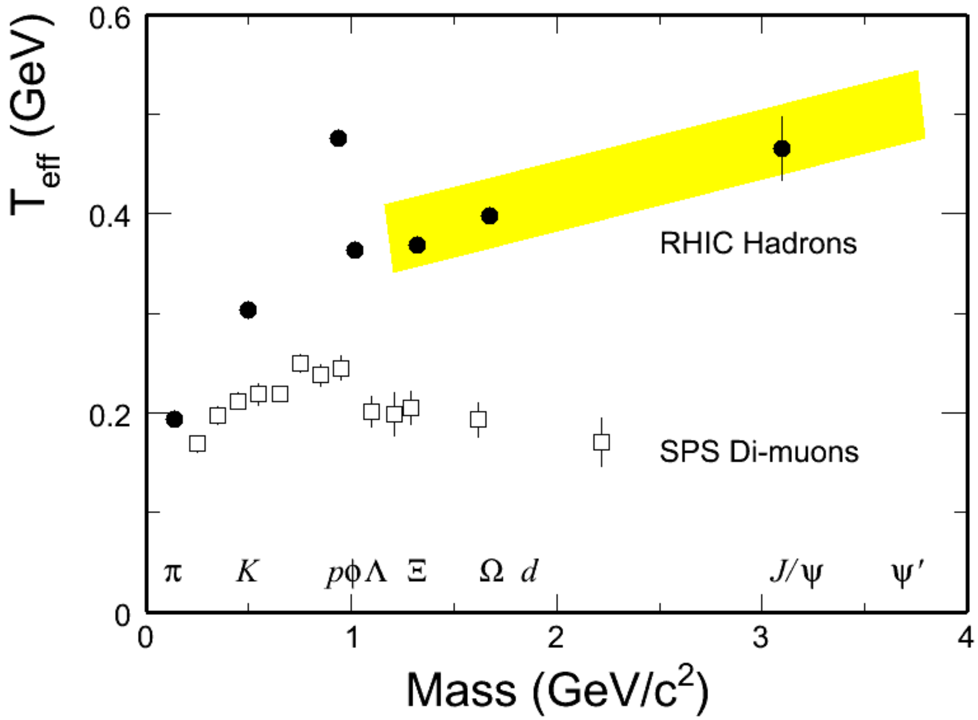
Provide two dimensions (mass vs p_T)

✓*mapping to the collisions dynamics*

- **Low mass region (LMR):**
  - ✓*in-medium modifications of vector mesons*
  - ✓*chiral symmetry restoration*
- **Intermediate mass region (IMR):**
  - ✓*thermal radiation expected to have significant contribution*
  - ✓*dominated by charm in p+p, but the contribution is expected to be modified in Au+Au*
- **High mass region (HMR):**
  - ✓*heavy quarkonia*
  - ✓*Drell-Yan contribution*

Motivation(3)

RHIC Au + Au 200 GeV / SPS In + In 17.2 GeV



NA60, PRL 100, 022302 (2008)
STAR, NPA 757,102 (2005)
PHENIX, PRL 98, 232301 (2007)

Different slope in m_T spectra in low and intermediate mass at SPS energy

➢*hint of partonic thermal dileptons*

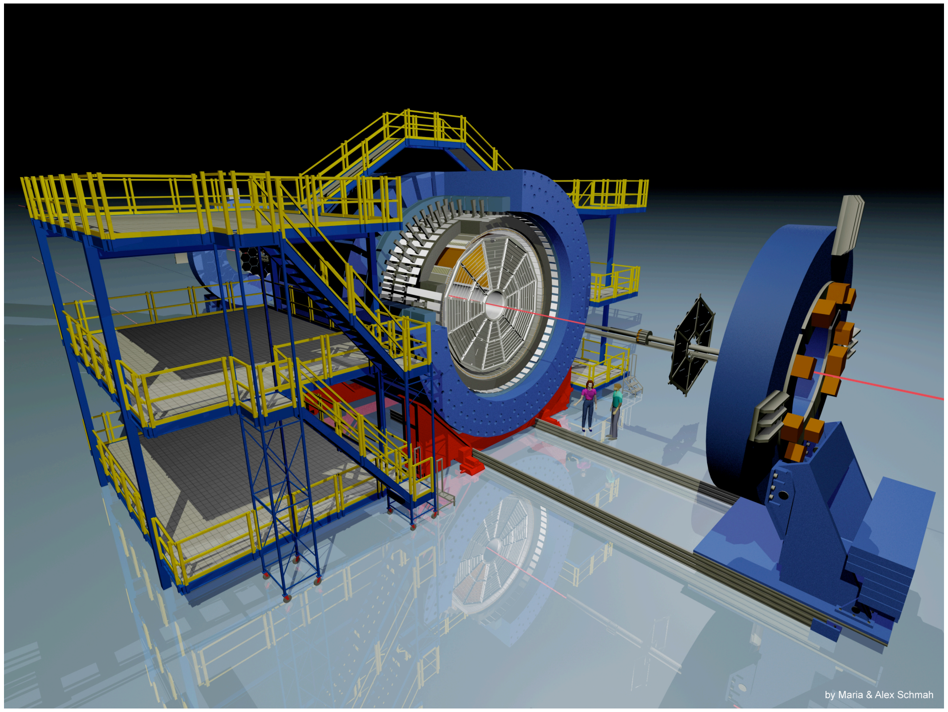
$$q\bar{q} \rightarrow l\bar{l}$$

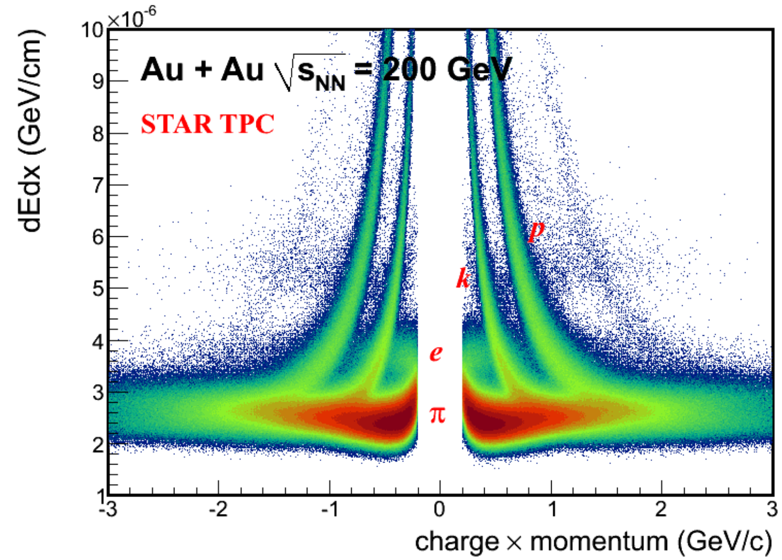
What about at RHIC energy?

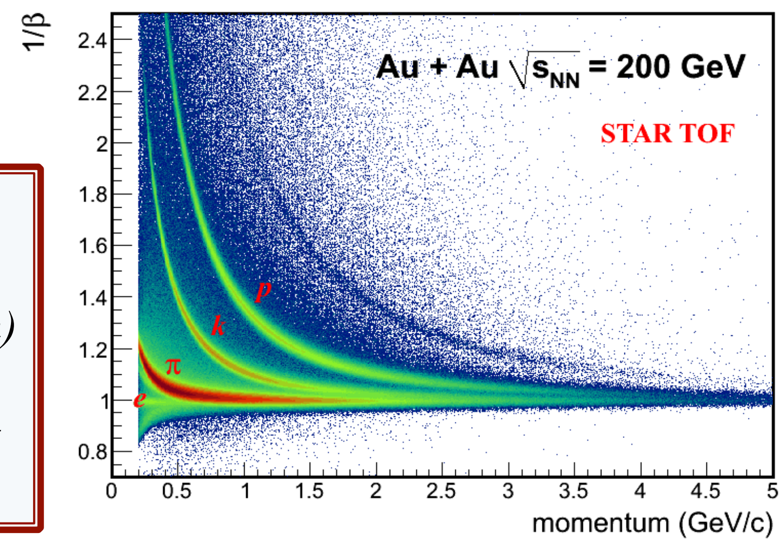
➢**Experimental observables**

- *production cross section vs (mass, p_T)*
- *elliptic flow*

STAR detector



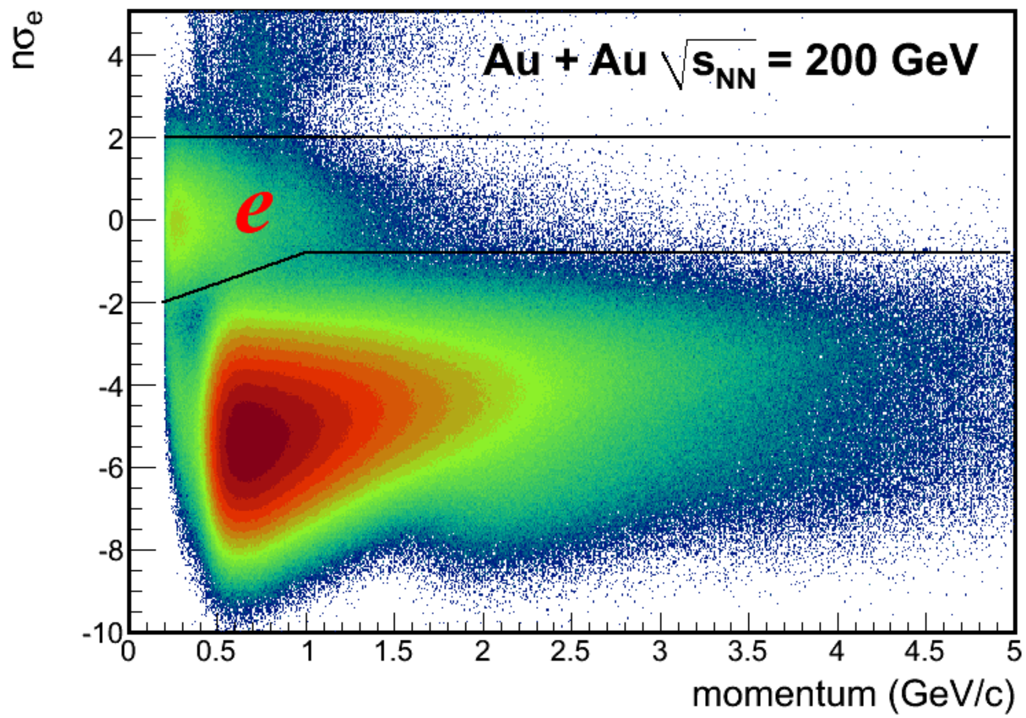




- **Time Projection Chamber** ($0<\phi<2\pi$, $|\eta|<1$)
  Tracking – momentum
  Ionization energy loss – dE/dx (particle identification)
- **Time Of Flight detector** ($0<\phi<2\pi$, $|\eta|<0.9$)
  Timing resolution <100ps - significant improvement for PID

Electron Identification

TOF velocity cut to remove slow hadrons



$$n\sigma_e = \frac{\log(\frac{dE/dx}{B_e})}{\sigma_e}$$

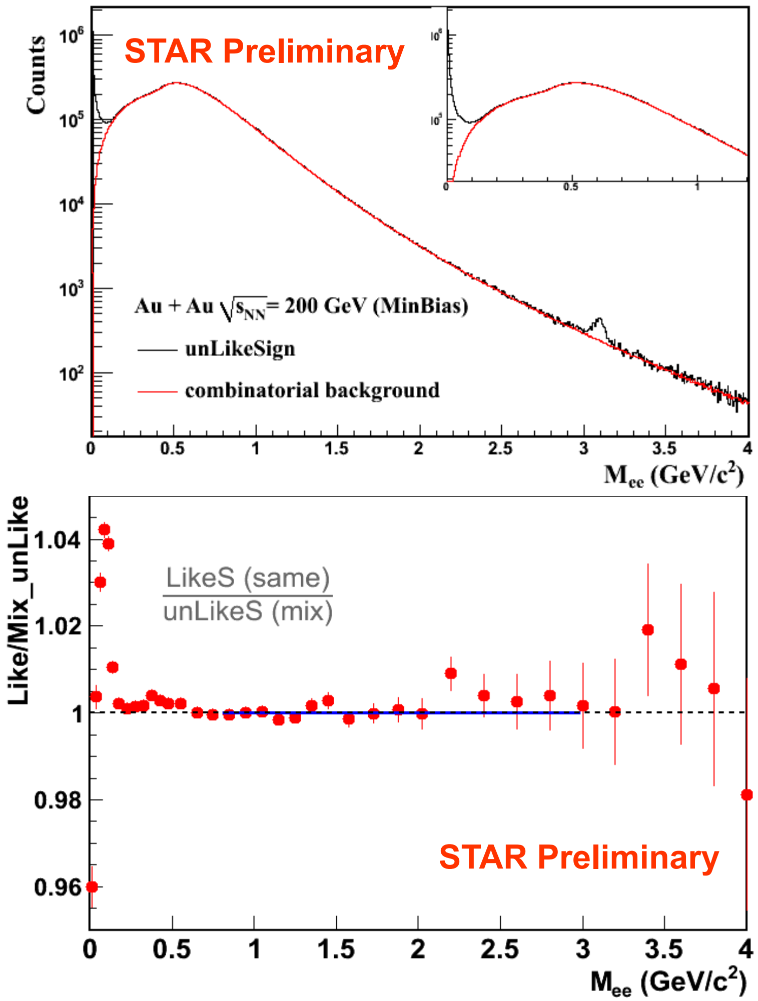
➢**Clean electron PID in p+p and Au+Au collisions with a combination of TPC dE/dx and TOF velocity**

✓*electron purity ~99% in p +p collision, ~97% in Au + Au MinBias collision.*

✓*hadron contamination contribution to the correlated background is small, and has been included in the systematic uncertainties (Au +Au).*

Background Reconstruction

Background: combinatorial + correlated background
Signal: particle decay + QGP/medium pair prod.

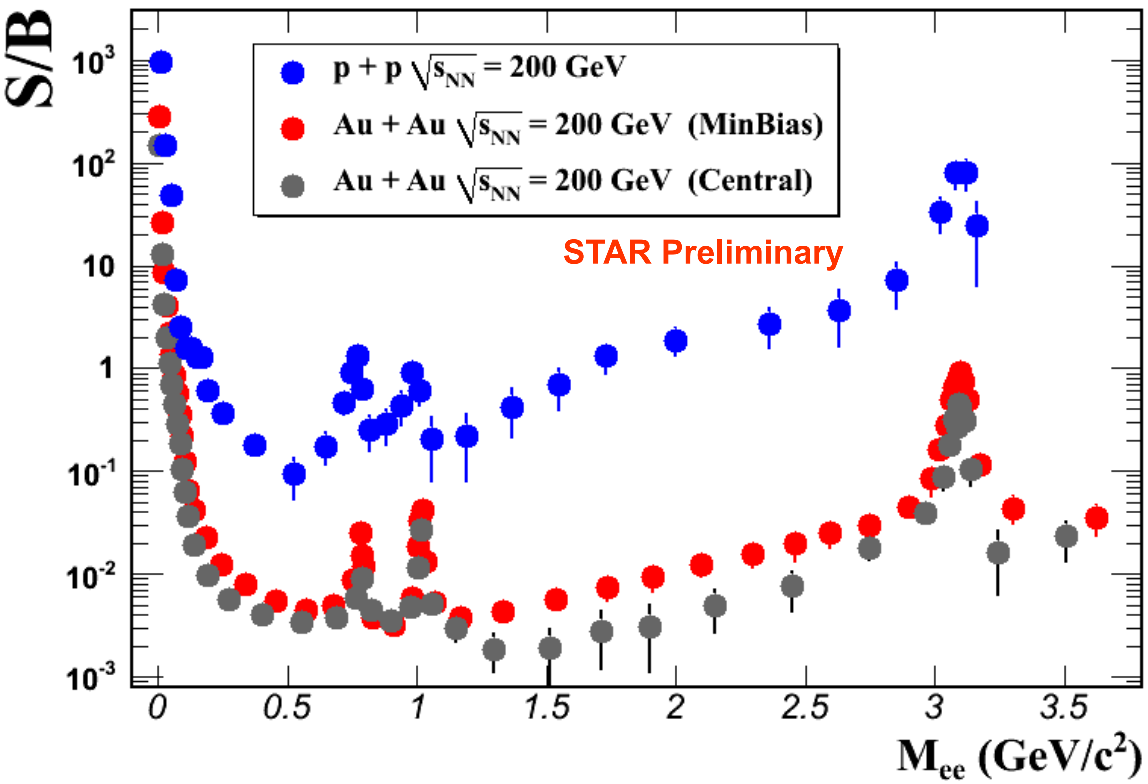


- **Conversion electrons removed from pair reconstruction**
- **Background**
  - **a. Low mass region**
    - *Like Sign – acceptance corrected*
    - *Cross pair and Jet contribution*
  - **b. Mass>0.75GeV/c²**
    - - *Mixed Event*
    - - *Like Sign*
- **Systematic errors**
  - - *acceptance uncertainty < 0.1 %*
  - - *normalization uncertainty < 0.1%*

$$B_{LikeSign} = 2\sqrt{N_{++}\cdot N_{--}}\cdot \frac{B^{Mix}_{+-}}{2\cdot\sqrt{B^{Mix}_{++}\cdot B^{Mix}_{--}}}$$

N : *same Event* , B^{mix} : *mixed Event*

Signal/Background



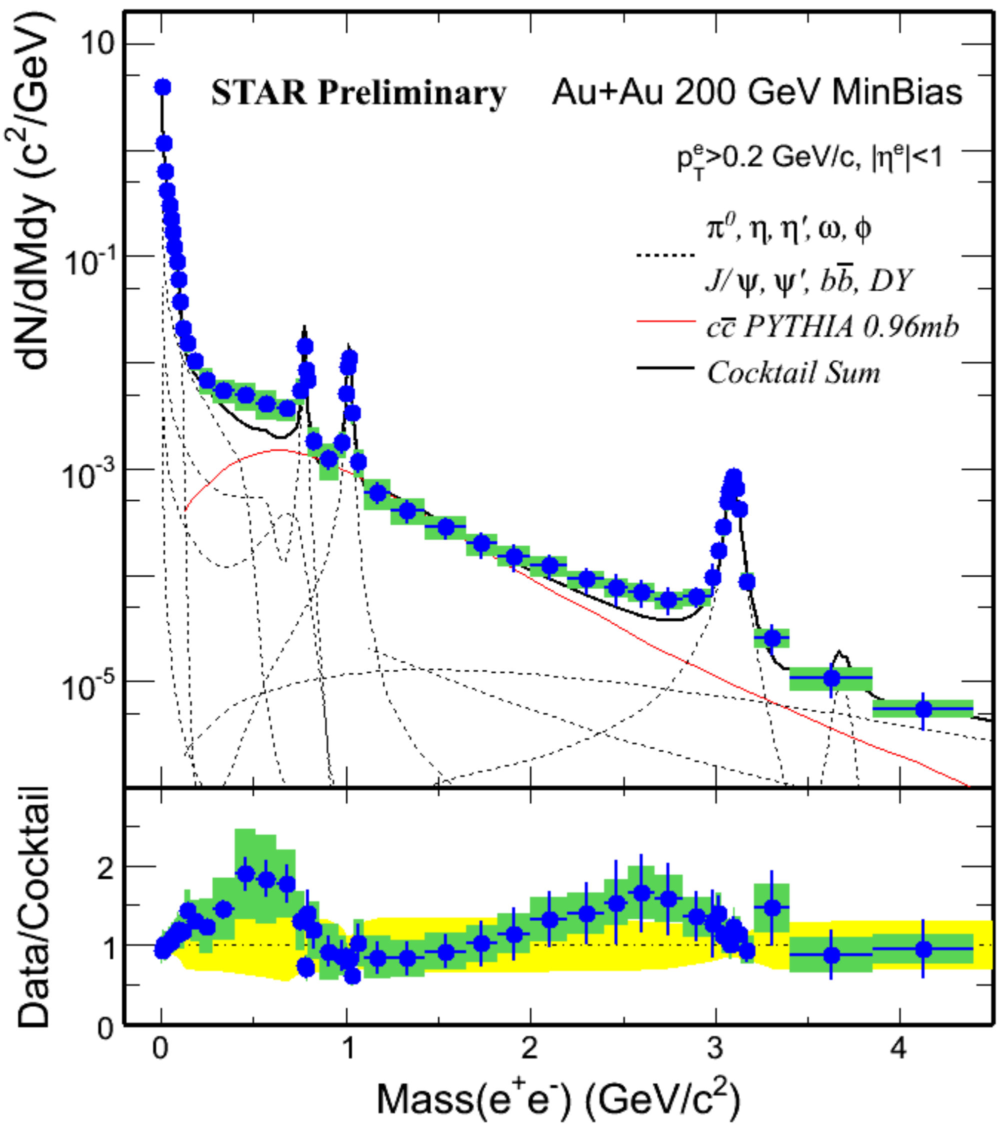
- **Signal/background ratio: mass(ee) ~ 0.5 GeV/c^2**

  ~ 1:10 for p + p collisions

  ~ 1:200 for Au + Au minbias collisions

  ~ 1:250 for Au + Au central collisions

Di-electron production in Au + Au collisions



~ 270M Au+Au MinBias events

➢ **Data show a hint of enhancement at LMR compared to the hadron cocktails w/o ρ.**

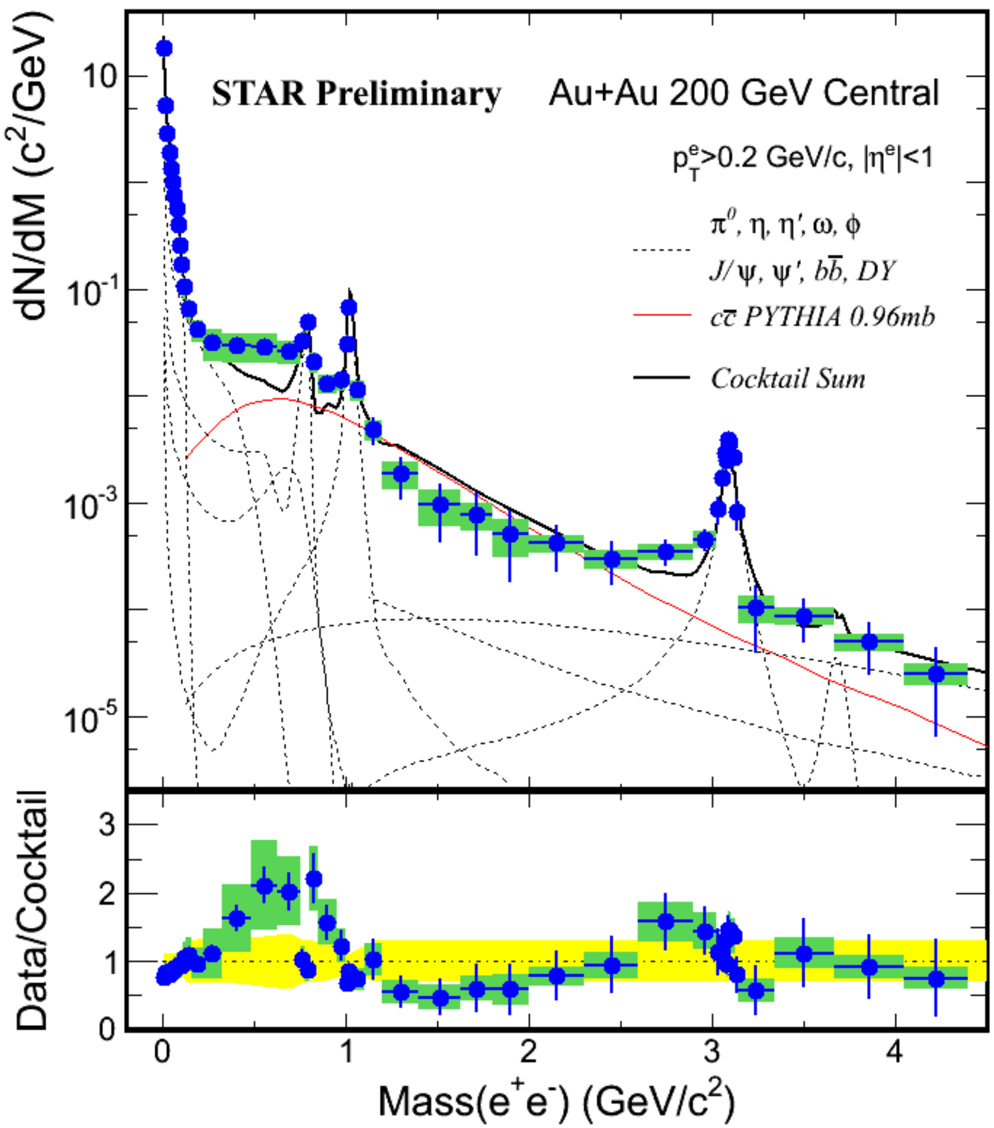
- ρ contribution not included in the cocktail

- charm = PYTHIAN_{bin} (0.96 mb) real contribution in Au+Au is an open question*

- $\pi^0(\pi^\pm)$, ϕ from STAR
- η, ω J/ψ from PHENIX

- Green box: syst. errors on data
- Yellow band: syst. errors on cocktail

Di-electron production in Au + Au collisions



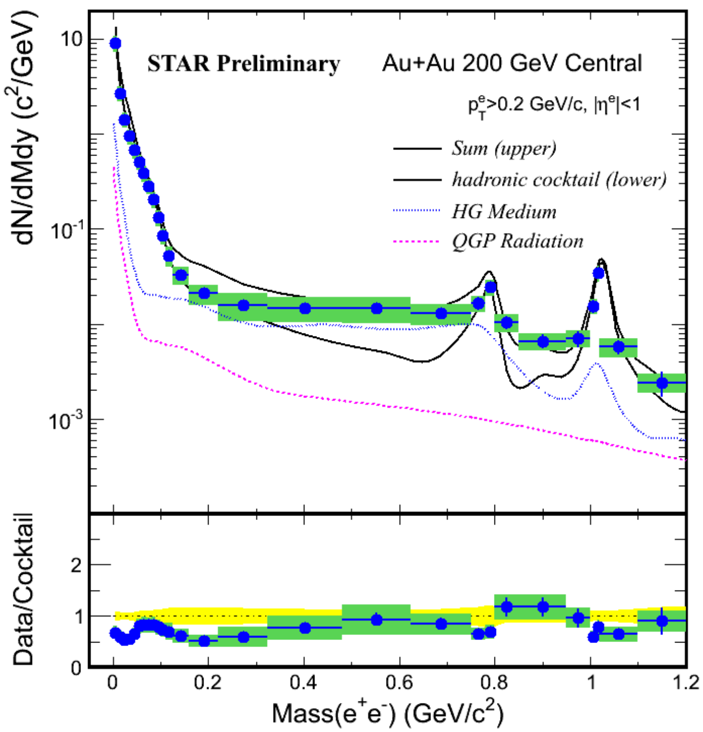
~ 150M Au+Au Central (0-10%)

➢ **Clearer LMR enhancement in central collisions compared to minbias collisions**

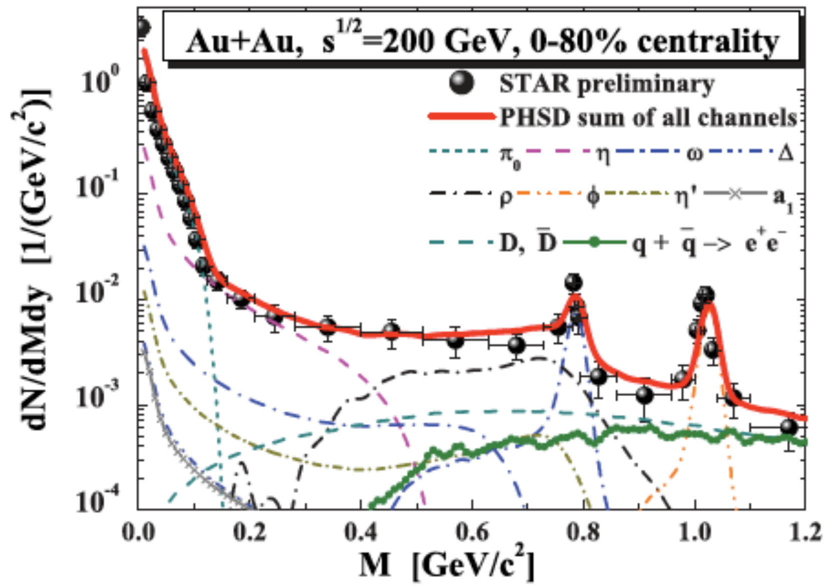
- *ρ contribution not included in the cocktail*

- *charm = PYTHIA*N_{bin} (0.96mb) overpredicts the data at IMR indicating charm modifications in central Au +Au collisions*

Theoretical comparison



Phys. Rev. C85 0249010 (2012)



- **HG_med, QGP from** **R. Rapp (private communication)**

  R. Rapp and J.Wambach, Adv. Nucl. Phys. 25, 1 (2000).

  Blue dotted: Hadronic gas medium modification

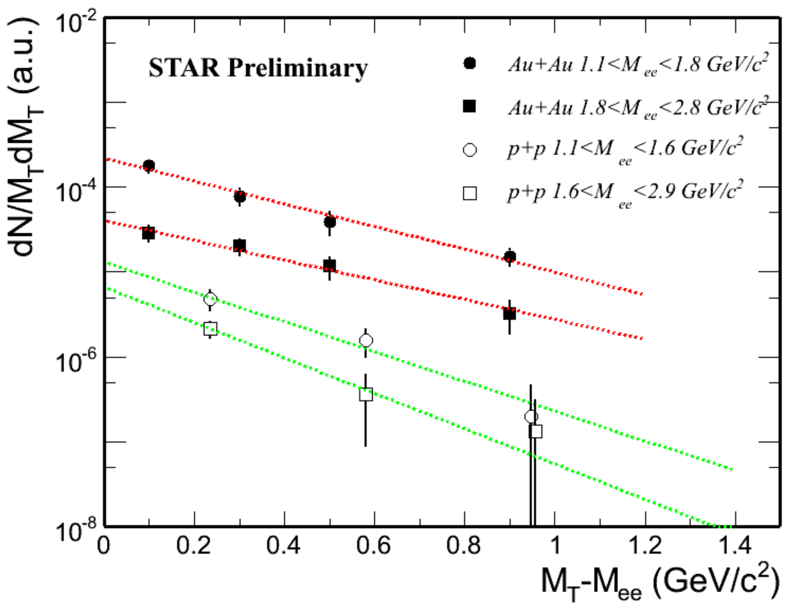
  Pink dotted: QGP radiation

  Solid lines: upper: cocktail + HG+QGP

  lower: hadronic cocktail

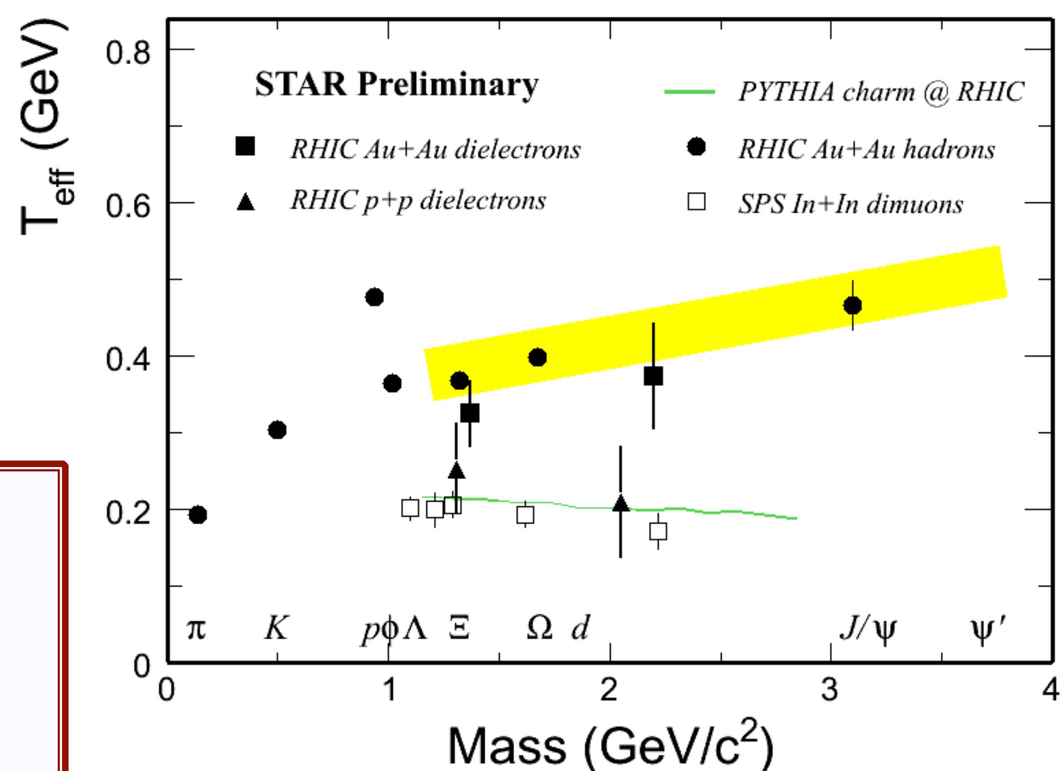
- **Parton-Hadron-String Dynamics(PHSD)**
  1. ***Collisional broadening of vector mesons***
  2. ***Microscopic secondary multiple-meson channels***
  3. ***Radiation from the strongly interacting QGP(sQGP)***
- **Hao-jie Xu et al Phys. Rev. C 2012 85 024906**
- **Yukinao Akamatsu et al Phys. Rev. C 2012 85 054903**
- **…**

Transverse mass spectra



A + A: Minbias collisions

RHIC Au + Au 200 GeV / SPS In + In 17.2 GeV

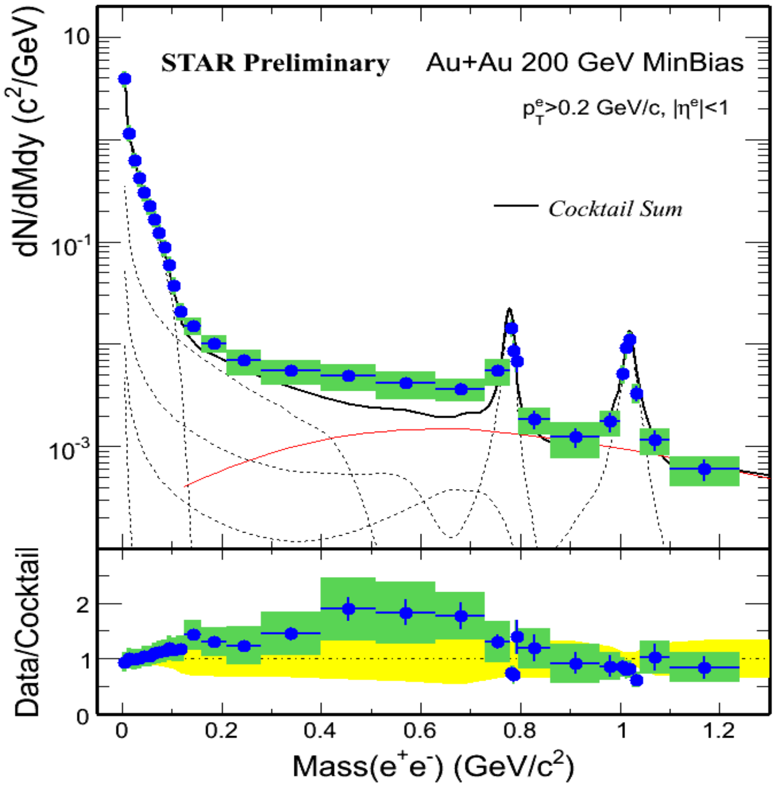


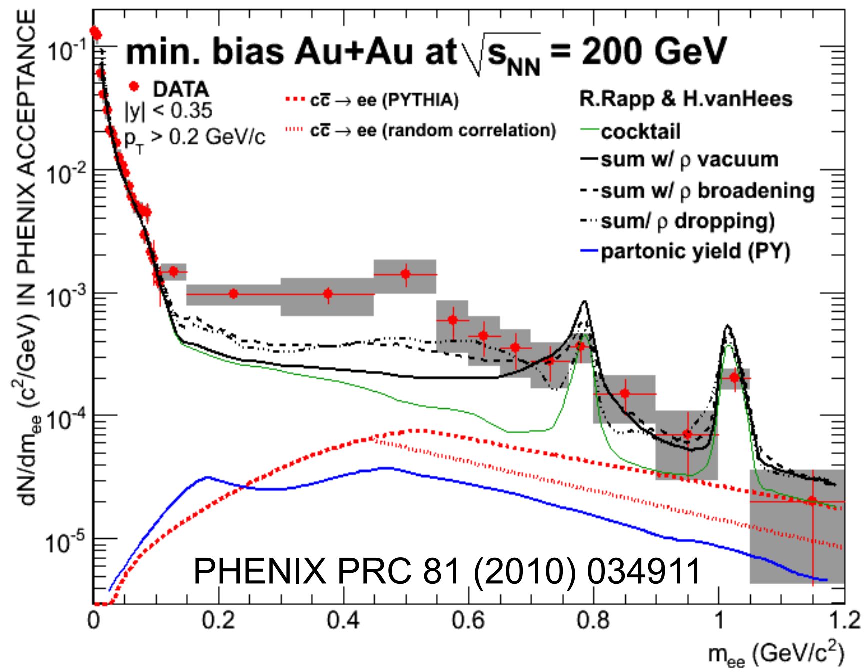
- **p + p result consistent with PYTHIA charm**
- **m_T slope parameter in Au+Au is higher than that in p + p**

  hint of thermal di-lepton production and/or charm modification
- **Inclusive di-lepton slope in Au+Au at RHIC is also higher than that (charm/DY subtracted) from SPS**

SPS data: charm/DY subtracted - PRL 100, 022302 (2008)
STAR data: inclusive di-electron, statistical error only

LMR Enhancement



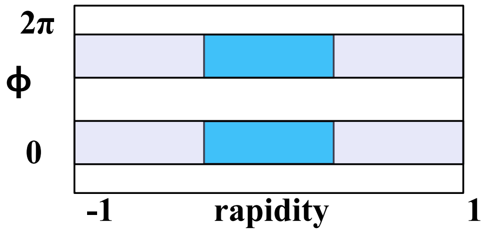


Enhancement factor in 0.15<M_{ee}<0.75 Gev/c^2

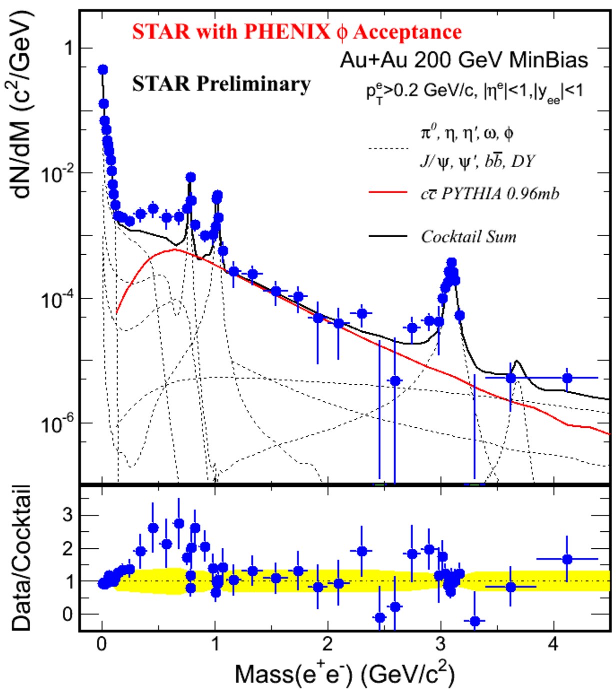
	Minbias (value ± stat ± sys)	Central (value ± stat ± sys)
STAR	1.53 ± 0.07 ± 0.41 (w/o ρ) 1.40 ± 0.06 ± 0.38 (w/ ρ)	1.72 ± 0.10 ± 0.50 (w/o ρ) 1.54 ± 0.09 ± 0.45 (w/ ρ)
PHENIX	4.7 ± 0.4 ± 1.5	7.6 ± 0.5 ± 1.3
Difference	2.0 σ	4.2 σ

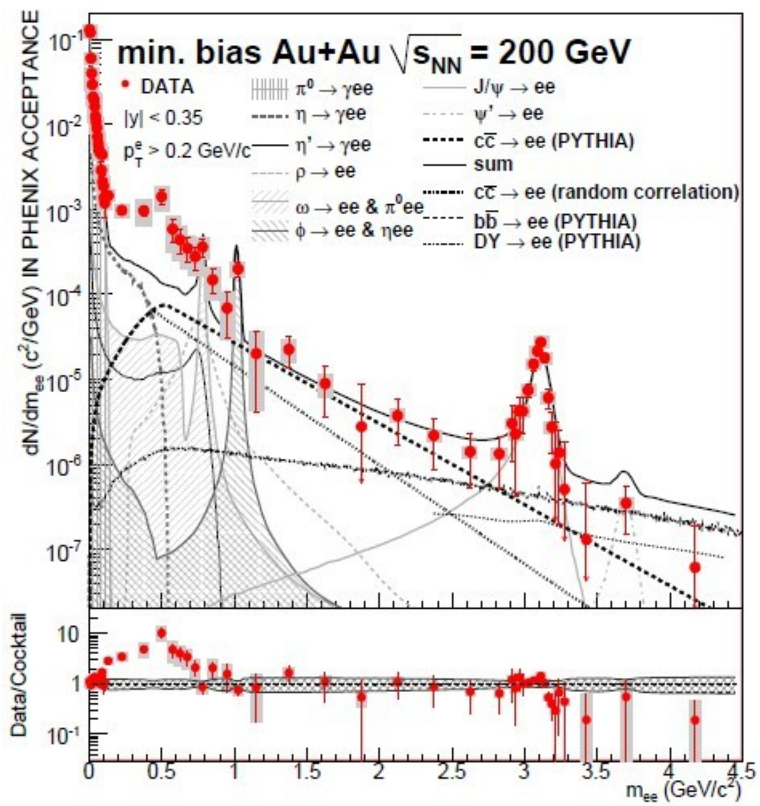
Note: Acceptance difference etc.

STAR and PHENIX



PHENIX data, PhysRevC.81.034911





➢ Single track acceptance in ϕ direction (one of the main difference between STAR and PHENIX)

use STAR data with PHENIX ϕ acceptance cut - (rapidity difference, more data)

Summary and Outlook

➢ **Low mass region:**

- Enhancement in Au + Au central collisions compared to the cocktail ***consistent with theoretical calculation with vector meson in-medium modification***

➢ **Intermediate mass region:**

- Inclusive di-electron m_T slope parameter is higher in Au + Au compared to p + p ***modification of charm and/or thermal radiation contribution ?***

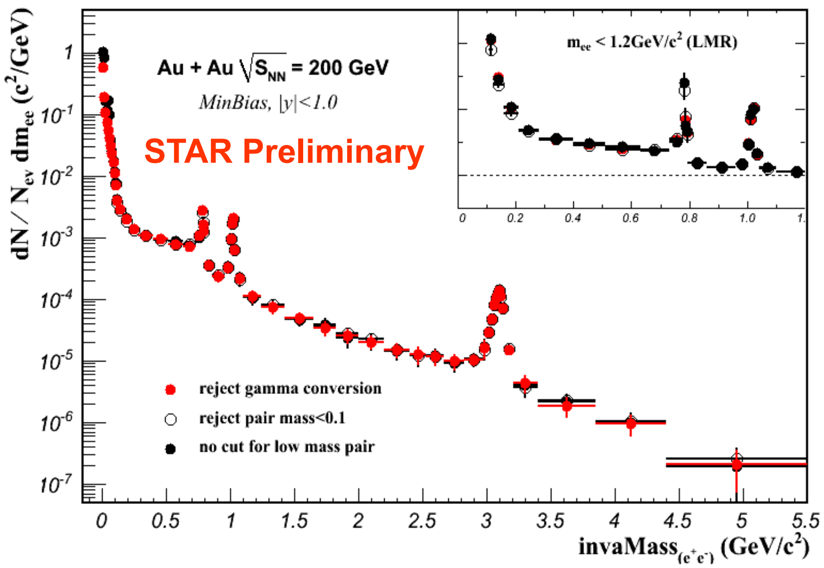
- Need more precise measurement to constrain charm and QGP thermal radiation contributions

Outlook:

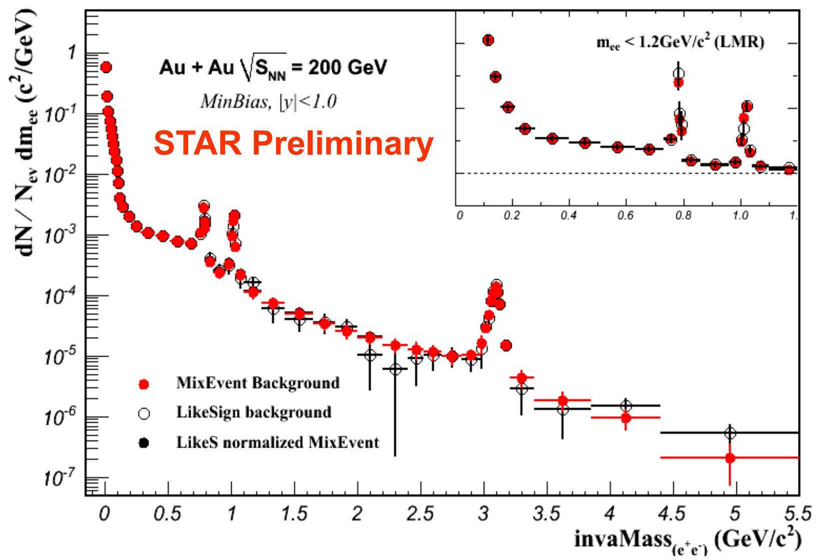
- in the future, STAR Heavy Flavor Tracker and Muon Telescope Detector, charm contribution! (D meson, eμ …) ***- LJ.Ruan Friday morning***

BACKUP

Systematic check



Different photonic rejection

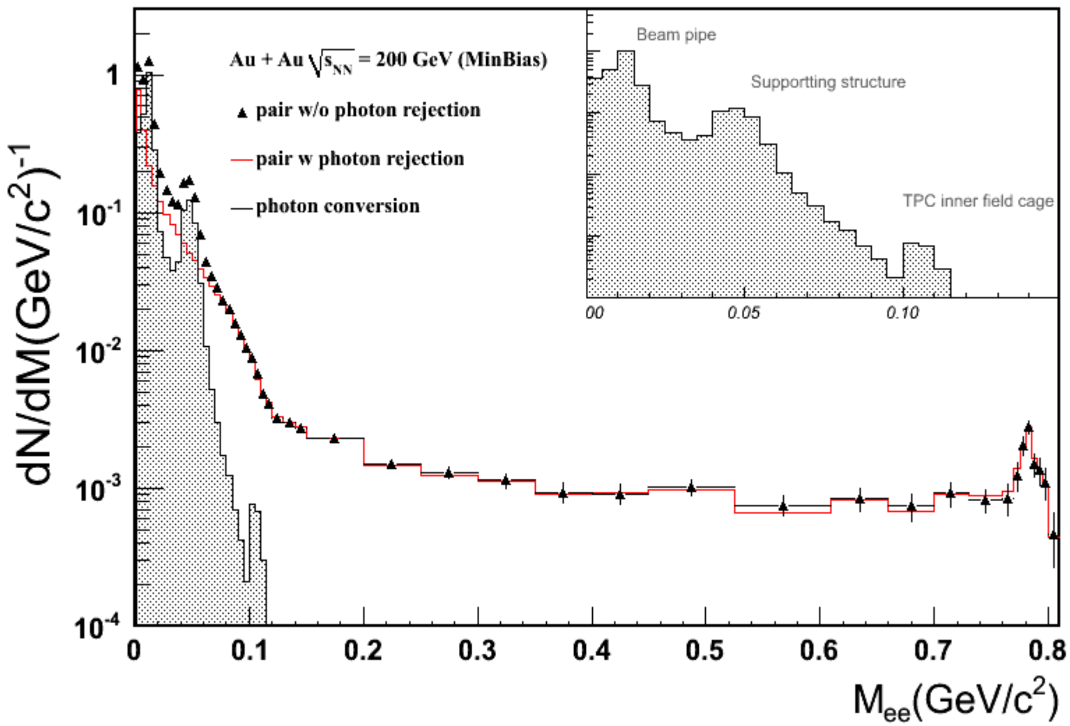


Different background subtraction

Included in systematic uncertainties

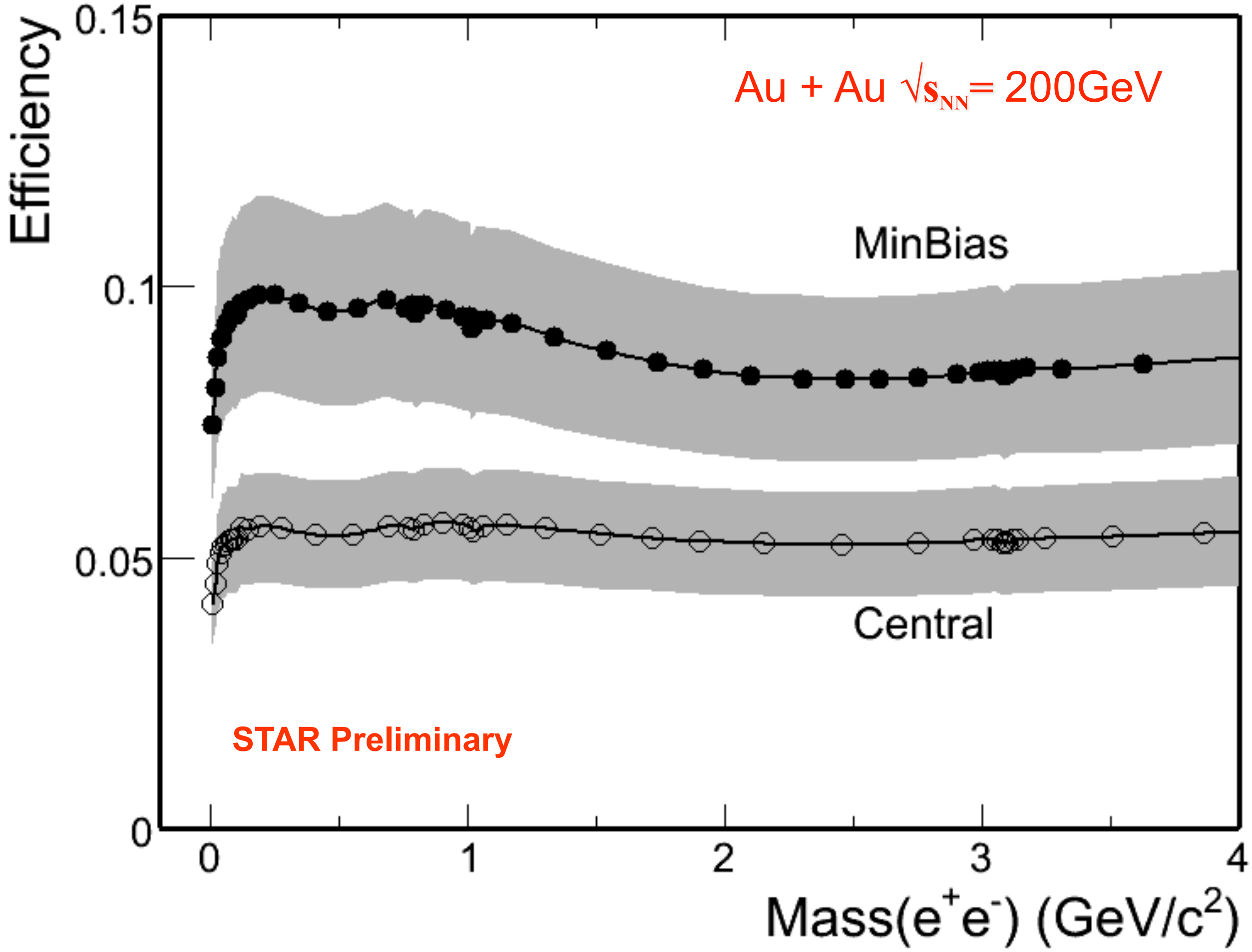
Photon conversion removal

Low material budget in run9 and run10



- Conversion electrons are removed from signal pair reconstruction.
- Difference between w/ and w/o photon conversion rejection to the final signal is less 10% at M>0.2GeV/c^2 (included in the systematic errors)

Efficiency



Au + Au √sNN= 200GeV
MinBias
Central
STAR Preliminary
Efficiency
0.15
0.1
0.05
0
0
1
2
3
4
Mass(e+e-) (GeV/c2)

Background Reconstruction

Like Sign:

$$1: B_{LikeSign} = 2\sqrt{N_{++} \cdot N_{--}} \cdot \frac{B_{+-}^{Mix}}{2 \cdot \sqrt{B_{++}^{Mix} \cdot B_{--}^{Mix}}}$$

$$2: B_{LikeSign} = a(N_{++} + N_{--}) \cdot \frac{B_{+-}^{Mix}}{(B_{++}^{Mix} + B_{--}^{Mix})b}$$

$$a = \frac{\int_0^\infty 2 \cdot \sqrt{N_{++} \cdot N_{--}} dmdpT}{\int_0^\infty (N_{++} + N_{--}) dmdpT} \quad , \quad b = \frac{\int_0^\infty 2 \cdot \sqrt{B_{++}^{mix} \cdot B_{--}^{mix}} dmdpT}{\int_0^\infty (B_{++}^{mix} + B_{--}^{mix}) dmdpT}$$

MixEvent:

- normalize mixed likeSign ++ and -- to same event ++ and --

$$A_+ = \int_{N.R.} \frac{N_{++}}{B_{++}^{Mix}} dmdpT \quad , \quad A_- = \int_{N.R.} \frac{N_{--}}{B_{--}^{Mix}} dmdpT$$

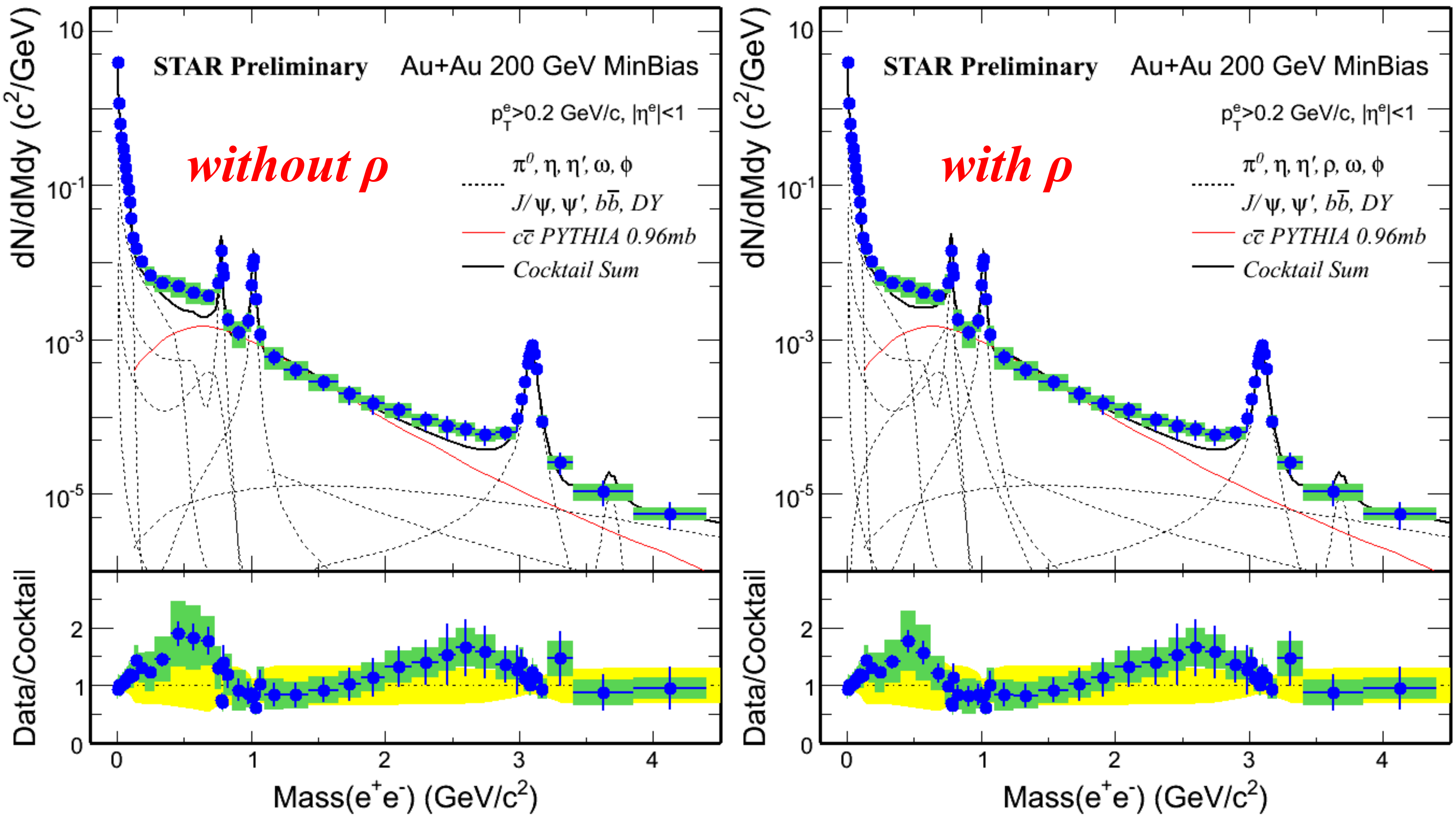
$$B_{++}^{mix} = \int_0^\infty A_+ B_{++}^{mix} dmdpT \quad , \quad B_{--}^{mix} = \int_0^\infty A_- B_{--}^{mix} dmdpT,$$

- normalize mixed unlikeSign (combinatorial background)

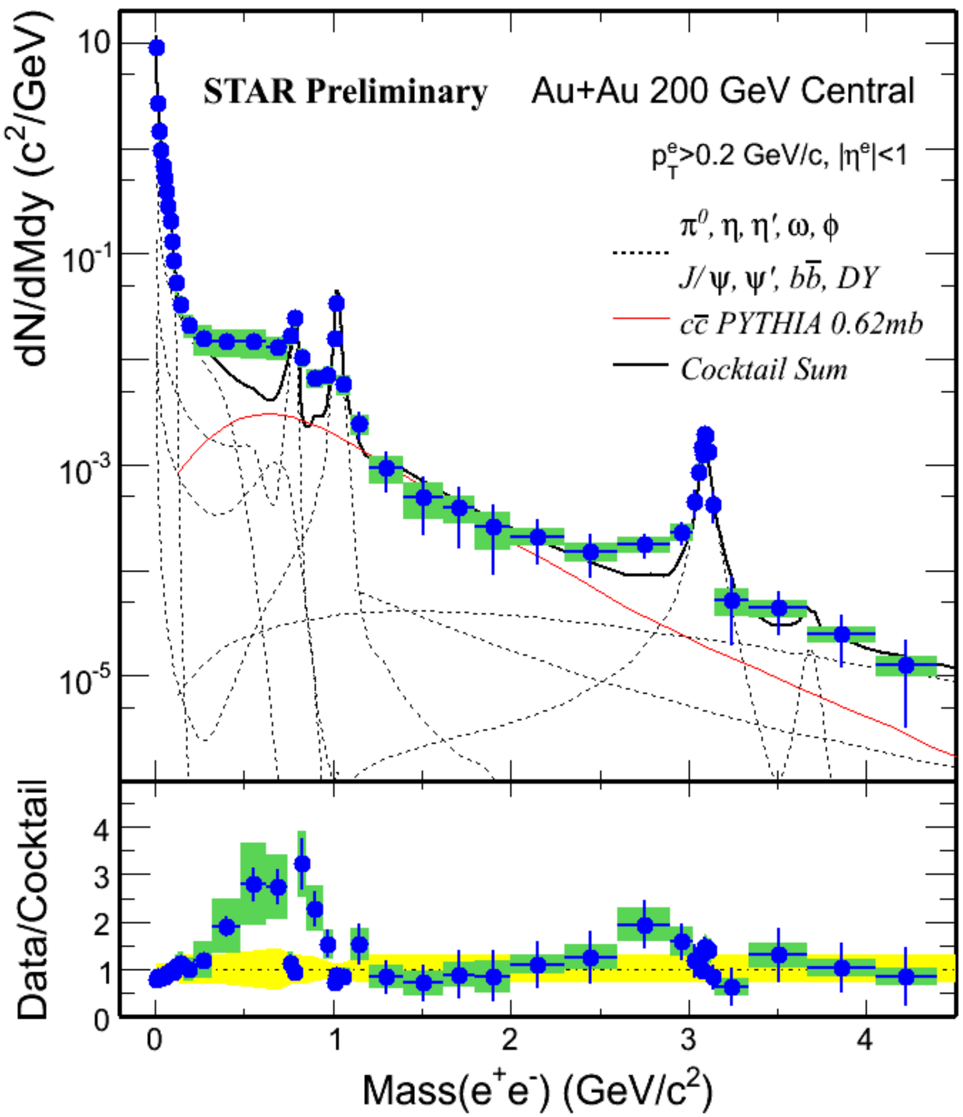
$$B_{+-}^{combinatorial} = \frac{2\sqrt{B_{++}^{mix} \cdot B_{--}^{mix}}}{\int_0^\infty B_{+-}^{mix} dmdpT} B_{+-}^{mix}$$

PHENIX PRC 81, 034911 (2010)

Cocktail with ρ



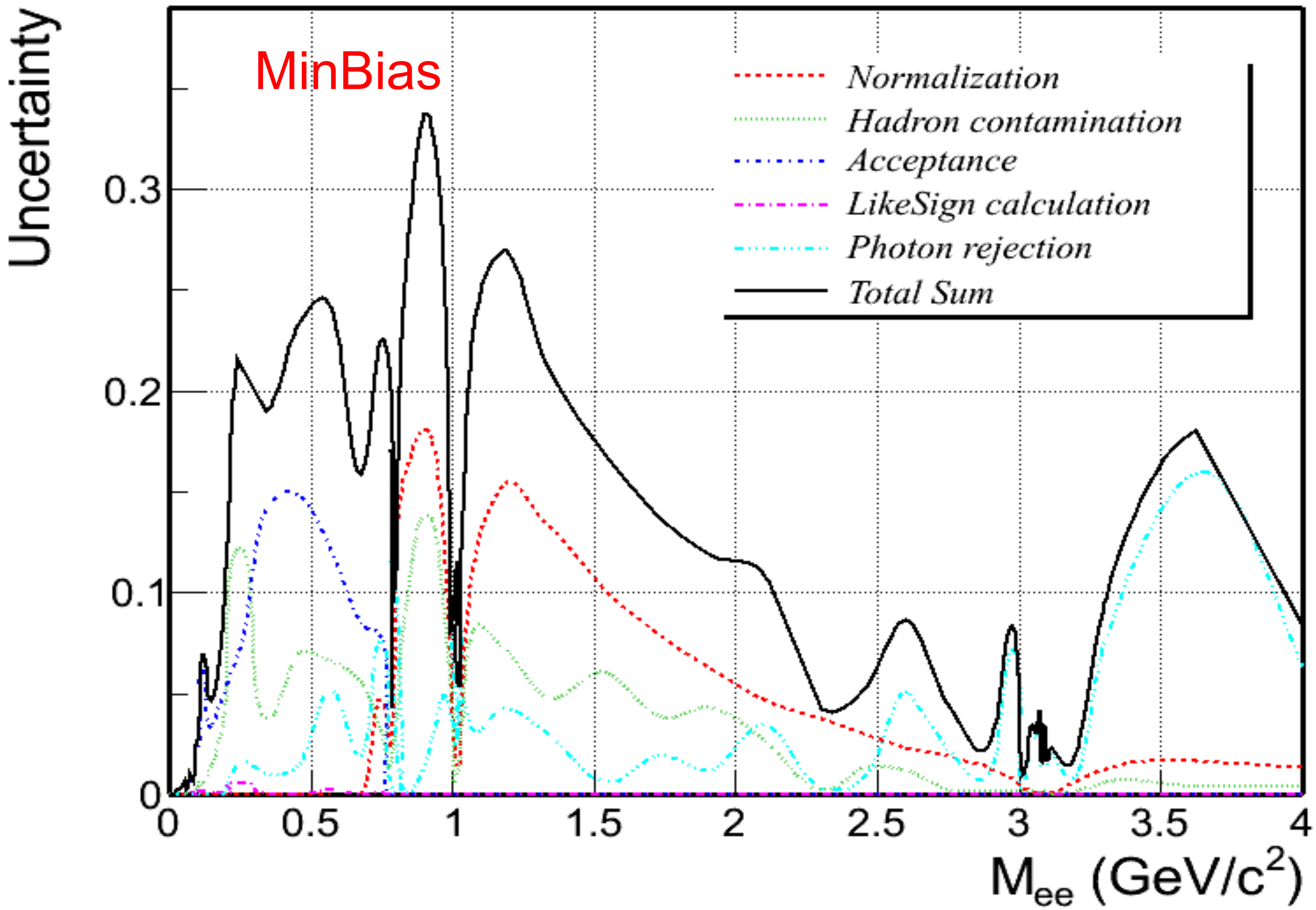
Enhancement in Central collisions



The fit of charm cocktail to the data gives:
0.62 ± 0.14 mb

PYTHIA setting for charm:
V6.416
MSEL=1,
PARP(91)=1.0 (kt),
PARP(67)=1 (parton shower level)

Systematic error



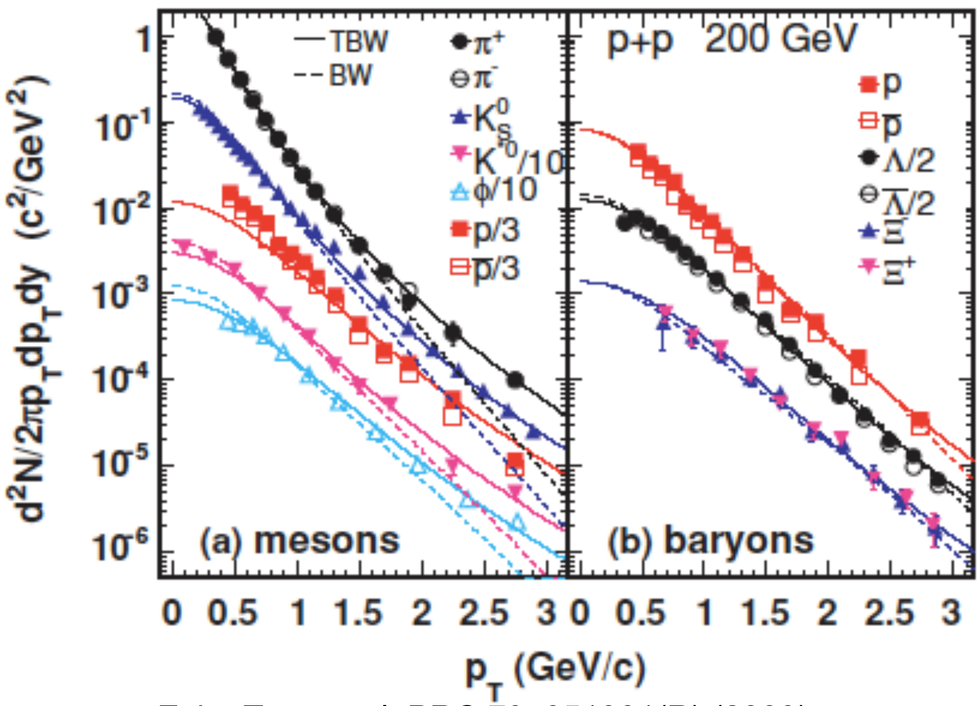
Cocktail

➢ **Inputs:**

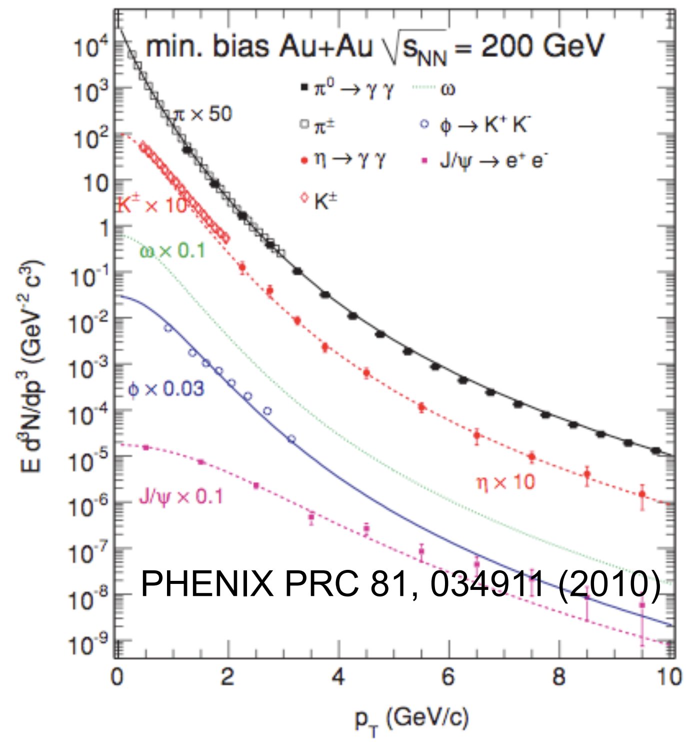
flat rapidity (-1,1) flat Φ (0, 2π)

p_T: in p+p, use Tsallis function fit for all measured particles

in Au+Au for measured π^0,J/ψ use Tsallis function fit, and use m_T-scaling for η, ω, φ, η`



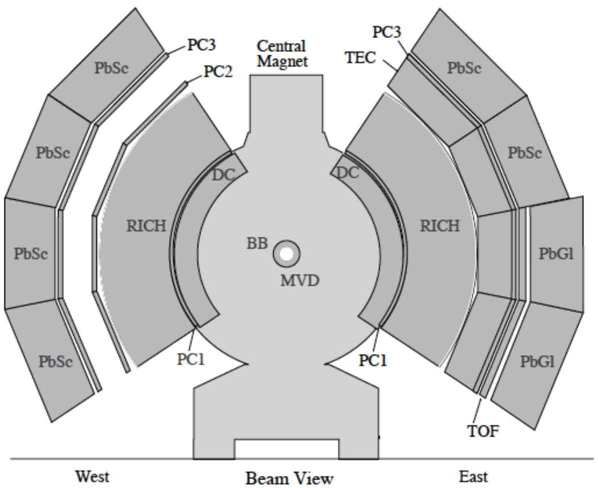
Zebo Tang et al, PRC 79, 051901(R) (2009)

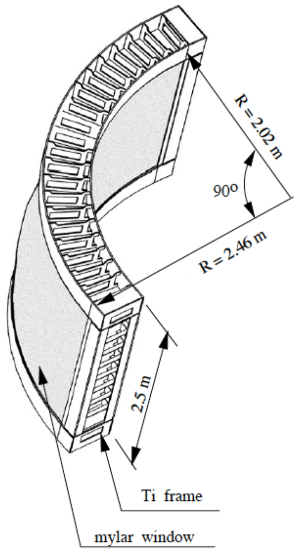


Considered minbias centrality definition difference between PHENIX (0-93%) and STAR (0-80%)

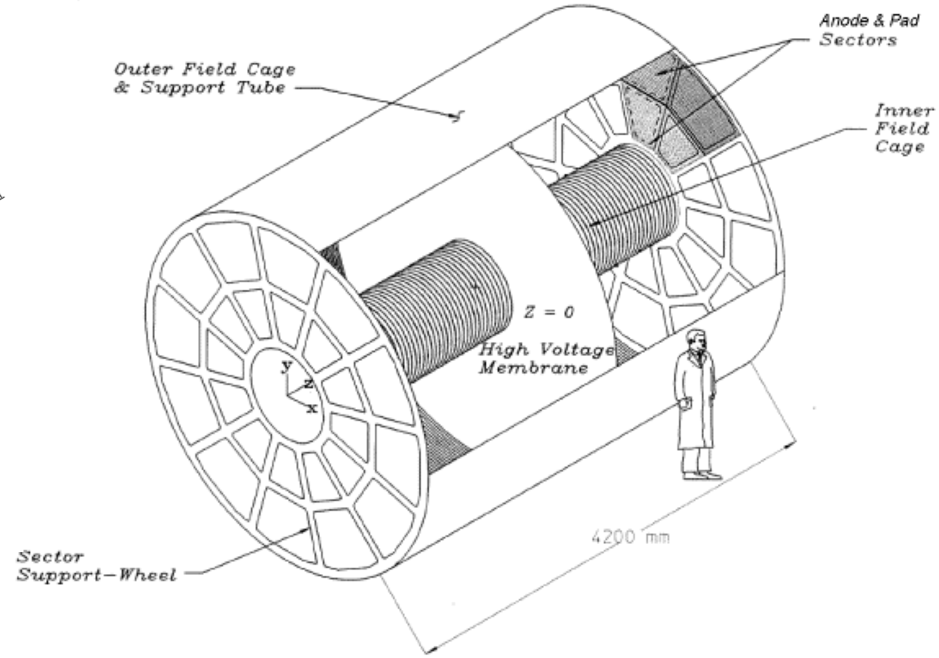
STAR and PHENIX

PHENIX



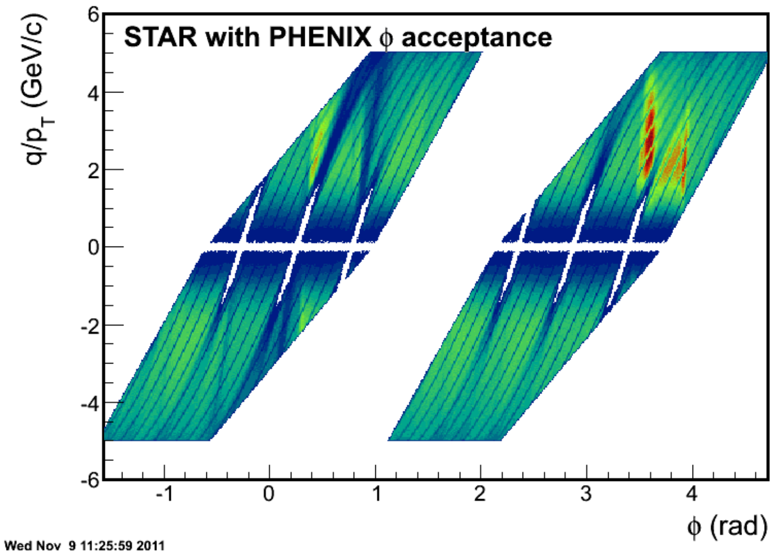


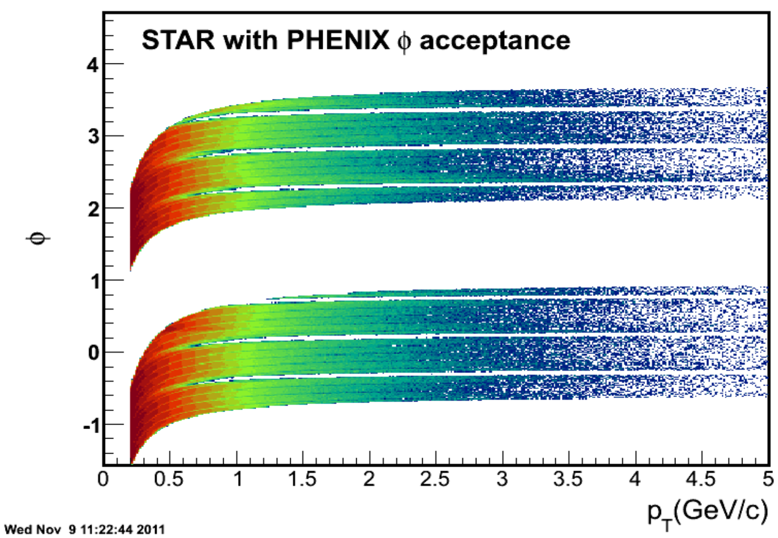
STAR



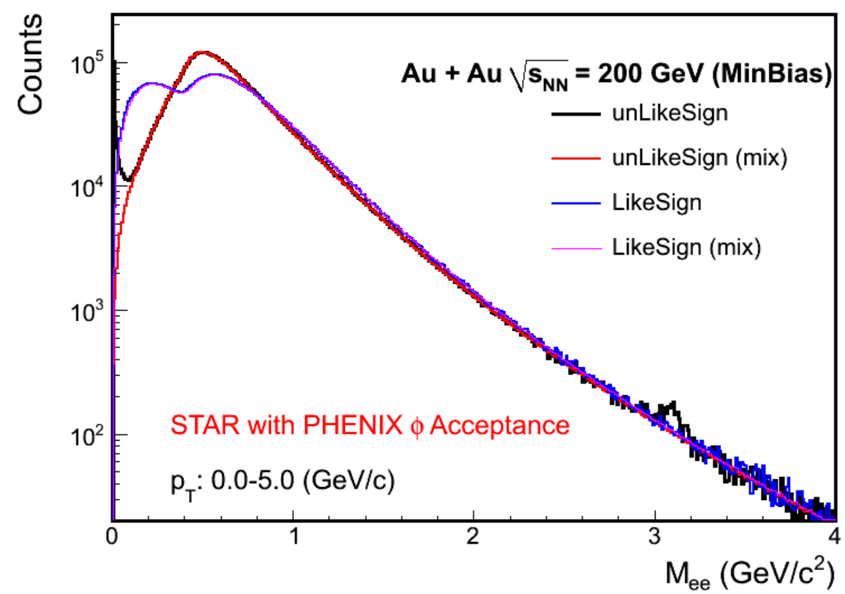
- **STAR**:
  12 sector east and west (in/out ,eta), 2π coverage, eta:+/-1
- **PHENIX**
  20 sector east and west arm, π coverage, eta:+/-0.35

STAR and PHENIX





PHENIX Acceptance, PhysRevC.81.034911

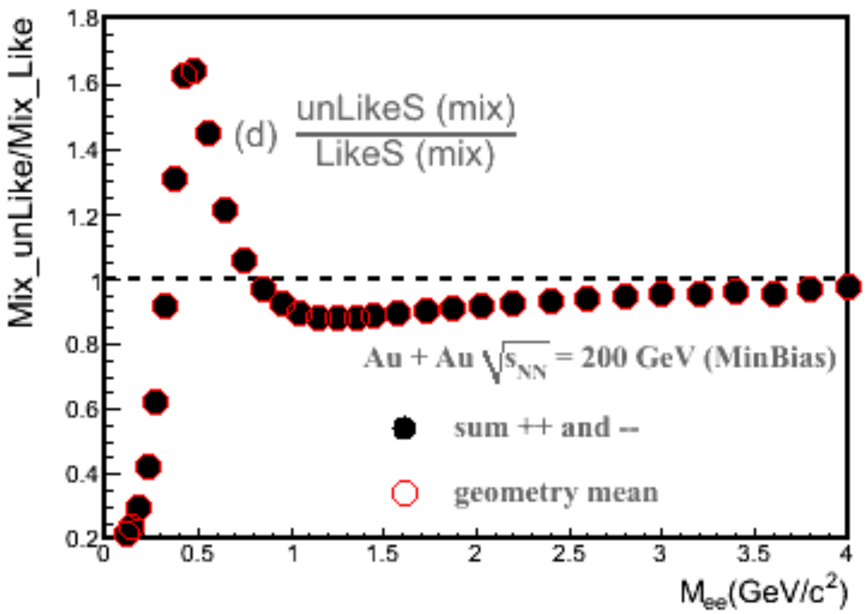


- **Signal track acceptance in ϕ direction**
- **ee pair mass distribution**

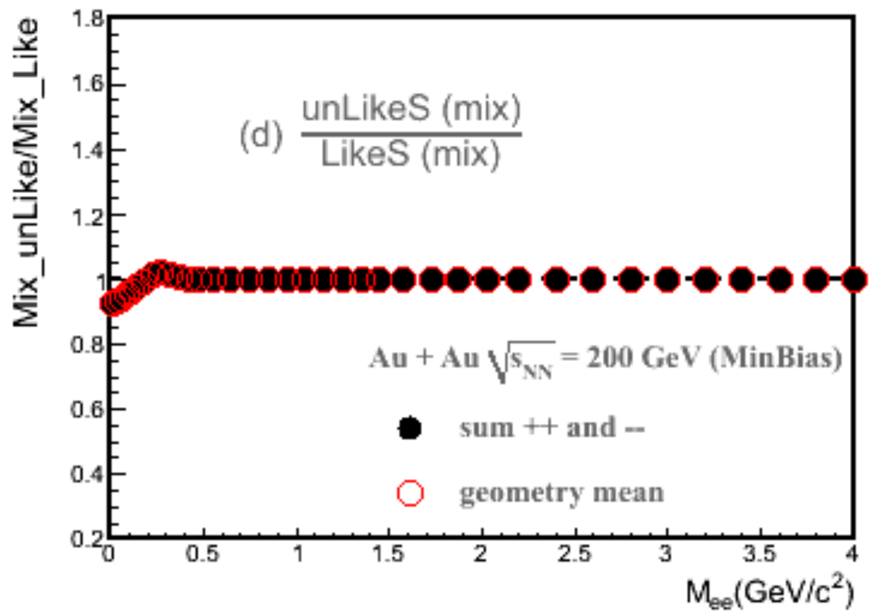
Like-Sign and unLike-Sign in same and mix event

STAR with PHENIX Φ acceptance

STAR with PHENIX Φ acceptance

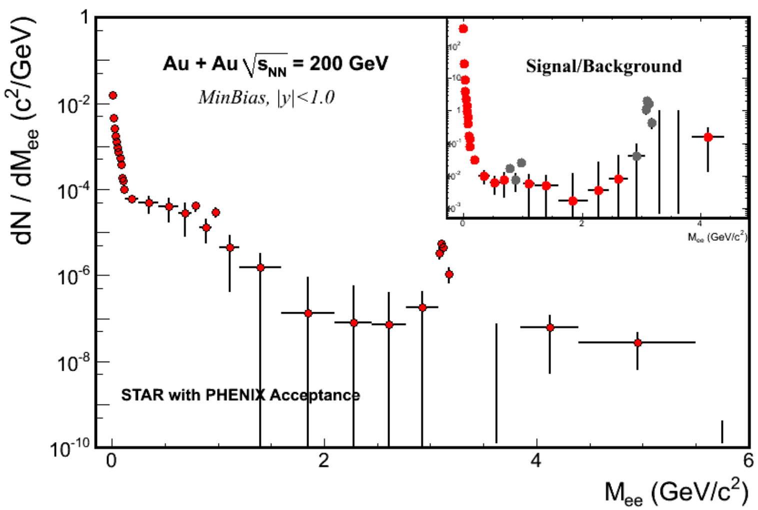


STAR

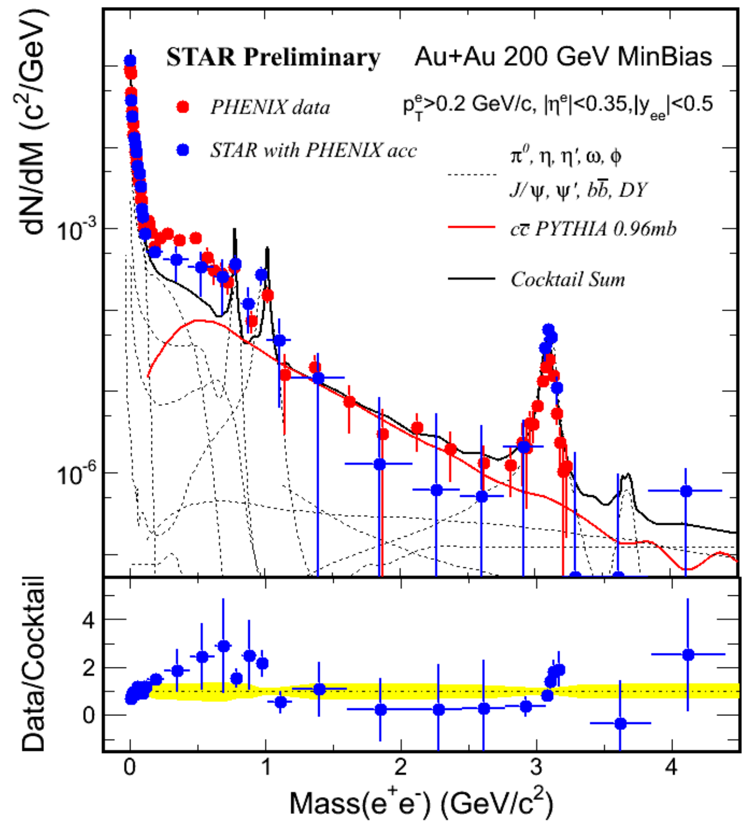


STAR with PHENIX acceptance

PHENIX Acceptance , PhysRevC.81.034911



Raw spectra



Efficiency correction

- **Signal track acceptance both in φ and rapidity direction**

  more data