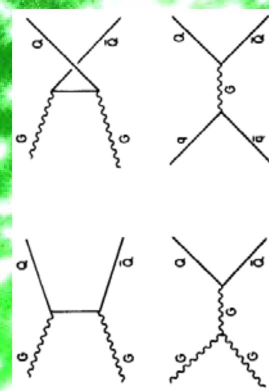
Experimental Results



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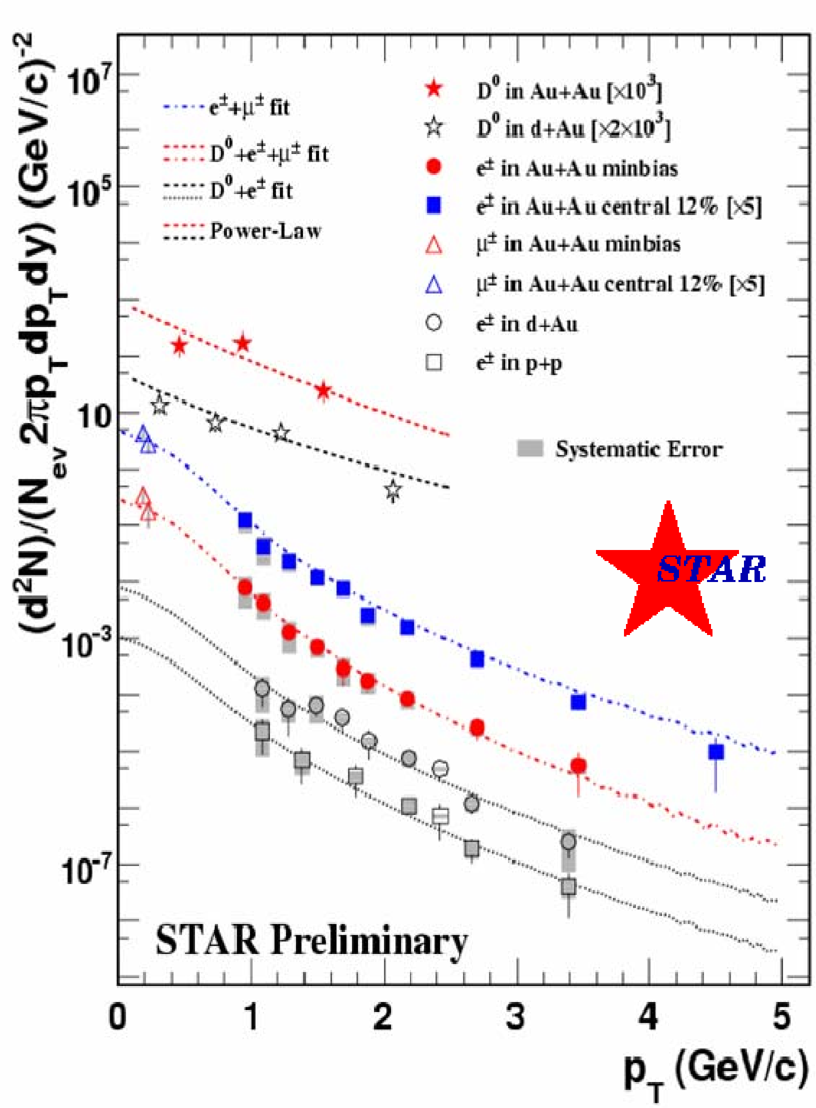
AGS/RHIC Users' Meeting 19/June/2007

Interest in Heavy Flavor

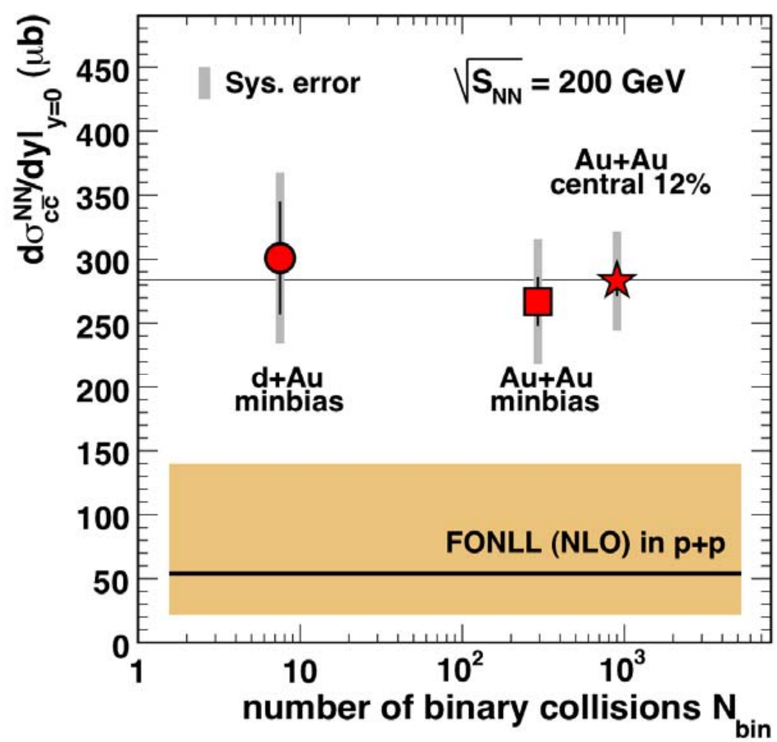
- Produced at initial impact
- Large mass: additional knob to probe QGP
  - Prediction: reduced energy loss ('dead cone' effect)
  - Prediction: quarkonium suppression
  - Heavy Quark flow: signature of thermalization
- Where are we with this program?

Charm Yields and Cross sections

$d\sigma^{NN}{}_{cc}/dy$ from p+p to A+A

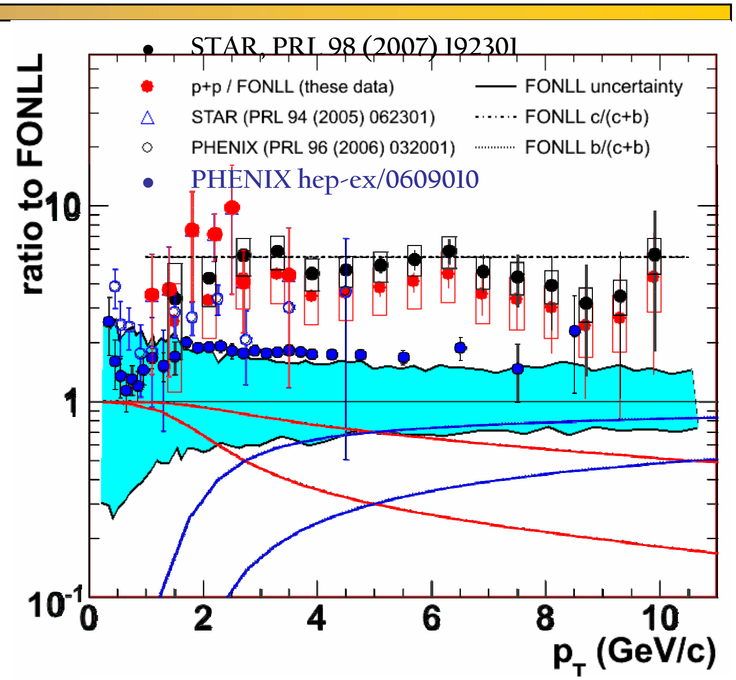


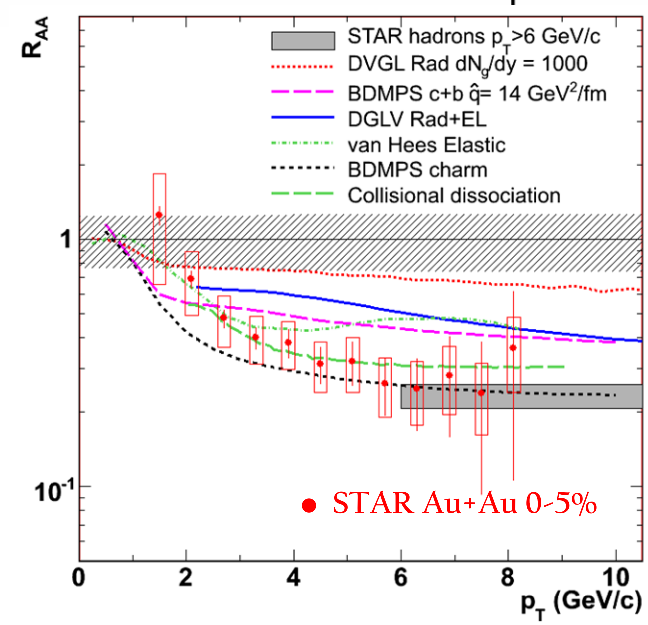
- D^0, e$^{\pm}$, and **μ**$^{\pm}$ combined fit
- Advantage: Covers ~95% of cross section
- Mid-rapidity $d\sigma^{NN}{}_{cc}/dy$ vs Nbin
- $\sigma^{NN}{}_{cc}$ follows binary scaling
  - Charm production from initial state (as expected)
- Higher than FONLL prediction in pp collisions.



Checking STAR electrons

- Discrepancy between STAR and PHENIX
  - Investigated method to estimate Photonic background. No issues found.
  - Reanalyzed from scratch
    - pp results change by ~25%
    - dAu results change by ~10%
    - AuAu results do not change
      - Within systematics
- Still difference btw. STAR & PHENIX
- R_{AA} still slightly below most c+b calculations.
- Future: low material run
  - Improve uncertainty on background
- Issue remains: no information on contribution from beauty.

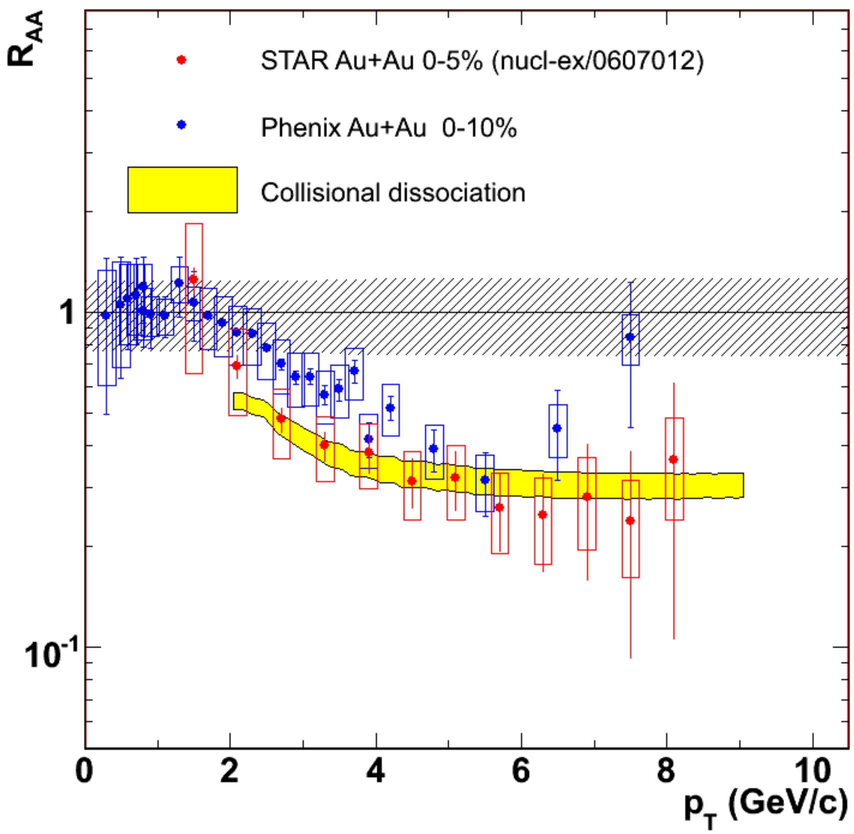




R_{AA} of electrons from heavy flavor decays

- ✯ PHENIX & STAR: rough agreement

→ disagreement is common to p+p & Au+Au, cancels in the nuclear modification factor R_{AA}

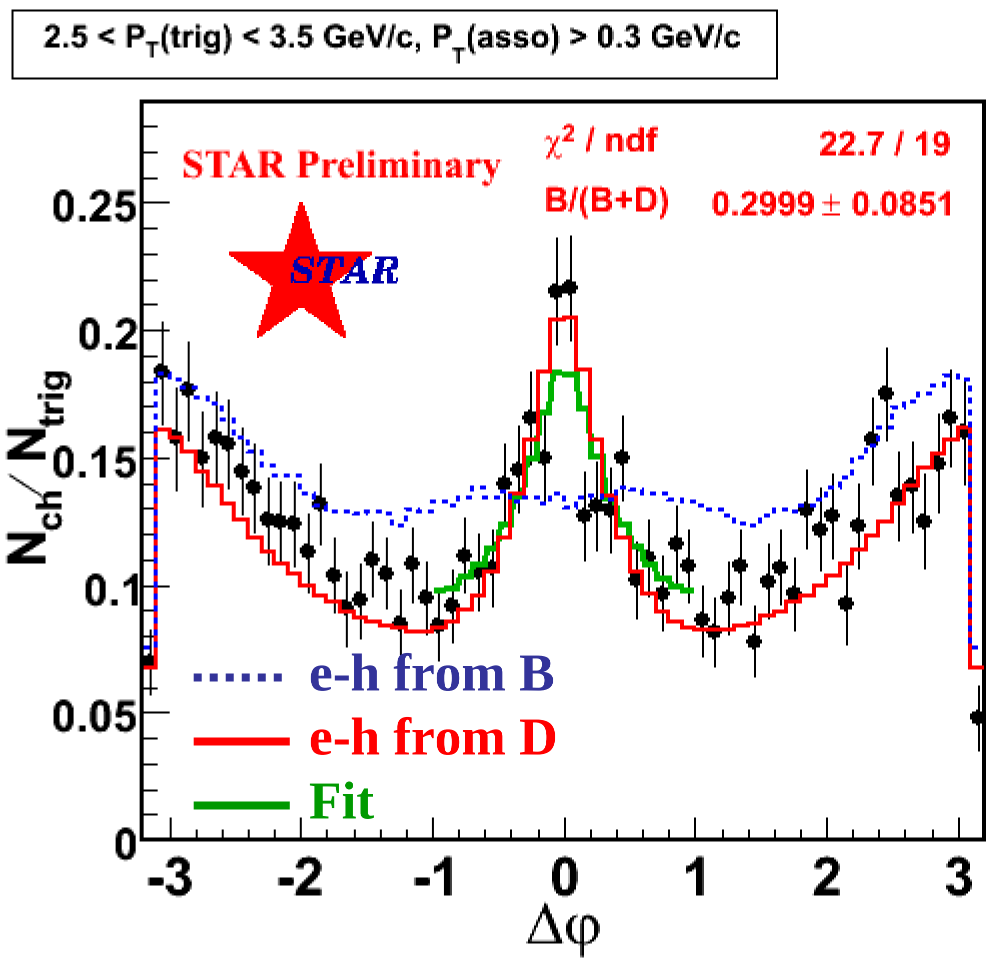


✧ describing the suppression is difficult for models

- radiative energy loss with typical gluon densities is not enough
  (Djordjevic et al., PLB 632(2006)81)
- models involving a very opaque medium agree better
  (Armesto et al., PLB 637(2006)362)
- collisional energy loss / resonant elastic scattering
  (Wicks et al., nucl-th/0512076,
  van Hees & Rapp, PRC 73(2006)034913)
- heavy quark fragmentation and dissociation in the medium → strong suppression for charm and bottom
  (Adil & Vitev, hep-ph/0611109)

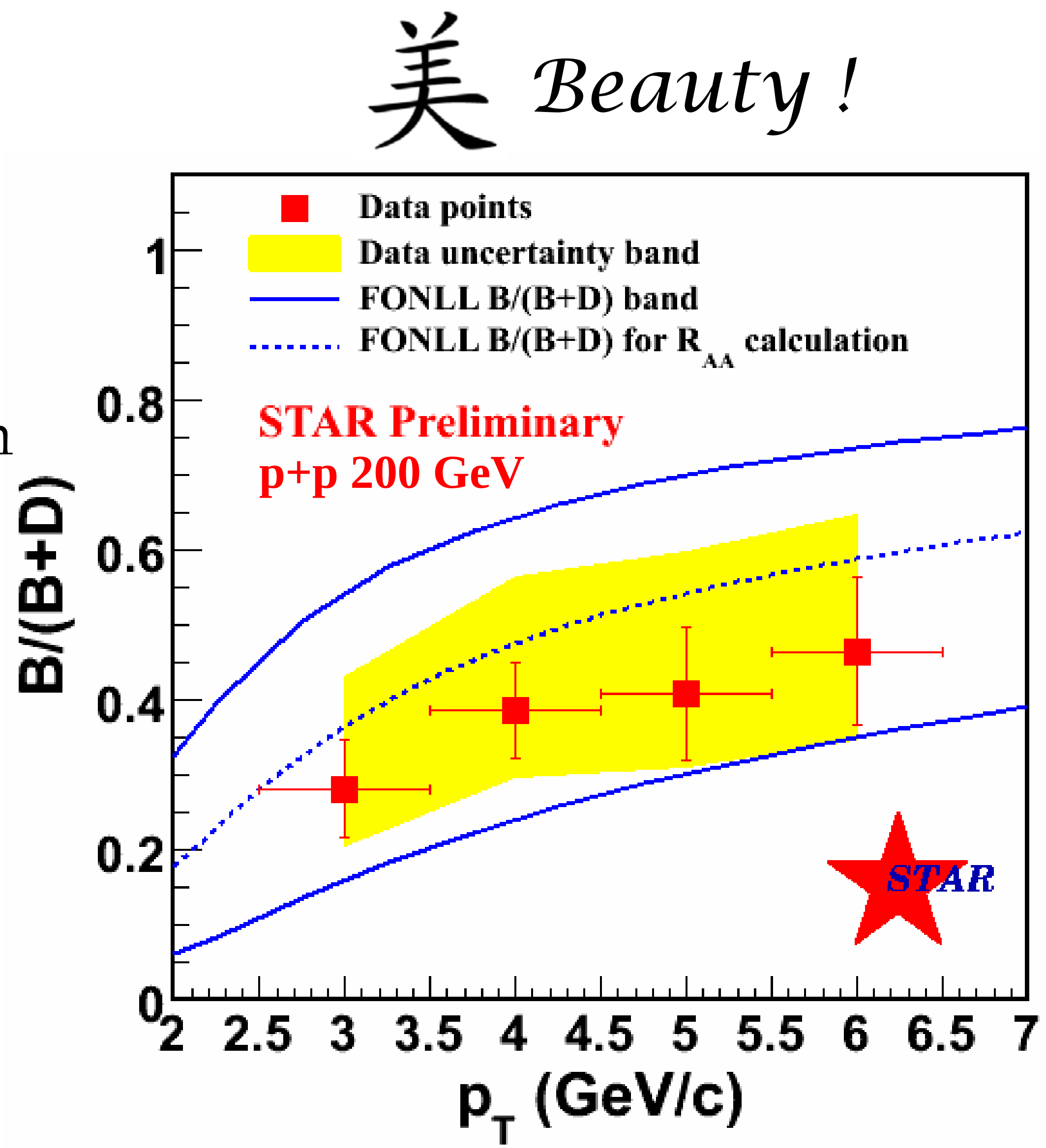
Can we tell how much beauty?

- Use e-h Correlation
  - Large B mass compared to D
  - Semileptonic decay: e gets larger kick from B.
  - Broadened e-h correlation on near-side.
- Extract B contribution
  - Use PYTHIA shapes
    - Con: Model dependent
    - Pro: Depends on decay kinematics →well described
  - Fit ratio B/(B+D)

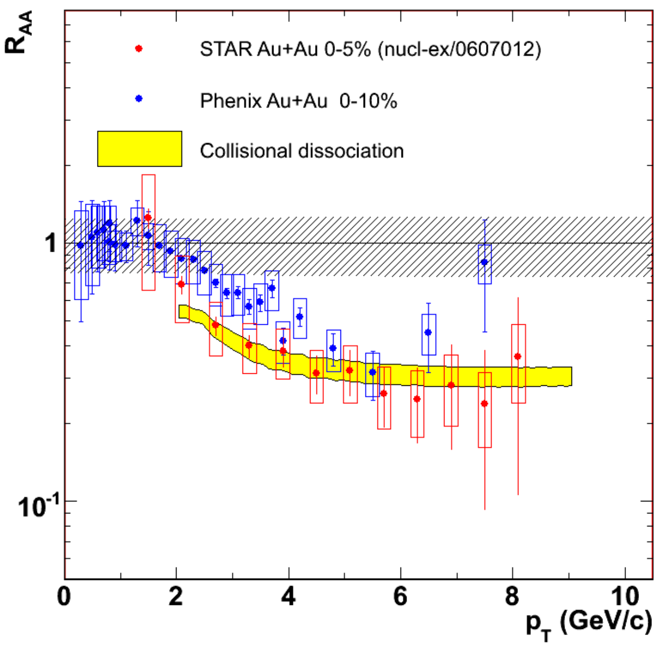


B contribution to NP electrons vs. p_T

- Fit e-h correlation with PYTHIA Ds and Bs
- Non-zero B contribution
- Contribution consistent with FONLL
  - Model dependent (PYTHIA)
  - Depends mainly on kinematics of D/B decay (not on Fragmentation).
- Dominant systematic uncertainty:
  - photonic background rejection efficiency
  - Additional uncertainties under study



R_{AA} and B/(B+D) implication



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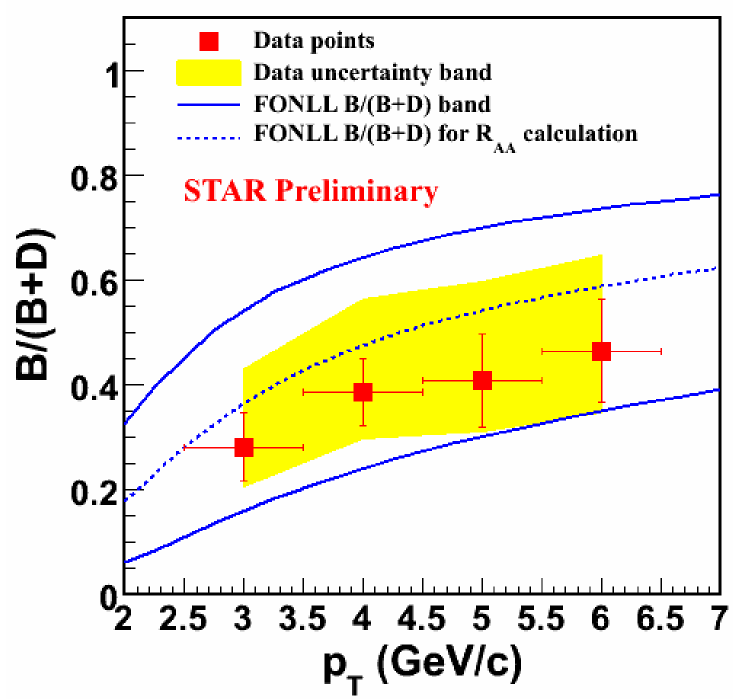


= B suppression

- **If**, NPE electrons are suppressed in AA wrt pp
- **and** B fraction is ~30-40% in pp **and also in AA**
- **then**, suppressing only charm contribution NPE does not work:
  - Need to suppress B contribution as well!

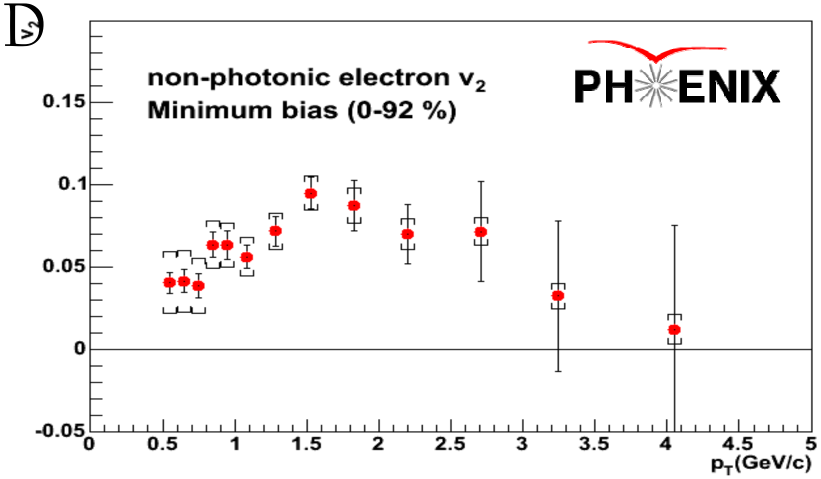
Charm Flow

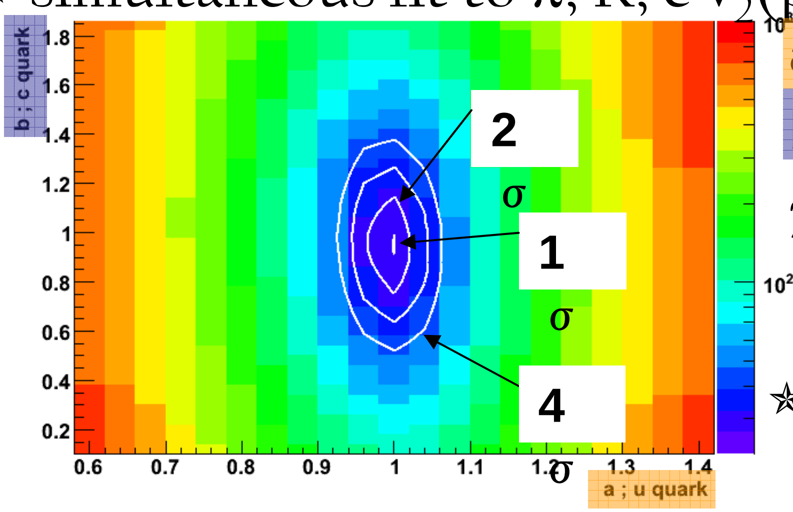
Does charm flow?

- strong elliptic flow of electrons from D meson decays → $v_2^D > 0$
- v_2^c of charm quarks?
- recombination Ansatz:
  (Lin & Molnar, PRC 68 (2003) 044901)

$$v_2^D(p_T) = a v_2^q\left(\frac{m_u}{m_D} p_T\right) + b v_2^q\left(\frac{m_c}{m_D} p_T\right) \to v_2^e$$

- universal $v_2(p_T)$ for all quarks
- simultaneous fit to π, K, e $v_2(p_T)$

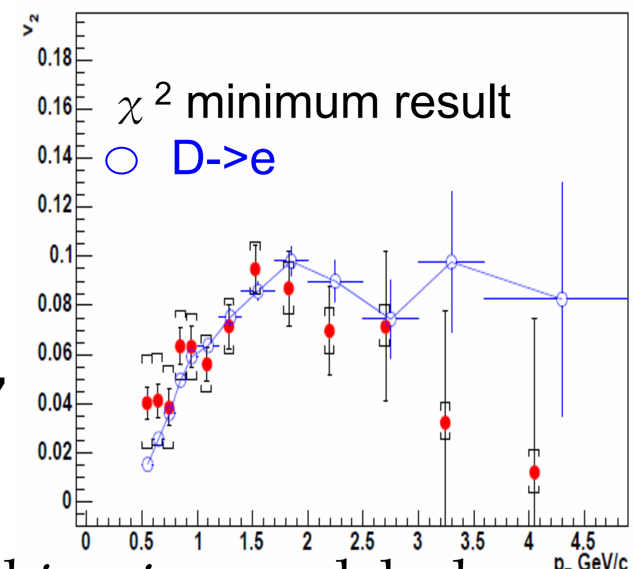




a = 1

b = 0.96

χ^2/ndf: 21.85/27

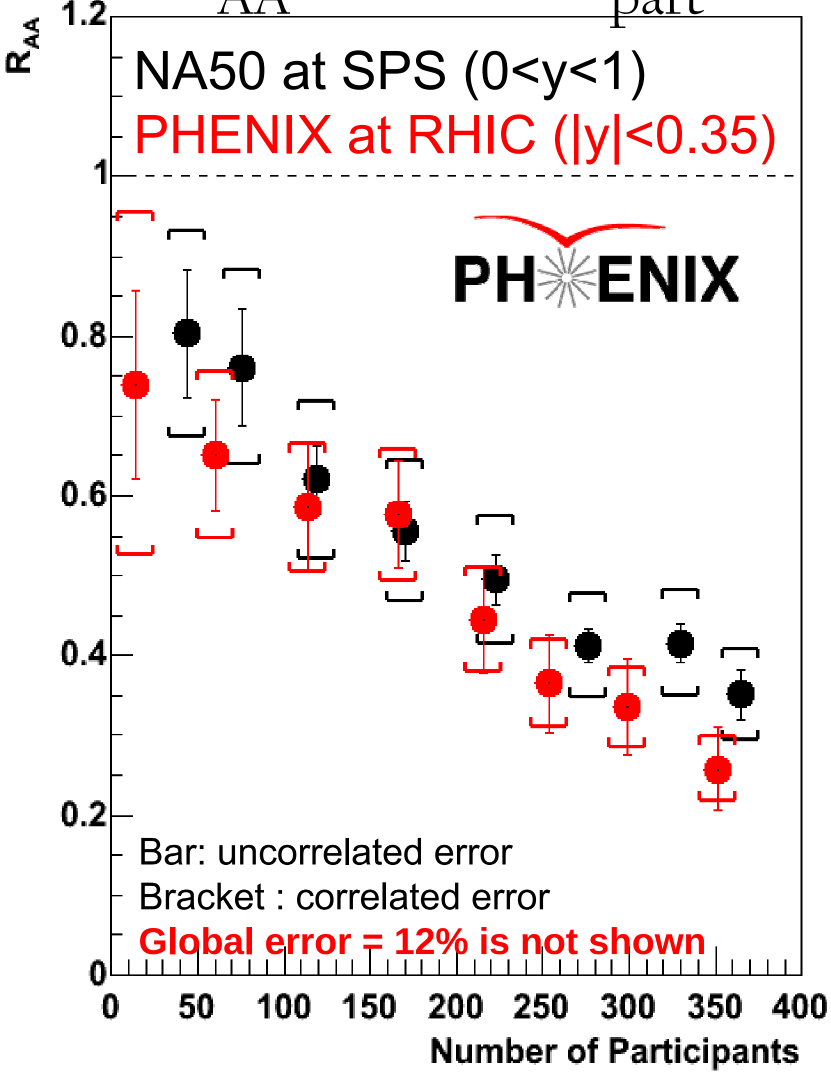


- within recombination model: charm flows as much as light quarks
  - implications: thermalization?

Quarkonium

J/ψ suppression: SPS vs. RHIC

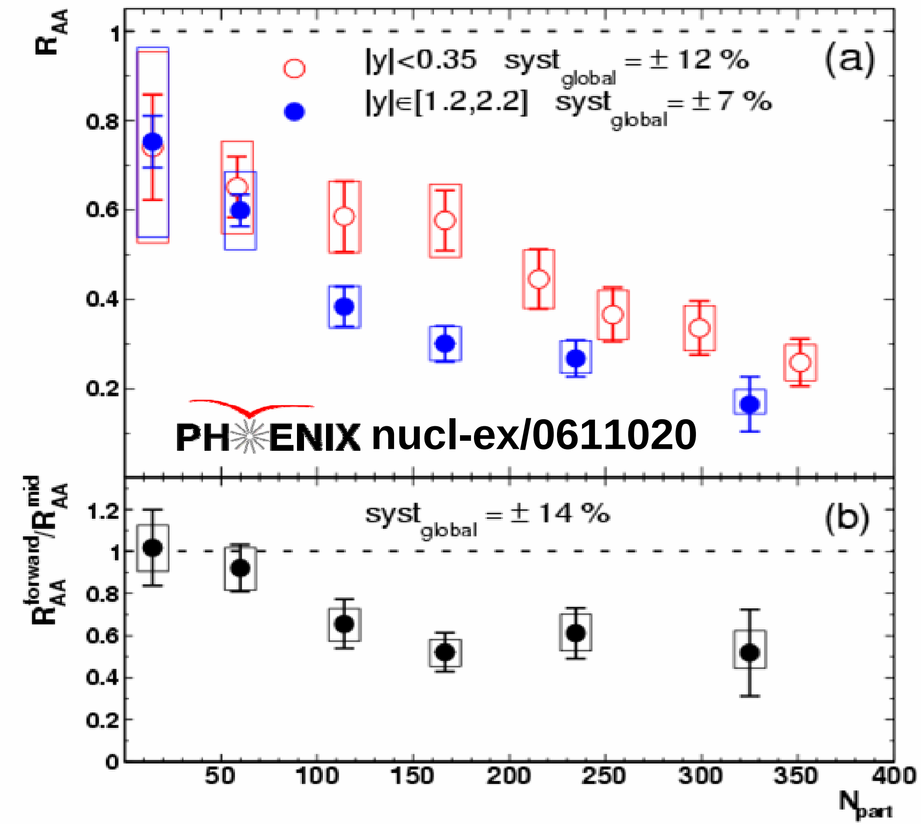
- R_{AA} versus N_{part}



- J/ψ suppression pattern
  - Pb+Pb from NA50 (0<y<1)
  - Au+Au from PHENIX (|y|<0.35)
  - Extremely Similar!!
- Is it a coincidence?
  - cold nuclear matter effects: (slightly) larger at SPS than at RHIC
    - need more d+Au data
    - plus recombination at RHIC?
- 'sequential dissociation' at SPS and RHIC?
  - J/ψ survives well above T_c
  - dissociation of ψ' and χ_c
    - feed down not well constrained (~40 %)
    - χ_c hard to measure

J/ψ at RHIC: rapidity dependence

- R_{AA}: rapidity dependence



- p+p ref. and Au+Au data
  - → rapidity and p_T spectra challenge for production models
- more suppression at forward rapidity!
  - opposite to trend from co-mover or CNM absorption
    - more co-movers at y~0
  - suppression not only driven by local particle density
  - more regeneration at y~0?
  - gluon saturation at forward y?
- models
  - no clear picture yet, but important new constraints
  - two (or more) ingredients needed to describe suppression pattern
    - suppression + regeneration
    - sequential dissociation + saturation

Sequential Screening

(Karsch, Kharzeev, Satz, hep-ph/0512239)

Sequential screening only of the higher-mass resonances that feed-down to the J/ψ; with the J/ψ itself still not dissolved?

. supported by recent Lattice calculations that give $T_{J/\psi} > 2\ T_C$

.gives similar suppression at RHIC & SPS (for mid-rapidity)

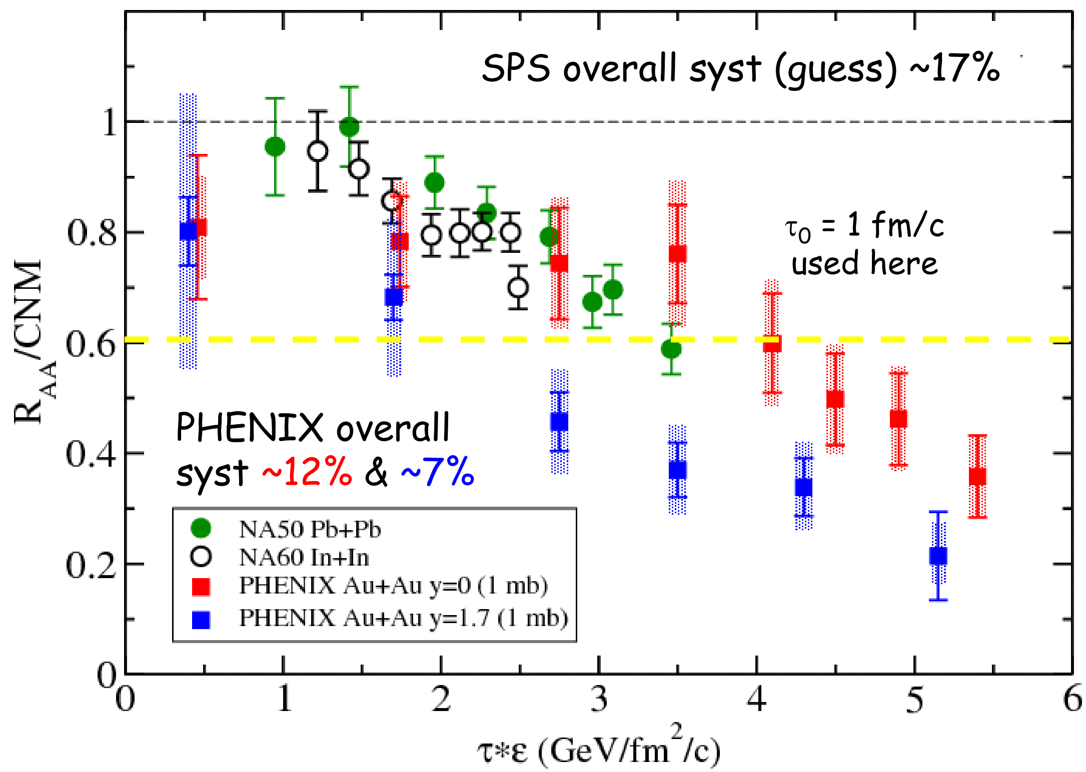
Quarkonium dissociation temperatures – Digal, Karsch, Satz

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

But carefull! Hard to know how to set relative energy density for RHIC vs SPS

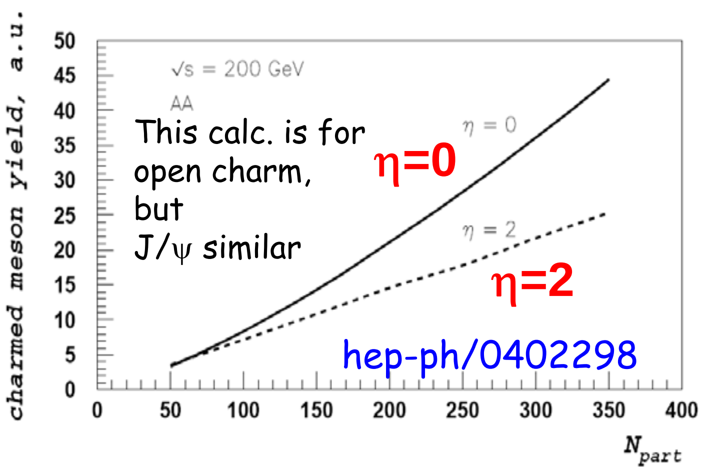
$$\epsilon_{Bj} = \frac{dE_T}{dy}\frac{1}{\tau_0 \pi R^2}$$

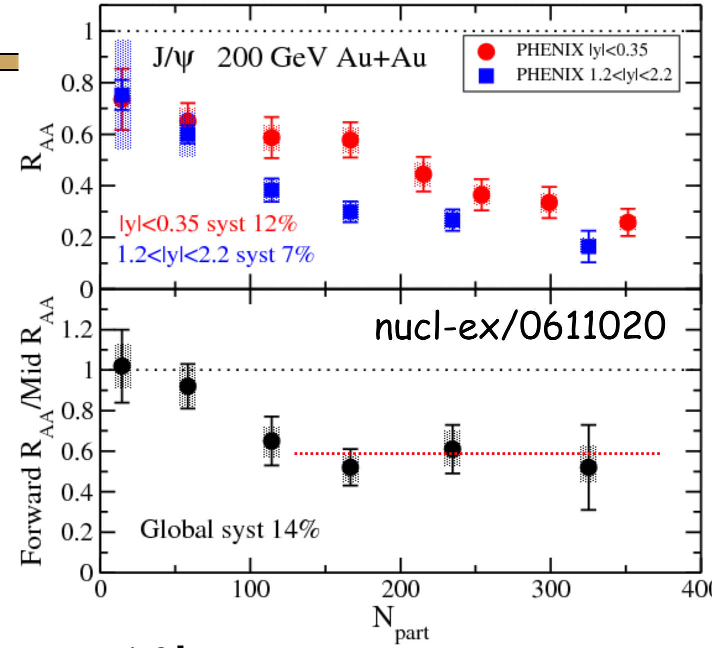
- τ_0 > 1 fm/c @ SPS?
  - 1.6 fm/c crossing time
- τ_0 smaller @ RHIC?



- Suppression stronger than possible from ψ′, χ_C alone?
- Gluon saturation can lower forward relative to mid-rapidity?

Sequential Screening Scenario

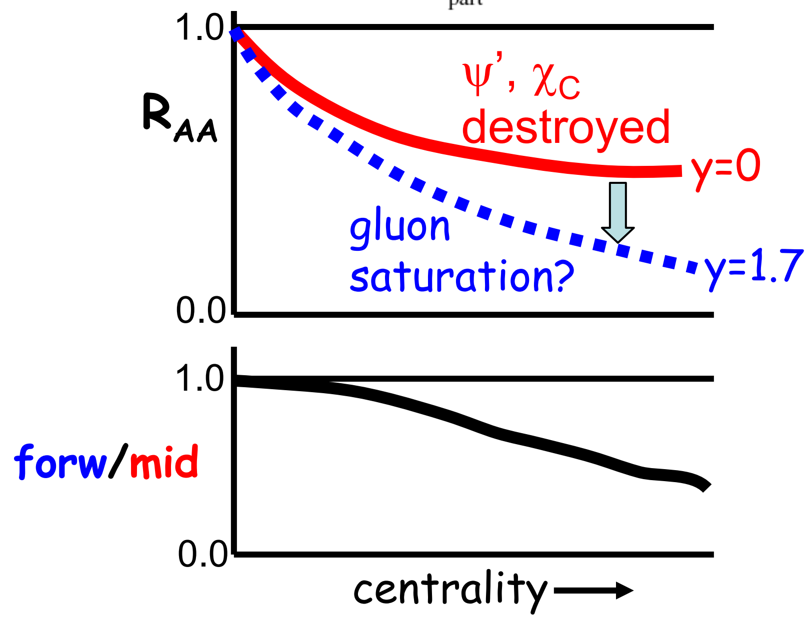




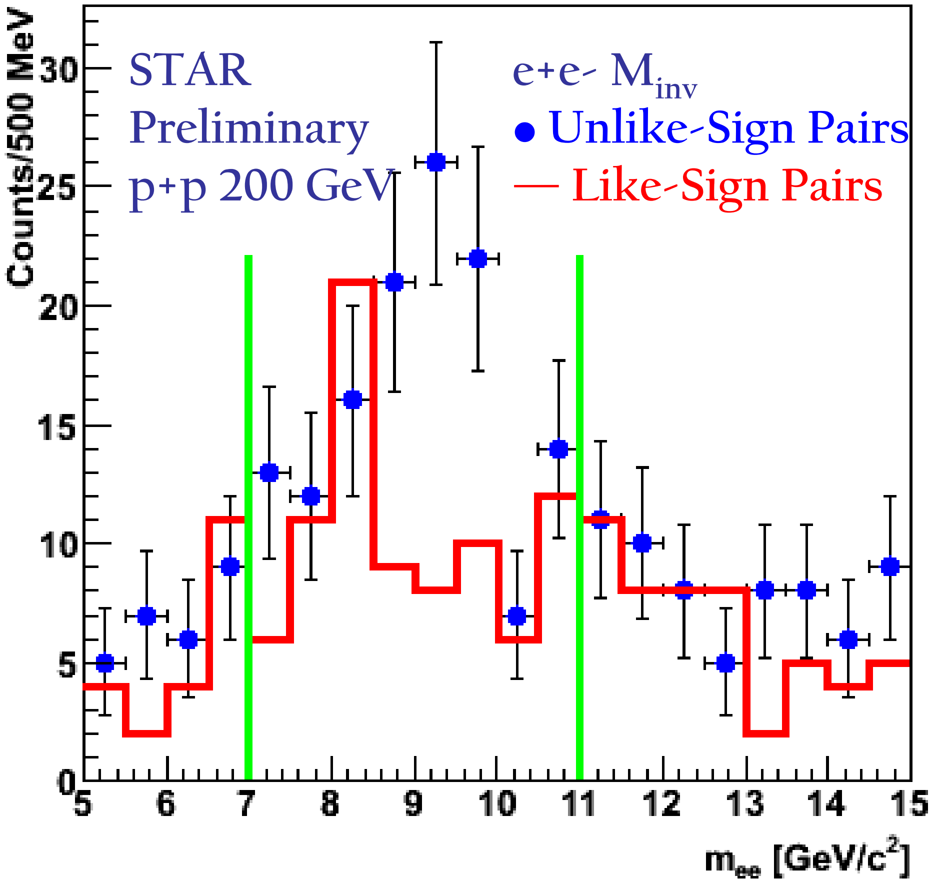
- QGP suppression of χ_C, ψ'

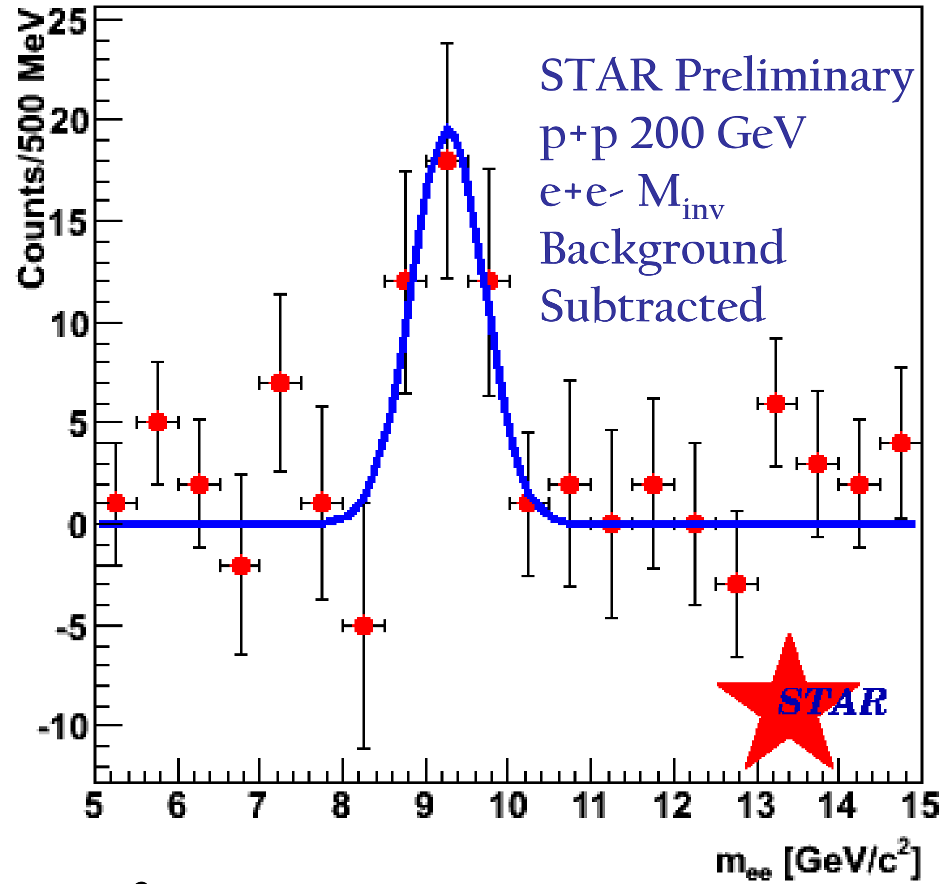
+ additional forward suppression from gluon saturation (CGC)

but approx. flat forward/mid above N_{part} ~ 100 seems inconsistent – forward should drop more for more central collisions as gluon saturation increases



More Beauty: ϒ signal in p+p

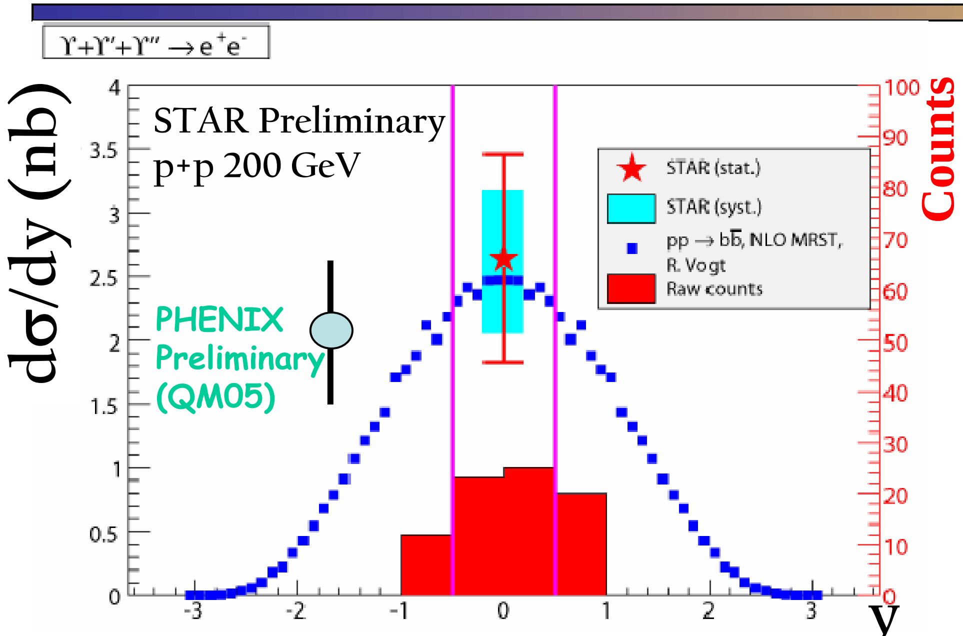


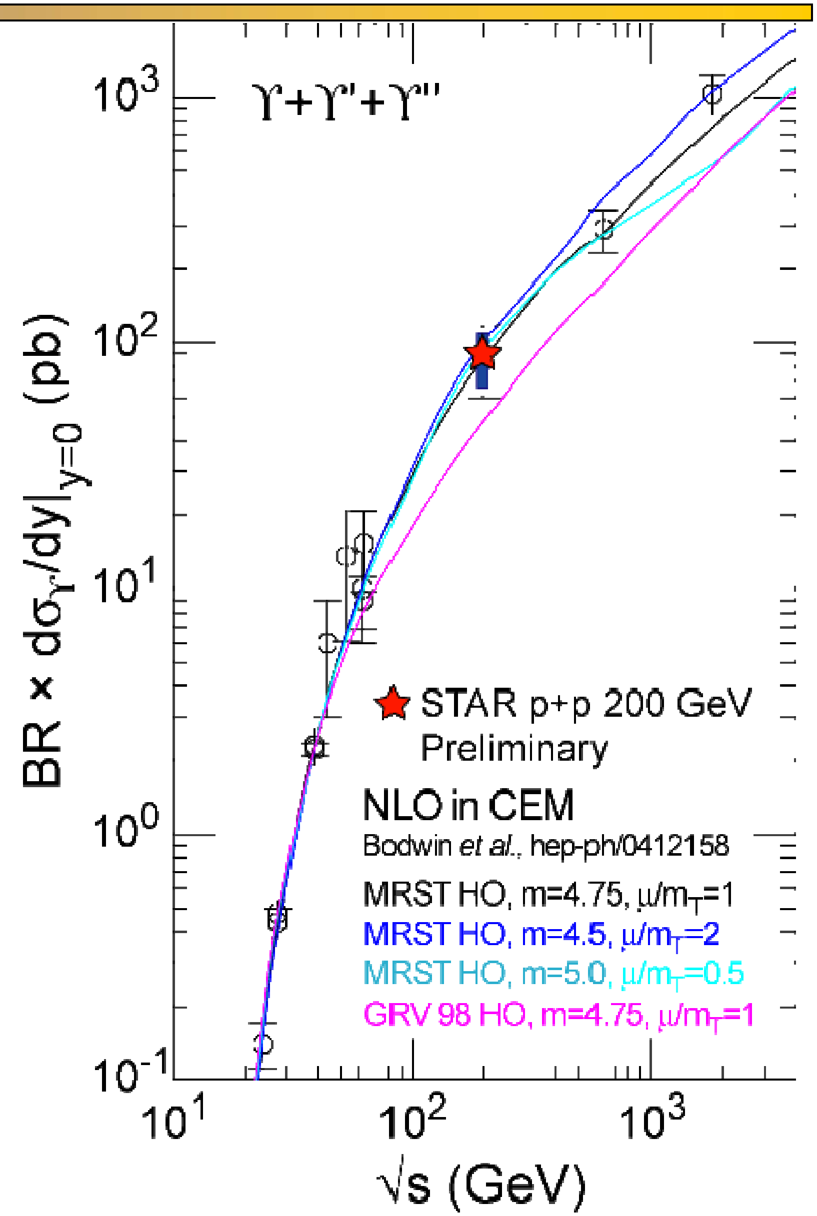


$$\int \mathfrak{L} dt = 9 pb^{-1}$$

- Large dataset sampled in Run VI
  - Luminosity limited trigger
  - Analyzed 5.6 pb^{-1}, with corrections.
- Measure ϒ(1s+2s+3s) dσ/dy at y=0

Mid-rapidity ϒ(1s+2s+3s) Cross section





- Integrate yield at mid-rapidity: |y|<0.5
- ϒ(1s+2s+3s) BR * dσ/dy
  - $91 \pm 28_{stat} \pm 22_{syst}$ pb^{-1} (Preliminary)
- Consistent with NLO pQCD calculations at midrapidity.
- Phenix + STAR Preliminary points:
  - Broader rapidity distribution?

Conclusions and Outlook

- Charm
  - pp, AA, dAu NPE, open charm
  - Still difference of ~2 btw STAR and PHENIX.
    - STAR Larger than NLO by ~4,
    - PHENIX at the top of NLO theoretical uncertainty
  - Flow: In recombination model, c quark flows like light quark.
  - Future:
    - low material run in STAR
    - open charm reconstruction in PHENIX and STAR w/ vertex detectors
- Beauty:
  - **Non-zero beauty contribution to non-photonic electrons**
  - **Together with AuAu NPE electron suppression:**
    - **Beauty suppression in Au+Au at RHIC ?!**
  - **Future handles to find B fraction via B decay geometry**
    - **Displaced electron+kaon DCA to primary vertex**
    - **Azimuthal correlation between electron+kaon**
- Quarkonium
  - **J/ψ : Larger suppression forward.**
    - **Need to invoke 2 or more mechanisms**
      - » **Melting of χ_C, ψ' + gluon saturation**
      - » **Suppression + Regeneration at midrapidity**
    - **Explanations don't match observed behavior vs centrality.**
  - **Υ(1s+2s+3s) in p+p**:
    - **Consistent with pQCD at y=0**.
    - Maybe wider than pQCD forward?