Heavy-Flavor at STAR

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Outline:

- Introduction
- Open Heavy Quarks
  - brief reviews
  - New progresses
- J/ψ, ϒ results
- Outlook

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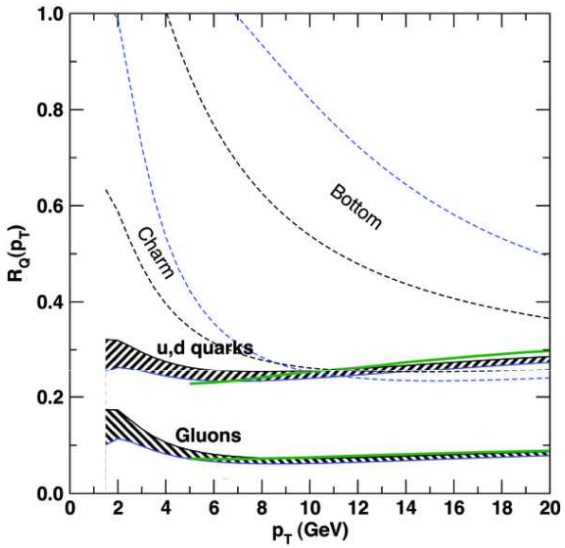
a passion for discovery

Office of Science U.S. DEPARTMENT OF ENERGY

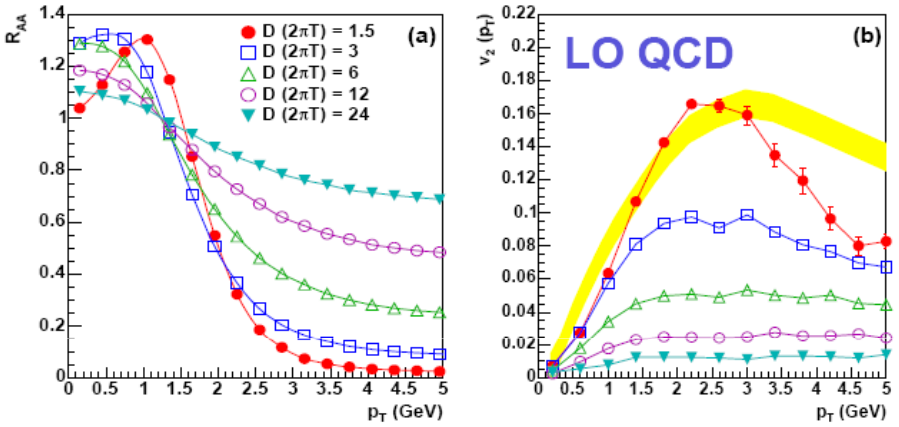
Heavy Quark Energy loss and thermalization

Deadcone effect of Energy loss



Y.L. Dokshitzer, D. Kharzeev, PLB519(2001)199
WHDG, arXiv:nucl-th/0512076

Brownian motion in thermal system



G. Moore, D. Teaney PRC 71 (2005) 064904;
H. Van Hees, R. Rapp PRC 71 (2005) 034907

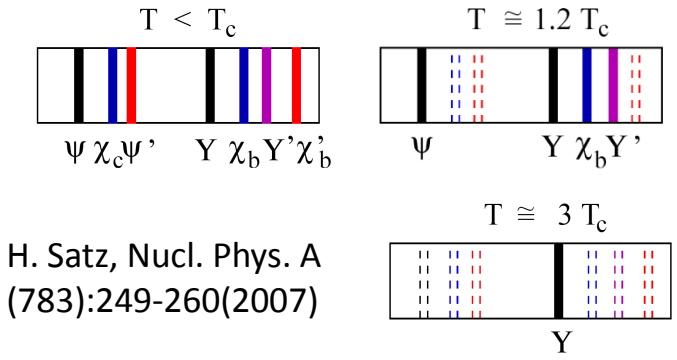
Upper bound on escaping parton p

D.E. Kharzeev, arXiv:0806.0358,0809.3000

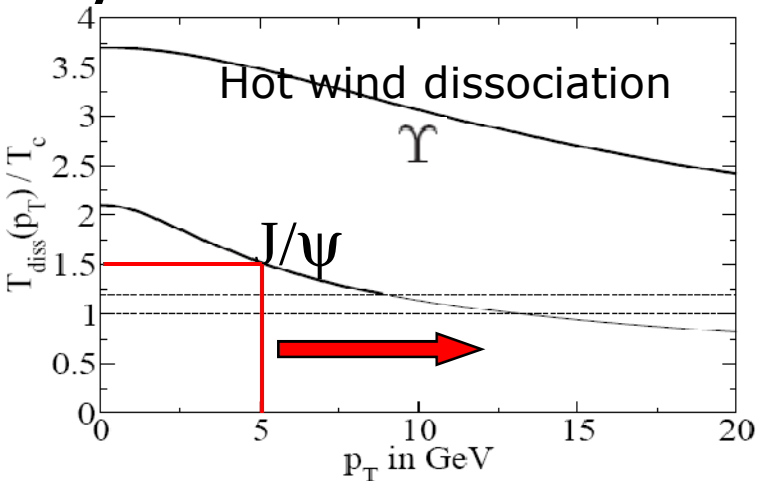
Heavy object in sQGP with AdS/CFT

H. Liu, K. Rajagopal and U.A. Wiedemann PRL 97, 182301(2006)
J. Casalderrey-Solana, D. Teaney PRD 74(2006) 085012

Quarkonium in heavy ion collisions



H. Satz, Nucl. Phys. A (783):249-260(2007)

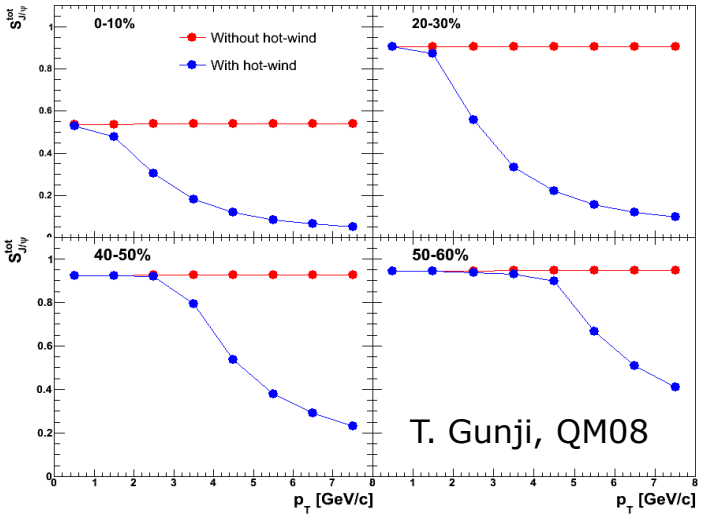


H. Liu, K. Rajagopal and U.A. Wiedemann
PRL 98, 182301(2007) and hep-ph/0607062
M. Chernicoff, J. A. Garcia, A. Guijosa hep-th/0607089

J/ψ suppression at low p_T could be from suppressed excited states (ψ', χ_c)
F. Karsch, D. Kharzeev and H. Satz, PLB 637, 75 (2006)

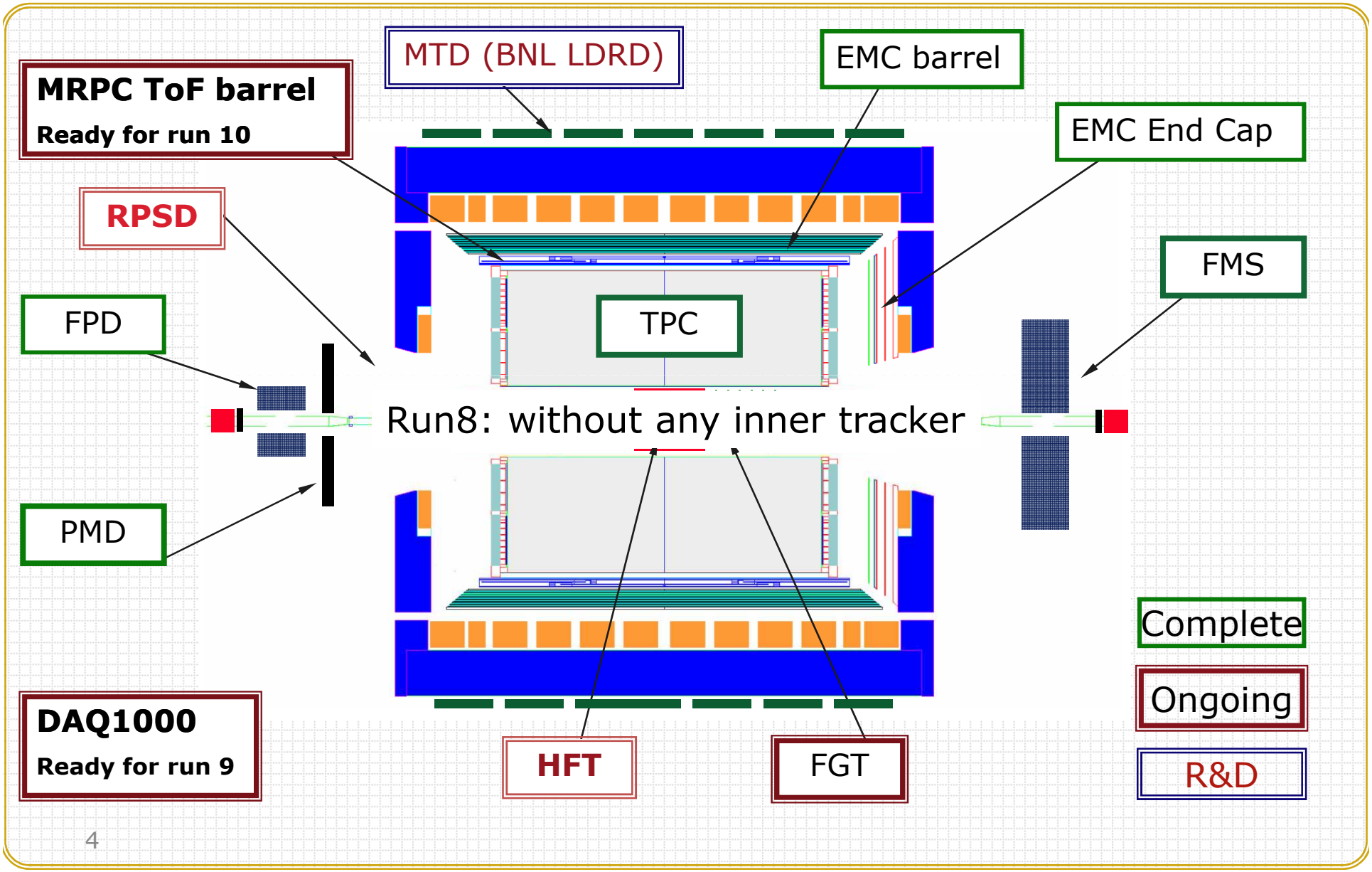
High p_T direct J/ψ suppression ➔ related to hot wind dissociation?

2-component approach
Dissociation+recombination
X. Zhao and R. Rapp, hep-ph/07122407



Color singlet model predicted an increase R_{AA}
(formed outside of medium)
K. Farsch and R. Petronzio, PLB 193(1987), 105
J.P. Blaizot and J.Y. Ollitrault, PLB 199(1987),499

The STAR Detector

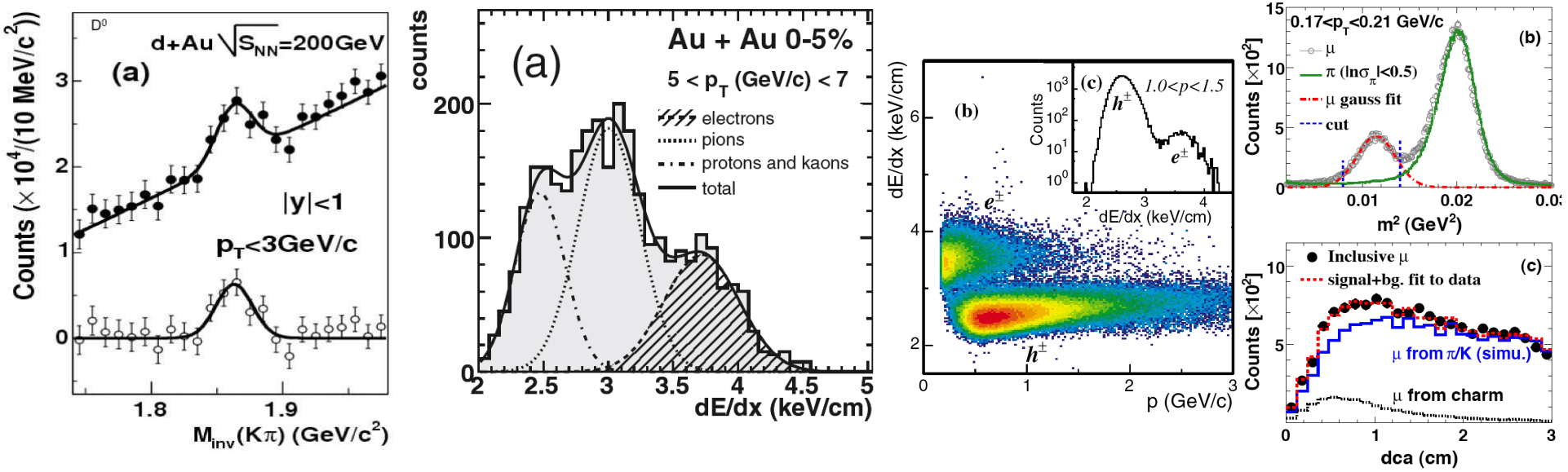


Measurements of inclusive open charm and bottom

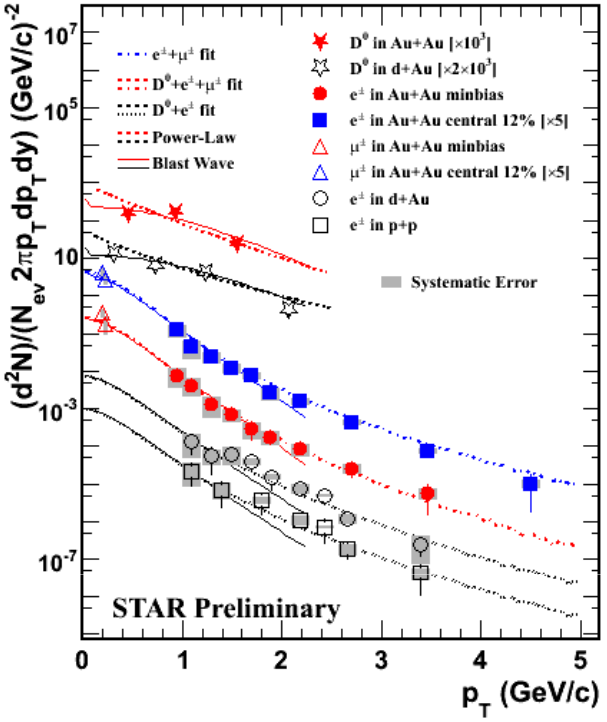
	D reconstruction	non-photonic electrons			low p_T muons
Sub-systems	TPC	TPC+TOF	TPC	TPC+EMC	TPC+TOF
p_T coverage (GeV/c)	$\sim 0.1-3$	$\sim 0.8-4$	$\sim 2-4$	$\sim 2-10$	$\sim 0.17-0.25$
$p+p$	–	✓	✓	✓	–
$d+\mathrm{Au}$	✓	✓	✓	✓	–
Cu + Cu	✓	–	–	✓	–
Au + Au	✓	✓	–	✓	✓

PRL94(2005)062301; PRL98(2007)192301; arXiv: 0805.0364

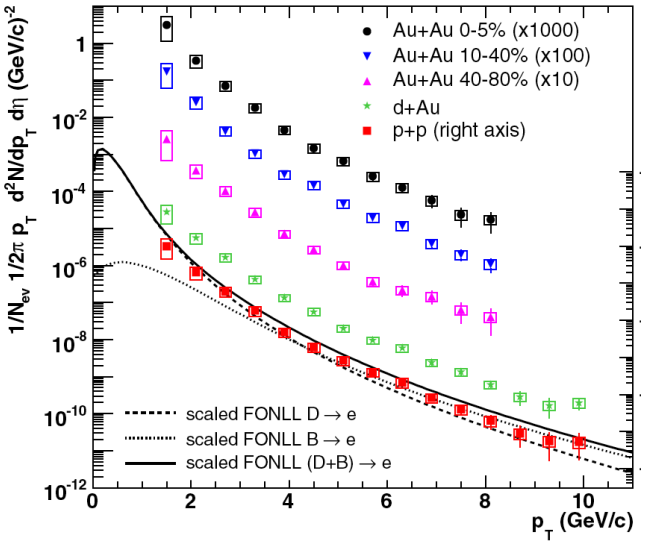
Xin Dong HP2008

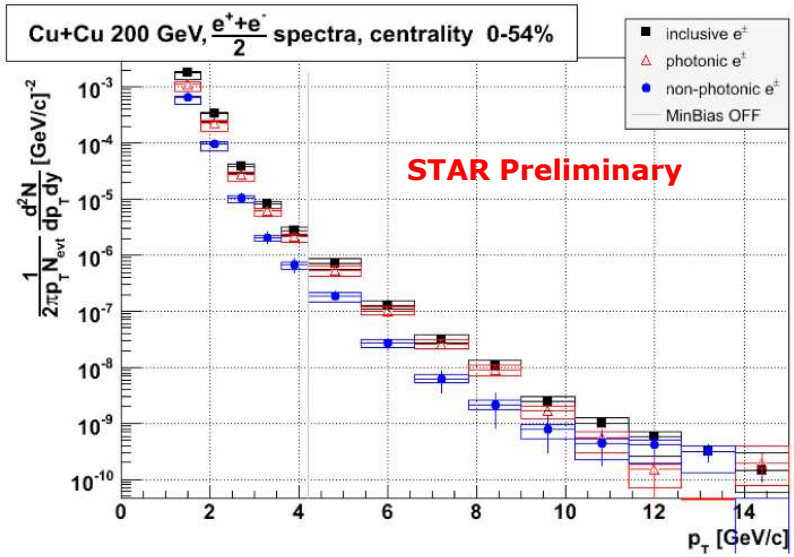


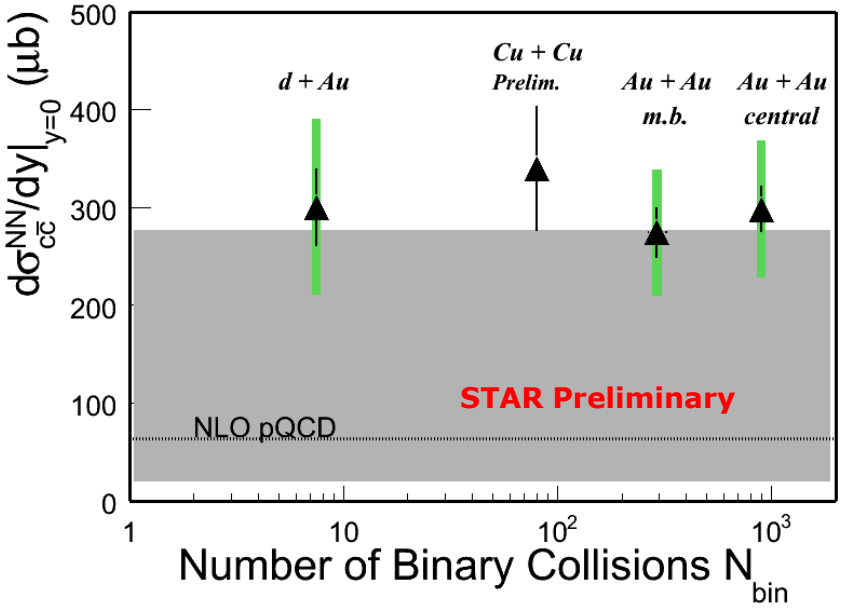
Inclusive Spectra



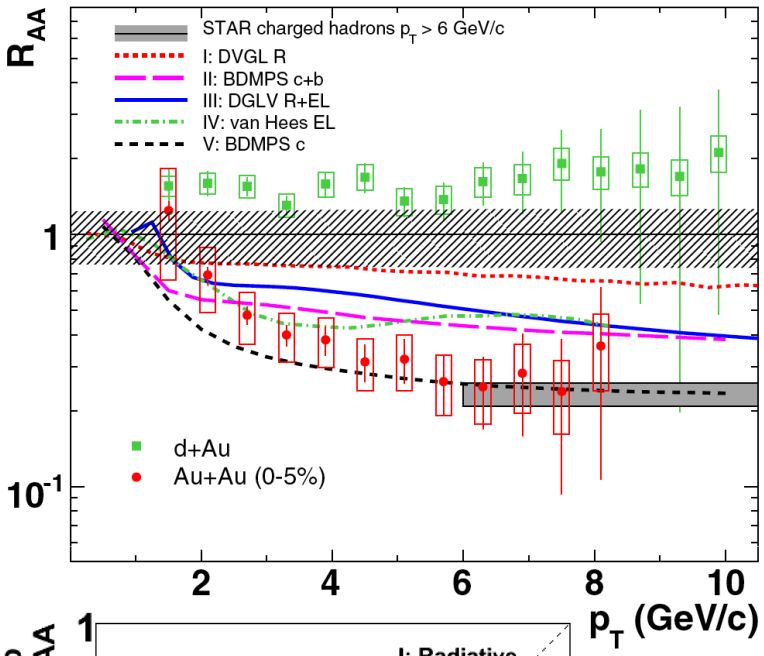
Species:
p+p, d+Au, Cu+Cu, Au+Au
Momentum range:
0<pt<10 GeV/c
Rapidity:
-0.5<y<0.5
Particles:
D0, e, μ

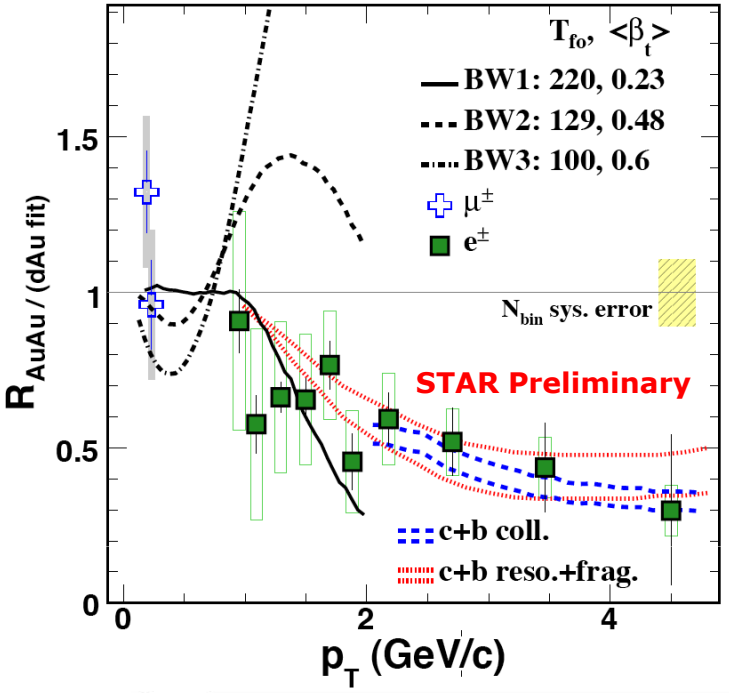


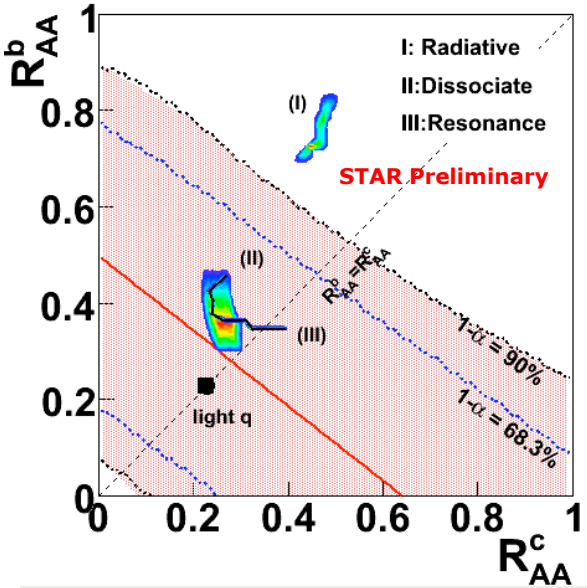




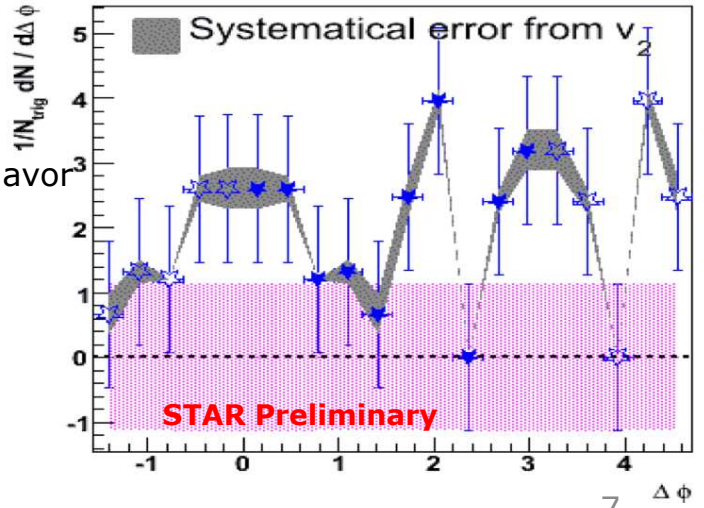
Energy loss and thermalization



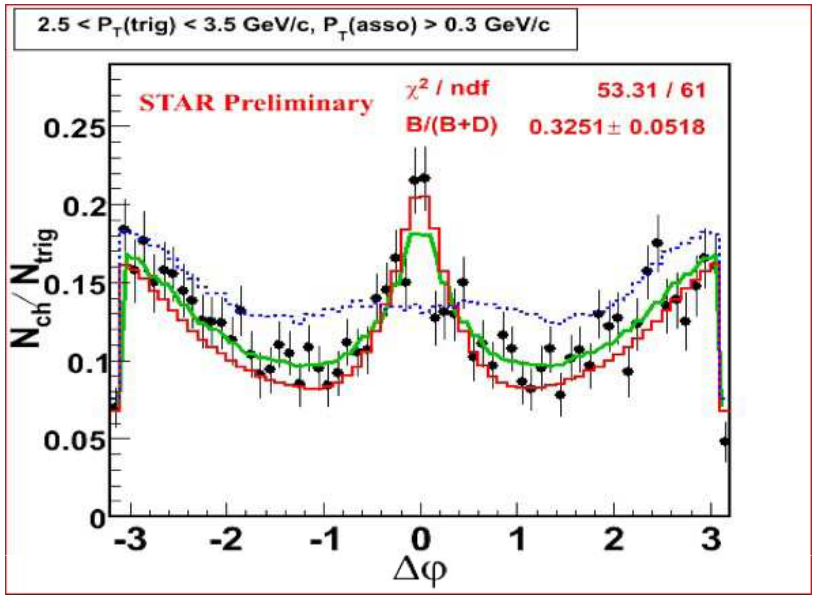


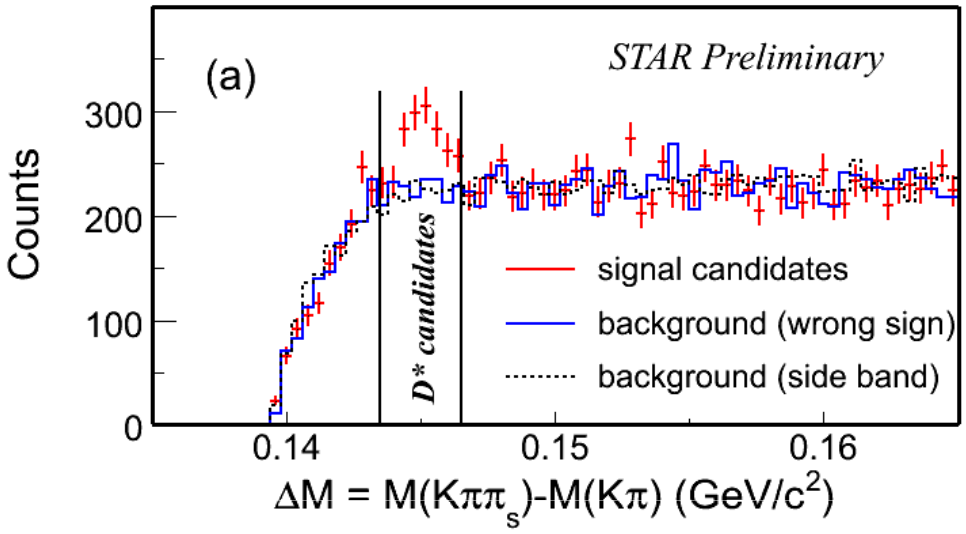


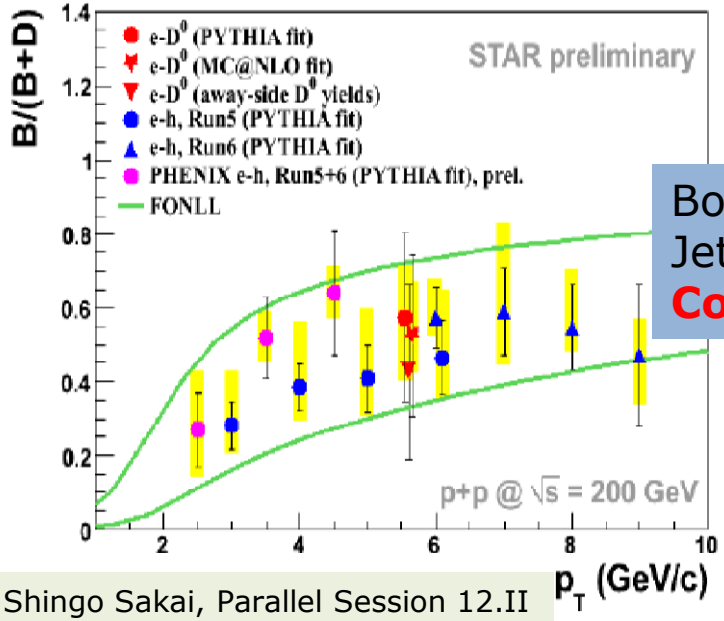
- Heavy quark suppression ~= light flavor
- Charm freeze out early
  (finite diffusion constant)
- Away-side exhibits broad structure



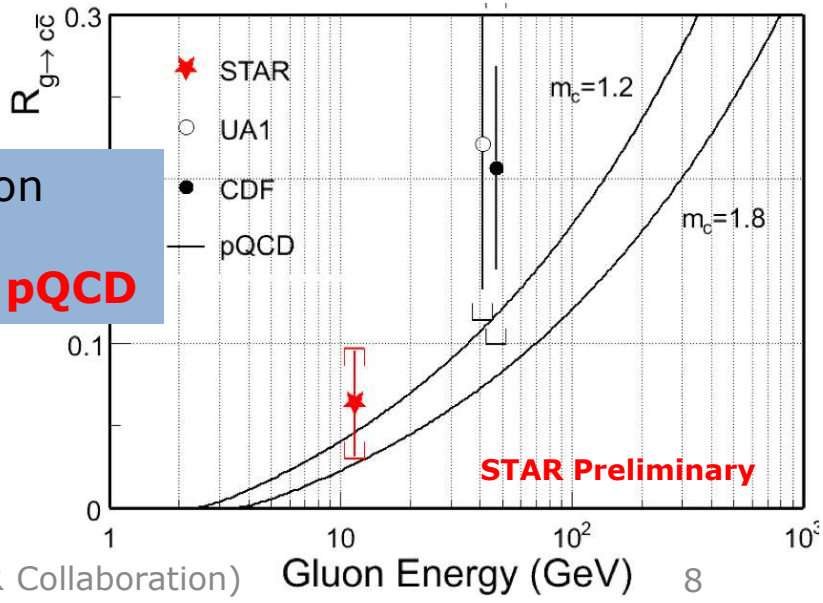
Heavy-flavor tagged correlations





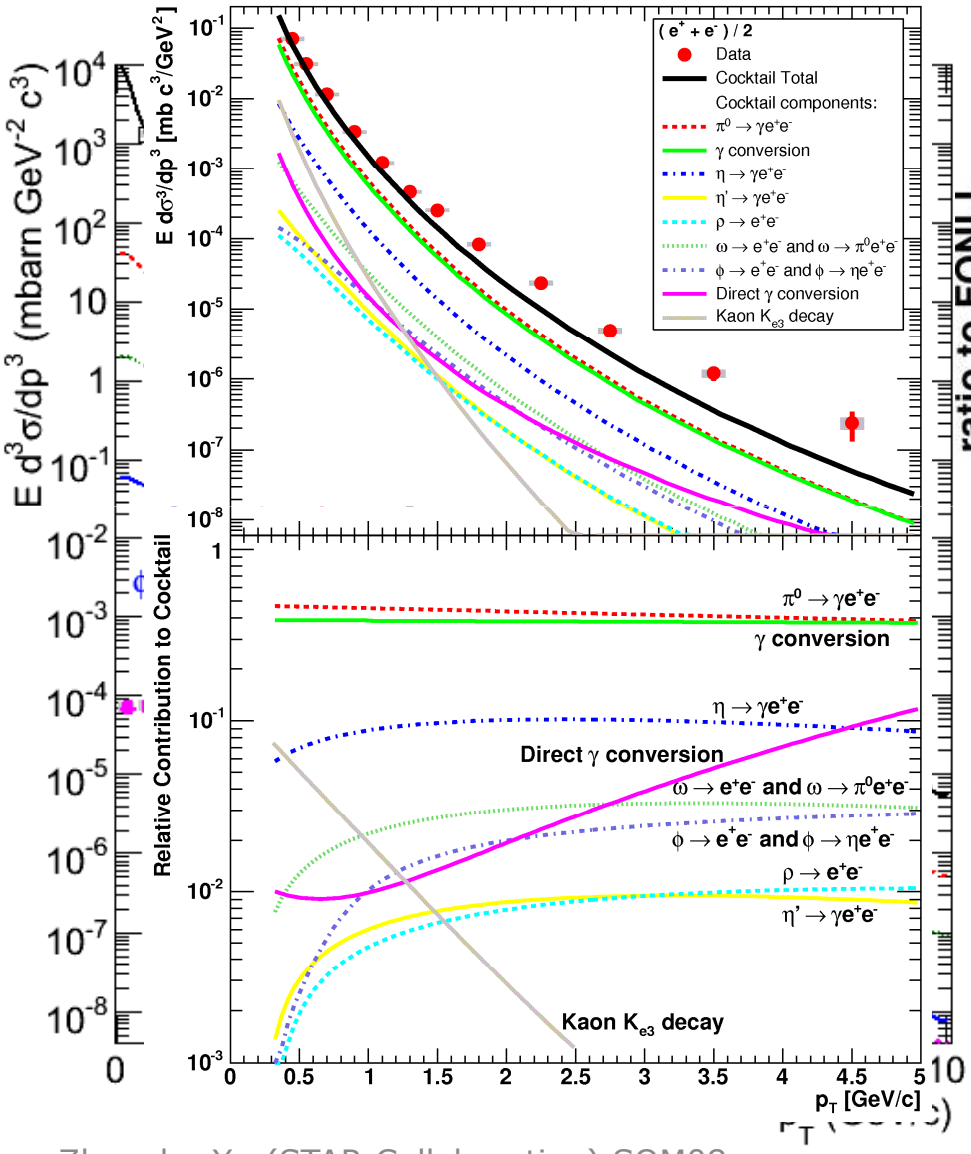


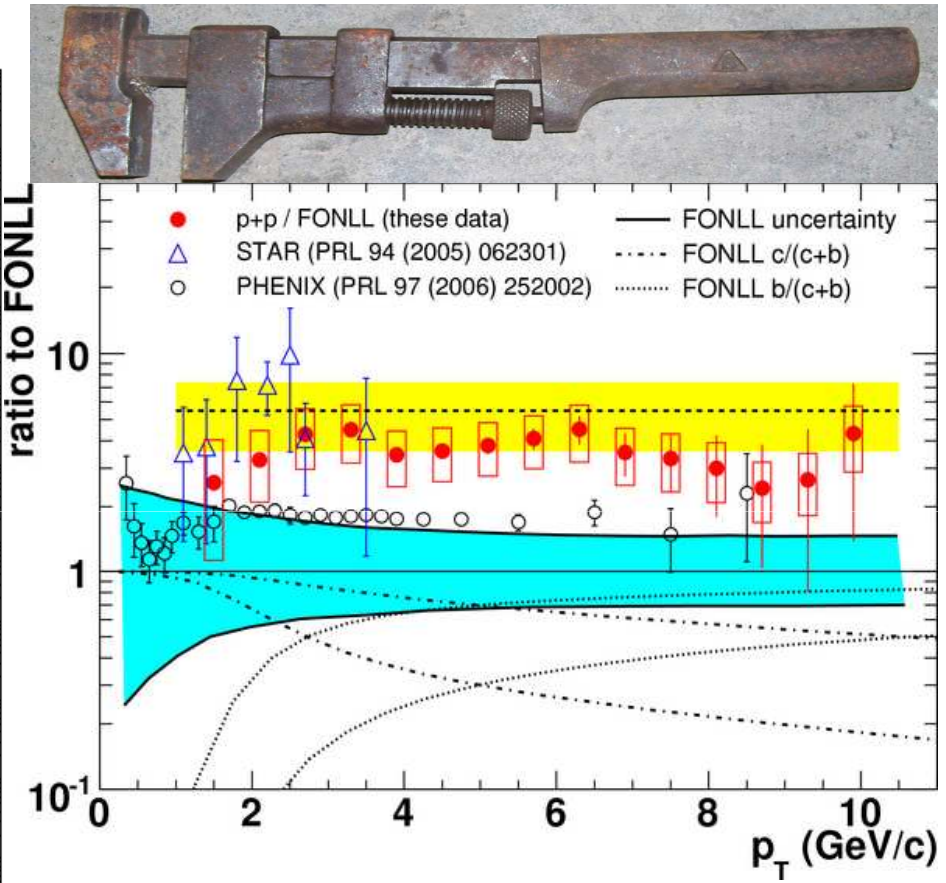
Bottom contribution
Jet Component
Consistent with pQCD



Shingo Sakai, Parallel Session 12.II

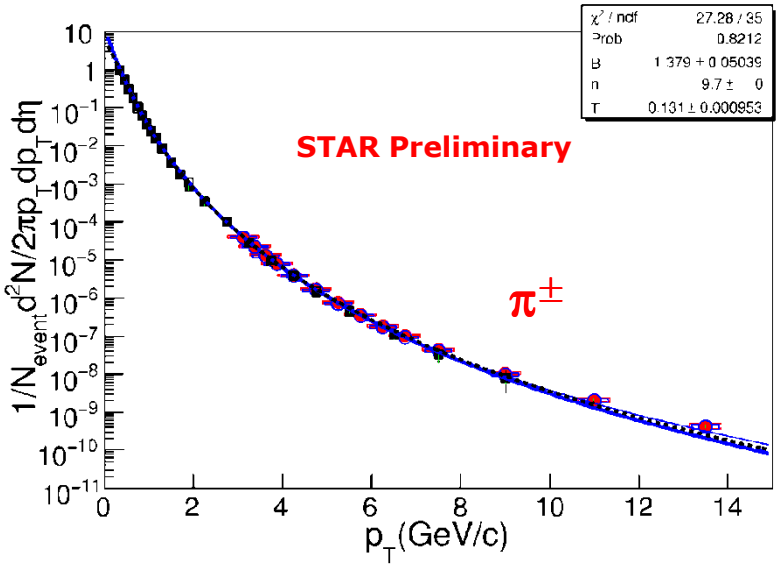
Discrepancy with PHENIX spectra

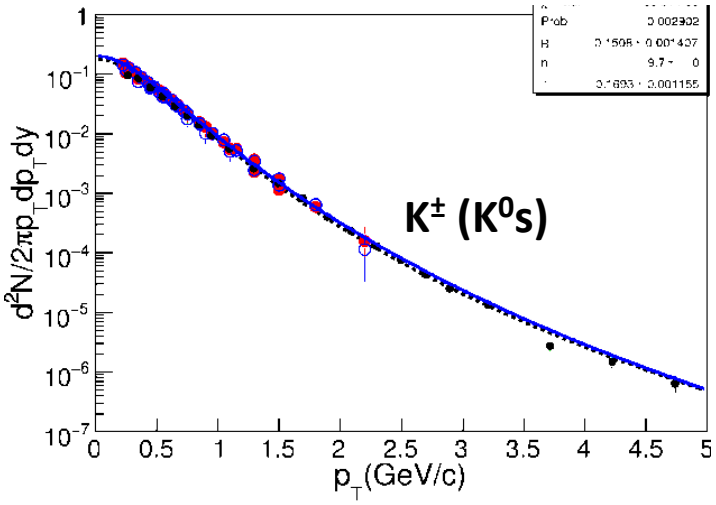




PHENIX: $A/(\exp(-a\, p_T - b\, p_T^2) + p_T/p_0)^n$:
A = 377 +/- 60 mb GeV^-2 c^3
a = 0.3565 +/- 0.014 c/GeV
b = 0.0680 +/- 0.019 (c/GeV)^2
p0 = 0.70 +/- 0.02 (c/GeV)
n = 8.25 +/- 0.04

STAR p+p NSD Spectrum Fits for cocktail method





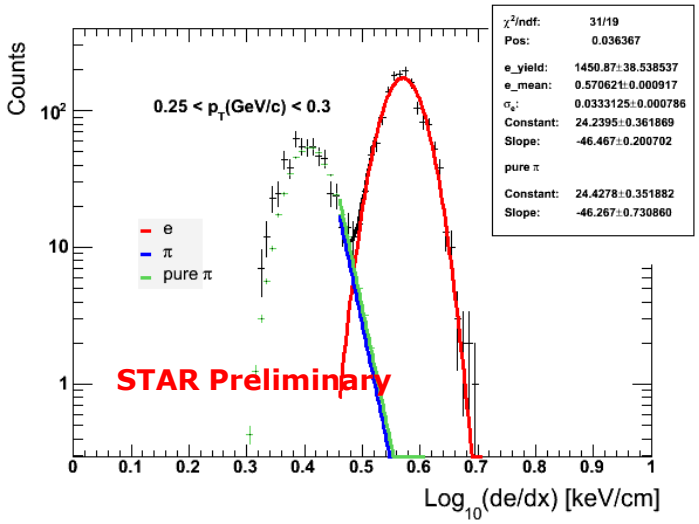
Cocktail method:

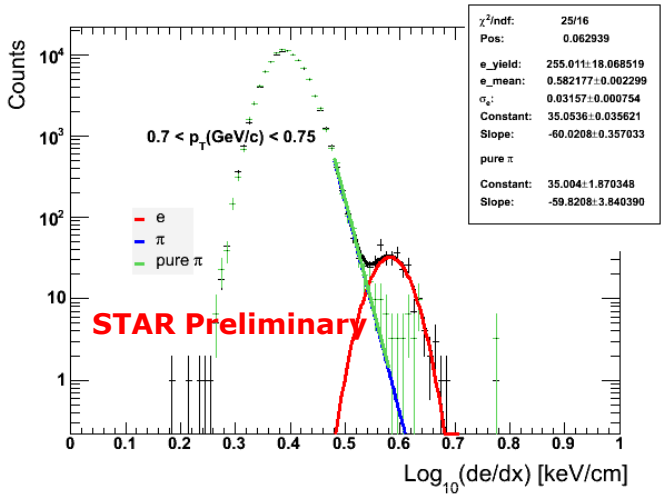
1. Photonic background in run8:
   ~50% from Dalitz decay
   ~50% from conversion
2. Cocktail from spectrum fit and material provides e/π ratio from photonic sources
3. Non-photonic electrons from d+Au fit/N_{bin} (D0, TOF, EMC measurements) /(π in p+p)
4. Inclusive e/π ratio from TOF+TPC data
5. Add 2)+3) to compare to 4)

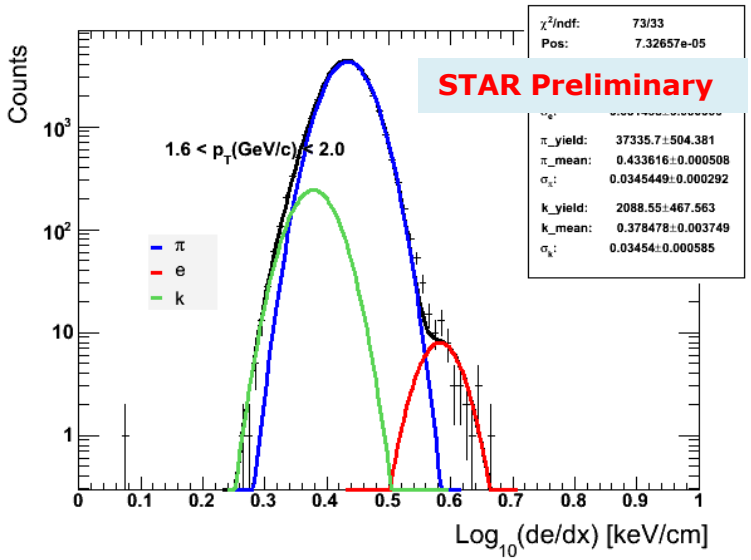
$\pi^{\pm}$,$K^{0\pm}$, ϕ ρ K* Spectrum fit well with One function: $A/(1+(mt-m0)/nT)^n$, Fixed n=9.7

Electron PID in run8 TOF

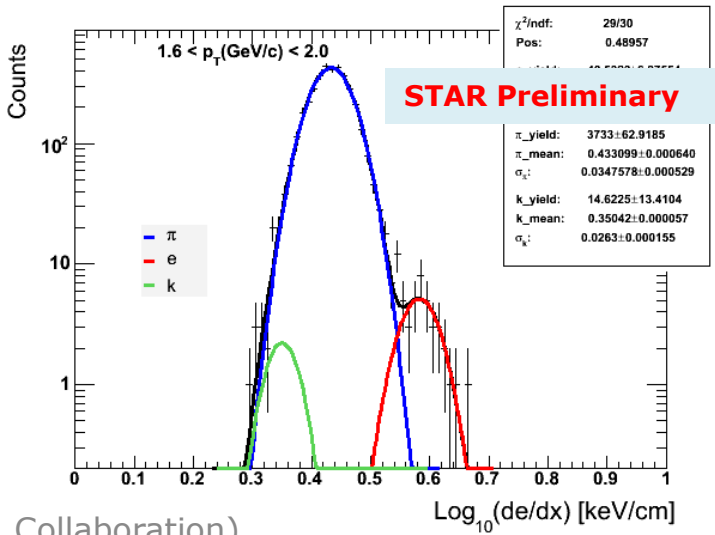
Removal of inner trackers



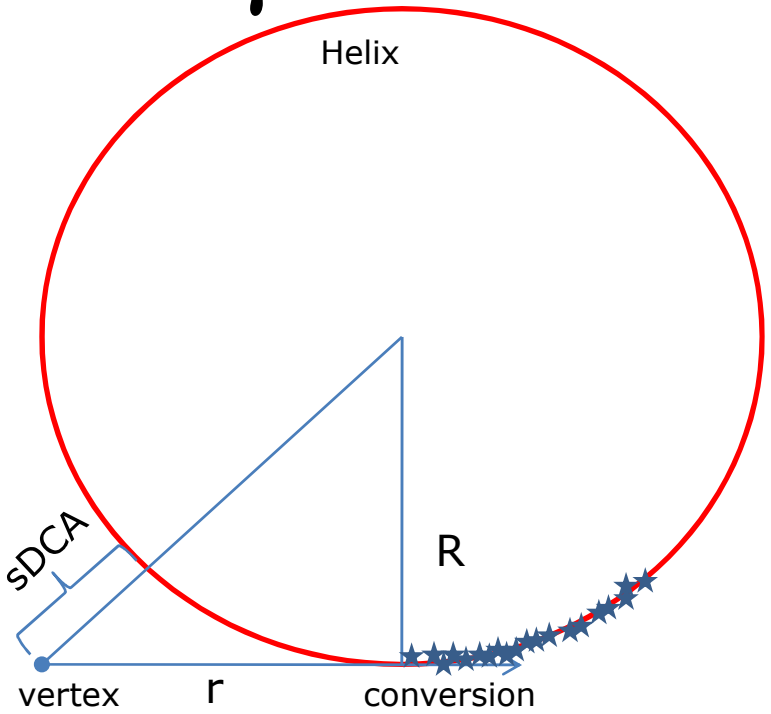




With EMC tower energy



γ Conversion Reconstruction

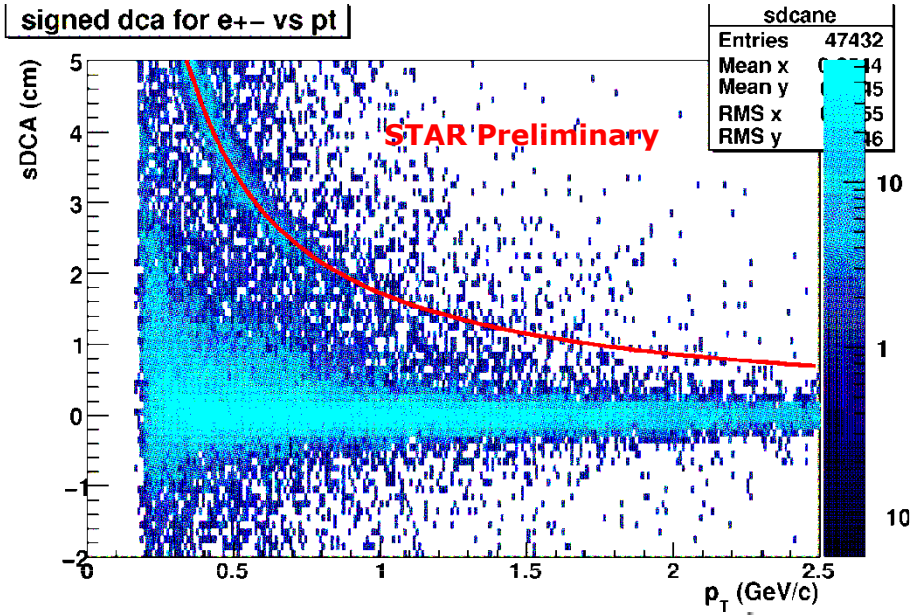


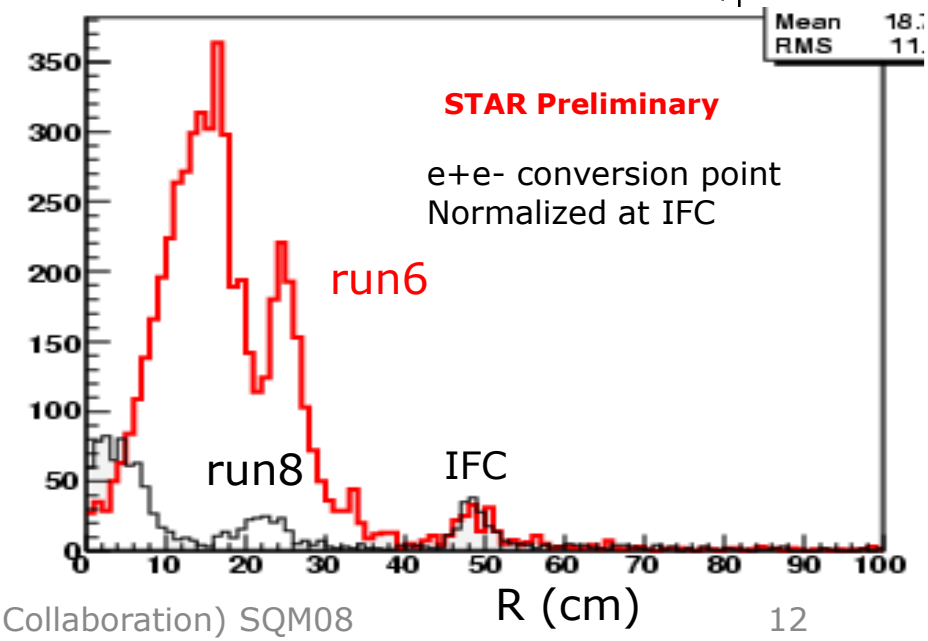
$$sDCA = \sqrt{R^2 + r^2} - R$$

$$= \sqrt{(p_T / 0.0015)^2 + r^2} - (p_T / 0.0015)$$

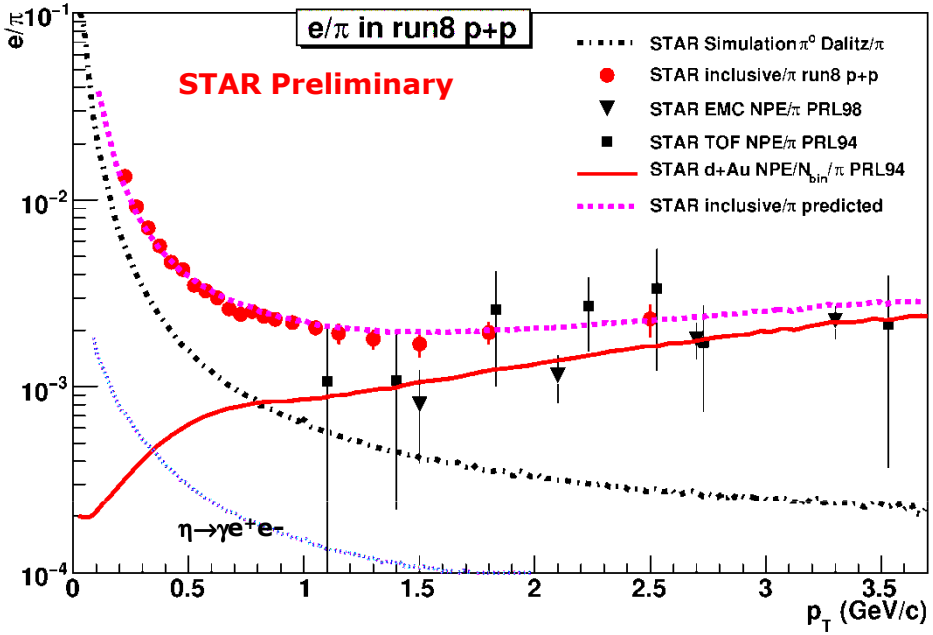
Inner Field Cage: r=48cm

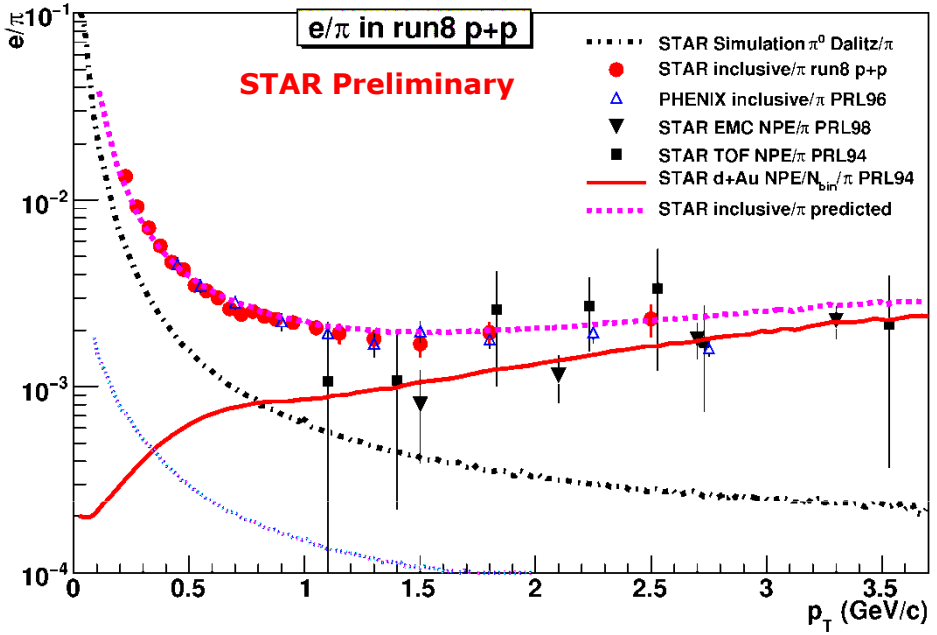
Jin Fu, Parallel session 12.I
Shingo Sakai, Parallel Session 12.II

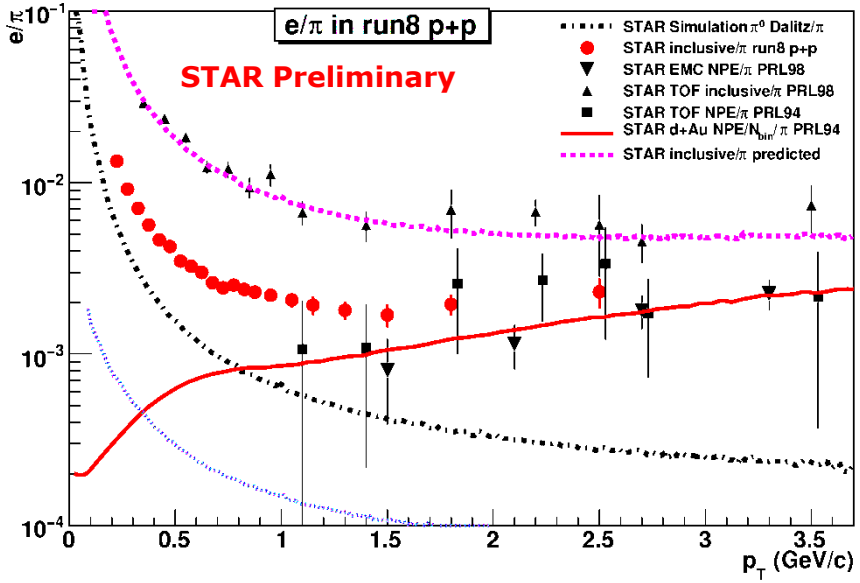




e/π ratio







Conversion in detector material x10 reduced
Run8 is consistent with run3 NPE results
Run8: 0.55%X_0 (beampipe 0.29%, air: 0.1%, wrap ~0.14%
run3: 5.5%X_0 (+ SVT…)

Detector Material is not the issue

Jin Fu, Parallel session 12.I

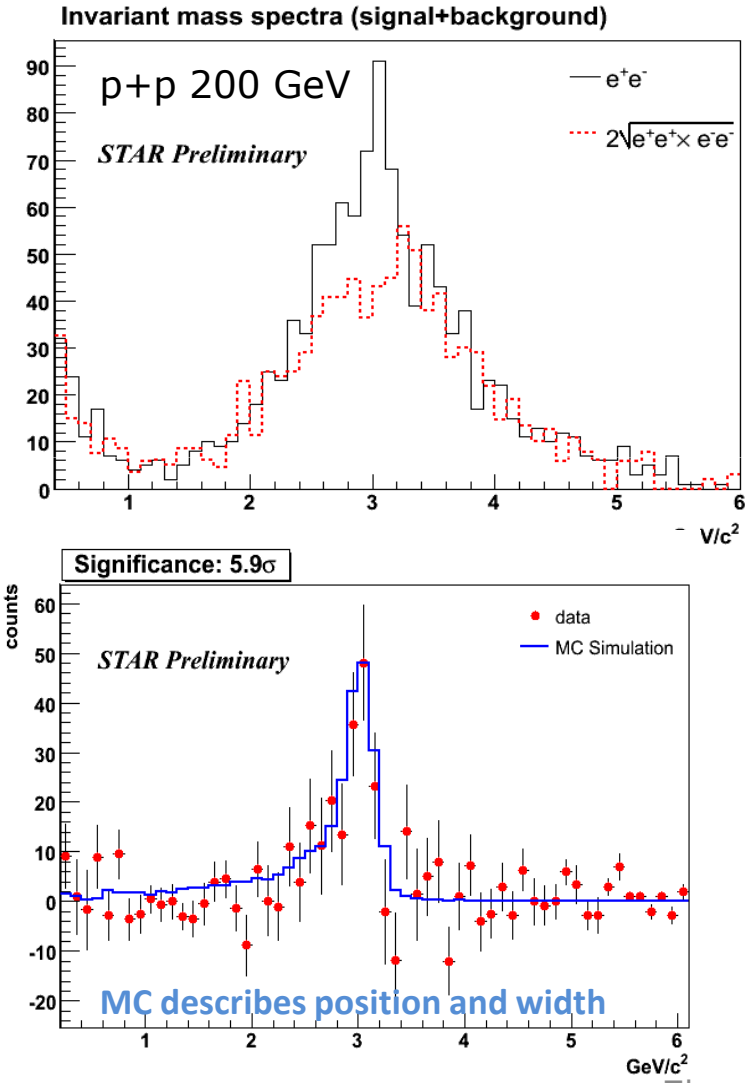
Open heavy-flavor Summary

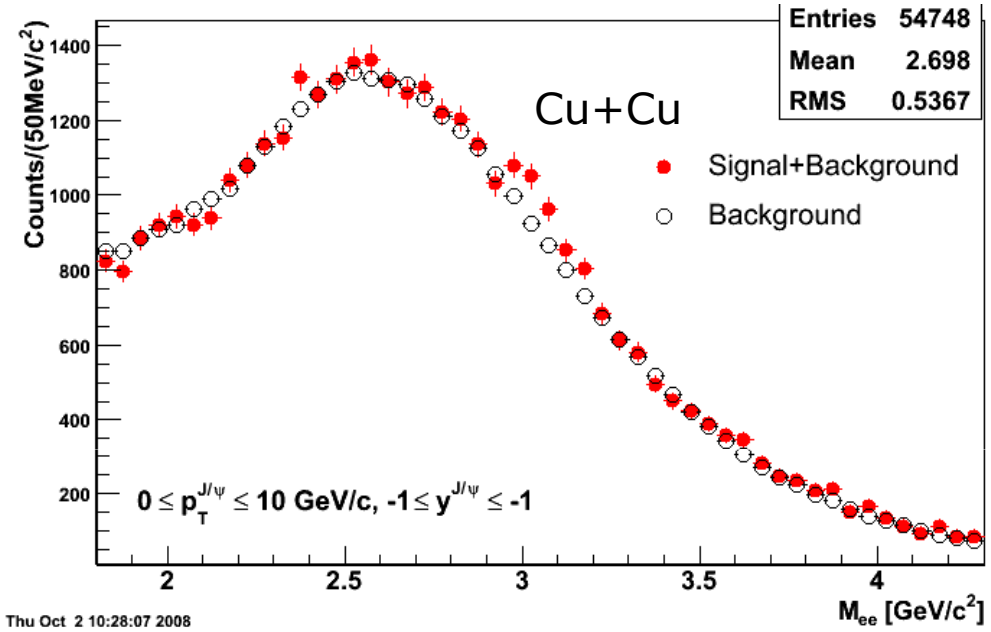
- Pt coverage: [0,10] GeV/c
- PID techniques:
  dE/dx, EMC, TOF
- PIDed particles:
  NPE, μ, D0, D*
- Detector Material:
  ~5.5%X_0 in run3—run7
  ~0.55%X_0 in run8
- Plans for next few months:
  NPE from TOF, EMC in p+p (2.7 pb^{-1}) and d+Au (30 nb^{-1}) minbias d+Au x3 run3

- Physics Conclusions:
  1. NPE Suppression at high-pt similar to light hadrons
  2. Binary Scaling of total cross-sections
  3. Large open charm cross-sections
  4. less radial flow than light hadrons
  5. Significant Bottom contribution to NPE
  6. Away-side Q-h ~= q-h
  7. Jet content of charm (~<10%)

Low p_T J/ψ in p+p and Cu+Cu at 200 GeV

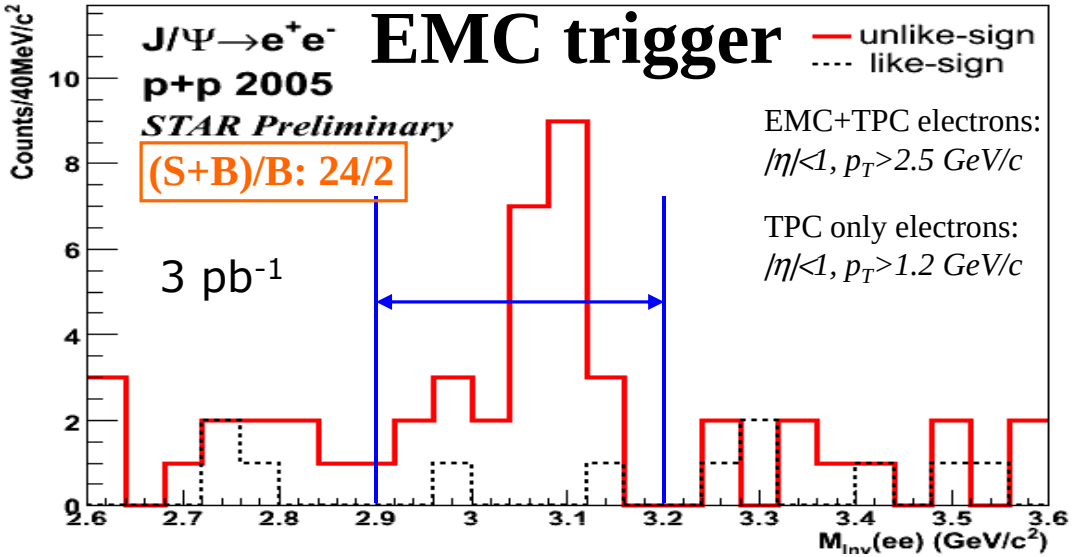
J/ψ trigger $0 < p_T < 5.5$ GeV/c

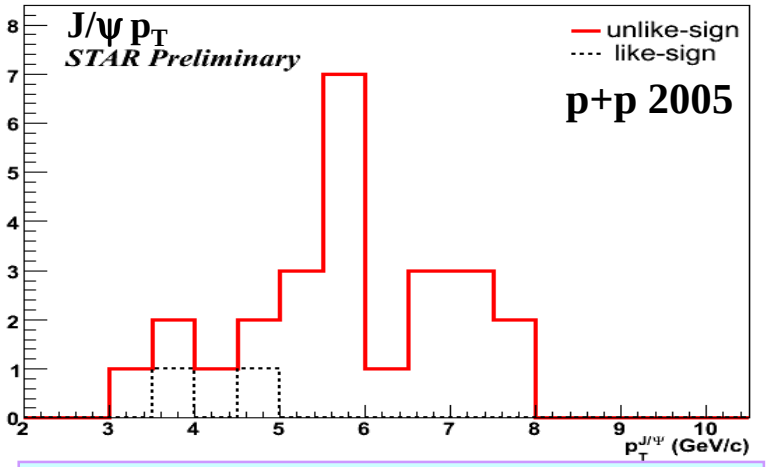




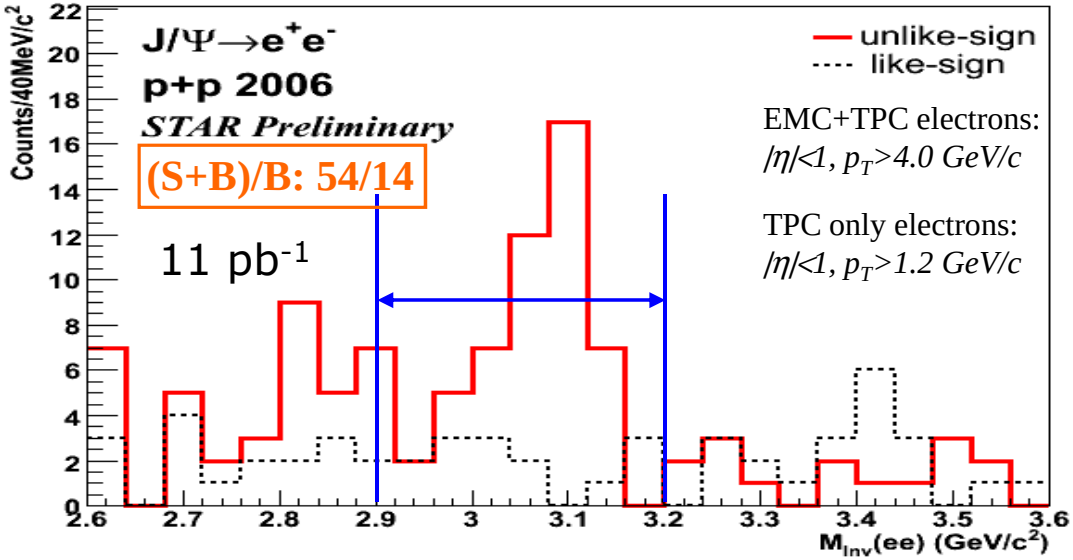
Details of analysis at low-p_T: Daniel Kikola, poster

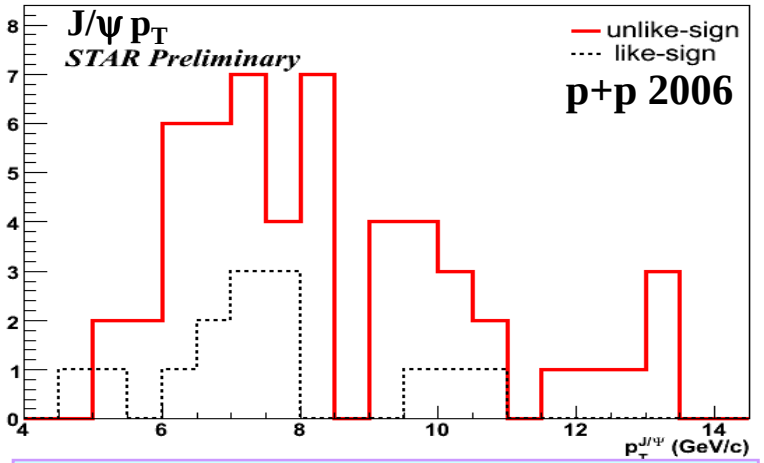
High p_T J/ψ in p+p at 200 GeV





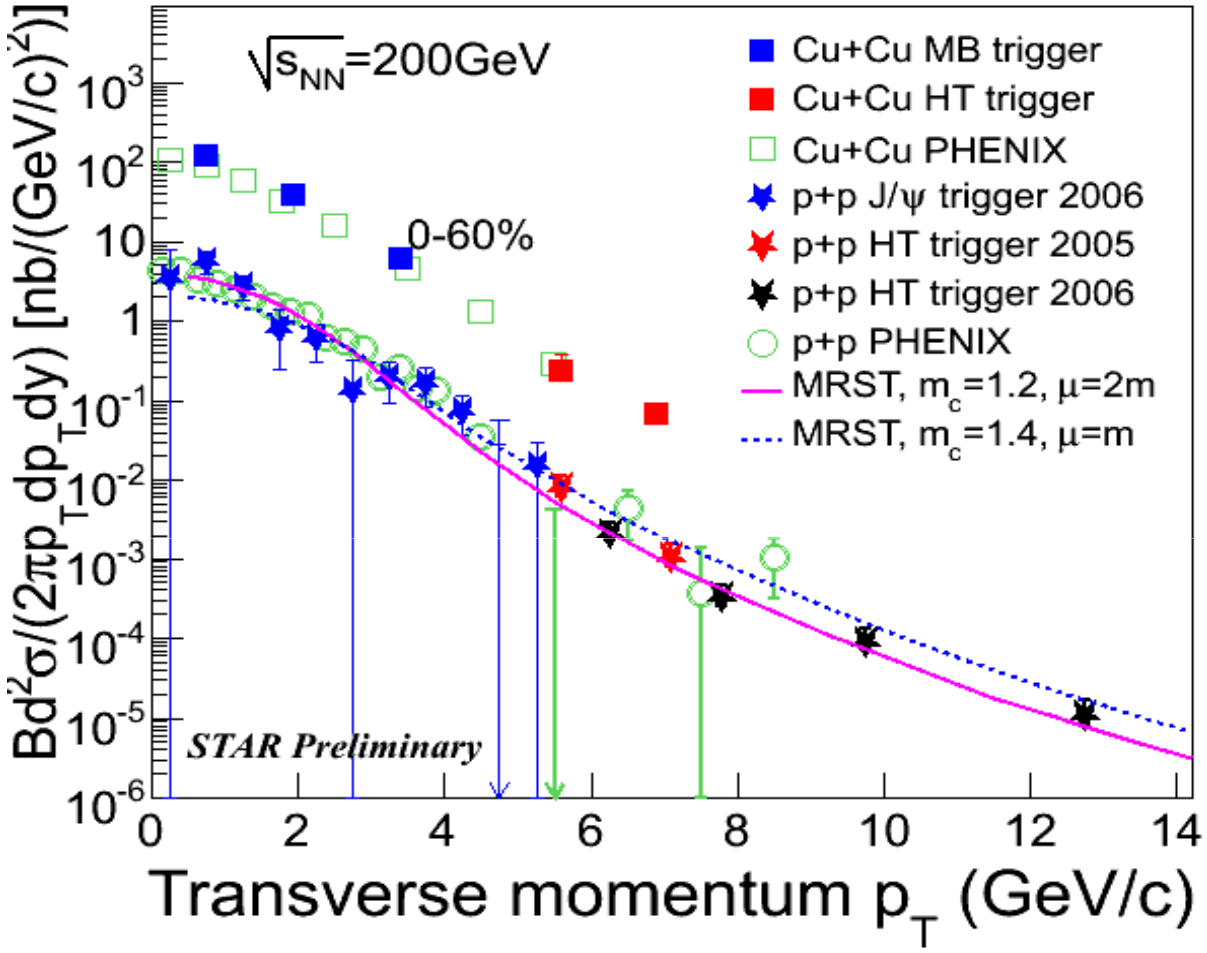
No background at p_T>5GeV/c





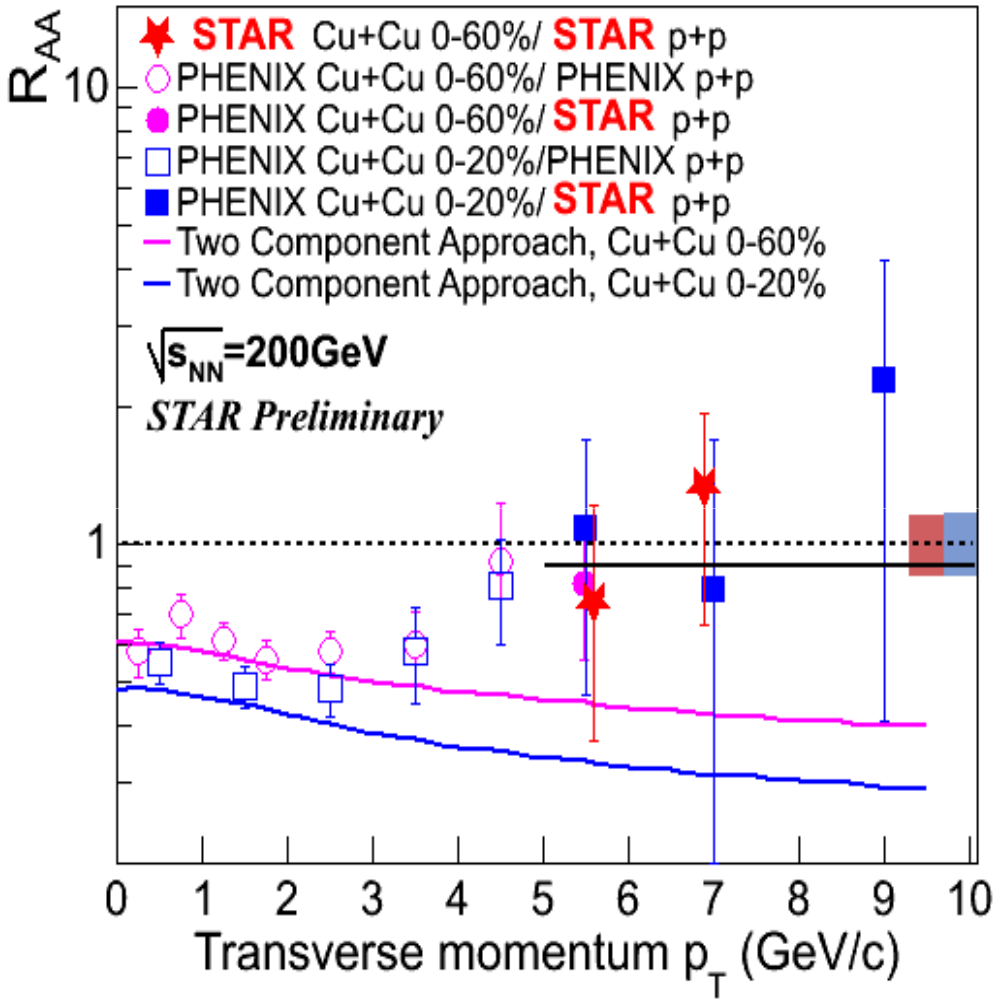
Reach higher p_T (~14GeV/c)

J/ψ spectra in p+p and Cu+Cu at 200 GeV



- Significantly extend p_T range of previous measurements in p+p at RHIC to 14 GeV/c
- Agreement of the measurements between STAR and PHENIX
- Consistent with Color Evaporation calculations (R. Vogt, Private communication)
- Cu+Cu: $0.5<p_T<8$ GeV/c

Nuclear modification factor R_{AA}



- Double the p_T range to 10GeV/c
- Consistent with no suppression at high p_T:

  $R_{AA}(p_T>5$ GeV/c) = 0.9 ± 0.2

  2σ above low-p_T data
- Indicates R_{AA} increase from low p_T to high p_T

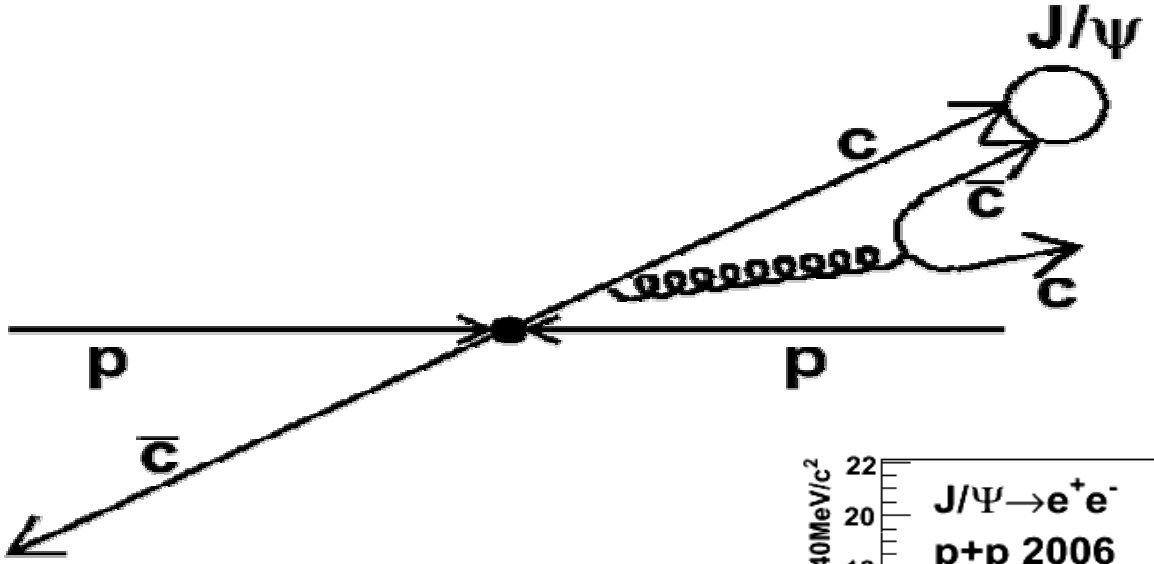
- Contrast to AdS/CFT prediction
- Formed out of medium?

Affect by heavy quark/gluon energy loss

- Decay from other particles?

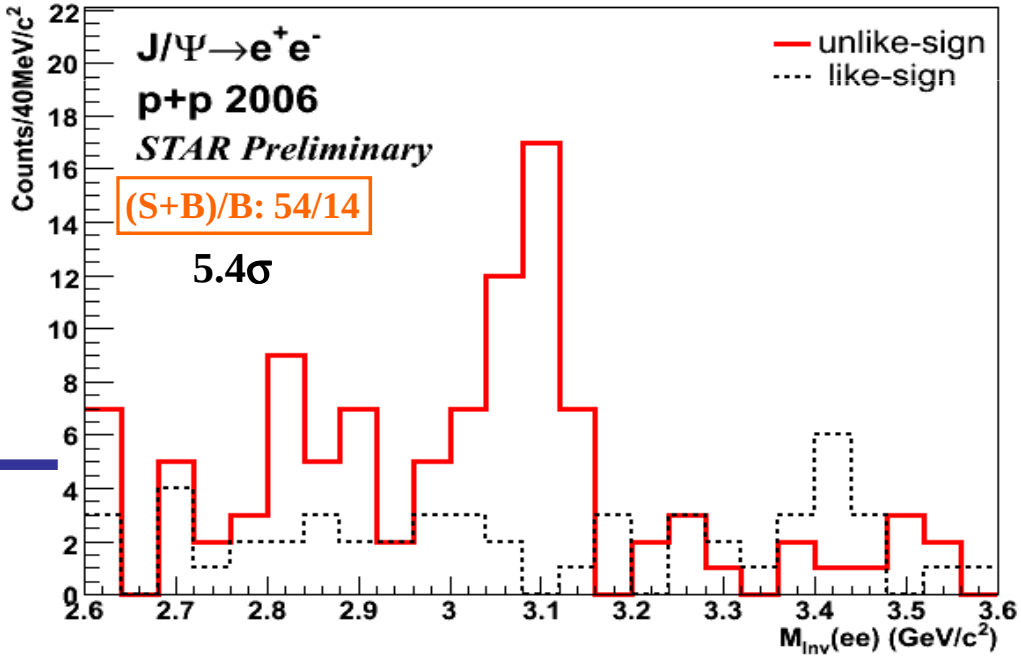
2-component Approach predicted slightly increase R_{AA} after more consideration *X. Zhao, WWND2008*

J/ψ-hadron correlation



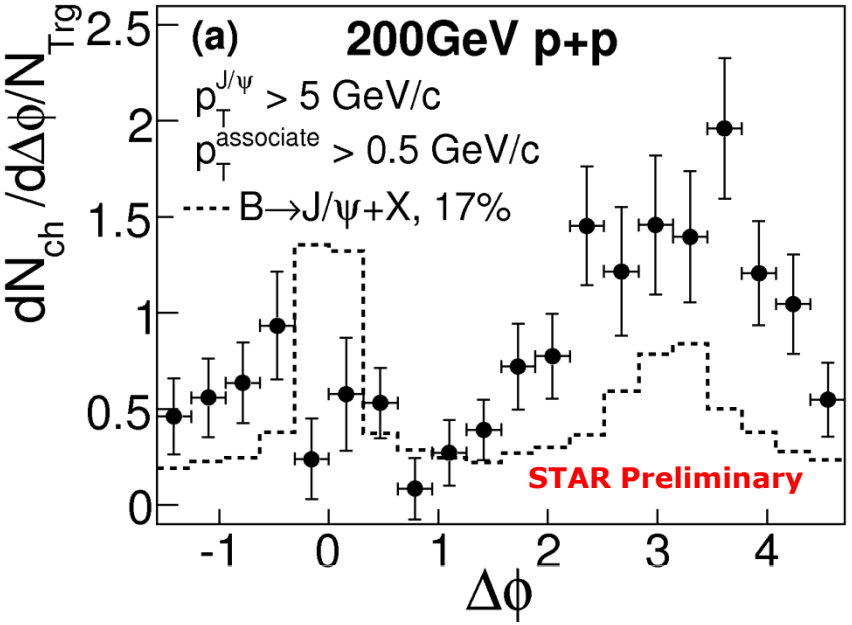
Near side correlation
Bottom decay or fragmentation

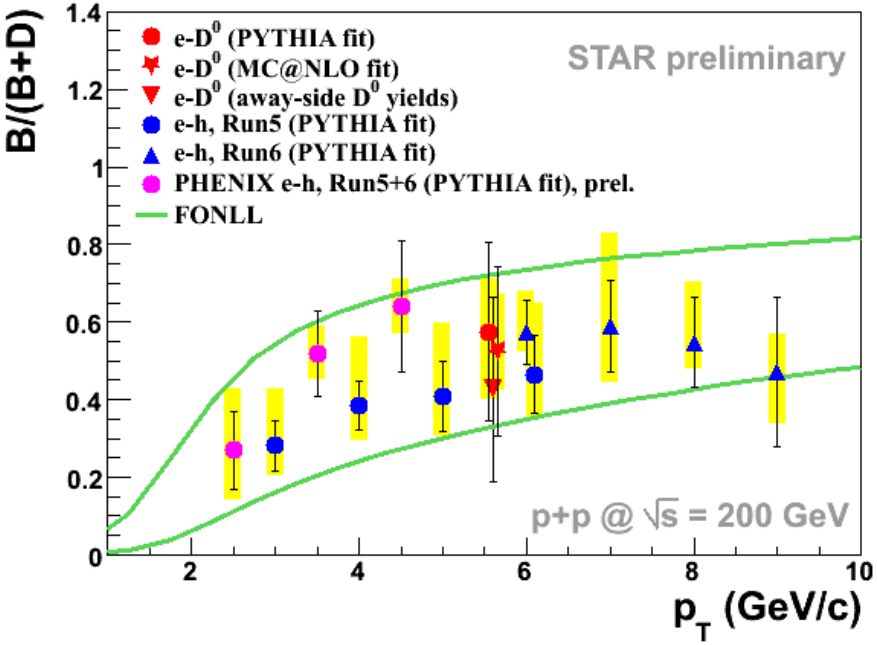
Heavy quark fragmentation

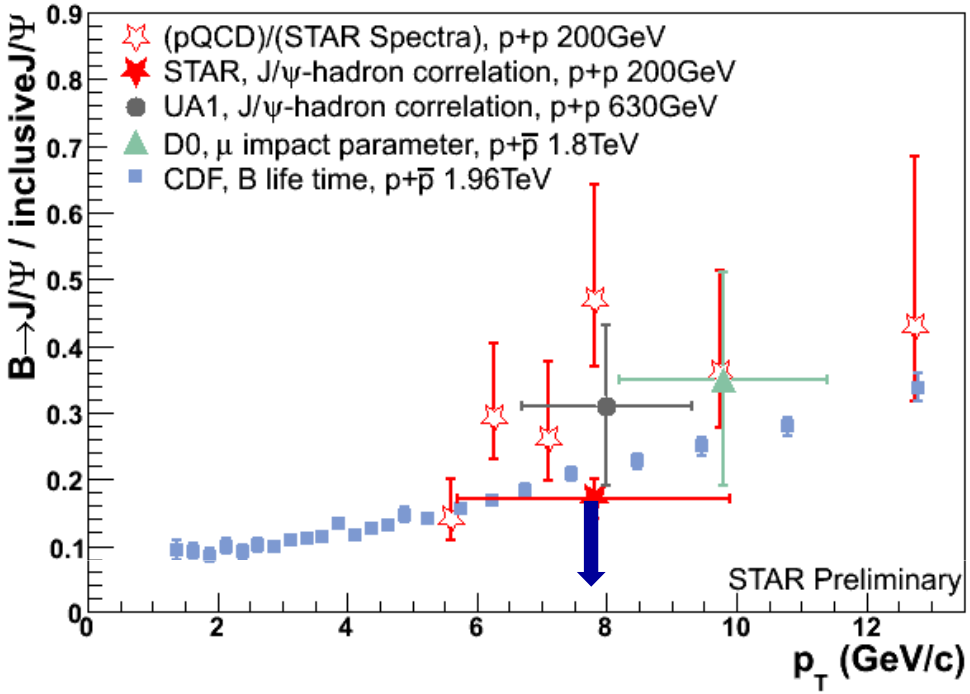


Good S/B ratio makes this measurement possible

Constrain Bottom yields

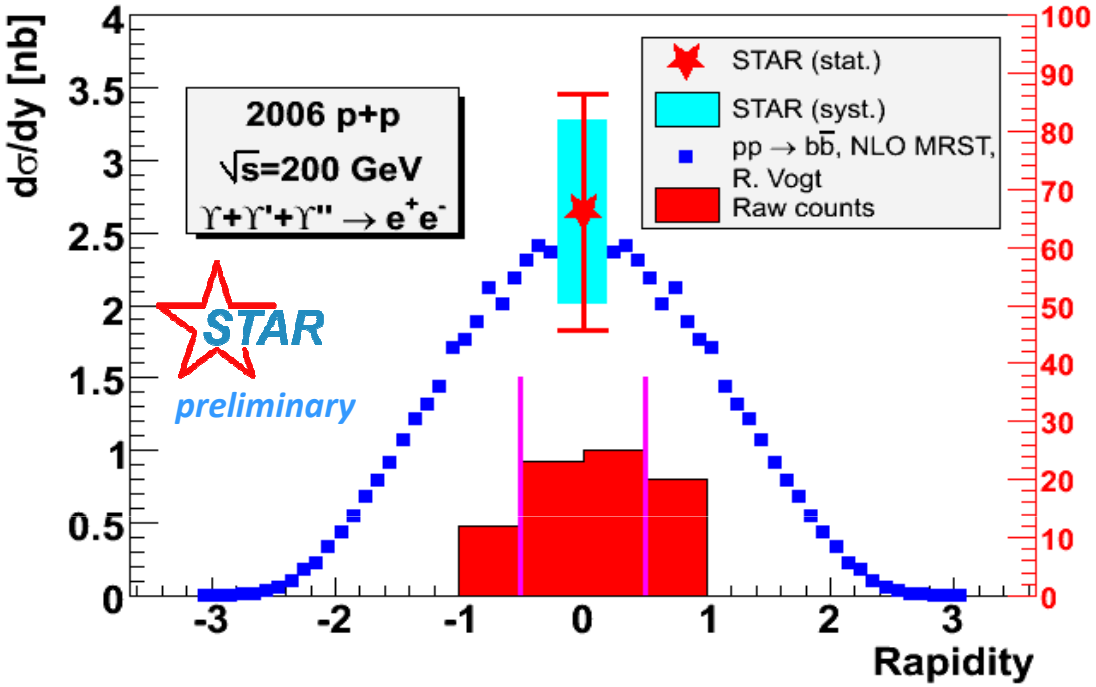




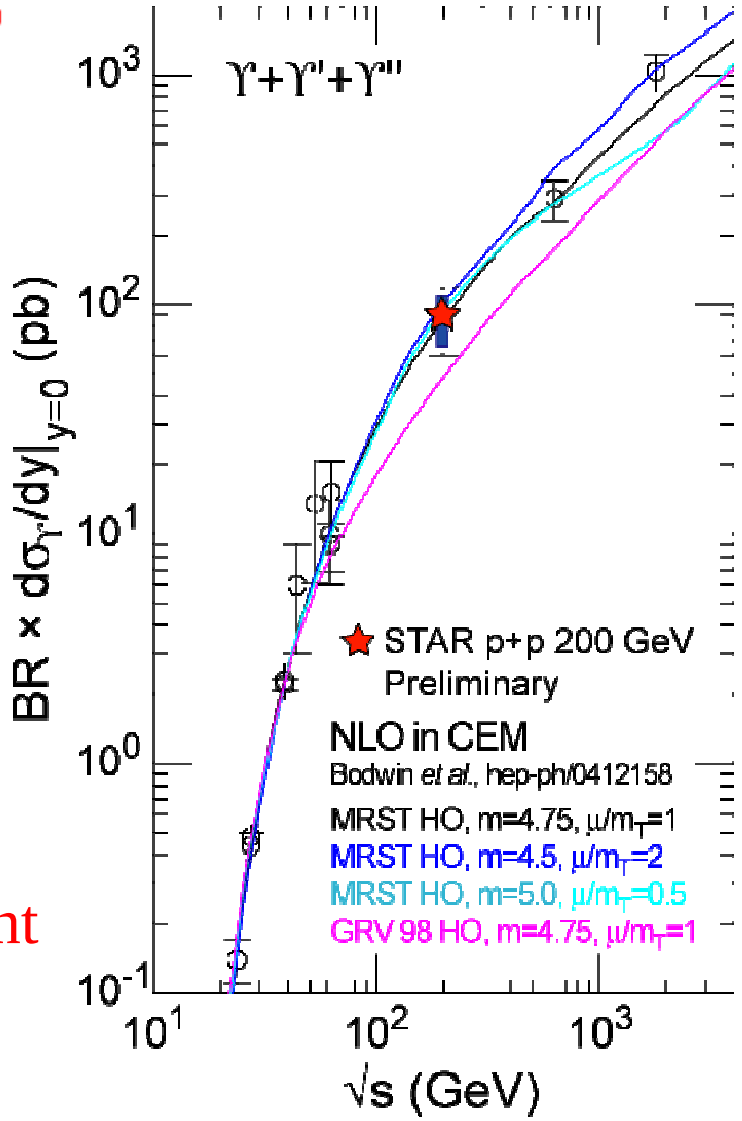


- pQCD predicts significant B➔J/Ψ
- Correlations shows low B contribution
- can used to further constrain B yields
- PYTHIA productions all show strong near-side correlation ➔ higher order production mechanism?
- constrain Correlation from jet fragmentation

ϒ cross-section in p+p



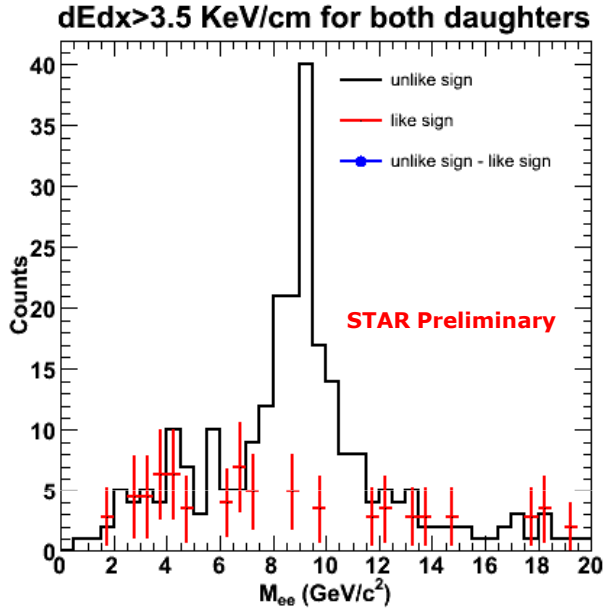
$B_{ee} \times (d\sigma/dy)_{y=0} = 91 \pm 28(stat.) \pm 22(syst.)$ pb

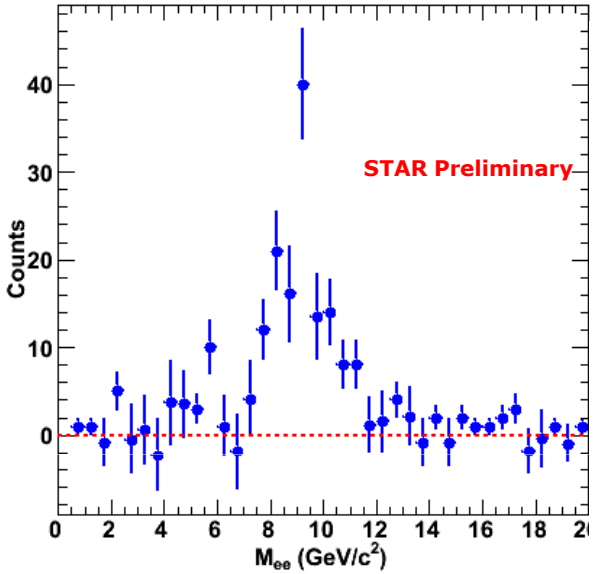


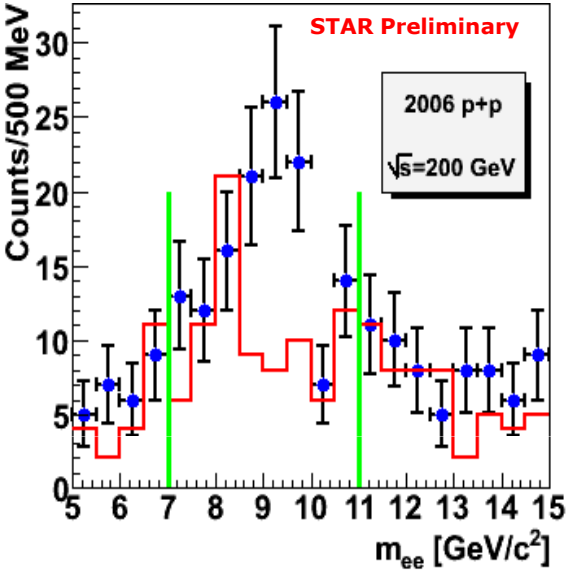
STAR 2006 √s=200 GeV p+p
ϒ+ϒ′+ϒ″→e^+e^- cross section consistent with pQCD and world data

Υ and high-pt J/Ψ in run8 dAu

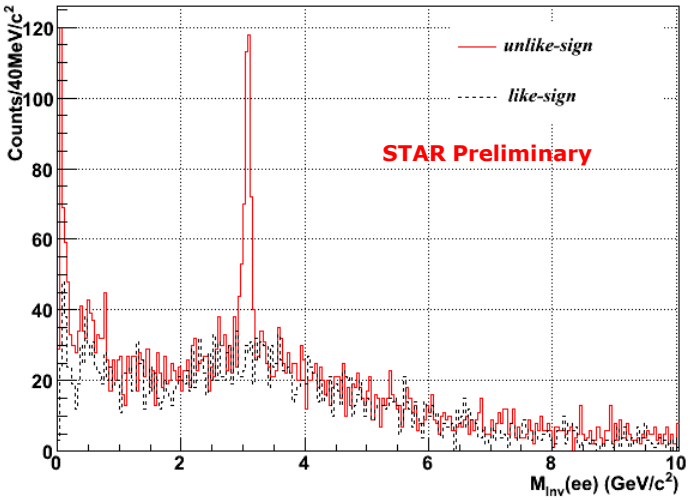
physics results in next few months!!!

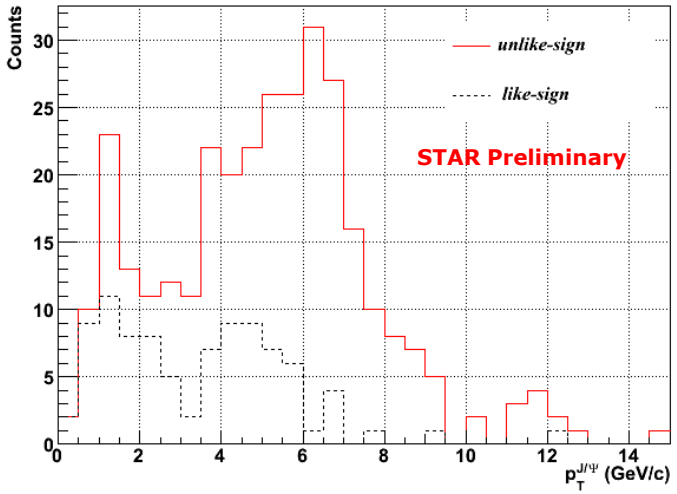






dAu data sampled luminosity: 31 nb^{-1} p+p equivalent: 13pb^{-1}

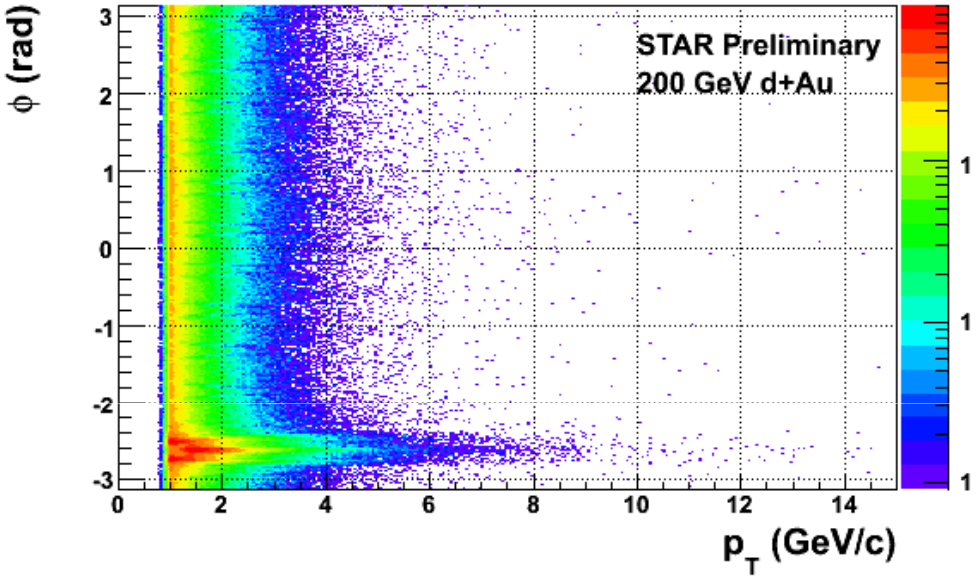


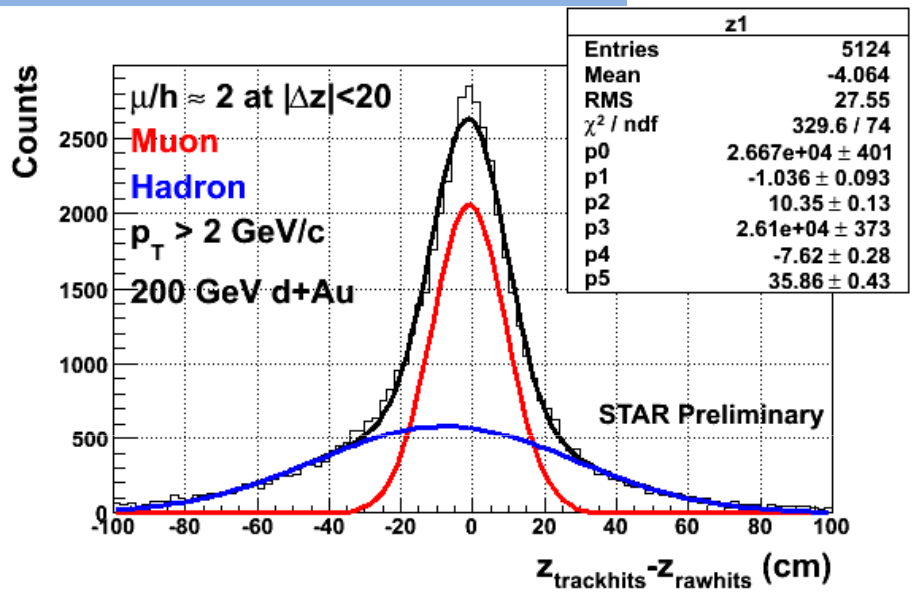


- J/Ψ spectra
- J/Ψ-h correlation
- Isolated J/Ψ
- Ψ(2S)
- χ_c

A prototype muon telescope (MTD) at STAR in d+Au collisions

physics results in next few months!!!





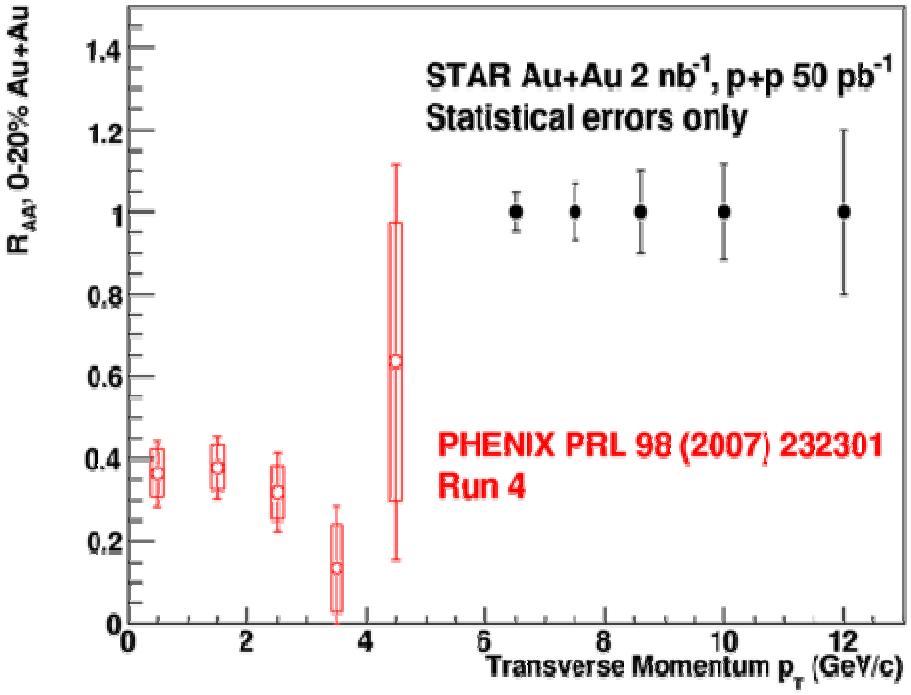
- MTD hits: matched with real high p_T tracks

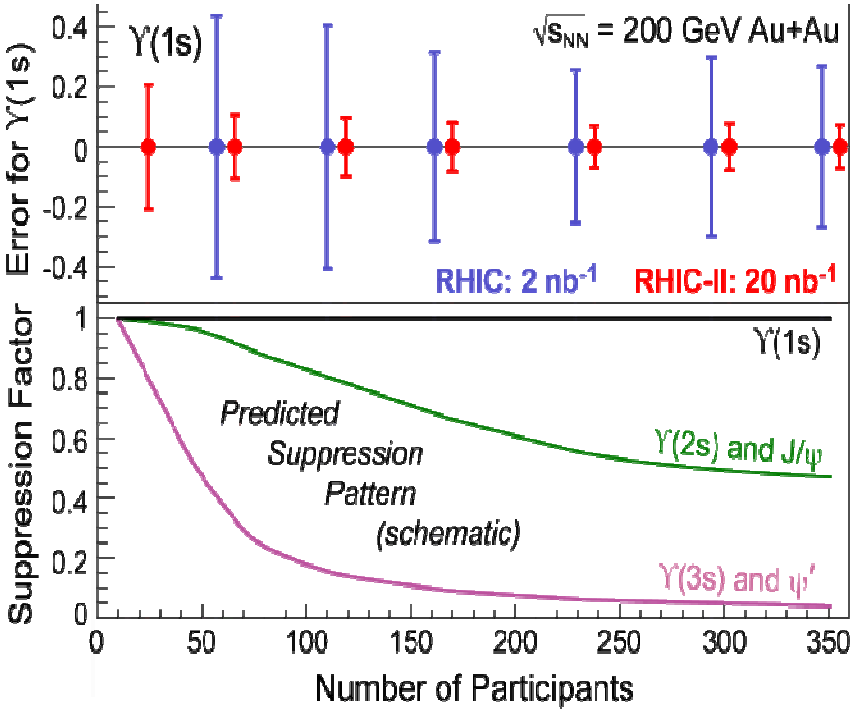
- Δz distribution has two components: narrow (muon) and broad (hadron) ones
- Sample luminosity: 4.19 pb-1
- In the process of decomposing the contributions using velocity, dE/dx, tracking topology, EMC

Physics (open heavy-flavor):

- Single muon spectrum
- e+μ mass spectrum
  first ever to directly measure irreducible charm dilepton background

High luminosity for Υ & high-p_T J/Ψ





Time-Of-Flight:

Electron identification

RHIC II + DAQ1000:

Enhance statistics

Summary (J/ψ)

- **J/ψ spectra in 200 GeV p+p collisions at STAR**
  1. Extend the p_T range up to ~14 GeV/c
  2. Spectra can be described by CEM and CSM.
  3. High p_T J/ψ follows x_T scaling with n=5.6
  4. Spectra at high p_T can be used to constrain B production

- **J/ψ–hadron azimuthal correlation in p+p**
  1. no significant near side correlation
     Expect strong near-side correlation from B→J/ψ+X
     Can be used to constrain J/ψ production mechanism
  2. Away-side spectra consistent with h-h correlation
     indicates gluon or light quark fragmentation

- **J/ψ R_{AA} from 200 GeV Cu+Cu collisions at STAR**
  1. Extend R_{AA} from p_T = 5 GeV/c to 10 GeV/c
  2. Indication of R_{AA} increasing at high p_T

Future

J/ψ results from Run 7 Au+Au

Upsilon R_{AA}

Run 8 (d+Au), Cold Nuclear Modification

Run9—10, Au+Au and p+p runs with TOF and DAQ1000

Longer term: RHIC II + Heavy-Flavor Tracker

Talks:

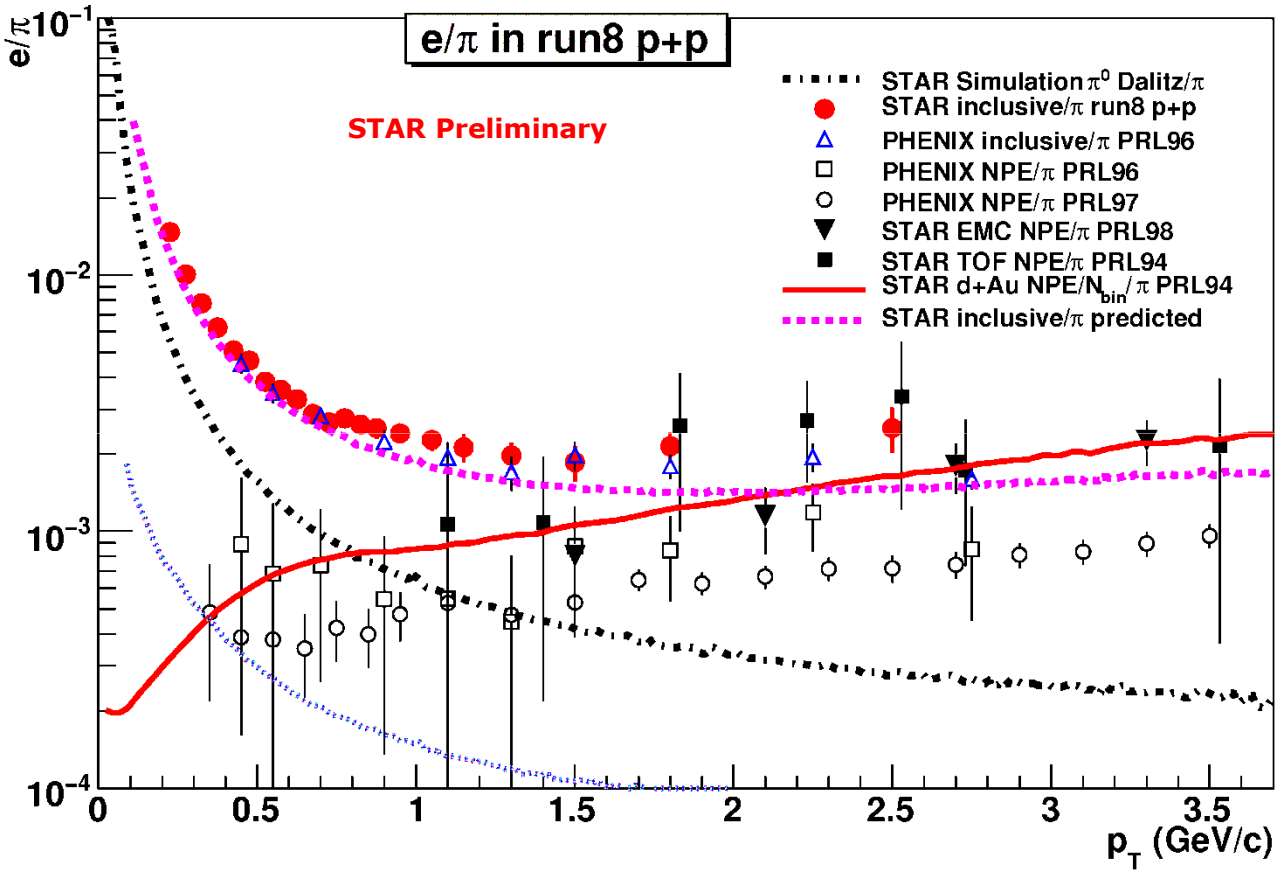
Non-photonic electron yields in p+p collisions
at STAR with reduced detector material ---------- Jin Fu

Study of b contributions to NPE by e-h correlation --- Shingo Sakai

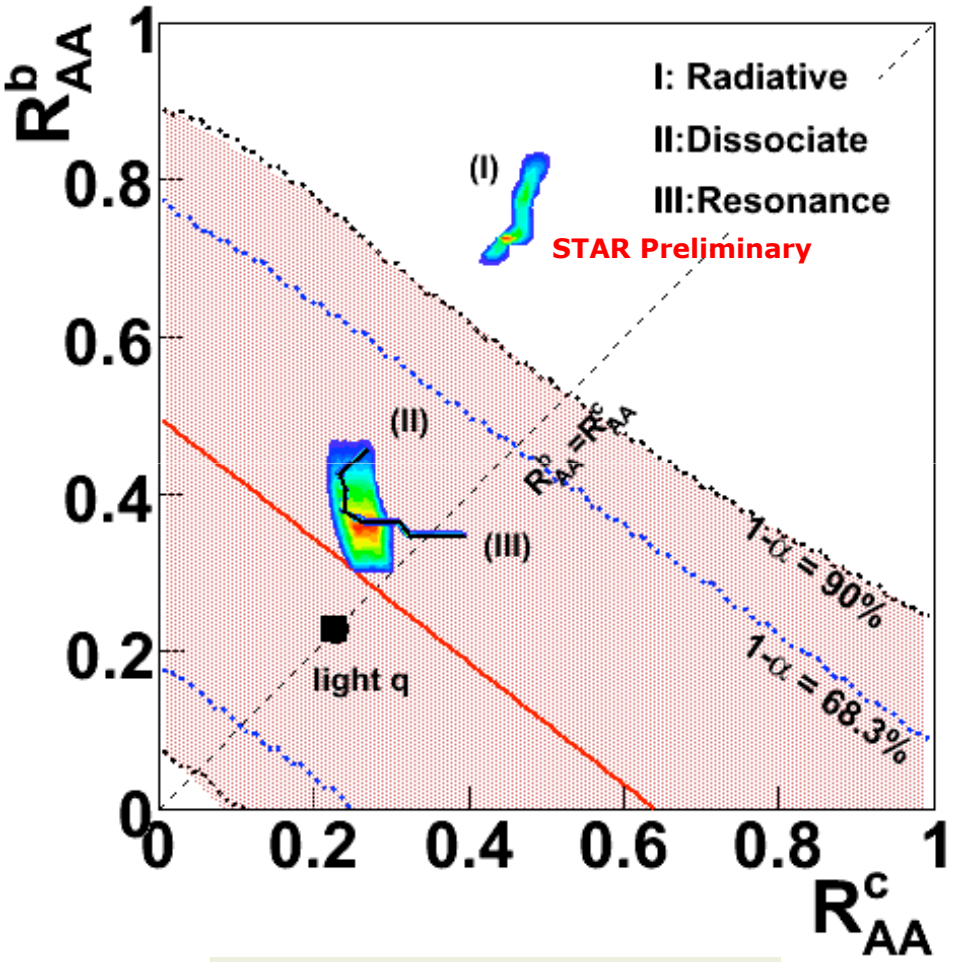
J/Ψ Spectra at low pt in Cu+Cu ---- Daniel Kikola

Backup slides

THE factor x2



Constrain on bottom suppression



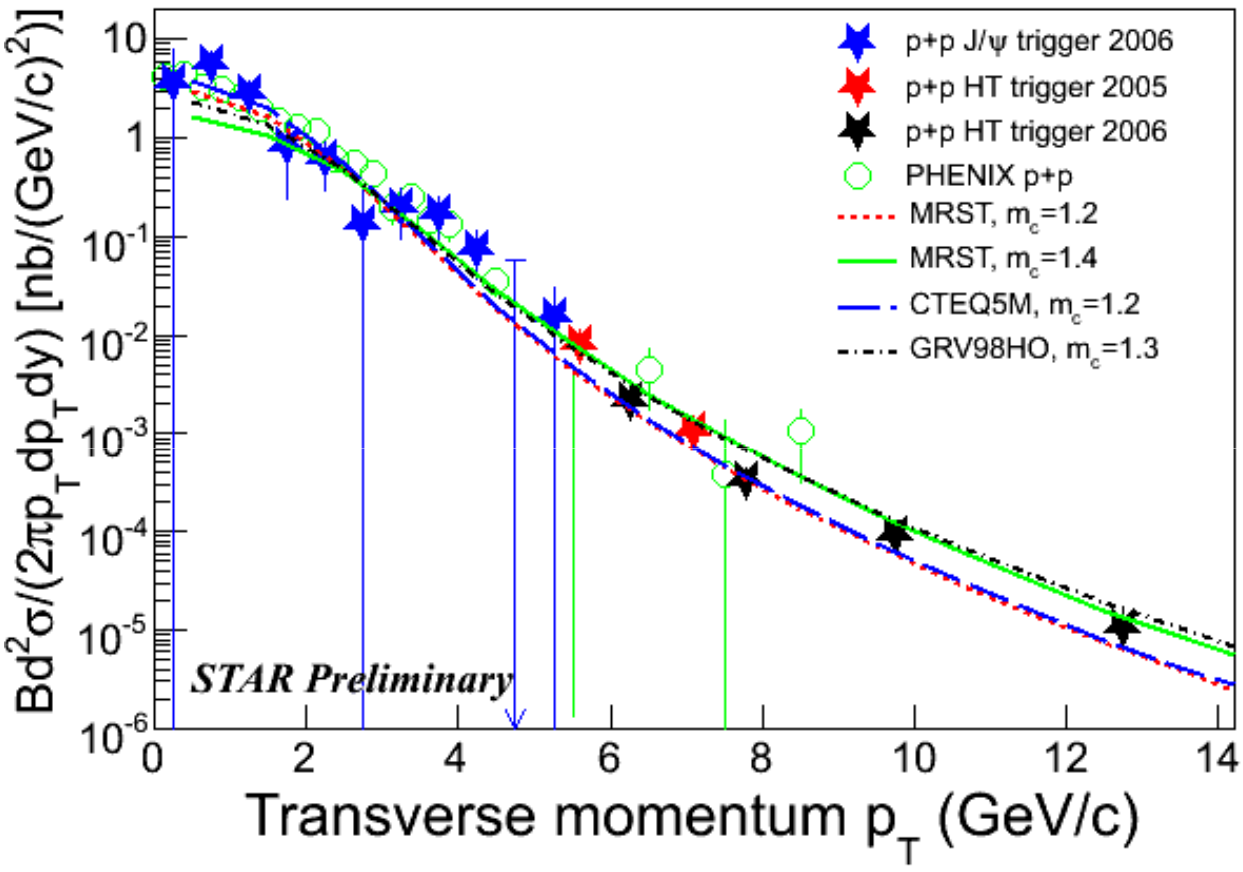
Shingo Sakai, Parallel Session 12.II

R^c_{AA} & R^b_{AA} correlation together with models

- Dominant uncertainty is normalization in RAA analysis
- $R^b_{AA} \neq 1$; B meson suppressed
- prefer Dissociate and resonance model (large b energy loss)

I; Phys. Lett. B 632, 81 (2006)
II; Phys. Lett. B 694, 139 (2007)
III; Phys.Rev.Lett.100(2008)192301

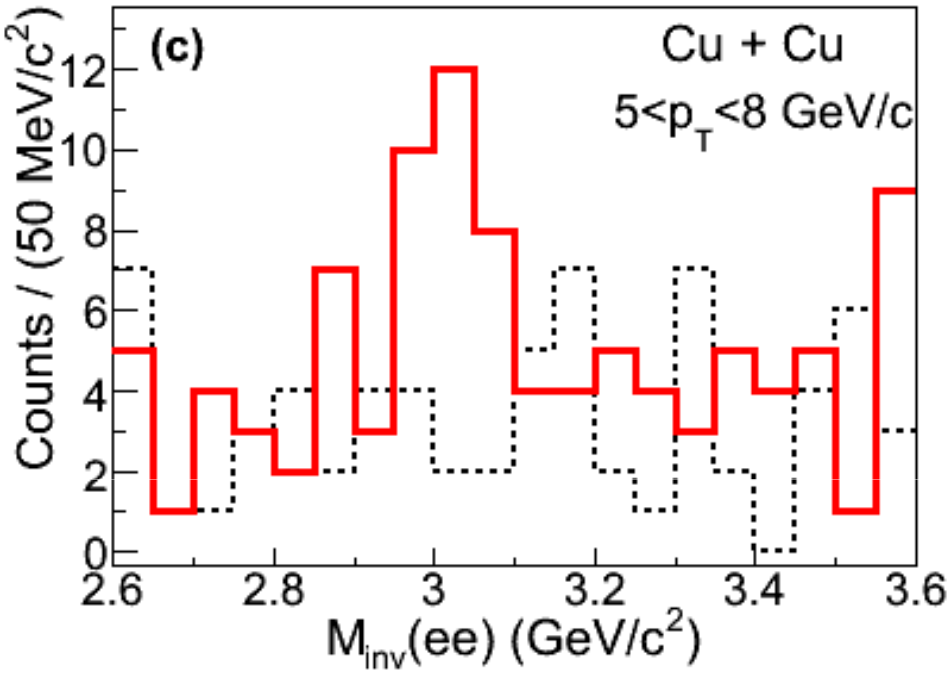
J/ψ spectra in p+p at 200 GeV



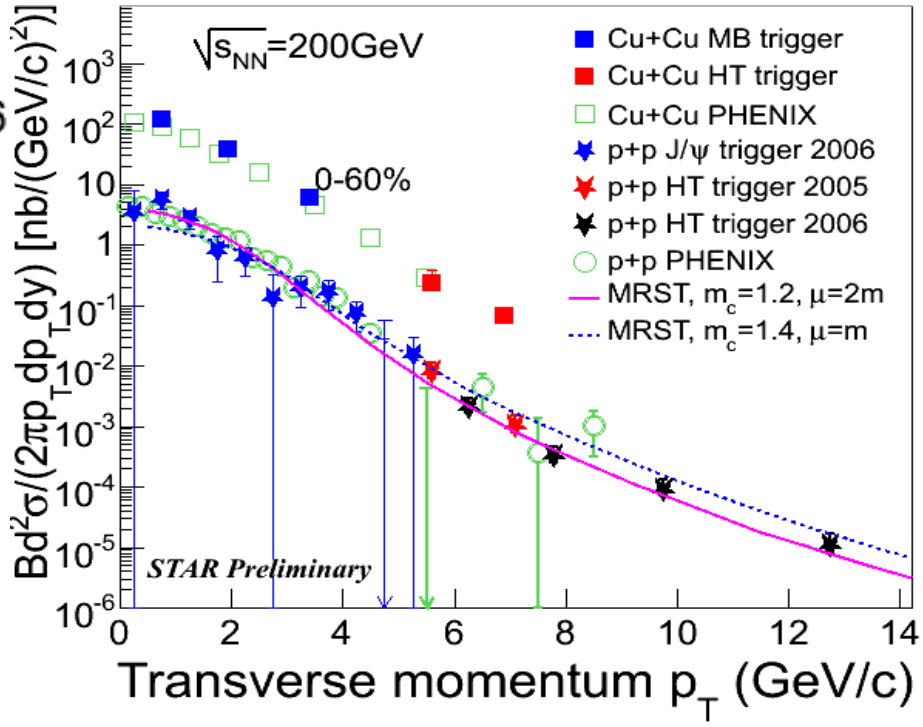
- Significantly extend p_T range of previous measurements in p+p at RHIC to 14 GeV/c
- Agreement of the measurements between STAR and PHENIX
- Consistent with Color Evaporation calculations (R. Vogt, Private communication)

J/Ψ in Cu+Cu

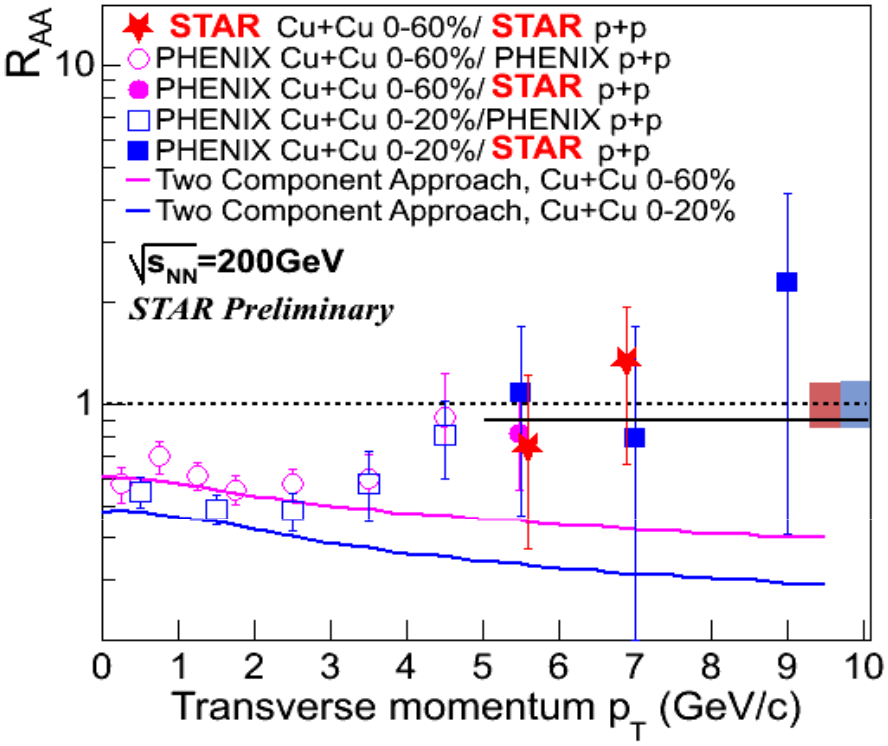
High p_T



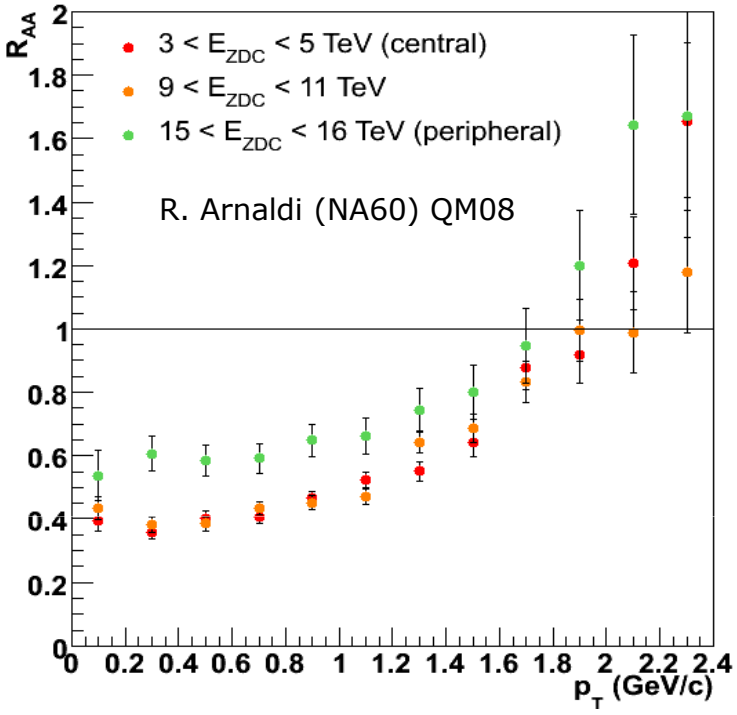
- Signal with good S/B ratio
- p_T range overlaps with p+p data
- Luminosity: 0.9 nb^{-1}



R_{AA} Comparison to NA60



RHIC: Cu+Cu, $\sqrt{s_{NN}} = 200GeV$
consistent with no suppression at $p_T > 5$ GeV

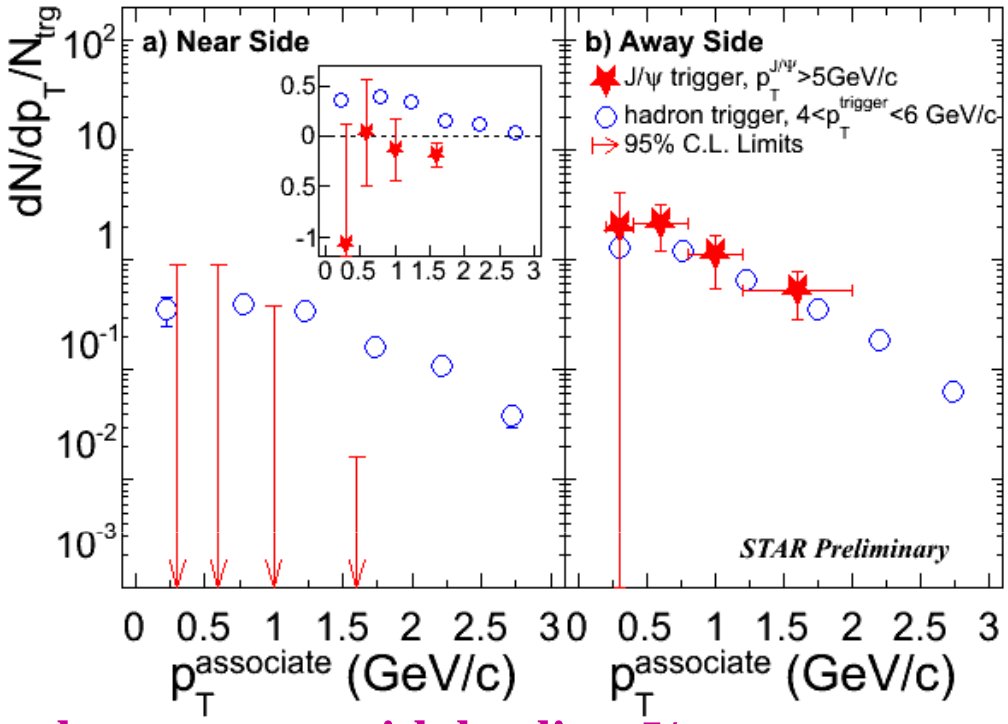


SPS: In+In, $\sqrt{s_{NN}} = 17.3GeV$,
consistent with no suppression at $p_T > 1.8$ GeV

Cronin
pA➔pp
Thermal fit

Important to understand production mechanism ➔

Yields in near/away side



Associated hadron spectra with leading J/ψ:

- Away side: Consistent with leading charged hadron correlation measurement (h-h)
  ➔away-side from gluon or light quark fragmentation
- Near side: Consistent with no associated hadron production
  B➔J/ψ not a dominant contributor to inclusive J/ψ
  constrain J/ψ production mechanism

pT dependent sDCA cut

$$econv = \sqrt{R^2 + r^2} - R$$
$$= \sqrt{(p_T / 0.0015)^2 + r^2} - (p_T / 0.0015)$$

-0.5<sDCA<econv->Eval(pt,30cm)
Blue curve, reject conversion with r>30cm
Red curve: resolution
black: conversion at IFC