CFRJS

Heavy flavor at STAR

Jaroslav Bielčík

for STAR collaboration

Czech Technical University

Prague

XVII International Workshop on Deep-Inelastic Scattering and Related Subjects

STAR

DIS conference, Madrid, April 2009

Outline

- Heavy ion program at RHIC in BNL
- Motivation for heavy flavor physics
- STAR detector
- Open heavy flavor
  - Charm mesons: D^0
  - Non-photonic electrons
- Quarkonia
  - J/ψ and Υ measurements

Relativistic Heavy Ion Collider

RHIC site in BNL on Long Island, USA

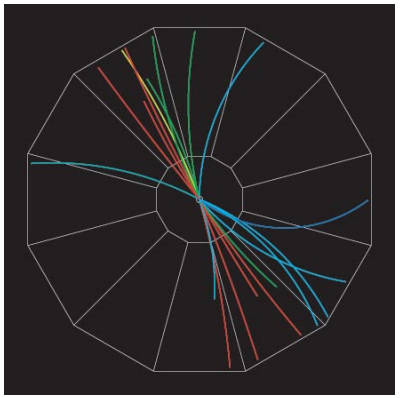
RHIC has been exploring nuclear matter at extreme conditions over the last few years

Lattice QCD predicts a phase transition from hadronic matter to a deconfined state, the **Quark-Gluon Plasma**

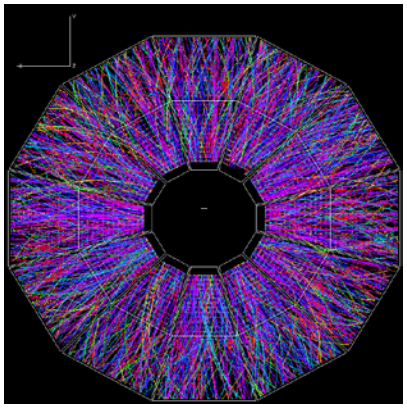
Colliding systems:
p↑+p↑, d+Au, Cu+Cu, Au+Au
Energies
$\sqrt{s_{NN}}$ = 20, 62, 130, 200GeV

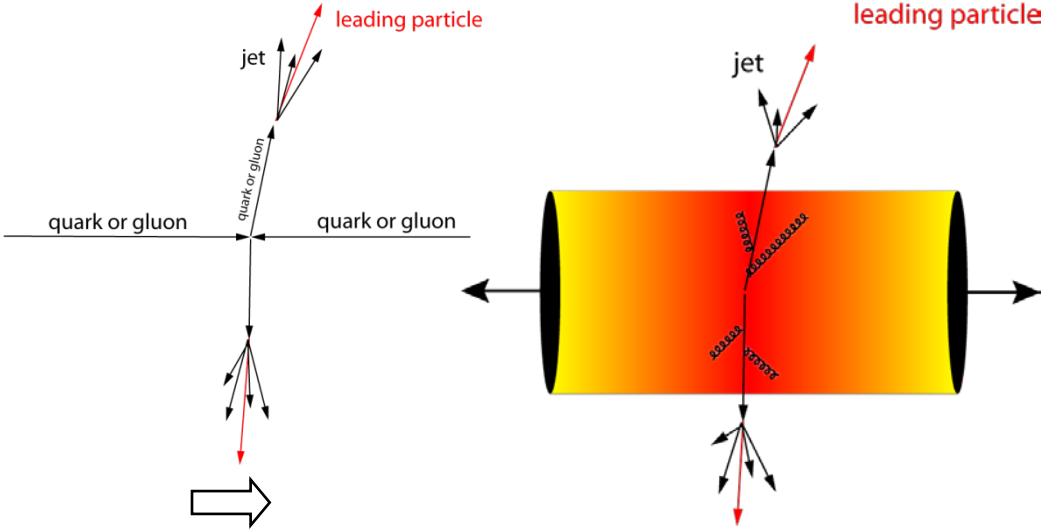
Probing of Dense Matter with jets

p+p Collision



Au+Au Collision





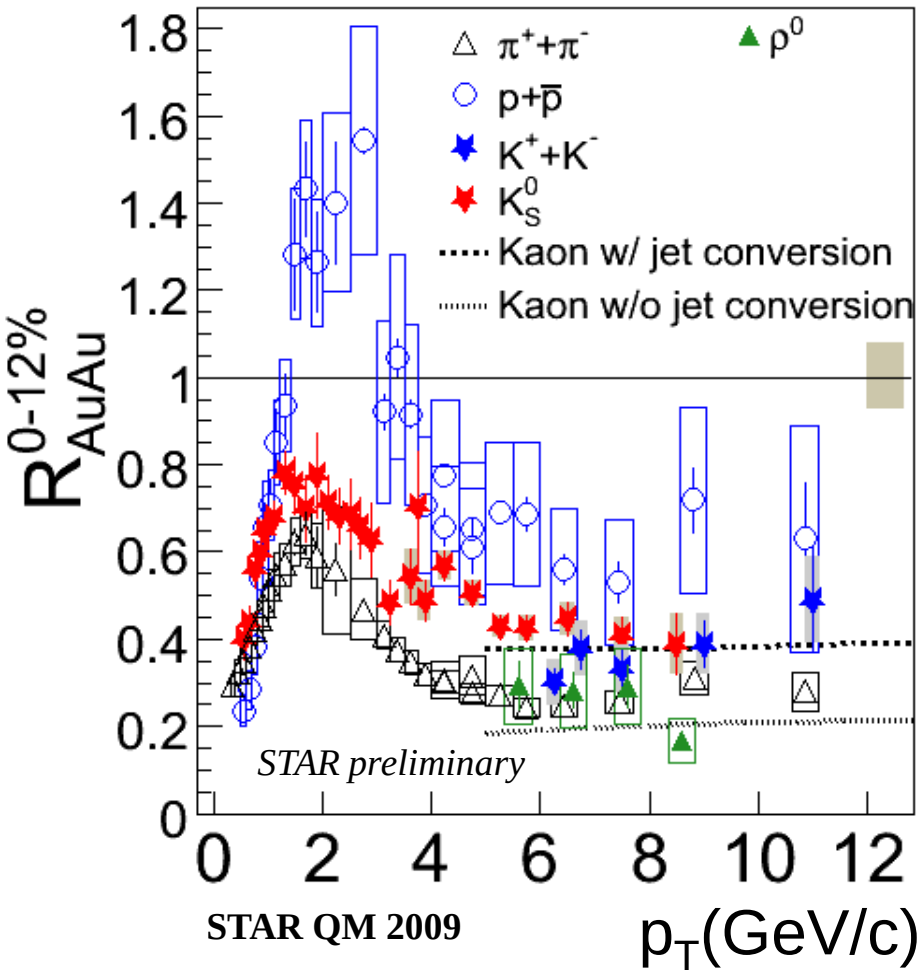
- nuclear modification factor R_{AA} :

$$R_{AA}(p_T) = \frac{Yield(A+A)}{Yield(p+p) \times \langle N_{coll} \rangle}$$

Average number of NN collisions in AA collision

- No "Effect" of nuclear matter: $R_{AA} = 1$ at higher momenta where hard processes dominate
- Suppression: $R_{AA} < 1$
- Partons interact with medium gluon radiation/energy loss
- measuring high-p_T particles in Au+Au vs. p+p to extract the properties of medium

Hadron suppression in central Au+Au



- **Hadron yields:**
  strongly suppressed
  in central Au+Au at 200 GeV

- **Large energy loss of light partons in the formed nuclear matter**

Energy loss depends on
properties of medium
(gluon densities, size)
properties of "probe"
(color charge, mass)

Heavy quarks as a probe

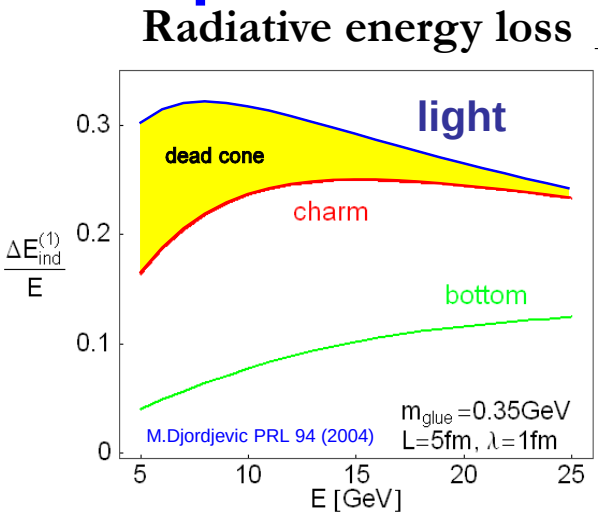
- p+p data:

→ baseline of heavy ion measurements
→ test of pQCD calculations

- Due to their large mass heavy quarks are primarily produced by gluon fusion in early stage of collision

→ production rates calculable by pQCD

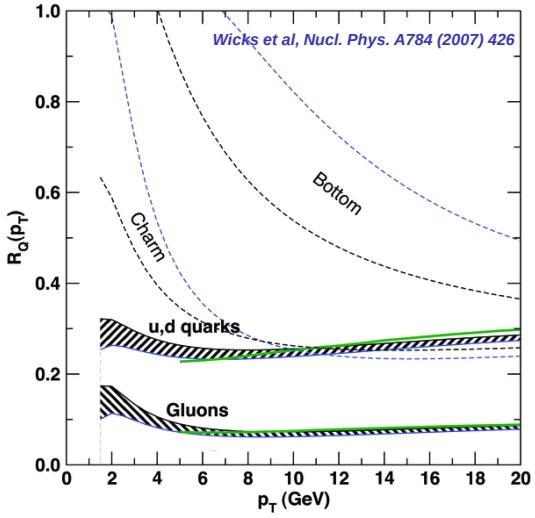
M. Gyulassy and Z. Lin, PRC 51, 2177 (1995)



- heavy ion data:

- Studying energy loss of heavy quarks

→ independent way to extract properties of the medium



Heavy flavor

Direct: reconstruction of all decay products

$$D^0 \to K^-\pi^+, \overline{D}^0 \to K^+\pi^-,$$

$$B.R. = 3.80 \pm 0.07\%$$

Indirect: charm and beauty via electrons

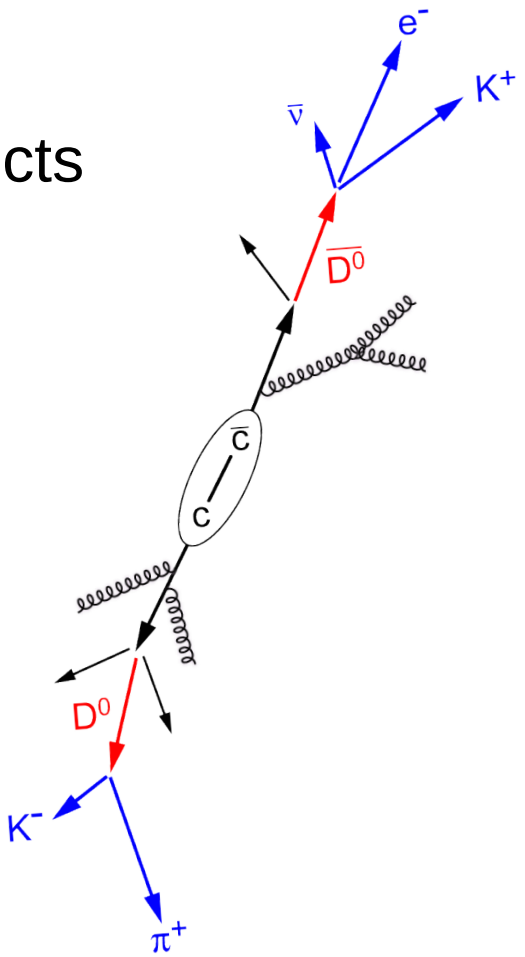
$c \to e^+ +$ anything (B.R.: 9.6%)

$b \to e^+ +$ anything (B.R.: 10.9%)

issue of photonic background

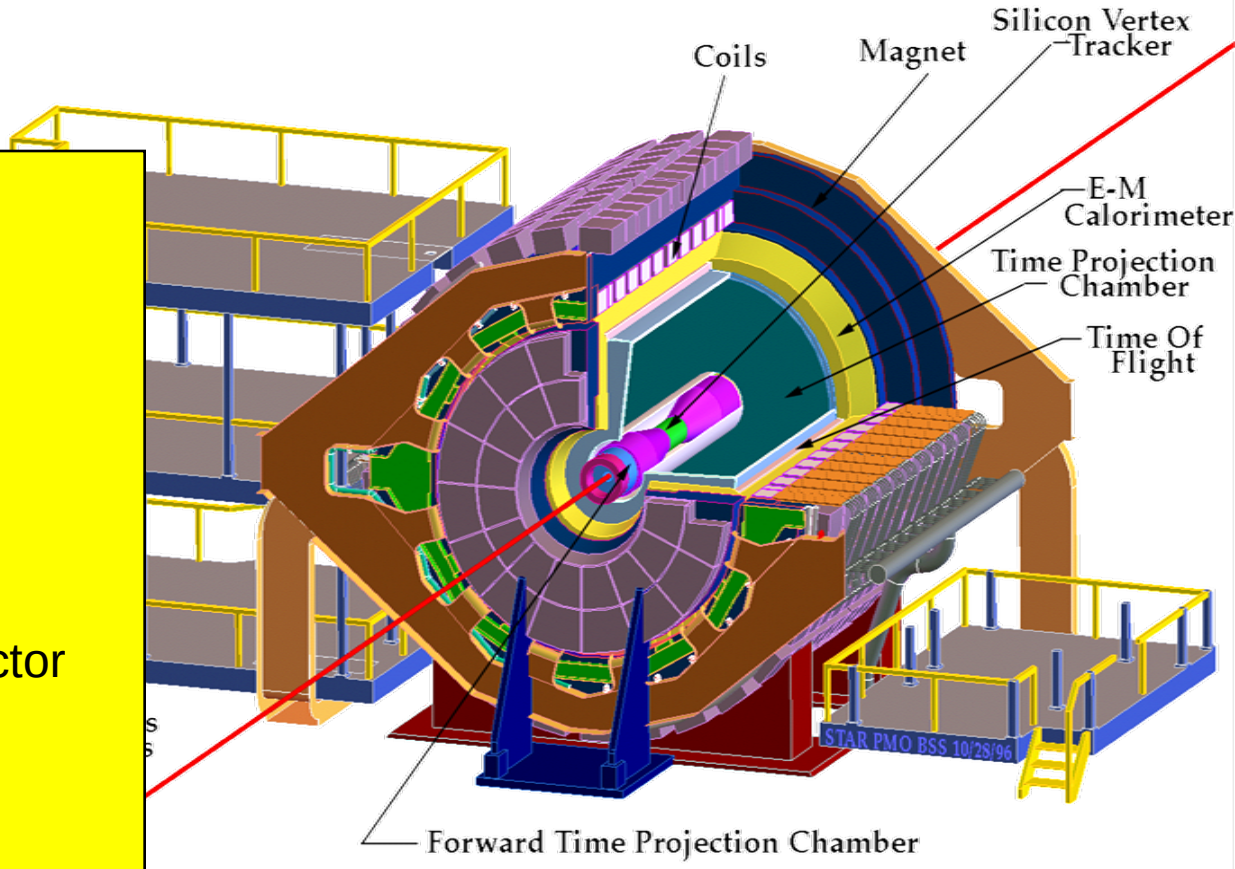
charm (and beauty) via muons

$c \to \mu+ +$ anything (B.R.: 9.5%)

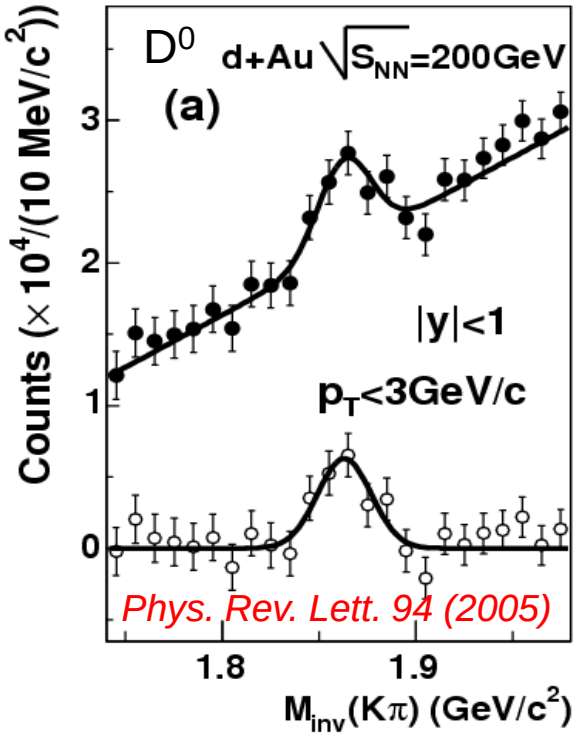


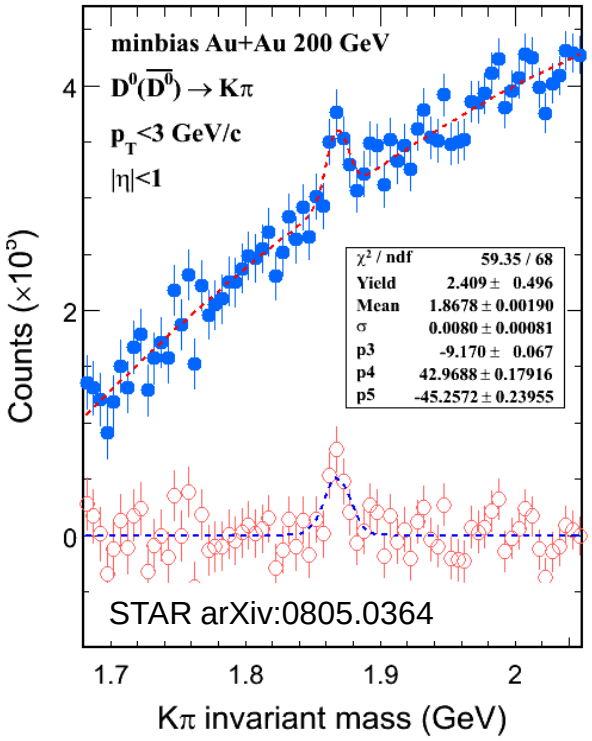
STAR detector

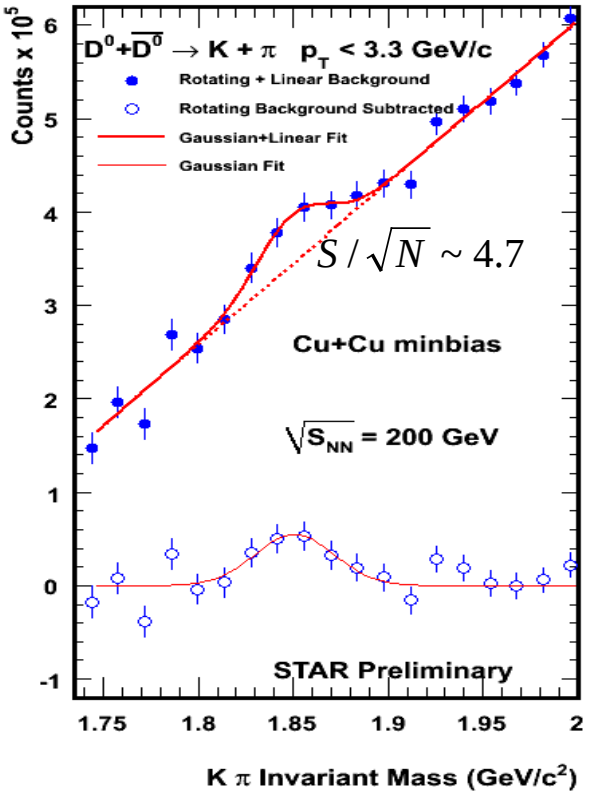
- TPC (tracking,p,dEdx)
  - $|\eta| < 1.5$
  - $\Delta p/p$ = 2-4%
  - $\sigma_{dE/dx}/dEdx$ = 8%
- BEMC (energy, trigger)
  - $|\eta| < 1$
  - $dE/E \sim 16\%/\sqrt{E}$
  - Shower maximum detector
- High tower trigger
- Upsilon high level trigger



Direct D-meson reconstruction at STAR

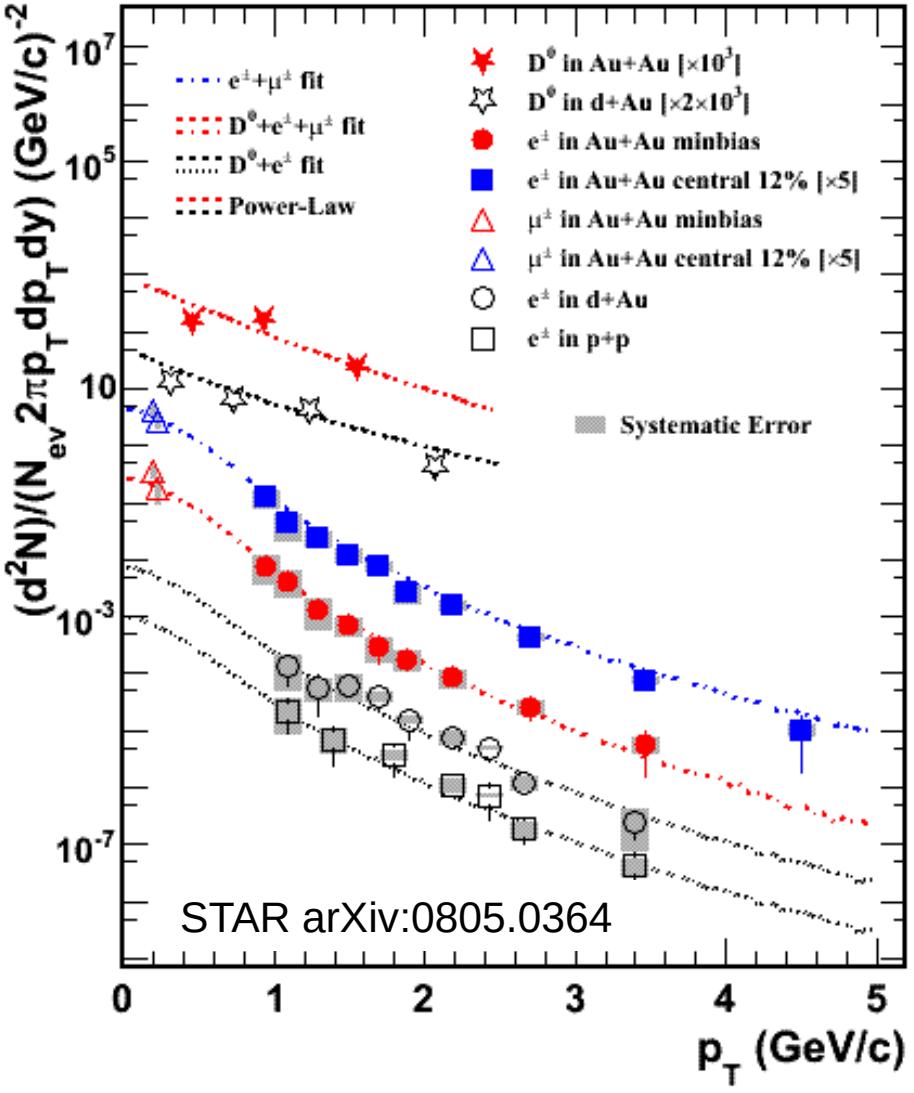






- Kπ invariant mass distribution in d+Au, Au+Au minbias, Cu+Cu minbias at 200 GeV collisions
- No displaced vertex used for open heavy flavor

Measurement of charm

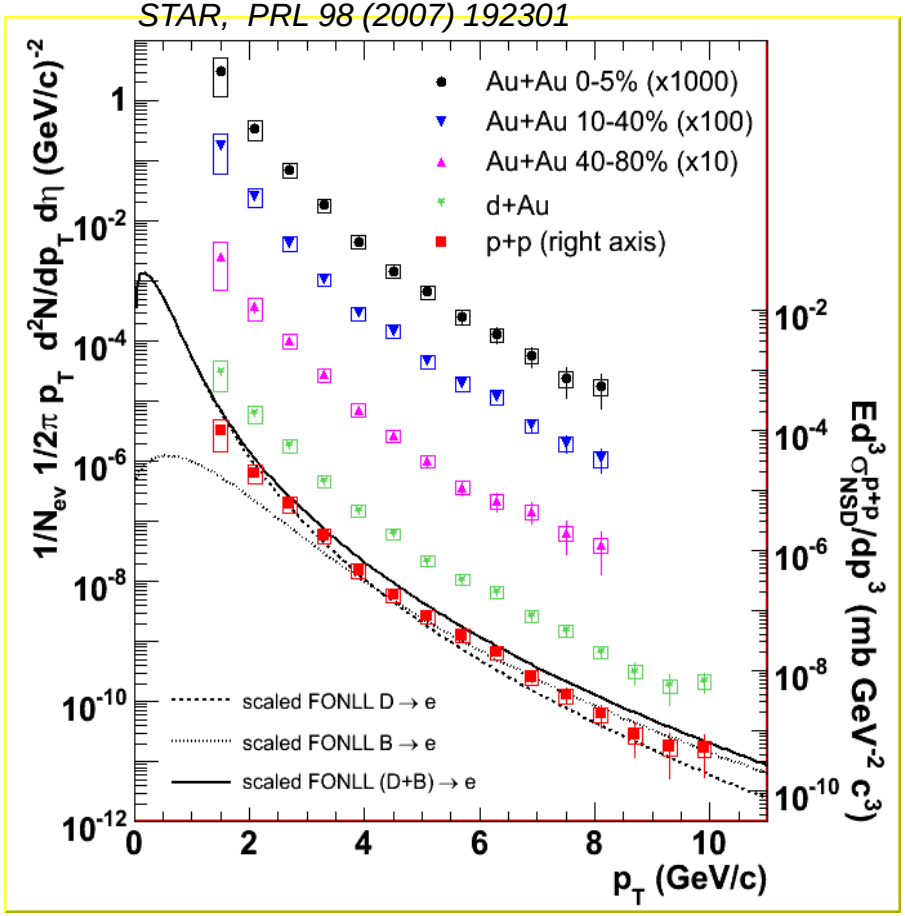


STAR charm measurement:

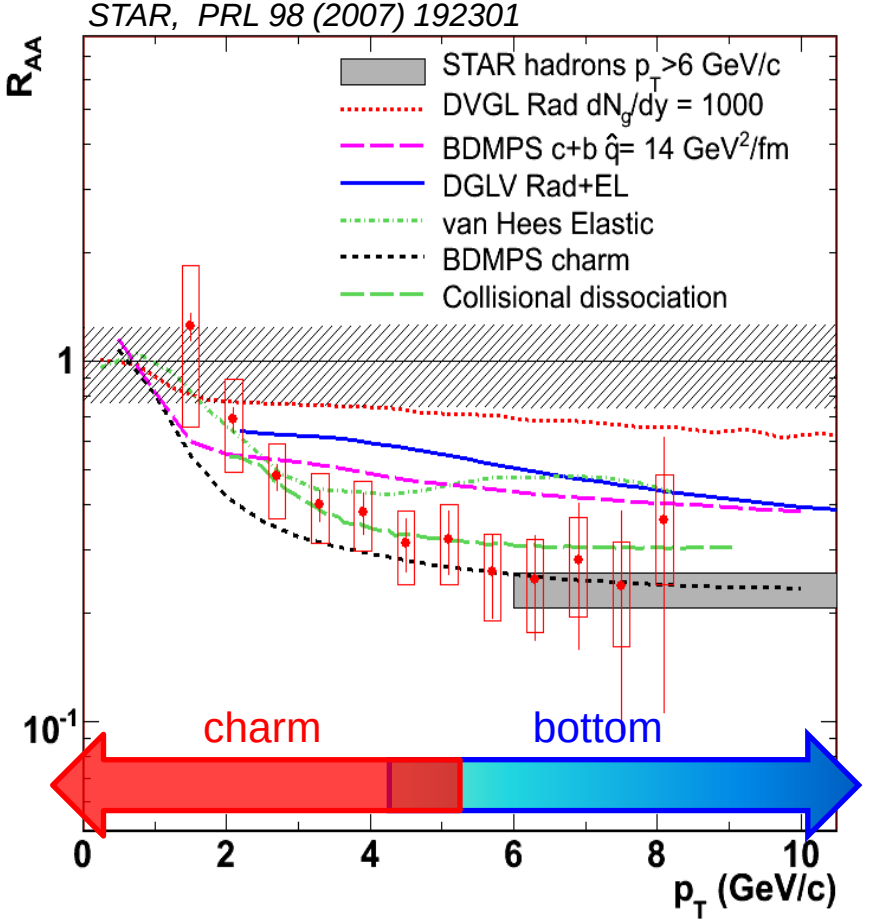
- D^0 in d+Au, Au+Au, Cu+Cu 200GeV
- low p_T muon in Au+Au 200GeV
- non-photonic electrons in p+p, d+Au, Cu+Cu, Au+Au 200GeV
- 90% of charm total kinematic range covered

Suppression of non-photonic electrons

STAR, PRL 98 (2007) 192301



STAR, PRL 98 (2007) 192301

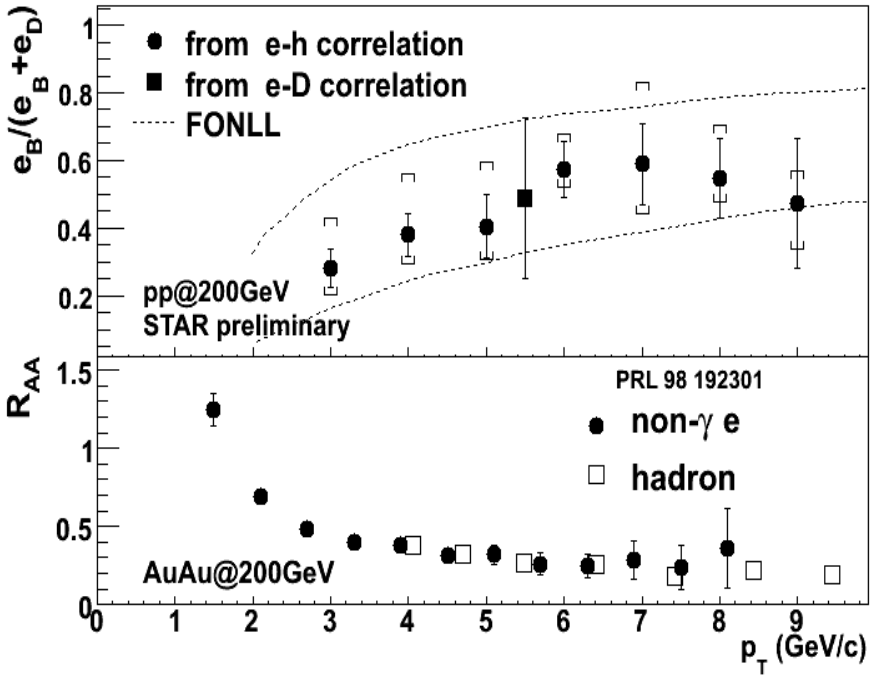


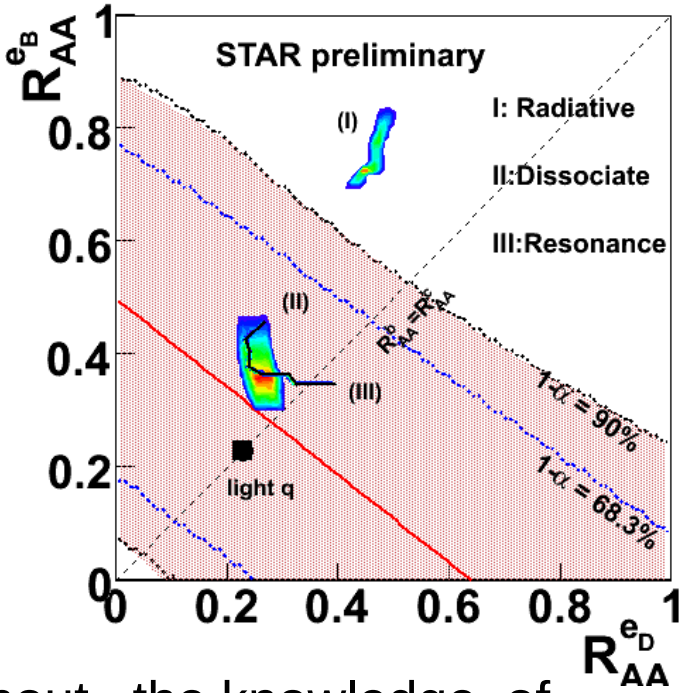
- Large suppression of non-photonics electrons similar to hadrons
- No satisfactory theoretical description yet

$$R_{AA}(p_t) = \frac{1}{N_{coll}} \times \frac{dN_{AA}/dp_t}{dN_{pp}/dp_t}$$

jaroslav.bielcik@fjfi.cvut.cz

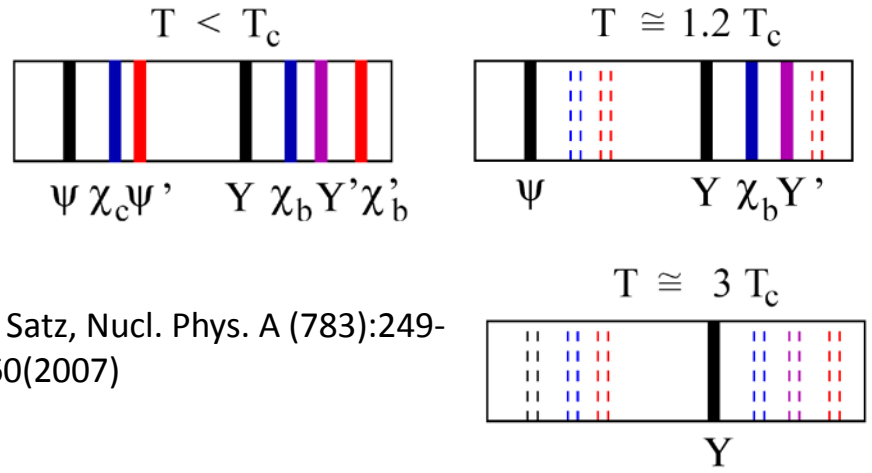
Bottom contribution to electron spectrum





- Difficult to interpret suppression without the knowledge of charm/bottom
- **Data** show non-zero **B contribution** consistent with FONLL
- Charm and bottom contribution comparable at p_T of 5 GeV
- B meson is also suppressed

Quarkonia at STAR



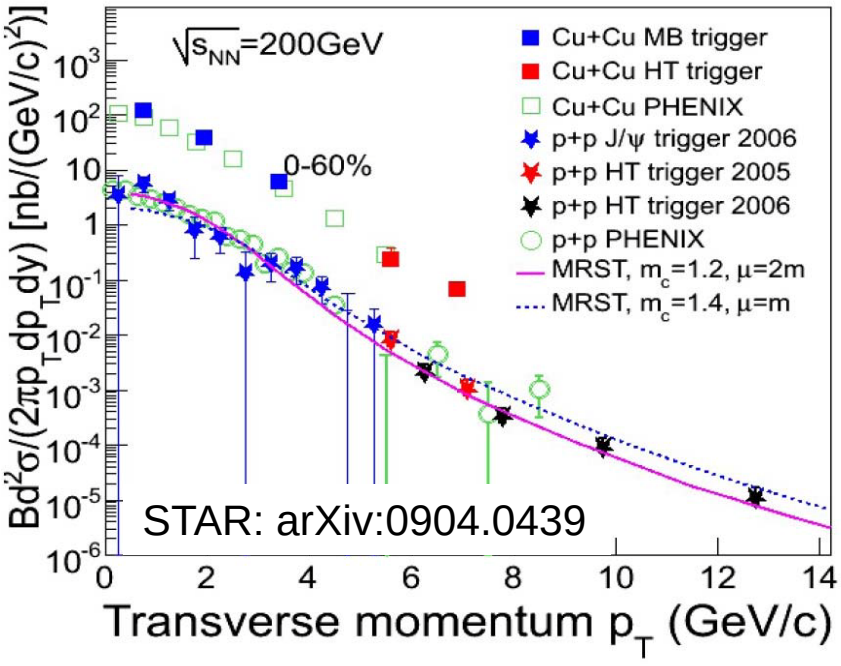
H. Satz, Nucl. Phys. A (783):249-260(2007)

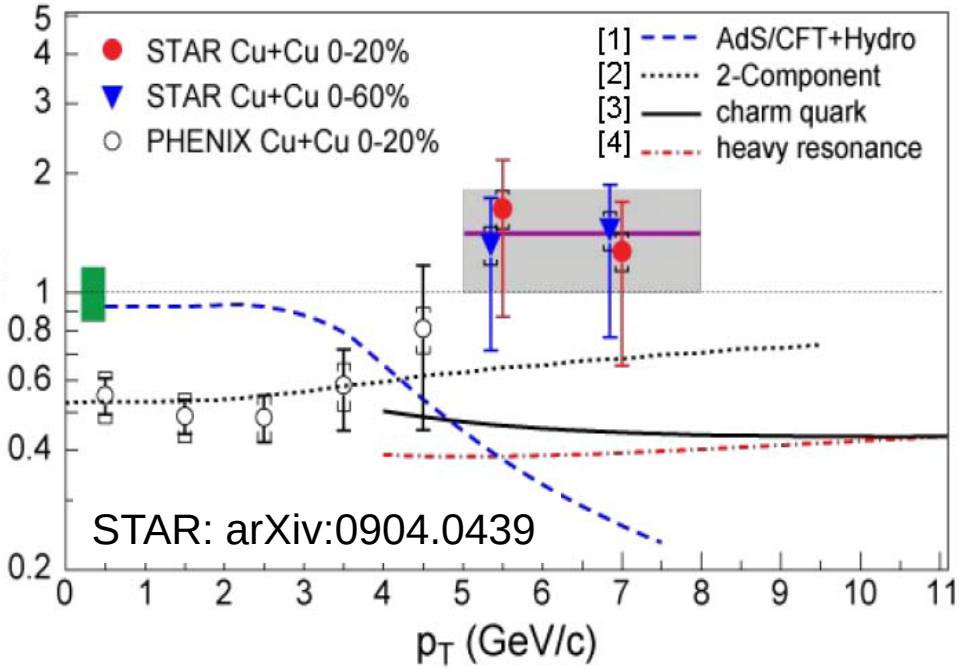
$J/\psi \rightarrow e^+e^-$

$\Upsilon \rightarrow e^+e^-$

- How they melt in hot/dense nuclear matter?
- What is production mechanism at RHIC?

J/ψ in p+p and Cu+Cu 200 GeV





- **$R_{AA}(p_T>5$ GeV/c) = 1.4± 0.4±0.2**
- Consistent with no suppression at high p_T

A. Adil and I. Vitev, Phys.Lett. B649, 139 (2007), private c.
S. Wicks et al., Nucl. Phys. A784, 426 (2007), and W. A. Horowitz private communication.

- Expectation of J/ψ suppression at high p_T from strong open charm suppression from color octet model

- Two component model+J/ψ form. time+ B feeddown describes the trend well

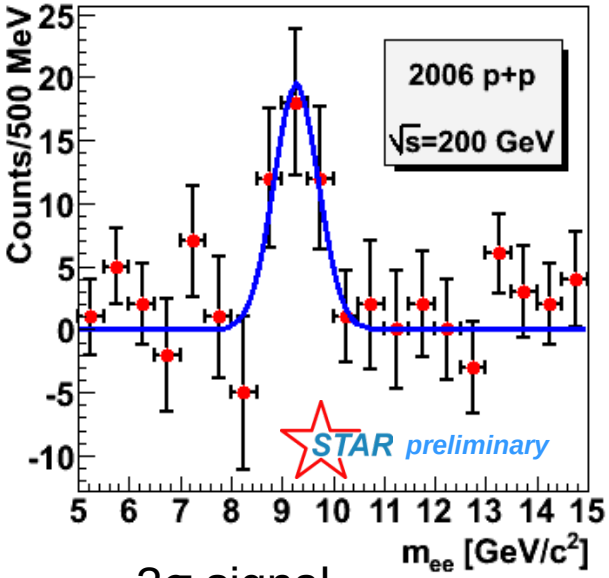
R. Rapp, X. Zhao, nucl-th/0806.1239

jaroslav.bielcik@fjfi.cvut.cz

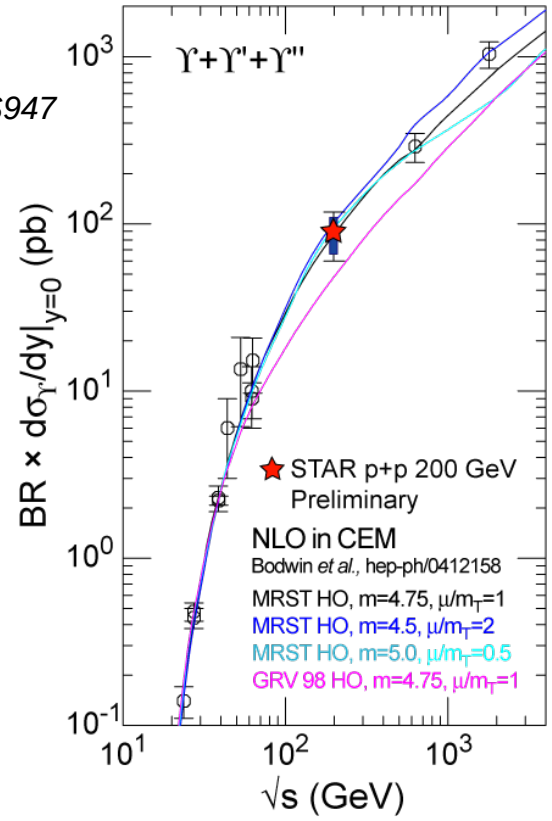
ϒ measurements in p+p and Au+Au

p+p 200 GeV

J. Phys. G: Nucl. Part. Phys. 34(2007)S947

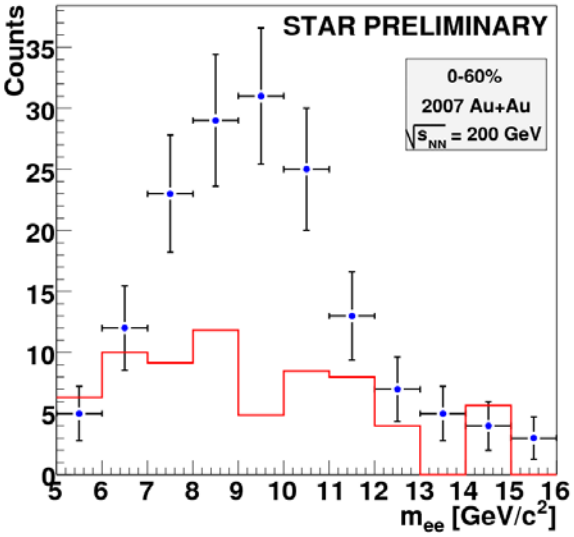


3σ signal



Au+Au 200 GeV

J. Phys. G: Nucl. Part. Phys. 35(2008)104153

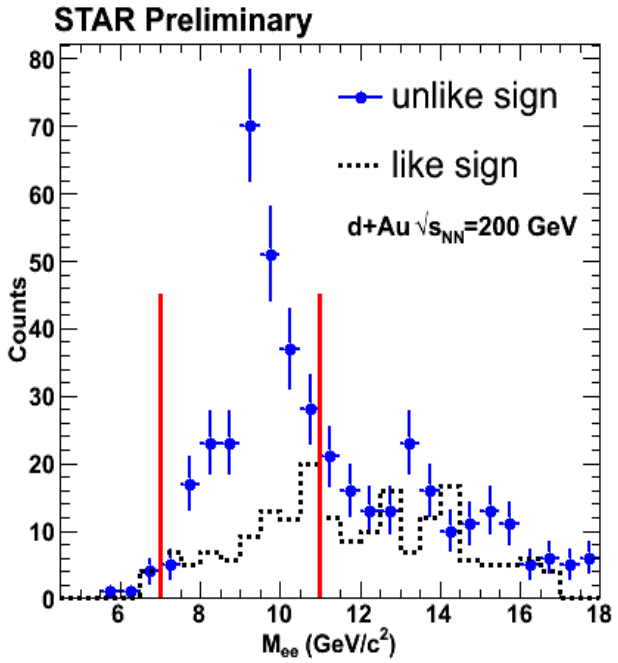


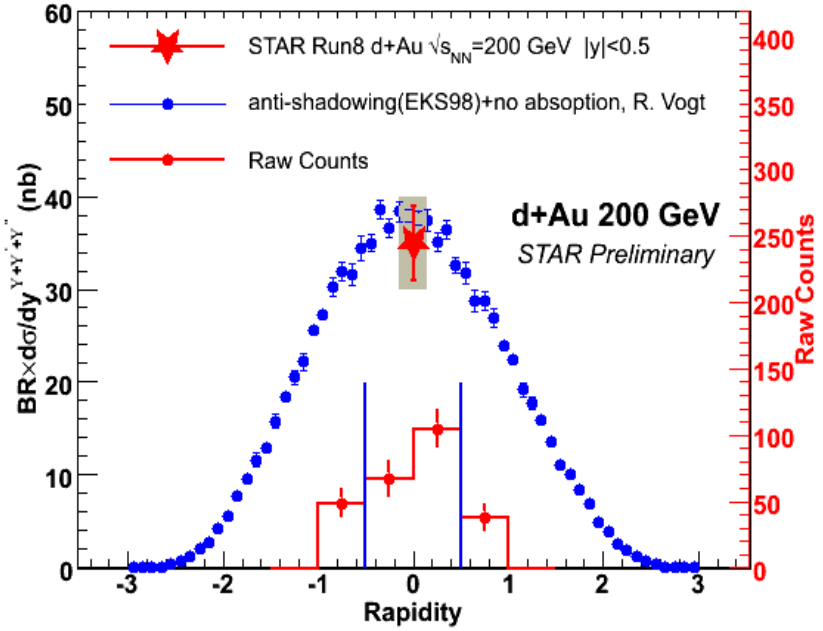
Cross section calculation is in progress

$$B_{ee} \times \left(\frac{d\sigma}{dy}\right)^{Y+Y'+Y''}_{y=0} = 91 \pm 28(stat.) \pm 22(syst.)\ pb$$

The cross section in p+p is consistent with pQCD

ϒ signal in d+Au 200 GeV collisions





- Strong signal (8σ significance) extracted

$$B_{ee} \times \left(\frac{d\sigma}{dy} \right)_{y=0}^{Y+Y'+Y''} = 35 \pm 4(stat.) \pm 5(syst.)\ pb$$

$$R_{dAu} = 0.98 \pm 0.32\ (stat.) \pm 0.28\ (sys.)$$

- Consistent with N_{bin} scaling of cross-section p+p ⟶ d+Au 200GeV

jaroslav.bielcik@fjfi.cvut.cz

Conclusions

- Heavy flavor is an important tool to understand medium properties
- **STAR** results are interesting and challenging

charm measurement

- Three different channels: D^0 ,μ, electrons

non-photonic electrons

- Bottom relative contribution consistent with FONLL
- Strong high-p_T suppression in Au+Au
- Heavy quark energy loss not fully understood

J/Psi

- Consistent with no suppression at high-p_T

Upsilon

- Cross section measurement in p+p and dAu
- Follows N_{bin} scaling

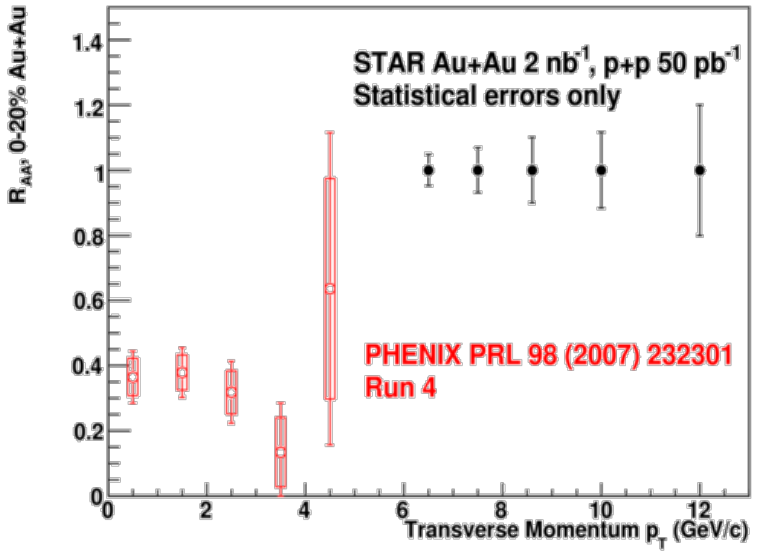
jaroslav.bielcik@fjfi.cvut.cz

Outlook

- High luminosity for Υ & high-p_T J/ψ:

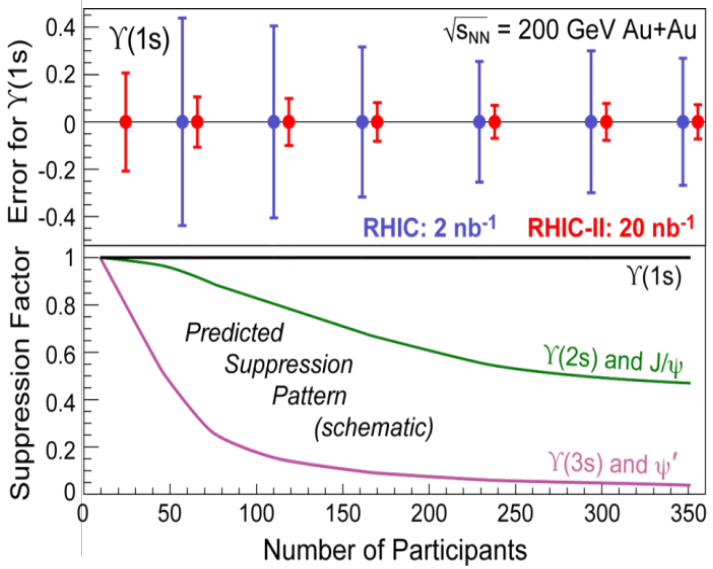
Time-Of-Flight:

Electron identification



RHIC II + DAQ1000:

Enhance statistics

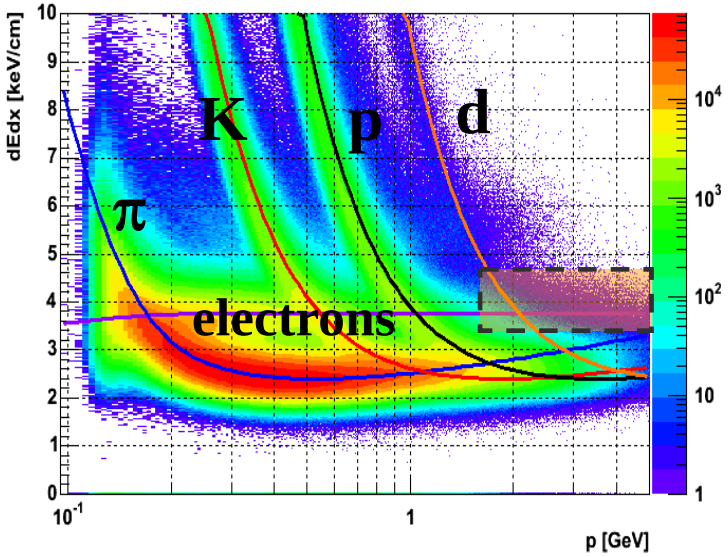


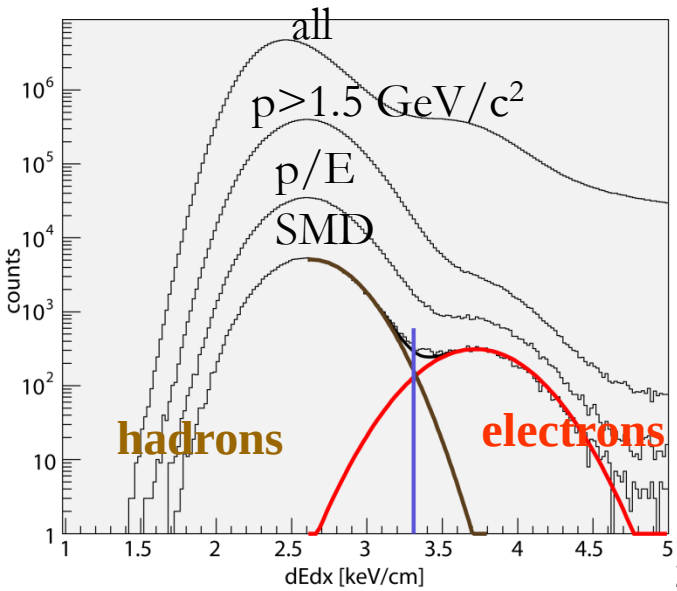
- Open charm : 2008 data d+Au 200 GeV with low material
  Heavy Flavor Tracker (HFT) for topological reconstruction

jaroslav.bielcik@fjfi.cvut.cz

Electron ID in STAR – EMC

1. TPC: dE/dx for p > 1.5 GeV/c
   - Only primary tracks (reduces effective radiation length)
   - Electrons can be discriminated well from hadrons up to 8 GeV/c
   - Allows to determine the remaining hadron contamination after EMC
2. EMC:
   a) Tower E ⇒ p/E~1 for e^-
   b) Shower Max Detector
      - Hadrons/Electron shower develop different shape



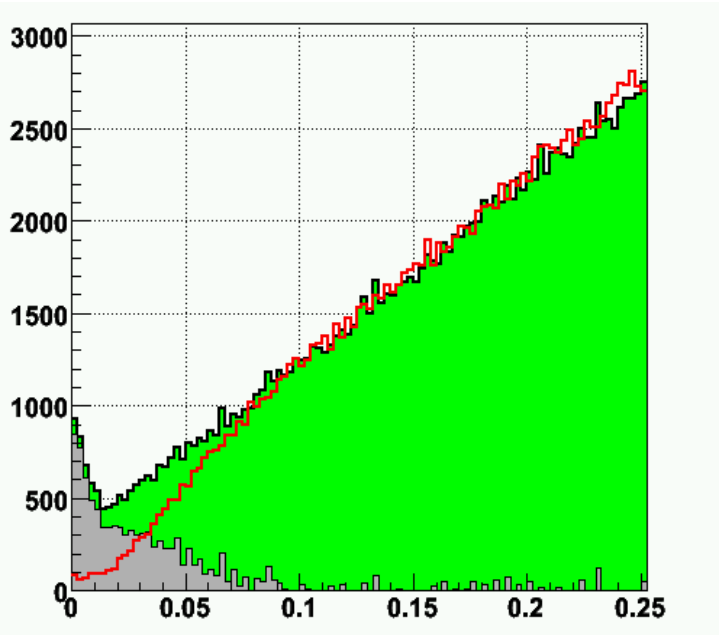


85-90% purity of electrons (p_T dependent)

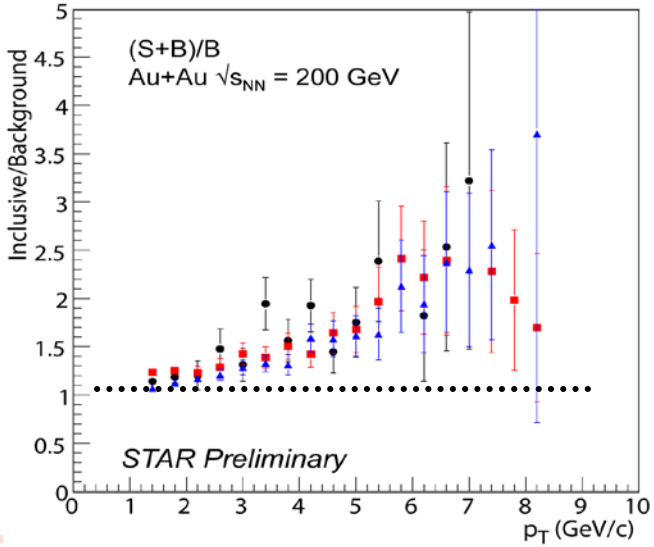
Photonic electrons background

- **Background: Mainly from γ conv and π^0,η Dalitz**
- **Rejection strategy:**

  For every electron candidate
  - Combinations with all TPC electron candidates
  - M_{e+e-}<0.14 GeV/c^2 flagged *photonic*
  - Correct for primary electrons misidentified as background
  - Correct for background rejection efficiency ~50-60% for central Au+Au

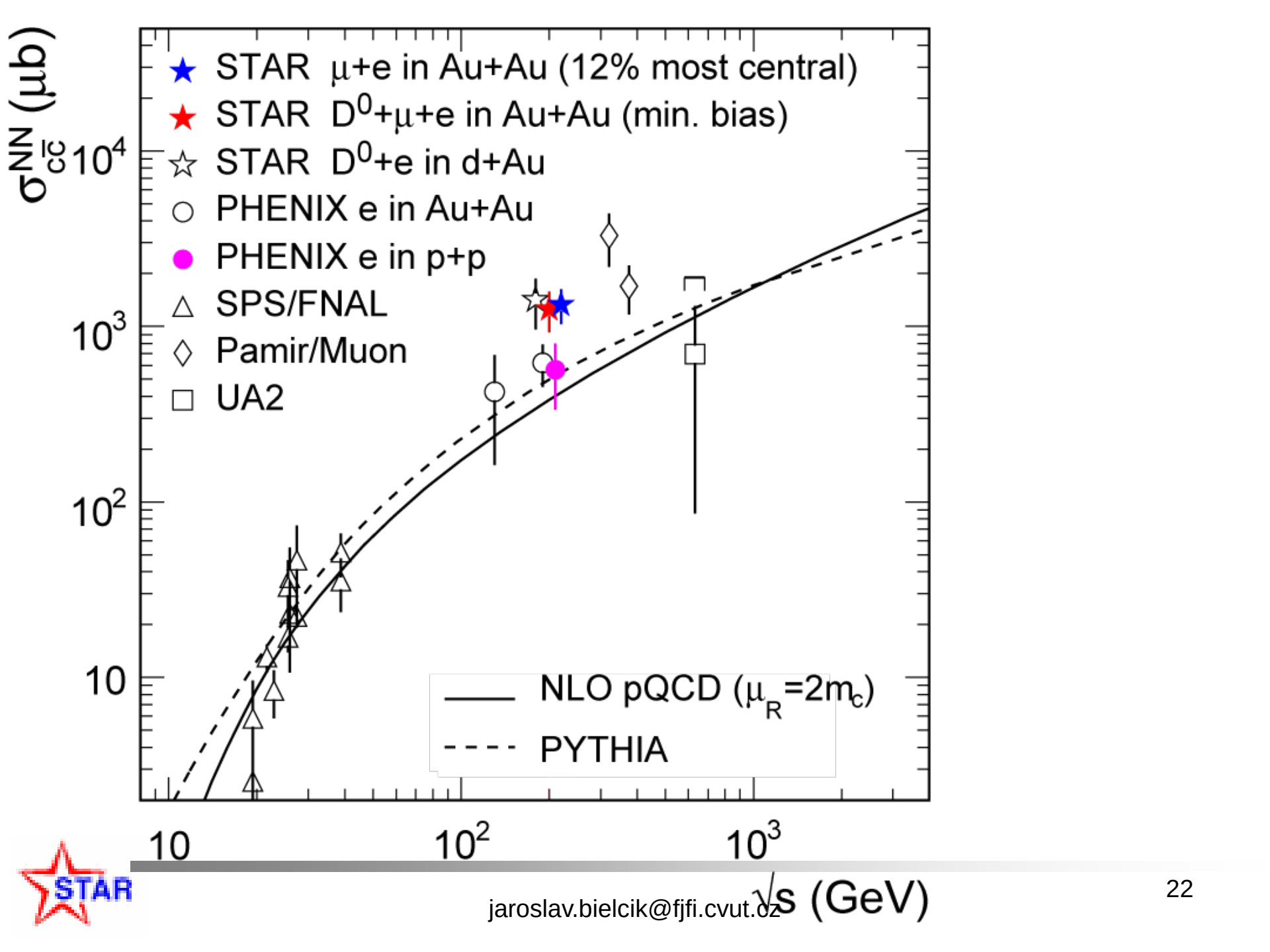


Inclusive/Photonic:

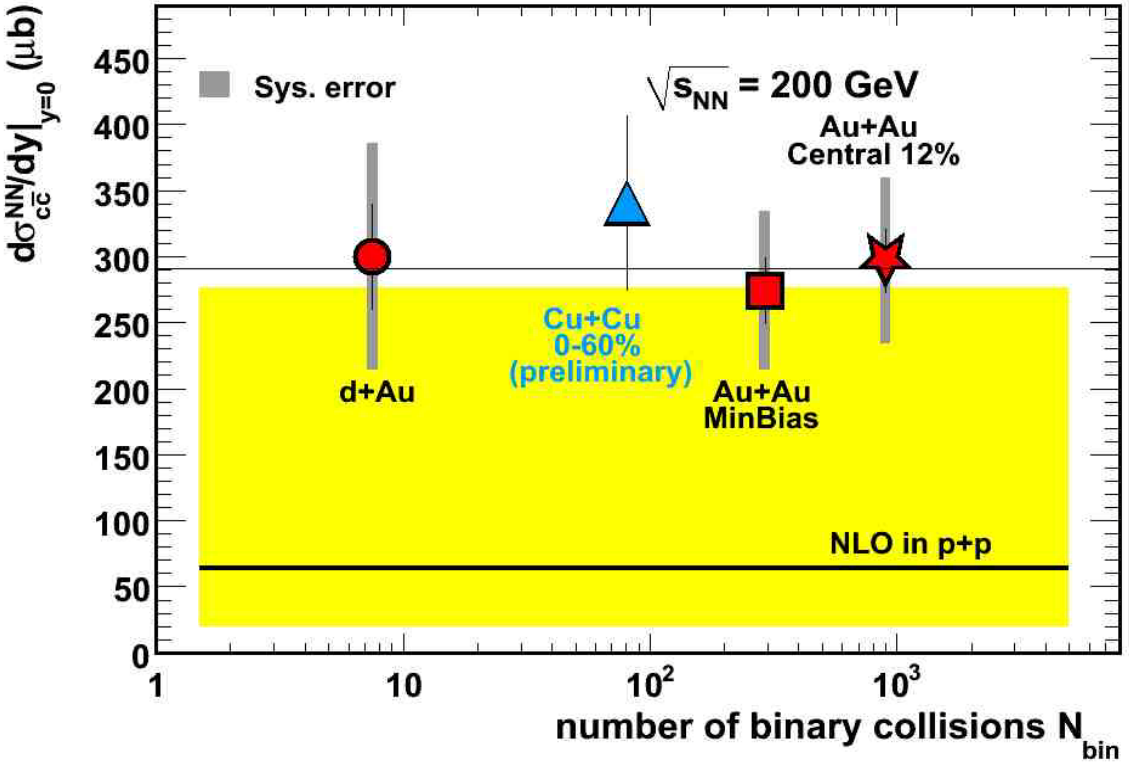


- **Excess over photonic electrons observed for all system and centralities**
  => non-photonic signal

jaroslav.bielcik@fjfi.cvut.cz


$\sigma_{c\bar{c}}^{NN}$ (μb)
STAR μ+e in Au+Au (12% most central)
STAR D^0+μ+e in Au+Au (min. bias)
STAR D^0+e in d+Au
PHENIX e in Au+Au
PHENIX e in p+p
SPS/FNAL
Pamir/Muon
UA2
NLO pQCD ($\mu_R=2m_c$)
PYTHIA
10^4
10^3
10^2
10
10
10^2
10^3
$\sqrt{s}$ (GeV)

Binary scaling of charm cross-Section

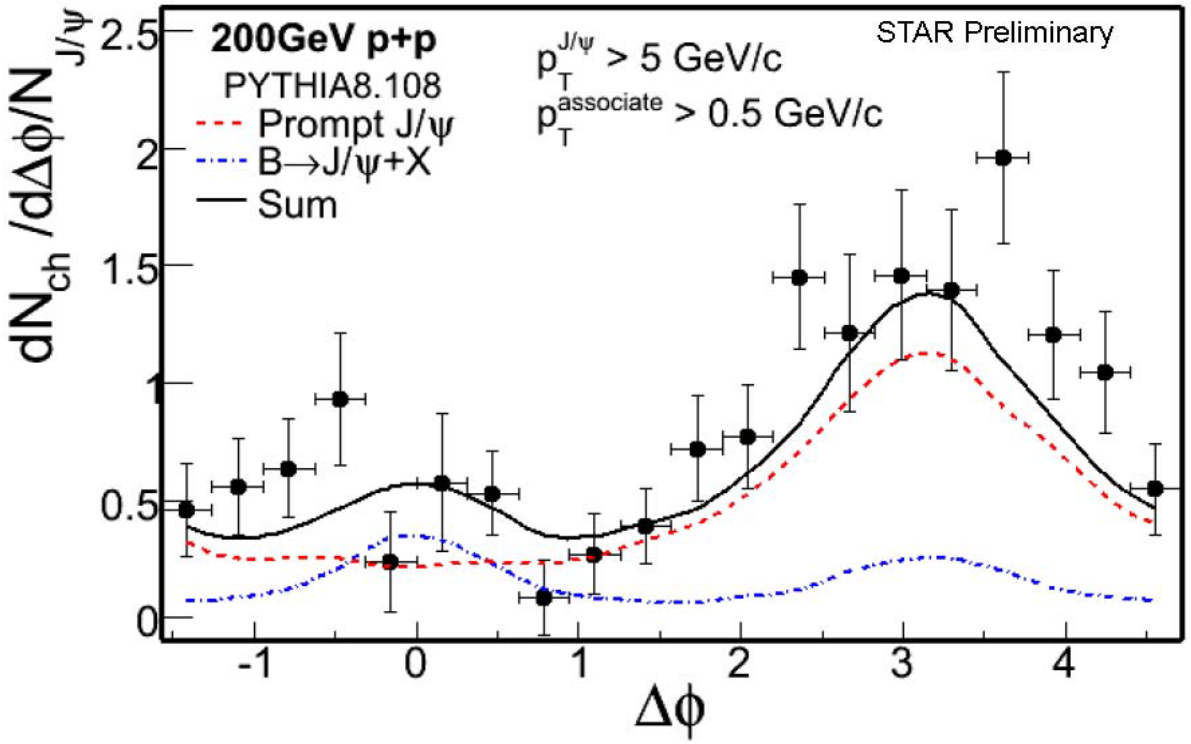


- observation of binary scaling
- large NLO uncertainties
- PHENIX values are lower

NLO Ref: R. Vogt, arXiv:0709.2531v1 [hep-ph]

STAR:
J. Adams et al. Phys. Rev. Lett 94, 062301 (2005)
S. Baumgart, arXiv:nucl-ex/0709.4223
B. Abelev et al.,, arXiv:nucl-ex/0805.0364

High-p_T J/ψ - hadron correlations



- Near-side correlation due dominantly to **B → J/ψ+X**
- B-meson feeddown to inclusive J/ψ production of **13%± 5%** at p_T > 5 GeV/c.