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Heavy Flavor production at RHIC

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INNOWACYJNA GOSPODARKA
NARODOWA STRATEGIA SPÓJNOŚCI

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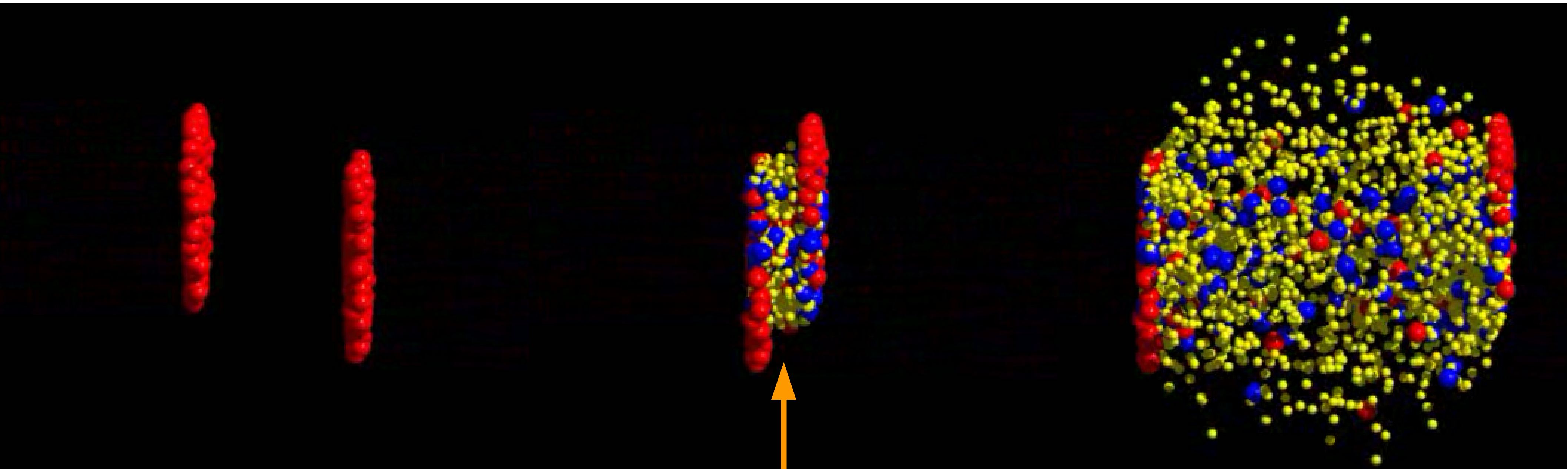
Heavy quark production at RHIC

Cold nuclear matter effects for bottom quarks

Relativistic Heavy Ion Collisions



UrQMD, http://urqmd.org/

- **c, b** quarks produced early
- **D**, **B** production in A+A $\rightarrow$ QGP properties

Experimental approach

1. baseline – **p+p**

2. "cold" nuclear matter effects – **d+Au**

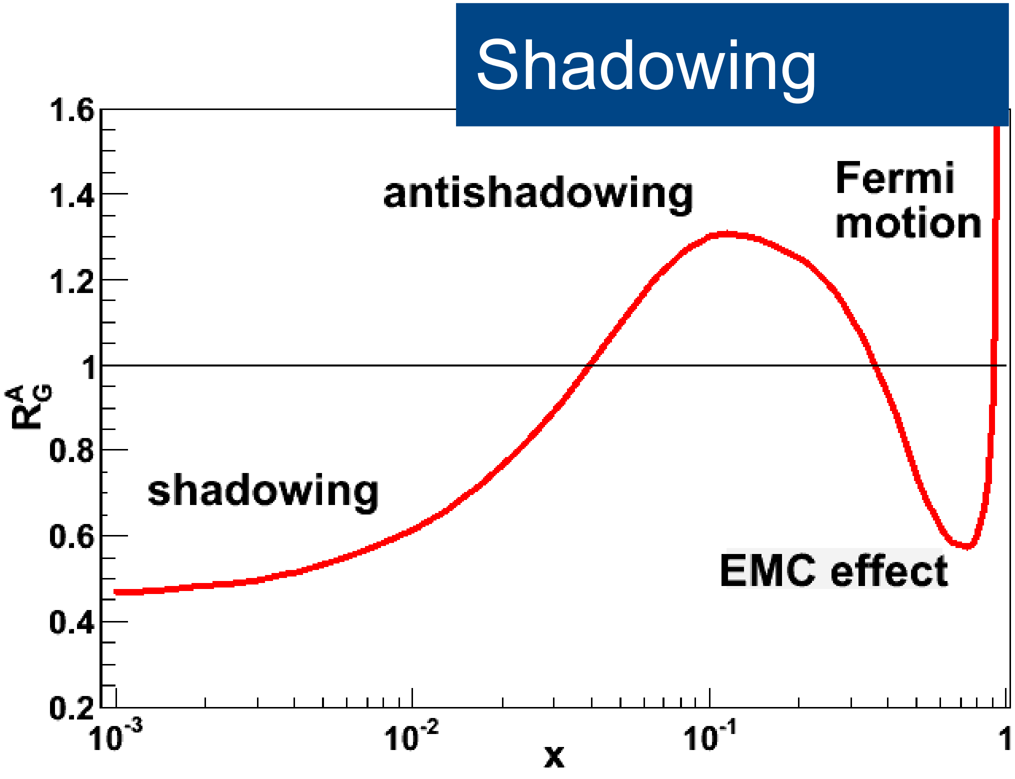
$$R_{dAu} = \frac{1}{\langle N_{coll} \rangle} \frac{dN/dy^{dAu}}{dN/dy^{pp}}$$

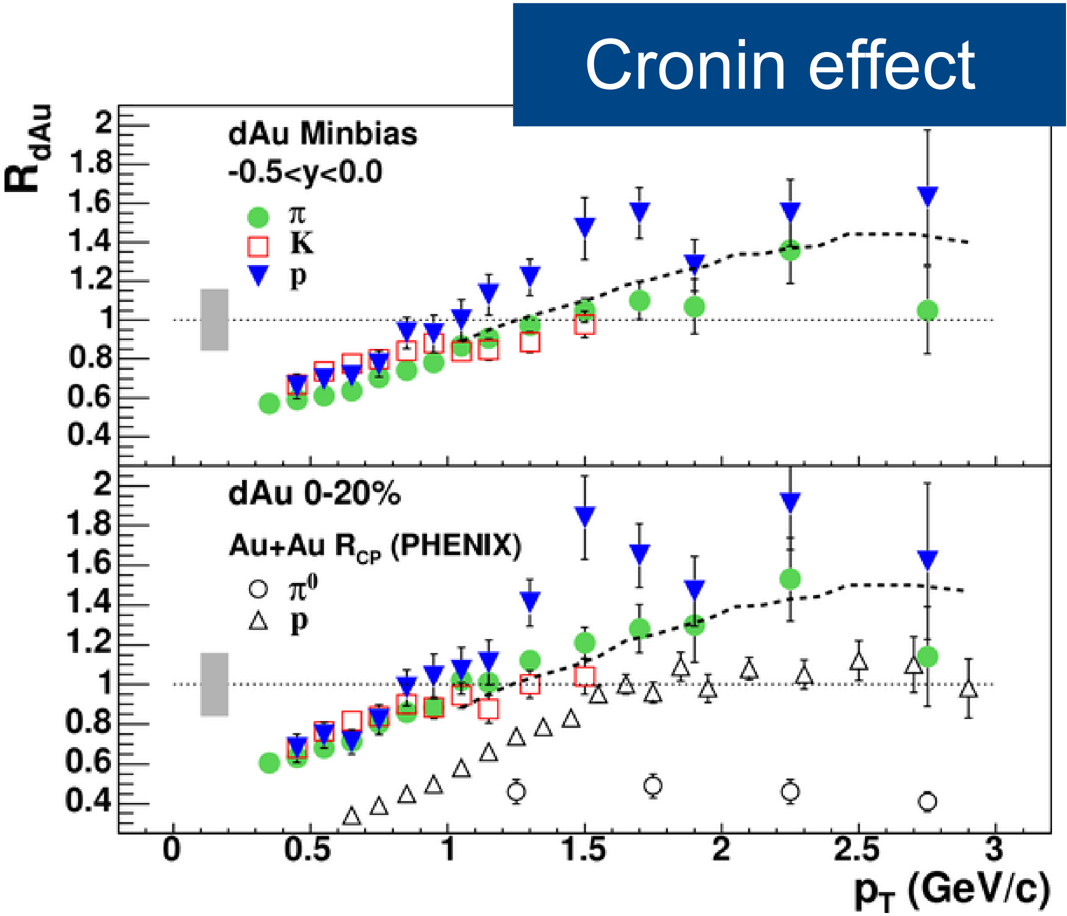
$R_{AA\ (dAu)} = 1$
if no modification
in the medium

3. modification in the hot/dense medium – **Au+Au**

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{dN/dy^{AuAu}}{dN/dy^{pp}}$$

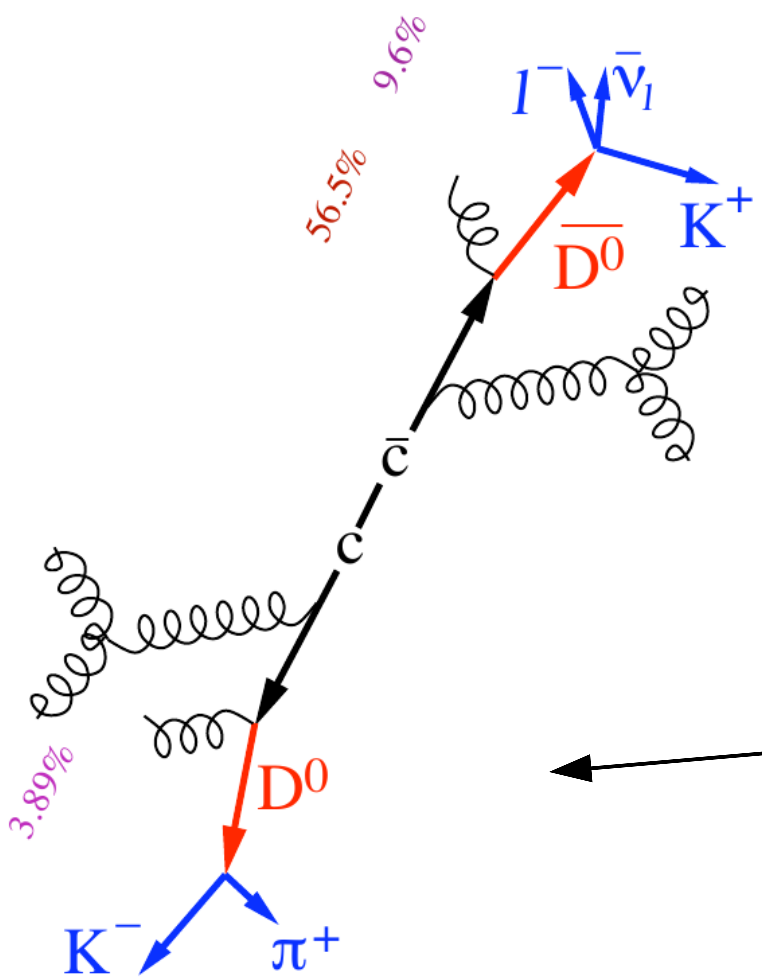
Cold nuclear matter effects





Phys. Lett. B 616 (2005) 8

Open heavy flavor at RHIC

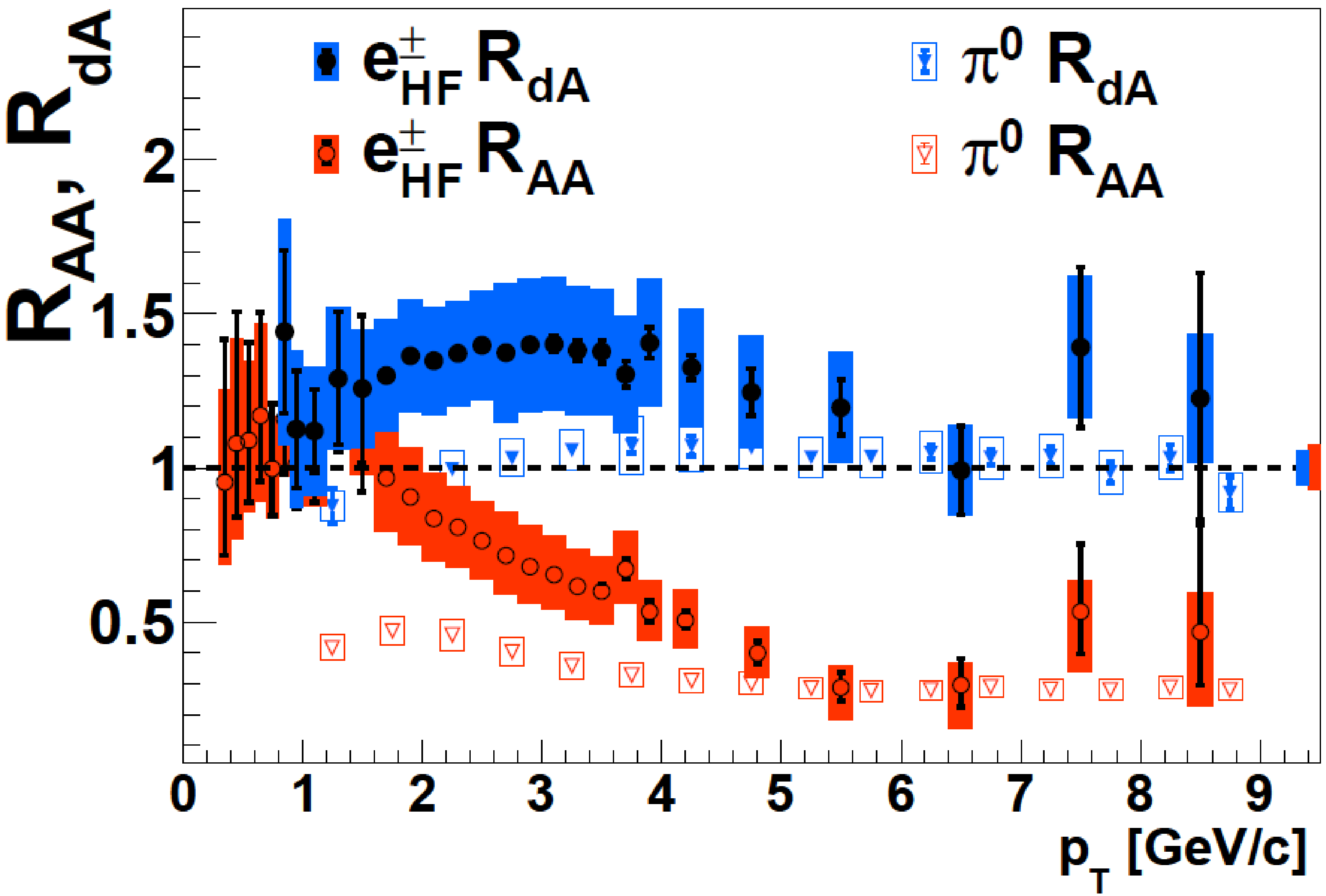


Electrons from semi-leptonic heavy flavor hadrons decay (b → e, c → e)

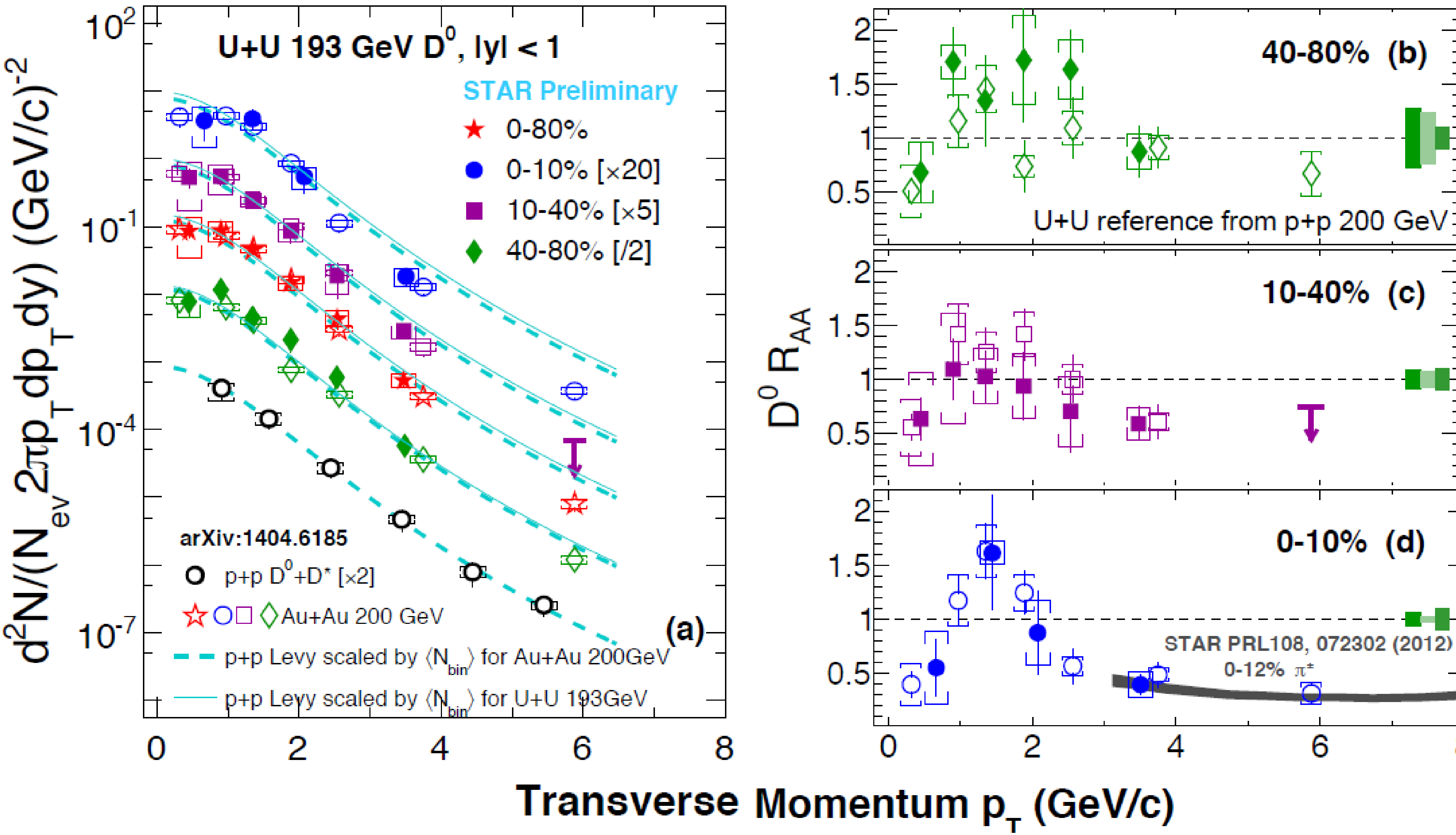
Direct open charm reconstruction

Courtesy of David Tlusty

e^{HF}: Cold vs Hot Nuclear metter



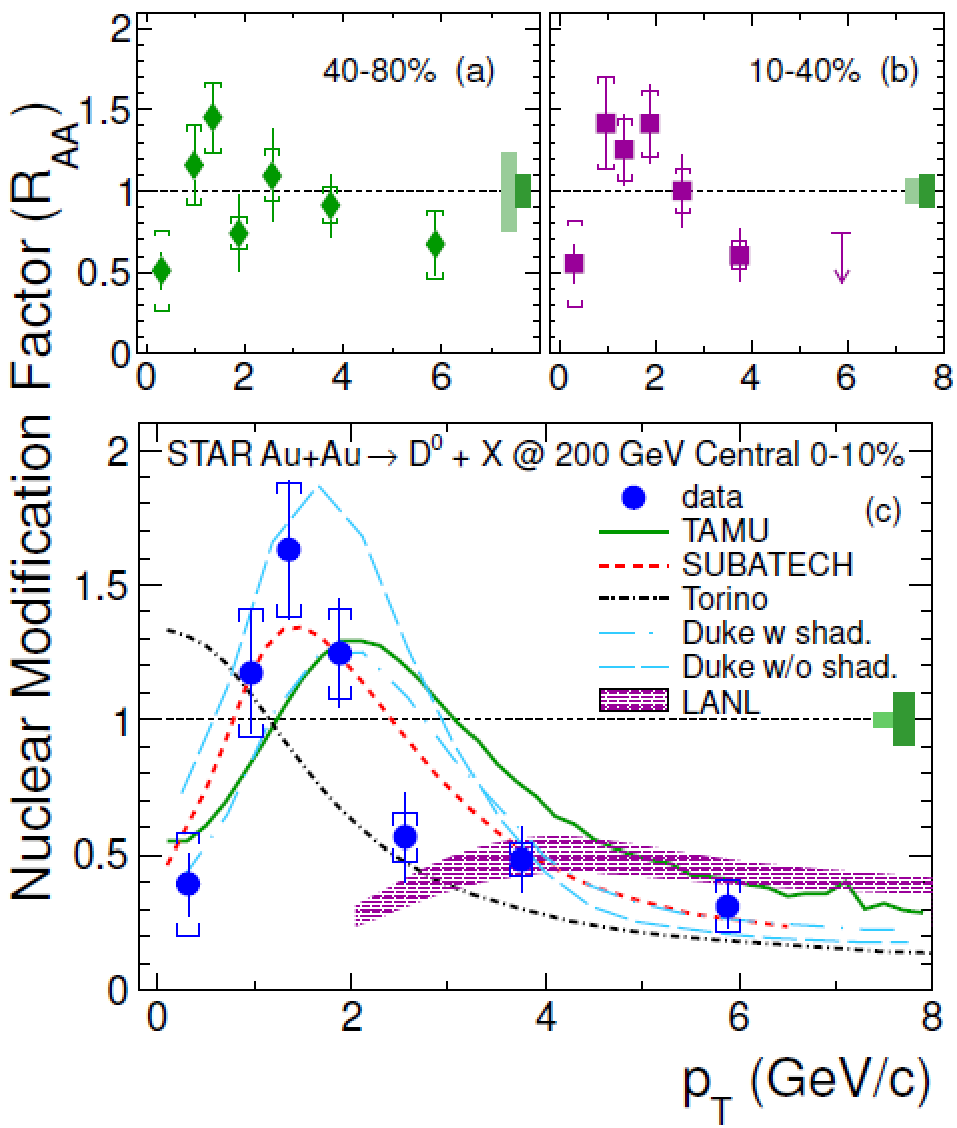
e^{HF} ($b \rightarrow e$, $c \rightarrow e$) suppressed at high p_T in Au+Au 200 GeV



Quark Matter 2014, Zhenyu Ye

U+U → ~20% larger energy density for the same centrality class than Au+Au

Open charm suppression



Suppression at high p_T in central and mid-central collisions

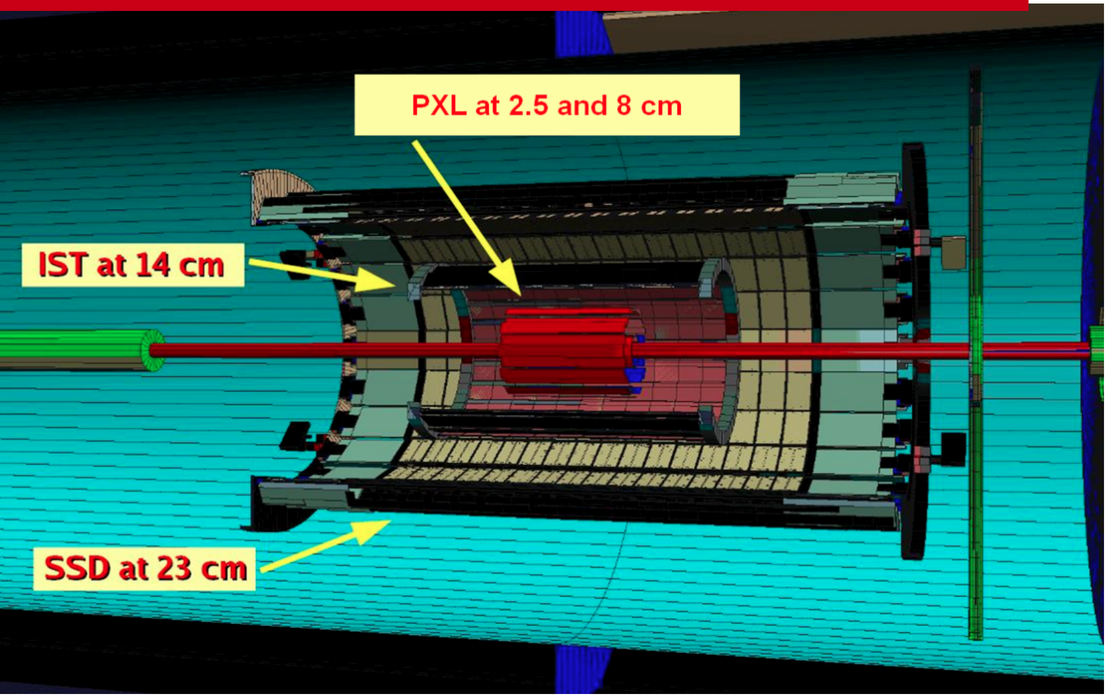
Enhancement at intermediate p_T:

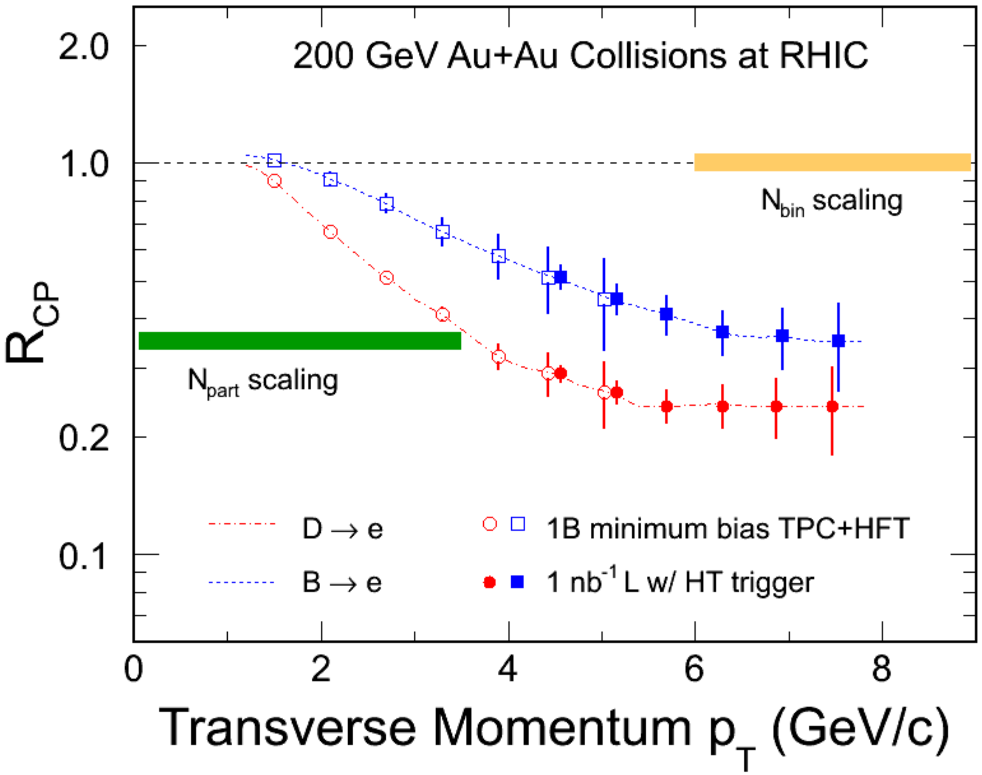
→ Radial flow (?)

→ Cronin enhancement + suppression at high p_T (?)

arXiv: 1404.6185

Heavy Flavor Tracker





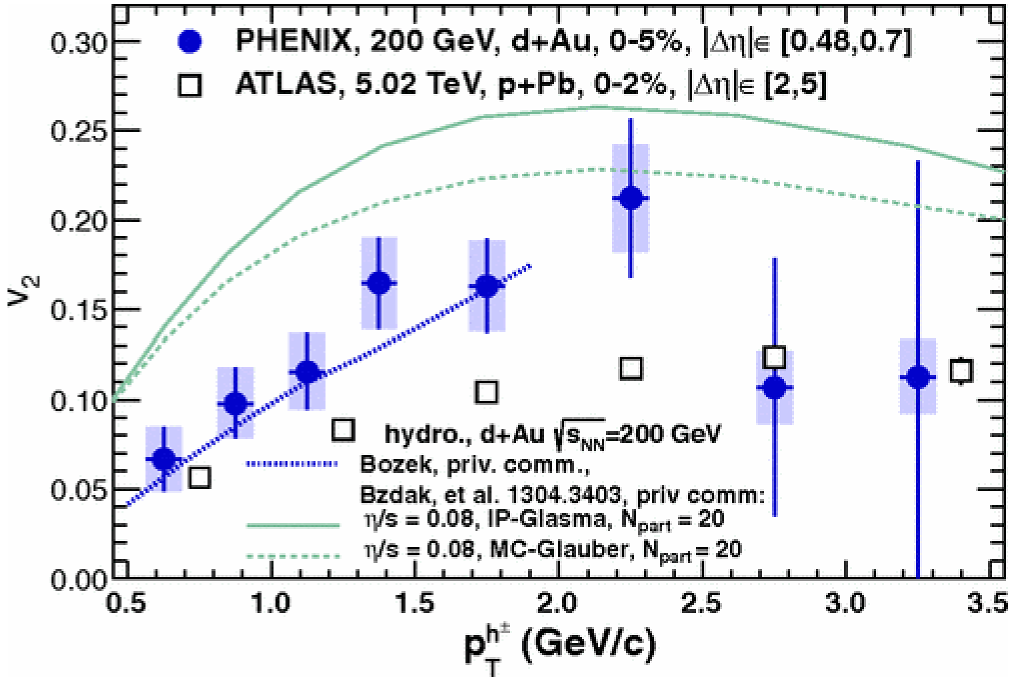
HFT available for RHIC Run-14 (a long Au-Au 200 GeV run)

charm → e and bottom → e separation in Au+Au

Cold nuclear matter effects for **c→e** and **b→e** ?

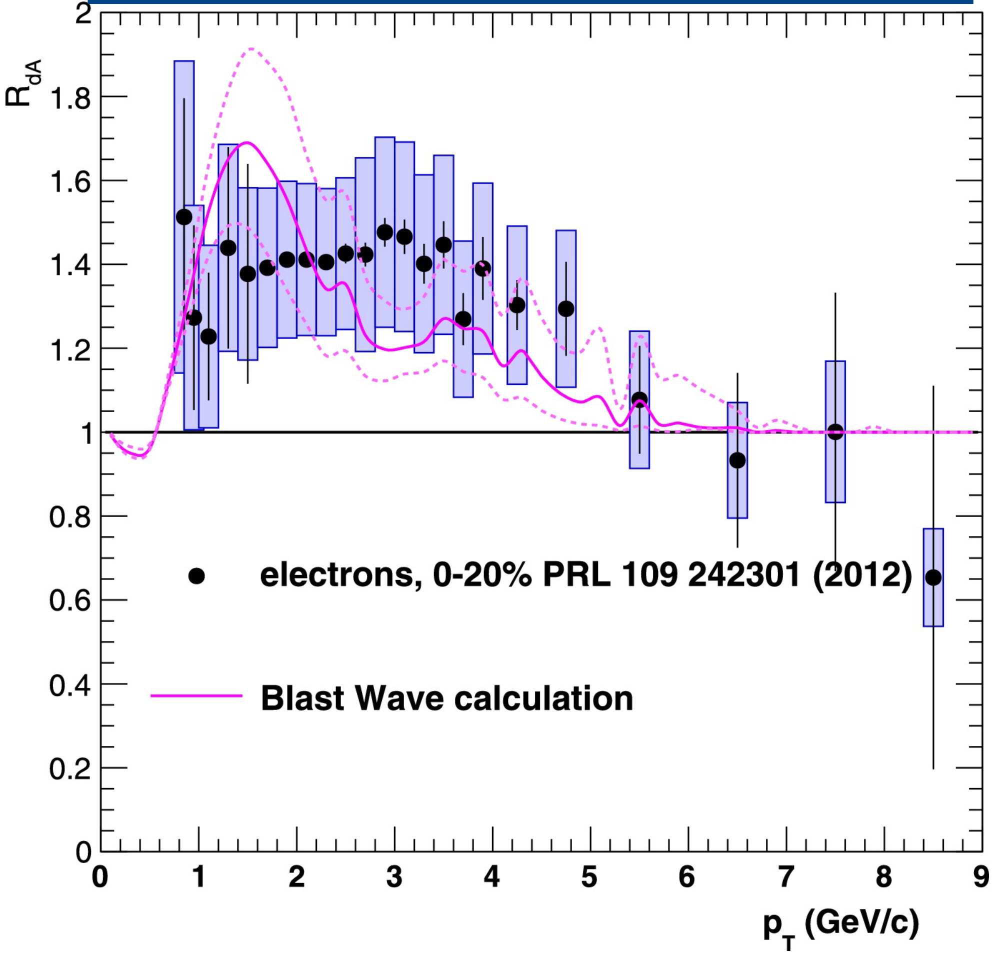
d+Au: reference or “mini-QGP” ?

Charged hadron



Phys. Rev. Lett. 111, 212301 (2013)

Heavy flavor decay electron



„Possible evidence for radial flow of heavy mesons in d+Au collisions”
Phys. Lett. B731 51-56 (2014)

Cold nuclear matter effects for charm and bottom

D. K., Andrzej Lipiec

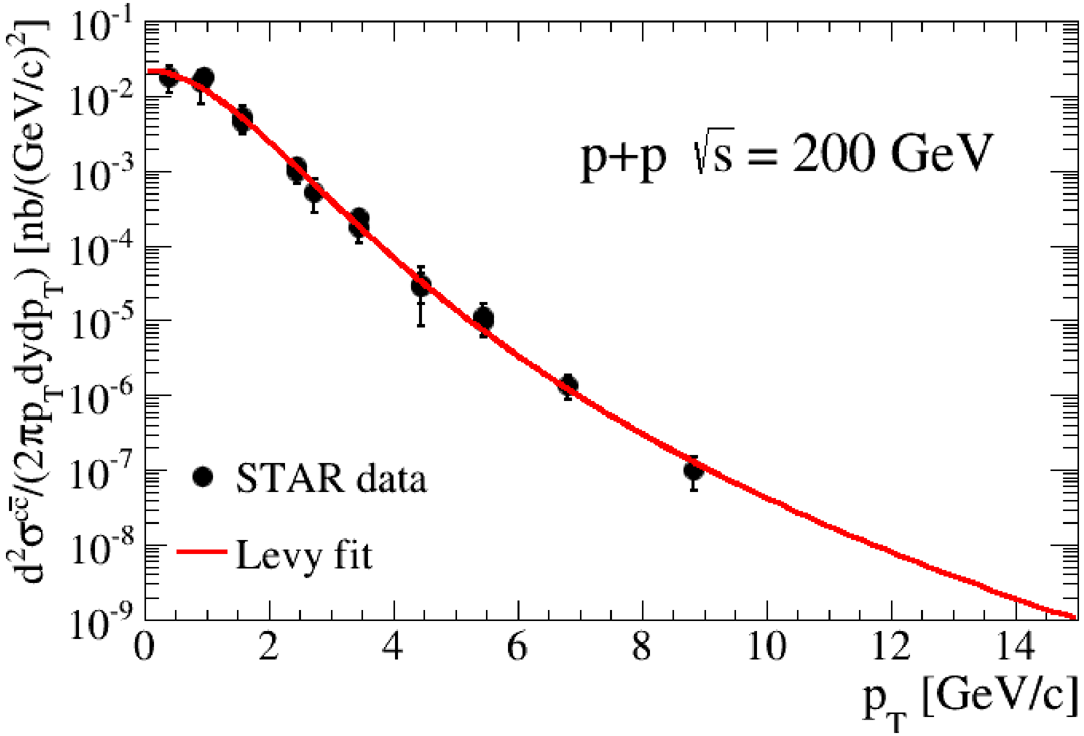
Input:

- charm spectrum in **p+p**
- $b \rightarrow e$ and $c \rightarrow e$ in **p+p**
- R_{pA} for charm quarks: initial k_T broadening and shadowing (EKS98)
- e^{HF} in d+Au

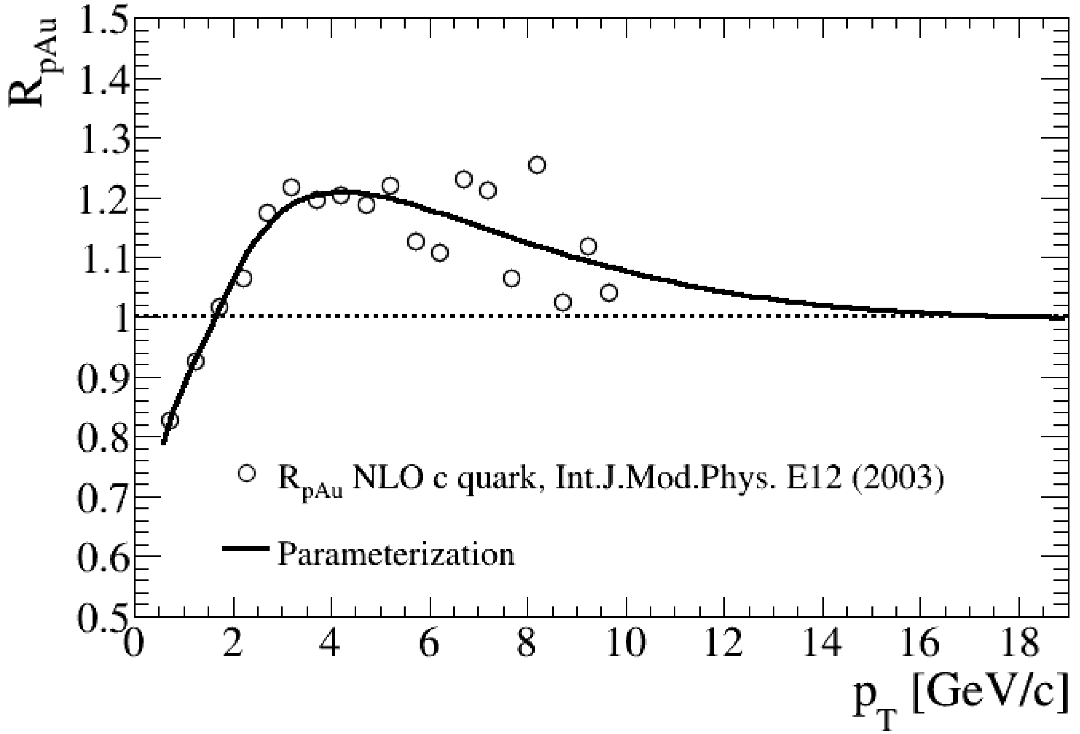
Charm spectrum in d+Au: $$\frac{dN^{dAu}}{dp_T} = R_{pA} \langle N_{bin} \rangle \frac{dN^{pp}}{dp_T}$$

Decay kinematics: PYTHIA8, BR = 10.5%

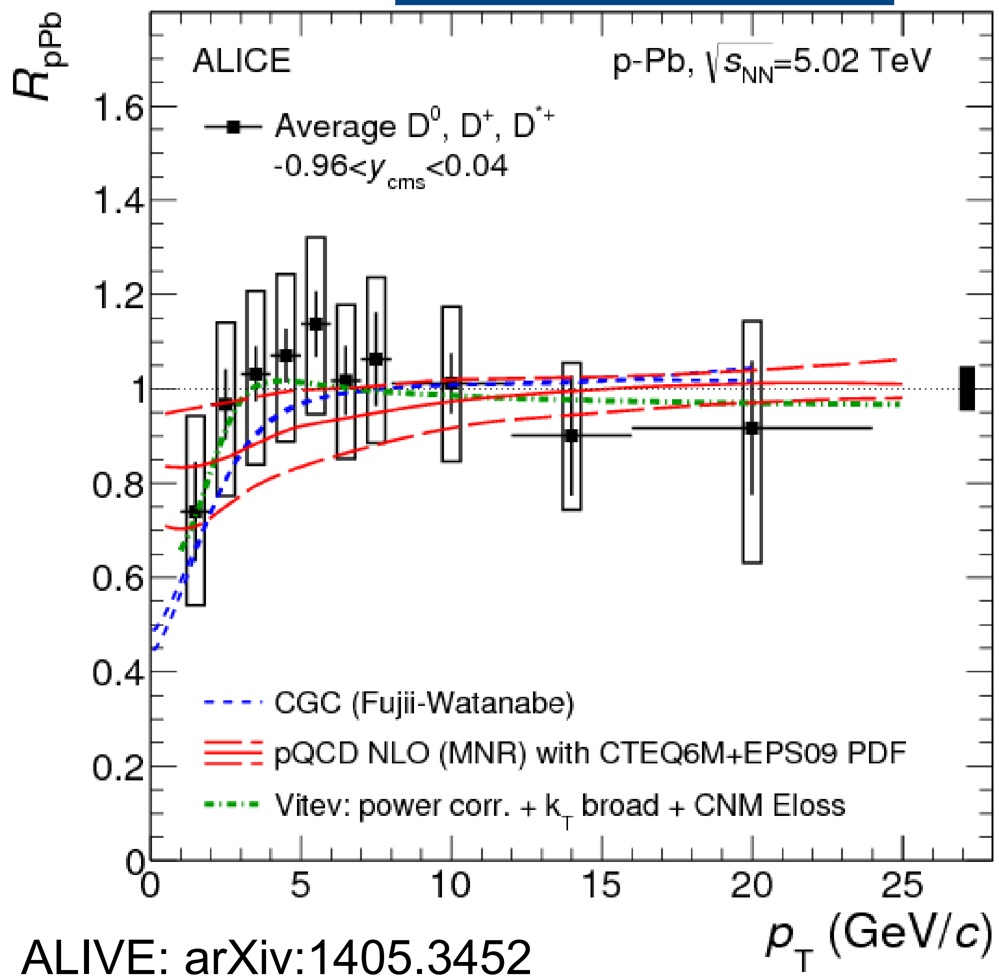
- Input:
  - charm spectrum in **p+p**



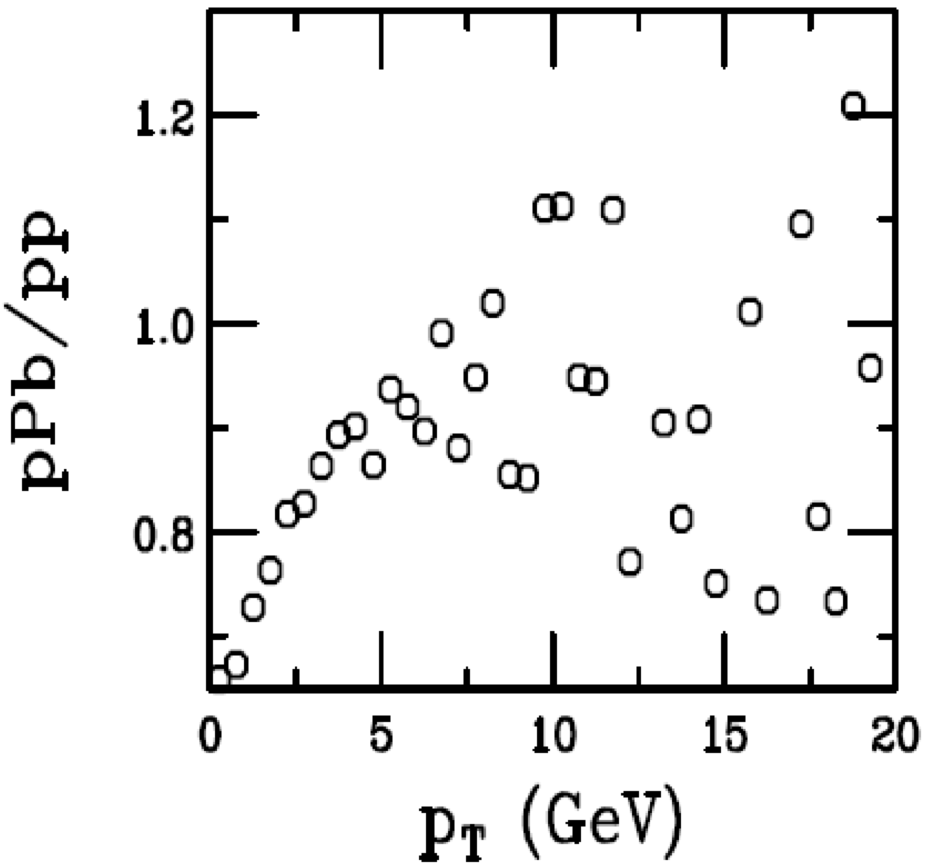
  - R_{pA} for charm quarks: initial k_T broadening and shadowing (EKS98)



p+Pb √5 TeV



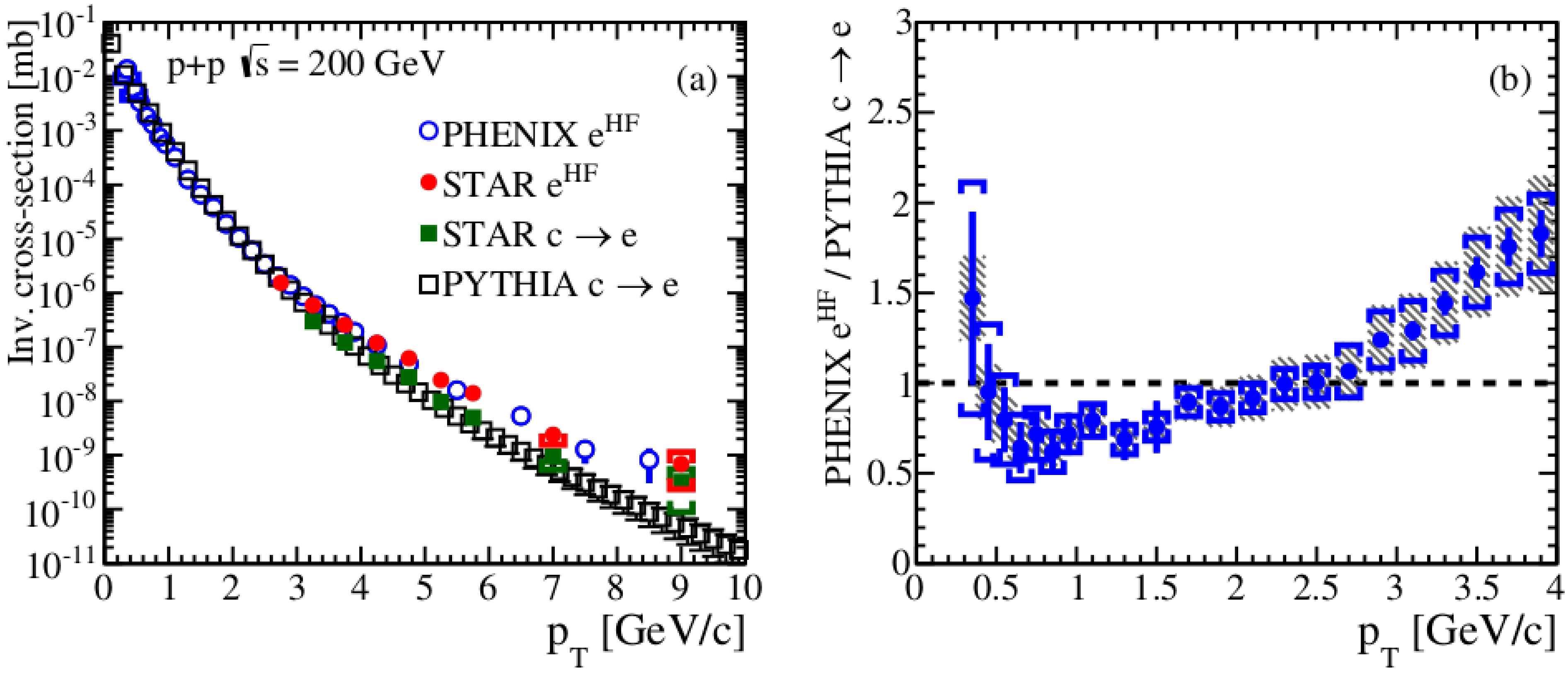
ALIVE: arXiv:1405.3452



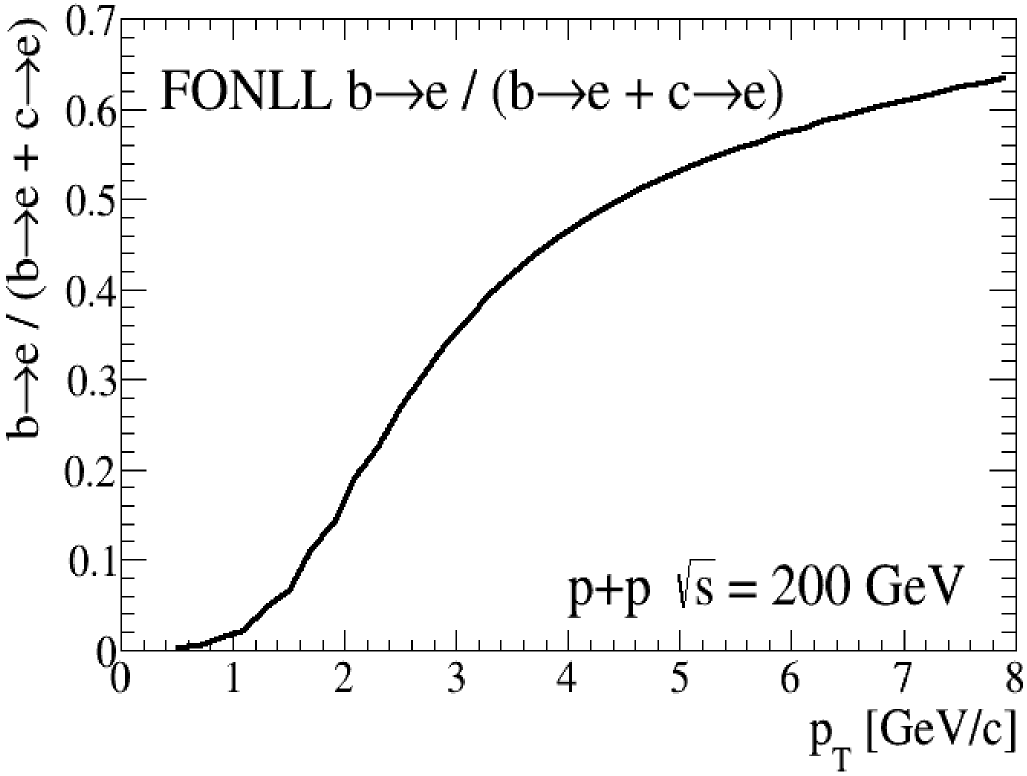
Inclusive NLO c quark production at √s = 5.5 TeV

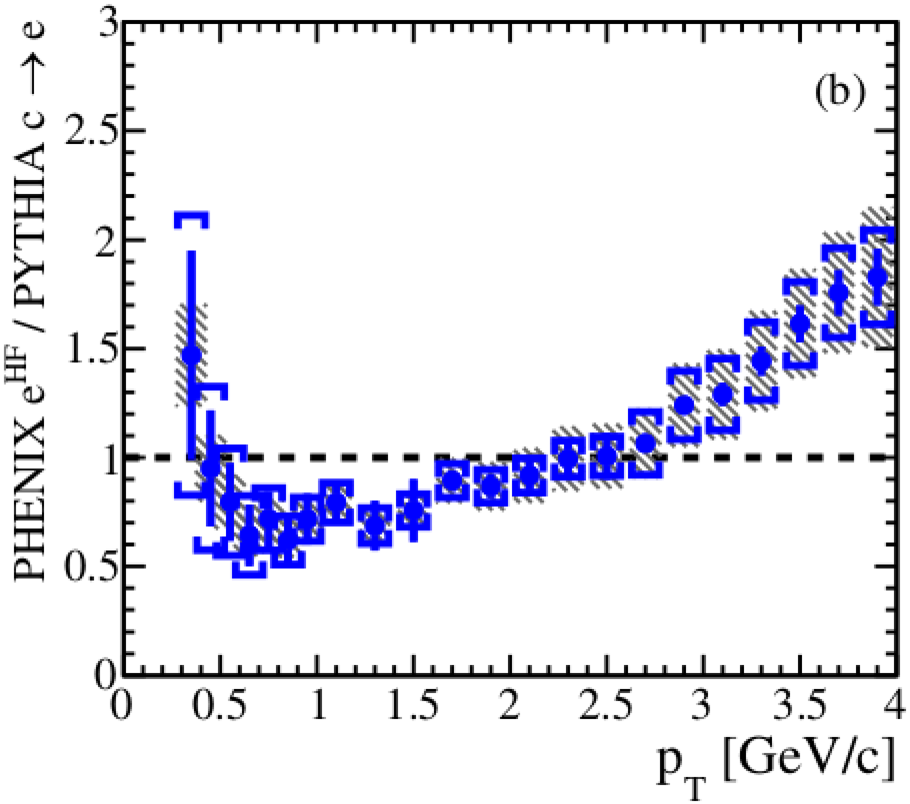
Int.J.Mod.Phys.E12:211-270,2003

e^{HF} p_T spectrum in p+p 200 GeV

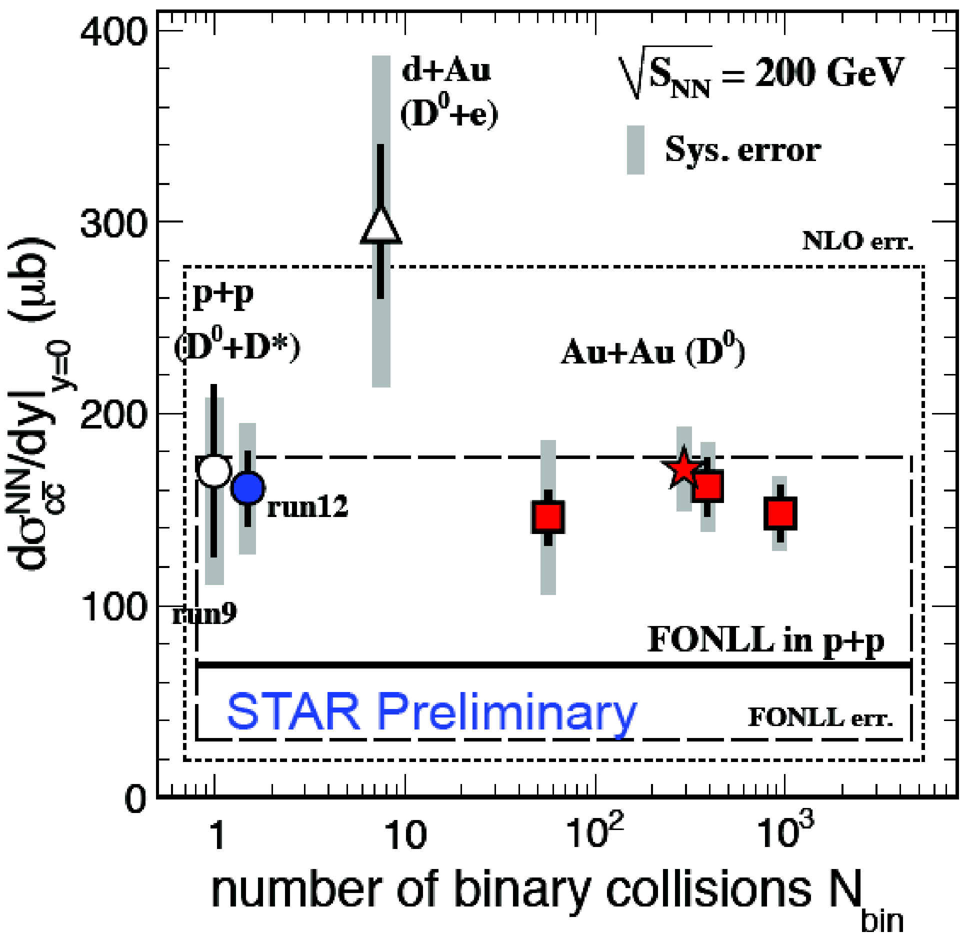


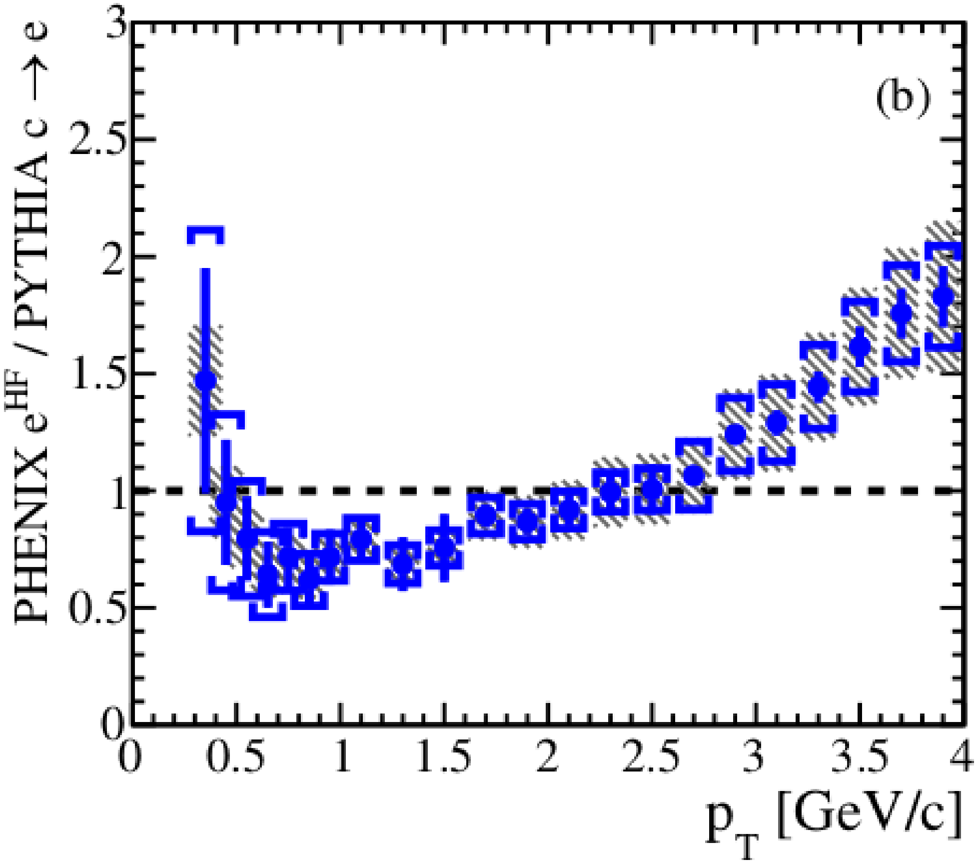
e^{HF} p_T spectrum in p+p 200 GeV





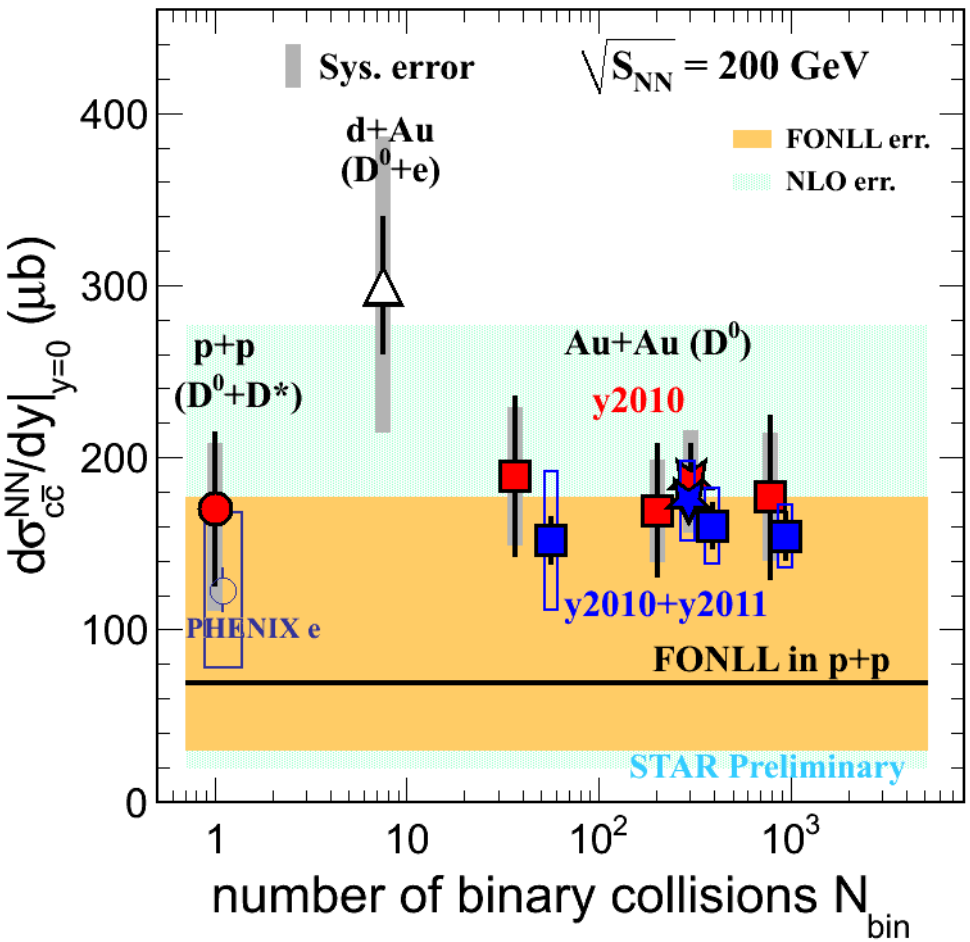
Phys.Rev.Lett. 95 (2005) 122001

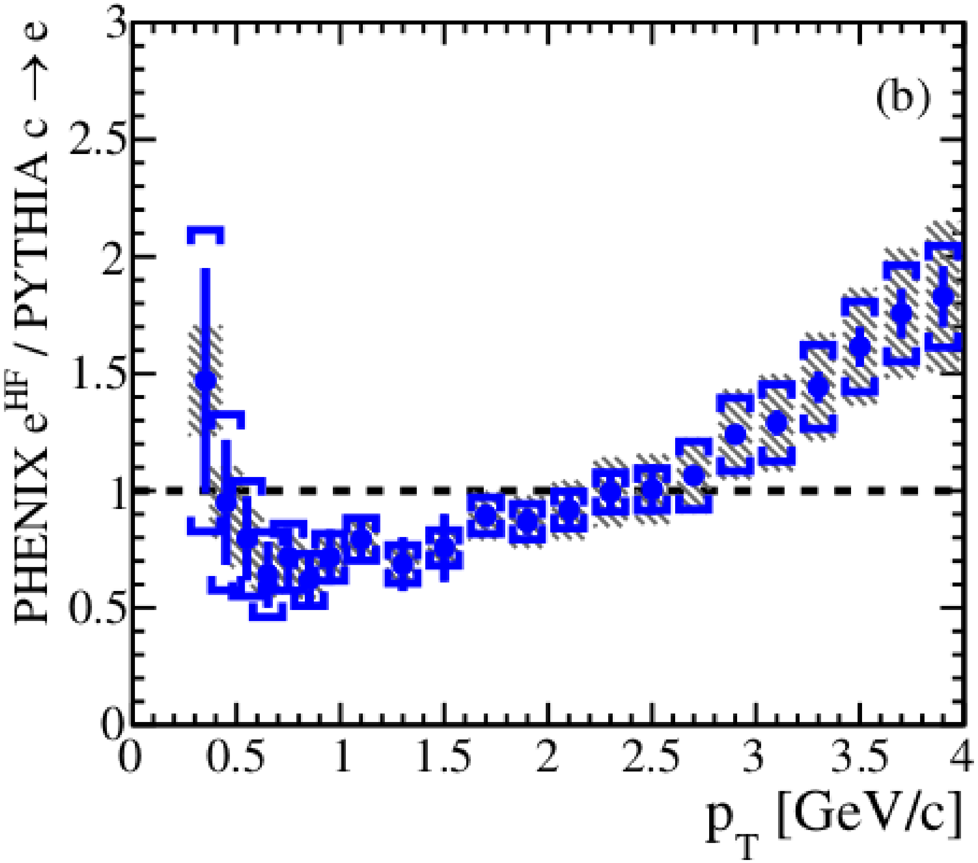




Good agreement considering difference in charm cross section:

STAR: $$\frac{d\sigma^{c\bar{c}}}{dy} = 161 \pm 20(stat.) \pm 34(syst.)\ \mu b$$



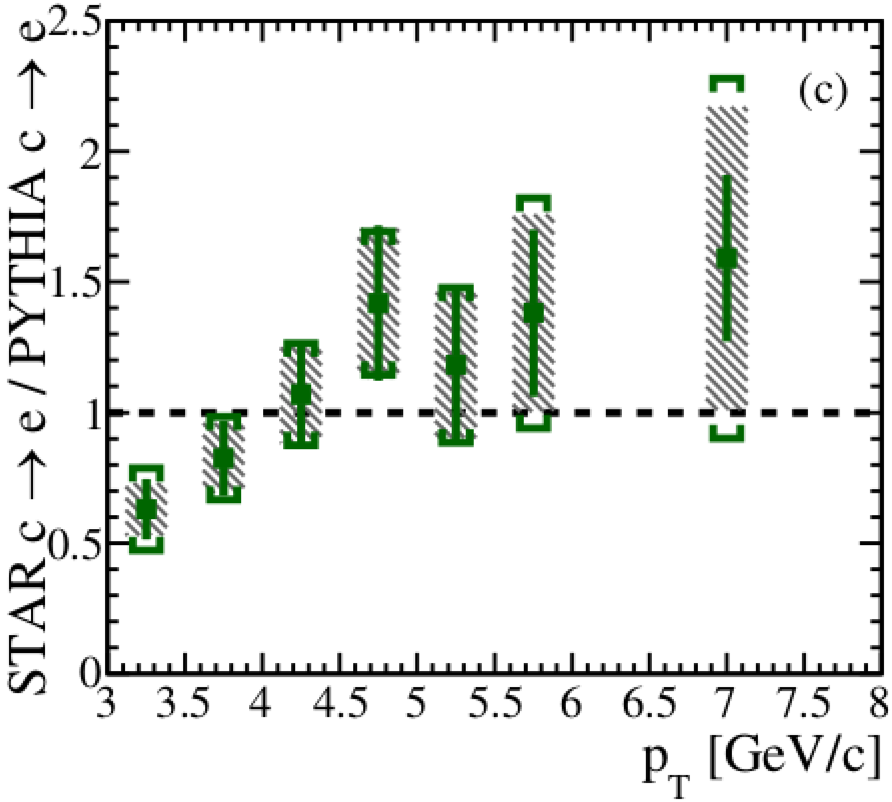


Good agreement considering difference in charm cross section:

STAR: $$\frac{d\sigma^{c\bar{c}}}{dy} = 161 \pm 20(stat.) \pm 34(syst.)\ \mu b$$

PHENIX: $$\frac{d\sigma^{c\bar{c}}}{dy} = 119 \pm 12(stat.) \pm 38(syst.)\ \mu b$$

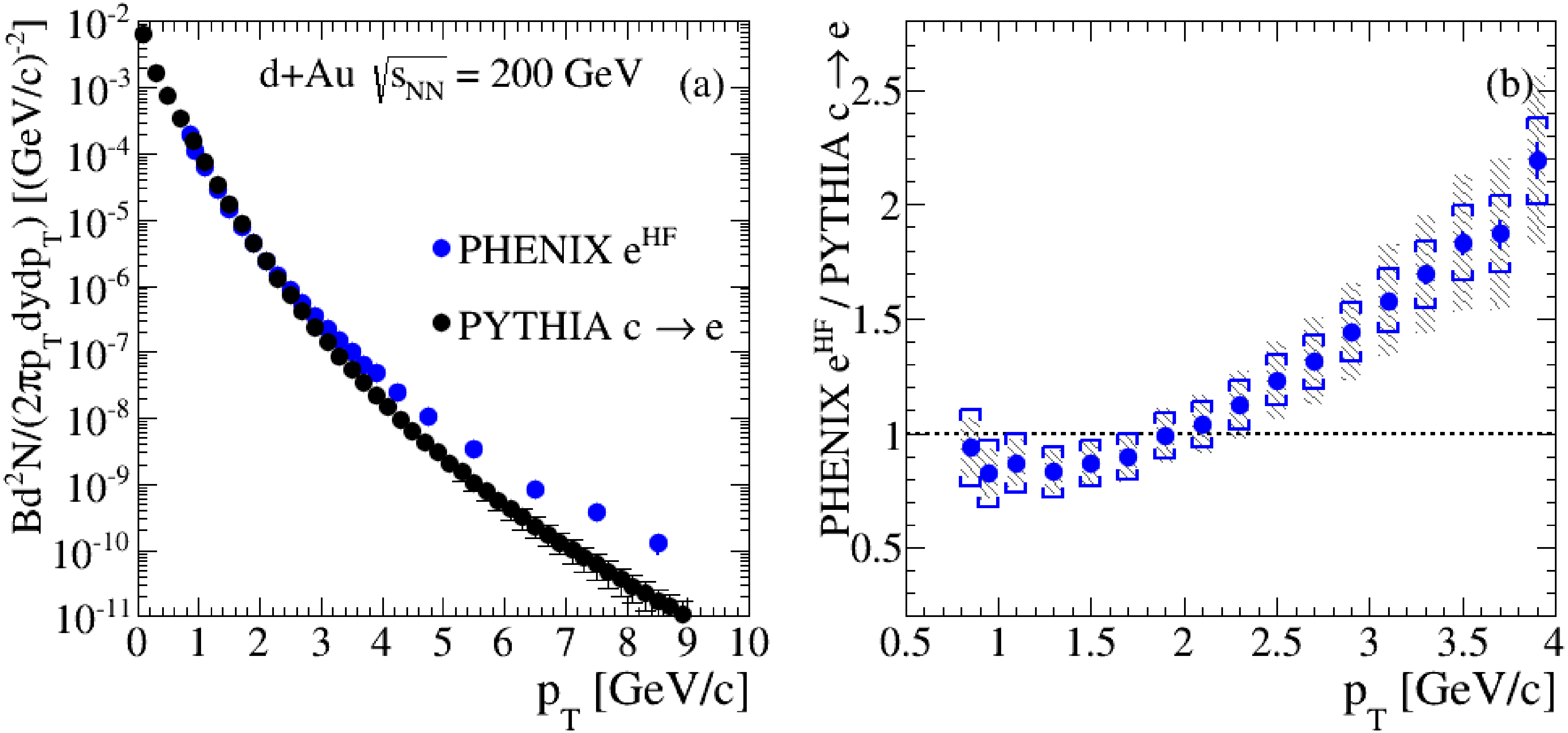
STAR c → e / Simulated c → e



Good agreement

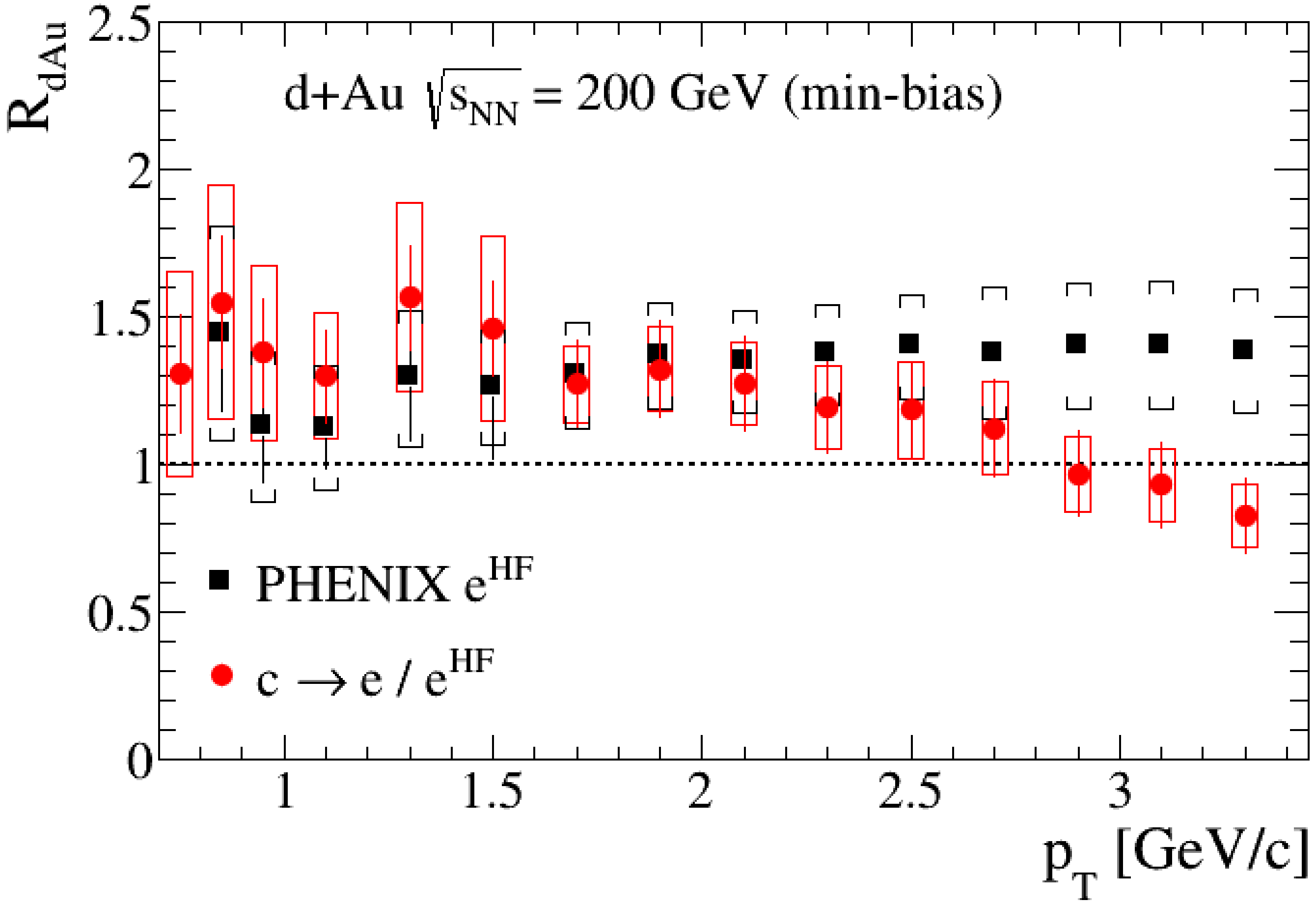
Limited precision at high p_T

e^{HF} p_T spectrum in d+Au 200 GeV



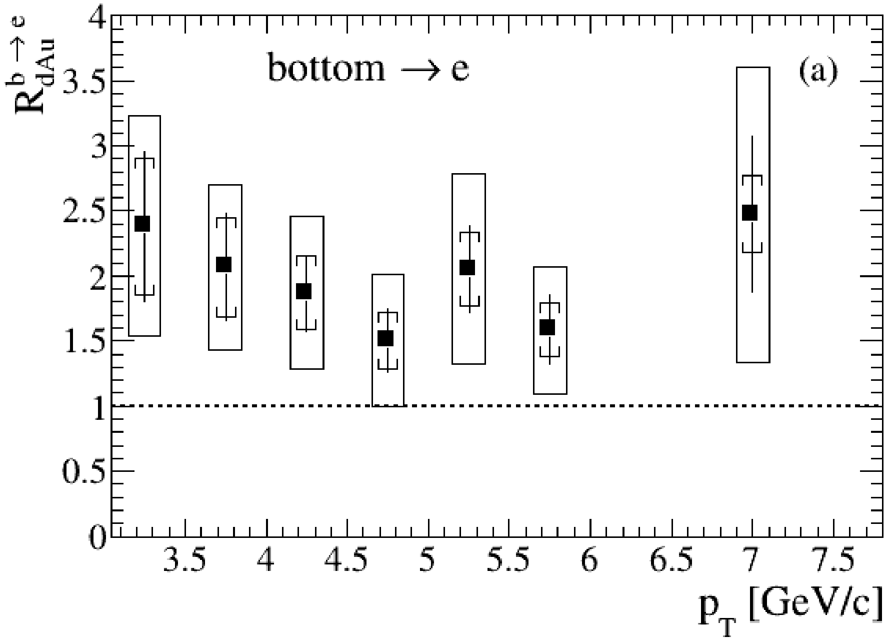
Enhancement for p_T < 2.5 GeV/c → shadowing + initial k_T breadboarding for charm quarks due to multiple scattering of incoming partons.

R_{dAu} for e^{HF} in d+Au 200 GeV

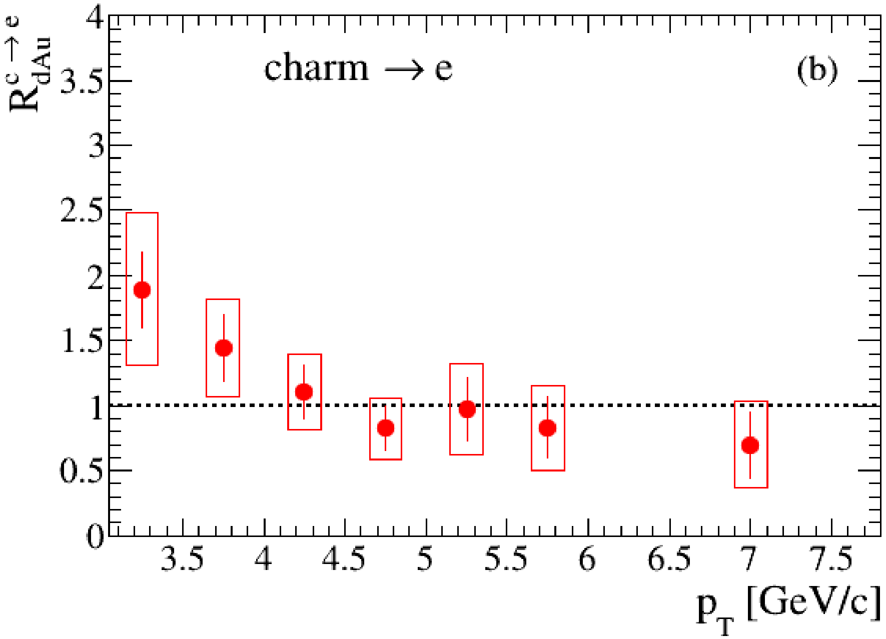


Enhancement for p_T < 2.5 GeV/c → shadowing + initial k_T breadboarding for charm quarks due to multiple scattering of incoming partons.

R_{dAu} for c → e and b → e



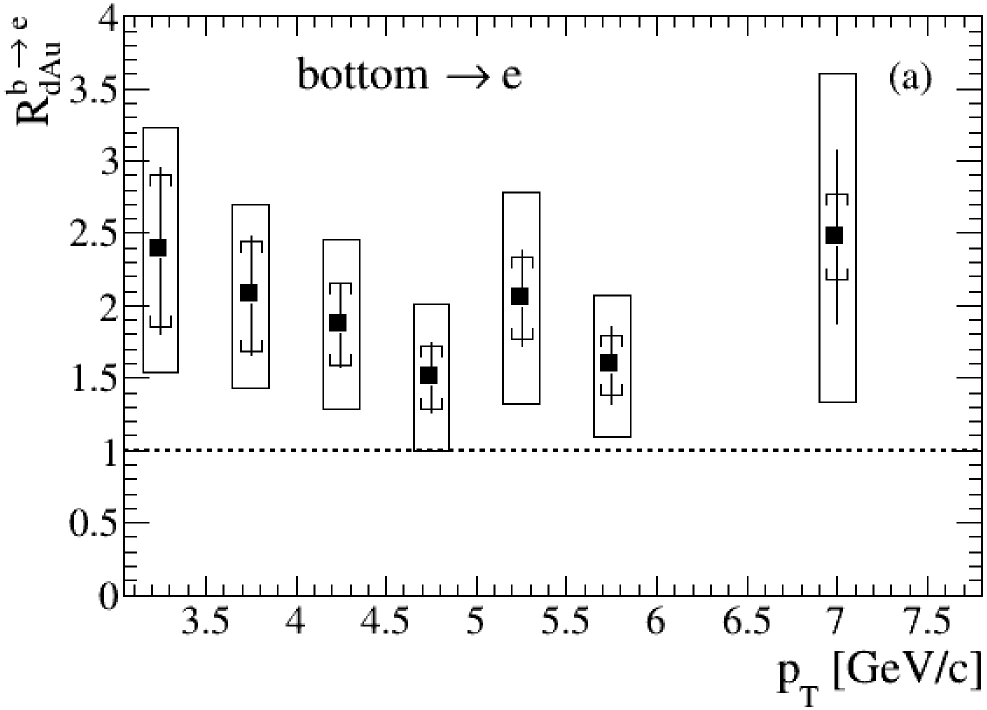
b → e: moderate enhancement, still comparable with unity



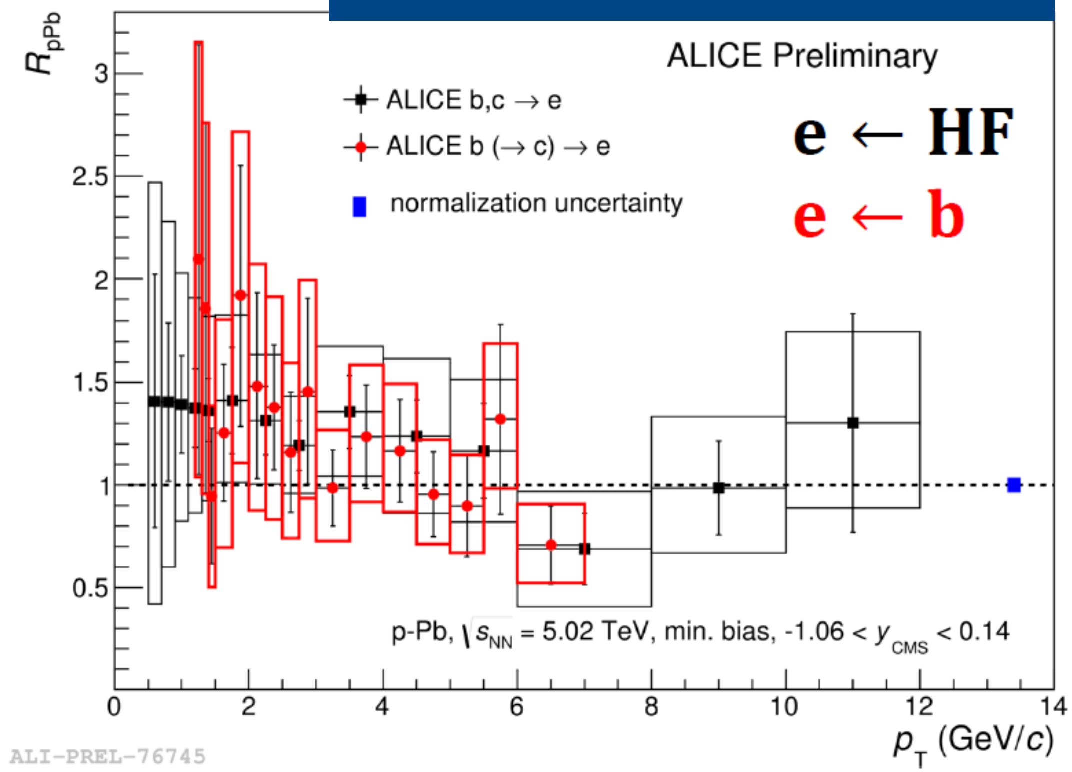
c → e: consistent with no modification in d+Au

R_{dAu} for c → e and b → e

RHIC: d+Au √5 TeV



LHC: p+Pb √5 TeV



RHIC: b → e: moderate enhancement, still comparable with unity

Similar behavior at LHC

Summary

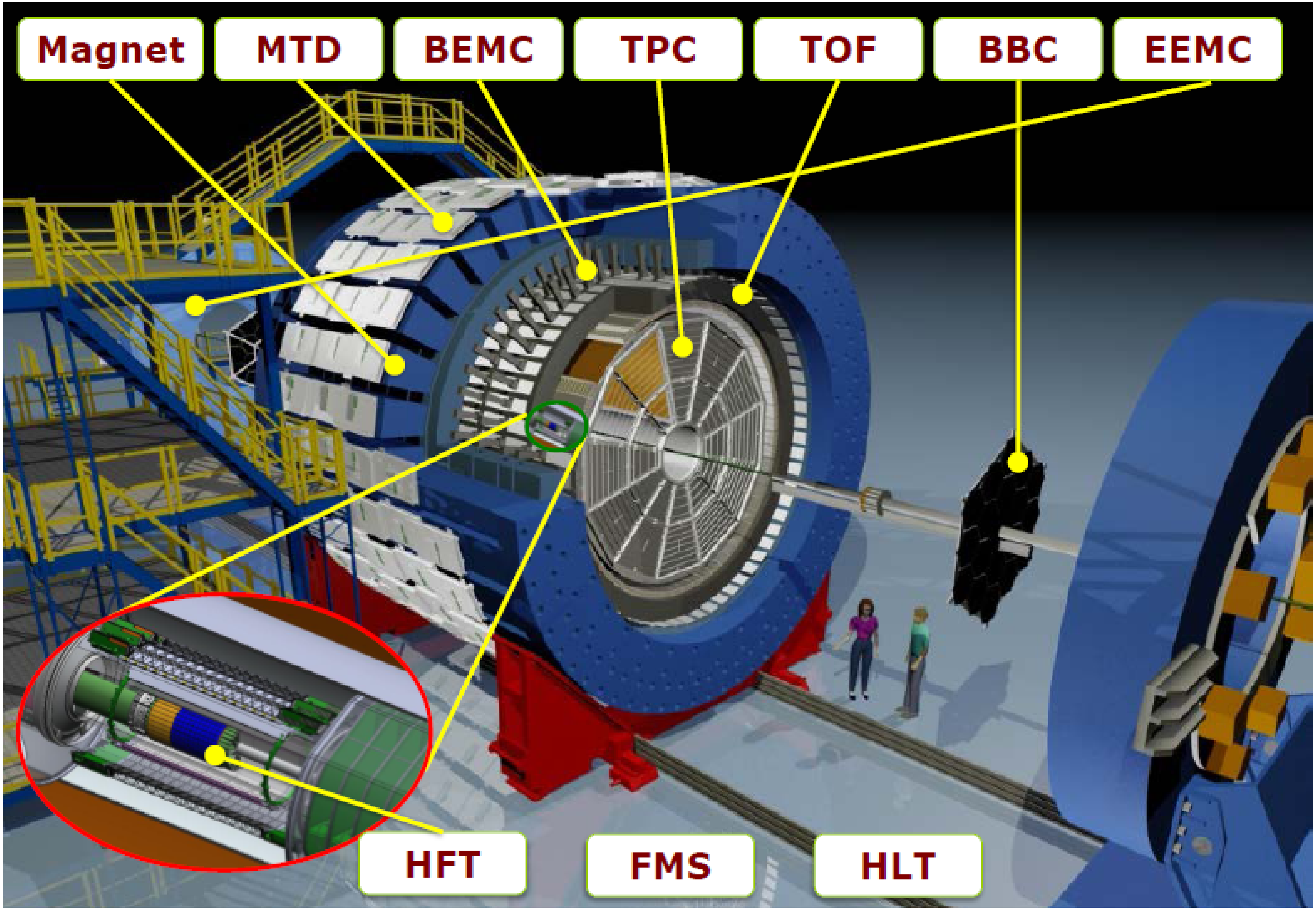
- Strong suppression of charmed mesons and e^{HF} at RHIC at high p_T

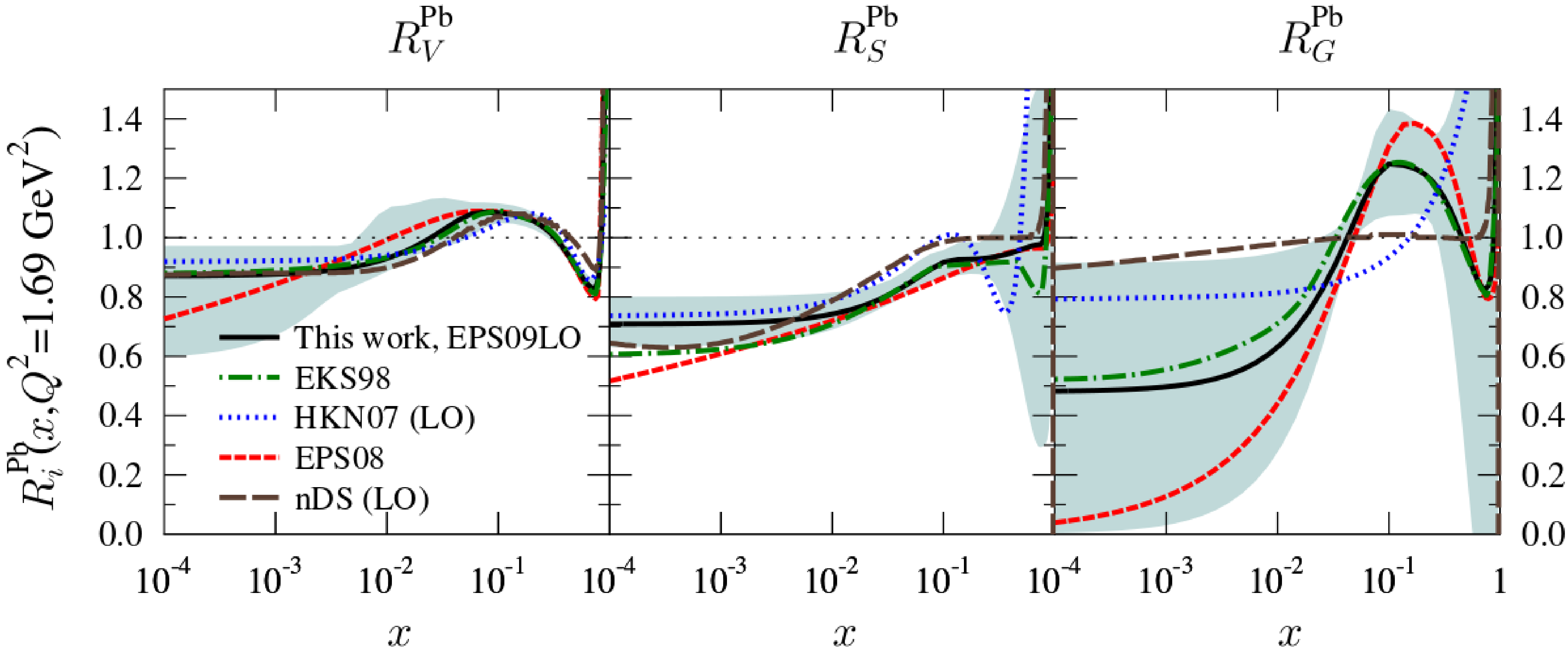
- e^{HF} enhancement in d+Au at low-p_T → consistent with **initial k_T breadboarding for charm quarks**

- Enhancement expected for **b** → **e** for 3 < p_T < 8 GeV/c in d+Au 200 GeV

Backup

STAR Experiment





JHEP 0904 (2009) 065

Initial k_T broadening

Arises from multiple scattering of the projectile partons in the target:

$$\langle k_T^2 \rangle_A = \langle k_T^2 \rangle_p + (\langle \nu \rangle - 1)\Delta^2(\mu)$$

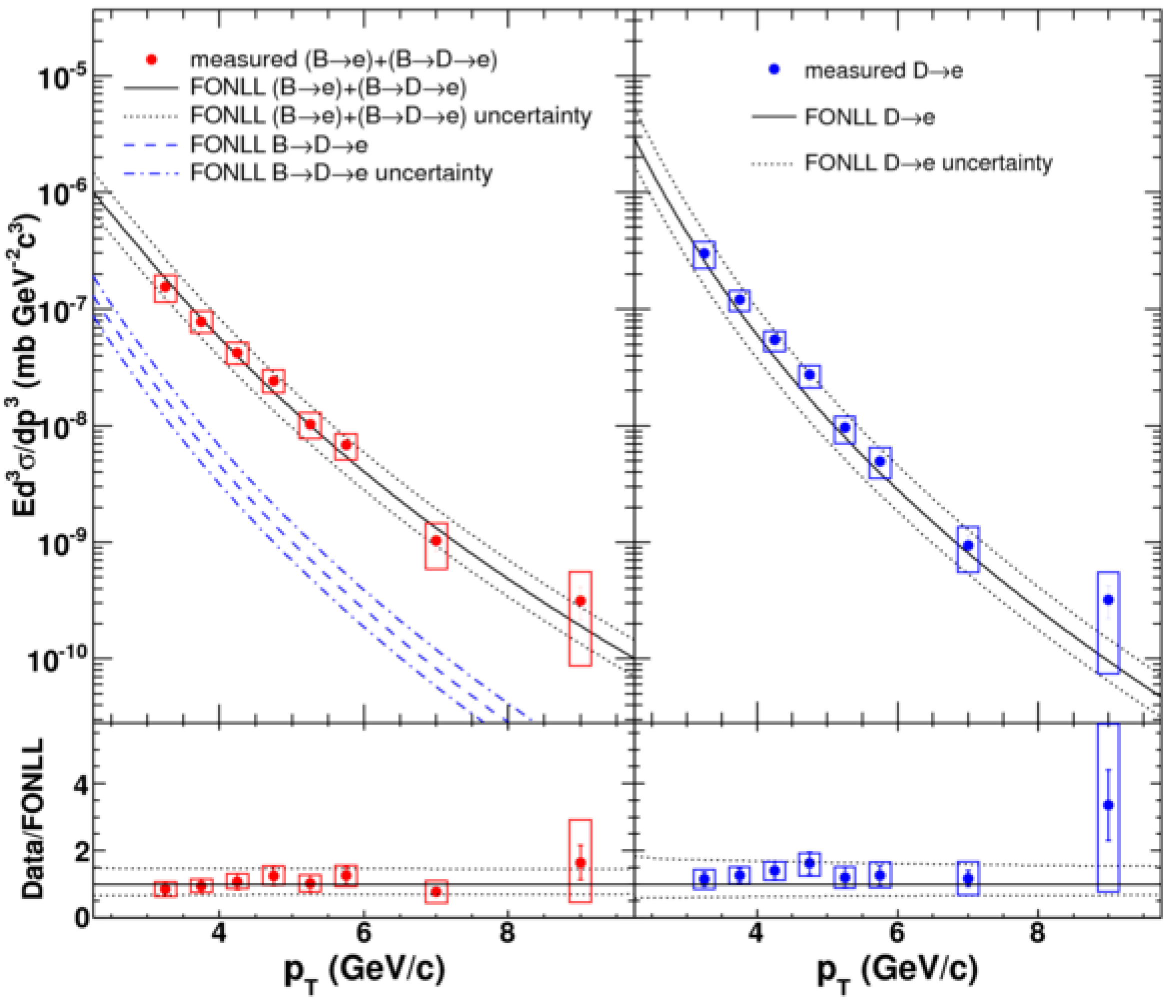
$$\langle k_T^2 \rangle_p = 1 \text{ GeV}^2$$

$$\langle \nu \rangle = \sigma_{NN} \frac{\int d^2b\, T_A^2(b)}{\int d^2b\, T_A(b)} = \frac{3}{2} \sigma_{NN} \rho_0 R_A$$

number of collisions in a p-A interaction

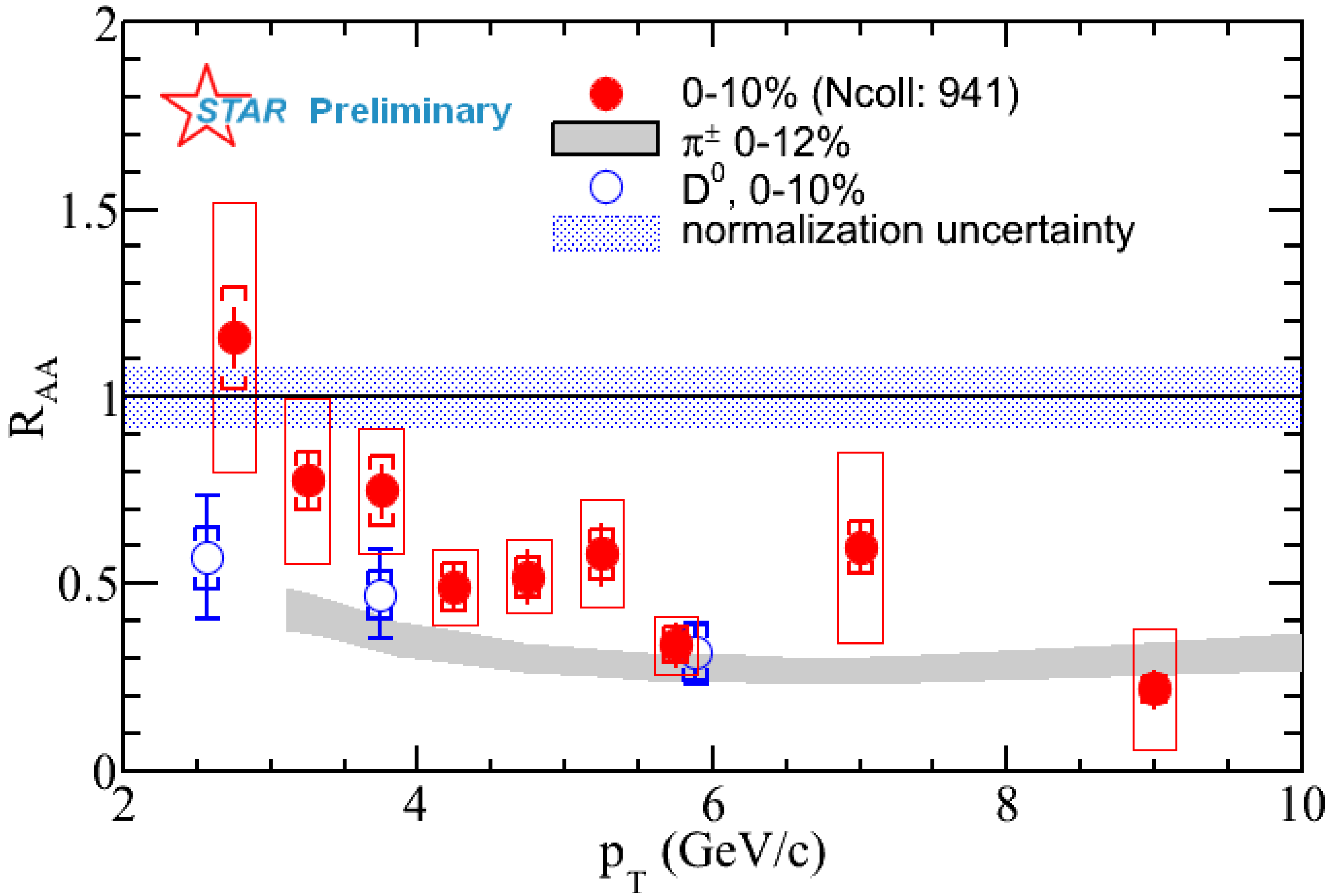
$$\Delta^2(\mu) = 0.225 \frac{\ln^2(\mu/\text{GeV})}{1 + \ln(\mu/\text{GeV})} \text{GeV}^2$$

$\mu = 2m_Q$ - scale, m_c = 1.2 GeV



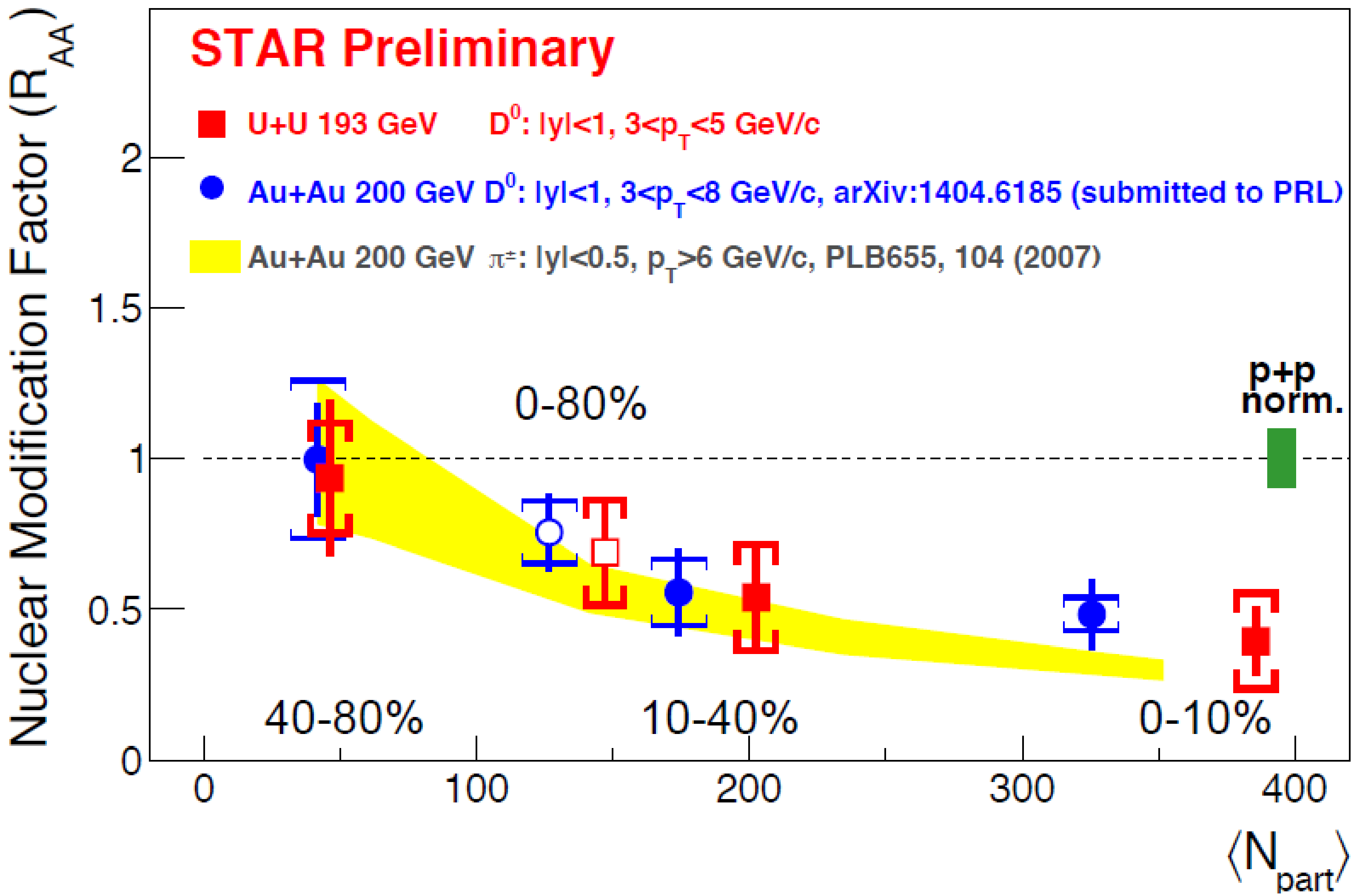
Phys. Rev. D 83 (2011) 52006

Heavy Flavor decay electrons in Au+Au 200 GeV

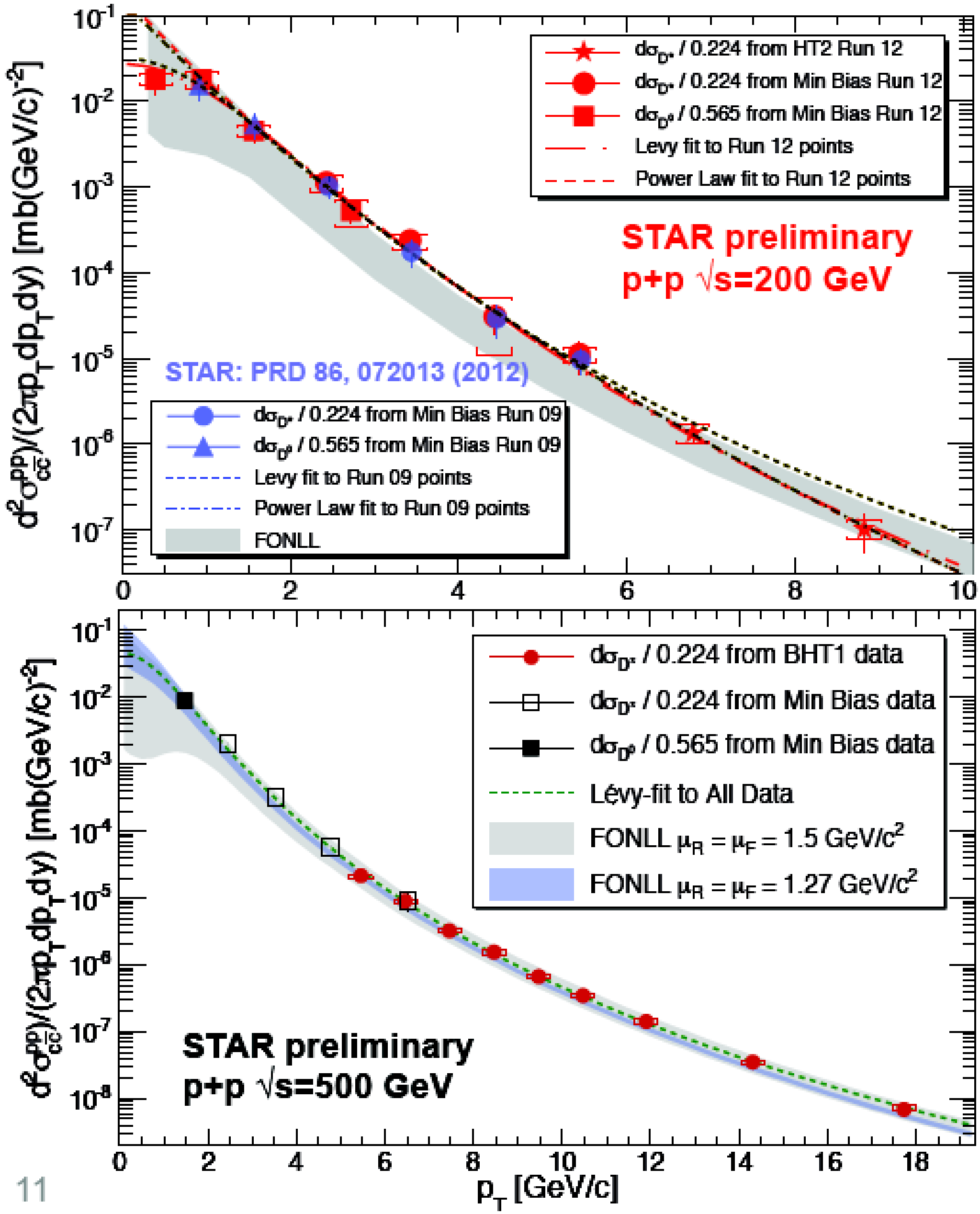


Strong suppression at high p_T in central collisions

D^0 and e^{HF} suppression → similar



Quark Matter 2014, Zhenyu Ye



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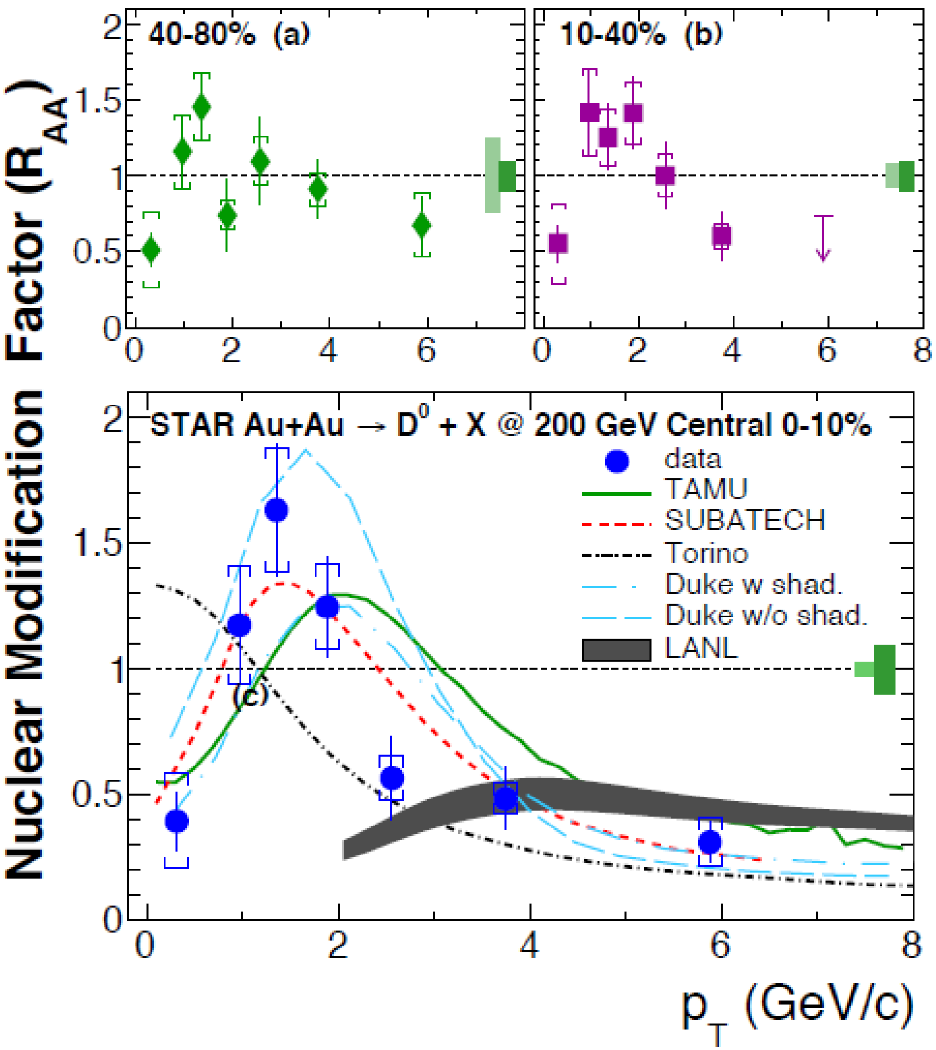
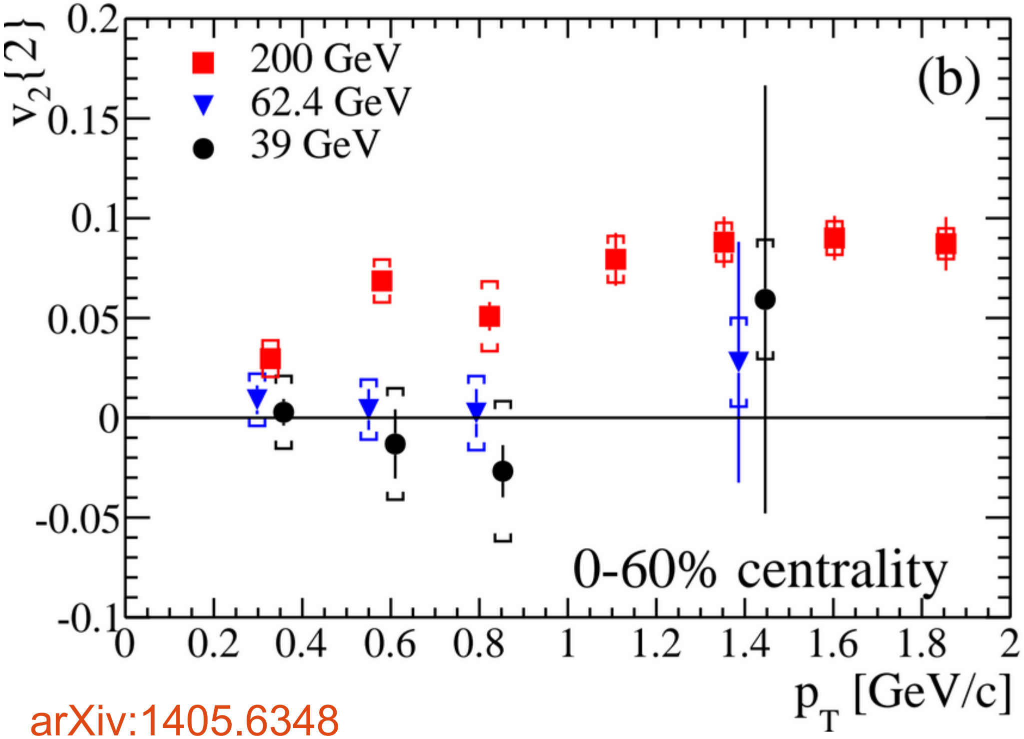


arXiv:1404.6185 (submitted to PRL)

	TAMU	SUBATECH	Torino	Duke	LANL
HQ prod.	LO	FNOLL	NLO	LO	LO
QGP-Hydro	ideal	ideal	viscous	viscous	ideal
HQ eLoss	coll.	coll. +rad.	coll. +rad.	coll. +rad.	diss. +rad.
Coalescence	Yes	Yes	No	Yes	No
Cronin effect	Yes	Yes	No	No	Yes
Shadowing	No	No	Yes	Yes/No	Yes

- Large suppression at high p_T points to strong charm-medium interaction;
- Indication of enhancement p_T~0.7-2GeV/c, described by models with charm quarks coalescence with light quarks;
- CNM effects could be important

Quark Matter 2014, Zhenyu Ye



arXiv:1405.6348