Open Charm Hadron Production in p+p, Au+Au and U+U Collisions at STAR

XXIV QUARK MATTER DARMSTADT 2014
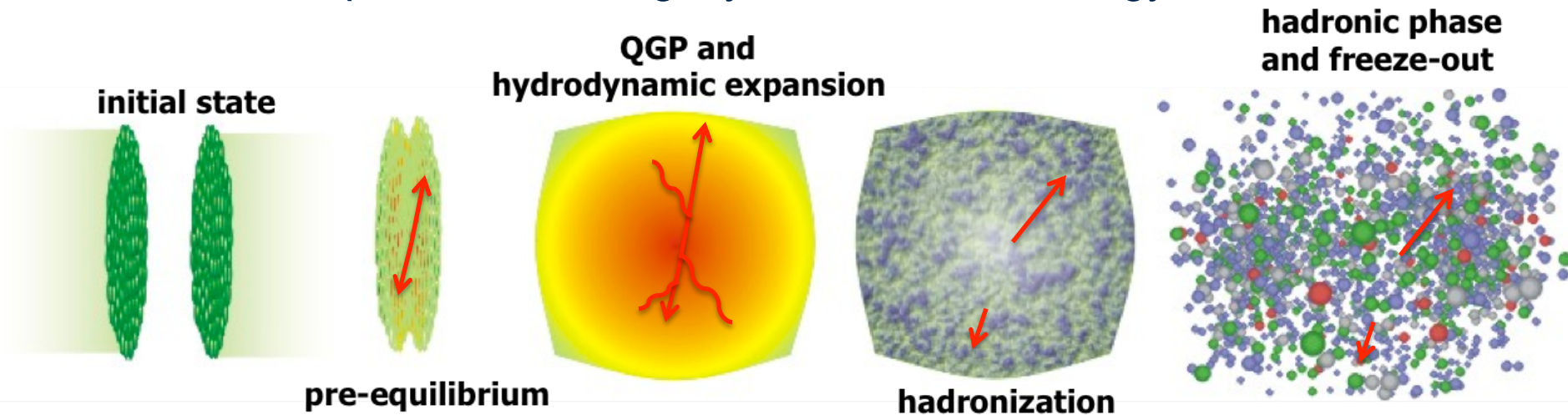
STAR

Zhenyu Ye[1,2] for the STAR Collaboration

1. University of Illinois at Chicago

2. Central China Normal University

The University of Illinois at Chicago

Office of Science
U.S. DEPARTMENT OF ENERGY

华中師範大學
HuaZhong Normal University

Why Heavy Flavor?

- HF quarks are primarily produced in initial hard scattering, and are exposed to the evolution of the hot nuclear matter created at RHIC.

- **Au+Au, Cu+Cu, U+U**
  - How does a parton lose its energy in the QGP?

    $\Delta E_g > \Delta E_{u/d/s} > \Delta E_c > \Delta E_b$?
  - Using the HF as a probe to study properties of the QGP and their dependence on e.g. system size and energy

initial state   QGP and hydrodynamic expansion   hadronic phase and freeze-out

pre-equilibrium   hadronization

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- **p+p**
  - Test of pQCD and reference for studies of the QGP
- **p+Au, d+Au**
 - Cold Nuclear Matter effects (shadowing, CGC, Cronin effect, …)

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STAR Experiment

TPC:
Tracking,
PID (dE/dx)

TOF:
PID (1/β)
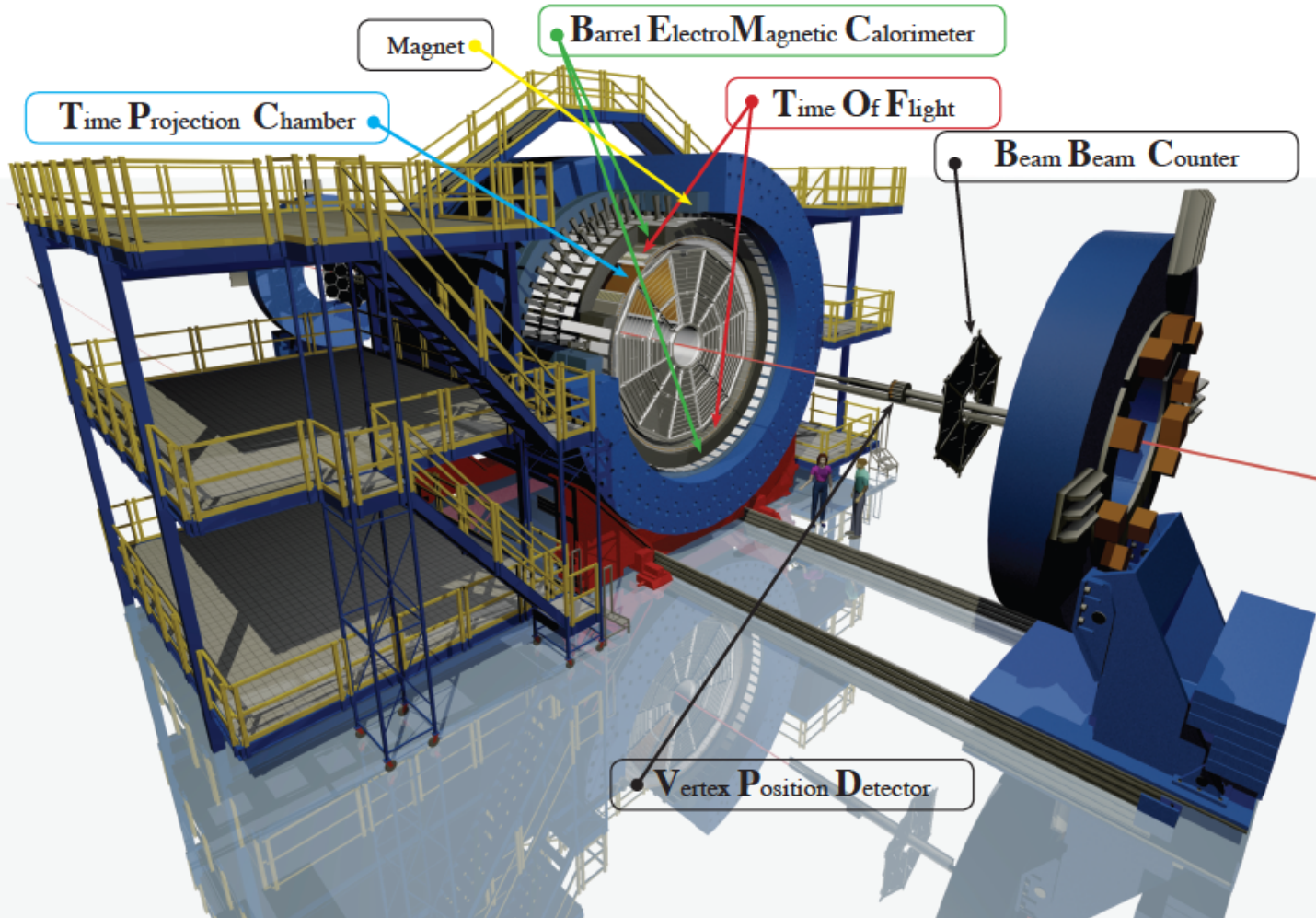
BEMC:
High Tower
trigger
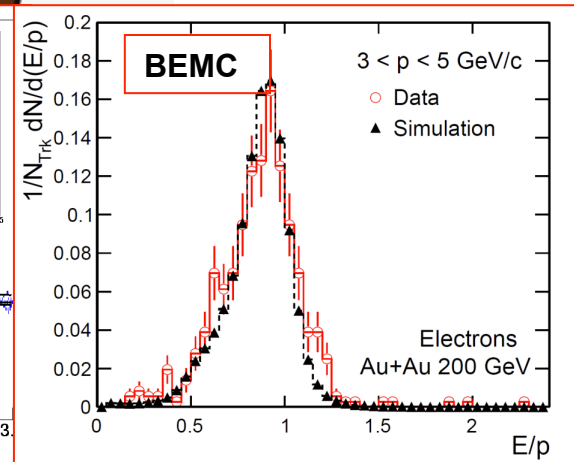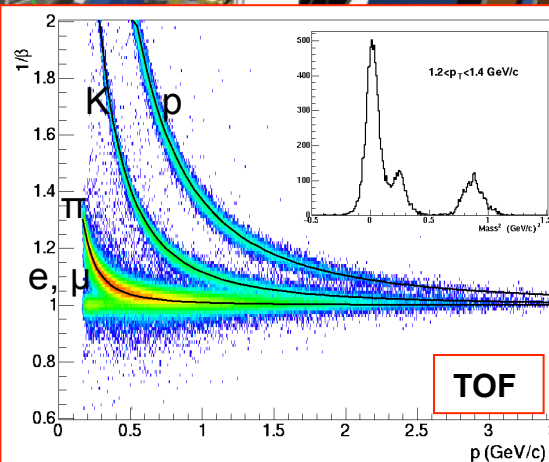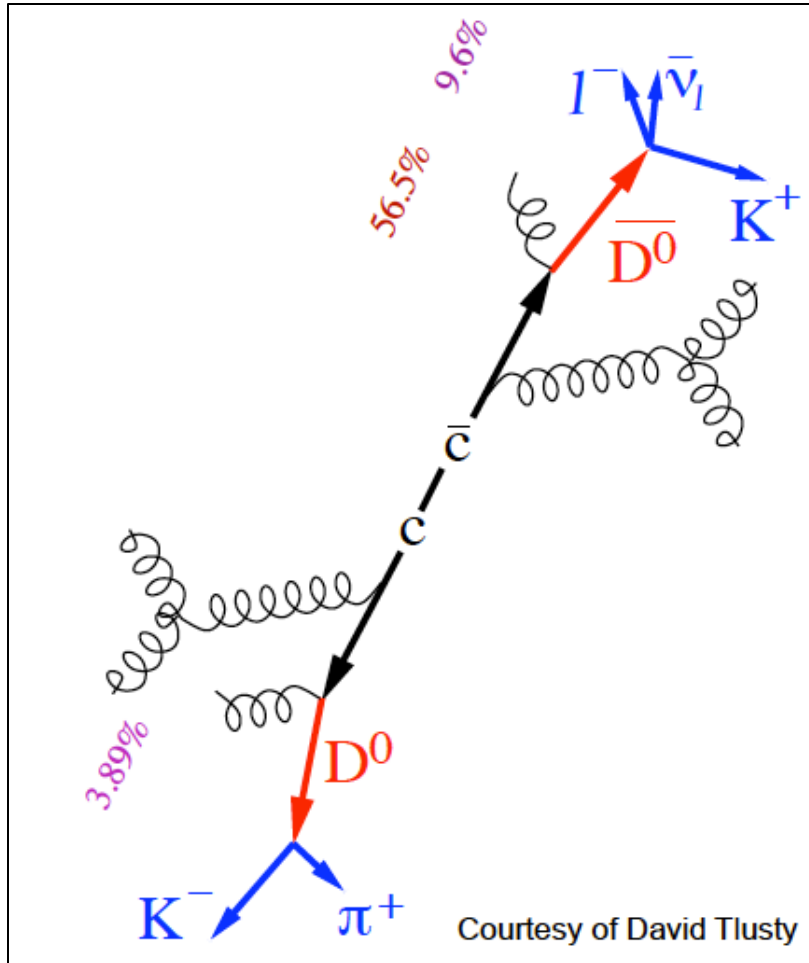
VPD:
MinBias
trigger

STAR Experiment
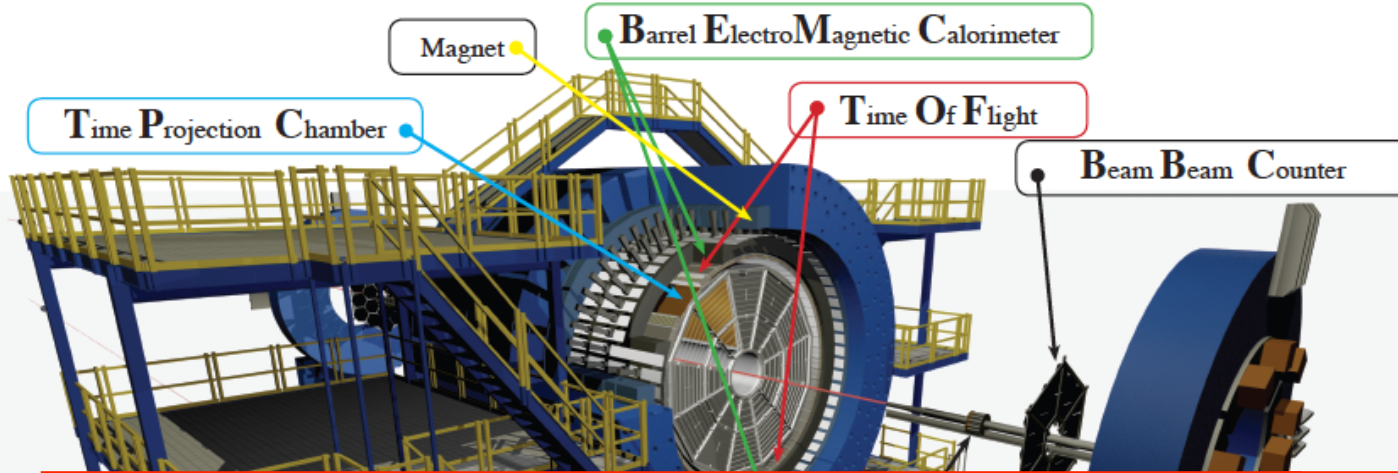
TPC: Tracking, PID (dE/dx)

TOF: PID (1/β)
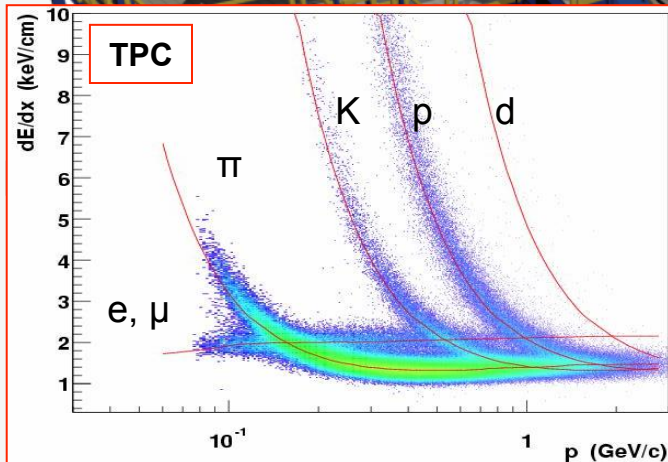
Courtesy of David Tlusty

Semi-leptonic channel:
- large branching ratio
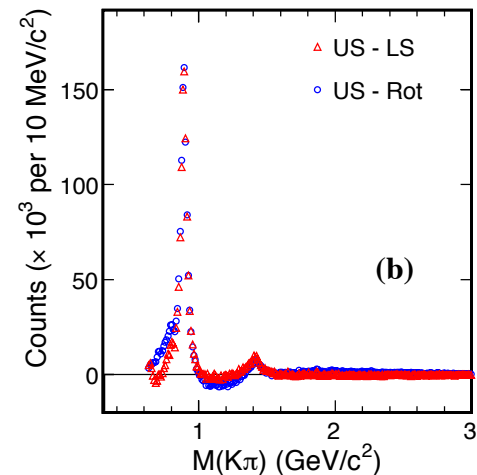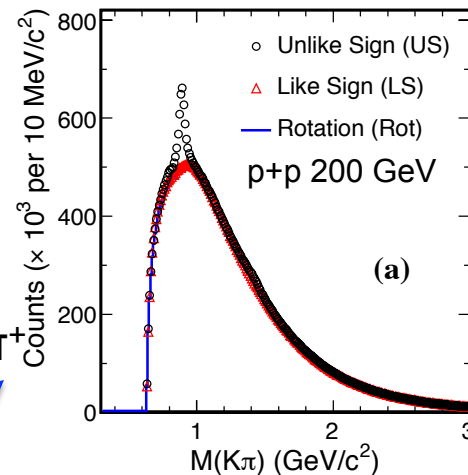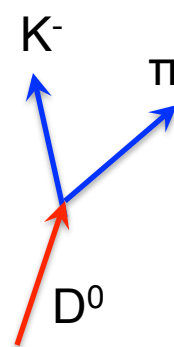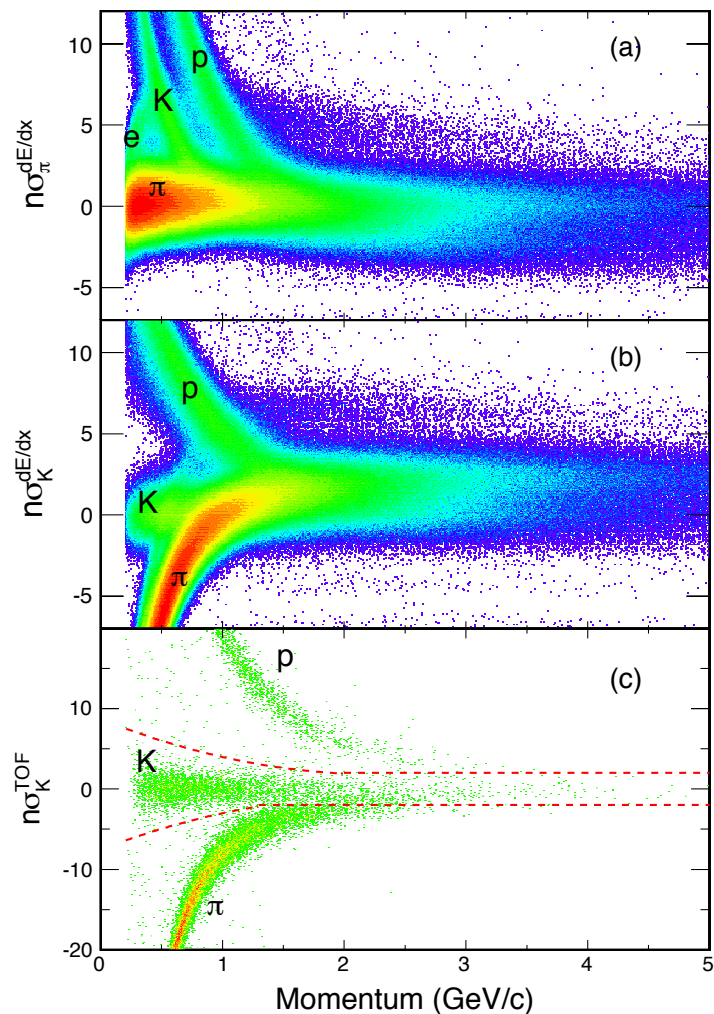- but no access to the kinematics of the original charm hadrons; contribution from both charm and bottom

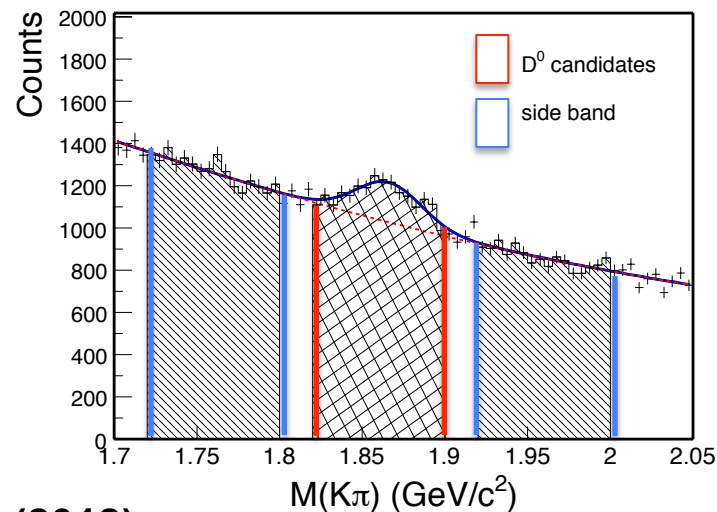(posters: Bai-F04, Dunkelberger-F14, Oh-F39, Rusnakov-F49)

Hadronic channel:
- fully reconstructed hadron kinematics
- but large background w/o good vertex measurement

K^-

π^+

D^0

Unlike Sign (US)
Like Sign (LS)
Rotation (Rot)

p+p 200 GeV

(a)

US - LS
US - Rot

(b)

$0.6 < p_T < 2.0$ GeV/c **US-LS**

$0.6 < p_T < 2.0$ GeV/c **US-Rot**

STAR: PRD 86, 072013 (2012)

8

K^-

π^+

π^+

D^0

D^{*+}

p+p 200 GeV

right sign
wrong sign
side band

$M(K\pi\pi)-M(K\pi)$ (GeV/c^2)

D^0 candidates
side band

$M(K\pi)$ (GeV/c^2)

9

STAR: PRD 86, 072013 (2012)

Quark Matter 2014, Zhenyu Ye

Open Charm Production
– p+p –

STAR preliminary
p+p √s=200 GeV

Legend (red, Run 12):
- $d\sigma_{D^*} / 0.224$ from HT2 Run 12
- $d\sigma_{D^*} / 0.224$ from Min Bias Run 12
- $d\sigma_{D^0} / 0.565$ from Min Bias Run 12
- Levy fit to Run 12 points
- Power Law fit to Run 12 points

STAR: PRD 86, 072013 (2012)

Legend (blue, Run 09):
- $d\sigma_{D^*} / 0.224$ from Min Bias Run 09
- $d\sigma_{D^0} / 0.565$ from Min Bias Run 09
- Levy fit to Run 09 points
- Power Law fit to Run 09 points
- FONLL

Y-axis: $d^2\sigma_{c\bar{c}}^{pp}/(2\pi p_T dp_T dy)$ [mb(GeV/c)$^{-2}$]

X-axis: p_T [GeV/c]
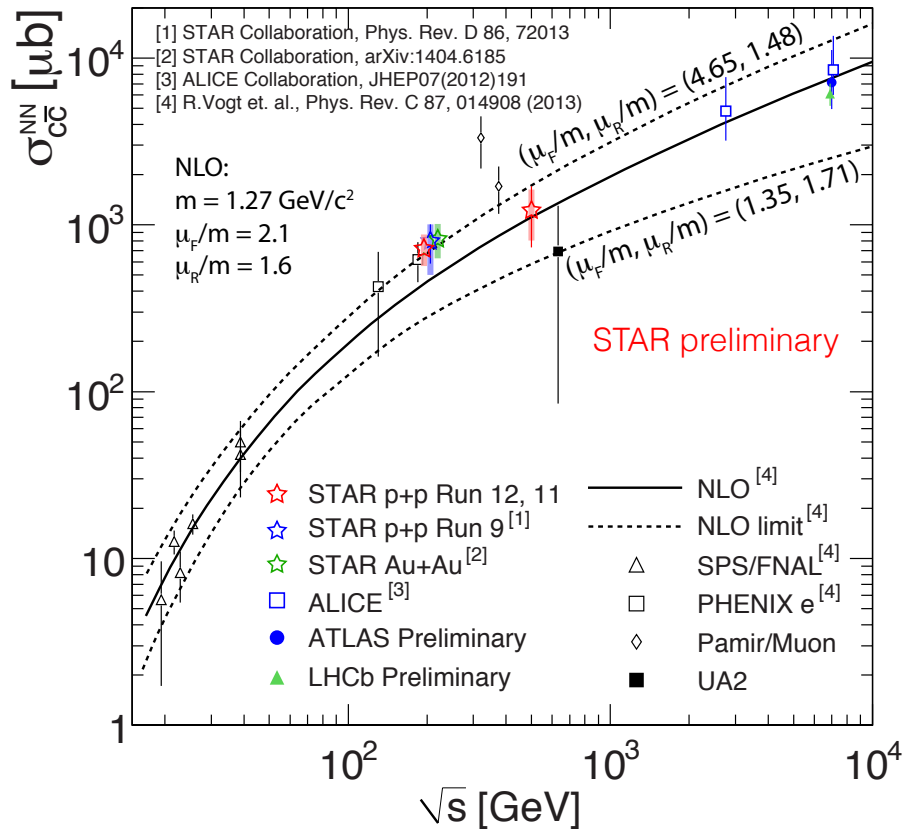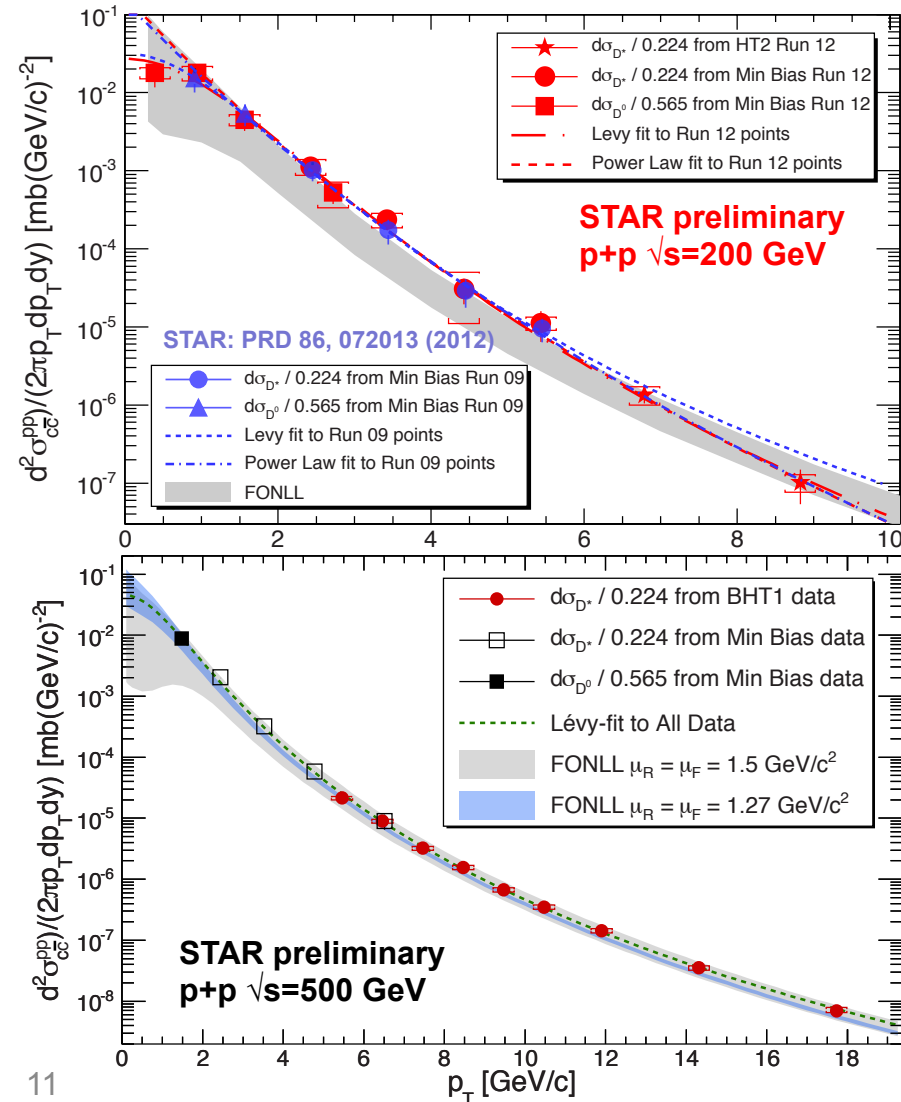
Open charm mesons measured down to $p_T \sim 0.4$ GeV/c;
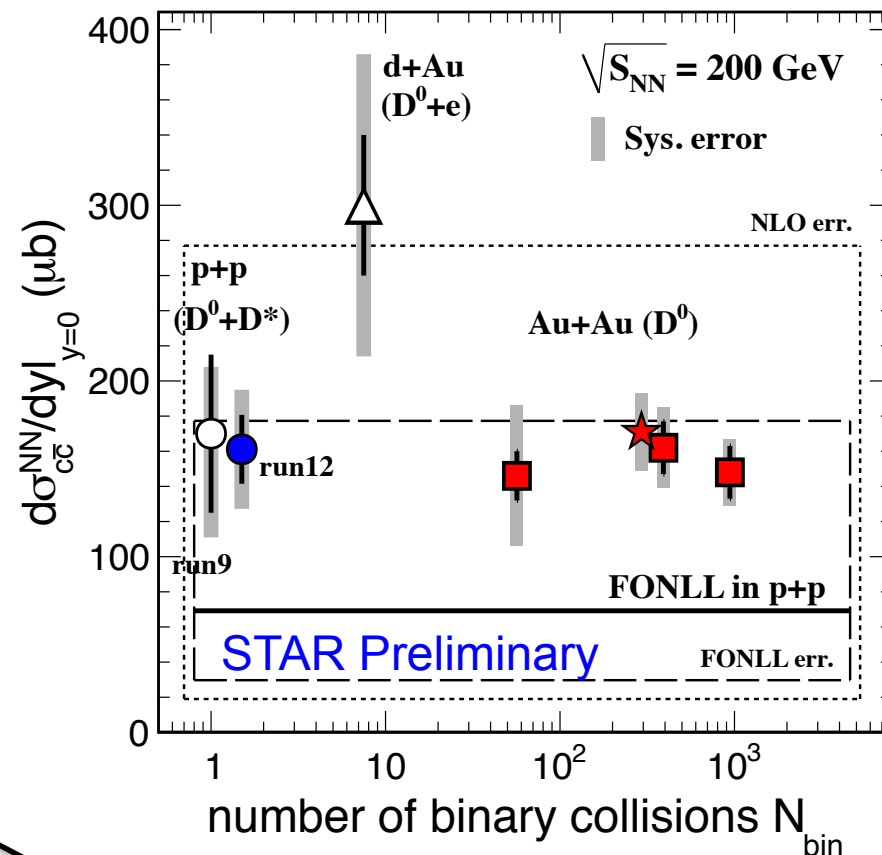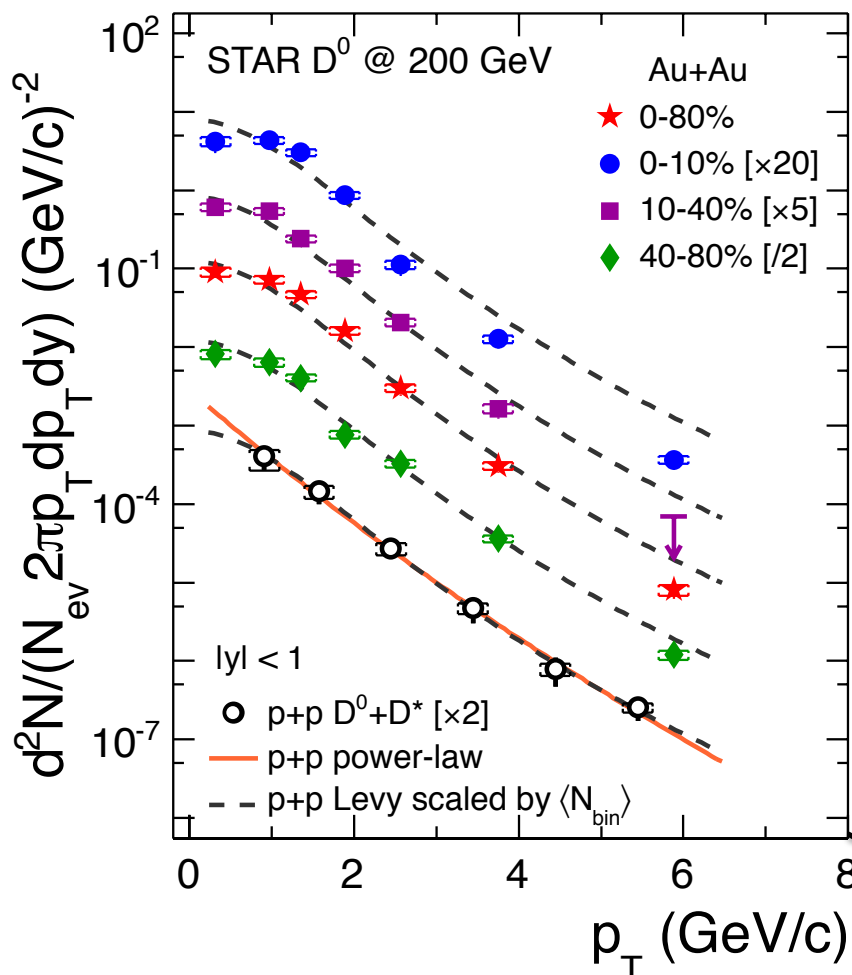Power-law does not describe low-p_T shape.

Open Charm Production
– p+p –

Data consistent with FONLL calculation within uncertainties

arXiv:1404.6185 (submitted to PRL)
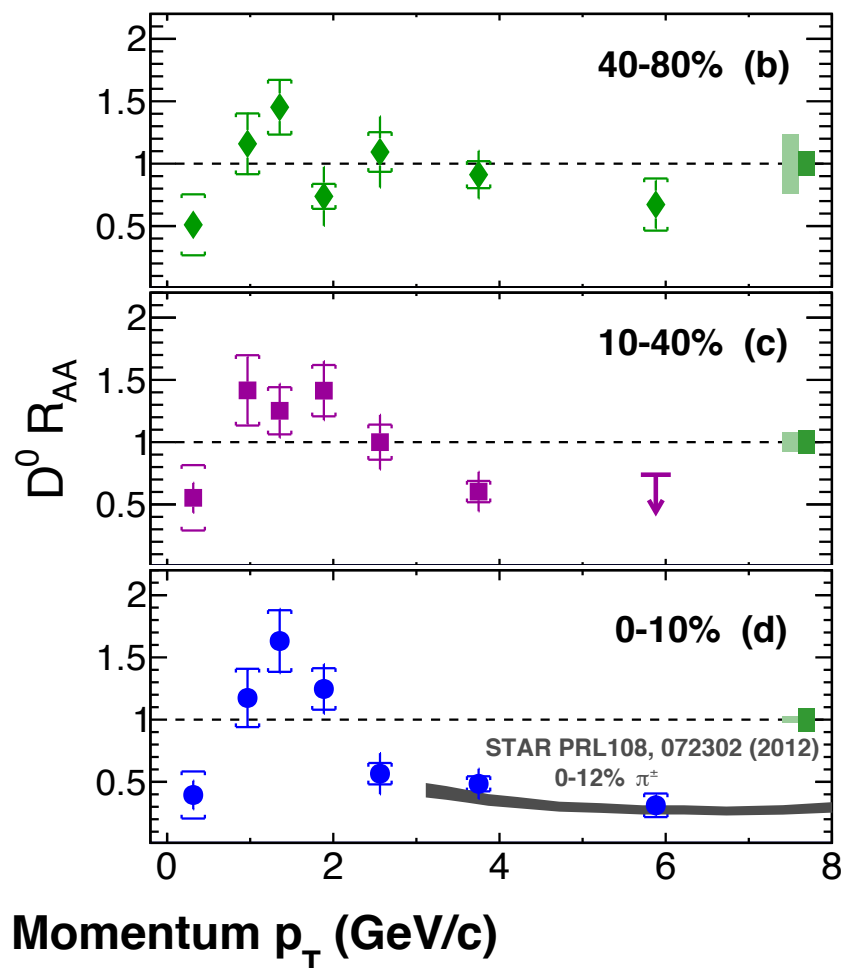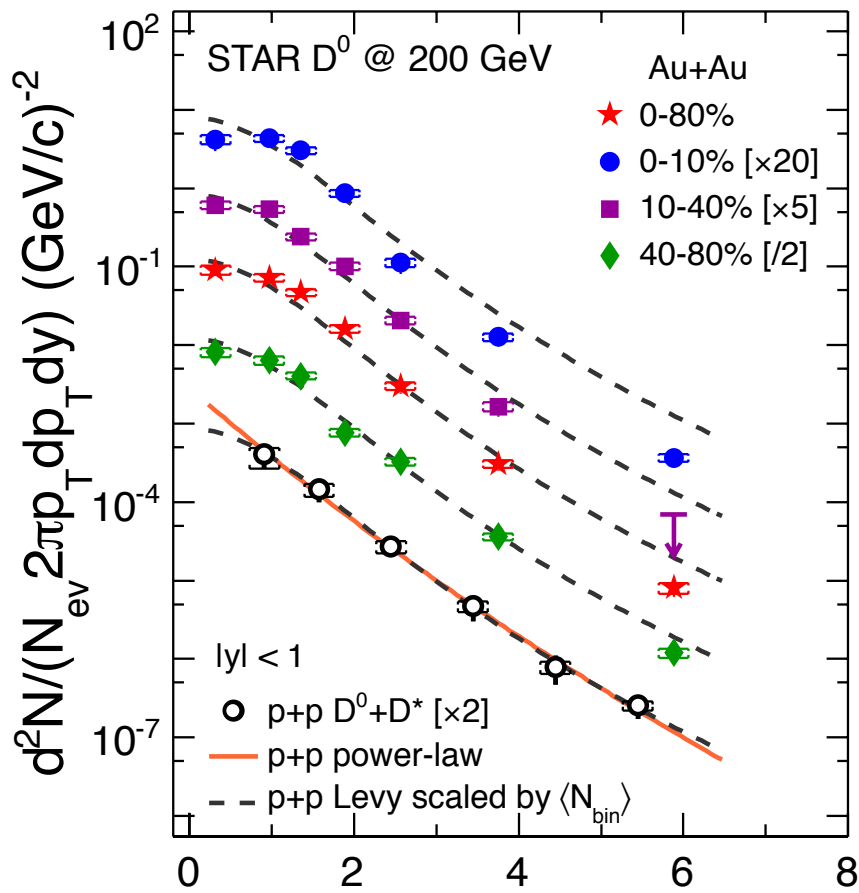
Total charm production scales with the number of binary collisions at RHIC

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Open Charm Production
– Au+Au –

Large suppression at high p_T and indication of enhancement at p_T~0.7-2GeV/c
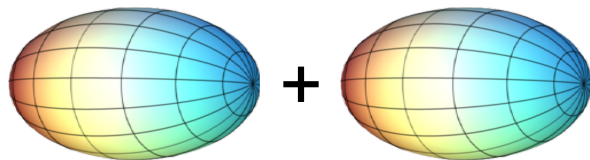
Au+Au Collisions

Oblate

U+U Collisions

Prolate

$\varepsilon_B^{UU}/\varepsilon_B^{AuAu}$ vs Centrality [%]

Kikola, Odyniec, Vogt, PRC 84, 054907 (2011)
Masui, Mohanty, Xu, PLB 679, 440 (2009)
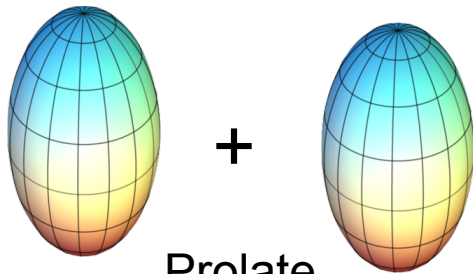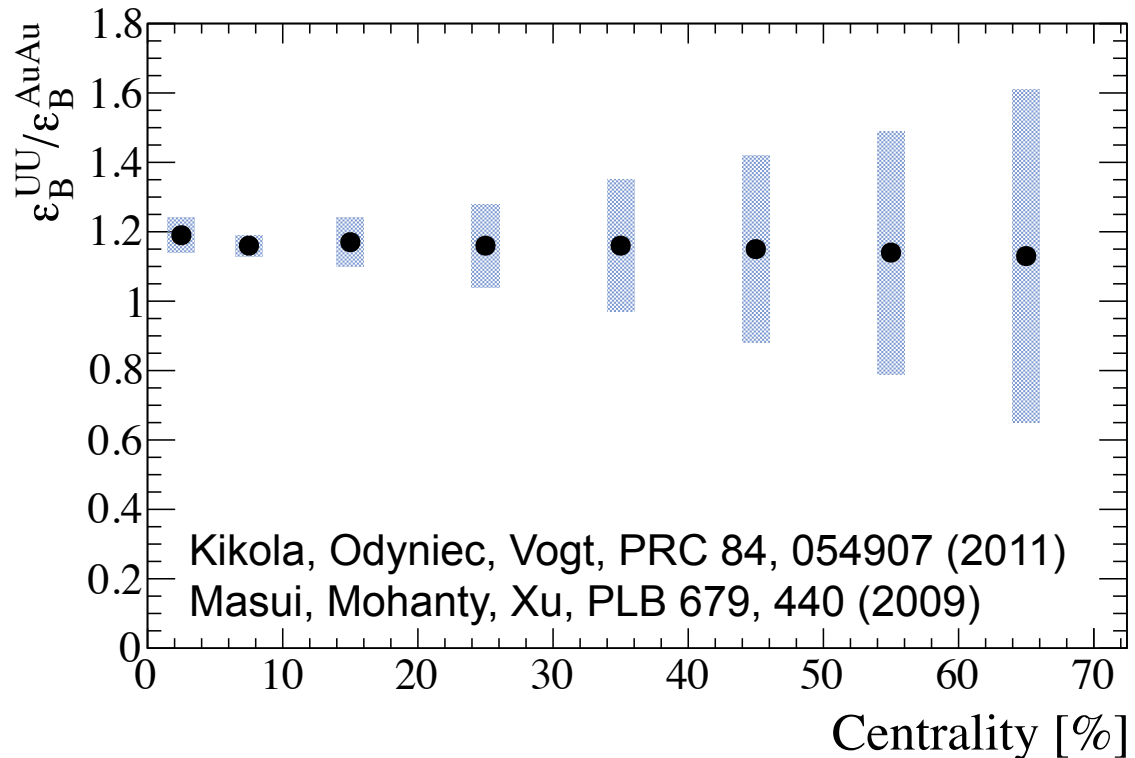
U+U collisions could have 20% higher energy density than Au+Au

14

R_AA similar trend in U+U collisions as in Au+Au collisions

Open Charm Production
– U+U –

STAR Preliminary

■ U+U 193 GeV D^0: |y|<1, 3<p_T<5 GeV/c

● Au+Au 200 GeV D^0: |y|<1, 3<p_T<8 GeV/c, arXiv:1404.6185 (submitted to PRL)

Au+Au 200 GeV $\pi^\pm$: |y|<0.5, p_T>6 GeV/c, PLB655, 104 (2007)

0-80%

p+p norm.

40-80%   10-40%   0-10%

Nuclear Modification Factor (R_{AA})

$\langle N_{part} \rangle$
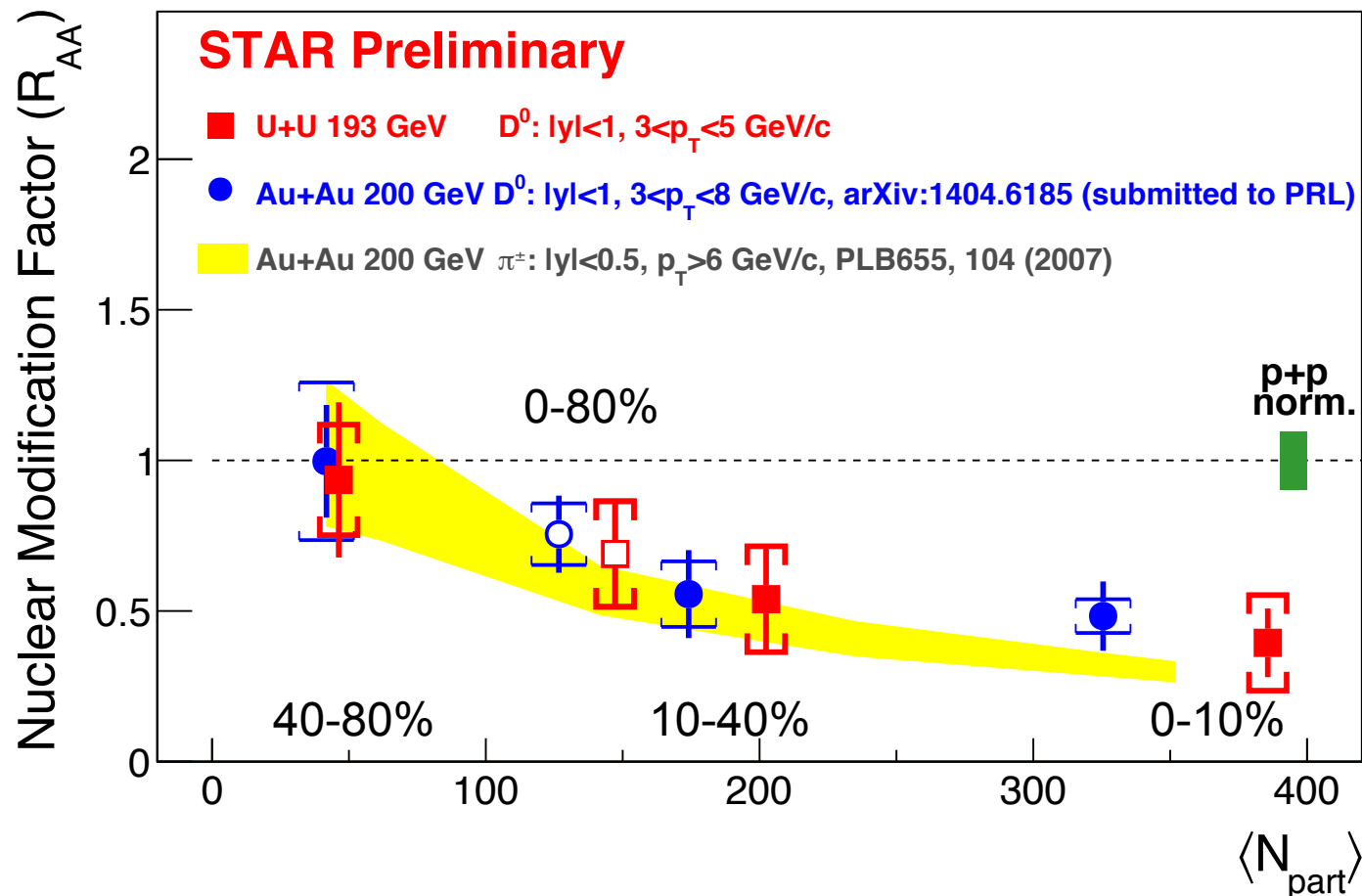
Suppression of open charm at high p_T in U+U collisions is similar to and extends the trend as that of open charm and pions in Au+Au collisions.

Nuclear Modification Factor

STAR Au+Au → D⁰ + X @ 200 GeV Central 0-10%

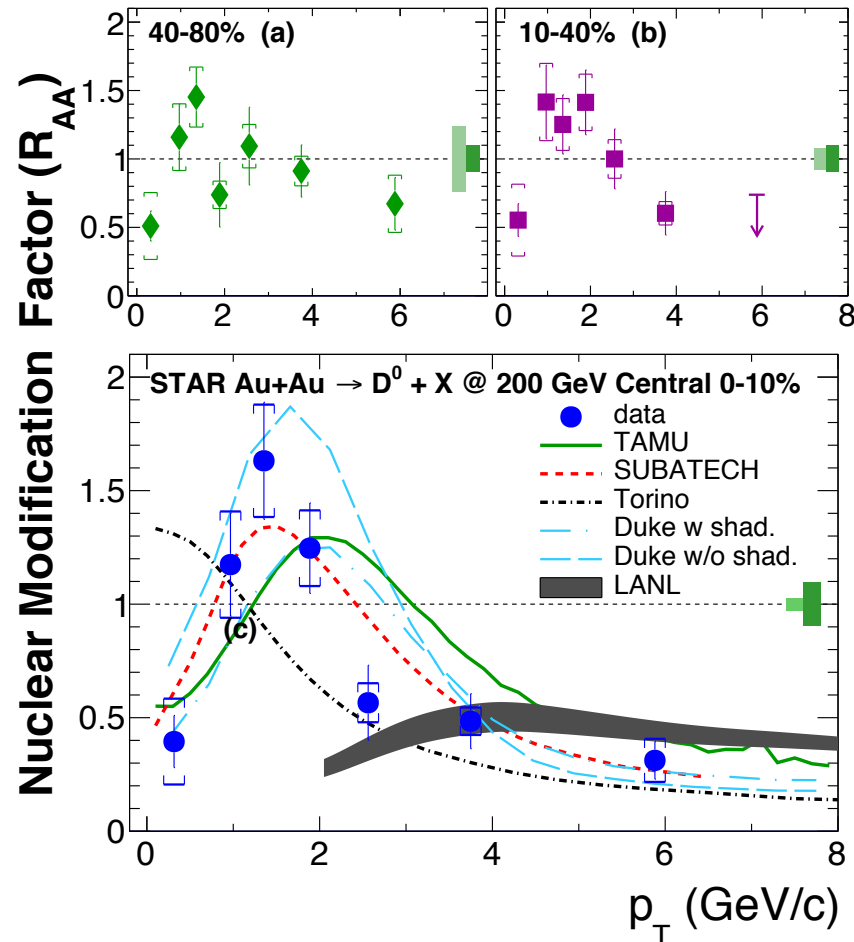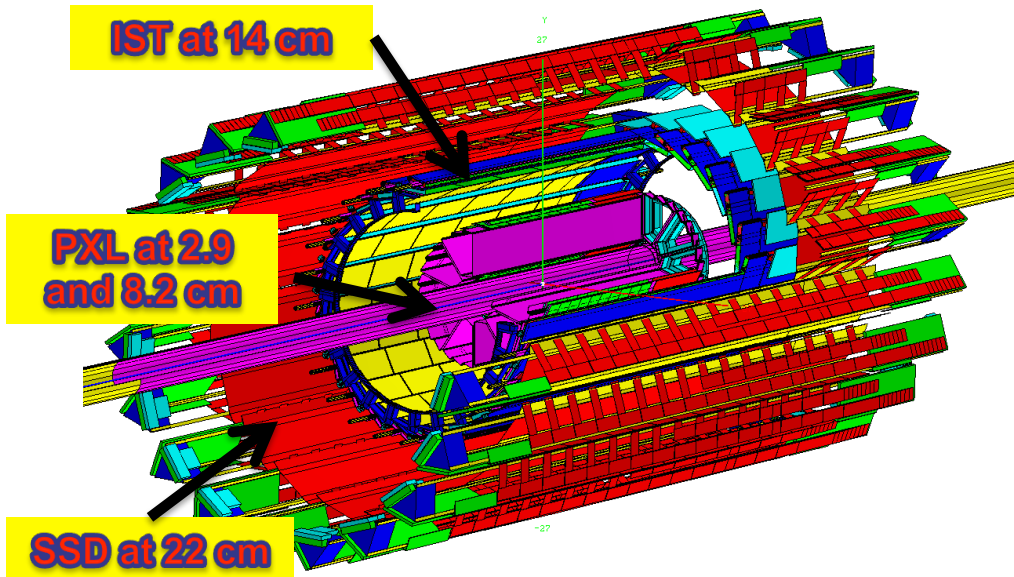|	TAMU	SUBATECH	Torino	Duke	LANL
HQ prod.	LO	FNOLL	NLO	LO	LO
QGP-Hydro	ideal	ideal	viscous	viscous	ideal
HQ eLoss	coll.	coll. +rad.	coll. +rad.	coll. +rad.	diss. +rad.
Coalescence	Yes	Yes	No	Yes	No
Cronin effect	Yes	Yes	No	No	Yes
Shadowing	No	No	Yes	Yes/No	Yes

- 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
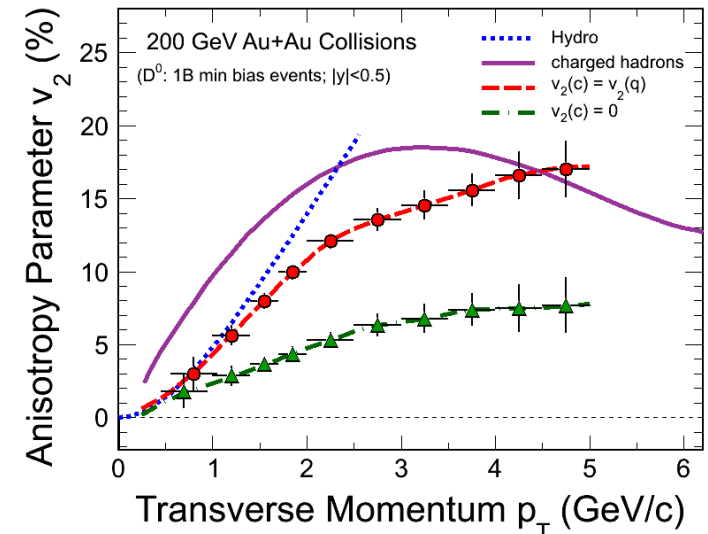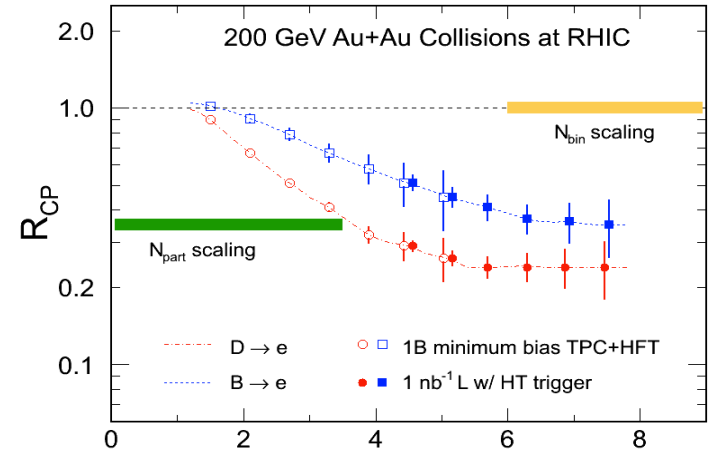
arXiv:1404.6185 (submitted to PRL)

Summary

- D^0/D* mesons reconstructed in hadronic decay channels, thanks to the excellent PID of the STAR detector.

- D^0/D* differential production cross-section measured for p_T~0.4-18 GeV/c in 200 and 500 GeV p+p collisions, consistent with FONLL calculations within uncertainties.

- Significant suppression at high p_T and indication of enhancement at p_T~0.7-2 GeV/c observed for D^0 production in both Au+Au and U+U collisions, which can be described by model calculations with strong charm-medium interaction and coalescence hadronization.

Quark Matter 2014, Zhenyu Ye

Outlook

IST at 14 cm

PXL at 2.9 and 8.2 cm

SSD at 22 cm

HFT CDR STAR-sn0600

200 GeV Au+Au Collisions at RHIC

N_{bin} scaling

N_{part} scaling

R_{CP}

$D \rightarrow e$ ○ □ 1B minimum bias TPC+HFT
$B \rightarrow e$ ● ■ 1 nb^{-1} L w/ HT trigger

200 GeV Au+Au Collisions
(D^0: 1B min bias events; |y|<0.5)

Hydro
charged hadrons
$v_2(c) = v_2(q)$
$v_2(c) = 0$

Anisotropy Parameter v_2 (%)

Transverse Momentum p_T (GeV/c)

- **Newly commissioned STAR HFT detector**
  - 2 layers of thin Silicon pixel (MAPS) 0.4% X_0/layer, 12x12μm, 360M pixels
  - 2 layers of Silicon pad/strip detectors fast readout, bridging TPC and PXL
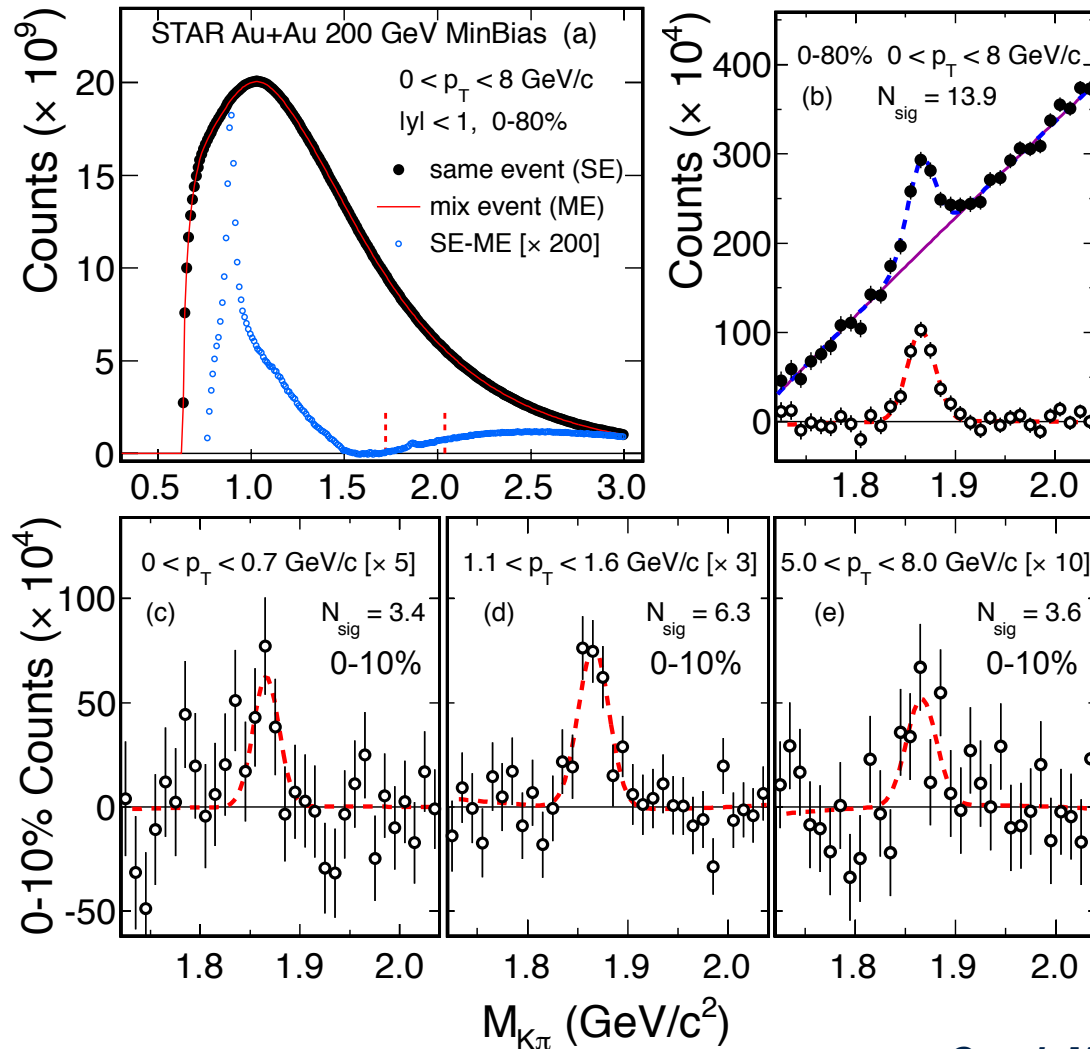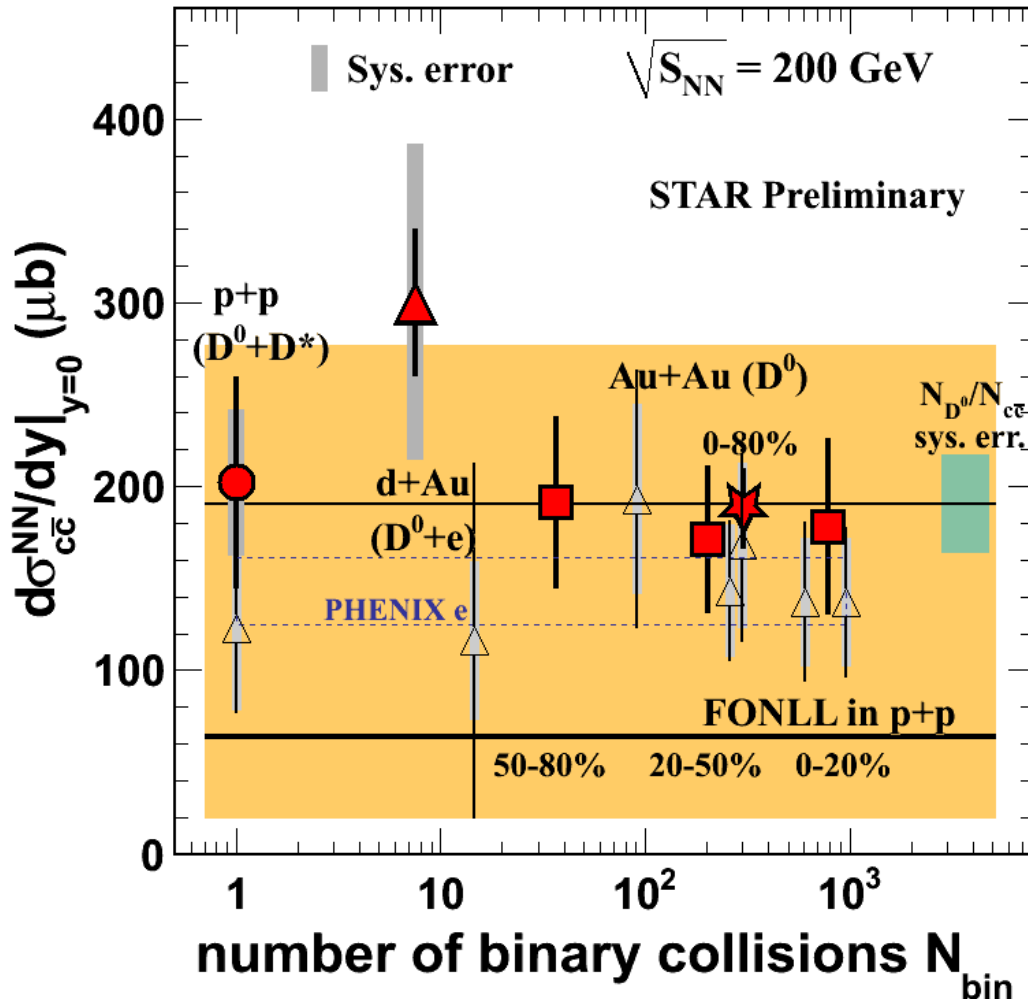- **Stay tuned for greatly improved R_{AA} and v_2 HF measurements from STAR soon !**

Talk: Qiu-557; Posters: Lomnitz-M13 and Wang-M30

Backup

D^0 Reconstruction in Au+Au

**Submitted to PRL
arXiv:1404.6185**

Open Charm Production

Submitted to PRL arXiv:1404.6185

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