Open bottom production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV with the STAR experiment

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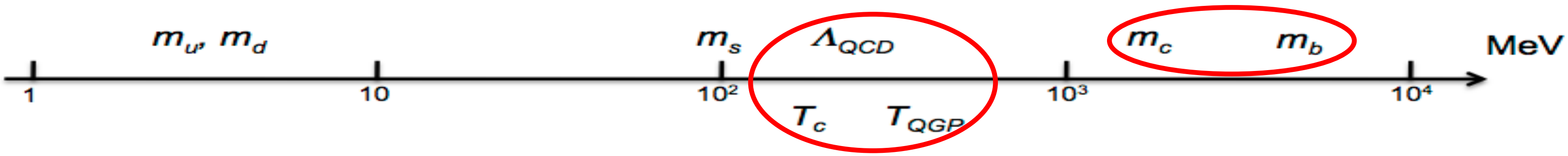
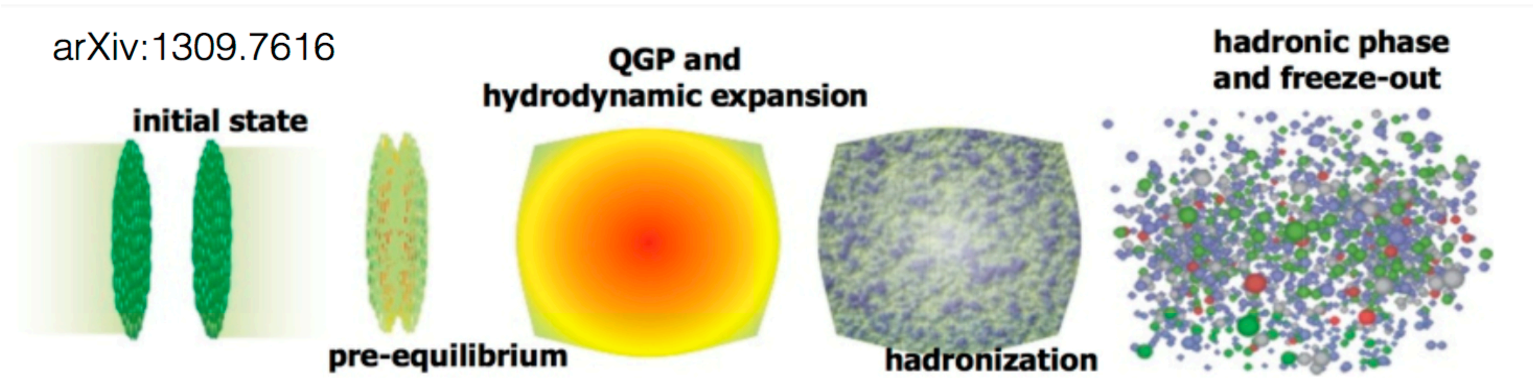
Outline

- Why heavy flavor?
- The STAR experiment
- Bottom production in 200 GeV Au+Au collisions
  - ★ ***B/D->e***
  - ★ ***B->J/ψ***
  - ★ ***B->D^0***
- Summary and Outlook

Why Heavy Flavor?

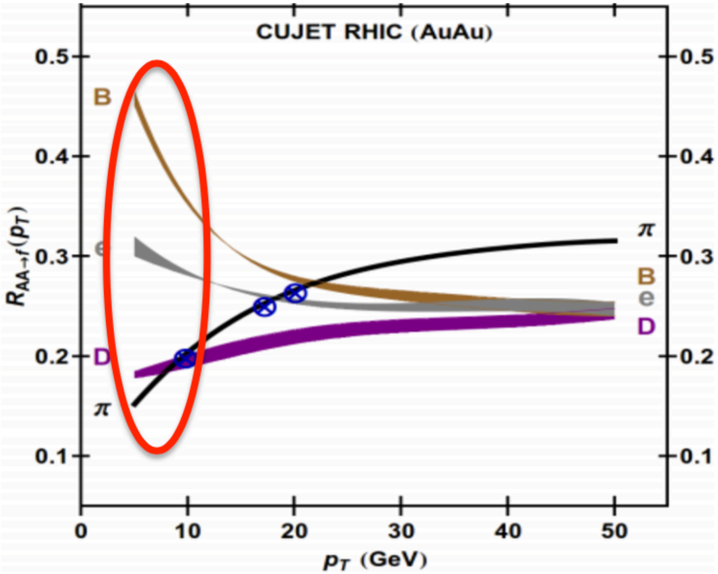


- $m_{c,b} \gg T_{QGP}$: dominantly produced in hard scatterings at the early stage of heavy-ion collisions.
  - ★ Experience all stages of QGP evolution
    → carry information of interactions with the medium.
  - ★ An excellent probe to study the properties of the QGP.

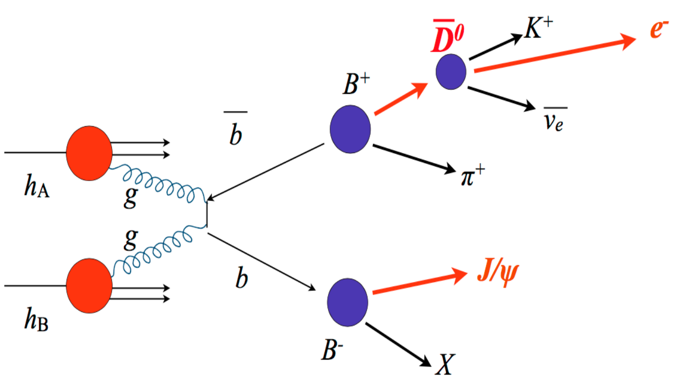


Observables:

- Study flavour dependence of parton energy loss.
  - → Theoretical prediction for ΔE in medium: $\Delta E_g > \Delta E_{u,d,s} >$ ΔE_c > ΔE_b.
  - → Precise measurements of *c* and *b* quark energy losses separately are crucial to test the **mass hierarchy** of the **parton energy loss**.



PRL 108 (2012) 022301



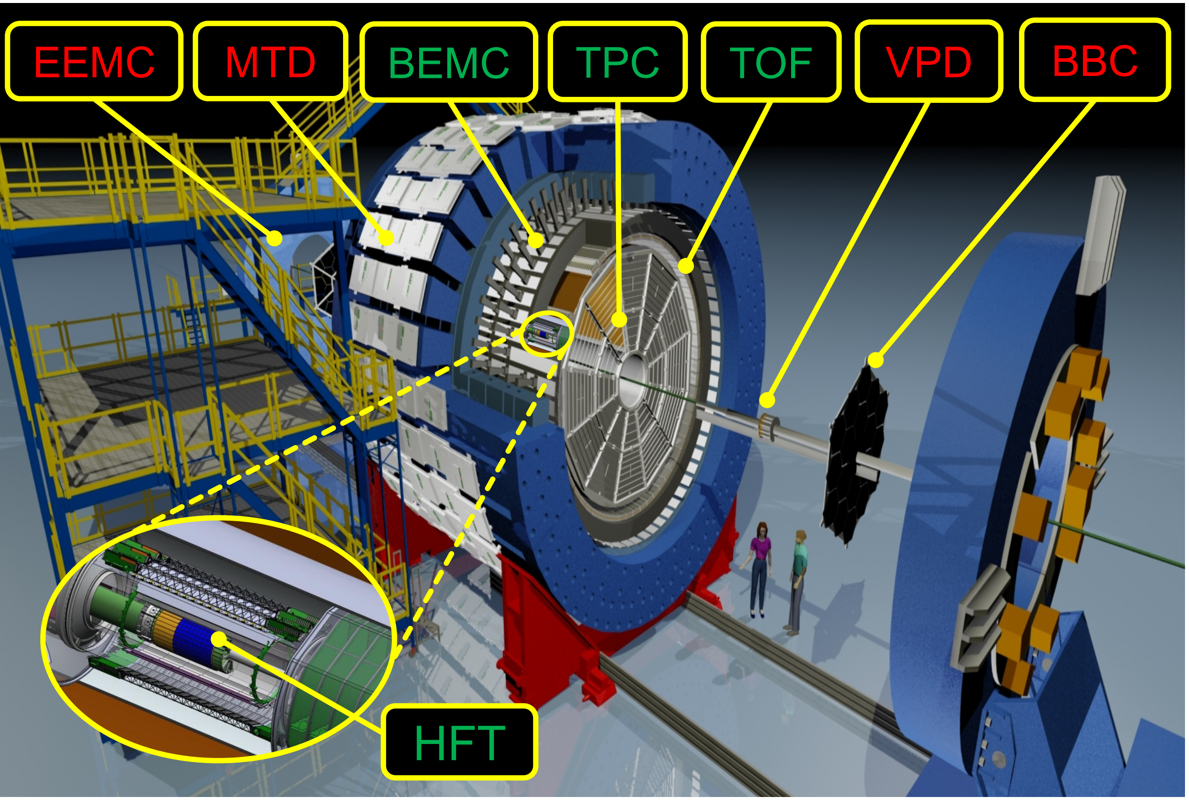
★ B->e

★ B->J/ψ

★ B->D^0

The STAR detector

★ |η|<1 and full azimuthal coverage



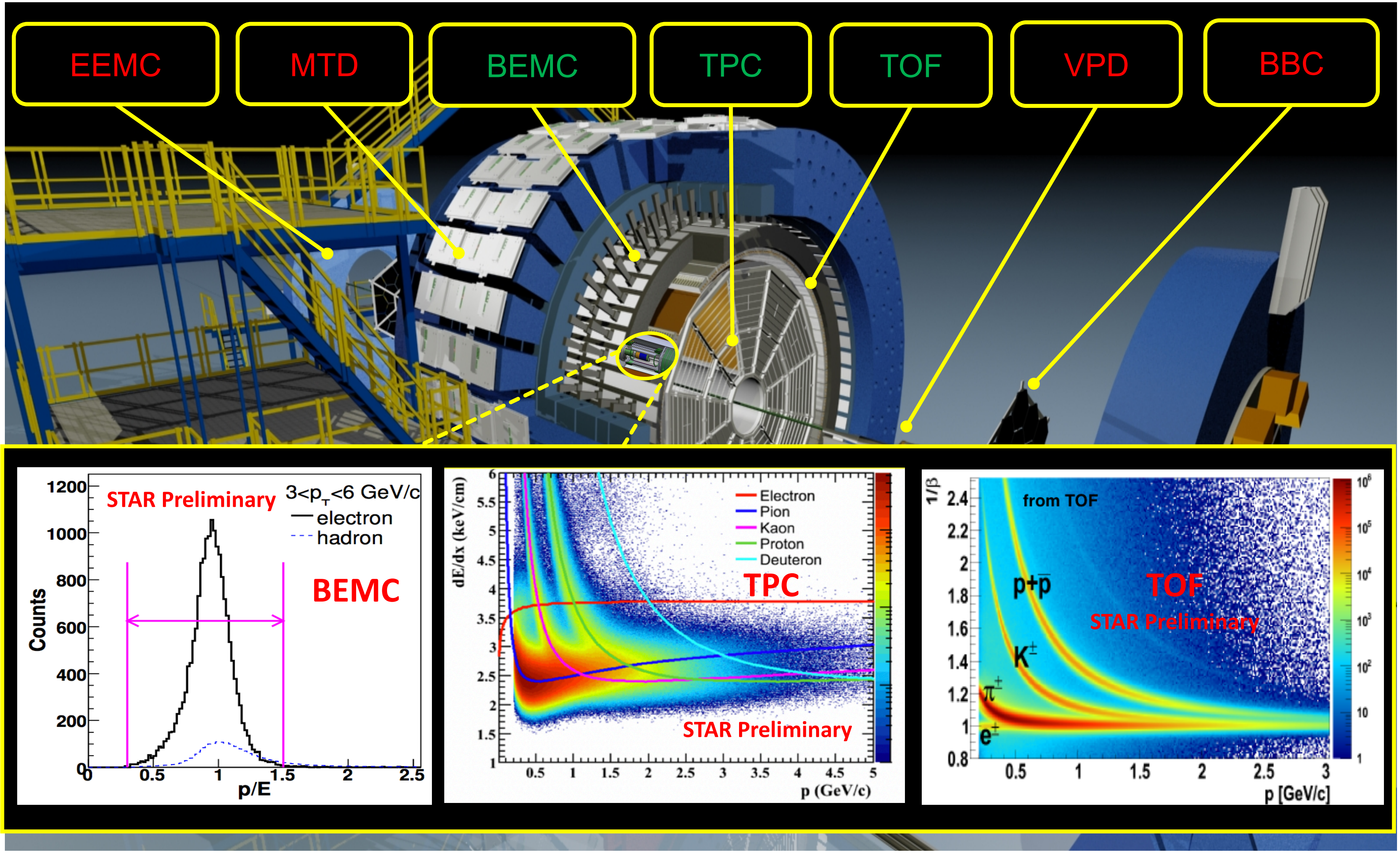
Time Projection Chamber (TPC)
- Momentum determination
- PID through dE/dx

Time of Flight (TOF)
- PID through time-of-flight
- Timing resolution:~85 ps

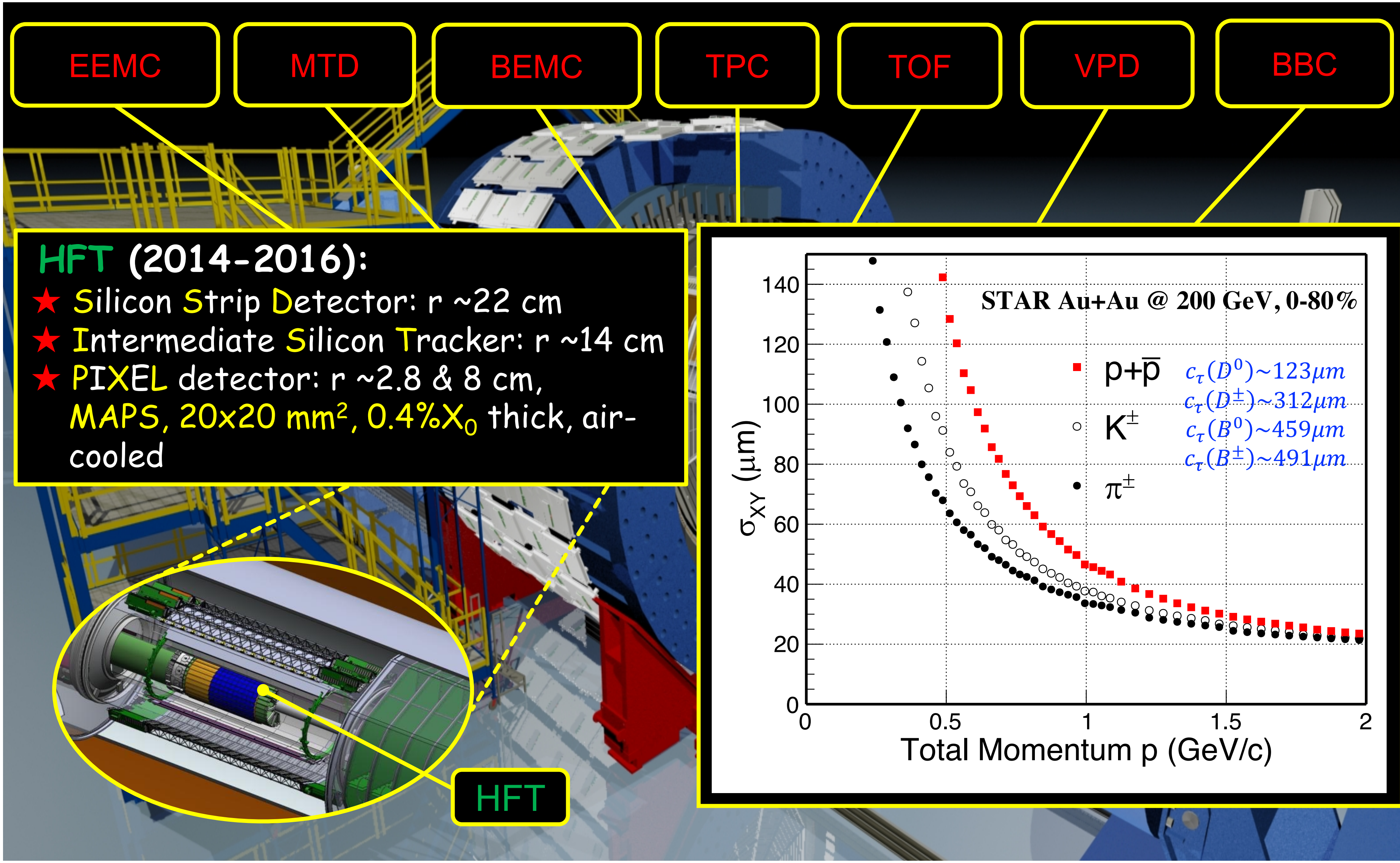
Barrel Electromagnetic Calorimeter (BEMC)
- PID through p/E
- Trigger on high-p_T electrons

Heavy Flavor Track (HFT)
- Precise measurements of displaced vertices

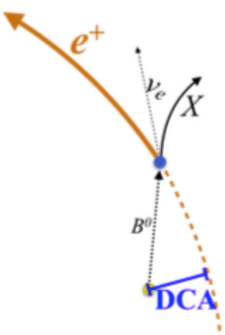
The STAR detector



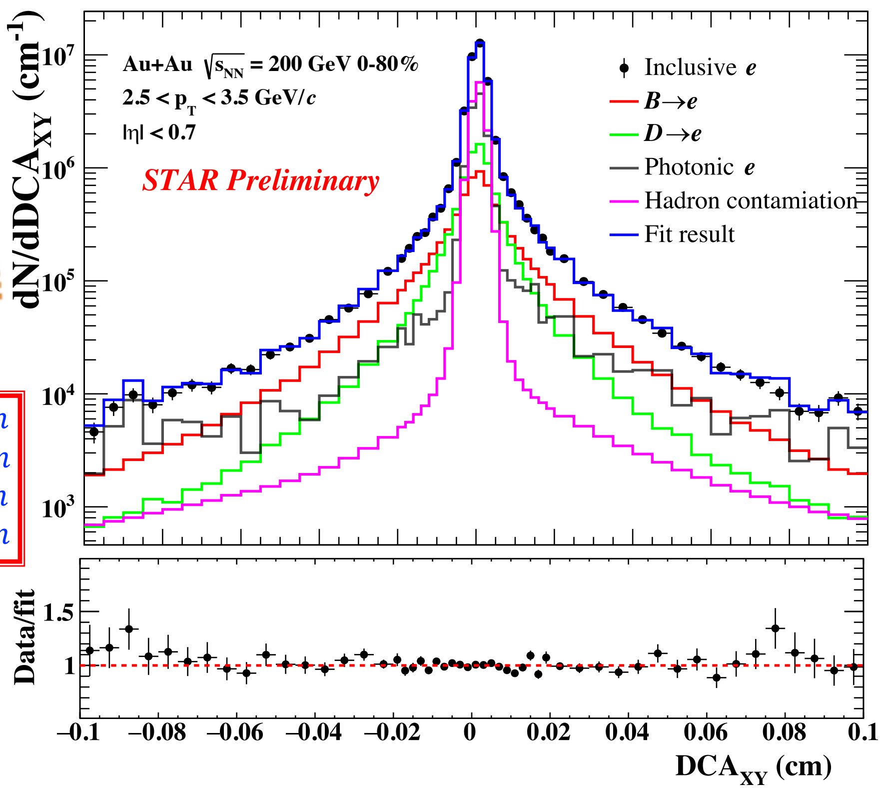
The STAR detector



Analysis Procedure - Template fitting of $B/D\to e$ in 200 GeV Au+Au collisions ~900M MB + ~0.2 nb^{-1} HT events

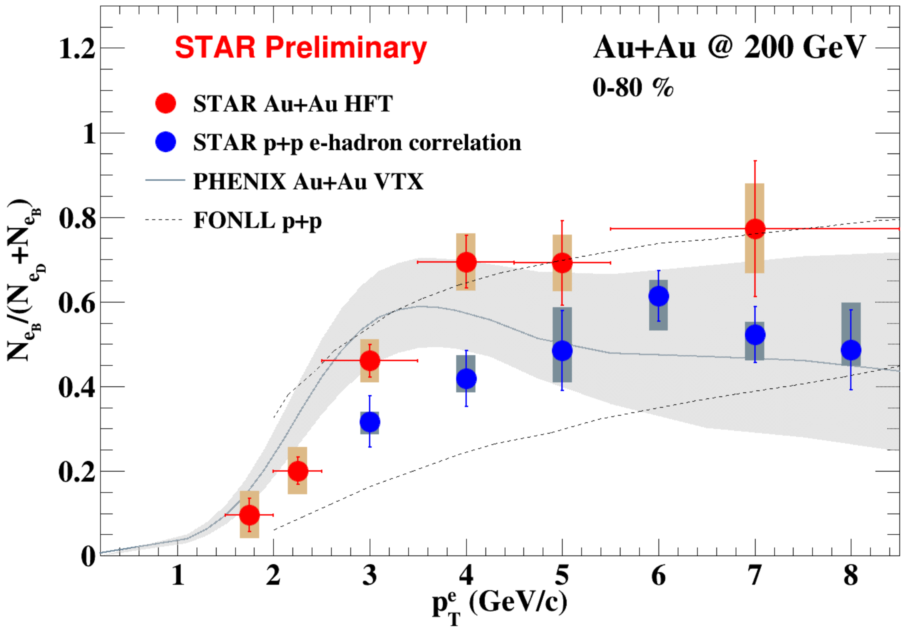


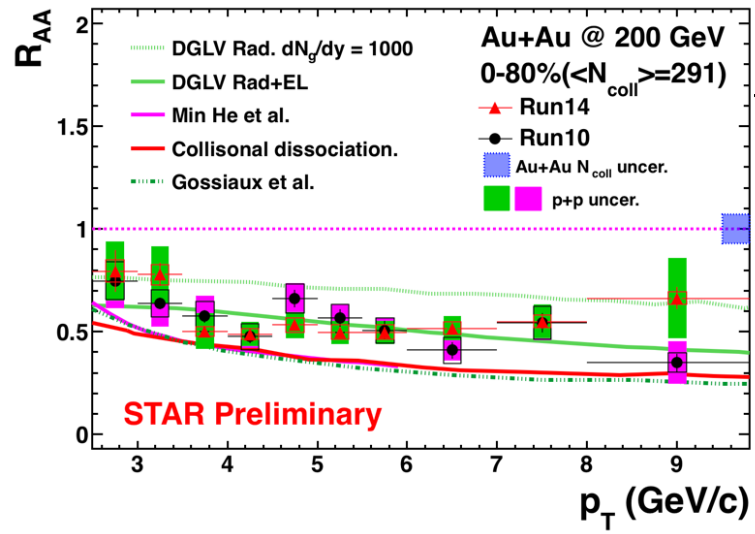
$c_\tau(D^0)\sim 123\mu m$
$c_\tau(D^\pm)\sim 312\mu m$
$c_\tau(B^0)\sim 459\mu m$
$c_\tau(B^\pm)\sim 491\mu m$



- **Inclusive electrons**
- Broader DCA_{XY} distribution for **bottom**- than **charm**-decayed electrons due to longer lifetime of B hadrons
  - → Signal template: Data-driven simulation + EvtGen decayer (D^0, $D^\pm$, B^0, $B^\pm$)
- Background:
  1. **Hadron contamination** – hadrons misidentified as electron candidates
     → Template: inclusive hadron distribution from data and contribution constrained using inclusive electron purity
  2. **Photonic electron** – gamma conversion and light meson Dalitz decays
     → Template: from data with correction factors extracted from Hijing simulations

B->e fraction in 200 GeV Au+Au collisions





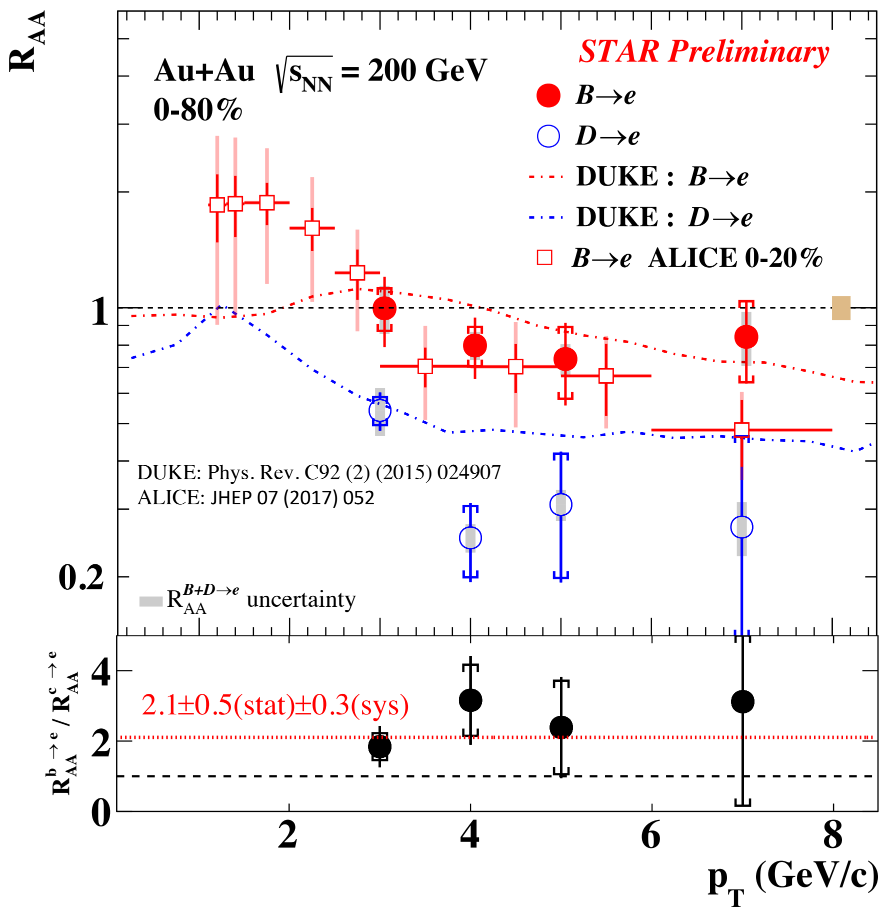
DHLV: Physics Letters B 632 (1) (2006) 81 86
Min He et al.: Phys. Rev. C 86 (2012) 014903
Phys. Rev. C 88 (2013) 044907.
Collisional dissociation: Phys. Rev. C 80 (2009) 054902
Gossiaux et al. Journal of Physics G: Nuclear and Particle Physics 37 (9) (2010) 094019
Phys. Rev. C 78 (2008) 014904
ActaPhys. Polon. B 43 (2012) 655 662

- Enhancement of the fraction of electrons from *B*-hadron decays is observed in Au+Au collisions compared to that in p+p collisions.

$$R_{AA}^{B\to e} = \frac{f_{Au+Au}^{B\to e}(data)}{f_{p+p}^{B\to e}(data)} R_{AA}^{HF_e}(data),$$

$$R_{AA}^{D\to e} = \frac{1 - f_{Au+Au}^{B\to e}(data)}{1 - f_{p+p}^{B\to e}(data)} R_{AA}^{HF_e}(data)$$

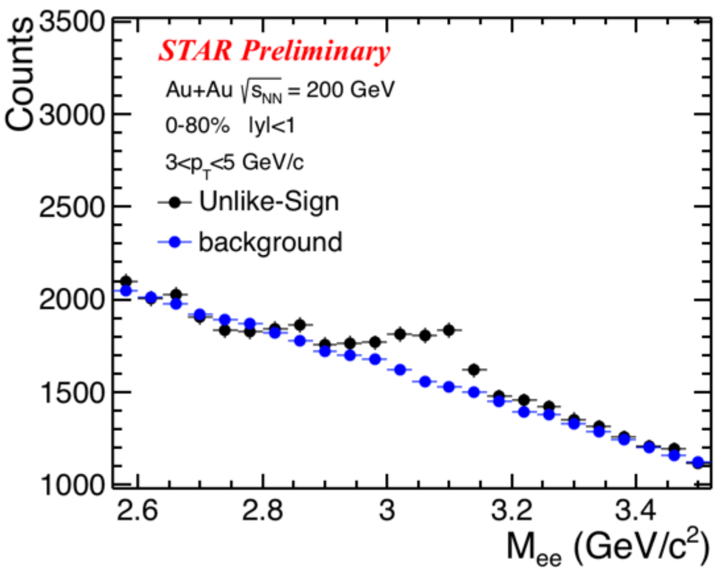
R_{AA} of B/D->e in 200 GeV Au+Au collisions

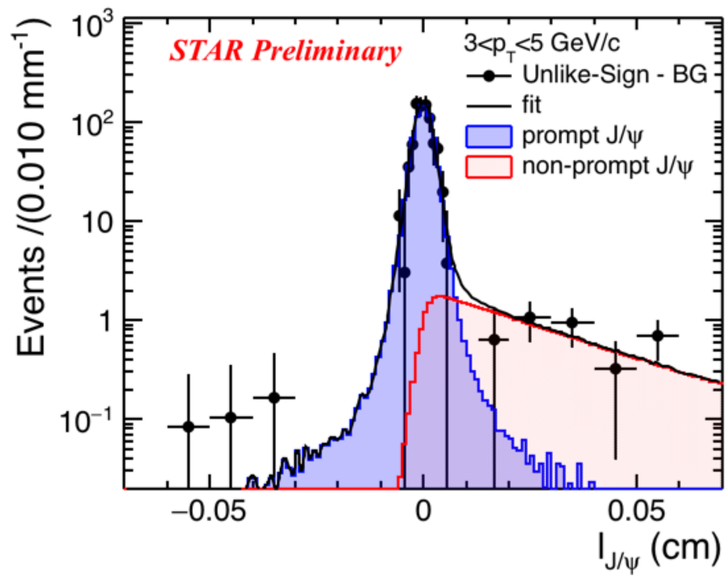


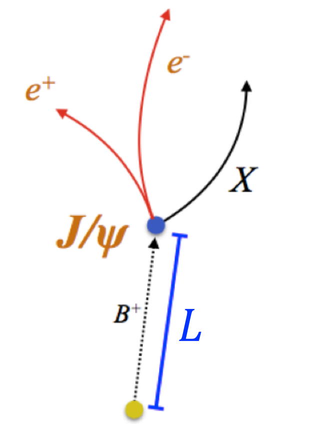
- First STAR measurements of electrons from charm and bottom hadron decays separately.
- $R_{AA}(e_D) < R_{AA}(e_B)$ (~2σ at 3 - 7 GeV/c).
- Consistent with mass hierarchy of parton energy loss ($\Delta E_c > \Delta E_b$) .

Analysis Procedure - Template fitting of $B\text{->}J/\psi$ in 200 GeV Au+Au collisions

~900M MB + ~1.2 nb^{-1} HT events





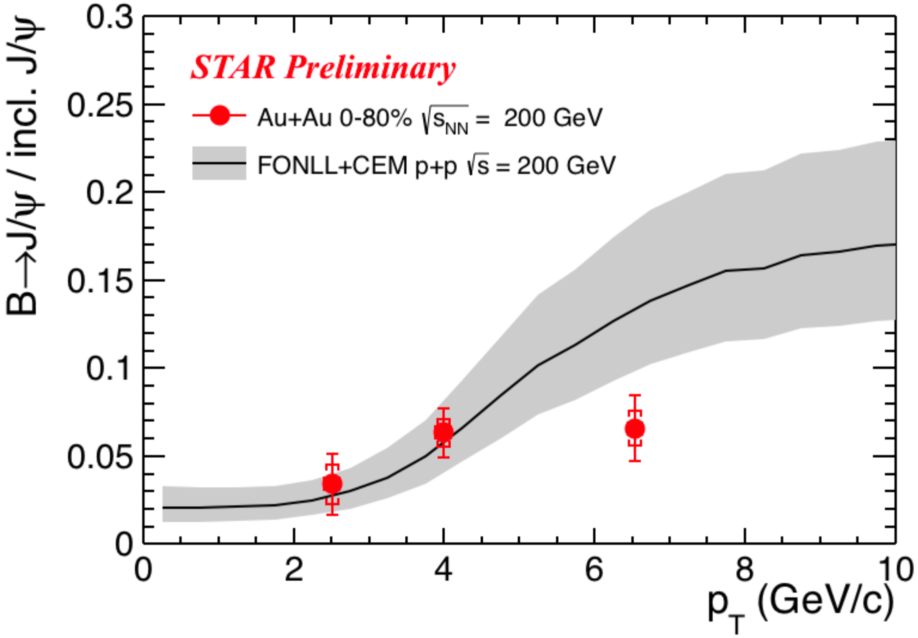


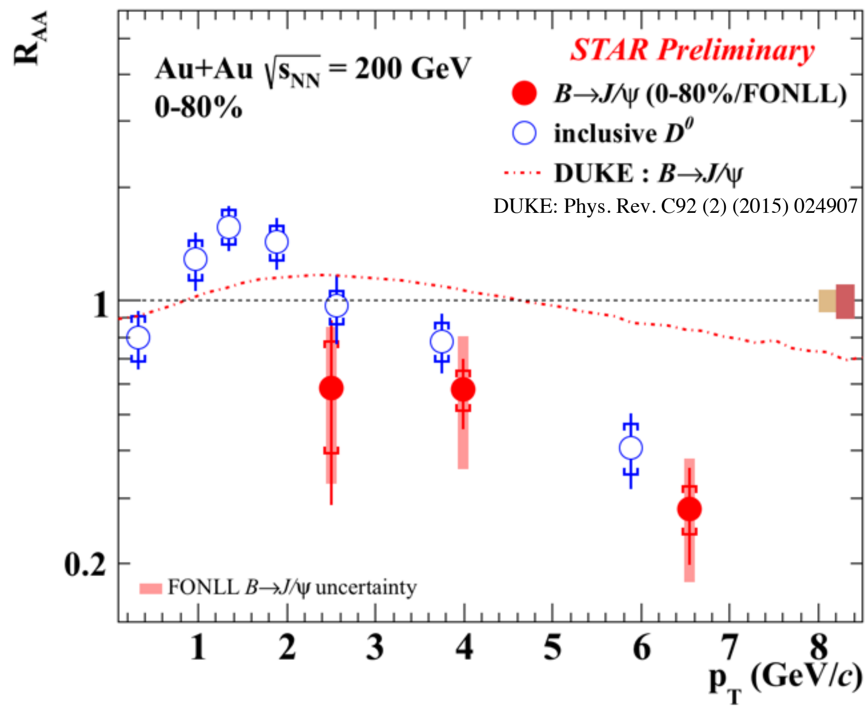
$$l_{J/\psi} = \frac{\vec{L} \cdot \hat{p}}{|\vec{p}|/c} \cdot M_{J/\psi}$$

- Obtain the pseudo-proper decay length ($l_{J/\psi}$) distribution of J/ψ.
- Template for prompt J/ψ: prompt J/ψ from FONLL + data-driven simulation of detector effects
- Template for non-prompt J/ψ: B-hadrons (B^0, $B^{\pm}$) from FONLL decayed to J/ψ via PYTHIA + data-driven simulation of detector effects

R_{AA} of $B \to J/\psi$ in 200 GeV Au+Au collisions

$$R_{AA}^{B\to J/\psi} = \frac{f_{Au+Au}^{B\to J/\psi}(data)}{f_{p+p}^{B\to J/\psi}(theory)} R_{AA}^{inc.\,J/\psi}(data)$$

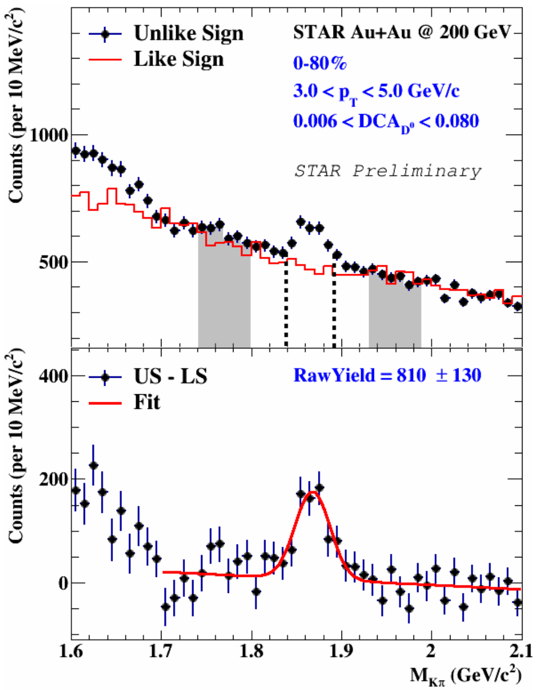


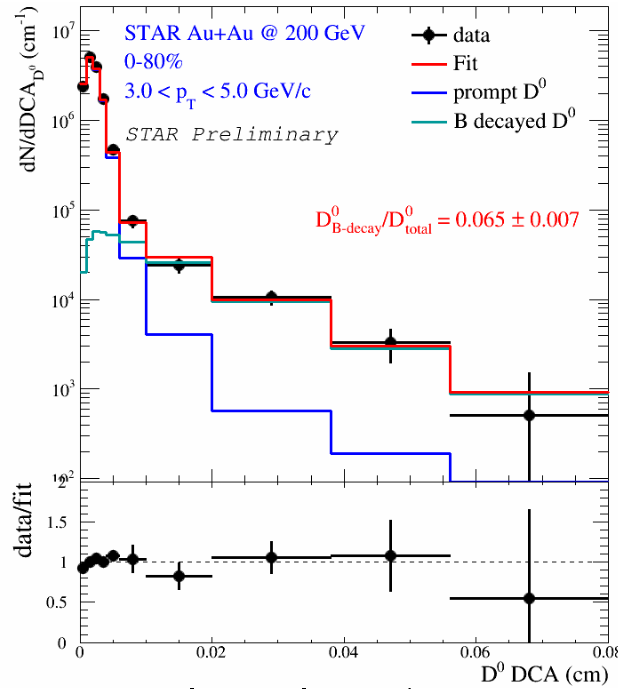


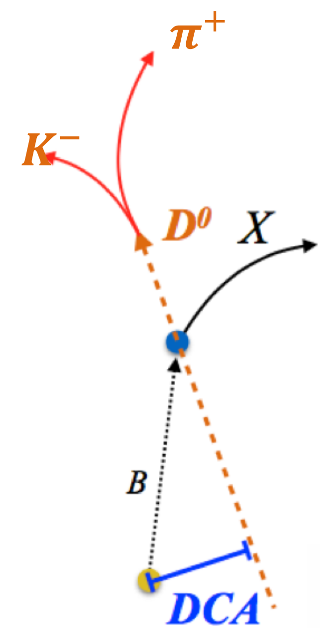
- **Strong suppression** is observed for non-prompt J/ψ at high p_T and is similar to that of D^0 mesons.

Analysis Procedure - Template fitting of $B \to D^0$ in 200 GeV Au+Au collisions

~900M MB

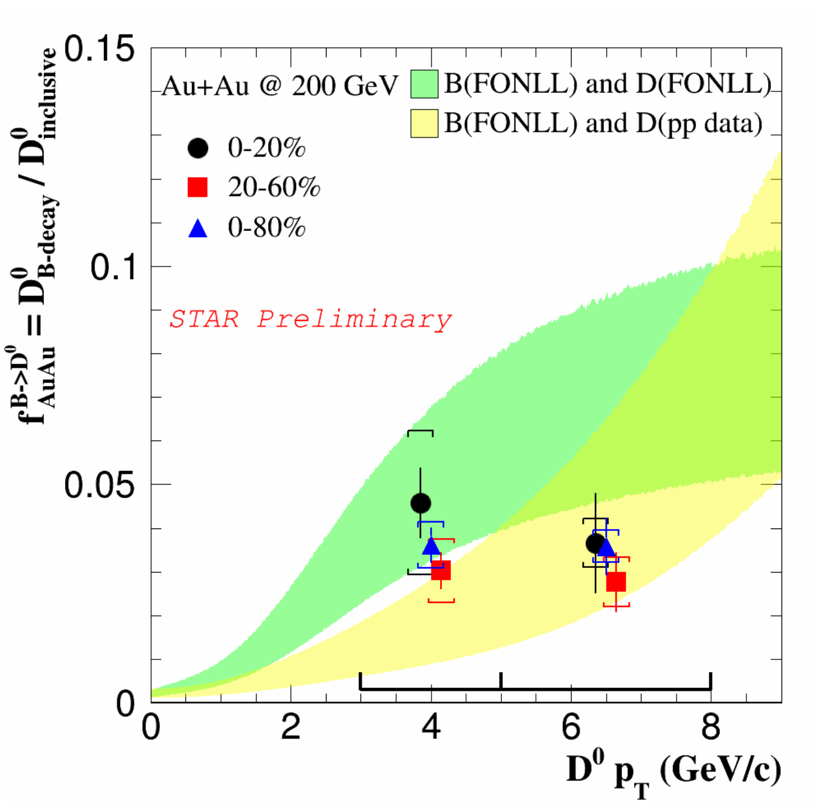


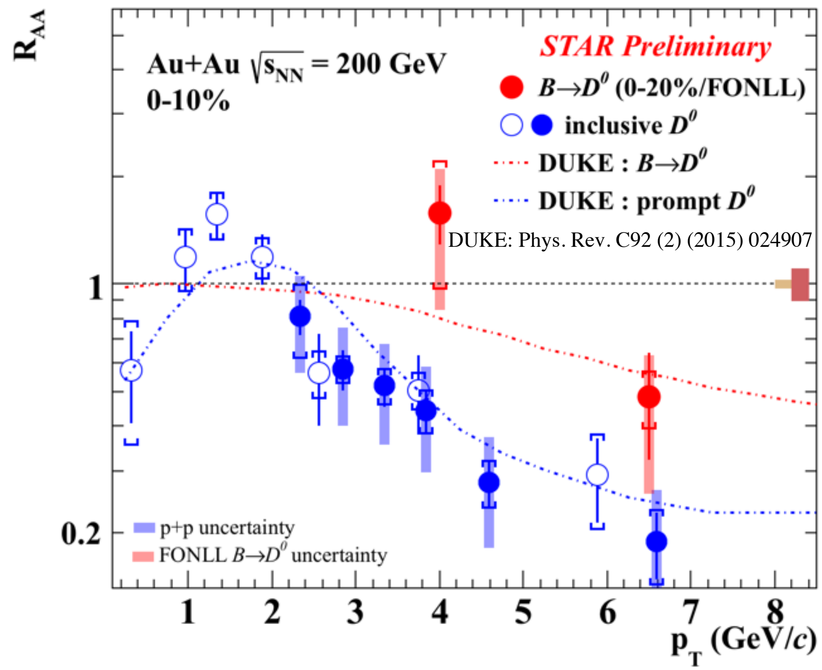




- Obtain the distance of closest approach to the primary vertex (DCA) distribution of D^0 from data.
- Template for prompt D^0 : prompt D^0 from FONLL + data-driven simulation of detector effects
- Template for non-prompt D^0: B-hadrons (B^0, $B^{\pm}$) from FONLL decayed to D^0 via PYTHIA + data-driven simulation of detector effects

R_{AA} of $B\text{->}D^0$ in 200 GeV Au+Au collisions

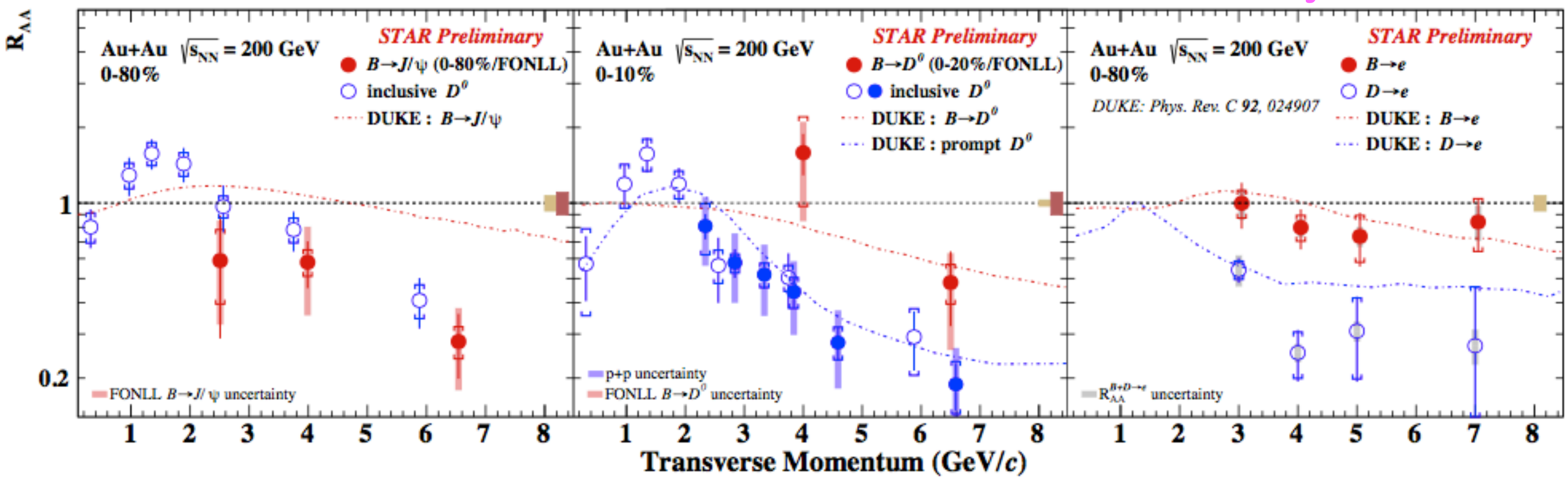




$$R_{AA}^{B\to D^0} = \frac{1}{< N_{coll} >} \frac{f_{Au+Au}^{B\to D^0} \times dN_{Au+Au}^{inc.\,D^0}/dp_T}{dN_{FONLL}^{B\to D^0}/dp_T}$$

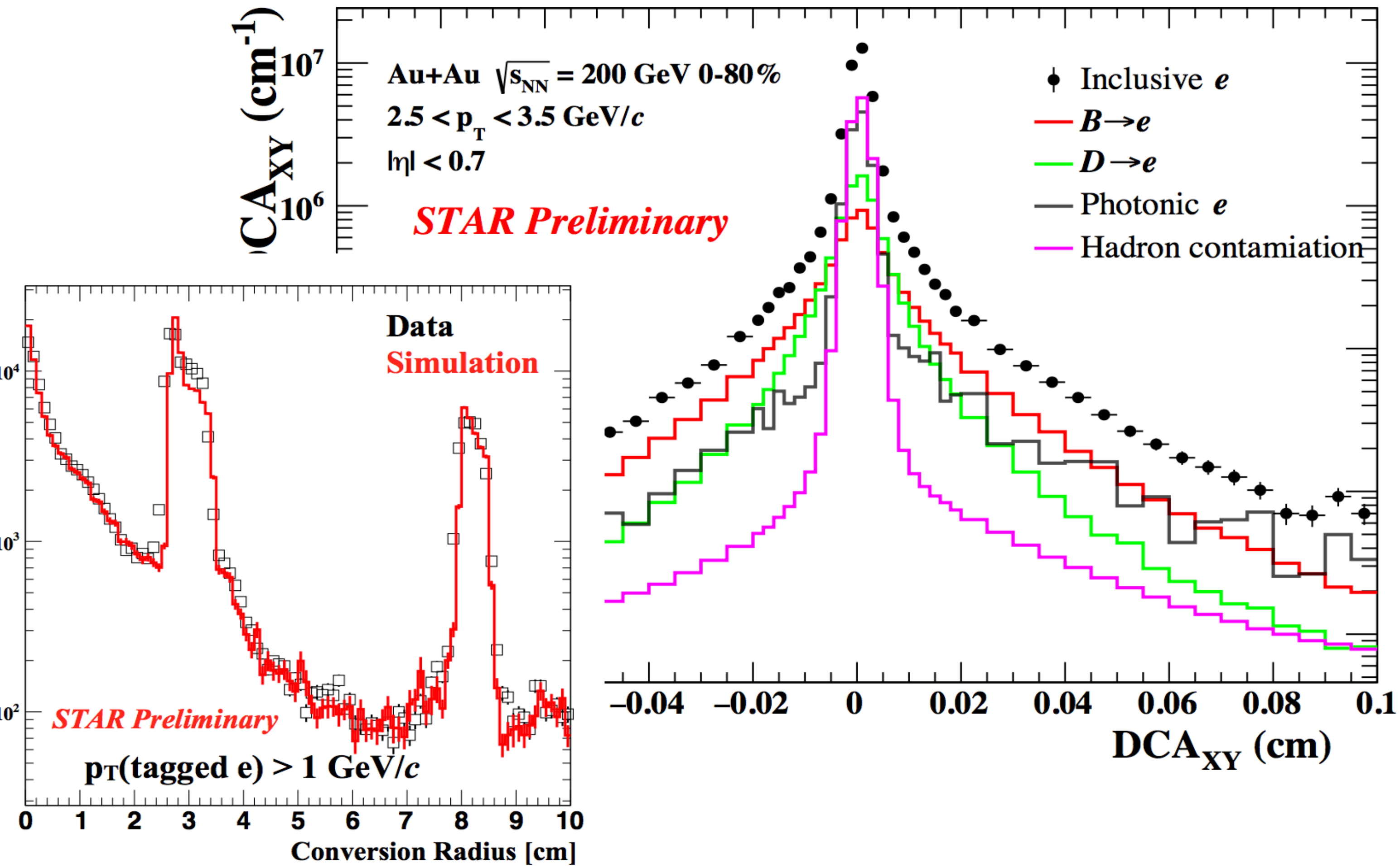
- **Strong suppression** of non-prompt D^0 is observed at high p_T.
- A hint of **less suppression** for non-prompt D^0 compared to prompt ones at $4 < p_T < 6.5$ GeV/c.

Summary



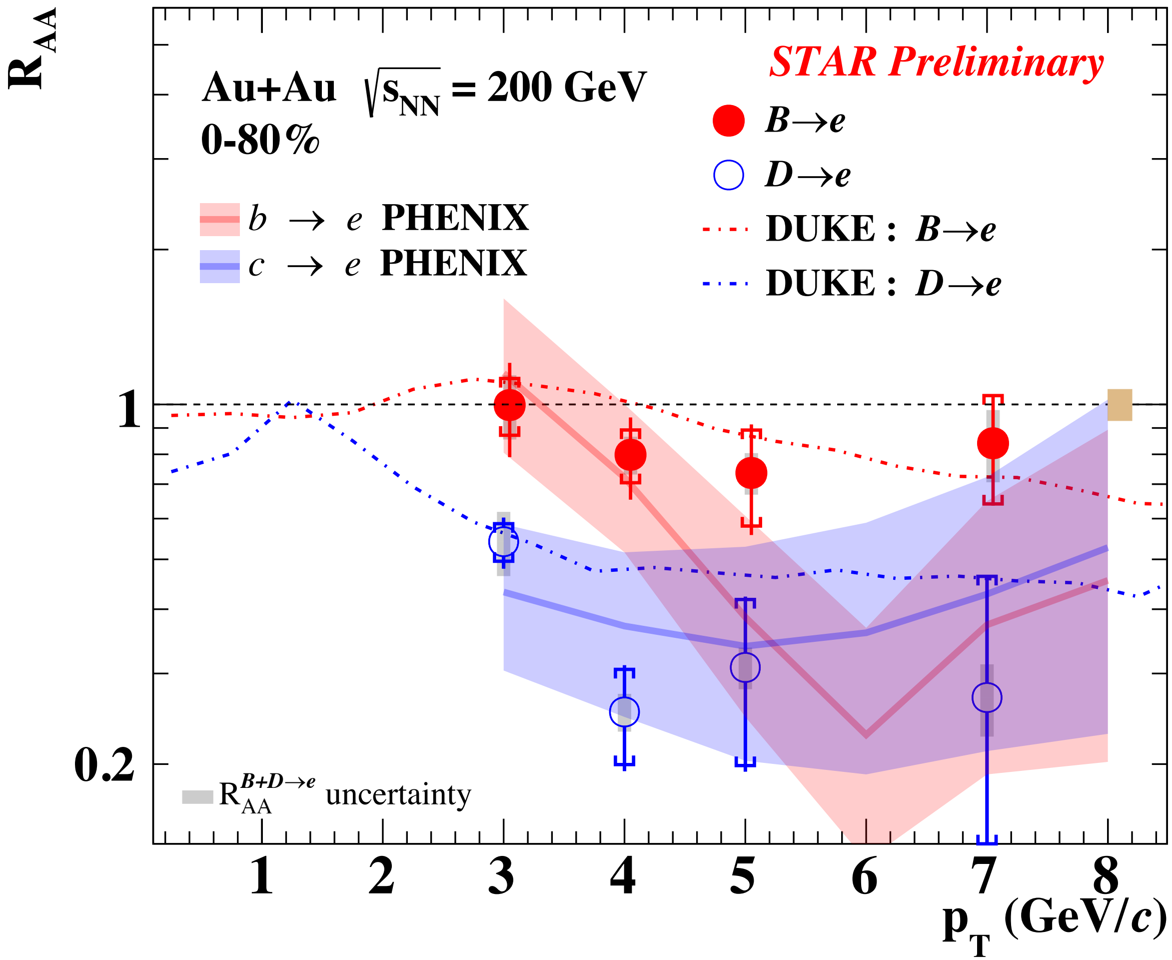
- **Measured *B* production via *J/ψ*, D^0 and electron decay channels in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV**
  1) Strong suppression for *B->J/ψ* and *B->D^0* at high p_T.
  2) Indication of less suppression for *B->e* than *D->e* (~2σ): consistent with $\Delta E_c > \Delta E_b$.
- **Outlook**
  A factor of ~ 2 more MB and ~ 5 more HT Au+Au events recorded in 2016.

Back up



- Radius distribution of photonic electron pairs in data can be well described by detector simulation.

B/D→e



Consistent with PHENIX result within uncertainty.

HFT Design

- HFT consists of 3 sub-detector systems inside the STAR Inner Field Cage

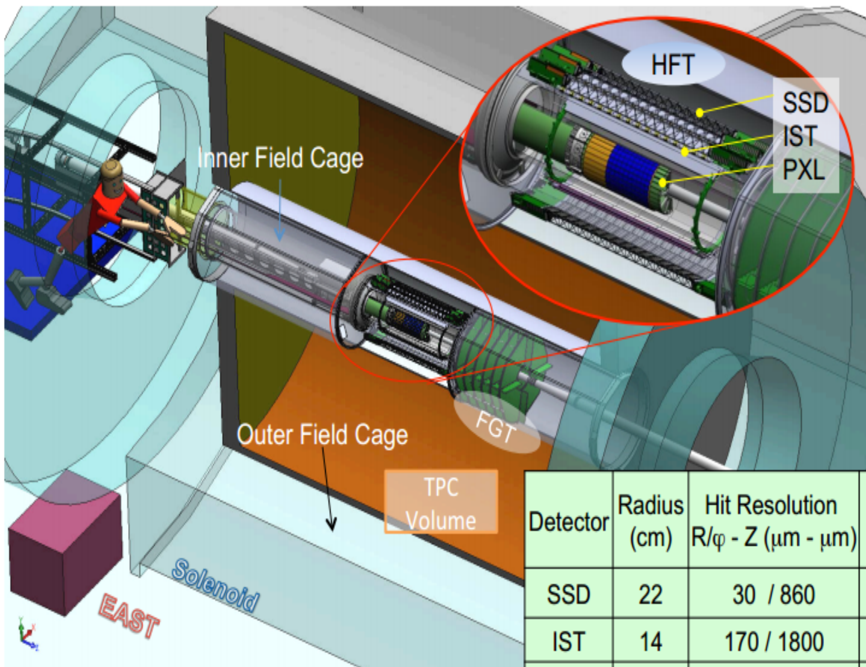
Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Thickness
SSD	22	30 / 860	1% X_0
IST	14	170 / 1800	1.32 %X_0
PIXEL	8	6.2 / 6.2	~0.52 %X_0
	2.8	6.2 / 6.2	~0.39% X_0

➢ **SSD** existing single layer detector, double side strips (electronic upgrade)

➢ **IST** one layer of silicon strips along beam direction, guiding tracks from the SSD through PIXEL detector **- proven pad technology**

➢ **PIXEL** double layers, 20.7x20.7 mm pixel pitch, 2 cm x 20 cm each ladder, 10 ladders, delivering ultimate pointing resolution. **- new active pixel technology**

HFT



Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Radiation length
SSD	22	30 / 860	1% X_0
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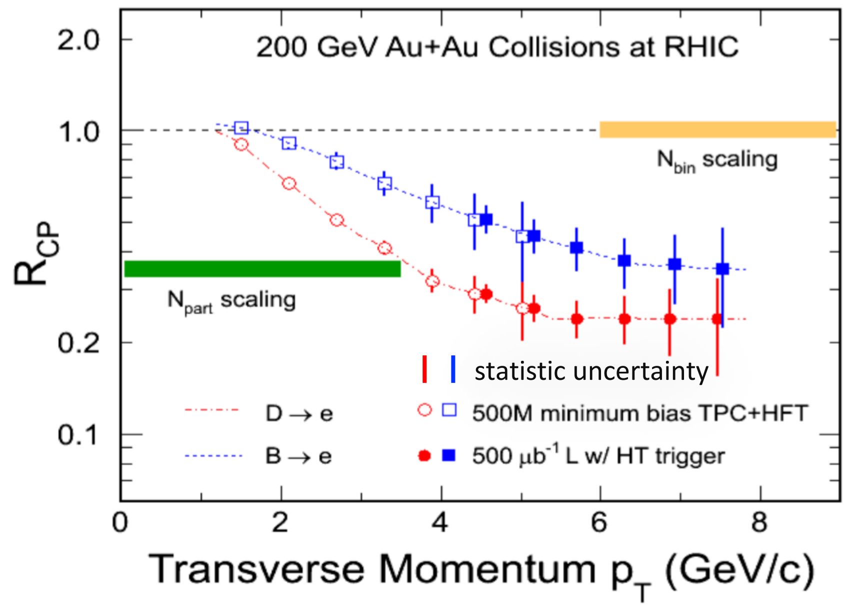
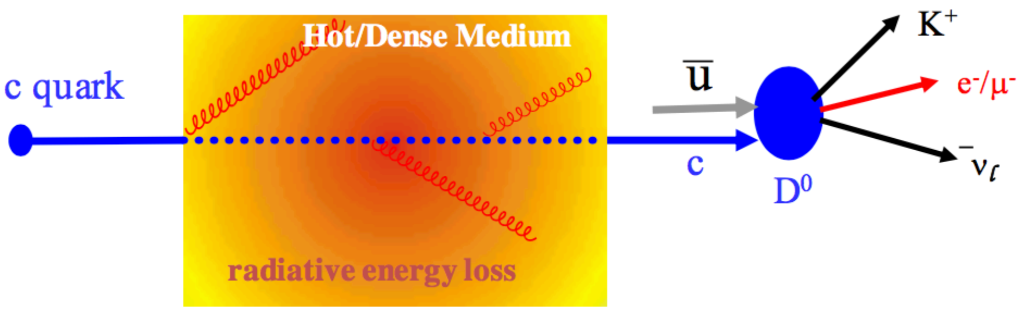
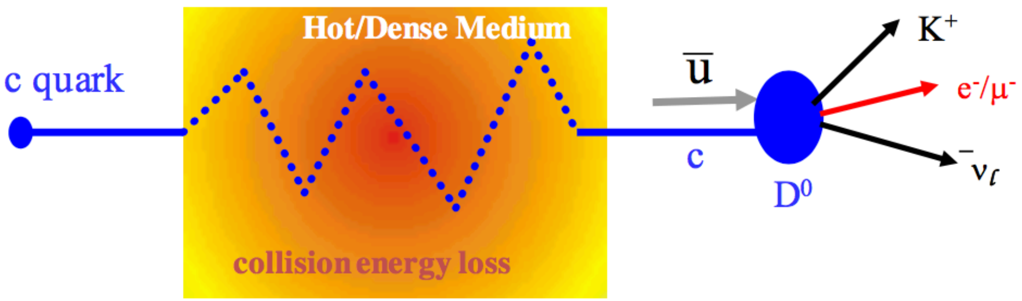


- ✓ HFT will allow a direct measurement of B->e spectrum in Au+Au collisions via reconstructing displaced decay vertices.
- ✓ Help better understand the interactions between heavy quarks and the medium.



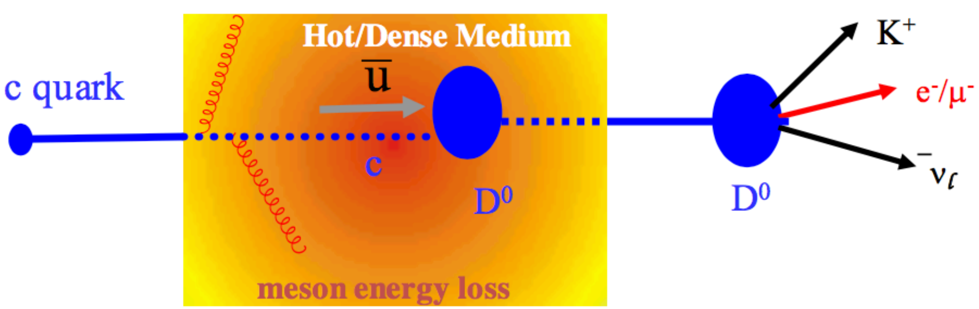
Gluon radiation and the dead cone effect. Suppressed at $\theta < M_Q/E_Q$

(Baier *et al*, Kharzeev *et al*, Djordjevic *et al*, Wiedemann *et al* .)



Collisional energy loss. Heavy quarks lose energy through elastic collisions with other partons.

(Teaney *et al*, Rapp *et al*, Molnar *et al*, Gossiaux *et al.*)



Vitev, et al

Collisional Dissociation. Medium induced dissociation of heavy mesons.