Measurements of Open Heavy Flavor Production through Semi-leptonic Decay Channels at the STAR experiment

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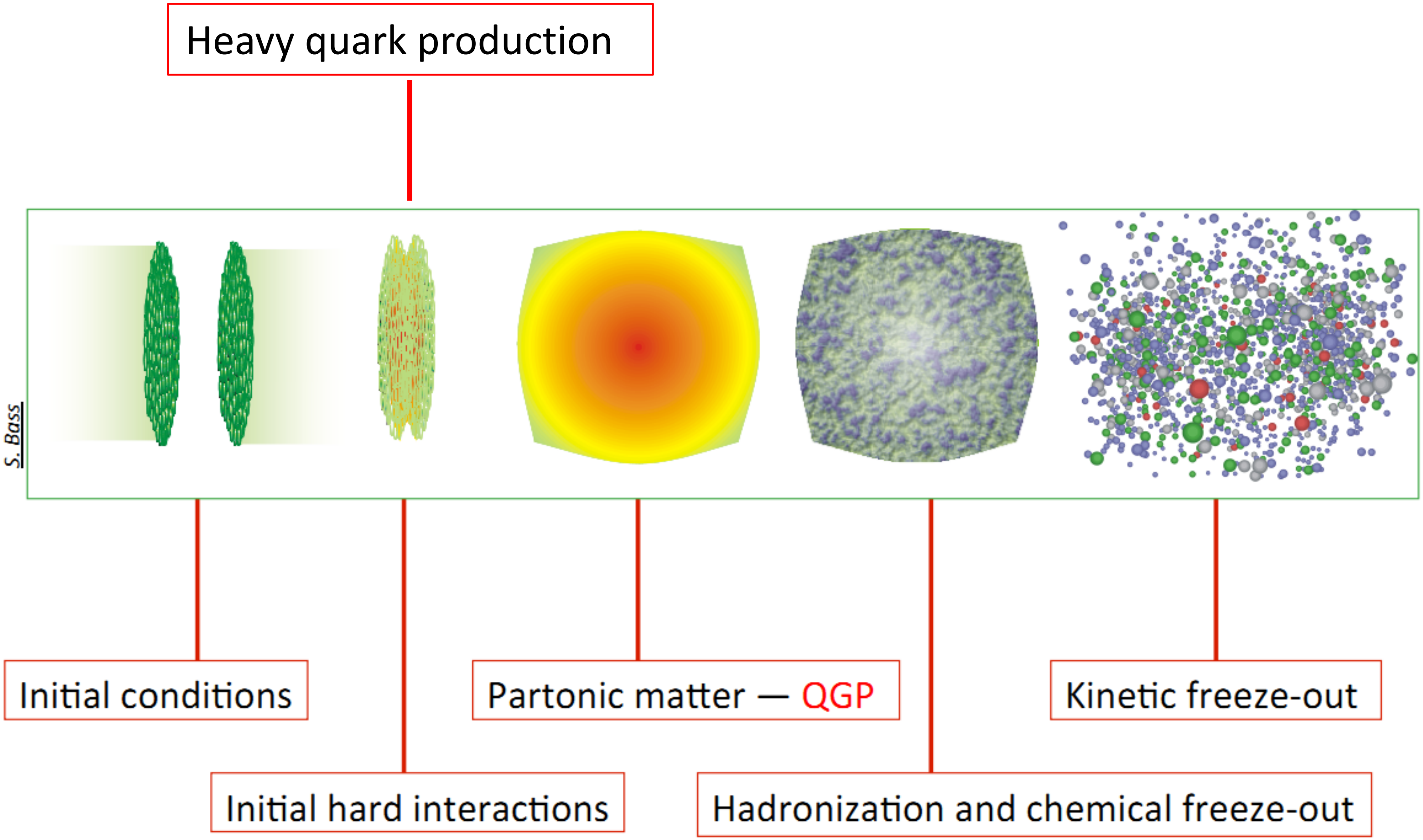
The 33rd Winter Workshop on Nuclear Dynamics
January 8-14 2017, Snowbird Resort, Utah

Outline

- Motivation
- STAR experiment
- Non-Photonic Electron (NPE) measurements:
  - -> Reference from p+p collisions at $\sqrt{s}$ = 200 GeV
  - -> Nuclear modification factor (R_{AA}) in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
- Heavy Flavor Tracker prospects
- Summary

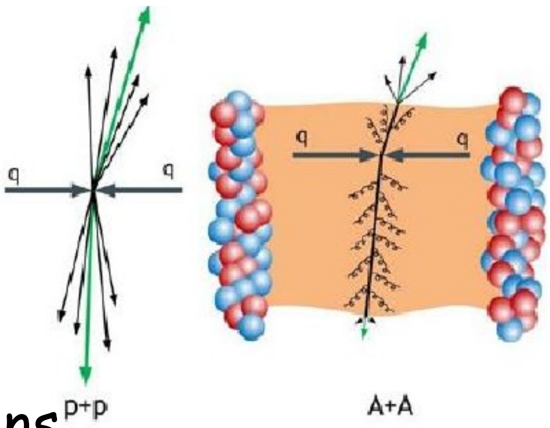
Motivation



The time evolution of a high-energy heavy-ion collision.

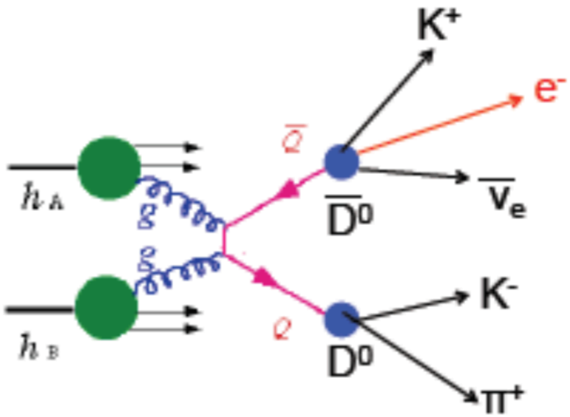
Heavy quarks (charm and bottom)

- Large masses, dominantly produced in hard scatterings at the early stage
- Probe to the QCD medium properties
  - ->energy loss (R_{AA})
  - ->thermalization (elliptic flow v_2)
- pp collisions: test the validity of pQCD and provide the reference for heavy-ion collisions

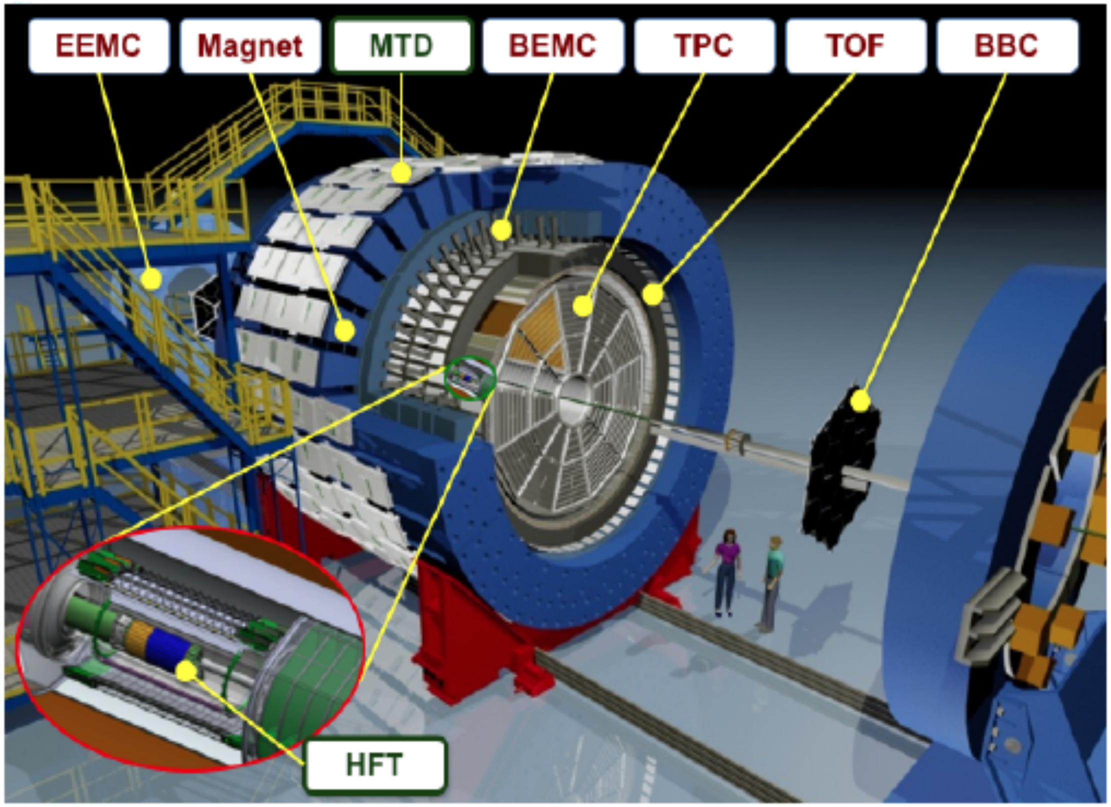


Non-Photonic Electrons (NPE)

- Produced from semi-leptonic decays of open heavy flavor hadrons
- A good proxy to heavy flavor quark production



STAR Detector



Time Projection Chamber (TPC)

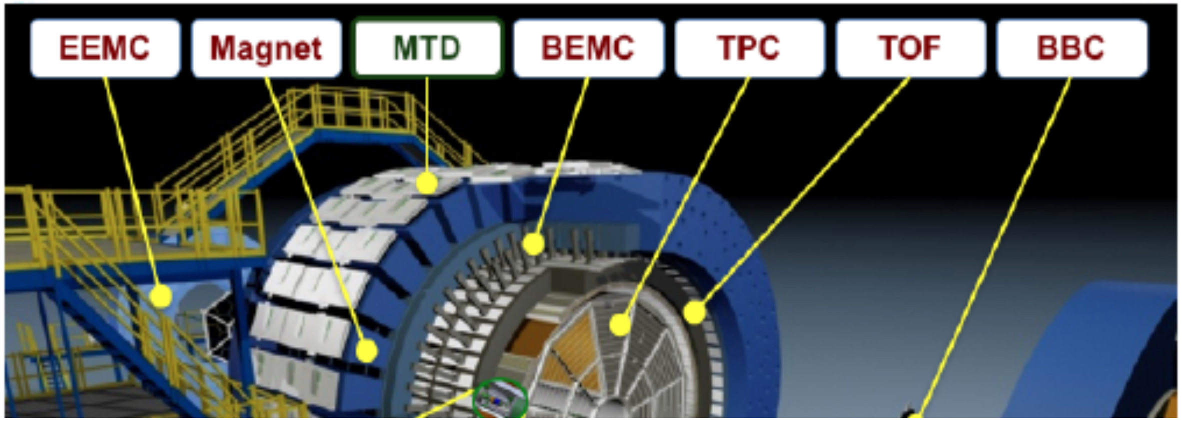
- |eta|<1.0,full azimuth
- Tracking, momentum.
- PID through dE/dx

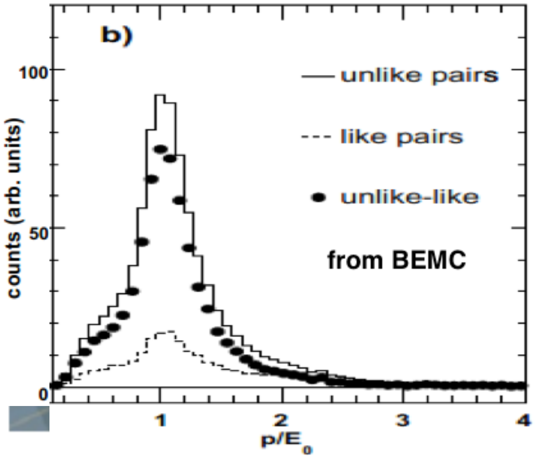
Time of Flight (TOF)

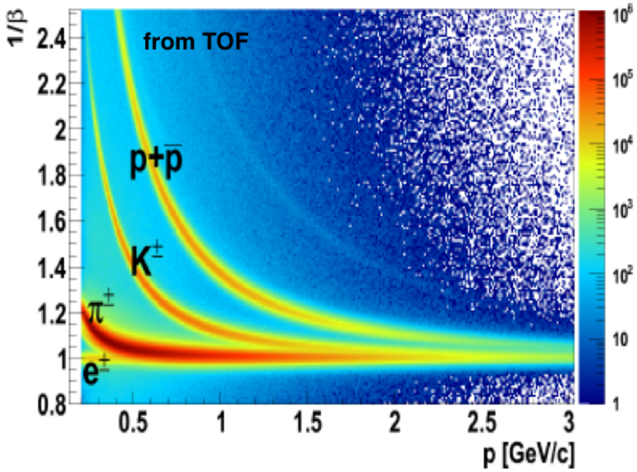
- |eta|<1.0,full azimuth
- PID through time-of-flight
- Timing resolution:~85 ps.

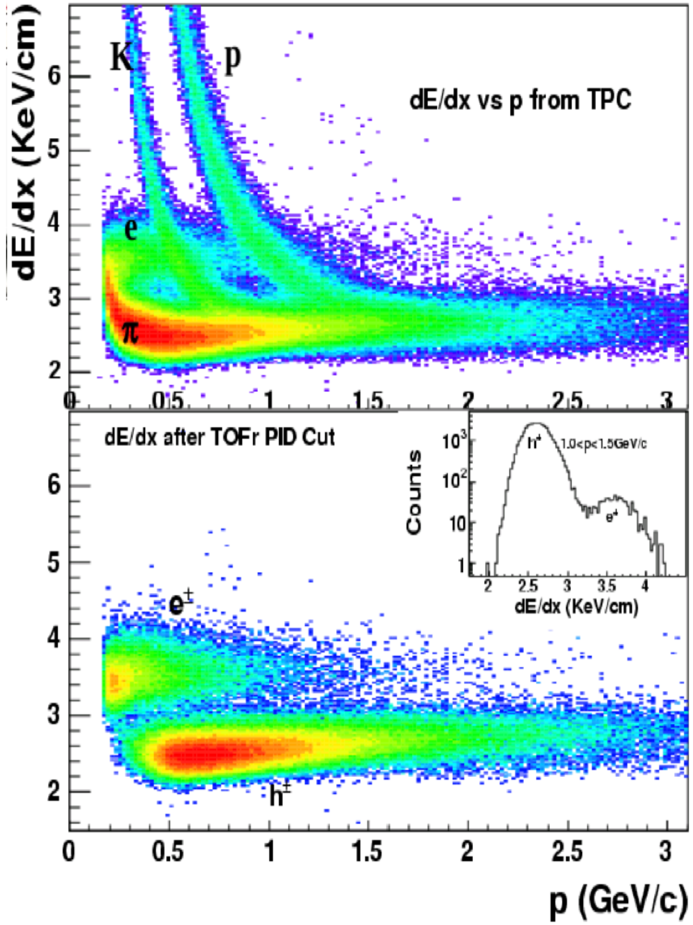
Barrel Electromagnetic Calorimeter (BEMC)

- |eta|<1.0,full azimuth
- PID through p/E
- Fast online trigger


EEMC
Magnet
MTD
BEMC
TPC
TOF
BBC


b)
unlike pairs
like pairs
unlike-like
from BEMC
counts (arb. units)
p/E0


from TOF
1/β
p+p̄
K±
π±
e±
p [GeV/c]


dE/dx vs p from TPC
K
p
e
π
dE/dx (KeV/cm)
dE/dx after TOFr PID Cut
e±
h±
Counts
dE/dx (KeV/cm)
p (GeV/c)

Methodology

Inclusive electrons
After electron ID

- **Non-photonic electrons**
  From D/B hadron decays
- **Photonic electrons**
  Partially reconstructed through e^+e^- pairs
  - γ conversion $\gamma \rightarrow e^+e^-$
  - π^0 Dalitz decay $\pi^0 \rightarrow \gamma e^+e^-$
  - η Dalitz decay $\eta \rightarrow \gamma e^+e^-$
- **Hadron contamination**
  Statistically subtracted

NPE yield after background subtraction

$$N_{npe} = N_{inclusive} * purity - N_{photonic}/\varepsilon_{photonic}$$

- purity: purity of inclusive electron sample
- $\varepsilon_{photonic}$: photonic electron reco. efficiency

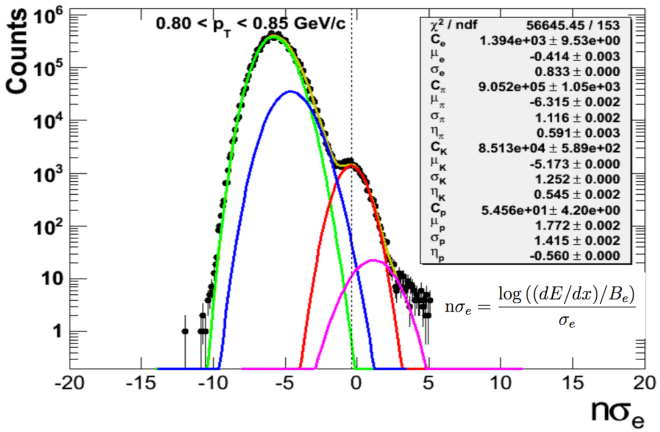
NPE invariant cross section:

$$E\frac{d^3\sigma}{dp^3} = \frac{1}{L}\frac{1}{2\pi p_T dp_T dy}\frac{N_{npe}}{\varepsilon_{Total}}$$

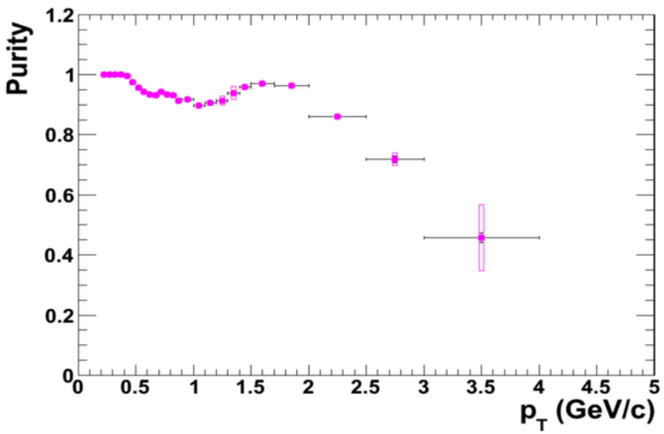
$$\varepsilon_{total} = \begin{cases} \varepsilon_{dE/dx}\varepsilon_{BEMC}\varepsilon_{trigger}\varepsilon_{tracking} & p_T > 1.5GeV/c \\ \varepsilon_{dE/dx}\varepsilon_{TOF}\varepsilon_{tracking} & p_T < 1.5GeV/c \end{cases}$$

Low p_T measurements from Run12 200 GeV p+p collisions

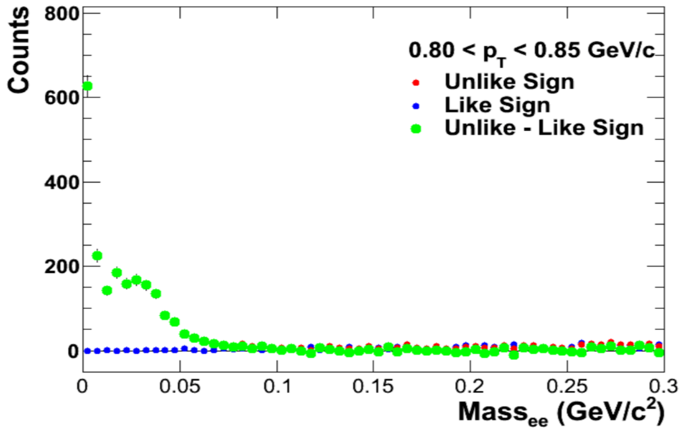
Inclusive electron

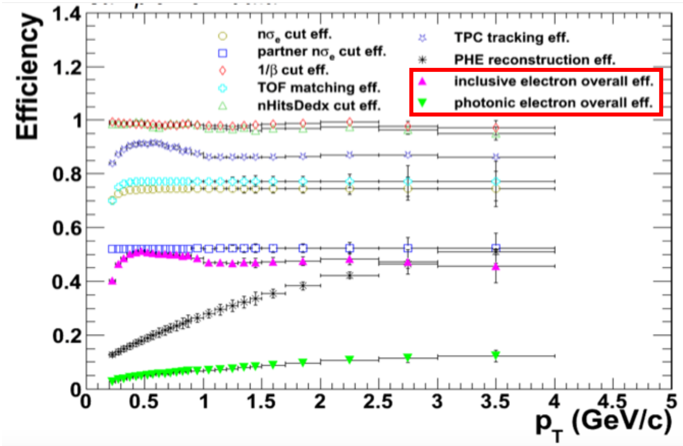


$$n\sigma_e = \frac{\log((dE/dx)/B_e)}{\sigma_e}$$

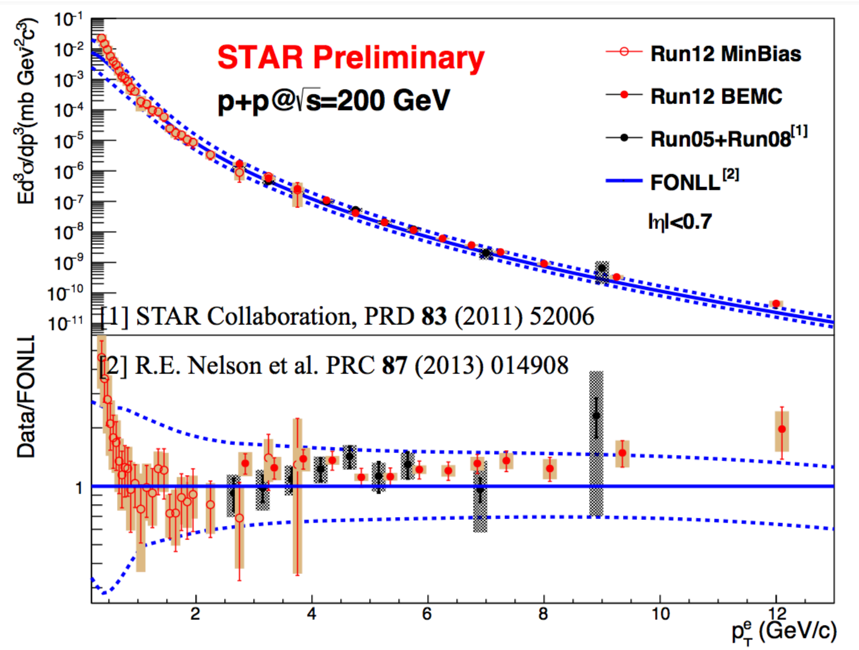


Photonic electron identification



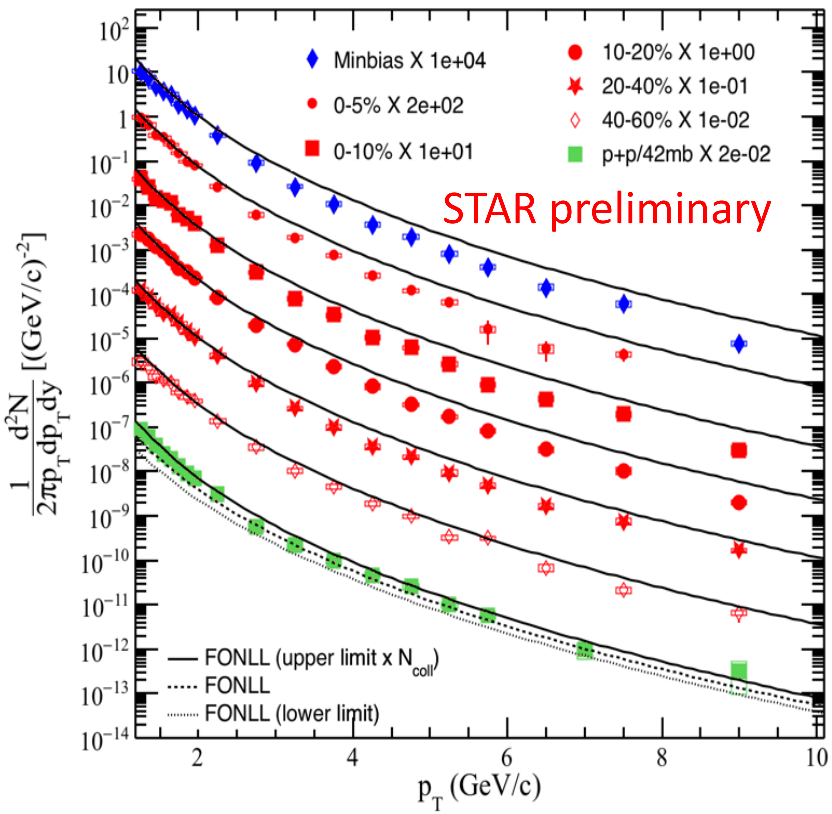


NPE cross section from Run12 200 GeV p+p collisions



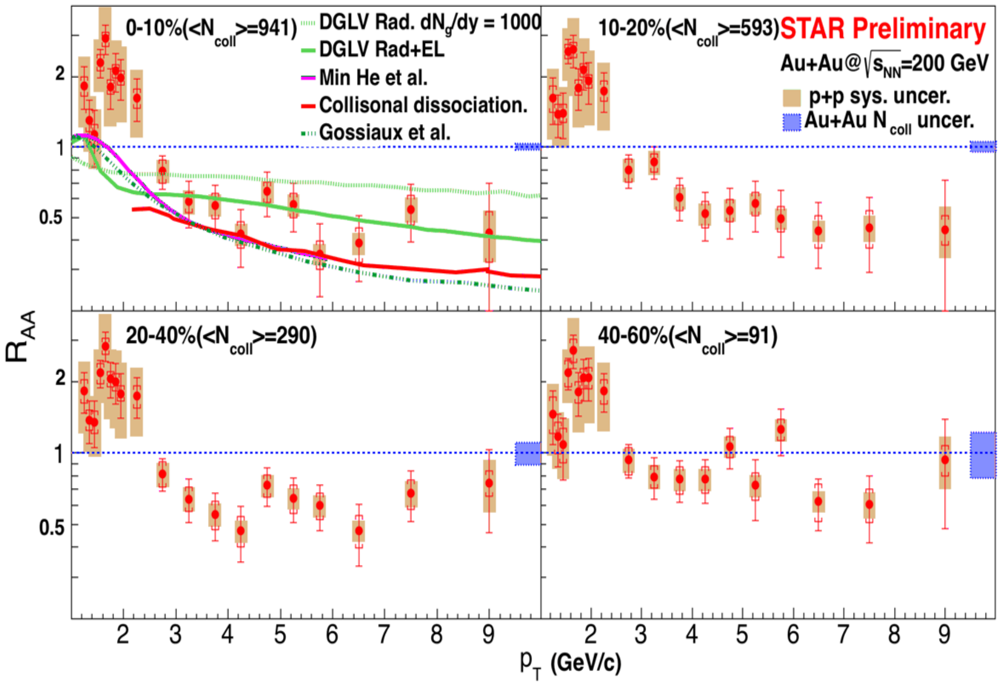
- Spectrum was extended to the low p_T region.
- Consistent with pQCD calculation and previous STAR result.
- Greatly reduced uncertainty, leading to a reduction in the uncertainty of R_{AA} measurements in heavy-ion collisions.

NPE yield from Run10 200 GeV Au+Au collisions



- In central collisions, there are significant differences between Au+Au measurements and the scaled FONLL calculation, indicating existence of hot medium effects.
- From central to peripheral collisions, the difference is getting smaller, which is consistent with less QGP effects in peripheral collisions.
- The analysis with Run14 200 GeV Au+Au data is ongoing.

NPE R_{AA} in 200 GeV Au+Au collisions

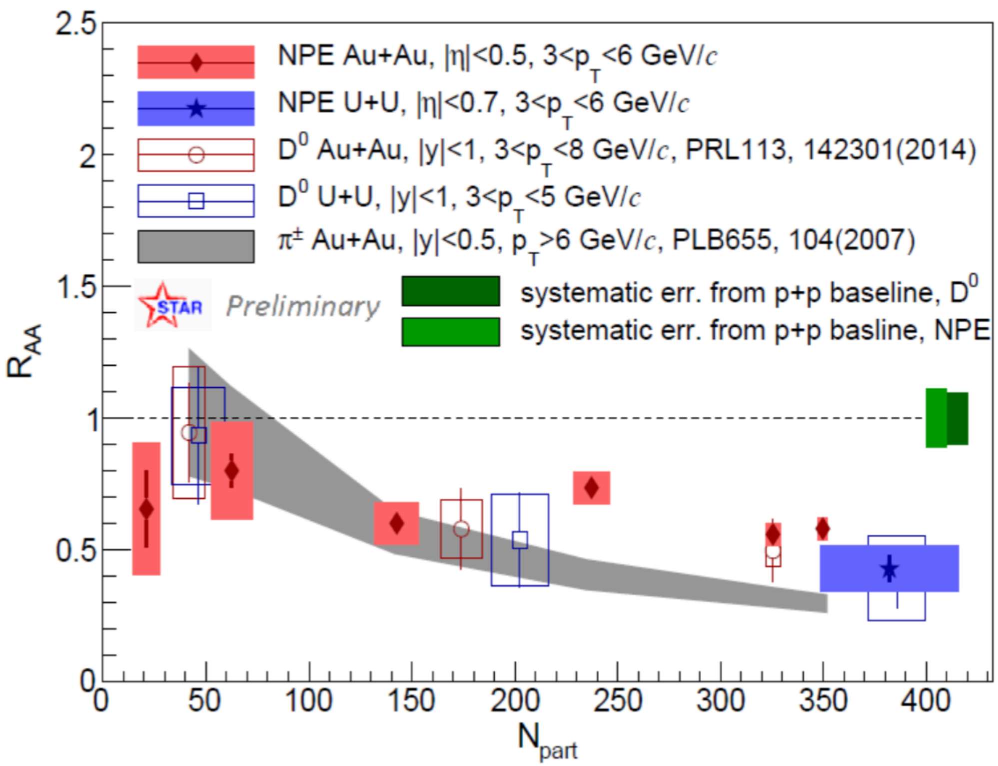


$$R_{AA} = \frac{1}{<N_{coll}>} * \frac{dN_{AA}/dy}{dN_{pp}/dy}$$

- ✓ Enhancement at low p_T, with large systematic uncertainties from pp reference.
- ✓ Strong suppression is observed at high p_T in central collisions.

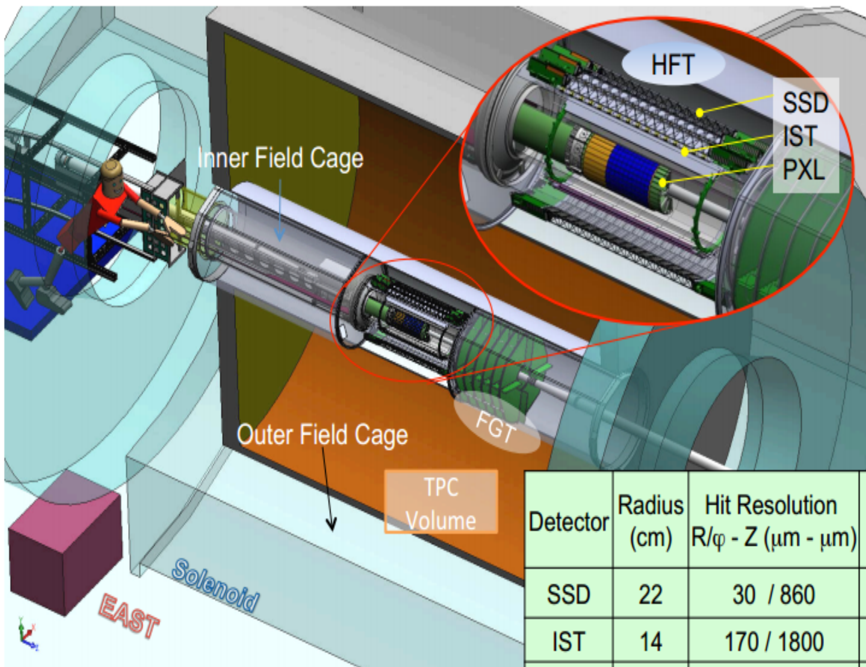
NPE R_{AA}

Compare NPE R_{AA} with D^0 and light hadron R_{AA} in different heavy-ion collision systems.

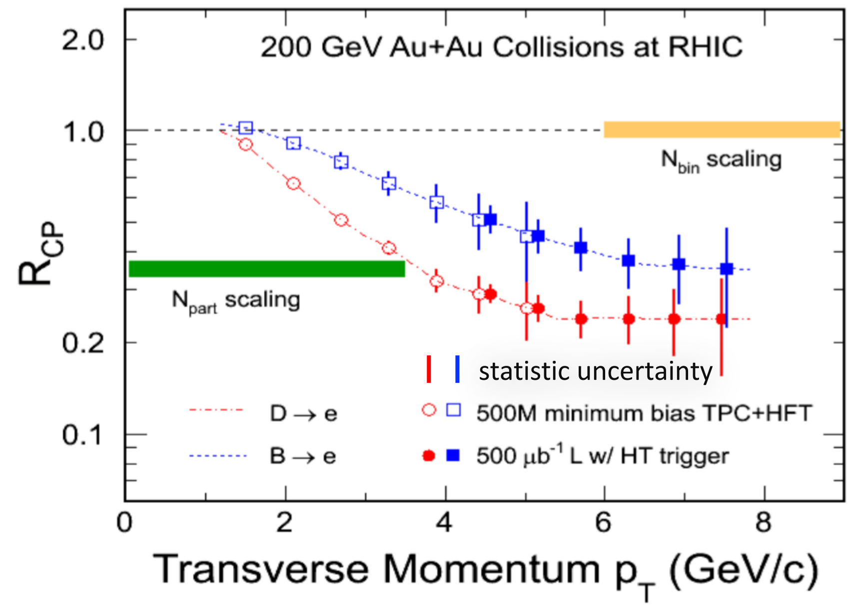


- ✓ Suppression of NPE at high p_T in central Au+Au collisions is similar to that of D^0 mesons and light hadrons in Au+Au collisions as well as NPE and D^0 mesons in central U+U collisions.

HFT

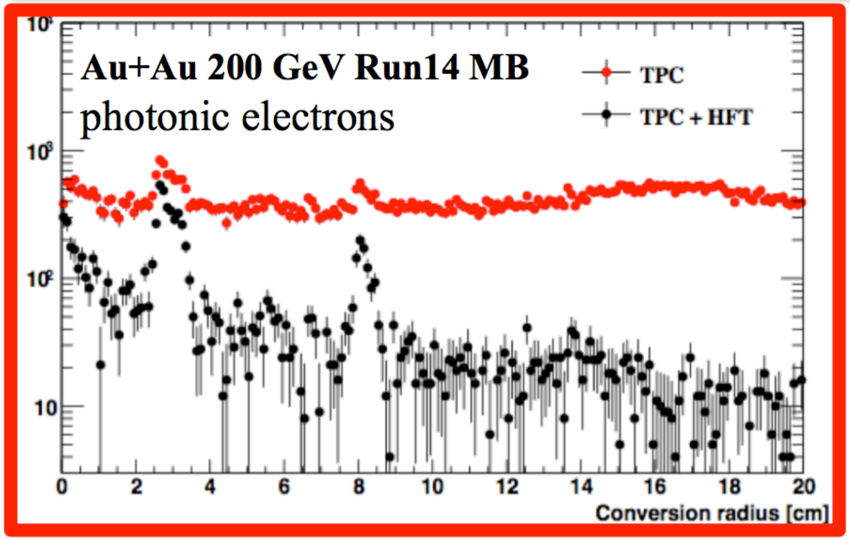


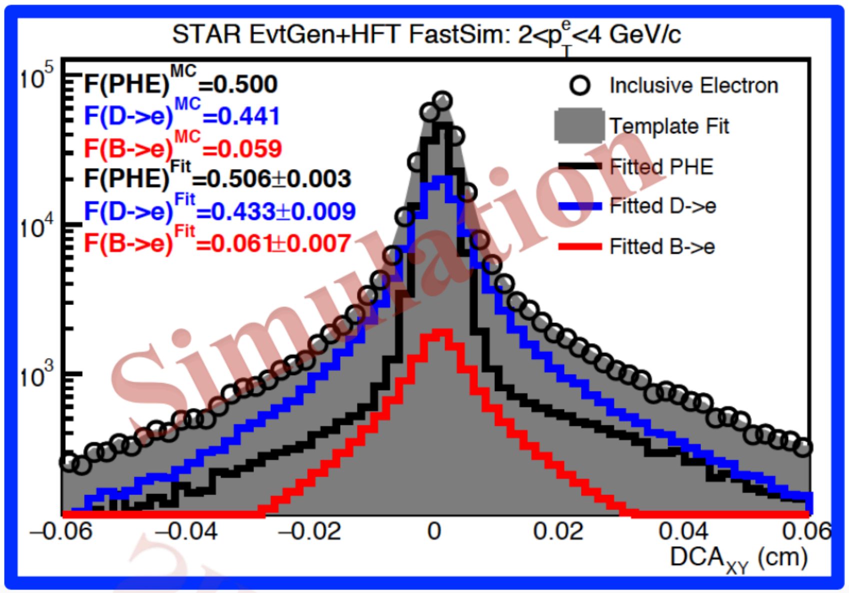
Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Radiation length
SSD	22	30 / 860	1% X_0
IST	14	170 / 1800	1.32% X_0
PIXEL	8	6.2 / 6.2	~0.52% X_0
	2.8	6.2 / 6.2	~0.39% X_0



- ✓ 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.

Simulation of e_D and e_B





- Photon conversion background can be significantly suppressed by requiring hits in the first HFT PXL layer.
- Simulation with HFT for electrons decayed from D and B hadrons:
  - DCA distributions for D and B decayed electrons, and photonic electrons (PHE) are obtained from fast simulation using realistic detector resolutions from data
  - Pseudo data generated and fitted to D/B/PHE MC templates, with stat. uncertainty at p_T = 2-4 GeV/c:
  - $\delta D/D \sim 3\%$
  - $\delta B/B \sim 12\%$
- With full statistics of Run14+16 data, precise measurements are possible.

Summary

- **NPE cross section in p+p collisions at $\sqrt{s}$ = 200 GeV**
  1) measured over a broad p_T range 0.3-12 GeV/c with significantly improved precision than previous measurements.
  2) consistent with pQCD calculation.

- **NPE R_{AA} in Au+Au collisions at $\sqrt{s}$ = 200 GeV**
  1) observed large suppression at high-p_T in central collisions, which is consistent with substantial energy loss of heavy quarks in the dense matter.
  2) likely an enhancement at low p_T, suggesting the scenario that charm quarks recombine with light quarks in the medium with strong radial flow.

- **Look forward to separating charm and bottom contributions to NPE in Au+Au collisions with HFT data.**

Back up

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**

Background from hadron decays

Study background by simulations

1) $K \rightarrow e\pi v(K_{e3})$:

$K^{+} \rightarrow e^{+}\pi^{0}v$ $\quad K_{L}^{0} \rightarrow e^{\pm}\pi^{\mp}v$

2) *dielectron decays of vector mesons :*

$\omega \rightarrow e^{+}e^{-}/\omega \rightarrow \pi^{0}e^{+}e^{-}$ $\quad \phi \rightarrow e^{+}e^{-}/\phi \rightarrow \eta e^{+}e^{-}$