中国物理学会高能物理分会
第十届全国会员大表大会暨学术年会

Measurements of electrons from heavy flavor decays in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR experiment

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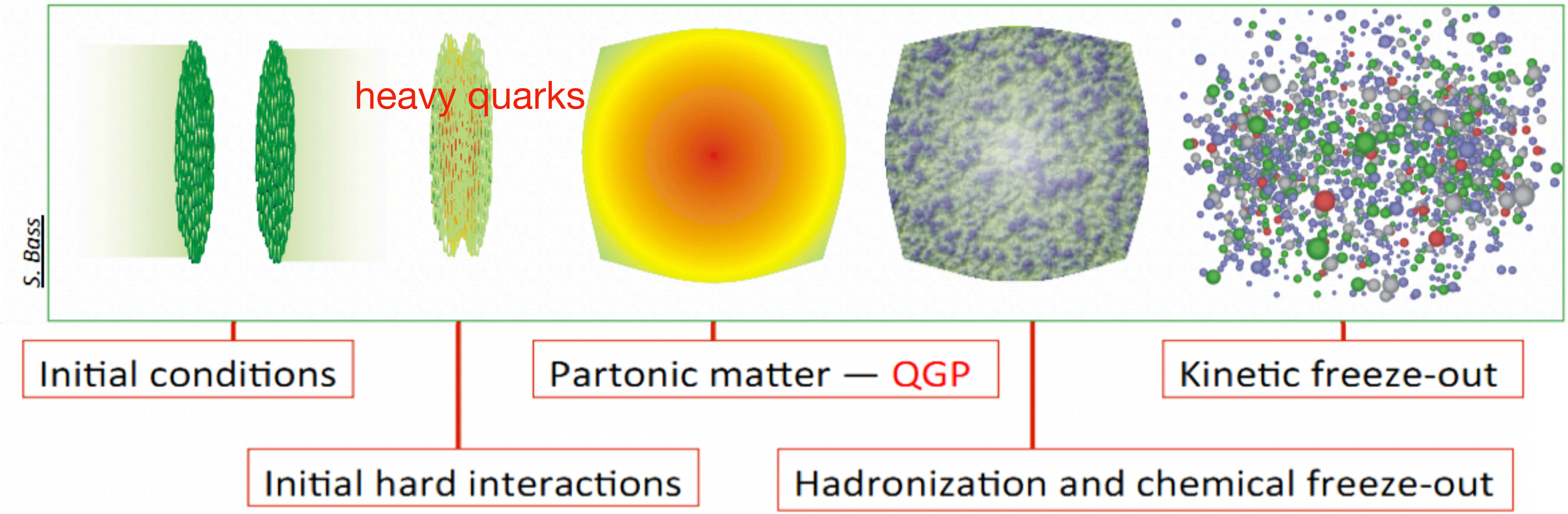
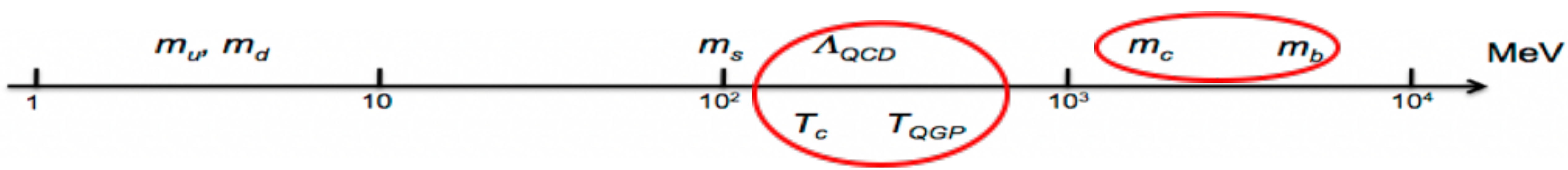
Outline

- Why heavy flavor?
- STAR experiment
- Non-Photonic Electron (NPE) measurements in 200 GeV Au+Au collisions:
  - ★ Nuclear modification factor (R_{AA})
  - ★ B/D → e
- Summary and Outlook

Why heavy flavor?

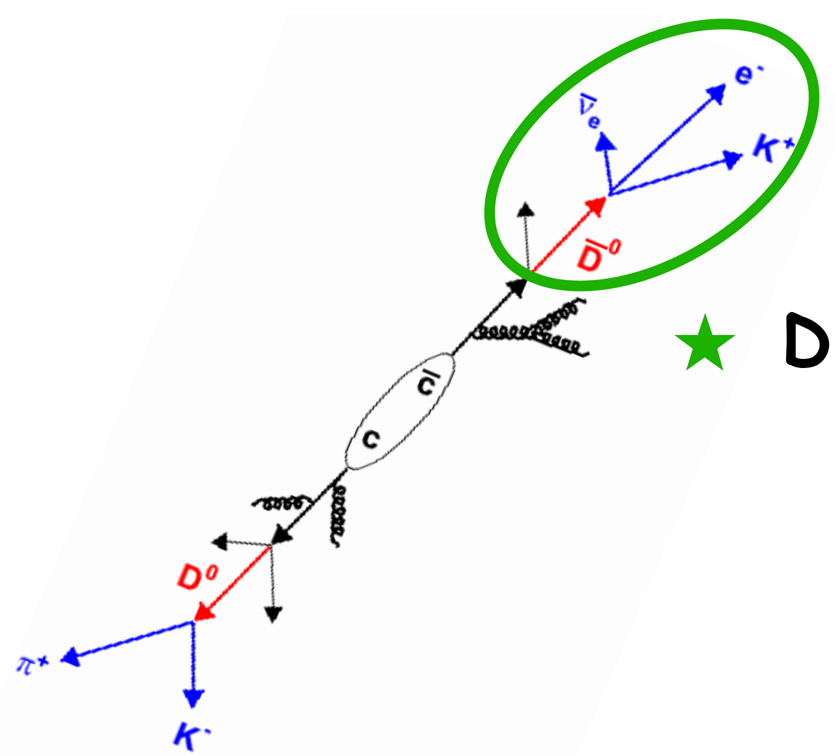




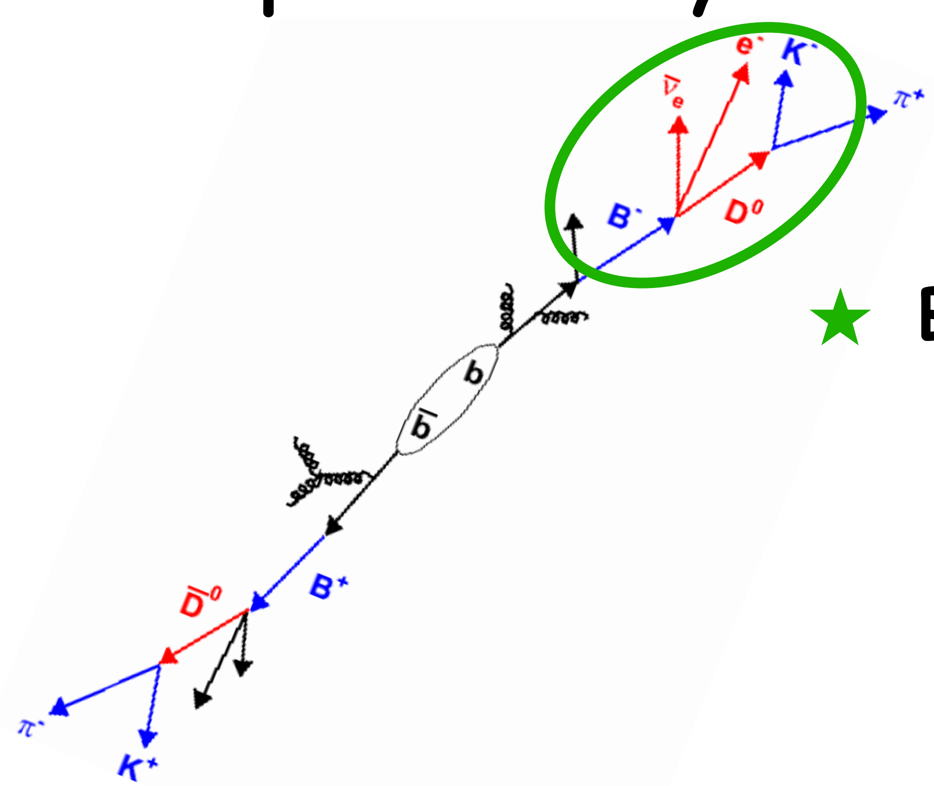
- $m_{c,b} >> T_{QGP}$: **dominantly produced at the early stage**
  - ★ experience all stages of QGP evolution.
  - ★ an excellent probe to study the properties of the QGP.

Observable

- **Energy loss of heavy quarks: a unique tool to study the interactions between heavy quarks and the QGP, and the QGP properties.**
  - ★Theoretical prediction for ΔE in medium: $\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$.
  - ★Precise measurements of c and b quark energy losses separately are crucial to test the mass hierarchy of the **parton energy loss**.
- **Indirect measurement through semi-leptonic decay channels (NPE).**

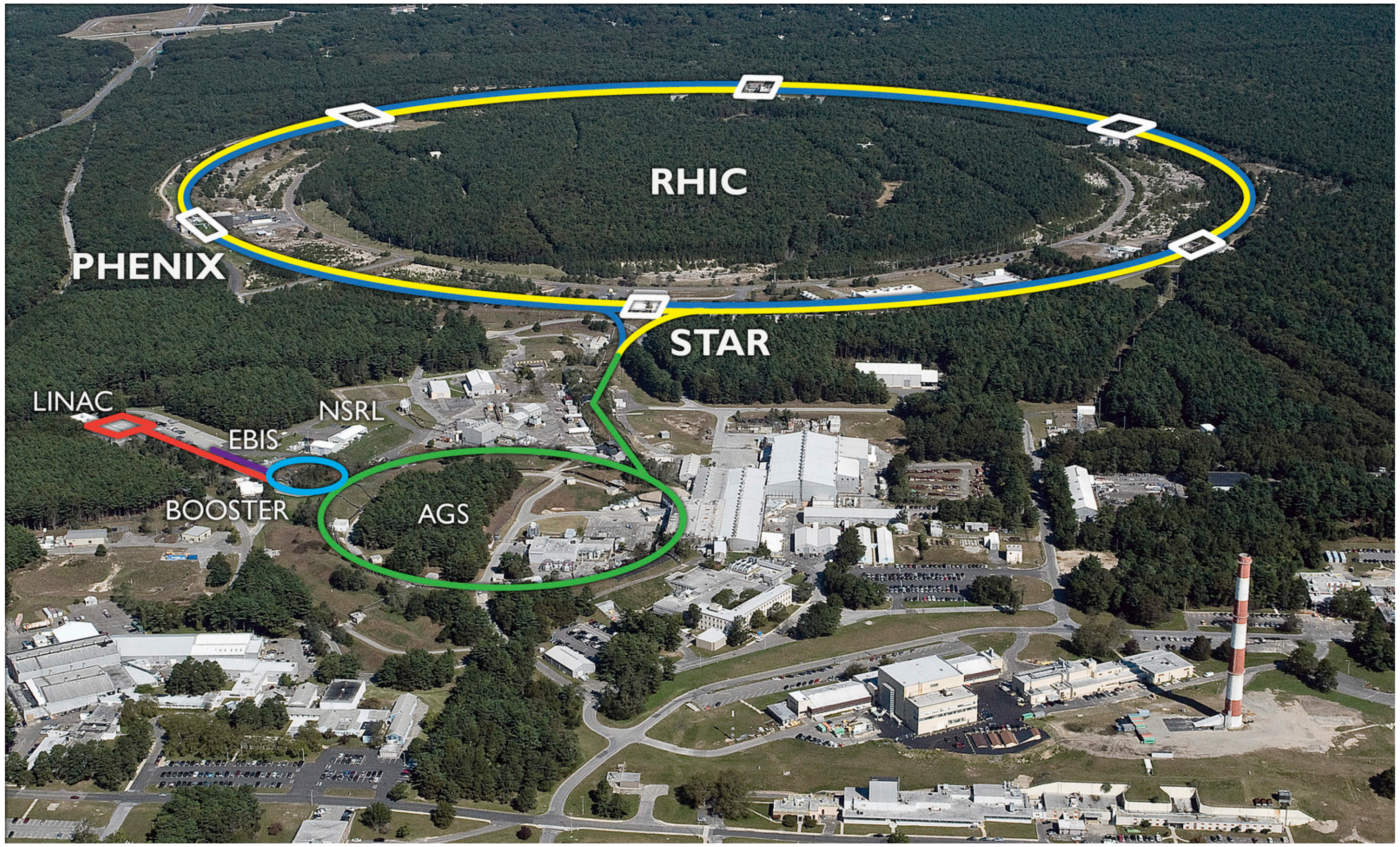


★ D → e



★ B → e

Relativistic Heavy Ion Collider (RHIC)



EBIS: Pre-injector system for RHIC. Create highly charged ion beams, which are accelerated by two small linear accelerators and carried to the Booster.

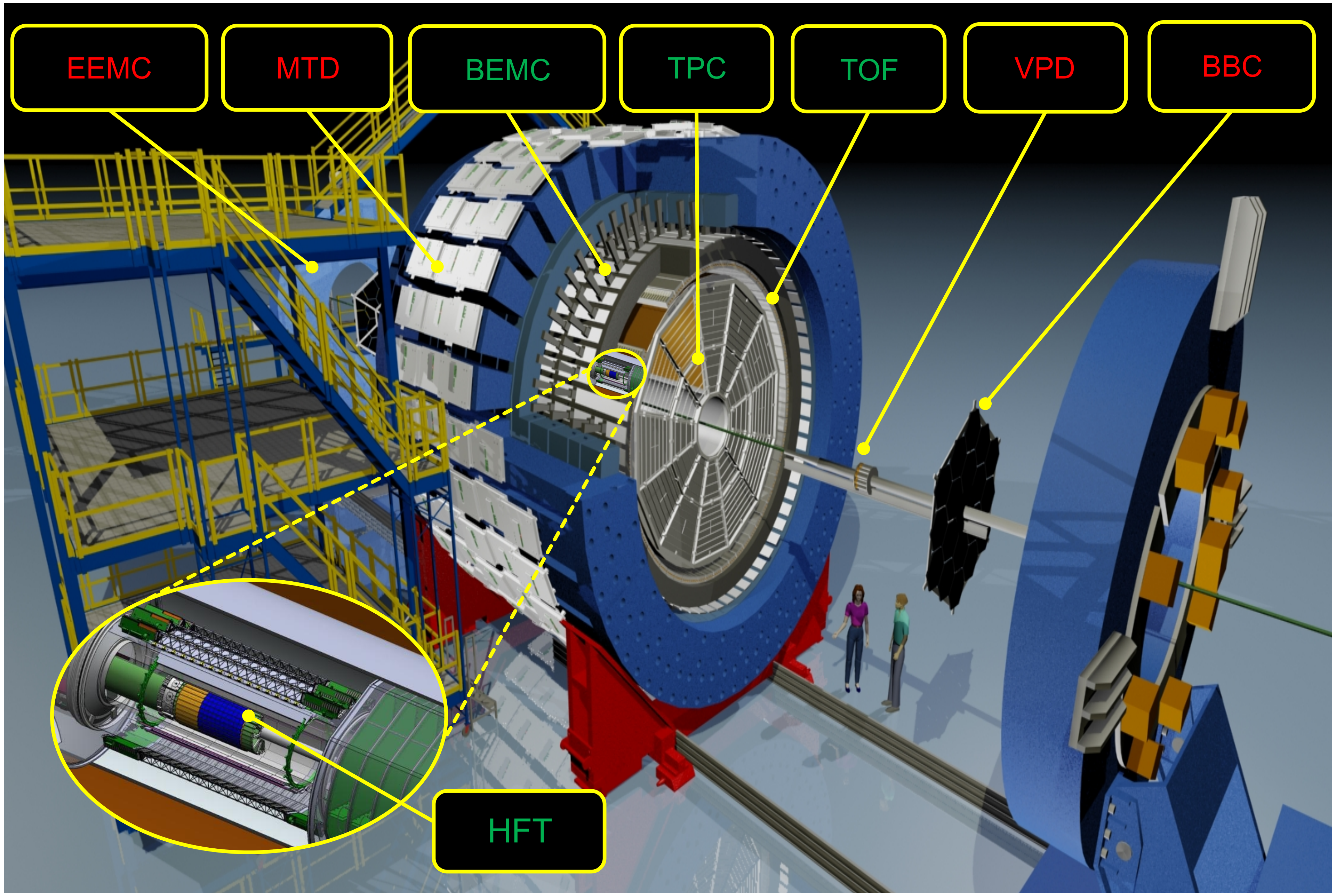
Booster: with each pass, ion beams are accelerated to higher energies.

AGS: Alternating Gradient Synchrotron. Inject the beams via a beamline into the two rings of RHIC.

RHIC: both beams get a final acceleration and collide .

Solenoidal Tracker At RHIC (STAR)

- |η|<1 and full azimuthal coverage



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

Time of Flight (TOF)
- PID through the $1/\beta$
- Timing resolution:~85 ps

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

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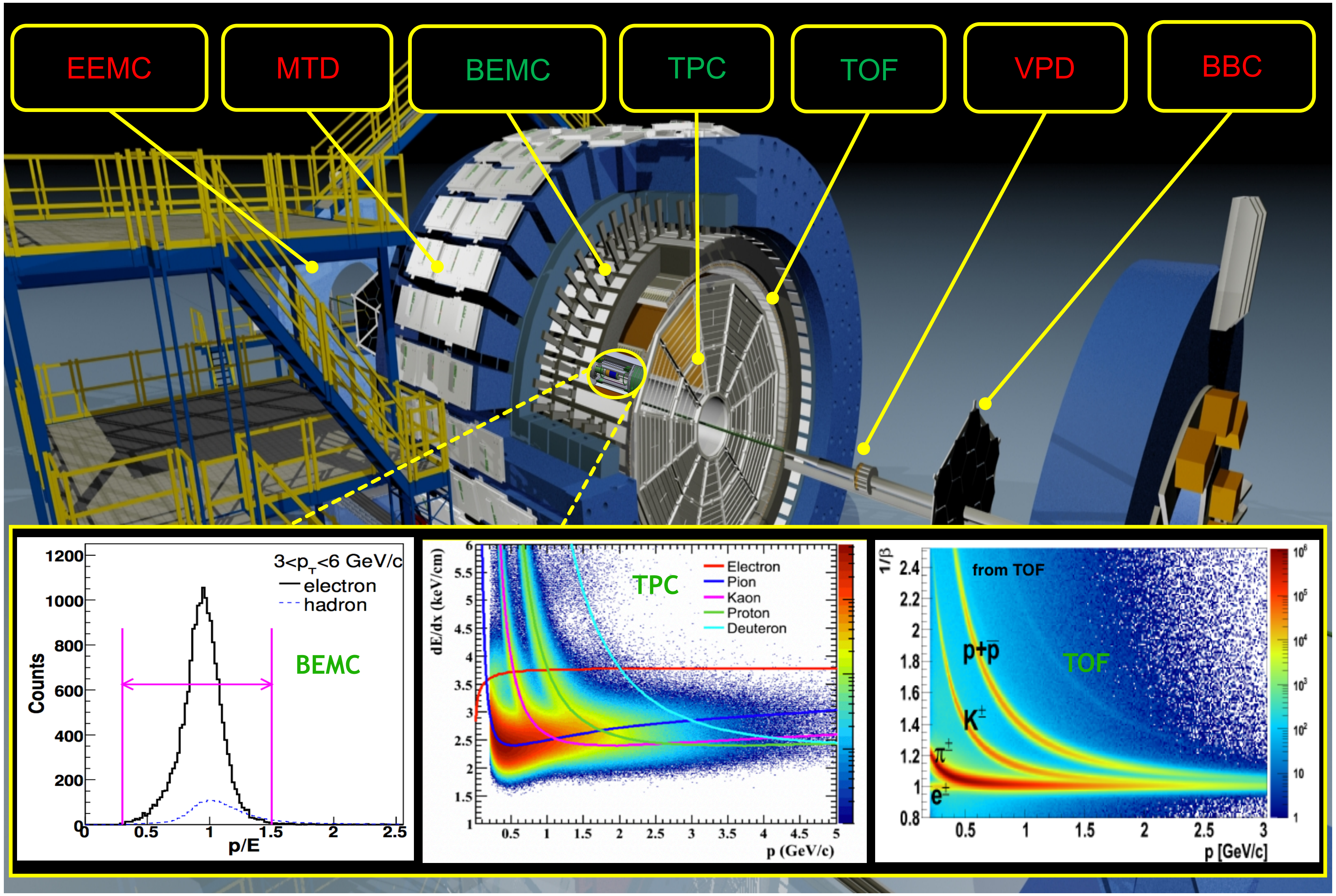

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Methodology

Inclusive electrons
After electron ID

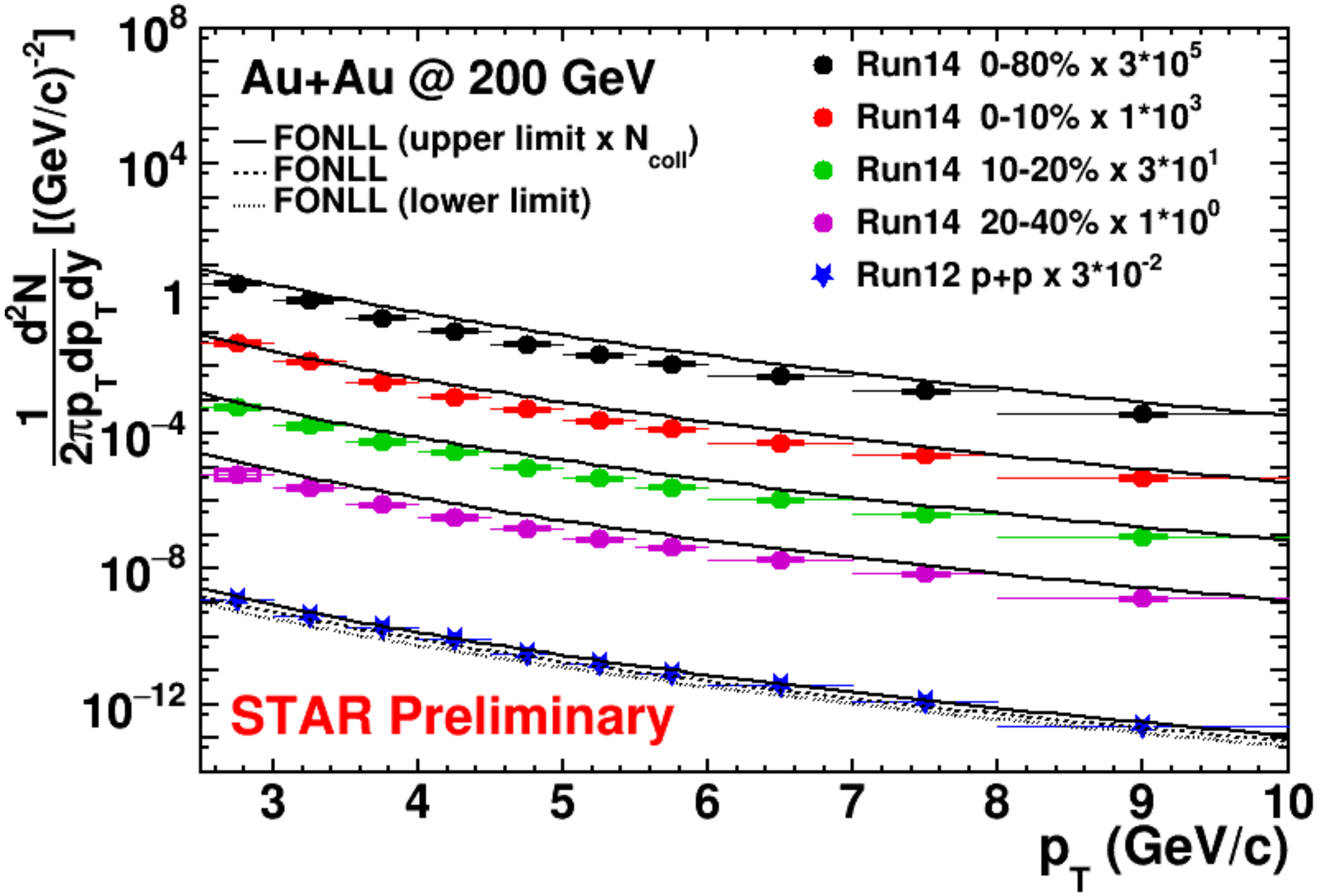
- **Non-photonic electrons**
  From D/B hadron decays
- **Photonic electrons**
  Partially reconstructed through e^+e^- pairs
  - γ conversion $\gamma \to e^+e^-$
  - π^0 Dalitz decay $\pi^0 \to \gamma e^+e^-$
  - η Dalitz decay $\eta \to \gamma e^+e^-$
- **Hadron decayed electrons**
  From J/Ψ and vector mesons decays, and K_{e3}
  Statistically subtracted

NPE yield can be calculated as:

$$Y_{npe} = \frac{N_{inclusive} * purity - \frac{N_{photonic}}{\varepsilon_{photonic}}}{\varepsilon_{total}} - N_{hadron\ decays}$$

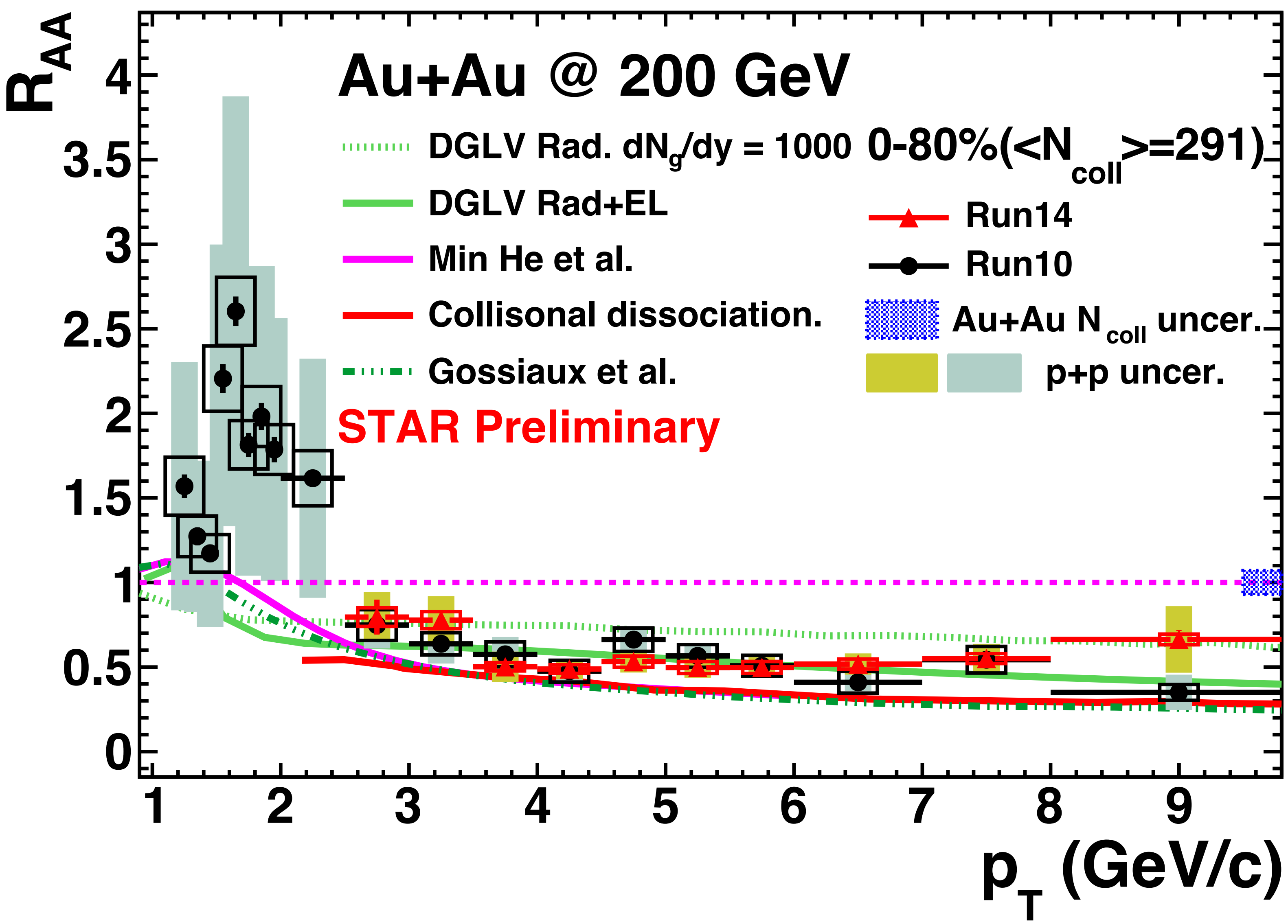
NPE invariant yields

NPE yields from 2014 200 GeV Au+Au collisions



- In central collisions, there are significant differences between Au+Au measurements and the scaled FONLL calculation, indicating existence of hotmedium effects.
- From central to peripheral collisions, the difference is getting smaller, which is consistent with less QGP effects in peripheral collisions.

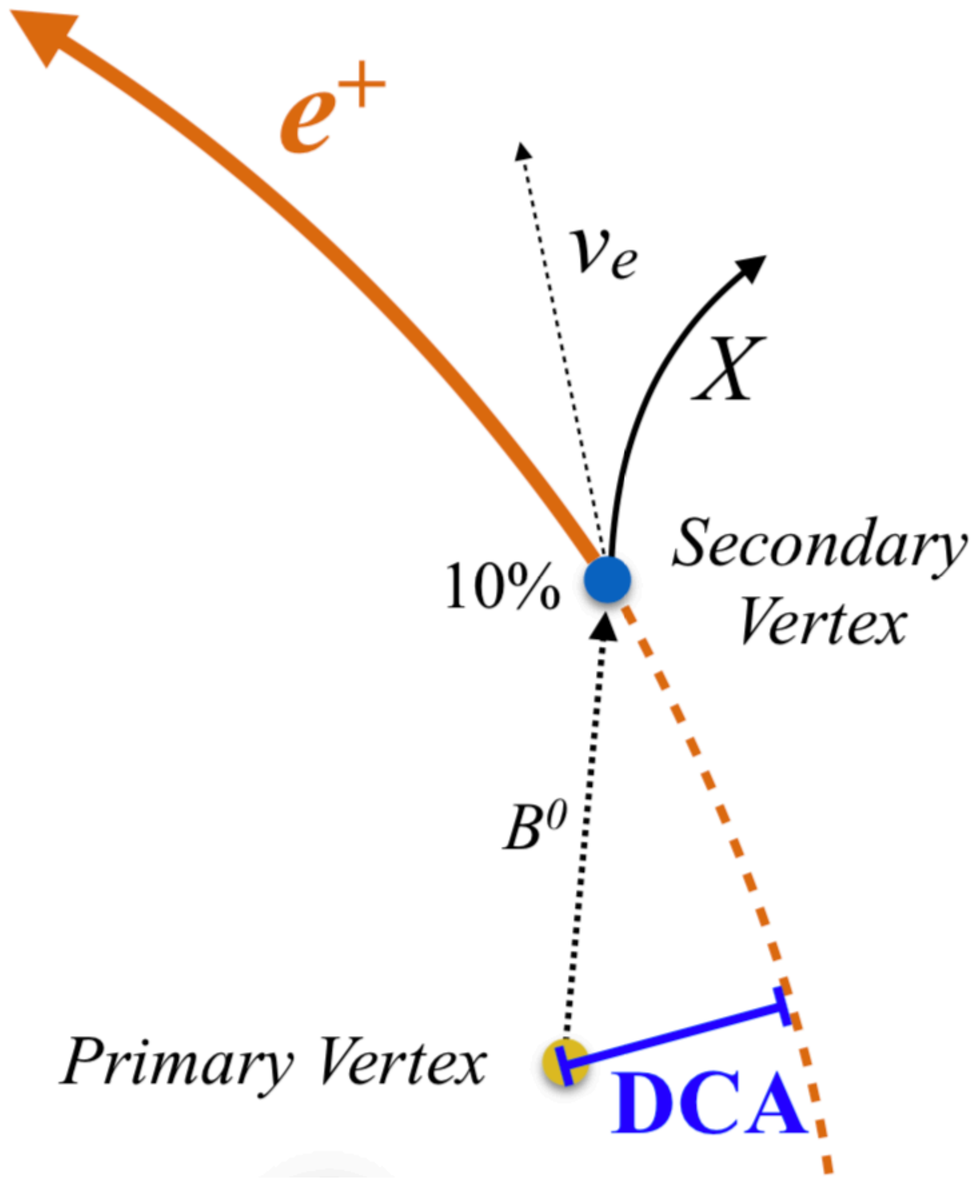
NPE R_{AA} from 2010 and 2014 200 GeV Au+Au collisions



$$R_{AA} = \frac{1}{< N_{coll} >} * \frac{d^2N_{AA}/dp_T/dy}{d^2N_{pp}/dp_T/dy}$$

- New result is consistent with previous one within uncertainty.
- Enhancement at low p_T, with large uncertainties from pp reference.
- **Strong suppression** is observed at high p_T.

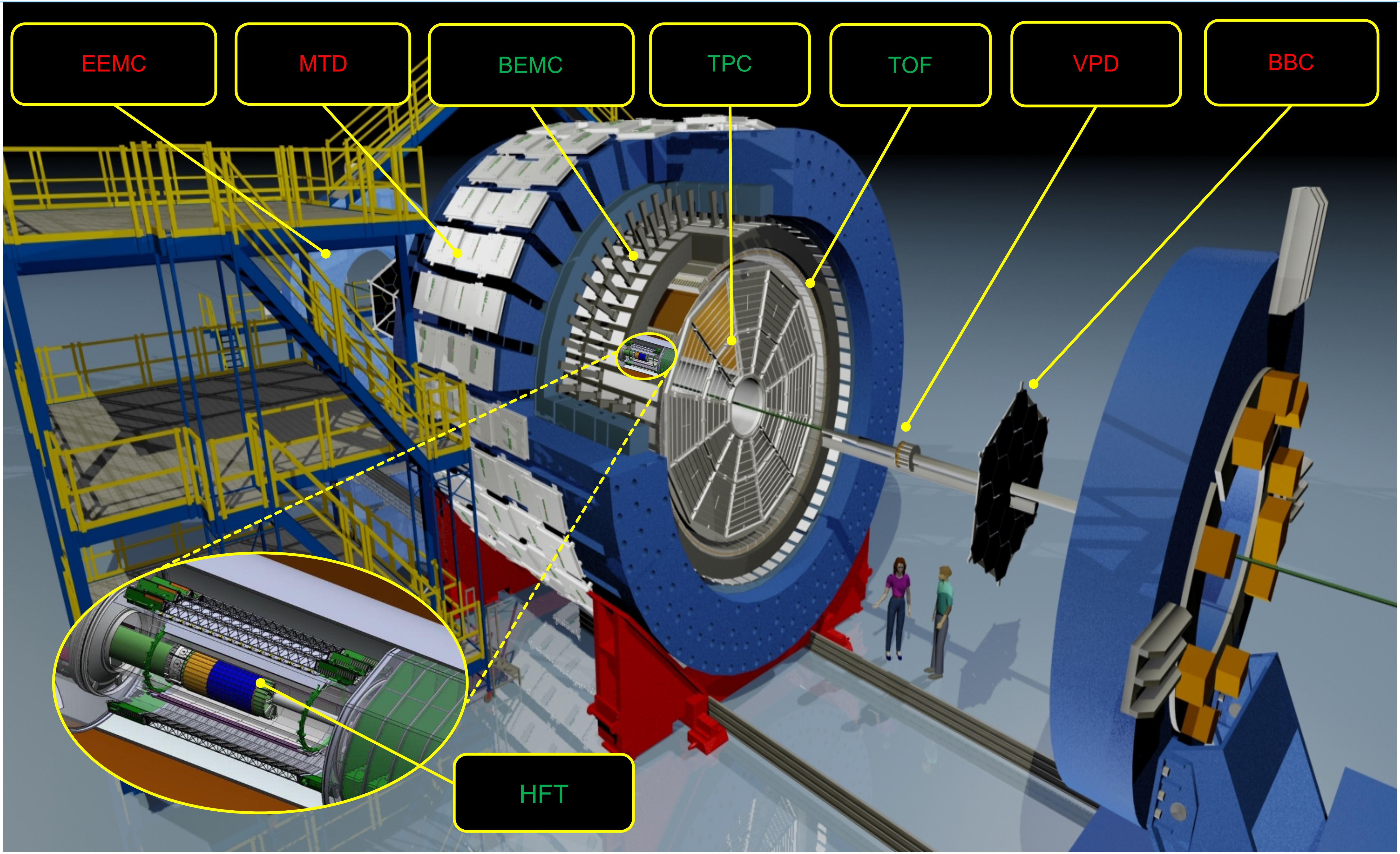
B/D → e identification



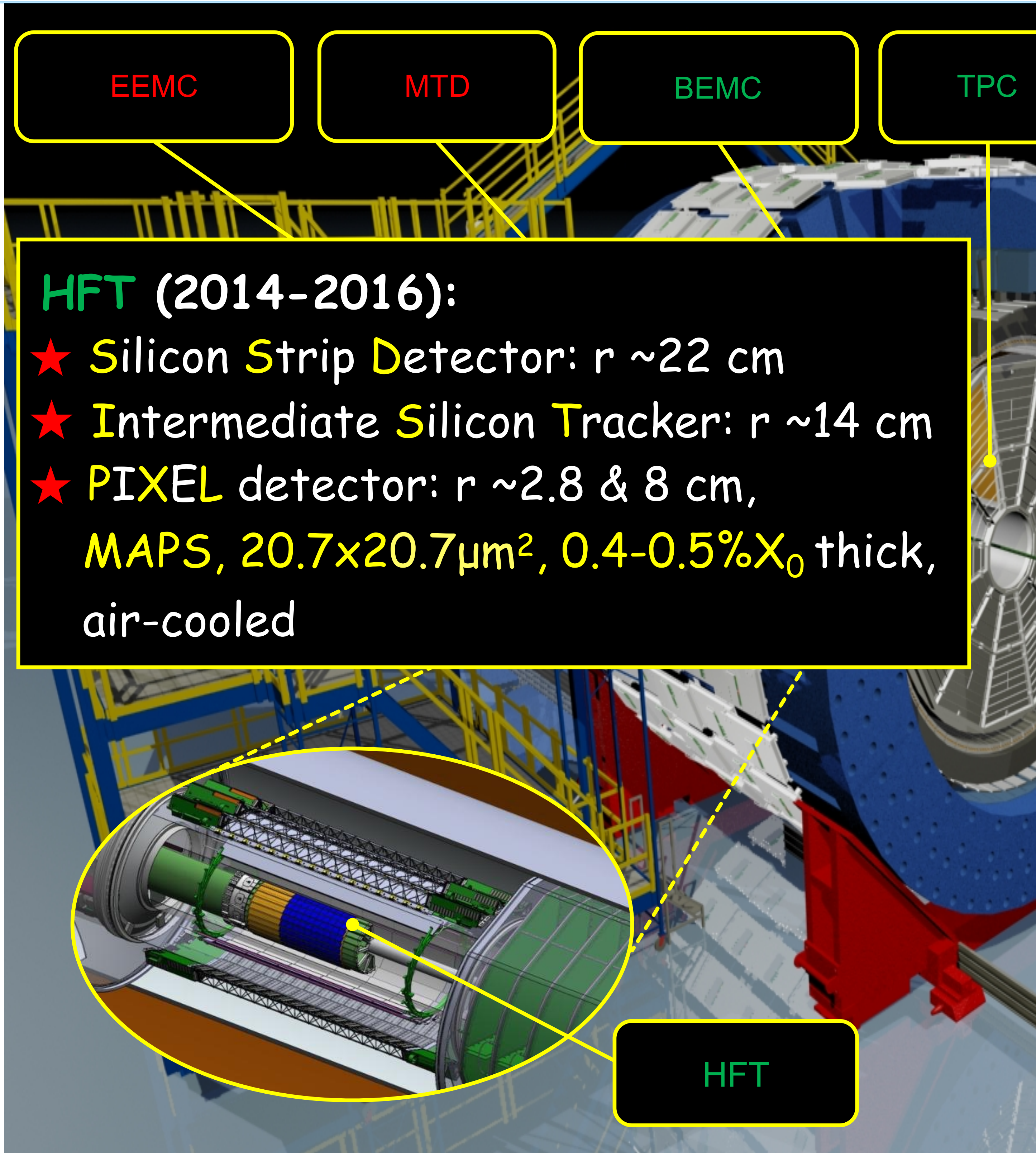
Particle	c_τ
D^0	$123\mu m$
$D^\pm$	$312\mu m$
B^0	$459\mu m$
$B^\pm$	$491\mu m$

- **DCA: the distance of closet approach to the event primary vertex.**

Heavy Flavor Tracker (HFT)

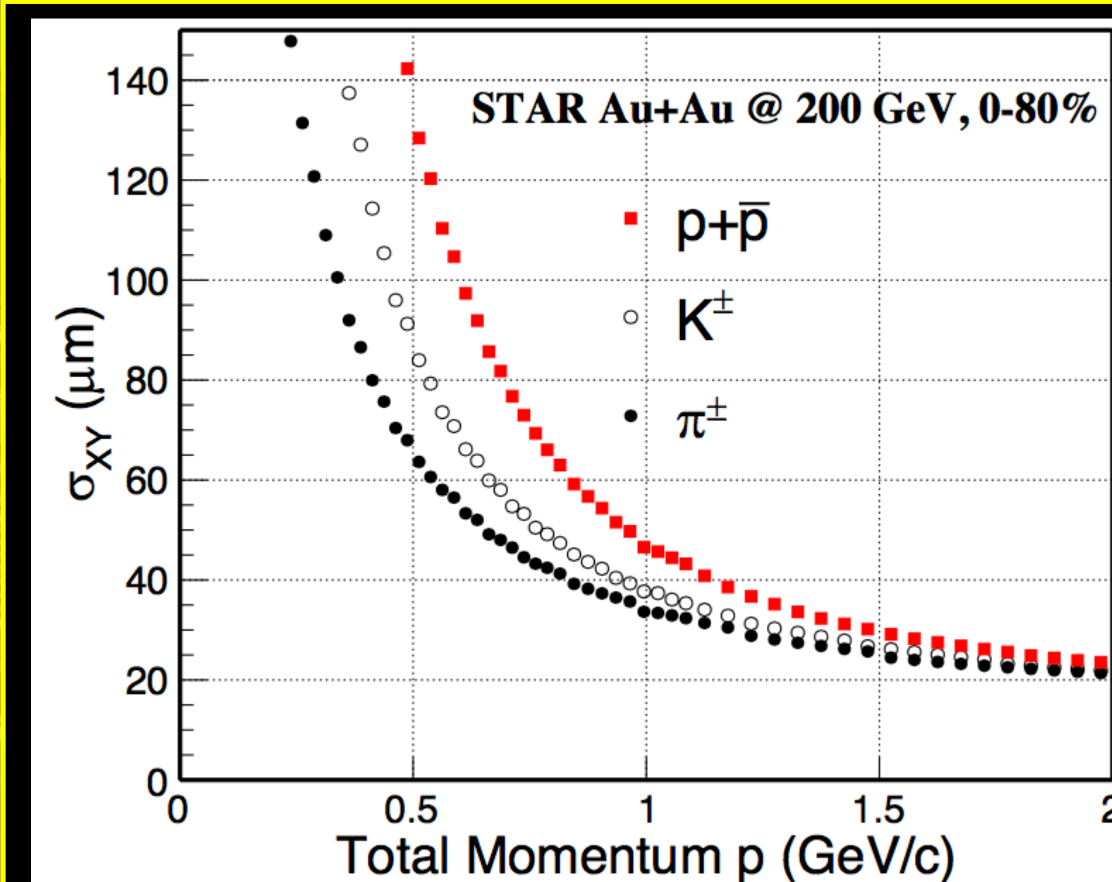


Heavy Flavor Tracker (HFT)



HFT (2014-2016):

- ★ Silicon Strip Detector: r ~22 cm
- ★ Intermediate Silicon Tracker: r ~14 cm
- ★ PIXEL detector: r ~2.8 & 8 cm, MAPS, 20.7x20.7μm², 0.4-0.5%X_0 thick, air-cooled

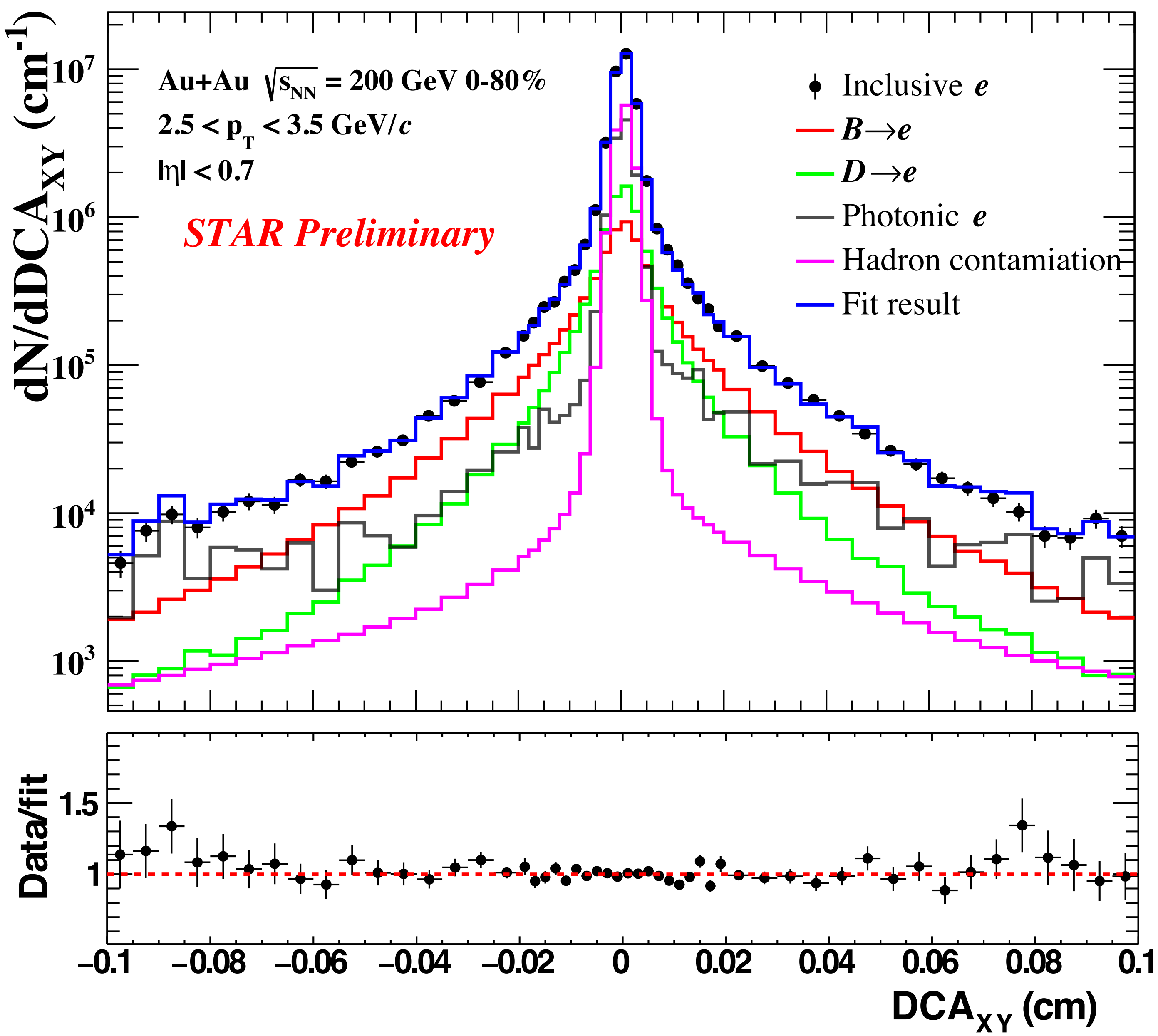


★ Precise reconstruction of displaced decay vertices.

Extract B/D → e

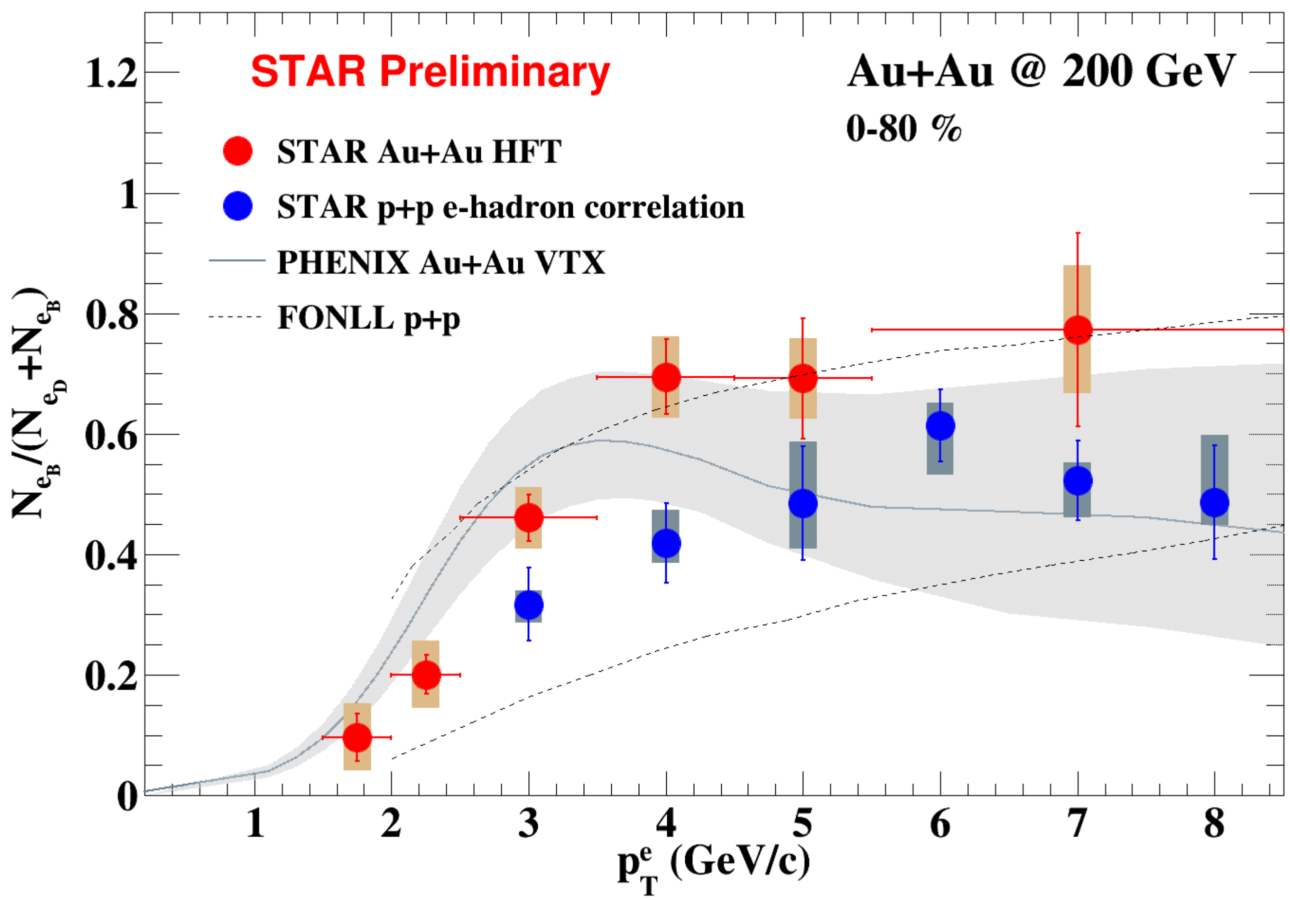
Analysis Procedure - Template fitting of DCA_{xy} distribution for inclusive electron with different sources

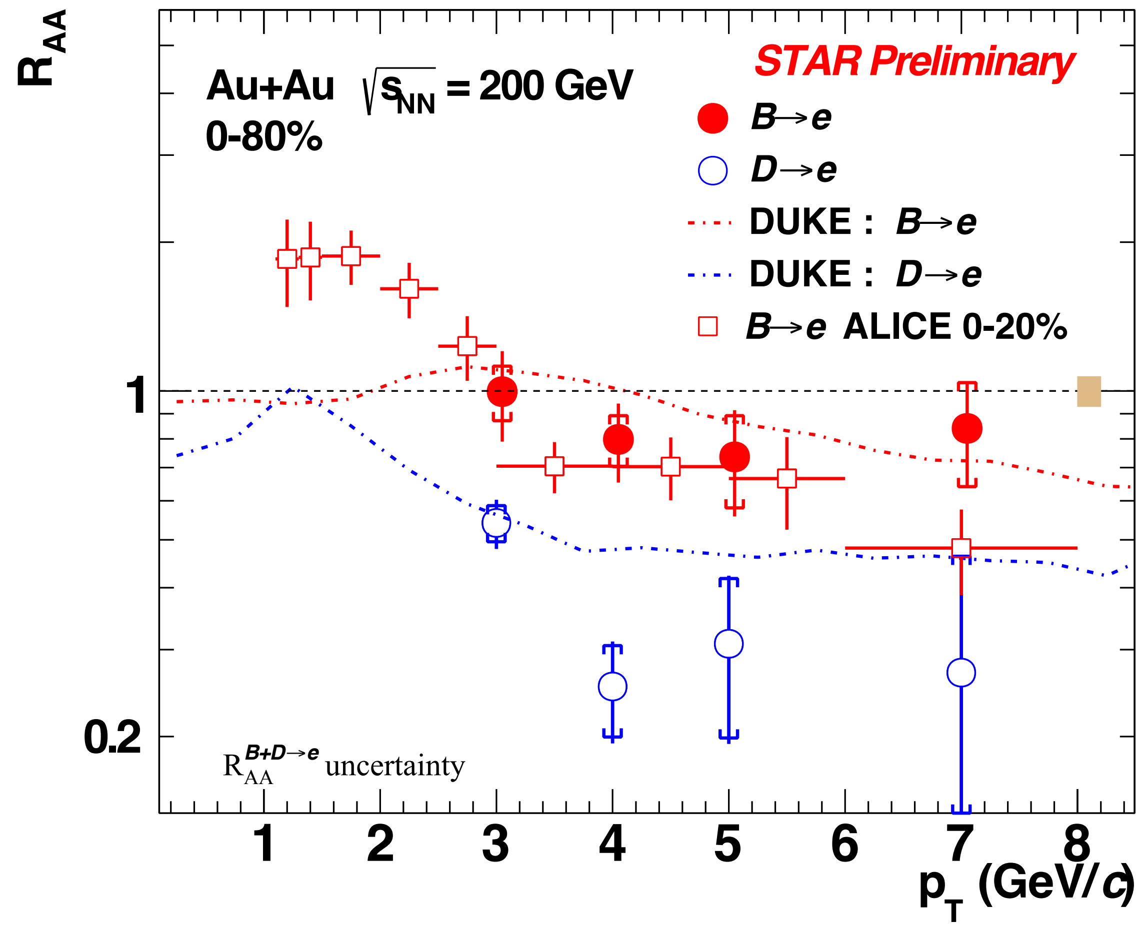
~900M MB + ~0.2 nb^{-1} HT events



- **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/D → e R_{AA}





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

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

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

- First STAR measurements of electrons from charm and bottom hadron decays separately in heavy-ion collisions.
- **R_{AA} (e_D) < R_{AA} (e_B)** (~2σ at 3 - 7 GeV/c).
- Consistent with mass hierarchy of parton energy loss (**ΔE_c > ΔE_b**) .

Summary

- **NPE yields and R_{AA} in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV**

  1) observed large suppression at high-p_T, which is consistent with substantial energy loss of heavy quarks in the dense matter.
  2) possibly an enhancement at low p_T, which can be caused by charm quark energy loss and/or recombination with light quarks in the medium with strong radial flow.

- **Measured B production via electron channel in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV**

  1) 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.

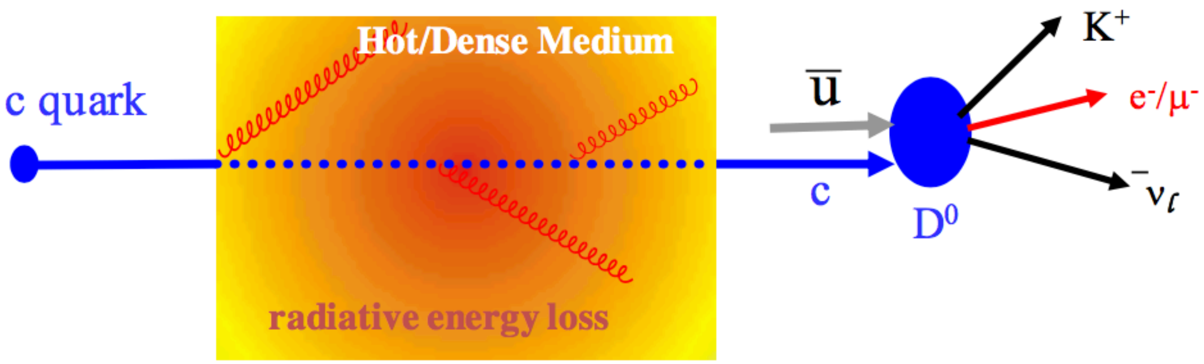
BACK UP

HFT Design

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

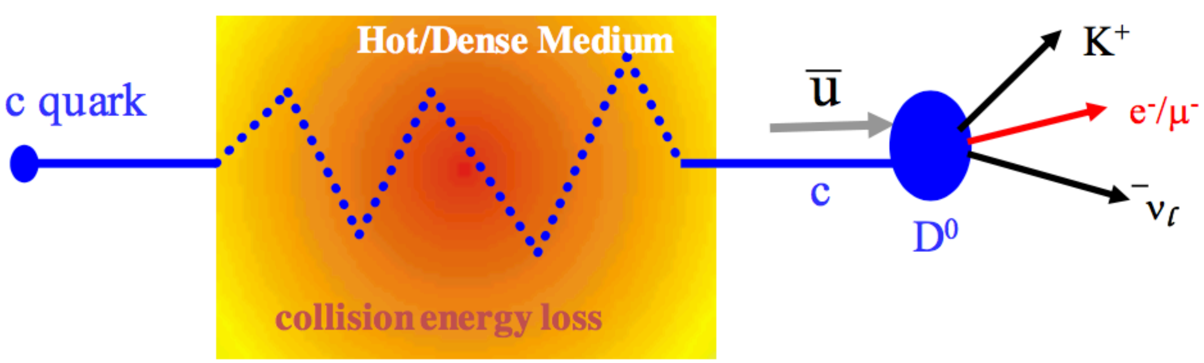
Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Thickness
SSD	22	30 / 860	1% X_0
IST	14	170 / 1800	1.32 %X_0
PIXEL	8	6.2 / 6.2	~0.52 %X_0
	2.8	6.2 / 6.2	~0.39% X_0

- **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**



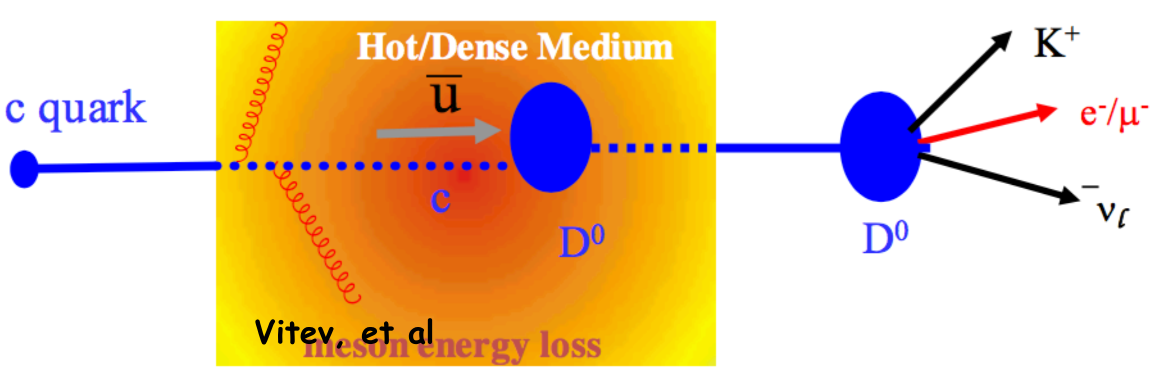
(Baier *et al*, Kharzeev *et al*, Djordjevic *et al*, Wiedemann *et al* .)

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



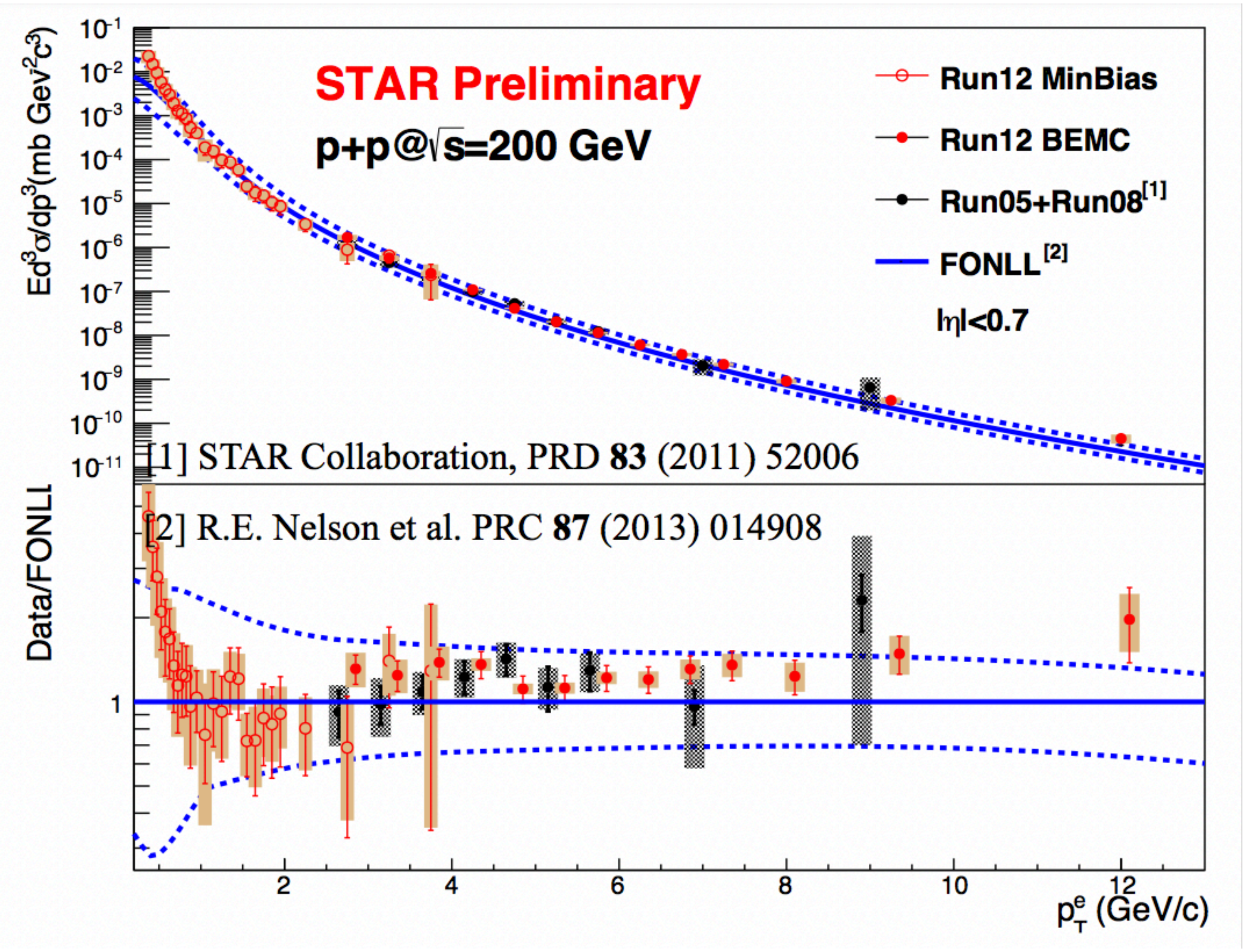
(Teaney *et al*, Rapp *et al*, Molnar *et al*, Gossiaux *et al.*)

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

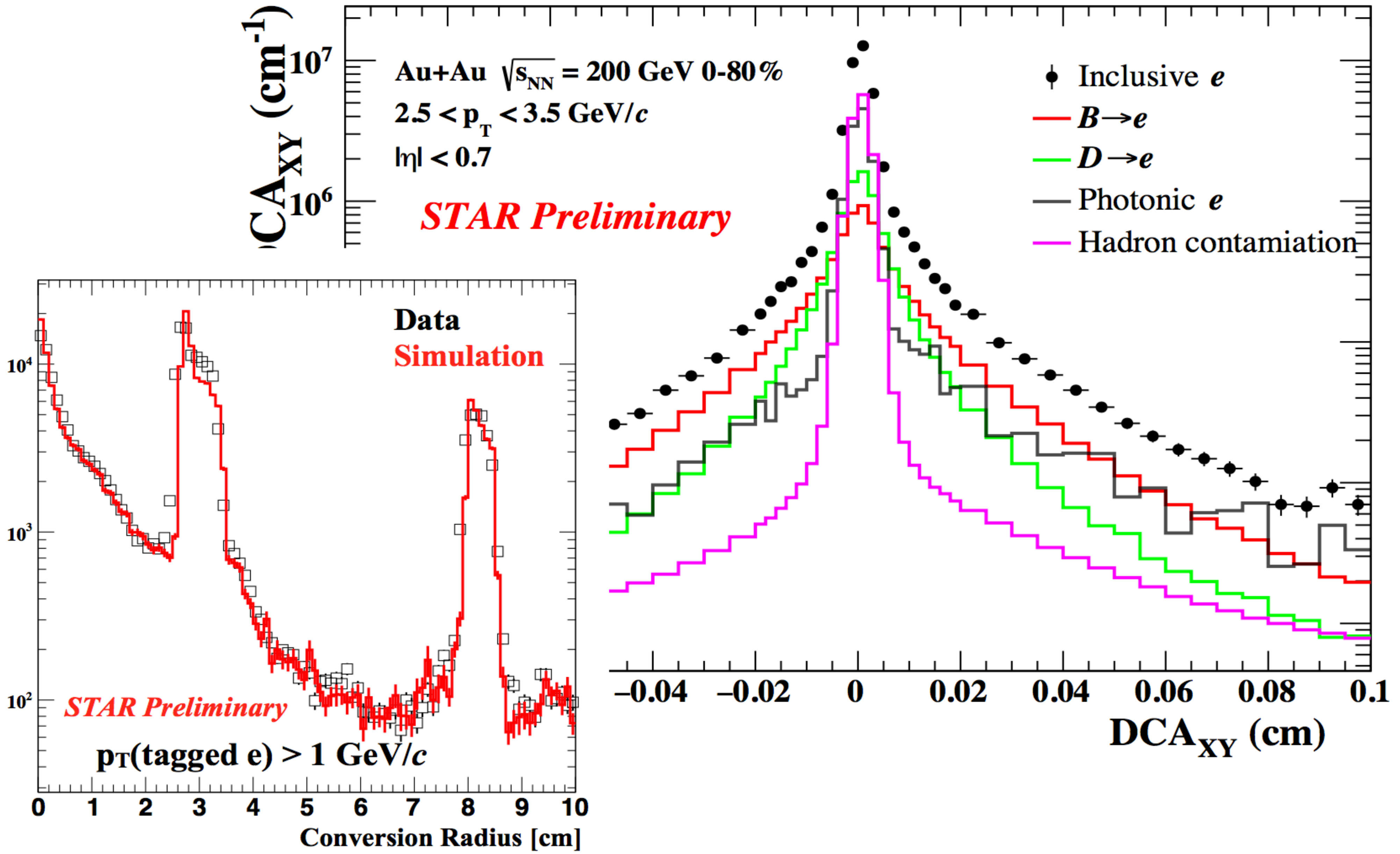


Collisional Dissociation. Medium induced dissociation of heavy mesons.

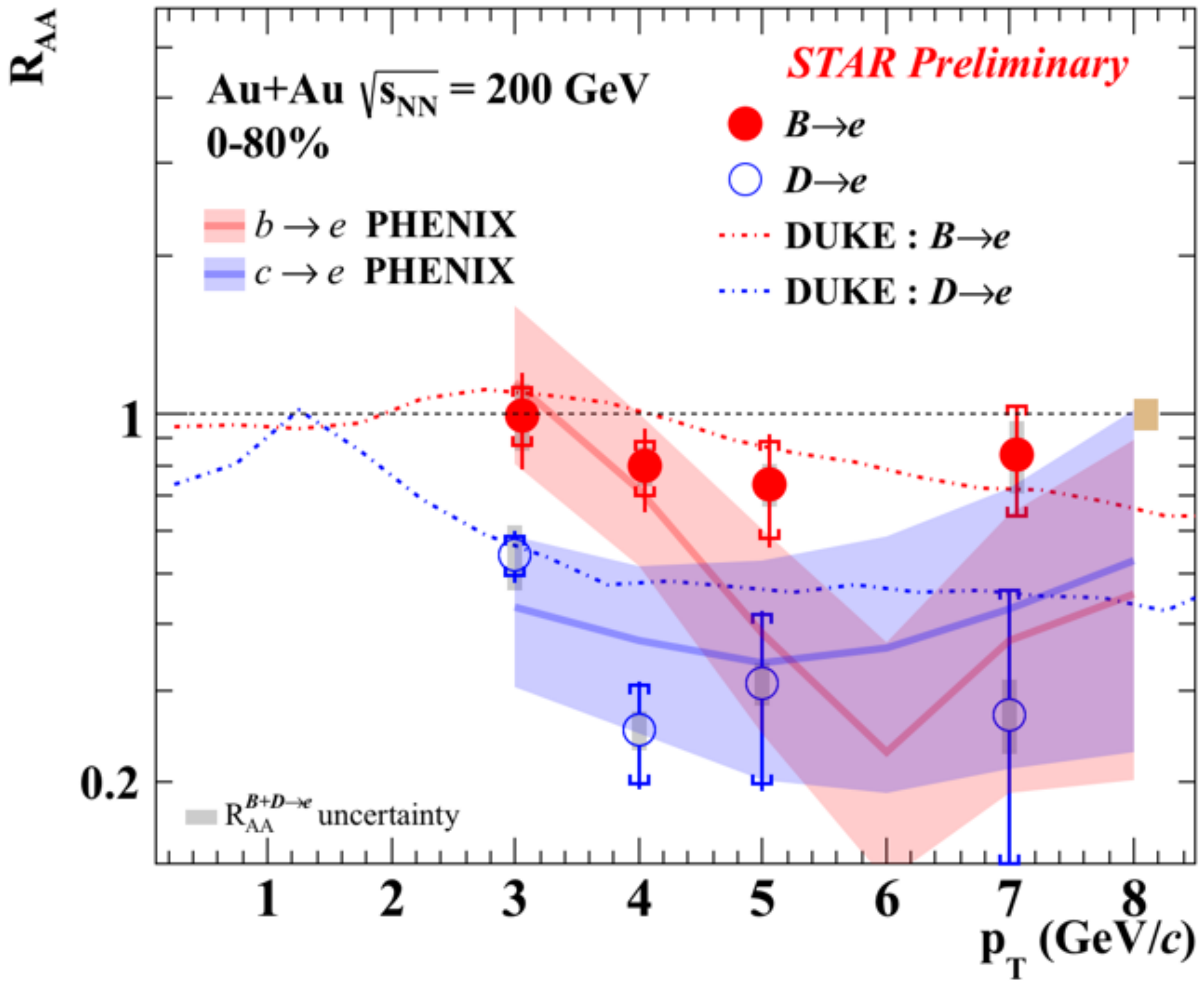
NPE cross section from Run12 200 GeV p+p collisions



- 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.



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



Consistent with PHENIX result within uncertainty.