Measurements of non-photonic electrons in STAR

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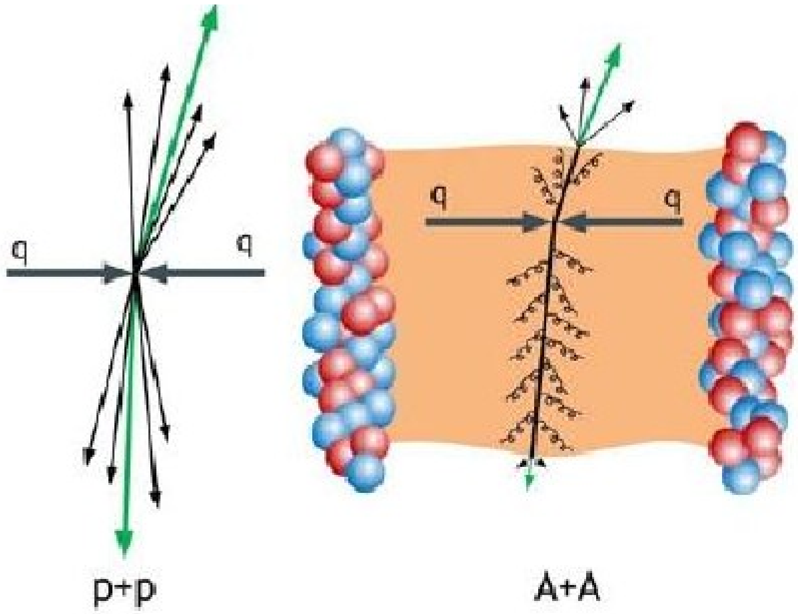
Outline

- Motivation.
- Non-photonic electrons (NPE) analysis method.

- NPE results:
  - → p+p at 200 GeV.
  - → Au+Au collisions, nuclear modification factor R_{AA} at 200 GeV.
  - → Azimuthal anisotropy v_2 in Au+Au at 200 GeV.

Heavy ion collisions

- Heavy ion collisions:
  → hot and dense nuclear matter formation - Quark-Gluon Plasma
  → cold and hot nuclear matter effects



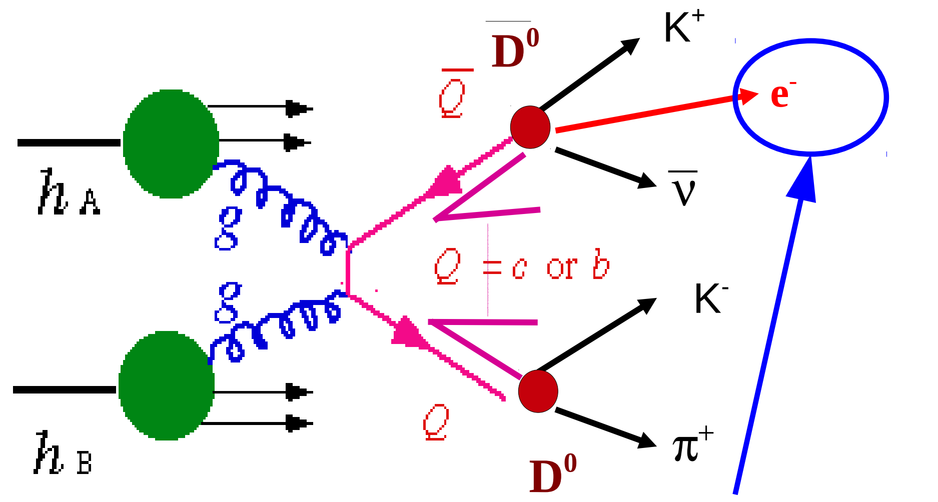
- p+p collisions:
  → baseline

- Medium effects quantified by nuclear modification factor:
  → R_{dA} – cold nuclear matter effects.
  → R_{AA} – hot nuclear matter effects.

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

Heavy quarks

- Heavy quarks:
  - → large masses
  - → early production
  - → p+p collisions - test of the validity of the pQCD



Non-photonic electron

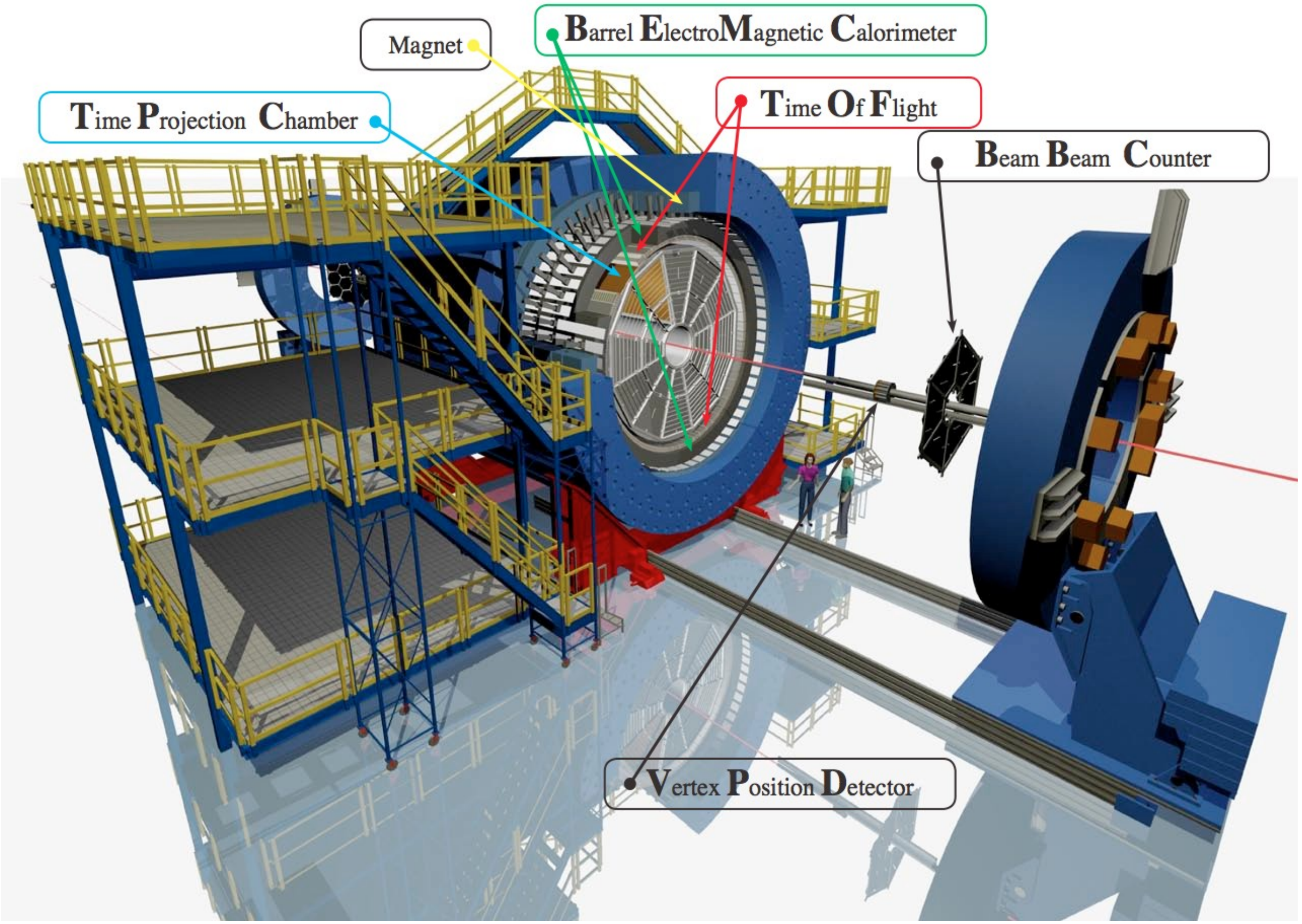
- Heavy ion collisions:
  - → energy loss (nuclear modification factor R_{AA})
  - → thermalization (elliptic flow v_2)

- Study of non-photonic electrons is a good way to measure production of bottom and charm hadrons via semi-leptonic decays.

$$b \rightarrow e^{\pm} + anything\,(10.86\,\%) \qquad c \rightarrow e^{\pm} + anything\,(9.6\,\%)$$

STAR detector at RHIC

Solenoidal Tracker At RHIC : $-1 < \eta < 1, 0 < \phi < 2\pi$



Time Projection Chamber (TPC) – tracking, particle identification, momentum

Time of Flight detector (ToF) – particle identification at low p_T region.

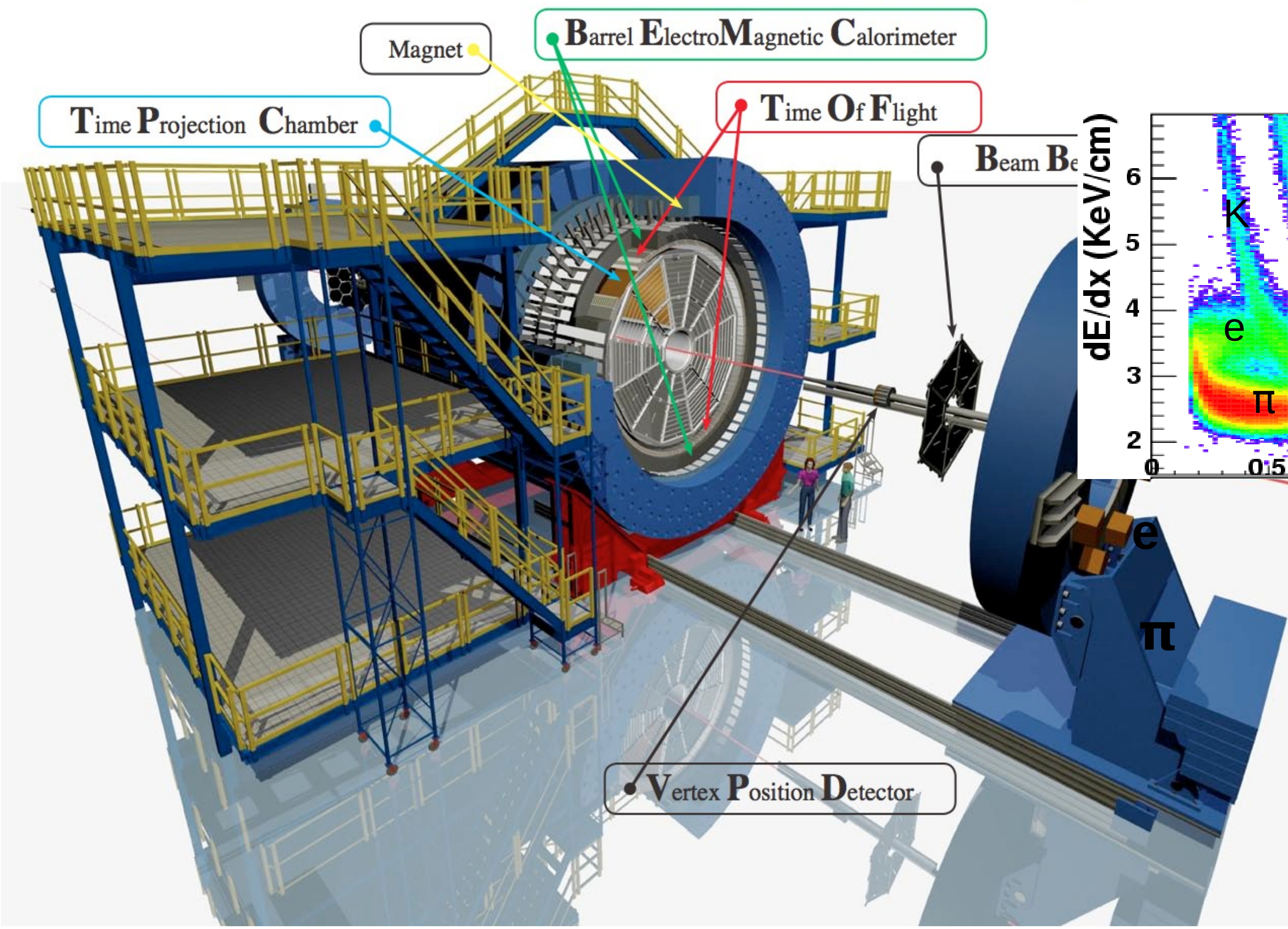
BEMC – electron identification at high p_T region, triggering (High Tower triggers)

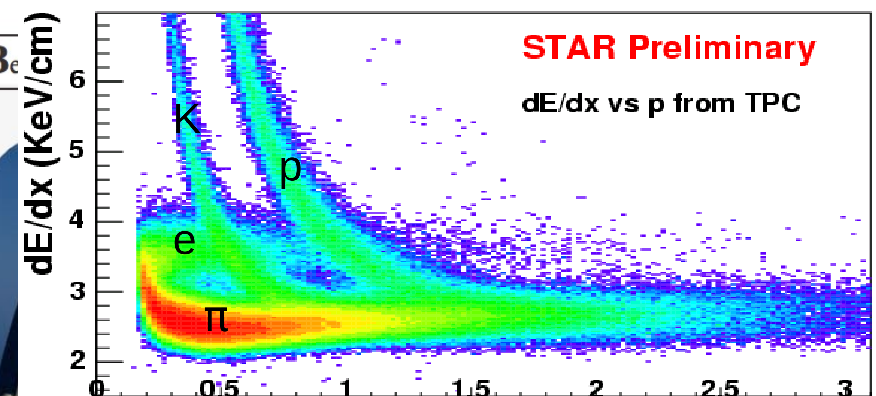
BSMD – electron identification at high p_T

STAR detector at RHIC

Solenoidal Tracker At RHIC : $-1 < \eta < 1, 0 < \phi < 2\pi$

Electron identification with TPC in low p region.



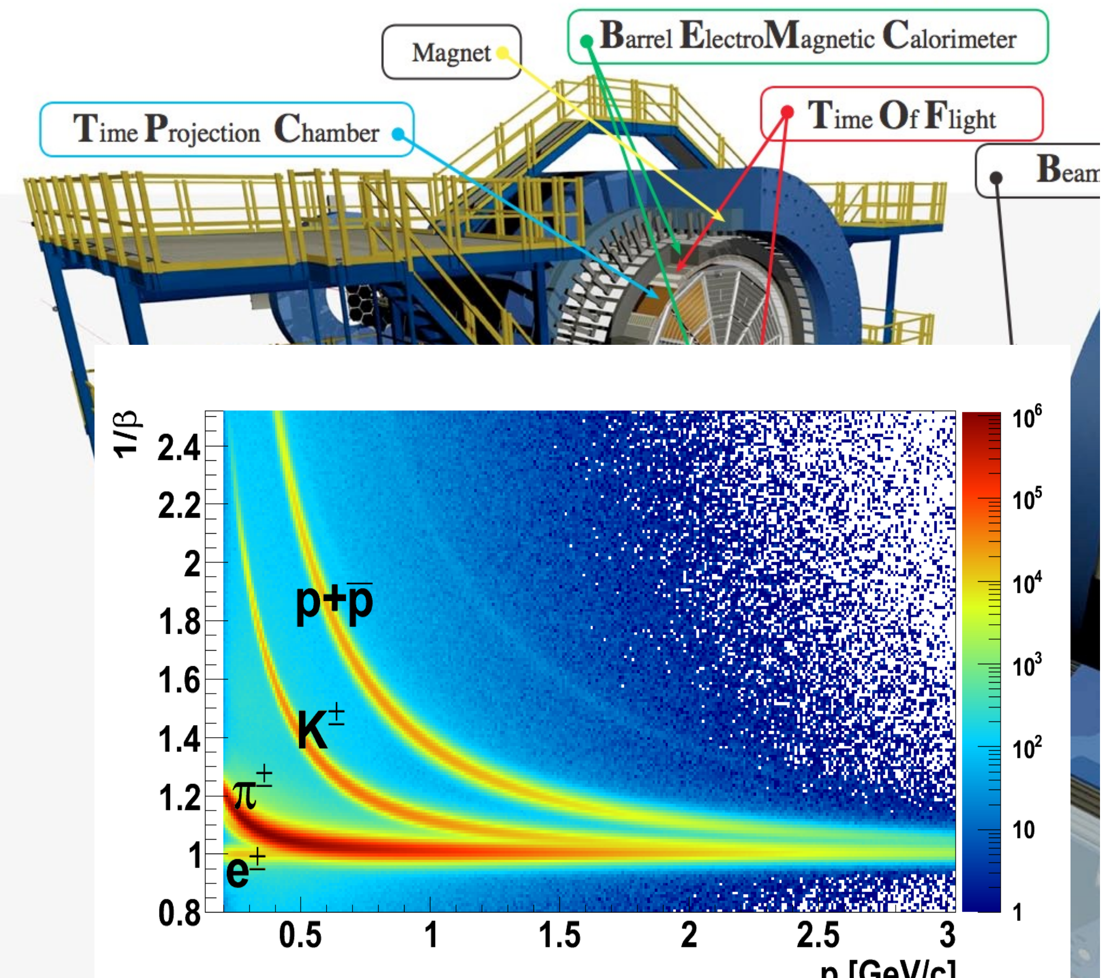


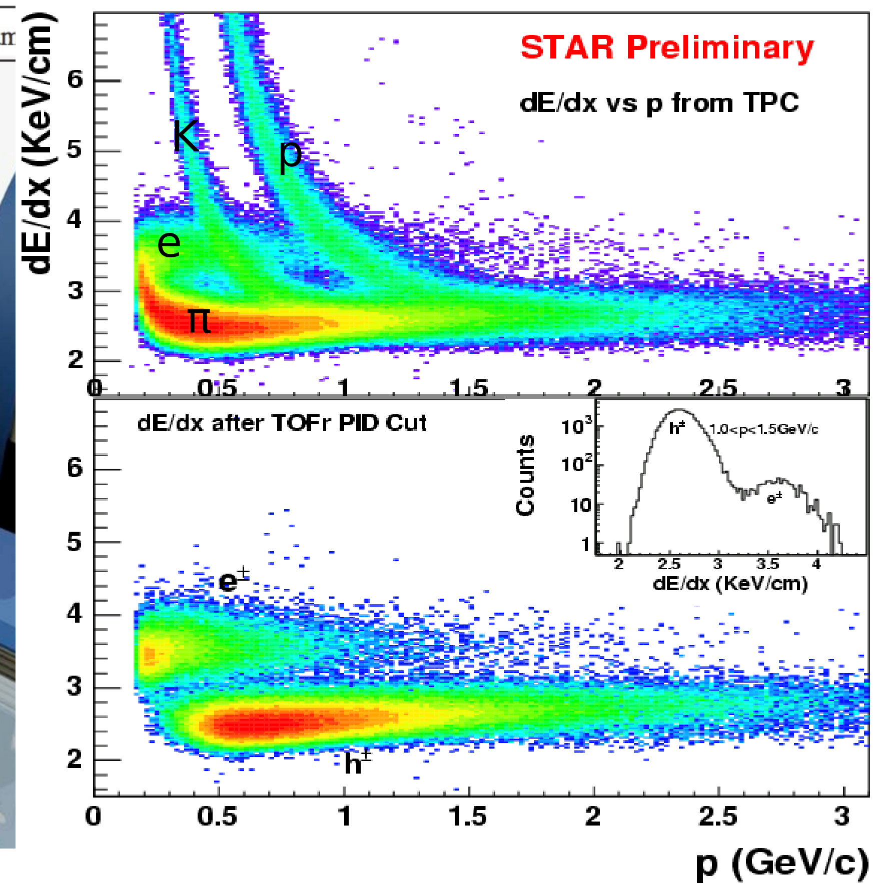
p_T(GeV/c)

STAR detector at RHIC

Solenoidal Tracker At RHIC : $-1 < \eta < 1, 0 < \phi < 2\pi$

TPC and TOF together are great tool for distinguish electrons and hadrons in low p

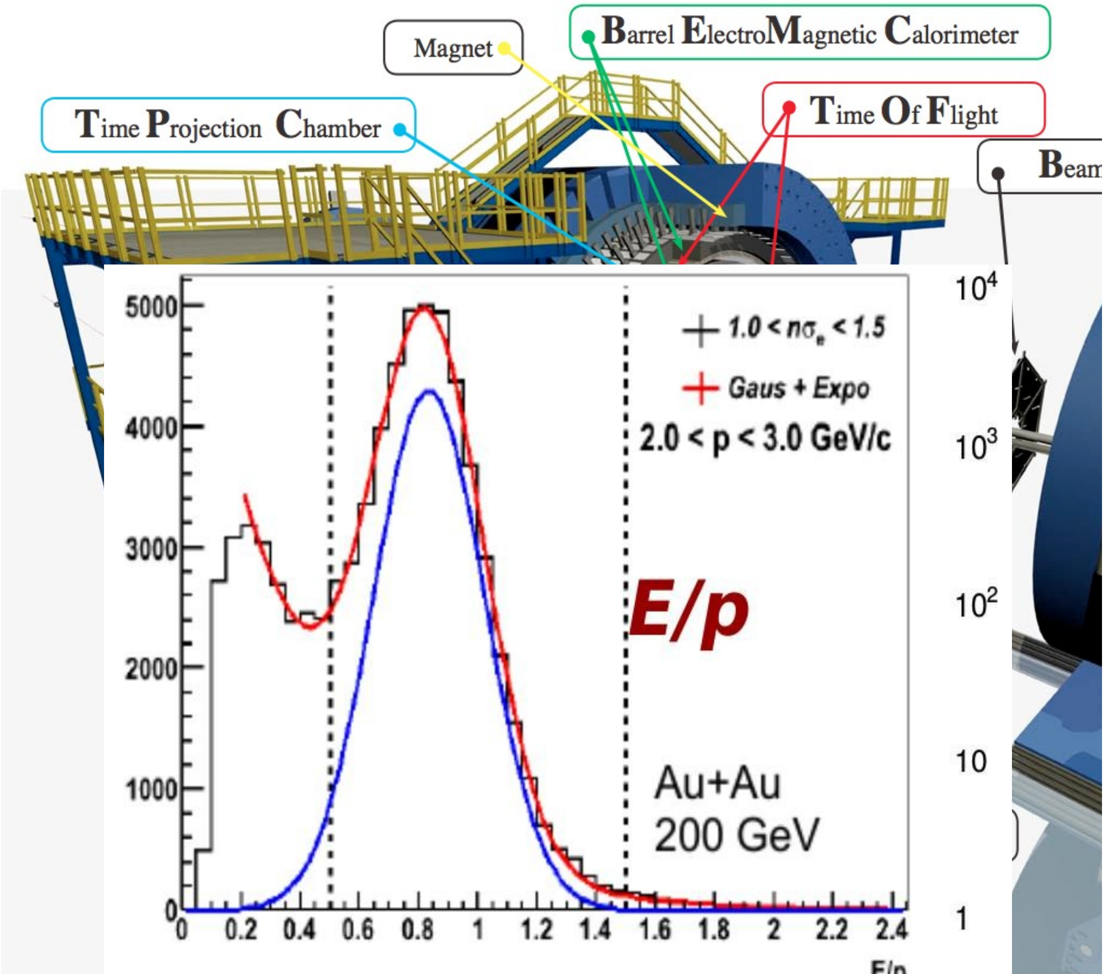


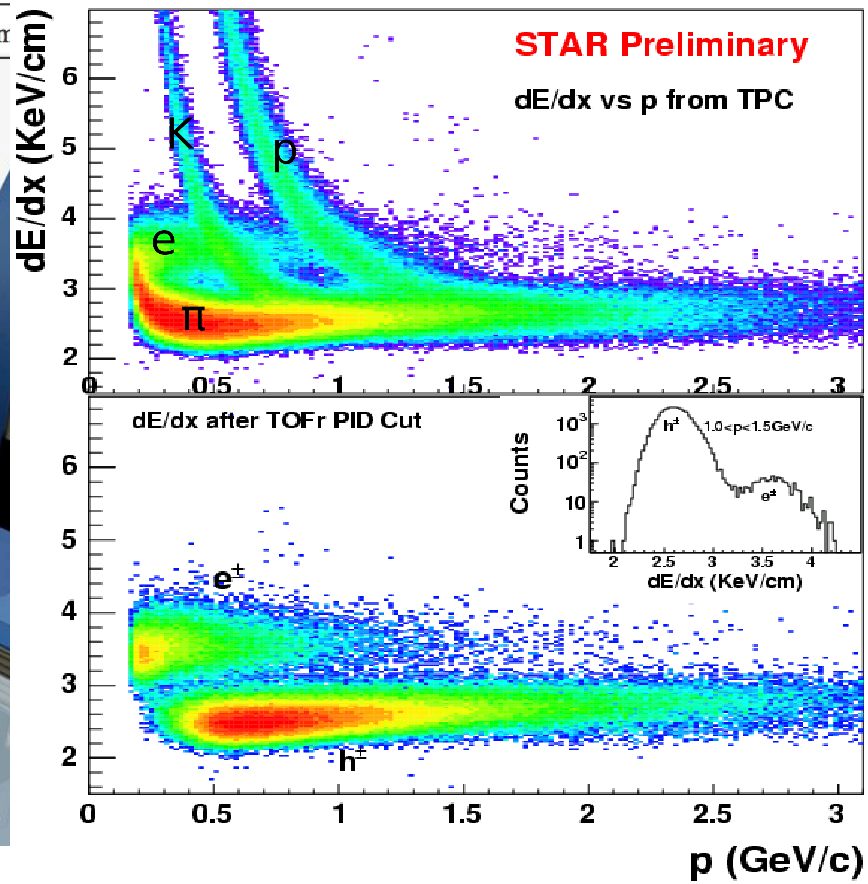


STAR detector at RHIC

TPC and BEMC together are used for electron identification at high p_T region.

Solenoidal **T**racker **A**t **R**HIC : $-1 < \eta < 1,\ 0 < \phi < 2\pi$





NPE analysis method

$$NPE = N_{Inclusive} * purity_{Inclusive} - \frac{N_{Photonic}}{\epsilon_{Photonic}}$$

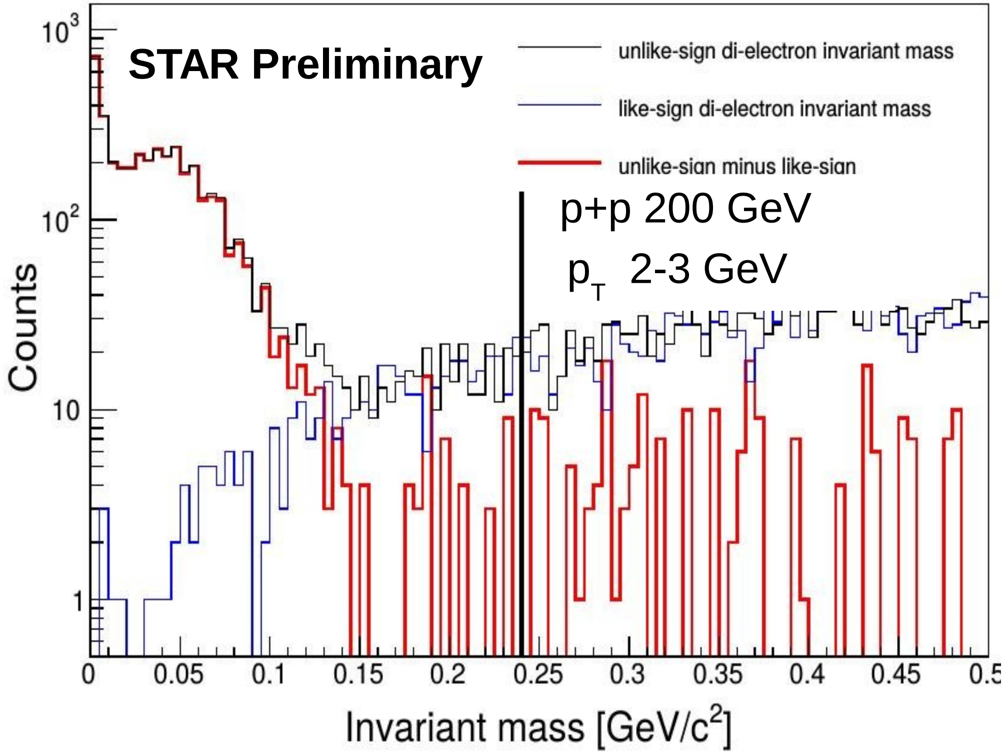
- Inclusive electrons – identification with TPC, TOF, BEMC.

- Photonic electrons – background
  → identified via small e^+e^- invariant mass
  → statistically reconstructed
  → main background comes from:

  Dalitz decay: $\pi^0 \rightarrow \gamma + e^+ + e^-$ (BR: ~1.2%)

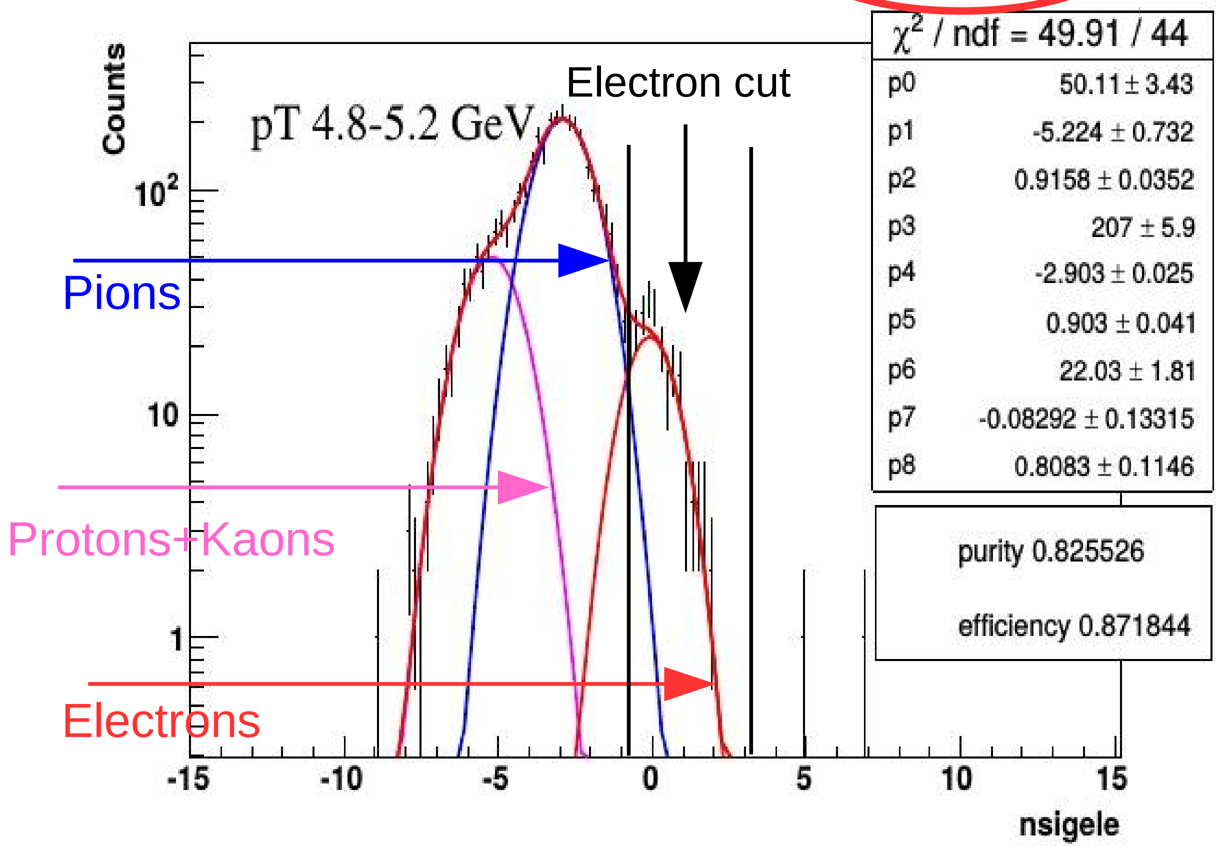
  Gamma conversions: $\gamma \rightarrow e^+ + e^-$

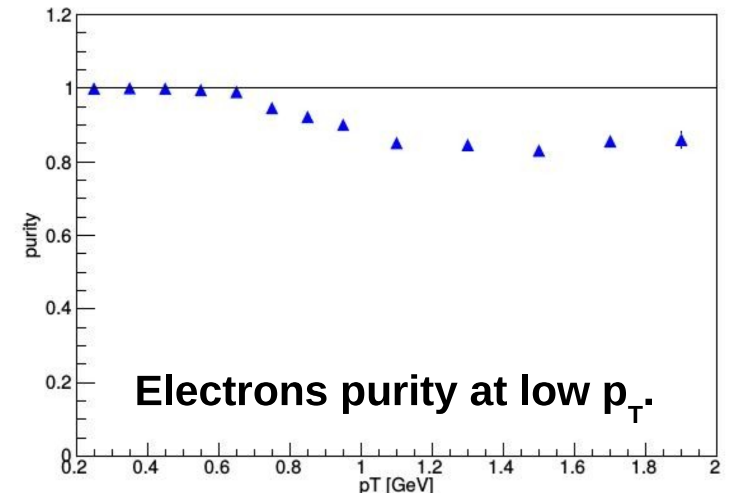
  → corrected for reconstruction efficiency via simulation.

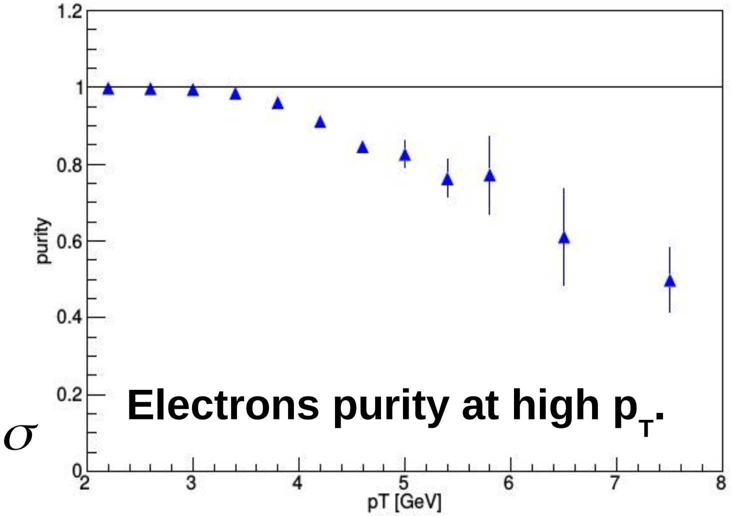


Inclusive electron purity

$$NPE = N_{Inclusive} * purity_{Inclusive} - \frac{N_{Photonic}}{\epsilon_{Photonic}}$$



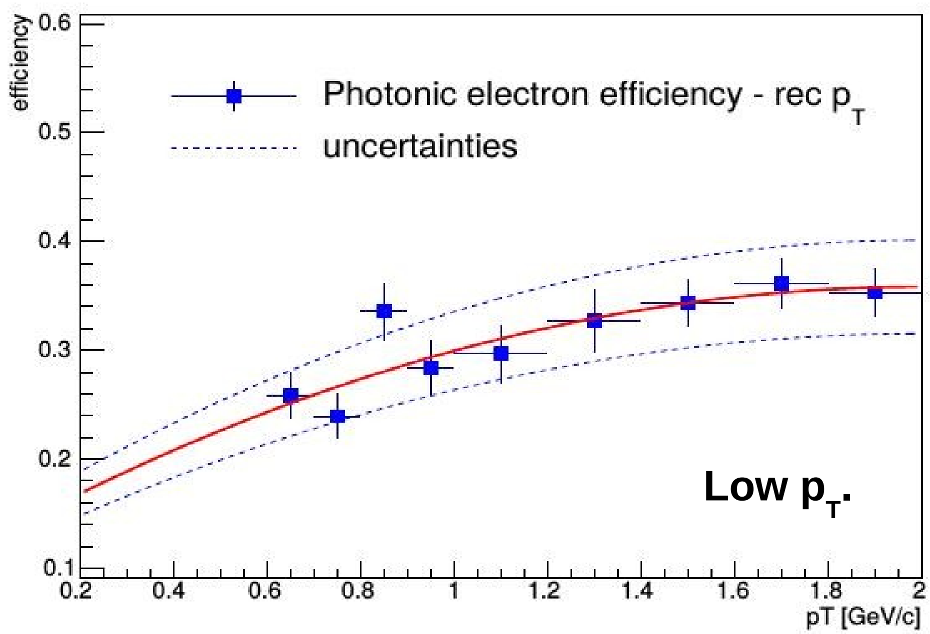


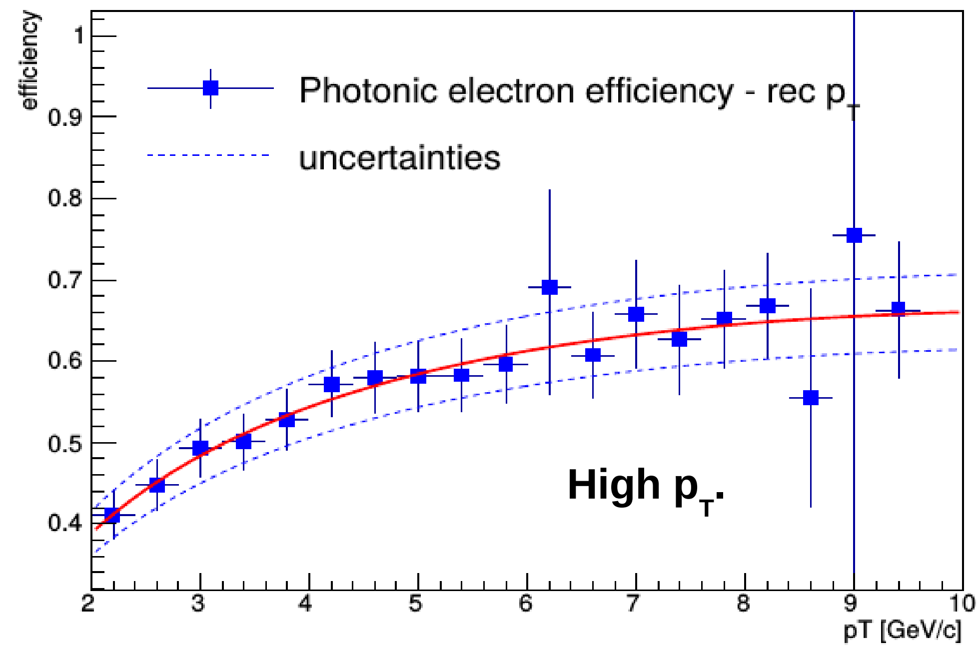


- Multi-gaussian fit to the nsigele distribution.

$$nsigele = \ln\left(\frac{dE/dx_{exp}}{dE/dx_{Bethe/Bloch_e}}\right) / \sigma$$

Photonic background reconstruction efficiency



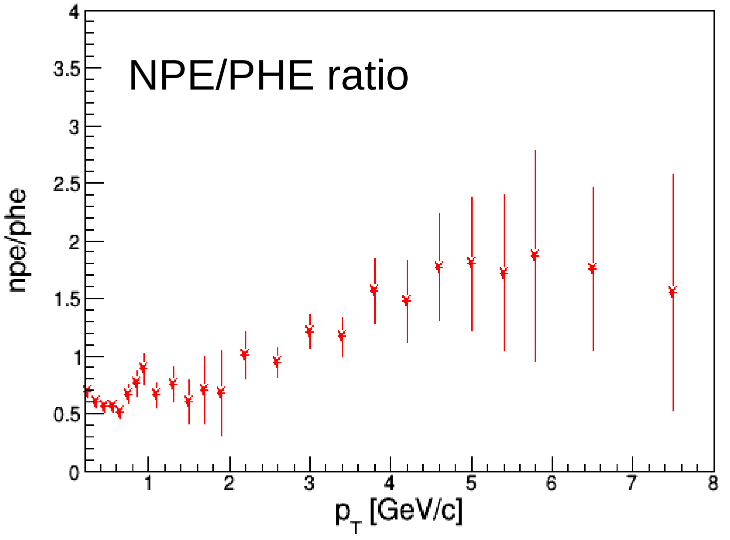


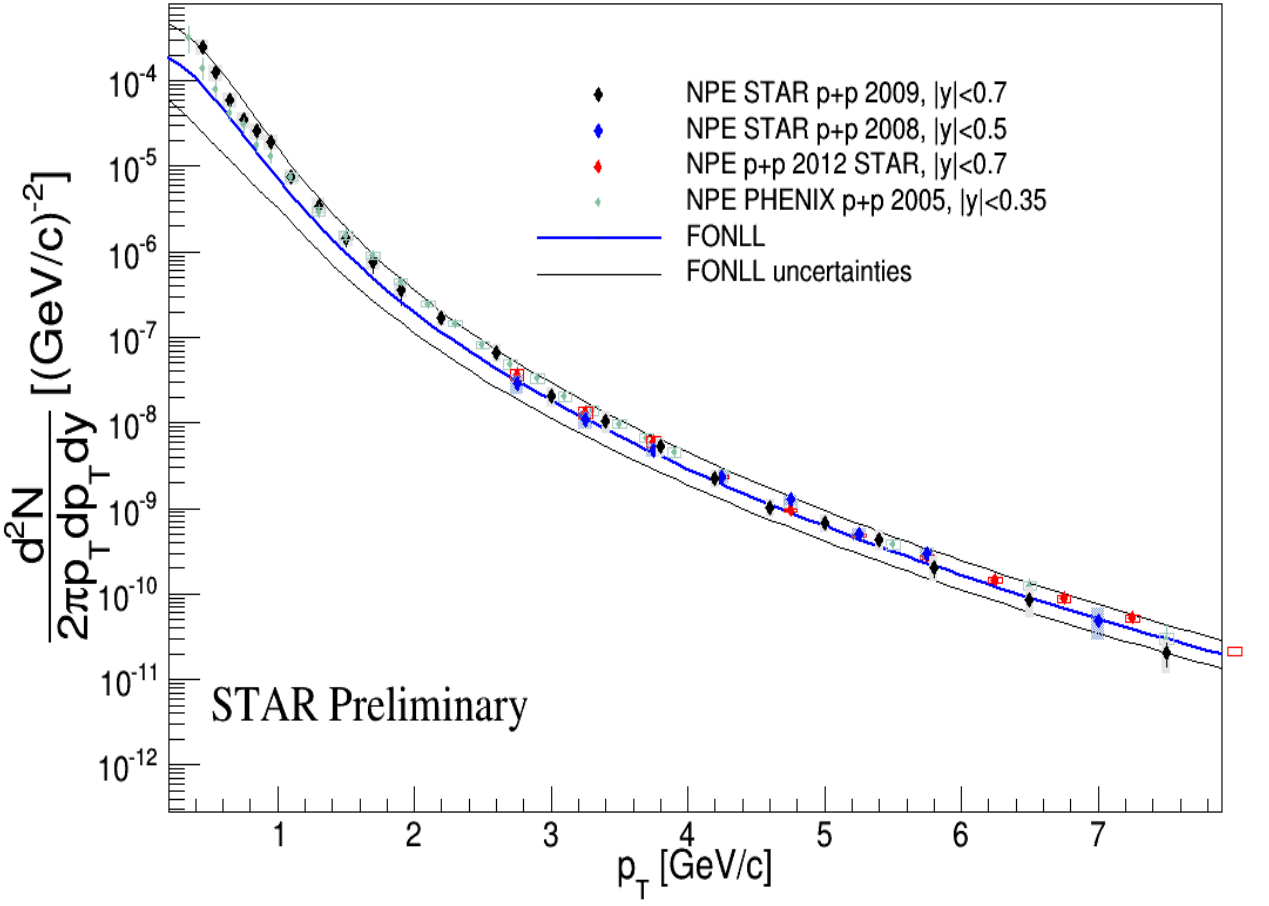
- Photonic electron recontruction efficiency from simulation.

$$NPE = N_{Inclusive} * purity_{Inclusive} - \frac{N_{Photonic}}{\epsilon_{Photonic}}$$

NPE in p+p collisions at √s=200GeV

- p+p at 200GeV data (year 2009):
- Spectrum was extended to the low p_T region.





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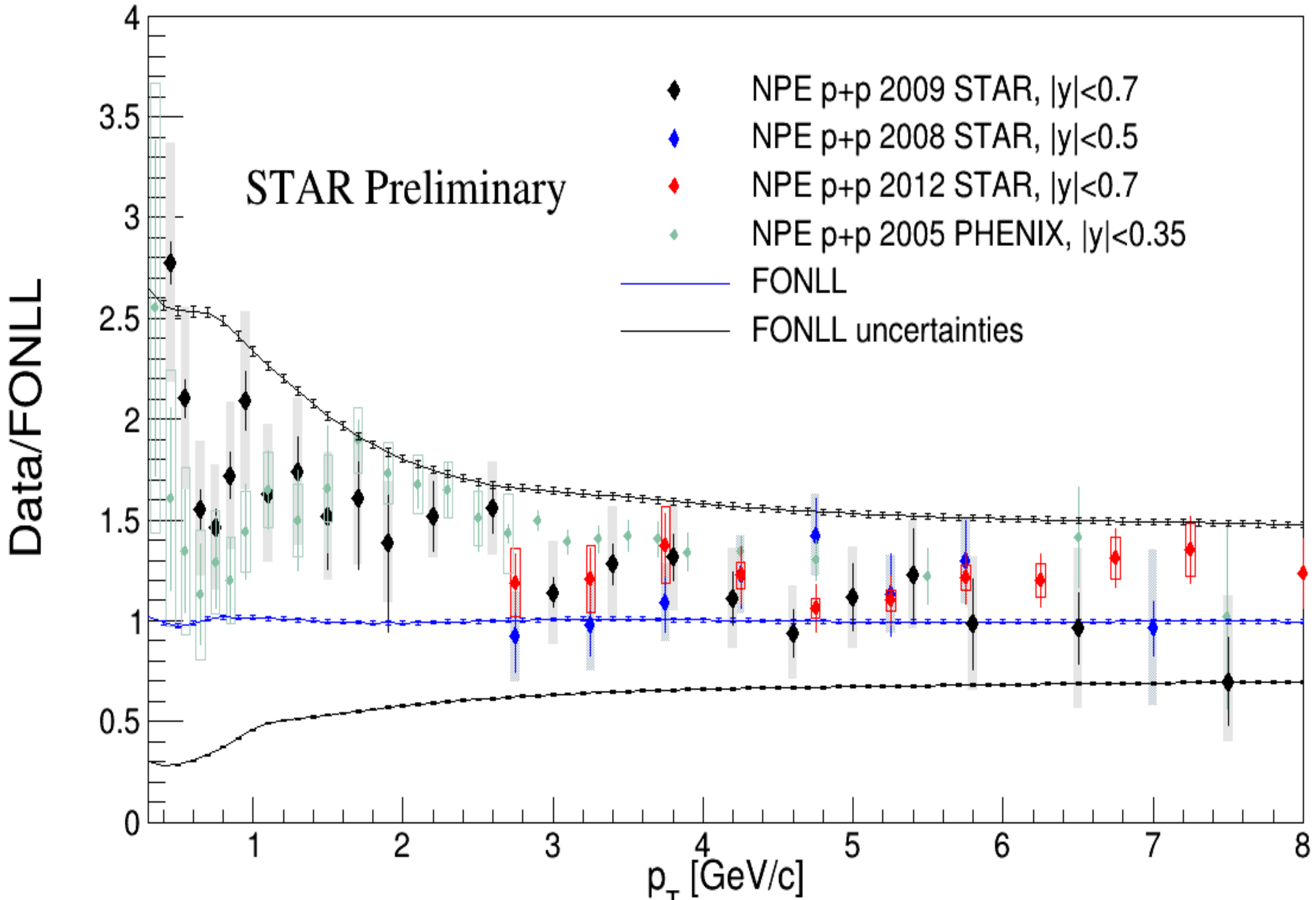
p+p 2008 - H. Agakishiev et al. [STAR Collaboration], Phys. Rev. D83, 052006,(2011)
p+p PHENIX - A.Adare et al. [PHENIX Collaboration], , Phys. Rev. C84, 044905 (2011).
FONLL - M. Cacciari, P. Nason and R. Vogt, Phys. Rev. Lett. 95, 122001 (2005)

Data to FONLL ratio

- Spectrum was extended to the low p_T region.
- Consistent with pQCD FONLL calculation (Fixed Order plus Next-to-Leading Logarithms).



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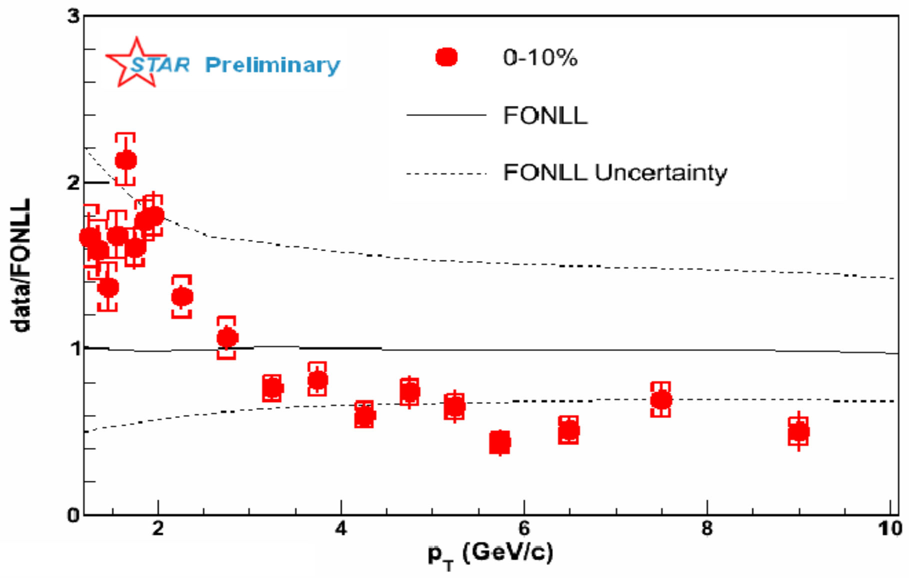
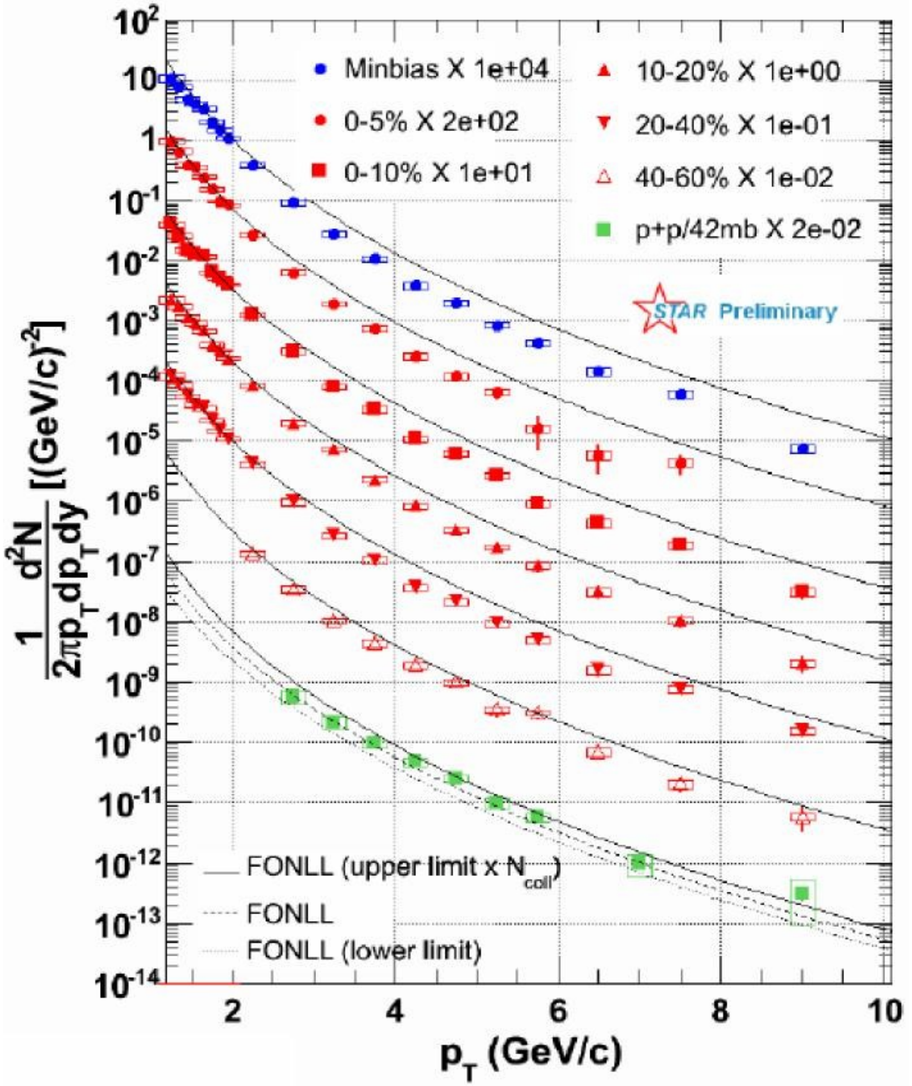
NPE in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV

- Au+Au at 200GeV (year 2010 data):
  → suppression at high p_T compared with FONLL calculations



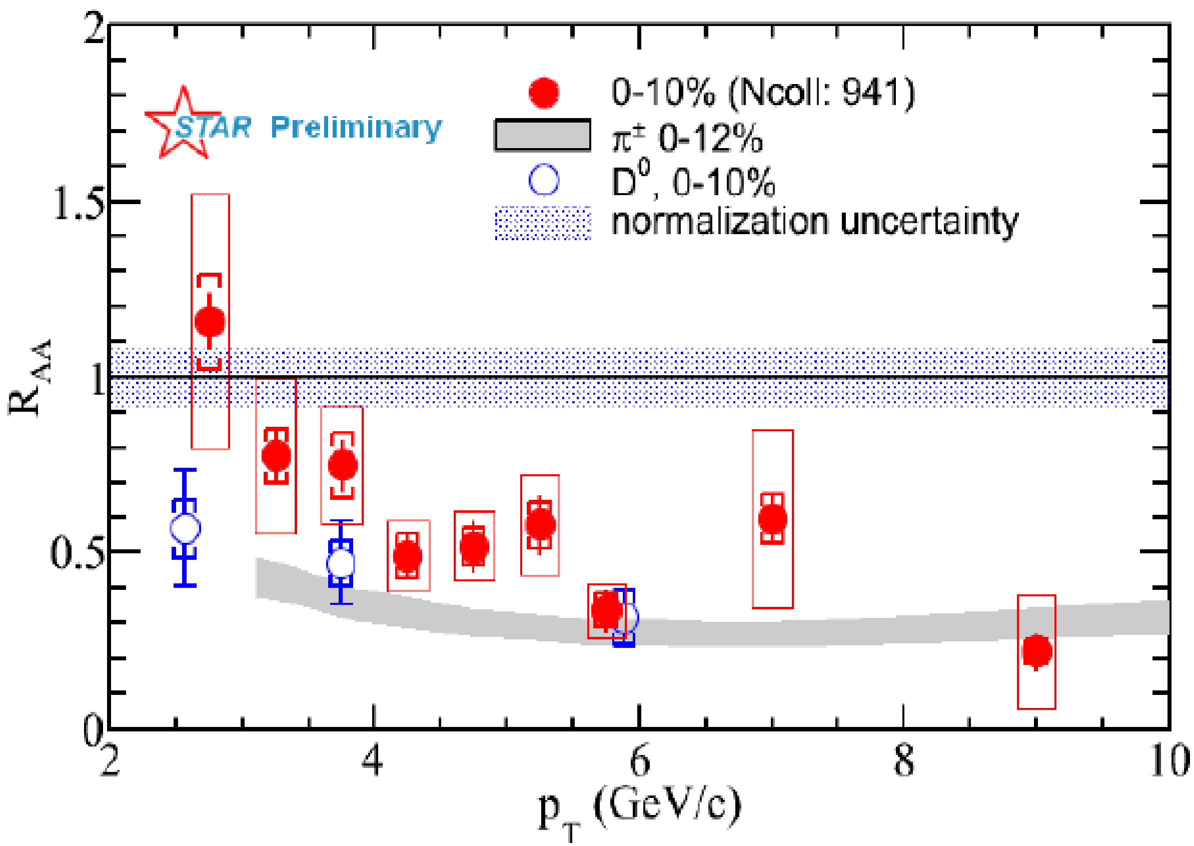


Nuclear Modification Factor in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV

→ Strong suppression is observed at high p_T.

→ Strong suppression is similar as for D^0 mesons and light hadrons.

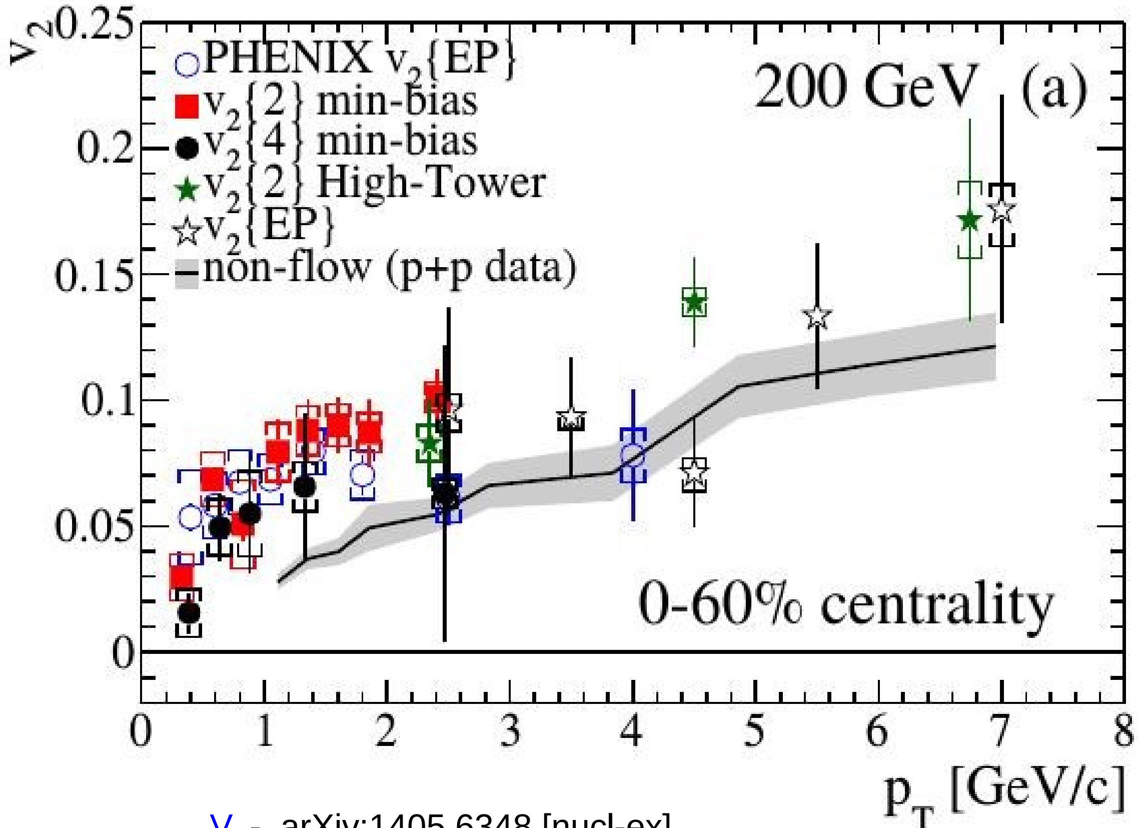
$$R_{AA} = \frac{1}{<N_{coll}>} * \frac{dN_{AA}/dy}{dN_{pp}/dy}$$



D^0 - arXiv:1404.6185 [nucl-ex] – accepted by PRL

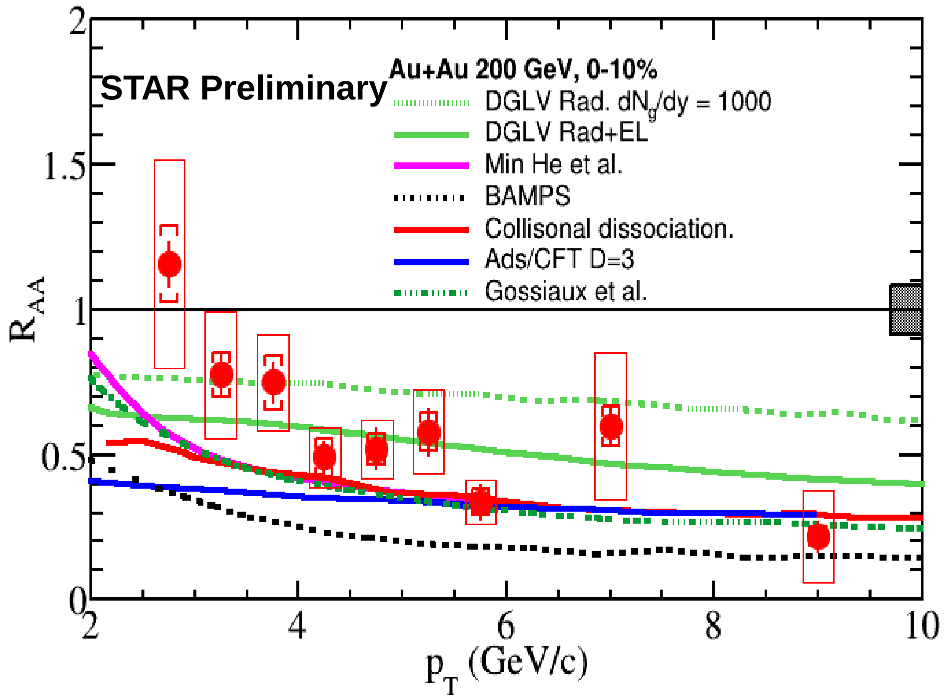
NPE elliptic flow in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

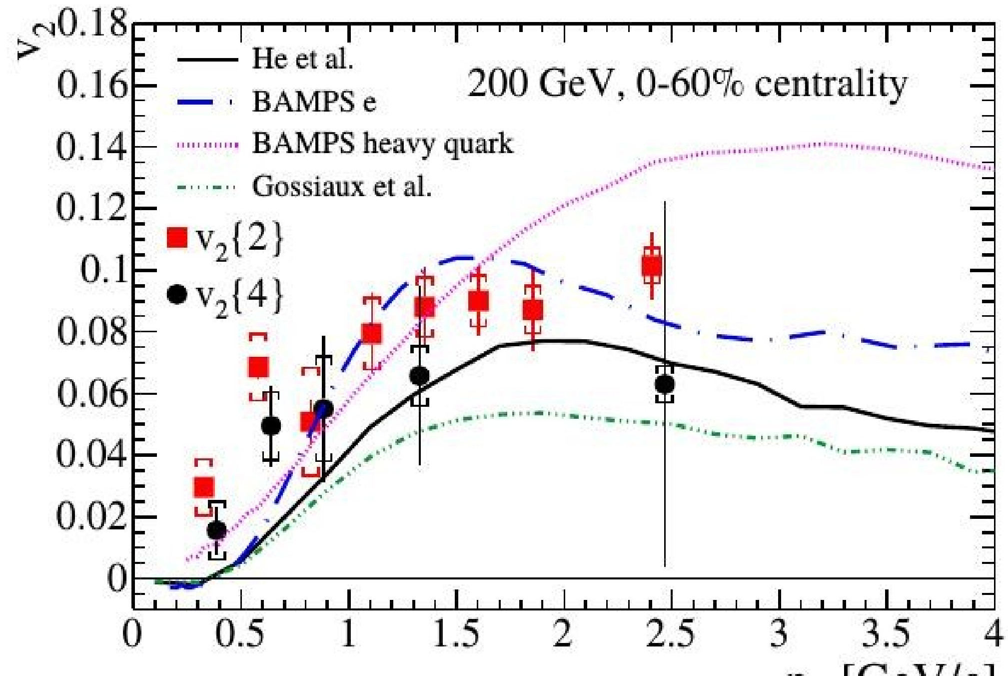
- Initial geometry asymmetry → final momentum anisotropy.
- Results obtain using 2-particle and 4-particle correlations.
- Finite v_2 at low p_T together with strong suppression in high p_T indicates strong charm-medium interaction.
- Increase of v_2 at high p_T can arise from jet-like correlations or from path length dependence of heavy quark energy loss.



V_2 - arXiv:1405.6348 [nucl-ex]

NPE R_{AA} and elliptic flow in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV





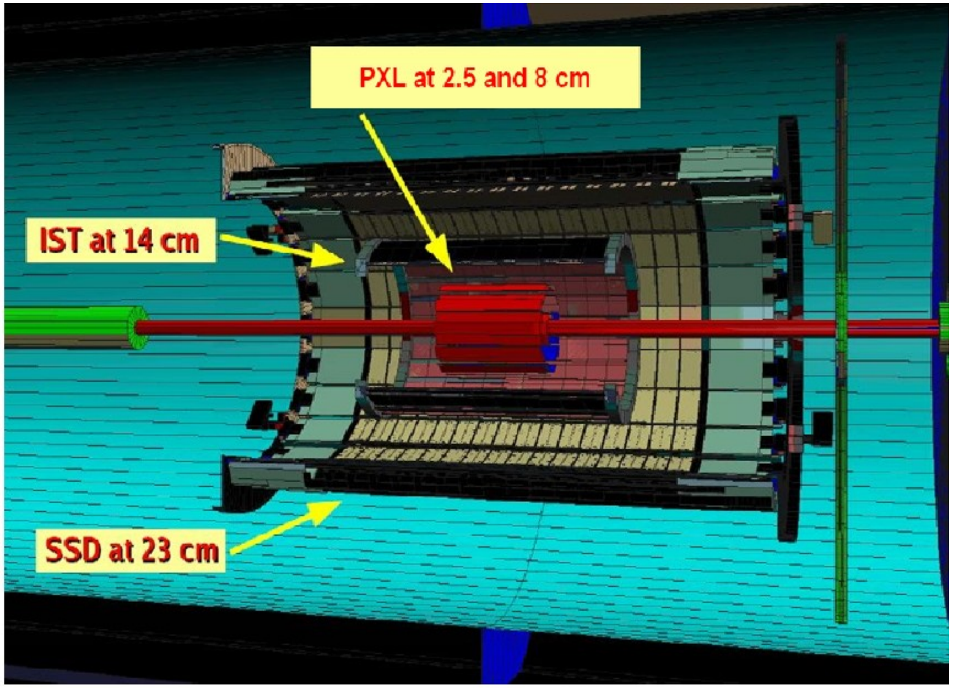
V_2 - arXiv:1405.6348 [nucl-ex]

Gluon radiation scenario alone fails to explain large NPE suppression at high p_T.

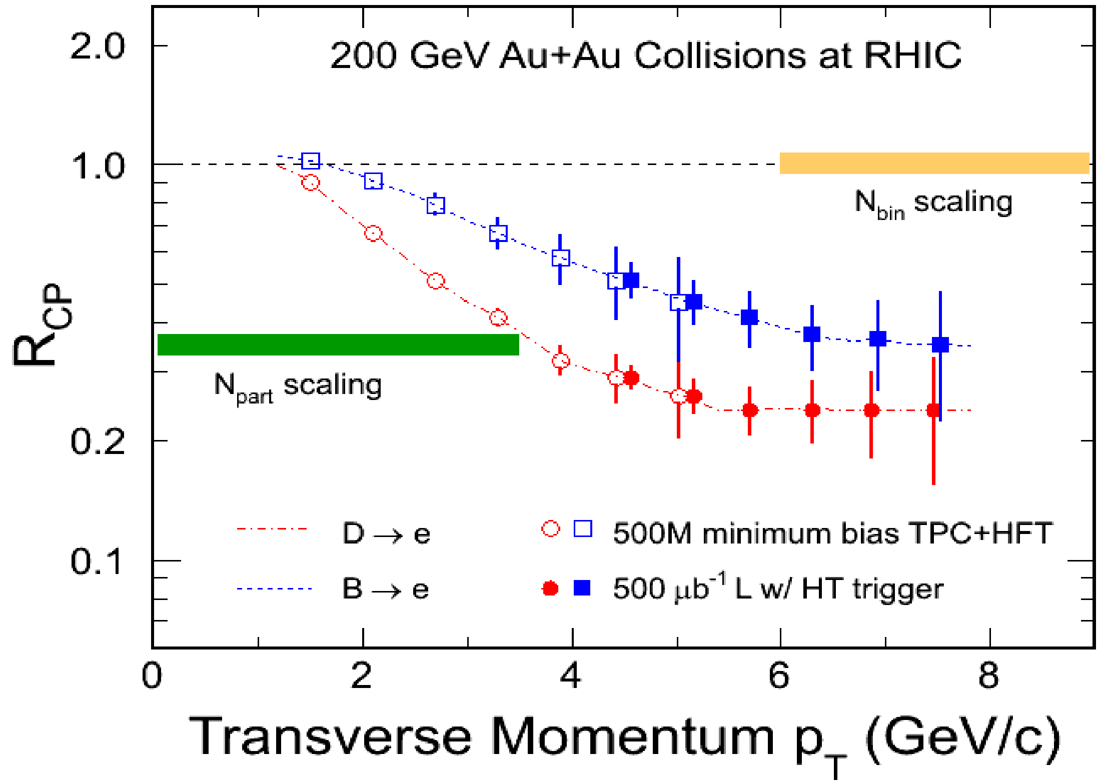
Finite elliptic flow together with large suppression at high p_T at $\sqrt{s_{NN}}$ = 200 GeV indicate that heavy quarks interact strongly with the surrounding partonic medium.

It's challenging for model calculations to describe the suppression and v_2 simultaneously.

Heavy flavor tracker (HFT)



Projected NPE results with HFT



Curves: H. van Hees *et al*. Eur. Phys. J. **C61**, 799(2009).

- Heavy Flavor Tracker (HFT) - Year 2014.
- HFT will allow measurement of B → e and D → e spectrum separately in Au+Au.

Conclusions

- Measurement of the NPE spectrum in p+p collisions was extended to the low p_T region.
- We observed strong suppression of NPE in Au+Au collisions. Similar suppression as for light hadrons.
- NPE v_2 at 200 GeV: finite v_2 at low p_T together with strong suppression at high p_T indicates a strong charm-medium interaction.
- The new HFT detector will allow measurement of $B \rightarrow e$ and $D \rightarrow e$ spectra separately.

Thank you!