Measurements of non-photonic electrons in STAR

Olga Rusňáková for the STAR Collaboration

Faculty of Nuclear Sciences and Physical Engineering

Czech Technical University in Prague

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Outline

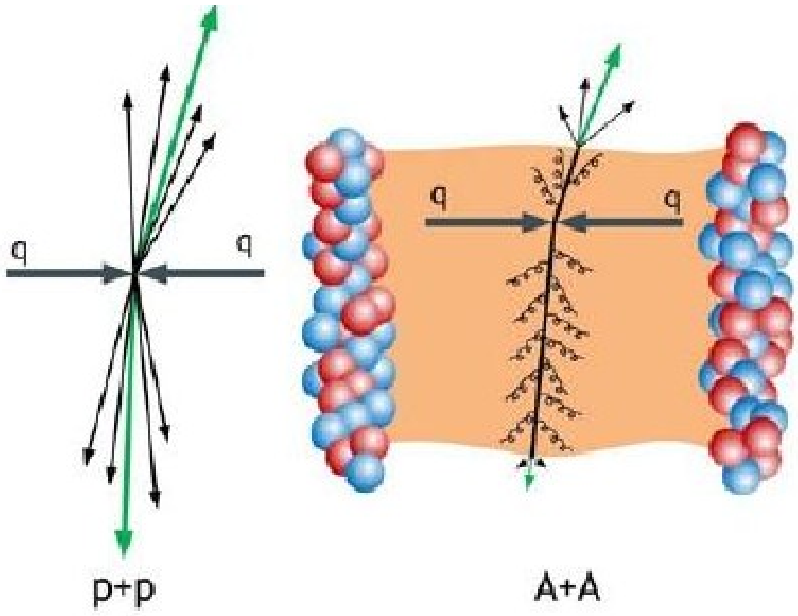
- Motivation
- Non-photonic electron (NPE) analysis method

- NPE results:
  - → p+p at 200 GeV
  - → Au+Au – nuclear modification factor R_{AA} at 200 GeV

    – elliptic flow v_2 in Au+Au at 39, 62.4, and 200 GeV

Heavy-ion collisions

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

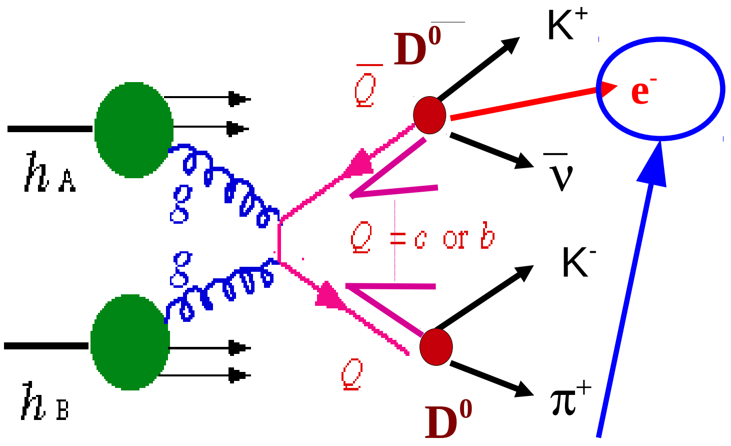
$$R_{AA} = \frac{1}{<N_{coll}>} * \frac{dN_{AA}/dy}{dN_{pp}/dy}$$

Non-photonic electrons

Semi-leptonic decay of bottom and charm hadrons → non-photonic electrons.

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

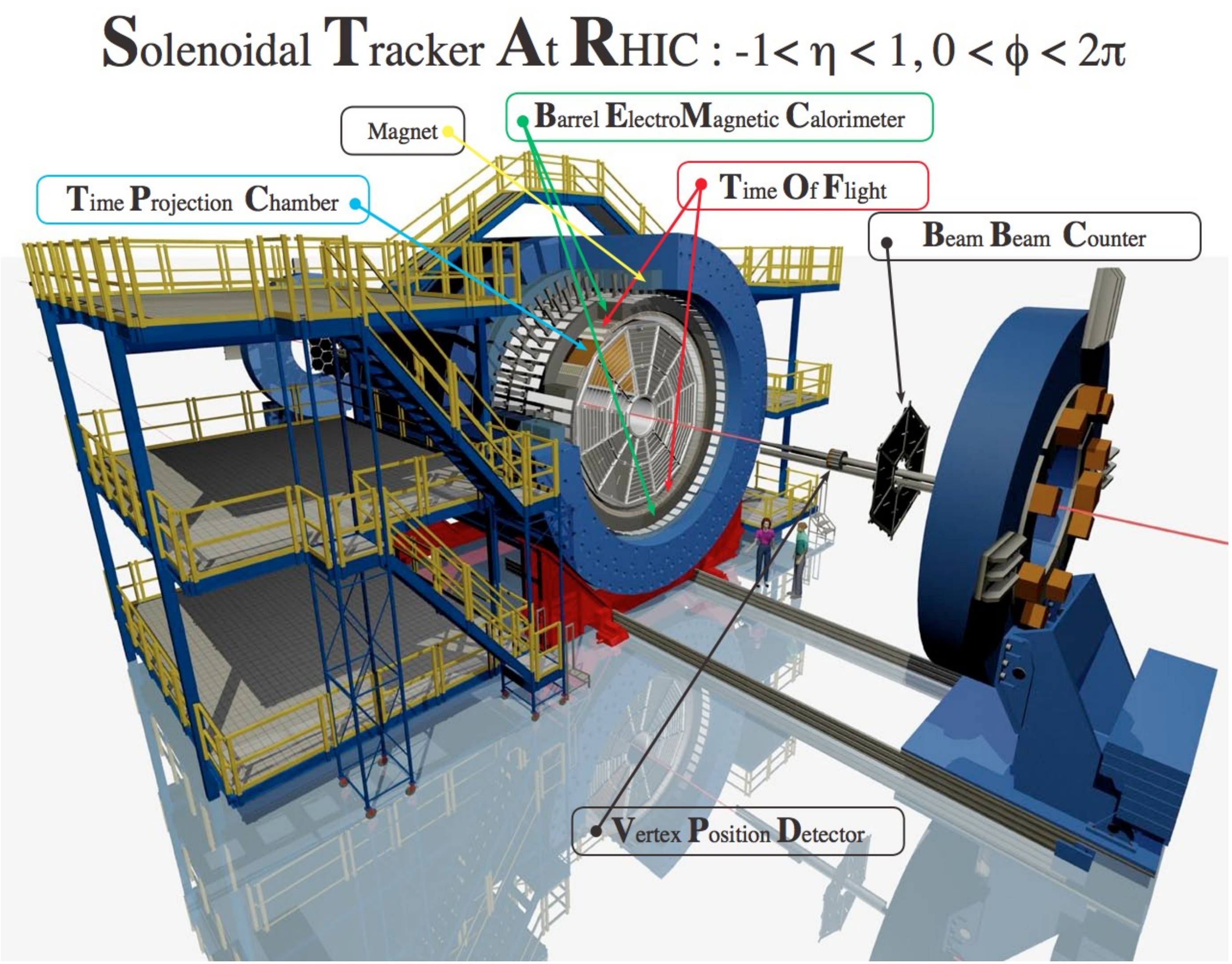
- Heavy quarks:
  - → large masses
  - → early production
  - → p+p collisions - test of the validity of the pQCD



Non-photonic electron

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

STAR detector at RHIC



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

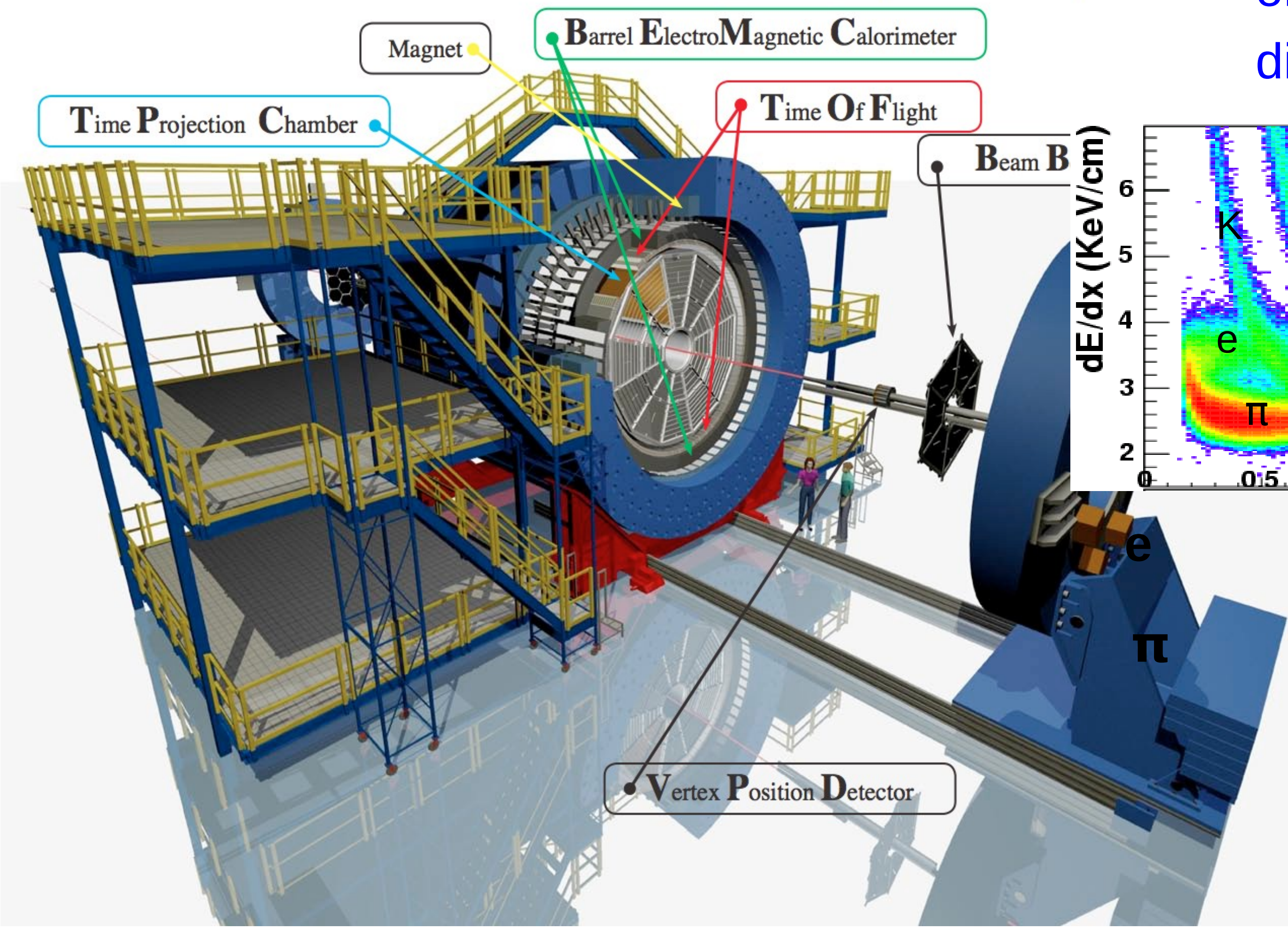
Time of Flight detector (ToF) – particle identification at low p_T region

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

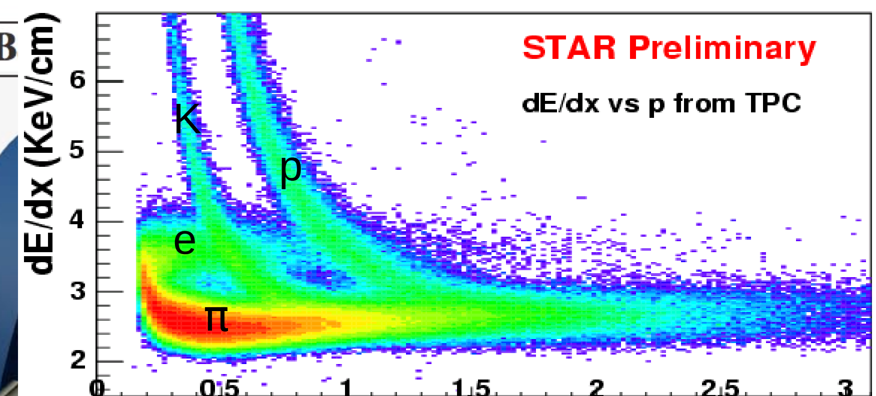
Barrel Shower Maximum Detector (BSMD) – electron identification at high p_T

STAR detector at RHIC

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



Electron identification with only TPC at low p region is difficult.

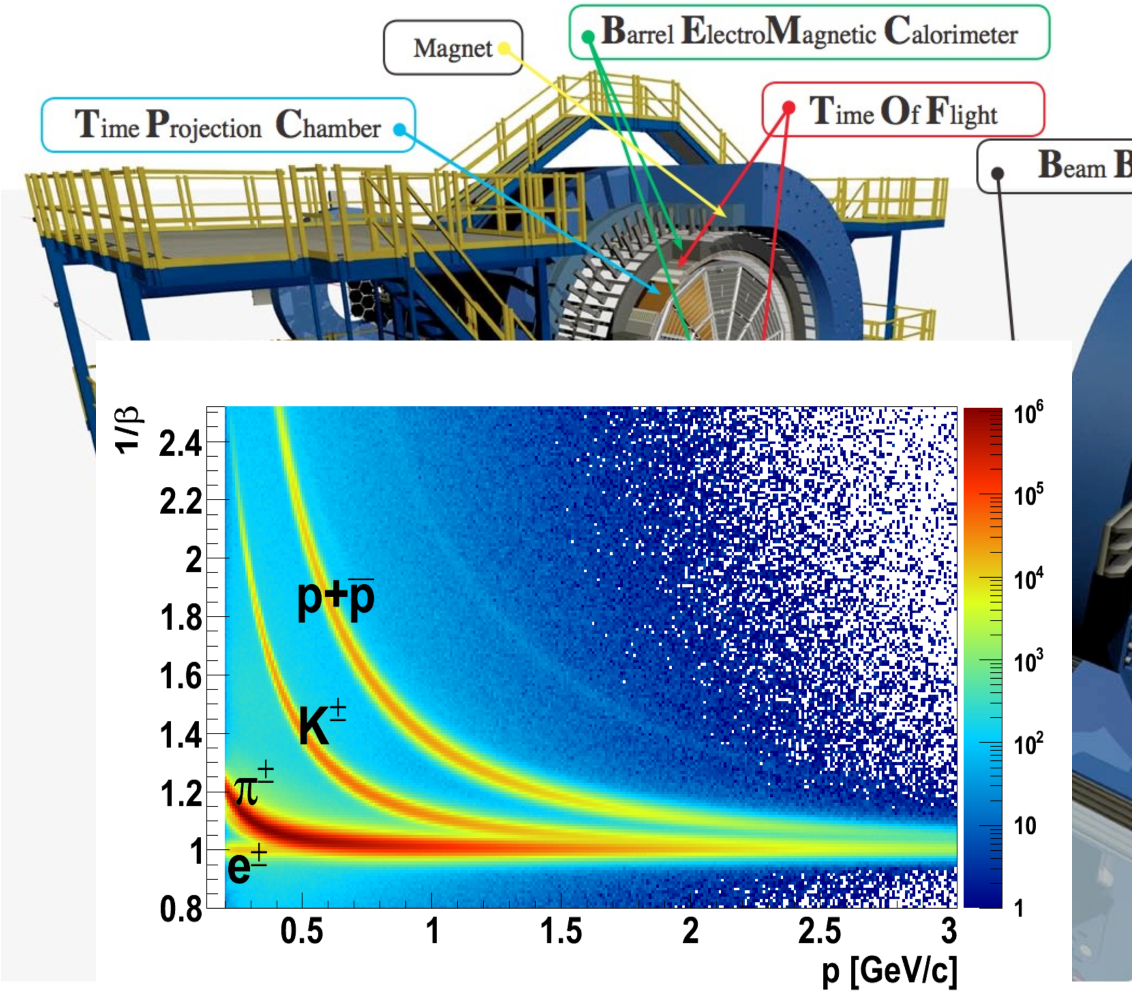


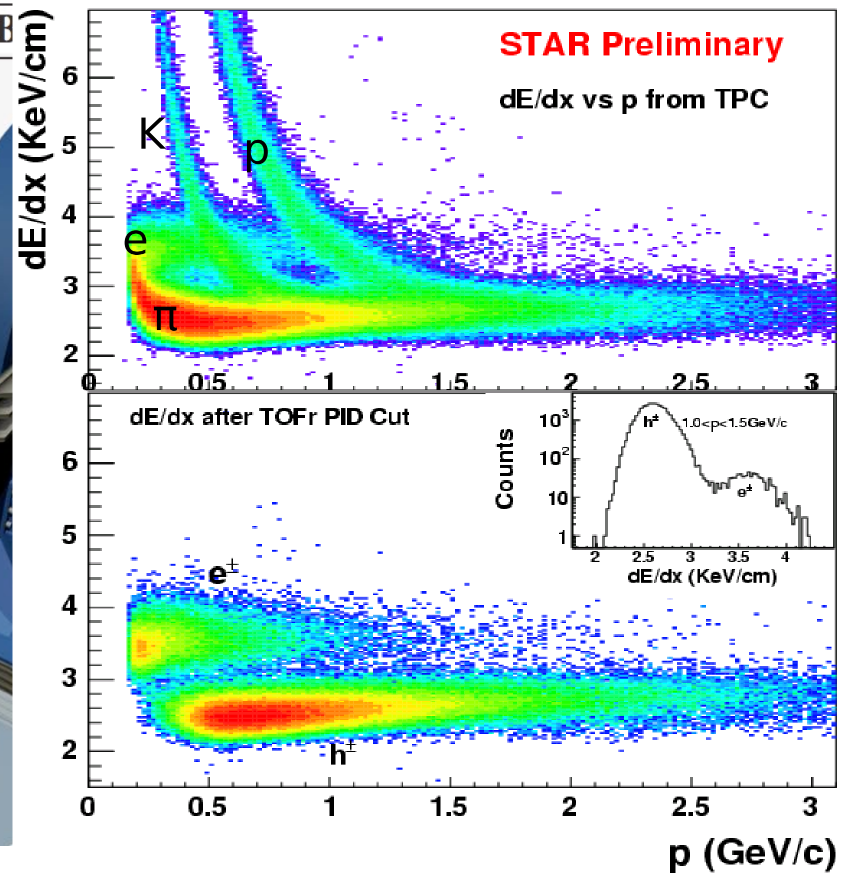
p_T(GeV/c)

STAR detector at RHIC

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

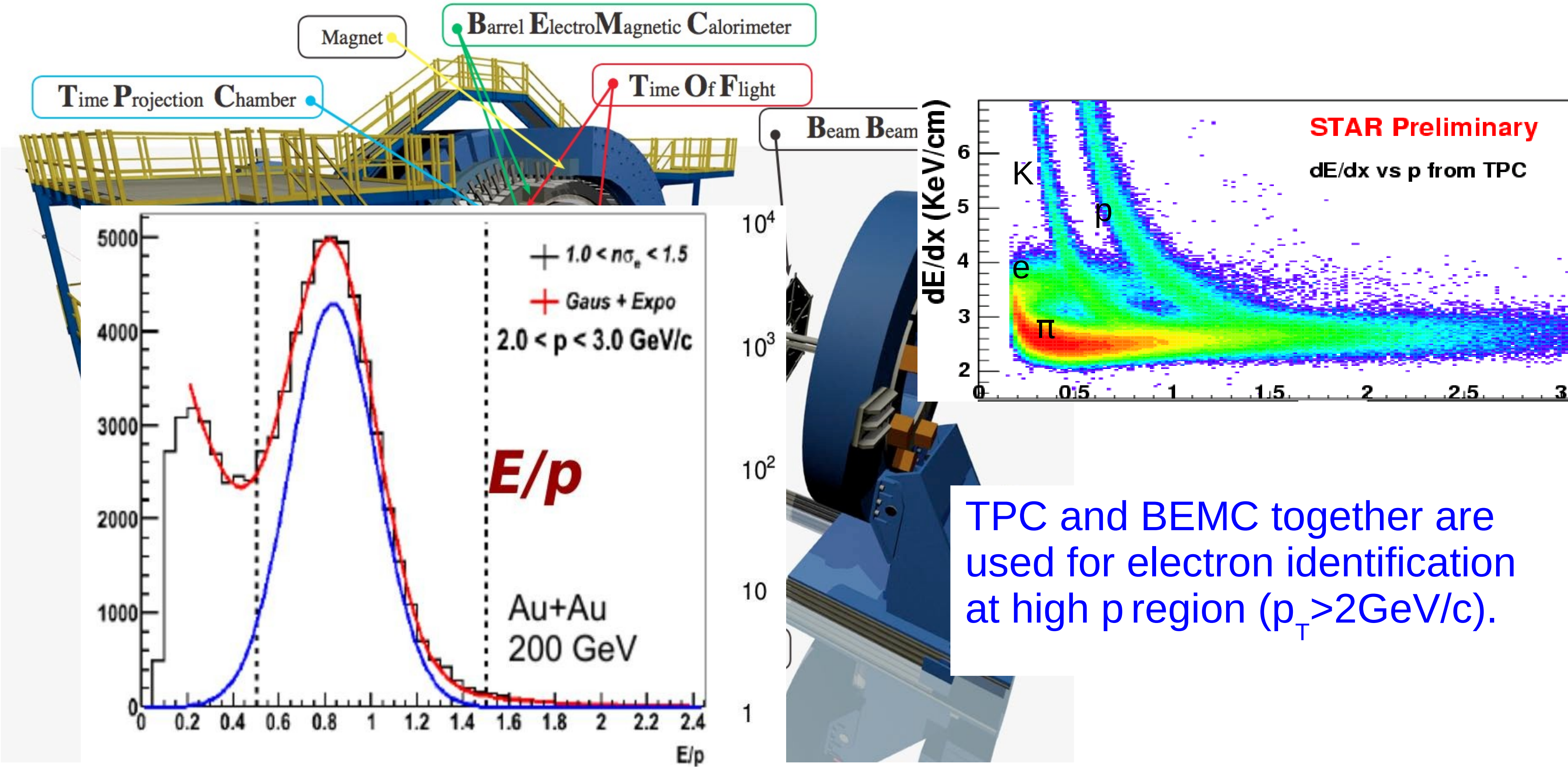
TPC and TOF together are great tool to distinguish electrons and hadrons at low p region (p_T<2GeV/c).





STAR detector at RHIC

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



TPC and BEMC together are used for electron identification at high p region (p_T>2GeV/c).

Analysis method

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

- Inclusive electrons – identification with TPC, TOF, BEMC.
- Main background - photonic electrons

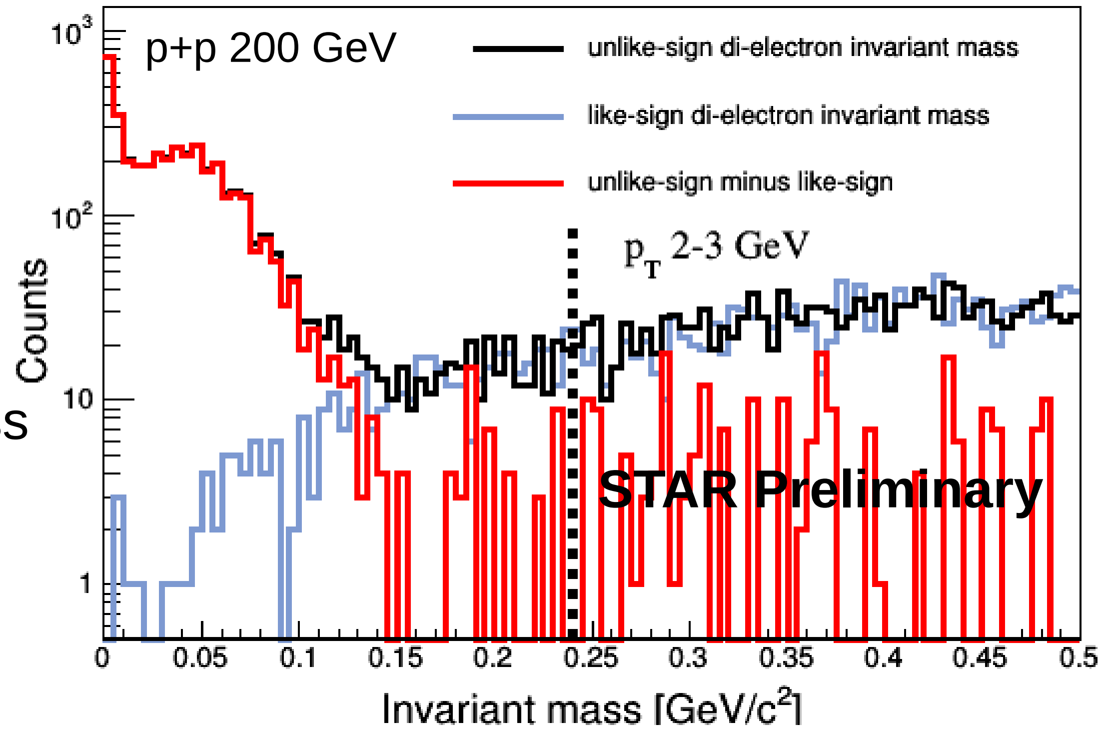
  Dalitz decay: $\pi^0 \rightarrow \gamma + e^+ + e^-$ (BR: ~1.2%)

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

→ identified via small e^+e^- invariant mass

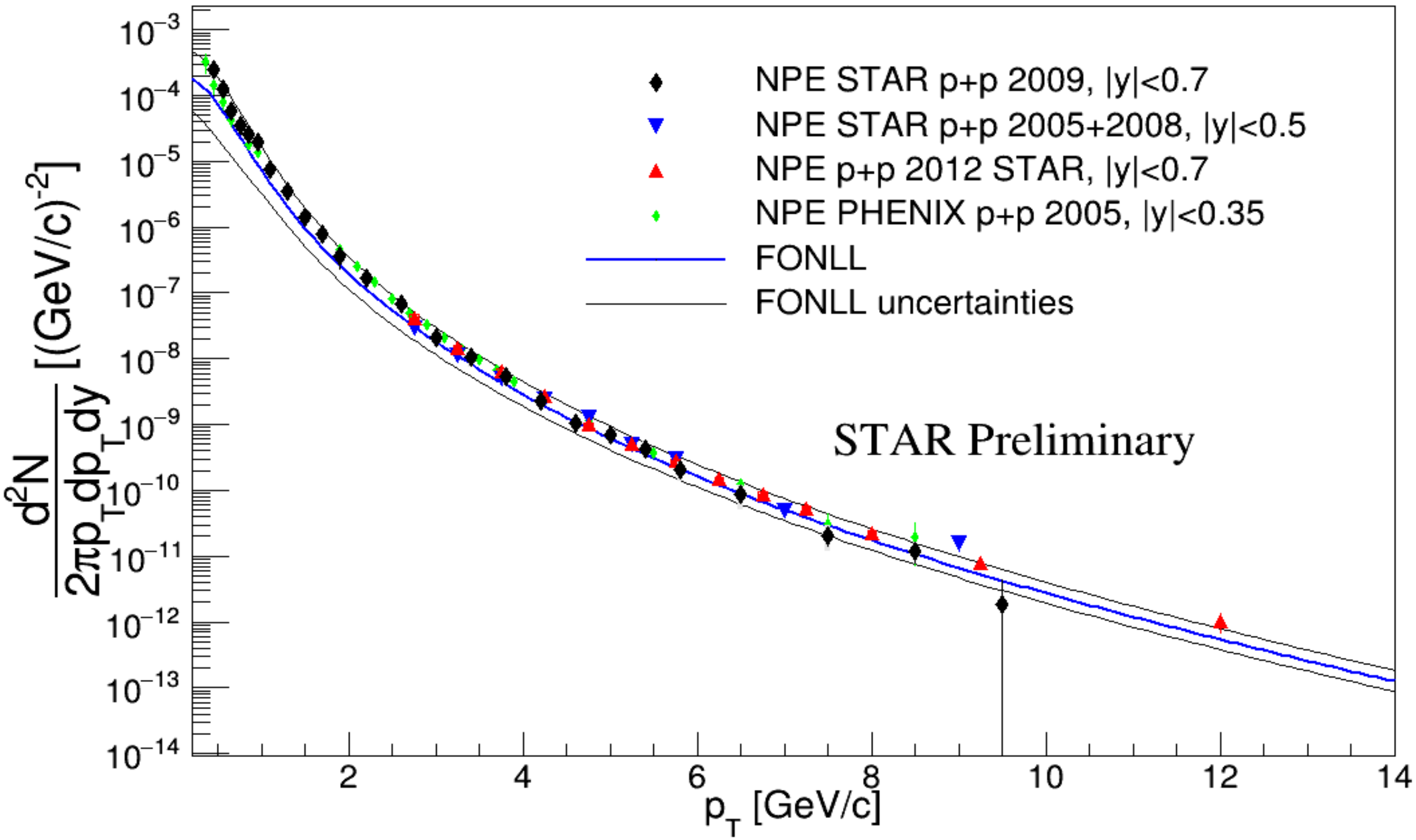
→ statistically reconstructed

→ corrected for reconstruction efficiency via simulation



NPE in p+p collisions at √s=200GeV

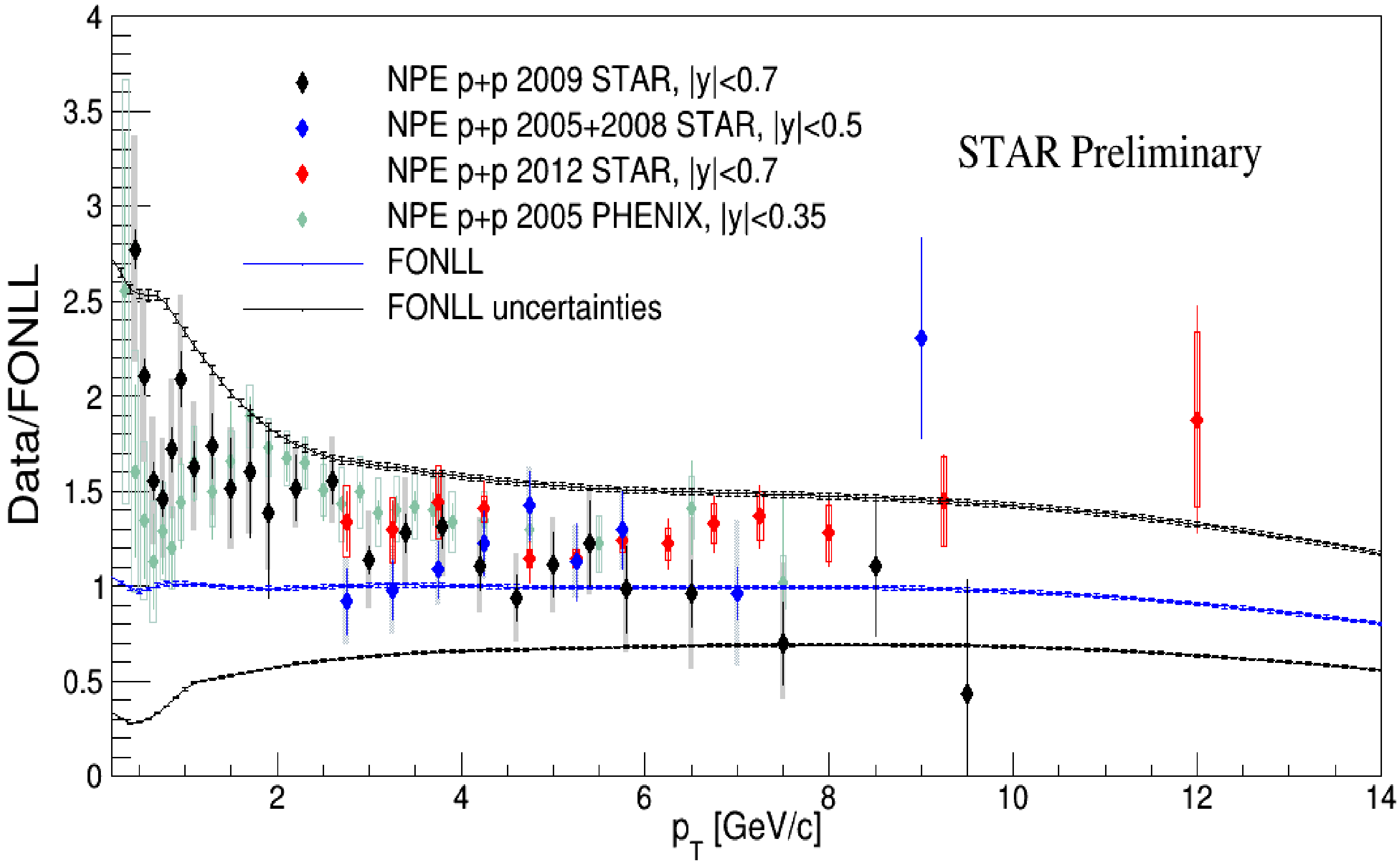
- p+p at 200GeV data (year 2009 and year 2012)
- Spectrum is reconstructed at wide p_T range.
- Results are compared with FONLL pQCD. (Fixed Order plus Next-to-Leading Logarithms).



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

- Results compared with FONLL calculation.
- Results are consistent with FONLL and with other RHIC NPE results.



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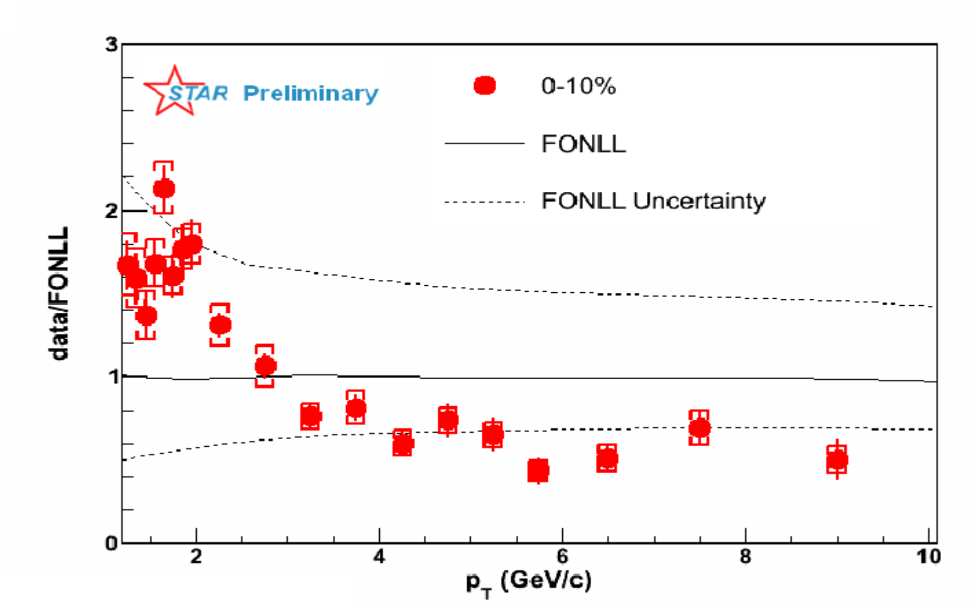
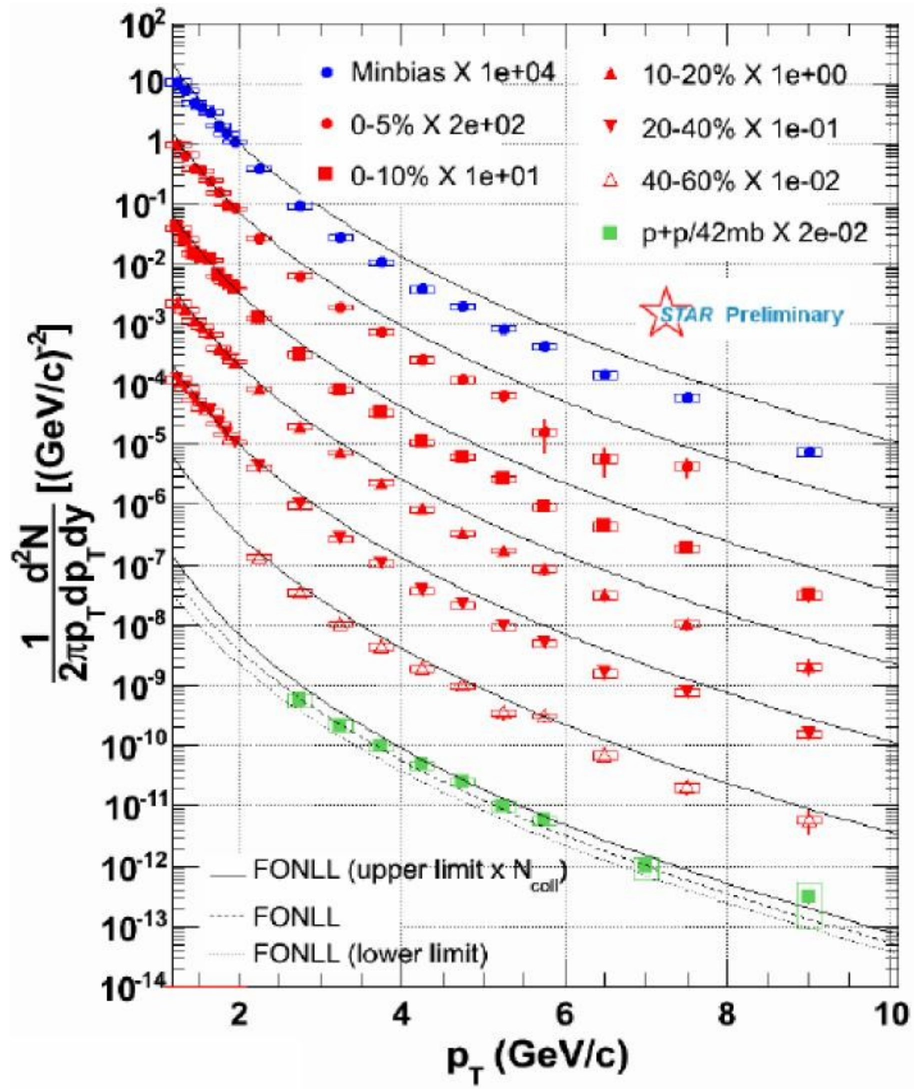
NPE in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV

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

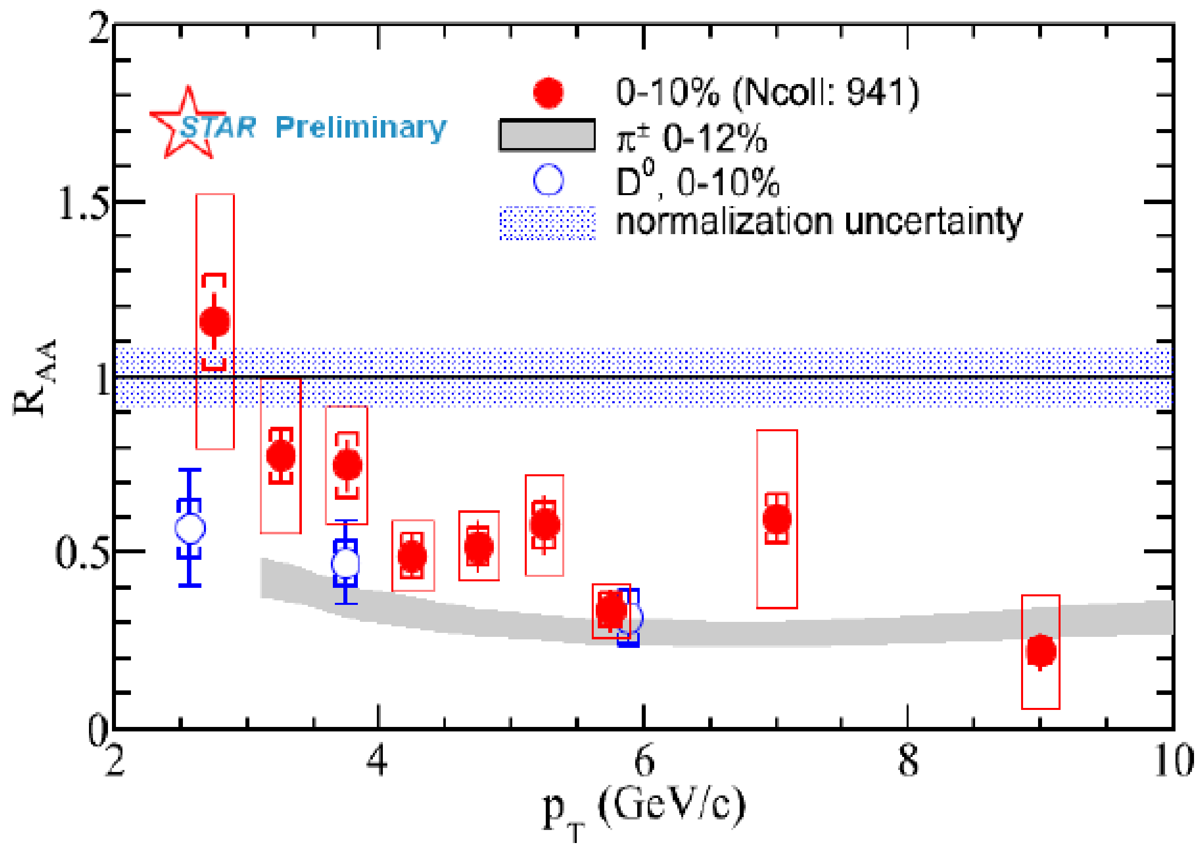




Nuclear Modification Factor in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV

→ Strong suppression is observed at high p_T.

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

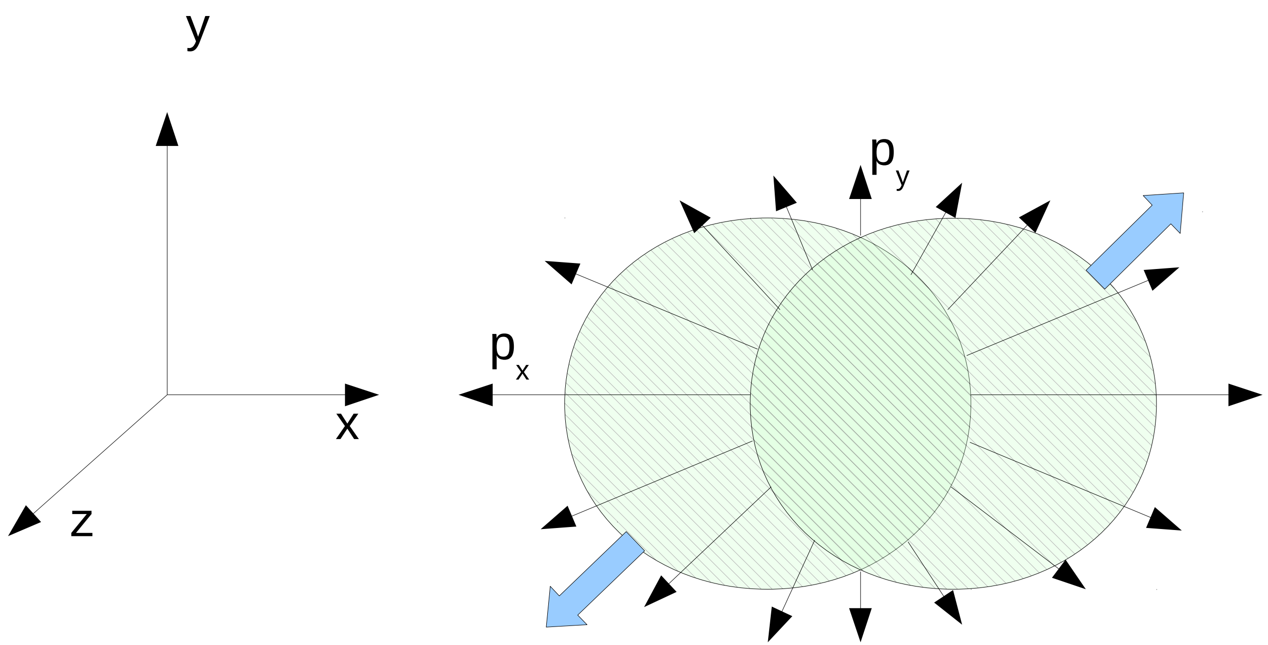


D^0 - Phys. Rev. Lett. 113, 142301 (2014).

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

Elliptic flow in Au+Au collisions

- Elliptic flow v_2 describes the collective evolution of system.
- Initial geometry asymmetry → final momentum anisotropy
- NPE v_2 measurement serves as a proxy for heavy quark v_2.

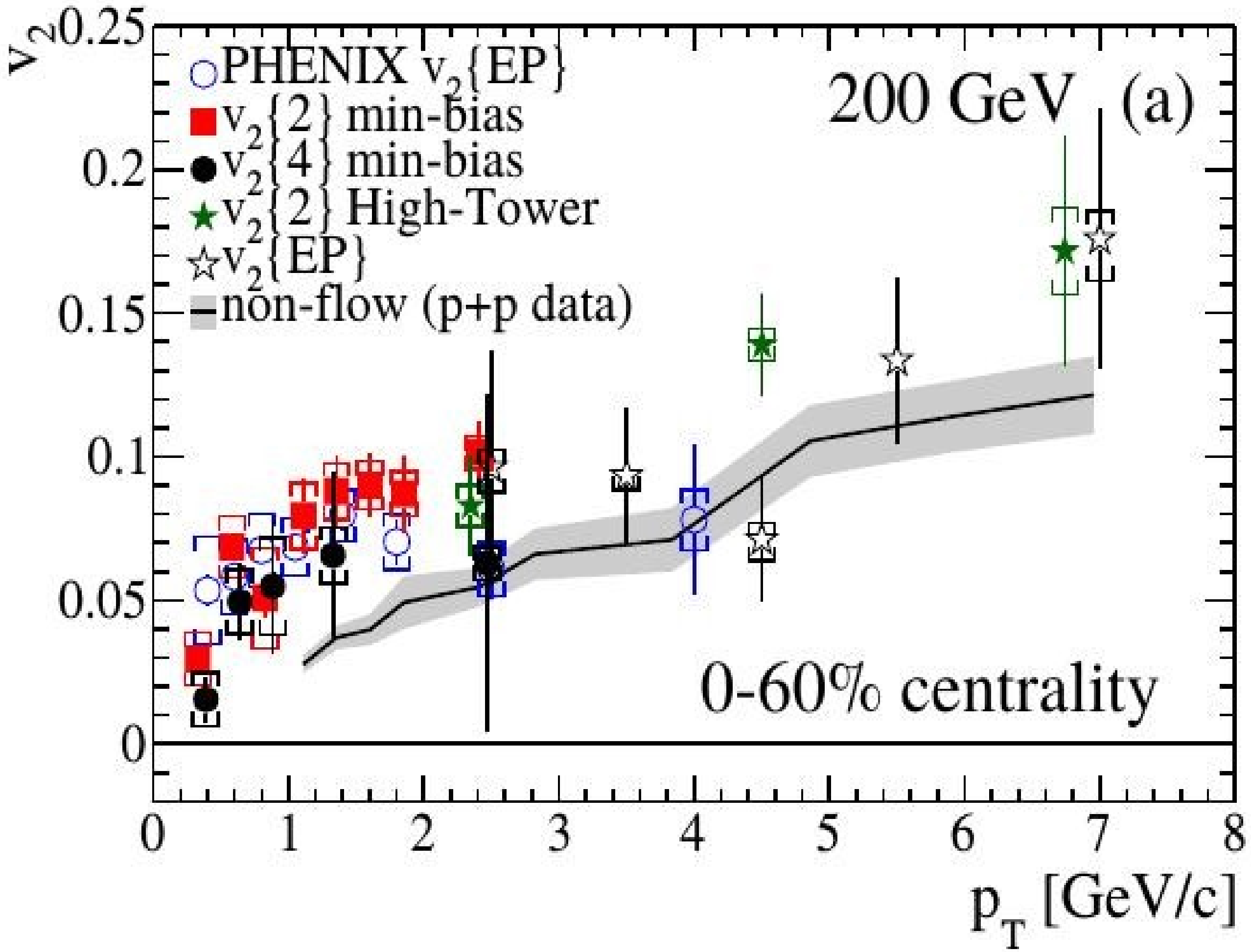


$$\frac{dN}{d\varphi} \propto \left(1+2\sum v_n \cos[n(\varphi-\psi_n)]\right)$$

$$v_n = \langle \cos n(\varphi-\psi_n) \rangle$$

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

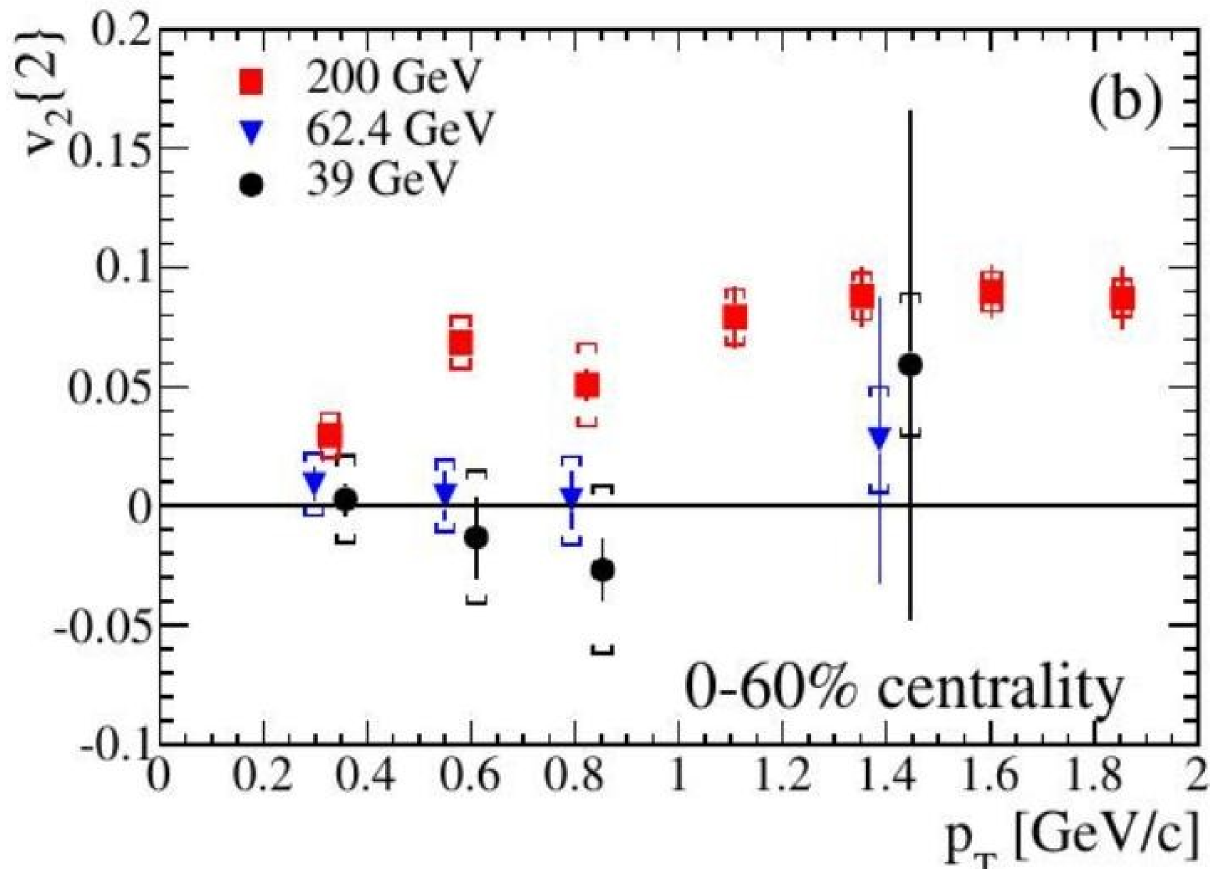
- Results obtained using 2-particle and 4-particle correlations.
- With different contributions from fluctuations and non-flow contribution, $v_2\{2\}$ gives upper and $v_2\{4\}$ gives lower limit on elliptic flow.
- We observed finite v2{2} and v2{4} for p_T>0.5 GeV/c at $\sqrt{s_{NN}}$=200 GeV.



arXiv:1405.6348 [nucl-ex]

NPE elliptic flow in Au+Au collisions at $\sqrt{s_{NN}}$ = 39 and 62.4 GeV

- $v_2\{2\}$ Beam Energy Scan results
- Energy dependance of the strength of heavy quarks interaction with hot and dense medium.
- Inclusive charged hadron v_2 approximatelly independent of beam energy.
- NPE $v_2\{2\}$ at 39 and 62.4 GeV is consistent with zero.



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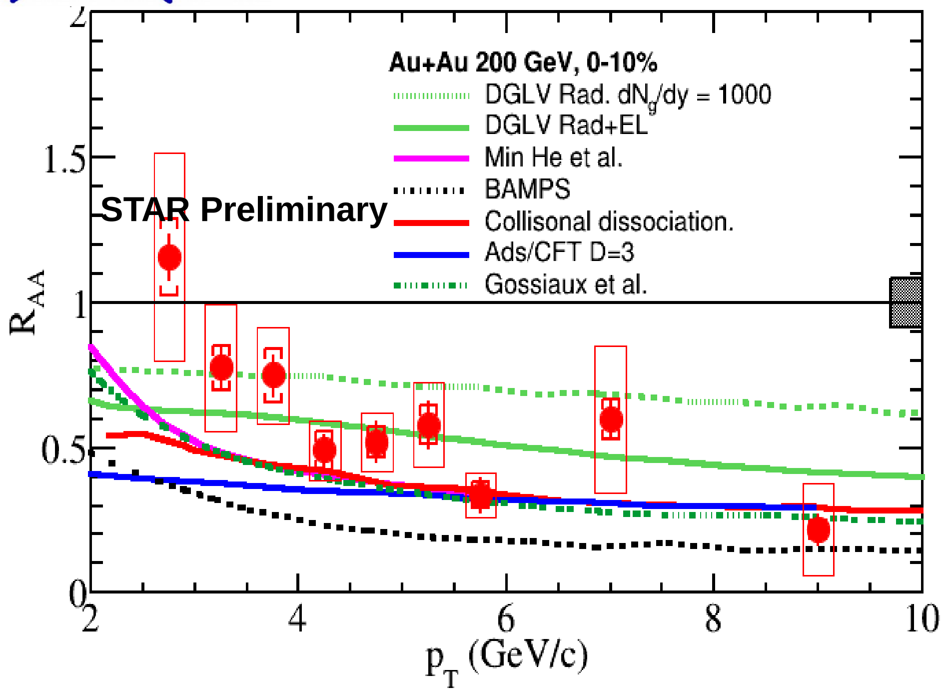
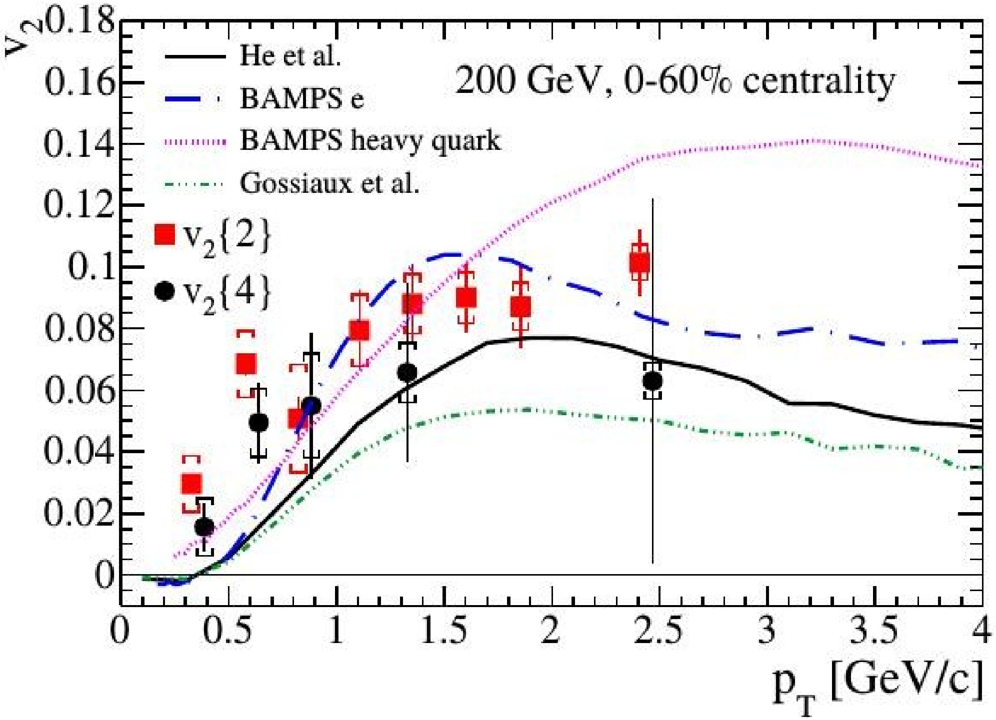
NPE R_{AA} and elliptic flow - model comparision





arXiv:1405.6348 [nucl-ex]

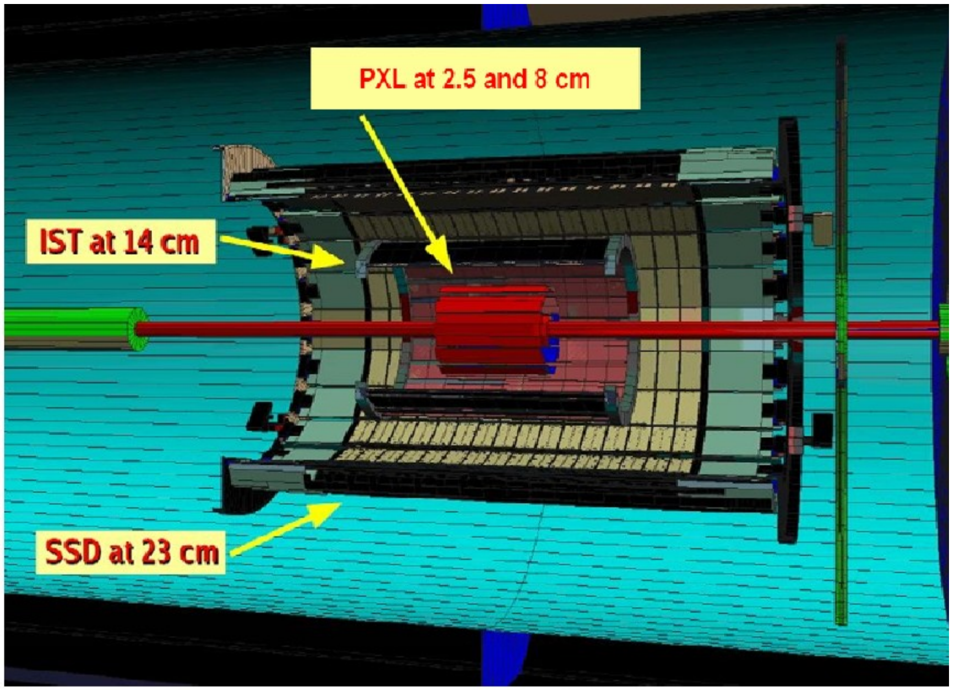
Brackets – syst. errors from Au+Au analysis
Boxes – syst. and stat. errors from p+p analysis

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

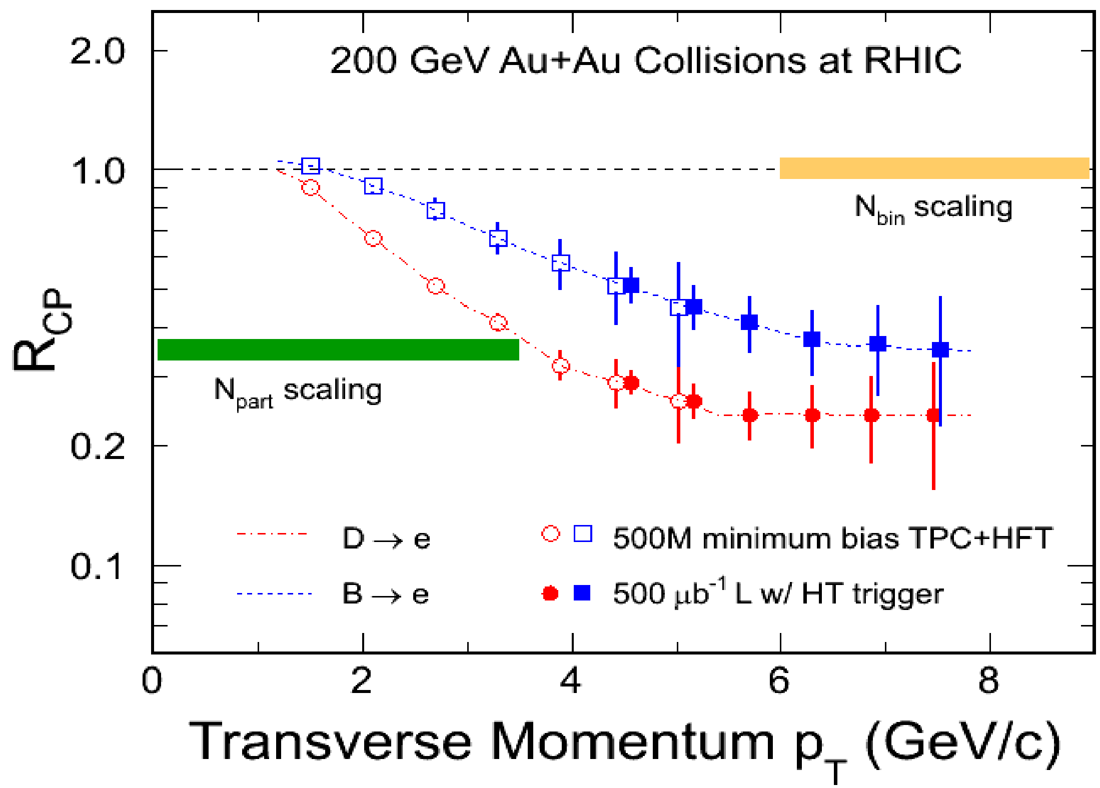
Finite elliptic flow together with large suppression at high p_T at $\sqrt{s_{NN}}$= 200 GeV indicates that heavy quarks interact strongly with the surrounding partonic medium.

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).

- HFT allows measurement of B → e and D → e spectrum separately in Au+Au.

Conclusions

- Measurement of the NPE spectrum in p+p collisions at $\sqrt{s}$=200 GeV was extended to the low p_T region.
- We observed strong suppression of NPE in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV.
- NPE v_2 at $\sqrt{s_{NN}}$=200 GeV in Au+Au collisions: finite v_2 at low p_T together with strong suppression at high p_T indicates a strong charm-medium interaction.
- NPE v_2 at $\sqrt{s_{NN}}$=39 and 62.4 GeV in Au+Au collisions: v_2 consistent with zero.
- The new HFT detector will allow measurement of $B \rightarrow e$ and $D \rightarrow e$ spectra separately.

Thank you!