Open charm hadron measurement in p+p and Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV in STAR

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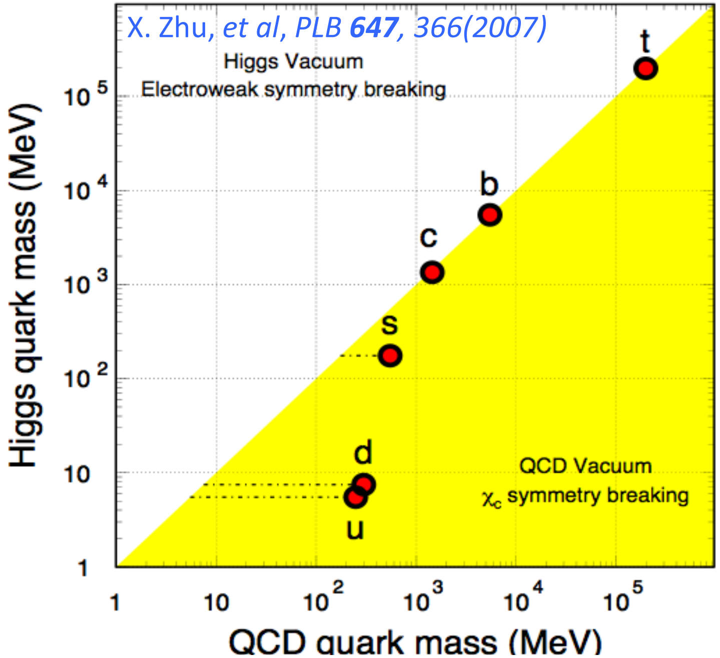
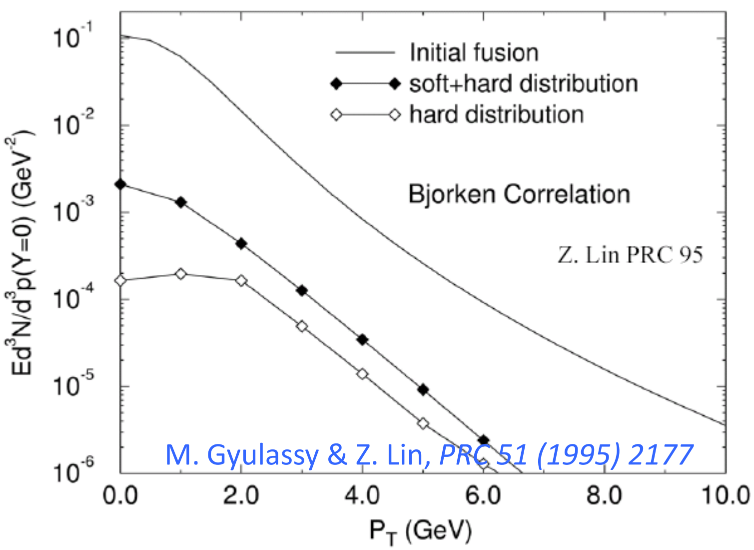
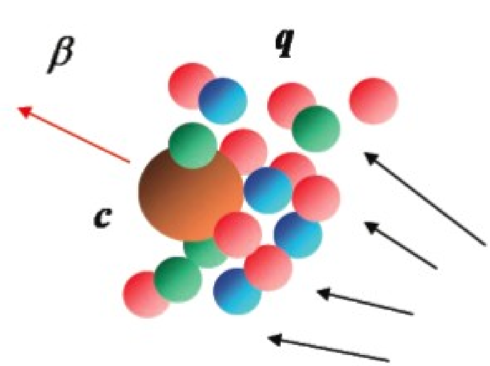
Outline:

- Motivation
- D^0 and D^* measurement in p+p collisions at 200 GeV
- D^0 measurement in Au+Au collisions at 200 GeV
- Charm cross section, R_{AA}
- Summary and outlook

Why study heavy quarks?







- Higgs mass: electro-weak symmetry breaking (current quark mass).
- QCD mass: Chiral symmetry breaking (constituent quark mass).
- Strong interactions do not affect heavy quark mass.

➢ Study properties of the hot and dense medium at the early stage of heavy-ion collisions.

➢ Test pQCD at RHIC.

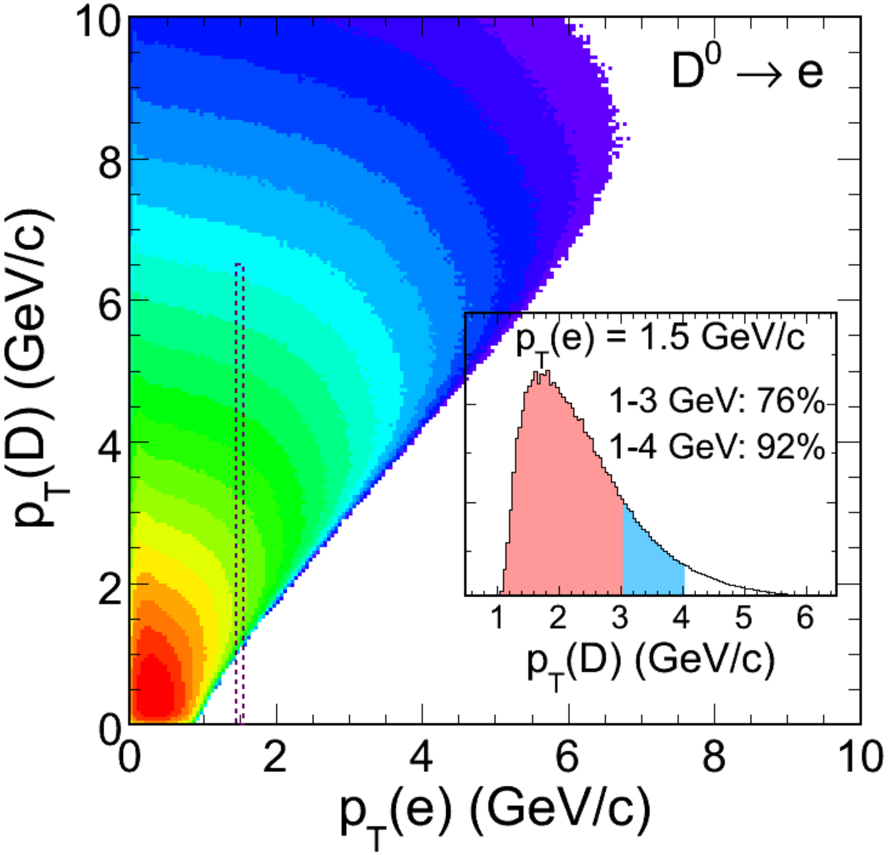
➢ Charm collectivity => Light flavor thermalization.

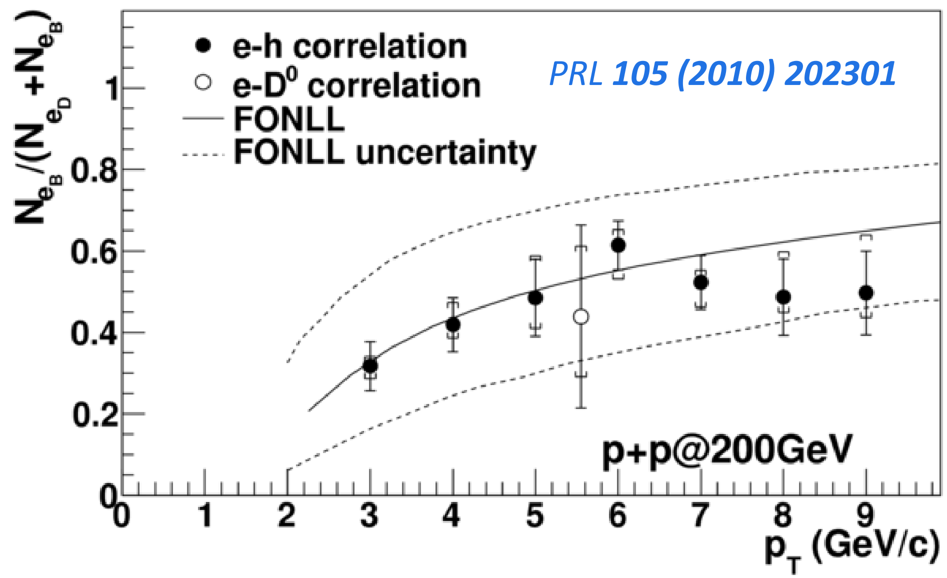
Why measure D mesons?

Known limitations in semi-leptonic channel.

1) Kinematics smearing due to decay.

2) Suffering from charm and bottom contributions.

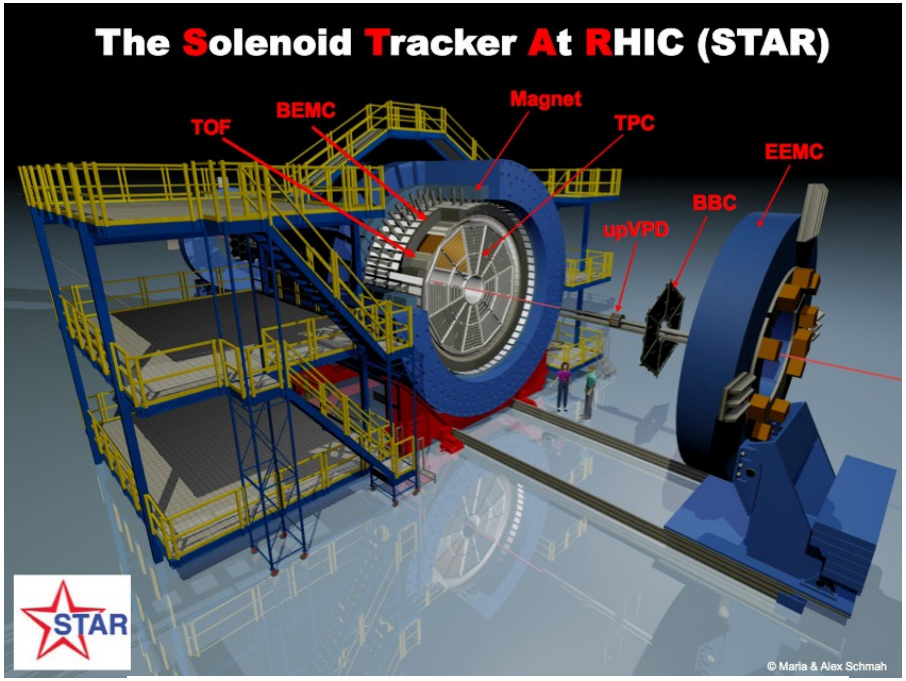




Both FONLL calculation and experimental data from electron channel are with large uncertainties.

Direct measurement of D meson provides clean information of charm quark.

STAR detector and Particle ID



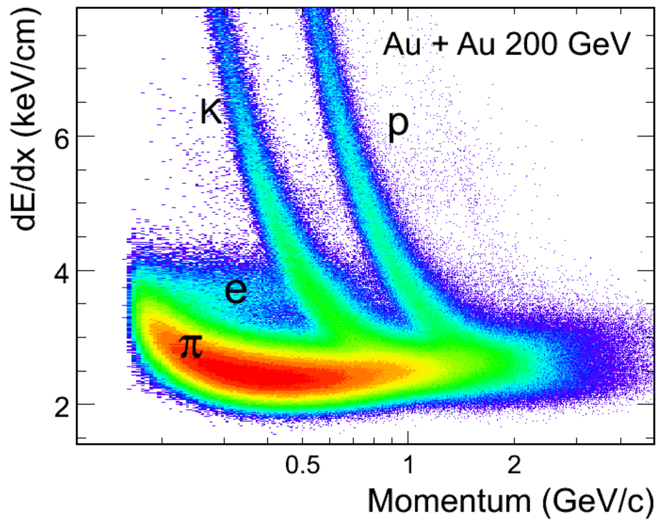
Large acceptance

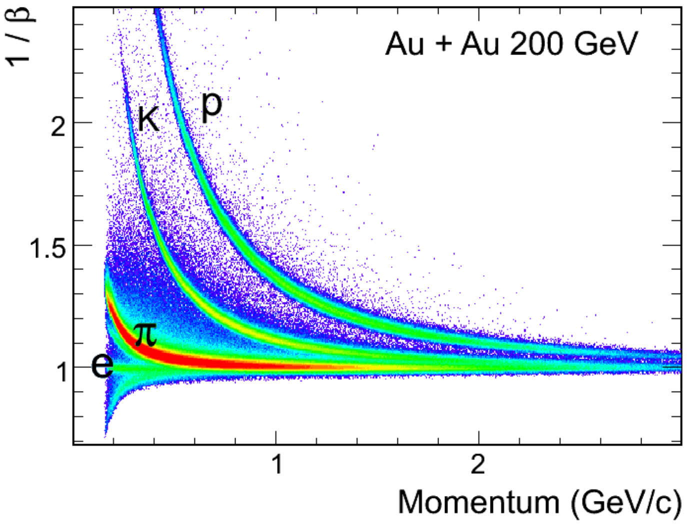
$|\eta|<1, \ 0<\phi<2\pi$

Year 2009 72% of full TOF

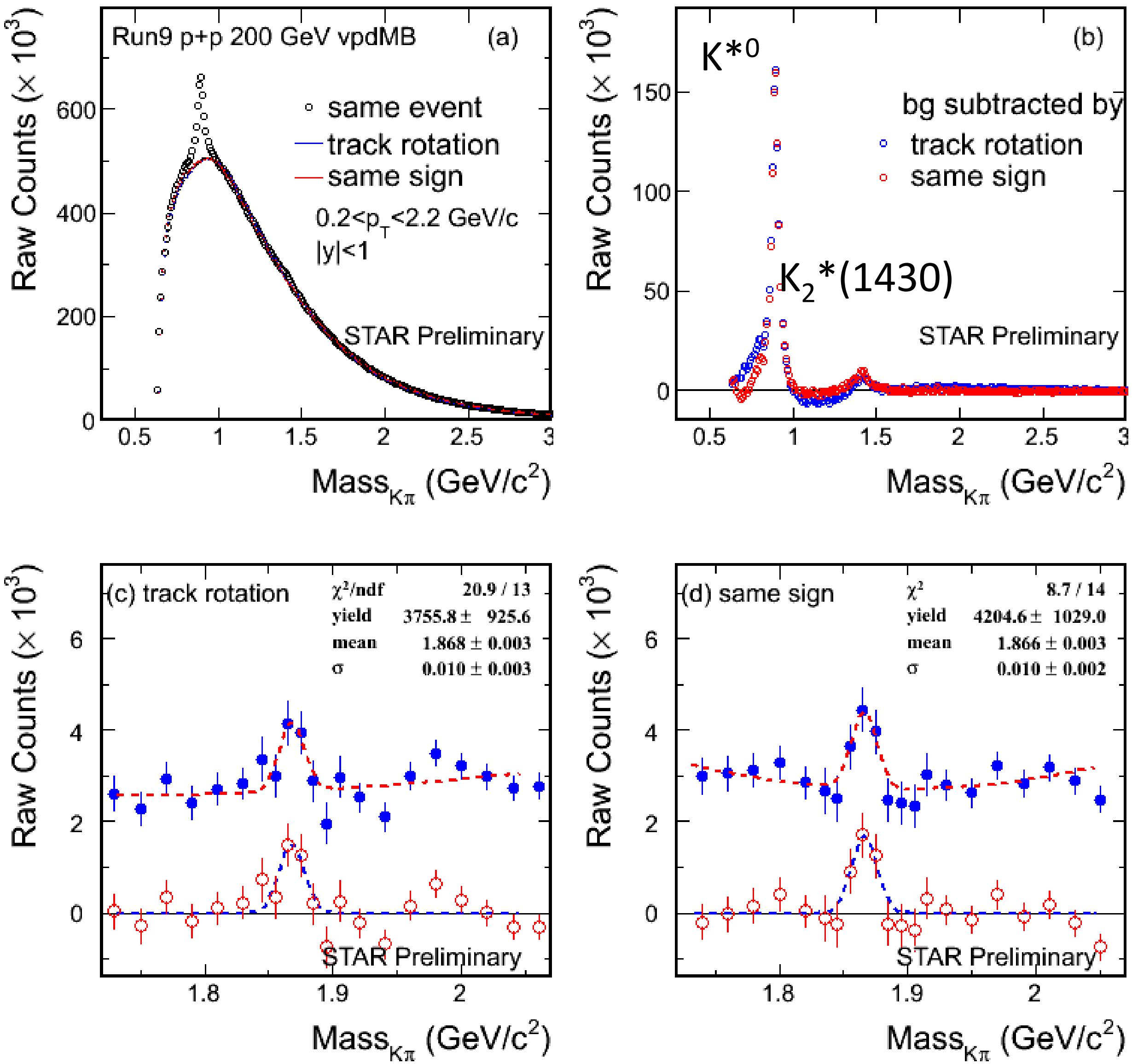
Year 2010 100% of full TOF

- Time Projection Chamber
  dE/dx, momentum
- Time Of Flight detector
  particle velocity $1/\beta$





D^0 signal in p+p 200 GeV



$D^0(\overline{D^0}) \rightarrow K^{\mp}\pi^{\pm}$

B.R. = 3.89%

p+p minimum bias 105 M

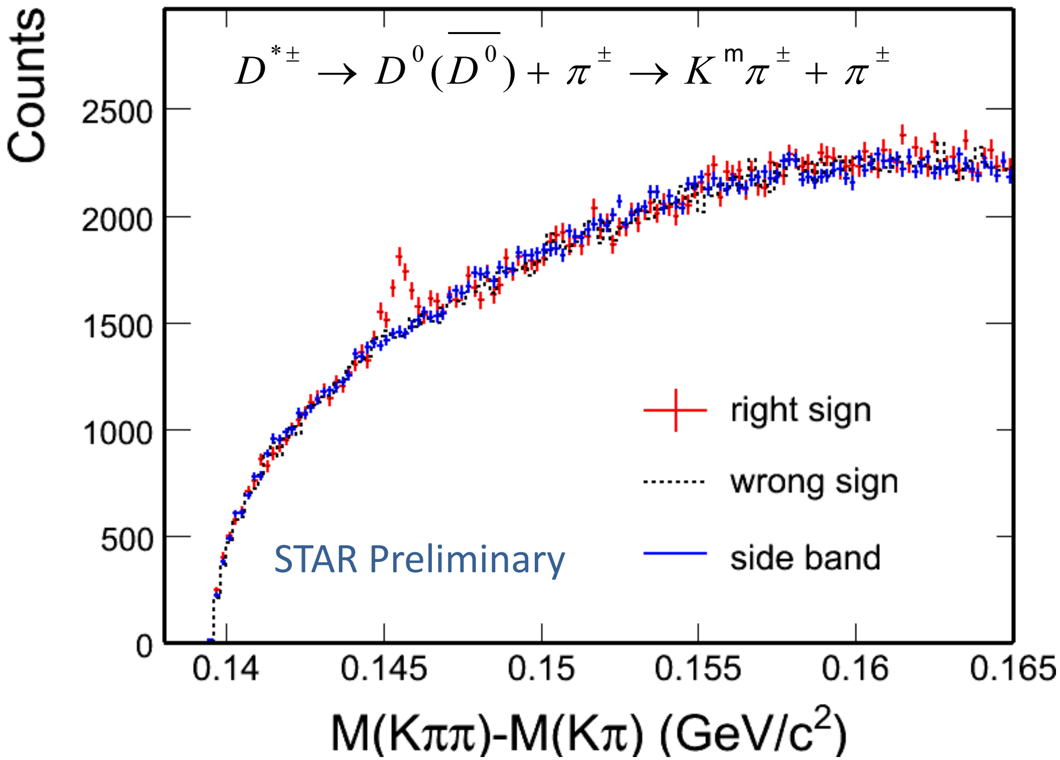
4-σ signal observed.

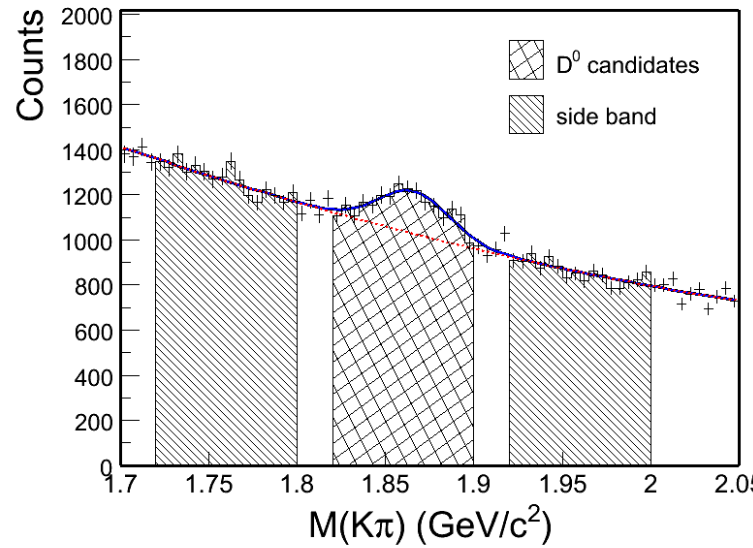
Different methods reproduce combinatorial background.

Consistent results from two background methods.

PDG mass = 1864.5 ± 0.4 MeV

D* signal in p+p 200 GeV





B.I.~Abelev, *et al., PRD 79 (2009) 112006.*

Minimum bias 105M events in p+p 200 GeV collisions.

Two methods to reconstruct combinatorial background: wrong sign and side band.

8-σ signal observed.

Background combinations:

Wrong sign:

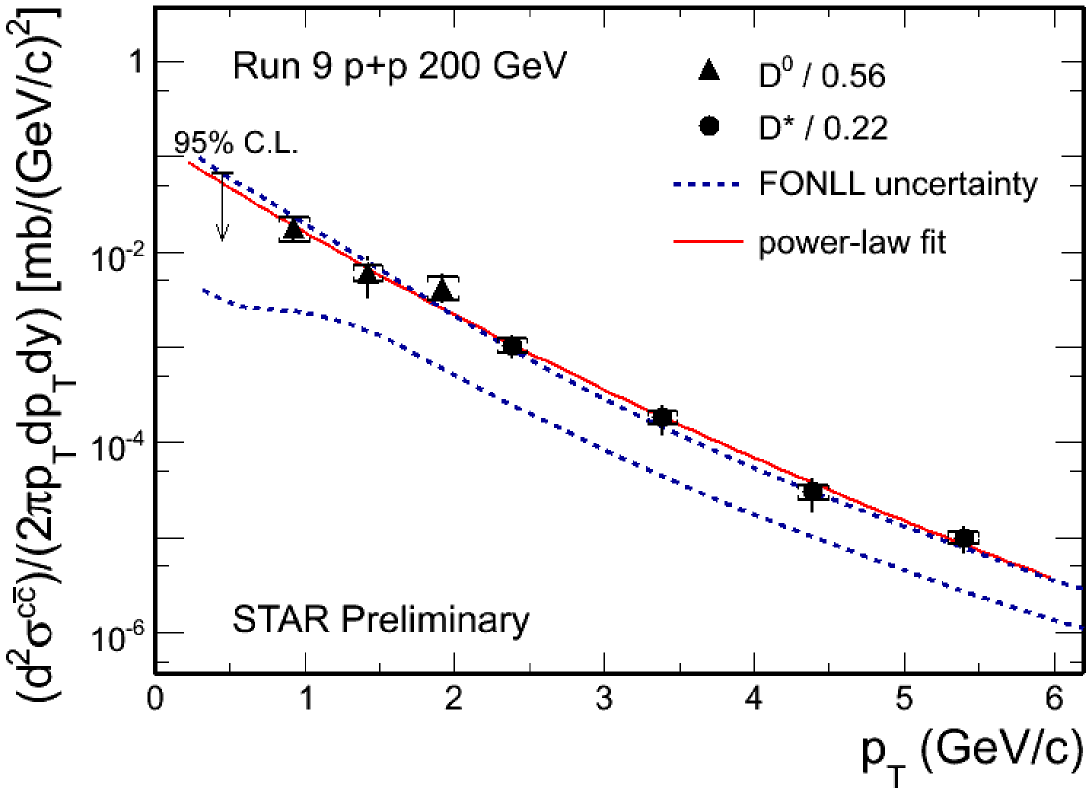
D^0 and π^-, $\overline{D}^0$ and π^+

Side band:

$1.72 < M(K\pi) < 1.80$ or

$1.92 < M(K\pi) < 2.0$ GeV/c²

D^0 and D* p_T spectra in p+p 200 GeV



D. Tlusty poster - #328

D^0 scaled by $N_{cc} / N_{D0} = 1 / 0.56$[1]

D* scaled by $N_{cc} / N_{D*} = 1 / 0.22$[1]

Consistent with FONLL[2] upper limit.

$Xsec = dN/dy|^{cc}_{y=0} \times F \times \sigma_{pp}$

$F = 4.7 \pm 0.7$ scale to full rapidity.

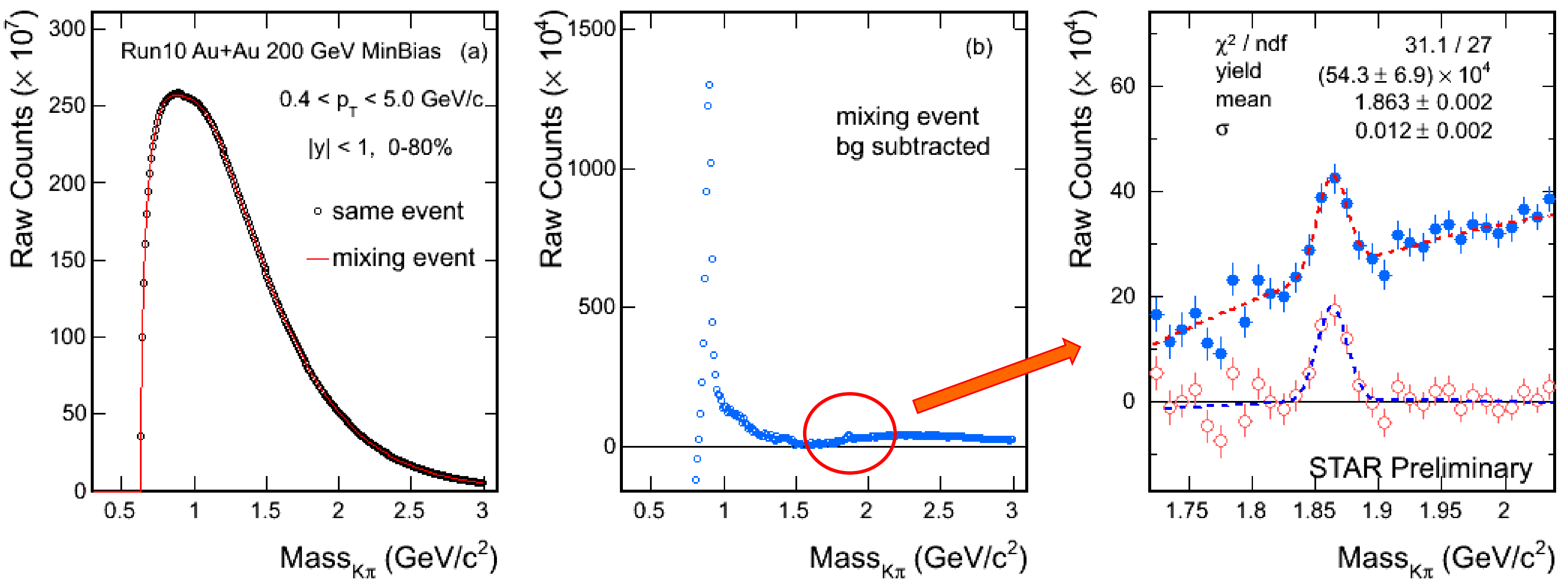
$\sigma_{pp}(NSD) = 30$ mb

The charm cross section at mid-rapidity is:
202 ± 56 (stat.) ± 40 (sys.) ± 20 (norm.) μb

The charm total cross section is extracted as:
949 ± 263 (stat.) ± 253 (sys.) μb

[1] C. Amsler et al. (Particle Data Group), PLB 667 (2008) 1.
[2] Fixed-Order Next-to-Leading Logarithm: M. Cacciari, PRL 95 (2005) 122001.

D^0 signal in Au+Au 200 GeV



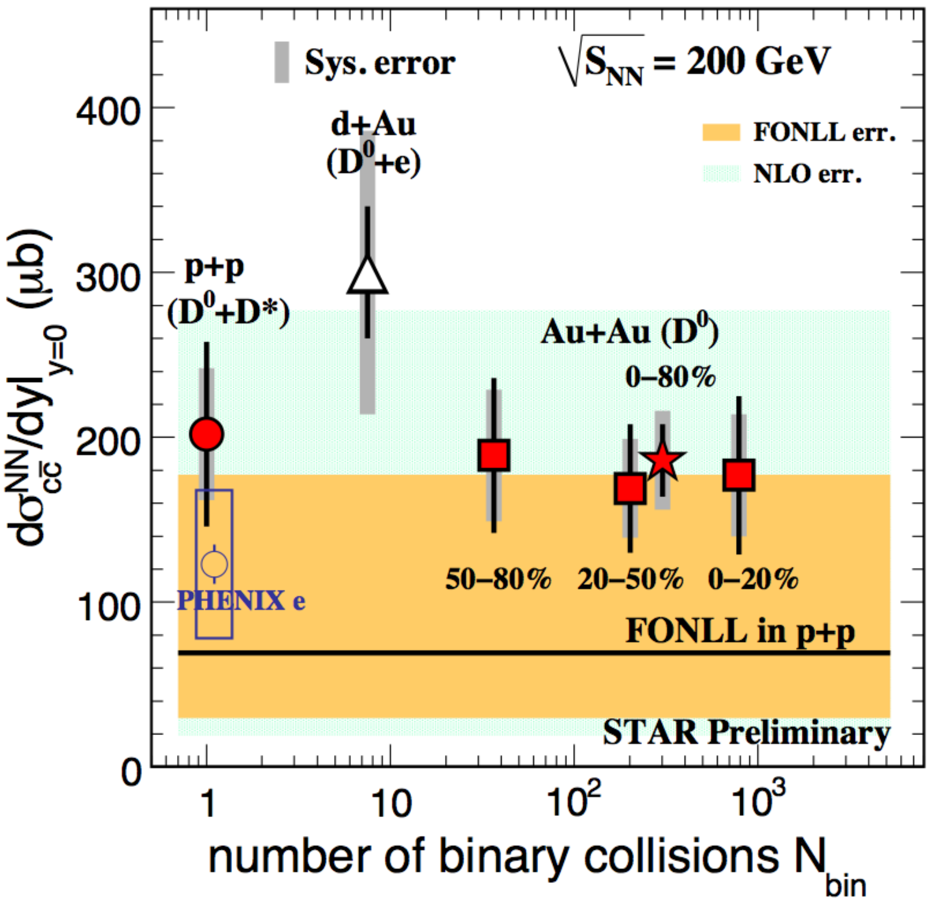
Year 2010 minimum bias 0-80% 280M Au+Au 200 GeV events.

8-σ signal observed.

Mass = 1863 ± 2 MeV (PDG value is 1864.5 ± 0.4 MeV)

Width = 12 ± 2 MeV

Charm cross section vs N_{bin}



All of the measurements are consistent.

Year 2003 d+Au : D^0 + e

Year 2009 p+p : D^0 + D*

Year 2010 Au+Au: D^0

Assuming N_{D0} / N_{cc} = 0.56 does not change.

Charm cross section in Au+Au 200 GeV:

Mid-rapidity:

186 ± 22 (stat.) ± 30 (sys.) ± 18 (norm.) μb

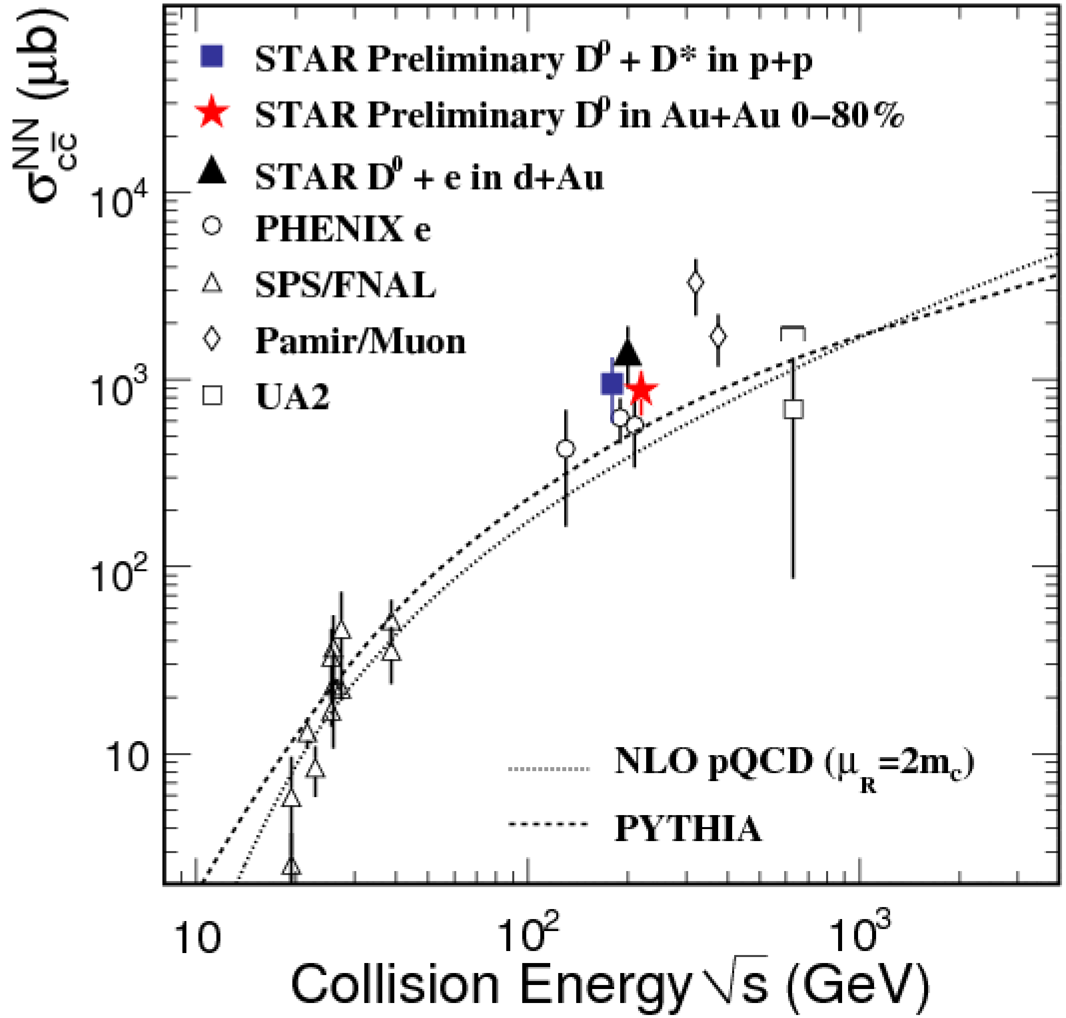
Total cross section:

876 ± 103 (stat.) ± 211 (sys.) μb

[1] STAR d+Au: J. Adams, et al., PRL 94 (2005) 62301
[2] FONLL: M. Cacciari, PRL 95 (2005) 122001.
[3] NLO: R. Vogt, Eur.Phys.J.ST 155 (2008) 213
[4] PHENIX e: A. Adare, et al., PRL 97 (2006) 252002.

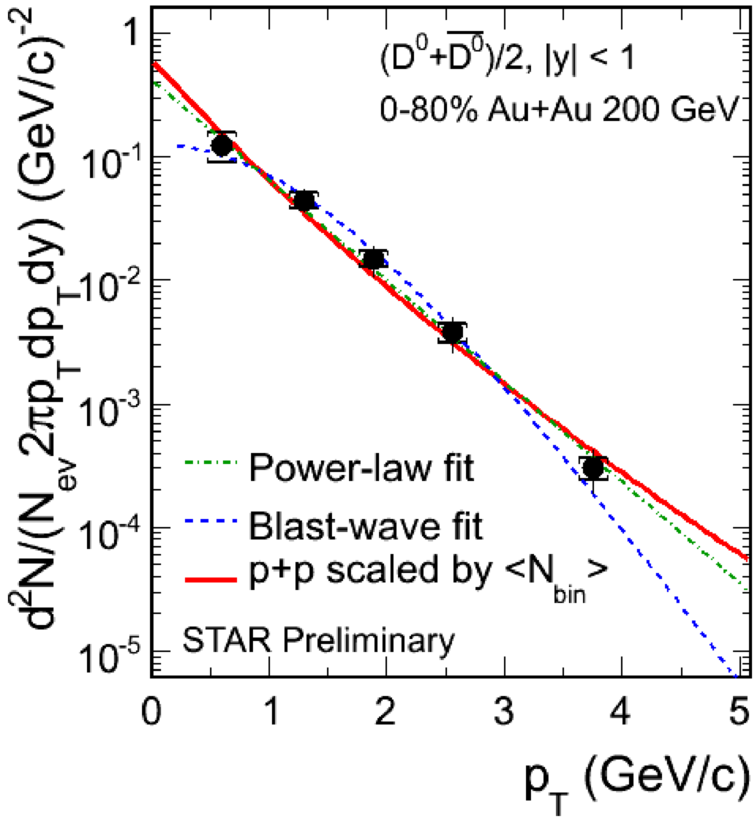
Charm cross section follows number of binary collisions scaling =>
Charm quarks are mostly produced via initial hard scatterings.

Charm cross section vs $\sqrt{s_{NN}}$

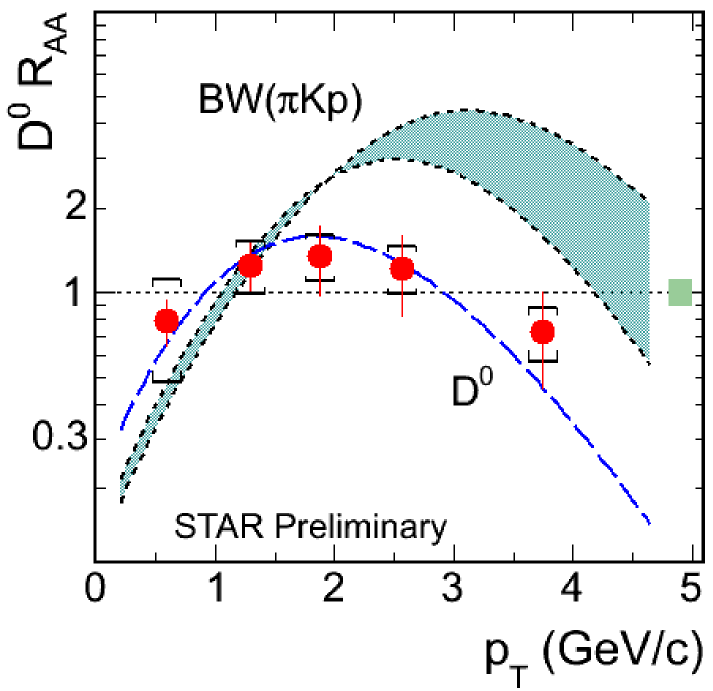


Compared with other experiments, provide constraint for theories.

D^0 R_{AA} vs p_T



BW (πKp): B. I. Abelev, et al., Phys. Rev. C 79 (2009) 34909.



D^0 Au+Au 0-80% divided by p+p with <N_{bin}> scaled.

No obvious suppression at p_T < 3 GeV/c.

Blast-wave predictions with light hadron parameters are different from data.

=> D^0 freeze out earlier than light hadrons.

Summary

◆ D^0 and D^* are measured in p+p 200 GeV up to p_T = 6 GeV/c.

◆ D^0 is measured in Au+Au 200 GeV up to p_T = 5 GeV/c.

◆ The charm cross section per nucleon-nucleon collision in mid-rapidity is measured to be

p+p: 202 ± 56 (stat.) ± 40 (sys.) ± 20 (norm.) mb

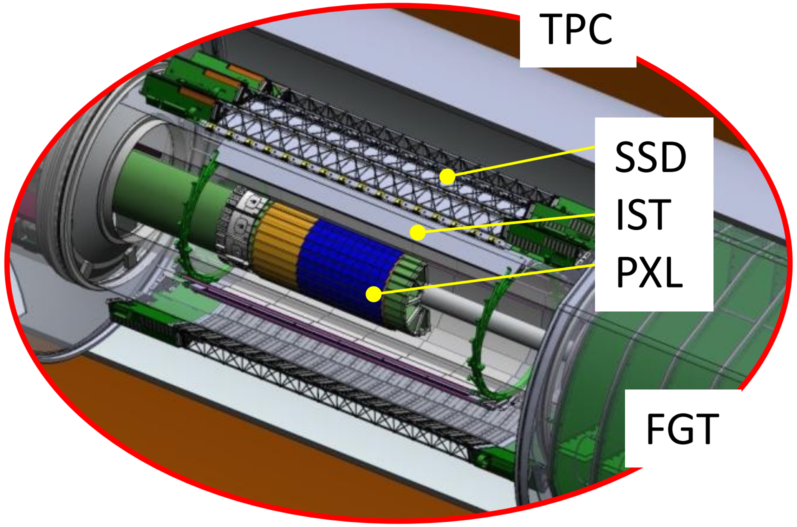
Au+Au: 186 ± 22 (stat.) ± 30 (sys.) ± 18 (norm.) mb

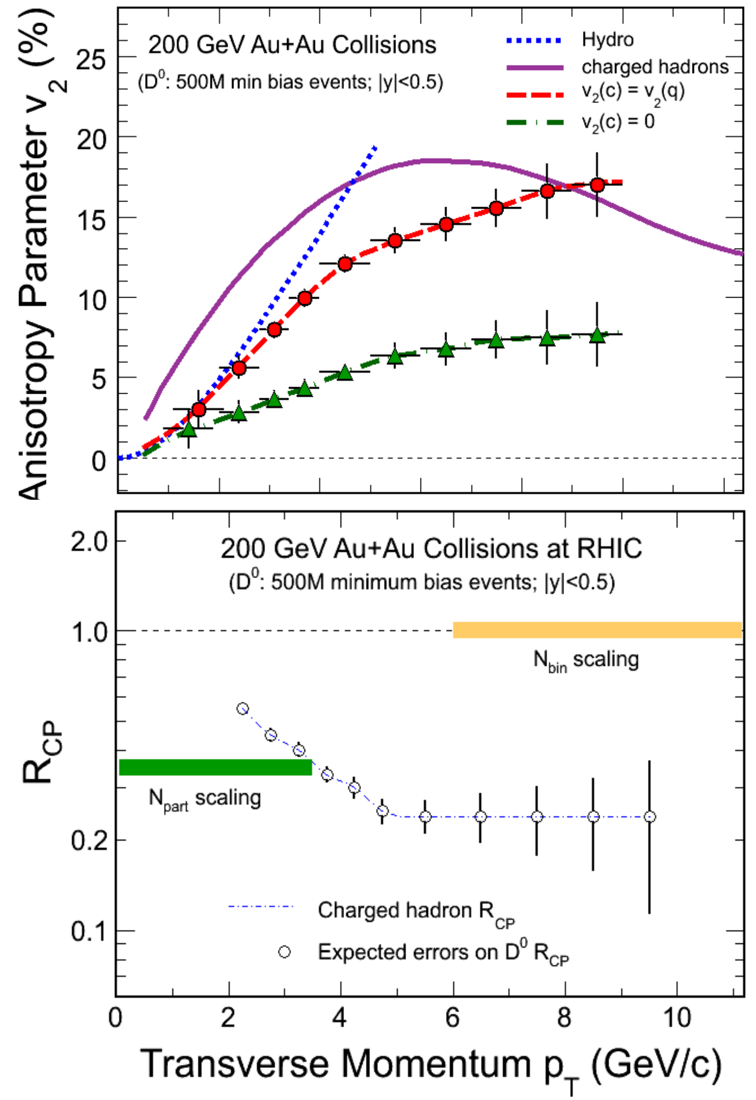
◆ Charm cross sections at mid-rapidity follow number of binary collisions scaling, which indicates charm quarks are mostly produced via initial hard scatterings.

◆ D^0 nuclear modification factor R_{AA} is measured. No obvious suppression observed at p_T < 3 GeV/c.

◆ Blast-wave predictions with light hadron parameters are different from D^0 data, which indicates that D^0 decouples earlier from the medium than light hadrons.

Outlook





STAR Heavy Flavor Tracker Project.

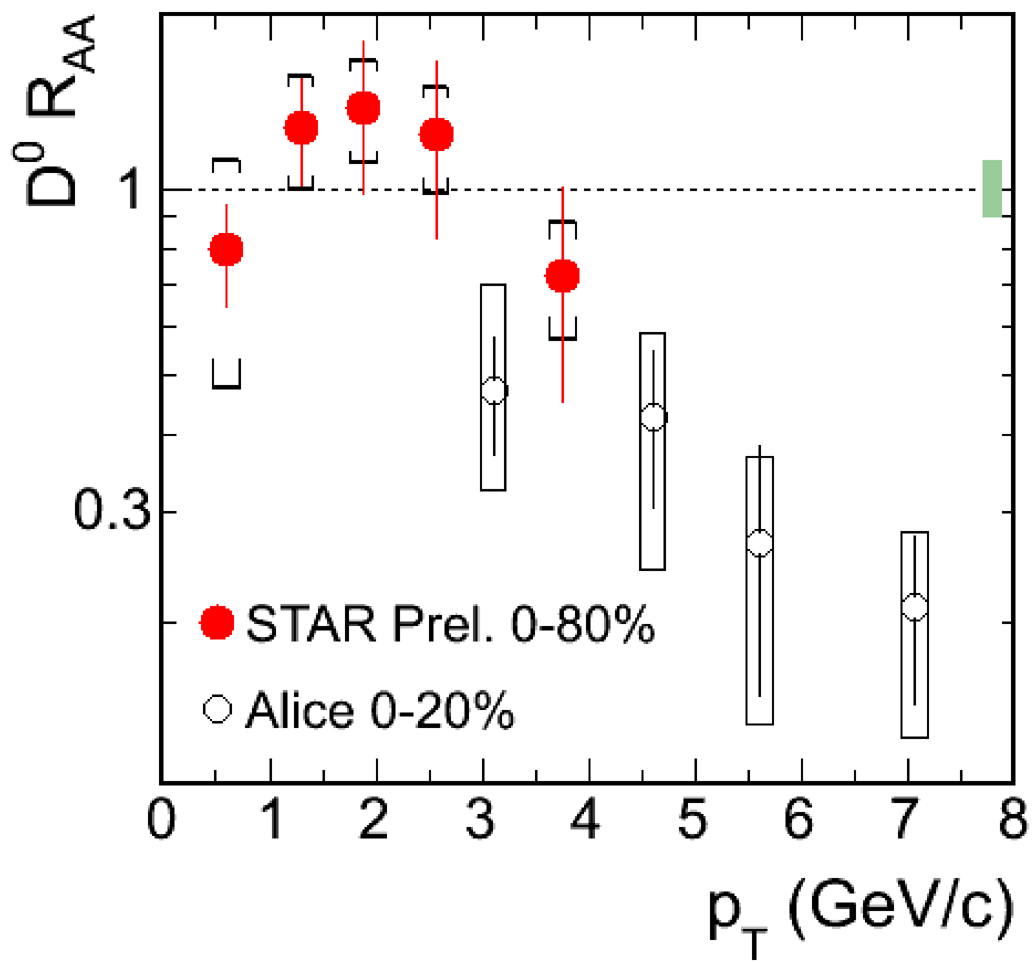
- ✓ Reconstruct secondary vertex.
- ✓ Dramatically improve the precision of measurements.

  Dca resolution: < 20 μm at p_T > 2 GeV/c.
- ✓ Address physics related to heavy flavor.

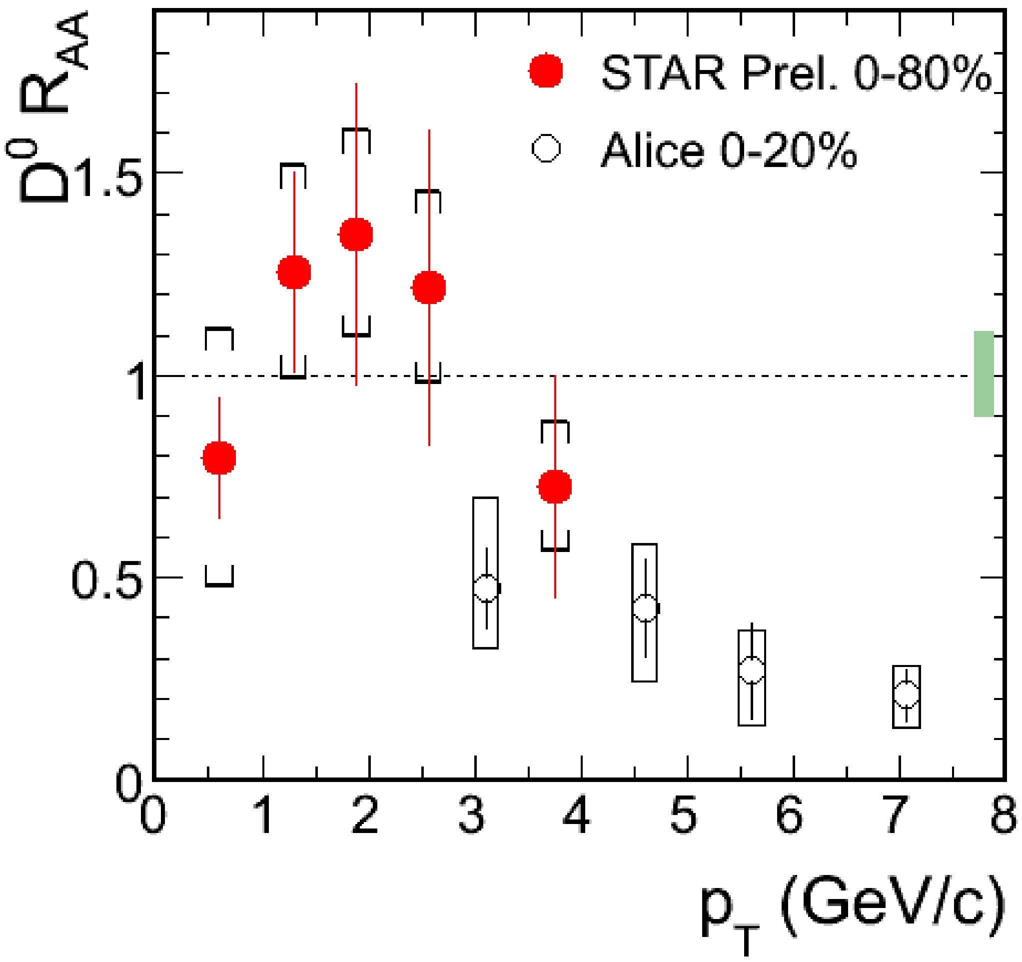
v_2 : thermalization

R_{CP}: charm quark energy loss mechanism.

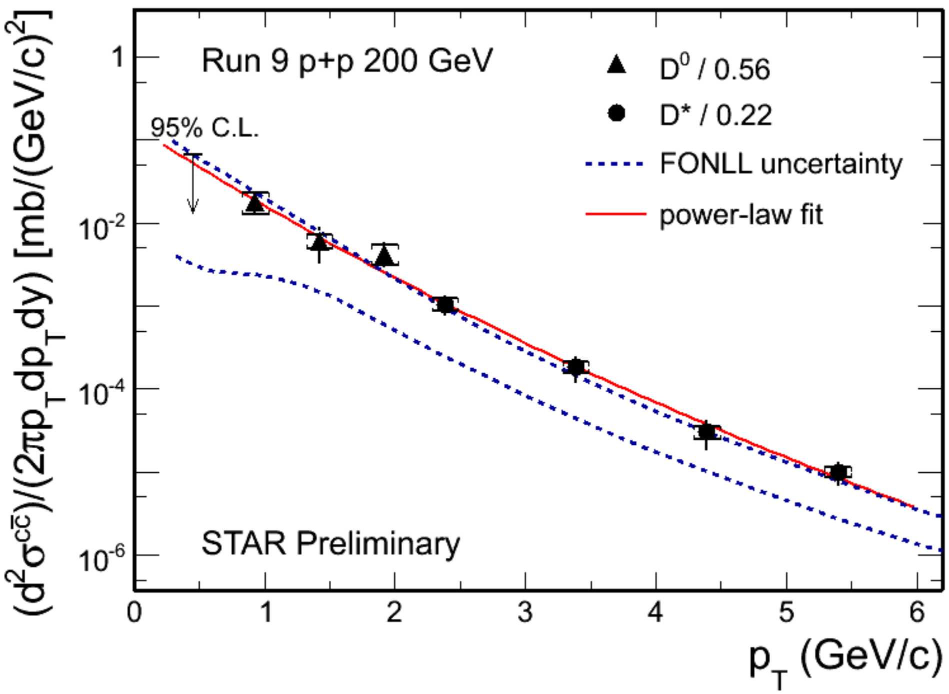
D^0 R_{AA} compared with Alice result

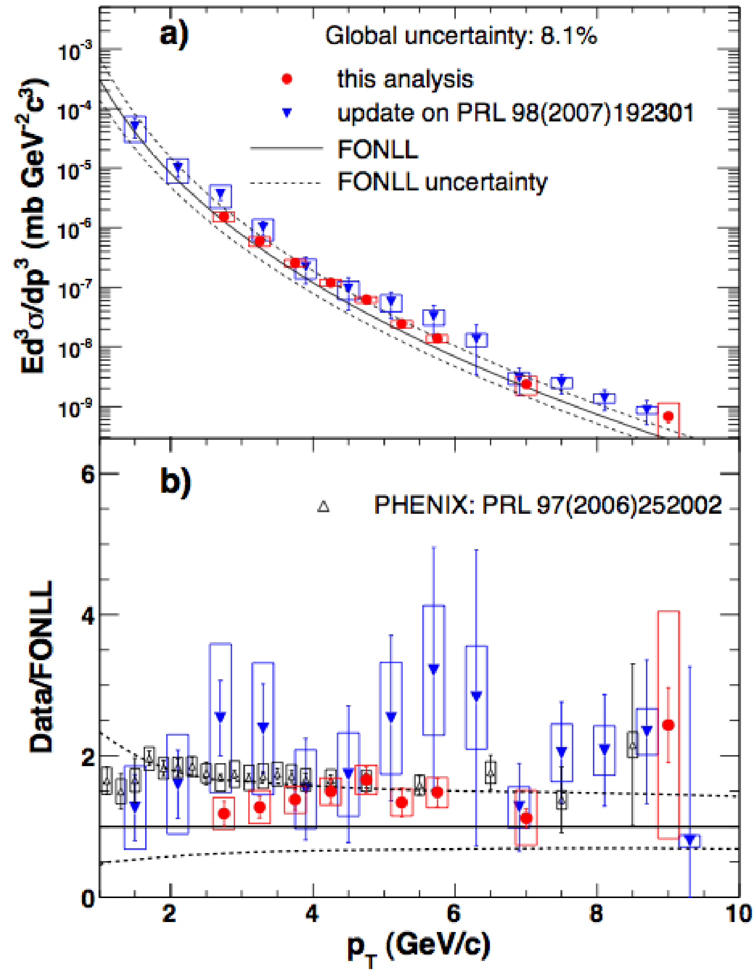


D^0 R_{AA} compared with Alice result



Data consistent with theory

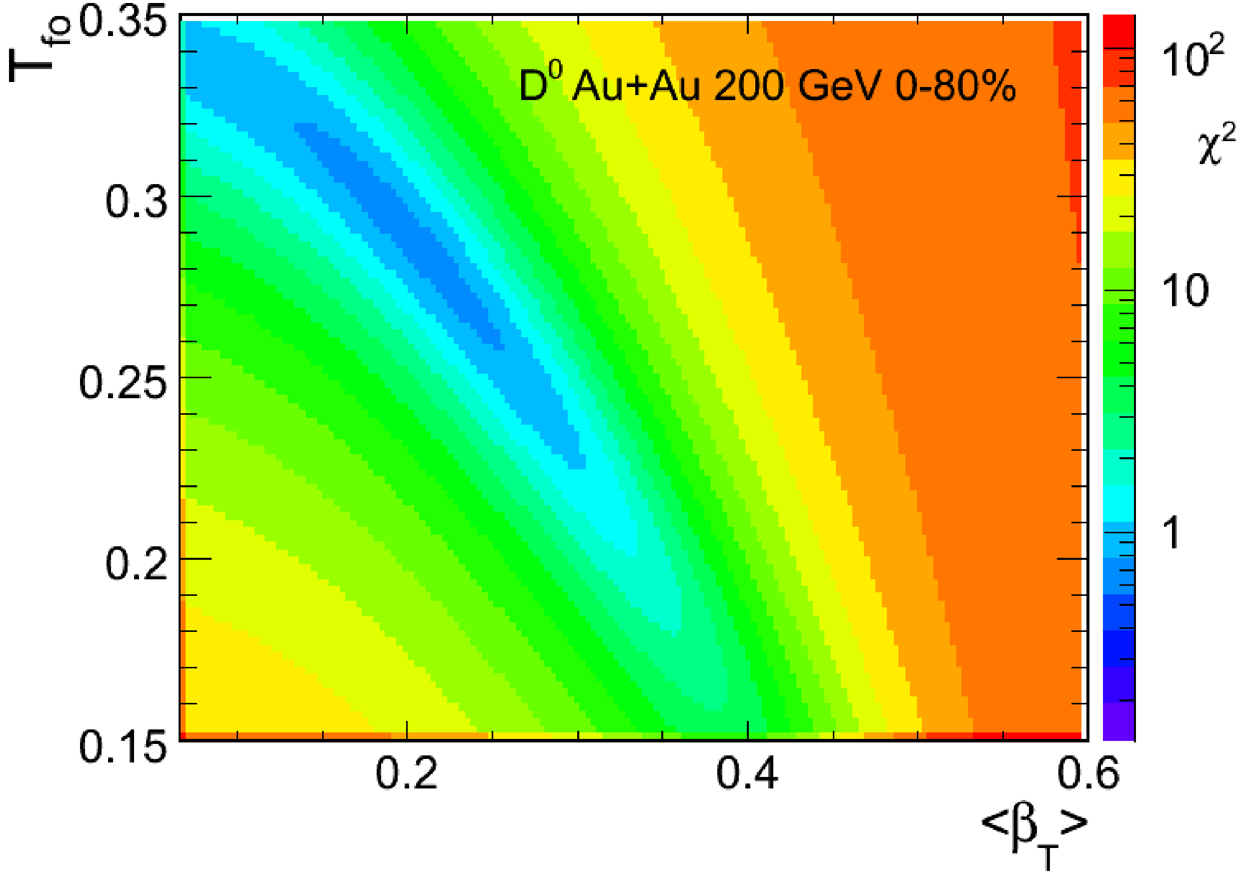




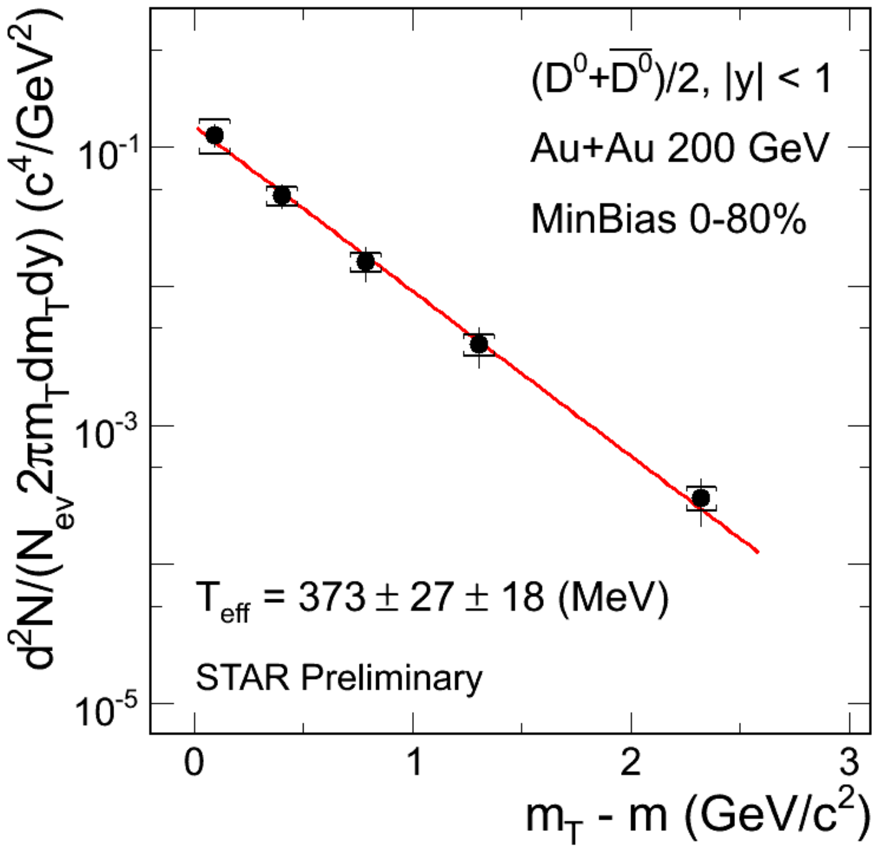
Both D-meson and NPE measurements are consistent with FONLL upper bound.

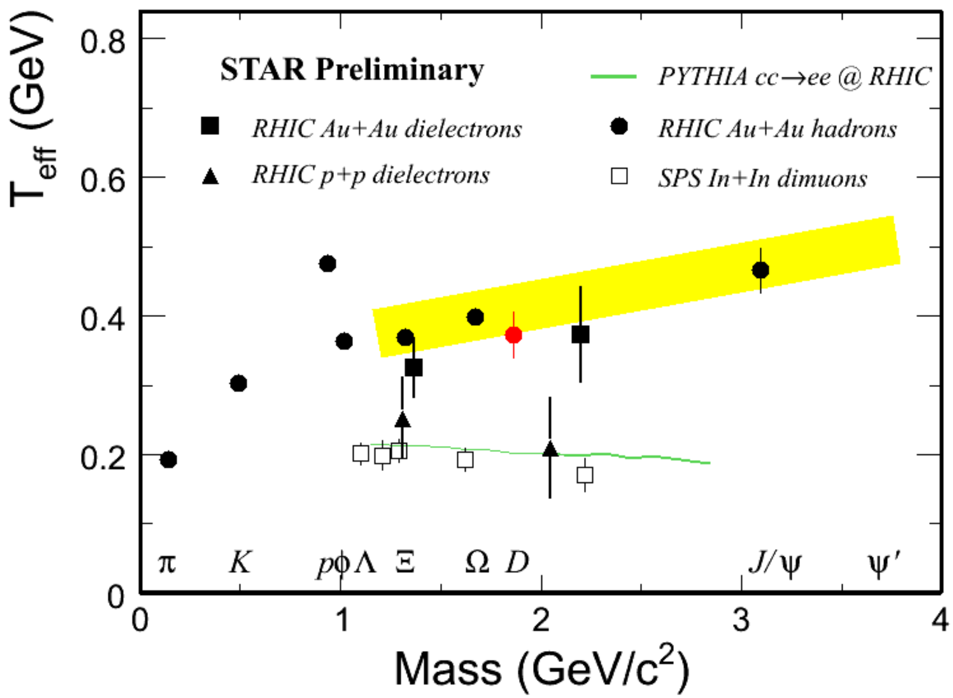
H. Agakishiev, *et al., PRD 83 (2011) 052006*

Blast-wave contor



D^0 m_T slope





$$T_{eff} = T_{fo} + m \times \beta^2$$

Partonic collectivity?

Does charm follow the trend of strangeness? Or smaller velocity?

Interactions between charm and medium?