Open charm hadron production via hadronic decays at STAR

David Tlusty

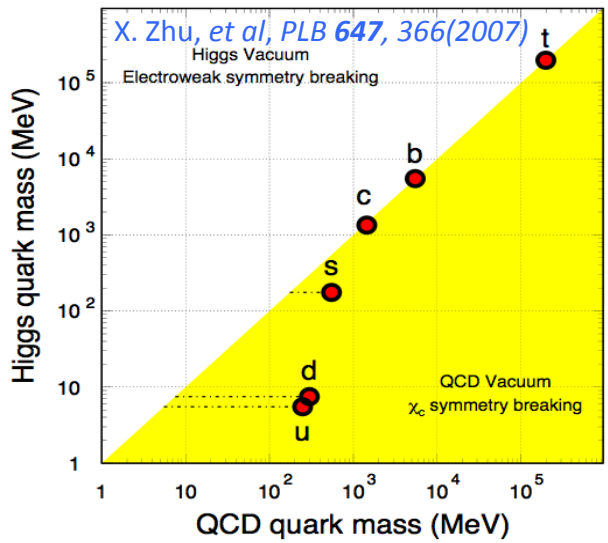
NPI ASCR, CTU Prague

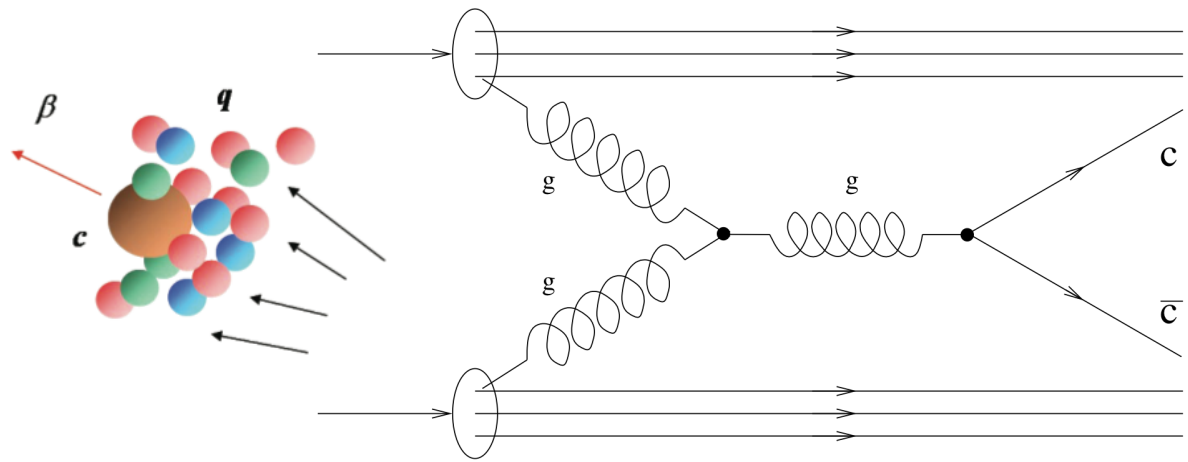
for the STAR collaboration

Outline

1. Motivation
2. Analysis methods, Detector Setup and Particle Identification
3. D^0 and D* in p+p 200 GeV collisions
4. D^0 in Au+Au 200 GeV collisions
5. Analysis status on D^0 and D* in p+p 500 GeV collisions
6. Summary

Why to study heavy quarks





- ★ Produced in initial hard partonic collisions
- ★ Sensitive to initial gluon density and gluon distribution. Due to it's large mass a good pQCD test at RHIC collision energies.
- ★ Heavy quark mass is believed to be external to QCD (=> stay heavy even in QGP)
- ★ Couple differently with the medium than light quarks. Reveal critical features of the medium
  - ★ Spectra could be significantly modified but still would retain memory about their interaction history

How to measure charm quarks

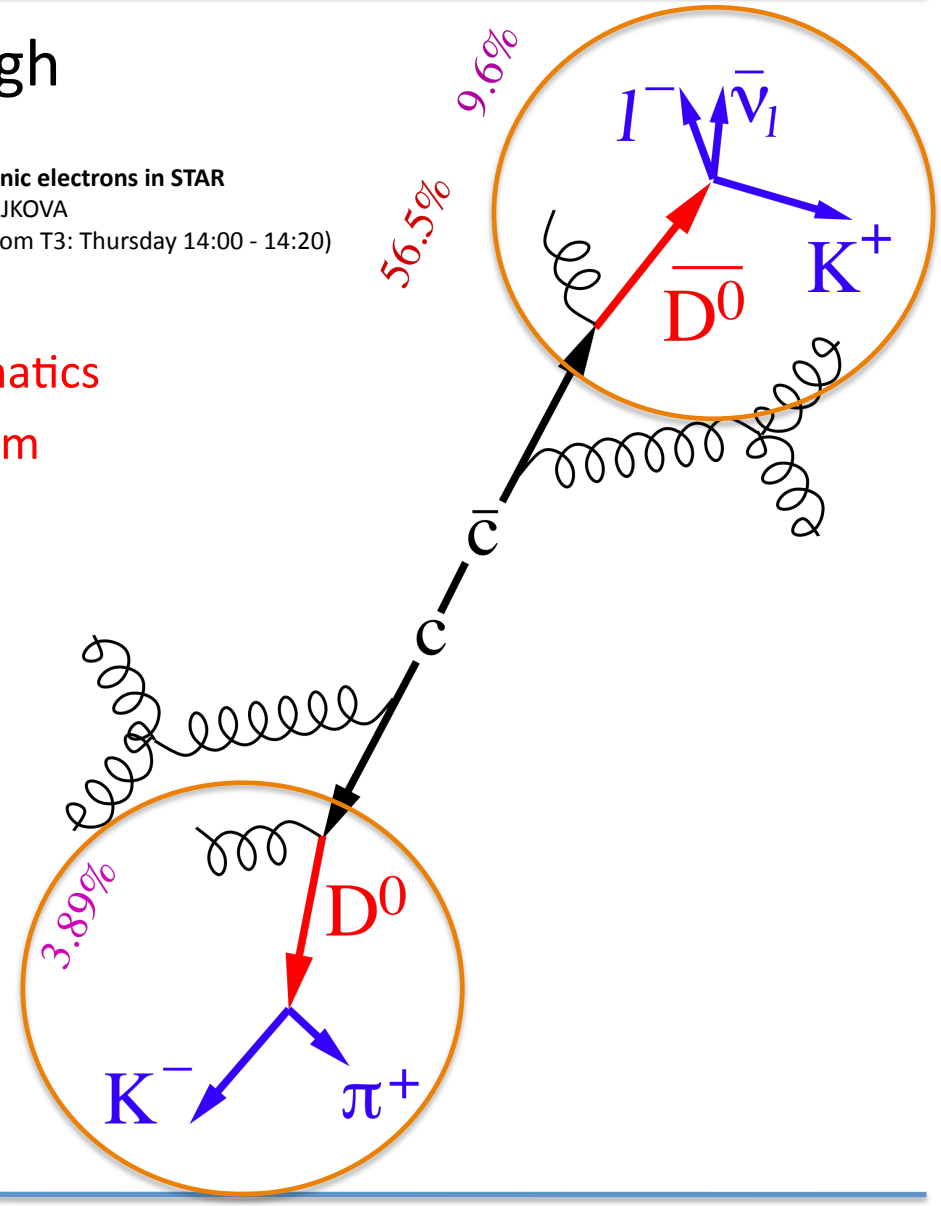
★ Indirect measurements through semi-leptonic decay

- ★ can be triggered easily (high p_T)
- ★ higher B.R.
- ★ indirect access to the heavy quark kinematics
- ★ contribution from both charm and bottom hadron decays

non-photonic electrons in STAR
by Olga HAJKOVA
(parallel room T3: Thursday 14:00 - 14:20)

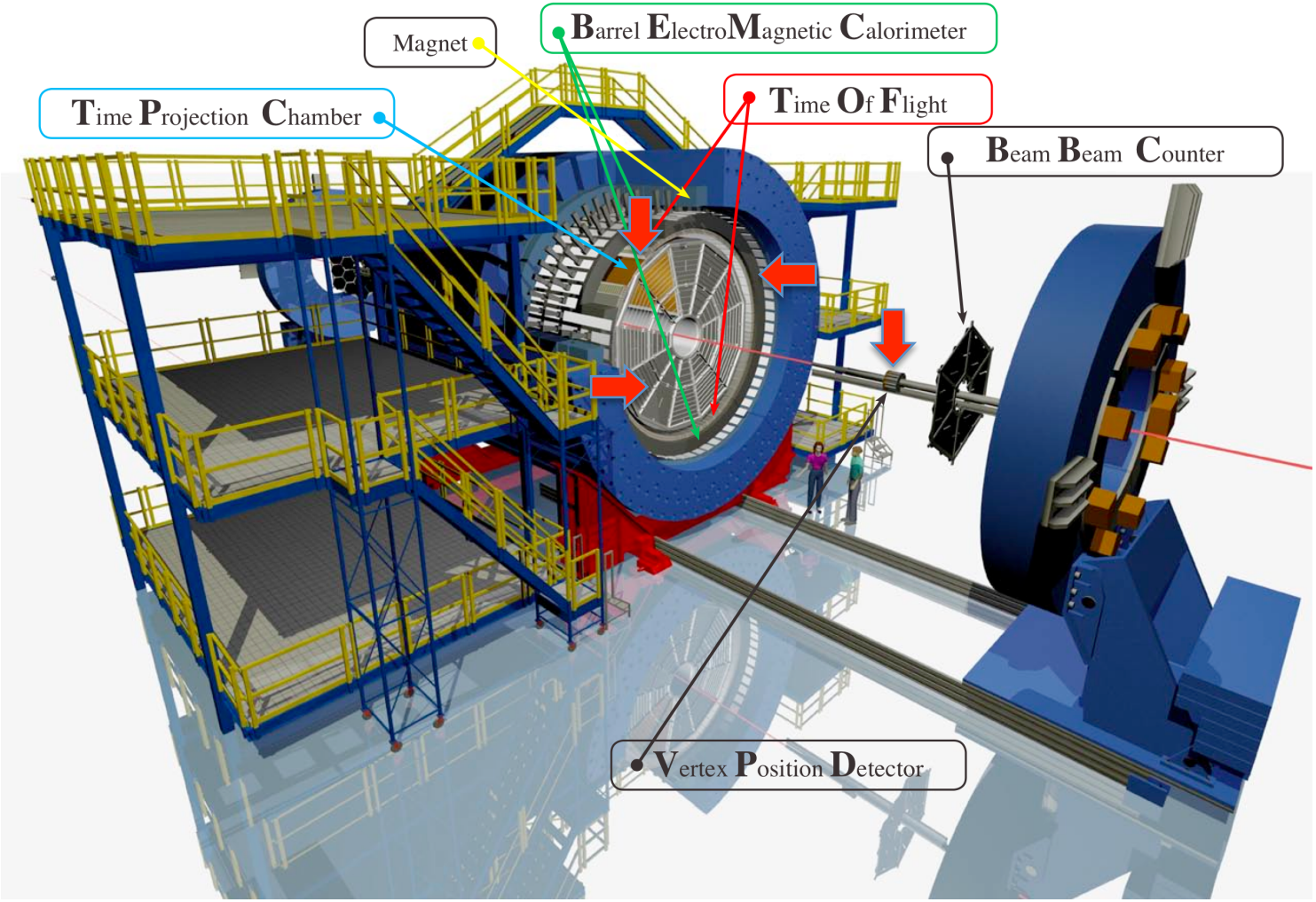
★ Direct reconstruction

- ★ direct access to heavy quark kinematics
- ★ difficult to trigger (high energy trigger only for correlation measurements)
- ★ smaller Branching Ratio (B.R.)
- ★ large combinatorial background (need handle on decay vertex)



The STAR detector

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



★ VPD:
minimum bias trigger

★ TPC:
PID, tracking

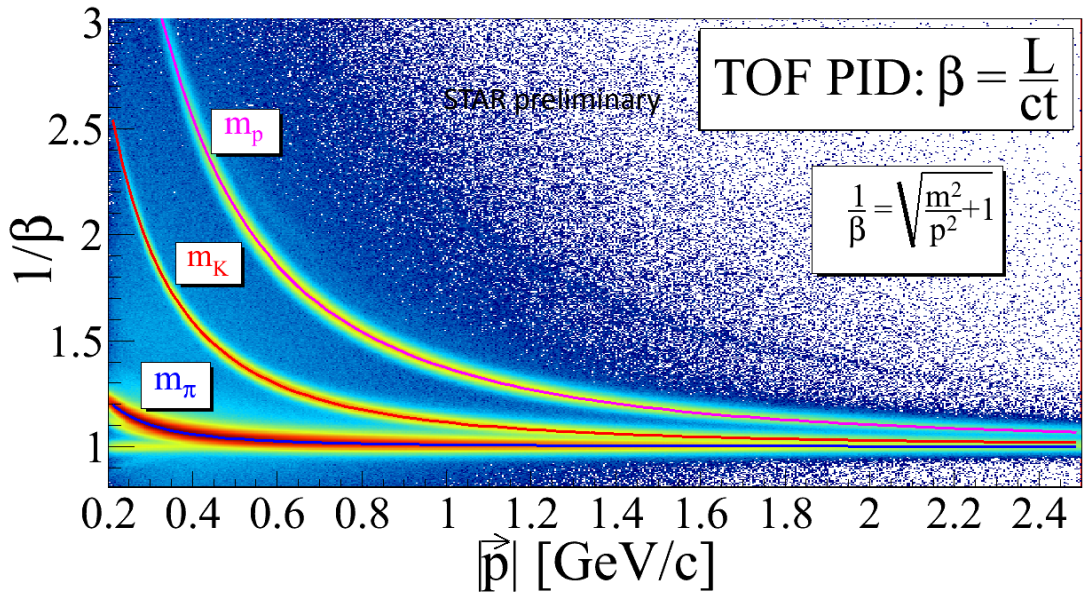
★ TOF:
PID (β, time resolution
= 110 ps in p+p,
= 100 ps in Au+Au)

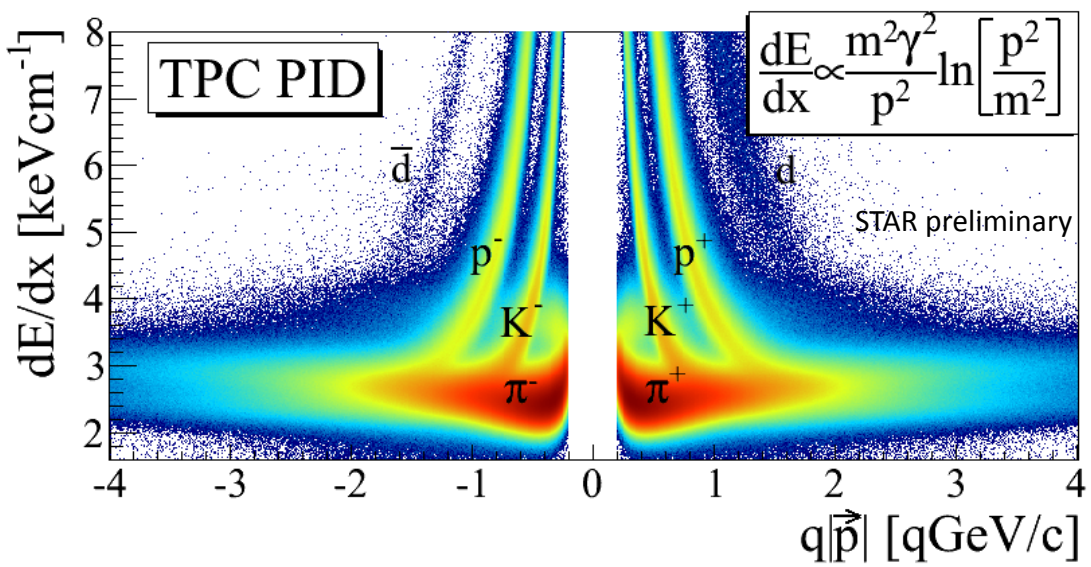
★ BEMC:
remove pile-up tracks,
Energy triggers

Year 2009 72% of full TOF

Year 2010/2011 100% of full TOF

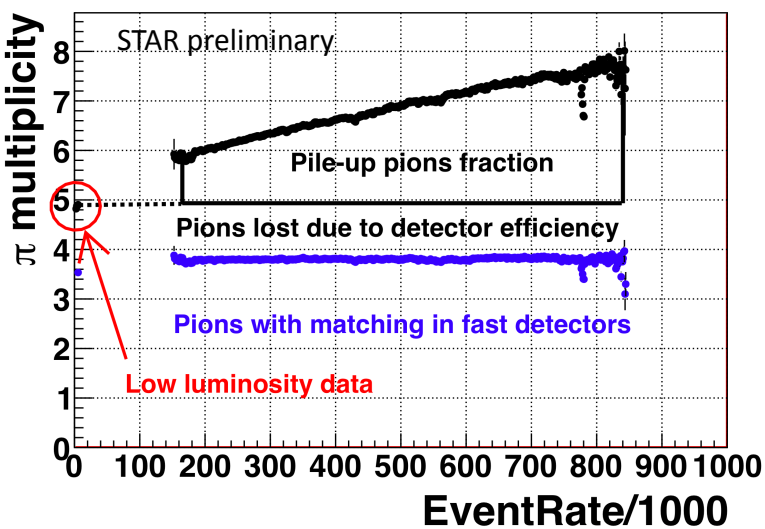
Hadron Identification





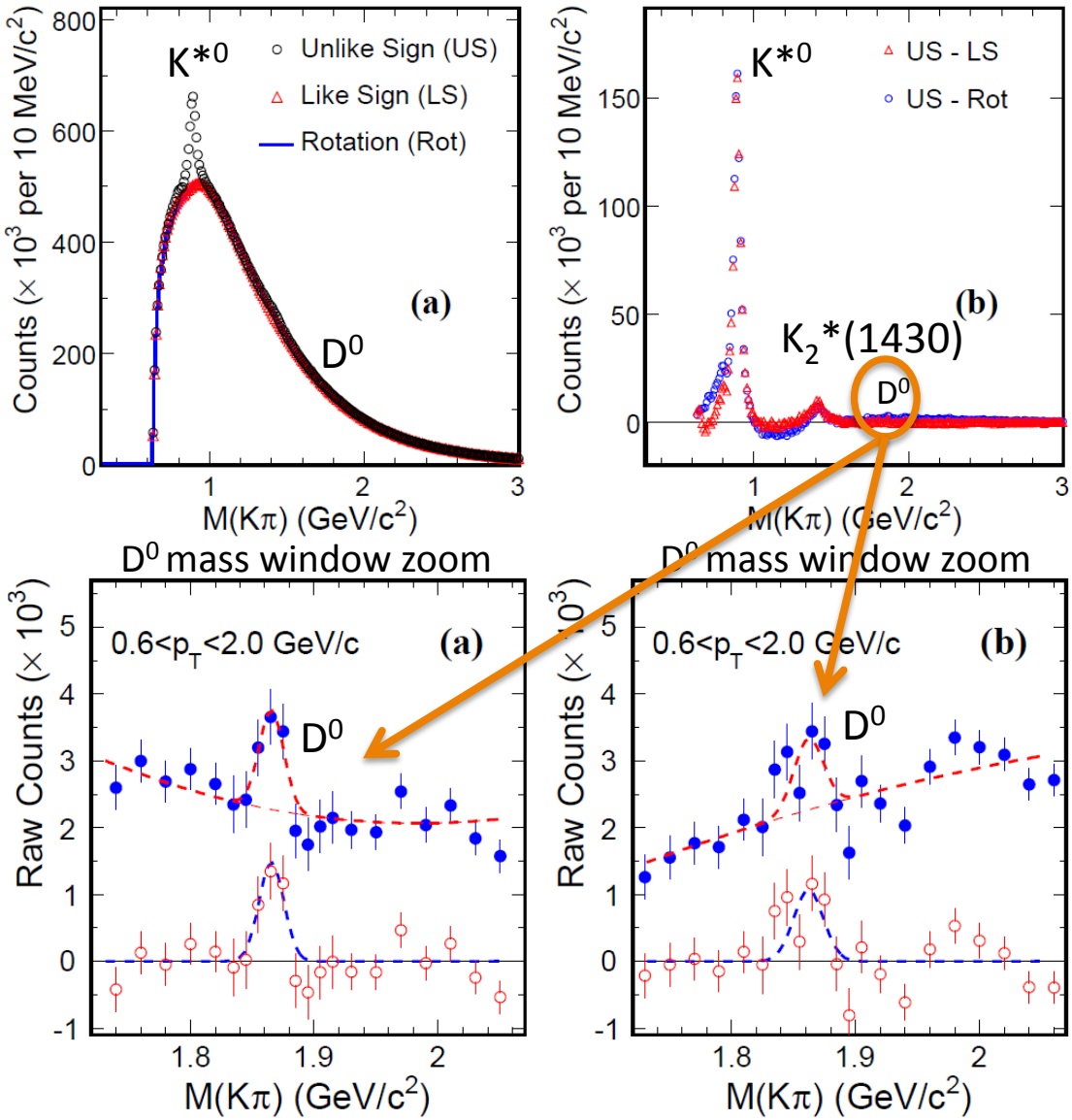
Kaons: TOF only

Pions: TOF if available, otherwise TPC dE/dx with matching to BEMC required to remove pile-up tracks

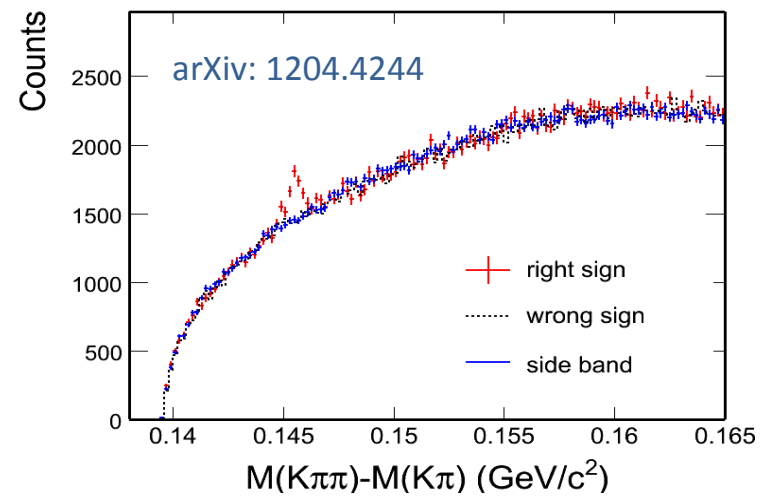


D^0 and D* signal in p+p 200 GeV

arXiv: 1204.4244



$$D^{*\pm} \to D^0(\overline{D^0}) + \pi^\pm \to K^\mp\pi^\pm\pi^\pm$$

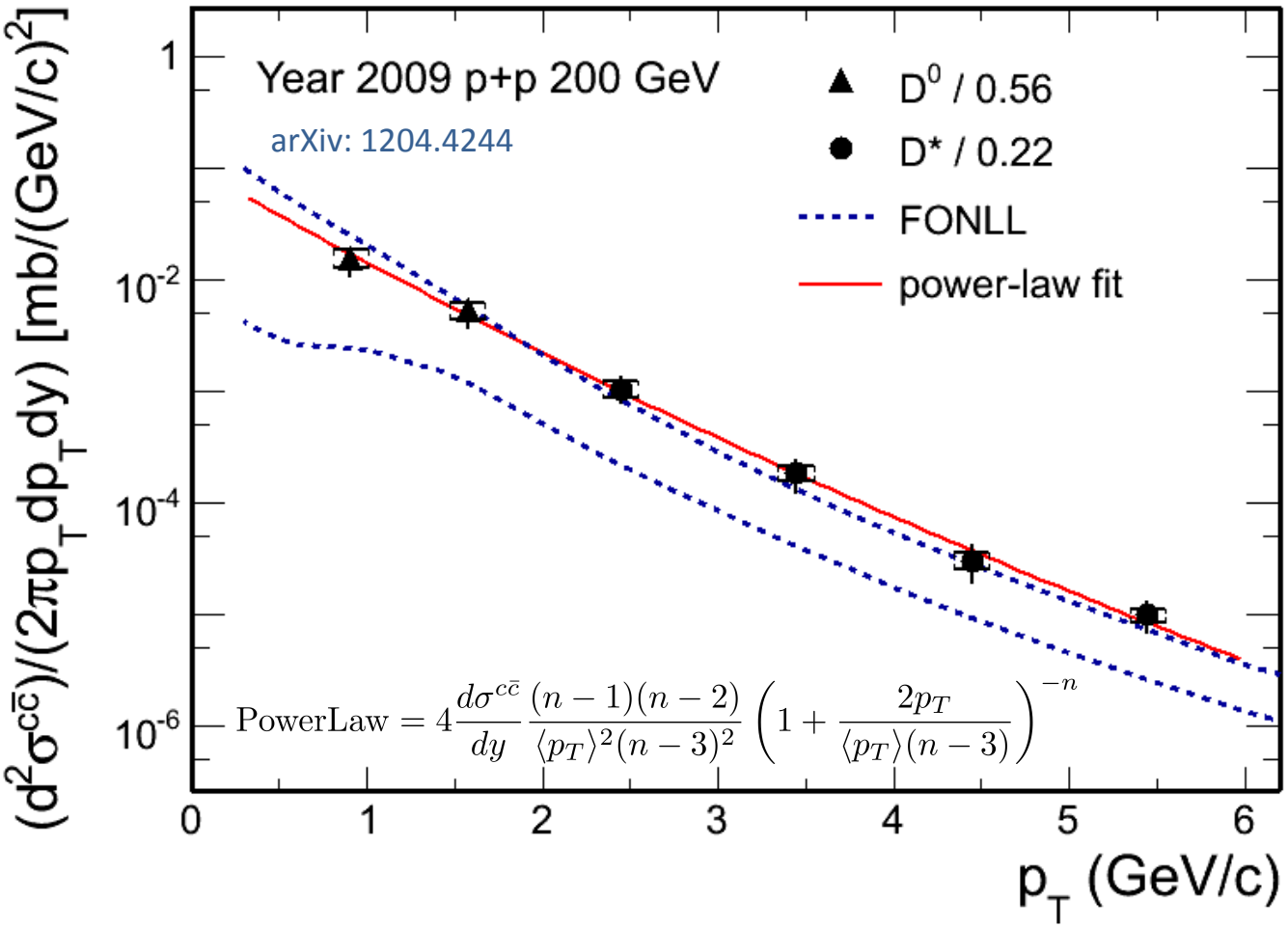


p+p minimum bias 105 M

Different methods reproduce combinatorial background.

Consistent results from two background methods.

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



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

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

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

F = 4.7 ± 0.7 scale to full rapidity.

σ_{pp}(NSD) = 30 mb

The charm cross section at mid-rapidity is:

$170 \pm 45(\mathrm{stat.})^{+37}_{-51}(\mathrm{sys.})\ \mu\mathrm{b}$

The charm total cross section is extracted as:

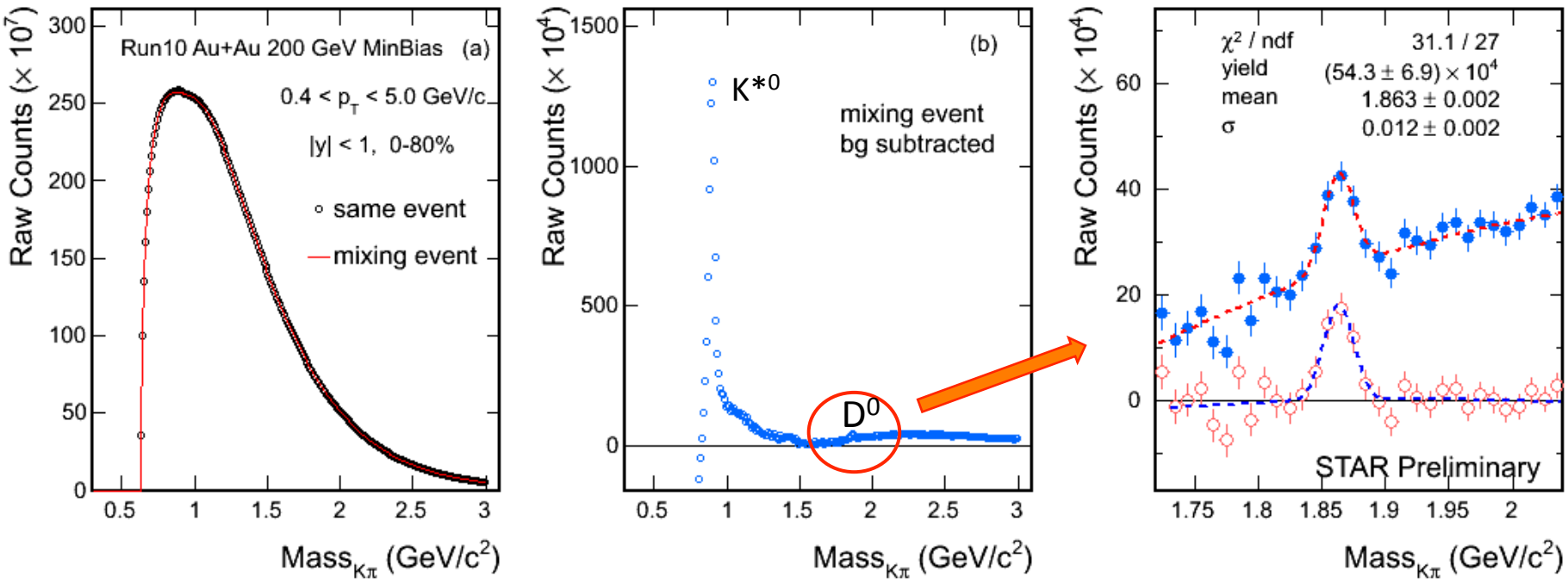
$797 \pm 210(\mathrm{stat.})^{+208}_{-262}(\mathrm{sys.})\ \mu\mathrm{b}$

Consistent with FONLL[2] upper limit.

[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

STAR, Quark Matter 2011, JPG 38, 124142 (2011)



Minimum bias 0-80% 280M Au+Au 200 GeV events.

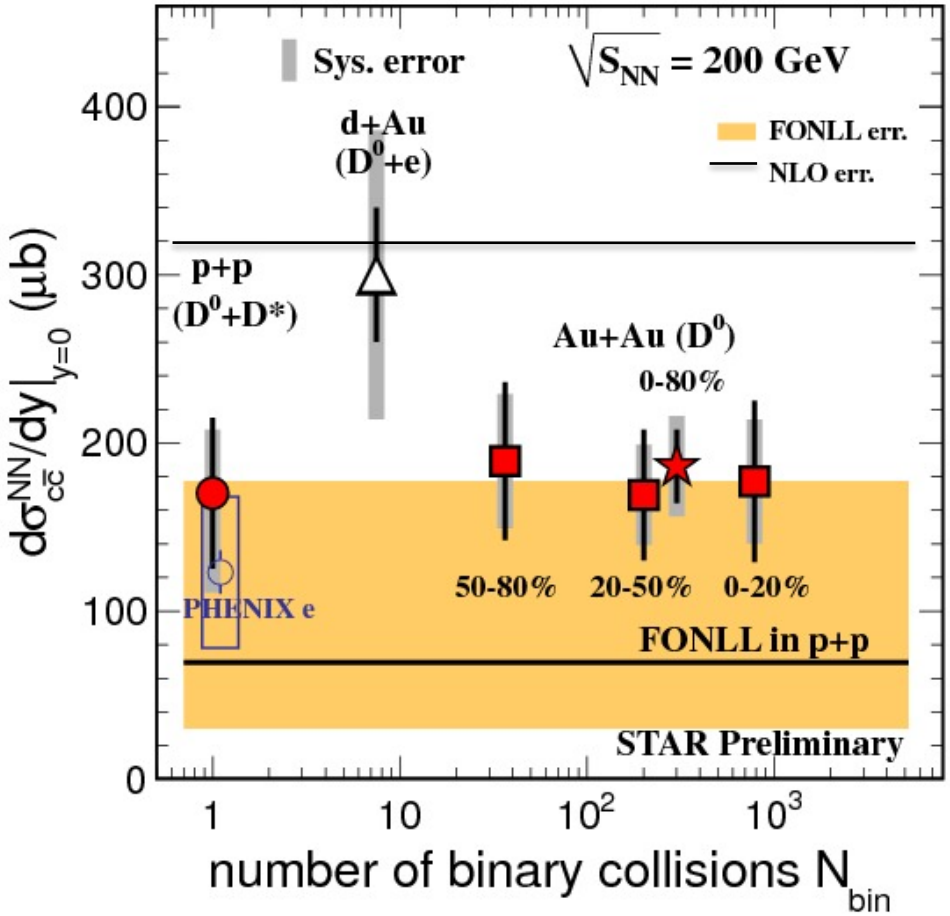
$S/\sqrt{(S+B)} = 8$

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

Width = 12 ± 2 MeV

Number-of-binary-collisions scaling

STAR, Quark Matter 2012, JPG 38, 124142 (2011)
arXiv:1204.4244.



Measurements from Year 2009 p+p D^0+D^* and Year 2010 Au+Au D^0 are consistent

Charm cross section in Au+Au 200 GeV is estimated from D^0 cross section, scaled by fragmentation ratio 0.56:

Cross section at mid-rapidity:

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

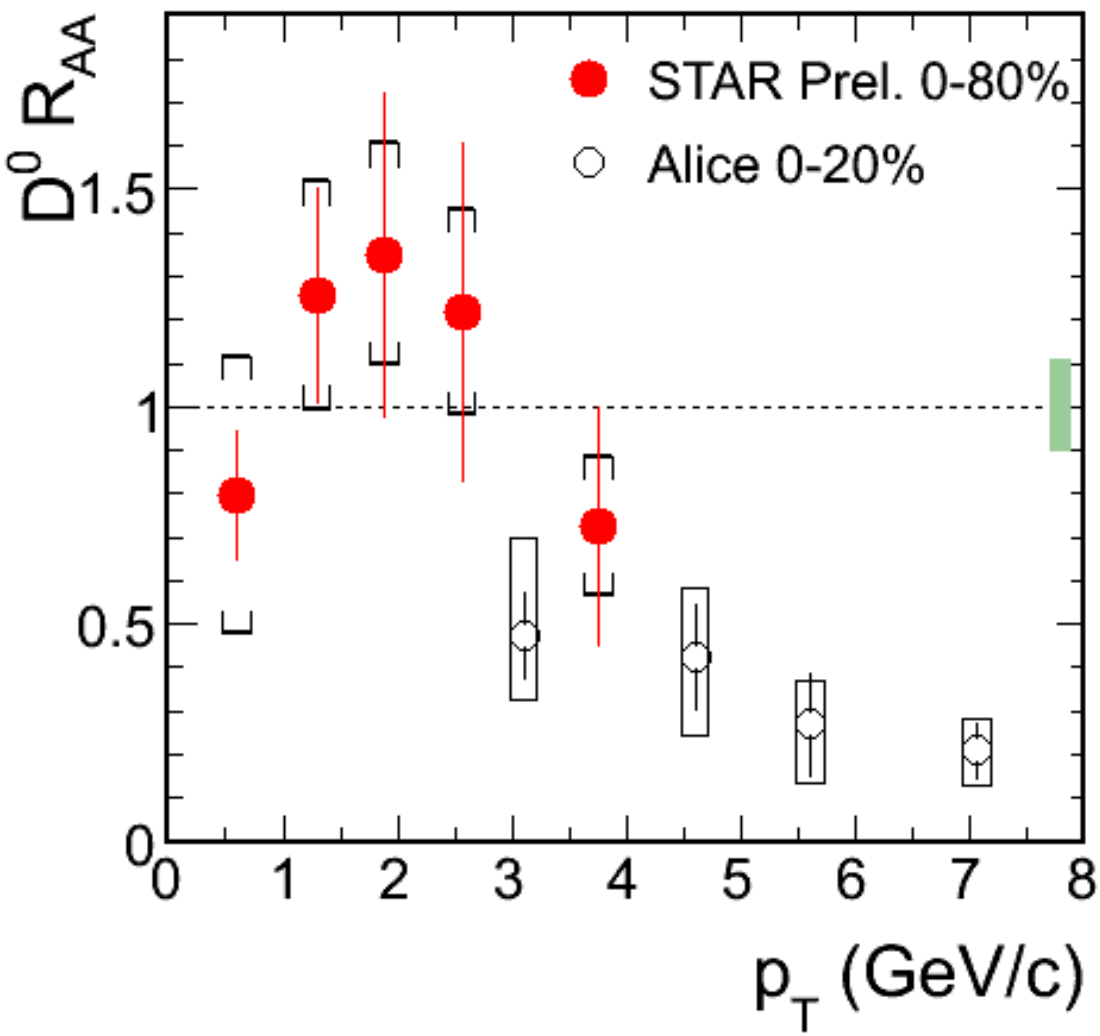
Total cross section:

876 ± 103 (stat.) ± 211 (sys.) μb

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

Charm cross section follows number of binary collisions scaling => Charm quark produced at early stage of collisions.

D^0 R_{AA} vs p_T



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

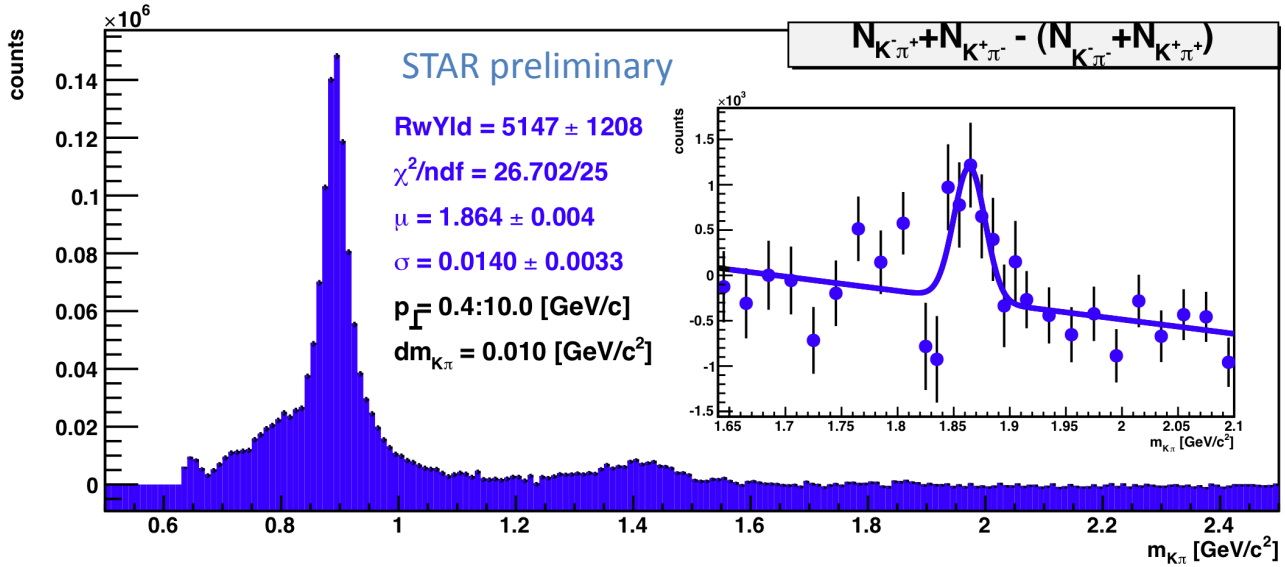
★ Below 3 GeV/c, R_{AA} consistent with unity.

★ ALICE results shows D meson is suppressed at high p_T.

★ At present, The Non-photonic Electrons analysis is the key to study high p_T charm and bottom production at RHIC.

★ Heavy Flavor Tracker, the new STAR subsystem, will make a significant improvement

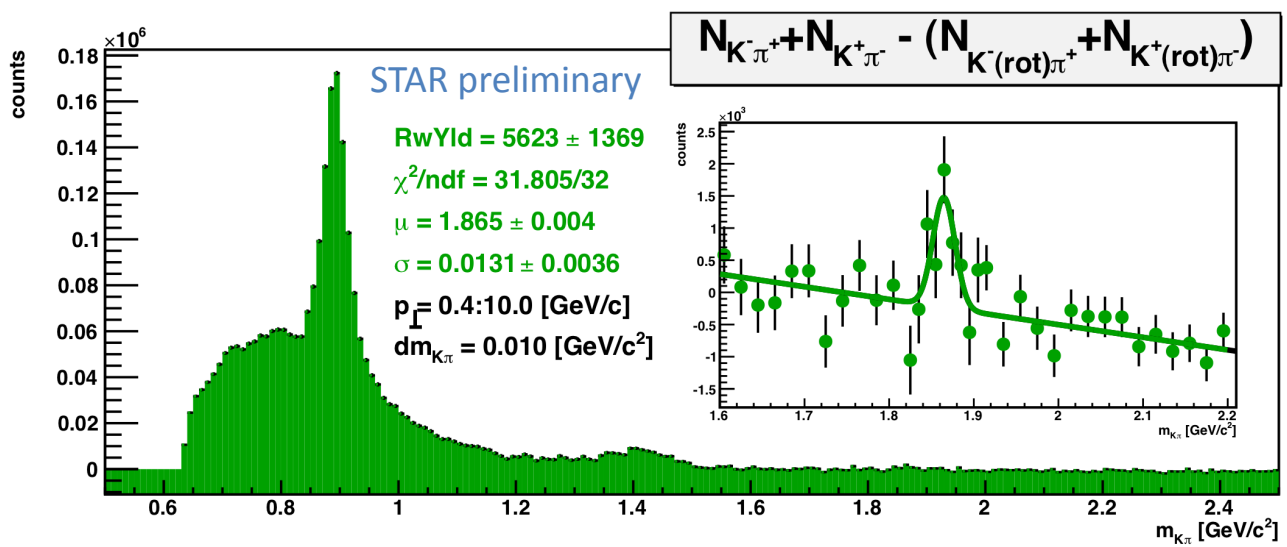
D^0 signal in p+p 500 GeV



Like-sign background subtracted.

$S/\sqrt{(S+2B)} = 4$

from 52 M minimum bias events

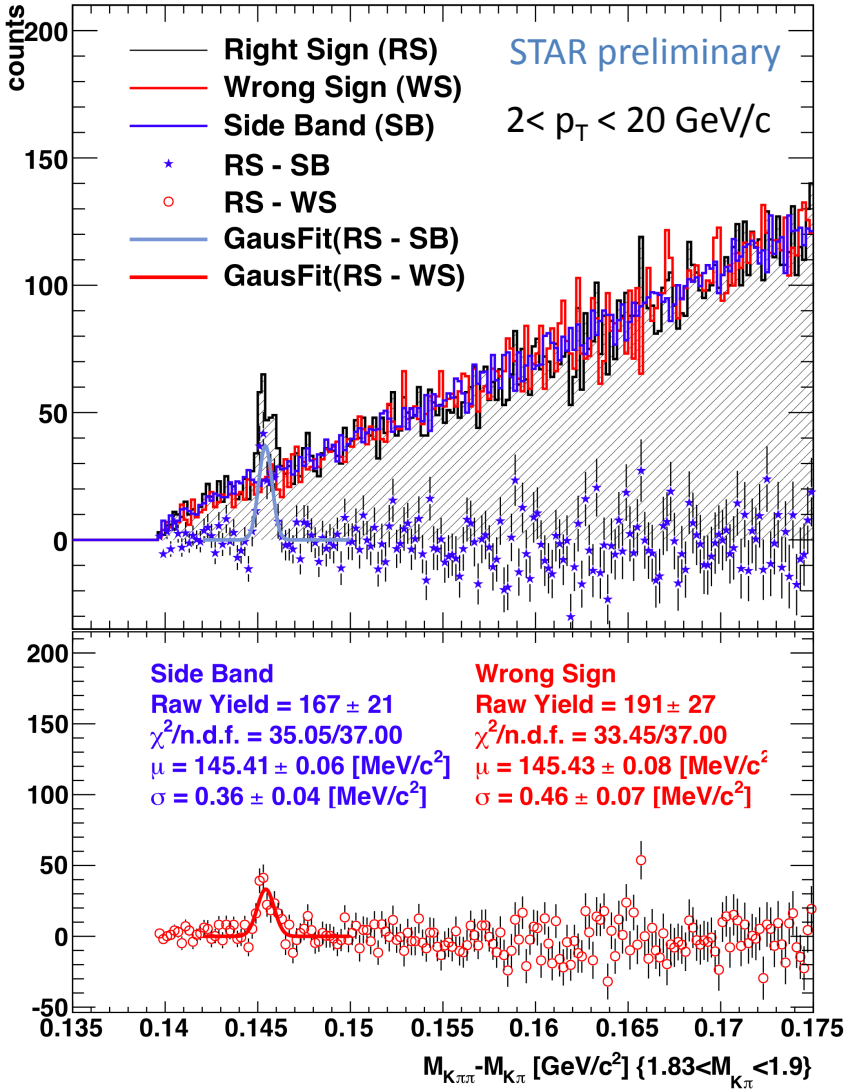


Rotated background subtracted.

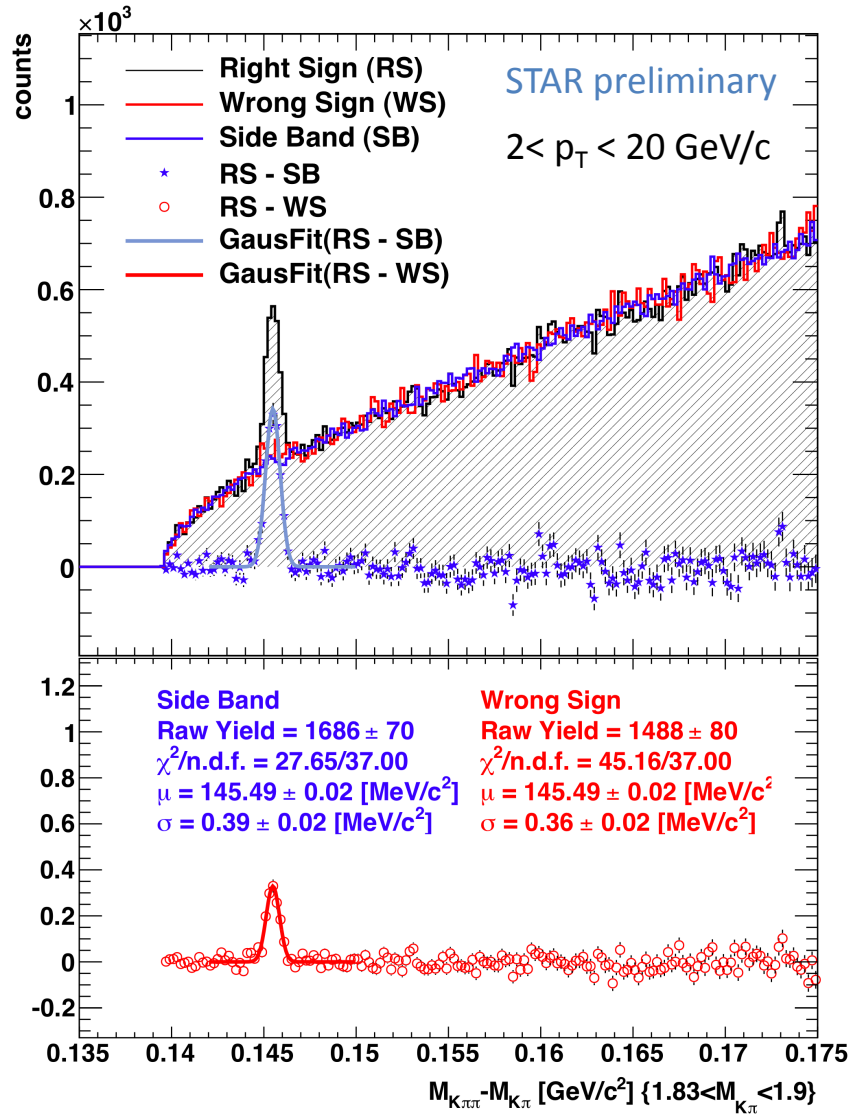
$S/\sqrt{(S+2B)} = 4.1$

D* in p+p 500 GeV

Minimum bias events



High tower triggered events



Summary

★ D^0 and D* are measured in p+p 200 GeV up to 6 GeV/c
the first direct measurement at RHIC

★ $\mathrm{d}^2\sigma^{c\bar{c}}/p_T\mathrm{d}p_T\mathrm{d}y$ consistent with FONLL upper limit.

★ Sufficient D^0 and D* signal from p+p 500 GeV collisions promises first open charm cross section calculation in such energy with p_T coverage being 0.4 – 7.0 GeV/c

★ D^0 are measured in Au+Au 200 GeV up to 5 GeV/c.

★ 1) Charm cross sections at mid-rapidity follow number of binary collisions scaling

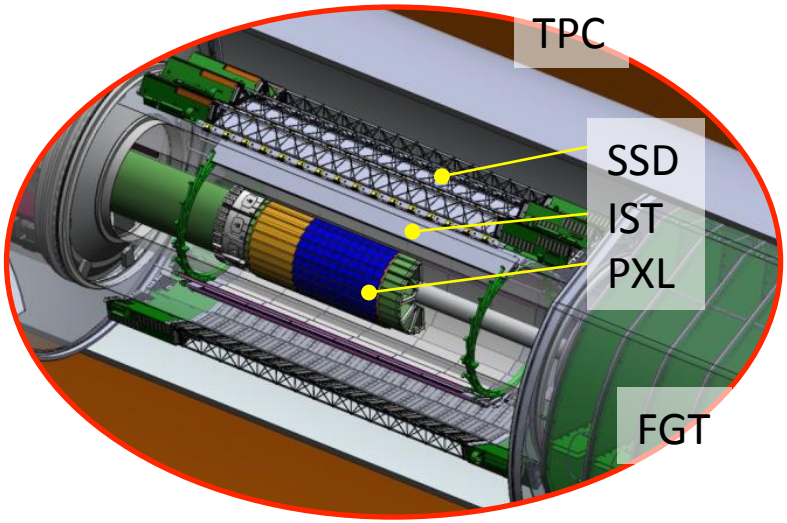
2) R_{AA} is consistent with unity for p_T < 3 GeV/c.

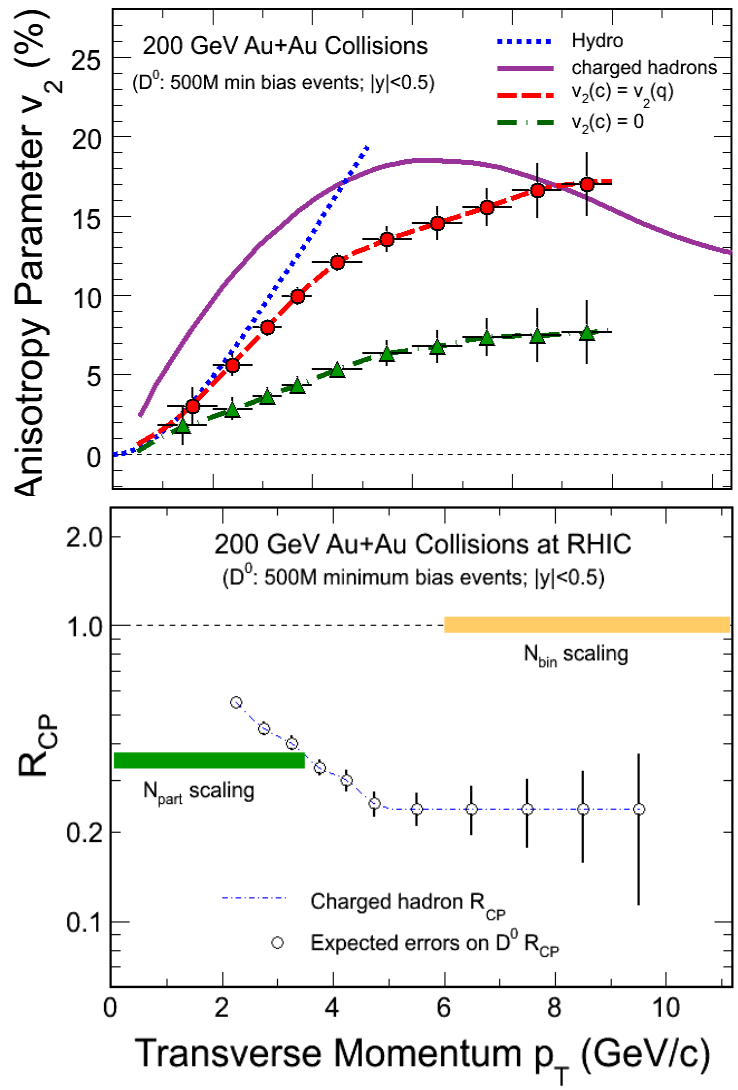
=> charm is produced at early stage of the collisions.

★ Run 2011 Au+Au data with twice more statistics will allow us to extend the R_{AA} p_T range up to 7 – 8 GeV/c.

Backup Slides

Heavy Flavor Tracker





STAR Heavy Flavor Tracker Project.

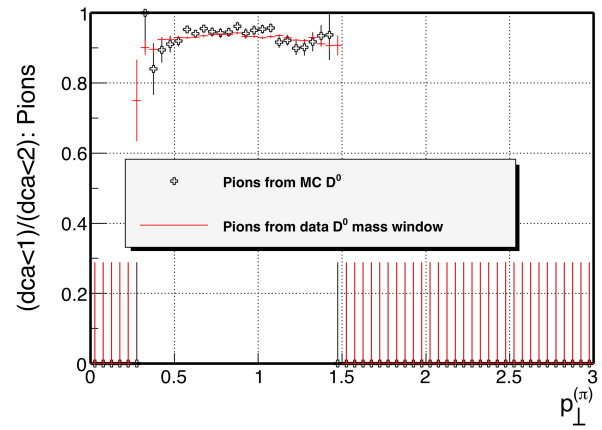
- ✓ Reconstruct secondary vertex.
- ✓ Dramatically improve the precision of measurements.
- ✓ Address physics related to heavy flavor.

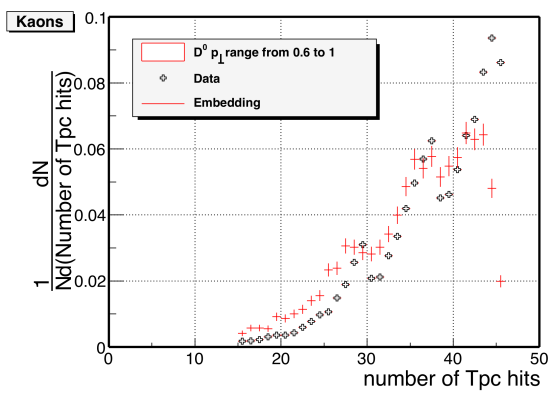
v_2 : thermalization

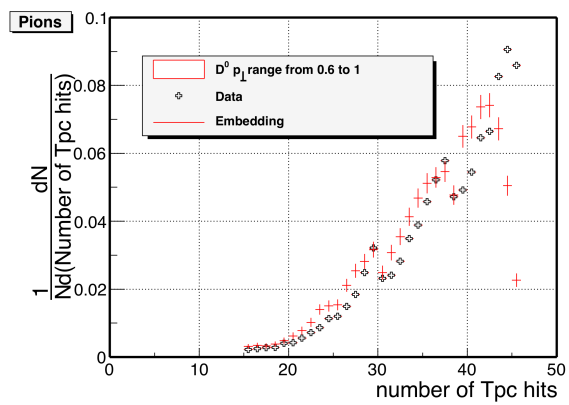
R_{CP}: charm quark energy loss mechanism.

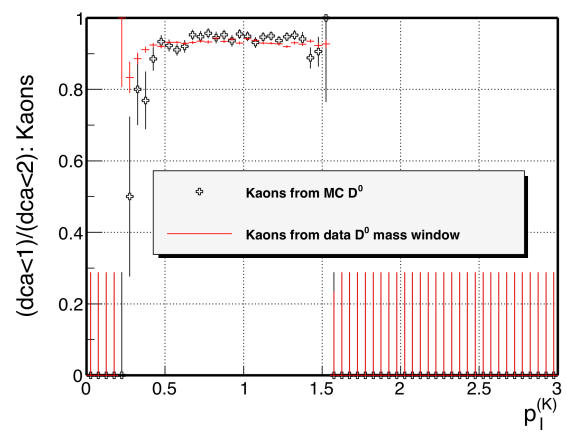
Systematic error study

1) Raw Counts – Difference between methods
2) nFitPoints - difference between MC(nFitPts>25)/MC(nFitPts>15) and Data(nFitPts>25)/Data(nFitPts>15)
3) DCA - difference between MC(dca<1)/MC(dca<2) and Data(dca<1)/Data(dca<2)

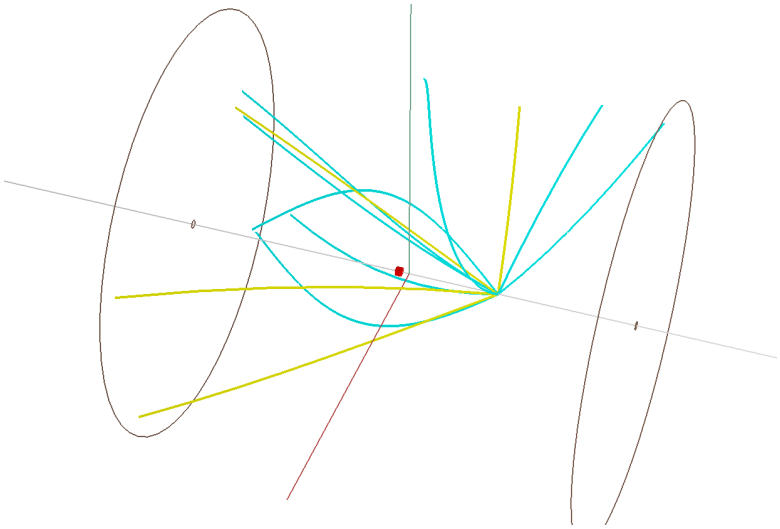


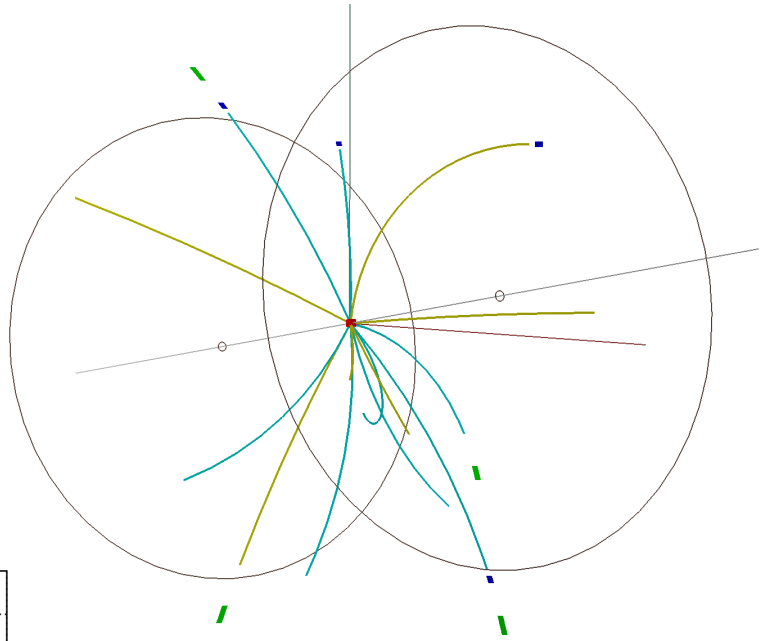


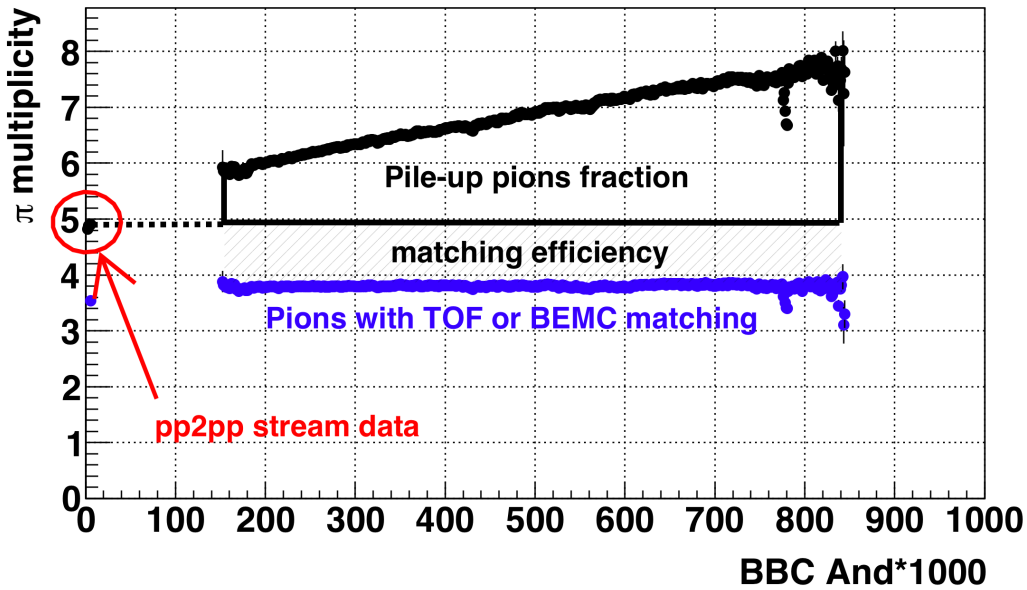




Pile-up removal







- pp collisions peak luminosity $L_{peak} = 5*10^{31}\ cm^{-2}s^{-1}$ in year 2009.
- EventRate = $L_{peak}*\sigma^{NSD}$(30 mb) = 1.5 MHz
- TPC readout ~ 80 μs => TPC sees tracks from 120 collisions. Pile-ups are removed by
  - |VpdVz - TpcVz| < 6cm cut
  - TPC PPV reconstruction algorithm

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