Nuclear Modification Factor of D^0 Mesons in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

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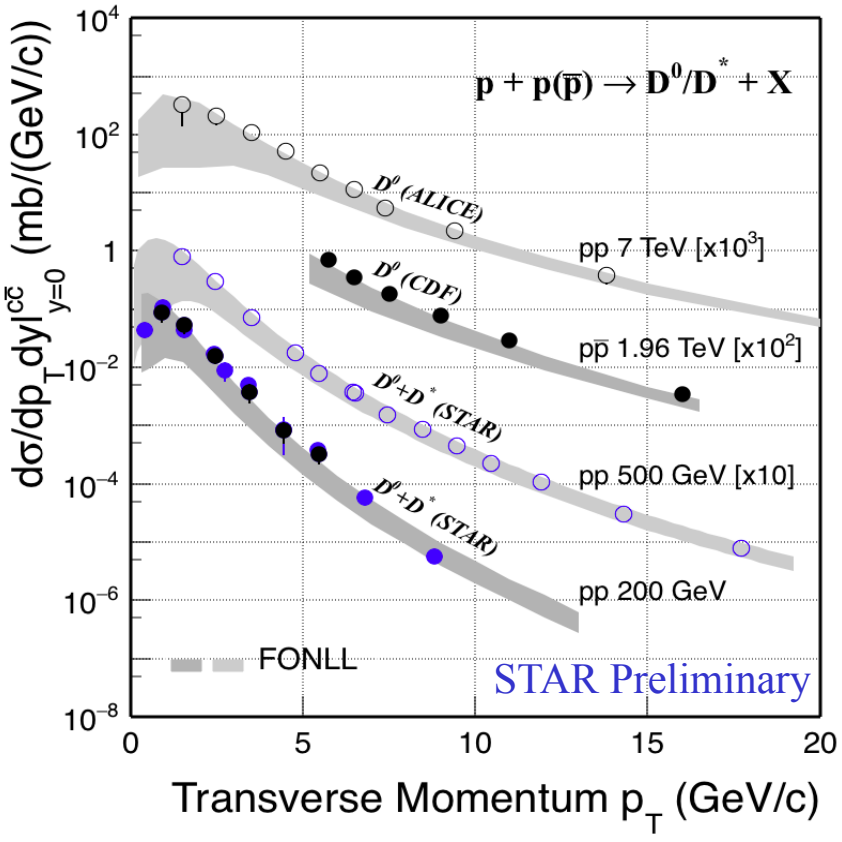
Motivation

Charm quarks: $m_c >> \Lambda_{QCD}$, $T_{QGP(RHIC/LHC)}$

- Produced early in collision at RHIC through hard scattering
- Experience the whole evolution of the system -> good probe for medium properties



Perturbative QCD calculations (FONLL) are consistent with experimental data.

STAR: PRD 86 (2012) 072013,
NPA 931 (2014) 520
CDF: PRL 91 (2003) 241804
ALICE: JHEP01 (2012) 128
FONLL: PRL 95 (2005) 122001

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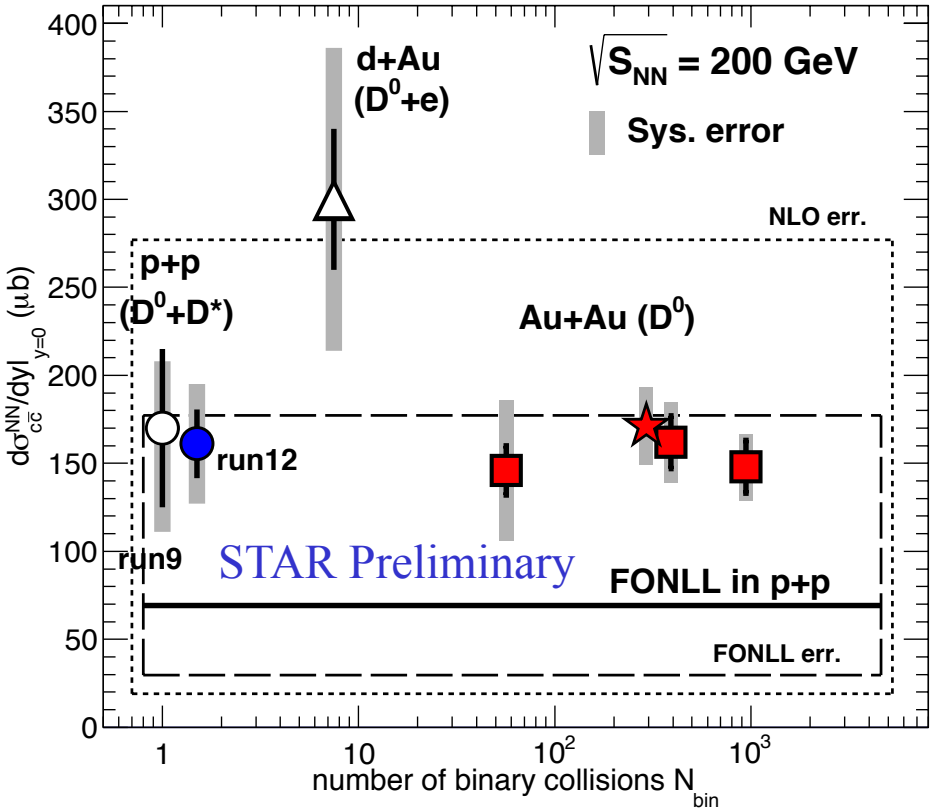


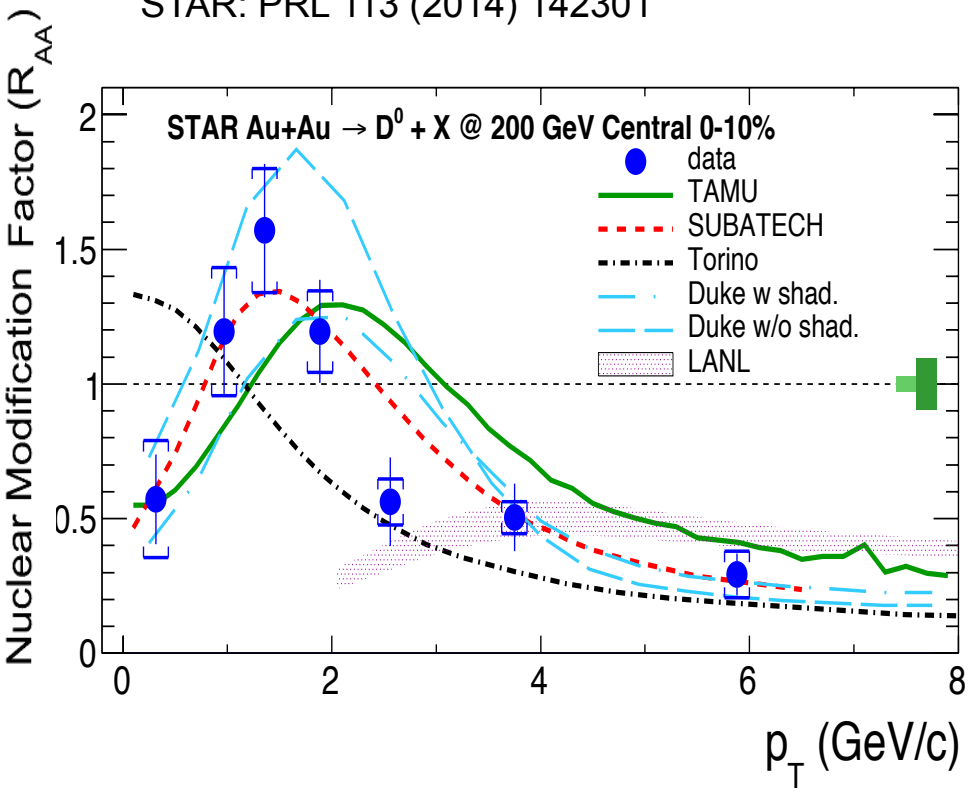
Perturbative QCD calculations (FONLL) are consistent with experimental data.

Charm cross section follows number of binary collisions scaling =>
At RHIC, charm quarks are produced via initial hard scatterings.

STAR: PRL 94 (2005) 62301,
PRD 86 (2012) 072013,
PRL 113 (2014) 142301
FONLL: PRL 95 (2005) 122001
NLO: Eur.Phys.J.ST 155 (2008) 213

STAR ☆ Results Before the Heavy Flavor Tracker

STAR: PRL 113 (2014) 142301



- High p_T: large suppression due to energy loss, strong charm-medium interaction.
- Enhancement at p_T ~0.7-2 GeV/c, described by models with coalescence of charm and light quarks.

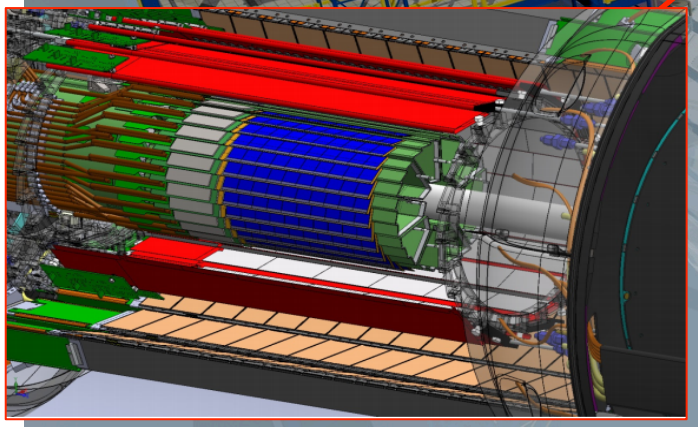
- Precision measurement is needed to further constrain models and to quantify medium properties.
- New 2014 Au+Au results with HFT will be presented
  -- p+p and p+Au data with HFT are recorded (run 2015)

STAR Detector

Time Projection Chamber:
Tracking, PID (dE/dx)

Time Of Flight detector:
PID (1/β)

Heavy Flavor Tracker



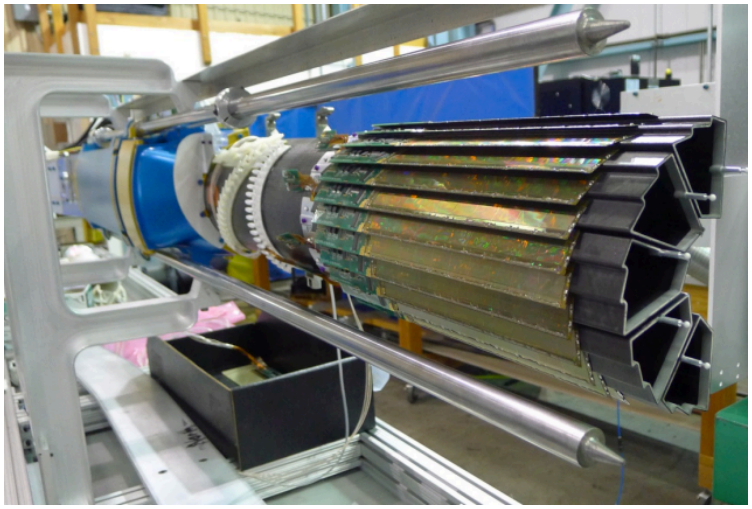
HFT:

- Silicon Strip Detector: r ~22 cm
- Intermediate Silicon Tracker: r ~14 cm
- PIXEL detector: r ~2.8 & 8 cm,
  MAPS, 20x20 μm^2, 0.4%X_0, air-cooled

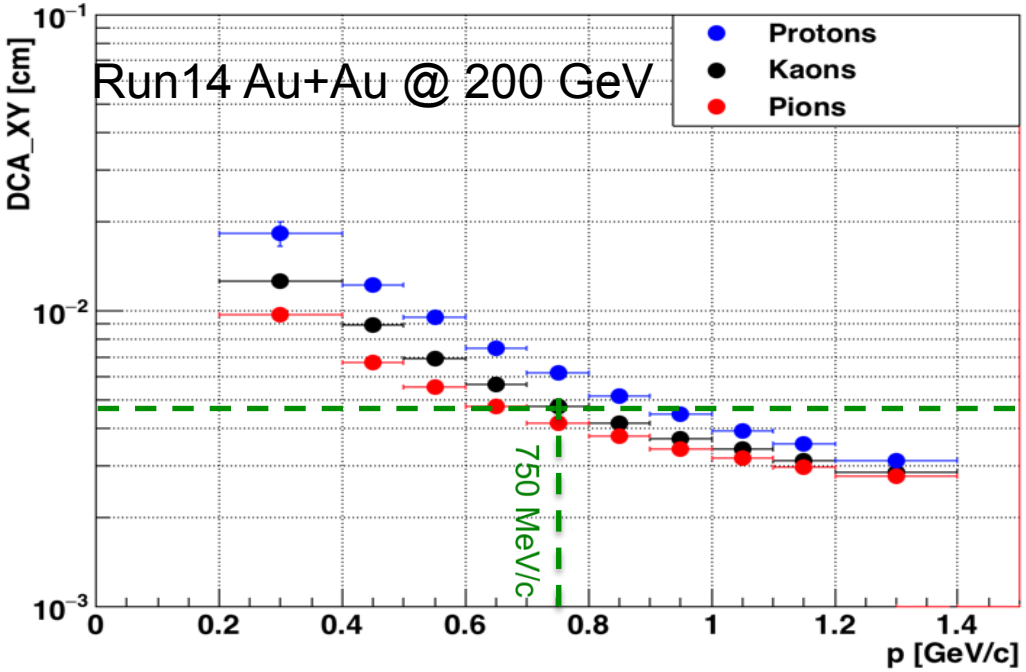
HFT Performance

Au+Au at $\sqrt{s_{NN}}$ = 200 GeV, with Heavy Flavor Tracker
~780M minimum bias events analyzed (out of total 1.2B recorded in 2014)

PIXEL detector



DCA Resolution



DCA (Distance of Closest Approach) resolution

- ~ 30 μm at high p_T
- Kaon with p = 750 MeV/c, DCA resolution <50 μm

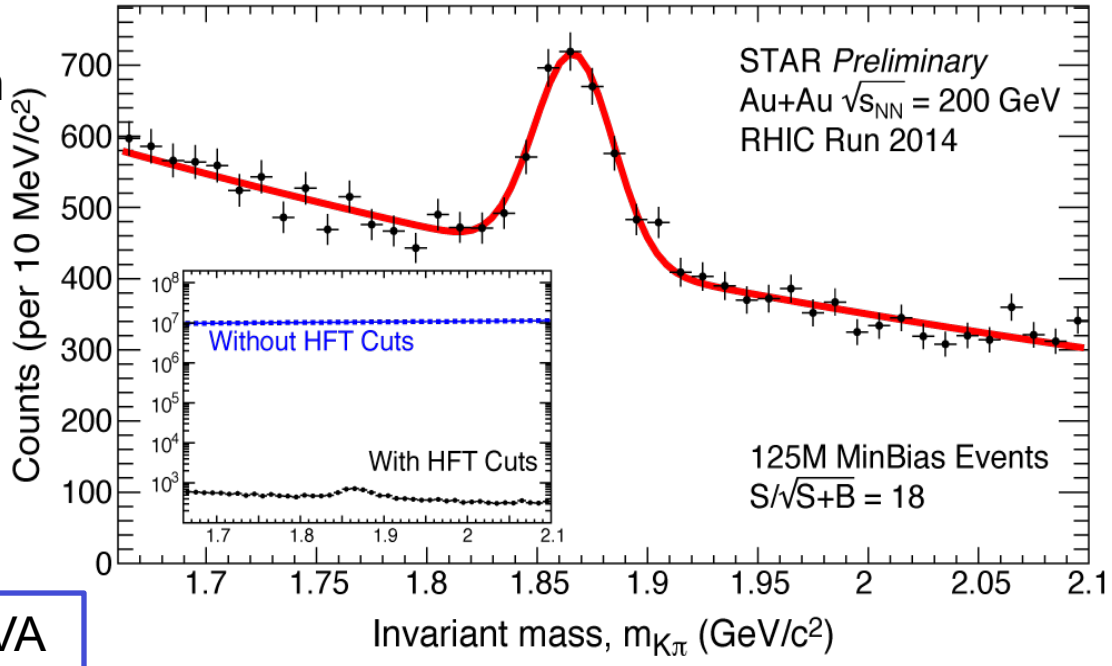
D^0 Meson Reconstruction

Direct topological reconstruction through hadronic channel:

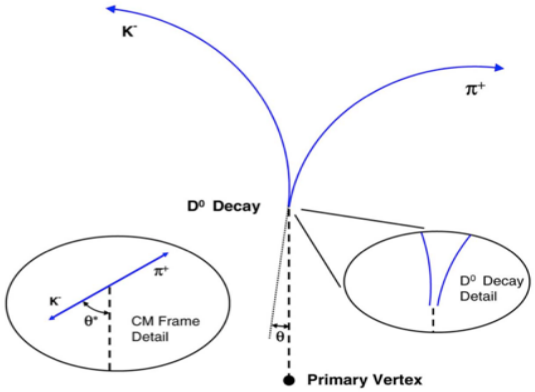
$$D^0(\overline{D^0}) \rightarrow K^{\mp}\pi^{\pm}(BR\ 3.89\%)$$

$$c\tau \approx 120\mu m$$

With HFT:
Greatly reduced combinatorial background

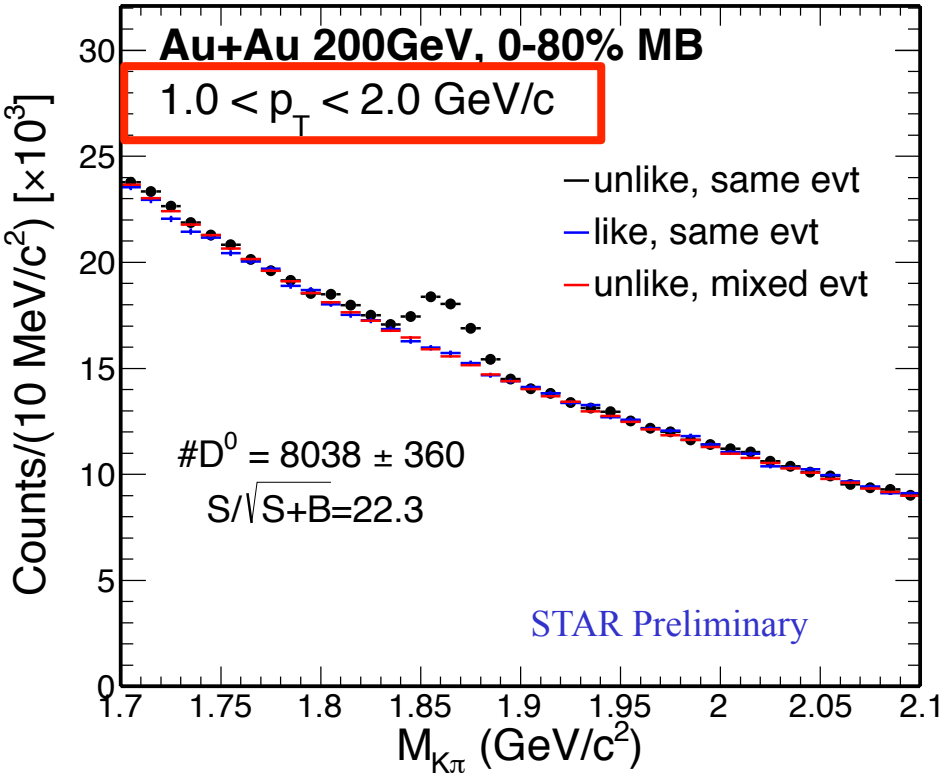


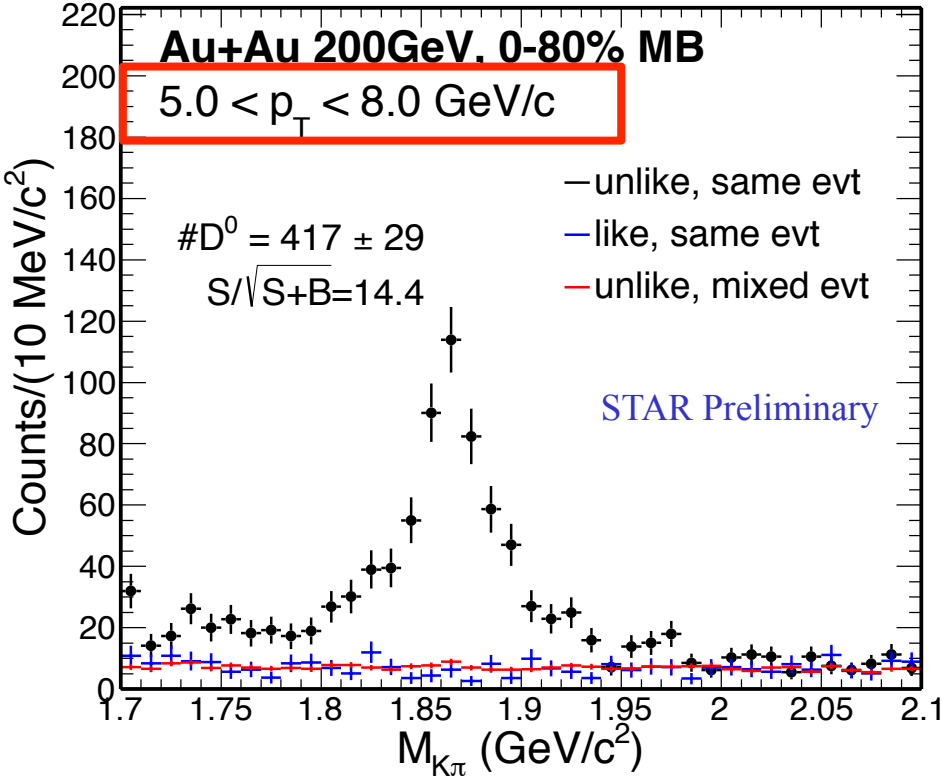
Topological cuts optimized by TMVA (Toolkit for Multi Variate Analysis)



D^0	w/o HFT	with HFT
Year	2010 + 2011	2014
Significance per billion events	13	51

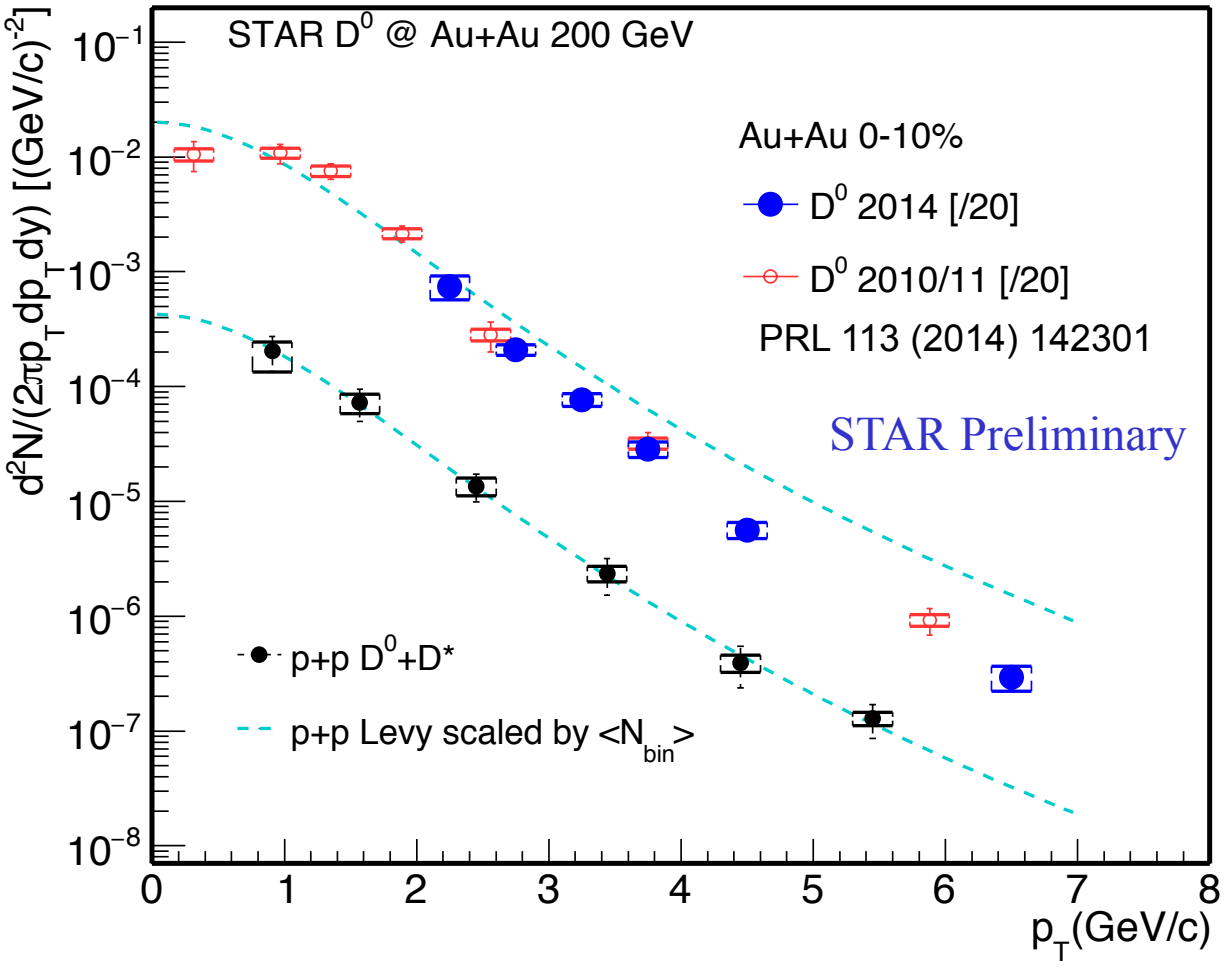
D^0 Meson Signal





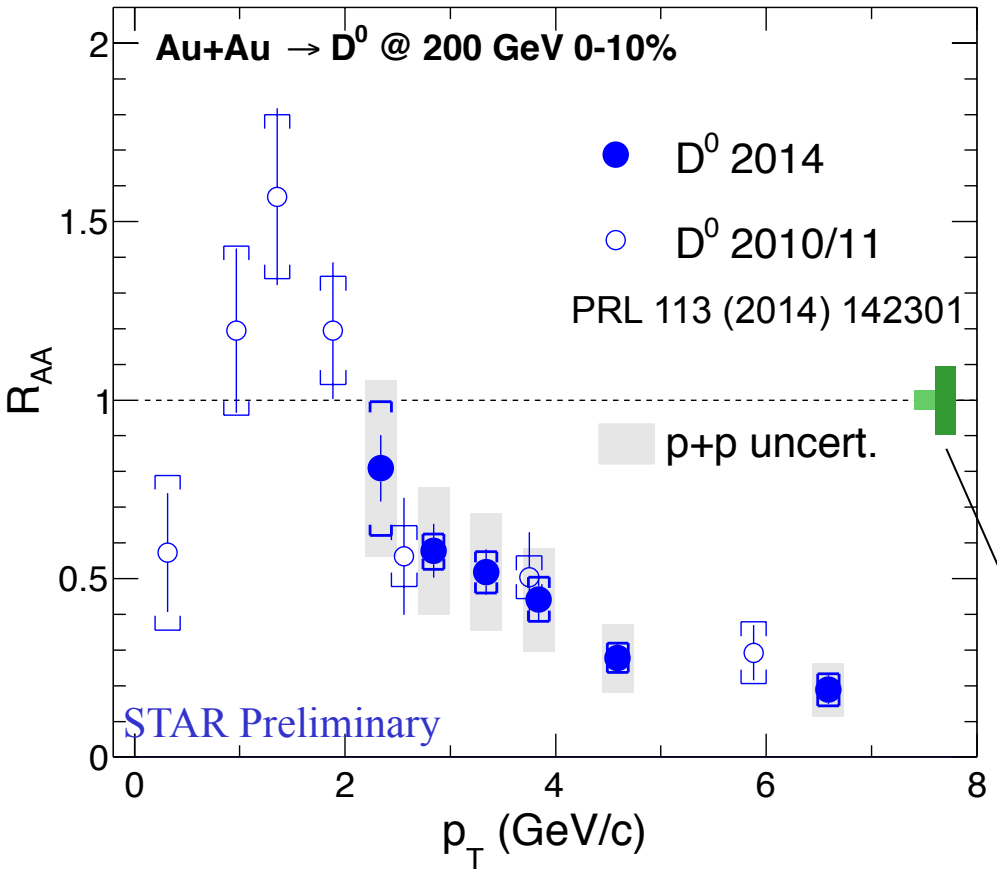
- With the HFT, significantly enhanced D^0 signal-to-background ratios in a broad range of transverse momentum

Invariant yield



- [High p_T] Consistent with published result, with improved statistical precision
  - Finalizing systematic uncertainties for p_T< 2 GeV/c

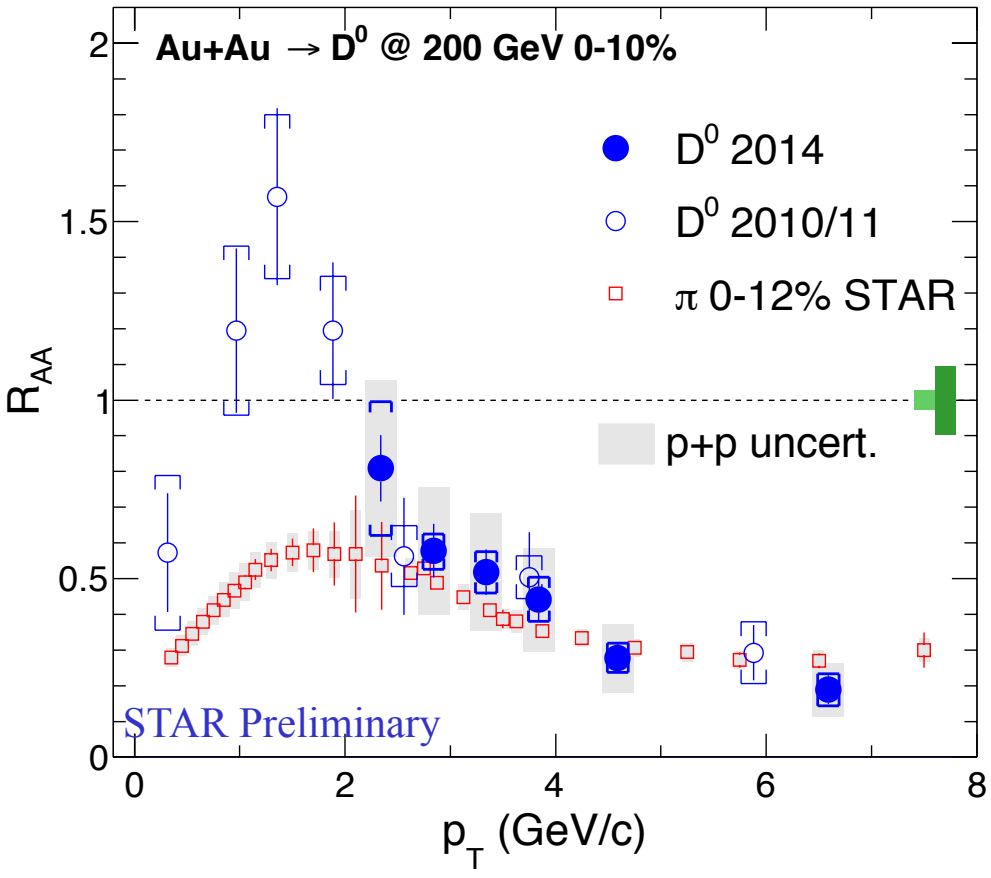
Nuclear Modification Factor



- High p_T: significant suppression in central Au+Au collisions
- New Au+Au results have improved statistical and systematic precision
- p+p precision to be improved using 2015 data with HFT

AuAu N_{coll} uncertainty [left]
pp normalization uncertainty [right]

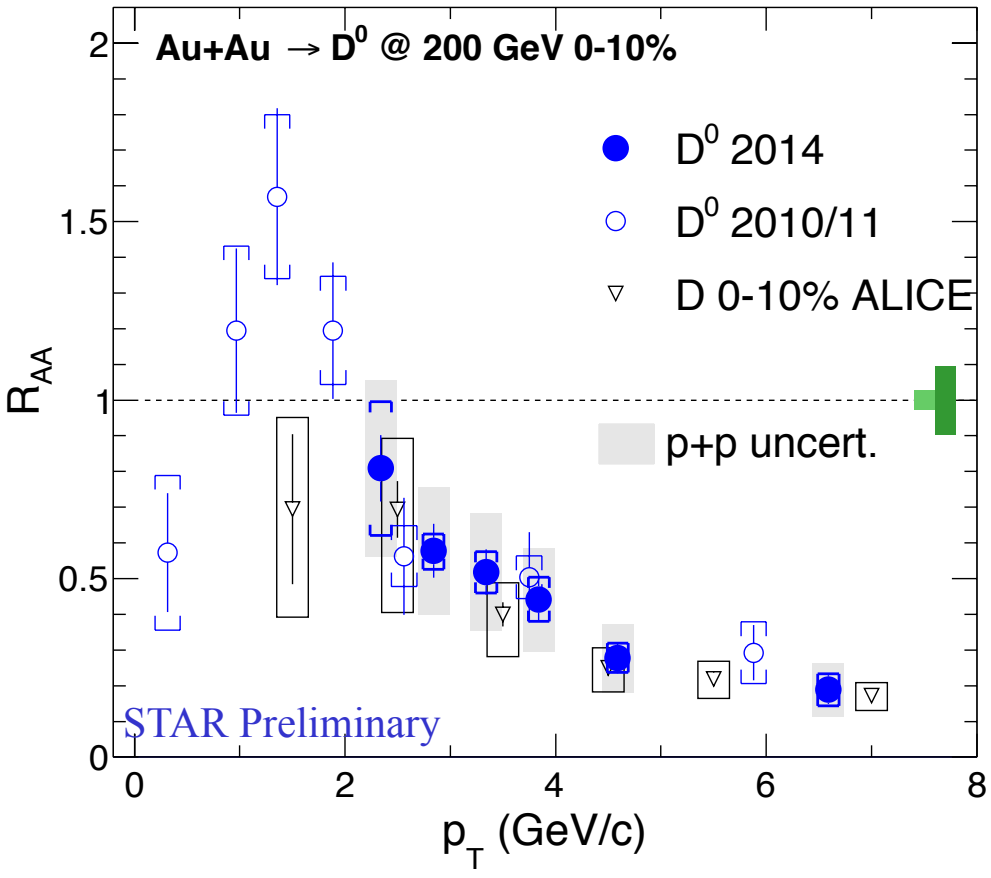
R_{AA} : D^0 vs. π



- $R_{AA}(D) \sim R_{AA}(\pi)$ at p_T>4 GeV/c

STAR D^0: PRL 113 (2014) 142301
STAR π : PLB 655 (2007) 104

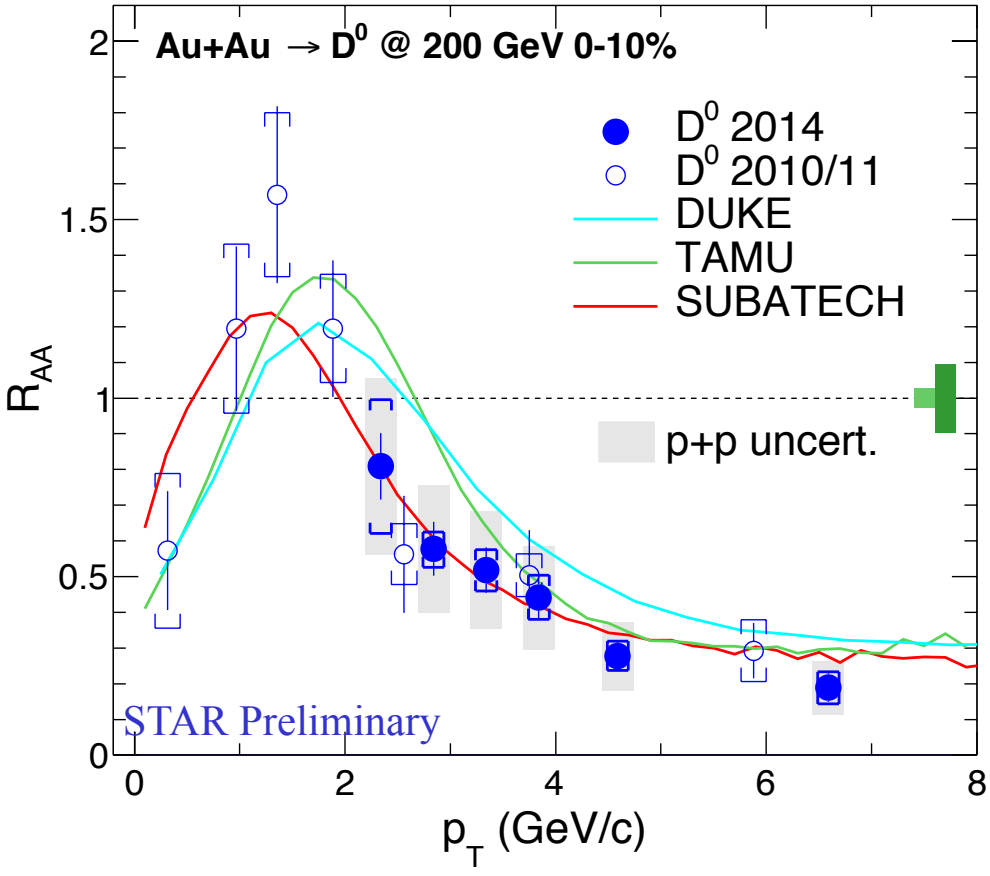
R_{AA} : RHIC vs. LHC



- R_{AA}@ RHIC ~ R_{AA}@LHC

STAR D^0: PRL 113 (2014) 142301
ALICE D: arXiv: 1509.06888

R_{AA} : Comparison to Models



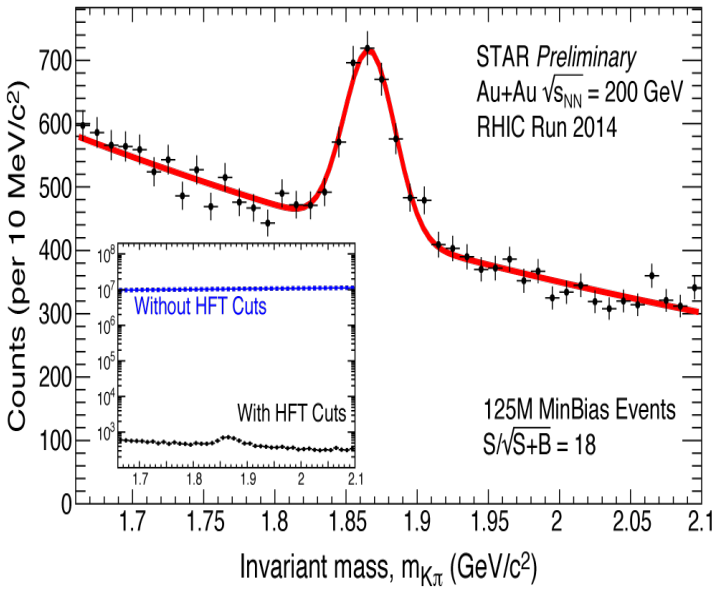
- DUKE: Langevin simulation, input parameter $(2\pi T)D = 7$ (tuned to the LHC data)
- TAMU: non-perturb., Full T-matrix treatment, $(2\pi T)D = 2\text{-}10$
- SUBATECH: perturb. +HTL +resummation, $(2\pi T)D = 2\text{-}4$

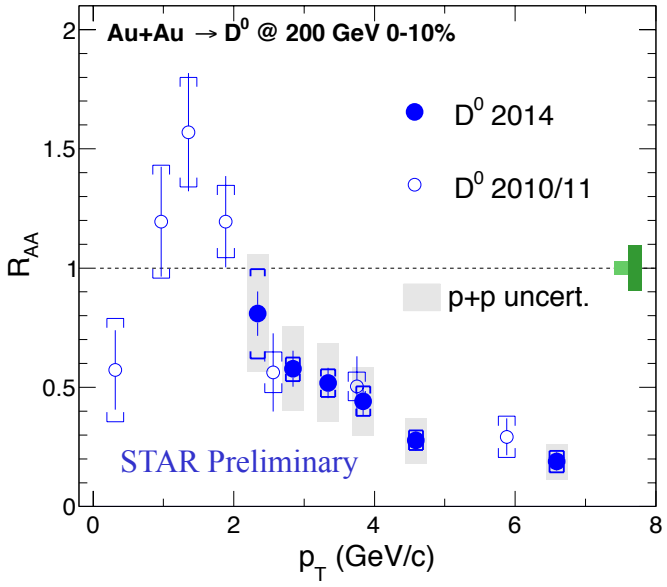
Data compatible with models which predict the value of diffusion coefficient in the range $2 < (2\pi T)D < 10$, same models can also reproduce the measured D^0 v_2 [QM15,talk ID:493]

STAR: PRL 113 (2014) 142301
DUKE: PRC 92 (2015) 024907
Theory: arXiv:1506.03981(2015)

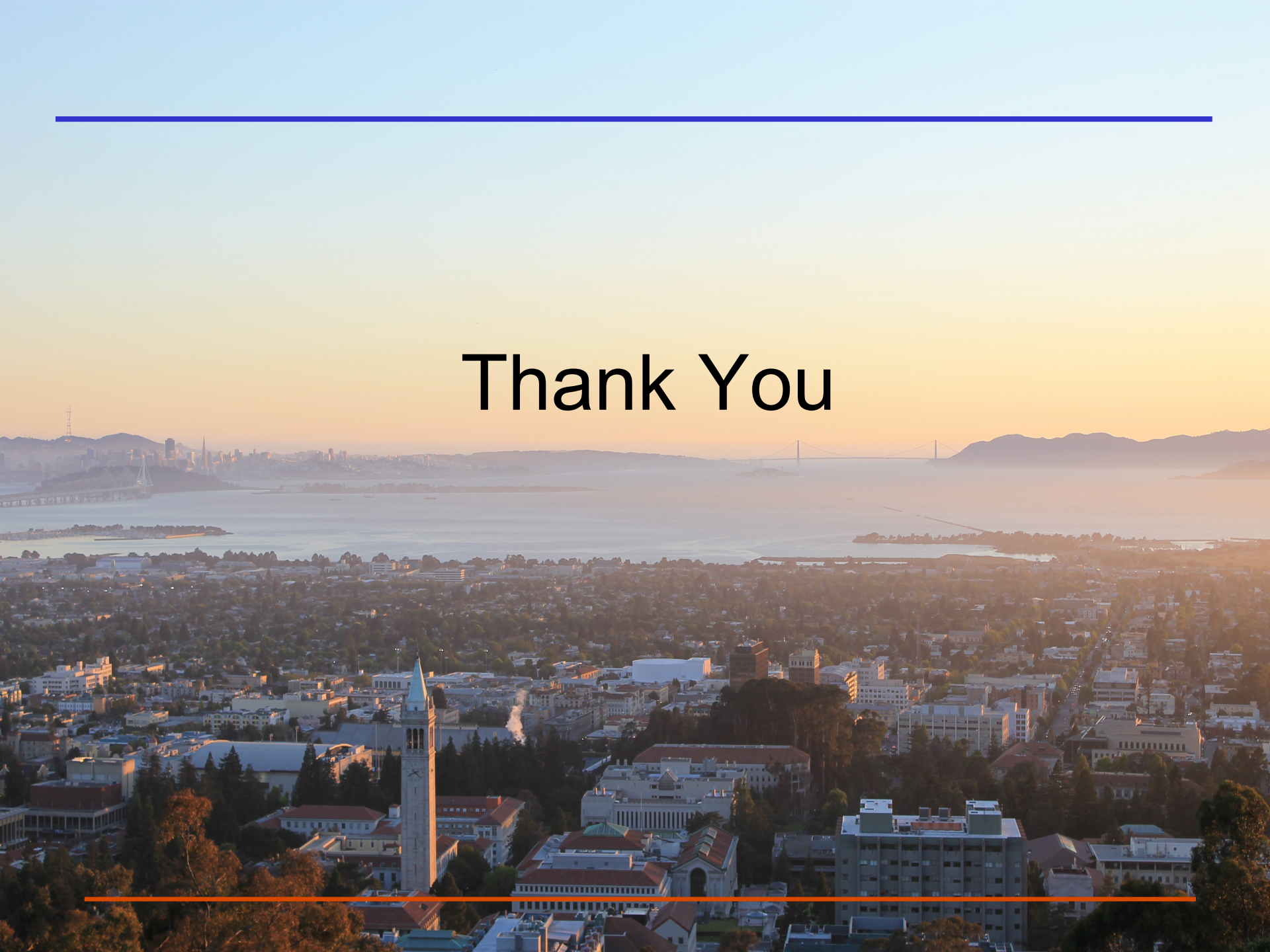
Theory curves: latest calculations from private communications

Summary & Outlook





- First measurement of D^0 R_{AA} using STAR HFT.
  - Significant suppression at high p_T in central Au+Au collisions
  - Improved data precision, will further constrain models
  - Extracted diffusion coefficient $2 < (2\pi T)D < 10$ for central Au+Au collisions at RHIC, consistent with what we learned from the charm hadron v_2 measurements
- Near future outlook with HFT
  - Year 2014 full D^0 spectra and R_{AA} is coming soon
  - Year 2015 p+p and p+Au data is on the way
  - Year 2016 Au+Au 2 Billion minimum bias events, high statistics data will help to reduce the uncertainty of the medium property $(2\pi T)D$


Thank You

Efficiency Correction

D^0 efficiency = TPC tracking eff ⊗ HFT tracking eff ⊗ topological cuts

Data-driven simulation (5-15% p_T-dependent systematics)

- HFT matching and resolution smearing using distributions extracted from data:
  - HFT eff. × geometrical acceptance: (HFT matched tracks) / TPC tracks.
  - Spatial resolution: DCA distributions of HFT matched tracks (XY-Z dependence).

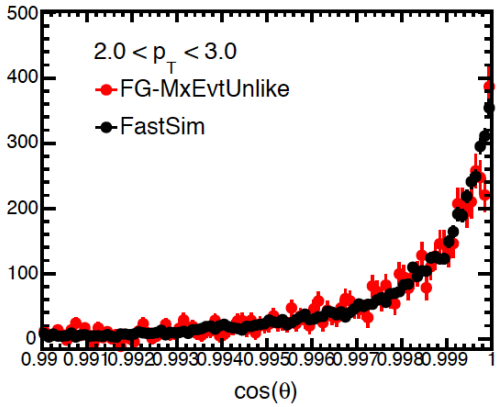
Luminosity, centrality, azimuth and pseudo-rapidity dependence have been considered.

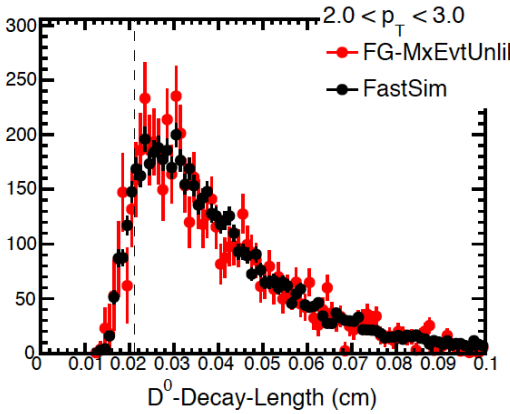
Embedding (~3% systematic uncertainty)

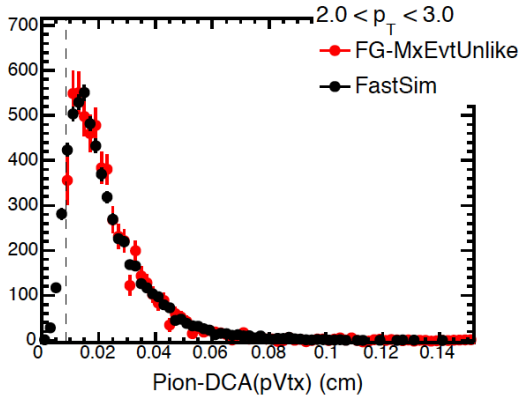
- Full STAR GEANT simulation

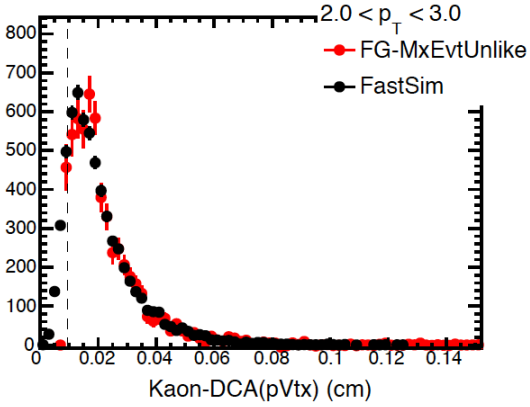
  + MC embedded in real raw data + data reconstruction chain

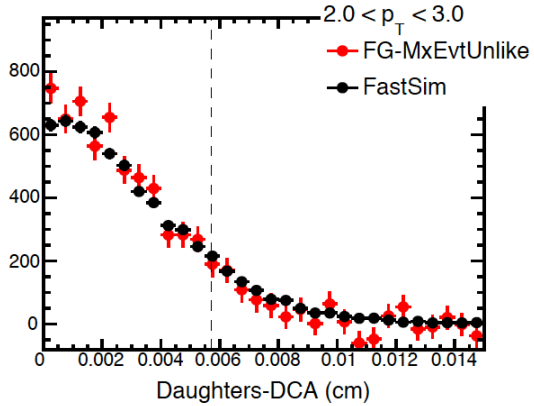
Topology distribution comparison

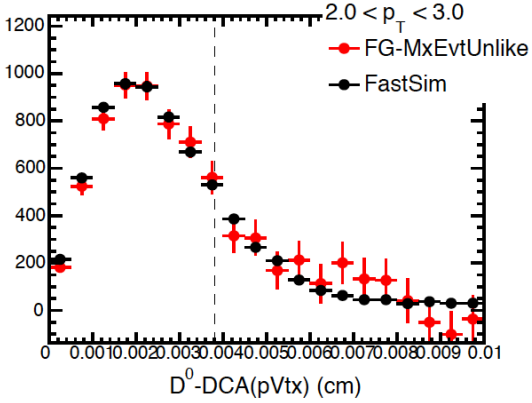




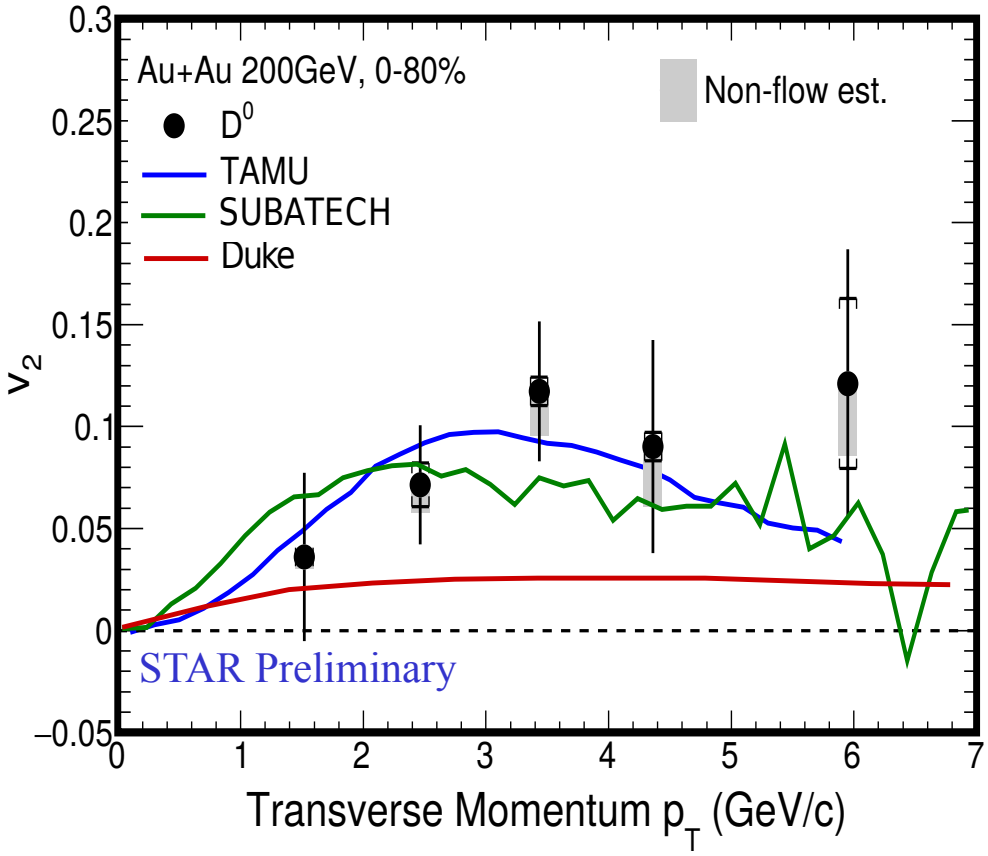








V_2 : Comparison to Models



Also good agreement between models and experiment for v_2

Compatible with models predicting a value of diff. coefficient between 2 to ~10

Theory curves: latest calculations from private communications