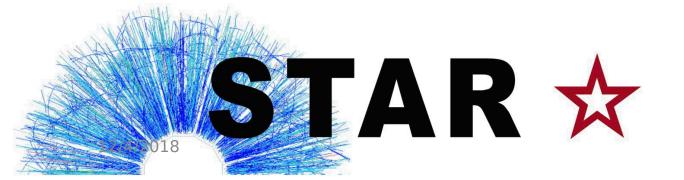
Production of D * Mesons in Heavy—ion Collisions Measured by the STAR Experiment

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Zimanyi School 2018, Budapest, 12/4/2018





Outline

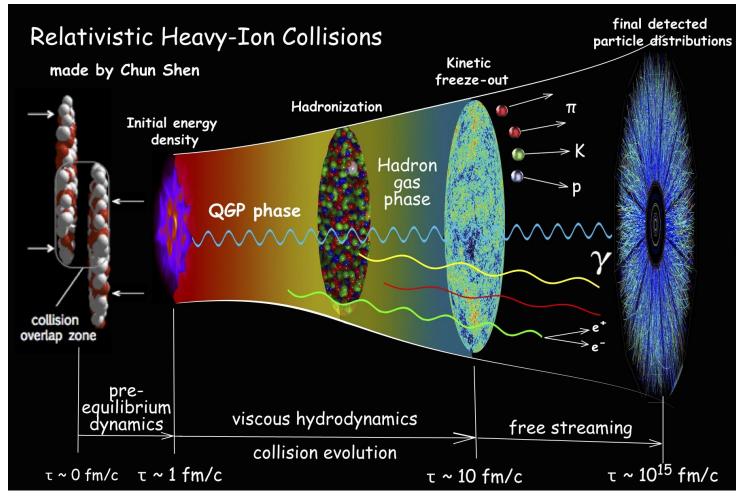


- Physics Motivation
- STAR Experiment
- D * Analysis in Au+Au Collisions
 - Dataset and analysis method
 - Selection criteria for topological variables
 - Raw yield extraction
 - Nuclear modification factor
- Improvement Using TMVA
 - BDT training
 - Comparison to standard method
- Summary

Physics Motivation



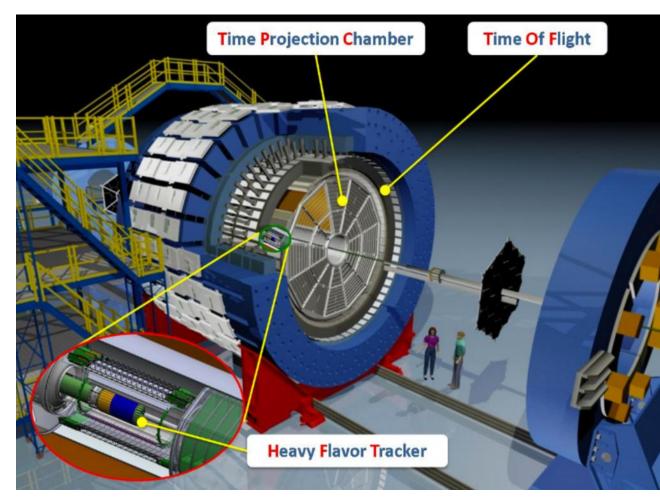
- Quark-Gluon Plasma (QGP) is created in ultrarelativistic heavy-ion collisions
- Heavy quarks serve as a probe of the QGP
- We study interactions of heavy quarks with the medium:
 - energy loss
 - collective flow
 - hadronization



STAR Experiment

STAR

- Located at Brookhaven National Laboratory, USA
- TPC Time Projection Chamber
 - tracking
 - particle identification via energy loss (dE/dx)
- TOF Time–of–Flight detector
 - particle identification via flight time $(1/\beta)$
 - extend particle identification at p > 1 GeV/c

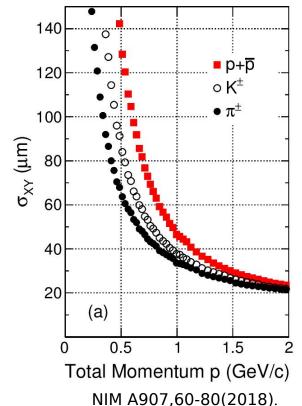


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- HFT Heavy Flavor Tracker
 - 2 layers of silicon pixel and 2 layers of strip detectors (one not used in 2014)
 - operating in 2014–2016
 - excellent spatial resolution ($\sigma \sim 46 \ \mu m$ for 750 MeV/c kaons)
 - topological reconstruction of open–charm hadrons eg. Λ_c , D^\pm , D^0 , D_s







Analysis Method

STAR

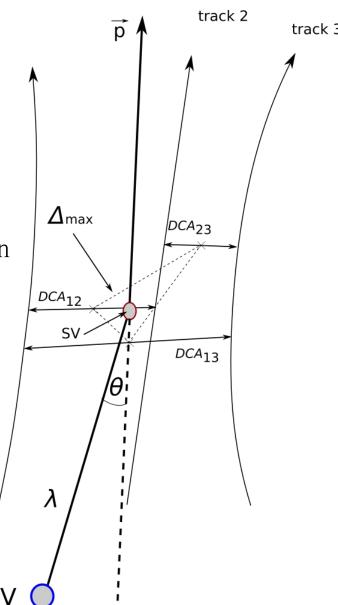
• D \pm : m = 1870 GeV/ c^2 , $c \tau = 312 \pm 2 \mu m$

• D \pm -> K \mp π \pm π BR: (8.98 \pm 0.28) %

• Wrong-sign K π π combinations used for background estimation

• PID using TPC and TOF (when available)

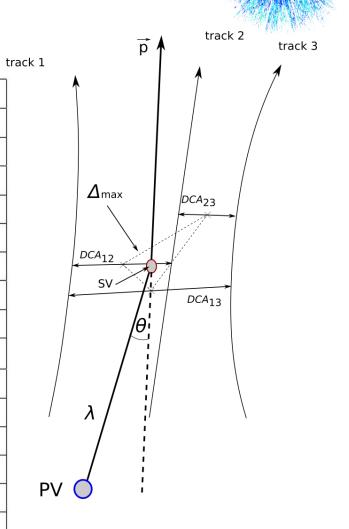
- Topological variables for $K\pi\pi$ candidates
 - DCA of K and π to the primary vertex
 - D \pm decay length λ (distance between PV and SV)
 - Pointing angle (θ)
 - Maximum distance of pair vertices (Δ_{max})
 - DCA of K π and π π pairs (DCA₁₂, DCA₂₃, DCA₁₃)



track 1

Selection Criteria

Type	Cut	Value(s)	
Event Selection -	Primary vertex (PV) position	$ V_{\rm z} < 6 { m cm}$	
	Difference of PV positions from TPC and VPD	$ V_{\rm z} - V_{\rm z}^{\rm VPD} < 3 \text{ cm}$	
	TPC Hits	$N_{\rm TPC} > 20$	
Track Selection	HFT Hits	2 PXL and IST	
	Pseudorapidity	$ \eta < 1$	
	Daughter transverse momentum	$p_{\mathrm{T}} > 0.5 \; \mathrm{GeV}/c$	
Particle Identification	TPC energy loss - pions	$ n_{\sigma}^{\pi} < 3$	
	TPC energy loss - kaons	$ n_{\sigma}^{\mathrm{K}} < 2$	
	Particle flight time	$\left \frac{1}{\beta} - \frac{1}{\beta_{\rm th}} \right < 0.03$	
Topological Cuts	Daughter pairs DCA	$DCA_{pair} < 80 \ \mu m$	
	Decay length	$30 < \lambda < 2000 \; \mu \text{m}$	
	Maximum distance of pair vertices	$\Delta_{\rm max} < 200~\mu{\rm m}$	
	Pointing angle	$\cos \theta > 0.998$	
	Pion DCA to PV	$DCA_{\pi} > 100 \ \mu \text{m}$	
	Kaon DCA to PV	$DCA_{\rm K} > 80~\mu{\rm m}$	



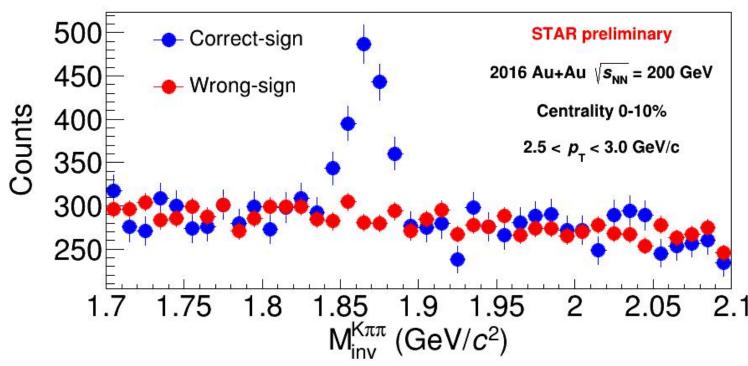
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Raw Yield Extraction



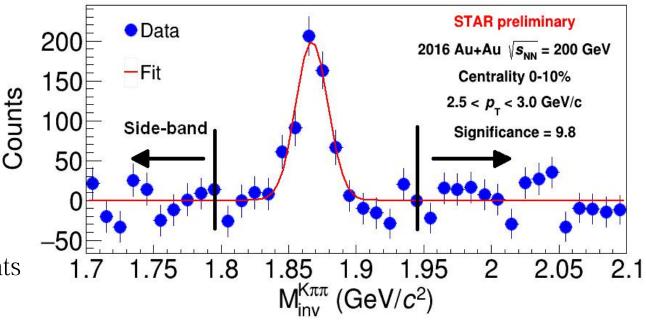
- Estimate background from wrong—signs
- Scale background by (# of correct–signs)/(# of wrong–signs) outside 3σ of signal peak
- Subtract background



Raw Yield Extraction



- Estimate background from wrong—signs
- Scale background by (# of correct–signs)/(# of wrong–signs) outside 3σ of signal peak
- Subtract background
- Obtain the raw yield using bin counting method and calculate signal significance
- The D $^\pm$ signal significance varies between 3.1 and 12.1 for 1 < p_T < 7 GeV/c in 0–10% central events

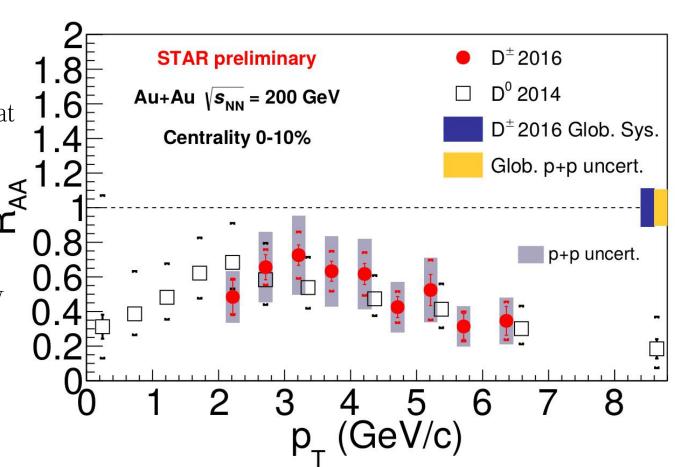


Recent HFT Results



$$R_{\rm AA} = \frac{\frac{d^2 N_{\rm AA}}{dp_{\rm T} dy}}{\langle N_{\rm coll} \rangle \times \frac{d^2 N_{\rm pp}}{dp_{\rm T} dy}}$$

- ~1.0 B Au+Au events at $\sqrt{s_{NN}}$ = 200 GeV with HFT from 2016 analyzed (see Jan Vanek's talk)
- Significant suppression in central Au+Au collisions at high p_T interaction of charm quarks with the medium
- Suppression consistent with D⁰
- ~900 M min-bias Au+Au events at $\sqrt{s_{NN}}$ = 200 GeV with HFT from year 2014 available

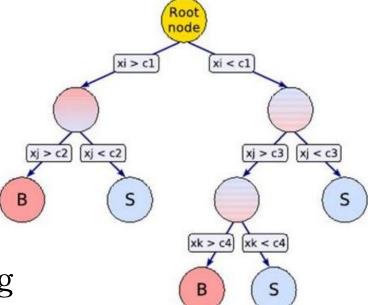


TMVA Improvement



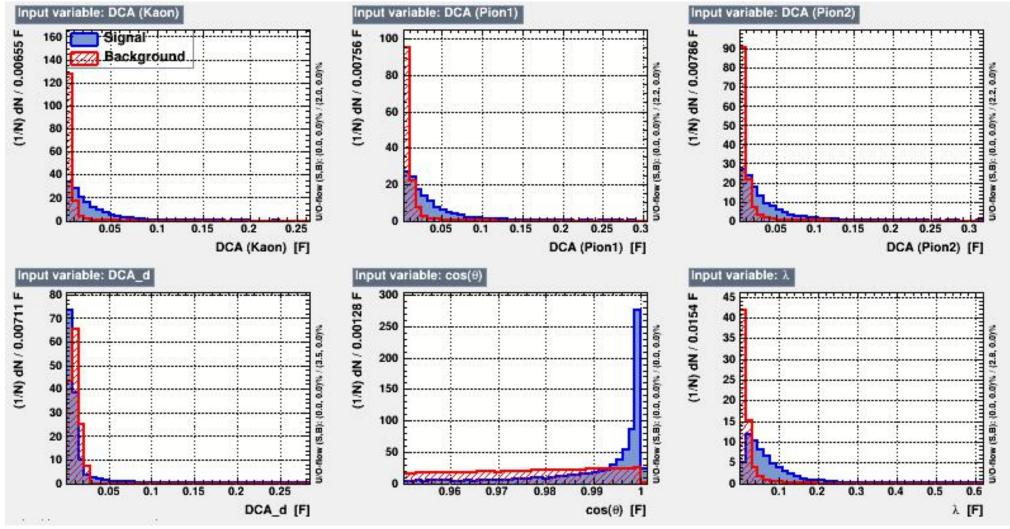
• we use Boosted Decision Trees (BDT) to improve the signal significance

- training signal sample from FastSim (8.37 M),
- background from data wrong–signs (8.41 M)
- variables used for optimization:
 - DCA_K, DCA_π, DCA_{pair}
 - $\cos \theta$, λ
- •850 trees with depth 3 (standard settings) boosting
- dependence on variables boiled down to 1 number BDT response (-1 = pure background, 1 = pure signal in ideal case)



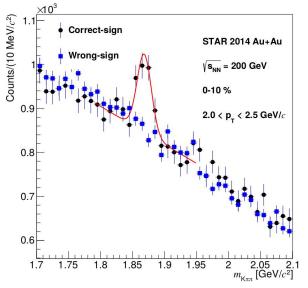


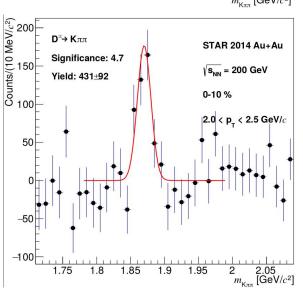
Topological Variable Distributions

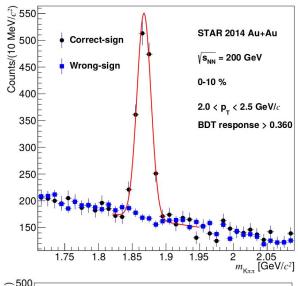


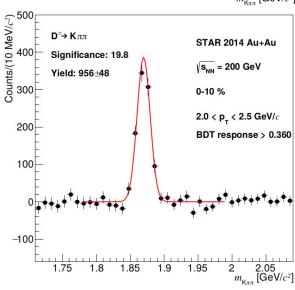
Comparison: Straight Cuts vs. TMVA BDT

- No peak in wrong—signs
- Largest improvement of significance for the lowest p_T bin – factor of 4.2







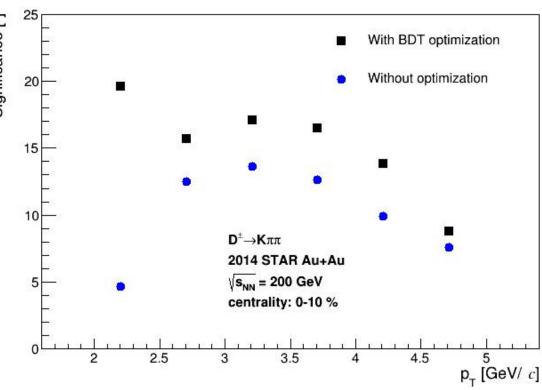


Signal Significance: Straight Cuts vs. TMVA:BDT STAR



• STAR 2014 Au+Au at $\sqrt{s_{NN}}$ = 200 GeV, 0–10 % most central collisions (103.0 M events)

	Straight cuts		BDT		Sig. ratio
p _T [GeV/c]	Yield [–]	Sig. [–]	Yield [–]	Sig. [–]	Sig. ratio
2.0 - 2.5	431 ± 92	5	956 ± 48	20	4.2
2.5 – 3.0	630 ± 50	13	1237 ± 79	16	1.3
3.0 – 3.5	433 ± 32	14	533 ± 31	17	1.3
3.5 - 4.0	259 ± 21	13	468 ± 28	17	1.3
4.0 – 4.5	153 ± 15	10	264 ± 19	14	1.4
4.5 – 5.0	77 ± 10	8	110 ± 13	9	1.2



Summary and Outlook



- HFT allows D \pm reconstruction in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
- D * is suppressed in central Au+Au collisions
 - Suppression of D ± is consistent with D⁰ results
 - Strong interaction between charm quarks and the QGP
- Measurement of D * production using TMVA:BDT method is in progress
 - We observe significant improvement in low p_T region
 - Effort being made to extend the measurement range to below 2 GeV/c

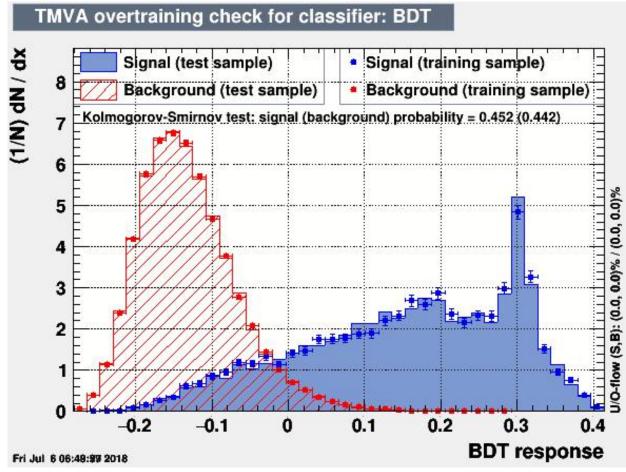


BACKUP

BDT Overtraining Check



• we want to avoid overtraining on statistical fluctuations



for $2.5 < p_T < 3.0 \text{ GeV/c}$, 0-10 %





