Topological Cut Optimization for Λ_c Reconstruction Using the Supervised Machine Learning Algorithm in TMVA at STAR

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Outline

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- Λ_c Decay Topology
- TMVA-Boosted Decision Trees
- Λ_c Reconstruction Results
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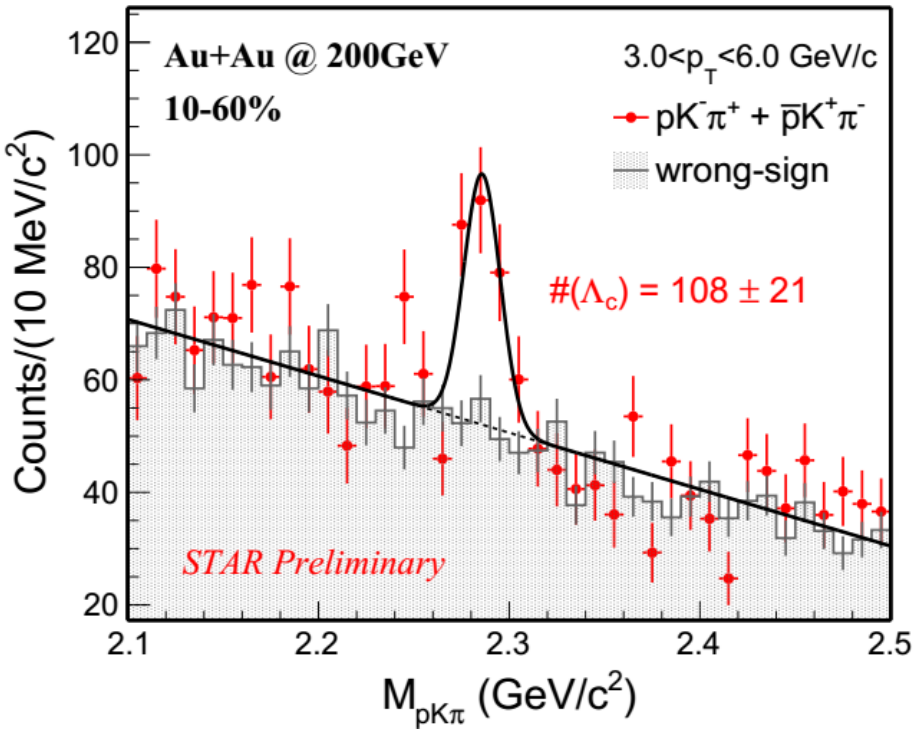
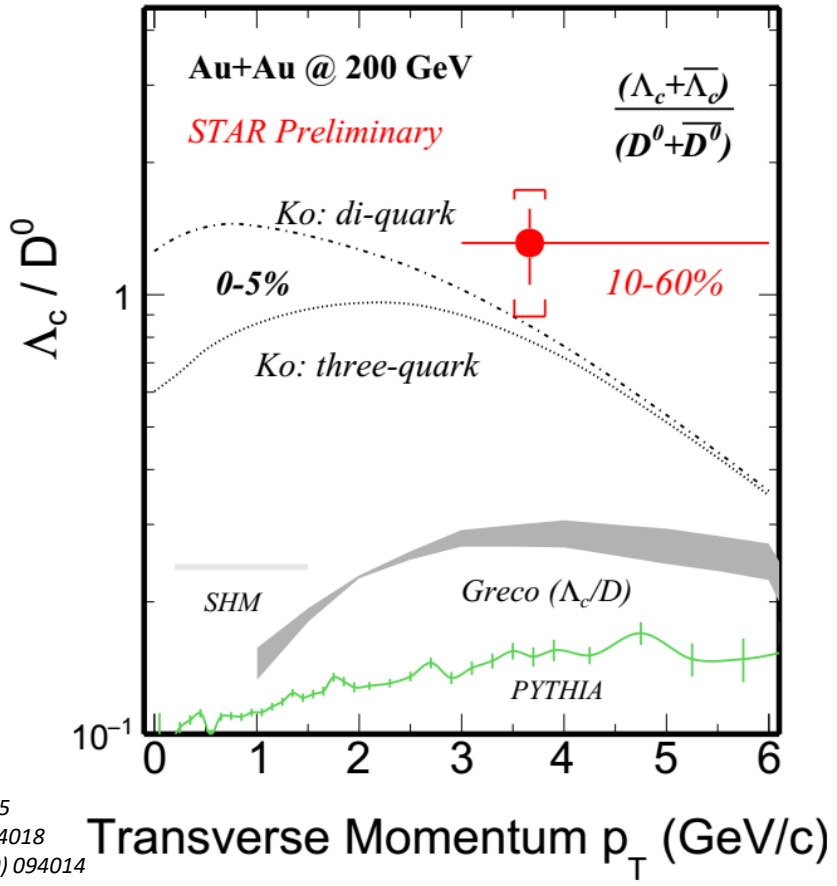
Motivation

- With the dataset of Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV recorded by STAR experiment at RHIC in 2014, $\Lambda_c^+(\overline{\Lambda}_c^-)$ signals were successfully reconstructed through the hadronic decay channel ($\Lambda_c^+ \rightarrow \pi Kp$).



Motivation

- A strong enhancement of Λ_c/D^0 compared to PYTHIA values is observed.
- Ko model including coalescence of thermalized charm quarks is consistent with data.
- Measurements of Λ_c production with better precision require further topological cut optimization.

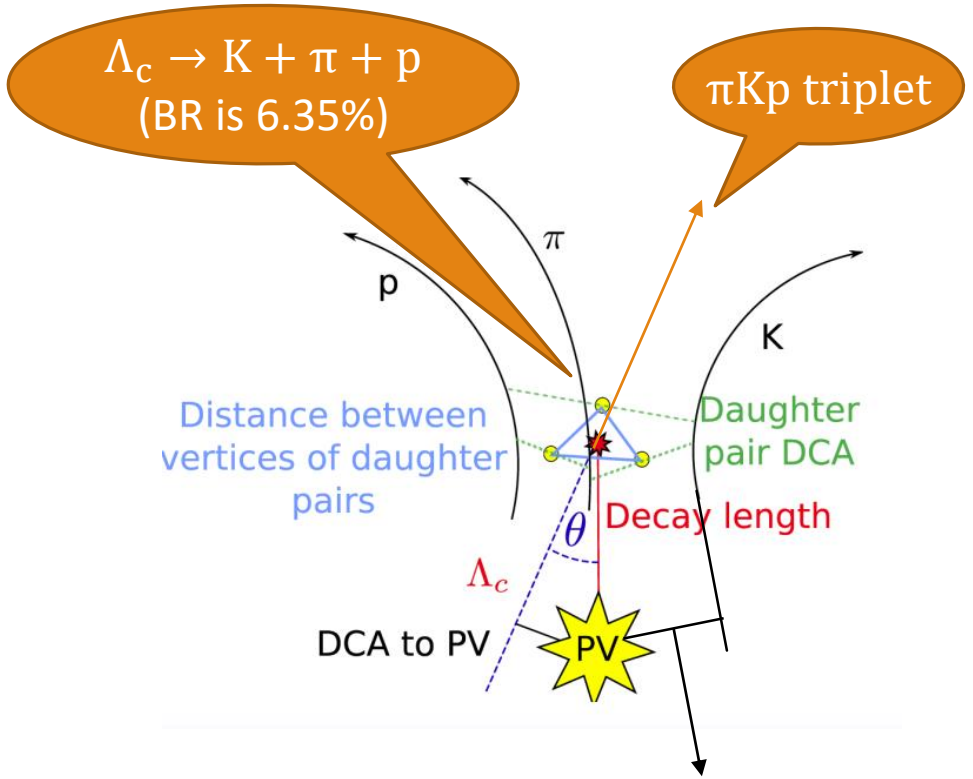


Ko: Phys.Rev.C 79 (2009) 044905
Greco: Phys.Rev.D 90 (2014) 054018
SHM: Journal of Phy.G 37 (2010) 094014

Λ_c Decay Topology

Constituent quarks	udc($\bar{u}\bar{d}\bar{c}$)
$c\tau$	60 μm
Mass	2286 MeV/c^2
Right-sign	$K^+\pi^-\bar{p}, K^-\pi^+p$
Wrong-sign	$K^+\pi^+\bar{p}$, $K^-\pi^-\bar{p}$, $K^+\pi^-p$, $K^+\pi^+p$, $K^-\pi^-p$, $K^-\pi^+\bar{p}$

Cut variables used for TMVA-BDT: daughter pion, Kaon and proton DCA to the primary vertex, DCA between daughters, cosθ (θ is shown on the right picture), Decay Length of Λ_c.



Distance of Closest Approach (DCA) to Kaon and PV

C. Patrignani et al. (Particle Data Group), Chin. Phys. C, 40, 100001 (2016) and 2017 update

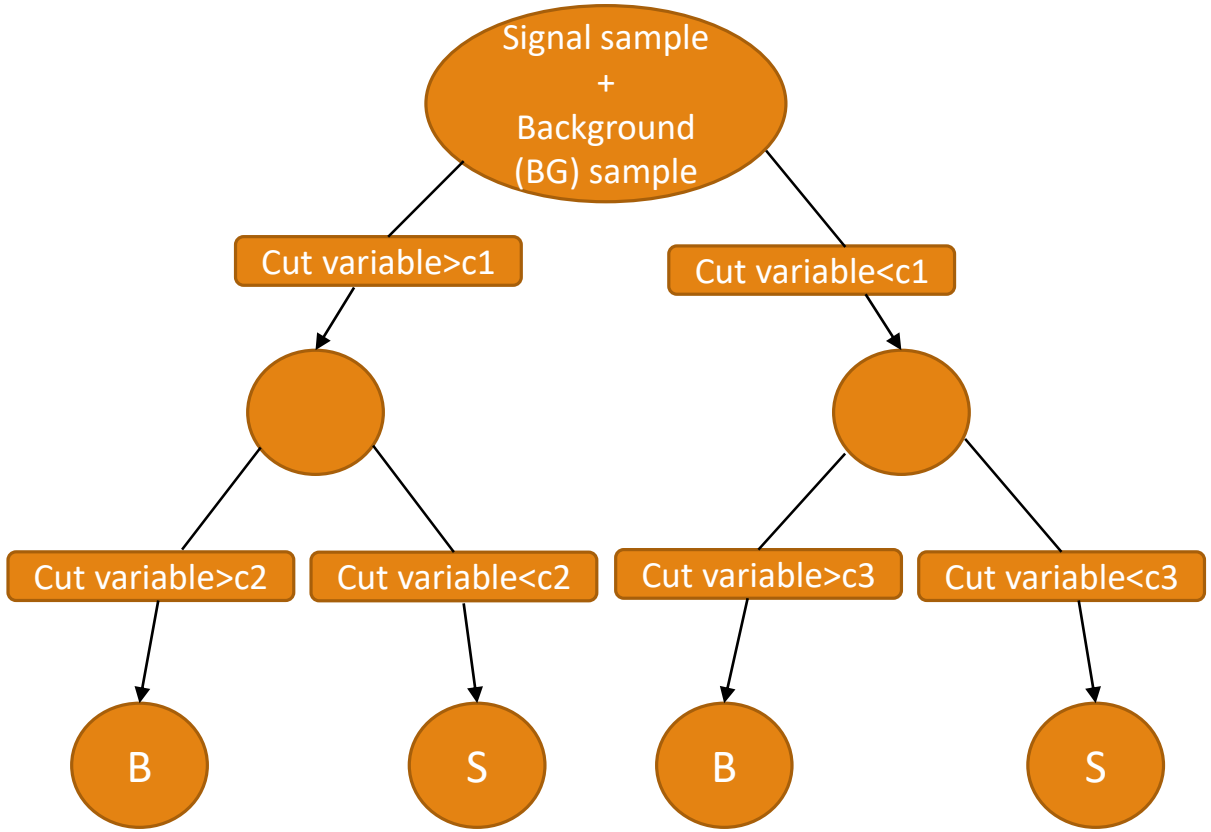
TMVA-Boosted Decision Trees

Build the first decision tree: give the maximum signal and background separation

S node (more signal)
B node (more BG)

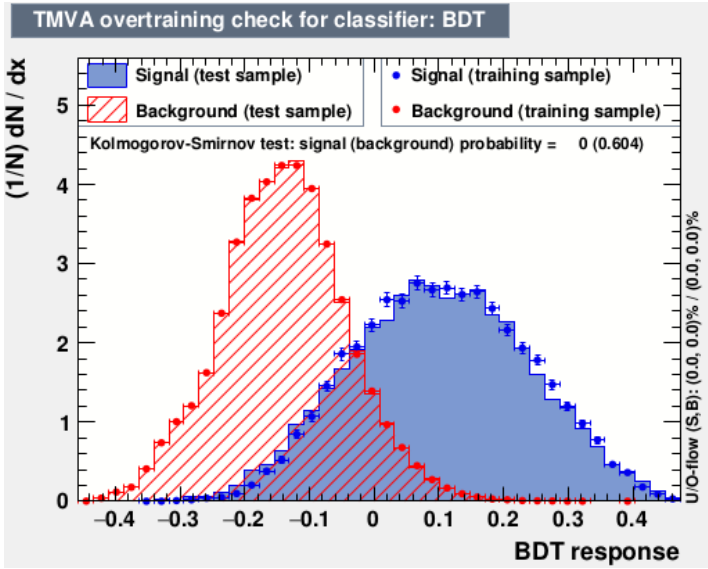
Reweight the misclassified events and then build decision tree forest

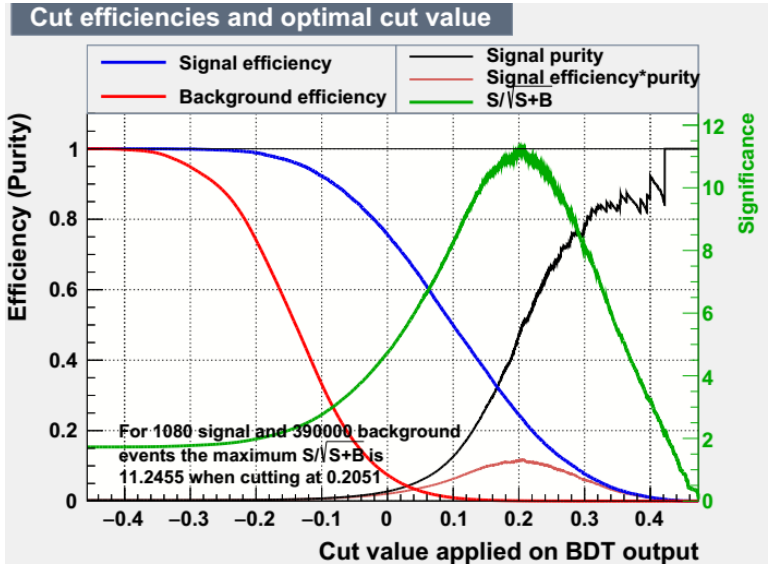
Get the BDT response according to the Adaptive Boost Algorithm



A. Hoecker et al. TMVA - Toolkit for Multivariate Data Analysis, PoS ACAT 040 (2007), arXiv:physics/0703039

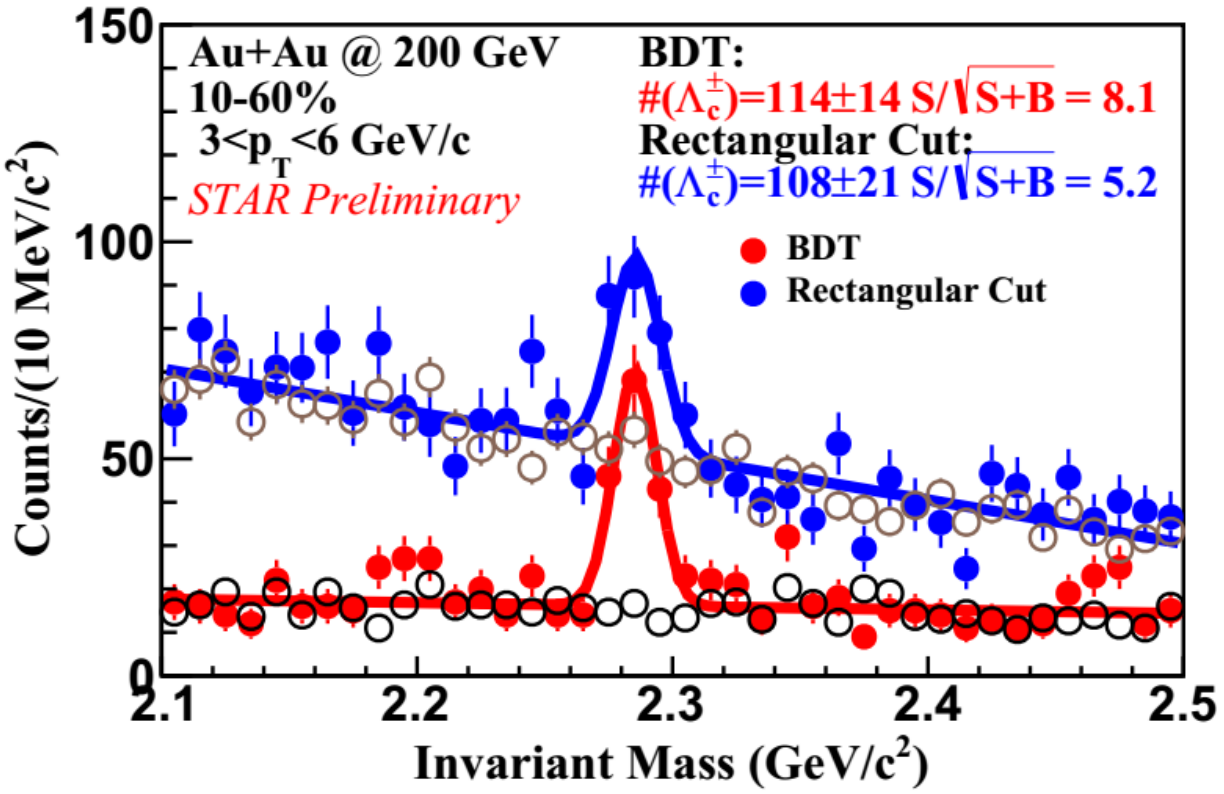
BDT Training and Cut





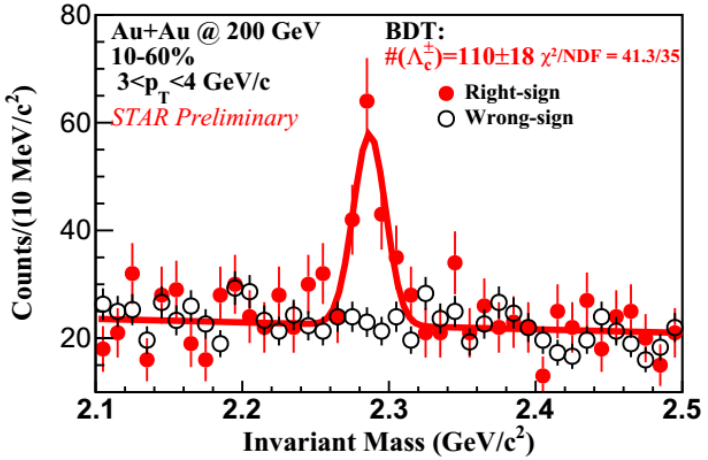
- Λ_c signal sample is from simulation (EvtGen + data-driven fast simulator). Background sample is from experimental data.
- Left: one half of the sample was used for the training (symbols) and the other was used to perform the over-training test (curves). -> Consistent with each other: no over-training.
- Right: significance as a function of the BDT response (green line) after BDT training.

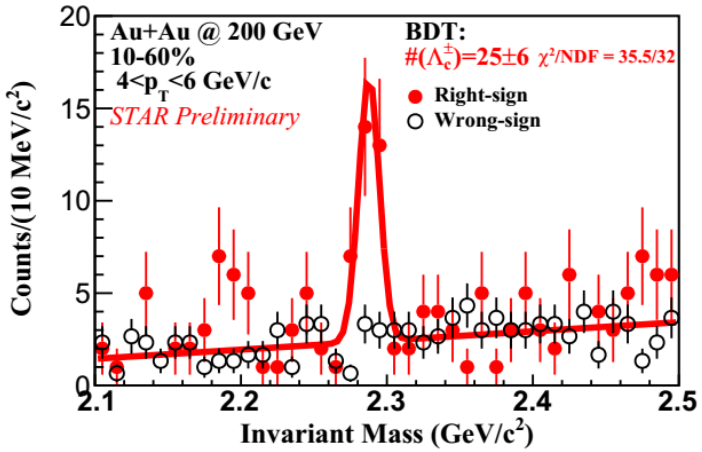
Λ_c Reconstruction Results

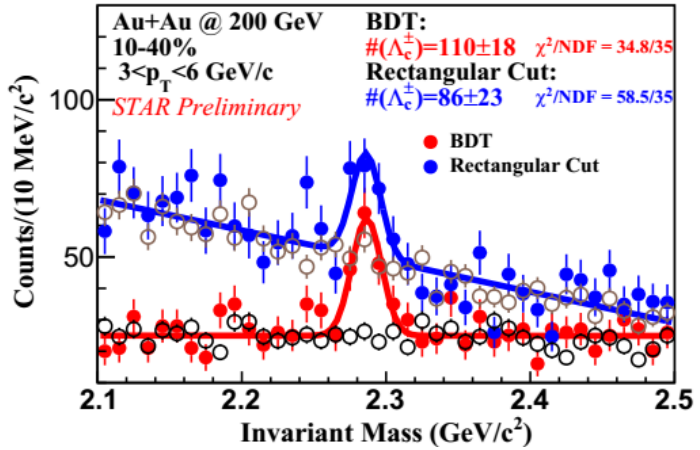


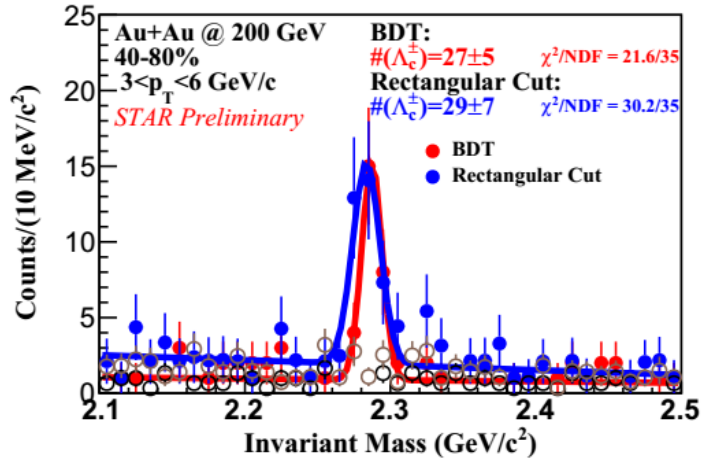
- 2014 data, ~ 900 M events: Λ_c candidates from right-sign combination (solid symbols) and background from wrong-sign (open symbols).
- Raw yield and significance are calculated within 3 sigma range by bin counting.
- Compared to the result using the TMVA-Rectangular Cut method, the TMVA-BDT method increases the significance by about 50%.
- The signal number remains the same but background is suppressed by a factor of 4 with TMVA-BDT.

p_T and Centrality Dependence





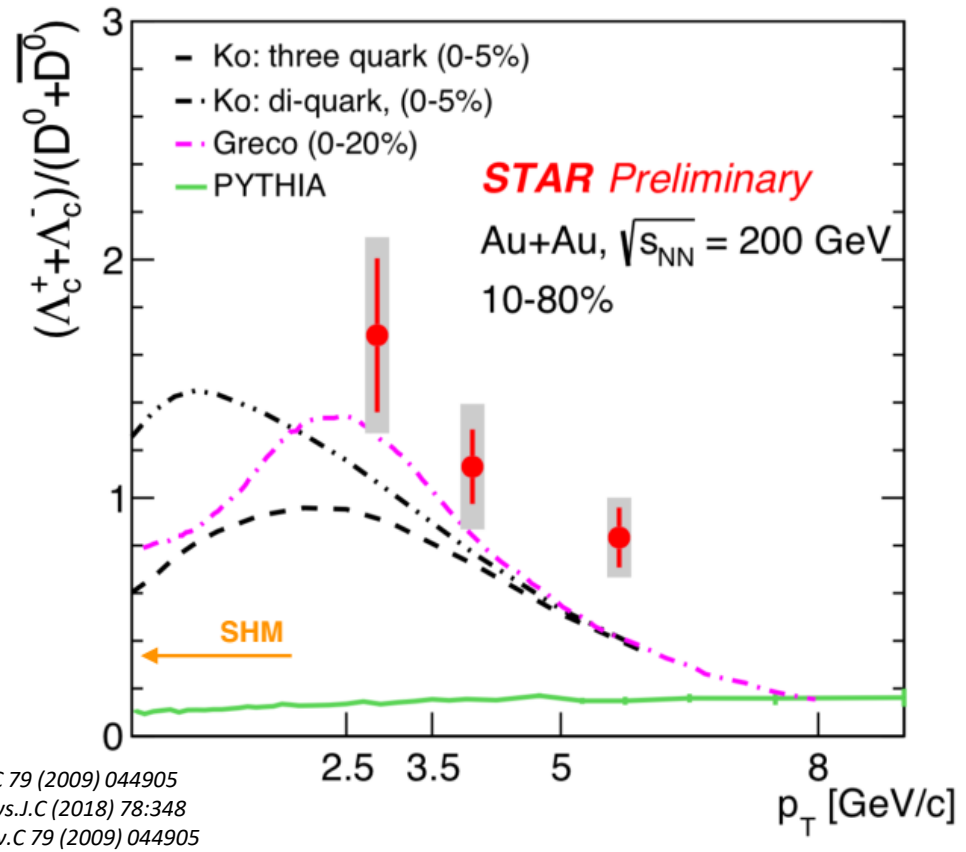




	Range	Rectangular Cut	BDT
Significance	$3<p_T<4$ GeV/c, 10-60%	4.5	6.7
Significance	$4<p_T<6$ GeV/c, 10-60%	4.0	4.2
Significance	$3<p_T<6$ GeV/c, 10-40%	4.1	6.6
Significance	$3<p_T<6$ GeV/c, 40-80%	4.5	5.1

Latest Λ_c/D^0 from STAR

- A strong enhancement of Λ_c/D^0 compared to PYTHIA values is observed. The enhancement increases as p_T decreases.
- Coalescence model predictions are closer to data, but the observed enhancement is larger than that predicted by models, particularly at higher p_T.
- Ratio not described by Statistical Hadronization Model prediction.



Ko: Phys.Rev.C 79 (2009) 044905
Greco: Eur.Phys.J.C (2018) 78:348
SHM: Phys.Rev.C 79 (2009) 044905

Summary

- Extraction of Λ_c signal from Au+Au data has been optimized using the TMVA-Boosted Decision Trees method in different centrality and p_T bins.
- Compared to the TMVA-Rectangular Cut method, the TMVA-BDT method improves the signal significance for Λ_c by up to 60% depending on p_T and centrality.
- The strong enhancement of Λ_c/D^0 compared to PYTHIA is consistent with coalescence hadronization of deconfined charm quarks in the medium.