Production of $D_s^{\pm}$ Mesons in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV by STAR

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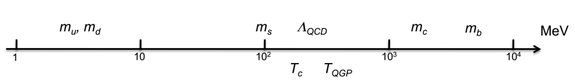
Abstract

Charm quarks are excellent probes to study properties of the Quark-Gluon Plasma (QGP) created in ultra-relativistic heavy-ion collisions. In particular, measurements of the $D_s^{\pm}$ meson production can provide valuable information on the strangeness enhancement in the QGP as well as the charm quark hadronization mechanisms in heavy-ion collisions. In this poster, we present results from the STAR experiment on invariant yields of $D_s^{\pm}$ mesons as a function of transverse momentum for different centrality classes of Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. The measurements utilize the data with the Heavy Flavor Tracker from 2014 and 2016. The yield ratio between the strange ($D_s^{\pm}$) and non-strange (D^0) open charm mesons is shown, and compared to PYTHIA and other model calculations. A clear enhancement relative to the PYTHIA calculation is seen in the ratio, while model calculations incorporating strangeness enhancement and charm quark coalescence hadronization are closer to data. These results suggest that recombination of charm quarks with equilibrated strange quarks in the QGP plays an important role in charm quark hadronization.

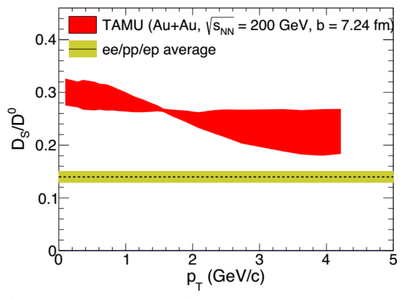
Heavy Quarks and Why Study $D_s^{\pm}$?



- $m_{c,b} >> T_{QGP}$: predominately created from initial hard scatterings, relaxation time is comparable with life-time of the QGP phase.

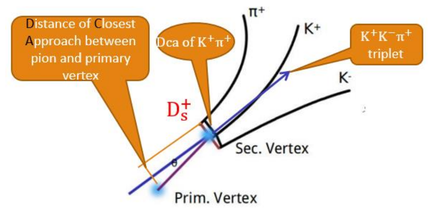
f (c->$D_s^{\pm}$)	f (c->D^0)	$D_s^{\pm}/D^0$
0.0802	0.6086	0.132

Average fractions of charm quark fragmentation into hadrons from combining ee/pp/ep collision data [1].



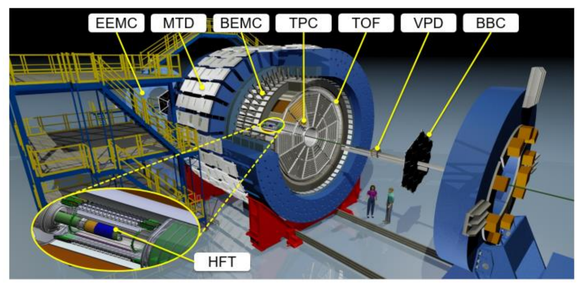
- The strangeness enhancement in QGP + recombination of charm quarks with equilibrated strange quarks → The enhancement of $D_s^{\pm}/D^0$ yield ratio in Au+Au collisions compared to that in ee/pp/ep collisions [2].

$D_s^{\pm}$ Decay Topology and STAR Experiment



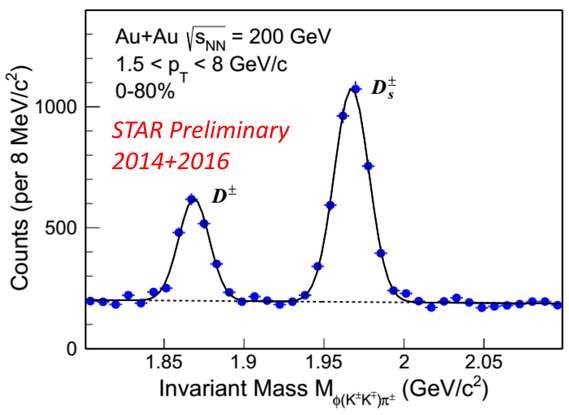
$$D_s^{\pm} \rightarrow \phi + \pi^{\pm} \rightarrow K^{\pm} + K^{\mp} + \pi^{\pm}$$
$$c\tau(\phi) = 4.65 \times 10^{-8}\,\mu m$$

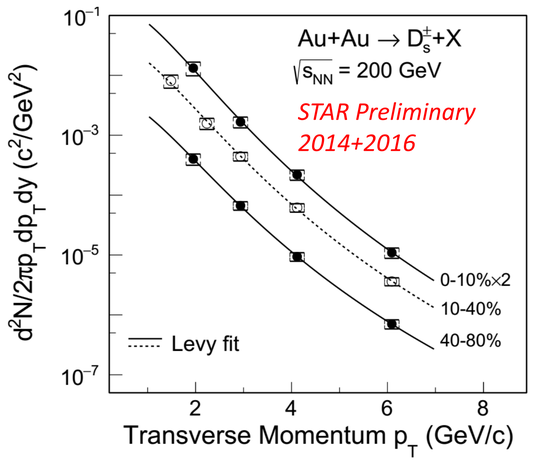
$D_s^{\pm}$	
Quark constituent	$c\bar{s}$ ($\bar{c}s$)
Branching ratio [3]	2.27 %
$c\tau$	150 μm
Rest mass	1967 MeV/c^2



- TPC + HFT: track reconstruction of charged particles ($\pi^{\pm}$, $K^{\pm}$).
- HFT: Excellent vertex position resolution. Greatly improves signal-to-background ratio for reconstruction of open charm hadrons.
- TPC + TOF: identification of charge particles.

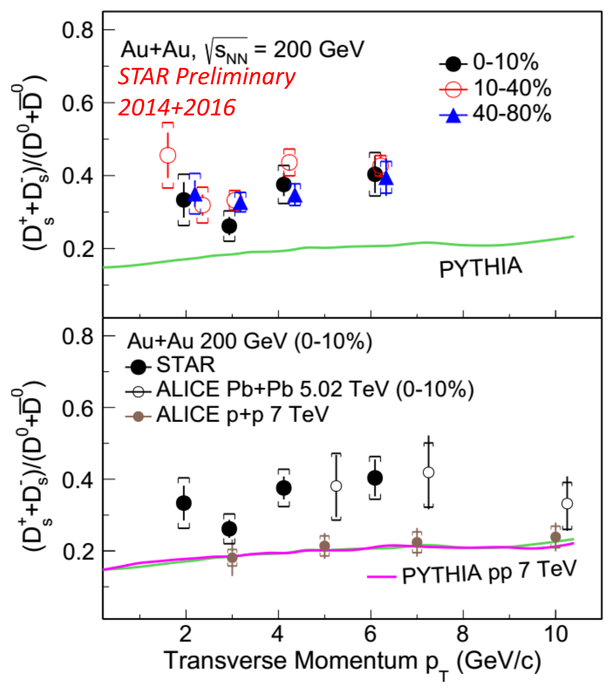
Invariant Mass Distribution and p_T Spectrum from Combined 2014 and 2016 Data





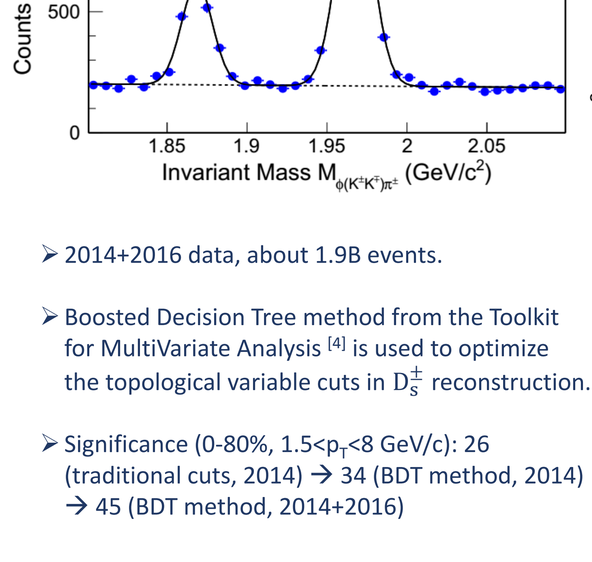
- 2014+2016 data, about 1.9B events.
- Boosted Decision Tree method from the Toolkit for MultiVariate Analysis [4] is used to optimize the topological variable cuts in $D_s^{\pm}$ reconstruction.
- Significance (0-80%, 1.5<p_T<8 GeV/c): 26 (traditional cuts, 2014) → 34 (BDT method, 2014) → 45 (BDT method, 2014+2016)
- $D_s^{\pm}$ invariant yield as a function of p_T in various centrality bins in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Vertical bars (mostly smaller than markers) and brackets on data points represent statistical and systematic uncertainties, respectively.
- Solid and dashed lines depict Levy function fits to the p_T spectrum in each centrality bin.

p_T and Centrality Dependence of $D_s^{\pm}/D^0$ Yield Ratio



- $D_s^{\pm}/D^0$ yield ratio: large enhancement (~1.5-2 times) relative to PYTHIA, no strong centrality dependence.
- Compatible with ALICE [5][6] data in Pb+Pb collisions in the overlapping p_T region.

Comparison with Model Calculations



- The Catania [7] and TAMU [8] model calculations with only coalescence hadronization of charm quarks describe the data for p_T > 4 GeV/c, but deviates at lower p_T. The Catania model with coalescence + fragmentation hadronization better describe the data for p_T < 4 GeV/c, but disagrees with data for p_T > 4 GeV/c.
- Tsinghua model calculations incorporating strangeness enhancement and sequential coalescence hadronization [9] of charm quarks qualitatively describe our measurements.

Summary

- The $D_s^{\pm}$ invariant yield and $D_s^{\pm}/D^0$ yield ratio are measured as a function of p_T for different collision centrality at mid-rapidity (|y|< 1) in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.
- A clear enhancement in the $D_s^{\pm}/D^0$ yield ratio is found in different centrality and p_T bins compared to the values from PYTHIA for p+p collisions at the same collision energy. The enhancement shows weak p_T and centrality dependence.
- The measurements can be qualitatively described by model calculations incorporating strangeness enhancement and (sequential) coalescence hadronization of charm quarks.
- Data suggests that coalescence hadronization play an important role in charm quark hadronization in heavy-ion collisions.

References

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