Measurement of D± meson production in Au+Au collisions at $\sqrt{s_{NN}}=200$ GeV with the STAR experiment

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**Physics Motivation**

- **Quark-Gluon Plasma (QGP)** can be studied using relativistic heavy-ion collisions.

- At RHIC energies, **charm quarks** are produced predominantly through hard partonic scatterings at **early stage** of Au+Au collisions:
  - They experience the **whole evolution of the medium**

- **Charm quark energy loss** in the medium can be studied by measurement of open-charm meson nuclear **modification factor** $R_{AA}$
Nuclear modification factor:

\[ R_{AA}(p_T) = \frac{dN_{D}^{AA}/dp_T}{\langle N_{\text{coll}} \rangle dN_{D}^{pp}/dp_T} \]

- D⁰ mesons suppressed in central Au+Au collisions
  - Strong interactions between charm quarks and the medium
  - Suppression of D⁰ mesons comparable to light flavor hadrons at RHIC and D mesons at LHC
  - Reproduced by models incorporating both radiative and collisional energy losses, and collective flow

Measurement of D± is complementary to that of D⁰

- Independent cross-check of the D⁰ measurement
- Important contribution to total charm cross-section
- Three-body decay, larger decay length than D⁰

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STAR DETECTOR

- **Solenoidal Tracker At RHIC**
- **Heavy Flavor Tracker** (HFT, 2014–2016) is a 4-layer silicon detector
  - MAPS – 2 innermost layers (PXL1, PXL2), Strip detectors – 2 outer layers (IST, SSD)
- **Time Projection Chamber (TPC) and Time Of Flight (TOF)**
  - Particle momentum (TPC) and identification (TPC and TOF)
$D^\pm$ MEASUREMENTS WITH THE HFT

- Data used in this analysis are from 2014 and 2016 for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

- Total of ca. 2.3B good minimum bias events after event selection

- The HFT allows direct topological reconstruction of $D^\pm$ mesons through their hadronic decay
  - $D^\pm \rightarrow K^\mp \pi^\pm \pi^\pm$  
    - $c\tau = (311.8 \pm 2.1) \mu$m  
    - $BR = (8.98 \pm 0.28)\%$

EVENT AND TRACK SELECTION, PID

- **Event selection**
  - Position of primary vertex along the beam axis

- **Track selection**
  - Low $p_T$ cut – suppresses combinatorial background from low-$p_T$ particles
  - $|\eta| < 1$ – detector acceptance
  - Minimum number of hits in the TPC for each track – good track quality
  - At least three hits in HFT, one in PXL1, one in PXL2 and at least one in IST or SSD

- **Particle identification (PID)**
  - TPC – energy loss of charged particles in the TPC gas
  - TOF – velocity of the charged particles

- **Topological selection criteria**
  - Possible only with use of the HFT
  - Constrain topology of the reconstructed secondary vertex
  - Suppress combinatorial background
  - Optimized using TMVA

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D± RAW YIELD EXTRACTION

- Raw yield extracted from invariant mass spectra of Kππ triplets
  - Significant background suppression with TMVA optimization of the topological selection criteria
  - Improved signal significance
D± INVARIANT SPECTRUM

- Invariant yield is calculated according to:

$$\frac{d^2 N}{2\pi p_T dp_T dy} = \frac{Y_{\text{raw}}}{2\pi N_{\text{evt}} BR p_T \Delta p_T \Delta y \varepsilon(p_T)}$$

- $Y_{\text{raw}}$ = raw yield, $N_{\text{evt}}$ = number of events, $BR$ = branching ratio, $\varepsilon(p_T)$ = total $D^\pm$ reconstruction efficiency

- **Collision centrality classes**: 0-10%, 10-40%, 40-80%
  - Determined from charged track multiplicity in TPC matched to Glauber model simulation
Invariant spectra of $D^\pm$ and $D^0$ mesons measured in Au+Au collisions at $\sqrt{s_{NN}}=200$ GeV.

- Spectra are fitted by Levy function
- The $D^\pm$ results help to constrain the total open charm cross-section and for better understanding of charm quark hadrochemistry in Au+Au collisions
Reference: combined $D^0$ and $D^*$ measurement in 200 GeV $p+p$ collisions using 2009 data

- Similar level of suppression and centrality dependence for $D^\pm$ and $D^0$

- High-$p_T$ $D^\pm$ and $D^0$ suppressed in central Au+Au collisions
  - Strong interactions between charm quarks and the medium
The $D^\pm/D^0$ yield ratio is compared to PYTHIA 8 calculation
- Good agreement in all Au+Au centrality classes
- No modification of the $D^\pm/D^0$ yield ratio compared to PYTHIA
CONCLUSION

- STAR has extensively studied production of open-charm mesons in Au+Au collisions at $\sqrt{s_{NN}}=200$ GeV utilizing the Heavy-Flavor Tracker.

- The HFT allows direct topological reconstruction of hadronic decays of open-charm mesons.

- $D^\pm$ invariant spectrum measured for three centrality classes of Au+Au collisions:
  - 0-10%, 10-40%, 40-80%

- $D^\pm$ nuclear modification factor is consistent with that of $D^0$:
  - $D^0$ and $D^\pm$ mesons are significantly suppressed at high-$p_T$ in central Au+Au collisions.
  - Charm quarks interact strongly with the QGP.

- $D^\pm/D^0$ yield ratio:
  - Agrees with PYTHIA 8 calculation.
THANK YOU FOR ATTENTION

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Event and Track Selection, PID

- Example of analysis cuts for $D^\pm$ reconstruction using the HFT
- Event selection
  - Position of primary vertex along the beam axis
- Track selection
  - $p_T$ – suppresses combinatorial background from low-$p_T$ particles
  - nHitsFit – large number of TPC hits used for track reconstruction to ensure good track quality
  - Hit in at least three layers of the HFT
- PID: HFT+TPC+(TOF)
  - Hybrid TOF = use TOF only for tracks with valid TOF information
- Topological selection criteria
  - Possible only with use of the HFT
  - Constrain topology of the reconstructed secondary vertex
  - Suppress combinatorial background
  - Optimization using the TMVA

| Event selection | $|V_z| < 6 \text{ cm}$ |
| --- | --- |
| | $|V_z - V_z(\text{VPD})| < 3 \text{ cm}$ |
| Track selection | $p_T > 300 \text{ MeV}/c$ ($500 \text{ MeV}/c$) |
| | $|\eta| < 1$ |
| | nHitsFit > 20 |
| | nHitsFit/nHitsMax > 0.52 |
| | HFT track = PXL1+PXL2+(IST or SSD) |

| PID cuts | TPC | $|n\sigma_\pi| < 3$ |
| --- | --- | --- |
| | $|n\sigma_K| < 2$ |
| Hybrid TOF | $|1/\beta - 1/\beta_\pi| < 0.03$ |
| | $|1/\beta - 1/\beta_K| < 0.03$ |

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<th>Topological selection criteria</th>
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<td>$DCA_{K-PV}$</td>
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