Abstract

Beauty quarks are considered as one of the best probes of the strongly interacting medium created in relativistic heavy-ion collisions because they are predominantly produced via initial hard scatterings. Our measurements of the productions of B mesons provide information on the diffusion of beauty quarks and the flavor dependence of in-medium energy loss. In these studies, clarifying the hadronization mechanism is crucial for understanding the transport properties of beauty quarks. We show our experimental results on three sets of particles: nonprompt \( J/\psi \) and \( D^0 \), \( B^0 \) and \( \bar{B}^0 \), and prompt \( B^+ \) and \( B^- \). Our measurements of \( B^0 \) production can shed light on the mechanisms of beauty recombination in the medium. In addition, the measurements of meson productions containing both strange and beauty quarks can provide more information about strangeness enhancement in the quark-gluon plasma. The ratio of \( B^0 \) over \( B^+ \) nuclear modification factors at a nucleon-nucleon center-of-mass energy of 5.02 TeV, using fully reconstructed B mesons with the CMS detector, are presented. We will also show the nonprompt \( J/\psi \) and \( D^0 \) from the B meson decay as well as our precise measurement the prompt \( D^*_0 \) to \( D^0 \) ratio in pp and PbPb collisions.

Motivation

- Probe the Quark-Gluon Plasma by studying the energy loss mechanism of heavy quarks created in the early stages of hard scattering in relativistic heavy-ion collisions
- Investigate the effects of the Quark-Gluon Plasma on the hadronization mechanisms of heavy quarks by comparing the production of strange and non-strange B and D mesons
- Use nuclear modification factor \( R_{AA} \) to study the physics of flavor dependence of energy loss and strangeness enhancement

Charmed Hadrons Reconstruction Strategies

- \( J/\psi \) mesons are reconstructed from muon pairs \( (\ell/\overline{\ell} \rightarrow \mu^+\mu^-) \)
- Muon identification and selections are applied
- Nonprompt fraction is obtained from the 2D template fit on the \( J/\psi \) mass and distance of closest approach to the primary vertex
- \( D^0 \) mesons are reconstructed from \( K \) pairs \( (D^0 \rightarrow K^-\pi^+ \rightarrow \pi^-\pi^+\pi^0) \)
- Optimized BDT selections are applied on \( K \) track variables
- Nonprompt fraction is extracted from fits on the closest approach to the primary vertex of data with prompt and nonprompt Monte Carlo templates

Non-Prompt \( J/\psi \) and \( D^0 \) Meson Nuclear Modification Factor Results

- Significant suppression of the nonprompt \( J/\psi \) in PbPb compared to pp [1]
- Larger suppression of nonprompt in more central collisions than peripheral collisions
- No significant \( p_T \) dependence of nonprompt \( J/\psi \) for \( p_T > 5 \) GeV/c

Comparison with other heavy flavor measurements

- Nonprompt \( D^0 \) suppression between 2 – 100 GeV/c [2]
- Nonprompt \( D^0 \) \( R_{AA} \) is comparable to the \( B^+ \) \( R_{AA} \)
- Nonprompt \( D^0 \) \( R_{AA} \) is higher than prompt \( D^0 \) below 20 GeV/c; beauty quarks lose less energy than charm quarks in the QGP medium

Comparison with theoretical calculations

- Compatible with theories including collisional and radiative energy loss (e.g. CUE3)
- Model with collisional energy loss have different predictions at high \( p_T \) (e.g. PHSD)

Beauty Hadrons Reconstruction Strategies

B meson Decay Channels:

- \( B^+ \) mesons: \( B^+ \rightarrow J/\psi K^- \rightarrow \mu^+\mu^- K^+ \) (Branching ratio \( \approx 1.0 \times 10^{-5} \))
- \( B^0 \) mesons: \( B^0 \rightarrow J/\psi K^- \rightarrow \mu^+\mu^- K^+ \) (Branching ratio \( \approx 1.0 \times 10^{-5} \))

Reconstructions

- Not using hadronic particle identification
- Precise vertexing and tracking
- Statistically enriched and dedicated dimuon triggered datasets in pp and PbPb

B Meson Signal Extraction

- Signal extraction from fits on the B-meson invariant mass distributions
- Background: combinatorial background + other b hadrons
decays
- No significant strangeness enhancement for intermediate \( \psi \) production in \( B^+ \)
- Cubic most theoretical predictions between 7 – 50 GeV/c

Prompt \( D^*_0 \) and \( D^0 \) measurements

- Precise measurements of prompt \( D^*_0 \) and \( D^0 \) meson productions in both pp above 2 GeV/c and PbPb above 6 GeV/c [4]
- No significant strangeness enhancement for intermediate \( p_T \) 6 – 40 GeV/c in PbPb compared to pp within \( D^*_0 / D^0 \) uncertainties
- Both TAMU and PHSD agree reasonably well with the \( D^*_0 / D^0 \) ratio in pp
- PHSD predictions are comparable to the \( D^*_0 / D^0 \) double ratio in PbPb and pp

Summary

- Suppressions for B-meson, nonprompt \( J/\psi \), and nonprompt \( D^0 \) productions in PbPb collisions
- Indication of flavor dependence of parton energy loss
- Hint of greater \( B^0 / B^- \) ratio than unity
- No significant strangeness enhancement between intermediate \( p_T \) 6 – 40 GeV/c for \( D^*_0 / D^0 \)

More precise B-meson measurements with 2017 pp and 2018 PbPb dataset in the future

References