Heavy Flavor capabilities of the sPHENIX experiment

Hugo Pereira Da Costa (CEA-Saclay, LANL)

on behalf of the sPHENIX collaboration

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The sPHENIX detector

Acceptance:
- full azimuth
- $|\eta| \sim 1$
- $0.2 \text{ GeV}/c < p_T < 40 \text{ GeV}/c$

Magnet: Babar 1.5 T super conducting solenoid

Tracking:
- 3 MAPS layers (MVTX)
- 2 silicon strips layers (INTT)
- QuadGEM-based TPC

Calorimetry:
- Electromagnetic calorimeter (EMCAL)
- Inner and Outer Hadronic Calorimeters

Collision rate: 50kHz (Au-Au), 3MHz (pp)

Data acquisition rate: 15 kHz
The sPHENIX detector

Construction: now until end of 2021
Installation: 2022
Data taking: from 2023 to 2025
(before start of EIC construction)

[BUP] sPH-TRG-2020-001
Heavy Flavor physics motivation

sPHENIX goal: study the inner structure of the QGP formed in 200 GeV Au-Au collisions over a wide range of length and energy scales

Open Heavy Flavor:
- Energy loss in QGP; interplay between collisional and radiative
- Transport coefficients and in particular HQ diffusion coefficient
- Hadronization in the QGP (baryon to meson ratio)

Quarkonia:
Long history of measurements at SPS, RHIC, LHC ($J/\Psi$, $\Psi(2S)$, $Y(nS)$)
Color screening in the QGP
Sequential suppression
Measure of QGP temperature
sPHENIX projections in one slide

with respect to past RHIC experiments sPHENIX will bring unprecedented precision and $p_T$ range for charm and first, precise beauty measurements

For jet capabilities, see talk by Yeonju Go, Thursday
Performance relevant to Heavy Flavor - Tracking

High tracking efficiency (>90%). Good for rare probes

DCA resolution critical for HF measurements
(need < 50 μm for $p_T = 1$ GeV/$c$ pion)

Momentum resolution is critical for Upsilon program and other inv. mass measurements
(need < 125 MeV/$c^2$ at Y mass)

MVTX detector improves DCA significantly, and to a lesser extent, momentum resolution
electron ID, Upsilon reconstruction

EMCAL energy resolution allows good rejection factor for $\pi/K/p$ with $E/p$ requirement

Upsilon inv. mass resolution < 125 MeV/c$^2$ - allows separation between $Y(nS)$ states


Electron ID @ 90% eff.

pp line shape normalized to 1S
b-jet tagging

Two approaches are followed:

• counting number of high-DCA tracks belonging to same jet
• secondary vertex reconstruction

Target working point for b-tagged jets: efficiency 40%, purity 40% (CMS *medium* settings - PRL. 113, 132301 (2014))

Both approaches allow to reach that point

Adding mass cut on secondary vertex brings improved purity
B-mesons from non-prompt $D^0$

Precise measurements provide discrimination between transport models

Study interplay between collisional and radiative energy loss
Critical to measure $R_{AA}$ and $v_2$, because it is challenging for models to describe both simultaneously $v_2$ (and $R_{AA}$ centrality dependence) $\rightarrow$ path-length dependence of $E_{\text{loss}}$, HQ diffusion coefficient in the QGP
Heavy flavor hadronization

STAR measured significantly larger $\Lambda_c/D^0$ in AA wrt PYTHIA pp calculations

Relevant to understanding hadronization in the QGP (coalescence)

Sizable contribution from hadrons to total charm cross section in AA

sPHENIX will provide measurement over $3<p_T<8$ GeV/c range, to better discriminate between models
D meson directed flow $v_1$

$v_1$ related to initial tilt of QGP source
larger $v_1$ predicted for HF due to T dependence of coupling to QGP
Differences between $D^0$ and $D^0\bar{b}$ attributed to initial magnetic field resulting from collision
sPHENIX will provide enough statistics to pin down possible difference between $D^0$ and $D^0\bar{b}$
b-tagged jets projections

Complementary to single hadron measurements

Jets provide better access to parton-level quantities

sPHENIX relevant $p_T$ range: 15-45 GeV/c

Expect to be dominated by radiative energy loss

Strong constraints on transport models
Proposed in Kang, Reiten, Vitev, Yoon, PRD 99, 034006 (2019)
Studying di-b-jets suppresses contribution to b production from gluon splitting
(already disfavored at RHIC wrt LHC)
Measuring di-jet inv. mass is complementary to $p_T$ imbalance
Provides enhanced sensibility to transport properties (here $g_{\text{med}}$, jet-to-medium coupling)
Illustrate close collaboration with theory community to make the most of the apparatus/data
Upsilon projections

To be compared to

Much improved precision wrt available measurements at RHIC
Similar to what is achieved at LHC
Comparison to LHC critical to understand temperature dependence
Y(3S) measurement challenging due to anticipated full suppression.
Will provide CL.
Summary and outlook

sPHENIX will:

- bring improved measurements to RHIC in the charm sector (statistics, $p_T$ range)
- bring new, precise measurements in the beauty sector (both open and hidden)
- thus bridge the gap to LHC experiments

Outlook:

- (from Justin’s talk) sPHENIX is ~half completed. In time for first data taking in 2023
- first Mock Data Challenge early 2021 to sharpen our production, tracking and analysis tools (ACTS, KFParticle ...), consolidate the projections presented here with e.g. realistic tracking, more accurate detector description, etc.
- study new channels (e.g. $D^+$, $D^*$, $D_s$ ...)
Early MDC1 output

PYTHIA 8.3 pp + ccbar, bbbar events
KFParticle to handle decay kinematics
No PID information, except for $D_s$

Thank you!