the sPHENIX Program for Quarkonia and Open Heavy Flavor

Outline: ● sPHENIX Intro ● Detector & Status ● physics program

Jin Huang
for sPHENIX Collaboration
Jet cor. & substructure
Vary momentum/angular size of probe

Parton energy loss
Vary mass/momentum of probe
g, u, d, s

Upsilon spectroscopy
Vary size of the probe
\(\Upsilon(2s) - 0.78\) fm
\(\Upsilon(3s) - 0.56\) fm
\(\Upsilon(1s) - 0.28\) fm

Cold QCD
Vary temperature of QCD matter

See also sPHENIX Overview by Hideki Okawa, 16 Jun 2022, 11:15, Grand Ballroom
Strangeness in Quark Matter 2022

Jin Huang <jihuang@bnl.gov>
Completed Outer HCal installed around the magnet!

Hcal: steel scintillator sampling calorimeter
- First barrel HCal at RHIC
- Hadron $dE/E \sim 14\% + 65\%/\sqrt{E}$
- 0.1x0.1 towers
- ~6 hadronic interaction length for full calo stack
Completed Outer HCal installed around the magnet!

1.4 T former Babar magnet. Shipped to BNL in 2015, tested to full field.
Inner hadronic calorimeter: just installed last week!

Inner Hcal: Al-scintillation tile sampling calorimeter
Mechanical support for EMCal + EM-shower tail catcher
+ constraint longitudinal position of hadronic shower
EMCal: Scintillator Fiber Tungsten sampling calo.

- $\text{EM } dE/E < 5\% + 16\%/\sqrt{E}$
- 0.025x0.025 towers
sPHENIX Tracking Detectors

Detectors inside the magnet

1.6 m

2.1 m
Main tracker: Time projection chamber (TPC)

Outer Field Cage  Inner Field Cage

HV Tested Modules

Test Fit Perfect
Precision vertex trackers

- **MVTX**: MAPS based vertex tracker, 3 layers
  - Using staves from ALICE1 ITS2 upgrade
  - ALPIDE chip, 30um pitch, Low mass (~0.3% $X_0$)
  - 5um position resolution, 5-10us integration time

- **INTT**: silicon strip tracker, 2 layers
  - 78 um pitch, provides timing tag resolving bunch crossing
Silicon vertex tracker in assembly

MVTX assembly in progress at LBNL

INTT stave completed, CF parts at BNL

8-stave full readout and control chain test @LANL
sPHENIX Trackers in pp/pA
Streaming readout 10% of all collisions

sPHENIX streaming DAQ for tracker

MVTX RU, 200M ch
INTT ROC, 400k ch
ALPIDE (ALICE/sPHENIX), FPHX (PHENIX)

TPC FEE, 160k ch
SAMPAv5 (ALICE/sPHENIX)

BNL-712 / FELIX v2 x38 (ATLAS/sPHENIX)
FELIX Ref: 10.1109/tim.2019.2947972

Global Timing Module
(NSLS II/sPHENIX)
Receiving from RHIC RF
low glitter clock source

48x 10-Gbps bi-directional
optical links per FELIX

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Strangeness in Quark Matter 2022
### Proposed run schedule, year 1-3

- **sPHENIX BUP2022 [sPH-TRG-2022-001]**, 24 (& 28) cryo-week scenarios

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<td>Au+Au</td>
<td>200</td>
<td>24 (28)</td>
<td>9 (13)</td>
<td>3.7 (5.7) nb⁻¹</td>
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<td>–</td>
<td>5</td>
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<td>24 (28)</td>
<td>20.5 (24.5)</td>
<td>13 (15) nb⁻¹</td>
<td>21 (25) nb⁻¹</td>
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RHIC PAC-2021 Report: “sPHENIX construction, installation and operation to accomplish its science goals is now the overarching priority for RHIC for the next 4 – 5 years.”
Tracking performance

- Precision tracking → First separated three Upsilon states @ RHIC

![Graph showing the tracking performance with the title 'sPHENIX simulation' and data points for different conditions.

- Black dots: 3MHz pp
- Red circles: 50kHz 0-20fm AuAu

![Graph showing the mass distribution of e^+e^- pairs with the title 'sPHENIX Simulation' and additional information about the simulation conditions and event count.]
Suppression with clear distinction of three Upsilon states

Color dipoles probing the QGP at three length scales
Cleanly separate open bottom meson via DCA

DCA resolution of charged pions

- sPHENIX simulation
- $n_{TPC} > 20$, $n_{MVTX} > 2$
- 3MHz pp
- 50kHz 0-20fm AuAu

Prompt and non-prompt D-meson DCA

[sPH-HF-2017-002]

- sPHENIX Simulation
- $\sqrt{s_{NN}} = 200\text{ GeV}$
- 0-10%, 24B
- $4.0 < p_T < 5.0$
Access b-quark suppression/v2 via non-prompt $D$

- Bringing high precision non-prompt-$D$ suppression and flow to RHIC

- Probe the mass dependence of quark energy loss in QGP, light $\rightarrow c \rightarrow b$
- Sensitive to pick up collision energy loss
- Determine the bottom quark collectivity
- Clean access to $D_{HQ}$ at RHIC energy

$p + p$ baseline uniquely enabled by streaming data

[sPH-TRG-2022-001]
News from beam use proposal 2020 – hadronization

- STAR and ALICE collaboration reported enhanced charm baryon to meson ratio → challenging hadronization models
- sPHENIX streaming readout will deliver first $p + p$ measurement at RHIC
- sPHENIX will also map out the $\Lambda_c/D$ ratio over momentum dependence
Higher $p_T$: bottom quark via $b$-jet

- New for RHIC, enabled by precision tracking and full calorimetric jet
Large b-jet statistics $\rightarrow$ further differential studies

- Examples are di-b-jet pair mass and b-jet substructure
- Expect significant mass effect at the b-jet kinematics region at sPHENIX
Summary

- Unique capabilities to probe QGP at distinct length and mass scales at RHIC
  - Fate of Υ(3S) at RHIC
  - Precision open HF physics, in particular via b-quark
- Enabled by precision tracking, full calorimetric jet and high throughput streaming DAQ
- First collision in 8 months!