Highlights of this talk:

- sPHENIX science mission & core physics program
- sPHENIX detector & beam use proposal
- Projected results & construction update

Parallel sPHENIX talks in previous days:

- Future Cold-QCD Physics Program with sPHENIX (Jin Huang)
- sPHENIX Heavy Flavor Overview (Cameron Dean)
The goals of experiments at RHIC and the LHC as a result of the 2015 Long Range Plan for Nuclear Science are two-fold:

1. To map the QCD phase diagram with experiments planned at RHIC.
2. To probe the inner workings of quark-gluon plasma (QGP) by resolving its properties at shorter and shorter length scales.
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A state-of-the-art jet detector called sPHENIX is under construction to elucidate properties of the QGP at shorter and shorter length scales.
sPHENIX Collaboration

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- More than 320 members from 84 institutions in 14 countries as of 2021
- Over 100 bi-weekly general meetings since inception

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**Upsilon spectroscopy**

Vary size of the probe:

- $\gamma(3s)$ - 0.78fm
- $\gamma(2s)$ - 0.56fm
- $\gamma(1s)$ - 0.28fm
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Cold QCD physics: transverse single spin asymmetries (TSSAs)
sPHENIX Detector Overview

**Calorimetry**
- Outer Hadronic Calorimeter (oHCAL)
- Inner Hadronic Calorimeter (iHCAL)
- Electromagnetic Calorimeter (EMCAL)

**Magnet**
- 1.4T superconducting solenoid used by the BaBar experiment

**Tracking**
- Time Projection Chamber (TPC)
- Intermediate Silicon Tracker (INTT)
- MAPS-based Vertex Tracker (MVTX)

**Performance**
- **High data rate**: read out rate of 15 kHz for all subdetectors
- **Acceptance**: hermetic coverage over full azimuth & pseudorapidity $|\eta| \leq 1.1$ for the tracking & calorimeter systems
sPHENIX Tracking System

**MVTX**: high resolution vertexing
- 3 layers of Monolithic Active Pixel Sensors based on ALICE ITS-II
- Nearest to the collision point, spatial resolution of $5 \mu m$ for tracks with $p_T > 1$ GeV

**INTT**: pileup event separation
- Silicon strip detector surrounding the MVTX
- Associates fully reconstructed tracks with the event that produced them

**TPC**: momentum measurement
- Compact ($r = 80$ cm) & main tracking element filled with Ne-CF$_4$ gas mixture
- Ungated, with GEM-based read out, spatial resolution of $< 200 \mu m$
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**Open heavy flavor measurement**

The MVTX higher resolution, read out rate, and larger acceptance compared to previous RHIC detectors will enable a state-of-the-art open heavy flavor program at RHIC.
sPHENIX Calorimeter System

**Hadronic calorimetry**
- First at RHIC (at mid-rapidity)
- Plastic scintillating tiles + tilted steel plates with embedded WLS fibers (oHCAL);
  scintillating tiles + Al plates for the iHCAL
- Overall tile segmentation of $\Delta \eta \times \Delta \phi \approx 0.1 \times 0.1$

**Electromagnetic calorimetry**
- Scintillating fibers in tungsten and epoxy
- High segmentation for HI collisions:
  $\Delta \eta \times \Delta \phi \approx 0.025 \times 0.025$
- Good energy resolution: $\sigma_E/E < 15%/\sqrt{E}$
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Jet measurement
- The large hadronic calorimeter acceptance (full azimuth & pseudorapidity $|\eta| \leq 1.1$) enables unbiased selection (& triggering in p+p) for jets
- Improves jet resolution & extends the range for high $p_T$ single hadron measurements
sPHENIX 3-Year Run Plan


<table>
<thead>
<tr>
<th>Year</th>
<th>Species</th>
<th>√s_{NN} [GeV]</th>
<th>Cryo Weeks</th>
<th>Physics Weeks</th>
<th>Rec. Lum.</th>
<th>Samp. Lum.</th>
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<td>2023</td>
<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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**Year 1 (2023):**
- Commissioning high multiplicity Au+Au run
- Measurement of standard Au+Au candles at RHIC
# sPHENIX 3-Year Run Plan


| Year | Species | $\sqrt{s_{NN}}$ [GeV] | Cryo Weeks | Physics Weeks | Rec. Lum. $|z|<10$ cm | Samp. Lum. $|z|<10$ cm |
|------|---------|----------------------|------------|---------------|----------------|----------------|
| 2023 | Au+Au   | 200                  | 24 (28)    | 9 (13)        | 3.7 (5.7) $nb^{-1}$ | 4.5 (6.9) $nb^{-1}$ |
| 2024 | $p^\uparrow p^\uparrow$ | 200  | 24 (28) | 12 (16) | 0.3 (0.4) $pb^{-1}$ [5kHz] | 45 (62) $pb^{-1}$ |
|      |         |                      |            |               | 4.5 (6.2) $pb^{-1}$ [10%-str] |               |
| 2024 | $p^\uparrow$+Au | 200  | –        | 5            | 0.003 $pb^{-1}$ [5kHz] | 0.11 $pb^{-1}$ |
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| 2025 | Au+Au   | 200                  | 24 (28)    | 20.5 (24.5)  | 13 (15) $nb^{-1}$ | 21 (25) $nb^{-1}$ |

Year 2 (2024) :
- Commissioning $p+p$
- $p^\uparrow + p^\uparrow$, $p^\uparrow$+Au: HI reference set and cold QCD
## sPHENIX 3-Year Run Plan

### sPHENIX Beam Use Proposal (BUP) sPH-TRG-2020-001, August 31, 2020.

| Year | Species | $\sqrt{s_{NN}}$ [GeV] | Cryo Weeks | Physics Weeks | Rec. Lum. $|z| < 10$ cm | Samp. Lum. $|z| < 10$ cm |
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| 2023 | Au+Au   | 200                    | 24 (28)    | 9 (13)        | 3.7 (5.7) $nb^{-1}$   | 4.5 (6.9) $nb^{-1}$    |
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|      |         |                        |            |               | 0.02 $pb^{-1}$ [10%-str] |                       |
| 2025 | Au+Au   | 200                    | 24 (28)    | 20.5 (24.5)   | 13 (15) $nb^{-1}$      | 21 (25) $nb^{-1}$     |

### Year 3 (2025):
- Very large Au+Au heavy-ion set for jet and heavy flavor physics
- 141 B events recorded in total
(left) Projected total yields for jets, photons and charged hadrons in 0-10% Au+Au events and p+p events (right) corresponding $R_{AA}$ projections

**[BUP] sPH-TRG-2020-001**

- 2023-2025 data taking will have kinematic reach out to $\approx 70$ GeV for jets, and $\approx 50$ GeV for hadrons and photons.
- The kinematic reach will resolve varying theoretical prediction for $R_{AA}$ at higher $p_T$.
Large sample of physics objects (above a $p_T$ threshold) will enable the study of jet internal structure and photon+jet correlations

The large data set allows for highly differential high $p_T$ observables
sPHENIX Probes: Upsilon Spectroscopy

(Left) Projected statistical uncertainties for the $R_{AA}$ of the $\Upsilon(1S)$ and $\Upsilon(2S)$ states as a function $N_{\text{part}}$.

(Right) Corresponding $p_T$ dependence.

Clear separation of $\Upsilon$ states allows for comparison between RHIC and LHC measurements.

Crucial measurement, since the temperature profiles from hydrodynamic calculations show important differences with collision energy.
Clear separation of $\Upsilon$ states allows for comparison between RHIC and LHC measurements

Crucial measurement, since the temperature profiles from hydrodynamic calculations show important differences with collision energy
High precision and data rate will allow for studies of mass-dependent energy loss and collectivity in the quark-gluon plasma.
Projected statistical uncertainties for the midrapidity direct photon TSSAs compared to theoretical calculations corresponding $D^0$ measurement

\[ \text{[BUP] sPH-TRG-2020-001} \]

- The photon and $D^0$ spin asymmetry measurements have deep connections to nucleon partonic structure
Jet TSSA measurement at sPHENIX will be complementary to future jet TSSA measurement at the EIC, allowing for a fundamental test of QCD factorization in p+p and e+p interactions.
Detector Construction Update
Outer Hadronic calorimeter

- oHCAL sectors complete at BNL!
- Empty tiles rack
Inner Hadronic calorimeter

- iHCAL sectors at TSI in Ames
- First 8 sectors ships to BNL next week!
- Tiles already at BNL
Time Projection Chamber

- Outer field cage Kapton application
- R1 pad plane complete at SBU
- Wagon Wheel w/ R1, R2, R3
1st sPHENIX component Installed in sPHENIX Hall, 5/27/21
1/4 of the sPHENIX cradle now mounted as of a few days ago
Construction will be complete at the end of the year!
Summary

**sPHENIX will perform at:**

- High rate, large acceptance, precision tracking and dedicated EM and hadronic calorimeter systems

**sPHENIX will enable very high precision measurements of:**

- Jet correlations & substructure, open heavy flavor, \( \Upsilon \) spectroscopy, at unprecedented kinematic range at RHIC

**sPHENIX aims to meet science mission goal of:**

- Probing the microscopic nature of the quark-gluon plasma

First data taking begins in 2 years!

Thank you!

Ejiro Umaka on behalf of sPHENIX Collaboration
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