sPHENIX Overview

Christopher McGinn
20 July 2022
Brookhaven National Lab
Werequire a detector that can study all this physics!

- Precise tracking and vertexing
- Hermetic calorimetry
- High-datarates and triggering

QGP E-Loss

Christopher McGinn
sPHENIX Physics Program

- u, d, s
- c
- b

QGP E-Loss  Substructure

• We require a detector that can study all this physics!
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QGP E-Loss
Substructure

Sequential Quarkonia Melting
sPHENIX Physics Program

QGP E-Loss  
Substructure  
Sequential Quarkonia Melting  
Cold QCD

u,d,s  
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Werequireadetectorthatcanstudyallthisphysics!

Precisetrackingandvertexing

HermeticCalorimetry

High-dataratesandtriggering

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QGP E-Loss  Substructure
• We require a detector that can study all this physics!
  • Precise tracking and vertexing
  • Hermetic Calorimetry
  • High-data rates and triggering
sPHENIX Detector Design

Tracking Detectors

SC magnet
flux return door
INTT
MVTX

cryogenic chimney

outer HCal
inner HCal
EMCal
TPC

support carriage

Not shown: MinimumBiasDetector (MBD) and sPHENIX Event Plane Detector (sEPD)
sPHENIX Detector Design

Tracking Detectors

Calorimetry

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sPHENIX Detector Design

Tracking Detectors

Calorimetry

Magnet System

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**sPHENIX Detector Design**

- **Tracking Detectors**
- **Calorimetry**
- **Magnet System**

- Not shown: Minimum Bias Detector (MBD) and sPHENIX Event Plane Detector (sEPD)

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Tracking Subdetectors

Tracking Systems from interior-to-exterior:

1. MAPS Vertex Detector (MVTX)
   - High-precision vertexing

2. Intermediate Silicon Strip Tracker (INTT)
   - High-precision timing for beam crossing

3. Time Projection Chamber (TPC)
   - High-precision momentum measurement

4. Time Projection Outer Tracker (TPOT)
   - Correct for TPC space charge distortions
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4. Time Projection Outer Tracker (TPOT)
   • Correct for TPC space-charge distortions
- 3 Layers of Monolithic Active Pixels (MAPs)
  - Chosen for reduced material budget
- Distance of Closest Approach (DCA) resolved at $<10 \mu m$ for $p_T > 2$ GeV
- Essential to heavy flavor program
• 4 layer (2 hit) silicon strip detector
• Timing resolution $\sim 100$ns
  • Only tracking detector capable of resolving single RHIC bunch crossing
- Compact, spanning $20 < r < 78$ cm
  - Active region begins at $r > 30$ cm
- Gateless, employs GEMs to minimize ion backflow (IBF)
  - Continuous streaming readout
  - $< 0.5\%$ IBF in testing
- 8 Micromegas-based detectors
- Inserted between TPC and EMCal
- Correct for beam-induced space charge distortions of the TPC
  - Black-to-blue dots on right
- Also provides another hit for tracking
Calorimetry Subdetector System

Calo. Systems from interior-to-exterior:

1. Electromagnetic Calorimeter (EMCal)
   - Enables $\gamma$, jet, and $\gamma \rightarrow ee$

2. Inner Hadronic Calorimeter (IHCal)
   - Inducing hadronic shower pre-magnet for jet measurement

3. BaBar Superconducting Magnet
   - Not an active part of the system but defines inner/outer HCal

4. Outer Hadronic Calorimeter (OHCal)
   - Primary detector of hadronic shower for jets
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   • Primary detector of hadronic shower for jets
• **SPACAL** sampling calorimeter
  • Scintillating fibers embedded in tungsten bricks
• Each tungsten brick covers $0.025 \times 0.025$ of $\Delta \eta \times \Delta \phi$
  • Comparable to CMS ECal granularity
• Spans pseudorapidity of $\pm 1.1$, $\sim 20 \times X_0$
• Relative energy resolution expected $\sim 16\%/\sqrt{E}$
Inner and Outer HCal

- **IHCal**: Al and scintillating plates w/ WLS fibers
- **OHCal**: Steel and scintillating plates w/ WLS fibers
  - Also acts as magnetic flux return
- Spans $\eta$ of $\pm 1.0$ in $0.1 \times 0.1$ $\Delta \eta \times \Delta \phi$
- High-$p_T$ resolution converges on 13.5%
- Installation now complete!
sEPD and MBD

- **sPHENIX Event Plane Detector (sEPD)**
  - Enables event plane determination far from measured jet production
  - 2 wheels of scintillator w/ embedded WLS fibers; follows STAR design
- **Minimum Bias Detector:**
  - Beam-beam counter repurposed from PHENIX for Min. Bias triggering
  - Covering pseudorapidity 3.51-4.61
• **Hybrid system: Calorimeter triggered, tracking is streaming**

**DAQ and Trigger**

- **sEPD**
- **MBD**
- **Calorimeters**
- **TPC**
- **INT**
- **MVTX**
- **FEE**
- **ROC**
- **RU**
- **ADC**
- **DCM**
- **SEB**
- **DAM**
- **EBDC**
- **Ethernet Switch**
- **Buffer Box**
- **SDCC Tape**
# Streaming DAQ Impact

<table>
<thead>
<tr>
<th>M.B. p+p</th>
<th>Data Mode</th>
<th>Year-2024, triggered DAQ per-1kHz M.B. trigger</th>
<th>Year-2024, w/ str. tracker</th>
<th>Year 2026 w/ str. tracker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stats</td>
<td></td>
<td>1 Billion M.B. evts 0.026 pb(^{-1}) recorded</td>
<td>250 Billion M.B. evts 6.2 pb(^{-1}) recorded</td>
<td>3.2 Trillion M.B. evts 80 pb(^{-1}) recorded</td>
</tr>
<tr>
<td>Physics Reach</td>
<td>B → D(^0) → πK (R_{AA}) ref.</td>
<td>620 evts</td>
<td>150k evts</td>
<td>2M evts</td>
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<td></td>
<td>D(^0) → πK pair Diffusion of c+(\bar{c})</td>
<td>620 evts</td>
<td>150k evts</td>
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<td>Λ(_{c}) → πKp Charm hadronization</td>
<td>1.3k evts</td>
<td>310k evts</td>
<td>4M evts</td>
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<td></td>
<td>Prompt D(^0) → πK Tri-Gluon Corr. via TSSA</td>
<td>0.2M evts</td>
<td>50M evts</td>
<td>0.6B evts</td>
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- **Trigger (MBD, jet, γ)** cannot get us to open HF
- **Streaming output, however, does in p+p in p+A**
## Run Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Species</th>
<th>$\sqrt{s_{\text{NN}}}$ [GeV]</th>
<th>Cryo Weeks</th>
<th>Physics Weeks</th>
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<td>Au+Au</td>
<td>200</td>
<td>24 (28)</td>
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<td>3.7 (5.7) nb$^{-1}$</td>
<td>4.5 (6.9) nb$^{-1}$</td>
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<td>0.01 pb$^{-1}$ [10%-str]</td>
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**Commissioning + Initial QGP Data**

**Reference Data**

**Cold QCD Data**

**Full QGP Data**
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**Full QGP Data**

- **Data-taking fast approaching!**
- **What are some prospective physics plans?**

---

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Projected $R_{AA}$’s

- sPHENIX $R_{AA}$ reach nicely complements existing LHC kinematics
- sPHENIX $x_{J\gamma}$ accesses partonic energy loss at different QGP T
- For more details, see Tim Rinn’s talk!

Projected $\gamma^* +$jets balance

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- sPHENIX $x_{J\gamma}$ accesses partonic energy loss at different QGP T
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Heavy Flavor Physics Projections

**b-jet Invariant Mass**
- Jet program naturally lends itself to heavy-flavor jets
- Open HF also viable w/ sPHENIX for mass dependent studies
- For more details, see Cameron Dean’s talk!
Quarkonia Projections

\( \Upsilon \) Mass

- Measure \( \Upsilon \) 1S, 2S, and 3S sequential suppression
  - Expect monotonic increasing suppression w/ nS state
- Measure as a function of \( N_{\text{part}} \) and \( p_T \)
- For more details, see Marzia Rosati’s talk!
Cold QCD Projections

TSSA for photons in p+p

• TSSA: Transverse Single Spin Asymmetry
  • Accesses the spin structure of nucleons
• For more details, see Ralf Seidl’s talk!
• Also, see Ron Belmont’s talk for bulk physics!
• The sPHENIX detector at RHIC will feature:
  • High precision vertexing and tracking
    • Via the combined MVTX-INTT-TPC-TPOT system
  • Full calorimetry for measurement of jets, photons, and tagging $\gamma \rightarrow ee$
    • Covers $2\pi$ in azimuth, $\pm 1.1$ in $\eta$
Conclusion

The sPHENIX detector at RHIC will feature:

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Physics program of:

- Partonic energy loss and substructure modification
- Sequential suppression of Quarkonia states
- Initial state physics in cold-QCD program
- Bulk physics, open heavy flavor, and more!

First collisions expected Spring 2023!

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