sPHENIX Overview

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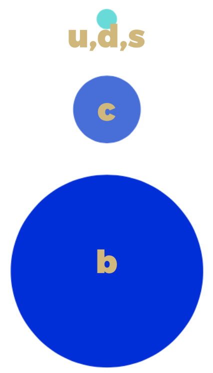
20 July 2022

Brookhaven National Lab

University Colorado Boulder

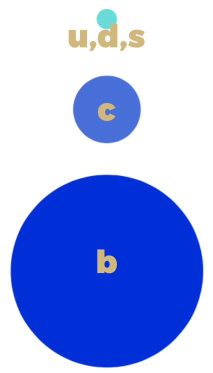
sPHENIX

sPHENIX Physics Program



QGP E-Loss

sPHENIX Physics Program



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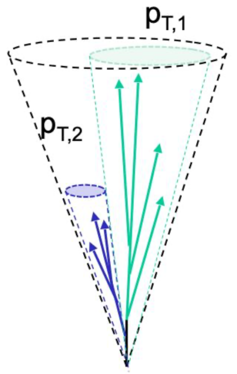
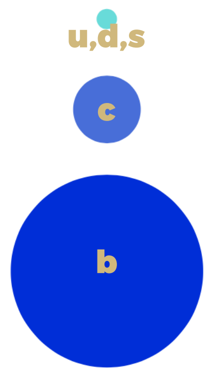


Substructure

sPHENIX Physics Program



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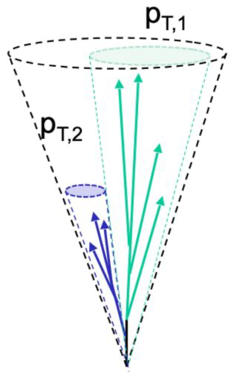

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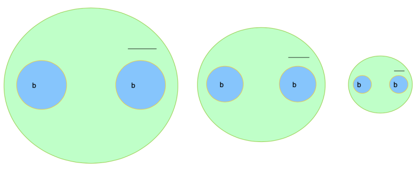
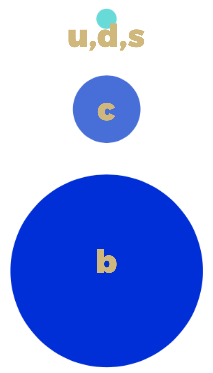


Sequential Quarkonia Melting

sPHENIX Physics Program



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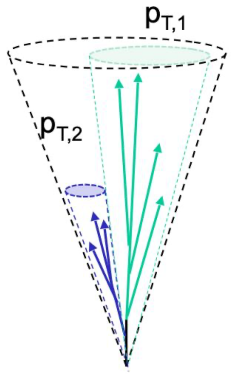

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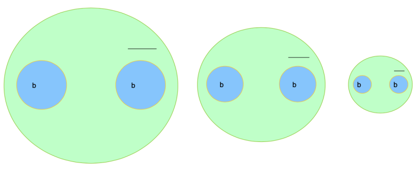

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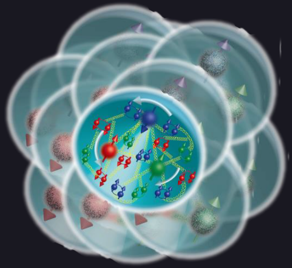
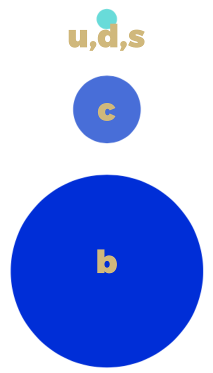


Cold QCD

sPHENIX Physics Program



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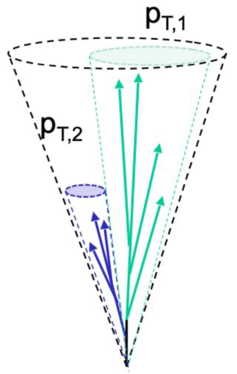

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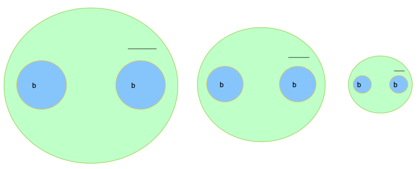

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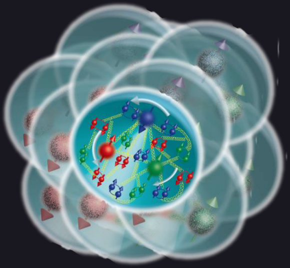
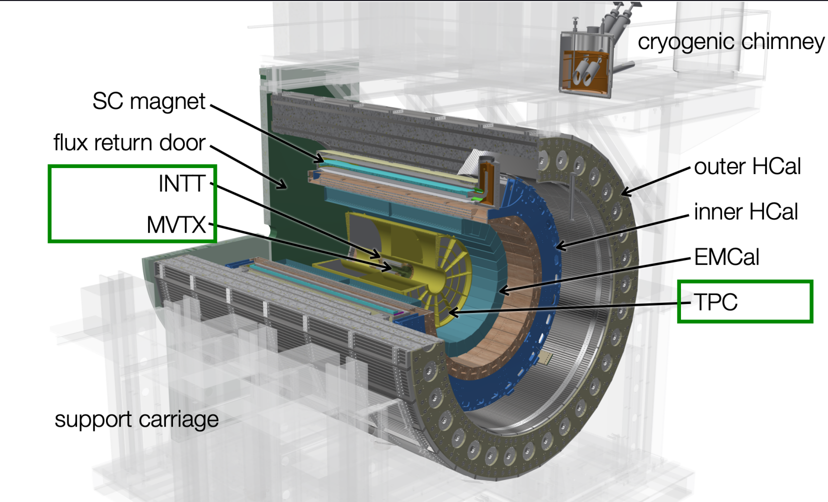


Cold QCD

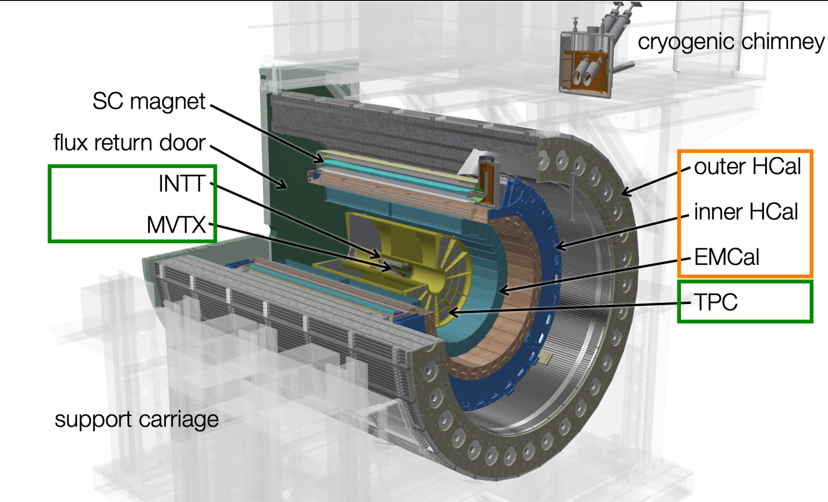
- We require a detector that can study all this physics!
  - Precise tracking and vertexing
  - Hermetic Calorimetry
  - High-data rates and triggering

sPHENIX Detector Design



Tracking Detectors

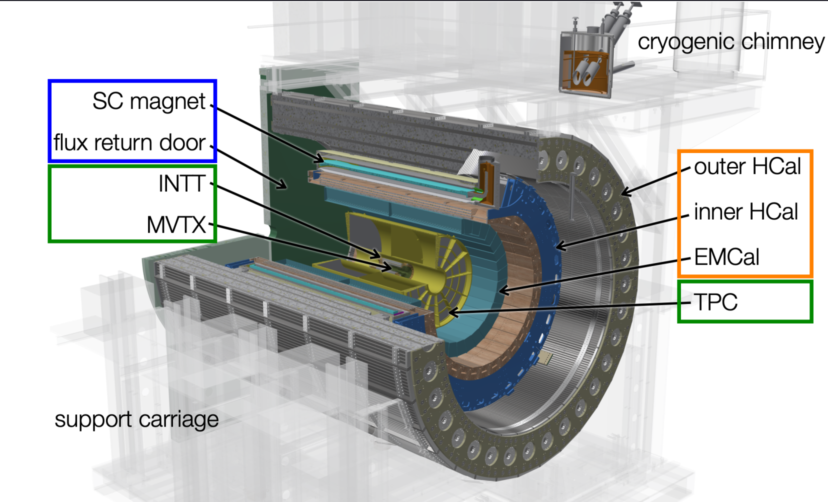
sPHENIX Detector Design



Tracking Detectors

Calorimetry

sPHENIX Detector Design

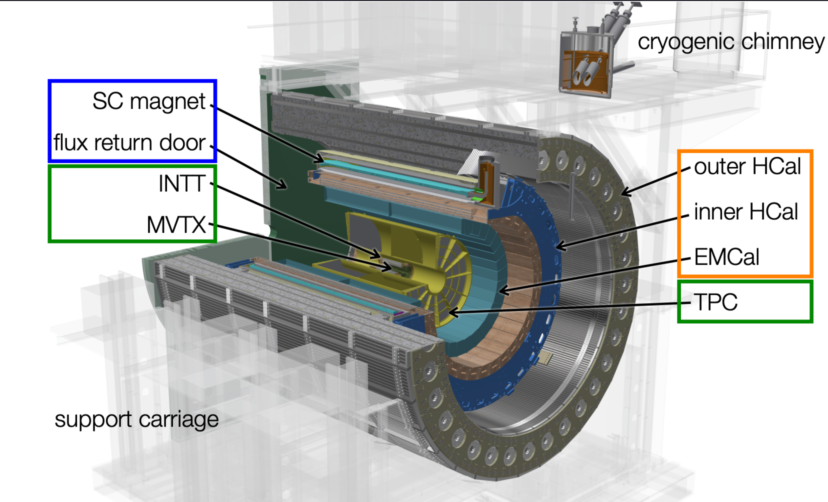


Tracking Detectors

Calorimetry

Magnet System

sPHENIX Detector Design



Tracking Detectors

Calorimetry

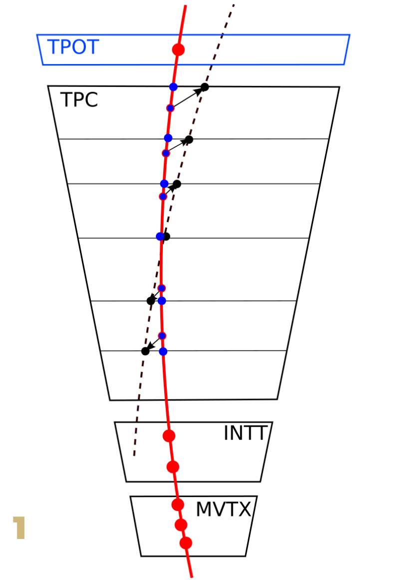
Magnet System

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

Tracking Subdetectors

Tracking Systems from interior-to-exterior:

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

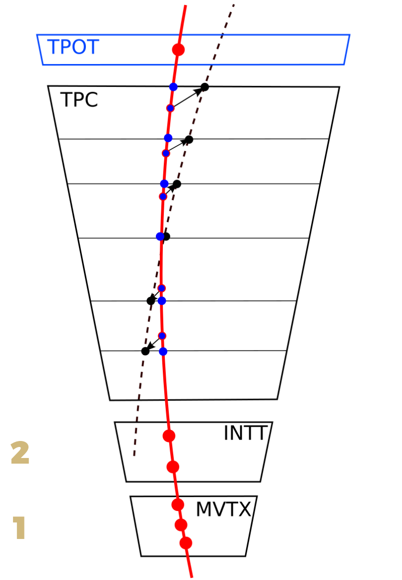


Tracking Subdetectors

Tracking Systems from interior-to-exterior:

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

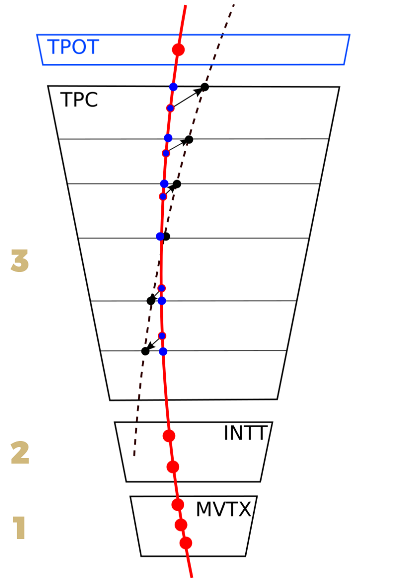
2. **Intermediate Silicon Strip Tracker (INTT)**
   - **High-precision timing for beam crossing**



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**



Tracking Subdetectors

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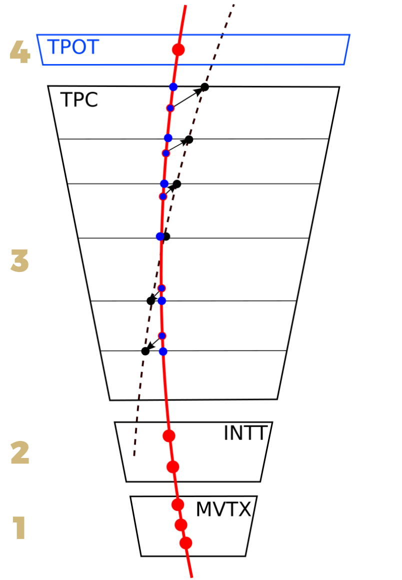
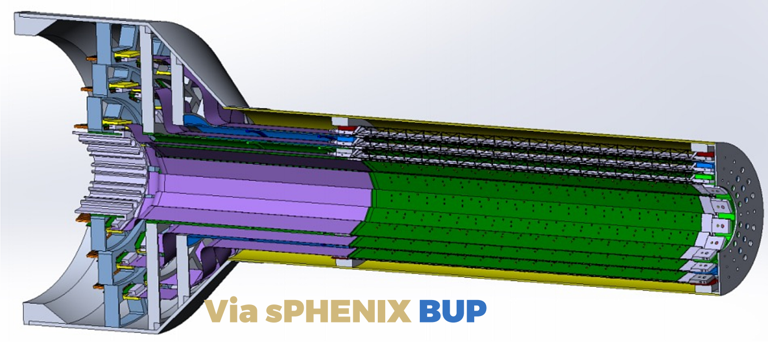
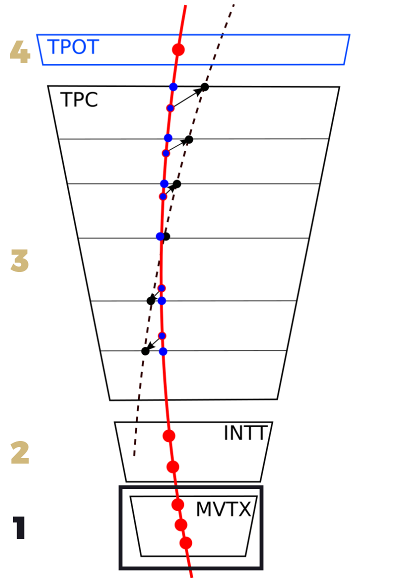
1. **MAPS Vertex Detector (MVTX)**
   - **High-precision vertexing**
2. **Intermediate Silicon Strip Tracker (INTT)**
   - **High-precision timing for beam crossing**
3. **Time Projection Chamber (TPC)**
   - **High-precision momentum measurement**
4. **Time Projection Outer Tracker (TPOT)**
   - **Correct for TPC space-charge distortions**



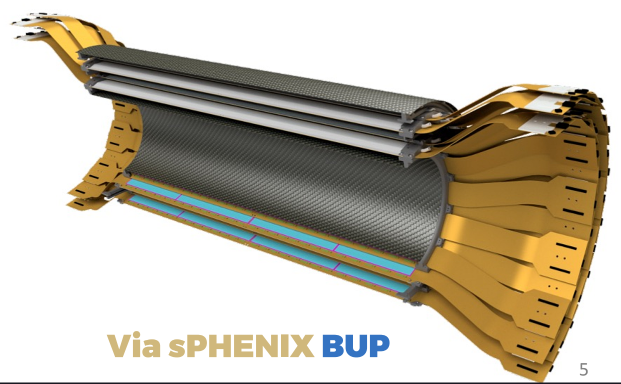
MVTX



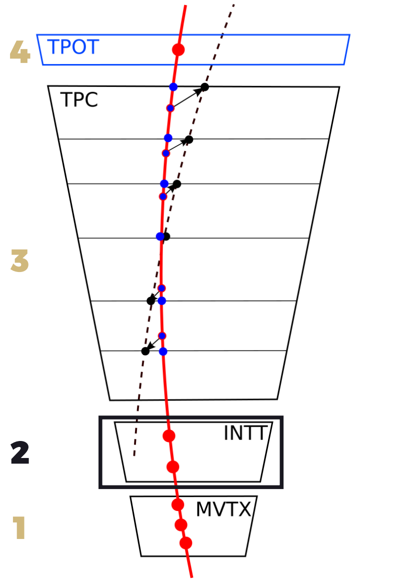


- 3 Layers of Monolithic Active Pixels (MAPs)
  - Chosen for reduced material budget
- Distance of Closest Approach (DCA) resolved at < 10 μm for p_T > 2 GeV
  - Essential to heavy flavor program

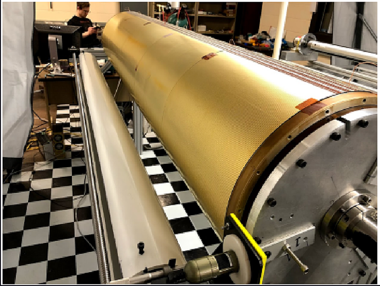
INTT

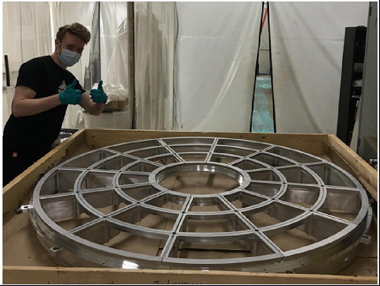


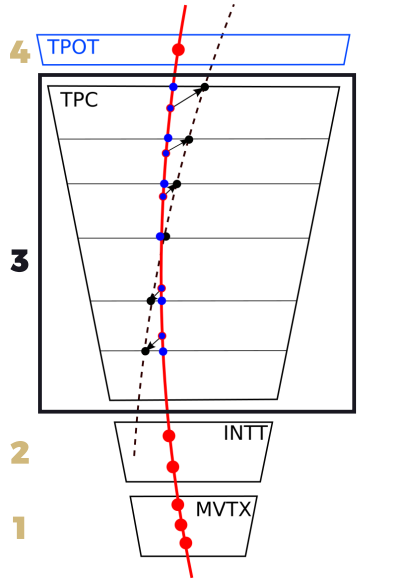
- **4 layer (2 hit) silicon strip detector**
- **Timing resolution ~100ns**
  - **Only tracking detector capable of resolving single RHIC bunch crossing**



TPC

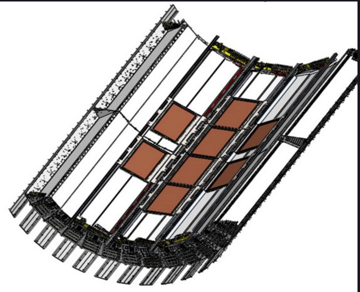


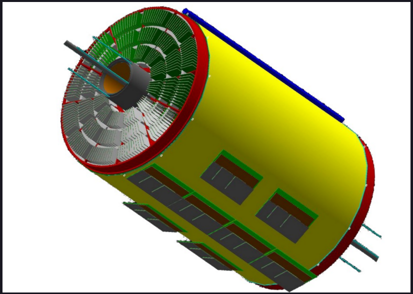


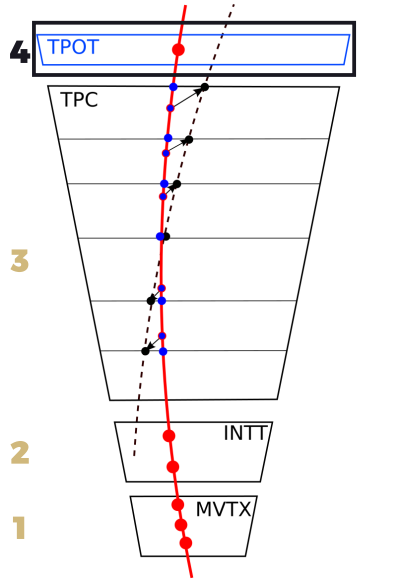


- **Compact, spanning 20 < r < 78 cm**
  - **Active region begins at r > 30cm**
- **Gateless, employs GEMs to minimize ion backflow (IBF)**
  - **Continuous streaming readout**
  - **< 0.5% IBF in testing**

TPOT





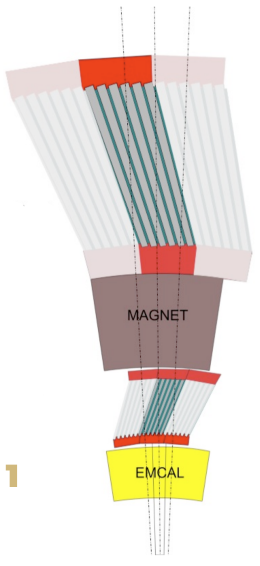


- 8 Micromegas-based detectors
- Inserted between TPC and EMCal
- Correct for beam-induced space charge distortions of the TPC
  - Black-to-blue dots on right
- Also provides another hit for tracking

Calorimetry Subdetector System

Calo. Systems from interior-to-exterior:

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



1

Calorimetry Subdetector System

Calo. Systems from interior-to-exterior:

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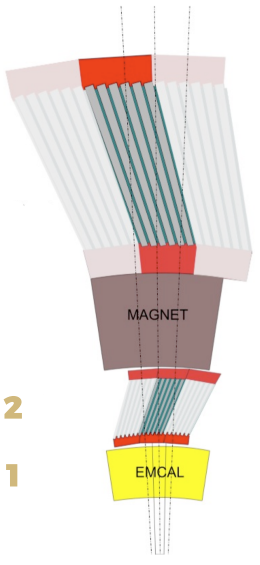
2. **Inner Hadronic Calorimeter (IHCal)**
   - **Inducing hadronic shower pre-magnet for jet measurement**



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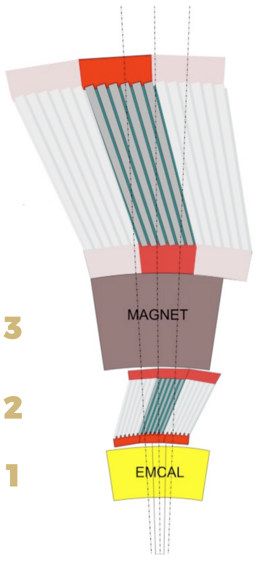
3. **BaBar Superconducting Magnet**
   - Not an active part of the system but defines inner/outer HCal

3

2

1



Calorimetry Subdetector System

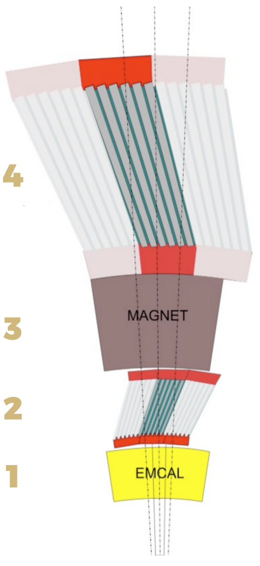
Calo. Systems from interior-to-exterior:

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

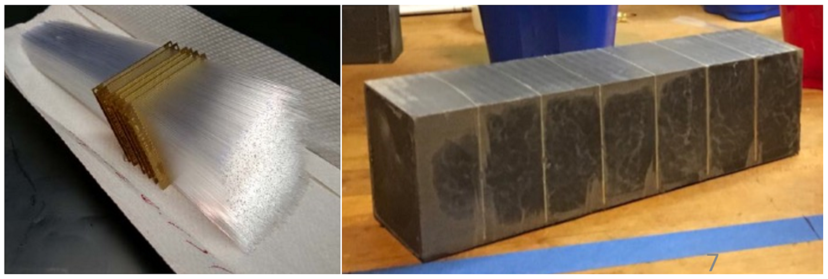
2. **Inner Hadronic Calorimeter (IHCal)**
   - Inducing hadronic shower pre-magnet for jet measurement

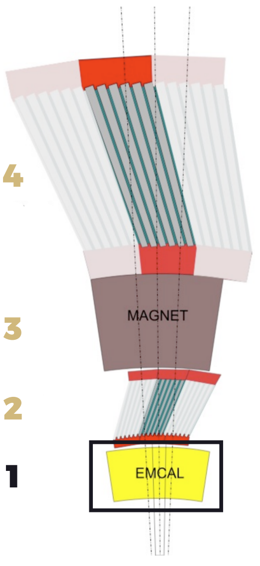
3. **BaBar Superconducting Magnet**
   - Not an active part of the system but defines inner/outer HCal

4. **Outer Hadronic Calorimeter (OHCal)**
   - Primary detector of hadronic shower for jets



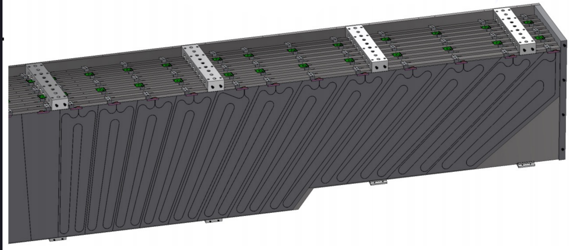
EMCal

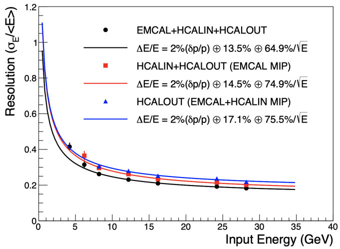


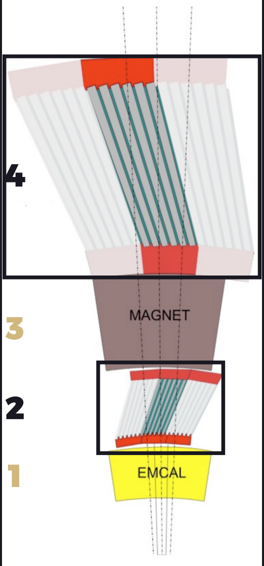


- **SPACAL sampling calorimeter**
  - **Scintillating fibers embedded in tungsten bricks**
- **Each tungsten brick covers 0.025 x 0.025 of $\Delta\eta$ x $\Delta\phi$**
  - **Comparable to CMS ECal granularity**
- **Spans pseudorapidity of $\pm$1.1, $\sim$20 X_0**
- **Relative energy resolution expected $\sim$16%/$\sqrt{E}$**

Inner and Outer HCal

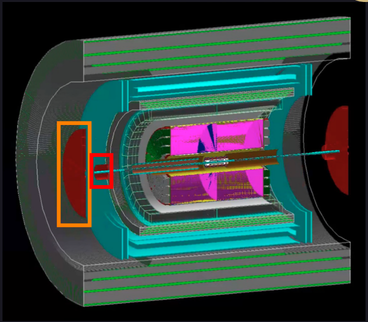




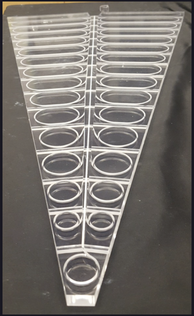


- **IHCal: Al and scintillating plates w/ WLS fibers**
- **OHCal: Steel and scintillating plates w/ WLS fibers**
  - **Also acts as magnetic flux return**
- **Spans η of $\pm$1.0 in 0.1 x 0.1 $\Delta\eta$ x $\Delta\phi$**
- **High-p_T resolution converges on 13.5%**
- **Installation now complete!**

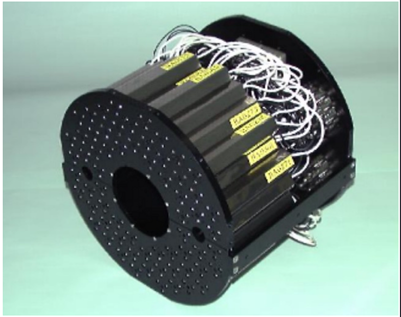
sEPD and MBD



sPHENIX w/ sEPD/MBD



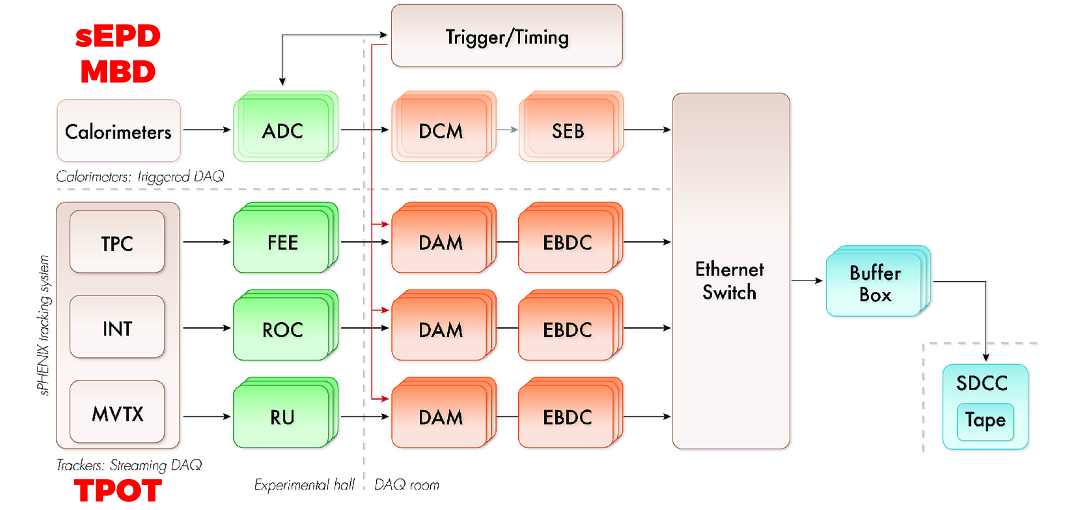
sEPD



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

DAQ and Trigger



- **Hybrid system: Calorimeter triggered, tracking is streaming**

Streaming DAQ Impact

		Year-2024, triggered DAQ per-1kHz M.B. trigger	Year-2024, w/ str. tracker	Year 2026 w/ str. tracker
M.B. p+p	Data Mode	Each 1k Hz M.B. trigger w/ 4×10^{-4} of M.B. coll. triggered	10% M.B. events str. recorded	100% M.B. events str. recorded
	Stats	1 Billion M.B. evts 0.026 pb^{-1} recorded	250 Billion M.B. evts 6.2 pb^{-1} recorded	3.2 Trillion M.B. evts 80 pb^{-1} recorded
Physics Reach	$B \to D^0 \to \pi K$ R_{AA} ref.	620 evts	150k evts	2M evts
	$D^0 \to \pi K$ pair Diffusion of $c+\bar{c}$	620 evts	150k evts	2M evts
	$\Lambda_c \to \pi K p$ Charm hadronization	1.3k evts	310k evts	4M evts
	Prompt $D^0 \to \pi K$ Tri-Gluon Corr. via TSSA	0.2M evts	50M evts	0.6B evts

- **Trigger (MBD, jet, γ) cannot get us to open HF**
- **Streaming output, however, does in p+p in p+A**

Run Schedule

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z \rvert$ <10 cm	Samp. Lum. $\lvert z \rvert$ <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} [5 kHz] 4.5 (6.2) pb^{-1} [10%-str]	45 (62) pb^{-1}
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5 kHz] 0.01 pb^{-1} [10%-str]	0.11 pb^{-1}
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

Commissioning +Initial QGP Data

Run Schedule

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Cold QCD Data

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Reference Data

Cold QCD Data

Full QGP Data

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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} [5 kHz]	45 (62) pb^{-1}
			Streaming →		4.5 (6.2) pb^{-1} [10%-str]	
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5 kHz]	0.11 pb^{-1}
			Streaming →		0.01 pb^{-1} [10%-str]	
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

Commissioning +Initial QGP Data

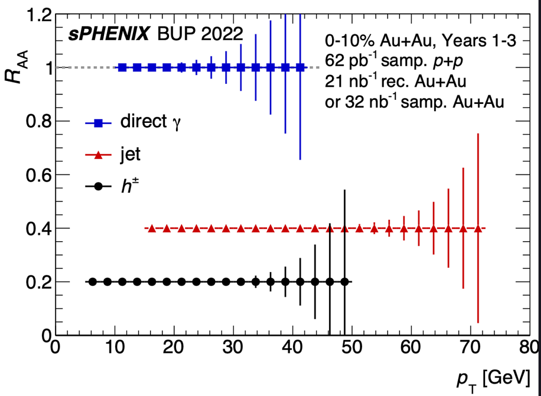
Reference Data

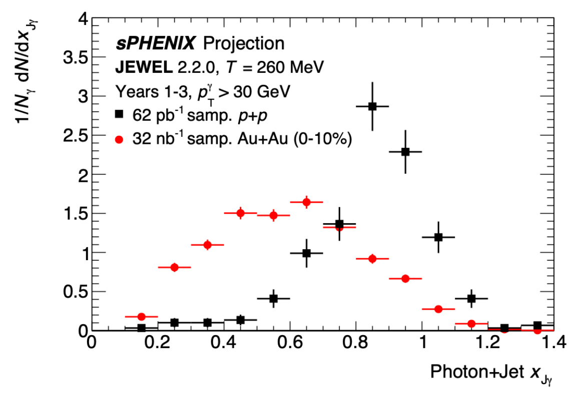
Cold QCD Data

Full QGP Data

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

Jet Physics Projections

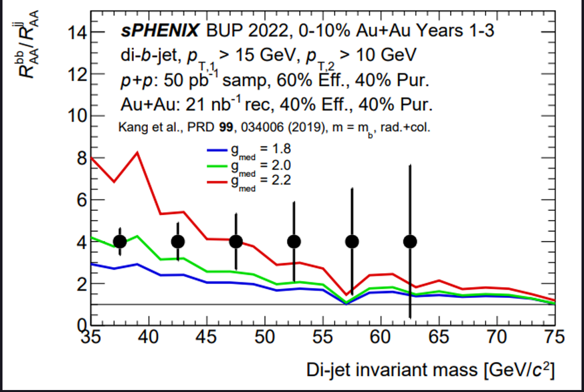


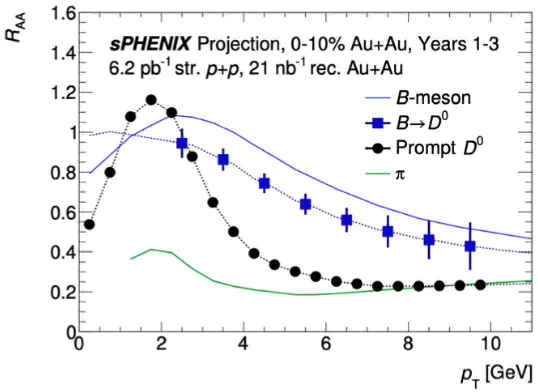


Projected R_{AA}'s **Projected γ+jets balance**

- **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!**

Heavy Flavor Physics Projections

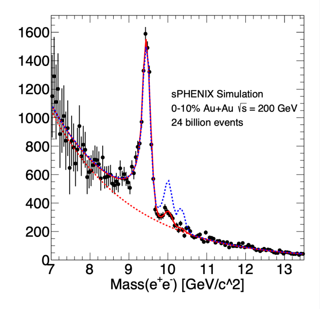


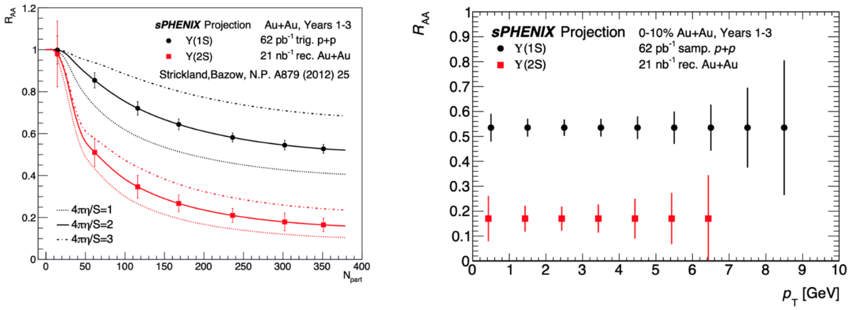


b-jet Invariant Mass **Open HF R_{AA}**

- 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



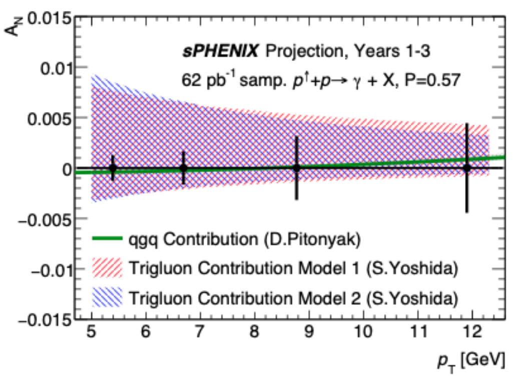


Υ Mass

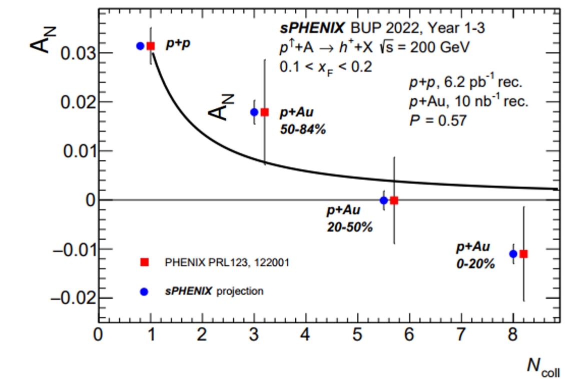
Υ R_{AA} v. N_{Part} and p_T

- Measure Υ 1S, 2S, and 3S sequential suppression
  - Expect monotonic increasing suppression w/ nS state
- Measure as a function of N_{part} and p_T
- For more details, see Marzia Rosati's talk!

Cold QCD Projections



TSSA for photons in p+p



TSSA for hadrons in p+p and p+Au

- **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!**

Conclusion

- 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 $\Upsilon \rightarrow$ee
    - Covers 2π in azimuth, $\pm$ 1.1 in η

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

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First collisions expected Spring 2023!