The sPHENIX Experiment at RHIC

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U.S. DEPARTMENT OF ENERGY | Office of Science

ICHEP 2022 BOLOGNA

sPHENIX Science Mission

❑ **The first new detector at RHIC in >20 years.**

The 2015
LONG RANGE PLAN
for NUCLEAR SCIENCE

❖ Completing the scientific mission of RHIC.

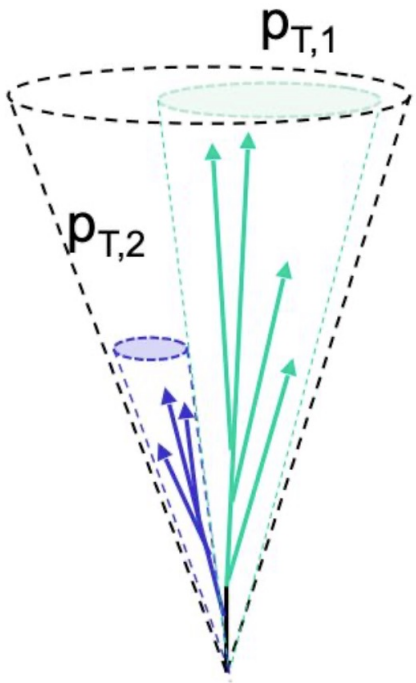
> There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

❖ **Complementarity to LHC.**

Different initial conditions and evolution for QGP between RHIC and LHC ➔ allows study of scale and temperature dependence

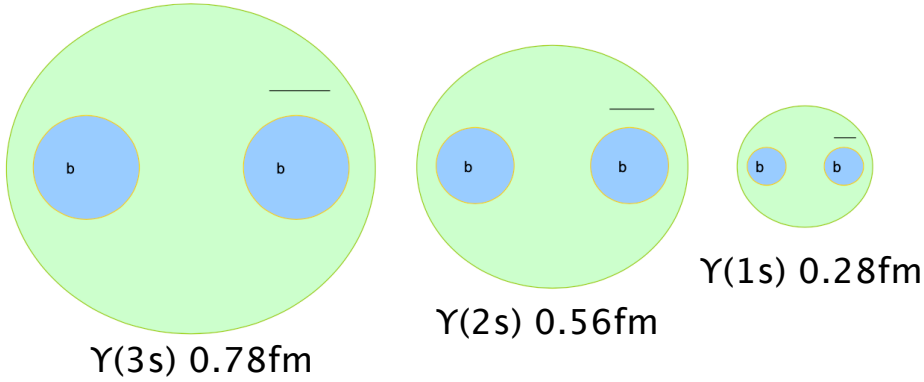
❑ sPHENIX as the highest priority for Runs 2023-2025 (PAC Report, Sep. 2020)

The sPHENIX Physics Program



Jet structure

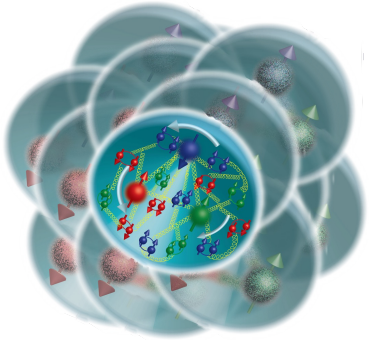
vary momentum/angular scale of probe



Quarkonium spectroscopy

vary size of probe

sPHENIX

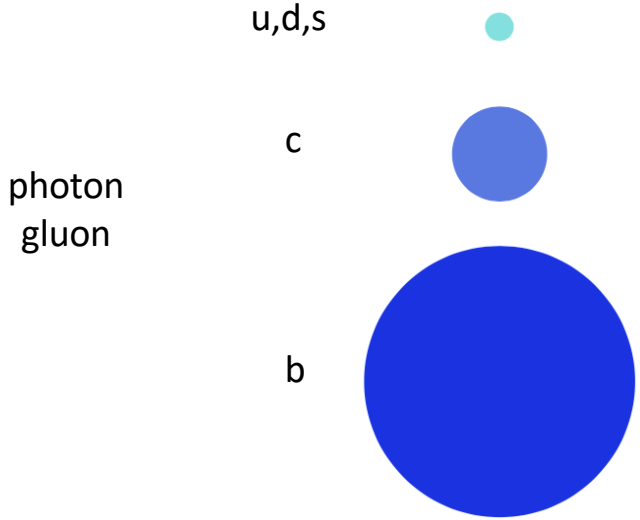


Cold QCD

study proton spin,
transverse-momentum,
and nuclear effects

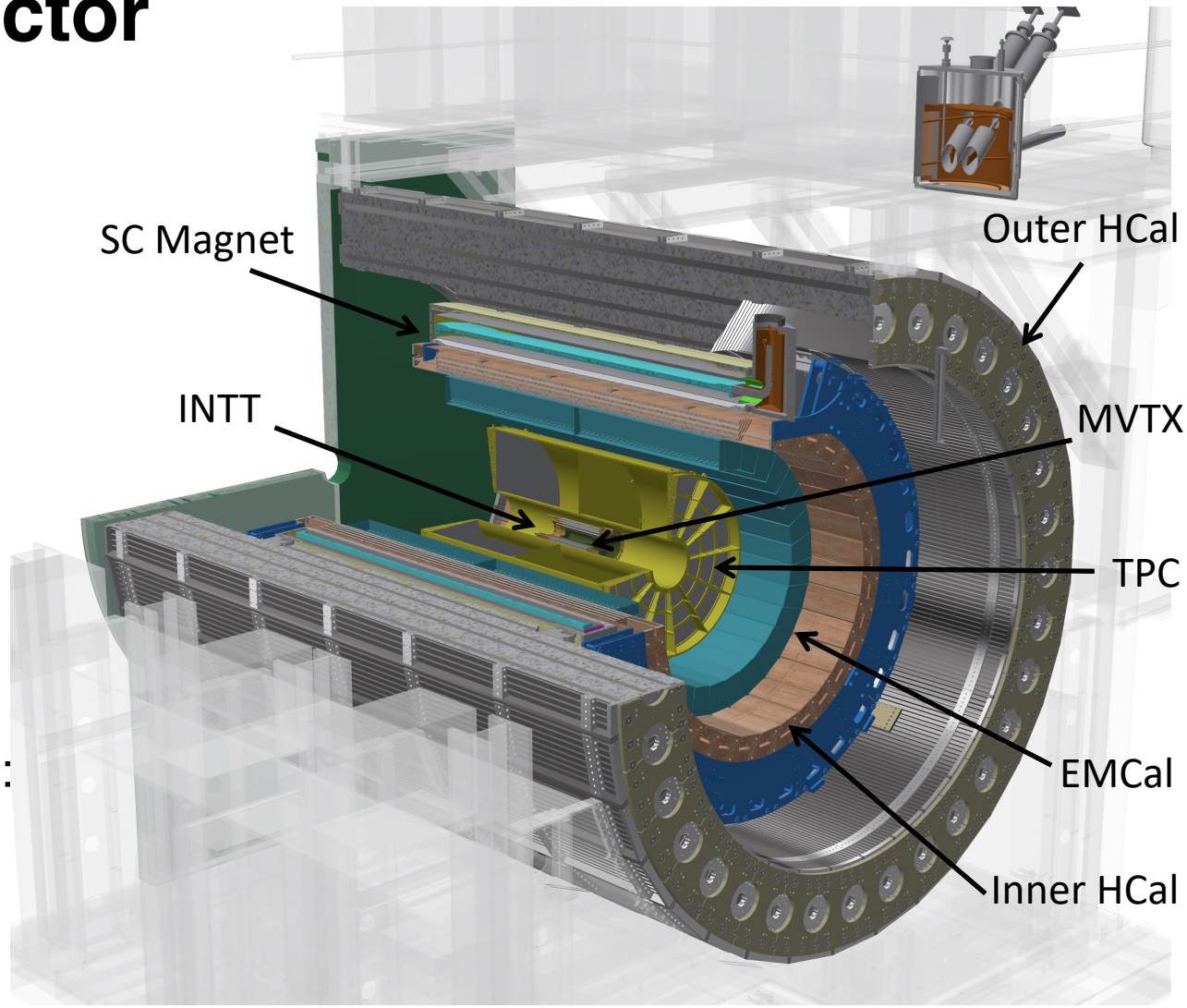
Parton energy loss

vary mass/momentum of probe



sPHENIX Detector

- 1.4 T Solenoid from BaBar
- Hermetic coverage: $|\eta|<1.1$
- Precision tracking
- Large-acceptance EM+Had calorimeters
- High rate (15 kHz) DAQ: trigger capability with streaming readout



→ brings first full jet reconstruction & b-jet tagging at RHIC!!

sPHENIX Tracking Detectors

MVTX (2.3 < r < 3.9 cm): precision vertexing

- 3 layers of Monolithic Active Pixel Sensors (MAPS) closely based on ALICE's ITS2
- 5 μm position resolution for tracks with p_T>1 GeV

INTT (7 < r < 12 cm): pileup separation

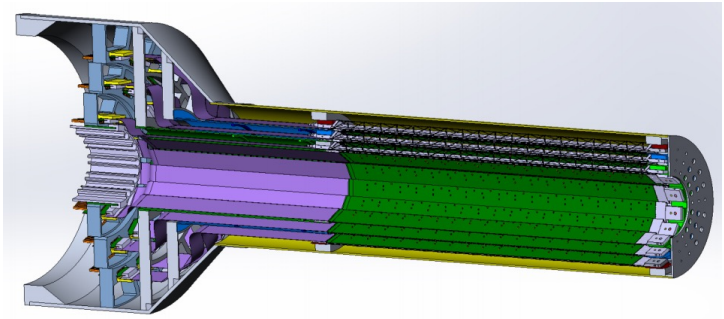
- 2 layers of silicon strips (86μm pitch)
- single-beam-crossing timing resolution

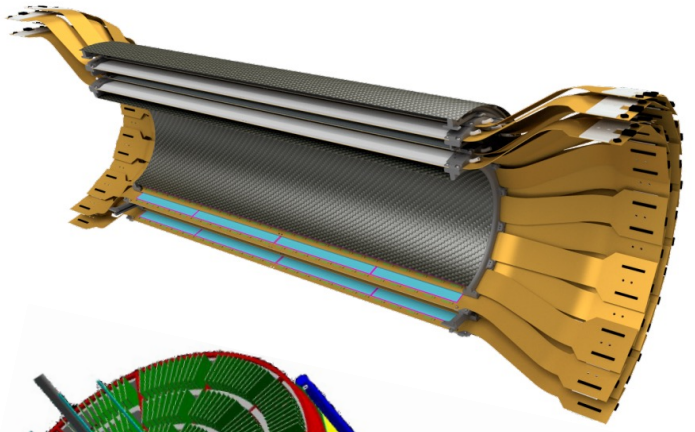
TPC (30 < r < 78 cm): momentum measurement

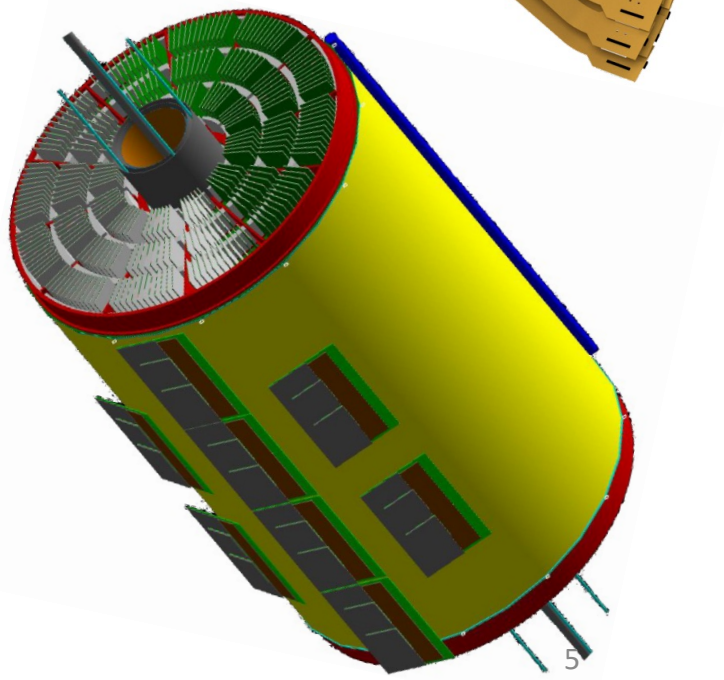
- Very compact GEM-based TPC: 48 layers with gateless and continuous readout.

TPC Outer Tracker (TPOT): calibration of beam-induced space charge distortions

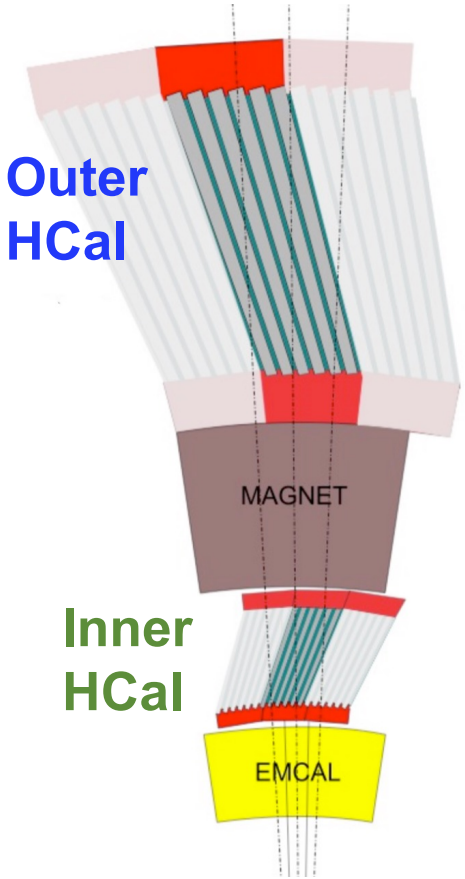
- 8 modules of Micromegas inserted between TPC and EMCal







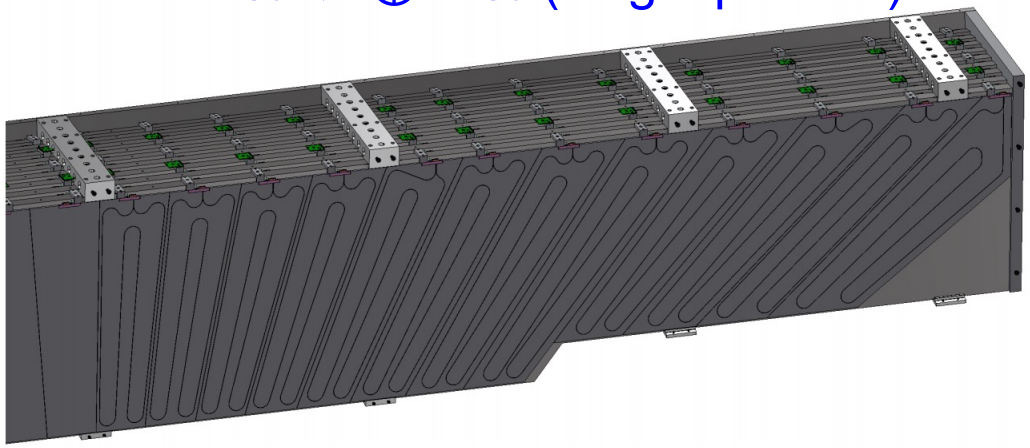
sPHENIX Calorimeters



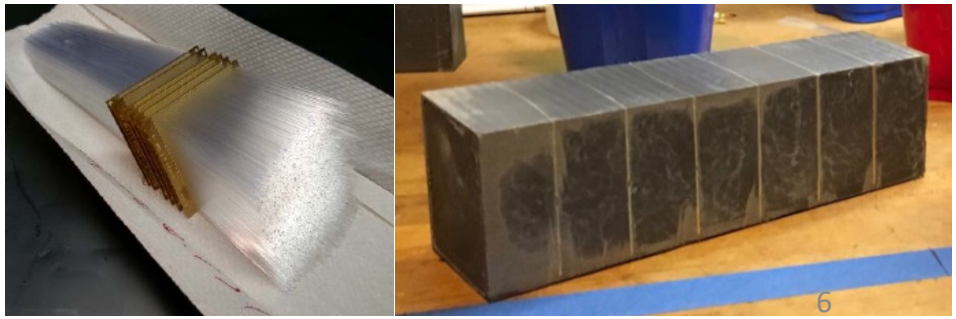
Outer HCal: Steel absorber plates and scintillating tiles with embedded WLS fibers

Inner HCal: Al absorber plates and scintillating tiles with embedded WLS fibers

Resolution ~ 88%/√E⊕12% (single particle) for overall HCal.



EMCal: Tungsten-scintillating fiber sampling calorimeter (SPACAL type).
18 X_0, 1 λ. Δη x Δϕ=0.025x0.025.
Resolution ~ 16%/√E ⊕5%.



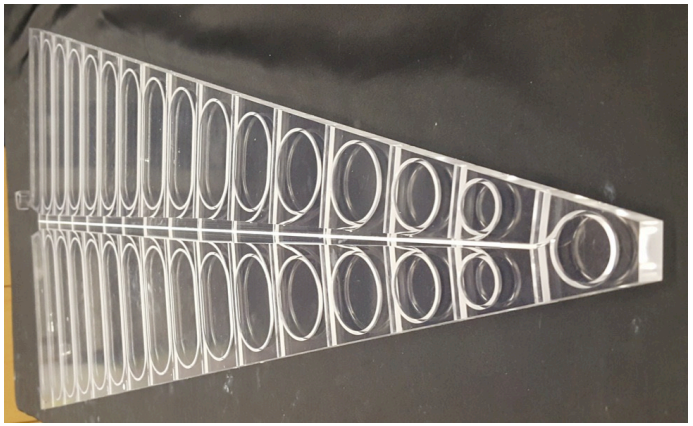
Minimum Bias & Event Plane Detectors

Minimum Bias Detector (MBD)
[3.51 < |η| < 4.61]

- Reuse of the PHENIX Beam-Beam Counter
- 128 channels of 3 cm thick quartz radiator on mesh dynode PMT
- 120 ps timing resolution

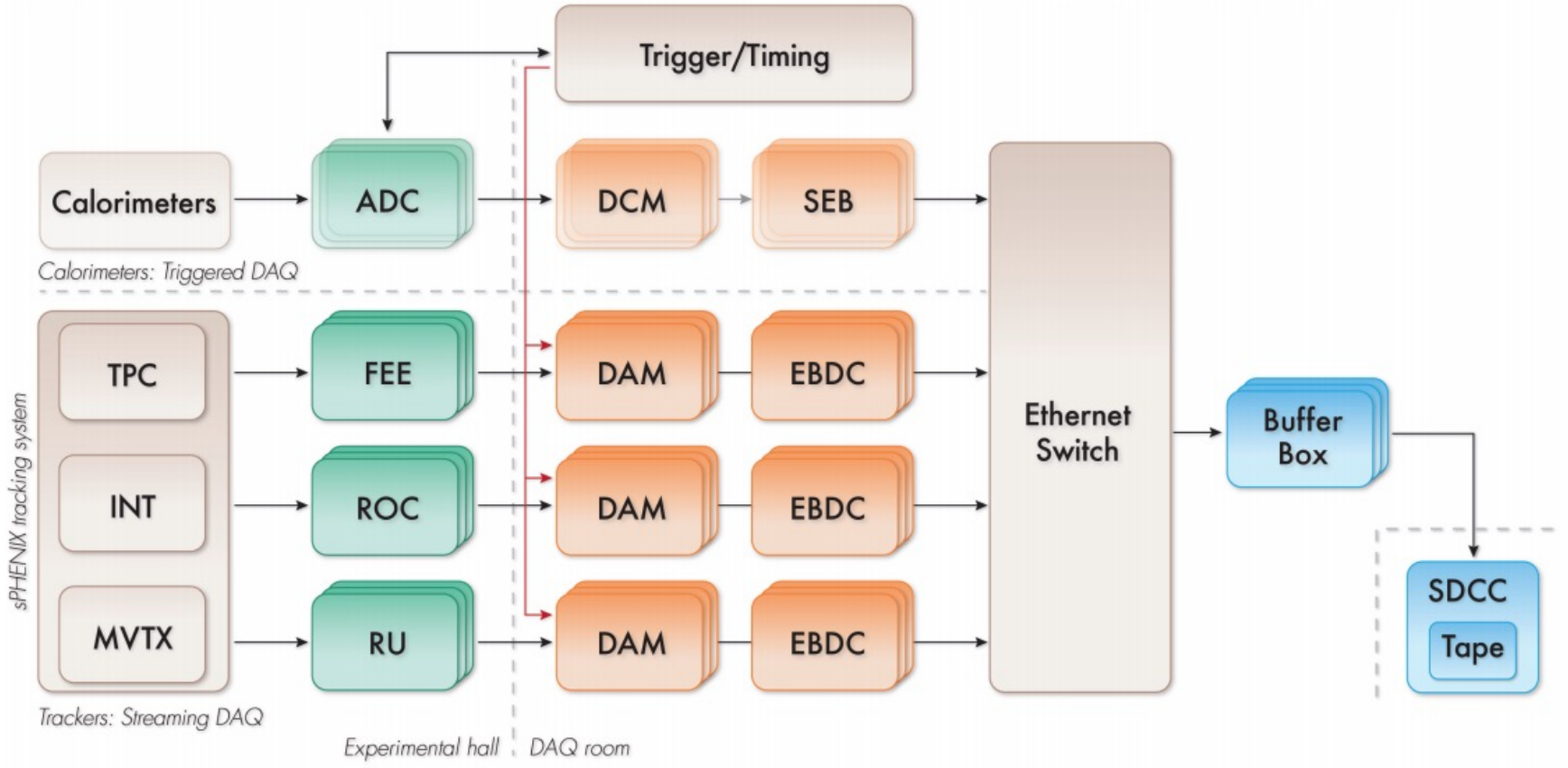
sPHENIX Event Plane Detector (sEPD)
[2.0 < |η| < 4.9]

- 1.2-cm-thick scintillator w/ wavelength shifting fibers
- 2 wheels of scintillator tiles
- Provides significant improvement in the event plane resolution



Hybrid DAQ Structure

- **A hybrid of TPC/INTT/MVTX streaming & calorimeter triggers**



- **Streaming readout:** triggerless configuration recording 10% of all collisions.
  → increases amount of Run-24 pp data by orders of magnitude
- **Crucial for open heavy flavor physics** as well as cold QCD measurements.

Run Plan (2023-2025)

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}

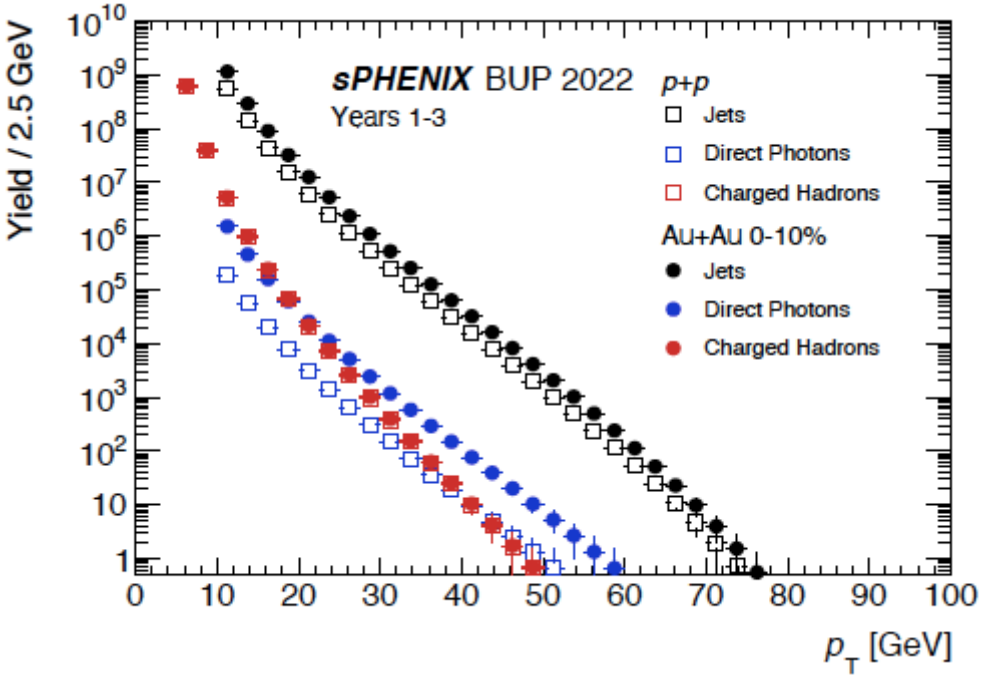
Year-1 (Au+Au): Commissioning, calibration, HI standard candle

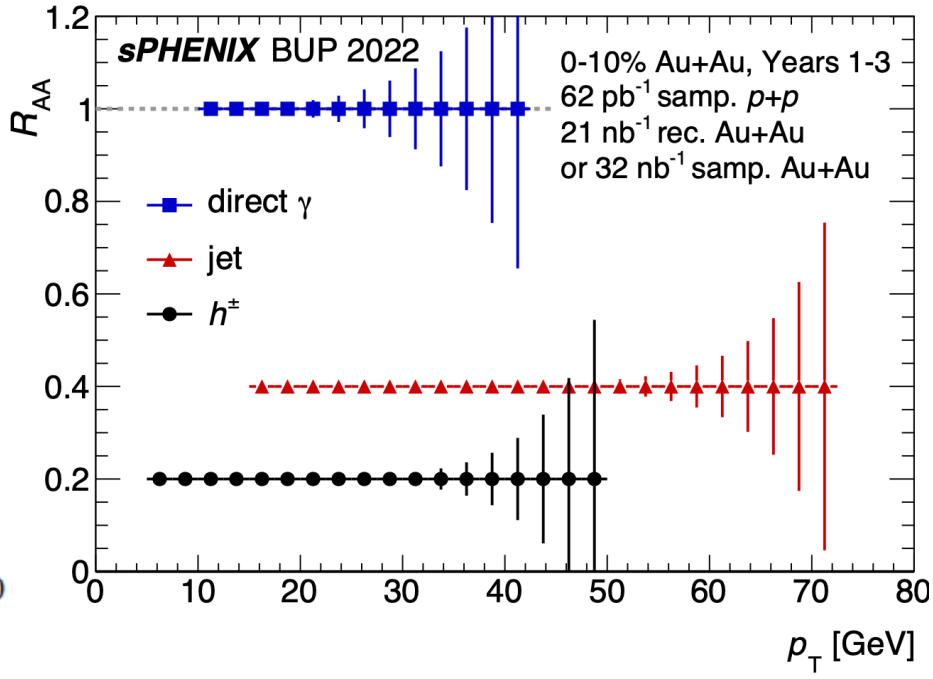
Year-2 (pp & pAu): Reference for HI measurements & cold QCD measurements

Year-3 (Au+Au): High statistics HI

- **Scientific mission of sPHENIX can be achieved with 3 years of running.**
- Consistent with the currently envisioned **Electron Ion Collider (EIC) schedule.**

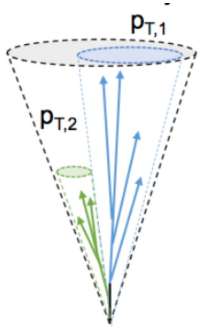
High p_T Probes

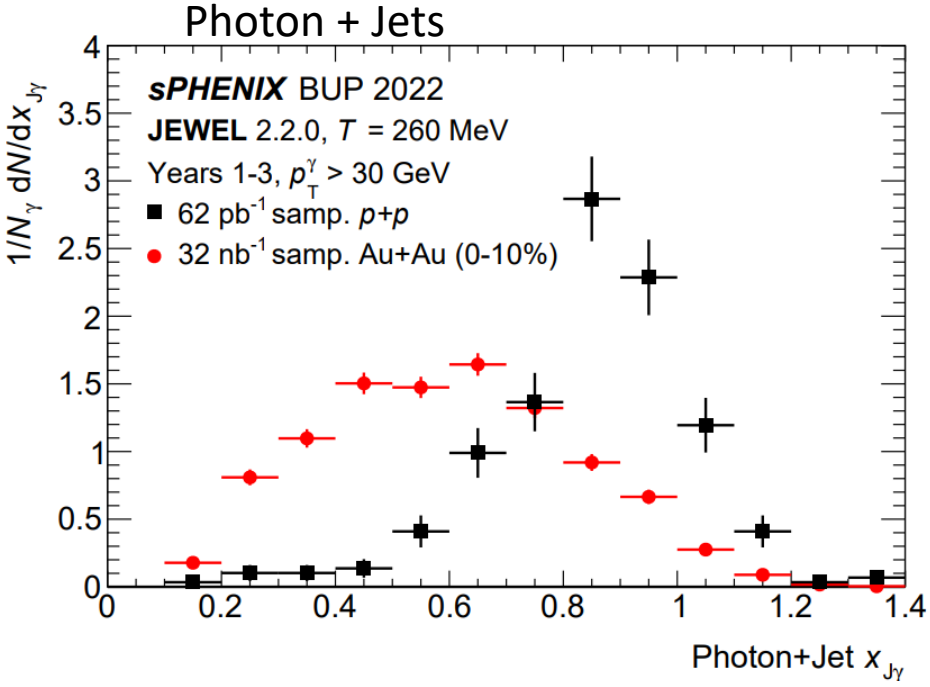


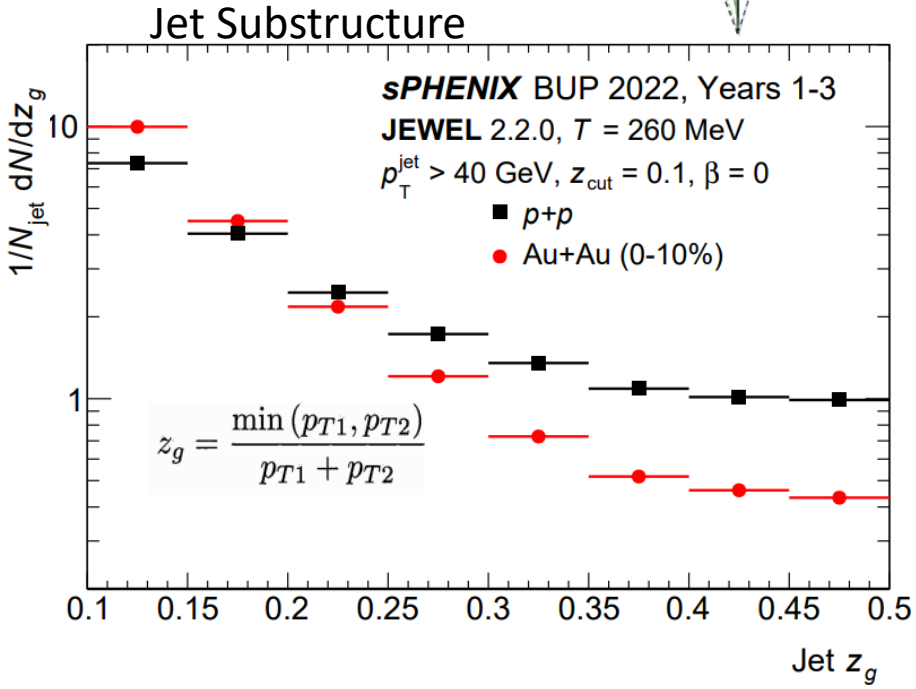


- Jet measurements up to 70 GeV, 50 GeV for hadrons ➔ kinematic overlap with the LHC; possible for the first time at RHIC.
- Precision measurements at low p_T ➔ crucial for precise measurements of QGP properties

Jet Correlations & Substructure





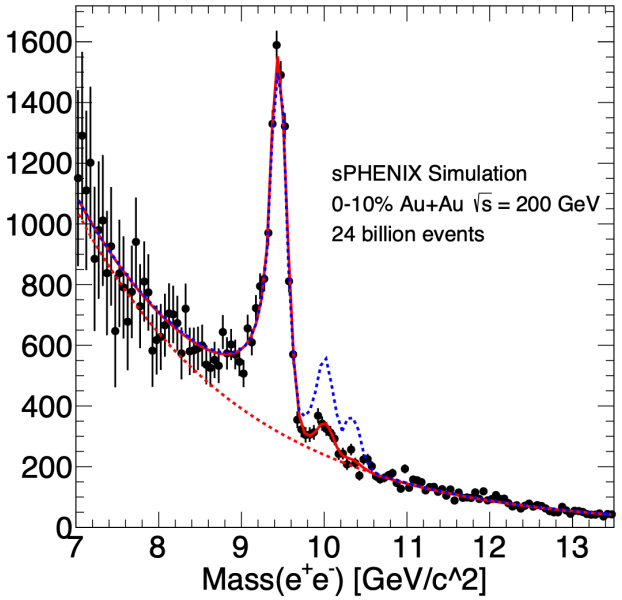


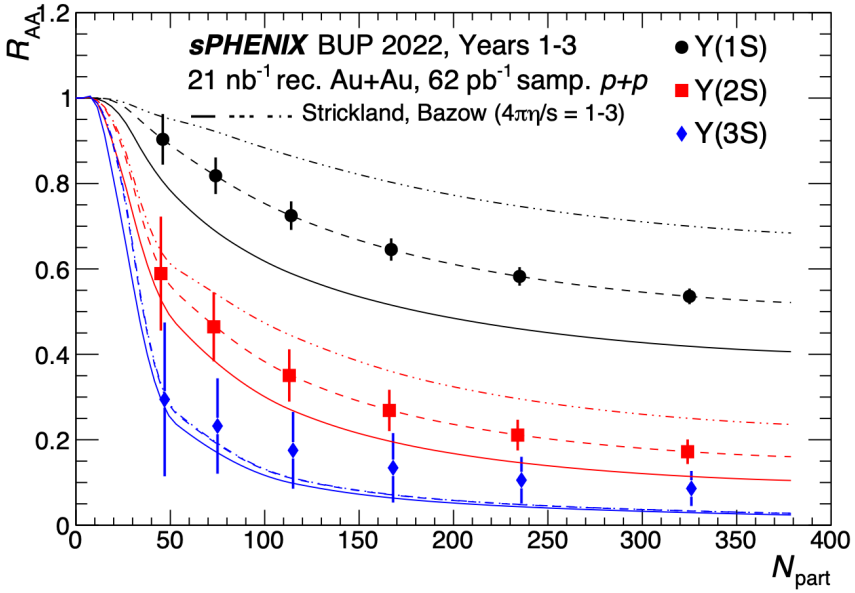
- A “flagship” measurement.
- Dramatic difference expected b/w RHIC & LHC energies (W. Dai, I. Vitev, and B.-W. Zhang PRL 110, 142001)

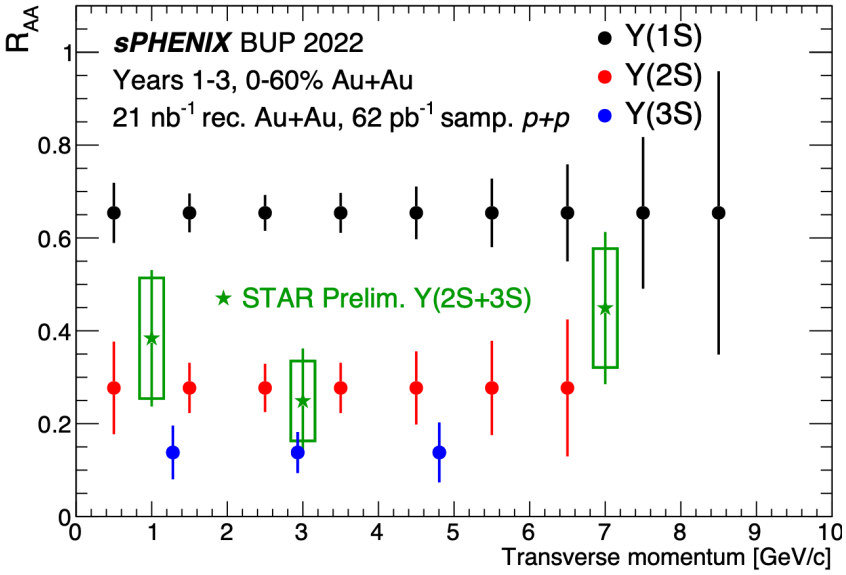
- Explore parton shower development in QGP.
- Connection to fundamental QCD & a probe to measure the QGP properties.

Upsilon R_{AA}

- First separated three Upsilon states @ RHIC
- $\Upsilon(3S)$ projected, given the observation of $R_{\mathrm{AA}}(3S)/R_{\mathrm{AA}}(2S)$ ~ 0.5 at the LHC.
- sPHENIX has the unique opportunity to discover the $\Upsilon(3S)$ suppression at RHIC.

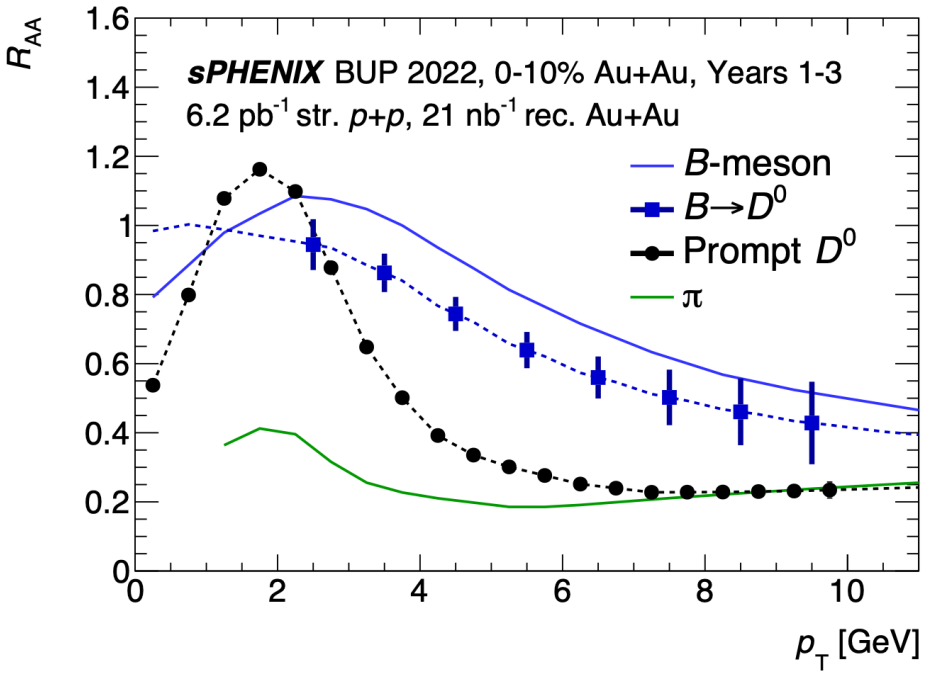


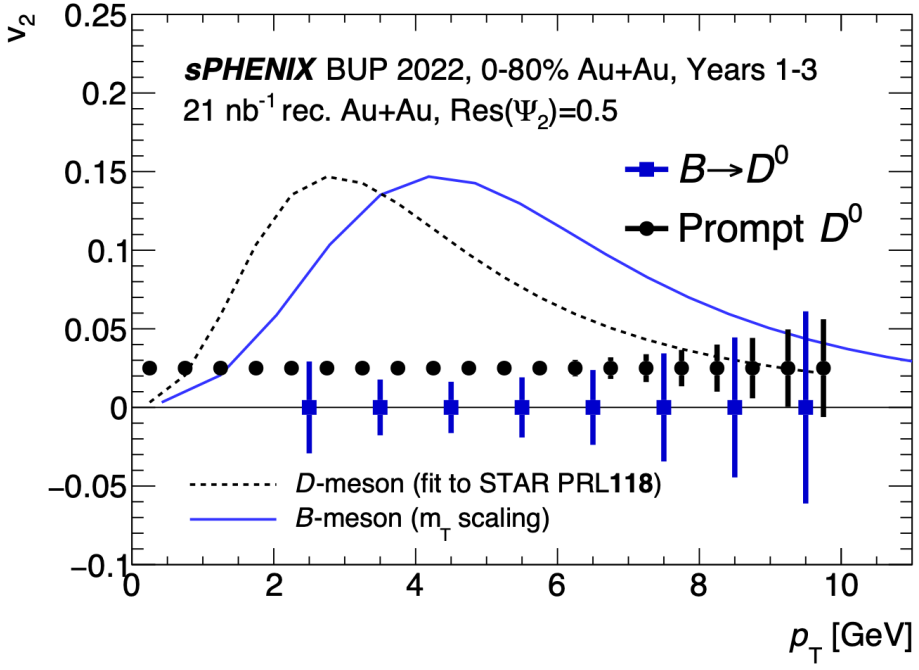




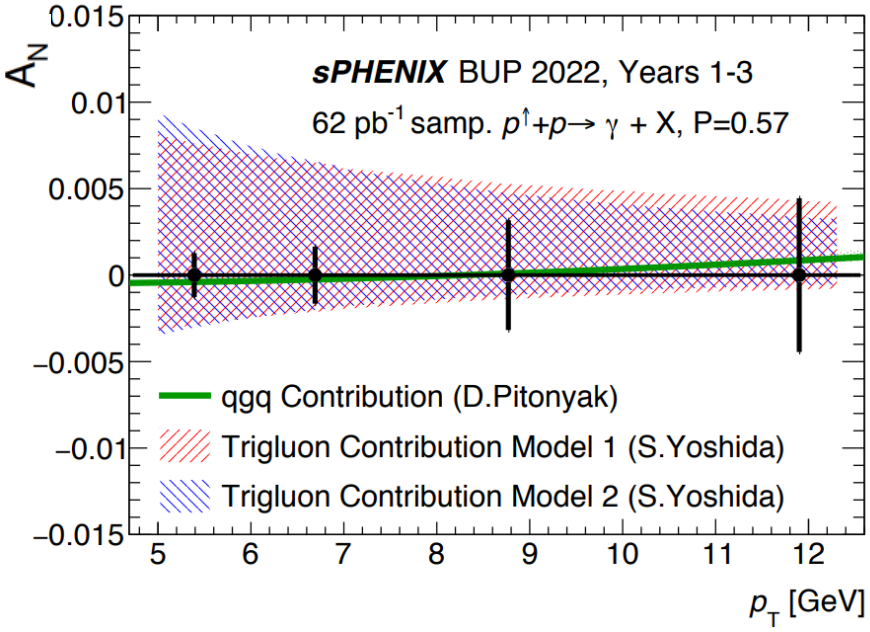
Heavy Flavor R_{AA} & Flow

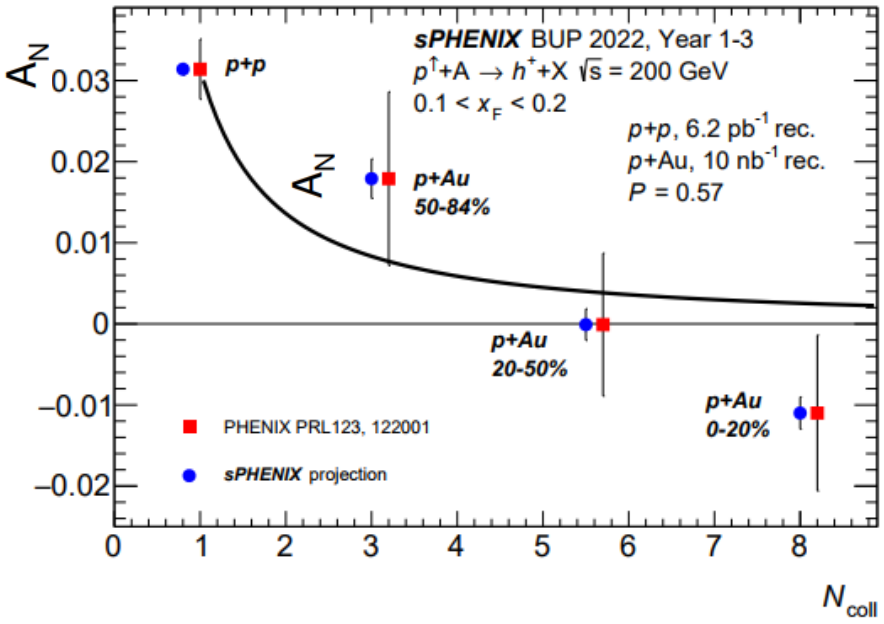
- Streaming readout allows collecting a huge MB data for unbiased HF down to p_T~0 GeV.
- High precision non-prompt-*D* suppression and flow at RHIC ➔ Access b-quark suppression/v_2 via non-prompt *D*
- Determination of b-quark R_{AA} → clean access to diffusion at RHIC

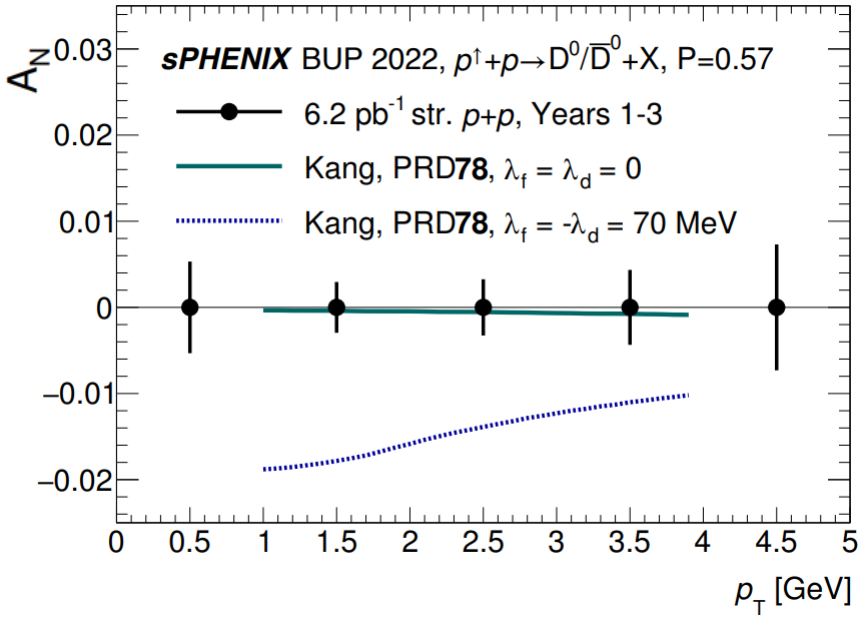




Cold QCD







- Access to transverse single spin asymmetries (TSSAs) via prompt photon & D^0 ➠ gluon dynamics in transversely polarized nucleons w/ tri-gluon correlations.
- In *p*+Au, measuring nuclear dependence of TSSA will offer insight to its origin (much improved precision from PHENIX).

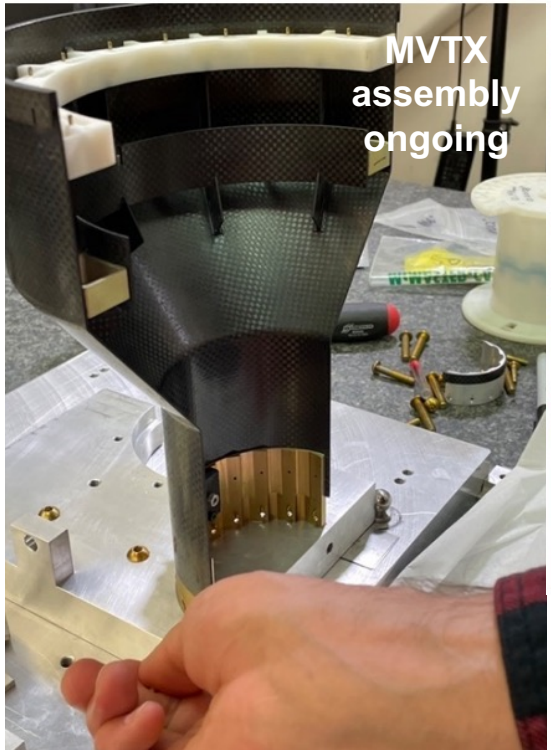
Toward the First Data Taking

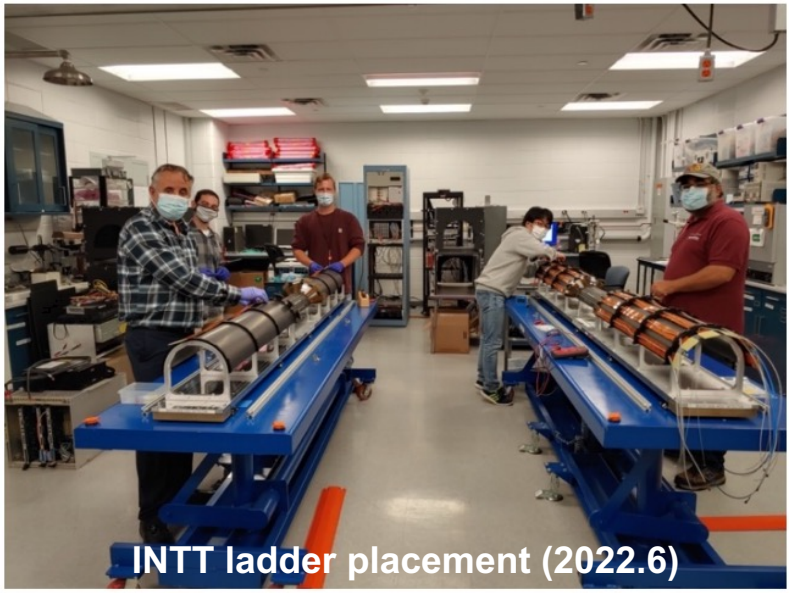

North side of sPHENIX w/ O&IHCal installed

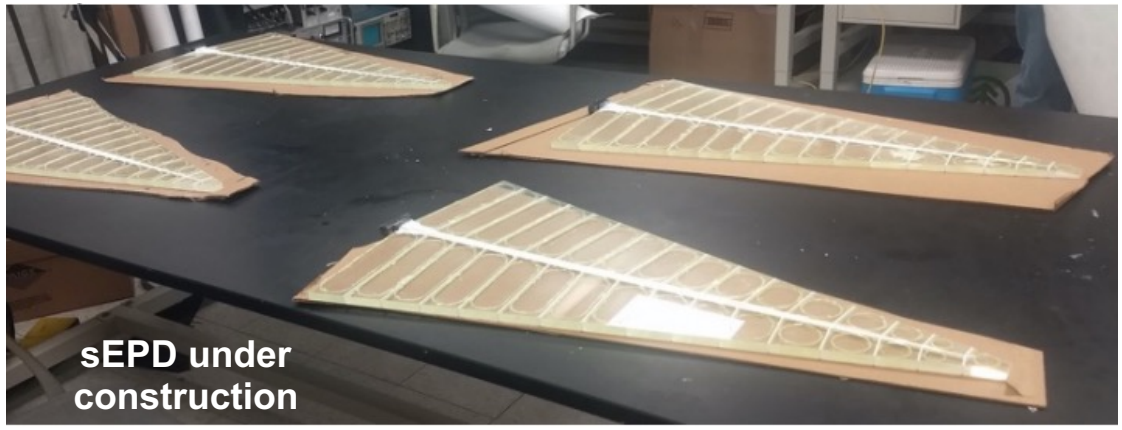
Installation tests of EMCal

- OHCAL & IHCal are complete, installed and tested)
- EMCAL complete (ready to install)
- All Calorimeter electronics complete including digitizers

Toward the First Data Taking

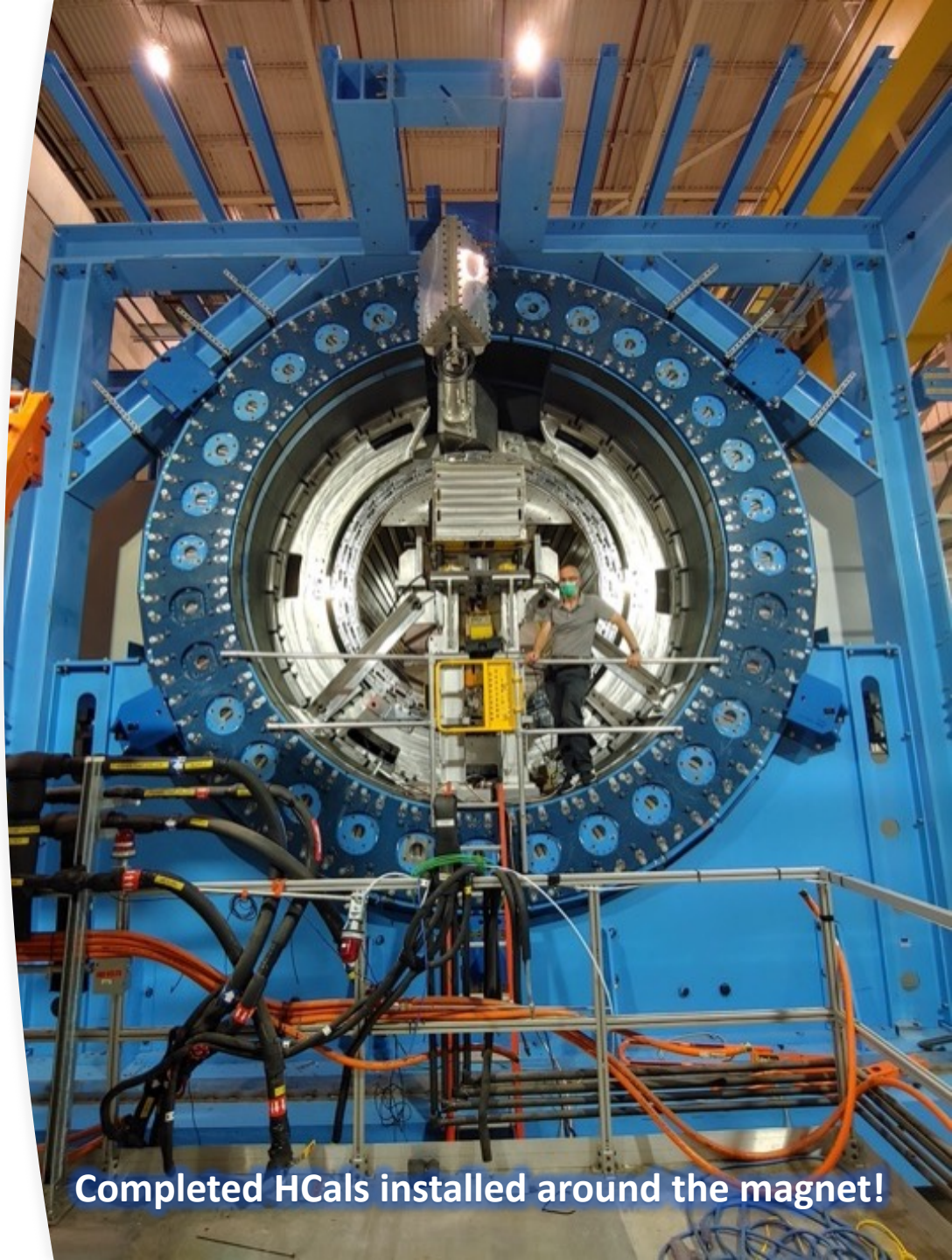






Summary

- sPHENIX is the first new detector at RHIC in >20 years.
- sPHENIX provides unique opportunities in low energy & offer kinematic overlap with the LHC.
- Wide range of physics covered in sPHENIX: jet correlations & substructure, Υ spectroscopy, open heavy flavor & cold QCD.
- Detector construction & data taking preparation on schedule!
- Preparing for the first data taking in 7 months!



Completed HCals installed around the magnet!

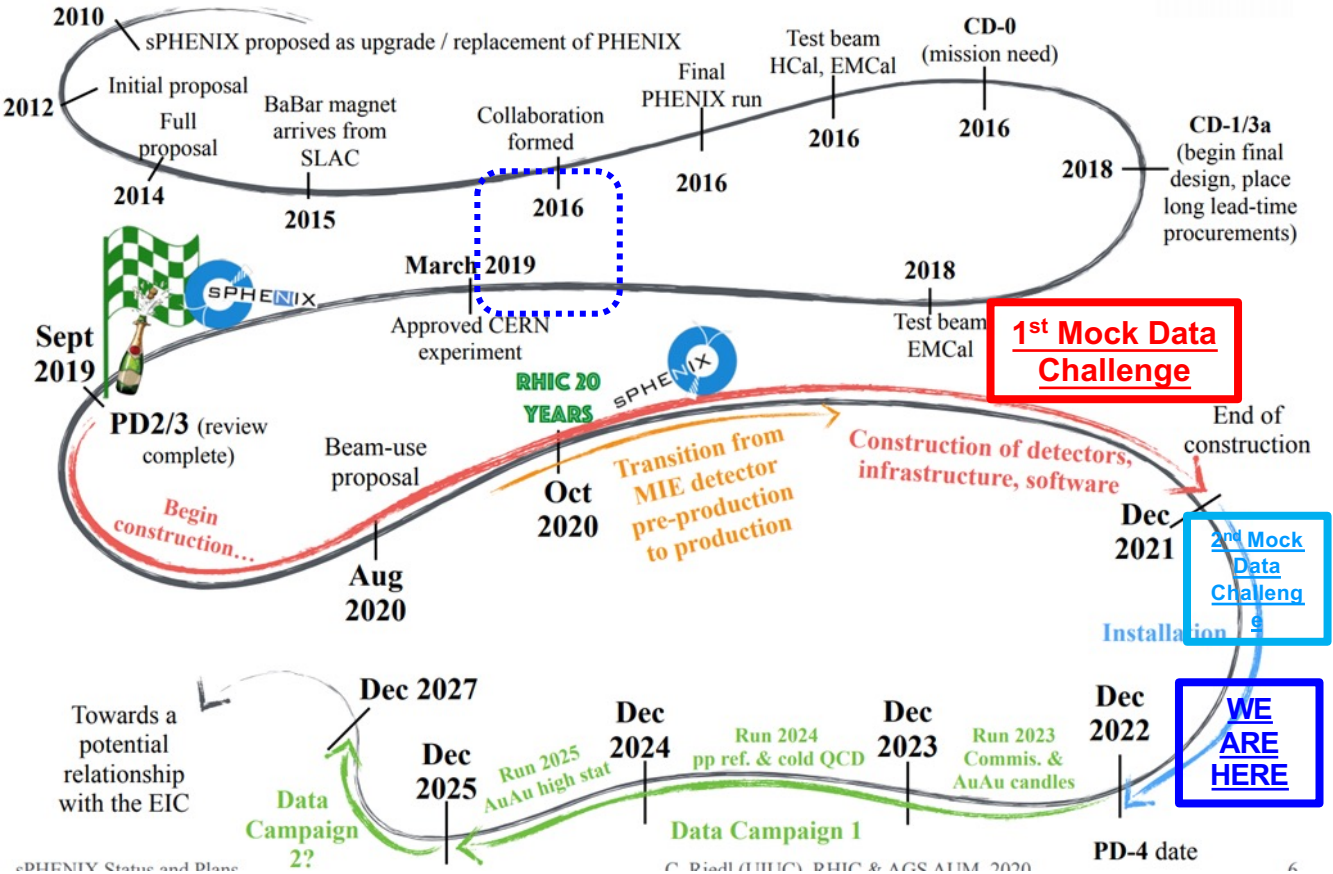
Thank you!

Abstract: The sPHENIX experiment at RHIC

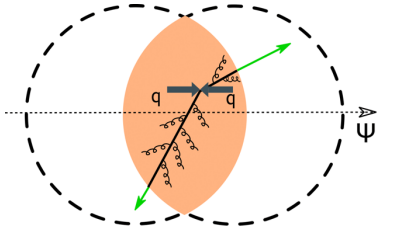
The sPHENIX detector at the BNL Relativistic Heavy Ion Collider (RHIC) is currently under construction and on schedule for first data in early 2023. Built around the BaBar superconducting solenoid, the central detector consists of a silicon pixel vertexer, a silicon strip detector with single event timing resolution, a compact TPC, novel EM calorimetry, and two layers of hadronic calorimetry. The plan is to use the combination of electromagnetic calorimetry, hermetic hadronic calorimetry, precision tracking, and the ability to record data at high rates without trigger bias to make precision measurements of Heavy Flavor, Upsilon and jets to probe of the Quark Gluon Plasma (QGP) formed in heavy-ion collisions. These measurements will have a kinematic reach that not only overlaps those performed at the LHC, but extends them into a new, low-pT regime. sPHENIX will significantly expand the observables and kinematic reach of these measurements at RHIC and provide a comparison with the LHC measurements in the overlapping kinematic region. The physics program, its potential impact, and recent detector development will be discussed in this talk.

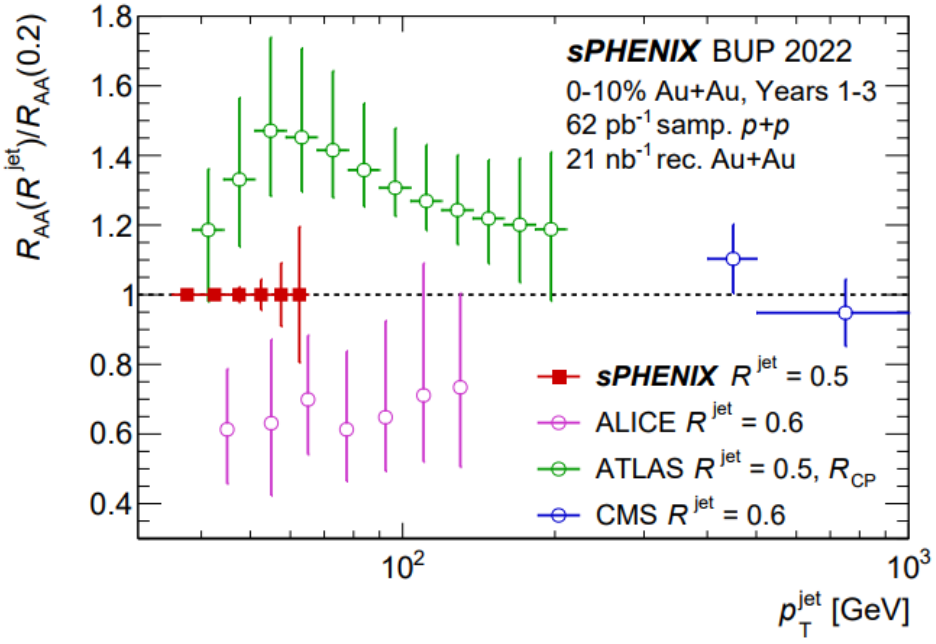
Schedule

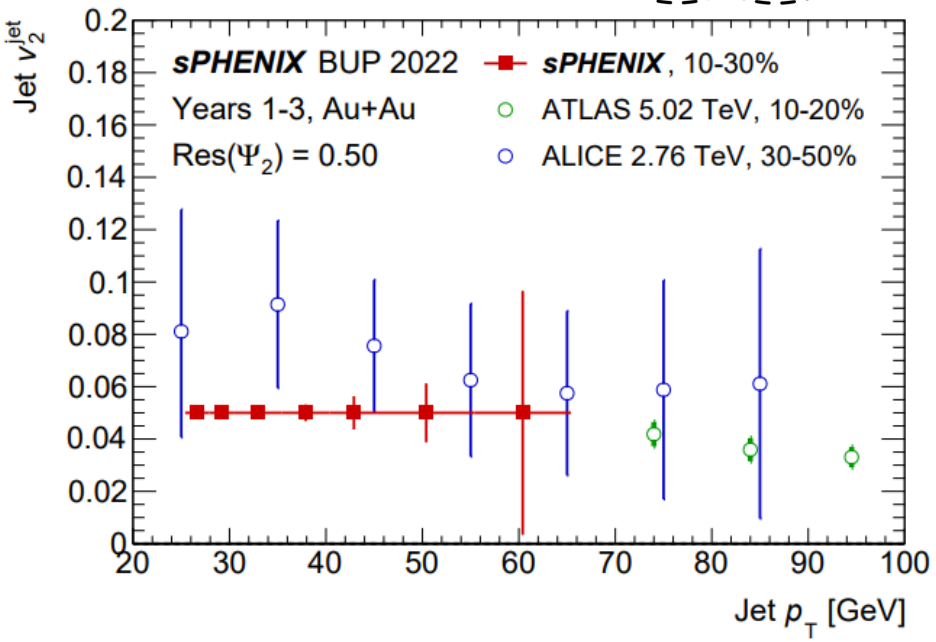
- **Successful 1st Mock Data Challenge in 2021:** testing the full chain of generation, G4 sim, reconstruction & analyses.
- **Detector installation & 2nd Mock Data Challenge ongoing!**
- **Data taking from 2023!**



Unique Jet Opportunities







- Open question: What is the interplay between out of cone energy loss and medium response vs. jet structure dependence?
  - Tension in LHC results at low p_T
- Jet v_2: unable to simultaneously describe suppression and anisotropy in most models.

→ sPHENIX can precisely measure low p_T region, which is challenging at the LHC.

Heavy Flavor Jets R_{AA}

- **First b-tagging at RHIC**, enabled by precision tracking and full calorimetric jet
- Enhanced sensitivity with dijet pair mass & ratio to the inclusive jet measurement.
- Sufficient statistics to measure b-jet substructure: **sensitive to the role of parton mass.**