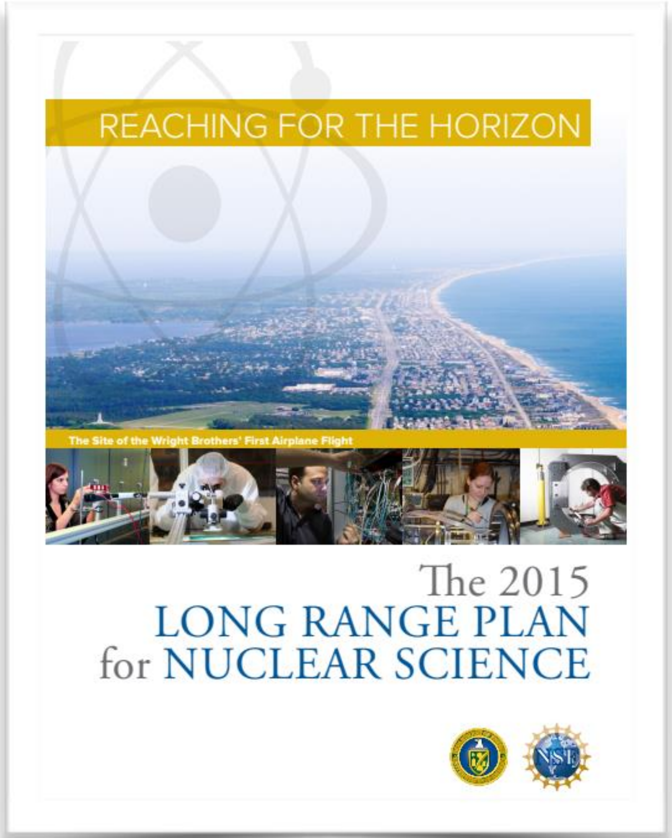
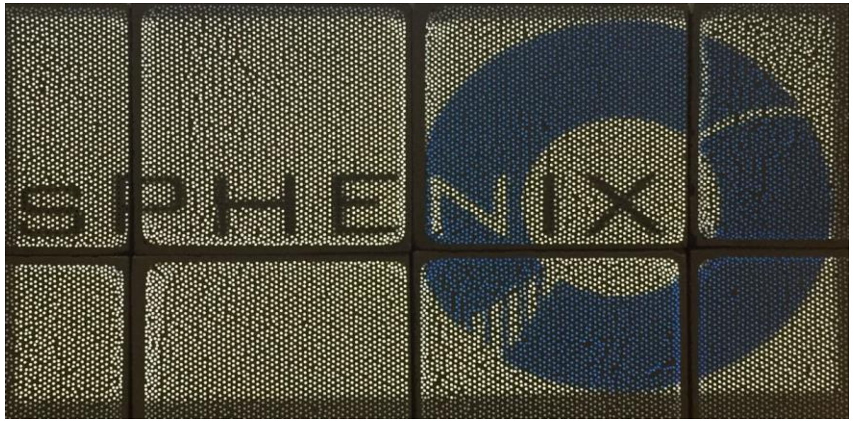
Unlocking the Physics of the Quark Gluon Plasma with the sPHENIX Experiment at RHIC

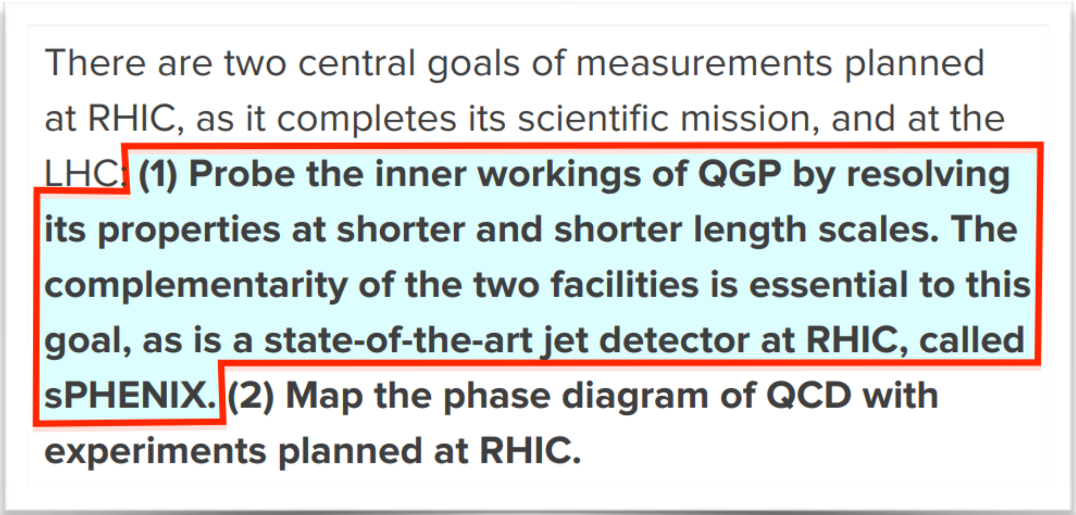
Timothy Rinn on behalf of the sPHENIX collaboration

sPHENIX: state-of-the-art Jet Detector at RHIC



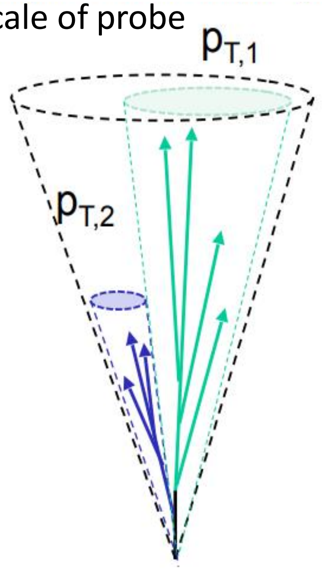
Section 2.2: Page 22



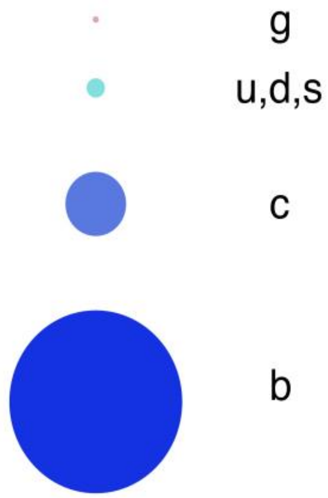

There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art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

sPHENIX Core Physics Program

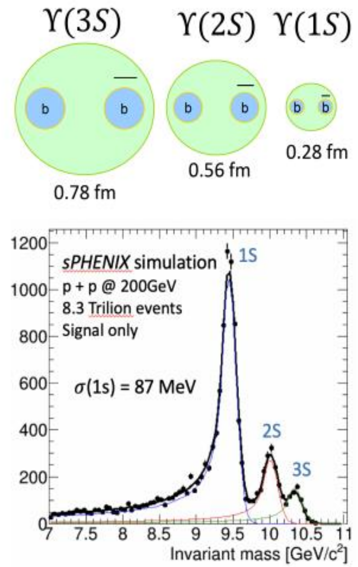
Jet cor. & substructure
Vary momentum/angular scale of probe



Open heavy flavors
Vary mass/momentum of probe

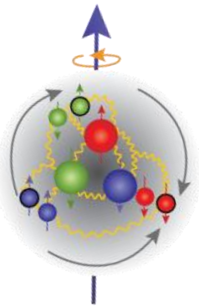


Upsilon spectroscopy
Vary size of the probe



Cold QCD
Spin-orbit correlations in transversely polarized nucleons

Cold nuclear matter effects and hadronization

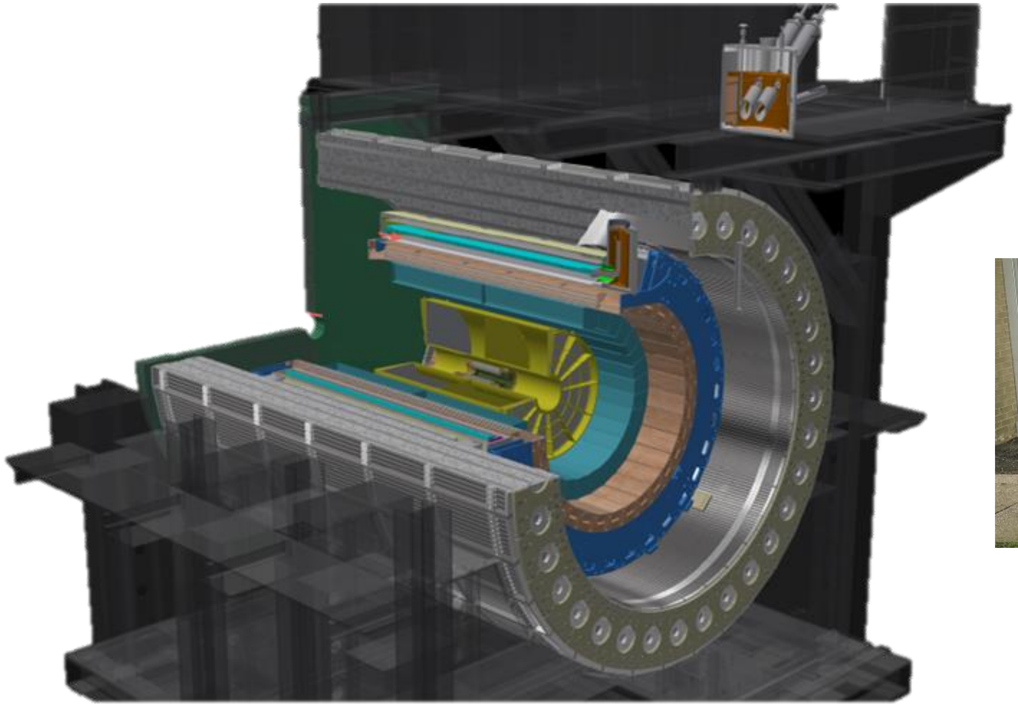


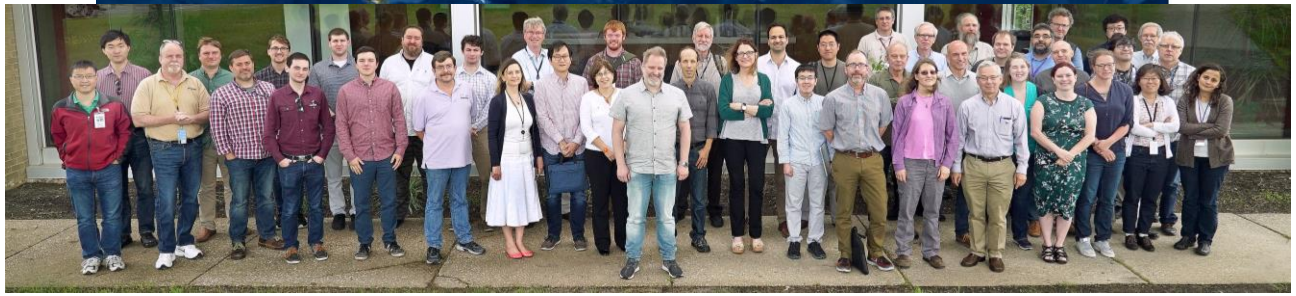
sPHENIX Proposal:
https://inspirehep.net/literature/1341090

sPHENIX Collaboration

Large global Effort

- Over 300 members
- 83 institutions
- 14 Countries





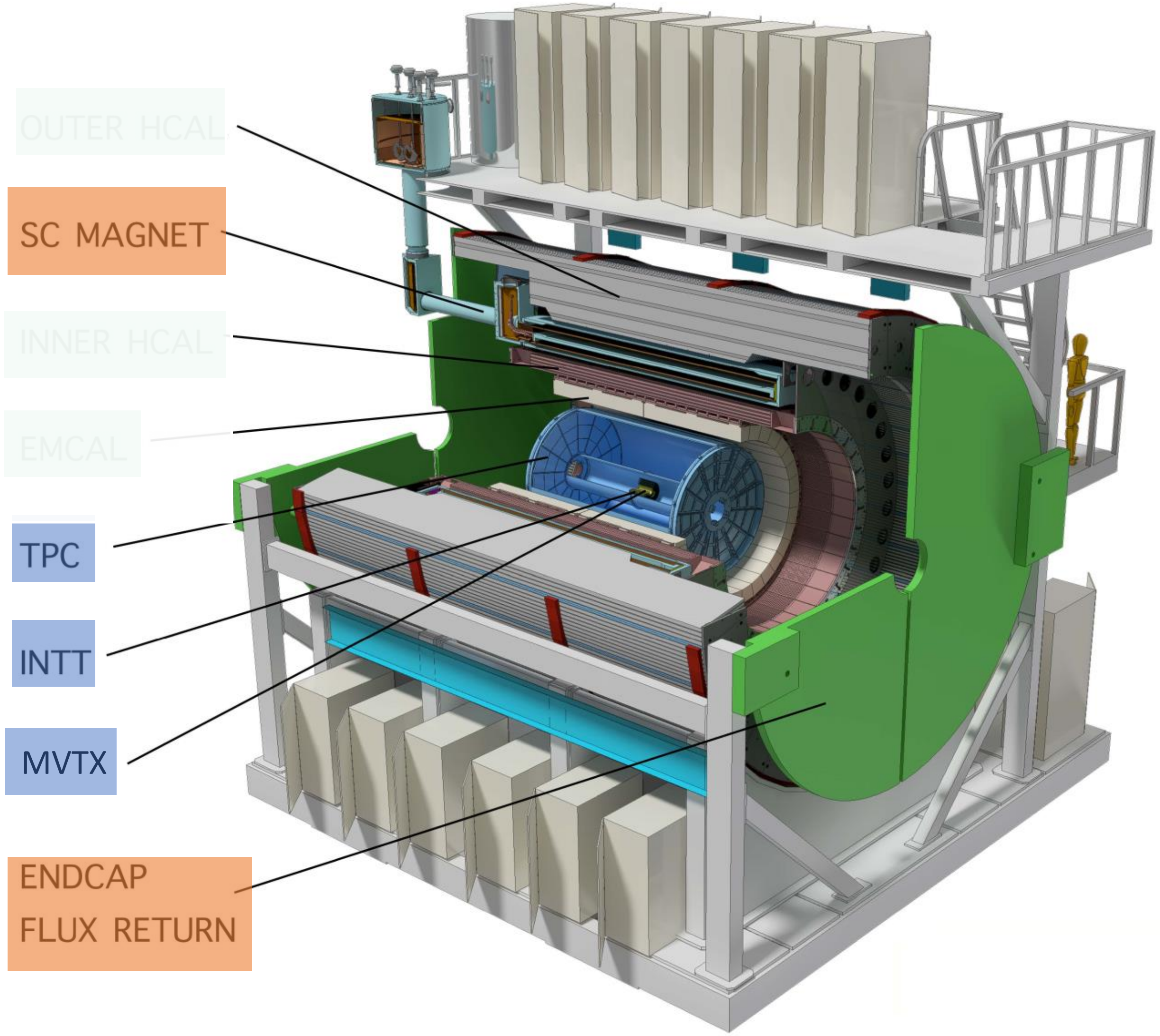
sPHENIX Detector:

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

Superconducting Magnet (1.4 T solenoid)

Calorimetry:
Electromagnetic Calorimeter (EMCal)
inner Hadronic Calorimeter
outer Hadronic Calorimeter

High Rate DAQ and trigger system:
15 kHz Trigger, >10 GB/s DAQ



sPHENIX Tracking:

MAPS-based Vertex Tracker (MVTX)

- 3 layers of Monolithic Active Pixel Sensors (ALICE)
- Short integration time (few μs)
- Great spatial resolution < 6 [μm]
- Ultra-thin ~0.3%X_0

precise vertexing

Intermediate Silicon Tracker (INTT)

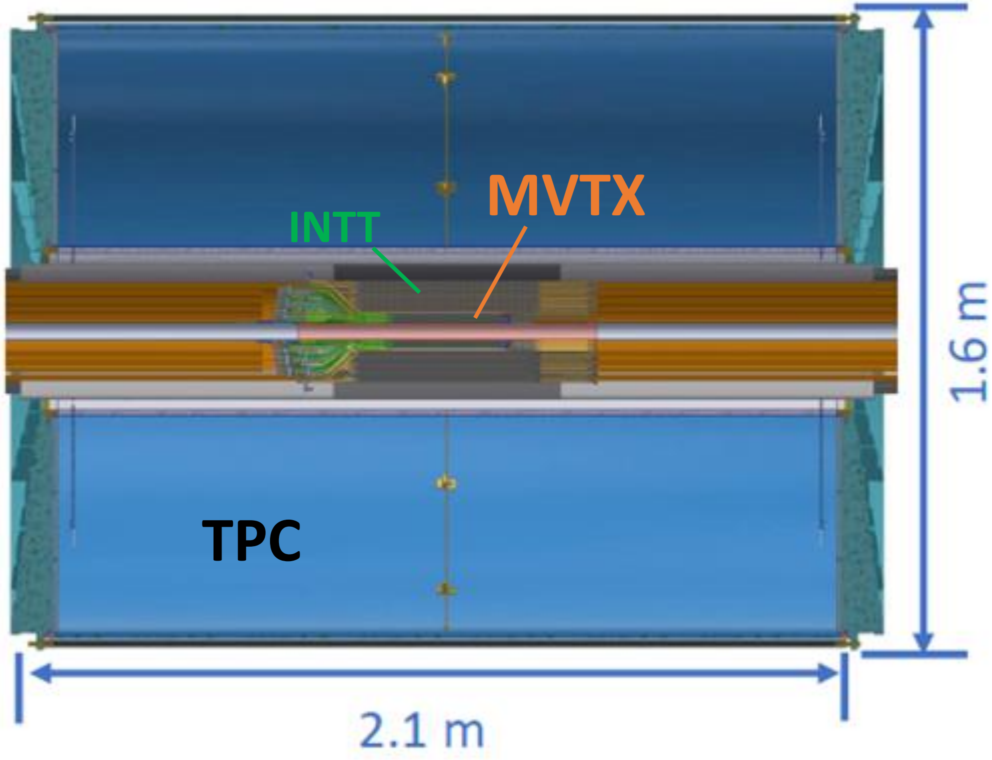
- 2 layers of strip silicon sensors

pattern recognition & timing

Time Projection Chamber (TPC)

- Compact: 20 < r [cm] < 78
- Spatial resolution < 200 μm
- Charge collection via GEMs

momentum measurement



sPHENIX Detector:

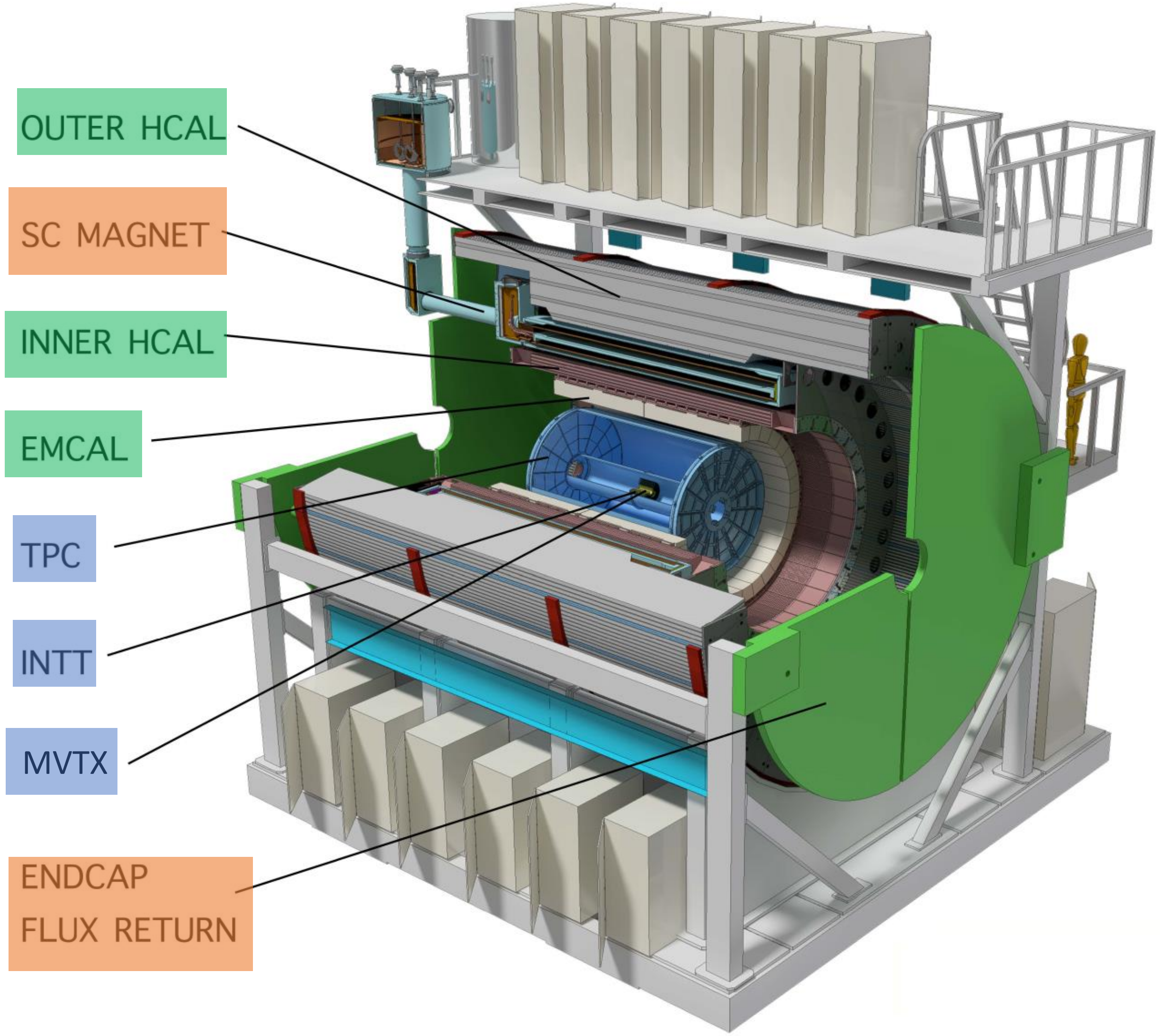
Tracking system:
MAPS-based Vertex Tracker (MVTX)
Intermediate Silicon Tracker (INTT)
Time Projection Chamber (TPC)

Superconducting Magnet (1.4 T solenoid)

Calorimetry:
Electromagnetic Calorimeter (EMCal)
inner Hadronic Calorimeter
outer Hadronic Calorimeter

High Rate DAQ and trigger system:

15 kHz Trigger, >10 GB/s DAQ



sPHENIX Calorimetry:

Full Electromagnetic and Hadronic calorimeter system!

- Large Acceptance: $|1.1| < \eta$ and full 2π azimuthal coverage
- SiPM used for light collection/readout

outer Hadronic Calorimeter (Outer HCal)

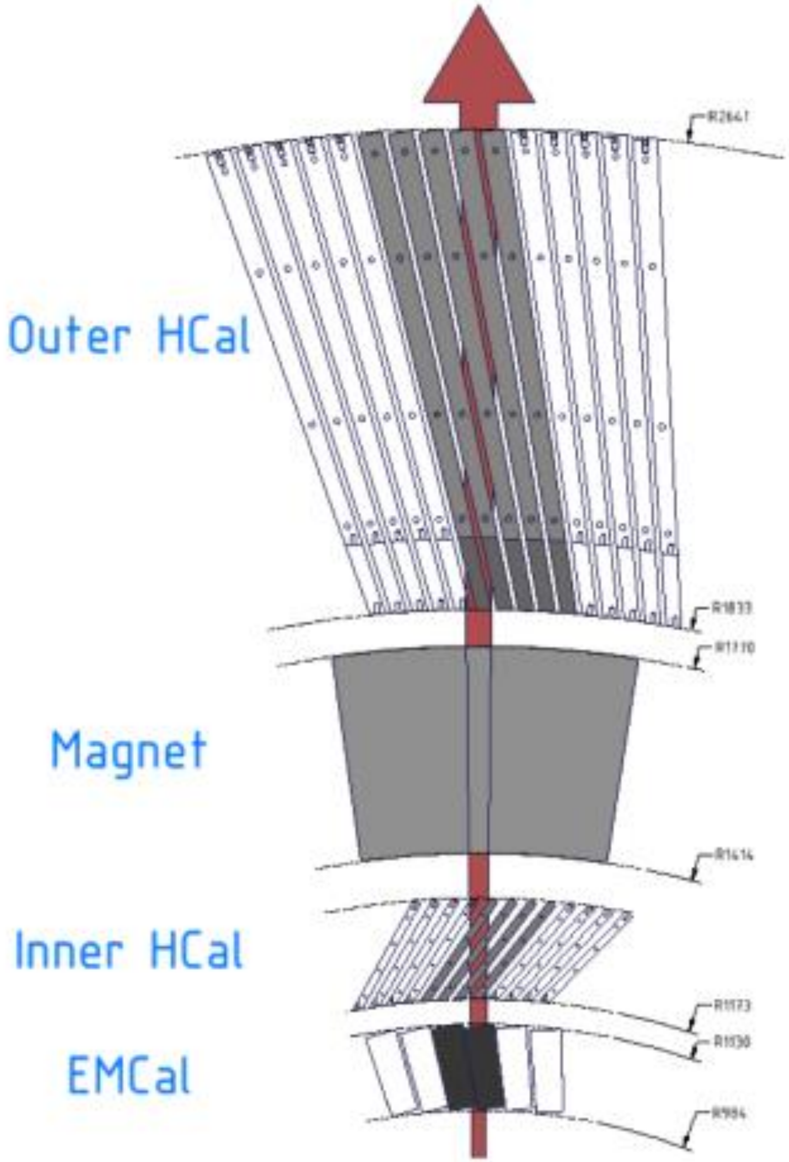
- Steel absorber plates and scintillating tiles with embedded WLS fibers
- $\Delta\eta \times \Delta\phi \approx 0.1$ x 0.1

inner Hadronic Calorimeter (iHCal)

- Aluminum absorber plates and scintillating tiles with embedded WLS fibers

Electromagnetic Calorimeter (EMCal)

- Tungsten powder with embedded scintillating fiber matrix
- $\Delta\eta \times \Delta\phi \approx 0.025$ x 0.025
- Compact design with large radiation length of material: ~14cm $\approx 20X_0$



sPHENIX run plan

Less than 2 years until first data!

An extensive three-year sPHENIX run is planned

- Variety of collision systems!

Additional running is proposed incase the EIC experiences delays

Anticipated run plan from beam use proposal

Year	Species	Energy	Physics Running Weeks	Sampled Luminosity $\|z\| < 10$ cm
2022		Installation and commissioning		
2023	Au+Au	200 GeV	13	6.9 nb^{-1}
2024	p+p	200 GeV	16	62 pb^{-1}
2024	p+Au	200 GeV	5	0.11 pb^{-1}
2025	Au+Au	200 GeV	24.5	25 nb^{-1}

Proposed expanded run plan

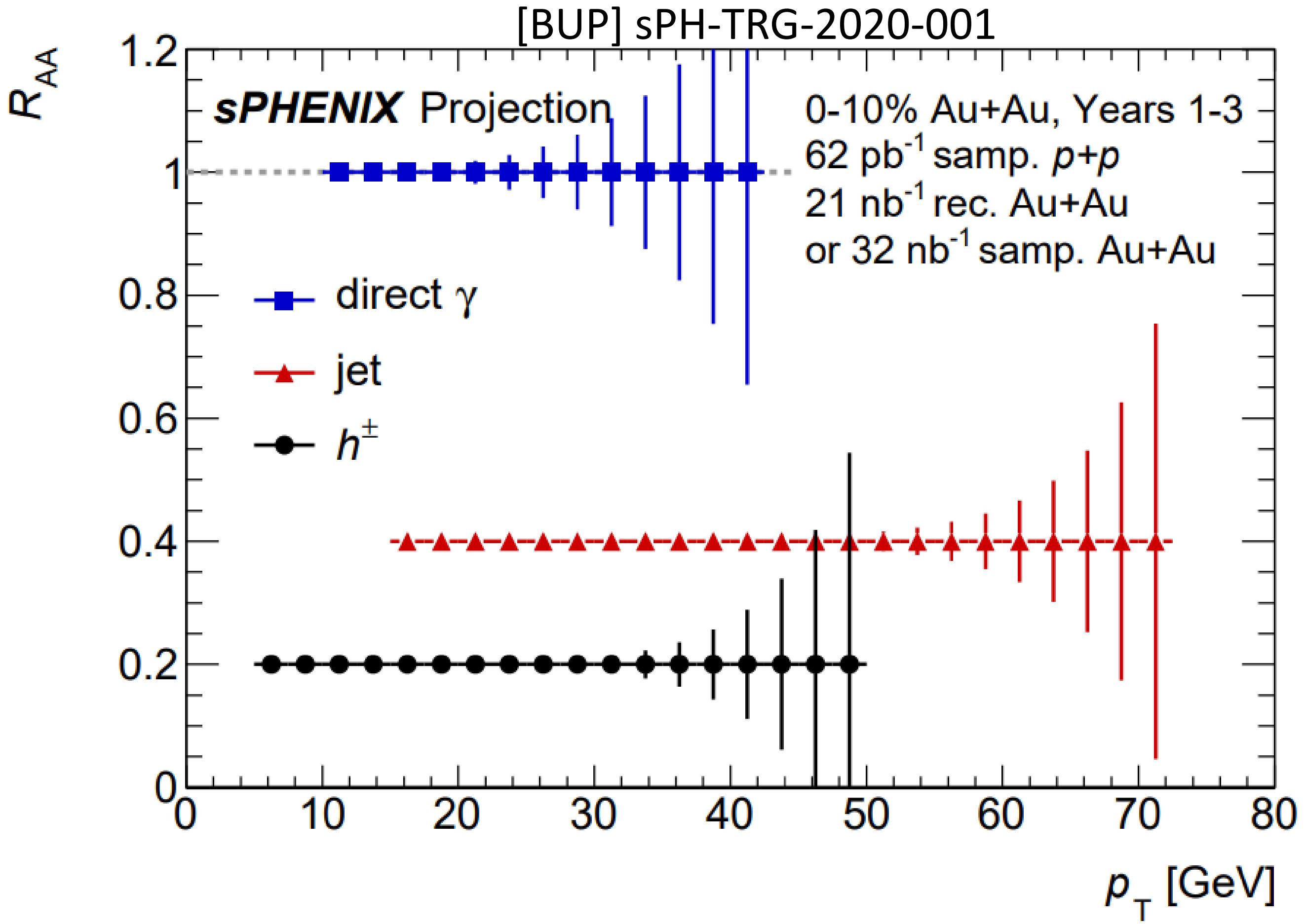
Year	Species	Energy	Physics Running Weeks	Sampled Luminosity $\|z\| < 10$ cm
2026	p+p	200 GeV	15.5	80 pb^{-1}
2026	O+O	200 GeV	13	37 nb^{-1}
2026	Ar+Ar	200 GeV	16	12 nb^{-1}
2027	Au+Au	200 GeV	24.5	30 nb^{-1}

sPHENIX Beam Use Proposal
[BUP] sPH-TRG-2020-001

$$R_{AA} \equiv \frac{1}{N_{Coll}} \frac{\frac{d^2N_{AA}}{dydp_T}}{\frac{d^2N}{dydp_T}}$$

Direct Photons, hadrons, and Jets:

Signal	Au+Au 0–10% Counts	p+p Counts
Jets $p_T > 20$ GeV	22 000 000	11 000 000
Jets $p_T > 40$ GeV	65 000	31 000
Direct Photons $p_T > 20$ GeV	47 000	5 800
Direct Photons $p_T > 30$ GeV	2 400	290
Charged Hadrons $p_T > 25$ GeV	4 300	4 100



Large statistic data samples will enable multi dimensional jet studies with new high p_T reach!

Direct Photons, hadrons, and Jets:

https://arxiv.org/pdf/2102.11337.pdf

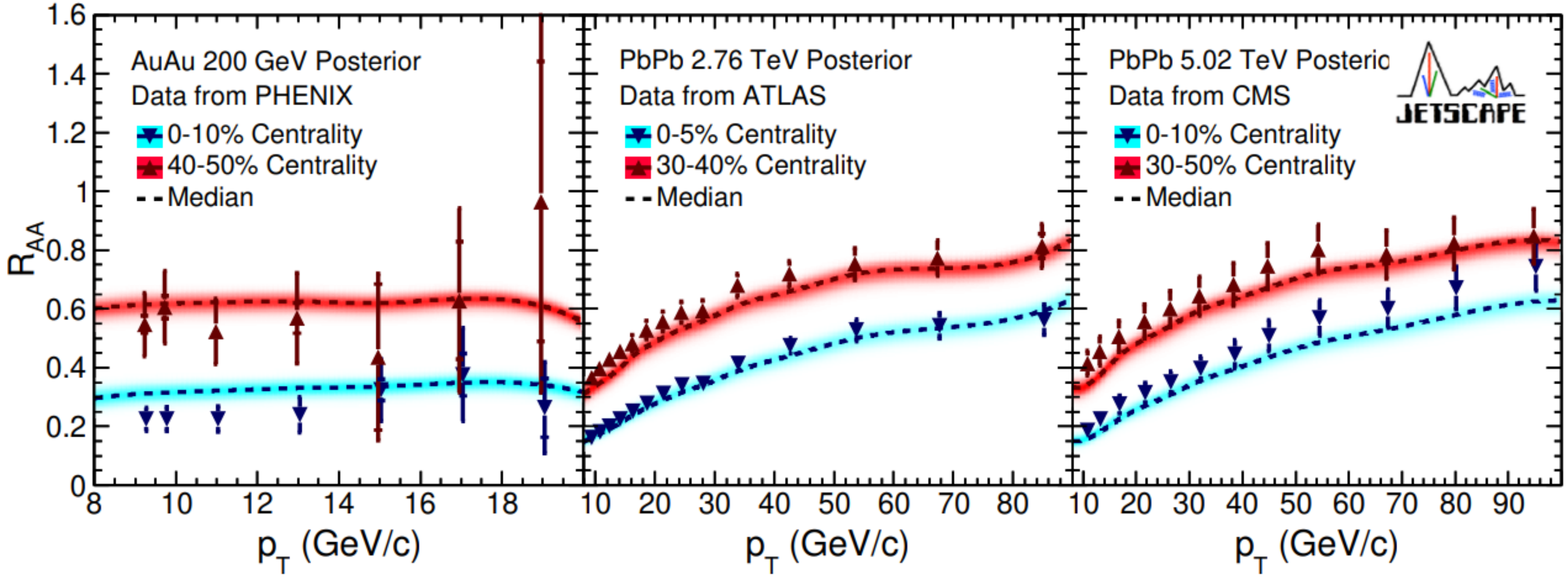


FIG. 7. (Color online) Posterior predictive distributions of inclusive hadron R_{AA} using LBT compared to the same data as Fig. 6.

- Bayesian analysis of world charged hadron R_{AA} data to extract the jet transport coefficient, $\hat{q}$, using the JETSCAPE framework

Direct Photons, hadrons, and Jets:

https://arxiv.org/pdf/2102.11337.pdf

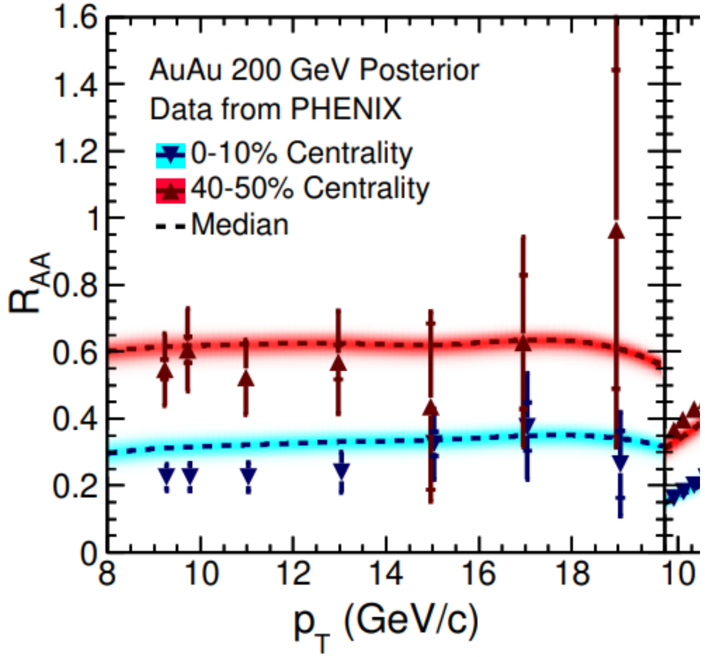
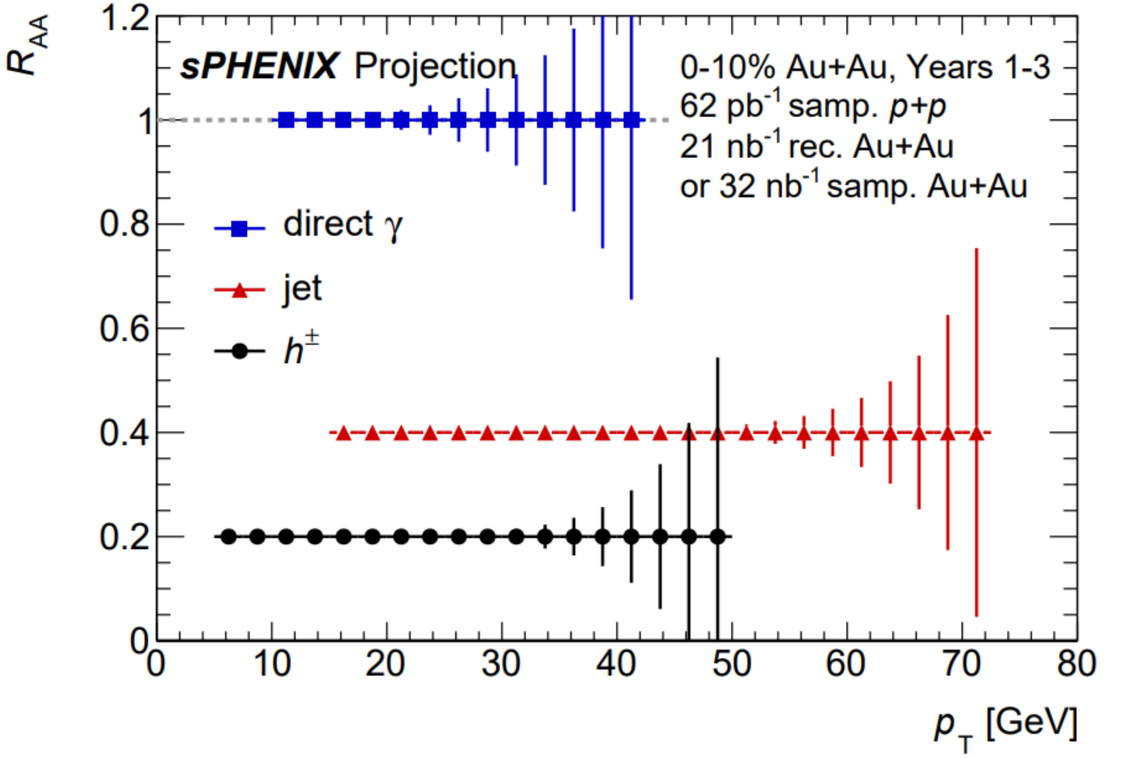
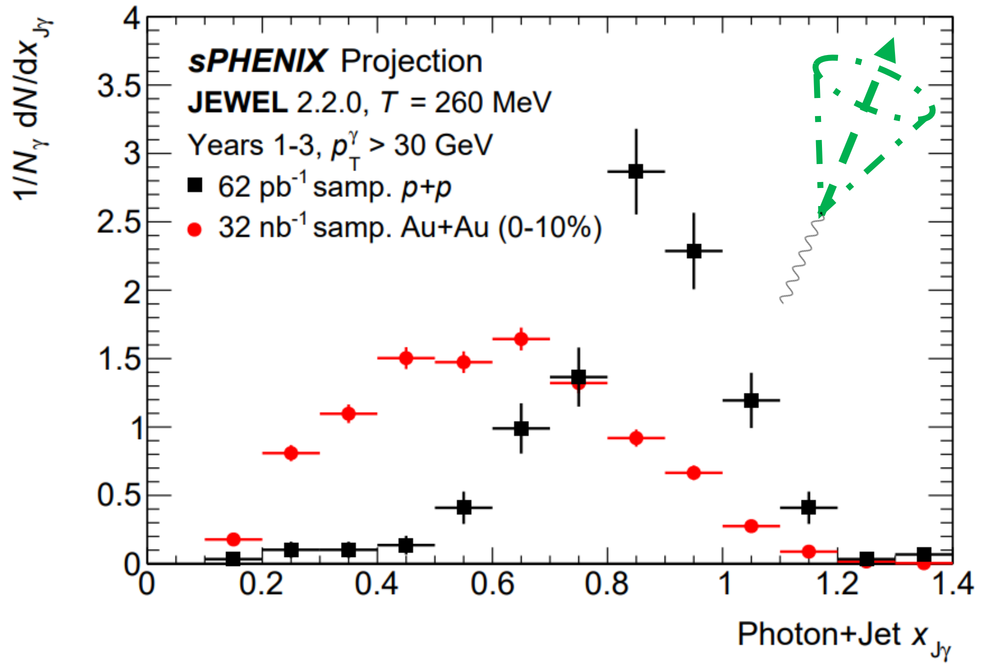


FIG. 7. (Color online) Posterior predictive distri ... a as Fig. 6.

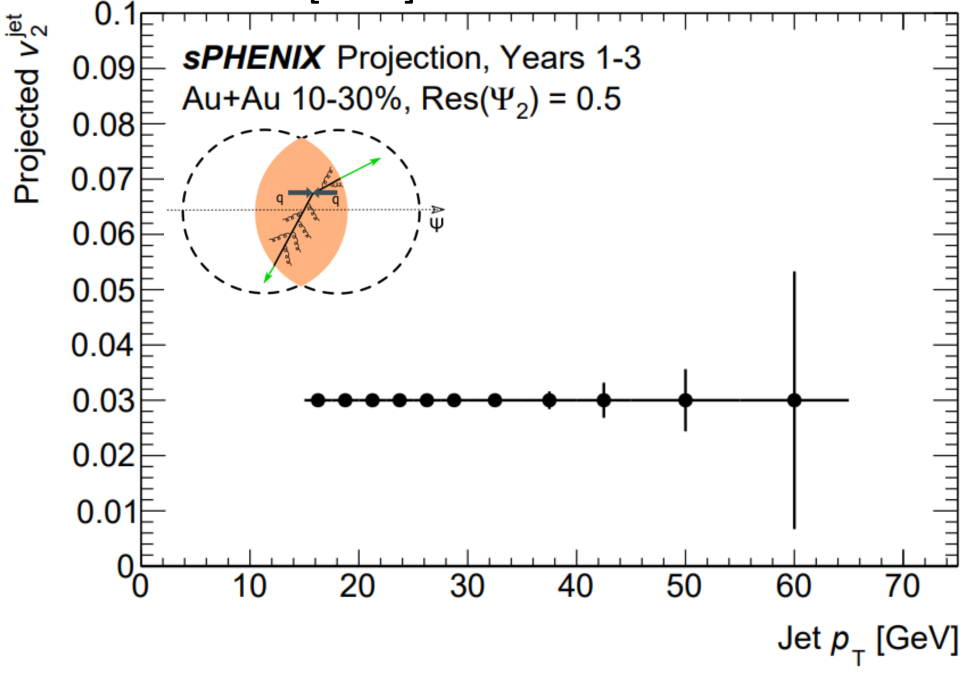


- Bayesian analysis of world charged hadron $\mathrm{R_{AA}}$ data to extract the jet transport coefficient, $\hat{q}$, using the JETSCAPE framework
- Enhanced charged R_{AA} precision and reach compared to PHENIX will provide constraint to theoretical models at RHIC energies

Jet Correlations:



[BUP] sPH-TRG-2020-001



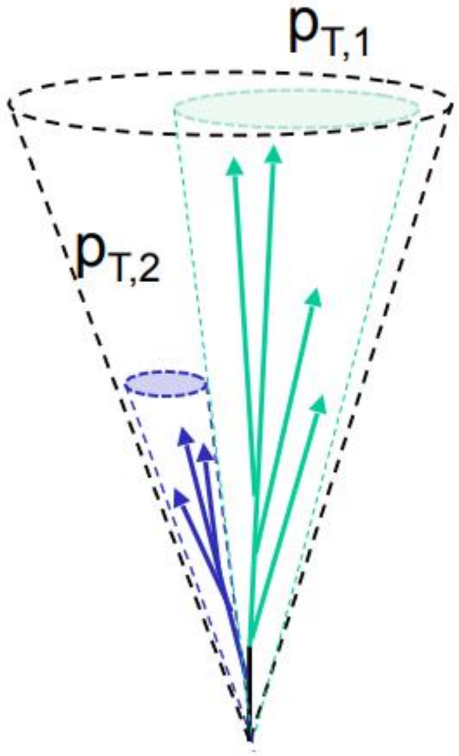
Large statistical sample enables high precision measurement of photon-jet balance

Ability to study event plane dependence to jet quenching

- Enable simultaneous comparison of models across LHC and RHIC energies

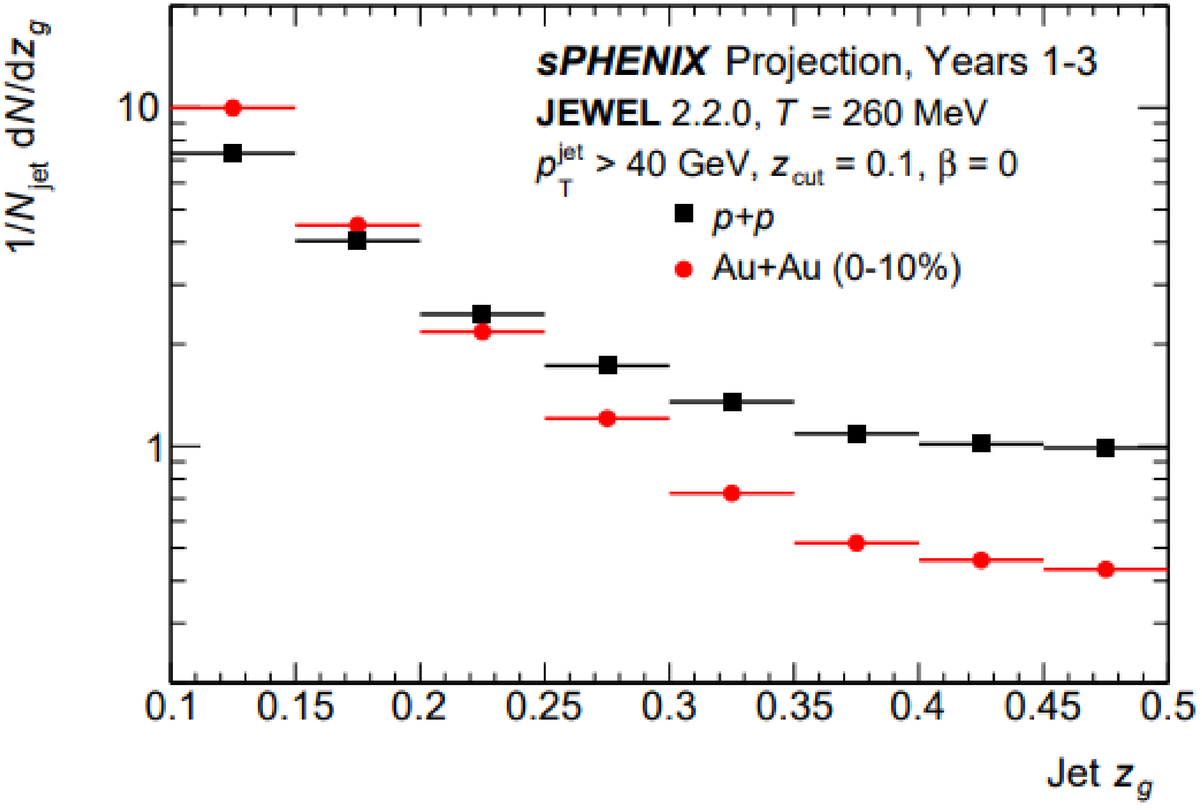
Jet Sub-structure:

sPHENIX fine segmentation in the calorimeter and tracking resolution will enable studies of jet sub-structure



$$z_g = \frac{p_{T,2}}{p_{T,2} + p_{T,1}}$$

Jet Sub-structure:
Splitting function

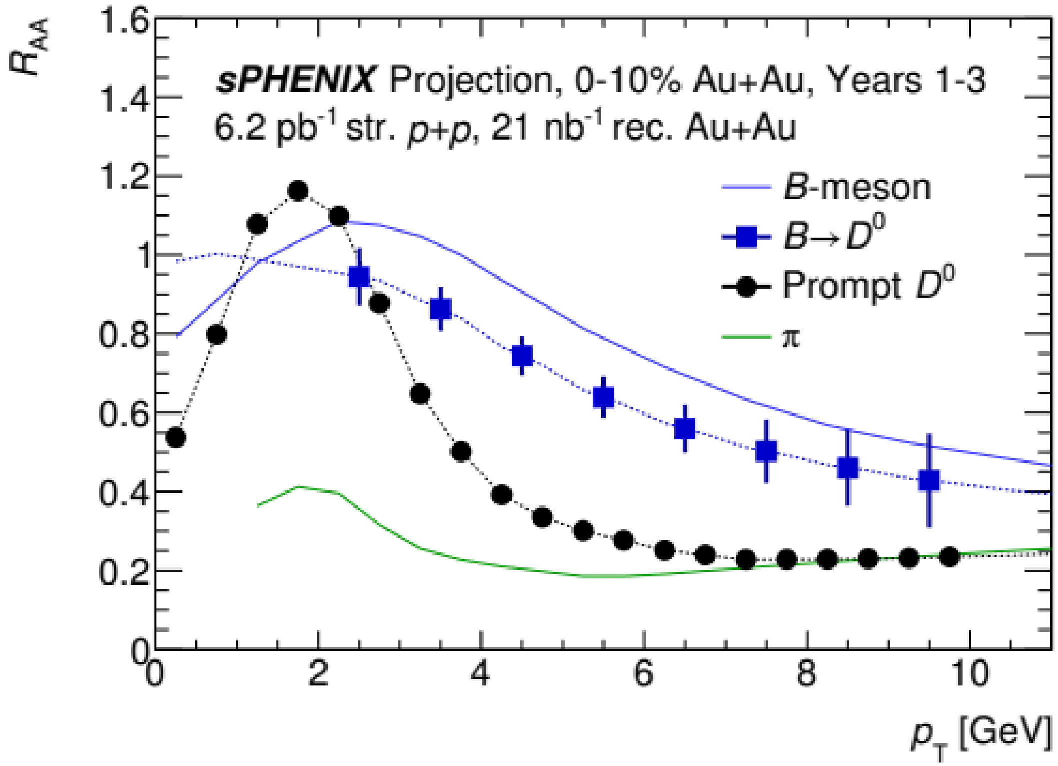


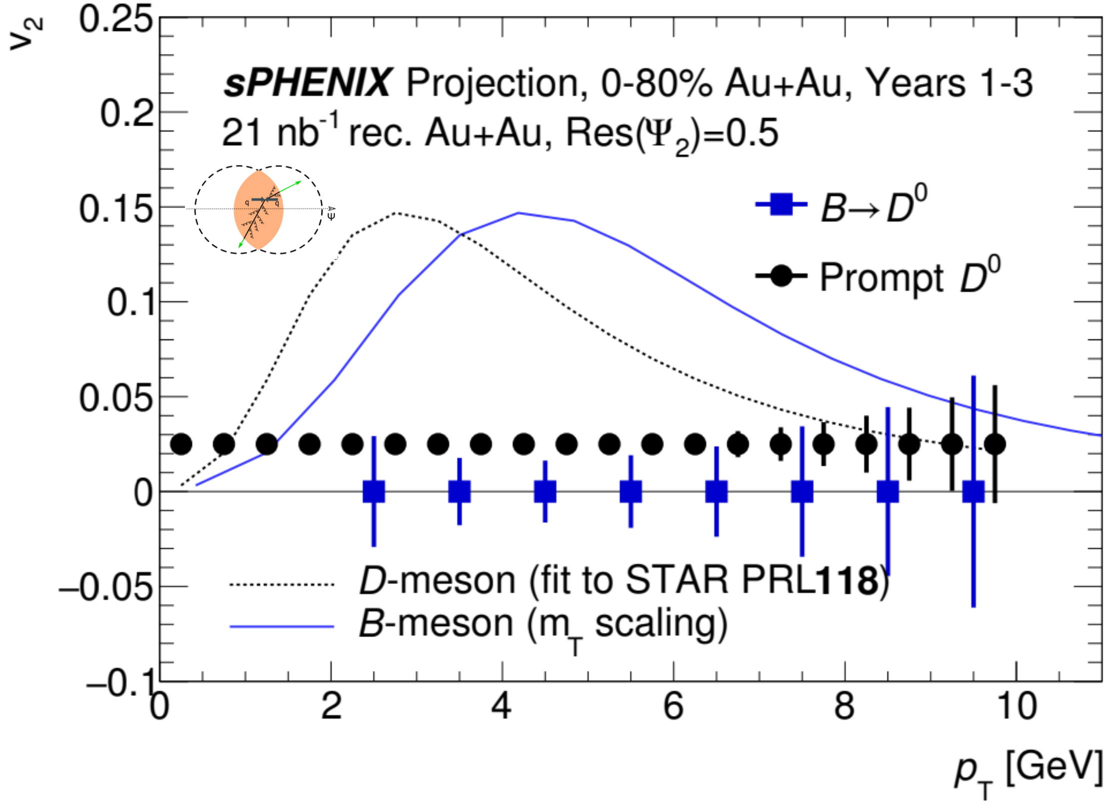
[BUP] sPH-TRG-2020-001

Open Heavy Flavor:

Precision tracking and vertexting will enable extensive heavy flavor measurements in sPHENIX

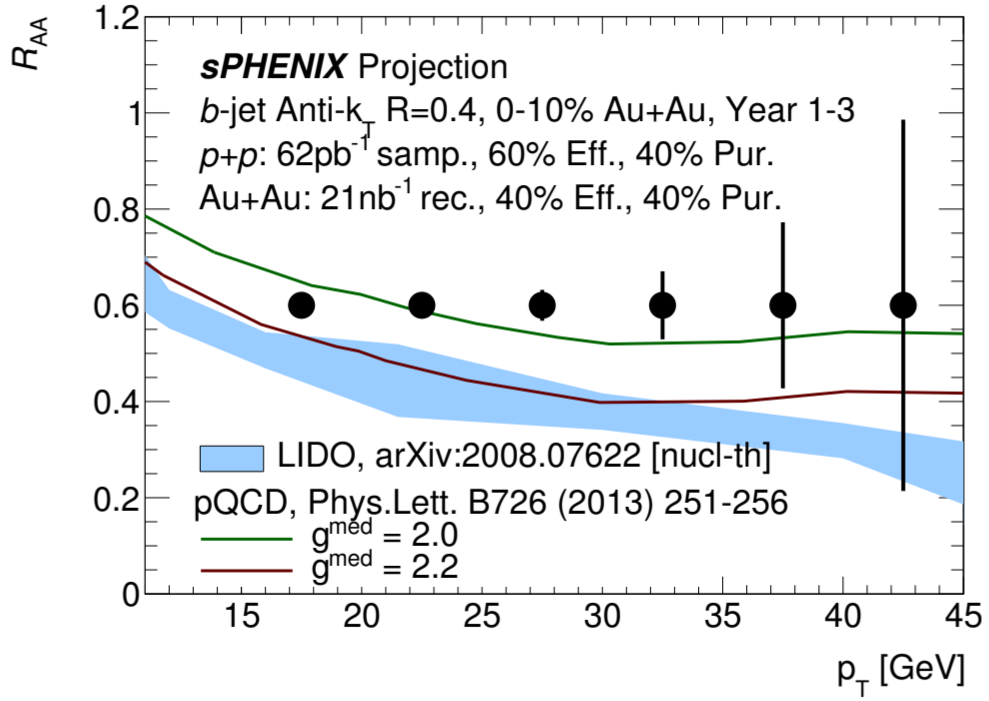
[BUP] sPH-TRG-2020-001



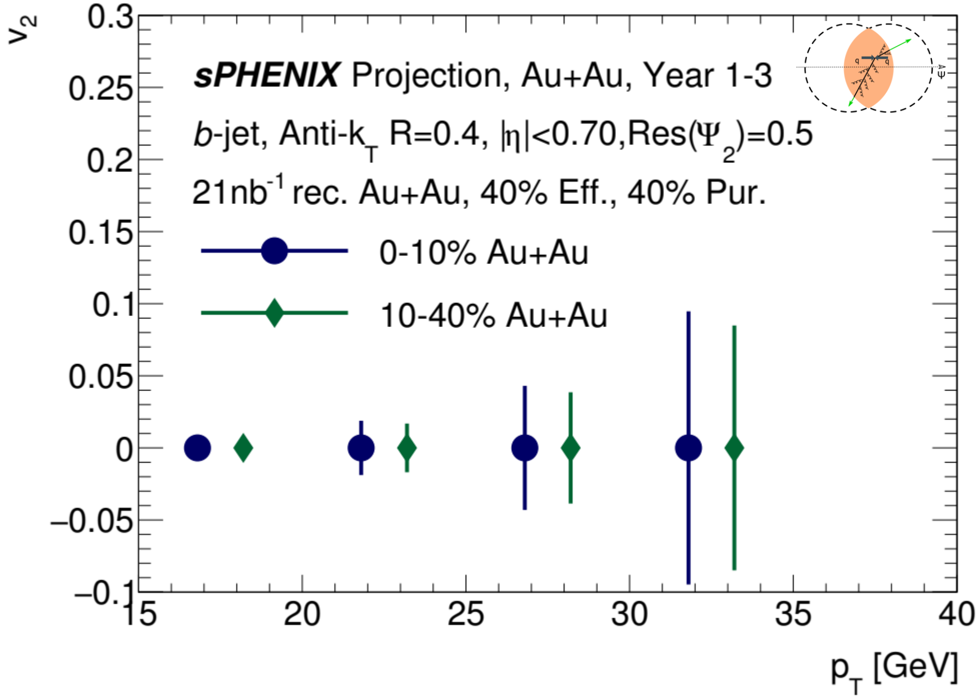


Heavy flavor quarks enables a powerful range with which to study the mass dependence to interactions within the QGP

Heavy Flavor Jets:



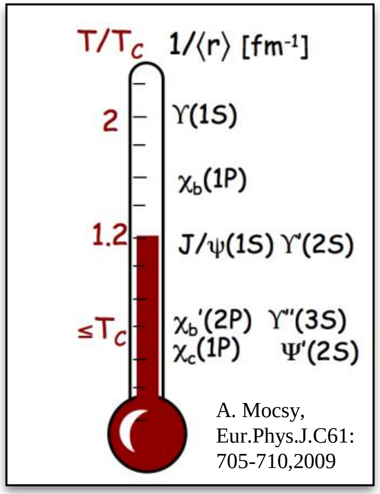
[BUP] sPH-TRG-2020-001



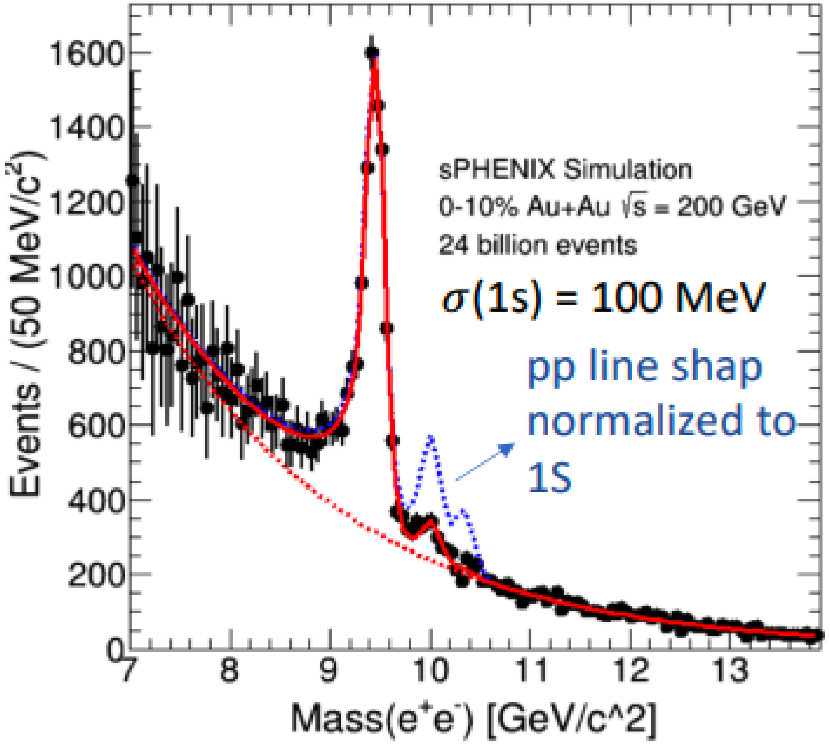
MVTX will enable heavy flavor jet tagging!

- Enables study at of heavy flavor at high p_T where the mass difference between heavy and light quarks is less significant

Upsilon Spectroscopy:

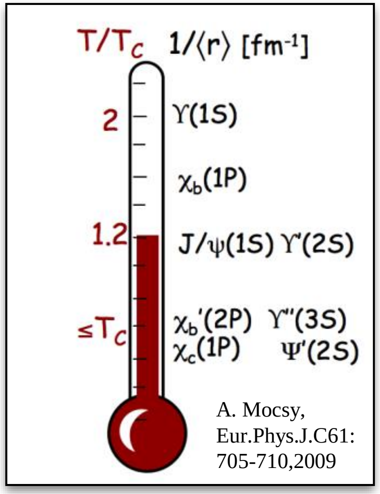


A. Mocsy, Eur.Phys.J.C61: 705-710,2009



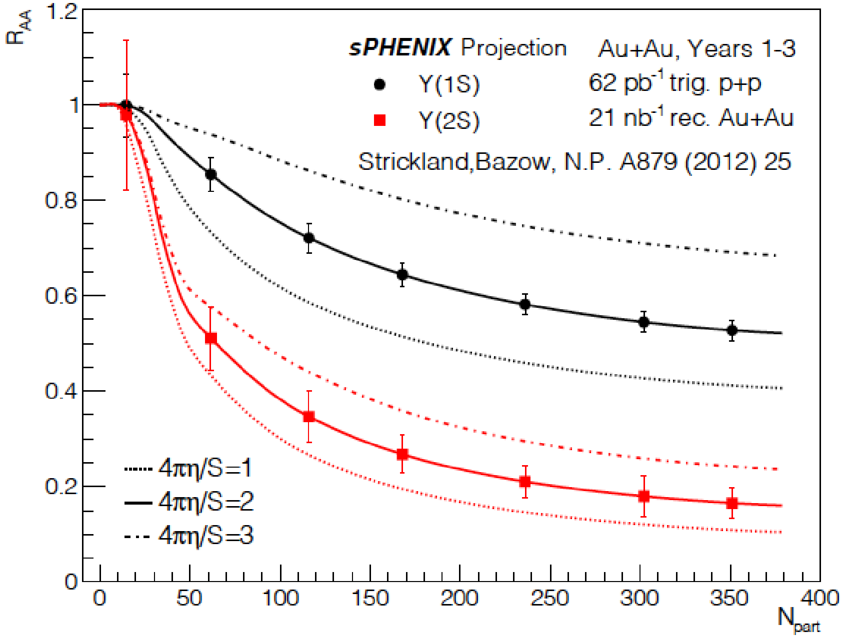
- The high-temperature medium induces melting of Upsilon states
  - Higher-mass states melt more readily at a fixed medium temperature

- Precise mass resolution of sPHENIX tracking will enable separation of ϒ states in both Au+Au and *pp*:
  - First for RHIC

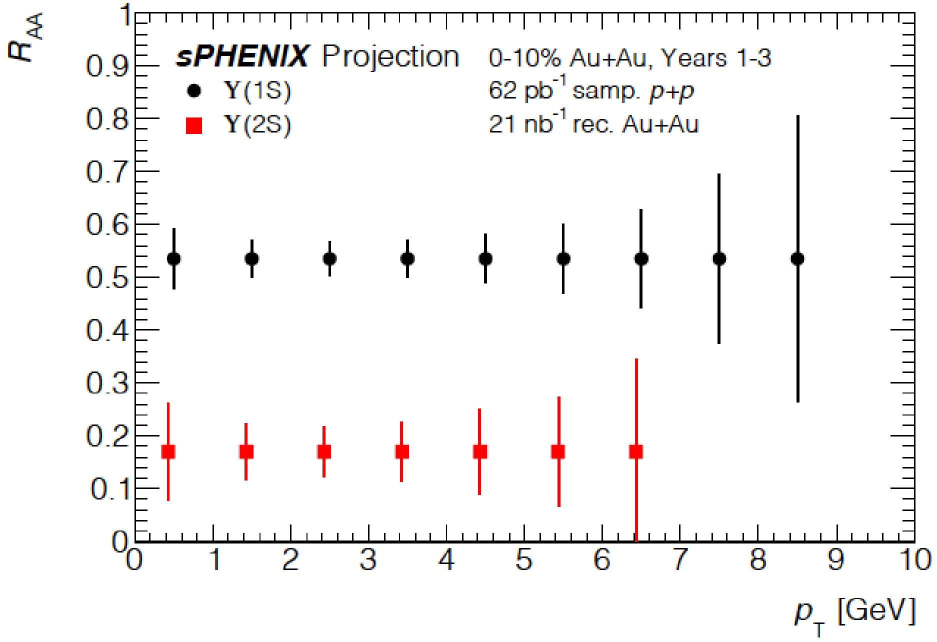


Upsilon Spectroscopy:

R_{AA} number of participant dependence

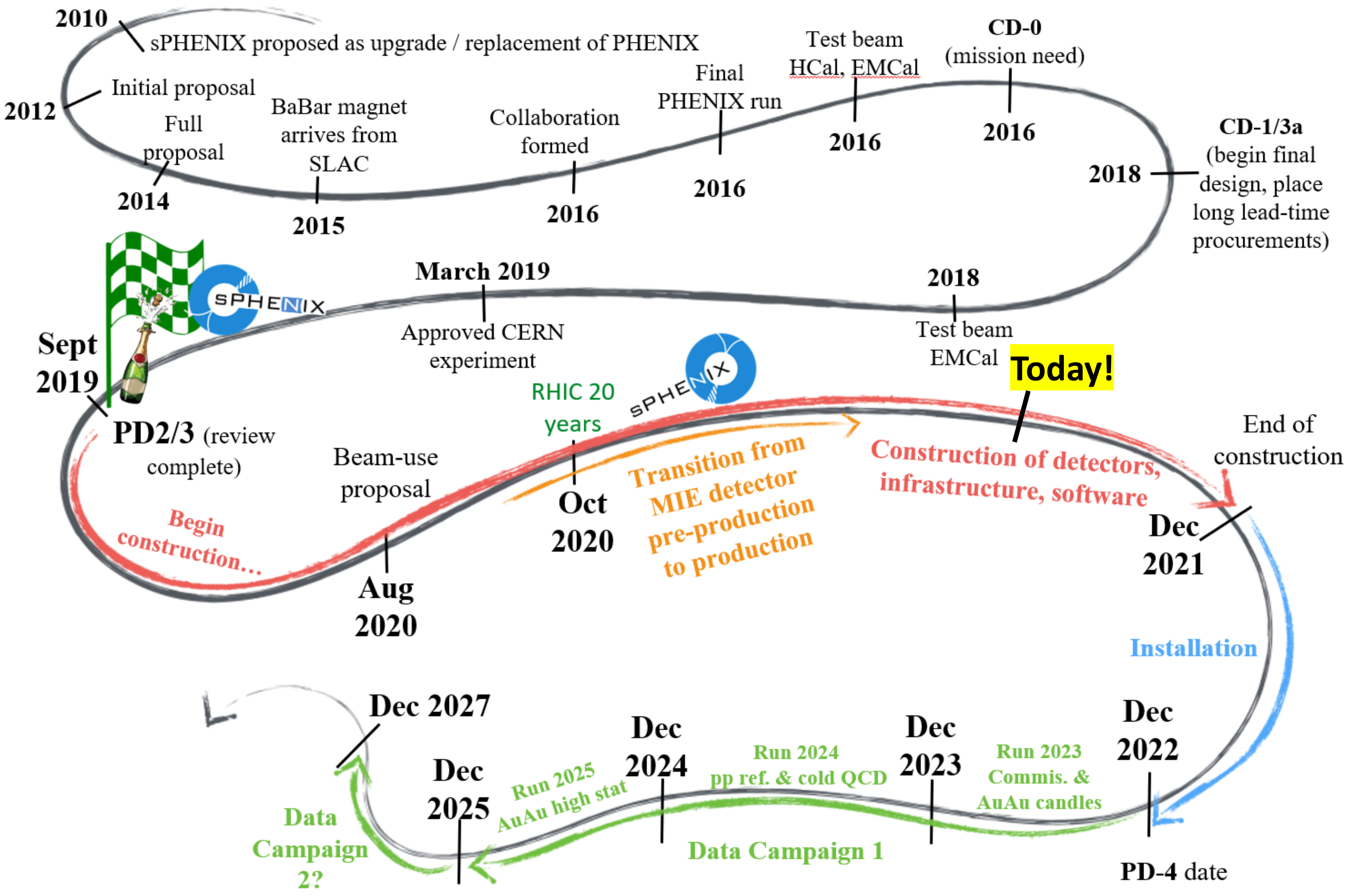


p_T dependence of Υ modification

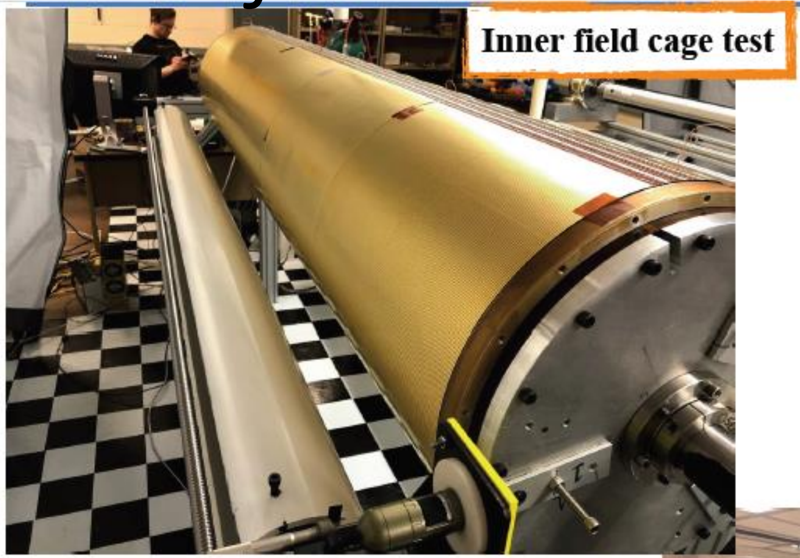


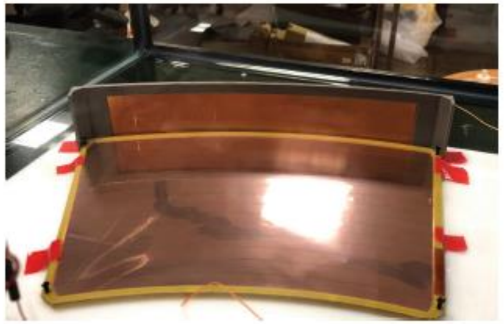
- sPHENIX will enable precise modification factor measurements of Υ suppression across centrality and Υ p_T for 1S and 2S states

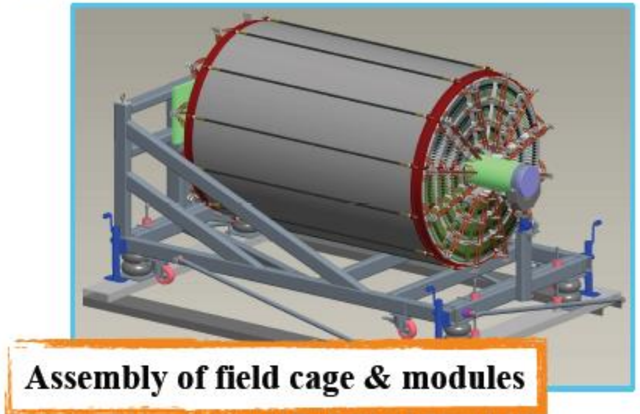
sPHENIX: A Timeline

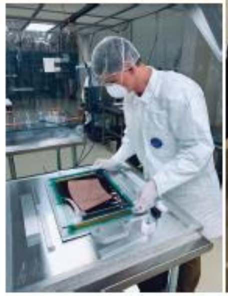


Time Projection Chamber Construction



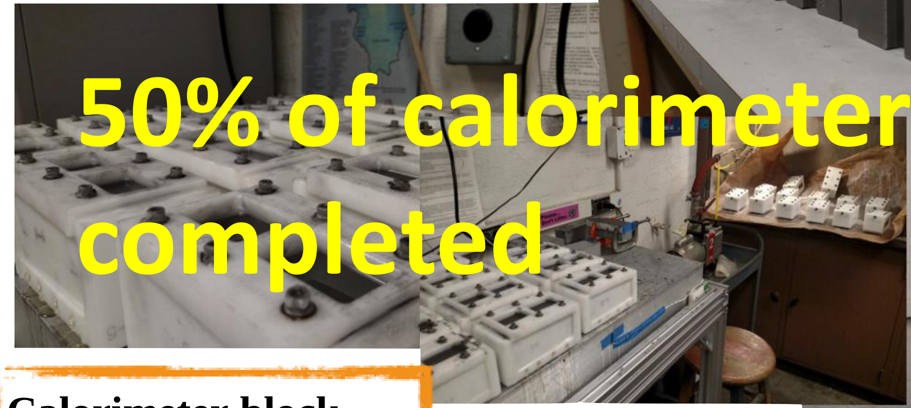




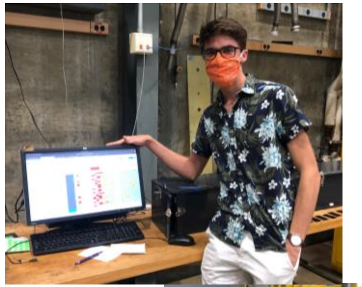


Electro-Magnetic Calorimeter Construction

Calorimeter block production at UIUC


50% of calorimeter blocks completed

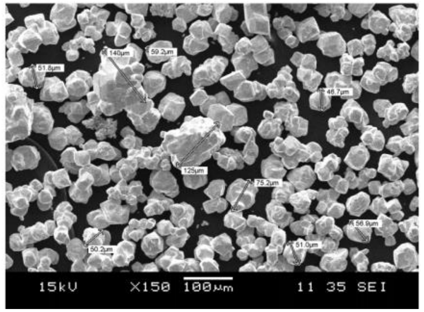


Calorimeter block production at Fudan

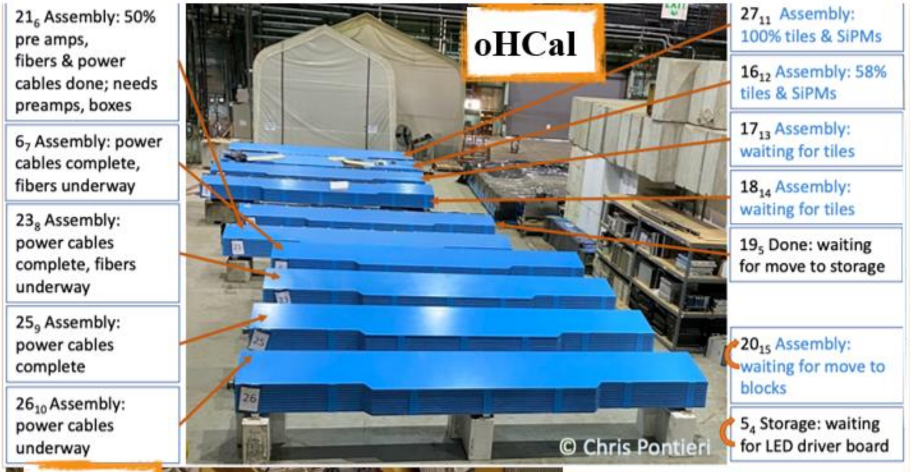


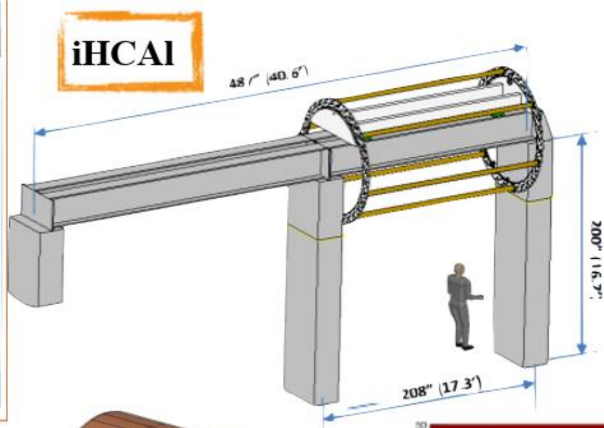
Sector Assembly and testing at BNL

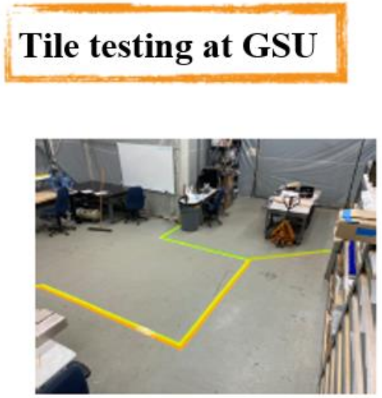
SEM - HC Starck



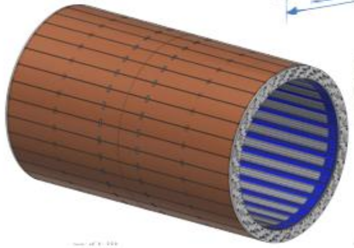
Hadronic Calorimeter Construction

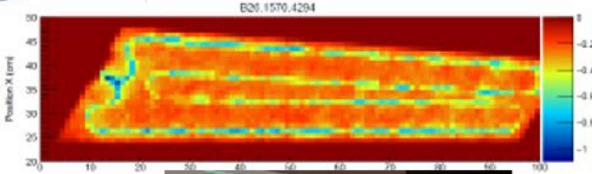


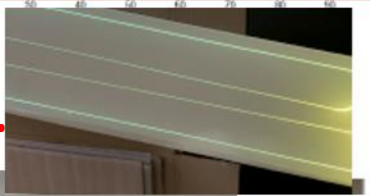




Sector 22_1 being put in storage



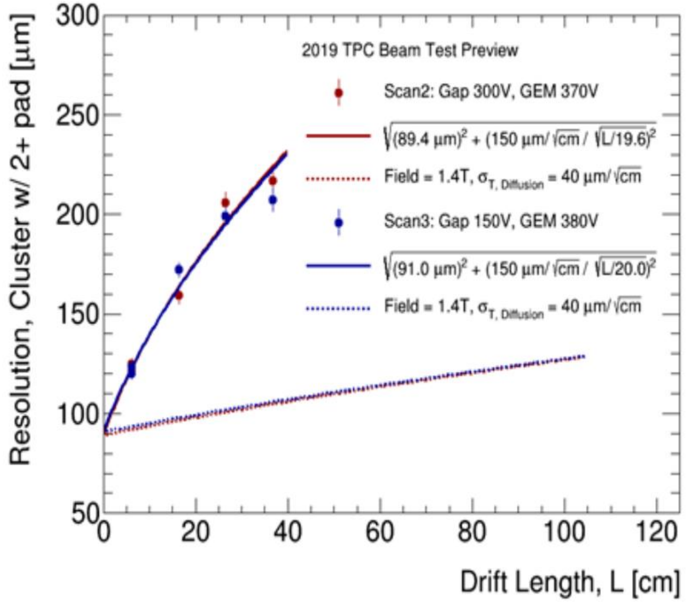




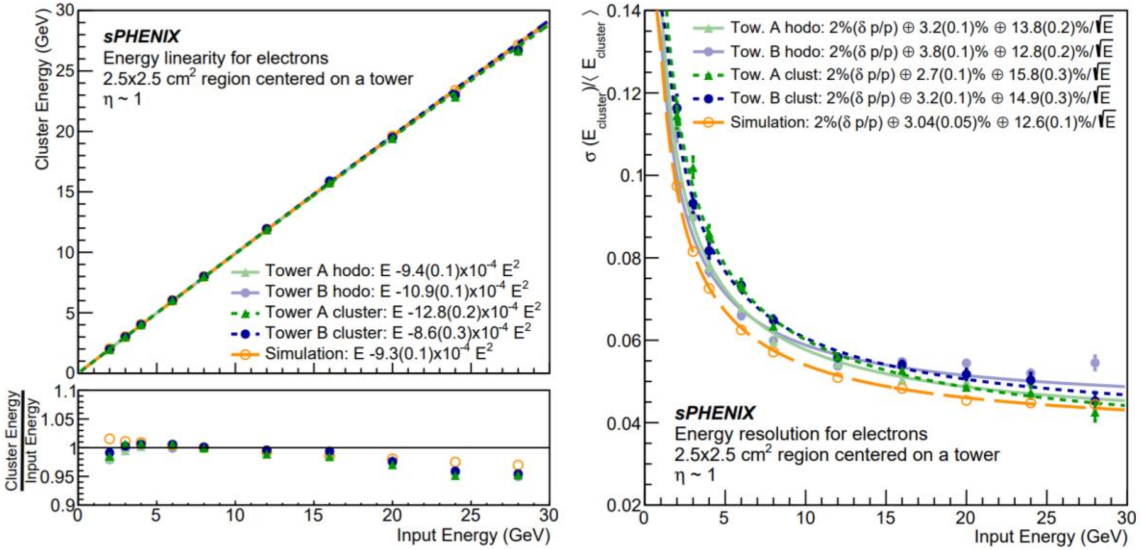
The OHCAL Sectors are complete.

Test Beams at FNAL:

Time Projection Chamber:

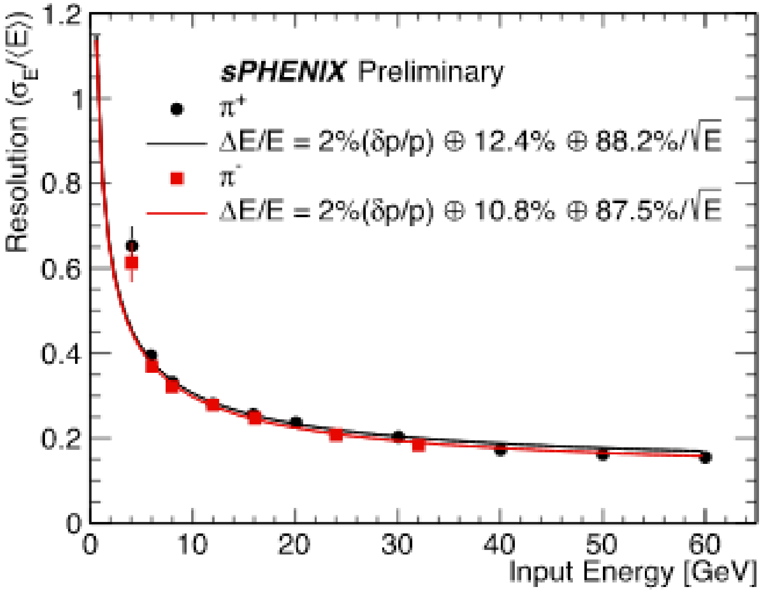


Electro Magnetic Calorimeter

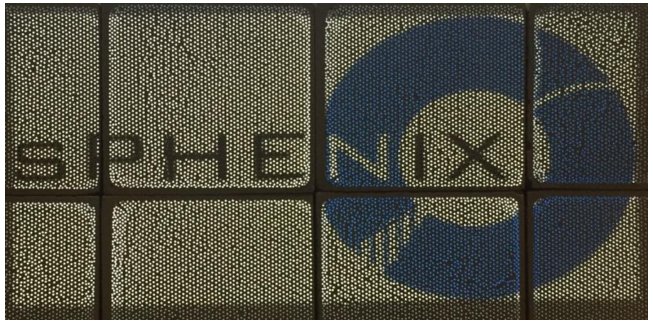


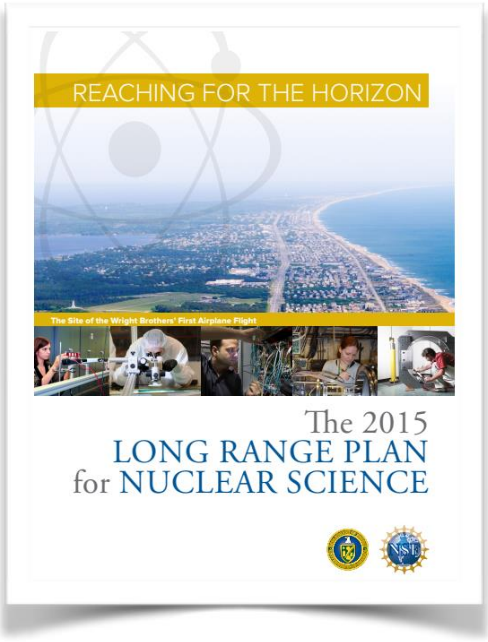
IEEETNS.2020.3034643

Hadronic Calorimeter



Summary and Outlook





- sPHENIX will enable a wide range of precision measurements of the QGP
  - Providing critical insights
  - First data expected in 2023!!

- Detector construction is well under way
  - Final installation and commissioning starting in December!