sPHENIX Status Report

Ejiro Umaka
on behalf of sPHENIX Collaboration

RHIC & AGS Annual Users' Meeting 2021

Virtual, June 8-11, 2021

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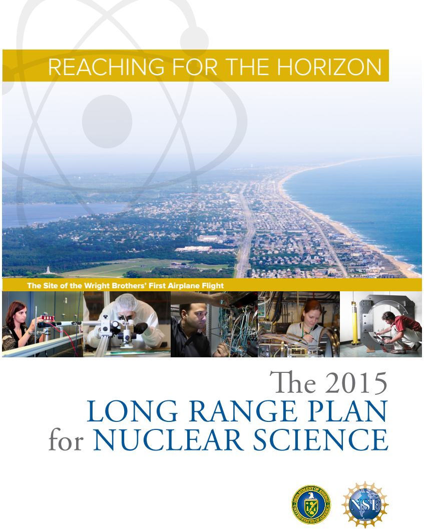
Highlights of this talk:

- 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)

sPHENIX Science Mission



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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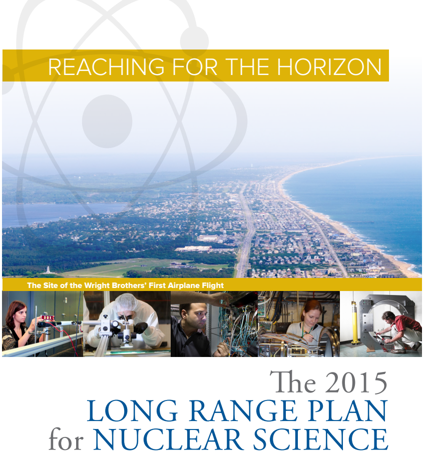

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2. To probe the inner workings of quark-gluon plasma (QGP) by resolving its properties at shorter and shorter length scales

- A state-of-the-art jet detector called **sPHENIX** is under construction to elucidate properties of the QGP at shorter and shorter length scales

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sPHENIX Collaboration

- **Officially formed in 2016**
- **More than 320 members from 84 institutions in 14 countries as of 2021**
- **Over 100 bi-weekly general meetings since inception**

Members from around the world gathered around a common science goal

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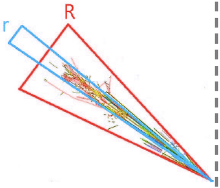
sPHENIX Core Physics Program

Jet correlation & substructure

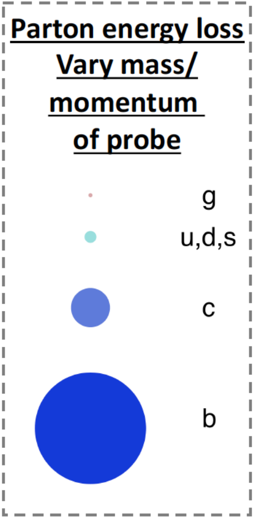
Vary momentum/ angular size of probe



Guided by the science mission, sPHENIX aims to :

probe the QGP in different ways :

- Vary probe's momentum and angular scale



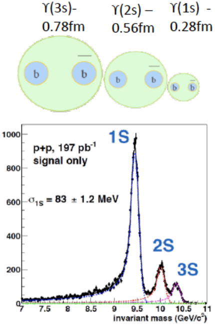
Guided by the science mission, sPHENIX aims to :

probe the QGP in different ways :

- Vary probe’s momentum and angular scale
- Vary probe’s mass and momentum

Upsilon spectroscopy

Vary size of the probe



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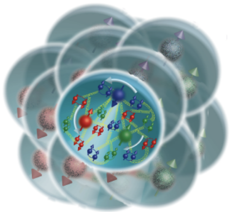
Cold QCD

Vary temperature of QCD matter



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probe the QGP in different ways :

- Vary probe's momentum and angular scale
- Vary probe's mass and momentum
- Vary probe's size
- **Cold QCD physics :** transverse single spin asymmetries (TSSAs)

sPHENIX Detector Overview

Calorimetry

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

Magnet

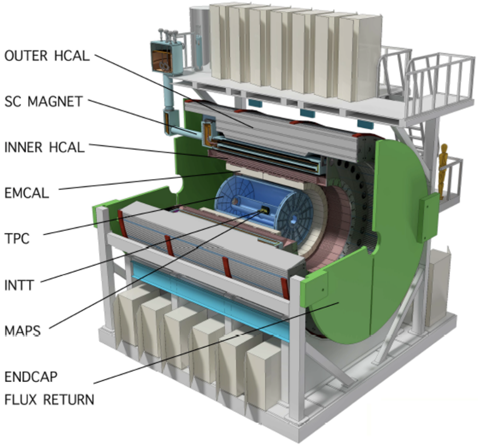
- 1.4T superconducting solenoid used by the BaBar experiment

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



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sPHENIX Tracking System

MVTX : *high resolution vertexing*

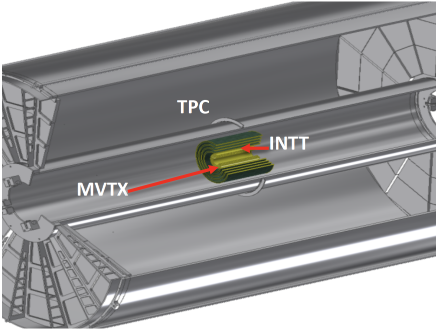
- 3 layers of Monolithic Active Pixel Sensors based on ALICE ITS-II
- Nearest to the collision point, spatial resolution of 5 μm for tracks with $p_T > 1$ GeV

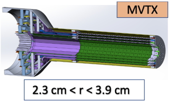
INTT : *pileup event separation*

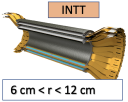
- Silicon strip detector surrounding the MVTX
- Associates fully reconstructed tracks with the event that produced them

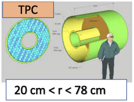
TPC : *momentum measurement*

- Compact (r = 80 cm) & main tracking element filled with Ne-CF_4 gas mixture
- Ungated, with GEM-based read out, spatial resolution of < 200 μm









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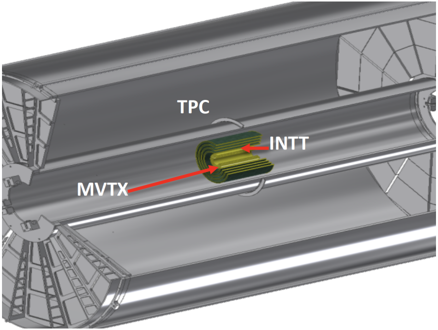

Open heavy flavor measurement

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

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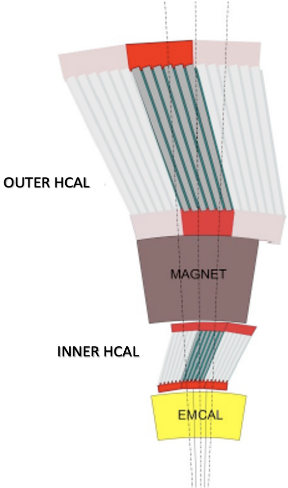
sPHENIX Calorimeter System

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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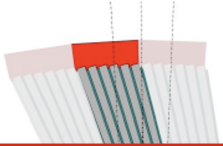

Jet measurement

- 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

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
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] 4.5(6.2) pb^{-1} [10%-str]	45 (62) 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 1 (2023) :

- Commissioning high multiplicity Au+Au run
- Measurement of standard Au+Au candles at RHIC

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Year 2 (2024) :

- Commissioning p+p
- $p^{\uparrow}+p^{\uparrow}$, $p^{\uparrow}$+Au : HI reference set and cold QCD

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Year 3 (2025) :

- Very large Au+Au heavy-ion set for jet and heavy flavor physics
- 141 B events recorded in total

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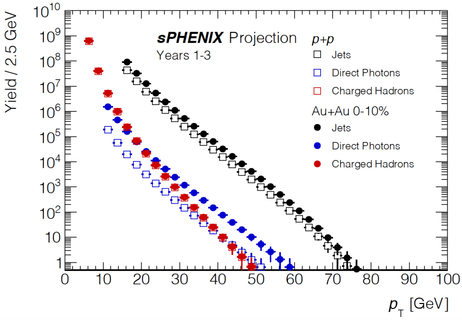
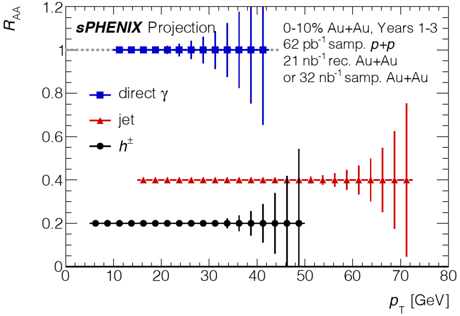
sPHENIX Probes : Jets and Photons

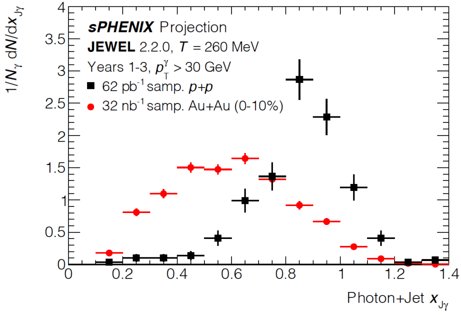


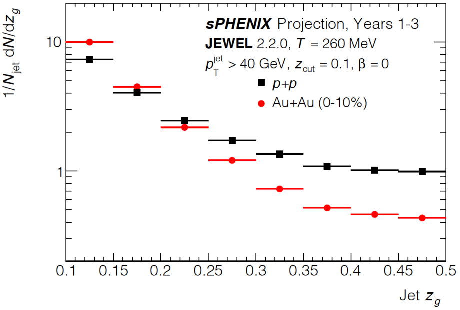


(left) Projected total yields for jets, photons and charged hadrons in 0-10% Au+Au events and p+p events
(right) corresponding R_{AA} projections
[BUP] sPH-TRG-2020-001

- 2023-2025 data taking will have kinematic reach out to ≈ 70 GeV for jets, and ≈ 50 GeV for hadrons and photons
- The kinematic reach will resolve varying theoretical prediction for R_{AA} at higher p_T

sPHENIX Probes : Jet Correlations and Substructure

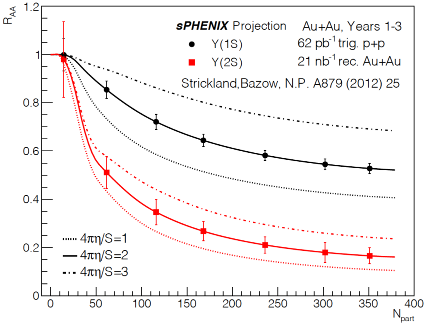


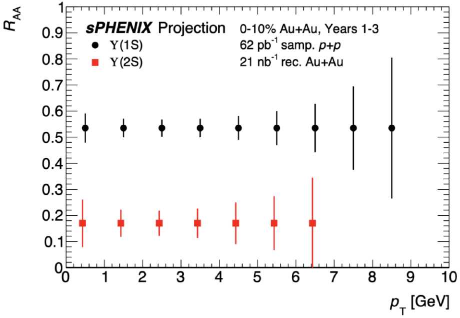


(left) Statistical projections for the jet-to-photon p_T balance for photons with $p_T > 30$ GeV
(right) subjet splitting fraction for jets with $p_T > 40$ GeV
[BUP] sPH-TRG-2020-001

- 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_{part}
(right) corresponding p_T dependence
[BUP] sPH-TRG-2020-001

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

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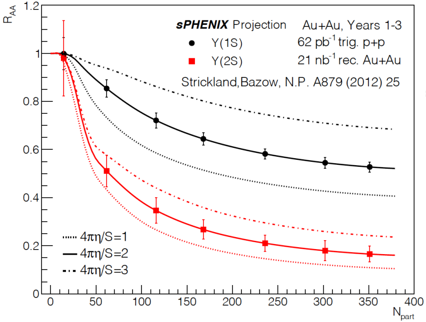

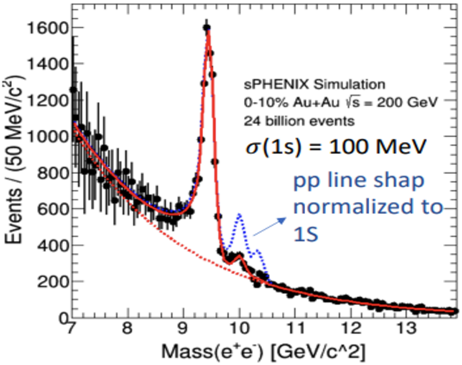

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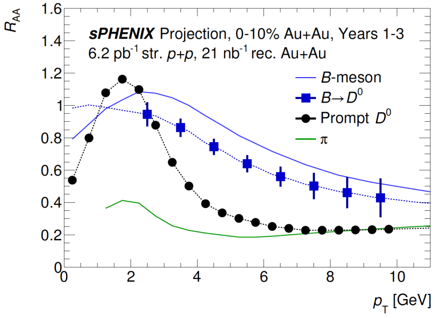
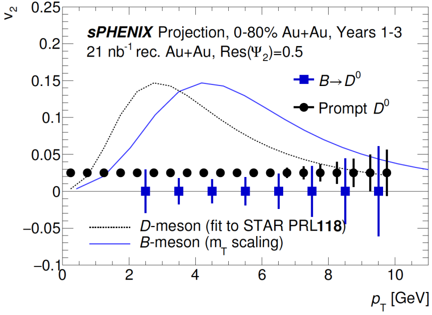
sPHENIX Probes : Open Heavy Flavor

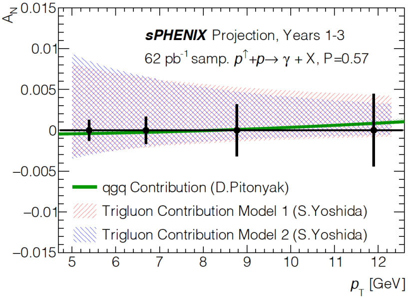


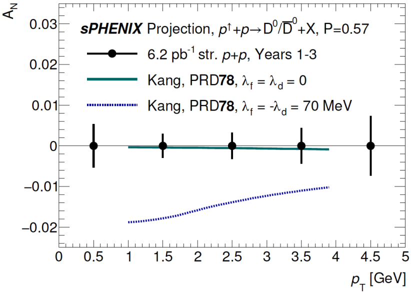


(left) Projected statistical uncertainties for nuclear modification factor R_{AA} measurements of non-prompt and prompt D^0 as a function of p_T in 0-10% central Au+Au collision
(right) corresponding v_2 projections in 0-80% centrality
[BUP] sPH-TRG-2020-001

- High precision and data rate will allow for studies of mass-dependent energy loss and collectivity in the quark-gluon plasma

sPHENIX Cold QCD Program





(left) Projected statistical uncertainties for the midrapidity direct photon TSSAs compared to theoretical calculations
(right) corresponding D^o measurement
[BUP] sPH-TRG-2020-001

- The photon and D^o spin asymmetry measurements have deep connections to nucleon partonic structure

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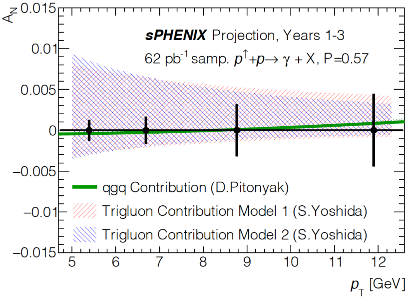

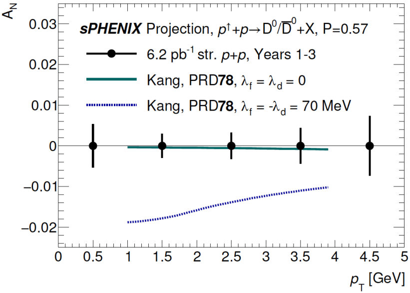

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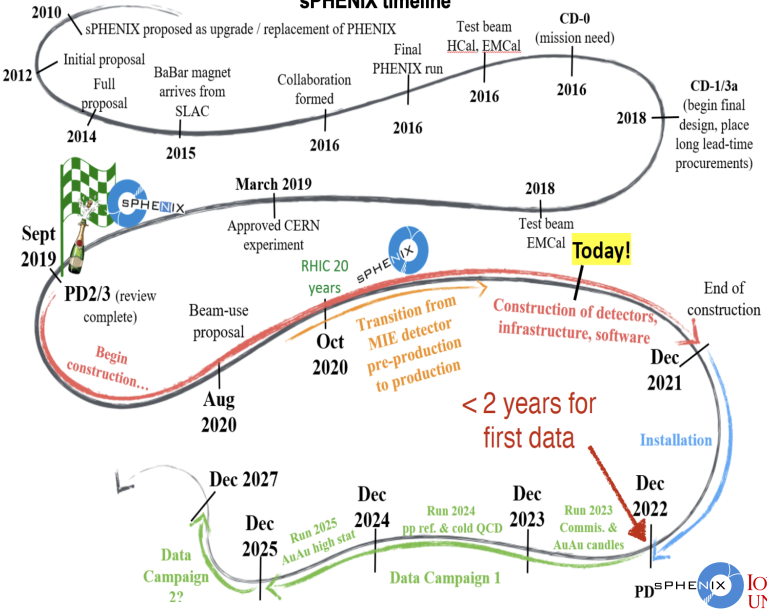
[BUP] sPH-TRG-2020-001

- 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

sPHENIX timeline



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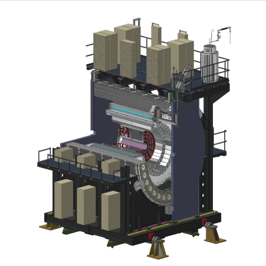


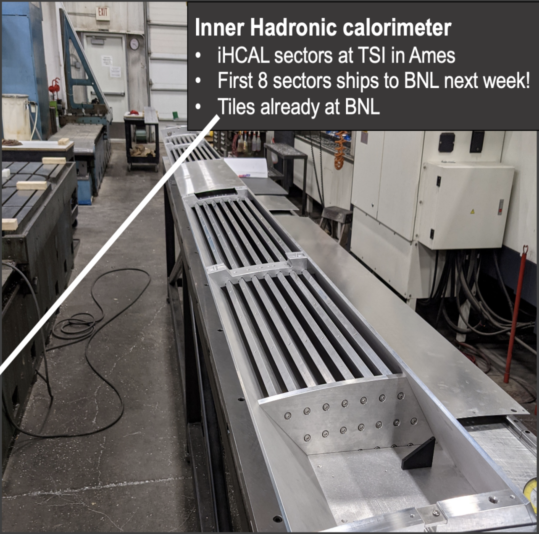
Detector Construction Update

Outer Hadronic calorimeter

- oHCAL sectors complete at BNL!
- Empty tiles rack

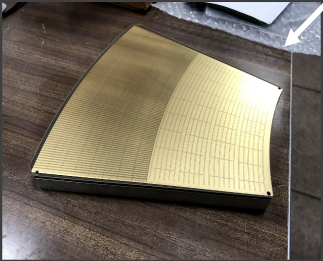
Inner Hadronic calorimeter

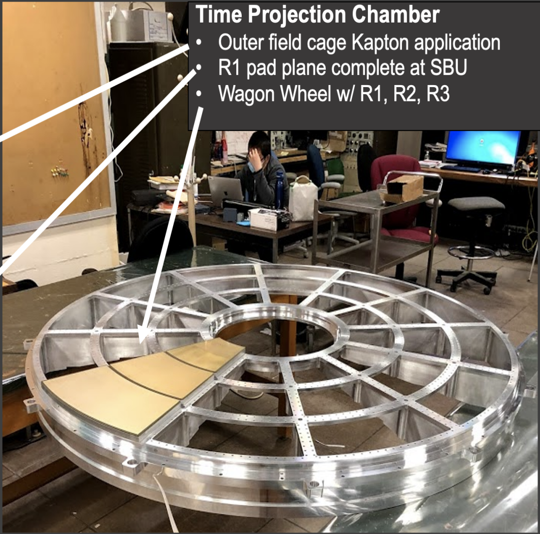
- iHCAL sectors at TSI in Ames
- First 8 sectors ships to BNL next week!
- Tiles already at BNL



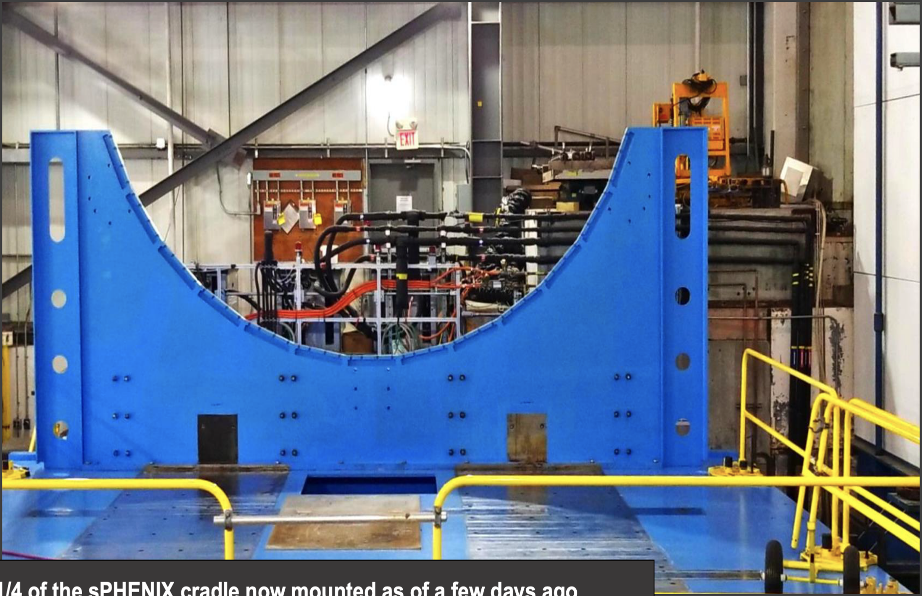
Time Projection Chamber

- 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**

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Thank you !

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