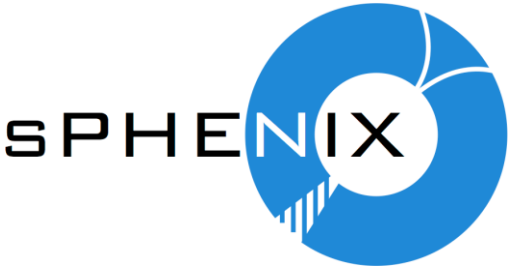
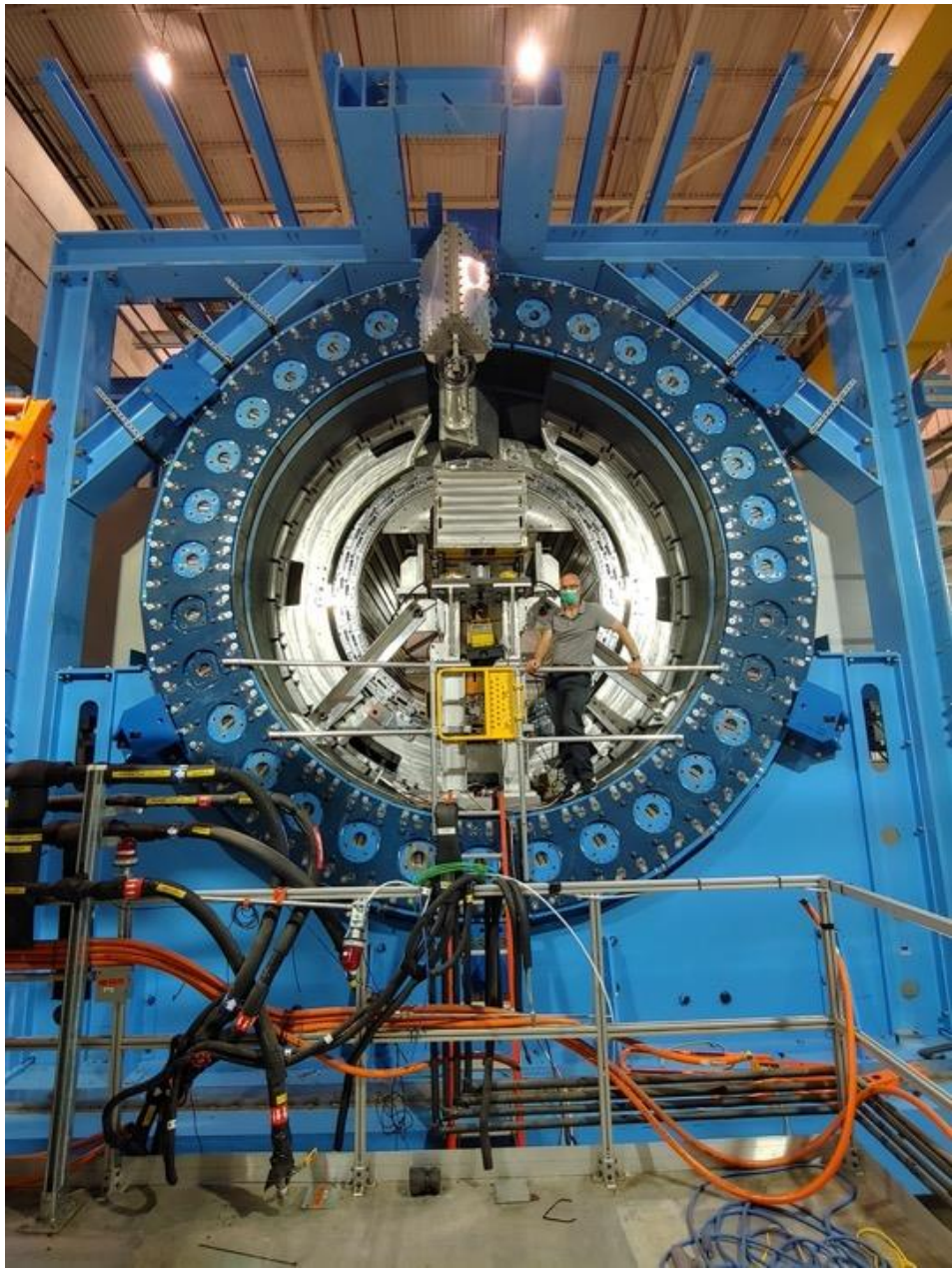
sPHENIX:
Status and Plans

Anders Knospe
Lehigh University
on behalf of the sPHENIX Collaboration
February 10, 2023

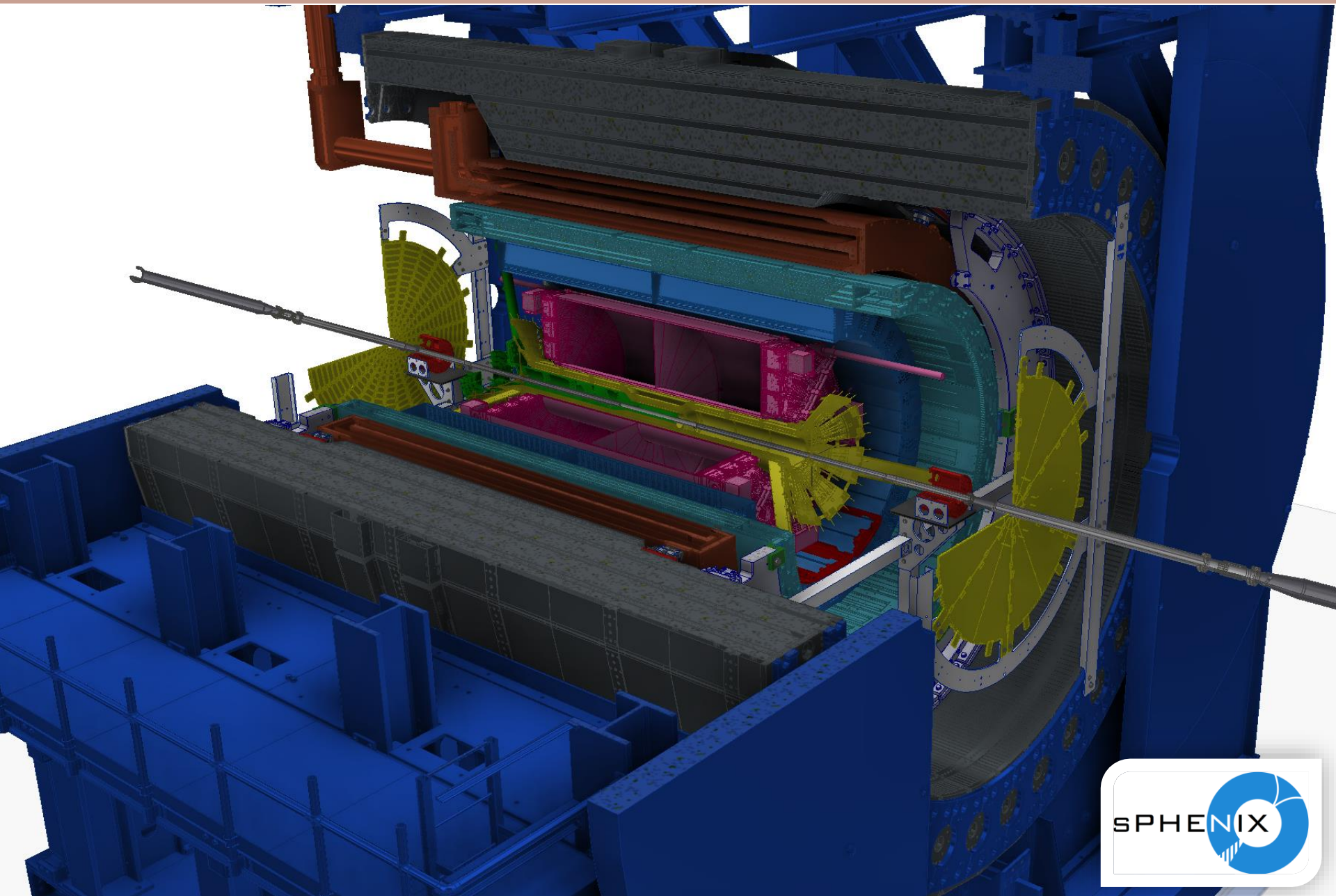


sPHENIX

- Radical upgrade of PHENIX detector being installed at RHIC
  - Has purpose-built capabilities not seen previously at RHIC
- Key requirement for completion of RHIC's scientific mission
  - Highest priority for runs 2023–2025
- RHIC & LHC are complementary: different initial conditions & QGP evolution → study scale and temp. dependence



sPHENIX Detector



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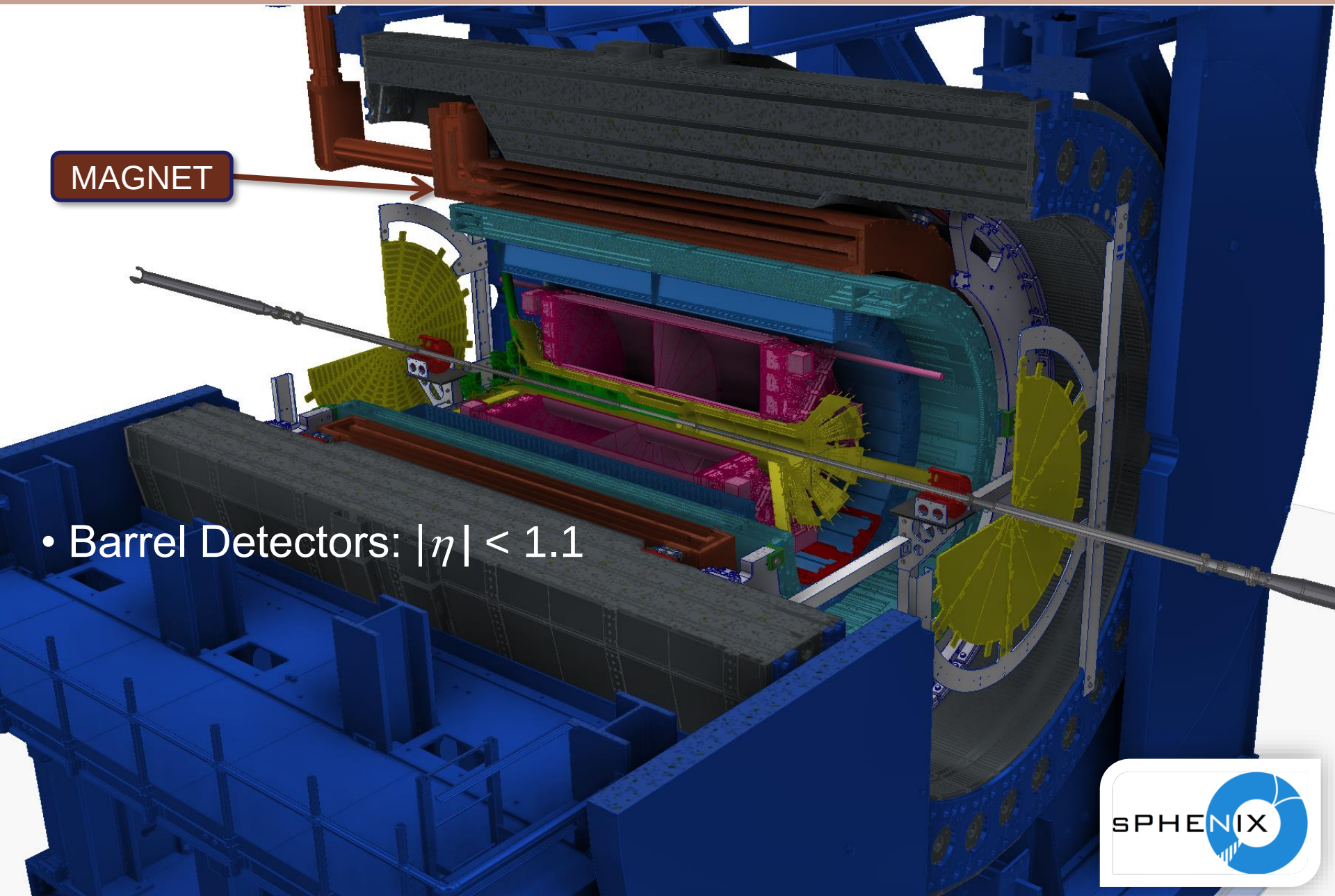
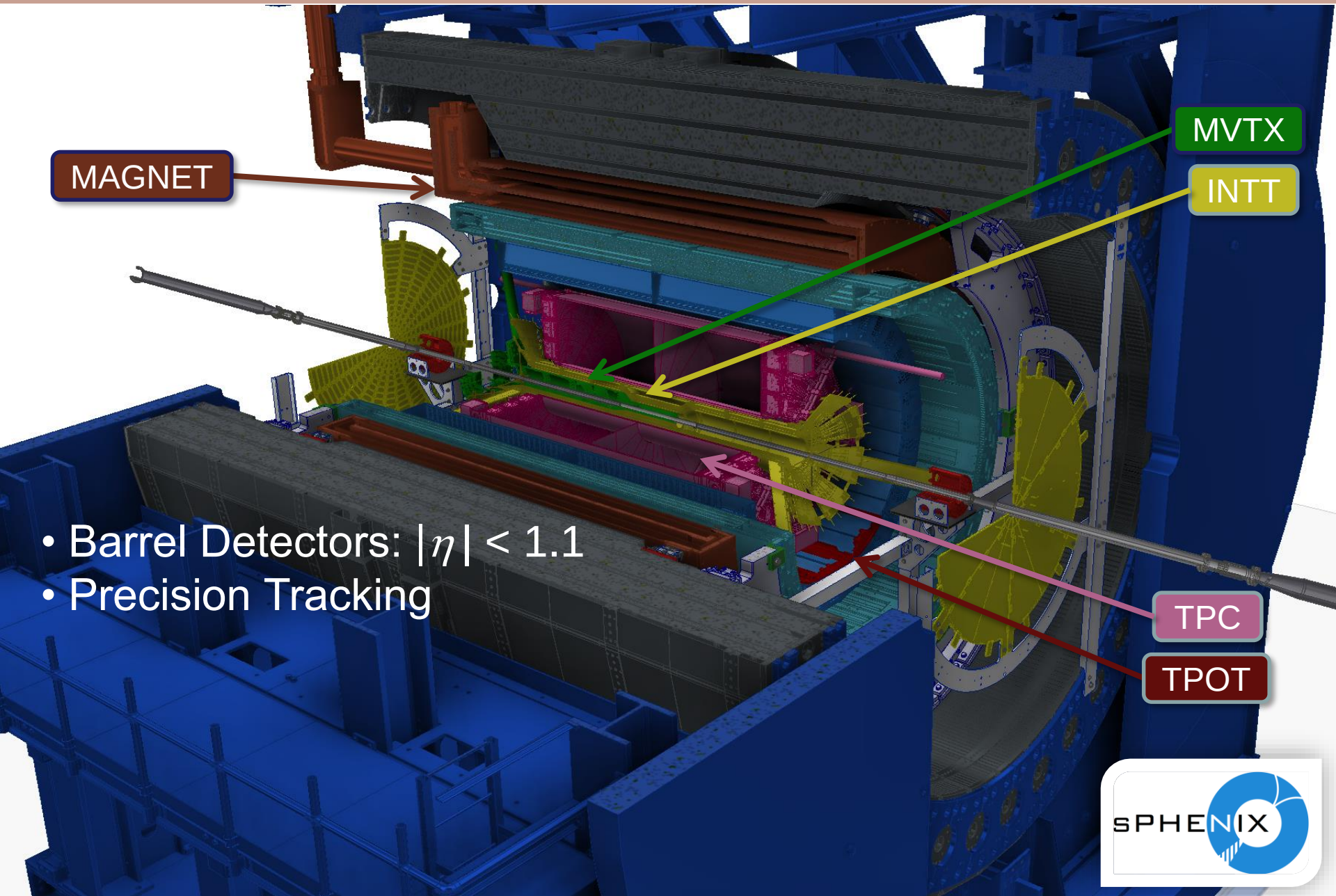


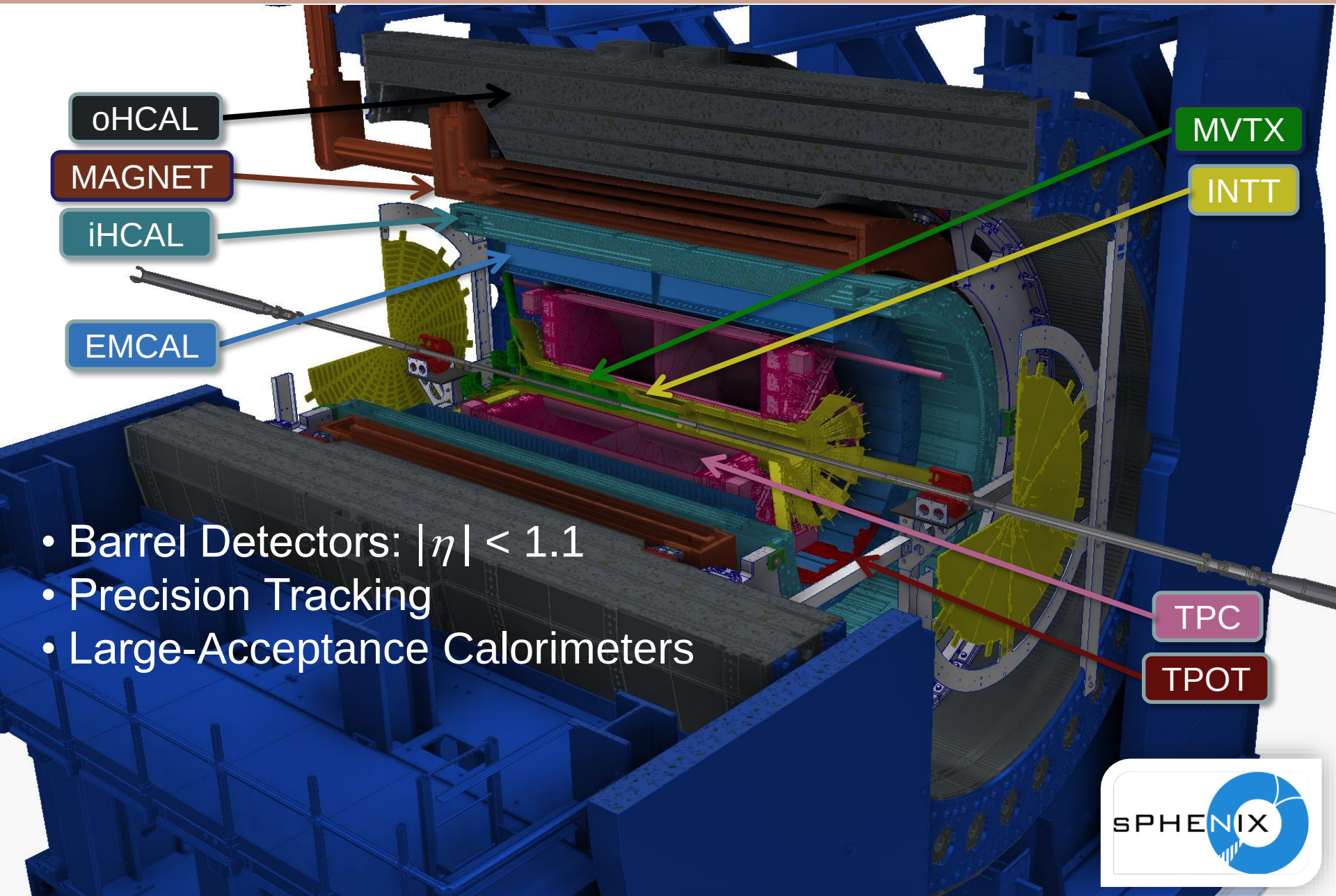
- Barrel Detectors: $|\eta| < 1.1$

sPHENIX Detector



- Barrel Detectors: $|\eta| < 1.1$
- Precision Tracking

sPHENIX Detector



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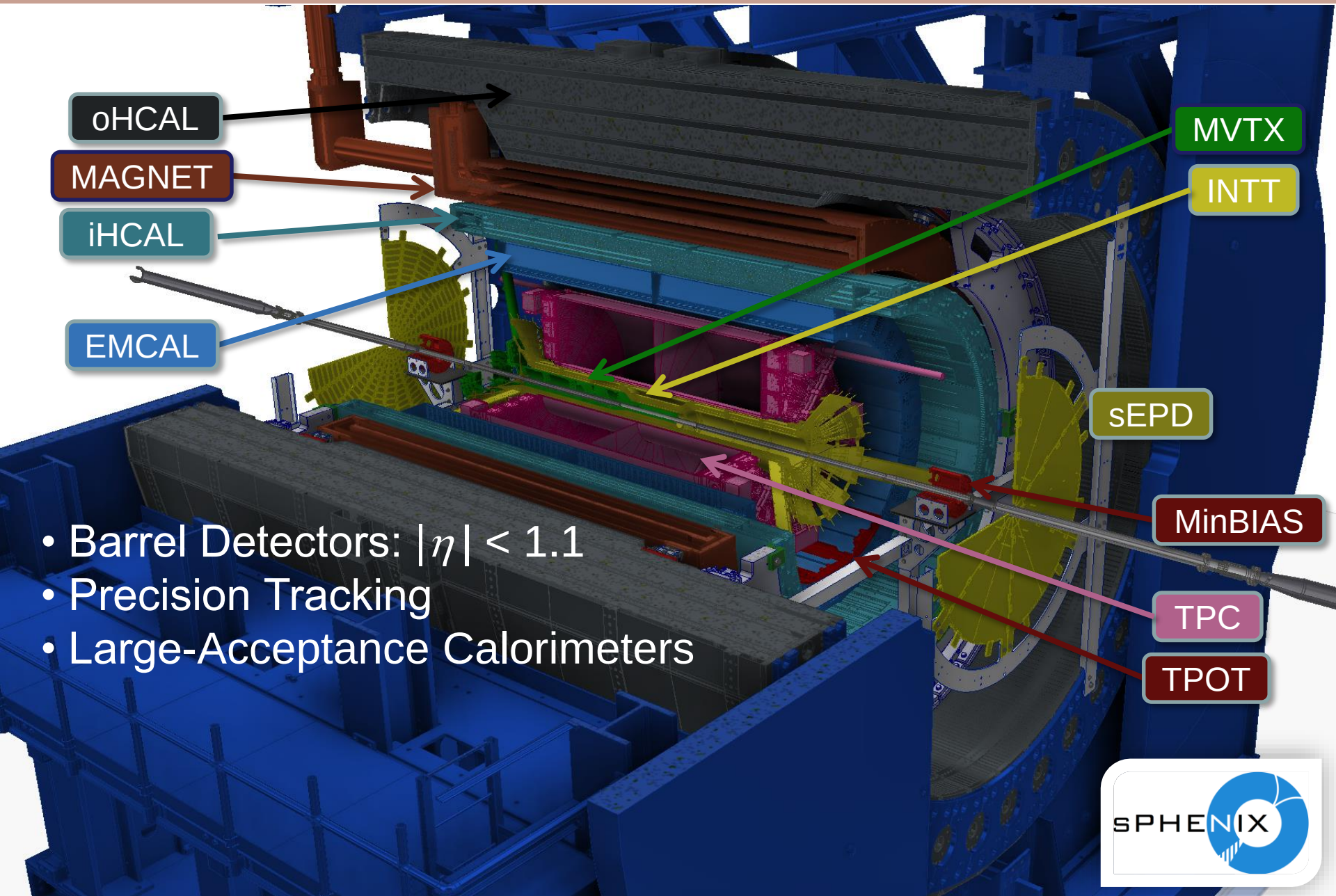
sPHENIX Detector



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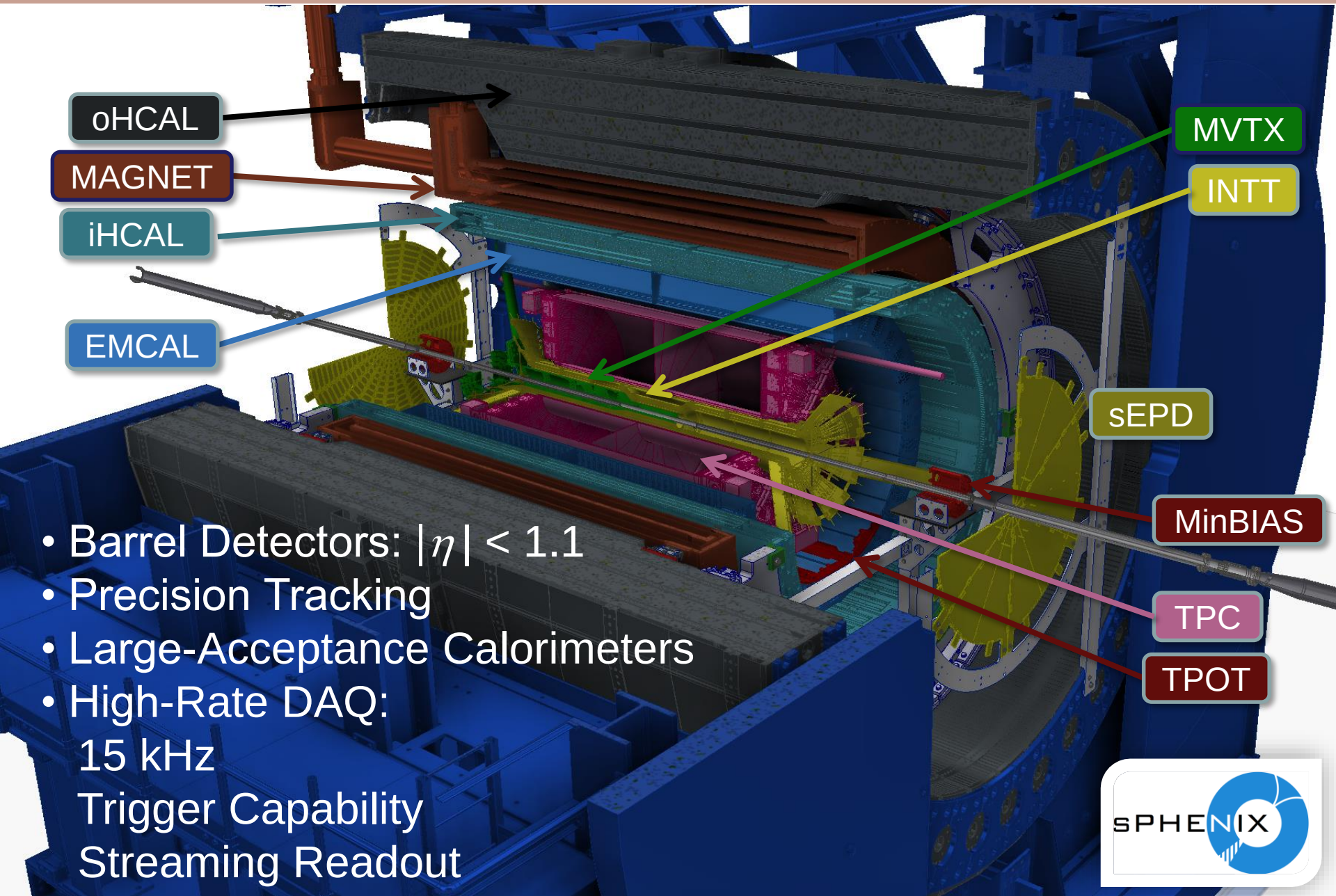
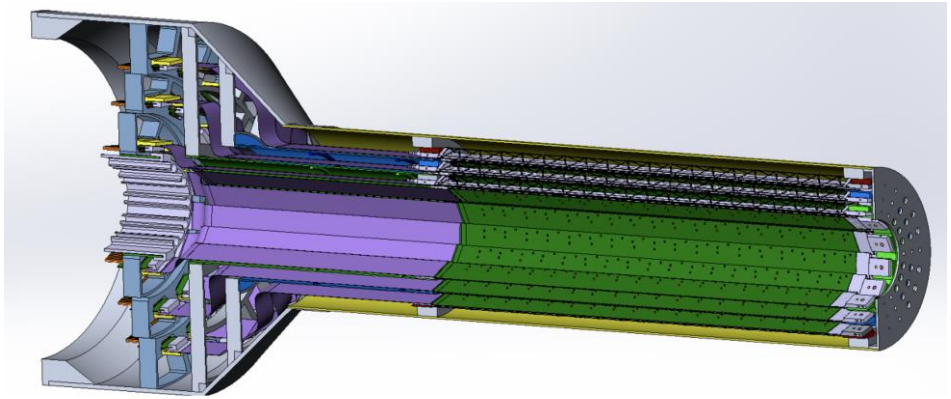
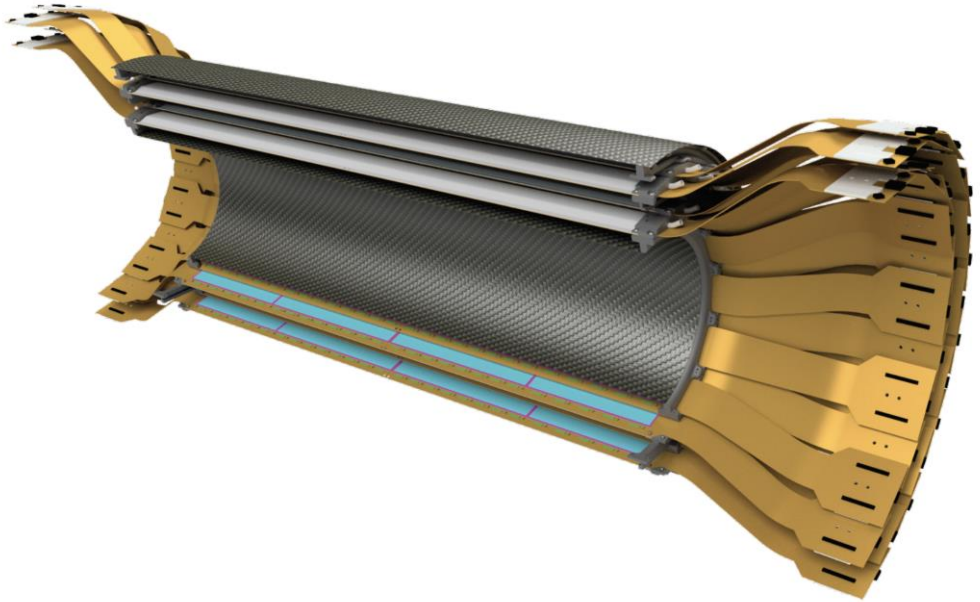


- Barrel Detectors: $|\eta| < 1.1$
- Precision Tracking
- Large-Acceptance Calorimeters
- High-Rate DAQ:
  - 15 kHz
  - Trigger Capability
  - Streaming Readout

Inner Tracking

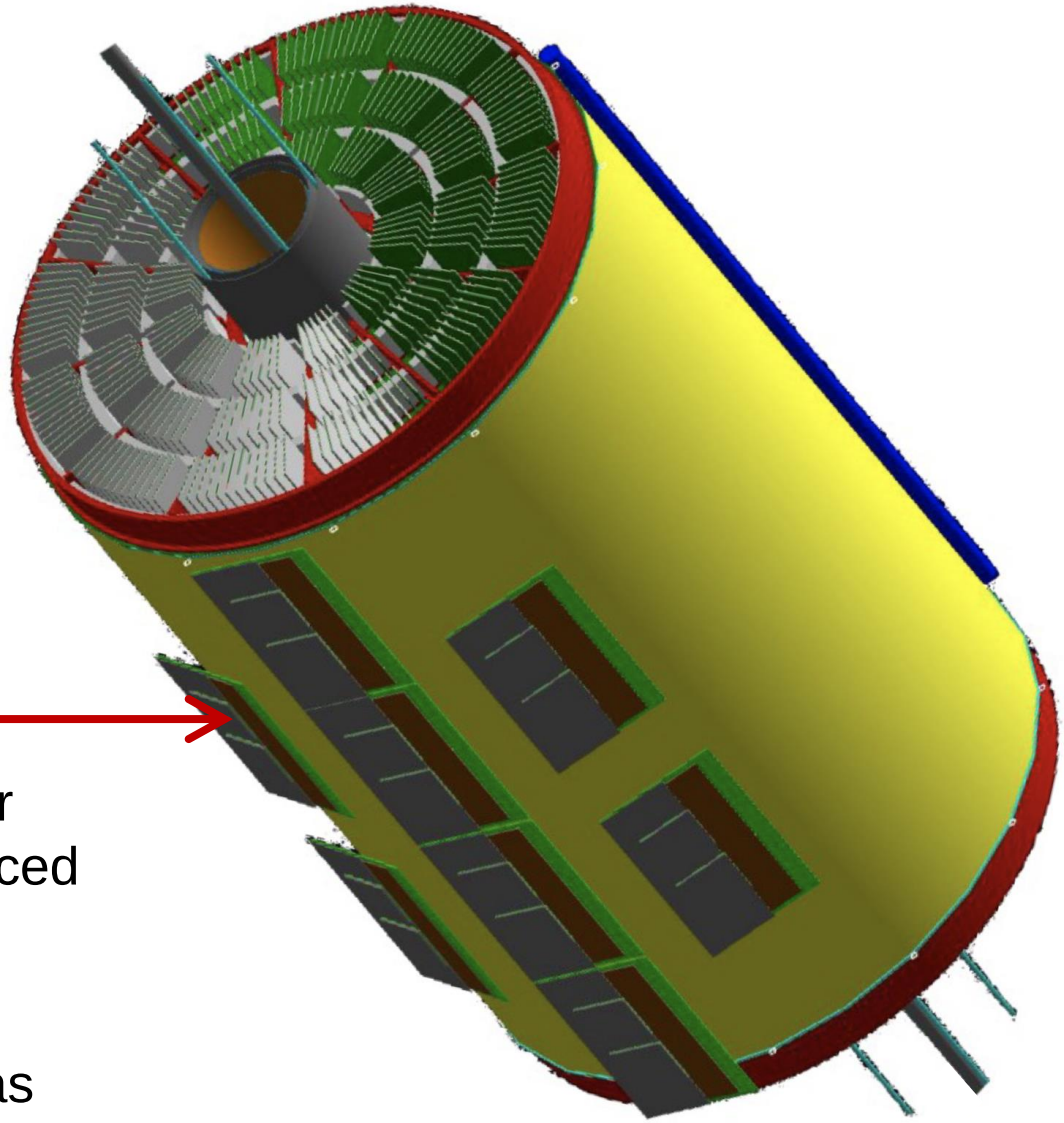
- **MVTX**
  - Precision vertexing
  - Position: 2.3 < *r* < 3.9 cm
  - 3 layers of Monolithic Active Pixel Sensors
  - Based on new ALICE ITS
  - Pixel size: 29×27 μm
  - Position resolution: 5 μm (tracks w/ p_T > 1 GeV/*c*)
- **INTT**
  - Position: 7 < *r* < 12 cm
  - 2 layers of Si strips
  - Pitch: 86 μm
  - Single-beam-crossing timing resolution





TPC & TPOT

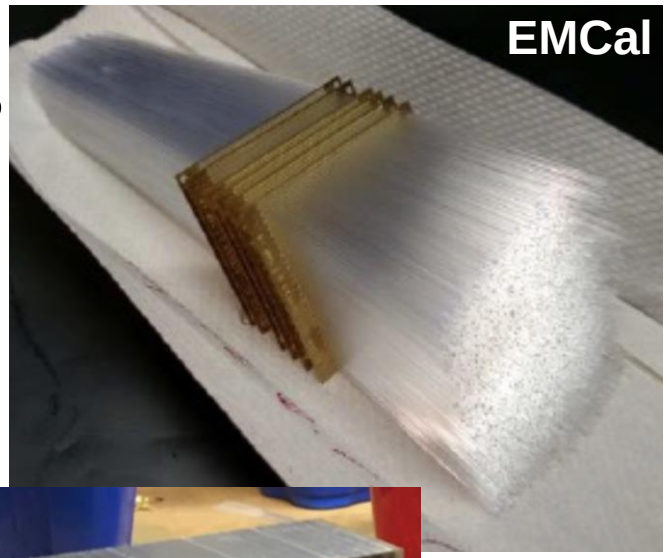
- **TPC**
  - Tracking
  - Position: $20 < r < 78$ cm
  - Compact, GEM-based
  - Effective hit resolution: ~250 μm
  - Continuous (non-gated) readout
- **TPOT**
  - Additional information for calibration of beam-induced space charge distortions
  - Position: outside TPC
  - 8 modules of Micromegas

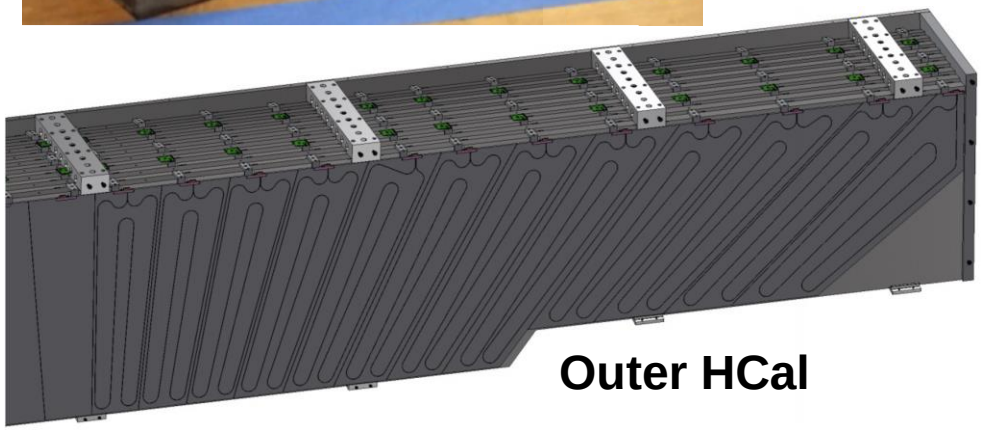


Calorimeters

- **EMCal**
  - Tungsten-Scintillating Fiber sampling calorimeter
  - Material: 20.1 X_0, 0.83 λ_{int}
  - Resolution: $16\%/\sqrt{E} \oplus 5\%$
- **HCal**
  - Inner & Outer HCals w/ magnet in between
  - Al (inner) & steel (outer) absorber plates
  - Scintillating tiles w/ embedded WLS fibers
  - Resolution: $88\%/\sqrt{E} \oplus 12\%$ (single particle)
- Total 5 λ_{int} for both calorimeters combined

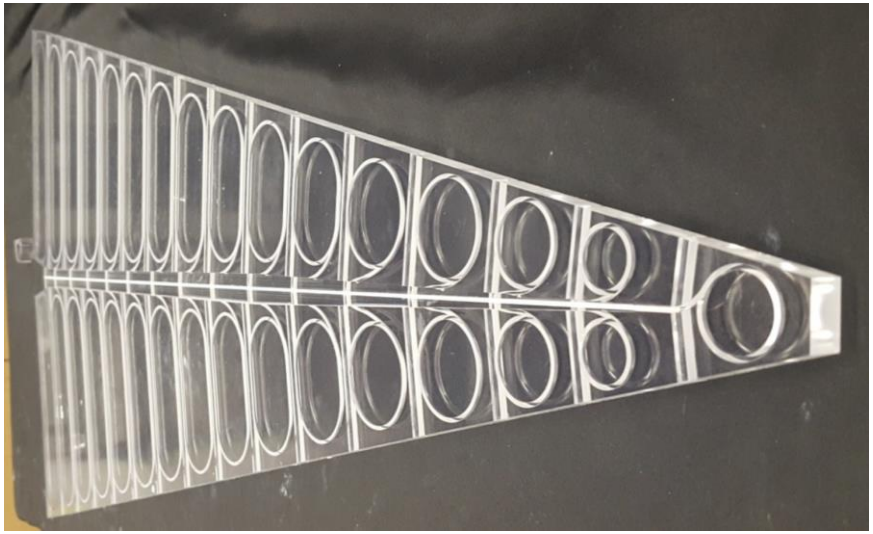
$\Delta\eta \times \Delta\phi = 0.025 \times 0.025$





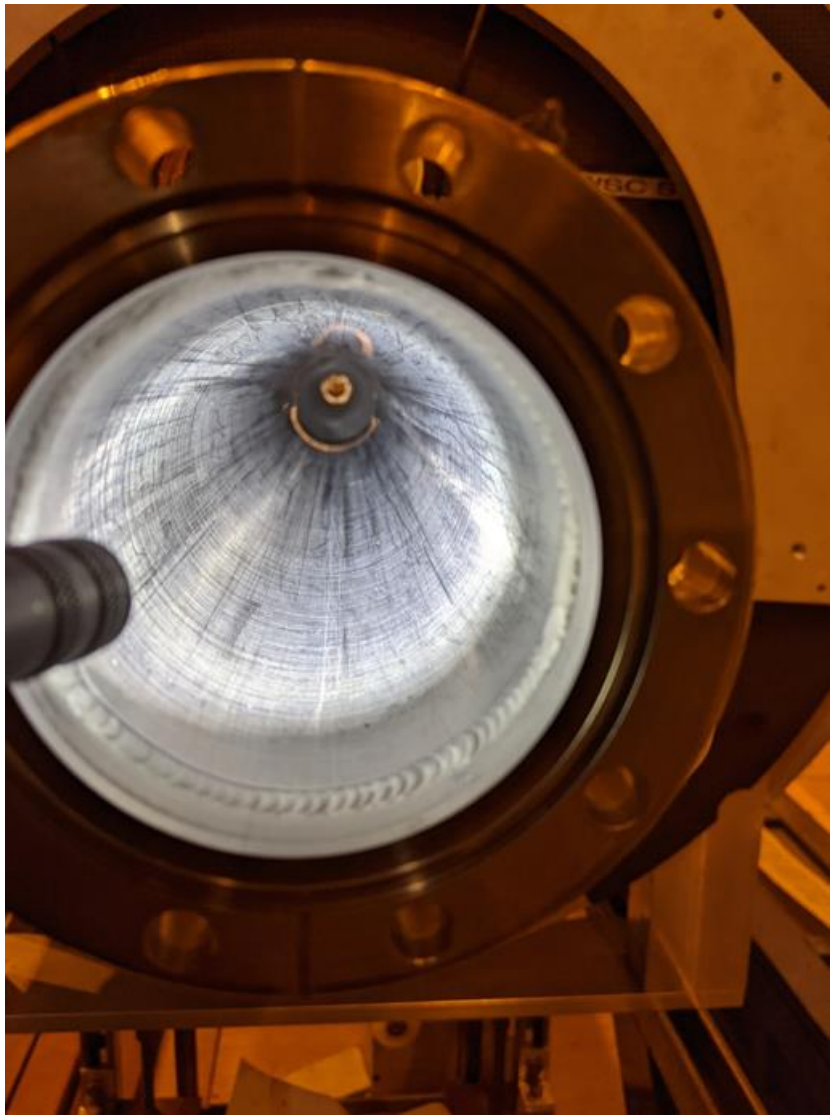
Event Characterization

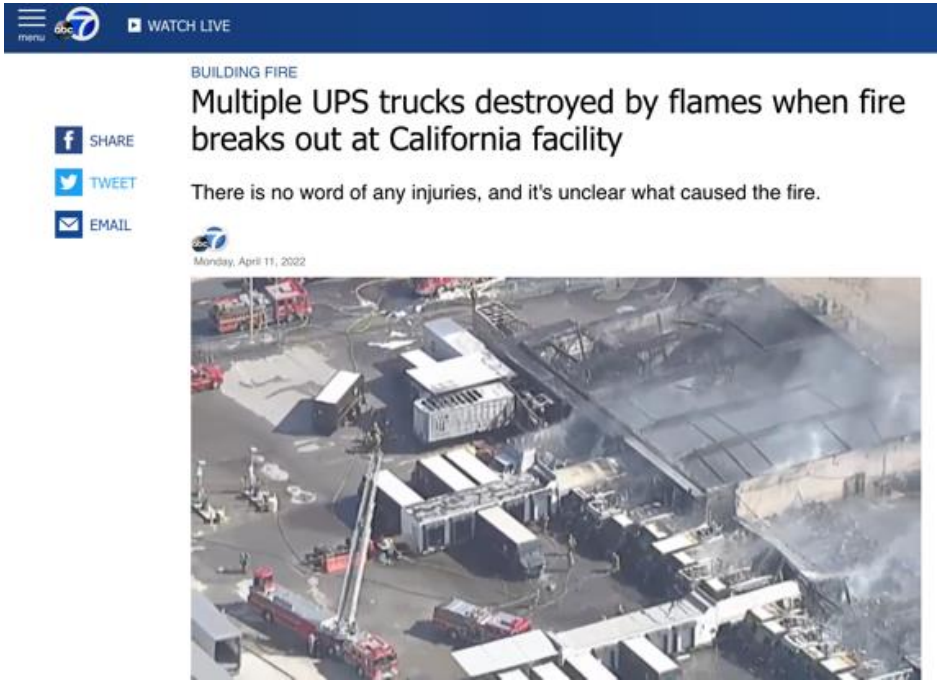
- **Min. Bias Detector (MBD)**
  - Covers $3.51 < |\eta| < 4.61$
  - Reuse PHENIX Beam-Beam Counter
  - 128 channels of 3 cm thick quartz radiator on mesh dynode PMT
  - Timing resolution: 120 ps
- **sPHENIX Event Plane Detector (sEPD)**
  - 2 wheels; $2.0 < |\eta| < 4.9$
  - Scintillator plastic (1.2 cm thick), embedded WLS fibers
  - Significant improvement of event plane resolution
  - Closely based on STAR EPD



Beampipe

- sPHENIX beampipe shipped to California for work
- Lost in warehouse fire in 2022!
- STAR had a spare beampipe that is in good condition and is compatible with sPHENIX design.





menu WATCH LIVE

SHARE
TWEET
EMAIL

BUILDING FIRE

Multiple UPS trucks destroyed by flames when fire breaks out at California facility

There is no word of any injuries, and it's unclear what caused the fire.

Monday, April 11, 2022

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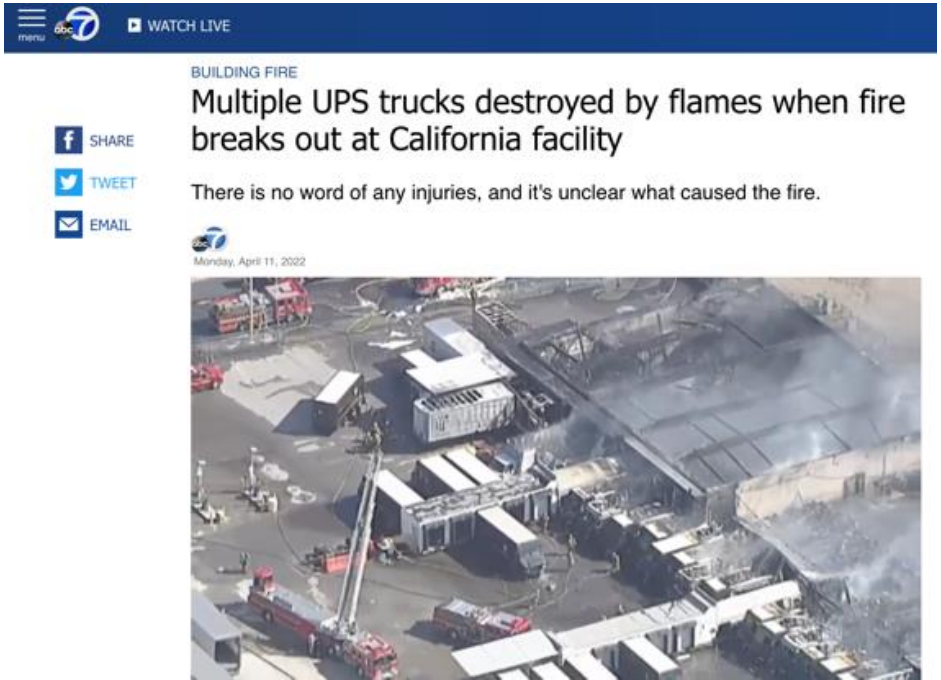
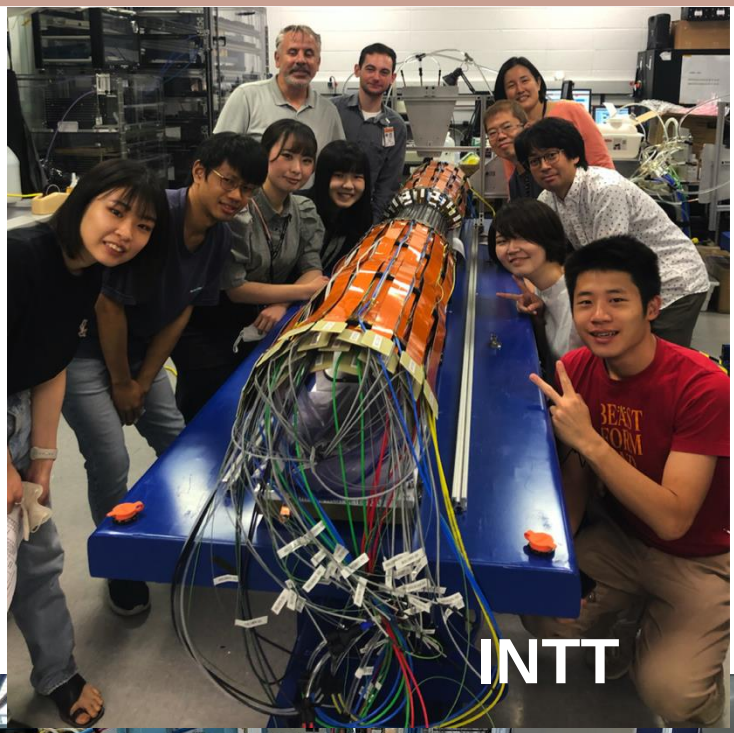


Beampipe installed on Tuesday and pump-down began on Wednesday!

Installation



Installation

- Detector has been moved into data-taking position
- Magnet mapping done by CERN team (center at 1.4 T)
- Most components have been installed
- Start of data taking is a few months away!

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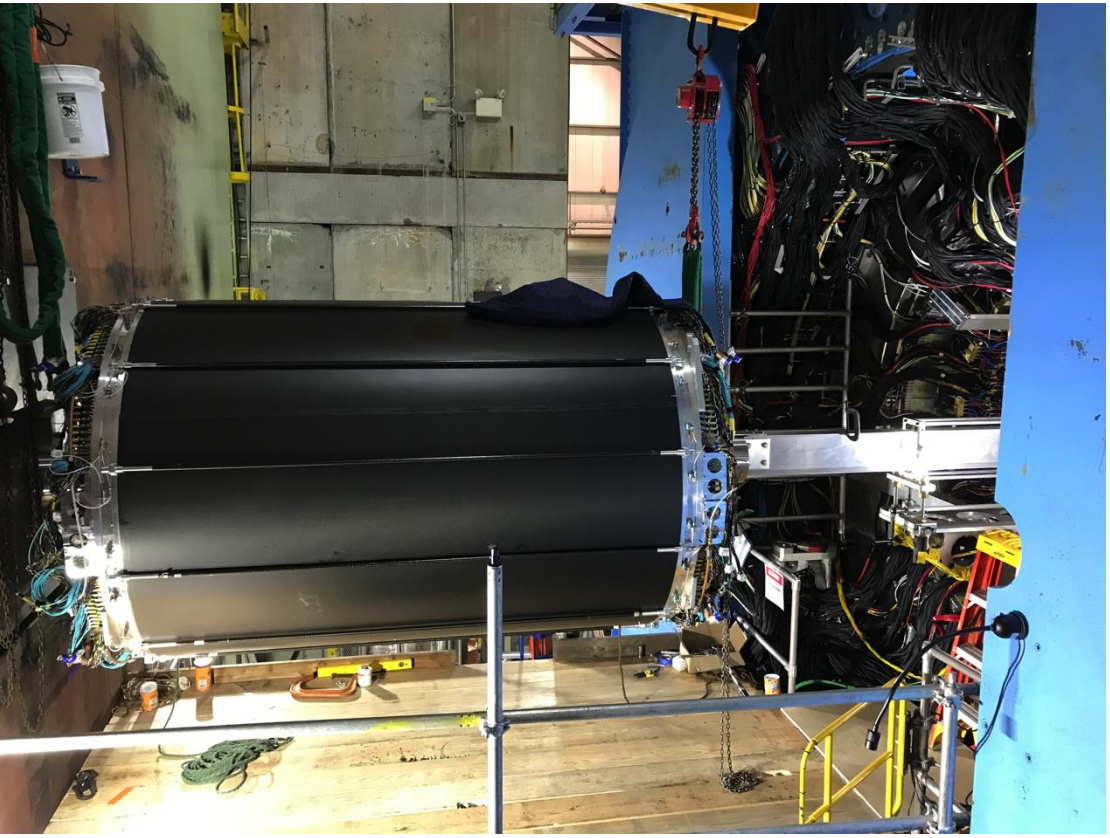
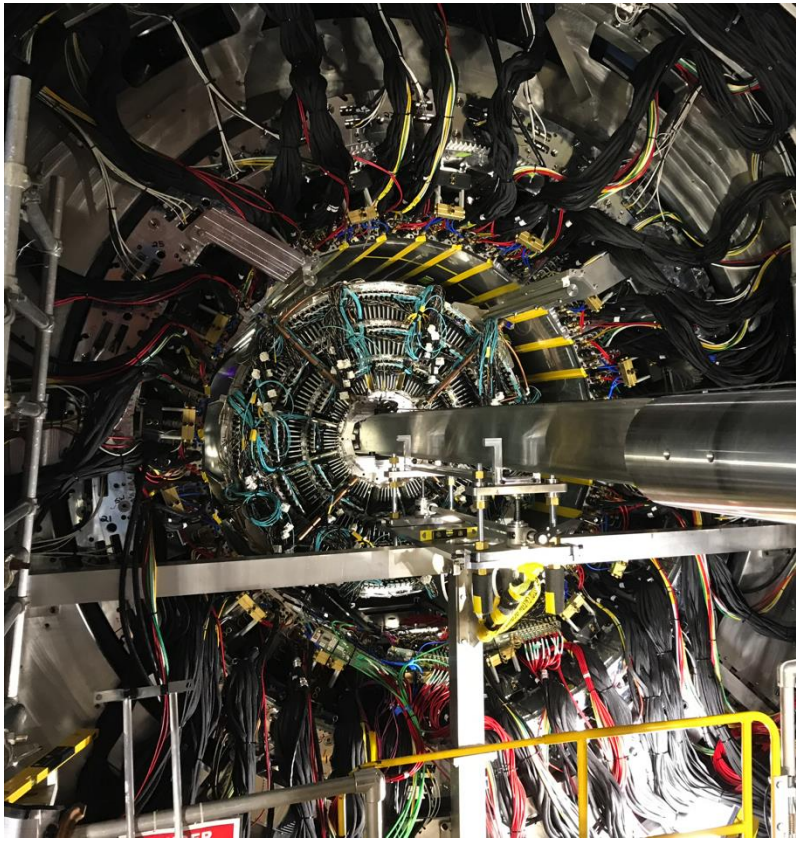
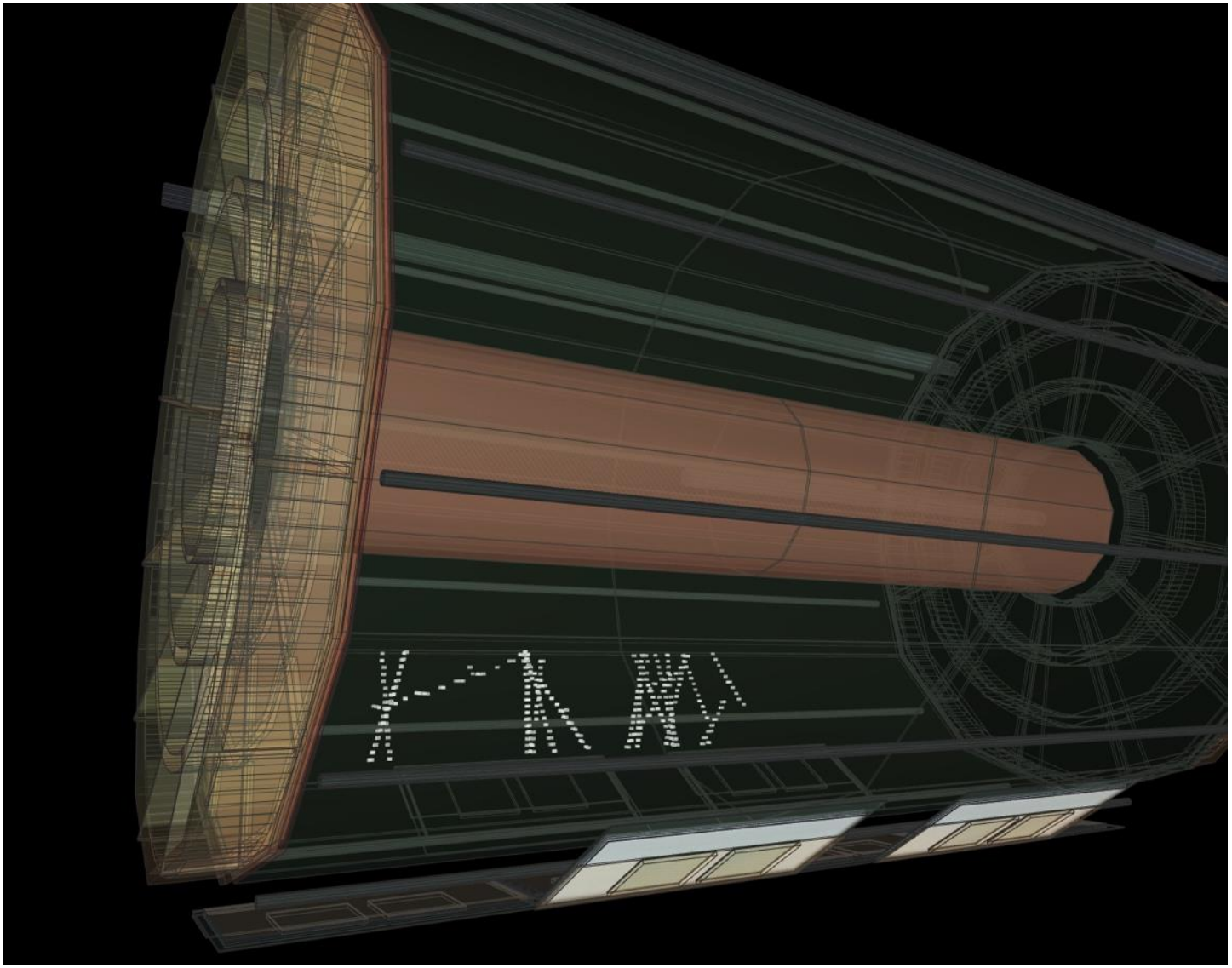




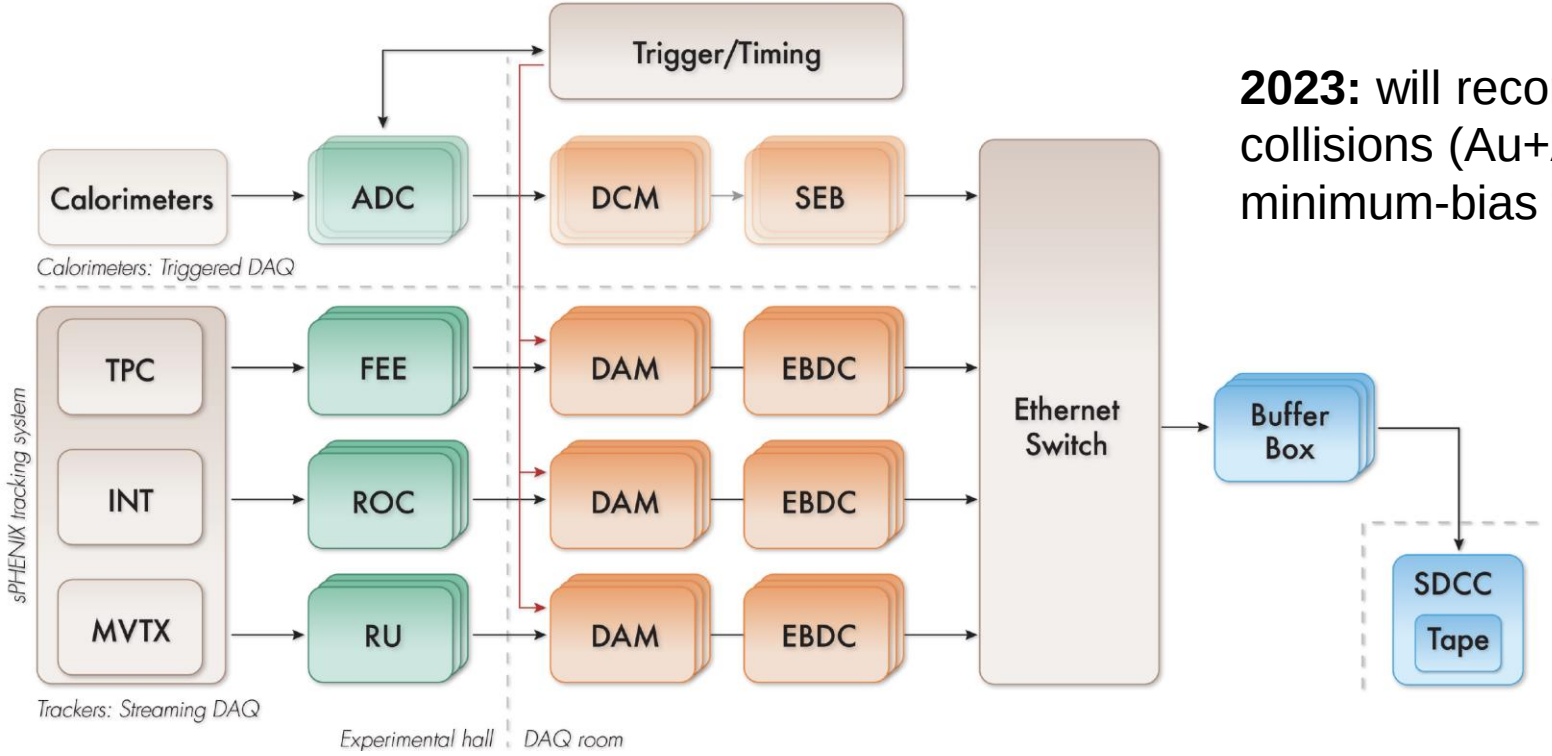
Cosmic Rays

- The TPC sees cosmic rays.



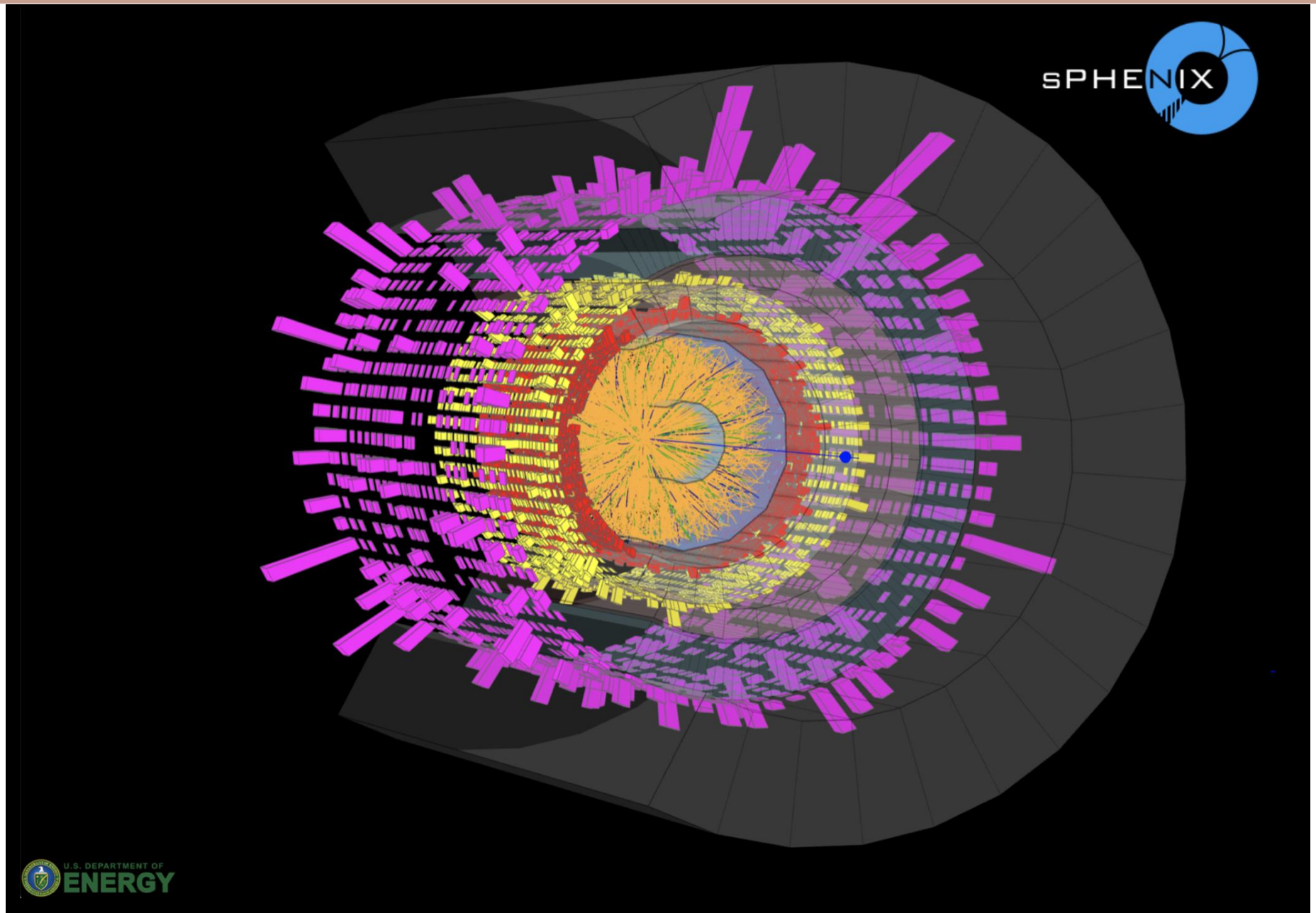
Data Acquisition

- Hybrid DAQ
- Triggered readout for calorimeters
- Streaming (triggerless) readout for tracking detectors
  - Records ~10% of all collisions
  - Key to get full *p*+*p* statistics in 2024
  - Crucial for HF & Cold QCD physics



2023: will record all collisions (Au+Au) w/ minimum-bias trigger

Event Display



Run Schedule

- sPHENIX scientific program can be completed with 3 years of running:

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}

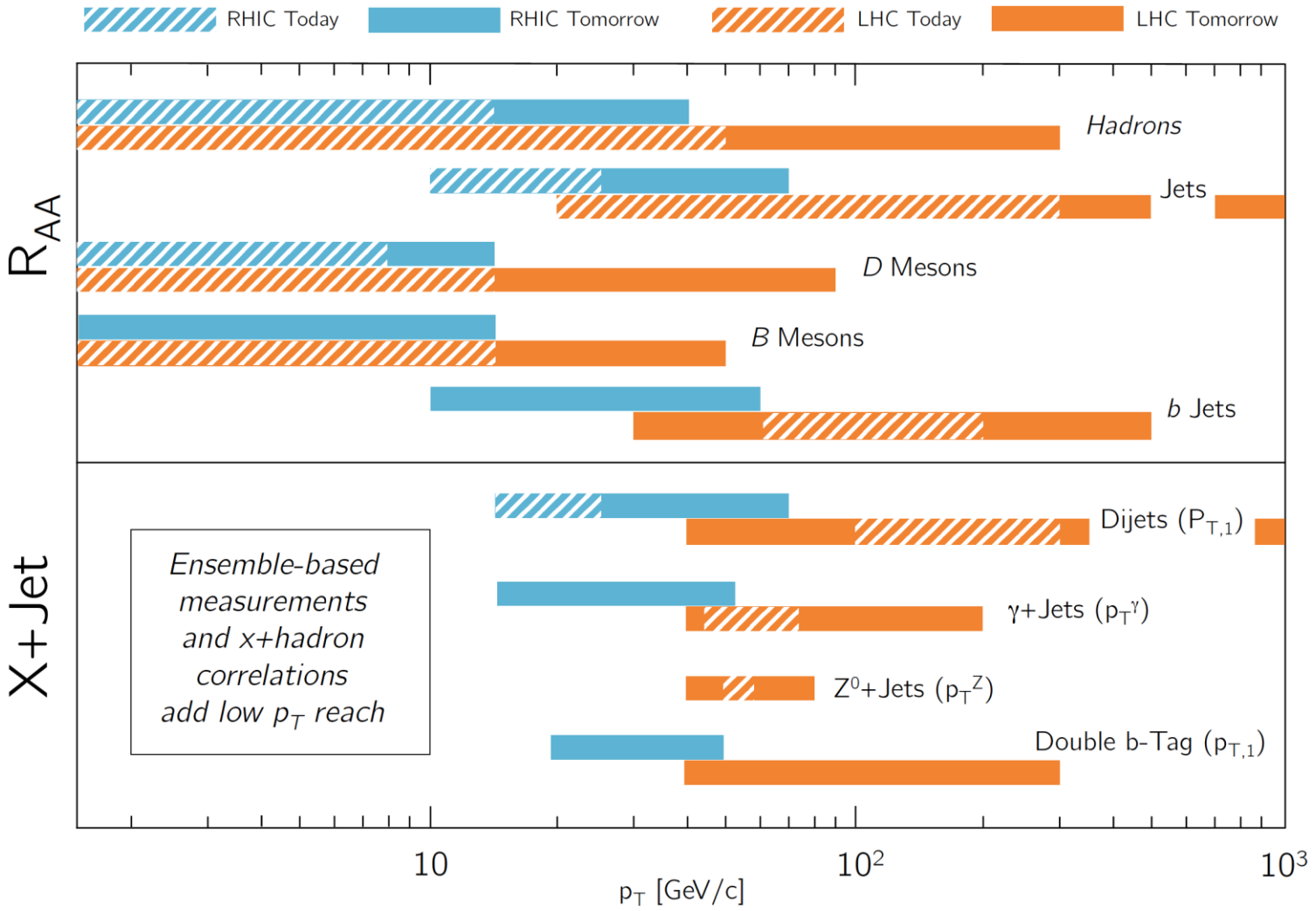
2023: Au+Au
Commissioning & Calibration, standard candle measurements, first sPHENIX physics

2024: p+p & p+Au
Reference measurements for heavy ions, cold QCD

2025: Au+Au
Heavy ions (high statistics)

RHIC & LHC

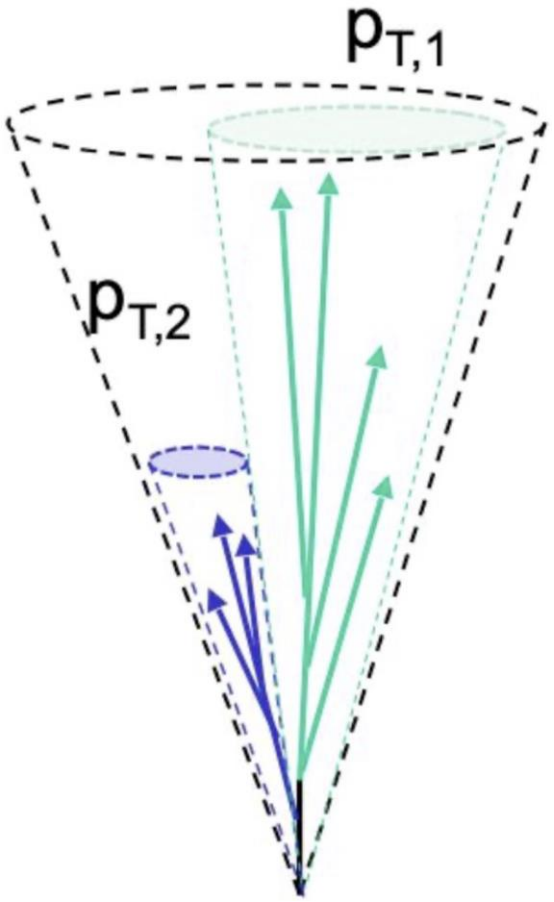
- sPHENIX enables expanded kinematic ranges for many observables → allows for overlap with LHC
- Some measurements for first time at RHIC!

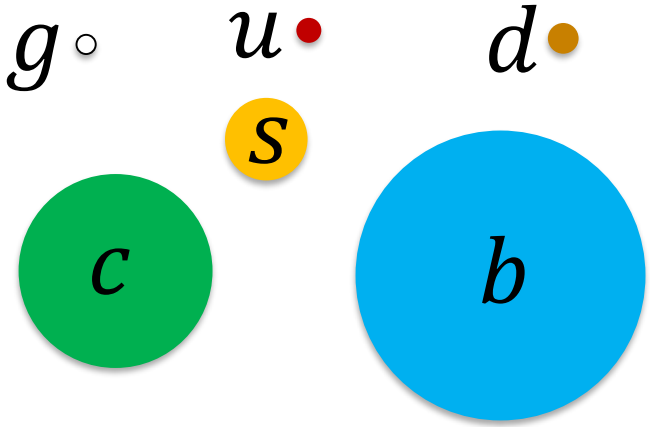


sPHENIX Physics Program

Jet Correlations & Structure

vary momentum & angular size of probe



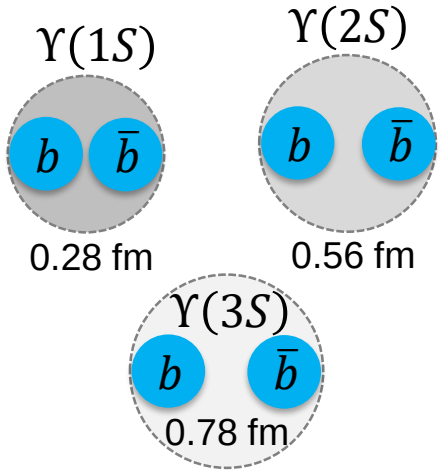


Heavy Flavor

vary mass & momentum of probe

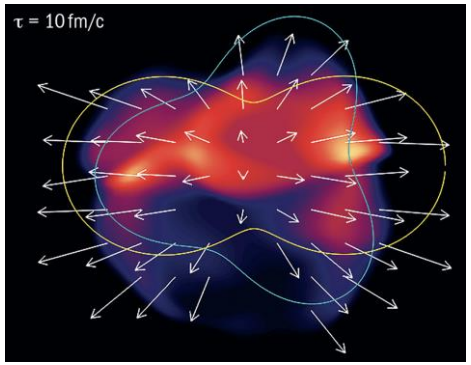
Quarkonia

vary size of probe

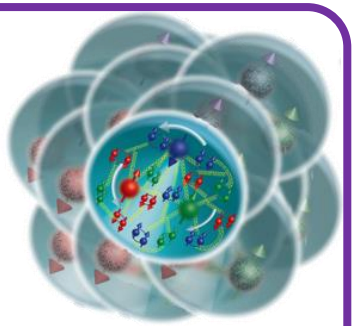


Bulk QCD

collective behavior in large & small systems

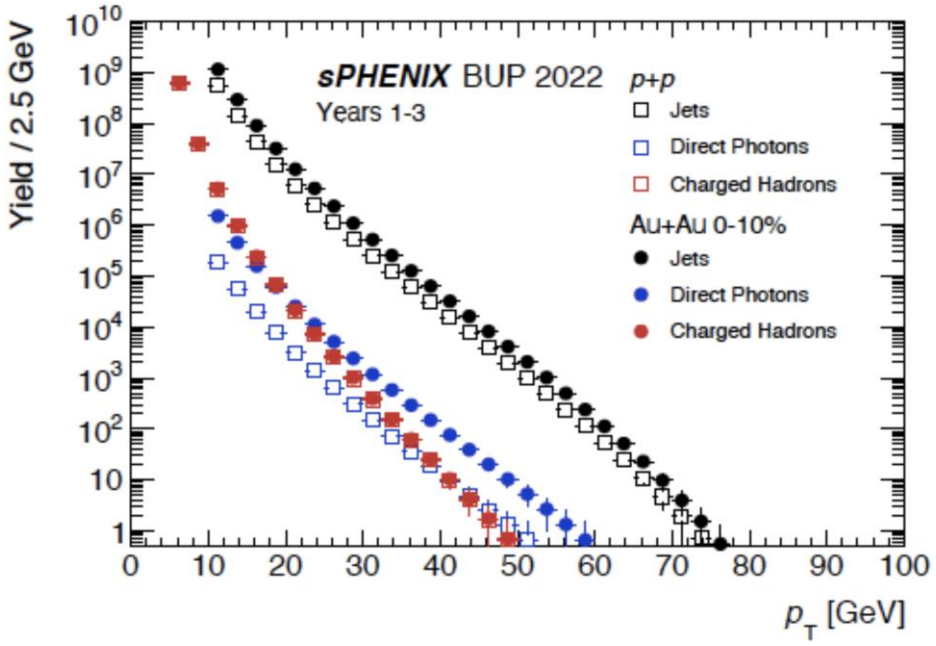


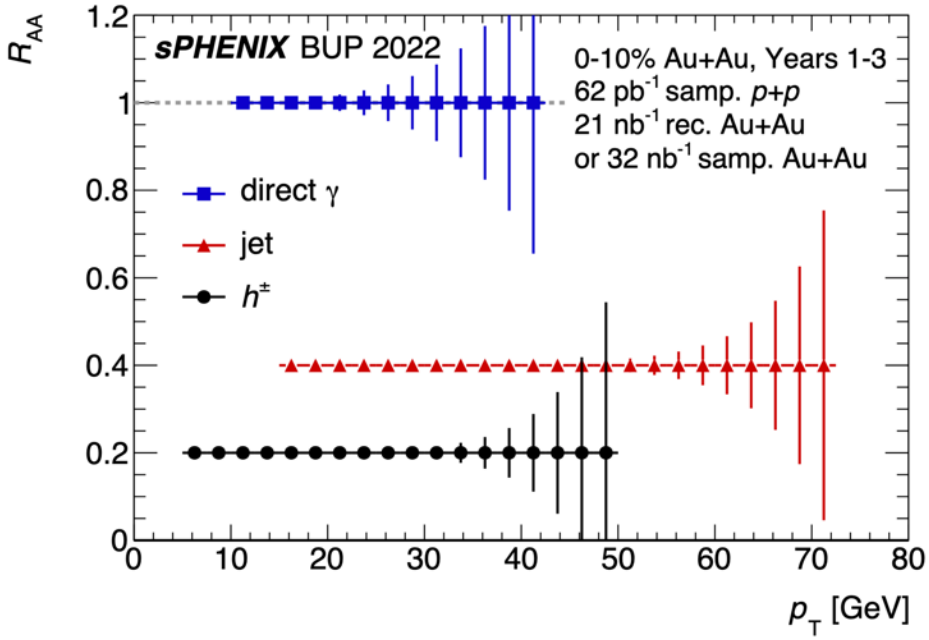
Cold QCD



vary temperature of QCD matter, study proton spin, transverse momentum, & nuclear effects

High-p_T Probes

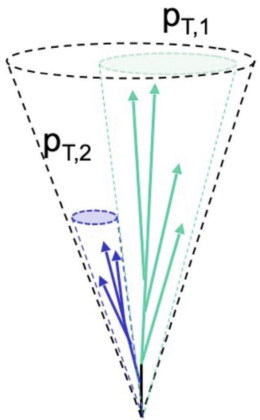




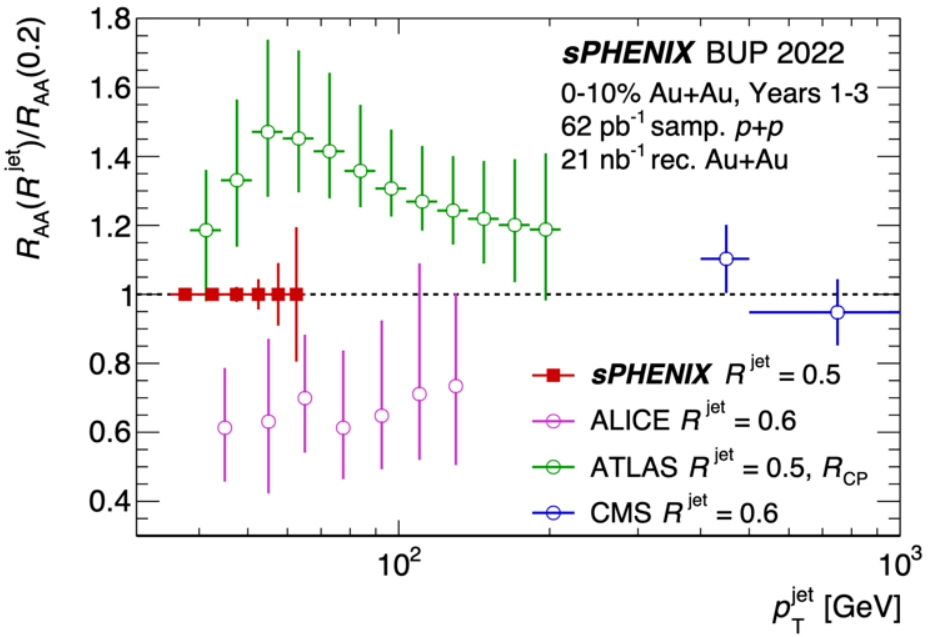
- In 3 years of data taking, sPHENIX will measure
  - Jets out to p_T ~ 70 GeV/c
  - Charged hadrons out to p_T ~ 50 GeV/c
  - Direct photons out to p_T ~ 40 GeV/c
- Kinematic overlap with LHC measurements
  - And access to kinematic regimes LHC can't explore

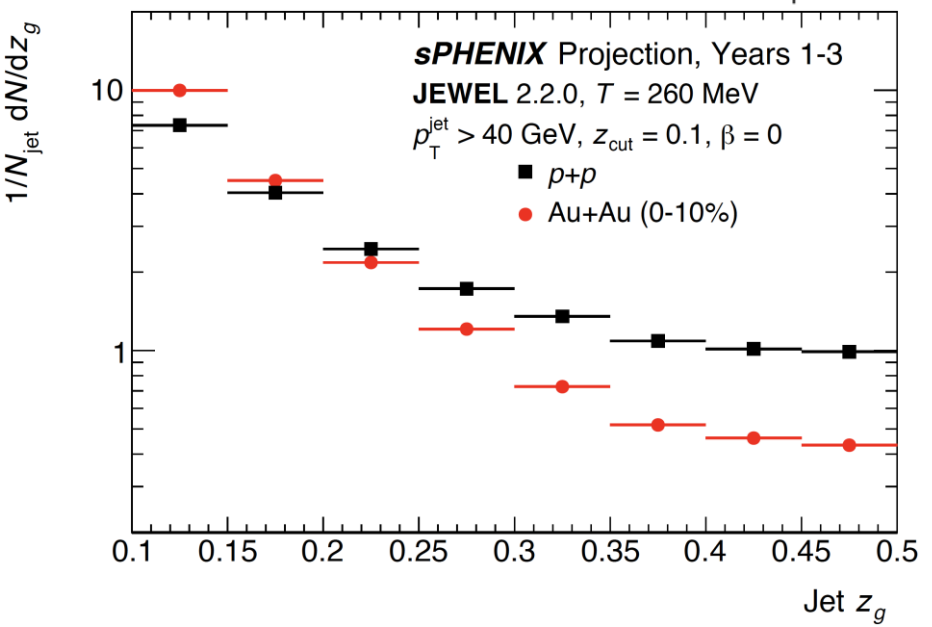
Jets

- Will measure jets for $p_T < 100$ GeV/c: tension in LHC jet results here
- Jet (sub)structure studies will be used to explore how energy loss depends on the parton shower
  - Connection to fundamental QCD
  - Probe to measure QGP properties



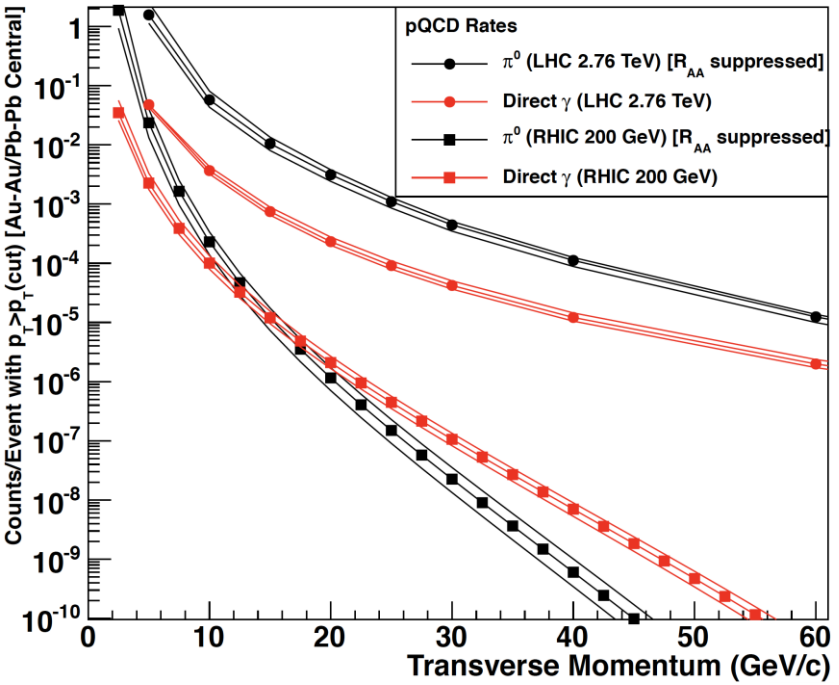
$$z_g \equiv \frac{min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

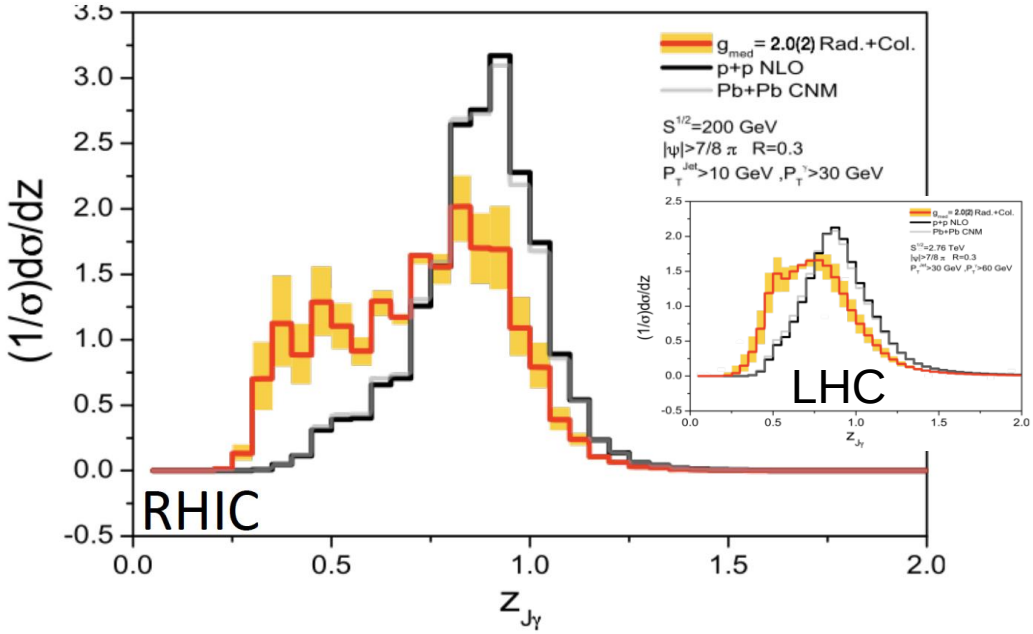


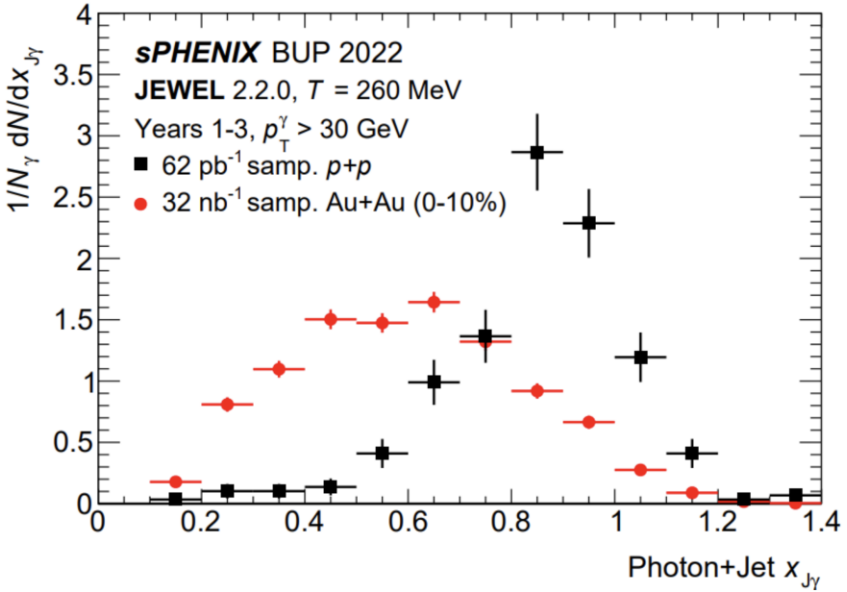


Photon-Tagged Jets

- Key measurement in sPHENIX physics program.
- RHIC is ideal for measuring direct photons.
- Measurements of $z_{J\gamma}$ may be more sensitive at RHIC.

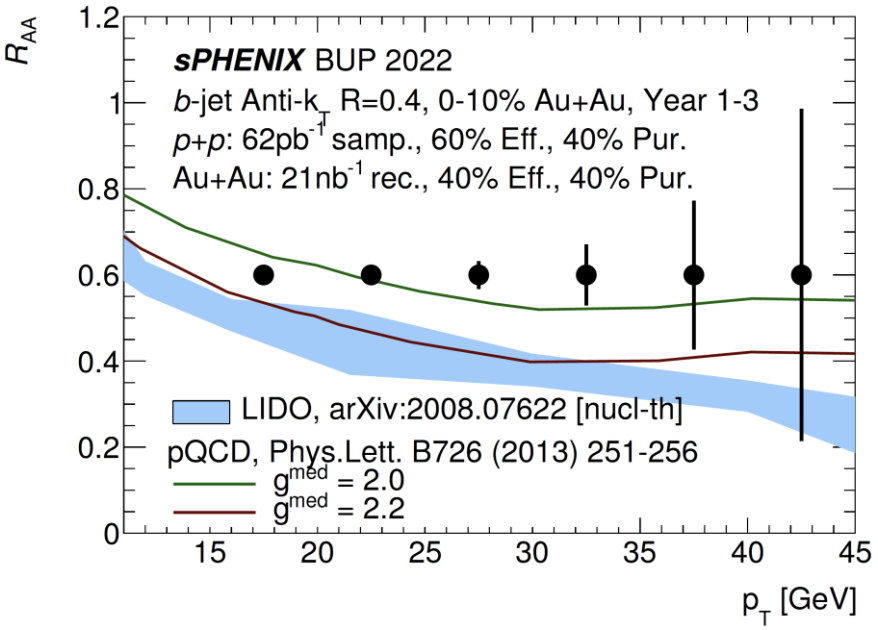


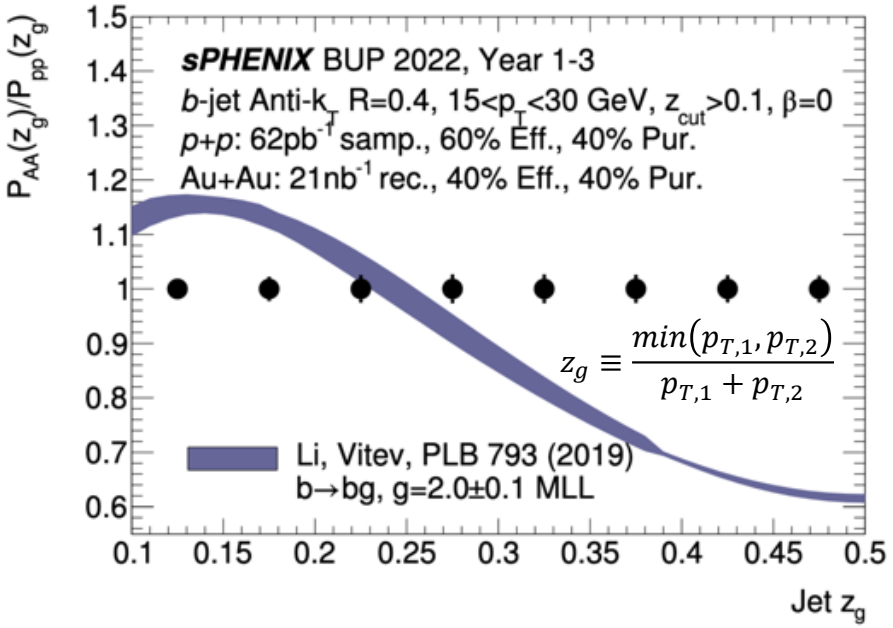


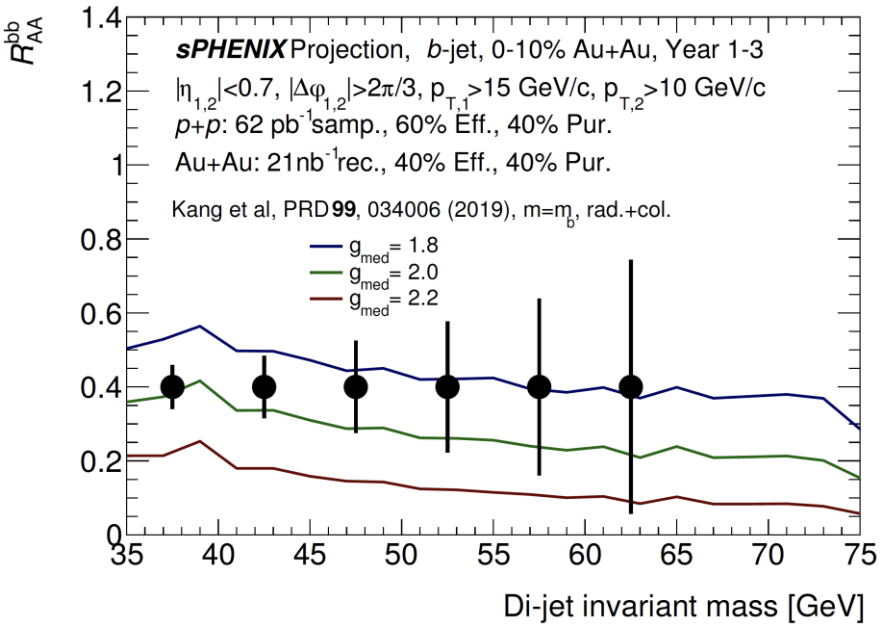


b-Tagged Jets

- Sensitive to collisional vs. radiative energy loss
- 1st RHIC *b*-jet measurement!
- Lower p_T range than LHC
  - Larger heavy-quark mass effect
- Studies of *b*-jet substructure

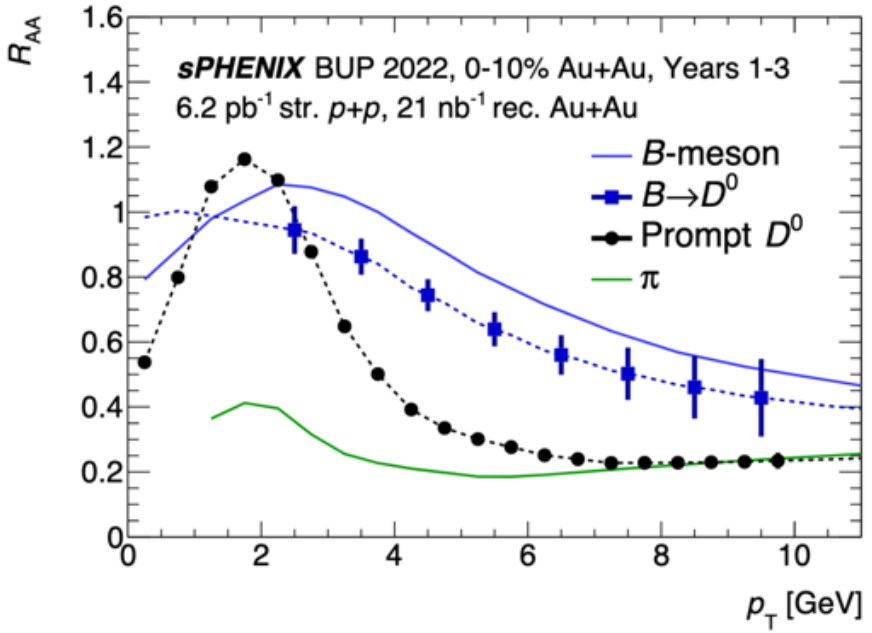


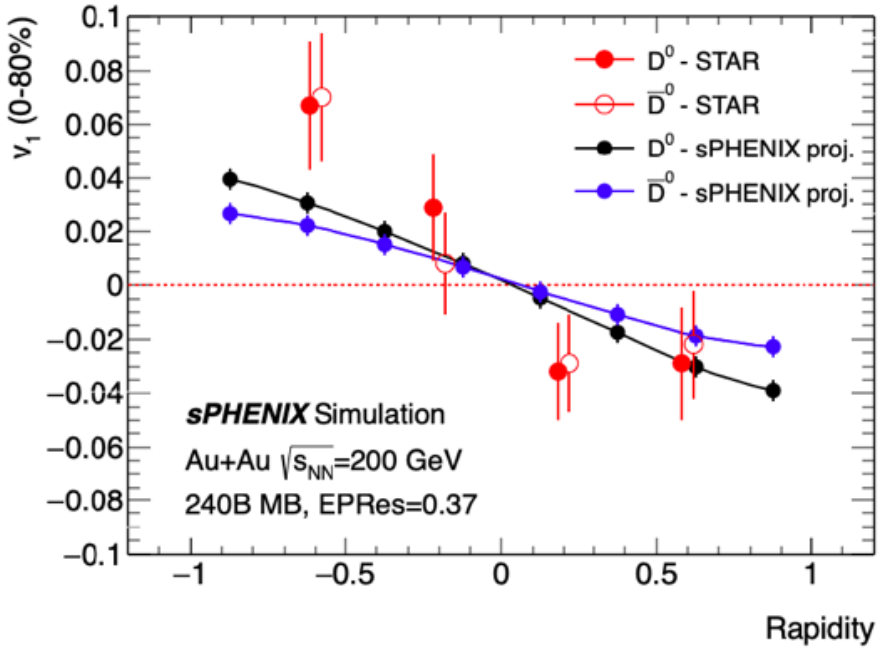


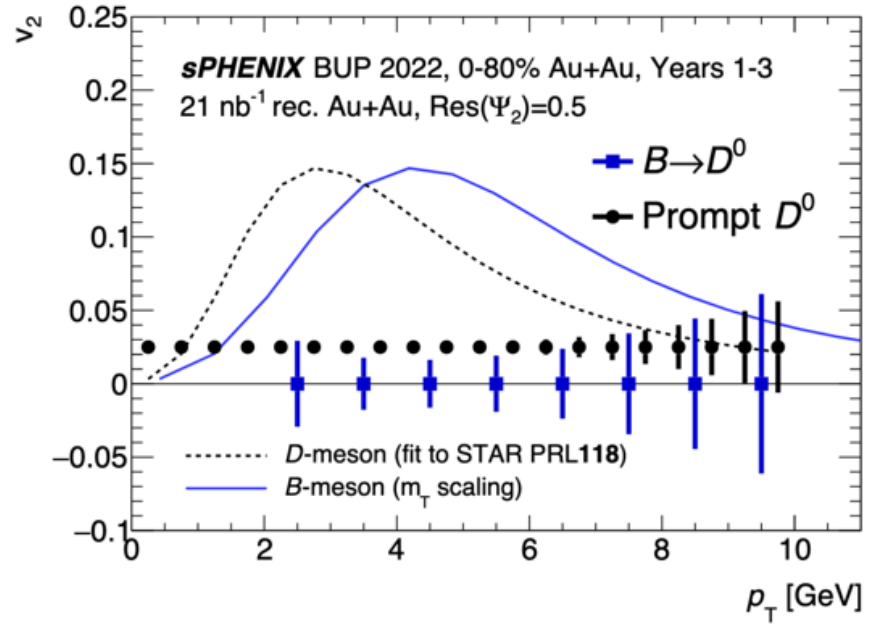


Open Heavy Flavor

- Streaming readout → large min. bias data set & HF measurements down to $p_T = 0$
- Will access *b*-quark R_{AA} & v_2 via non-prompt D^0, full *b*-hadron reconstruction.
- Transient magnetic field may influence v_1 differently for D^0 & $\overline{D}^0$

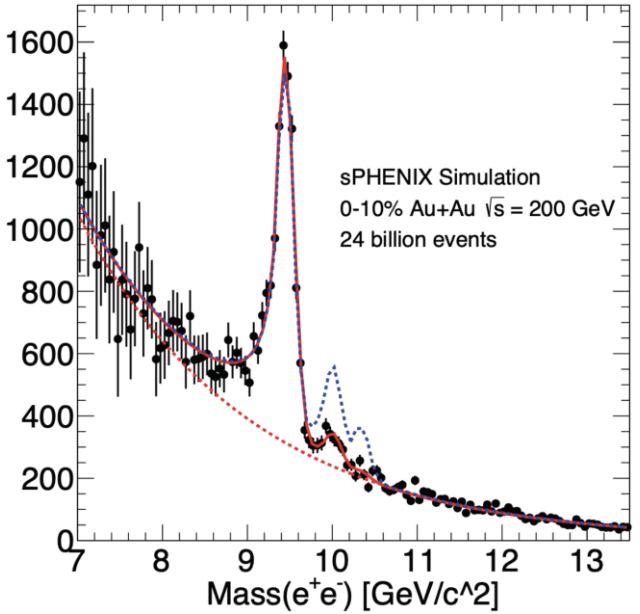


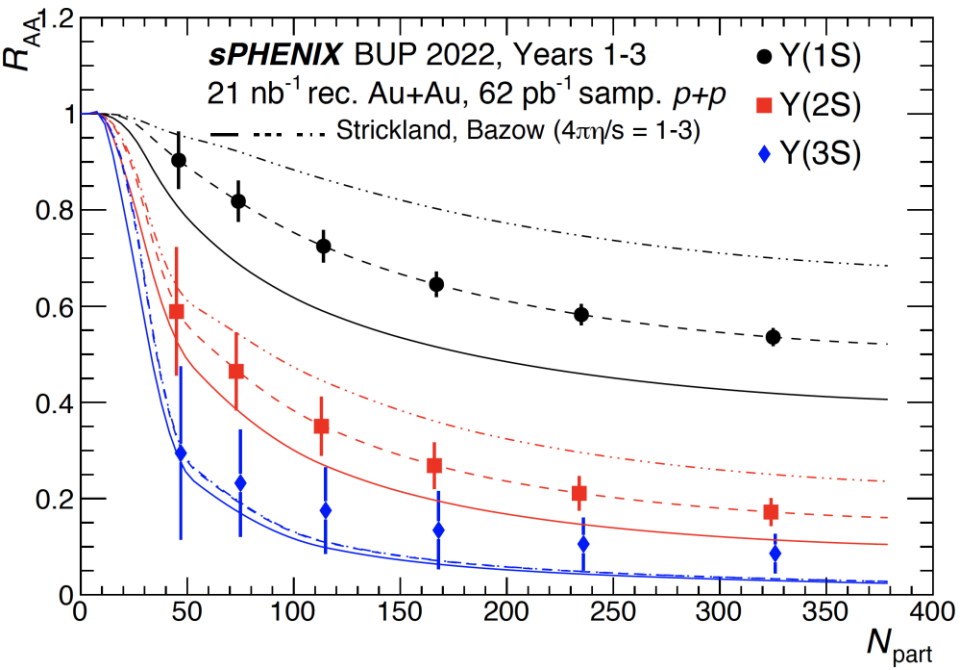


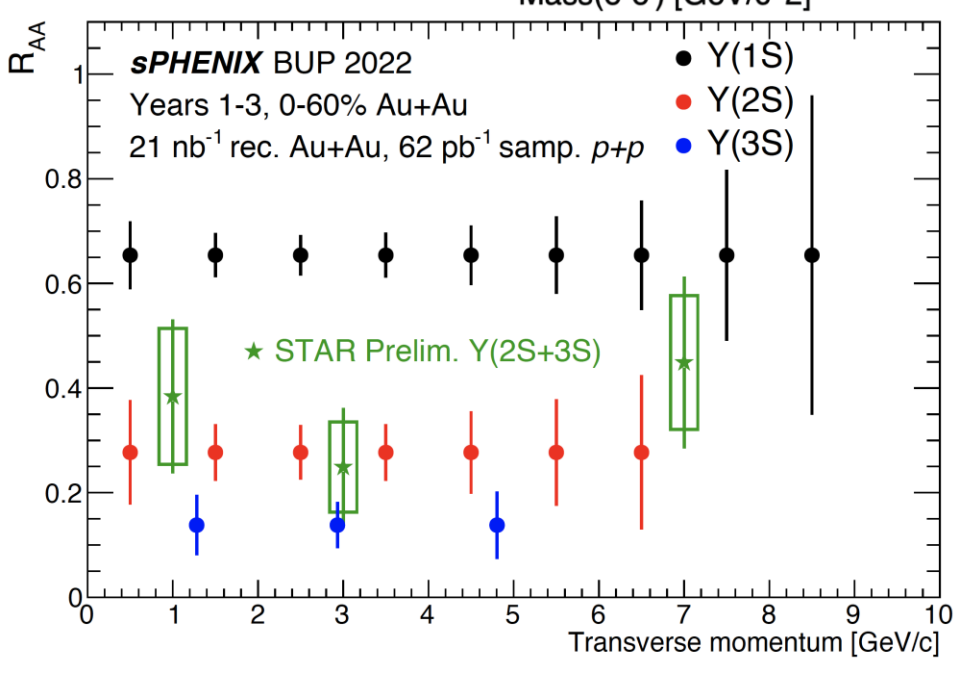


Quarkonia

- Excellent mass resolution will allow clean separation of three Υ states
  - First time at RHIC!
- Chance for clear measurement of Υ(3S) suppression → test of theoretical predictions
- ML tools for hadron rejection

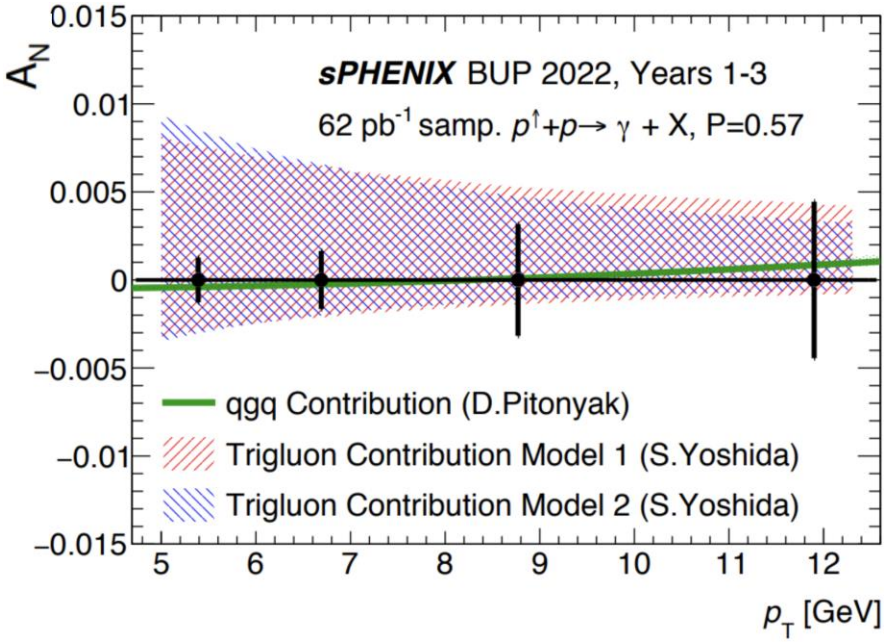


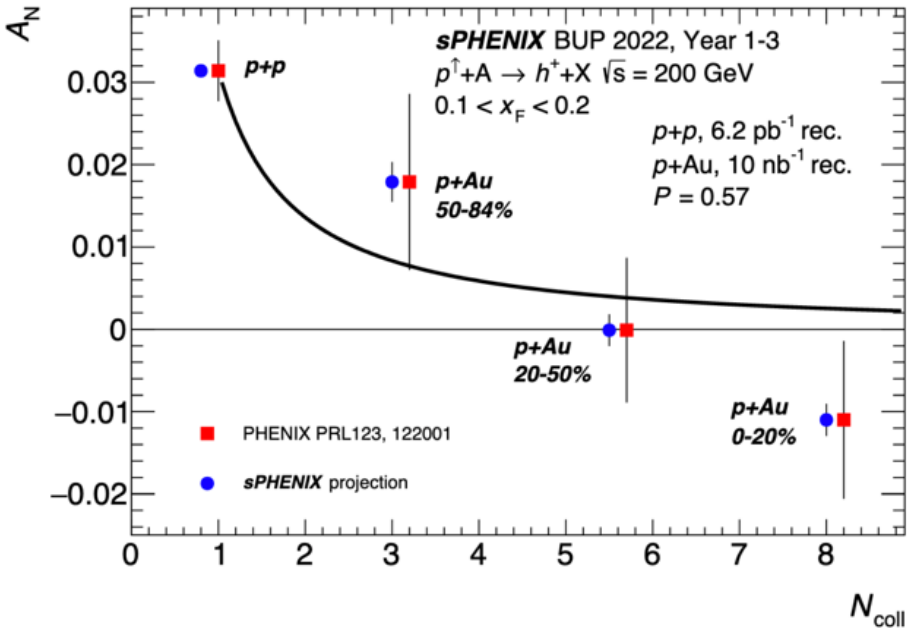


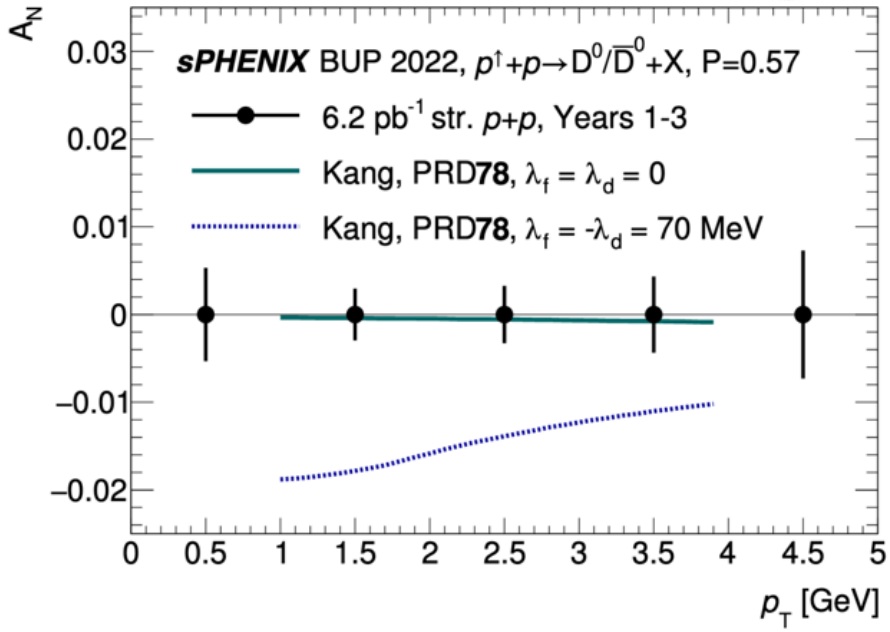


Cold QCD

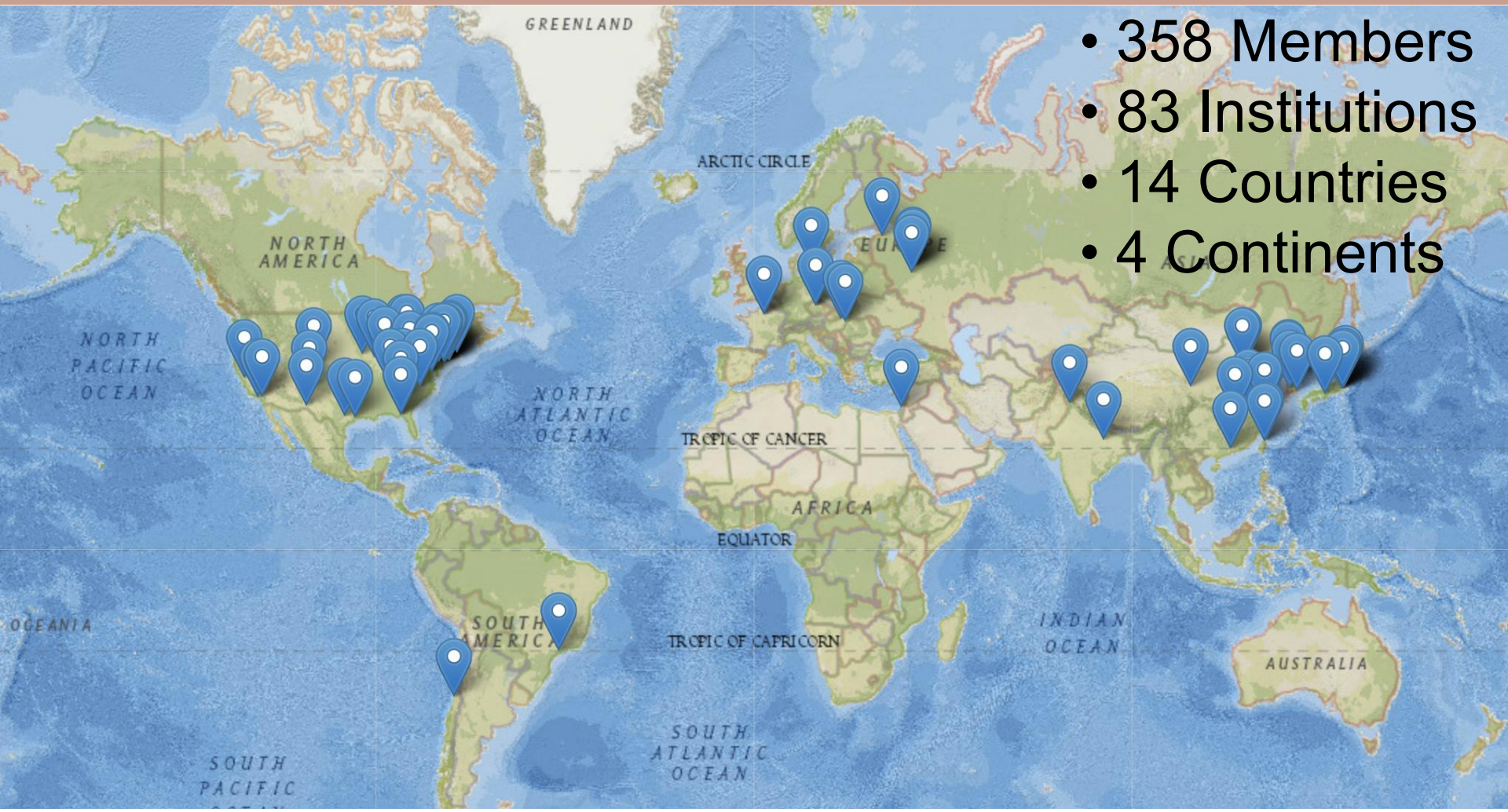
- TSSA via prompt γ & D^0
- *p*+Au: Measure nuclear dependence of TSSA
- Apply unique sPHENIX capabilities to answer questions posed by PHENIX measurements







sPHENIX Collaboration



- 358 Members
- 83 Institutions
- 14 Countries
- 4 Continents

- Encouraging diversity is a priority for our collaboration.
  - Diversity, Equity, & Inclusion training will be a requirement for being an sPHENIX author.

Conclusions

- sPHENIX is the first new detector at RHIC in > 20 years
  - Key component of RHIC's science mission for 2023–2025.
- The physics program focuses on measuring jet and heavy-flavor observables.
  - Much improved precision w.r.t. previous RHIC experiments.
  - First RHIC measurements of *b*-jets, $\Upsilon(3S)$ suppression.
  - Kinematic overlap with LHC also possible in many cases.
- Detector installation in progress
  - Most detectors installed inside magnet, detector is in position.
- We look forward to an exciting physics program!

Backup

Jet Azimuthal Anisotropy

- Event Plane Detector will improve resolution
  - More precise v_2 studies – including jet v_2
- sPHENIX jet v_2 will complement LHC measurements:
  - Lower p_T than ATLAS with comparable uncertainties
  - Overlaps with ALICE kinematic range
- Also plans to measure jet v_2 in p+Au collisions