Medium-energy Nuclear Physics at RHIC with sPHENIX and an sPHENIX Forward Upgrade

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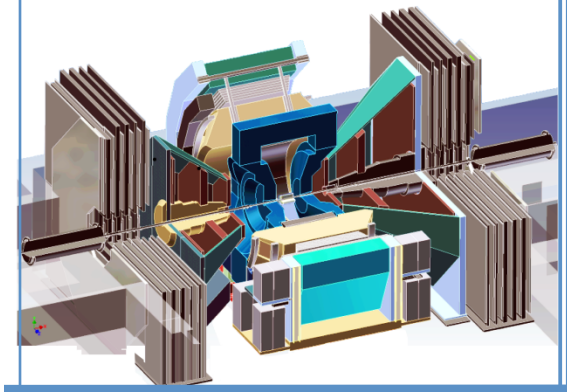
Evolution of the PHENIX Interaction region

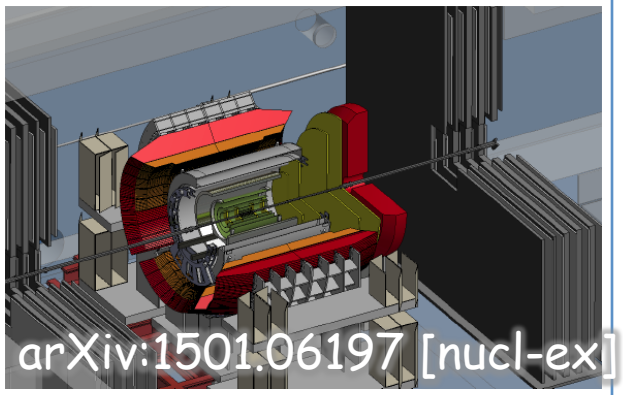
PHENIX experiment

- 16y+ operation
- Broad spectrum of physics (QGP, Hadron Physics, DM)
- 170+ physics papers with 24k citations
- Last run in this form 2016



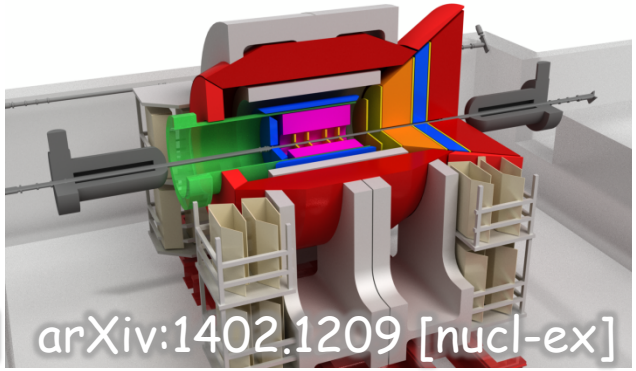
PHENIX

- Comprehensive central upgrade base on BaBar magnet
- Rich jet and beauty quarkonia physics program → nature of QGP
- Possible forward tracking, and calorimeter → Spin, CNM



An EIC detector

- Path of PHENIX upgrade leads to a capable EIC detector
- Large coverage of tracking, calorimetry and PID
- Open for new collaboration/ new ideas



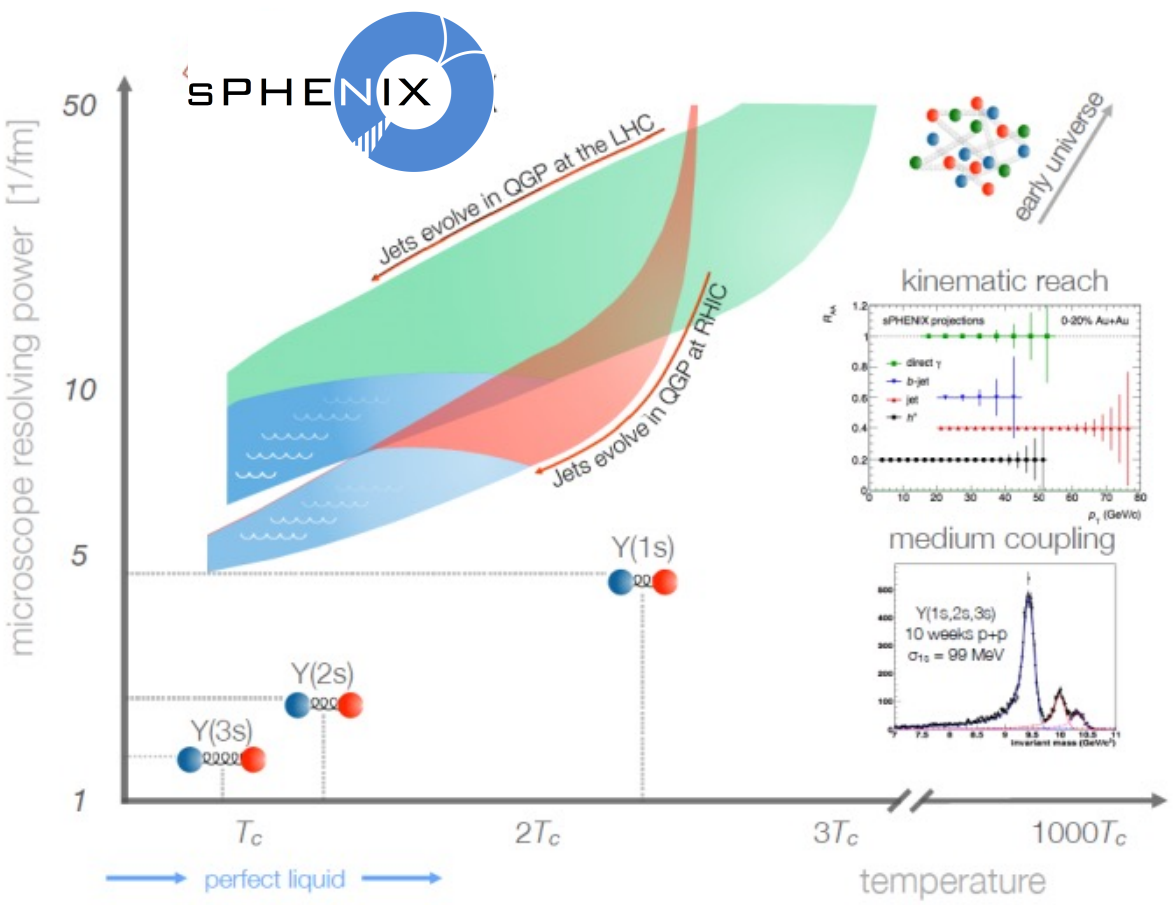
~2000 | 2017→2022, CD-0 @ 2016 | >2025 | Time

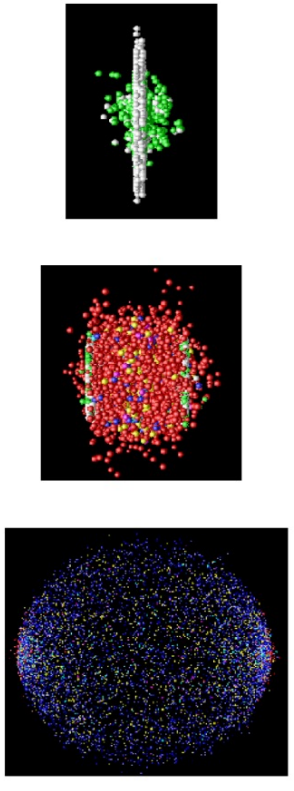
RHIC: A+A, spin-polarized p+p, spin-polarized p+A

EIC: e+p, e+A

Ultimate Mission of sPHENIX

Completion of the QGP Study at RHIC !!

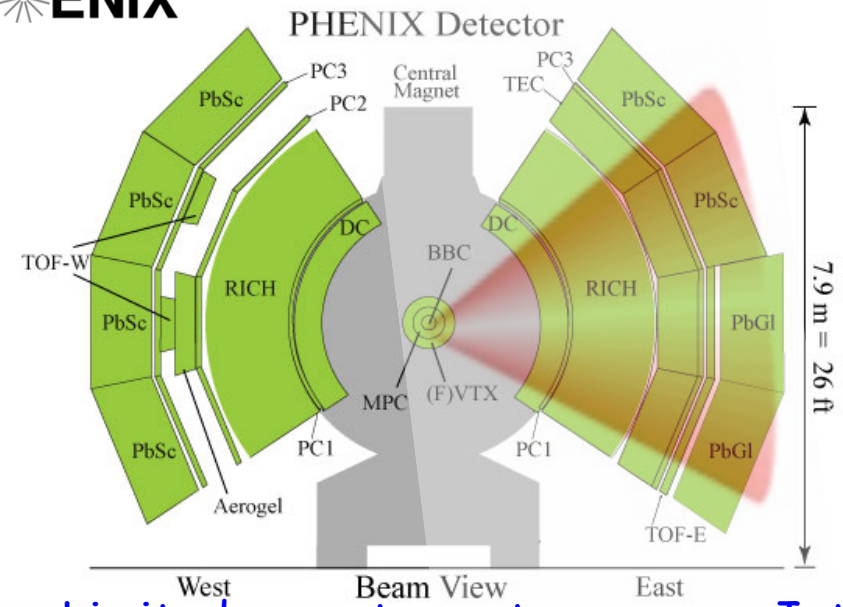




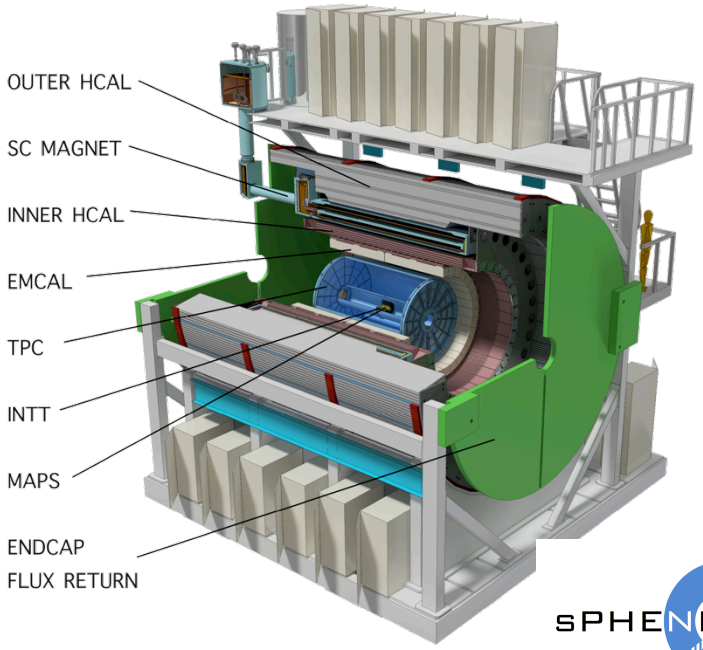
CD-0	Sept 2016
OPA CD-1 Review	May 2018
Construction Phase	Jul 2019
Ready for Beam	Jan 2023

Jet and heavy flavor as proves

What's new about sPHENIX

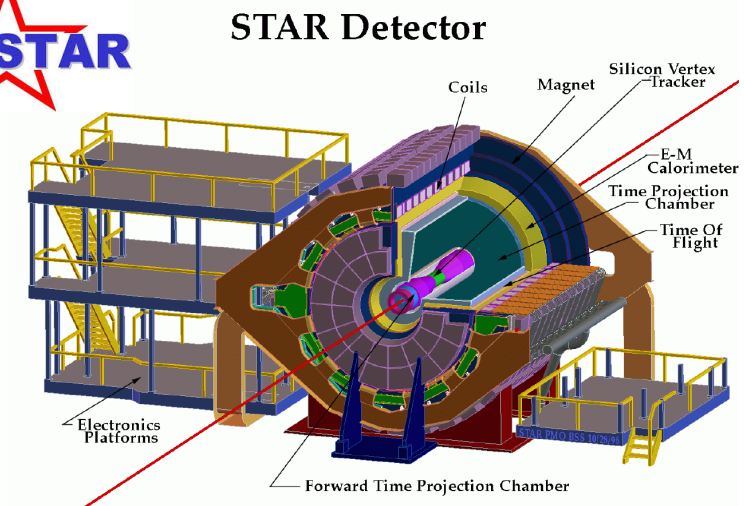


Limited acceptance to measure Jet.



sPHENIX

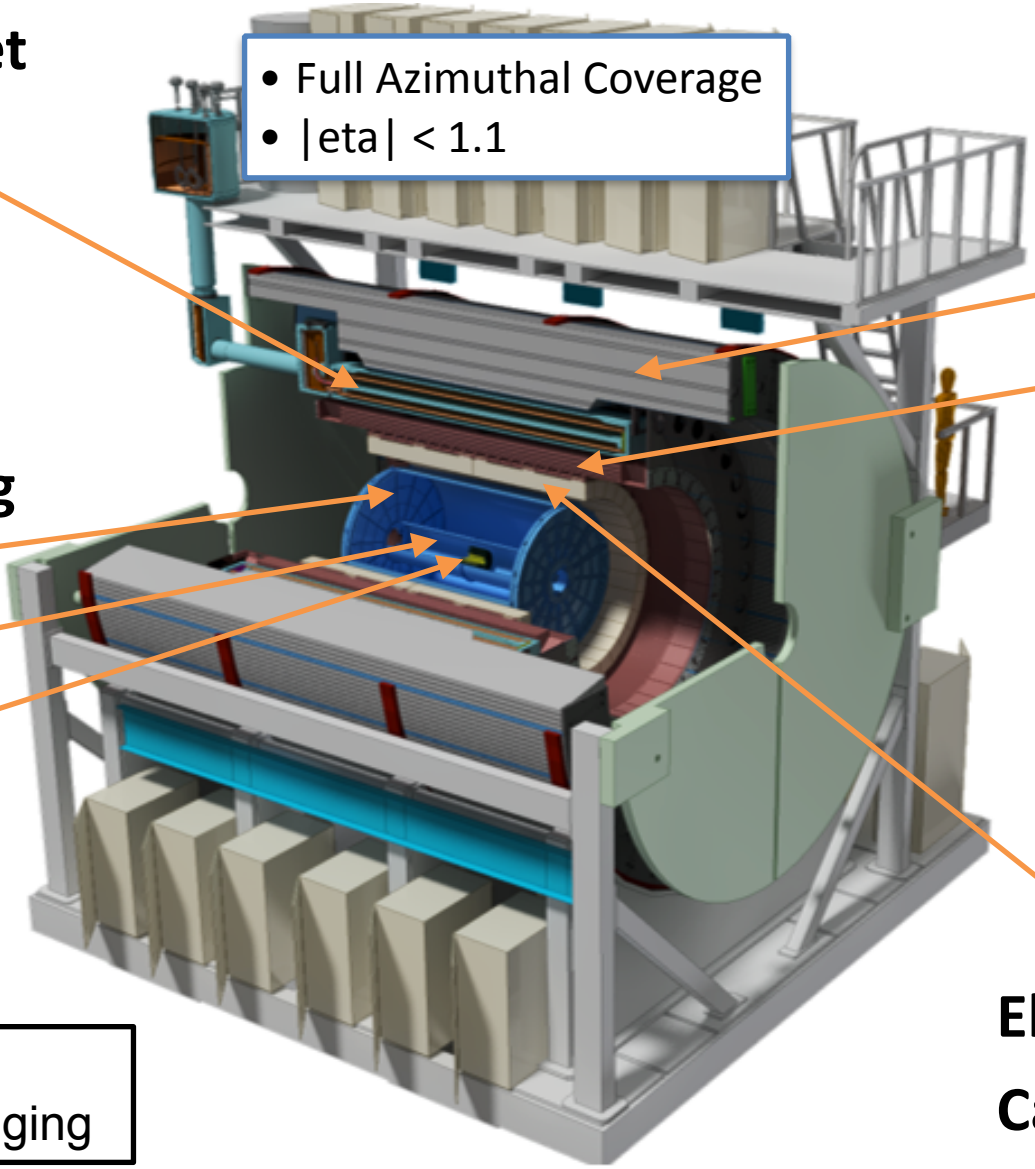
STAR



4π, but incomplete for jet without HCAL

4π & -1<η<1 with HCAL
Designed to be ideal detector for Jet

Detector Overview



Solenoid Magnet

- Full Azimuthal Coverage
- |eta| < 1.1

Hadronic Calorimeter

- Outer
- Inner

Central Tracking

- TPC
- INTT
- MVTX

Electromagnetic Calorimeter

15 kHz trigger
10 GB/s data logging

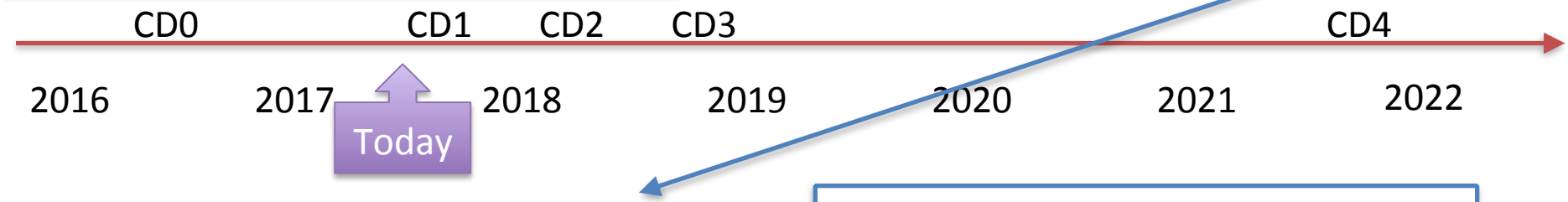
sPHENIX TimeLine

Detector Design
- Conceptual
- Preliminary
- Final

Construction

Installation and closeout

Start Data Taking



Year	System	Weeks	Samp. Lum, All Z
2022	Au+Au	16	34 nb^{-1}
2023	p+p	11.5	267 pb^{-1}
2023	p+Au	11.5	1.46 pb^{-1}
2024	Au+Au	23.5	88 nb^{-1}
2025	p+p	23.5	783 pb^{-1}
2026	Au+Au	23.5	92 nb^{-1}

200 GeV/c

Au+Au @ 200 GeV, |Z|<10 cm

Minimum Bias @ 15kHz
47B (2022) + 96B (2024) + 96B (2026) =
239 Billion Events

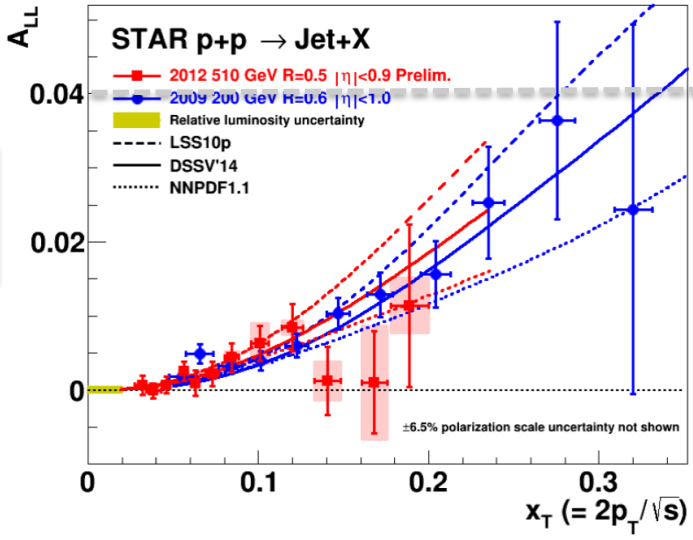
Level-1 Trigger (e.g. high pT photons)
550 Billion Events

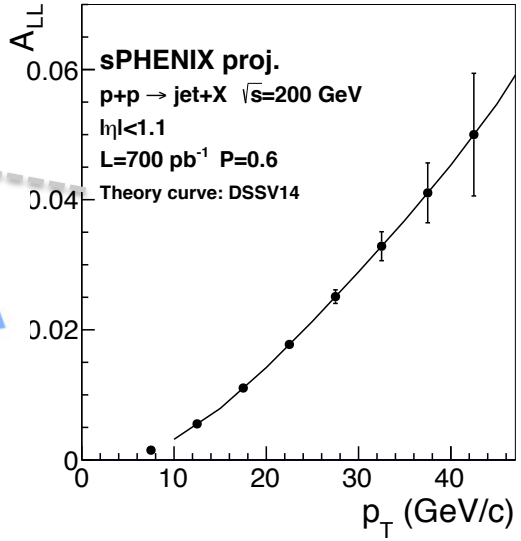
Au+Au @15kHz, All Z
1.5 Trillion Events

Quest for Gluon Spin

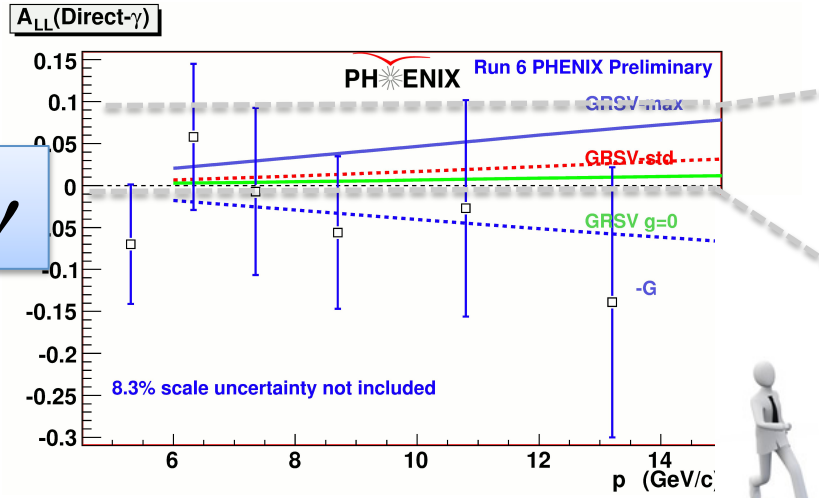
Drastic Improvement in statistics of Golden Probes

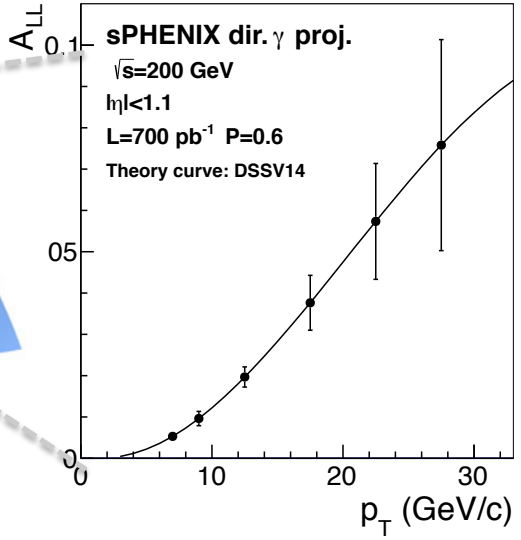
Jet





Direct -γ

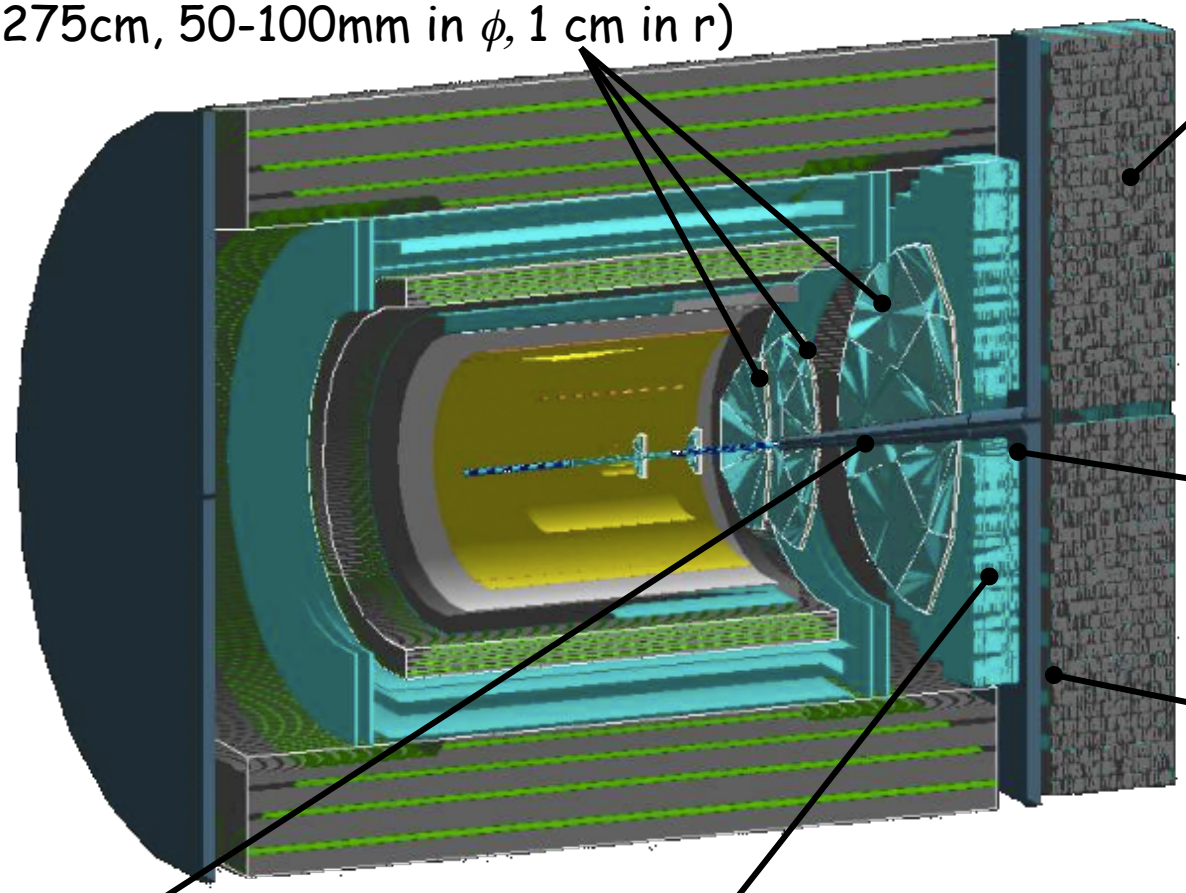




Physics Goals From Cold QCD Plan

- **Key Physics Observables:**
  - **Jets in polarized p+p:**
    - Jet A_N : Sivers/Twist-3 for u/d quarks
    - Angular distribution in jets : transversity
    - Di-Jet A_{LL} : Dg at low-x
  - **nFF's in p+A:**
    - Important measurement on the road to the EIC
  - **Drell-Yan and Direct Photons in p+A:**
    - Measurements of saturation, A-scan essential
  - **Diffraction in polarized p+p (200 GeV):**
    - A_{UT} from single-diffractive events
  - **Ultraperipheral Collisions in p+Au:**
    - "p-shine": gluon impact parameter distribution in Au nucleus via J/Y
    - "Au-shine": access GPD E_g in polarized p via J/Y production (A_{UT})
      - Sets the scale for a program to measure GPD E_g at the EIC!

Need Forward Rapidity Coverage!
BNL ALD has called for LOI's – June 2017



GEM/sTGC Tracking Stations (z = 120, 165, 275cm, 50-100mm in ϕ, 1 cm in r)

Pb/Sc sandwich hadronic calorimeter (NEW)
10 x 10 x 100 cm^3 towers
(1.2 < η < 4.0)

20x20 array of 2.2 x 2.2 x 18 cm^3 PbW (PHENIX MPC) crystals with 10x10 square hole (300 crystals total) 3.0-3.3 < η < 4.0

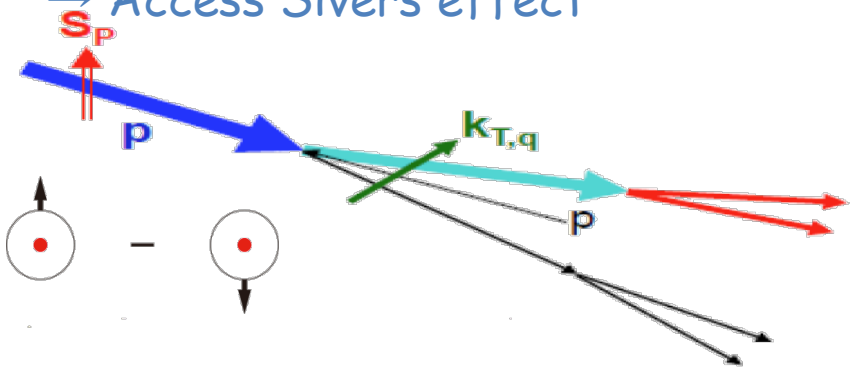
Flux return door between FEMC and FHCAL (10.2 cm)

Field shaper piston

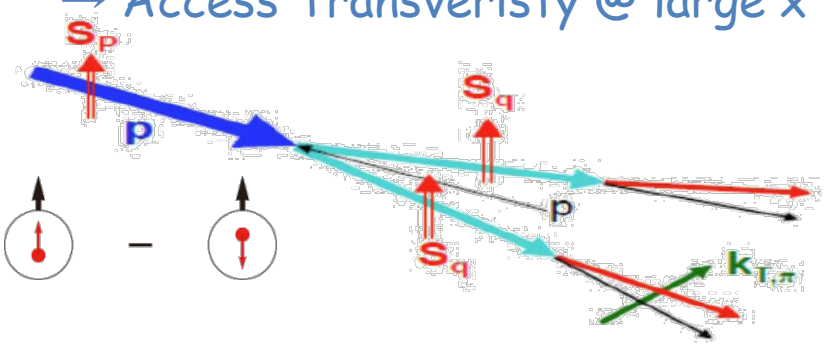
PHENIX PbSc modules (5.5 x 5.5 x 33 cm^3) organized in groups of four modules (3152 modules or 788 groups of 4) (1.4 < η < 3.0-3.3), energy resolution $8\%/\sqrt{E}$

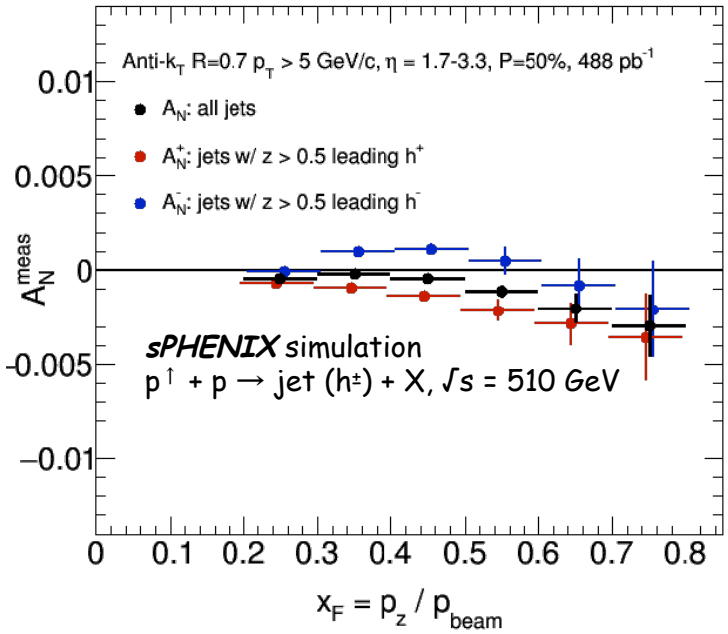
Forward jet → origin of transverse A_N

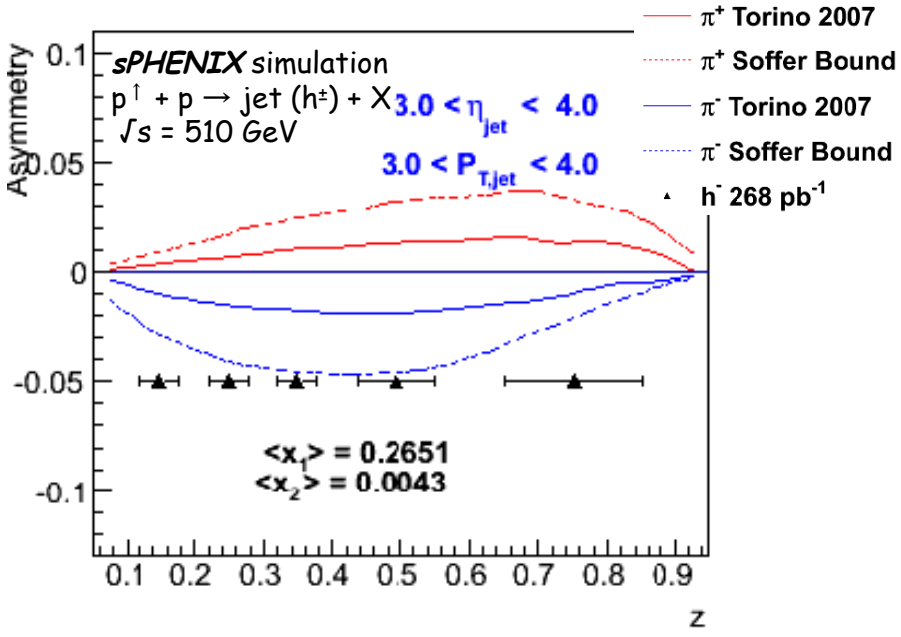
Charge-track tagged jet asymmetry
→ Access Sivers effect



Charge-track asymmetry in jet
→ Access Transveristy @ large x





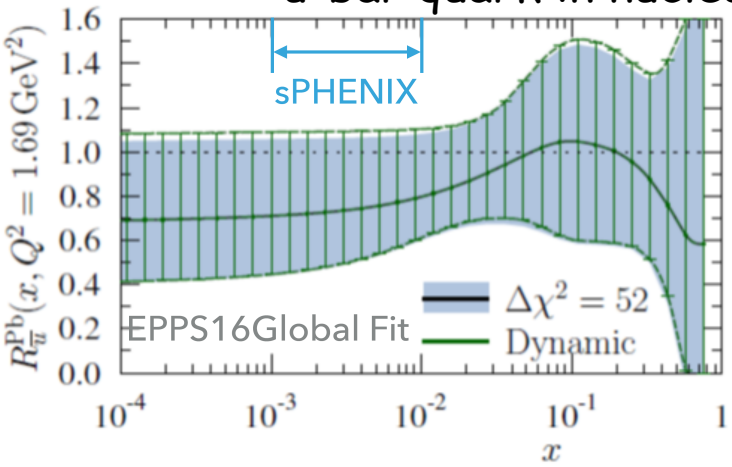


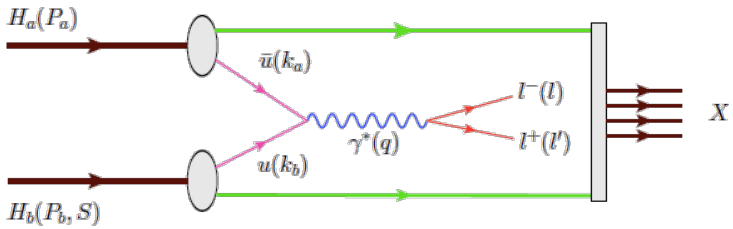
Check universality of Transversity @ SIDIS

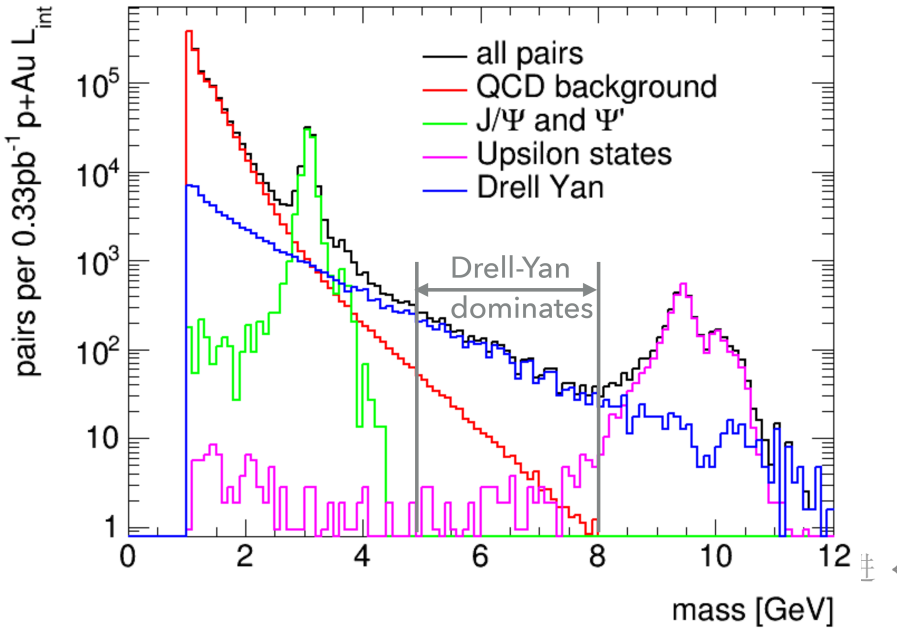
Forward DY

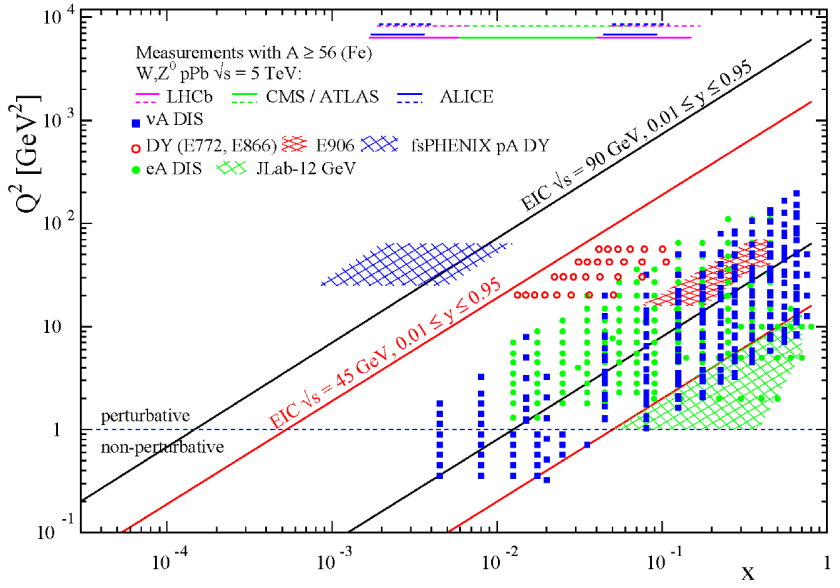
- DY in p+A provides clean access to sea quark distribution
  → gluon in nuclei
- fsPHENIX measure DY via di-electron final states
- Benefit from continuous and large calorimetry + tracking coverages

u-bar quark in nuclear

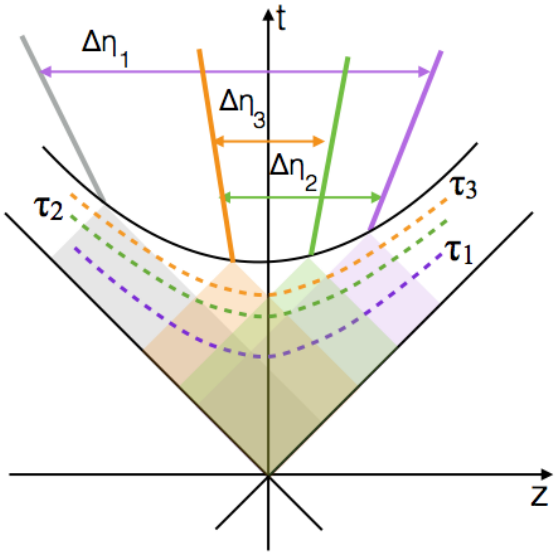






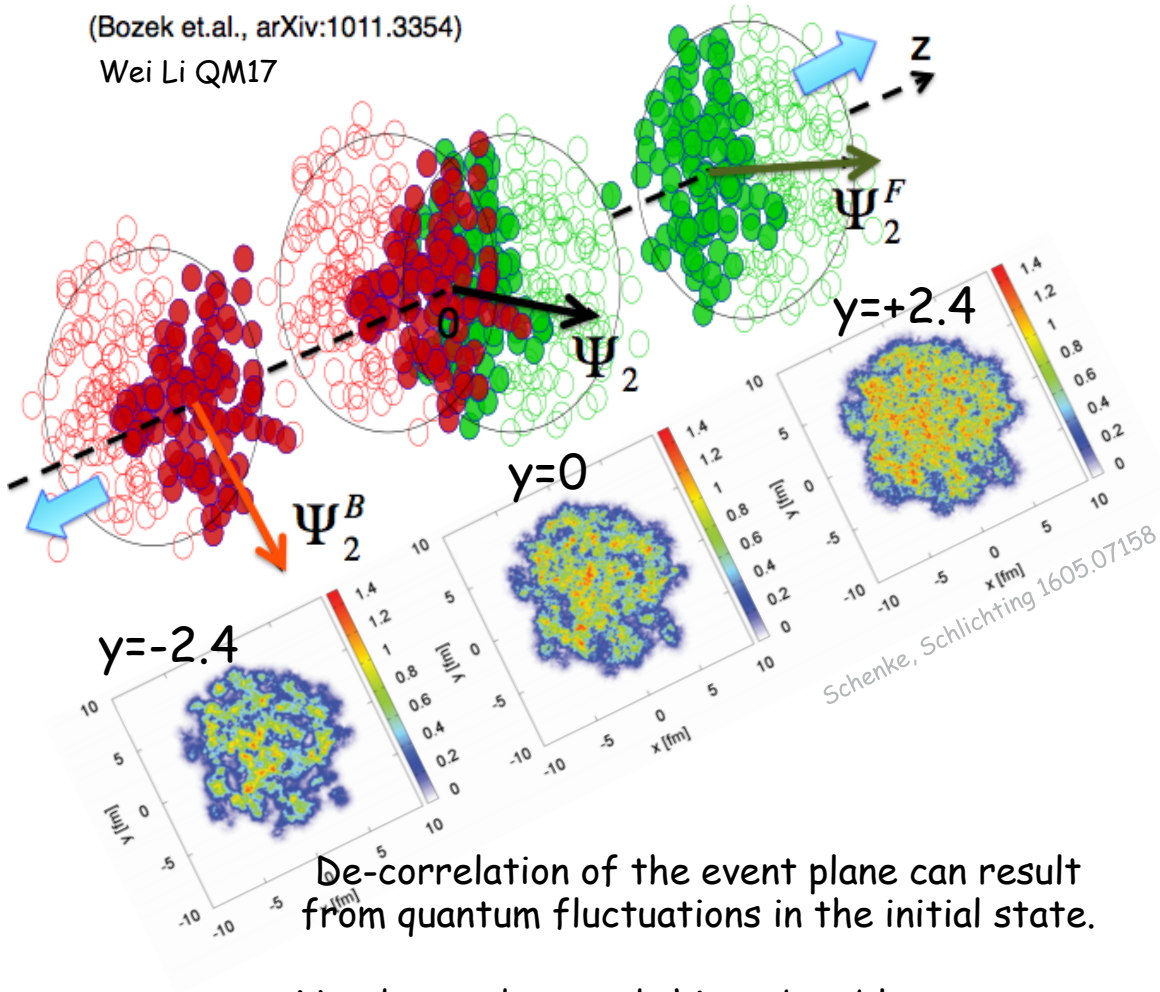


Heavy Ion Program with fsPHENIX



Due to causality, correlations that are widely separated in rapidity probe the earliest times.

Adding forward capabilities to sPHENIX will enable a new, complementary physics program to study the initial conditions in HI collisions.



De-correlation of the event plane can result from quantum fluctuations in the initial state.

Need to understand this to be able to extract $\eta/s(T)$ from hydrodynamic models.

Documentations

- sPHENIX Proposal (https://arxiv.org/pdf/1501.06197v1.pdf)
- sPHENIX CDR
- Medium-Energy Nuclear Physics Measurements with the sPHENIX Barrel
- sPHENIX Forward Instrumentation LOI

PHENIX

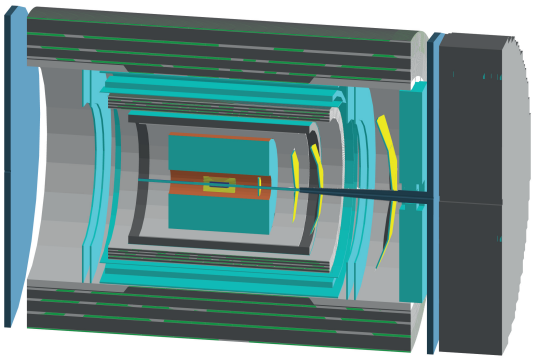
An Upgrade Proposal from the PHENIX Collaboration

November 19, 2014

sPHENIX-note sPH-cQCD-2017-001

sPHENIX Forward Instrumentation

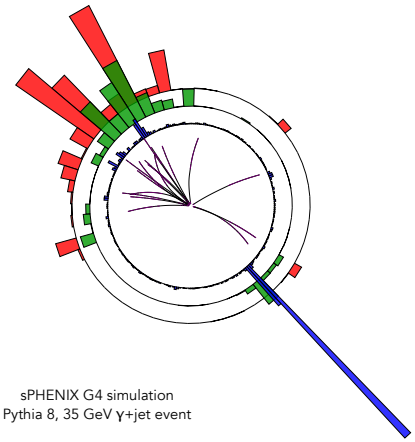
A Letter of Intent



The sPHENIX Collaboration
June 2017

sPHENIX-note sPH-cQCD-2017-002

Medium-Energy Nuclear Physics Measurements with the sPHENIX Barrel



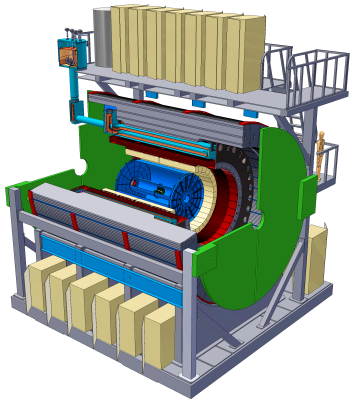
sPHENIX G4 simulation
Pythia 8, 35 GeV γ+jet event

The sPHENIX Collaboration
October 10, 2017

PHENIX

sPHENIX Conceptual Design Report

DRAFT VERSION 1.6
July 26, 2017



Summary

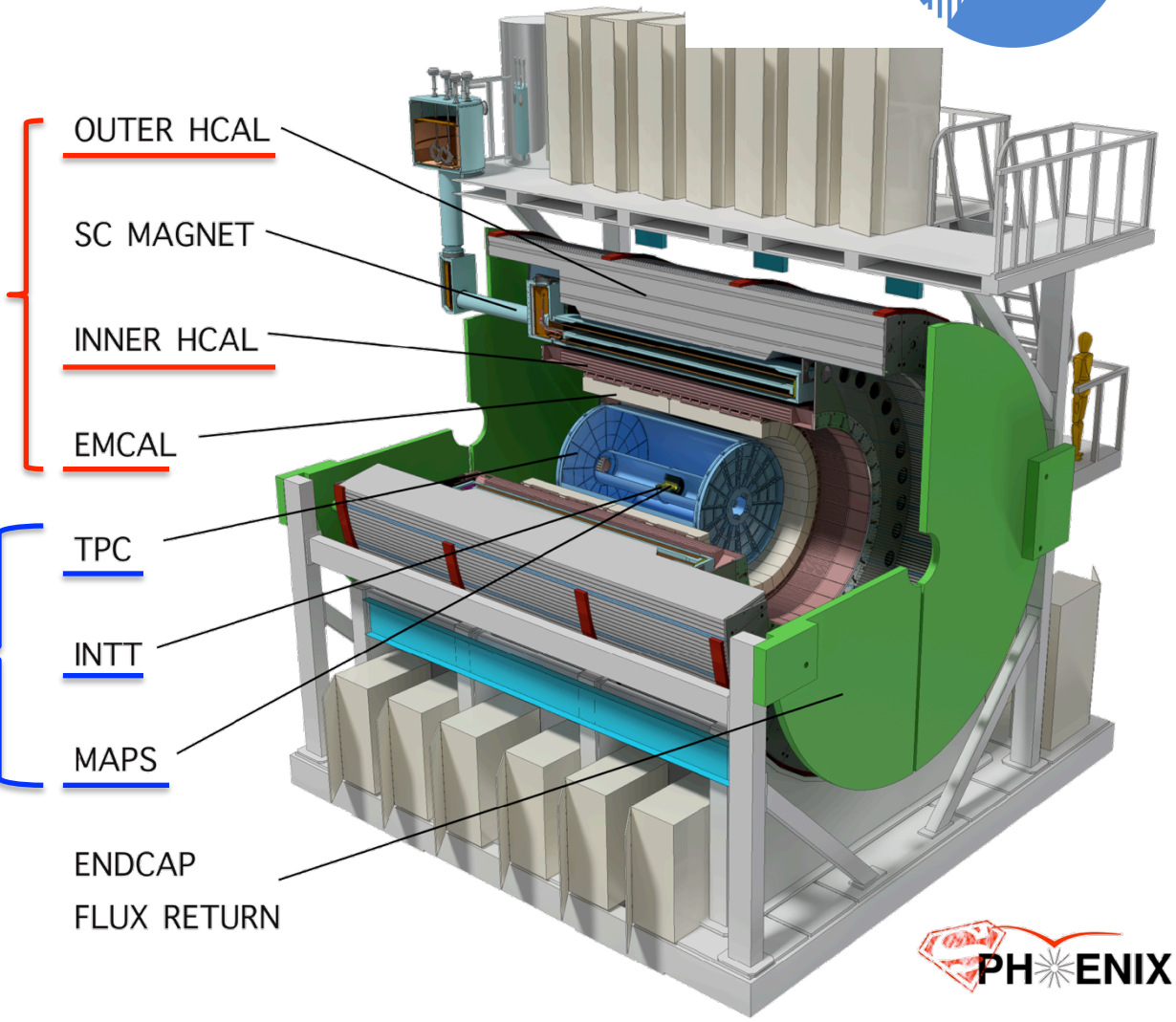
- sPHENIX: Study QGP with precision jet and beauty quarkonia @ RHIC
  - Completing scientific mission @ RHIC
- Hadronic physics opportunities in sPHENIX and proposed forward detector upgrade
  - Complementarity of hadronic collisions and DIS, e.g. JLab, COMPASS, EIC
- sPHENIX received CD-0 approved, in preparation for CD-1. Planned data taking start 2022.
- sPHENIX detector has advanced design.
  - Forward upgrade and EIC: many opportunities for joint detector R&D

BACKUP SLIDES

Detector Configuration

sPHENIX

EM & Hadron Calorimeters



# of Tracking stations
- MAPS:3
- INTT:4
- TPC:60

Momentum Resolution
~100 MeV/c

15 kHz trigger
10 GB/s data logging

PHENIX

Kinematic Coverage