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

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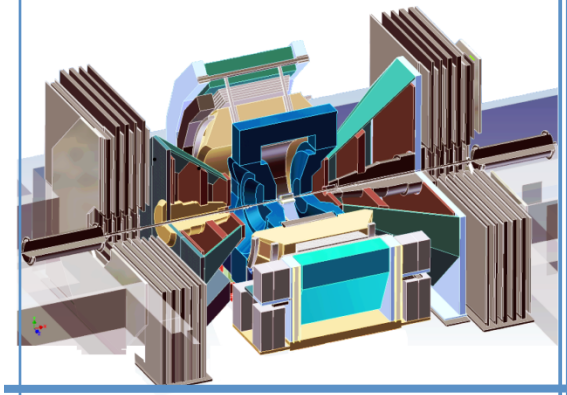
Evolution of the PHENIX Interaction region

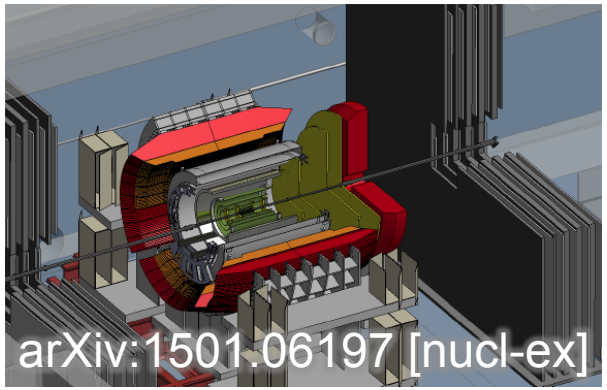
PHENIX experiment

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



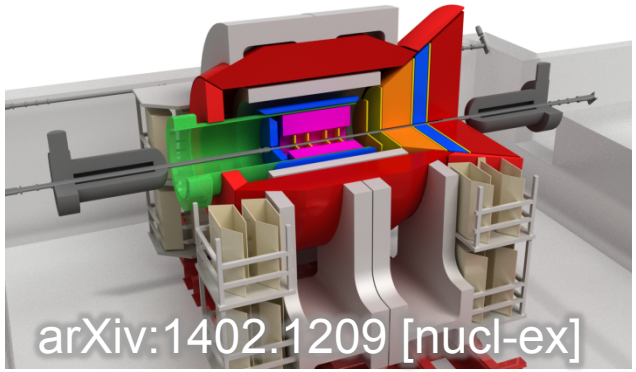
PHENIX

- 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



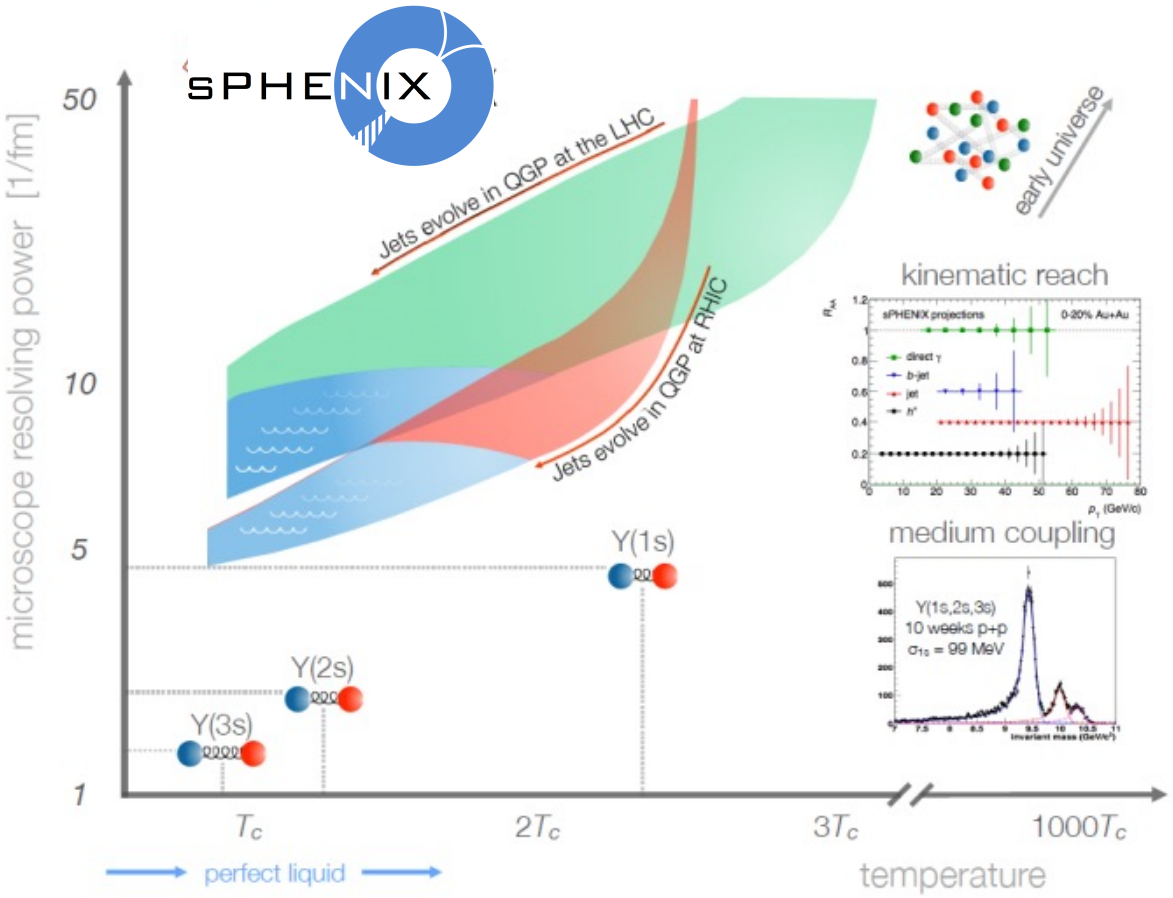
~2000 | 2017→2022, CD-0 @ 2016 | >2025 | Time

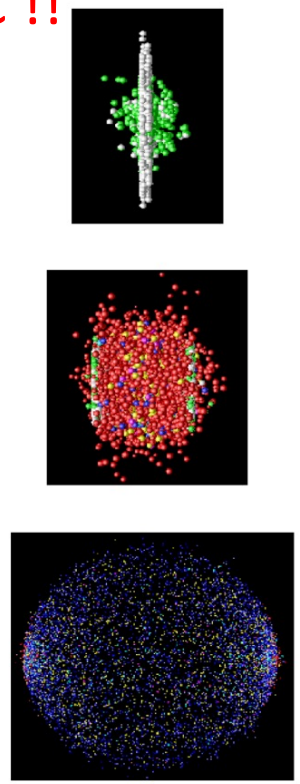
RHIC: A+A, spin-polarized p+p, spin-polarized p+A

EIC: e+p, e+A

Ultimate Mission of sPHENIX

Completion of the QGP Study at RHIC !!



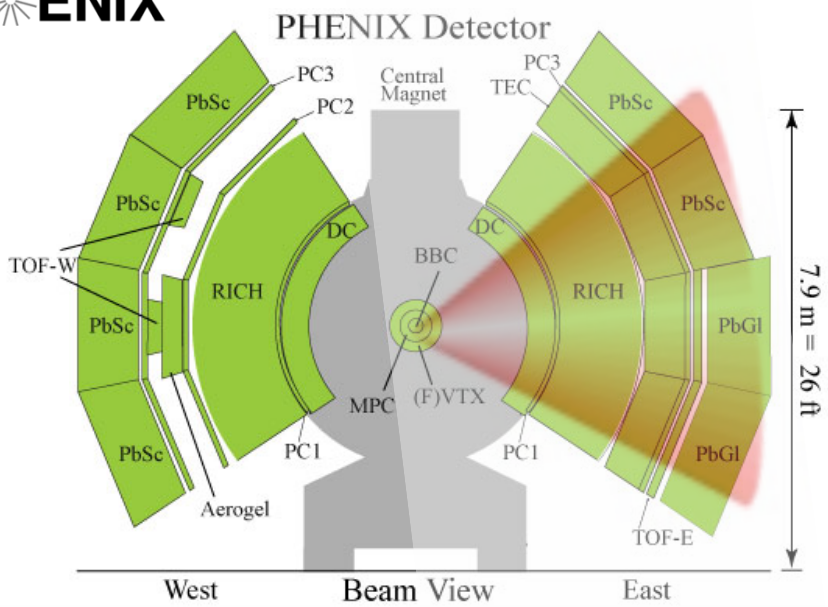


CD-0	**Sept 2016**
OPA CD-1 Review	**May 2018**
Construction Phase	**Jul 2019**
Ready for Beam	**Jan 2023**

Jet and heavy flavor as proves

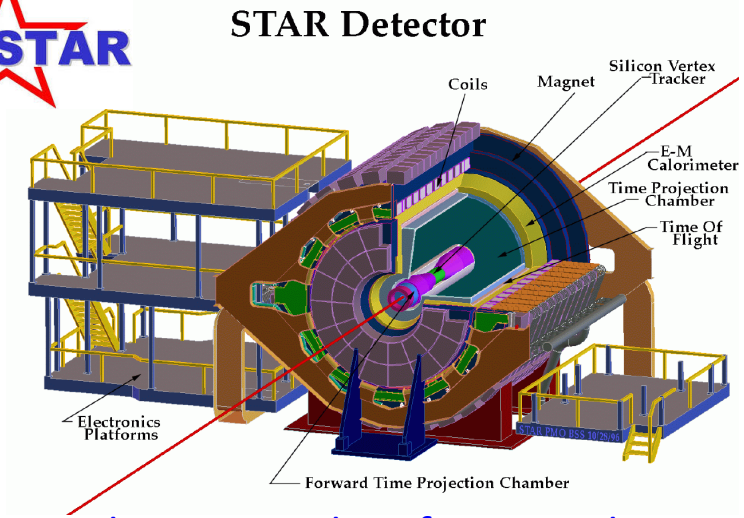
What's new about sPHENIX

PHENIX

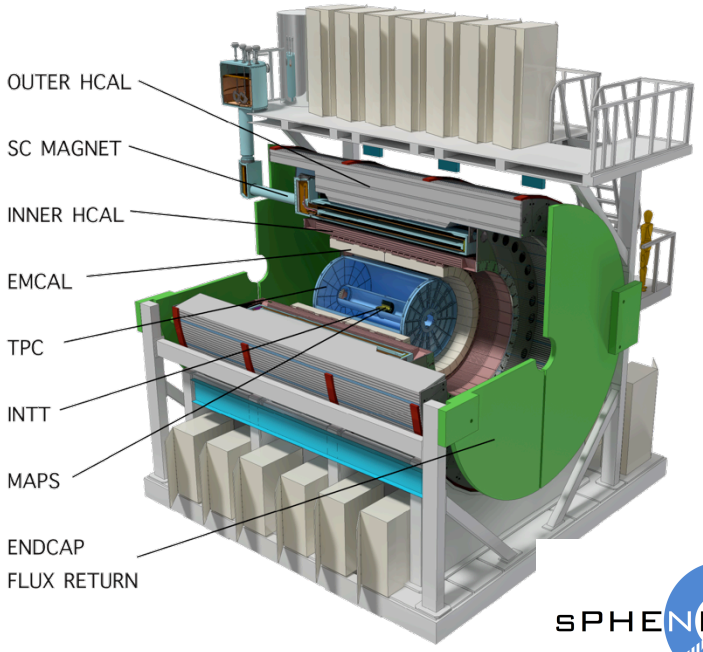


Limited acceptance to measure Jet.

STAR



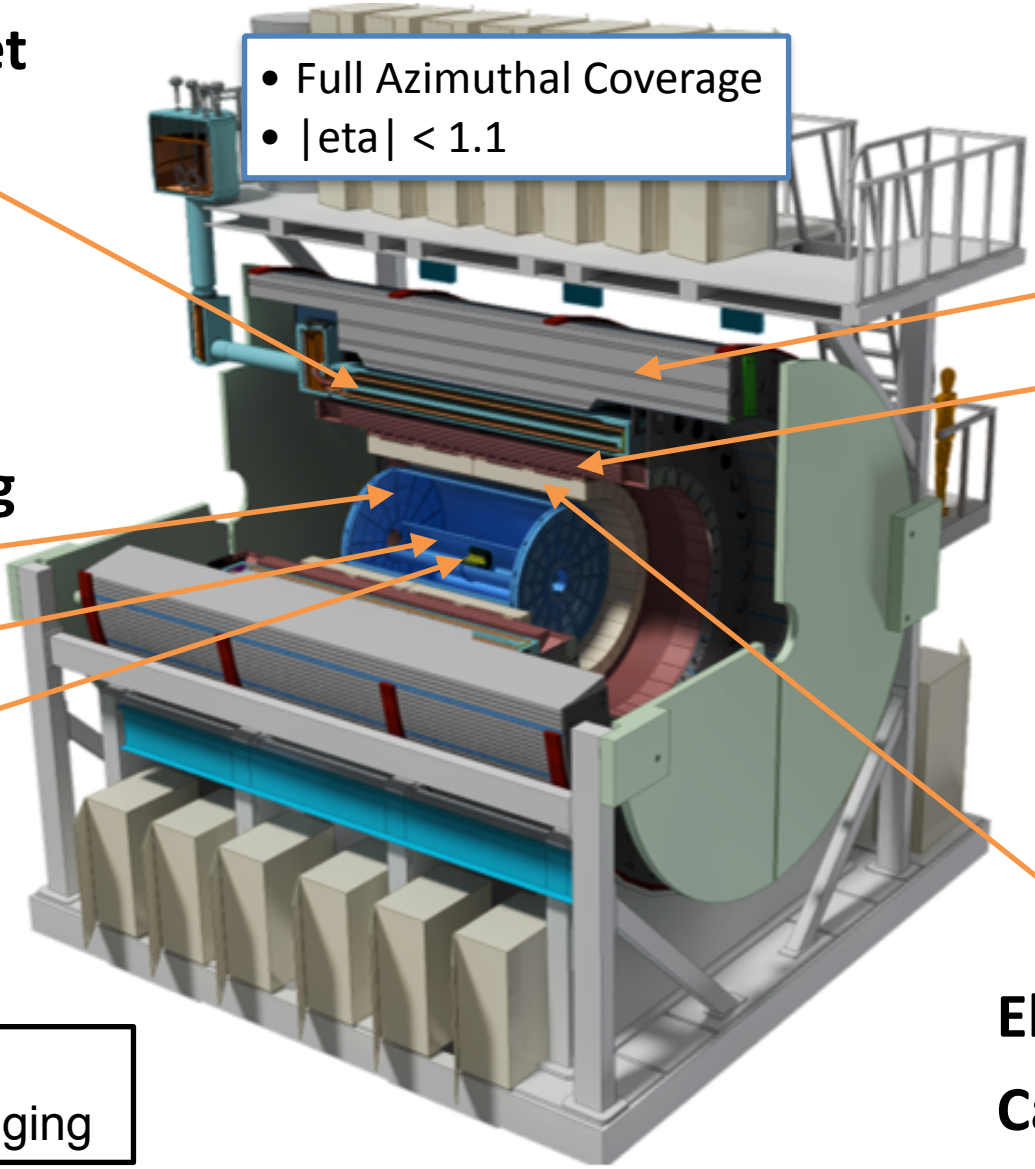
4π, but incomplete for jet without HCAL



sPHENIX

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

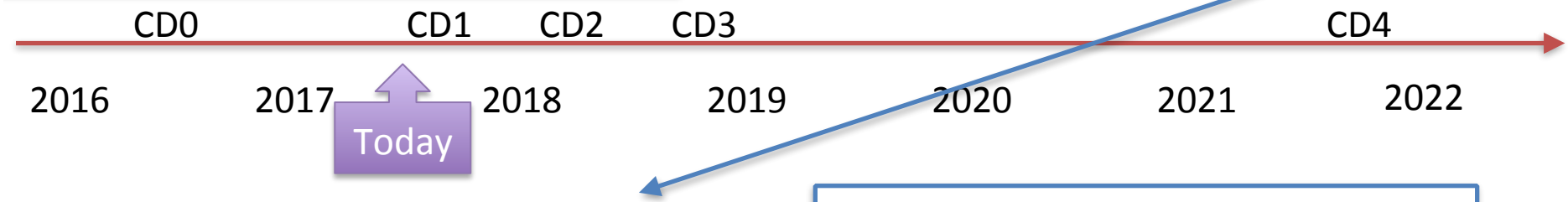
sPHENIX TimeLine

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

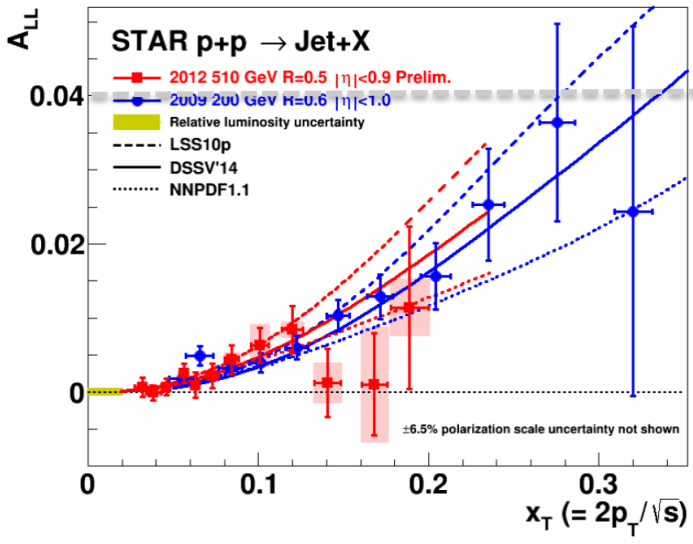
Level-1 Trigger (e.g. high pT photons)
550 Billion Events

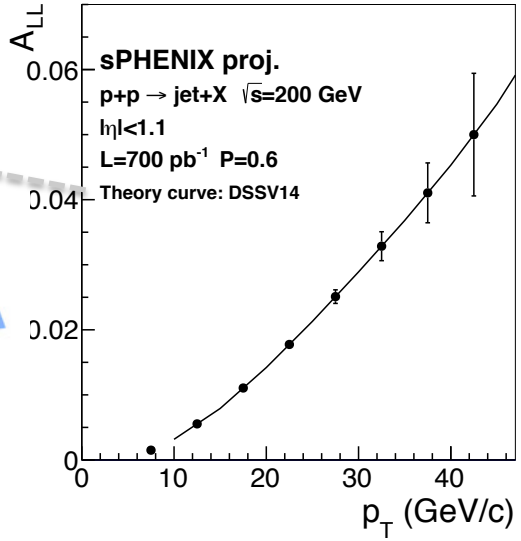
Au+Au @15kHz, All Z
1.5 Trillion Events

Quest for Gluon Spin

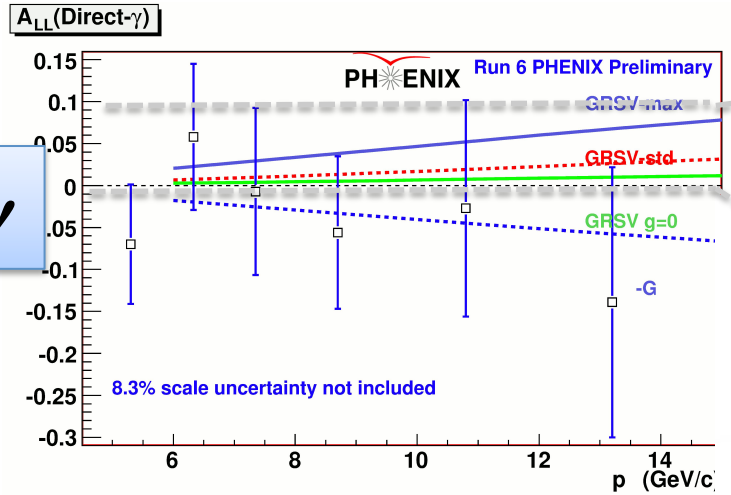
Drastic Improvement in statistics of Golden Probe

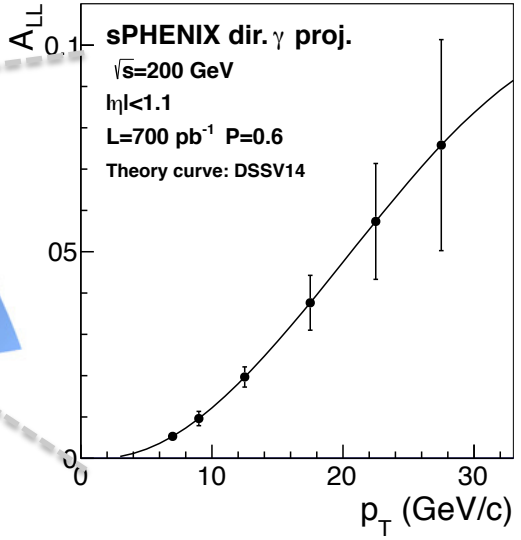
Jet





Direct -γ

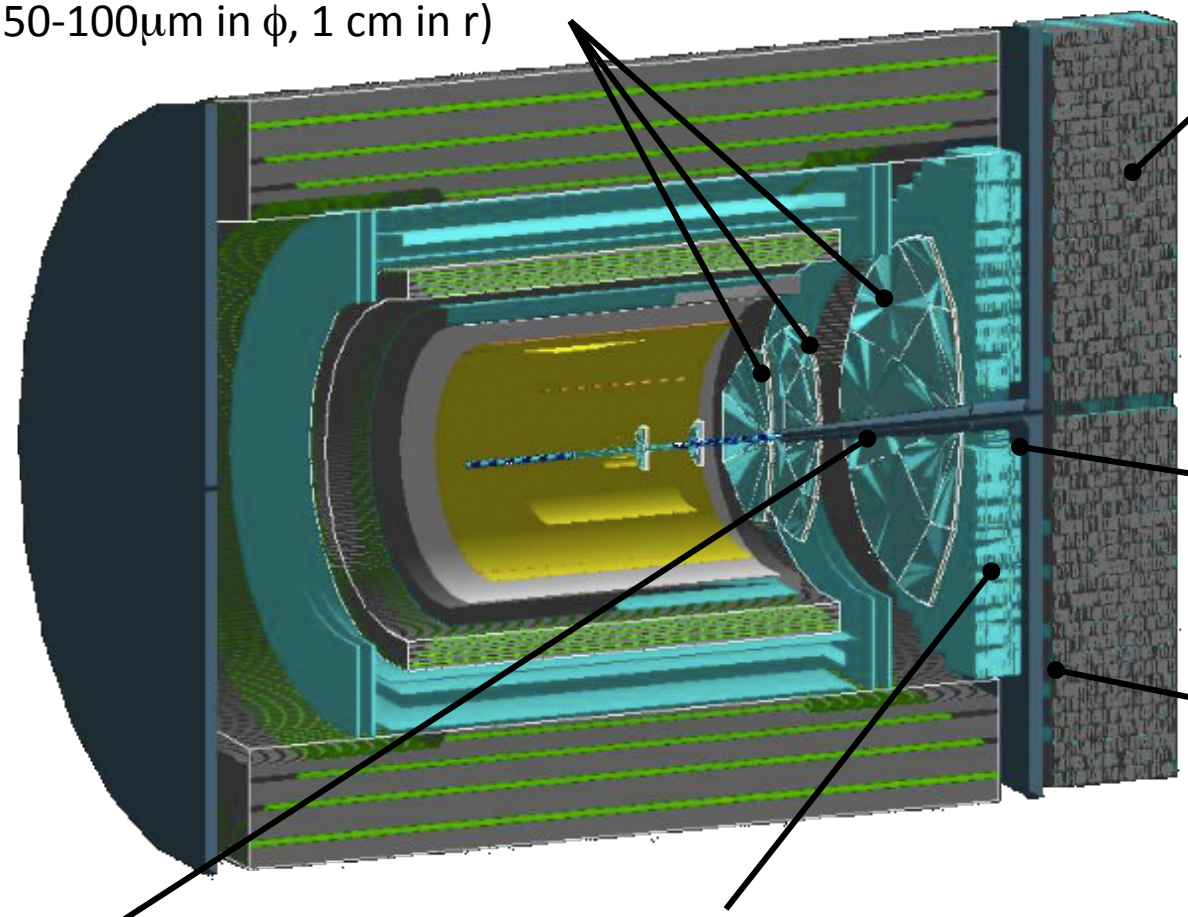




Physics Goals From Cold QCD Plan

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

- **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} : Δg 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/Ψ
    - "Au-shine": access GPD E_g in polarized p via J/Ψ production (A_{UT})
      - Sets the scale for a program to measure GPD E_g at the EIC!



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

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

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

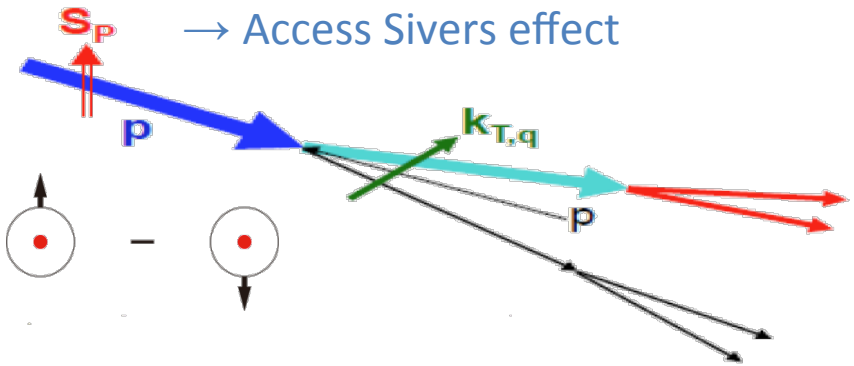
Flux return door between FEMC and FHCAL (10.2 cm)

Field shaper piston

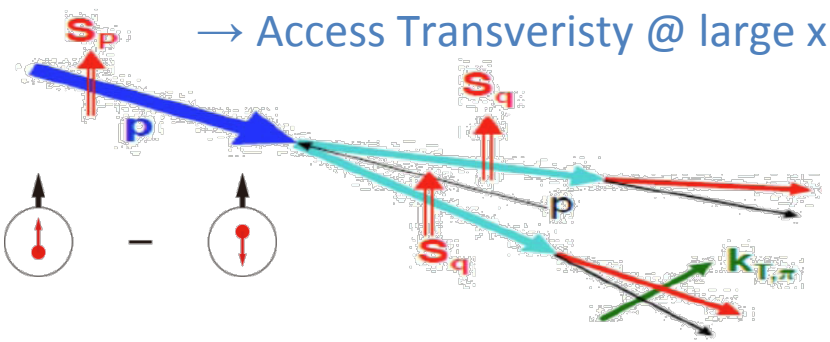
PHENIX PbSc modules (5.5 x 5.5 x 33 cm^3) organized in groups of four modules (3152 modules or 788 groups of 4)
($1.4 < \eta < 3.0\text{-}3.3$), energy resolution $8\%/\sqrt{E}$

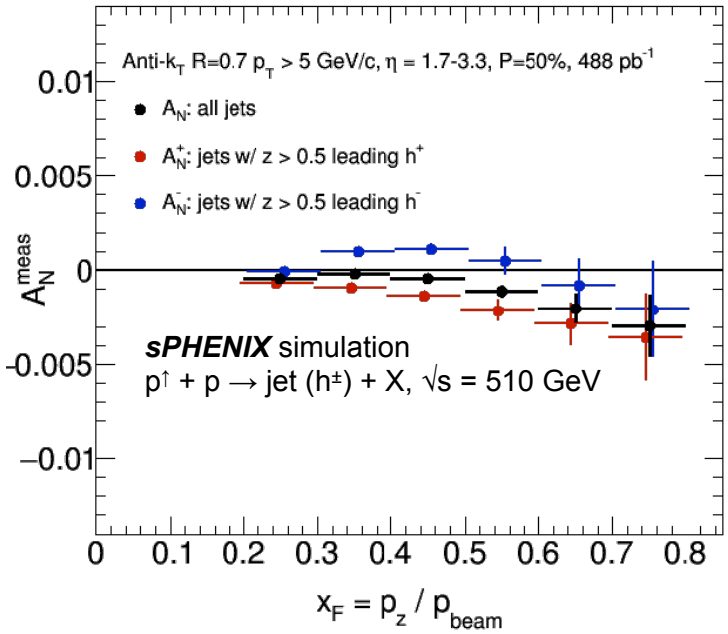
Forward jet ⟶ origin of transverse A_N

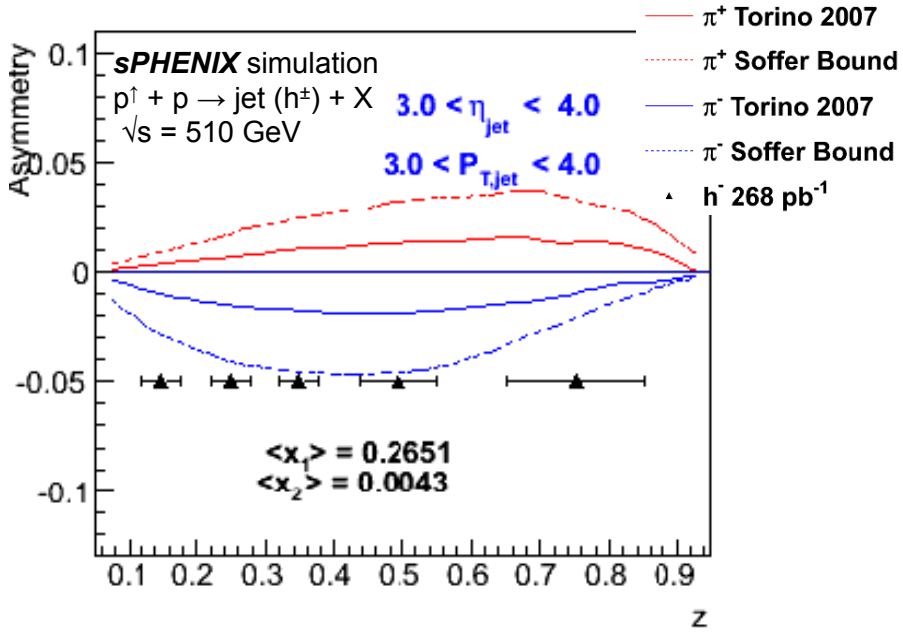
Charge-track tagged jet asymmetry
⟶ Access Sivers effect



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



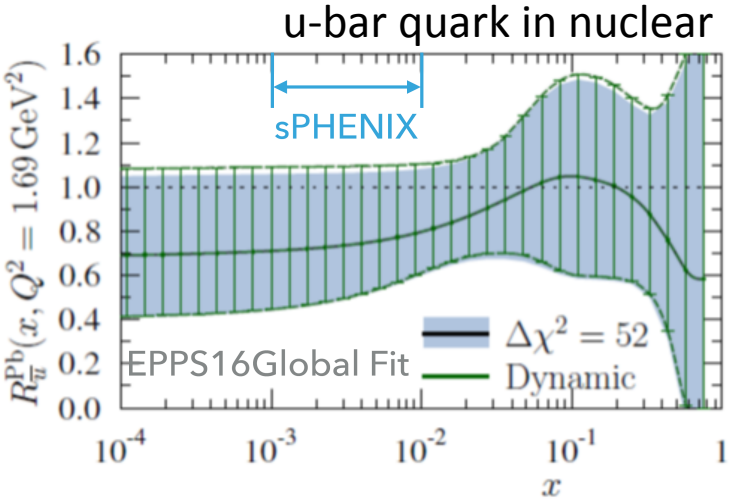


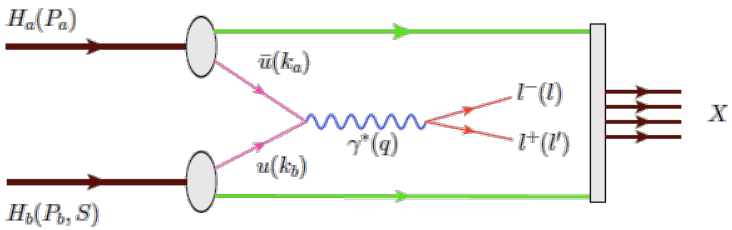


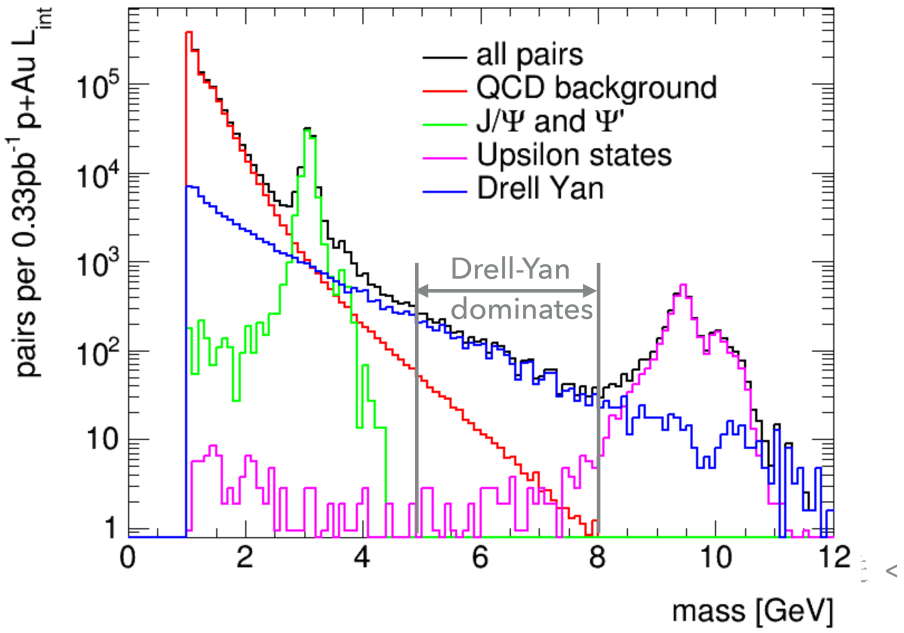
Check universality of Transversity @ SIDIS

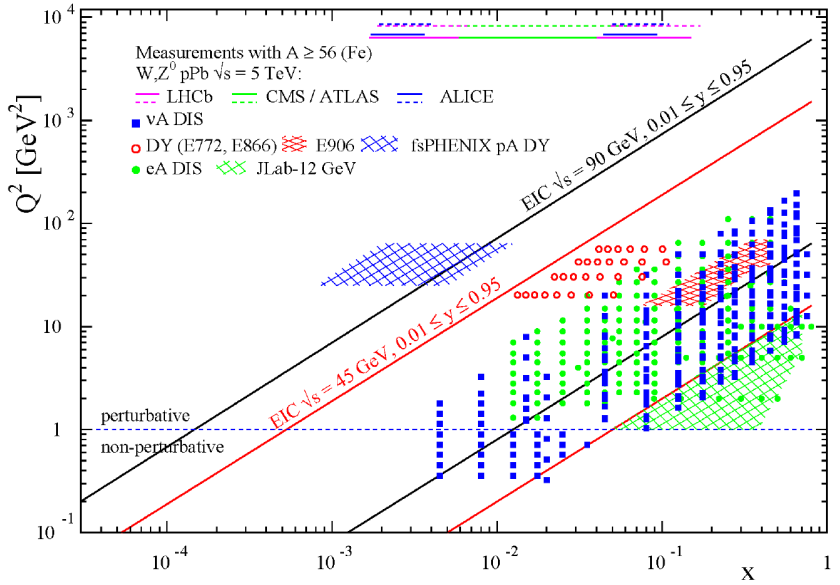
Forward DY

- 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

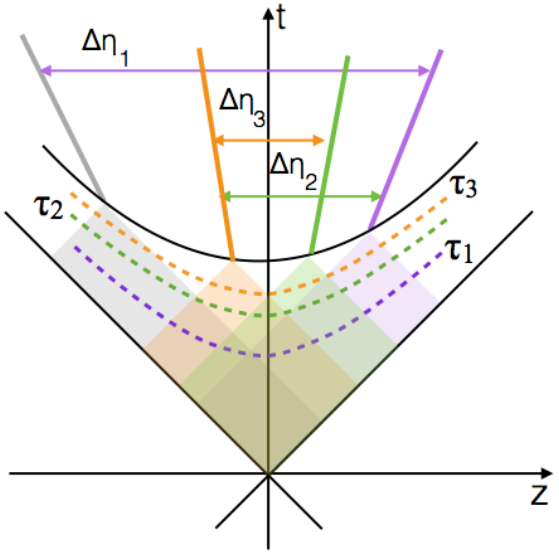






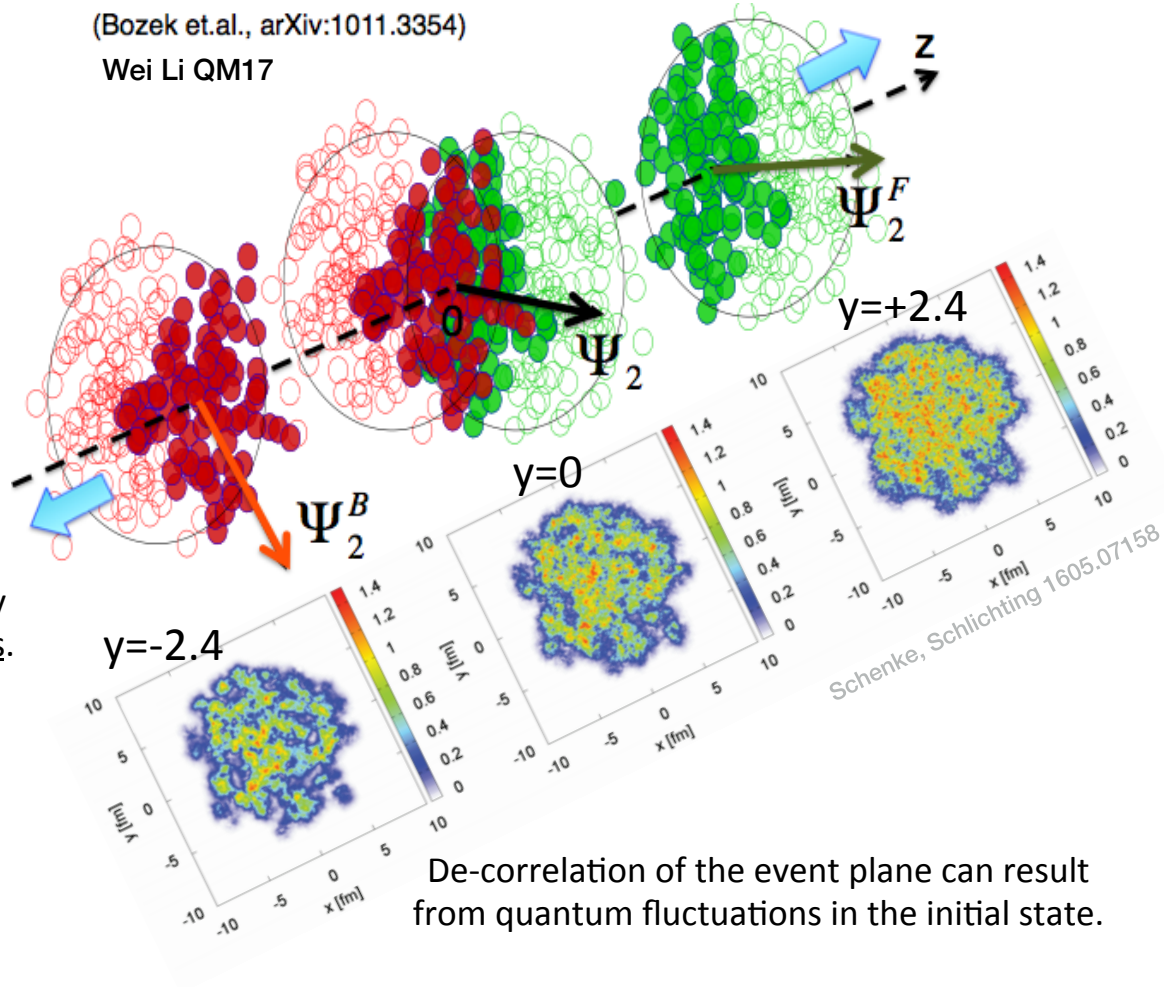


Heavy Ion Program with fsPHENIX



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

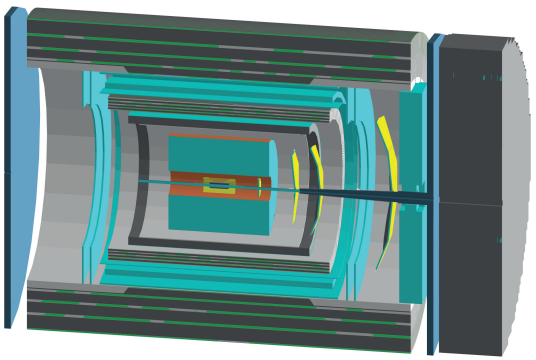
sPHENIX-note sPH-cQCD-2017-001

sPHENIX Forward Instrumentation

A Letter of Intent

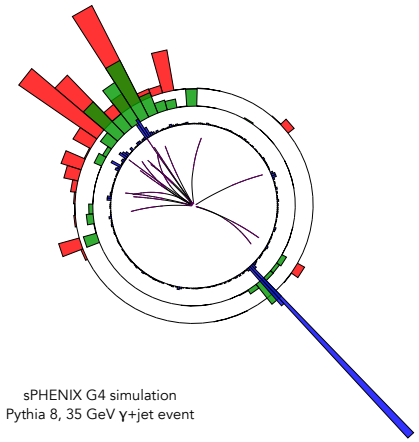
The sPHENIX Collaboration

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

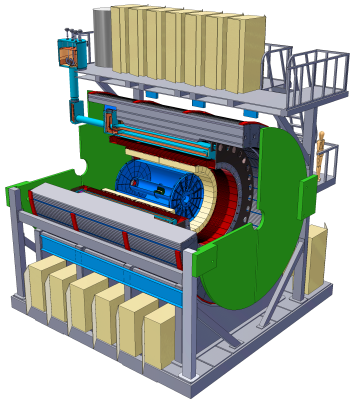
October 10, 2017

PHENIX

sPHENIX Conceptual Design Report

DRAFT VERSION 1.6

July 26, 2017



Summary

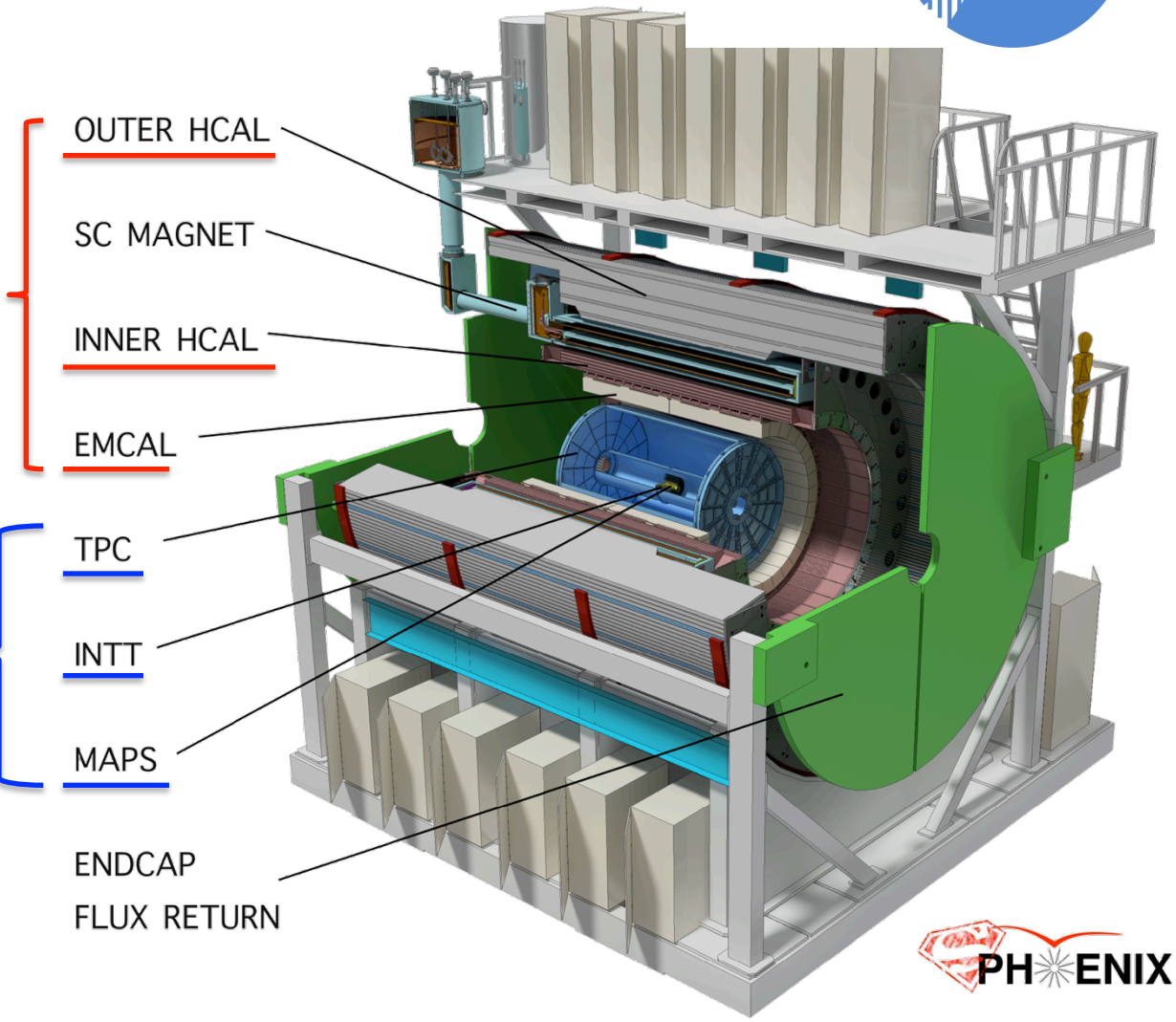
- sPHENIX: Study QGP with precision jet and beauty quarkonia @ RHIC
  - Completing scientific mission @ RHIC
- Hadronic physics opportunities in sPHENIX and proposed forward detector upgrade
  - Complementarity of hadronic collisions and DIS, e.g. JLab, COMPASS, EIC
- sPHENIX received CD-0 approved, 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