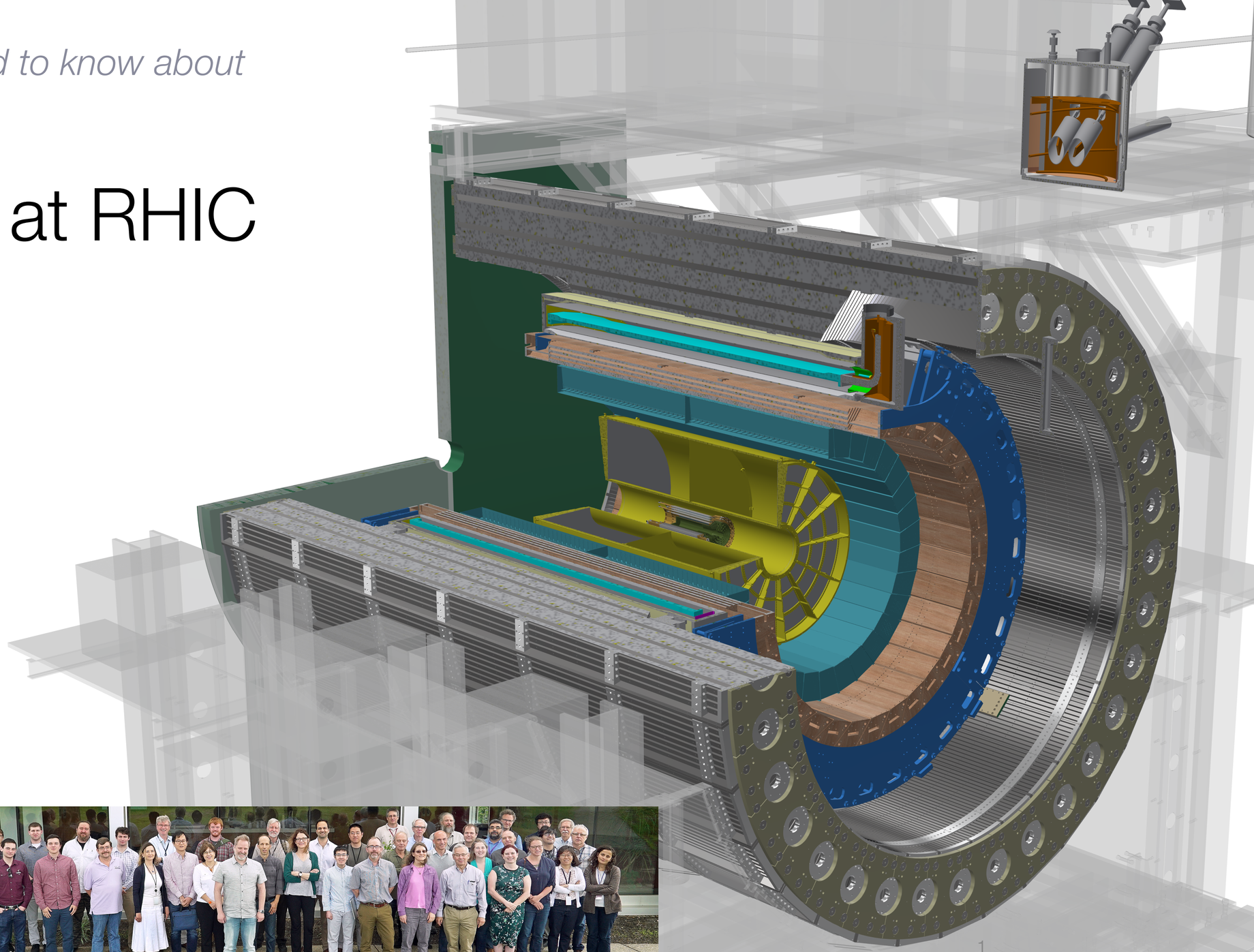
Everything you always wanted to know about

sPHENIX at RHIC

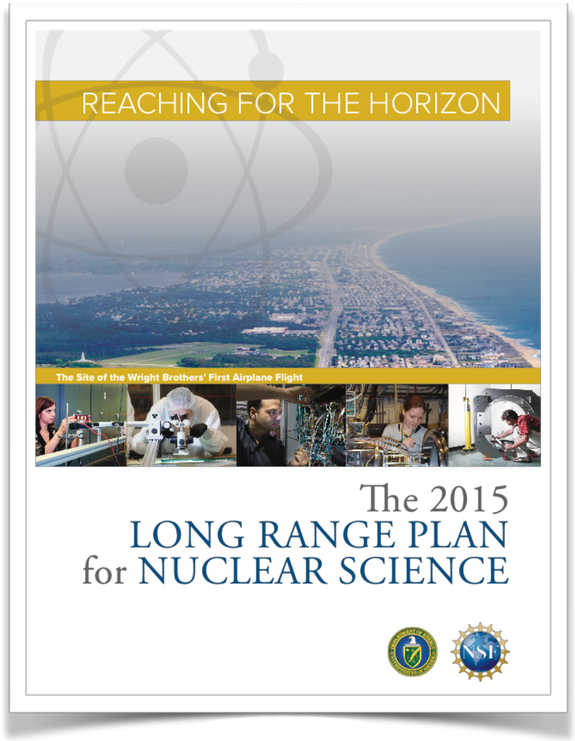


Gunther Roland for the
sPHENIX Collaboration

What is the sPHENIX science mission?

sPHENIX Science Mission

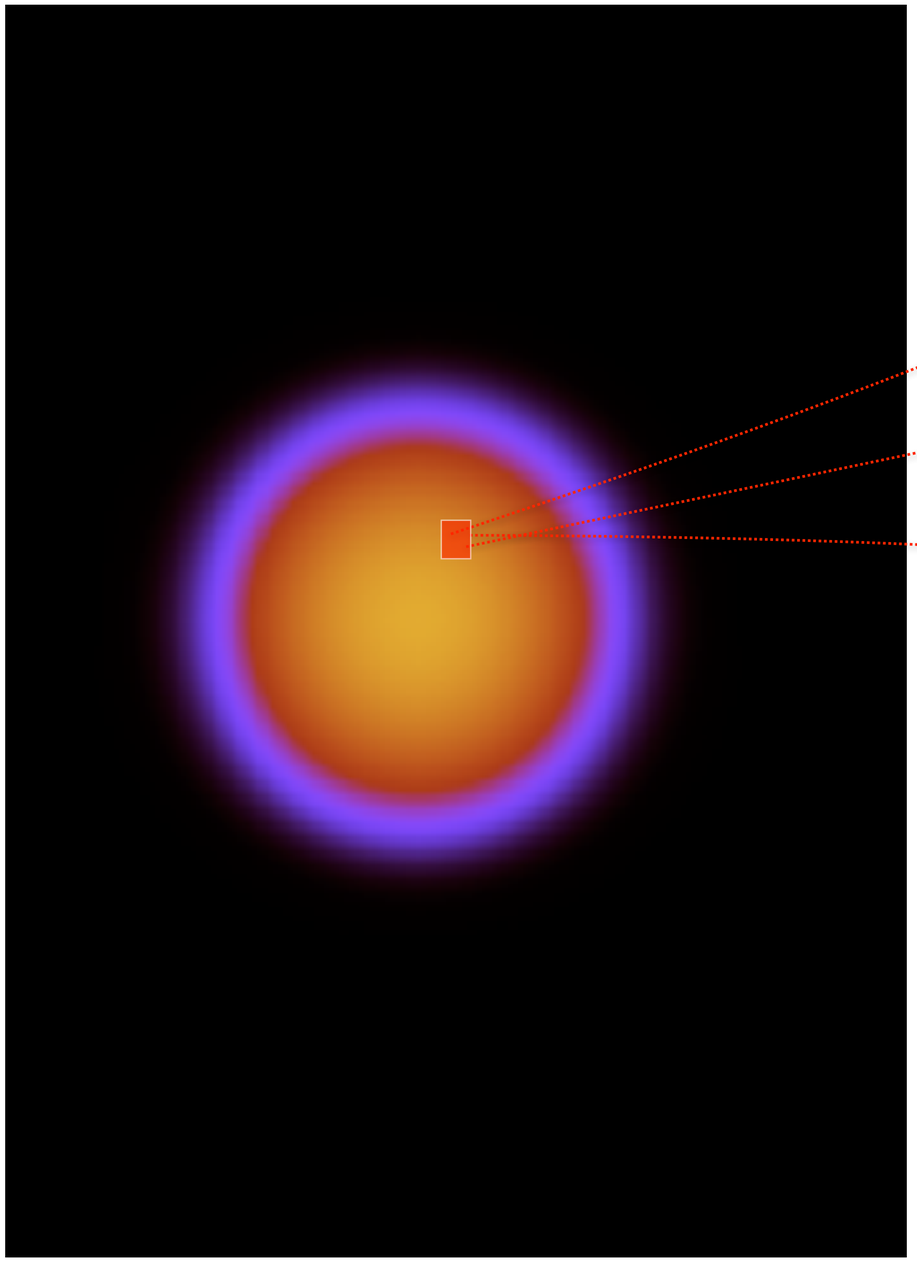
http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf

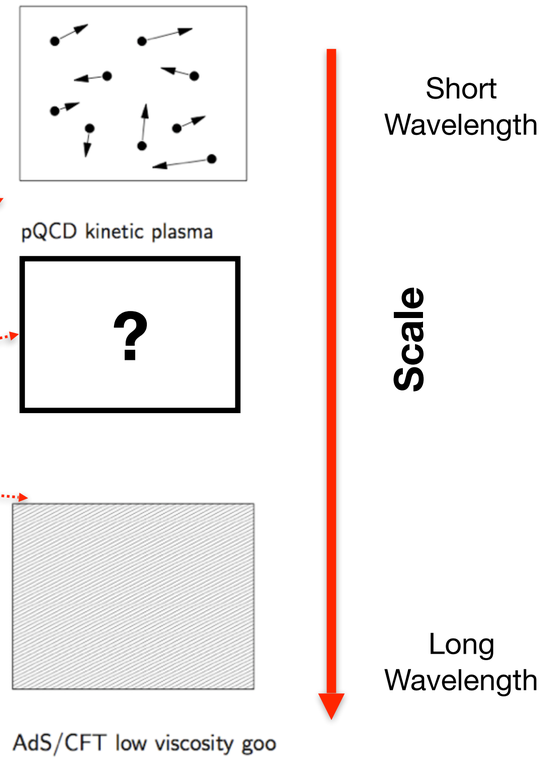


Section 2.2, page 22

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 Science Mission

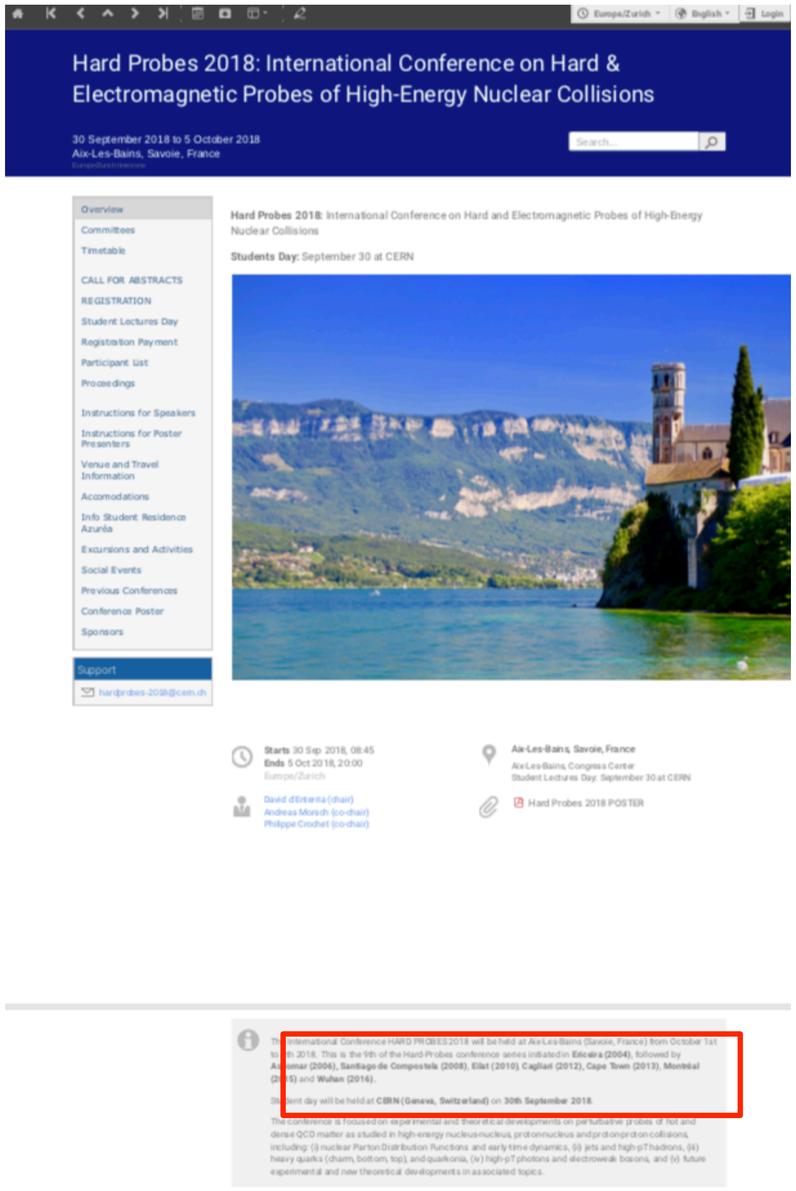




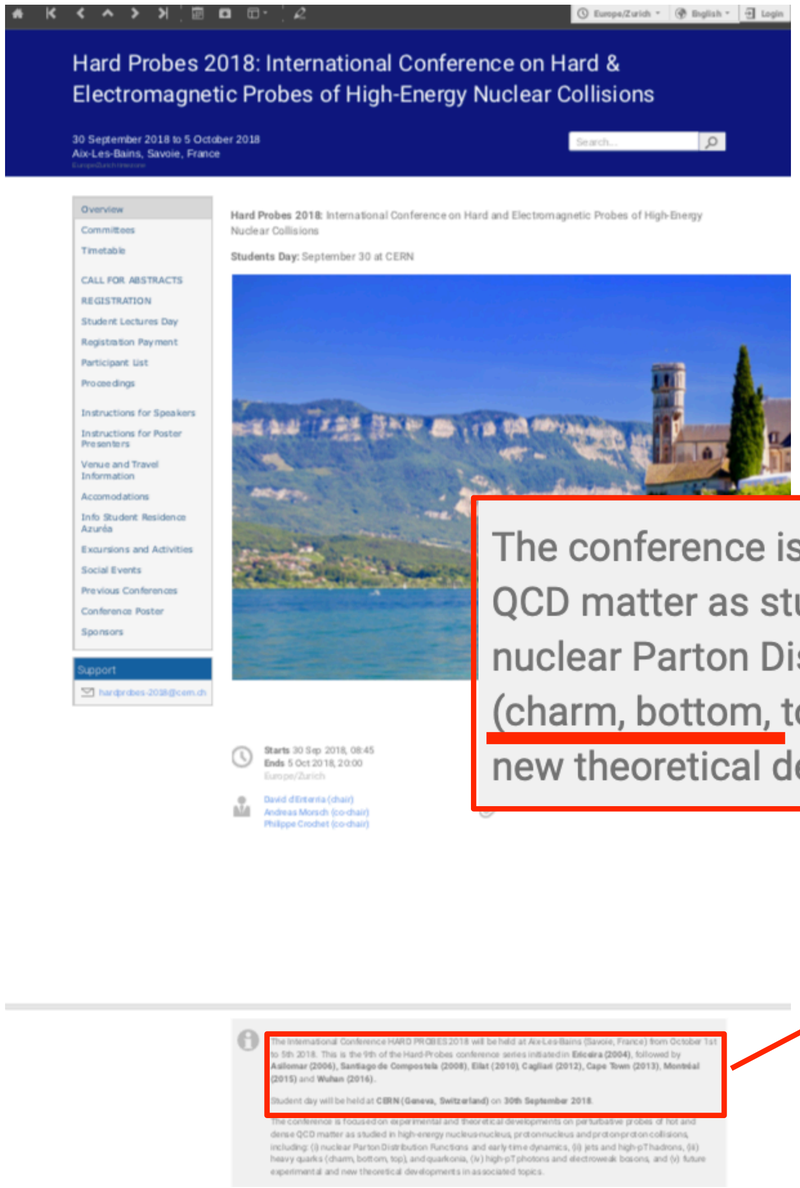
How does long-wavelength physics emerge from underlying gauge theory?

How will sPHENIX and LHC do this?

Hard Probe QGP Observables



Hard Probe QGP Observables



Comprehensive list of the sPHENIX observables

> The conference is focused on experimental and theoretical developments on perturbative probes of hot and dense QCD matter as studied in high-energy nucleus-nucleus, proton-nucleus and proton-proton collisions, including: (i) nuclear Parton Distribution Functions and early-time dynamics, (ii) jets and high-pT hadrons, (iii) heavy quarks (charm, bottom, top), and quarkonia, (iv) high-pT photons and electroweak bosons, and (v) future experimental and new theoretical developments in associated topics.

https://indico.bnl.gov/event/4640/attachments/18495/23200/sphenix-conceptual-design.pdf

Illustration: Scattering off QGP Constituents

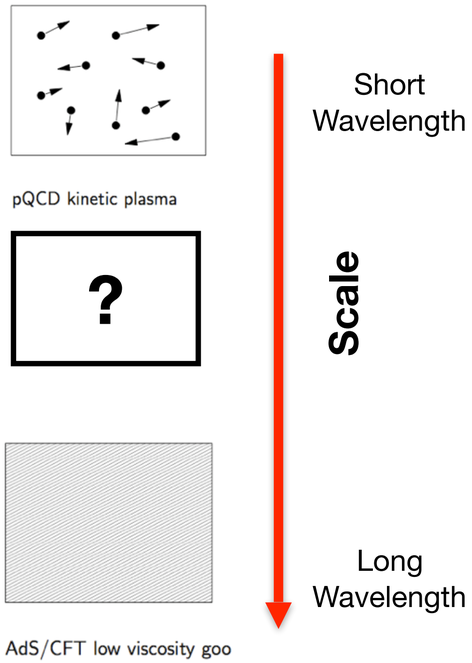
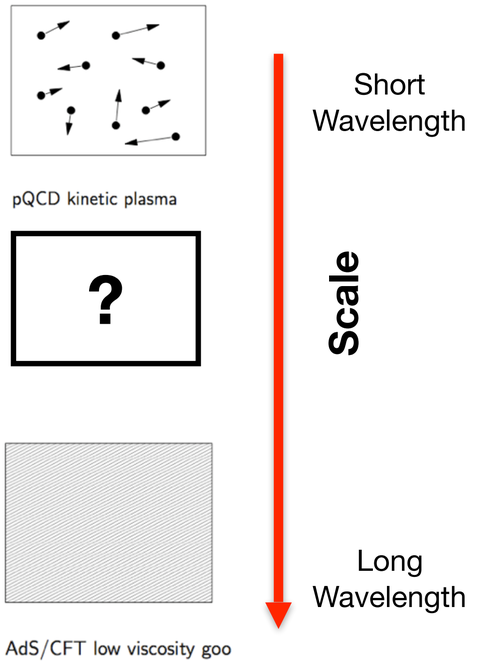


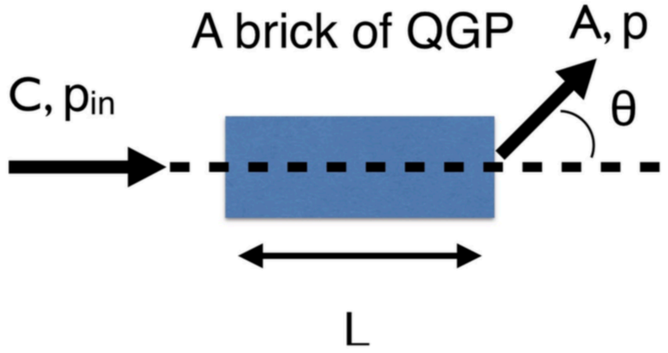
Illustration: Scattering off QGP Constituents

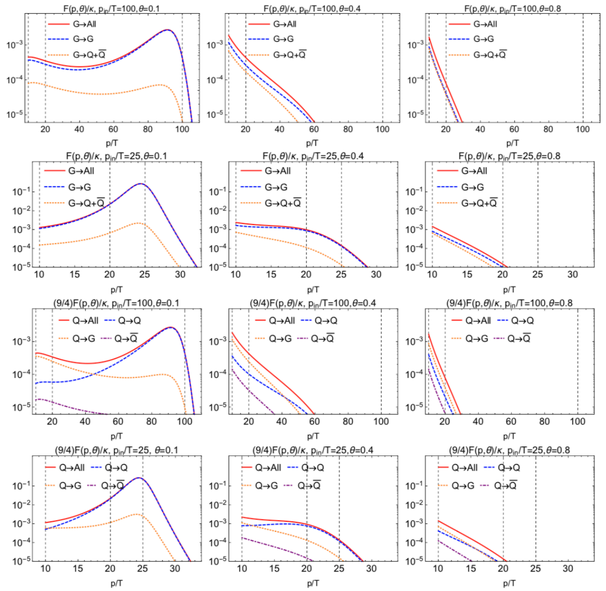
Talk by Yi Yin this morning

Molière Scattering in Quark-Gluon Plasma: Finding Point-Like Scatterers in a Liquid

Francesco D'Eramo,[a,b] Krishna Rajagopal,[c] Yi Yin[c]

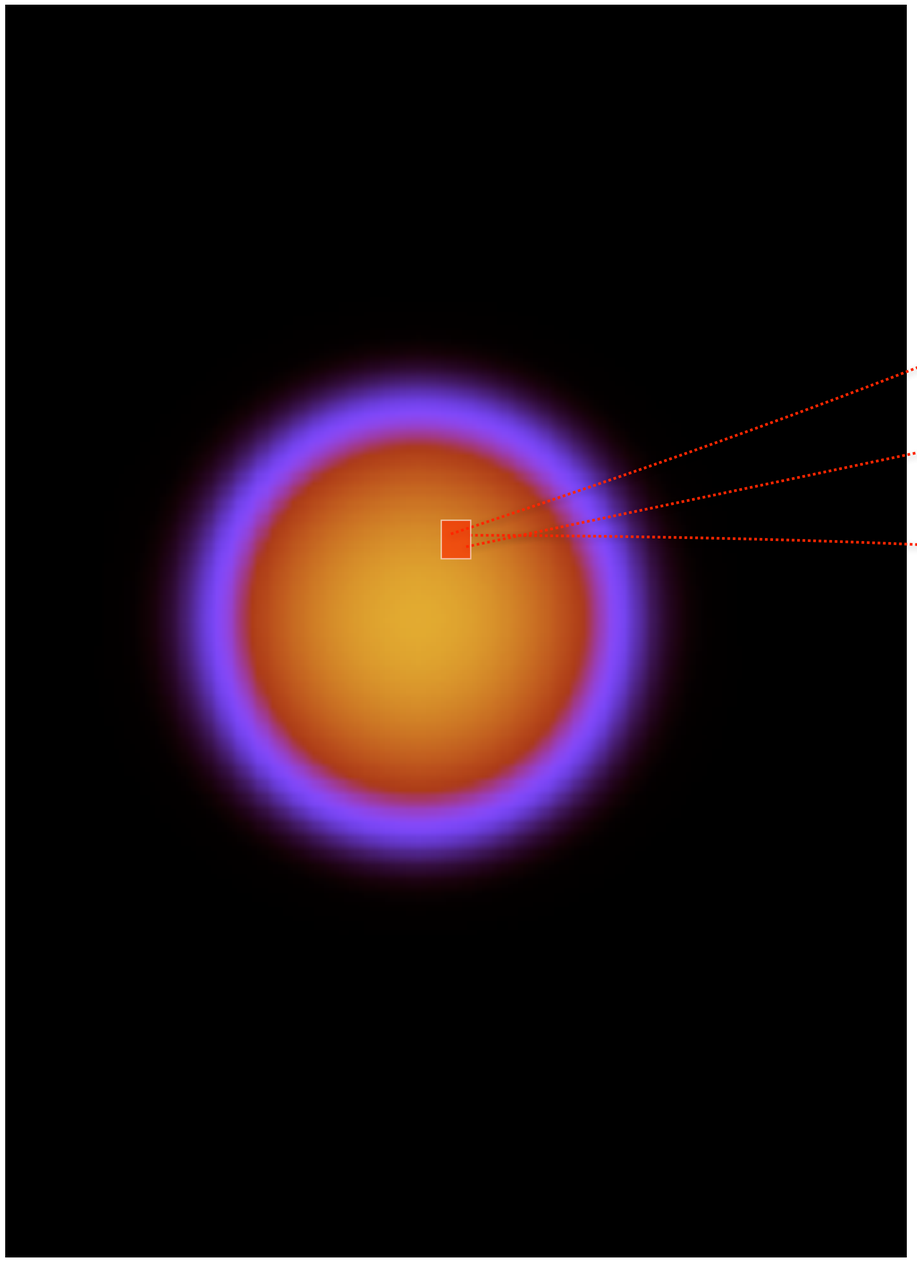


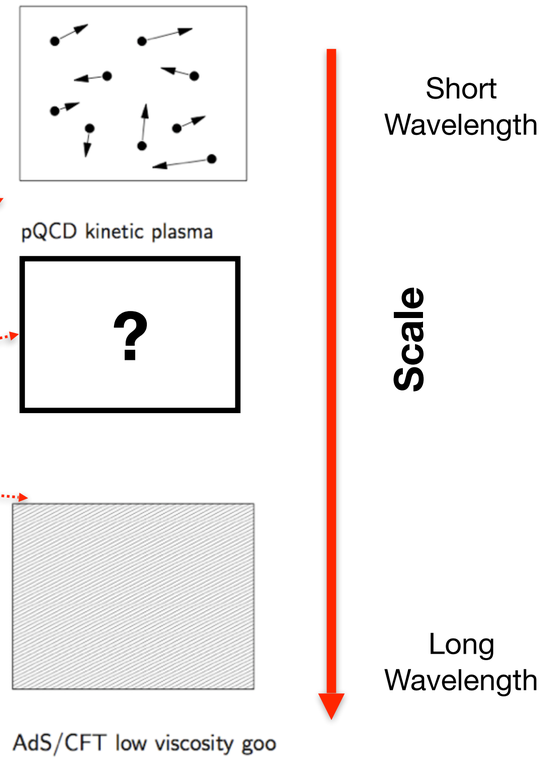




Need joint exp/theory effort over next decade to turn conceptual approach into well controlled observables

Experimental Approach





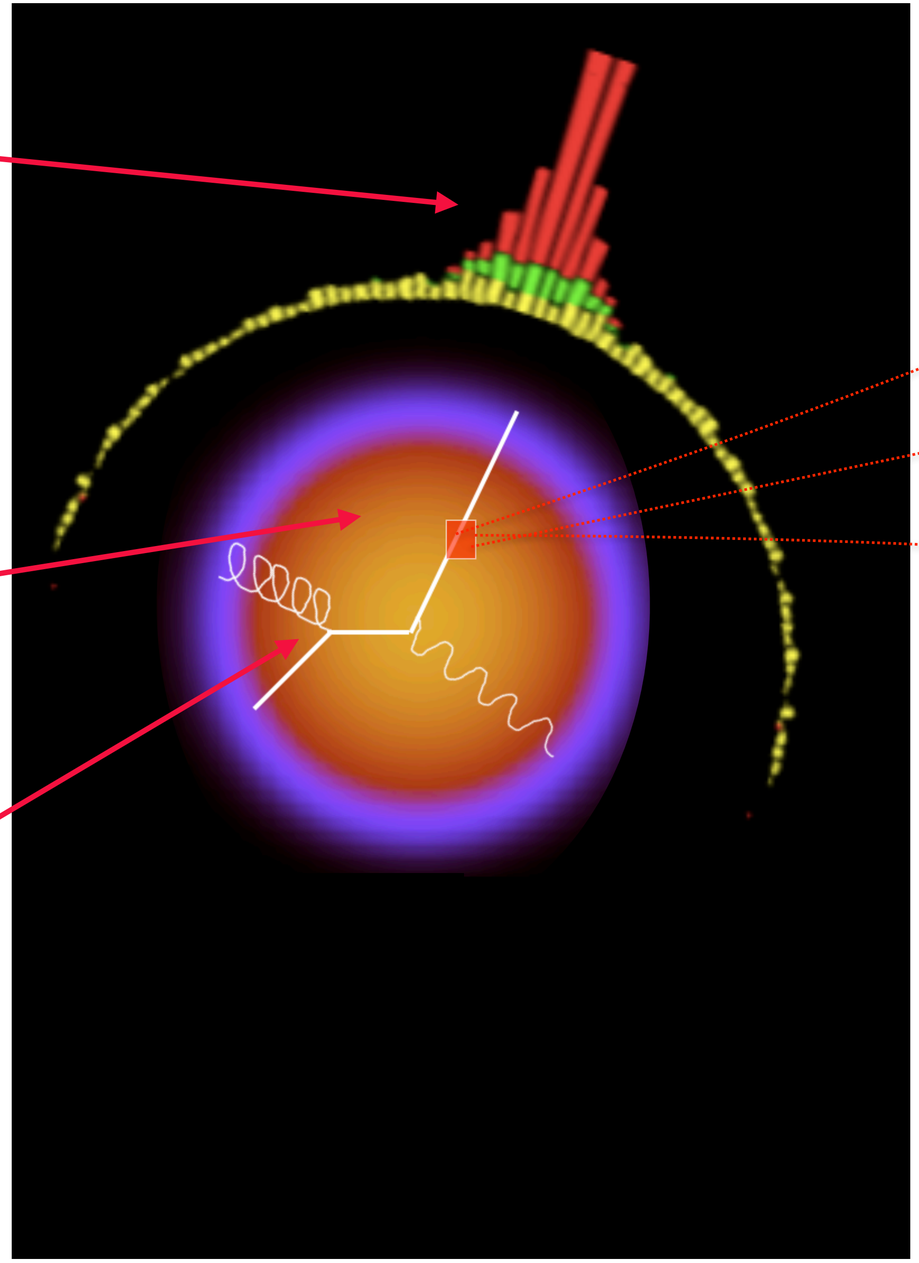
How does long-wavelength physics emerge from underlying gauge theory?

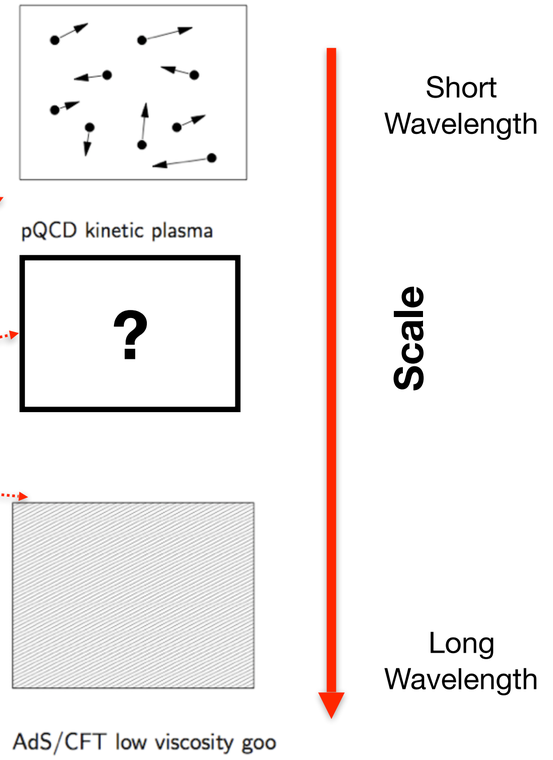
Experimental Approach

Full characterization of final state

Different QGP initial conditions and evolution at RHIC and LHC

Same hard process





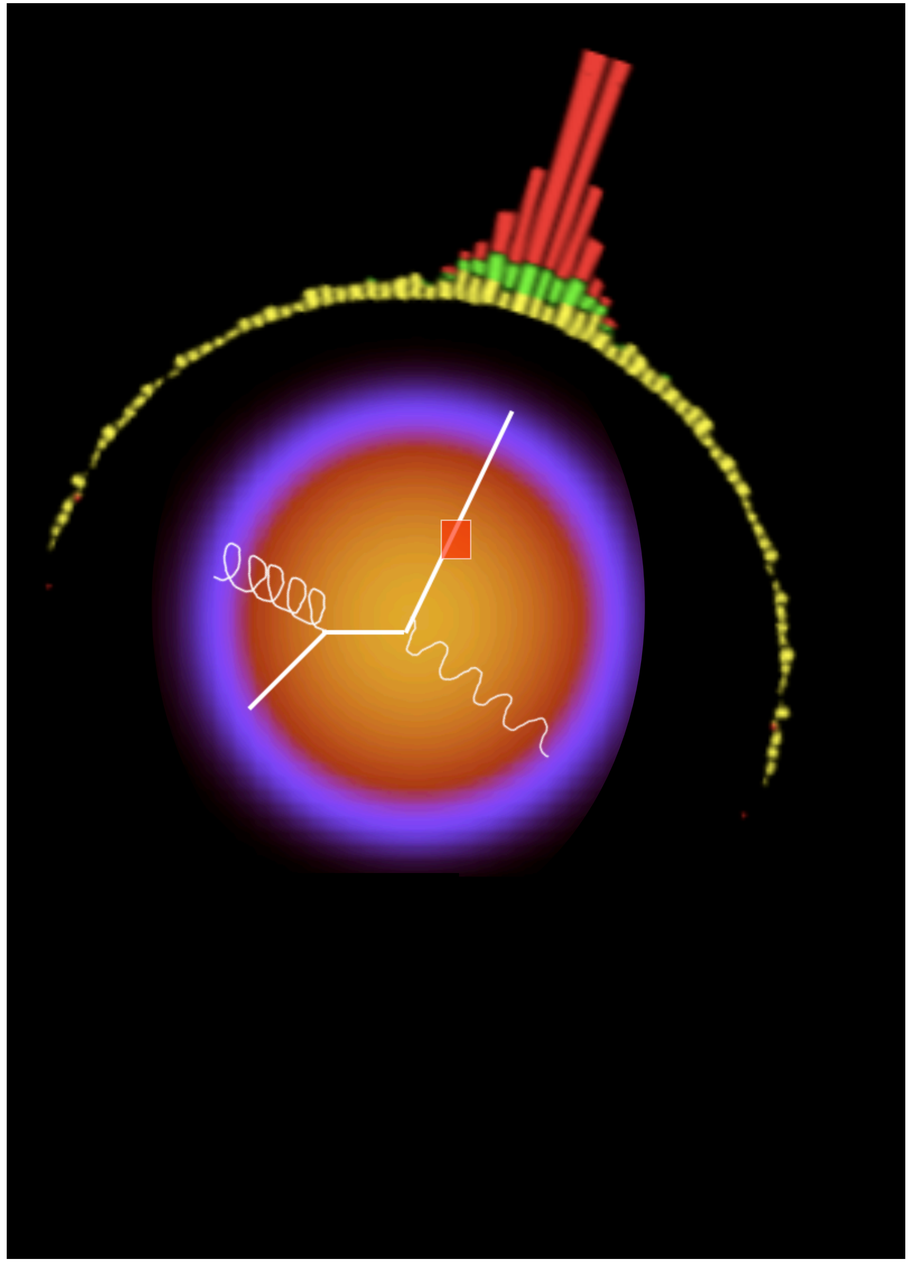
How does long-wavelength physics emerge from underlying gauge theory?

Experimental Approach

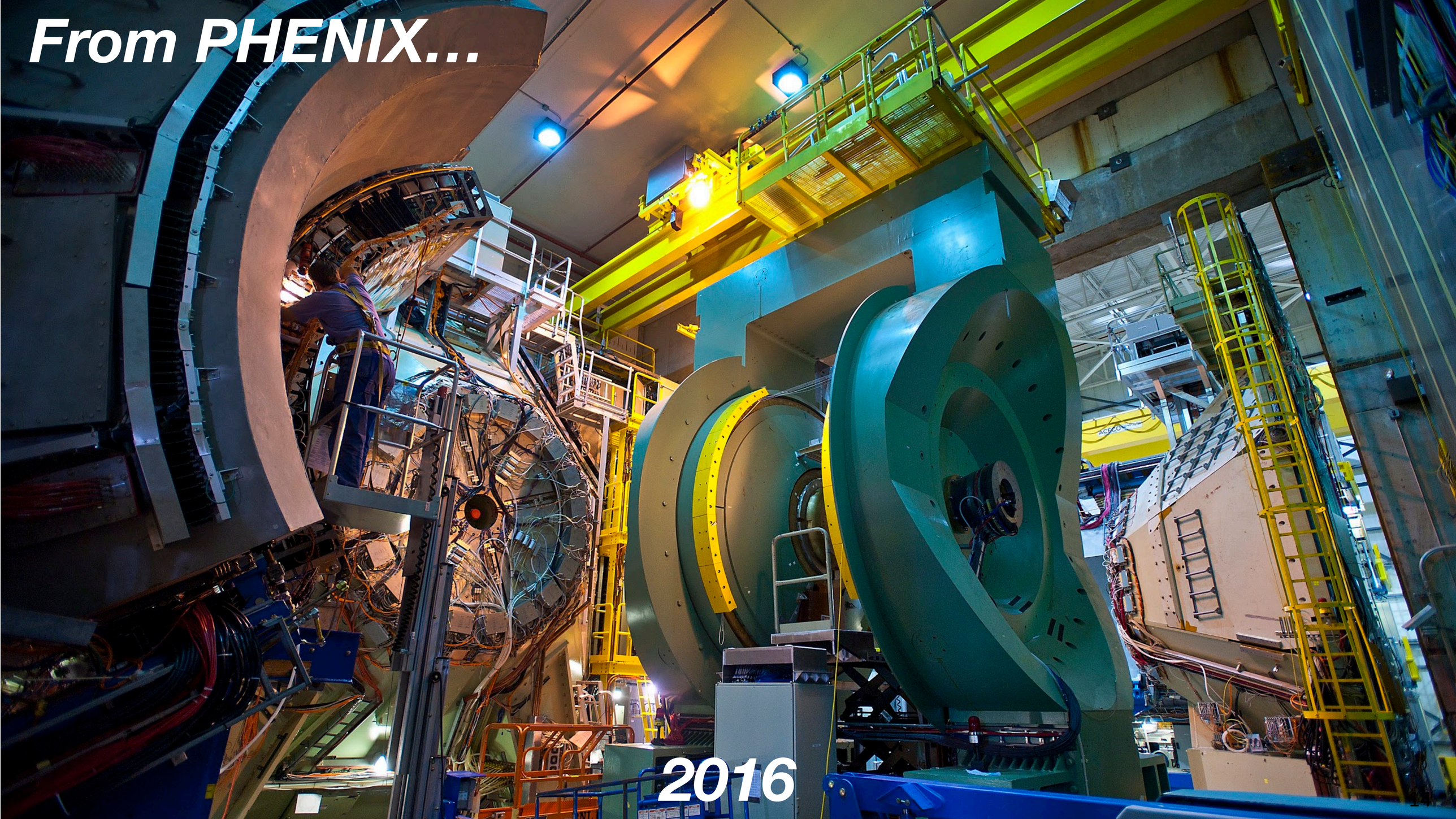
Full characterization of final state

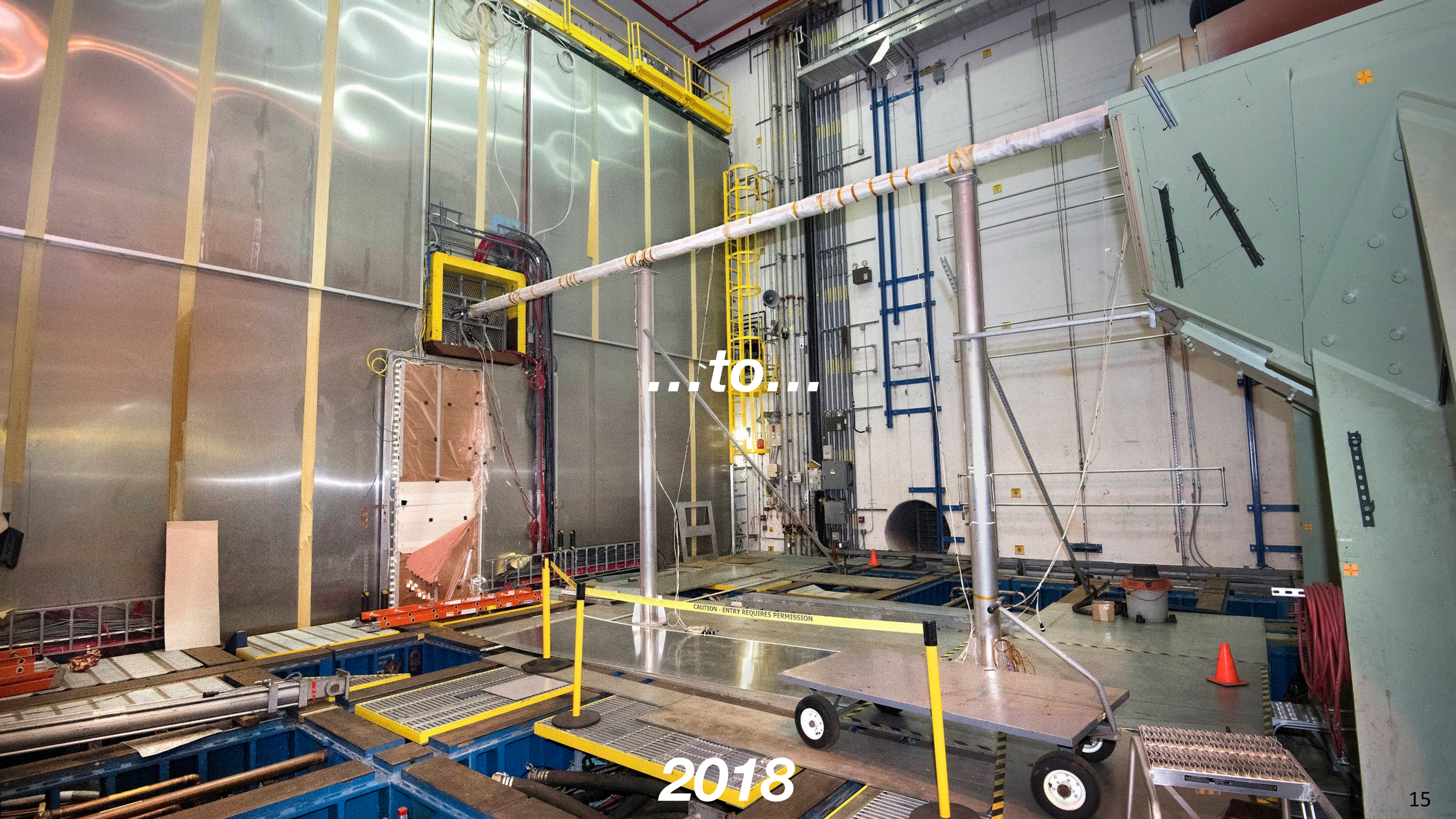
Ability to tag initial state and to fully characterize final state drives sPHENIX detector design

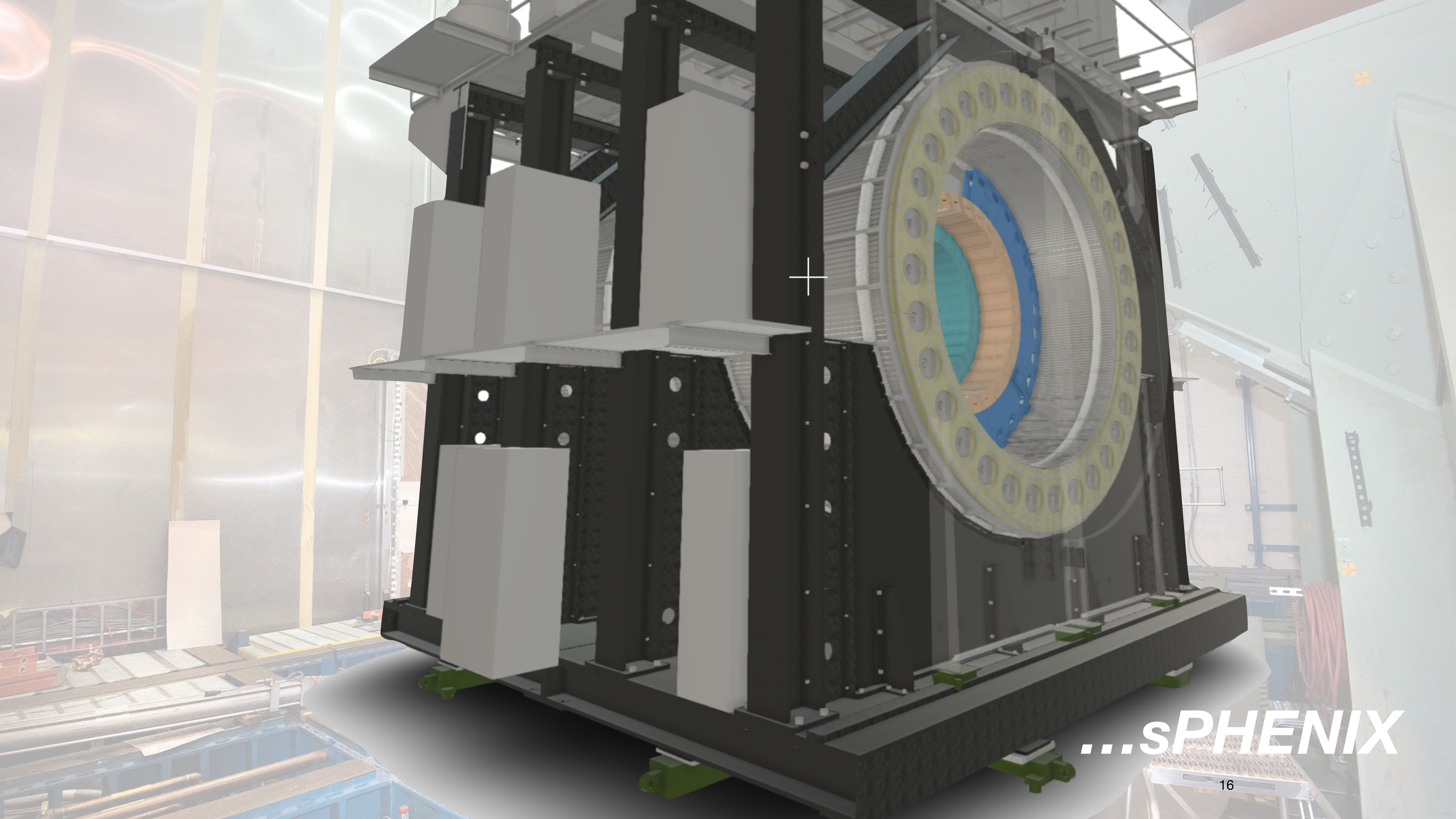
Same hard process



How do we get from *PHENIX* to ***s****PHENIX*?

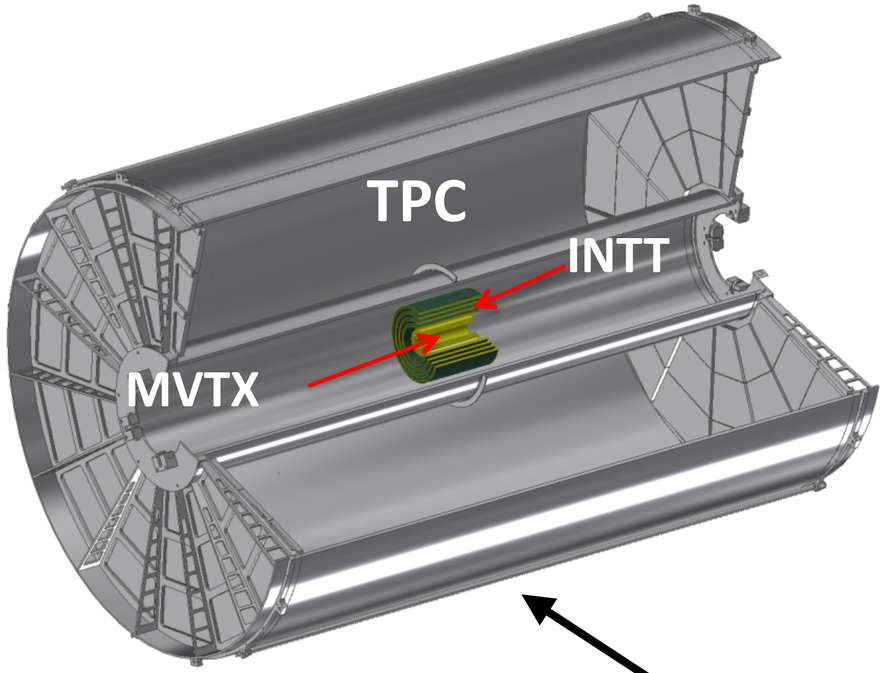

From PHENIX…
2016


...to...
2018
CAUTION - ENTRY REQUIRES PERMISSION


...sPHENIX

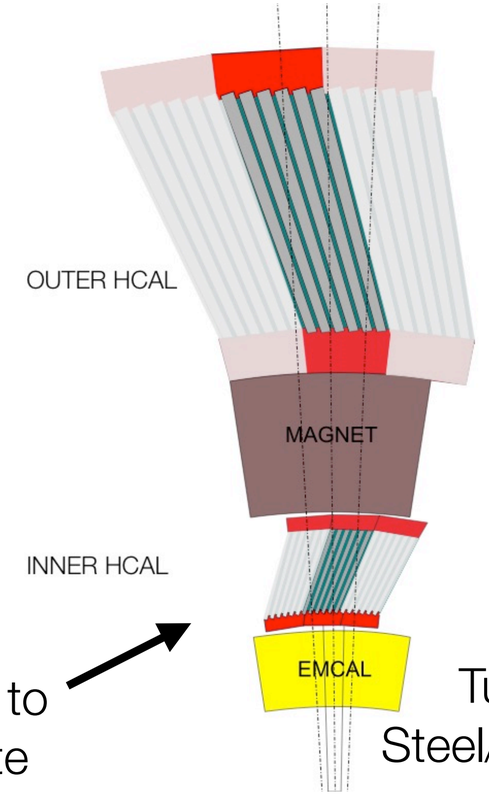
sPHENIX Subsystems

Tracker



Continuous readout TPC
Si strip intermediate tracker
3-layer MAPS-based μ vertex

Calorimeter stack



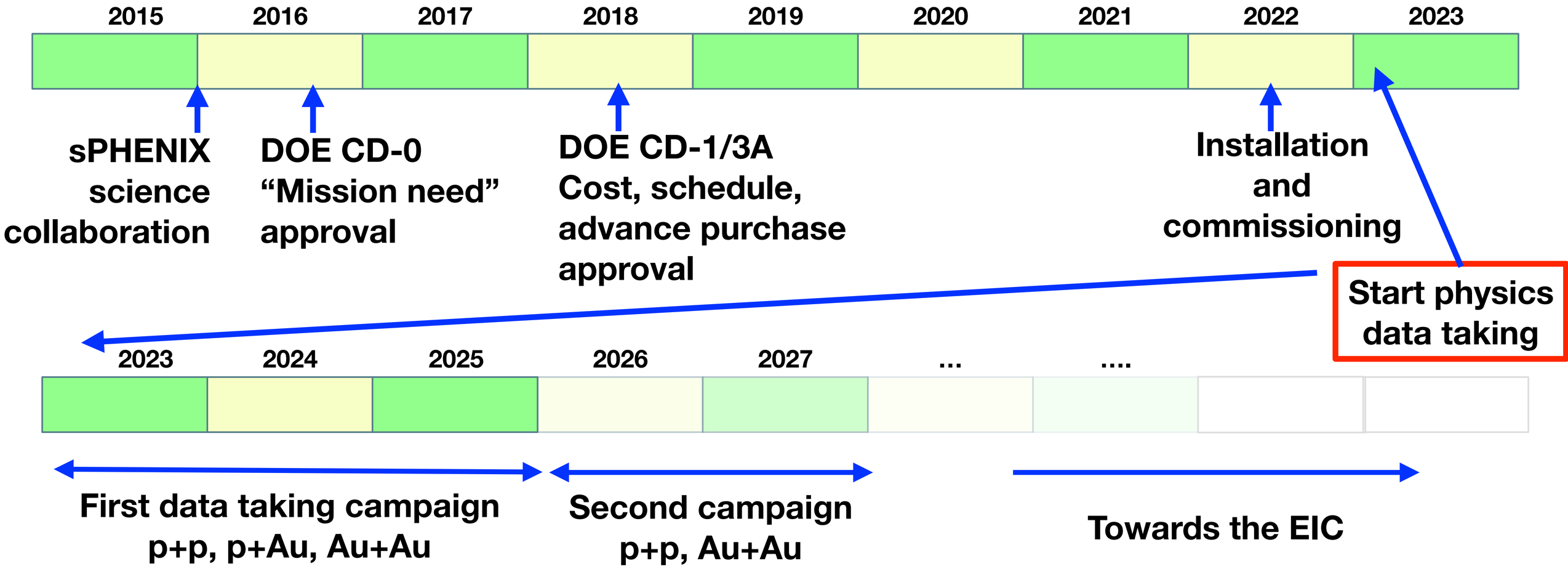
15kHz readout in Au+Au to
match RHIC collision rate

Tungsten/SciFi EMCal
Steel/plastic scintillator HCAL
SiPM readout

Qualitative improvement on 20 years of studies at RHIC through higher statistics (x10+), full calorimetry and higher precision tracking

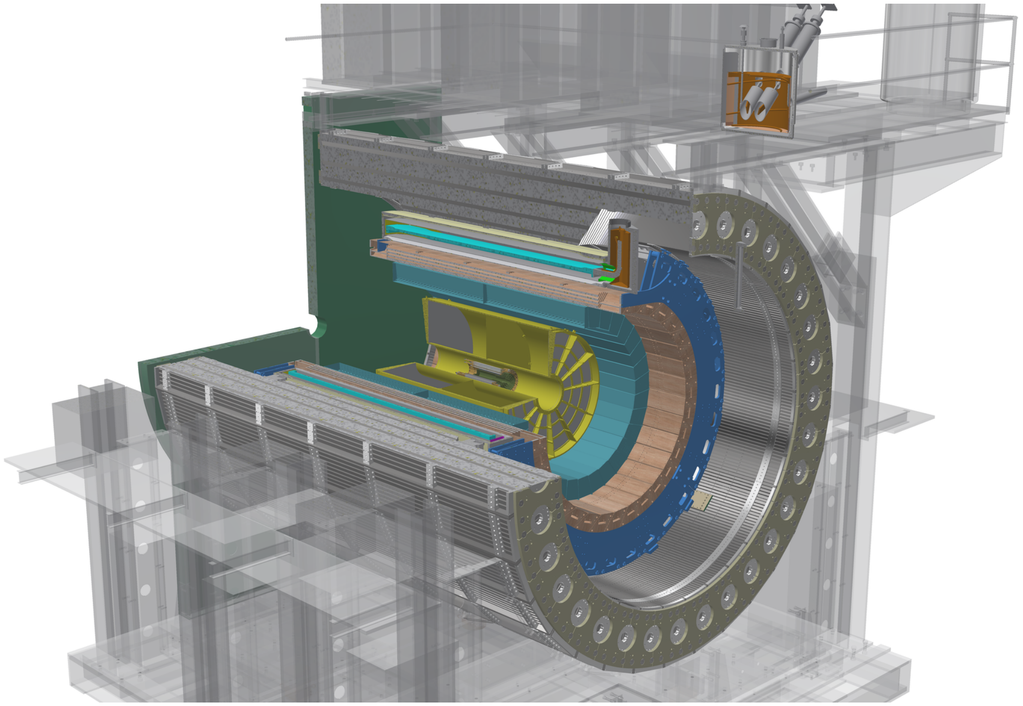
When will sPHENIX take data?

When Will sPHENIX Take Data?



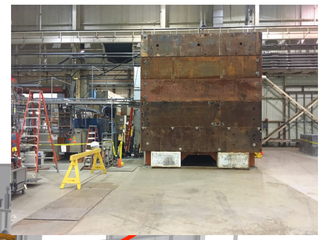
https://indico.bnl.gov/event/4788/attachments/19066/24594/sph-trg-000_06142018.pdf

sPHENIX *Today*

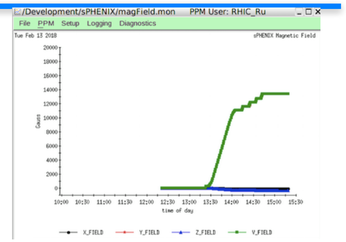


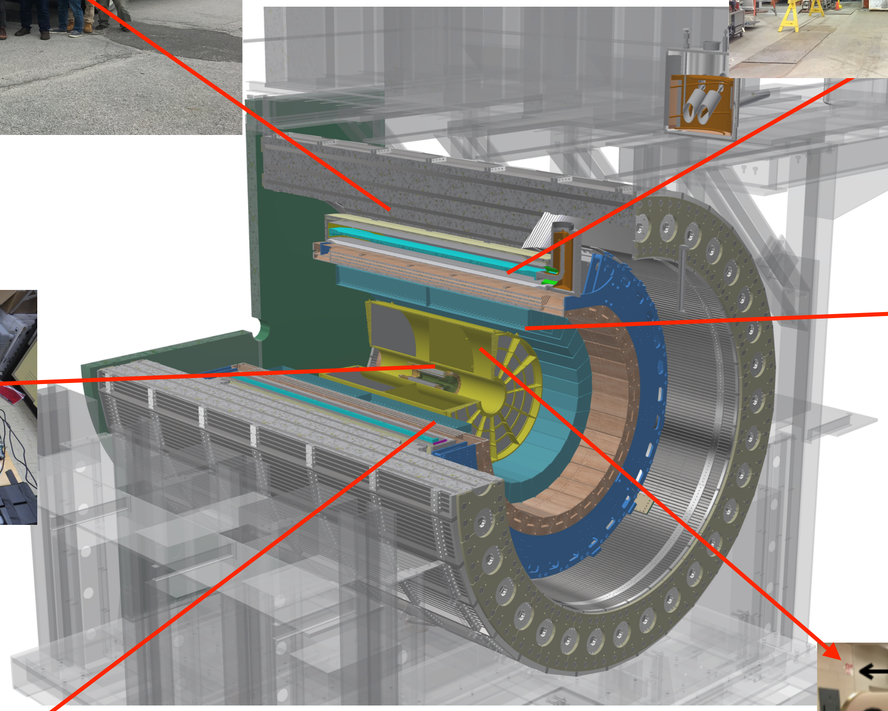
sPHENIX *Today*

Flux return/**oHCAL** absorber
First production sectors
arrived two weeks ago

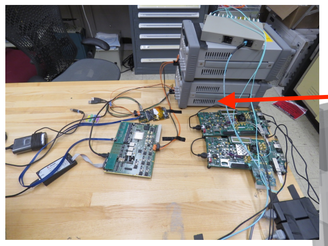


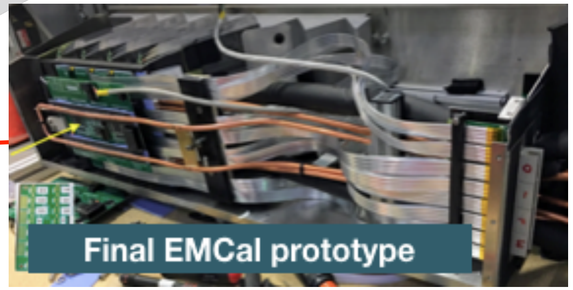
Full field **magnet** test
at 1.4T at BNL on
2/13/2018



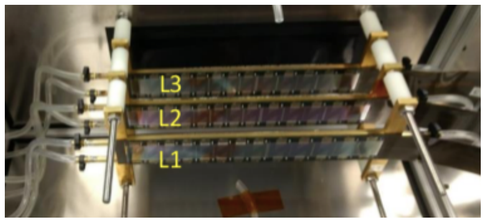


MVTX full chain test and beam
test in **Spring 2018**
Expecting stave procurement in
late 2018

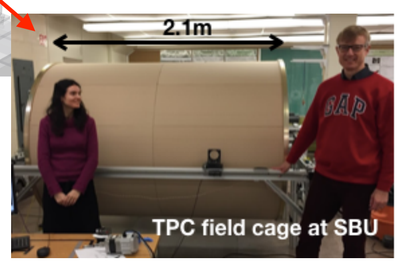




Approval of **EMCAL** materials
purchase received in **August '18**
"Sector 0" production starting
2018



INTT telescope beam test in
Spring 2018
Detector will be delivered by Riken

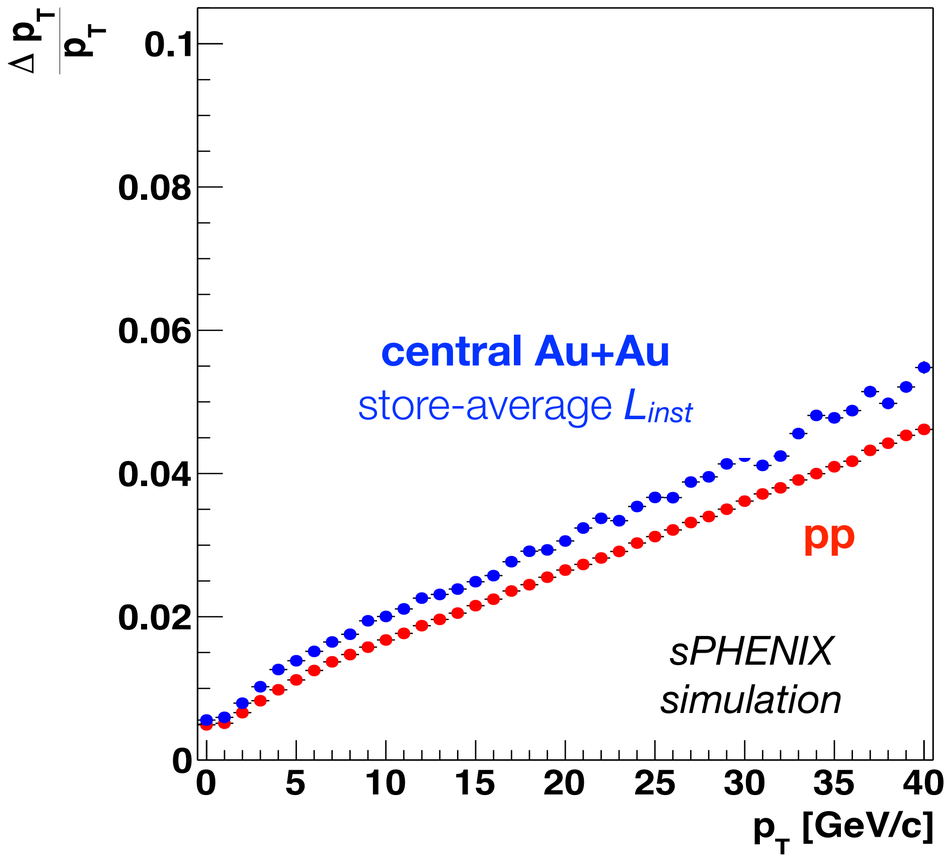


Beam test of **TPC** prototype in
June 2018
Ready for producing of full-size
field cage "prototype"

What are key sPHENIX performance parameters?

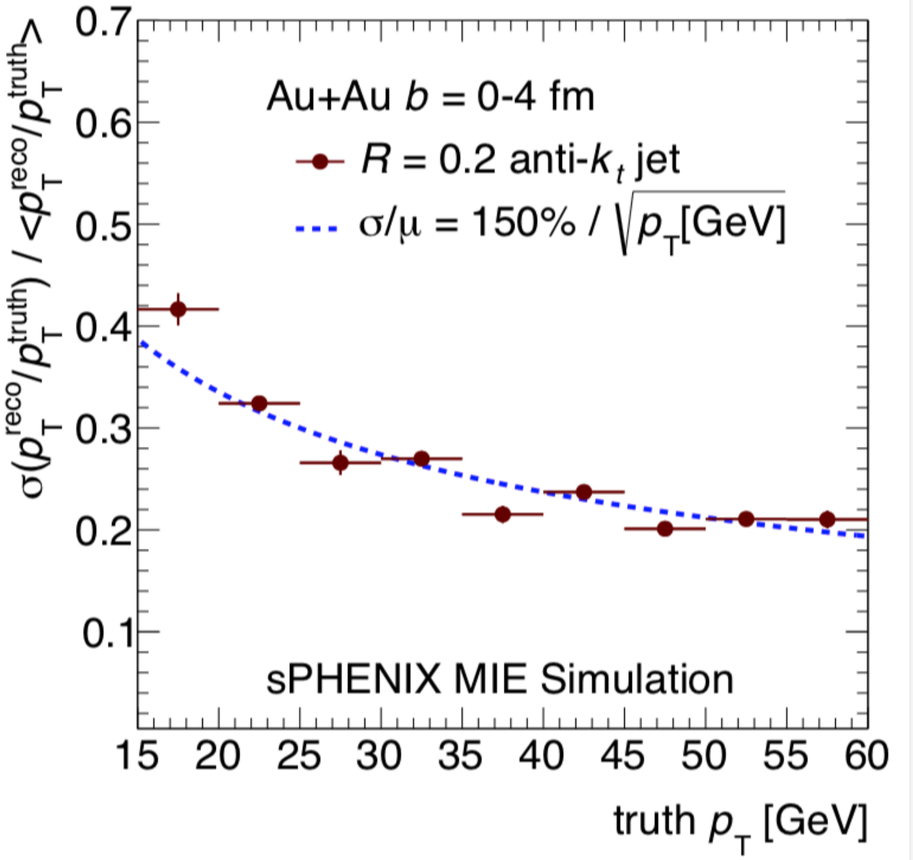
Performance Simulation: Track and Jet Resolution

Track pT resolution (central Au+Au)



High momentum resolution
Tracking efficiency > 90% in high pileup Au+Au environment

Single jet resolution (central Au+Au)

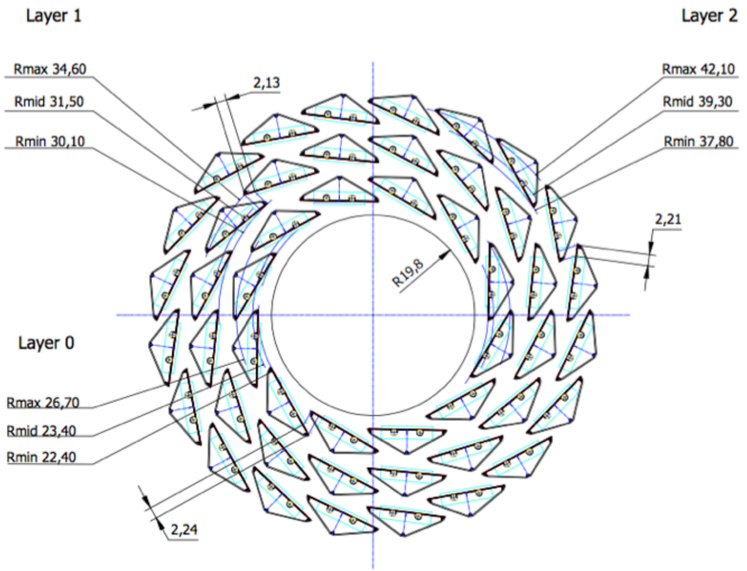


Calorimeter-related performance studied using GEANT simulations verified with **test beam data**

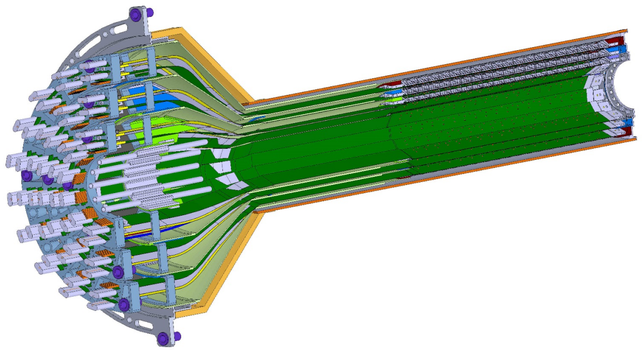
arXiv:1704.01461

Microvertex Tracker Performance

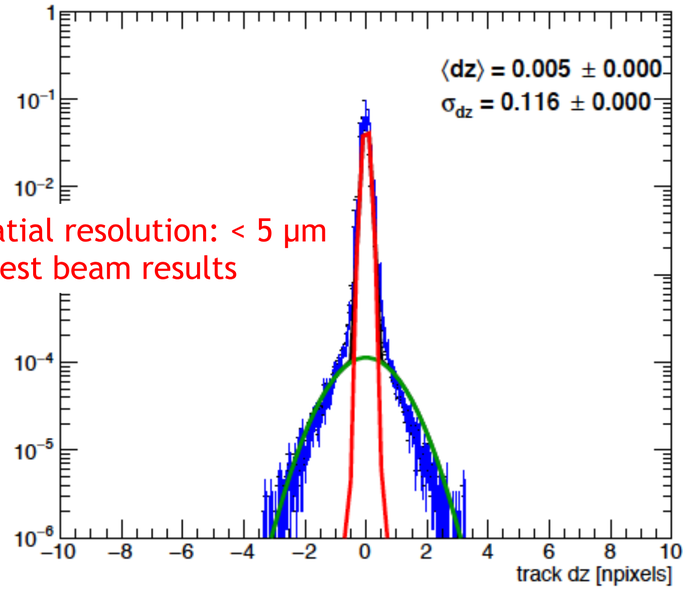
Stave layout beam view



MVTX based on copy of ALICE Inner Barrel staves



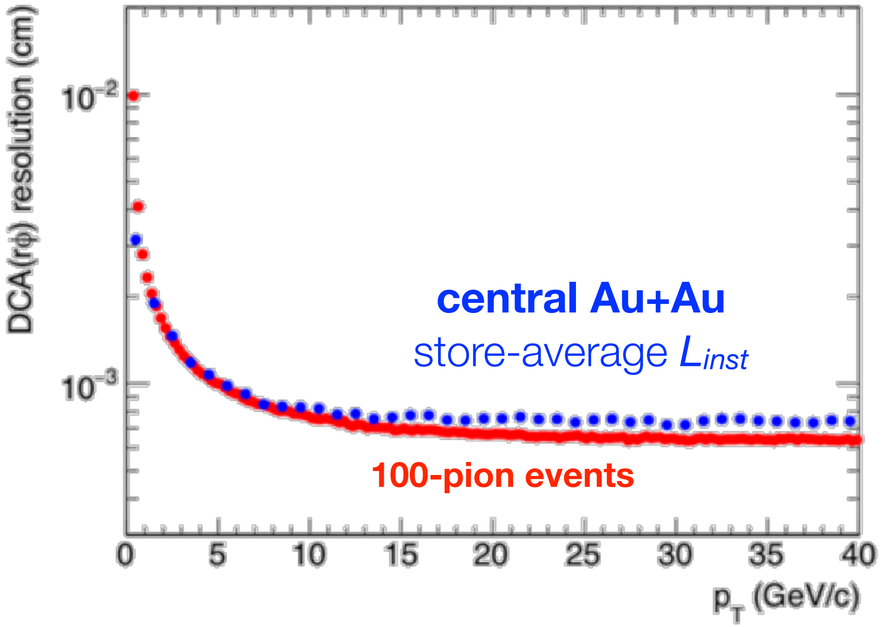
MVTX spatial resolution



Hit spatial resolution: < 5 μm
FNAL test beam results

Spatial resolution verified in full chain **test beam** at FNAL

MVTX DCA resolution



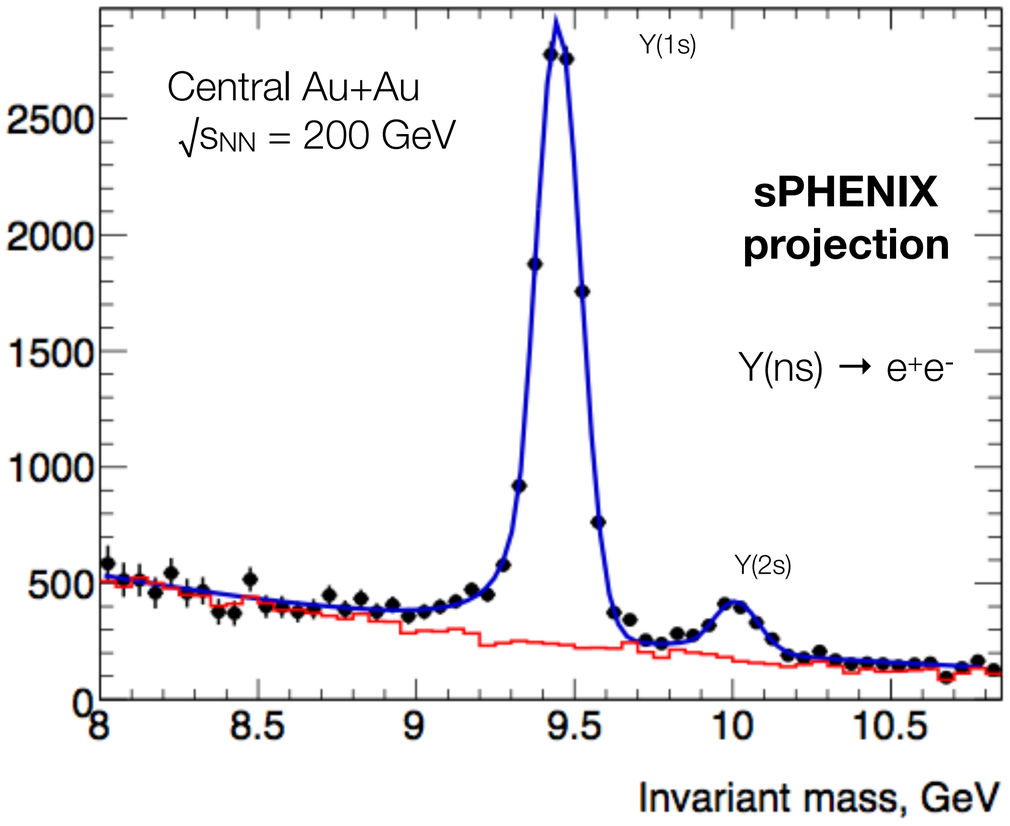
b-jet tagging and open HF hadrons through secondary vertexing

https://indico.bnl.gov/event/4072/attachments/11335/13816/sPH-HF-2018-001-final.pdf

What are some key sPHENIX measurements?

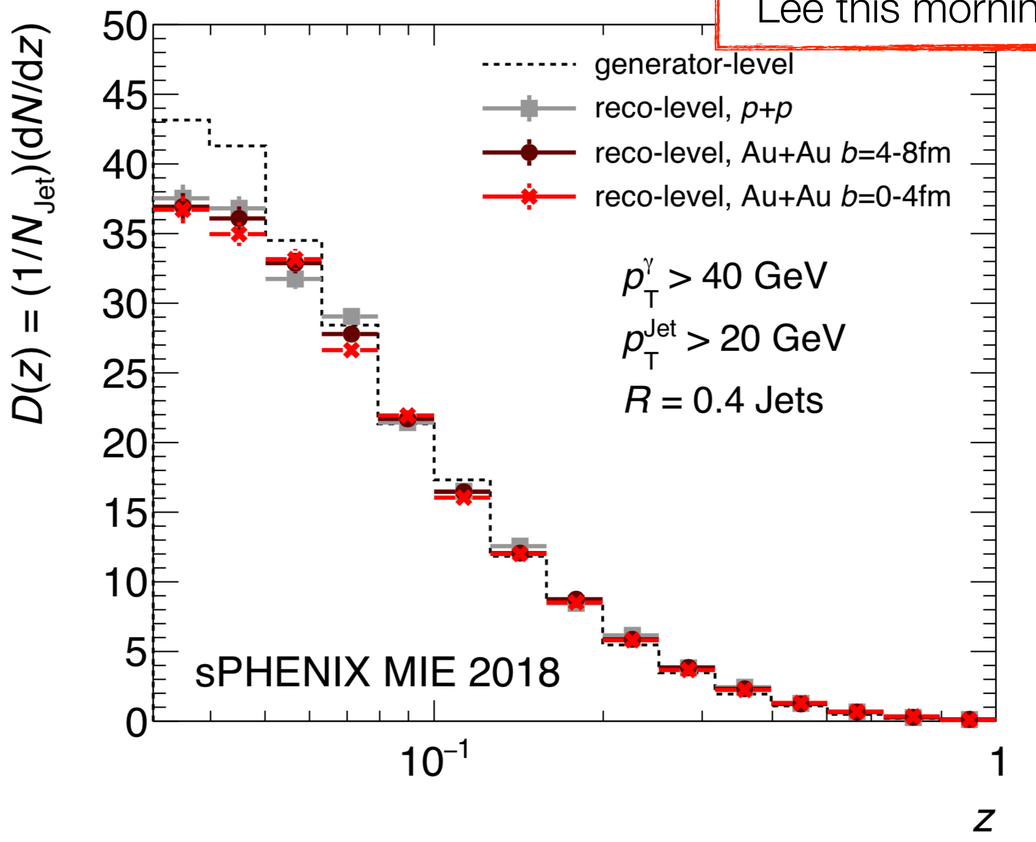
Examples: Upsilons and γ + Jet

Talk by Songkyo Lee this morning



High resolution Y spectroscopy

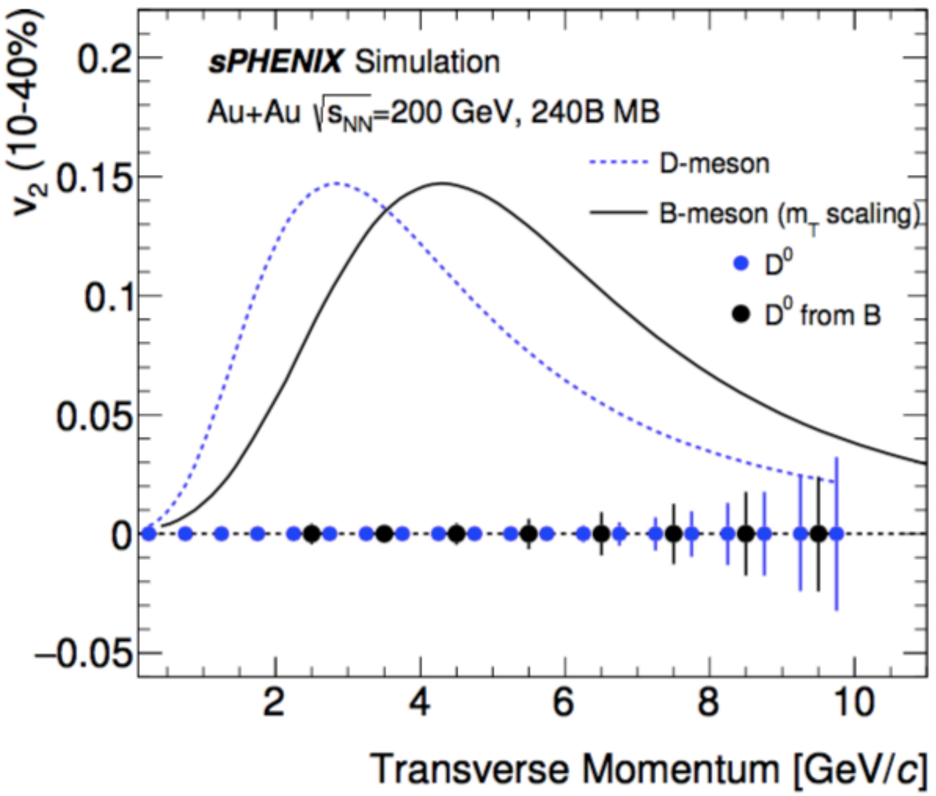
Sequential suppression of Y(nS) states



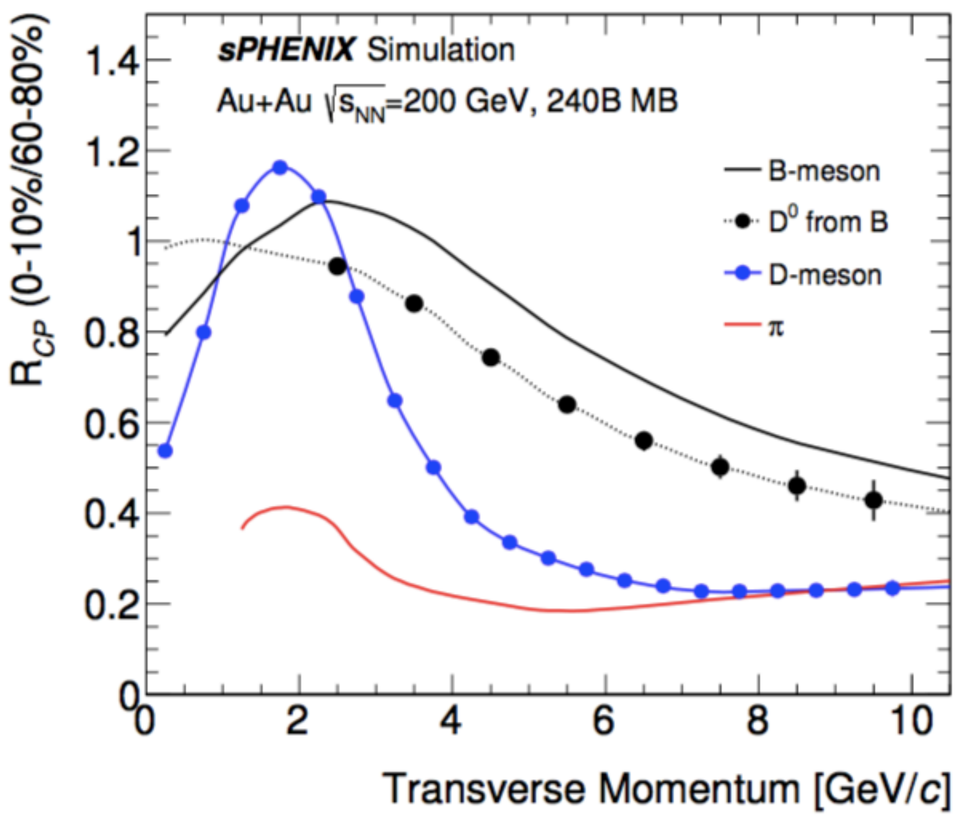
photon-jet Fragmentation Functions

Modification of parton shower in QGP

MVTX: World-class HF Science Program



Talk by Jin Huang this morning



Prompt and secondary D^0 flow

c and b quark thermalization in medium

Open heavy flavor suppression

Flavor dependence of energy loss

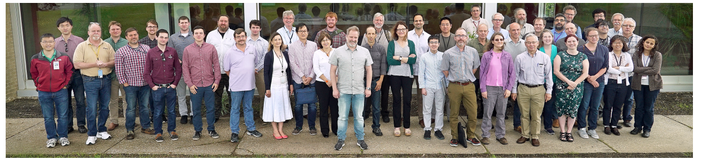
https://indico.bnl.gov/event/4072/attachments/11335/13816/sPH-HF-2018-001-final.pdf

“That looks awesome - can I join?”

sPHENIX Collaboration: 70 Institutions and Counting

Augustana University
Banaras Hindu University
Baruch College, CUNY
Brookhaven National Laboratory
China Institute for Atomic Energy
CEA Saclay
Central China Normal University
Chonbuk National University
Columbia University
Eötvös University
Florida State University
Fudan University
Georgia State University
Howard University
Hungarian sPHENIX Consortium
Insititut de physique nucléaire d'Orsay
Institute for High Energy Physics, Protvino
Institute of Nuclear Research, Russian Academy of Sciences, Moscow
Institute of Physics, University of Tsukuba
Institute of Modern Physics, China
Iowa State University
Japan Atomic Energy Agency
Joint Czech Group
Korea University
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Lehigh University
Los Alamos National Laboratory
Massachusetts Institute of Technology
Muhlenberg College
Nara Women's University
National Research Centre "Kurchatov Institute"
National Research Nuclear University "MEPhI"
New Mexico State University
Oak Ridge National Laboratory
Ohio University
Peking University
Petersburg Nuclear Physics Institute
Purdue University
Rice University
RIKEN
RIKEN BNL Research Center
Rikkyo University
Rutgers University
Saint–Petersburg Polytechnic University
Shanghai Institute for Applied Physics
Stony Brook University
Sun Yat Sen University
Temple University
Tokyo Institute of Technology
Tsinghua University
Universidad Técnica Federico Santa María
University of California, Berkeley
University of California, Los Angeles
University of California, Riverside
University of Colorado, Boulder
University of Debrecen
University of Houston
University of Illinois, Urbana-Champaign
University of Jammu
University of Maryland
University of Michigan
University of New Mexico
University of Tennessee, Knoxville
University of Texas, Austin
University of Tokyo
University of Science and Technology, China
Vanderbilt University
Wayne State University
Weizmann Institute
Yale University
Yonsei University

BNL, June '18



Santa Fe, Dec '17

BNL, June '17

GSU (Atlanta), Dec '16

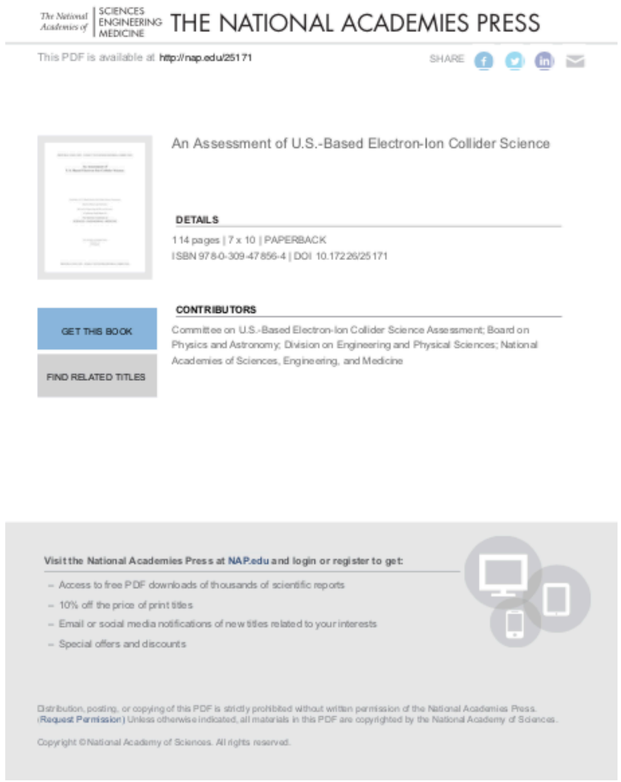
BNL, June '16

Rutgers, Dec'15

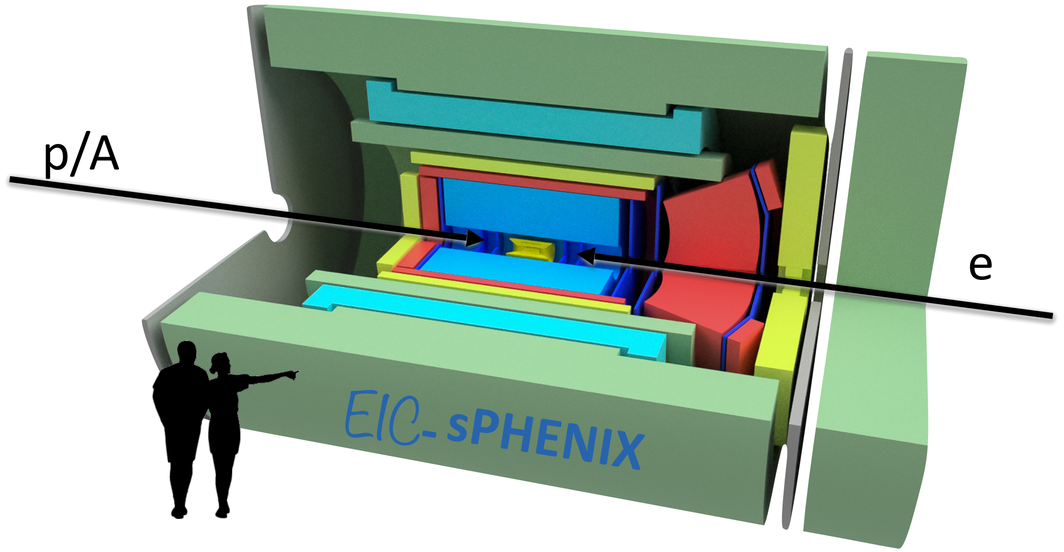
What will you do in late 2020's…2030's?

sPHENIX @ EIC

Timely: US National Academies of Science recommend construction of EIC



Study group (incl. non-sPHENIX members) working on EIC detector design based on sPHENIX/Babar magnet - Design Study Report in final review



7

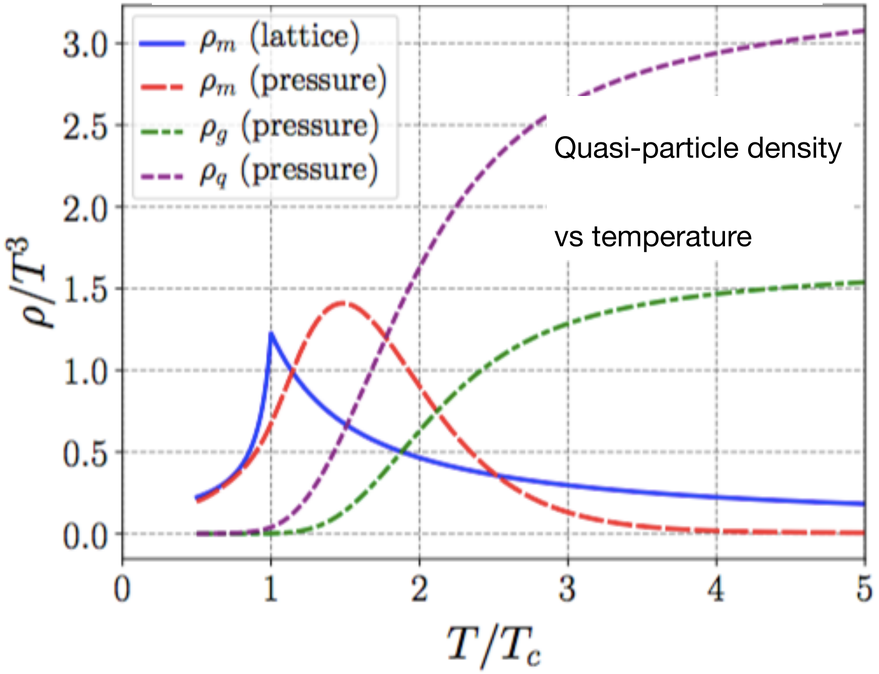
Outlook

- sPHENIX will probe microscopic structure of strongly coupled QGP
- New state of the art detector at RHIC, complementing capabilities of LHC
  - Upsilon spectroscopy
  - Jet suppression and substructure
  - Open heavy flavor over full kinematic range
- Growing international collaboration
- Work on sPHENIX is in full swing
- Exciting physics program at RHIC starting in 2023

Backup

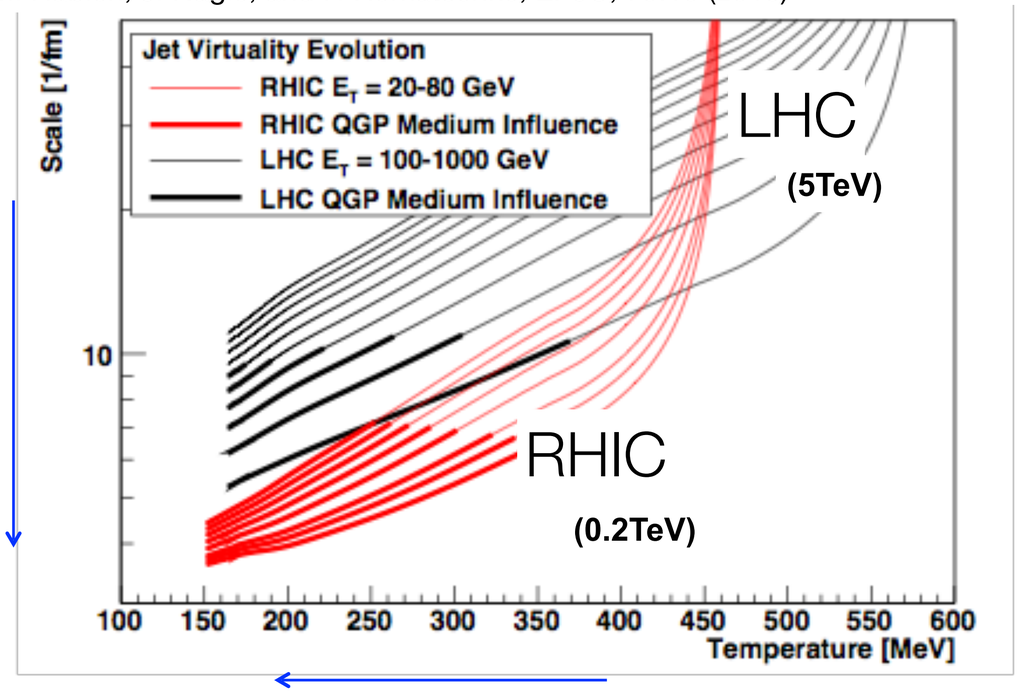
Complementarity: Why RHIC *and* LHC?

A. Ramamurti, E. Shuryak,arXiv:1708.04254



Structure of QGP expected to depend on temperature

M. Habich, J. Nagle, and P. Romatschke, EPJC, 75:15 (2015)



Initial QGP conditions and QGP evolution are different at RHIC vs LHC

RHIC QGP spends more time near T_c

➥ Use **combined RHIC and LHC data** to extract T dependence

Multi-year run plan for sPHENIX

Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

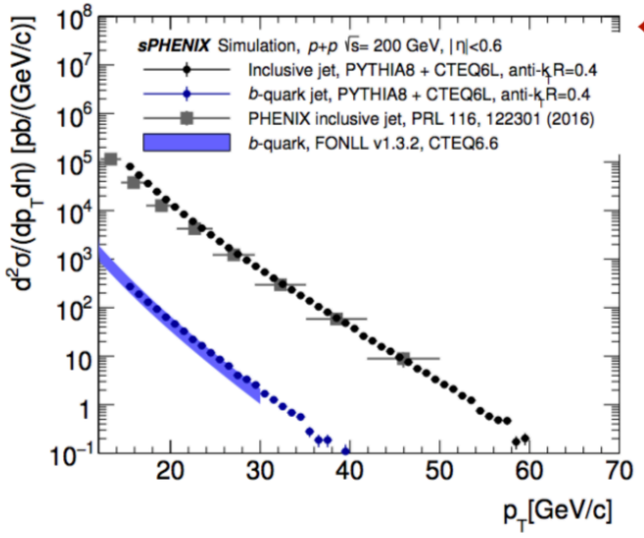
- Consistent with DOE CD-0 "mission need" document
- Incorporates BNL C-AD guidance on luminosity evolution
- Incorporates commissioning time in first year

Minimum bias Au+Au at 15 kHz for |z| < 10 cm:

47 billion (Year-1) + **96 billion** (Year-2) + **96 billion** (Year-3) = Total **239 billion events**

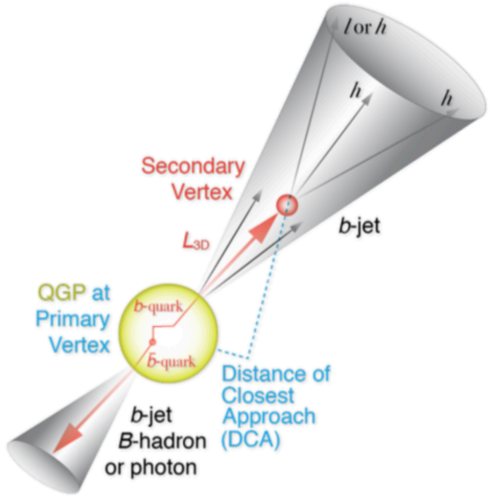
For topics with Level-1 selective trigger (e.g. high p_T photons), one can sample within |z| < 10 cm a total of 550 billion events.

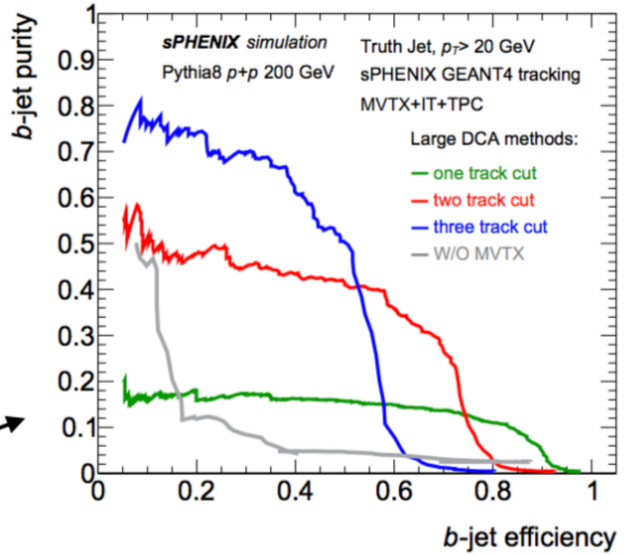
b-jet tagging

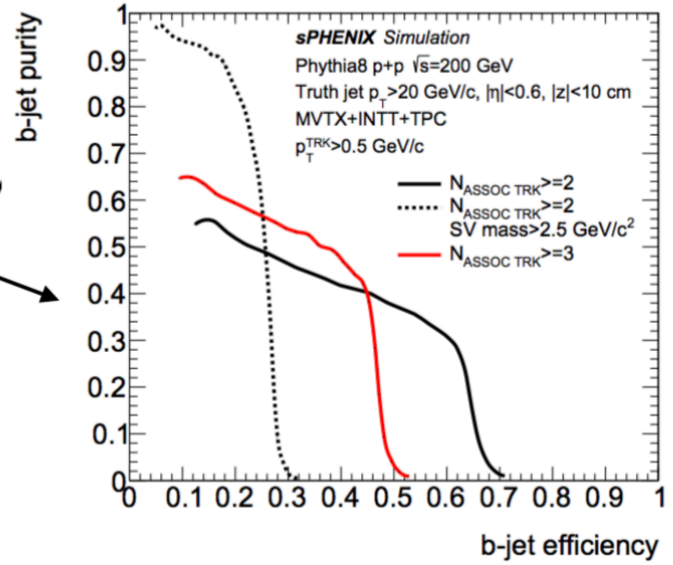


⇐ Need good efficiency & purity!

- Methods developed & evaluated in full detector simulation
- Multiple methods provide complementarity & cross checks
- **Large DCA:**
  - Count tracks in jet above DCA cut threshold
- **Secondary vertex:**
  - Reconstruct secondary vertex within jet

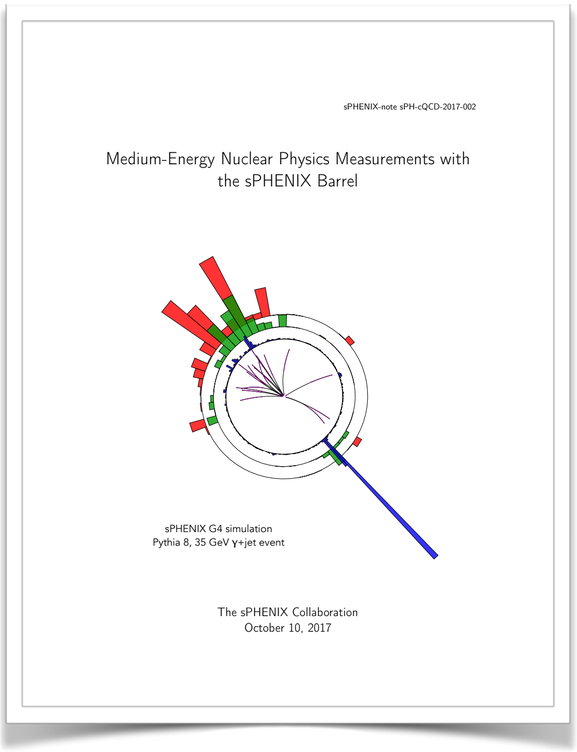






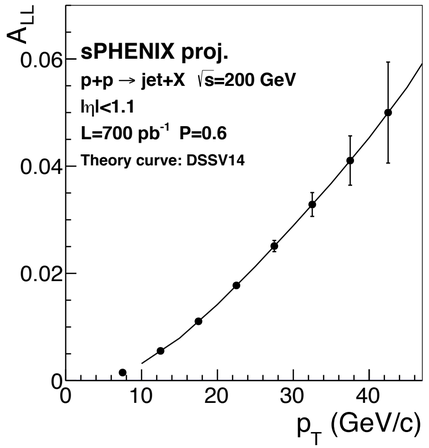
Cold QCD with sPHENIX barrel

Charge from ALD, delivered 10/2017

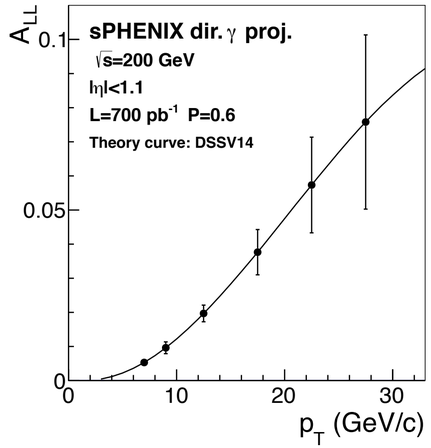


Projected capabilities for observables in longitudinally, transversely polarized collisions, nPDFs

jet A_{LL}



direct γ A_{LL}



dijet kinematics in sPHENIX barrel