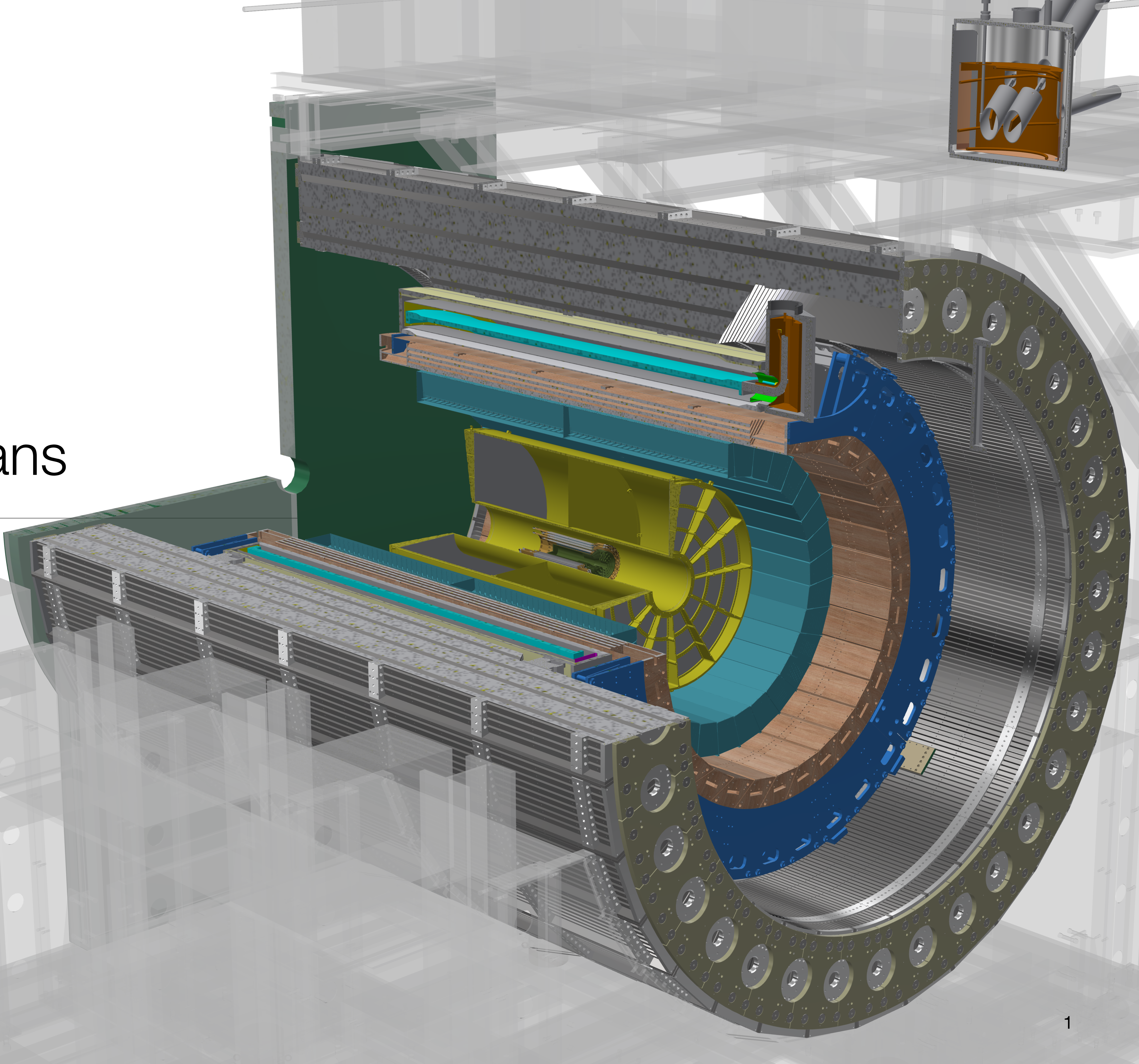
RHIC: sPHENIX – future plans

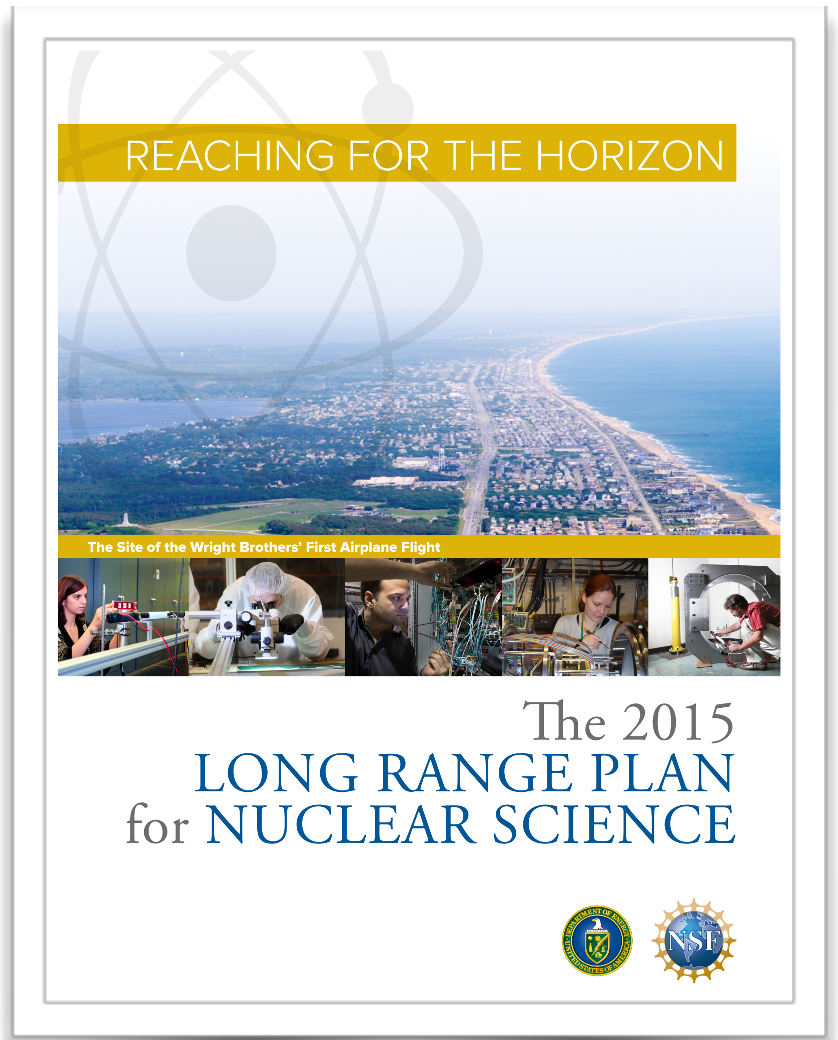
David Morrison (BNL)
Gunther Roland (MIT) | co-spokespersons

Ed O'Brien (BNL) | project director



complementarity

sPHENIX Science Mission in the DOE/NSF LRP



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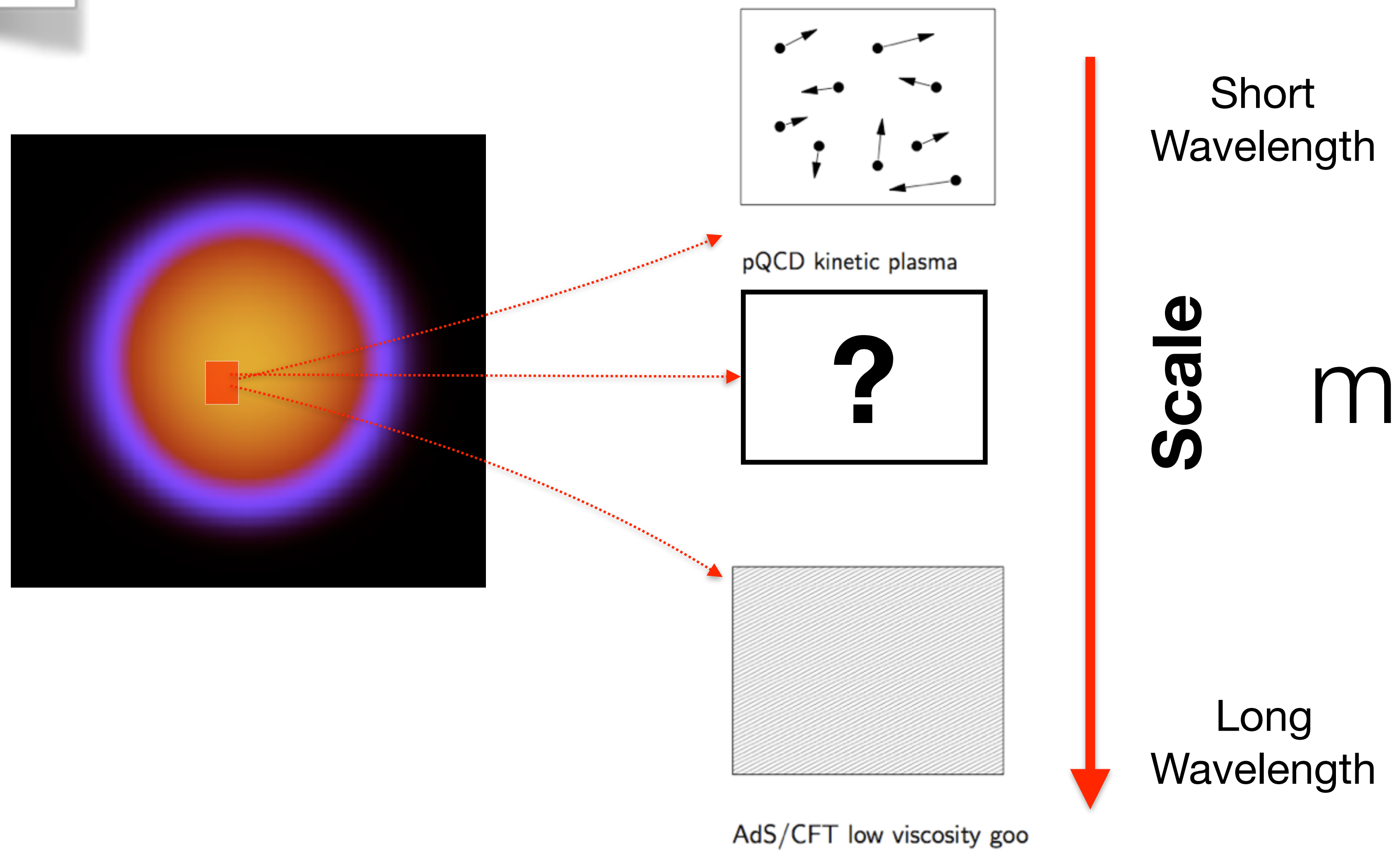
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

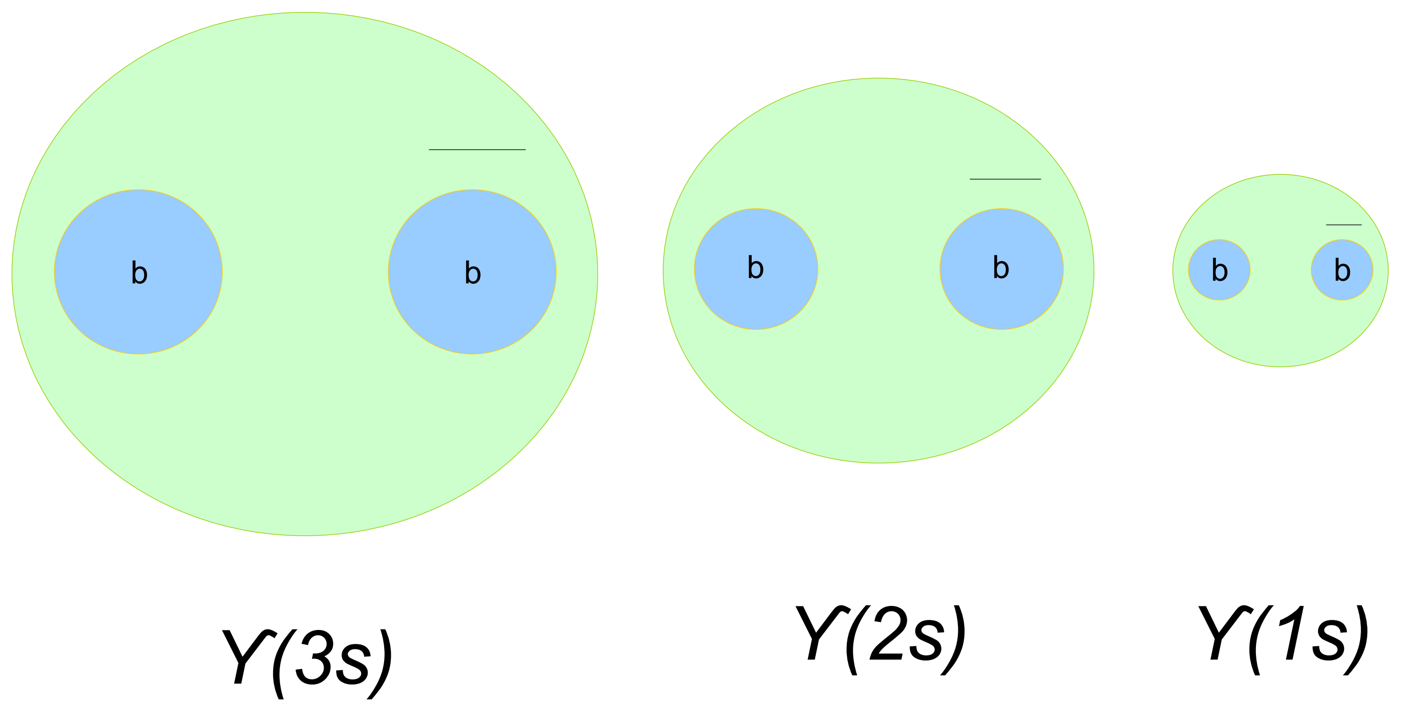


What is the microscopic structure of the QGP?

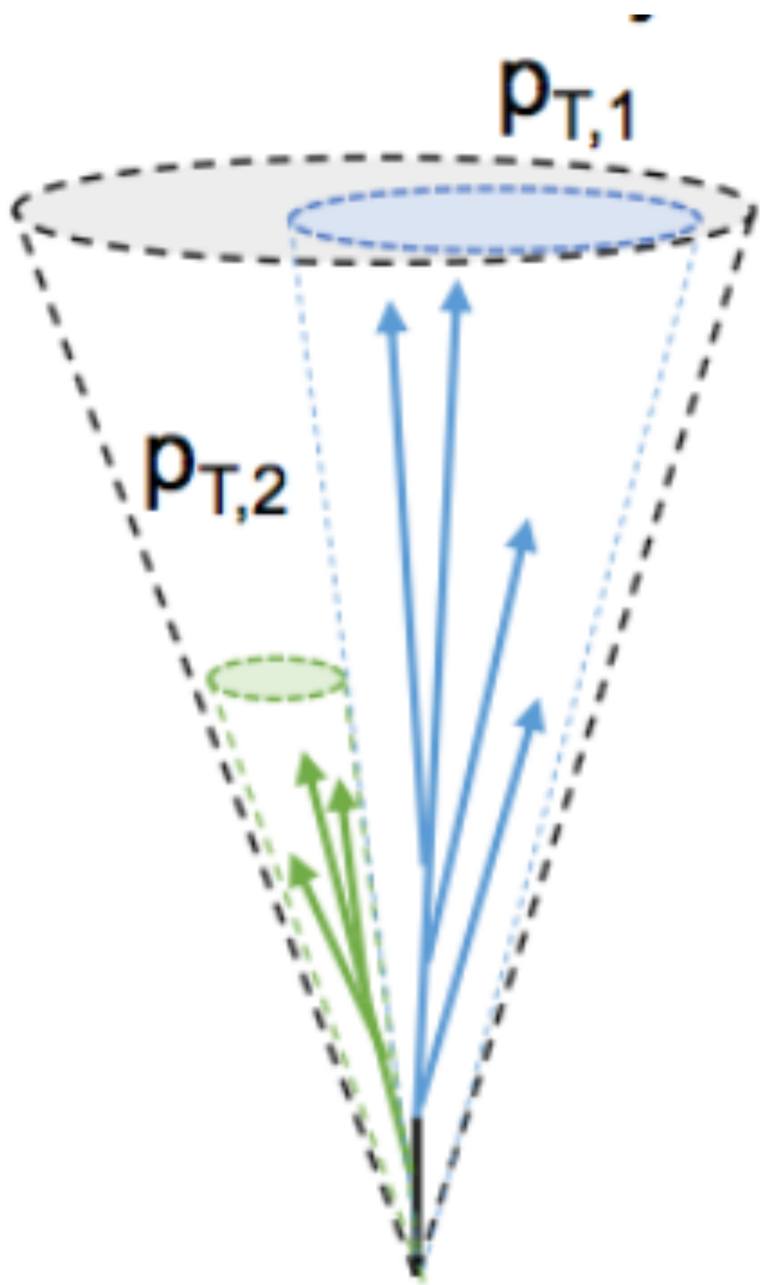
Core sPHENIX science program

Key approaches to study QGP structure at multiple scales with sPHENIX

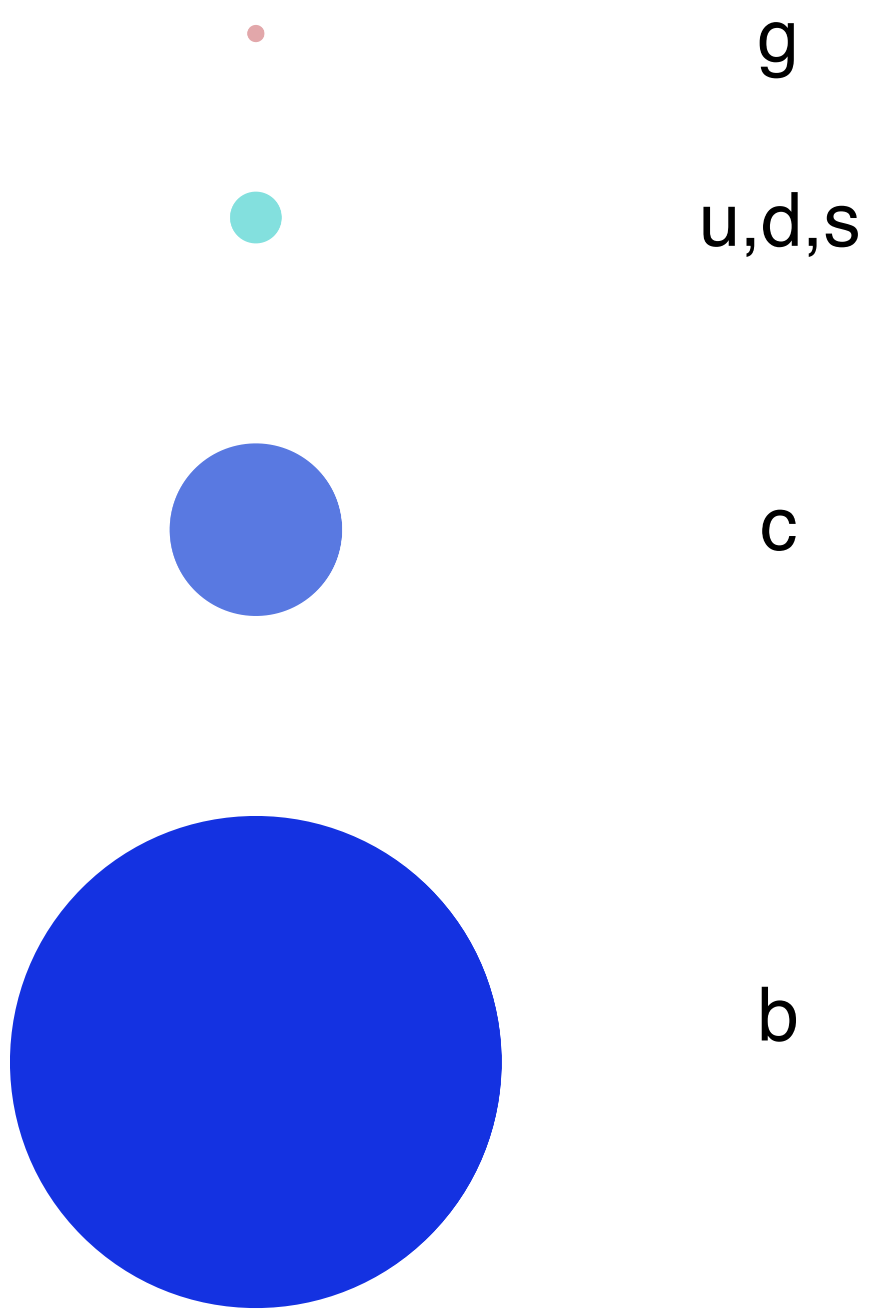
Quarkonium spectroscopy
vary size of probe



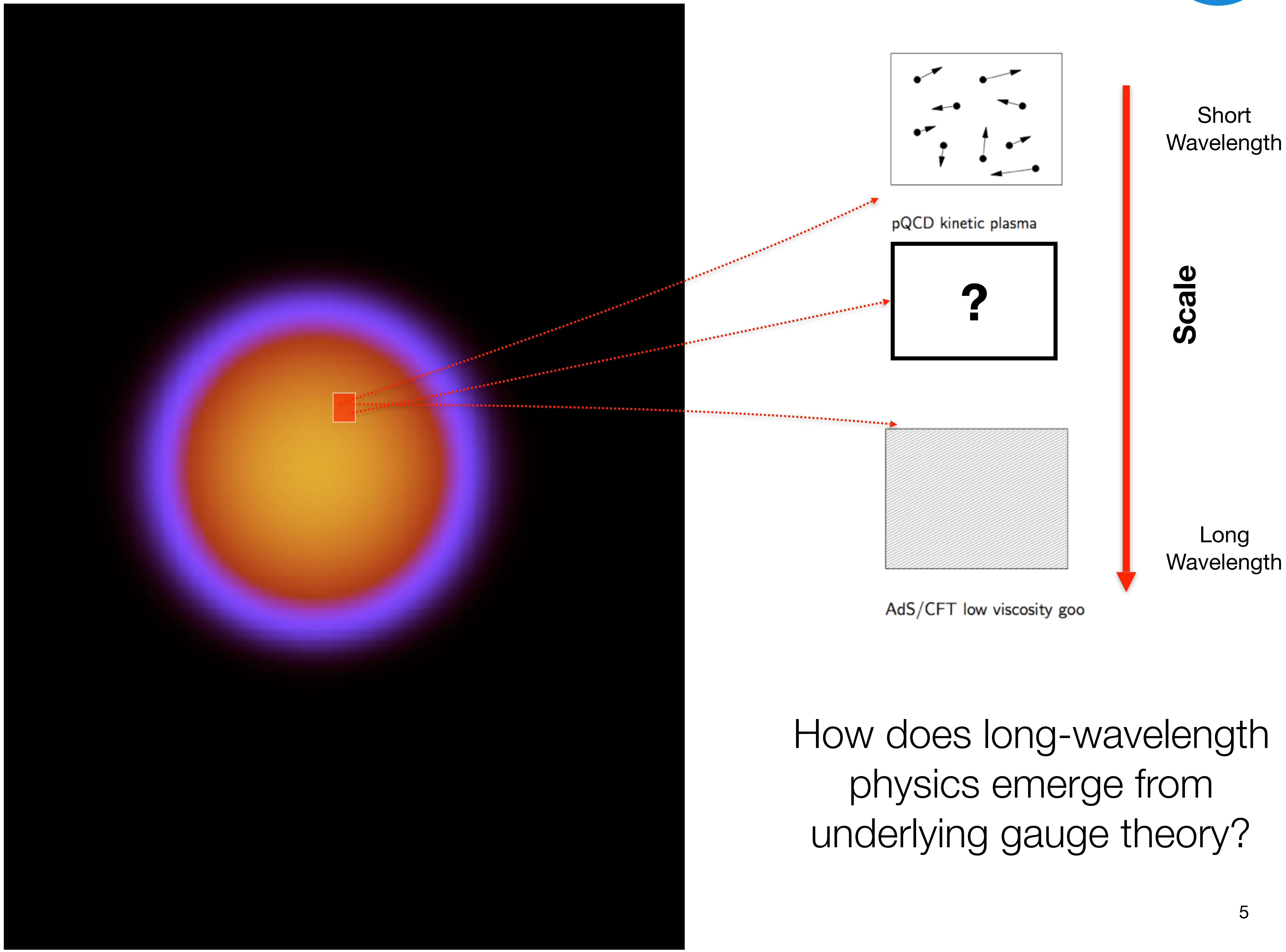
Jet structure
vary momentum/angular scale of probe



Parton energy loss
vary mass/momentum of probe



Experimental approach

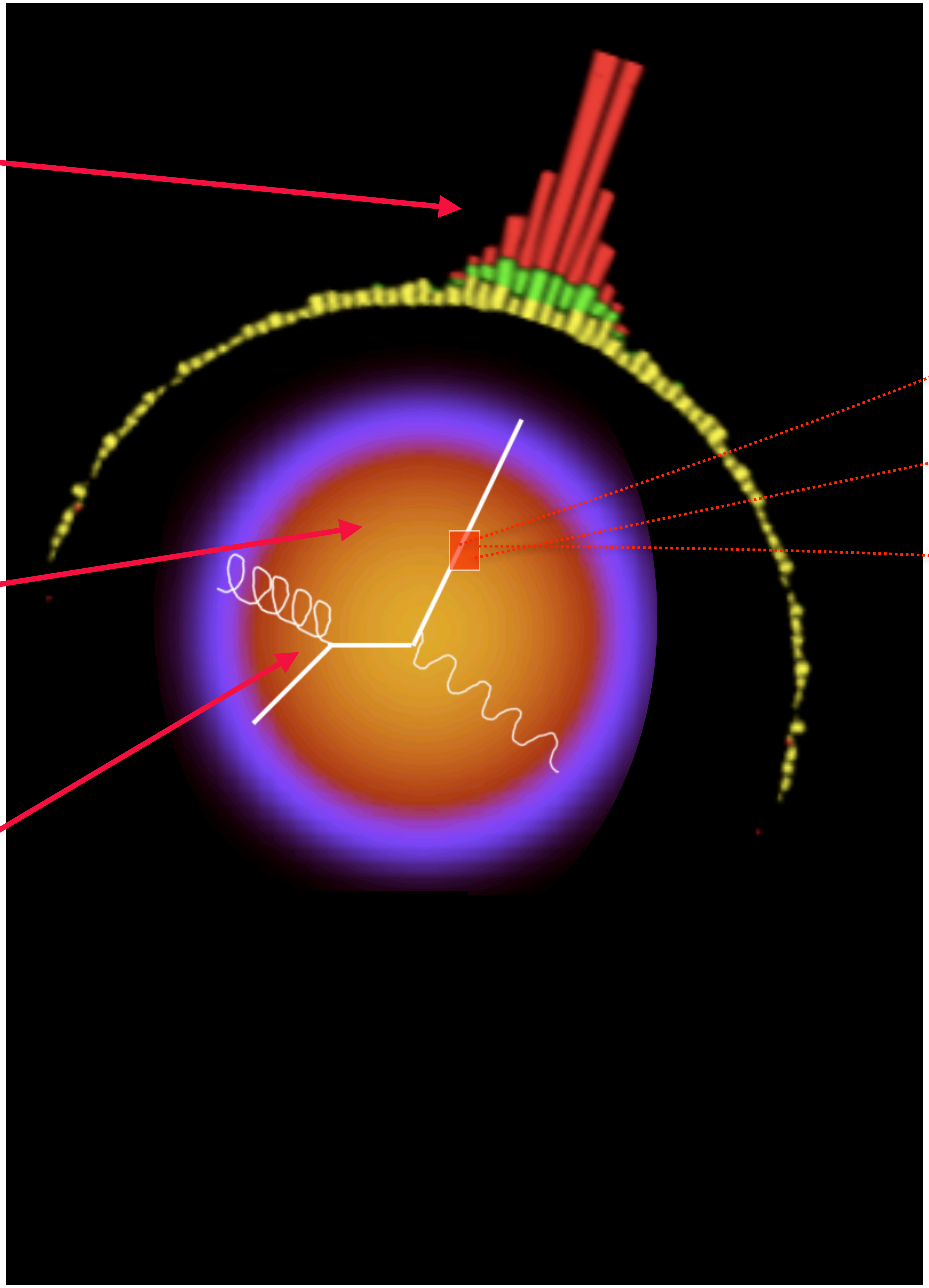


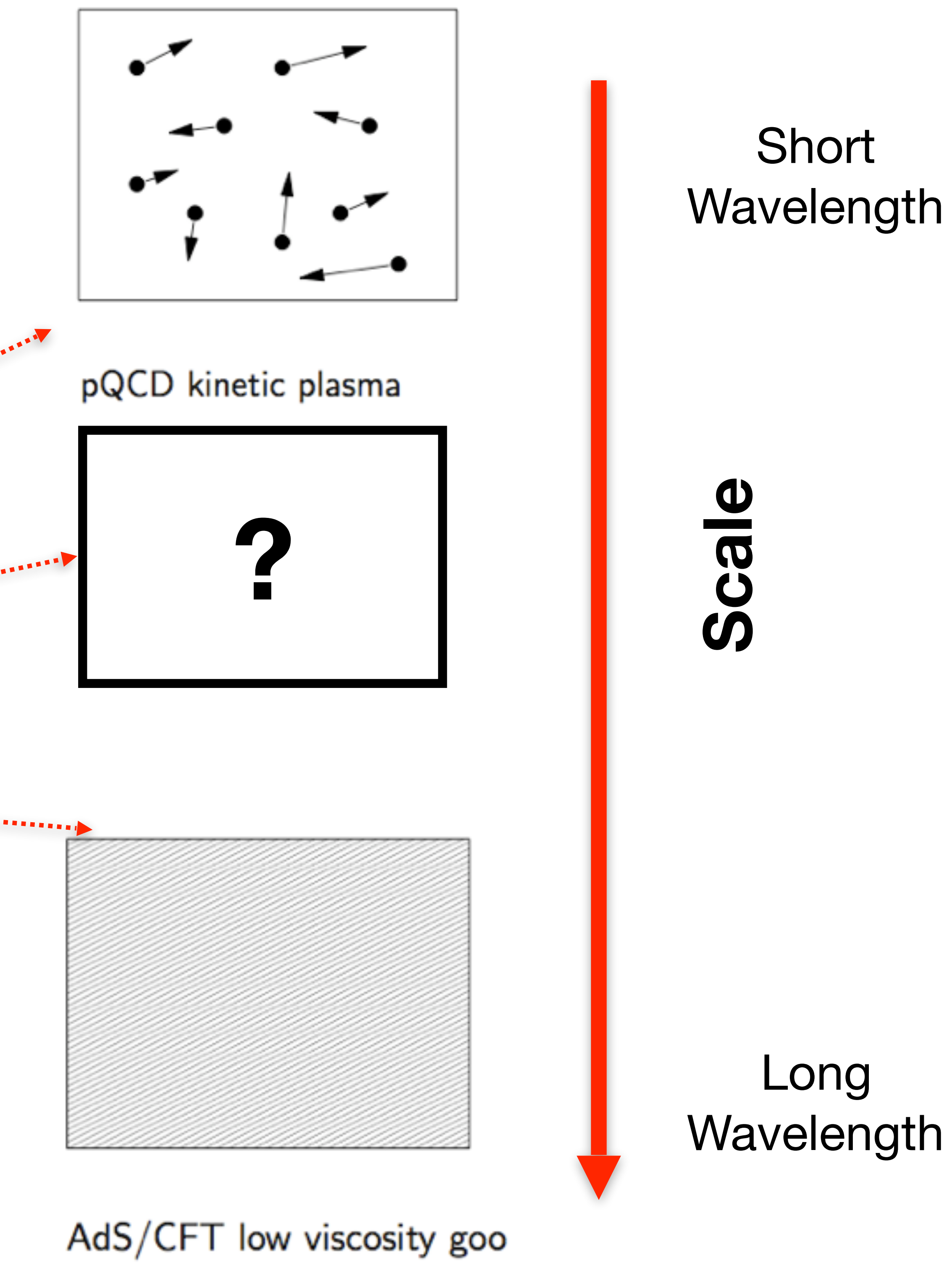
How does long-wavelength physics emerge from underlying gauge theory?

Full characterization of final state

Different QGP initial conditions and evolution at RHIC and LHC

Same hard process



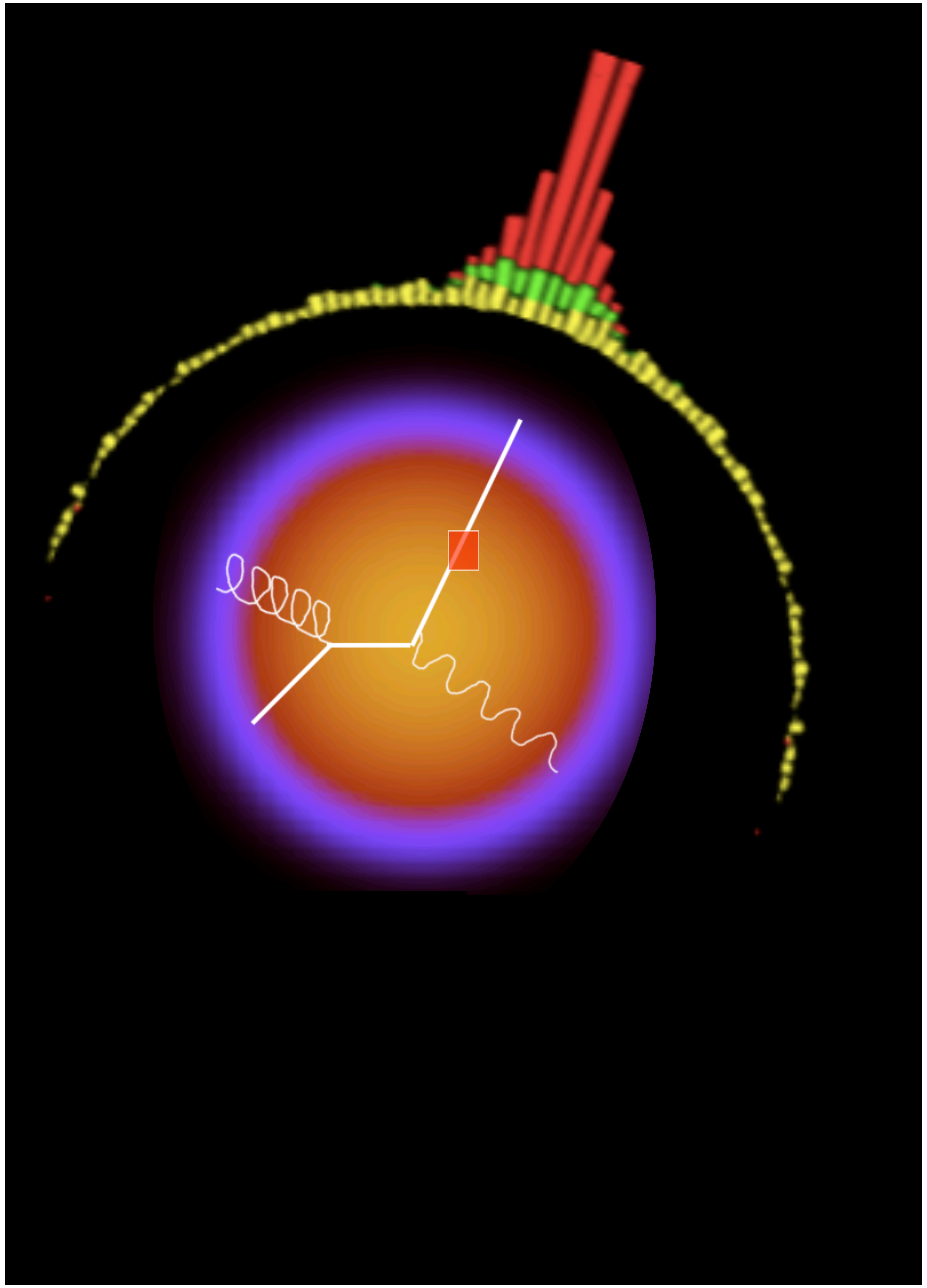


How does long-wavelength physics emerge from underlying gauge theory?

Full characterization of final state

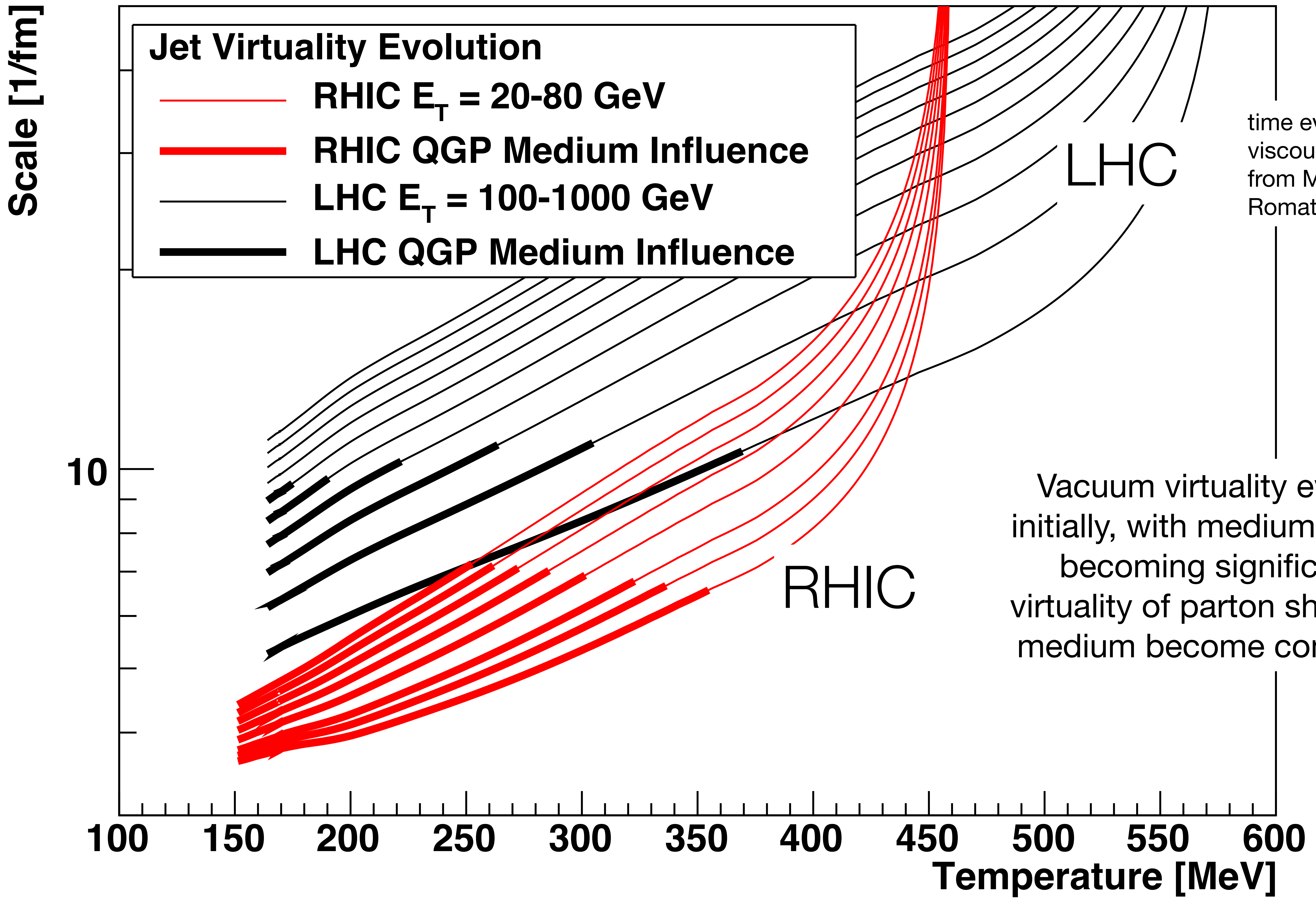
Ability to tag initial state and to fully characterize final state drives sPHENIX detector design

Same hard process



Complementarity of sPHENIX/LHC jets in evolving media

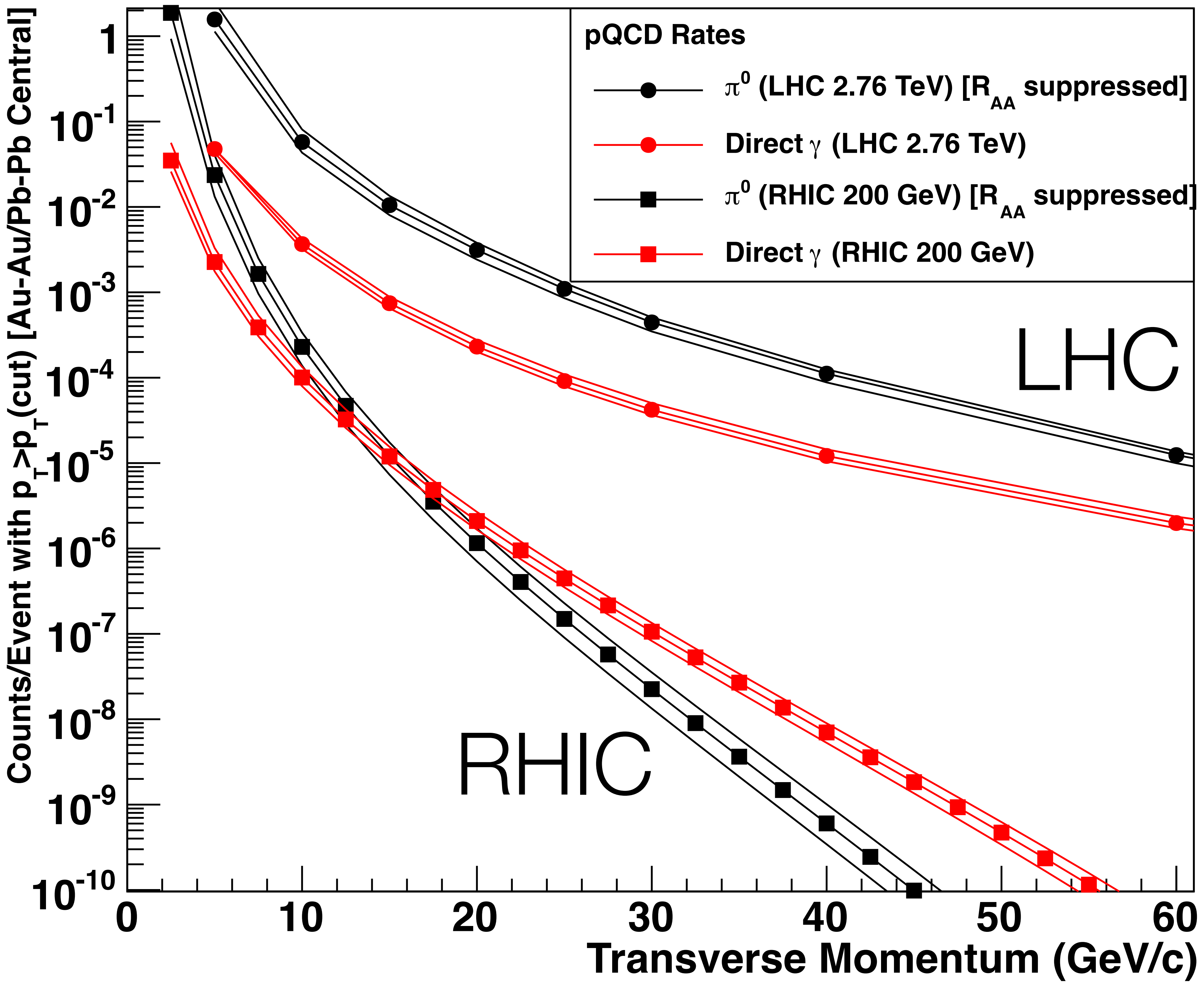
initial hard scattered parton virtuality in units of 1/fm as a function of the local temperature



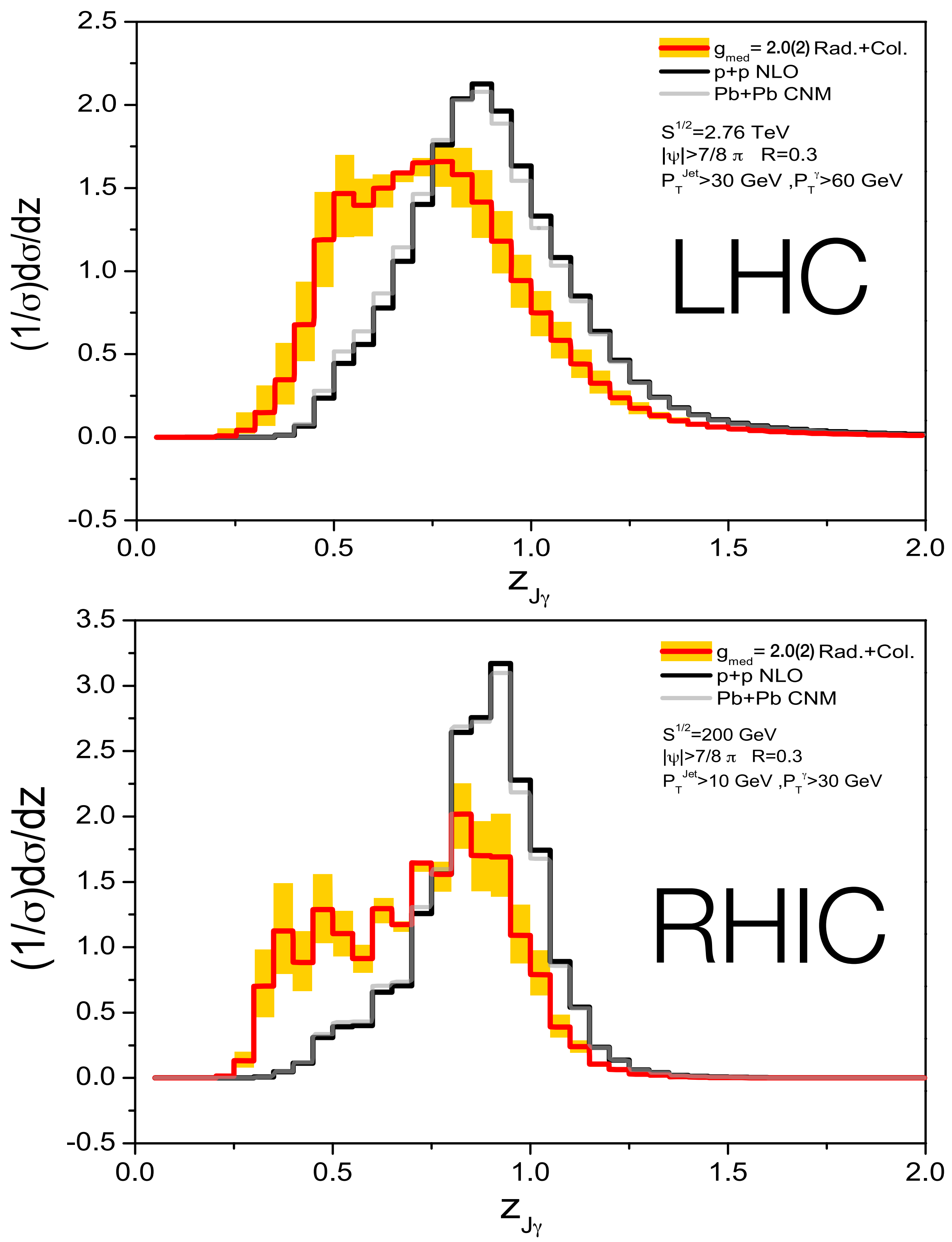
time evolution of pre-equilibrium dynamics, viscous hydrodynamics, and hadron cascade from M. Habich, J. Nagle, and P. Romatschke, EPJC, 75:15 (2015)

Vacuum virtuality evolution initially, with medium influence becoming significant as virtuality of parton shower and medium become comparable

Direct photons and photon triggered jets



Dai, Vitev, Zhang, PRL 110 (2013) 14, 142001

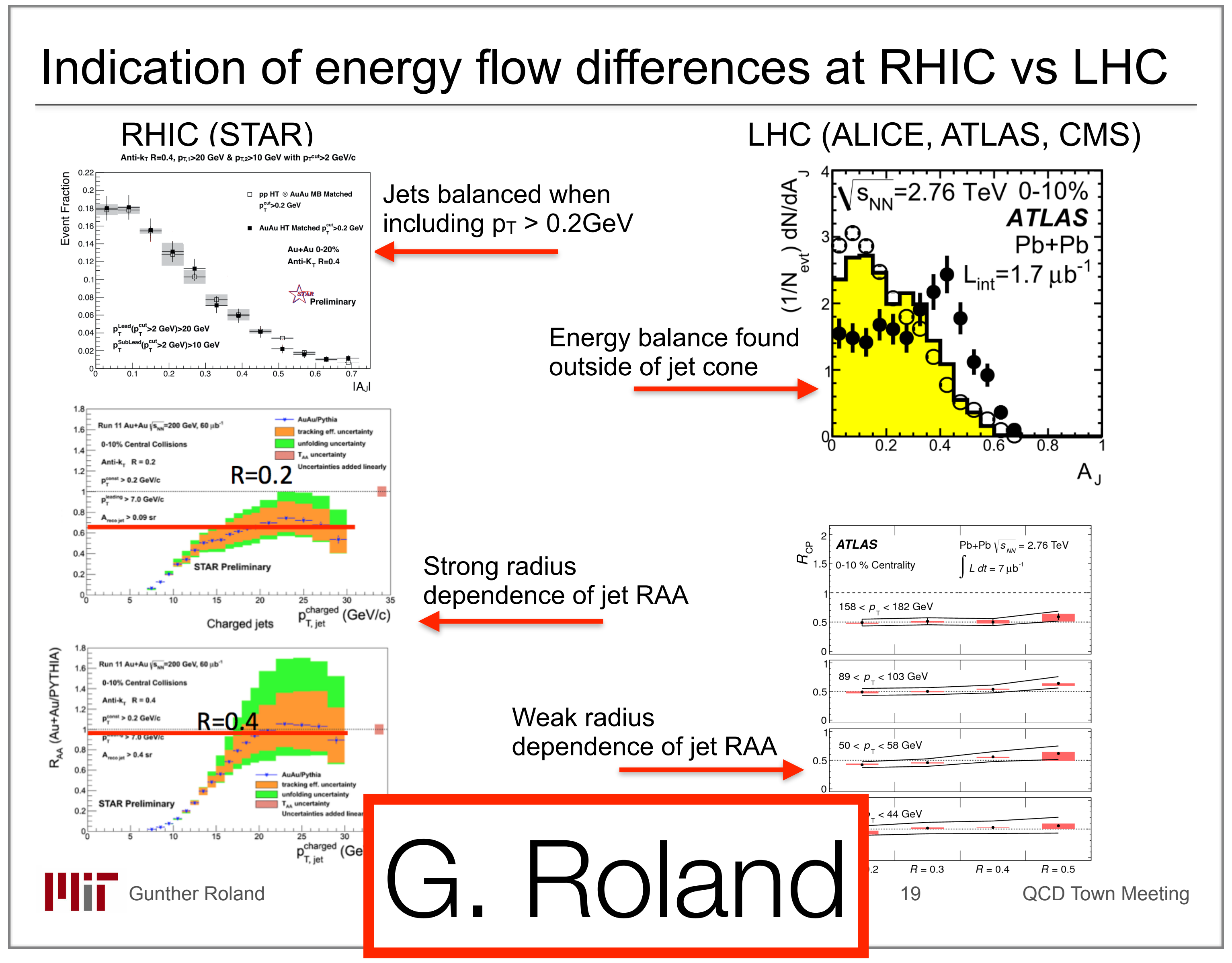


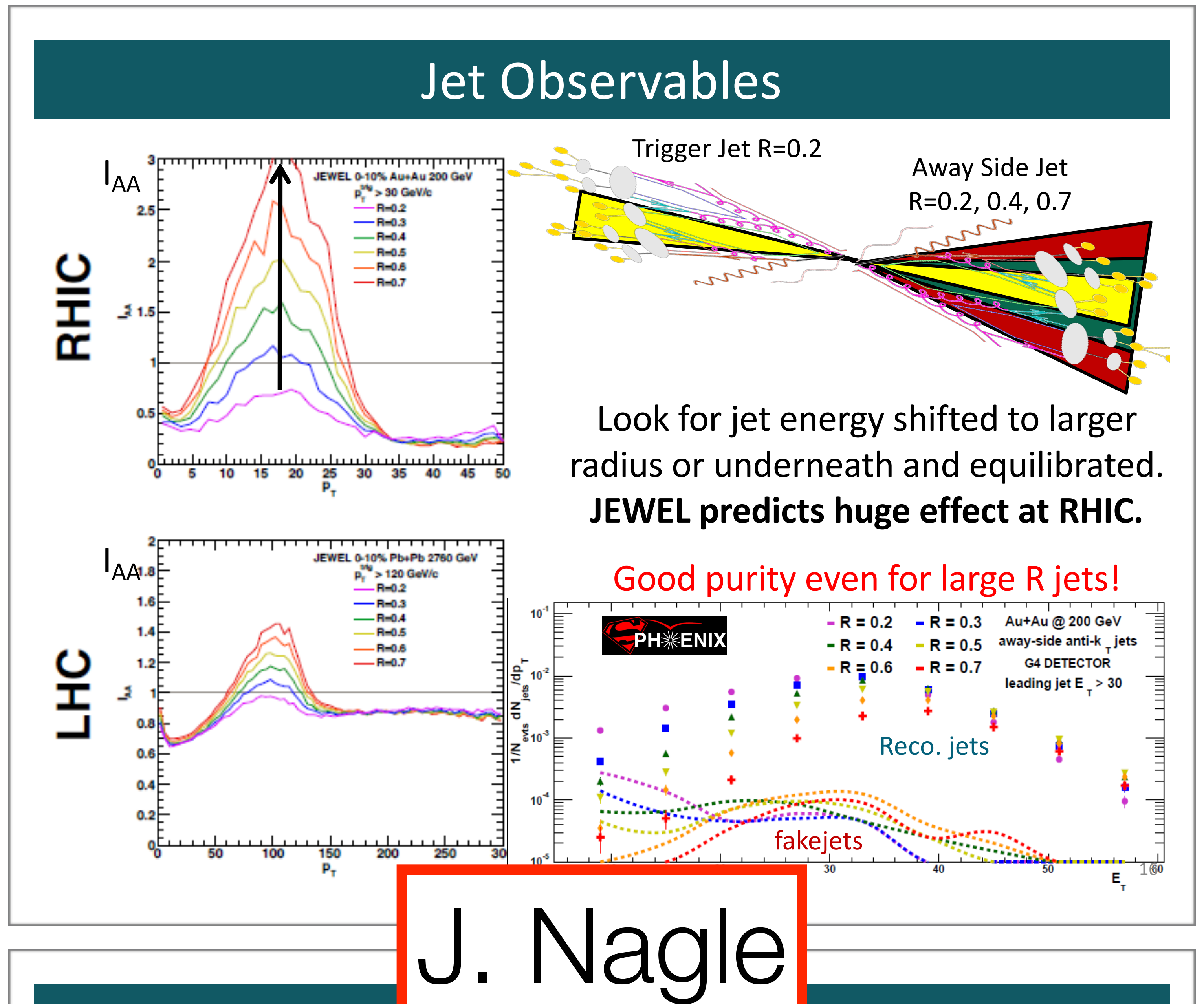
For γ (@ E = 20 GeV), S/B is 20x larger at RHIC; underlying event 2.5x smaller

"The steeper falling cross sections at RHIC energies lead not only to a narrower $z_{J\gamma}$ distribution in p+p collisions but also to larger broadening and shift in the $\langle z_{J\gamma} \rangle$. "

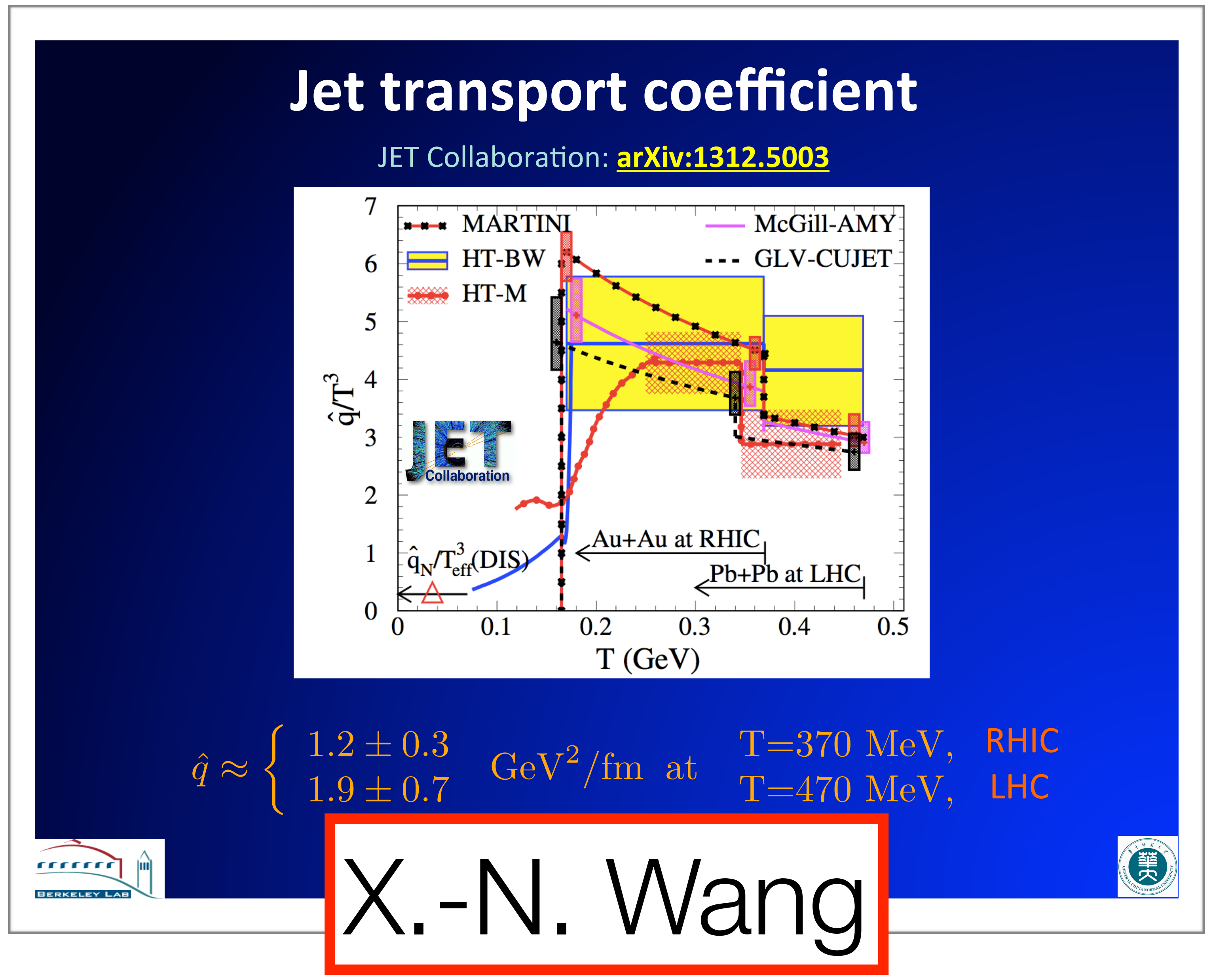
Joint Town Meetings on QCD, Temple University, September 2014

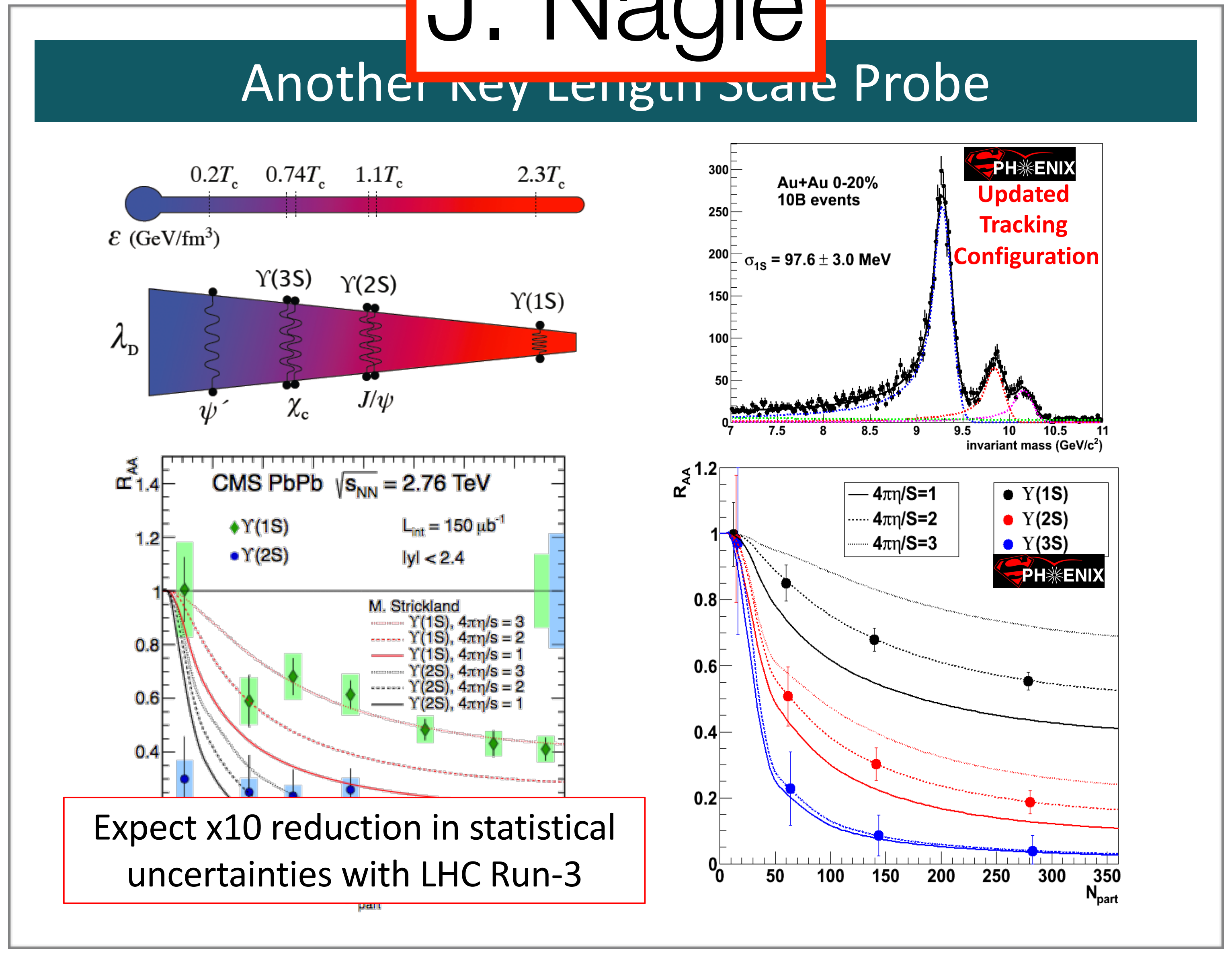
Presentations in Hot QCD session highlighted benefit of having RHIC/LHC data



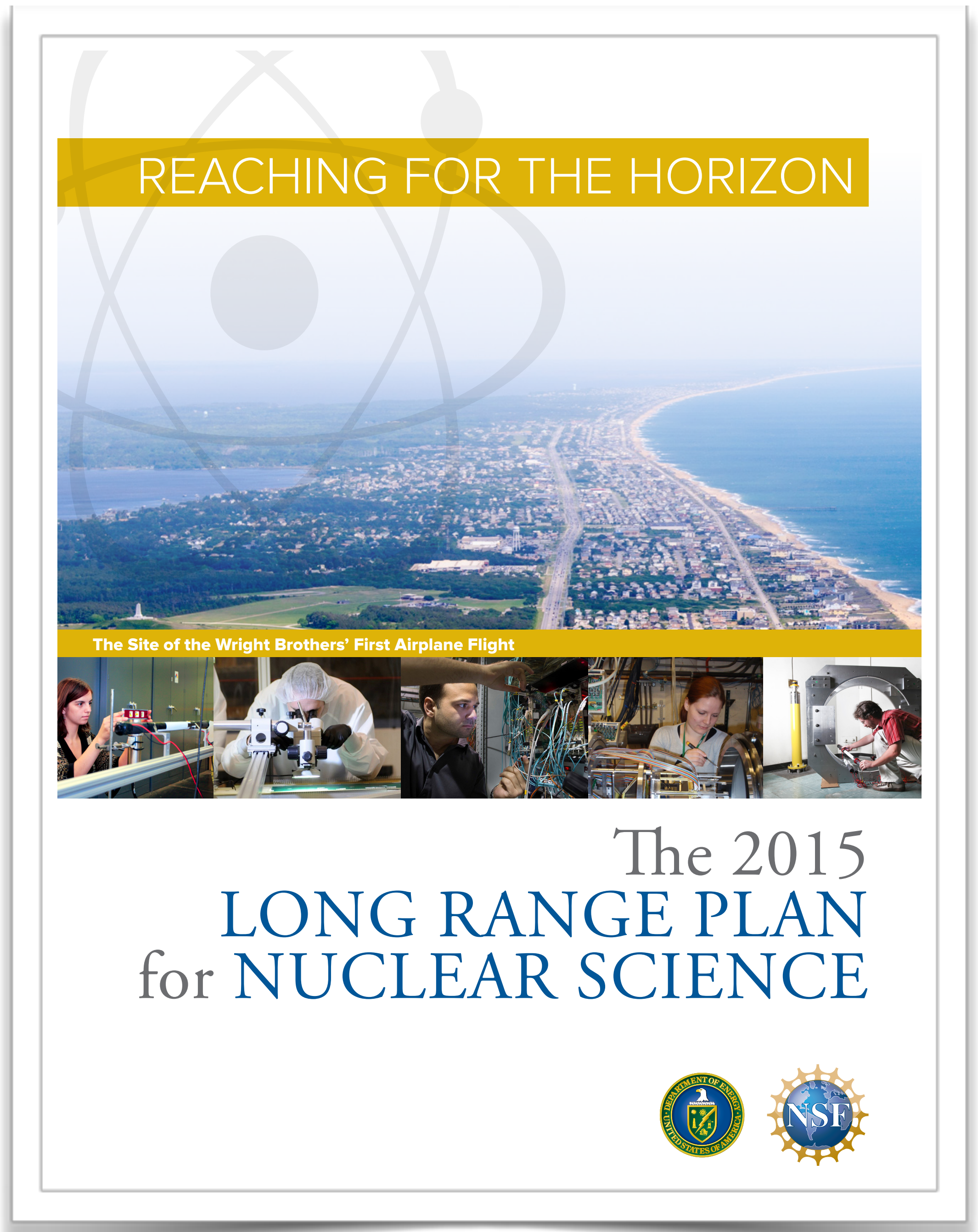


Community process leading to white papers and resolution meeting



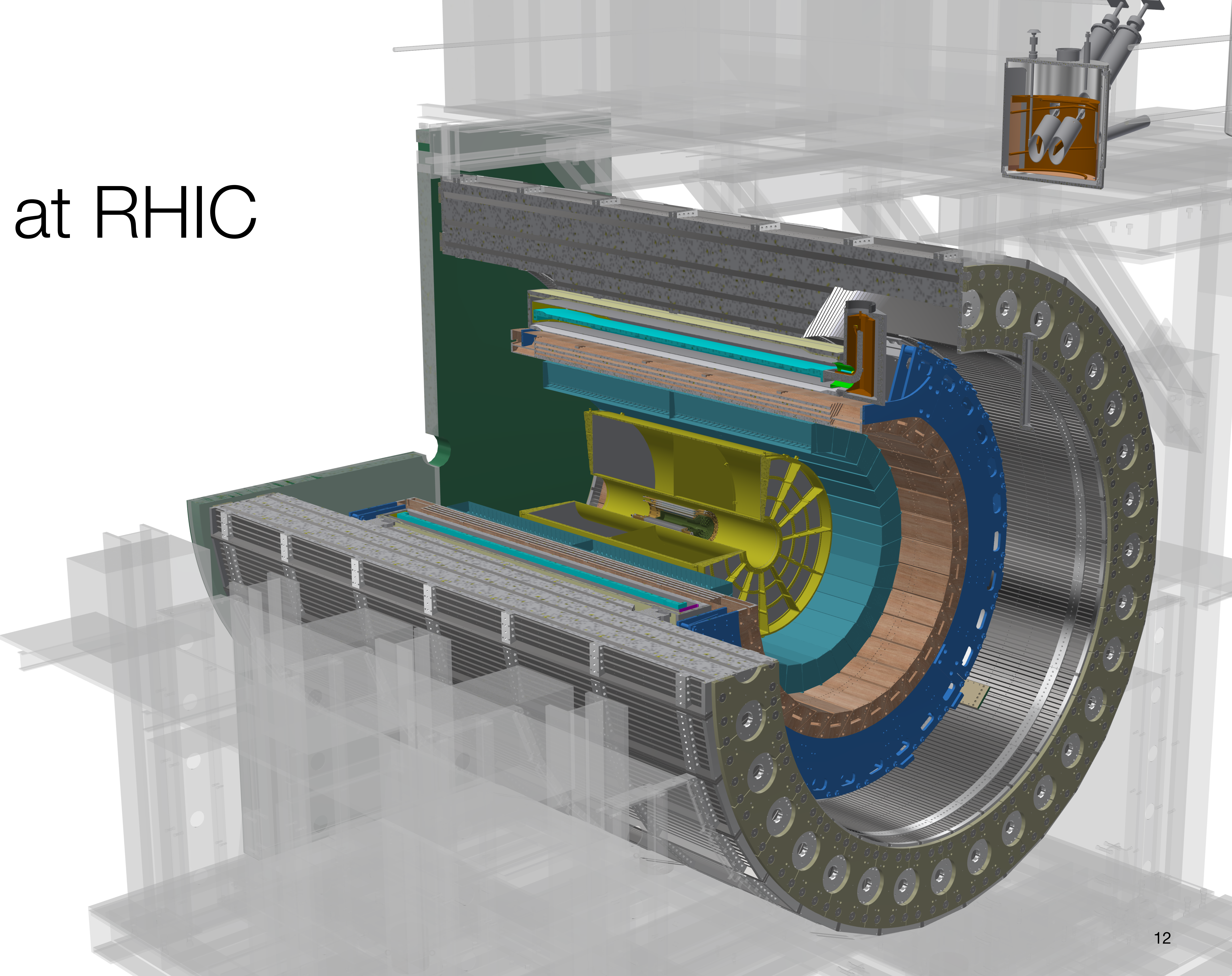


sPHENIX and complementarity in the Long Range Plan



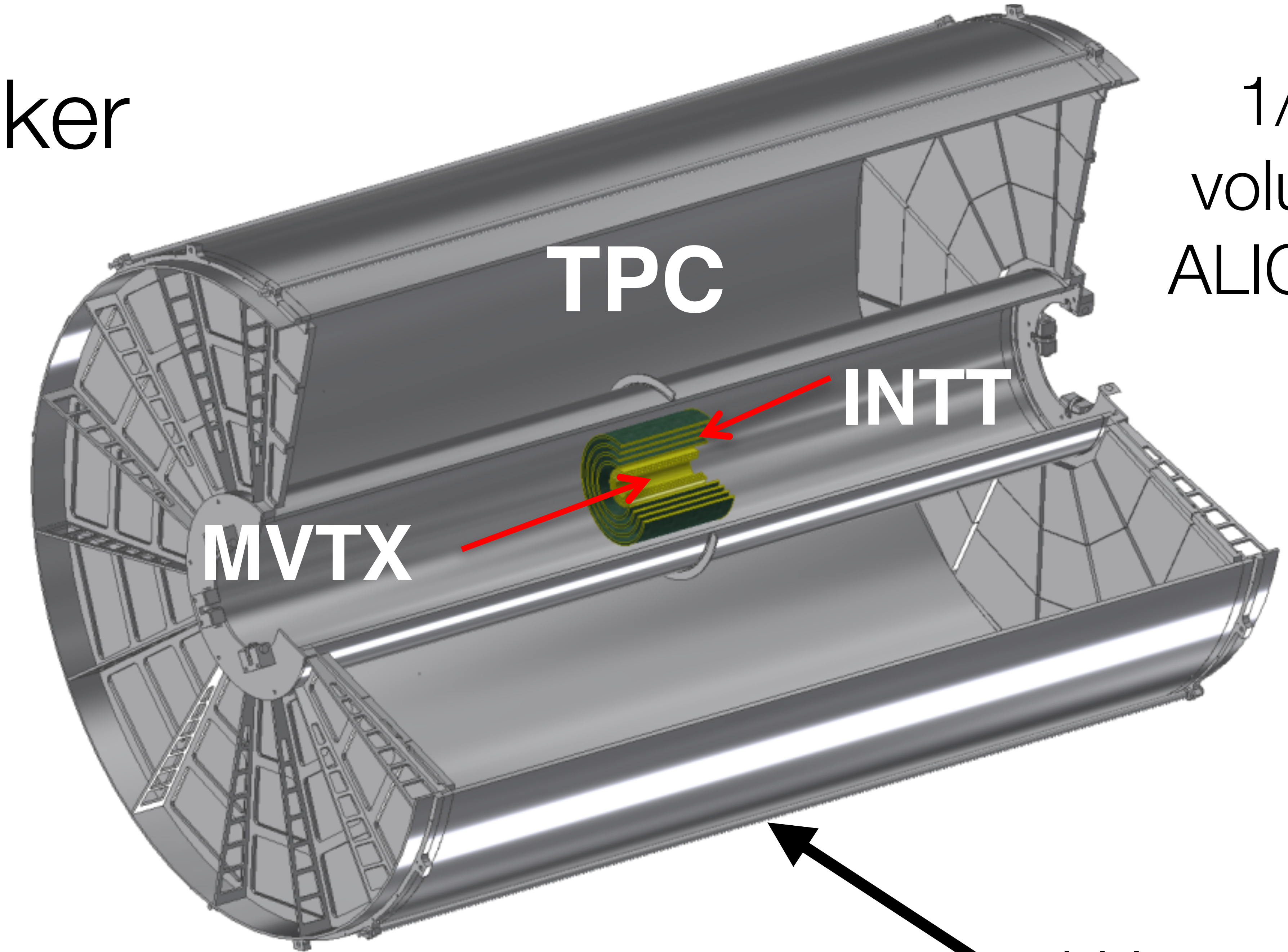
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

sPHENIX at RHIC



sPHENIX detector systems

Tracker

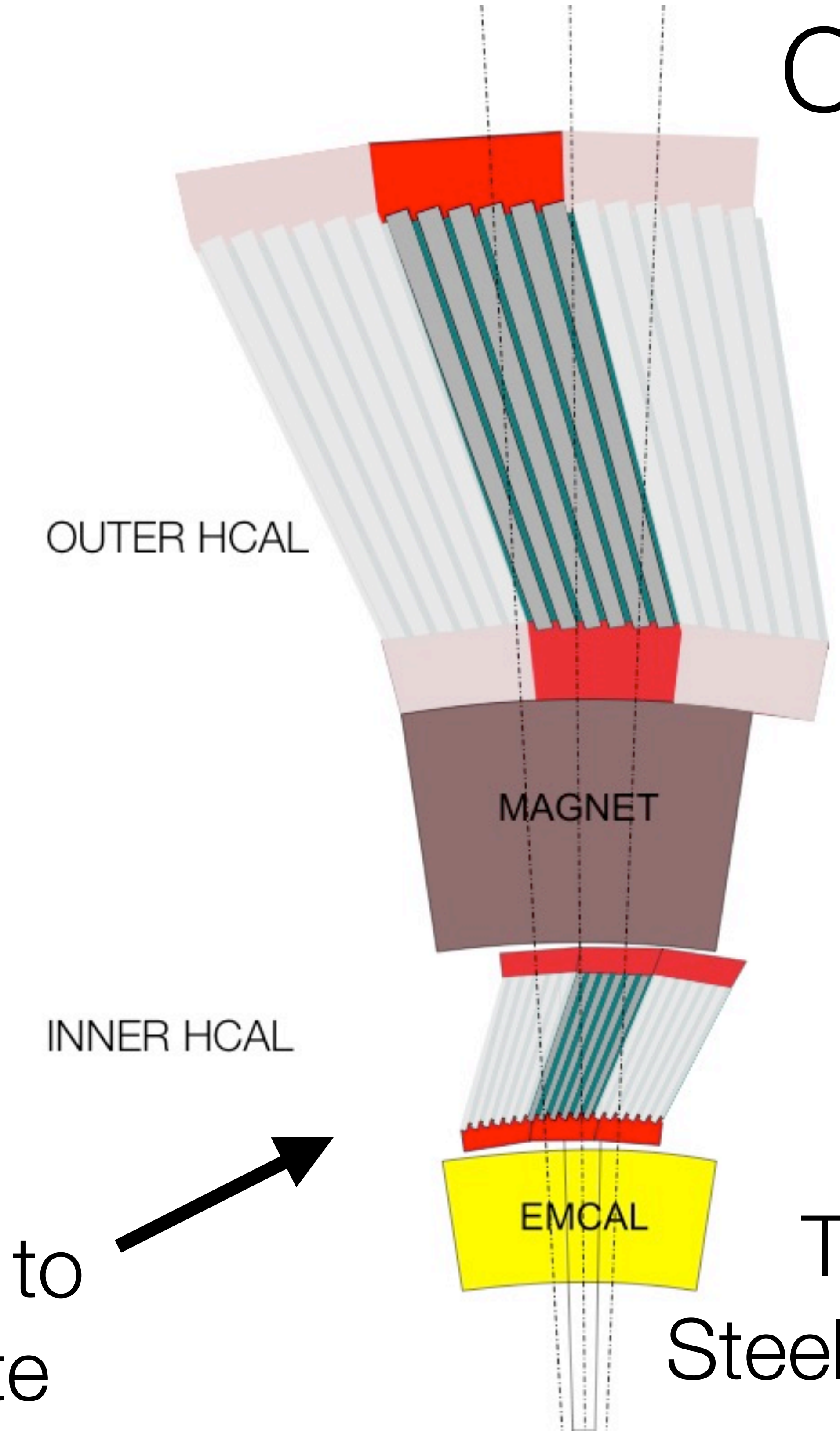


1/30th volume of ALICE TPC

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

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

Calorimeter stack



Tungsten/SciFi EMCal
Steel/plastic scintillator HCAL
SiPM readout

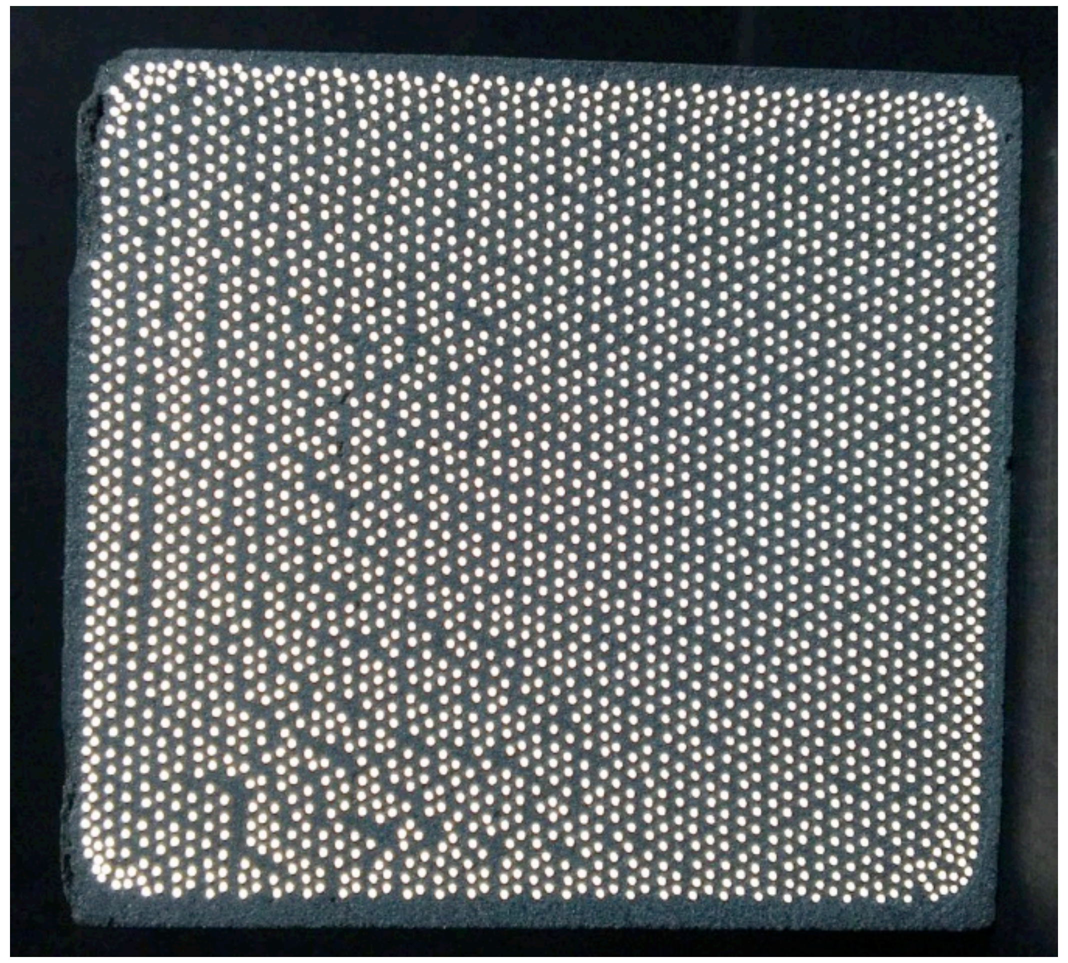
Qualitative improvement on 20 years of studies at RHIC through higher statistics (x10+), full calorimetry and higher precision tracking

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

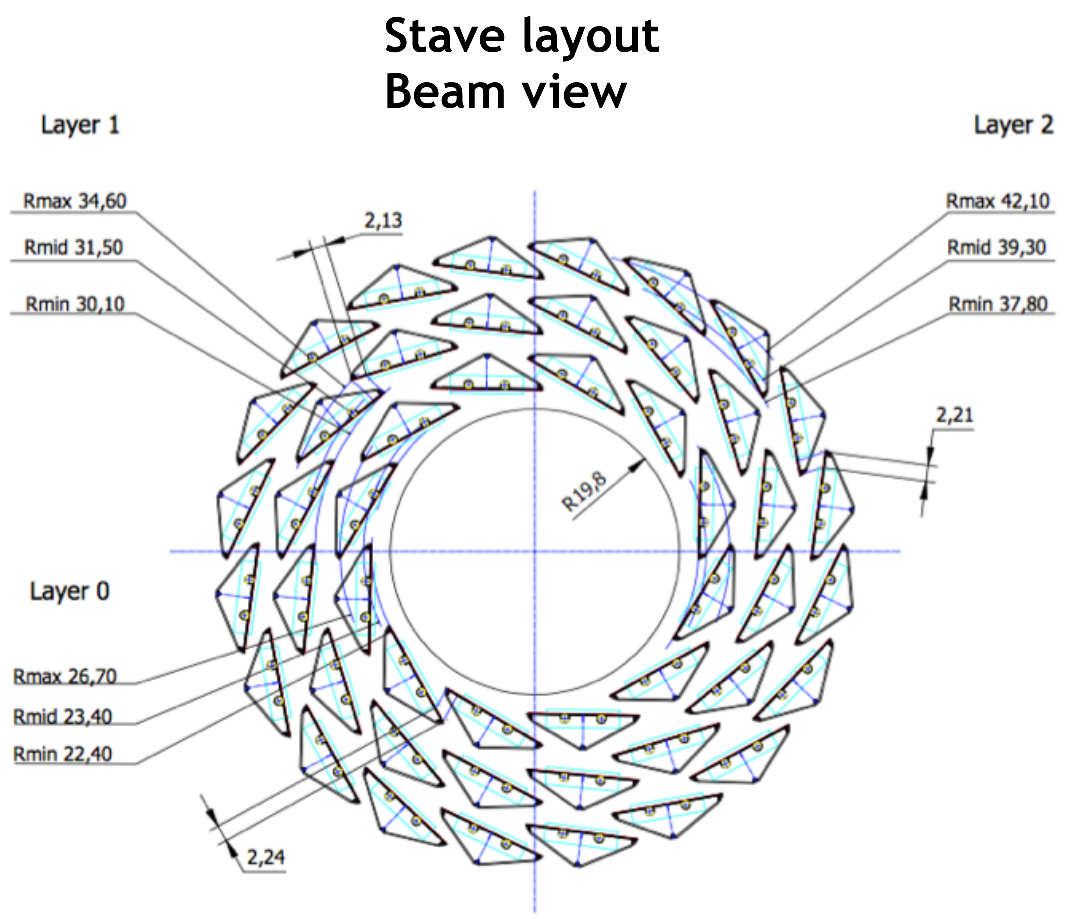

Slots for scintillating tiles, read-out using SiPMs
6.4 meters long, |η| < 1.1
32 modules form flux return
instrumented to be outer HCal
First production module delivered to BNL one month ago
Second module arrives on Friday
After that, they'll arrive at a rate of about one per week

Tungsten SciFi EMCal moving from R&D to pre-production

- technology pioneered by UCLA group
- now 2D projective, to be read out by SiPMs
- same electronics (up to form factor) as HCal
- production techniques advanced by UIUC group
- discussions to set up add'l production site in China

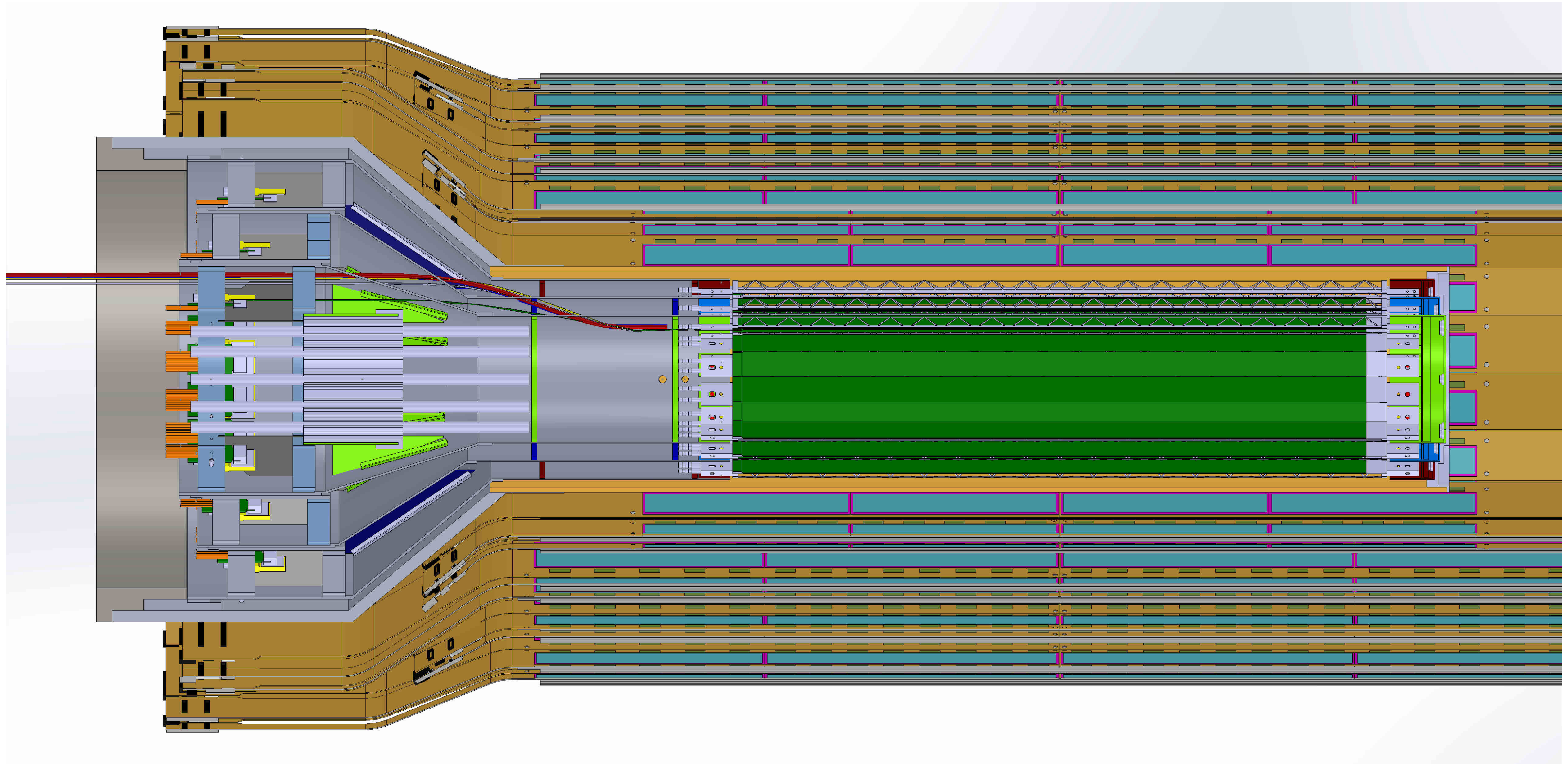


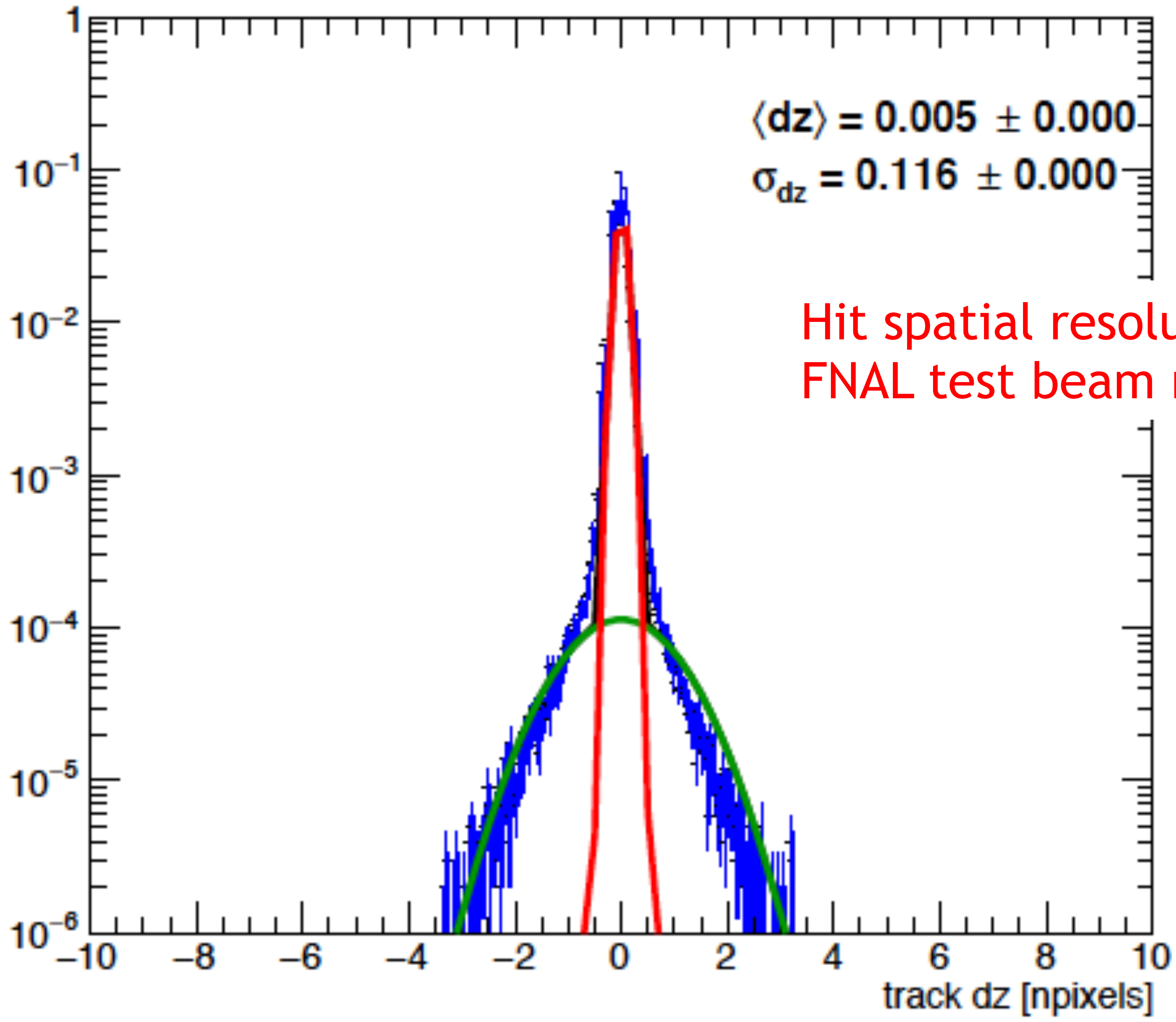
MVTX enables world-class HF science program



MVTX based on copy of ALICE staves with support structure modified for sPHENIX – integrate with silicon strip (INTT) and all fit inside TPC inner field cage.

LANL LDRD addressing key questions –demonstrating successful read-out chain test and stave performance in FNAL test beam

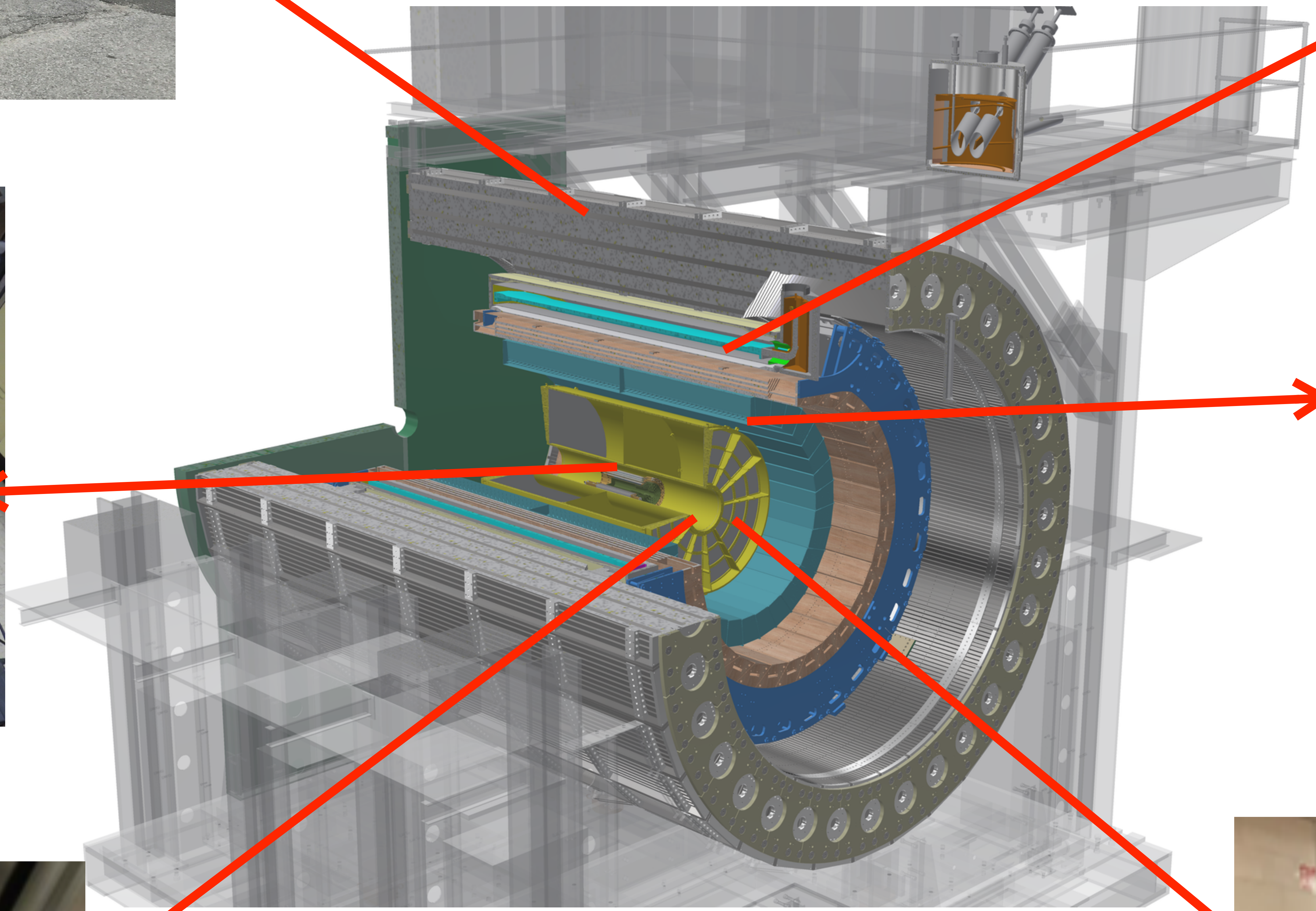


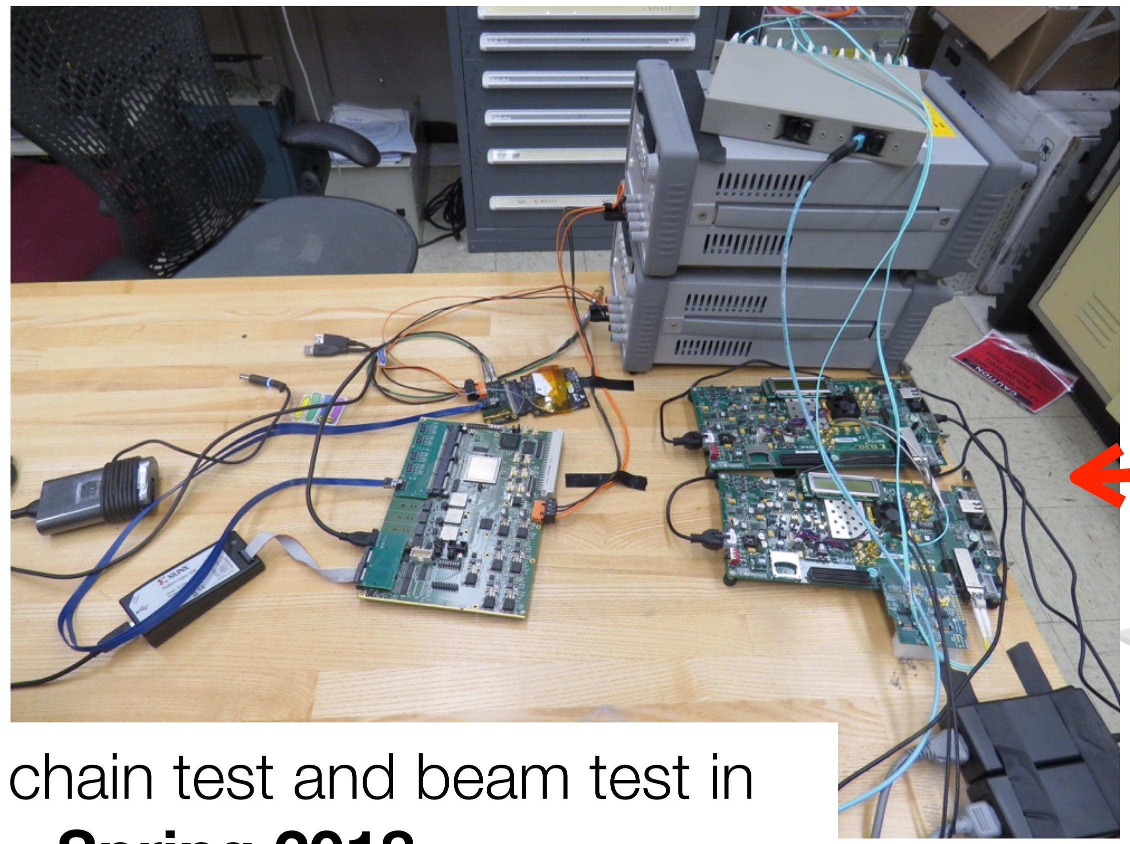


Hit spatial resolution: < 5 μm
FNAL test beam results

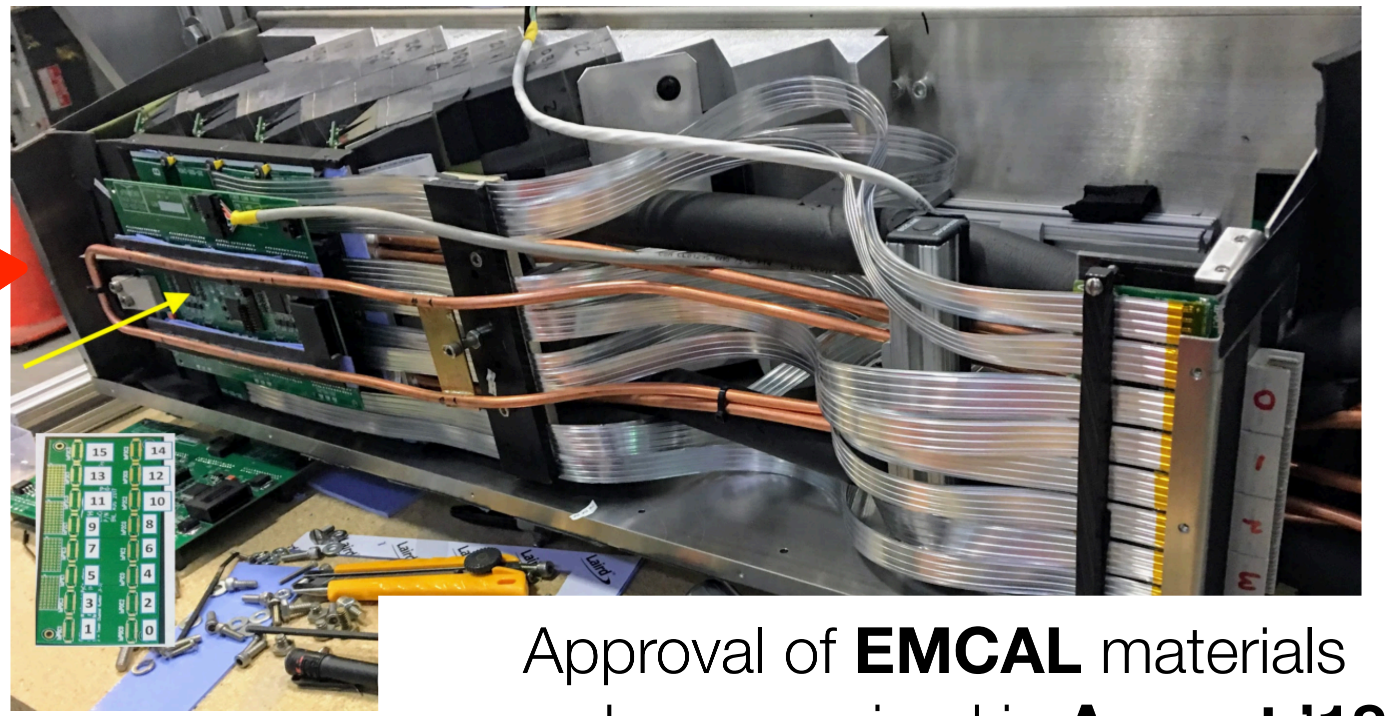
Flux return/**oHCAL** absorber
First production sectors
arrived one month ago

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

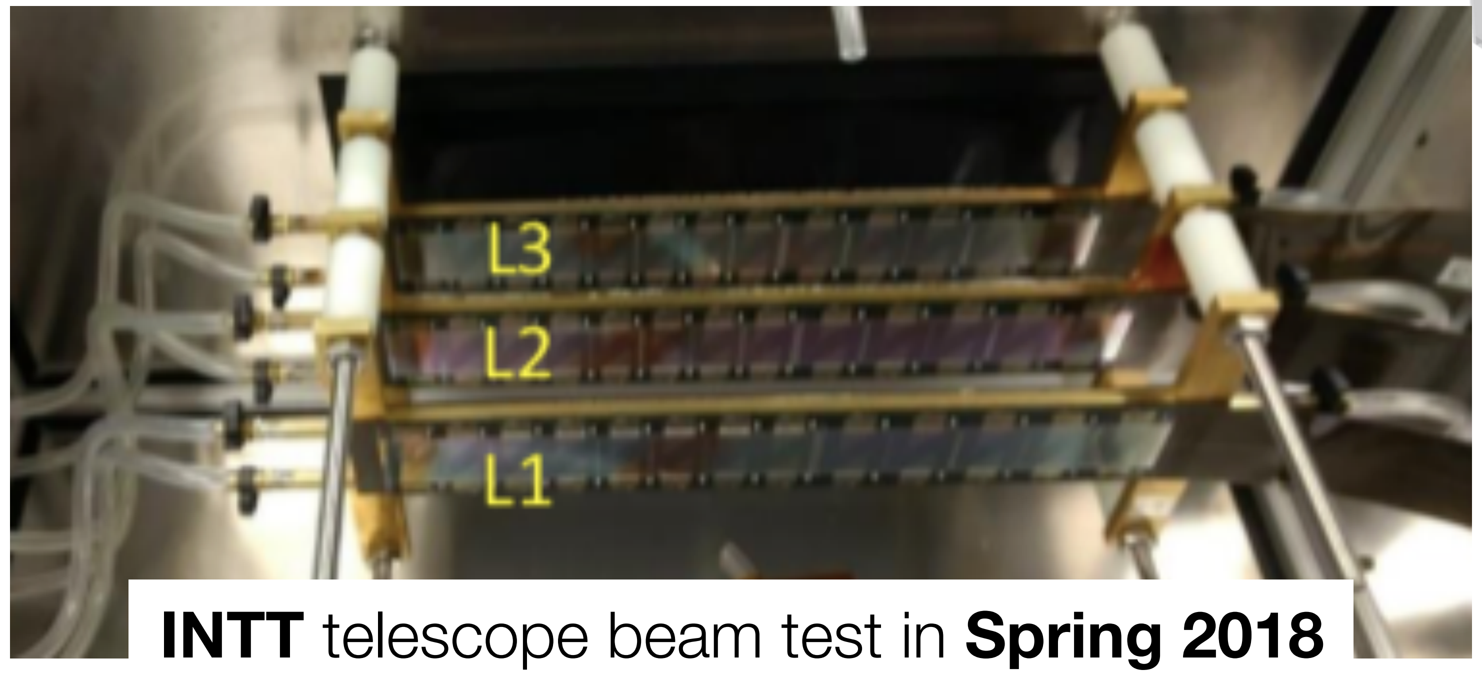




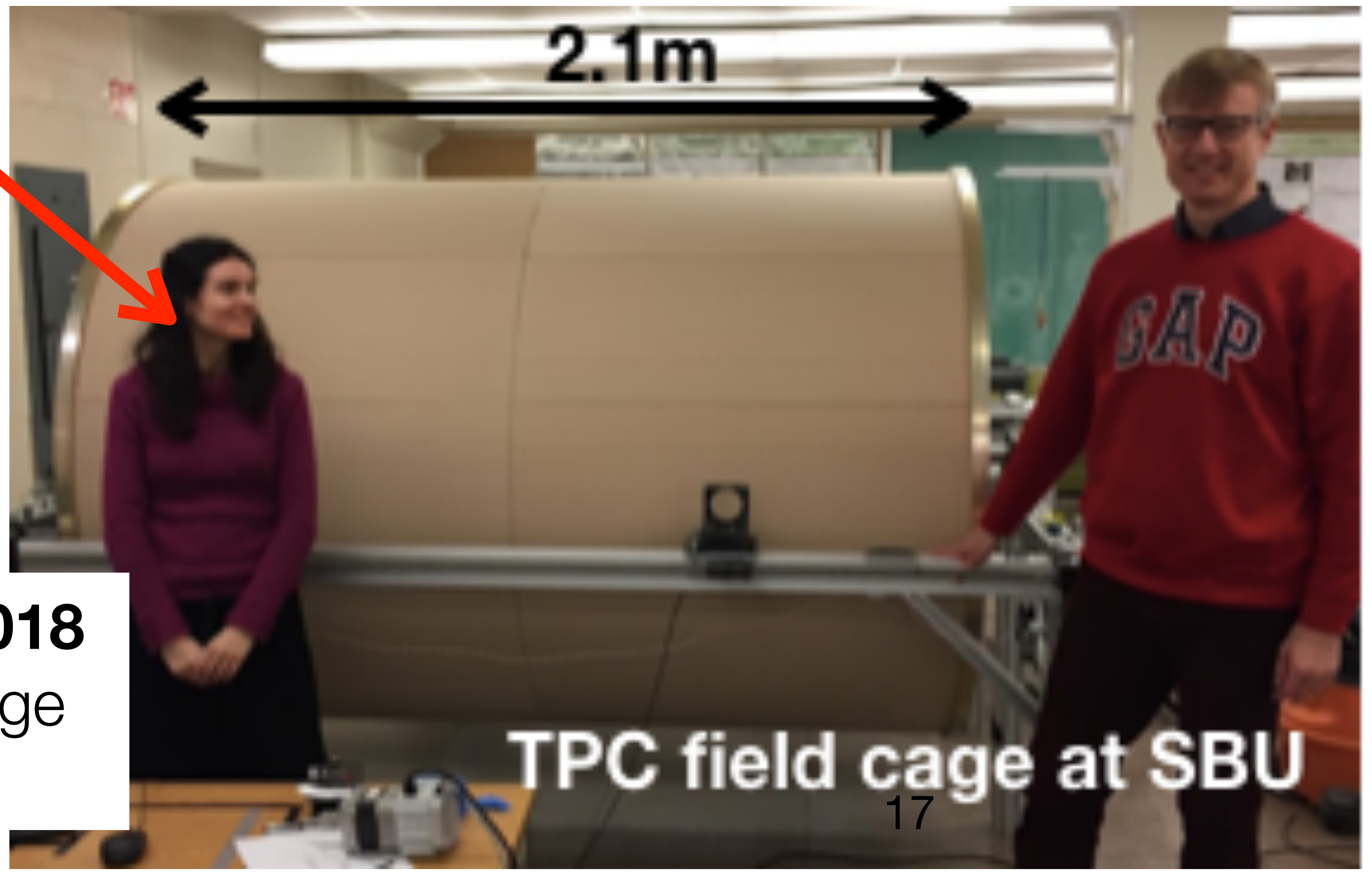
MVTX full chain test and beam test in
Spring 2018
Plans for stave procurement **early 2019**



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"


From PHENIX…
2016


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

...sPHENIX

When will sPHENIX take data?

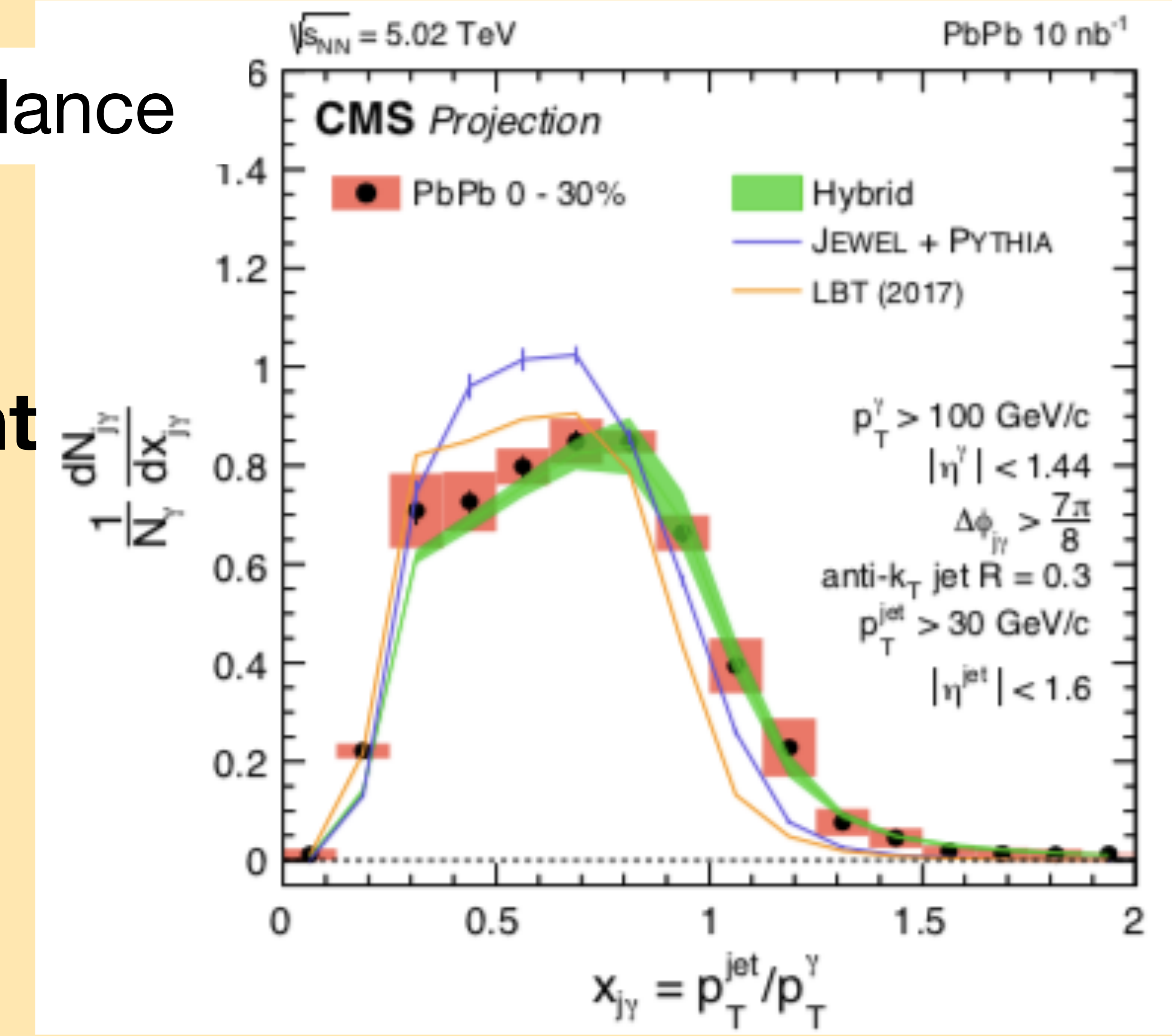
record 240B minimum bias Au+Au events
record 35/nb, sample 83/nb

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

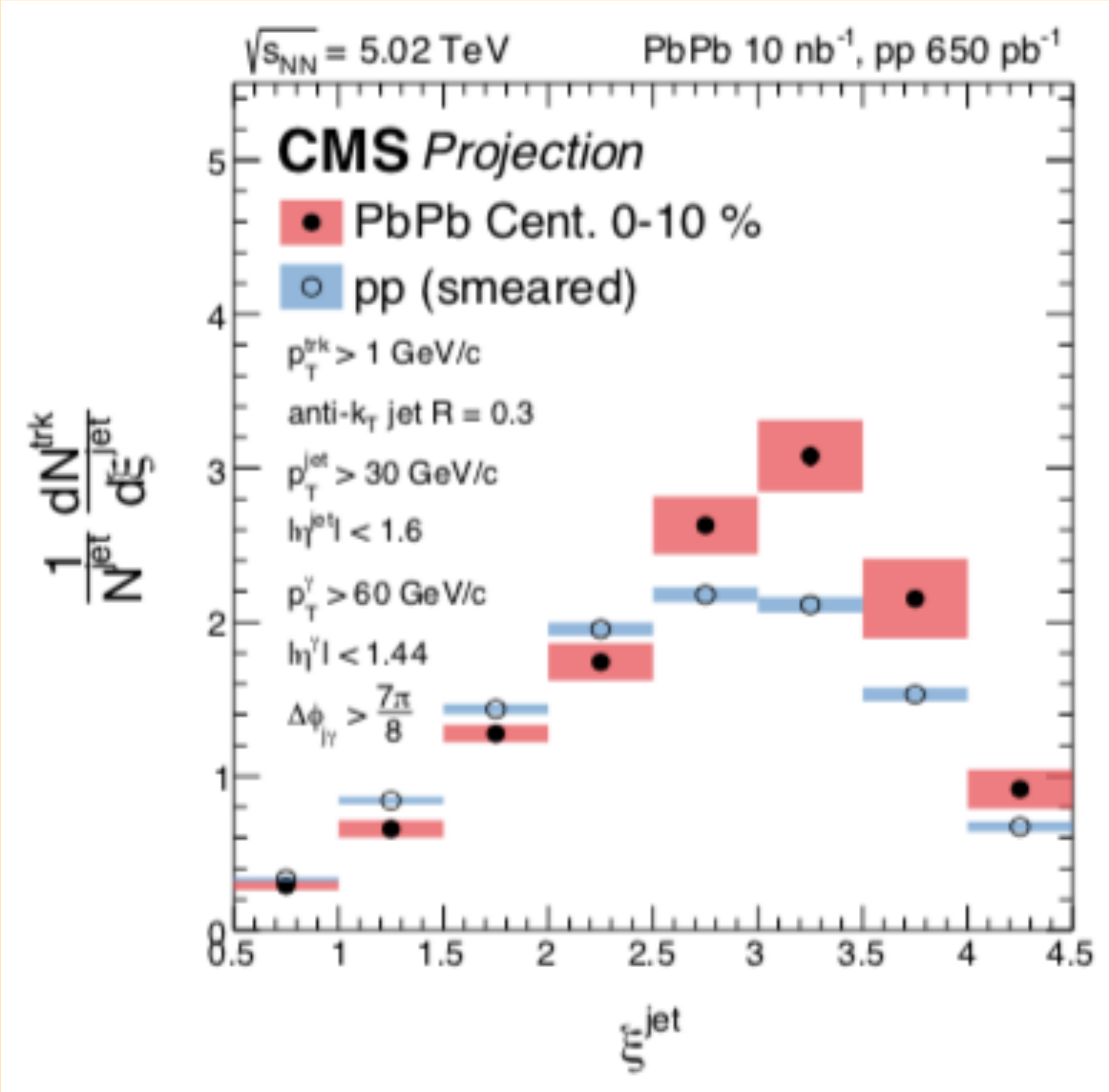
Physics projections: Jets in sPHENIX cf. LHC

γ+Jet momentum balance

Direct measurement of parton energy loss in the QGP

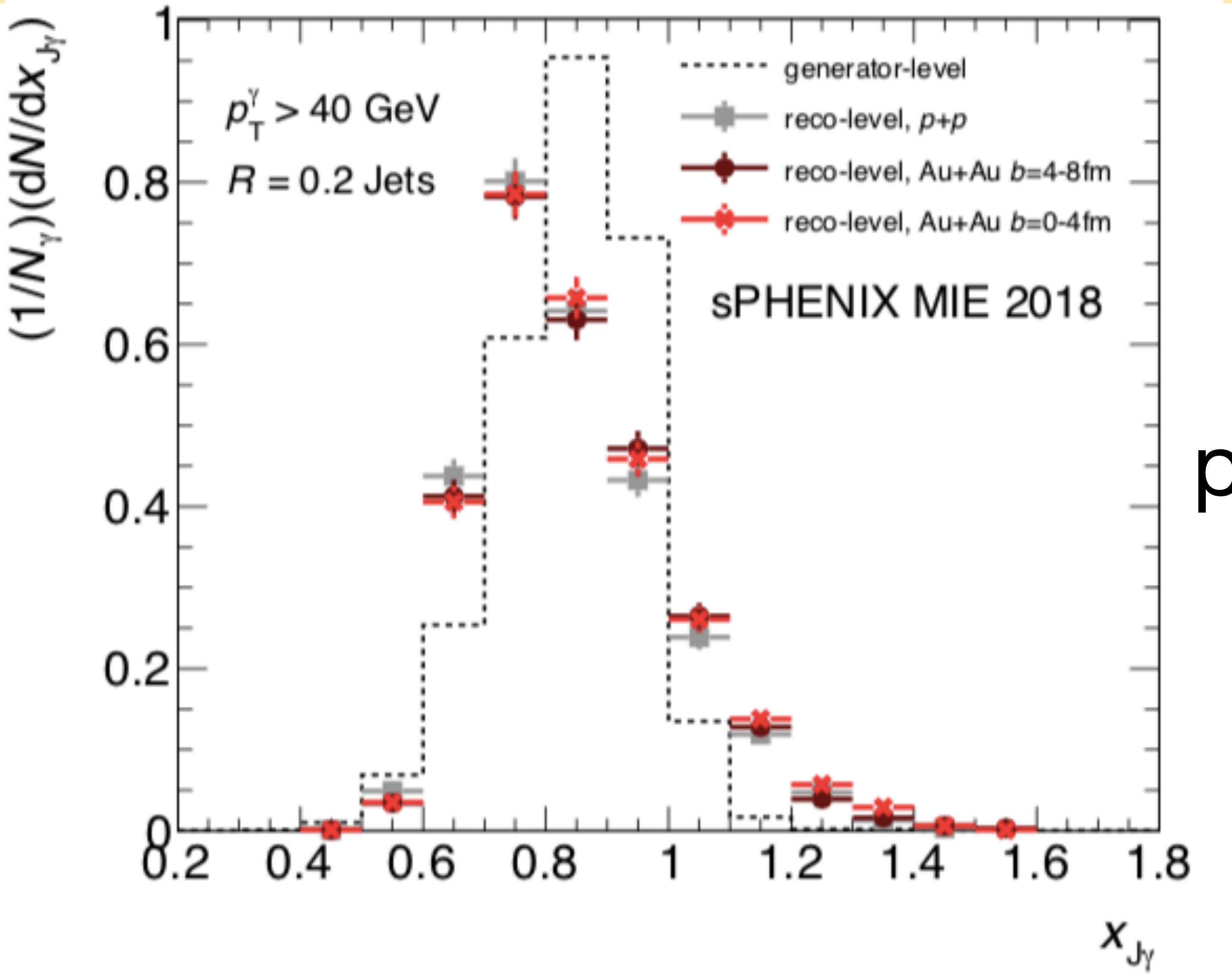


CMS projections for Run III+IV

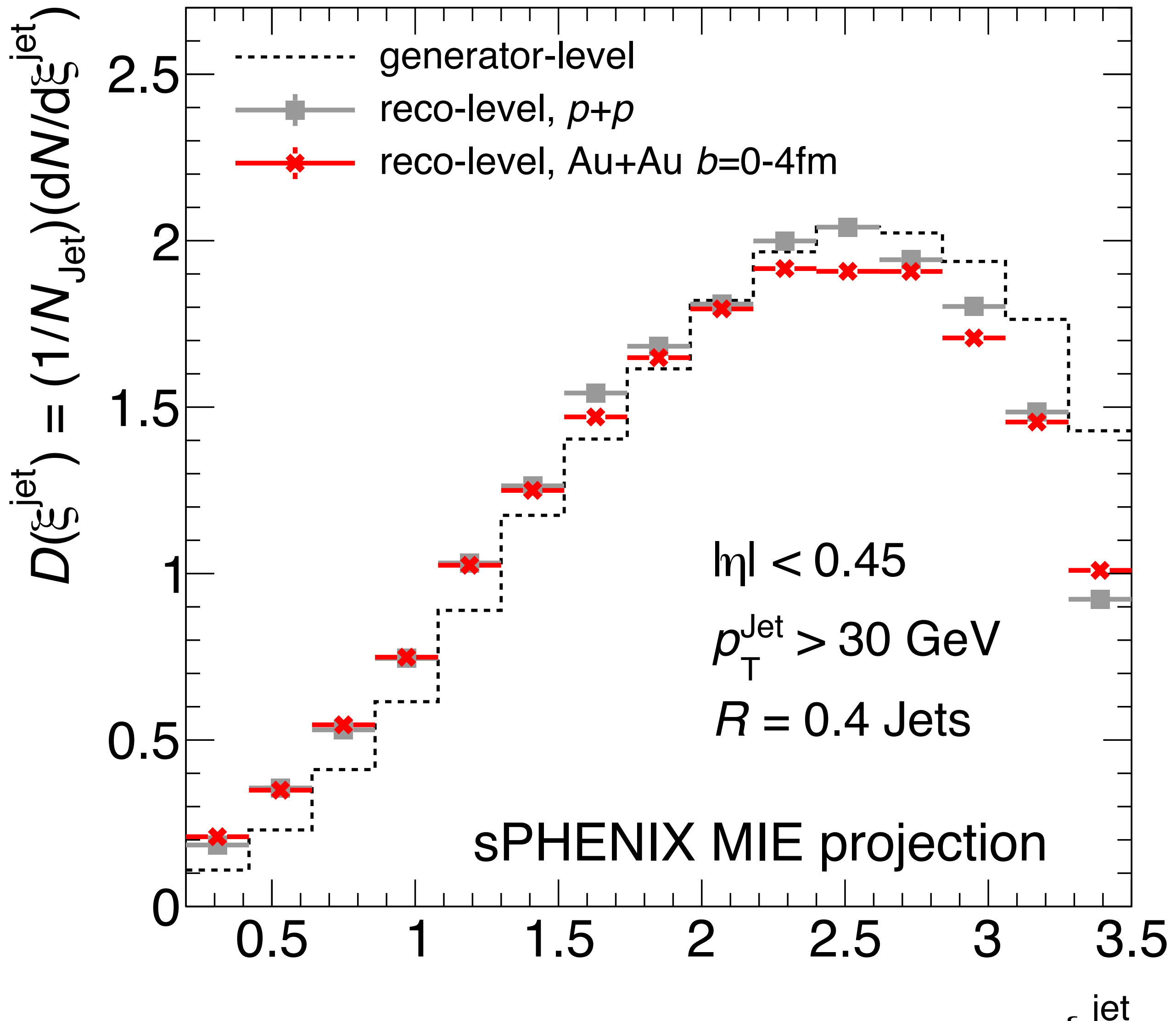


γ+Jet fragmentation function

Modification of parton shower in the QGP

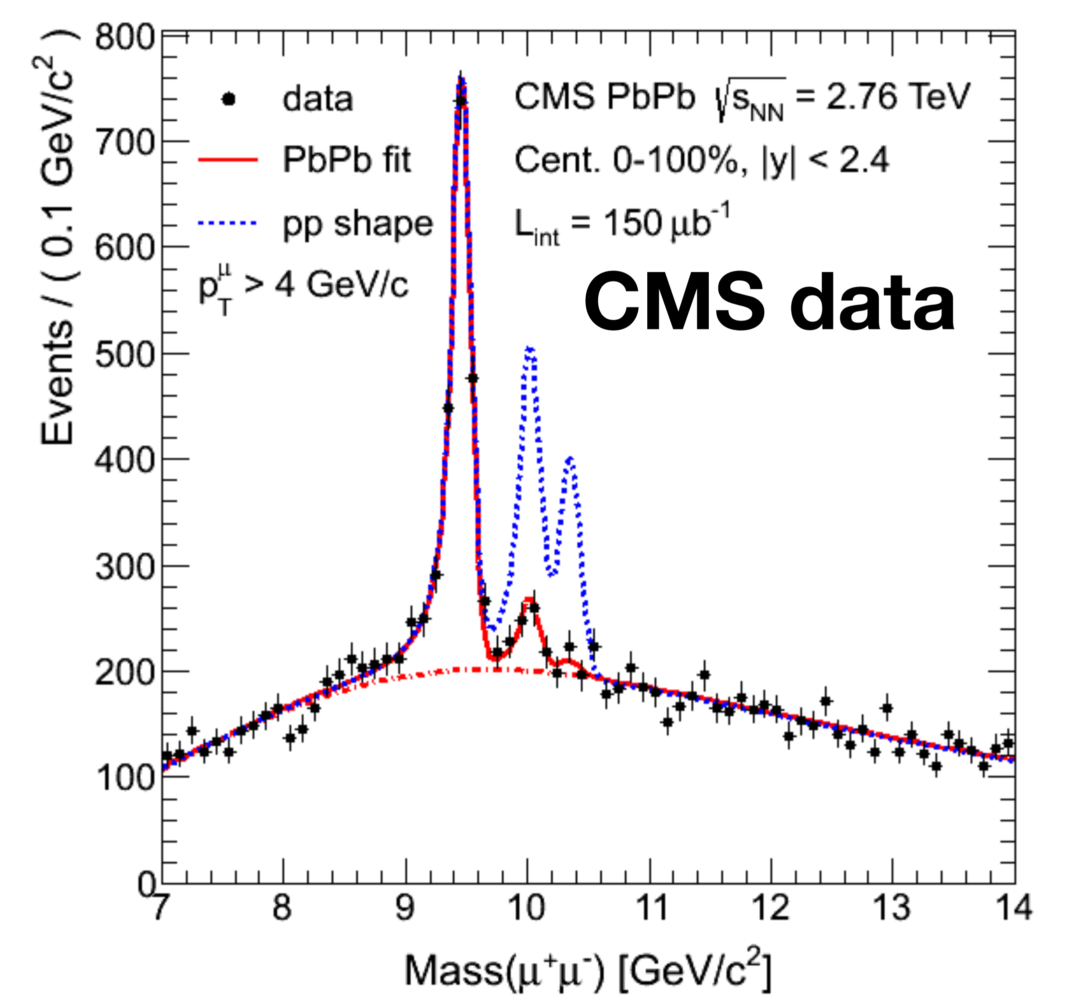


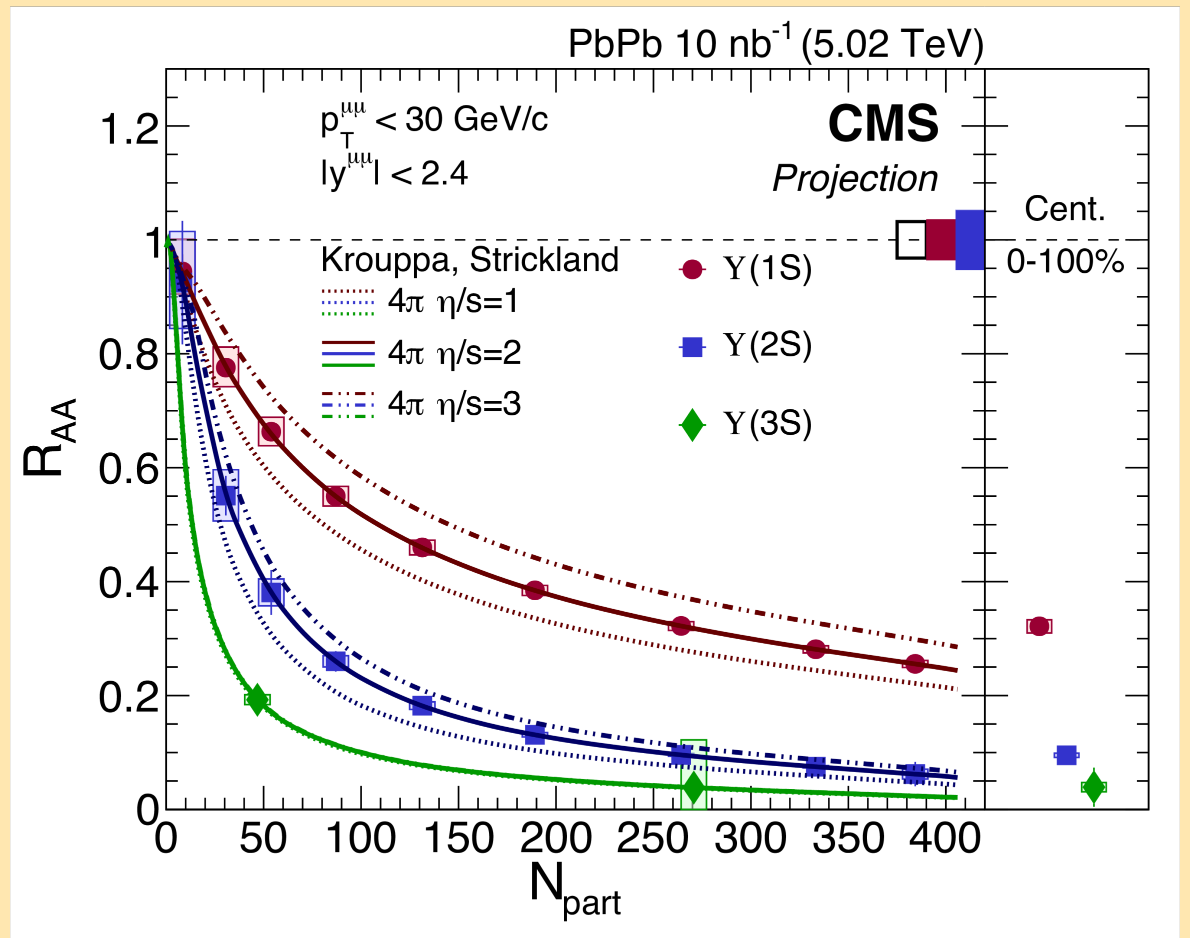
sPHENIX projections



sPHENIX projection 100B Au+Au

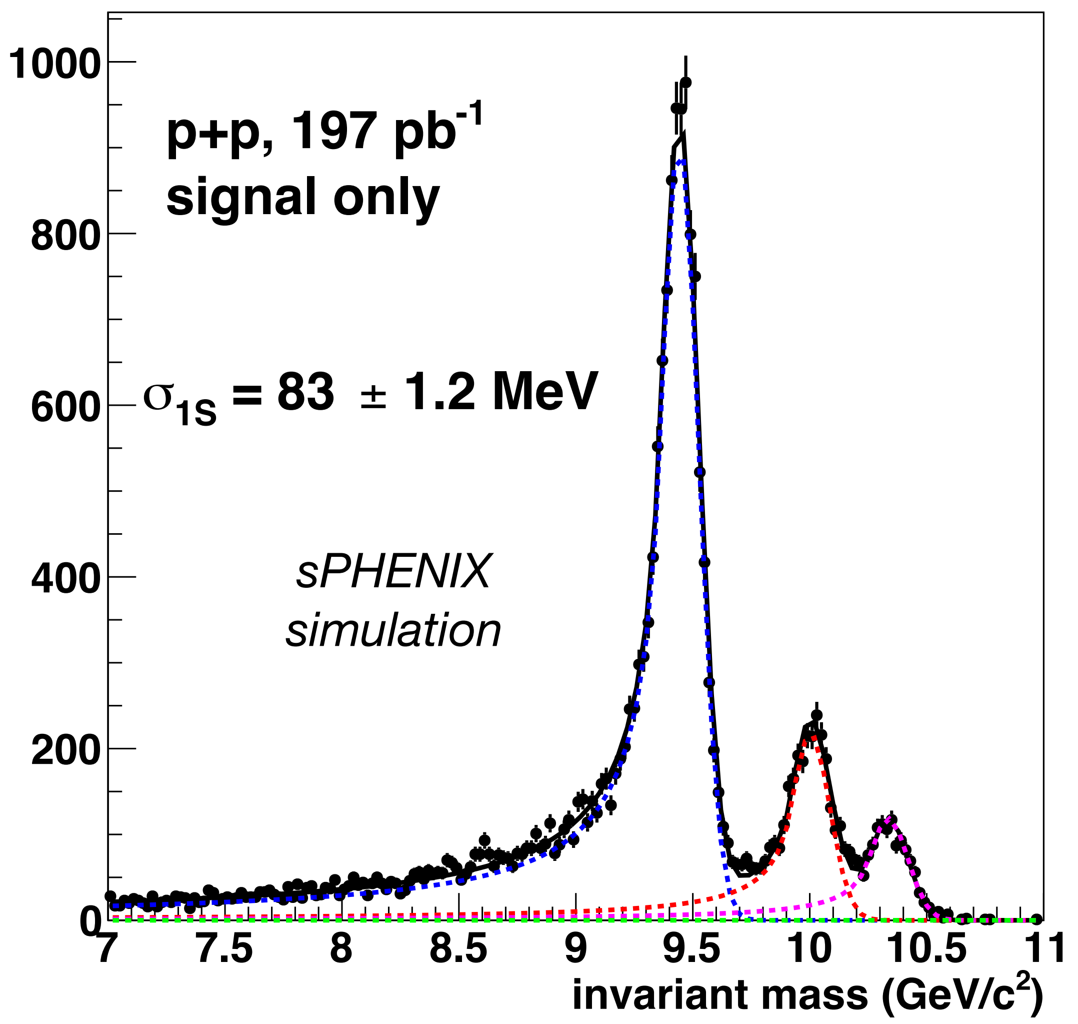
Physics projection: Upsilons at sPHENIX cf. LHC

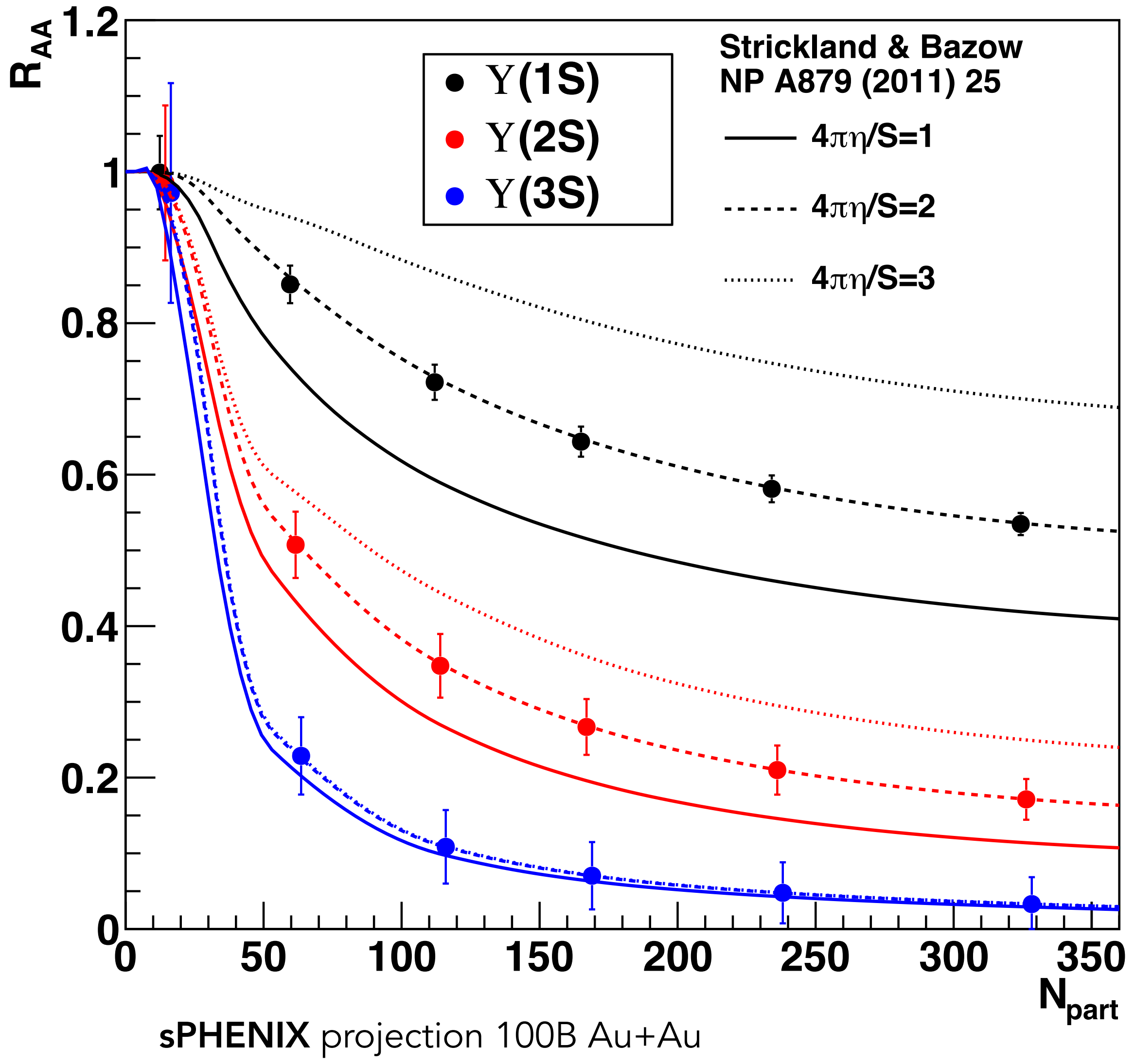




CMS projection for Run III+IV

Differential suppression of Y(nS) states depends on QGP Debye screening length

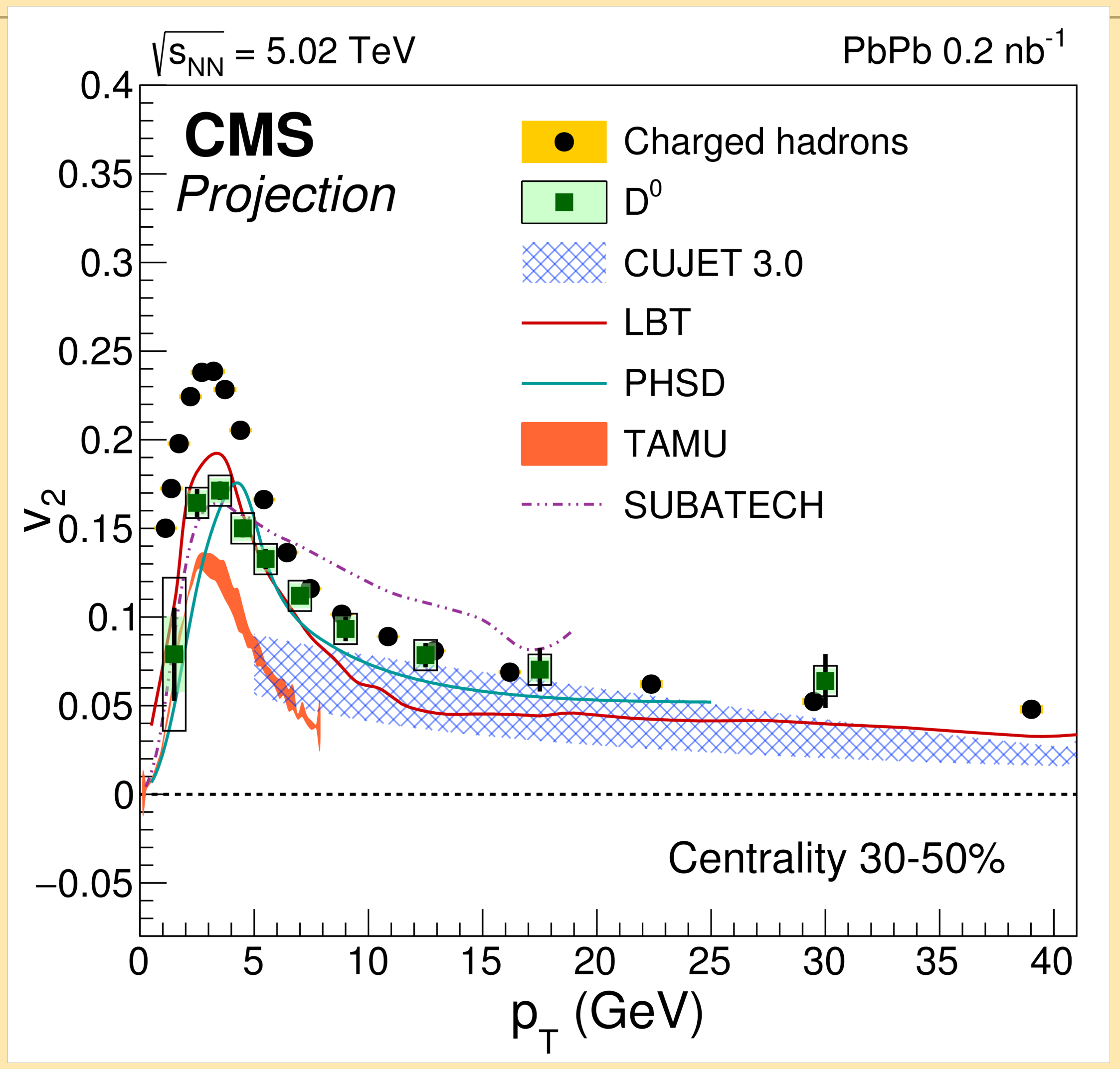




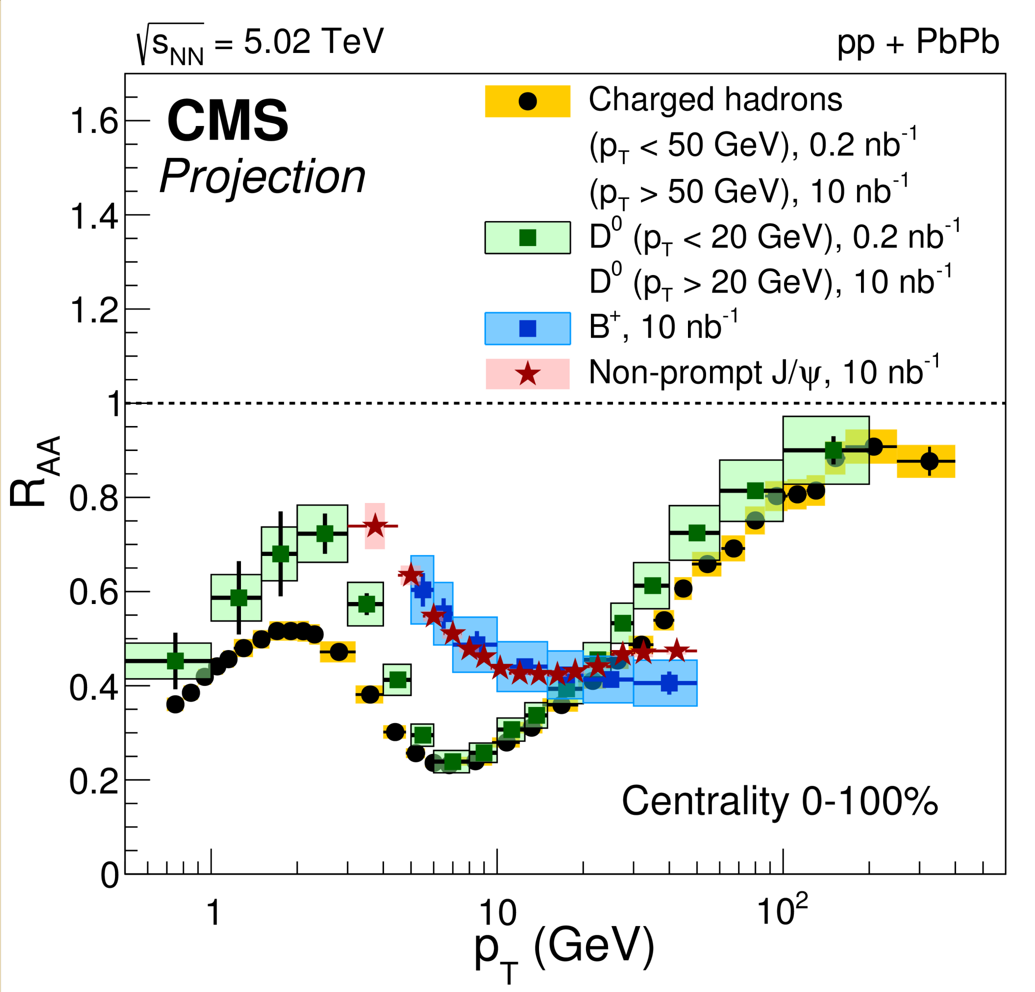
sPHENIX projection

Open heavy flavor at sPHENIX cf. LHC

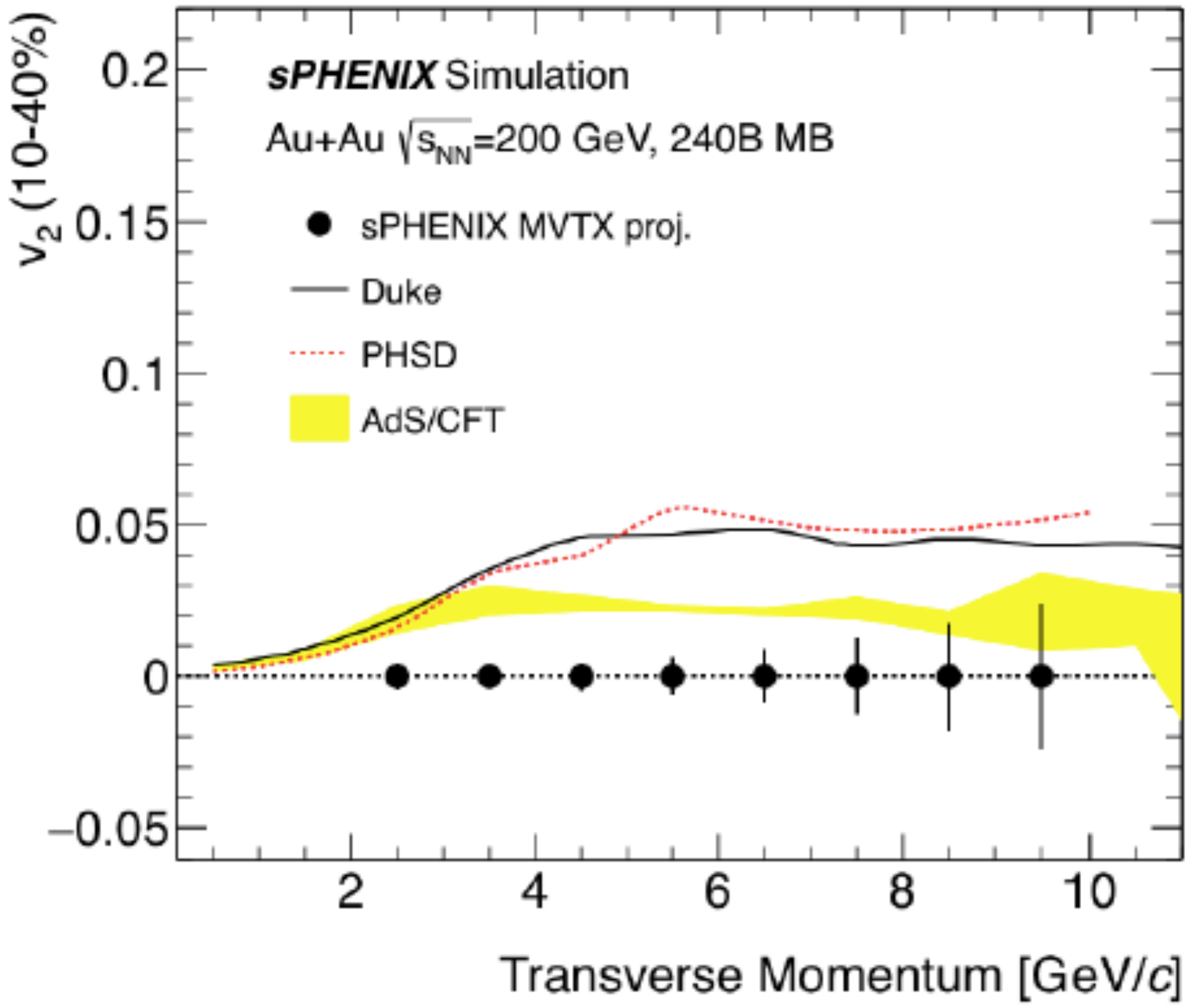
Elliptic flow measures *c* and *b* quark thermalization in medium



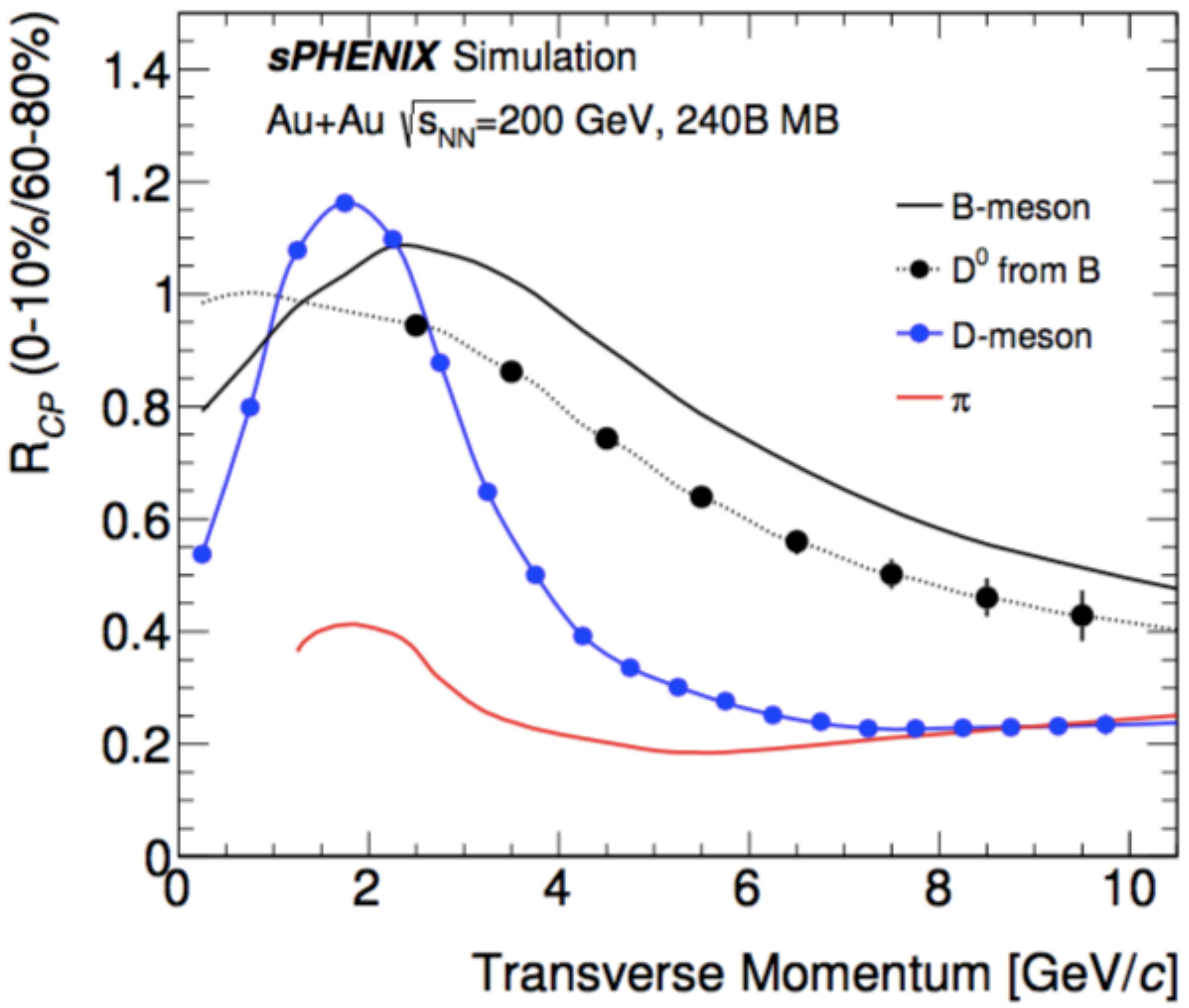
CMS projections for Run III+IV



Open heavy flavor suppression probes flavor dependence of energy loss



PHENIX projections



The sPHENIX collaboration – formed December 2015

More than 70 institutions currently, significant growth since formation

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
Charles University (CUNI), Prague
Czech Technical University in Prague (CTU)
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 UniversityOak 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

2016 2017 2018

How does sPHENIX tie into a broader strategy?

- Physics: hot QCD with different initial T to unravel the temperature dependence of transport properties. Notables: mid-rapidity hadronic calorimeter at RHIC for HEP-style jet measurements; manipulating $T_{initial}$ by varying $\sqrt{s}$ allows system size to remain unchanged.

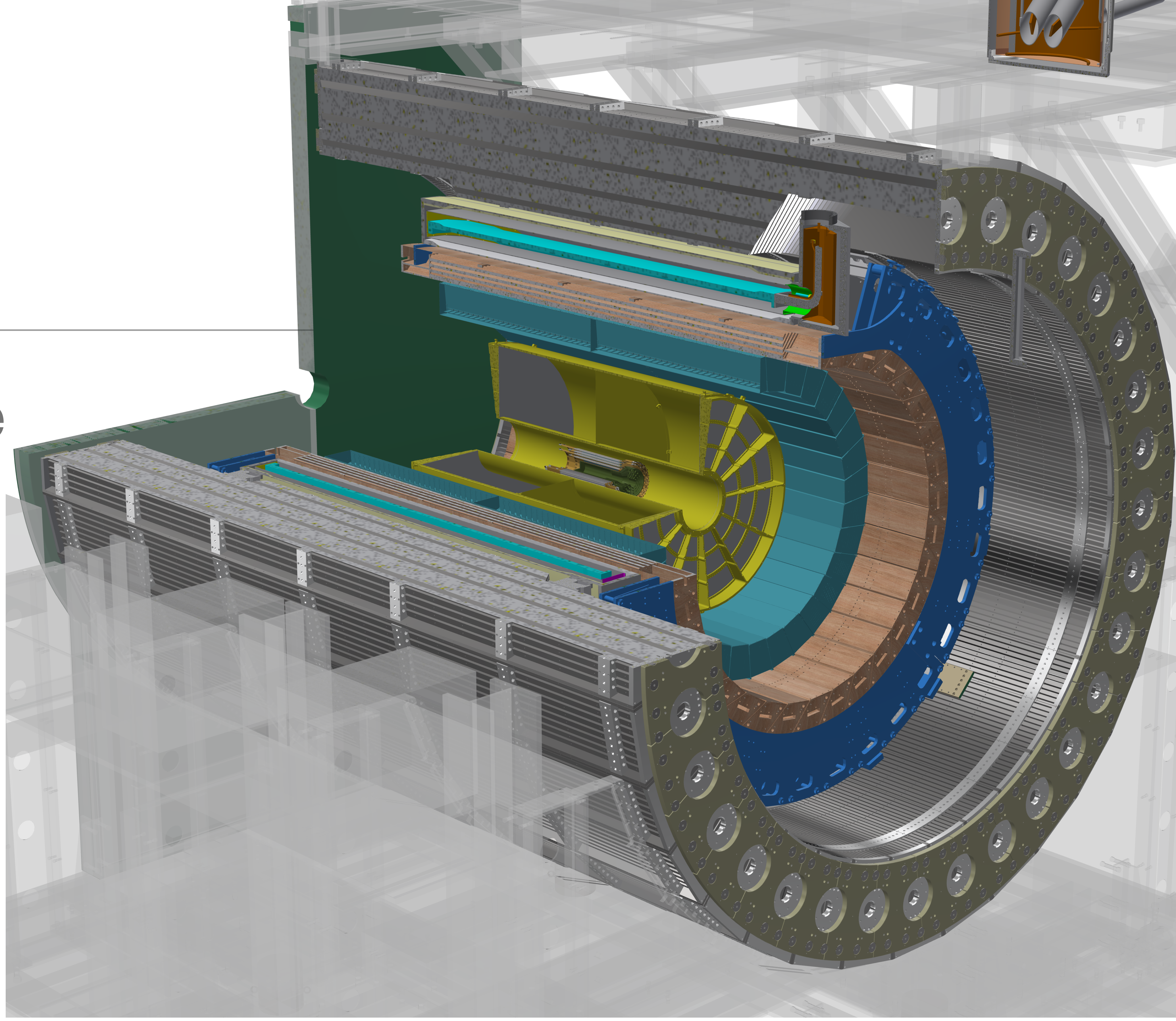
- Testing ground for new techniques: approaches developed for LHC PbPb can be prototyped/refined in RHIC AuAu with steeper spectra, lower UE multiplicities, $\gamma/\pi^0 > 1$ for $p_T > 20$ GeV/c

- Detector development: sPHENIX use of ALICE MAPS and RUs, and the ATLAS FELIX card strengthen justification for future development efforts. sPHENIX working with Sao Paolo producing SAMPA chips with 80ns shaping time.

- People and institutions: good alignment between sPHENIX and LHC HI run plans provides options for bridging efforts and collaboration.

- Theory: having suitable data at RHIC bolsters argument for extending calculations to lower energy and building frameworks (DOE JET collaboration, LANL LDRD, NSF JETSCAPE)

Summary



- sPHENIX continues to benefit greatly from US Long Range Plan and process – notably the QCD town meeting and white paper
- Greatly extended capabilities at RHIC, motivated by HEP experience and LHC HI successes – mid-rapidity hadronic calorimetry, momentum resolution, high rate DAQ exploiting full RHIC luminosity
- Continued extremely productive exchanges with LHC detector and electronic efforts – ALICE MAPS, TPC, SAMPA; ATLAS FELIX
- sPHENIX collaboration continues to grow – adding relevant physics and technological expertise.
- On track for 2023 start of sPHENIX data taking, construction begins now with CD-3A funds

From June 2017
RHIC Users' Meeting talk
by
BNL ALD Berndt Mueller

sPHENIX $\sqrt{s_{NN}}$ = 200 GeV tentative run plan

Year	Species	Goals
2022*	Au+Au	Commissioning Single jet, di-jet, photon-tagged jet, b-tagged jet spectra D-jet asymmetry IUpsilon spectra
2023	p+p p+Au	Reference data for modification of jets, di-jets, b-tagged jets Jet A_{LL} Reference data for cold nuclear matter effects
2024	Au+Au	Direct photon measurement Study of flavor dependence of jet observables Modification of jet fragmentation functions, jet splitting functions, other complex jet observables
2025	p+p	High statistics data for Upsilon modifications High statistics data for jet A_{LL}
2026	Au+Au	High statistics data for b-tagged jets and photon-tagged jets High statistics data for jet fragmentation functions, jet splitting functions, other complex jet observables High statistics data for high p_T direct photons High statistics data for Upsilon modifications, including Y(3S) Collective flow of b-quarks (B hadron elliptic flow)

campaign 1 (2022–2024)

campaign 2 (2025–2026)

*operations start now planned for 2023

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