Science and the Collaboration

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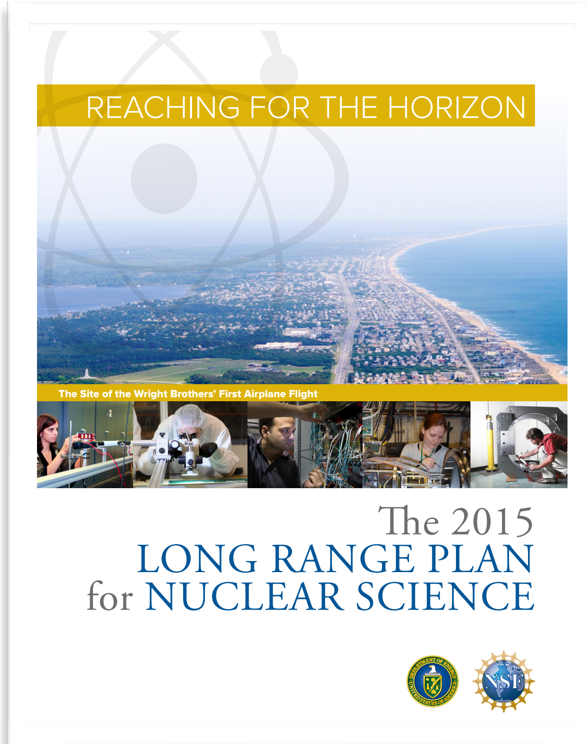
RECOMMENDATION I

The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made.

- *With the imminent completion of the CEBAF 12-GeV Upgrade, its forefront program of using electrons to unfold the quark and gluon structure of hadrons and nuclei and to probe the Standard Model must be realized.*
- *Expeditiously completing the Facility for Rare Isotope Beams (FRIB) construction is essential. Initiating its scientific program will revolutionize our understanding of nuclei and their role in the cosmos.*
- *The targeted program of fundamental symmetries and neutrino research that opens new doors to physics beyond the Standard Model must be sustained.*
- *The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter in the high temperatures of the early universe and to explore the spin structure of the proton.*

RECOMMENDATION IV

We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.



RECOMMENDATION III

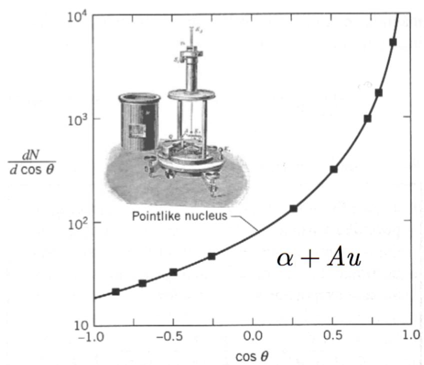
Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new electron ion collider (EIC), providing unprecedented precision and versatility. The realization of this instrument is enabled by recent advances in accelerator technology.

We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

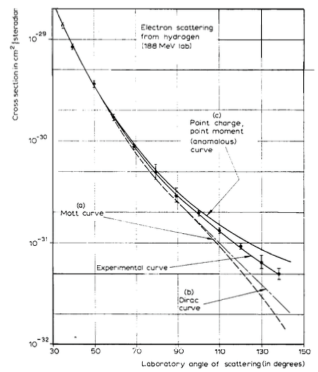
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art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

Probing the Structure of the QGP

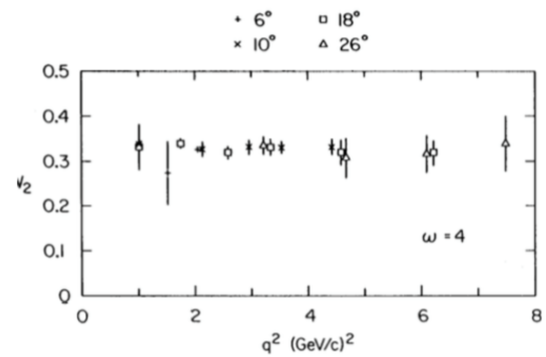
Atoms➔Nuclei



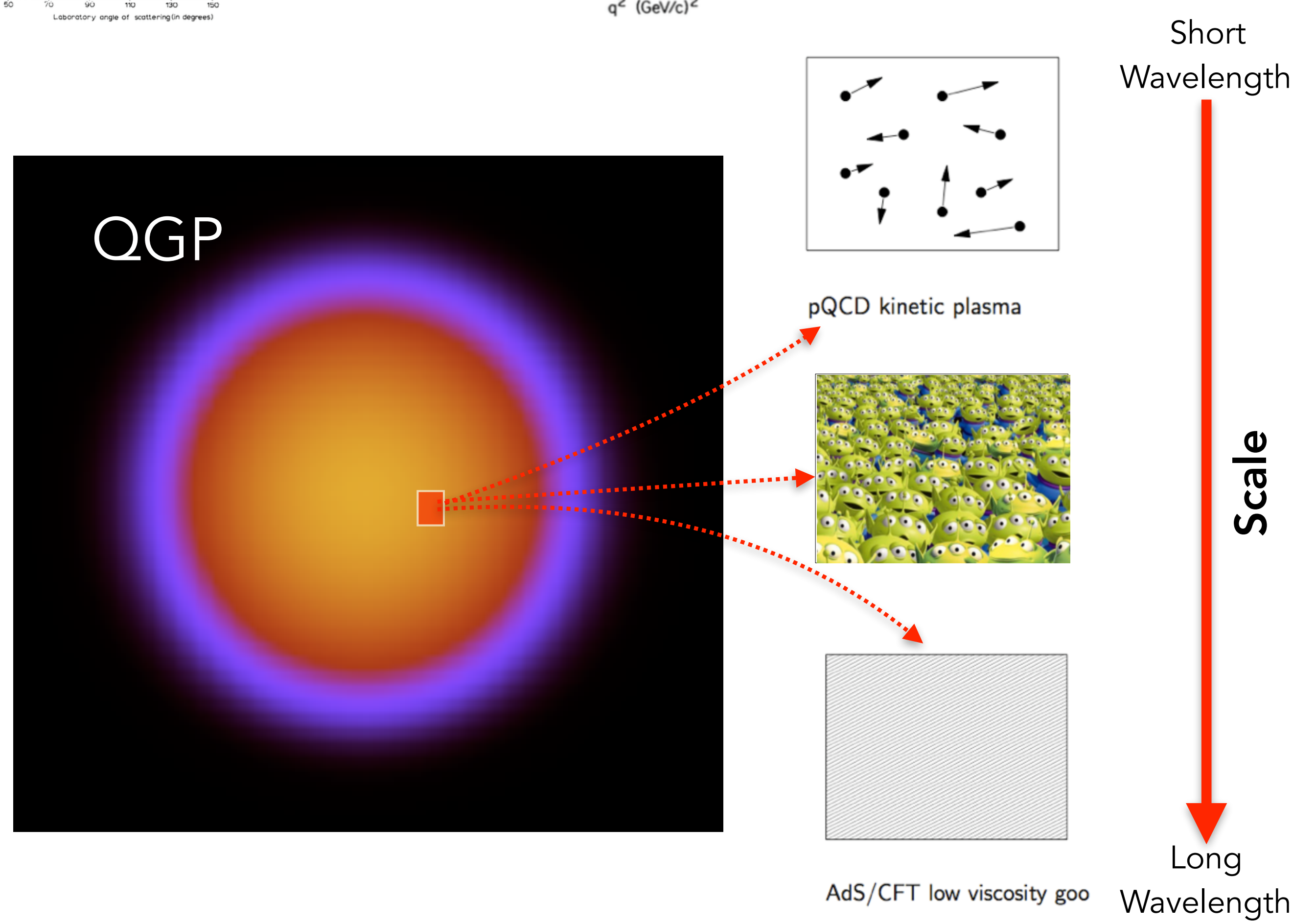
Nuclei➔Nucleons



Nucleons➔Quarks



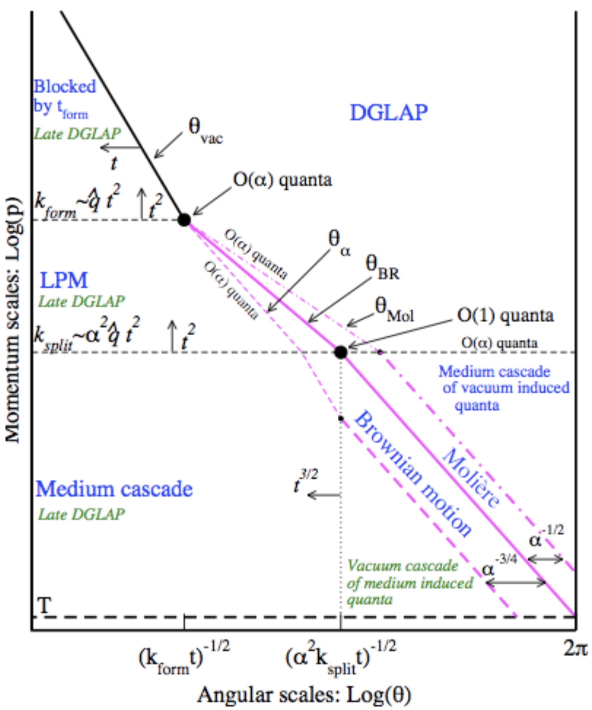
What is the microscopic structure of the QGP?

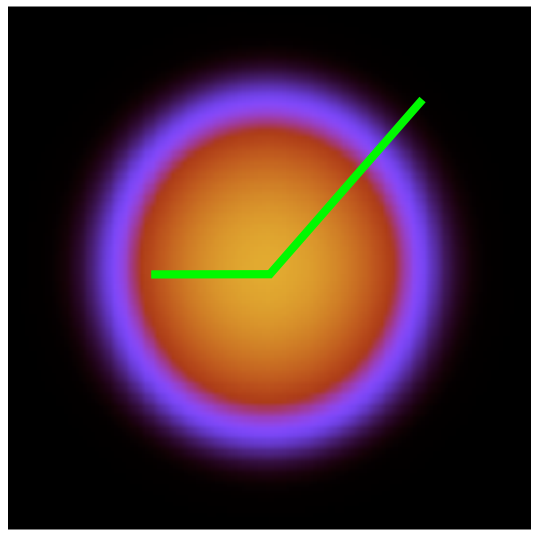


QGP physics with sPHENIX

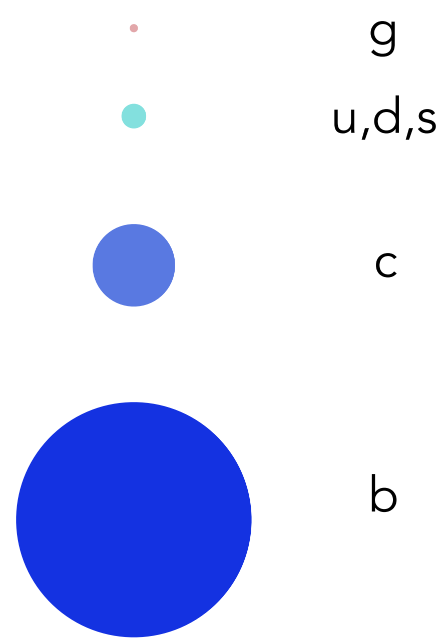
Three key approaches to study
QGP structure at multiple scales

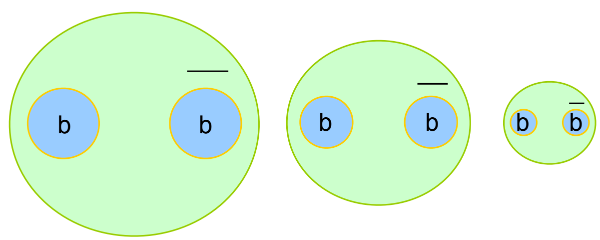
Jets and jet structure





Parton mass/flavor



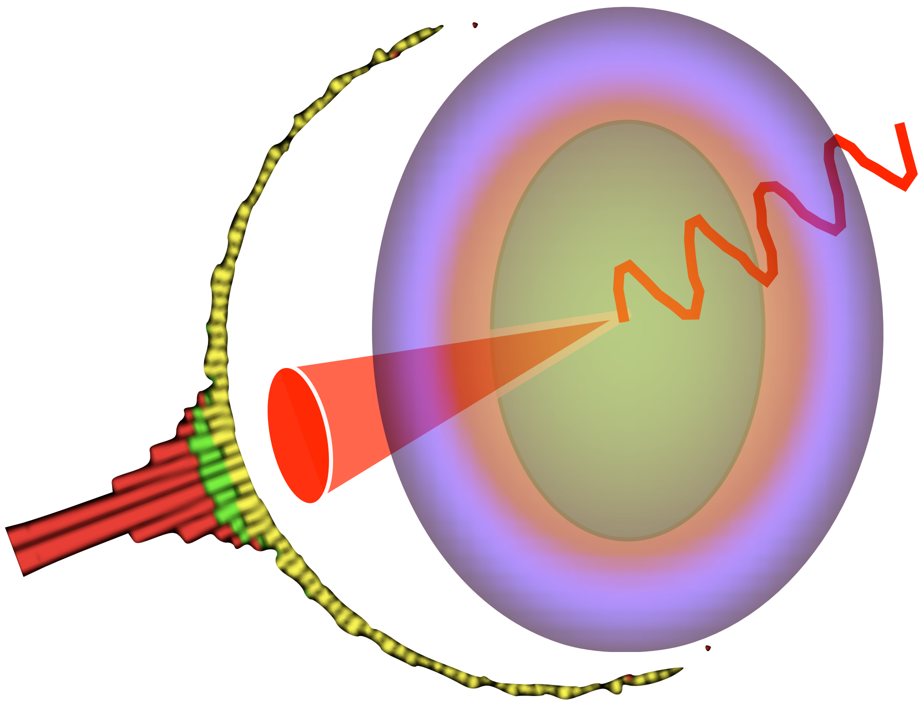


Υ(3s) Υ(2s) Υ(1s)

Upsilon spectroscopy

Physics drives detector requirements: Jets and HF

Unified approach to jet physics at RHIC and LHC



Use away- and near-side tags to control initial hard system:

- Parton flavor and mass
- Initial momentum
- Path length
- In-medium evolution
- Initial and final state radiation

➜

Photon and HF tagging

High rate

Control over jet energy scale

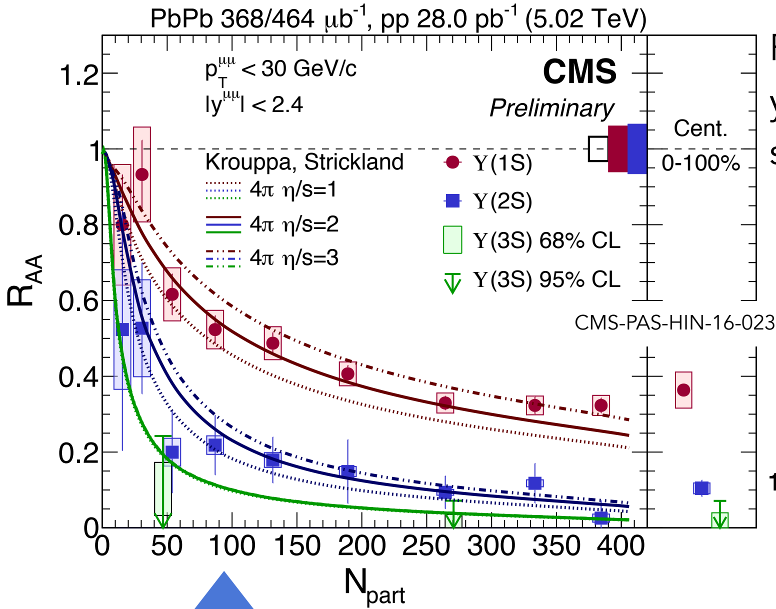
Fully characterize momentum flow near the jet, both "in-cone" and "out-of-cone"➜

Full azimuthal coverage w/ tracking and calorimetry

Large acceptance in p_T and rapidity

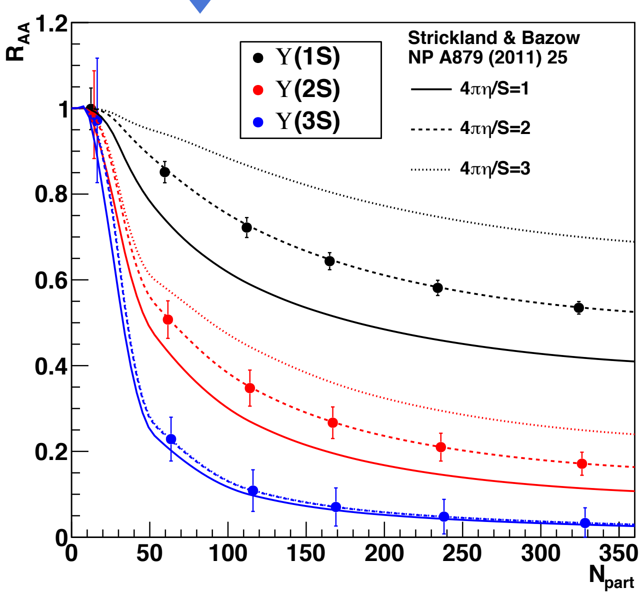
High tracking efficiency, low fake rate

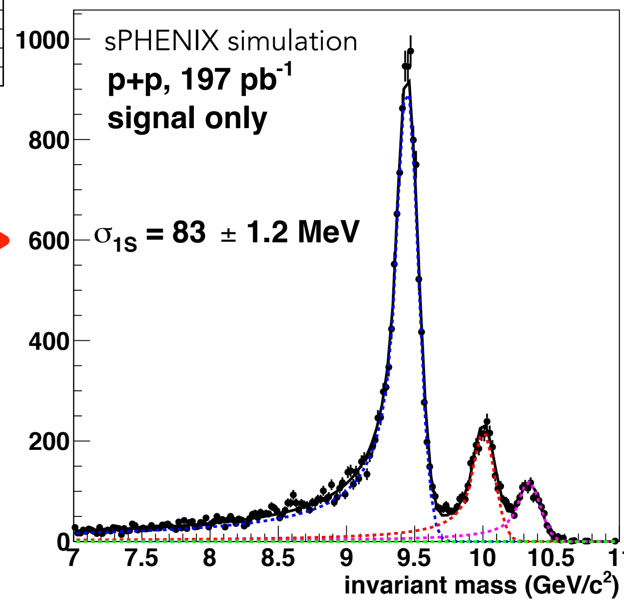
Physics drives detector requirements: Υ(ns)



R_{AA}: modification of Upsilon yields in Au+Au relative to suitably normalized yields in p+p

sPHENIX simulation
100B Au+Au





Count every Υ delivered:

- large acceptance (2π × |η| < 1)
- high rate capability (15 KHz – commensurate with RHIC projections)
- triggering in p+p and p+A

Identify delivered Υ's:

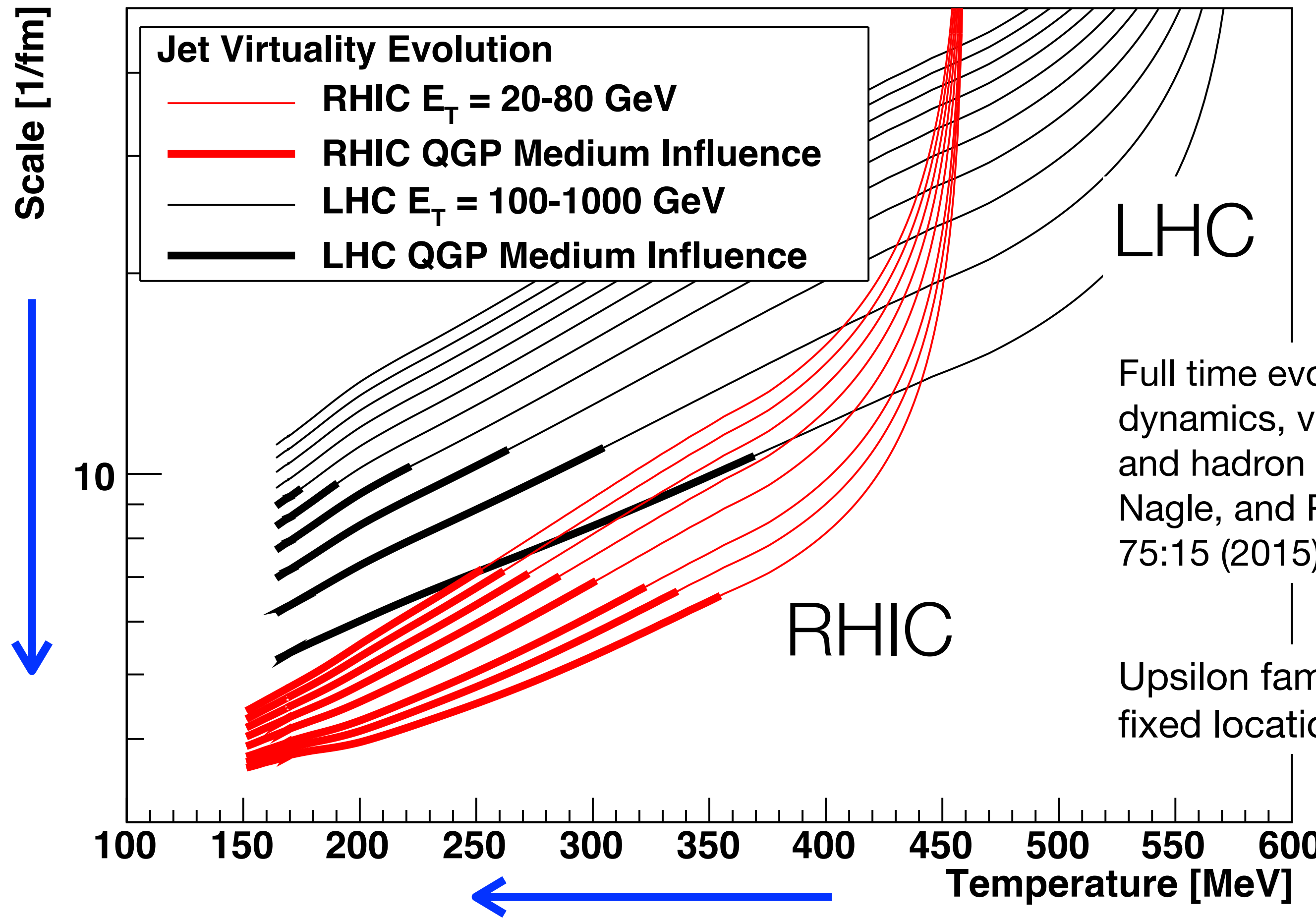
- high track reconstruction efficiency (> 90% @ 3 GeV/c)
- good electron ID (90:1 rejection in Au+Au)

Distinguish separate mass states

- excellent momentum resolution in p_T ~ 4-10 GeV/c (σ_M < 100 MeV/c²)

Evolving probes in evolving medium: RHIC ⊕ LHC

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

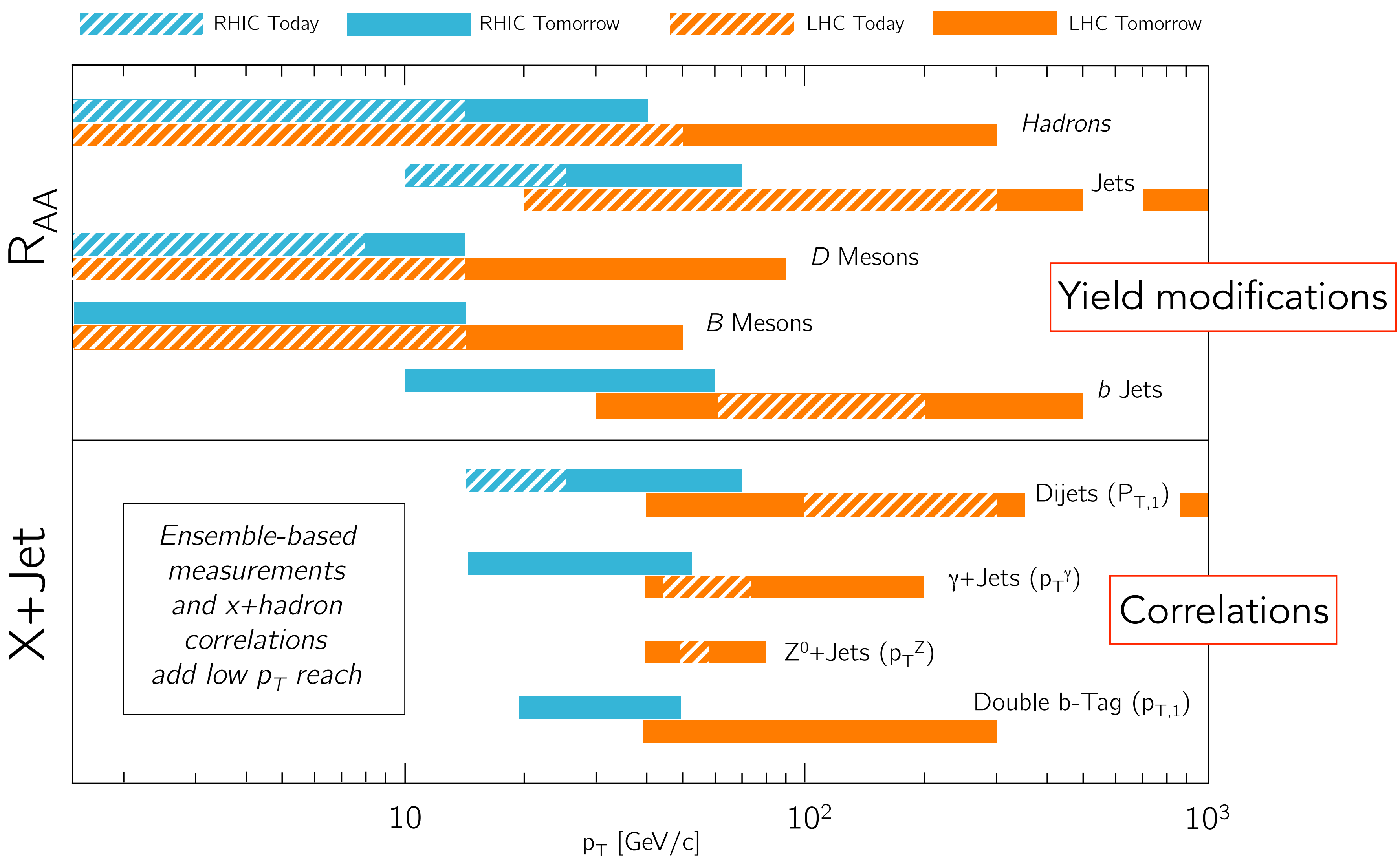


Full time evolution of pre-equilibrium dynamics, viscous hydrodynamics, and hadron cascade M. Habich, J. Nagle, and P. Romatschke, EPJC, 75:15 (2015)

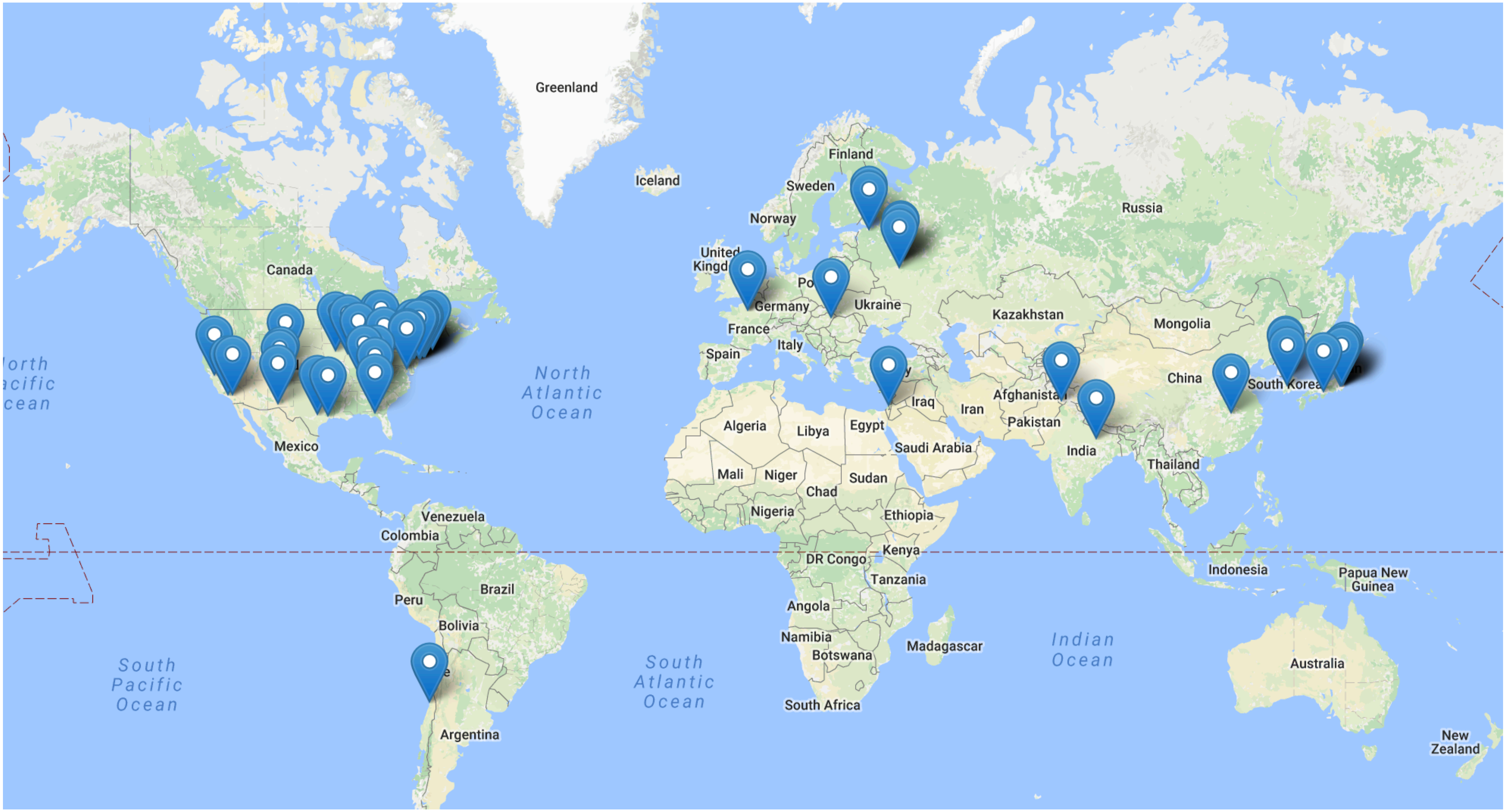
Upsilon family 1S, 2S, 3S establish fixed locations in this space

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

Physics drives detector requirements: RHIC ⊕ LHC



A worldwide collaboration



Growth of collaboration since CD-0

Expertise in relevant physics, MPGDs, silicon, TPCs. Discussions with University Sao Paulo, contacts with additional international institutions

64 institutions and counting

Augustana University
Banaras Hindu University
Baruch College, CUNY
Brookhaven National Laboratory
CEA Saclay
Central China Normal University
Chonbuk National University
Columbia University
Eötvös University
Florida State 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
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
Petersburg Nuclear Physics Institute
Purdue University
Rice University
RIKEN
RIKEN BNL Research Center
Rikkyo University
Rutgers University
Saint–Petersburg Polytechnic University
Stony Brook University
Temple University
Tokyo Institute of Technology
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
Vanderbilt University
Wayne State University
Weizmann Institute
Yale University
Yonsei University

June 13–14 sPHENIX Collaboration Meeting

Many collaboration-driven developments

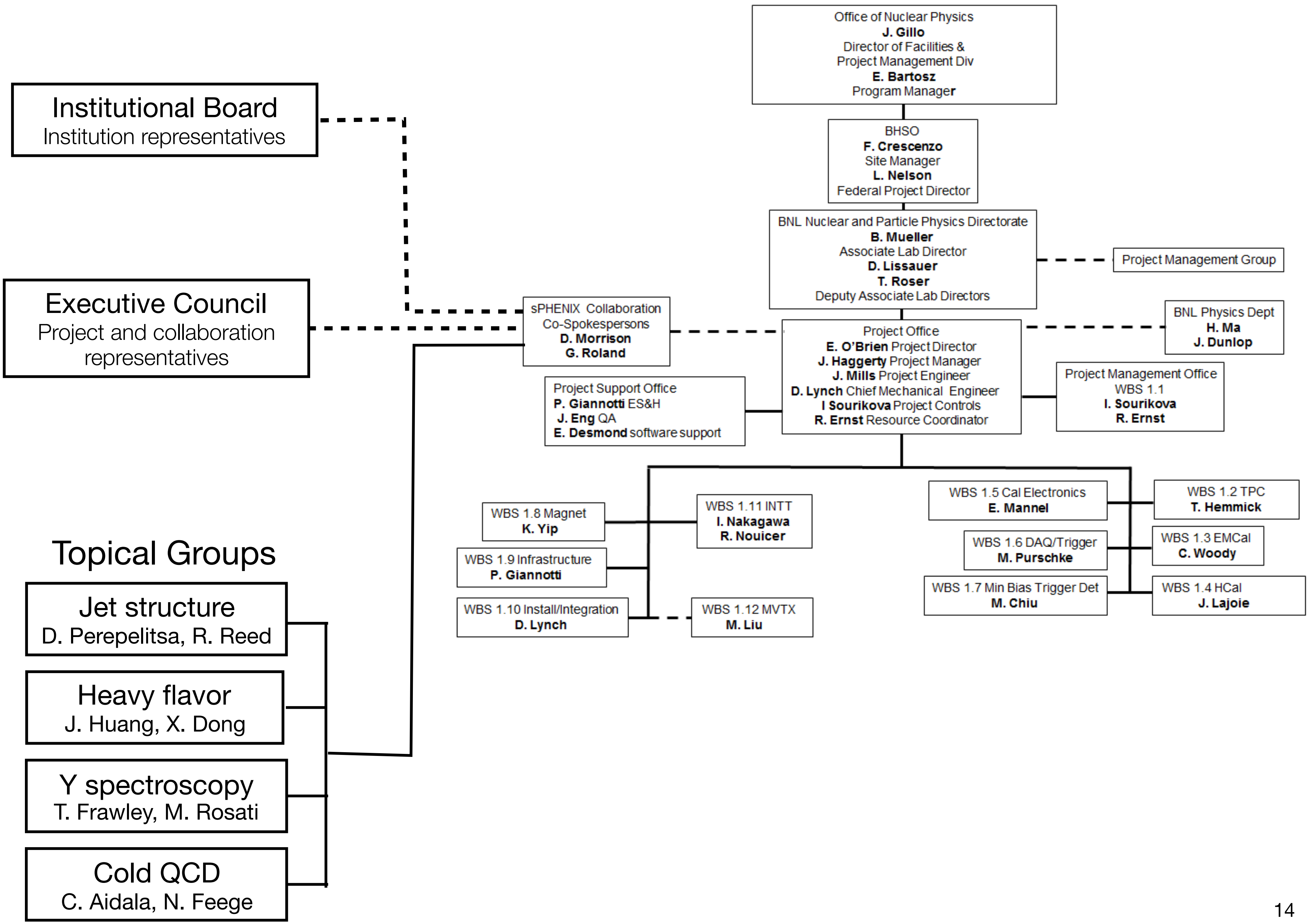
- Recrafting of tracking and vertexing approach, now using state-of-the-art 3rd party software for Kalman fitting and vertex finding (GENFIT, RAVE) with fully correct error propagation

- Reimplementation of ATLAS-style iterative background subtraction jet finding (Phys. Rev. C86 (2012) 024908), and import of STAR/ALICE-style jet area background subtraction

- Implementation of PHENIX-style clustering and CMS-style island clustering algorithm for the EMCal

- Guided by experience in other collaborations: two junior representatives on Executive Council, 3 of 11 elected/appointed EC are women, 3 of 8 Topical Group conveners are women, meetings are open to all, bi-weekly “general meetings”, working with GUV Center and ITD/RACF to improve access for all collaborators

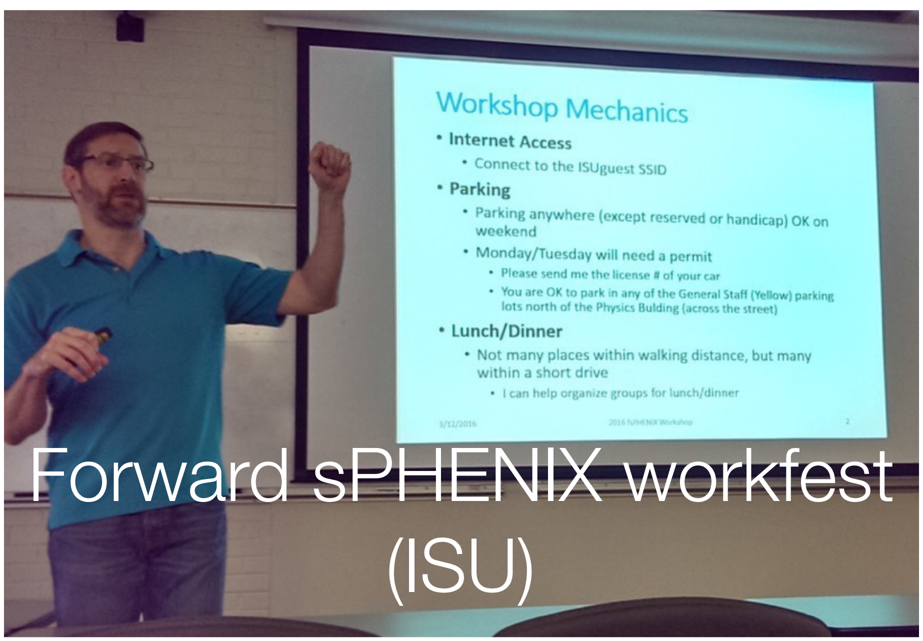
Collaboration ↔ Project



Coordination examples: “workfests”

MAPS cost and schedule workfest (LANL)

HF tagged jets workfest (BNL)

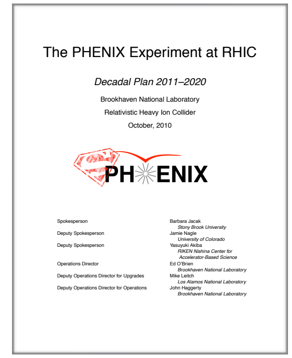


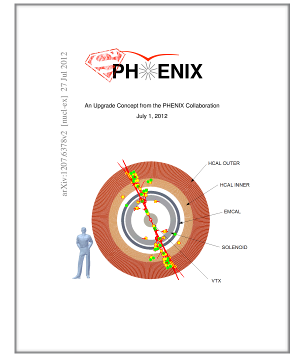
Forward sPHENIX workfest (ISU)

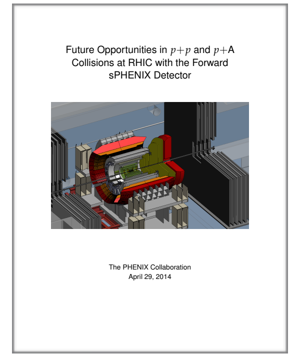
- Continues practice that was very productive in developing sPHENIX proposals
- Invite outside experts when appropriate – e.g., discussion with ALICE & STAR experts on space charge distortion in TPC

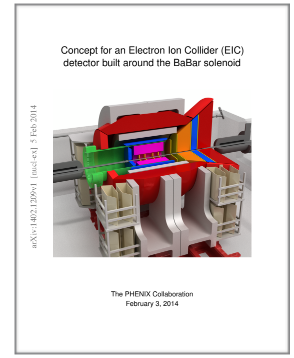
Seven-years of steady development

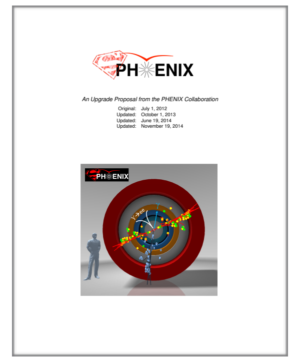
- sPHENIX Concept in the PHENIX Decadal Plan (charged by ALD Steve Vigdor): October 2010
- Original proposal http://arxiv.org/abs/1207.6378: July 2012
  (new superconducting solenoid & optional additional tracking)
- BNL Review (chaired by Tom Ludlam) of sPHENIX proposal: October 2012
- Updated sPHENIX proposal: October 2013
- BNL Review (chaired by Sam Aronson) of “ePHENIX” LOI: January 2014
- “ePHENIX” White Paper (http://arxiv.org/abs/1402.1209): February 2014
- Future Opportunities in p+p and p+A with the Forward sPHENIX Detector (http://www.phenix.bnl.gov/phenix/WWW/publish/dave/sPHENIX/ pp_pA_whitepaper.pdf): April 2014
- Updated proposal, submitted to DOE: June 2014 (incorporation of Babar magnet and tracking)
- DOE Science Review: July 2014
- Updated Proposal http://arxiv.org/abs/1501.06197 : November 2014
- DOE Science Review (chaired by Tim Hallman): April 2015 – successful science review
- sPHENIX pCDR: November 2015
- MVTX pre-proposal: March 2017
- Modest forward upgrade LOI: June 2017
- sPHENIX CDR: July 2017

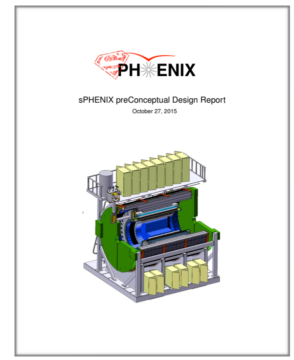


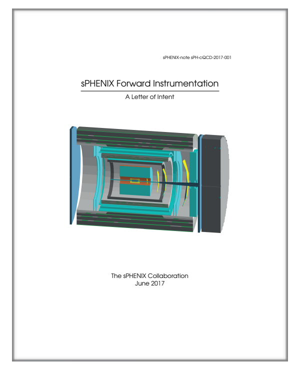


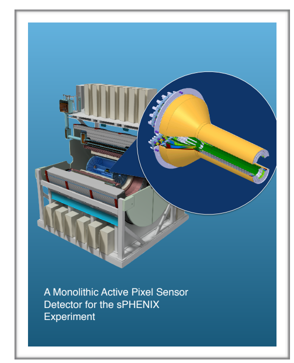


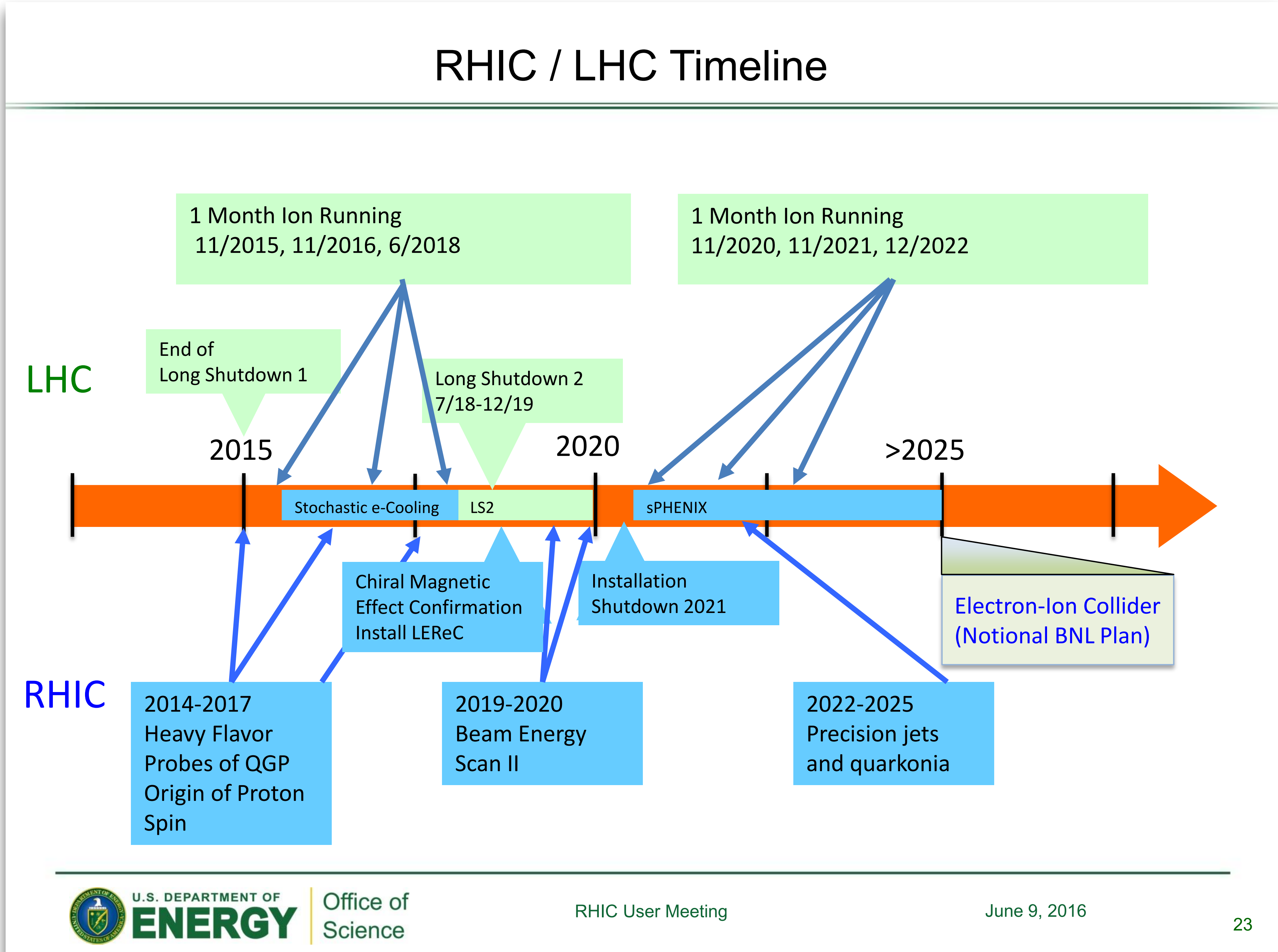












Slide from Tim Hallman’s talk at RHIC Users’ Meeting, June 2016

Multi-year run plan scenario for sPHENIX

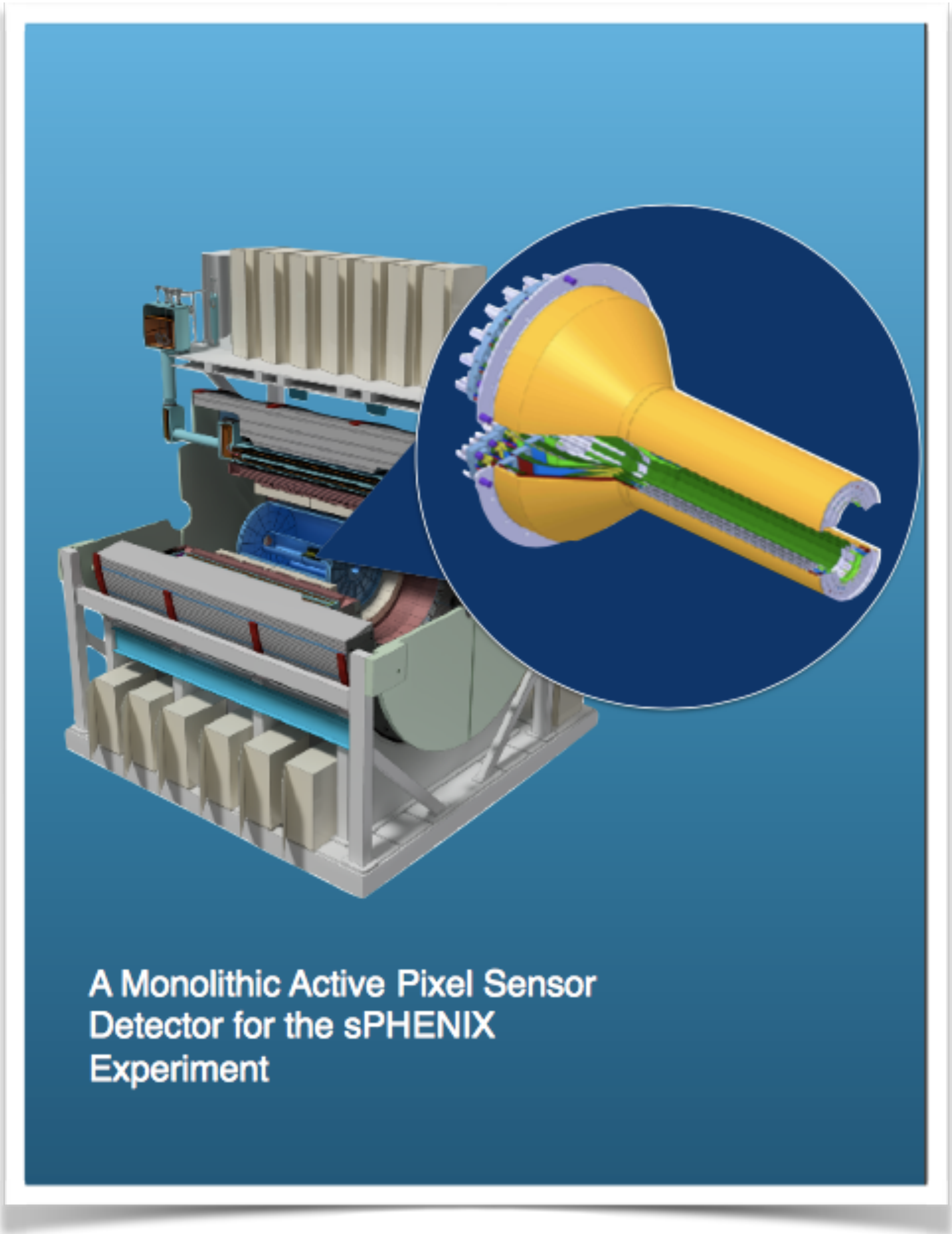
Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
2022	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
2023	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
2023	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
2024	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
2025	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
2026	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

- Guidance from ALD to think in terms of a multi-year run plan
- Consistent with language in DOE CD-0 "mission need" document
- Incorporates updated C-AD guidance now officially documented
- Run plan relates to capabilities of full barrel detector
- Incorporates commissioning time in first year

Minimum bias Au+Au at 15 kHz for |z| < 10 cm:
47 billion (2022) + **96 billion** (2024) + **96 billion** (2026) = Total **239 billion events**

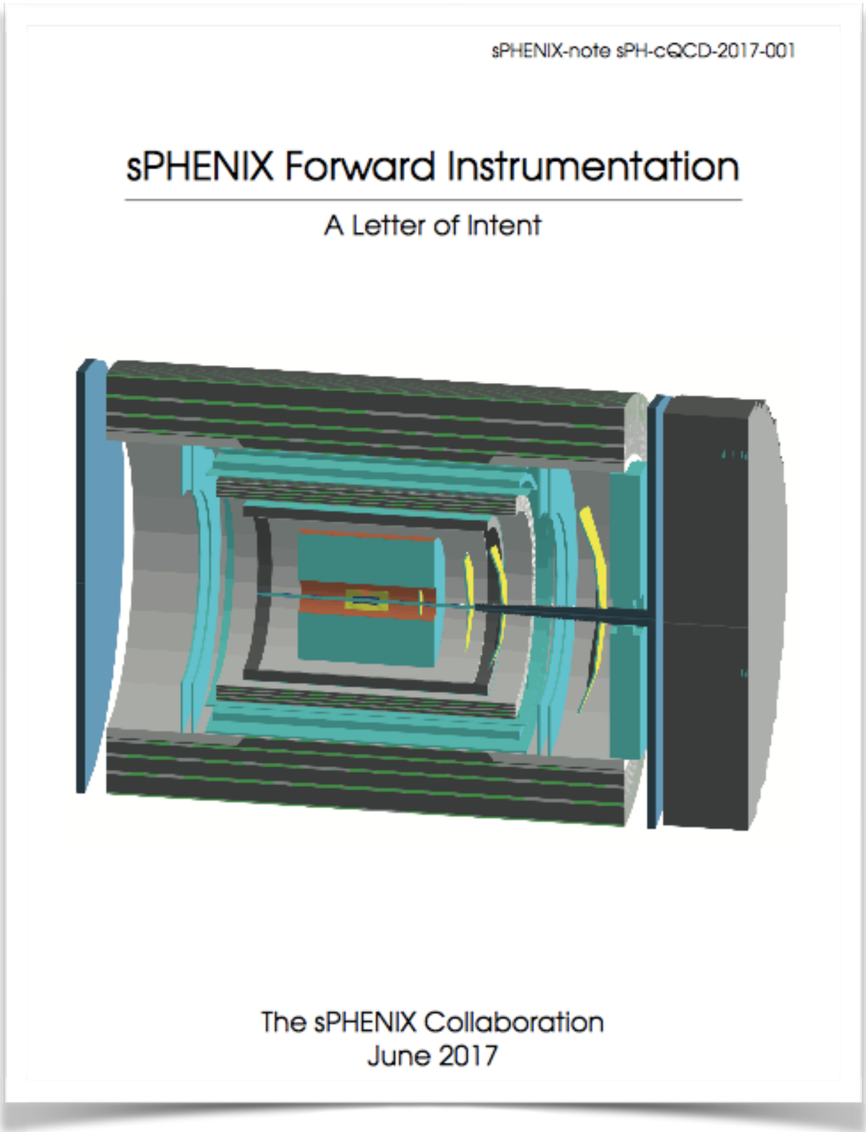
For topics with Level-1 selective trigger (e.g. high p_T photons), one can sample within |z| < 10 cm a total of 550 billion events. One could consider sampling events over a wider z-vertex for calorimeter only measurements, 1.5 trillion events.

MVTX pre-proposal and beyond



- MVTX as separate project outside of, but pursued in parallel to, baseline MIE detector
- Enables open HF and HF-tagged jet addition to physics program of baseline detector
- MVTX consortium developed MVTX pre-proposal, with Director's review at BNL on July 10-12, 2017

Modest Forward Upgrade LOI



- Invitation by ALD to STAR and sPHENIX on February 22. Submitted to ALD on June 3
- Contributions across collaboration, led by cold QCD topical group.
- In addition to p+p and p+A program, collaboration excited by strengthening of core sPHENIX program by adding forward instrumentation to high-rate, deep calorimetry, high resolution tracking, precise vertexing of barrel.
    - E.g., dijets and (central-forward) gamma+jet over extended rapidity range $-1 < \eta < 4$

Outlook

- sPHENIX scientific collaboration full engaged working towards start of physics in early 2020s
- Ongoing efforts to strengthen collaboration:
  - discussions with additional groups about joining sPHENIX
  - grow workforce from current collaborators
- Ongoing efforts with theory community to strengthen science case (e.g., Jetscape, LANL LDRD)
- Collaboration is committed to building a world-class experiment with the capabilities needed to deliver the full suite of sPHENIX physics