The Future of RHIC

RHIC Retreat 2016
BNL
28 July 2016

James Dunlop (for Berndt Mueller)

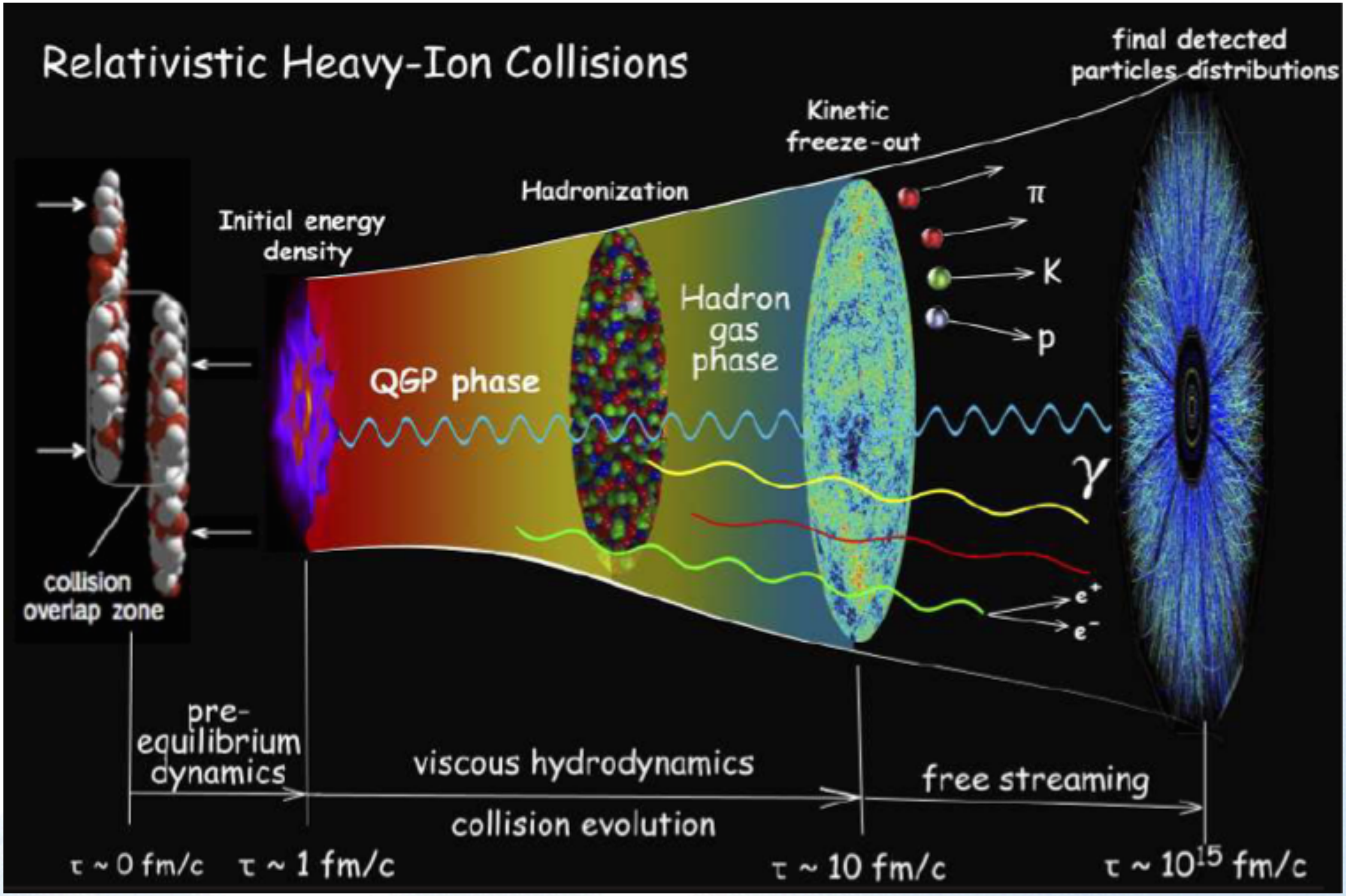
2015 Long Range Plan

RECOMMENDATION I

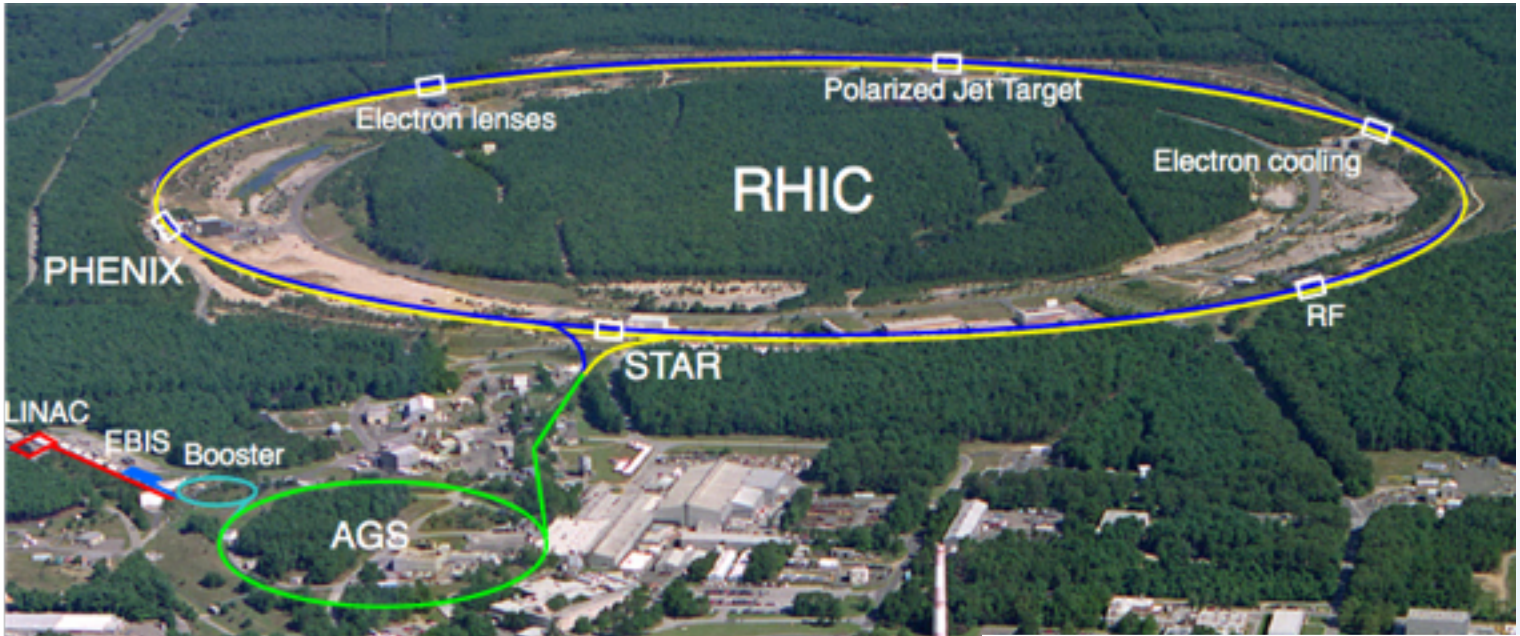
The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made.

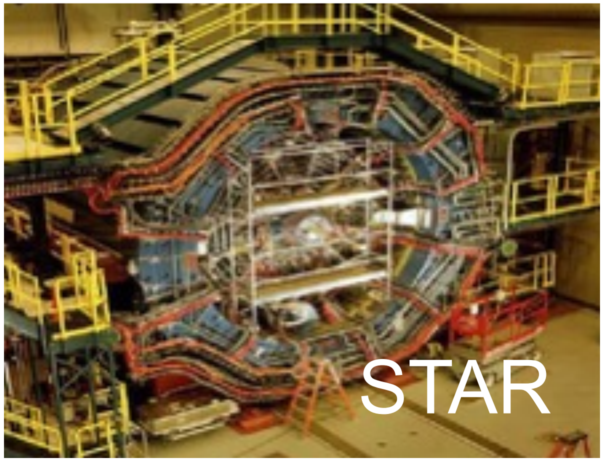
- *Complete and run CEBAF 12 GeV upgrade*
- *Complete FRIB at MSU*
- *Targeted program in neutrinos and fundamental symmetries*
- *The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter in the high temperatures of the early universe and to explore the spin structure of the proton.*

Standard model of the "Little Bang"

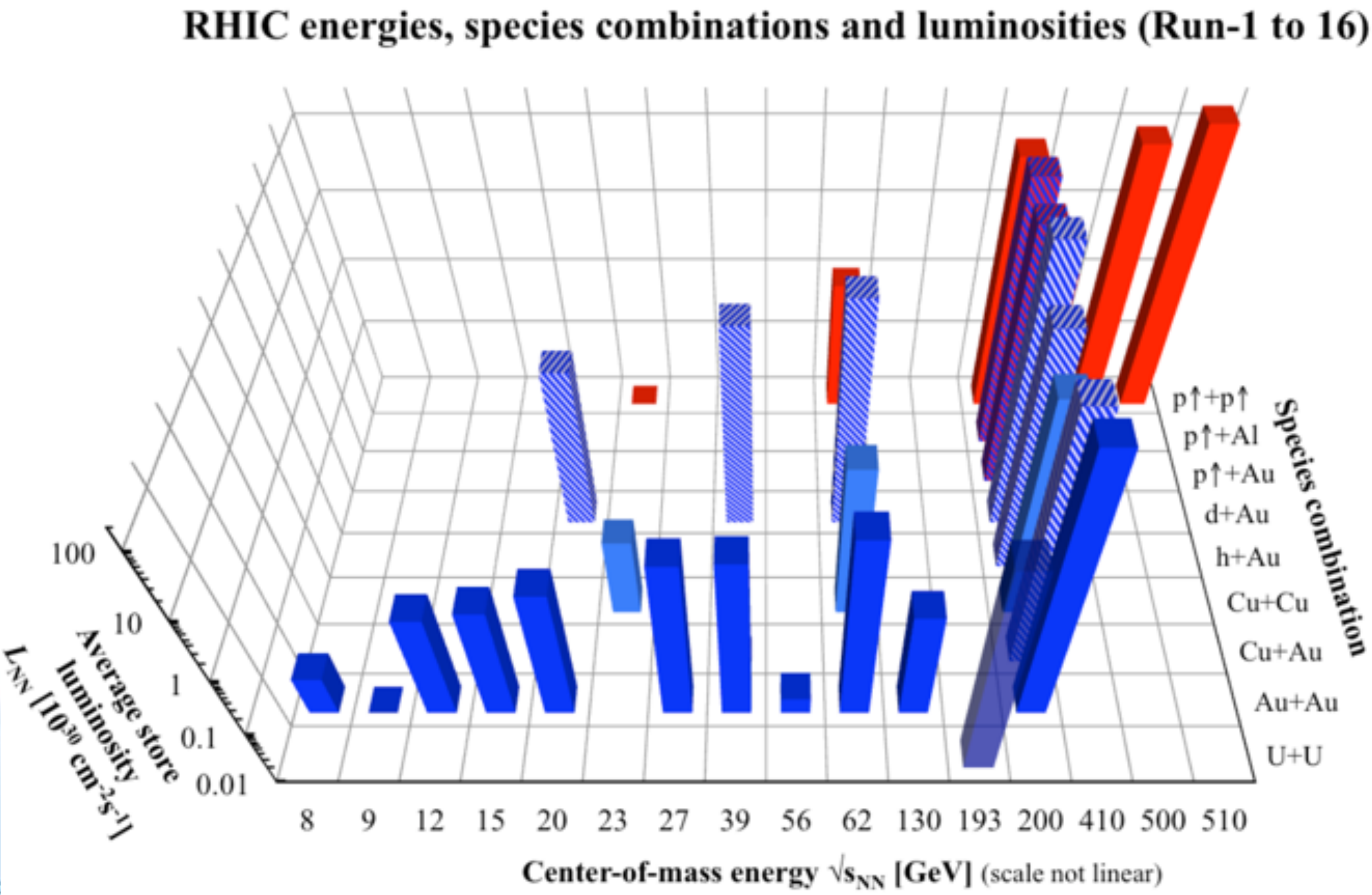


RHIC: Champion of versatility





You want it - you can have it!



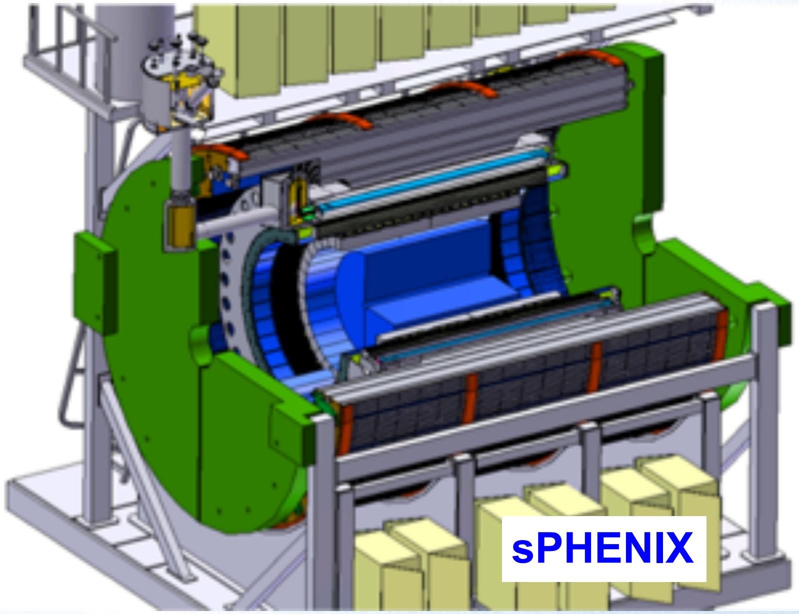
Continuing the RHIC scientific mission

Status: RHIC-II configuration is operational

- **RHIC reached 44 times design luminosity**

Plan:

- **2014−16: Heavy flavor program (complete)**
- **2017: Transverse spin physics in QCD**
- **2018: Isobar system test of chiral symmetry**
- ***2018: Low energy e-cooling & iTPC upgrade***
- **2019−20: High precision scan of the QCD phase diagram & search for critical point**
- ***2021: Install sPHENIX***
- **2022−??: Probe structure of perfect liquid QGP with precision measurements of jet quenching and other hard QCD probes**

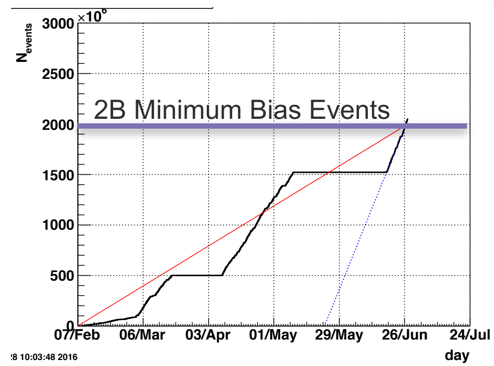


RHIC remains a unique discovery facility

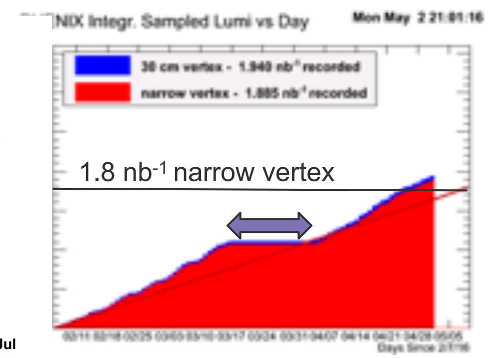
Run-16 Plan

- High luminosity 200 GeV Au+Au run (10 weeks)
- Study heavy flavor flow, especially charmed baryons, parton energy loss in QGP, quarkonium studies (for NP milestone DM12)
- PHENIX exceeded luminosity goal
- STAR exceeded minbias goal
- (in spite of 19-day interruption!)

STAR



PHENIX



- d+Au beam energy scan (5 weeks)
- Study beam energy dependence of small system collectivity and QGP properties

d+Au 200 GeV, 62.4 GeV, 39 GeV, 19.6 GeV completed; all goals achieved

Run-17 Plan

- High luminosity 510 GeV polarized p+p run (12 weeks)
- Study scale evolution of the Sivers effect in W-boson production; possibly confirm sign change of Sivers effect relative to DIS (NP Milestone HP13)

- Proof of Principle test of coherent electron cooling (1 week)

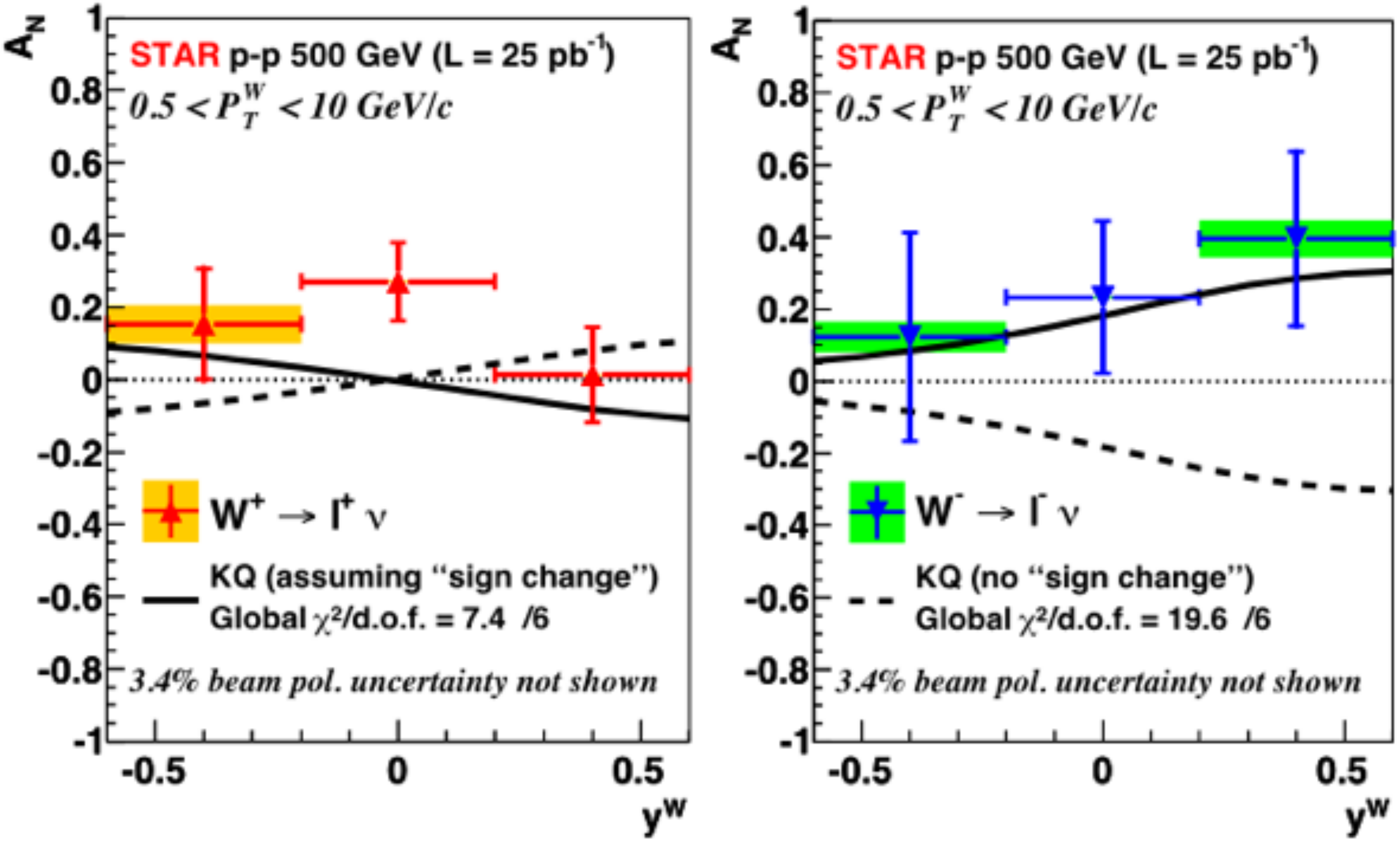
Run-18 Plan

- Isobar system (^{96}Ru - ^{96}Zr) run (8 weeks)
- Critical signature of Chiral Magnetic Effect
- Possibly 27 GeV Au+Au (2 weeks)

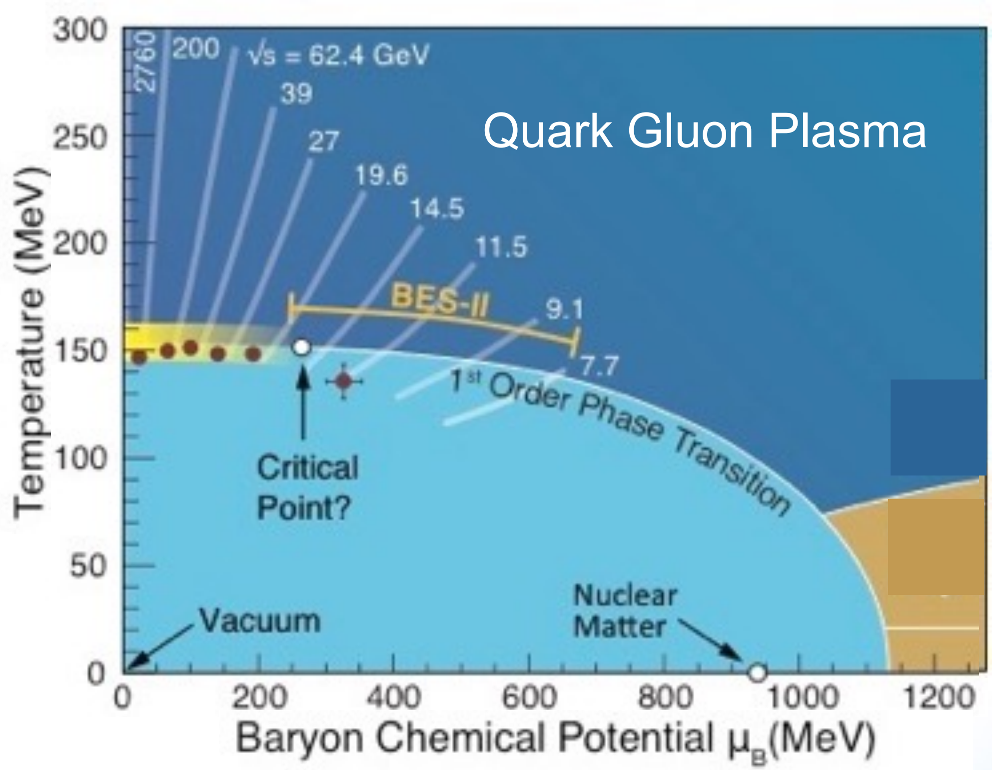
Endorsed by 2016 RHIC PAC

W Sivers function (Run-17)

Phys. Rev. Lett. 116 (2016) 132301



Studying the Phases of QCD with RHIC



Breaking of chiral symmetry in QCD generates most of the visible mass of the universe. Is chiral symmetry restored in these collisions?

At low density, the phase transition between QGP and hadrons is smooth. Is there a 1st order transition and a critical point at higher density?

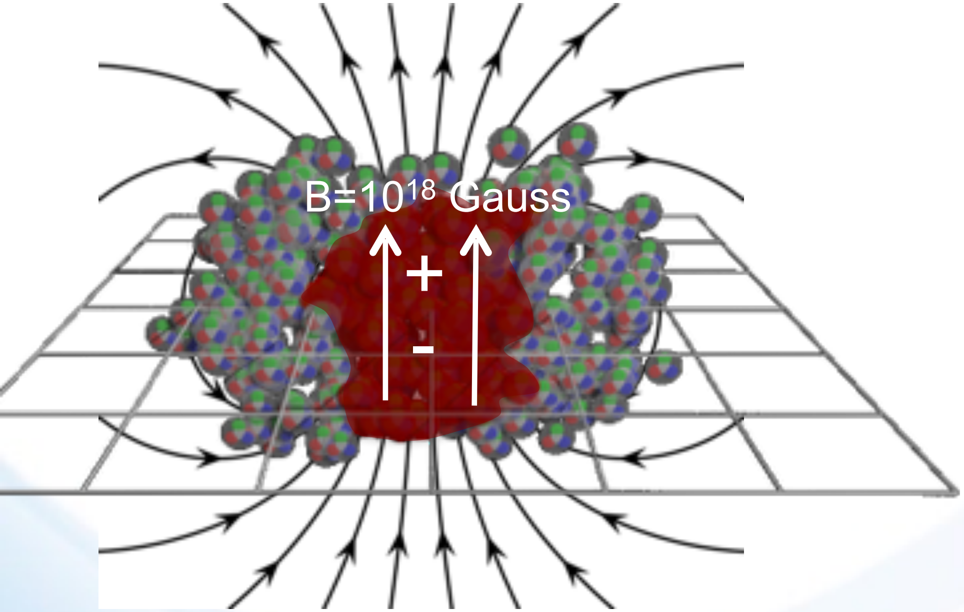
Probing Chiral Symmetry with Quantum Currents

The chiral anomaly of QCD creates differences in the number of left and right handed quarks.

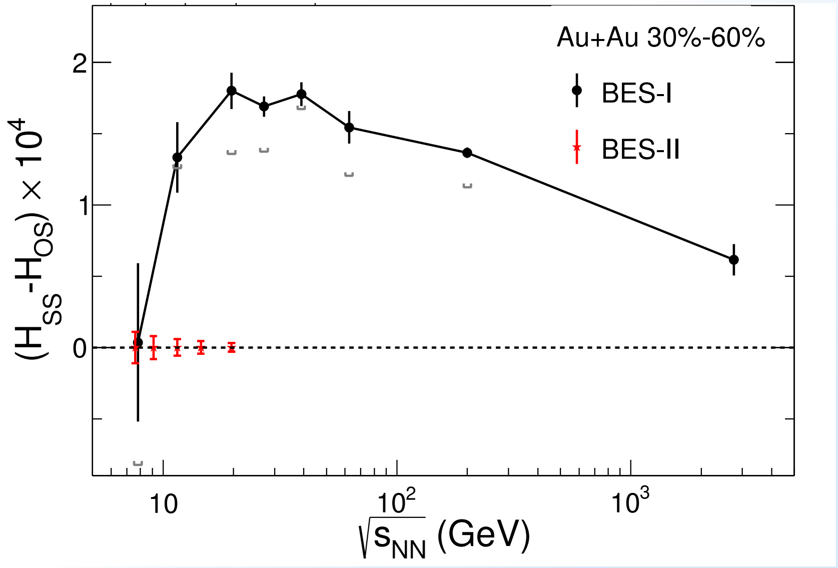
A similar mechanism in the electroweak theory is likely responsible for the matter/antimatter asymmetry of our universe

In a chirally symmetric QGP, this imbalance can create charge separation along the magnetic field (chiral magnetic effect – just discovered in CM at BNL)

charge separation



observed at all but the lowest energy

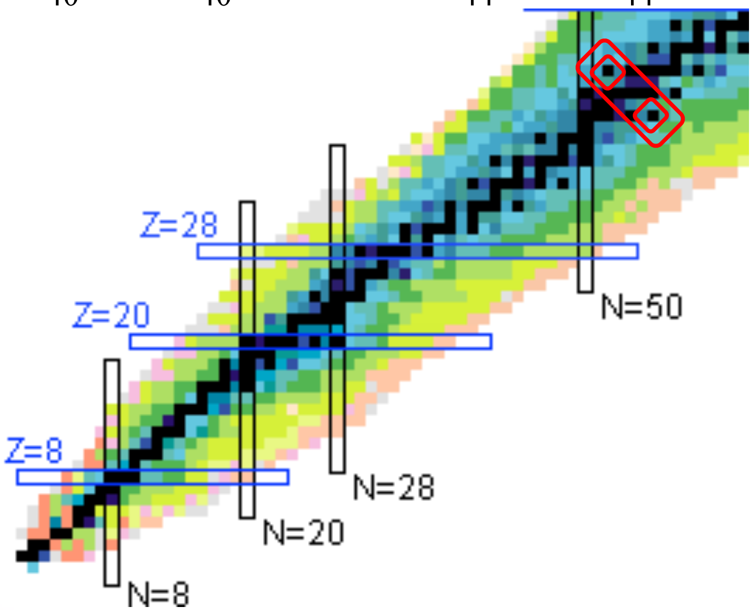


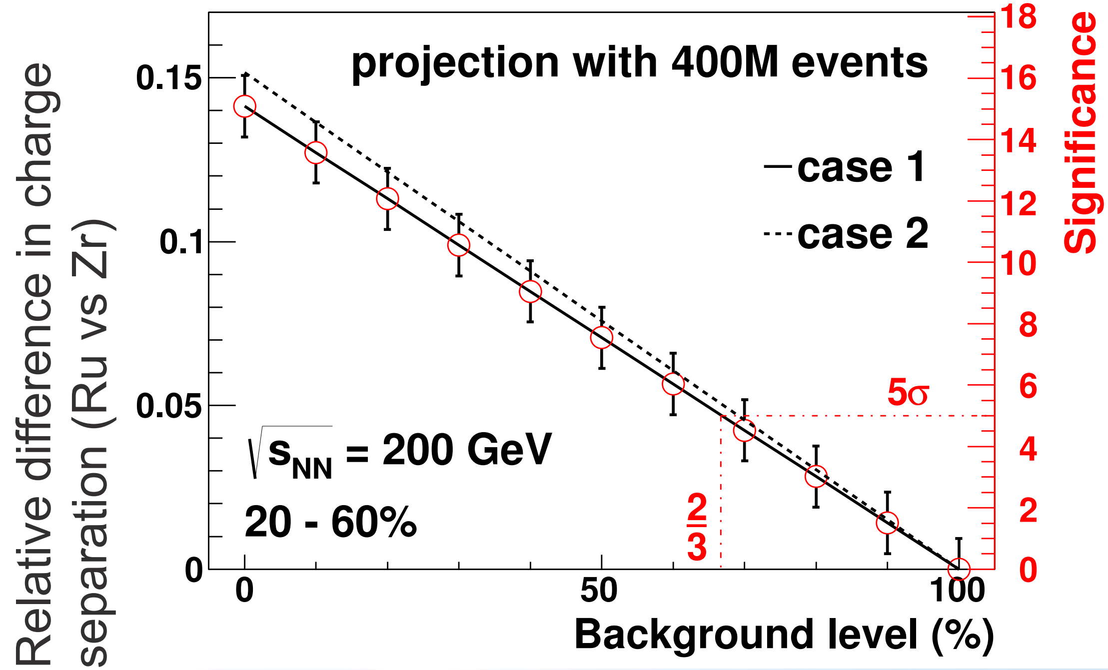
But models with magnetic field-independent flow backgrounds can also be tuned to reproduce the observed charge separation.

Probing Chiral Symmetry (Run-18)

Current understanding: backgrounds unrelated to the chiral magnetic effect may be able to explain the observed charge separation

$^{96}_{40}Zr + ^{96}_{40}Zr$ vs. $^{96}_{44}Ru + ^{96}_{44}Ru$

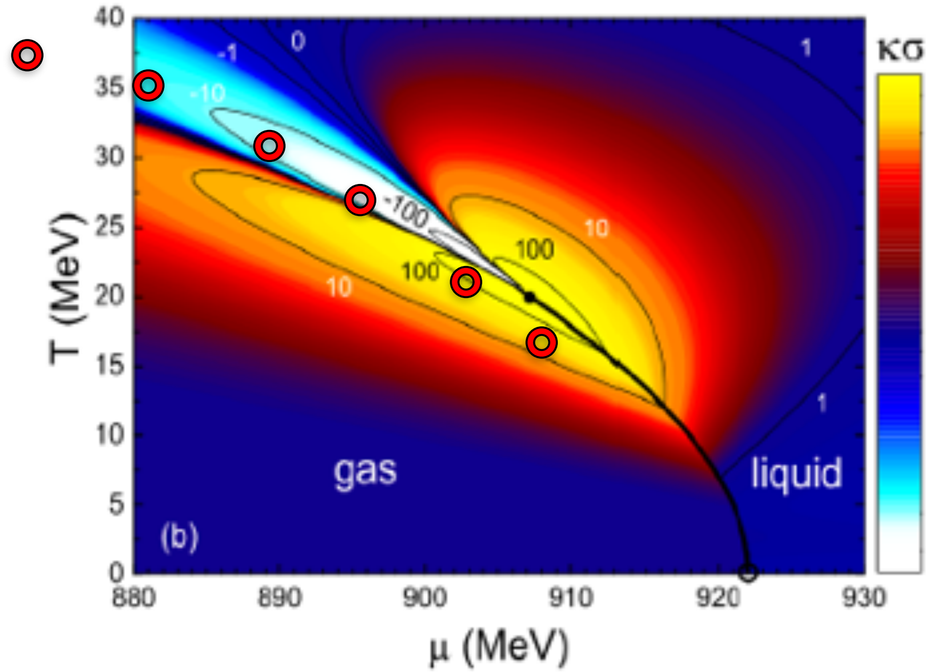


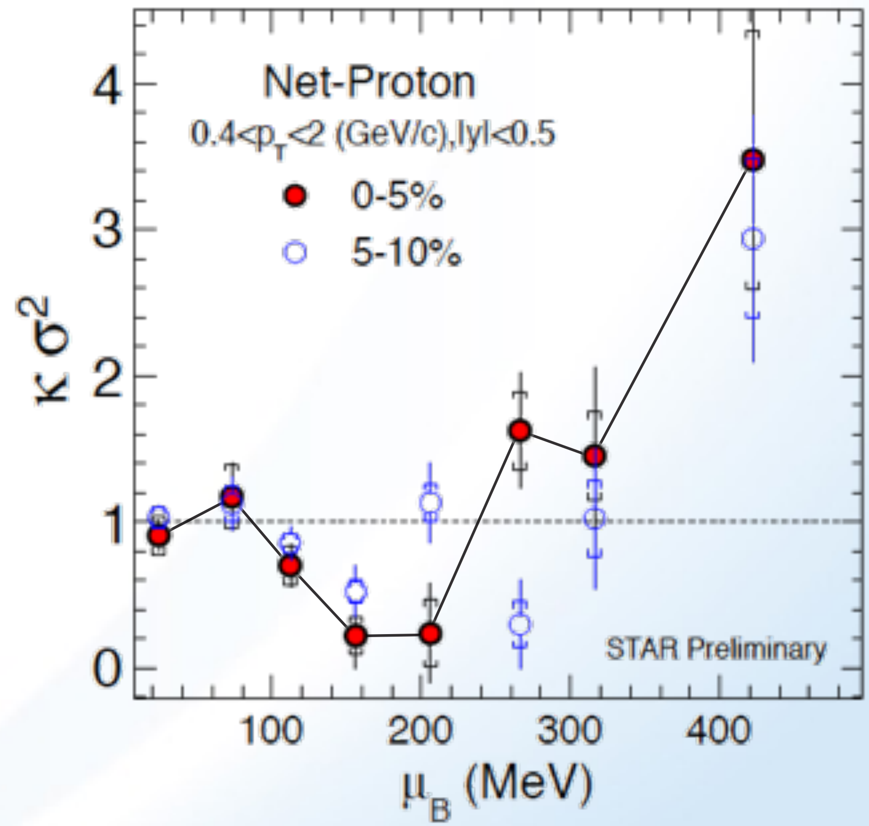


Isobar collisions will tell us what fraction of the charge separation is due to CME to within +/- 6% of the observed signal

Open question: Critical Behavior?

The moments of the distributions of conserved charges are related to susceptibilities and are sensitive to critical fluctuations





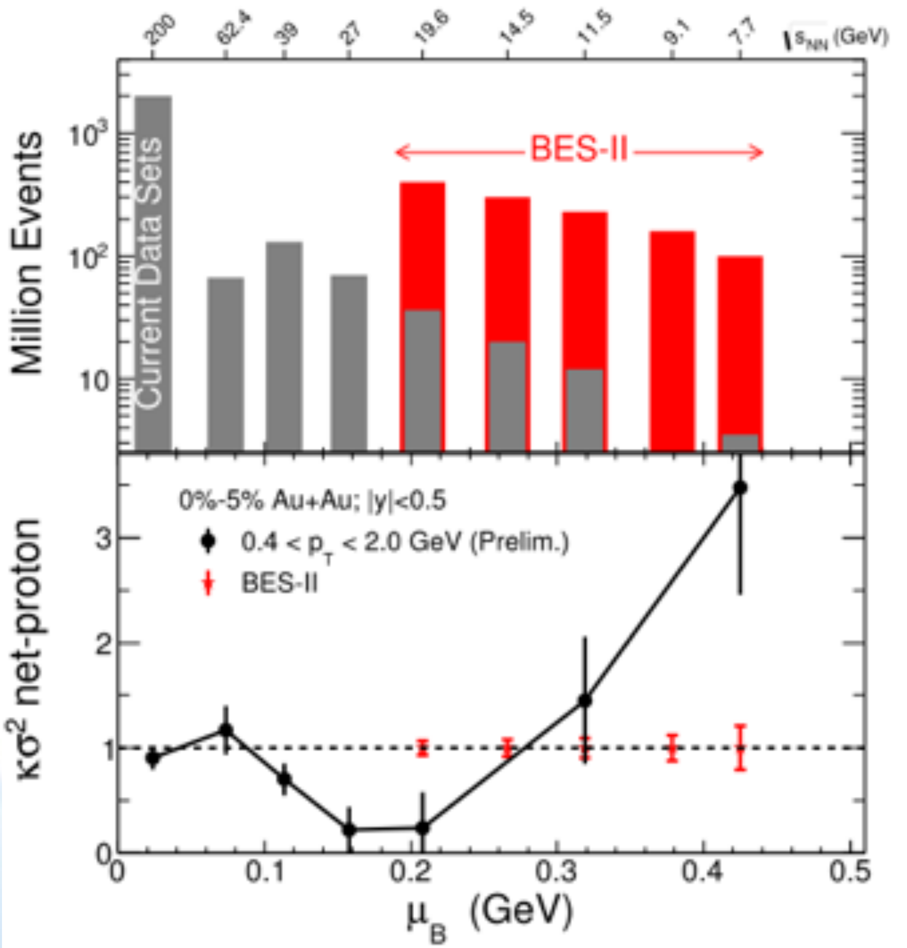
Higher moments like kurtosis*variance $\kappa\sigma^2$ change sign near the critical point

Non-monotonic trend observed in BES-I with limited statistical precision!

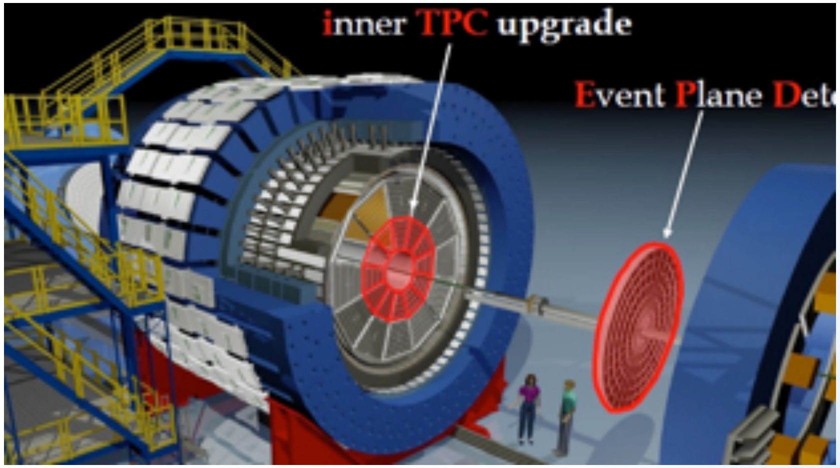
Mapping the QCD phase diagram in BES-II

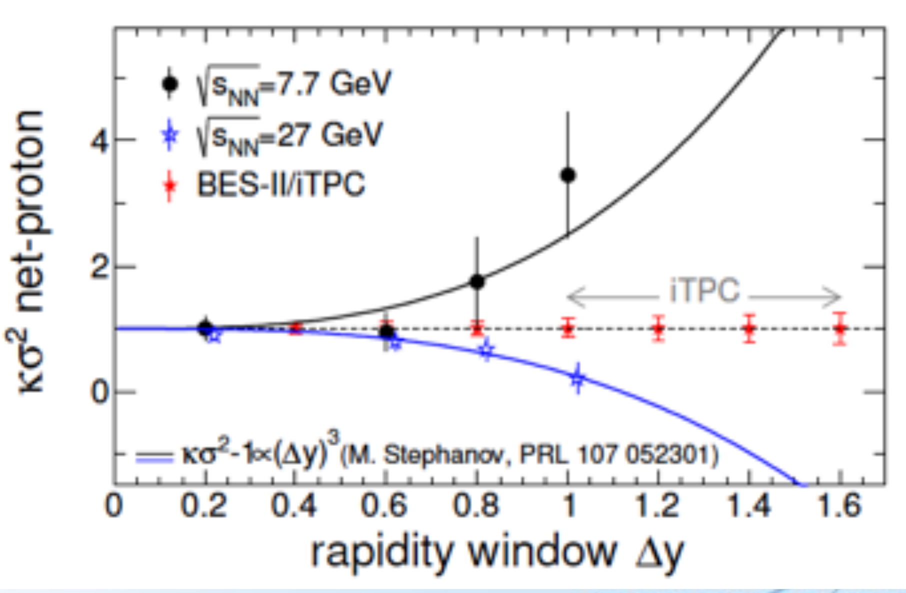
Higher statistics

Low energy RHIC electron cooling upgrade



Larger acceptance





The overarching scientific question:

How do asymptotically free quarks and gluons create the near-perfect liquidity of the QGP?

or

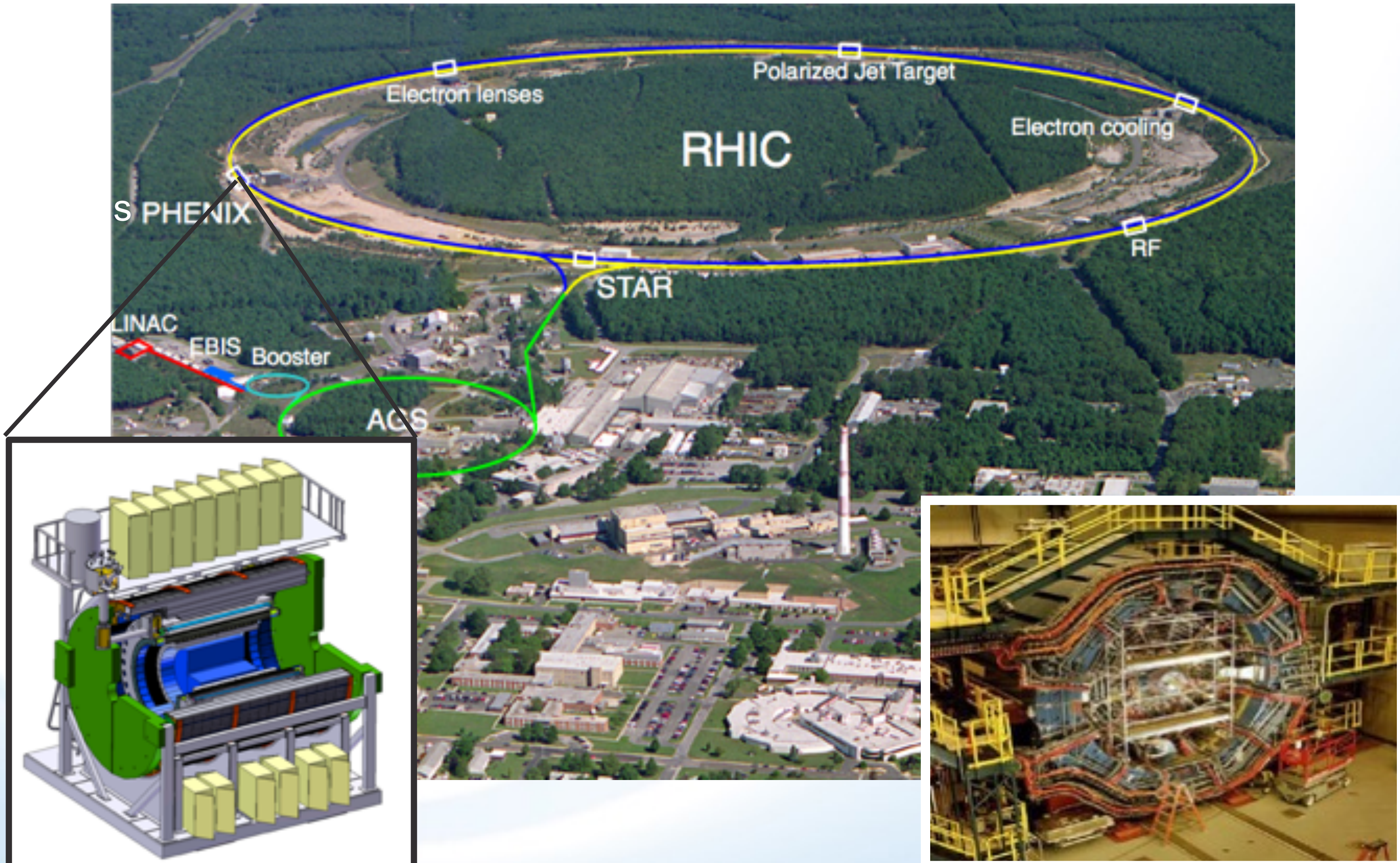
What degrees of freedom not manifest in the QCD Lagrangian produce the near-perfect liquidity of the QGP?

The (experimental) answer:

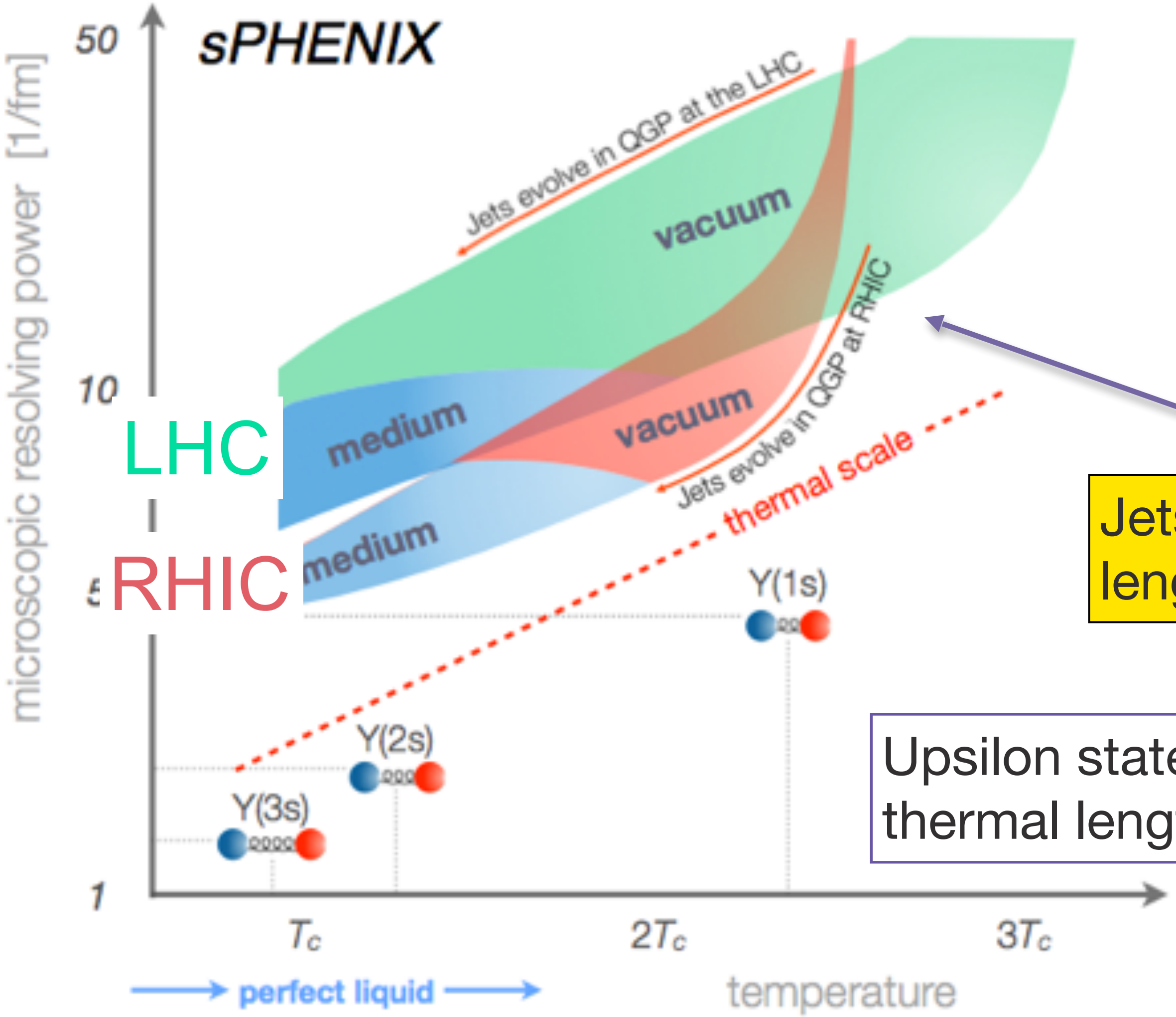
Deploy probes with a resolution that reaches well below the thermal ~ 1 fm scale of the bulk:

Jets & b-quark (Upsilon) states

The RHIC Facility in 2022



Probing scales in the medium

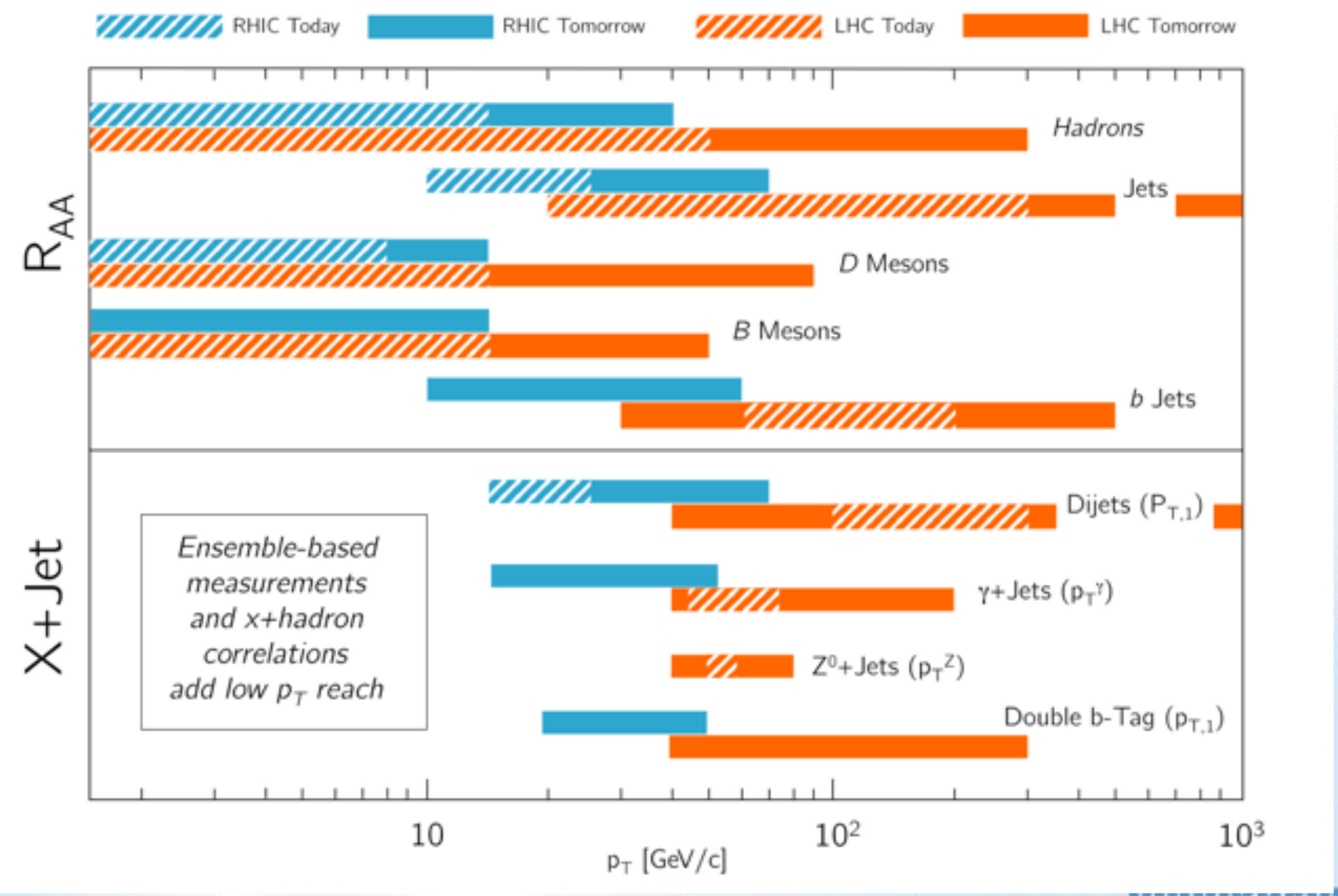


How does the perfect fluidity of the QGP emerge from the asymptotically free theory of QCD?

Jets probe sub-thermal length scales

Upsilon states probe thermal length scales

RHIC & LHC complementarity



The Future of RHIC is Bright !