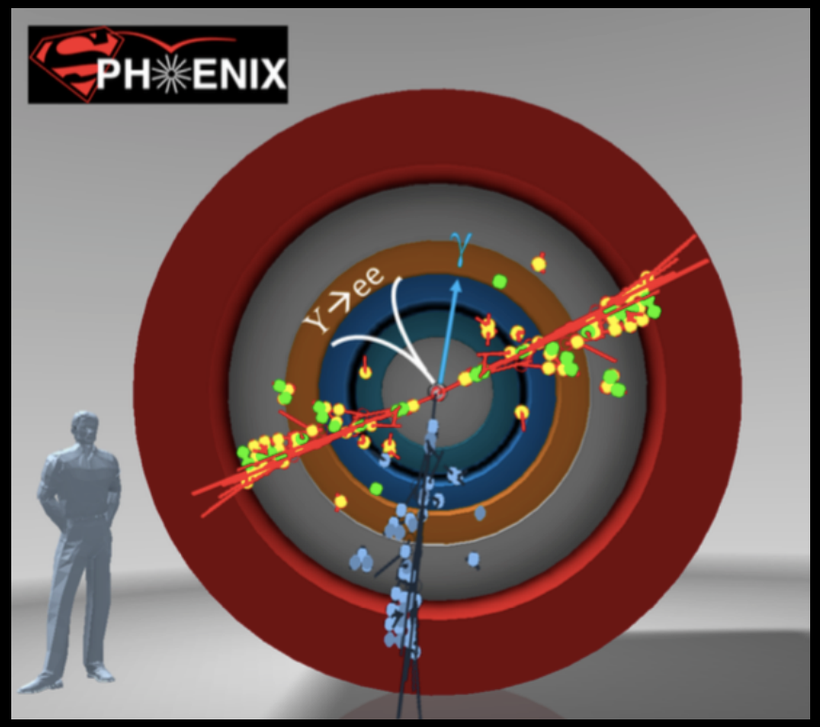
Realizing the Long Range Plan at RHIC: QGP Hard Probes

Gunther Roland

in 10 min

Realizing the Long Range Plan at RHIC: QGP Hard Probes

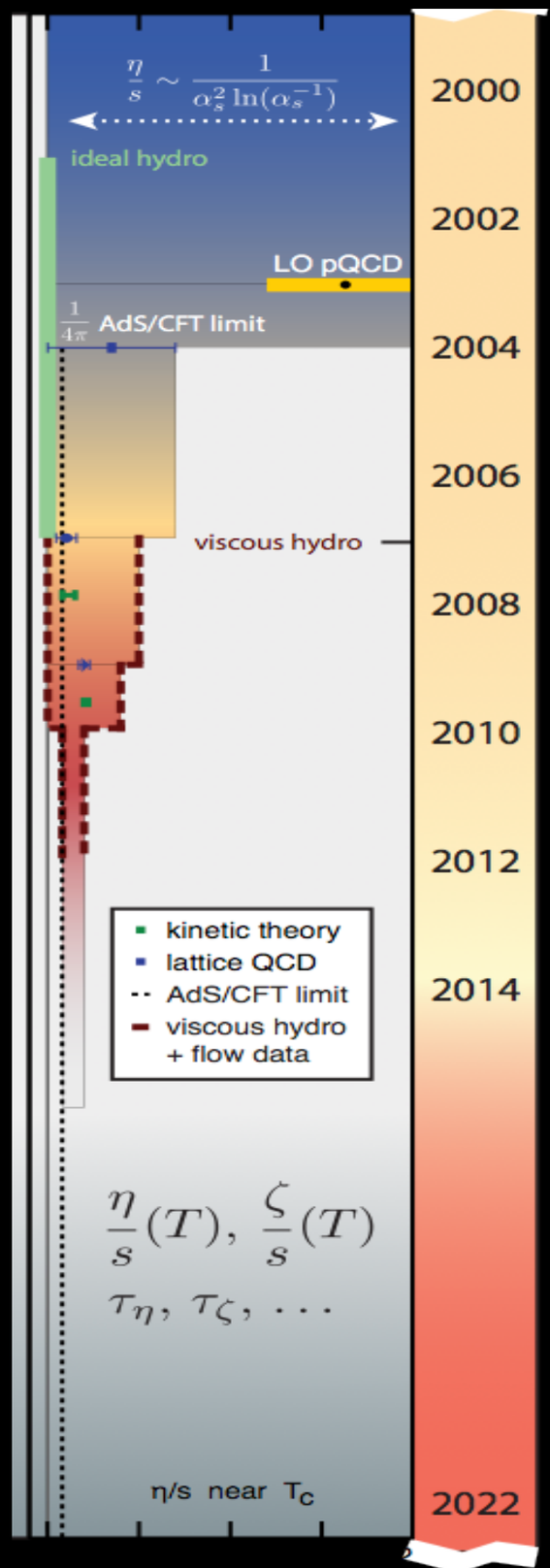
BM: "…the kind of talk you would give if you had 10 minutes to explain to someone (like yourself or an prospective MIT student) why the science program of sPHENIX is compelling"

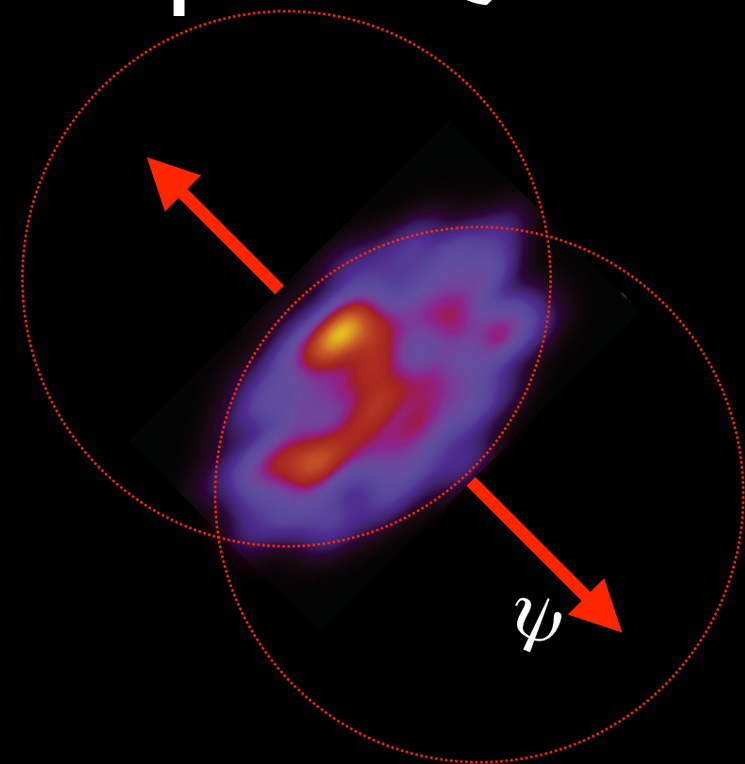


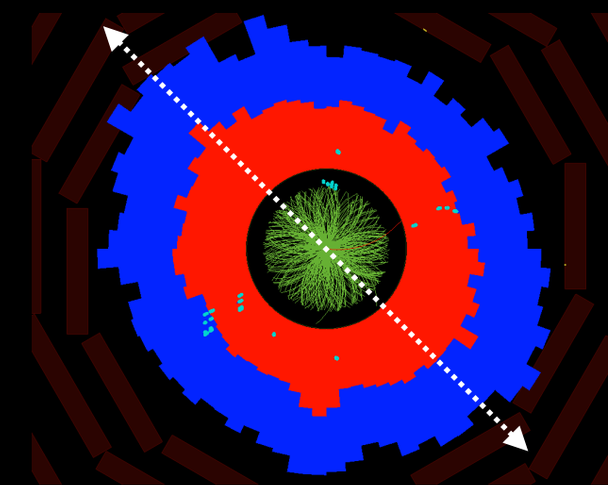
see talks by
Jin Huang, Sarah Campbell,
Megan Connors, Berndt Mueller,
Tim Hallman

Gunther Roland
MIT

Strongly Coupled Quark-Gluon Plasma





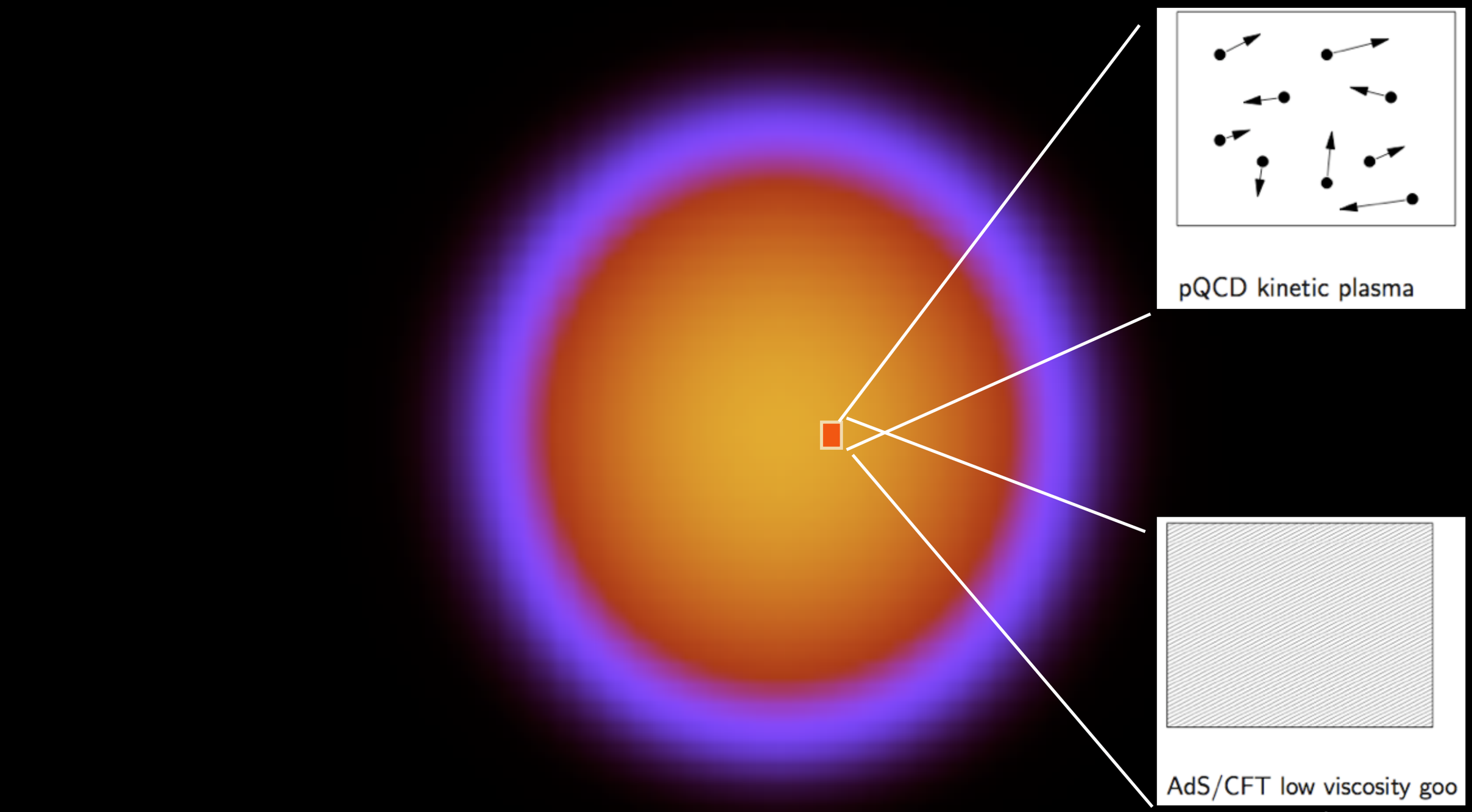


Established viscous hydrodynamics as successful effective theory of long-wavelength dynamics of QGP (at few x Tc)

Explained structure and fine-structure of final state correlations based on understanding of initial geometry at (thermal) O(1fm) scale and transport coefficient η/s ~ 1/(4π)

Demonstrated unique place of sQGP among known states of matter; broad connection with other strongly coupled materials (from string theory to cold atoms)

How does QGP work?

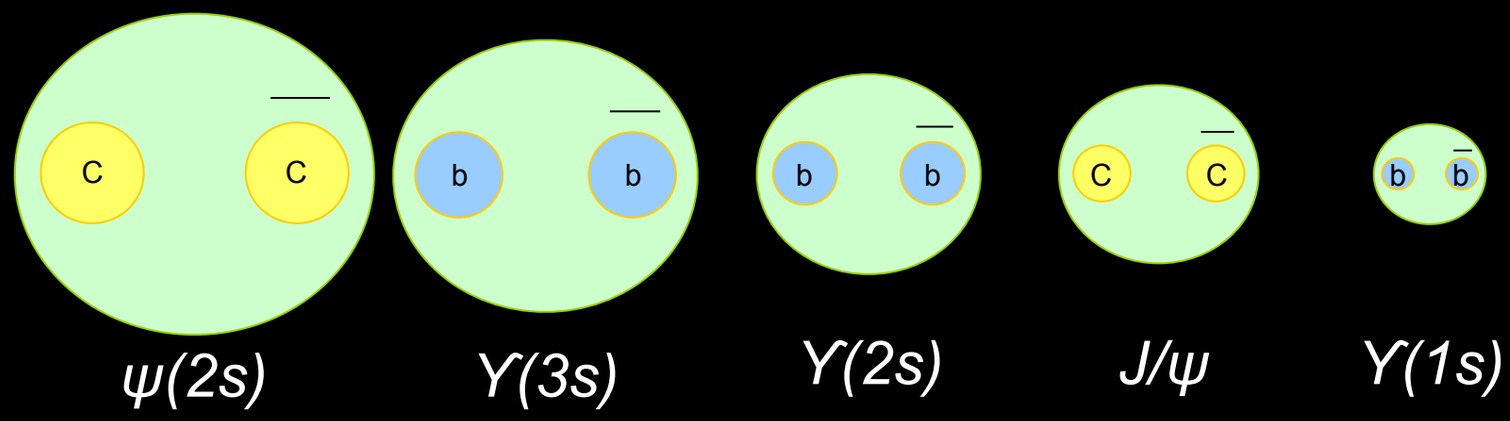


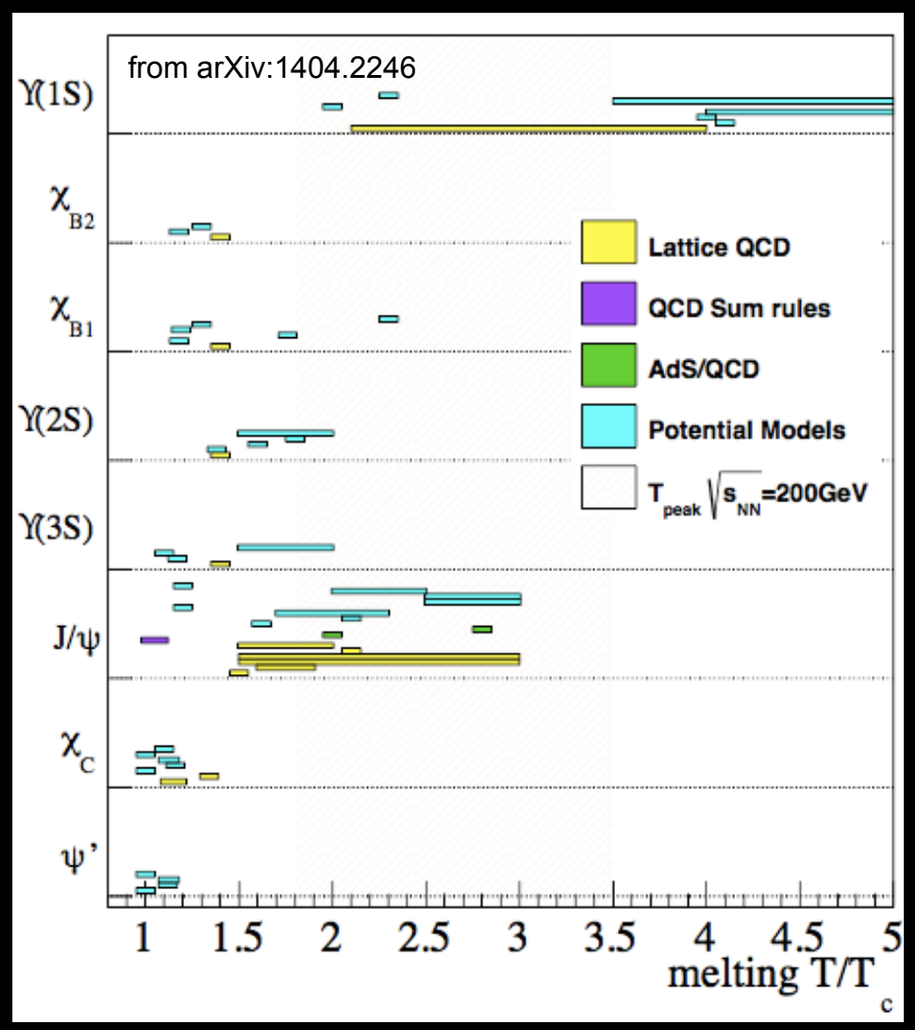
from Thomas Schafer

Use probes at multiple scales to study QGP's microscopic structure

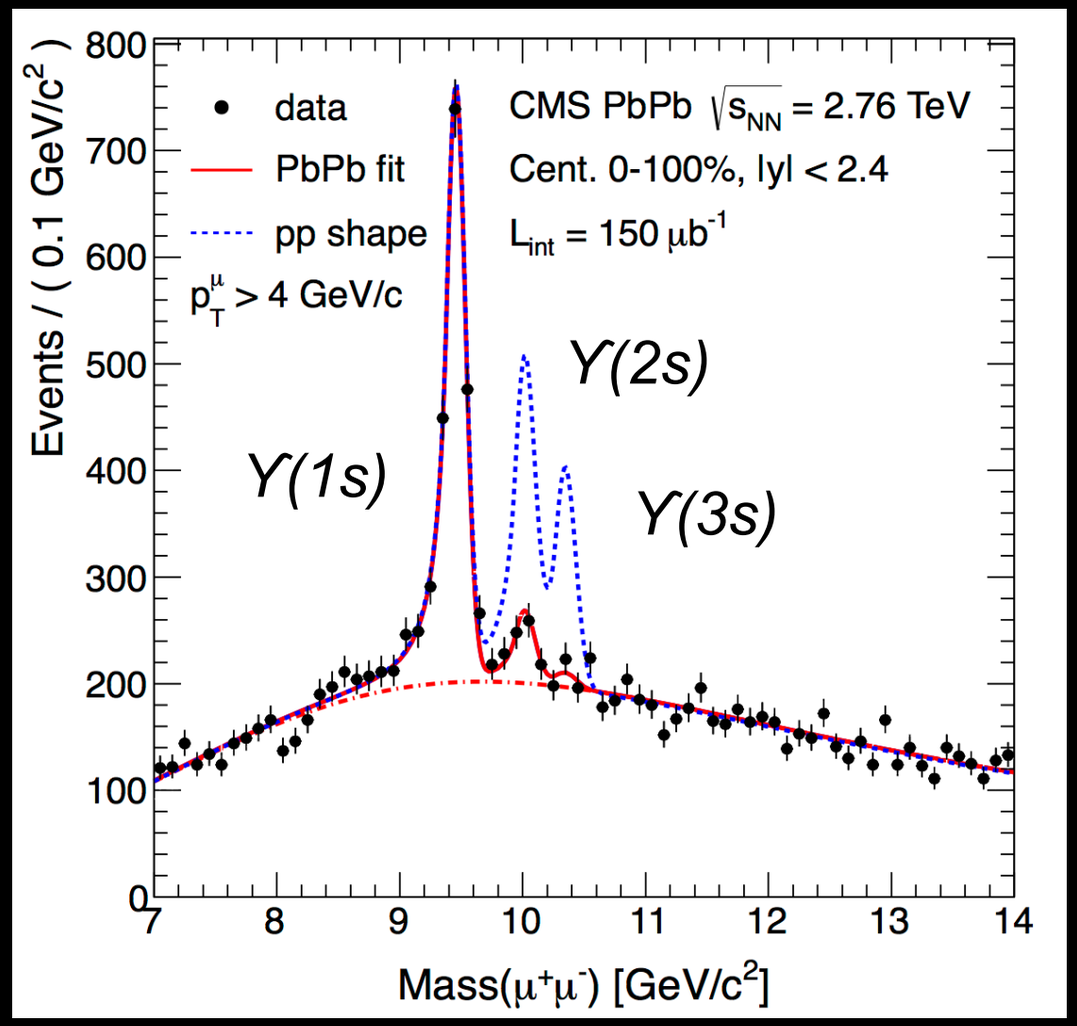
Multi-Scale Probes

Multi-Scale Probes



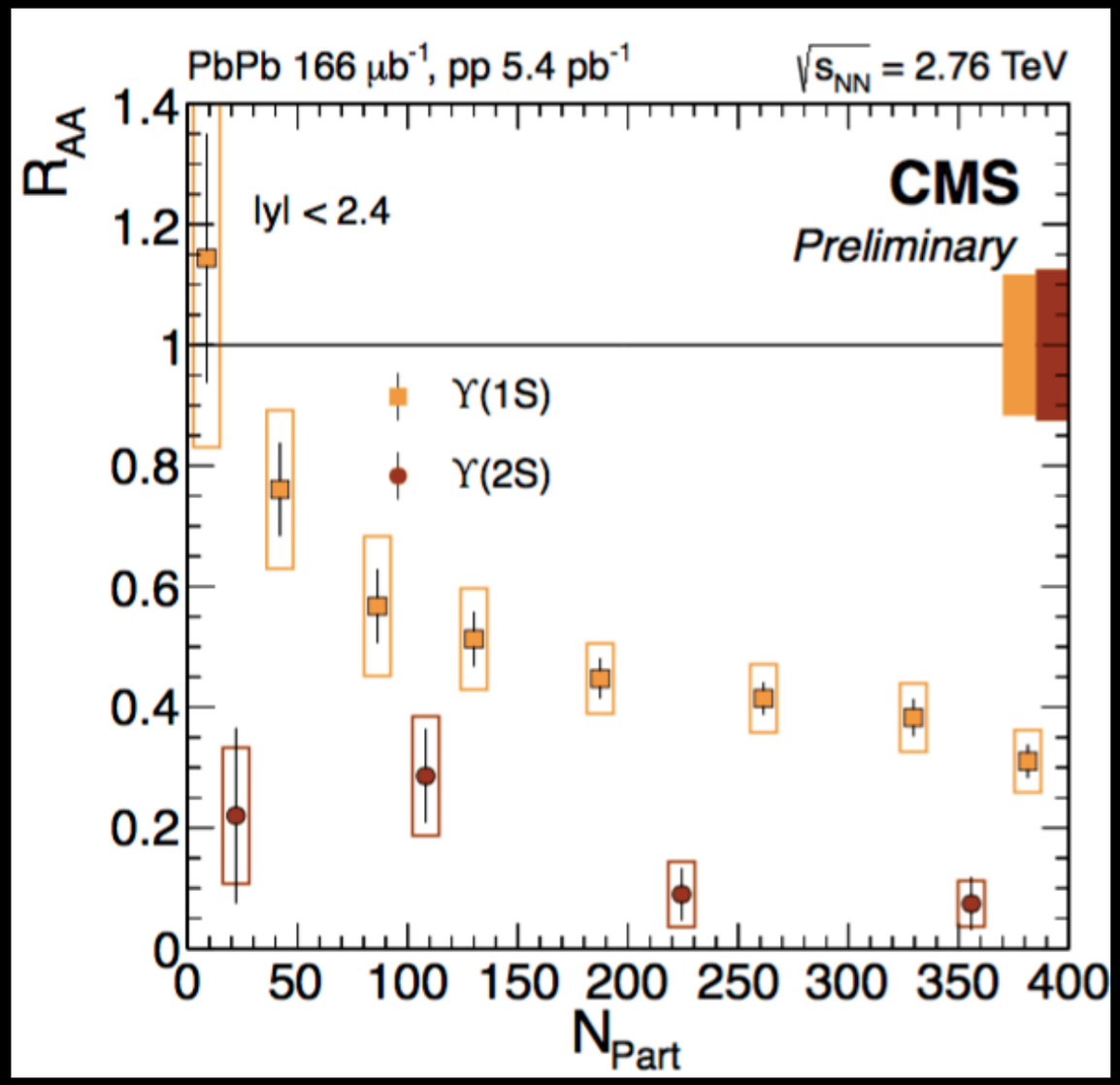


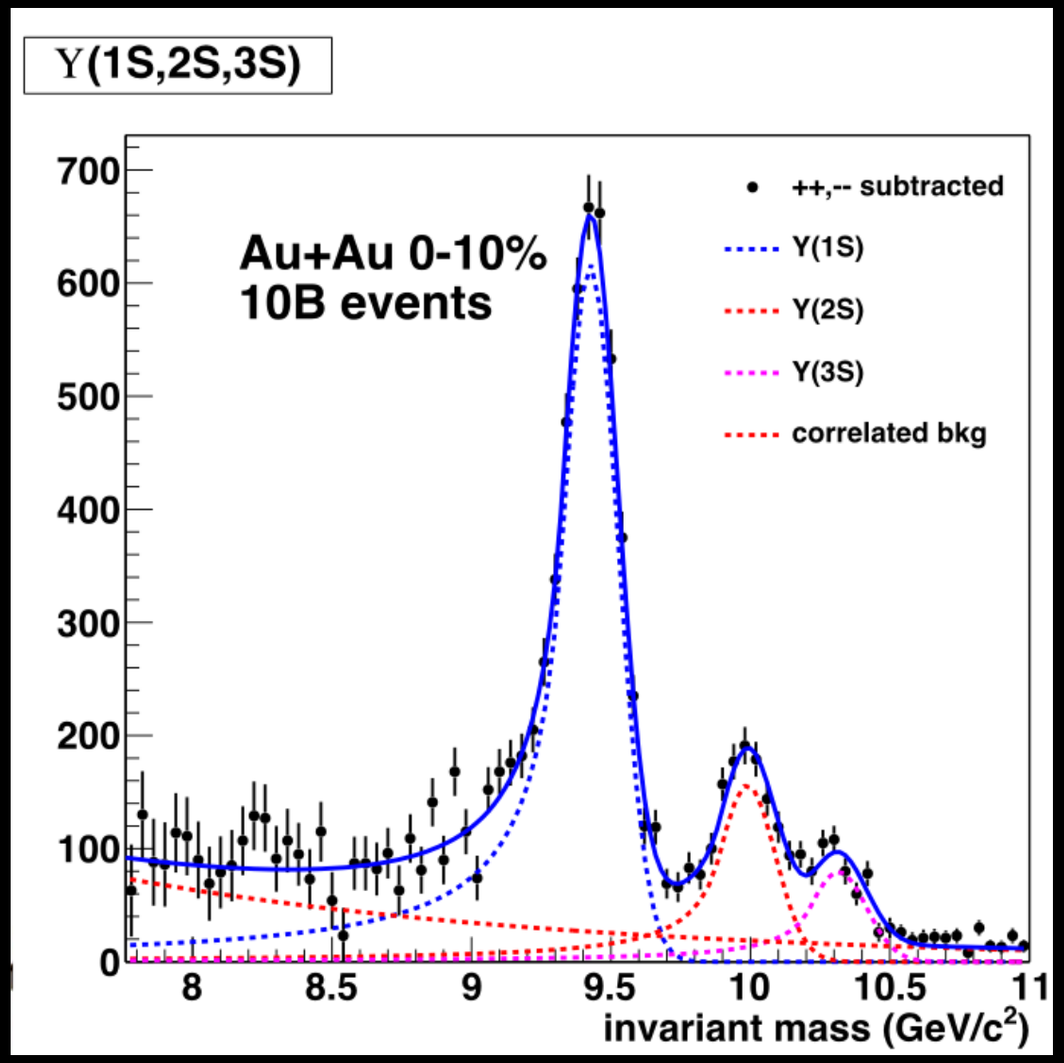
QGP temperature associated with characteristic scale (screening length)



Match of characteristic scale of probe and medium

Multi-Scale Probes

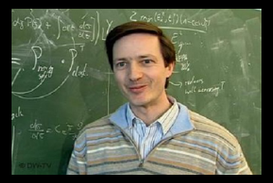




Rapid disappearance of Y(2s), Y(3s) in peripheral events is puzzling ➜
Statistics, statistics, statistics…

Count every Y delivered ➜
high rate, large acceptance

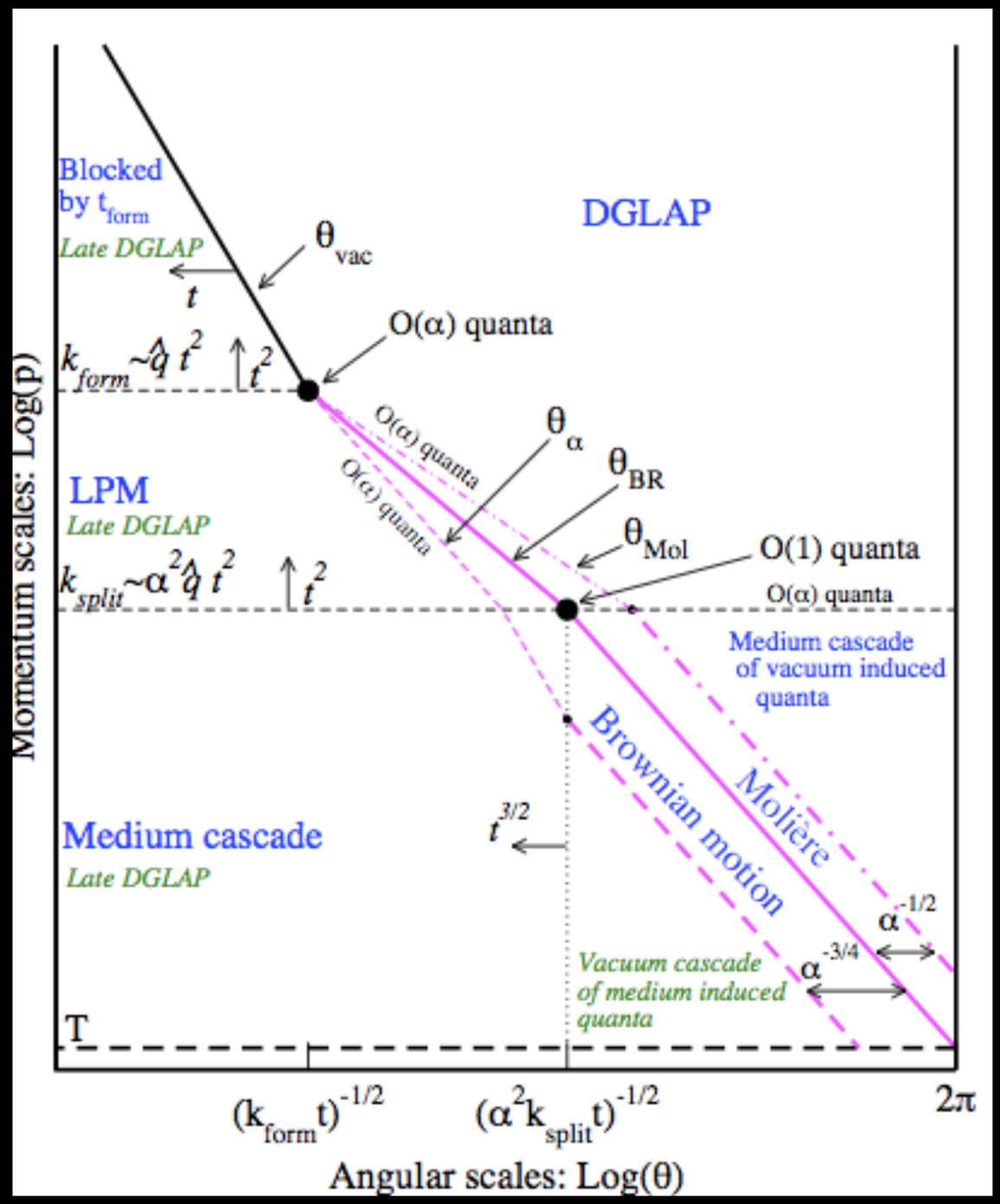
Make every Y count ➜
excellent momentum resolution



Kurkela, Wiedemann, arXiv:1407.0293

Jets as multi-scale probes

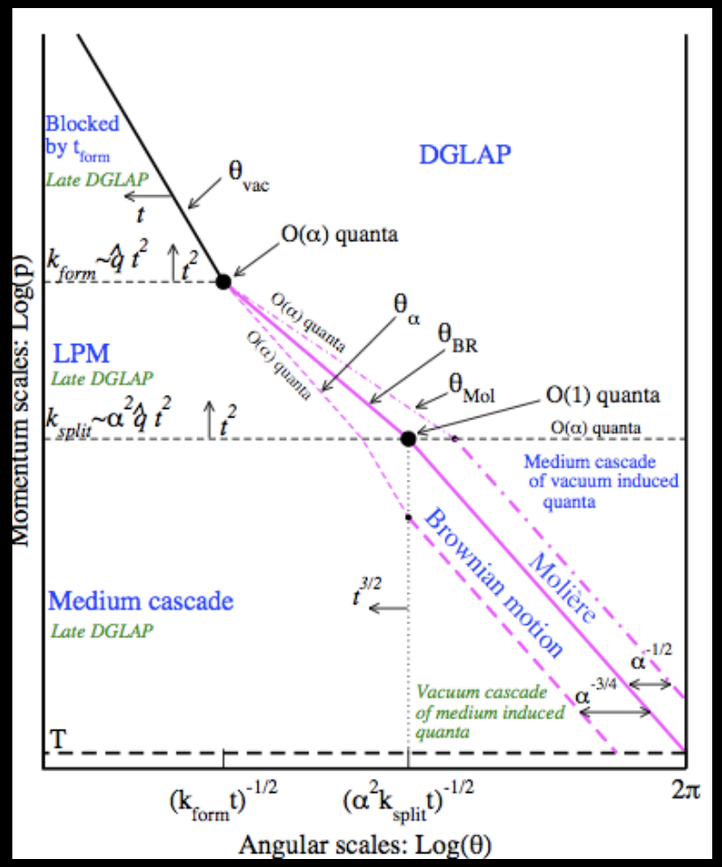
Angular and momentum structure of intra-jet parton cascade



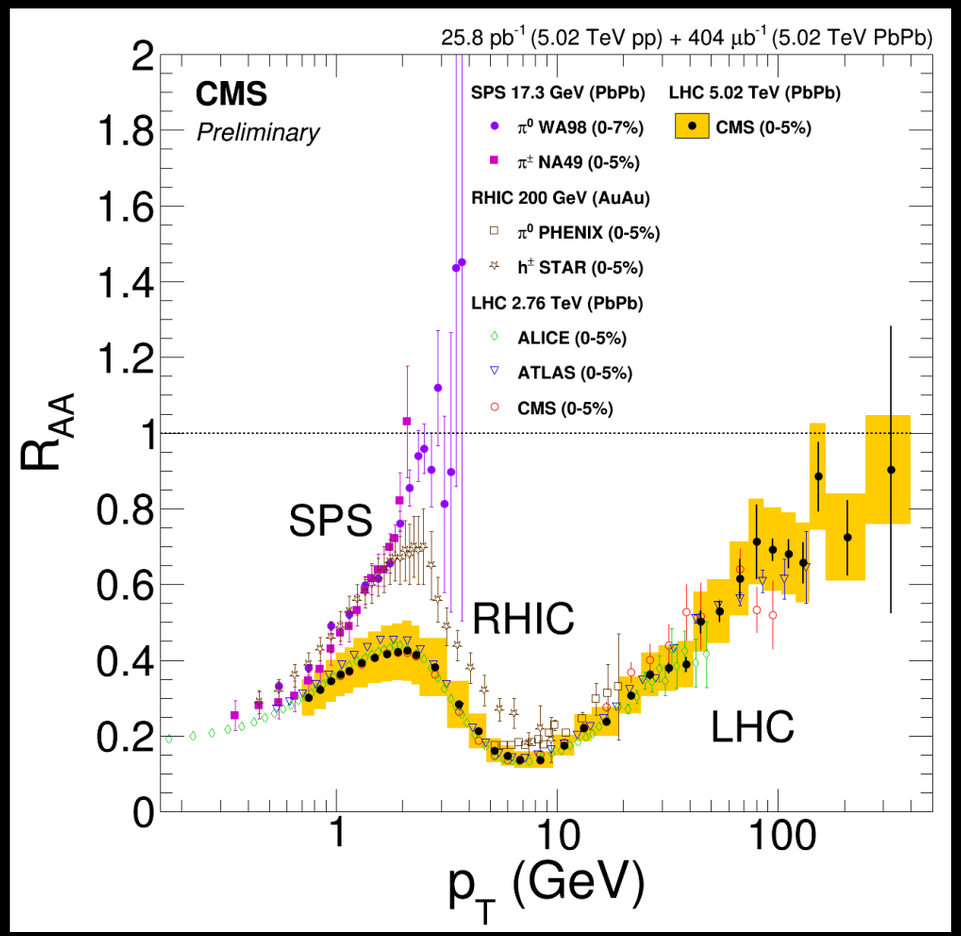
Jet evolves in angular and momentum space

At different scales, evolution is dominated by different mechanisms:

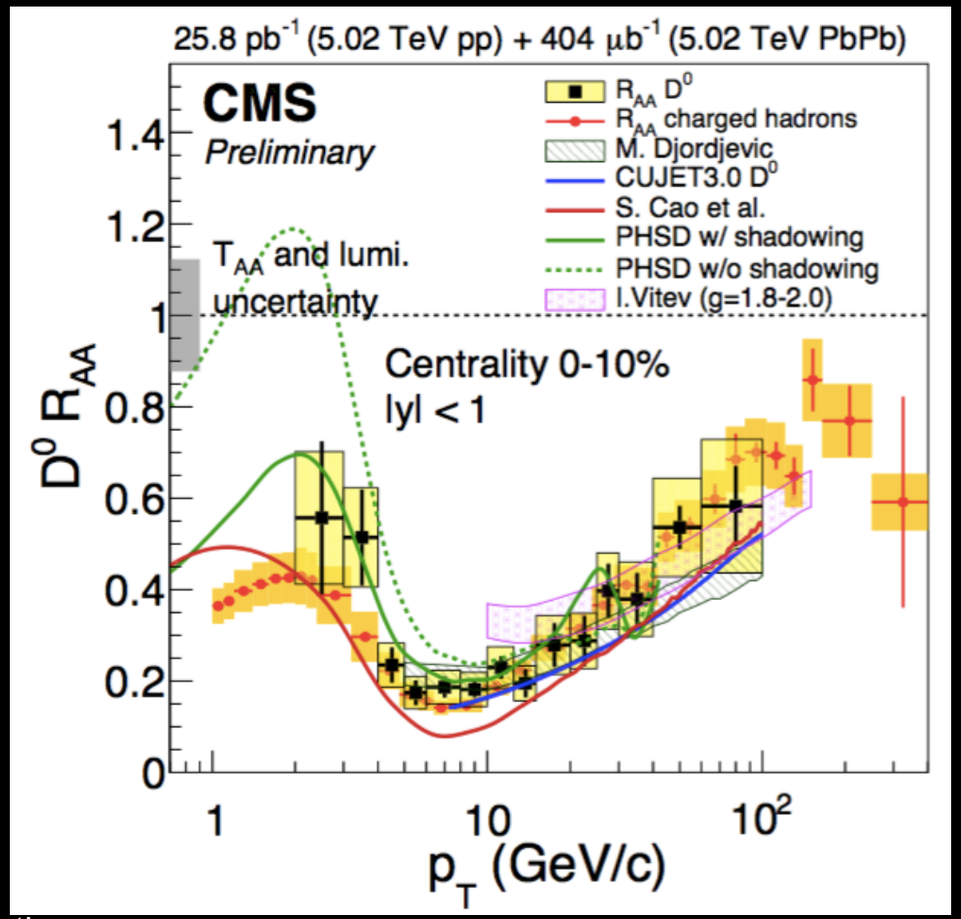
- vacuum evolution
- (jet-constituent)-medium scattering
- in-medium cascade

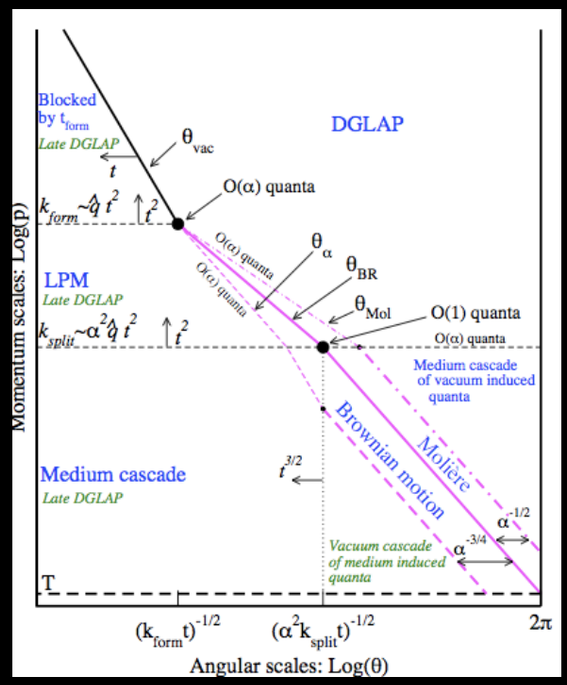


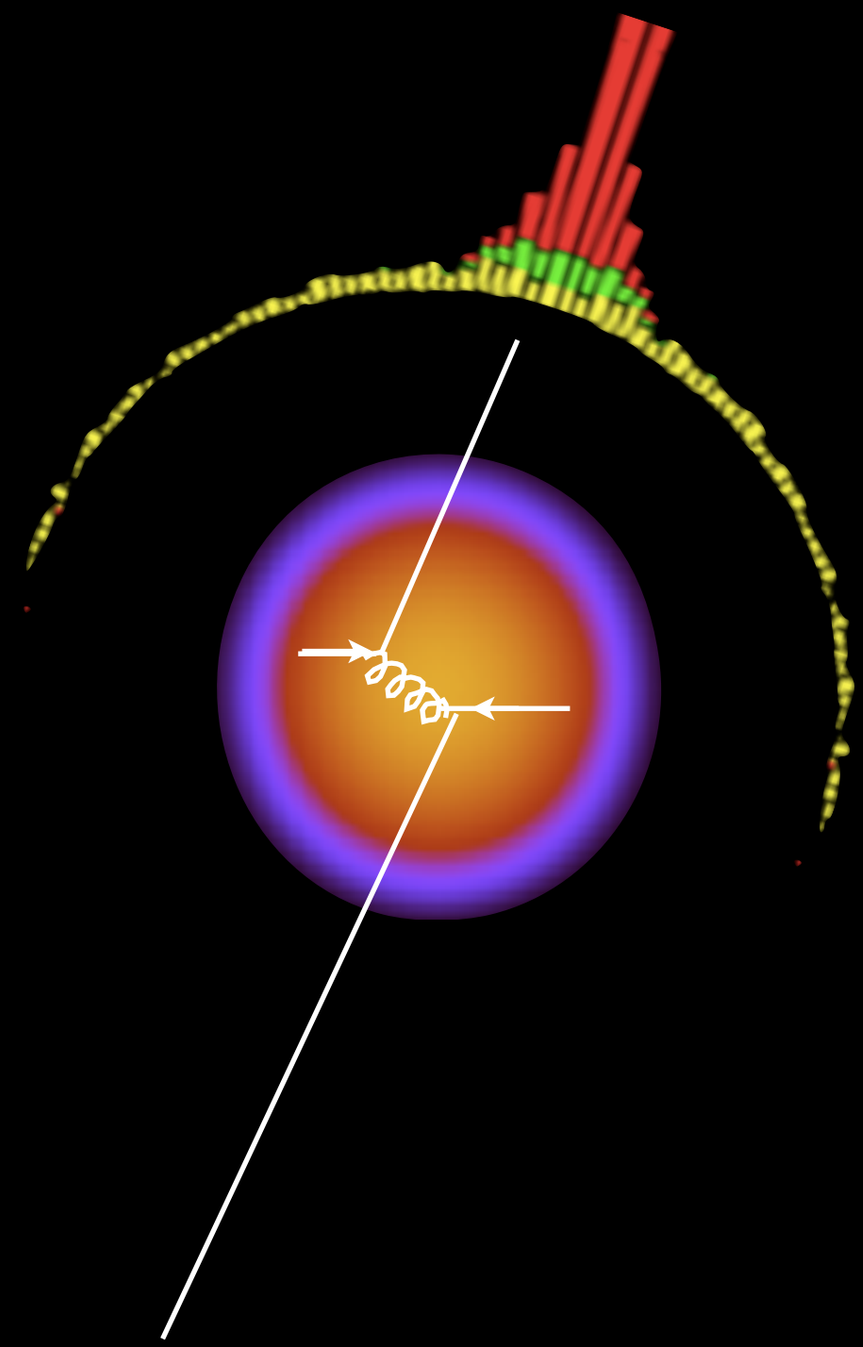
?

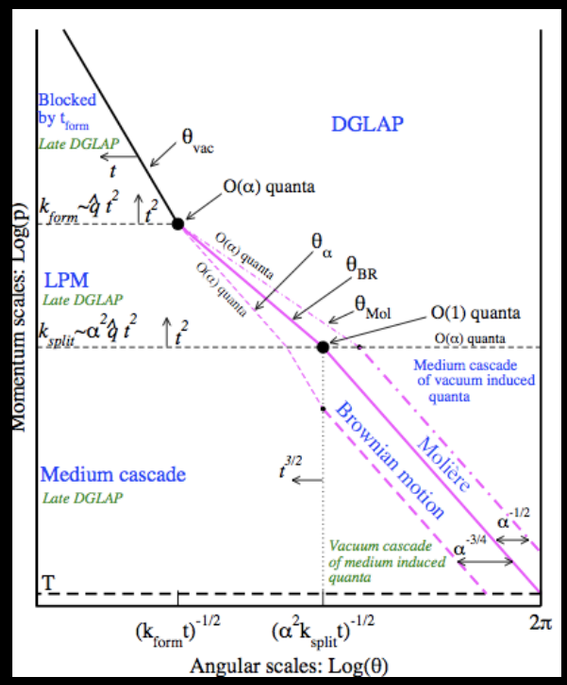


Doubtful that R_{AA}-type measurements can pin-point physics at specific scales

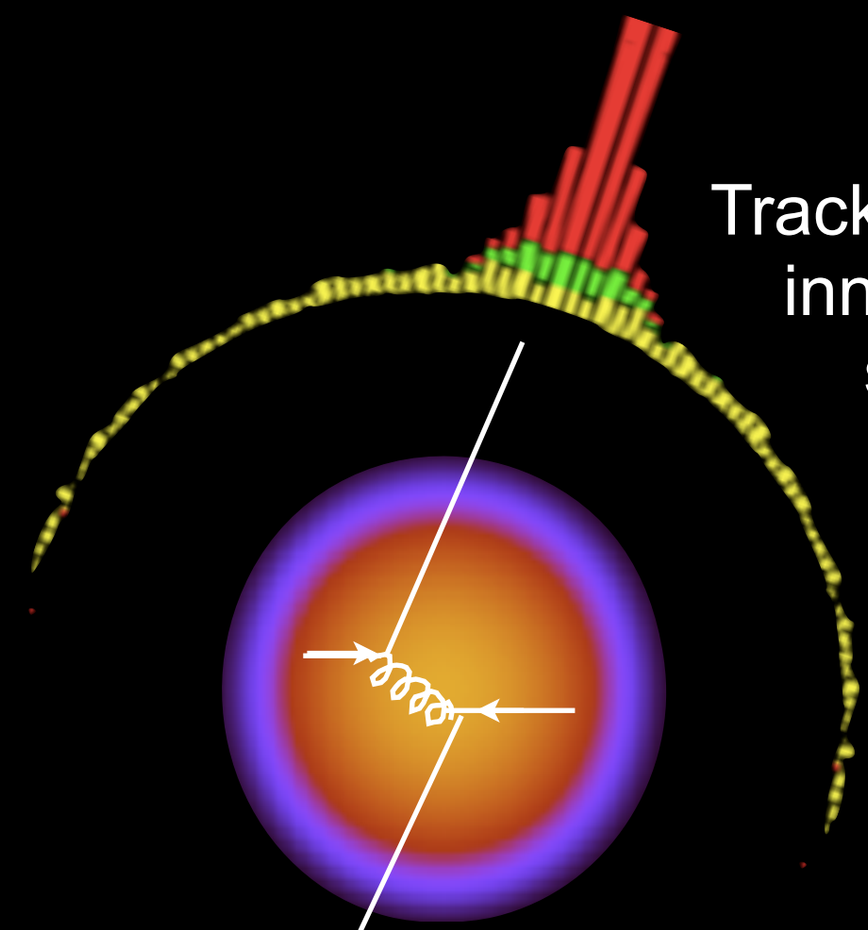



Blocked
by t_{form}
Late DGLAP
DGLAP
θ_{vac}
O(α) quanta
$k_{form} \sim \hat{q}\, t^2$
t^2
θ_α
θ_{BR}
θ_{Mol}
O(1) quanta
O(α) quanta
LPM
Late DGLAP
$k_{split} \sim \alpha^2 \hat{q}\, t^2$
Medium cascade
of vacuum induced
quanta
Brownian motion
Molière
Medium cascade
Late DGLAP
$t^{3/2}$
$\alpha^{-1/2}$
$\alpha^{-3/4}$
Vacuum cascade
of medium induced
quanta
T
$(k_{form} t)^{-1/2}$
$(\alpha^2 k_{split} t)^{-1/2}$
2π
Momentum scales: Log(p)
Angular scales: Log(θ)





Calorimetry to find jet
(+measure energy)



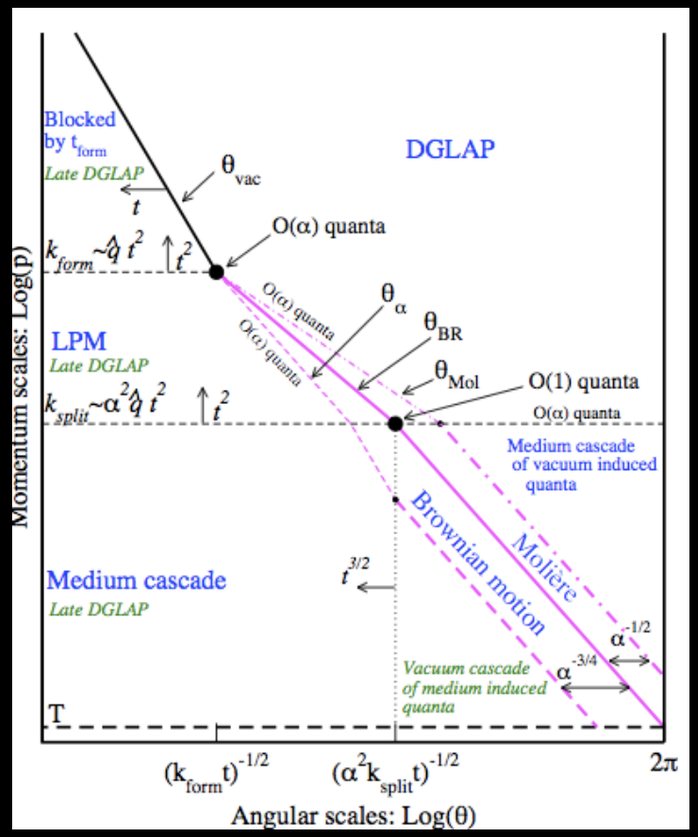
Tracking to characterize inner and extended structure of jet

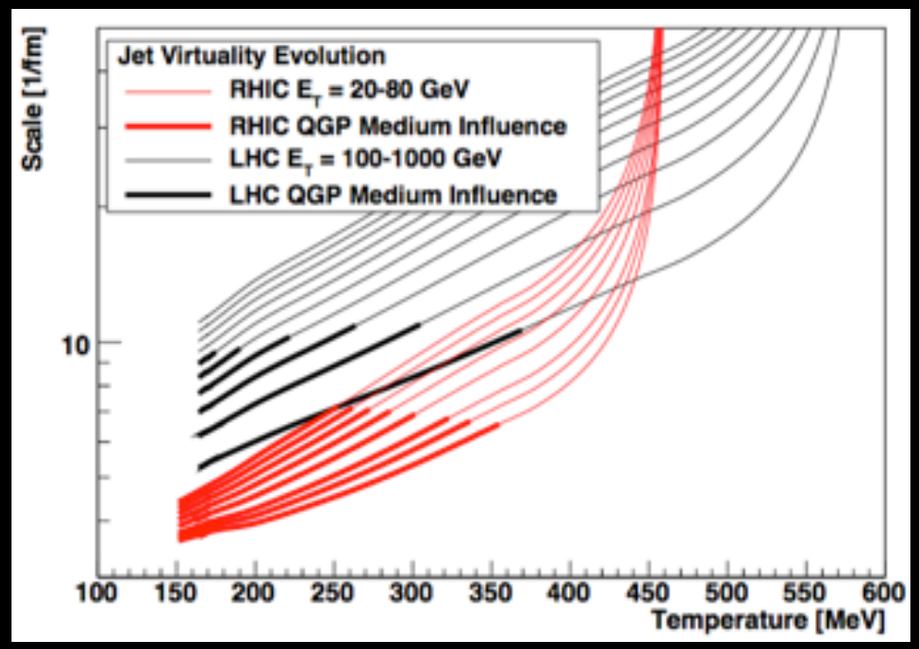
Use away-side and/or same side tags to systematically control jet system:

- Initial parton energy, color charge: Z and γ tag
- Geometry: hadron vs jet vs Z/γ tag
- Parton flavor/mass: D, B, c/b-tag, displaced J/ψ

➔ do this jet-by-jet

Why RHIC and LHC?



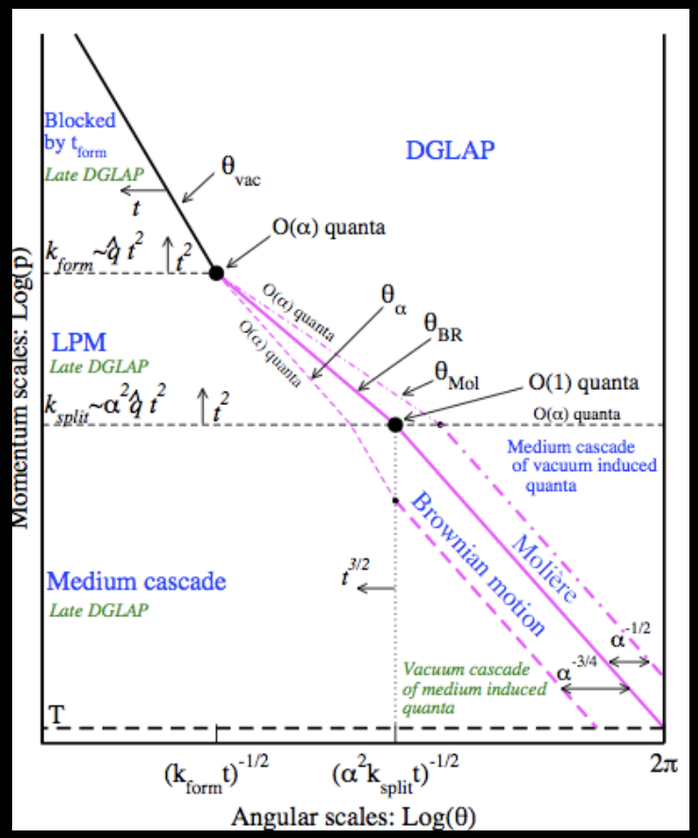


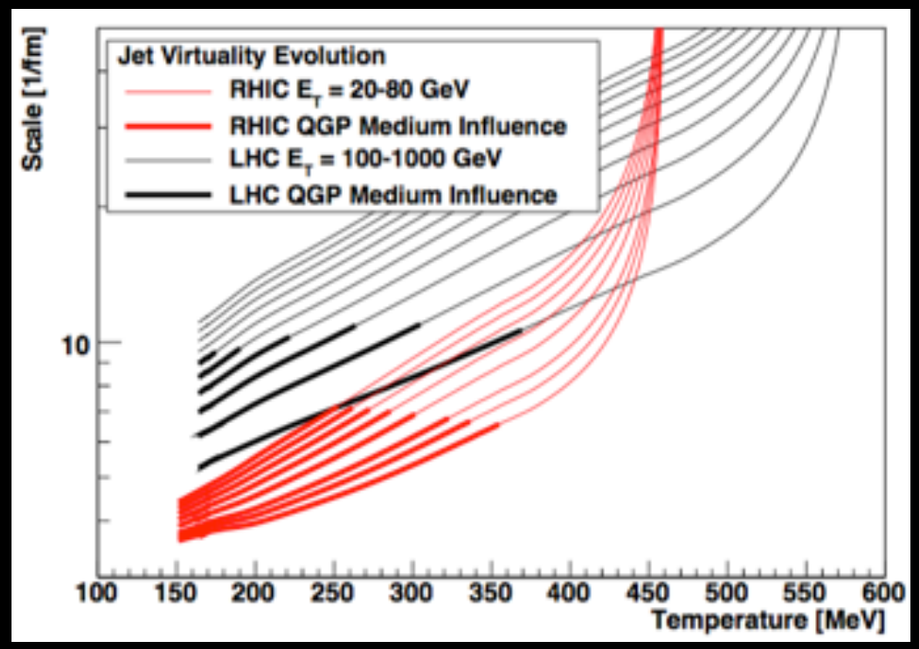
Evolving jets….. in ……..evolving medium

2 unknowns ➜ 2 measurements

in particular to learn about structure near T_C

Why RHIC and LHC?





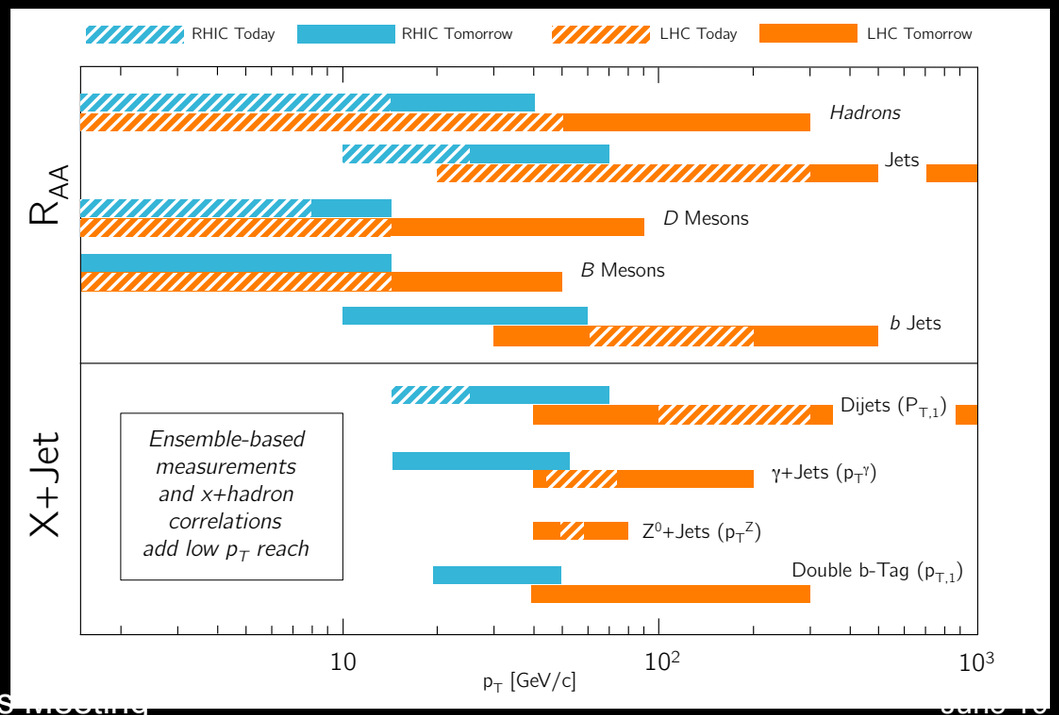
Evolving jets….. in ……..evolving medium

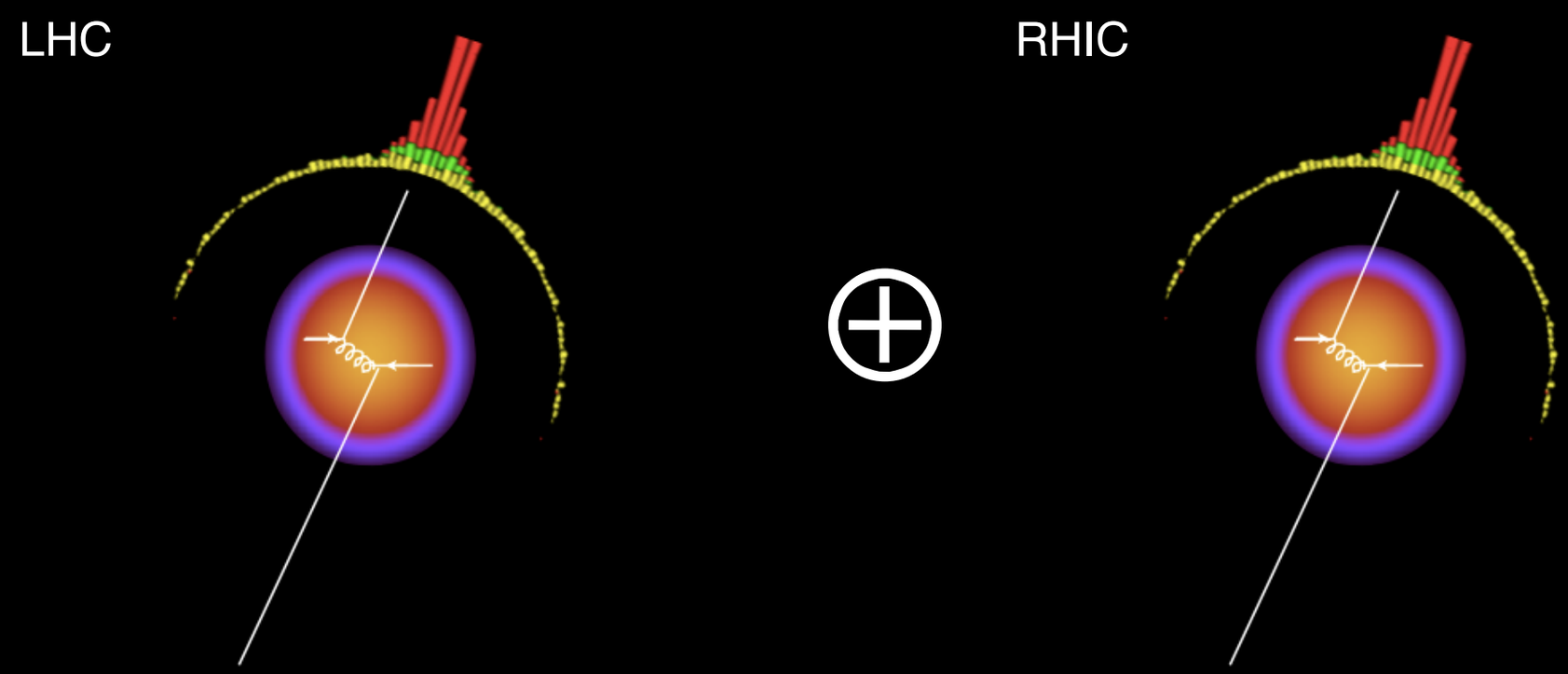
2 unknowns ➜ 2 measurements

in particular to learn about structure near T_C

Match RHIC/LHC capabilities to allow direct comparison

- High rate
- Large acceptance
- Full calorimetry
- High momentum resolution
- Precision overtaxing

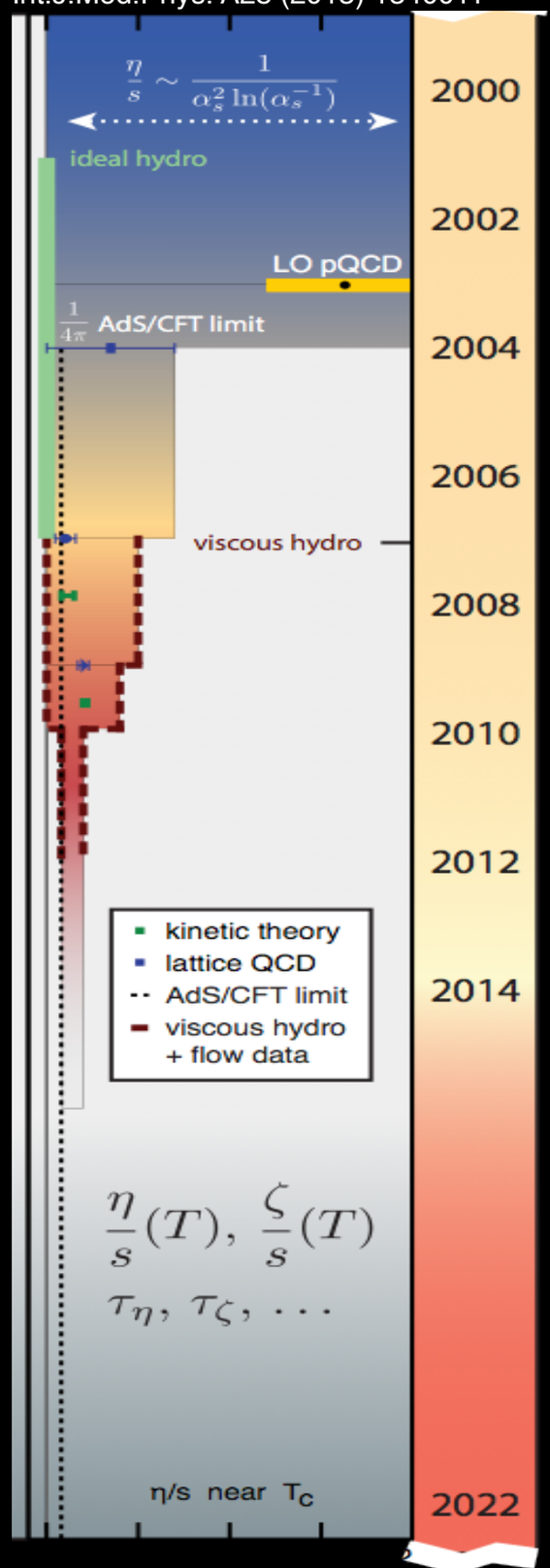




There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art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

Flashback

Gale, Jeon, Schenke
Int.J.Mod.Phys. A28 (2013) 1340011



Learn from Hydro history:

- It took 15 years to get to where we are (+ decades in the wilderness before that)
- It took key technical progress in theory (viscous hydro)
- It took several experimental surprises (large flow in Cu+Cu, flow in p+p, p+A)
- It took some detours that led to new insights (from mach cones to v_n)

Long road ahead

- Need a close collaboration between experiment and theory

The Jet Energy-loss Tomography with a Statistically and Computationally Advanced Program Envelope (JETSCAPE) collaboration

Mission

Microseconds after the Big Bang, the universe was filled with an extremely hot fluid called the Quark-Gluon Plasma. As the universe expanded, this plasma cooled and condensed into the building blocks of ordinary matter around us: protons, neutrons, and atomic nuclei. Droplets of this fluid, which exists only at temperatures above 2 trillion Kelvin, are generated and studied in the laboratory today using collisions of high-energy heavy ions, at Brookhaven National Laboratory and CERN. A key method to study the Quark-Gluon Plasma is the generation of high-energy quarks and gluons in the collision, which interact with the hot plasma and emerge as "jets" of particles that are measured by experiments. These jets provide powerful tools to study the internal structure of the plasma, analogous to tomography in medical imaging. However, interpretation of jet measurements requires sophisticated numerical modeling and simulation, and comparison of theory calculations with experimental data demands advanced statistical tools. The JETSCAPE Collaboration, an interdisciplinary team of physicists, computer scientists, and statisticians, will develop a comprehensive software framework that will provide a systematic, rigorous approach to meet this challenge. Training programs, workshops, summer schools and MOOCs, will disseminate the expertise needed to modify and maintain this framework.

http://jetscape.wayne.edu

JETSCAPE

- PI's: Abhijit Majumder, Bass, Fries, Gale, Heinz, Jacak, Jacobs, Putschke, Roland, Schwiebert, Soltz, Wang, Wolpert
- Funded by NSF ($3.6M total for postdocs, workshops etc over 4 yrs)
- Start date: June 2016
- Experiments: Work on interface of simulations/analyses with JETSCAPE