Advances in theory relevant for the heavy-ion program

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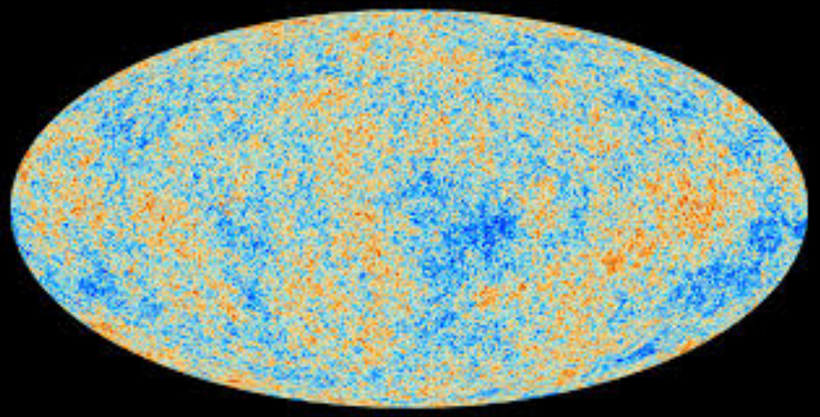
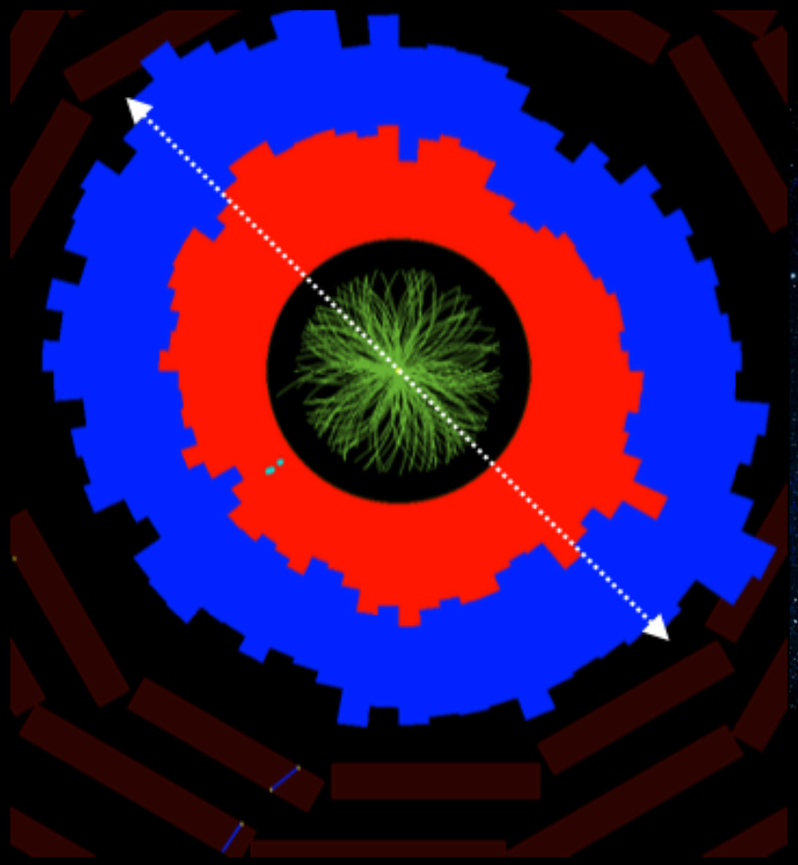
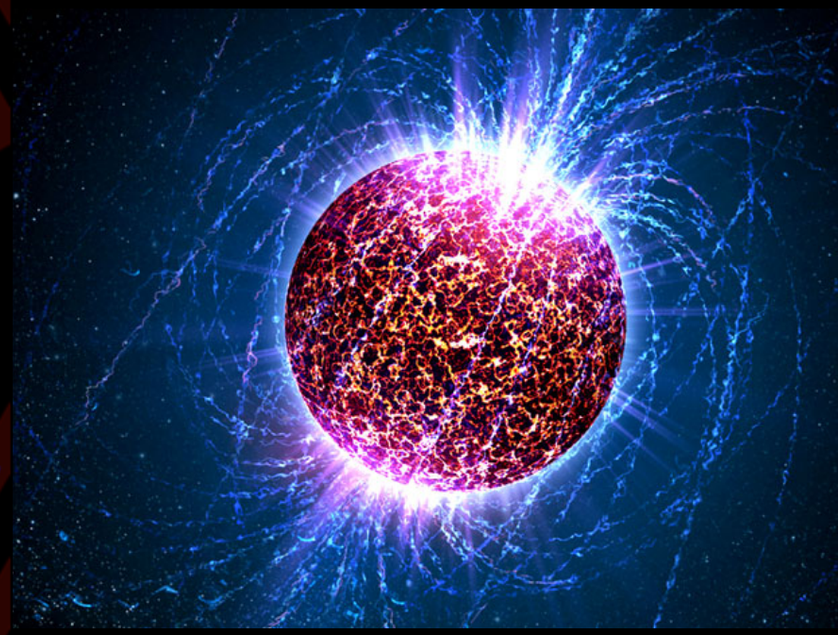
QFT in extreme conditions (T,μ) is a broad endeavour with applications in:

- Ultrarelativistic nuclear collisions
- Cosmology — **Baryogenesis, reheating, phase transitions,...**
- Astrophysics — **Neutron stars, magnetogenesis...**
- Also: condensed matter physics

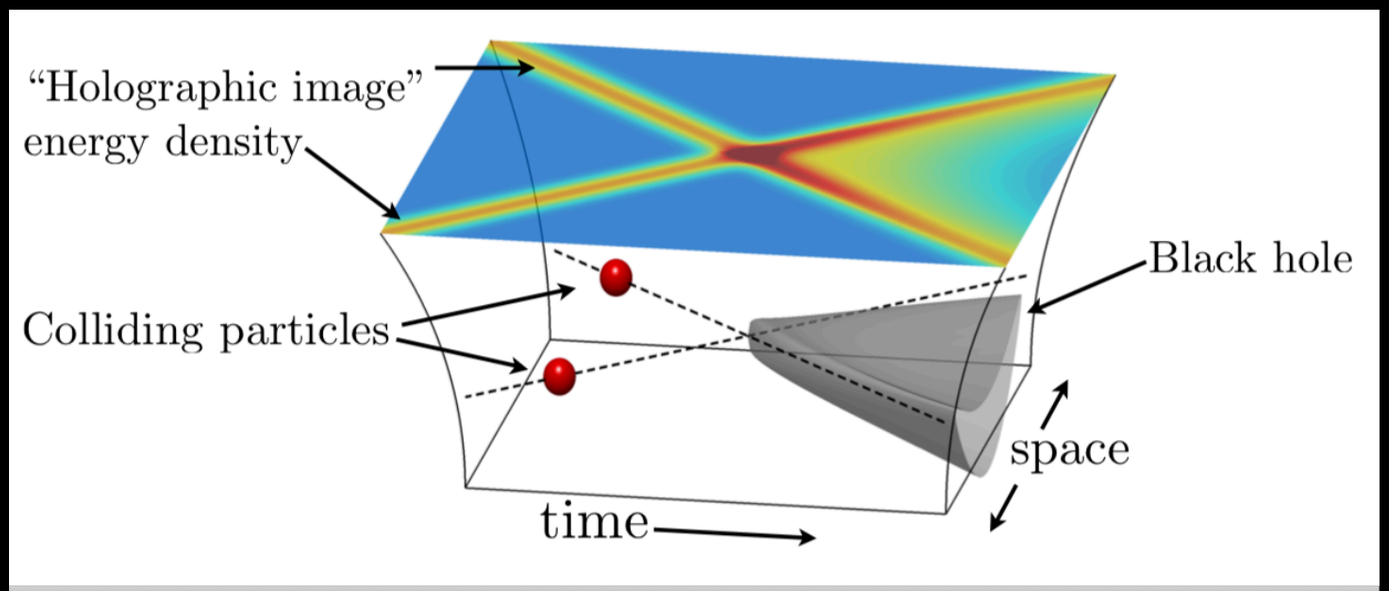




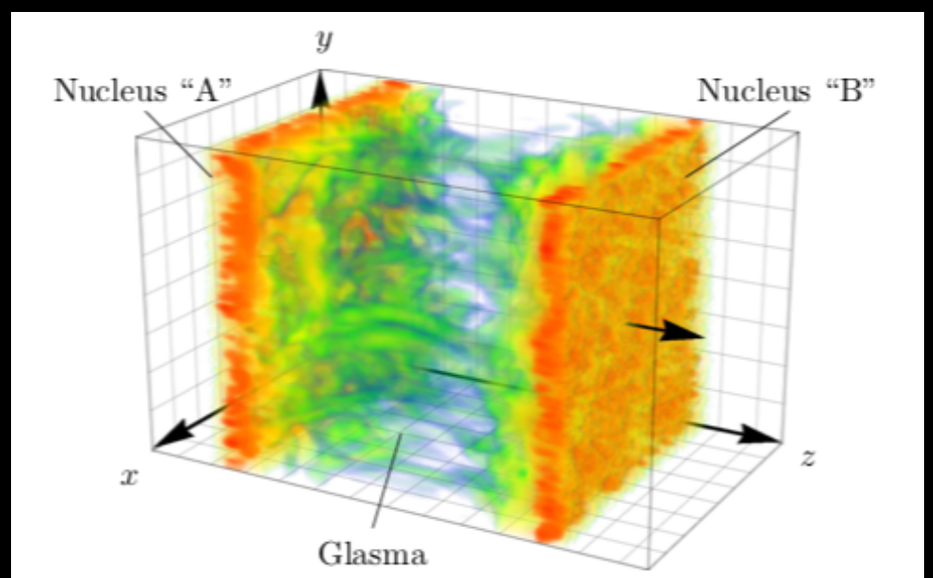


Experimental program in Heavy-Ion collisions important as *motivator* and *testbed* of **qualitatively** new theoretical endeavours:

- Development of relativistic fluid dynamics
- Strongly coupled plasmas — **Medium without quasi-particles, application of string theory,…**
- Far-from-equilibrium plasmas — **Hydrodynamization, anisotropic plasmas, strong gauge fields,…**
- Transport and fluid dynamics with quantum anomalies
- …



Chesler



Ipp, Mueller PLB771 (2017)

Theory efforts in QFT act as a link to the wide-most user community:

- e.g. Chiral magnetic effect in Weyl semimetals

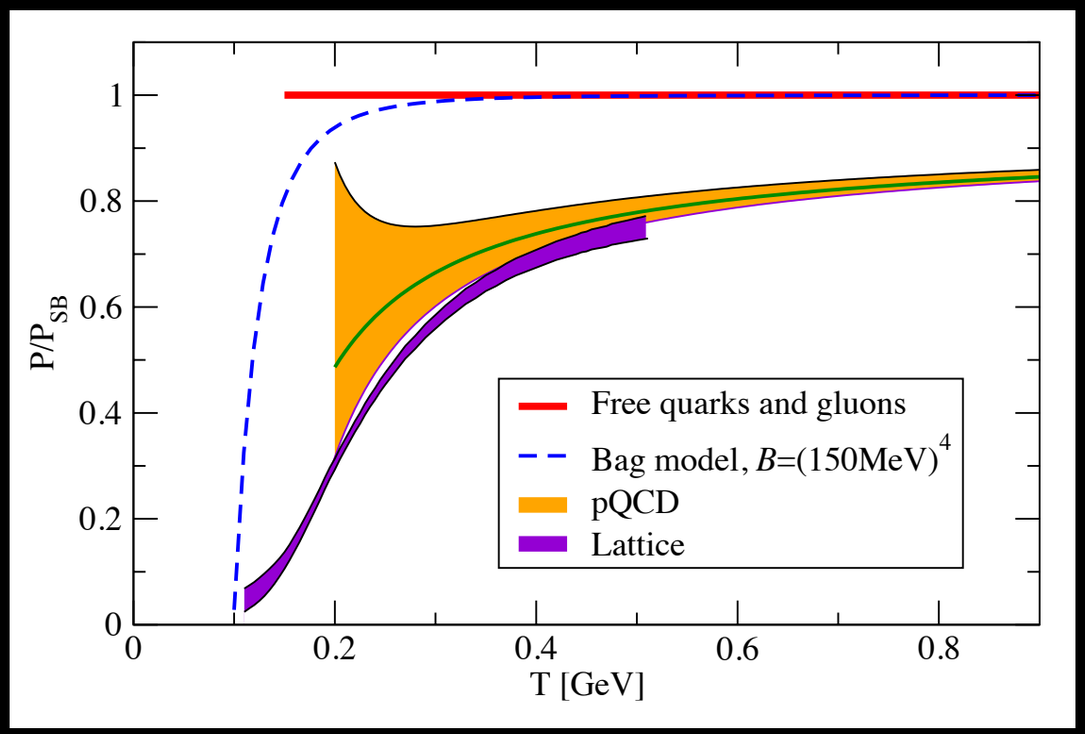
Li et al. Nature Physics 12, (2016)

- e.g. EoS of Neutron stars

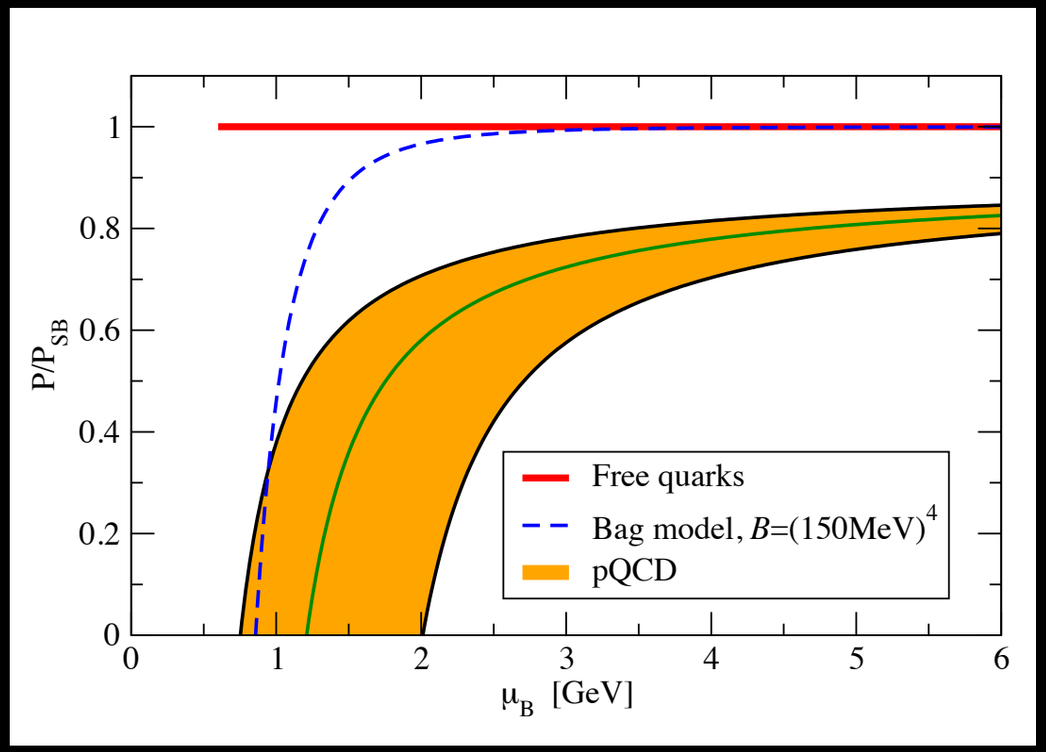
Exploration of EoS driven by HIC, constrains neutron stars

- ….

Hot quark gluon plasma



Cold quark matter



Fraga et al. Astrophys.J. 781 (2014)

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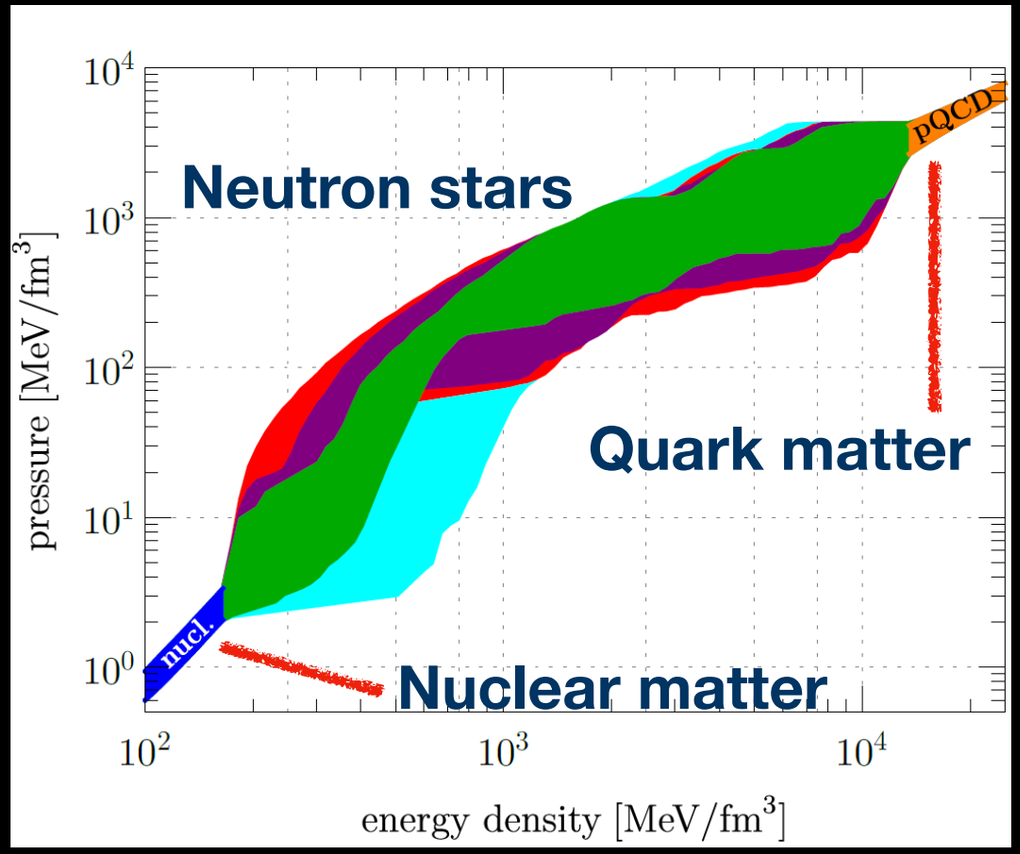
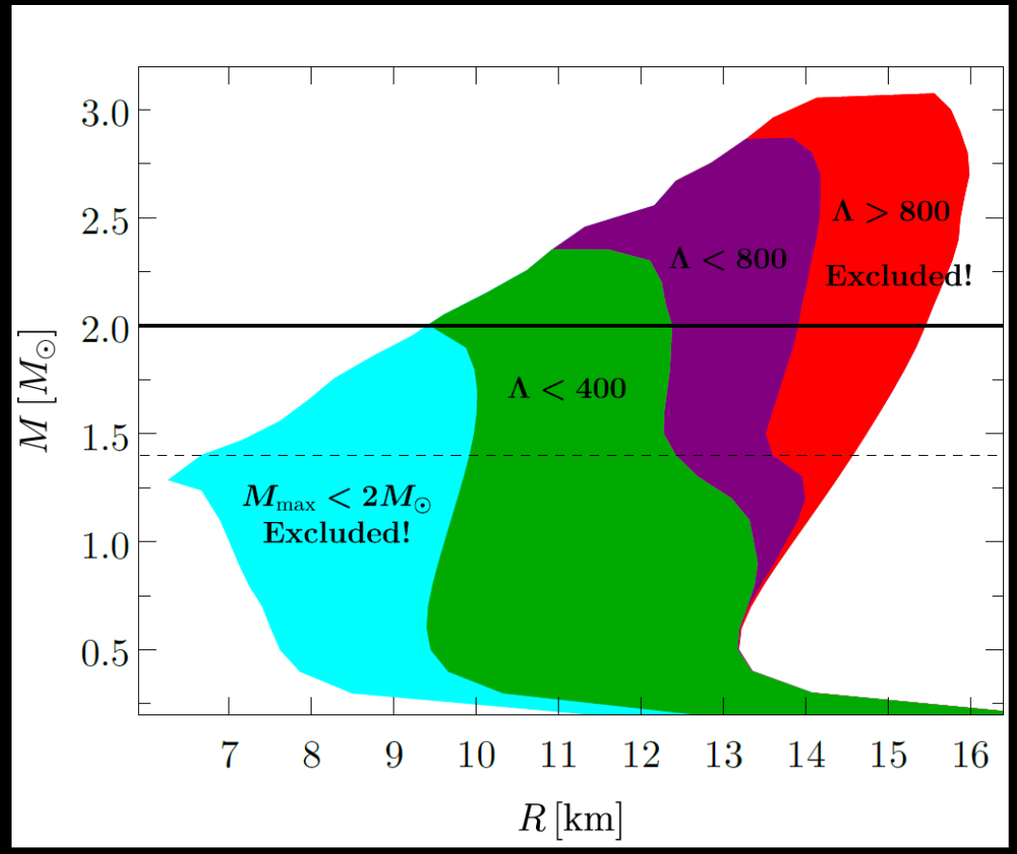
Equation of state



Neutron stars



Annala et al. PRL 120 (2018)

Advances in QFT at large needed meet upcoming phenomenological challenges:

Hydrodynamization and thermalization:

- How to understand hydrodynamization at intermediate coupling?
- What happens to systems that have time to hydrodynamize only incompletely?
- How the physics that lead to hydrodynamization in large systems (AA) presents itself in small systems (pp, pA)?

Escape mechanism

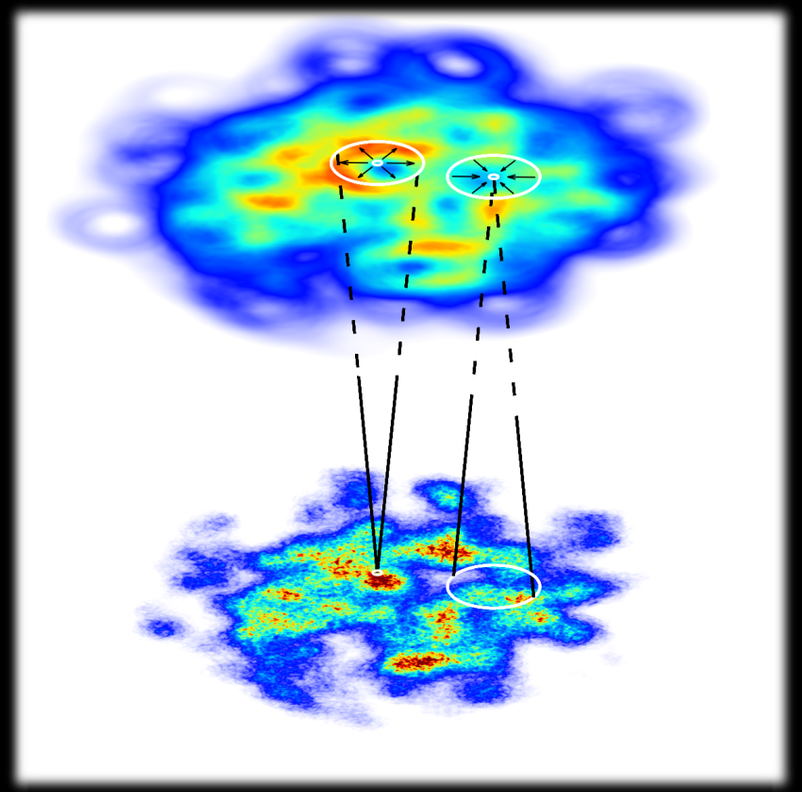
- What is the baseline on top of which these signals are interpreted?

CGC, initial state correlations

Needed:

Unified description of soft particle production in small and large systems

QFT based understanding of kinetic transport and fluid dynamics in setups that are capable of both hydrodynamics and free streaming



KoMPoST 1805.01604

Advances in QFT at large needed meet upcoming phenomenological challenges:

Jet quenching and jet thermalization:

- How does the crossover from vacuum splitting to medium induced splitting happen?
- How does the physics that leads to hydrodynamization also leads to jet quenching and jet thermalization
- How can large-angle (Moliere) scattering be used to study the microscopic structure of QGP?

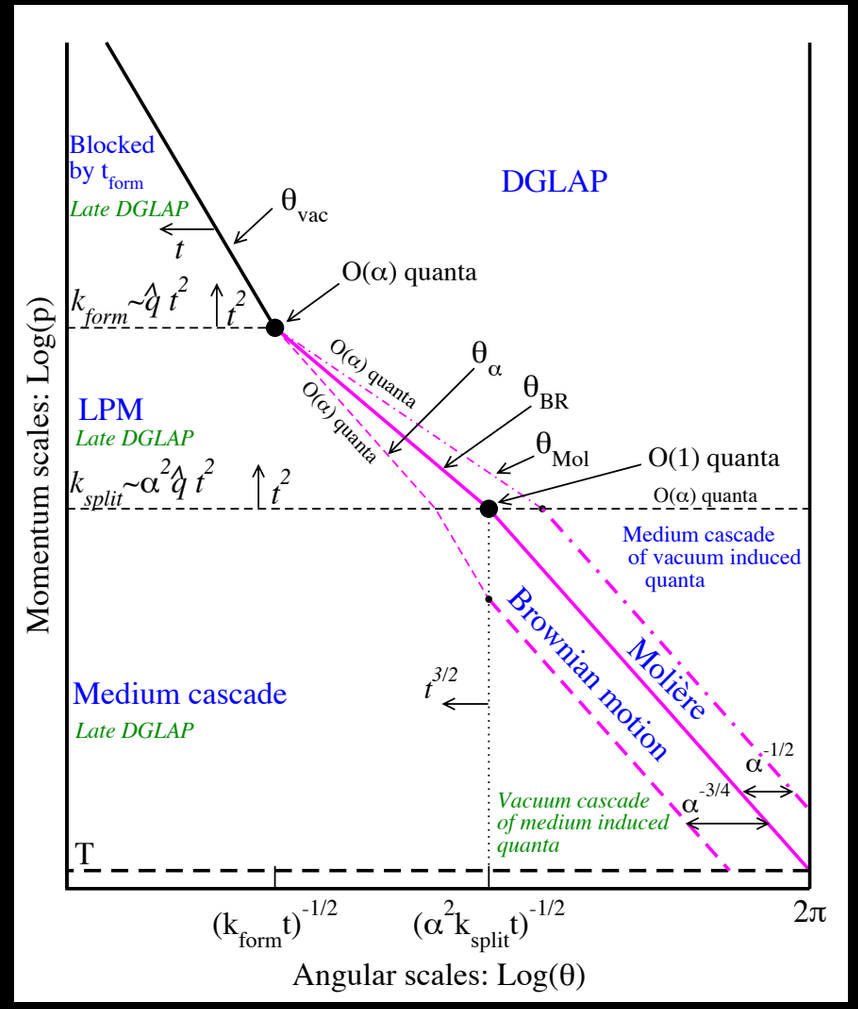
Needed:

Interplay between high-energy QFT, thermal field theory, and modelling

Unified description of jet quenching and soft particle production

see Korinna's talk

PLB740 (2015)



Advances in QFT at large needed meet upcoming phenomenological challenges:

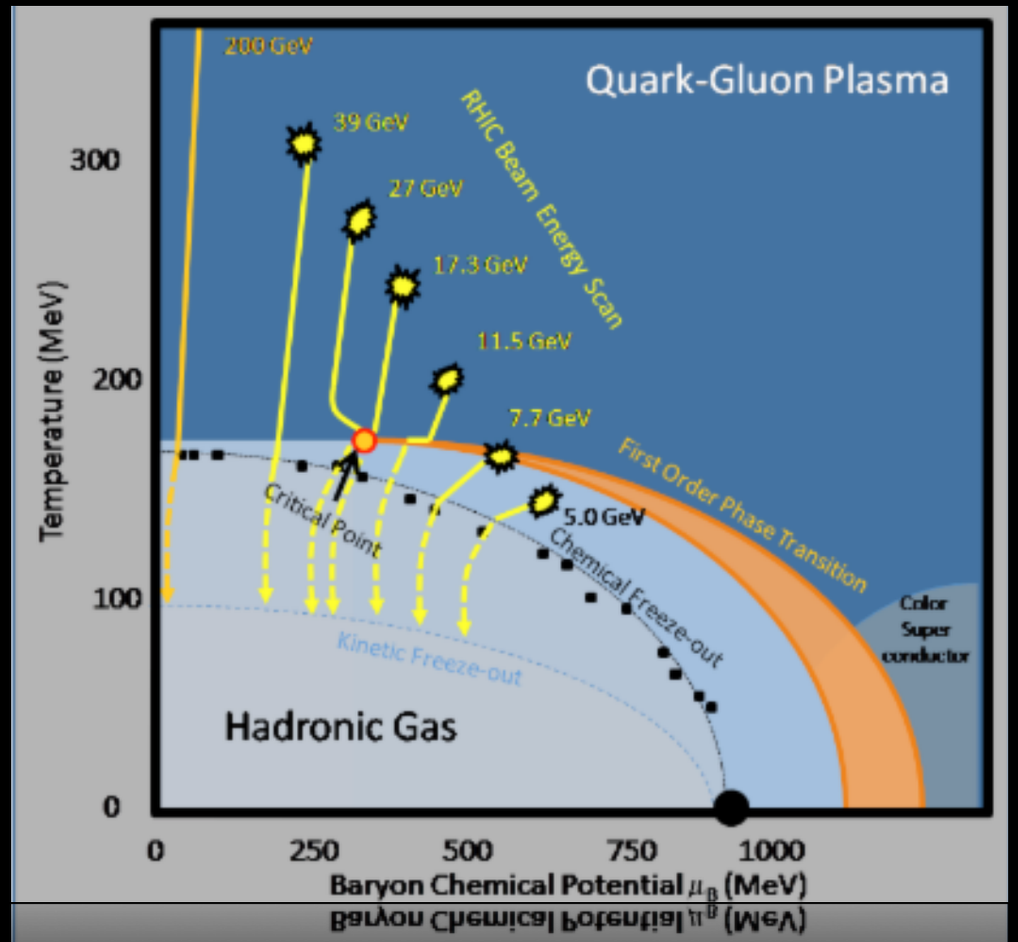
Search for critical point:

- How to empirically determine the existence/non-existence of the QCD critical point?

Needed:

Role of (critical) fluctuations in hydrodynamics

Fundamental developments in QCD at high baryon densities



- Heavy-ion program is conceptually **broad** and **deep**
- Acts as a **testbed** and a **motivator** for qualitatively new advances in QFT
- Theory **links** the Heavy-ion programme to other communities and established lasting results including—but not limited to—phenomenology
- The exceptional intellectual richness and diversity, and strengthening interconnection to neighbouring fields (lattice QCD, high energy physics, astrophysics, string theory, cosmology,…) should be further encouraged and strengthened for the field to strive