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The Way Forward - Closing Remarks at Quark Matter 2017

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Abstract

This contribution is a written version of my closing talk [1] presented at the Quark Matter 2017 [2] conference. Neither the talk nor this contribution to the conference proceedings is intended as a comprehensive summary [1]. Rather, a brief discussion is presented of emerging themes and challenges in the field of relativistic heavy ion physics.

Keywords: QCD phase diagram, quark-gluon plasma, QGP, sQGP

1. Introduction

The Quark Matter 2017 meeting in Chicago was the latest in a long line of this venerable conference series, which has played a central role in defining the field of relativistic heavy ion physics. More than 200 talks were presented, the majority of them by young researchers. More than 400 students and postdoctoral fellows attended the pre-conference Student Day [4]. It is those researchers who will truly define "the way forward." In what follows I will outline some of the opportunities and challenges that await them. Space restrictions, be they the publisher's page limit or the author's cranial capacity, do not allow for a comprehensive review. The reader is encouraged to prepend to any work cited the phrase "as but one example."

2. From Stamp Collecting to Physics

The witty and engaging remarks of U.S. Congressional Representative Raja Krishnamoorthi included Ernest Rutherford's famous statement "All science is either physics or stamp collecting." (While attributed to and characteristic of Rutherford the evidentiary chain is somewhat strained [5].) But before raising our reductionist flag of victory, we should remind ourselves that our own field has its philatelistic aspects. That this is the case is suggested by Figure 1, showing the wide variety of schematic representations of the QCD phase diagram. The variety here is not simply reflective of artistic freedom; it is also indicative of scientific ignorance. The incredible successes of the RHIC and LHC heavy ion programs have been narrowly confined to the region $\mu_B \ll T$ where the baryon chemical potential μ_B is much smaller than the temperature T. In this regime the QCD phase transformation is known to be a smooth cross-over, and quantitative contact

[1]Those seeking such a summary should consult Jürgen Schukraft's masterful overview[3] in the opening talk of the conference.

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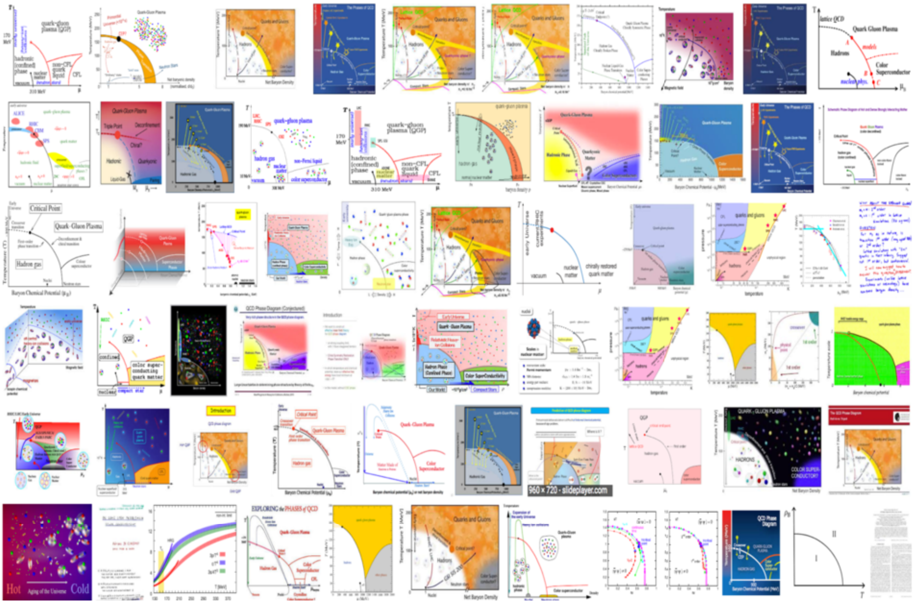

Fig. 1: A selection of representations of the QCD phase diagram in the (μ_B, T) plane.

between experimental observables and the QCD equation of state is being made via lattice QCD (LQCD) calculations and Bayesian methodologies (see Section 3).

It has long been predicted that thermal QCD exhibits a critical end point at finite μ_B/T [6, 7, 8]. Discovery of this feature along with the phenomena expected with a first-order phase transition would greatly expand our knowledge of the QCD phase diagram. In the next decade experimental measurements will be made in the energy range from $\sqrt{s_{NN}} \sim 40$ GeV down to $\sim$2 GeV required to access the region of the phase diagram where $\mu_B \sim T$. The RHIC Beam Energy Scan II program[9] and fixed target measurements at the CERN SPS by NA61/SHINE [10] and at GSI by HADES [11] are underway. There is an associated theory effort that will be essential in interpreting the data and mapping experimental observables to QCD calculations [12]. Both hydrodynamic models and LQCD calculations face challenges in the presence of significant baryon chemical potential, but recent developments on both fronts suggest quantitative precision is within reach. Motivation for this effort is provided not only by the ongoing experimental program but also by the considerable expansion of these investigations that will be enabled by JINR NICA [13], GSI FAIR [14], and JPARC-HI [15]. It should also be noted in this context that the recent addition of LHCb to the LHC heavy ion program opens a new window of investigation, with its superb particle identification capabilities at forward rapidities ($\eta \sim [2, 5]$. While at LHC energies one still expects for these larger rapidities $\mu_B \ll T$, it is nonetheless a new region in the phase diagram for studying hadrochemistry.

3. From Discovery to Precision

More than a decade ago, experimentalists at RHIC issued a call for increased control of correlated errors and systematic uncertainties in theoretical calculations [16]. Five years later, similar remarks were made in my opening talk at Quark Matter 2009 [17]. It is enormously gratifying to see 10+ years of sustained theoretical effort come to fruition in recent publications [18, 19, 20] and at this conference [21]. This is illustrated in Figure 2, taken from Ref. [21], which shows the range and correlations of various model parameters such as the switching temperature between hydrodynamic and transport calculations, the functional forms of the kinematic shear and bulk viscosities, etc., as constrained by (some of) the experimental data