Relativistic Heavy-Ion Physics

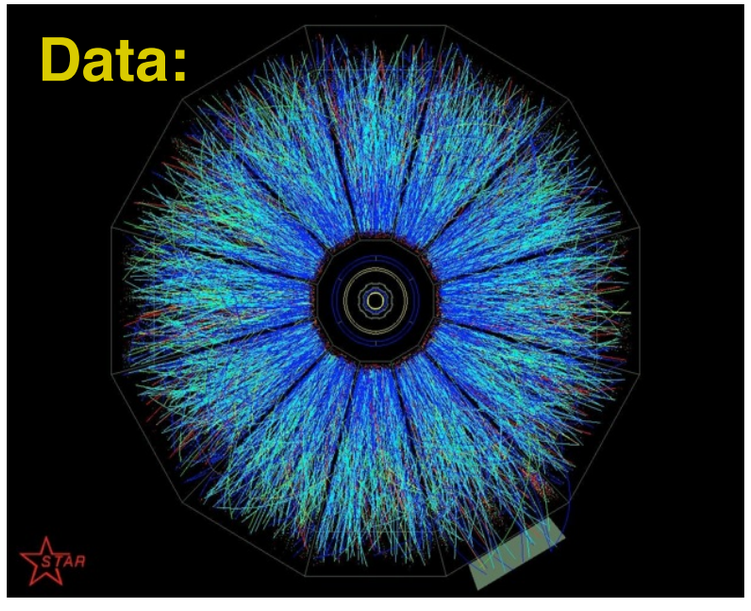
Goals:

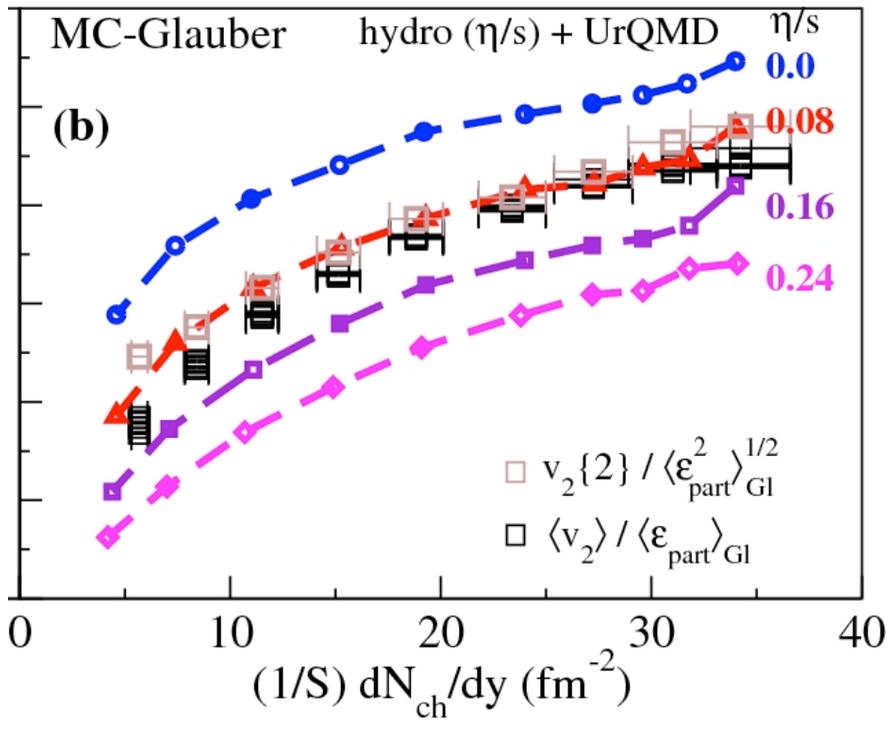
- determine the initial state & non-equilibrium dynamics leading to QGP formation
- characterize the phase structure of QCD matter by quantitative extraction of its medium parameters, such as transport coefficients, Eqn. of State …

Discoveries:

- strongly interacting QGP:
  - near-ideal fluid with η/s near quantum limit
  - suppression of high-pT hadrons
  - constituent quark number scaling of elliptic flow
  - suppression & flow of heavy quarks
  - sequential melting of quarkonia
- suppression of particle production in low-x regime

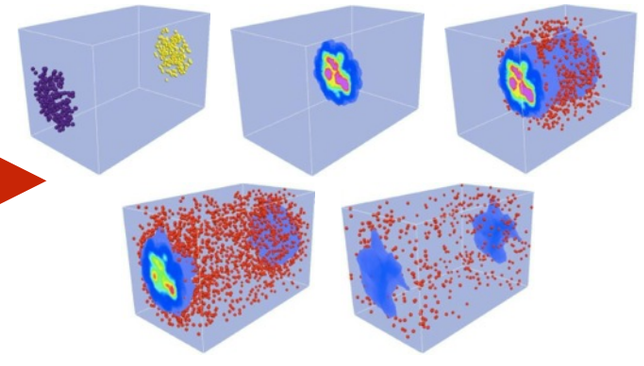
Knowledge extraction via Model-to-Data comparison:





Model:

initial conditions, τ_0, η/s, ζ/s, ….



- essential for success of RHIC program
- requires significant computational resources

extracted QGP properties: η/s, …

Computational Needs: Case Studies

Duke QCD Group:

- 2 senior scientists, 2 postdocs, 3 graduate students
- research focus: modeling of relativistic heavy-ion collisions and knowledge extraction via a comprehensive model to data comparison
- parameter extraction for one model design: 2.5 hours per 2+1D vRFD+micro event, 1000 events per parameter set, 6 parameters varied simultaneously, 10 values per parameter, 10 centrality bins: 1,500,000 cpu hours on the OSG
- science extraction: multiple model designs, approx. 20 million cpu hours per year capacity computing (3+1D vRFD: factor 10 more!)
- data storage: 10+ TB per month; currently cpu is being traded against storage, i.e. data is discarded after initial analysis, to be regenerated later if again required
- required local computational resources: approx. 50 nodes and a 100 TB storage array; annual upkeep/renewal cost about $10K

BNL Nuclear Theory:

- 2 senior scientists, 3 postdocs, 1 graduate student
- research focus: ab-initio calculation of early-time non-equilibrium heavy-ion collision evolution using real-time Lattice field theory techniques
- science extraction: approx. 4.5 million cpu hours per year on massive parallel systems (leadership computing)
- data storage: 10 TB per year
- note that BNL NT also has a model-to-data analysis effort with requirements analogue to Duke Group

multiple other RHIC Theory Groups:

- needs range from desktop computing to resources on the BNL and/or Duke scale
- OSU, MSU, Stonybrook, TAMU, UIC, ISU, Kent State, Wayne State, MIT, ECU, Minnesota, LBNL, NCSU, Columbia, Purdue

Moving Forward…

- computational nuclear theory is essential for the success of the overall RHIC program
- requires significant resources across all scales: leadership, capacity and desktop computing

Recommendations to include in WP:

- continuing support of capacity computing at NERSC and the Open Science Grid by the DOE and NSF with provisions to expand resources with increasing demand
- allow University groups to allocate modest funds ($10K-20K annually) through their regular grants for small scale local computing resources
- development and deployment of distributed and/or highly networked data storage capabilities that interface with the OSG and other distributed computing resources (local/campus grids); this could go hand in hand with an improved tie-in of large scale storage at National HPC resources with grid computing setups