Beam Energy Scan theory talks summary

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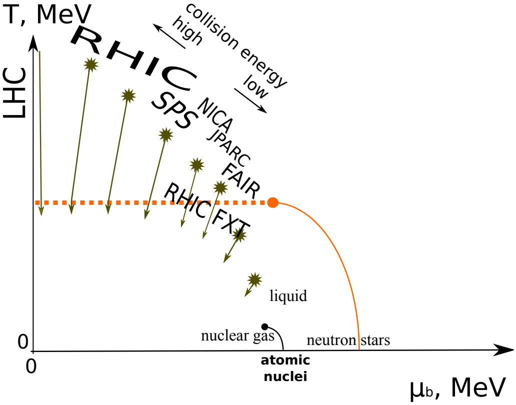
RHIC/AGS Users' Meeting

INSTITUTE for NUCLEAR THEORY

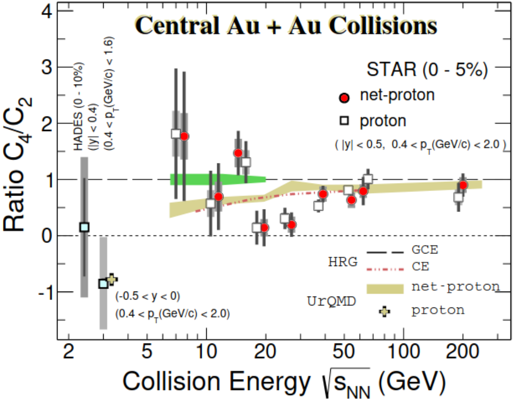
RHIC goals



- Learn properties of quark-gluon plasma
- Probe the Equation of State (EoS) of strongly-interacting matter including search for critical point and phase transition

RHIC results challenging theory I

Proton fluctuations [2112.00240]: only non-critical models available

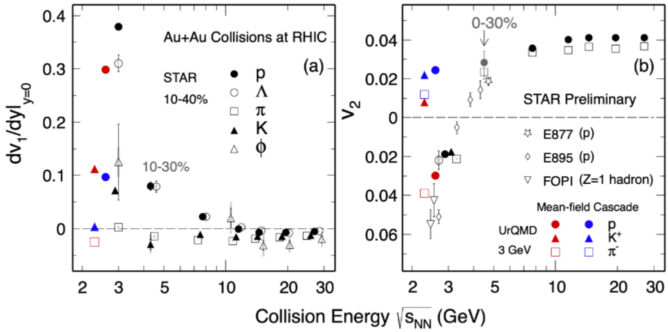


What do we learn from this measurement?

RHIC results challenging theory II

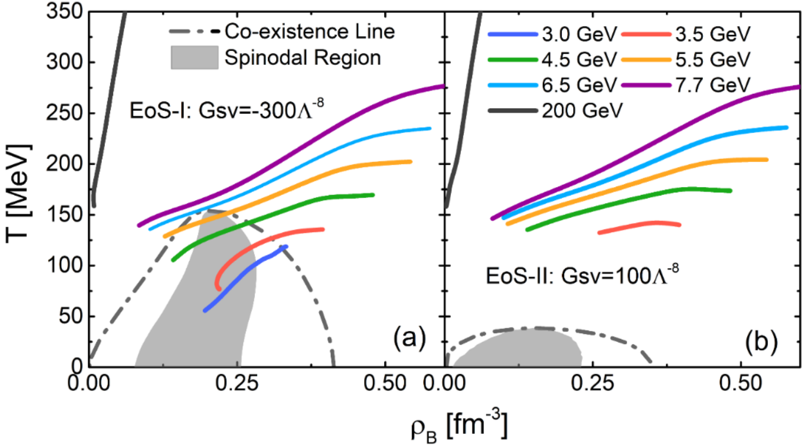
Proton, pion, light nuclei flow [2112.05424, 2112.04055]

- Large sensitivity to EoS [nucl-th/0208016]
- Negative proton dv_1/dy – EoS softening, likely indication of phase transition [nucl-th/0406018,1803.02053]
- Notice: maximum $R^2_{out} - R^2_{side}$ at the same energy range [1411.7931]
- EoS softening at which (T, μ)? Can be far away from chemical freeze-out (T, μ). Need simulations and Bayesian analysis!



RHIC results challenging theory III

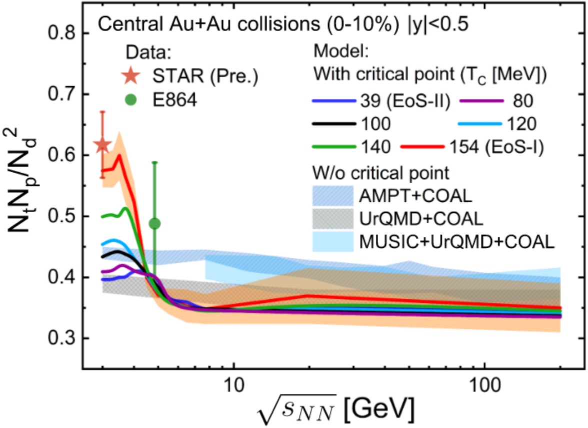
Light nuclei yields, tp/d^2 sensitive to spinodal region [2205.11010]



Is RHIC observing a spinodal region?

RHIC results challenging theory III

Light nuclei yields, tp/d^2 sensitive to spinodal region [2205.11010]



Is RHIC observing a spinodal region?

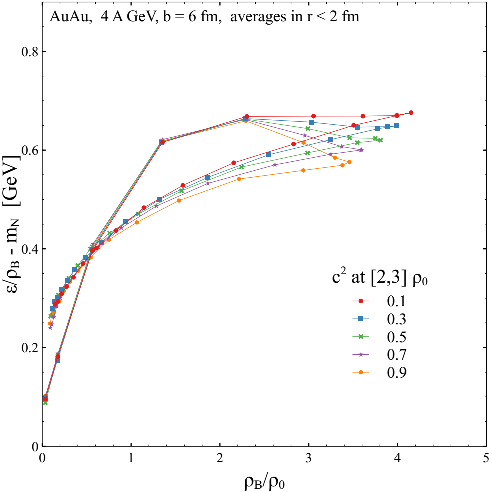
Theoretical approaches, their advantages and challenges

- Hydro+ or fluctuating hydro (+ transport)
  - ✓ Includes critical fluctuations   × only up to 2nd order so far
- Hydro (+ transport)
  - ✓ Easy to build in custom EoS
  - ✓ Easy to adjust viscosity
  - × Handling spectators (important for flow) under development
  - × Handling phase separation under development
  - × Initial state: compression should depend on EoS
  - × Uncertainties at particlization
- Transport
  - ✓ Spectators, initial state compression
  - ✓ No equilibrium assumption
  - ✓ Can handle phase transitions
  - ✓ Can handle critical fluctuations
  - × Harder to build in a custom EoS
  - × Unknown degrees of freedom

Today's theory talks: focusing on fluctuations

- Mayank's talk
  - Development of framework to treat hydro fluctuations
  - Including fluctuation-dissipation theorem
  - Rather small influence of thermal fluctuations on observables
- Maneesha's talk
  - New method: turning hydro fluctuations into particles
  - Tested in hydrodynamics (boost-invariant + radial expansion)
  - Certain sensitivity of proton scaled variance and rapidity correlations to vicinity to the phase trajectory of the fireball and to diffusion parameter
- Jan's talk
  - Does transport stage change fluctuations? Yes – for kurtosis
  - Tests in equilibrated box: fluctuations in a fixed volume
  - Scattering influences cumulants even when potentials are absent
  - Scattering makes inferring baryon cumulants from proton cumulants harder

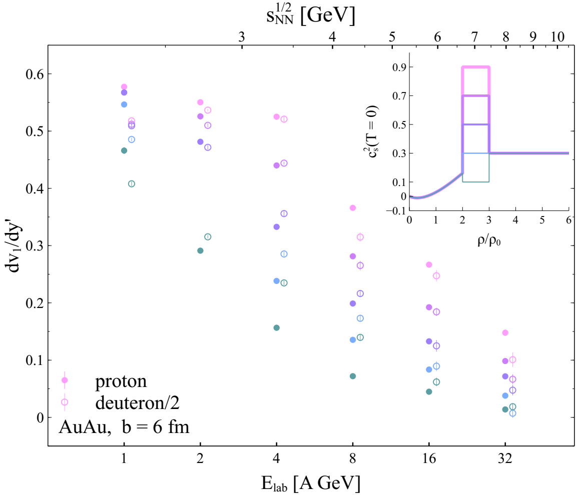
Alternative approach: Transport approach with flexible EoS



Flow is very sensitive to the stiffness of EoS

Working towards Bayesian analysis of flow + HBT + fluctuations

Alternative approach: Transport approach with flexible EoS



Flow is very sensitive to the stiffness of EoS

Working towards Bayesian analysis of flow + HBT + fluctuations

Summary of summary

- Hydro + afterburner approaches making progress towards realistic calculation of fluctuations
  - ✓ Account for fluctuation-dissipation theorem [Mayank]
  - ✓ Particlization of fluctuations [Maneesha]
  - ✓ Testing afterburner effects [Jan]
- Pure transport approaches need more attention
  - Already results for light nuclei are encouraging: maybe we evidence spinodal region at RHIC
  - Bayesian analysis of flow using transport with tunable equation of state would be helpful – work in progress