



Future Plans for Workflows

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Outline

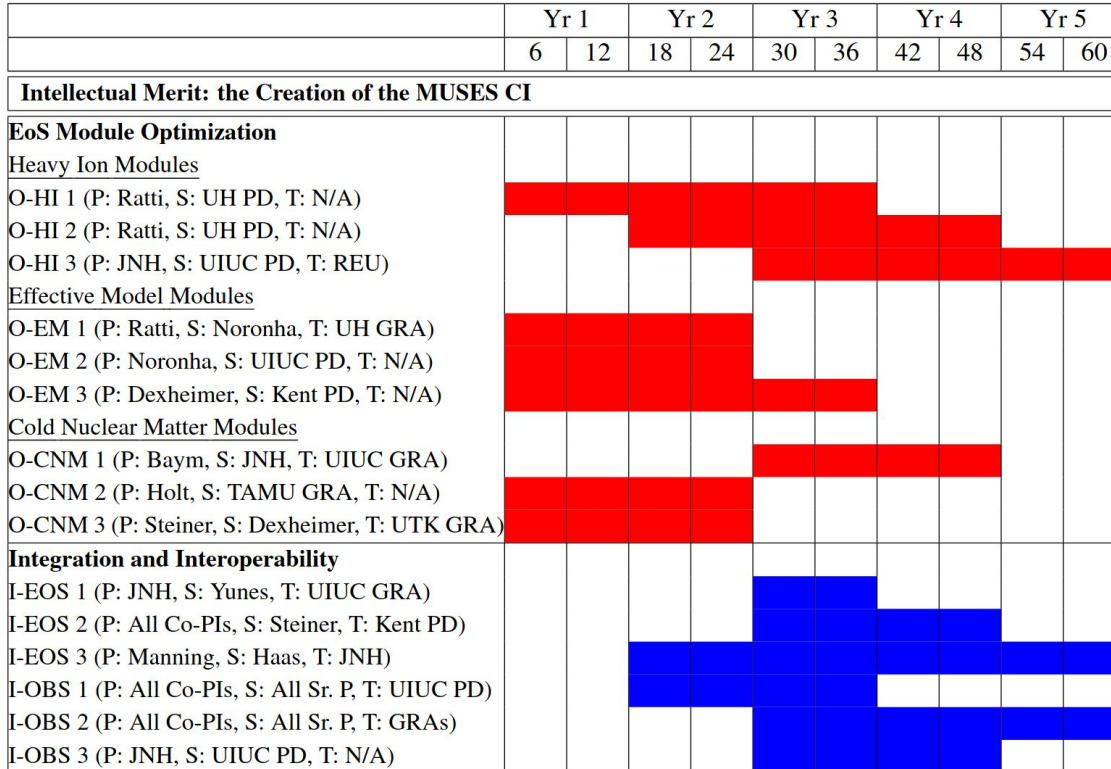
What we have (or are finishing):

- Zero temperature
- Finite temperature
- Standard outputs (+ CompOSE, QLIMR, flavor equil)

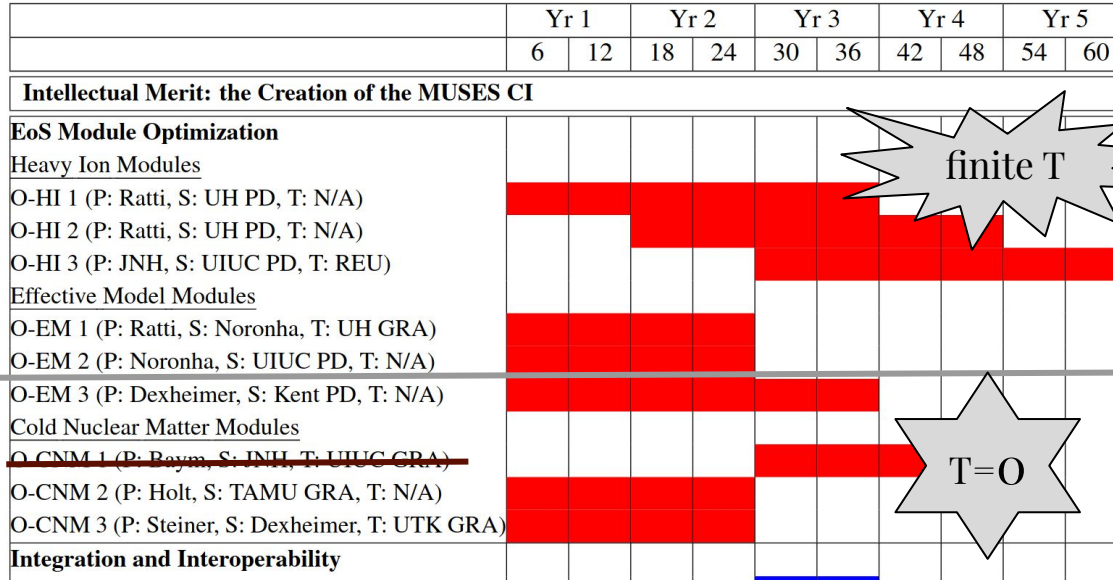
What we will do next:

- Extend EoS's to different domains
- Work on non-EoS modules
- Connect EoS's in different ways
- Combine different EoS and modules
- Develop more observable modules

Gantt Chart

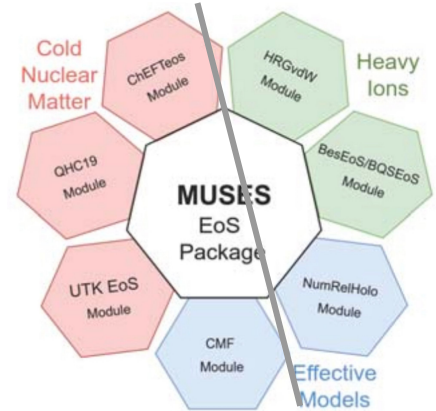


Gantt Chart



finite T

T=O



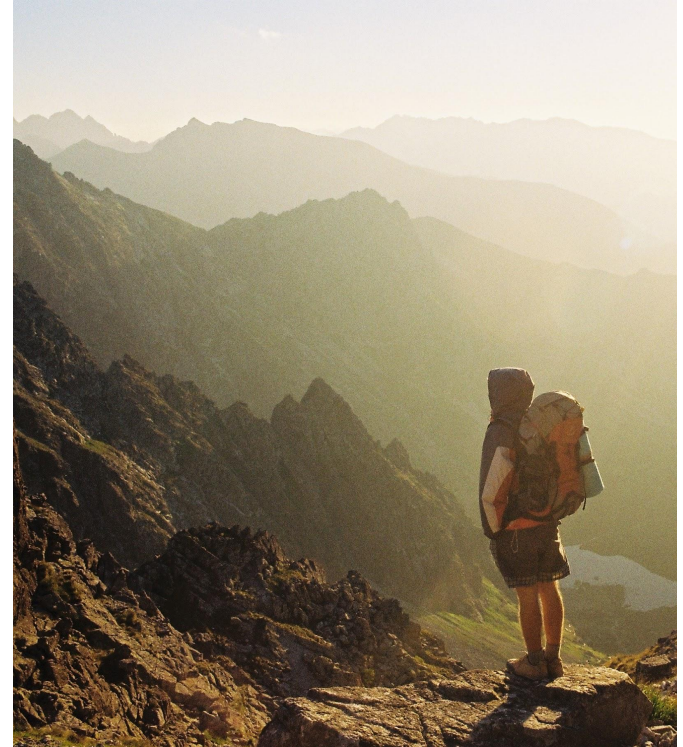
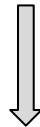
- I-EOS 1.** Smooth transitions (i.e. continuous derivatives) when connecting modules in the same phase.
- I-EOS 2.** Phase Matching modules at first-order phase transition coexisting lines or regions through different approaches, including interpolations and physical mixtures of phases.
- I-EOS 3.** Development of an integrated and interoperable EoS Package.

Gantt Chart

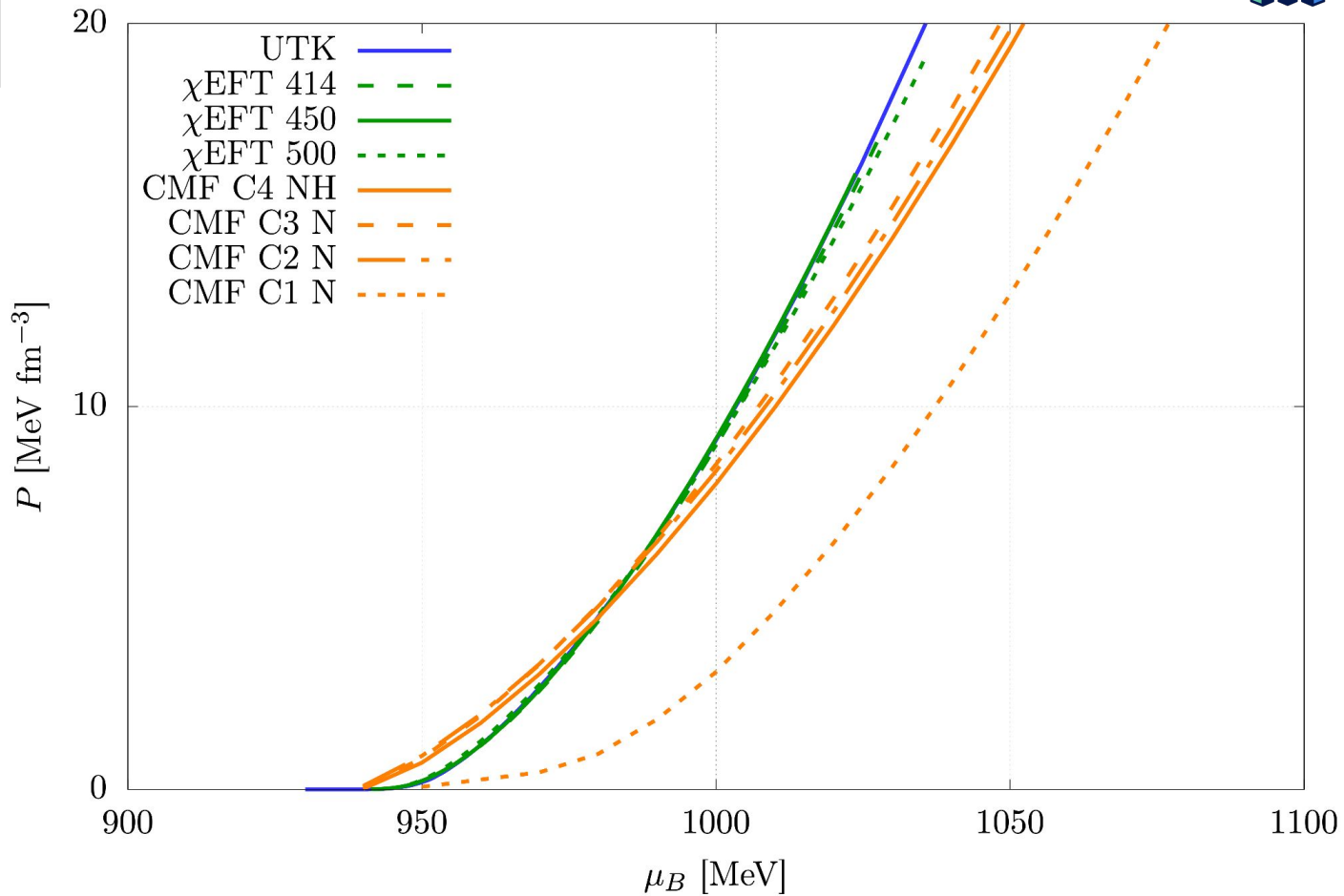
	Yr 1		Yr 2		Yr 3		Yr 4		Yr 5		
	6	12	18	24	30	36	42	48	54	60	
Intellectual Merit: the Creation of the MUSES CI											
Web-based Tools and Services.											
D-1 (P: Carrasco Kind, S: Manning, T: N/A)	█										
API Server and Job Management System.											
D-2 (P: Carrasco Kind, S: Manning, T: N/A)			█								
Deployment Framework.											
D-3 (P: Carrasco Kind, S: Manning, T: N/A)					█						
Broader Impacts: Community integration, education, outreach											
Release (P: Carrasco Kind, S: Manning, T: Yunes)						Annual Continuous					
User Support (P: Manning, S: JNH T: Yunes)											
Tutorials (P: JNH, S: Manning, T: UIUC REU)						Continuous					
Workshops (P: Yunes, S: Ratti, T: All Co-PIs)		WS1		WS2		WS3		WS4		WS5	
Publications and Presentations (All personnel)				Continuous							

What we have: zero T

- 2D UTK, χ EFT, CMF
(μ_B and μ_Q - for CMF also μ_S)
- Fully integrated into lepton module
(beta equilibrium and charge neutrality)
- Connected through synthesis module
(using hyperbolic tan - not yet producing microscopic properties)
- Going through QLIMR
- Only individual EoS go into flavor equilibration module
- CompOSE for CMF only



EoS's



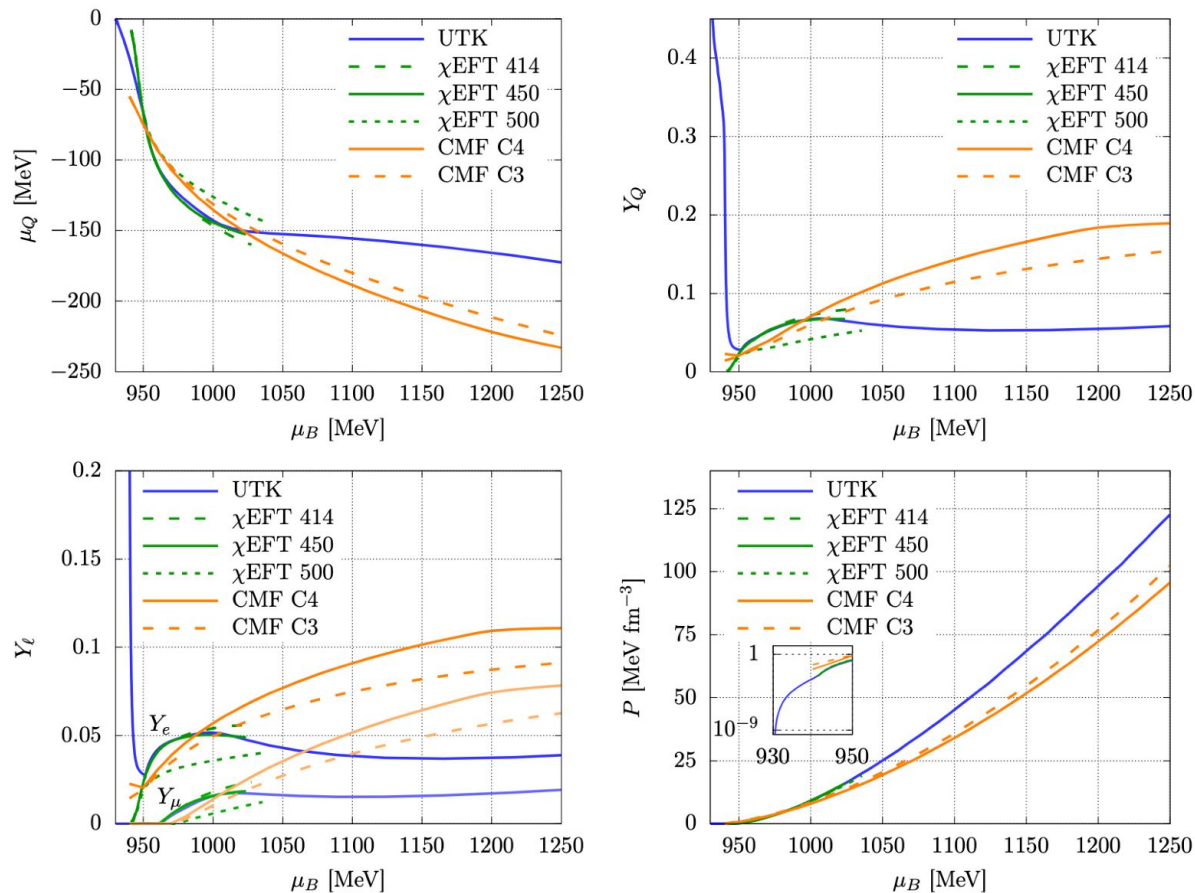
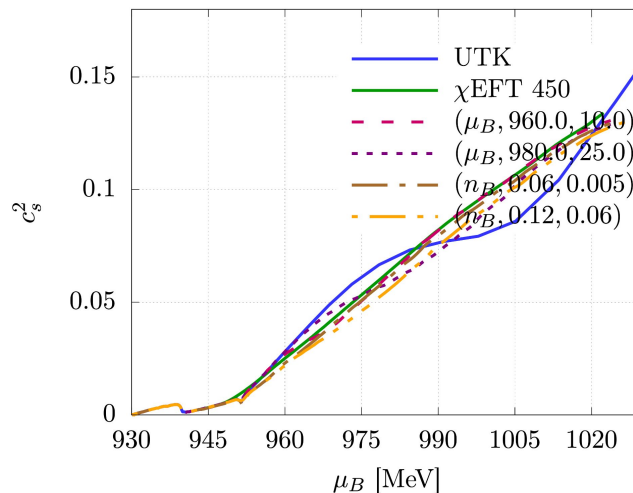
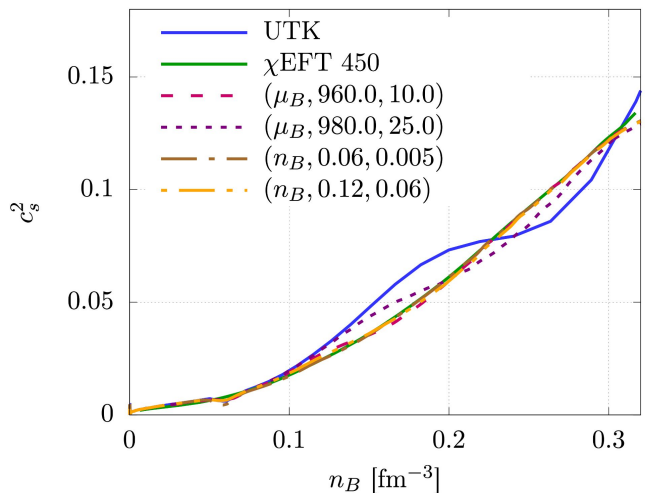
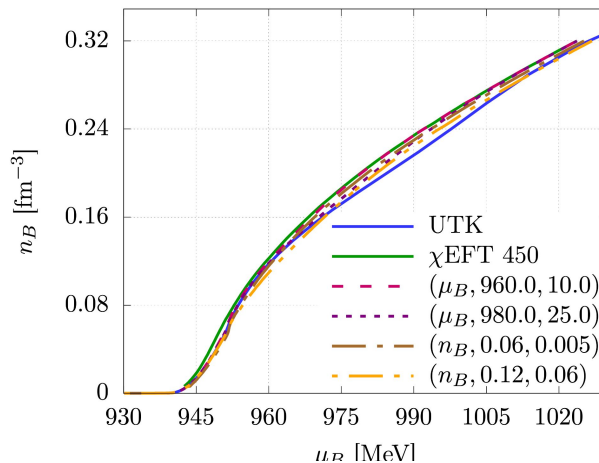
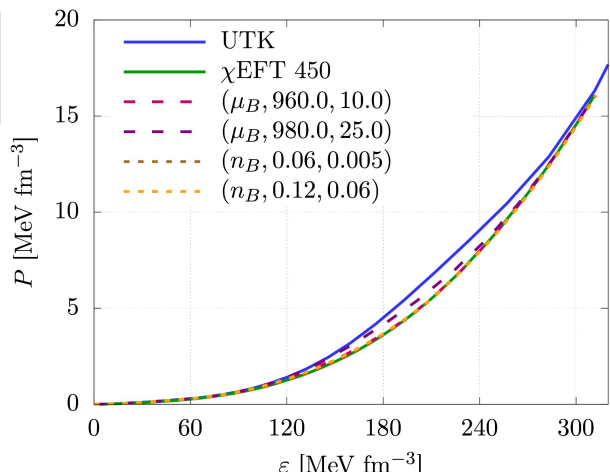
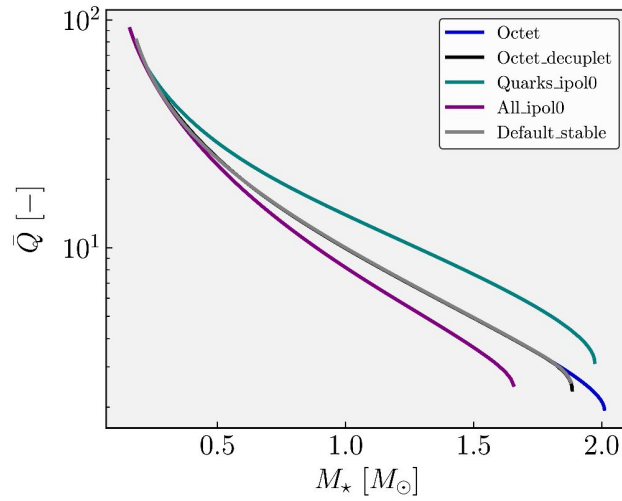
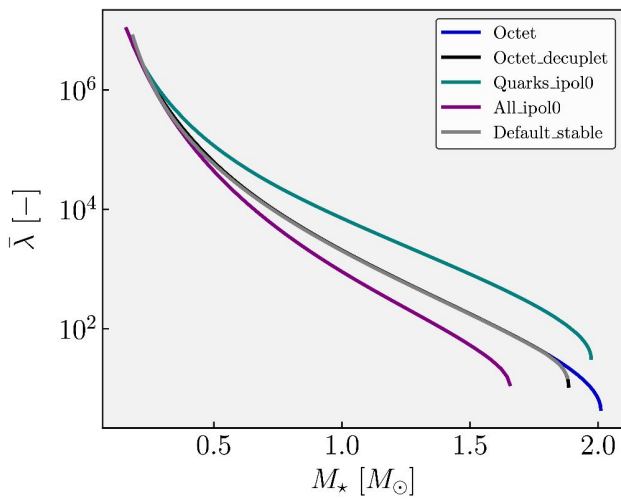
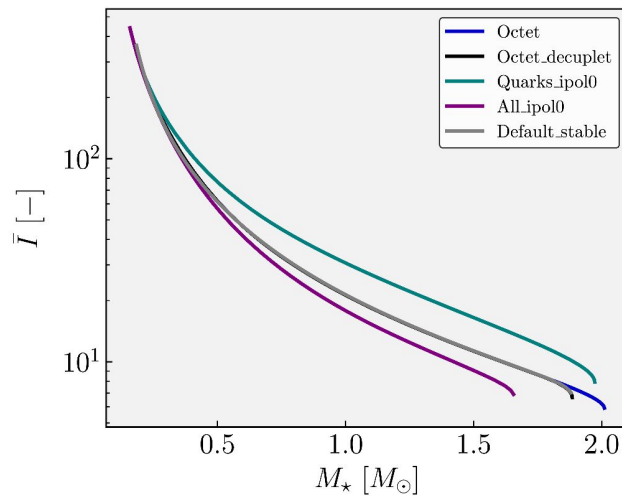
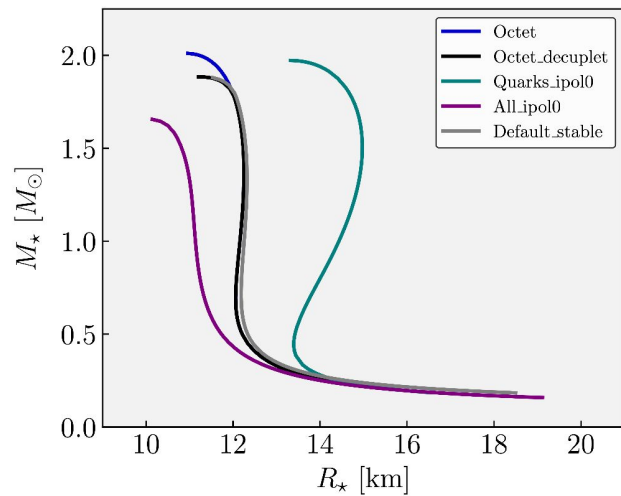


FIG. 1. Results from the Lepton module for different EoS's: charge-neutral β -equilibrium charge chemical potential, (hadronic and quark) charge fraction, electron fraction, and muon fraction, all as a function of baryon chemical potential.

Synthesis module





Flavor
Equilibration
module

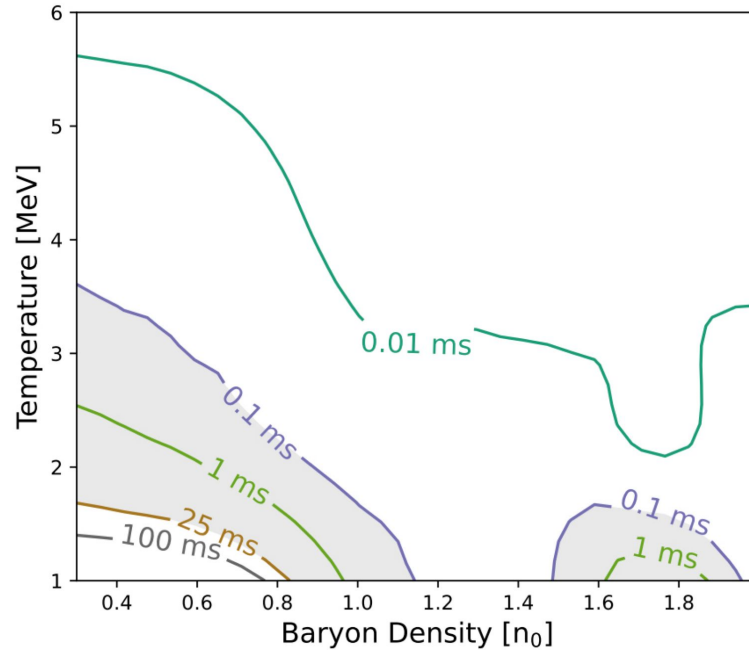


FIG. 2. Flavor relaxation time $1/\gamma$ in the density-temperature plane for the χ EFT 450 EoS. The gray shaded region indicates the density/temperature range where the flavor relaxation time scale is comparable to the ~ 1 ms period of the density oscillations expected in neutron stars and their mergers.

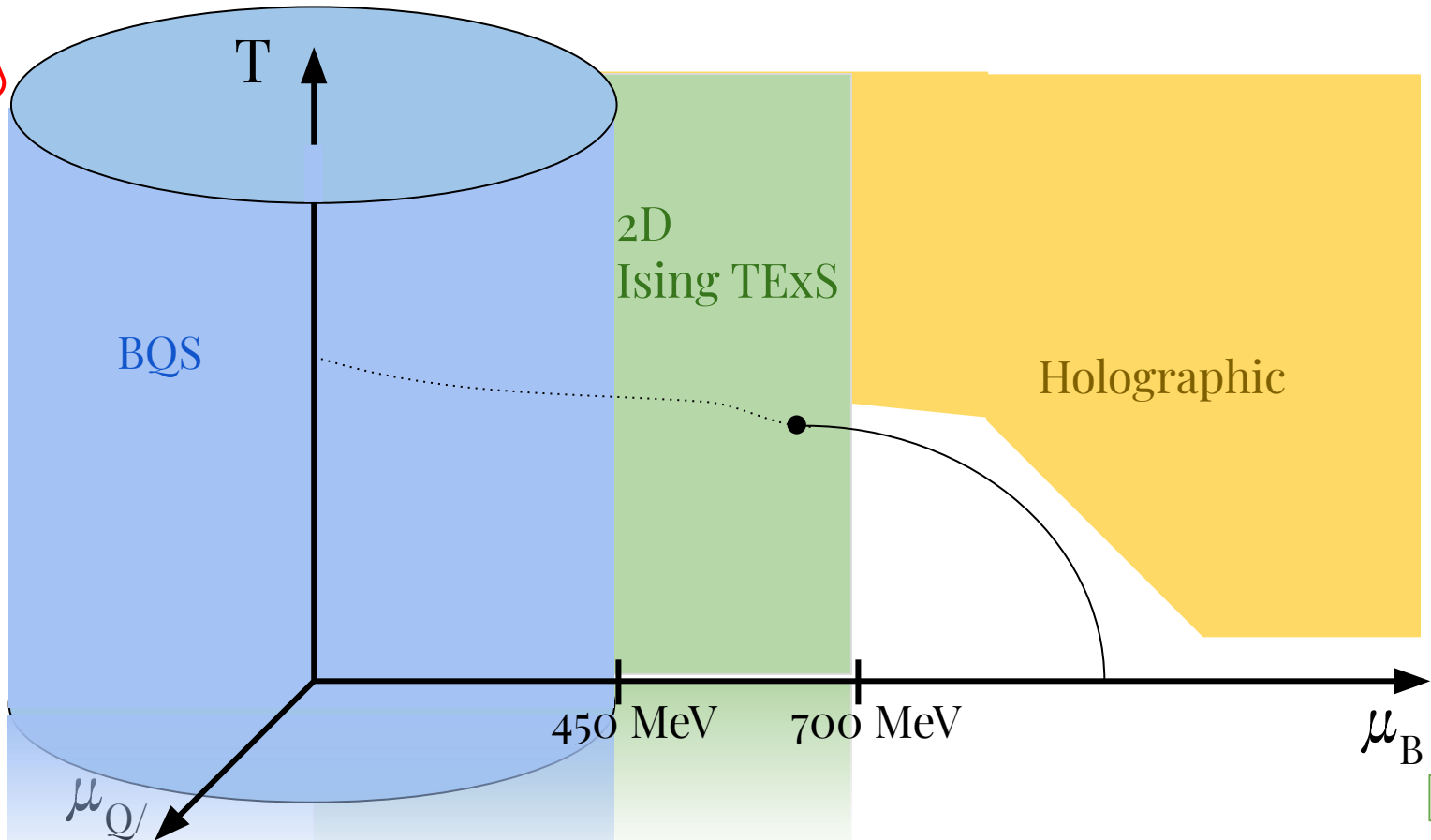
What we have: finite T

- 2D EoS: Ising-TEoS and Holographic
(including 1st order PT and CP)
- 4D EoS: BQS *(including crossover)*
- No connection yet
but HRG embedded by construction
in BQS and Ising-TEoS

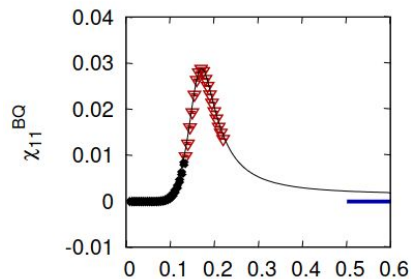
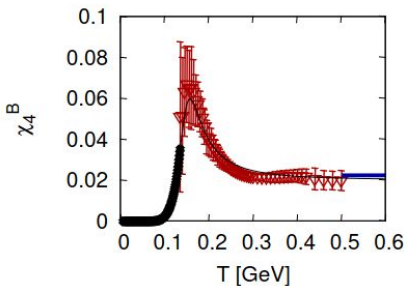
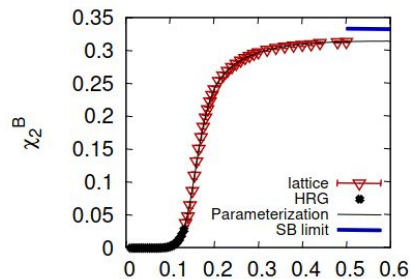


EoS's

alpha-release

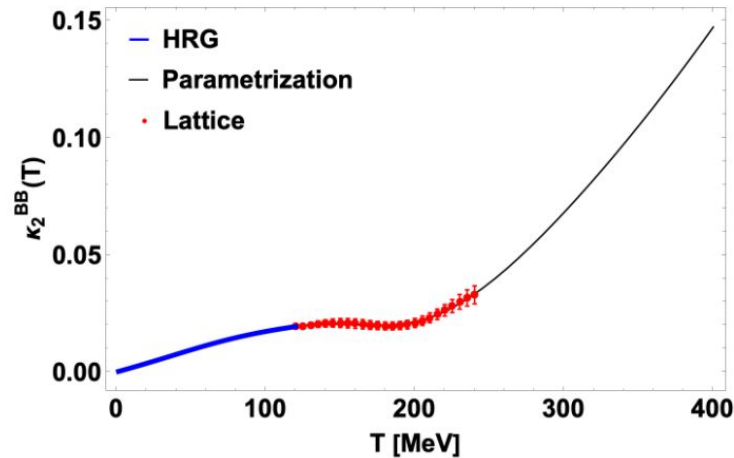


BQS module



$$\frac{p(T, \mu_B, \mu_Q, \mu_S)}{T^4} = \sum_{i,j,k} \frac{1}{i!j!k!} \chi_{ijk}^{BQS} \left(\frac{\mu_B}{T}\right)^i \left(\frac{\mu_Q}{T}\right)^j \left(\frac{\mu_S}{T}\right)^k$$

Ising-TEoS module



$$T'(T, \mu_B) = T \left[1 + \kappa_2^{BB}(T) \left(\frac{\mu_B}{T}\right)^2 + \dots \right]$$

$$T \frac{\chi_1^B(T, \mu_B)}{\mu_B} = \chi_2^B(T', 0)$$

Future Papers so far using MUSES workflows

- Study of phase stability within 3-D CMF: μ_B , μ_Q , and μ_S (*finishing*)
- Connecting UTK, χ EFT, and CMF with lepton, synthesis and QLIMR (*finishing*)
- Connecting QLIMR with modified Gaussian Processes (*in progress*)
- BQS EOS ran in CCAKE (*paper out tomorrow*)
- PDG21+ list used to calculate shear viscosity for heavy-ion collisions (*finishing*)
- Bayesian analysis in holography at finite strangeness or electric charge (*in progress*)
- Bayesian holography with 1st order line matched with HRG (*over summer*)

What do we do next? Extend EoS's to different domains

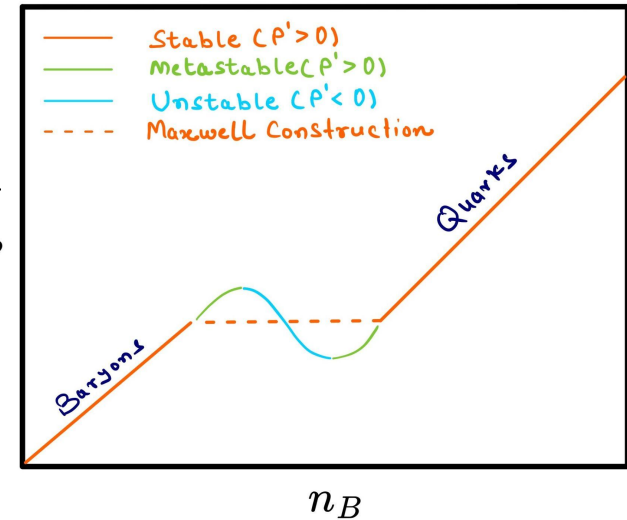
- New nuclear properties module
- CMF written at finite T and B
- UTK explored in T
- UTK including strangeness and finite μ_s
- χ EFT including different potentials (T)
- Extend Holographic to μ_Q and μ_s (*+mixed angles..*)
- TExS (lattice-based reaching 700 MeV) :
 - Extend 2D-TExS \Rightarrow 4D-TExS
 - Include critical line/surface in 4D-TExS..?
- Add HRG module (*whole hadronic phase region*)
- Test large YQ's for supernovae

What do we do next? Develop more observable modules

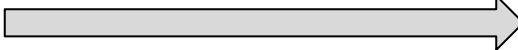
- Partial pressures: breaking down pressure contributions from each combination of (B,Q,S) values
(coupling to BQS module)
- Freeze-out physics from FIST: extract values of (T, μ_i) from particle yields
(single-module workflow)
- NEWS** Transport coefficients: extracting transport coefficients from any given EoS using a microscopic approach (*e.g.* DQPM) by matching thermo
(coupling to any EoS module \Rightarrow proof of concept with Holographic)

What do we do next? Work on non- EoS's modules

- Produce microscopic properties from hyperbolic tan in synthesis module
- Use QLMR to study metastable phases (*not going to unstable: for deconfinement in CMF it is just the whole hadronic branch*)
- CompOSE output for combined EoS
- Upload files for input
- New derivative module (*also calculating stability and causality*)
- Functional forms: Gaussian processes, spectrals EoS, polytropes



What do we do next? Connect EoS's in different ways

- Pasta phases 
- Mixed phases
- First order PT's?
- We will not worry about gaps

