Temperature and Strong Magnetic Field Effects in Dense Matter

Accepted in Phys. Rev. D, e-Print: 2304.02454

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MUSES collaboration

Center for Nuclear Research

KENT STATE UNIVERSITY

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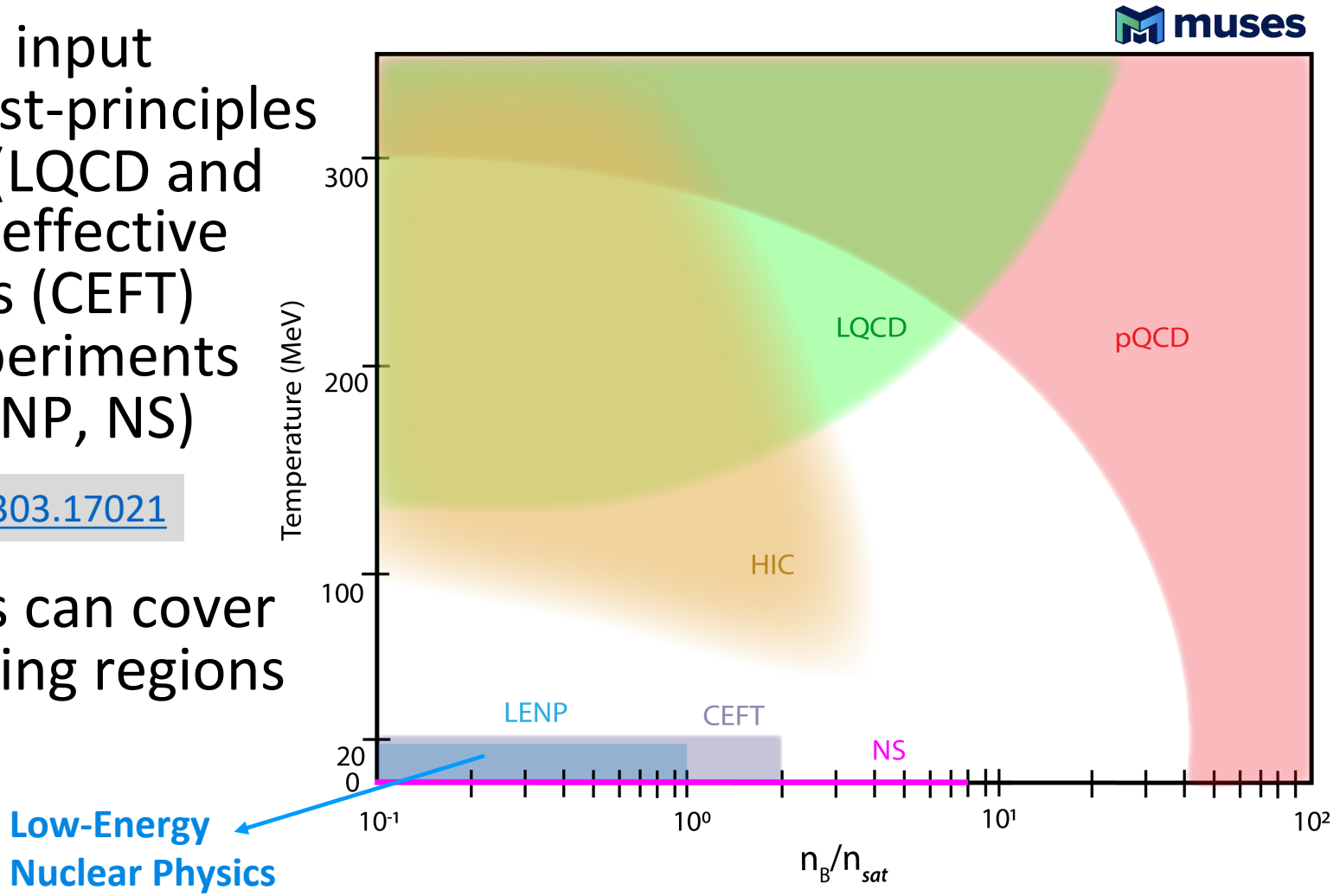
QCD Phase Diagram

- Current input from first-principles theory (LQCD and pQCD), effective theories (CEFT) and experiments (HIC, LENP, NS)

e-Print: 2303.17021

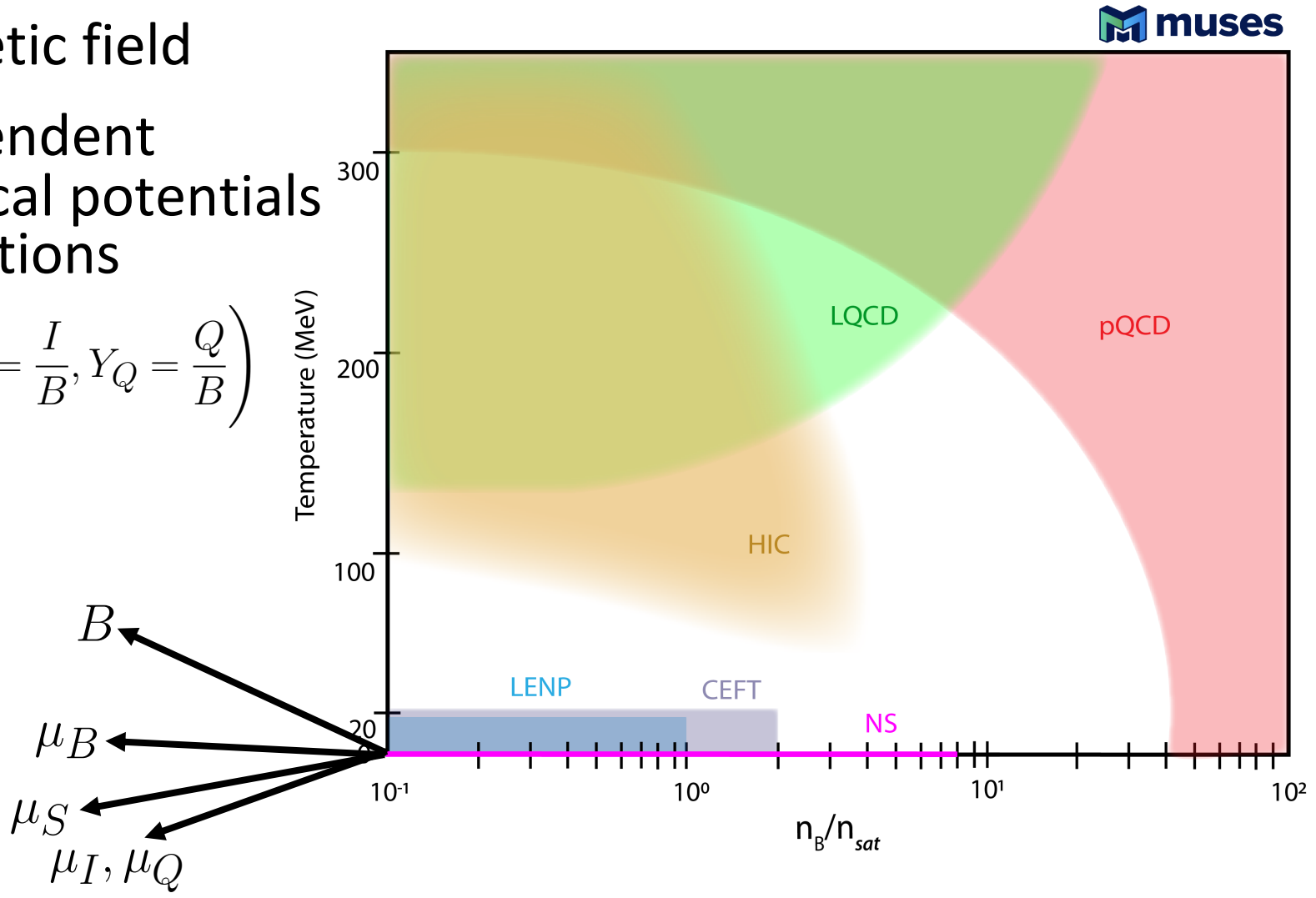
- Models can cover remaining regions



What about Other Dimensions?

- Magnetic field
- Independent chemical potentials or fractions

$$\left(Y_S = \frac{S}{B}, Y_I = \frac{I}{B}, Y_Q = \frac{Q}{B}\right)$$



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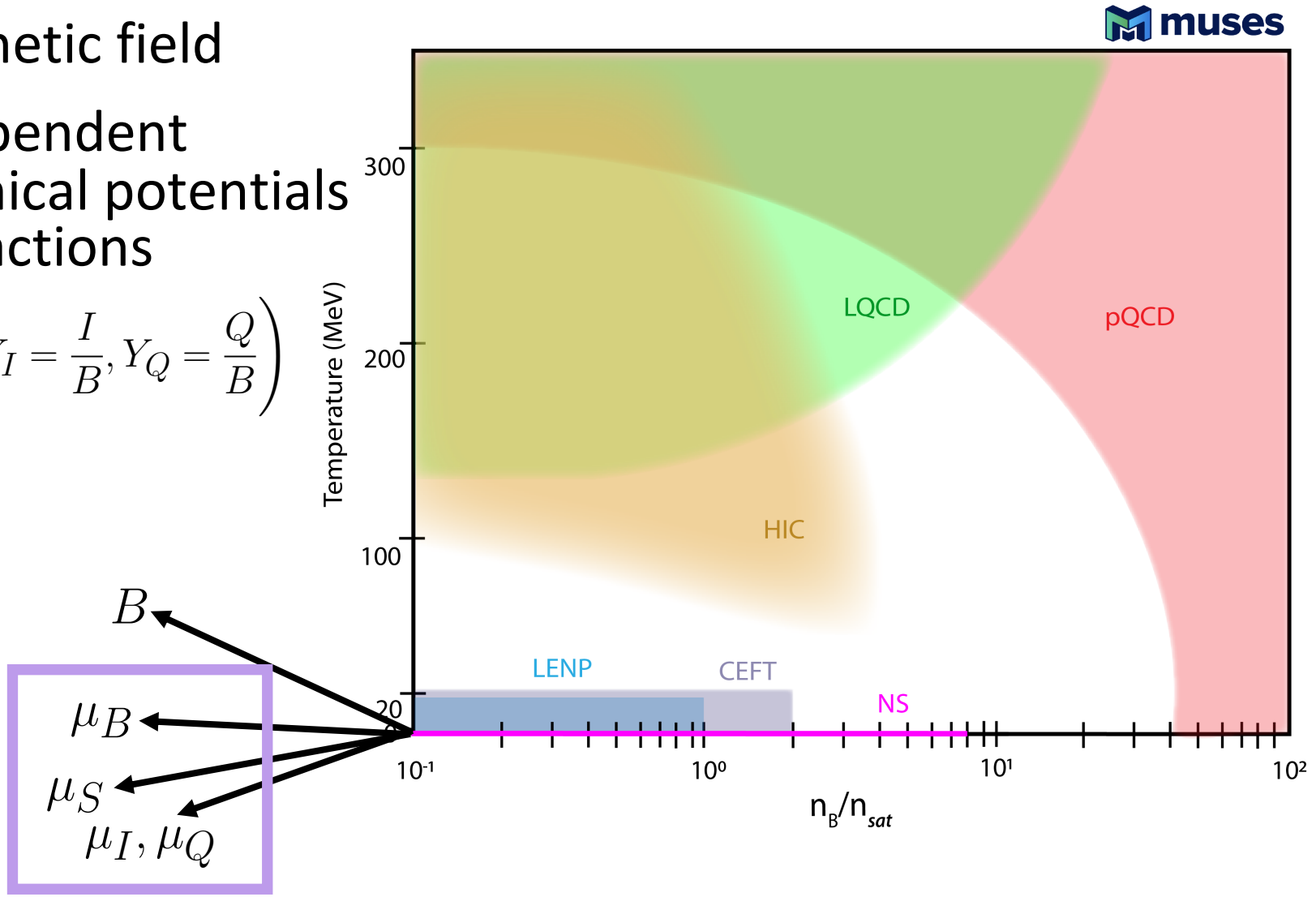
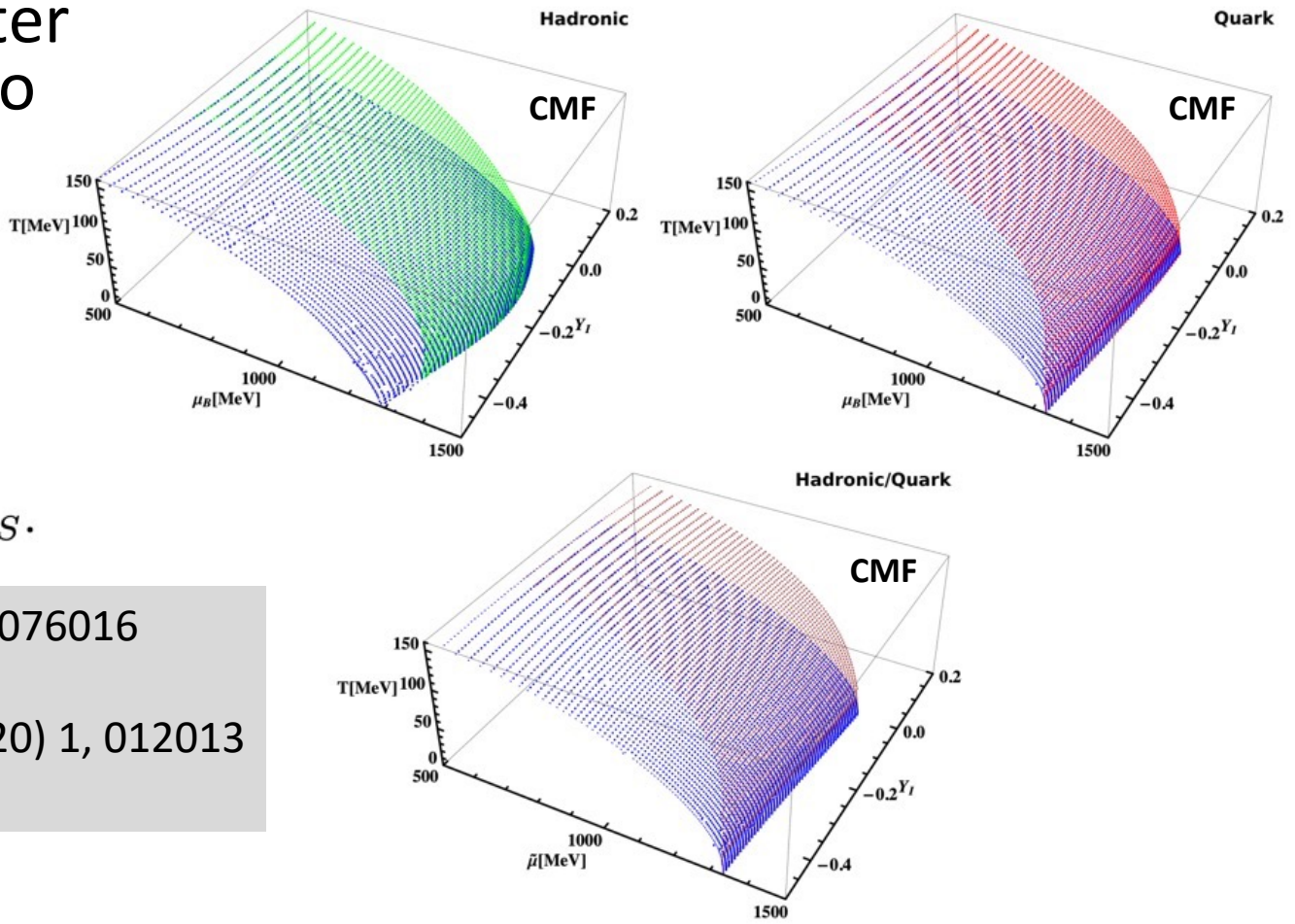


Isospin and Strangeness

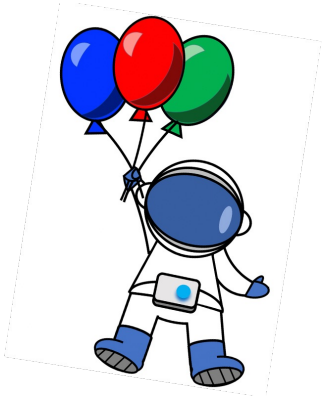
- Deconfinement to quark matter depends on strangeness fraction Y_S and isospin fraction Y_I (or charge fraction Y_Q)
- For strange matter ($Y_S \neq 0$) there is no simple relation between fractions

$$Y_Q = Y_I + \frac{1}{2} - \frac{1}{2} Y_S,$$

$$\tilde{\mu} = \mu_B + Y_Q \mu_Q + Y_S \mu_S.$$



Phys.Rev.D 102 (2020) 7, 076016
e-Print: 2004.03039 and
J.Phys.Conf.Ser. 1602 (2020) 1, 012013
e-Print: 2010.00996



Higher Order Phase Transitions in Neutron Stars

Alexander Clevinger

Kent, Ohio, USA

Quark Matter 2023

Clevinger Quark Matter 2023

Talk by Alexander Clevinger in Astophysics

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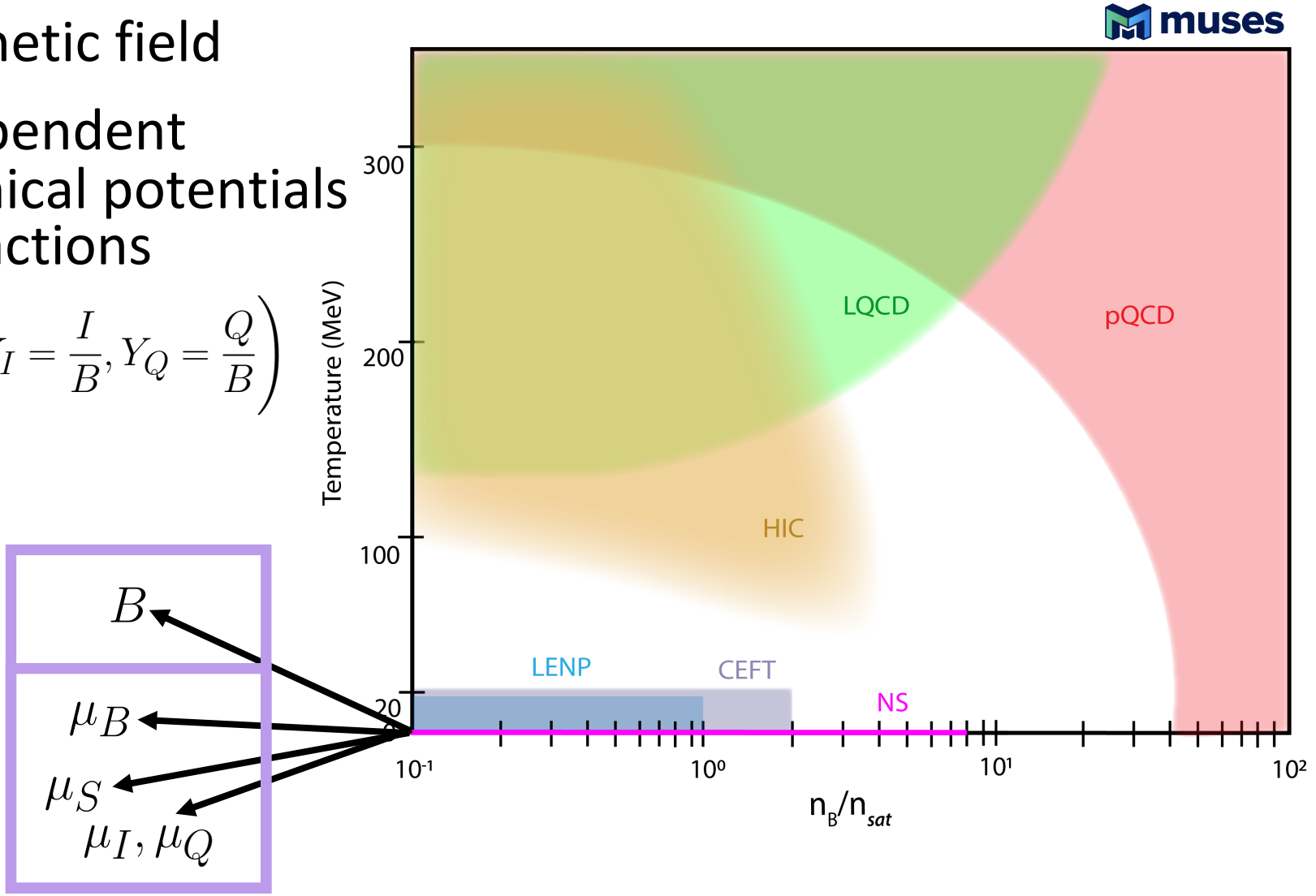
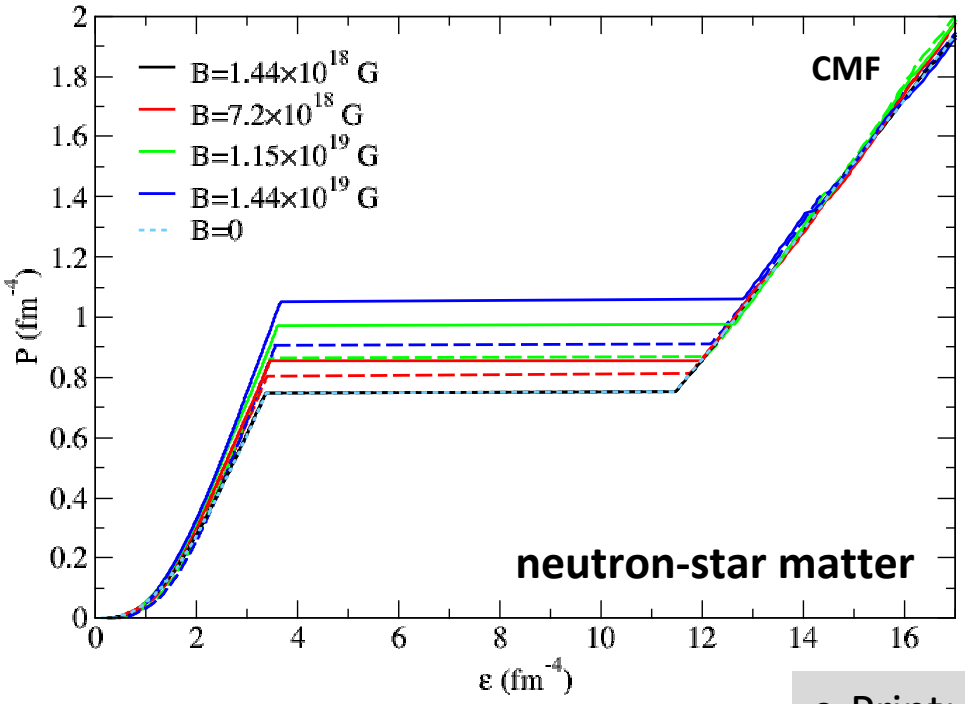
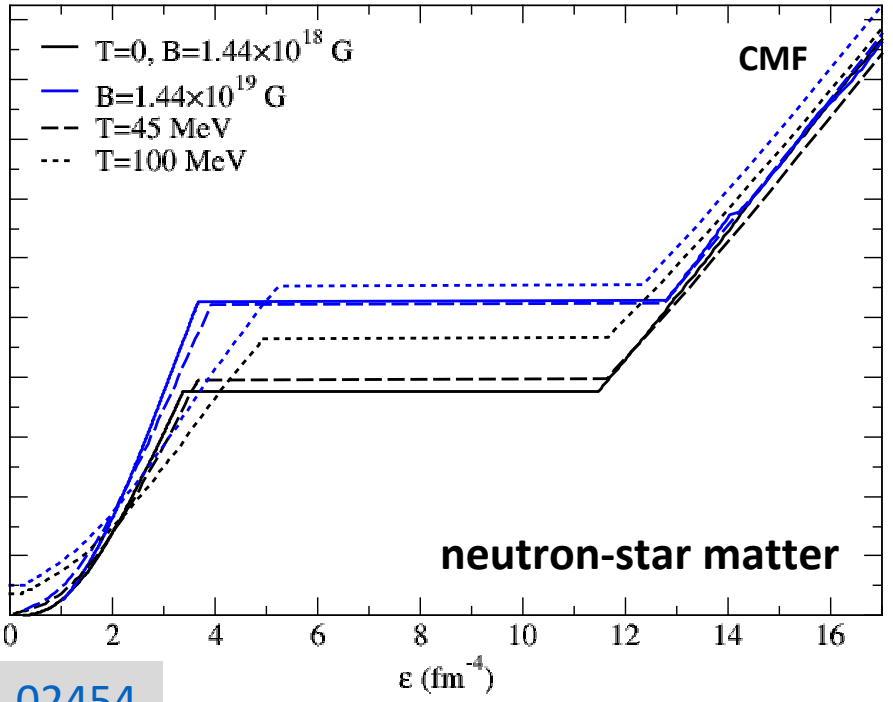


Magnetic Fields

- Deconfinement also depends on magnetic field **B**





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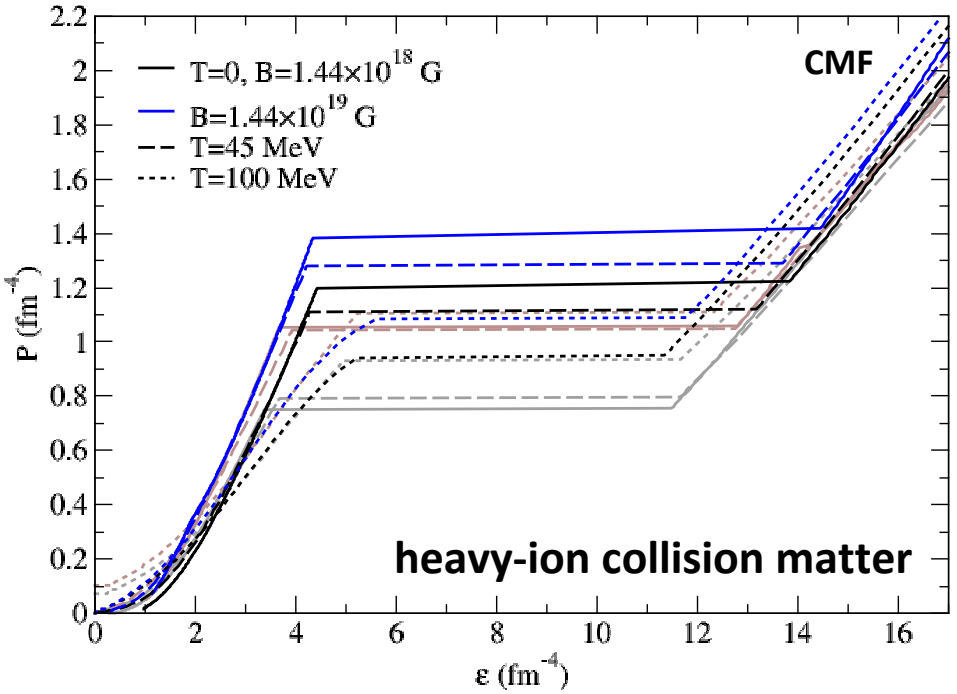
- (Stronger) phase transition takes place at larger ε and μ_B for larger B in CMF model
- (Weaker) phase transition takes place at lower μ_B for larger T

Magnetic Fields

- Neutron-star vs. heavy-ion collision matter also change dependence on **B**



- Neutron-star matter also shown for comparison in different colors

  B=1.44x10^{18} G for neutron-star matter

  B=1.44x10^{19} G for neutron-star matter

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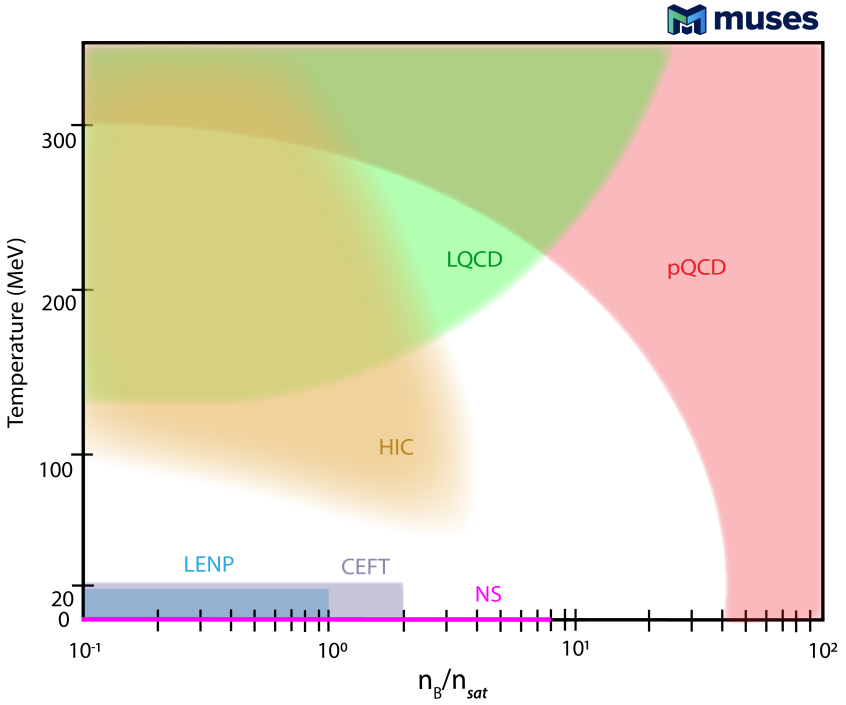
- Phase transition takes place at larger μ_B and is stronger for heavy-ion collision matter (for any **T** and **B**) in CMF model

Conclusions and Outlook

- Neutron-star matter allows access to strange and highly isospin-asymmetric matter at large densities
- Neutron-star mergers will very soon also inform us about dense and hot matter (while also strange and highly isospin asymmetric)



- Magnetic fields are expected to be enhanced in mergers
- The multidimensional QCD phase diagram is slowly becoming constrained but requires a combined description
  ➤ MUSES cyberinfrastructure https://muses.physics.illinois.edu/

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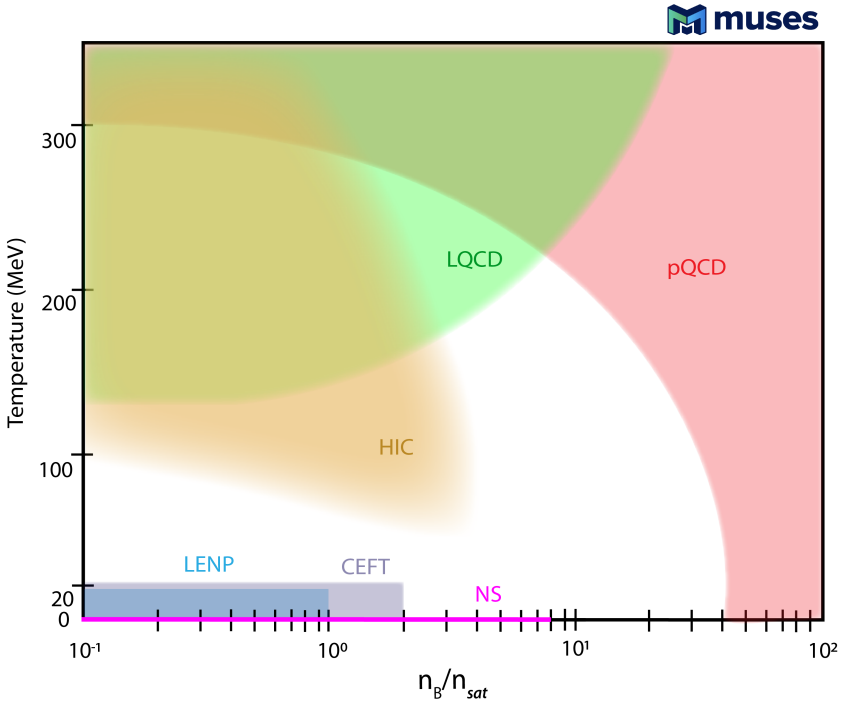

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Poster 116
Nikolás Cruz Camacho

- Modular Unified Solver of the Equation of state
- Modular: while at low μ_B the EoS is known from 1st principles, at high μ_B there will be effective theories and different models for the user to choose
- Unified: different modules will be merged together to ensure maximal coverage of the phase diagram
- Developers: physicists + computer scientists will work together to develop the software that generates EoS's over large ranges of temperature and chemical potentials to cover the whole phase diagram
- Users: interested scientists from different communities, who provide input to the future open-source cyberinfrastructure

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