AdS/QCD Critical Point via Scalar-Dilaton Coupling

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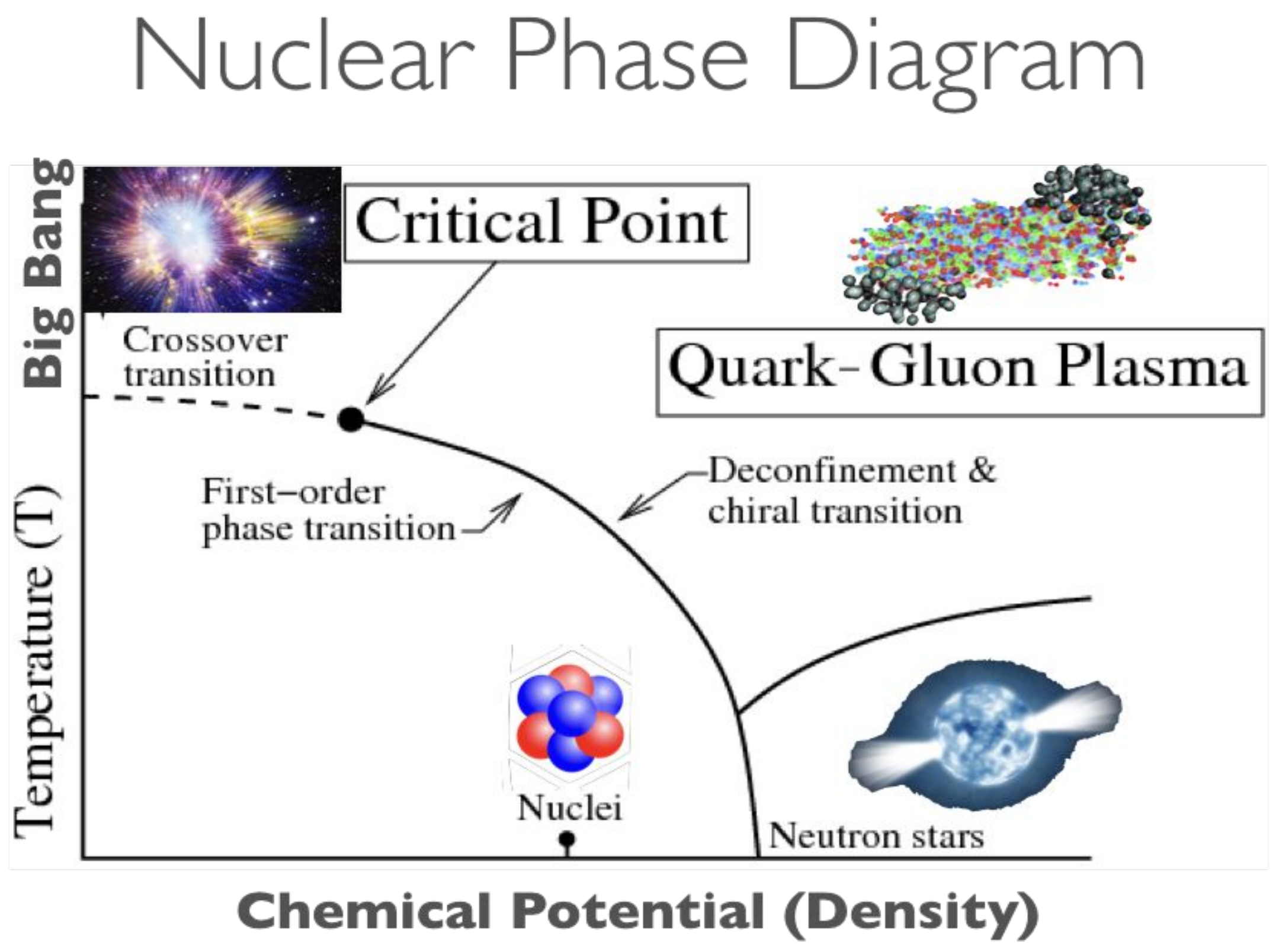
Physics background



This phase diagram is similar to one of ordinary matter with temperature vs. pressure. When matter crosses a critical point of high temperatures and pressures, it reaches a supercritical state or becomes a plasma. Nuclear matter is similar, becoming a quark-gluon plasma at its respective critical points.

Black hole in curved spacetime

The two may seem irrelatable, but a 5-D blackhole in curved spacetime describes the quantum theory of the strong nuclear force. This relation is suggested by string theory, and provides feasible means for solving the equation of motion computationally for the chiral field χ(z)

$$\chi'' + -\left(\frac{3}{z} + \Phi' - \frac{f'}{f}\right)\chi' - \frac{1}{z^2 f}\left((m_5^2 - \lambda_1\Phi)\chi + \frac{1}{2}\lambda_2\chi^3 + 3\lambda_3\chi^2\right)$$

Blackness function: *f(z)*, determines black hole type. We use a charged black hole to include chemical potential.

Quadratic Dilaton: Sets the overall energy scale: $\Phi(z) = \mu_g z^2$

λ_1: Strength of coupling between dilaton and chiral fields.

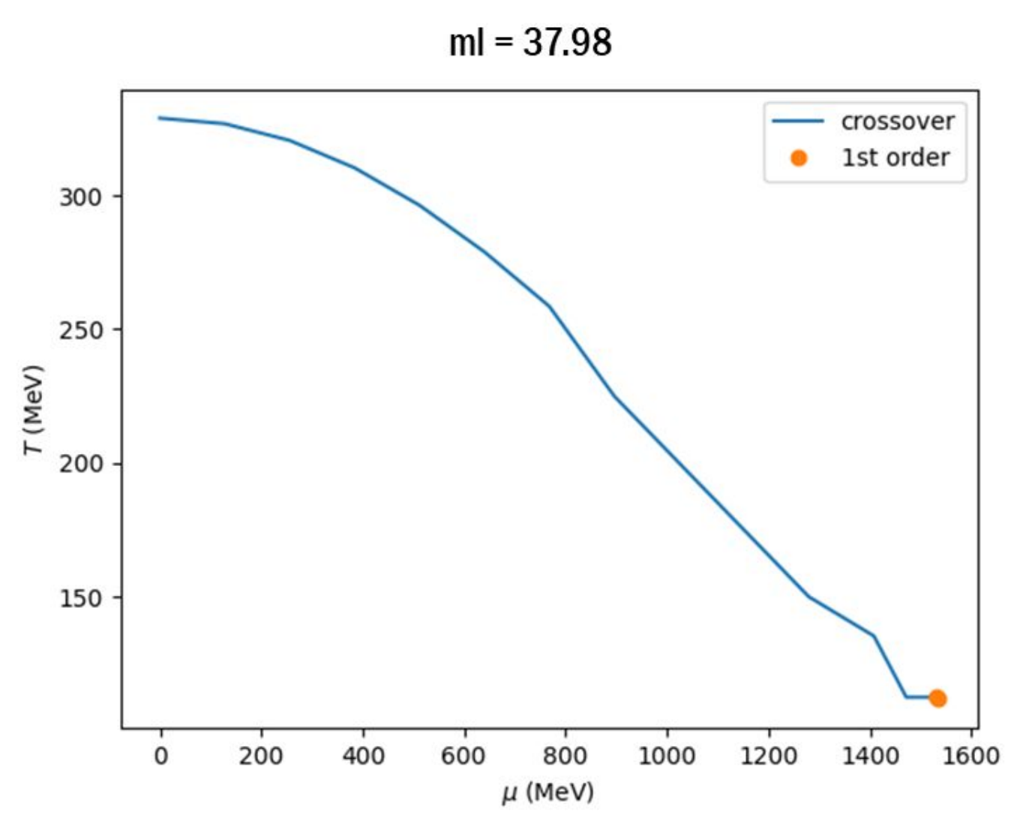
Chiral field mass: Fixed by AdS/CFT correspondence $m_5^2 = -3$

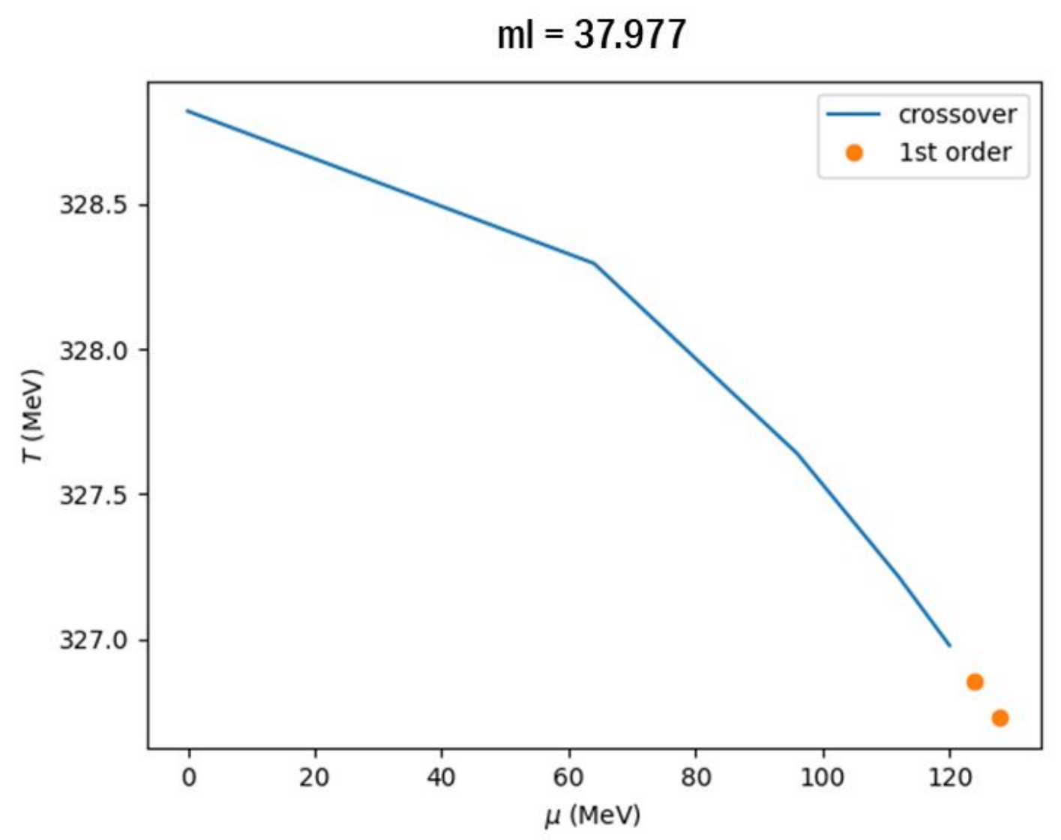
Chiral potential: Higher-order terms of χ are needed for 3 symmetric quark flavors

Phase boundary and critical points

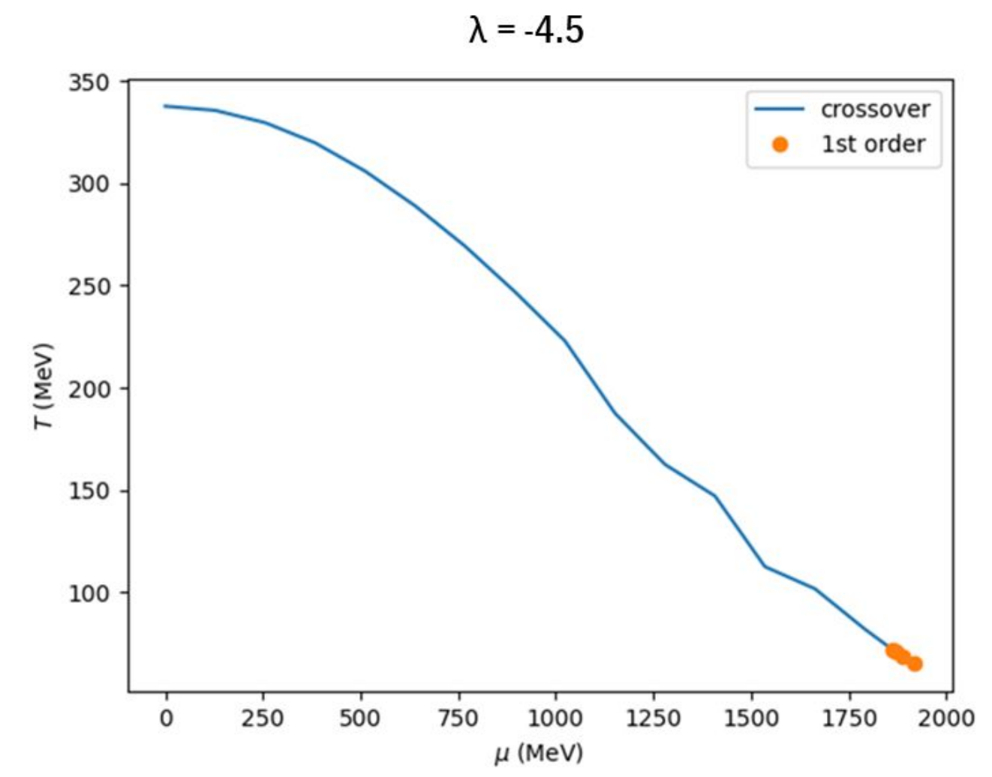
The chiral phase boundary is plotted in terms of temperature and chemical potential μ. The boundary depends upon the choice of quark mass and chiral-dilaton coupling λ_1.

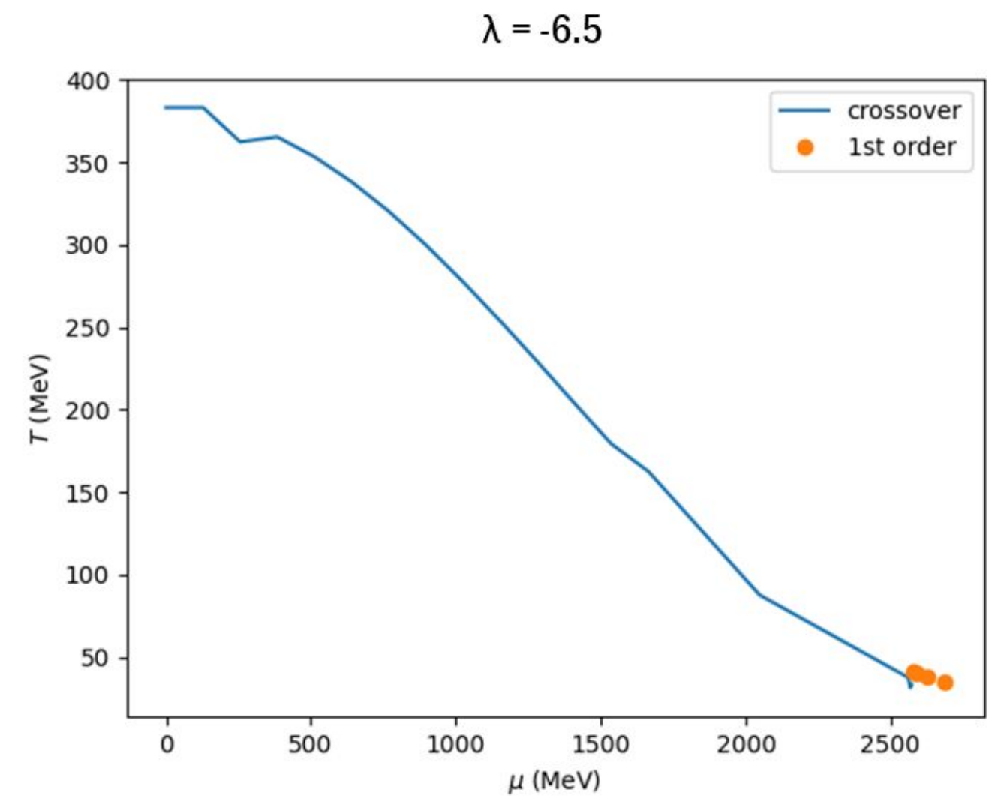
The blue line indicates a crossover phase transition and the orange points indicate a first-order phase transition. We fine tune the quark mass and value of λ to find where the transition is first order when $\mu = 0$. The following two plots illustrate the significant changes in the phase diagram in response to a small change in quark mass.





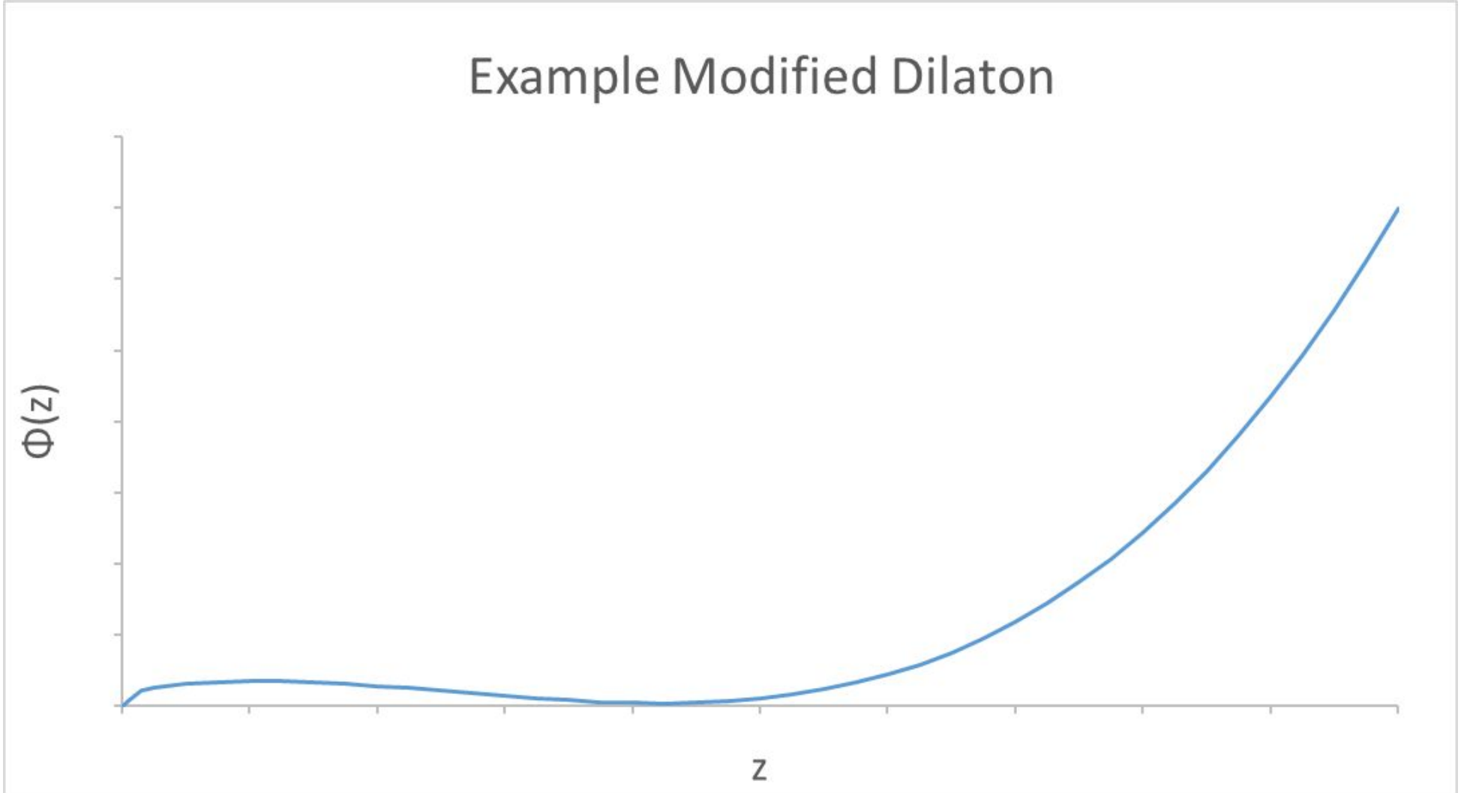
The plots below display a similar great response to small changes in the value of λ.





Takeaways and Future Work

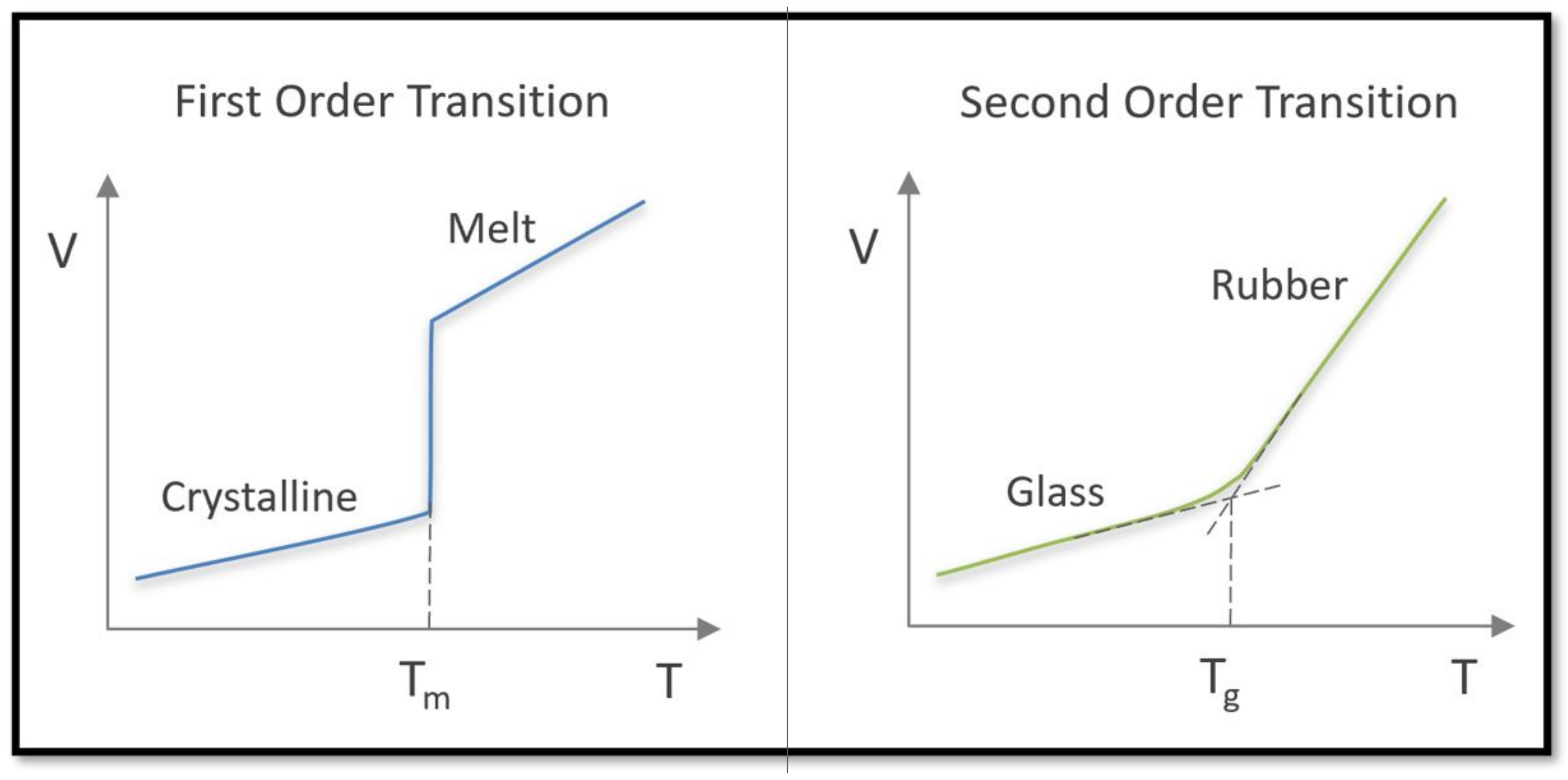
- Conditions for critical points improves as quark mass is decreased while abs λ is increased for $\mu = 0$.
- Small changes in these values are necessary, resulting in significant responses in the phase diagram with minimal changes in the temperature range or value of σ
- Future work:
  - Modified dilaton
  - Dcalar fields and dilatons near black holes, within context of quantum gravity



Chiral phase transition

The chiral field at small z is given by the AdS/CFT correspondence: $\chi(z \to 0) = m_q z + \sigma z^3$

The chiral condensate σ is varied until the numerical solution does not diverge at the black hole horizon.



First order phase transitions show a discontinuity indicating the transition is sudden and distinct. Each part of the system has completed the transition, or has not. This is a more typical type of phase transition, an example being liquid water to vapor. During the transition, it is always clear what parts are water and what is vapor.

Second order phase transitions instead show a continuous nature, implying the transition is not immediate but transitions through a medium where neither phase is distinguishable.

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