# Chiral phase transition in finite temperature and densitys for three flavour QCD

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# Quantum Chromodynamics (QCD)

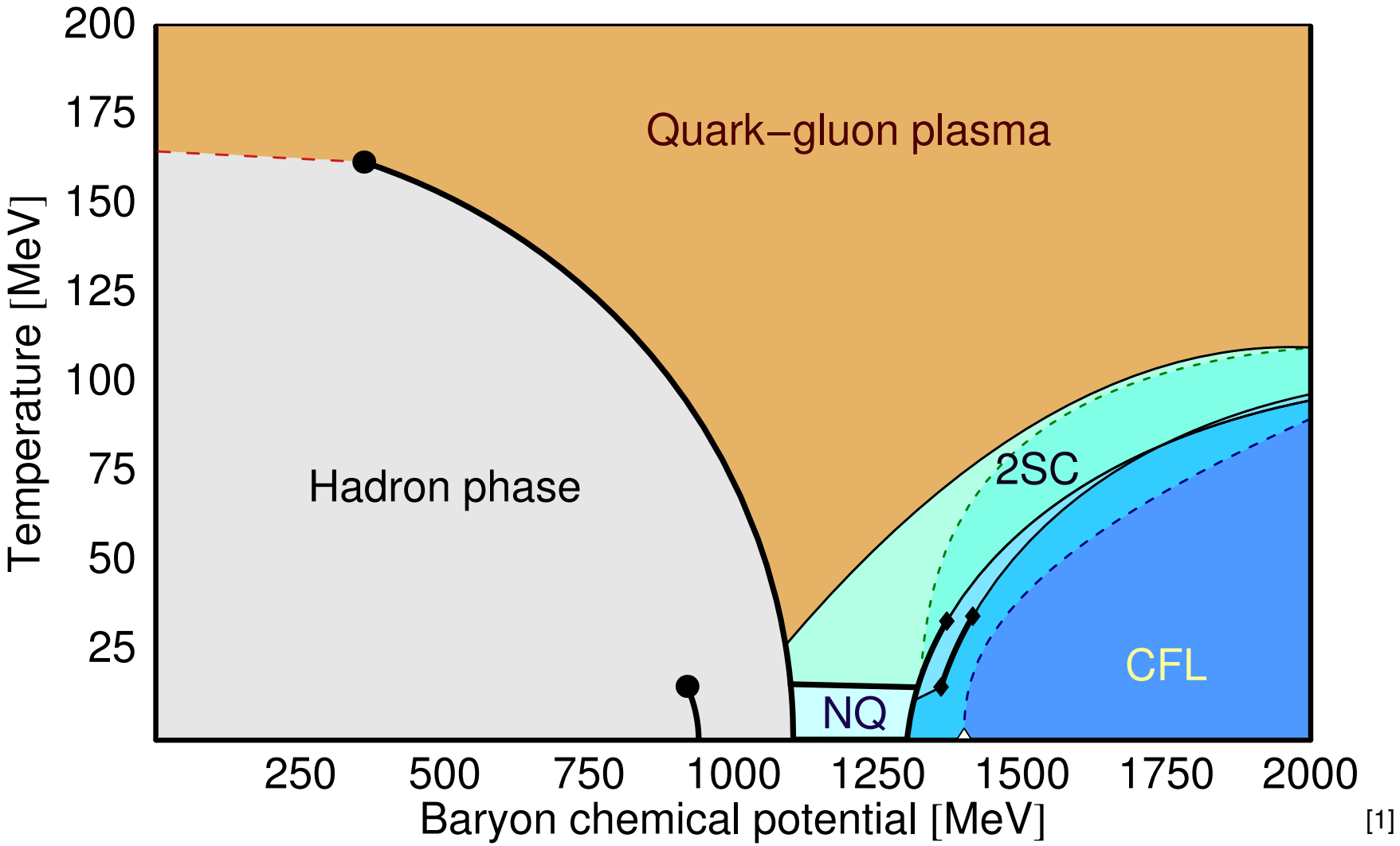
Quantum Chromodynamics is the theory of strong interactions.

Some properties:

- Felt by the quarks (and gluons), mediated by exchanging gluons
- Strongly coupled, nonperturbative
- Confined

But there exists other phases in QCD where the physics is very different.

# Phase diagram of QCD




[1]

[1] S.B. Ruester, V. Werth, M. Buballa, I.A. Shovkovy, D.H. Rischke, Phys.Rev.D72 (2005)

# Motivation

There are many situations where high temperature and density is interesting

- Early universe
- Dense starts
- Supernovae explosions
- Heavy Ion Collisions

# Phases $\leftrightarrow$ Symmetries

We can only transition into a new phase if there is a fundamental change in the system

Possible symmetries in QCD:

- Gauge transformations
- Flavour rotations
- Chiral transformations
- ...

# Chiral symmetry breaking

The Dirac Lagrangian decomposed into right- and left-handed spinor fields

$$\mathscr{L} = i\bar{\psi}_L \not{D} \psi_L + i\bar{\psi}_R \not{D} \psi_R + \bar{\psi}_L m \psi_R + \bar{\psi}_R m \psi_L$$

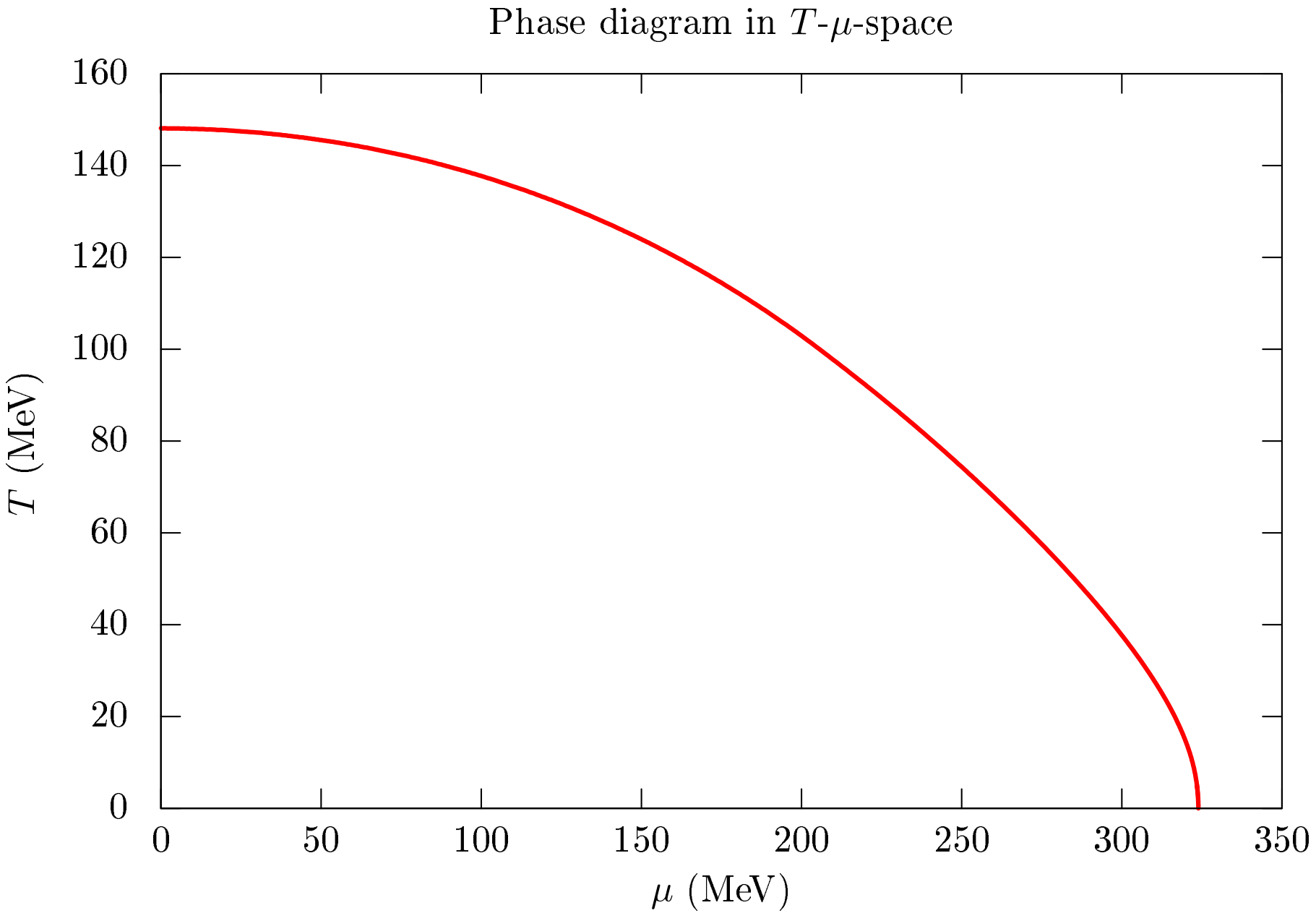
As long as $m \neq 0$, we cannot transform the left and right handed fields independently in flavour space

$\Rightarrow$ Chiral symmetry is broken

# Models and Approximations

QCD is a tough theory to do work with, and a lot of it has been done with numerical lattice calculations. For an analytic study, multiple approximations is commonly used

- Linear Sigma Model (L$\sigma$M) or Nambu-Jona-Lasinio Model (NJL)
- Mean field approximations
- Perturbative methods or Nonperturbative Renormalization group methods


Phase diagram in $T$-$\mu$-space
160
140
120
100
80
60
40
20
0
$T$ (MeV)
0
50
100
150
200
250
300
350
$\mu$ (MeV)

# Conclusion and Outlook

- Looking for symmetry breaking/restoration, we can find phase transitions
- Perturbation theory doesn't give satisfactory results
- Two-flavour QCD doesn't tell us the whole story
- Renormalization group equation approach to three-flavour QCD will hopefully do better

Questions?

# Questions?

Thank you for your time