Figure 2.25 from page 92 of *Exploring the Heart of Matter*

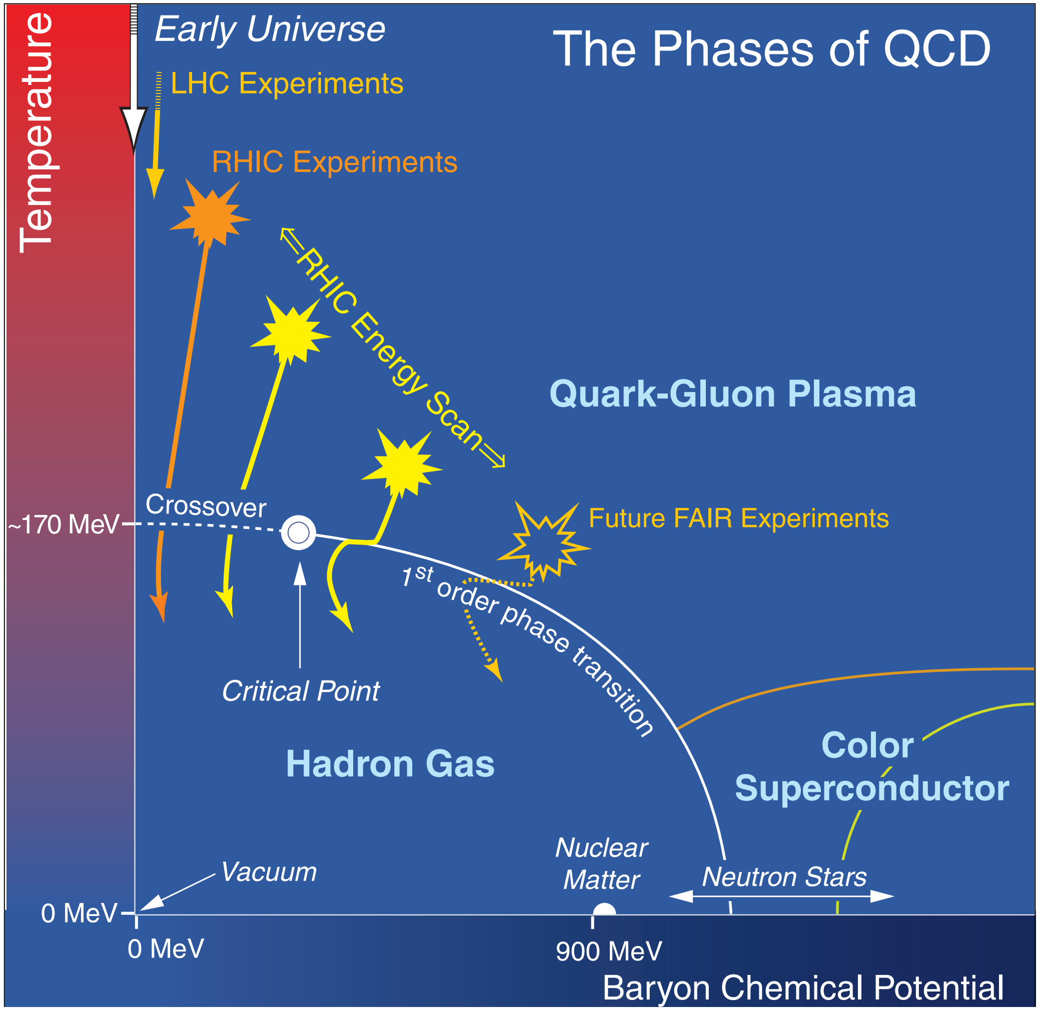
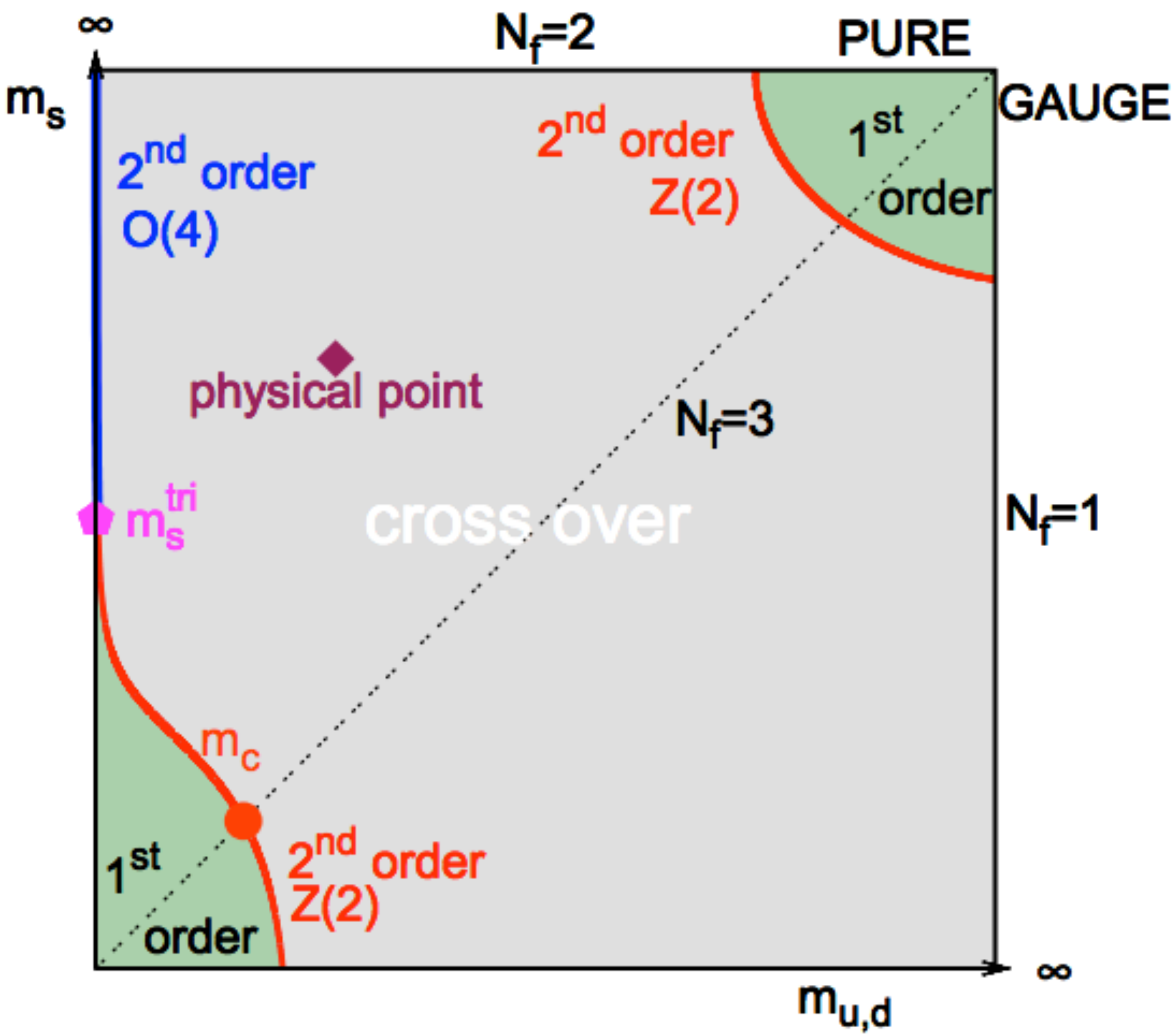


FIGURE 2.25 The phase diagram of QCD is shown as a function of baryon chemical potential (a measure of the matter to antimatter excess) and temperature. A prominent feature in this landscape is the location of the critical point, which indicates the end of the first-order phase transition line in this plane. SOURCE: DOE/NSF, Nuclear Science Advisory Committee, 2007, *The Frontiers of Nuclear Science: A Long Range Plan.*

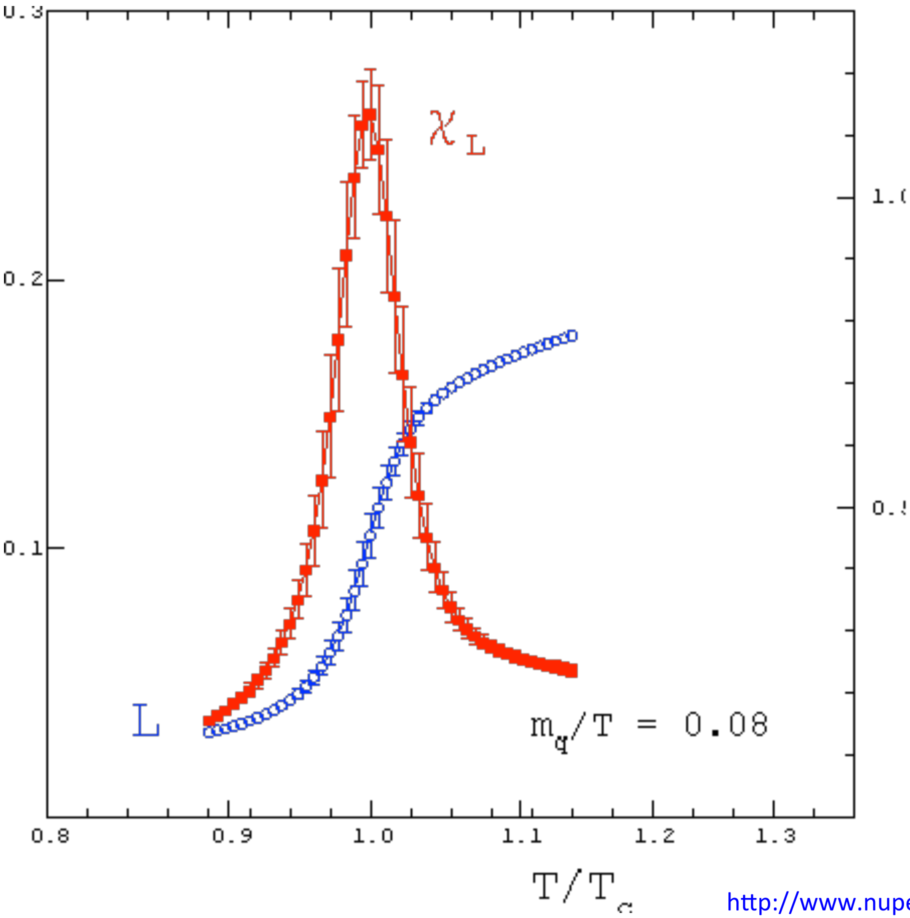
Lattice QCD calculations: Order of the phase transition

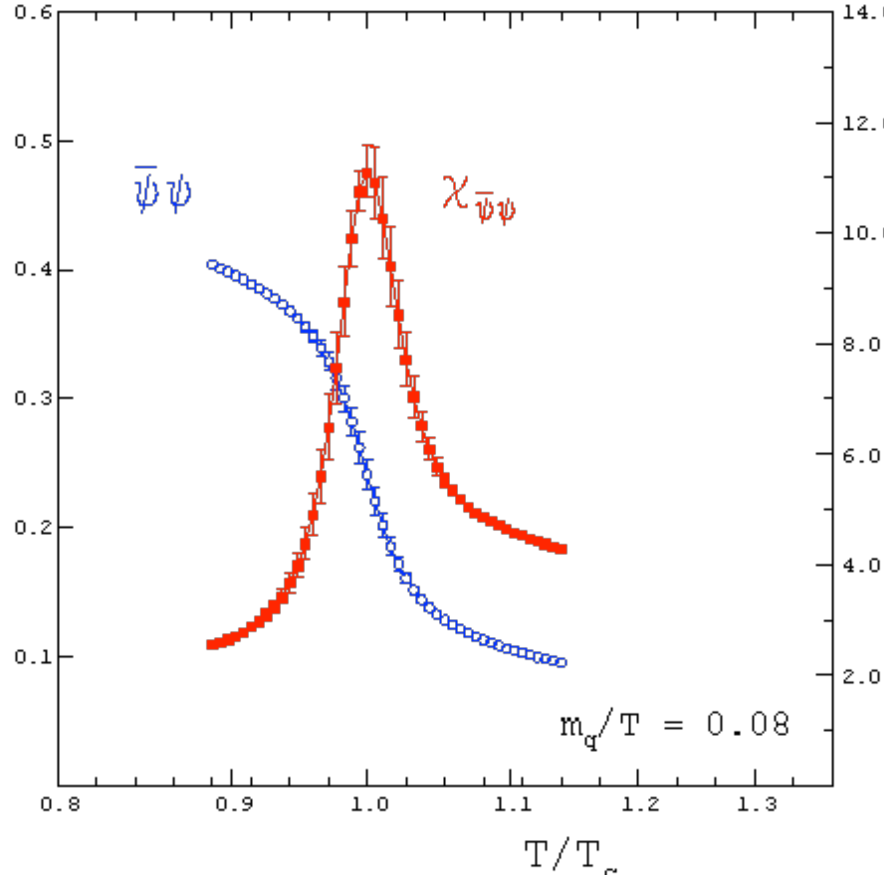
http://quark.phy.bnl.gov/~htding/usqcd/scaling.html



- As function of light quark masses (x-axis) and strange quark mass (y-axis)

Lattice QCD calculations across phase transition

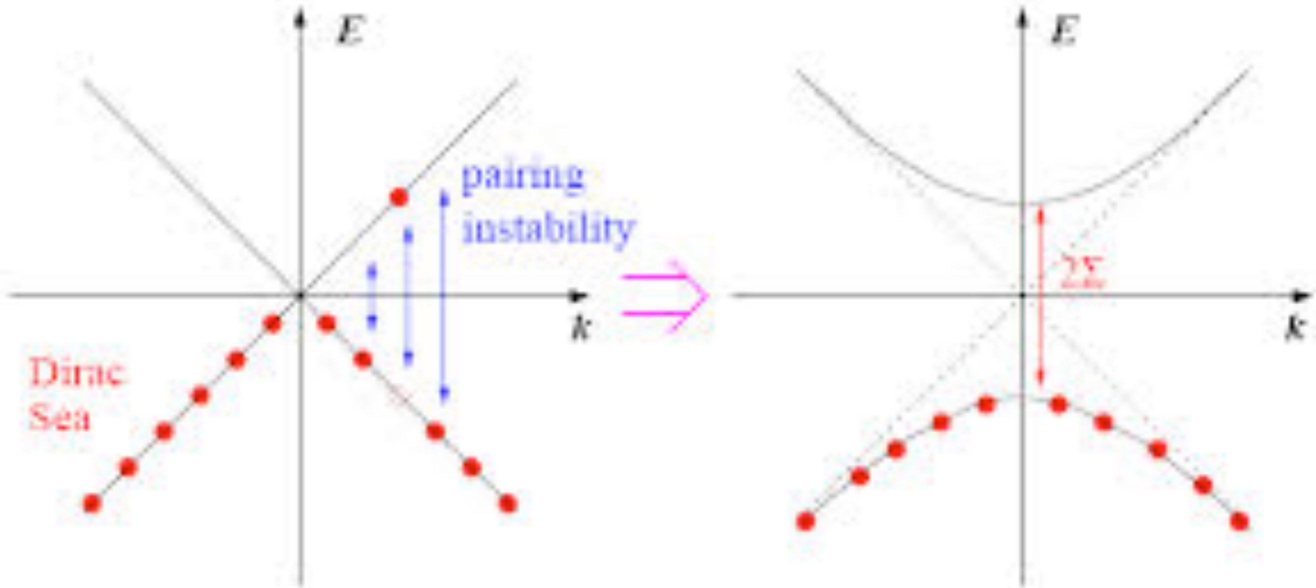


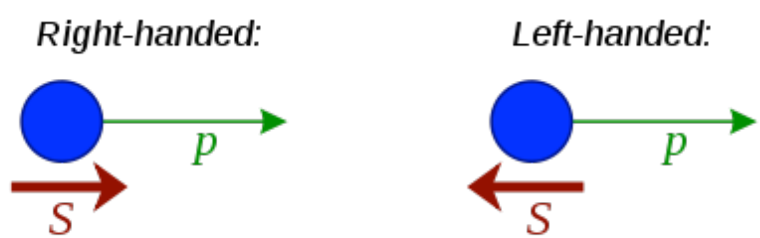


http://www.nupecc.org/report97/report97_nnc/node14.html

- T_c is the critical temperature, so phase transition at $T/T_c = 1$
- Left: Wilson loop L, which is a measure of the quark free energy: jumps at deconfinement
- Right: quark condensate, analogous to magnetization in ferromagnet: jumps at restoration of chiral symmetry (cf. restoration of rotation symmetry in magnet at Curie temperature)
- Deconfinement and chiral symmetry restoration transitions → same temperature!

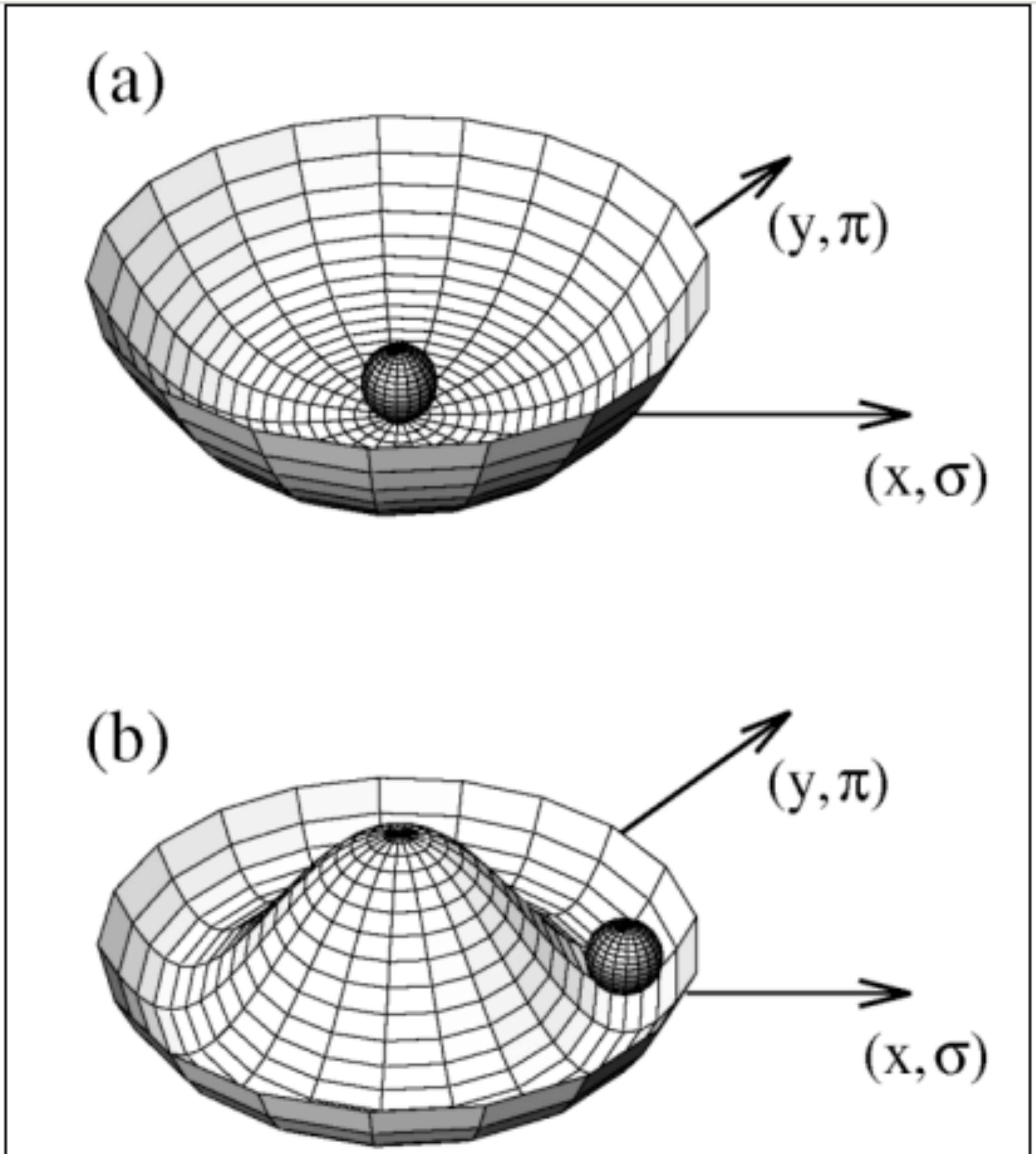
QCD vacuum: Chiral symmetry breaking → quark condensate





- Massless quarks are either right-handed or left-handed (you can think of this as analogous to left or right circularly polarized light): spin S and momentum p
- Quark condensate acts like a background field to propagating quarks, that gives them a mass → "constituent quarks"
- The quark condensate breaks the chiral symmetry in the sense that a non-zero spontaneous magnetization breaks rotational invariance in a ferromagnet.

QCD vacuum: Chiral symmetry breaking → classical model



http://www-np.ucy.ac.cy/HADES/physics/physics_main.html

Figure 2.2: Classical mechanics potential model illustrating chiral symmetry breaking. The potential in a) is symmetric. In b) the potential is still symmetric, but the symmetry of the ground state is spontaneously broken as the ball rolls to a certain point in the potential and selects a direction, which breaks the symmetry. However, a rotation (moving the ball in the valley) does not cost energy [7].