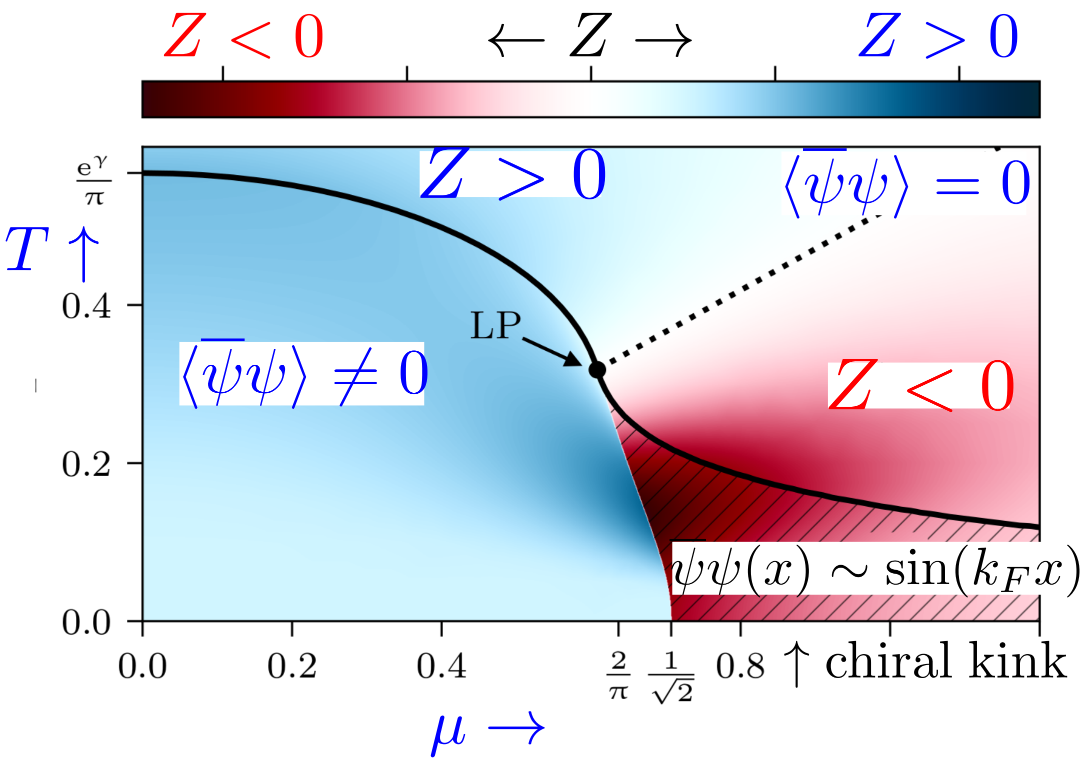
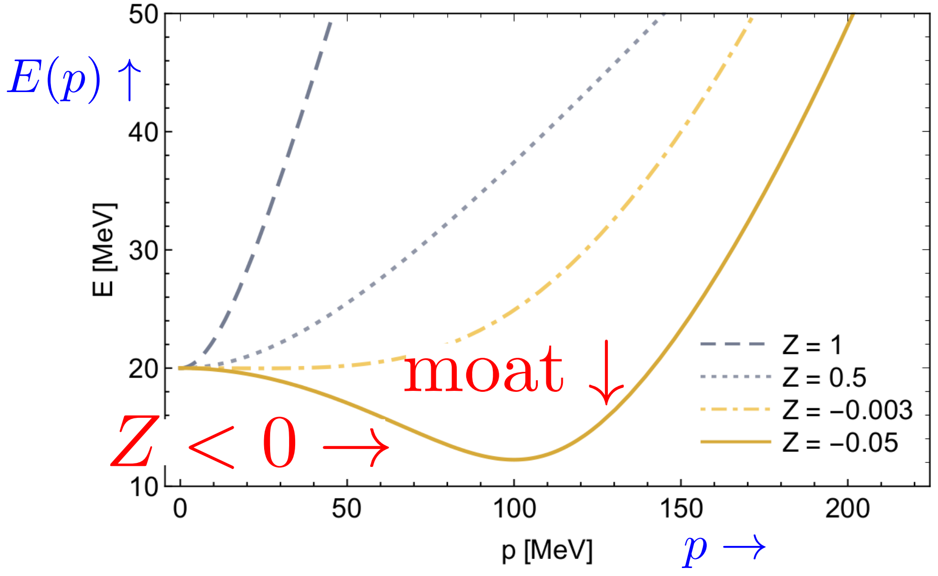
QCD at T, μ≠0: *more* than just a CEP

In eff. Lag for σ, π : critical end point (CEP), λ = 0
Can also have "moat" regime, Z < 0
Koenigstein et al, 2112.07024: in soluble model in 1+1 dim.'s, CEP and *big* moat regime (region in red)

$$\mathcal{L}_{\text{eff}} = Z(\partial_i \vec{\phi})^2 + m^2 \vec{\phi}^2 + \lambda(\vec{\phi}^2)^2 + \ldots$$

In moat regime, the energy of a pion is minimal at *non*-zero momentum.
Can lead to chiral kinks (left fig.), \
and chiral spirals (σ, π)





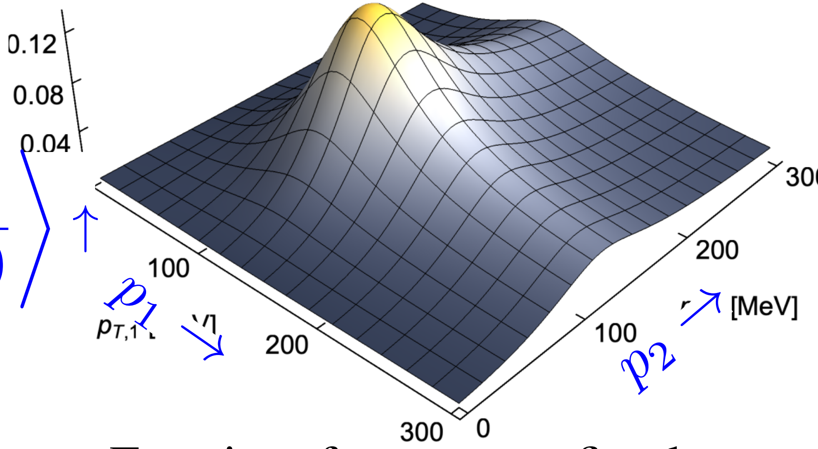
Finding a moat (spectrum) in experiment

In moat regime, *natural* to generate pion/kaon & quarkyonic condensates: RDP+..., 1801.08156
Pions probably form Quantum Pion Liquid: RDP+..., 2005.10259; RDP, 2202.01086
Related to "PT" symmetry @ nonzero μ: Schindler+… 2110.14009

Moat regimes occur over a *much* larger region, in μ and T, than the basin of attraction to a CEP
Because the sigma is *really* heavy in vacuum, and *mas* 0
Moat regime gives non-thermal behavior:
usual Bose-Einstein with unusual dispersion relation

Also, characteristic two particle correlations:
N(p) = # pions at some momentum p
RDP & Rennecke, 2103.06890
Without moat, this is *very* flat.
With moat, *big* peak at $p \neq 0$
Will also affect HBT.

$$\left\langle \frac{N(p_1, p_2)}{N(p_1) N(p_2)} \right\rangle \uparrow$$



QCD at low T, moderate μ is *quarkyonic*: excitations near Fermi surface are confined
Produces distinctive signals: Glozman+..., 2204.05083
Especially interesting is the ω meson: Sasaki, 2207.00274: most sensitive to baryons
(*Very*) close to a CEP *is* "universal", but *non*-universal phenomena *may* dominate for most T & μ