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Main interest: strongly coupled QFTs

key question:
What is the computational complexity
of "solving" a strongly coupled QFT?

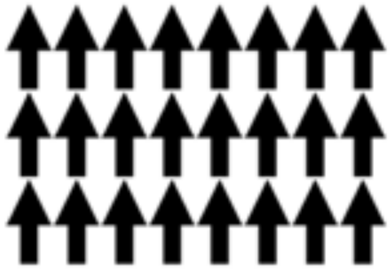
To solve = to be able to make quantitatively accurate predictions
(spectrum, scattering amplitudes, etc)

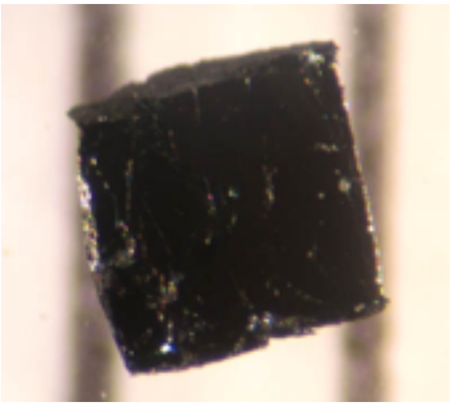
Examples of strongly coupled CFTs relevant for the real world

Particle physics: QCD

Statistical and condensed matter physics: ∞ many examples


helium near superfluid transition


ferromagnets near Curie temperature


high Tc superconductors

Gapped vs gapless theories

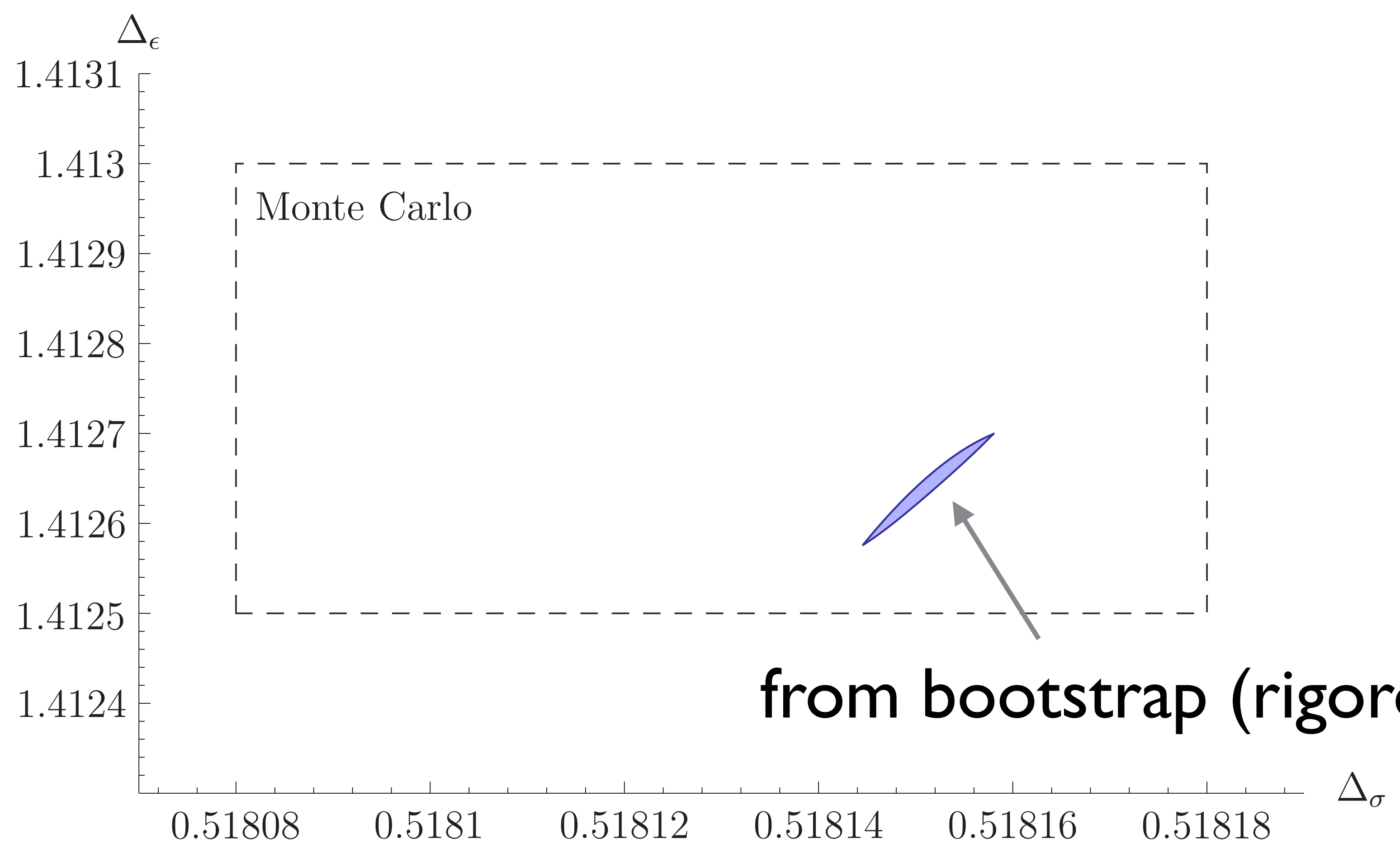
Some strongly coupled theories at low energies develop a mass gap,
others remain massless and yet strongly interacting (CFTs)

CFTs are particularly relevant for the theory of phase transitions,
and also for some ideas about BSM

CFTs can be solved/constrained using the "conformal bootstrap" approach
actively developed at CERN

Alessandro Vichi, Miguel Paulos, myself
as well as former fellows Sheer El-Showk, Balt van Rees

Dimensions of the leading operators in the 3d Ising model:



Δ_σ=0.518151(6), Δ_ε=1.41264(6)

from Simmons-Duffin 1502.02033

What about gapped strongly coupled theories?

(like low-energy QCD)

Lattice Monte Carlo simulations are one option.

(originates from statistical mechanics)

There is a whole array of alternative methods motivated by quantum condensed matter physics:

Density Matrix Renormalization Group,
Matrix Product States,
Entanglement Renormalization…

(typically limited to d=2)

I've been exploring one method which belongs to the same group but has a chance to be extendable to d>2

Hamiltonian Truncation

is a variant of Rayleigh-Ritz method of QM applied to QFT

sometimes we say that QCD vacuum is filled with quark-antiquark pairs forming a condensate

$$\text{true QCD vacuum} = c_0|0\rangle + c_2|q\bar{q}\rangle + c_4|q\bar{q}q\bar{q}\rangle + \ldots$$

similarly we say that a meson is a q-qbar valence pair with an admixture of an arbitrary number of sea q-qbar pairs:

$$\text{meson} = c_2|q_i\bar{q}_j\rangle + c_4|q_i\bar{q}_j q\bar{q}\rangle + \ldots$$

Hamiltonian truncation is trying to make this quantitatively precise.

Works for simple theories (like scalar phi^4 in d=2 and slightly above)

Challenges: increase d, extend to gauge theories