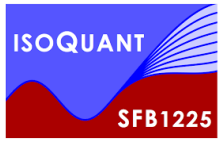

Complex Langevin simulations of a finite density matrix model for QCD

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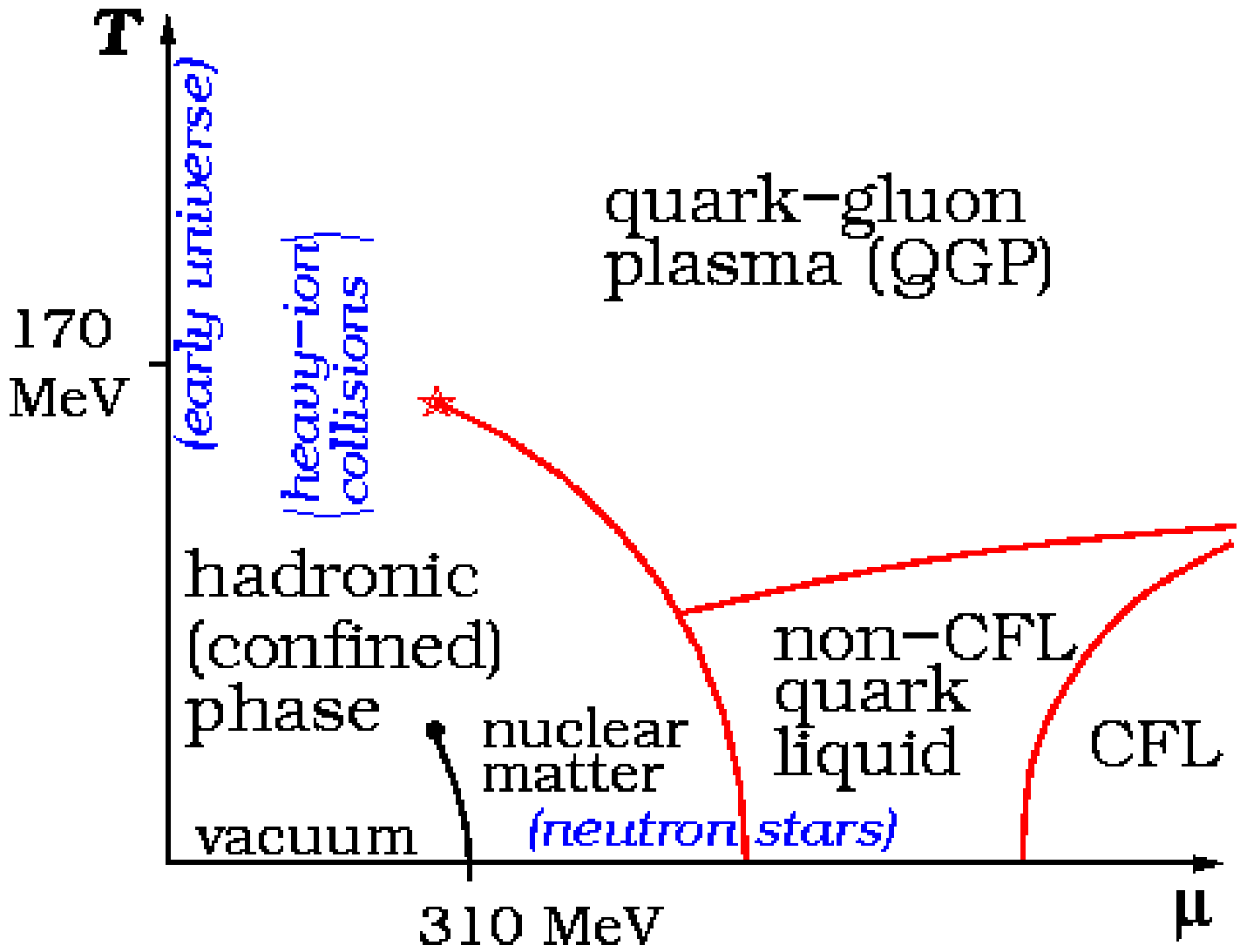
22.01.2018

56th International Winter Meeting on Nuclear Physics

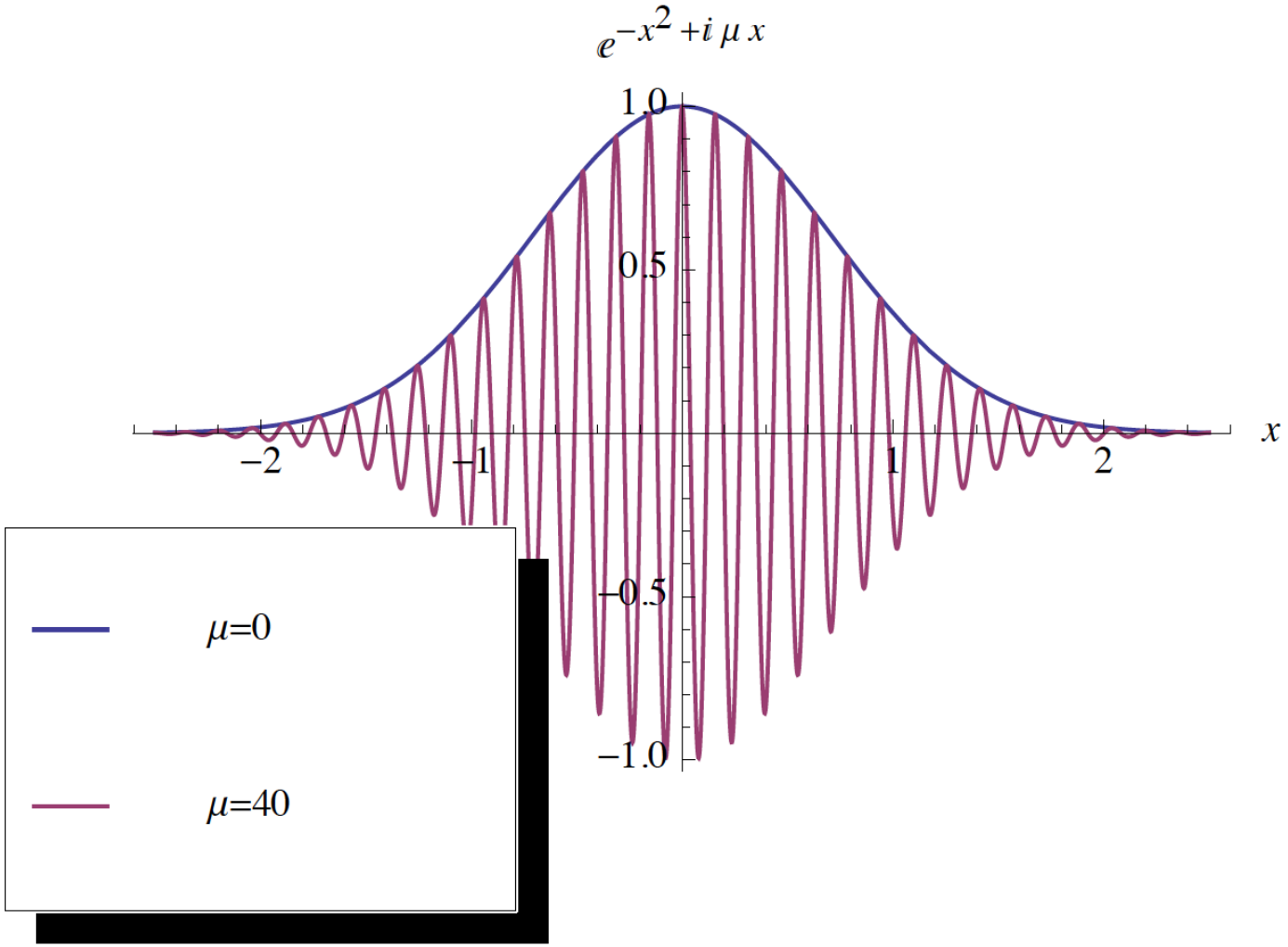
In collaboration with J. Bloch (Regensburg U.), J. Glesaaen (Swansea U.), J. Verbaarschot (Stony Brook U.)

Phase diagram from a theorist's viewpoint



(Courtesy of wikipedia)

The sign problem



Many approaches

- Conventional/Monte Carlo based methods
  - Reweighting
  - Taylor expansion
  - Imaginary μ
  - Strong Coupling Expansion
  - Mean Field analyses
- Alternative methods
  - Stochastic Quantization-Complex Langevin
  - Lefschetz Thimble
  - Canonical ensembles
  - Dual variables
  - Density of States

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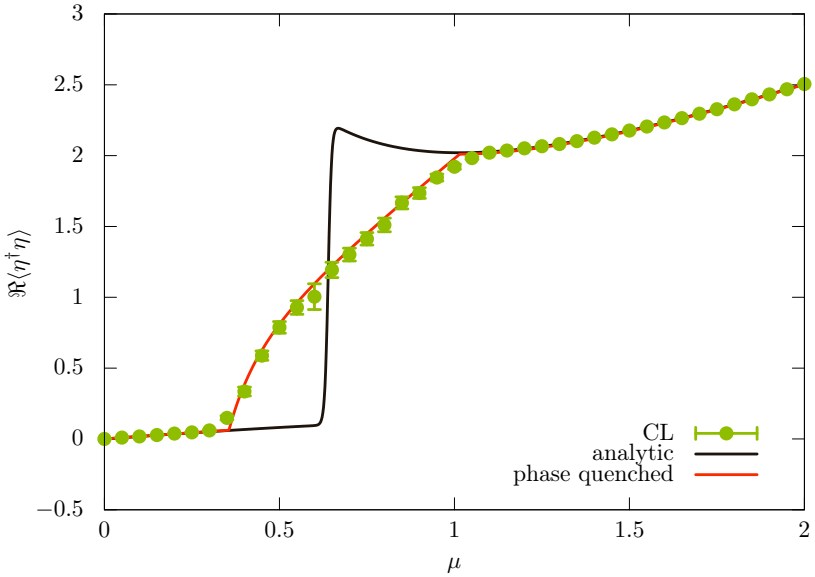
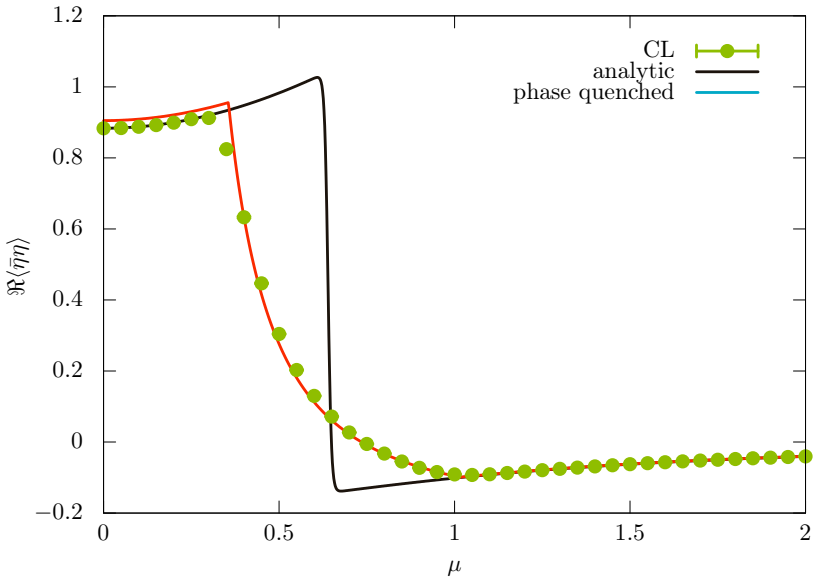
RMT

- focus on a much simpler theory than QCD. Random Matrix Theory
- same flavor symmetries with QCD which uniquely determine (in the ϵ-regime)
  - mass dependence of the chiral condensate $\langle \bar{\eta}\eta \rangle = \partial_m \log Z$
  - the baryon number density $\langle \eta^\dagger \eta \rangle = \partial_\mu \log Z$

μ-scan for $m = 0.2$



$\langle\eta^\dagger\eta\rangle$ for $m = 0.2$



$\langle\bar{\eta}\eta\rangle$ for $m = 0.2$

Attempts to fix it

- gauge cooling
- the shifted representation
- the deformation technique
- reweighted complex Langevin

Thanks a lot for your attention!!!