TENSOR RENORMALIZATION GROUP APPROACH FOR (3+1)D FINITE DENSITY QCD AT STRONG COUPLING LIMIT

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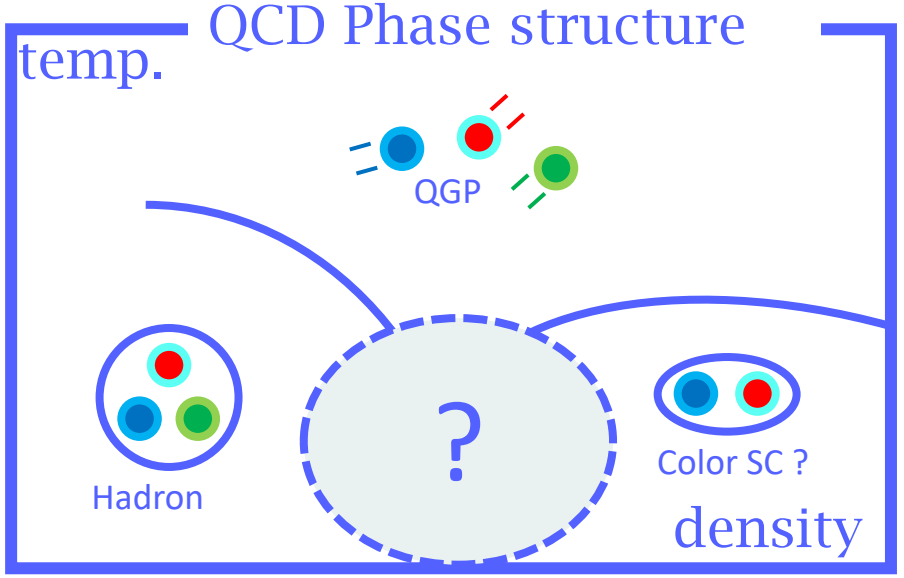
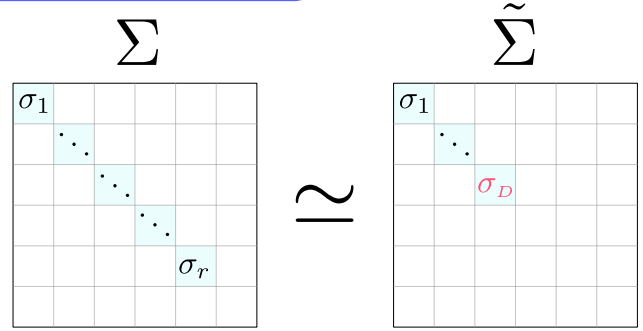
GOAL : First-principles calculations of finite density QCD

- **QCD** : A 4D Theory of the Strong Force
  - Interactions between quarks and gluons
    → color confinement , hadron mass …
  - Related to neutron star at **finite density**
  - First-principals calculation is needed
  - Lattice QCD has sign problem
  - We need alternative algorithms

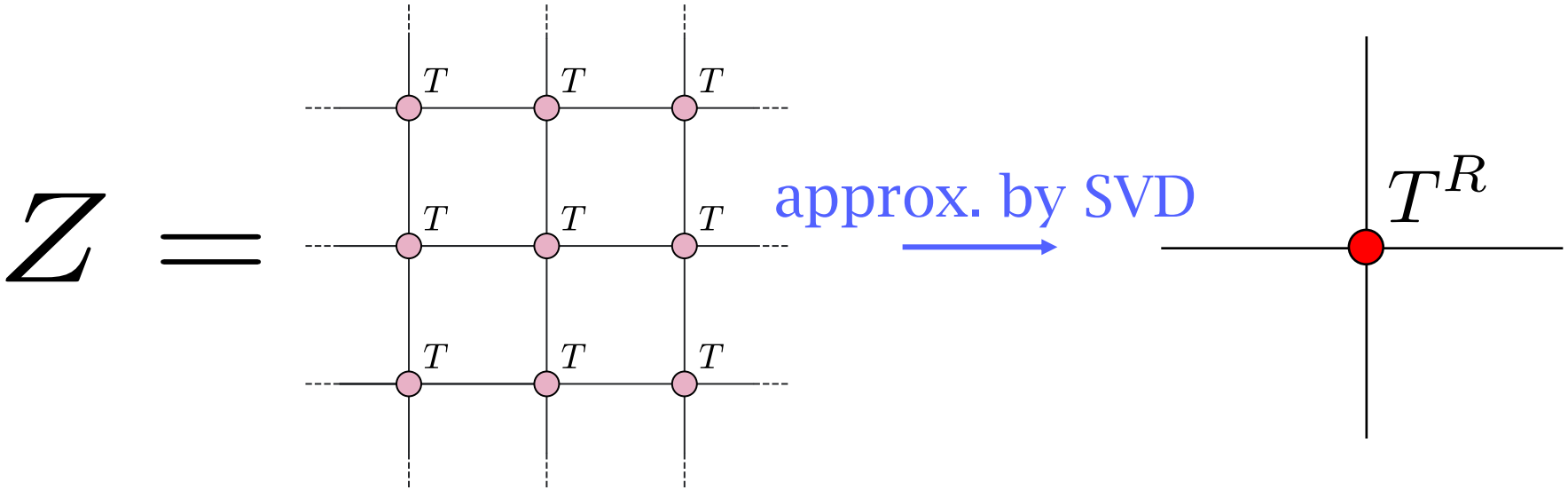


METHOD : Tensor Renormalization Group

- Numerical method to calculate partition function
- Approximation based on SVD
- Applicable for fermion systems
- No sign problem → Apply for finite density QCD ?



Truncation of singular values



TARGET : (3+1)d QCD at strong coupling limit

$$S[U,\chi,\bar{\chi}] = \cancel{\underbrace{\beta\sum_n[1-\tfrac{1}{2}\sum_{\mu<\nu}\mathrm{Tr}\,U_{\mu\nu}(n)]}_{\text{Gauge action}}} + \underbrace{\sum_n\left[\tfrac{1}{2}\sum_{\nu=1}^{4}\eta_\nu(n)\left(e^{\mu\delta_{\nu,4}}\bar{\chi}(n)U_\nu(n)\chi(n+\hat{\nu}) - e^{-\mu\delta_{\nu,4}}\bar{\chi}(n+\hat{\nu})U_\nu^\dagger(n)\chi(n)\right) + m\,\bar{\chi}(n)\chi(n)\right]}_{\text{Fermion action (staggered, finite } \mu)}.$$

- No dynamical gauge field
- Searching of CEP by Grassmann TRG