$\mathcal{N} = 4$ supersymmetric Yang-Mills thermodynamics to order λ^2 from EFT

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Construction of SUSY-EFT

- The partition function in the full theory is:

$$\mathcal{Z}_{\mathrm{SYM}_{4,4}} = \int \mathcal{D}\bar{\eta}\mathcal{D}\eta\mathcal{D}\bar{\psi}_i\mathcal{D}\psi_i\mathcal{D}A_\mu^a\mathcal{D}\Phi_A^a \; e^{-\int_0^\beta d\tau \int d^3x \, \mathcal{L}_{\mathrm{SYM}_{4,4}}} ,$$

- Integrating out the non-static modes:

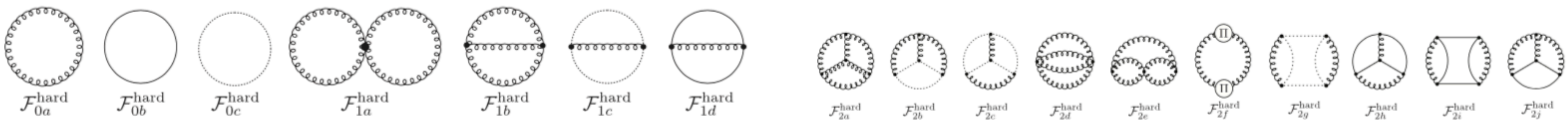
$$\mathcal{Z} = \int \mathcal{D}\bar{\eta}\mathcal{D}\eta\mathcal{D}A_0^a\mathcal{D}A_i^a\mathcal{D}\Phi_A^a e^{-f_E V - \int d^3x \, \mathcal{L}_{\mathrm{ESYM}}}$$

f_E → coefficient of unit operator

The most general form $\mathcal{L}_{ESYM}$ is

$$\begin{aligned}\mathcal{L}_{\mathrm{ESYM}} = &\frac{1}{2}\mathrm{Tr}[G_{ij}^2] + \mathrm{Tr}[(D_iA_0)(D_iA_0)] \\ &+ \mathrm{Tr}[(D_i\Phi_A)(D_i\Phi_A)] + m_E^2\mathrm{Tr}[A_0^2] \\ &+ m_S^2\mathrm{Tr}[\Phi_A^2] + h_E\mathrm{Tr}[(i[A_0,\Phi_A])^2] \\ &+ \frac{1}{2}g_3^2\mathrm{Tr}[(i[\Phi_A,\Phi_B])^2] + \mathcal{L}_{\mathrm{gf}} + \mathcal{L}_{\mathrm{gh}} + \delta\mathcal{L}_{\mathrm{ESYM}},\end{aligned}$$

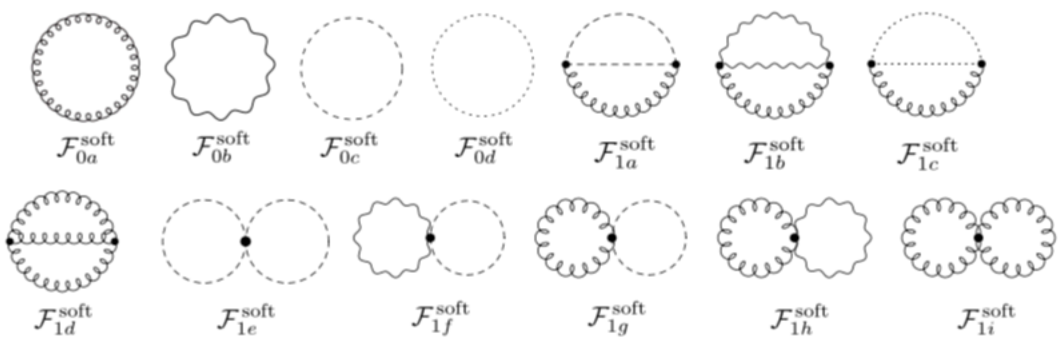
Hard contribution to $SYM_{1,10}$ free energy density



$$f_E(\Lambda)T = -d_A \frac{\pi^2 T^4}{6}\left\{1 - \frac{3}{2}\frac{\lambda}{\pi^2} + \left[3\log\frac{\Lambda}{4\pi T} + \frac{39}{16} + \frac{3}{2}\gamma_E + \frac{3\zeta'(-1)}{2\,\zeta(-1)} - \frac{1}{2}\log 2\right]\left(\frac{\lambda}{\pi^2}\right)^2\right\}$$

CALCULATIONS IN THE EFFECTIVE THEORY

- In the EFT technique the soft contribution is obtained by performing two-loop perturbative calculations in the effective theory.



$$f_M = -d_A \frac{\pi^2 T^3}{6}\left\{(3+\sqrt{2})\left(\frac{\lambda}{\pi^2}\right)^{\frac{3}{2}} + \left[-3\log\frac{\Lambda}{4\pi T} - \frac{81}{16} - \frac{9\sqrt{2}}{8} - \frac{21}{8}\log 2 + \frac{3}{2}\log\frac{\lambda}{\pi^2}\right]\left(\frac{\lambda}{\pi^2}\right)^2\right\}.$$

- The complete result for the free energy through order λ^2 for general N_c is

$$\mathcal{F}_{0+1+2} = (f_E + f_M)T = -d_A\frac{\pi^2 T^4}{6}\left\{1 - \frac{3}{2}\frac{\lambda}{\pi^2} + (3+\sqrt{2})\left(\frac{\lambda}{\pi^2}\right)^{\frac{3}{2}} + \left[-\frac{21}{8} - \frac{9\sqrt{2}}{8} + \frac{3}{2}\gamma_E + \frac{3\zeta'(-1)}{2\zeta(-1)} - \frac{25}{8}\log 2 + \frac{3}{2}\log\frac{\lambda}{\pi^2}\right]\left(\frac{\lambda}{\pi^2}\right)^2\right\}$$

Scaled entropy density as a function of λ