Holographic Entanglement Entropy In Effective Theories of Strongly Coupled Systems

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Abstract

We choose two types of strongly coupled systems described by an effective theory in low energy or long wavelength. In one system, we study the near equilibrium thermal systems macroscopically described by fluid states and and another the macroscopic phase transition in superconductors which is driven by some strongly coupled meachanism. We compute and study the HEE in these systems.

HEE in relativistic hydro flows

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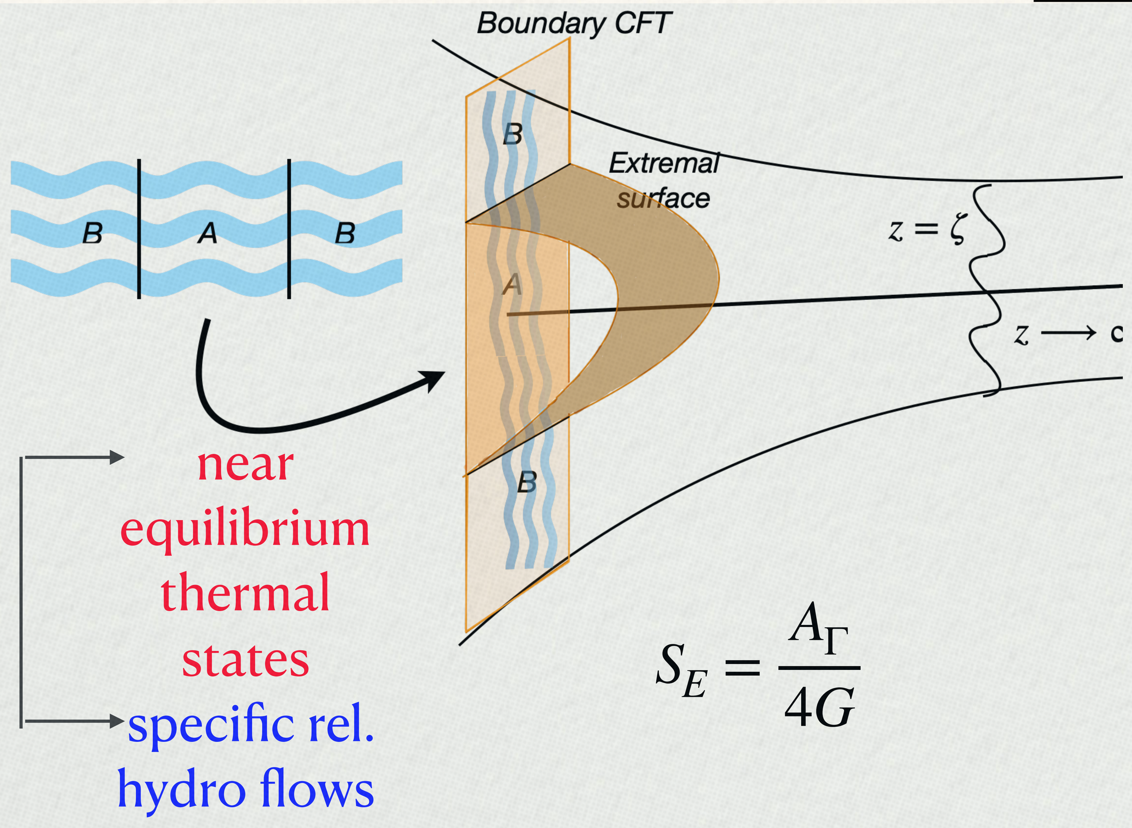


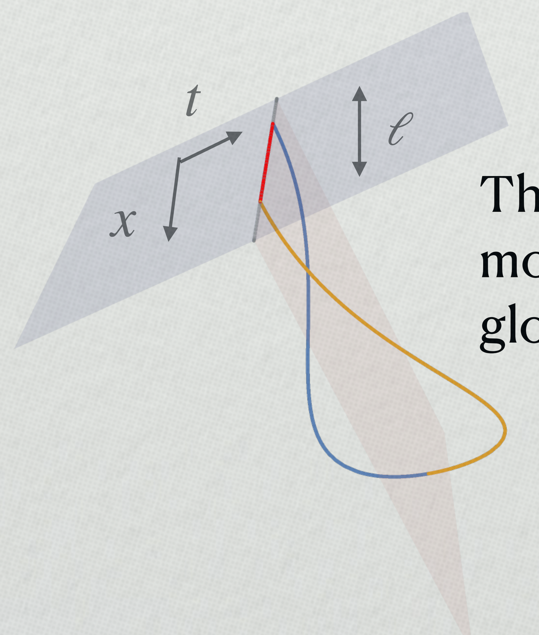
$$S_E = \frac{A_\Gamma}{4G}$$

Fluid/gravity maps the fluid flows into fluctuating AdS black brane geometry

Staionary fluid flow Fluctuating fluid

Steady state fluid flow is fluid moving with constant vel v which is dual to constantly boosted AdS black brane

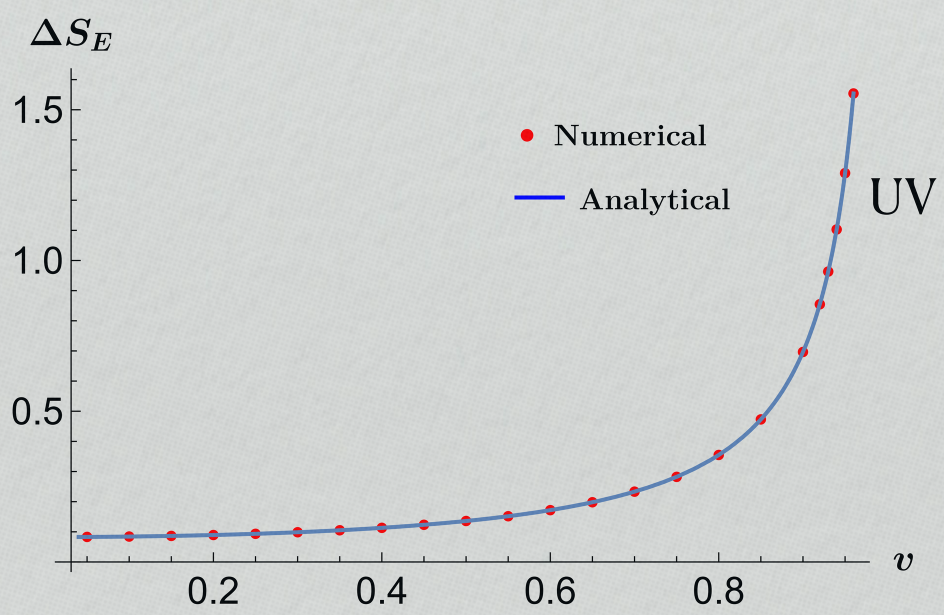
$d = 2$



The extremal surface moves out of the global bulk time-slice

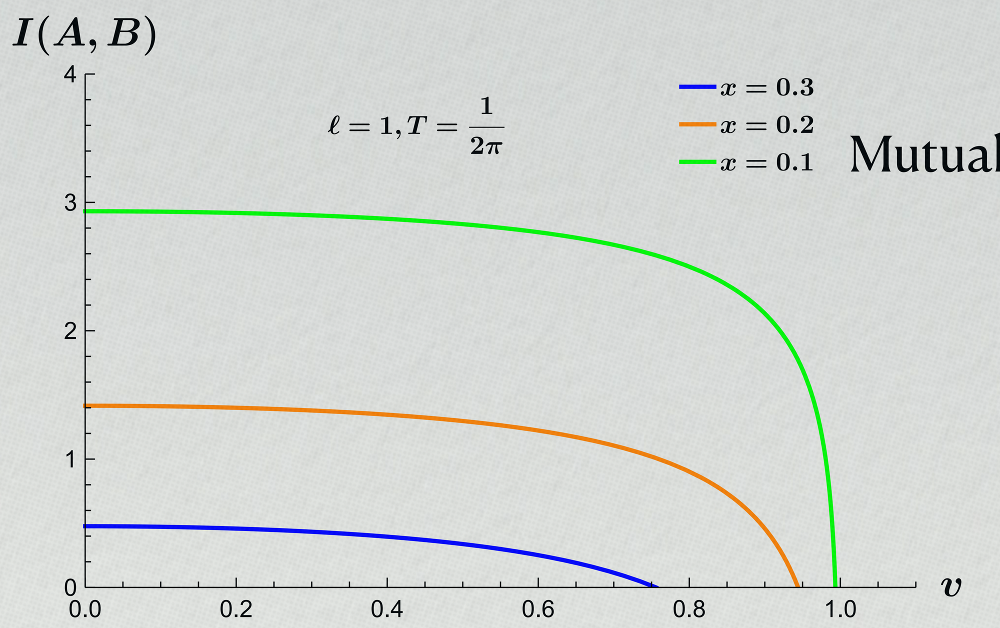
$$\mathcal{S}_A(\ell, v) = \frac{c}{6} \ln\left(\frac{\beta^2}{\pi^2 \epsilon_{uv}^2} \sinh\left(\frac{\pi \alpha \ell}{\beta}\right) \sinh\left(\frac{\pi \ell}{\alpha \beta}\right)\right)$$

This is an exact analytical result in $d = 2$



UV regulated HEE

$\Delta S_E \sim \gamma$ in large vel. limit at any temp.



Mutual Information (MI)

$I(A, B)$ goes to zero at critical vel. v_c even when the separation length is smaller than x_c

$d = 3,4$ **has same behaviour**

Staionary fluid flow **Fluctuating fluid**

In the excited fluid states the fluid configurations are propagating sound waves or a propagating pressure pulse constructed by superposing the linearized sound wave solution

We computed the HEE for this fluid configurations in $d = 2$ where the fluid is non-dissiative and the higher dimensional dissipative fluids in $d = 3$ and 4.

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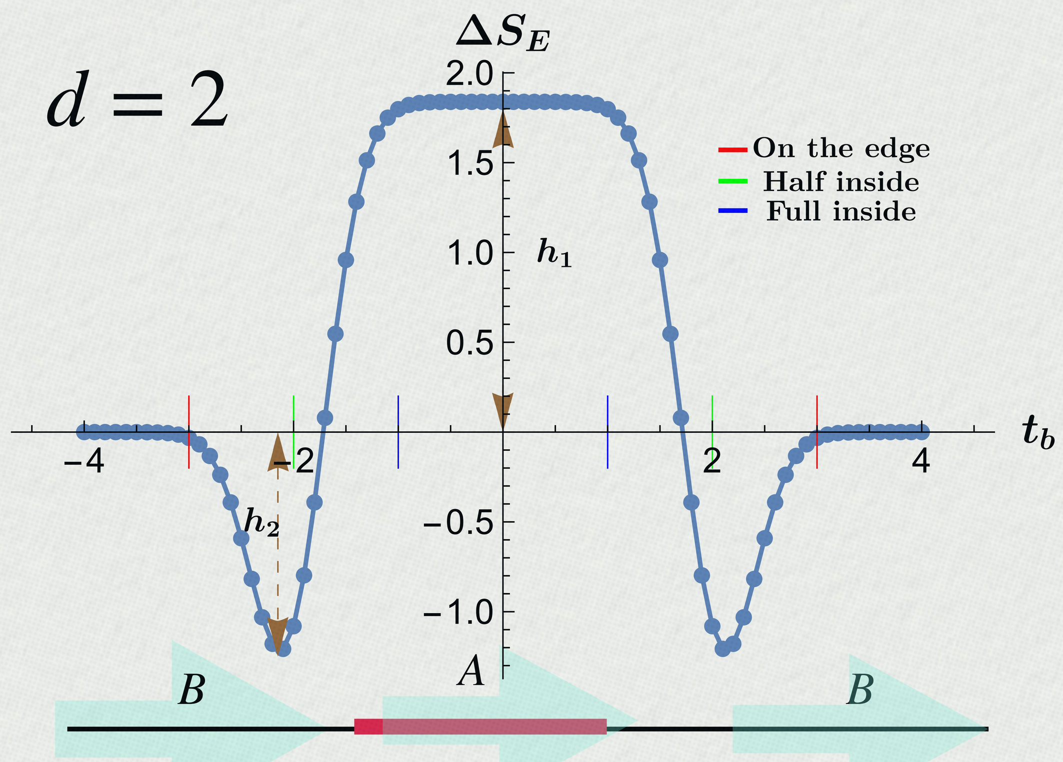
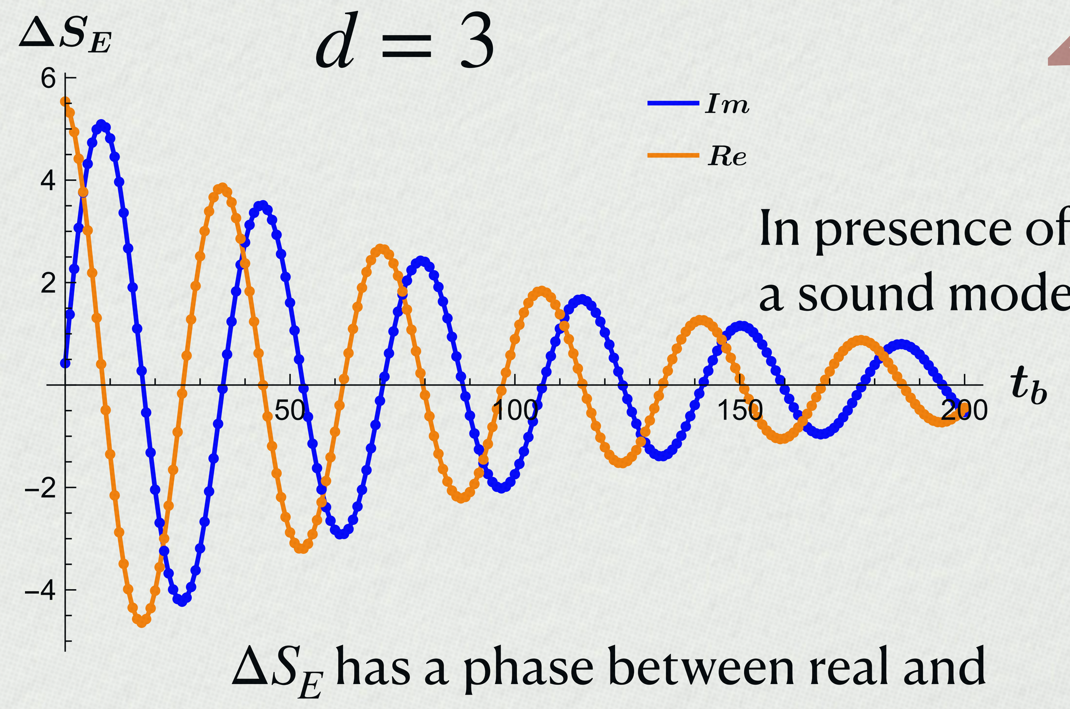
$d = 2$



Change of HEE as pressure pulse moves through subsystem

$d = 3$



In presence of a sound mode

ΔS_E has a phase between real and Imaginary pieces and vanishes at late Time.

$d = 4$

$\Delta S_E \sim e^{-\lambda t_b} \frac{1}{\epsilon_{uv}}$, In $d = 4$, an additional UV divergence appears, sub-leading to 'area law'. It is damped so vanishes in the equilibrium state. Regulating the additional UV divergent part the behaviour in $d = 4$ is similar to $d = 3$.

HEE in holographic superconductors

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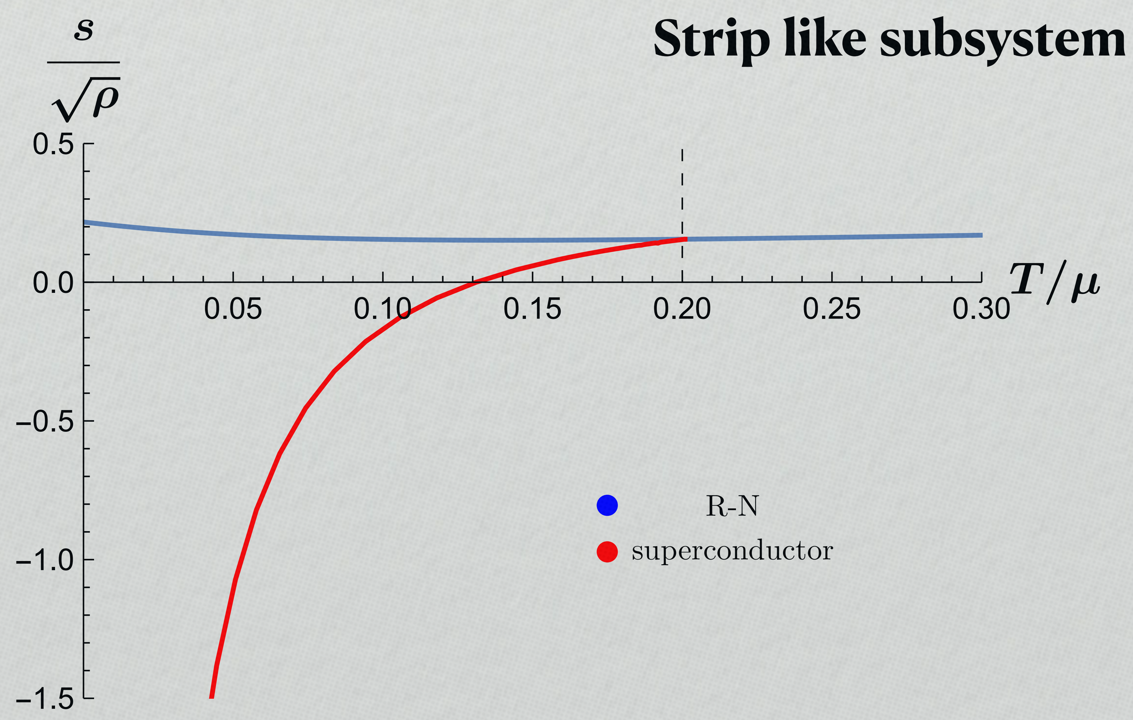
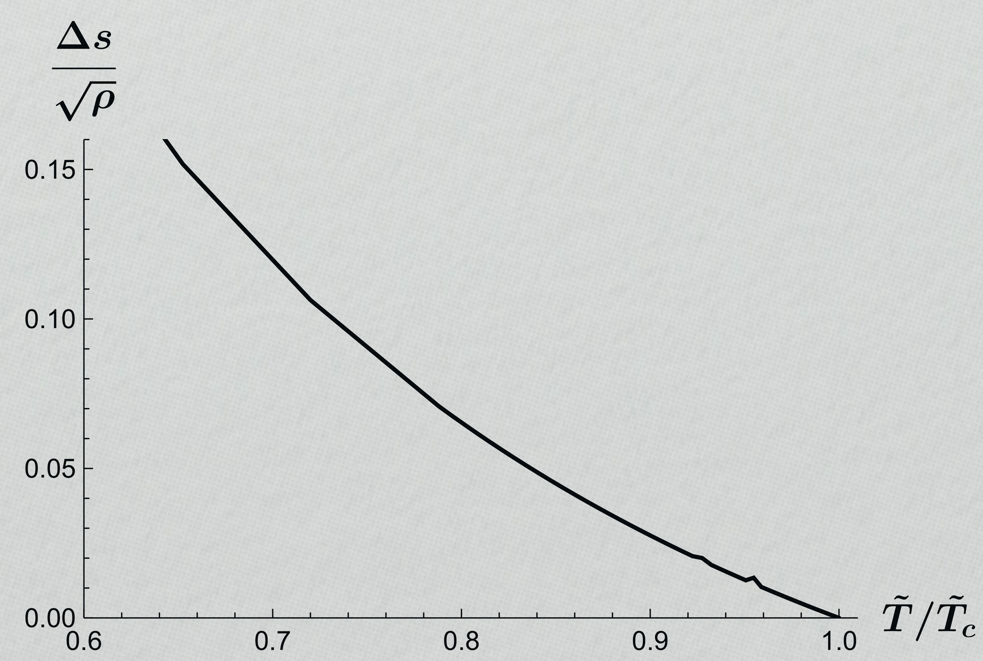
For d dimensional holographic superconductor in the boundary theory we consider an Einstein-Maxwell-scalar system in $d + 1$ AdS bulk. The superconducting phase is characterized by the condensation of a charged operator $\mathcal{O}$ below the critical T_c on the field theory side; this corresponds to an instability of the black hole against the charged scalar field perturbation at T_c.

We compute the HEE in these systems for strip and circular disk like subsystem in $3 + 1$ bulk.

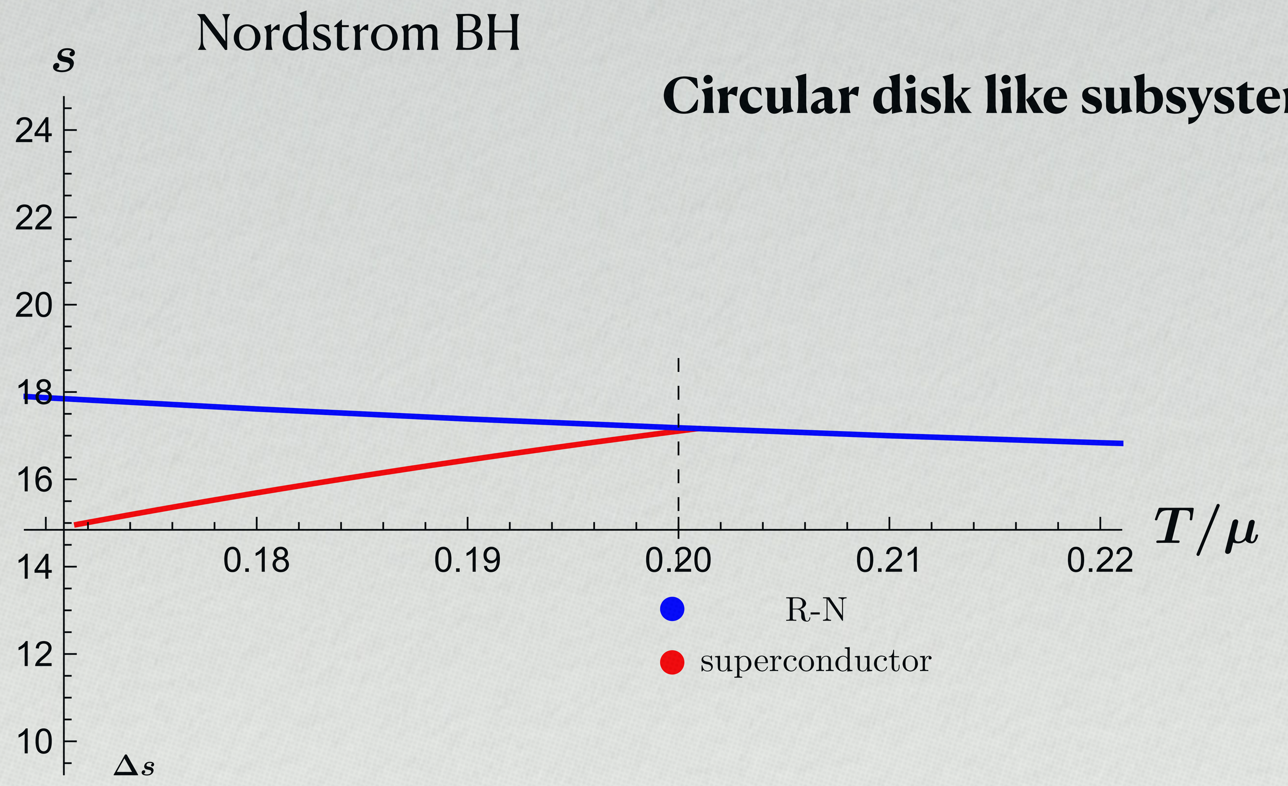
Strip like subsystem

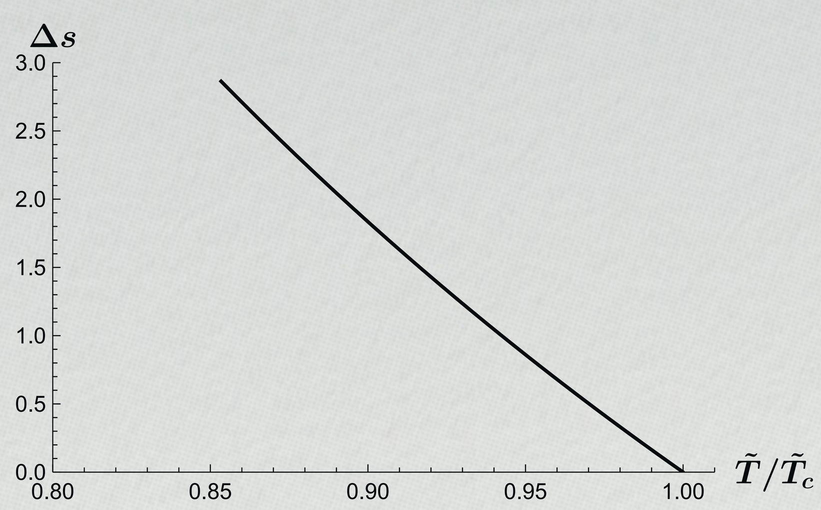


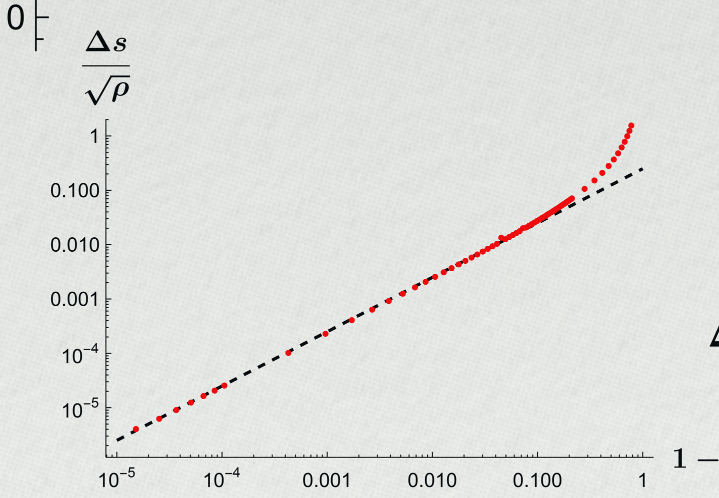


At high temp. $> T_c$, there is no charged condensate. The bulk solution is AdS Reissner-Nordstrom BH

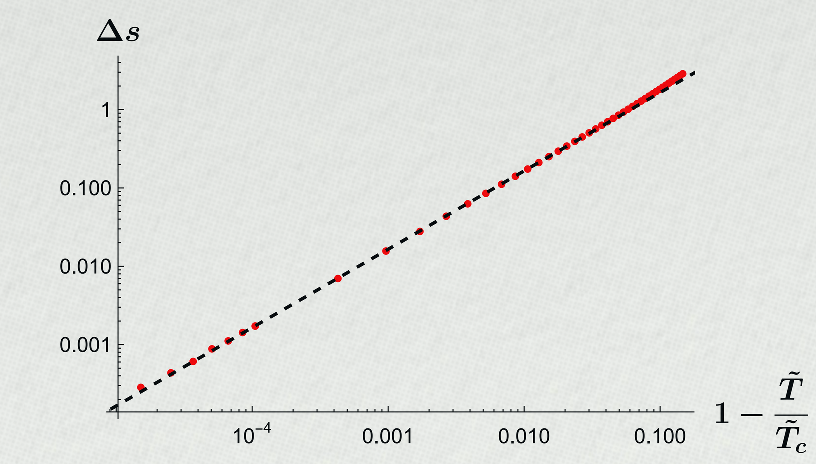
Circular disk like subsystem







$$\Delta S_E \sim \left(1 - T/T_c\right)$$



It matches with the mean free field theory result in $3 + 1$ D

References: arxiv: hep-th/2211.14271, arxiv: hep-th/ 1202.2605, arxiv: hep-th/ 1906.02452, arxiv: hep-th/ 1202.2605, arxiv: hep-th/ 0810.1563, arxiv: hep-th/0905.0932