Time Shifts via Various Double Trace Deformations

Masamichi Miyaji

hep-th/1804.xxxx

Yukawa Institute for Theoretical Physics, Kyoto University

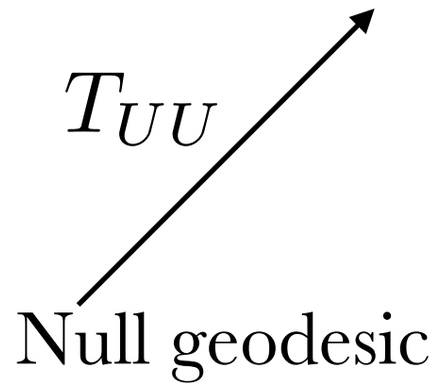
Holography, Quantum Entanglement and Higher Spin Gravity II
Mar.14th-16th, 2018 @ YITP, Kyoto U

Averaged Null Energy

(Achronal) Averaged Null Energy Condition

For every complete achronal null geodesic γ,

$$\int_\gamma dU T_{UU} \geq 0$$



- Proven for states of unitary, Lorentz invariant QFTs on flat space and static bifurcate Killing horizons.
  [Faulkner, Leigh, Parrikar, Wang (2016)]

- Existence of macroscopic traversable wormhole

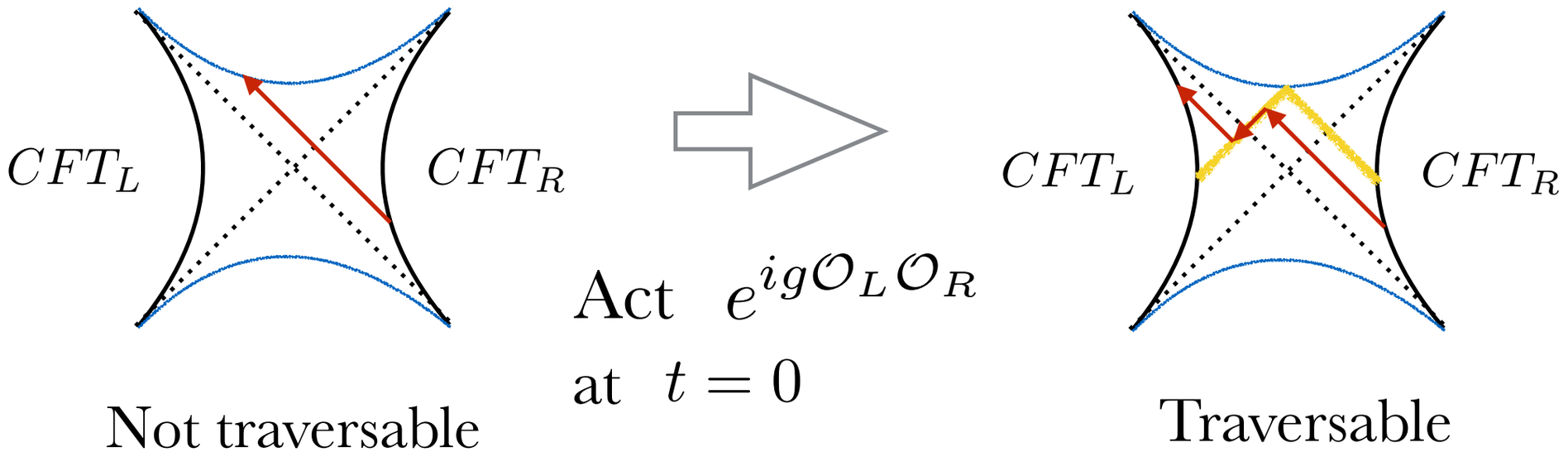
→ Negative null energy → Possible violation of ANEC
[Hochberg, Visser (1998)]

- Averaged null energy measures time shift assuming Einstein equation.

Traversable Wormhole and AdS/CFT

Non local double trace deformation [Gao, Jafferis, Wall] [Maldacena, Stanford, Yang]

Two sided black hole has non-traversable wormhole.



- Null rays from one boundary can reach another after deformation.
- Non-traversable wormhole → Traversable wormhole
- Explicit reference of time → No time machines!

What to do

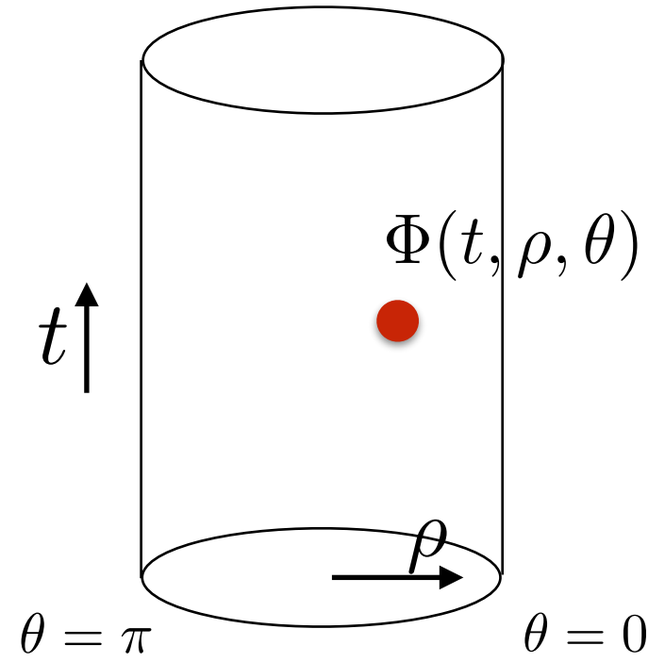
We study ANE with various kinds of double trace deformations, and time dependent situation, in single sided situation.

Deformations

$$H + g\delta(t)\mathcal{O}(t,0)\mathcal{O}(t,\pi)$$

$$H + g\delta(t)\Phi(t,\rho_0,0)$$

$$H + g\delta(t)\Phi(t,\rho_0,0)\Phi(t,\rho_0,\pi)$$



$\mathcal{O}(t,\theta)$:boundary primary operator with dimension Δ

$\Phi(t,\rho,\theta)$:HKLL bulk local operator of $\mathcal{O}$

$$ds^2 = \frac{1}{cos^2\rho}(-dt^2 + d\rho^2 + sin^2\rho d\theta^2)$$

Motivation of this work

Why are double trace deformations interesting?

- To study traversable wormhole in AdS/CFT set up

- Entangling operation

  Tensor network, Complexity etc

- New class of quench

- To produce causally & topologically nontrivial spacetimes

  With HKLL bulk local operator deformation, it should be done more flexibly…

Boundary double trace

Hamiltonian: $H + g\delta(t)\mathcal{O}(t,0)\mathcal{O}(t,\pi)$

Negative null energy and violation of ANEC are confirmed!

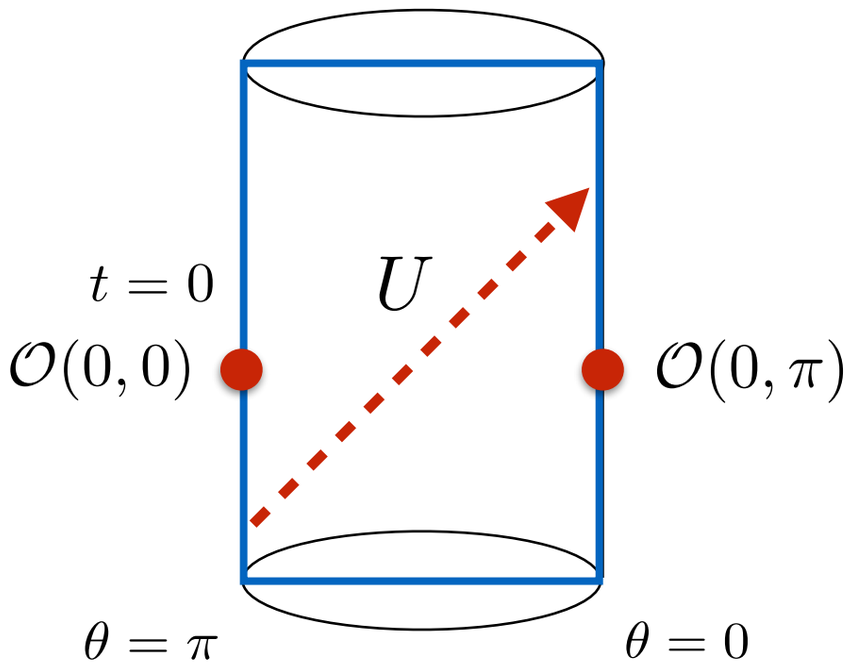
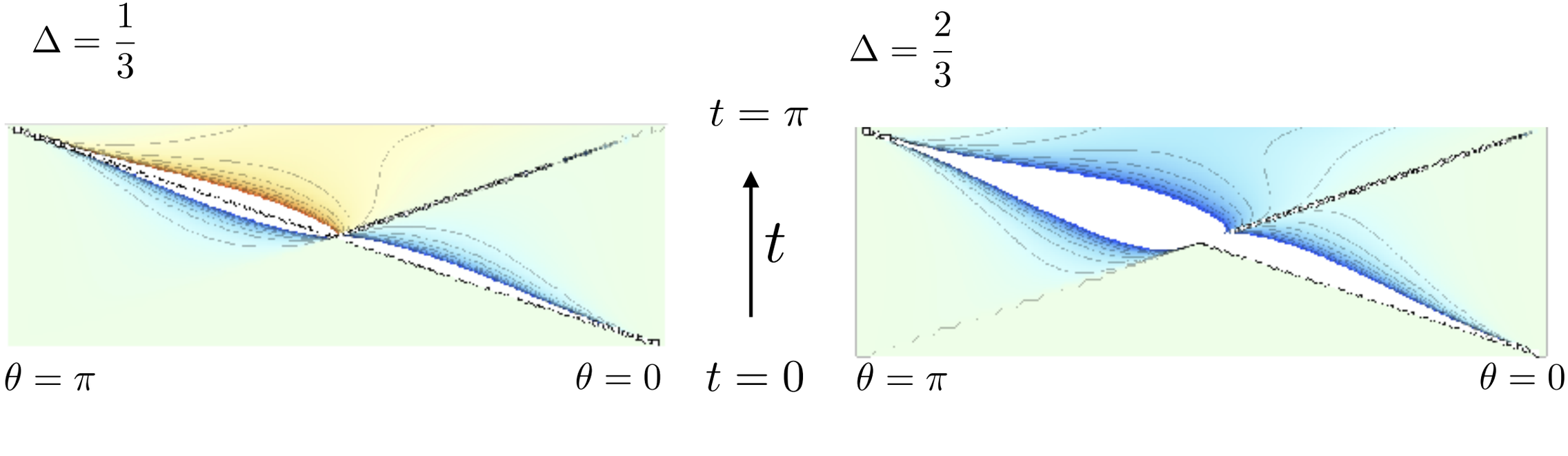


Fig. Plot of T_{UU} , in unit of g



Bulk single trace

Hamiltonian: $H + g\delta(t)\Phi(t, \rho_0, 0)$

Localized source of positive null energy is confirmed!

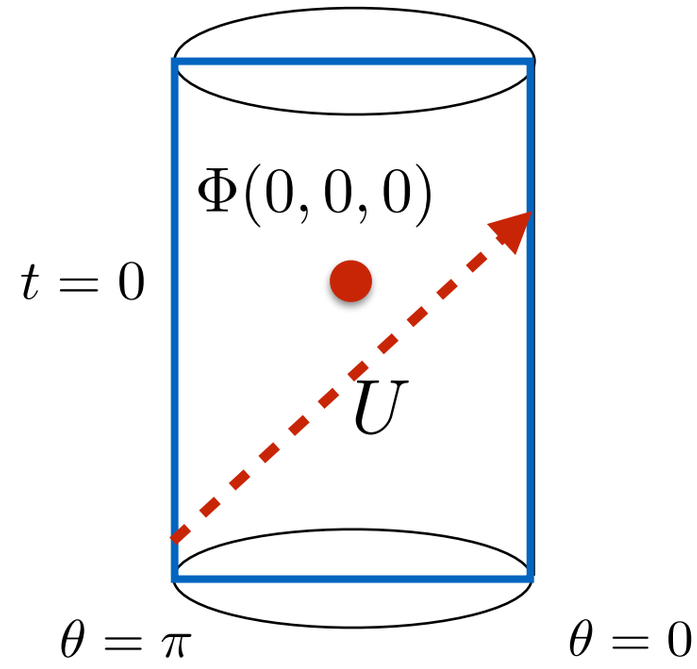
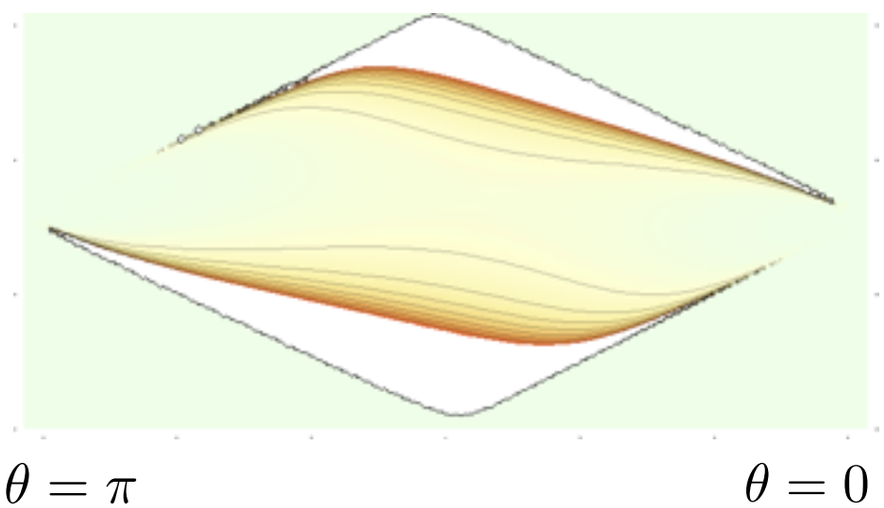
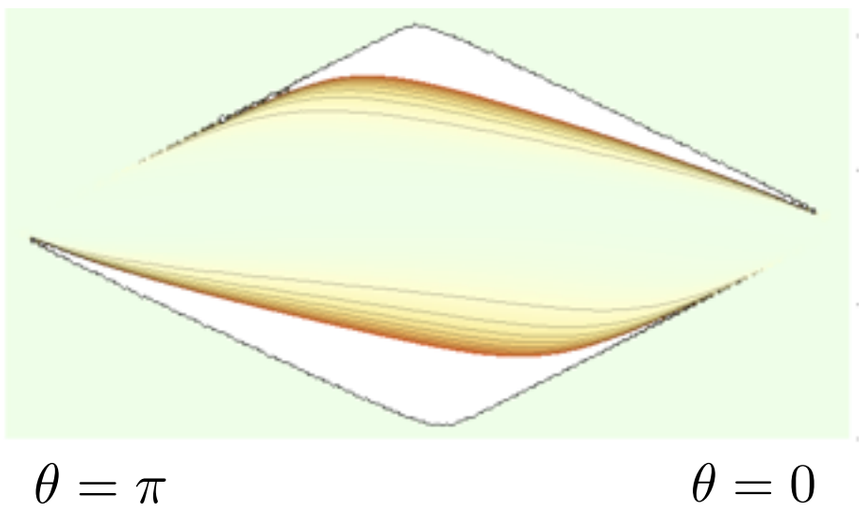


Fig. Plot of T_{UU} , in unit of g^2

$\Delta = \frac{1}{3}$



$\Delta = \frac{2}{3}$



Bulk double trace

Hamiltonian: $H + g\delta(t)\Phi(t, \rho_0, 0)\Phi(t, \rho_0, \pi)$

Localized source of negative null energy and violation of ANEC are confirmed!

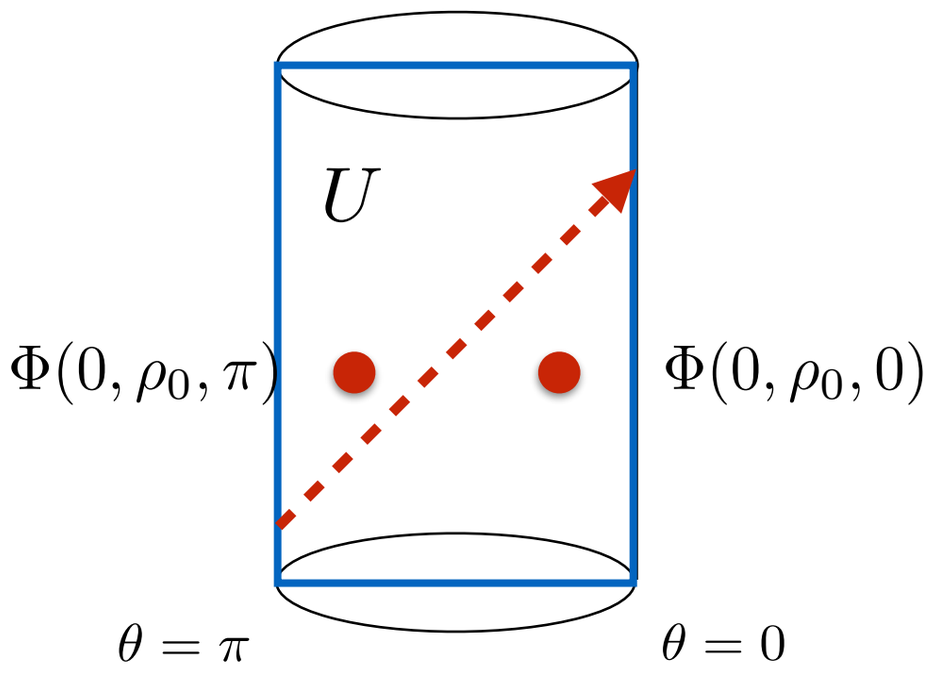
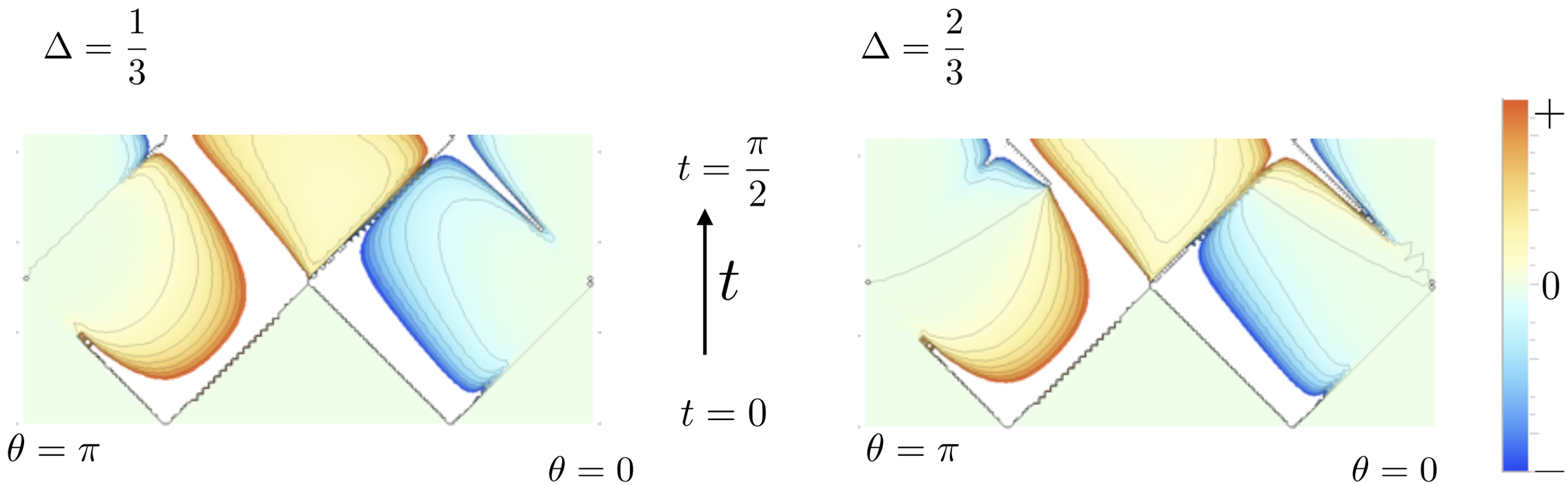


Fig. Plot of T_{UU} for $\rho_0 = \frac{\pi}{4}$, in unit of g



Ongoing generalization

- Heavy double trace deformation

$$H + g\delta(t)\mathcal{O}(t,0)\mathcal{O}(t,\pi) \qquad \Delta_{\mathcal{O}} = \mathcal{O}(c^1)$$

We need to evaluate $\langle[\mathcal{O}(\tilde{t},0)\mathcal{O}(\tilde{t},\pi),\Phi(t,\rho,\theta)]\Phi(t',\rho',\theta')\rangle$ using large c conformal block.

- More generalized double trace deformations in two sided BH_2:

$$e^{ig\mathcal{O}_L\mathcal{O}_R} \quad \Rightarrow \quad e^{ig\sum_i a_i\mathcal{O}_L(p_-^{(i)})\mathcal{O}_R(p_-'^{i})}$$

Conclusion

- We considered deformation using bulk local operator

- Deformations via bulk field induced localized source in the bulk

- Single trace deformation gives positive null energy, and double trace deformation gives negative null energy as well as negative ANE.

- Those bulk local deformations may be used to model nonlocal interactions in gravity or string theory.

Future directions

- Entanglement entropy

- Apply parallel discussion in quantum quench

- Relation to non locality of gravity

- To produce causally & topologically nontrivial spacetimes as initial conditions