HOLOGRAPHIC QUENCHES WITH A GAP

Esperanza Lopez

together with E. da Silva, J. Mas and A. Serantes, arXiv:1604. 08765

Quenches & revivals in holography

quantum quench $H_0\ ,\ |\Psi_{gs}\rangle_{H_0} \longrightarrow H\ ,\ |\Psi(t)\rangle_H$

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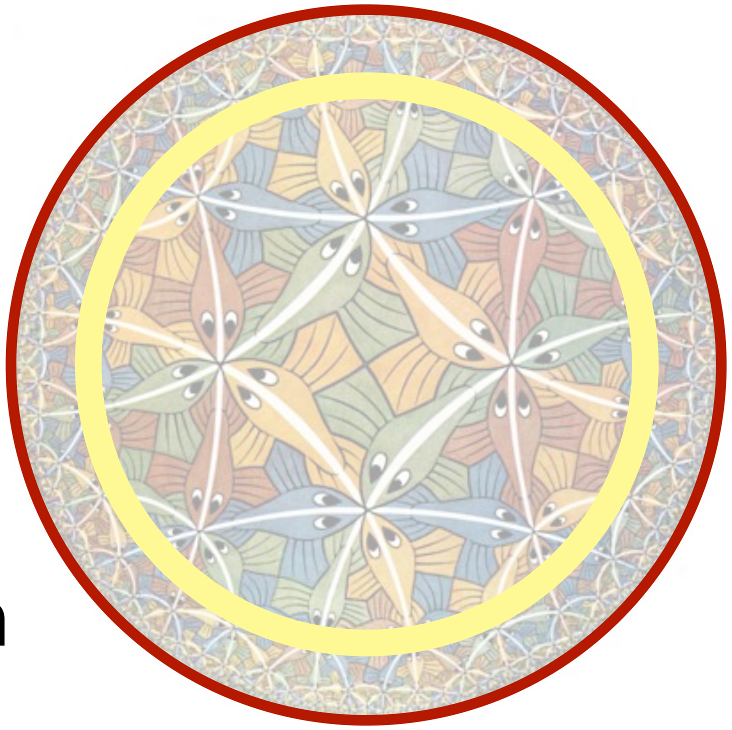

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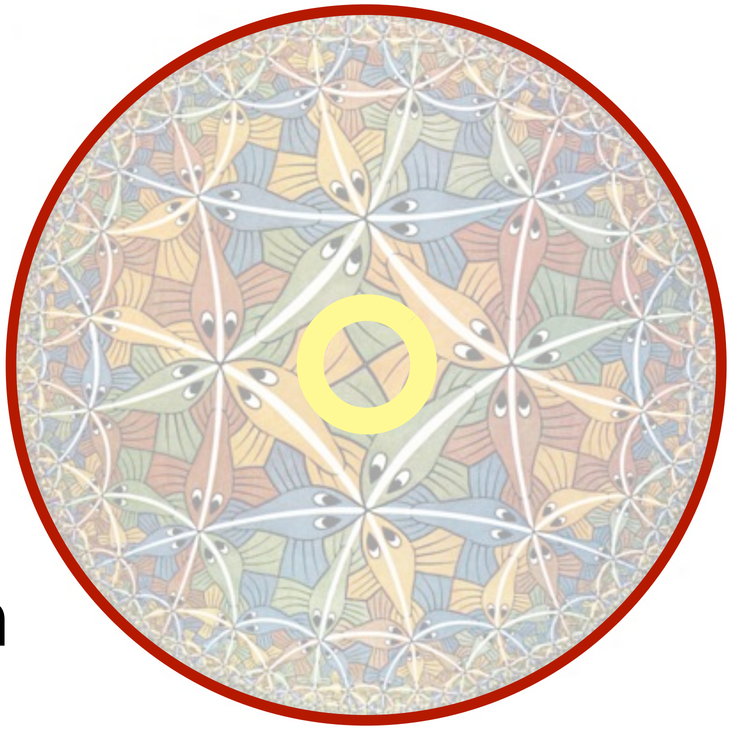

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reflecting boundary

bouncing geometries in AdS

(Bizon, Rostworowski 2011; Buchel, Lehner, Liebling, 2012;......)

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↕ (Abajo, da Silva, Lopez, Mas, Serantes, 2014)

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compare with results from other approaches:
tensor networks

The model

quench dynamics of a 1+1 massive QFT

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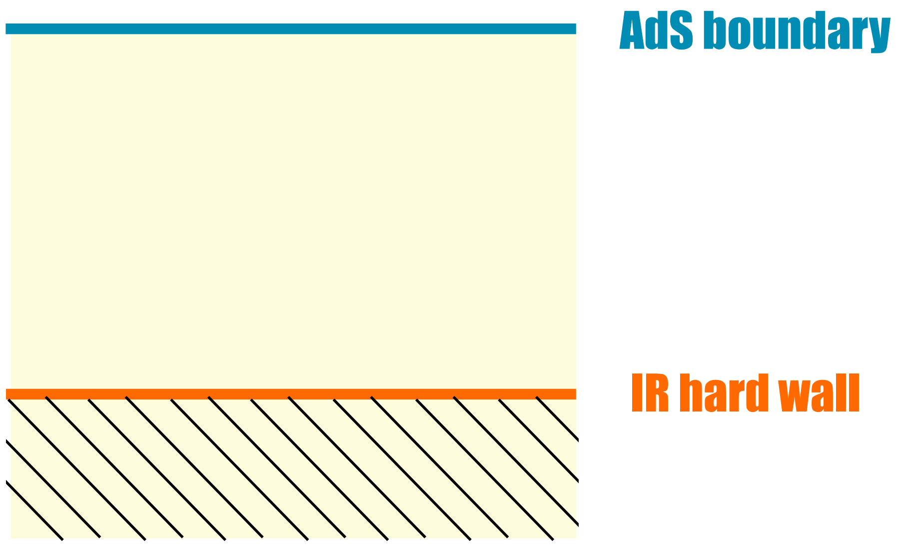
AdS_3 with an IR cutoff + massless scalar



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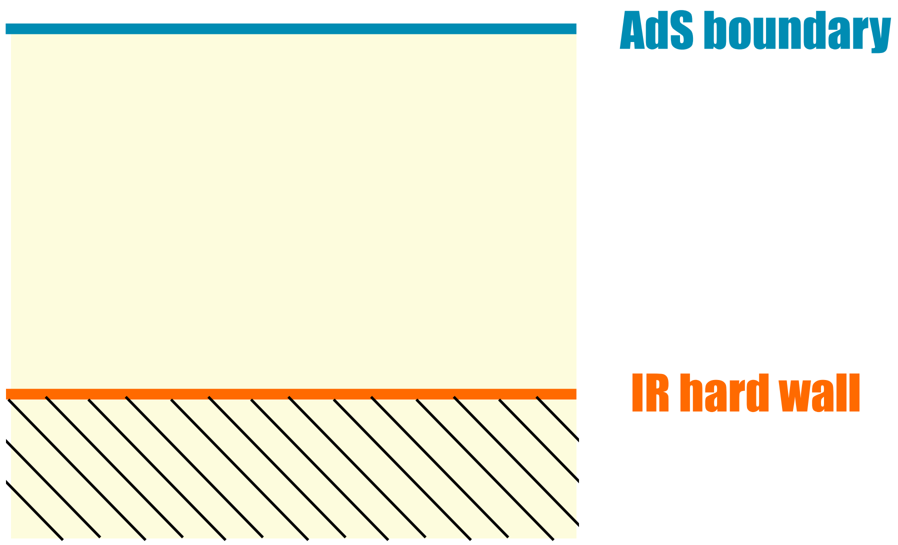

D,N boundary conditions at the wall

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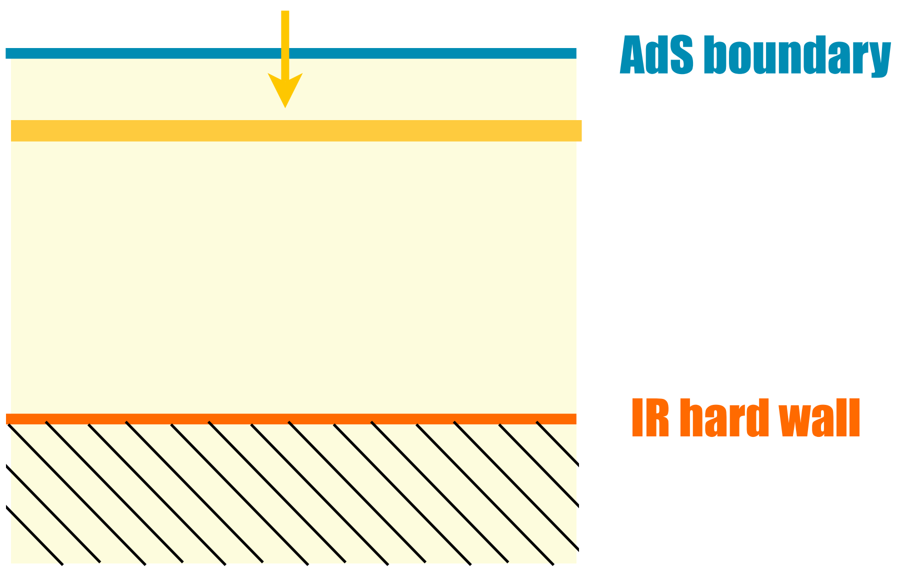

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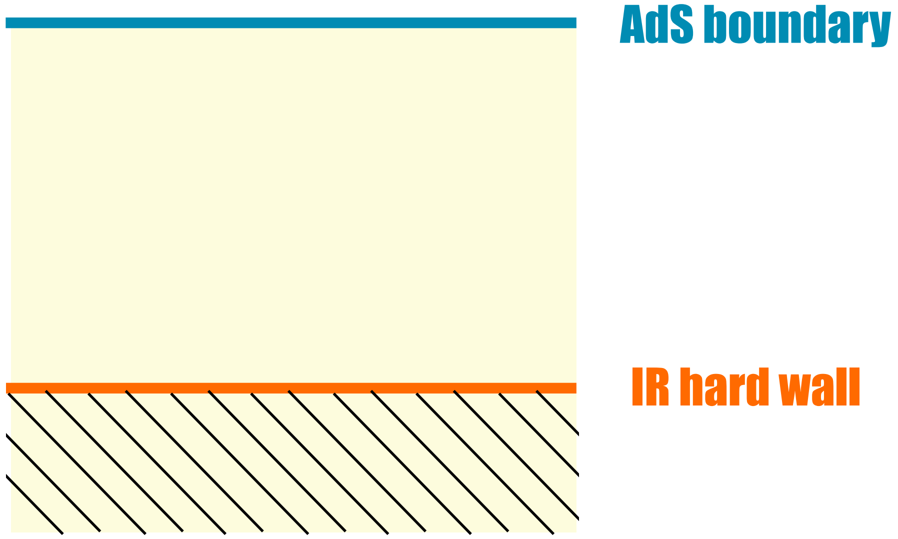

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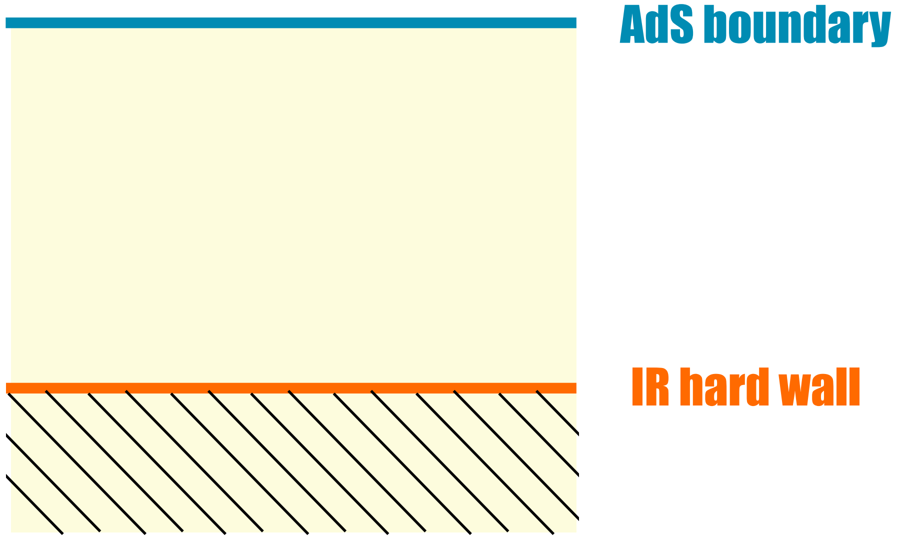

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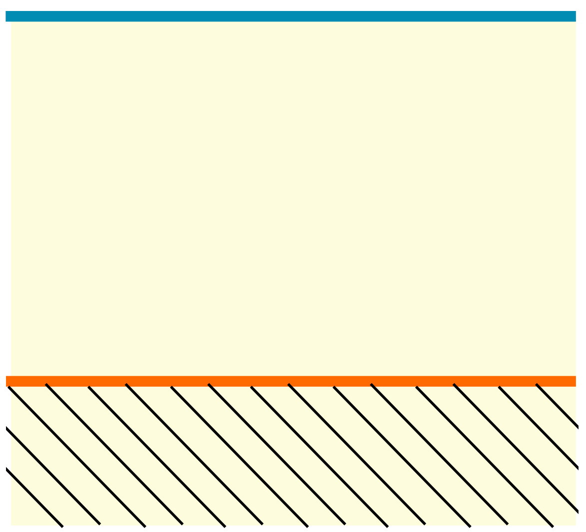

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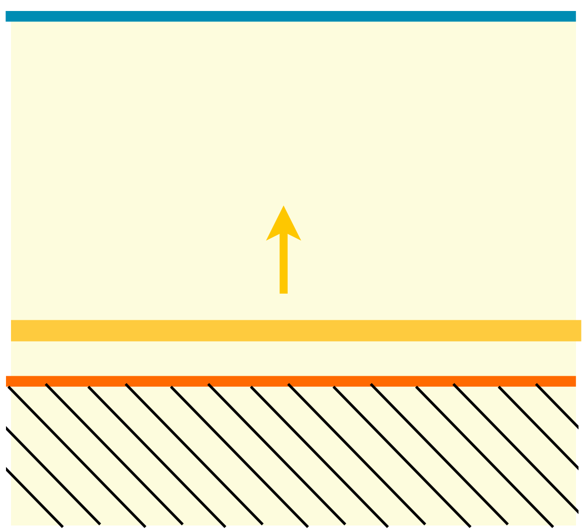

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$\Delta t <$ IR scale

out of equilibrium

Static solutions with Φ=0

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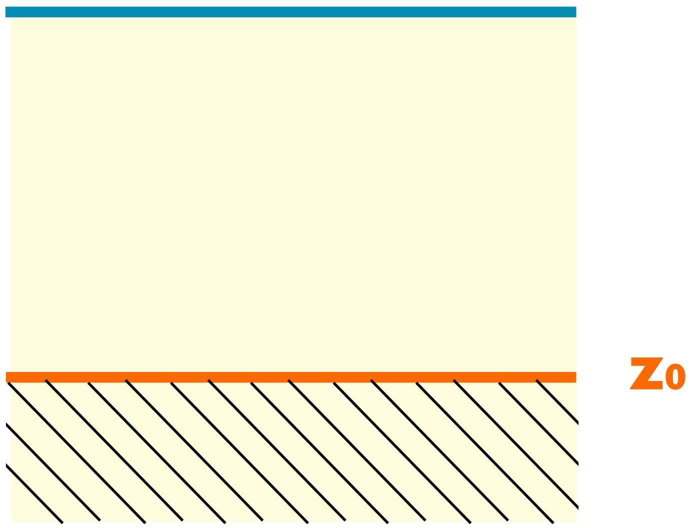

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$M_0 z_0^2 > 1$: **black hole**

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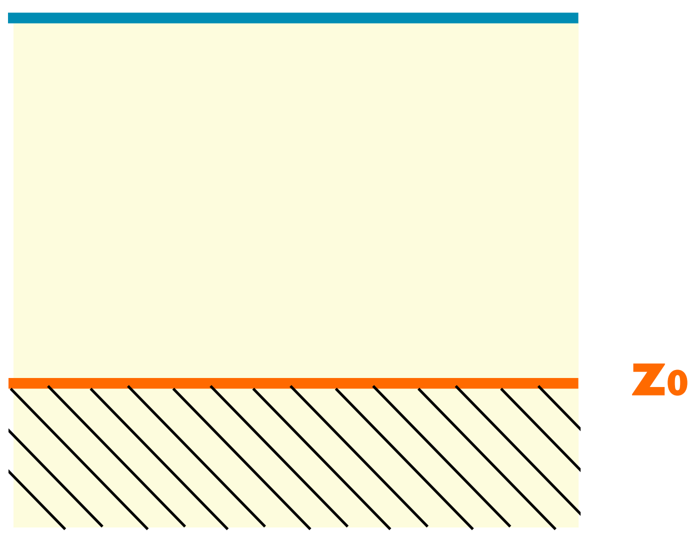

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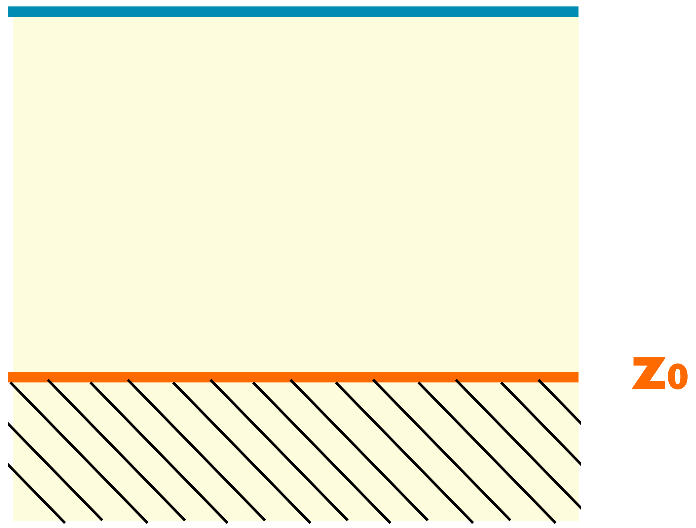

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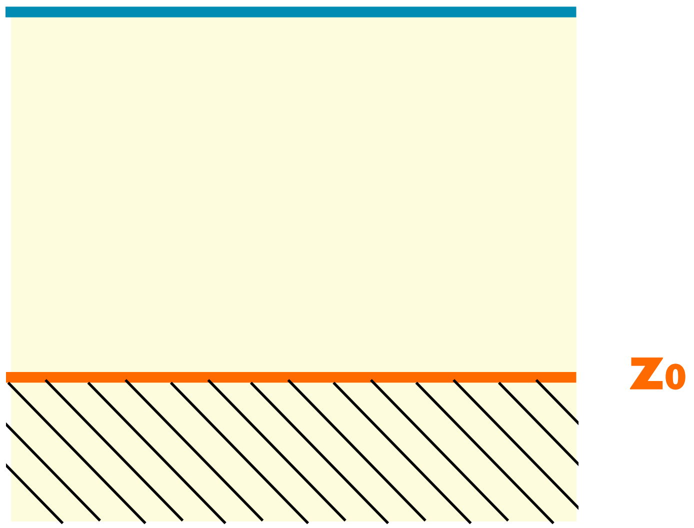

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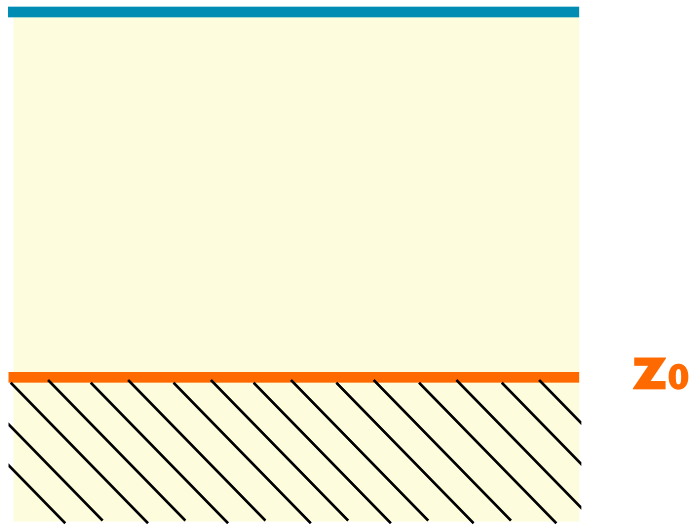

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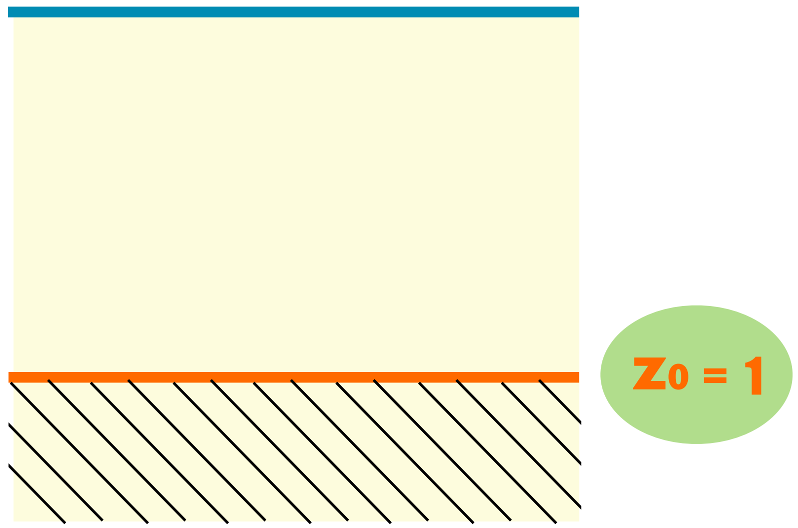

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Dirichlet bc at the wall :

static solutions with a non-trivial scalar profile

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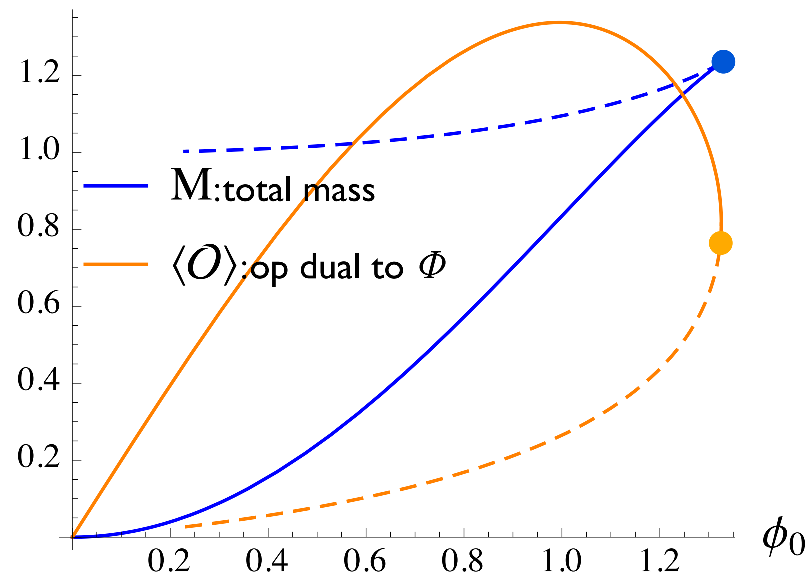

given M_0

solitons up to a threshold Φ_0 (M_0)

stable and unstable branches

stable solitons with M>1

Φ_0 : scalar field at the wall

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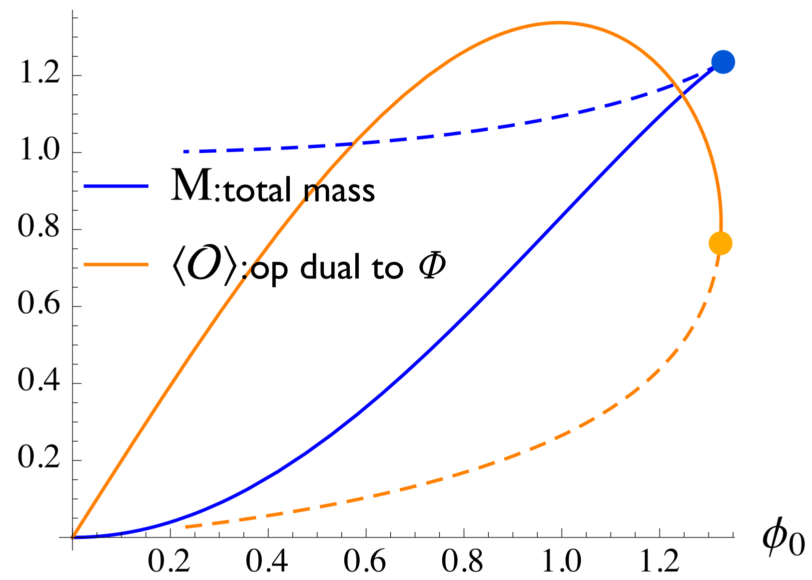

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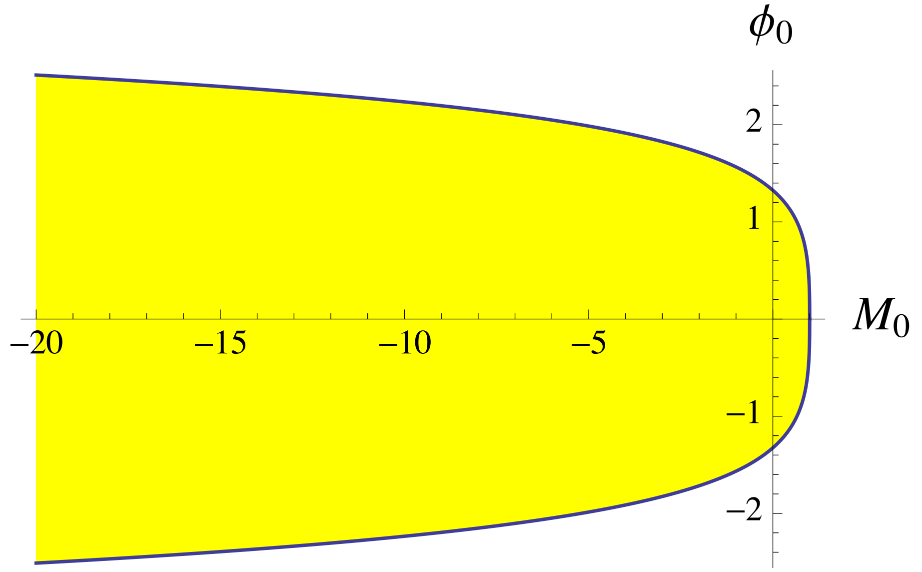

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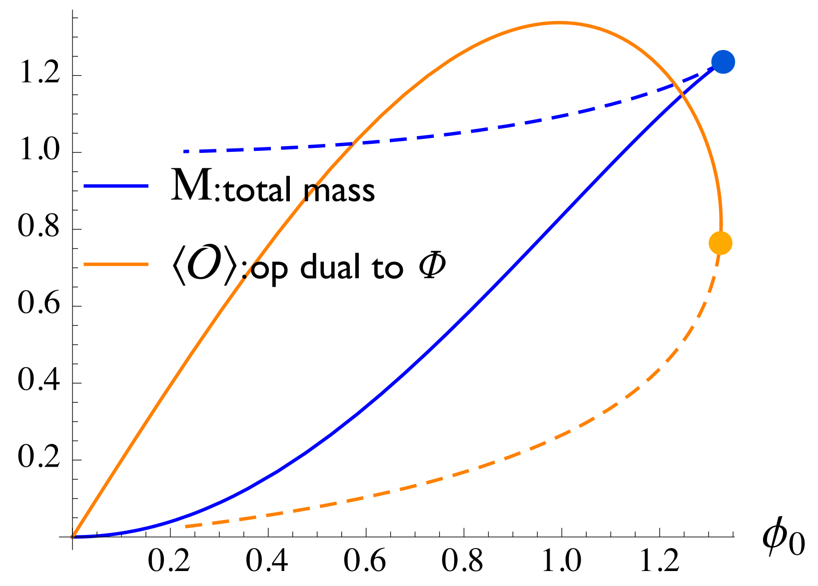

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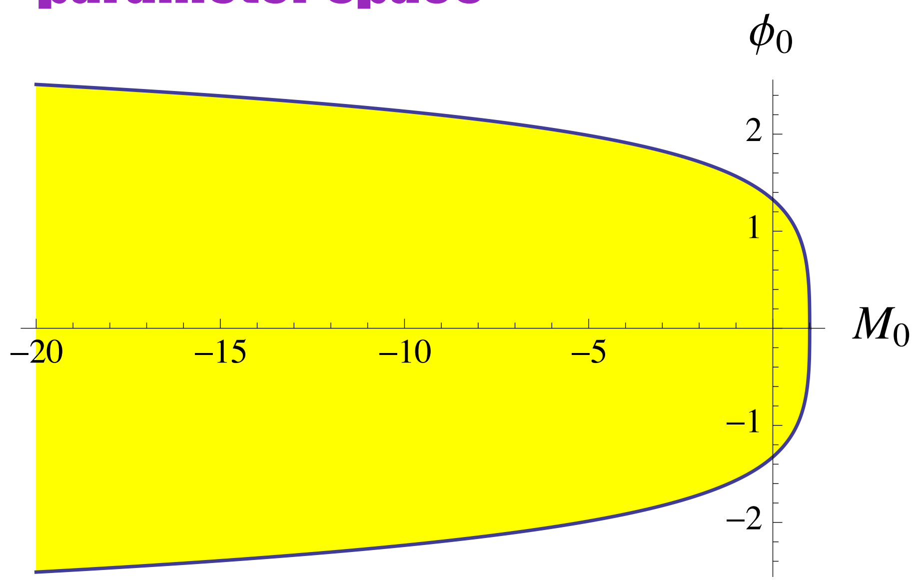

boundary conditions can not be changed by bulk dynamics

{ M_0 , Φ_0 } = **couplings**

solitons = vacua

Mass gap

lowest pole of 2-point function

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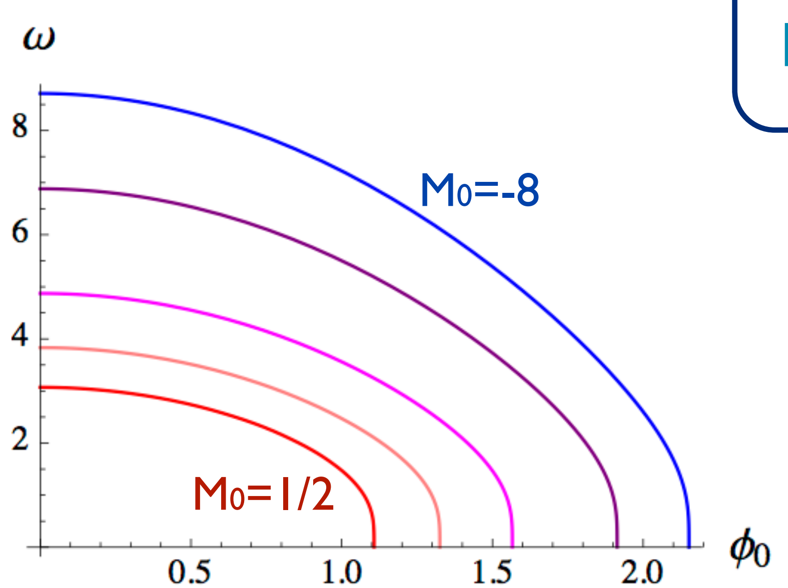
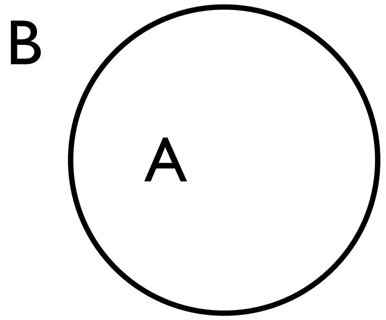


the gap increases with negative M_0,
closes up with growing Φ_0

Entanglement entropy

$$S(A) = -\mathrm{Tr}\, \rho_A \log \rho_A$$



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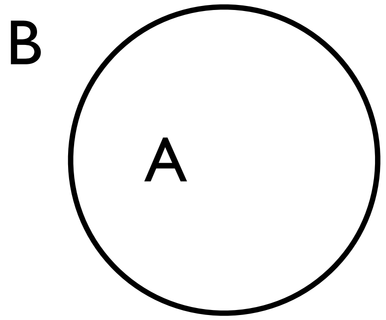

Area law

$S(A) \propto \partial A$

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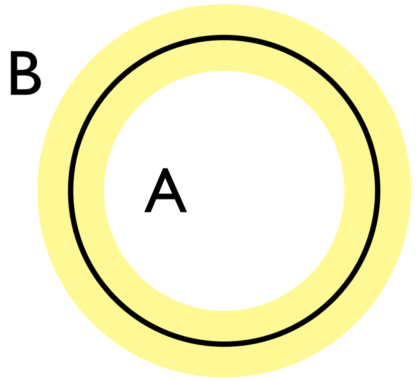

ξ : correlation length

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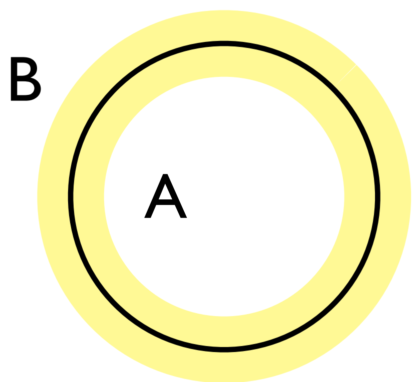

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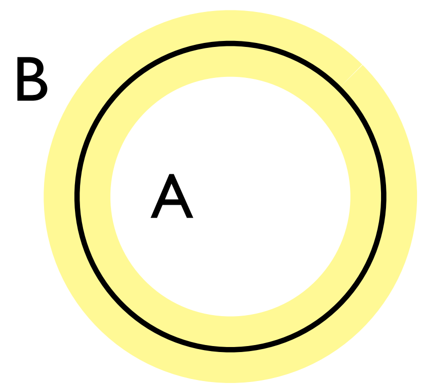

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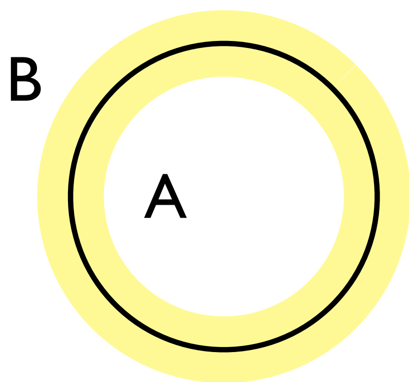

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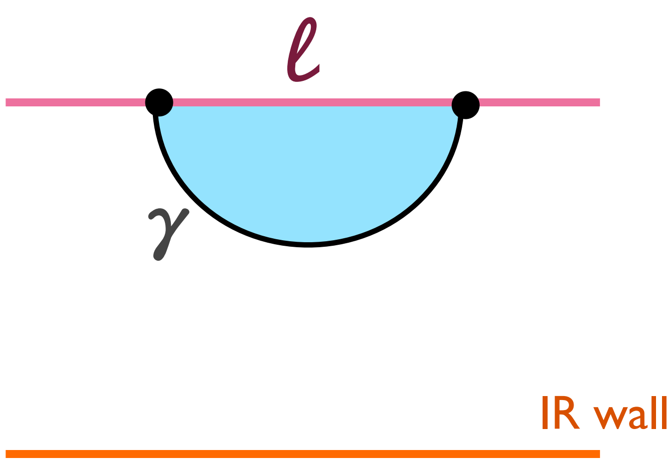

$S(\ell) \propto \mathrm{length}(\gamma)$

(Ryu, Takayanagi, 2006)

ℓ homologous to γ

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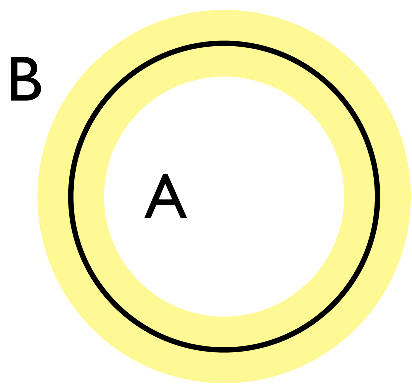

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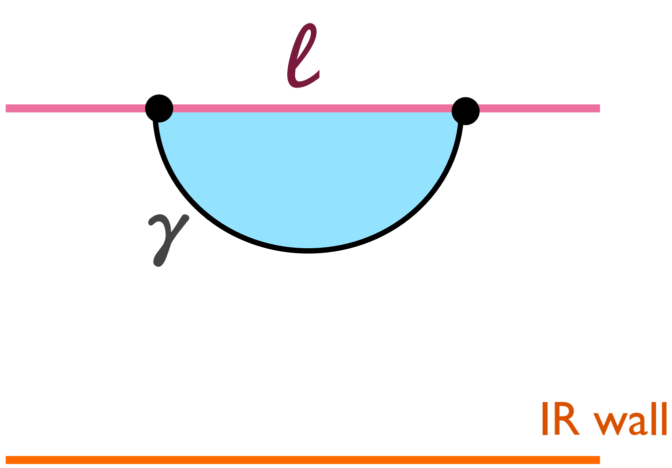

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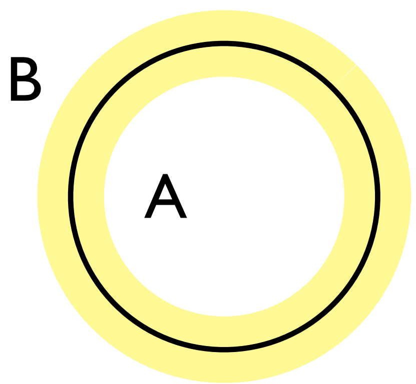

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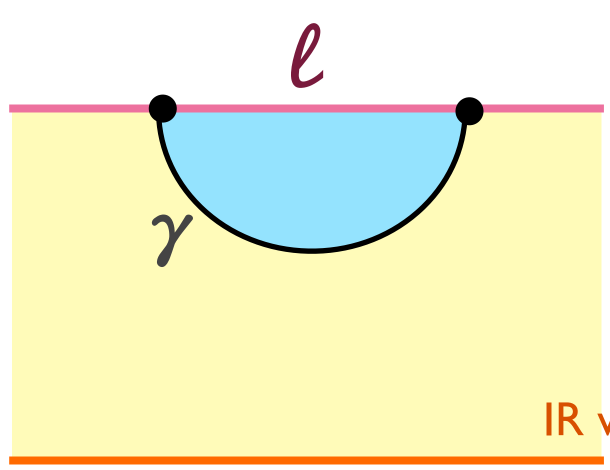

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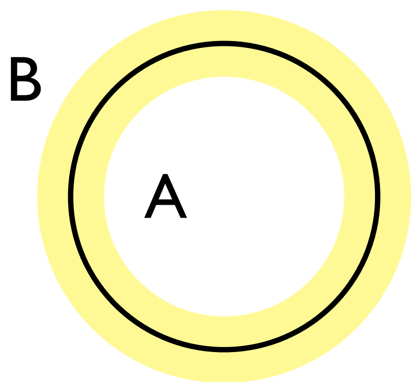

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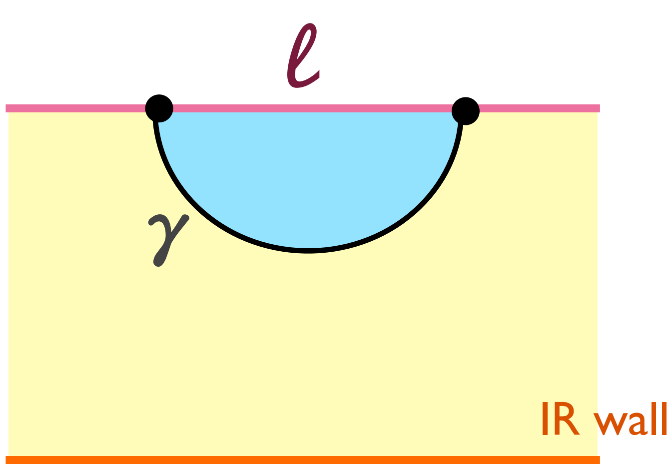

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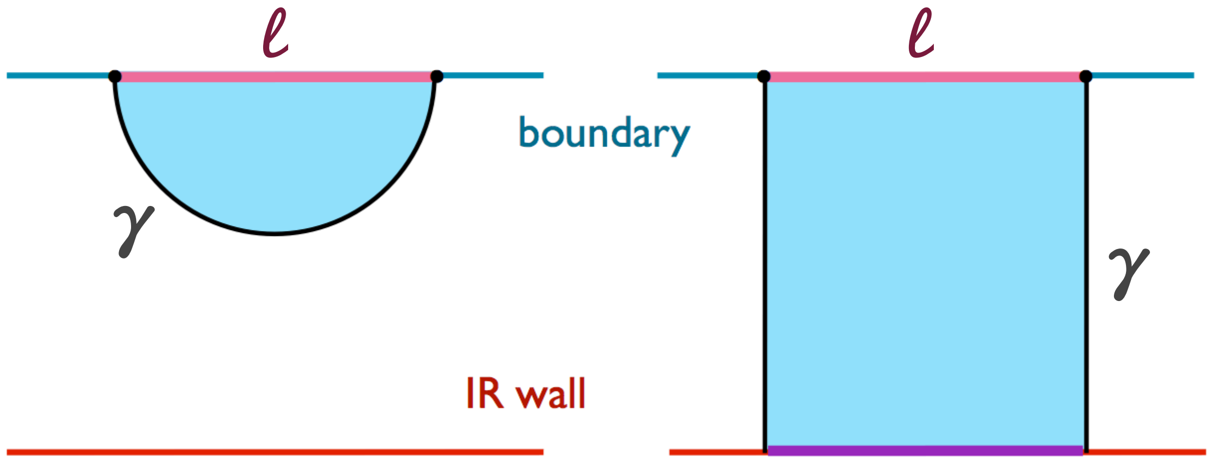
pure state
$S(A)=S(B)$

in the absence of horizons: **pure states**

Correlation length



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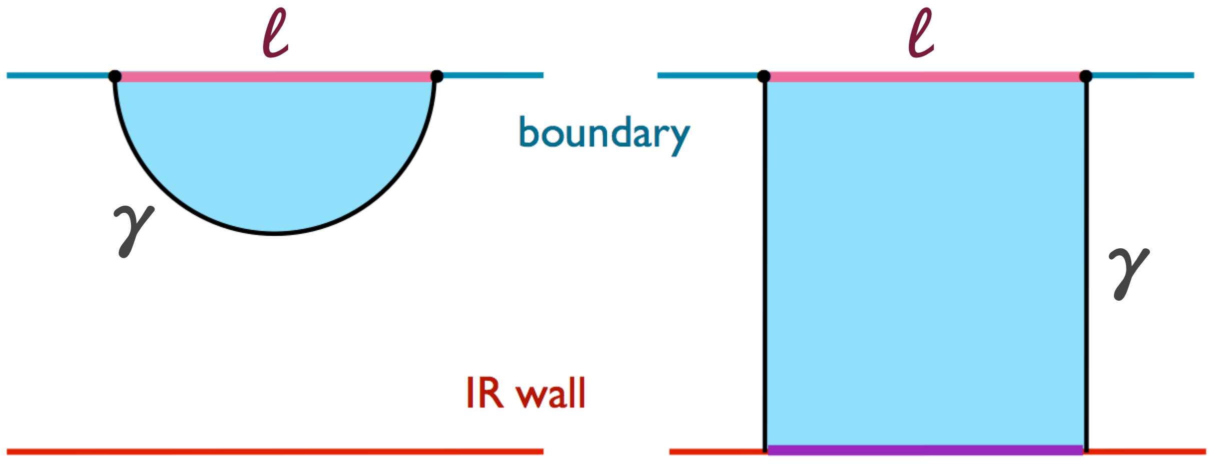

$S(\ell) \propto \log(\ell)$

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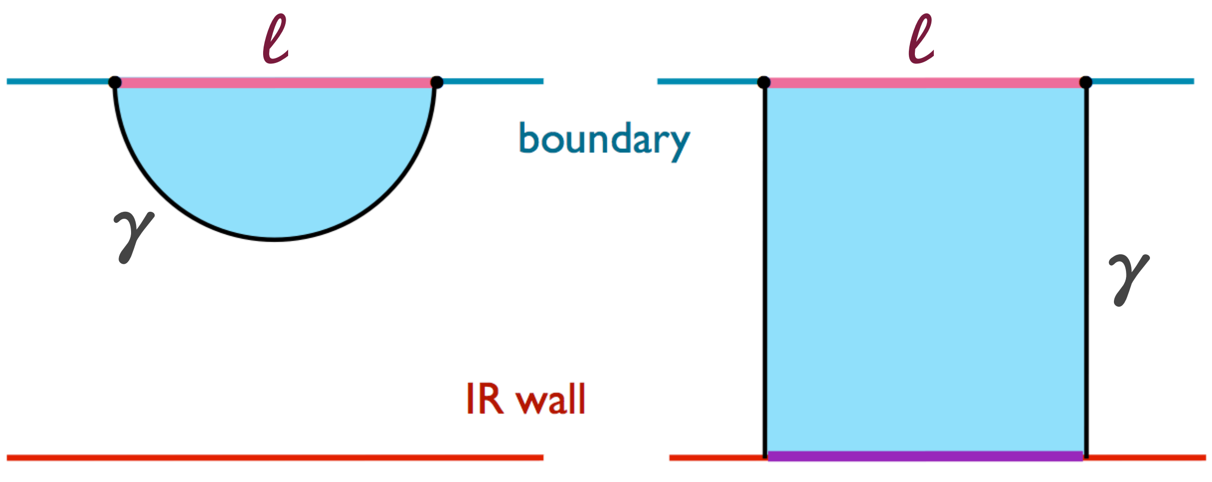

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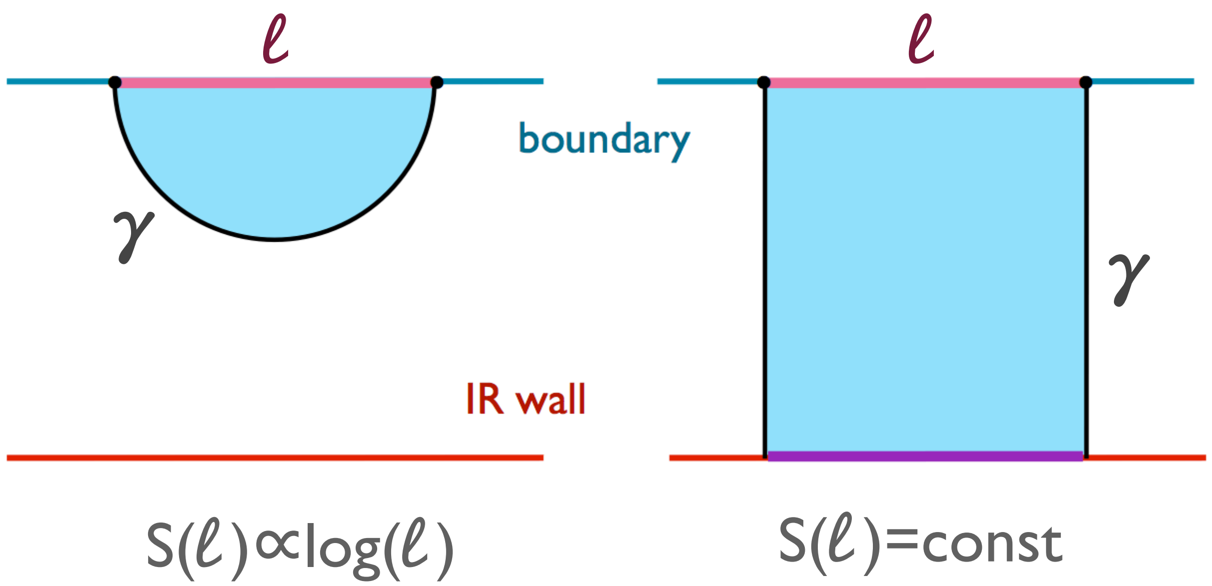

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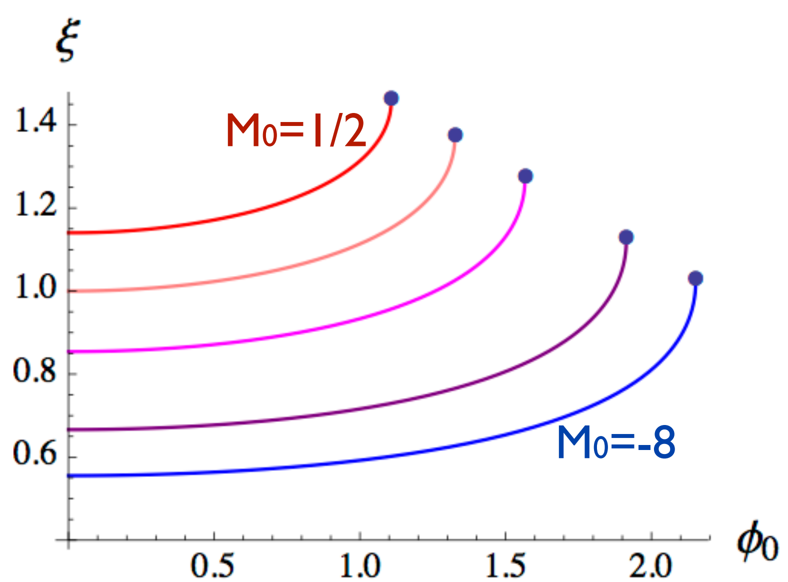

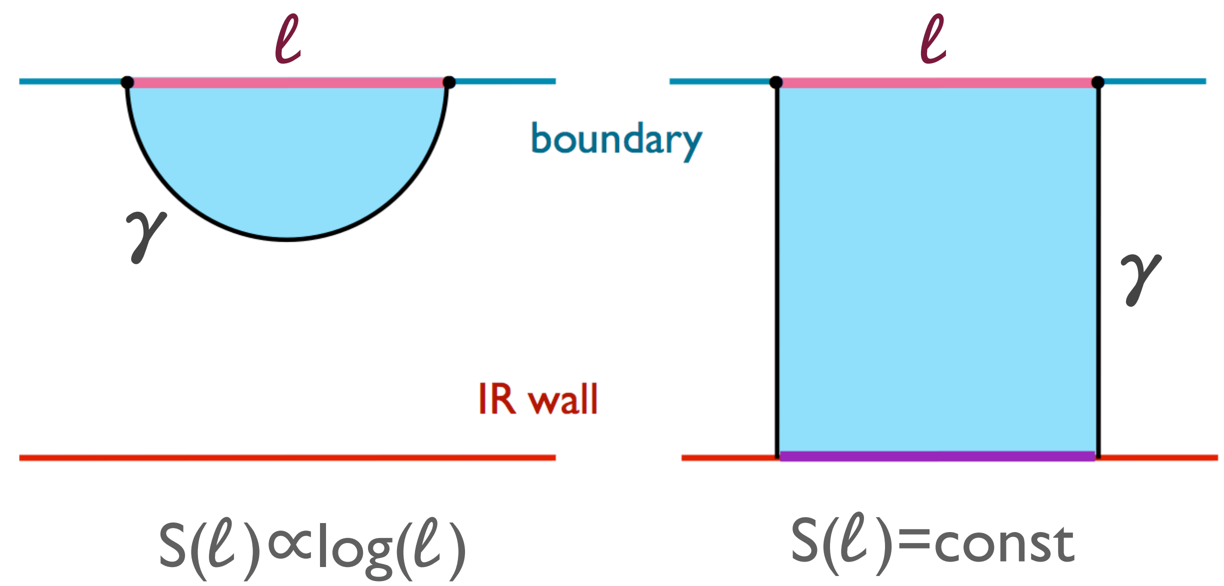

ξ decreases with negative M_0, increases with Φ_0

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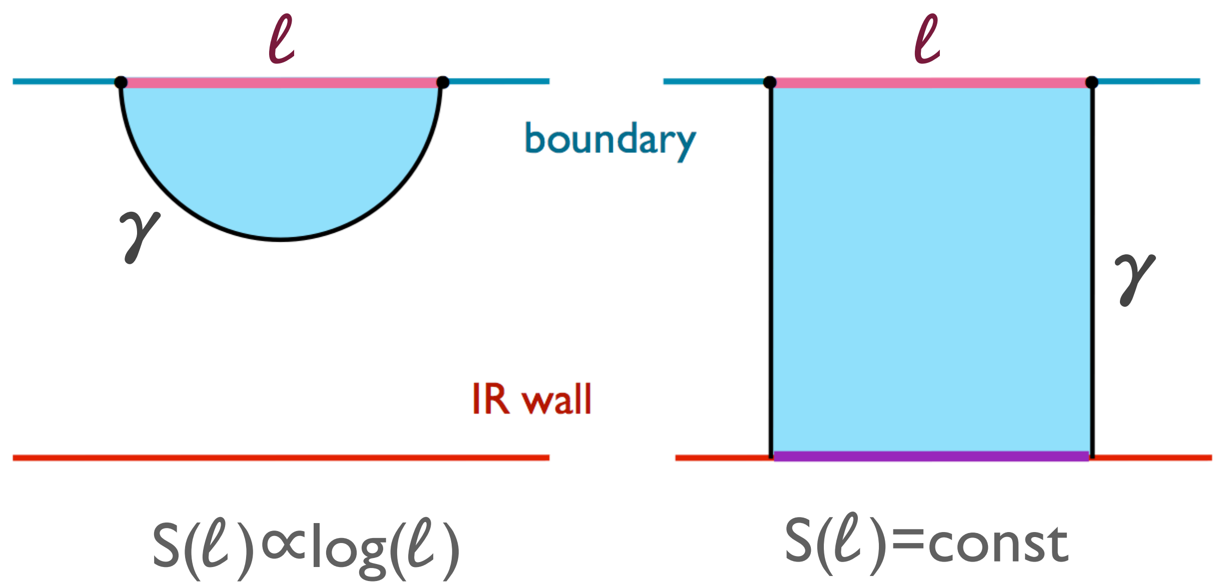

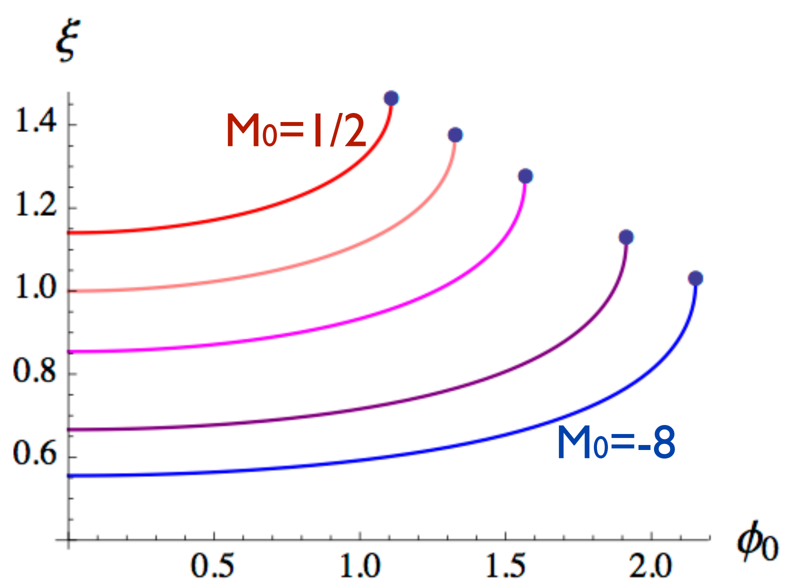

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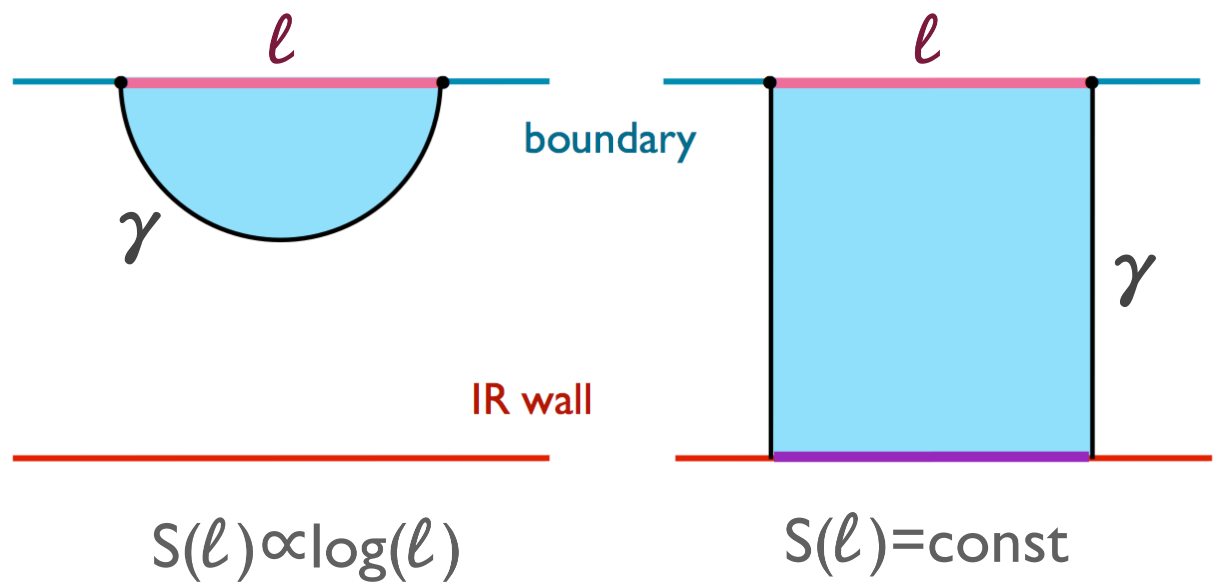

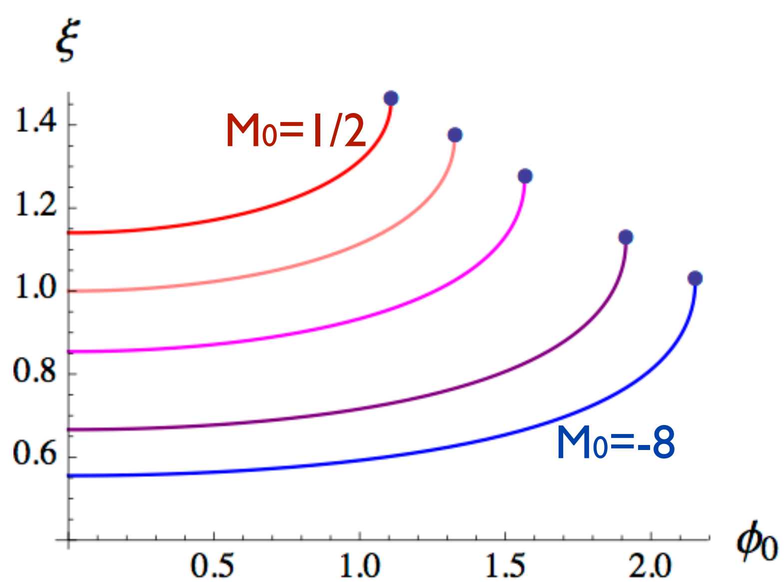

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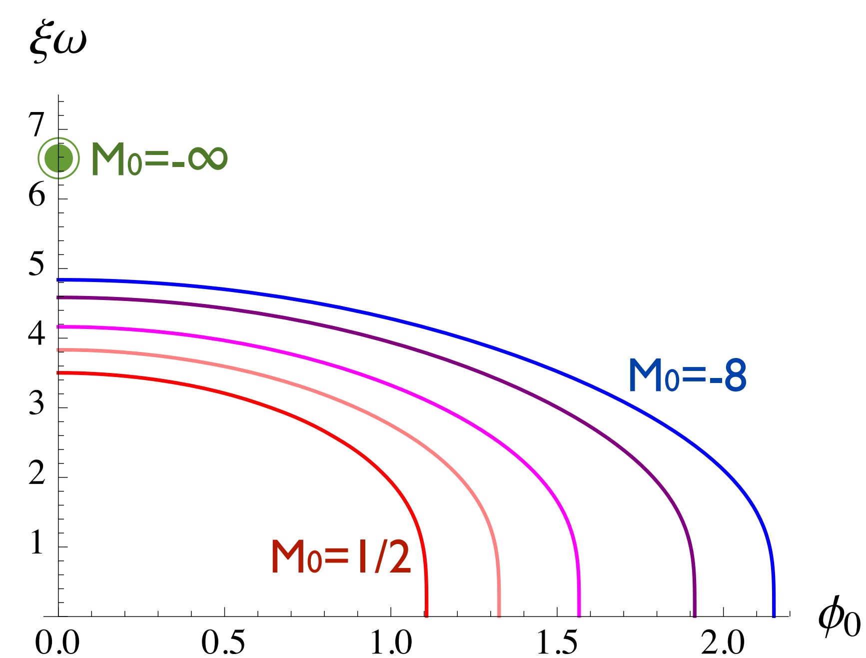

Holographic quench

simple gapped model with 2 couplings, which control IR physics

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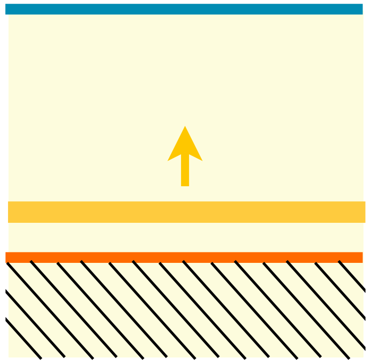
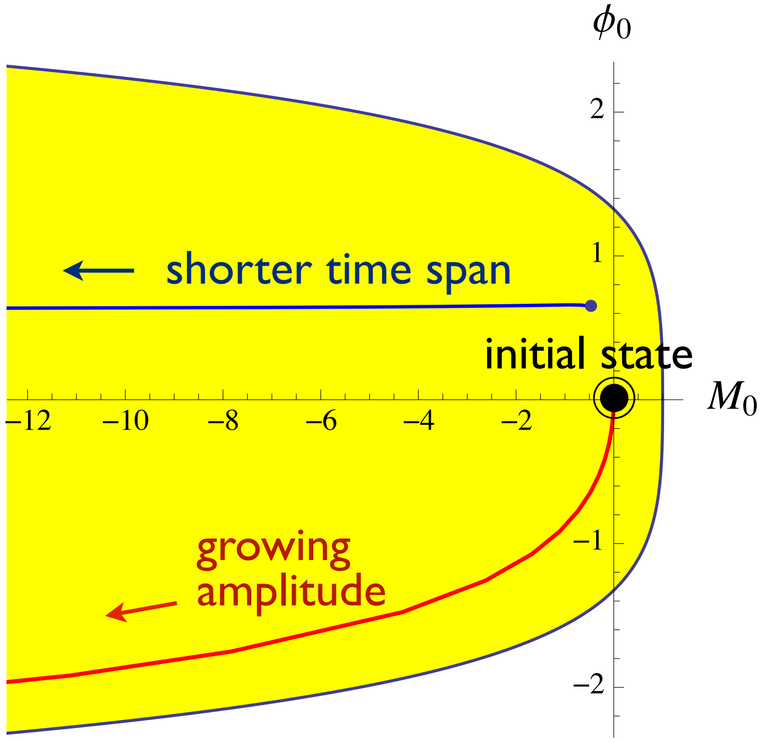


M = M0 + MΦ = const

energy exchange



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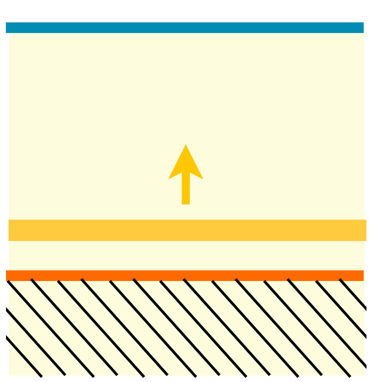
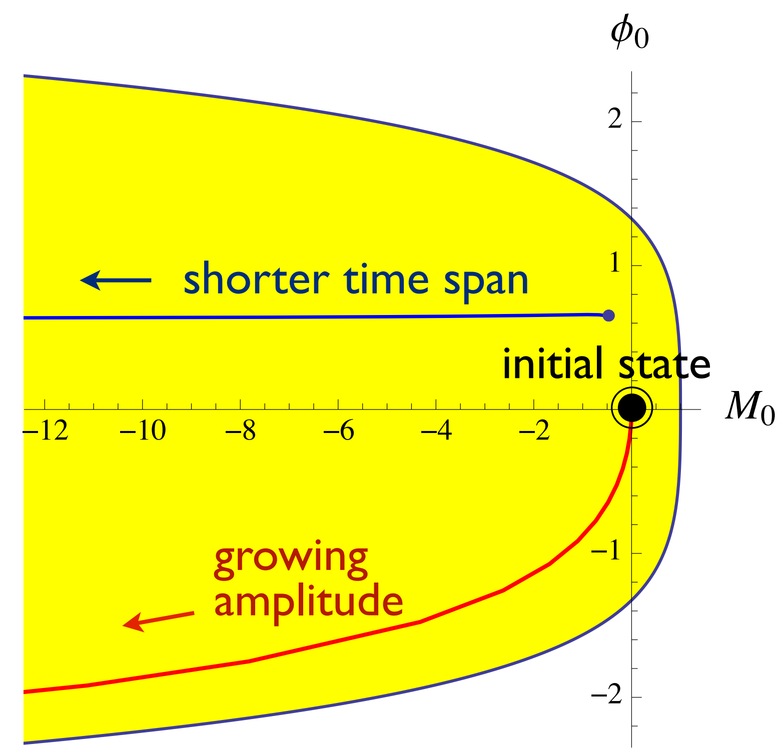


M<1 : ever bouncing



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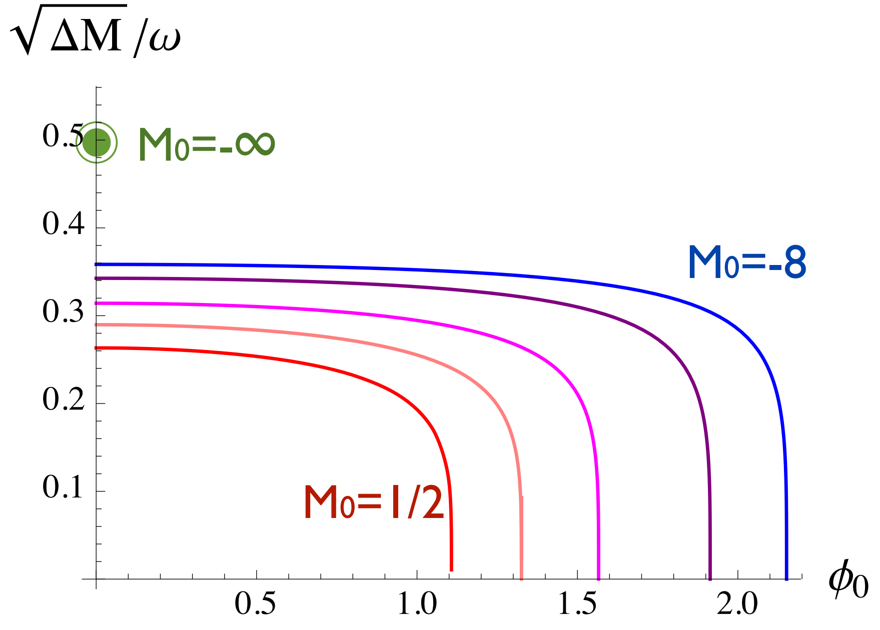

Decoding oscillating geometries

associated field theory state *mechanism behind revivals*

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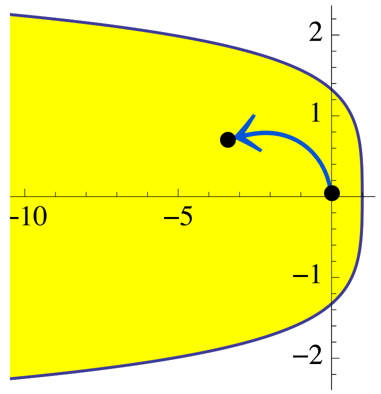

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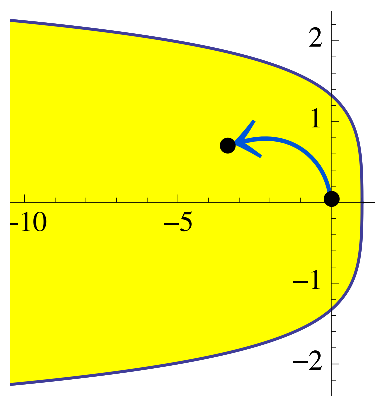

$\tilde{\alpha} > 1$: adiabatic change

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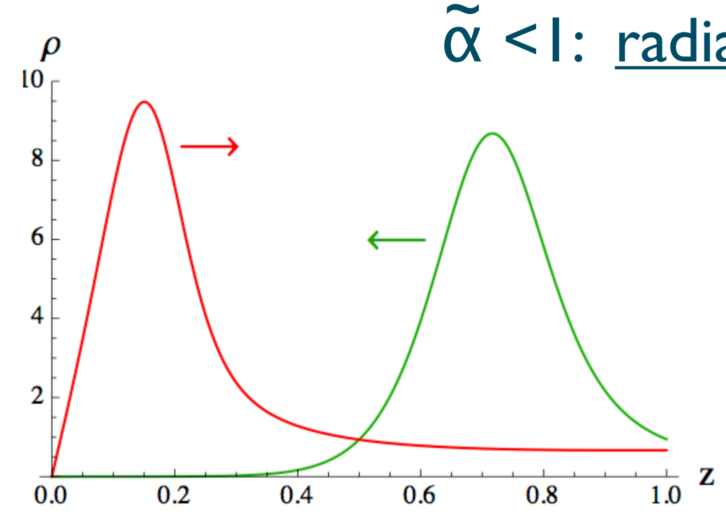

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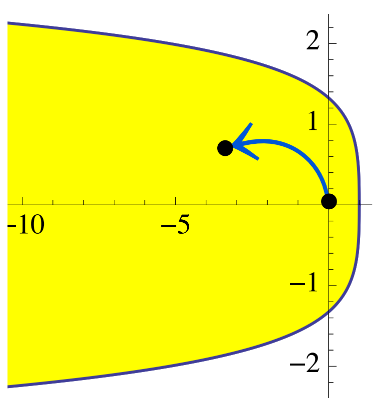

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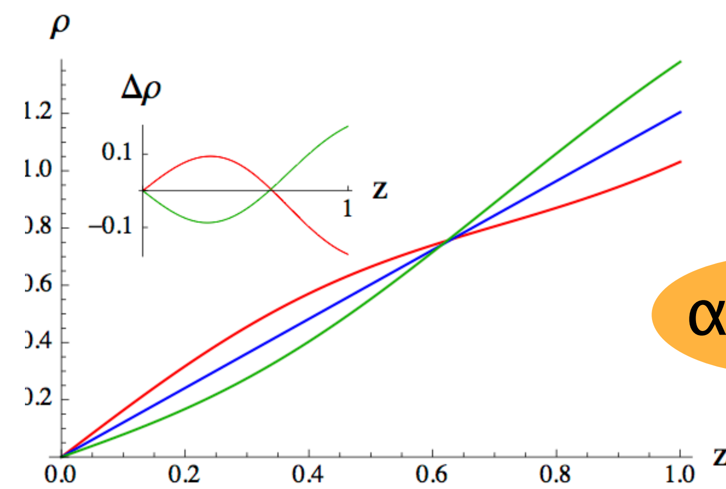
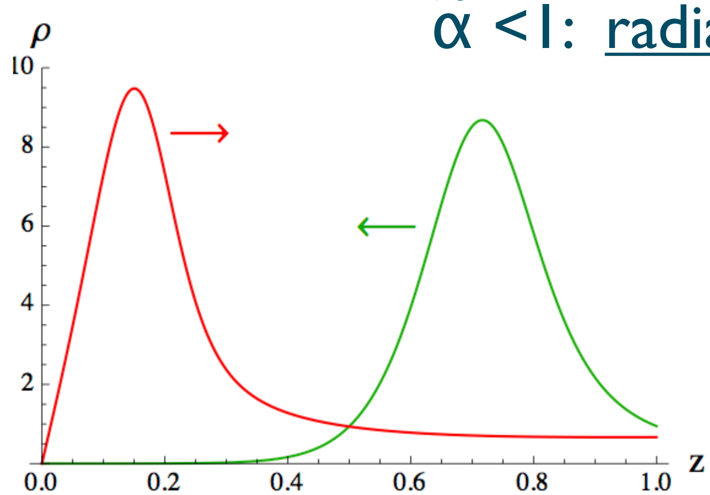


$\alpha = 0.8$

$\tilde{\alpha} \approx 1$: standing wave

$\tilde{\alpha} < 1$: radial localization



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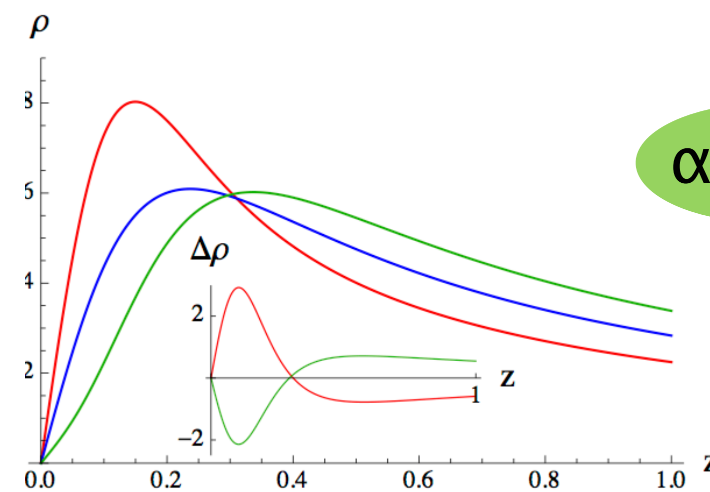

$\alpha = 0.2$

Energy density

energy density above vacuum normalized to that for fast thermalization

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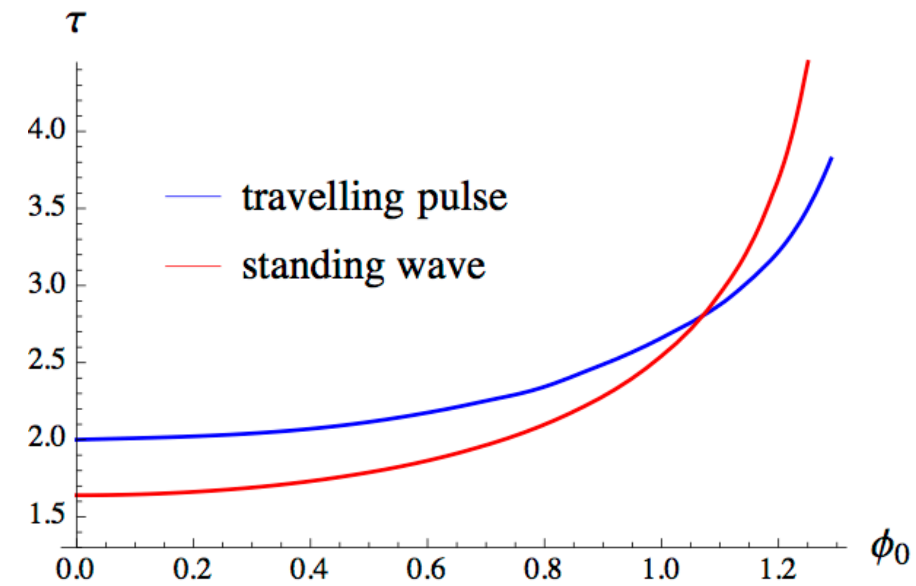
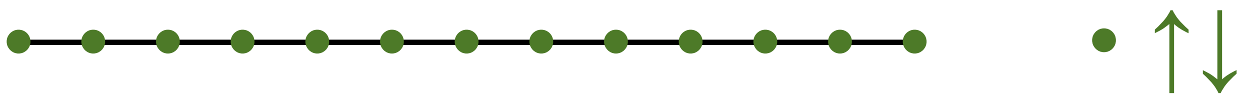
larger far from stability threshold



Tensor networks

variational ansatz for QFT states
based on entanglement properties

$$|\Psi\rangle = \sum c_{i_1 i_2 \ldots i_N} |i_1 i_2 \ldots i_N\rangle$$



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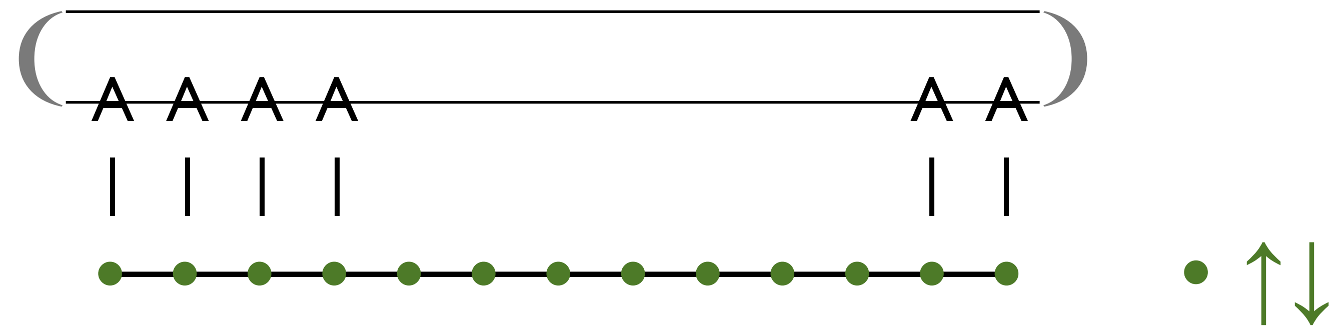

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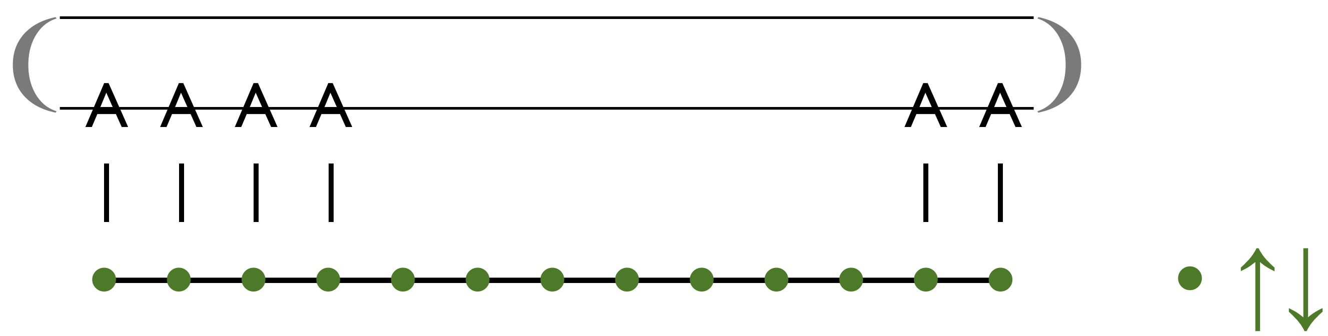

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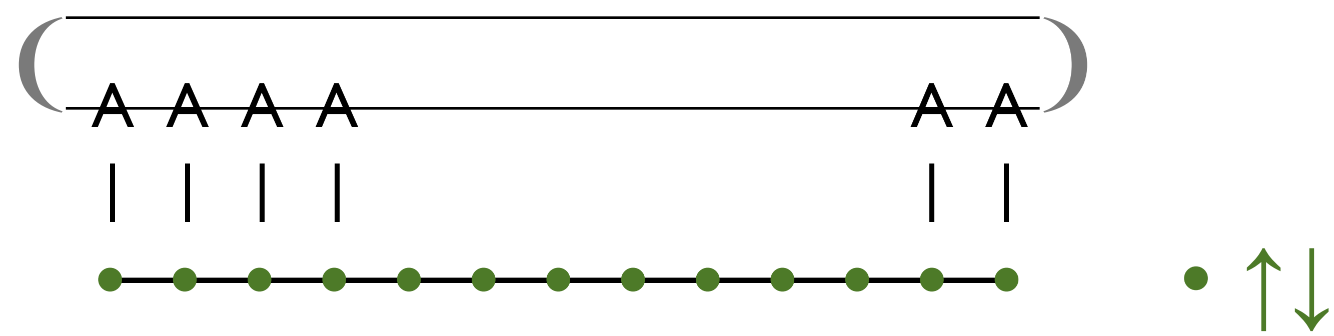

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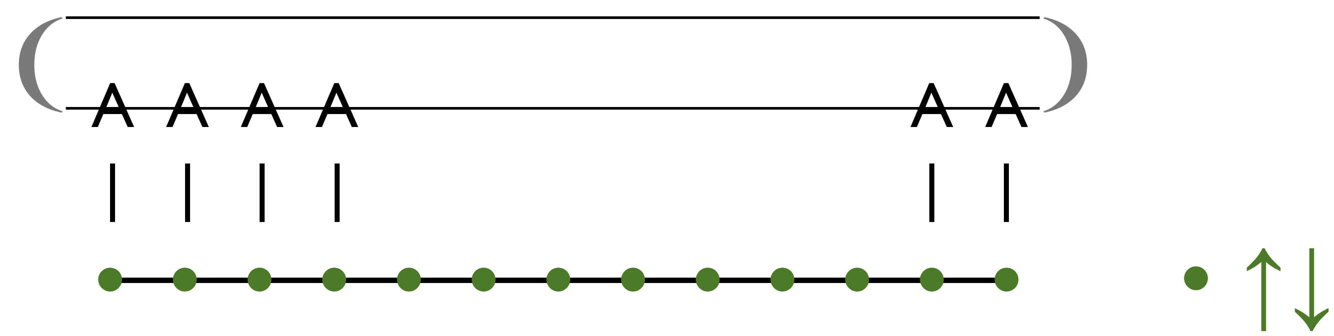

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Schwinger model

ground state, low lying spectrum (Banuls,Cichy,Jansen,Cirac, 2013; Rico et al, 2013)

real time simulations: Schwinger mechanism, quenches

(Pichler et al 2015; Buyens et al, 2014,2016)

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massive Schwinger model + *quench: turn on abruptly an electric field*

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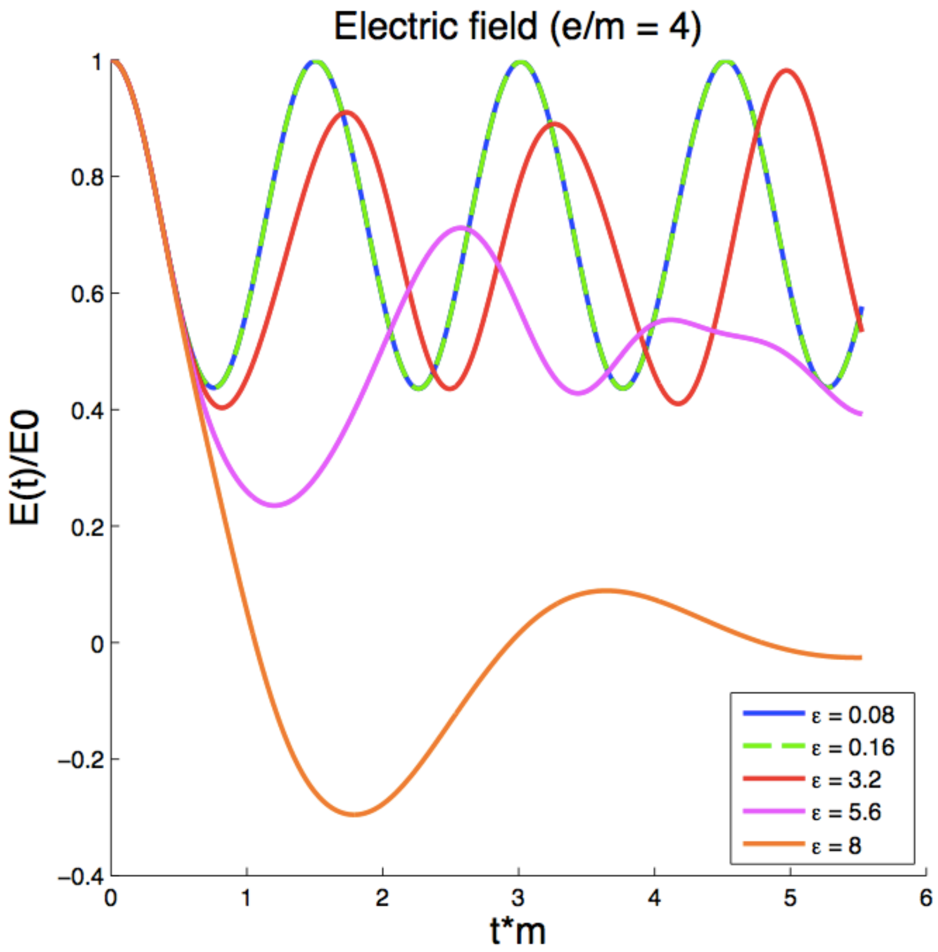

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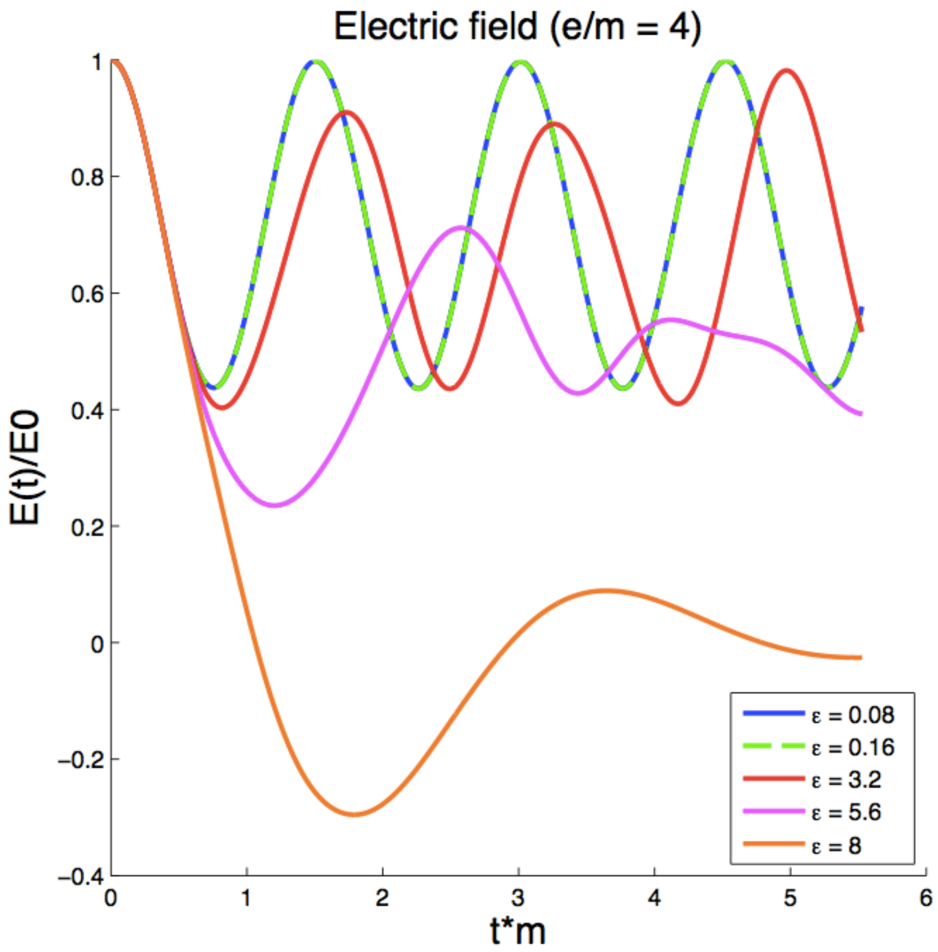

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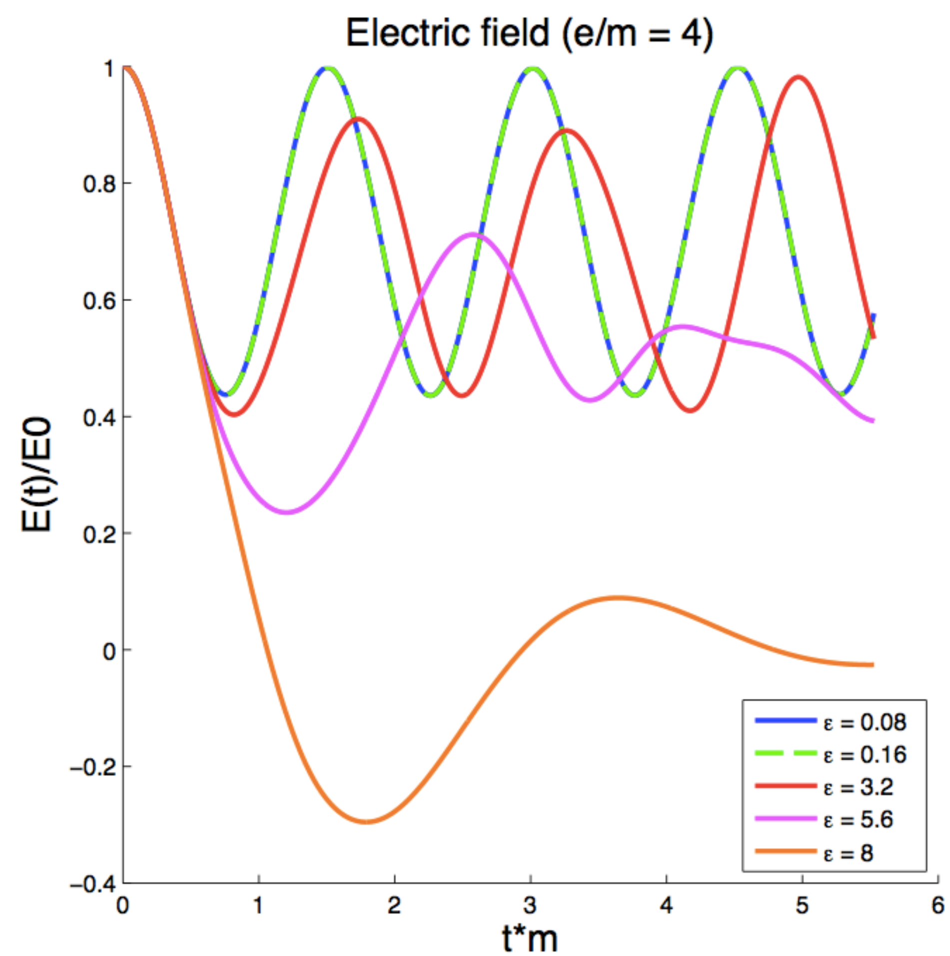

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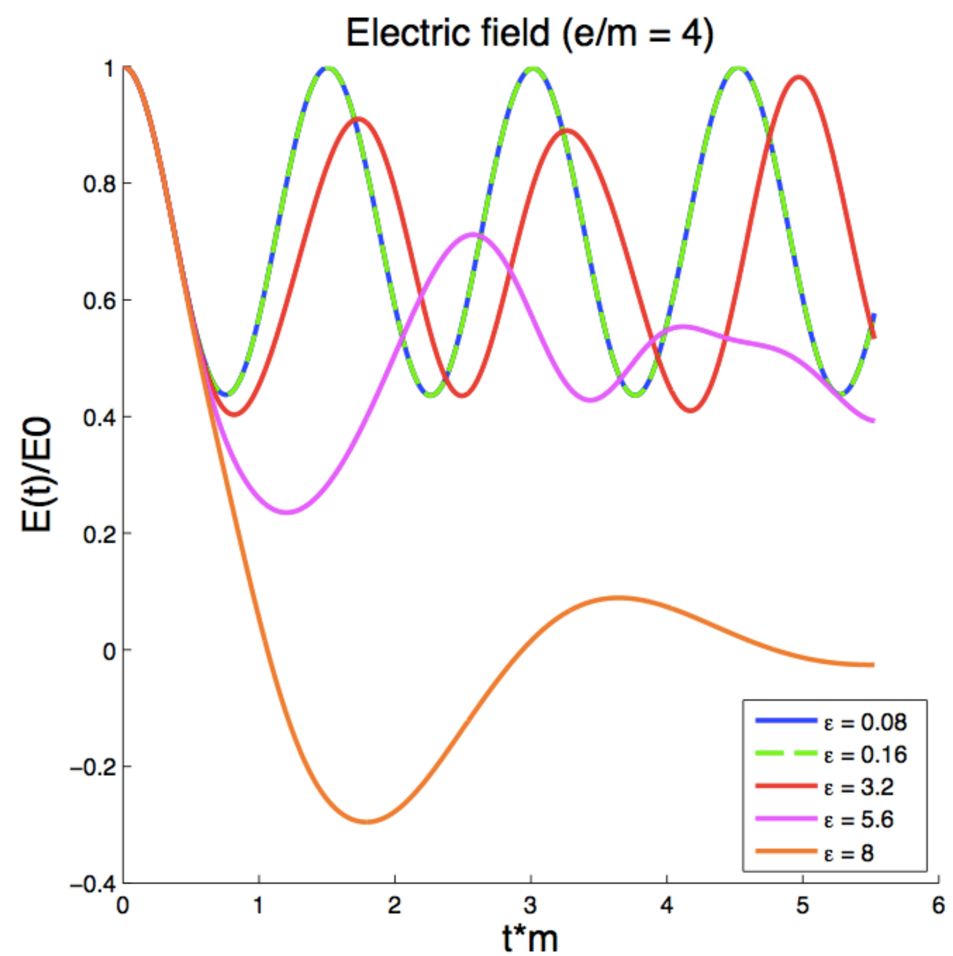

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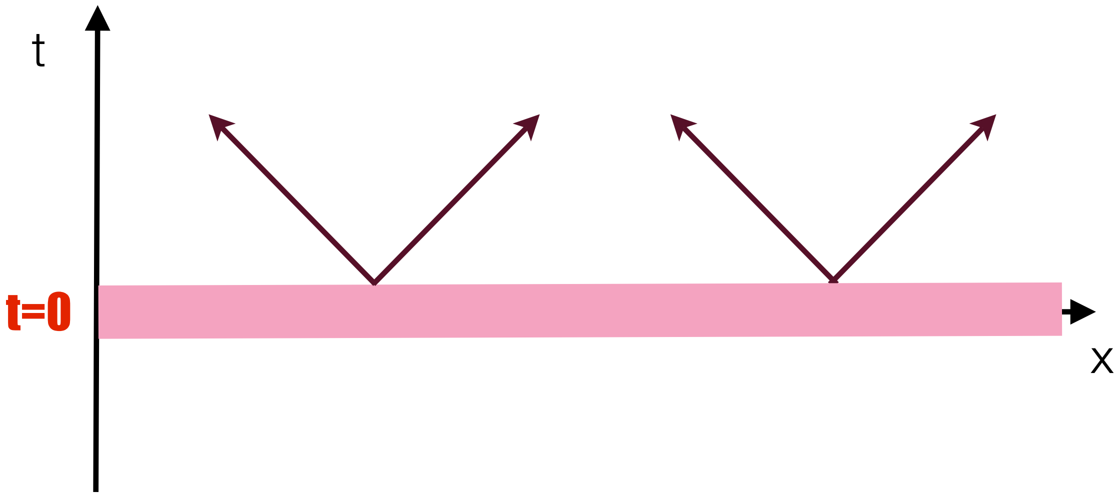

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stronger correlations when emitted at **close points**

entangled pairs stream away at **c=1**

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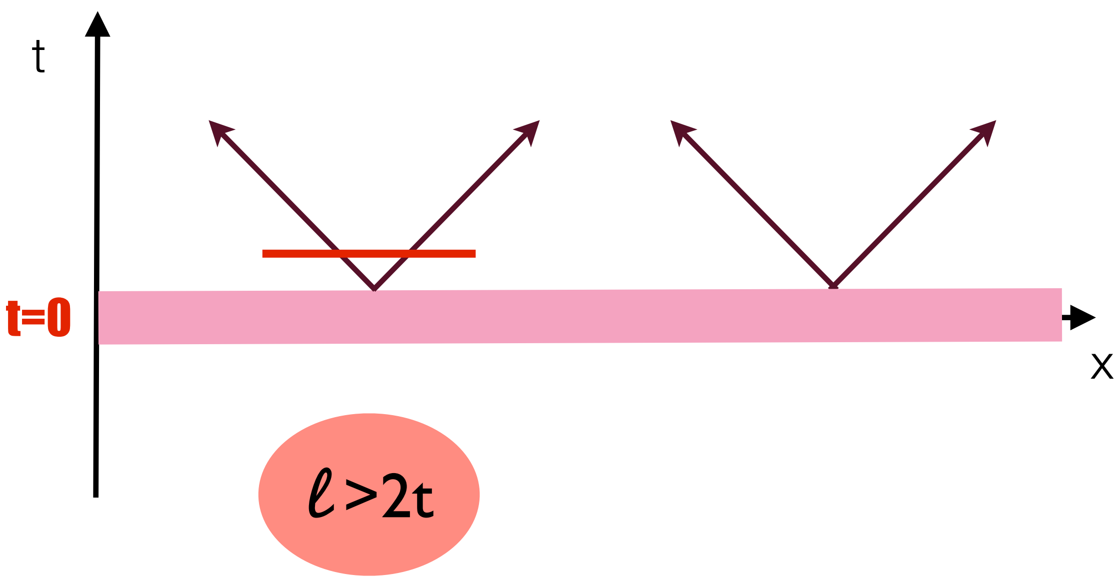

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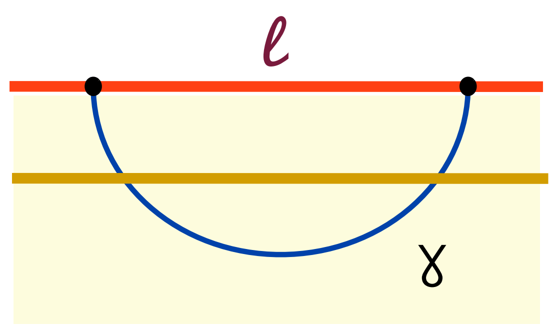

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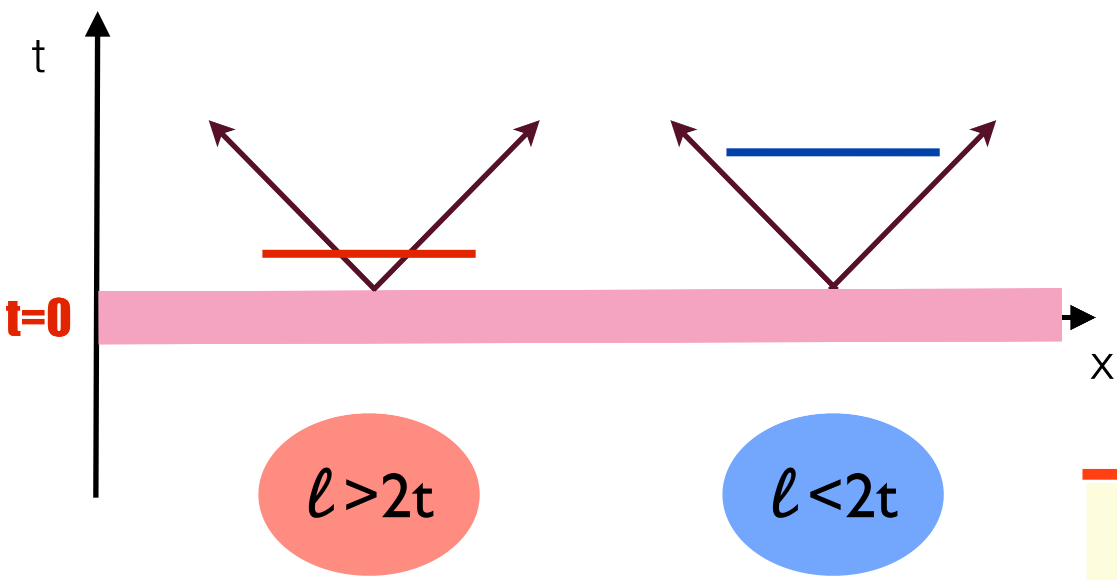

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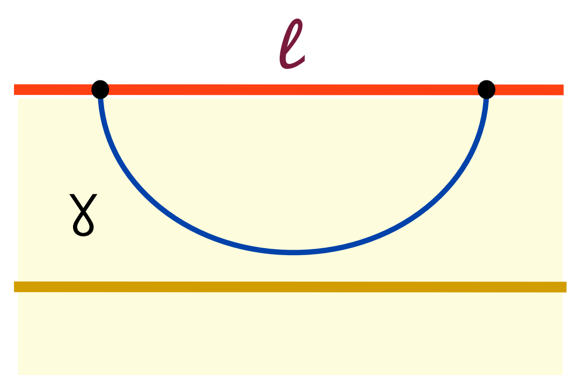

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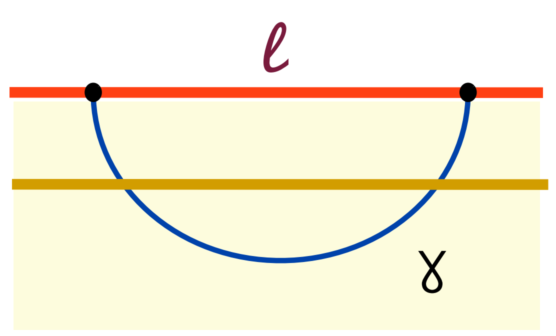

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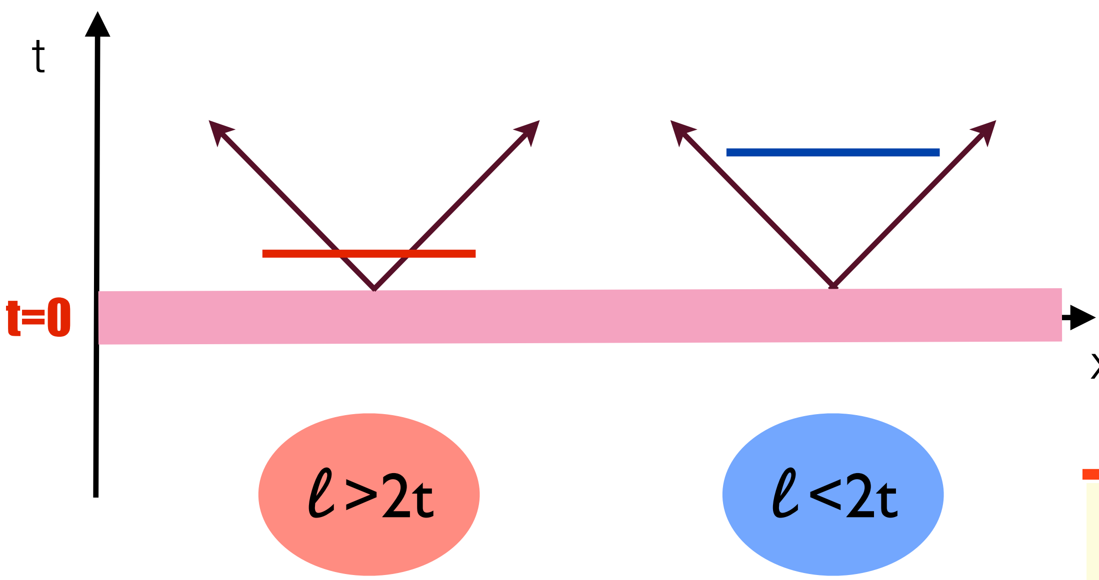

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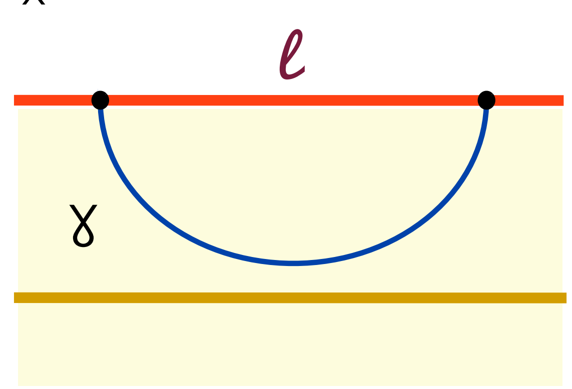

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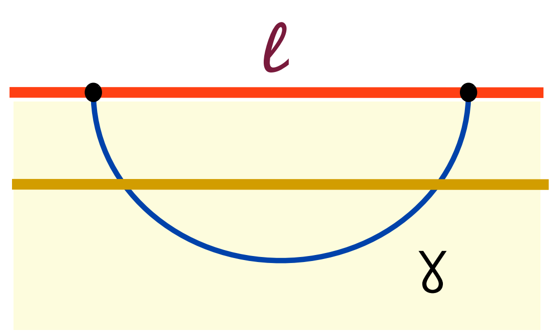

shell infall ⟷ drift away of entangled excitations

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lowest excitation Δm $\longrightarrow$ lowest normal mode

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$\longrightarrow$ *no radial displacement*

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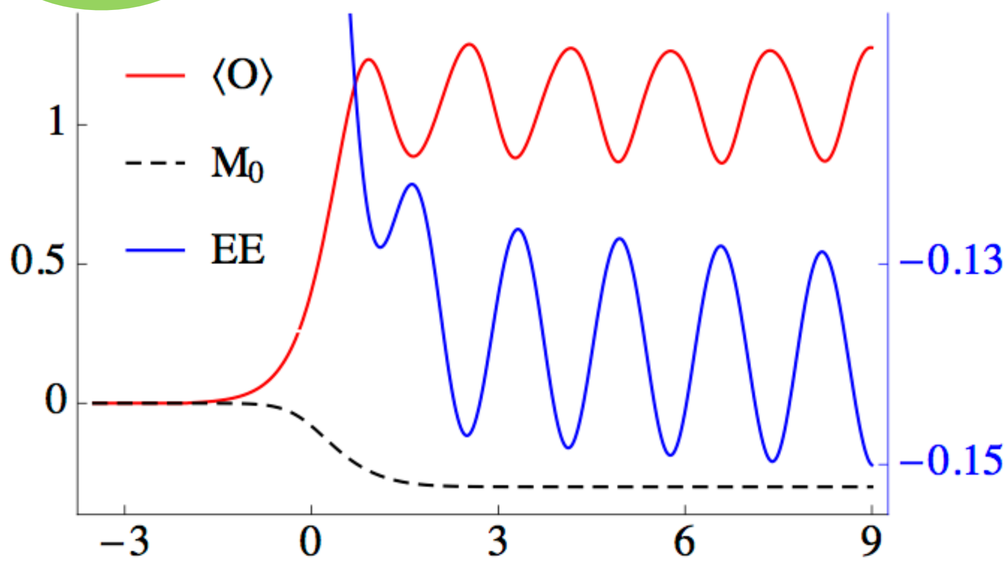

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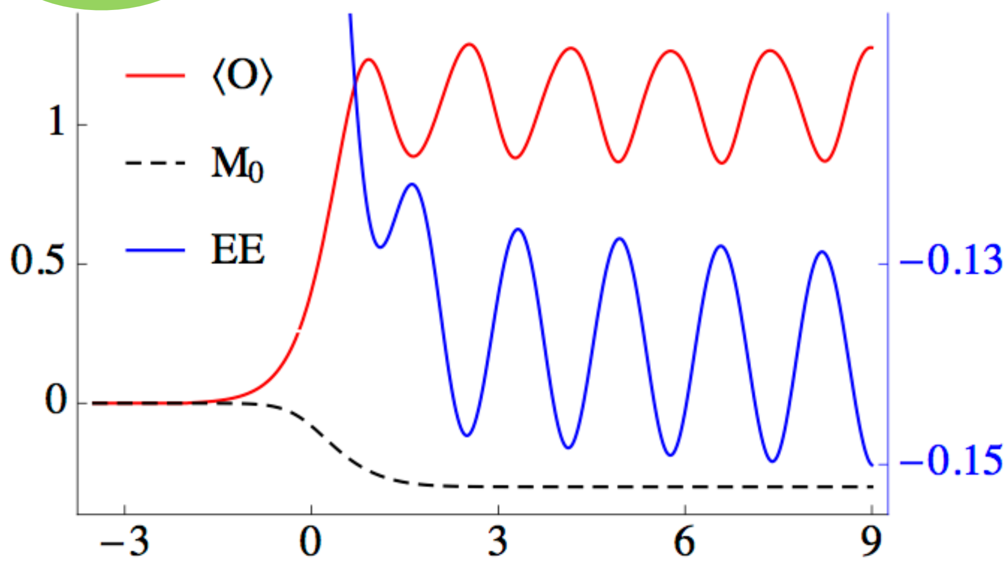

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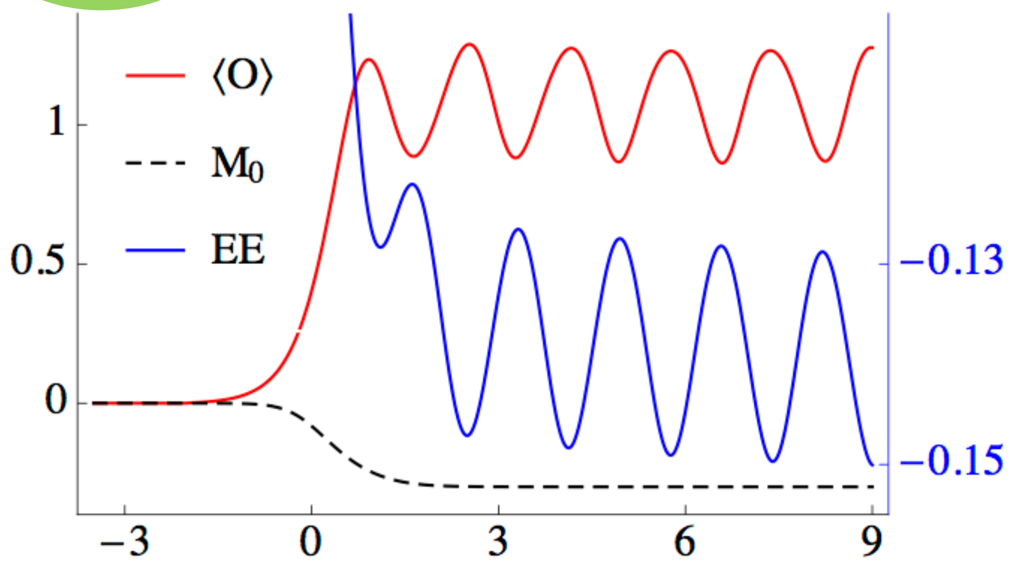
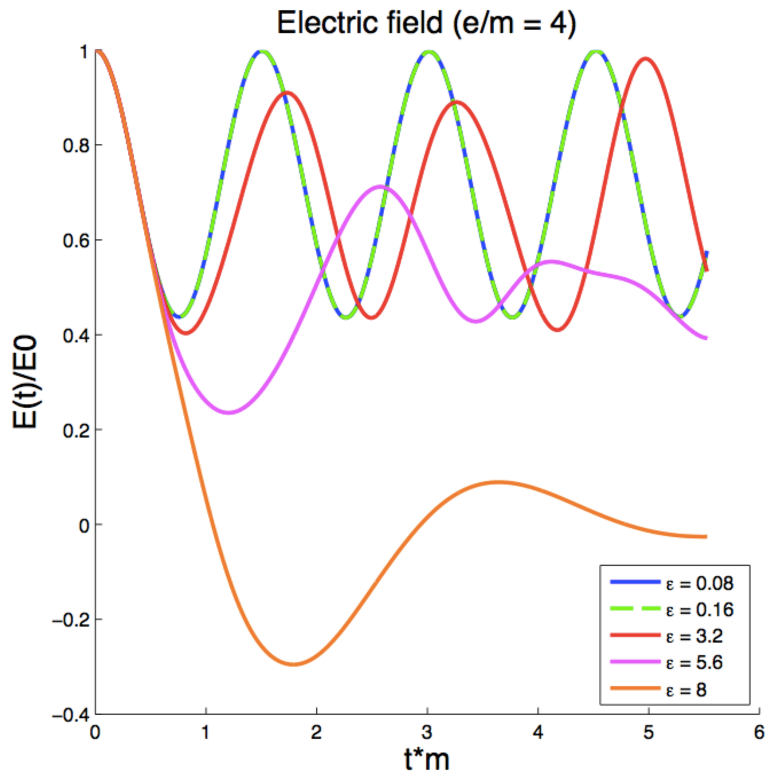


lowest excitation Δm ⟶ lowest normal mode

small energy quench maps to standing scalar pulse

momentum zero coherent state
⟶ no radial displacement

electric field
↓
vev of ***O***



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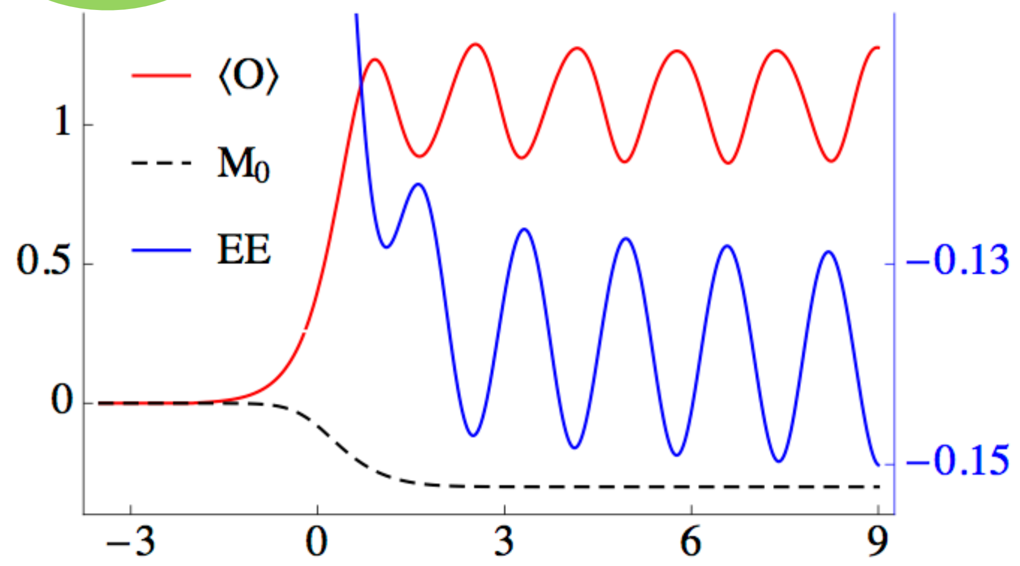

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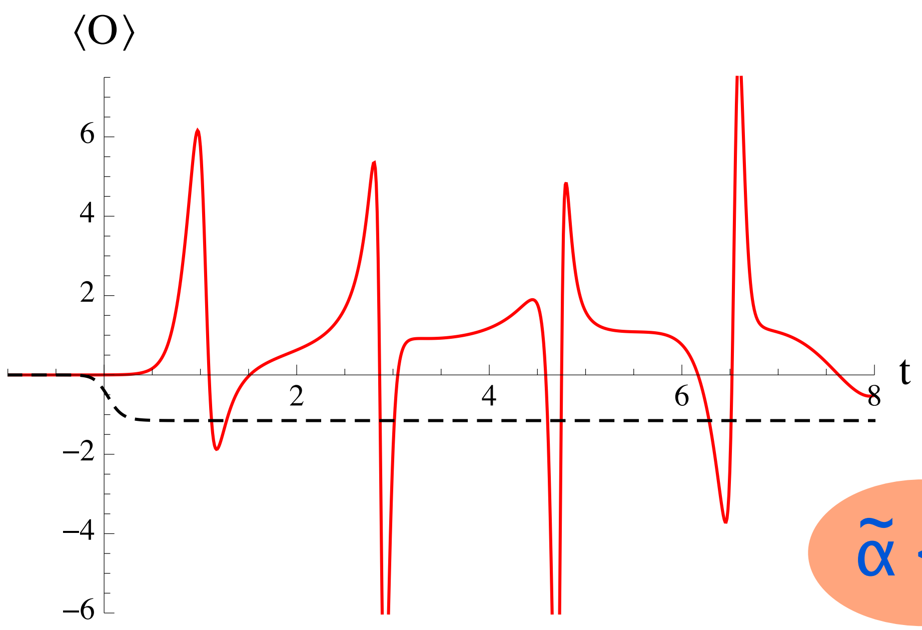

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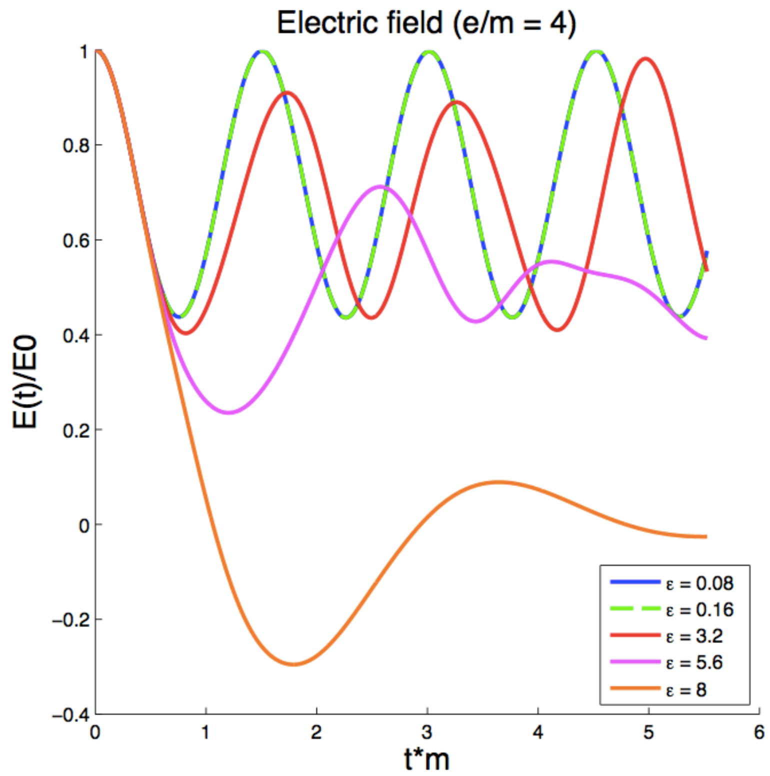

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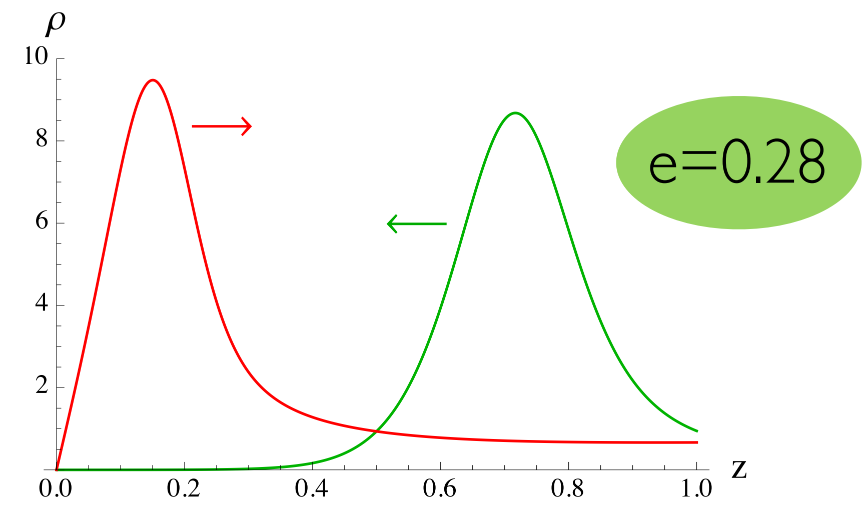

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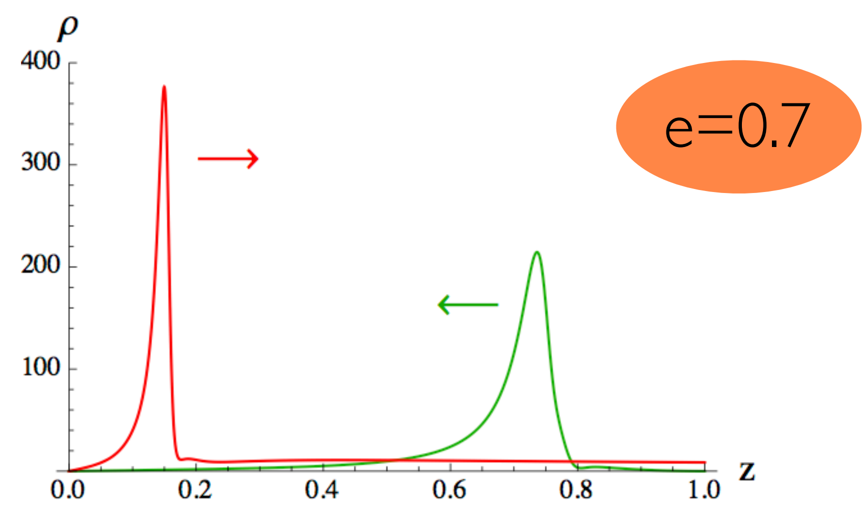

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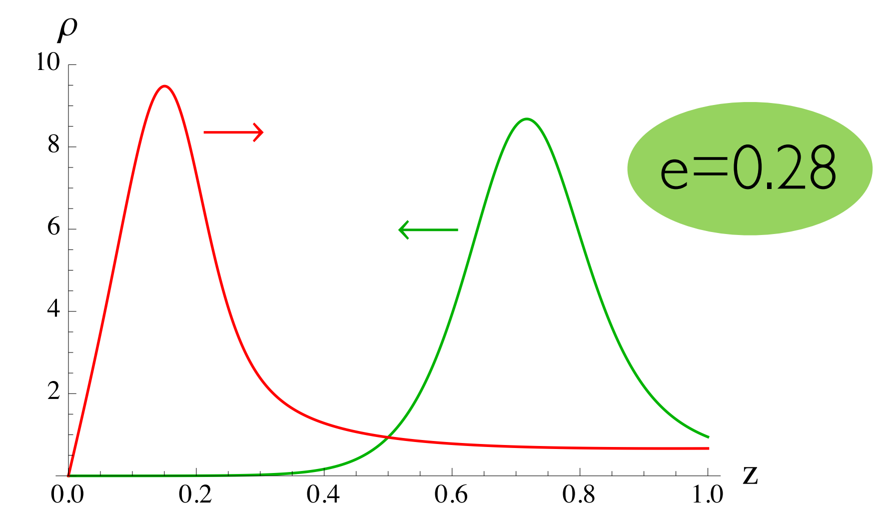

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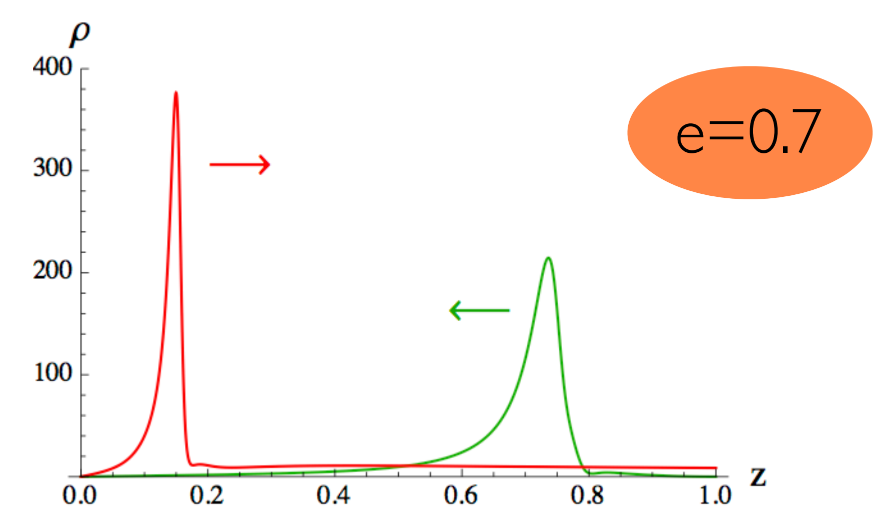

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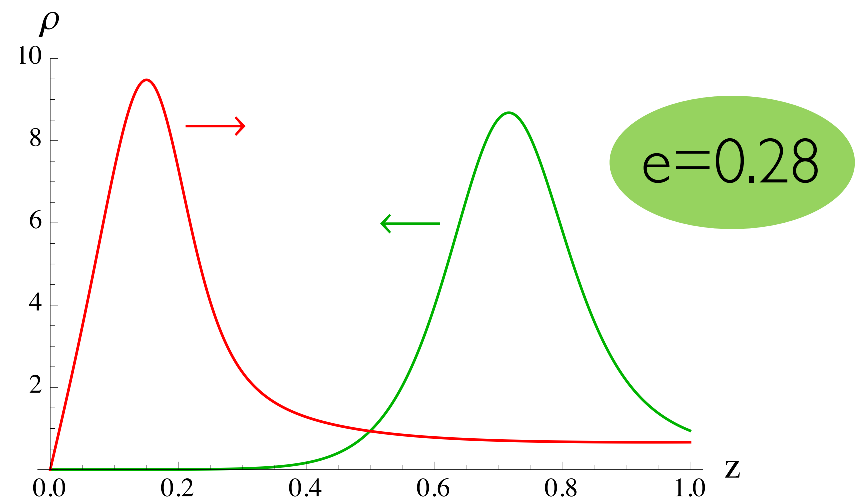
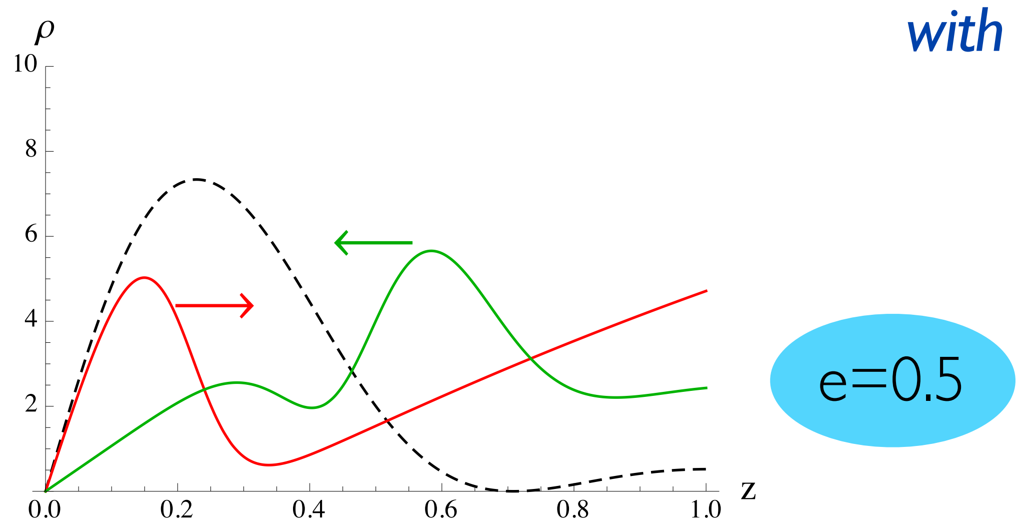


check (2) $\Phi = \Phi_{sol} + \varepsilon$ lowest normal mode

radial localization increases with energy



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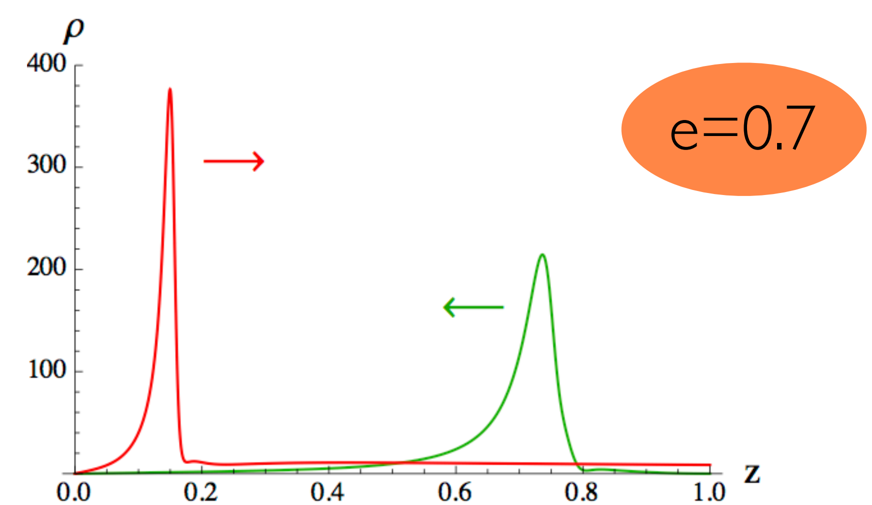

The holographic dual of a quench

quench: sudden action abrupt time variation of boundary conditions

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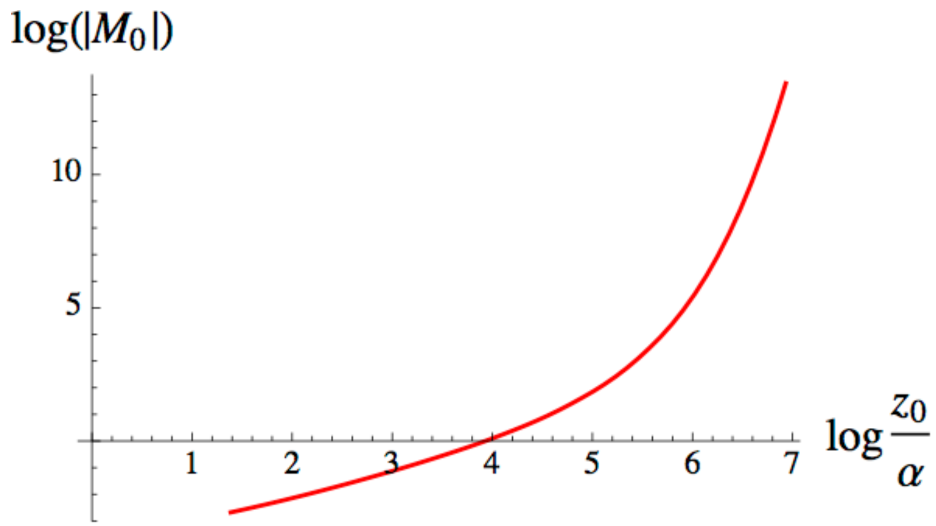

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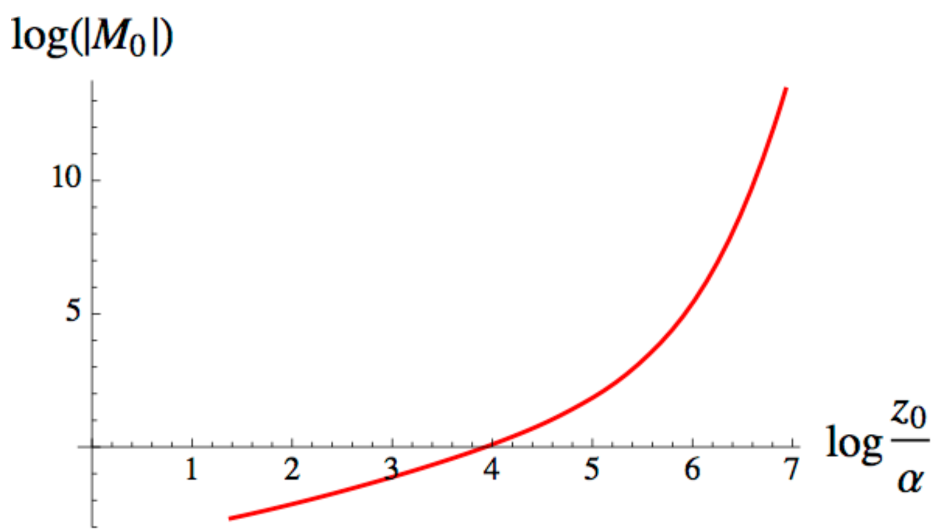

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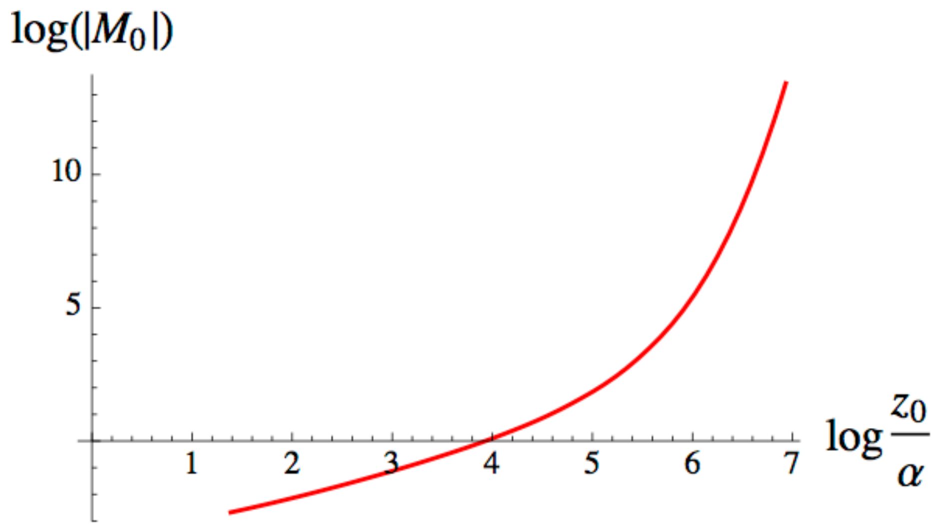

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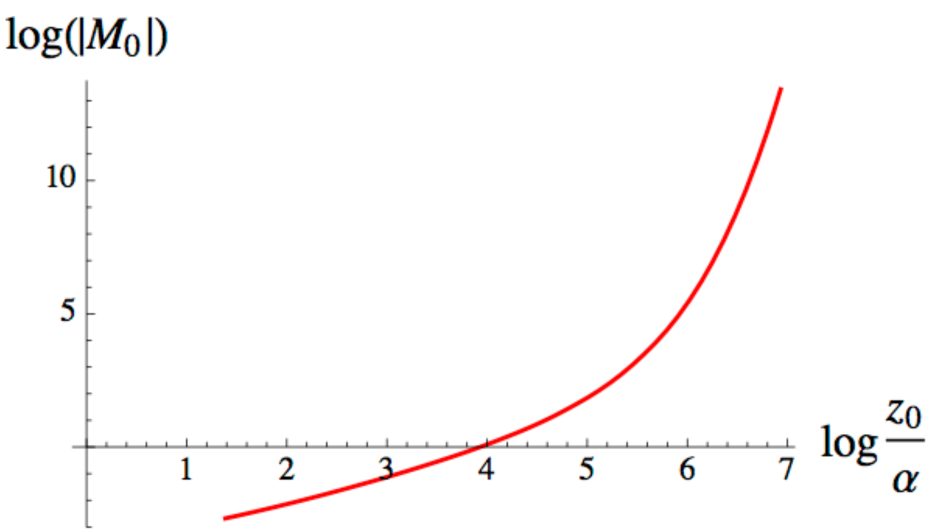

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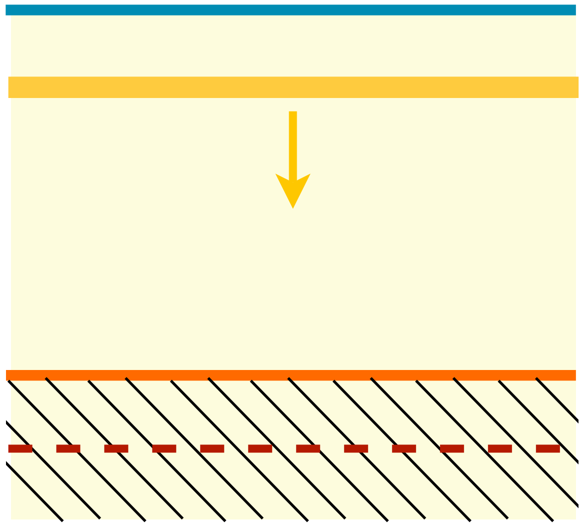

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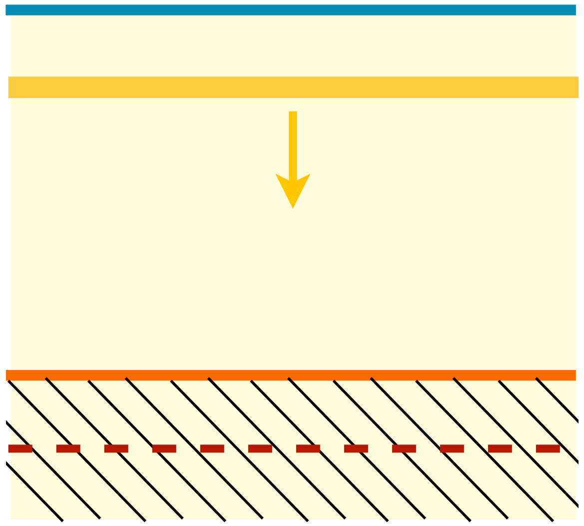

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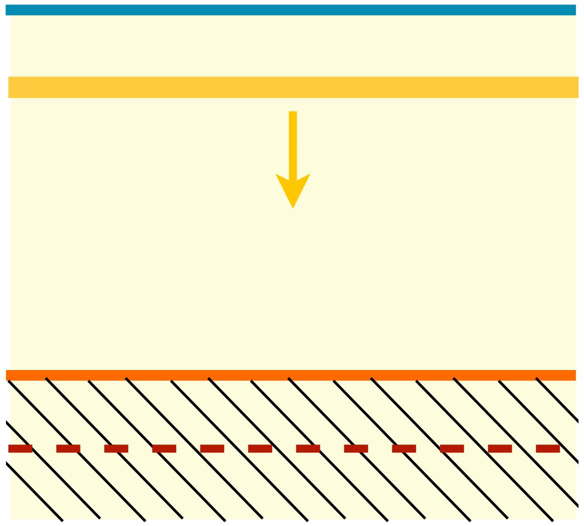

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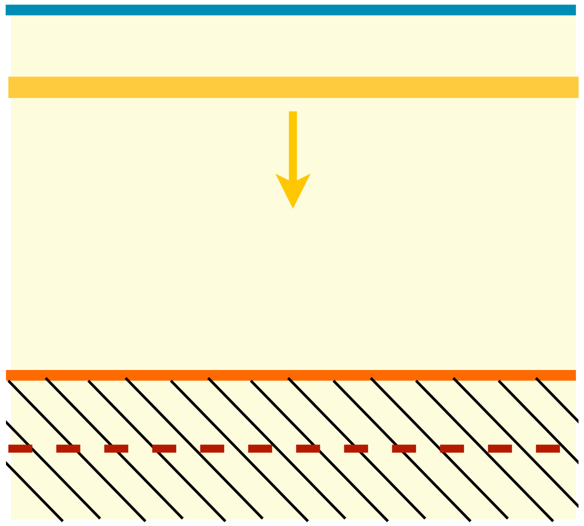

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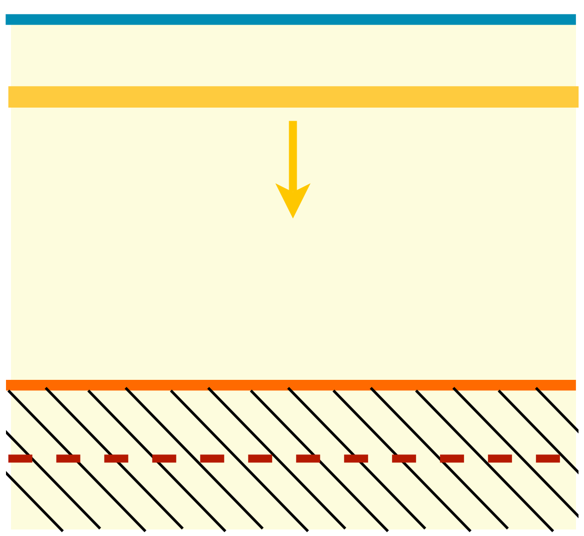

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Thanks