

Bouncing Universe

and non-BPS branes

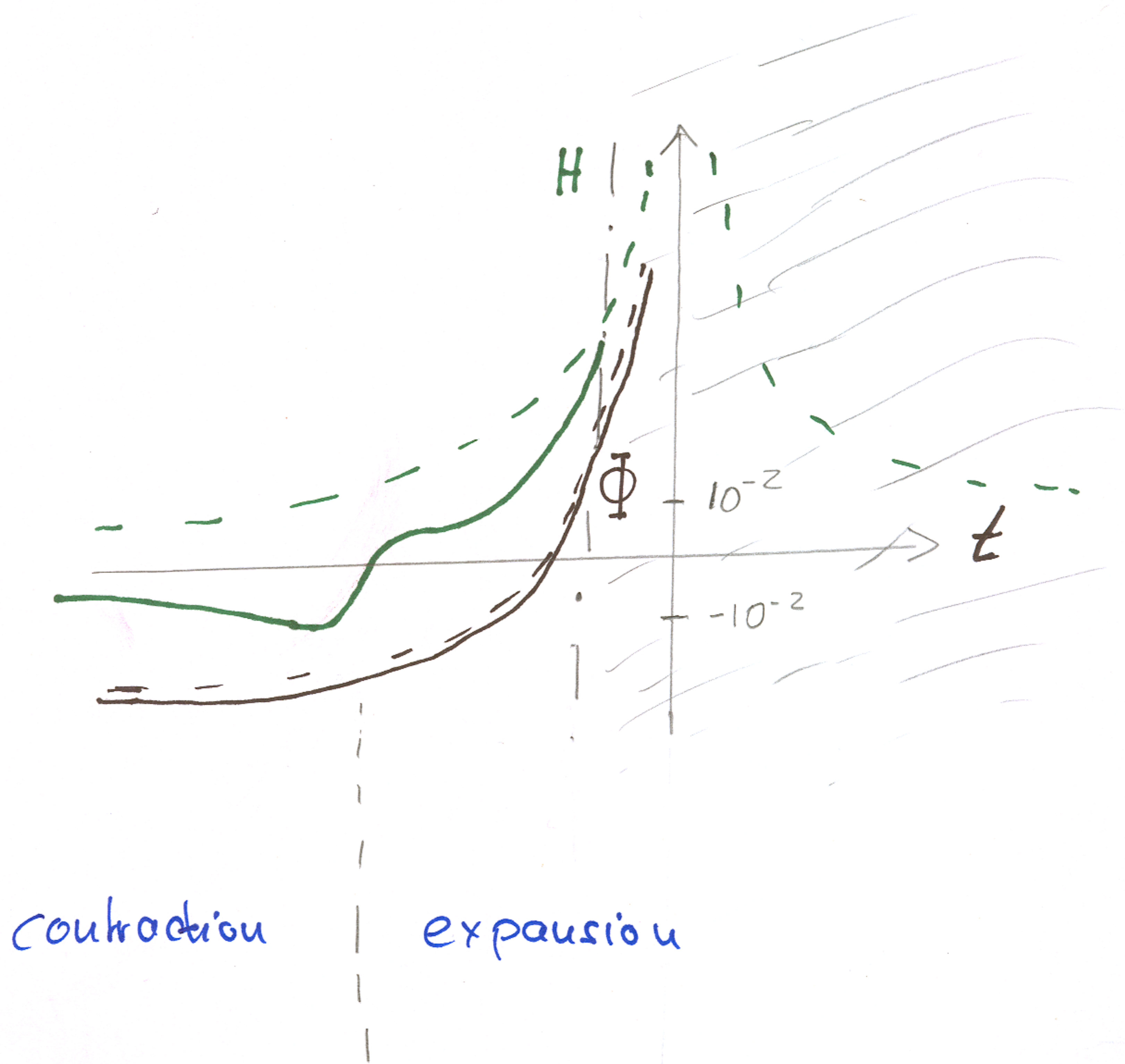
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I) Introduction & Results



Hubble

Dilaton

Pre-big bang Model

+ non-BPS brane

∴ String frame!
(10-D)

II) Pre Big-bang Model (G. Veneziano, ...)

$$S = \frac{1}{2\alpha_{10}^2} \int d^{10}x e^{-2\Phi} \sqrt{-g} (R + 4 \partial_\mu \Phi \partial^\mu \Phi)$$

+ S_{matter}

e.o.m.:

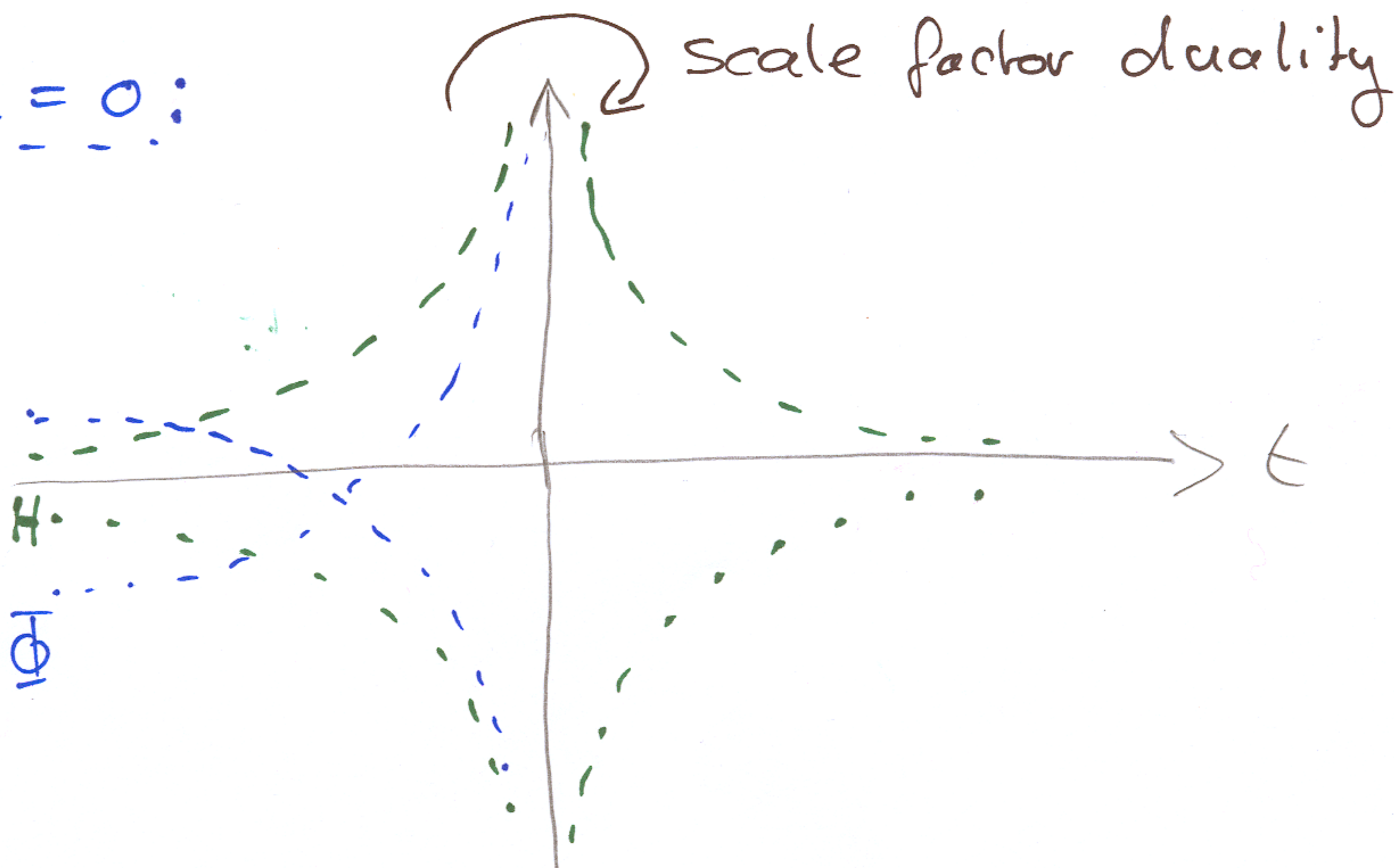
$$72 H^2 - 36 H \dot{\Phi} + 4 \dot{\Phi}^2 = e^{2\Phi} \varepsilon \quad (i)$$

$$2 \ddot{\Phi} - 8 \dot{H} + 16 H \dot{\Phi} - 2 \dot{\Phi}^2 - 36 H^2 = \frac{1}{2} e^{2\Phi} \rho \quad (ii)$$

$$2 \ddot{\Phi} - 18 H \dot{\Phi} - 2 \dot{\Phi}^2 - 9 \dot{H} - 45 H^2 = \frac{1}{4} e^{2\Phi} \rho \quad (iii)$$

$$\dot{\varepsilon} + 9(H(\varepsilon + \rho) - \dot{\Phi} \rho) = 0$$

$S_m = 0$:



Bounce

$H=0$, $\dot{H} > 0$ requires pressure, $P > 0$

Since

$$0 < \dot{H} + 9H^2 - 2H\dot{\Phi} = \frac{e^{2\Phi}}{4} P$$

$\therefore P < 0$ for DBI action!

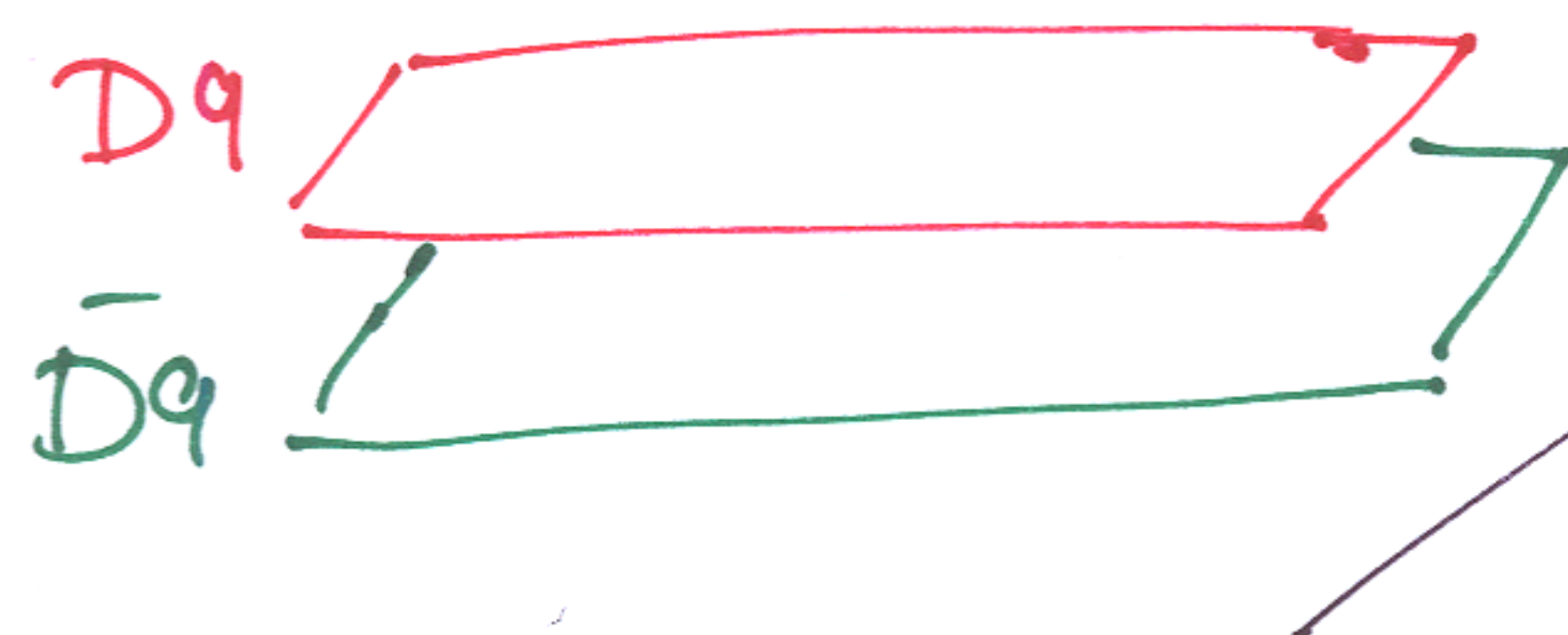
$$\left[L = e^{-T} \sqrt{1 + (\partial T)^2} \right]$$

$T = \text{scalar}$

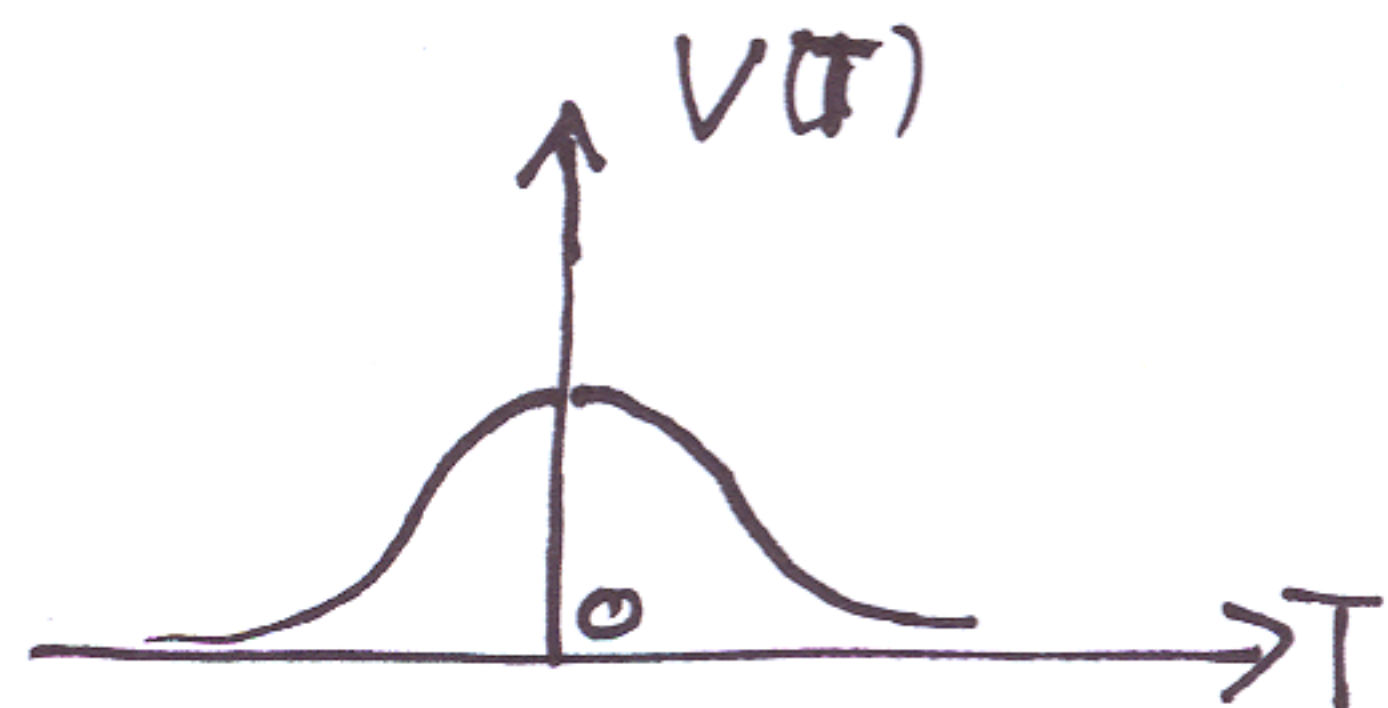
$\therefore$ need higher derivatives.

III) Non-BPS branes

($2\alpha = 1$)

II B: $D9$  $(-1)^{F_L} \Rightarrow$ Non BPS $D9$ in IIA.

construct the tachyon action:



general action $S = \tau_9 \int L(T, \partial T, \partial^2 T, \dots) e^{-\Phi}$

$$L = \sum_{\alpha, \beta} c_{\alpha\beta} T^{2\alpha} (\partial_\mu T \partial^\mu T)^\beta \quad (*)$$

⊕

$T(t) = \chi d_t(t) \hat{=}$ exactly marginal (world sheet) deformation

$\Rightarrow$ classical solution for (*)

⊕ $V(T) = e^{-T^2}$

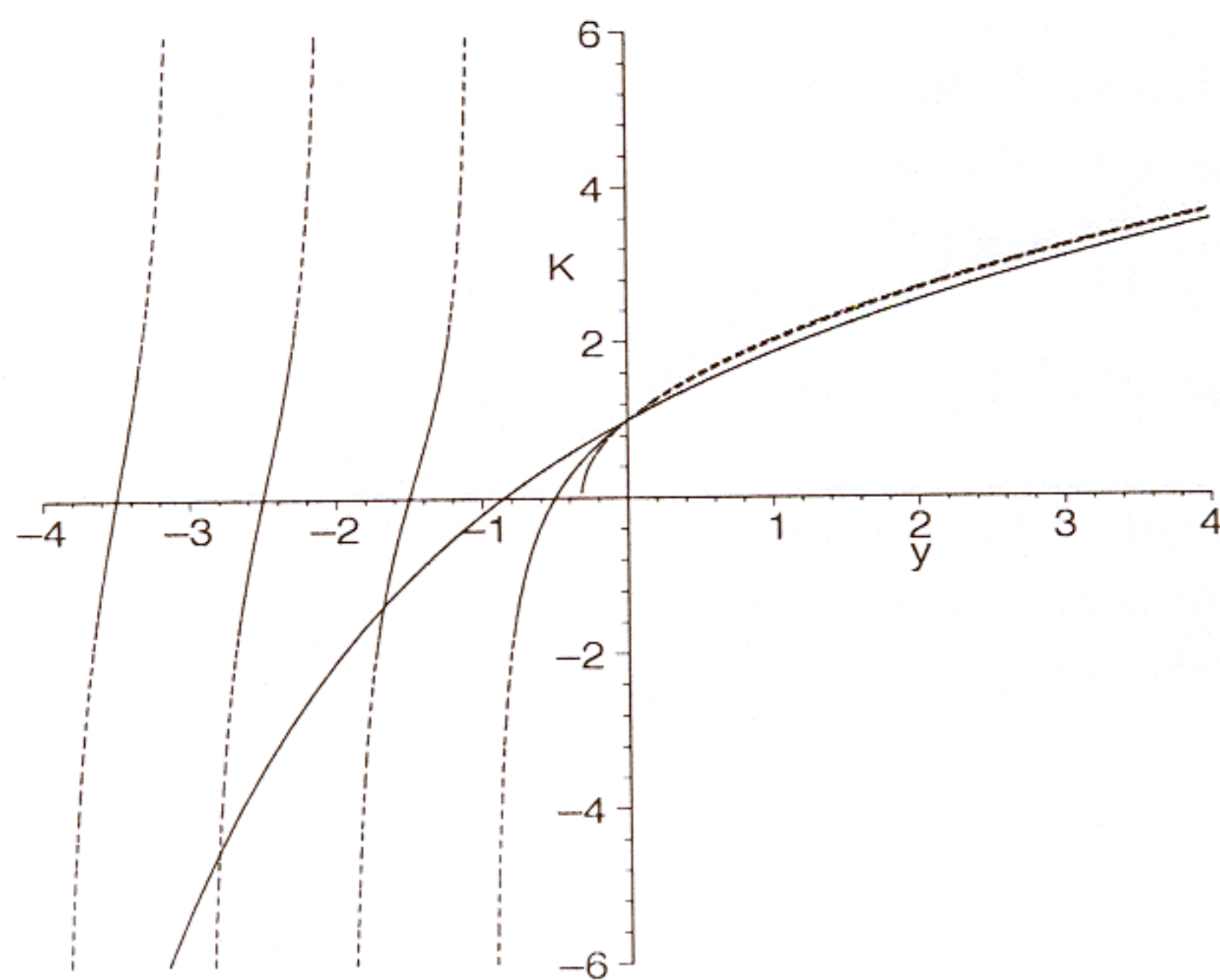
$\Rightarrow$

Tachyon Action (I.S. + N. Lambert '00)

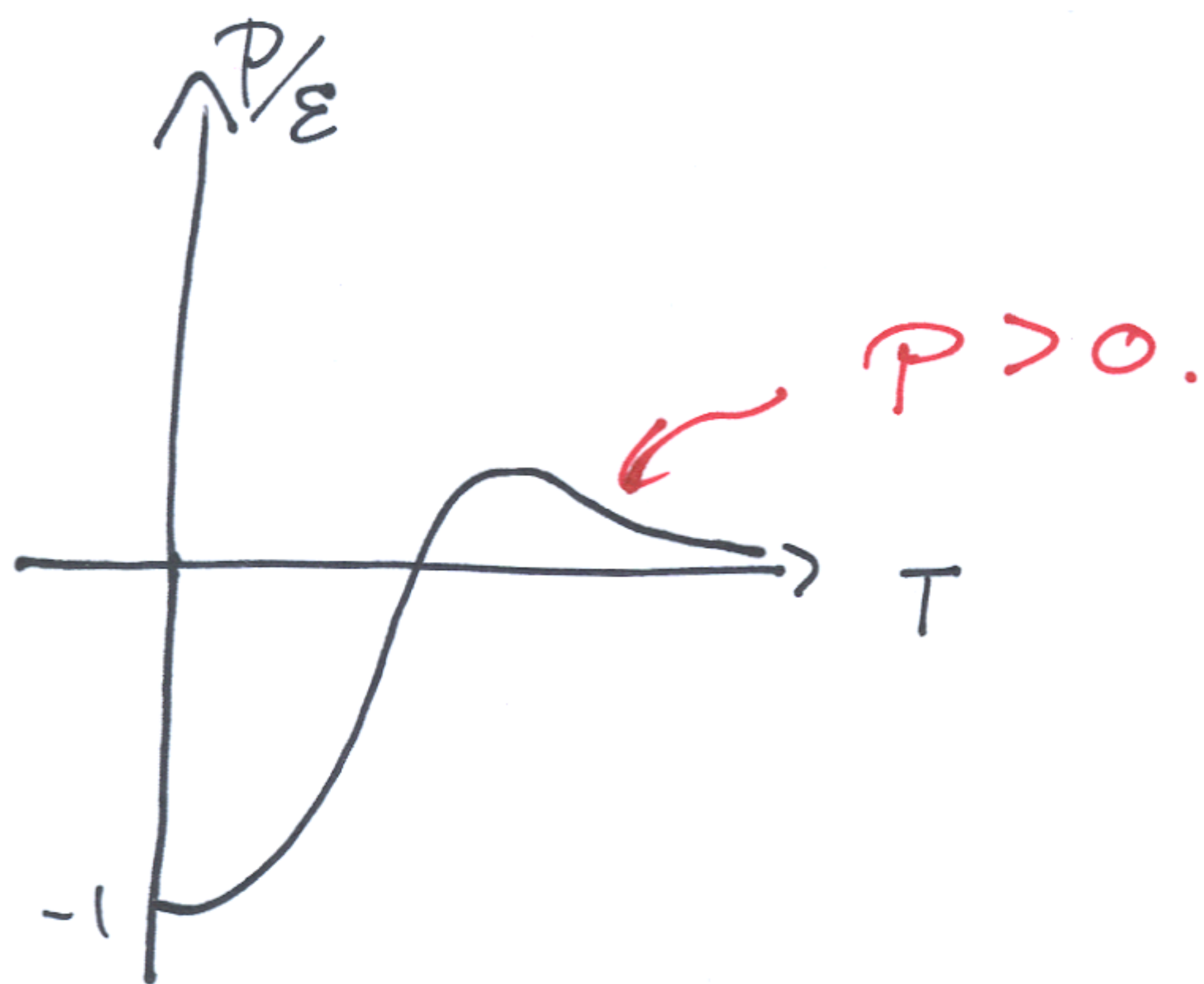
$$L = e^{-T^2} \left[e^{-(\partial T)^2} + \sqrt{\pi (\partial T)^2} \operatorname{erf}((\partial T)^2) \right]$$

$\underbrace{\hspace{15em}}_{=: K((\partial T)^2)}$

$$\mathcal{E} = \tau_g e^{-T^2 + \dot{T}^2}$$

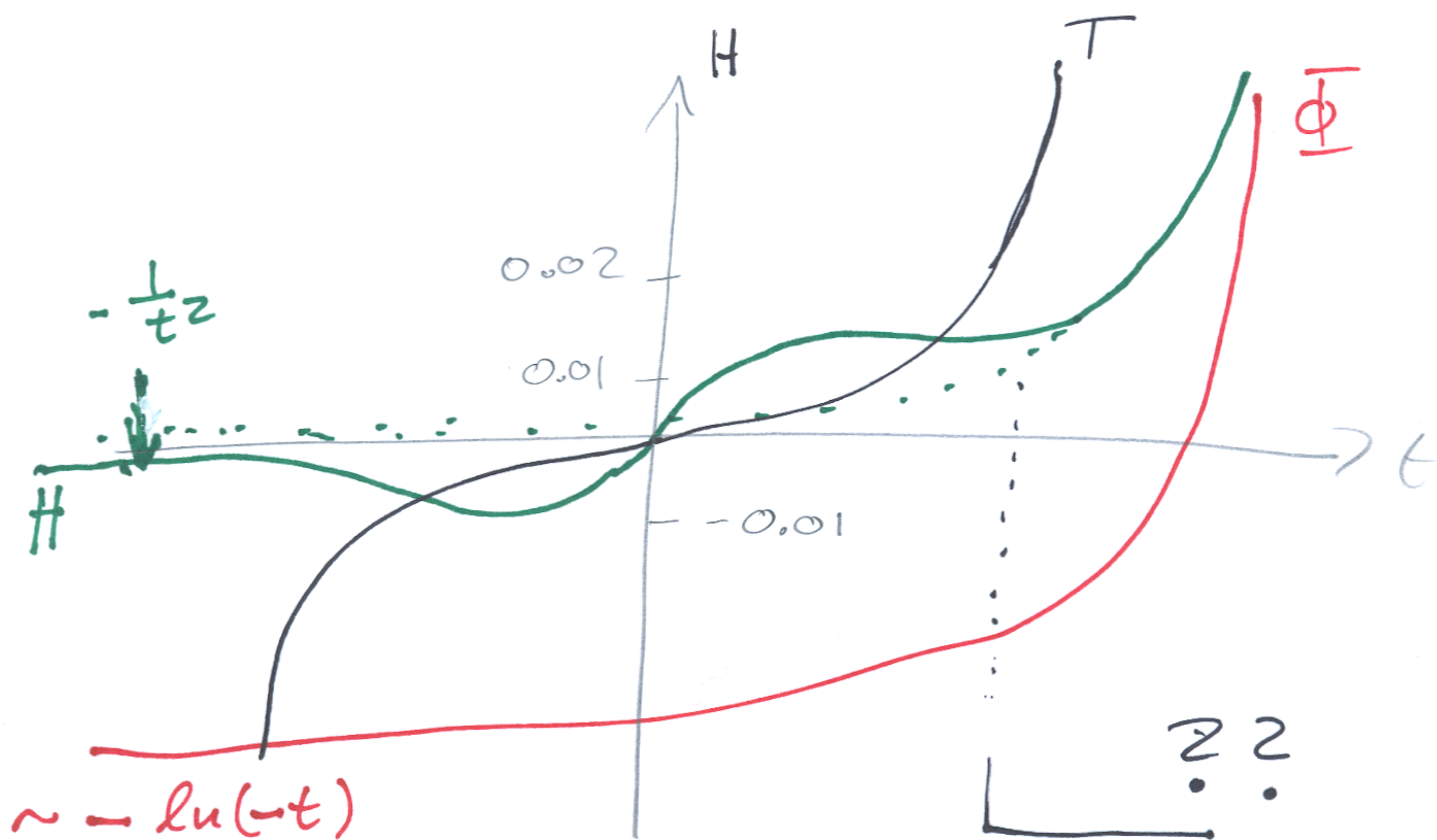


Legend
----- BSFT
————— Eq. (4.29)
..... BI



$\therefore$ SUSY spontaneously broken via $\mathcal{Z}$ -symmetry non-invariance of S_{brane} .

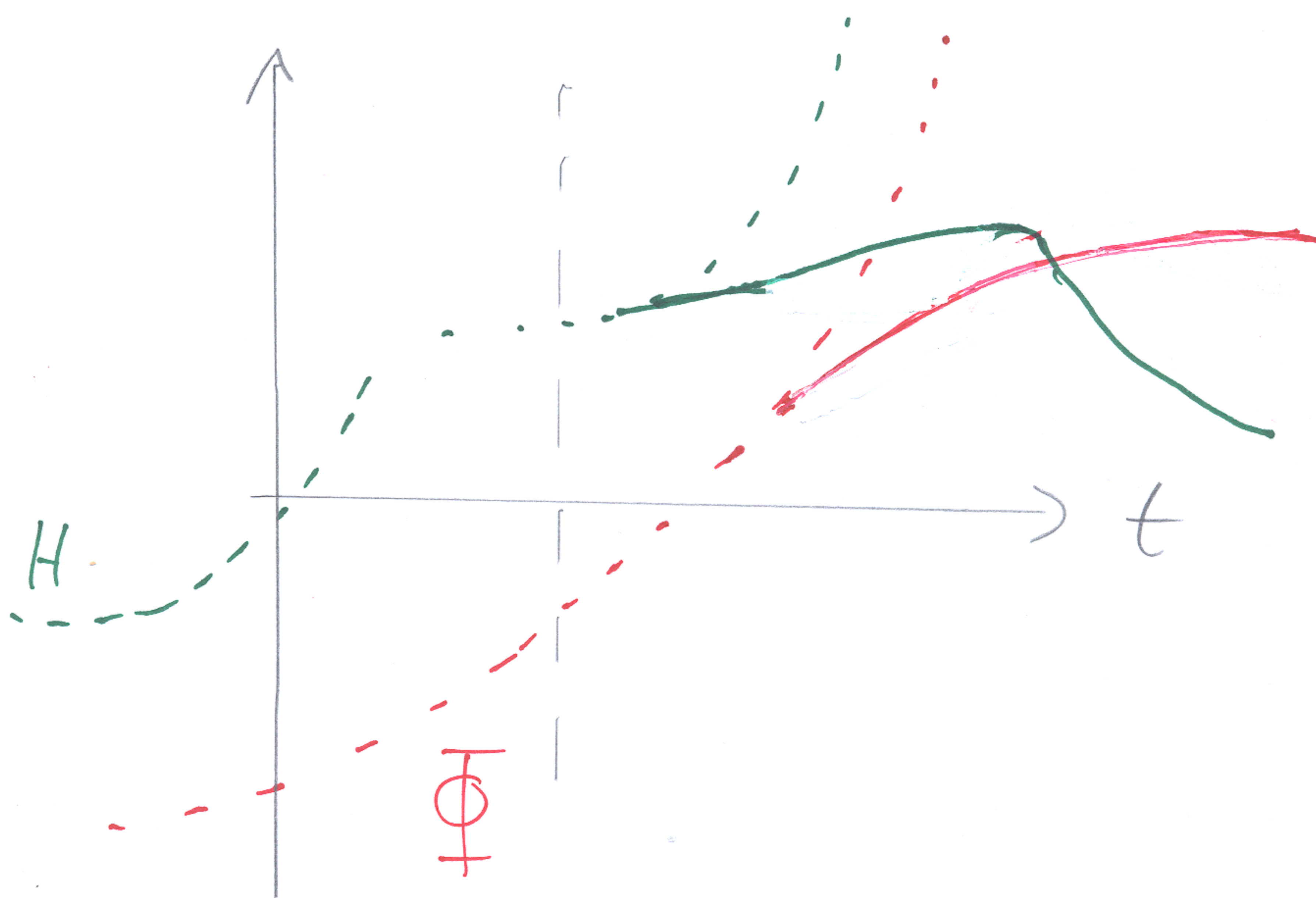
Solution of coupled system:



IV) Pre big bang singularity

▣ Add a potential for Φ :

$$V(\Phi) = \frac{1}{10} \text{Re}(\Phi - \Phi_0)$$



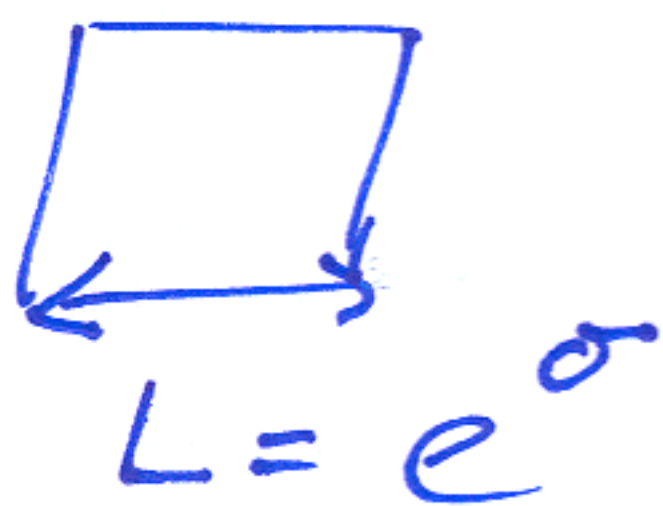
$\therefore V(\Phi)$ is ad hoc!

V) Discussion & Outlook

■ Bounce (in string frame) due to non-BPS brane without ghosts (cf. Electroweak model)

Generalisations

- Orbifold: $D9 / (\mathbb{T}^6 / \mathbb{Z}_2)$

T^6 : 
 $L = e^\sigma$

$t \rightarrow -\infty, \sigma \rightarrow \infty$



$t \rightarrow 0, \sigma \ll -1$

