



The role of impurities in cosmological phase transitions

Simone Blasi
DESY Hamburg

Introduction

Higgs mechanism + Hot Big Bang = cosmological phase transitions

Key to address SM open questions: e.g. matter/antimatter asymmetry, dark matter...

Aftermath of phase transitions directly observable in gravitational waves!

QCD and EWPT are not first order in the SM: need for new particles or new symmetries

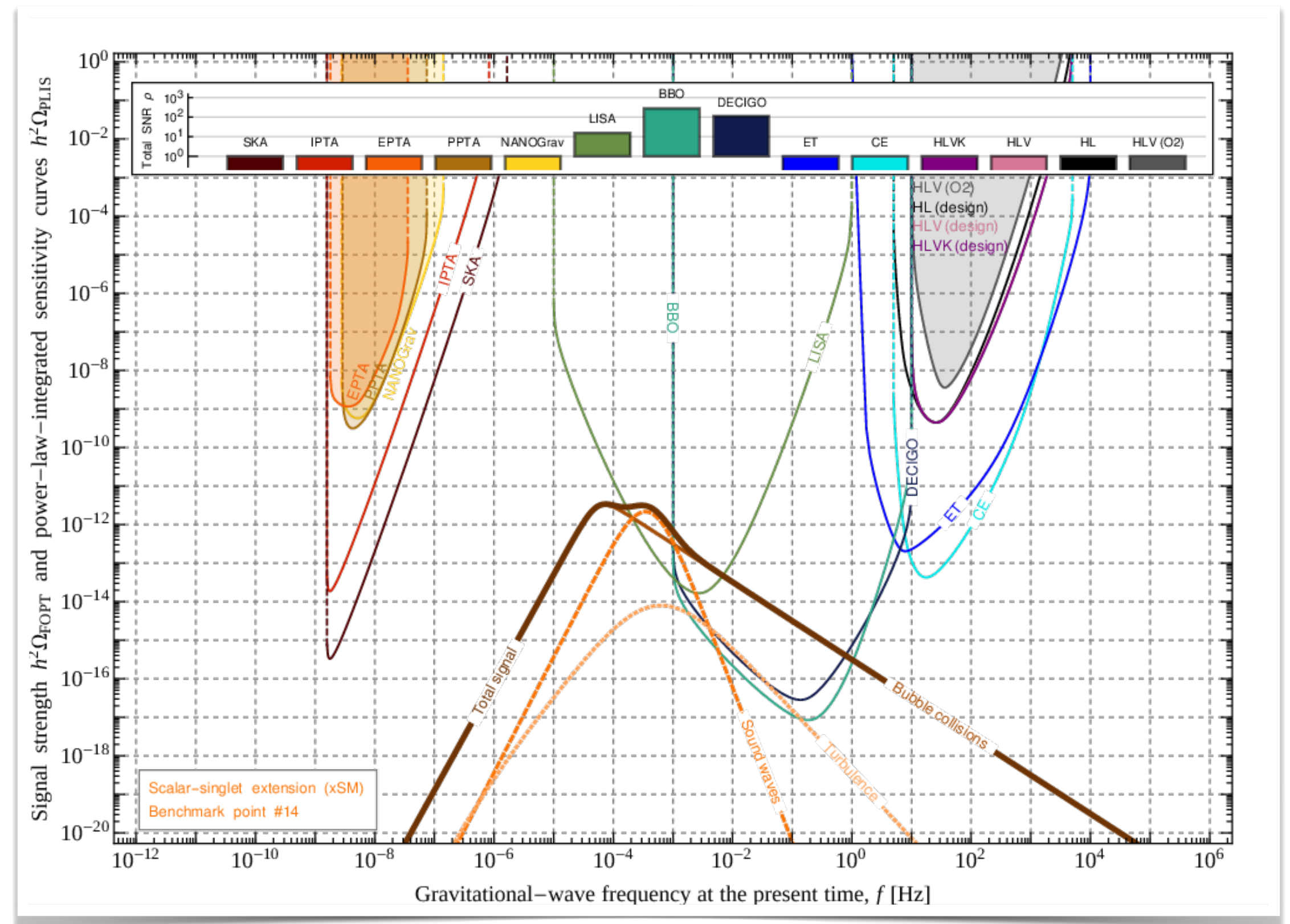


Fig. from Schmitz [2002.04615] JHEP

Nucleation theory

- Assume thermal fluctuations in homogeneous spacetime:

$$\phi(\mathbf{x}, \tau) = \phi(r), \quad r = |\mathbf{x}|$$

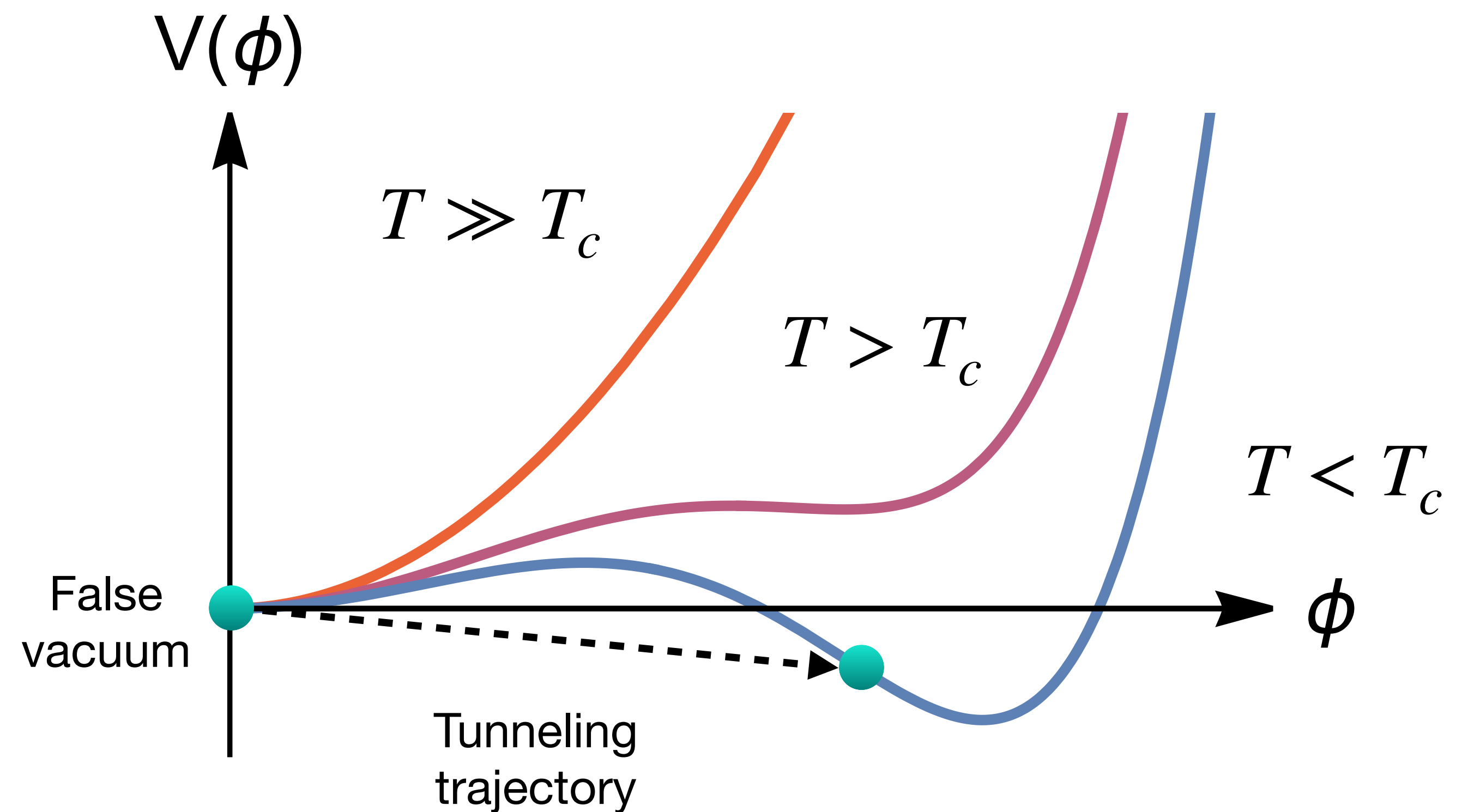
- Tunneling rate per unit volume given by O(3) action S_3/T

$$\gamma_V \sim T^4 \exp(-S_3/T)$$

Coleman 1977 (PRD)

Callan, Coleman 1977 (PRD)

Linde 1983 (NPB)



Nucleation theory

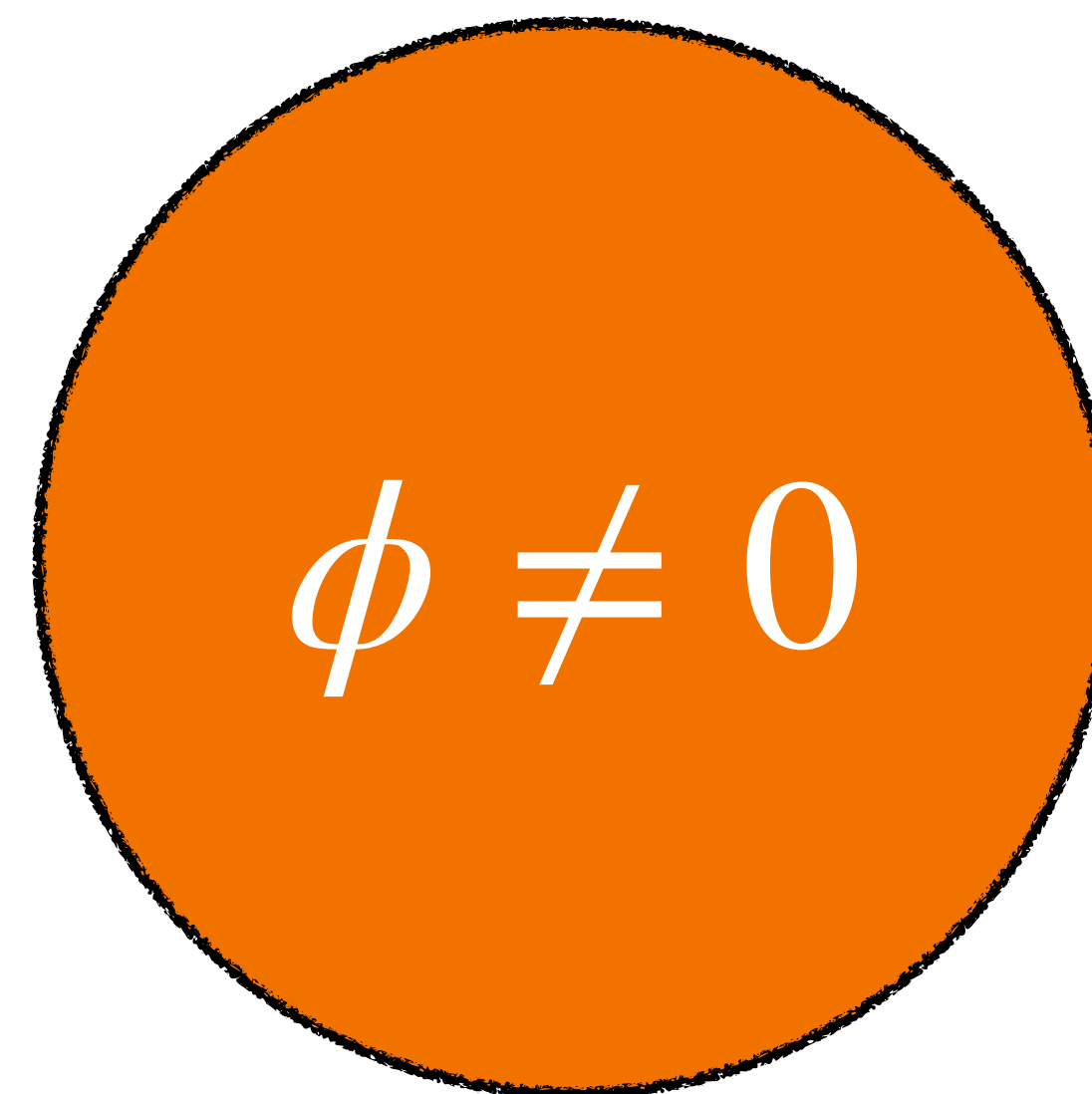
Coleman 1977 (PRD)
Callan, Coleman 1977 (PRD)
Linde 1983 (NPB)

- Assume thermal fluctuations in homogeneous spacetime:

$$\phi(\mathbf{x}, \tau) = \phi(r), \quad r = |\mathbf{x}|$$

- Tunneling rate per unit volume given by O(3) action S_3/T

$$\gamma_V \sim T^4 \exp(-S_3/T)$$



$$\phi = 0$$

What about impurities?

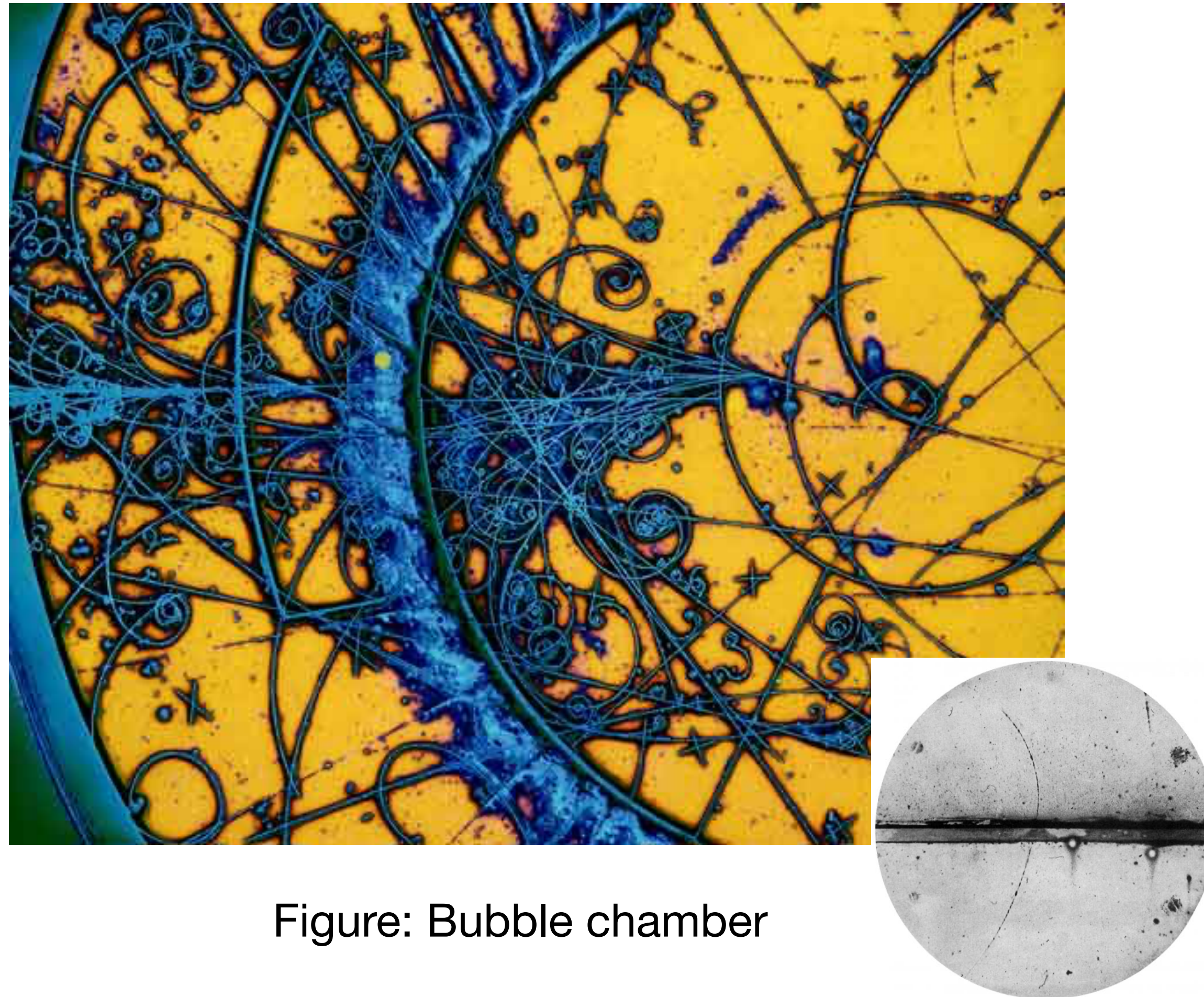


Figure: Bubble chamber



MONOPOLE AND VORTEX DISSOCIATION AND DECAY OF THE FALSE VACUUM

Paul Joseph STEINHARDT

Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Received 17 February 1981

“**If monopole** (or vortex) **solutions exist** for a metastable or false vacuum, **a finite density of monopoles** (or vortices) **can act as impurity sites that trigger inhomogeneous nucleation** and decay of the false vacuum.”

Impurities in the early universe

Yutaka Hosotani

Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104

(Received 1 November 1982)

“Now one has to ask the following question: **Is the early universe really sufficiently pure in order for supercooling to take place?** The aim of this paper is to show that in most cases the early universe is very pure. [...] In this paper we consider **ordinary particles as impurities.**”

Cosmic separation of phases

Edward Witten*

Institute for Advanced Study, Princeton, New Jersey 08540

(Received 9 April 1984)

“In particle physics it is often assumed that phase transitions are nucleated by thermal fluctuations. In practice, [...] except in very pure, homogeneous samples, **phase transitions are often nucleated by various forms of impurities and inhomogeneities of nonthermal origin.**”

“What if the transition was nucleated by impurities? In this case **the mean spacing between bubbles has nothing to do with free energies** of nucleation and is simply the spacing between the relevant impurities.”

The nature of impurities

- Compact objects and gravitational effects

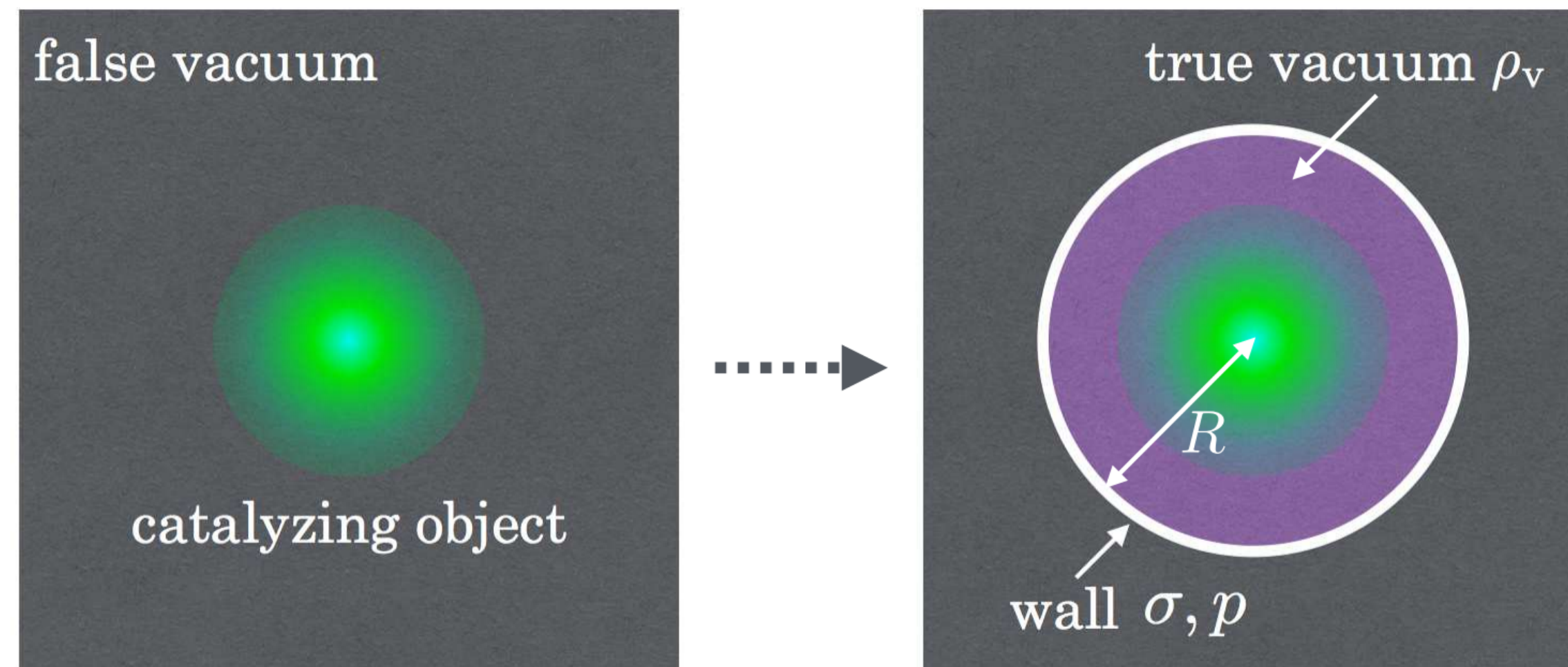


Fig. from Oshita, Yamada,
Yamaguchi [1808.01382], PLB

- Primordial density fluctuations

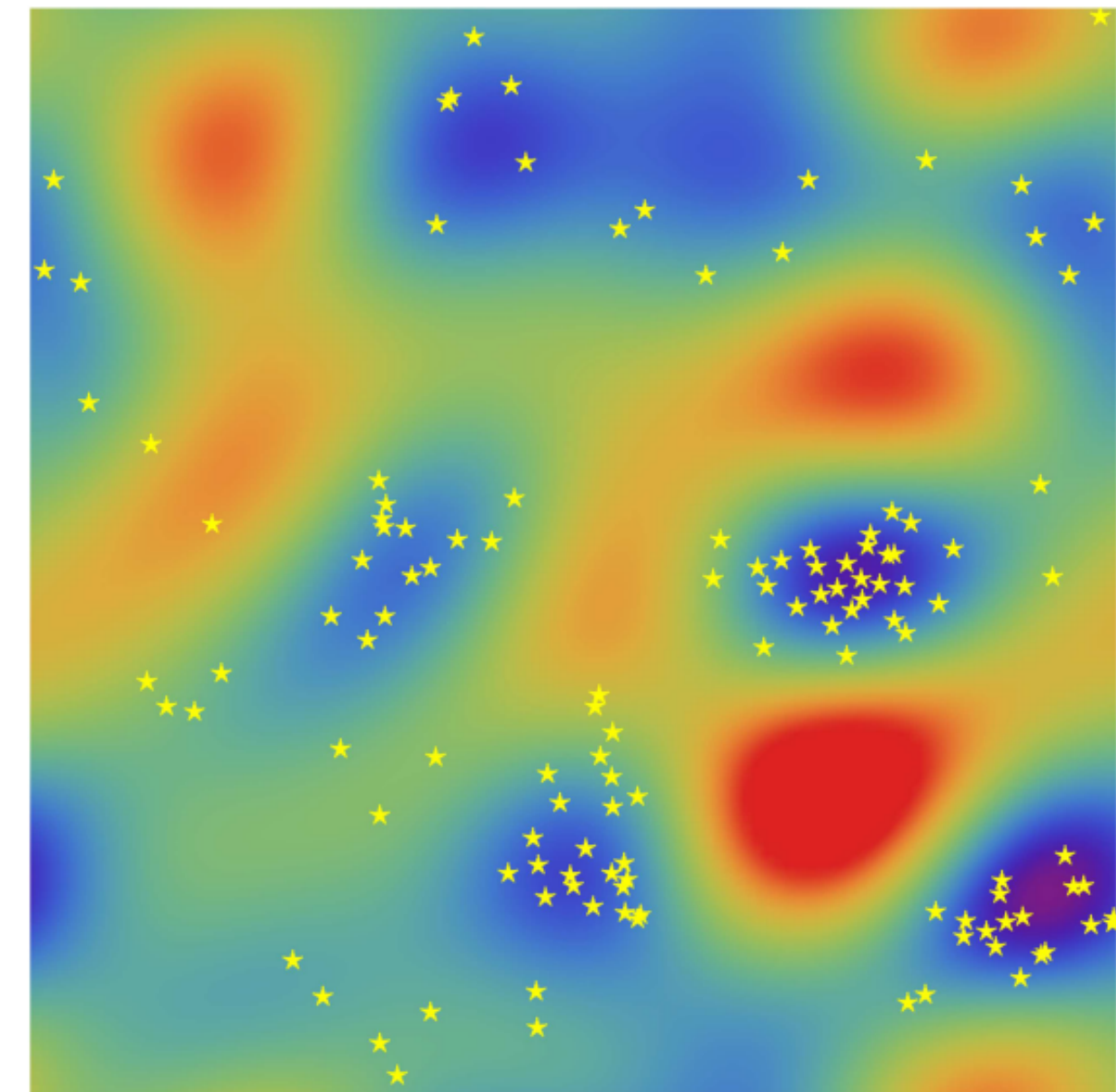


Fig. from Jinno, Konstandin, Rubira,
van de Vis, [2108.11947], JCAP

The nature of impurities

- Topological defects

Domain walls

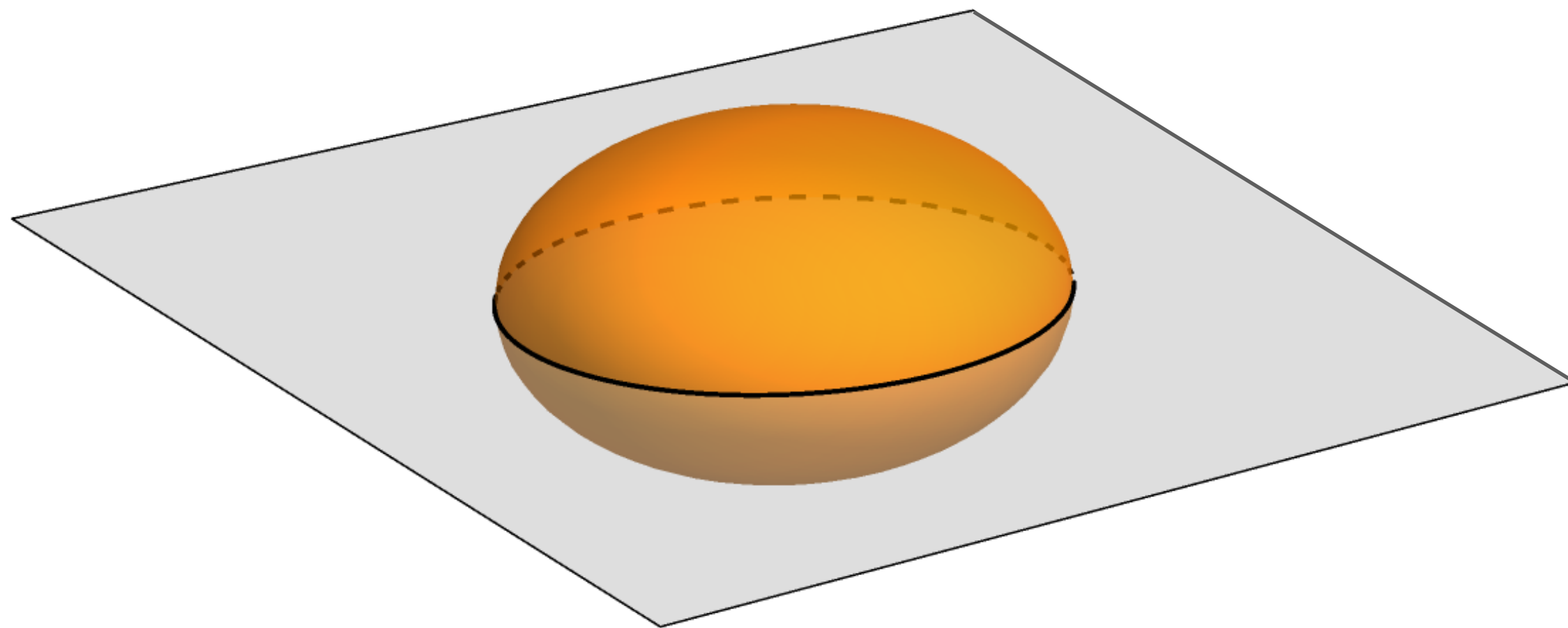


Fig. From Agrawal, **SB**, Mariotti, Nee
[2312.06749]

Strings

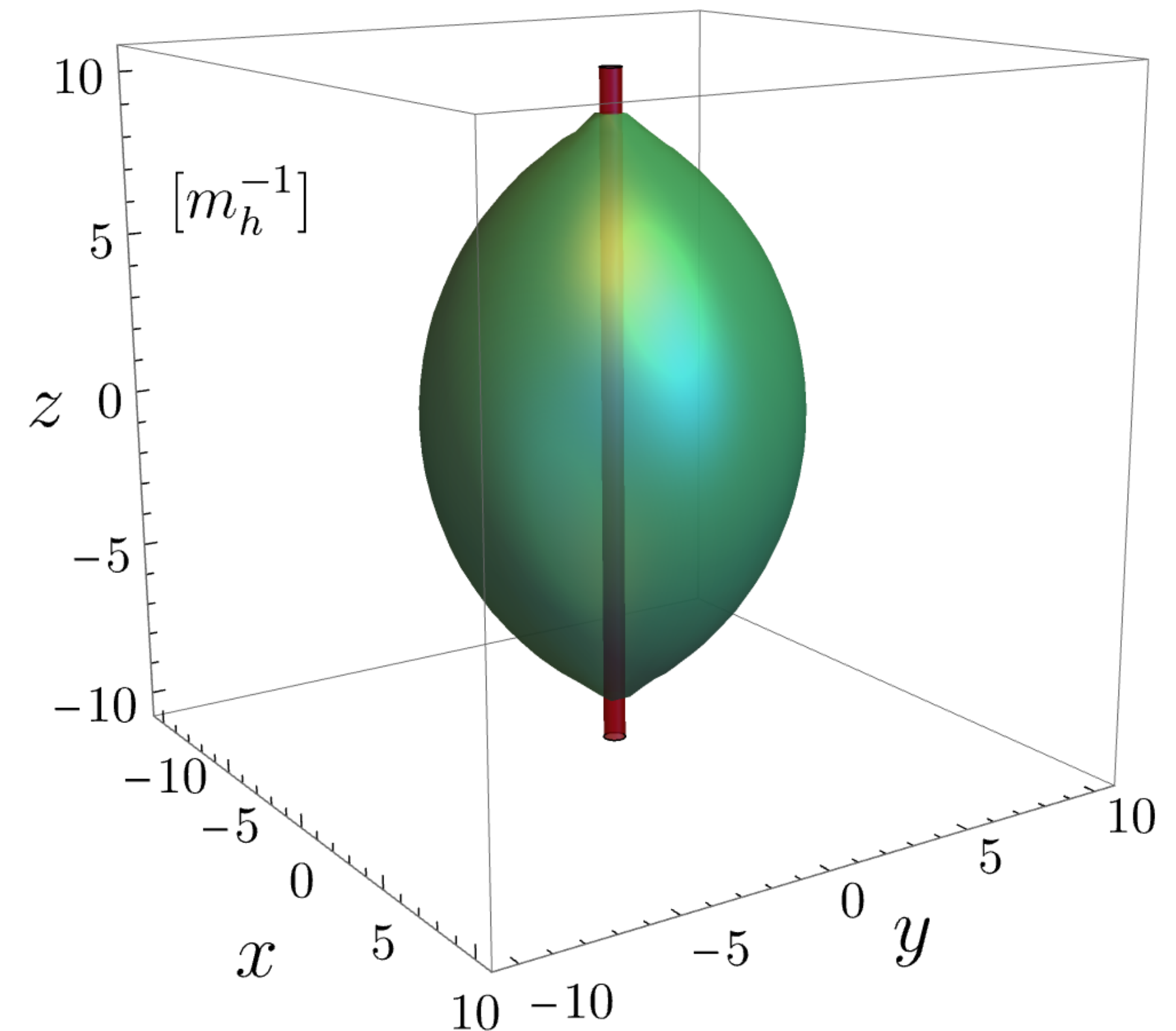


Fig. From **SB**, Mariotti,
[2405.08060]

Topological classification

Defect	Dimension	Homotopy	Mass
Domain walls	2	$\pi_0(\mathcal{M})$	σL^2
Strings	1	$\pi_1(\mathcal{M})$	μL

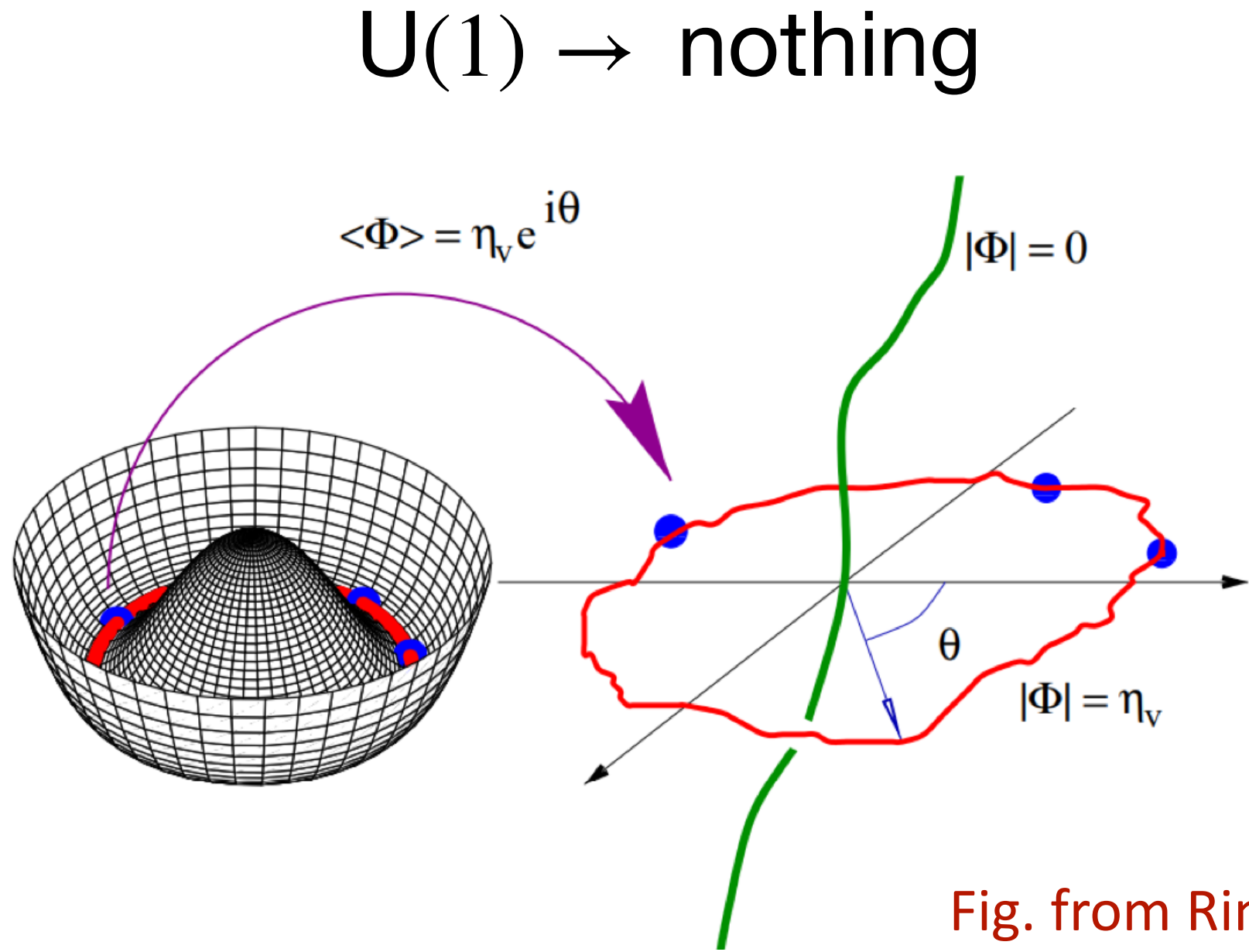
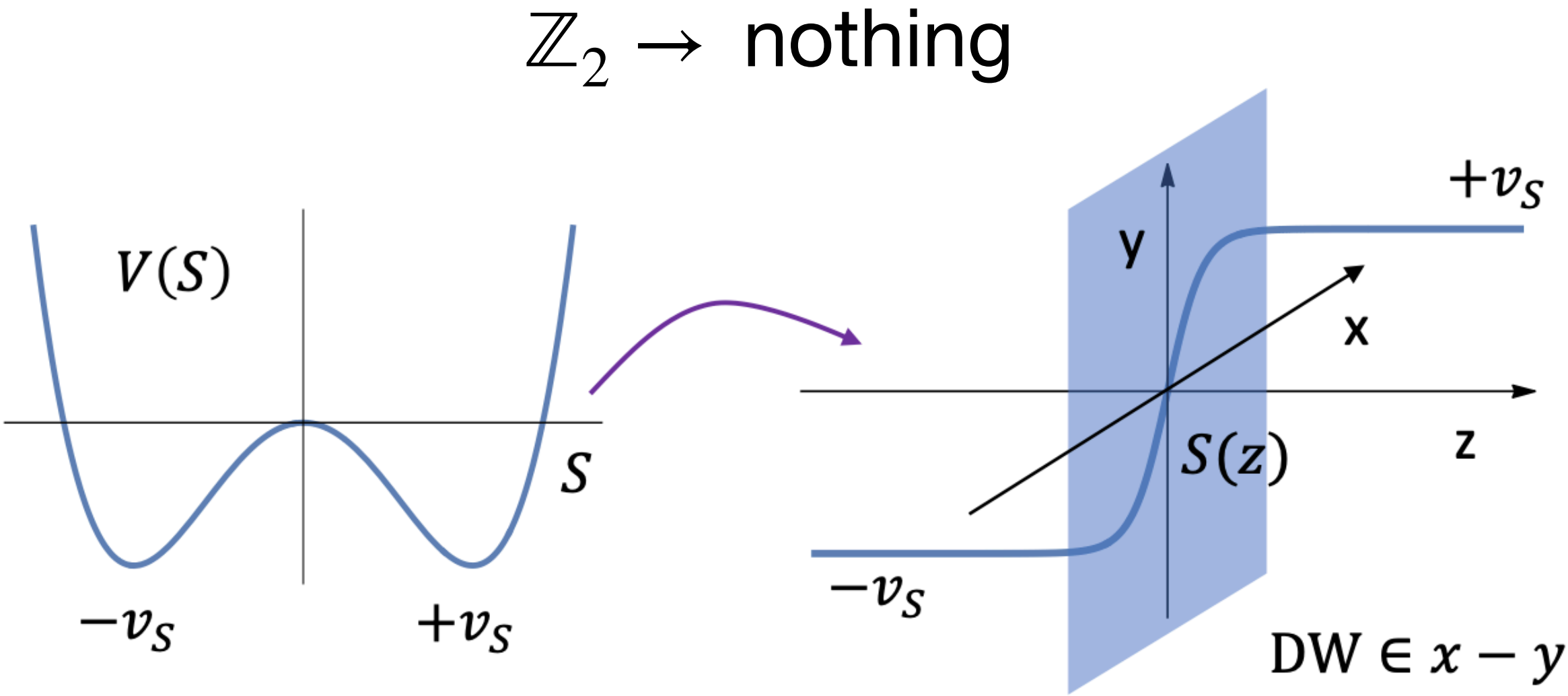


Fig. from Ringeval 2010

EWPT with a singlet

- SM + scalar singlet with $\mathbb{Z}_2 : S \rightarrow -S$

$$V = -\frac{1}{2}(\mu^2 - c_h T^2)h^2 + \frac{1}{4}\lambda h^4 \\ -\frac{1}{2}(m^2 - c_s T^2)S^2 + \frac{1}{4}\eta S^4 \\ + \frac{1}{2}\kappa h^2 S^2$$

* $\mathbb{Z}_2$ breaking terms destabilize the wall network and are set to zero in the following

See e.g. Espinosa, Gripaios, Konstandin, Riva [1110.2876] JCAP

EWPT with a singlet

- SM + scalar singlet with $\mathbb{Z}_2 : S \rightarrow -S$

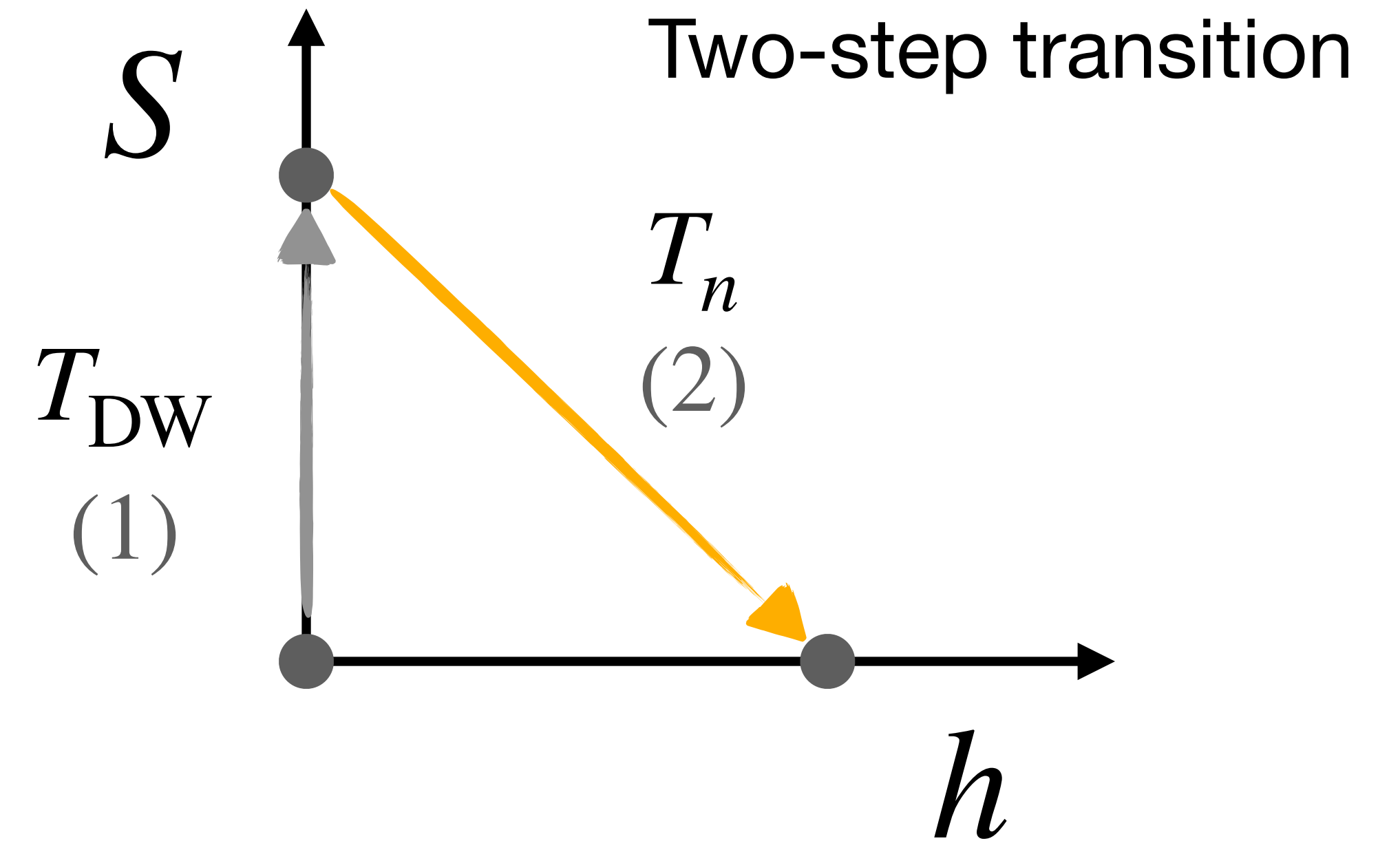
$$V = -\frac{1}{2}(\mu^2 - c_h T^2)h^2 + \frac{1}{4}\lambda h^4$$

$$-\frac{1}{2}(m^2 - c_s T^2)S^2 + \frac{1}{4}\eta S^4$$

$$+\frac{1}{2}\kappa h^2 S^2$$

* $\mathbb{Z}_2$ breaking terms destabilize the wall network and are set to zero in the following

See e.g. Espinosa, Gripaios, Konstandin, Riva [1110.2876] JCAP



EWPT with a singlet

- SM + scalar singlet with $\mathbb{Z}_2 : S \rightarrow -S$

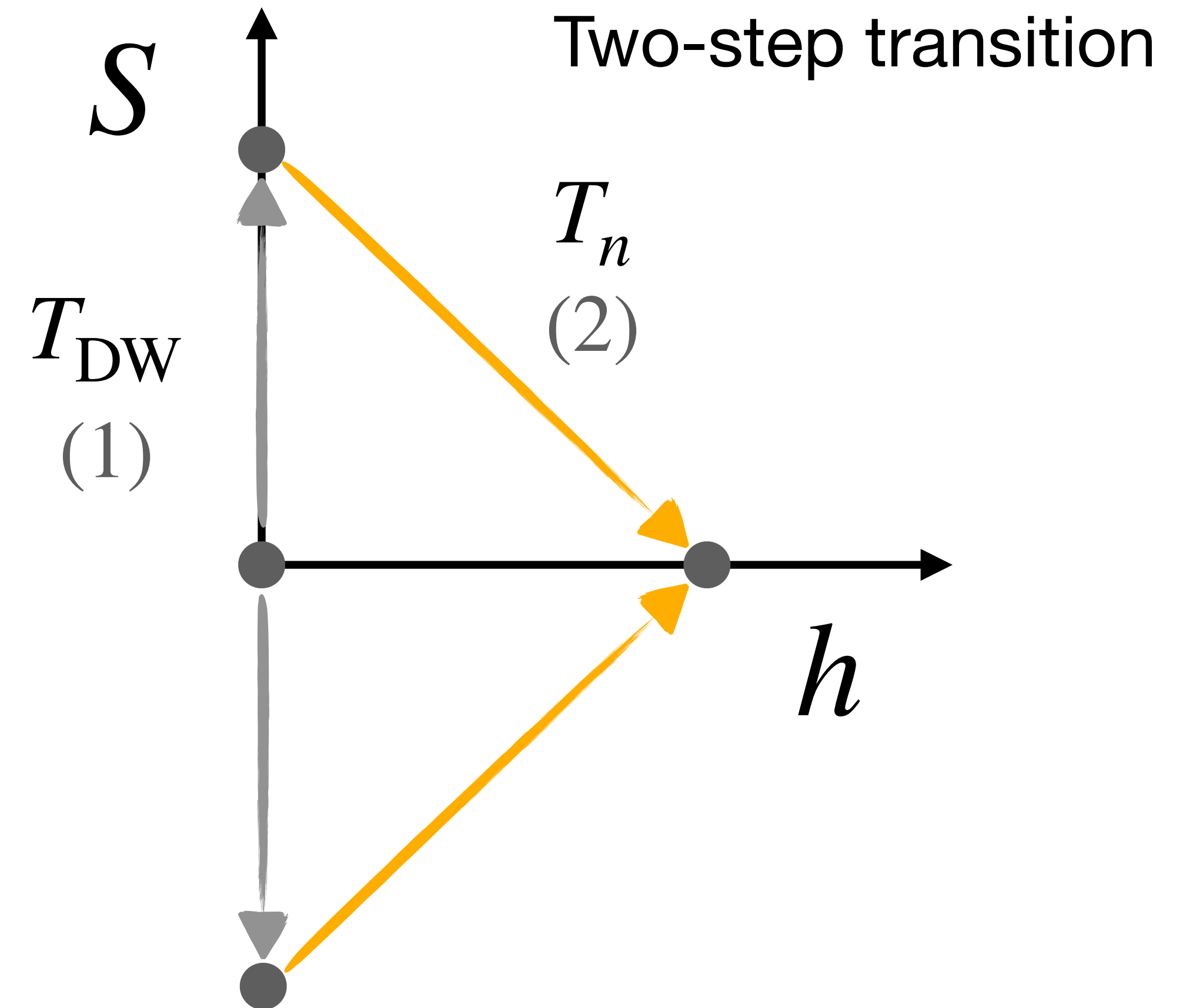
$$V = -\frac{1}{2}(\mu^2 - c_h T^2)h^2 + \frac{1}{4}\lambda h^4$$

$$-\frac{1}{2}(m^2 - c_s T^2)S^2 + \frac{1}{4}\eta S^4$$

$$+\frac{1}{2}\kappa h^2 S^2$$

* $\mathbb{Z}_2$ breaking terms destabilize the wall network and are set to zero in the following

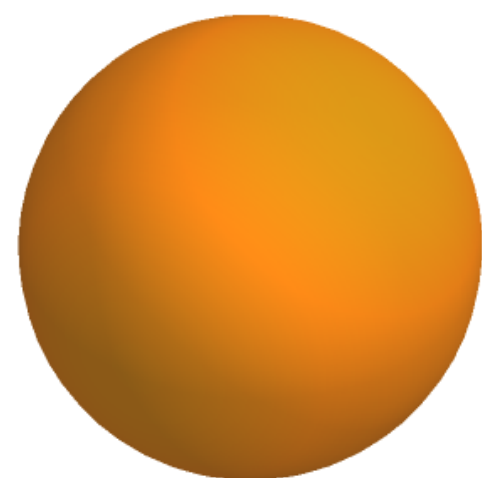
See e.g. Espinosa, Gripaios, Konstandin, Riva [1110.2876] JCAP



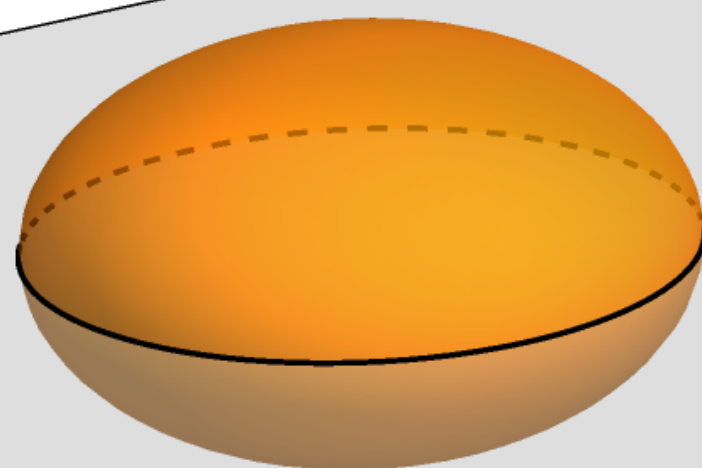
EWPT with a singlet

- Competition between homogenous and seeded nucleation for 2nd step:

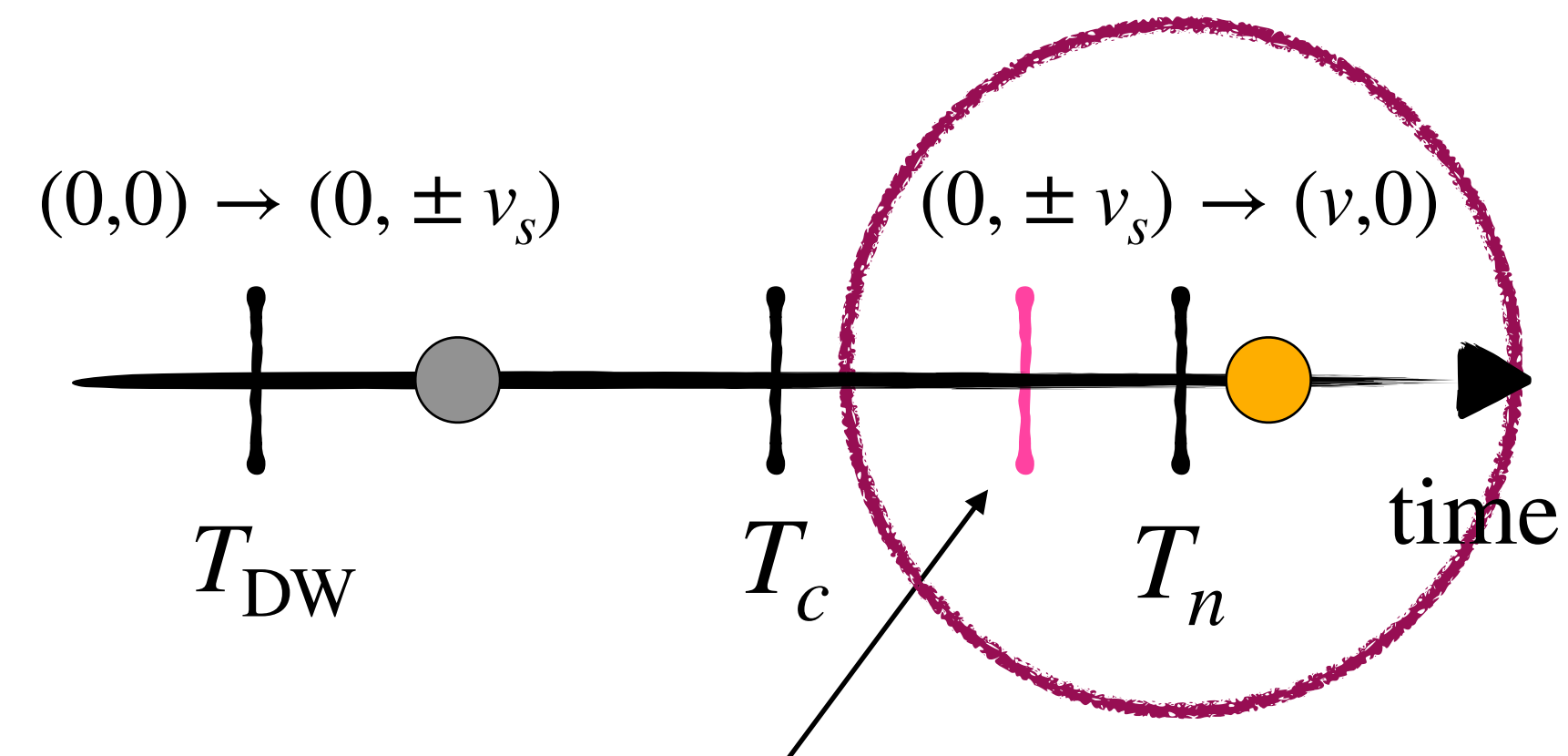
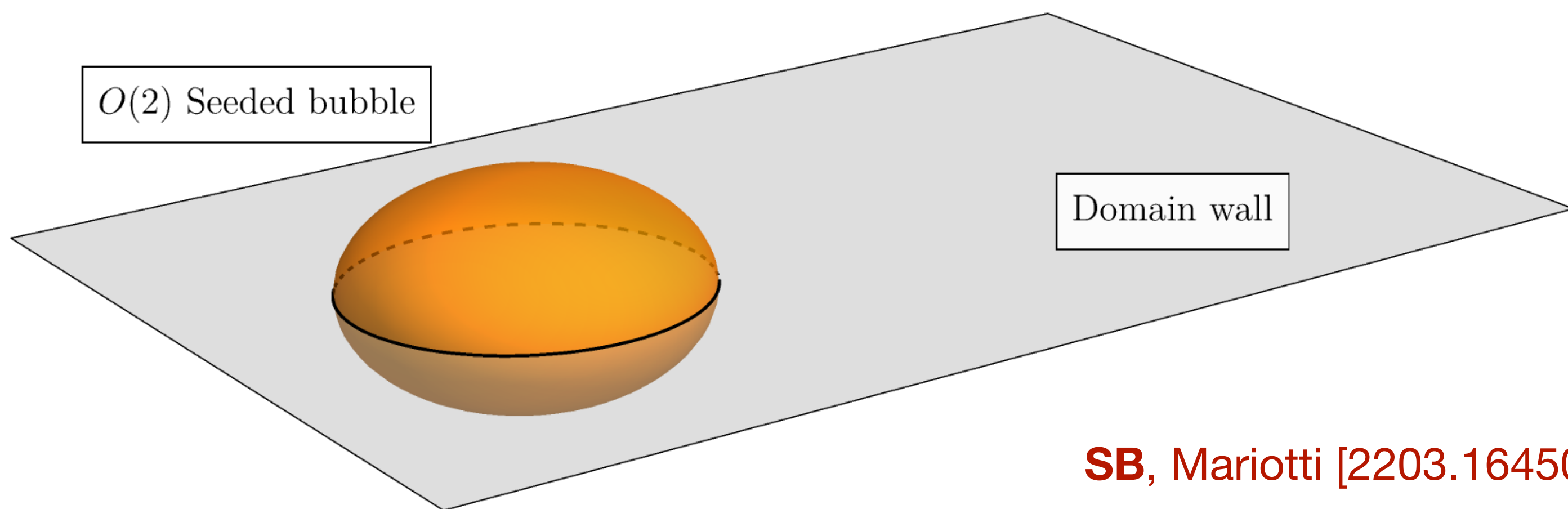
$O(3)$ Hom. bubble



$O(2)$ Seeded bubble



Domain wall



At T_n^{seed} bubbles may nucleate *on the walls*

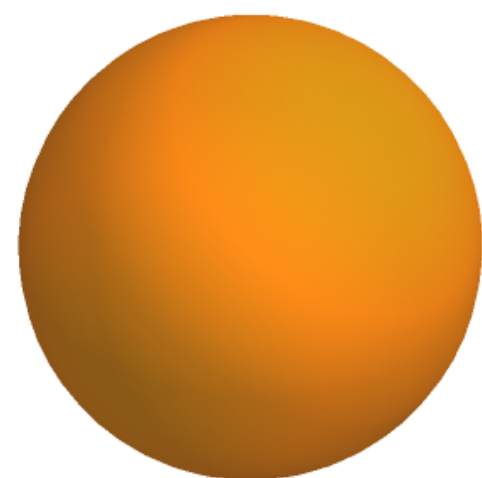
SB, Mariotti [2203.16450], PRL

Agrawal, **SB**, Mariotti, Nee [2312.06749] JHEP

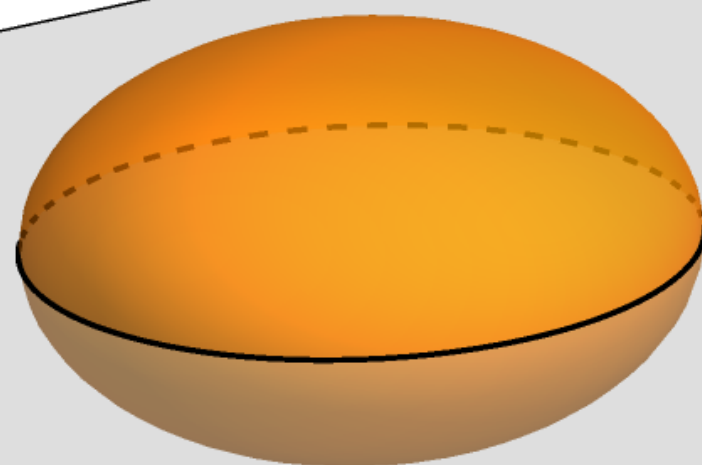
EWPT with a singlet

- Competition between homogenous and seeded nucleation for 2nd step:

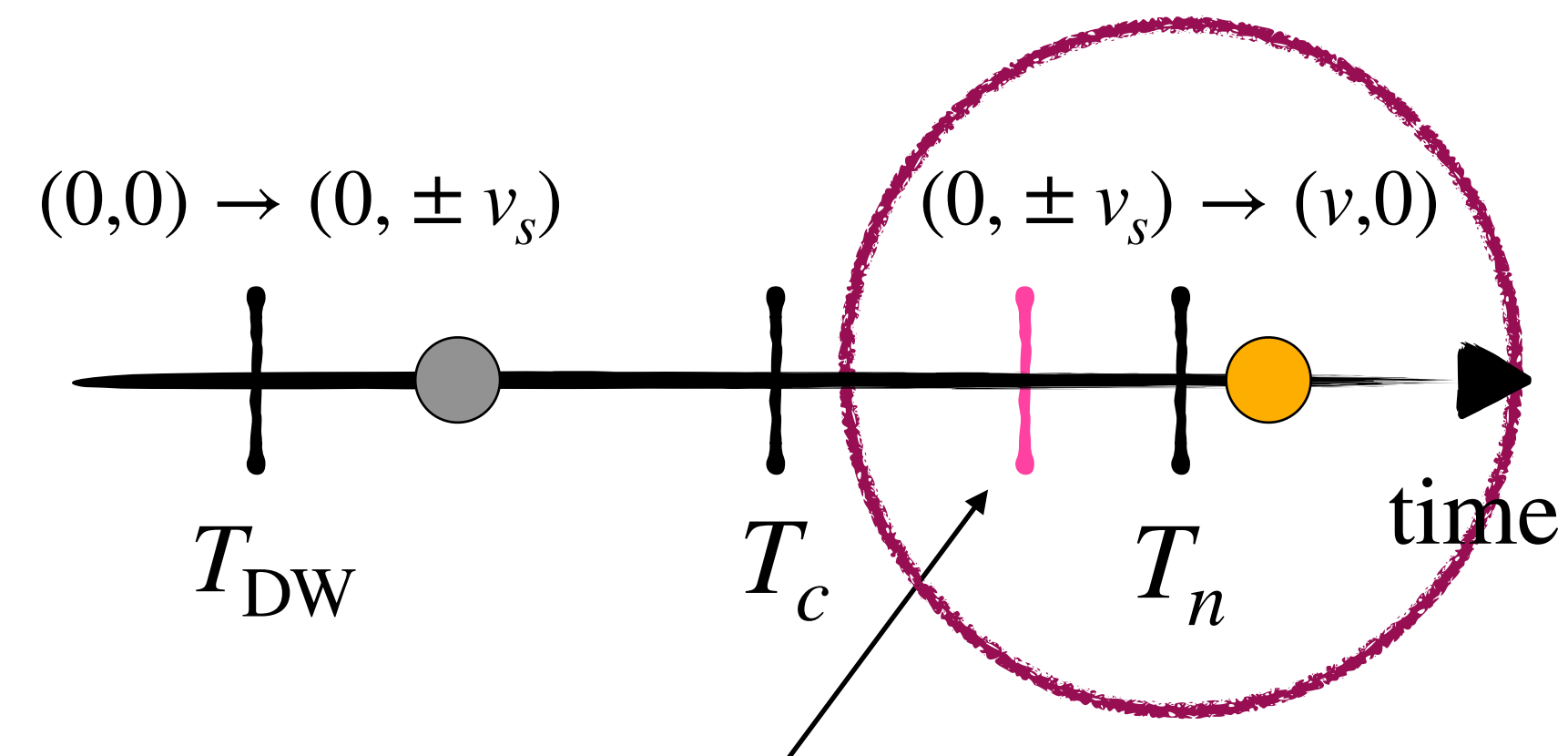
$O(3)$ Hom. bubble



$O(2)$ Seeded bubble



Domain wall



At T_n^{seed} bubbles may nucleate *on* the walls

- Define nucleation rate per unit surface
- Stricter nucleation condition (only on sub manifold)

Lazarides, Shafi, Kibble 1982, PRD

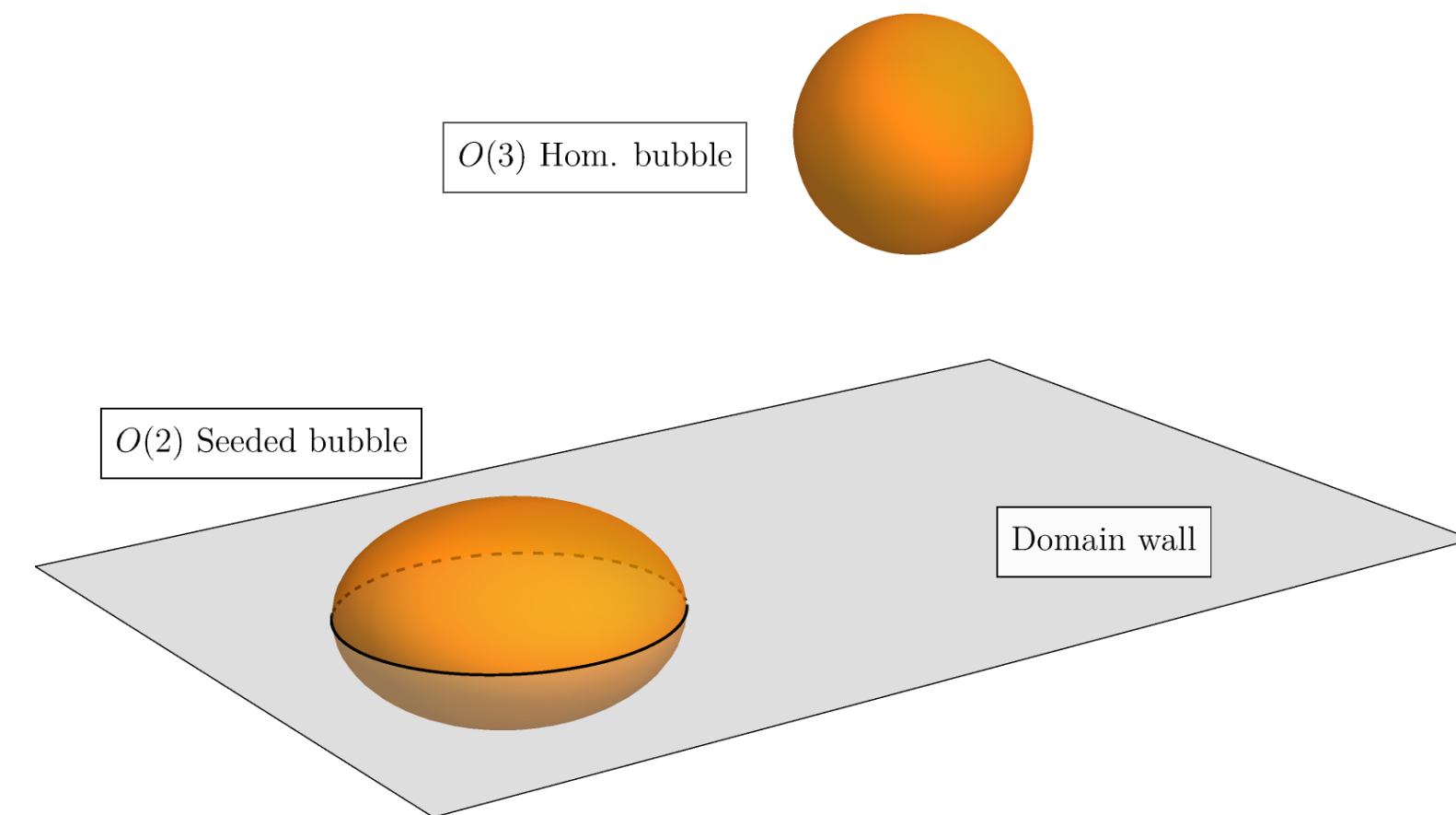
Perkins, Vilenkin 1992, PRD

SB, Mariotti [2203.16450], PRL

Agrawal, **SB**, Mariotti, Nee [2312.06749] JHEP

EWPT with a singlet

Only $O(2)$ symmetry



1. Solving coupled **system of PDEs**

- “Exact”
- Physical picture?
- Which initial conditions for the algorithm?

2. **Thin wall** approximation

- Limited validity
- Intuitive picture
- Simple calculation

3. **Kaluza-Klein** decomposition

- Quantitative results
- Still intuitive
- Initial conditions for num. algorithms and cross-checks

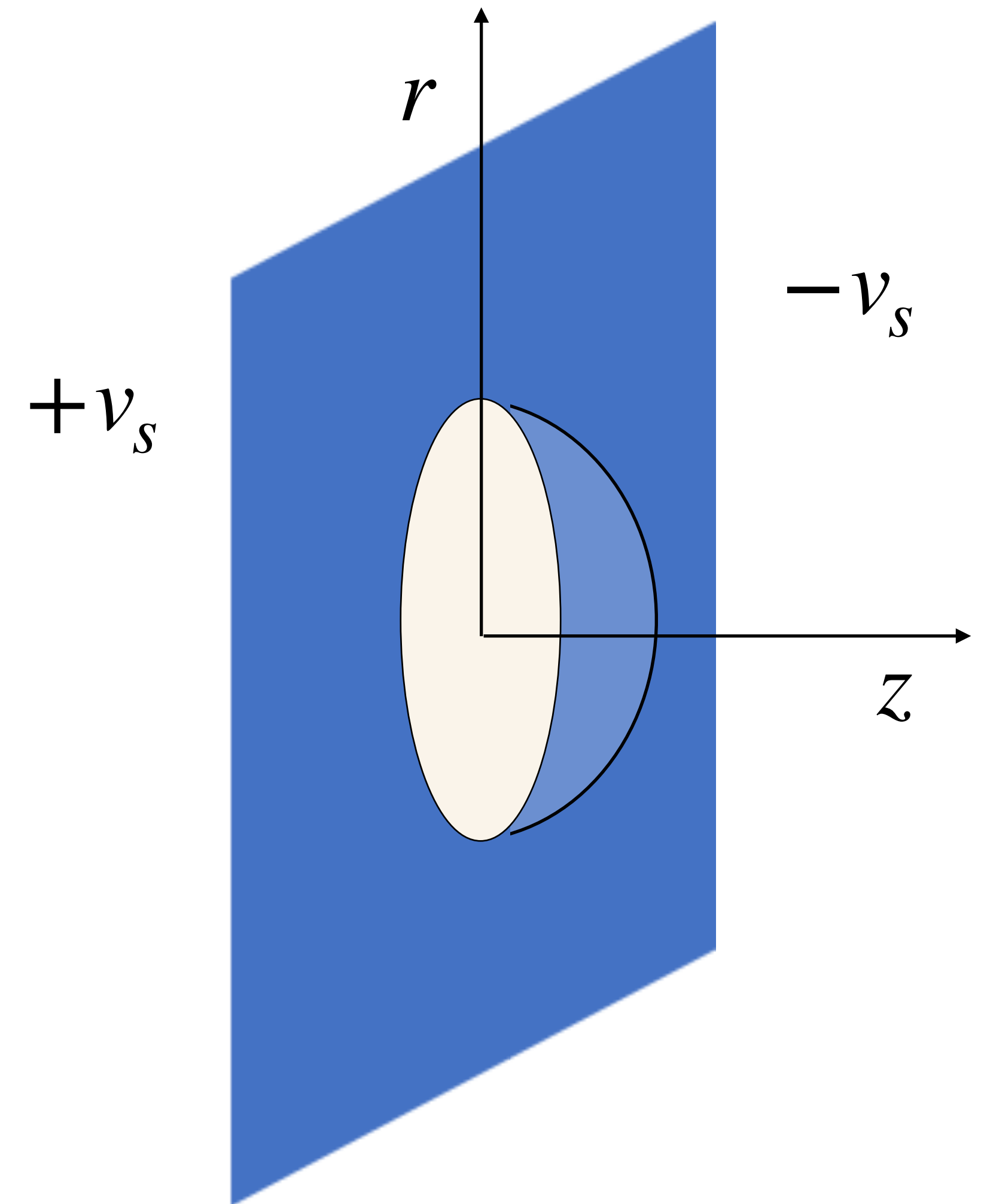
1. Equations of motion

False vacuum is non-trivial as it depends on z

$$\frac{\partial^2 \phi}{\partial r^2} + \frac{1}{r} \frac{\partial \phi}{\partial r} + \frac{\partial^2 \phi}{\partial z^2} = \frac{\partial V}{\partial \phi}, \quad \phi = h, S$$

$$S(\infty, z) = S_{DW}(z), \quad S(r, \pm \infty) = \pm v_s,$$

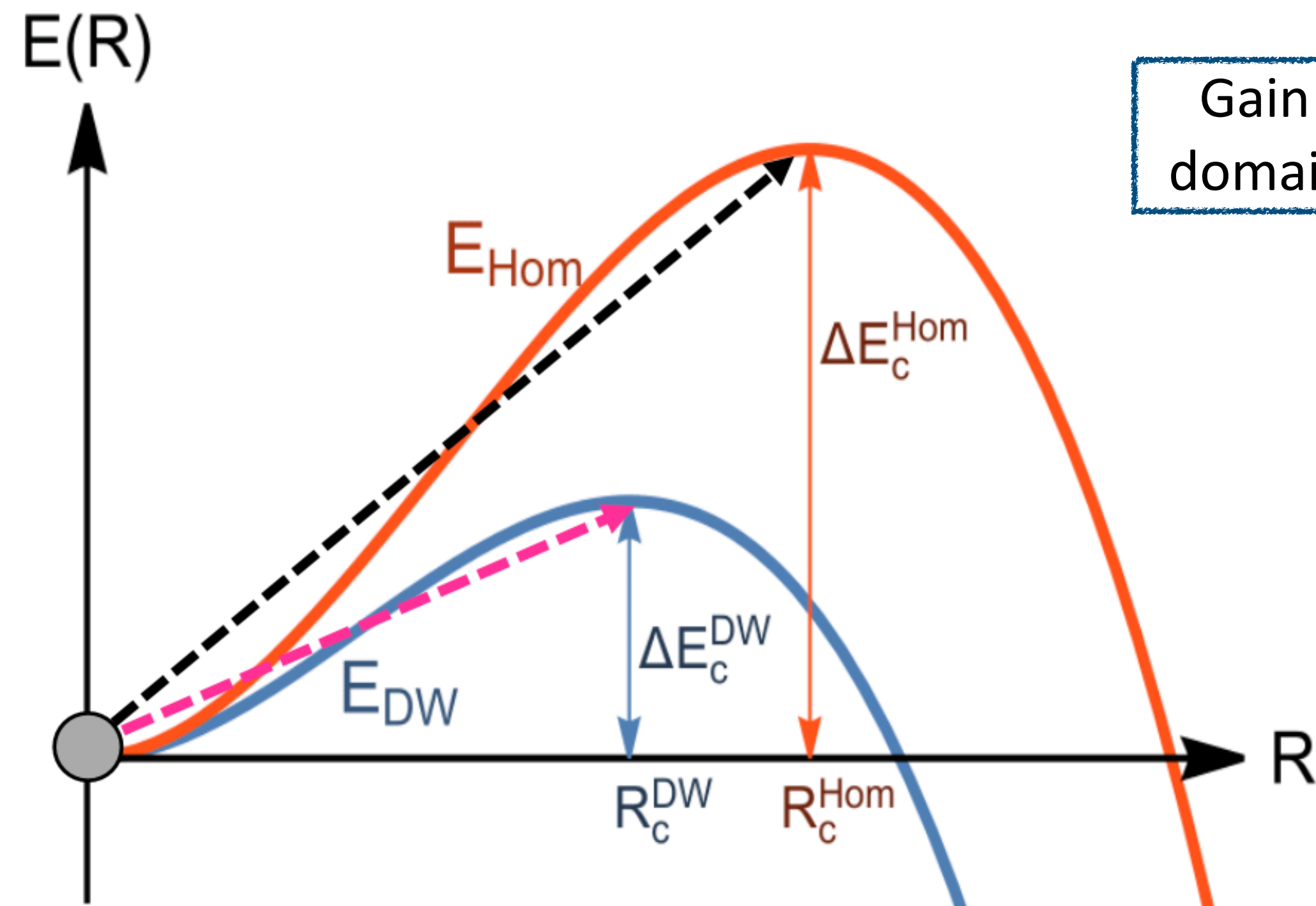
$$h(\infty, z) = h(\rho, \pm \infty) = 0$$



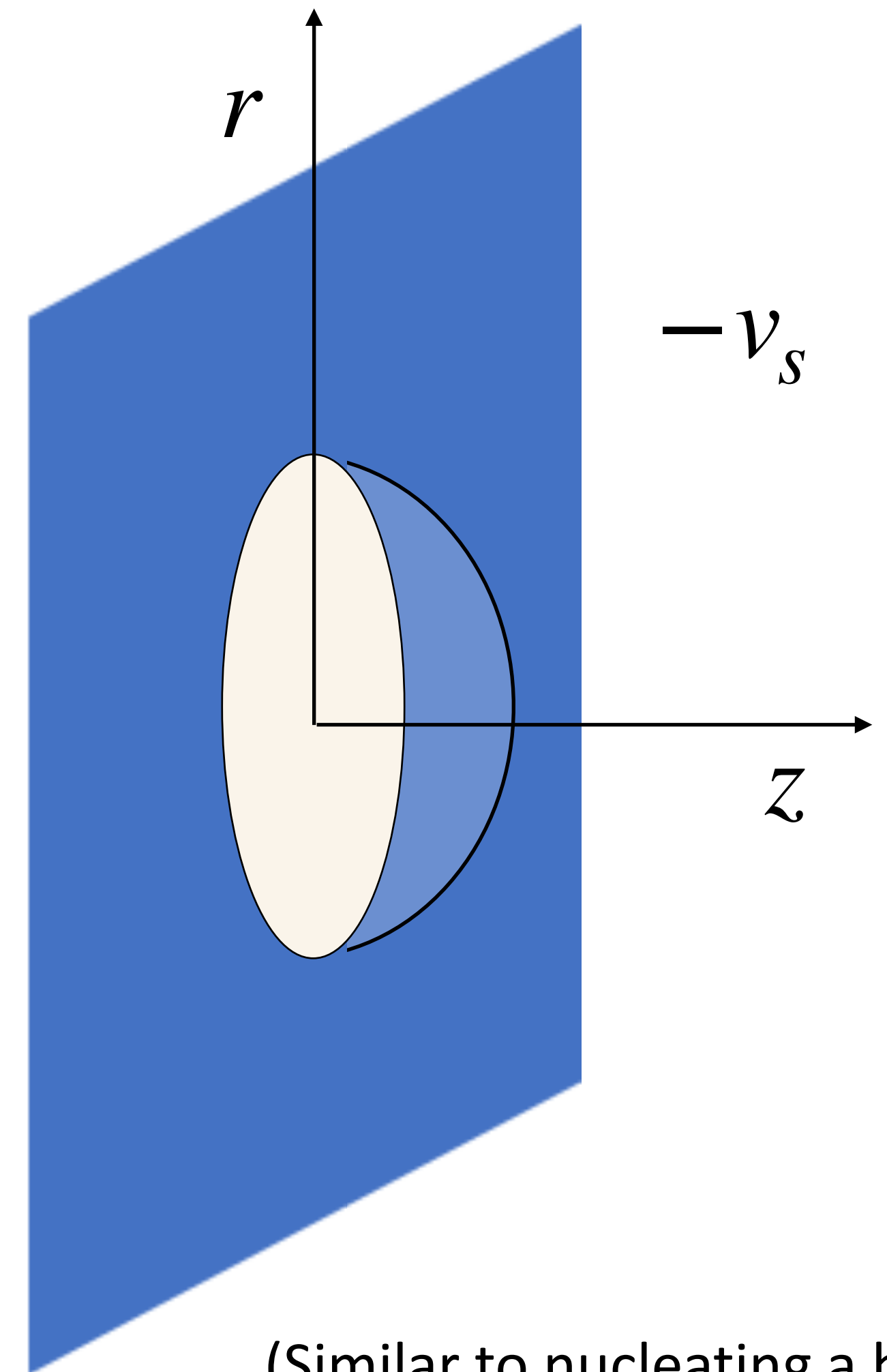
2. Thin wall approximation

$$E(R) = -\frac{4\pi}{3}\epsilon R^3 + 4\pi \left(\sigma_B - \frac{1}{4}\sigma_{DW} \right) R^2$$

Gain by eating up
domain wall surface



$+v_s$



(Similar to nucleating a hole
in string-wall networks)

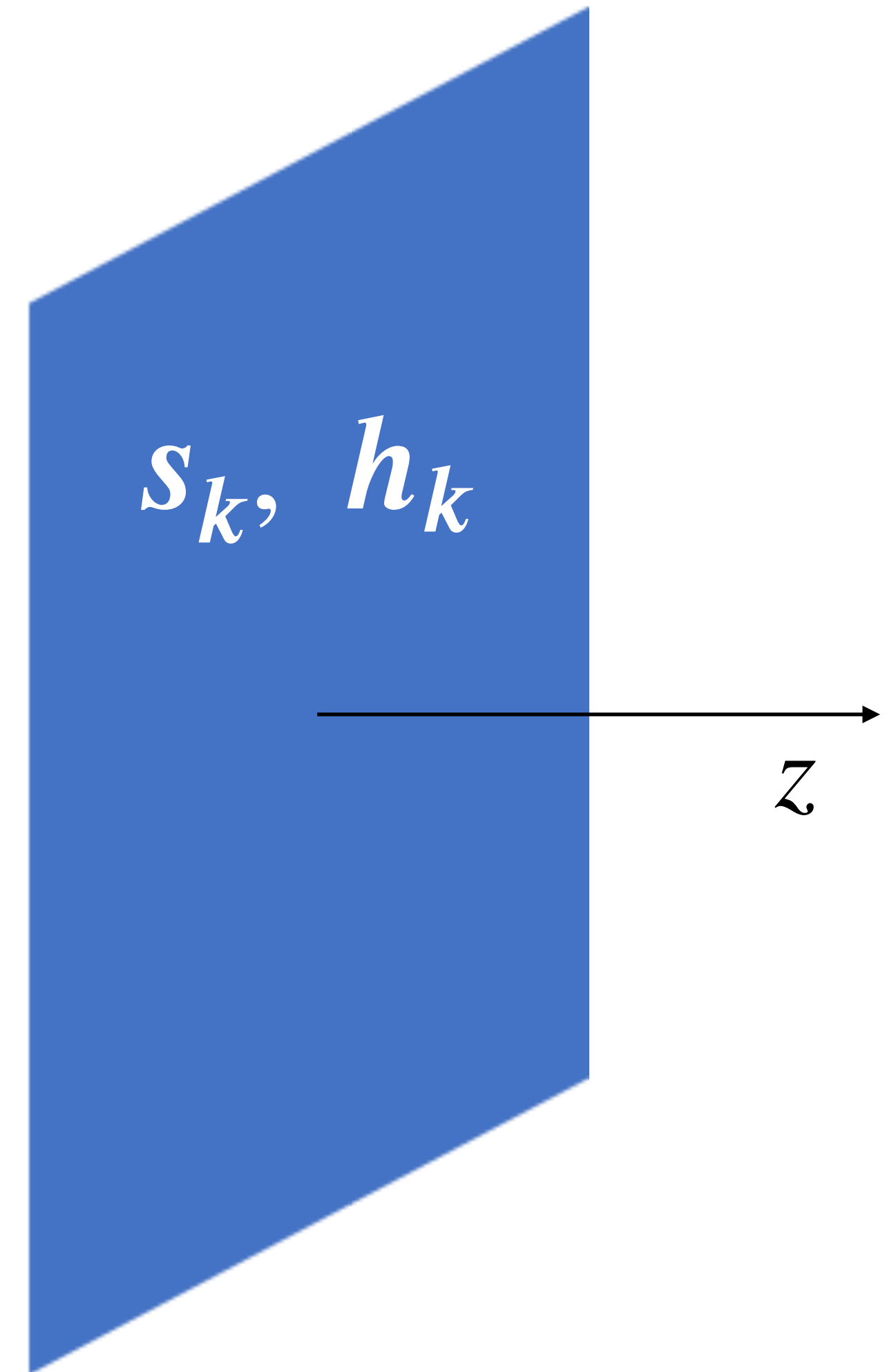
3. Kaluza-Klein decomposition

- Expand the fields around the domain wall background:

$$S = S_{\text{DW}}(z) + \sum_k s_k(x_\mu) \sigma_k(z)$$

$$h = \sum_k h_k(x_\mu) \phi_k(z)$$

$$x_\mu = t, x, y$$



3. Kaluza-Klein decomposition

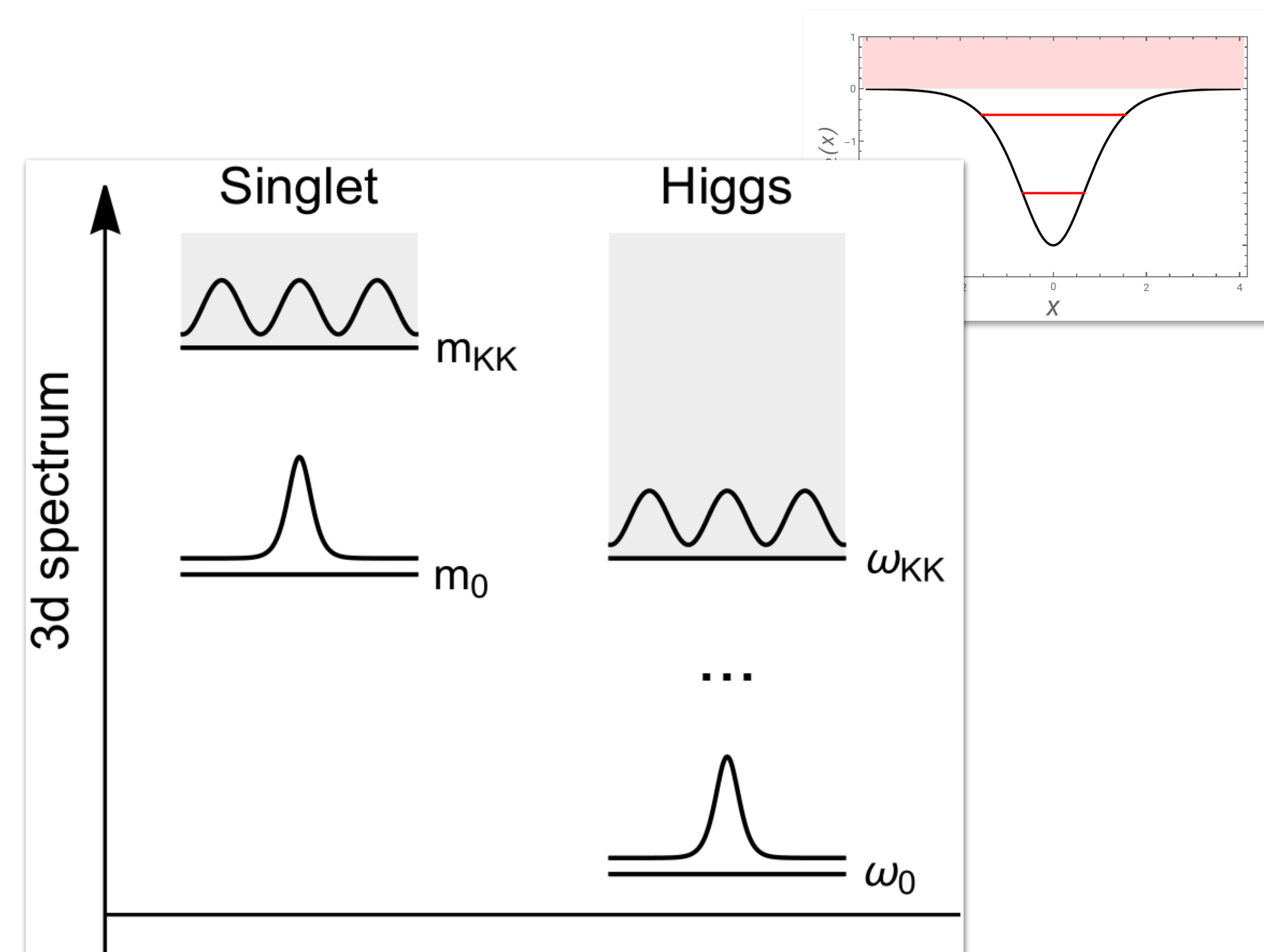
- Expand the fields around the domain wall background:

$$S = S_{\text{DW}}(z) + \sum_k s_k(x_\mu) \sigma_k(z)$$

$$h = \sum_k h_k(x_\mu) \phi_k(z)$$

$$x_\mu = t, x, y$$

- Eigenspectrum of excitations:



3. Kaluza-Klein decomposition

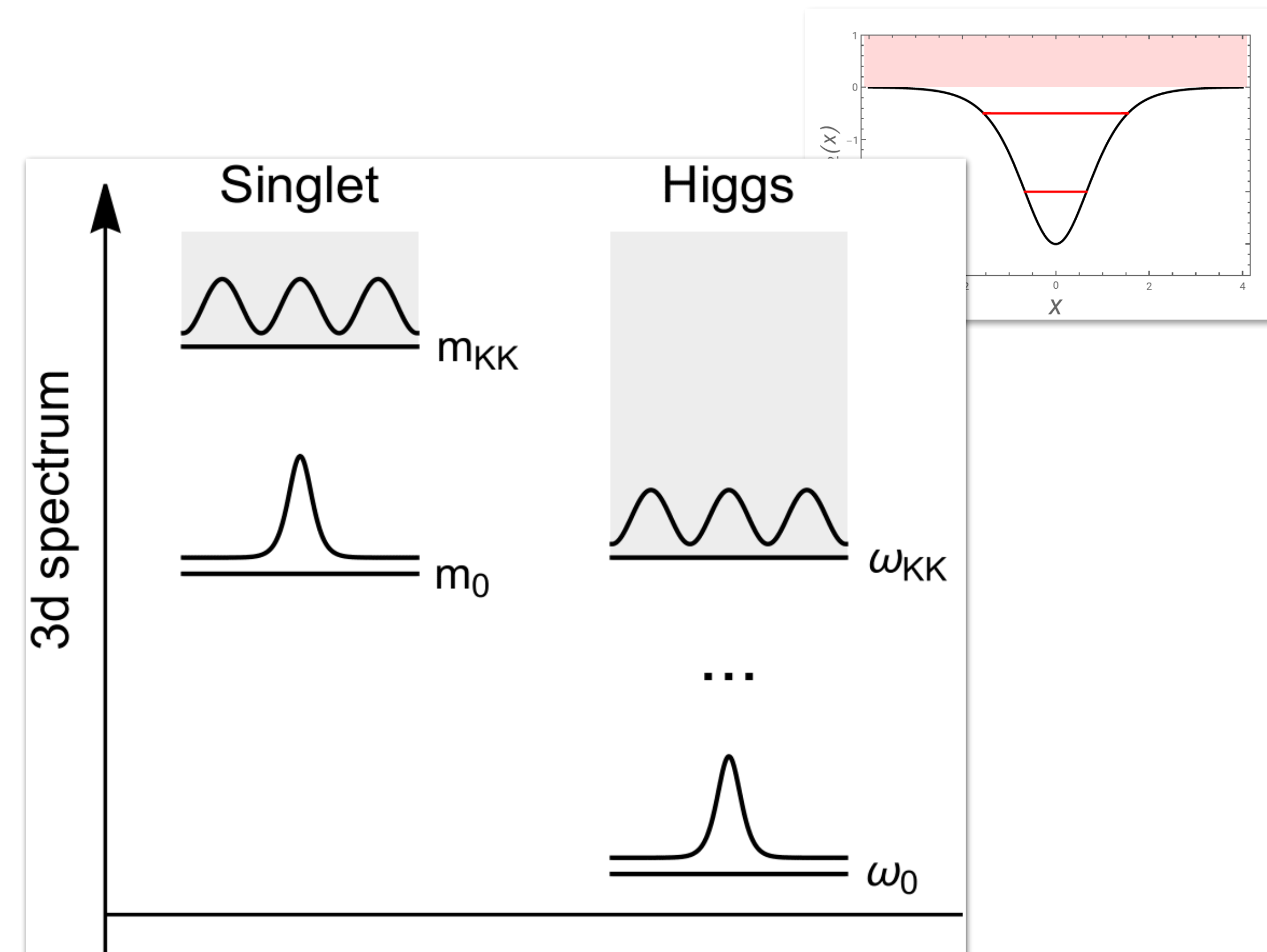
- Integrate along z to obtain 3d action and integrate out continuum excitations:

$$S_{3d} = \int d^3x \frac{1}{2}(\partial_\mu h_0)^2 + \frac{1}{2}(\partial_\mu s_0)^2 - V_{3d}^{\text{eff}}(h_0, s_0)$$

Seeded tunneling as homogeneous problem in lower dimension!

↓
Tunneling trajectory can be obtained
with CosmoTransitions

- Eigenspectrum of excitations:



3. Kaluza-Klein decomposition

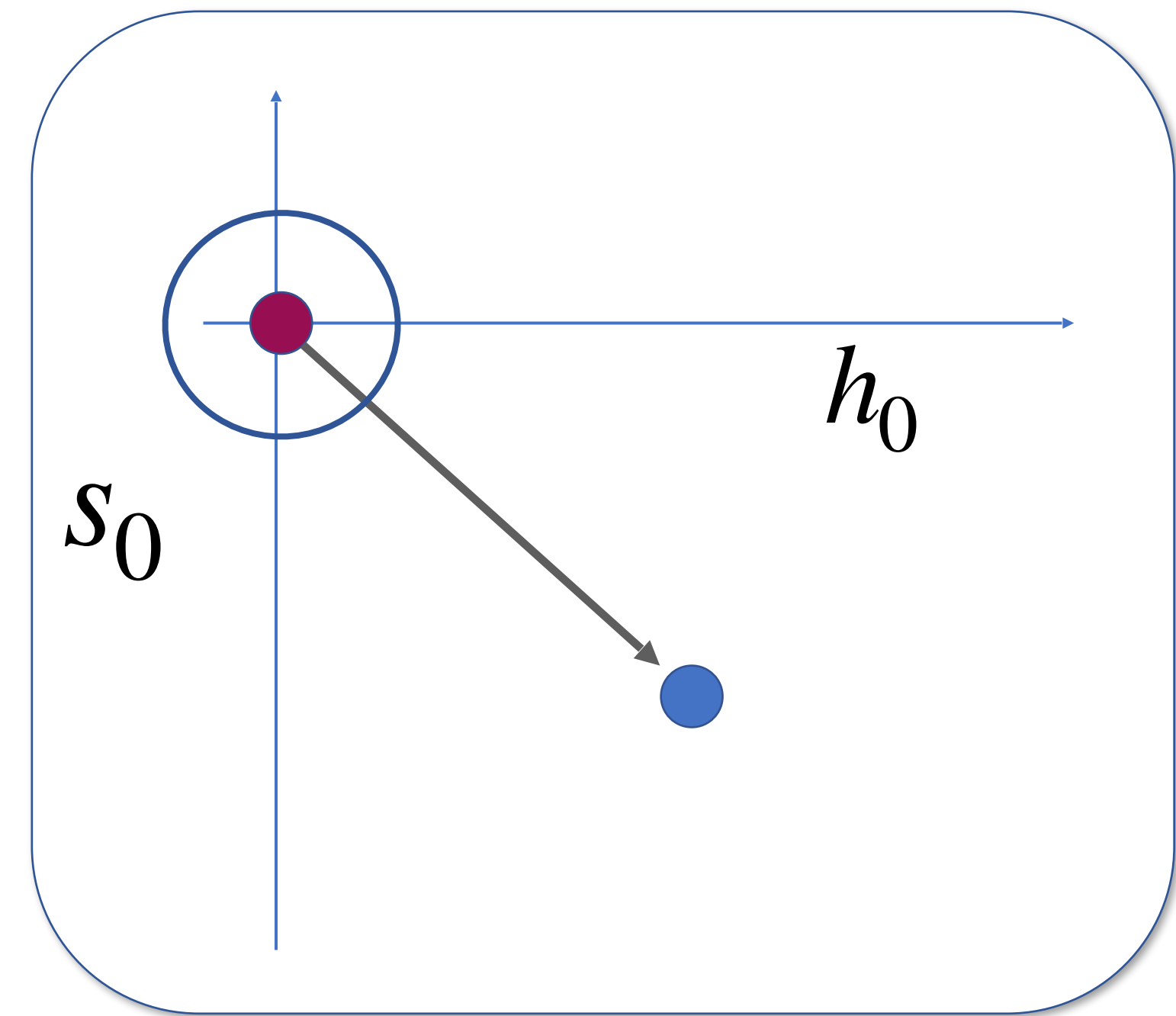
- Integrate along z to obtain 3d action and integrate out continuum excitations:

$$S_{3d} = \int d^3x \frac{1}{2}(\partial_\mu h_0)^2 + \frac{1}{2}(\partial_\mu s_0)^2 - V_{3d}^{\text{eff}}(h_0, s_0)$$

Seeded tunneling as homogeneous problem in lower dimension!

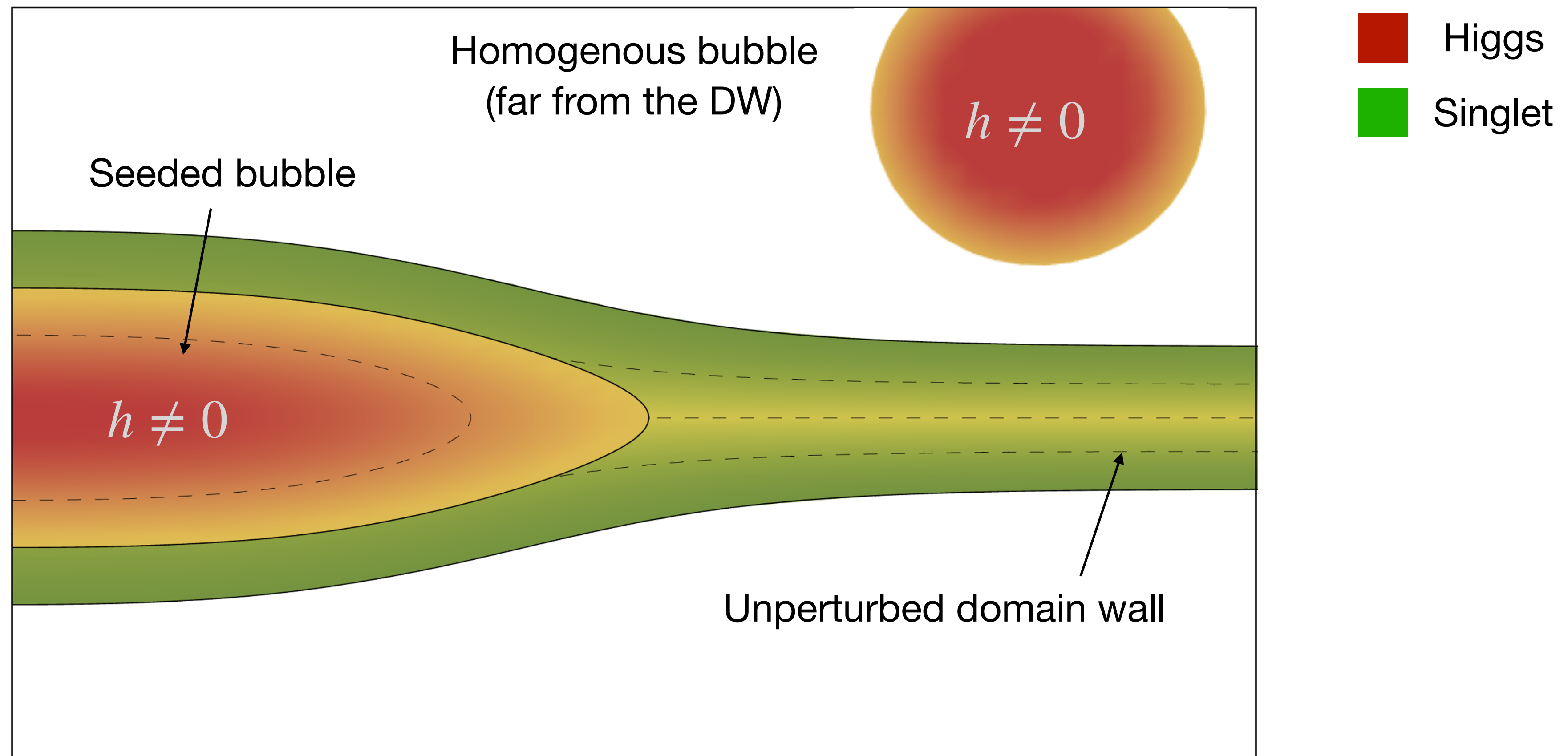


Tunneling trajectory can be obtained
with `CosmoTransitions`

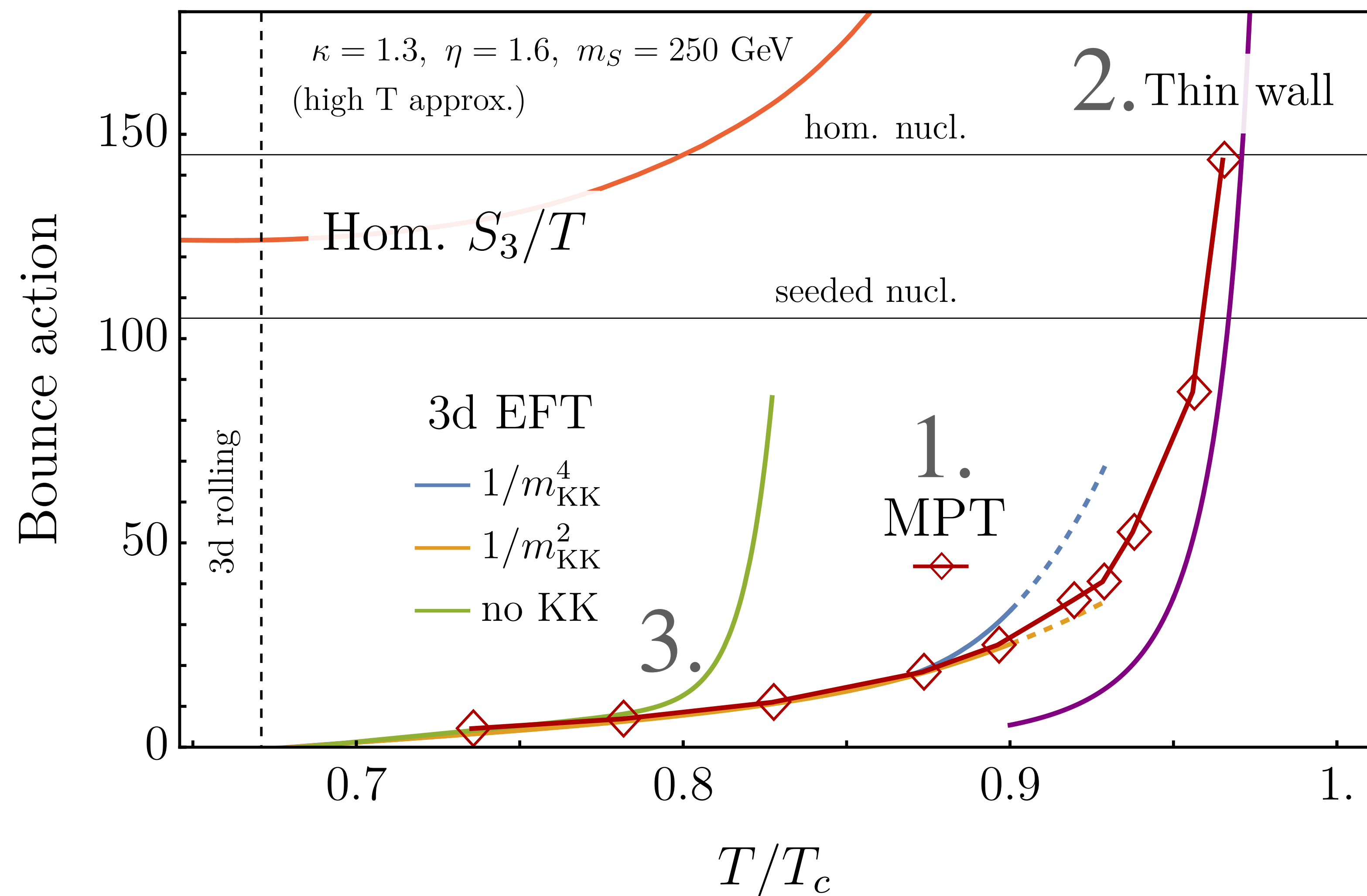


3. Kaluza-Klein decomposition

- With tunneling solution for h_0, s_0 at hand we can reconstruct full profiles:



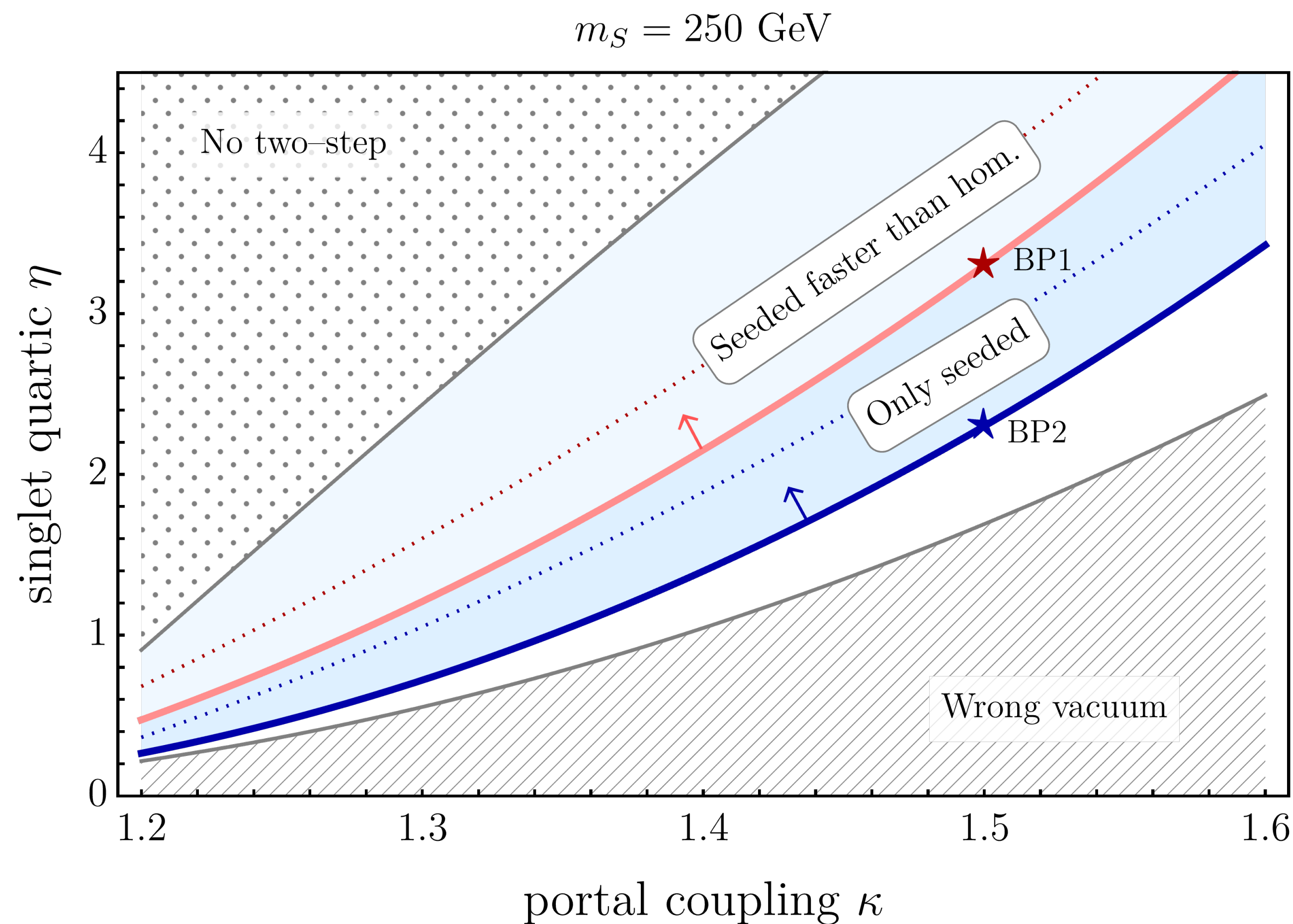
Comparison of the methods



Agrawal, **SB**, Mariotti,
Nee [2312.06749] JHEP

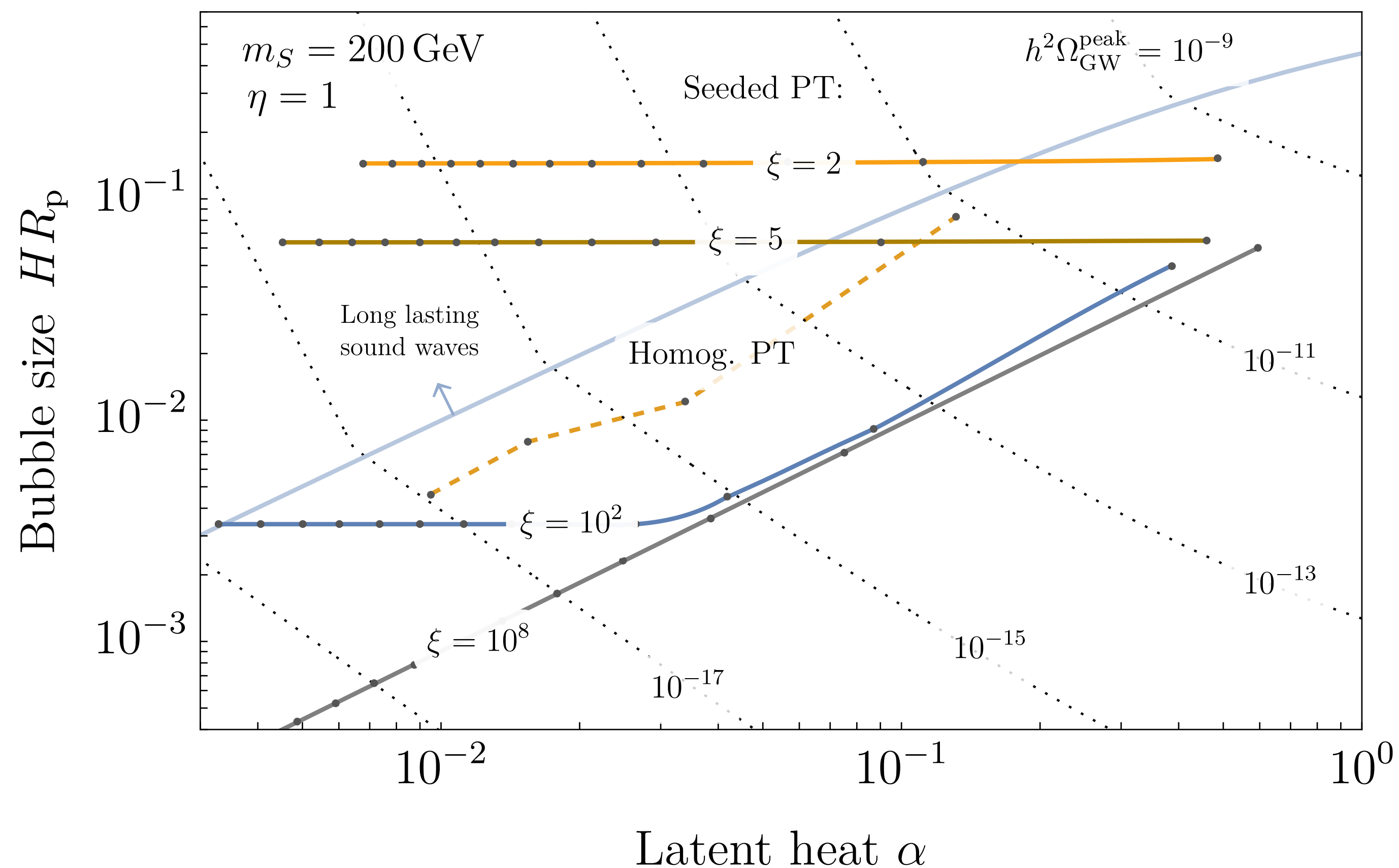
EWPT with a singlet

- Seeded transition is faster in all the two-step parameter space
- New parameter space becomes viable thanks to seeded tunneling



EWPT with a singlet

- *Homogenous PT*: bubble size and strength are strongly correlated
- *Seeded PT*: pheno controlled by the number of defects per Hubble volume ξ
 1. **Sparse** networks $\xi \sim 1$: size determined by average distance between defects
 2. **Dense** networks $\xi \gg 1$: bubble size determined by nucleation rate



EWPT with a singlet

- Domain wall network mimicked by Ising model
- Spectrum shifted to IR with enhanced amplitude

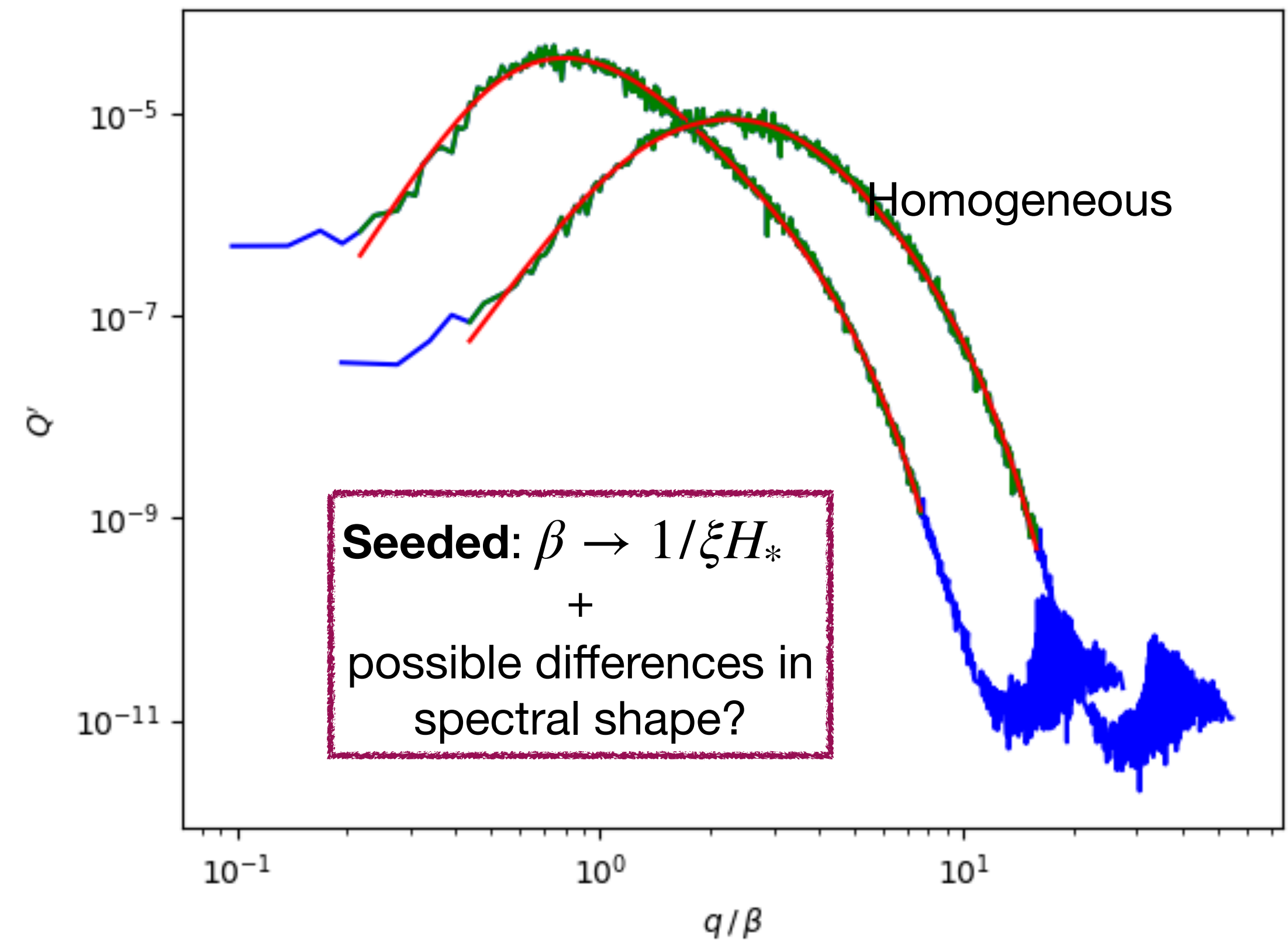
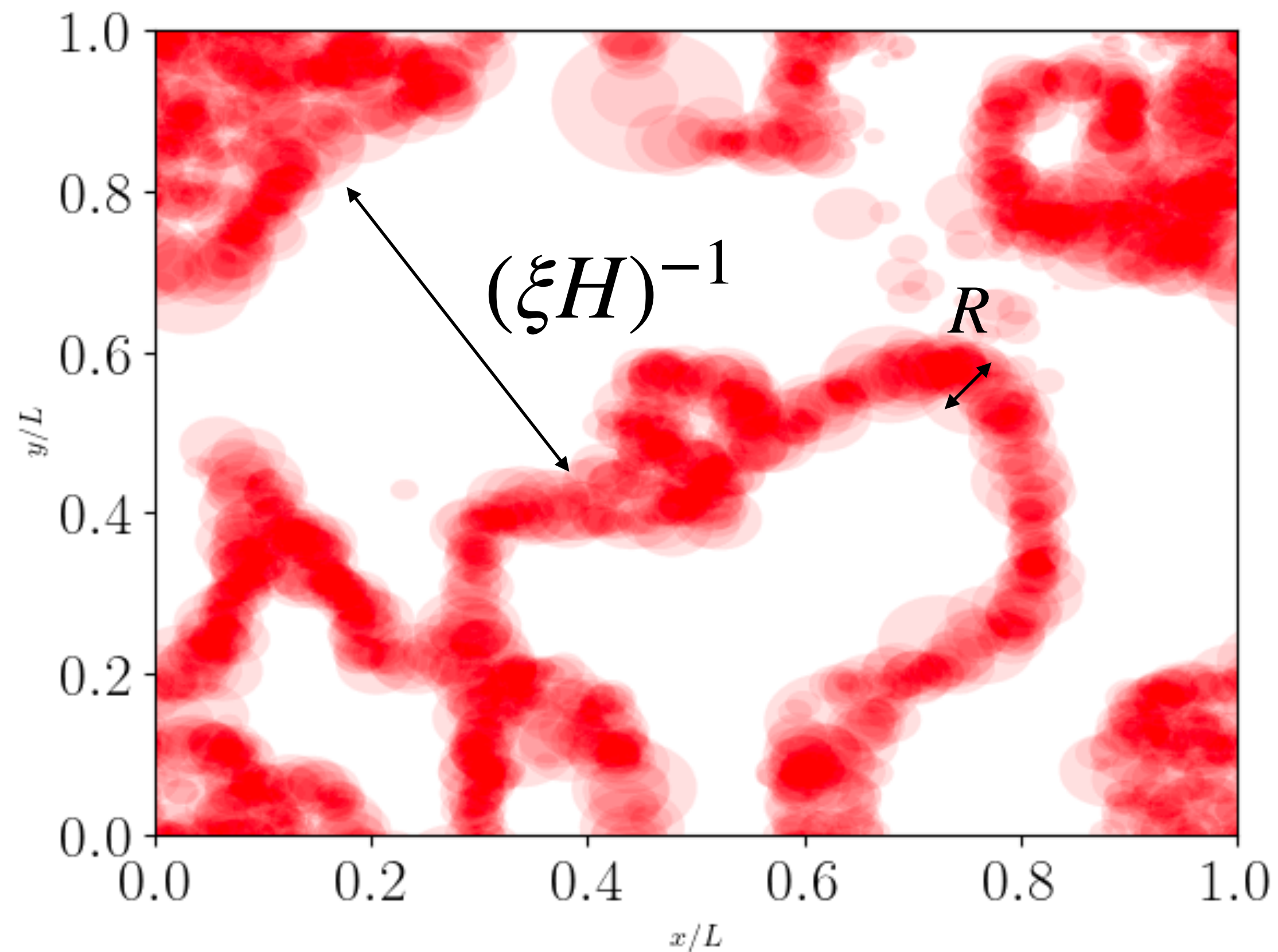
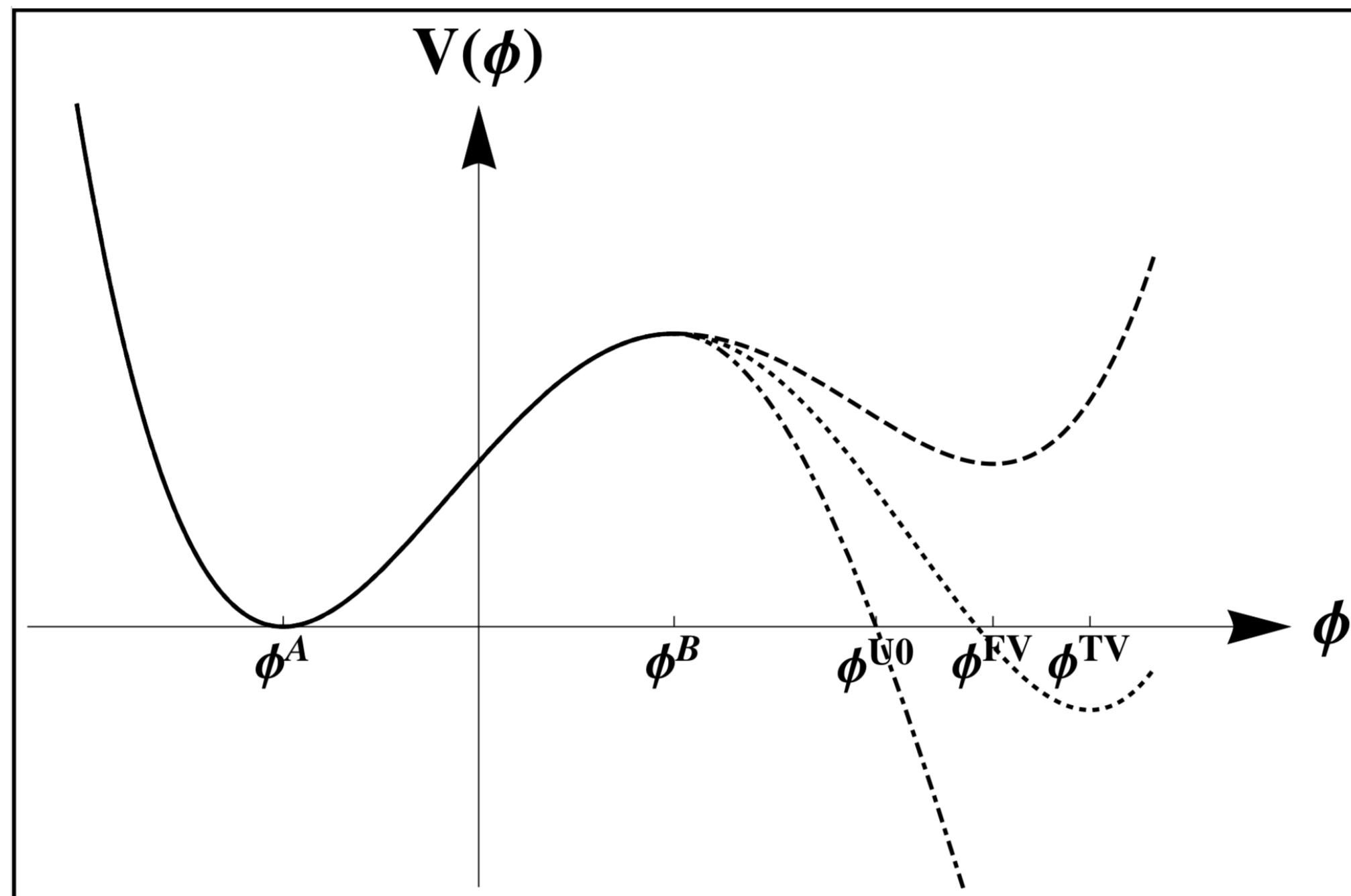


Fig. from **SB**, Jinno, Konstandin, Rubira, Stomberg [2302.06952] JCAP

Tunneling rate from real-time simulations

- Langevin approach to mimic the thermal bath via fluctuation-dissipation:



$$(\partial_t^2 - \nabla^2)\phi(\vec{x}, t) + \frac{\partial V(\phi)}{\partial \phi} + \eta \dot{\phi}(\vec{x}, t) = \xi(\vec{x}, t)$$

$$\langle \xi(\vec{x}, t) \xi(\vec{x}', t') \rangle = \Omega \delta^3(\vec{x} - \vec{x}') \delta(t - t')$$

$$\langle \xi(\vec{x}, t) \rangle = 0$$

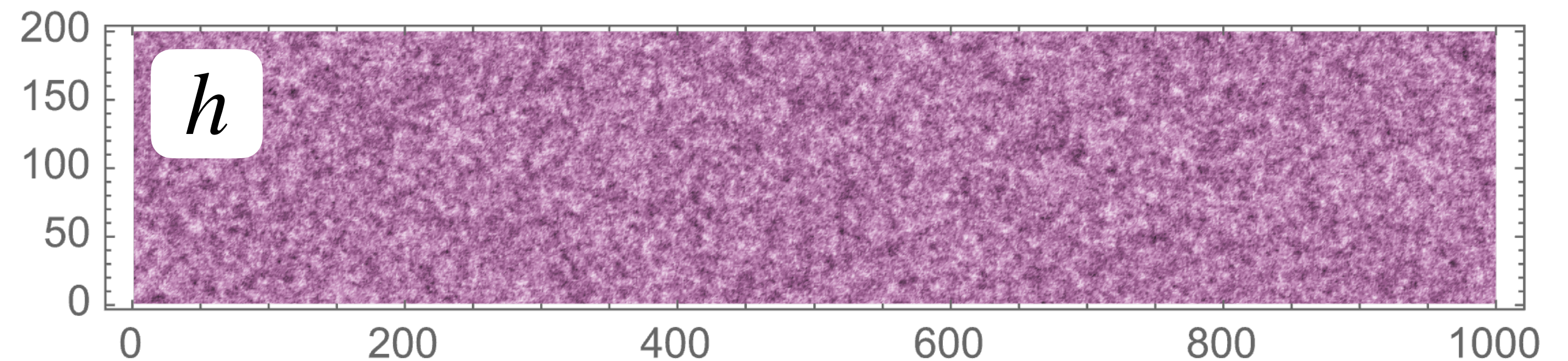
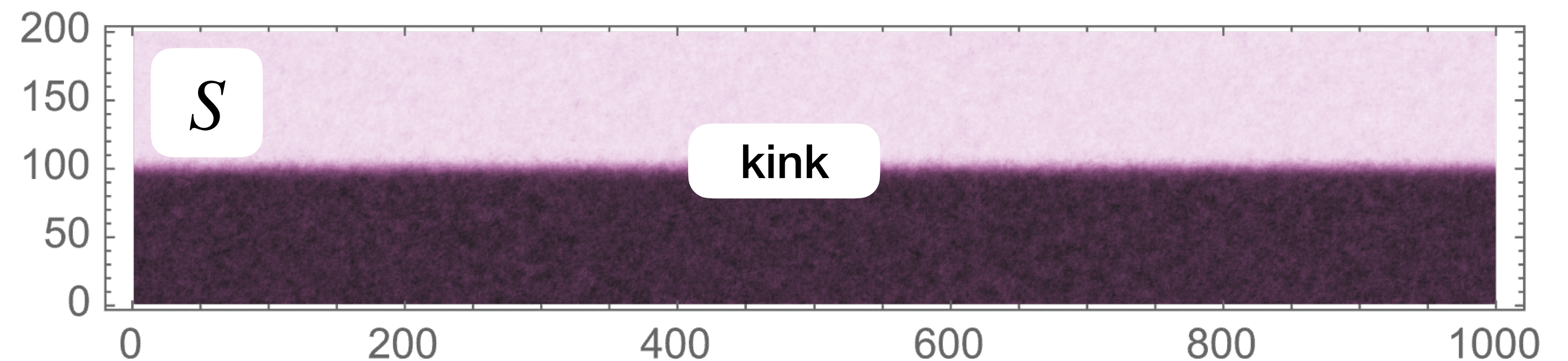
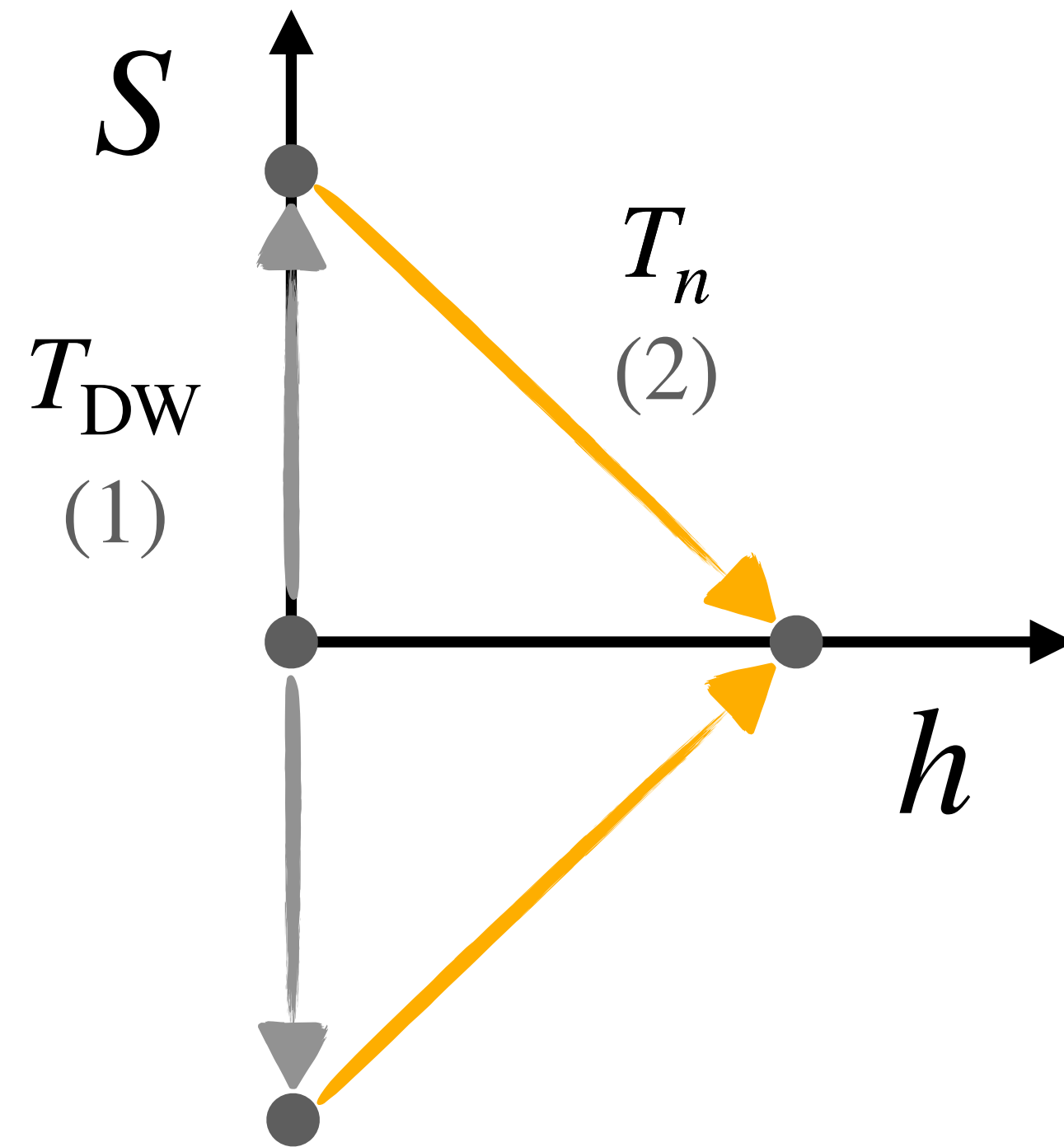
Satisfying: $\Omega = 2\eta/\beta = 2\eta k_B T$

Tunneling rate from real-time simulations

SB, Ekstedt

- Initial conditions such there is one defect (kink) in the simulation box in $d = 2 + 1$

$$\omega \sim T < T_{\text{DW}} \quad t = 0$$

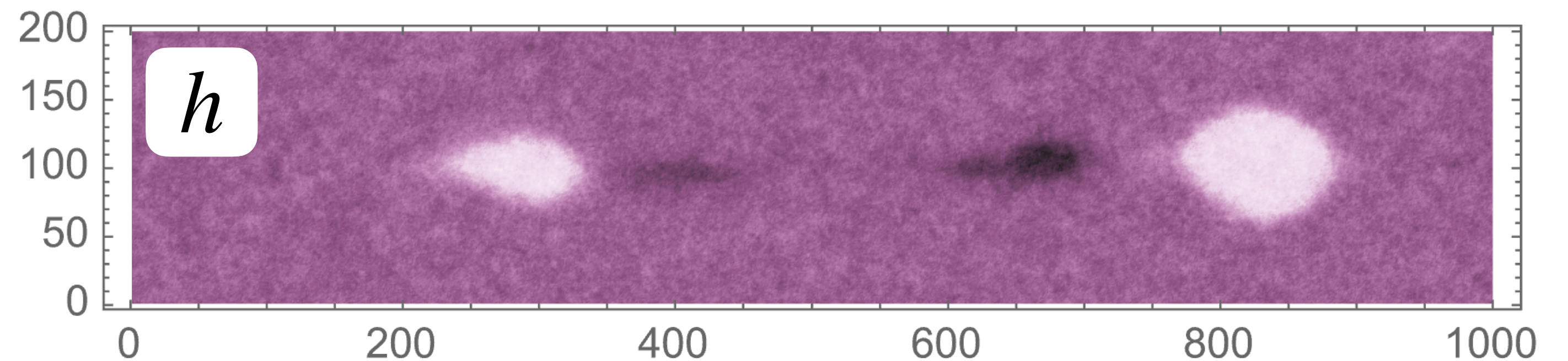
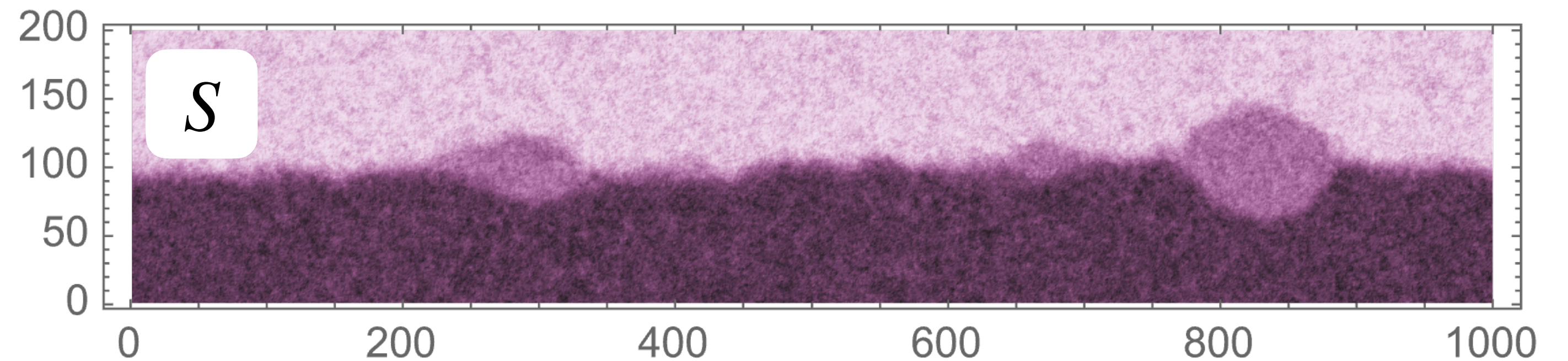
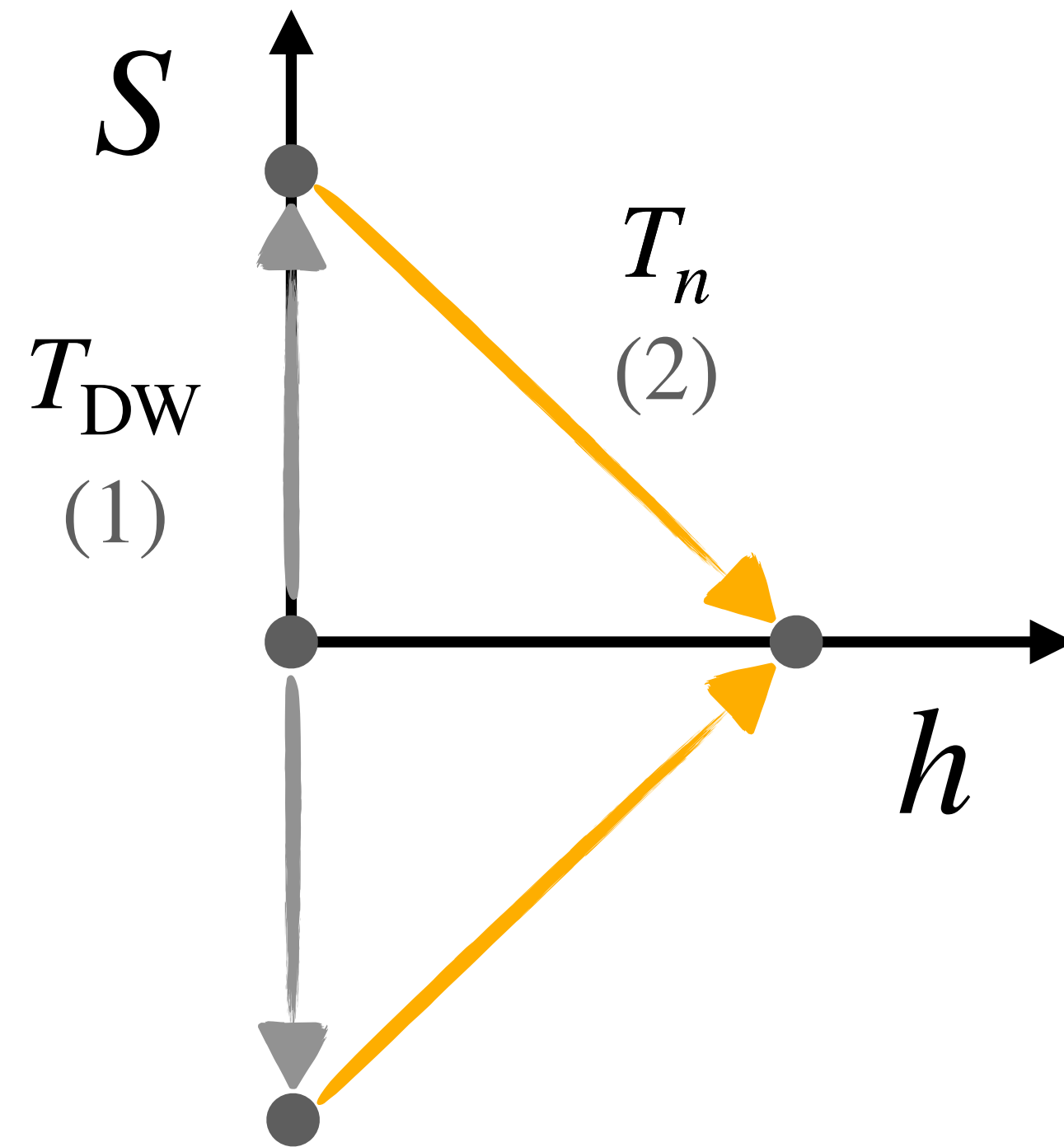


Tunneling rate from real-time simulations

SB, Ekstedt

- Initial conditions such there is one defect (kink) in the simulation box in $d = 2 + 1$

$$\omega \sim T < T_{\text{DW}} \quad t \sim (L \cdot \Gamma_{\text{seed}})^{-1}$$



Tunneling rate from real-time simulations

SB, Ekstedt

- Testing the theory prediction

$$\Gamma = A \cdot e^{-S/T}$$

Nucleation rate per unit length
per unit time

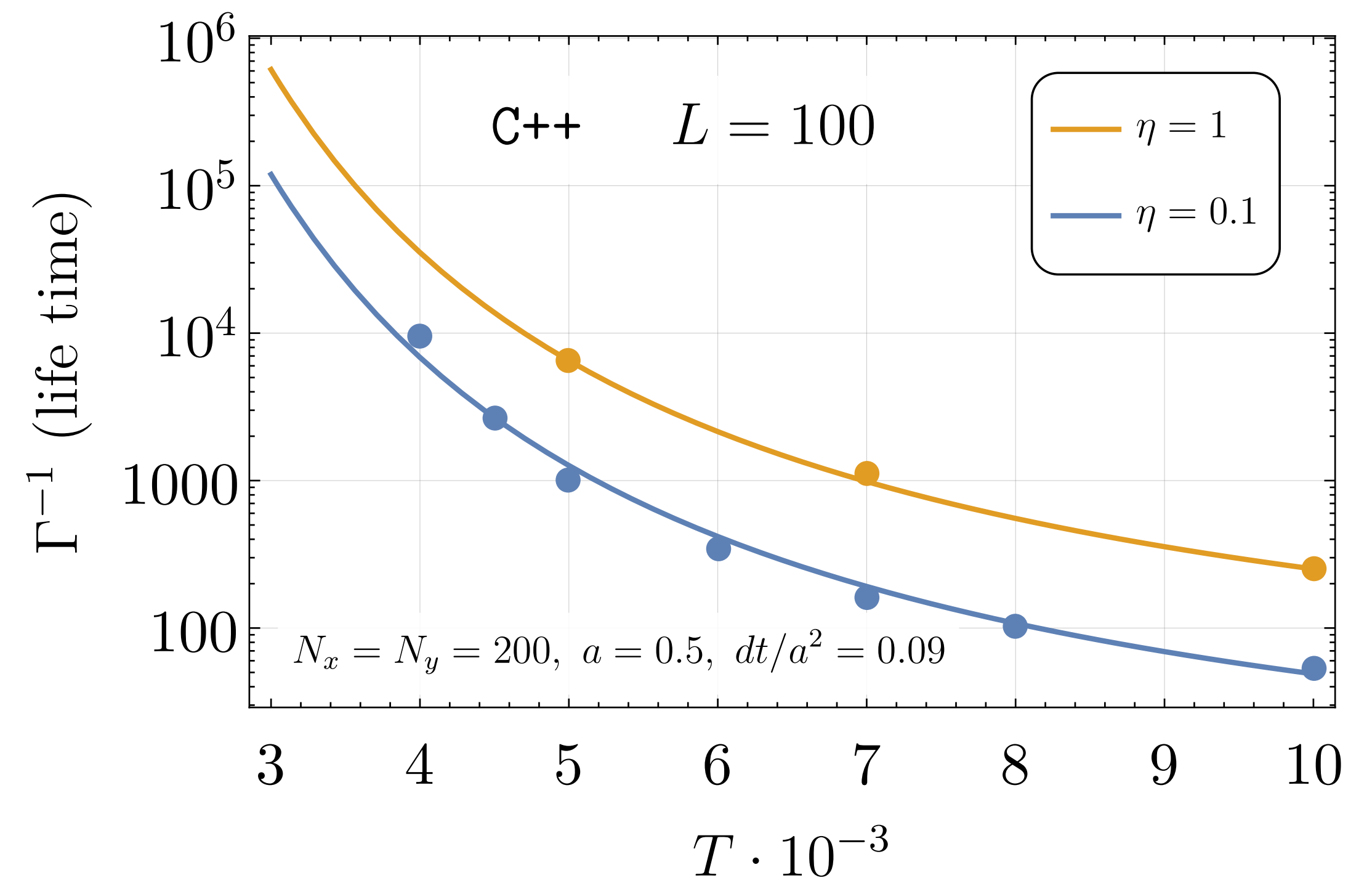
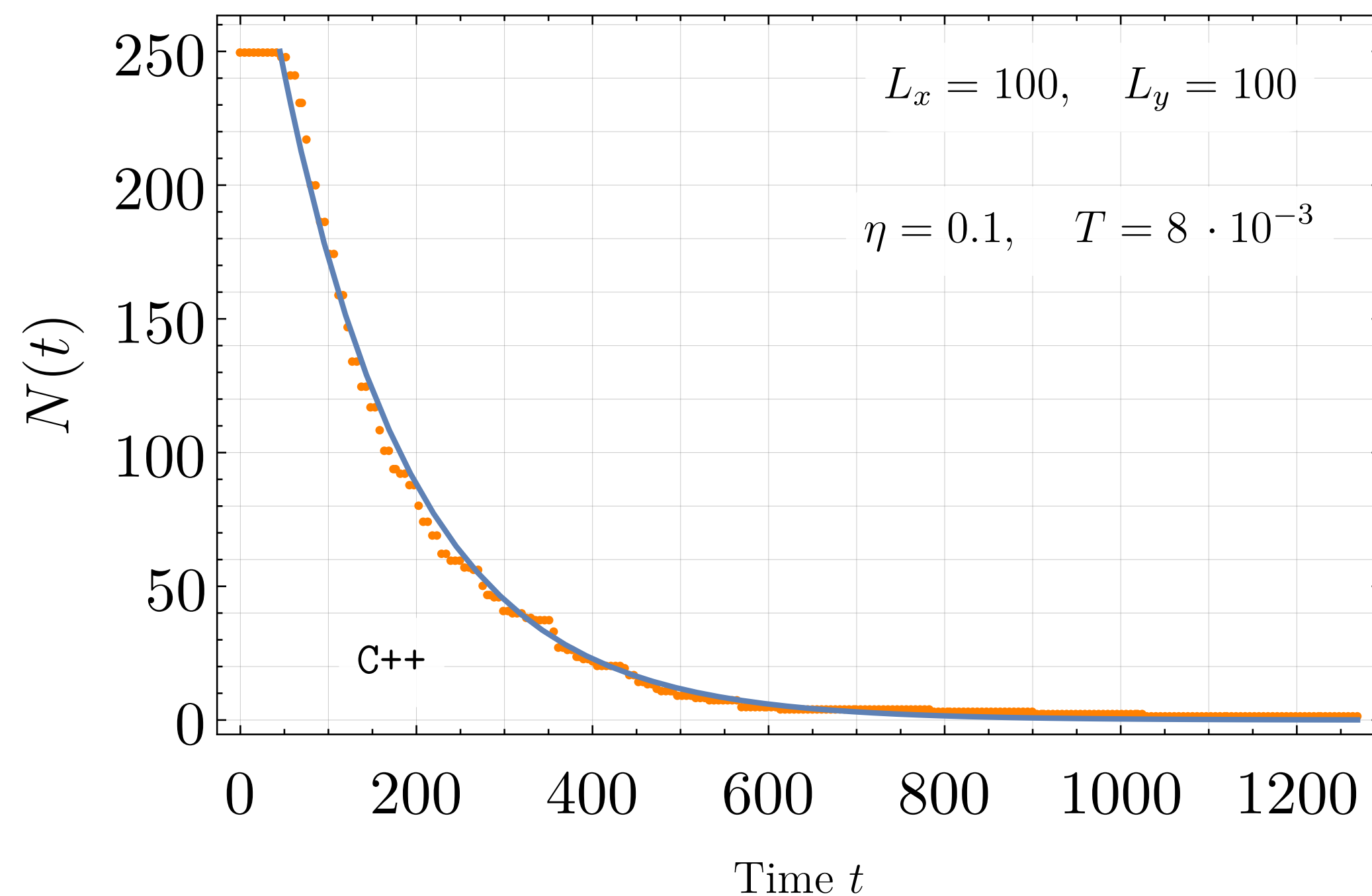
- Evaluation of the prefactor in the KK theory (so far estimated as $A \sim \sigma_{\text{DW}}$)

Ekstedt, Gould, Hirvonen [2308.15652] JHEP

Tunneling rate from real-time simulations

SB, Ekstedt

- Collect nucleation events and build a survival plot for the false-vacuum

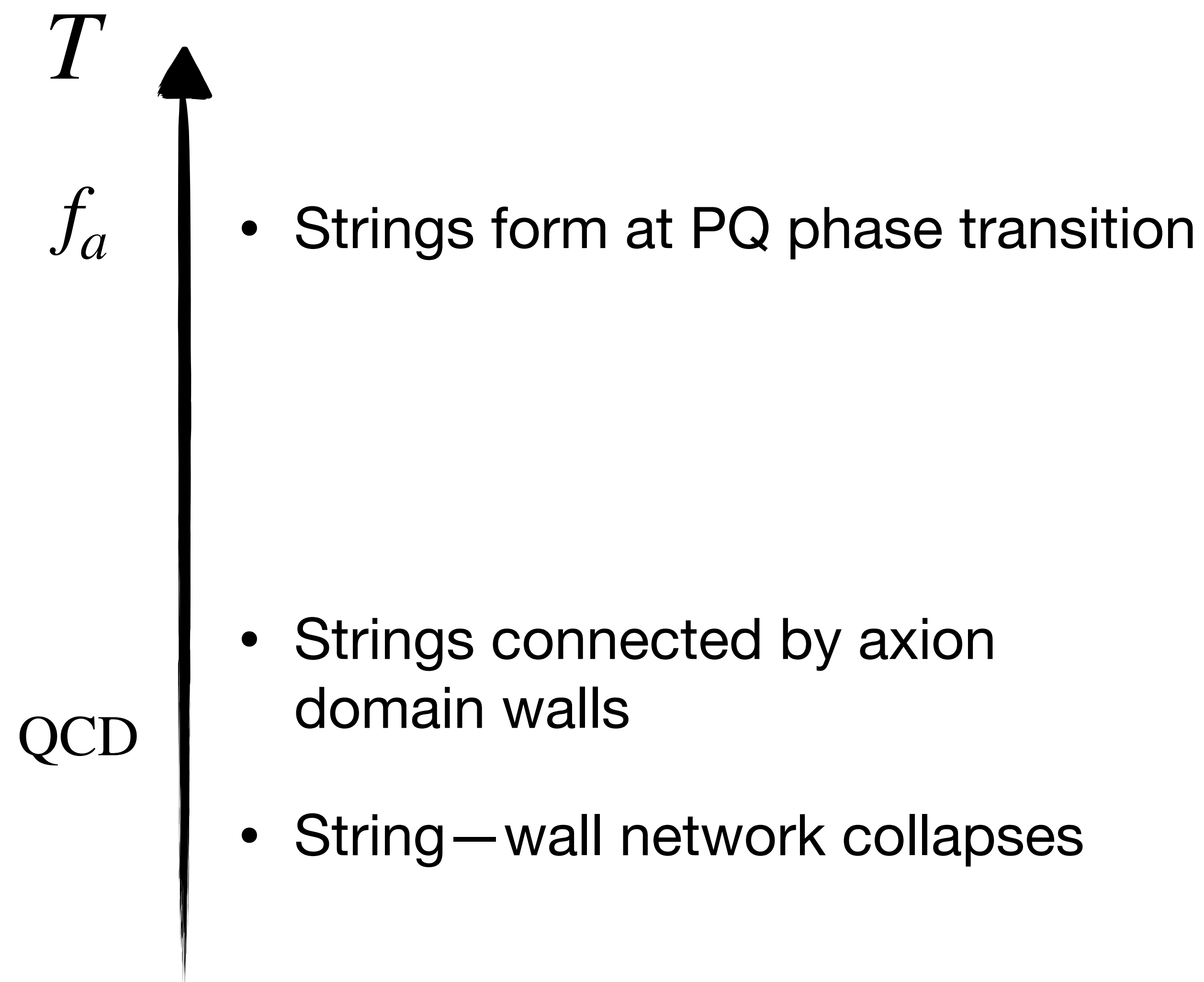


Good agreement *but*, extrapolation to continuum/infinite volume, renormalization...?

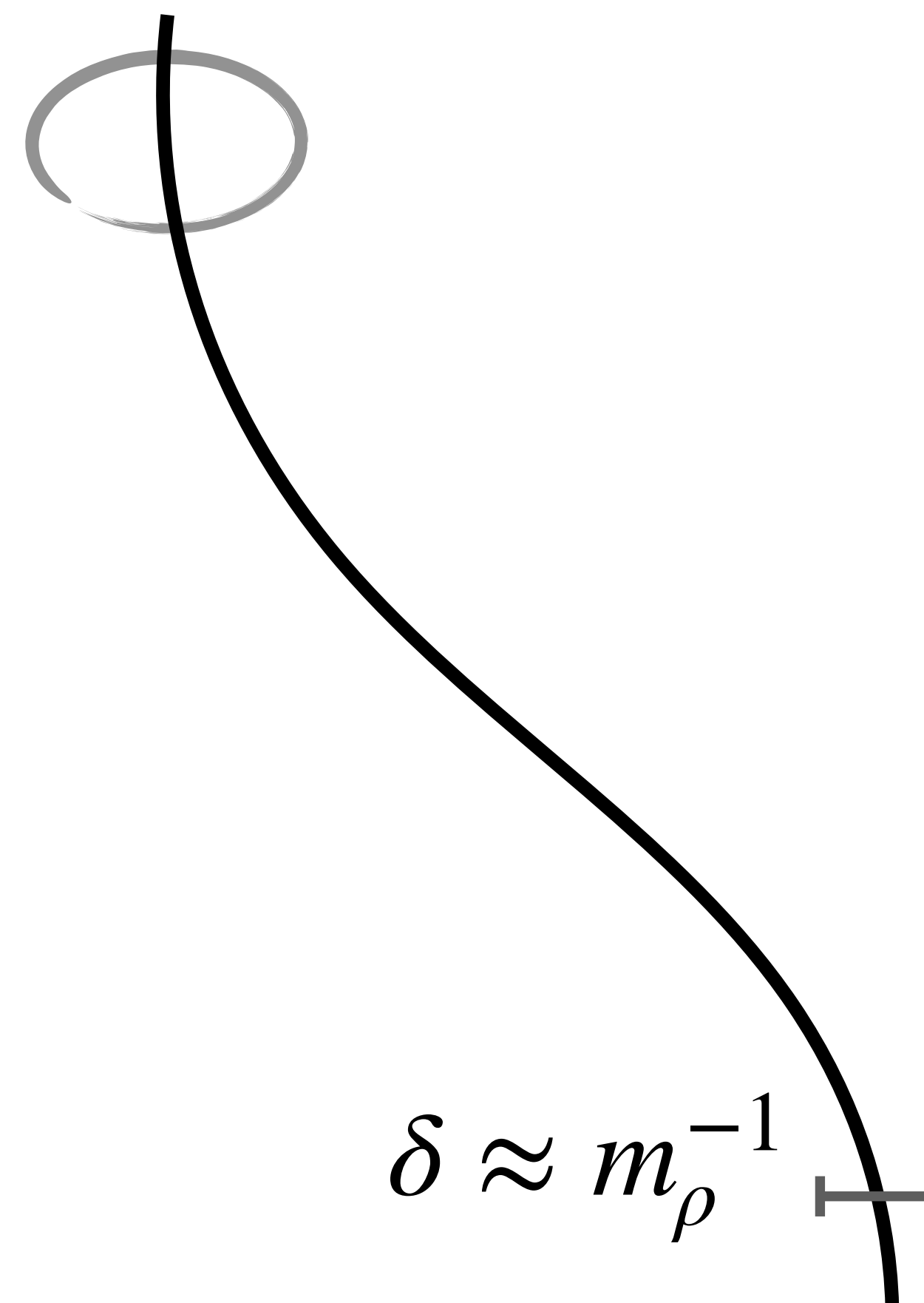
What about other defects?

SB, Mariotti [2405.08060]

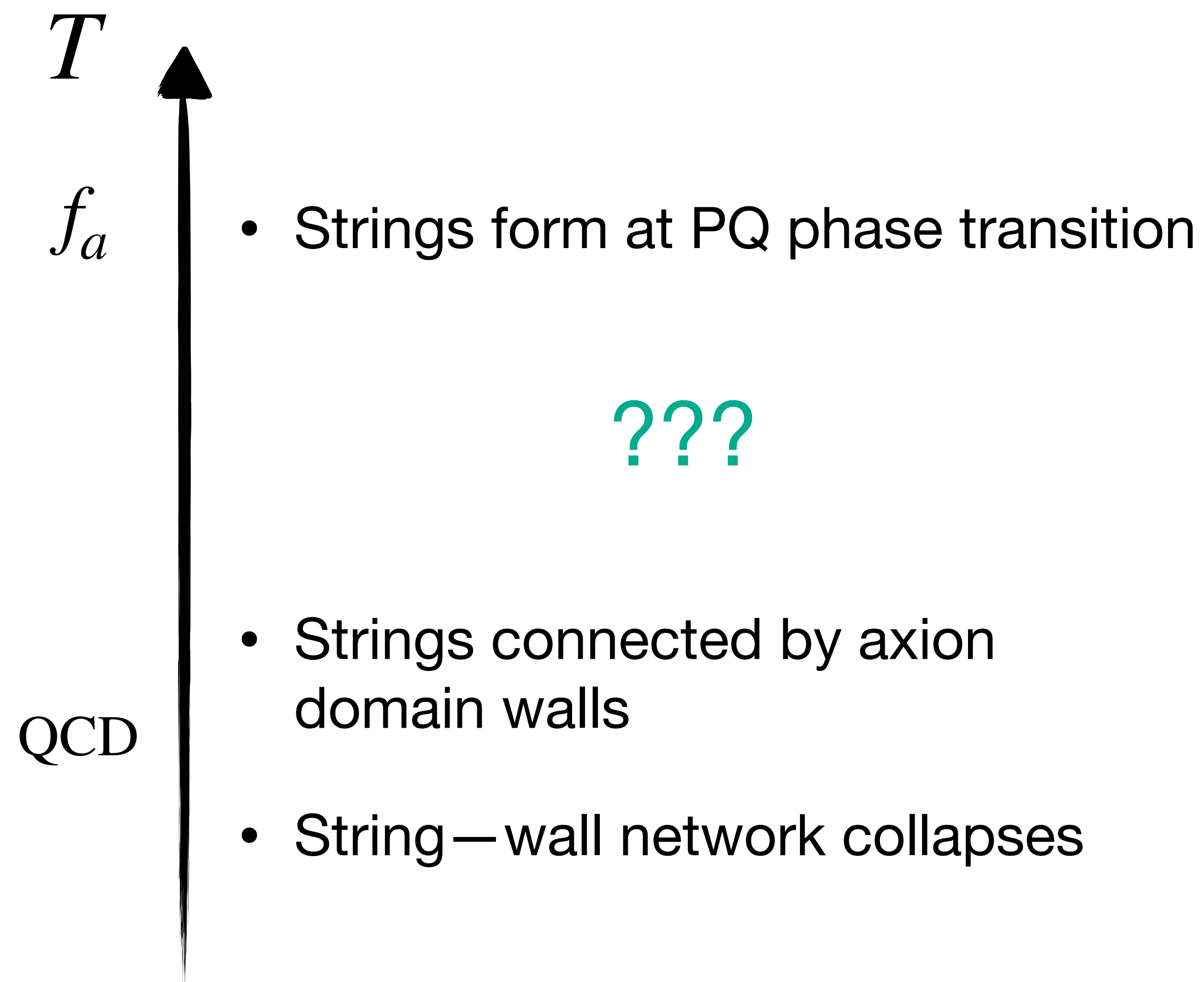
QCD axion strings



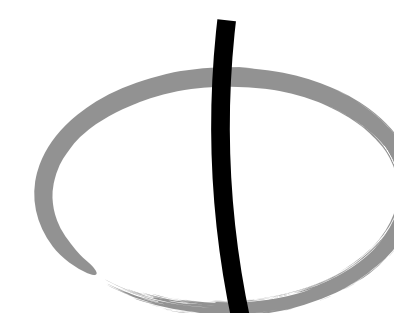
$$\alpha(\theta) : 0 \rightarrow 2\pi$$



QCD axion strings



$$\alpha(\theta) : 0 \rightarrow 2\pi$$

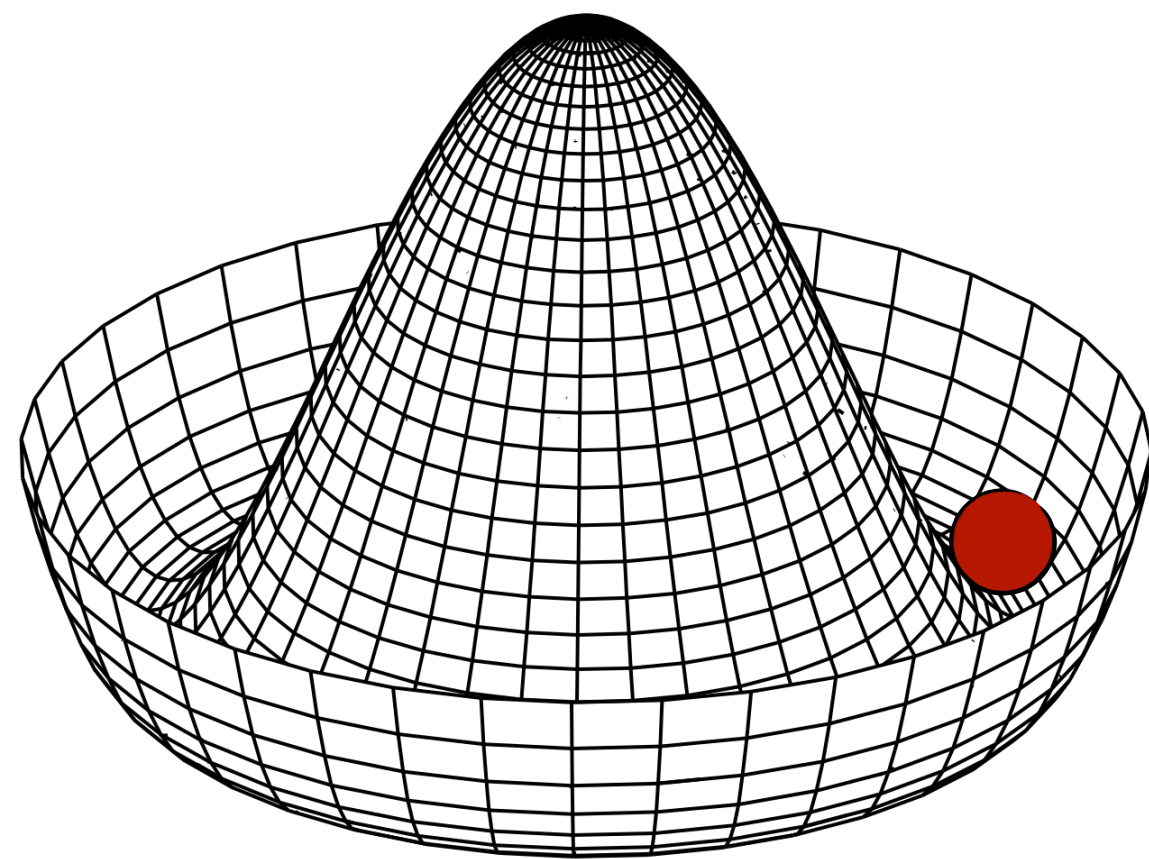


$$\delta \approx m_\rho^{-1}$$

QCD axion strings

- Potential for PQ field

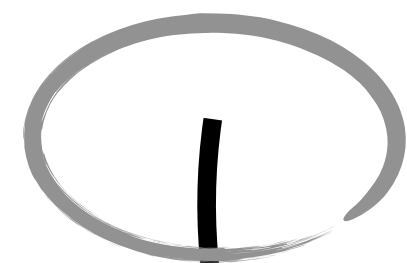
$$\Phi = \rho e^{i\alpha}$$



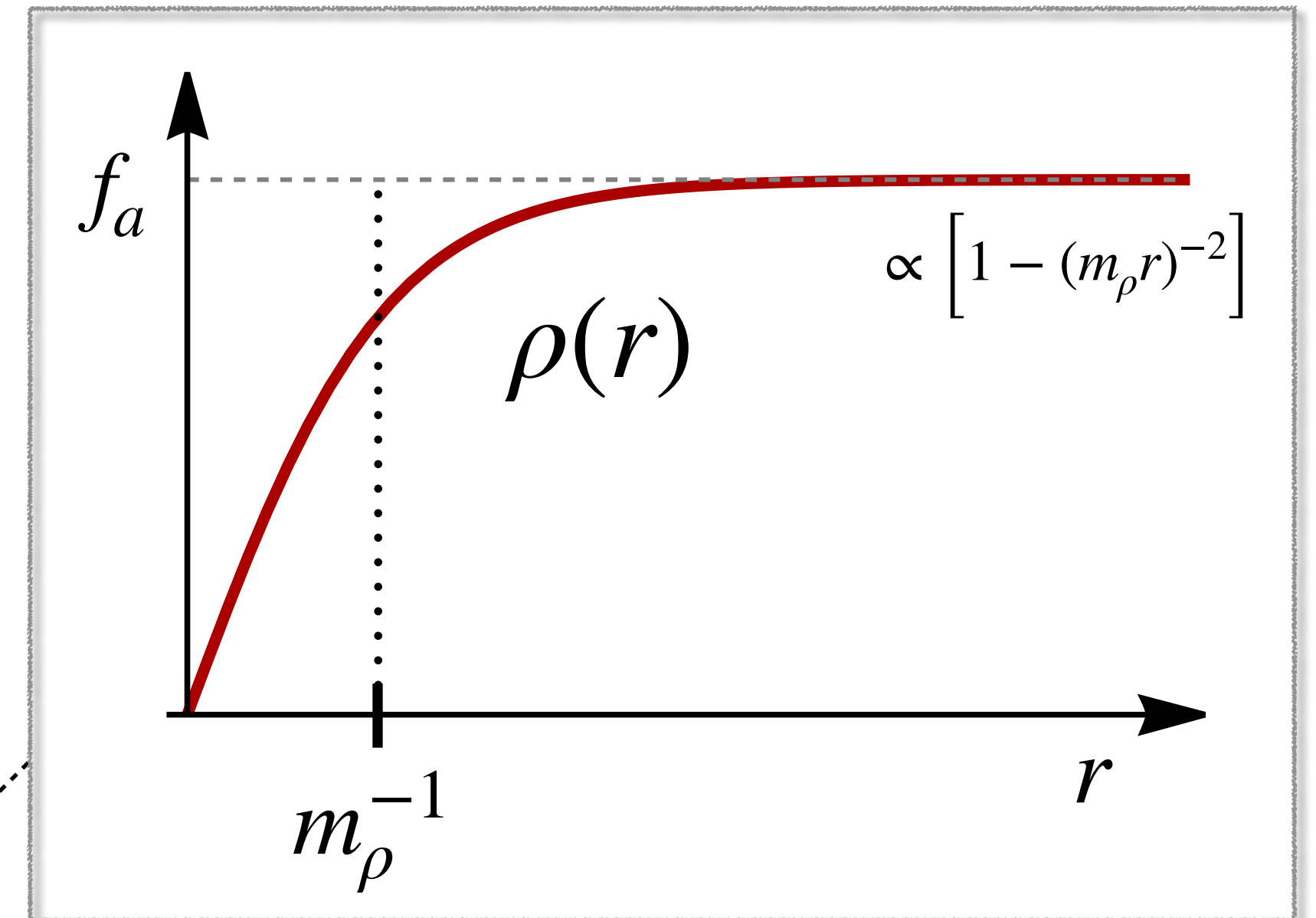
$$V_{\text{PQ}}(\Phi)$$

- Global string solution

$$\alpha(\theta) : 0 \rightarrow 2\pi$$



$$\delta \approx m_\rho^{-1}$$



QCD axion strings

- Consider the minimal KSVZ axion model with a Higgs portal:

$$\mathcal{V} = V_{\text{PQ}}(|\Phi|) + V_{\text{EW}}(|\mathcal{H}|; T) + \kappa \left(|\Phi|^2 - \frac{f_a^2}{2} \right) \left(|\mathcal{H}|^2 - \frac{v^2}{2} \right)$$

$$V_{\text{PQ}}(|\Phi|) = \eta \left(|\Phi|^2 - \frac{f_a^2}{2} \right)^2$$

QCD axion strings

- Consider the minimal KSVZ axion model with a Higgs portal:

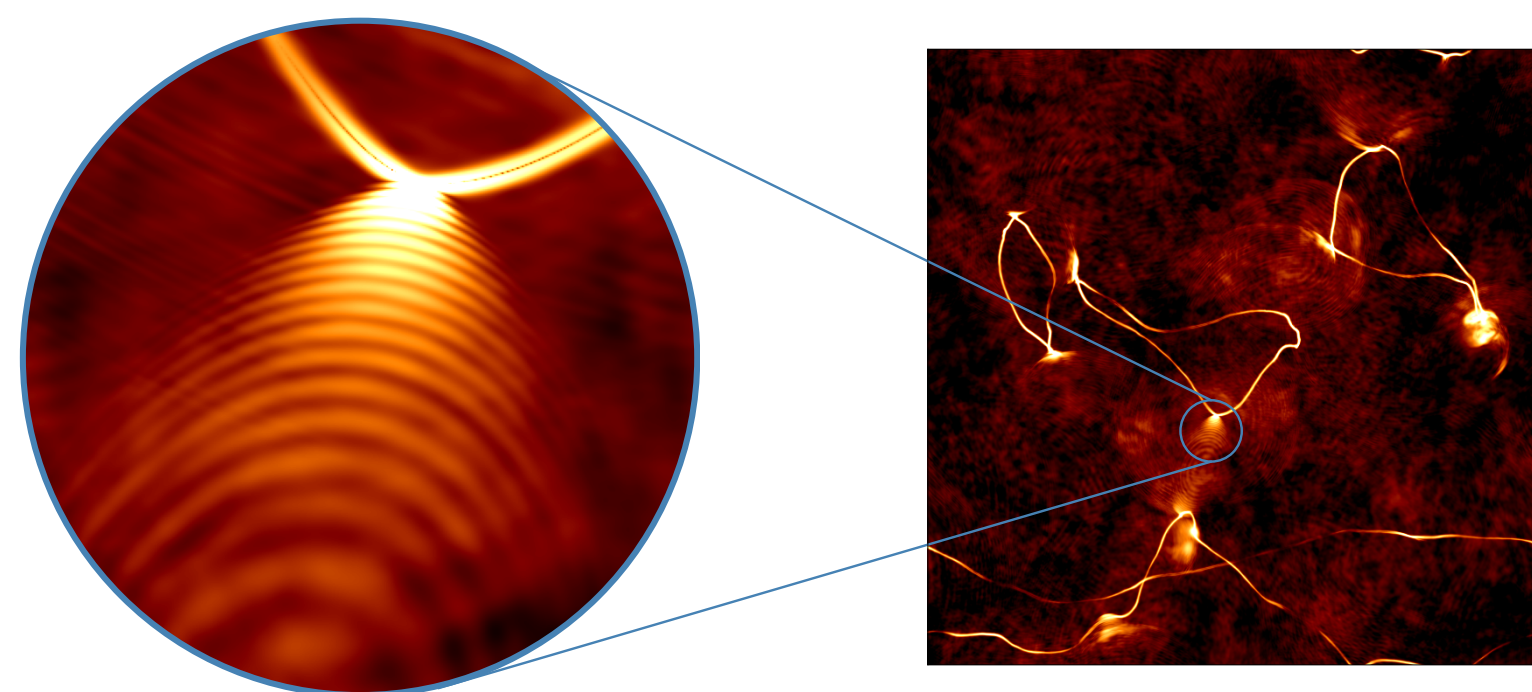
$$\mathcal{V} = V_{\text{PQ}}(|\Phi|) + V_{\text{EW}}(|\mathcal{H}|; T) + \kappa \left(|\Phi|^2 - \frac{f_a^2}{2} \right) \left(|\mathcal{H}|^2 - \frac{v^2}{2} \right)$$

$$V_{\text{PQ}}(|\Phi|) = \eta \left(|\Phi|^2 - \frac{f_a^2}{2} \right)^2$$

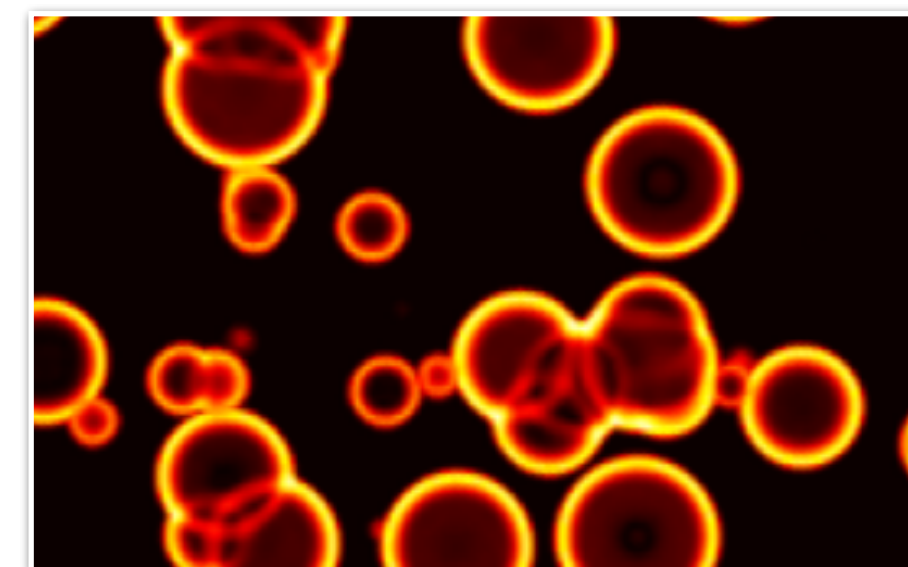
QCD axion strings

- Consider the minimal KSVZ axion model with a Higgs portal:

$$\mathcal{V} = V_{\text{PQ}}(|\Phi|) + V_{\text{EW}}(|\mathcal{H}|; T) + \kappa \left(|\Phi|^2 - \frac{f_a^2}{2} \right) \left(|\mathcal{H}|^2 - \frac{v^2}{2} \right)$$

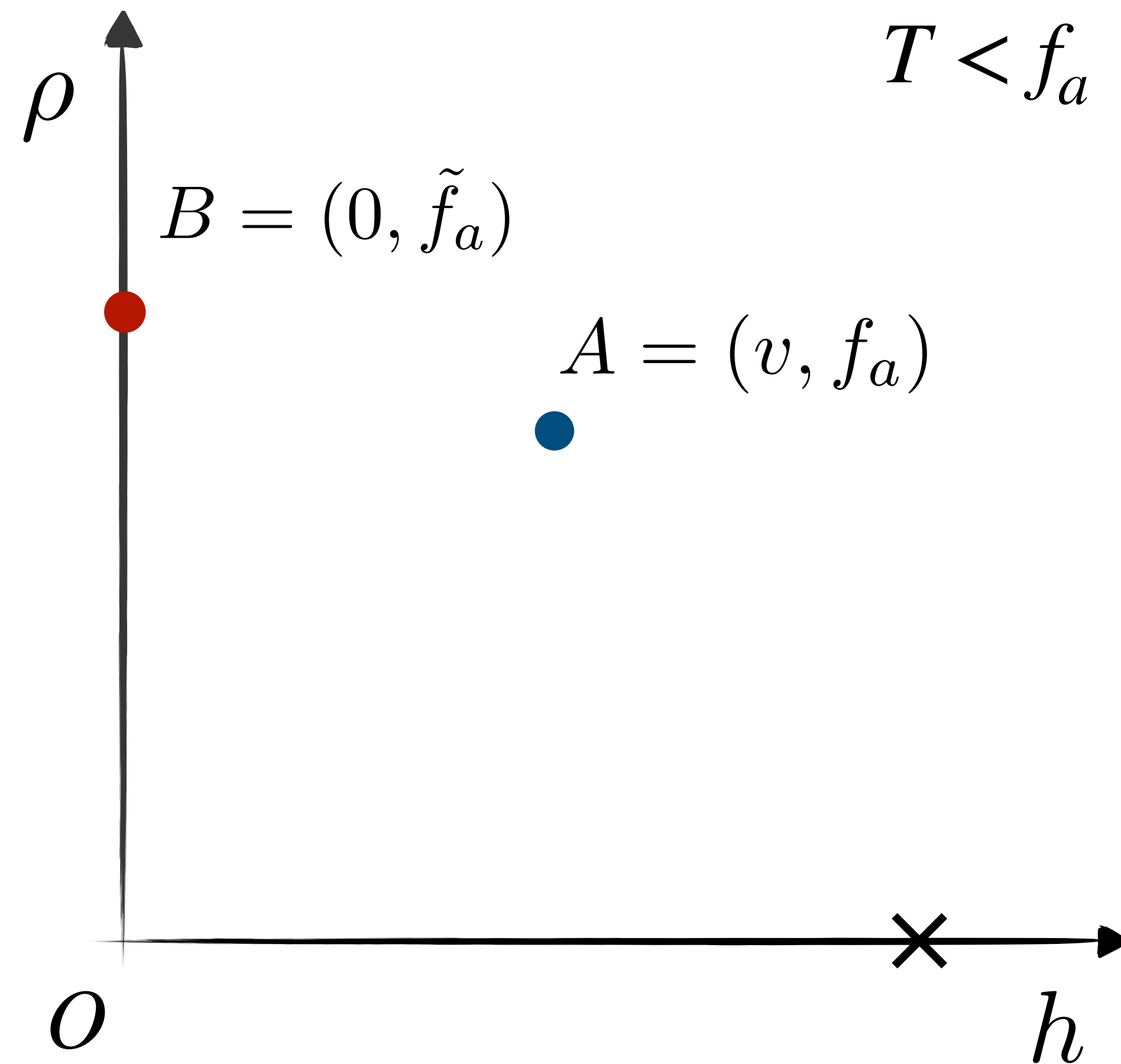


How do axion strings affect
electroweak symmetry breaking?



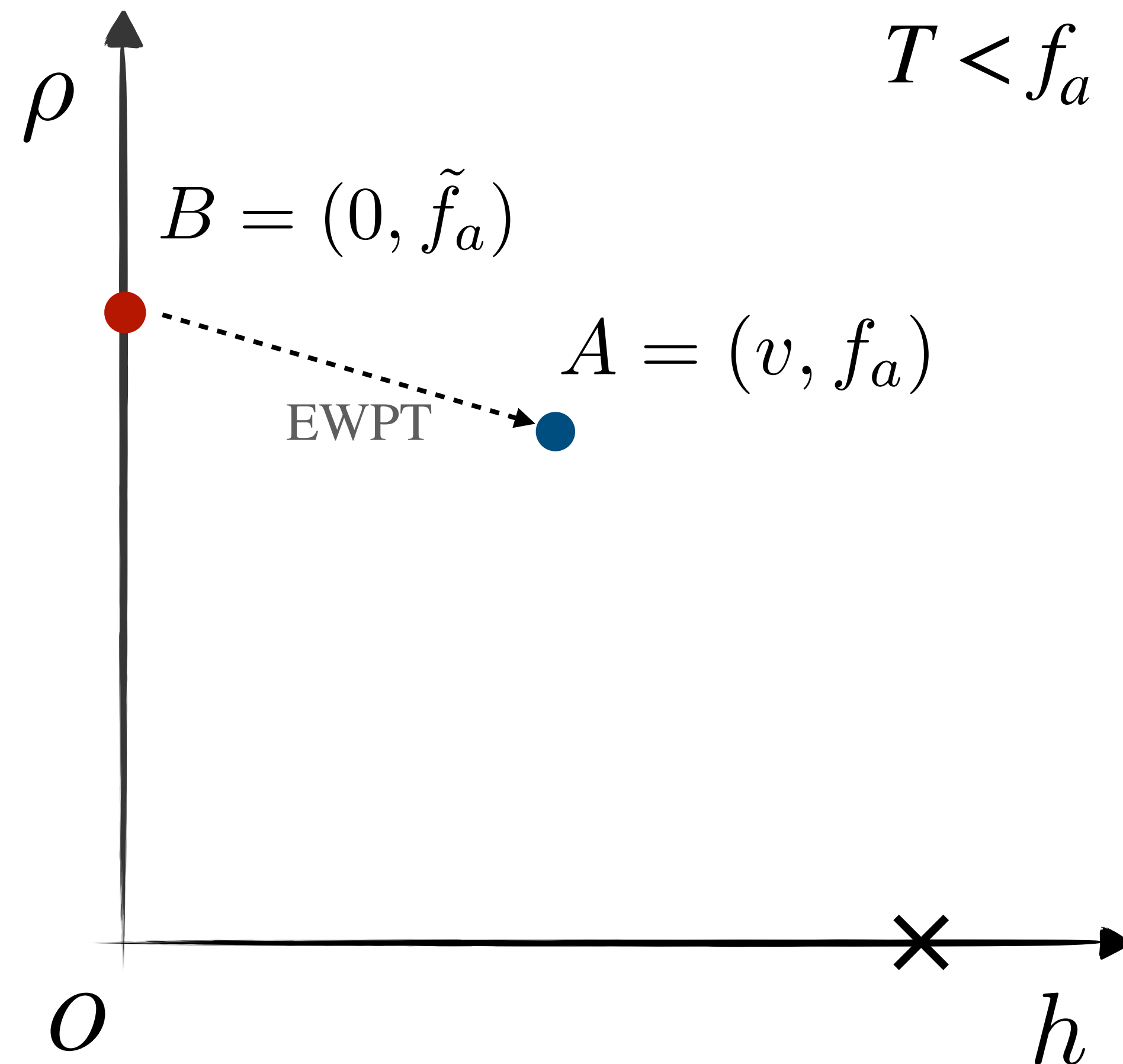
String solutions

- Relevant points in field space:



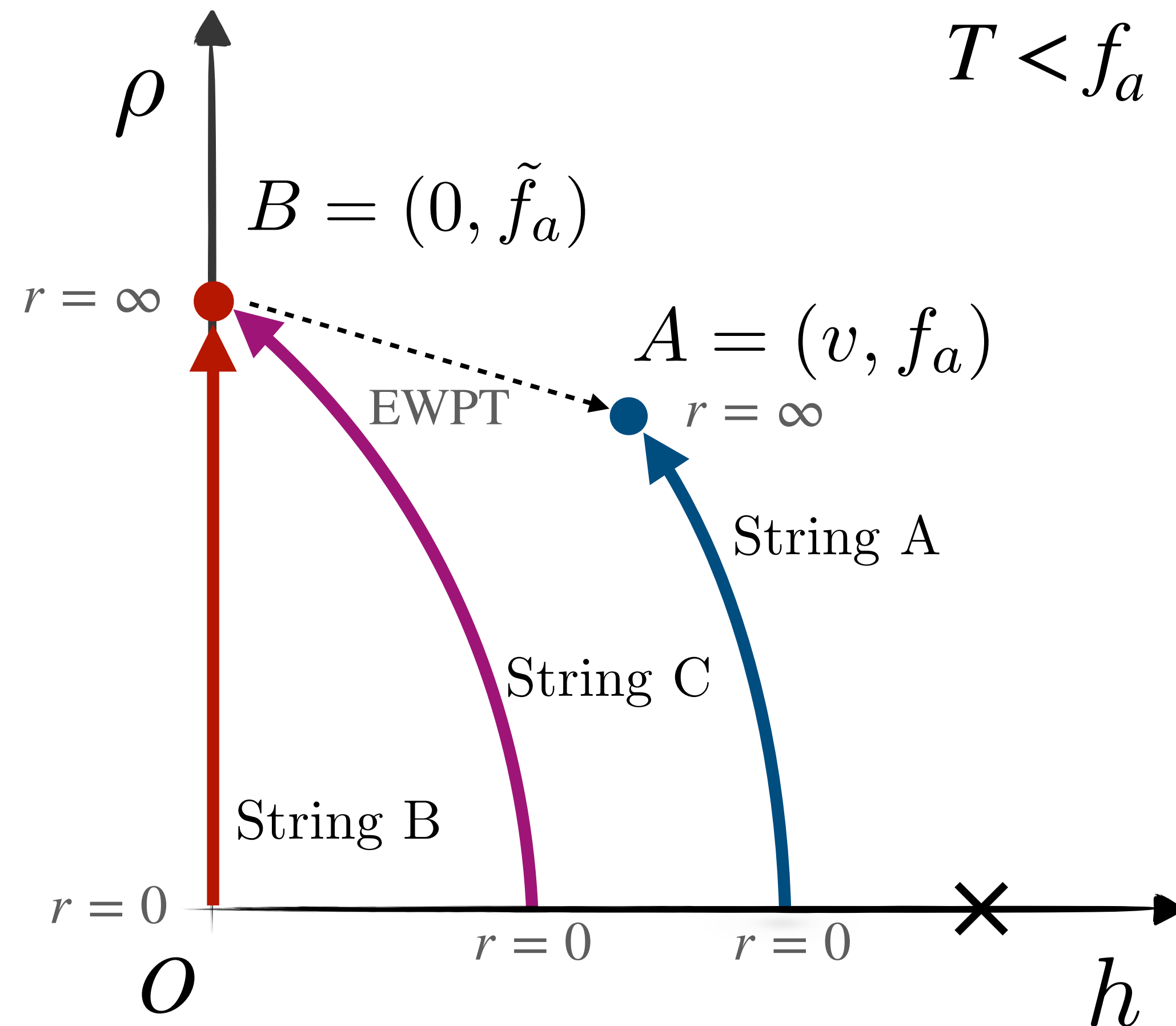
String solutions

- Relevant points in field space:



String solutions

- Relevant points in field space:



EFT with heavy defects

- Large hierarchy between the mass of the Higgs and the PQ radial mode

EFT with heavy defects

- Large hierarchy between the mass of the Higgs and the PQ radial mode
- Physics captured by electroweak scale EFT, SM + axion (or ALP):

$$S_{\text{EFT}}[h] = \int d^4x \left\{ \frac{1}{2} (\partial_\mu h)^2 - V_{\text{EW}}(h) - \frac{1}{2} \frac{\kappa}{\eta} (\partial_\mu \alpha)^2 h^2 + \pi \frac{\kappa}{\eta} C(\epsilon) \delta^{(2)}(r - \epsilon) h^2 \right\}$$

EFT with heavy defects

- Large hierarchy between the mass of the Higgs and the PQ radial mode
- Physics captured by electroweak scale EFT, SM + axion (or ALP):

$$S_{\text{EFT}}[h] = \int d^4x \left\{ \frac{1}{2}(\partial_\mu h)^2 - V_{\text{EW}}(h) - \frac{1}{2} \frac{\kappa}{\eta} (\partial_\mu \alpha)^2 h^2 + \pi \frac{\kappa}{\eta} C(\epsilon) \delta^{(2)}(r - \epsilon) h^2 \right\}$$

EFT with heavy defects

- Large hierarchy between the mass of the Higgs and the PQ radial mode
- Physics captured by electroweak scale EFT, SM + axion (or ALP):

$$S_{\text{EFT}}[h] = \int d^4x \left\{ \frac{1}{2}(\partial_\mu h)^2 - V_{\text{EW}}(h) - \frac{1}{2} \frac{\kappa}{\eta} (\partial_\mu \alpha)^2 h^2 + \pi \frac{\kappa}{\eta} C(\epsilon) \delta^{(2)}(r - \epsilon) h^2 \right\}$$

- Explicit UV scale:

$$\epsilon \sim 1/m_\rho$$

- Axion-Higgs portal, in the string background:

$$\alpha = \theta \Rightarrow \partial_\mu \alpha \sim 1/r$$

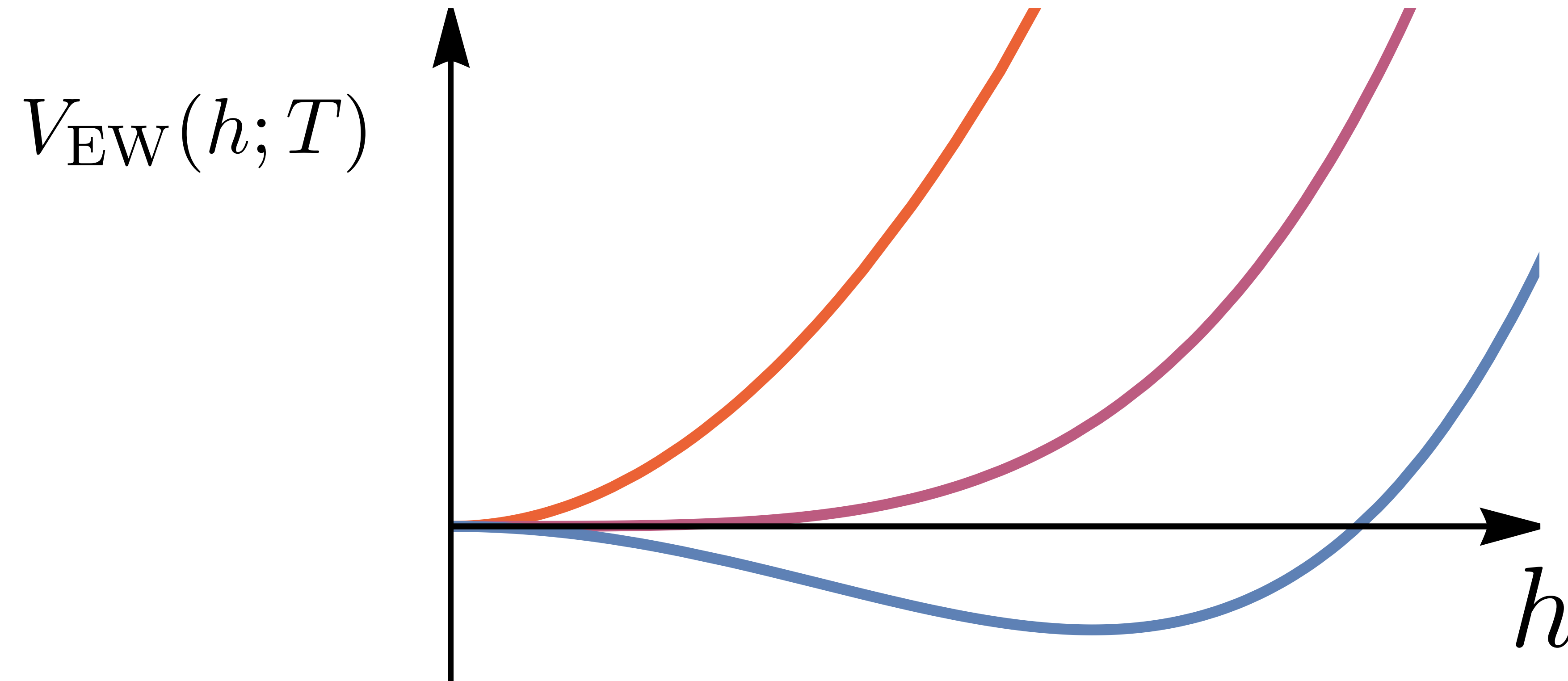
- δ -potential imposes UV matching condition:

$$\epsilon h'(\epsilon) = -C(\epsilon) \frac{\kappa}{\eta} h(\epsilon)$$

SM + PQ

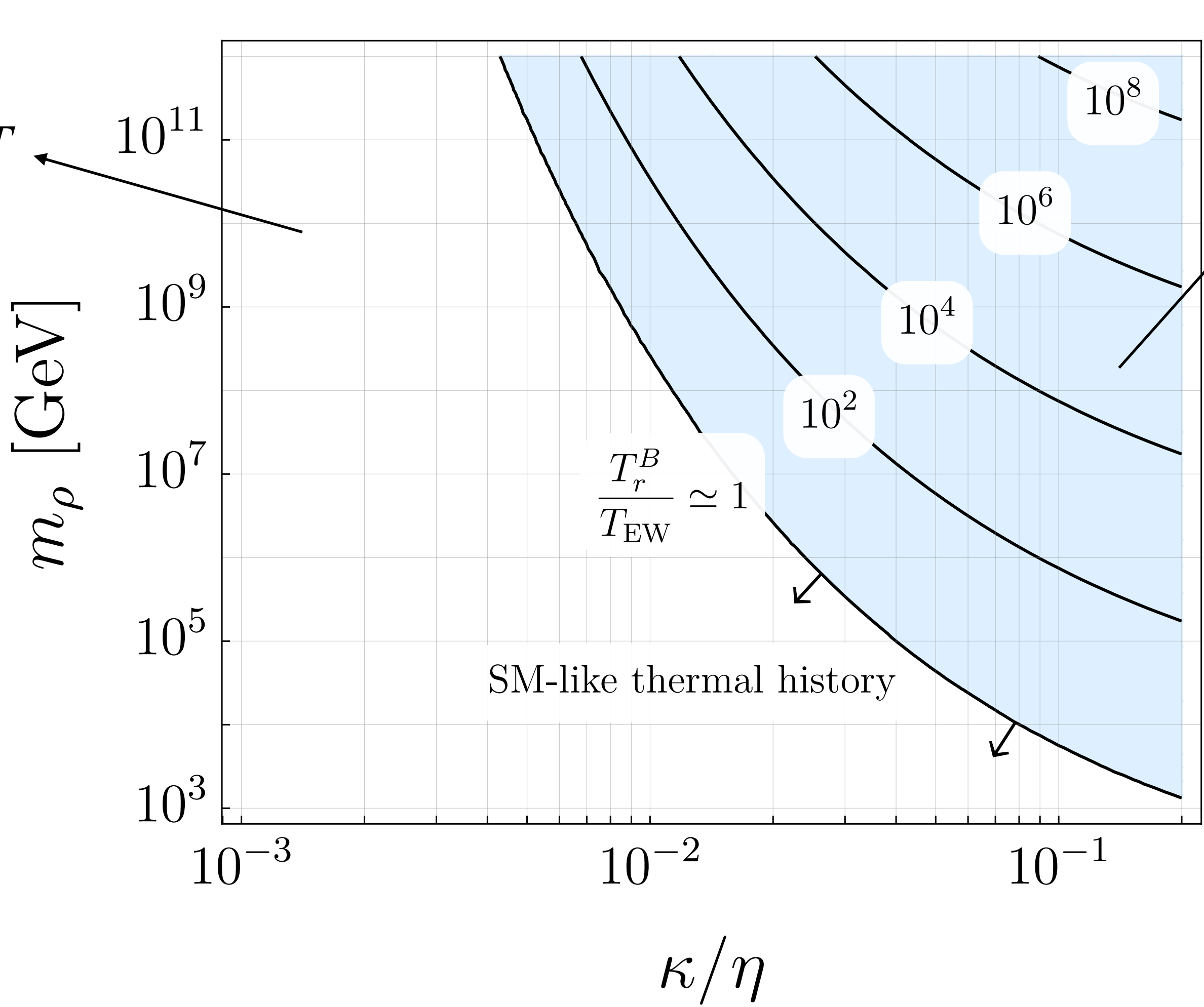
- Higgs potential in the SM:

$$V_{\text{EW}}(h; T) = -\frac{1}{2} (\mu^2 - c_h T^2) h^2 + \frac{1}{4} \lambda h^4$$



SM + PQ

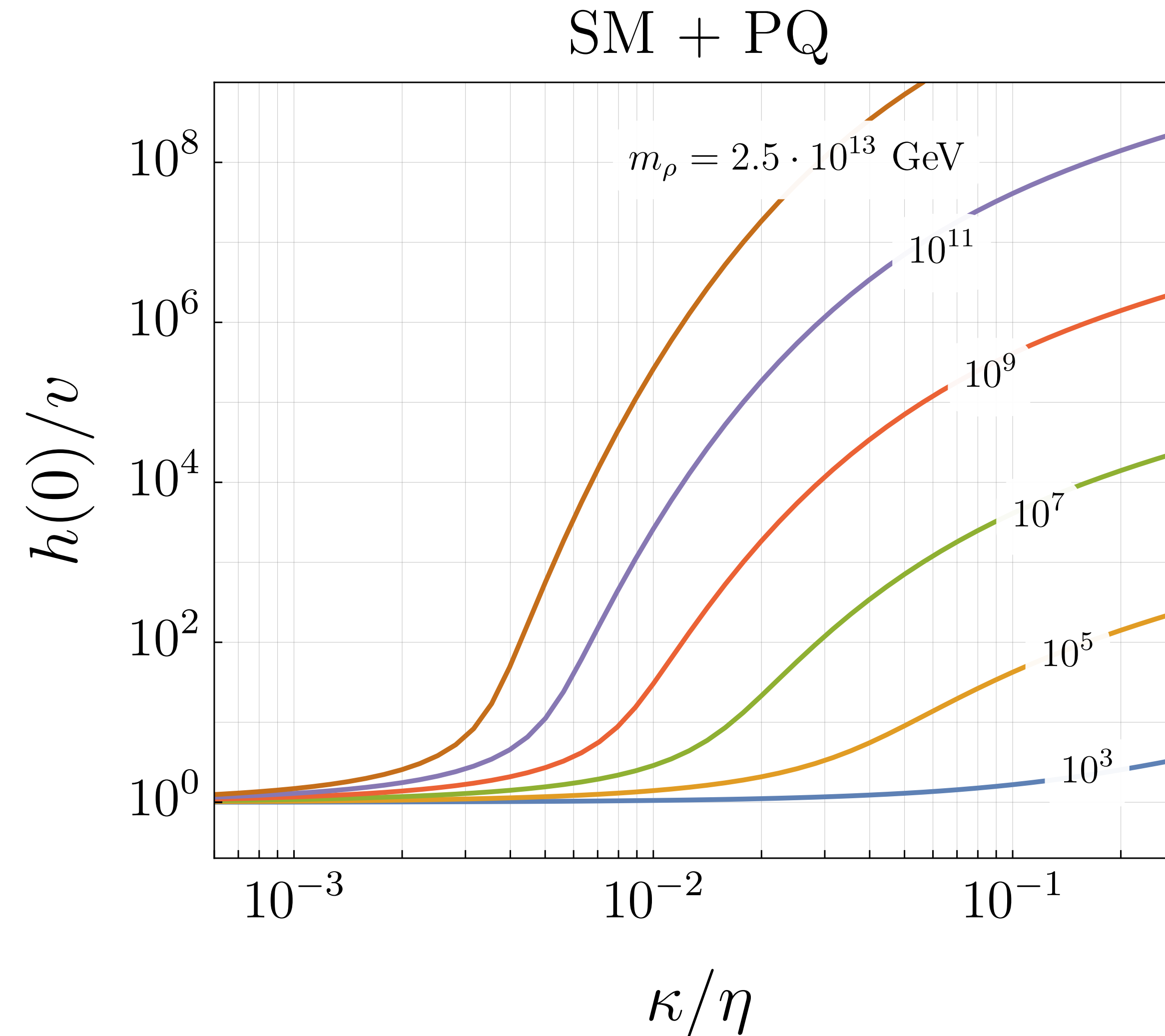
Higgs gets a vev $h \sim v$ in the string and in the bulk at same T



Higgs gets $h \gg v$ in the strings at $T \gg T_{EW}$

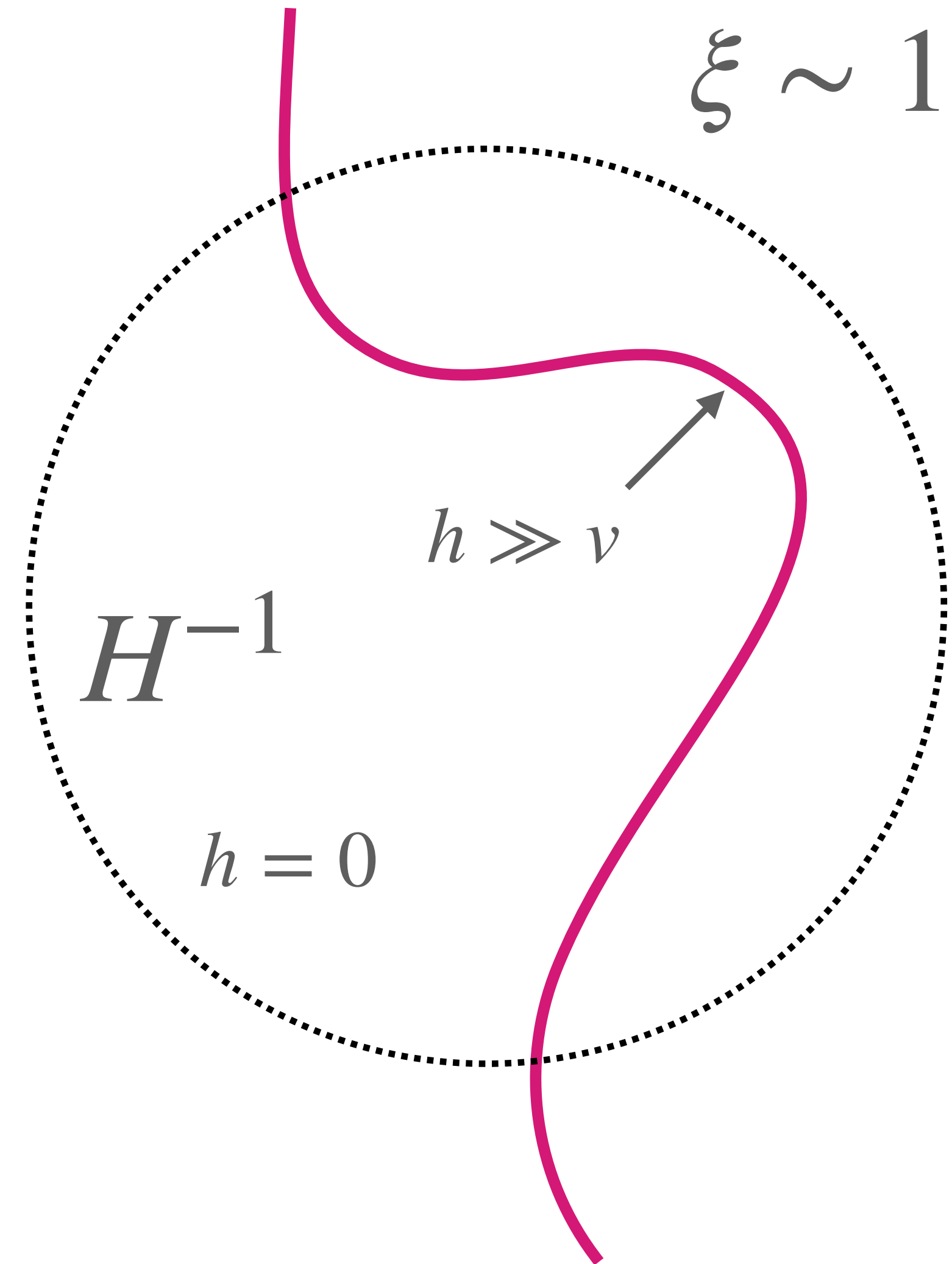
SM + PQ

- Size of the Higgs field at the string core:



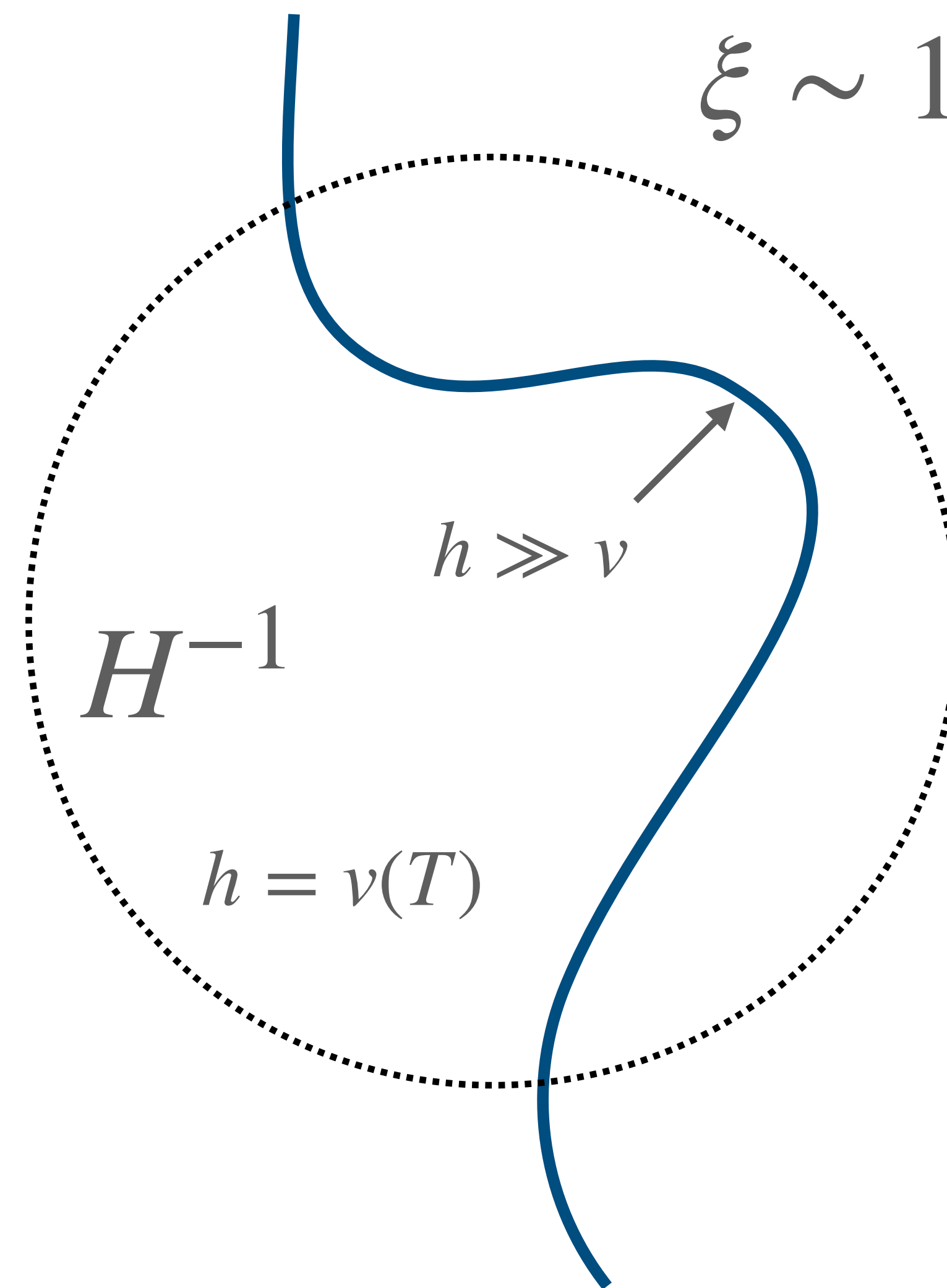
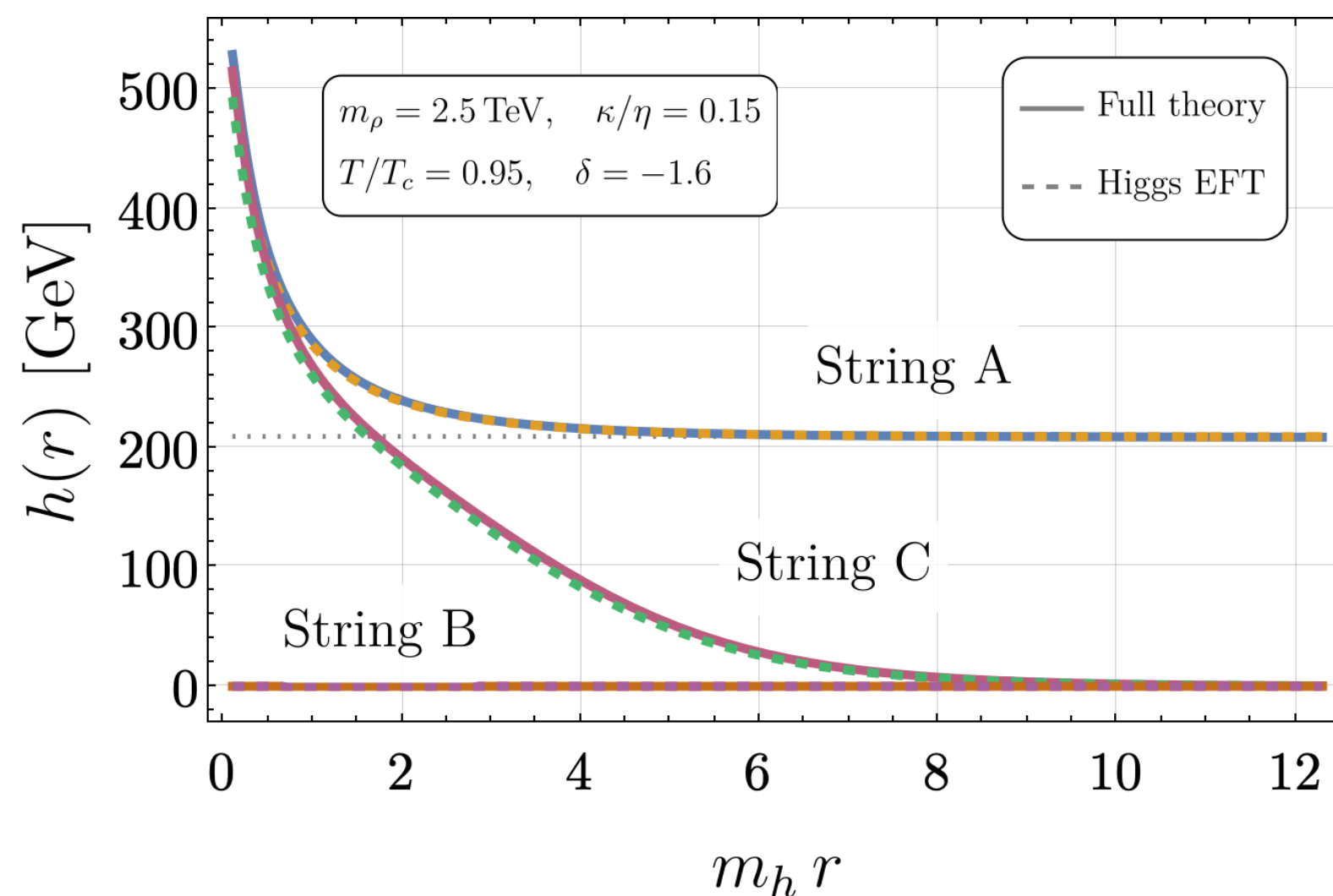
SM + PQ

- At $T \gg T_{\text{EW}}$ axion strings have a (potentially very large) Higgs core



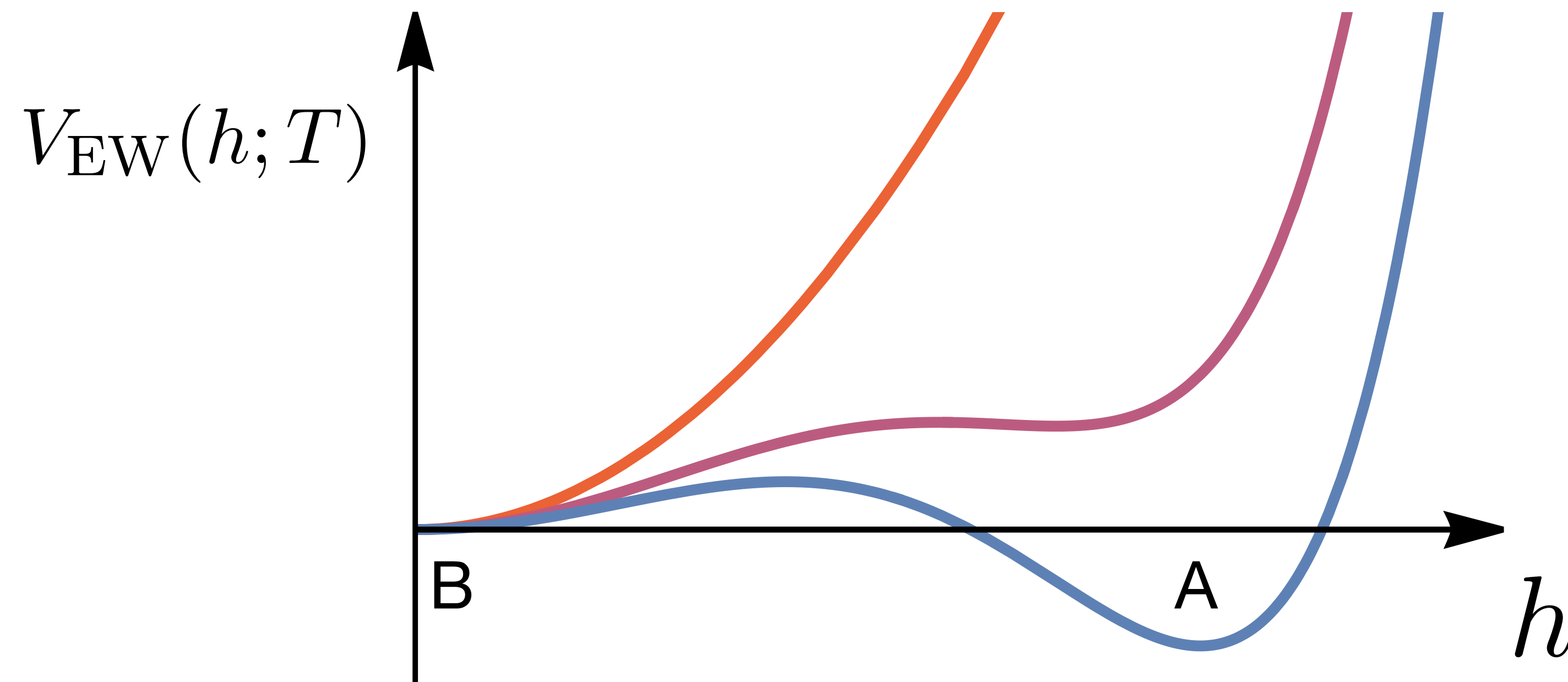
SM + PQ

- At $T \gg T_{\text{EW}}$ axion strings have a (potentially very large) Higgs core
- At $T \leq T_{\text{EW}}$ the core merges smoothly with the vev in the bulk



FOPT + PQ

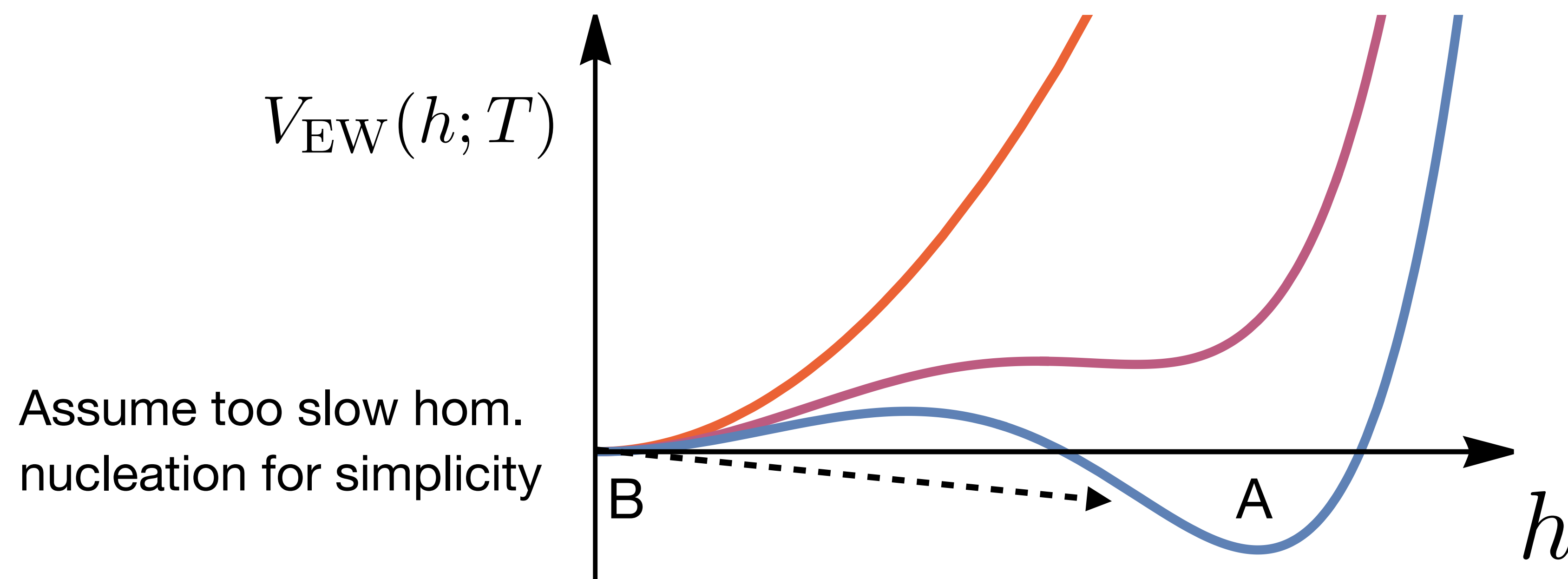
- Consider first order EWPT with false vacuum B metastable at $T = 0$



$$V_{\text{EW}}(h; T) = -\frac{1}{2} (\mu^2 - c_h T^2) h^2 + \frac{\delta}{3} \frac{m_h^2}{v^2} h^3 + \frac{1}{4} \lambda h^4$$

FOPT + PQ

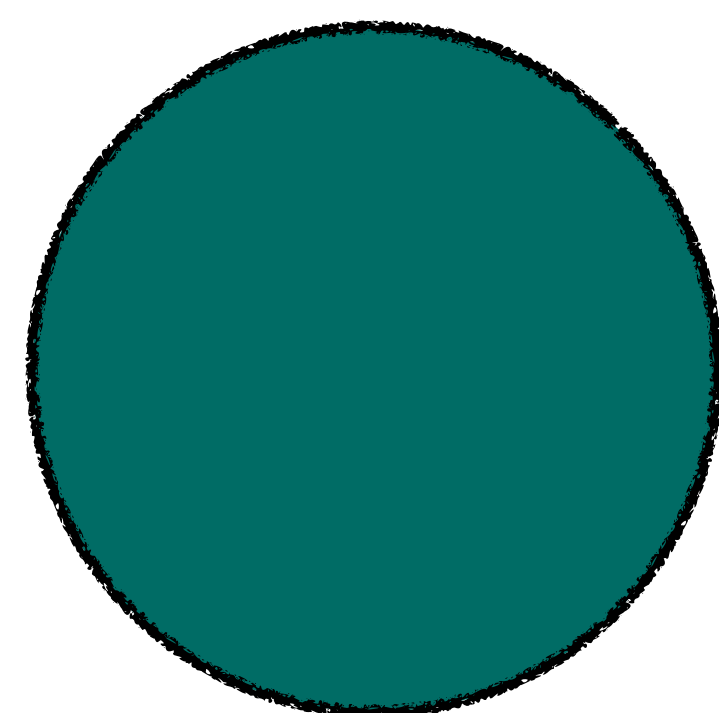
- Consider first order EWPT with false vacuum B metastable at $T = 0$



$$V_{\text{EW}}(h; T) = -\frac{1}{2} (\mu^2 - c_h T^2) h^2 + \frac{\delta}{3} \frac{m_h^2}{v^2} h^3 + \frac{1}{4} \lambda h^4$$

FOPT + PQ

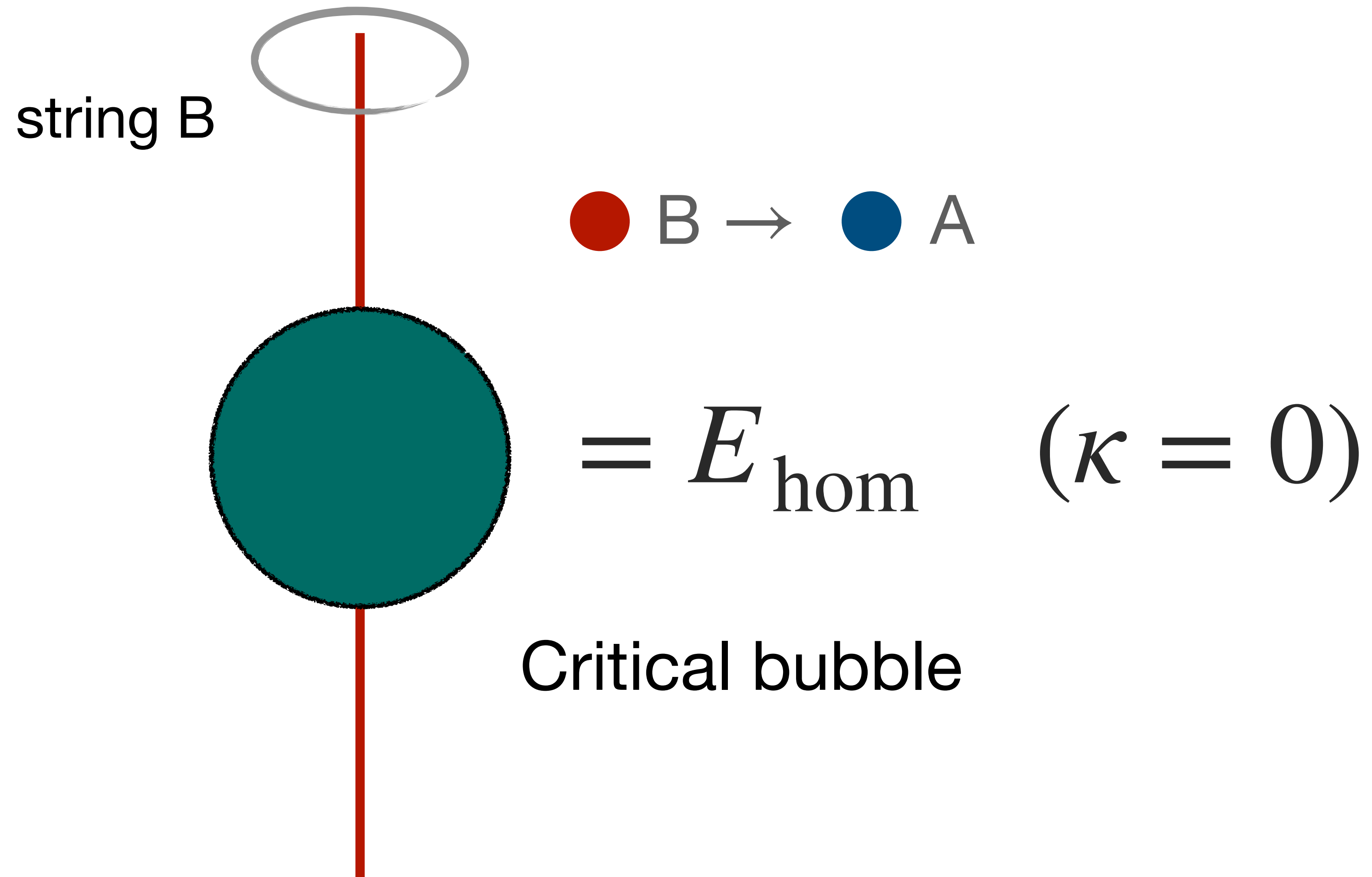
● B → ● A



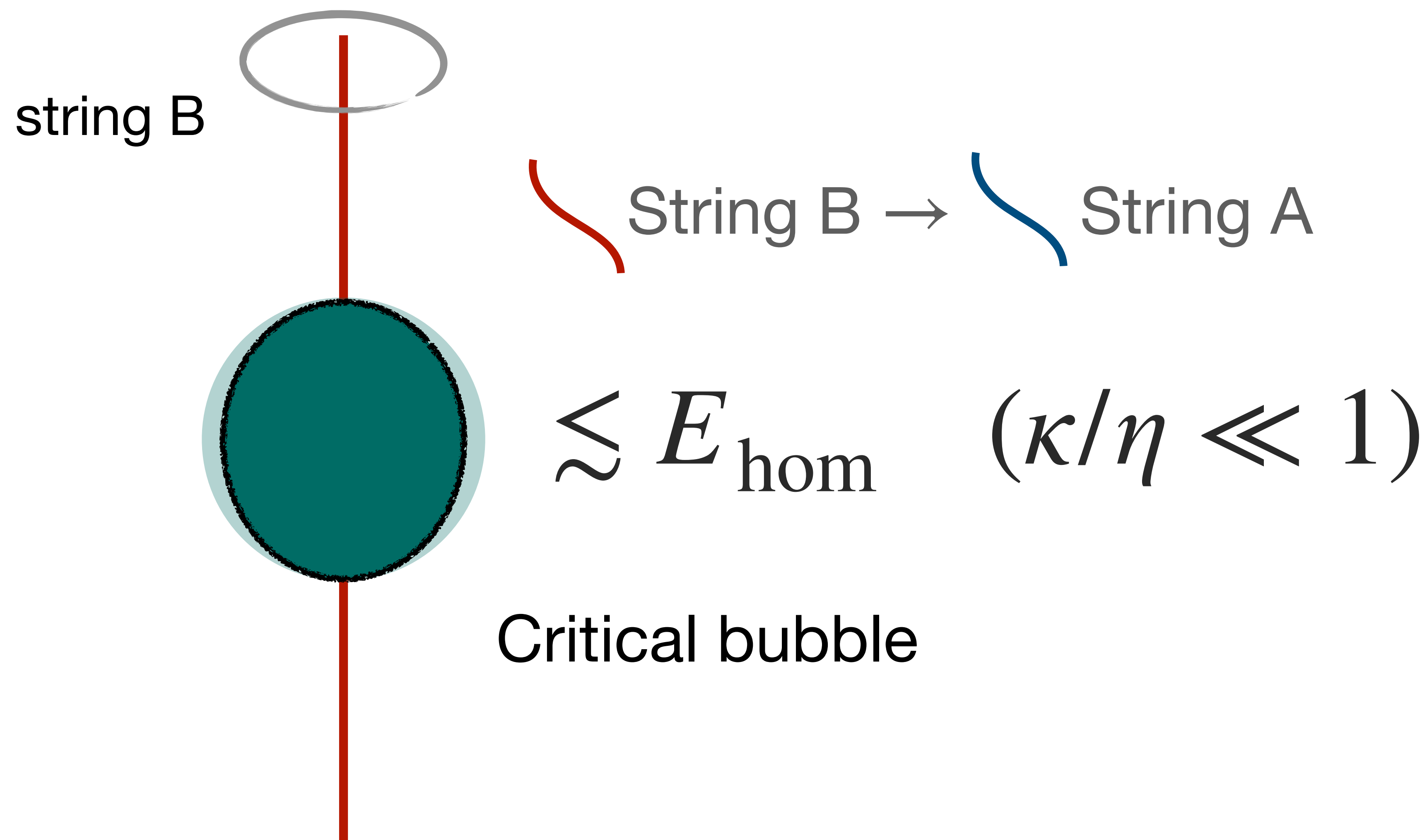
$$= E_{\text{hom}}$$

Critical bubble

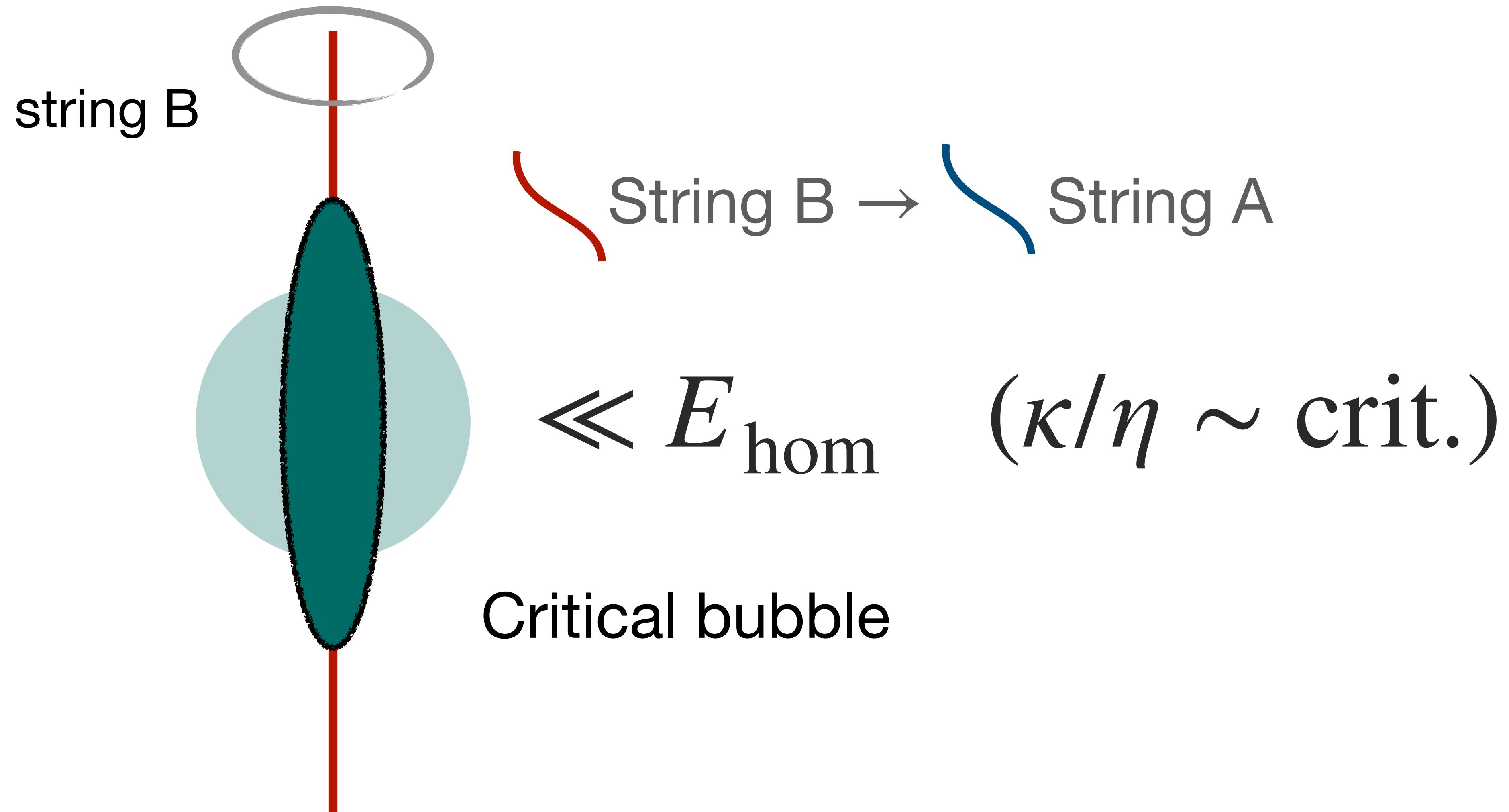
FOPT + PQ



FOPT + PQ



FOPT + PQ



FOPT + PQ

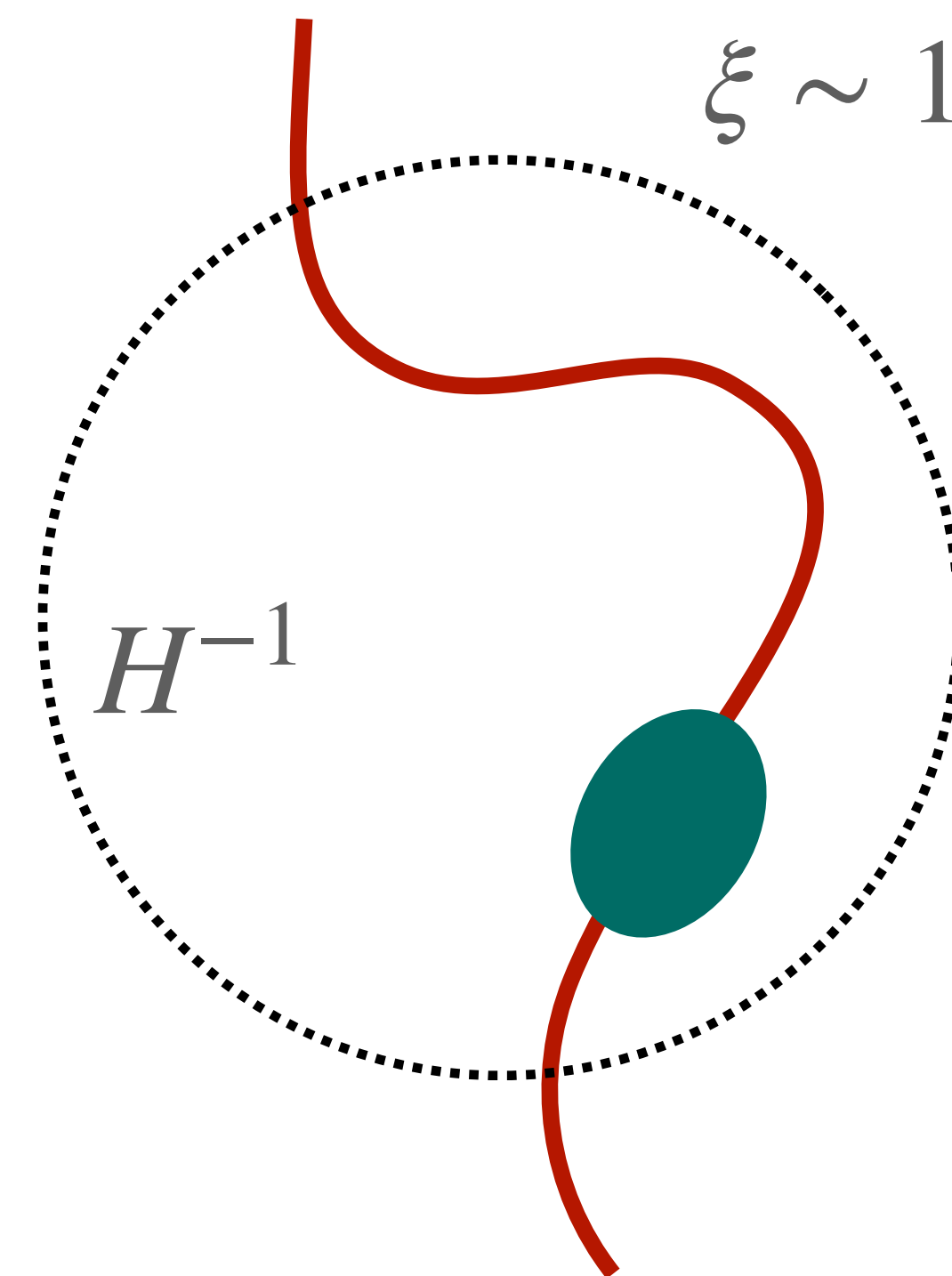
- How to evaluate the seeded action?
 - **PDE** solution obtained numerically

$$\partial_z^2 h + \partial_r^2 h + \frac{1}{r} \partial_r h + (\kappa/\eta) \frac{h}{r^2} = V'_{\text{EW}}(h)$$

$$\epsilon \partial_r h|_{r=\epsilon} = -\frac{\kappa}{\eta} C(\epsilon) h|_{r=\epsilon}, \quad \partial_z h|_{z=0} = 0$$

$$h|_{|z|=\infty} = 0, \quad h|_{r=\infty} = 0$$

} Boundary conditions



FOPT + PQ

- How to evaluate the seeded action?
 - **PDE** solution obtained numerically

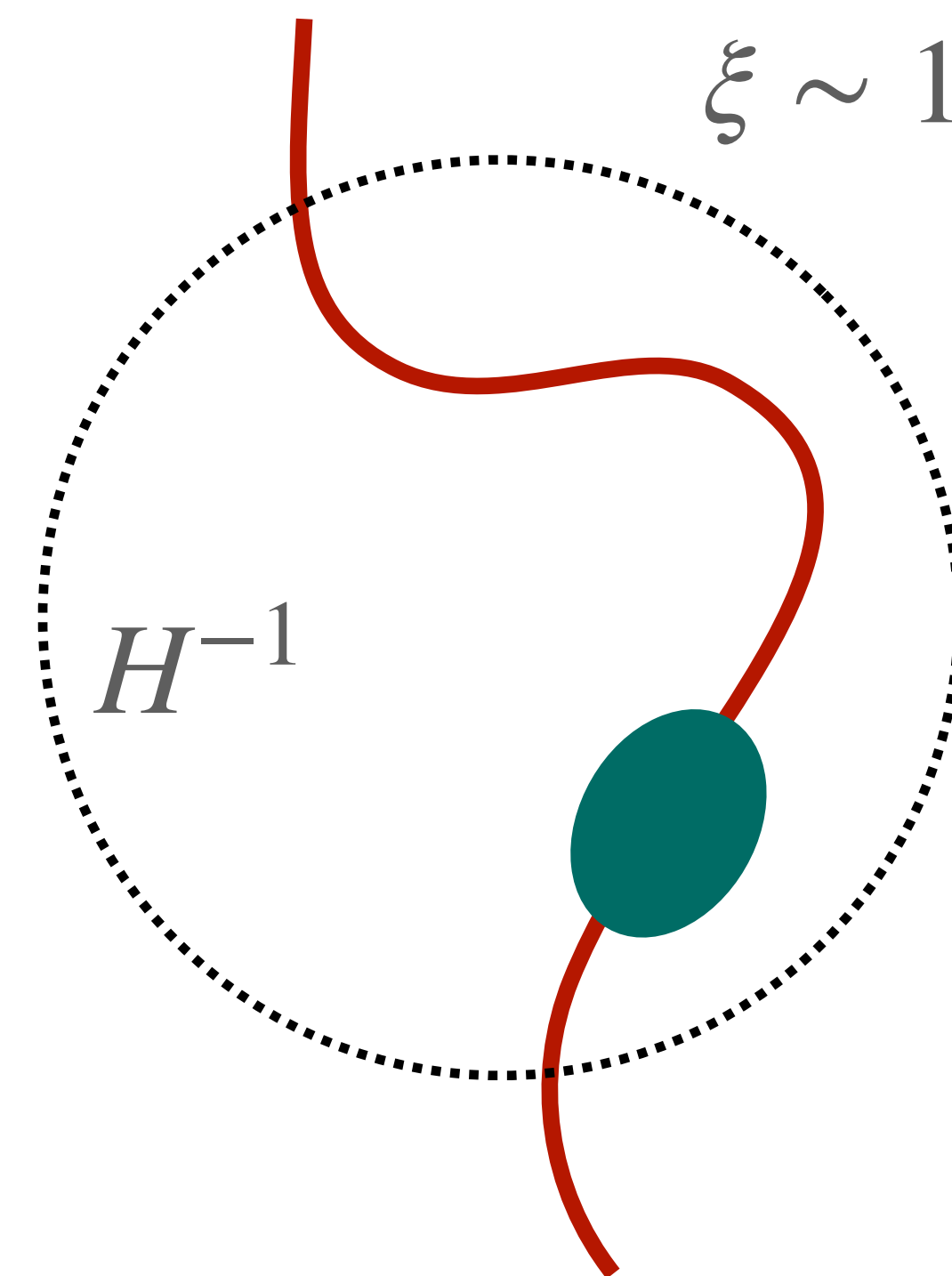
$$\partial_z^2 h + \partial_r^2 h + \frac{1}{r} \partial_r h + (\kappa/\eta) \frac{h}{r^2} = V'_{\text{EW}}(h)$$

$$\epsilon \partial_r h|_{r=\epsilon} = -\frac{\kappa}{\eta} C(\epsilon) h|_{r=\epsilon}, \quad \partial_z h|_{z=0} = 0$$

$$h|_{|z|=\infty} = 0, \quad h|_{r=\infty} = 0$$

} Boundary conditions

● = O(3) breaking



FOPT + PQ

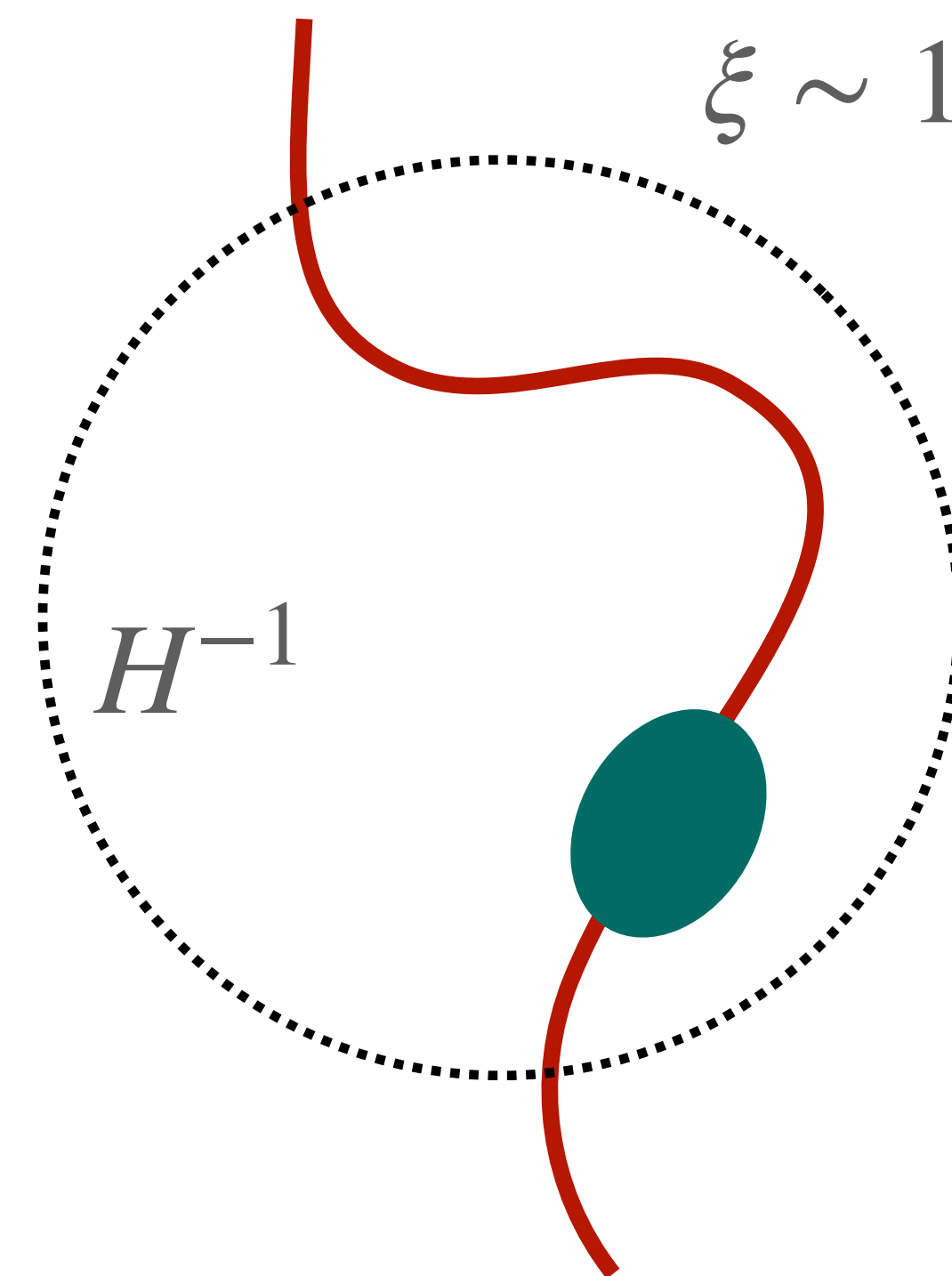
- How to evaluate the seeded action?
 - **Linear**: seeded bubble as small perturbation of homogeneous (spherical) bubble:

$$S_{\text{string}} = S_{\text{hom}} + \delta S_{\text{TW}}$$

$$\delta S_{\text{TW}} = -2\pi R \frac{\kappa}{\eta} \log(R m_\rho) h_r^2(0) \equiv 2\pi R \Delta\mu_{\text{eff}}$$

Radius hom. bubble

Release point
hom. bubble



FOPT + PQ

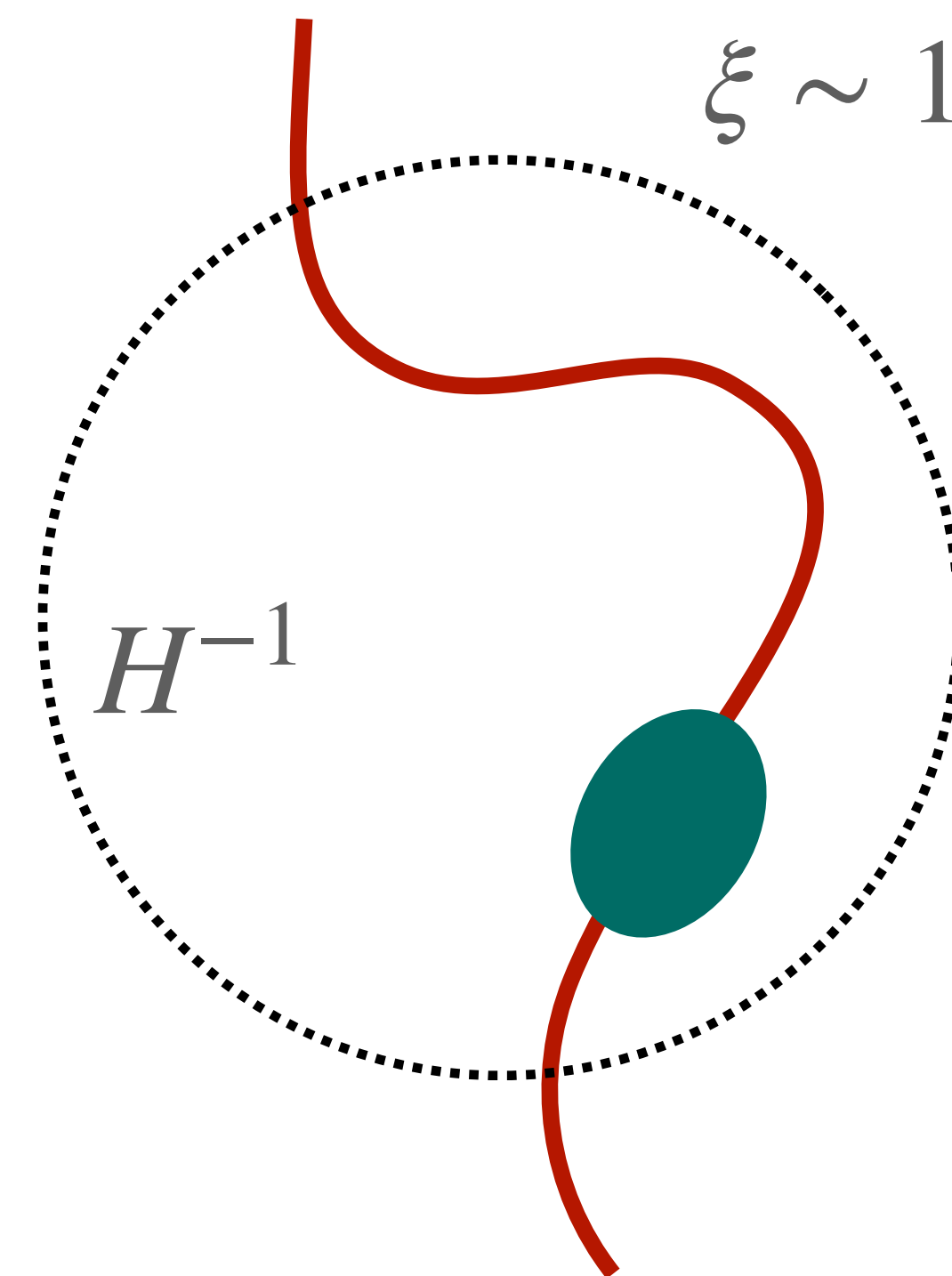
- How to evaluate the seeded action?
 - **Linear**: seeded bubble as small perturbation of homogeneous (spherical) bubble:

$$S_{\text{string}} = S_{\text{hom}} + \delta S_{\text{TW}}$$

$$\delta S_{\text{TW}} = -2\pi R \frac{\kappa}{\eta} \log(R m_\rho) h_r^2(0) \equiv 2\pi R \Delta\mu_{\text{eff}}$$

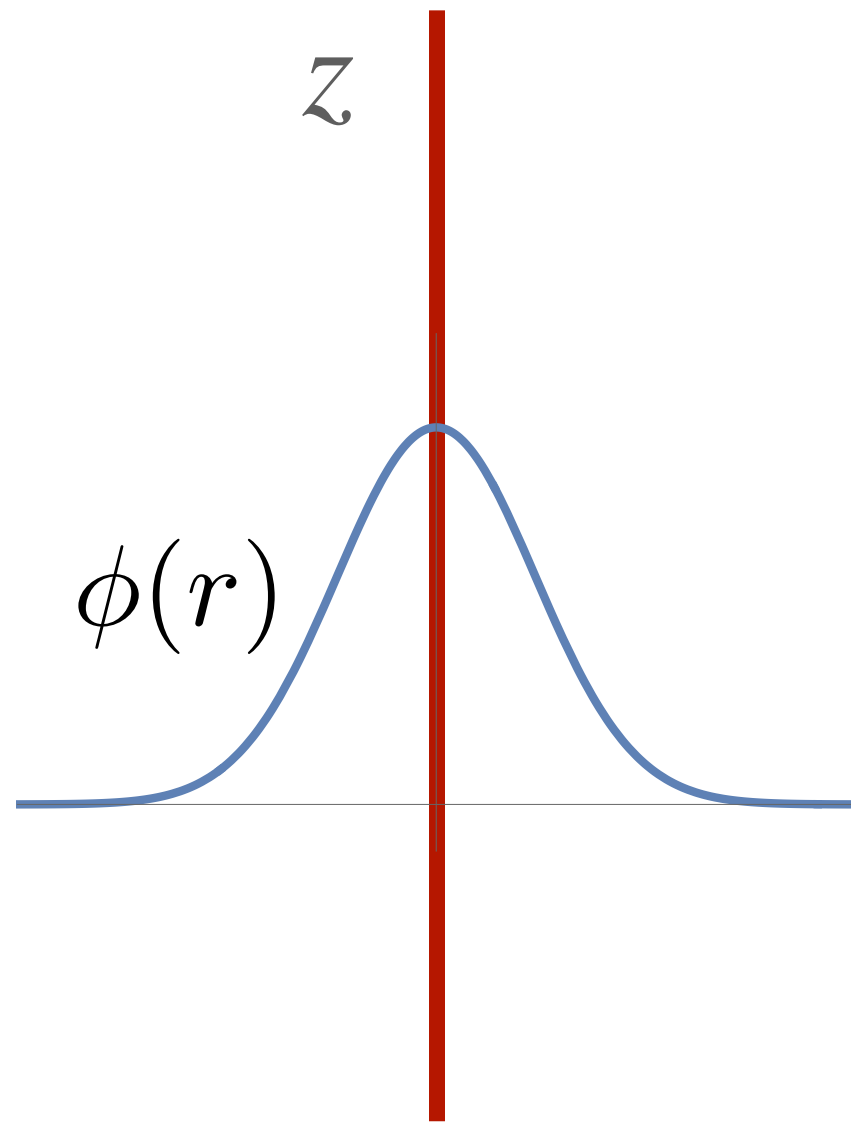
Radius hom. bubble

Release point
hom. bubble



FOPT + PQ

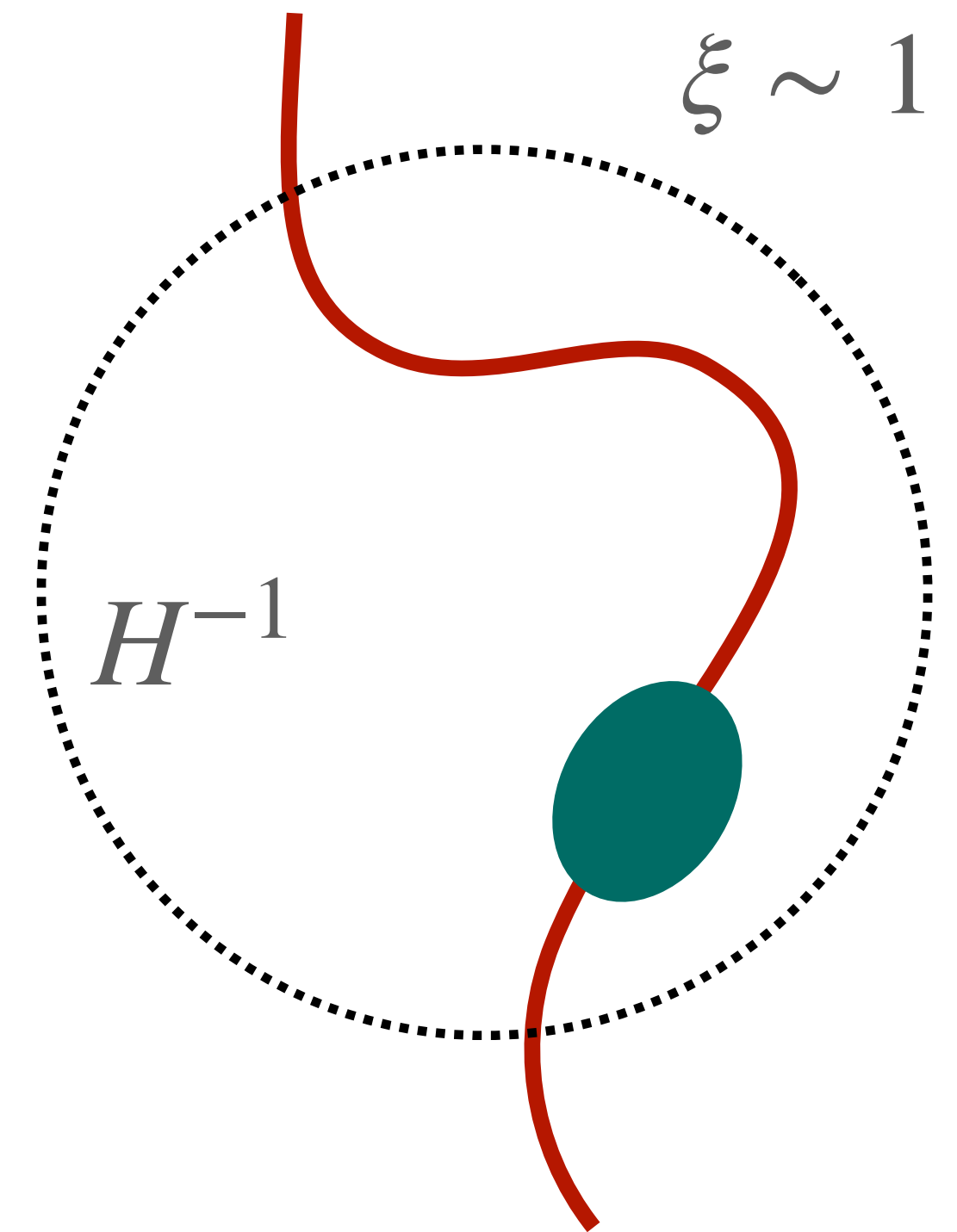
- How to evaluate the seeded action?
 - **EFT** on the string for the lightest Higgs mode



$$h(x^\mu) = \phi(r)h_0(z, t)$$

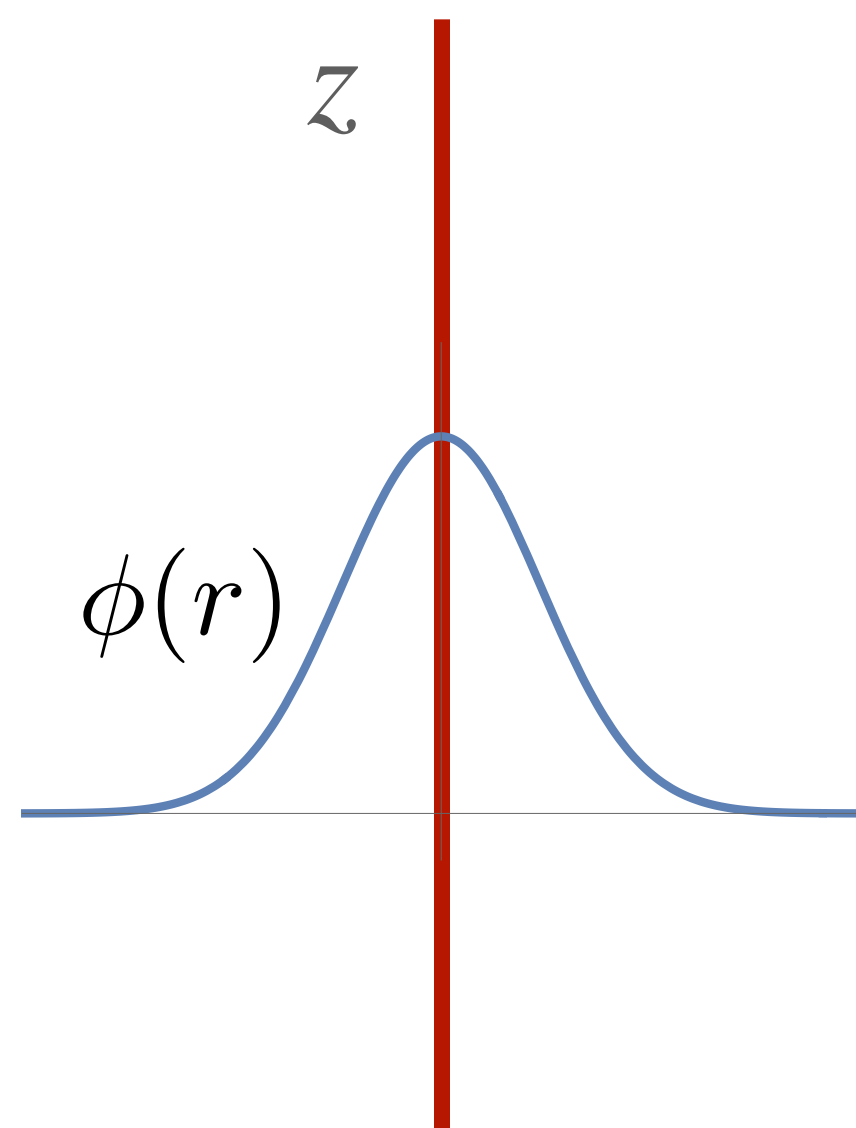
$$S_{1+1}[h_0] = \int dz dt \left\{ \frac{1}{2} (\partial_\mu h_0)^2 - \tilde{V}(h_0) \right\}$$

$$\tilde{V}(h_0) = \frac{1}{2} \omega^2 h_0^2 - \frac{1}{3!} c_3 h_0^3 + \frac{1}{4!} c_4 h_0^4$$



FOPT + PQ

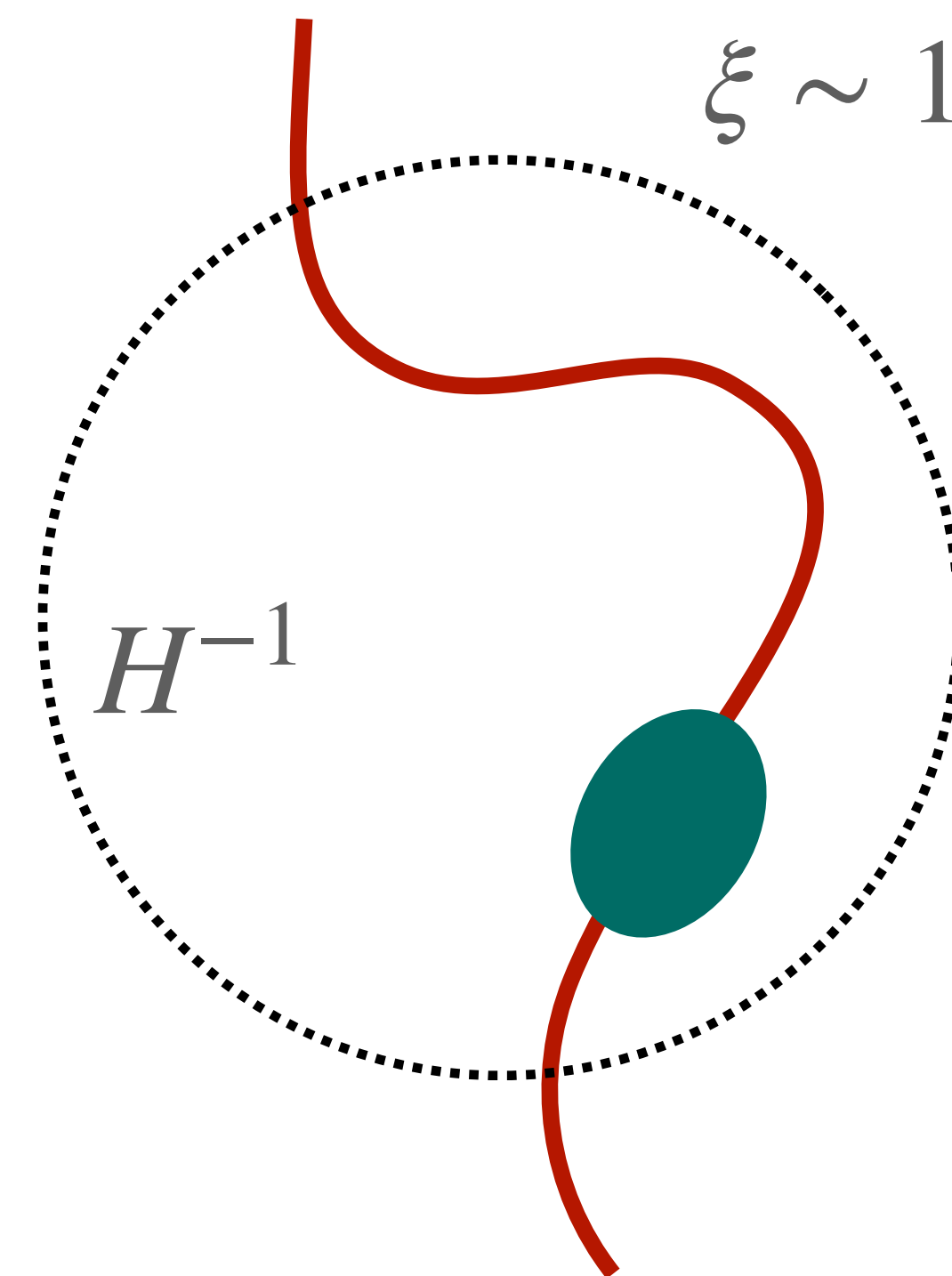
- How to evaluate the seeded action?
 - **EFT** on the string for the lightest Higgs mode



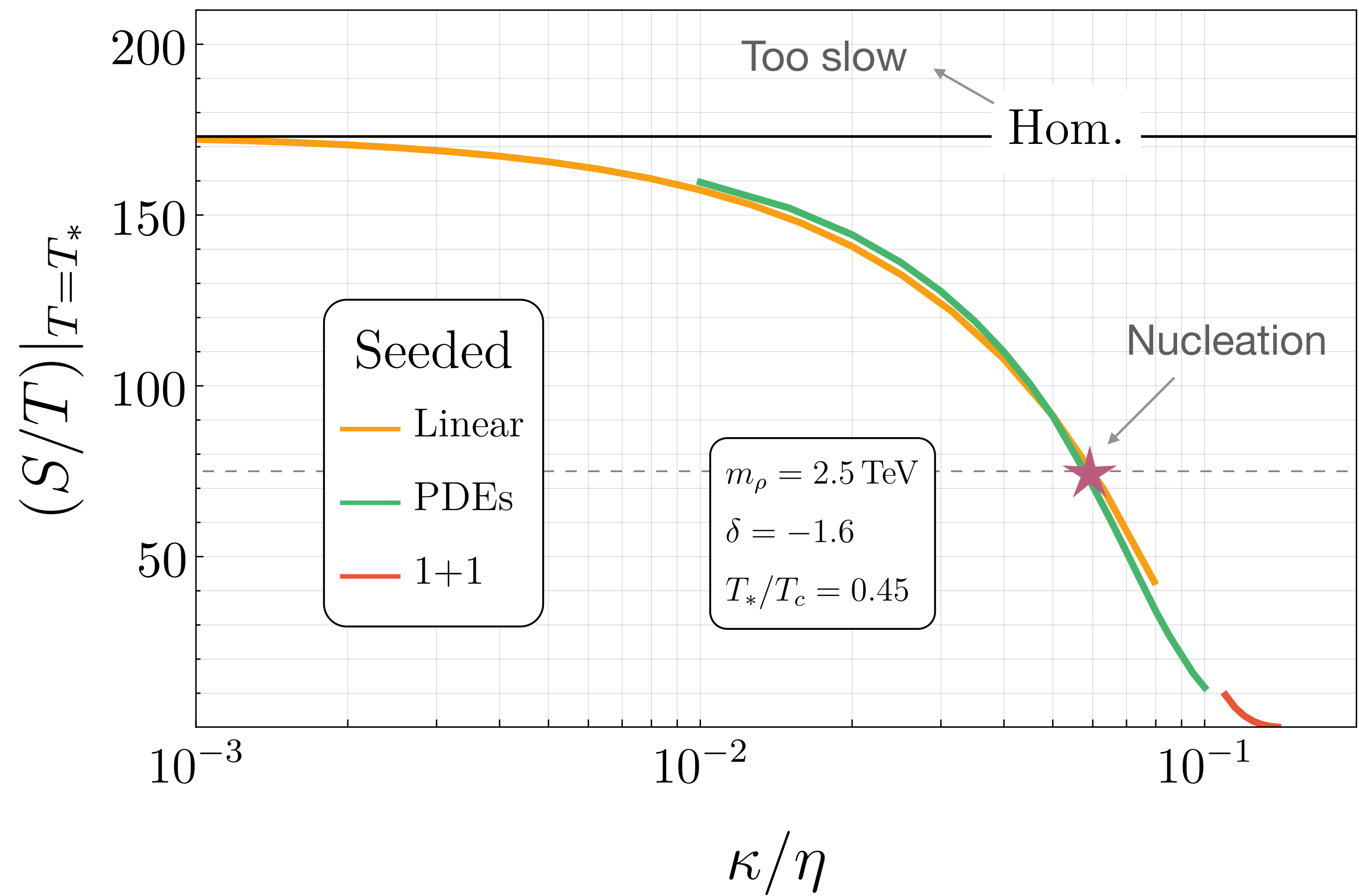
$$h(x^\mu) = \phi(r)h_0(z, t)$$

$$S_{1+1}[h_0] = \int dz dt \left\{ \frac{1}{2} (\partial_\mu h_0)^2 - \tilde{V}(h_0) \right\}$$

$$\tilde{V}(h_0) = \frac{1}{2} \omega^2 h_0^2 - \frac{1}{3!} c_3 h_0^3 + \frac{1}{4!} c_4 h_0^4$$

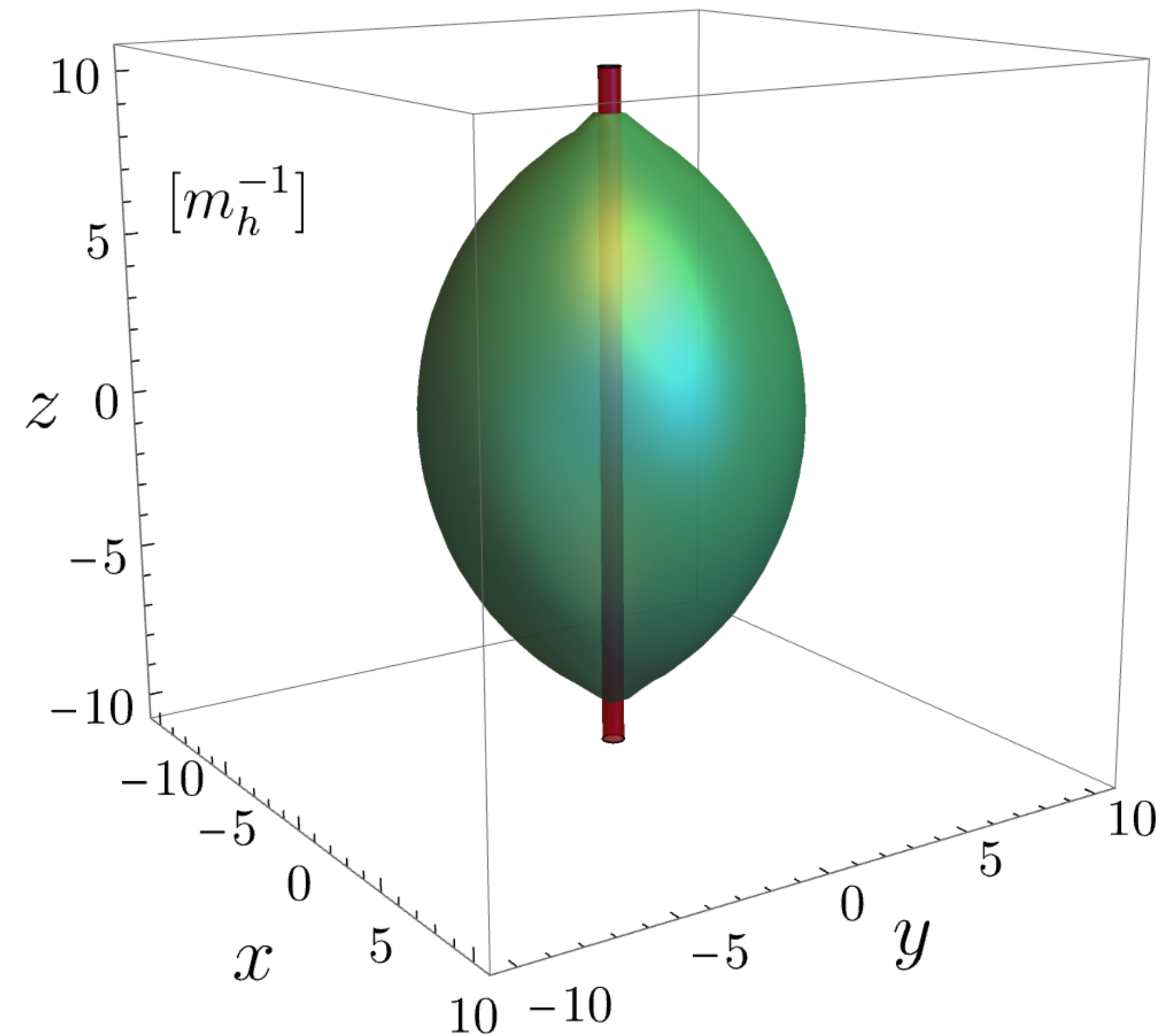
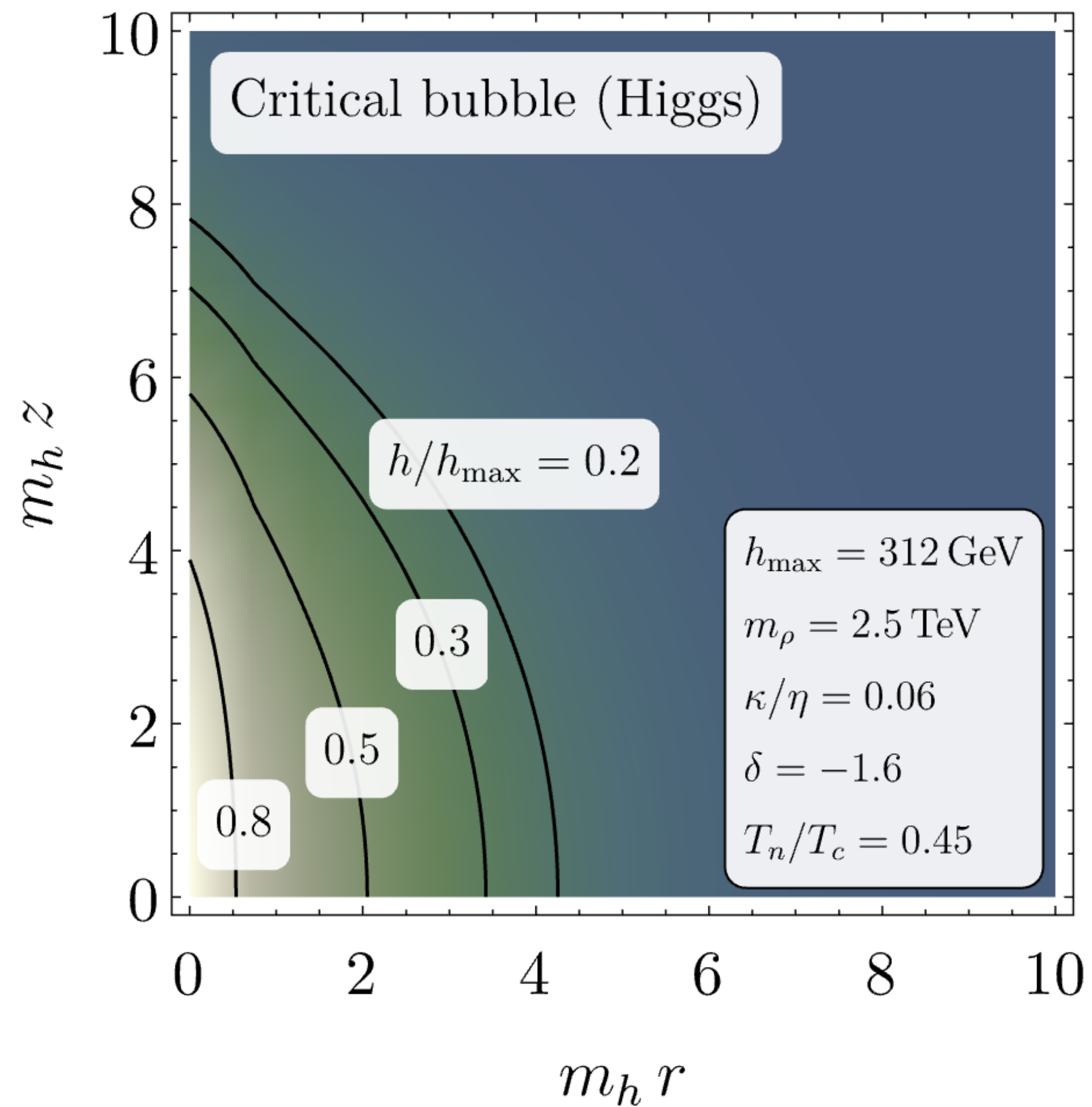


FOPT + PQ



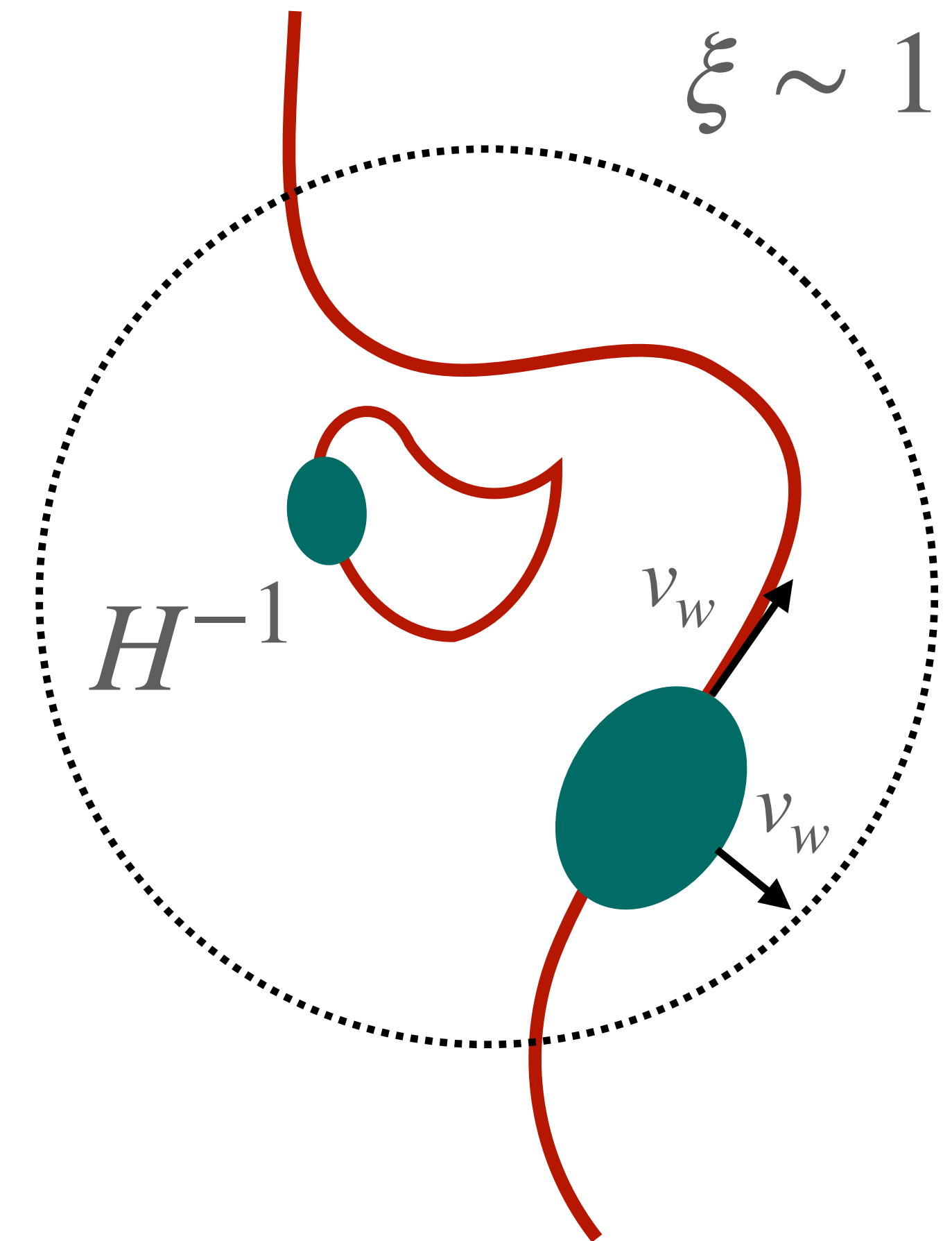
FOPT + PQ

- Profile of the critical bubble: ★



FOPT + PQ

- Percolation as interplay between seeded nucleation rate and density of defects
- Axion—seeded EWPT effectively $\beta/H \sim \xi \sim 10$
- Different velocities parallel or orthogonal to the string?
- Gravitational wave emission before collision (non-spherical bubbles)?



Summary

- The presence of impurities in the early Universe can strongly affect the way a phase transition proceeds
- The xSM with Z_2 symmetry is arguably the simplest (and complete) example for a seeded EWPT
- Other defects can exist at the time of the EWPT: dedicated study of QCD axion strings in KSVZ model with Higgs portal
- Pheno aspects of seeded phase transitions: percolation, slow transitions, expansion of non—spherical bubbles, features in the GW signal?

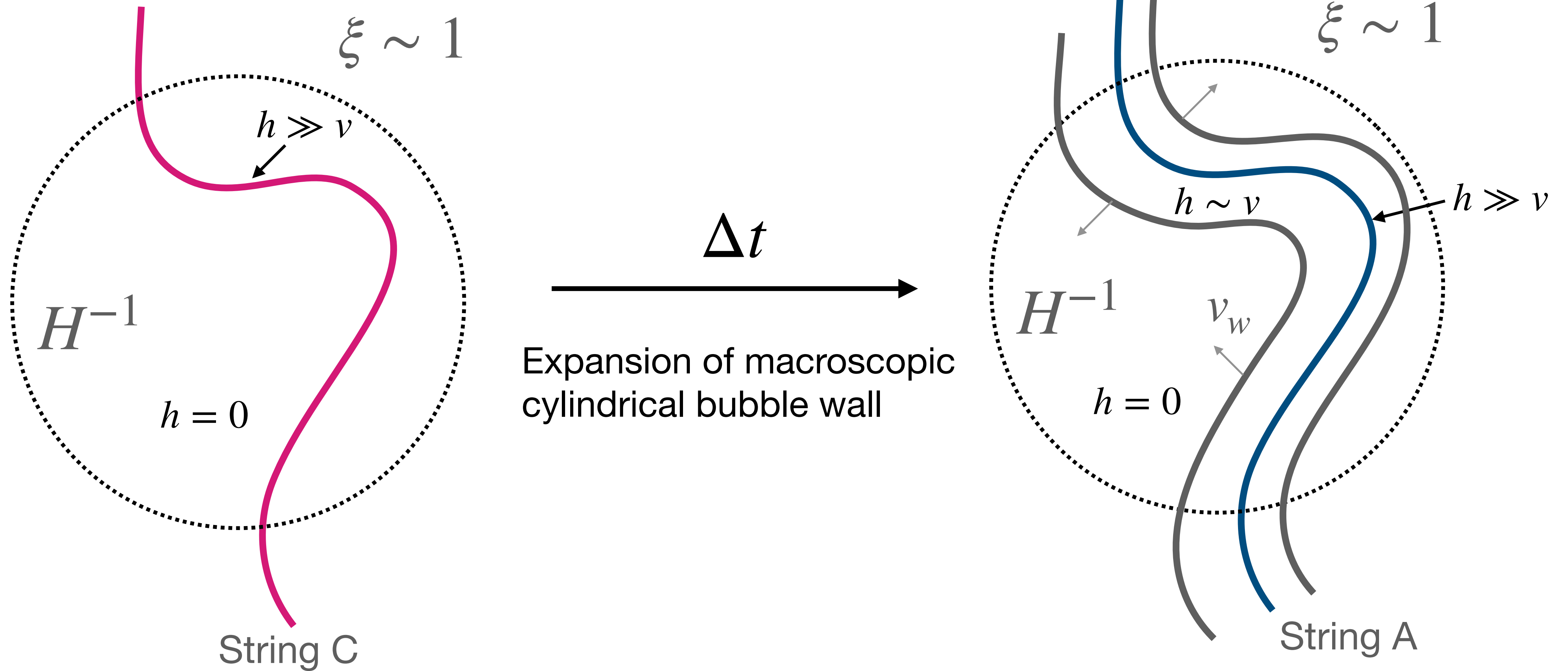
Summary

- The presence of impurities in the early Universe can strongly affect the way a phase transition proceeds
- The xSM with Z_2 symmetry is arguably the simplest (and complete) example for a seeded EWPT
- Other defects can exist at the time of the EWPT: dedicated study of QCD axion strings in KSVZ model with Higgs portal
- Pheno aspects of seeded phase transitions: percolation, slow transitions, expansion of non—spherical bubbles, features in the GW signal?

Thank you!

FOPT + PQ

See also Yajnik, PRD (1986)



Seeded EWPT at LISA

