INERT SCALARS AND VACUUM STABILITY

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VACUUM (META)STABILITY

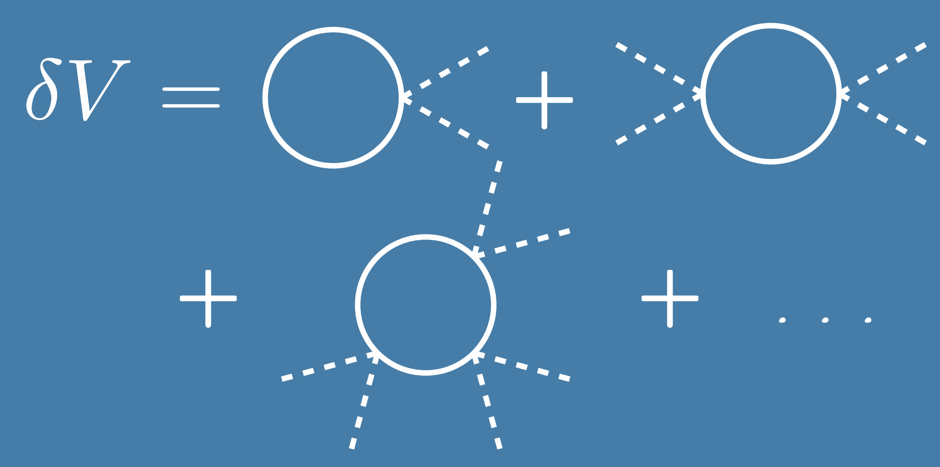
A vacuum state of a theory is the state of the lowest energy. For a theory to be physical, vacuum has to be stable, i.e., be

- a global minimum of the potential (absolute stability), or
- a local minimum that is not prone to quantum tunneling (metastability).

The SM vacuum is a long-lived metastable state. Is the vacuum state of a model with extended scalar sector stable?

EFFECTIVE POTENTIAL

A tool to analyze vacuum stability is the effective potential.



Fermions contribute with the "-" sign, and bosons with "+".

RUNNING COUPLINGS

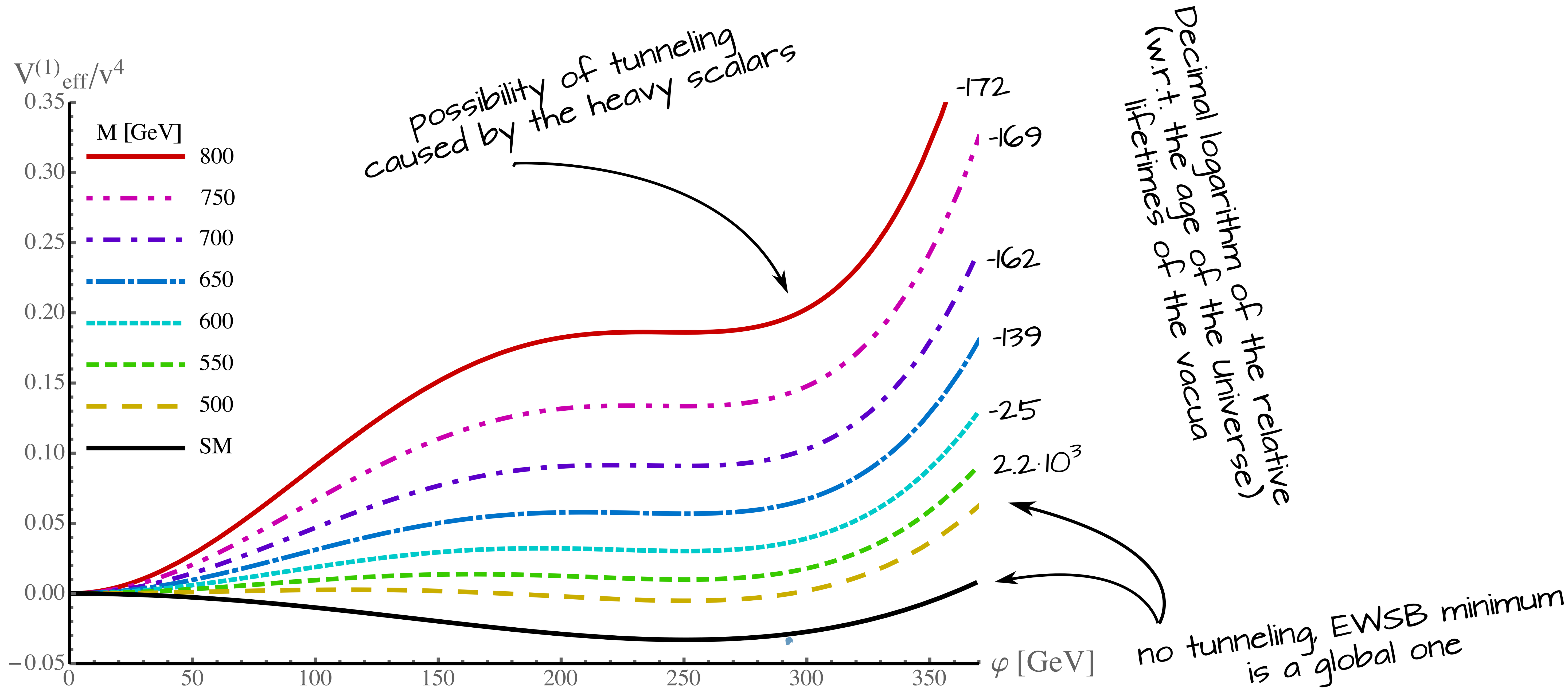
Heavy top quark pulls the running Higgs self-coupling towards negative values, which makes the potential unbounded from below.

It has been shown that the presence of additional scalars improves the behavior of the potential at large field values, and it bends down later than the SM potential.

QUESTIONS: Is the improved behavior of effective potential at large field values enough for stability? What about metastability? Can the additional scalars modify the potential at low field values?

MODEL: Inert Doublet Model with dark (inert) scalars integrated out. Particle content: h - SM-like Higgs boson (mass = 125 GeV), H - DM candidate, A - pseudoscalar, $H^{\pm}$- charged scalars. Here: $H^{\pm}$ and A are degenerate,

VACUUM STRUCTURE AROUND THE EW SCALE AND LIFETIMES OF THE VACUA



TUNNELING TIME

If two minima are present, quantum tunneling between them can occur. Nonetheless, if the lifetime of the local minimum is longer than the age of the Universe, it can constitute a viable vacuum state for a theory.

Lifetime of the vacuum relative to the age of the Universe is evaluated with the use of

$$t \sim e^{S_E(\phi_b)}$$

$S_E(\phi_b)$ Euclidean action on the bounce solution

HEAVY = LESS STABLE

For very heavy dark scalars very short lifetime of EWSB vacuum is predicted, e.g., with M=800 GeV, log(t)=-172. It agrees with approximate solutions which show that tunneling time grows with the energy difference between the minima, and decreases with the height of the barrier between them.

Even though heavy scalars improve the behavior of the potential at large field values, at low energies they may cause significant instability.

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