The Higgs mass metastability bound

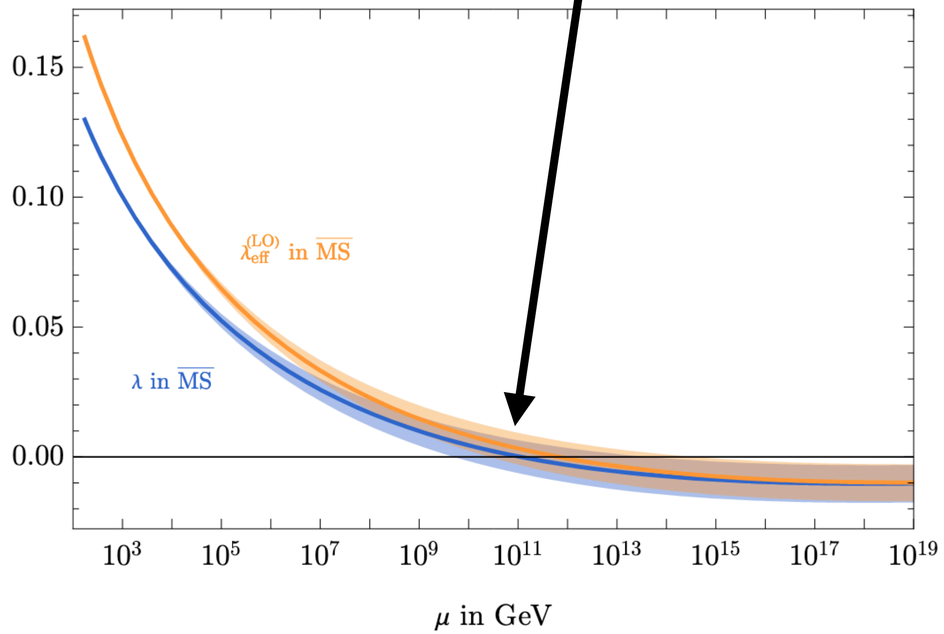
Thomas Steingasser

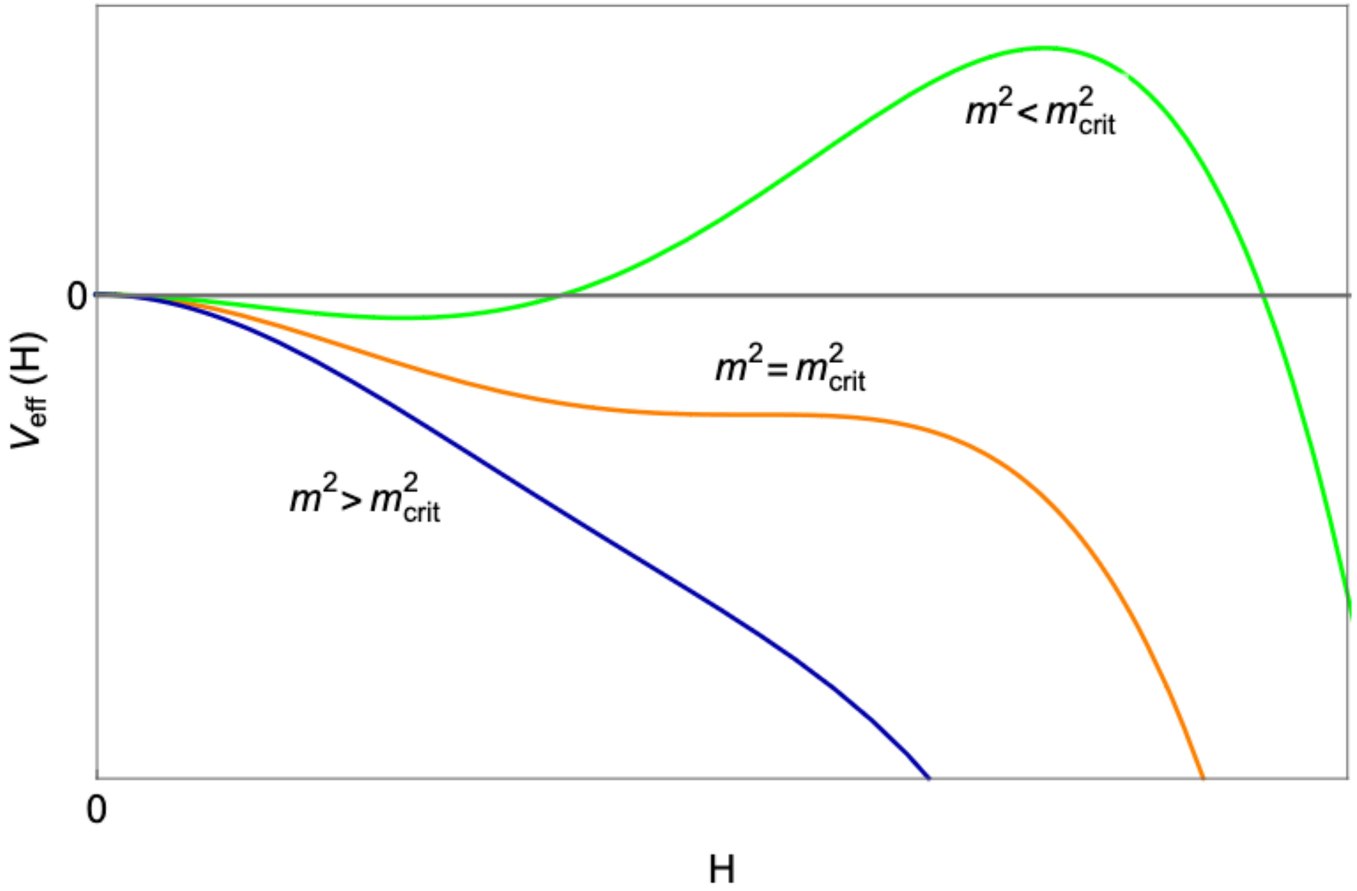
Massachusetts Institute of Technology
Black Hole Initiative at Harvard University

Metastability bound - idea

[1307.3536]
(D. Buttazzo et al)

$$m_h^2 \lesssim |\beta_\lambda| \mu_I^2$$





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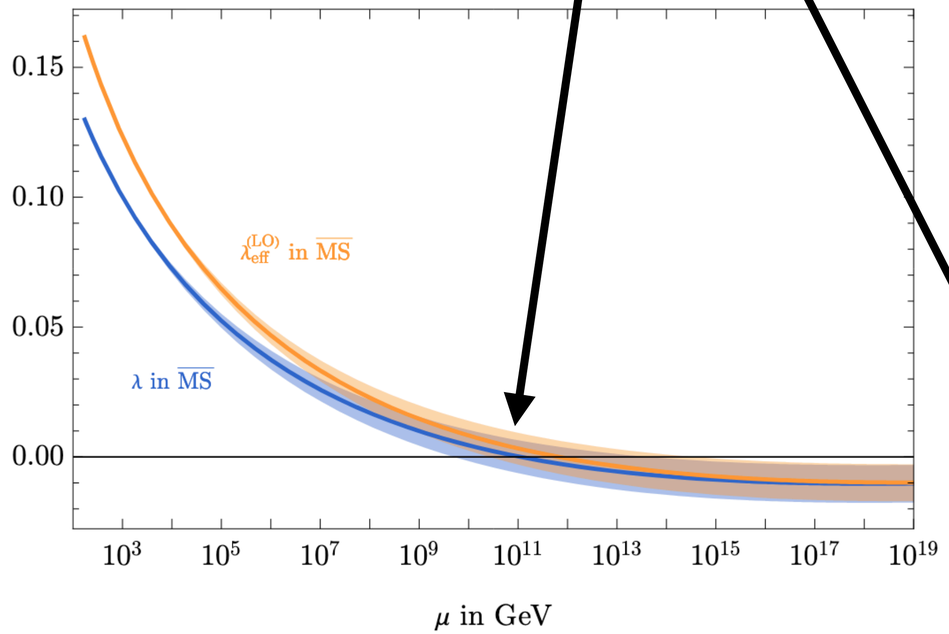
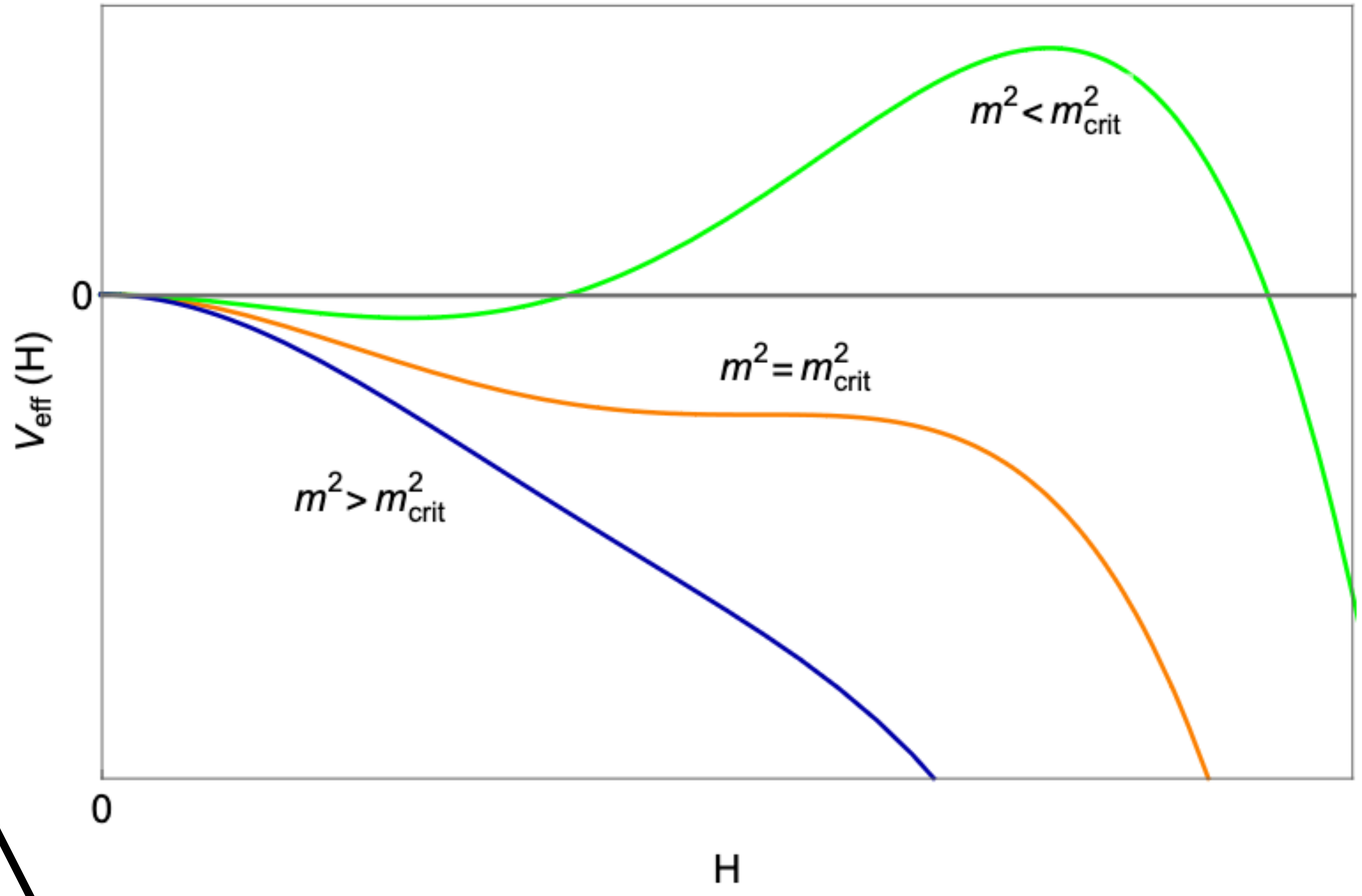
$$m_h^2 \lesssim |\beta_\lambda| \mu_I^2 \ll \Lambda_{UV}^2$$



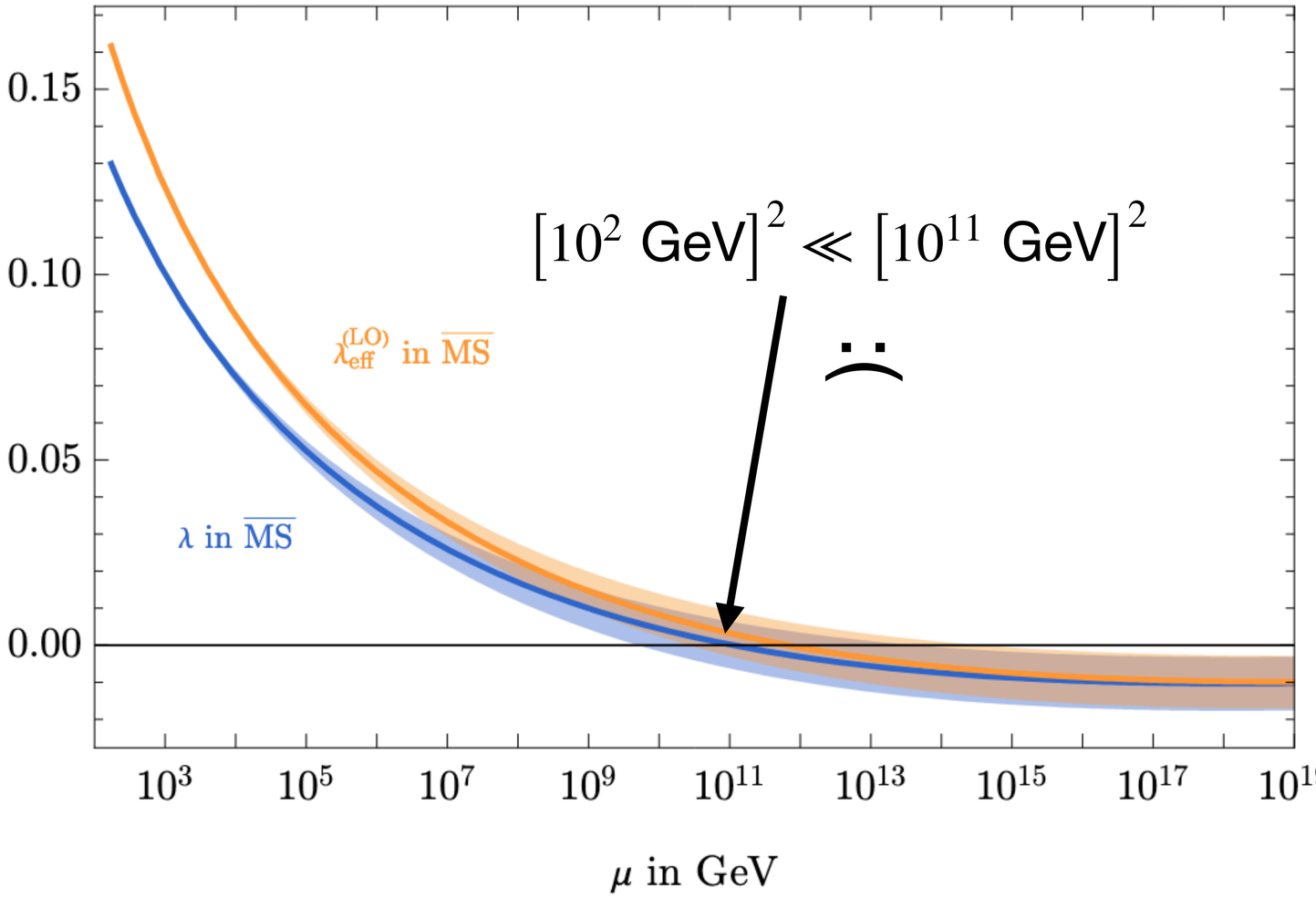


achieved by vacuum selection

Metastability bounds & phenomenology

Metastability bounds - BSM features

$$m_h^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{UV}^2$$



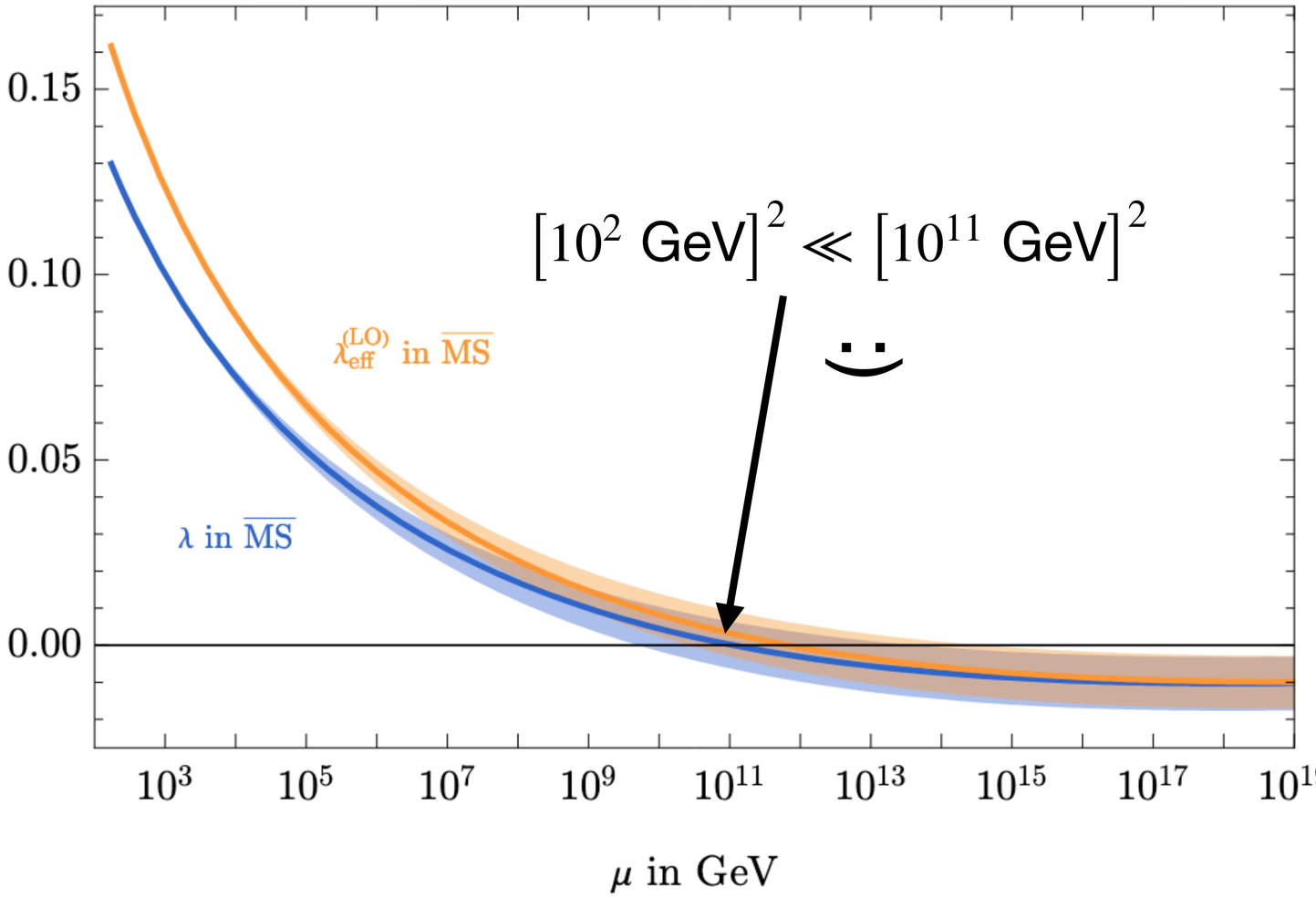
Metastability bounds - BSM features

$$m_h^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{UV}^2$$

needs BSM physics to change running

➡ Can be falsified!

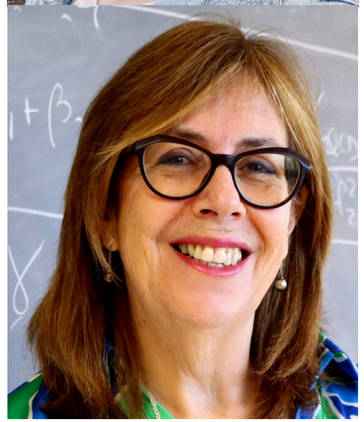
➡ “Decouples” from vacuum selection!

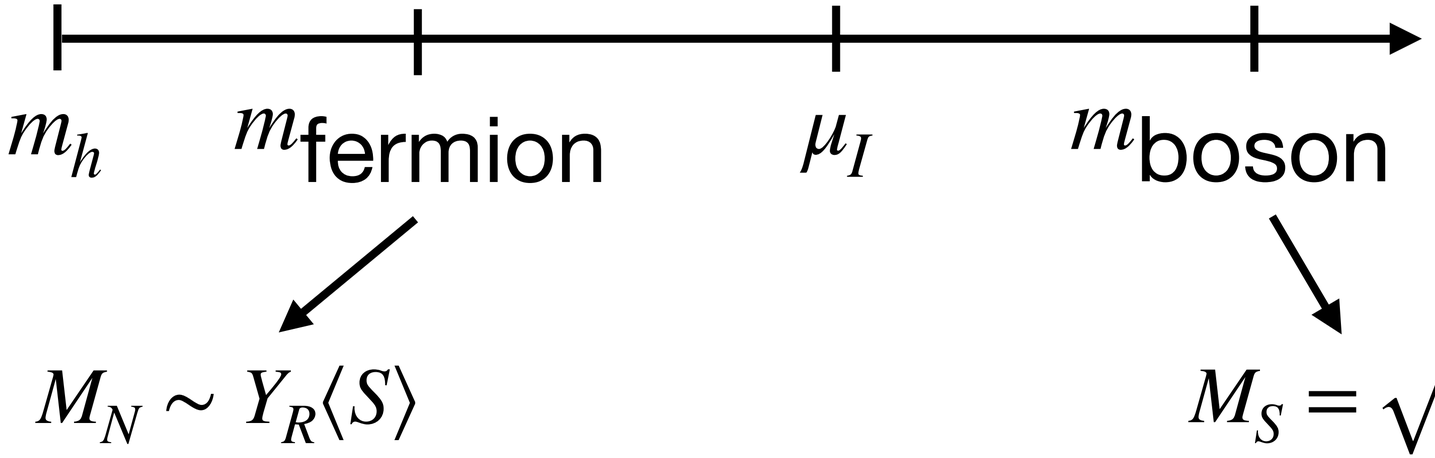


Example - Majoron model

[2503.03825]:
(V. Enguita,
B. Gavela, TS)

Majoron model → Rhns in **low-scale** seesaw
+ singlet scalar for mass term

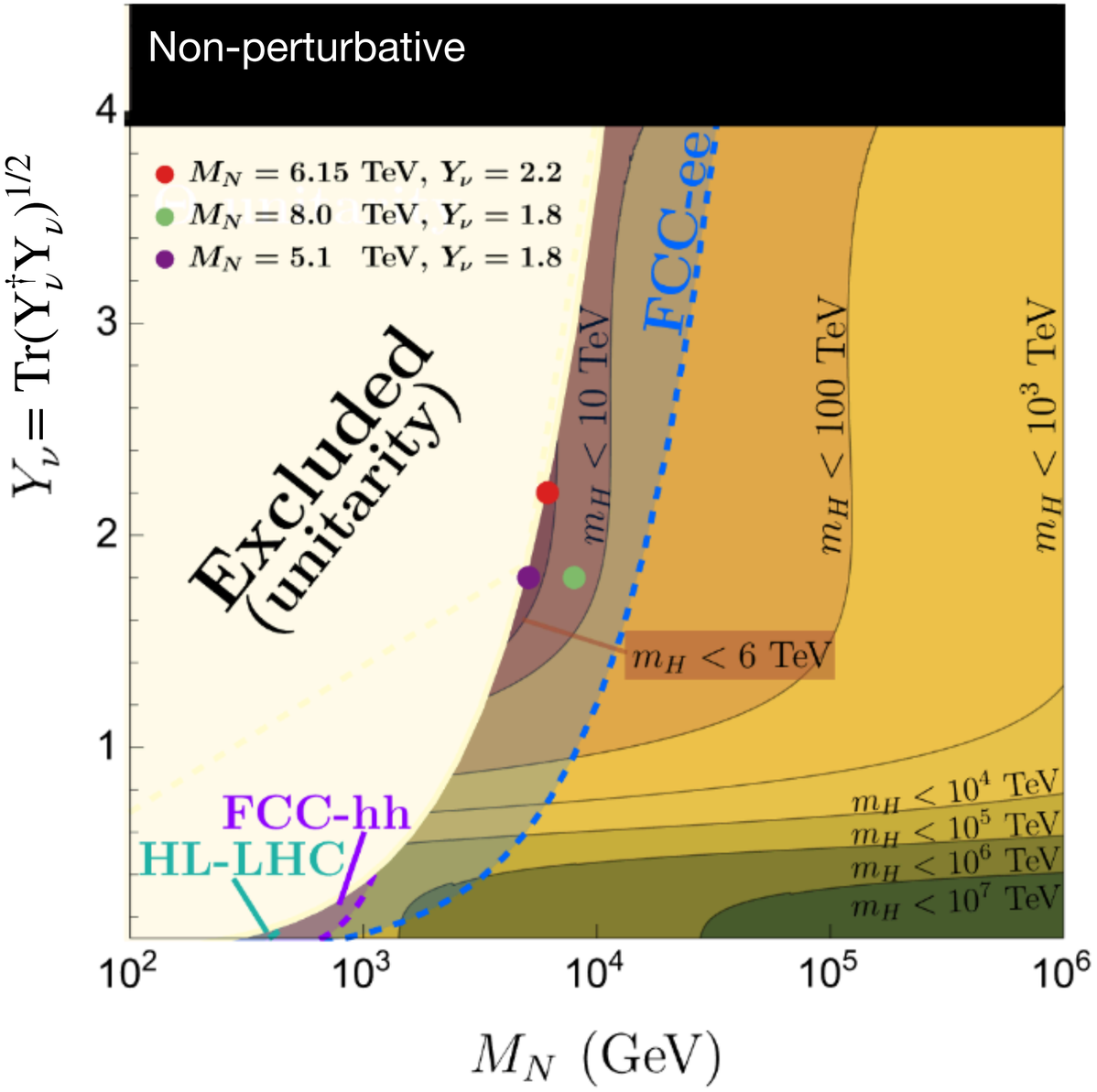


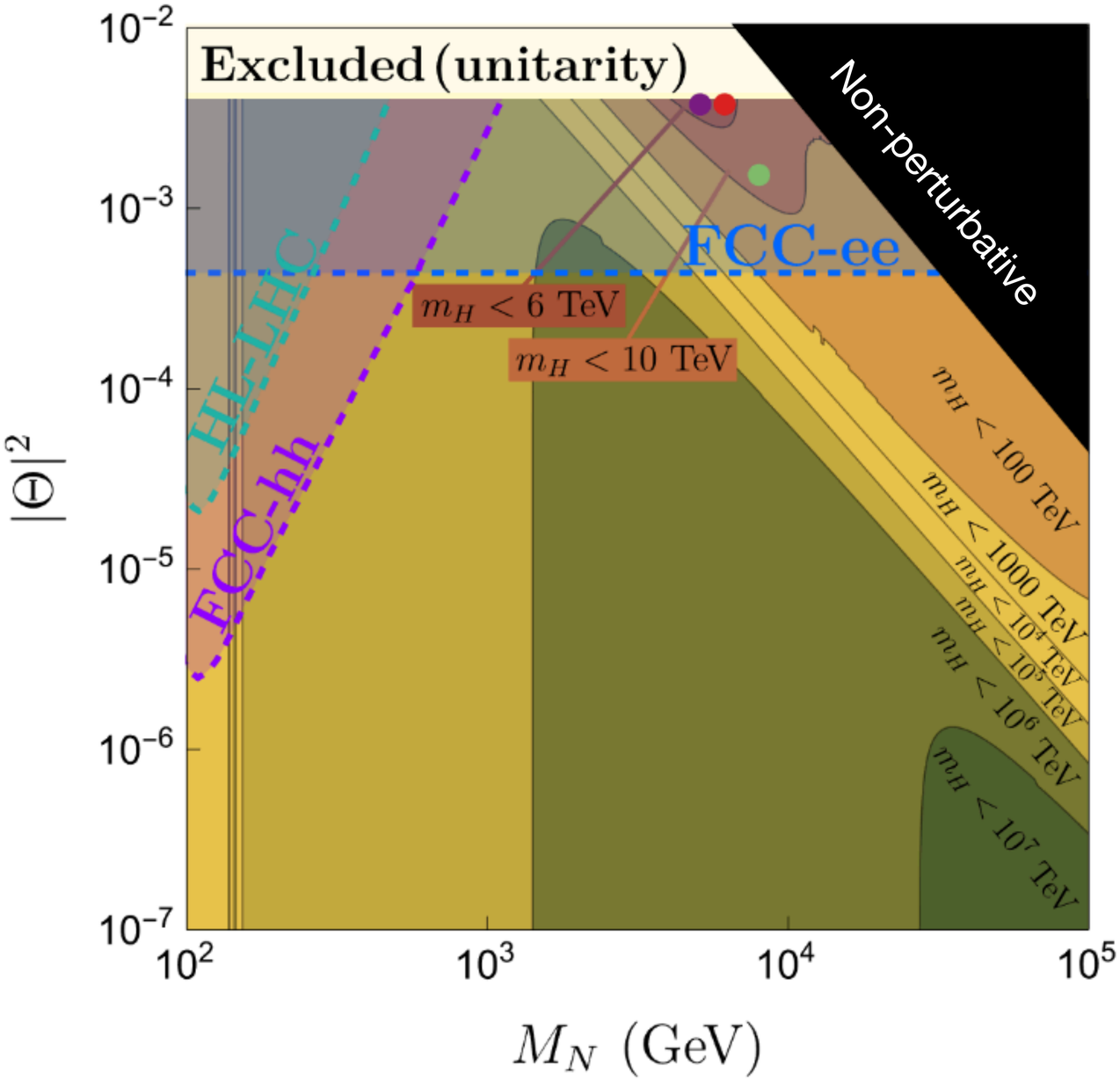


→ lowers μ_I

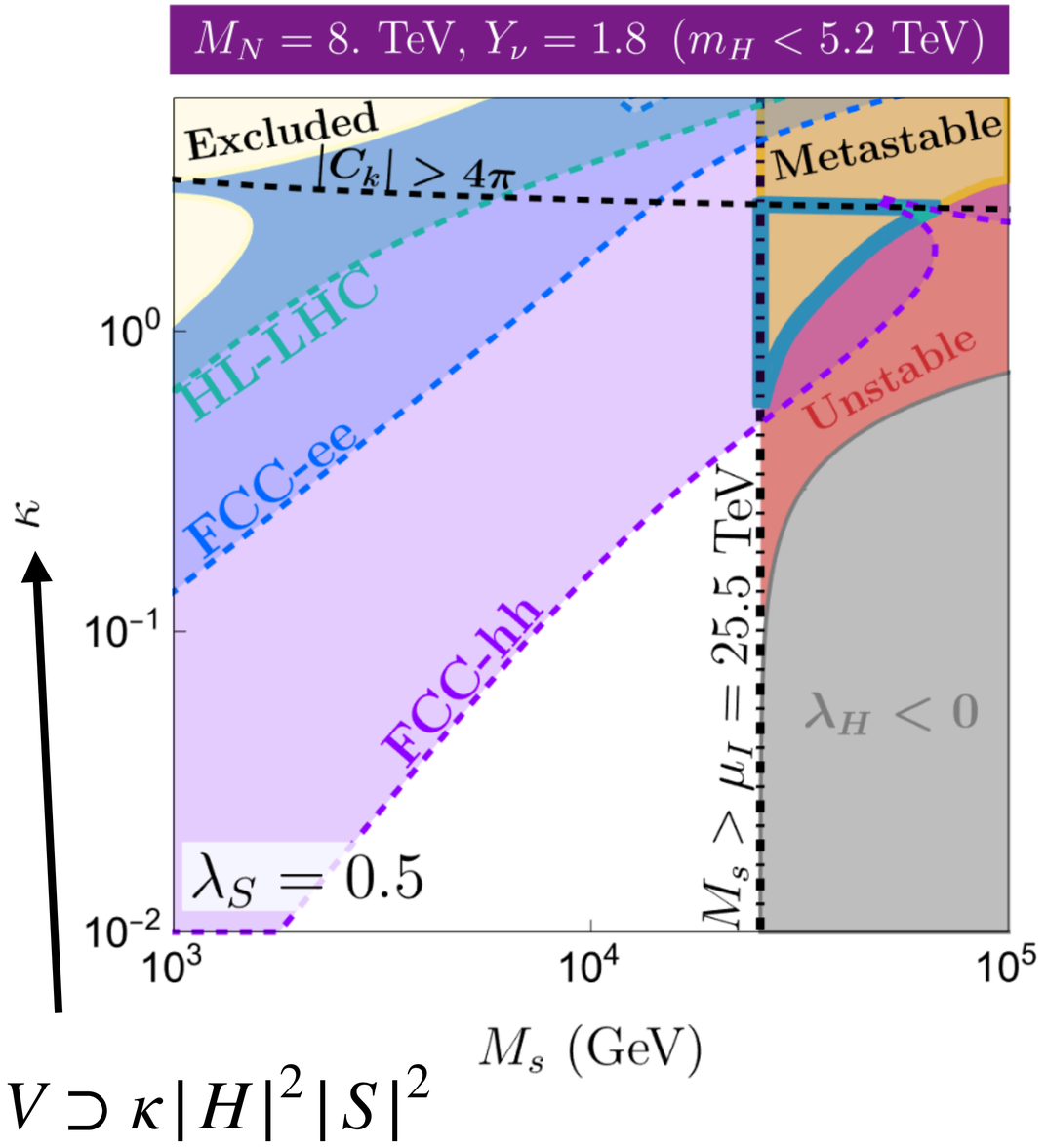
→ saves vacuum

Metastability bound @FCC - RHNs





Metastability bound @FCC - Majoron



$V \supset \kappa |H|^2 |S|^2$

strong destabilization

⬇

strong stabilization

⇕

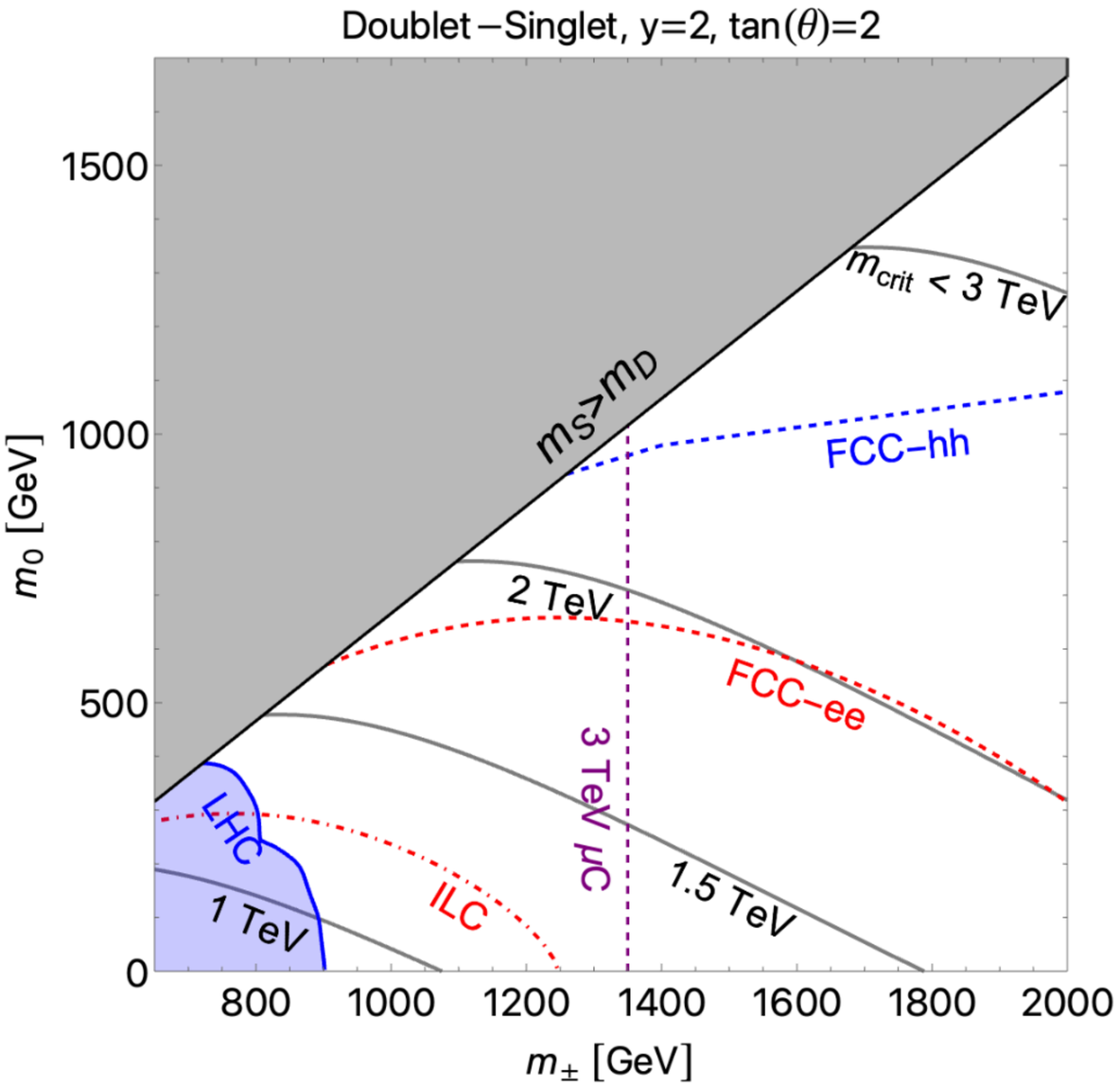
large κ or “small” M_S

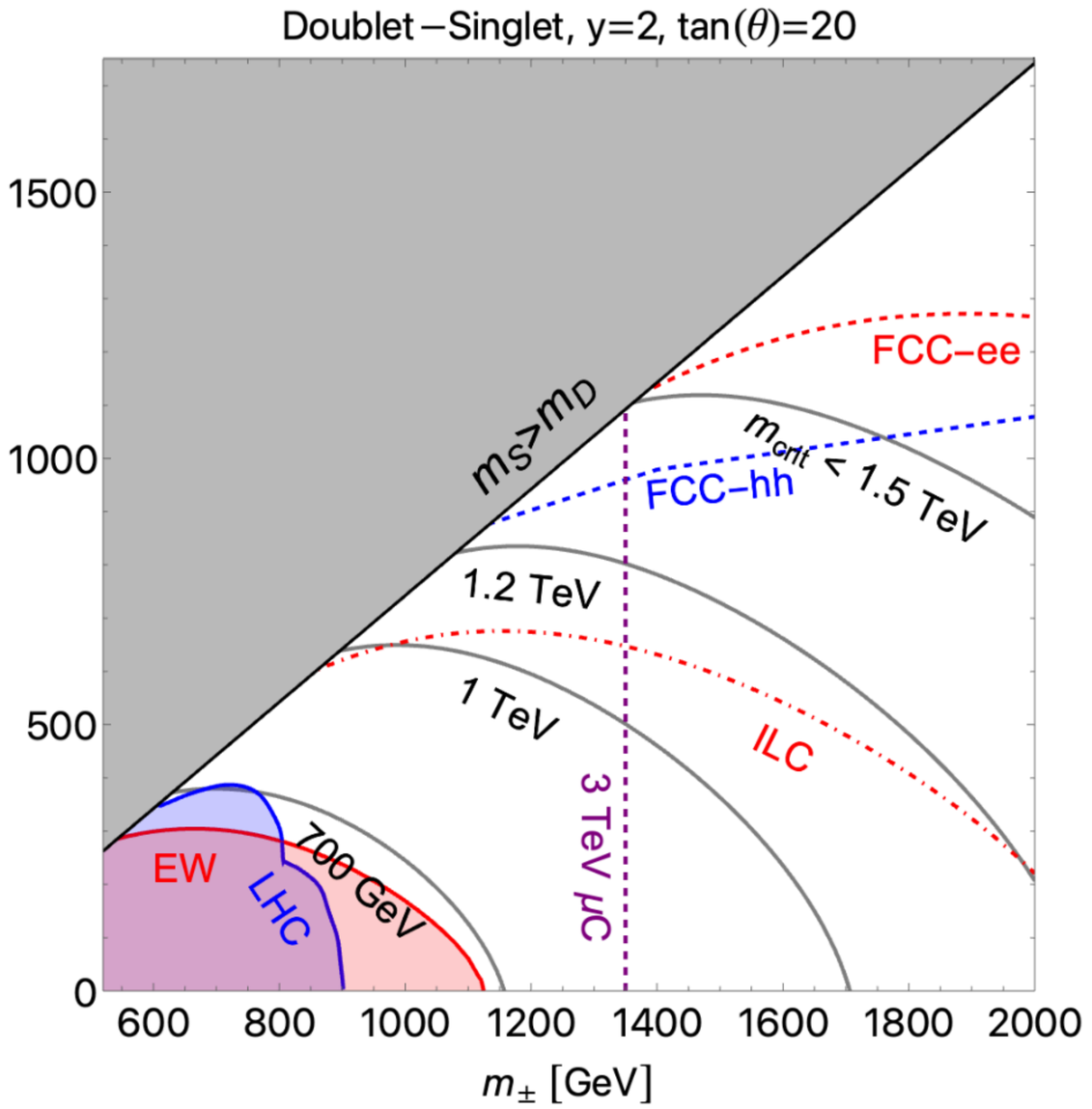
⇕

strong signal:

$$\mathscr{L}_{H\Box} = -\frac{\kappa^2}{4\lambda_S M_S^2} |H|^2 \Box |H|^2$$

Example - Singlet-doublet model





Metastability bounds & vacuum selection

Metastability bound - concrete realizations

[2502.07876]
(S. Benevedes,
A. Ismail, TS)

Landscape
+crunching

[2108.09315]
(J. Khoury, TS)

[2408.10297]
(S. Benevedes,
S. Trifinopoulos, TS)

Metastability

$$m_h^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{\rm UV}^2$$

Metastability bound - concrete realizations

[2502.07876]
(S. Benevedes, A. Ismail, TS)

Landscape +crunching

e.g. sliding naturalness

$$m_h^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{\rm UV}^2$$

[2108.09315]
(J. Khoury, TS)

[2408.10297]
(S. Benevedes, S. Trifinopoulos, TS)

Metastability

[1907.07693]:
(J. Khoury, O. Parrikar)

$$\tau_{\rm ideal} \sim \frac{M_{\rm Pl}^2}{H_0^3} \sim 10^{130}\ \text{years}$$

Metastability bounds - with SSB

[2108.09315]:
(J. Khoury, TS)

Metastability+SSB ➡ $m^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{UV}^2$

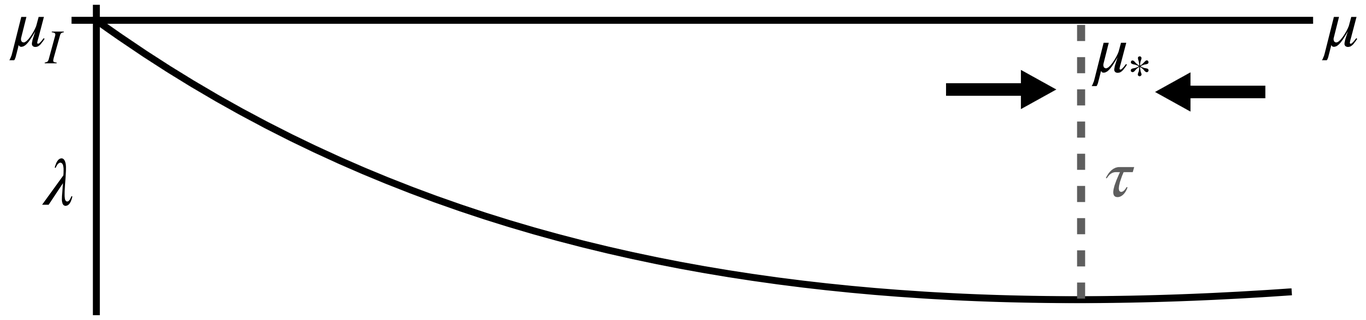
Metastability bounds - with SSB

[2108.09315]: (J. Khoury, TS) Metastability+SSB ➡ $m^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{UV}^2$

SM @ high energies: classically scale invariant: $V \simeq \lambda\phi^4$

➡ family of bounces: $\phi_R \propto \mu_R$, $S_E \propto |\lambda(\mu_R)|^{-1}$

$$\Gamma \sim \int d\mu_R\, e^{-|\lambda(\mu_R)|^{-1}} \sim e^{-|\lambda(\mu_*)|^{-1}} \quad \Rightarrow \partial_{\mu_R} S_E(\mu_*) \propto \beta_\lambda(\mu_*) = 0$$



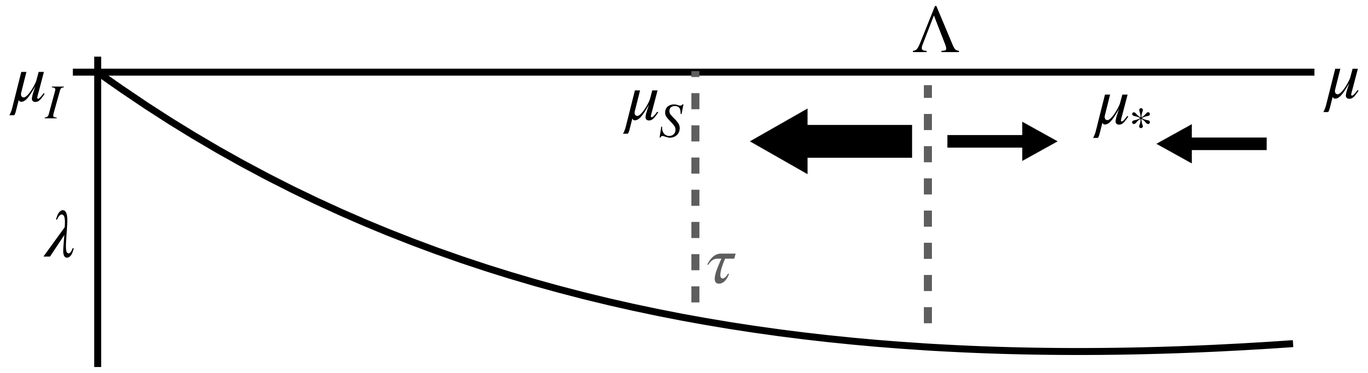
Metastability bounds - with SSB

[2108.09315]: (J. Khoury, TS) Metastability+SSB ➡ $m^2 \lesssim |\beta_\lambda(\mu_I)|\mu_I^2 \ll \Lambda_{UV}^2$

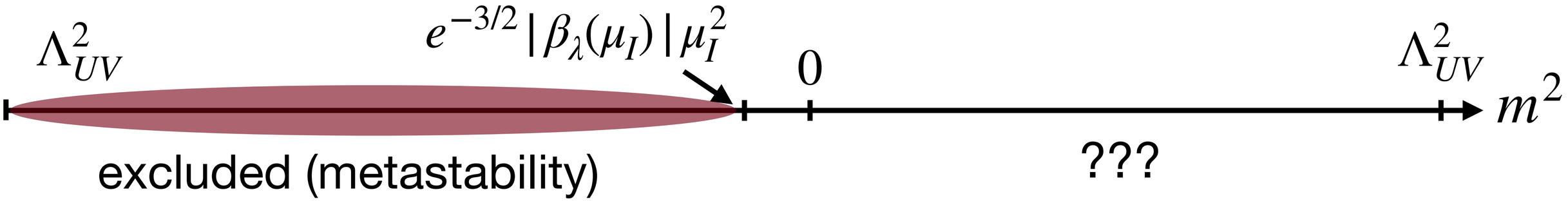
SM + dim6: almost classically scale invariant!

➡ family of bounces: $\phi_R \propto \mu_R$, $S_E \propto |\lambda(\mu_R)|^{-1} + \mu_R^2/\Lambda^2$

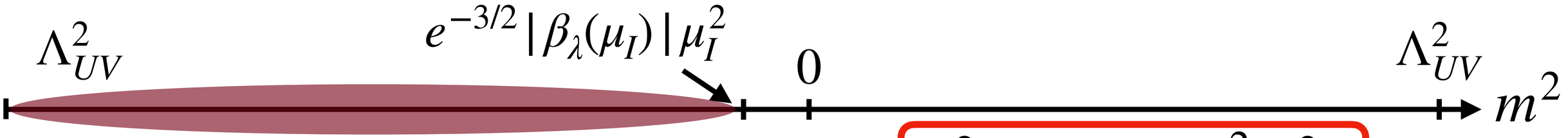
$$\Gamma \sim \int d\mu_R \, e^{-|\lambda(\mu_R)|^{-1} - \frac{\mu_R^2}{\Lambda^2}} \sim e^{-|\lambda(\mu_S)|^{-1} + \ldots} \Rightarrow \partial_{\mu_R}(|\lambda(\mu_R)|^{-1} + \mu_R^2/\Lambda^2) = 0$$



Extended metastability bounds - explaining SSB?



Extended metastability bounds - explaining SSB?

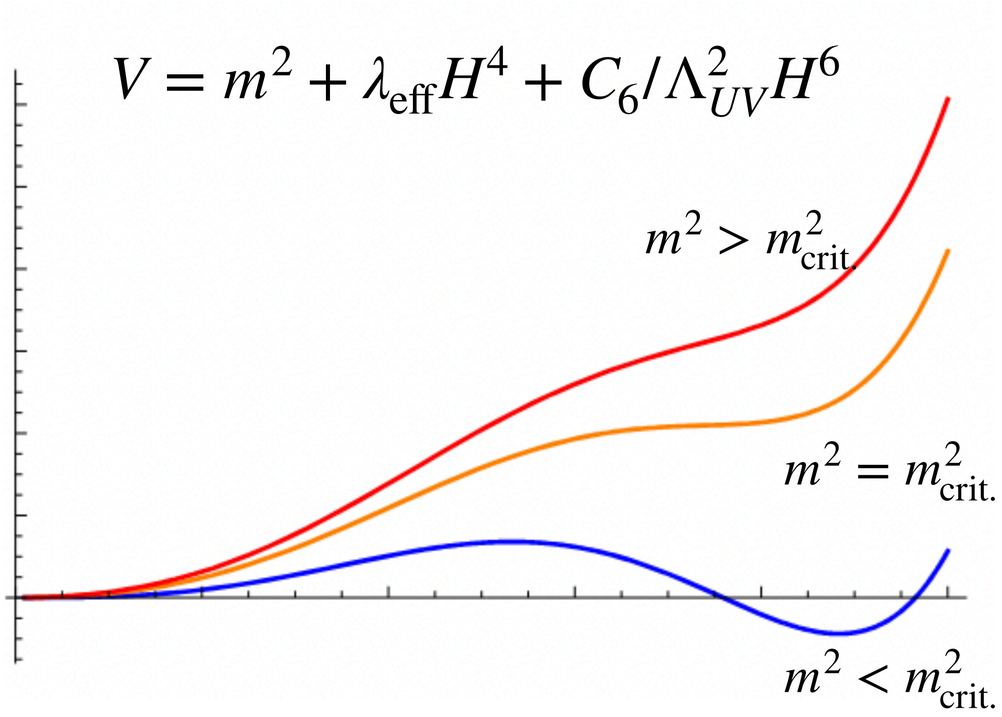


excluded (metastability)

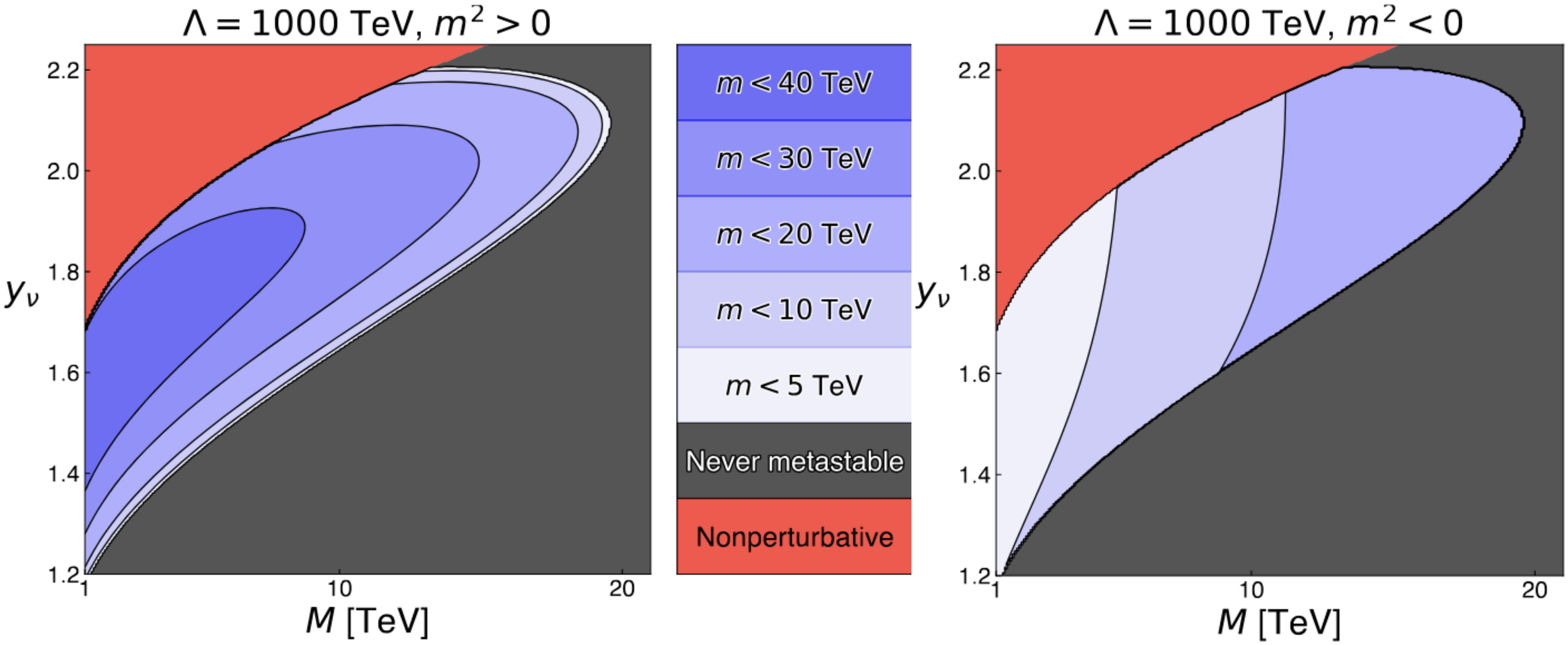
$$m^2 \lesssim |\beta_\lambda(\mu_I)|^2 \Lambda_{\rm UV}^2$$

[2408.10297]

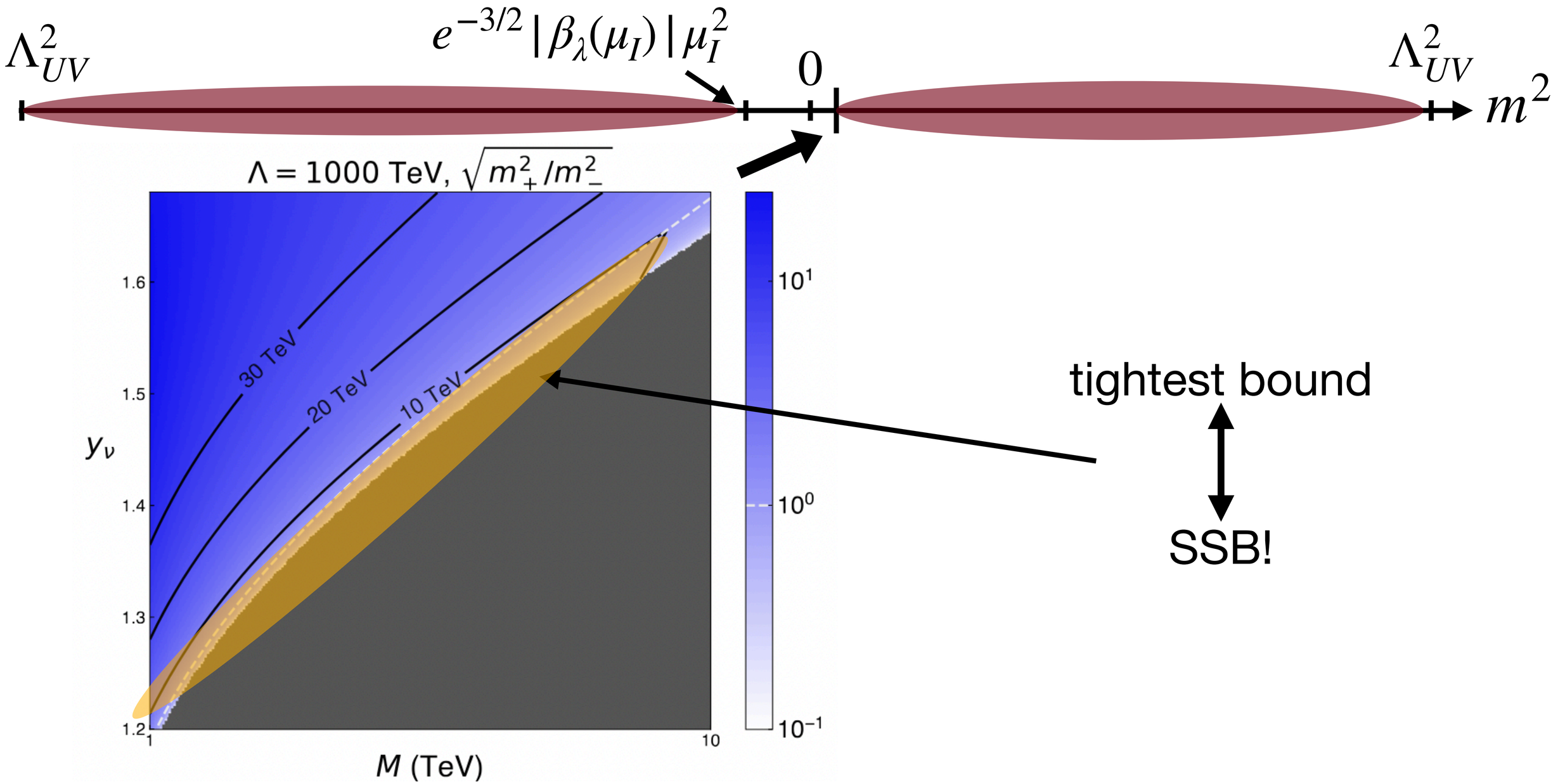
(S. Benevedes, S. Trifinopoulos, TS)



Extended metastability bounds - results



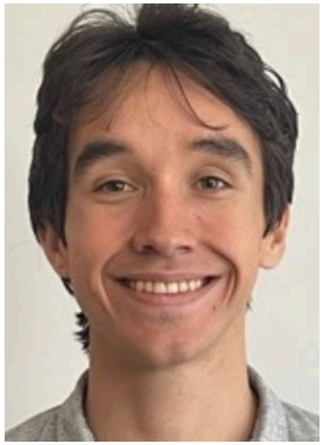
Extended metastability bounds - explaining SSB!

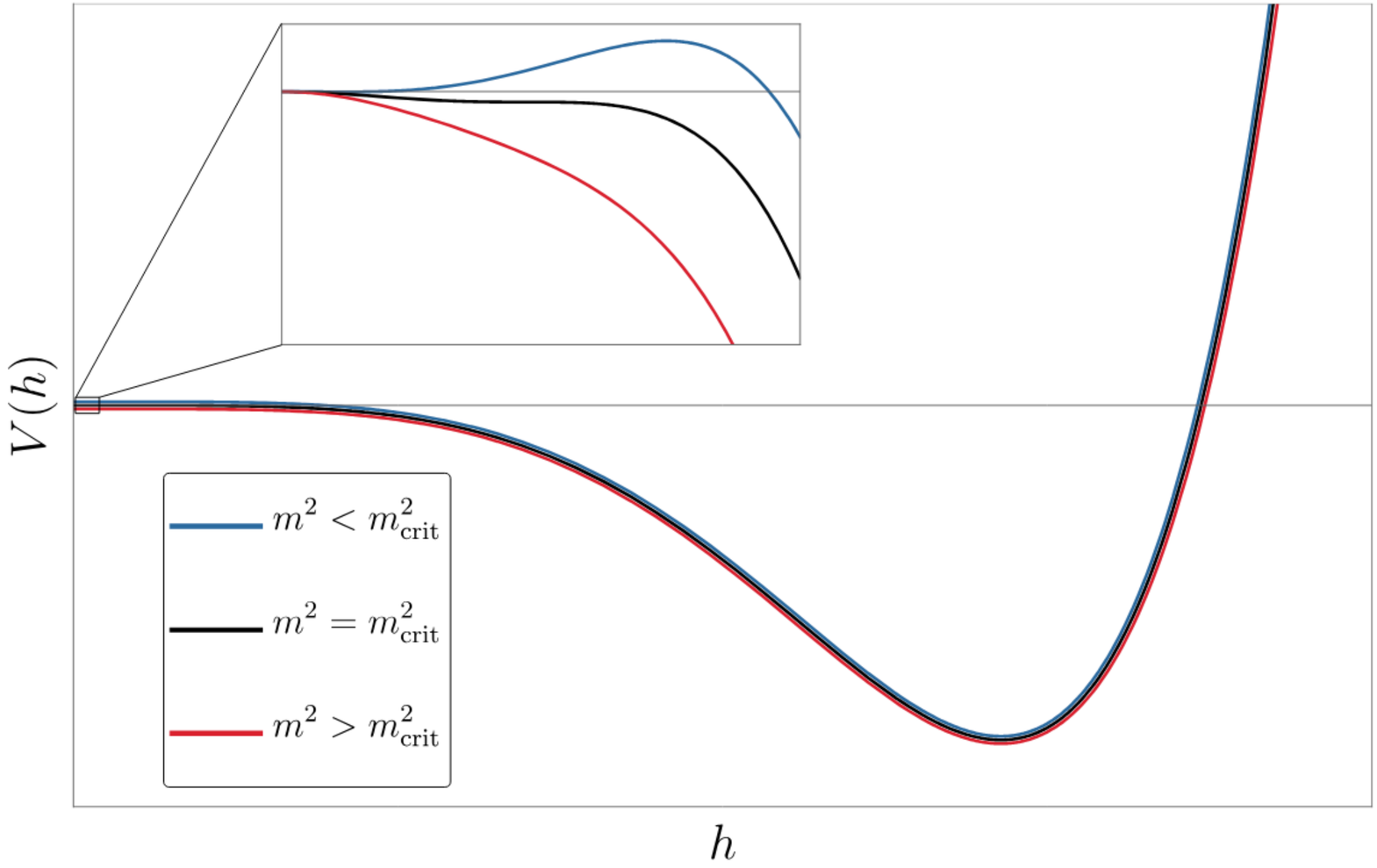


Higgs-driven Crunching

[2502.07876]:
(S. Benevedes, A. Ismail, TS)

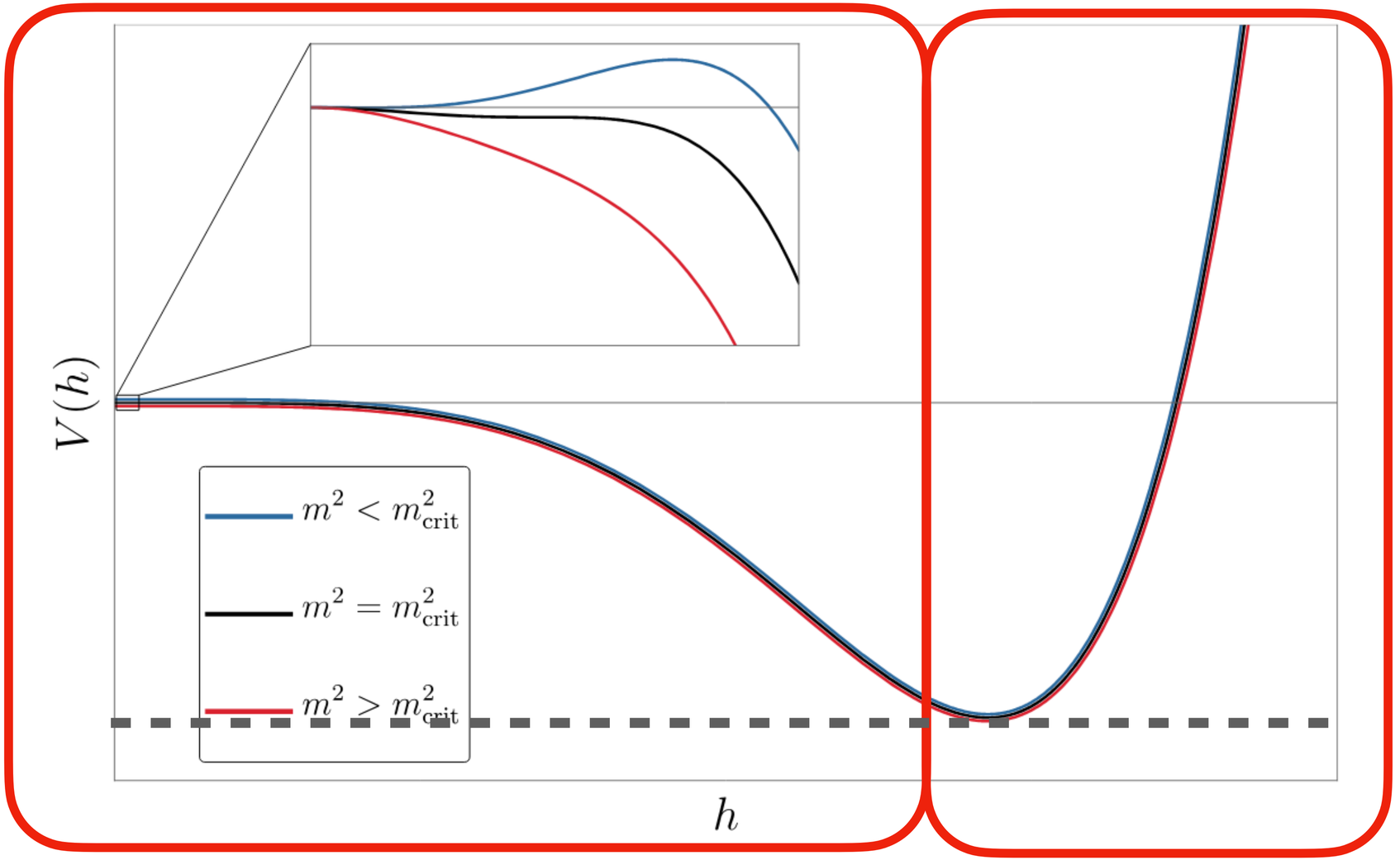
Metastability bound as “trigger”





Higgs-driven Crunching

SM+ fermions

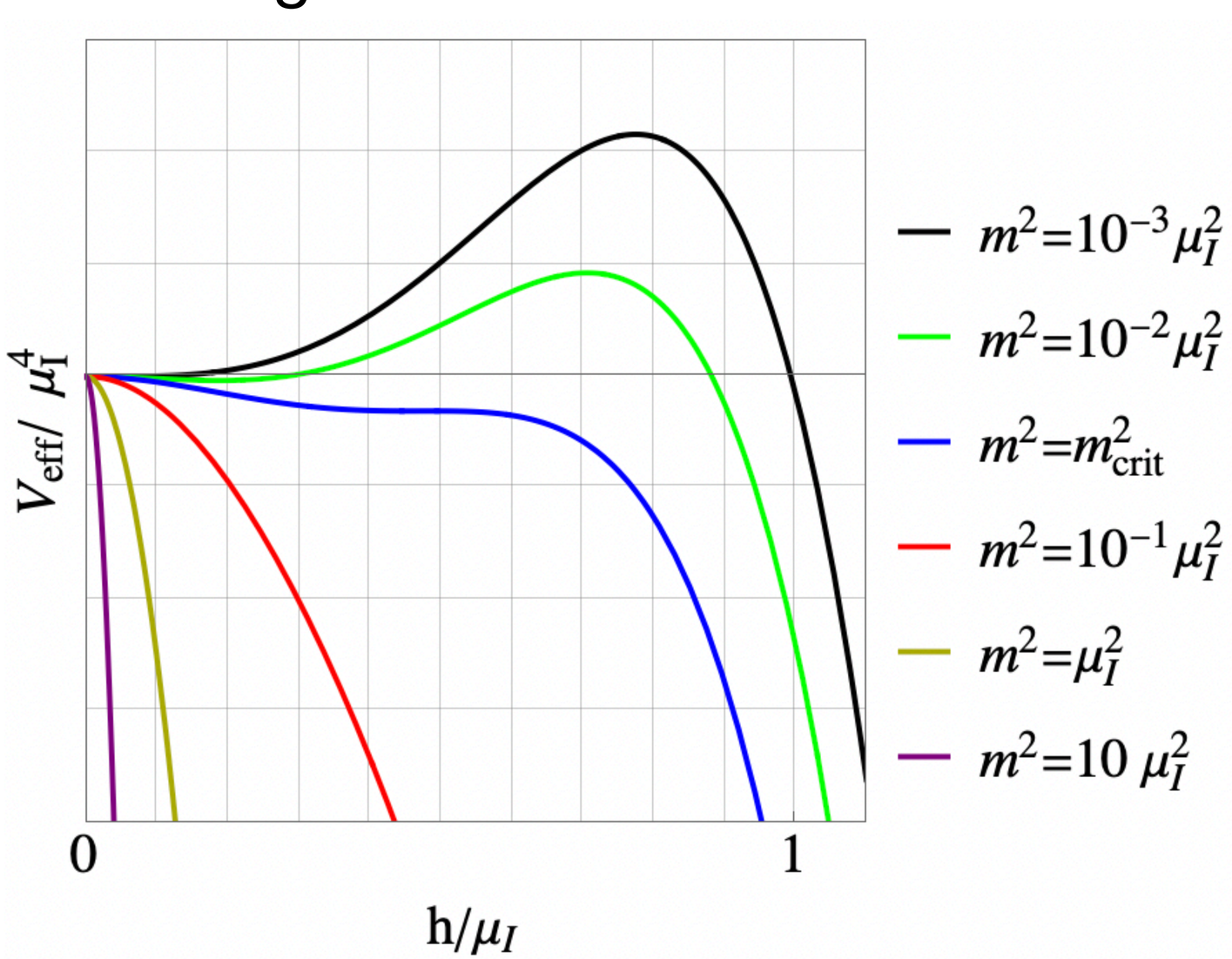


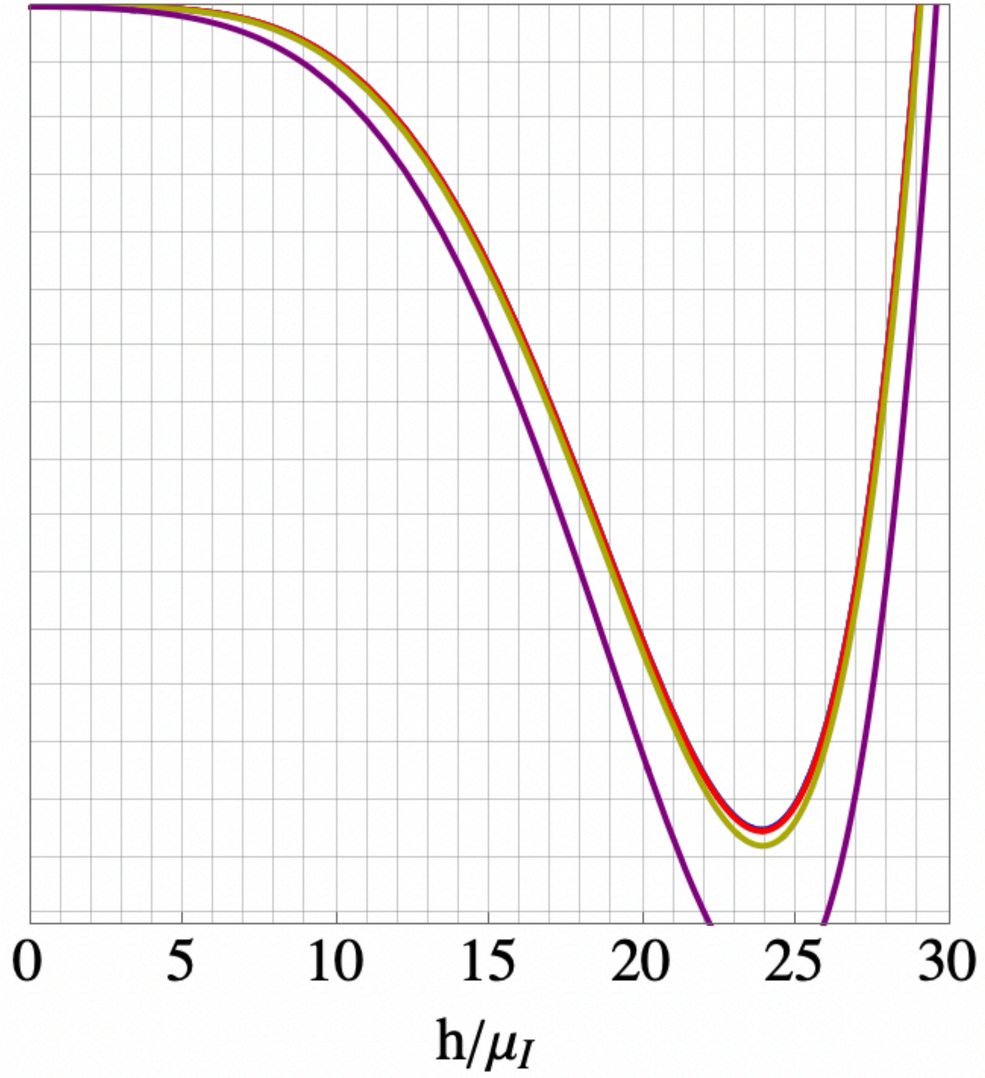
stabilizing new physics

$V_{\rm min} \sim -\Lambda^4_{\rm UV}$

Higgs-driven Crunching

Scanning mass:





Higgs-driven Crunching

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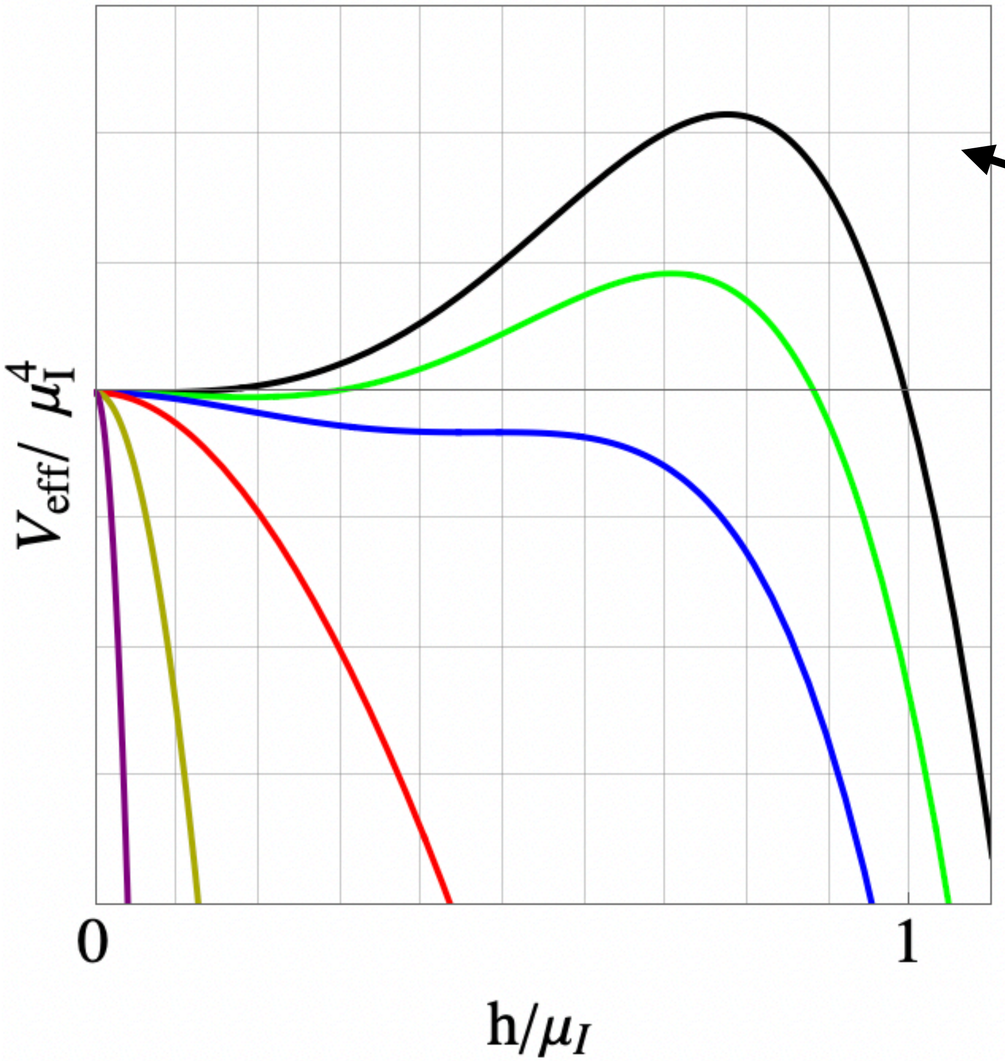
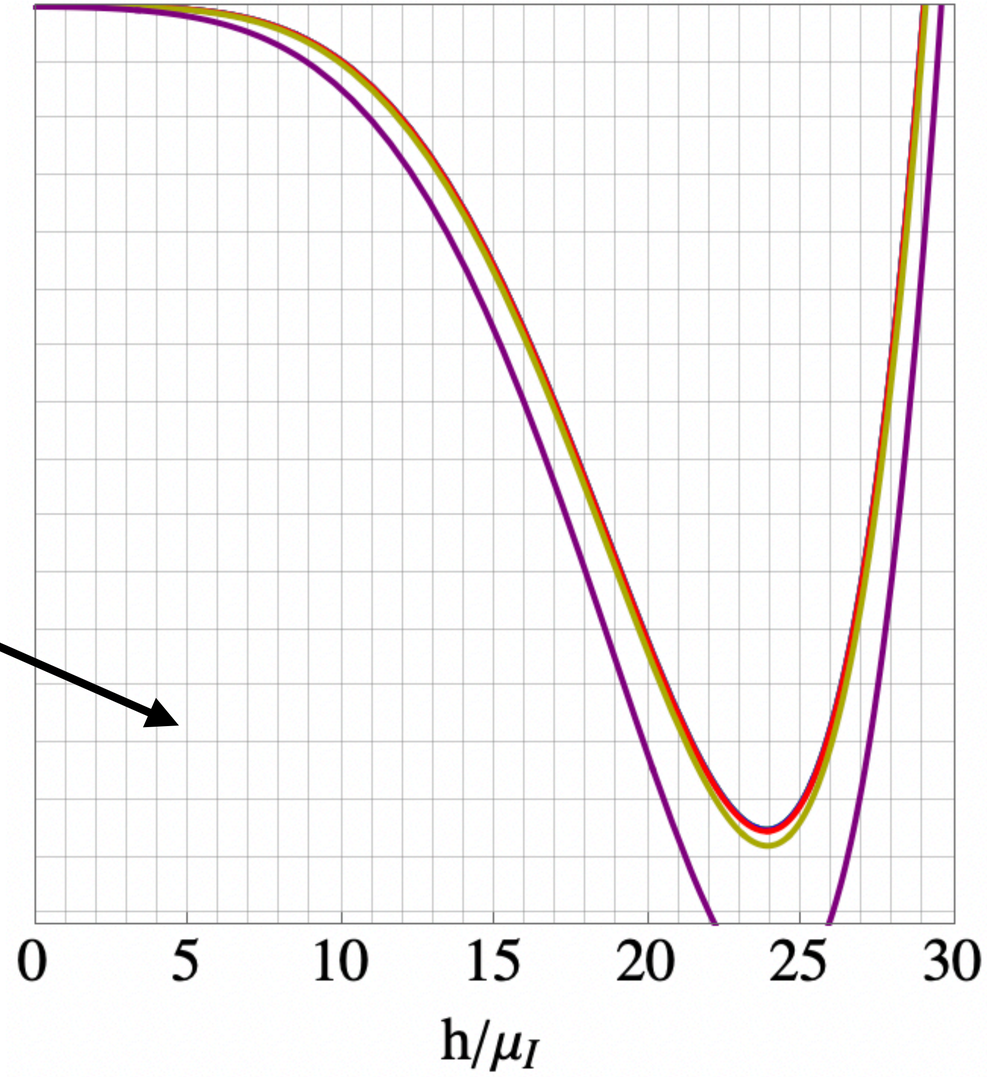


VERY sensitive

NOT VERY sensitive



Higgs-driven Crunching

Range of CC small enough → UV vacuum always crunches

→ only “radiatively generated vacua” feasible if elevated enough

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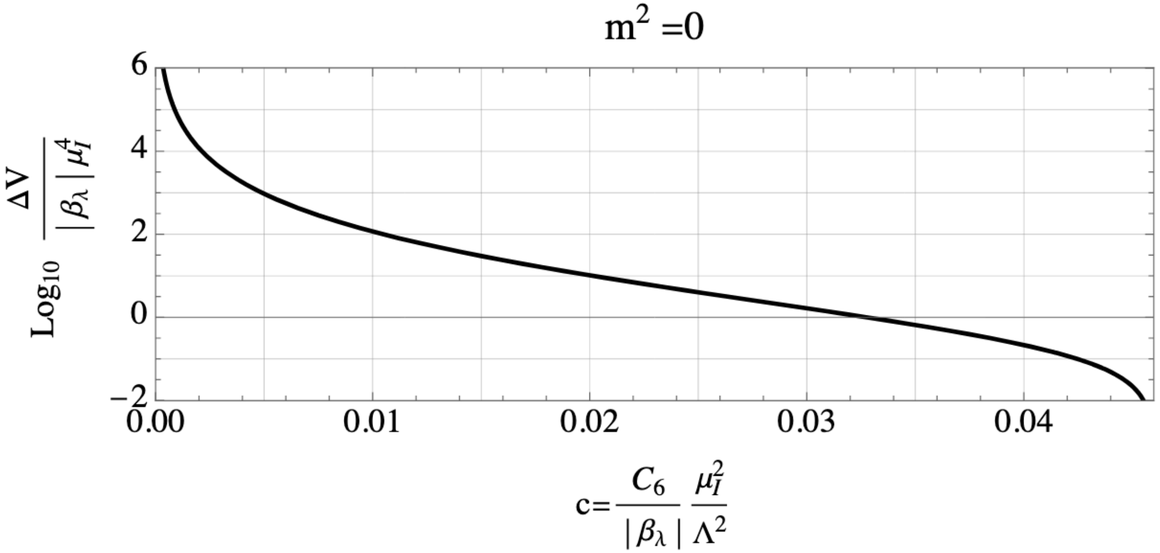
→* only "radiatively generated vacua" feasible if elevated enough

→ $m^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{UV}^2$



*Assuming SSB → from scanning (e.g. sliding naturalness)

Summary

Metastability bound: $m_h^2 \lesssim |\beta_\lambda(\mu_I)|\,\mu_I^2 \ll \Lambda_{UV}^2$

→ testable

→ “decoupling” of phenomenology and scanning details

simple intermediate scale model building

new possibility: solve hierarchy problem “indirectly”

efficient probing of many mechanisms

Thank you for your attention!

tstngssr@mit.edu