Vacuum Stability in the Standard Model and Beyond

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in collabortation with
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[arXiv 2401.08811]

Asymptotic Safety meets Particle Physics and Friends
DESY Hamburg,
December 19th 2024

Motivation

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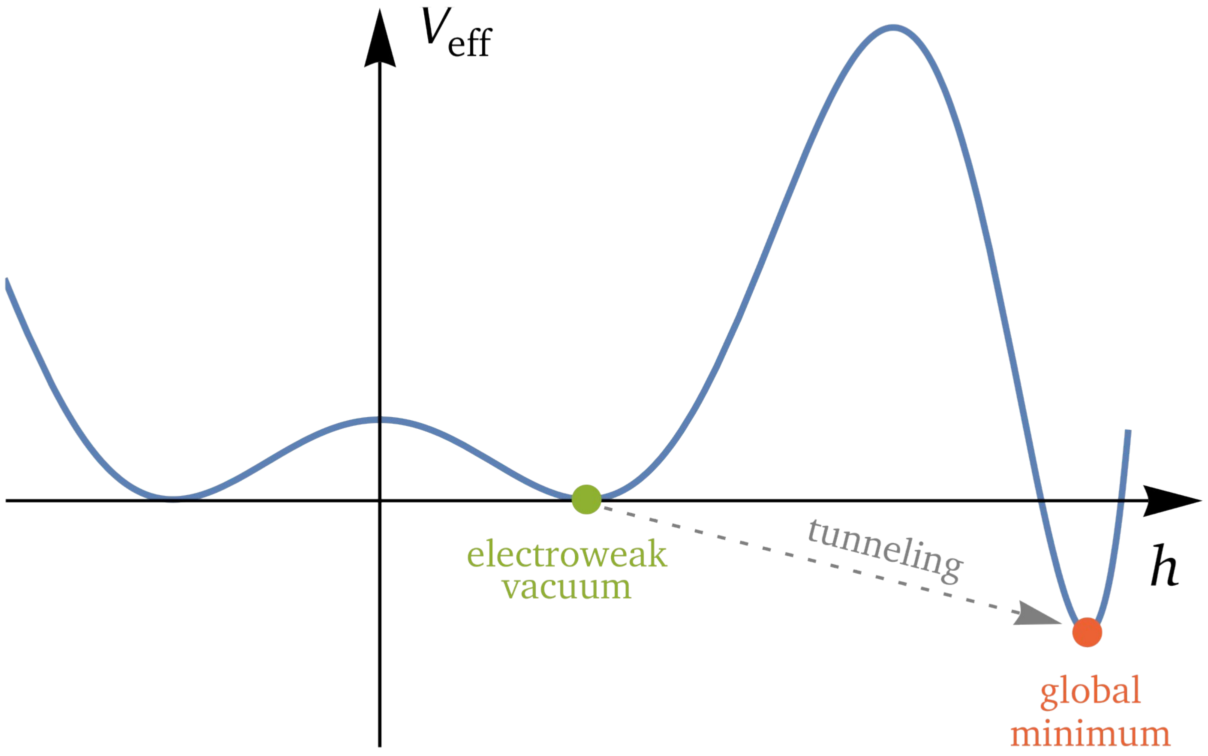

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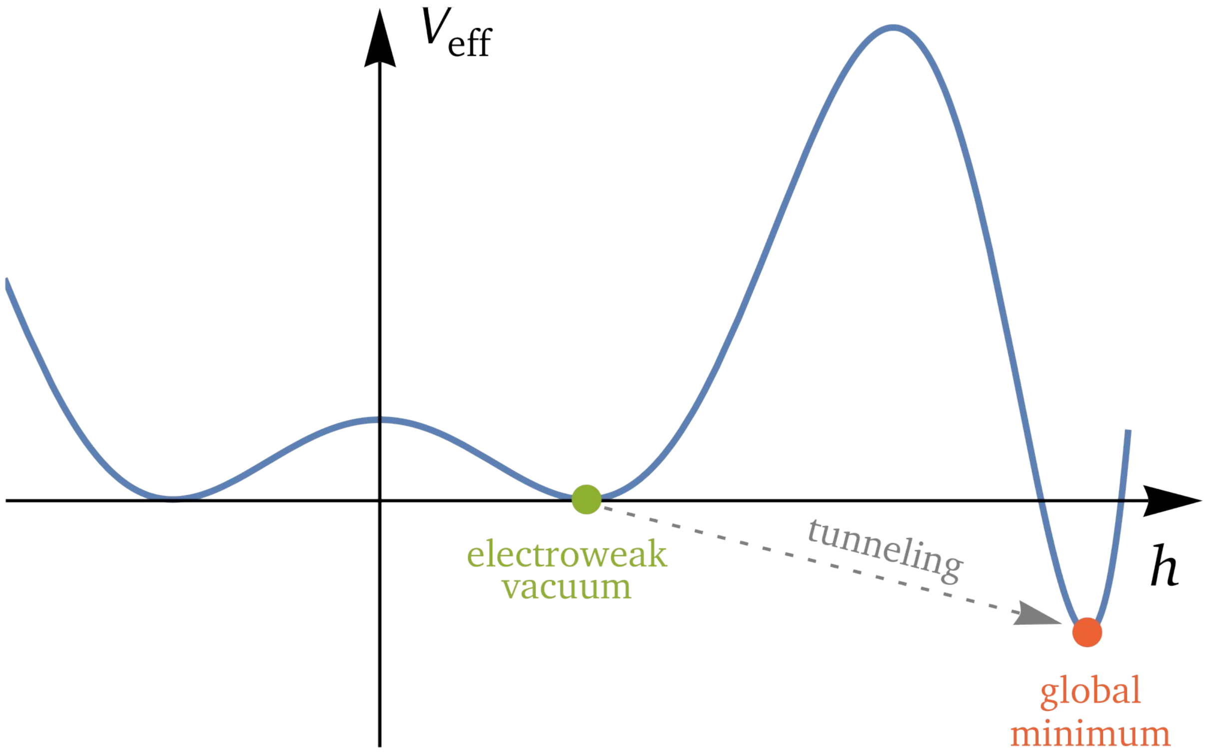

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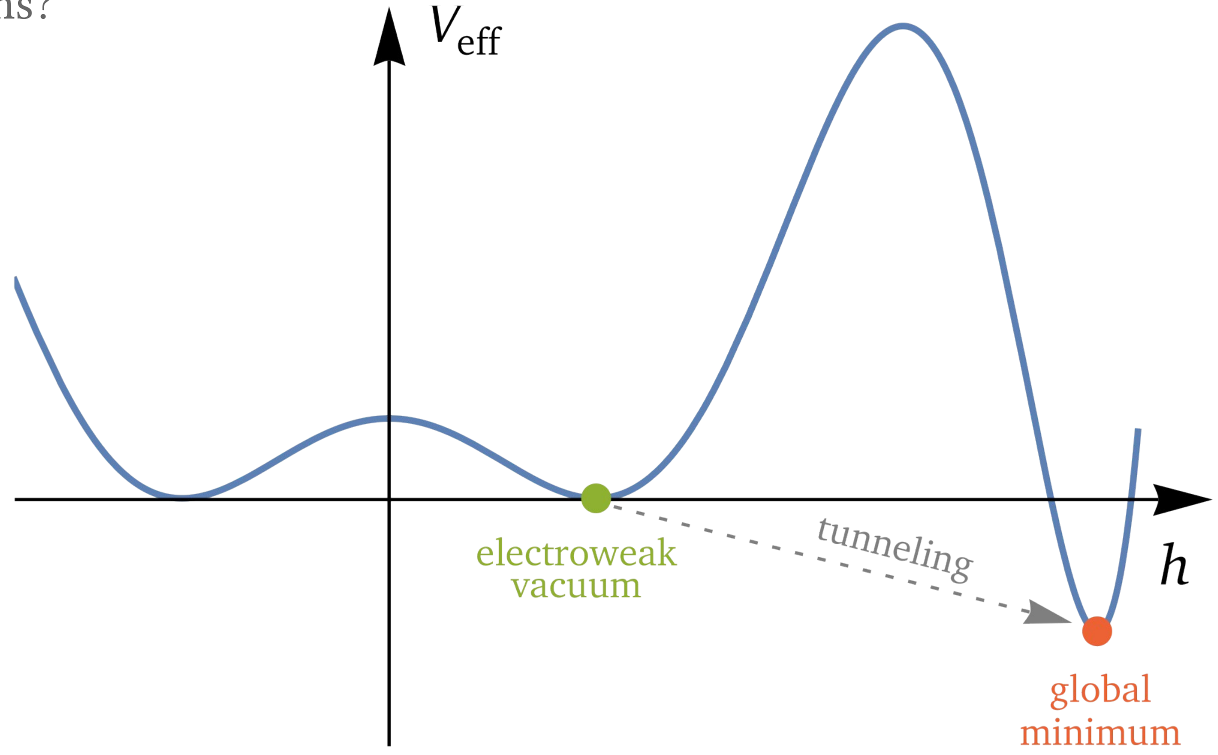

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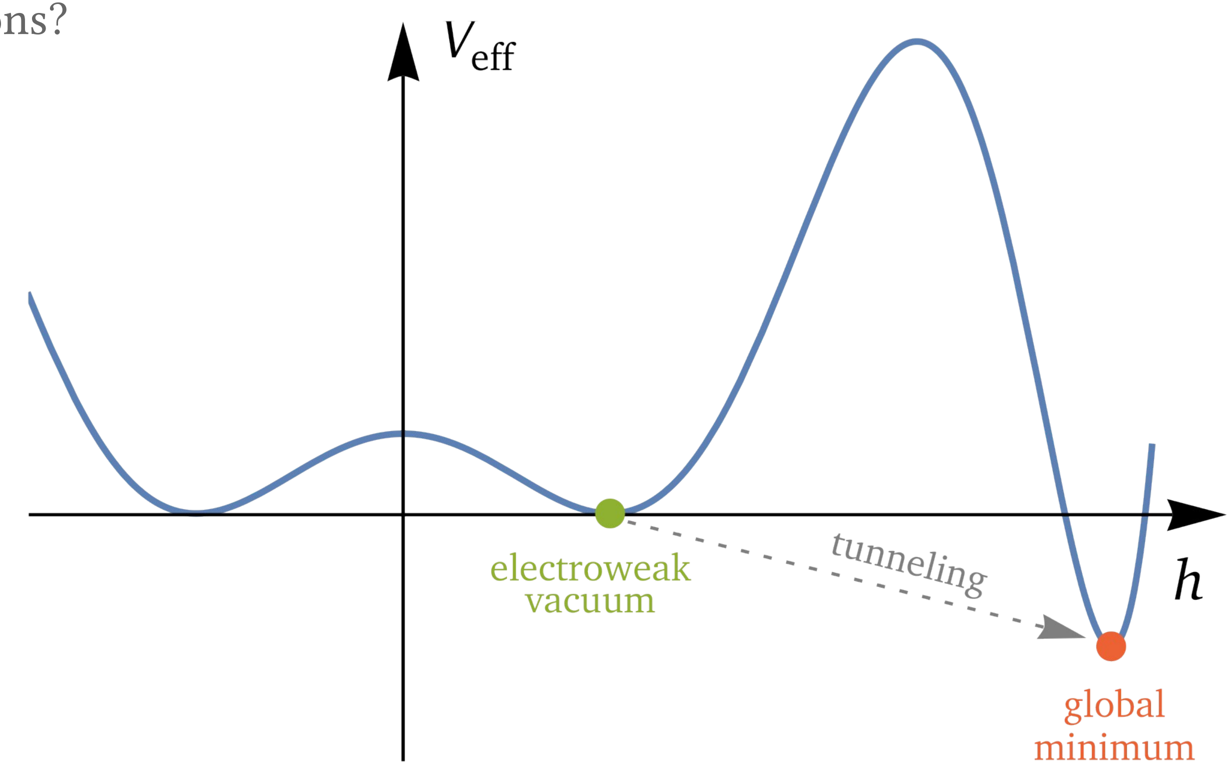

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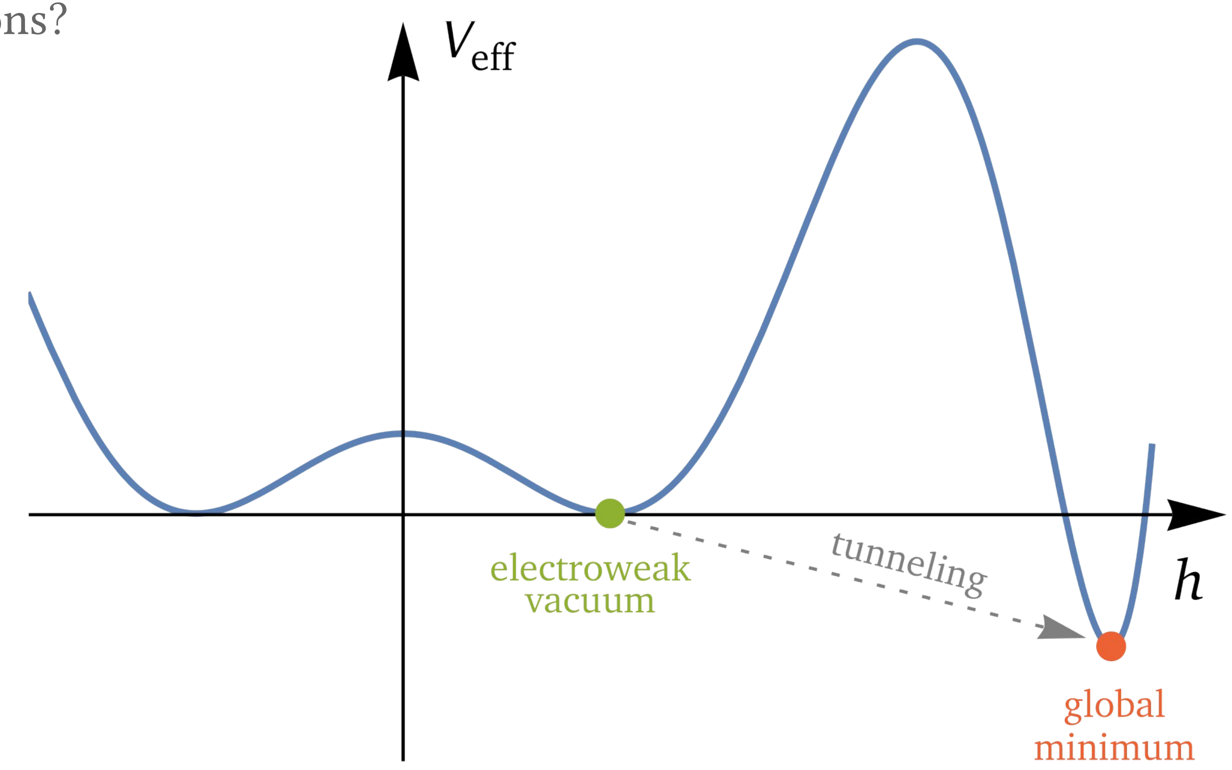

Outline

» Stability in the SM – An update
» BSM solutions

How to compute vacuum stability

1. Observables

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   - Top mass M_t
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PDG 2024

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at least 2L + 3L QCD [Martin, Patel, 2018]

$\longrightarrow$ running couplings at a referce scale $\alpha_x(\mu_{\mathrm{ref}})$

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   only interested in absolute stability

Effective Potential

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$\longrightarrow$ completely resum all logs $\ln h/\mu_{\text{ref}}$

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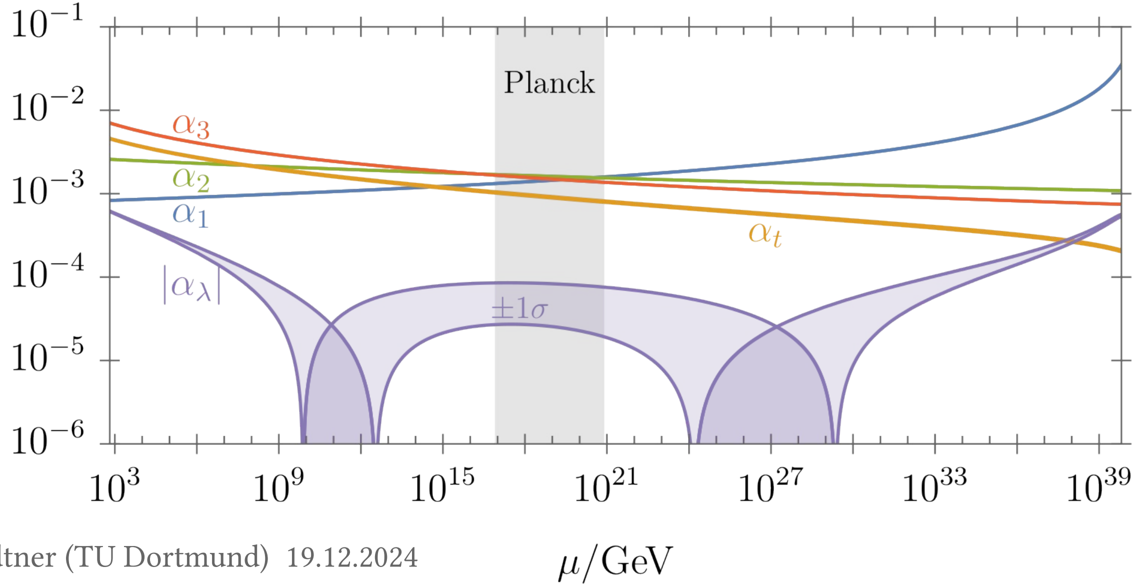

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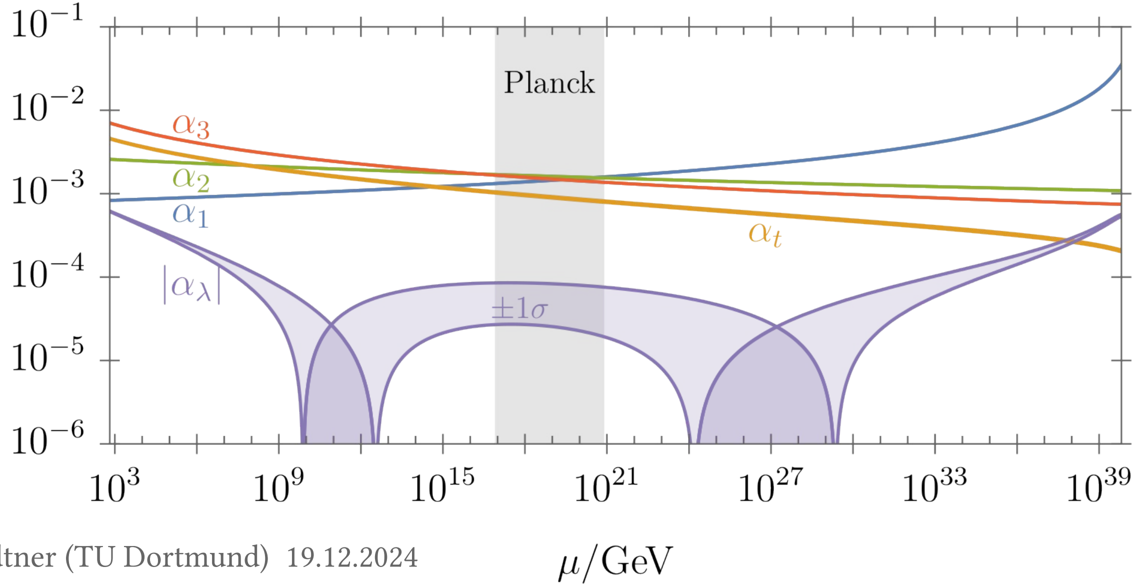

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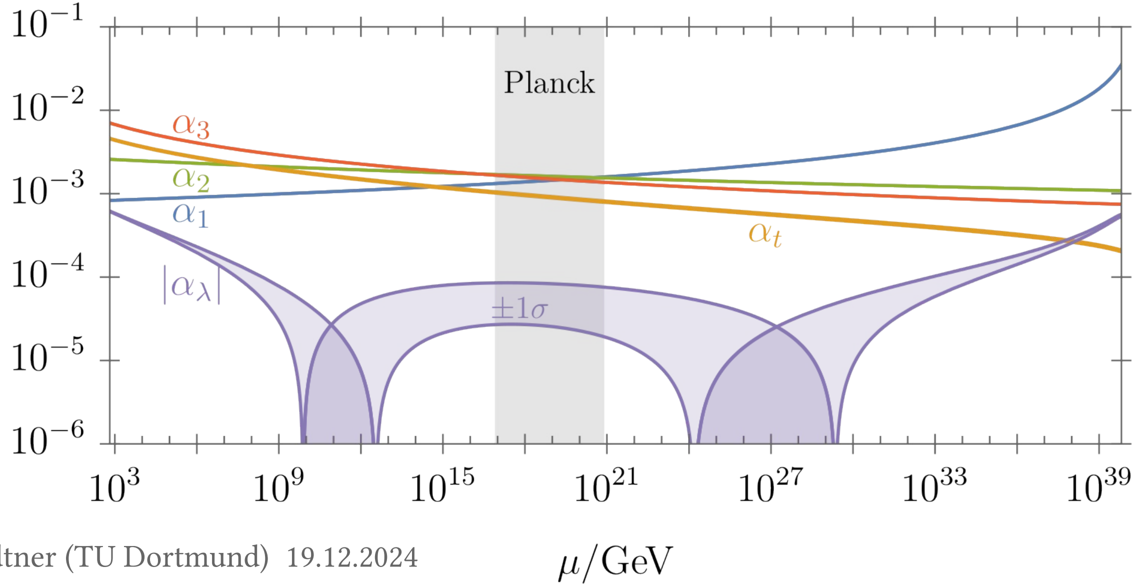

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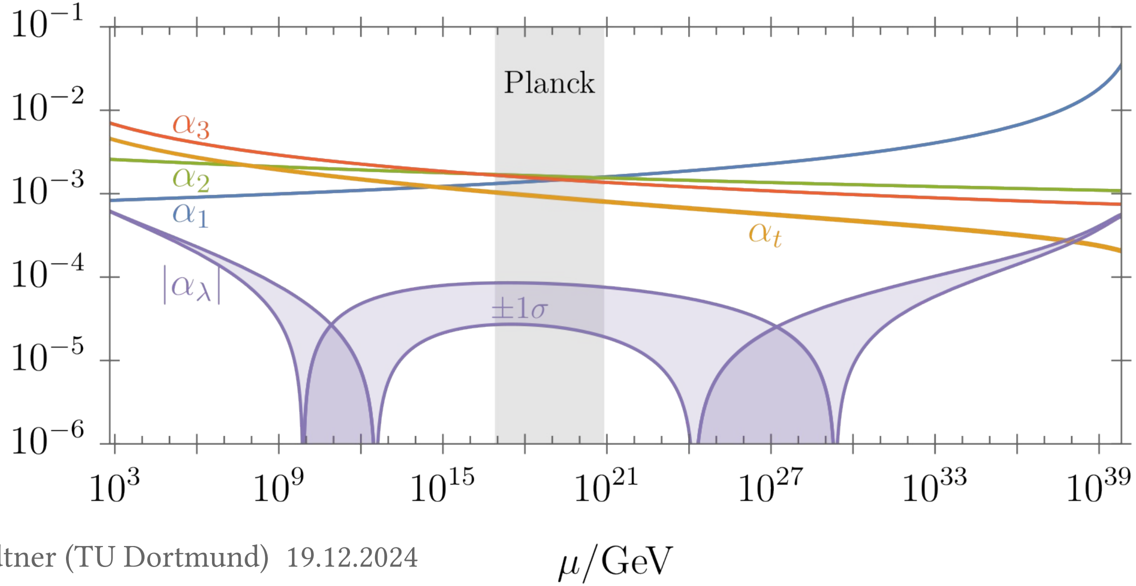

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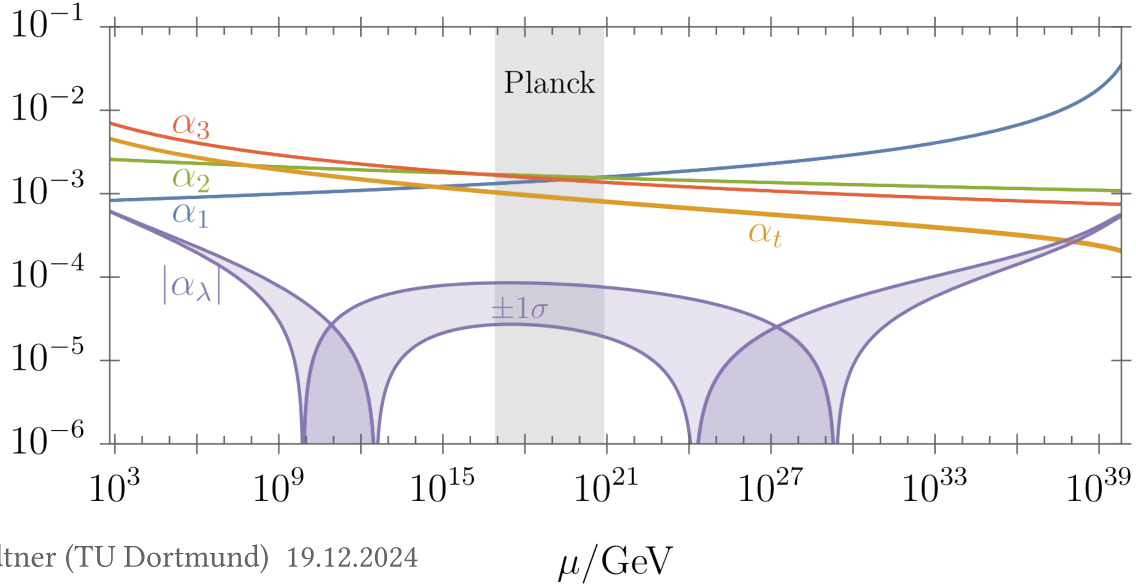

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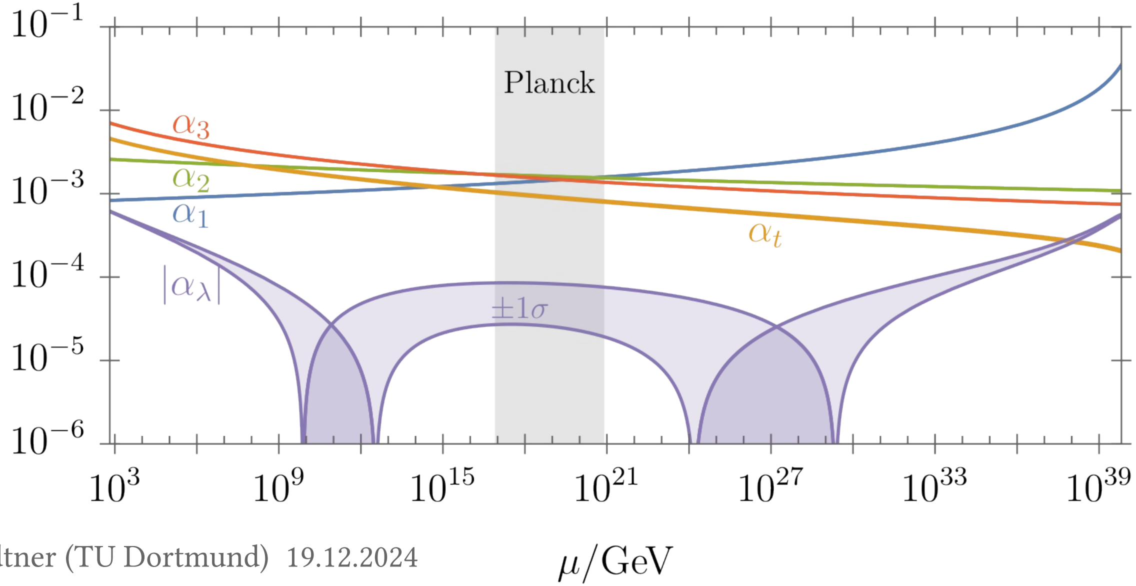

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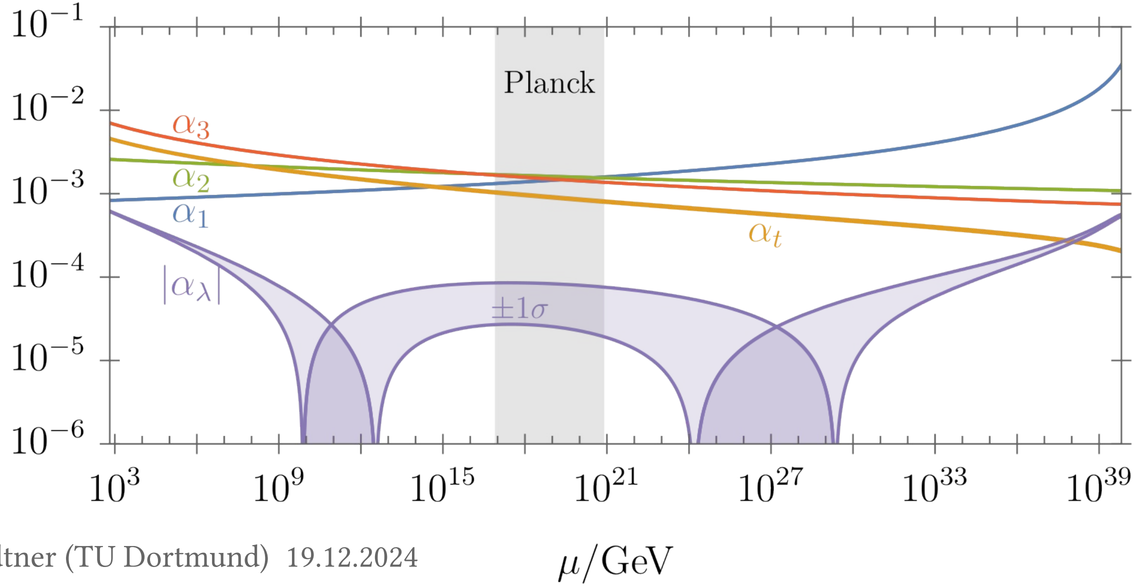

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pole mass: non-perturbative effects $\pm\Lambda_{\rm QCD}$

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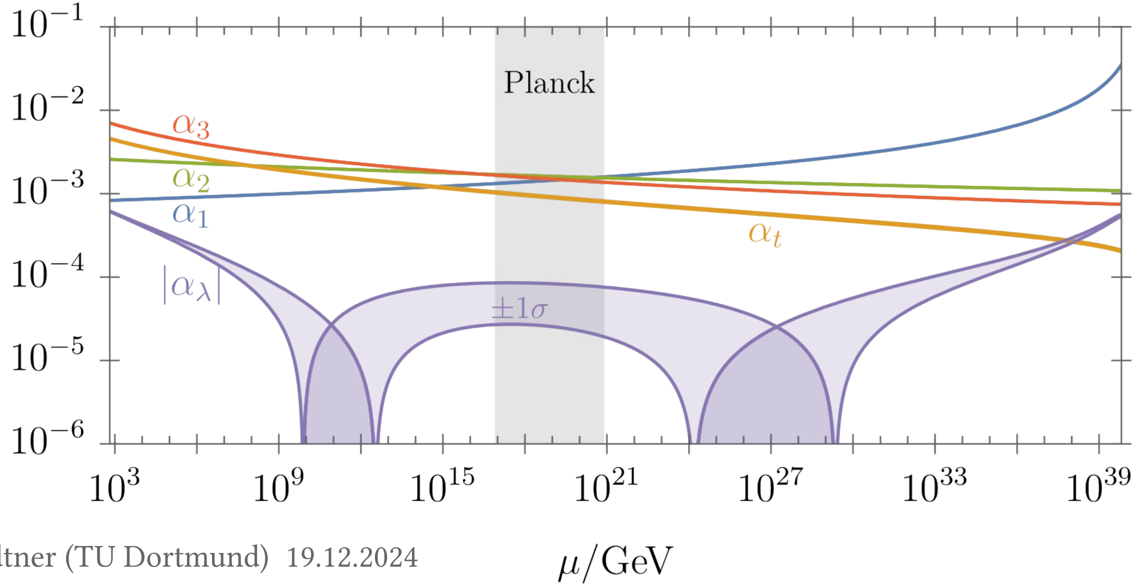

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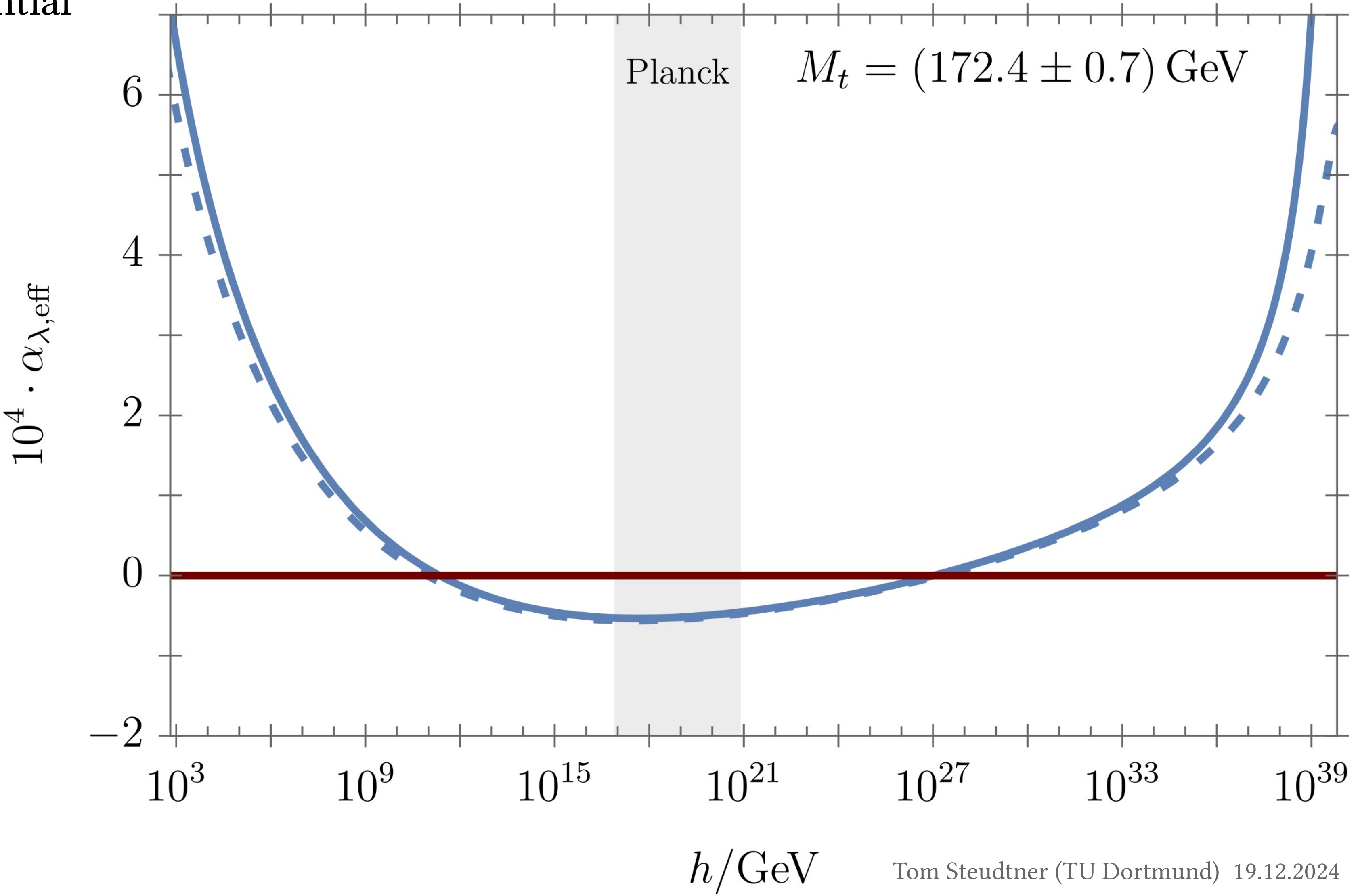

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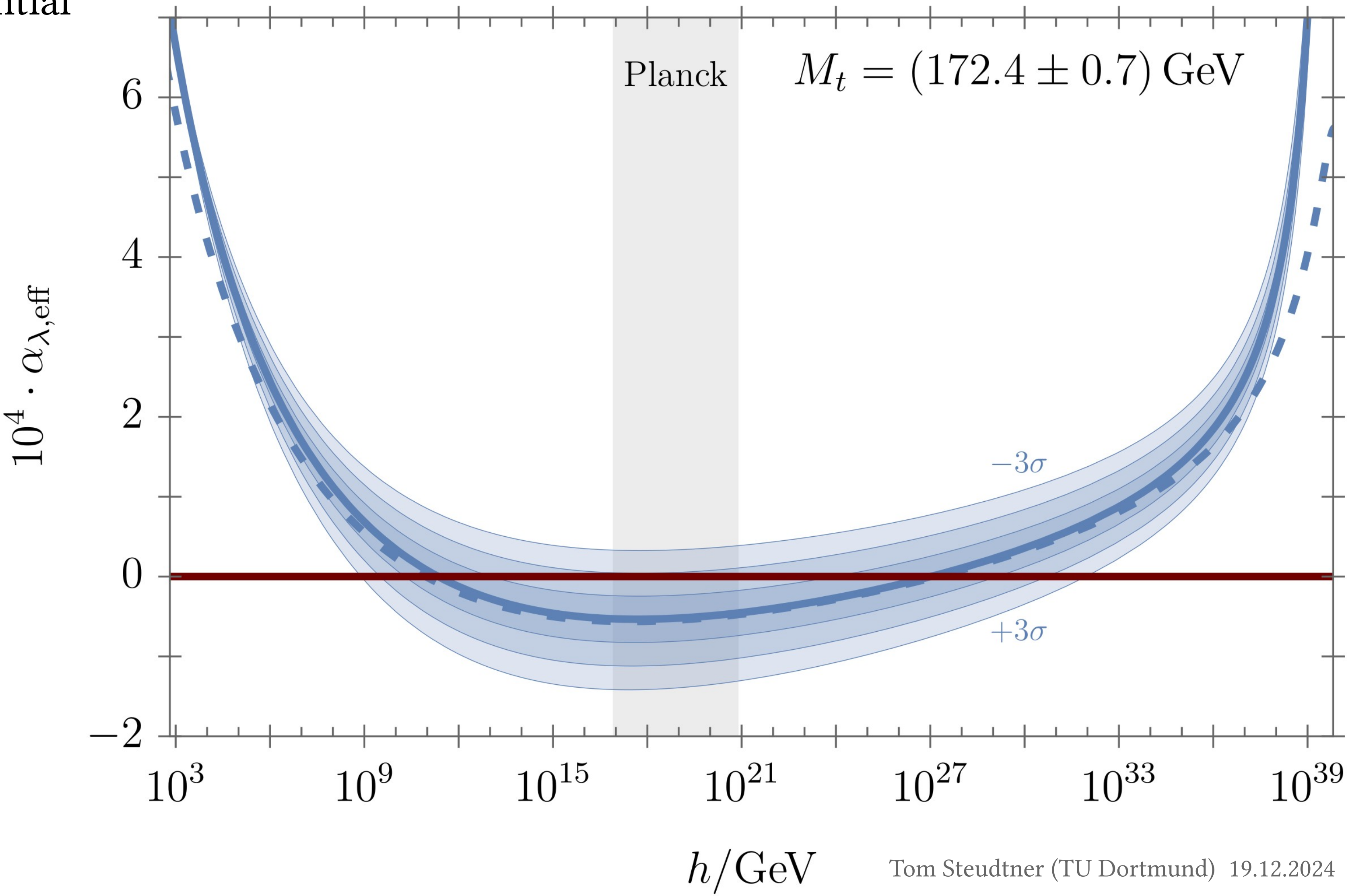
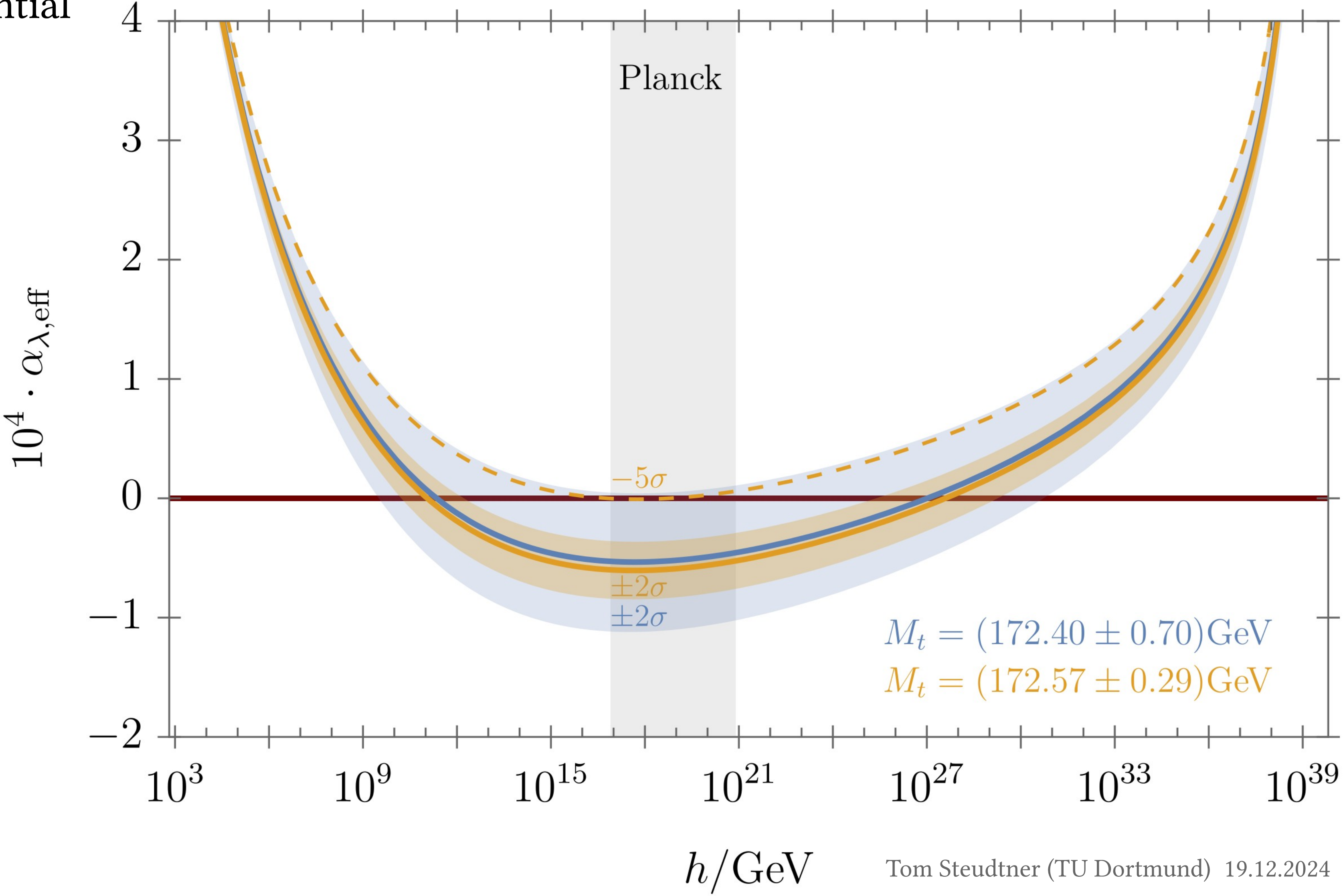
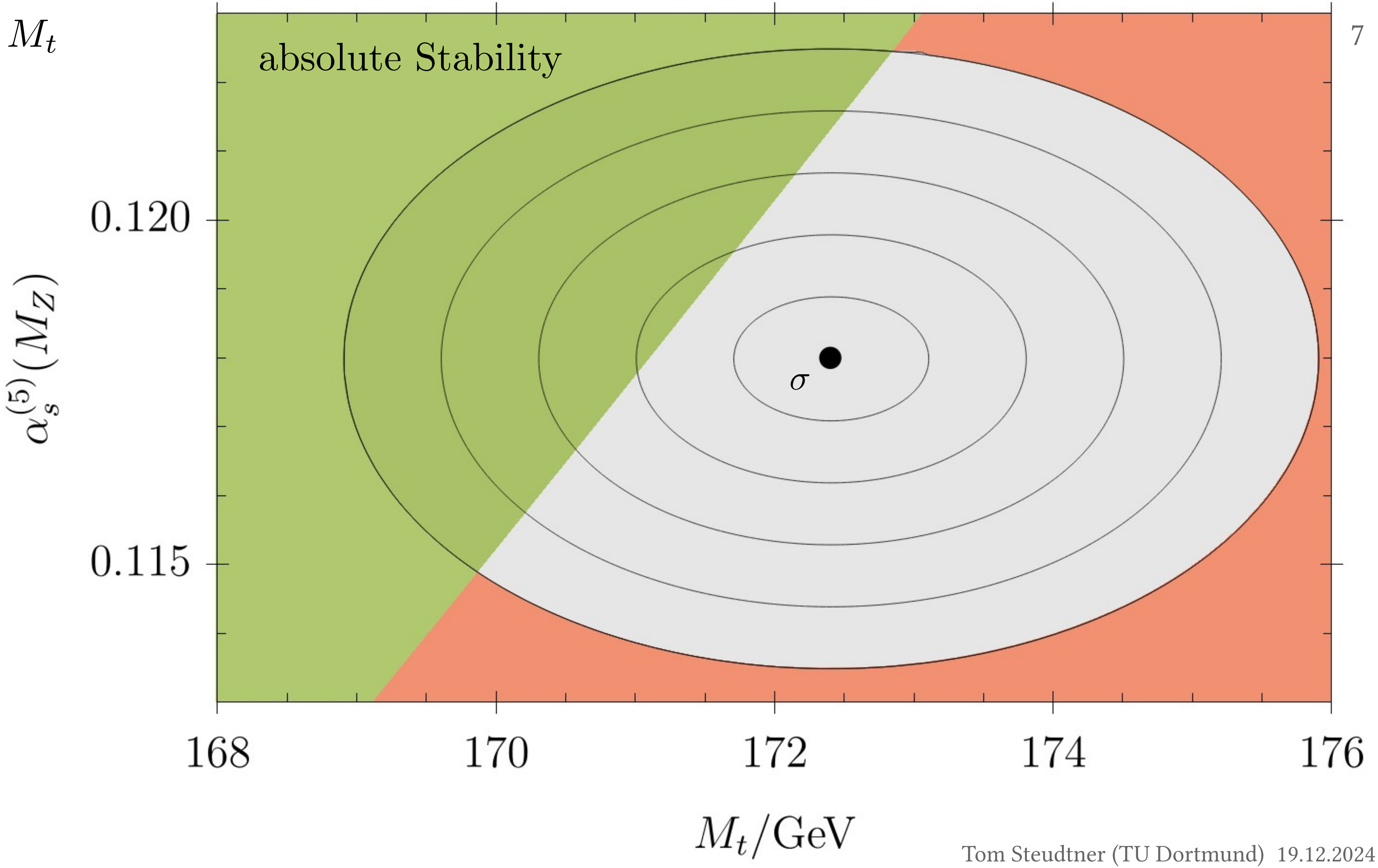
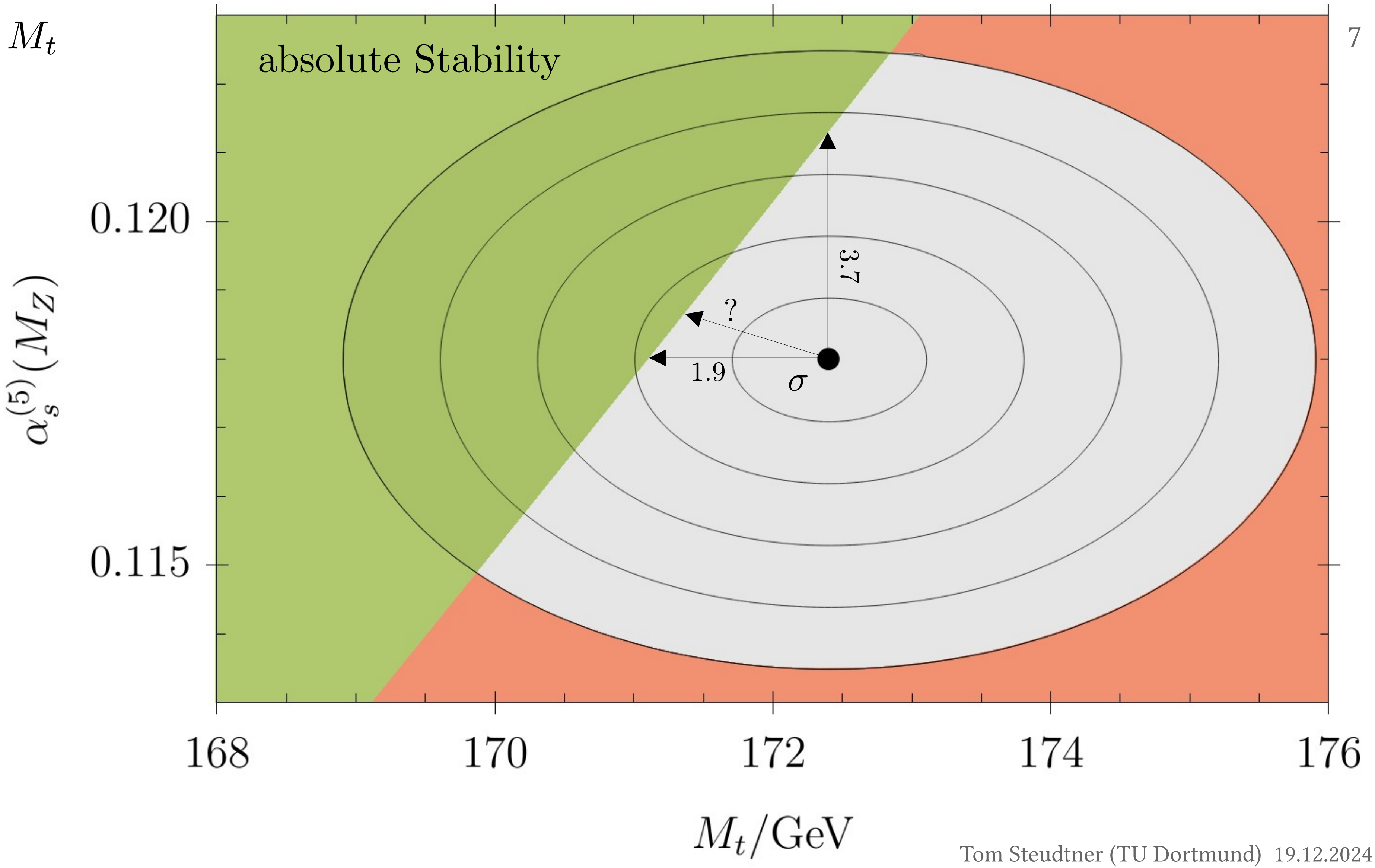


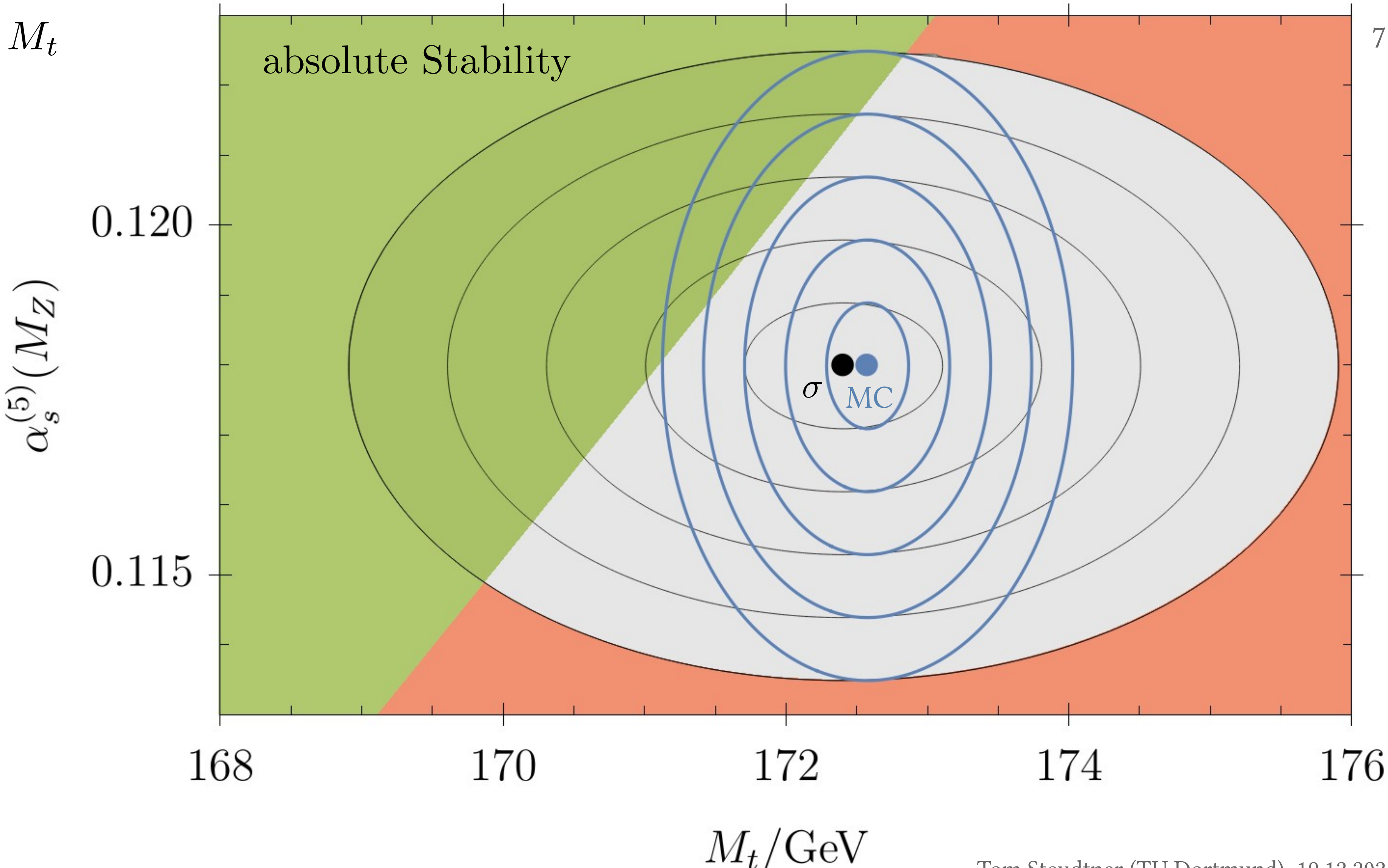
Effective Potential

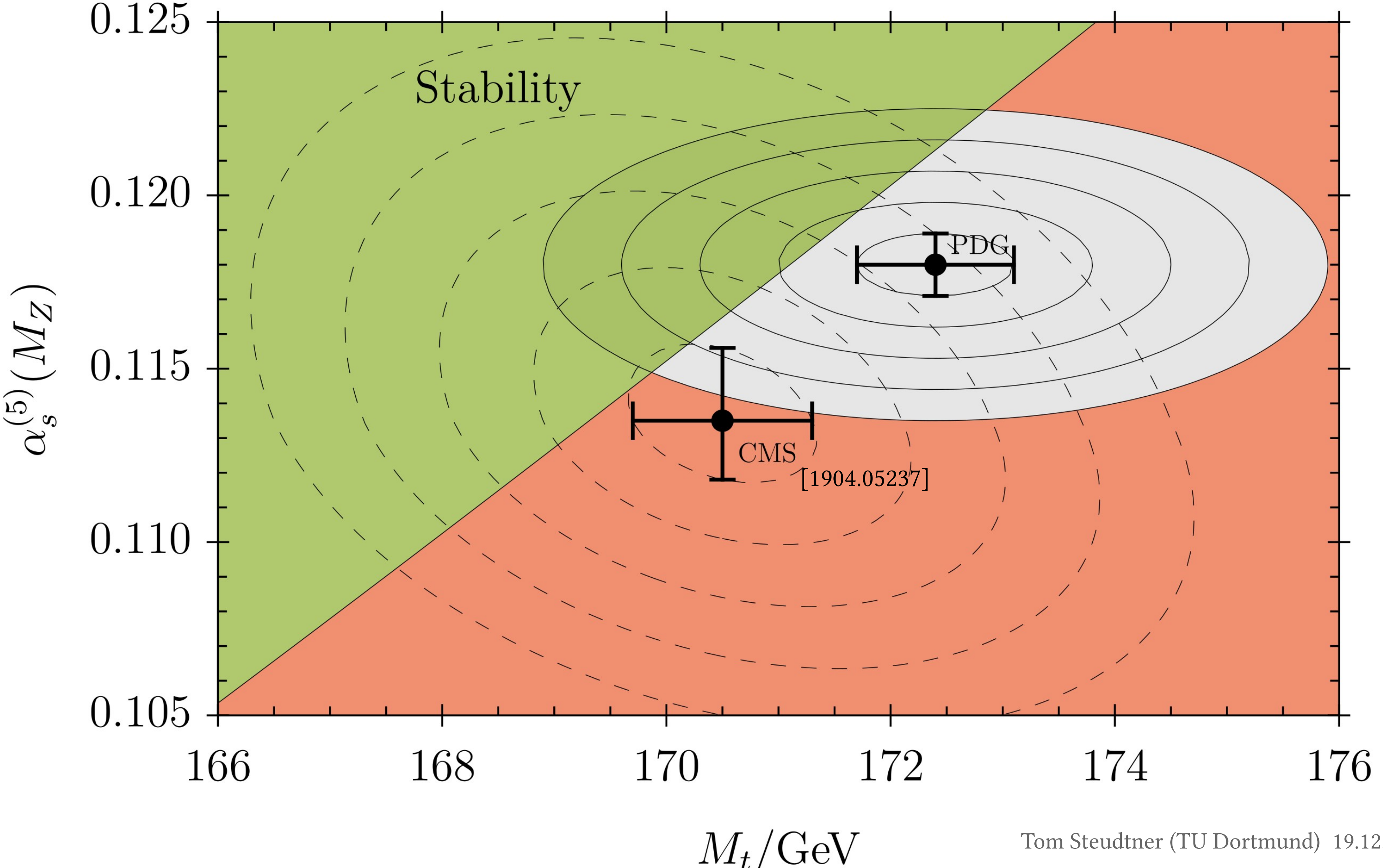



absolute Stability
0.120
0.115
$\alpha_s^{(5)}(M_Z)$
σ
168
170
172
174
176
M_t/GeV


absolute Stability
3.7
?
1.9
σ
0.120
0.115
$\alpha_s^{(5)}(M_Z)$
168
170
172
174
176
M_t/GeV

α_s vs. M_t

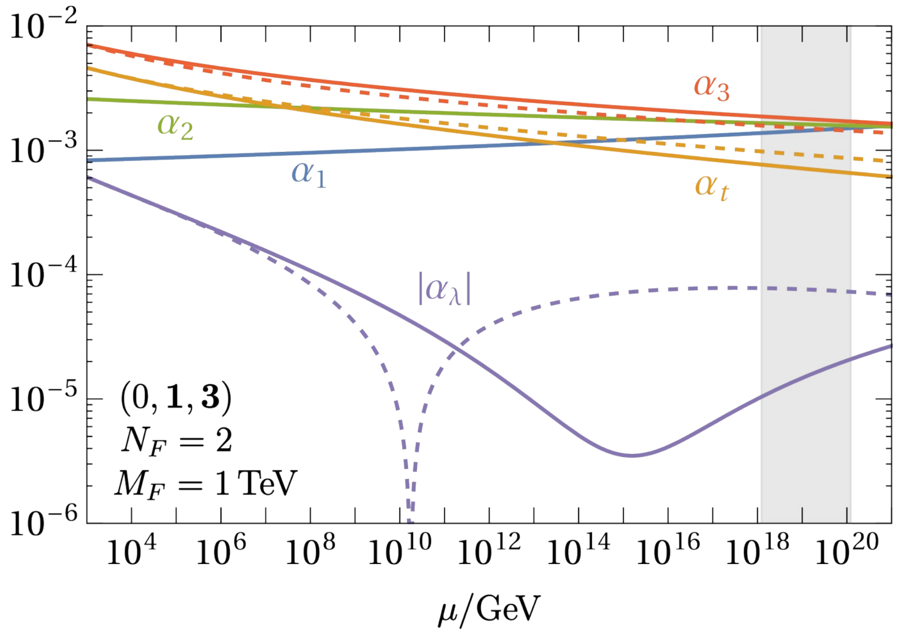

absolute Stability
0.120
0.115
$\alpha_s^{(5)}(M_Z)$
σ
MC
168
170
172
174
176
M_t/GeV


Stability
PDG
CMS
[1904.05237]
0.125
0.120
0.115
0.110
0.105
$\alpha_s^{(5)}(M_Z)$
166
168
170
172
174
176
M_t/GeV

Stability via BSM?

Stability via BSM?

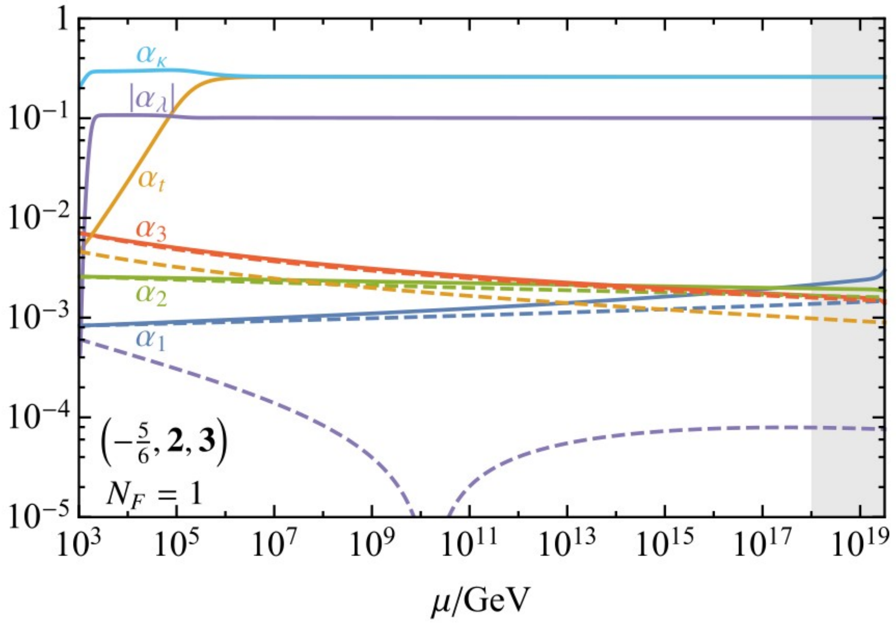
» Gauge Portal – adding new charged fermions
[Hiller, Höhne, Litim, TS 2022]



Stability via BSM?

» Gauge Portal – adding new charged fermions
[Hiller, Höhne, Litim, TS 2022]

» Yukawa Portal – sizable new Yukawa interactions
[Hiller, Höhne, Litim, TS 2022]



Stability via BSM?

- » Gauge Portal – adding new charged fermions
  [Hiller, Höhne, Litim, TS 2022]

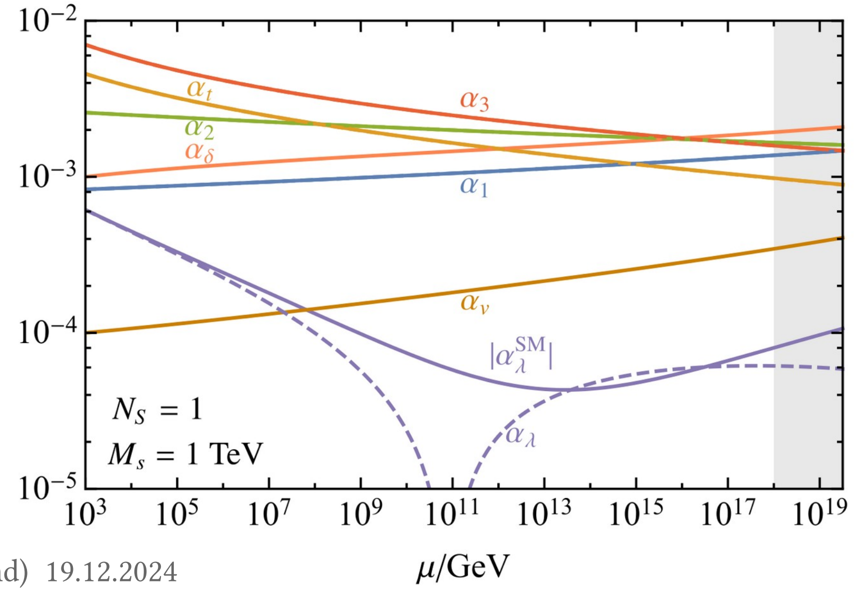
- » Yukawa Portal – sizable new Yukawa interactions
  [Hiller, Höhne, Litim, TS 2022]

- » Scalar Portal
  [Hiller, Höhne, Litim, TS 2024]

$$V_{H,S} = \lambda\,(H^\dagger H)^2 + \delta\,(H^\dagger H)(S^T S) + v\,(S^T S)^2$$

Portal coupling

$$\beta_\lambda = \beta_\lambda{}^{\mathrm{SM}} + \mathcal{N}\delta^2$$



Summary

- evidence for metastability of SM persists
- more precision measurements of $\alpha_s^{(5)}(M_Z)$ and M_t necessary to exlude stability at 5σ
- correlation important
- understanding of MC Top mass required
- instability is RG dominated

Summary

» evidence for metastability of SM persists
» more precision measurements of $\alpha_s^{(5)}(M_Z)$ and M_t necessary to exlude stability at 5σ
» correlation important
» understanding of MC Top mass required
» instability is RG dominated

» many BSM approaches to address SM instability
» can be valid until Planck scale
» testable at current and future colliders