Bare Higgs mass & potential at UV cutoff

Kin-ya Oda (Kyoto)

with

Yuta Hamada & Hikaru Kawai (Kyoto)

[arXiv:1210.2358]

※ picture from web

Finally we see Higgs candidate!

Plasmons, Gauge Invariance, and Mass

P. W. Anderson
Bell Telephone Laboratories, Murray Hill, New Jersey
(Received 8 November 1962)

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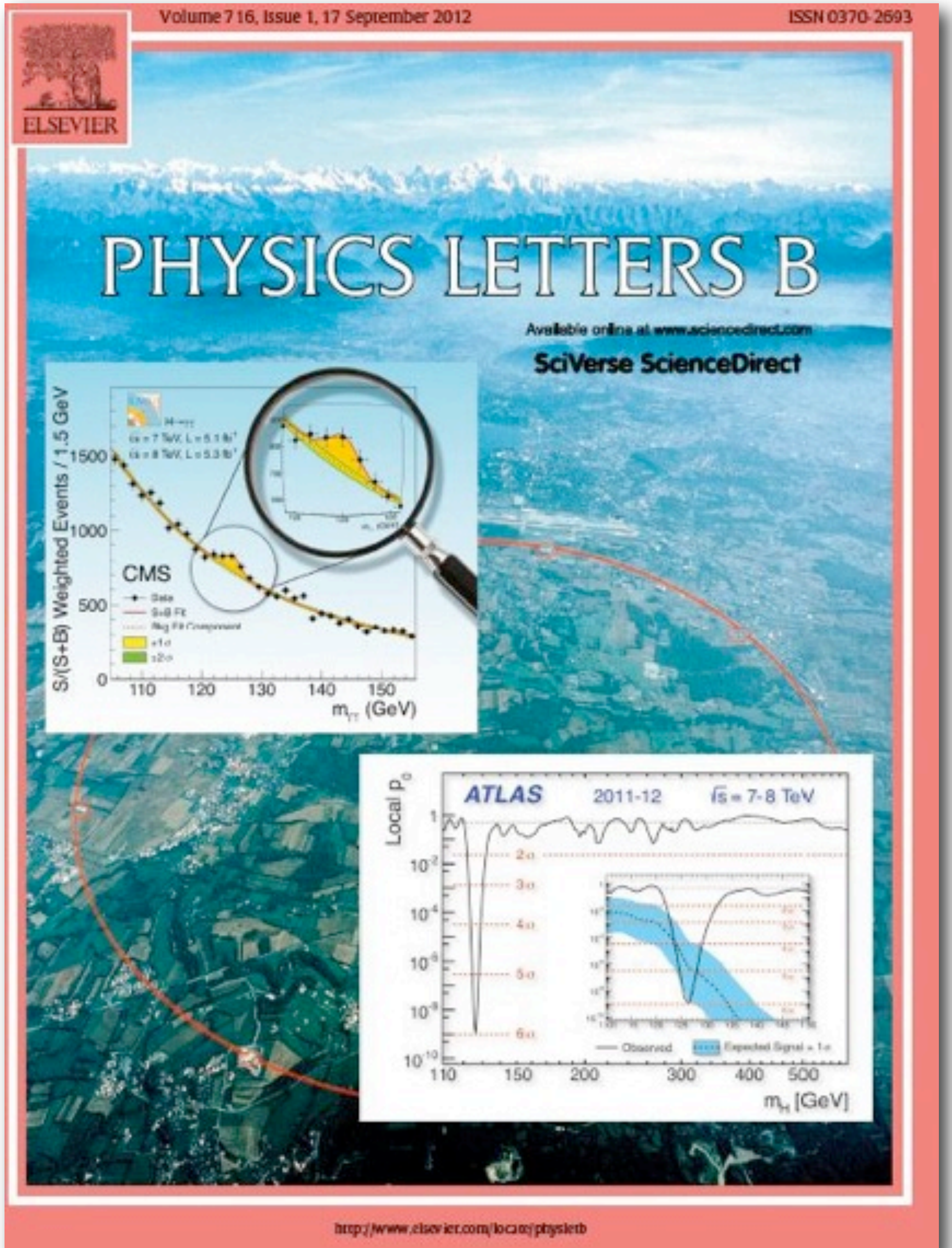
After half century!



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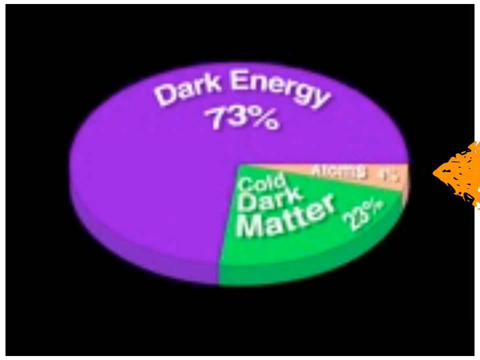
Great!

Then?

Is this end of story?

- We know there MUST be dark matter.
- What else?



SM: this portion only

- Suppose the most pessimistic scenario:
  - ★ We see **<u>only SM Higgs</u>** and nothing more at LHC.
- Can we still say something?
  - ★ Yes! This is the topic today.

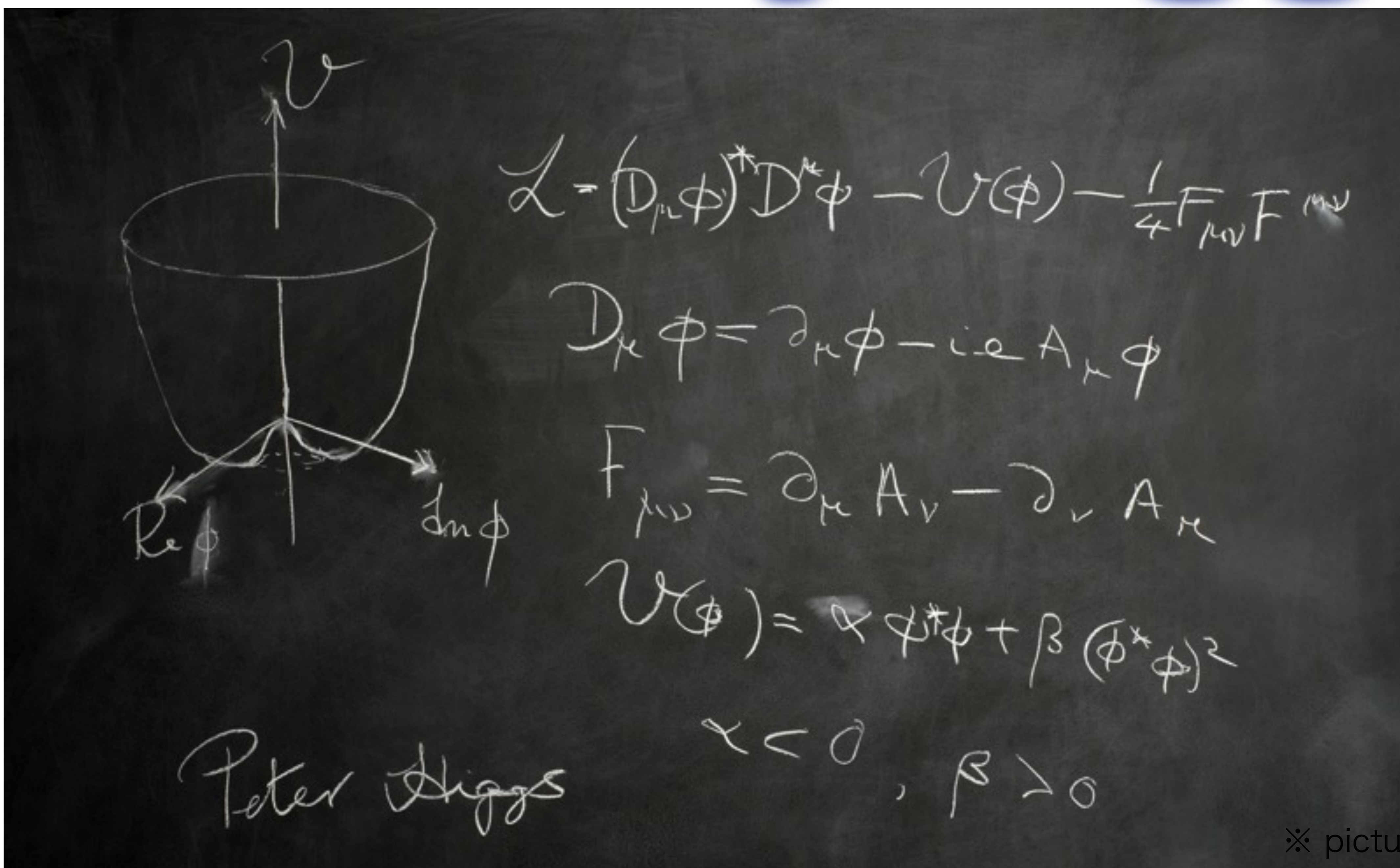
※ figure from web

Claim: Assuming desert, bare Higgs mass and potential are computable and give inputs for Planck scale physics!

Plan

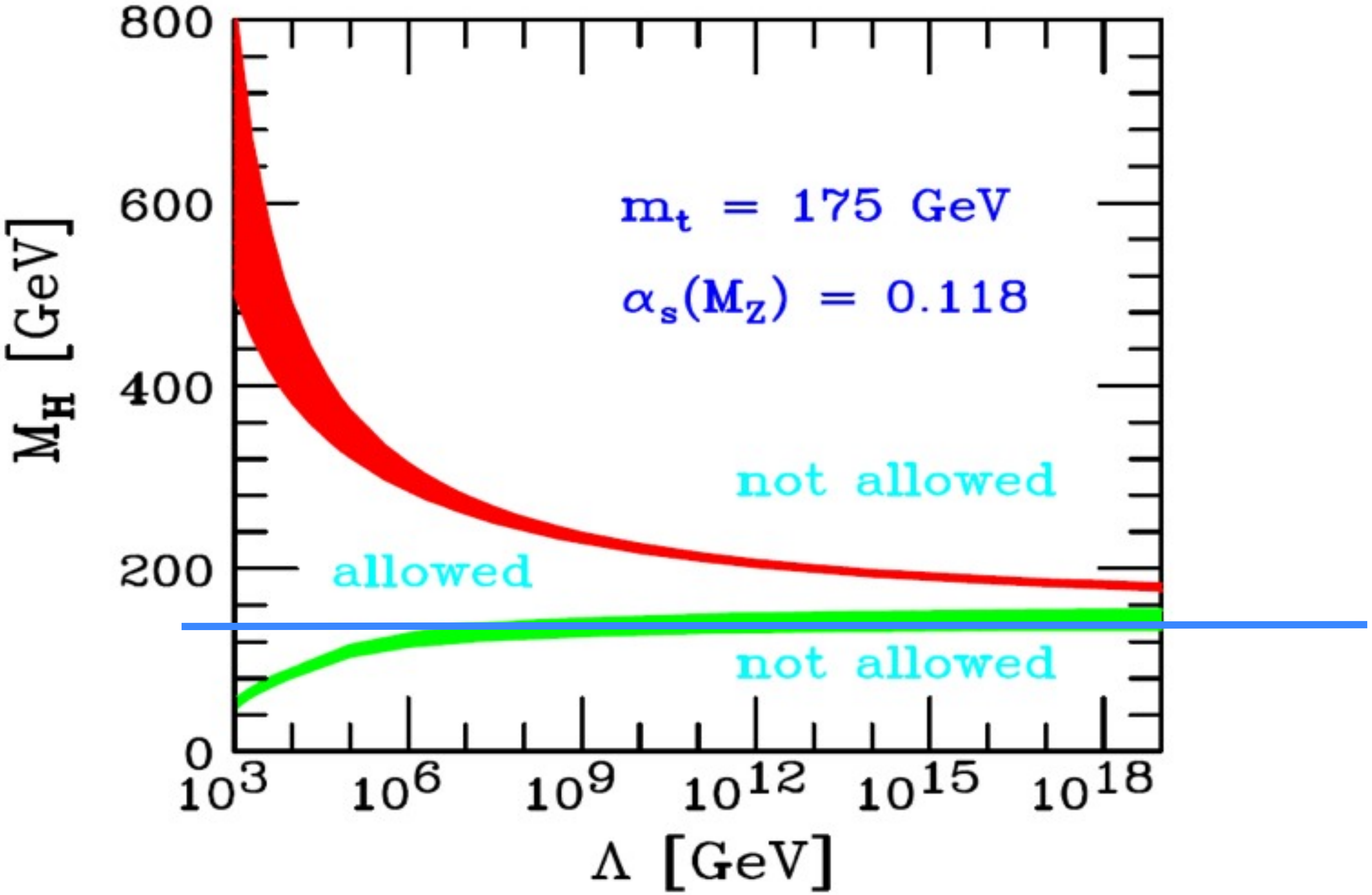
1. SM can possibly be valid up to Planck scale.
2. Bare Higgs mass is a computable quantity.
3. Flat potential at Planck scale allows "minimal Higgs inflation."

Higgs potential drawn by Higgs



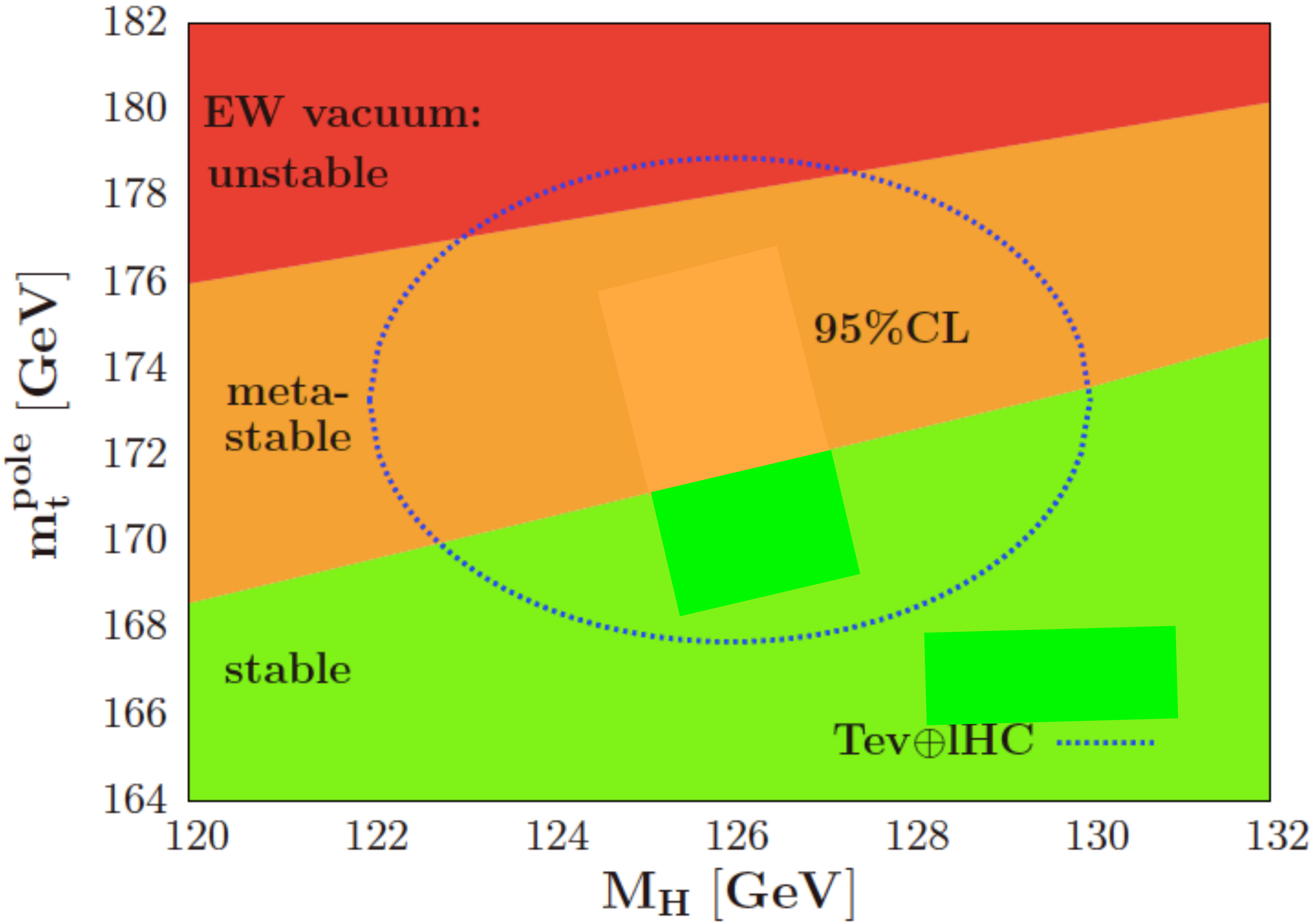
※ picture from web

SM can possibly be valid up to Planck scale



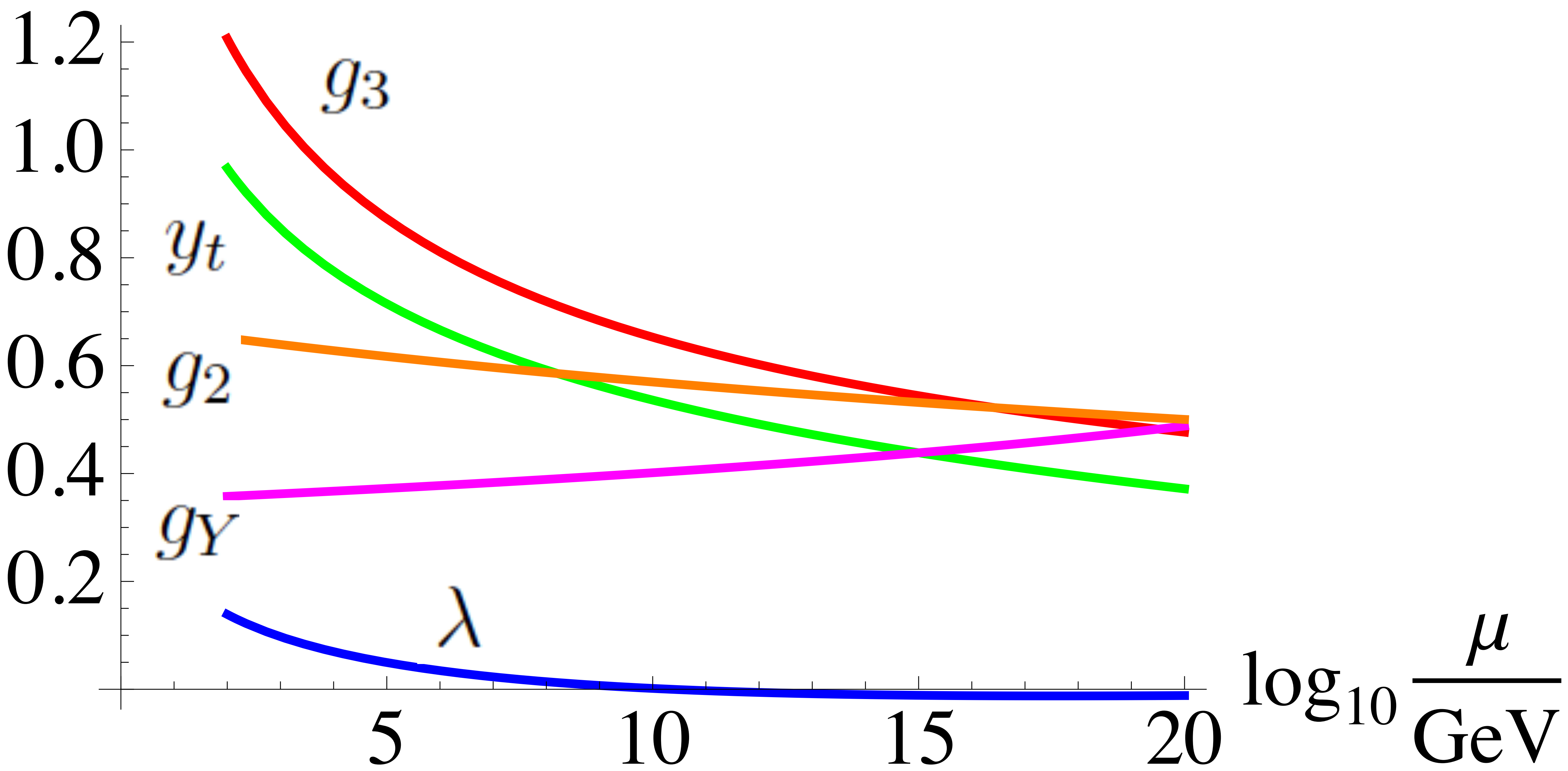
[Hambye & Riesselmann, 1997]

Up to date vacuum stability



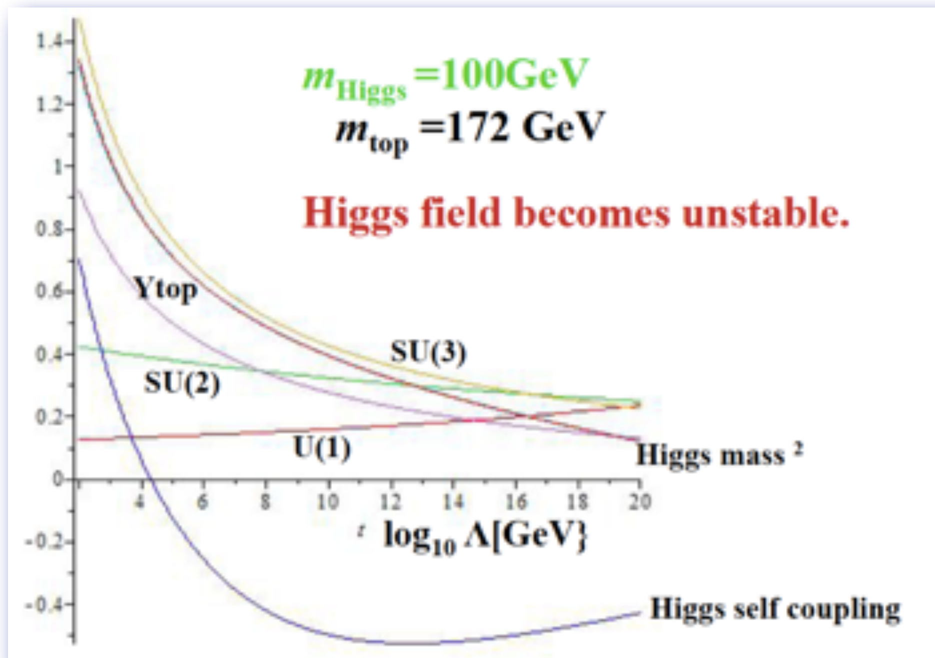
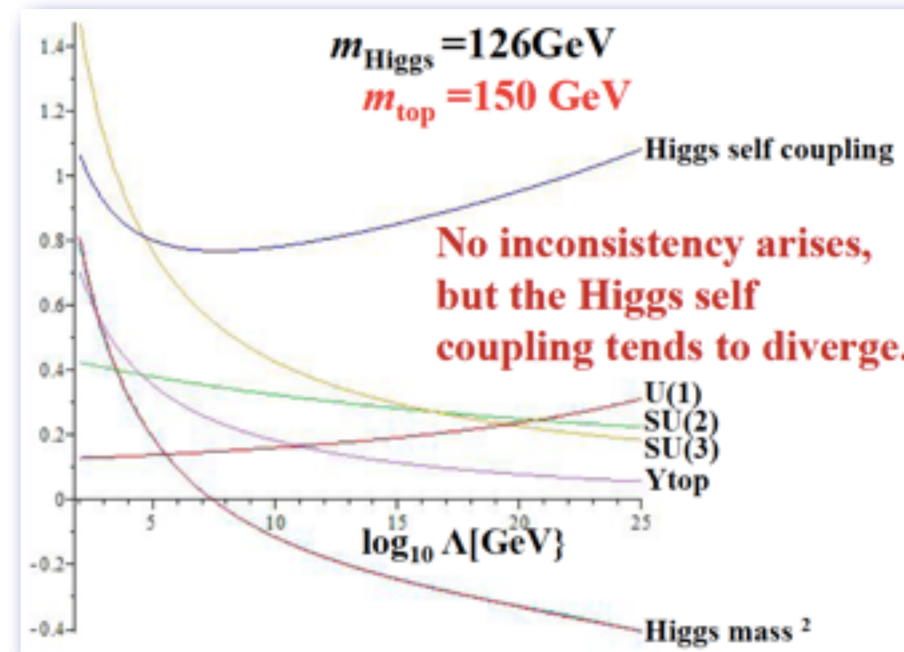
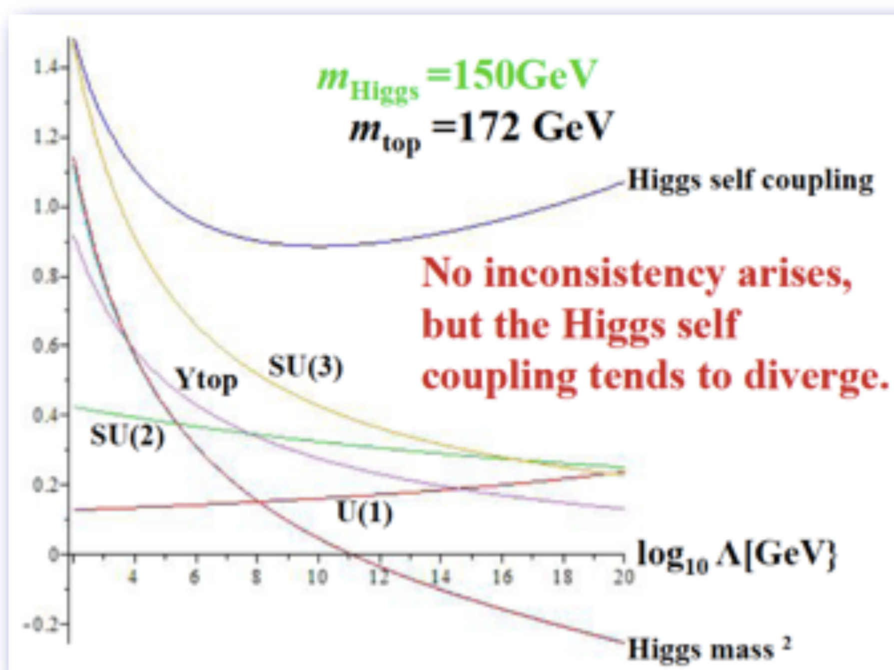
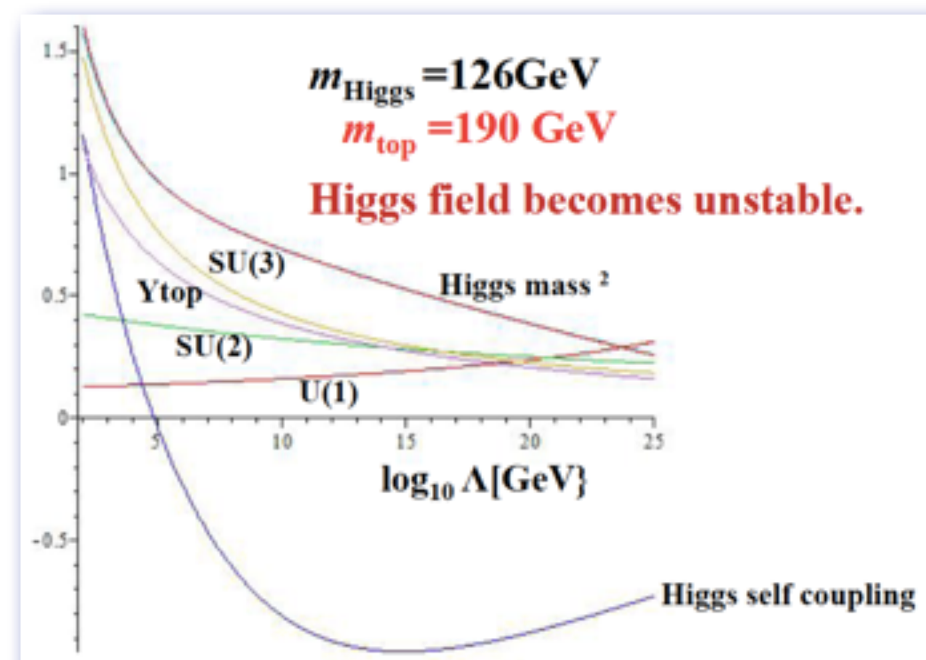
[Alekhin, Djouadi & Moch, 2012]

SM running couplings



[Hamada, Kawai, **KO,** 2012]

Nature has well chosen current top and Higgs masses

	...Higgs	...top
lighter...		
heavier...		

Hmm... SM may well valid up to Planck scale

Plan

1. SM can possibly be valid up to Planck scale.
2. Bare Higgs mass is a computable quantity.
3. Flat potential at Planck scale allows "minimal Higgs inflation."

What we do

- Because of Higgs discovery, we can discuss SM **bare Lagrangian** at Planck scale.

  ★ We evaluate **bare** Higgs mass/coupling.

  ★ Note: This is **not**, say, MS-bar running mass (in mass independent renormalization).

  ★ We compute **quadratic divergence** in **bare** Higgs mass up to **2-loop** orders.

- We find $m_B^2 = \lambda_B = 0$ is possible.

Basics on quadratic divergence

- $\underline{m_R^2} = \underline{m_B^2} + \underline{(\lambda^2/16\pi^2 + \cdots)\, \Lambda^2} + \underline{\delta m^2}$.

  renorm'd mass — bare mass — radiative corrections

- Mass independent renormalization scheme:

  I. Choose $\underline{m_B^2}$ so that $\underline{m_R^2 = 0}$ for $\underline{\delta m^2 = 0}$.

  ✳ In dim. reg. this happens to happen automatically.

  ✳ Does not mean absence of quadratic divergence.

  ✳ Otherwise, there would be no fine tuning problem at all!

  II. Add $\underline{\delta m^2}$ as perturbation → running mass.

- We do NOT treat running mass ($\propto \log\Lambda$, multiplicative) but bare mass ($\propto \Lambda^2$, subtractive).

1-loop result

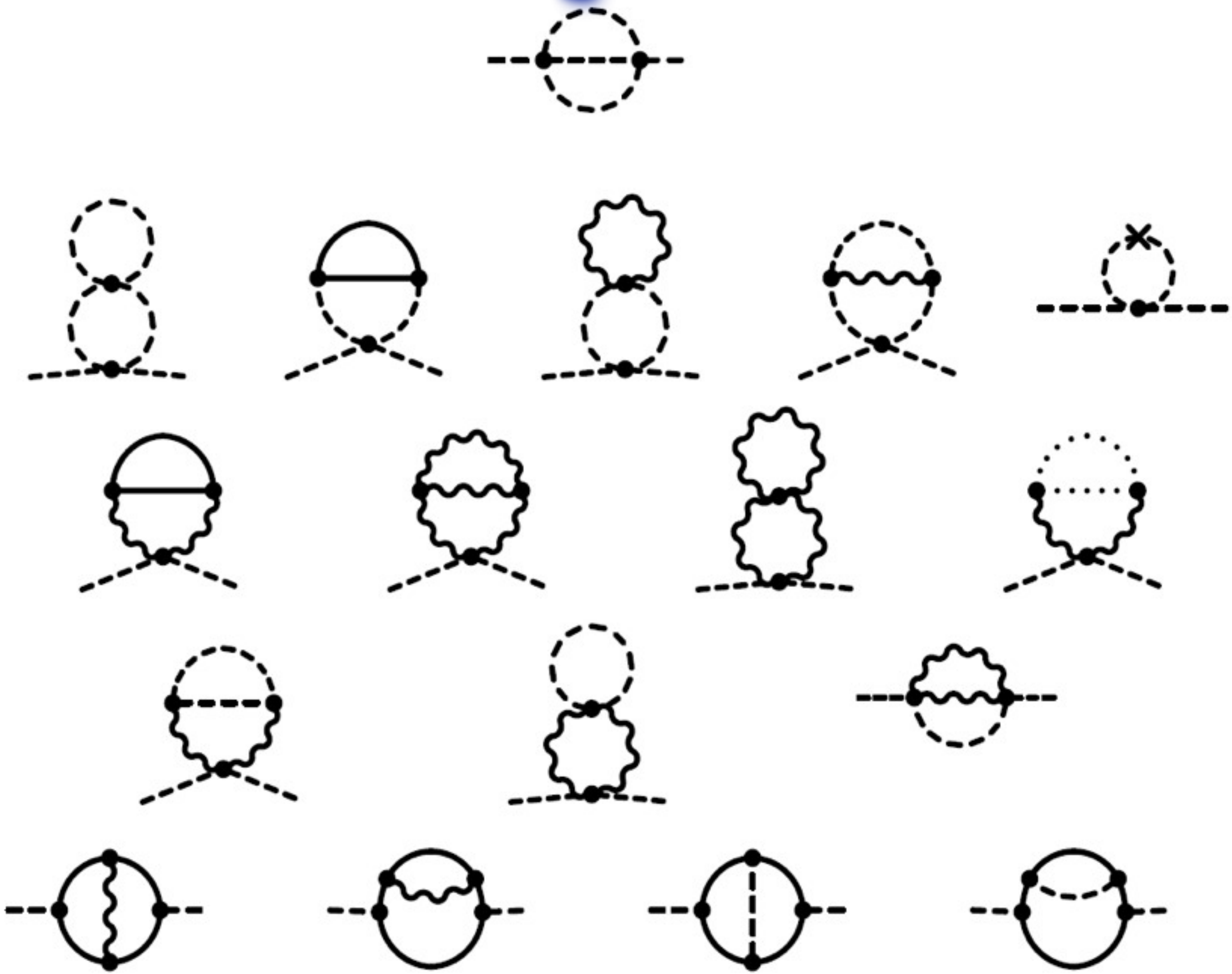
- At 1-loop order, it has been known:

$$m^2_{B,\,\text{1-loop}} = -\left(6\lambda_B + \frac{3}{4}g^2_{YB} + \frac{9}{4}g^2_{2B} - 6y^2_{tB}\right) I_1$$

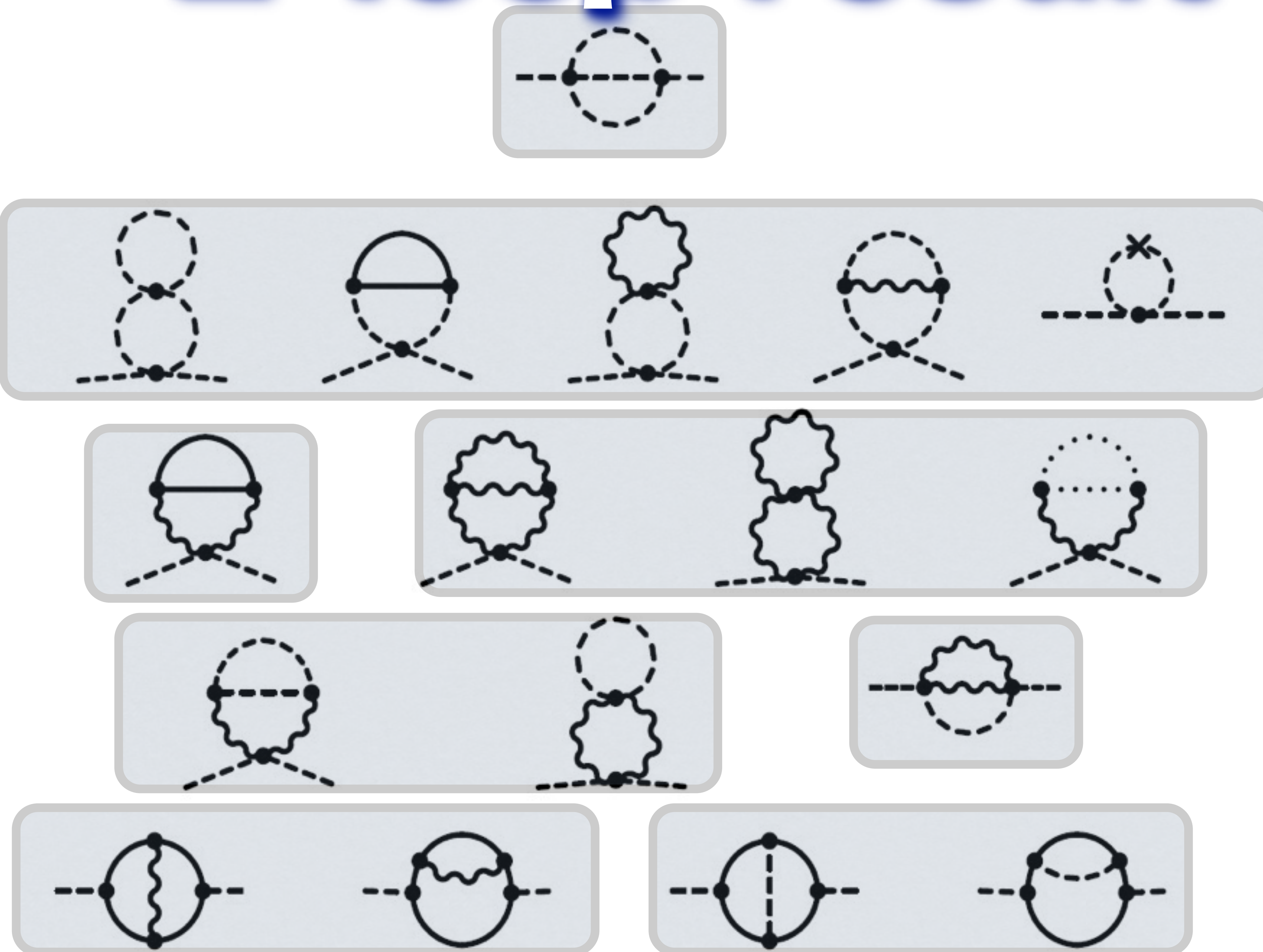
Cerebrated Veltman condition.

$$I_1 = \frac{\Lambda^2}{16\pi^2}$$

2-loop result



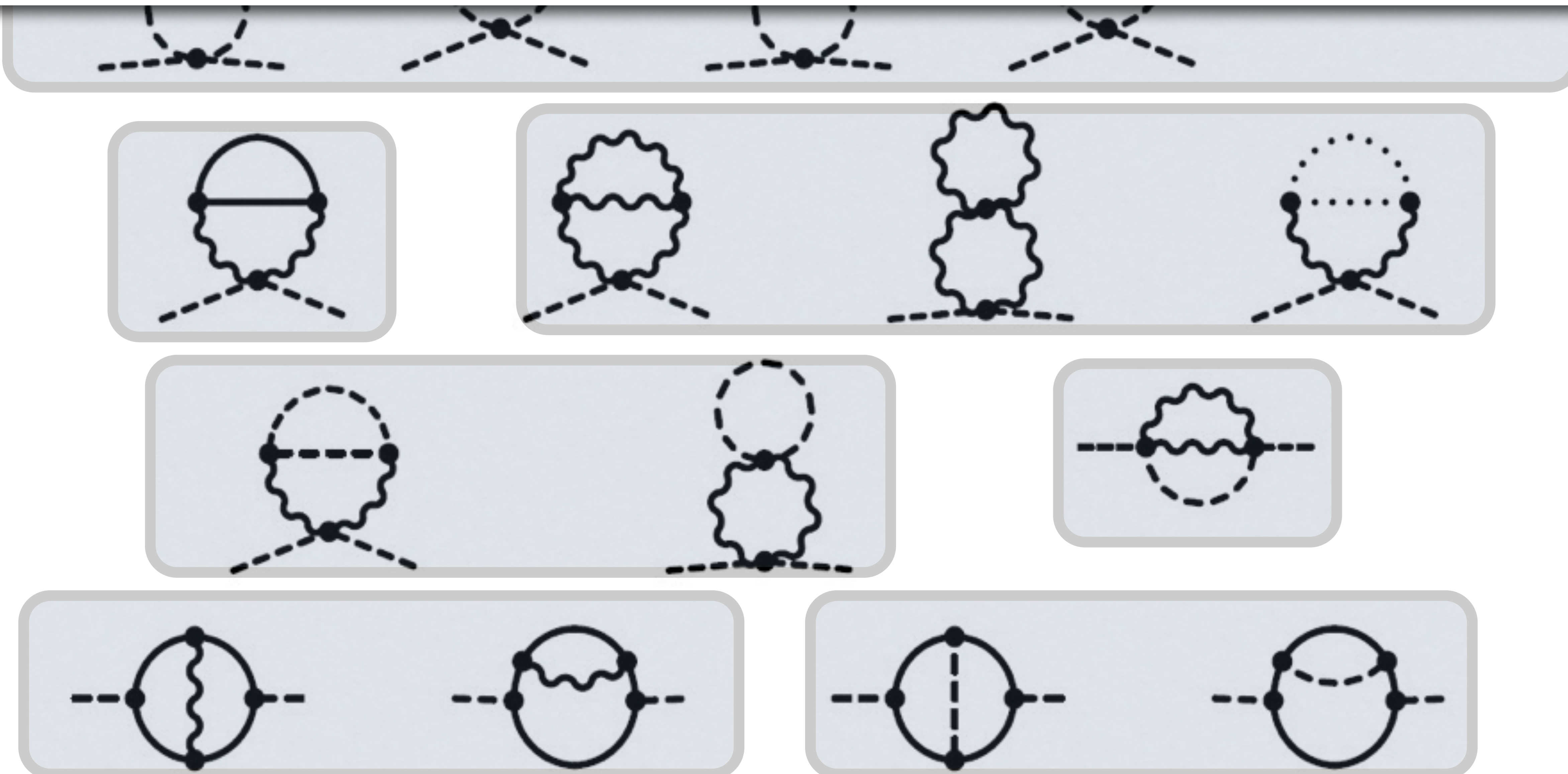
2-loop result



2-loop result

$$m_{B,\,\text{2-loop}}^2 = -\Bigg\{ 9y_{tB}^4 + y_{tB}^2 \left(-\frac{7}{12} g_{YB}^2 + \frac{9}{4} g_{2B}^2 - 16 g_{3B}^2 \right) + \frac{77}{16} g_{YB}^4 + \frac{243}{16} g_{2B}^4$$

$$+ \lambda_B \left(-18 y_{tB}^2 + 3 g_{YB}^2 + 9 g_{2B}^2 \right) - 10 \lambda_B^2 \Bigg\} I_2.$$



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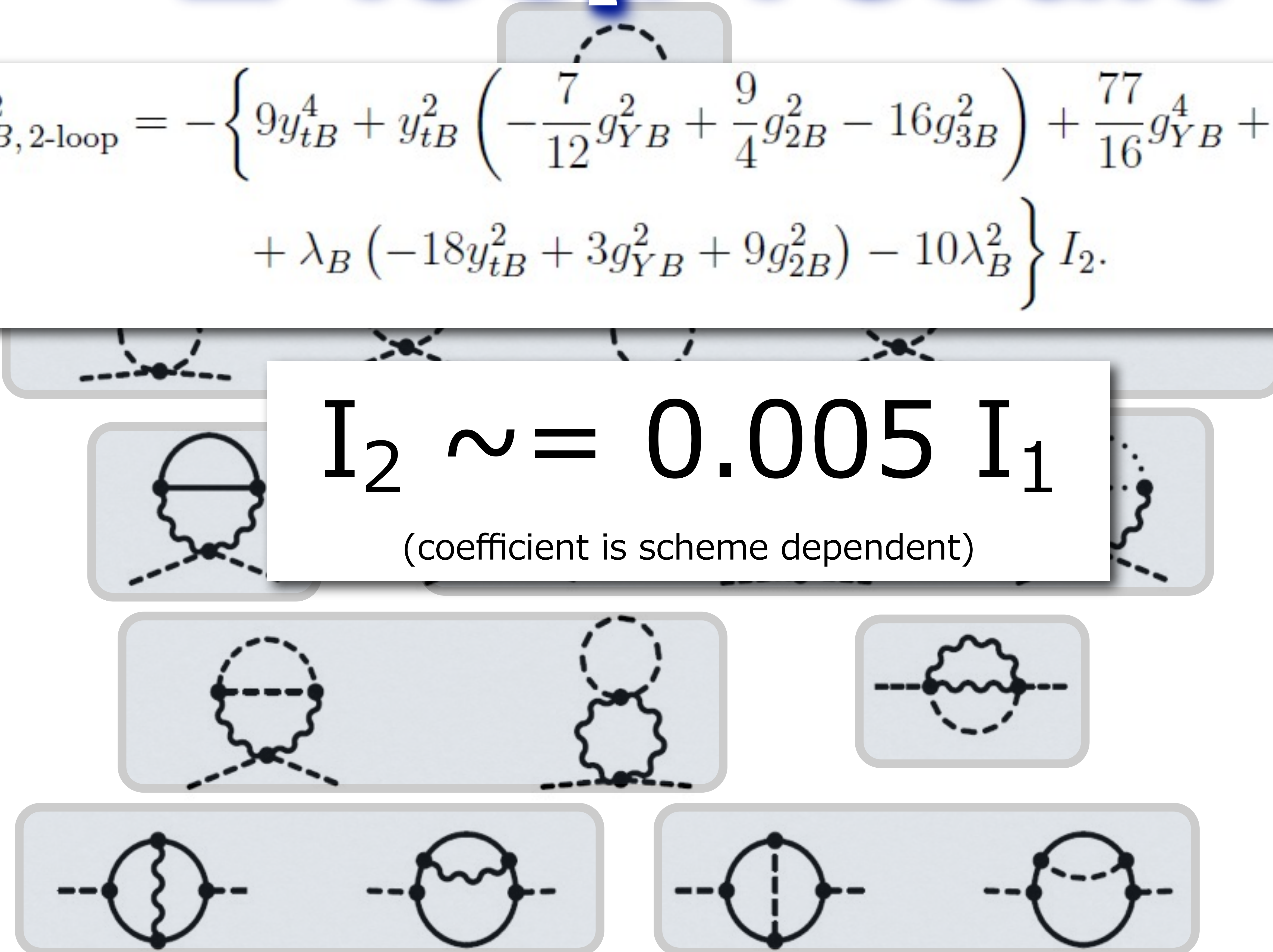

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$$I_2 \sim= 0.005\, I_1$$

(coefficient is scheme dependent)

2-loop result

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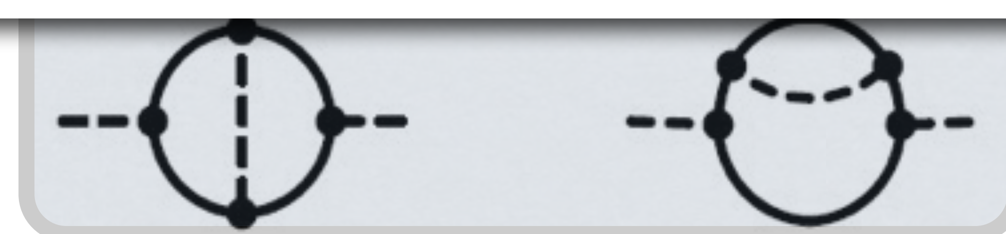
A check of regularization independence:
Smallness of two loop contribution.

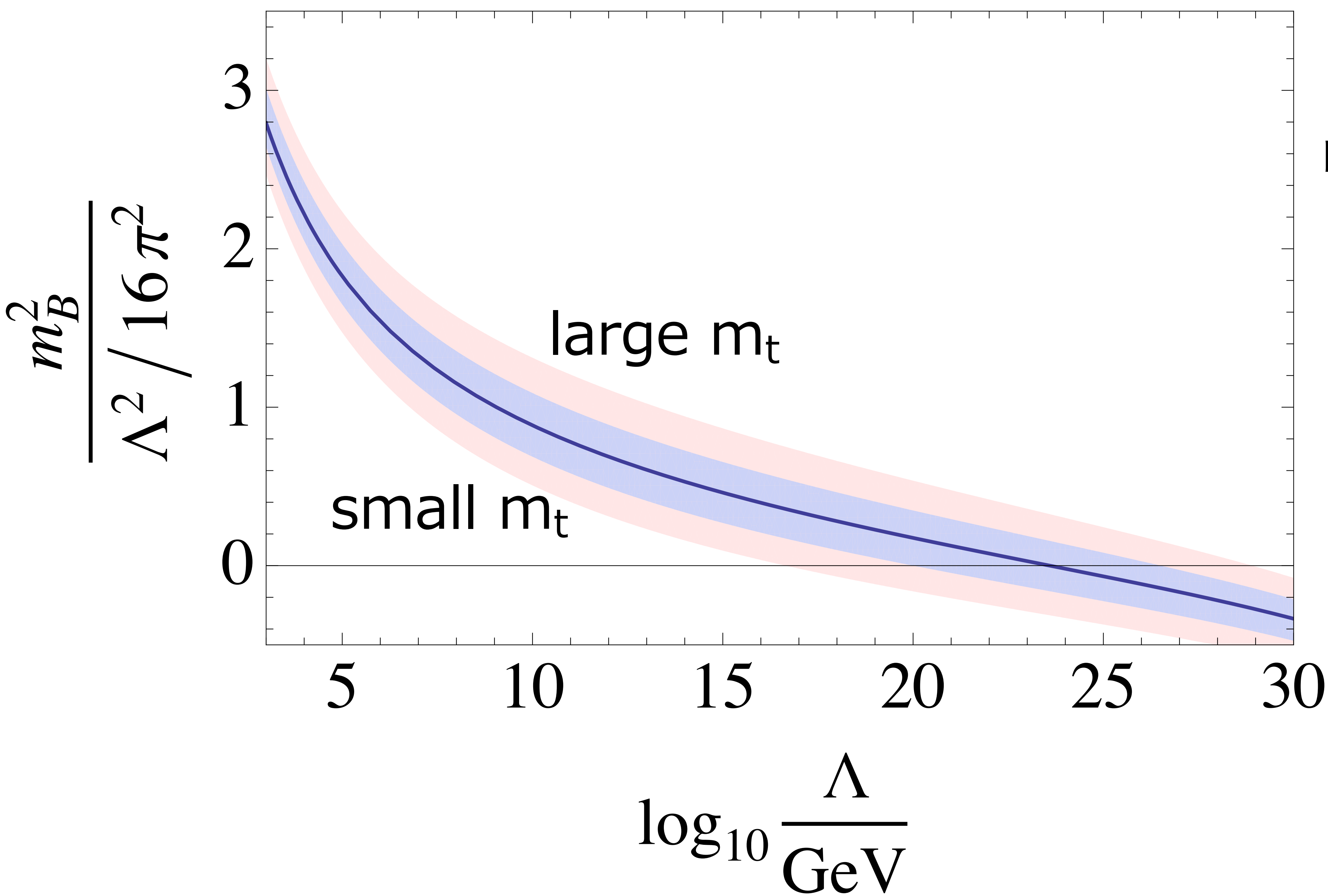


Result

Bare mass vanishes for $\Lambda = 10^{17} \sim 10^{28}$GeV

[Hamada, Kawai, **KO**, 2012]

$m_t^{\mathrm{pole}} = 173.3 \pm 2.8\,\mathrm{GeV}$



Note:

- Bare mass is **not** running.
- Bare couplings are approximated by running ones at Λ.

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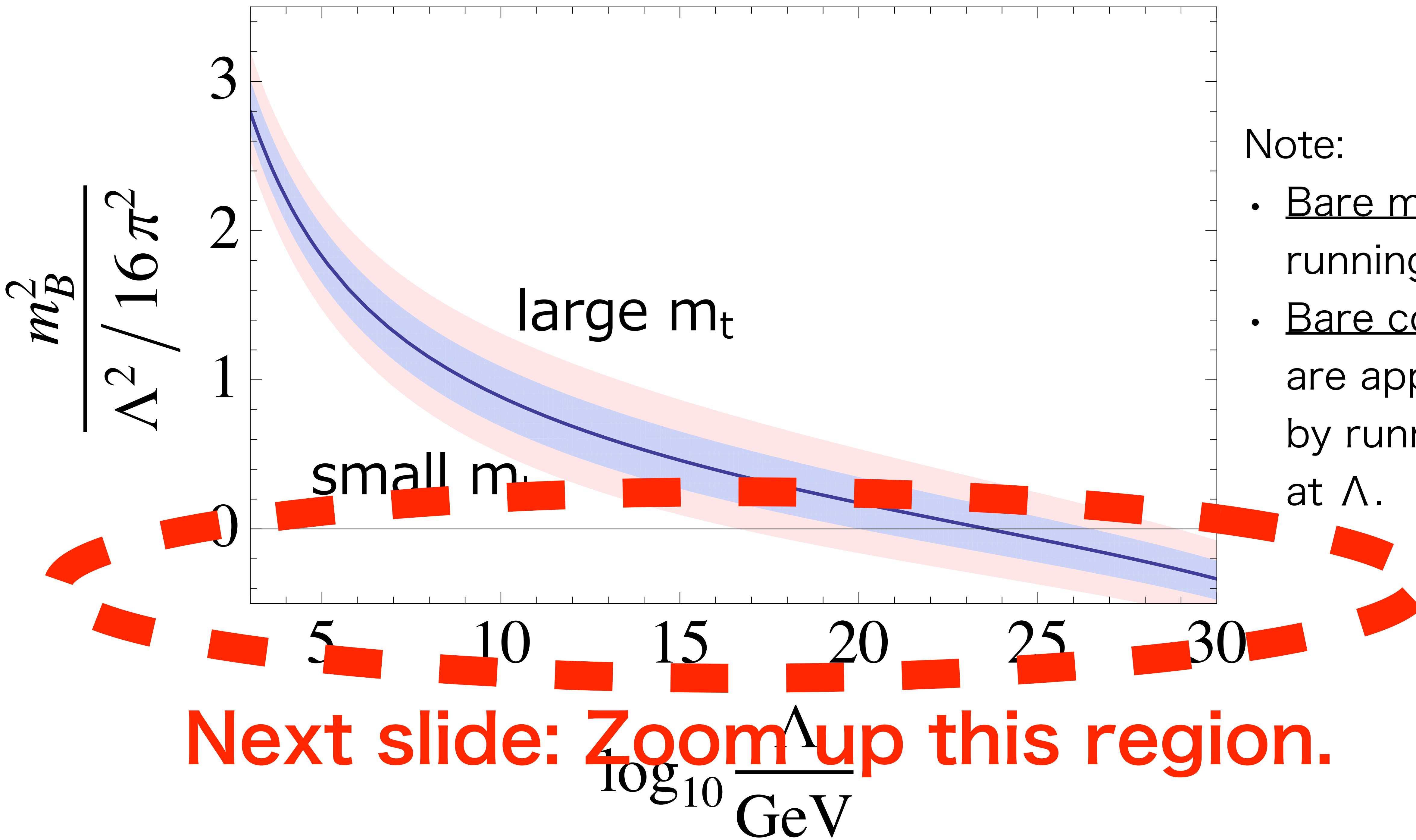

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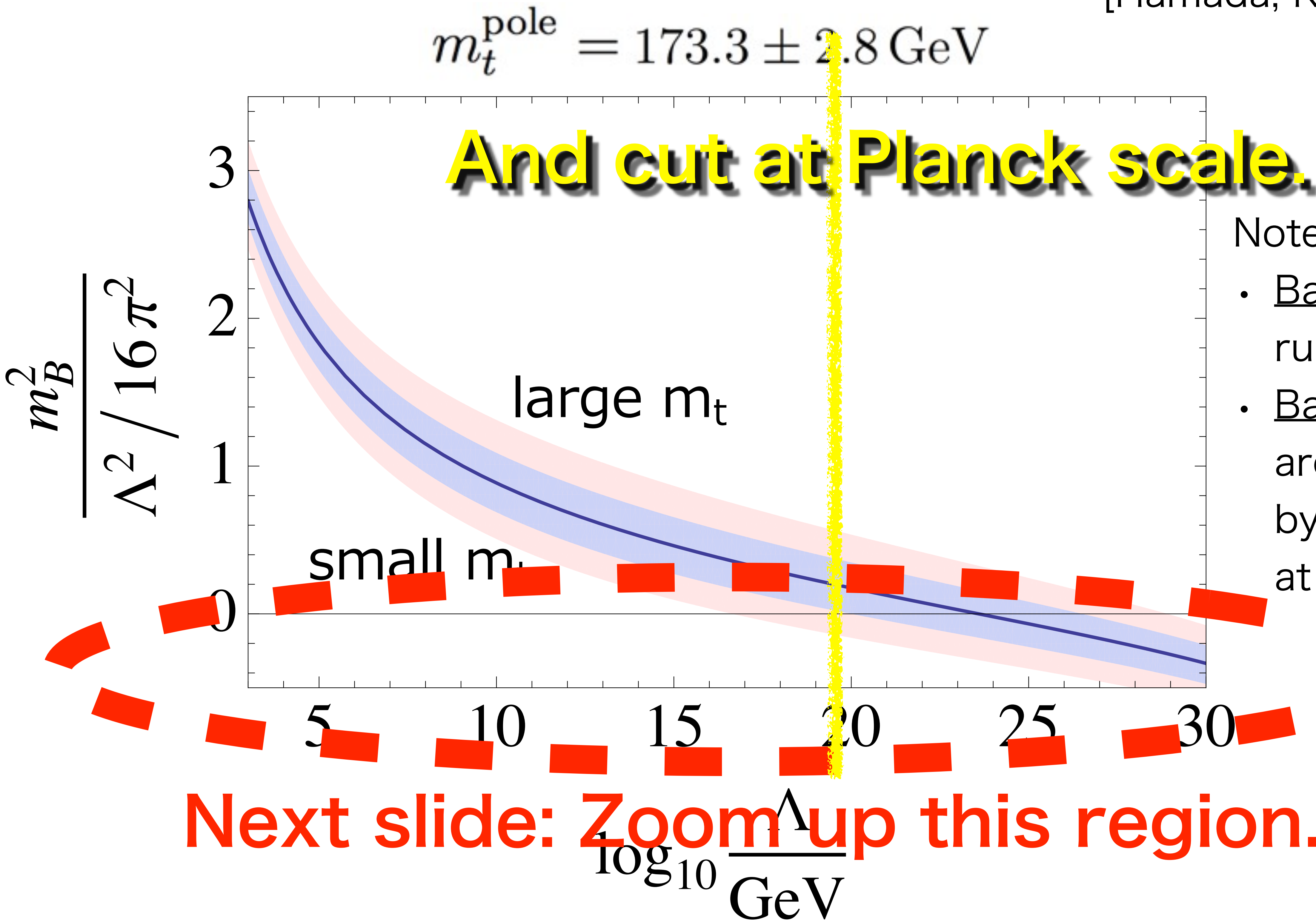

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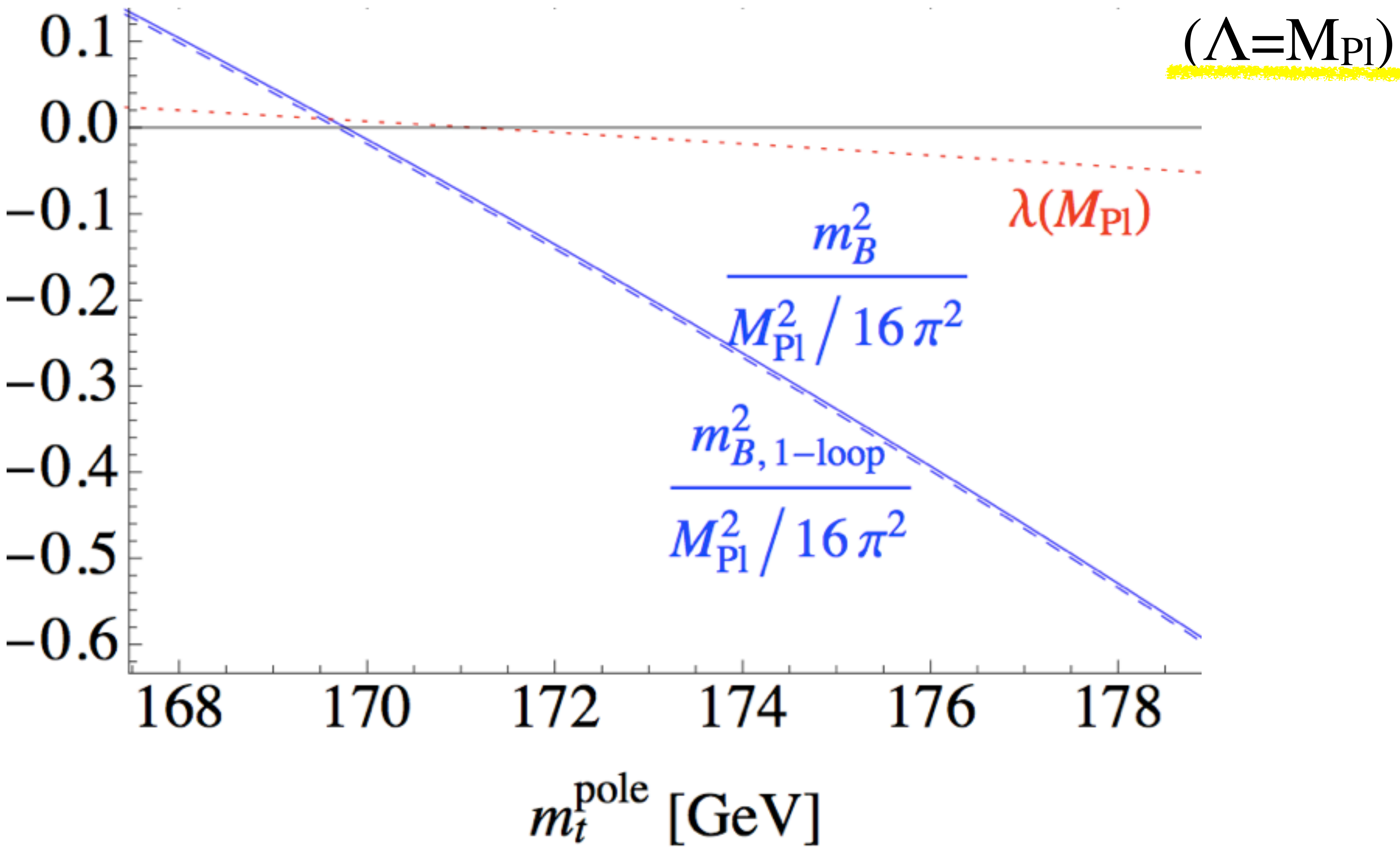
Both m_B^2 and λ almost vanish at Planck scale



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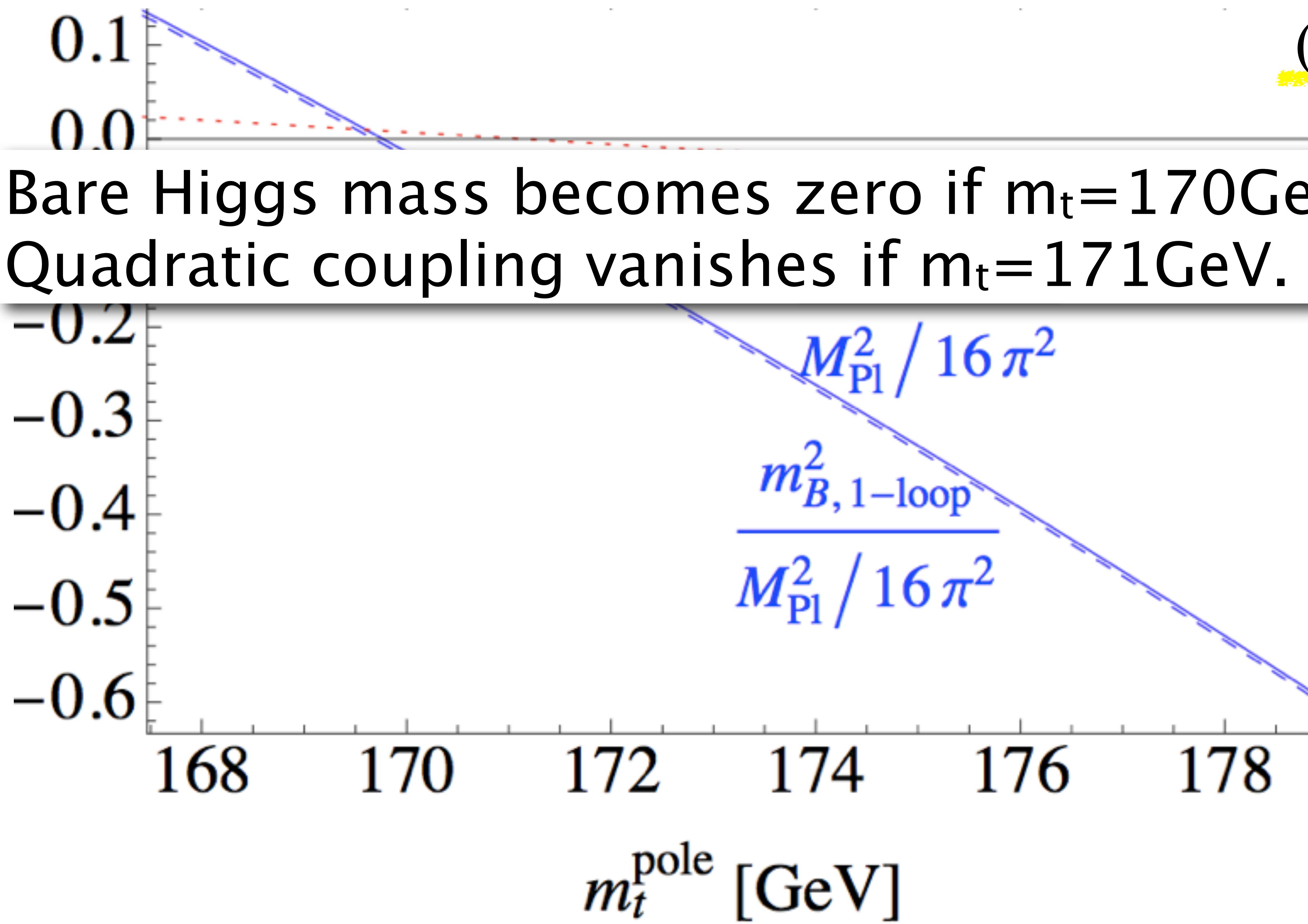

(Λ=M_{Pl})

Bare Higgs mass becomes zero if m_t=170GeV.
Quadratic coupling vanishes if m_t=171GeV.

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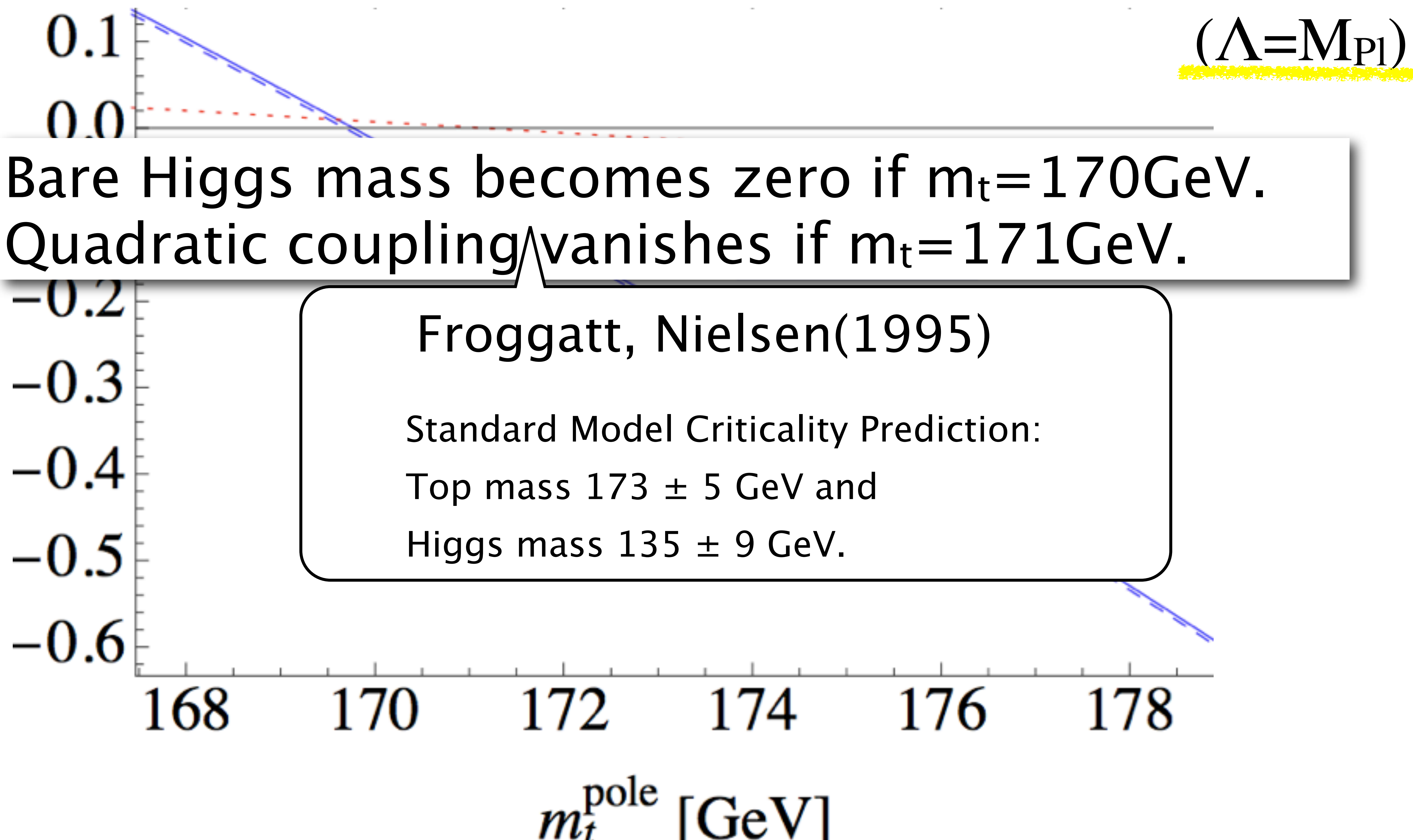

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Froggatt, Nielsen(1995)

Standard Model Criticality Prediction:
Top mass 173 ± 5 GeV and
Higgs mass 135 ± 9 GeV.

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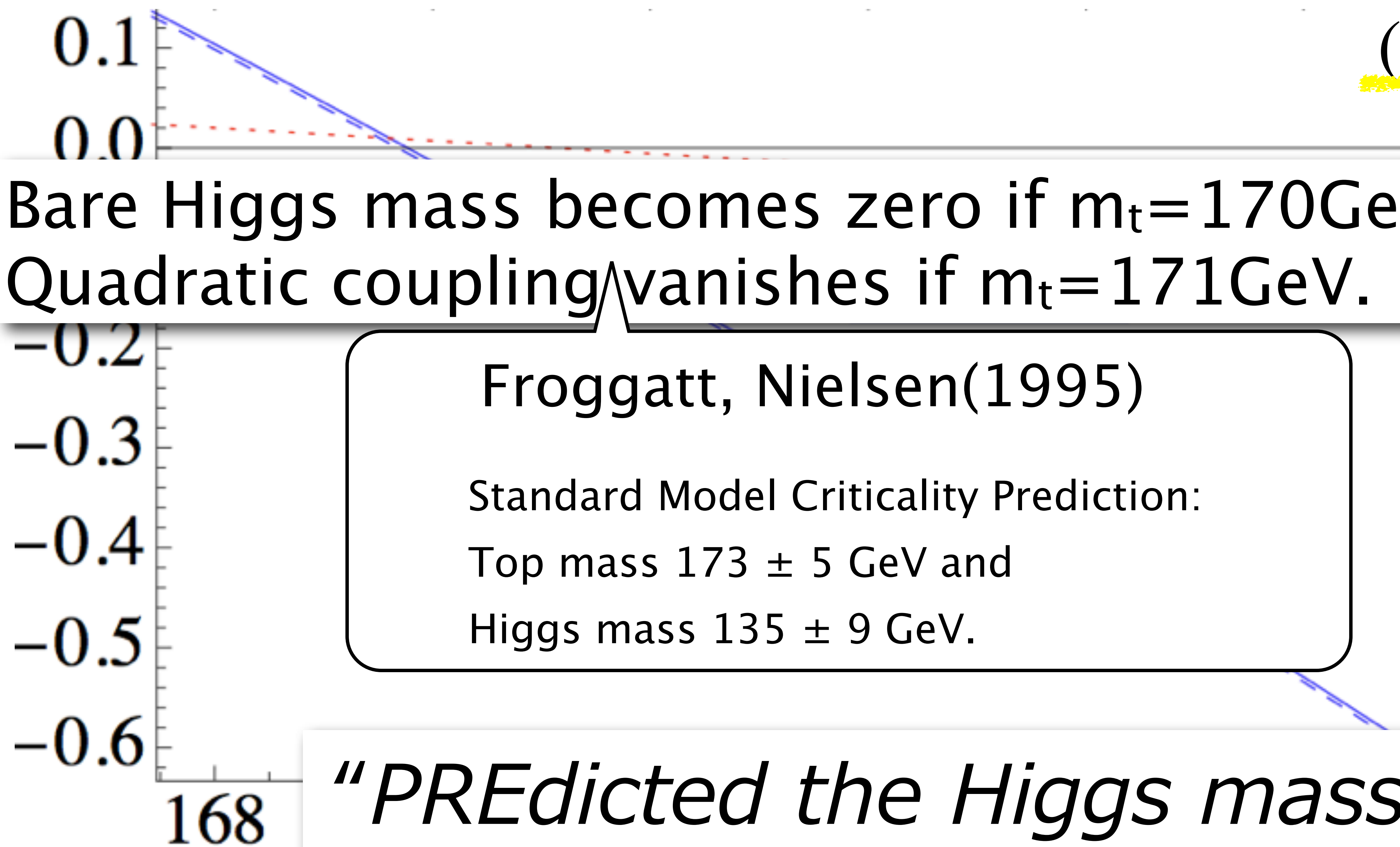
$(\Lambda = M_{Pl})$



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"PREdicted the Higgs mass"
H. B. Nielsen [1212.5716]

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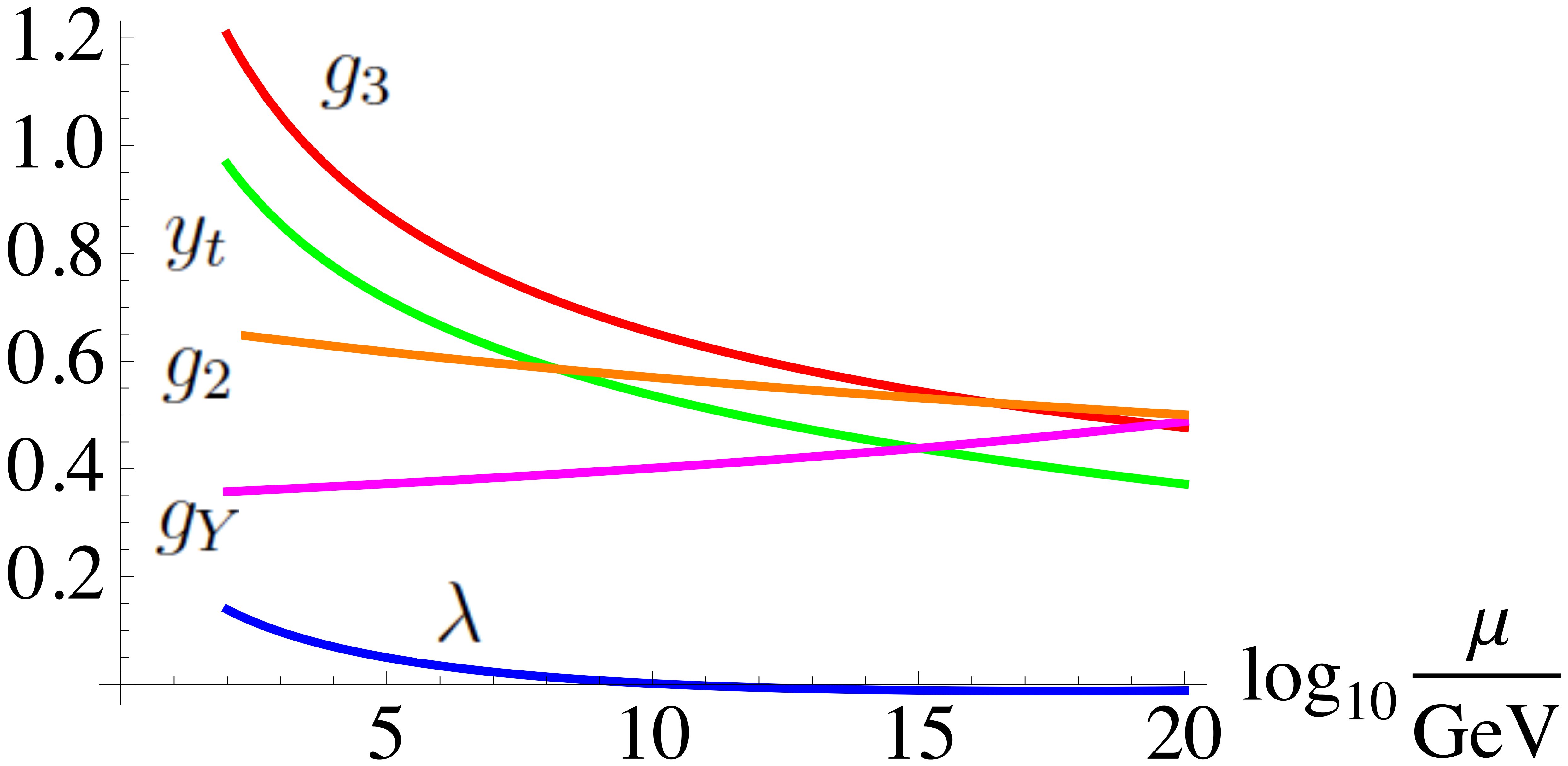
Recall SM running



[Hamada, Kawai, **KO,** 2012]

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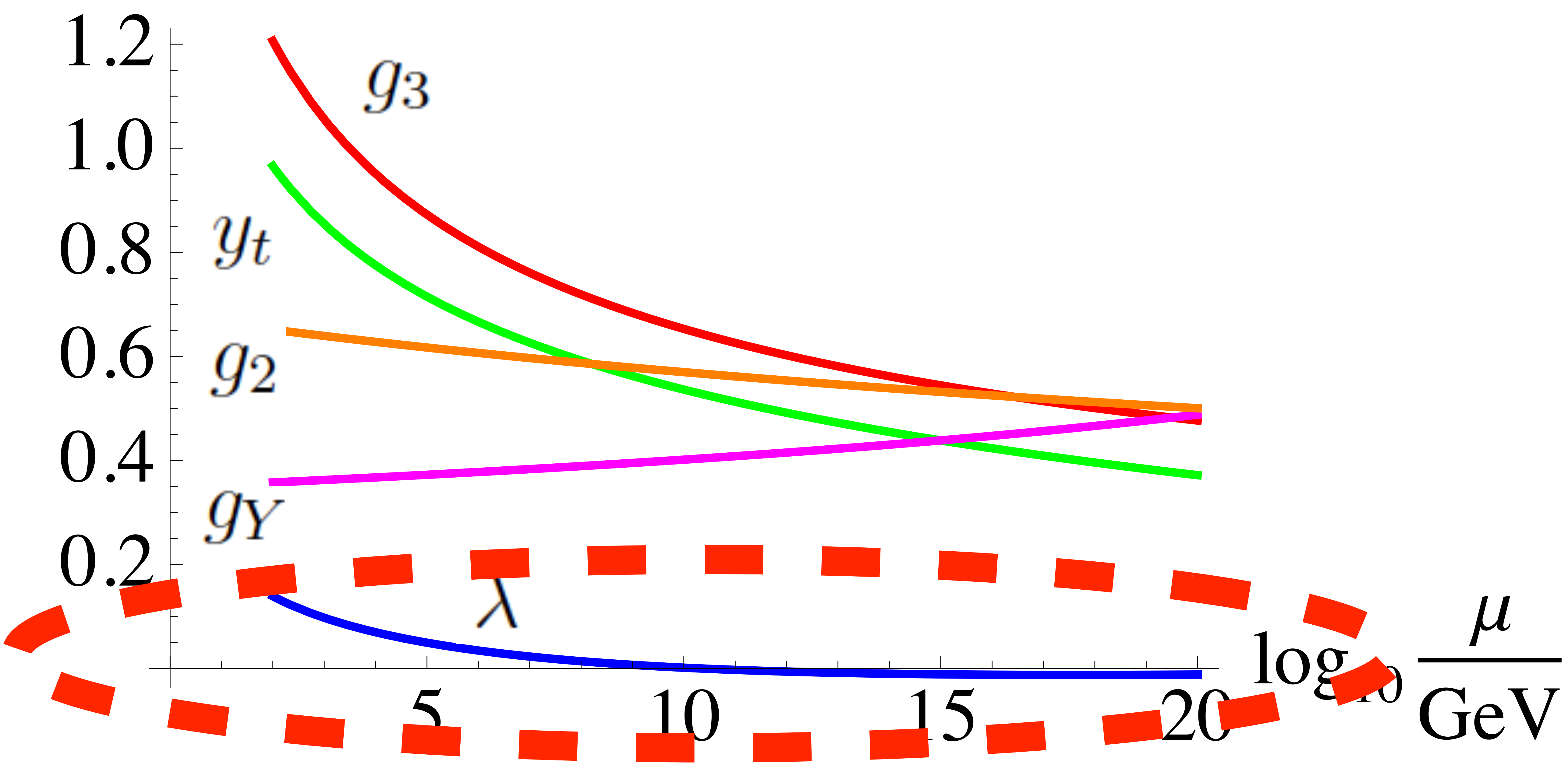
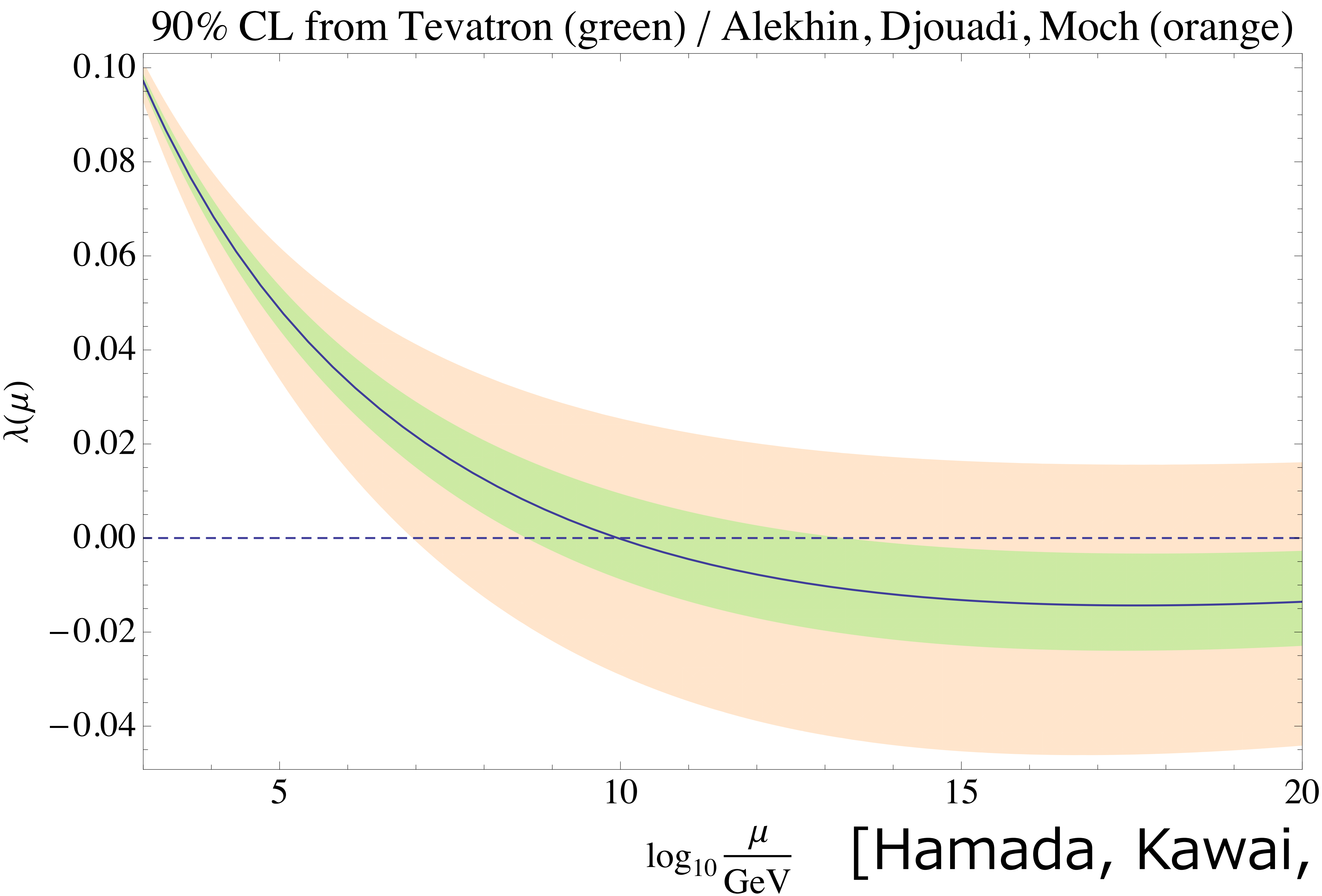


Next slide: Zoom up this region.

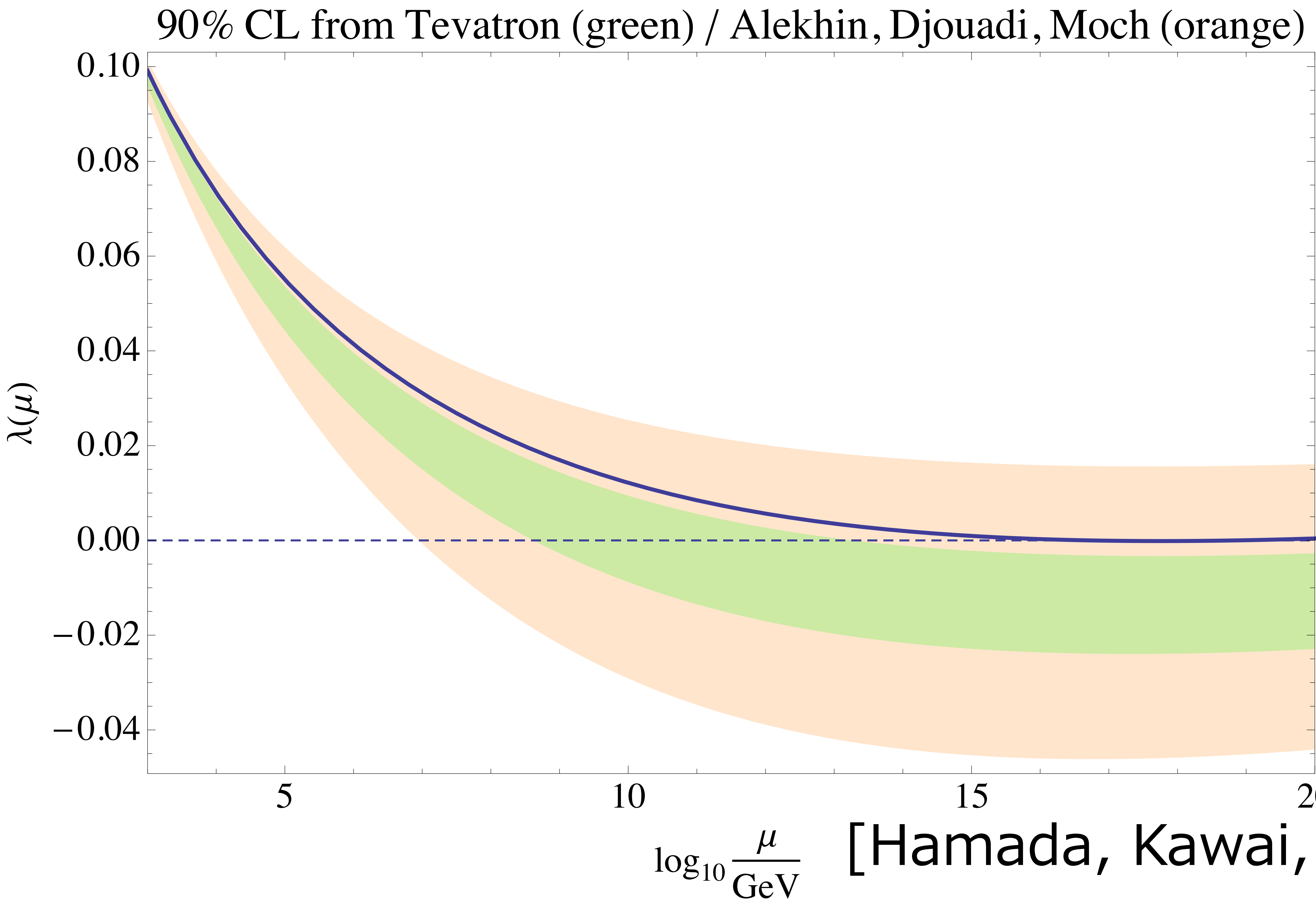
[Hamada, Kawai, **KO,** 2012]

Small quartic coupling at high energies



[Hamada, Kawai, **KO**]

Vanishing quartic for $m_t = 171\,\text{GeV}$



[Hamada, Kawai, **KO**]

Cosmological application of flat potential at Planck scale

Minimal Higgs inflation

[Hamada, Kawai, KO, 1302.XXXX]

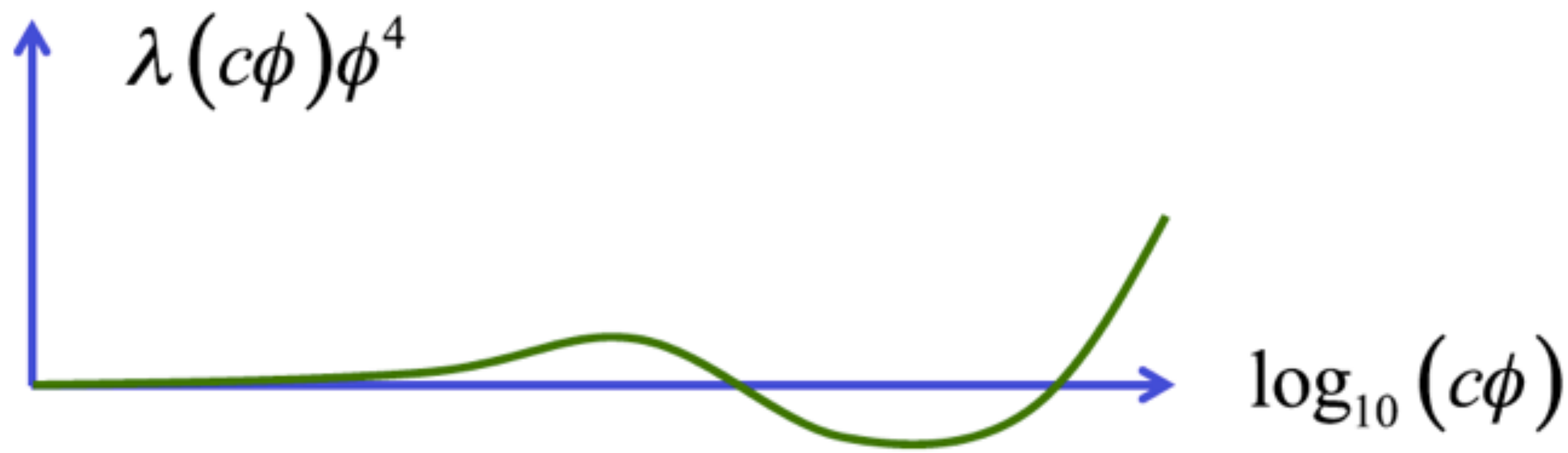
- Conventional **Higgs inflation** needs huge coupling to gravity: $\Delta L = \xi\, |H|^2 R$ with $\xi \sim 10^5$.
- λ can be as small as one wants at Planck scale.
- Why not using it? → Chaotic inflation with $\lambda\varphi^4$!
  - ✳ Fine tuning? You must anyway fine tune cosmological constant for any inflation to work.

★ If you do not like $\varphi >> M_P$, we have following solution.

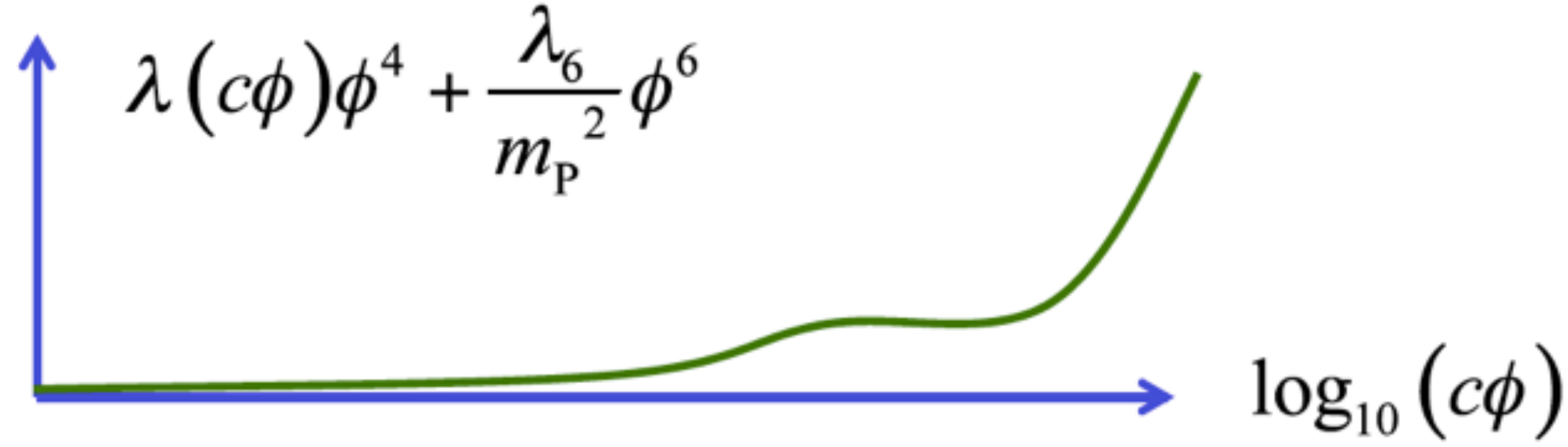
How to get $\phi \ll M_P$

[Hamada, Kawai, KO, 1302.XXXX]

- SM Higgs potential with radiative corrections (without fine tuning λ):



- Higher dimensional operator lifts it up:



Coming soon
Stay tuned!

Summary

1. SM can possibly be valid up to Planck scale.
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Discussions

- Supersymmetry restoration at Planck scale?
  - ★ Non-SUSY SM with bare-massless Higgs from superstring is in principle no problem in fermionic construction. Realistic model?
- Bare-mass/Higgs-inflation for other BSM models: 2HDM, seesaw, split/high-scale SUSY, Higgs portal DM, etc.
- A lot to do. Join!


Thank you!
※ pictures from web