About the role of Higgs boson in the evolution of the early universe?

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also see: www-com.physik.hu-berlin.de/~fjeger/Durham_1[2,3,4].pdf

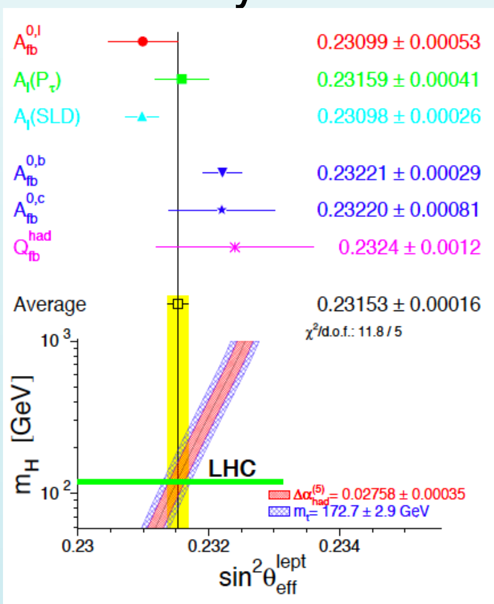
Outline of Talk:

- ❖Introduction
- ❖Low energy effective QFT of a cutoff system
- ❖Matching conditions
- ❖SM RG evolution to the Planck scale
- ❖The issue of quadratic divergences in the SM
- ❖Remark on the impact on inflation
- ❖Reheating and baryogenesis
- ❖Conclusion

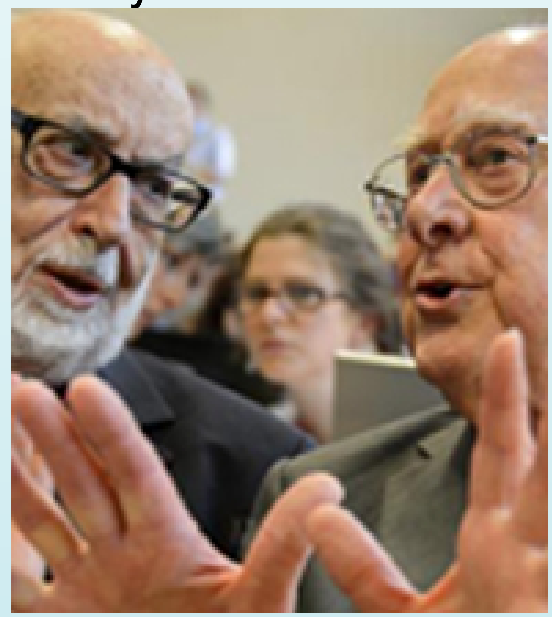
Introduction

✌ LHC ATLAS&CMS Higgs discovered ⇒ the SM completion

Higgs mass found by ATLAS and CMS agrees perfectly with the indirect bounds



LEP 2005 +++ LHC 2012

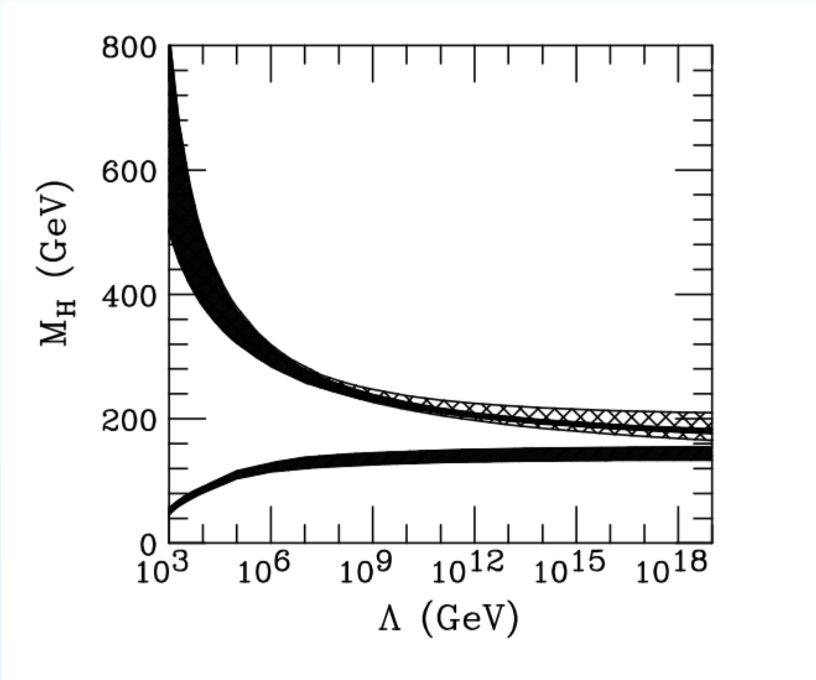


Englert&Higgs Nobel Prize 2013

Higgs mass found in very special mass range 125.9 ± 0.4 GeV

Common Folklore: hierarchy problem requires SUSY extension of the SM (no quadratic divergences)

Do we need new physics? Stability bound of Higgs potential in SM:



Riesselmann, Hambye 1996

$M_H < 180$ GeV

– first 2-loop analysis, knowing M_t –

SM Higgs remains perturbative up to scale Λ if it is light enough (upper bound=avoiding Landau pole) and Higgs potential remains stable ($\lambda > 0$) if Higgs mass is not too light [parameters used: $m_t = 175[150 - 200]$ GeV ; $\alpha_s = 0.118$]

Key object of our interest: the Higgs potential $V = \frac{m^2}{2} H^2 + \frac{\lambda}{24} H^4$

- Higgs mechanism

- when m^2 changes sign and λ stays positive $\Rightarrow$ first order phase transition
- vacuum jumps from $v = 0$ to $v \neq 0$

Note: the bare Lagrangian is the true Lagrangian (renormalization is just reshuffling terms) the change in sign of the bare mass is what determines the phase

- Hierarchy problem is a problem concerning the relationship between bare and renormalized parameters

- bare parameters are not accessible to experiment so who cares?

● SM as a low energy effective theory [LEESM scenario]

Our paradigm: at Planck scale a physical bare cutoff system exists ("the ether") with $\Lambda = M_{\rm Pl}$ as a real physical cutoff

❒ low energy expansion in E/Λ lets us see a renormalizable effective QFT: the SM
– as present (and future) accelerator energies $E <<<< M_{\rm Pl}$
all operators $\dim > 4$ far from being observable

❒ in this scenario the relation between bare and renormalized parameters is physics: bare parameters predictable from known renormalized ones

❒ all so called UV singularities (actually finite now) must be taken serious including quadratic divergences – cutoff finite ⇒no divergences!

● impact of the very high Planck cutoff is that the local renormalizable QFT structure of the SM is presumably valid up to 10^{17} GeV, this also justifies the application of the SM RG up to high scales.

- infinite tower of dim > 4 irrelevant operators not seen at low energy
  ⇒simplicity of SM!

- problems are the dim < 4 relevant operators, in particular the mass terms,

require "tuning to criticality" = chiral symmetry, gauge symmetry . In the symmetric phase of the SM, where there is only one mass (the others are forbidden by the known chiral and gauge symmetries), the one in front of the Higgs doublet field, the fine tuning has the form

$$m_0^2 = m^2 + \delta m^2 \; ; \quad \delta m^2 = \frac{\Lambda^2}{16\pi^2} C$$

with a coefficient typically $C = O(1)$. To keep the renormalized mass at some small value, which can be seen at low energy, m_0^2 has to be adjusted to compensate the huge number δm^2 such that about 35 digits must be adjusted in order to get the observed value around the electroweak scale.

Our Hierarchy Problem!

Matching conditions

m_{i0} bare, m_i the $\overline{\mathrm{MS}}$ and M_i the on-shell masses; μ_0 bare μ $\overline{\mathrm{MS}}$ scale

- relationship between $\overline{\mathrm{MS}}$ and on-shell renormalized parameters

$$m_b^2 = M_b^2 + \delta M_b^2\big|_{\mathrm{OS}} - \delta M_b^2\big|_{\overline{\mathrm{MS}}} = M_b^2 + \left(\delta M_b^2\big|_{\mathrm{OS}}\right)_{\mathrm{Reg}=\ln\mu^2} .$$

Correspondingly for other masses and coupling constants g, g', λ and y_f, which, however, usually are fixed using the mass-coupling relations in terms of the masses and the Higgs VEV v, which is determined by the Fermi constant $v = (\sqrt{2}G_\mu)^{-1/2}$.

$$M_Z = 91.1876(21)\ \mathrm{GeV}, \quad M_W = 80.385(15)\ \mathrm{GeV}, \quad M_t = 173.5(1.0)\ \mathrm{GeV},$$
$$G_F = 1.16637\times 10^{-5}\ \mathrm{GeV}^{-2}\ , \quad \alpha^{-1} = 137.035999\ , \quad \alpha_s(M_Z^2) = 0.1184(7)\ .$$

For the Higgs mass we adopt $M_H = 125.9 \pm 0.4$ GeV

SM RG evolution to the Planck scale

Using RG coefficient function calculations by

Jones, Machacek&Vaughn, Tarasov&Vladimirov, Vermasseren&vanRitbergen, Melnikov&van Ritbergen, Czakon, Chetyrkin et al, Steinhauser et al, Bednyakov et al.

Recent application to SM vacuum stability

Shaposhnikov et al, Degrassi et al, Maina, Hamada et al, ...

Solve SM coupled system of RG equations:

- for gauge couplings $g_3 = (4\pi\alpha_s)^{1/2}$, $g_2 = g$ and $g_1 = g'$
- for the Yukawa coupling y_t (other Yukawa couplings negligible)
- for the Higgs potential parameters λ and $\ln m^2$

with $\overline{\mathrm{MS}}$ initial values obtained by evaluating the matching conditions

The $\overline{\mathrm{MS}}$ Higgs VEV square is then obtained by $v^2(\mu^2) = \frac{6m^2(\mu^2)}{\lambda(\mu^2)}$ and the other masses by the relations

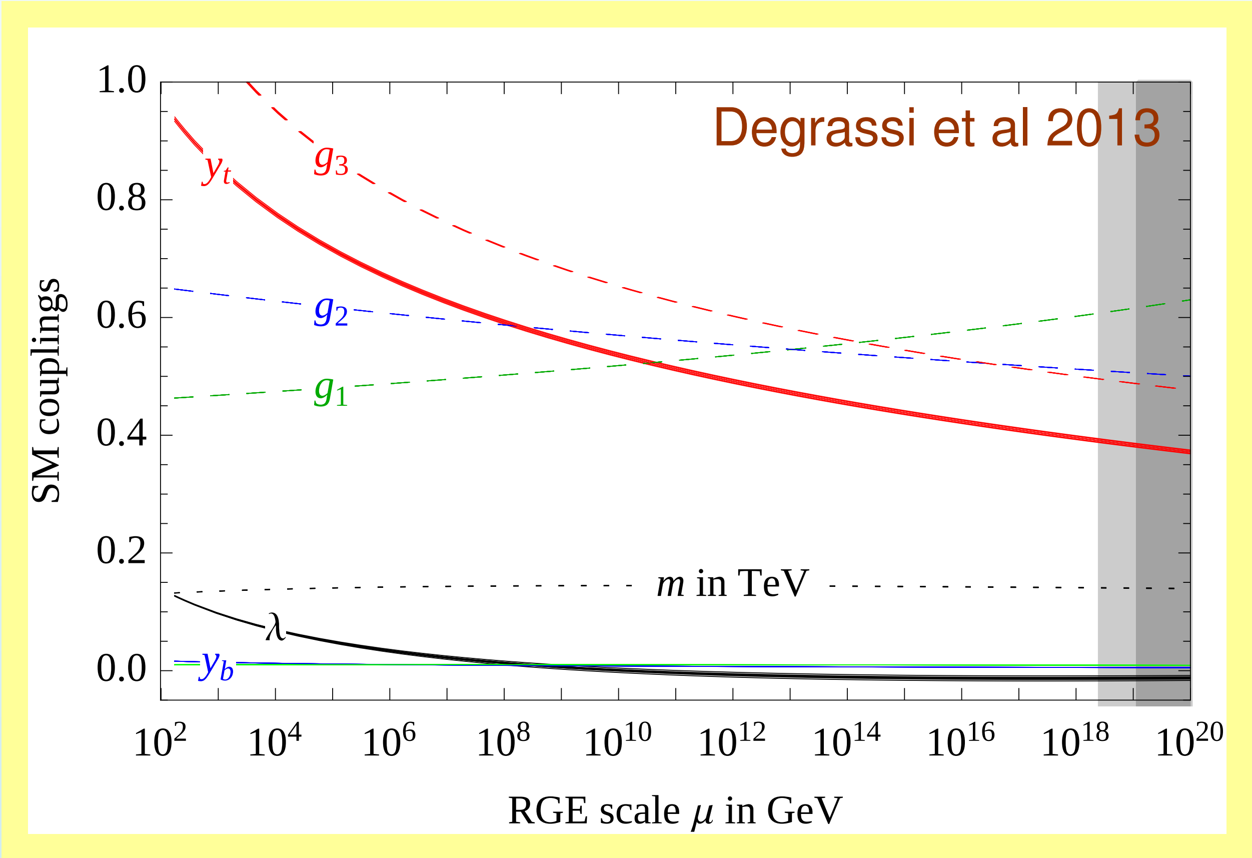
The RG equation for $v^2(\mu^2)$ follows from the RG equations for masses and massless coupling constants using one of the relations

$$v^2(\mu^2) = 4\,\frac{m_W^2(\mu^2)}{g^2(\mu^2)} = 4\,\frac{m_Z^2(\mu^2) - m_W^2(\mu^2)}{g'^2(\mu^2)} = 2\,\frac{m_f^2(\mu^2)}{y_f^2(\mu^2)} = 3\,\frac{m_H^2(\mu^2)}{\lambda(\mu^2)}\;.$$

As a key relation we will use F.J., Kalmykov, Veretin 2003

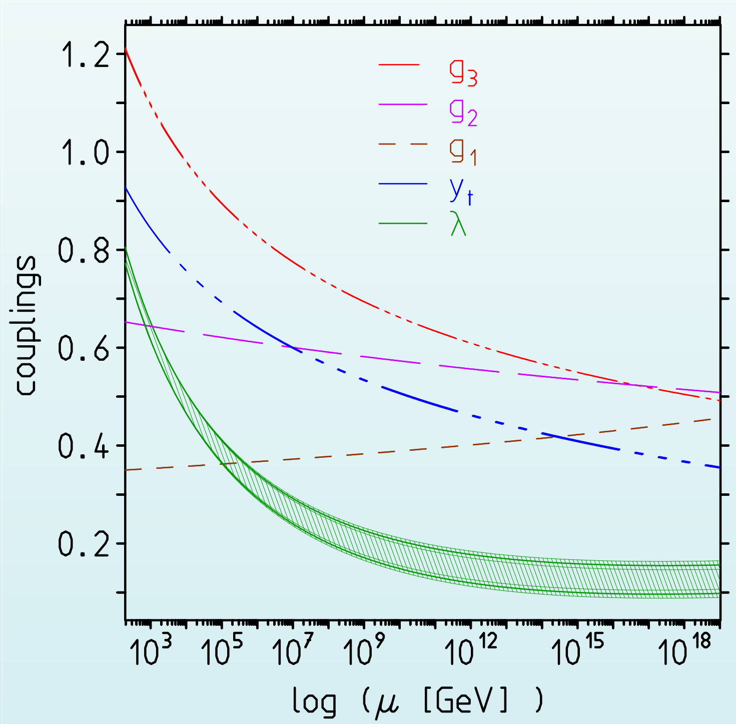
$$\mu^2\frac{d}{d\mu^2}v^2(\mu^2) = 3\,\mu^2\frac{d}{d\mu^2}\left[\frac{m_H^2(\mu^2)}{\lambda(\mu^2)}\right] \equiv v^2(\mu^2)\left[\gamma_{m^2} - \frac{\beta_\lambda}{\lambda}\right]$$

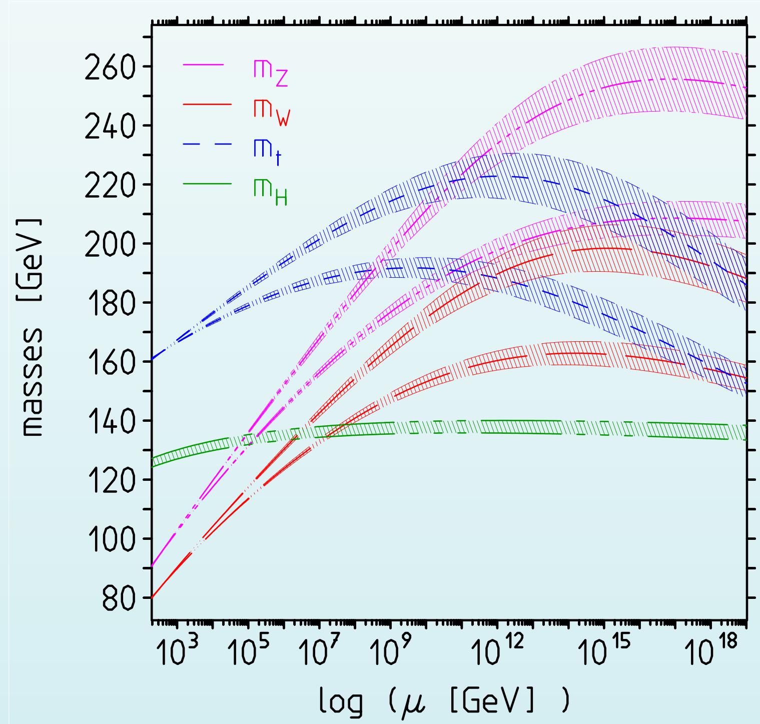
$$\gamma_{m^2} \equiv \mu^2\frac{d}{d\mu^2}\ln m^2\;, \beta_\lambda \equiv \mu^2\frac{d}{d\mu^2}\lambda\;, \gamma_{y_q} \equiv \mu^2\frac{d}{d\mu^2}\ln y_q\;,$$



Running of the SM gauge couplings $g_1 = \sqrt{5/3}g_Y, g_2,\ g_3$.

Find unstable vacuum (metastable in effective potential approach) $\lambda < 0$ for $\mu > 5 \times 10^{18}$ GeV





Left: the SM dimensionless couplings in the $\overline{\mathrm{MS}}$ scheme as a function of the renormalization scale for $M_H = 124 - 127$ GeV. Right: the running $\overline{\mathrm{MS}}$ masses for a Higgs mass of 124 GeV, higher bands, and for 127 GeV, lower bands.

- perturbation expansion works up to the Planck scale!
  no Landau pole or other singularities

- Higgs coupling decreases up to the zero of β_λ at $\mu_\lambda \sim 3.5 \times 10^{17}$ GeV, where it is small but still positive and then increases up to $\mu = M_{\rm Pl}$

❒ running top Yukawa QCD takes over: IR free ⇒UV free

❒ running Higgs self-coupling top Yukawa takes over: IR free ⇒UV free

Including all known RG coefficients (EW up incl 3–loop, QCD up incl 4–loop)

➠ except from β_λ, which exhibits a zero at about $\mu_\lambda \sim 10^{17}$ GeV, all other β-functions do not exhibit a zero in the range from $\mu = M_Z$ to $\mu = M_{\rm Pl}$.

➠ so apart form the $U(1)_Y$ coupling g_1, which increases only moderately, all other couplings decrease and perturbation theory is in good condition.

➠ at $\mu = M_{\rm Pl}$ gauge couplings are all close to $g_i \sim 0.5$, $y_t \sim 0.35$, $\sqrt{\lambda} \sim 0.32$.

- effective masses moderately increase (largest for m_Z by factor 2.8): scale like

$$m(\kappa)/\kappa \text{ as } \kappa = \mu'/\mu \to \infty,$$

i.e. mass effect get irrelevant as expected at high energies.

Comparison of $\overline{\rm MS}$ parameters at various scales: Running couplings for $M_H = 126$ GeV and $\mu_0 \simeq 1.4 \times 10^{16}$ GeV.

	my findings				Degrassi et al. 2013	
coupling \ scale	M_Z	M_t	μ_0	$M_{\rm Pl}$	M_t	$M_{\rm Pl}$
g_3	1.2200	1.1644	0.5271	0.4886	1.1644	0.4873
g_2	0.6530	0.6496	0.5249	0.5068	0.6483	0.5057
g_1	0.3497	0.3509	0.4333	0.4589	0.3587	0.4777
y_t	0.9347	0.9002	0.3872	0.3510	0.9399	0.3823
$\sqrt{\lambda}$	0.8983	0.8586	0.3732	0.3749	0.8733	i 0.1131
λ	0.8070	0.7373	0.1393	0.1405	0.7626	- 0.0128

Most groups find just instable vacuum at about $\mu \sim 10^9$ GeV! [not independent, same $\overline{\rm MS}$ input]

Note: $\lambda = 0$ is an essential singularity and the theory cannot be extended beyond a possible zero of λ: remind $v = \sqrt{6m^2/\lambda}$!!! i.e. $v(\lambda) \to \infty$ as $\lambda \to 0$
besides the Higgs mass $m_H = \sqrt{2}\, m$ all masses $m_i \propto g_i\, v \to \infty$ different cosmology

The issue of quadratic divergences in the SM

Hamada, Kawai, Oda 2012: coefficient of quadratic divergence has a zero not far above $\Lambda_{\rm Pl}$. My evaluation zero below $\Lambda_{\rm Pl}$ $\Rightarrow$has physical meaning

$$\delta m_H^2 = \frac{\Lambda^2}{16\pi^2}\, C_1$$

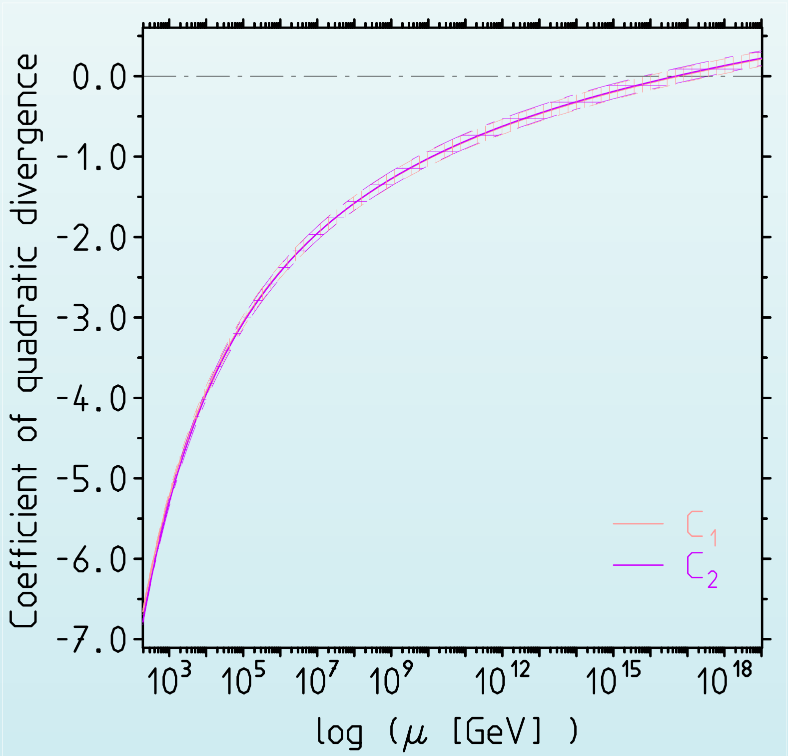
Veltman 1978 modulo small lighter fermion contributions, one-loop coefficient function C_1 is given by

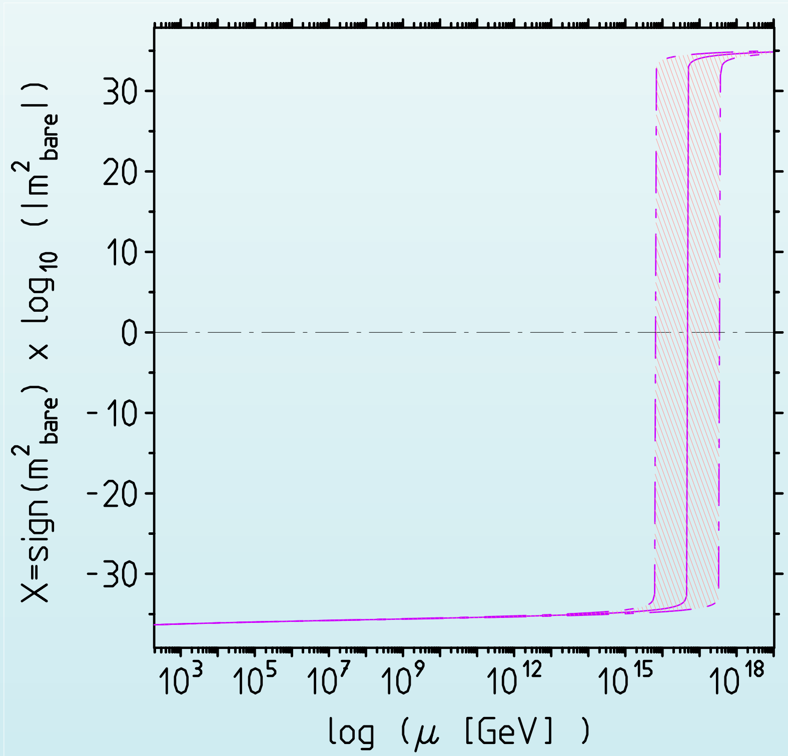
$$C_1 = \frac{6}{v^2}(M_H^2 + M_Z^2 + 2M_W^2 - 4M_t^2) = 2\,\lambda + \frac{3}{2}\,g'^2 + \frac{9}{2}\,g^2 - 12\,y_t^2$$

Key point:

C_1 is universal and depends on dimensionless gauge, Yukawa and Higgs self-coupling only, the RGs of which are unambiguous, similarly for the two-loop coefficient C_2 (where however results differ by different groups [non-universal?]). The correction is numerically small, fortunately.

Now the SM for the given parameters makes a prediction for the bare mass parameter in the Higgs potential:





The EW phase transition in the SM. Left: the zero in C_1 and C_2 for $M_H = 125.9 \pm 0.4$ GeV. Right: shown is $X = \text{sign}(m^2_{\text{bare}}) \times \log_{10}(|m^2_{\text{bare}}|)$, which represents $m^2_{\text{bare}} = \text{sign}(m^2_{\text{bare}}) \times 10^X$.

- in the broken phase $m^2_{\rm bare} = \frac{1}{2}\, m^2_{H\,\rm bare}$, which is calculable!

- the coefficient $C_n(\mu)$ exhibits a zero, for $M_H = 125$ GeV at about $\mu_0 \sim 7 \times 10^{16}$, not far below $\mu = M_{\rm Planck}$

- at the zero of the coefficient function the counterterm $\delta m^2 = m^2_{\rm bare} - m^2 = 0$ (m the $\overline{\rm MS}$ mass) vanishes and the bare mass changes sign

- this represents a phase transition (PT), which triggers the Higgs mechanism as well as cosmic inflation

- at the transition point μ_0 we have $v_{\rm bare} = v(\mu_0^2)$, where $v(\mu^2)$ is the $\overline{\rm MS}$ renormalized VEV

- the jump in vacuum density, thus agrees with the renormalized one: $-\Delta\rho_{\rm vac} = \frac{\lambda(\mu_0^2)}{24}\, v^4(\mu_0^2)$, and thus is $O(v^4)$ and **not** $O(M^4_{\rm Planck})$.

In any case at the zero of the coefficient function there is a phase transition, which corresponds to a restoration of the symmetry . Such transition would take place at a scale $\mu \sim 10^{16}$ to 10^{18} one to three orders of magnitude below the Planck scale, at cosmic times $\sim 0.23 \times 10^{-38}$ to 10^{-42} sec looks to have triggered inflation.

Hot universe ⇒finite temperature effects:

❐ finite temperature effective potential $V(\phi, T)$:

$T \neq 0$: $V(\phi, T) = \frac{1}{2}\left(g_T\, T^2 - \mu^2 \right) \phi^2 + \frac{\lambda}{24} \phi^4 + \cdots$

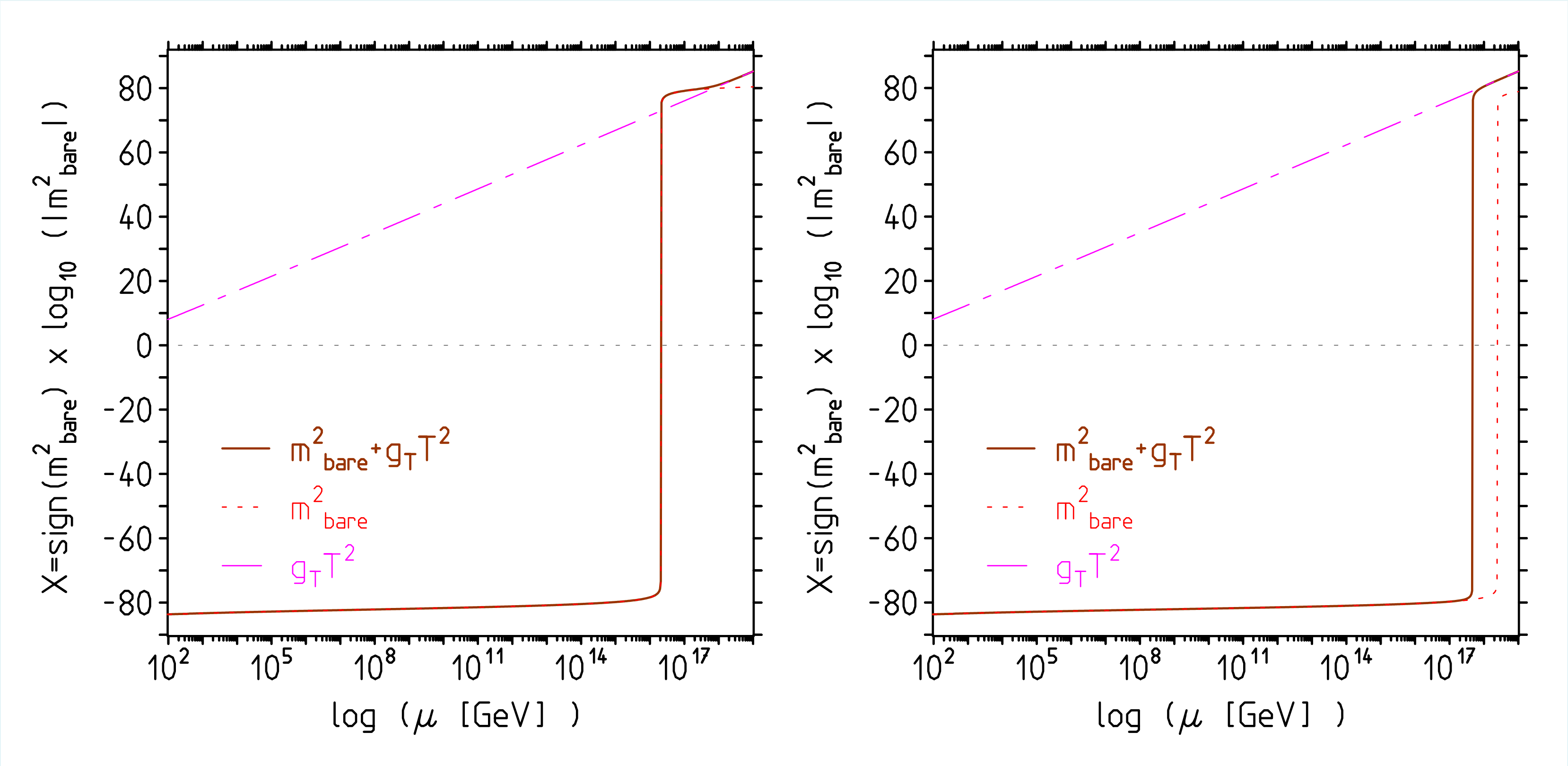
Usual assumption: Higgs is in the broken phase $\mu^2 > 0$

EW phase transition is taking place when the universe is cooling down below the critical temperature $T_c = \sqrt{\mu^2 / g_T}$.

My scenario: above PT at μ_0 SM in symmetric phase $-\mu^2 \to m^2 = (m_H^2 + \delta m_H^2)/2$

Is the phase transition is triggered by δm_H^2 or by $g_T\, T^2$ term? Which term is larger in the early universe?

$$g_T(M_{\rm Pl}) = \frac{1}{4v^2}\left(2m_W^2 + m_Z^2 + 2m_t^2 + \frac{1}{2}\,m_H^2\right) = \frac{1}{16}\left[3\,g^2 + g'^2 + 4\,y_t^2 + \frac{2}{3}\,\lambda\right] \approx 0.0980 \sim 0.1$$



Effect of finite temperature on the phase transition

Remark on the impact on inflation

Guth, Starobinsky, Linde, Albrecht et al, Mukhanov, ...

- the "inflation term" comes in via the SM energy-momentum tensor
- adds to the r.h.s of the Friedmann equation ($\dot{X}$ = time derivative of X)

$$\ell^2 \left(V(\phi) + \frac{1}{2}\,\dot{\phi}^2 \right)$$

$\ell^2 = 8\pi G/3$, $M_{\rm Pl} = (G)^{-1/2}$ is the Planck mass, G Newton's gravitational constant

- Inflation requires exponential growth $a(t) \propto \mathrm{e}^{Ht}$ of radius $a(t)$ of the universe

$H(t) = \dot{a}/a(t)$ the Hubble constant at cosmic time t

In our scenario in symmetric phase:

- Hubble constant during the very early radiation dominated era
  $H = \ell\,\sqrt{\rho} \simeq 1.66\;(k_B T)^2\;\sqrt{102.75}\,M_{\rm Pl}^{-1}$, at Planck time $H_i \simeq 16.83\,M_{\rm Pl}$

❐ Higgs contribution to energy momentum tensor ⇒contribution to energy density and pressure

$$\rho_\phi = \frac{1}{2}\dot{\phi}^2 + V(\phi)\;;\quad p_\phi = \frac{1}{2}\dot{\phi}^2 - V(\phi)\;.$$

❐ second Friedman equation $\ddot{a}/a = -\frac{\ell^2}{2}\,(\rho + 3p)$

❐ condition for growth $\ddot{a} > 0$ – requires $p < -\rho/3$ and hence – $\frac{1}{2}\dot{\phi}^2 < V(\phi)$

❐ first Friedman equation reads $\dot{a}^2/a^2 + k/a^2 = \ell^2\,\rho$

may be written as

$$H^2 = \ell^2\left[V(\phi) + \tfrac{1}{2}\,\dot{\phi}^2\right] = \ell^2\,\rho$$

field equation

$$\ddot{\phi} + 3H\dot{\phi} = -V'(\phi)$$

"flattenization" by inflation: curvature term $k/a^2(t) \sim k\ \exp(-2Ht) \to 0$ ($k = 0, \pm 1$ the normalized curvature)

$\Rightarrow$universe looks effectively flat ($k = 0$) for any initial k

Inflation looks to be universal for quasi-static fields $\dot{\phi} \sim 0$ and $V(\phi)$ large positive

$\Rightarrow a(t) \propto \exp(Ht)$ with $H \simeq \ell \sqrt{V(\phi)}$

This is precisely what the transition to the symmetric phase suggests: by very heavy Higgs $\rho_{\rm vac} = \langle V(\Phi) \rangle \approx m_b^2 \langle \Phi^+ \Phi \rangle$ =dark energy

The leading behavior is characterized by a free massive scalar field with potential

$V = \frac{m^2}{2}\phi^2$ $\Rightarrow$ $H^2 = (\dot{a}/a)^2 = \frac{m^2}{6}\phi^2$ and $\ddot{\phi} + 3H\dot{(\phi)} = m^2\phi$ ➠ damped HO!

Clearly supported by observation: Planck 2013 results

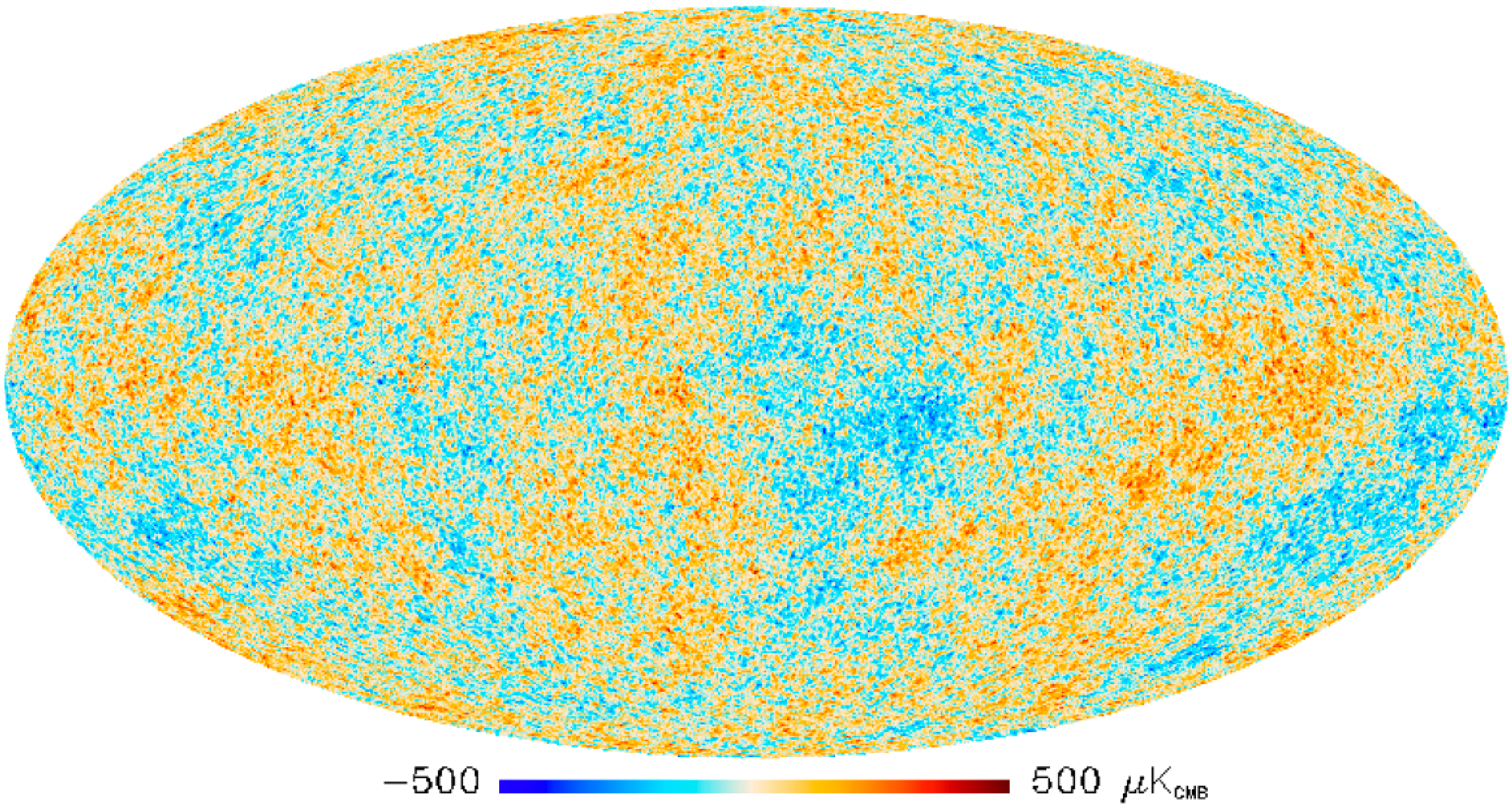


Fig. 14. The SMICA CMB map (with 3 % of the sky replaced by a constrained Gaussian realization).

The cosmological constant is characterized by the equation of state $w = p/\rho = -1$, in my scenario a prediction of the SM before the PT ($\mu > \mu_0$) which triggers inflation, and which is stopped by the PT ($\mu = \mu_0$); indeed Planck (2013) finds $w = -1.13^{+0.13}_{-0.10}$.

Scalar density fluctuations: $\delta\rho = \frac{\mathrm{d}V}{\mathrm{d}\phi}\,\delta\phi$ also look OK!

Planck data are consistent with Gaussian primordial fluctuations. There is no evidence for primordial Non Gaussian (NG) fluctuations in shapes (local, equilateral and orthogonal).

- The scenario suggested by the present analysis is a Gaussian potential with small anharmonic perturbations, since $m^2_{\rm bare}$ is predicted to be large while $\lambda_{\rm bare}$ remains small. Also the bare kinetic term is logarithmically "unrenormalized" only.

- numbers depend sensibly on what $\lambda(M_H)$ and $y_t(M_t)$ are (LHC & future ILC!)

Reheating and baryogenesis

❒ inflation: exponential growth = exponential cooling

❒ reheating: pair created heavy states $X, \bar{X}$ in originally hot radiation dominated universe decay into lighter matter states which reheat the universe

❒ baryogenesis: X particles produce particles of different baryon-number B and/or different lepton-number L

Sacharow condition for baryogenesis:

- $\not{B}$

❒ small $\not{B}$ is natural in LEESM scenario due to the close-by dimension 6 operators
Weinberg 1979, Buchmüller, Wyler 1985,Grzadkowski et al 2010

❒ suppressed by $(E/\Lambda_{\rm Pl})^2$ in the low energy expansion. At the scale of the EW phase transition the Planck suppression factor is 1.3×10^{-6}.

❒ six possible four-fermion operators all $B - L$ conserving!

- $\not{C}$, $\not{CP}$, out of equilibrium

X =Higgs! – unknown X particles are known very heavy Higgs in symmetric phase of SM: **Primordial Planck medium Higgses**

All relevant properties known: mass, width, branching fractions, CP violation properties!

$$m_{Hb} = \frac{M_{\rm Pl}}{4\sqrt{2}\pi}\sqrt{C(M_{\rm Pl})} \approx 3.6 \times 10^{17}\ \text{GeV}$$
$$\Gamma_H \simeq \Gamma(H \to t\bar{t}) = \frac{m_{Hb}}{16\pi} N_c\, y_t^2(M_{\rm Pl}) \simeq 7.5 \times 10^{-3}\, m_{Hb} \simeq 1.35 \times 10^{15}\ \text{GeV}$$
$$\tau_H = 1/\Gamma_H \simeq 5.0 \times 10^{-40}\ \text{sec}\,,$$

pretty stable! life time supports the argument that, for some time, the effective couplings essentially do not change when the system is driven out of equilibrium. Compare: Planck time $t_{\rm Pl} \simeq 5.4 \times 10^{-44}$ sec, EW transition $t_H \approx 4.7 \times 10^{-41}$ sec.

Stages: ❒ $k_B T > m_X$ ⇒thermal equilibrium X production and X decay in balance

❒ $H \approx \Gamma_X$ and $k_B T < m_X$ ⇒X-production suppressed, out of equilibrium

CP violating channels: [$\rho = 0.131,\ \eta = 0.345$] (note $y_t^2 \approx 0.123$ for dominant mode)
$H^+ \to t\bar{d}$ with rate $\propto y_t y_d V_{td} \sim 5.5 \times 10^{-8} (1 - \rho - \mathrm{i}\eta)$
$H^- \to b\bar{u}$ with rate $\propto y_b y_u V_{ub} \sim 1.2 \times 10^{-9} (\rho - \mathrm{i}\eta)$

after EW phase transition: $t \to W^{*+} d$ and $b \to W^{*-} u$ etc.

❖Matter production of fermions most abundantly produced for largest Yukawa couplings i.e predominantly into yet massless“would be heavy” states like top, bottom, τ, ...

❖after EW phase transition: the now heavy states decay into the lighter ones with the smallest Yukawas, cascading down the CKM coupling scheme.

Seems we are all descendants of tops!

Baryogenesis most likely a SM effect!

Conclusion

❑ Higgs not just the Higgs: its mass $M_H = 125.9 \pm 0.4$ GeV has a very peculiar value!!

➠ ATLAS and CMS results may “revolution” particle physics in an unexpected way, namely showing that the SM has higher self-consistency (conspiracy) than expected and previous arguments for the existence of new physics may turn out not to be compelling

➠ SM as a low energy effective theory of some cutoff system at $M_{\rm Pl}$ consolidated; crucial point $M_{\rm Pl} >>>> \ldots$ from what we can see!

❑ Last but not least in Higgs phase:

There is no hierarchy problem in the SM!

In the broken phase, characterized by the non-vanishing Higgs field vacuum expectation value (VEV) $v(\mu^2)$, all the masses are determined by the well known mass-coupling relations

$$m_W^2(\mu^2) = \frac{1}{4} g^2(\mu^2)\, v^2(\mu^2) \; ; \quad m_Z^2(\mu^2) = \frac{1}{4} (g^2(\mu^2) + g'^2(\mu^2))\, v^2(\mu^2) \; ;$$
$$m_f^2(\mu^2) = \frac{1}{2} y_f^2(\mu^2)\, v^2(\mu^2) \; ; \quad m_H^2(\mu^2) = \frac{1}{3} \lambda(\mu^2)\, v^2(\mu^2) \; .$$

My main theses:

- There is no hierarchy problem of the SM
- A super symmetric or any other extension of the SM cannot be motivated by the (non-existing) hierarchy problem
- running of SM couplings is triggering Higgs mechanism at about 10^{17} GeV as

the universe cools down, in the broken phase the Higgs is naturally as light as other SM particles which are generated by the Higgs mechanism

- in the early symmetric phase quadratically enhanced bare mass term in Higgs potential triggers inflation, if Higgs to be the inflaton this enhancement is mandatory. My view: inflation is an unavoidable prediction of the SM

- dark energy at inflation times is given by Higgs mass term in symmetric phase; $\rho_{\mathrm{vac}} \sim m_b^2 \Phi^+ \Phi$ is a field decaying according to field-and Friedman-equation i.e. cosmological constant is a field $\propto \phi^2(t)$ decaying dynamically rather fast

  latter lowered by large negative Higgs condensate contribution from EW phase transition (fine tuning problem unsolved but not obviously a big mystery!)

- the Higgs mechanism terminates inflation and triggers the electroweak phase transition; reheating likely proceeds via the four heavy decaying Higgses into top quark pairs (predominantly) just before the jump into the broken phase after which heavy states decay into light normal matter

- SM most likely is able to explain baryon-asymmetry
- beyond SM physics likely still must exist, cold dark matter in particular; maybe needed to stabilize vacuum; however should not deteriorate the good features of SM; if sterile singlet netrinos are Majorana very large unprotected mass term (dark matter, seesaw-mechanism etc) OK
- Planck medium certainly exhibits lots of (chaotic) modes which may survive at long ranges as new physics, however, should be natural in low energy expansion e.g. any kind of moderate renormalizable extension of the SM like additional $U(1)$ or $SU(4)$ etc
  not GUTs or SUSY [such highly tuned conspiracies are very improbable]
- the big issue very delicate conspiracy between SM couplings: precision determination of parameters more important than ever $\Rightarrow$
  the challenge for LHC and ILC (λ, y_t and α_s),
  and for low energy hadron facilities for (hadronic effects in $\alpha(M_Z)$ and $\alpha_2(M_Z)$)

Keep in mind: the Higgs mass miraculously turns out to have a value as it was expected form vacuum stability. It looks like a tricky conspiracy with other couplings to reach this “purpose”. If it misses to stabilize the vacuum, why does it just miss it almost not?

Why not simple although it may well be more complicated?

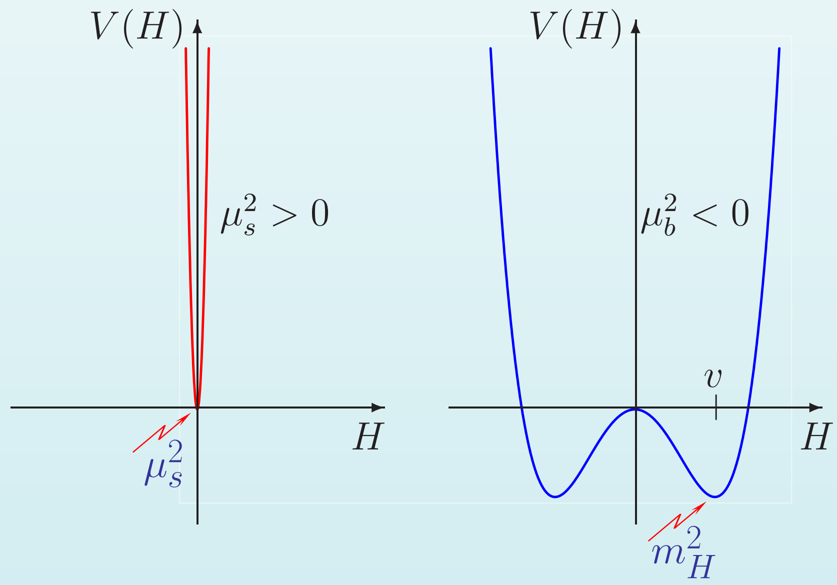
The SM seems to be much better than its reputation! A lot yet to be understood!

At least we now know why the top has to be so heavy
together with the Higgs so “light” given the gauge couplings

Thanks for your attention!

Bardzo dziękuję!

According to these well known relations why the Higgs should be of order of $\Lambda_{\rm Pl}^2$ while the others are small, of order v^2? Higgs naturally in the ballpark of the other particles! No naturalness problem!



Higgs potential of the SM a) in the symmetric ($\mu_s^2 > 0$) and b) in the broken phase ($\mu_b^2 < 0$). For $\lambda = 0.5$, $\mu_b = 0.1$ and $\mu_s = 1.0$

Masses given by curvature of the potential at the ground state need not be correlated, and in fact are not. Note not only sign of μ^2 changes but also its value!