Office hours, June 26, 2020

Friday, June 26, 2020 9:01 AM

Q: Why can you not give a fermion a vev?

A: Fermions transform in ½ rep. of Lorentz symmetry

$$\psi \to \left(\Lambda^{\mu}{}_{\nu}\right)^{1/2} \psi$$

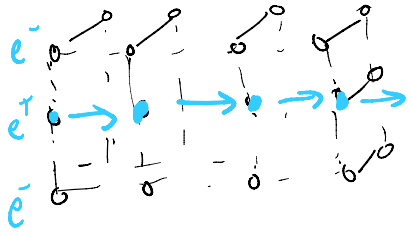
ψ spinor basis to contract Lorentz indices

$$\langle\psi\rangle \to \underbrace{\left(\Lambda^{\mu}{}_{\nu}\right)^{1/2}}_{\text{constant}} \langle\psi\rangle$$

Q: Vectors getting vev?

A. $\langle A_\mu \rangle = \text{const}$

Establishing a preferred frame.



Example of broken symmetry.

Crystal lattice structure does not respect continuous symmetry

Distinction is

$\mathcal{L}$ is Lorentz invariant

↳ describes interactions of ions under QED

But expanding on background that breaks to Lorentz symmetry.

Scalar vevs do not break Lorentz:

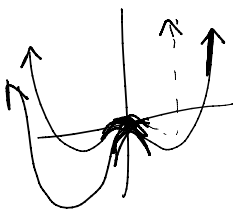
the vev background has no preferred direction, no preferred orientation

Q: At high T, Higgs potential in SM?

Q: At high T, Higgs potential in SM?

A: True that @ high T, we expect Higgs potential to restore EW symmetry.

At $T=0$: $V = \mu^2 |H|^2 + \lambda |H|^4$, $\mu^2 < 0$



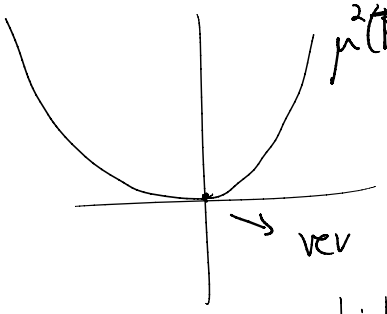
At high T: $V = \mu(T,H)^2 |H|^2 + \lambda(T,H) |H|^4$

$\mu^2(0,H) \sim$ 1-loop, n-loop corrections to μ^2

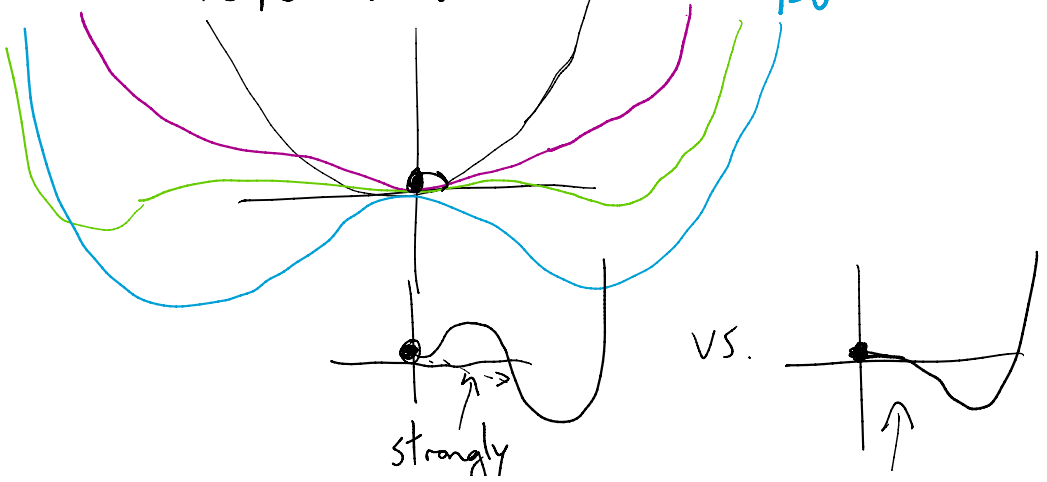
$\mu^2(T,H) \sim$ T=0 corrections + finite T corrections independent of $\langle H \rangle$, finite T corrections dependent on $\langle H \rangle$

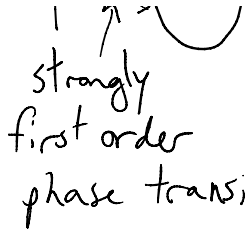
(field value)

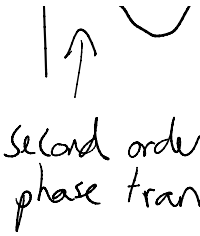
$\mu^2(T,H) > 0$ @ high T.



Temperature cools: high T, T_{int}, T_{int}, $T=0$





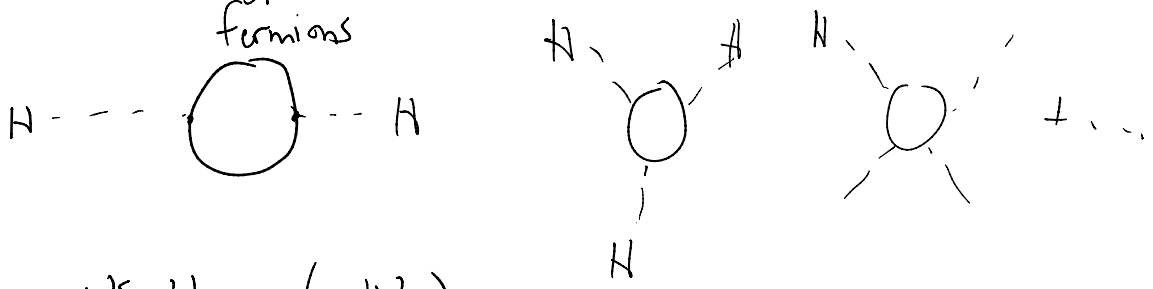


In SM, we calculate & find that for SM masses & couplings, we expect a second order phase transition.

What is this calculation? & Why do we need a first order phase transition for EW baryogenesis?

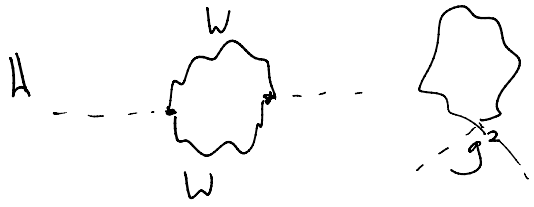
(1) Calculation

Evaluate Coleman Weinberg 1-loop correction to $V(H)$, and include finite T effects.

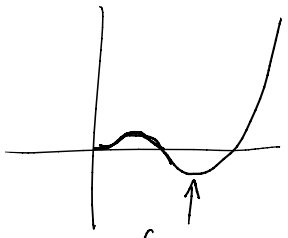


$$V_{corr.} \sim (-1)^{2s} \lambda^2 \log\left(\frac{H^2}{M^2}\right)$$

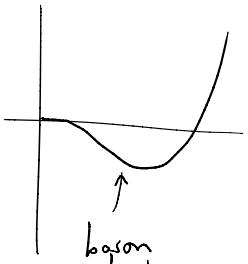
$$V_{full} = \mu^2 |H|^2 + \lambda |H|^4 + \sum_{f,b} (-1)^{2s} \lambda_{f,b}^2 \log\left(\frac{H^2}{M^2}\right)$$



fermions negative
bosons pos. (check signs)



fermion contrib. stronger to get 1st order



boson contrib. overwhelms fermions

If you do calc. with arbitrary top mass, fix W, get SFOPT for $m_t < 60$ GeV. Our $m_t = 173$ GeV.

Or For $m_h < 42$ GeV

A: Why SFOPT necessary?

3 commonly cited conditions for baryogenesis

Sakharov:

1. B violation
2. C + CP violation
3. Out of thermal equilibrium process.

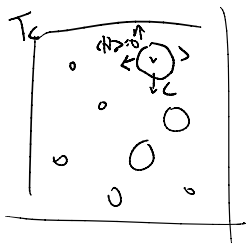
↳ In SM, B violation from EW sphalerons. nonperturbative, weakly coupled tunneling amplitudes that are very suppressed @ low T but unsuppressed @ high T.

EW sphaleron process act during the phase transition from $\langle H \rangle \neq 0$ to $\langle H \rangle = v$.

Only when tunneling amplitude between $\langle H \rangle = 0$ & $\langle H \rangle = v$.

Universe

$T \sim T_c$



$\Rightarrow \Delta B = 0$

$\Delta B \neq 0$

$\Delta B \neq 0 \rightarrow$

For 2nd PT, too smooth, bubbles do not form.
no baryon asymmetry.