$$V(\phi) = \tilde{\Lambda} - \frac{m^2}{2}\phi^2 + \frac{\lambda\phi^4}{4}$$

$m^2 > 0$

$\lambda > 0$

$$\left.\frac{dV}{d\phi}\right|_{\phi=v} = 0$$

$$\frac{d^2V}{d^2\phi} \geq 0$$

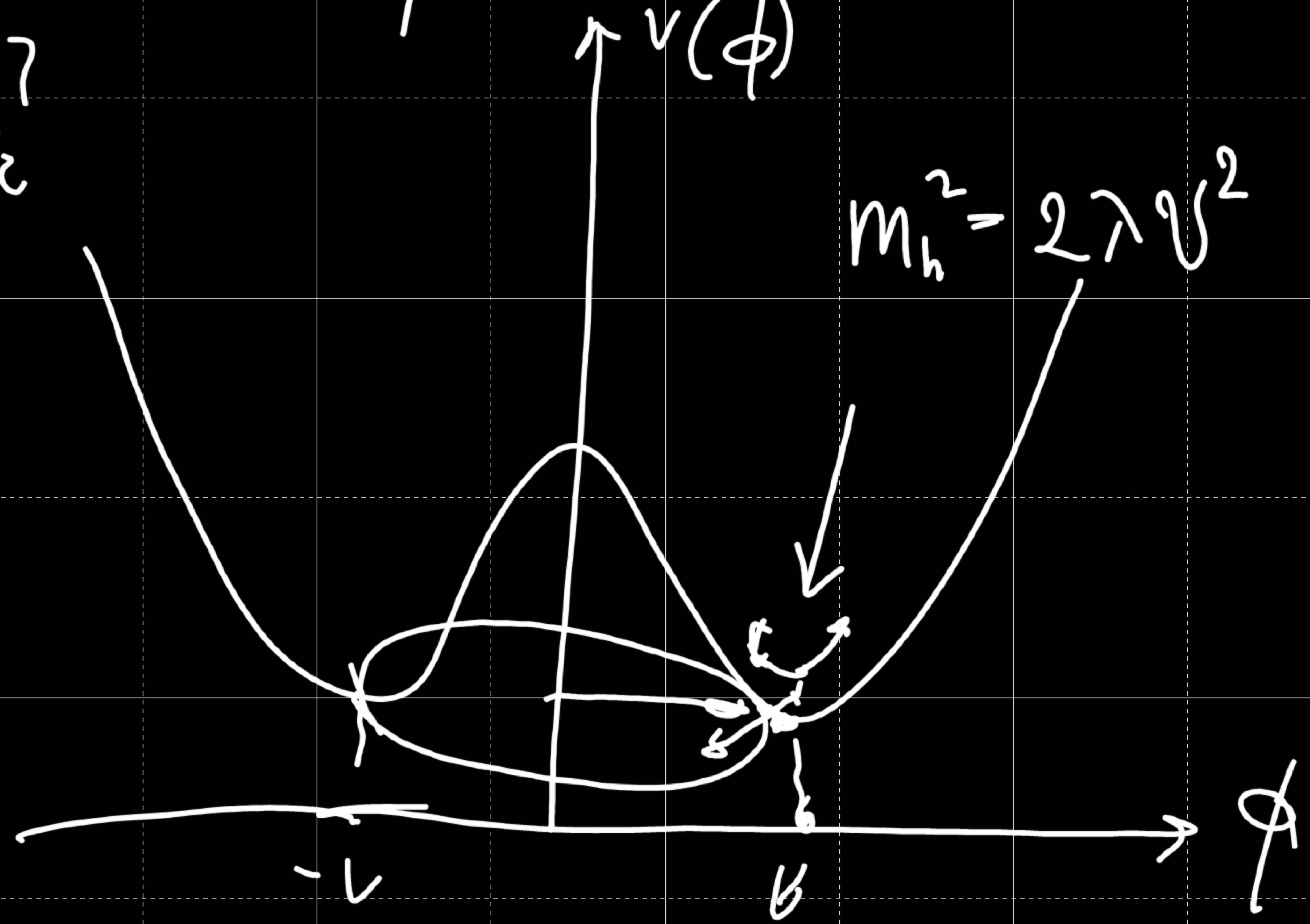
$\phi^2 = \phi_1^2 + \phi_2^2$

$\phi^2 = v^2 = \frac{m^2}{\lambda}$

$\phi_1 = v + h$

$\phi_2 = \chi$

$m_h^2 = 2\lambda v^2$



$$V(H) = -m^2 (H^\dagger H) + \lambda (H^\dagger H)^2$$

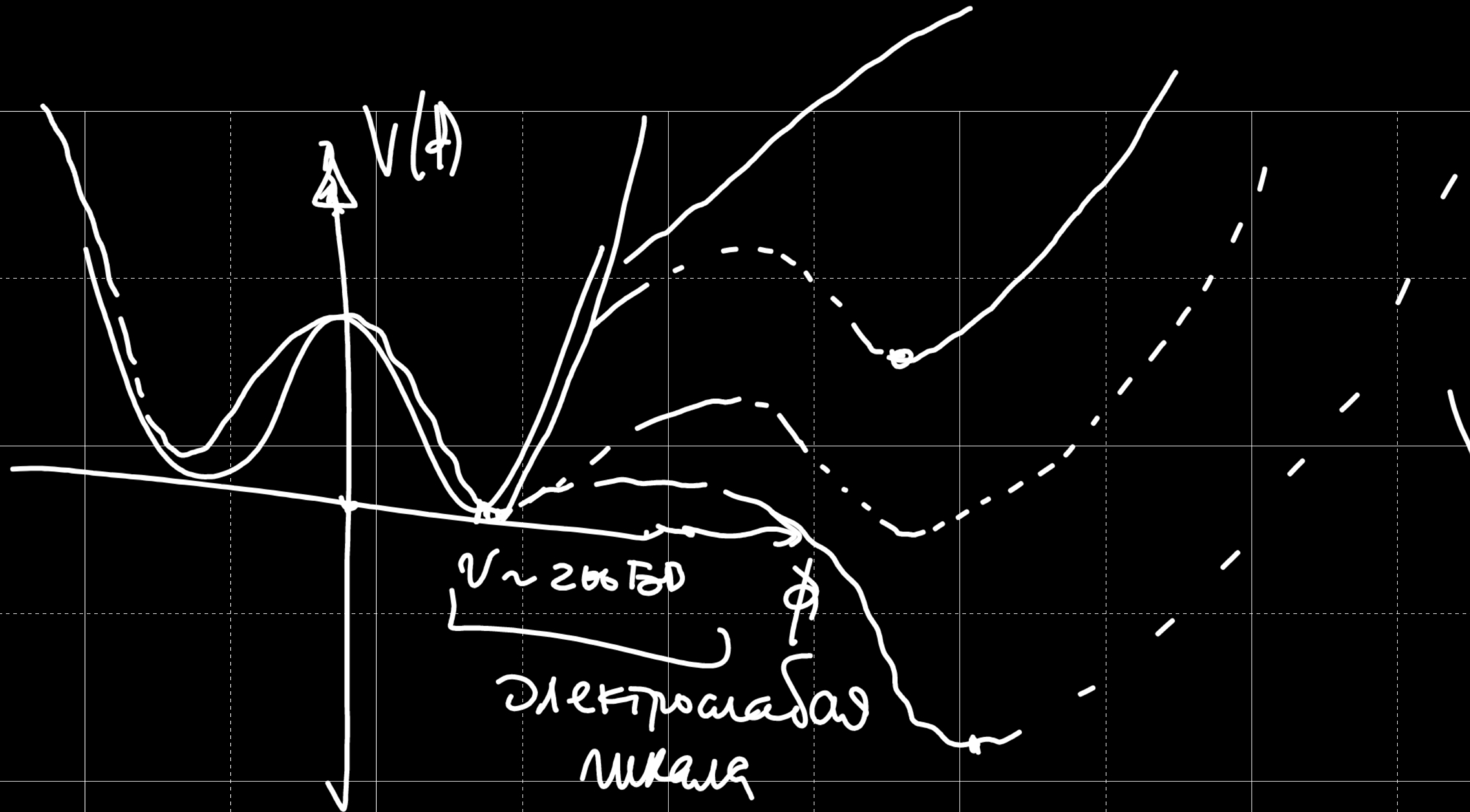
$$H = e^{i \frac{\sigma_a}{2} \chi_a(x)} \begin{pmatrix} 0 \\ \frac{1}{\sqrt{2}}(v+h) \end{pmatrix}$$

$$V(\phi) = \Lambda + \frac{\lambda}{4}(\phi^2 - v^2)^2$$

*) Λ – вакуум энергия (косм. пост) $\Lambda \sim (3 \cdot 10^{-3}$ эВ$)^4$

*) v – вакуум $\mu^- \to e^- \nu_\mu \bar{\nu}_e$ $v = 246$ ГэВ

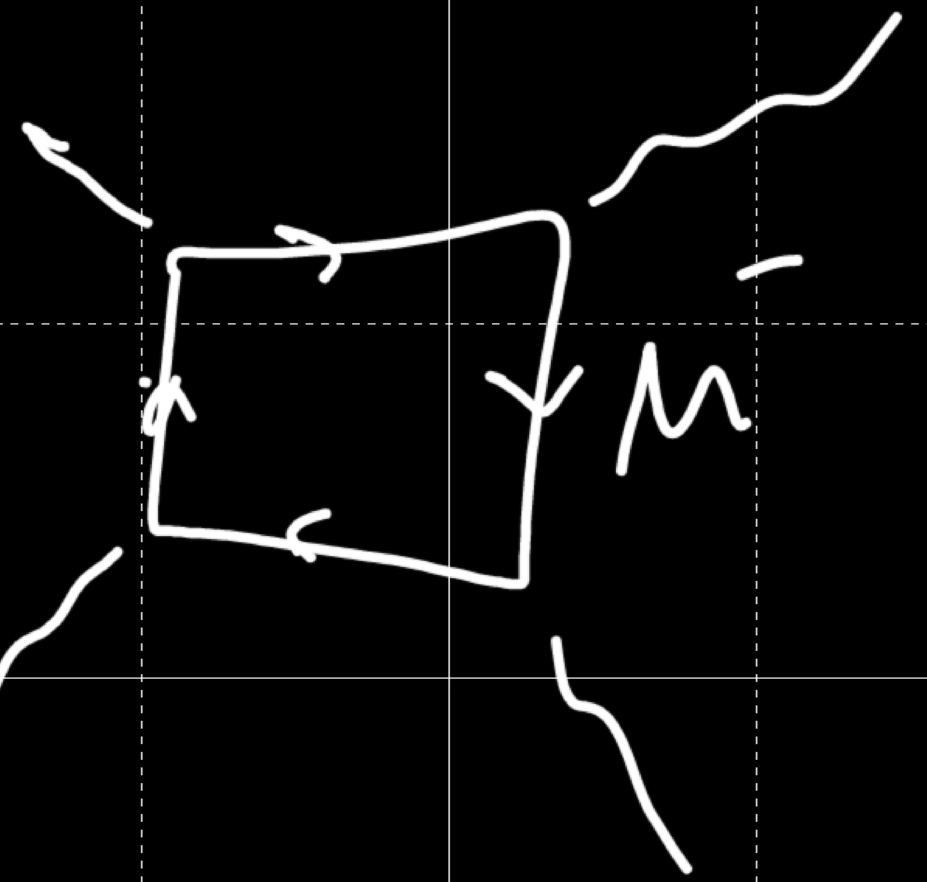
*) λ – масса M_h · $\lambda = 0{,}13$ $M_h = 125$ ГэВ



$$V(\phi) \to V_{eff}(\phi)$$

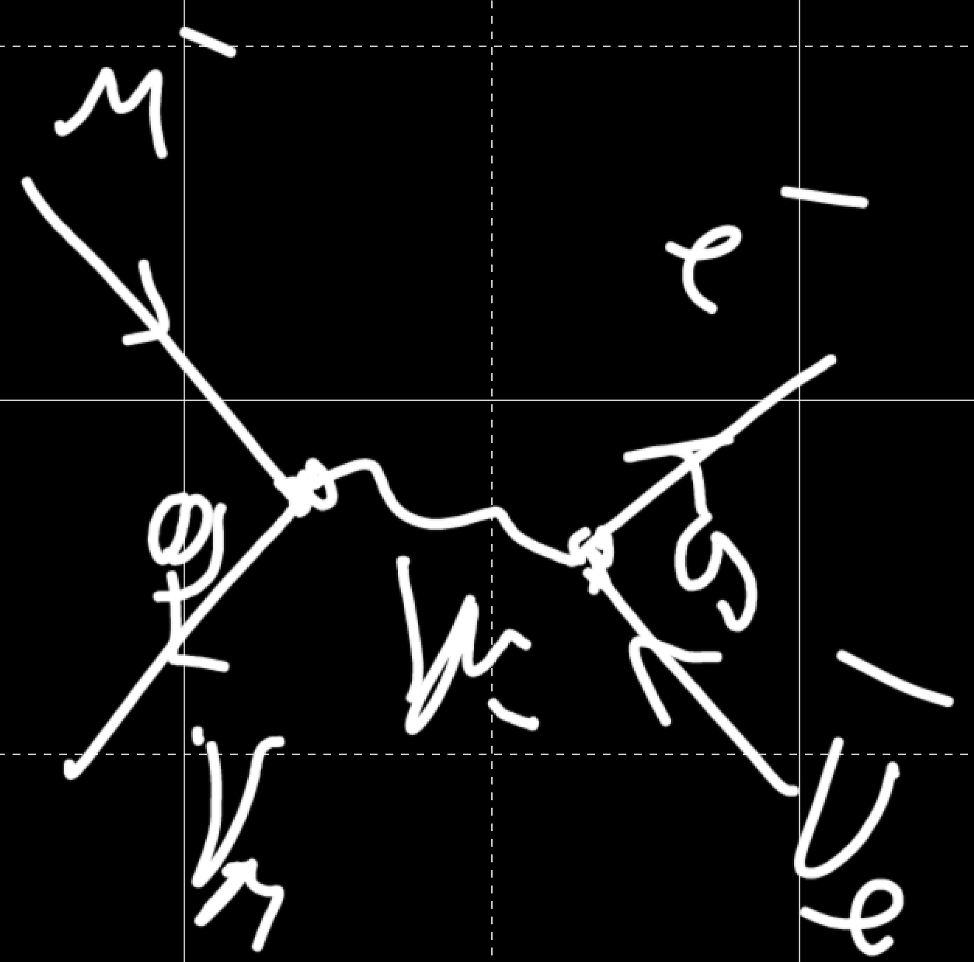
Эфф. действие и эфф потенциал

*) $S[\phi,\psi] \longrightarrow S_{eff}[\phi]$

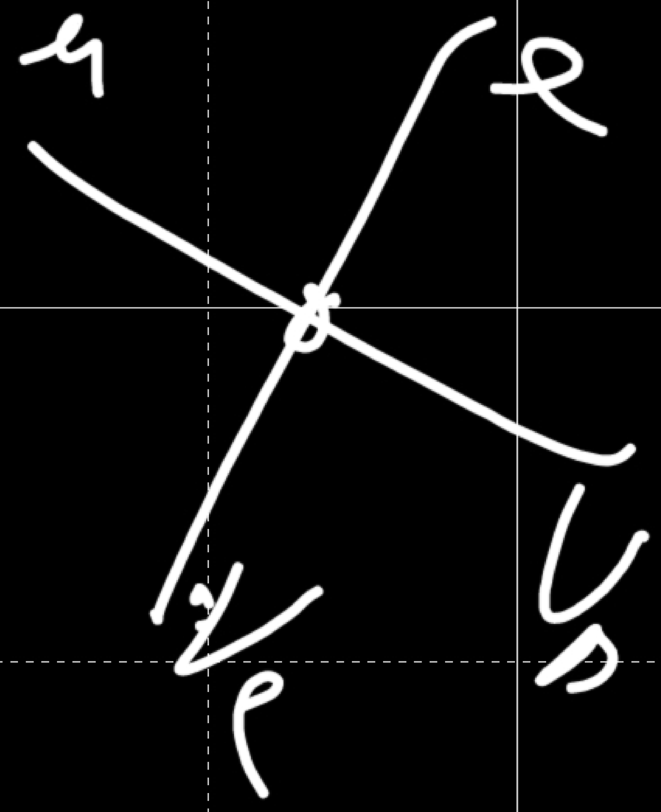


1) $e^{iS_{eff}[\phi]} = \int \mathcal{D}\psi \, e^{iS[\varphi,\psi]}$

2)



$\longrightarrow C_F$



$C_F \sim \frac{g^2}{M_W^2} \sim \frac{1}{v^2}$

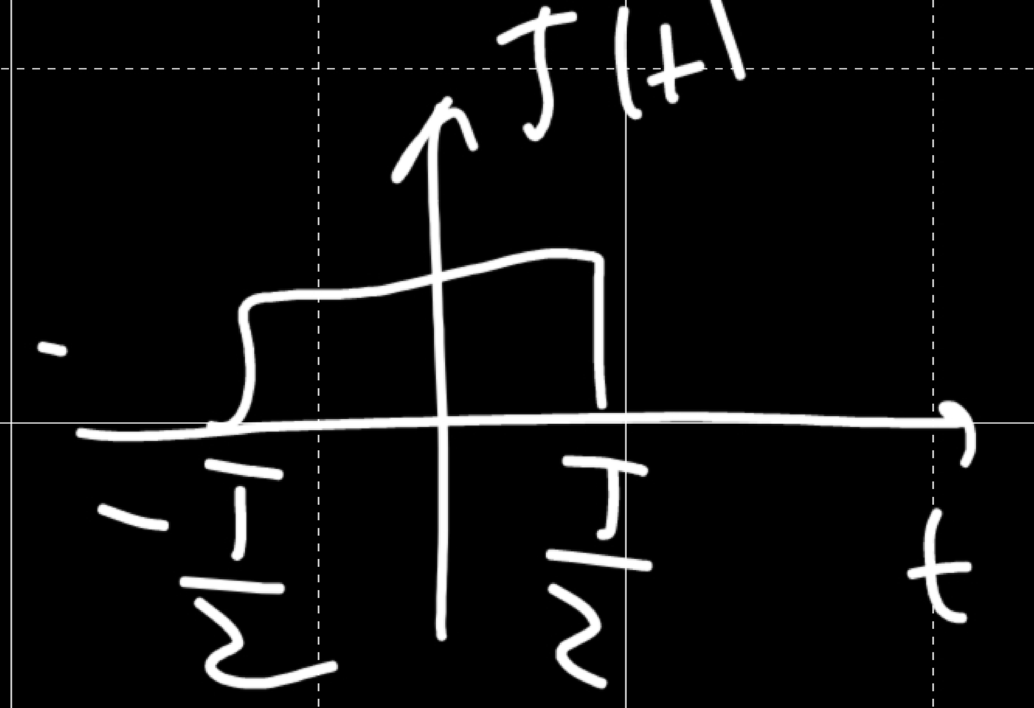
$$e^{iS_{\text{eff}}[\phi]} \stackrel{?}{=} \int d\varphi \, e^{iS[\varphi+\phi]}$$

$$\hat{\phi}(x) \qquad |0\rangle \qquad G_n(x_1 \ldots x_n) = \langle T \hat{\phi}_1(x_1) \ldots \hat{\phi}_n(x_n) \rangle =$$

$$Z[J(x)] = \sum_{n=0}^{\infty} \frac{G_n (iJ)^n}{n!} = \langle 0|0\rangle_J \left[= \int d\varphi \, \varphi(x_1) \ldots \varphi(x_n) e^{iS[\varphi]} \right.$$

$$Z[J] = \int d\varphi \, e^{\frac{i}{\hbar}\left(S[\varphi] + \varphi \cdot J\right)} = \langle 0^+ | 0^- \rangle_J \Rightarrow e^{-iE[J]\cdot T}$$

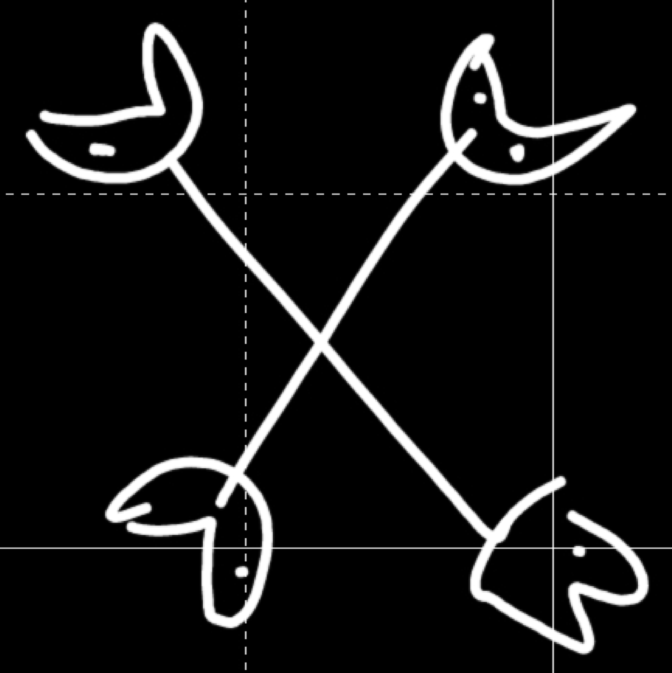
$$S[\varphi] = S_2[\varphi] + S_I[\varphi] = \frac{1}{2}\varphi_x K_{xy} \varphi_y + S_I[\varphi].$$



$$K_{xy} = \delta_{xy}(-\partial_x^2 - m^2)$$

$$\mathcal{L}_2 = \frac{1}{2}(\partial_\mu \varphi)^2 - \frac{m^2}{2}\varphi^2$$

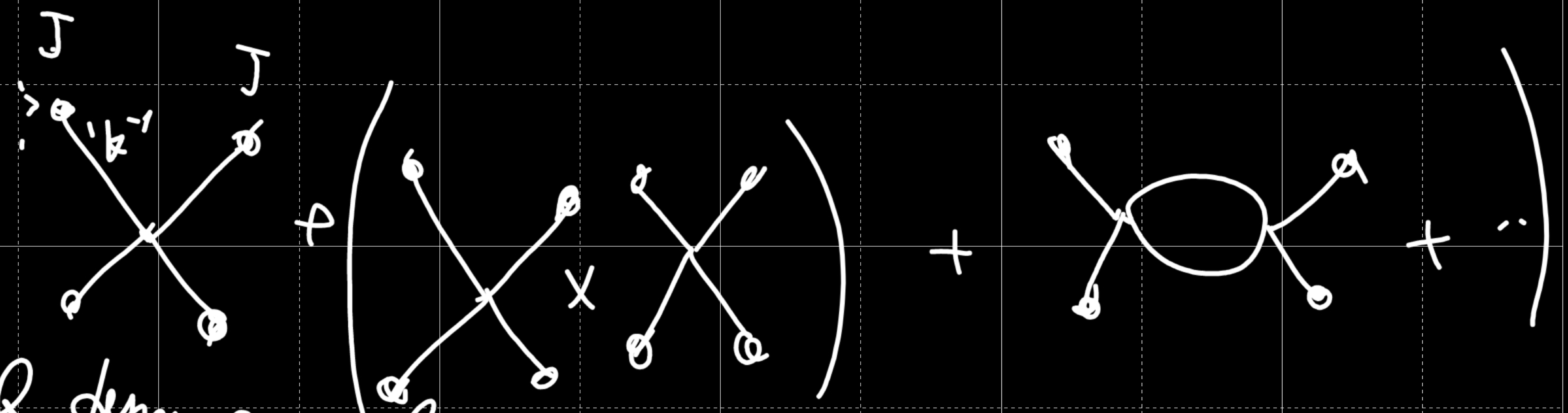
$$Z[J] = \exp\left(i S_I\left[\frac{\delta}{i\delta J}\right]\right) Z_0[J]$$

$$Z_0[J] = \int d\varphi\, e^{i\left(\frac{1}{2}\phi \cdot K \cdot \phi + \right.}$$, $=$ 

$$\phi \cdot K \equiv \int d^4x\, \phi(x) J(x)$$

$$= e^{-\frac{i}{2} J \cdot K^{-1} \cdot J} Z_0[0]$$

$$S_I = \int d^4x \left[\frac{\lambda \phi^4}{4} \right]$$

$$Z[J] = Z_0[J]\Big(1 +$$ 

$$Z[J] = e^{iW[J]}$$ → произв функ диаграмм

$$iW[J] = \sum_n \frac{W_n}{n!}(iJ)^n$$

$$-\frac{\delta W[J]}{\delta J(x)} = \frac{\langle 0|\phi(x)|0\rangle_J}{\langle 0|0\rangle_J} = \phi_J(x)$$

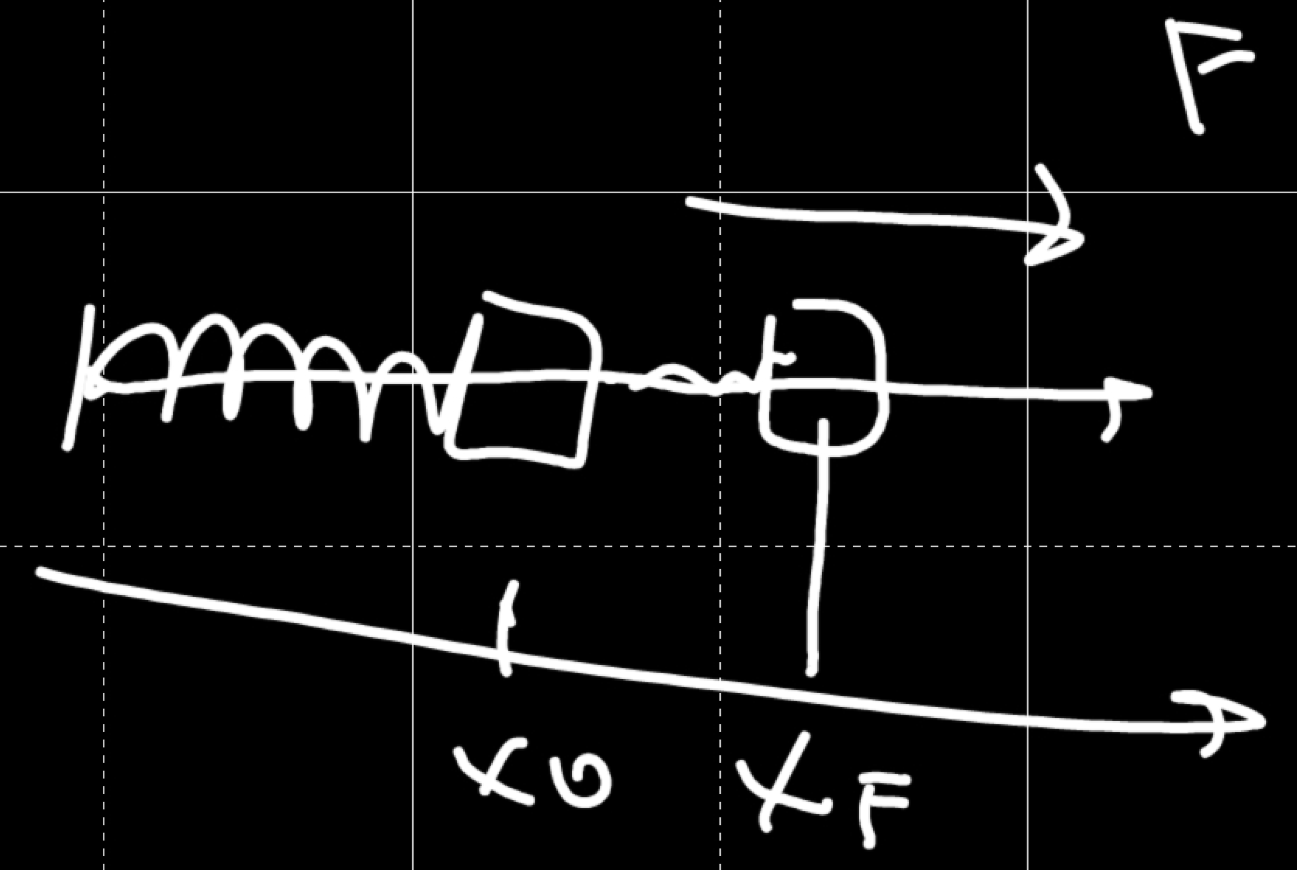
$$J(x) \longrightarrow \phi_J(x)$$

*) преобр Лежандр

$$W[J] \longrightarrow \boxed{\Gamma[\phi] = W[J_\phi] - \phi\cdot J_\phi}$$

$$J_\phi(x) \longrightarrow \phi(x)$$

$$\frac{\delta \Gamma[\phi]}{\delta \phi(x)} = -J_\phi$$



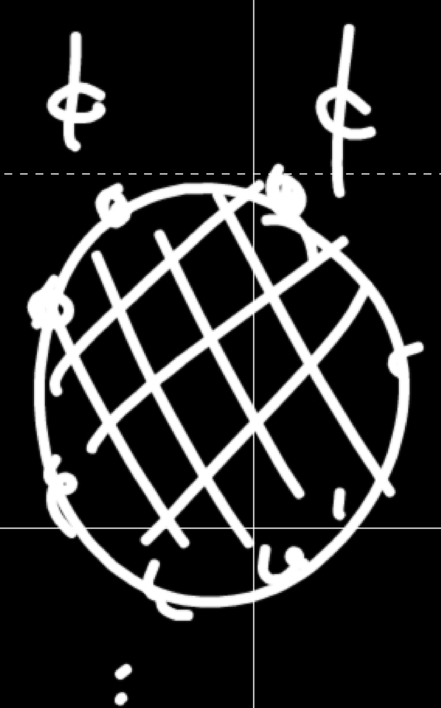
$$\left.\frac{\delta\Gamma}{\delta\phi}\right|_{\phi=\phi_c} = -J_{\phi_c} \longrightarrow \boxed{\left.\frac{\delta\Gamma}{\delta\phi}\right|_{\phi=\phi_c} = 0}$$

$$\frac{i}{p^2-m^2-\Sigma(p^2,m)}$$

← обобщ. класс. ур. движ

$$\Gamma[\phi] = \sum \frac{\Gamma_n}{n!}\phi^n \longrightarrow (W_2)_{xz}(\Gamma_2)_{zy} = -\delta_{xy}$$

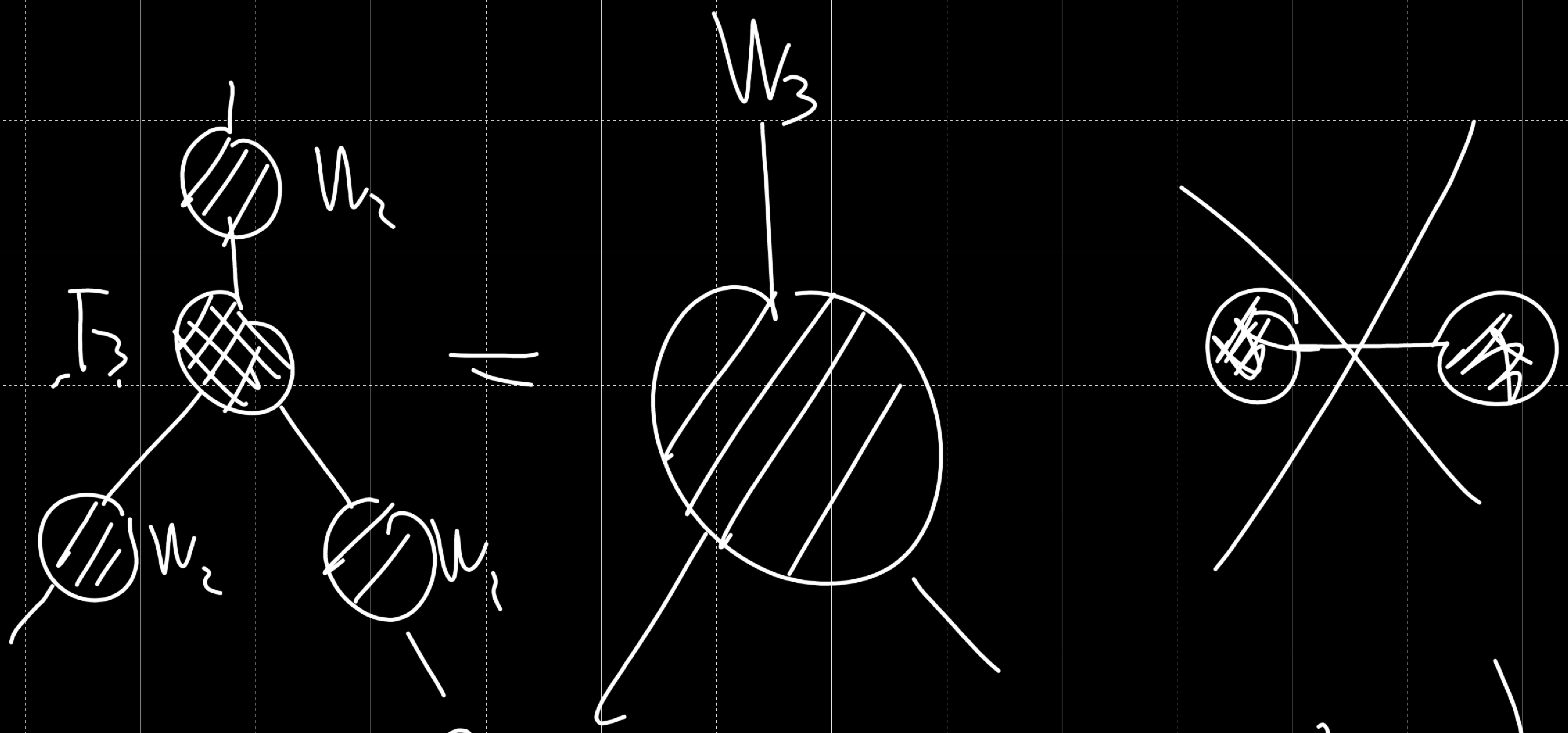
$$\sum \frac{1}{n!}$$



$$\boxed{\frac{\delta}{\delta\phi(x)}\frac{\delta W[J_\phi]}{\delta J(y)}}$$

$$= -\delta_{xz}$$

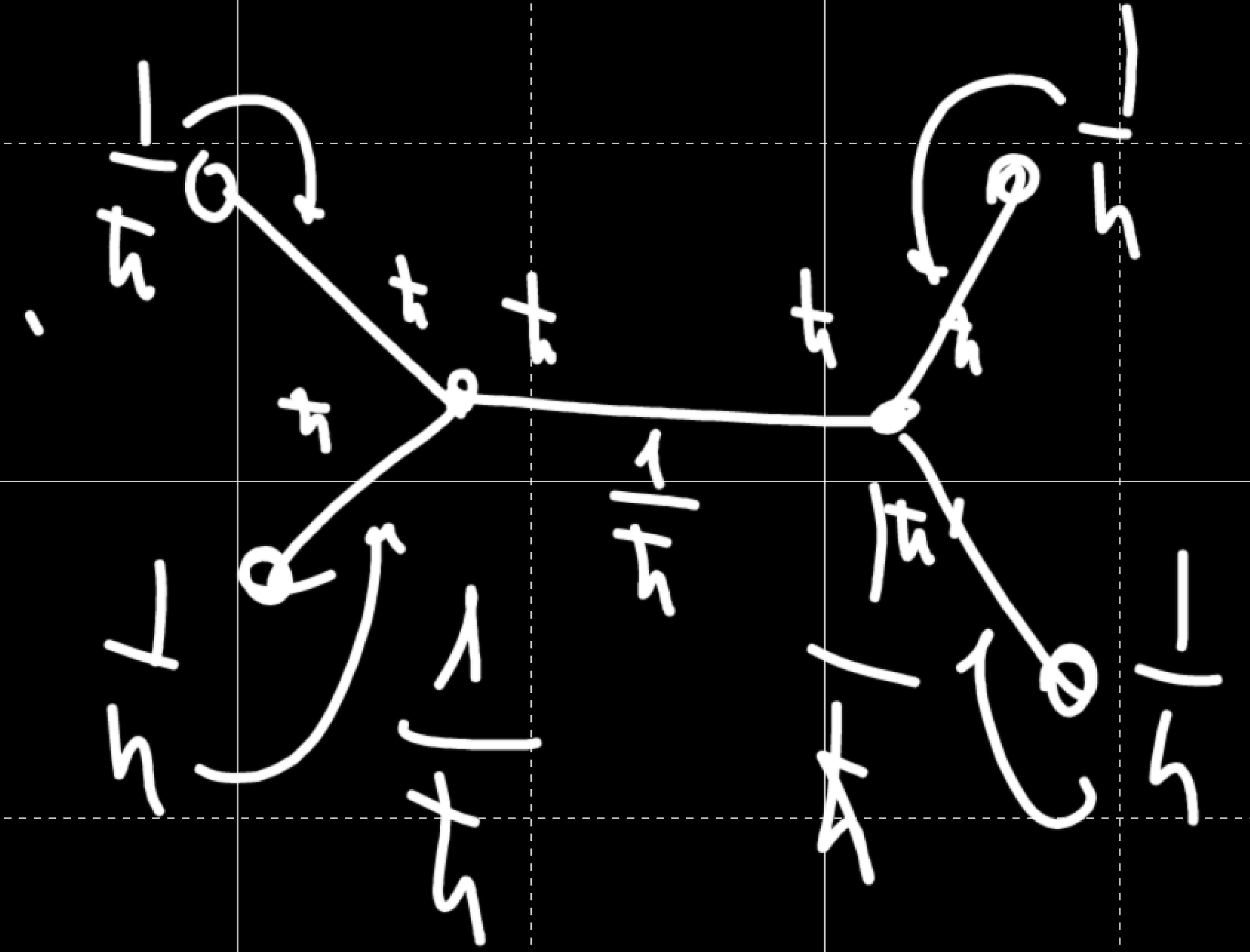
$$\frac{i}{p^2-m^2}\; i(p^2-m^2) = -1$$



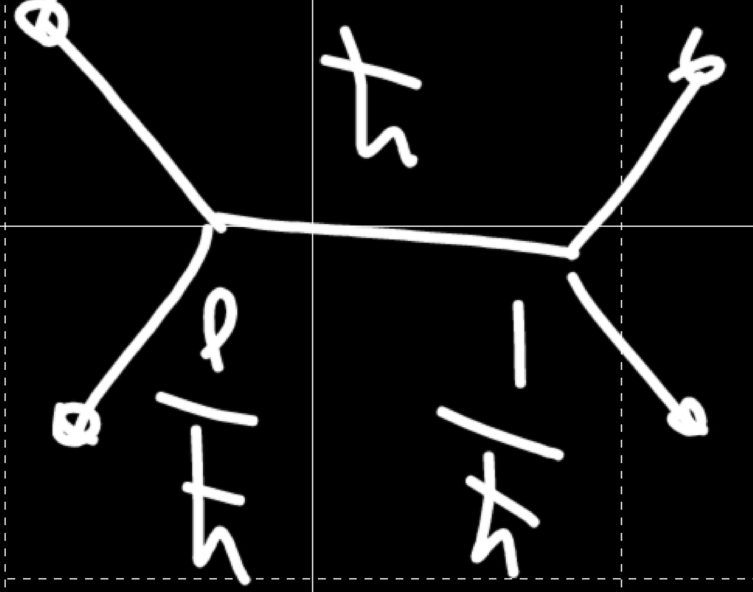
$$\Gamma[\phi] = \int d^4x \left(-V_{eff}(\phi) + Z(\phi)(\partial_\mu \phi)^2 + \dots \right) \longrightarrow -V_{eff}(\phi_0)\, V_3 \cdot T$$

$\phi = \phi_c = \mathrm{const}$

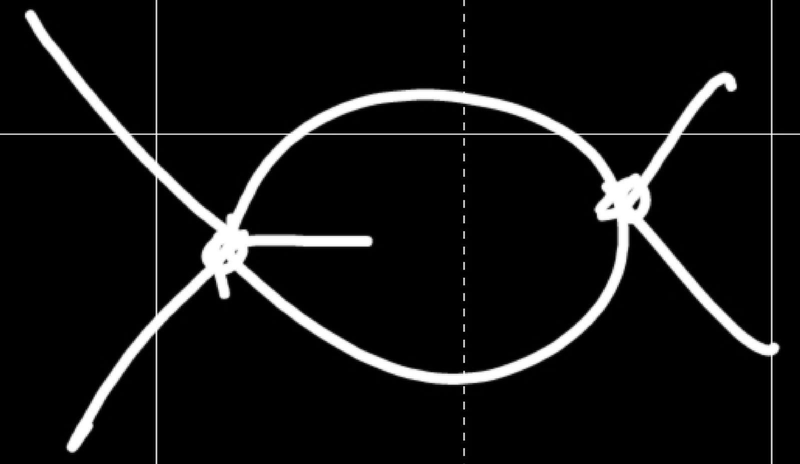
$$e^{iW[J]} = \int d\varphi\, e^{\frac{i}{\hbar}\left(S[\varphi] + \varphi\cdot J\right)} = \exp\left(\frac{i}{\hbar}\, \underset{?}{S_I}\left(\frac{\hbar\,\delta}{i\,\delta J}\right)\right) \exp\left(-\frac{i}{\hbar^{2}}\, J\cdot K^{-1}\cdot J\right)$$



$\longrightarrow$



$\sim \frac{1}{\hbar}$



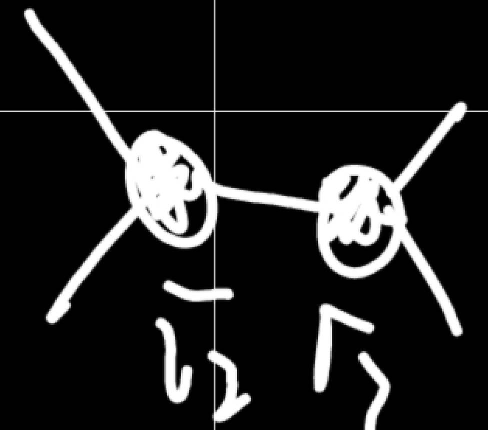
$\frac{1}{\hbar} \cdot \hbar^{1}$

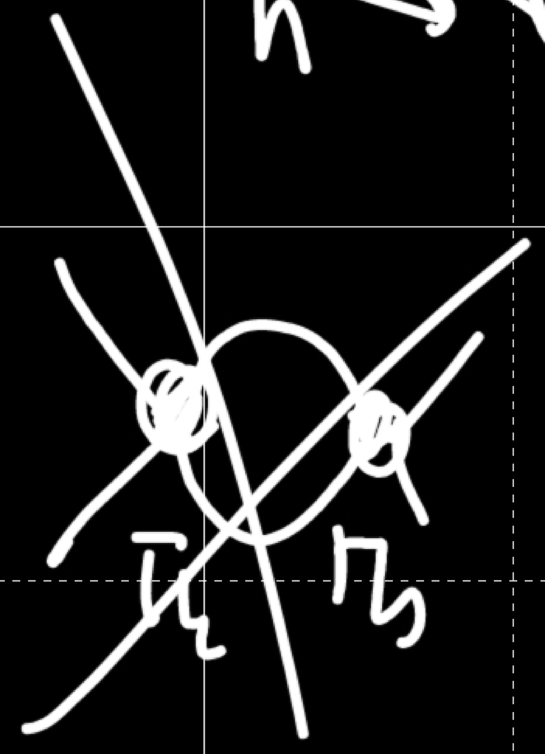
L-петлевая диаграмма $\boxed{\hbar^{L-1}}$

$$\Gamma[\varphi] = W[J_\varphi] - \varphi \cdot J_\varphi \longrightarrow W[J] = \Gamma[\varphi_J] + \varphi_J \cdot J$$

$$Z[J] = e^{\frac{i W[J]}{\hbar}} = e^{\frac{i}{\hbar}\left(\Gamma[\varphi_J] + \varphi_J \cdot J\right)} = \underset{\hbar \to 0}{=} \int d\varphi \, e^{\frac{i}{\hbar}\left(\Gamma[\varphi] + \varphi \cdot J\right)}$$

$$\varphi_J : \frac{\delta \Gamma}{\delta \varphi_J} = -J$$





$$W[J] \underset{\hbar \to 0}{=} \frac{\hbar}{i} \ln \int \cdots$$

$$\Gamma[\phi_c] = -VT\, V_{eff}(\phi_c) = -i \sum_{n=0}^{\infty} \frac{\Gamma_n}{n!} \phi_c^n =$$

$$= -i \sum_{n=0}^{\infty} \frac{\phi_c^n}{n!} \int d^4x_1 \dots d^4x_n\, \Gamma_n(x_1 \dots x_n) = -i \sum_n \frac{\phi_c^n}{n!} \delta(0)\, \tilde{\Gamma}_n(p_i = 0)$$

$$\left\{ \Gamma_n(x_1 \dots x_n) = \int \frac{d^4p_1}{(2\pi)^4} \dots \frac{d^4p_n}{(2\pi)^4} e^{i(p_1 x_1 + \dots + p_n x_n)} \delta(p_1 + \dots + p_n)\, \tilde{\Gamma}_n(p_1 \dots p_n) \right\}$$

$$(2\pi)^4 \delta(p_1) \dots \delta(p_n) (2\pi)^4$$

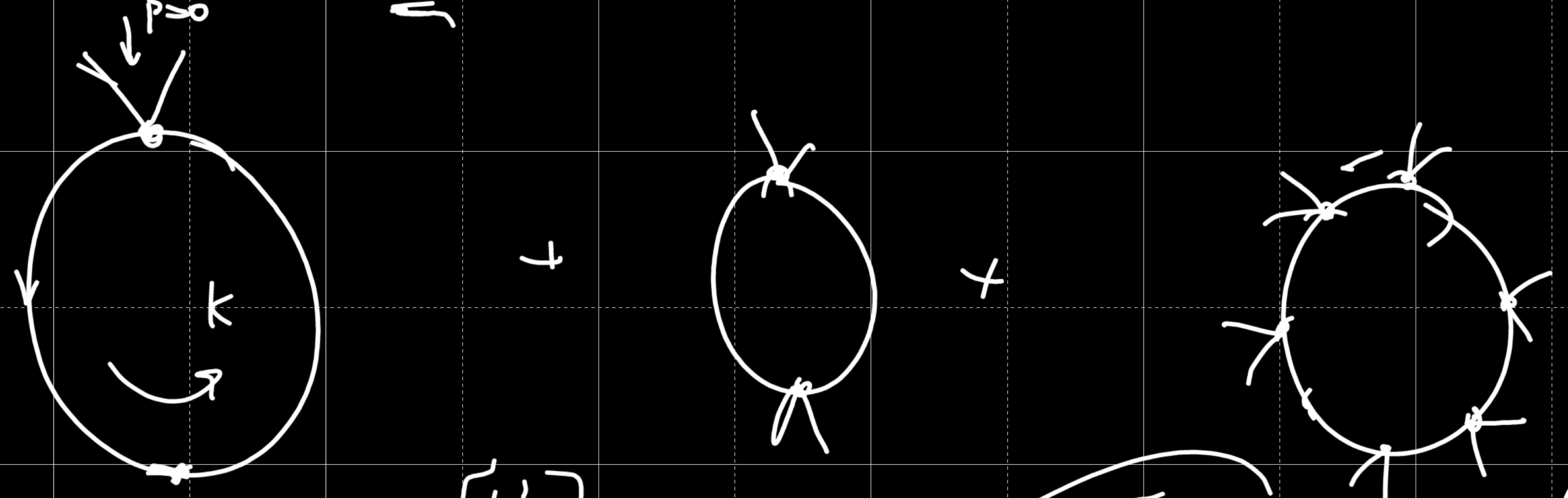
Минковский

$$V_{eff}(\phi_c) = i\sum_{n=0}^{\infty} \frac{\phi_c^n}{n!}\tilde{\Gamma}_n(0) \qquad \Gamma_n(p=\,) = \sum_{l=0}^{\infty}\Gamma_n^{(l)}(p=0)$$

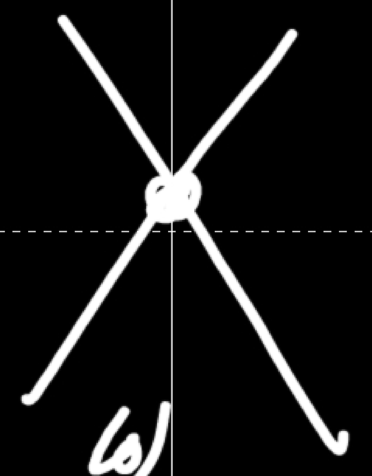
Д.з.

$$V_{eff}(\phi) = V(\phi) + \Delta V_1(\phi) + \dots$$

$$\boxed{\mathcal{L}_I = -\frac{\lambda}{4!}\phi^4 = -V(\phi)}$$



$-i\lambda$



$\Gamma_4^{(0)}(0)$

$$\int \frac{d^4k}{(2\pi)^4}\frac{i}{k^2+i\varepsilon}(-i\lambda)\left(\frac{\phi_c^2}{2}\right)\frac{1}{2}$$

$$\boxed{\frac{1}{2n}}\int d^4k\, \frac{i^n}{(k^2)^n}(-i\lambda)^n\left(\frac{\phi_c^2}{2}\right)^n$$

$$-\sum_n \frac{1}{n}(-x)^n = \ln(1+x) \qquad \frac{\lambda}{4!}\phi^4$$

Минк → Евкл

$$\Delta V(\phi_c) = i\sum_{n=1}^{\infty}\int \frac{1}{2n}\left(\frac{\lambda\phi_c^2}{2k^2}\right)^n d^4k \qquad \underrightarrow{k_0 \to i k_4}$$

$V(\phi) \ni \Lambda$

$$= -\sum_{n=1}^{\infty}\int d^4k_E \frac{1}{2n}\left(\frac{\lambda\phi_c^2}{-2k_E^2}\right)^n = \frac{1}{2}\int d^4k_E \ln\left(\underbrace{k_E^2 + \frac{\lambda\phi_c^2}{2}}_{\Lambda^2}\right)$$

*) расх.! ИК и УФ (регуляр + перенорм)

*) сложно обобщ на старшие петли!

$$(\lambda\phi_c^2)^2 \ln \Lambda^2$$

$$V_{\text{eff}}(\phi_c) = \frac{\lambda\phi_c^4}{4!} + \frac{(\lambda\phi_c^2)^2}{4(16\pi^2)}\left(\ln\frac{\lambda\phi_c^2}{\Lambda^2}\right) \cdots$$

$$+ (\lambda\phi_c^2)\cdot\Lambda^2 \cdots$$

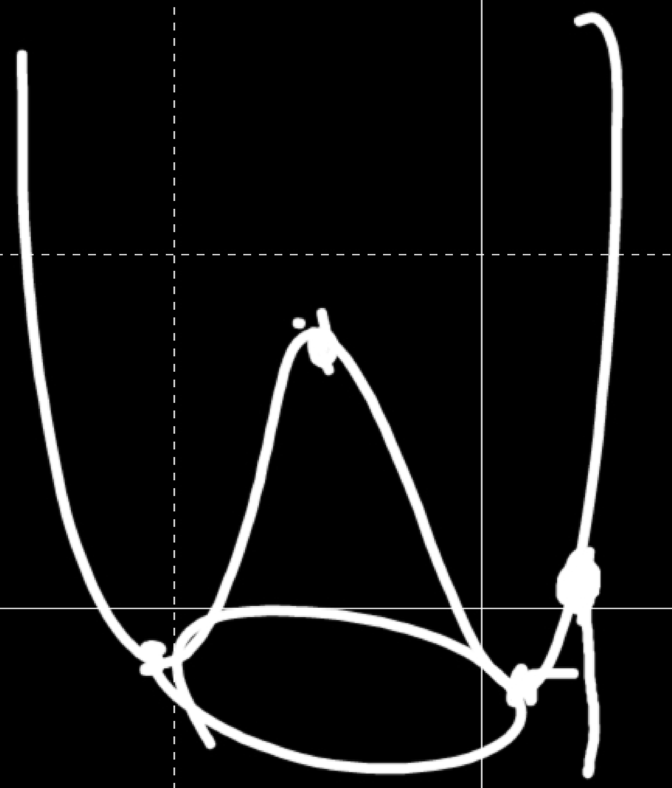
$$+ \Lambda^4 .$$

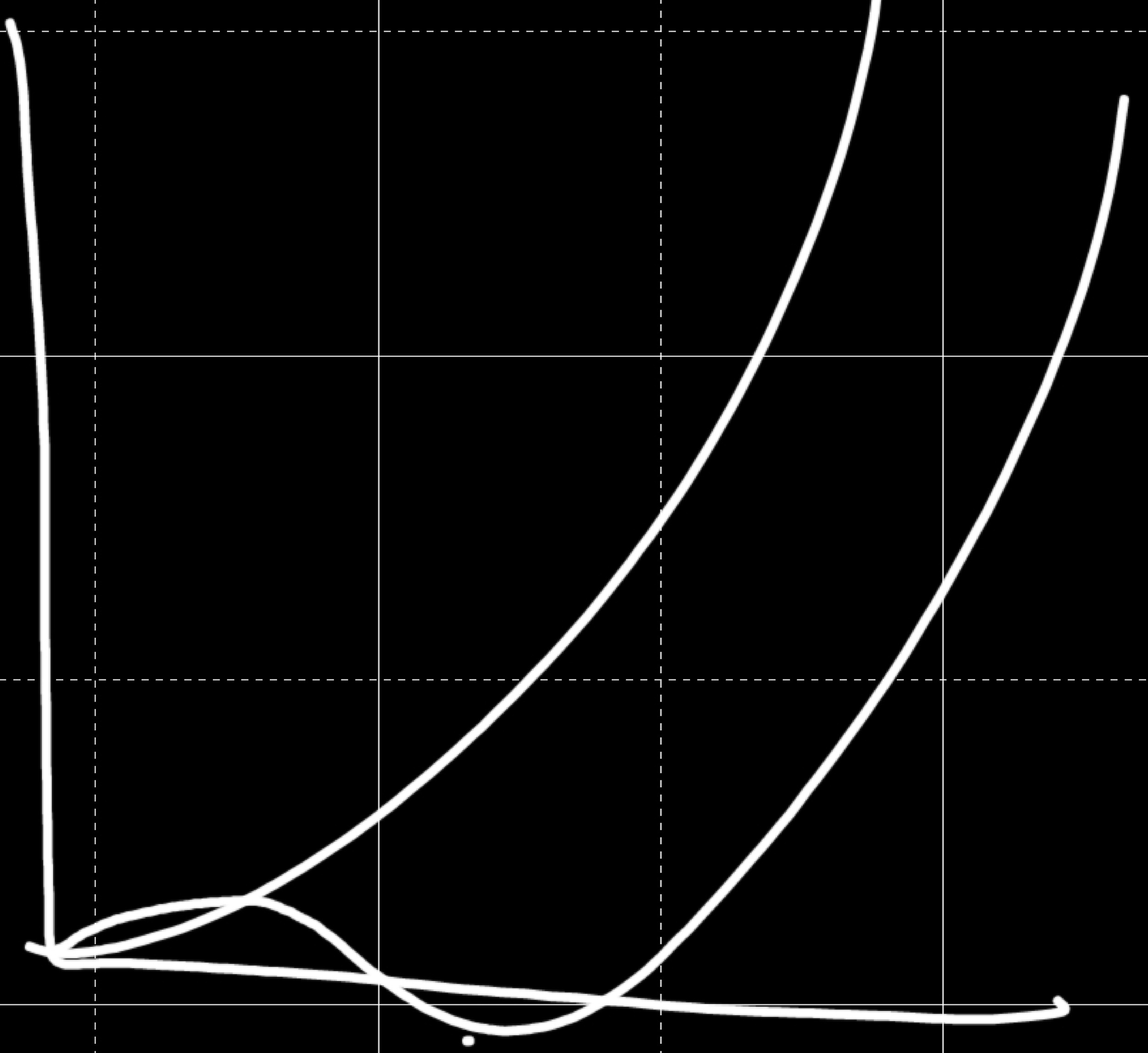
$$+ m^2\phi^2$$

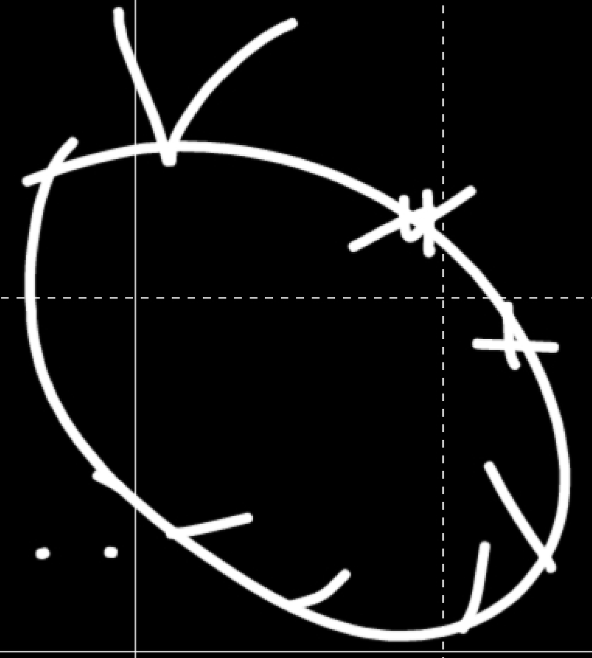
$$\frac{1}{k^2+m^2}$$

ϕ

$$\boxed{\lambda = 24}$$







$V_r(\phi) = \Lambda$ $\qquad T_{\mu\nu} - g^{\mu\nu}\mathcal{L} =$

$$\ln\left(1 + \frac{V''(\phi_c)}{K_E^2}\right) = \ln\left(\frac{K_E^2 + V''(\phi_c)}{K_E^2}\frac{\Lambda^2}{\Lambda^2}\right) = \ln\left(\frac{K_E^2 + V''(\phi_c)}{\Lambda^2}\right) + \ln\left(\frac{\Lambda^2}{K_E^2}\right)$$

$\tilde{\Lambda}$ $\qquad g_{\mu\nu}\Lambda, V(\phi)$

$\underline{\Lambda}\sqrt{-g}\,d^4x$ $\qquad \bar{N}^0 = \underline{u\bar{u}}$

$\langle T_{\mu\nu} h^{\mu\nu} \rangle$

$\theta^{\mu\nu}\left(\tilde{\Lambda} + \cdots\right)$