On the superfluid properties of polaritonic system

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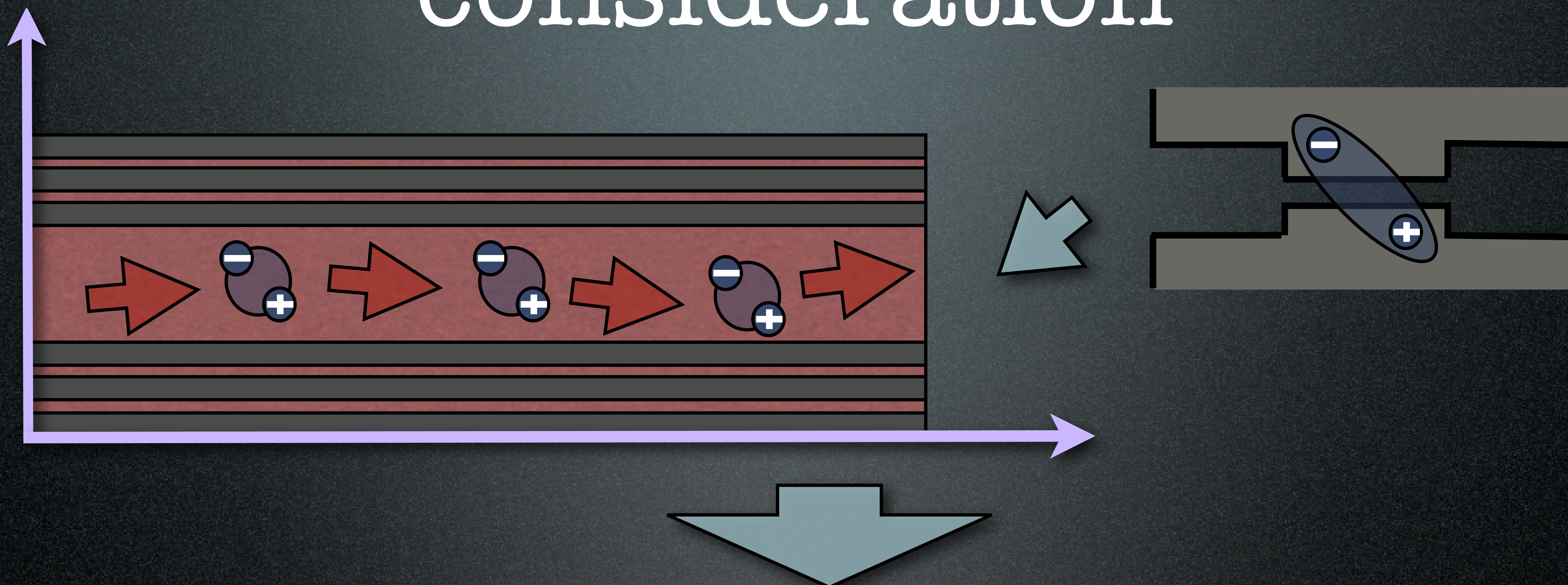
System under consideration



$$\hat{H} = \frac{1}{V}\sum_p \left(\varepsilon_{ph} \hat{a}_p^\dagger \hat{a}_p + \varepsilon_{ex} \hat{b}_p^\dagger \hat{b}_p + \frac{\Omega}{2}(\hat{a}_p^\dagger \hat{b}_p + \hat{a}_p \hat{b}_p^\dagger) \right) + \hat{H}_{ex-ex}$$

$$\varepsilon_{ph}(p) = c\sqrt{\left(\frac{\pi n}{L}\right)^2 + p^2} \approx E_0 + \frac{p^2}{2m_{ph}} \qquad \varepsilon_{ex}(p) = E_1 + \frac{p^2}{2m_{ex}}$$

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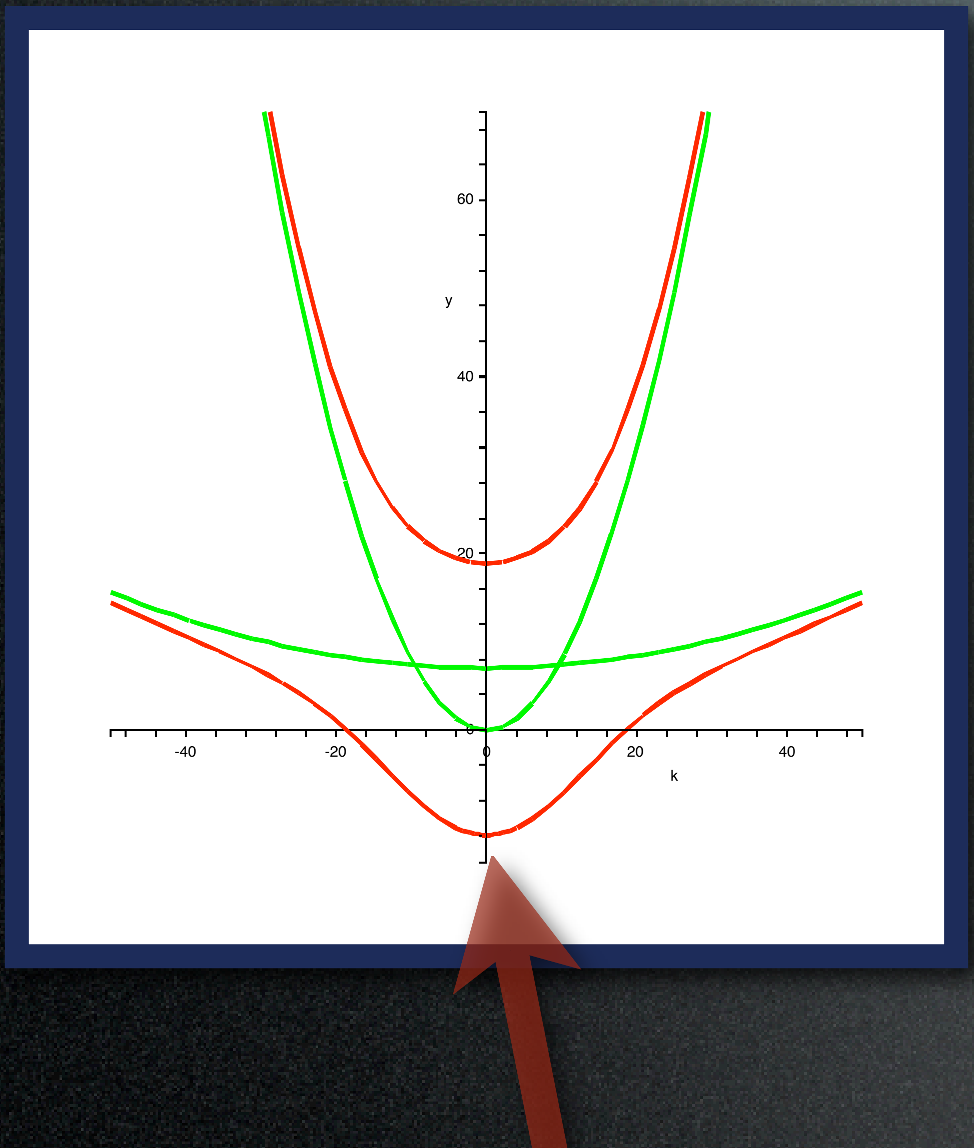


Small effective mass, therefore hight transition temperature

Long range order and superfluidity

$$\rho(r - r') \sim \frac{1}{|r - r'|^{\alpha}}$$

?

$$\alpha = \frac{mT}{2\pi n_s}$$

?

System under consideration is two-dimensional, therefore there are no bose condensate at finite temperature and transition into superfluid state is of Berezinskii-Kosterlitz-Thouless type

$$\alpha_{crit} = \frac{1}{4}$$

$$T_c = \frac{2\pi n}{m \ln \Gamma}$$

?

Effective action

$$\psi = \psi_l + \psi_{sh}$$

$$Z = \int \mathcal{D}\bar{\psi}\mathcal{D}\psi e^{-S}$$

$$\psi_l = \sqrt{\rho_0}e^{i\varphi} \qquad \psi_{sh} = \tilde{\psi}e^{i\varphi}$$

$$\partial_\mu(e^{i\varphi(x)}f(x)) = e^{i\varphi(x)}(\partial_\mu + i(\partial_\mu\varphi(x))f(x))$$

$$S = S_0 + \int d\tau d^2x J_\mu(x,\tau)A_\mu(x,\tau) +$$

$$+\frac{1}{2}\int d\tau d^2x d\tau' d^2x' \frac{\delta J_\mu(x,\tau)}{\delta A_\nu(x',\tau')}A_\mu(x,\tau)A_\nu(x',\tau') + ...$$

$$A_\mu = \partial_\mu\varphi \qquad J_\mu = \frac{\delta S}{\delta A_\mu} \qquad K_{\mu\nu} = \frac{\delta J_\mu}{\delta A_\nu}$$

Effective action

$$S_{eff} = \frac{1}{2}\int d\tau d^2x d\tau' d^2x' \Pi_{\mu\nu}(x,\tau,x',\tau') A_\mu(x,\tau) A_\nu(x',\tau')$$

$$\Pi_{\mu\nu}(x,\tau,x',\tau') = \langle \frac{\delta J_\mu(x,\tau)}{\delta A_\nu(x',\tau')} \rangle - \langle J_\mu(x,\tau) J_\nu(x',\tau') \rangle$$

$$\Pi_{\mu\nu}(q,i\omega_n) = \langle K_{\mu\nu}(q,i\omega_n) \rangle - \langle J_\mu(q,i\omega_n) J_\nu(-q,-i\omega_n) \rangle$$

In the zero frequency and low momentum limit

$$\langle J_\mu(q,0) J_\nu(-q,0) \rangle = \chi_l \frac{q_\mu q_\nu}{q^2} + \chi_t \left(\delta_{\mu\nu} - \frac{q_\mu q_\nu}{q^2} \right), \qquad q \to 0$$

One can show the following relation from the Sum Rule

$$K_{\mu\nu}(0,0) = \chi_l \delta_{\mu\nu}$$

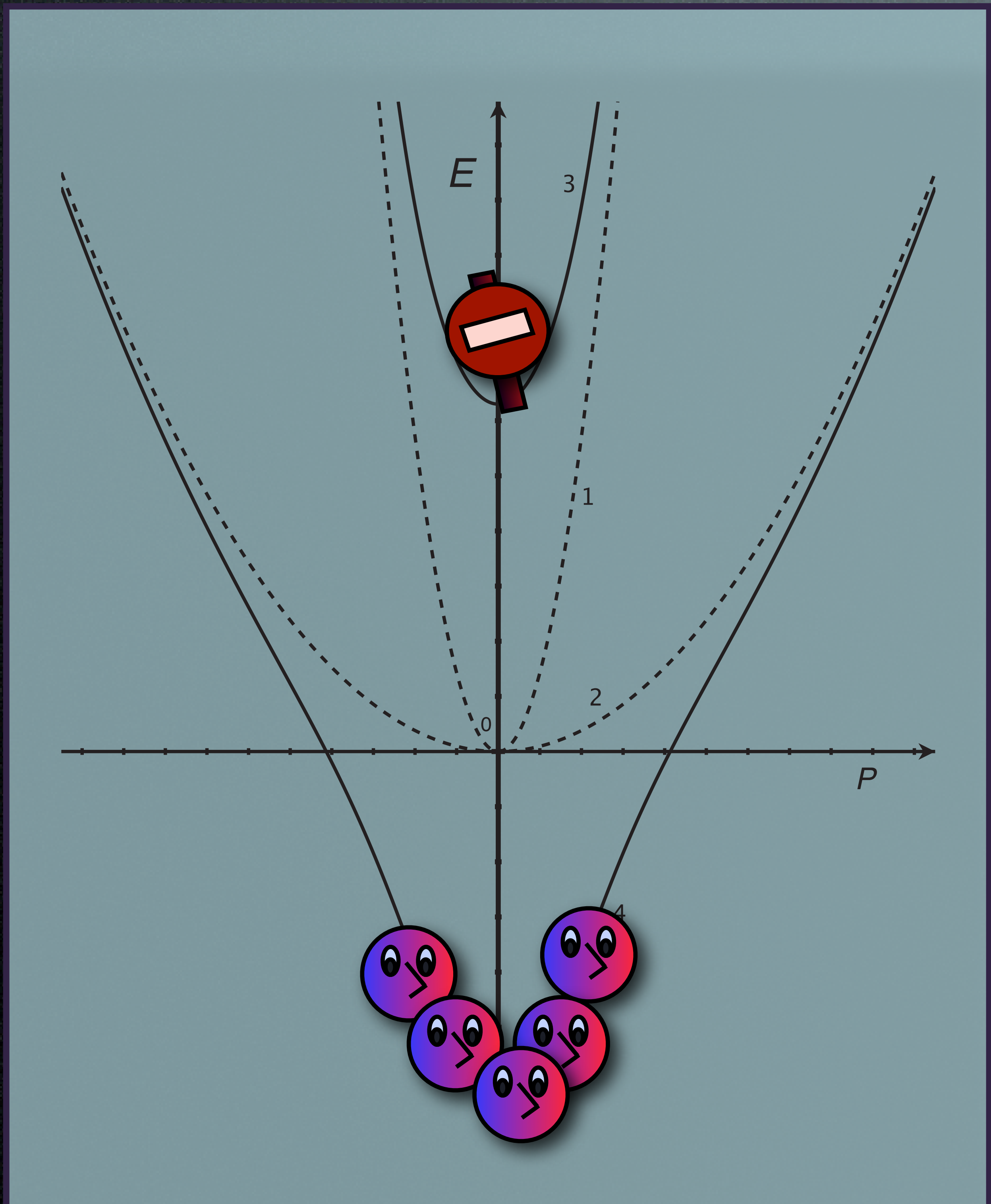
Effective action

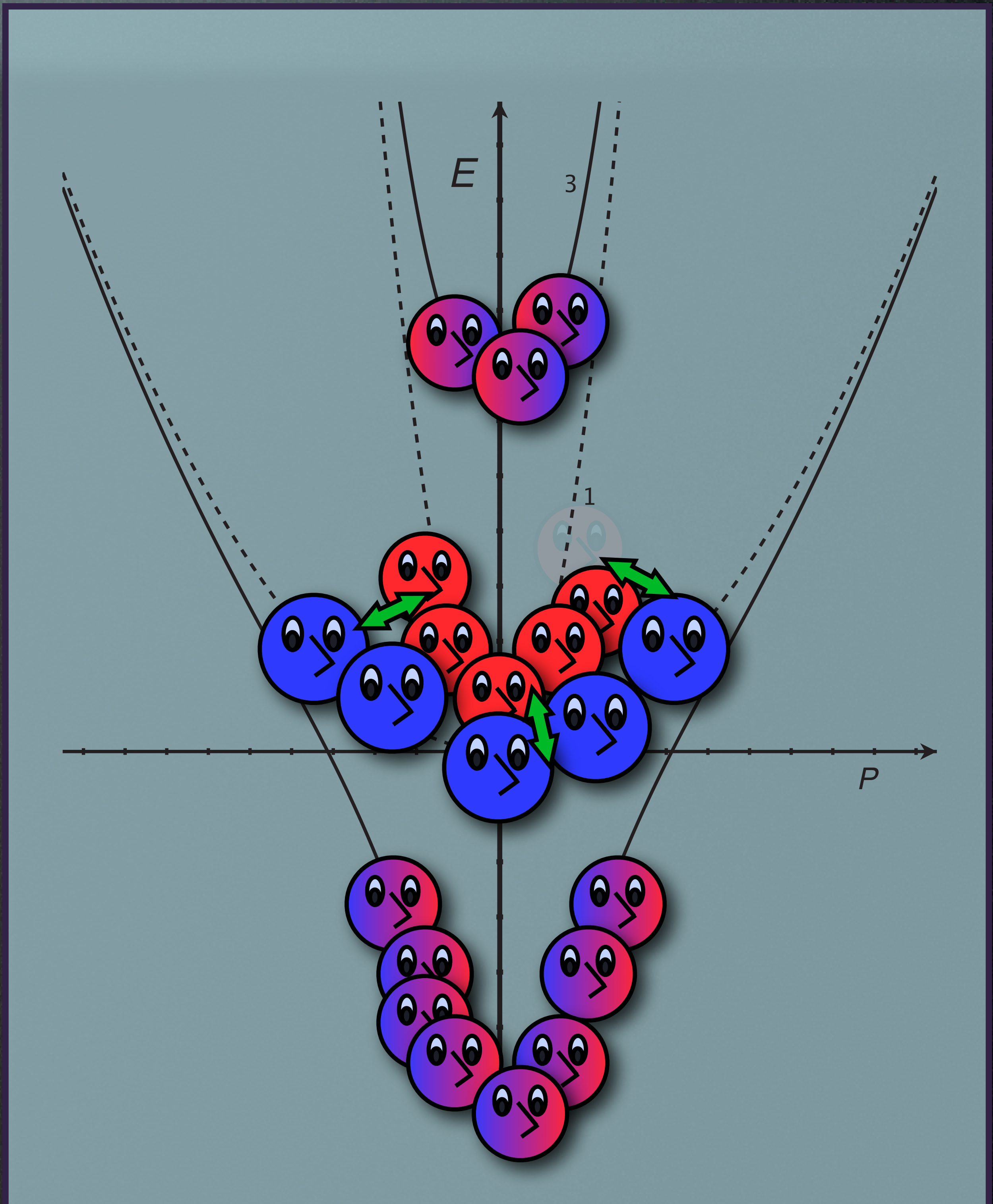
$$\Pi_{\mu\nu}(q,0) = (\chi_l - \chi_t)\left(\delta_{\mu\nu} - \frac{q_\mu q_\nu}{q^2}\right), \quad q \to 0$$

$$S_{eff} = \frac{\chi_s}{2T}\int (\partial_\mu \varphi_v(x))^2 d^2x$$

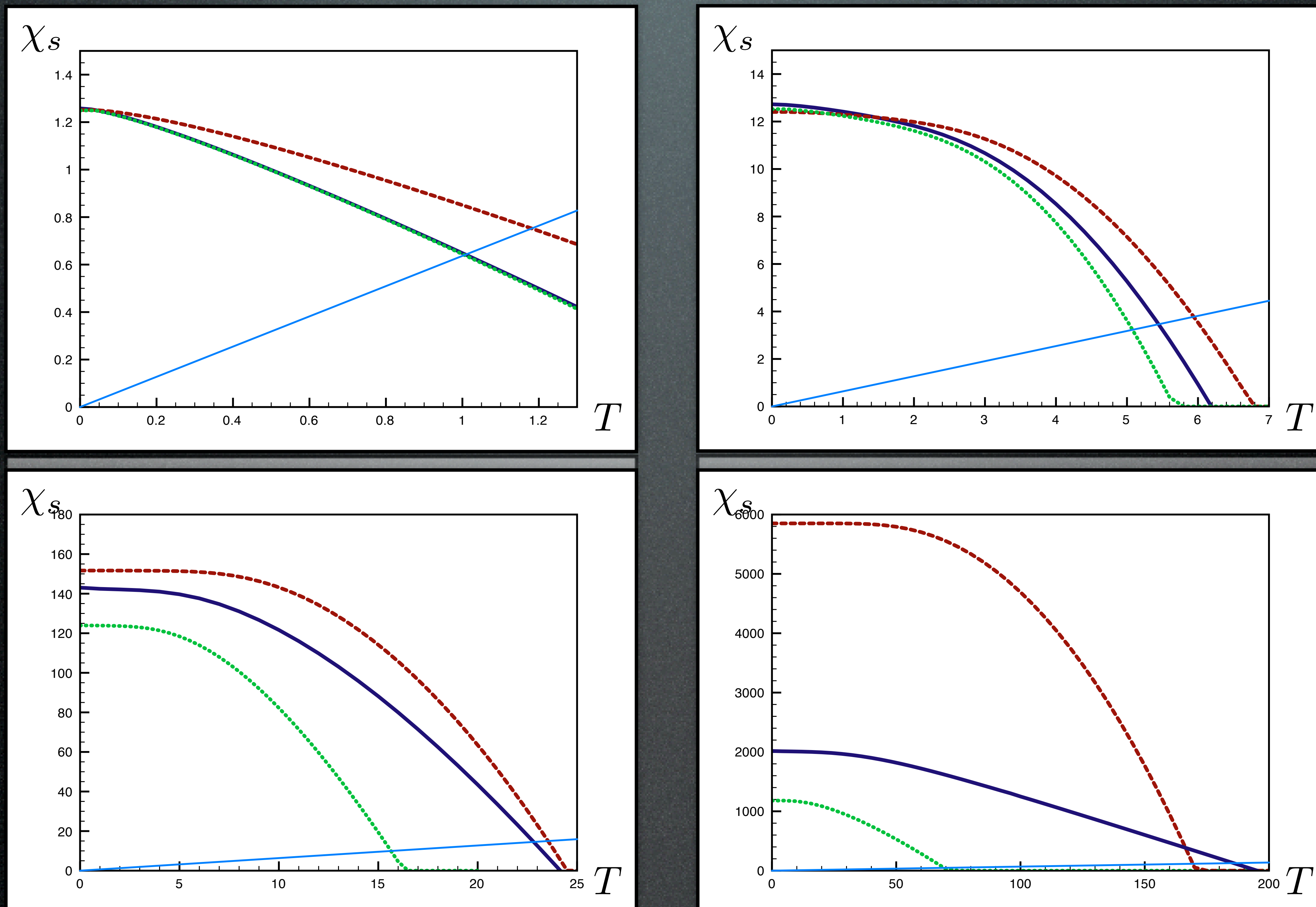
$$\chi_s = \chi_l - \chi_t$$

Considered approximations

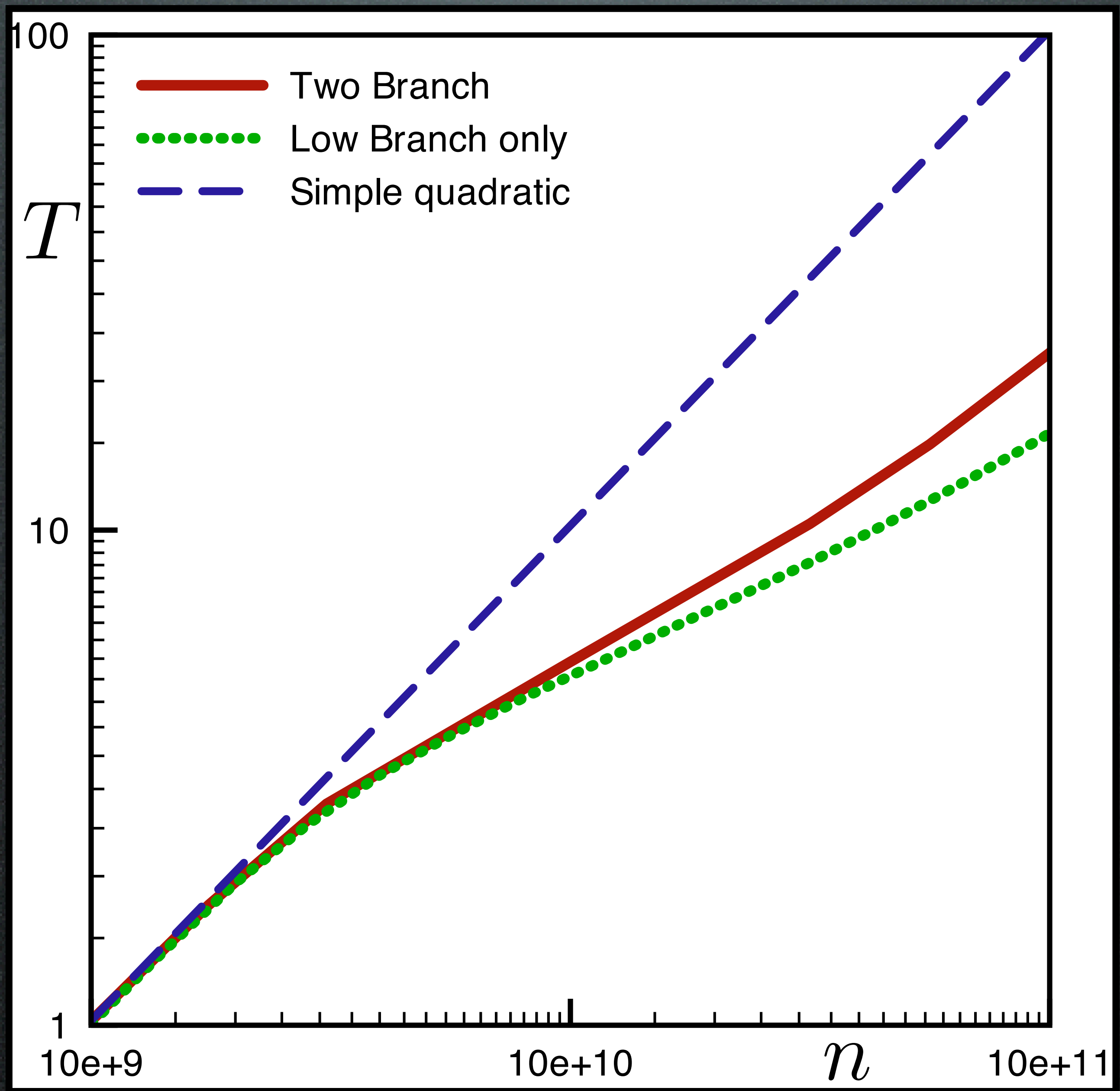




Result of calculations



Transition temperature



Conclusions

- Theory of superfluidity in polaritonic system are developed;
- Superfluid density are calculated as function of temperature;
- Temperature of Berezinskii-Kosterlitz-Thouless transition are obtained for weakly interacting bose gas of polaritons.