



$$H = \psi^\dagger \left(-\frac{\partial^2}{\partial x^2} \right) \psi + V_{int}$$

Linearization

$$H_F = \bar{\psi} i \not{\partial} \psi + V_{int}$$

particle-hole operator

$$\rho_q = \sum_n C_n^\dagger C_{n+q} = \text{Boson Operator}$$

Tomonaga Luttinger

$$\rho_q \propto \sqrt{\frac{qL}{2\pi}} b_q$$

$$H_B = \sum_q v_q b_q^\dagger b_q$$

$$\psi = e^{ikx} \psi_R + e^{-ikx} \psi_L$$

$$\psi_s = e^{i\Phi_s}$$

$$\mathcal{L} = \frac{1}{2} (\partial_t \phi)^2 - \frac{v^2}{2} (\partial_x \phi)^2 + \dots$$

Sine-Gordon model

$$\mathcal{L} = \frac{1}{2} (\partial \phi)^2 + A \cos(\beta \phi)$$

RG

