Driving Dipolar Fermions into the Quantum Hall Regime

SFB TRR/21 Control of Quantum Correlations in Tailored Matter

Universität Stuttgart

D. Peter[1], A. Griesmaier[2], T. Pfau[2] and H. P. Büchler[1]

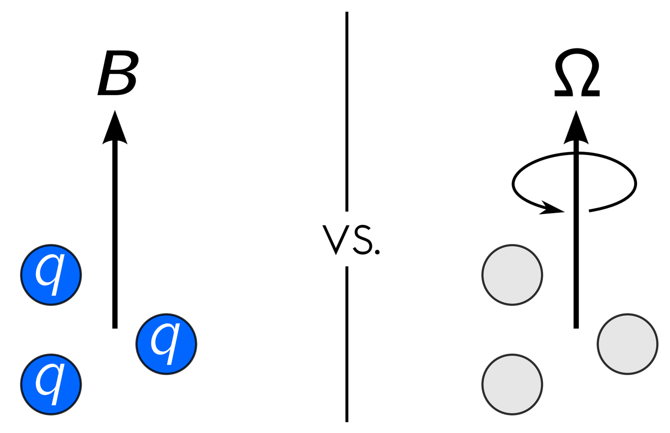
[1] Institut für Theoretische Physik III, Universität Stuttgart
[2] 5. Physikalisches Institut, Universität Stuttgart

Larmors Theorem

- ▷ Analogy between charged particles in a magnetic field and neutral particles in a rotating frame
- ▷ Basic motivation for rapidly rotating systems and our approach

$F_L \sim \boldsymbol{v} \times \boldsymbol{B}$

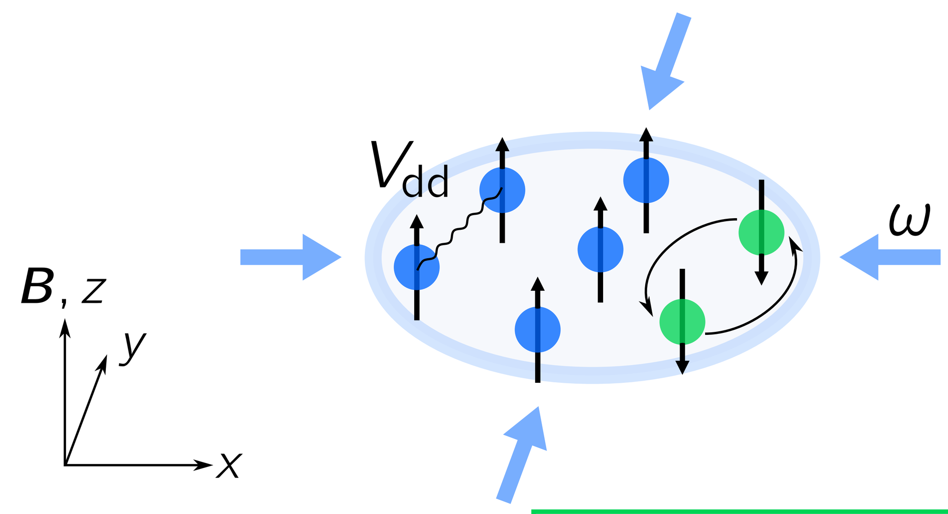
$\omega_c = \frac{qB}{mc}$



$F_C \sim \boldsymbol{v} \times \boldsymbol{\Omega}$

$\omega_c^{\text{eff.}} = 2\Omega$

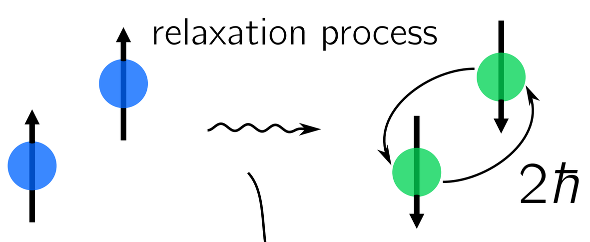
quasi-2d system



- ▷ spin-1/2 fermions with magnetic dipole moment
- ▷ strong confinement in z direction
- ▷ in-plane harmonic confinement $\omega \ll \omega_z$

dipolar relaxation

- ▷ Dipolar interaction between two magnetic dipoles with $\boldsymbol{\mu} = \mu_B g \boldsymbol{S}/\hbar = \mu_B g \boldsymbol{\sigma}/2$
- ▷ Relaxation process with spin-orbit coupling



$$V_{\text{dd}}(r,\phi) = \frac{C_{\text{dd}}}{r^3}\left[\sigma_i^z\sigma_j^z - \left(\sigma_i^+\sigma_j^- + 3\,e^{2i\phi}\,\sigma_i^-\sigma_j^- + \text{h.c.}\right)\right]$$

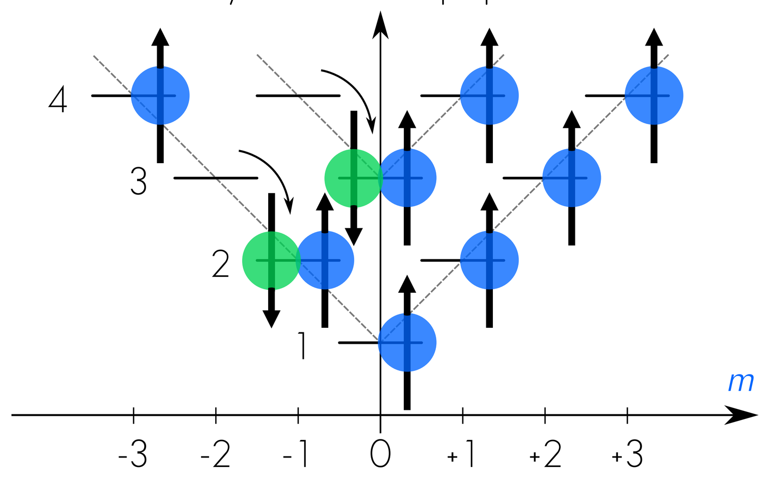
in-plane polar coordinates

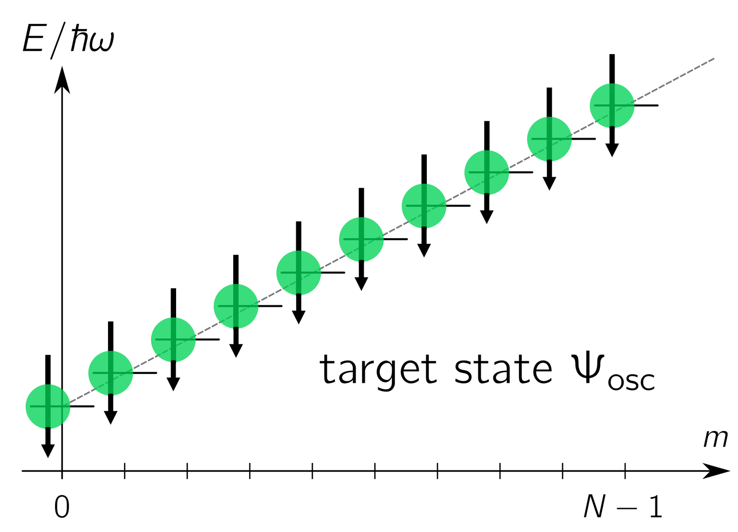
relaxation in-trap

radial quantum number

angular momentum (ħ)

$E/\hbar\omega = 2n + |m| + 1$





anti-symmetrizer

harmonic oscillator states

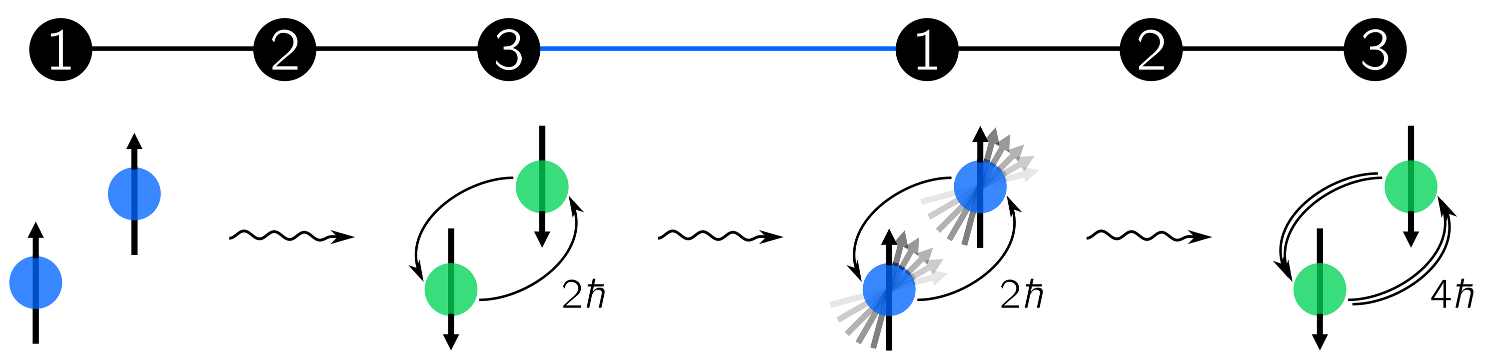
$$\Psi_{\text{osc}} = \langle z_1, z_2, \ldots, z_N | \mathcal{A} \prod_{m=0}^{N-1} |0, m\rangle = \mathcal{N}\left[\prod_{i<j}(z_i - z_j)\right] e^{-\frac{1}{2}\sum |z_k|^2} = \Psi_{\text{IQHE}}$$

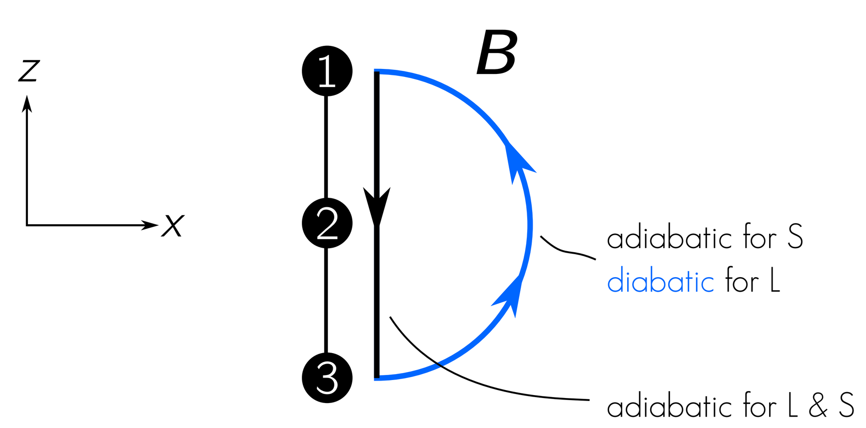
complex coordinates of the particles $z_k = (x_k + i y_k)/l_{\text{HO}}$

normalization

- ▷ The target state of our scheme is equivalent to the integer quantum Hall state

transfer scheme





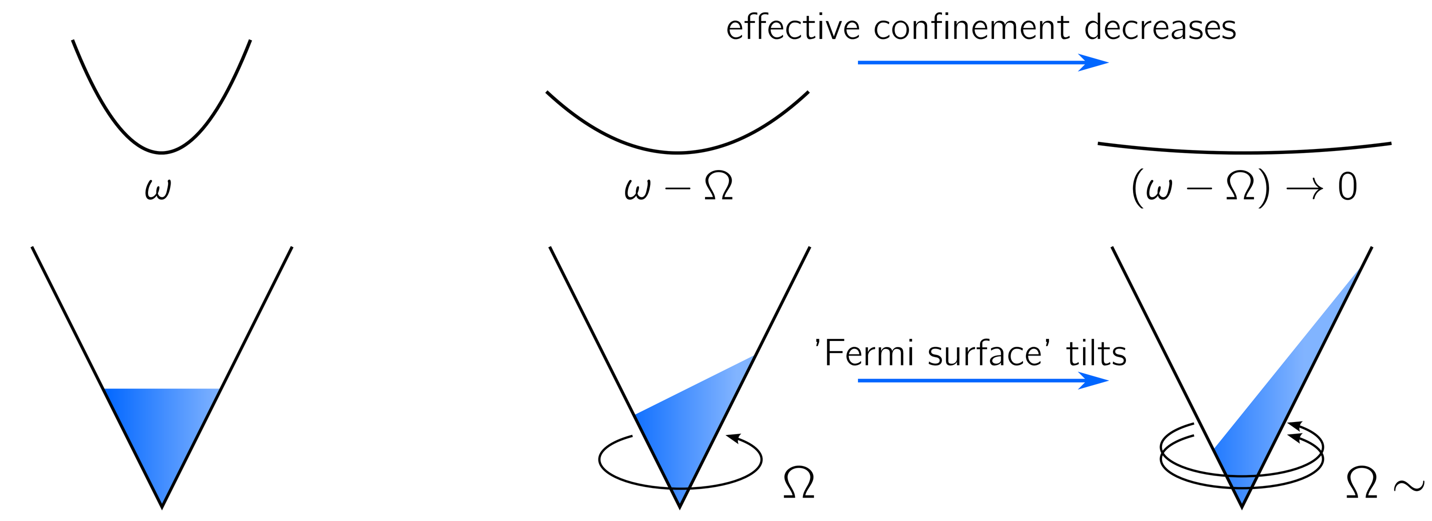
total angular momentum

$$\text{number of cycles} = \frac{N(N-1)/2}{N} \sim N/2$$

increase per cycle

- ▷ combination of adiabatic spin-flips with diabatic transfer

analytical model

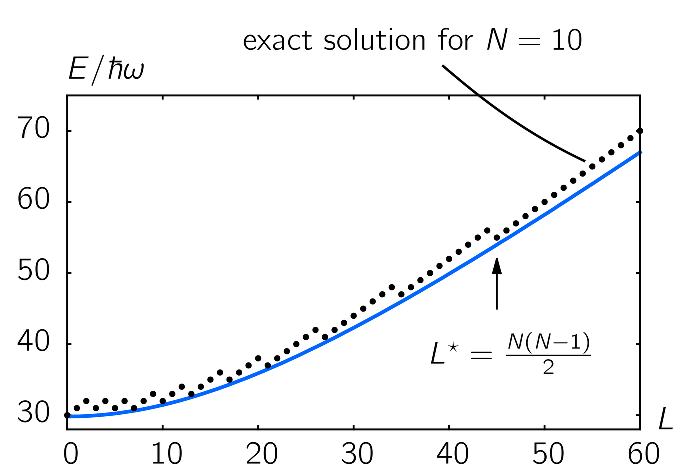


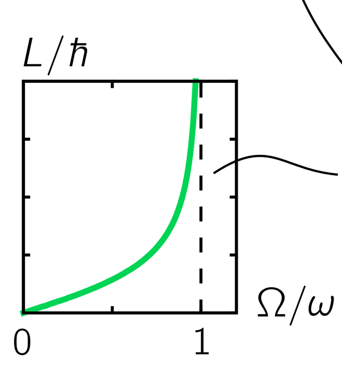
Simple analytical model in the limit $N \gg 1$

$$E(N,L)/\hbar\omega = \frac{1}{3}\sqrt{(2N)^3 + (3L)^2} = \begin{cases} (2N)^{3/2}/3, & L = 0 \\ L, & L \to \infty \end{cases}$$

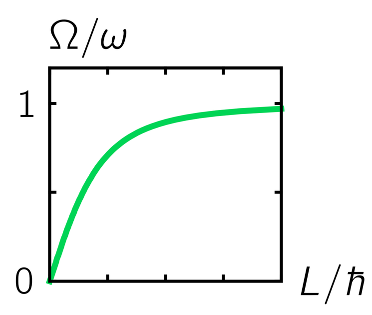
$$\Omega(N,L)/\omega = \frac{\partial E}{\partial L} = \frac{3L}{\sqrt{(2N)^3 + (3L)^2}}$$

$$L(N,\Omega) = \frac{(2N)^{3/2}}{3}\frac{\Omega/\omega}{\sqrt{1-(\Omega/\omega)^2}}$$





Instability for $\Omega = \omega$!



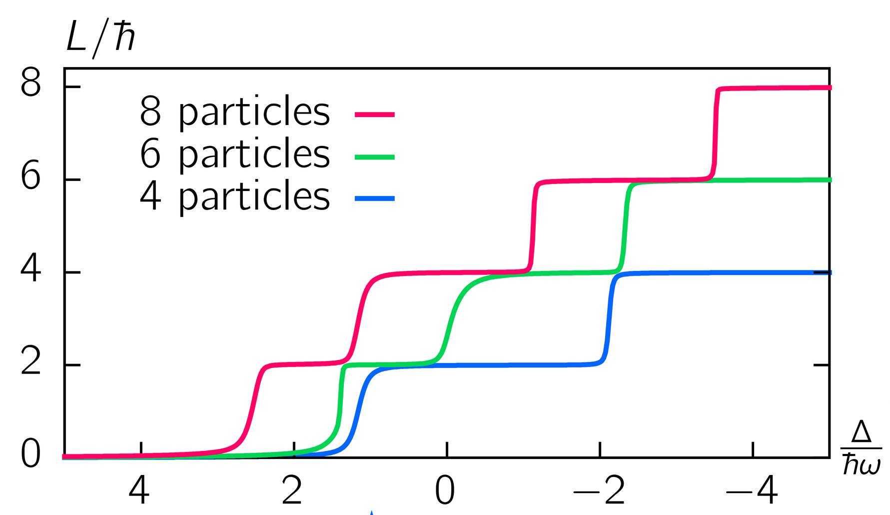
rapidly rotating systems: fixed Ω

Legendre transform

our approach: fixed L

full simulation

total angular momentum = transferred particles

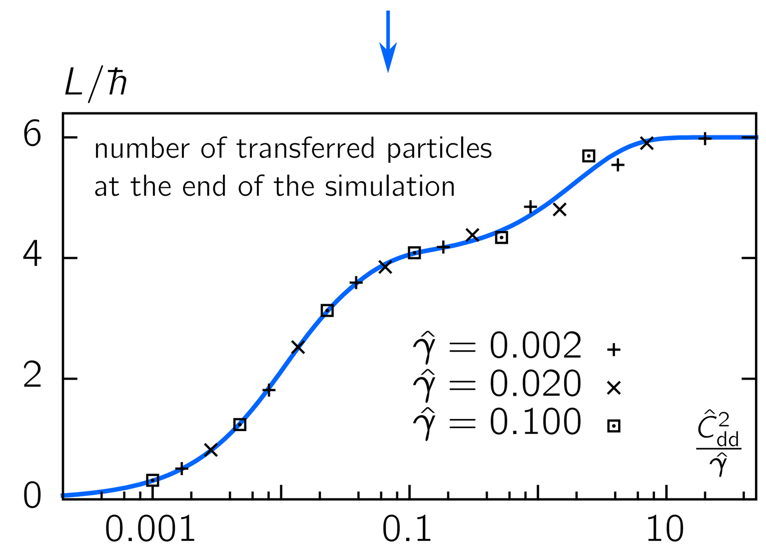


Zeeman shift $\Delta = \mu_B g B$

adiabatic transfer (rate $\gamma \to 0$)

- ▷ numerical simulation with full interactions
- ▷ angular momentum increases in steps of $2\hbar$

full time-dependent simulation



- ▷ only two relevant parameters: C_{dd} and γ

$$H = \sum_i \left[E_{nm} + \Delta(t)\,\delta_{\sigma,\downarrow}\right] c_i^\dagger c_i + \frac{1}{2}\sum_{ijkl} V_{ijkl}\, c_i^\dagger c_j^\dagger c_l c_k$$

$\Delta(t) = -\gamma t$; $E_{nm} = \hbar\omega(2n + |m| + 1)$; $V_{ijkl} \sim C_{\text{dd}}$; $i \equiv (n, m, \sigma)$

reference

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