



Statistically induced Phase Transitions & Anyons in 1D

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abstract

Here we propose an experimental setup to create **anyons** in one-dimensional lattices with fully **tuneable exchange statistics**. In our setup, anyons are created by bosons with occupation-dependent hopping amplitudes, which can be realized by laser-assisted Raman tunneling. The statistical angle can thus be controlled in situ by modifying the relative phase of two Raman laser beams. This opens the fascinating possibility of smoothly transmuting bosons via anyons into fermions and of inducing a phase transition by the mere control of the particle statistics as a free parameter.

In particular, we demonstrate how to induce a quantum phase transition from a superfluid into an exotic Mott-like state where the particle distribution exhibits plateaus at fractional densities.

anyons in 1D

Statistics

$$a_j a_k^\dagger - e^{-i\theta \text{sgn}(j-k)} a_k^\dagger a_j = \delta_{jk}$$

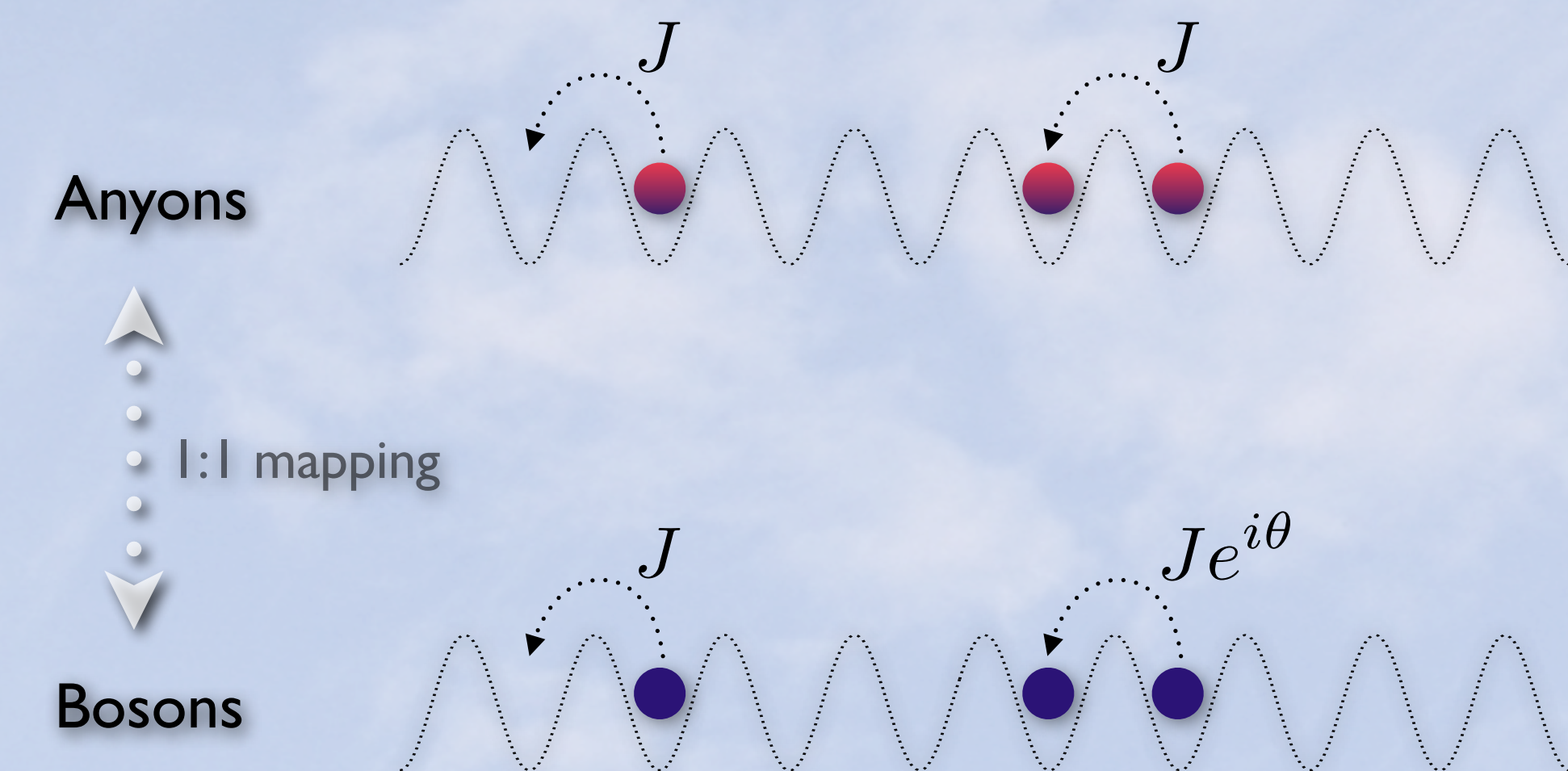
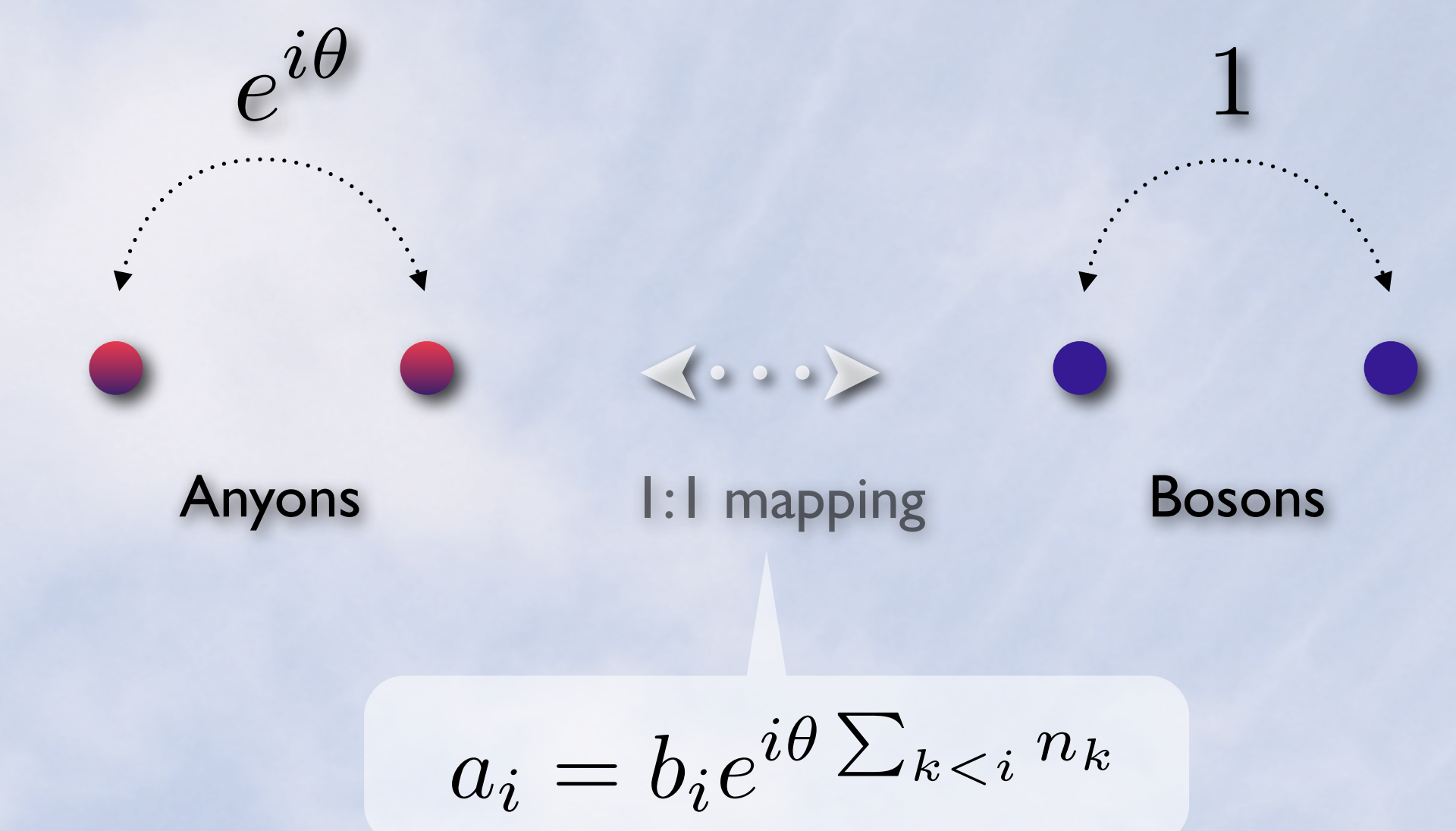
Goal: Anyon-Hubbard model

$$H^a = -J \sum_j (a_j^\dagger a_{j+1} + \text{h.c.}) + \frac{U}{2} \sum_j n_j (n_j - 1)$$

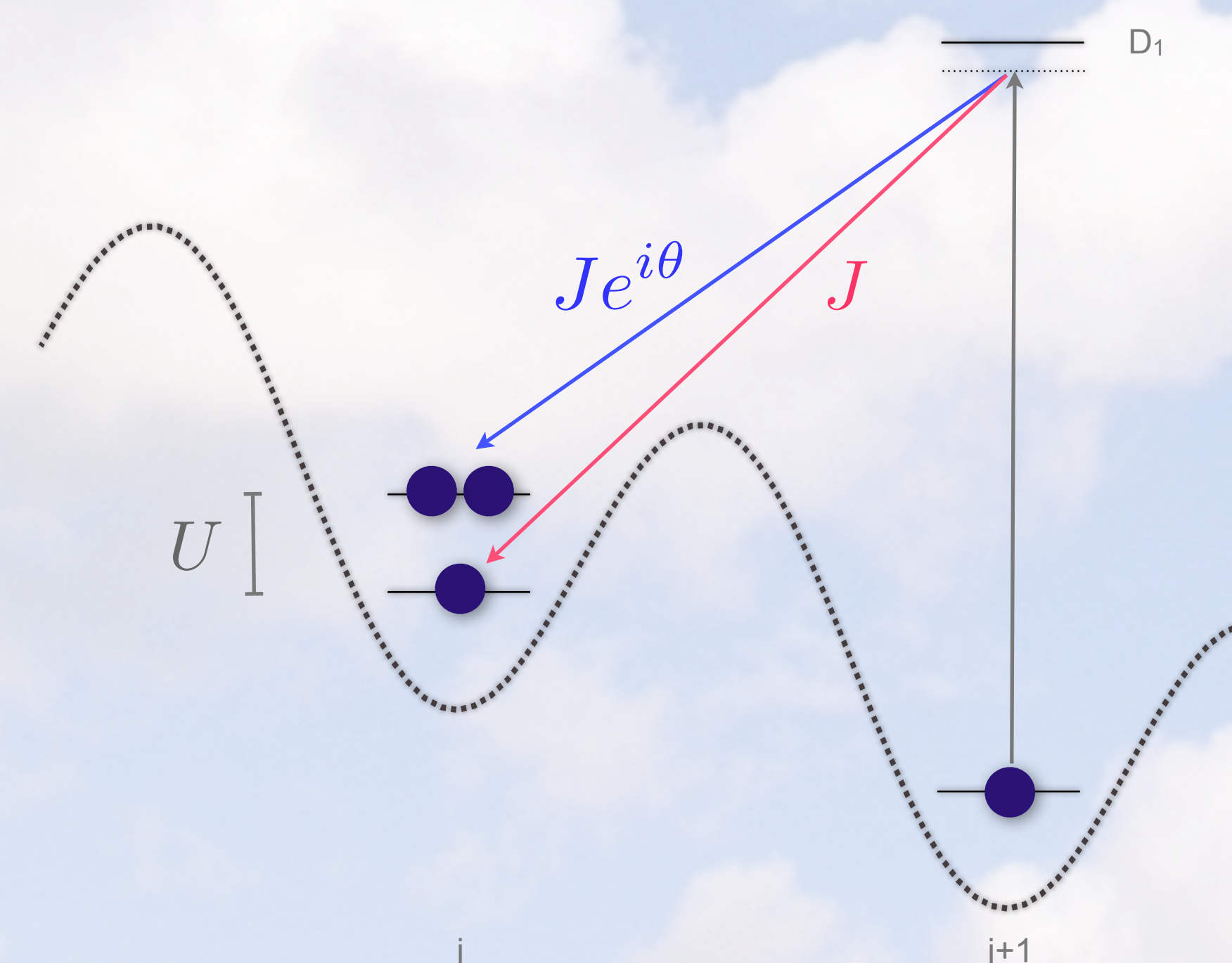
References:

- ▶ F. Wilczek, Phys. Rev. Lett. **48**, 1144 (1982)
- ▶ F.D.M. Haldane, Phys. Rev. Lett. **67**, 937 (1991)
- ▶ D. Jaksch and P. Zoller, New J. Phys. **5**, 56 (2003).

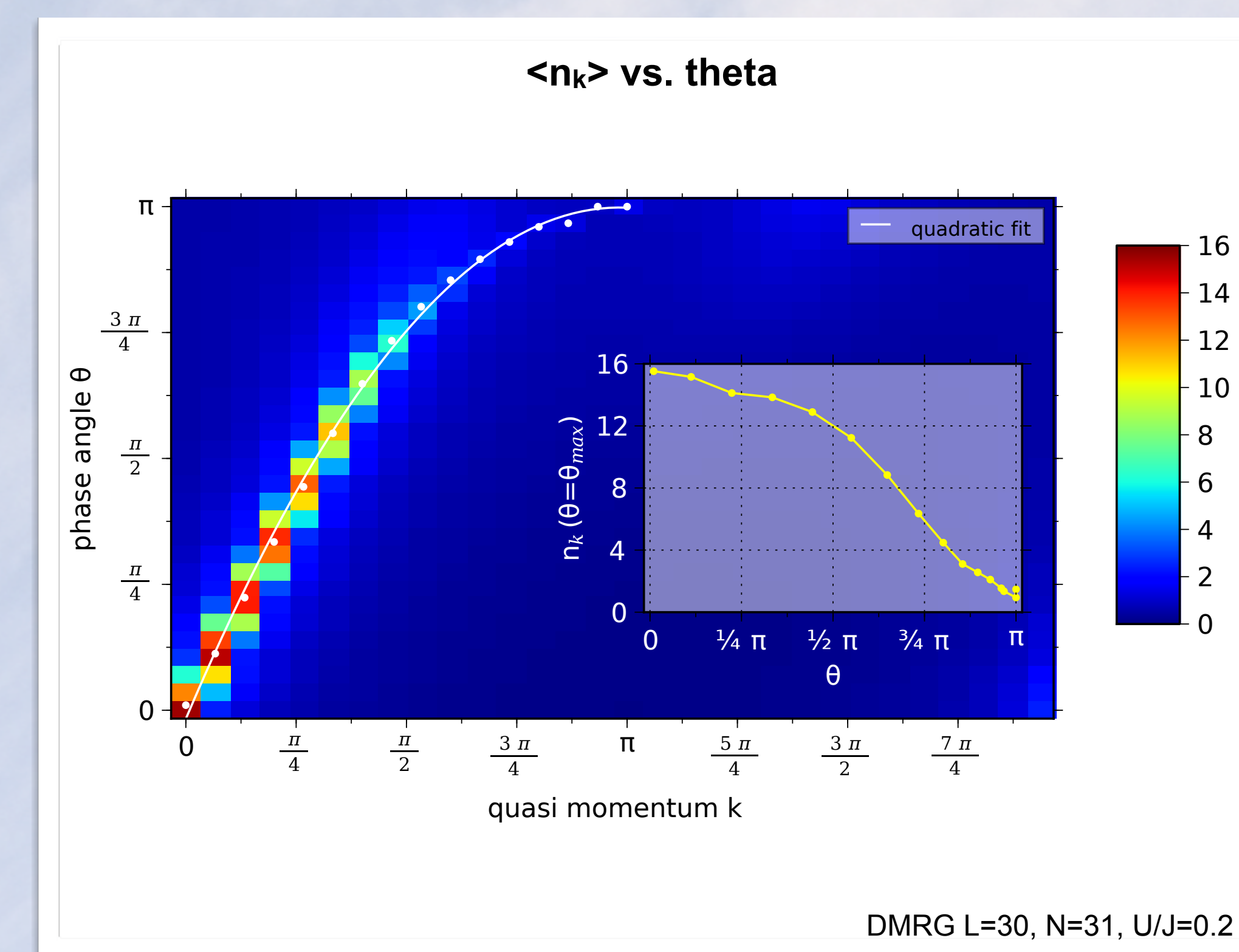
anyons – bosons



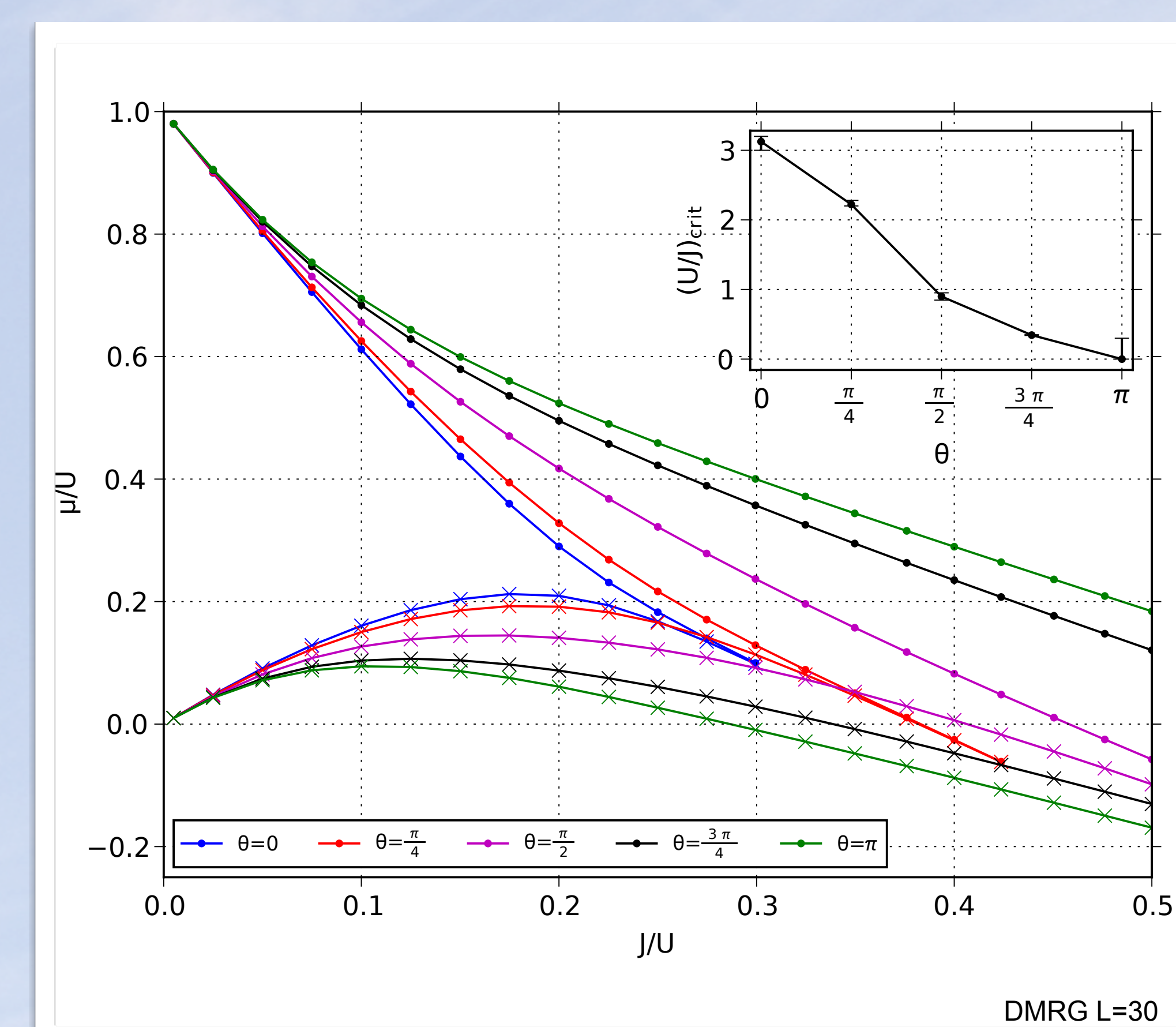
experimental realization



momentum distribution



phase diagram

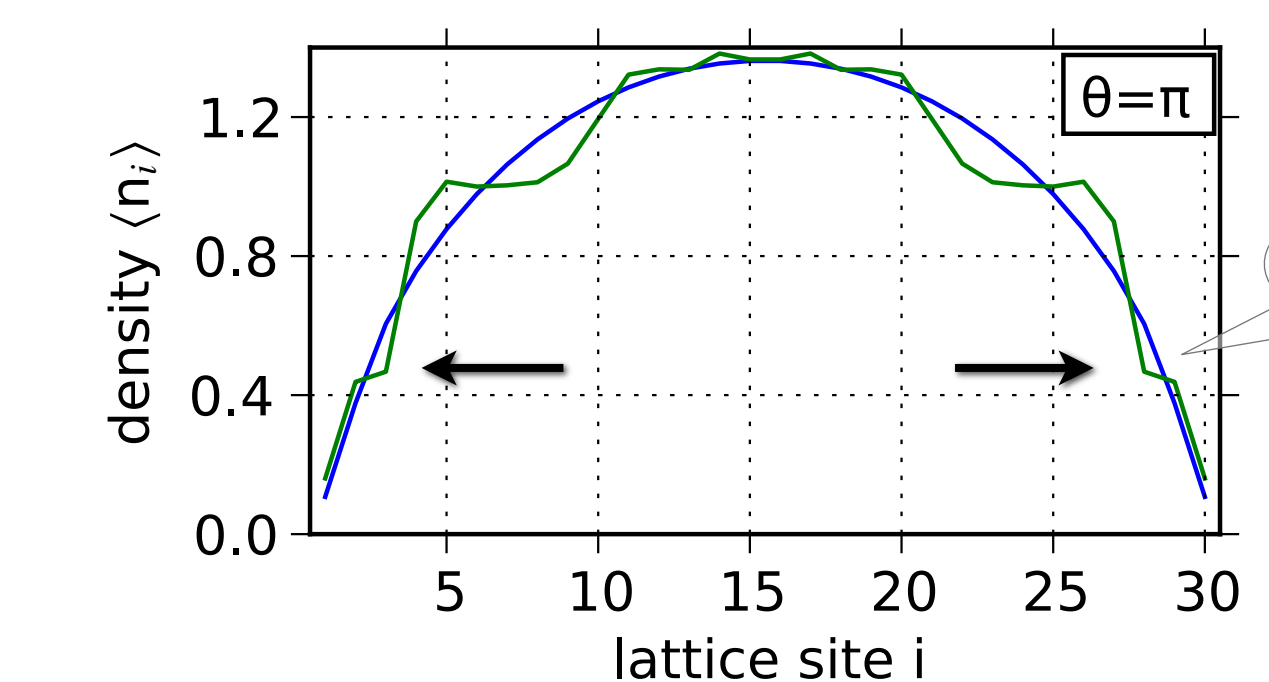
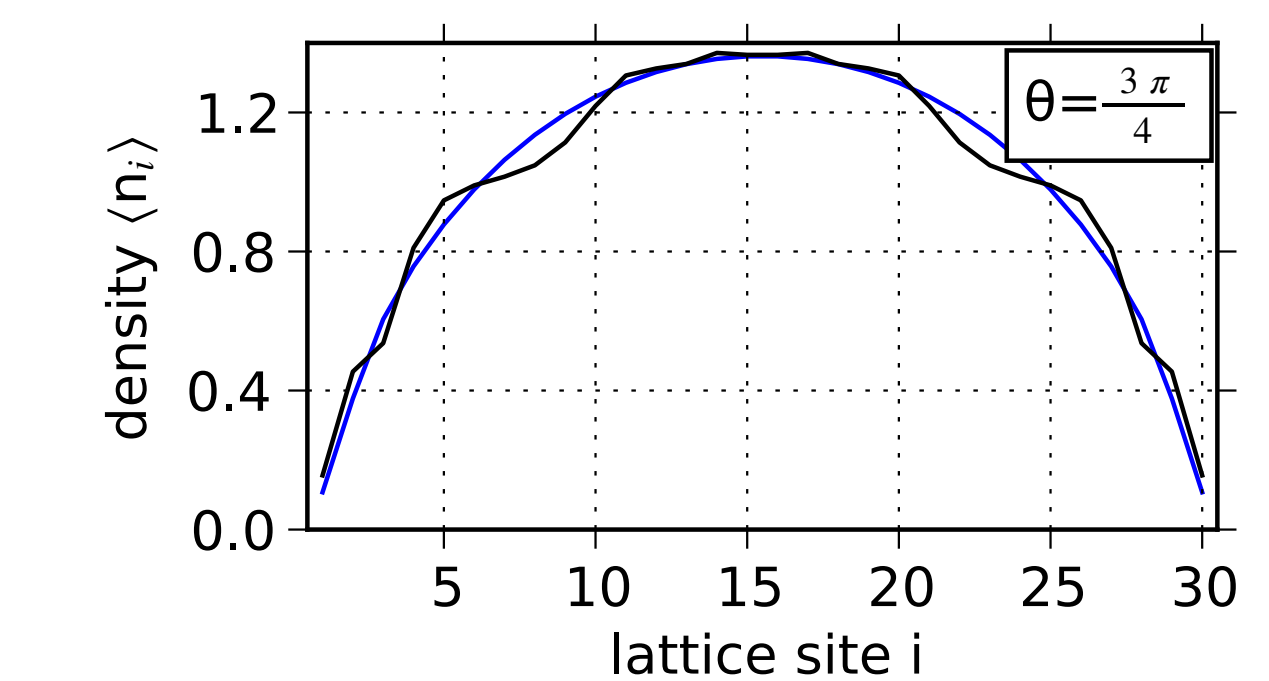
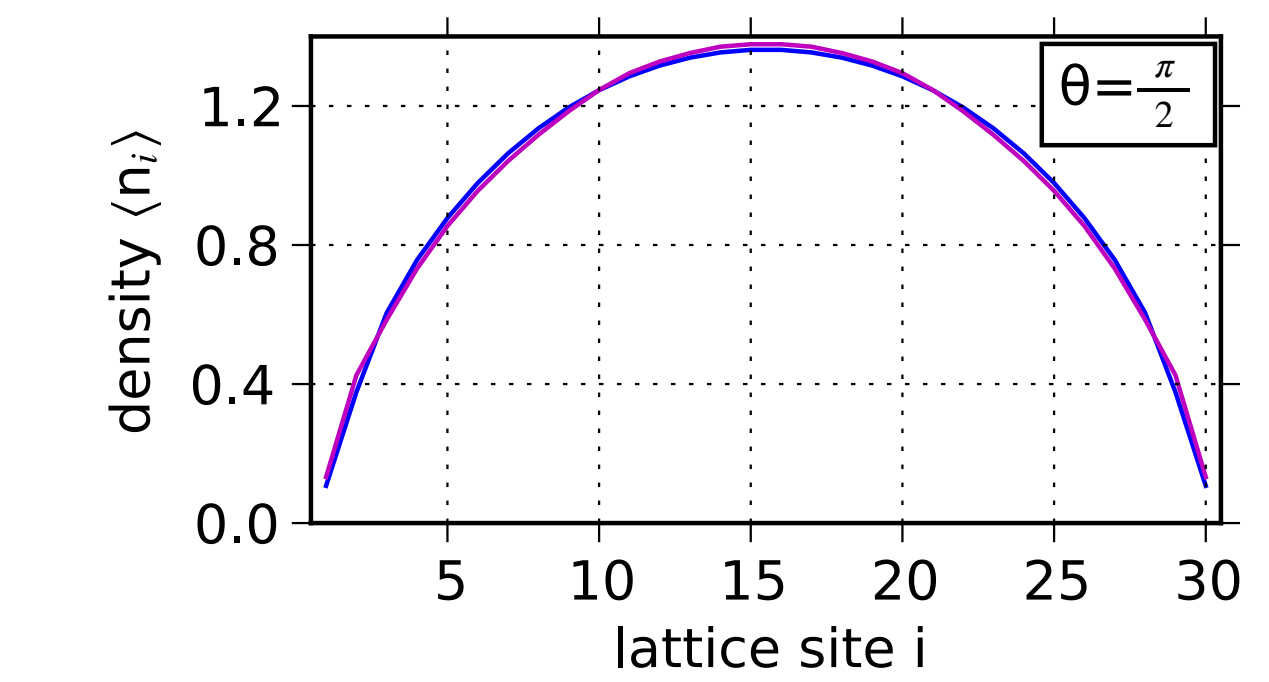
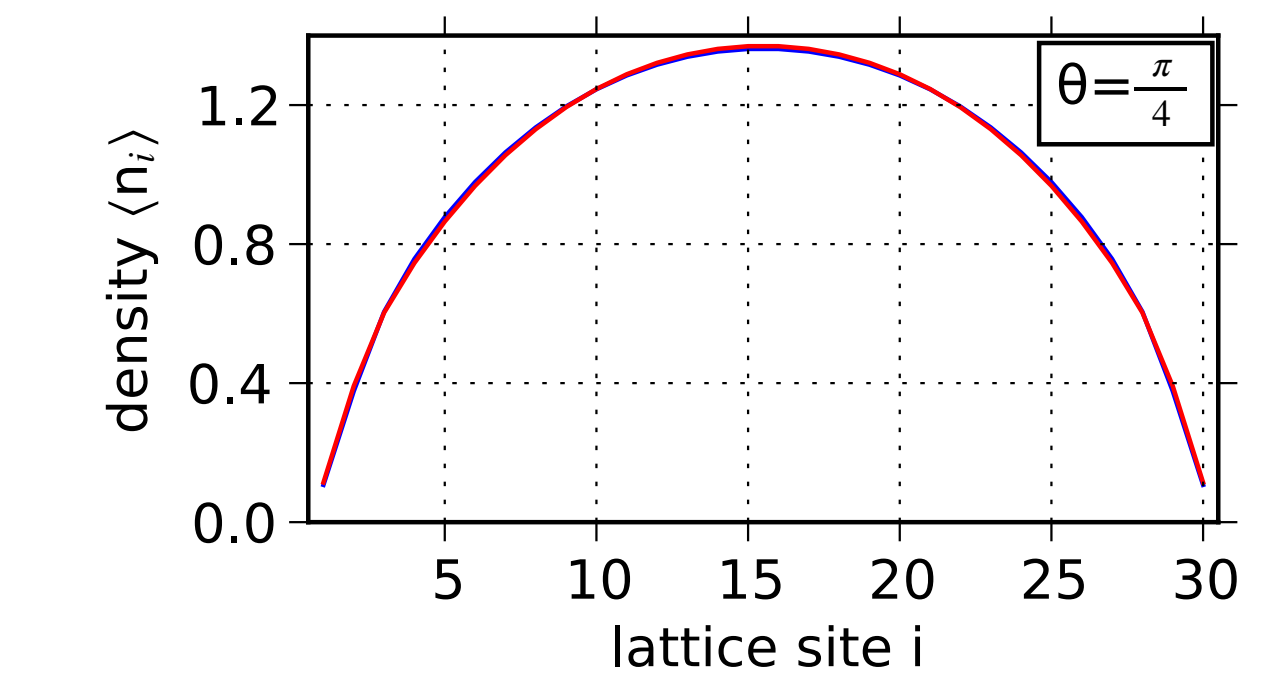


The Mott lobe (corresponding to $\langle n \rangle = 1$) expands with increasing statistical angle θ in both directions in the $(\mu/U, J/U)$ -plane.

This demonstrates the novel possibility to induce a quantum phase transition from the superfluid into the insulating, Mott-like phase, by simply changing the particle statistics.

fractional mott plateaus

Bosons in a harmonic trap



DMRG L=N=30, J/U=0.5, V/U=0.01