UNIVERSITY OF CAMBRIDGE

Few-atom approach to many-body physics

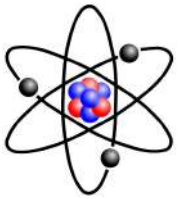
G.J. Conduit and P.O. Bugnion

POB, J. Lofthouse & GJC, Phys. Rev. Lett. **111**, 045301 (2013)

POB & GJC, Phys. Rev. A **87**, 060502(R) (2013)

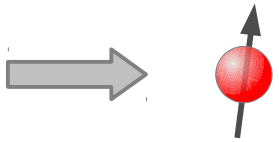
POB & GJC, Phys. Rev. A **88**, 013601 (2013)

Experimental setup



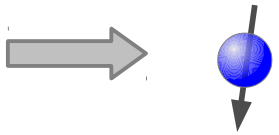
^{6}Li atom

$$|F = 1/2, m_F = 1/2\rangle$$



Up spin electron

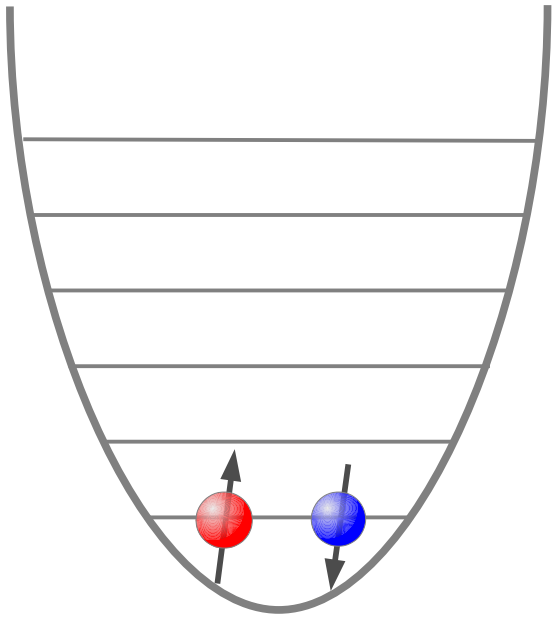
$$|F = 1/2, m_F = -1/2\rangle$$



Down spin electron

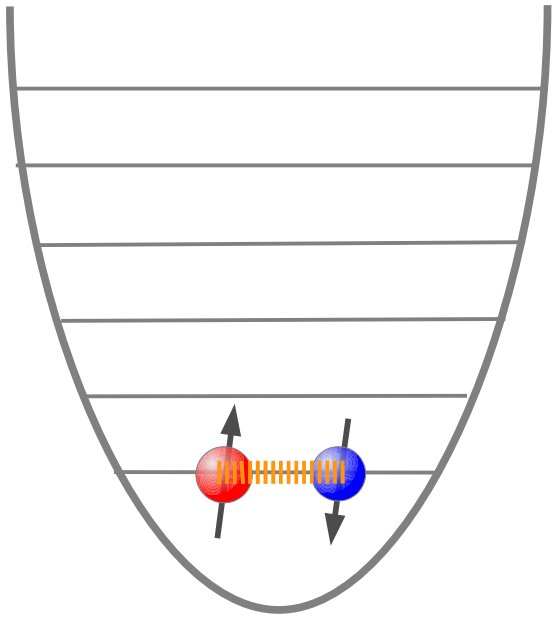
$$\hat{H} = -\frac{\nabla^2}{2} + g n_{\uparrow}(\vec{r})\, n_{\downarrow}(\vec{r})$$

Two distinguishable fermions

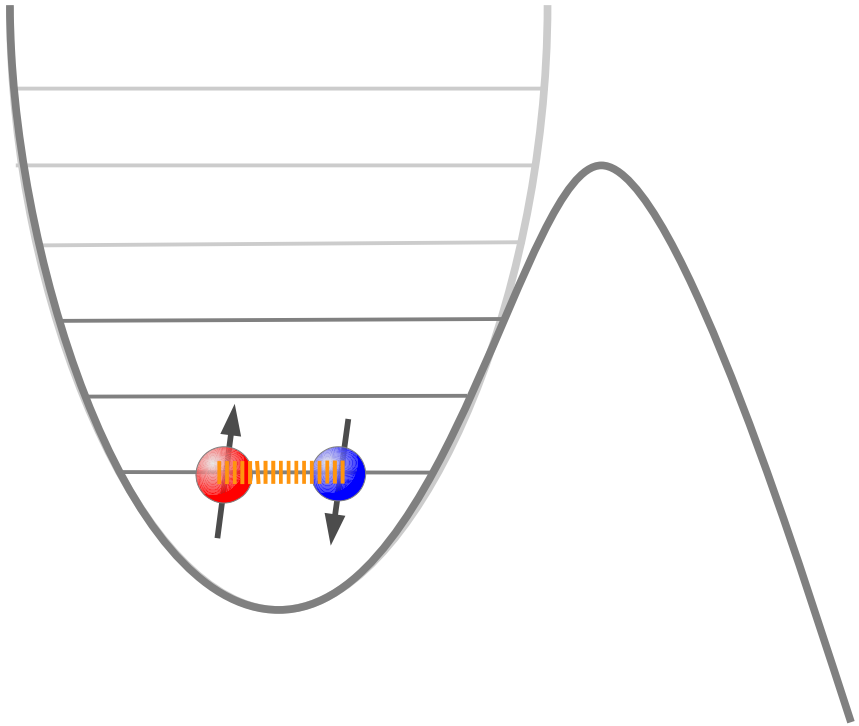


G. Zürn *et al*. PRL 108 075303 (2012)

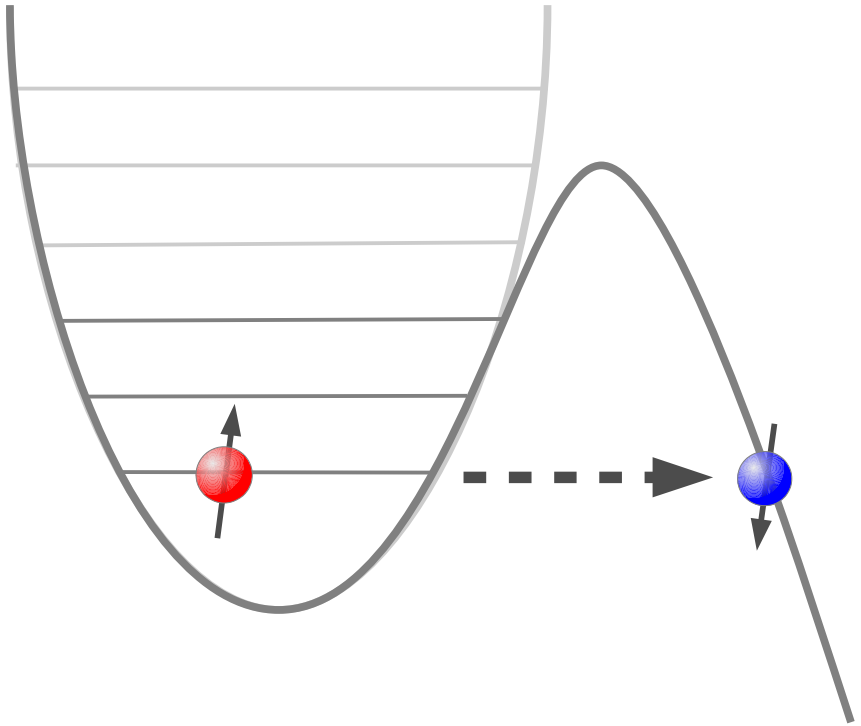
Two distinguishable fermions



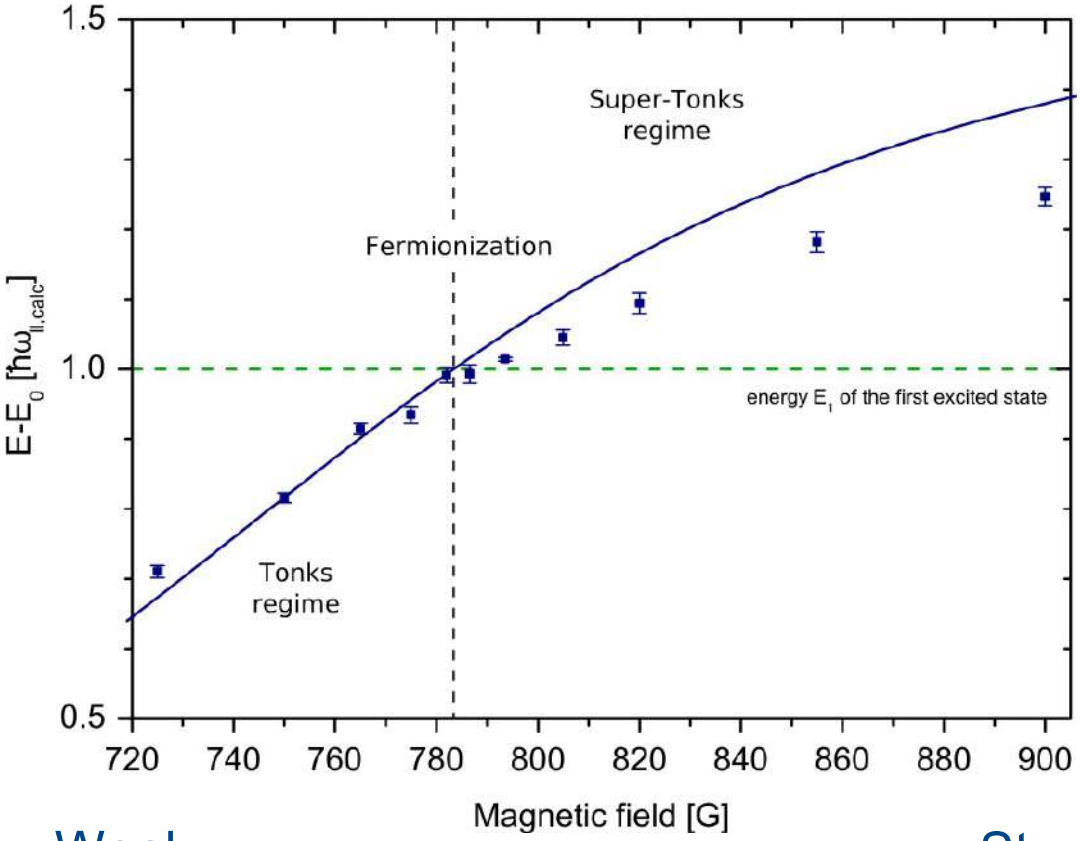
Two distinguishable fermions

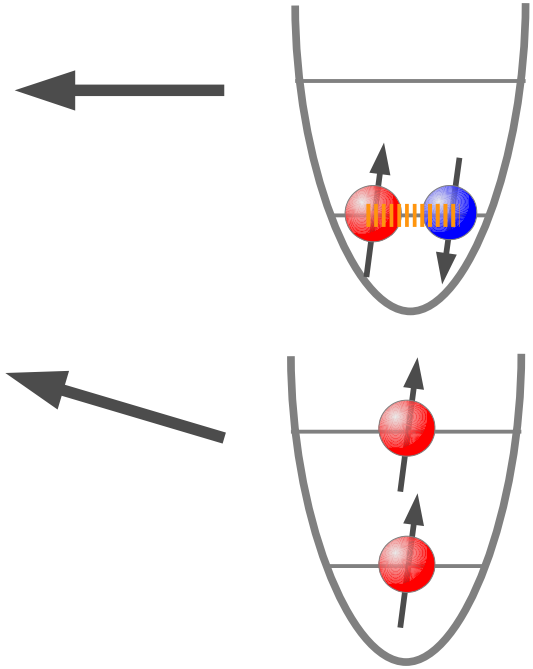


Two distinguishable fermions



Energy of states

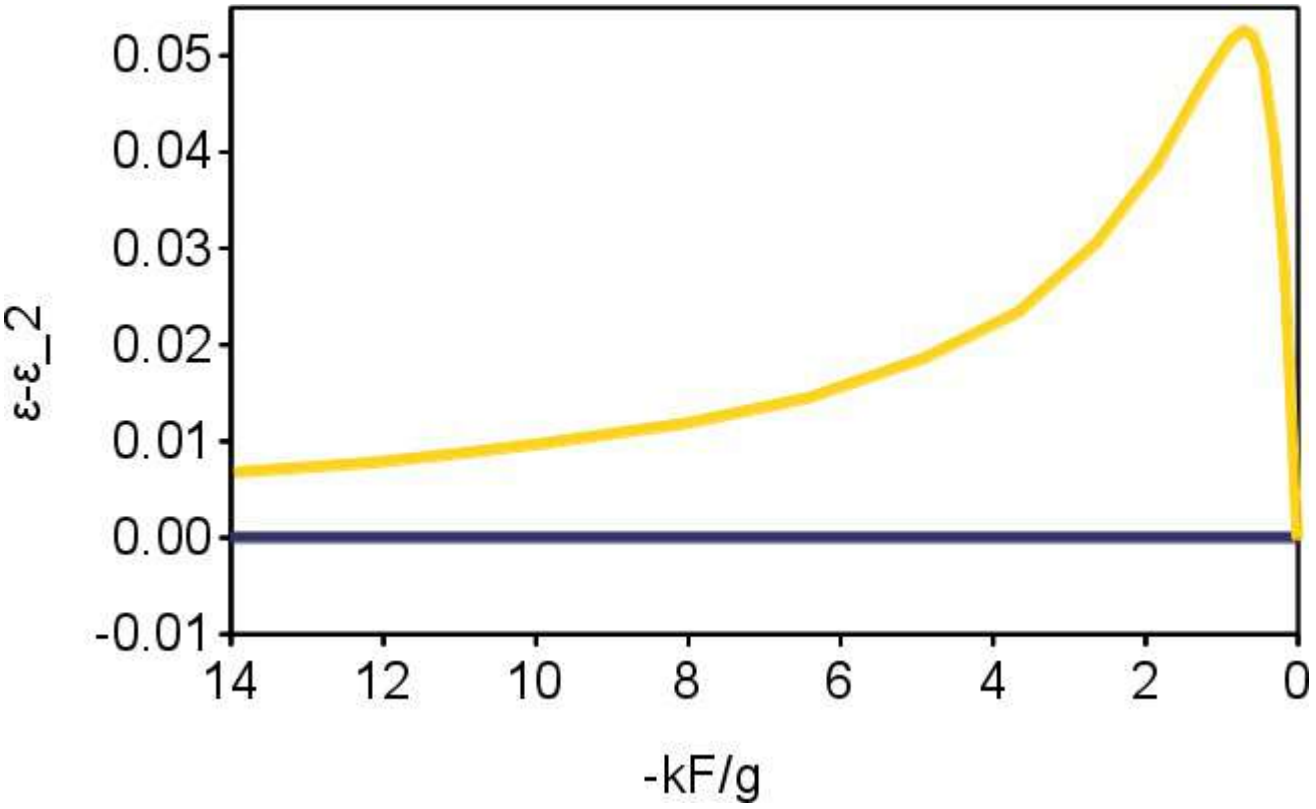


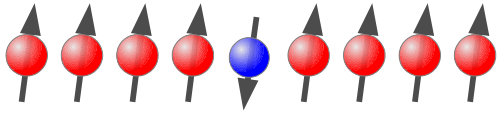


Weak repulsion

Strong repulsion

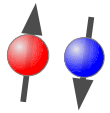
Polaron state





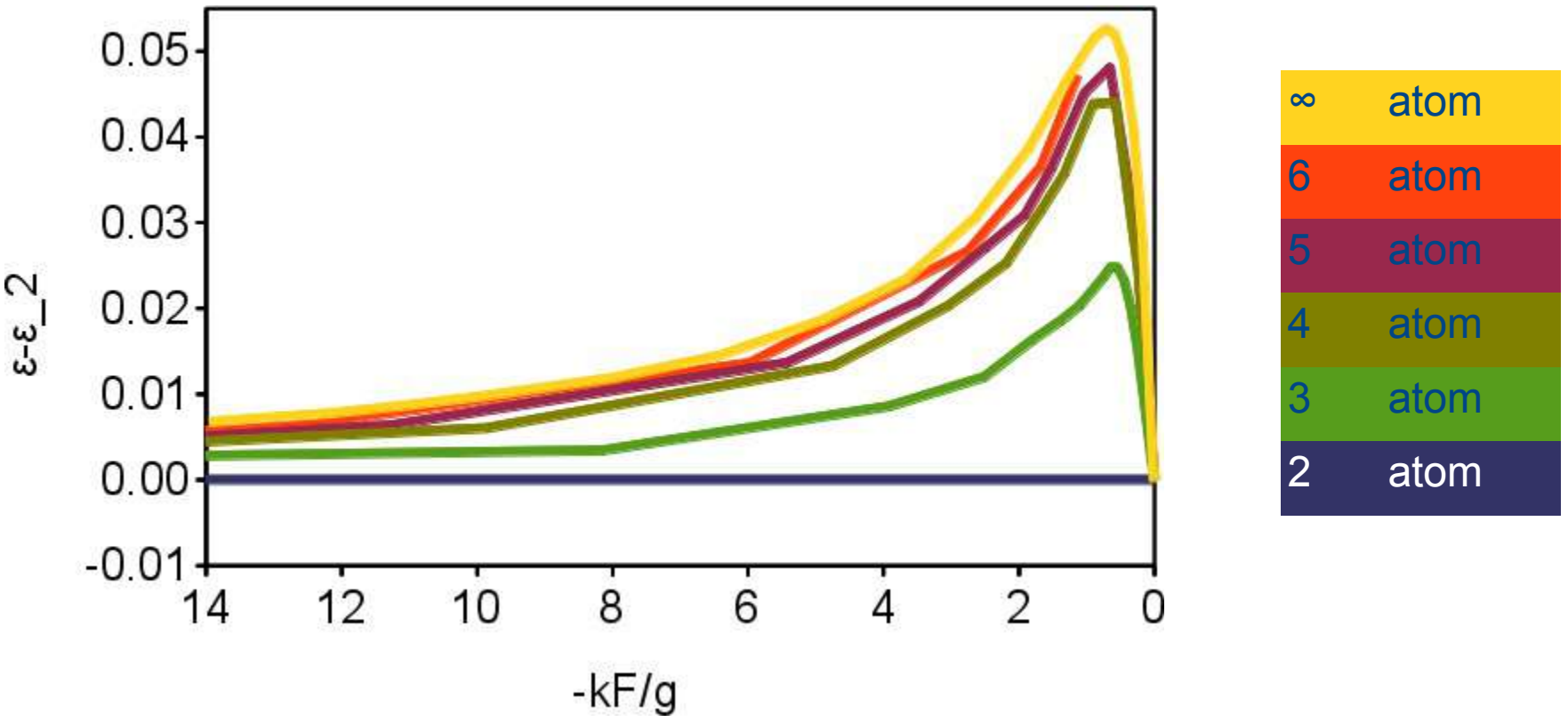
∞ atom

2 atom



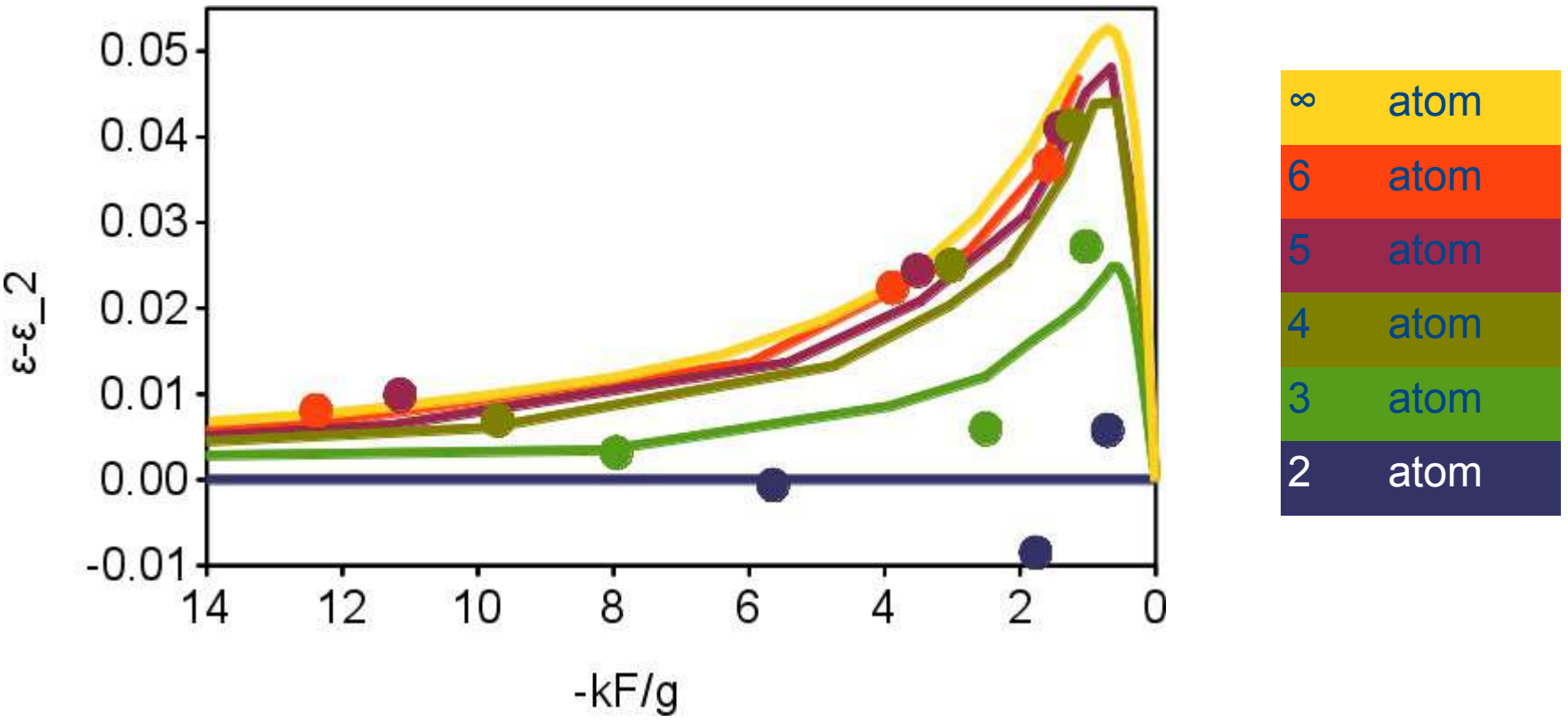
J.B. McGuire, J. Math. Phys. **6**, 432 (1965)

Polaron state



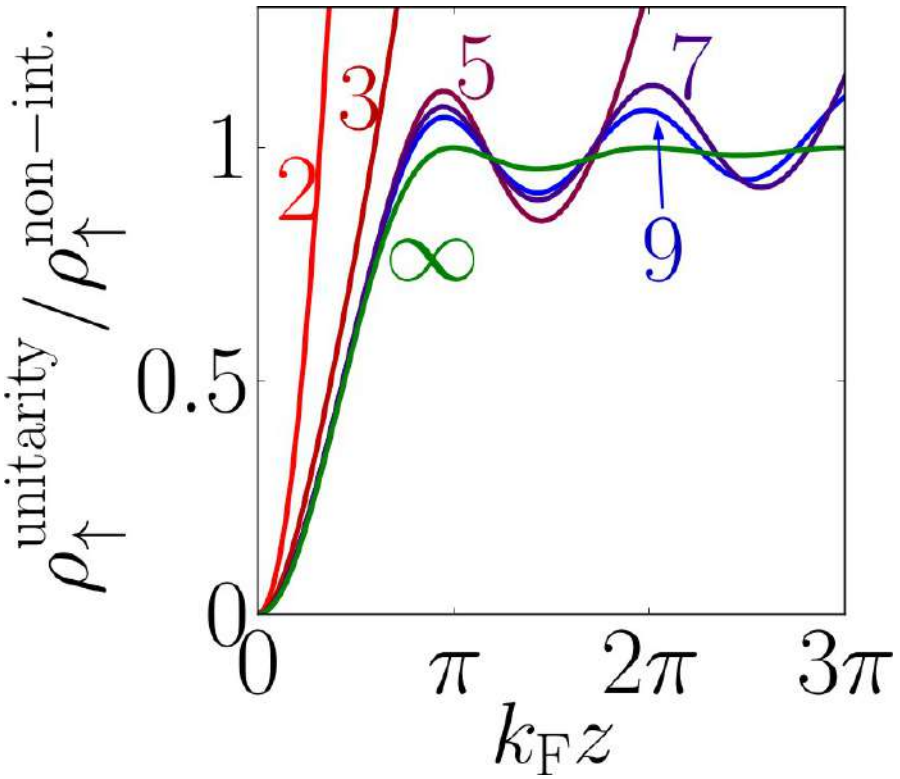
P.O. Bugnion & G.J. Conduit Phys. Rev. A **87**, 060502(R) (2013)

Polaron state



A. Wenz *et al.*, arXiv:1307.3443

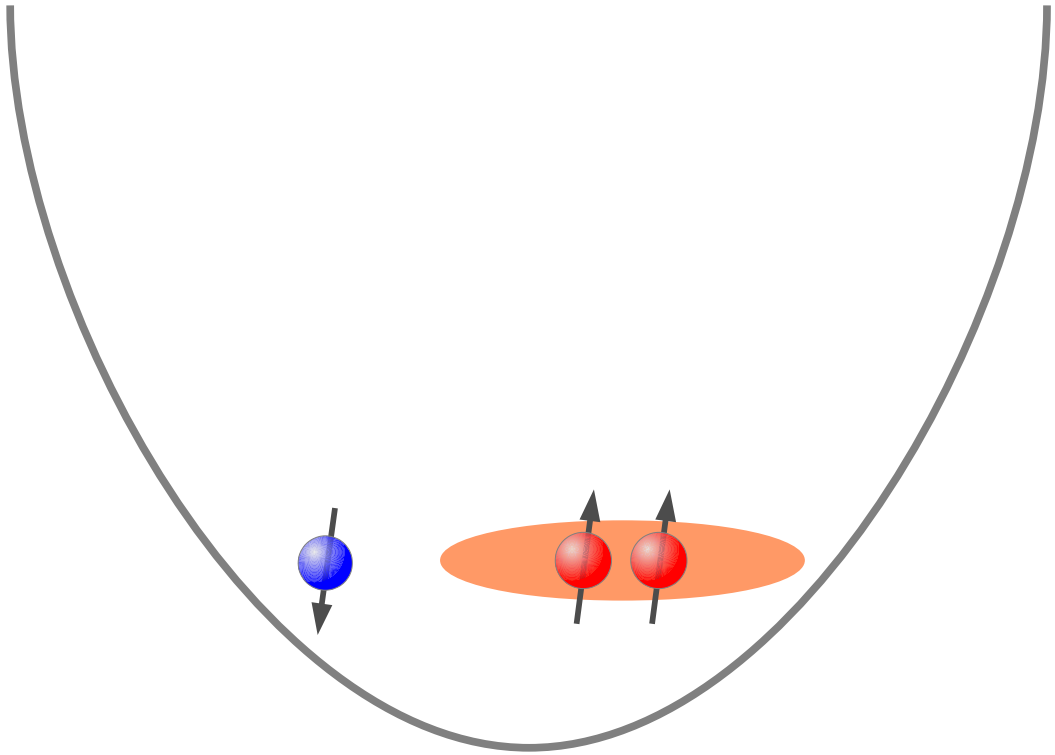
Polaron state



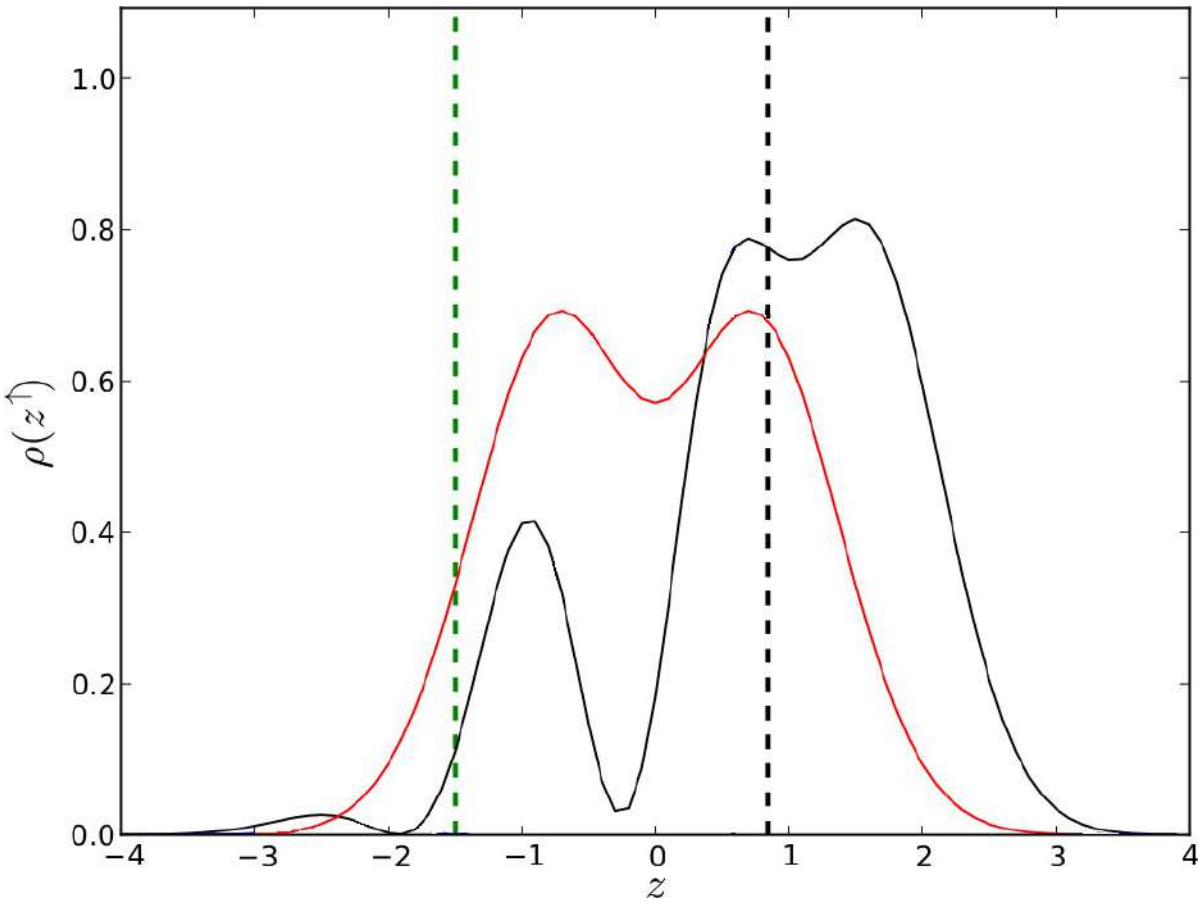
Stoner Hamiltonian

$$\hat{H} = -\frac{\nabla^2}{2} + g n_{\uparrow}(\vec{r})\, n_{\downarrow}(\vec{r}) + V(\vec{r})$$

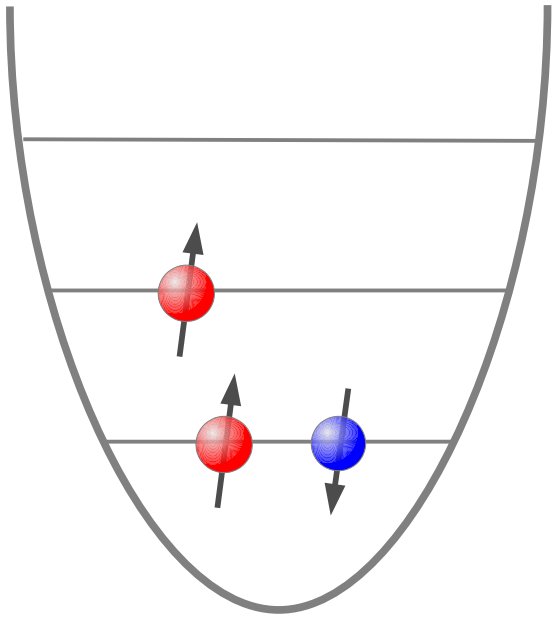
Density profiles



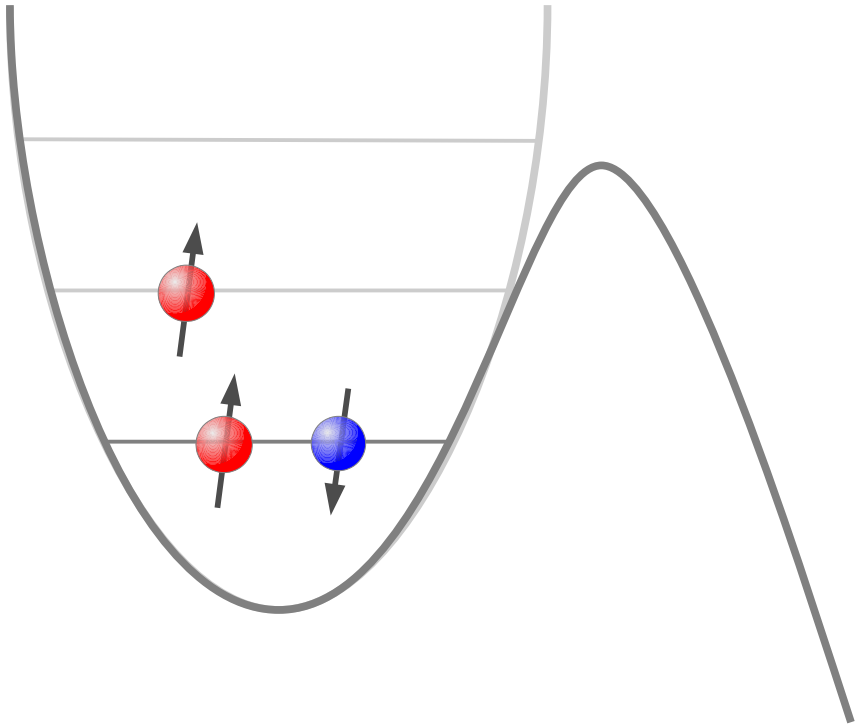
Density profiles



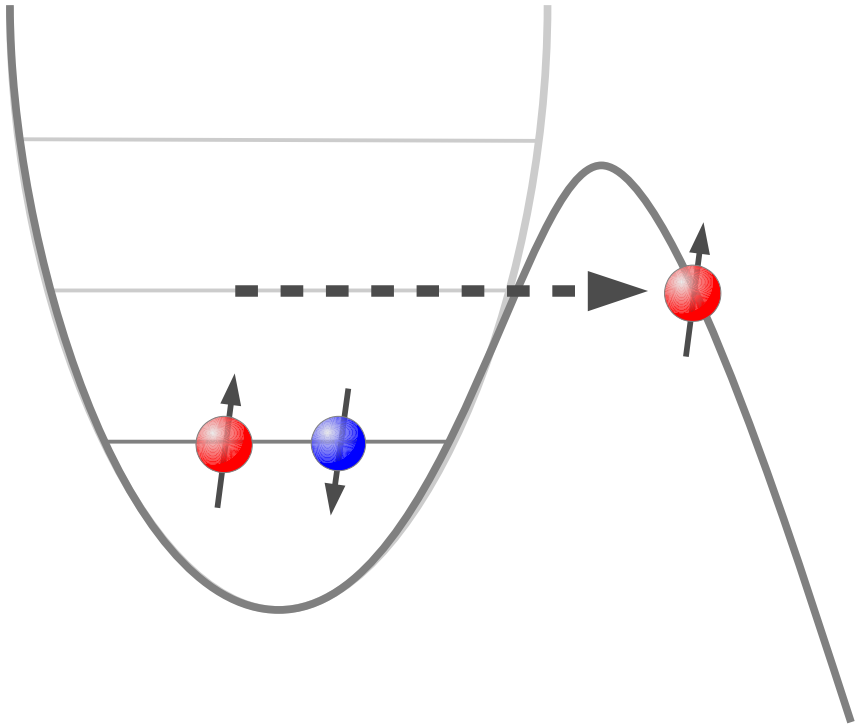
Polaron state



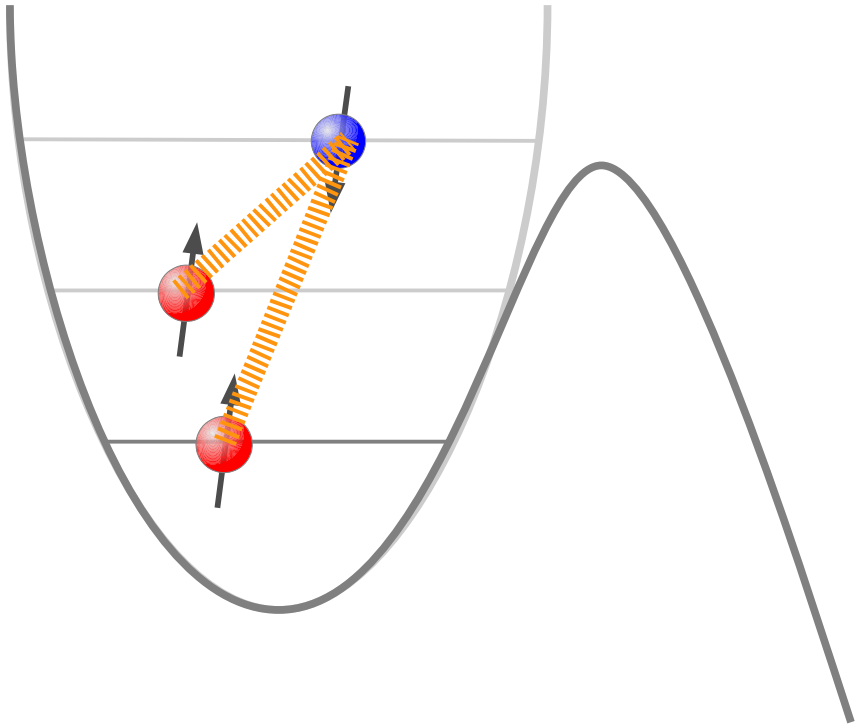
Polaron state



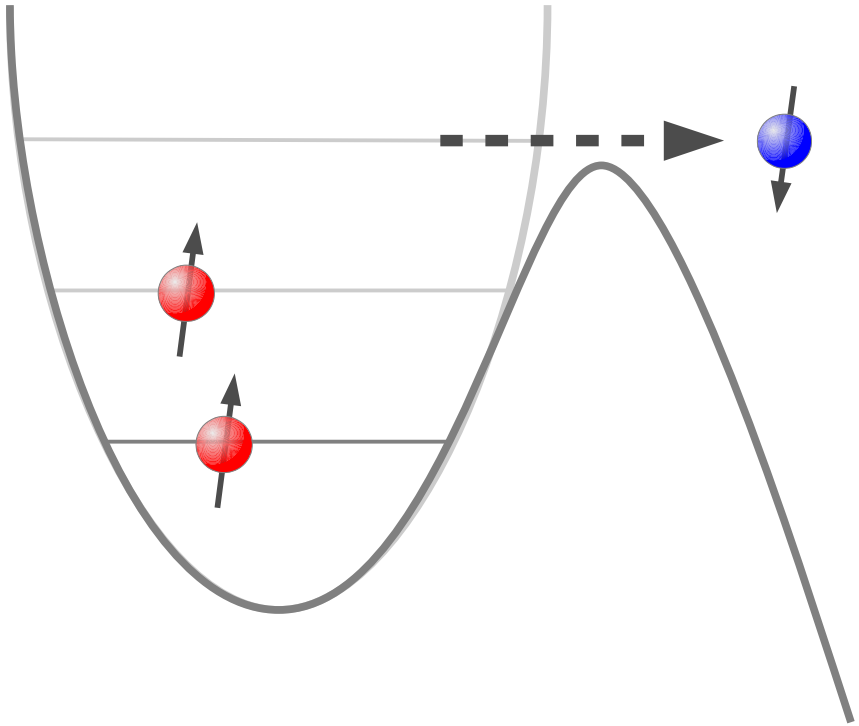
Polaron state



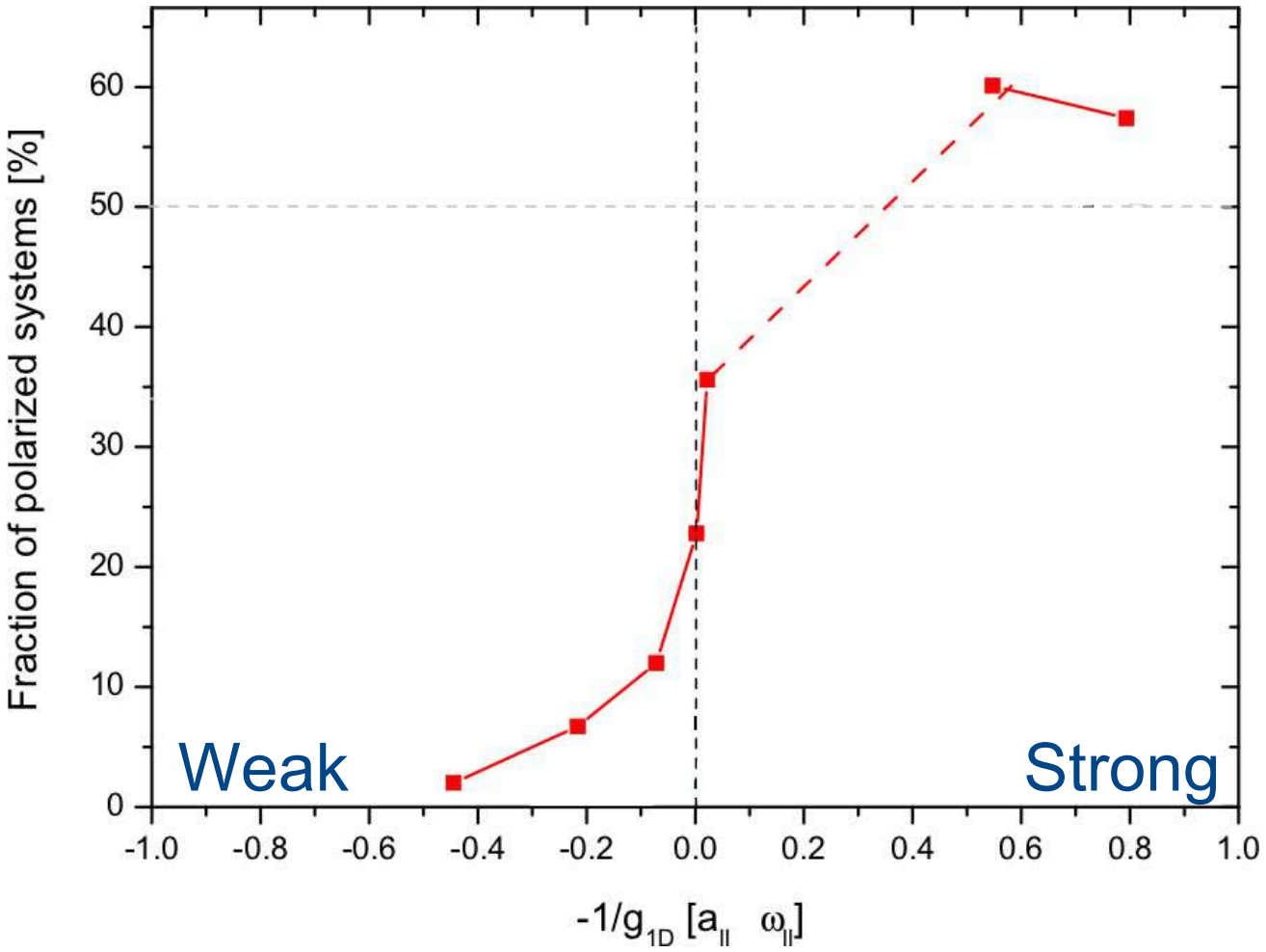
Polaron state

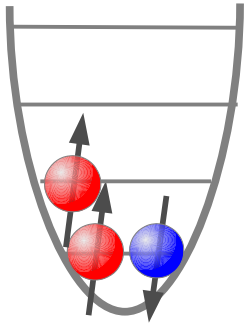


Polaron state

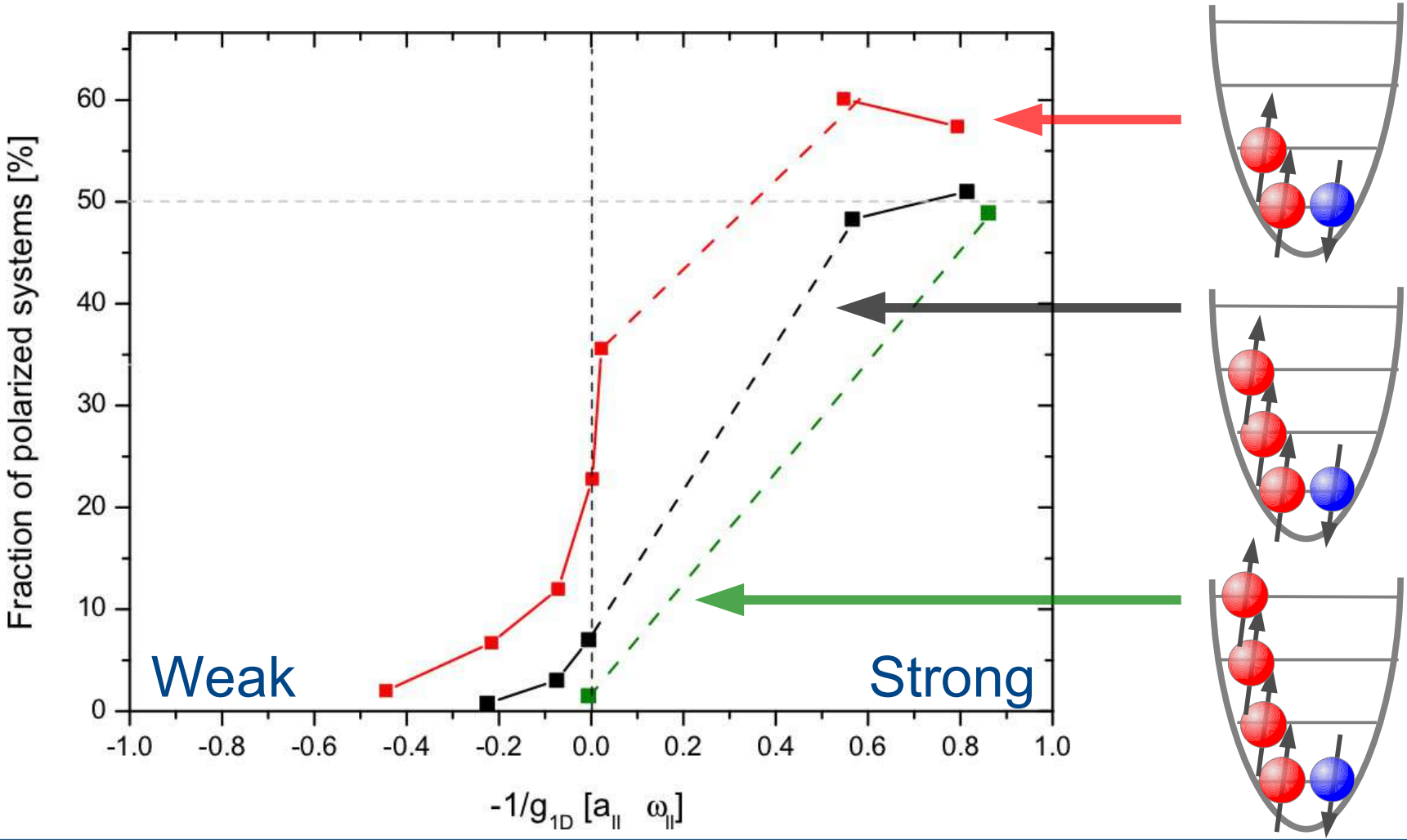


Loss region


Fraction of polarized systems [%]
60
50
40
30
20
10
0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Weak
Strong
-1/g1D [a⊥ ω⊥]

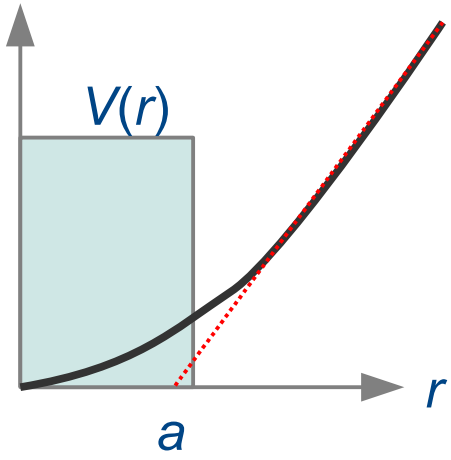


Tunneling probability



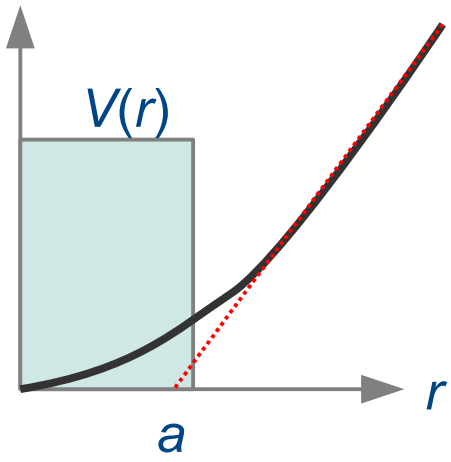
Two-atom scattering

Repulsive

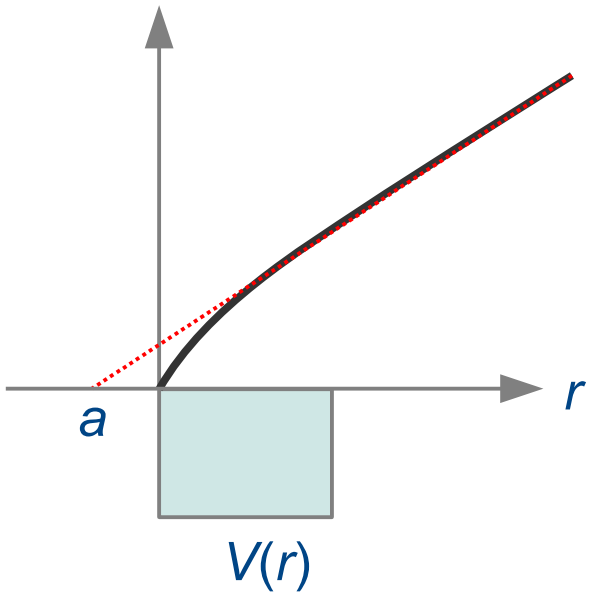


Two-atom scattering

Repulsive

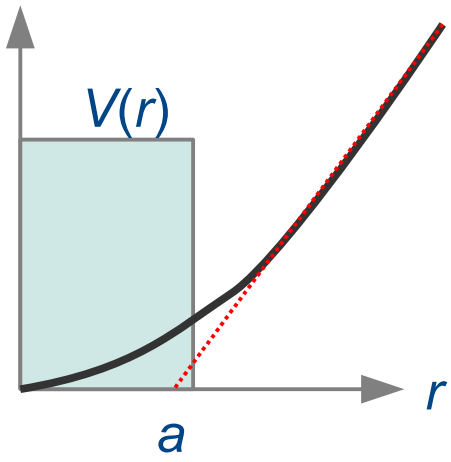


Attractive

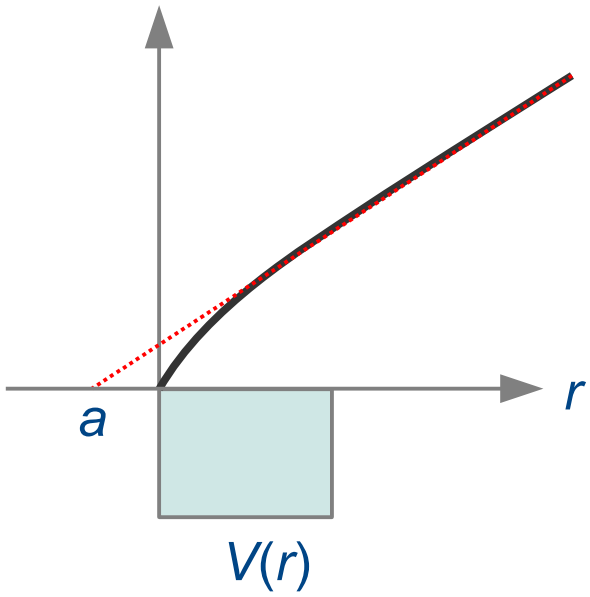


Two-atom scattering

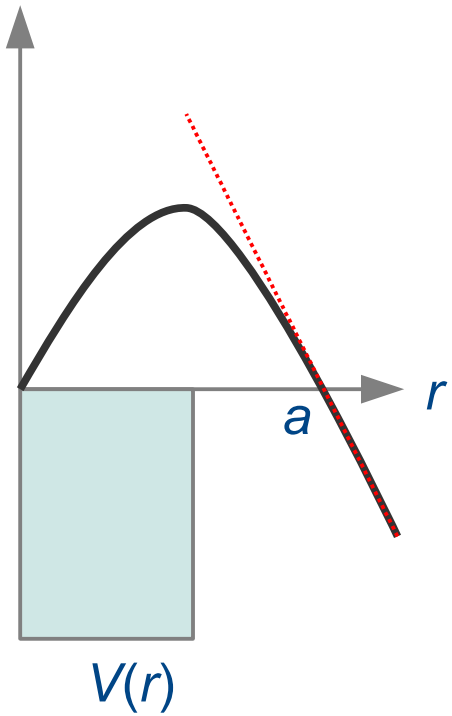
Repulsive



Attractive

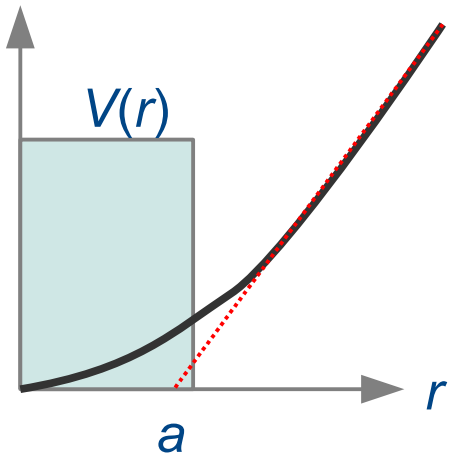


Repulsive

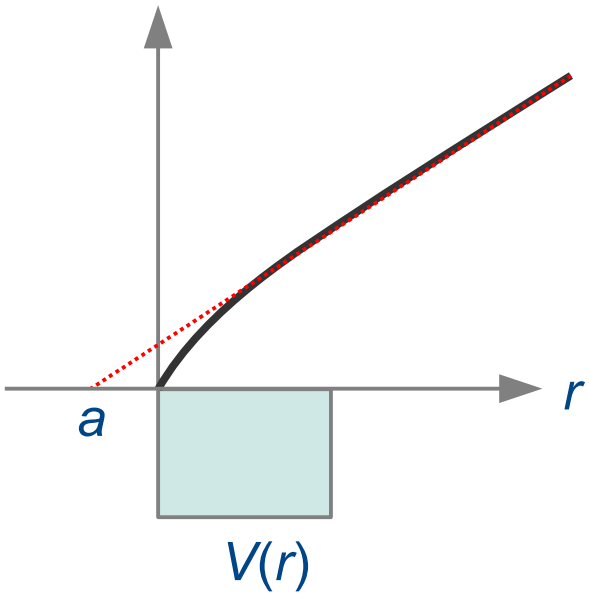


Two-atom scattering

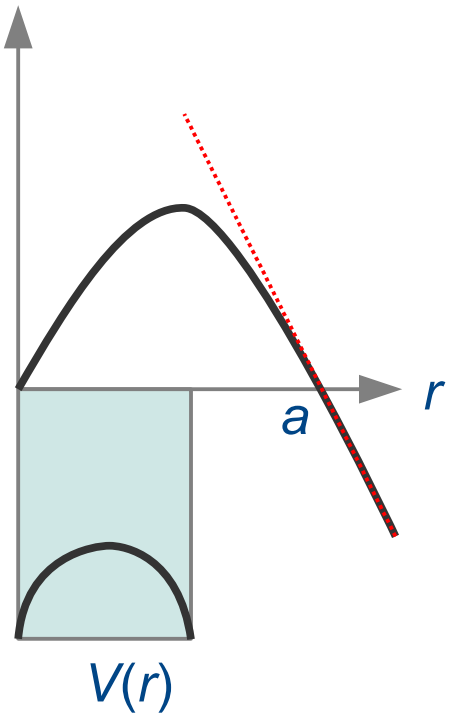
Repulsive



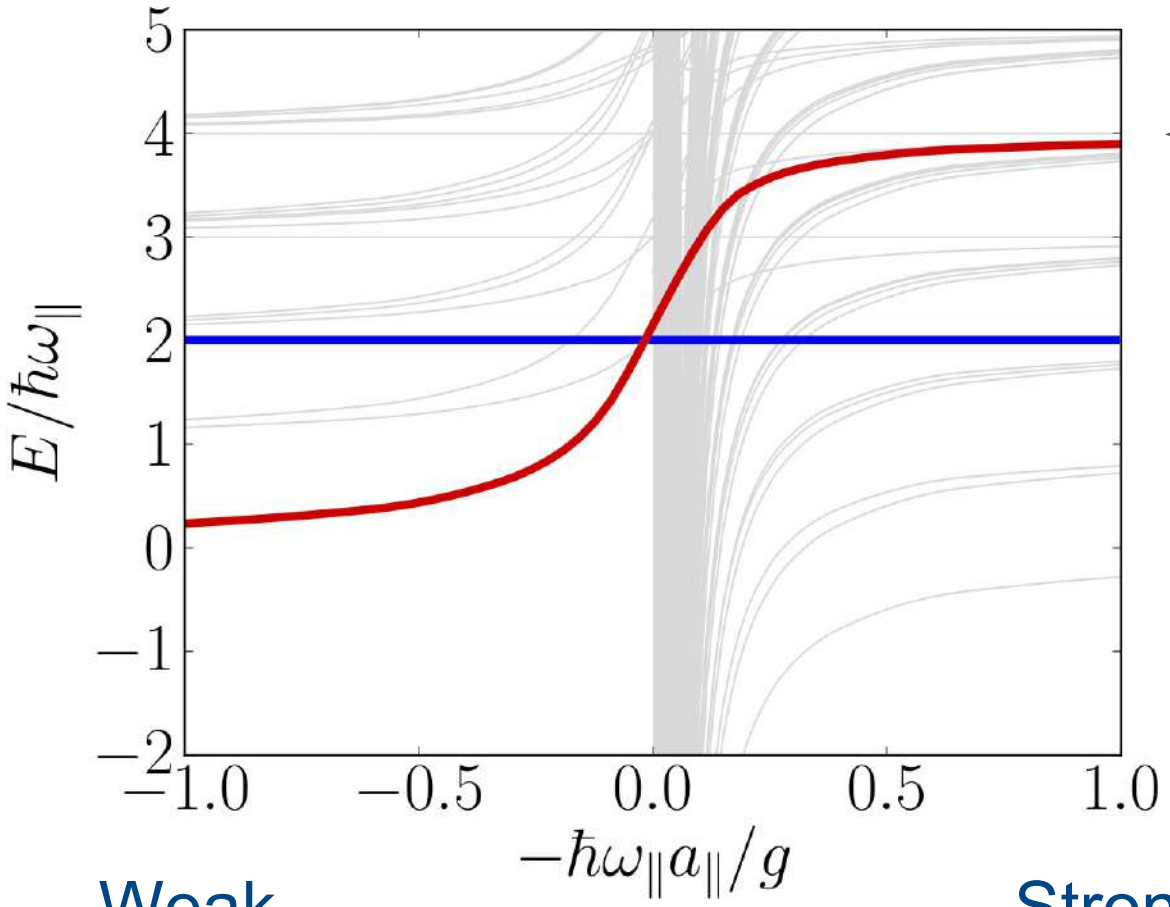
Attractive

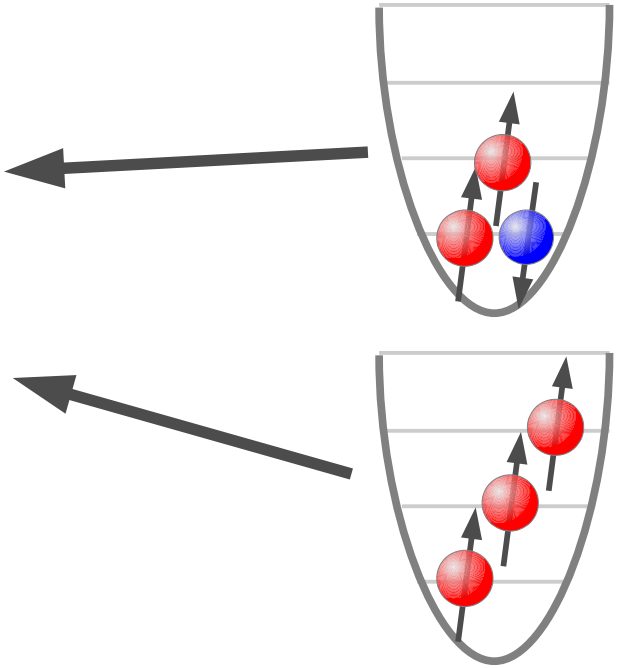


Repulsive



Three-atom bound state

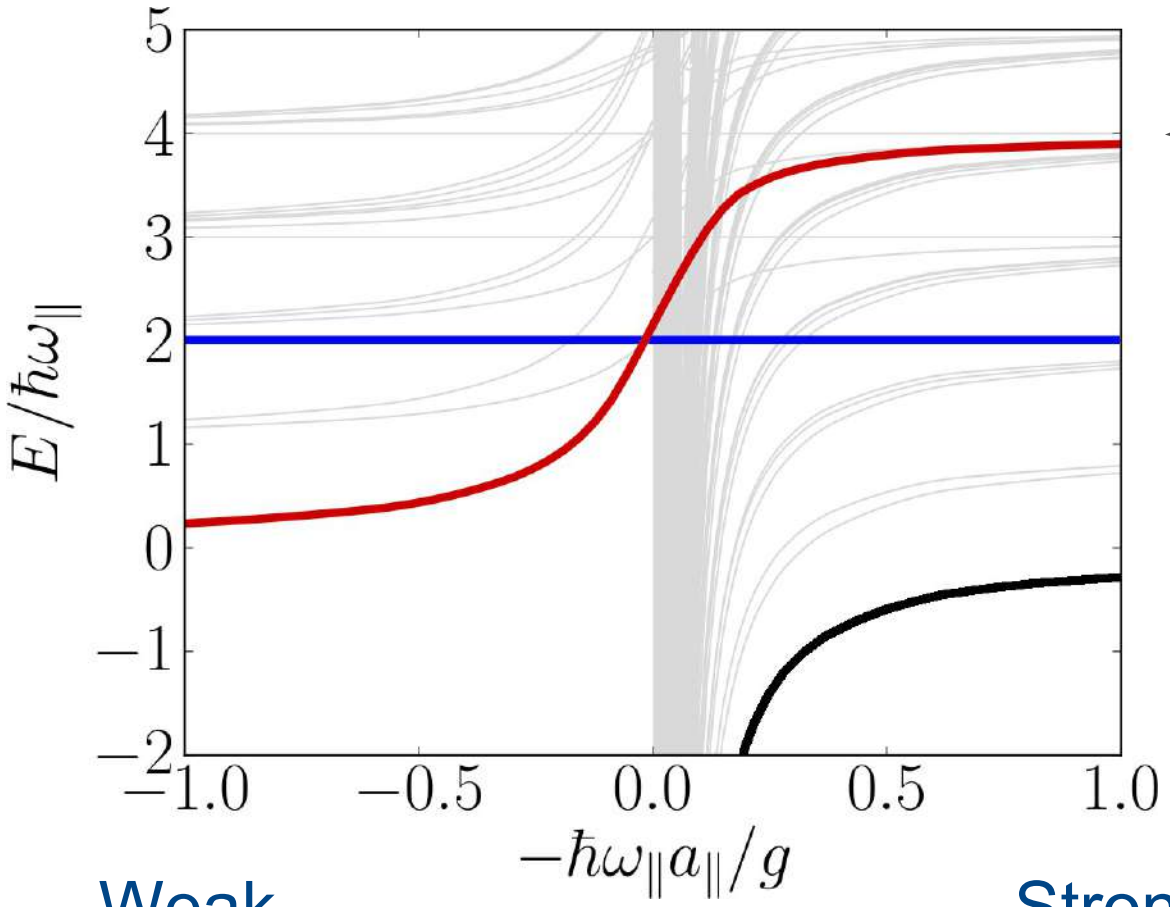


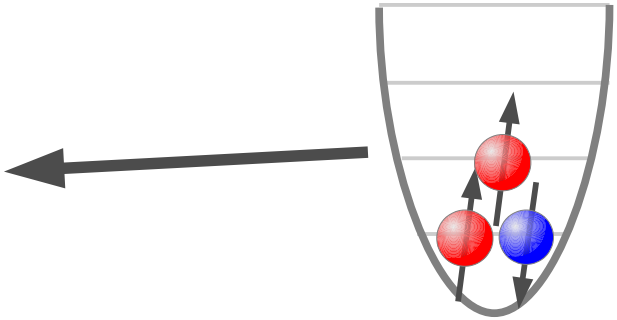


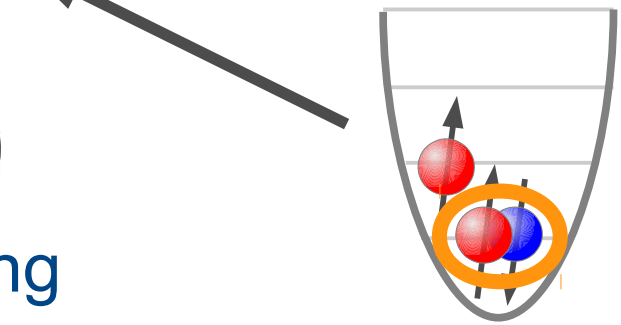
Weak

Strong

Three-atom bound state



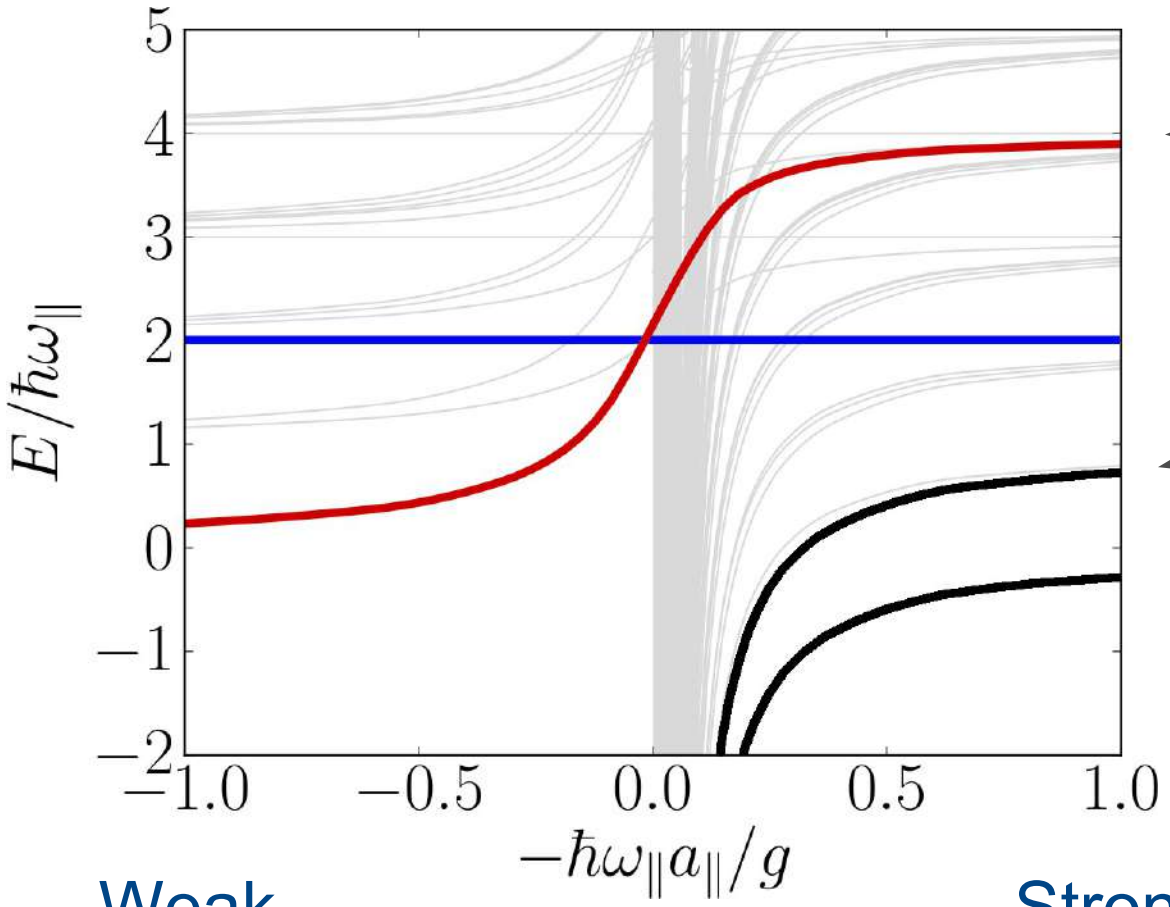




Weak

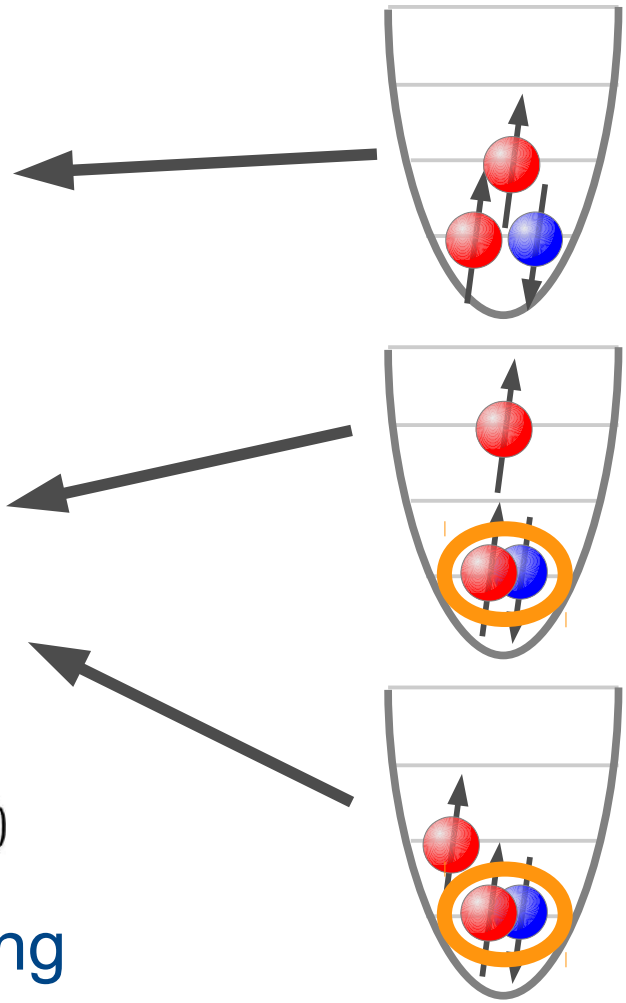
Strong

Three-atom bound state

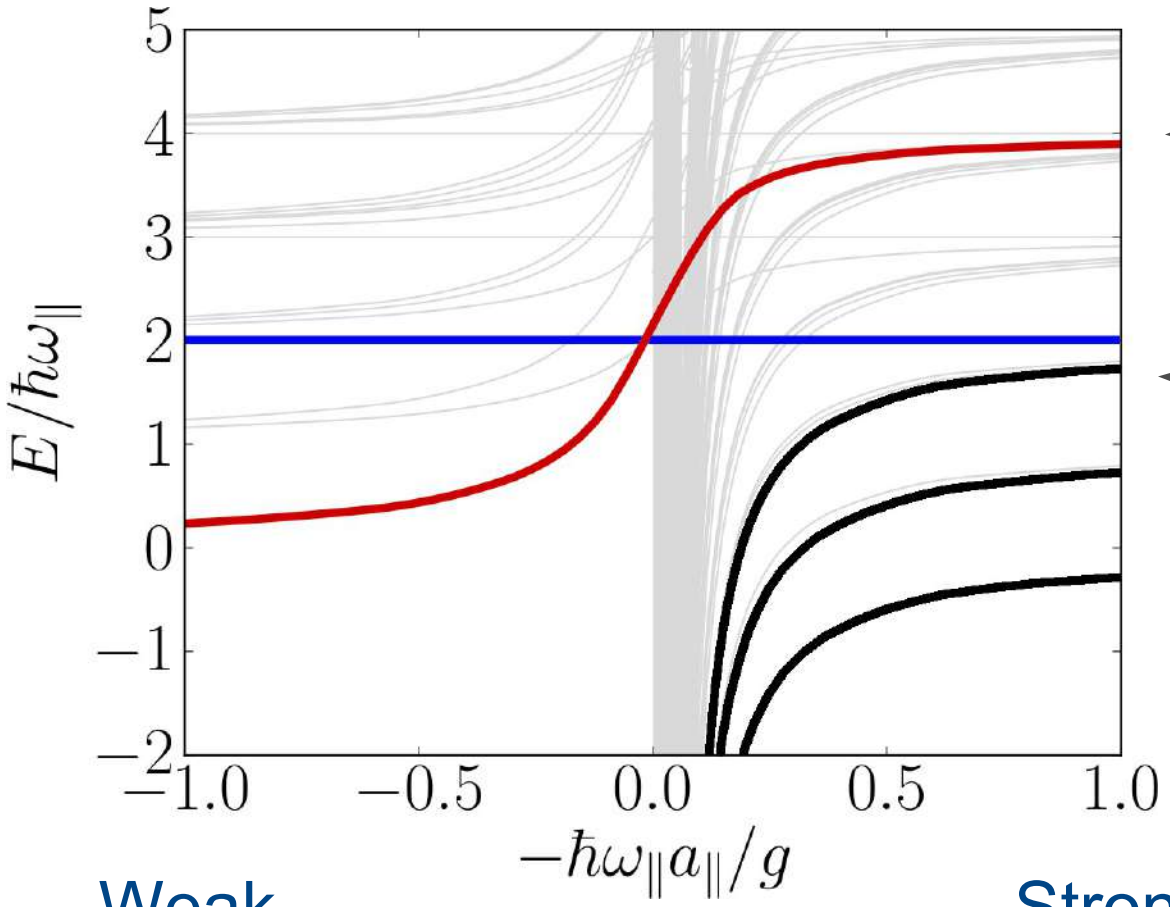


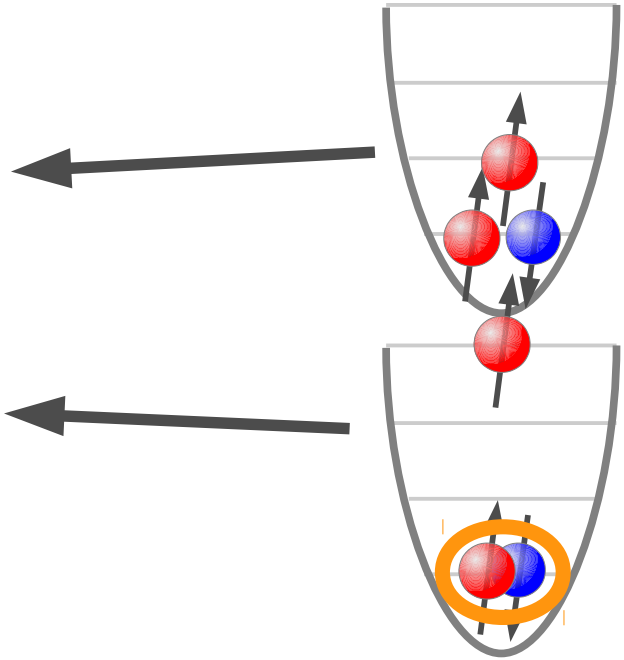
Weak

Strong



Three-atom bound state

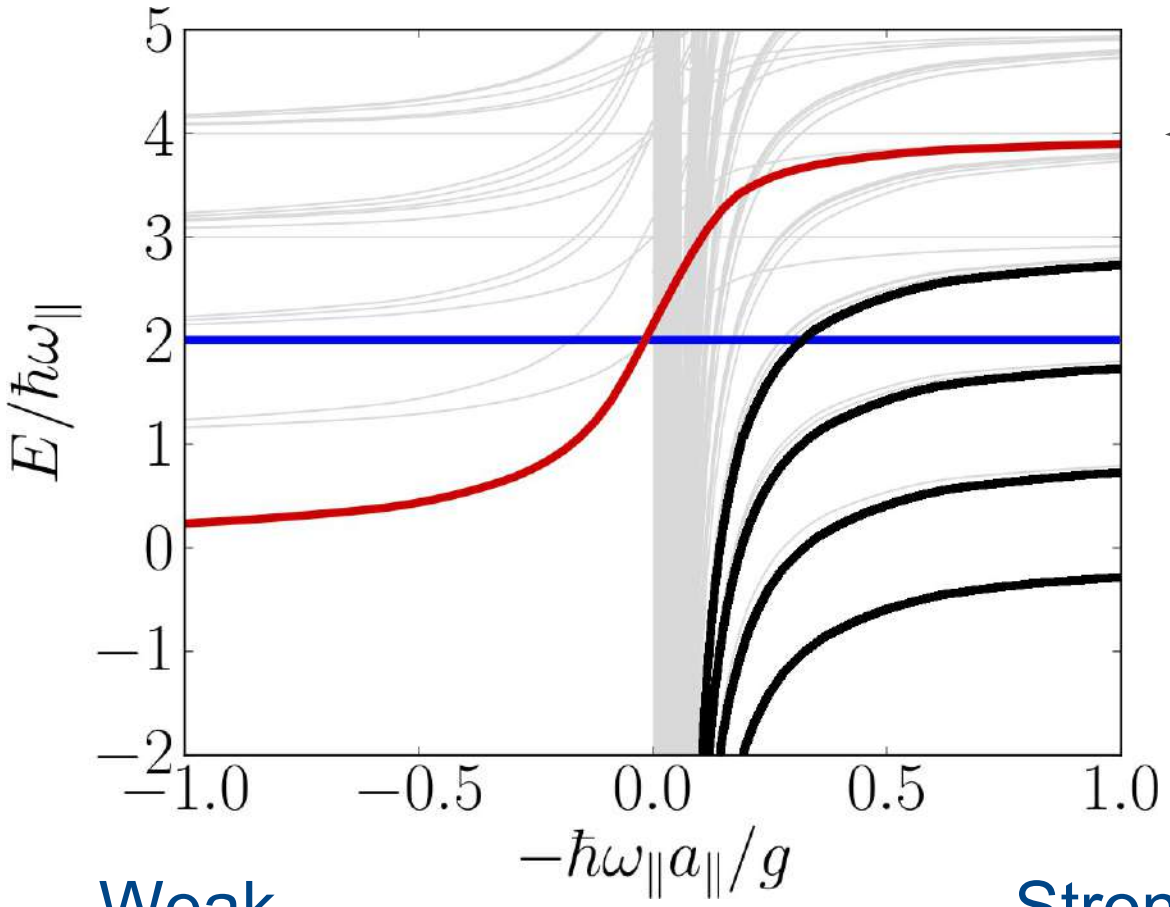


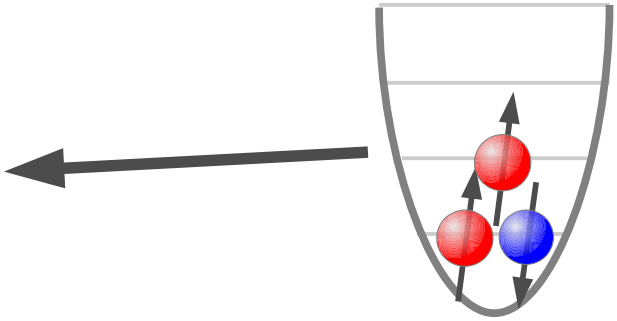


Weak

Strong

Three-atom bound state

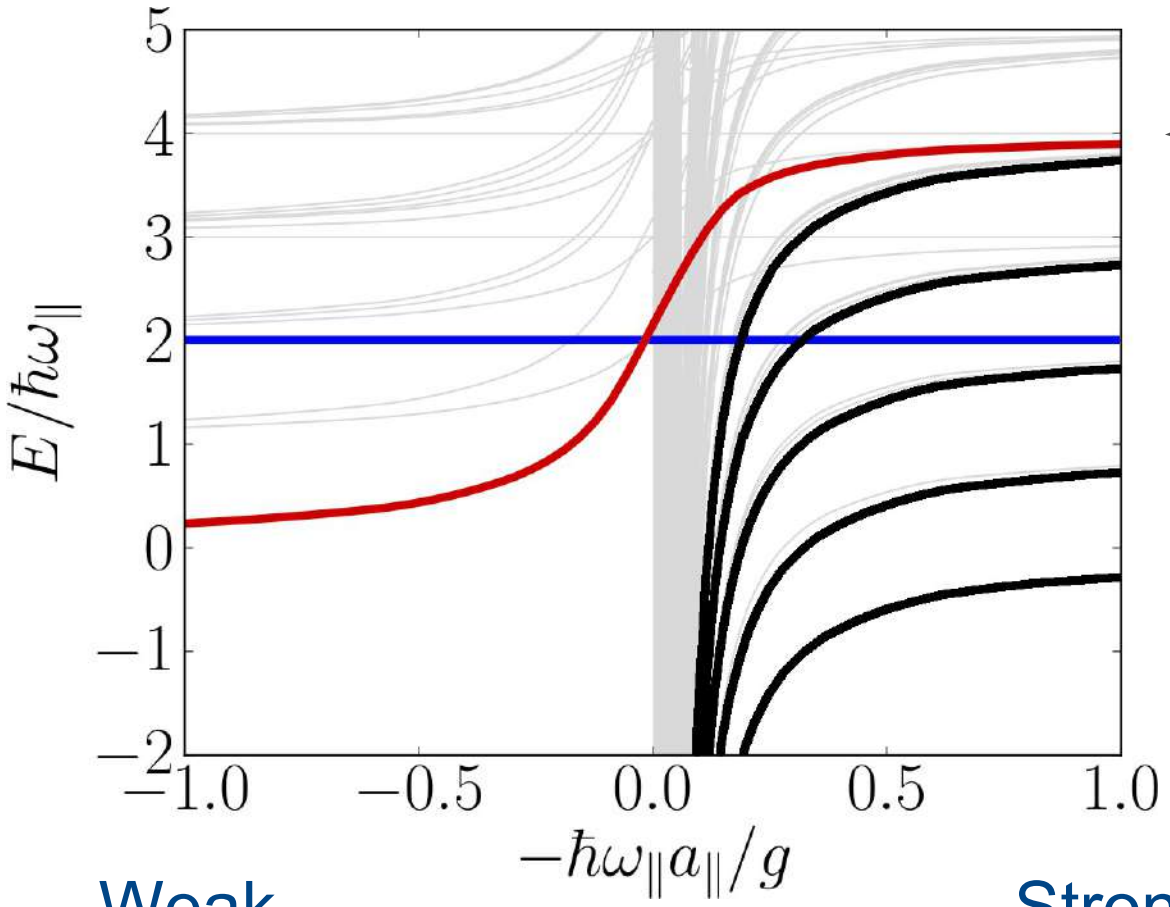


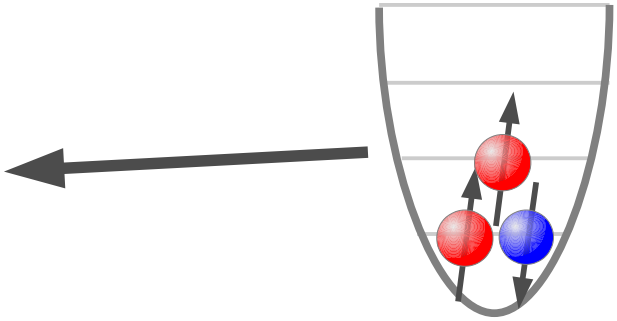


Weak

Strong

Three-atom bound state

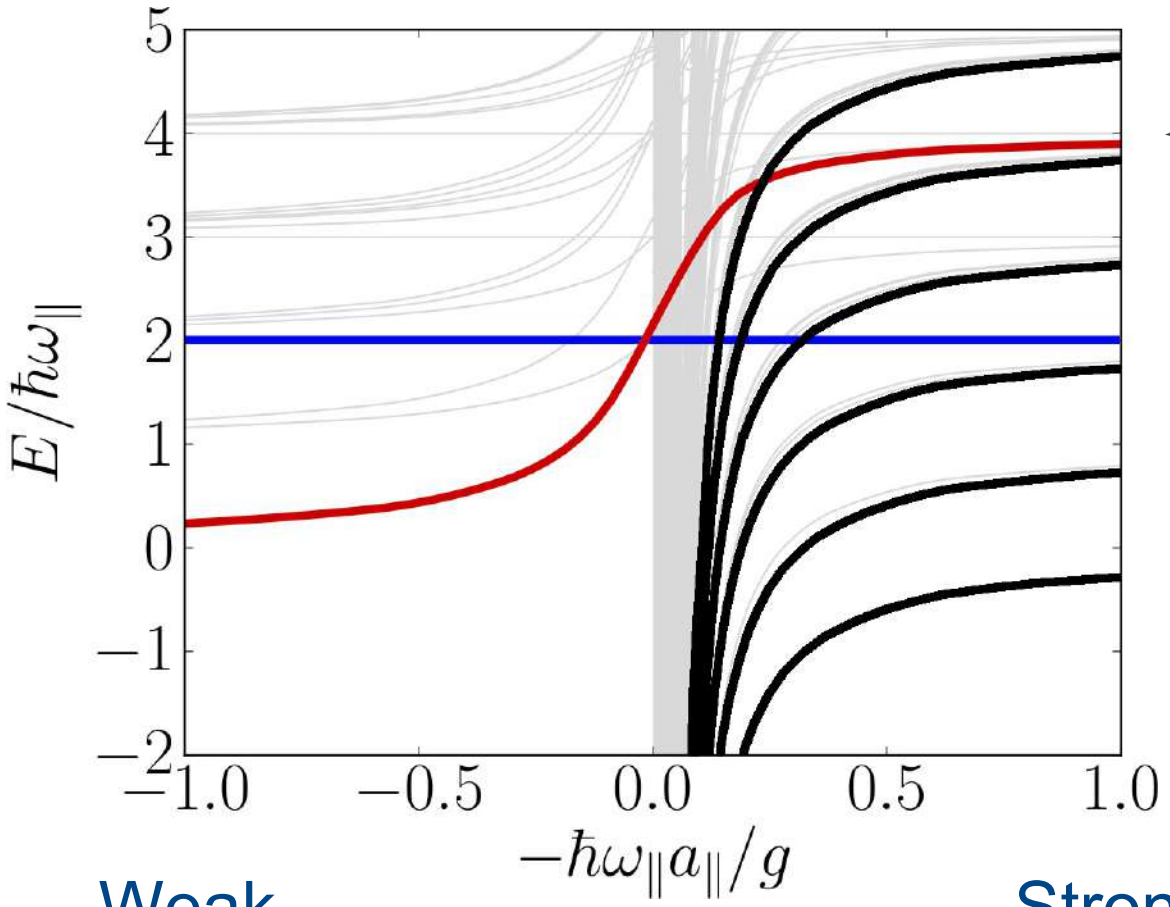


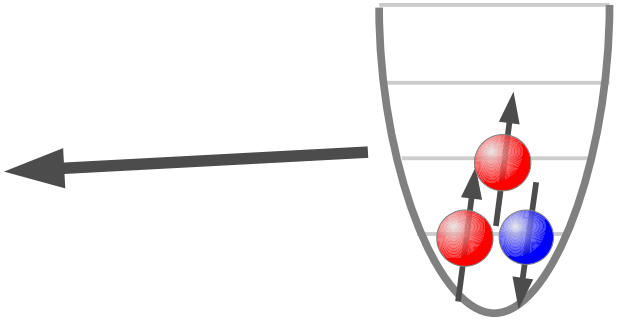


Weak

Strong

Three-atom bound state

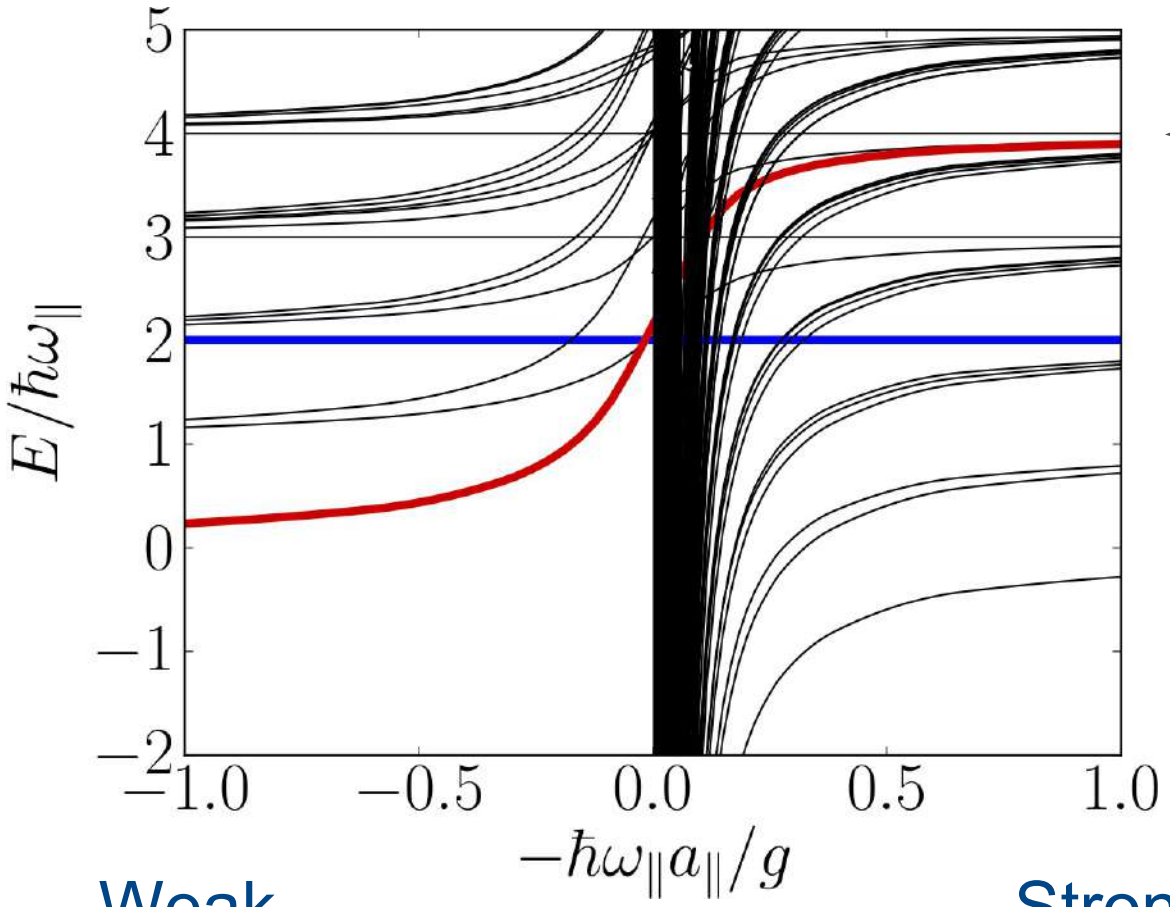


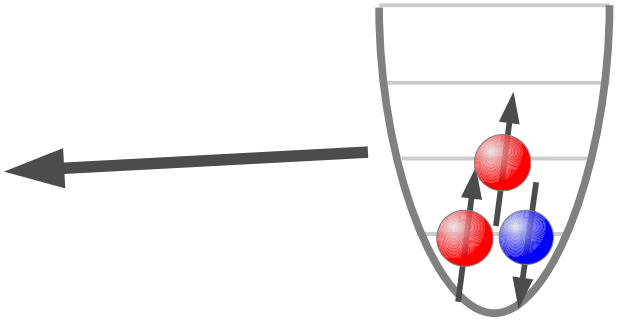


Weak

Strong

Three-atom bound state

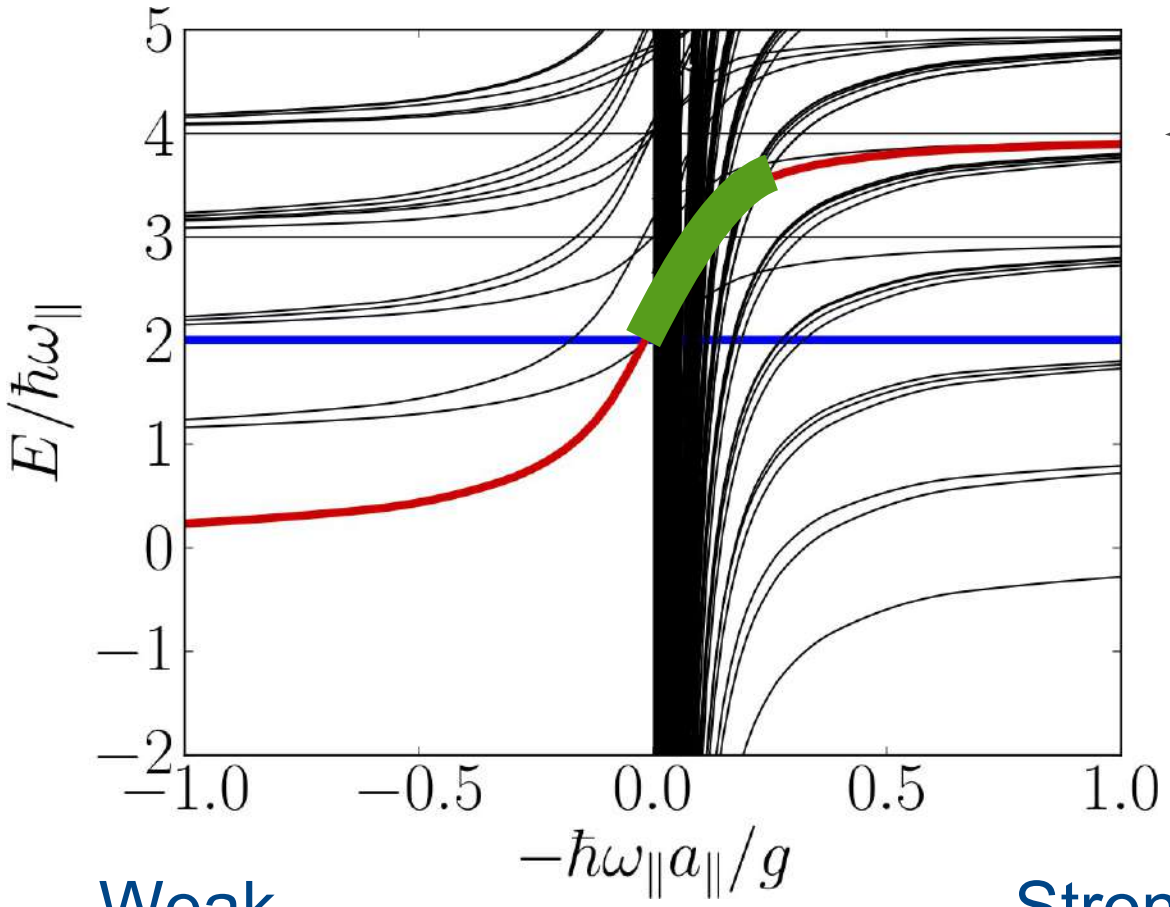


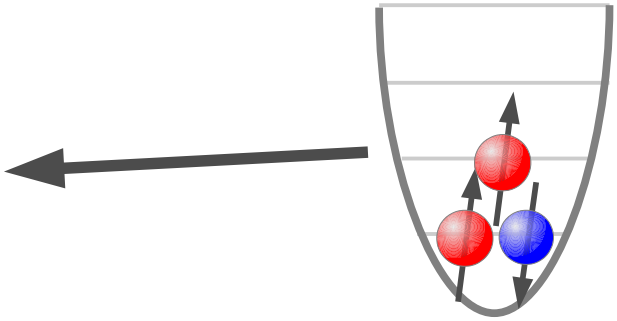


Weak

Strong

Three-atom bound state

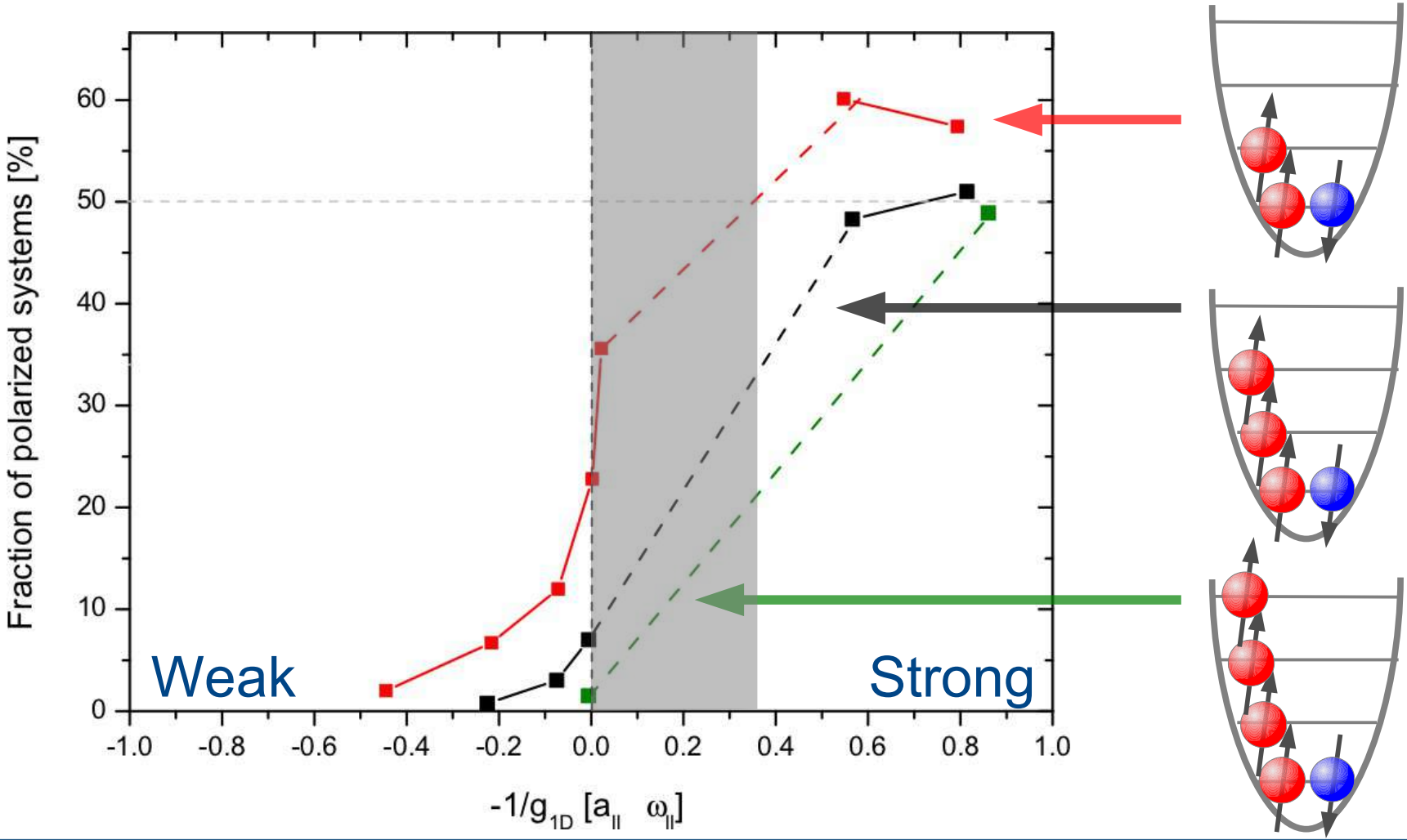




Weak

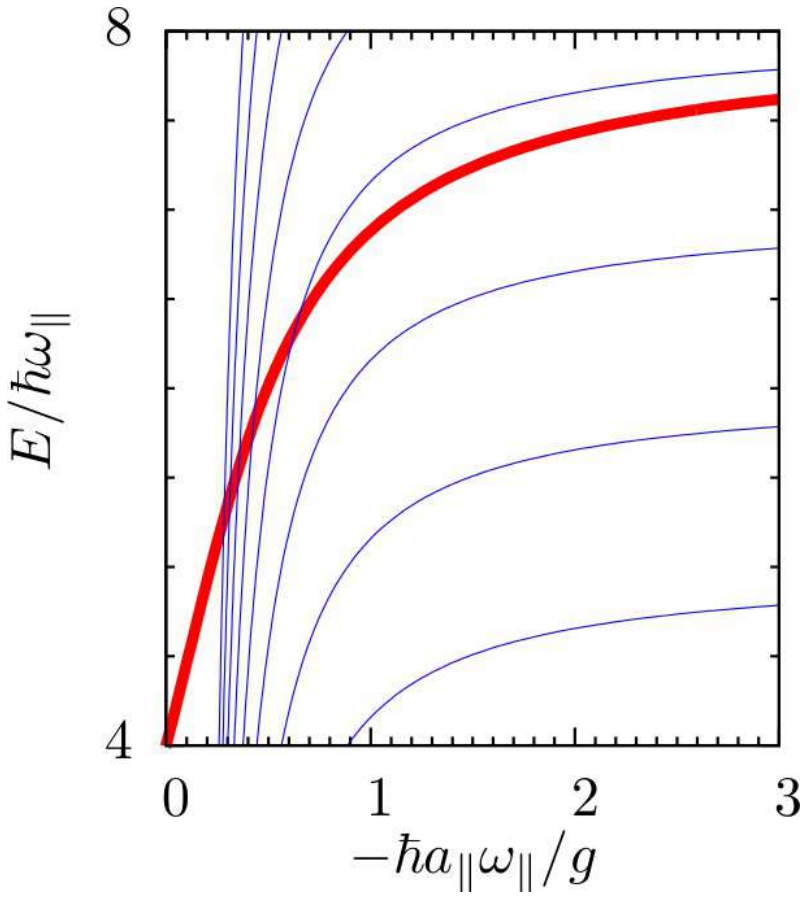
Strong

Tunneling probability

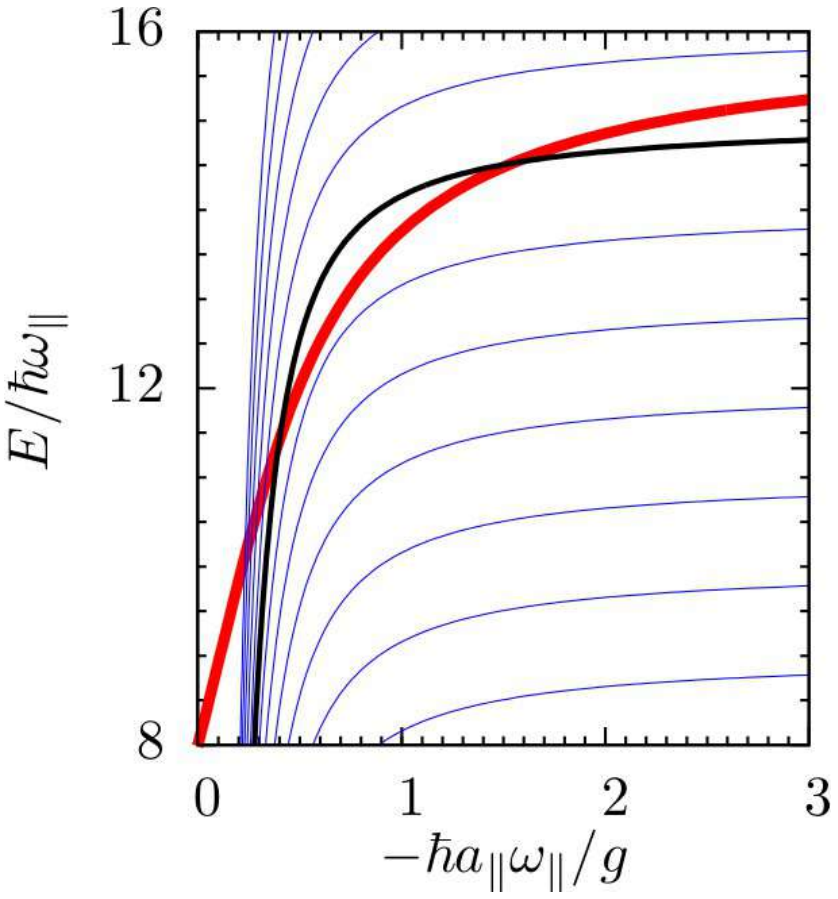


Band crossings

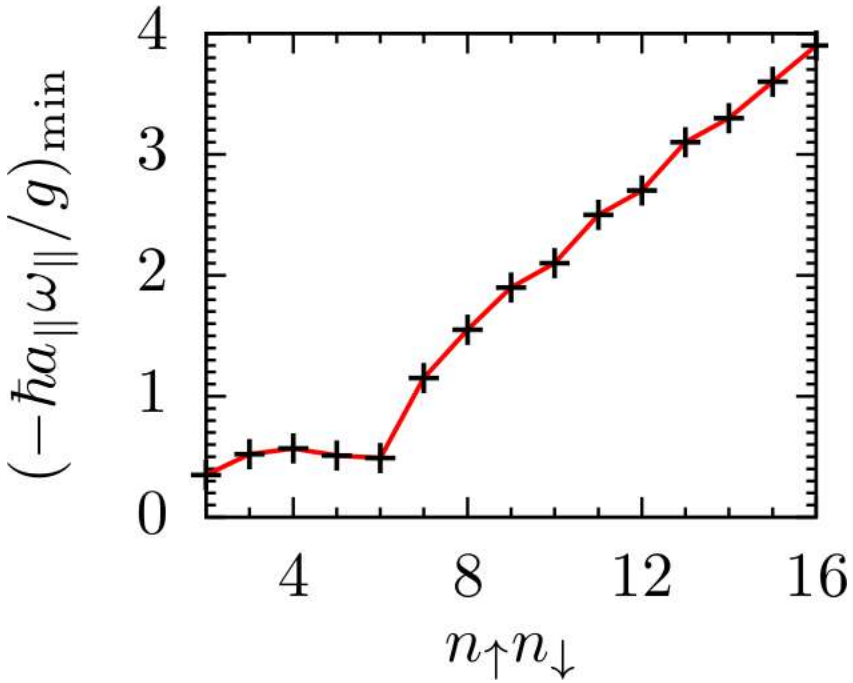
$n_\uparrow n_\downarrow = 4$



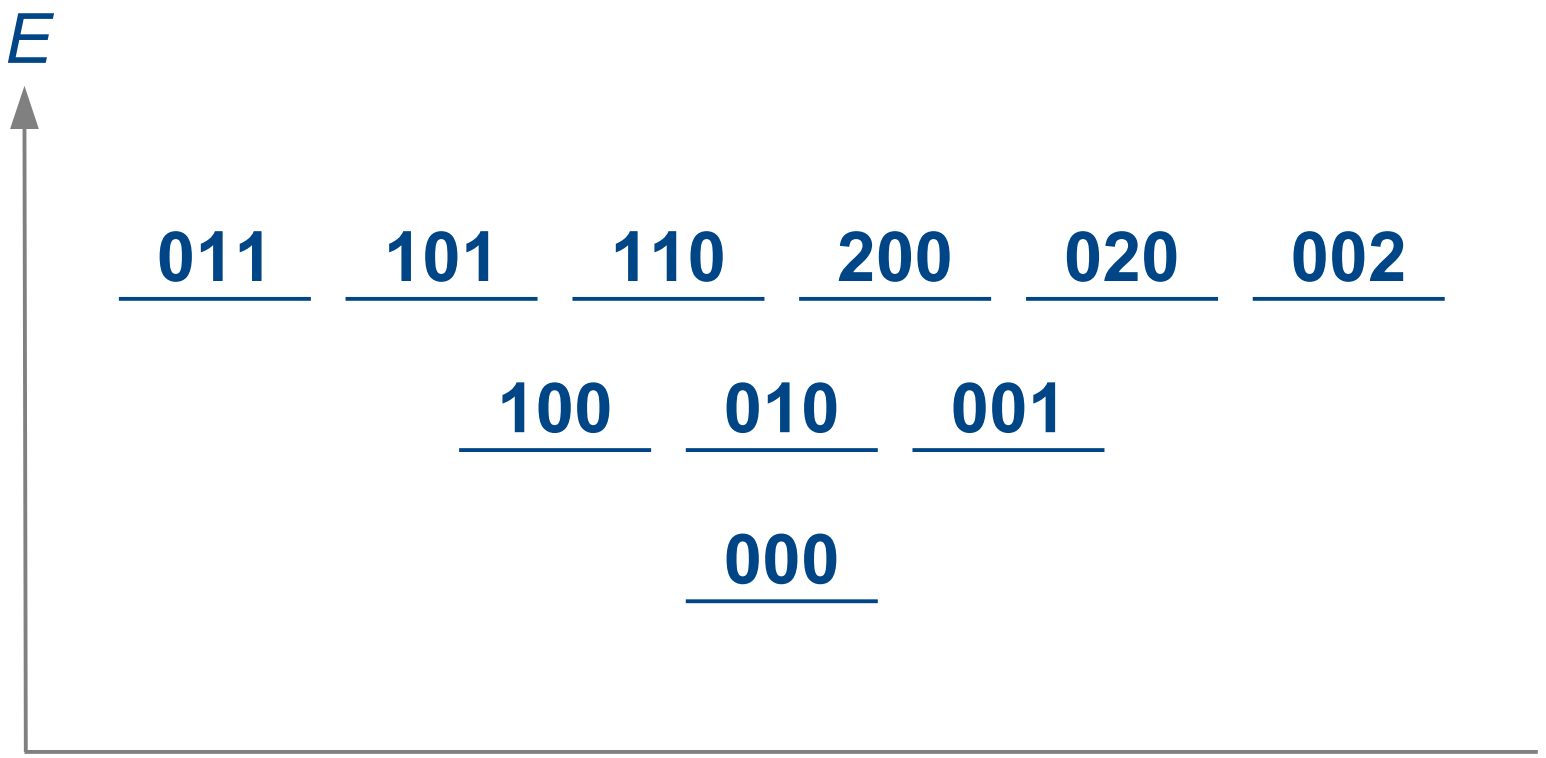
$n_\uparrow n_\downarrow = 8$



Band crossings



Inhomogeneous pairing



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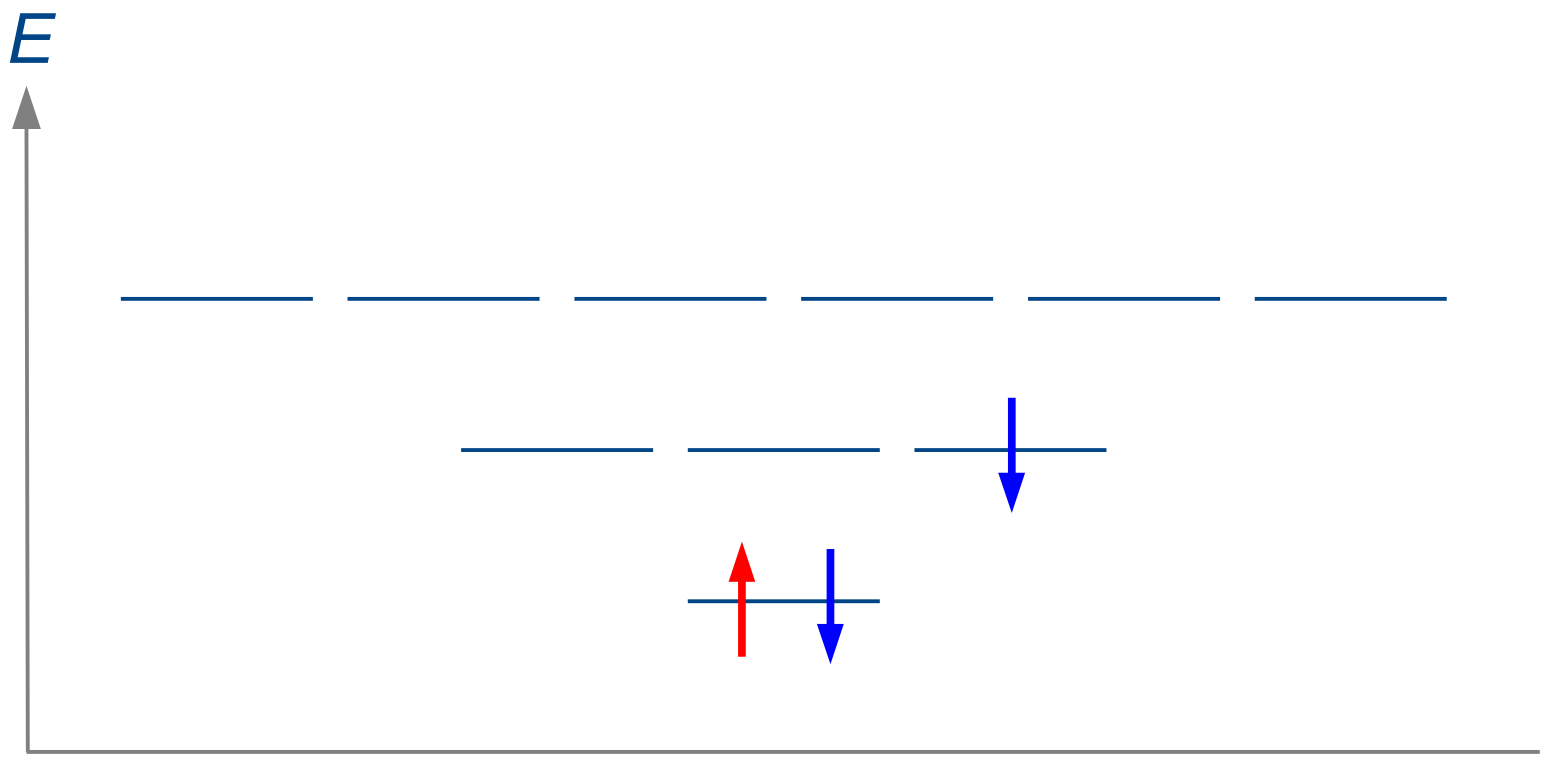

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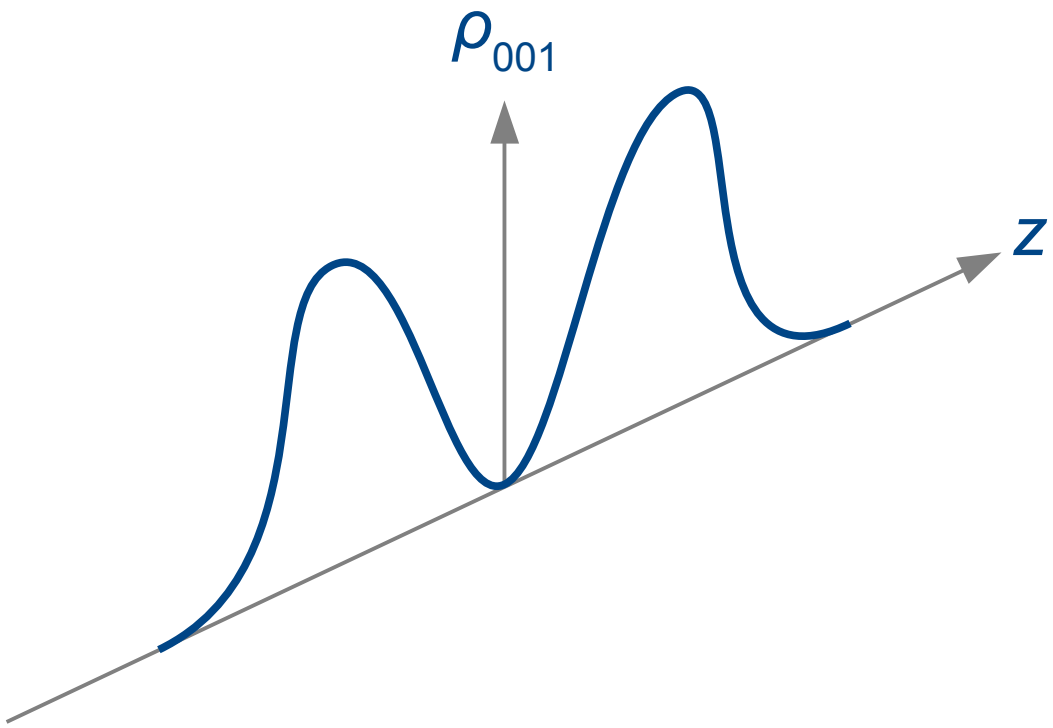
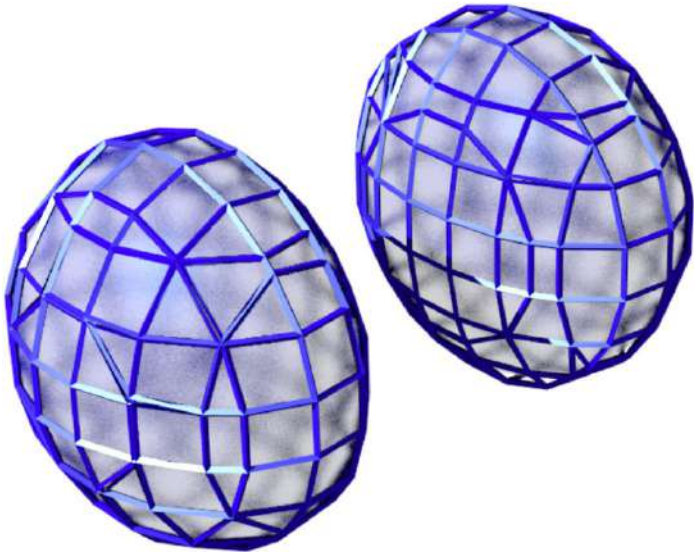
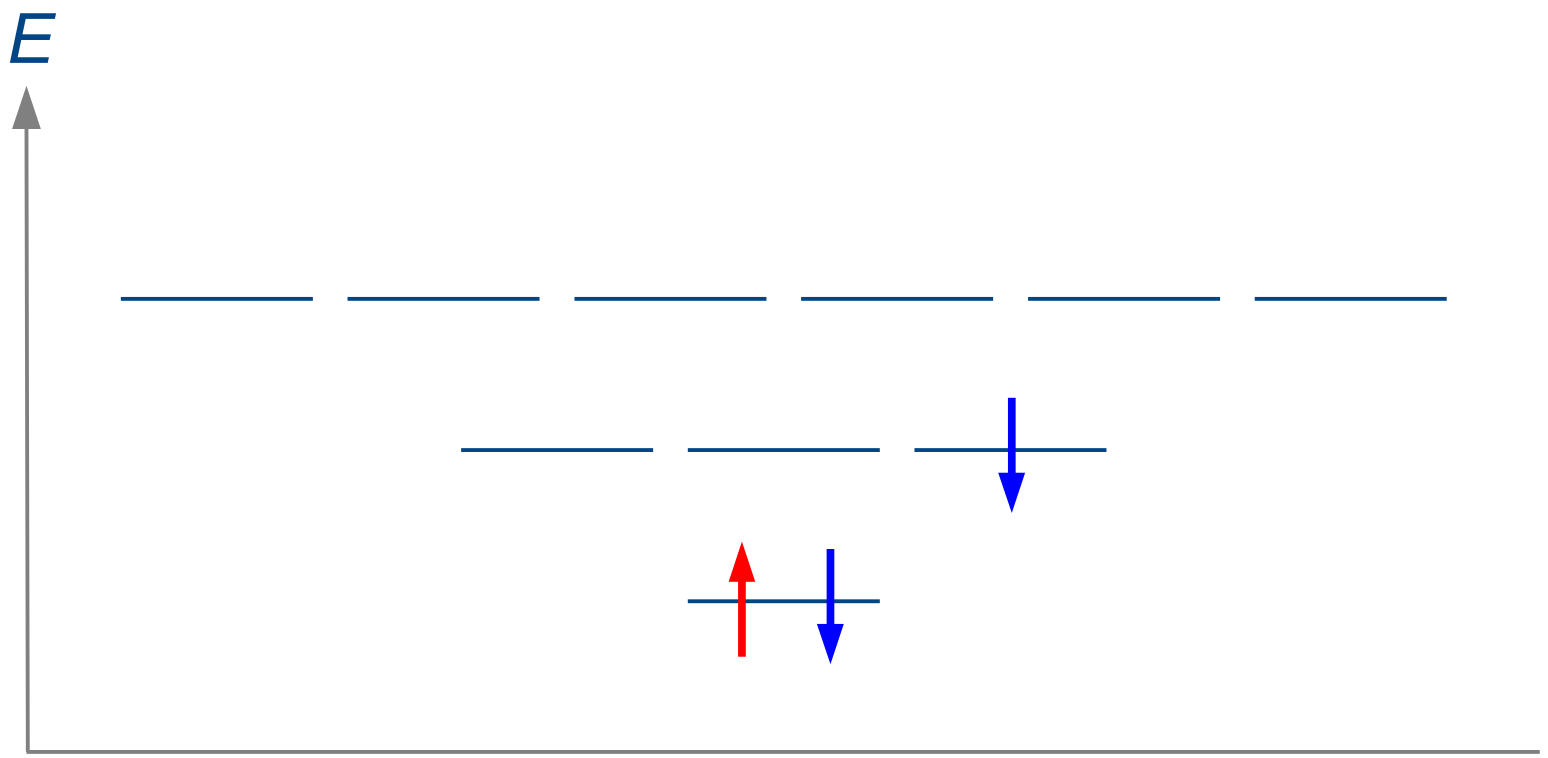


Inhomogeneous pairing



Inhomogeneous pairing



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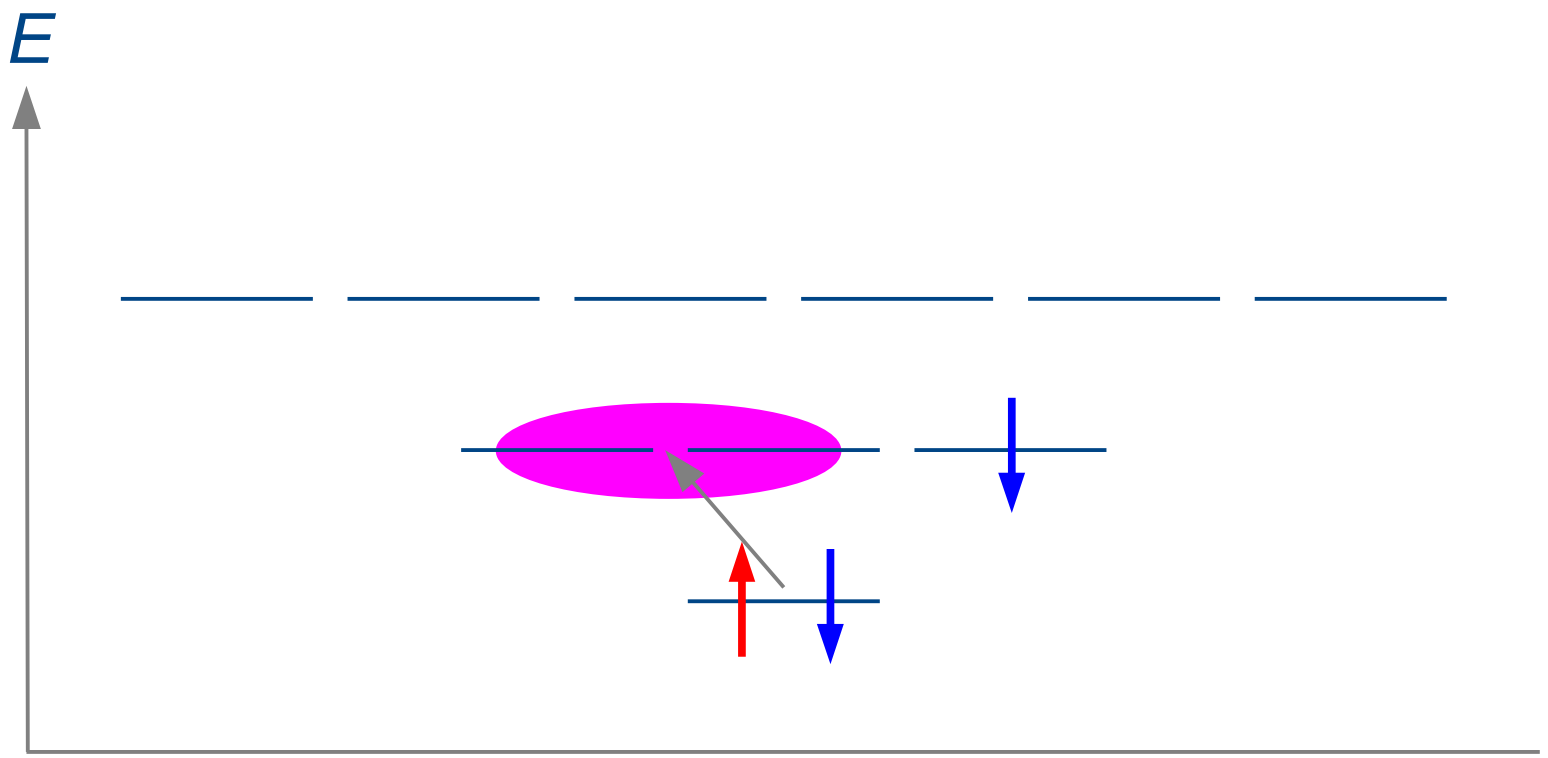
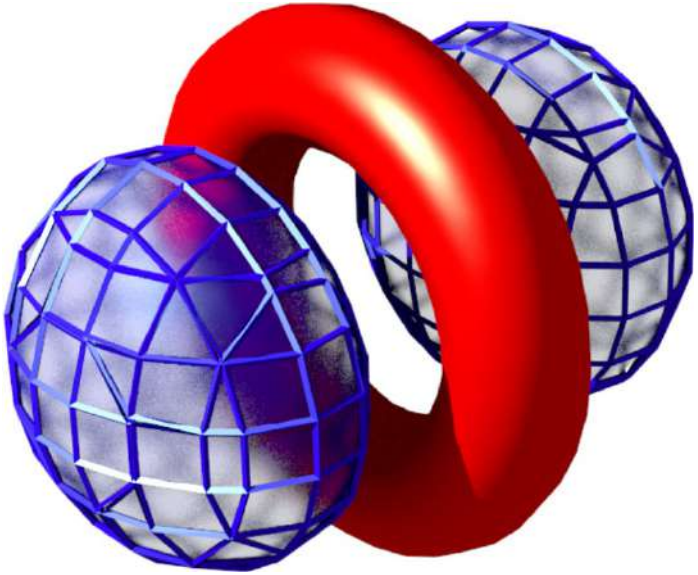
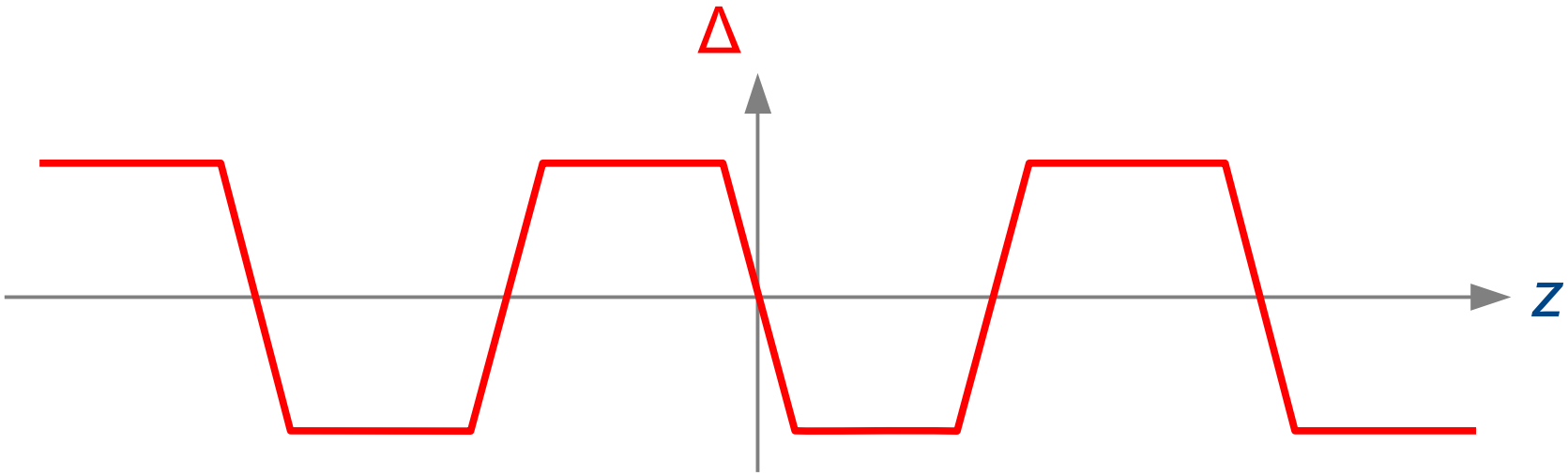


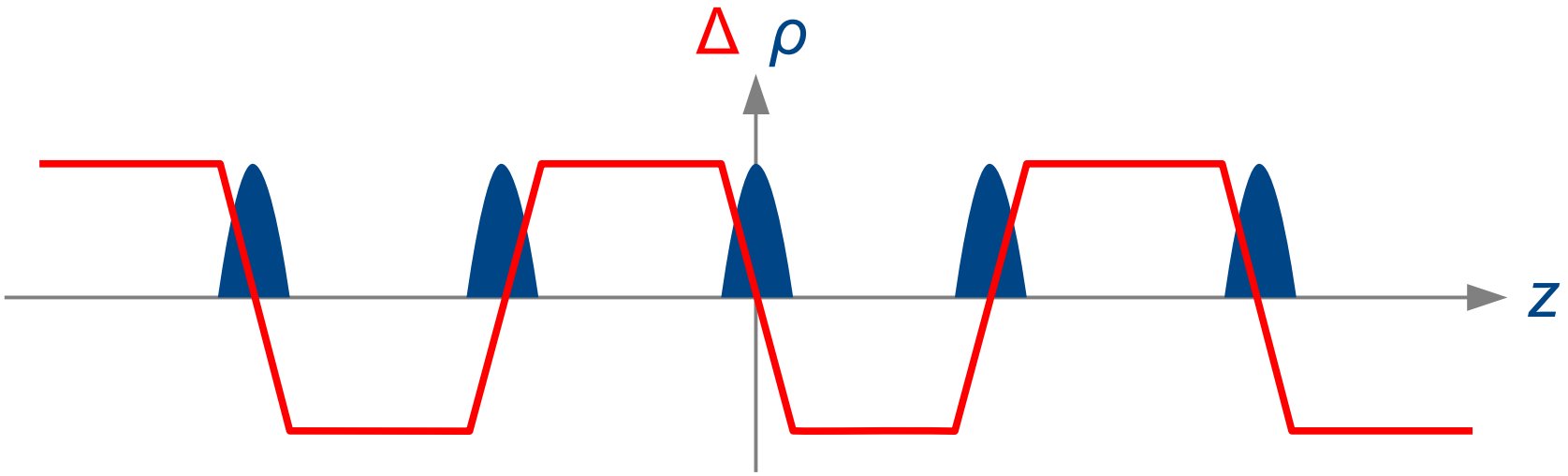
Inhomogeneous pairing



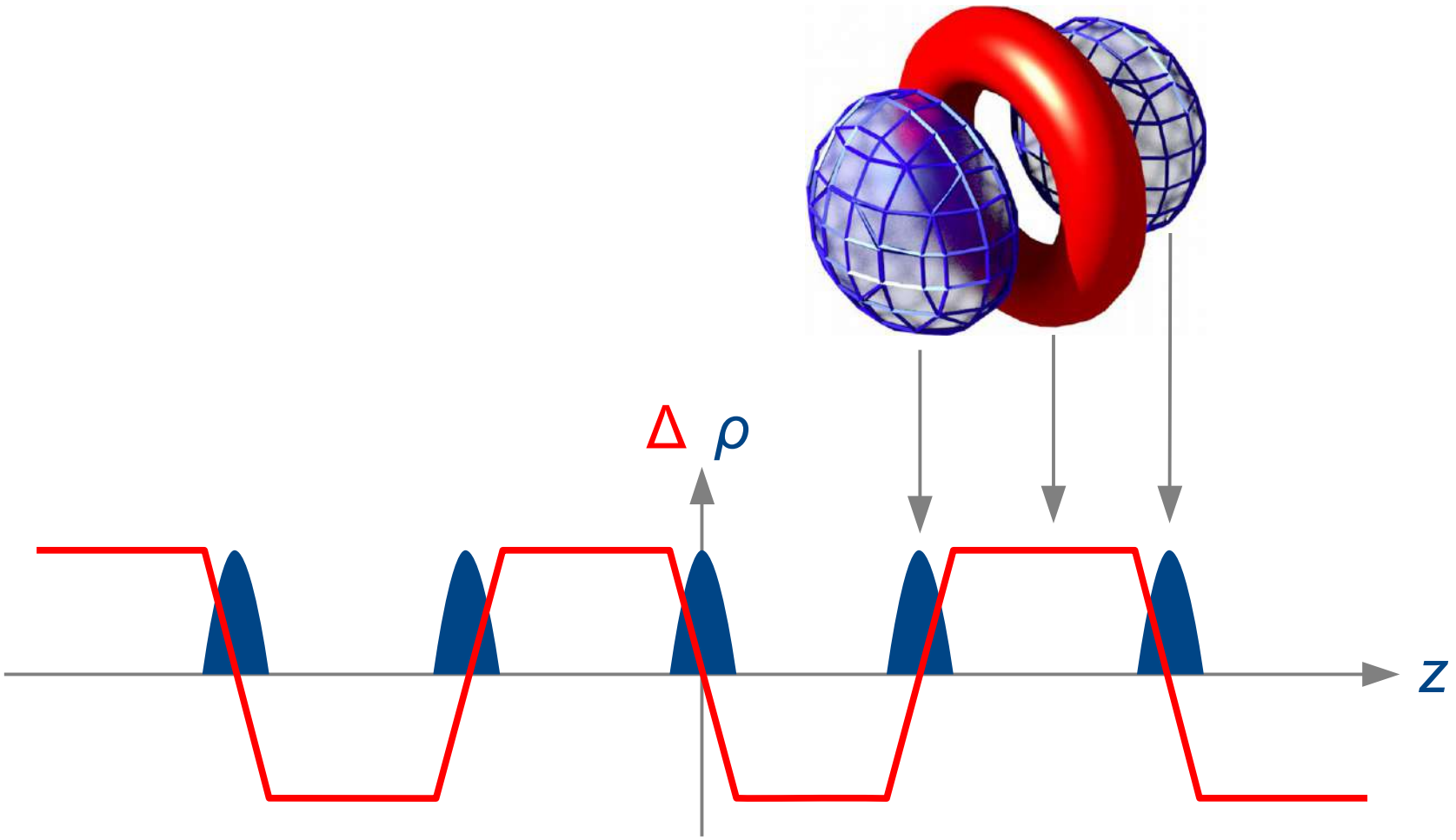
Inhomogeneous pairing



Inhomogeneous pairing

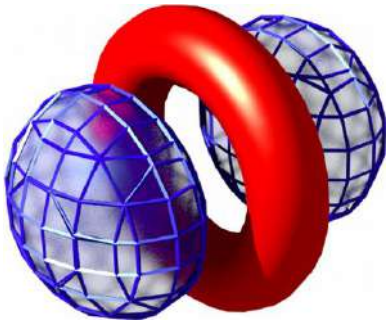


Inhomogeneous pairing

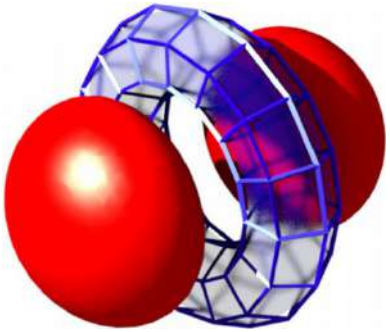


Inhomogeneous pairing

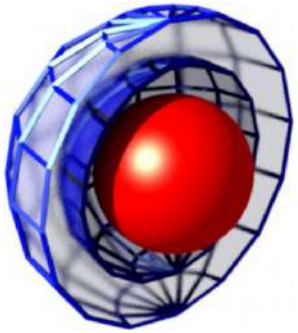
(2,1) (3,2) (4,3)



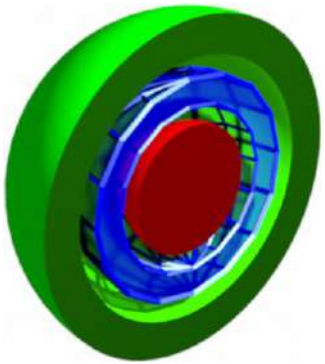
(3,1) (4,2)



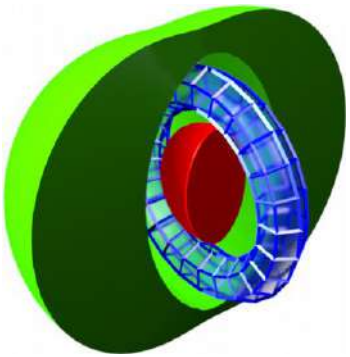
(4,1)



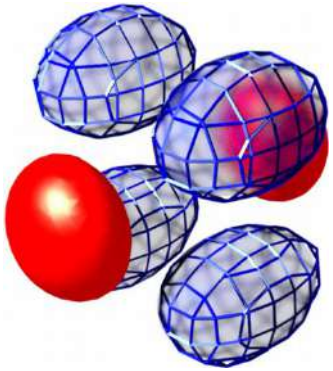
$(2,1)^s$ (5,1)



$(2,1)^d$ (5,2)

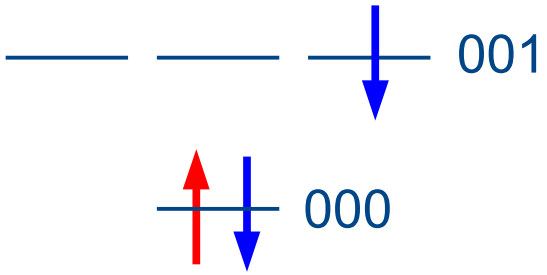


$(2,1)^g$

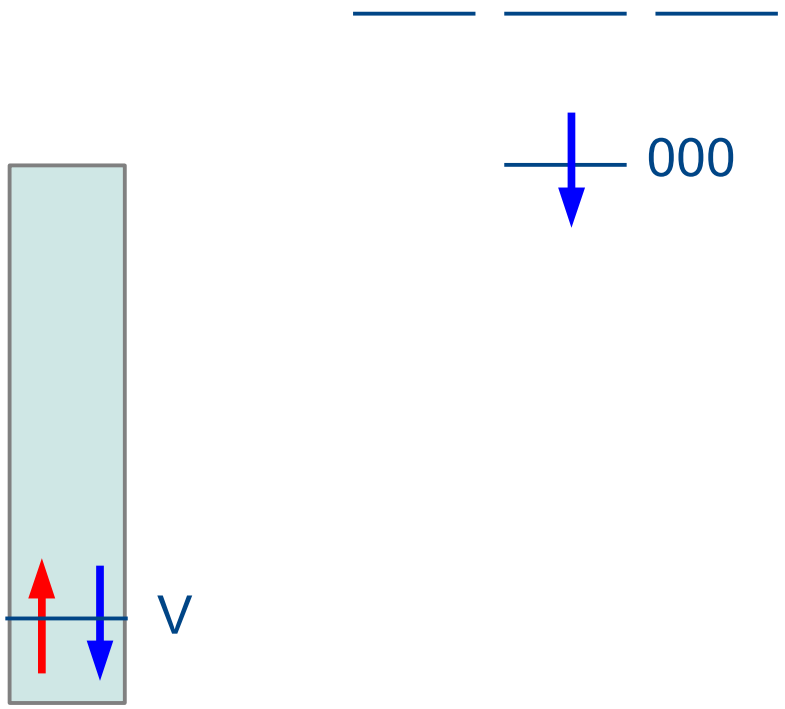


Inhomogeneous pairing

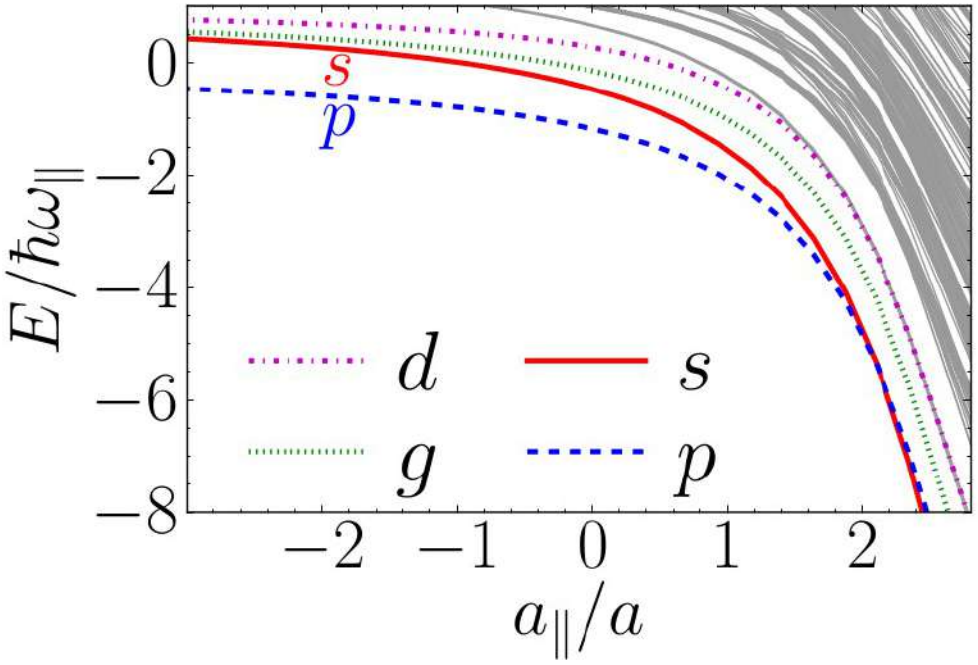
Weak interactions



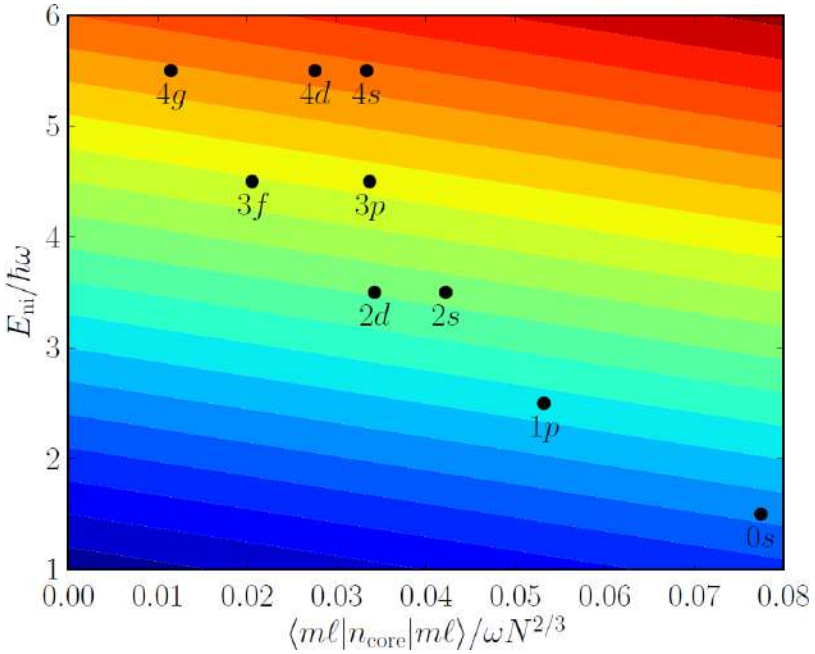
Strong interactions



Inhomogeneous pairing

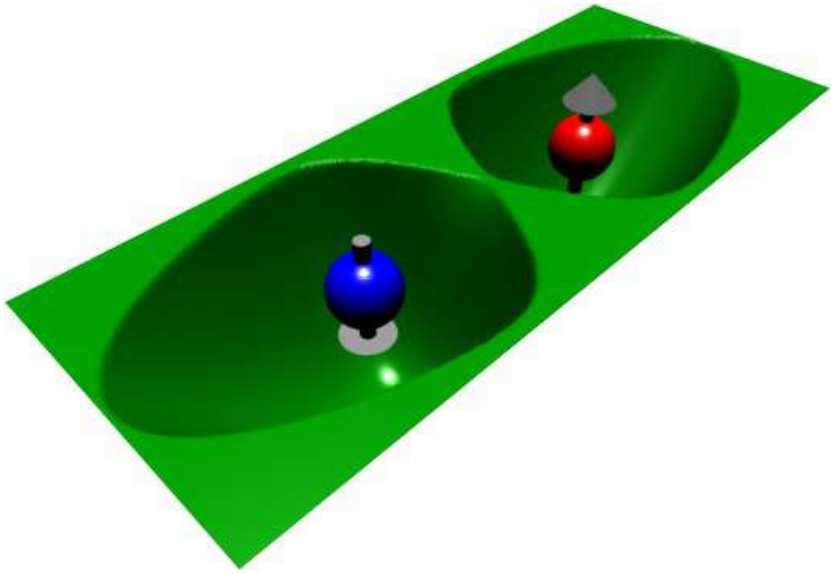


Other phenomena



Hund's rules

P.O. Bugnion, J.A. Lofthouse & GJC



Exchange interactions

P.O. Bugnion & GJC
Phys. Rev. A **88**, 013601 (2013)

Summary

A few-fermion system provides insight into many-body physics

Discretization of energy levels means that losses occur in narrow range of interaction strengths

Observation of Fermi surface and magnetic correlations