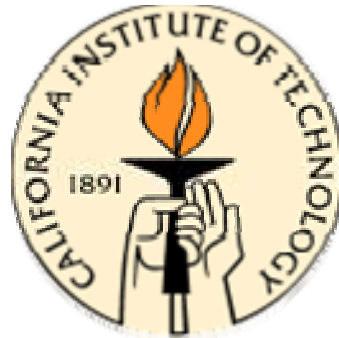
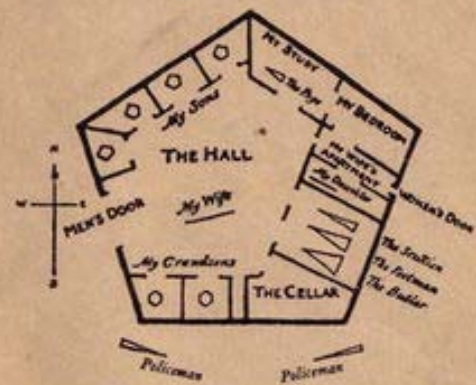
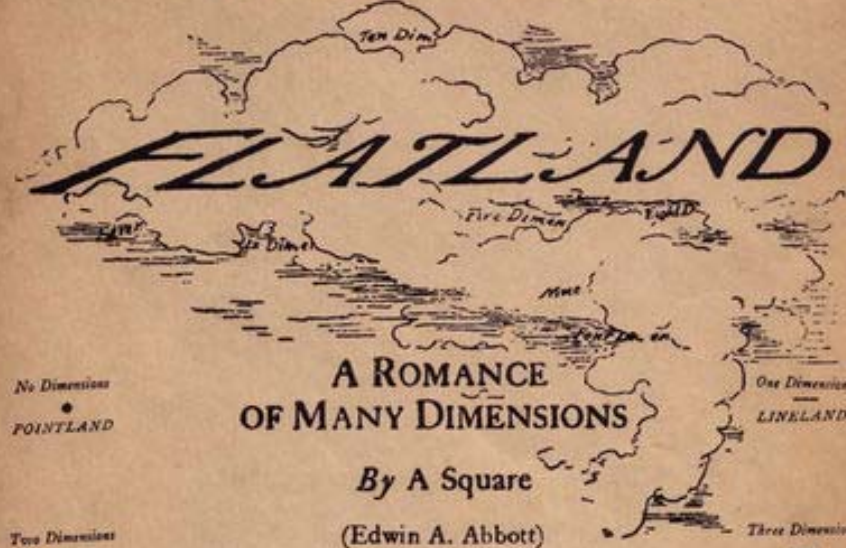


Physics in Flatland

Jim Eisenstein



"O day and night, but this is wondrous strange"



"And therefore as a stranger give it welcome."

BASIL BLACKWELL · OXFORD

Price Seven Shillings and Sixpence net

Edwin Abbott Abbott
1884



A confession...

I am
a
condensed matter physicist.



A confession...

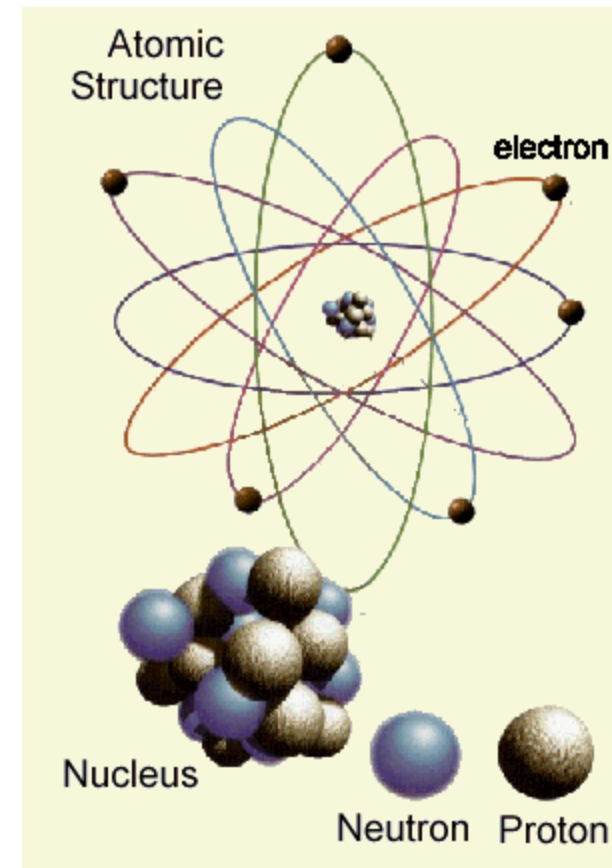
I am
a
condensed matter physicist.



Condensed matter



Not condensed matter



The Essence of Condensed Matter Physics:



The Essence of Condensed Matter Physics:

whole > Σ (*parts*)

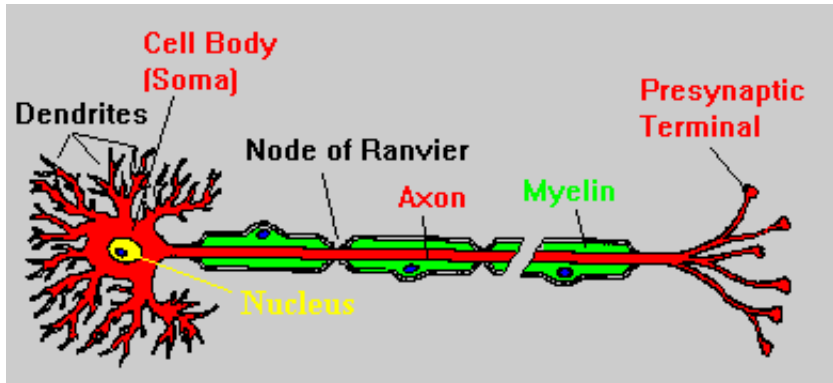


The Essence of Condensed Matter Physics:

whole > Σ (*parts*)

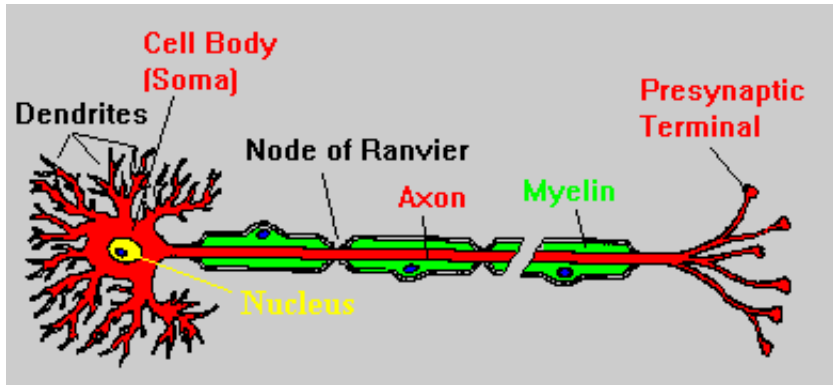
“Emergent” phenomena





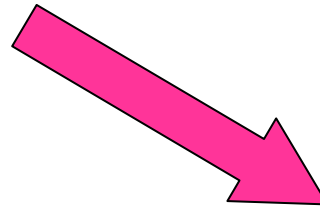
1 neuron





1 neuron

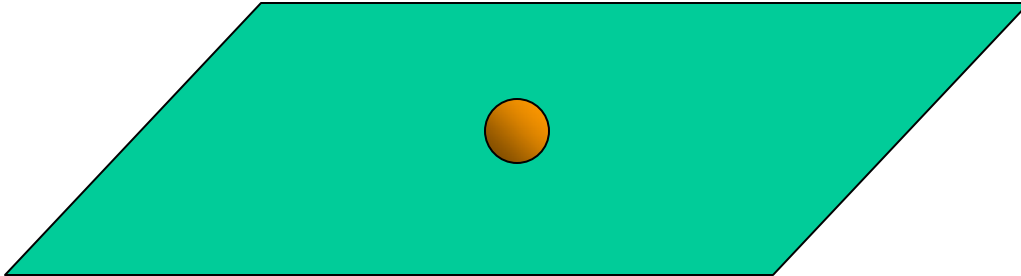
??



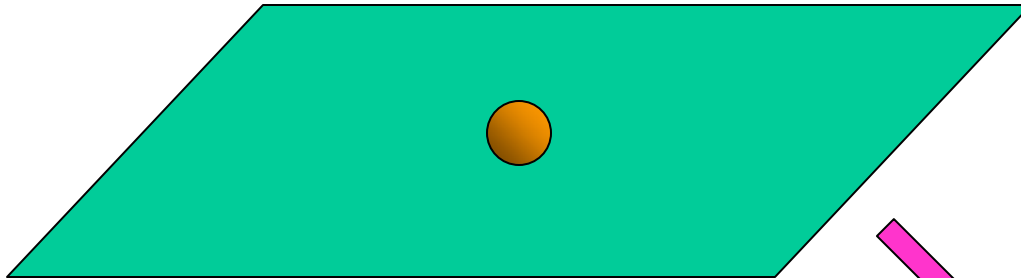
100 billion neurons



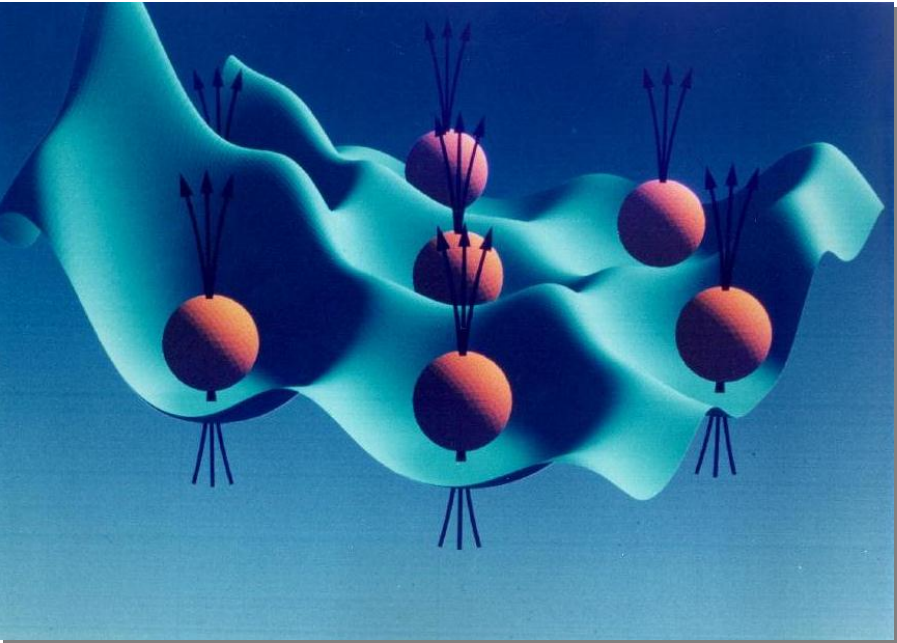
1 electron



1 electron



??



100 billion electrons

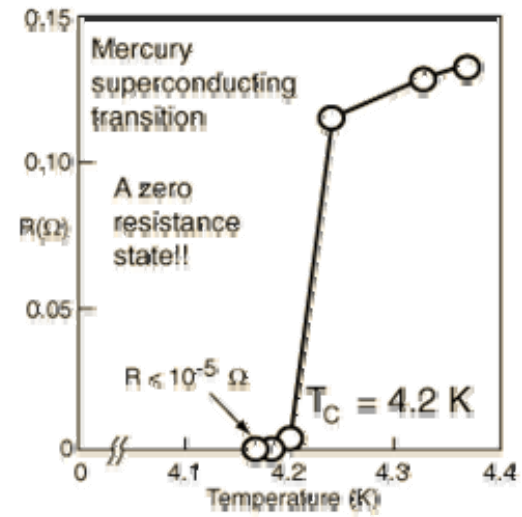


Fractional quantum Hall liquid

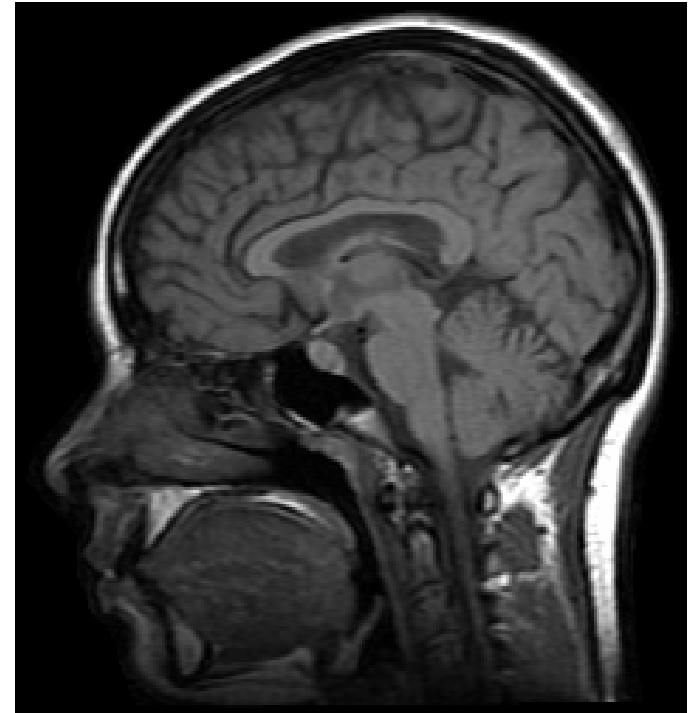
An Hoary Example: Superconductivity



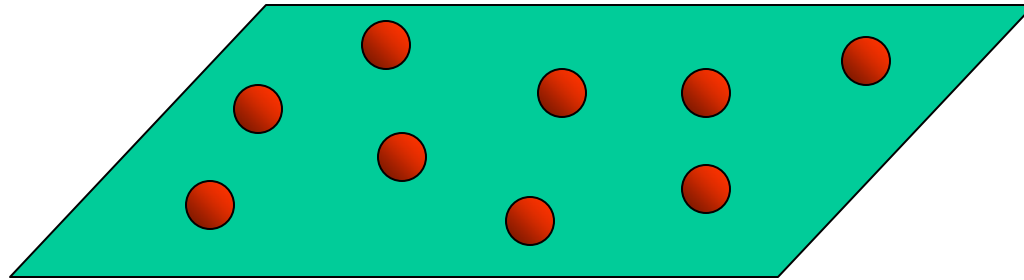
Onnes, 1911



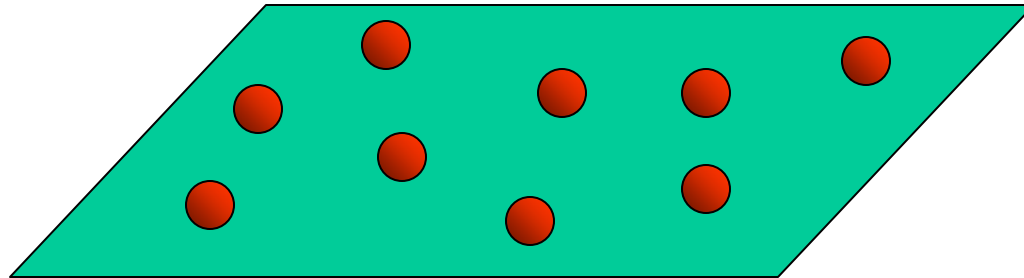
Not so useless after all...



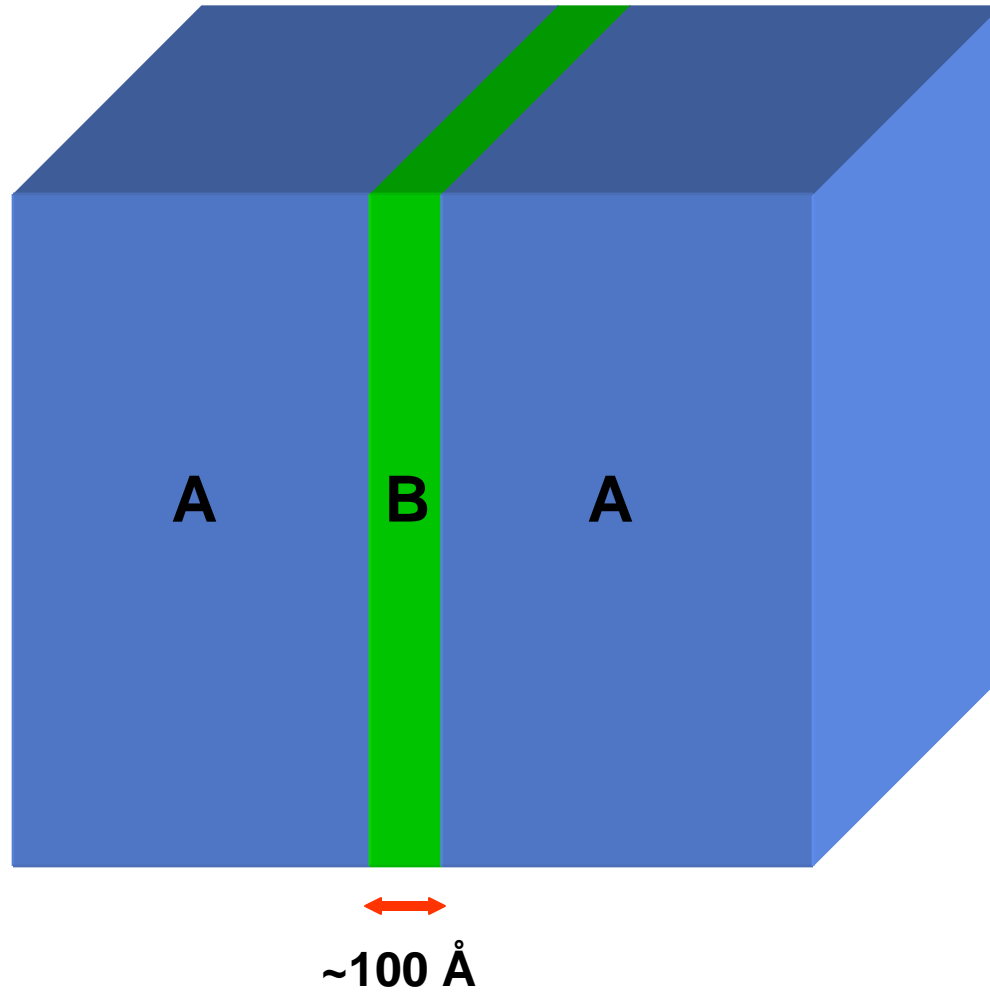
Two-Dimensional Electron Gas



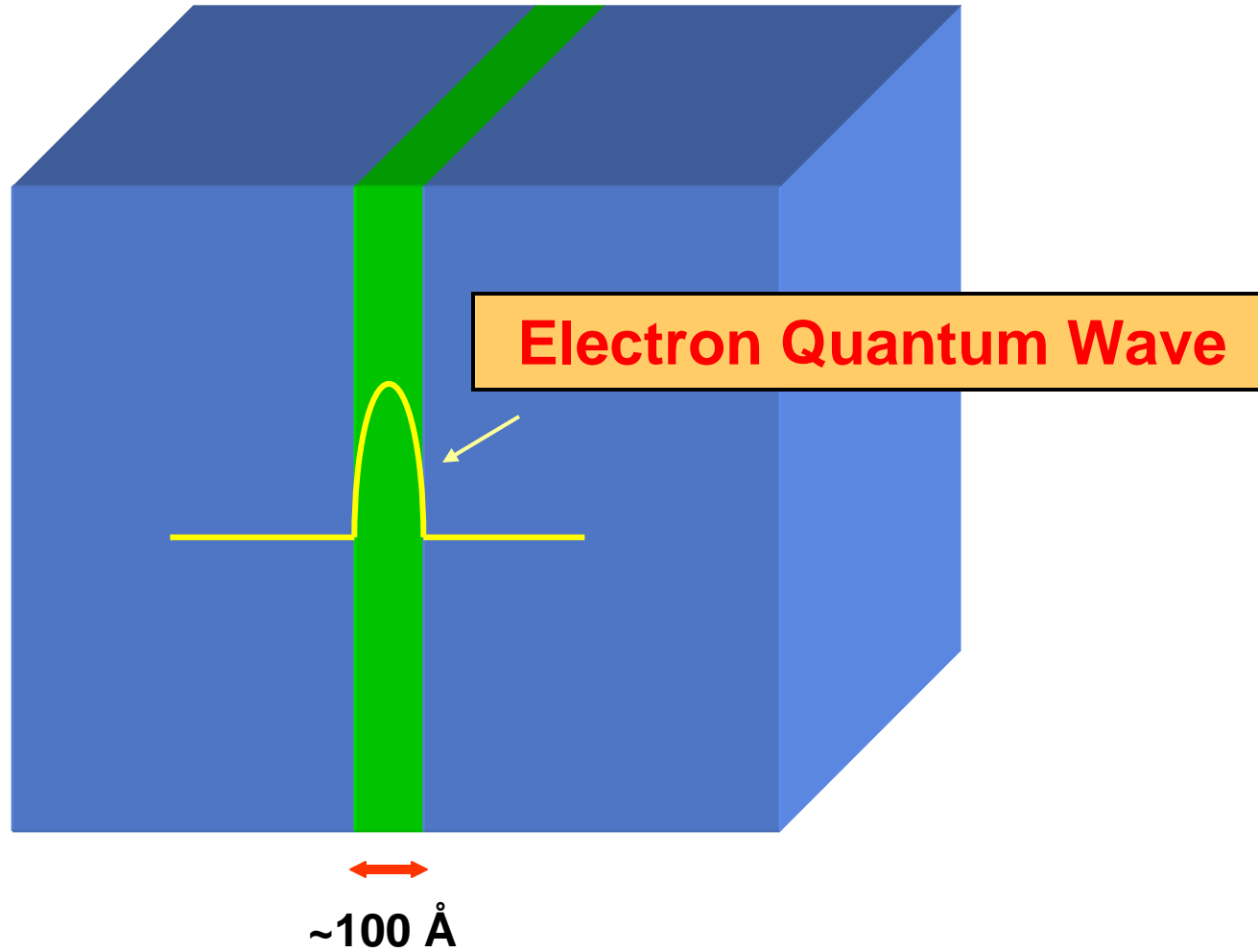
Two-Dimensional Electron Gas



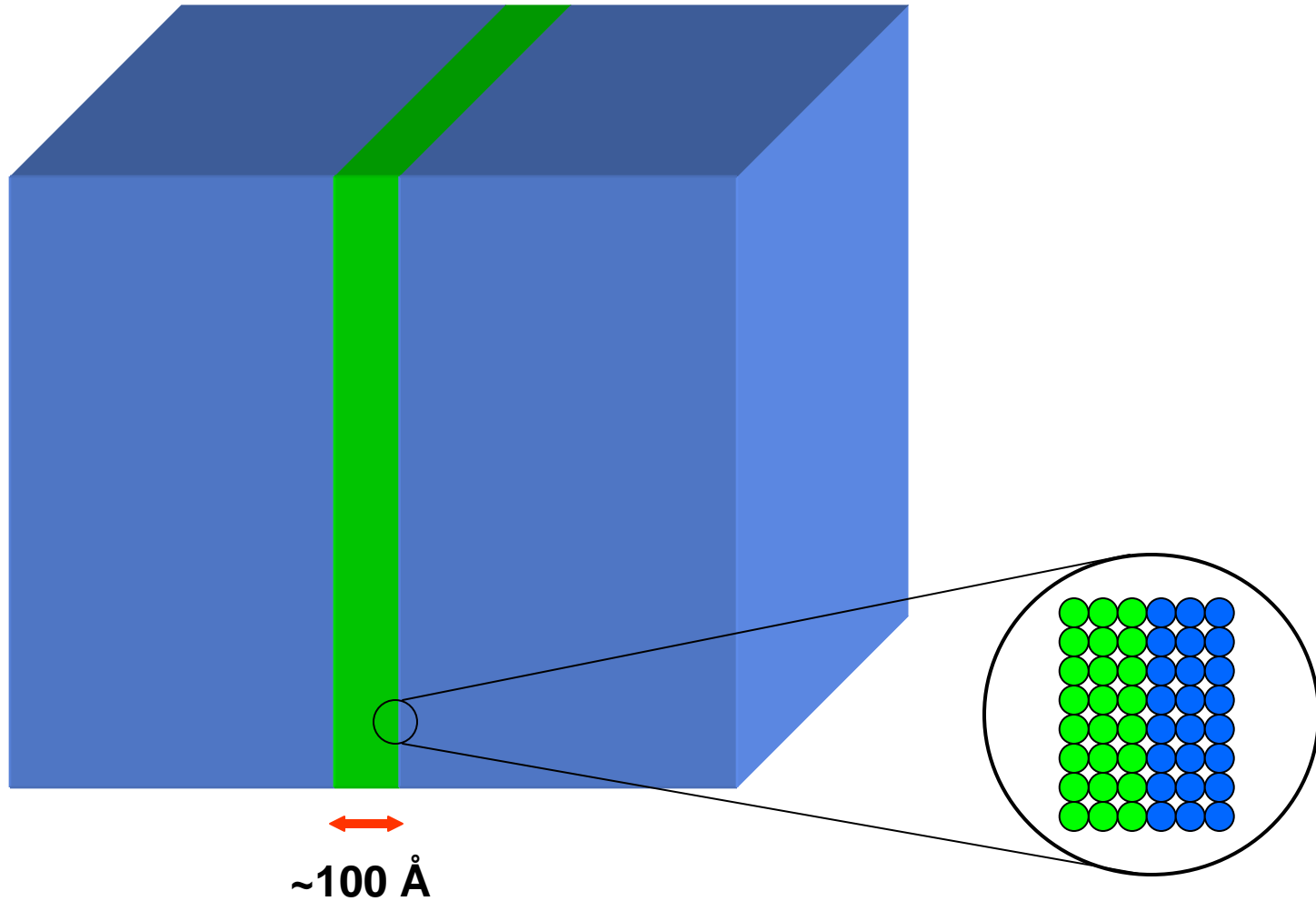
A Semiconductor Sandwich



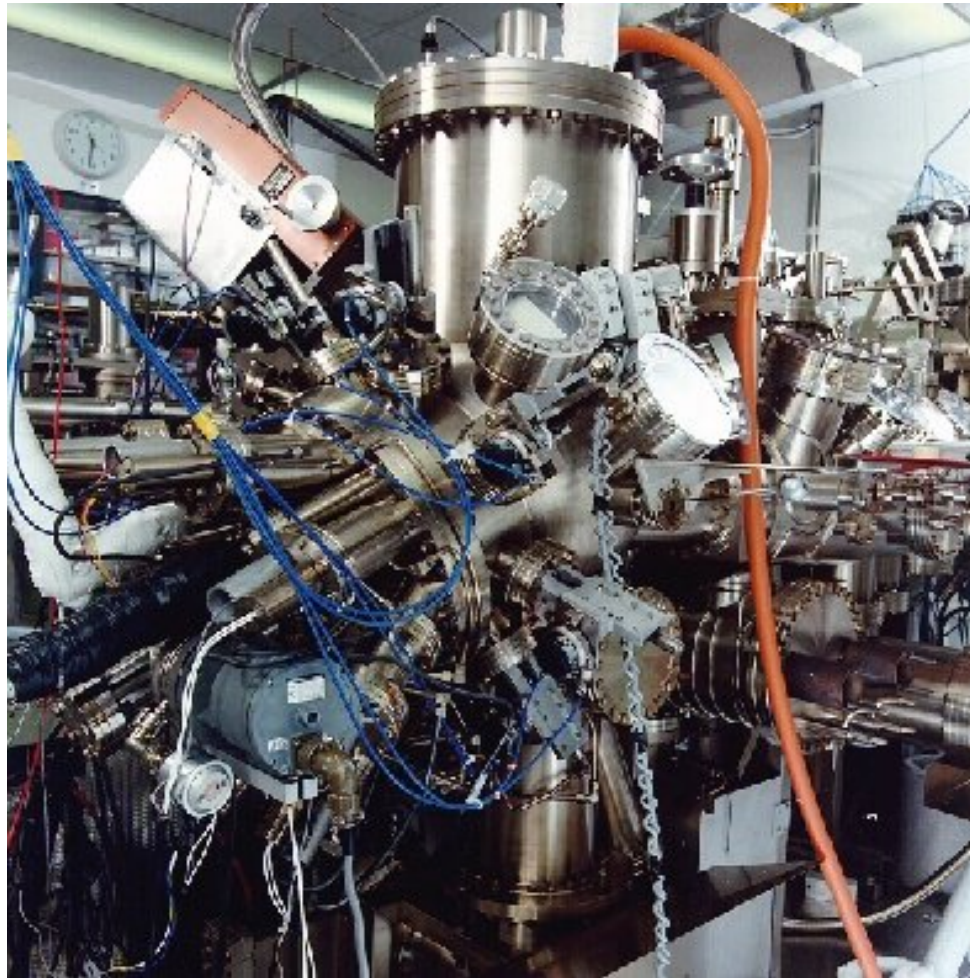
Quantum Confinement



Perfect Registry

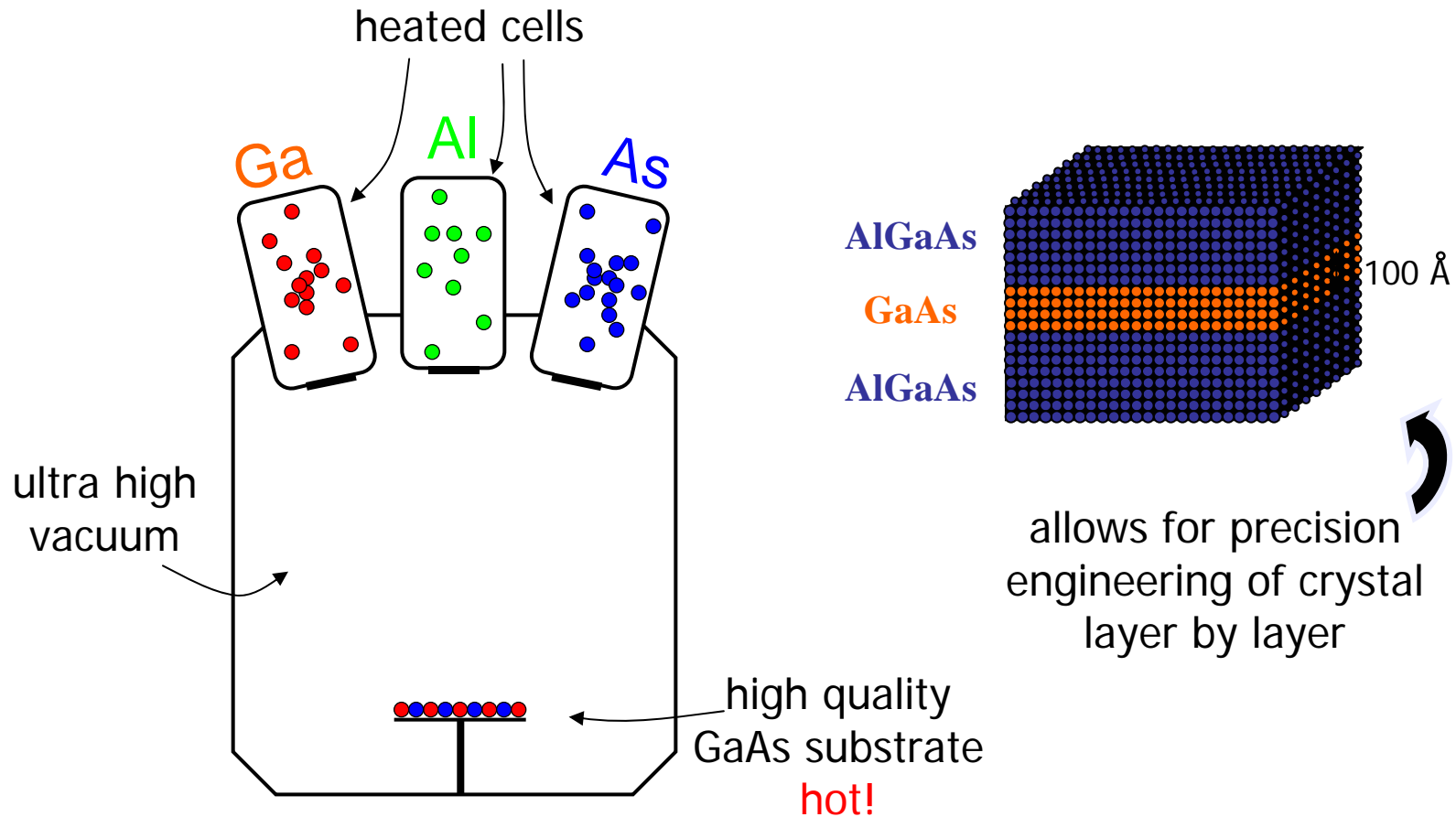


Molecular Beam Epitaxy
“spray painting with atoms”

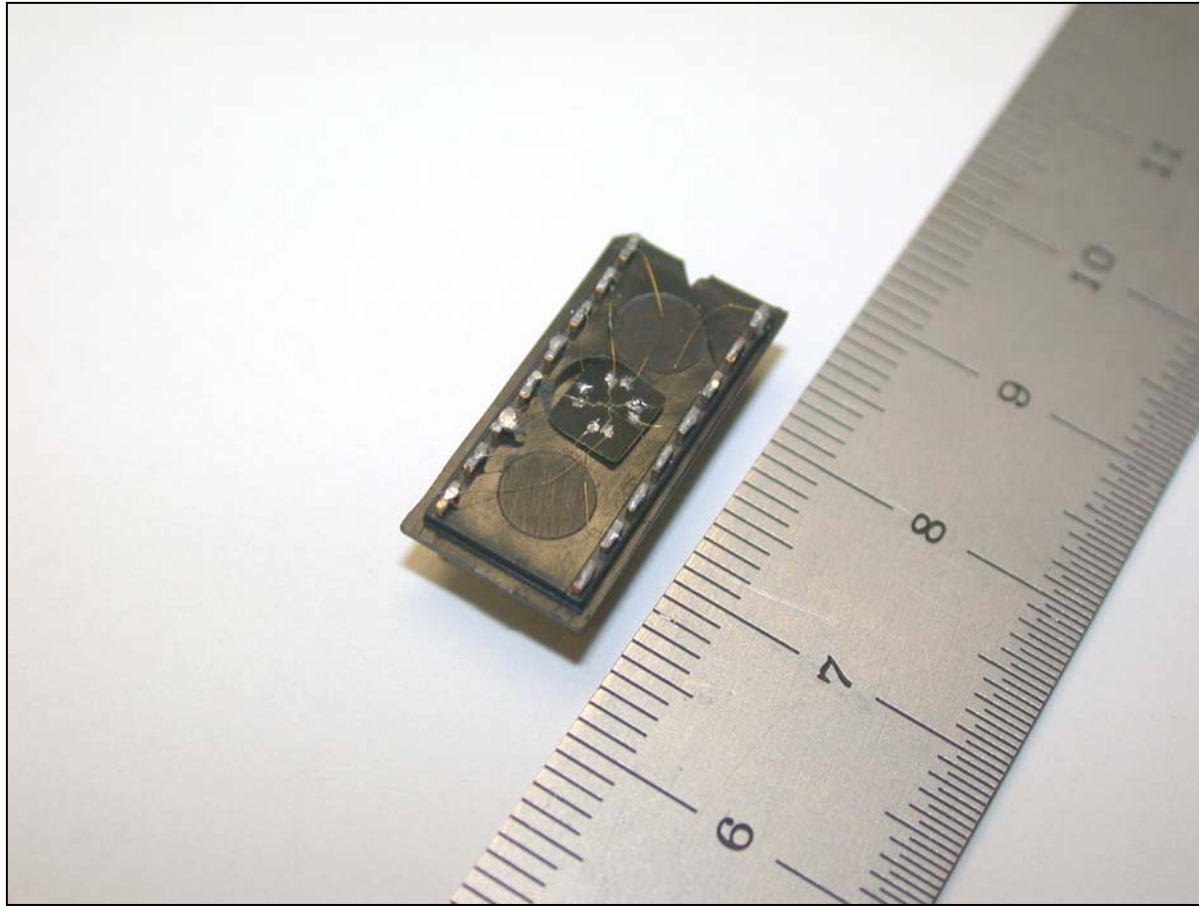


Molecular Beam Epitaxy

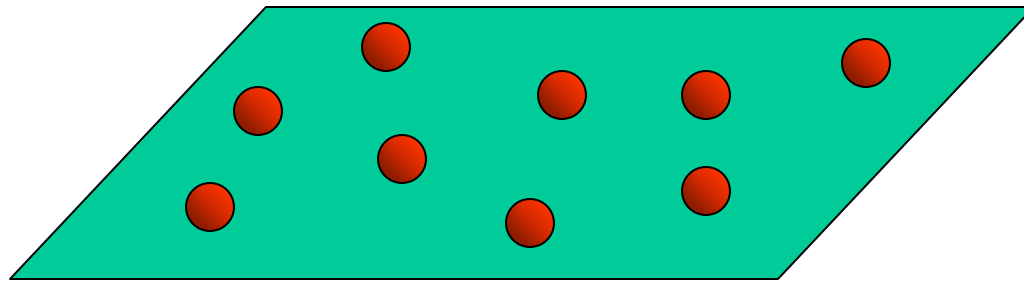
“spray painting with atoms”



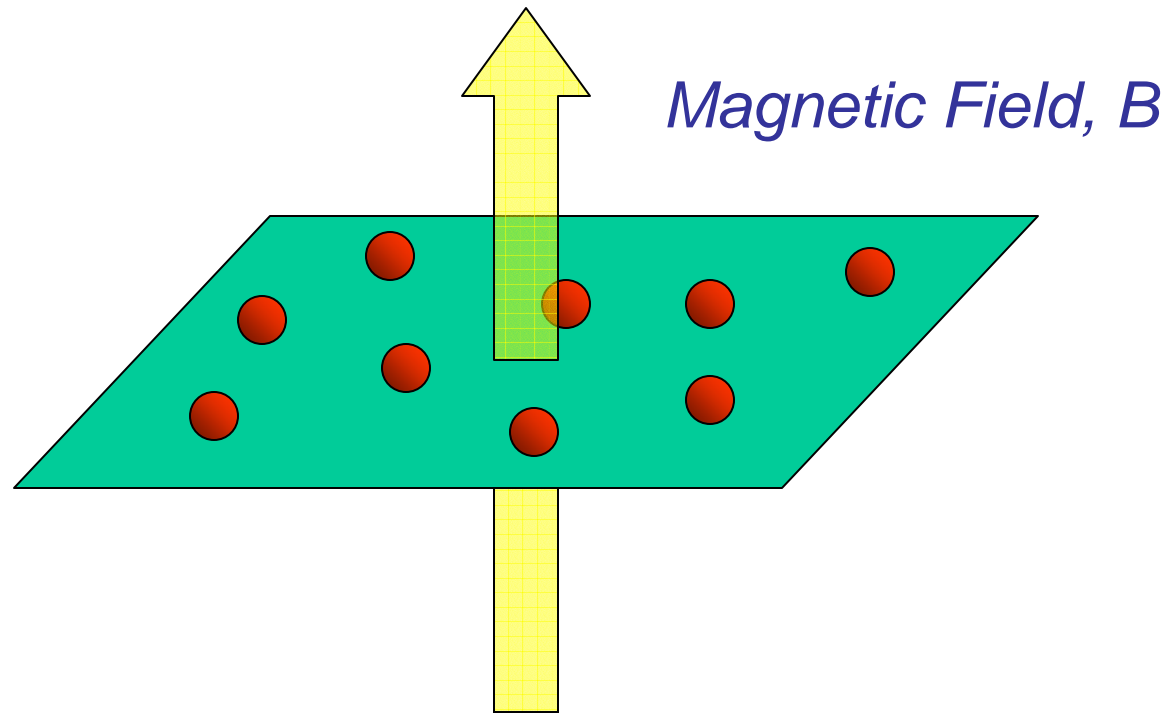
The final product



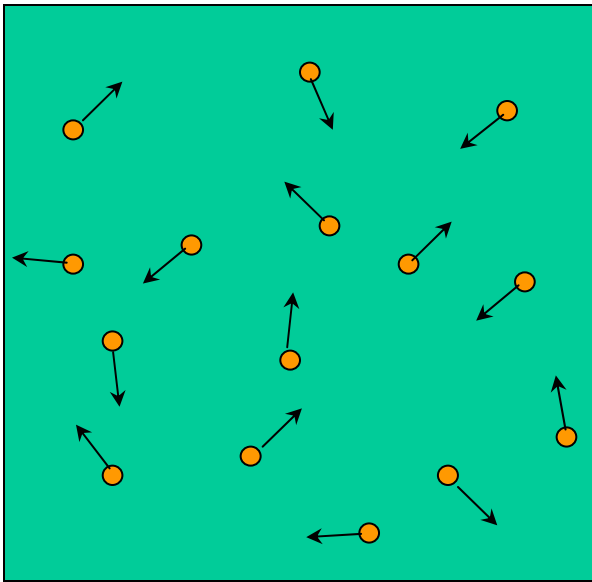
Two-Dimensional Electron Gas



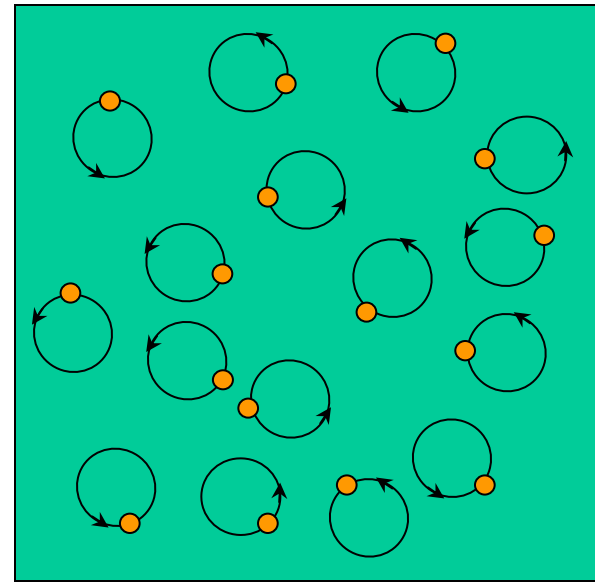
2D Electrons in a Magnetic Field



Why Magnetic Fields?



No magnetic field



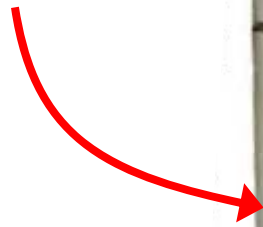
Big magnetic field

Magnetic field enhances COLLECTIVE behavior

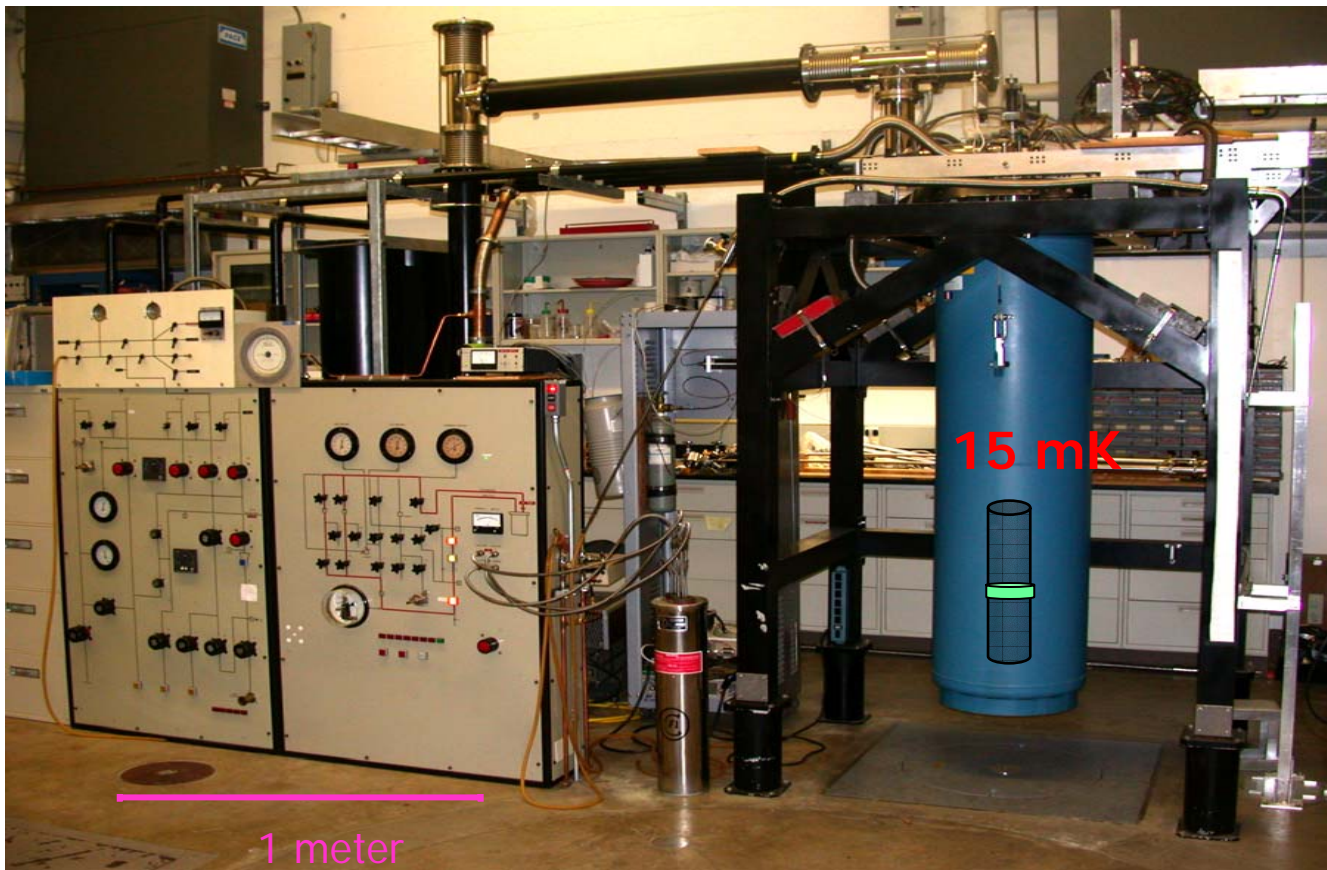


Low temperatures

+5° C



Really low temperatures!



$$T = 15 \text{ mK} = -273.15 \text{ }^\circ\text{C} + .015 \text{ }^\circ\text{C}$$

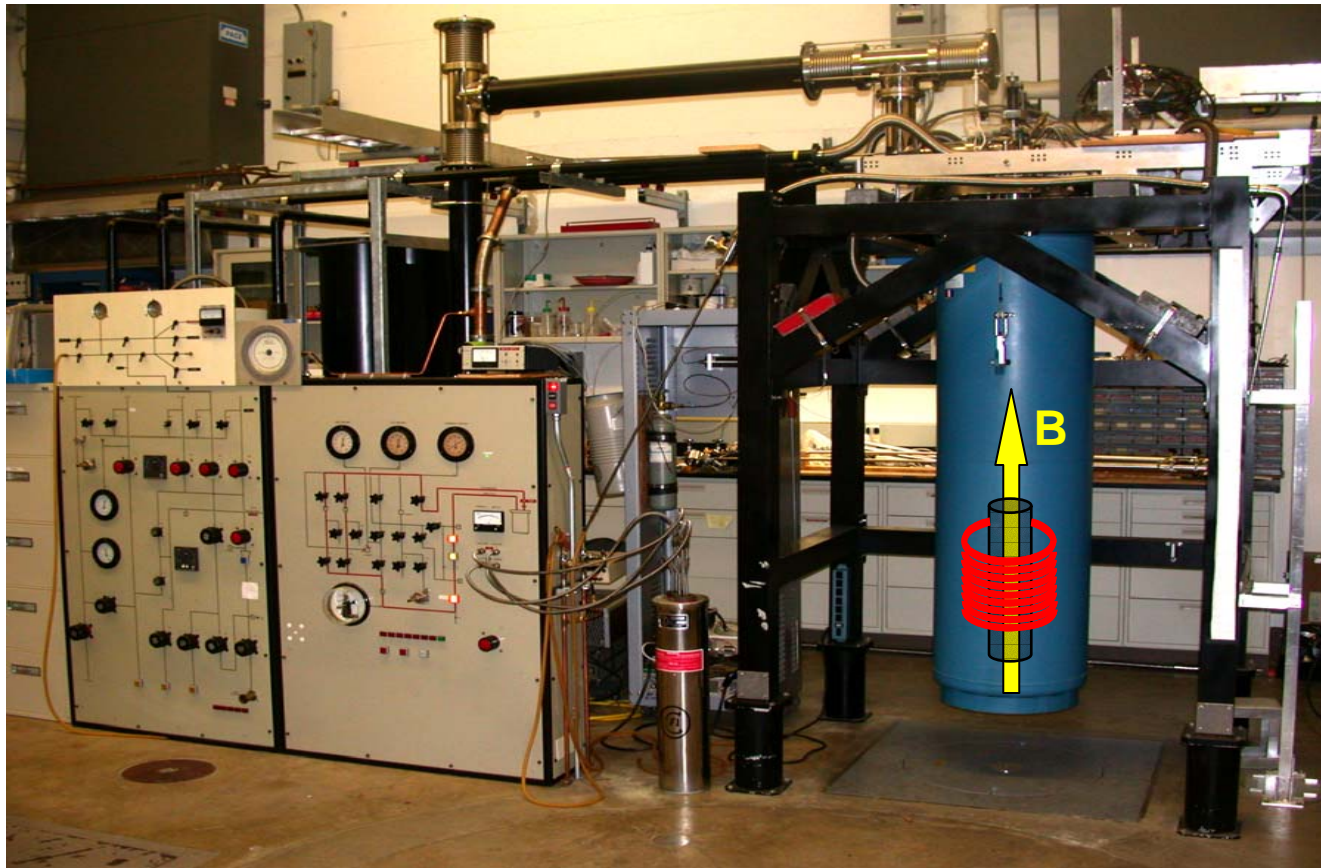
ABSOLUTE ZERO



Big magnetic fields



Really big magnetic fields!



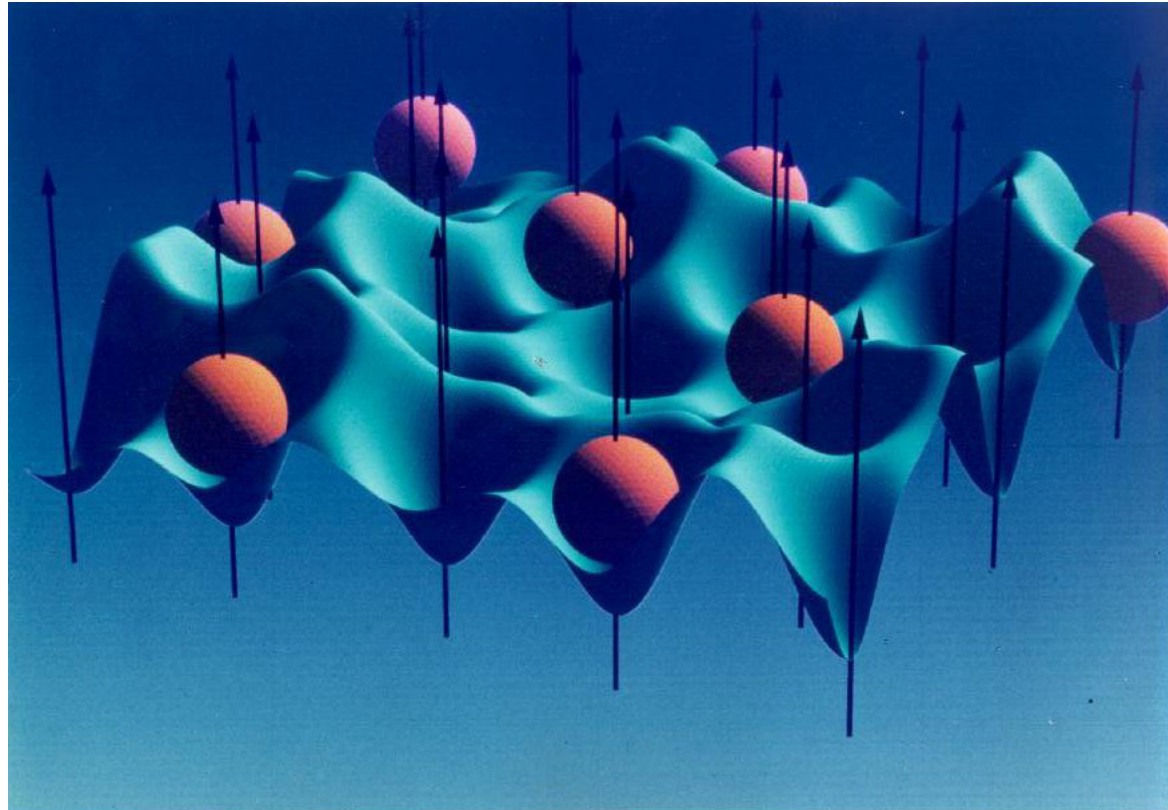
B ~ 150,000 Gauss ~ 500,000 x Earth's Magnetic Field



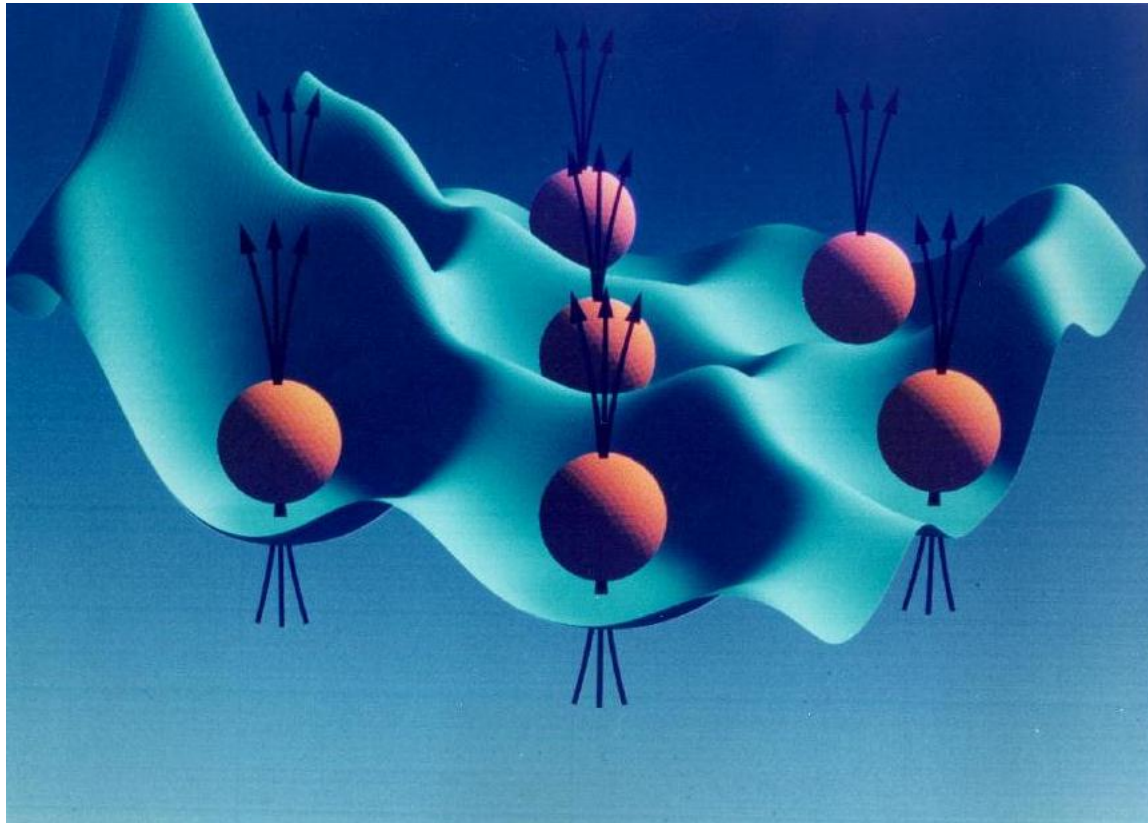
1998 Nobel Prize in Physics to Tsui, Stormer and Laughlin



Independent Electrons



A *New* Phase of Matter: The Fractional Quantum Hall Liquid



Scuba Diving in the Fractional Quantum Hall Sea



Scuba Diving in the Fractional Quantum Hall Sea

$$T = 0 \quad B = B_c$$

A featureless liquid.

No individual electrons visible!



Scuba Diving in the Fractional Quantum Hall Sea

$$T > 0 \quad \text{or} \quad B = B_c \pm \delta B$$



Weird New Particles



$+e/3$



$-e/3$

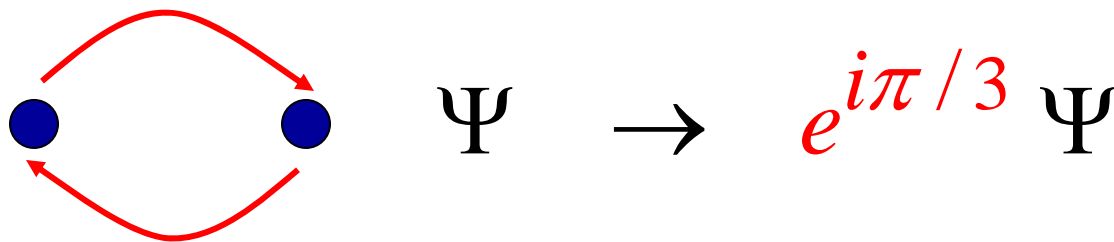
Particles with fractional charge!



Really Weird New Particles!



Particles with fractional charge and fractional statistics!



Anyons



*Only Two Kinds of Particles in Nature:
Bosons and Fermions*



Enrico Fermi

electrons, protons,
neutrons, etc.

Obey Pauli Exclusion
Principle



Satyendranath Bose

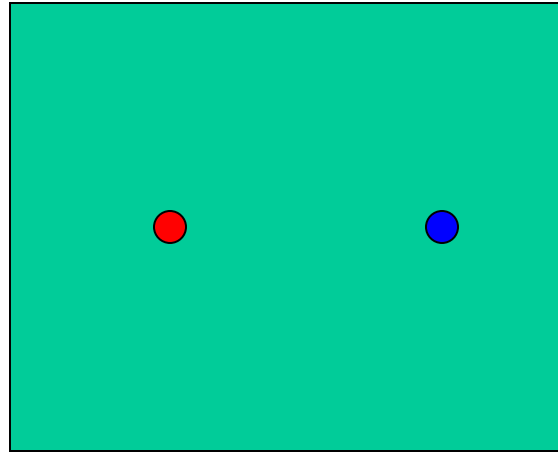
photons, mesons, etc.

Don't!



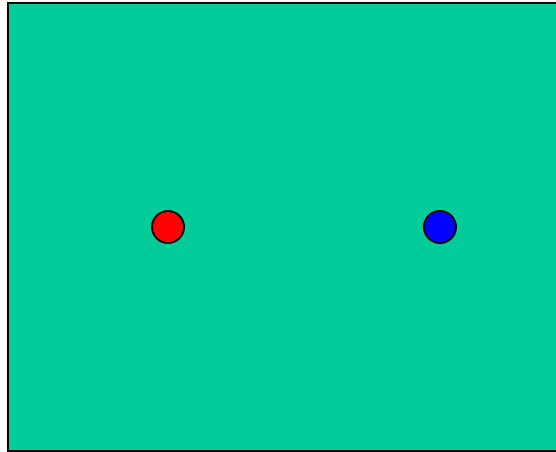
A vanity of three dimensions...

Trading Places and Braiding Your Hair



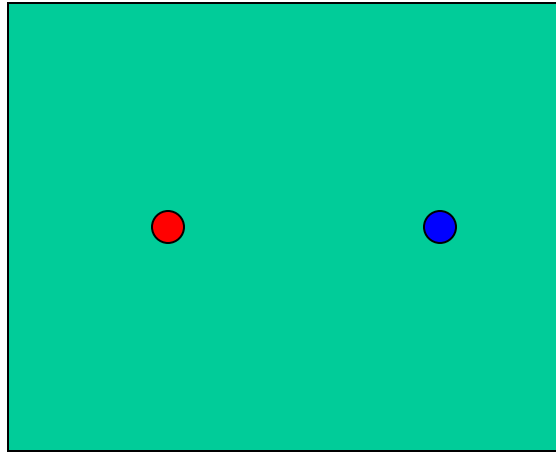
Trading Places and Braiding Your Hair

T :



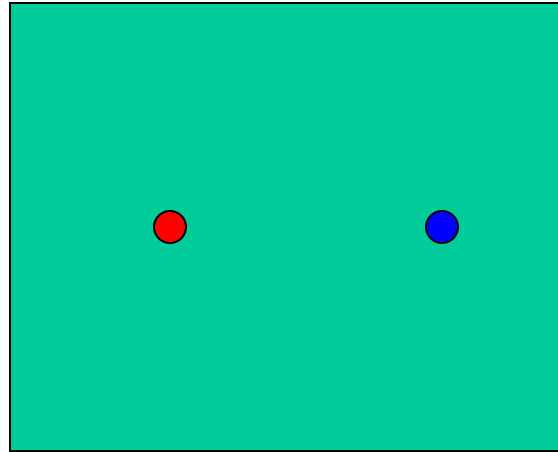
Trading Places and Braiding Your Hair

T^2 :



Trading Places and Braiding Your Hair

T^2 :



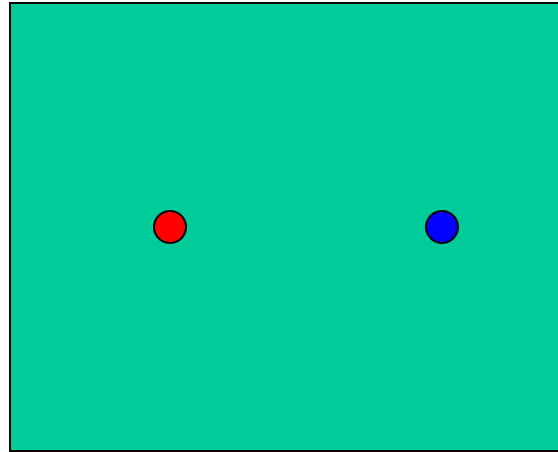
In 3 dimensions $T^2 = 1$

$T = +1$ or $T = -1$



Trading Places and Braiding Your Hair

T^2 :



In 3 dimensions $T^2 = 1$

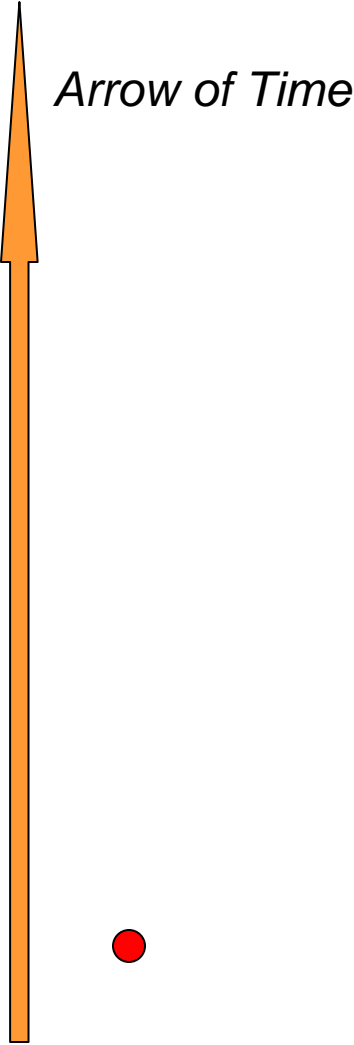
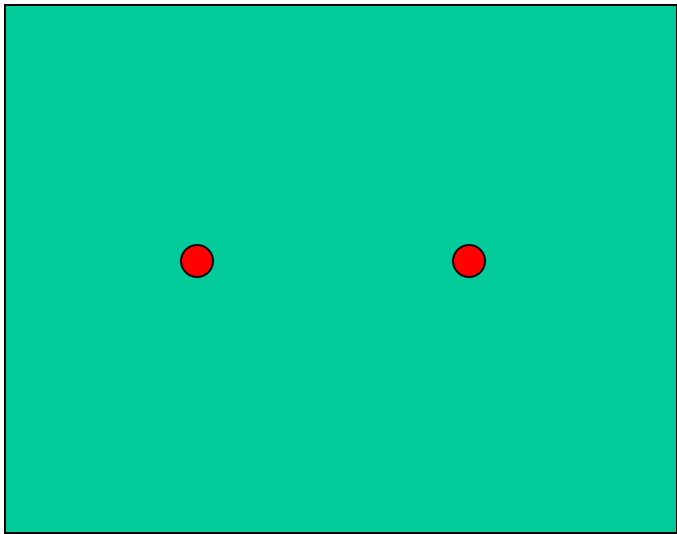
$T = +1$ or $T = -1$

BOSONS

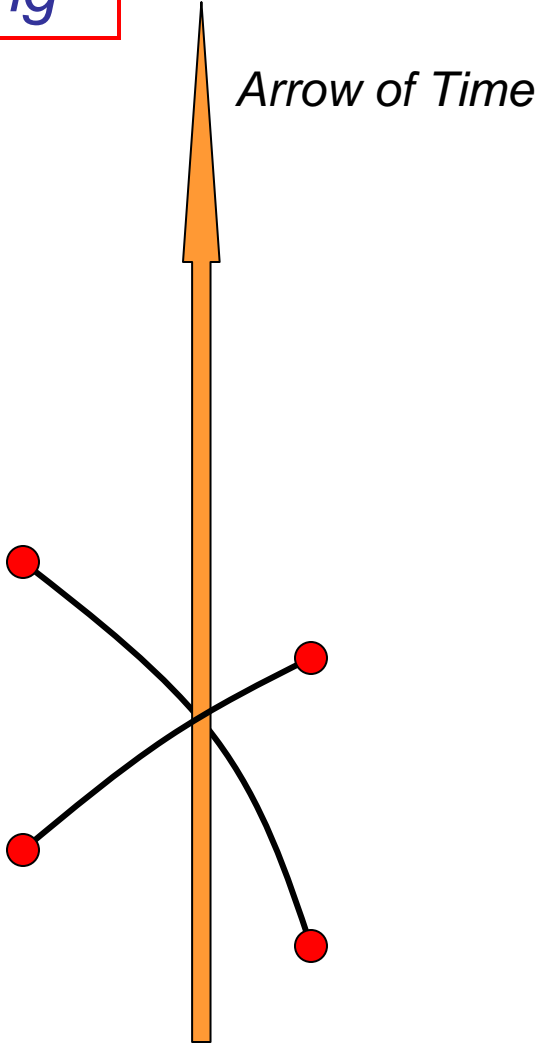
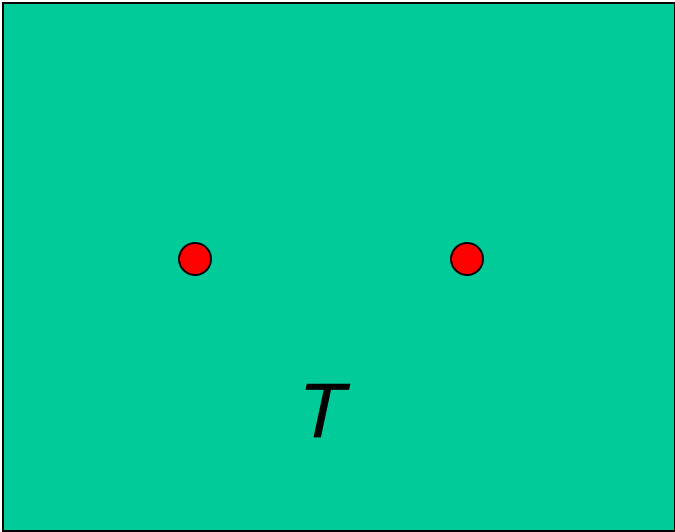
FERMIONS



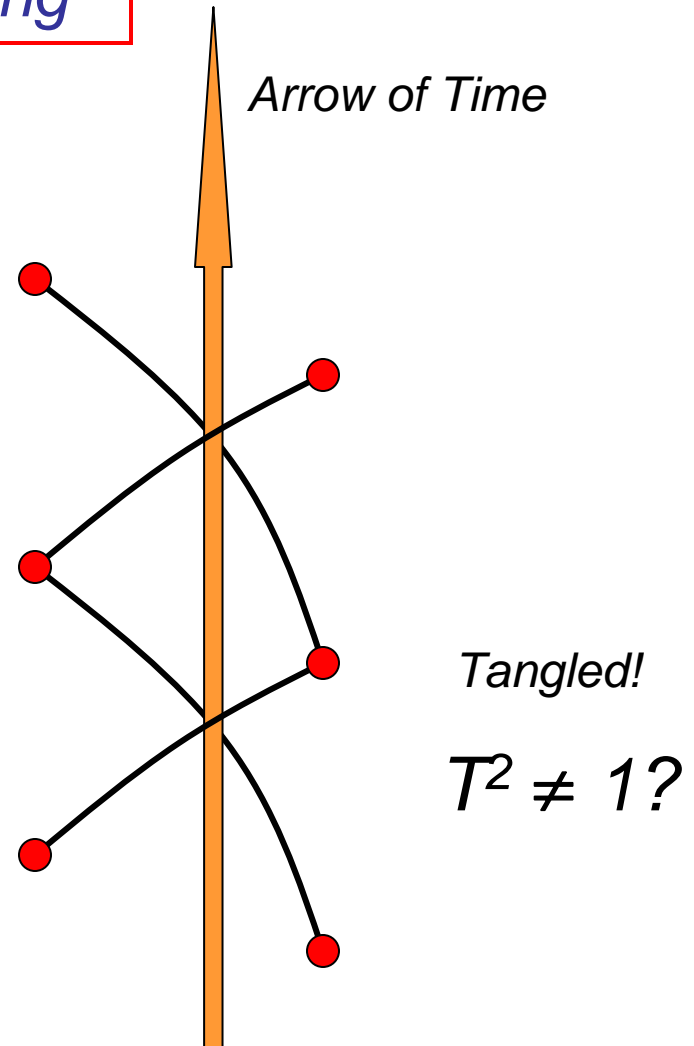
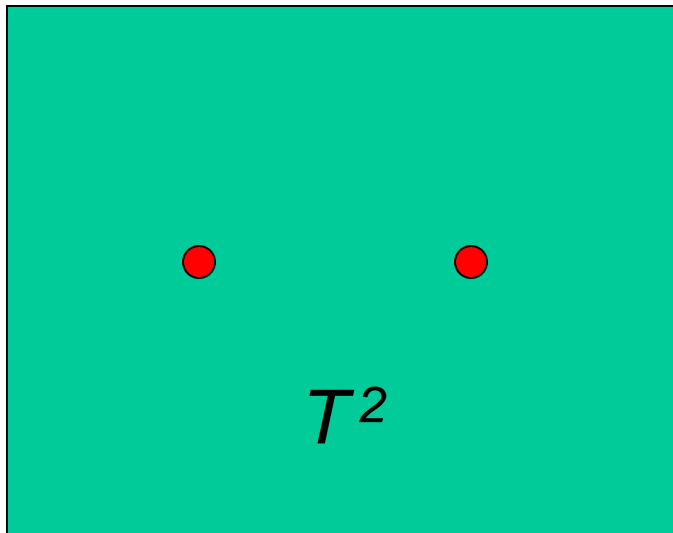
2D is Different: Trading vs. Braiding



2D is Different: Trading vs. Braiding



2D is Different: Trading vs. Braiding



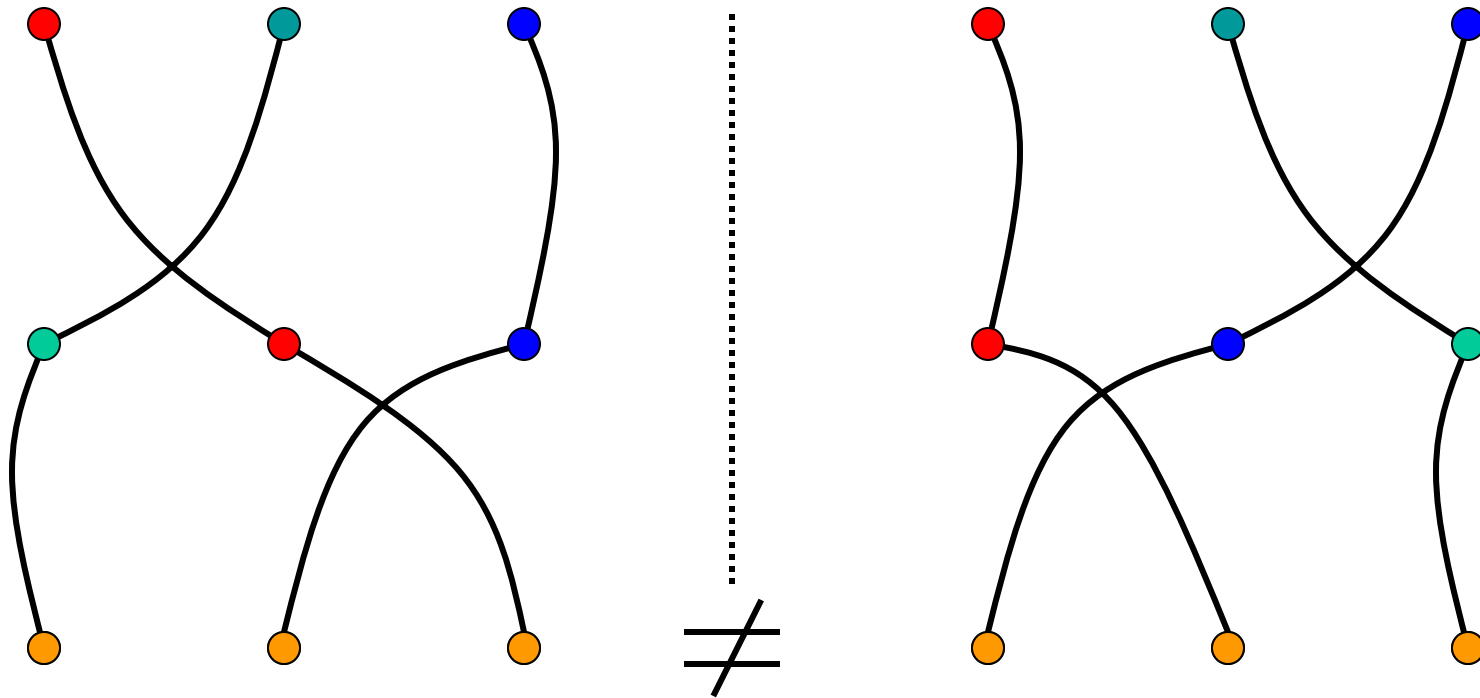
Does braiding matter in the real world?

In Fractional Quantum Hall Land:

YES



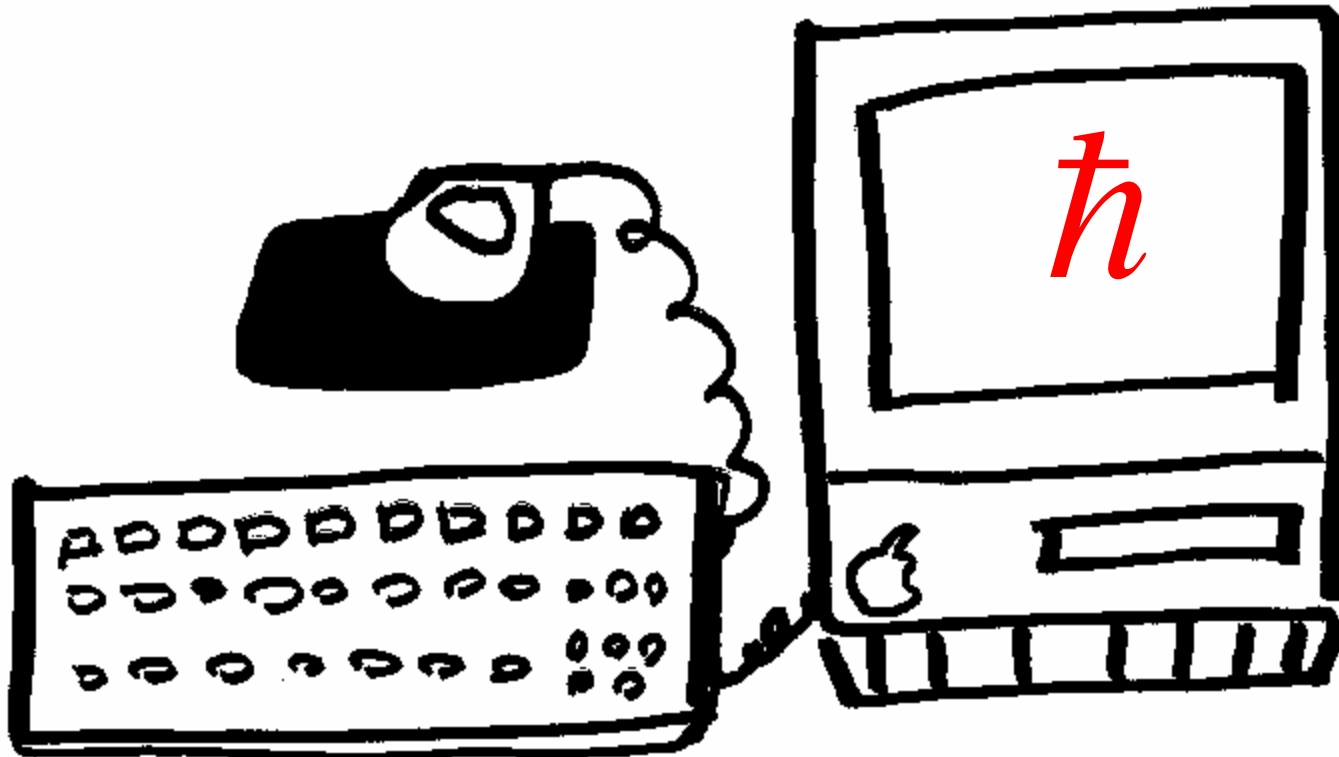
If that isn't bad enough: Braiding is Non-Abelian!



They may look the same, but in the 2D quantum world they may be different!



Is it good for ANYTHING?



A QUANTUM COMPUTER



Thanks for listening!

