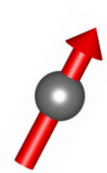
How far can the field go?

penetration depth, London equations

flux quantization

Fritz London



by Alexander Tsirlin, Leipzig University

Lecture 3: April 18, 2024

London gauge

Standard
track gauge

1435 mm

Image credit: SPSmiler (public domain)

London gauge

Standard
track gauge

1435 mm

London gauge will be our standard gauge for now

Image credit: SPSmiler (public domain)

Personality

Fritz London

Fritz London

- 1921: PhD in philosophy
- 1922–24: gymnasium science teacher
- 1927–33: Schrödinger's assistant in Berlin
- 1927: theory of chemical bond (Heitler-London scheme)
- 1930: theory of molecular interactions (London force)

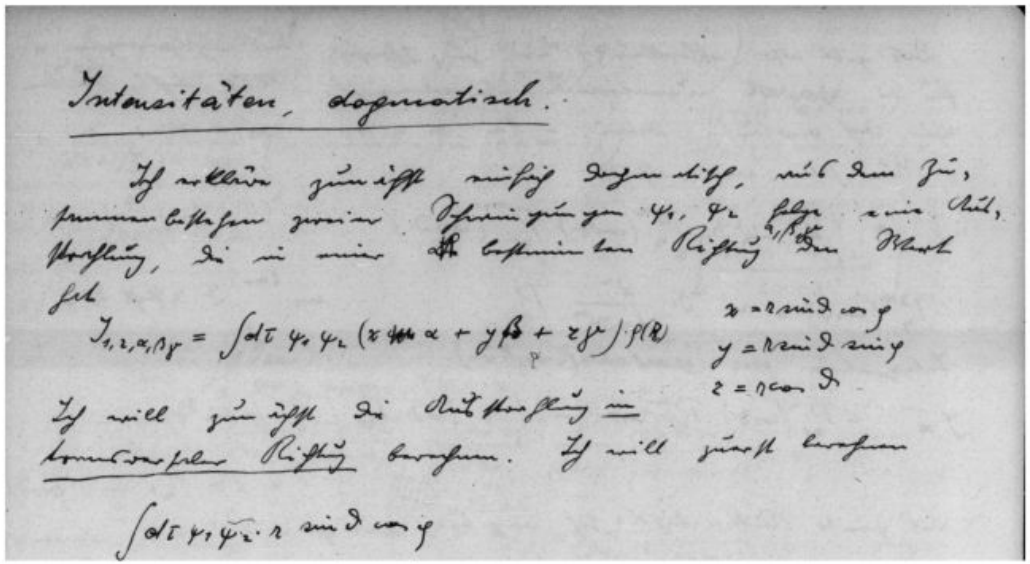
Fritz London
1900–1954

Tuesday, 23 Apr 2024 at 16:30

Dr. Alexander Blum

MPI Wissenschaftsgeschichte Berlin

Matrices vs. wave functions: Schrödinger's notebooks and his equivalence proof



- 1921: PhD in philosophy
- 1922–24: gymnasium science teacher
- 1927–33: Schrödinger's assistant in Berlin
- 1927: theory of chemical bond (Heitler-London scheme)
- 1930: theory of molecular interactions (London force)
- 1933: emigrates to England (Oxford) together with his younger brother Heinz
- 1935: London equations

Fritz London
1900–1954

London brothers

Heinz London
1907–1970

experiment

Fritz London
1900–1954

theory

- 1927: theory of chemical bond (Heitler-London scheme)
- 1930: theory of molecular interactions (London force)
- 1935: London equations
- 1936: moves to Paris
- from 1936: superfluidity and superconductivity
- from 1939: professor at Duke University, North Carolina, US
- 1950: influential book *Superfluids*

Fritz London
1900–1954

- 1927: theory of chemical bond (Heitler-London scheme)
- 1930: theory of molecular interactions (London force)
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- from 1939: professor at Duke University, North Carolina, US

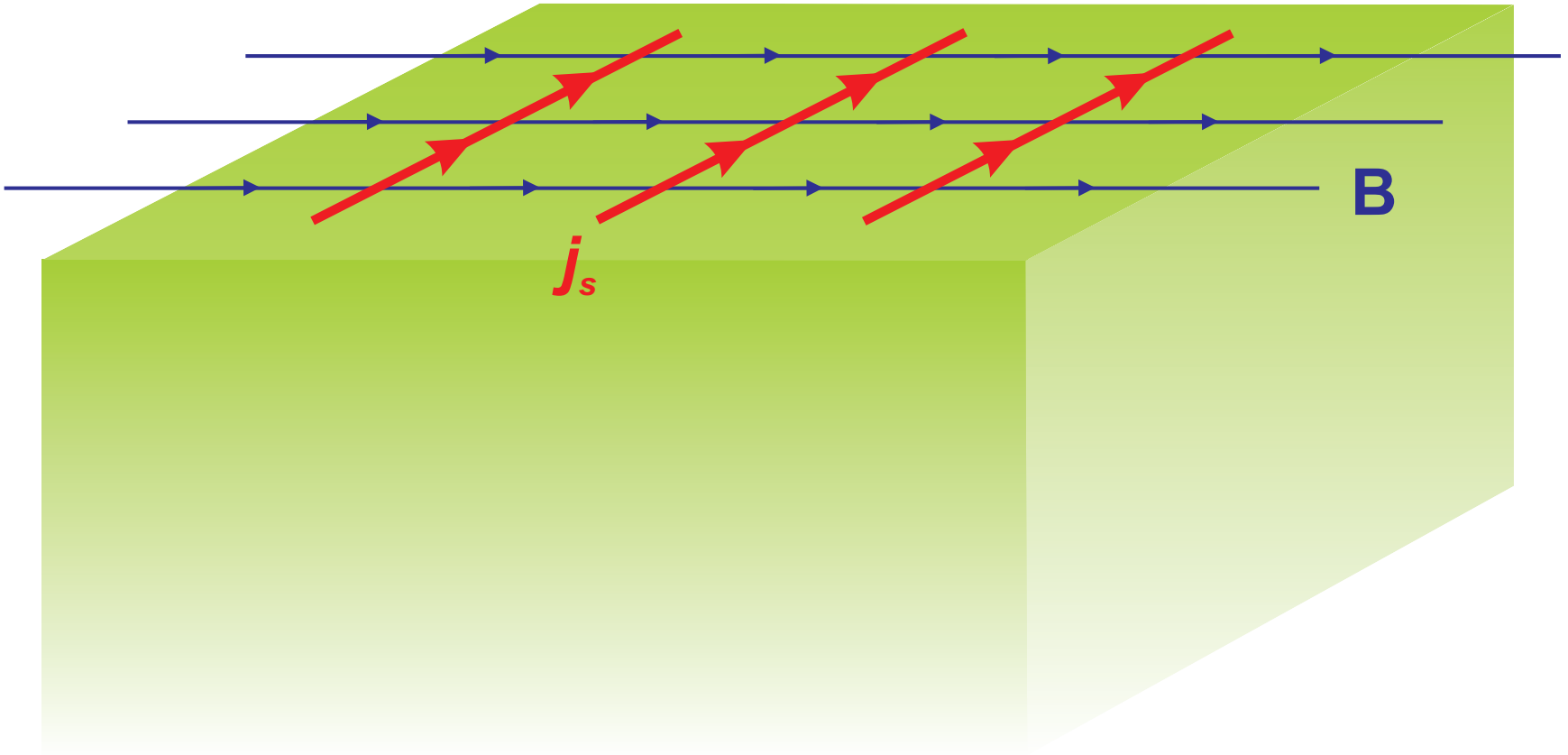
- 1950: influential book *Superfluids*

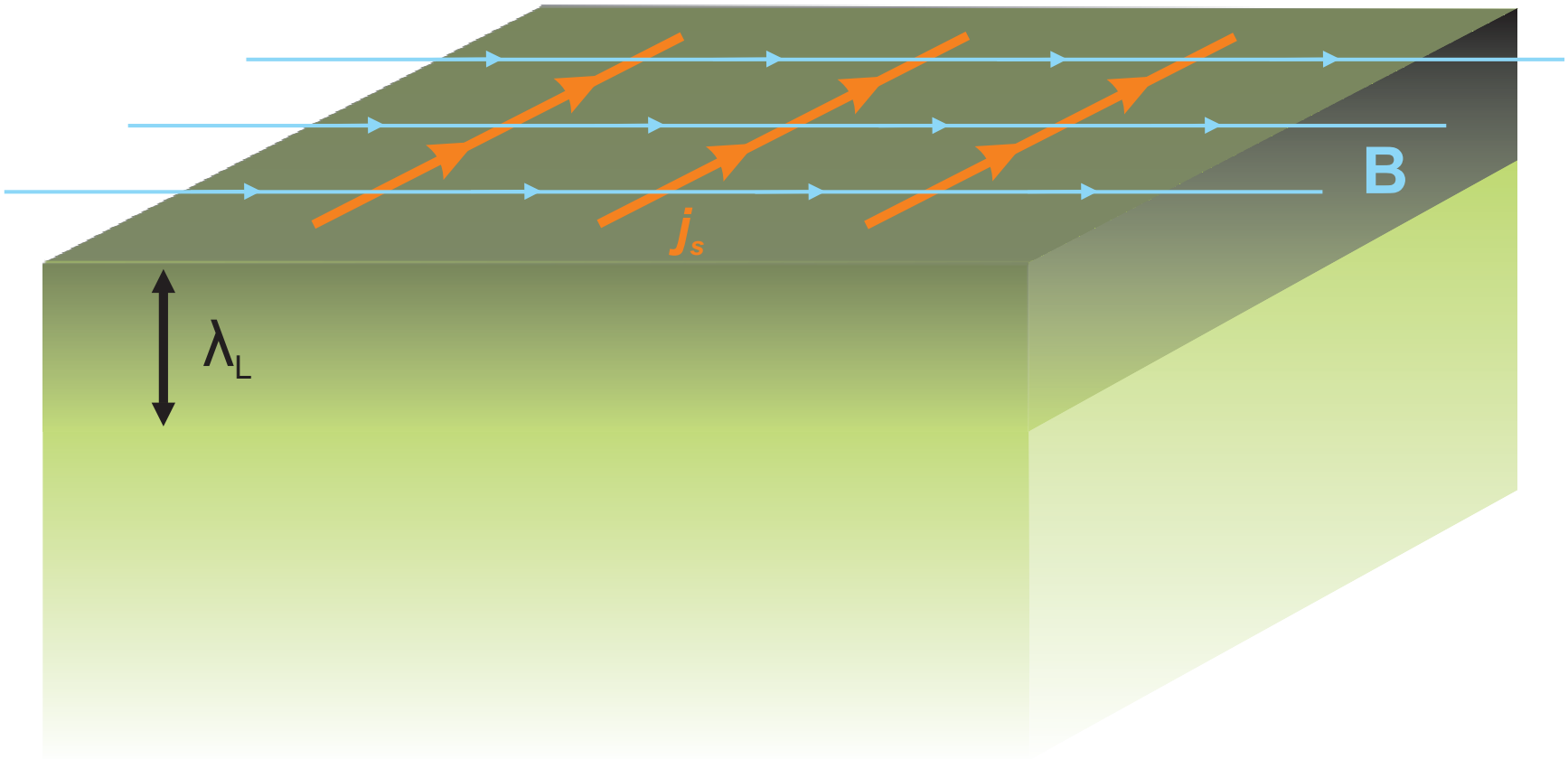
"The fact that in 15 years London has not seen fit to make any substantial alterations to the fundamental framework of his theory is to be regarded not as evidence of a conservative nature, but as testimony to the **logical beauty of the theory in its original form**"

Brian Pippard

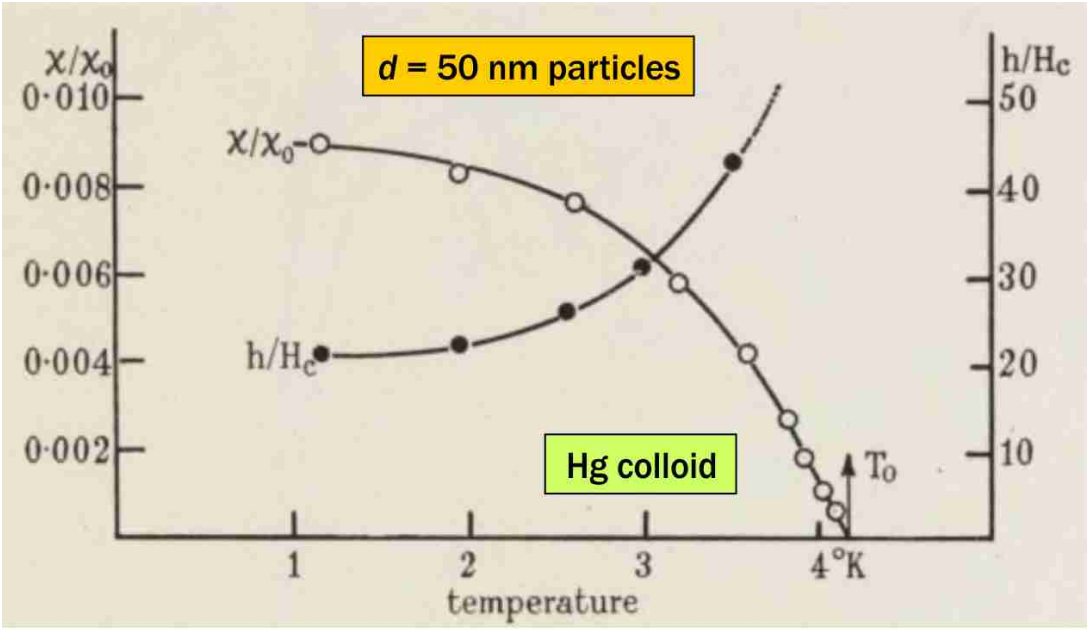
Fritz London
1900–1954

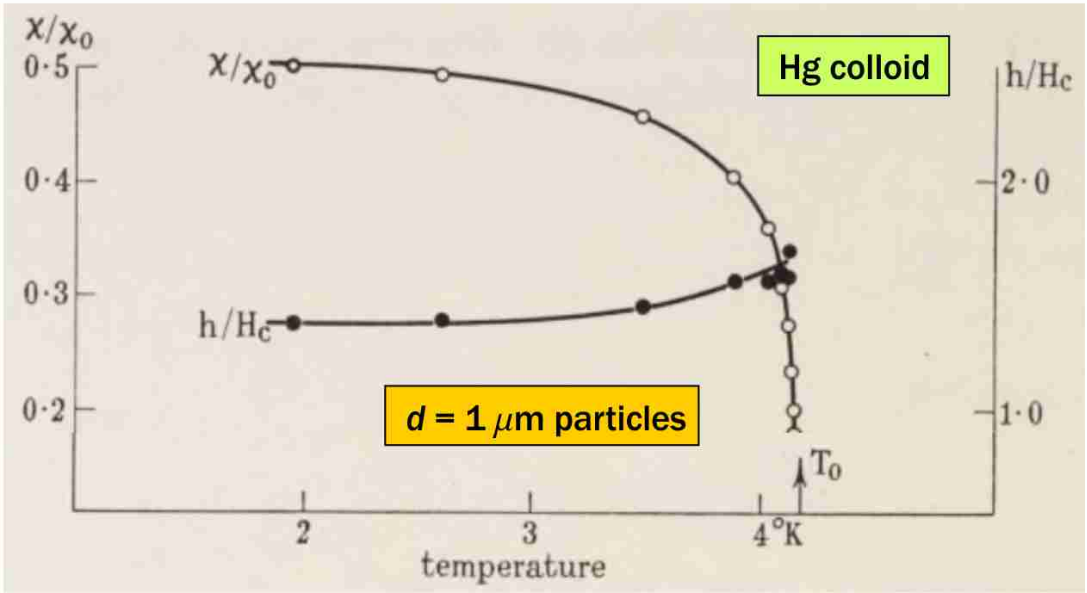
Penetration depth




B
j_s
λ_L

Penetration depth from dc-susceptibility





With $d \ll \lambda_L$,
the susceptibility goes
below the Meissner limit

particle size decreases

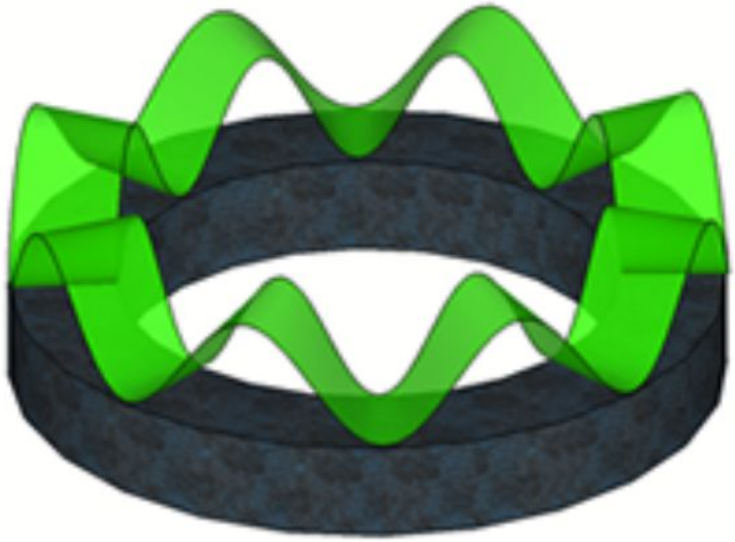
D. Shoenberg, Proc. Royal Soc. 175, 49 (1940)

Experiment

flux quantization

Continuity of the phase

phase discontinuous ✗



phase is continuous ✓

Image credit: Supra2011 (fair use)

Measurement of flux quantization

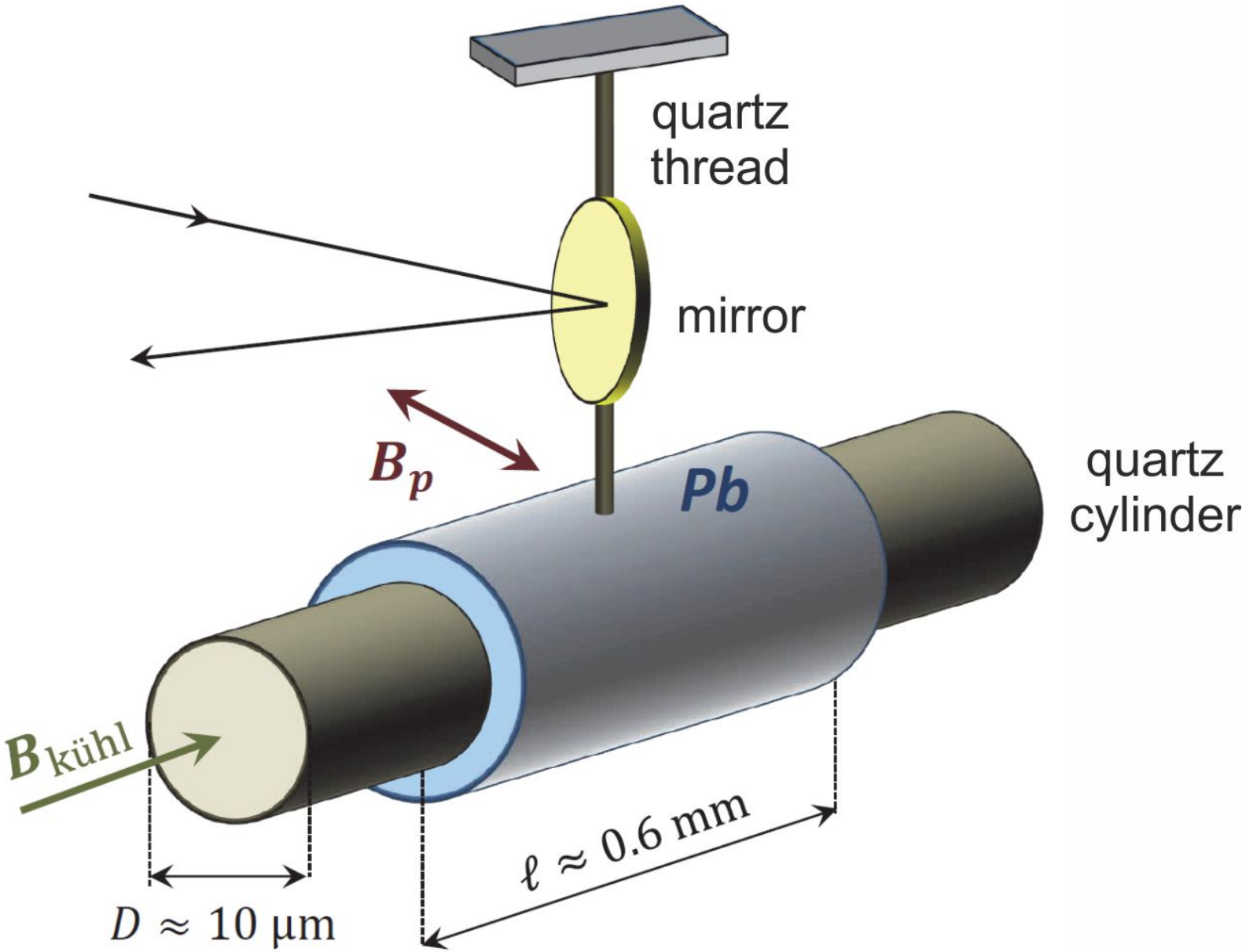
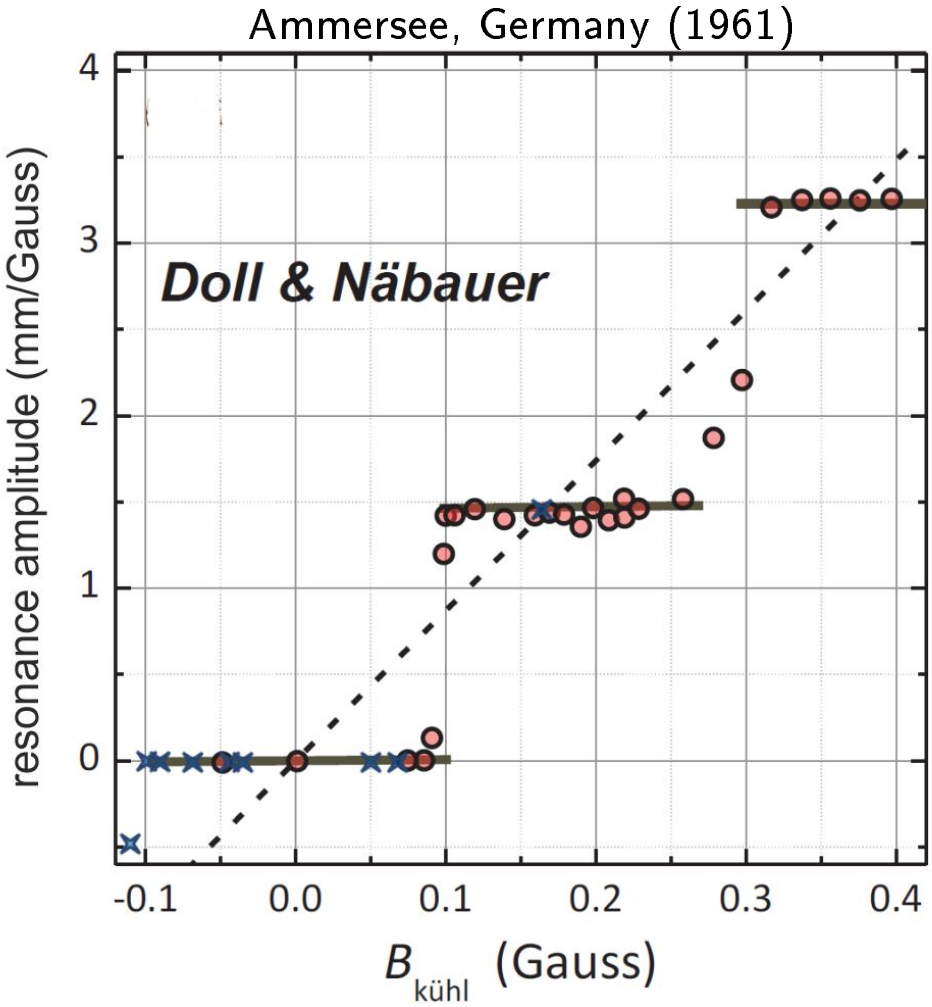
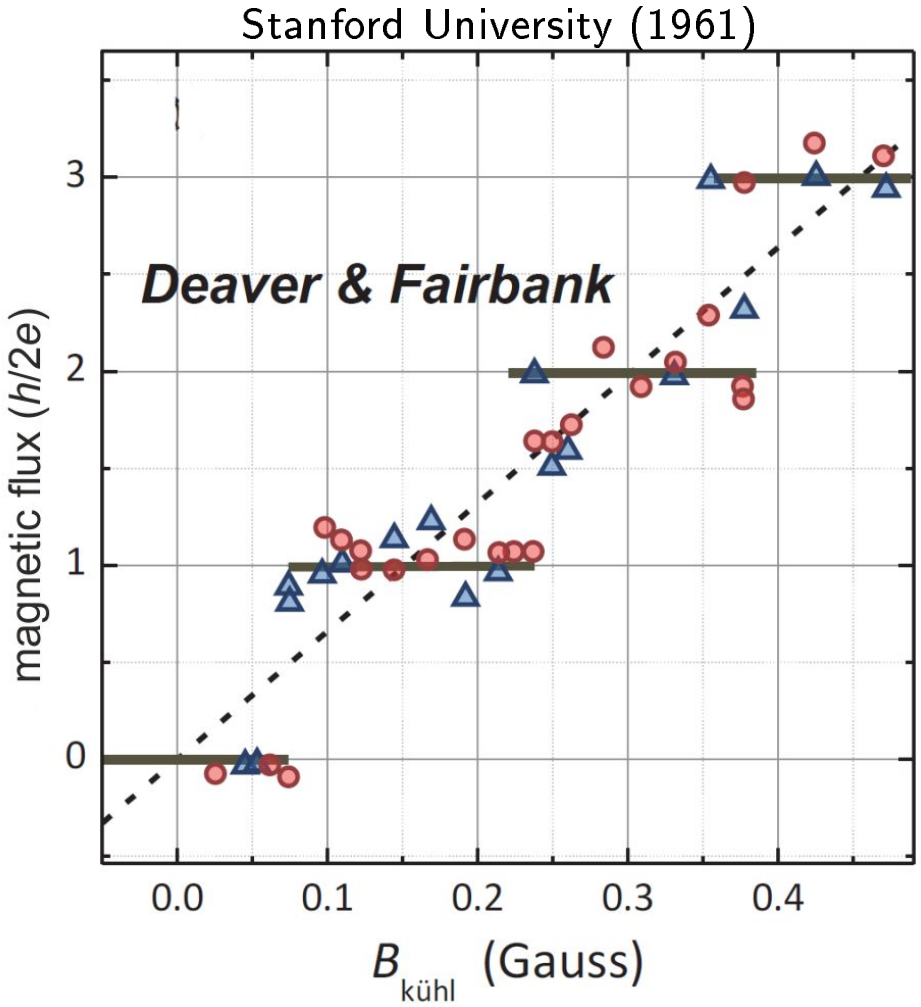


Image credit: Gross and Marx, Festkörperphysik

Flux quantization: When magnetism climbs stairs





Both experiments consistently indicated $\Phi_0 = \pi\hbar/e$

Image credit: Gross and Marx, Festkörperphysik

Macroscopic manifestation of a quantum state

Microscopic: quantum nature of the superconducting state

phase coherence

Macroscopic: measurable effect for the magnetic flux

Thinking big

Fritz London's single-minded thinking led him to surpass even Einstein, as he believed correctly that quantum mechanics was right at all scales, including the macroscopic.

Nature 437, 625 (2005)

Microscopic: quantum nature of the superconducting state

phase coherence

Macroscopic: measurable effect for the magnetic flux

Thinking big

Fritz London's single-minded thinking led him to surpass even Einstein, as he believed correctly that quantum mechanics was right at all scales, including the macroscopic.

$\longrightarrow$ Supercurrent is related to the gradient of phase, $\nabla\theta$

Nature 437, 625 (2005)