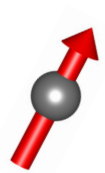
# BCS and conventional superconductivity

BCS coherence length, pair-breaking current

tunneling experiments

magnesium diboride ($MgB_2$)



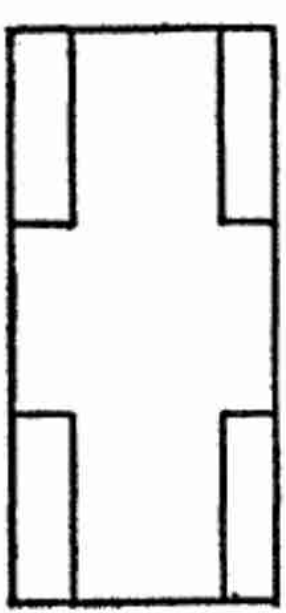
by Alexander Tsirlin, Leipzig University

Lecture 11: June 20, 2024

# Experiment

*tunneling spectroscopy*

# Tunneling experiments



Glass substrate
with In contacts

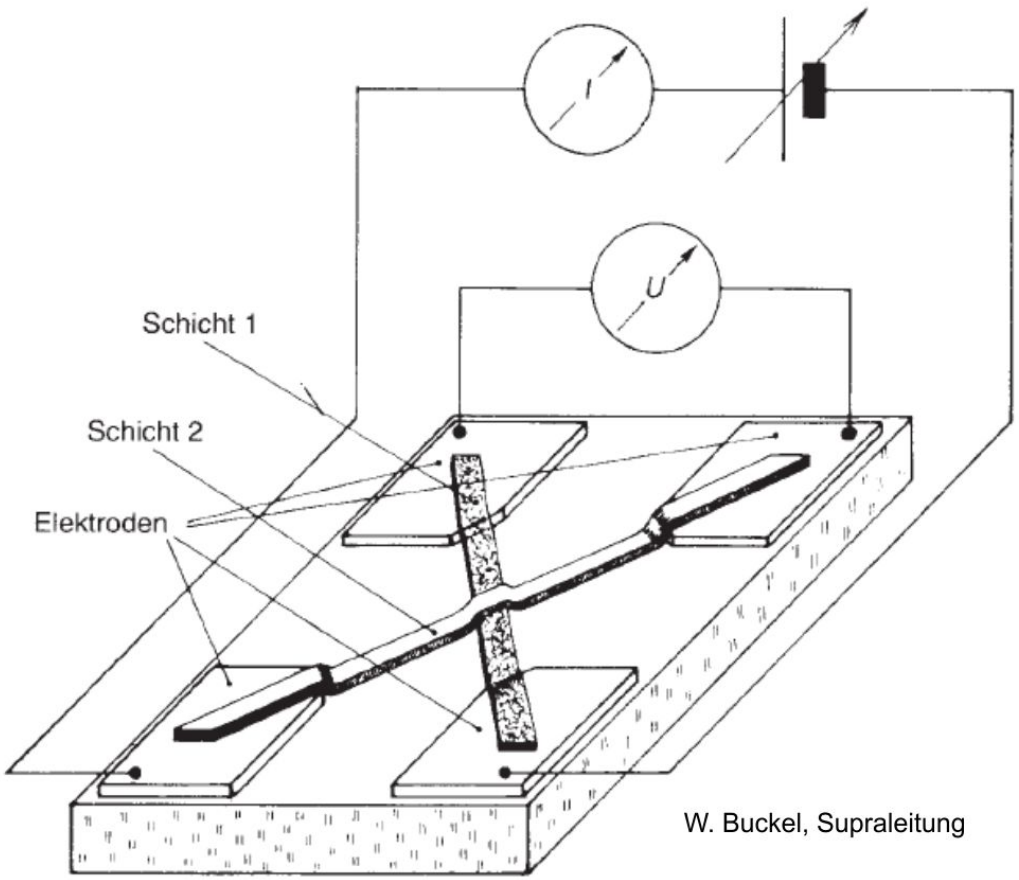
Al strip

Al strip oxidized
($Al_2O_3$ surface layer)

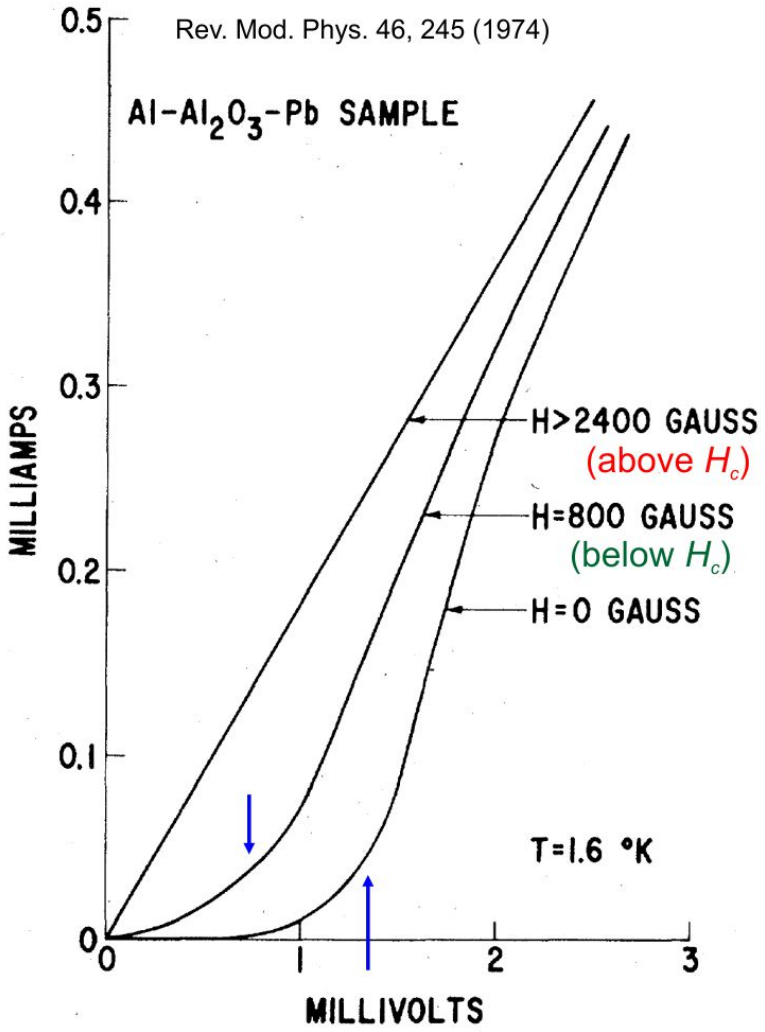
Pb strip forms
the tunneling contact

Phys. Rev. 122, 1101 (1961)

# Tunneling: superconductor to normal metal




W. Buckel, Supraleitung

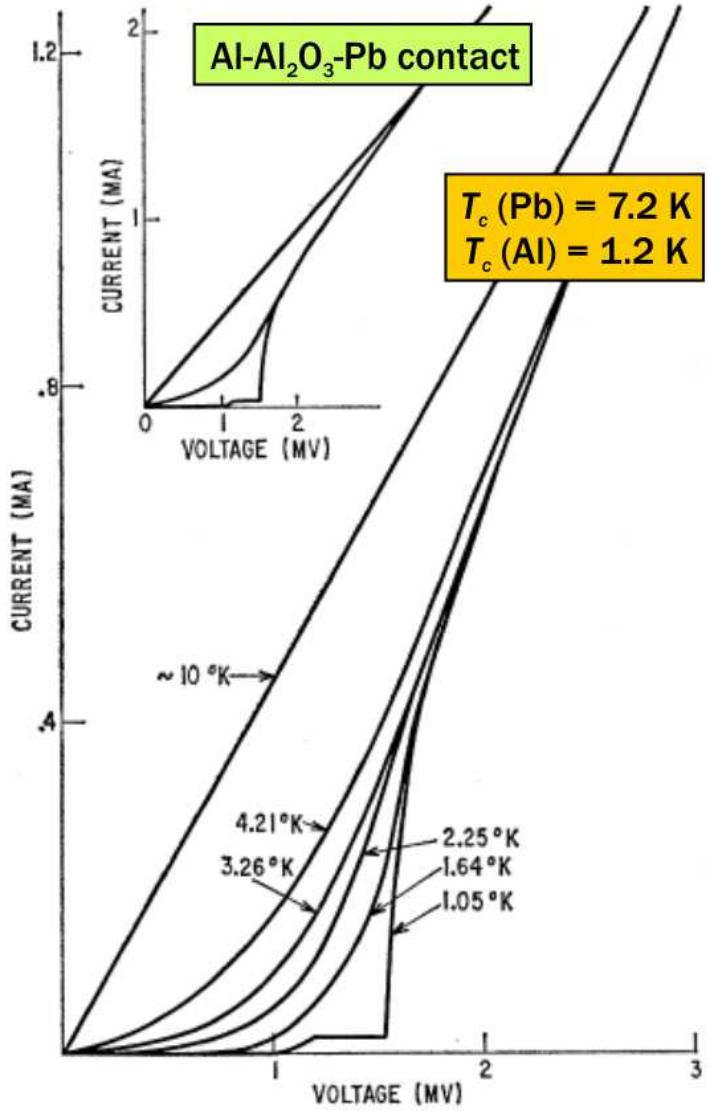



Superconducting gap is extracted from the current-voltage characteristic

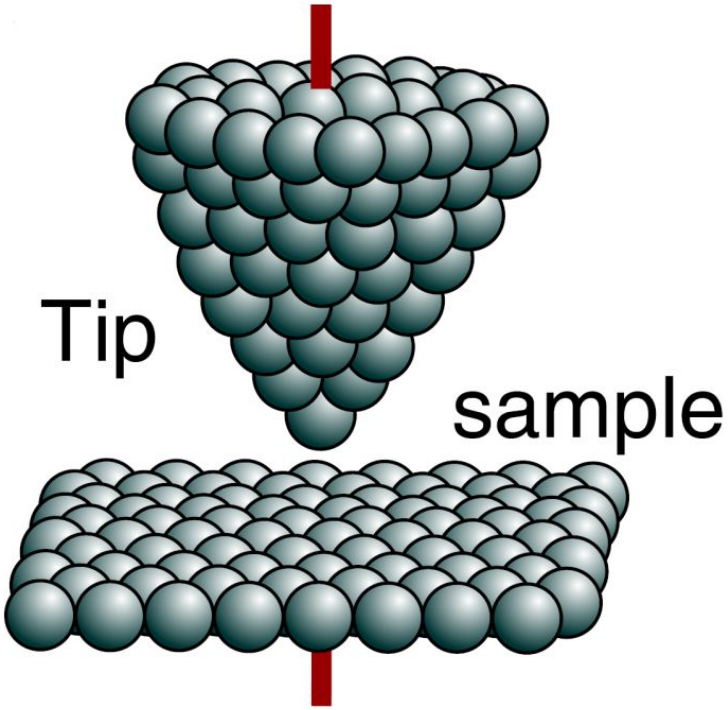
# Tunneling: superconductor to superconductor

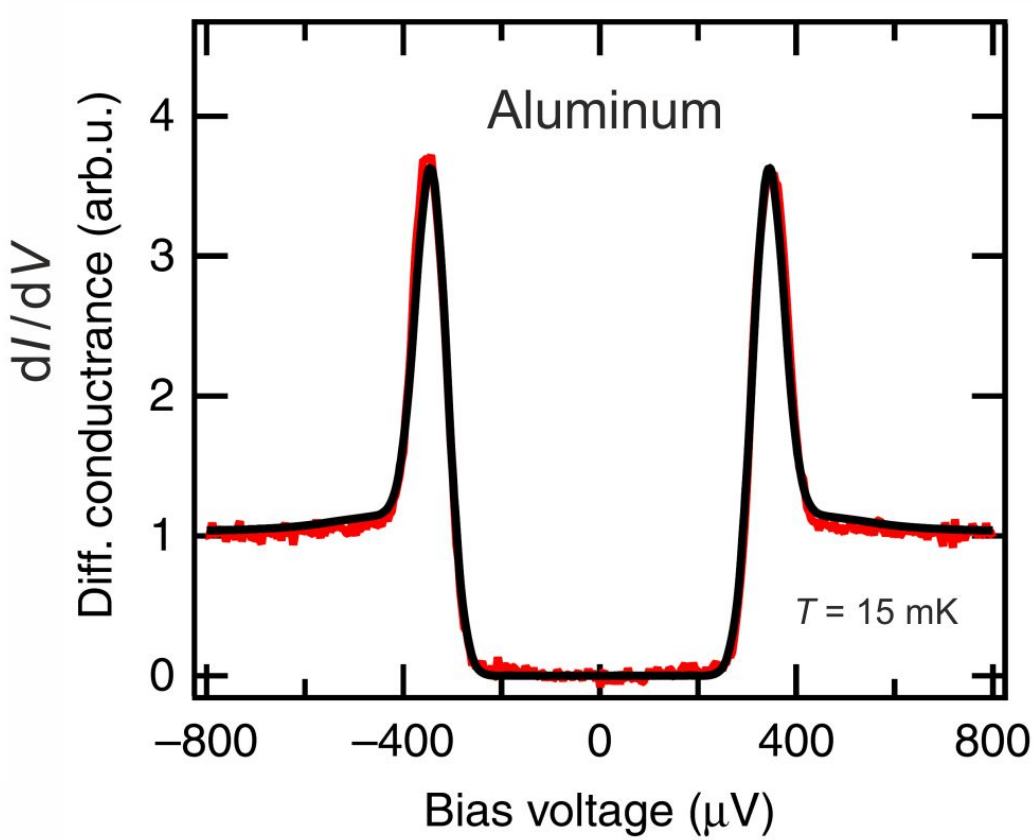
Ivar Giæver
born 1929

first tunneling experiments
in early 1960's



# Scanning tunneling spectroscopy (STS)




STS is the best (yet local!) probe of the low-energy DOS

Nature Comm. 7, 13009 (2016)

Superconductors now come in more flavors
than Baskin-Robbins ice-cream...

Leon Cooper, 50 years of BCS

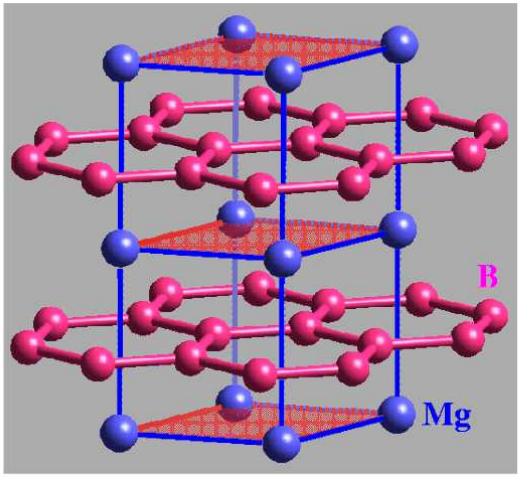
| Element | $T_c$ in Kelvin | Superconducting gap: $2\Delta_0/k_BT_c$ tunnelling experiments | ultrasonic experiments | light absorption |
|---|---|---|---|---|
| Sn | 3,72 | 3,5 ± 0,1 (1,15) | – | 3,5 |
| In | 3,4 | 3,5 ± 0,1 (1,05) | 3,5 ± 0,2 | 3,9 ± 0,3 |
| Tl | 2,39 | 3,6 ± 0,1 (0,75) | – | – |
| Ta | 4,29 | 3,5 ± 0,1 (1,30) | 3,5 ± 0,1 | 3,0 |
| Nb | 9,2 | 3,6 (2,90) | 4,0 ± 0,1 | 2,8 ± 0,3 |
| Hg | 4,15 | 4,6 ± 0,1 (1,65) | – | 4,6 ± 0,2 |
| Pb | 7,2 | 4,3 ± 0,05 (2,70) | | 4,4 ± 0,1 |

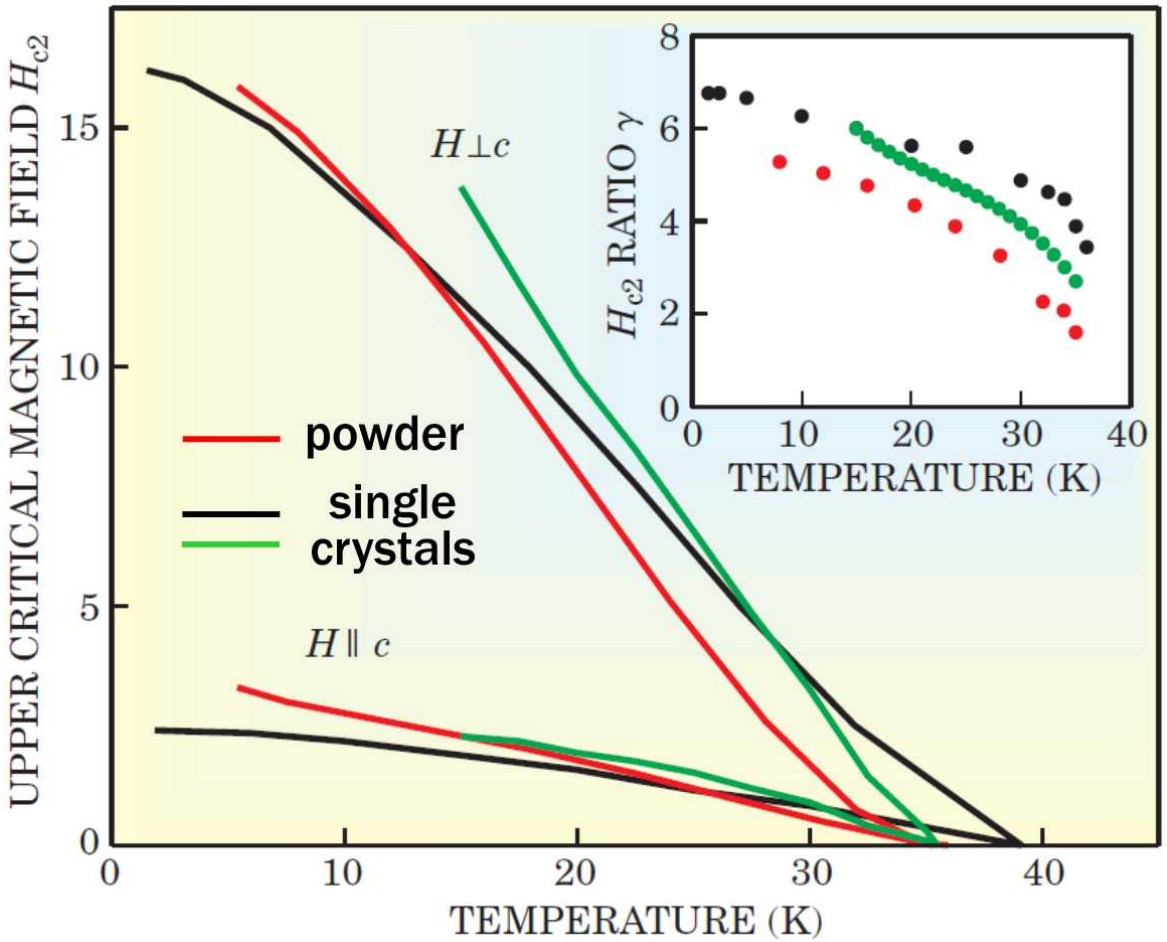
Buckel, Supraleitung

# Material / Technology

*magnesium diboride*

# Genie from the bottle: $MgB_2$

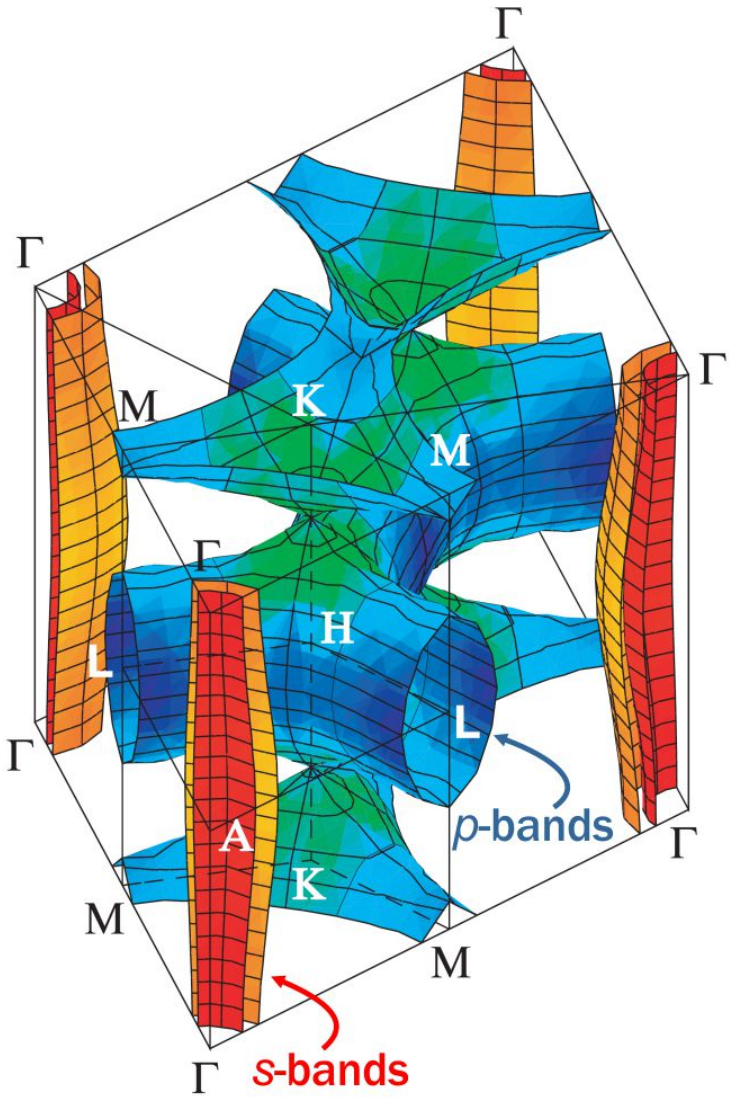


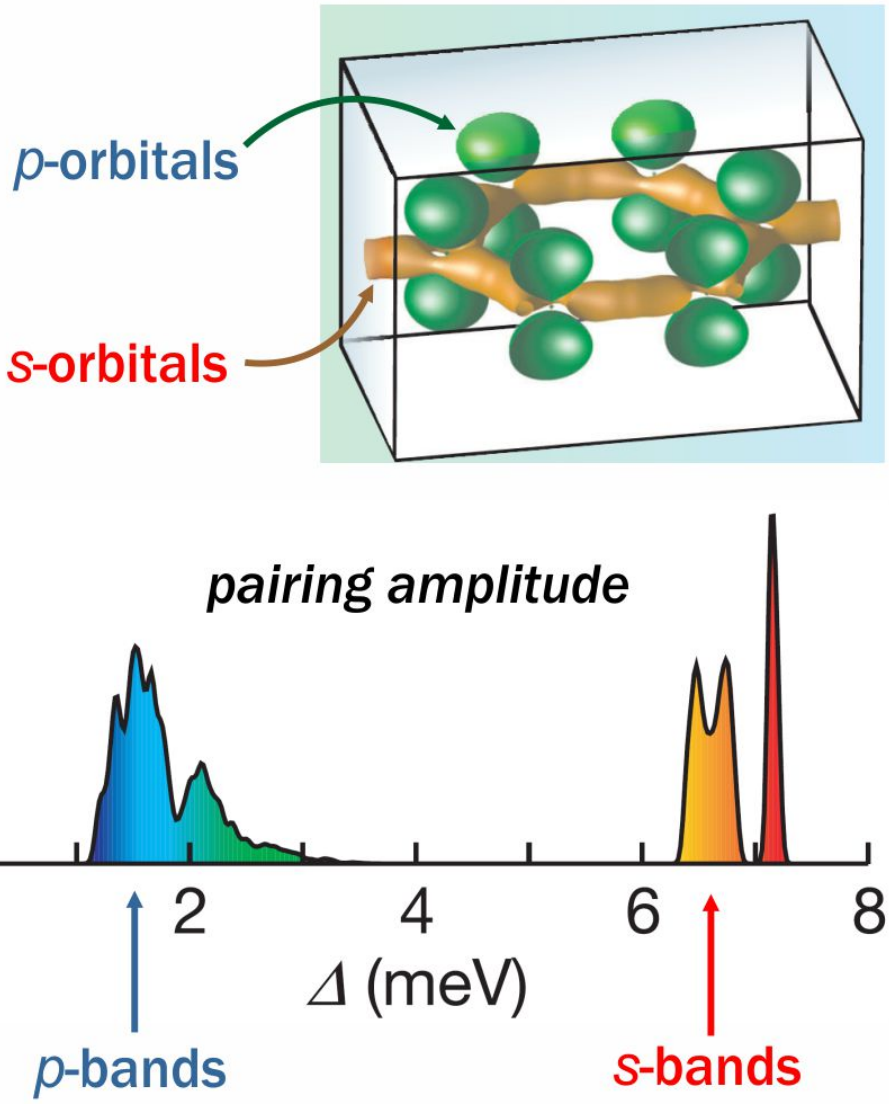




- Discovered in 2001; simple and widely available; $T_c = 32 \div 39\,\mathrm{K}$
- Strong anisotropy, moderate critical fields (can be improved by suitable processing)

Physics Today 464, 183 (2003)

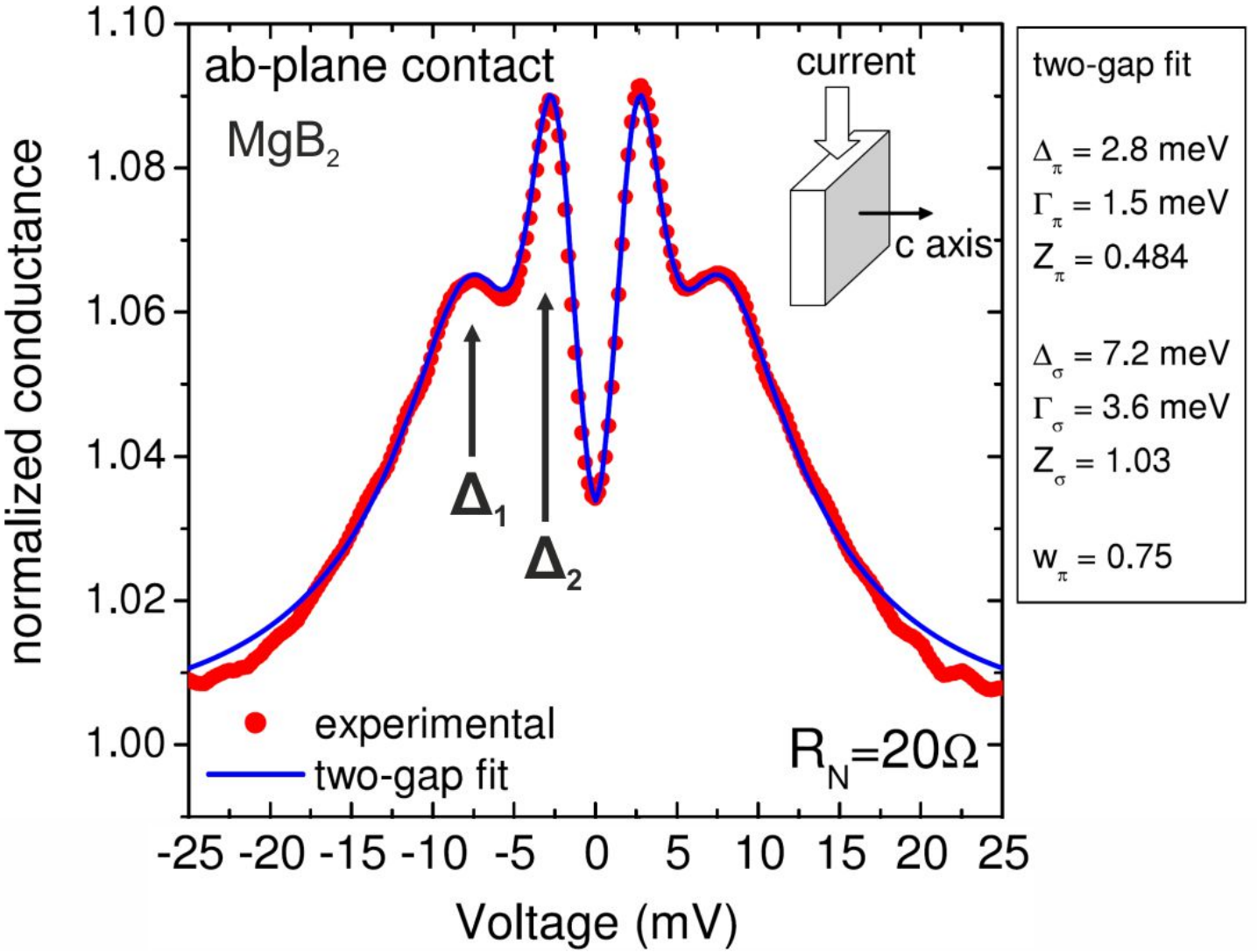
# New mechanism: two-gap superconductivity



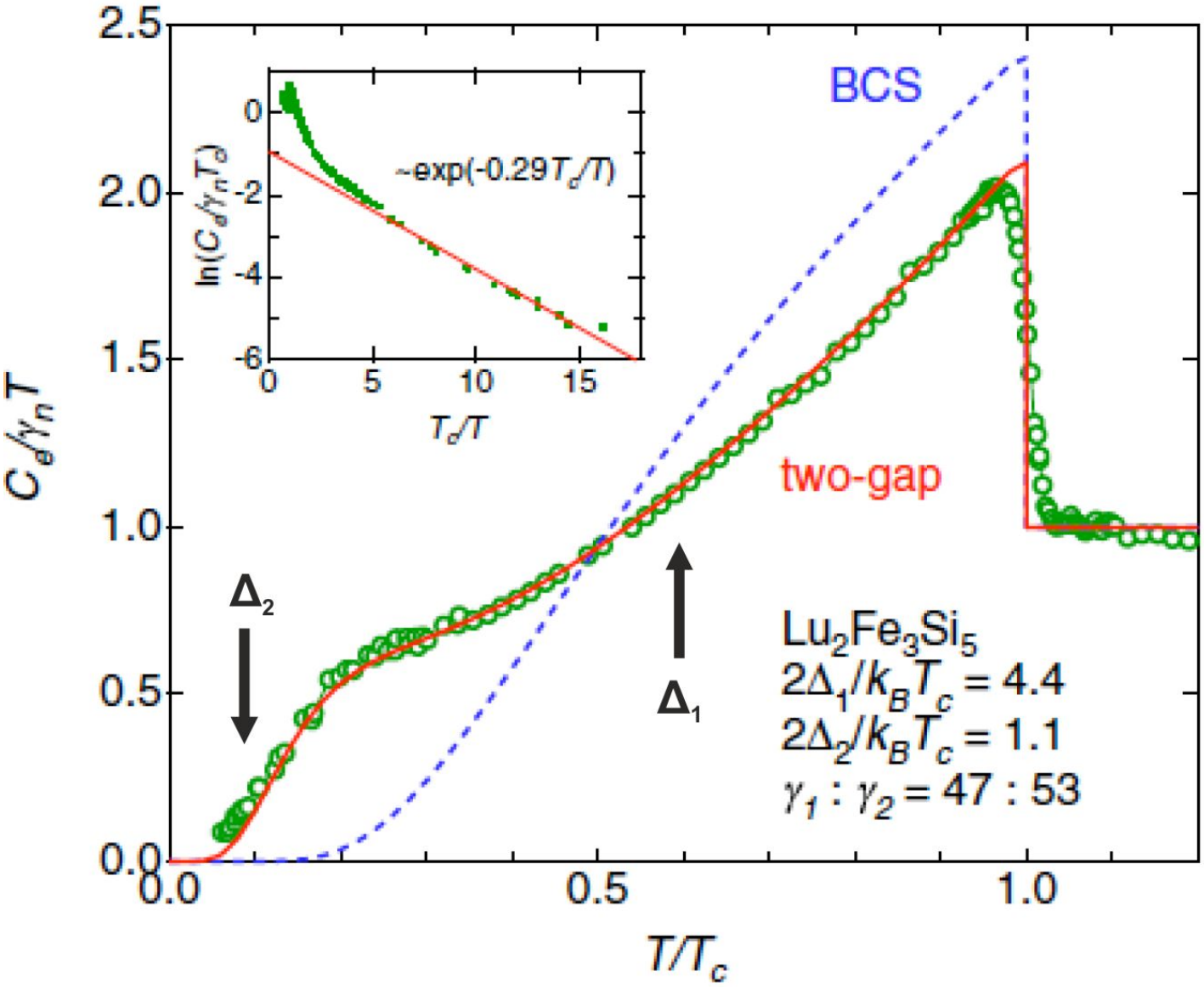

Nature 418, 758 (2002) and Physics Today 464, 183 (2003)

# Two gaps in the tunneling

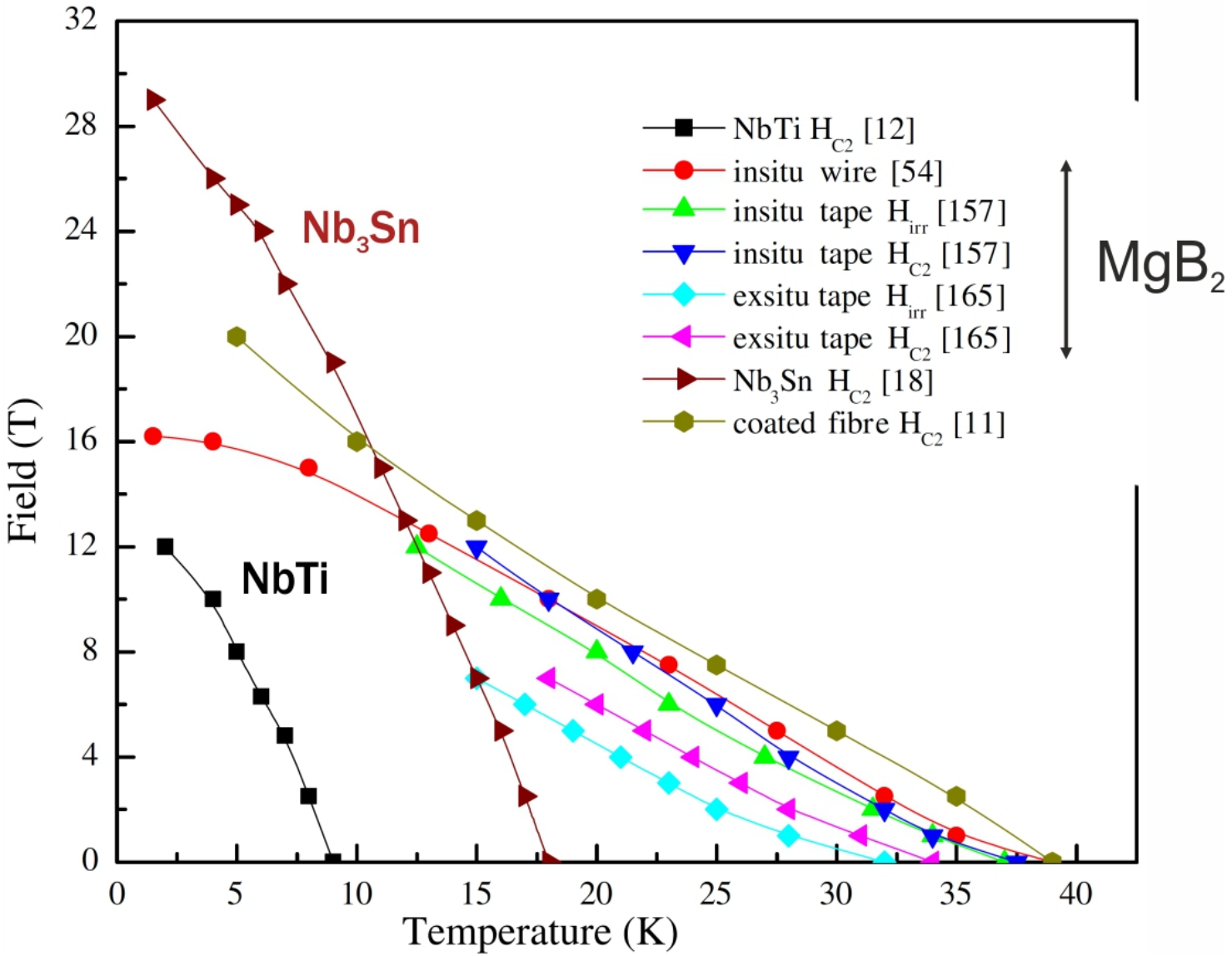



Supercond. Sci. Tech. 23, 043001 (2010)

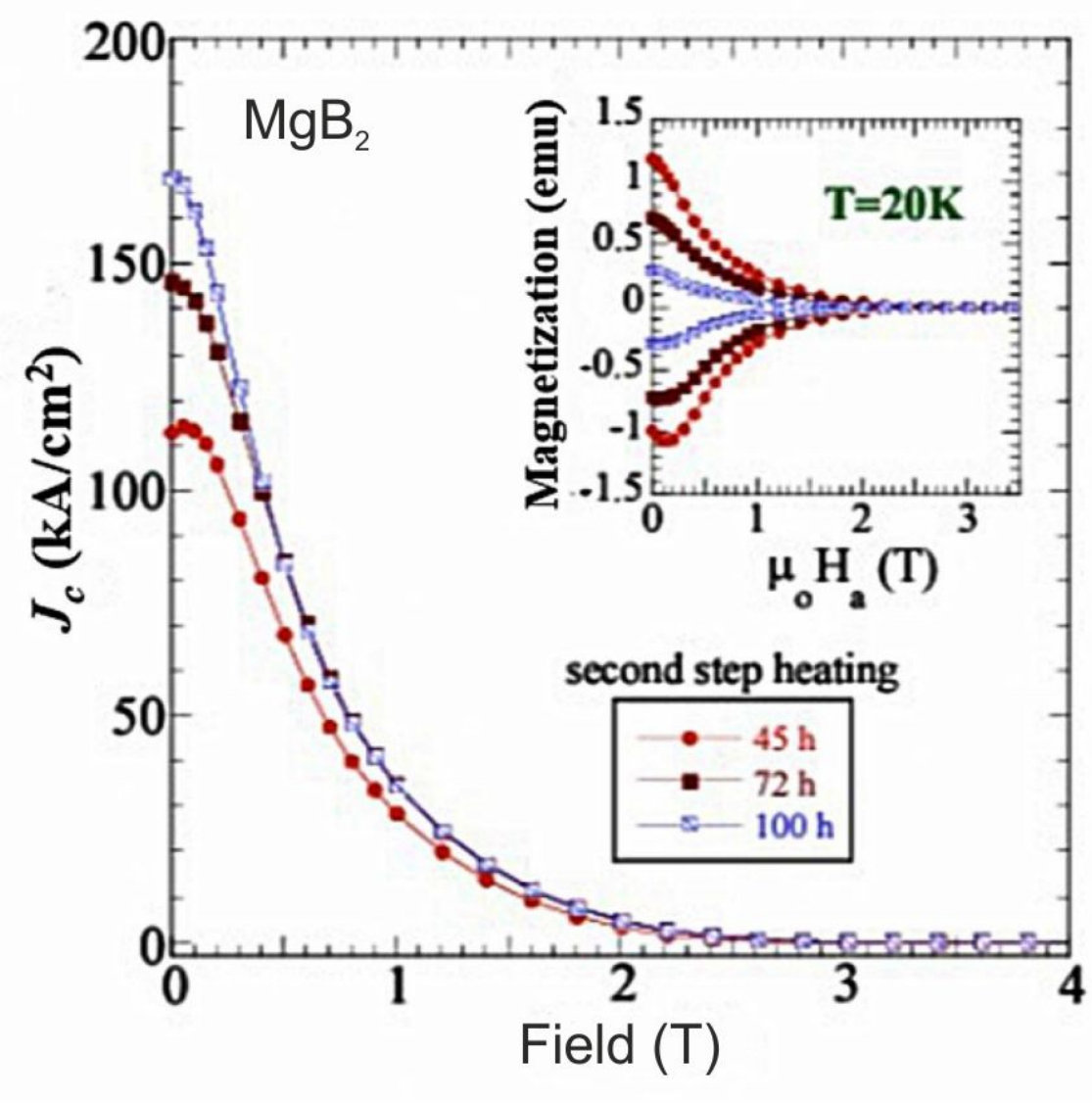
# Two gaps in the specific heat




J. Phys. Conf. Series 150, 052264 (2009)

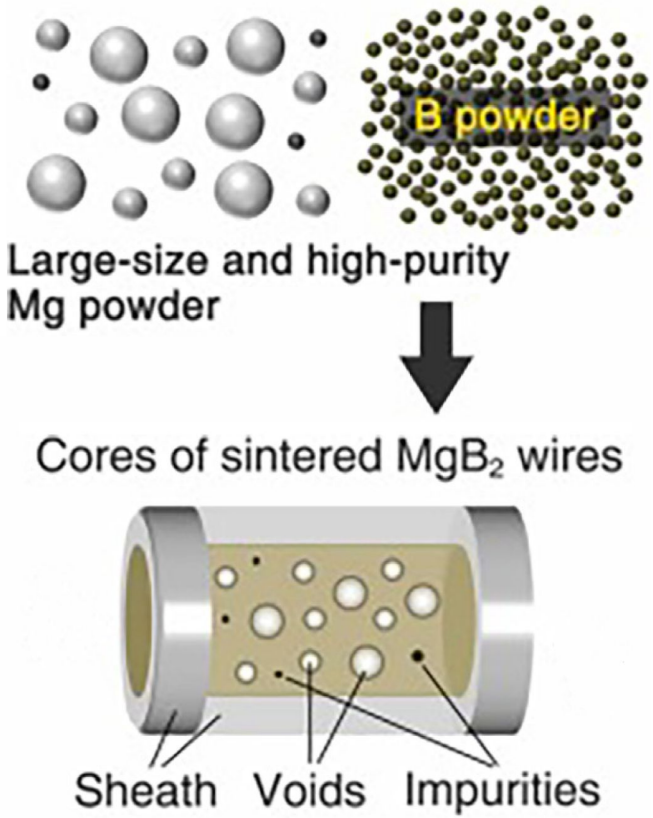



Supercond. Sci. Technol. 20, R1 (2007)

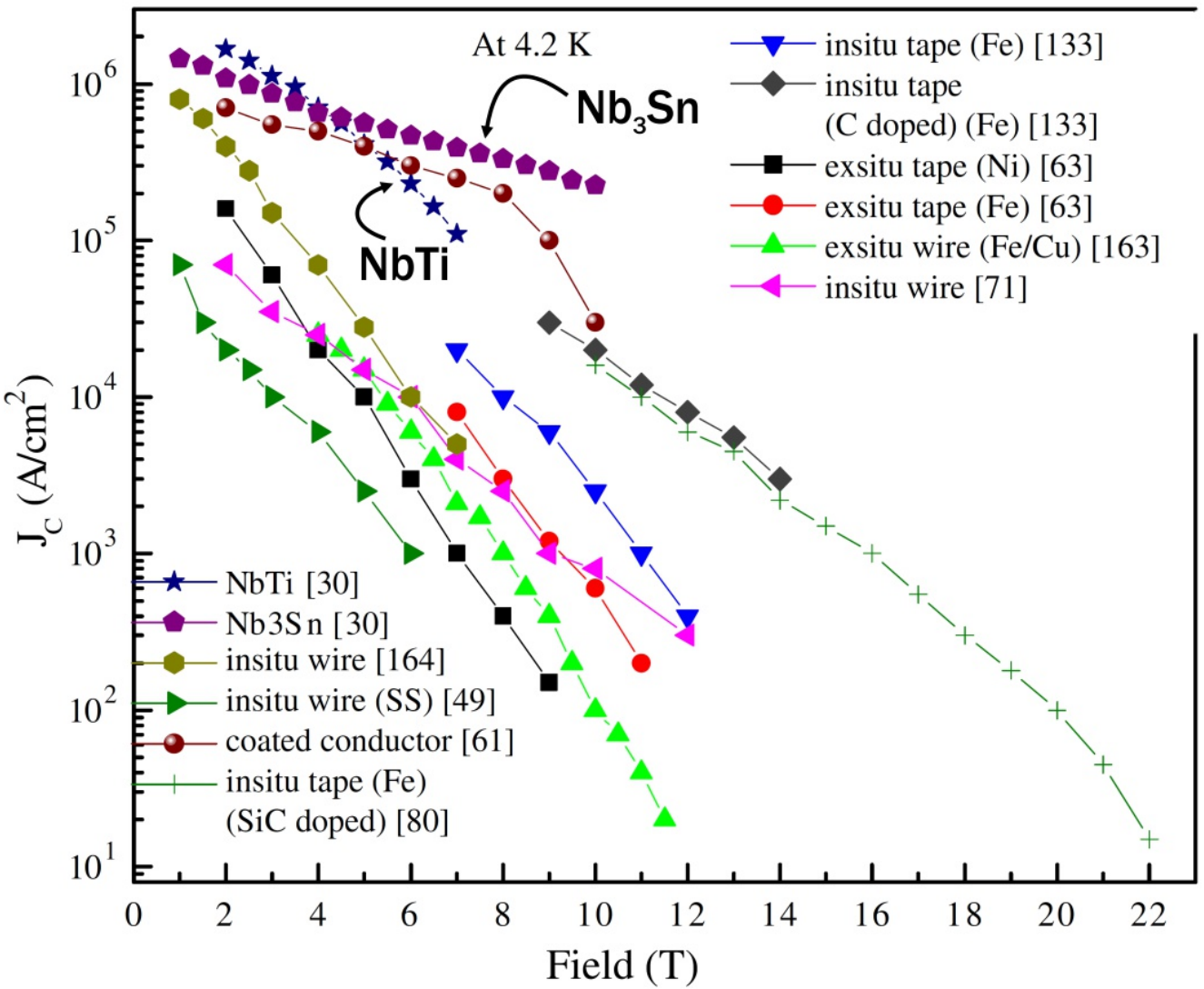



Drastic reduction with the field

Inefficient pinning

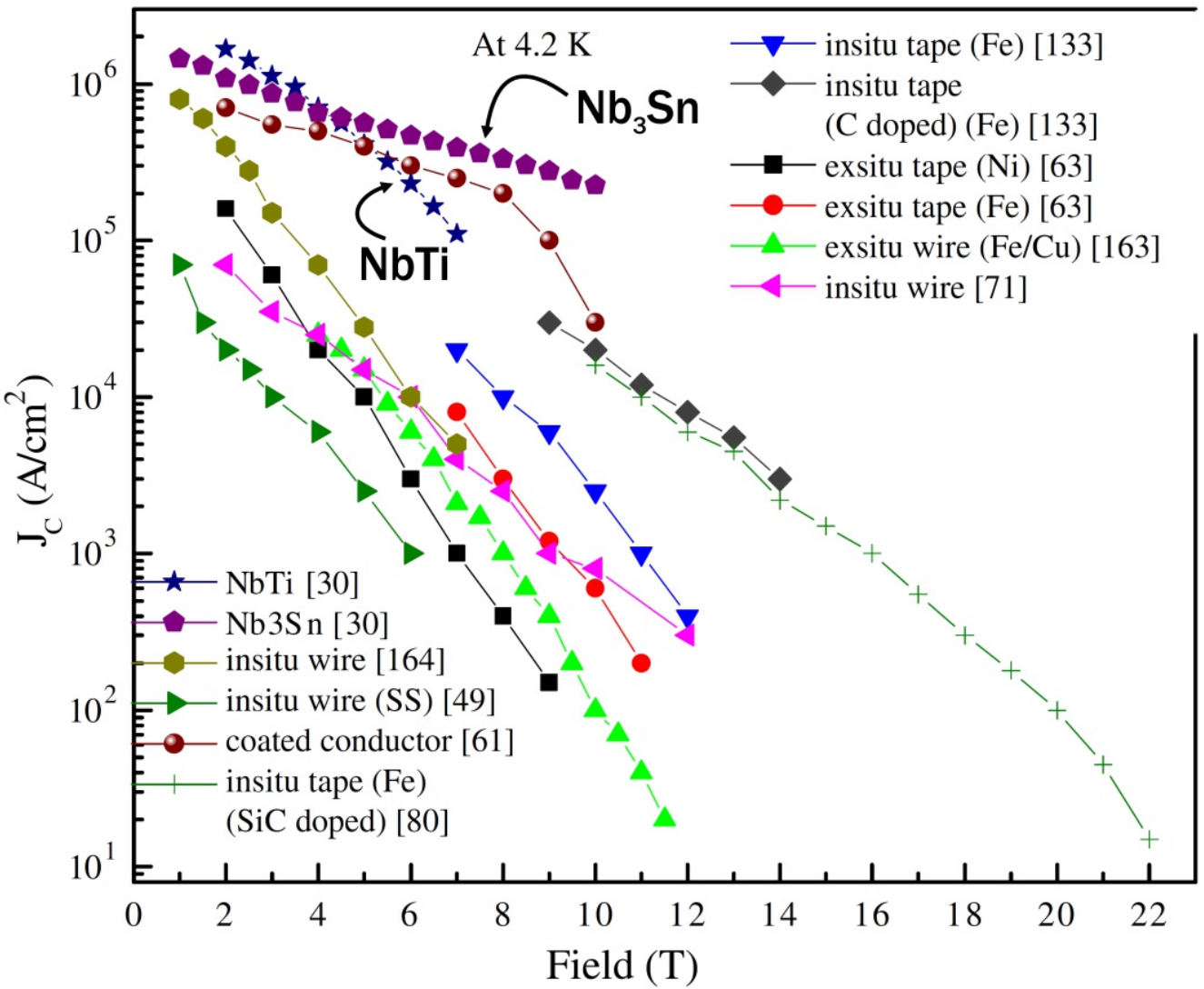



Superconductivity 9, 100083 (2024), J. Phys. D 57 053001 (2024)




$MgB_2$

Supercond. Sci. Technol. 20, R1 (2007)




$MgB_2$

Supercond. Sci. Technol. 20, R1 (2007)

You can't use $MgB_2$ to build a superconducting magnet...