UCR Physics & Astronomy 50th Anniversary Symposium

High Temperature Superconductivity

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University of California, San Diego

MAPLE GROUP
Physics of Correlated Electron Materials

Sep. 2002: Ph. D. student

Apr. 2003: Prof. Douglas E. MacLaughlin

Muon Spin Relaxation and Rotation Studies of the Filled Skutterudite Alloys
$Pr(Os_{1-x}Ru_x)_4Sb_{12}$ and $Pr_{1-y}La_yOs_4Sb_{12}$

ICM 2006

TRIUMF beamtime 2006

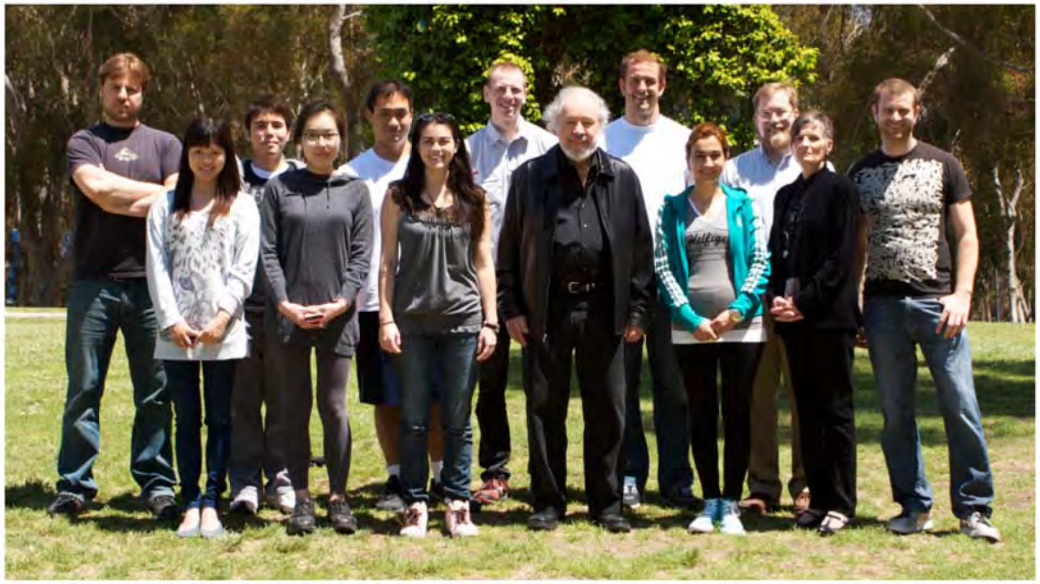
Retirement Party 2007

TRIUMF beamtime 2009

Jun. 2007: Ph.D.

Jul. 2007 - Apr. 2008 : postdoc at UCR

Jun. 2008 - Oct. 2009
Sep. 2010 - present : postdoc at UCSD, Maple's Lab







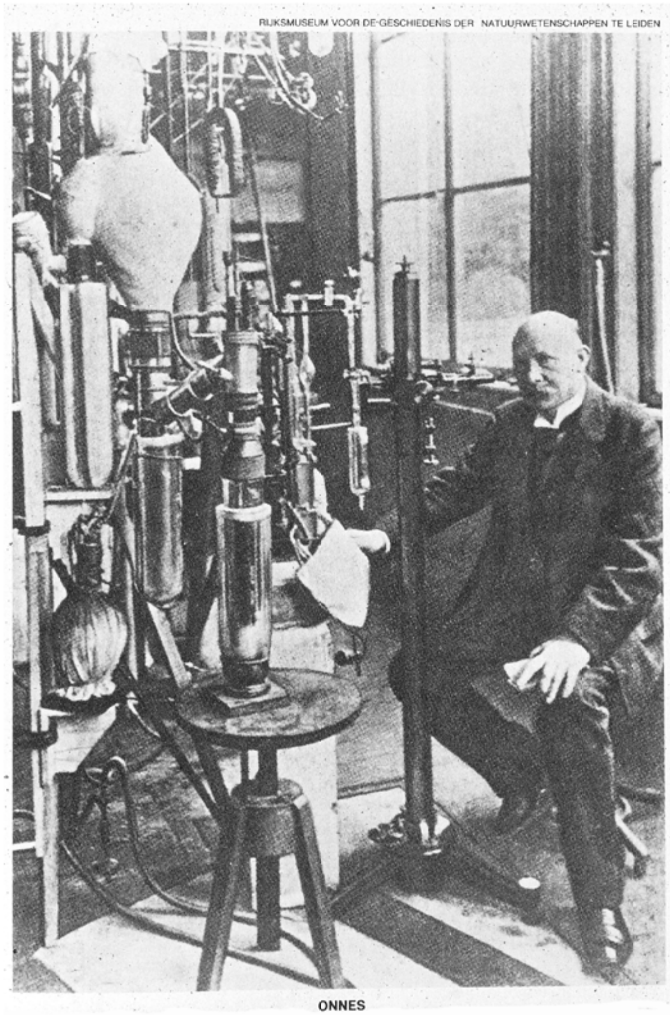




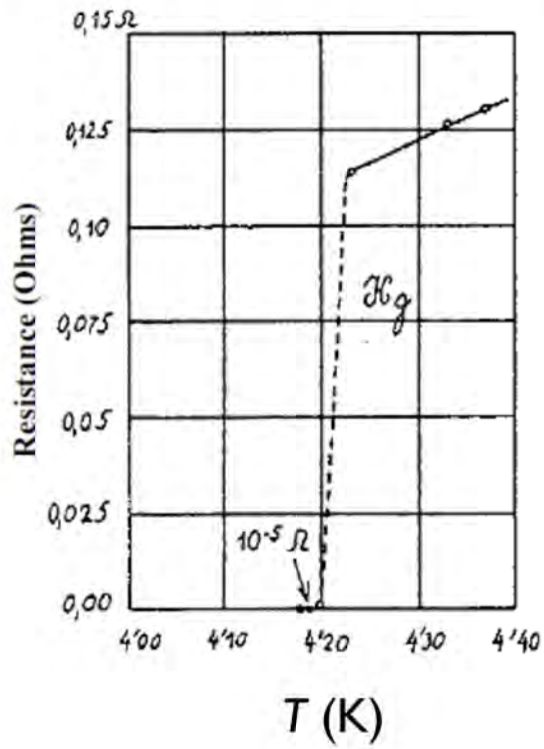

Superconductivity

SUPERCONDUCTOR:

An element, inter-metallic alloy, or compound that will conduct electricity without resistance below a certain temperature. Resistance is undesirable because it produces losses in the energy flowing through the material.



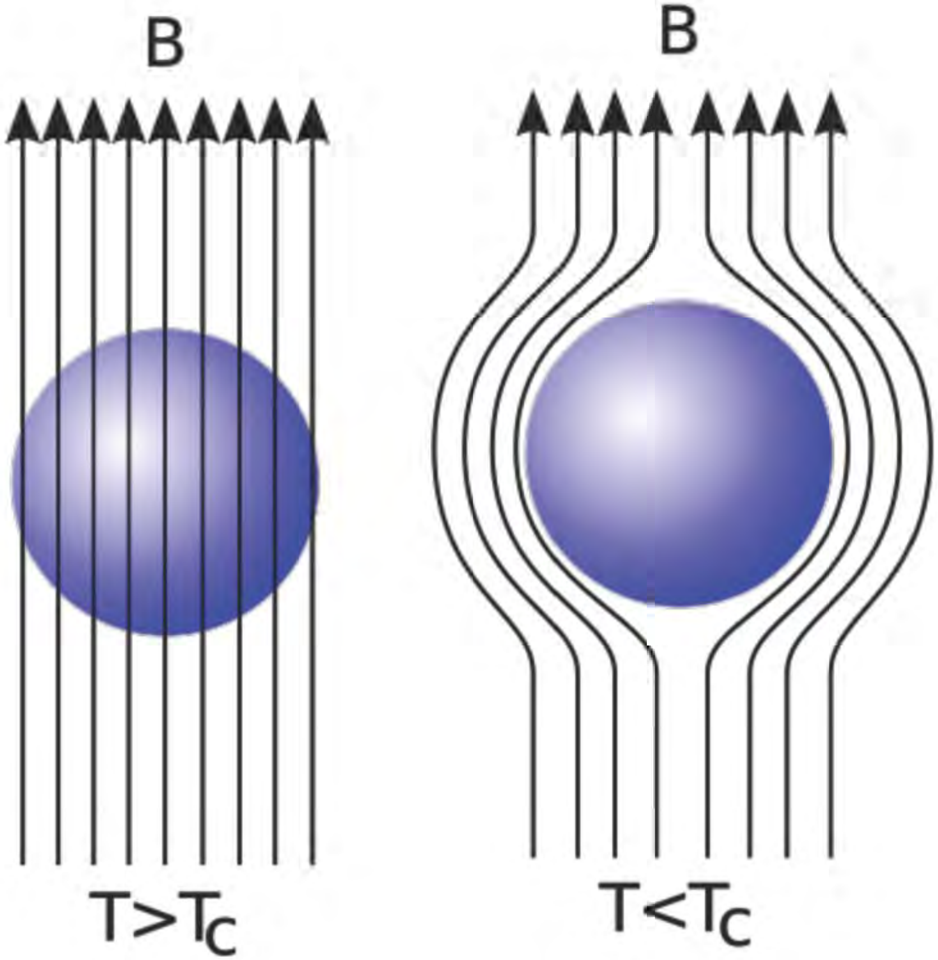
- Heike Kamerlingh Onnes (Dutch)
- Below temperature of liquid helium, 4.2 K (-452 F, -269 C), resistance of Hg disappeared (1911)
- Onnes won a Nobel Prize in physics(1913)



Meissner effect

The expulsion of a magnetic field from a superconductor during its transition to the superconducting state (1933).

Walther Meissner and Robert Ochsenfed (German)



A magnetic levitating above a high temperature superconductor, cooled with liquid nitrogen

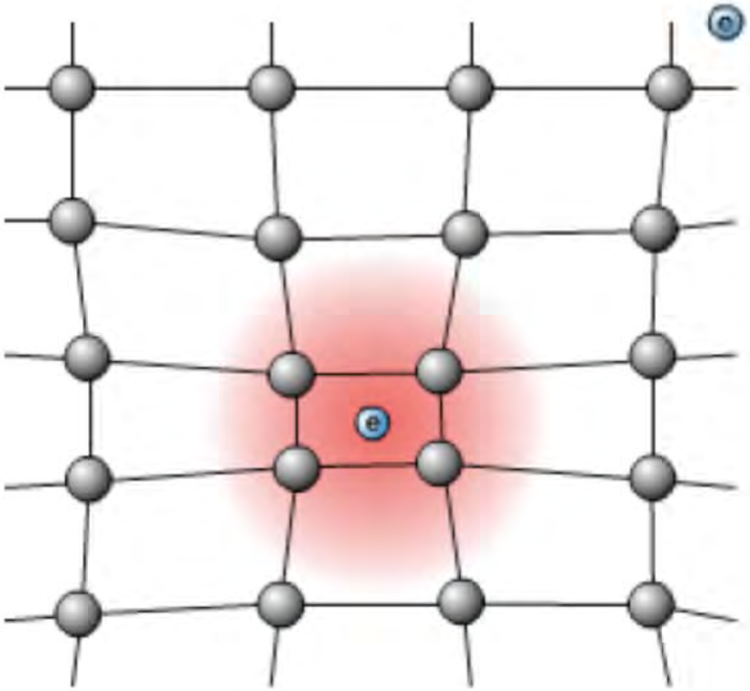
BCS theory

- The first widely-accepted theoretical understanding of superconductivity (1957).
- Nobel prize (1972)
- For elements and simple alloys
- Explained the superconducting current as a superfluid of Cooper pairs, pairs of electrons interacting through the exchange of phonons.

John Bardeen, Leon Cooper, and John Schrieffer (American)

Original publication: Phys. Rev. 108, 1175 (1957)

Cooper Pair



- More resistant to vibrations within the lattice
- Move through the lattice relatively unaffected by thermal vibrations

BCS theory predicted: max T_c 30-40 K (-243 - -233℃)

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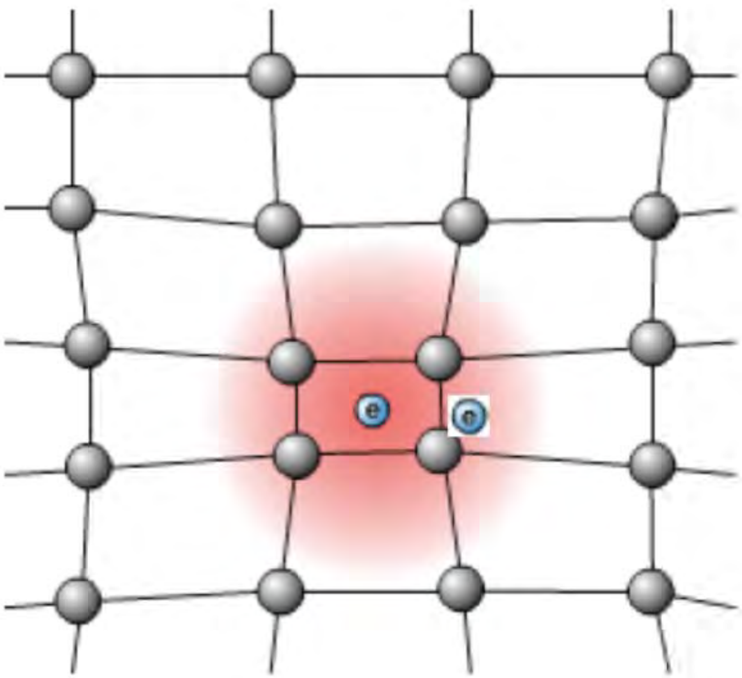

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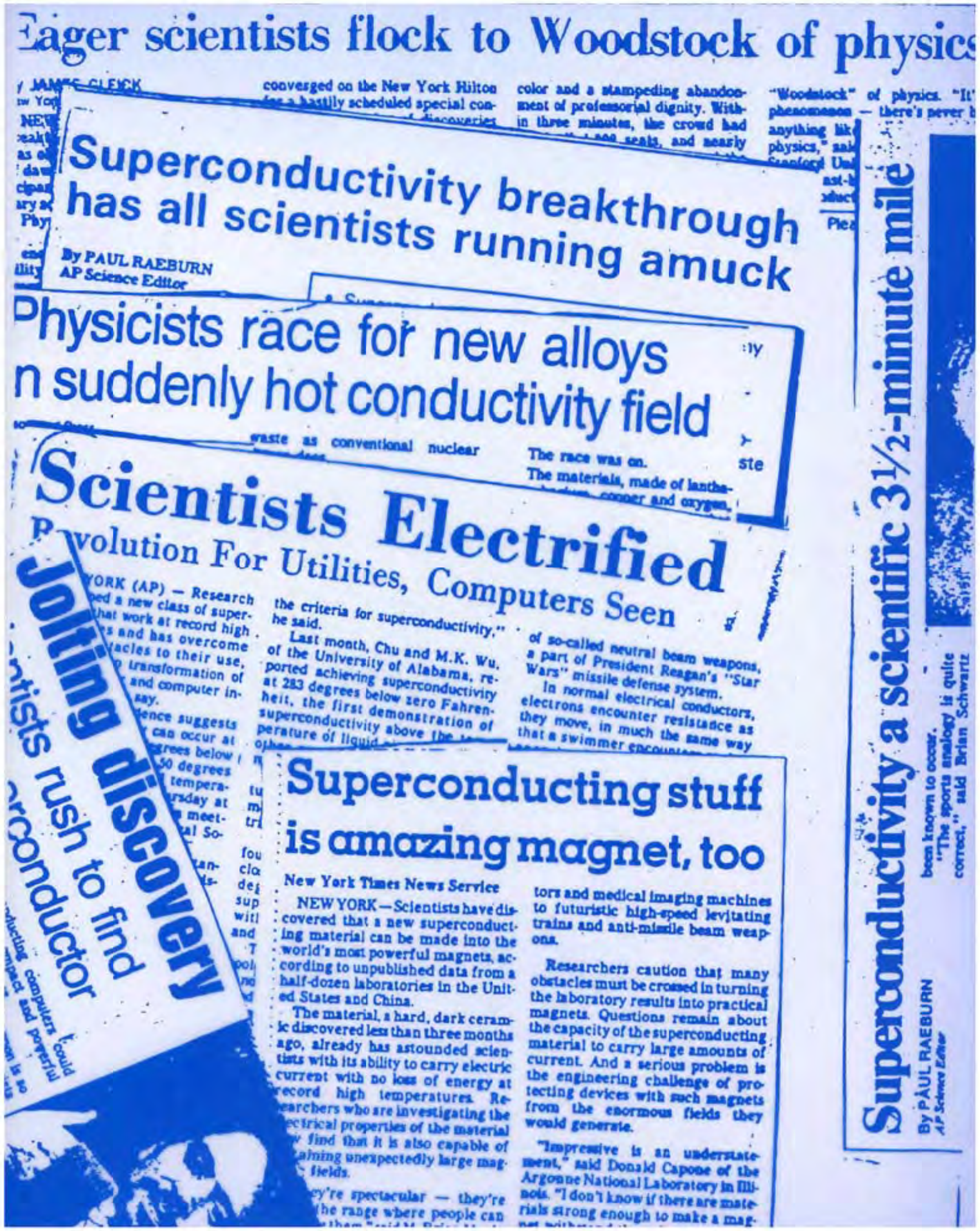
Breakthrough in superconductivity in 1986



First high temperature superconductor

In 1986, a brittle ceramics compound: Ba-La-Cu-O, T_c = 30 K (58 K)
Alex Müller and Georg Bednorz (Switzerland)
Nobel Prize (1987)

Cuprates

- In 1987, $Y_{1.2}Ba_{0.8}CuO_4$ (YBCO) T_c = 93 K (> 77 K, the boiling point of nitrogen)
- In 1988, $BiSrCaCu_2O_x$ (BSCCO) T_c =108 K, and $Tl_2Ba_2Ca_2Cu_3O_{10}$ (TBCCO) T_c =127 K.
- In 2009, $HgBa_2Ca_2Cu_3O_x$ (HBCCO), T_c =135 K, the highest-temperature superconductor at ambient pressure. T_c =164 K under high pressure.

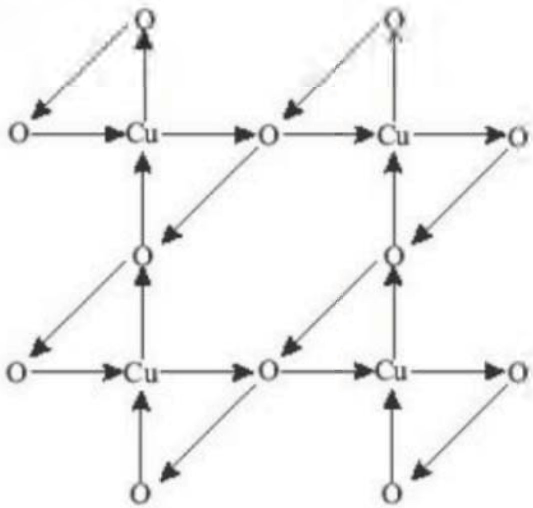
Iron arsenides

- In 2008 $SmFeO_{1-x}F_xAs$, T_c = 55 K

High Temperature Superconductivity Theory

- Varma's theory

Electric current loops (1996)
First directly verified by a French-German team, led by Philippe Bourges (2006)



Distinguish Professor: Chandra Varma

Applications of Superconductors

- Efficient Electricity Transportation

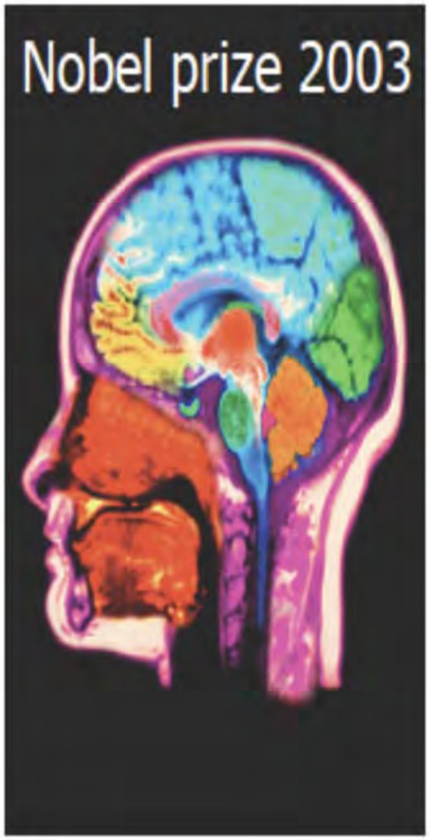
  Efficient conductors

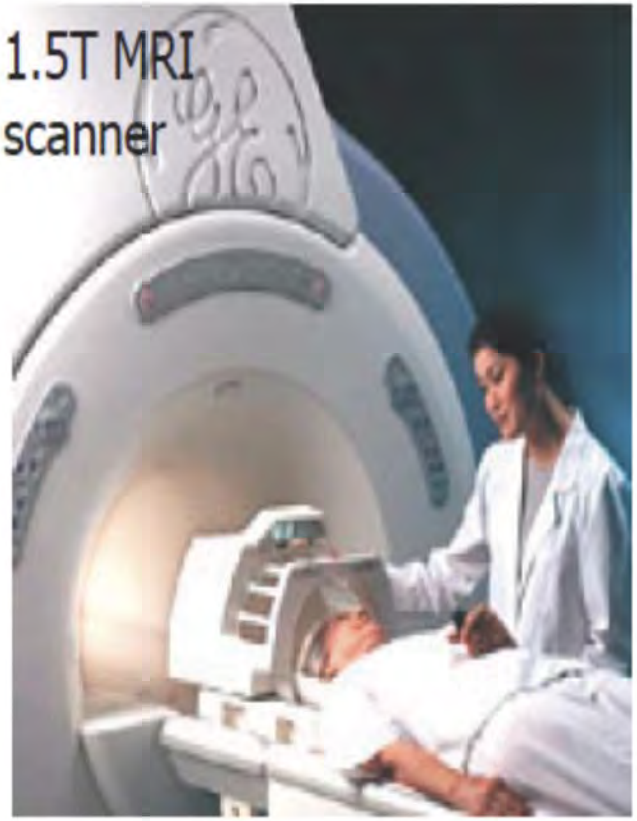
  Efficient in generating electricity (99%)

• Magnetically levitated trains (MAGLEV)

The highest recorded speed: 361 miles per hour, Japan 2003

- Magnetic Resonance Imaging (MRI)





- Synchrotrons and Cyclotrons (Particle Colliders)

Fermilab (Chicago)

High field accelerator magnets

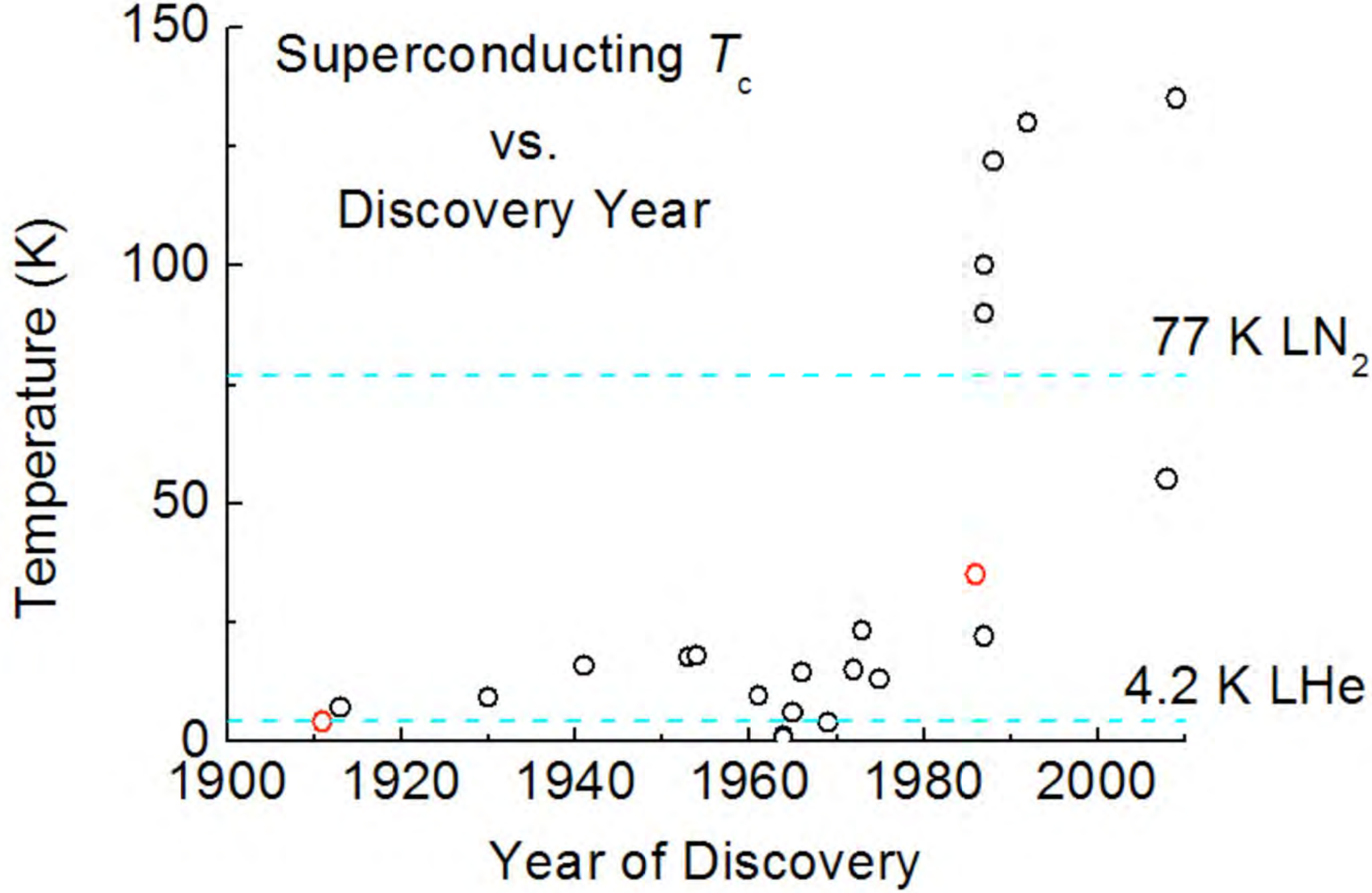

Nuclear power plant
Small-size SMES
500 kV AC power transmission
Medium-size SMES
Underground power station
Linear catapult
Electric propulsion ship
66 kV superconducting cable
Compressed air tank
Fuel cell
Small-size SMES
Switching station
6 kV uninterruptible power distribution cable
LNG combined cycle power generation
Electric car
Small-size SMES
Common duct
Distribution substation
Photovoltaic generation
Superconducting linear motor car (MAGLEV)

Highest T_c=135 K

=-138 ℃

=-216.4 °F

room temperature is 300 K



High temperature superconductivity are found in two classes of correlated electron materials:

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Cooper pairing mechanism: spin fluctuations
Magnetism is important to produce high T_c!

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Current strategy for searching for high temperature superconductivity is to investigate strongly correlated electron materials, which contain elements with partially-filled *d*- and *f*-electron shells, and have low symmetry.

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High temperature superconductivity may be lurking nearby!

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