Today's Goals

Consolidate our knowledge from previous lectures

Example of graphene

Resolved the crystal structure of a new 200 K superconductor

Structure factor analysis

Discuss different scattering techniques

Instrumentation & Facilities

8 NOBEL PRICES ON SUPERCONDUCTIVITY AND SUPERFLUIDITY

In 1913, Heike Kamerlingh Onnes received the Nobel Prize in Physics "for his investigations on the properties of matter at low temperatures, which led, inter alia, to the production of liquid He4", and the discovery of superconductivity.

In 1962, Lev Davidovich Landau received the Nobel Prize in Physics "for his pioneering theories for condensed matter, specially liquid helium."

In 1972, John Bardeen, Leon N. Cooper and J. Robert Schrieffer received the Nobel Prize in Physics "for the jointly developed theory of superconductivity, usually called the BCS theory."

In 1973, Brian David Josephson received one half of the Nobel Prize in Physics "for his theoretical predictions of the properties of a supercurrent through a tunnel barrier, in particular those phenomena which are generally known as the Josephson Effects.

In 1978, Pyotr Leonidovich Kapitsa received one half of the Nobel Prize in Physics "for his basic inventions and discoveries in the area of low temperature physics," which included the discovery of superfluidity in He.

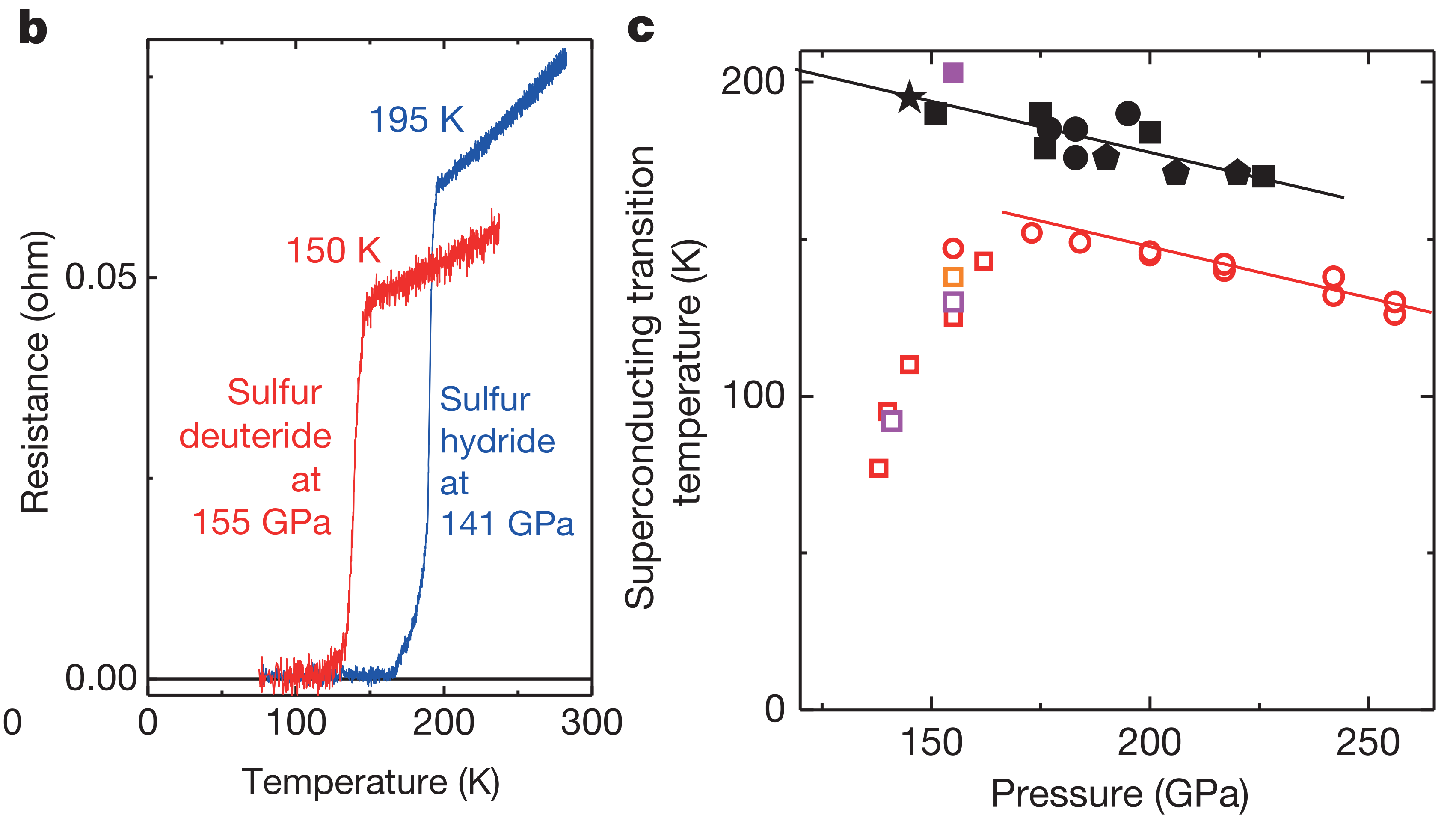
In 1987, J. Georg Bednorz and K. Alexander Müller received the Nobel Prize in Physics "for their important breakthrough in the discovery of superconductivity in ceramic materials."

In 1996, David M. Lee, Douglas D. Osheroff and Robert C. Richardson received the Nobel Prize in Physics "for their discovery of superfluidity in helium-3."

In 2003, Alexei A. Abrikosov, Vitaly L. Ginsburg and Anthony J. Leggett received the Nobel Prize in Physics "for pioneering contributions to the theory of superconductors and superfluids.

2015 – BREAKTHROUGH

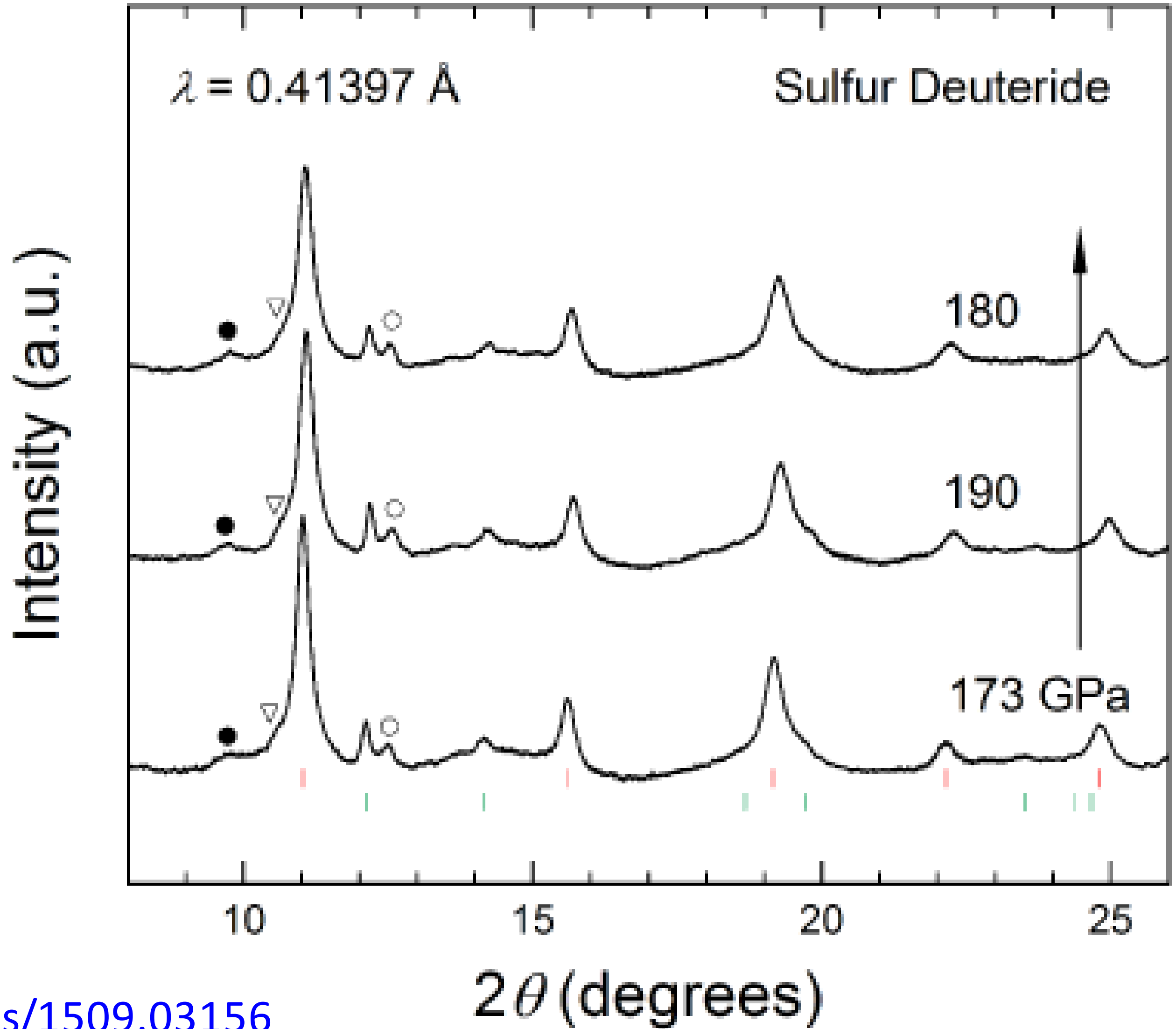
Superconductivity above 200 K



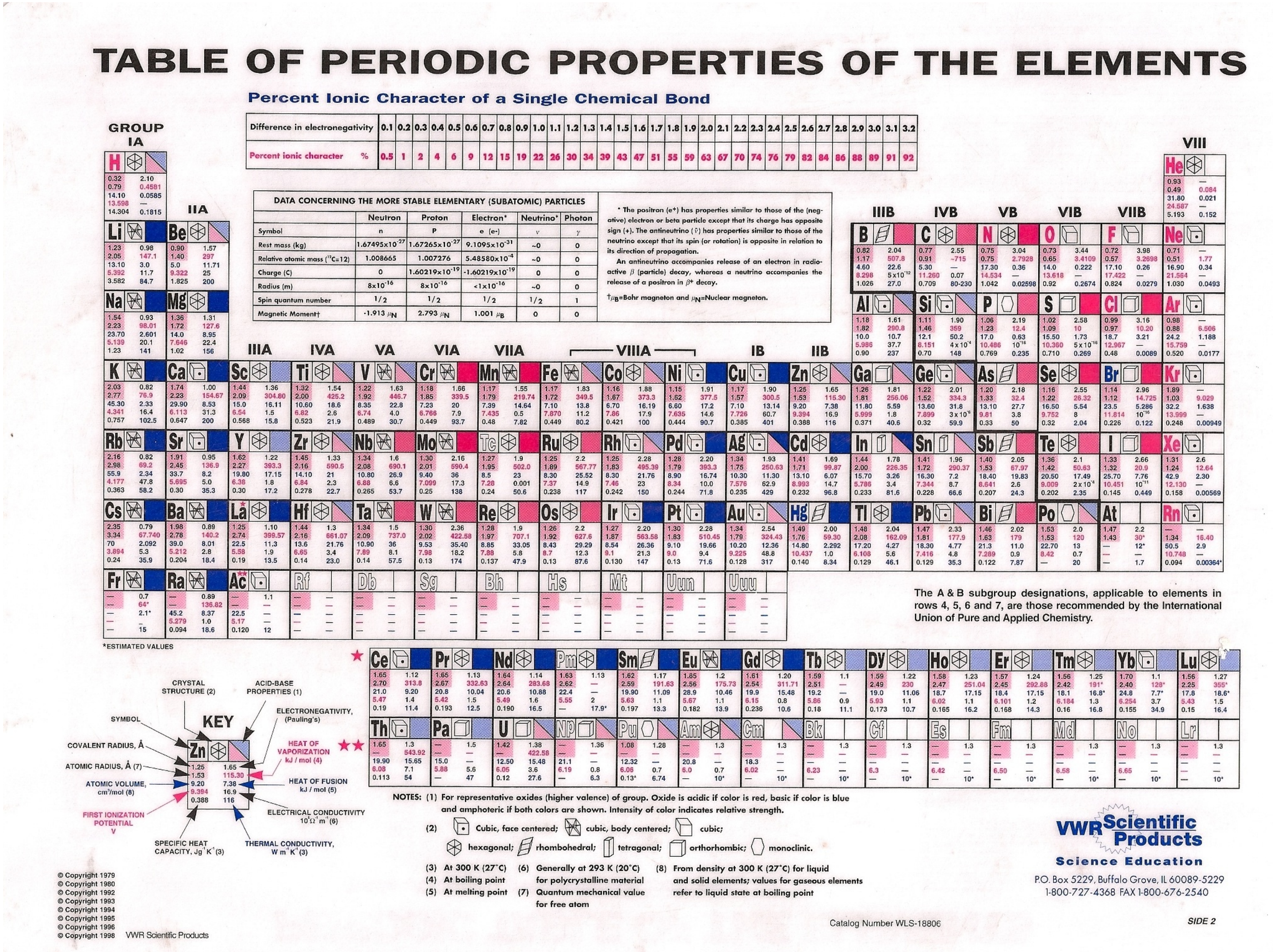
Nature **525**, 73–76 (03 September 2015)

2015 – BREAKTHROUGH

What is the crystal structure????



http://arxiv.org/abs/1509.03156



http://infohost.nmt.edu/~burleigh/MATE235.htm

COMMON CRYSTAL STRUCTURES

BCC - Structure

Name	Sym	#
Barium	Ba	56
Cesium	Cs	55
Chromium	Cr	24
Europium	Eu	63
Francium	Fr	87
Iron	Fe	26
Lithium	Li	3
Manganese	Mn	25
Molybdenum	Mo	42
Niobium	Nb	41
Potassium	K	19
Radium	Ra	88
Rubidium	Rb	37
Sodium	Na	11
Tantalum	Ta	73
Tungsten	W	74
Vanadium	V	23

FCC - Structure

Name	Sym	#
Actinium	Ac	89
Aluminum	Al	13
Argon	Ar	18
Calcium	Ca	20
Cerium	Ce	58
Copper	Cu	29
Einsteinium	Es	99
Germanium	Ge	32
Gold	Au	79
Iridium	Ir	77
Krypton	Kr	36
Lead	Pb	82
Neon	Ne	10
Nickel	Ni	28
Palladium	Pd	46
Platinum	Pt	78
Radon	Rn	86
Rhodium	Rh	45

DIFFRACTION METHODS

Powder diffraction:

Powder sample, monochromatic light, variable scattering angle detection

Single crystal diffraction:

Single crystal sample, monochromatic light, variable scattering angle detection
+ sample rotation

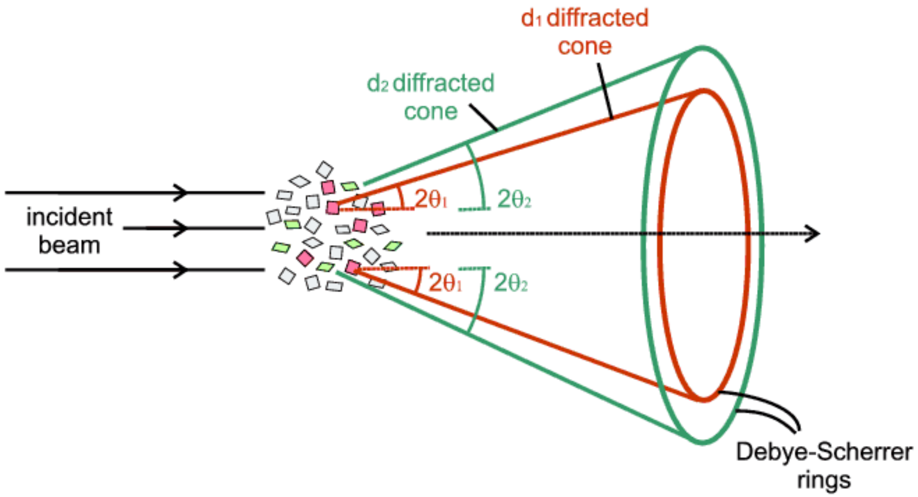
Laue diffraction:

Single crystal sample, polychromatic light (white beam)

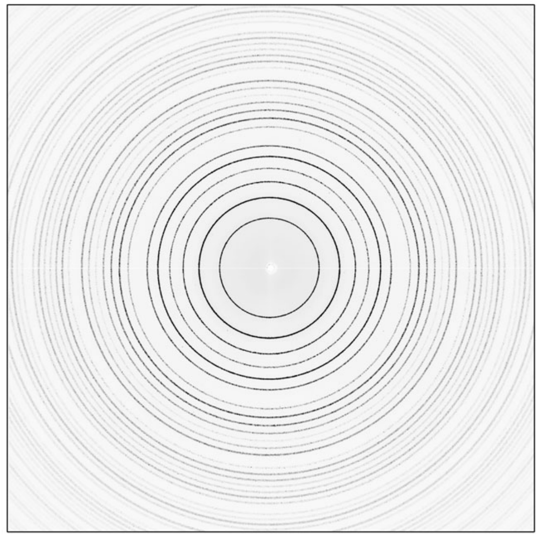
Scattering facilities around Zurich

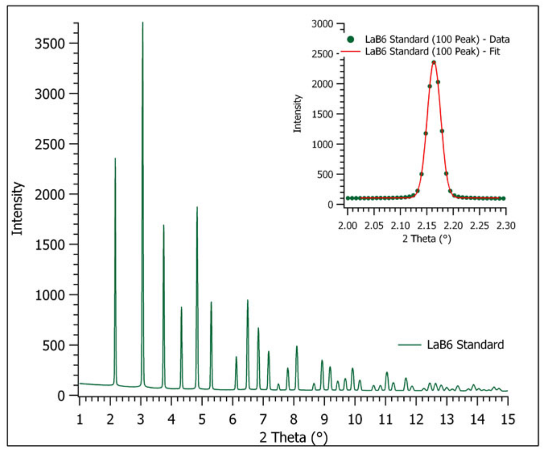
Paul Scherrer Institute

POWDER DIFFRACTION



http://pd.chem.ucl.ac.uk/pdnn/diff2/kinemat2.htm



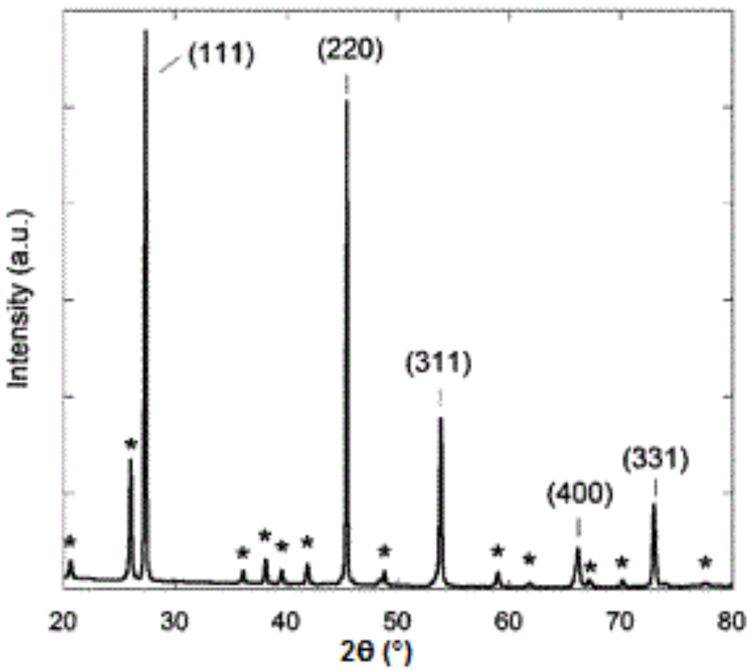


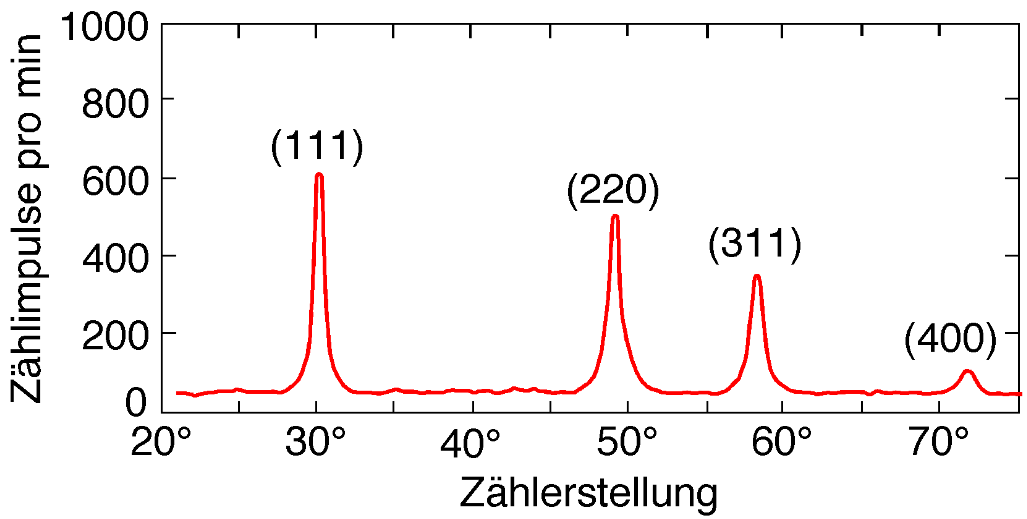
http://www.diamond.ac.uk/Beamlines/Engineering-and-Environment/I12/applications/diffraction.html

POWDER DIFFRACTION

X-ray Powder diffraction – Germanium

Neutron Powder diffraction – Diamond





Neutronenbeugung an Diamantpulver (nach *G. Bacon*). Man erkennt Beugungsmaxima an vier Netzebenenscharen, die mit den kristallographischen Indizes (111), (220), (311) und (400) bezeichnet sind

http://cnx.org/contents/URlgriBl@2/Powder-X-Ray-Diffraction

H. W. Chiu, C. N. Chervin, and S. M. Kauzlarich, *Chem. Mater.*, 2005, **17**, 4858.

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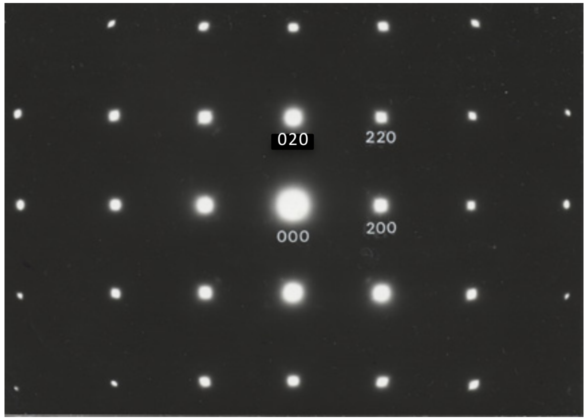
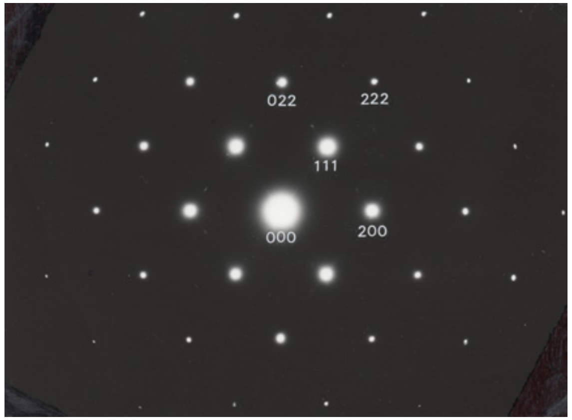
SINGLE CRYSTAL ELECTRON DIFFRACTION

TEM diffraction patterns of a gold-film

Gold film



Scattering plan: (100) & (010)



Scattering plan: (100) & (011)

(a) and (b) are [001] and [110] incidence of the electron beam.

http://www.k5.dion.ne.jp/~inos1936/shozoHP1E.html

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TEM diffraction patterns of a gold-film

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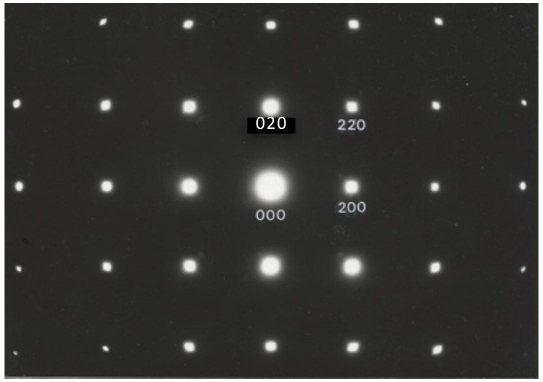

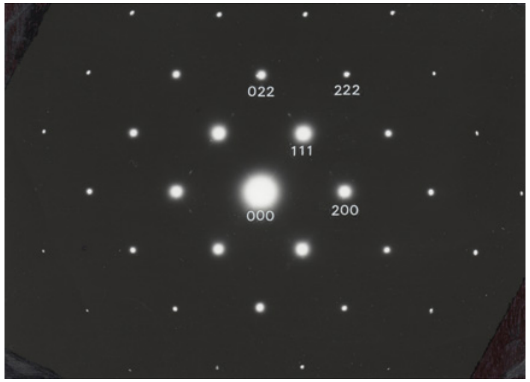

Scattering plan: (100) & (010)

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(a) and (b) are [001] and [110] incidence of the electron beam.

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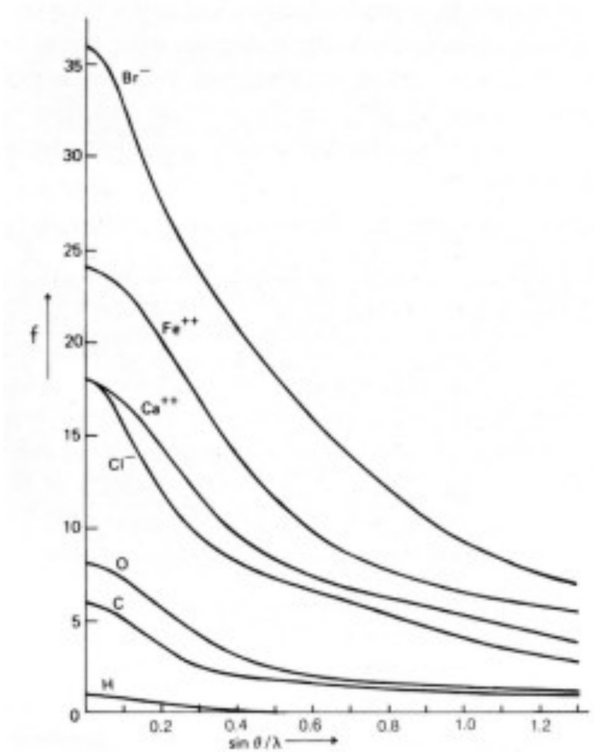
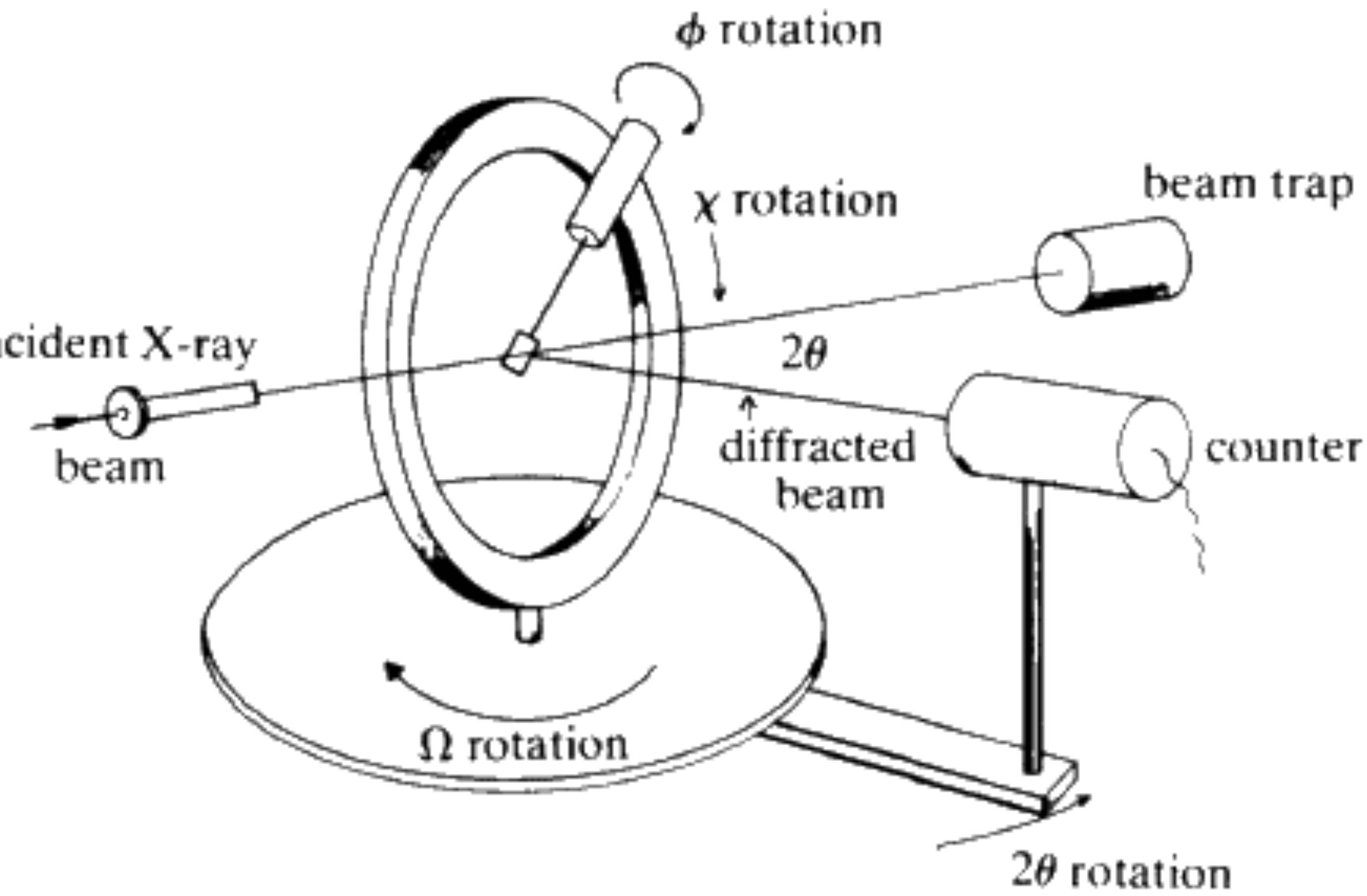
FORM FACTOR



http://www.xtal.iqfr.csic.es/
Cristalografia/parte_05-en.html

Schematic of 4-circle diffractometer



http://serc.carleton.edu/research_education/geochemsheets/techniques/SXD.html

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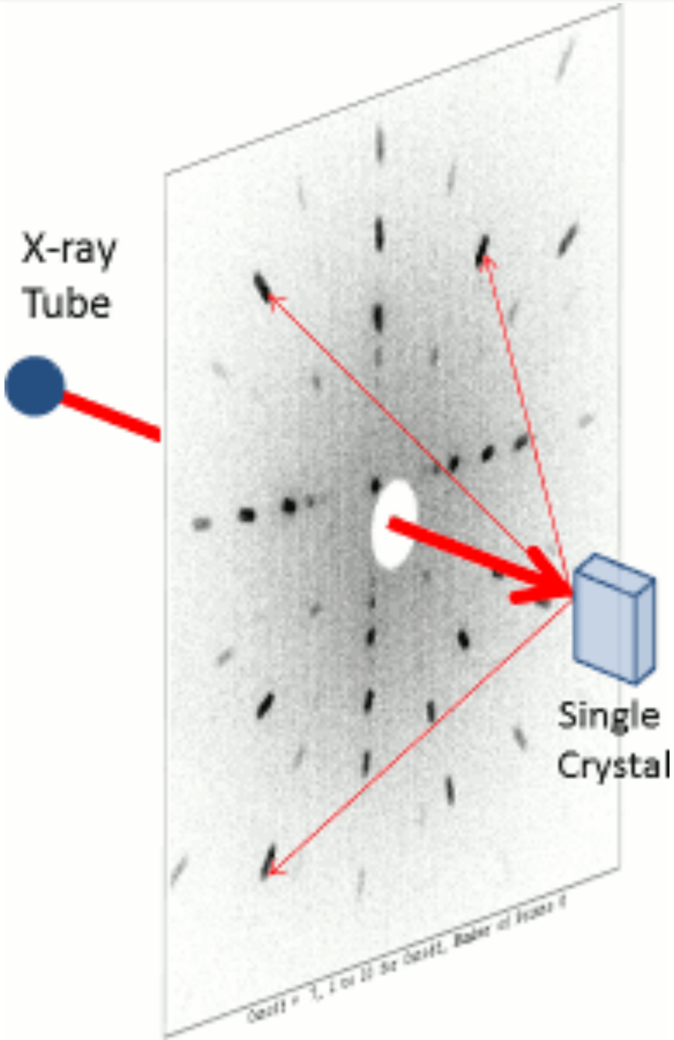
LAUE BACK REFLECTION GEOMETRY



$$2d \sin \theta = n\lambda \,,$$

http://multiwire.com/index.shtml

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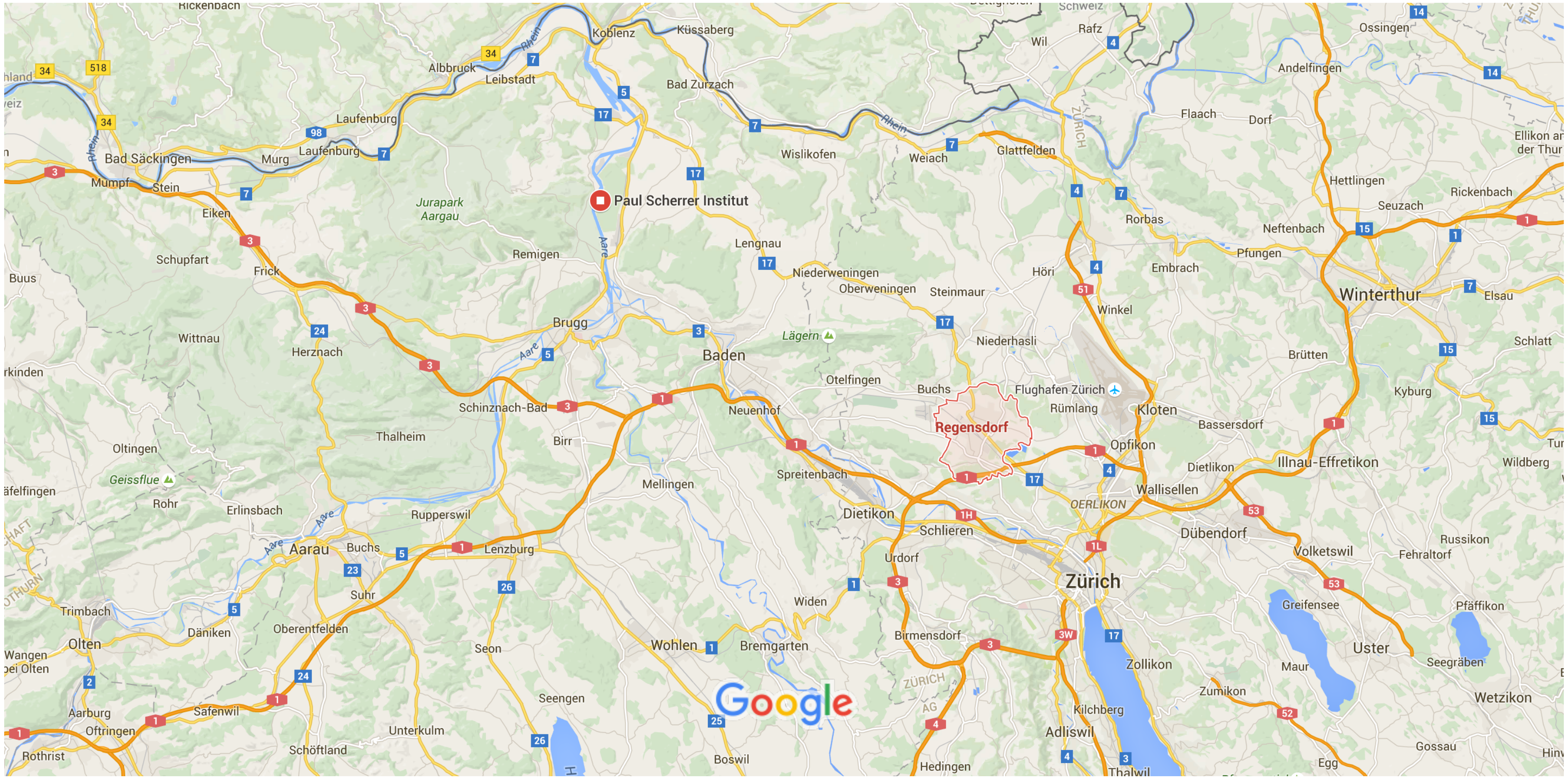
PAUL SCHERRER INSTITUTE (PSI)

https://www.psi.ch

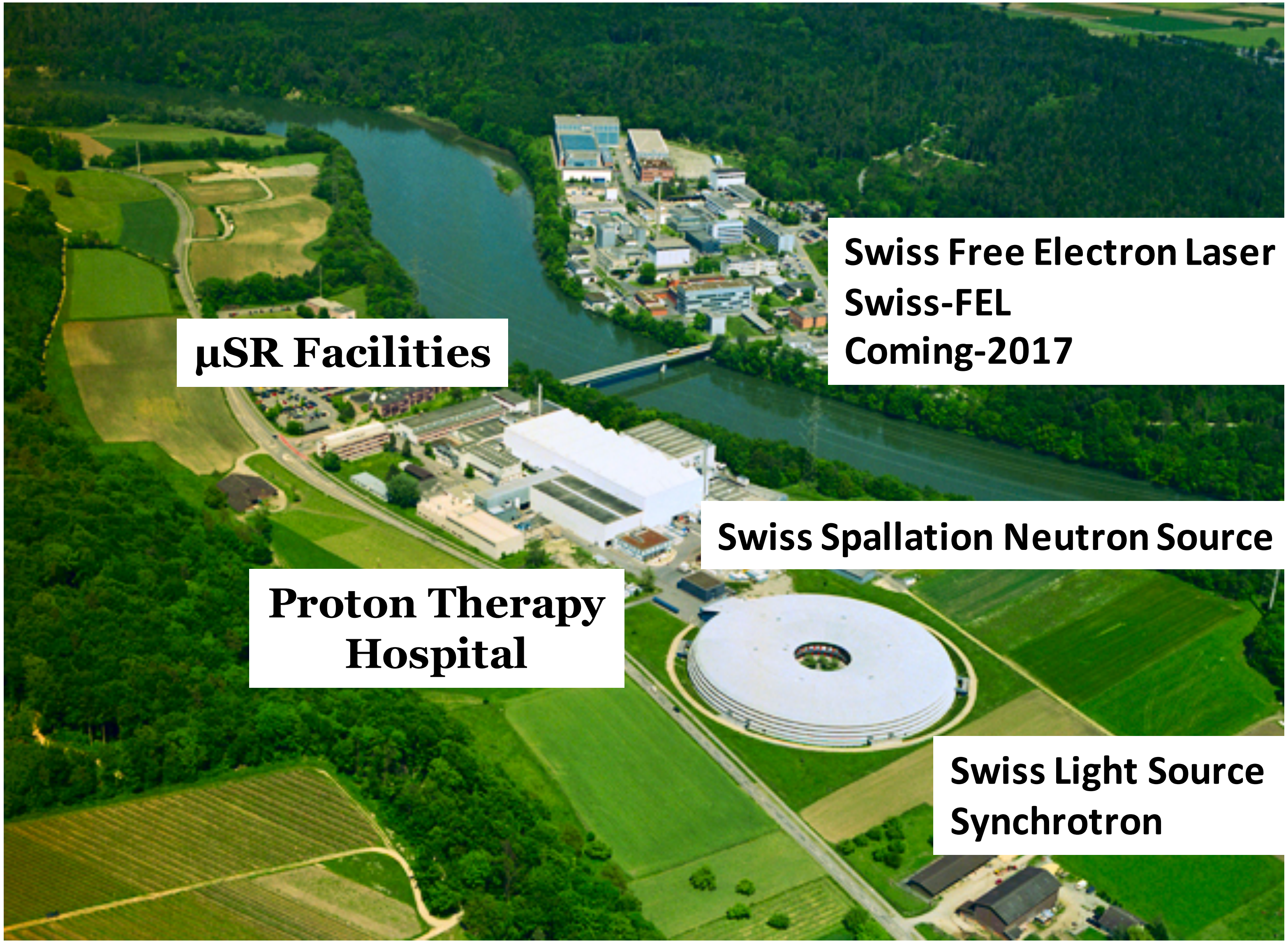
PAUL SCHERRER INSTITUTE (PSI)



Kartendaten © 2016 GeoBasis-DE/BKG (©2009),Google 5 km

Google Maps

PAUL SCHERRER INSTITUTE (PSI)



https://www.psi.ch

Neutron powder diffractometer @ PSI

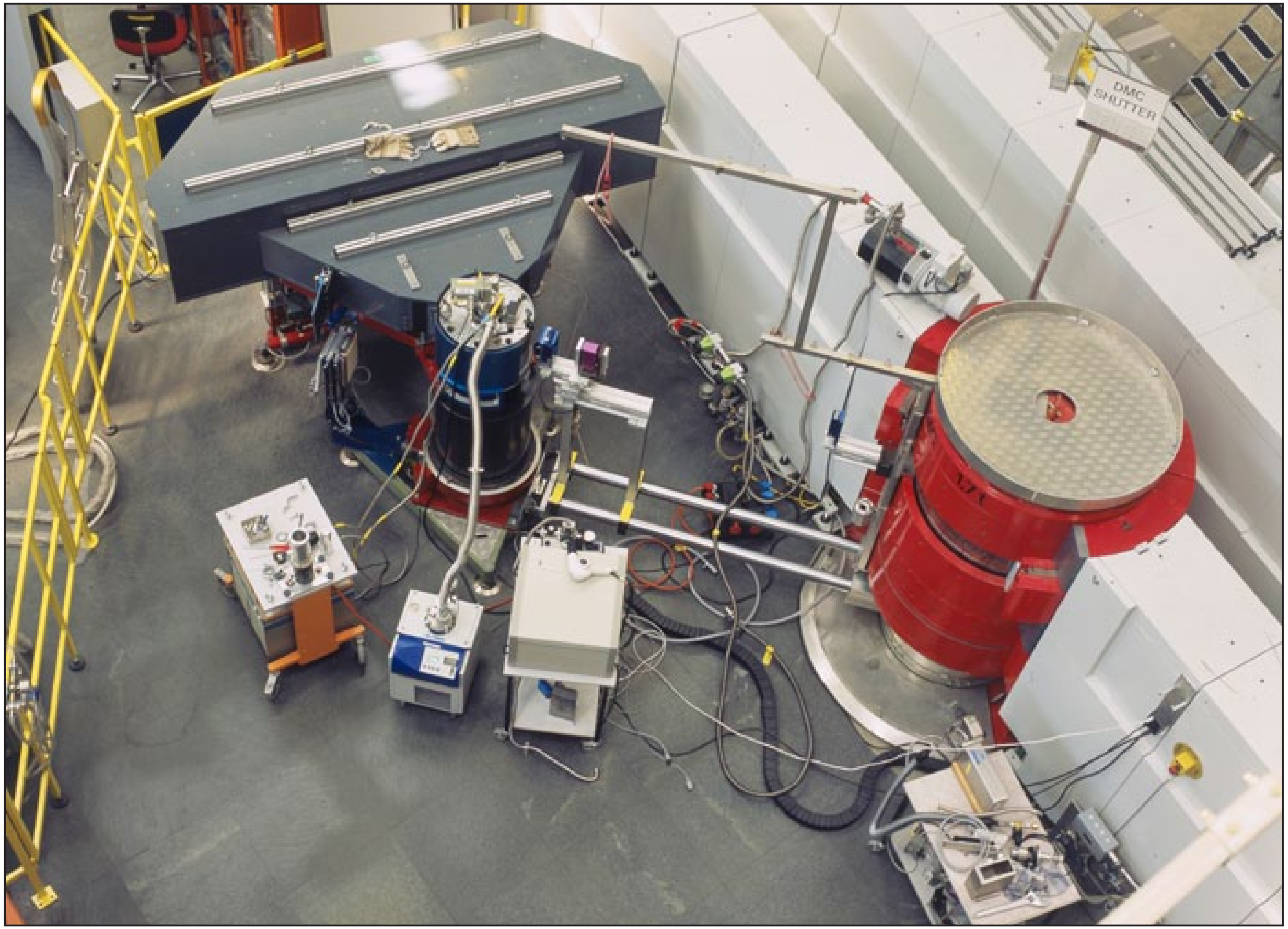
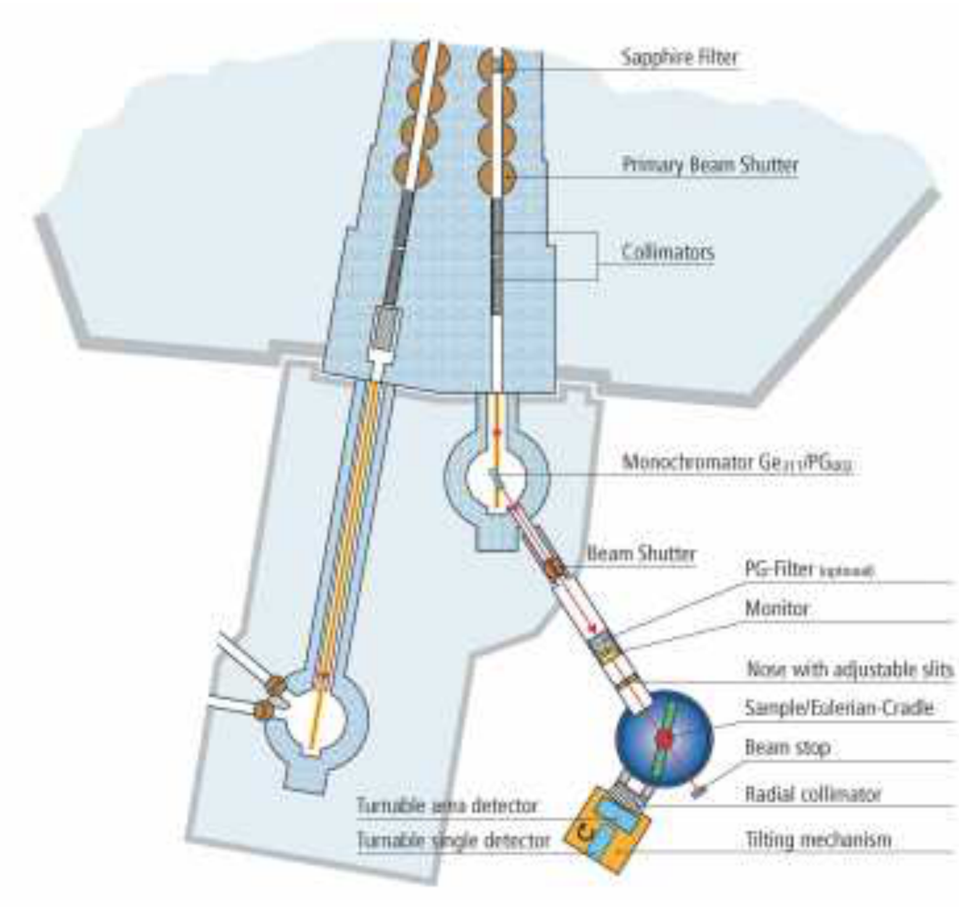
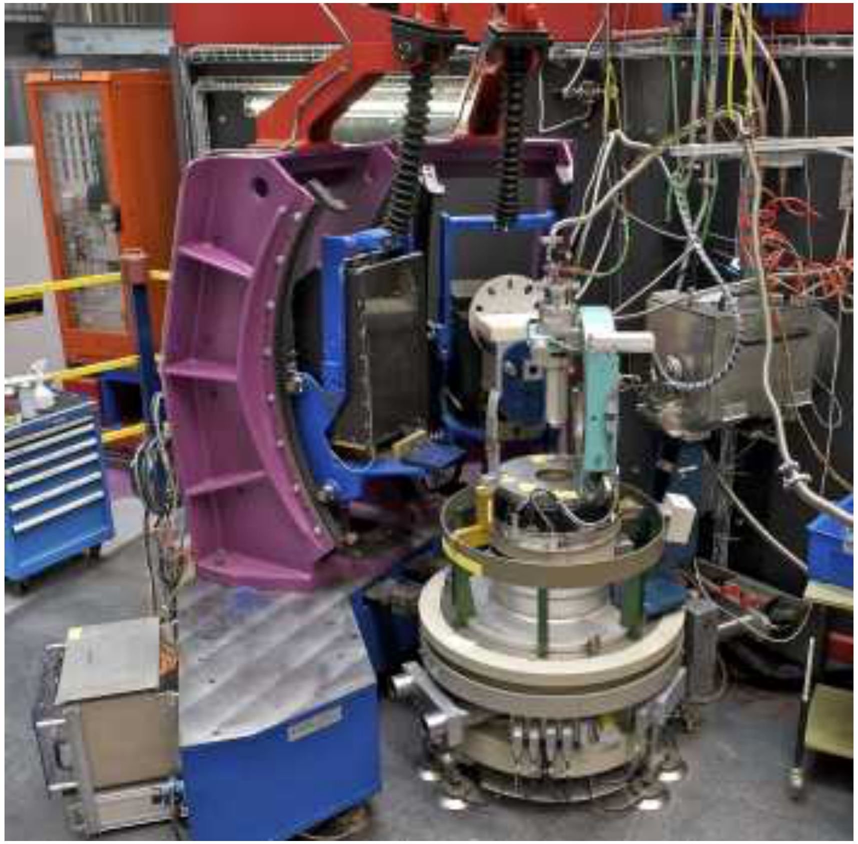


Figure 3: **The DMC powder diffractometer is also appropriate for the investigation of magnetic phenomena.**

Neutron single crystal diffractometer @ PSI





European facilities

Topic of next week's lecture