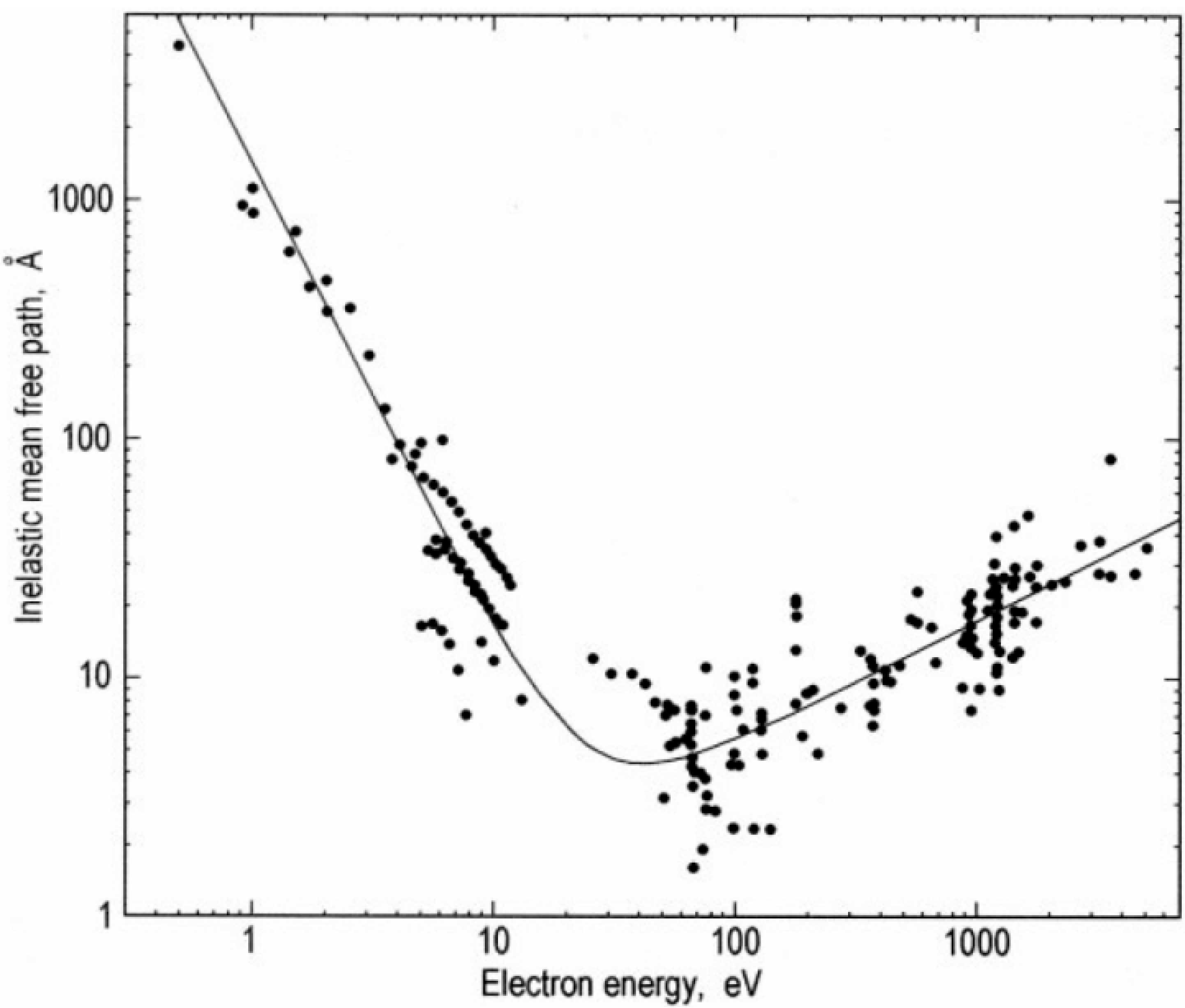
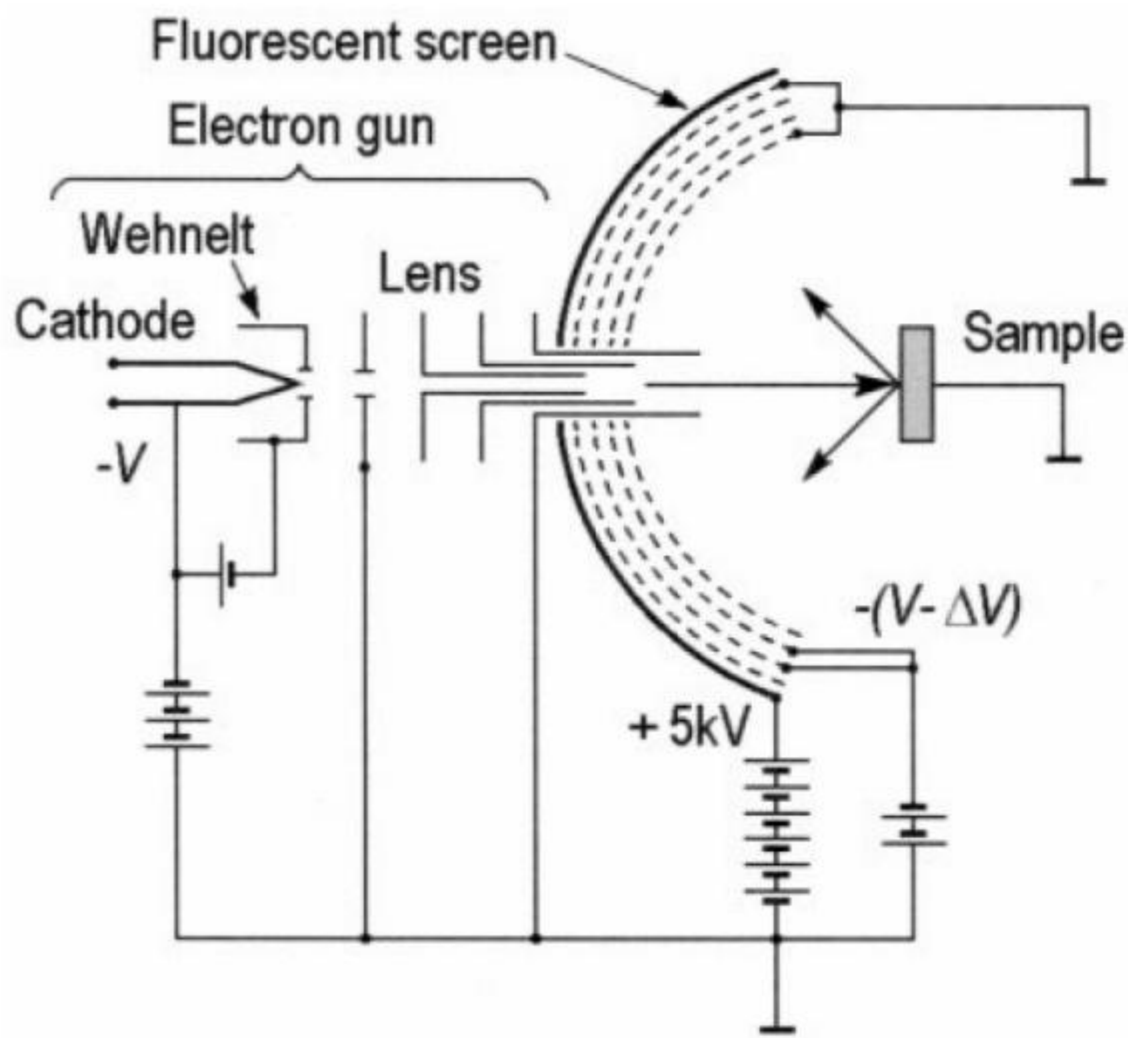
The Universal Curve for the Electron Mean Free Path

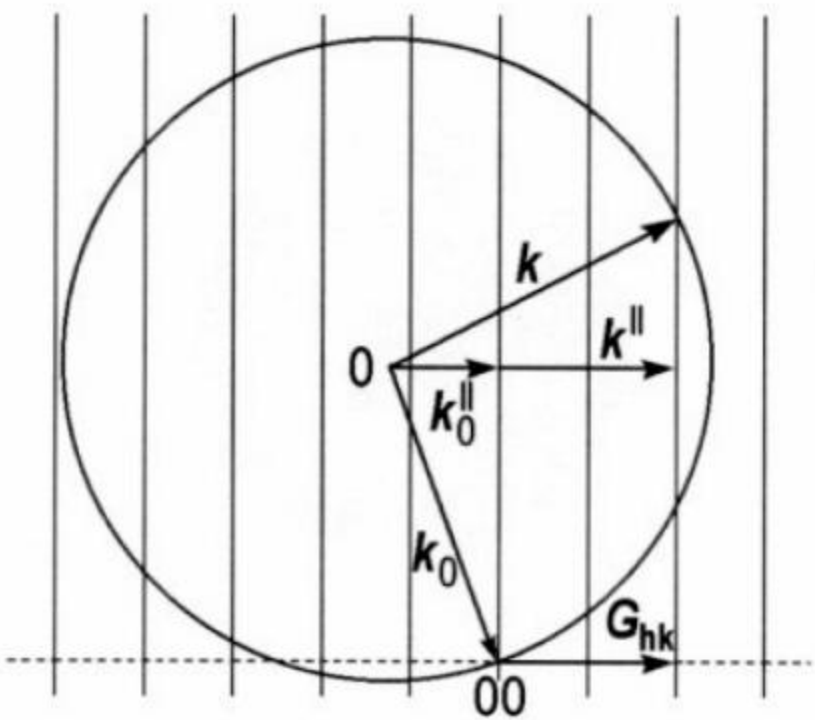


Nobel price in physics 1937 for Davisson (shared with Thomson) *"for their experimental discovery of the diffraction of electrons by crystals"*

Schematics for a Rear View LEED System

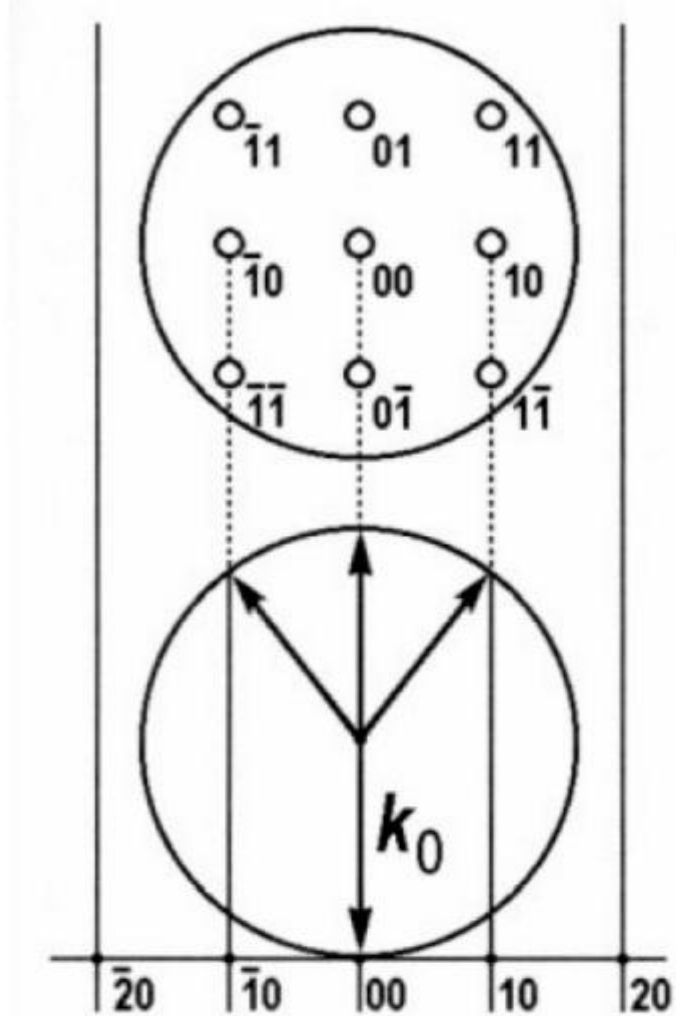


Ewald Construction for a 2D Lattice



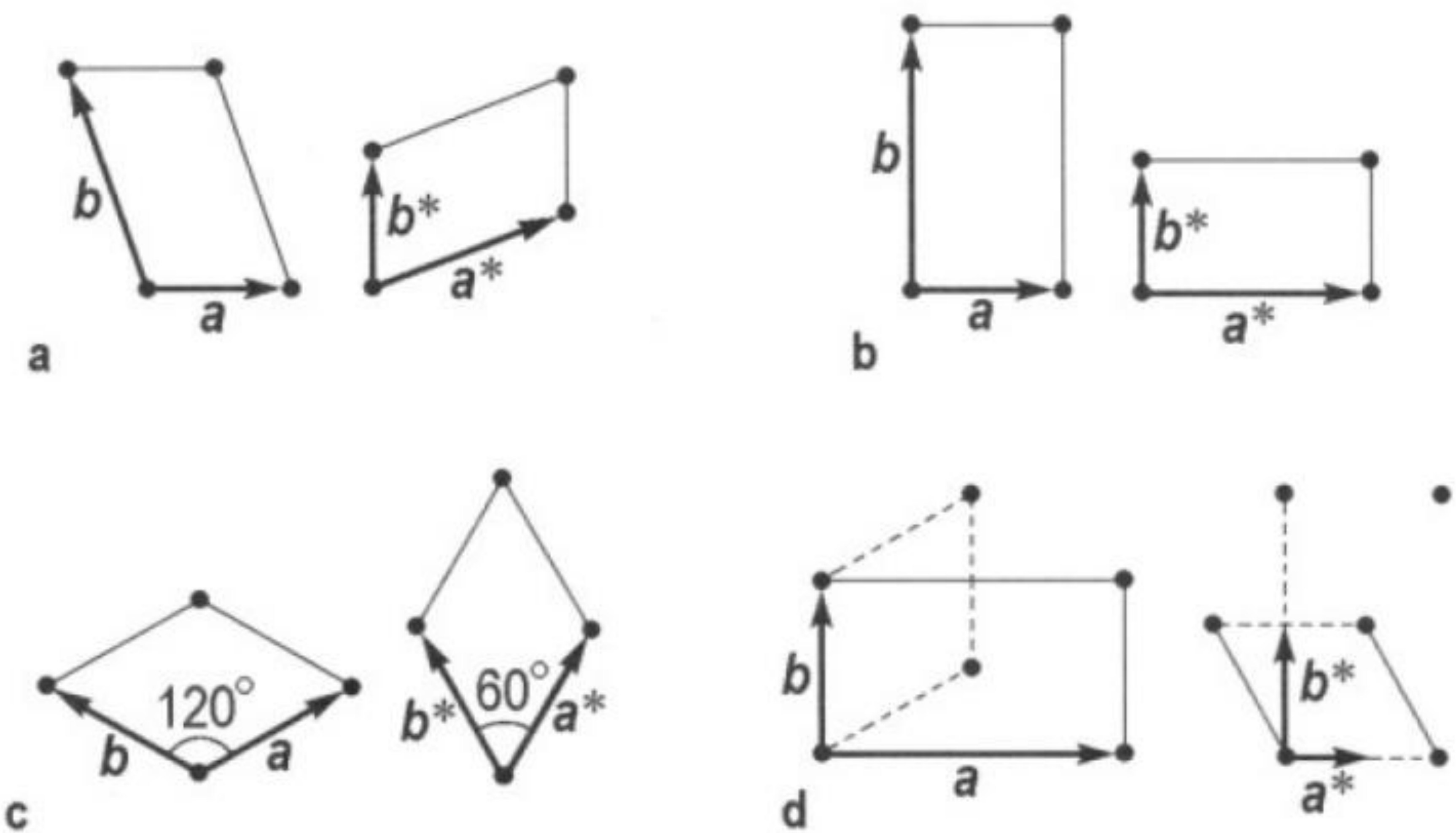
$$k^{\parallel} - k_0^{\parallel} = G_{hk}$$

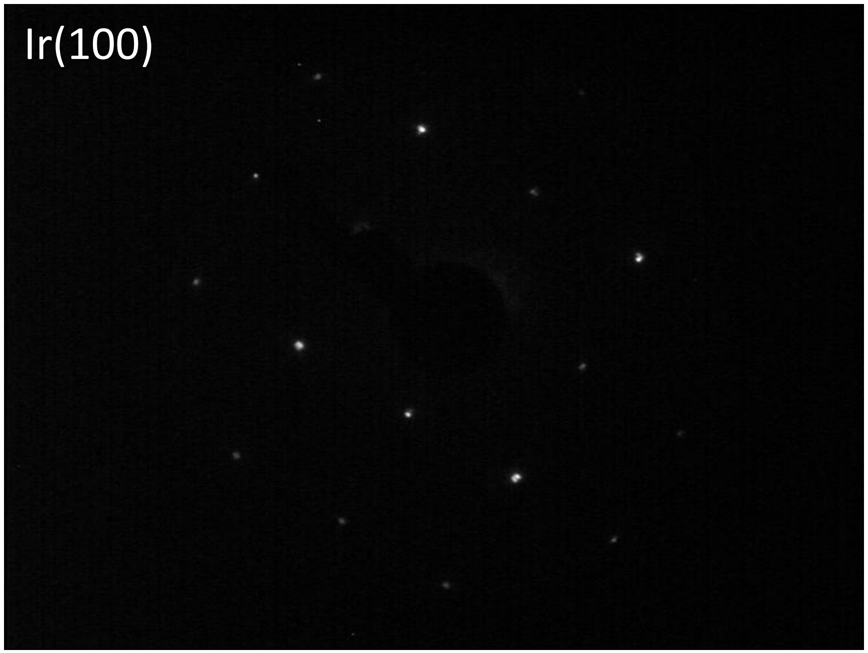
general situation

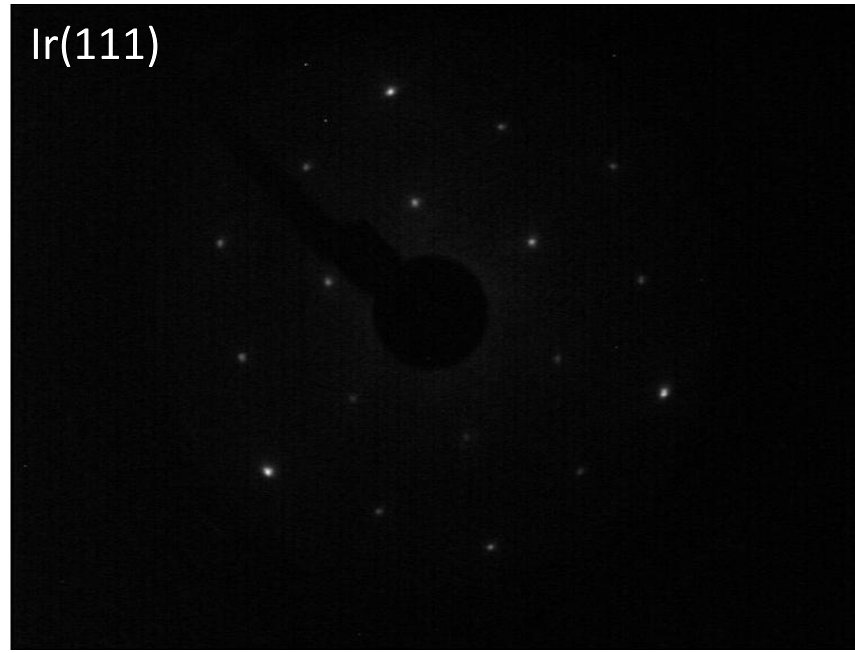


spot indexing and typical LEED situation
with normal electron incidence

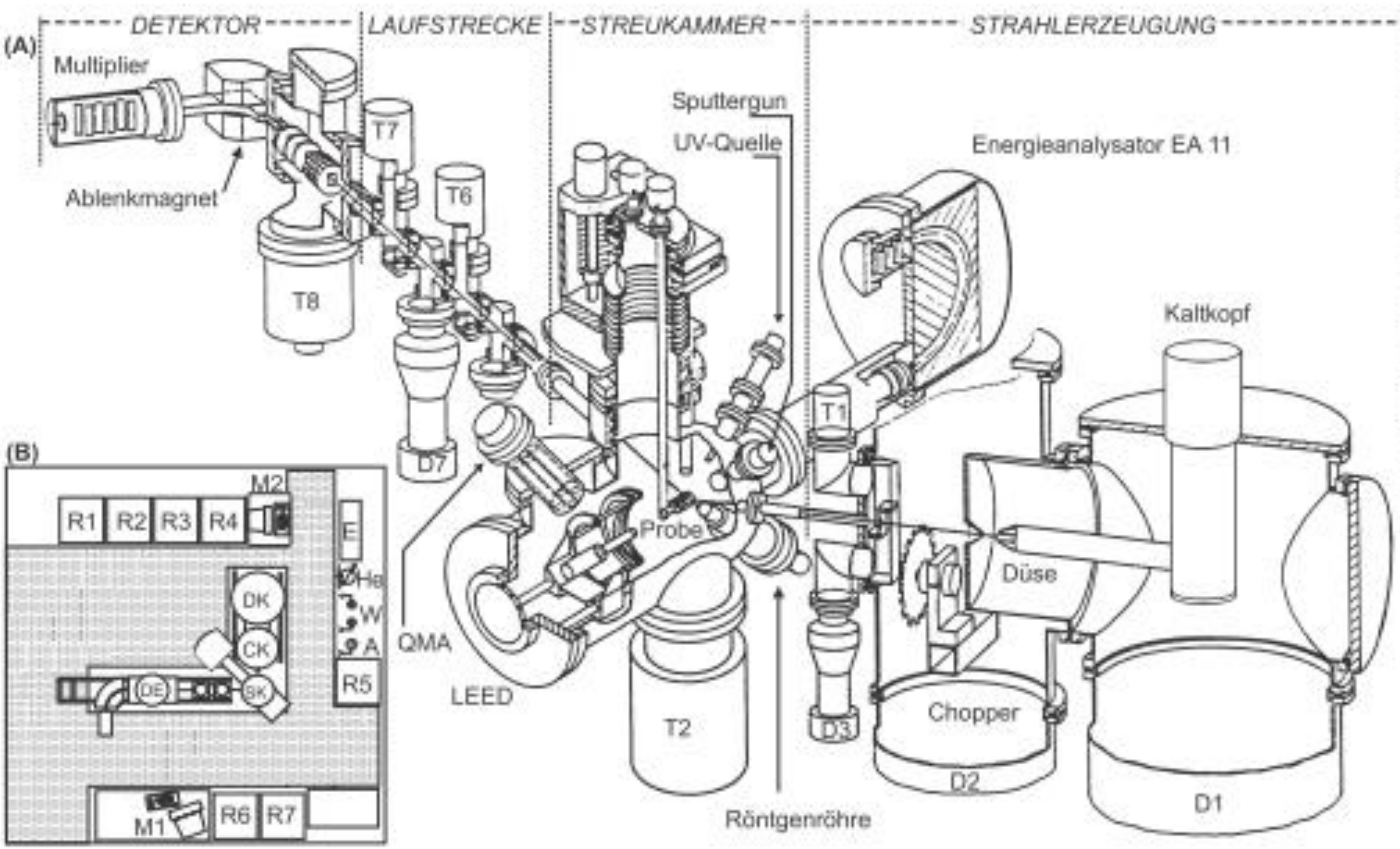
2D Real Space and Reciprocal Space Unit Meshes and Primitive Translations




Ir(100)


Ir(111)

Nobel price in physics 1943*"for his contribution to the development of the molecular ray method (and his discovery of the magnetic moment of the proton)"*



DETEKTOR
LAUFSTRECKE
STREUKAMMER
STRAHLERZEUGUNG
(A)
Multiplier
Ablenkmagnet
T7
T6
T8
D7
Sputtergun
UV-Quelle
Energieanalysator EA 11
Kaltkopf
T1
Probe
Düse
QMA
LEED
T2
Röntgenröhre
D3
Chopper
D2
D1
(B)
M2
R1
R2
R3
R4
E
He
W
A
DK
CK
DE
SK
R5
M1
R6
R7

HAS

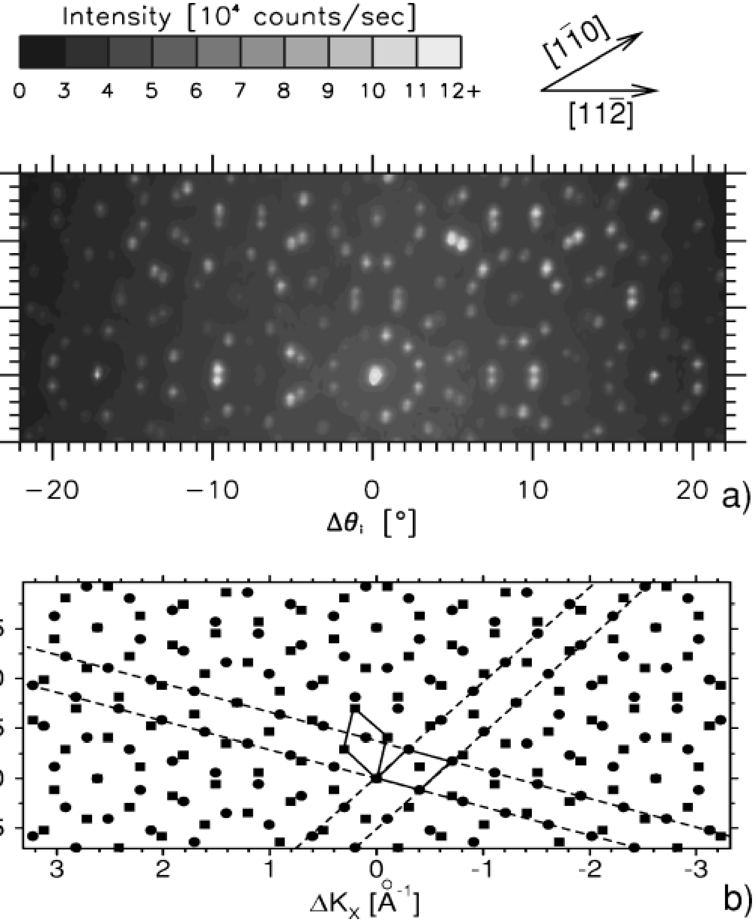
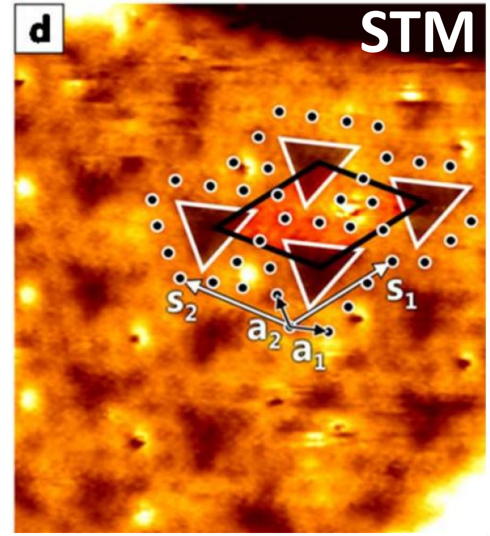
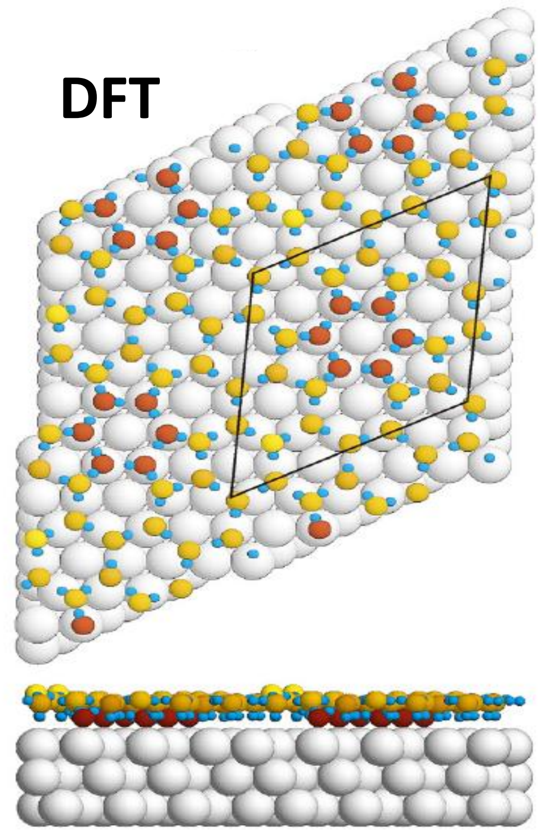


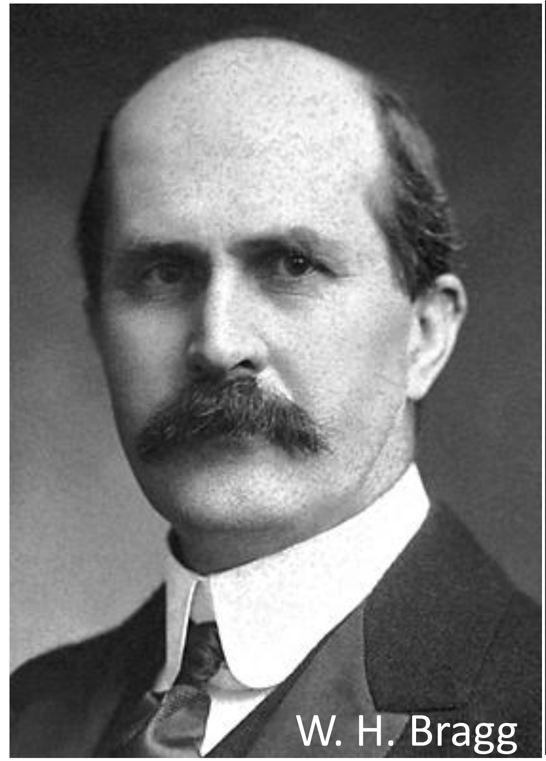
FIG. 2. (a) Two-dimensional helium diffraction pattern for a complete bilayer (Phase II) of D_2O on Pt(111) at an incident helium energy of 22 meV, and a temperature of $T_s = 130$ K. The complete diffraction pattern can be constructed from two domains of a epitaxially rotated water overlayer whose reciprocal unit cells are $(\sqrt{39}\times\sqrt{39})R16.1°$, as shown in (b). The two different domains are shown by the filled circles and squares, respectively. Exactly the same diffraction pattern was observed for H_2O.

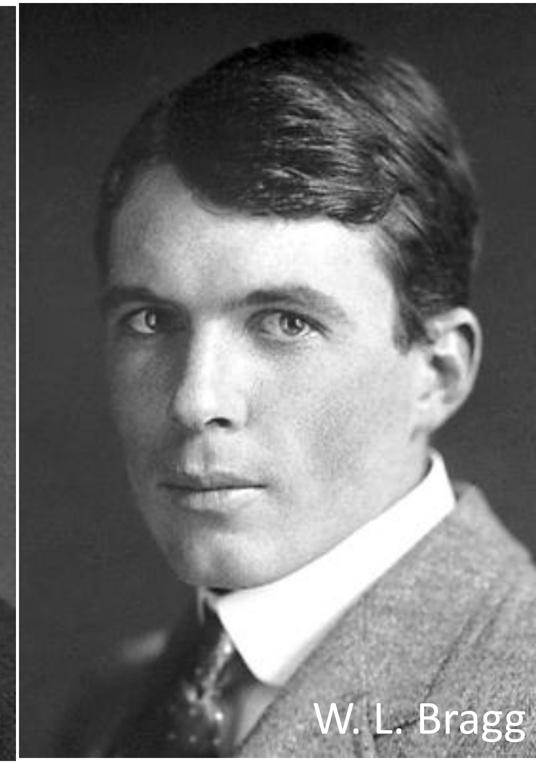
A. Glebov, A. P. Graham, A. Menzel, and J. P. Toennies
Max Planck Institut für Strömungsforschung, Bunsenstrasse 10, Göttingen, Germany

J. Chem. Phys. **106** (22), 8 June 1997



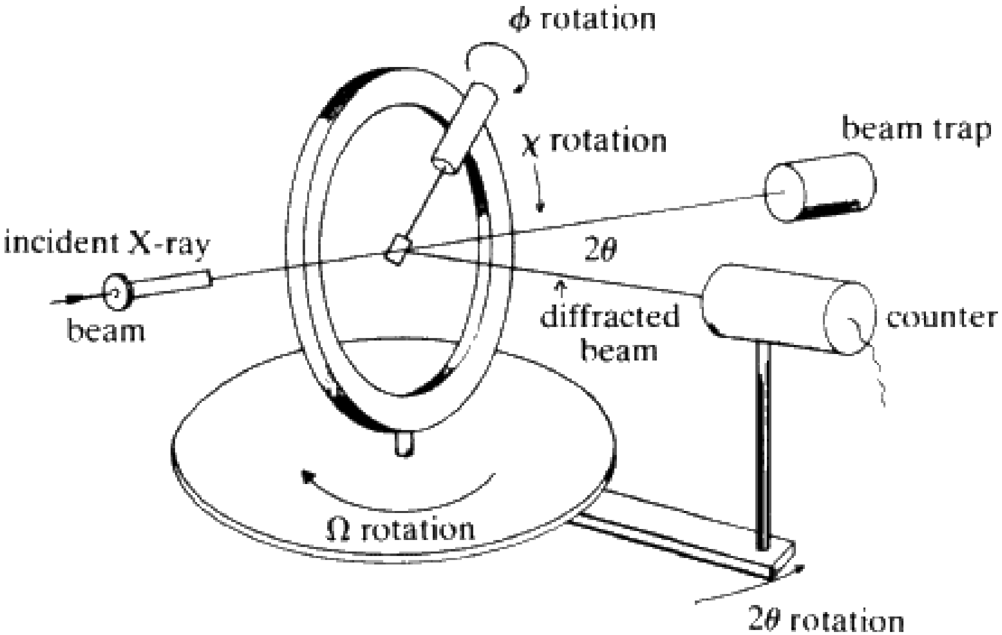




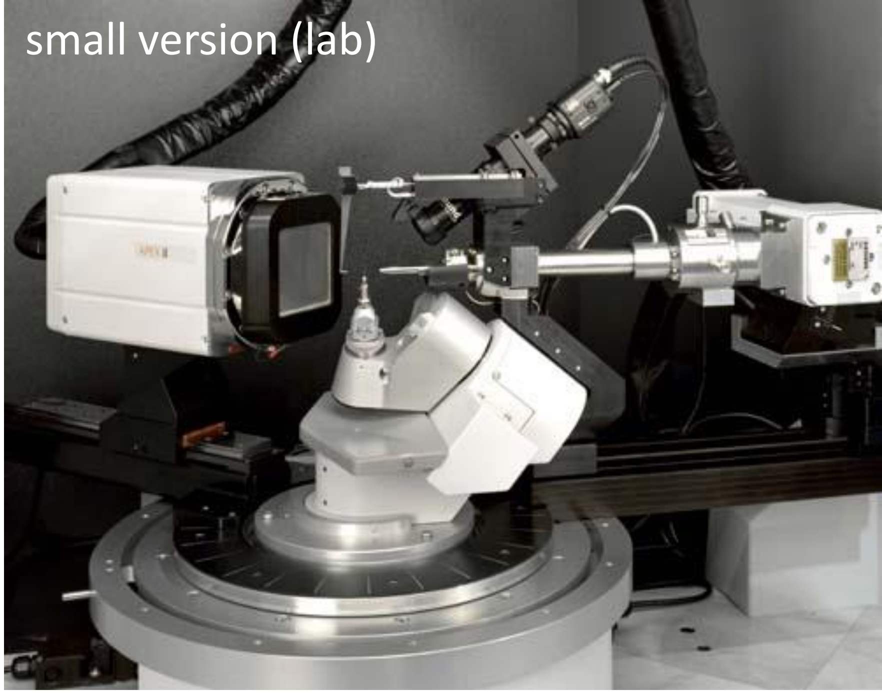


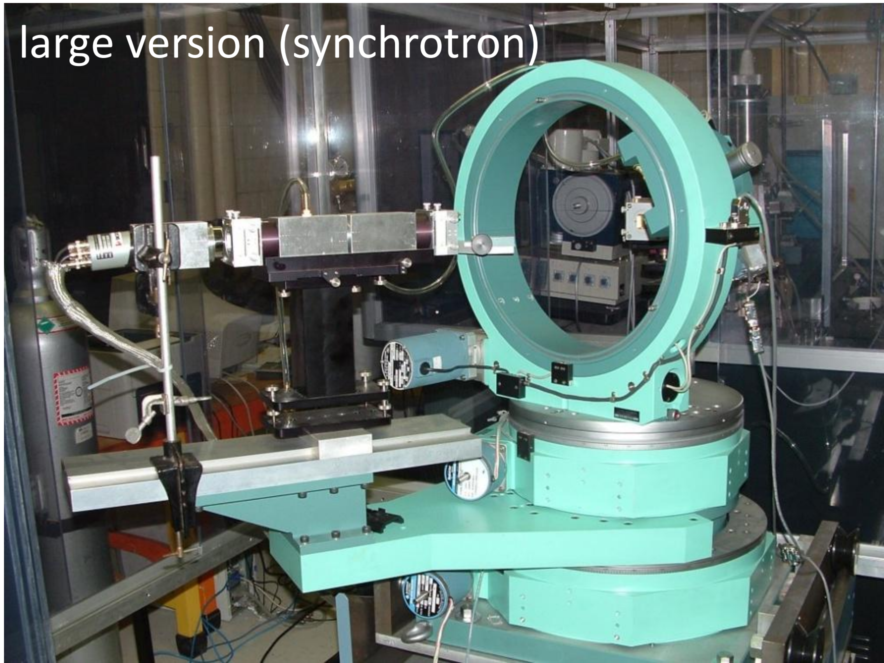
Nobel price in physics 1914 *“for his discovery of the diffraction of X-rays by crystals”*

Nobel price in physics 1915 *"for their services in the analysis of crystal structure by means of X-rays"*



Four circle diffractometer
(Eulerian cradle)

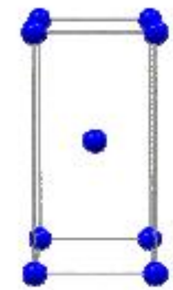


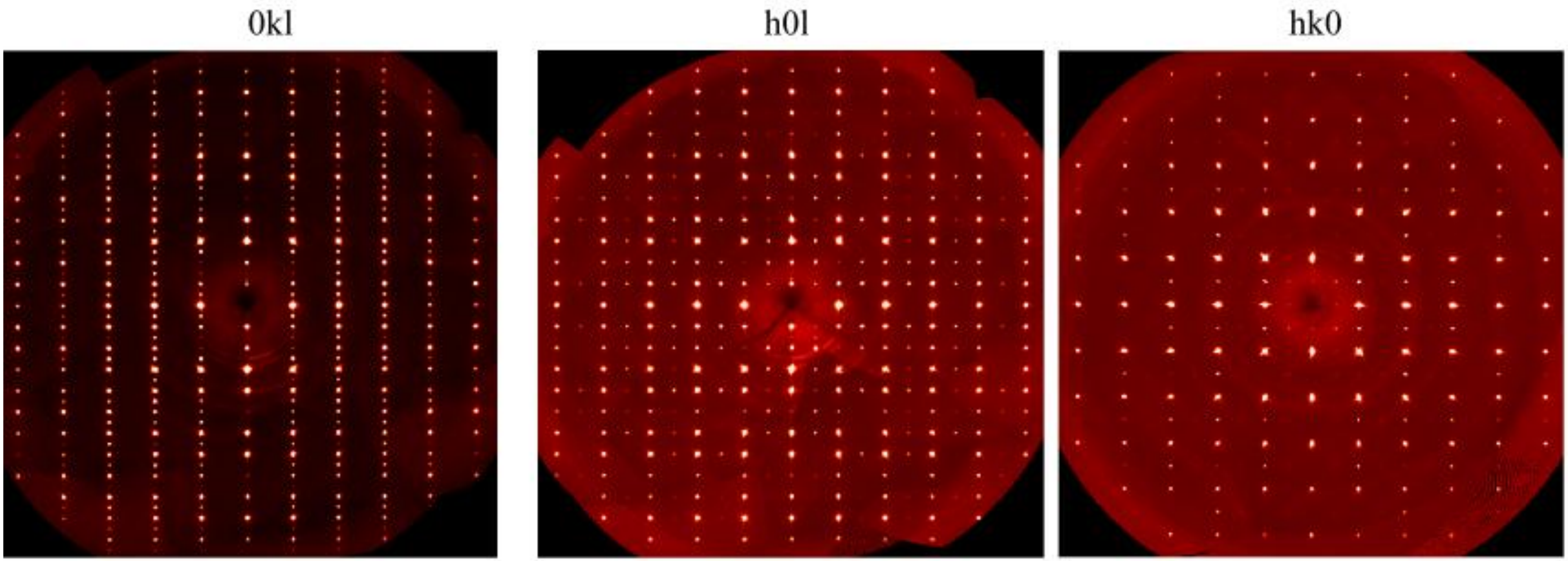


Beispiel : Ca_2RuO_4

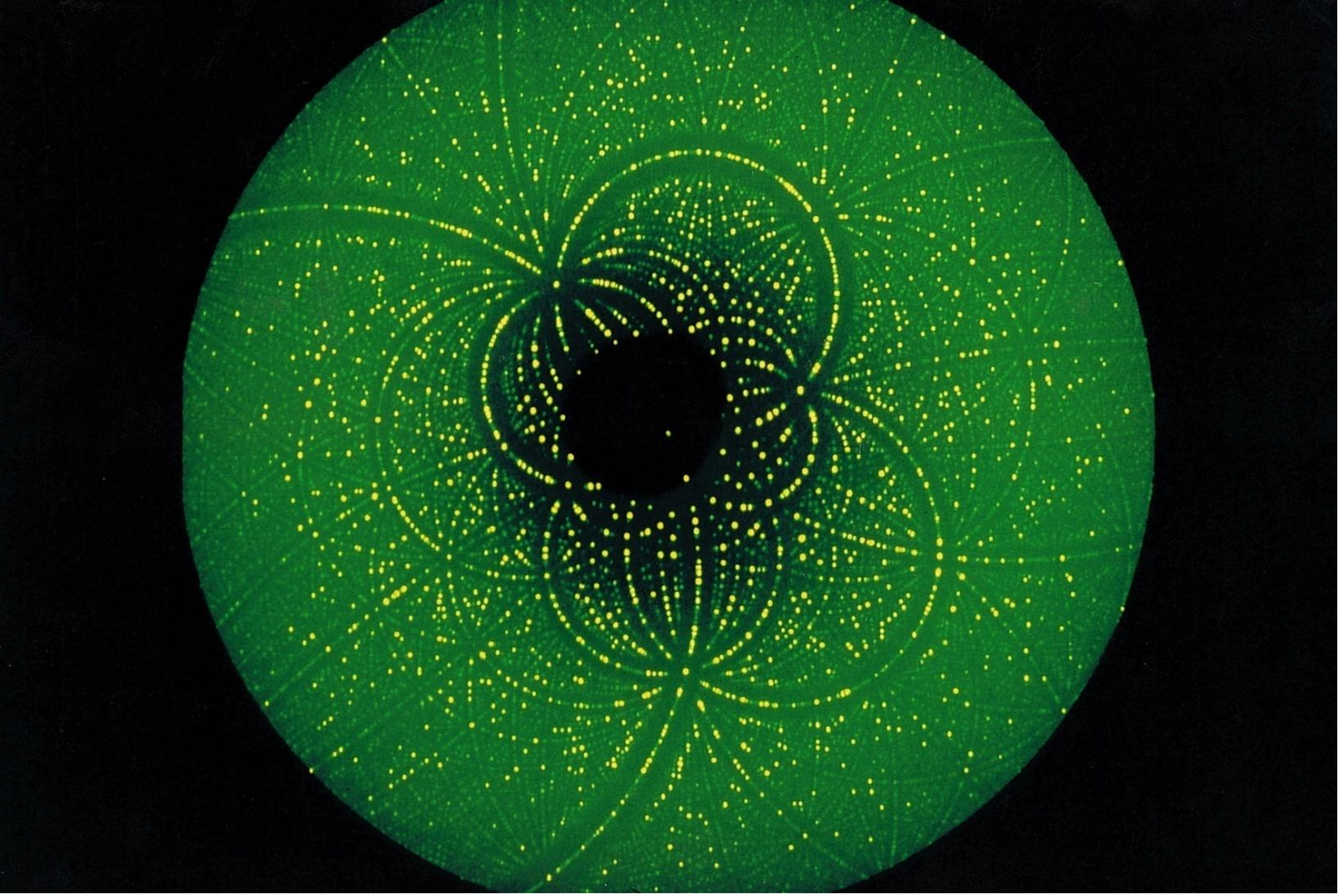
Raumgruppe I4/mmm : Auslöschungsbedingungen

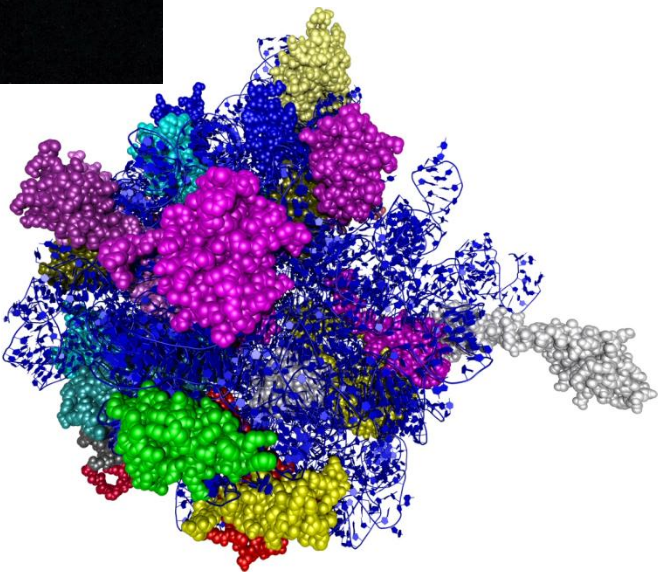
Überstruktur durch Oktaederverkippung

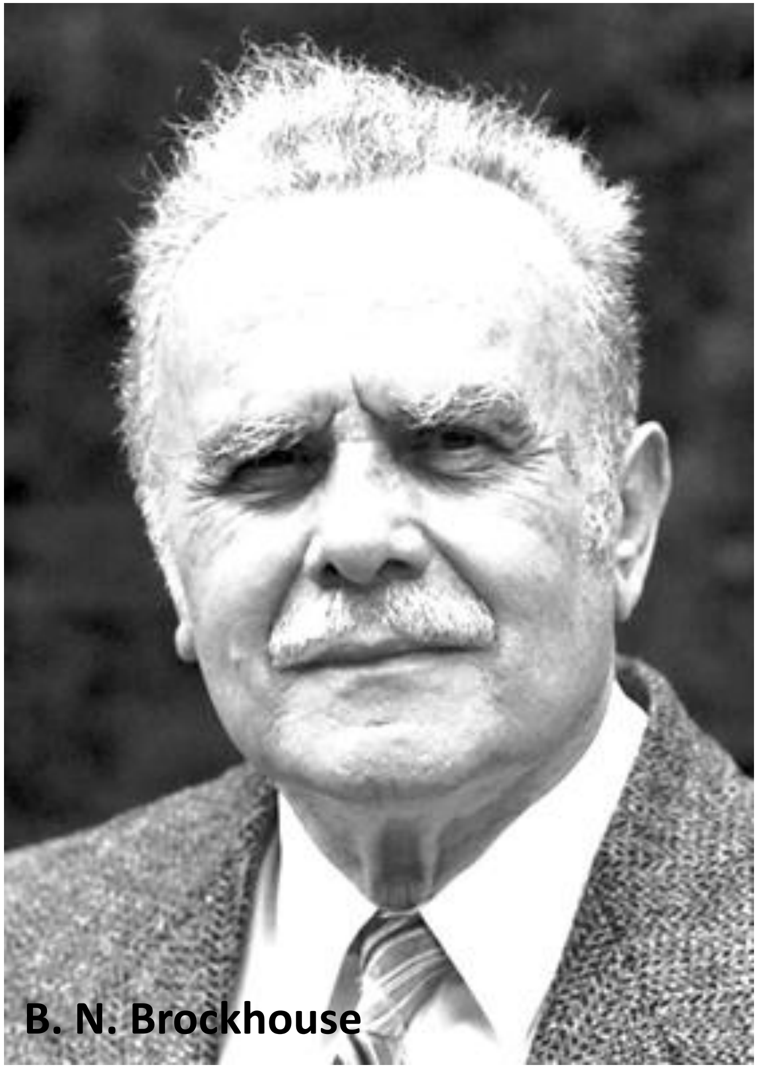


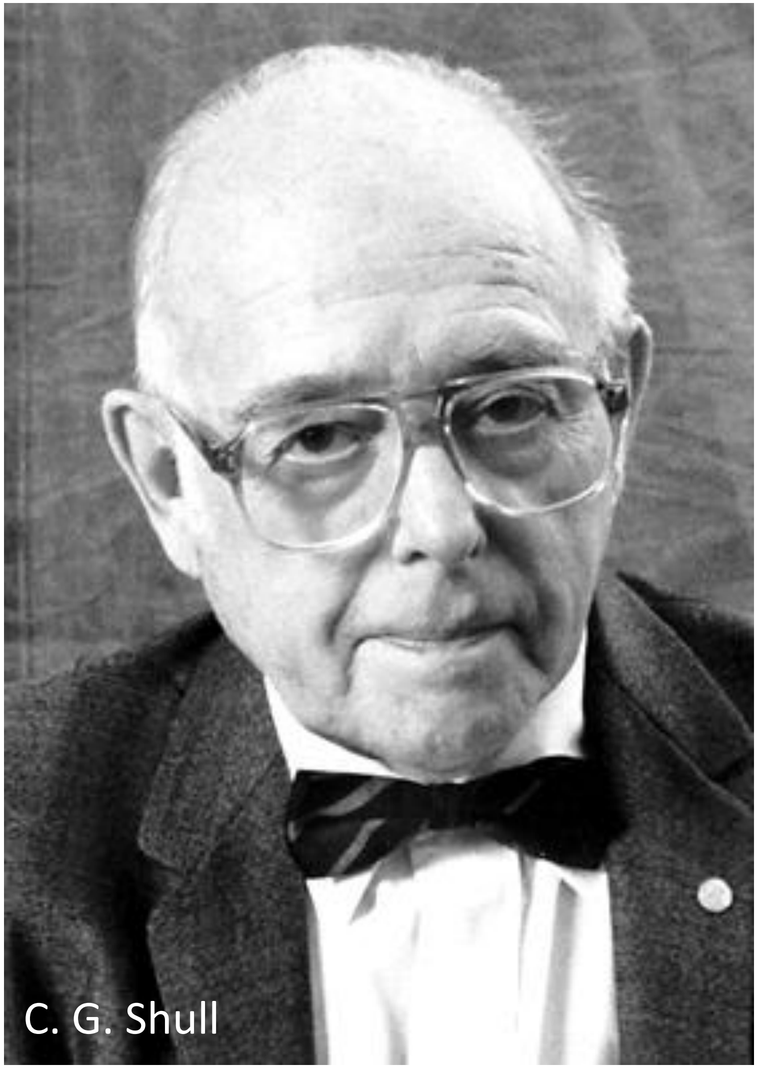


Streukarten entsprechend unterschiedlichen Ebenen im reziproken Raum. Man erkennt starke Fundamental-Reflexe und schwache Überstrukturen aufgrund der strukturellen Verzerrung.









Nobel price in physics 1994 *"for pioneering contributions to the development of neutron scattering techniques for studies of condensed matter"* jointly with one half to Bertram N. Brockhouse *"for the development of neutron spectroscopy"* and with one half to Clifford G. Shull *"for the development of the neutron diffraction technique"* **(work done in the 1950s-1960s)**

Neutrons

Neutrons are **NEUTRAL** particles. They

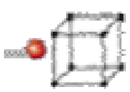
- are highly penetrating,
- can be used as nondestructive probes, and
- can be used to study samples in severe environments.

Neutrons have a **MAGNETIC** moment. They can be used to

- study microscopic magnetic structure,
- study magnetic fluctuations, and
- develop magnetic materials.

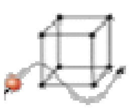
Neutrons have **SPIN**. They can be

- formed into polarized neutron beams,
- used to study nuclear (atomic) orientation, and
- used for coherent and incoherent scattering.



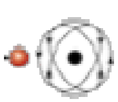
The **ENERGIES** of thermal neutrons are similar to the energies of elementary excitations in solids. Both have similar

- molecular vibrations,
- lattice modes, and
- dynamics of atomic motion.



The **WAVELENGTHS** of neutrons are similar to atomic spacings. They can determine

- structural sensitivity,
- structural information from 10^{-13} to 10^{-4} cm, and
- crystal structures and atomic spacings.



Neutrons "see" **NUCLEI**. They

- are sensitive to light atoms,
- can exploit isotopic substitution, and
- can use contrast variation to differentiate complex molecular structures.

$M_n = 1.674928.10^{-27}$kg

$= 1.001\ M_{Proton}$

$\tau =$ 885 s (β decay)

$n \rightarrow p + e^- + \nu_e + 0.78$MeV

n: $E = h^2/2M_n\lambda^2 = 81.1\text{meV}/\lambda^2$

photon: $E = hf = hc/\lambda = 12398\text{eV}/\lambda$

$k = 2\pi/\lambda$ $p = h/\lambda$

units:

1 meV=11.6 K=8.066/cm=0.241THz

	λ[Å]	k[1/Å]	v(m/s)	E	best ΔE/F
Photon light	5000	10^{-3}	3.10^8	eV	10^{-8}
X-ray	1	1	3.10^8	keV	10^{-6}
electron	1	1	6.10^7	150eV	10^{-5}
neutron	1	1	400	meV	10^{-6}

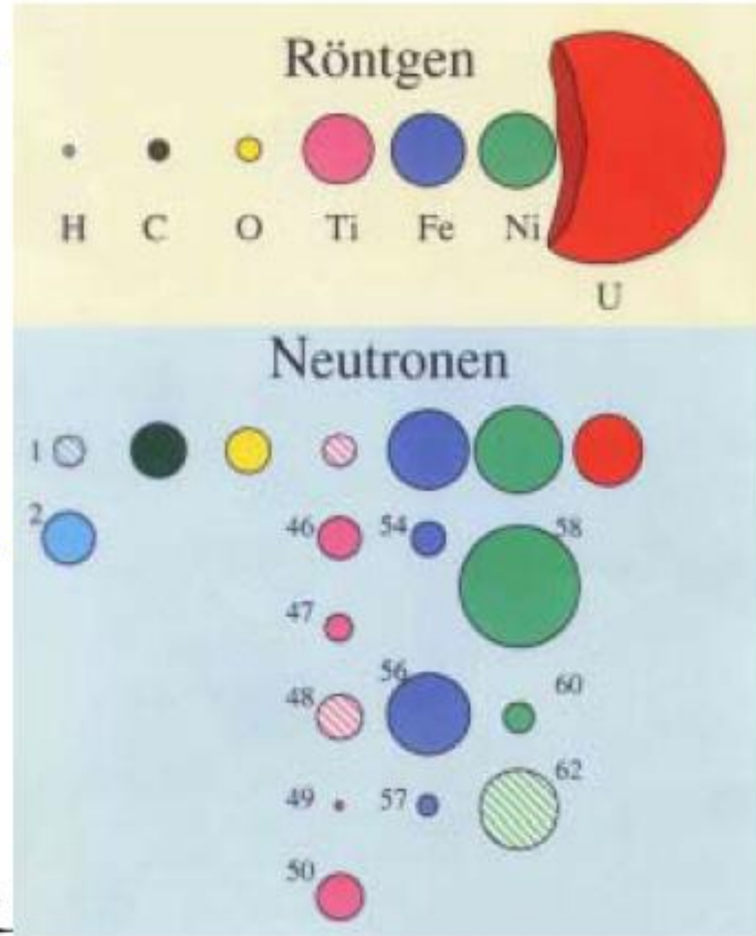
-Neutronen sind neutral ($Q<10^{-20}e$)

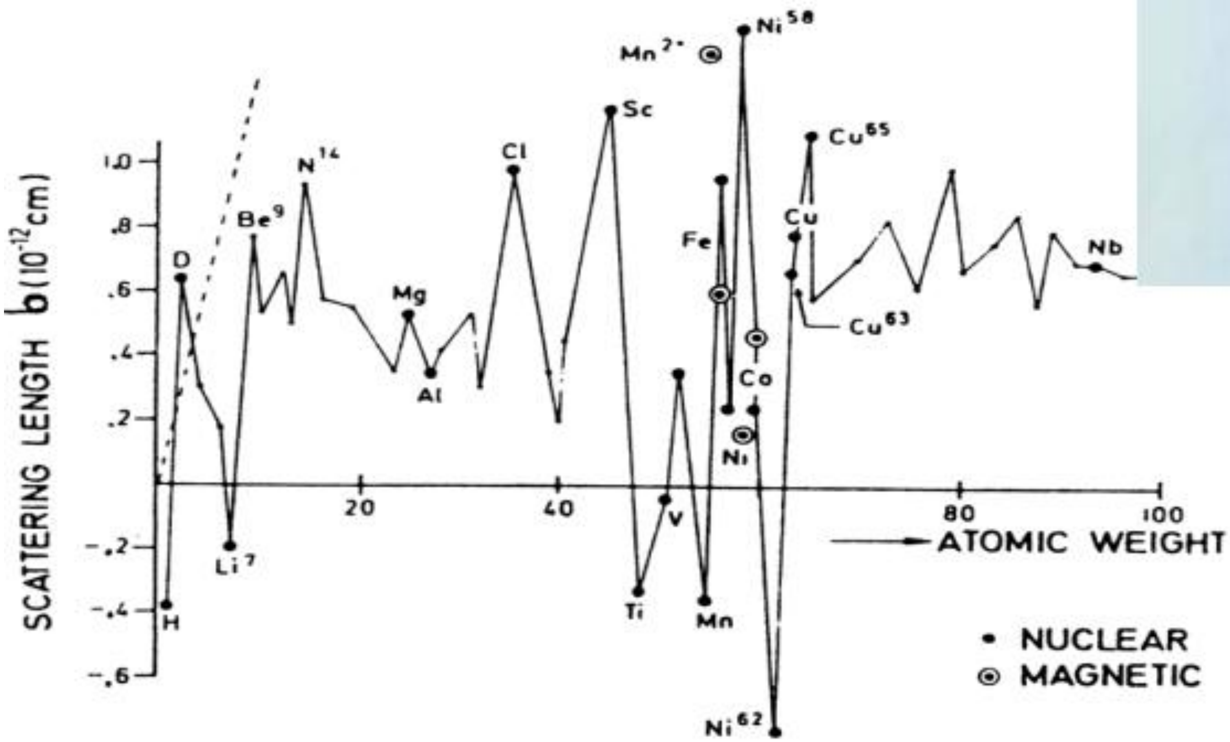
-Wechselwirkung mit den Atomkernen

→lokal

→nicht direkt von Z abhängig

→**Bestimmung leichter und schwerer Atome !!!**





Neutrons – Photons

Neutrons:

Particle beam (neutral)
$E=h^2/2m_N\lambda^2=81.1 meV/\lambda^2$
Low brilliance (particles/cm2/sr/meV)
Interactions with the nuclei and the magnetic moment of unpaired electrons

Scattered by all elements, also the light ones like the hydrogen isotopes

Deep penetration depth (bulk studies of samples)

Less intense beam measuring larger samples

Applications:
Magnetic structures & excitations, critical scattering

Photons:

Light beam
$E=hf=hc/\lambda=12398 eV/\lambda$
High brilliance
Interactions with the electrons surrounding the nuclei

Mainly scattered by heavy elements

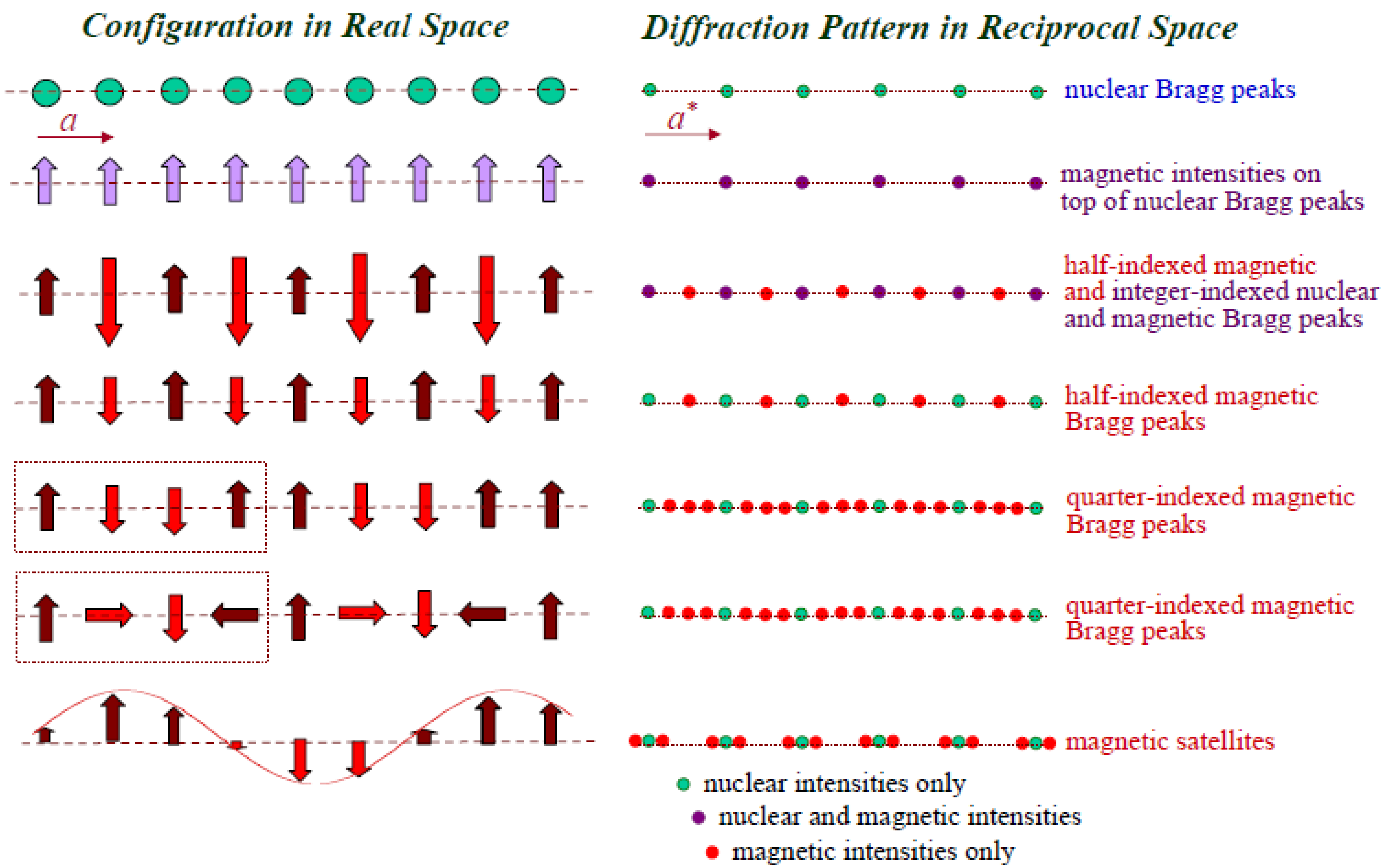
Small penetration depth (surface studies of samples)

Very intense beam measuring small or ultra-dilute samples

Applications:
Surface studies, element and shell sensitive resonant magnetic scattering, magnetic dichroism, magnetic Materials with high neutron absorption

Where do the Magnetic Reflections appear?

assuming one atom per unit cell



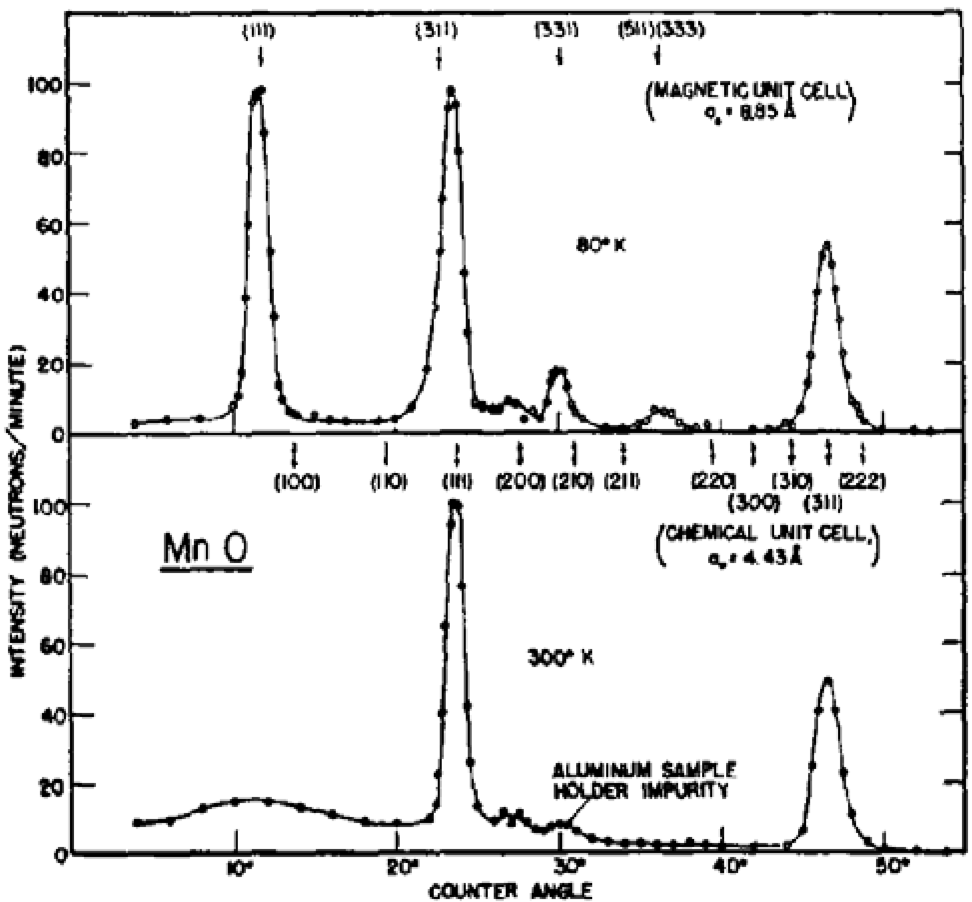


FIG. 1. Neutron diffraction patterns for MnO at room temperature and at 80°K.