Grenoble France

- World's most intense neutron source
- ~300 staff
- ~1250 visiting scientists each year
- ~500 scientific papers each year
- physics, chemistry, biology, materials

ILL member countries are shown in green

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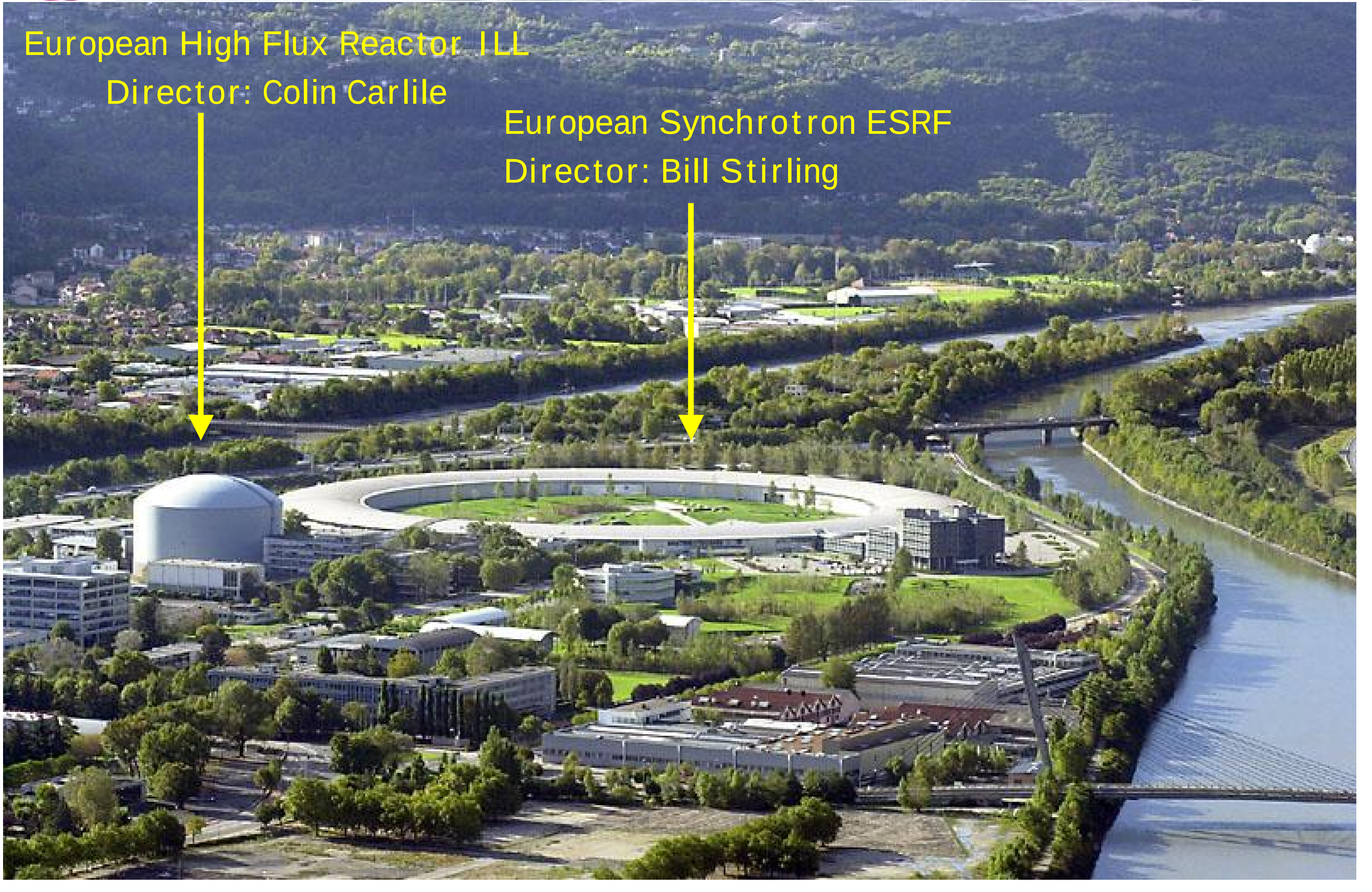
ILL member countries are shown in green

Materials Research at CCLRC European Labs.

Alan Hewat, ILL Grenoble



An Interesting Environment – On a Good Day

An Interesting Environment – On a Bad Day

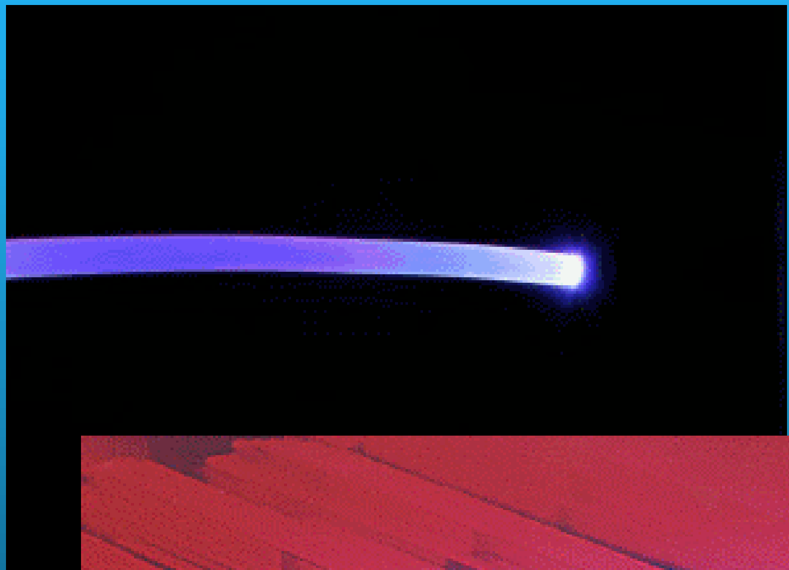
Why International ?

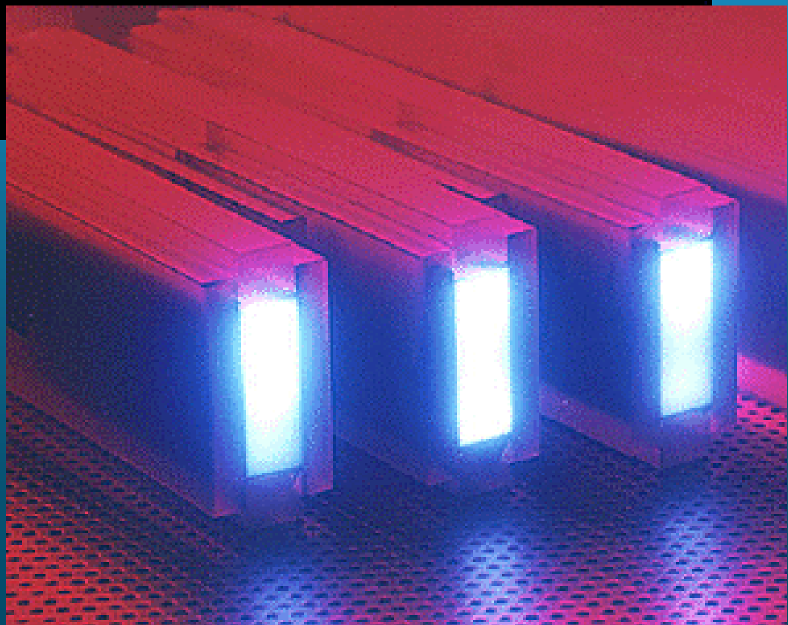
- Publicising UK Science ("Rayonnement" of the country).
- Meeting people with other ideas ("canteen" effect).
- Cost effective (cost/instrument day is actually lower).

Why Neutrons ?

- Neutrons are electrically neutral & more penetrating than X-rays.
- Light atoms scatter neutrons as strongly as heavy atoms.
- Neutrons are tiny magnets, & can determine magnetic structures.

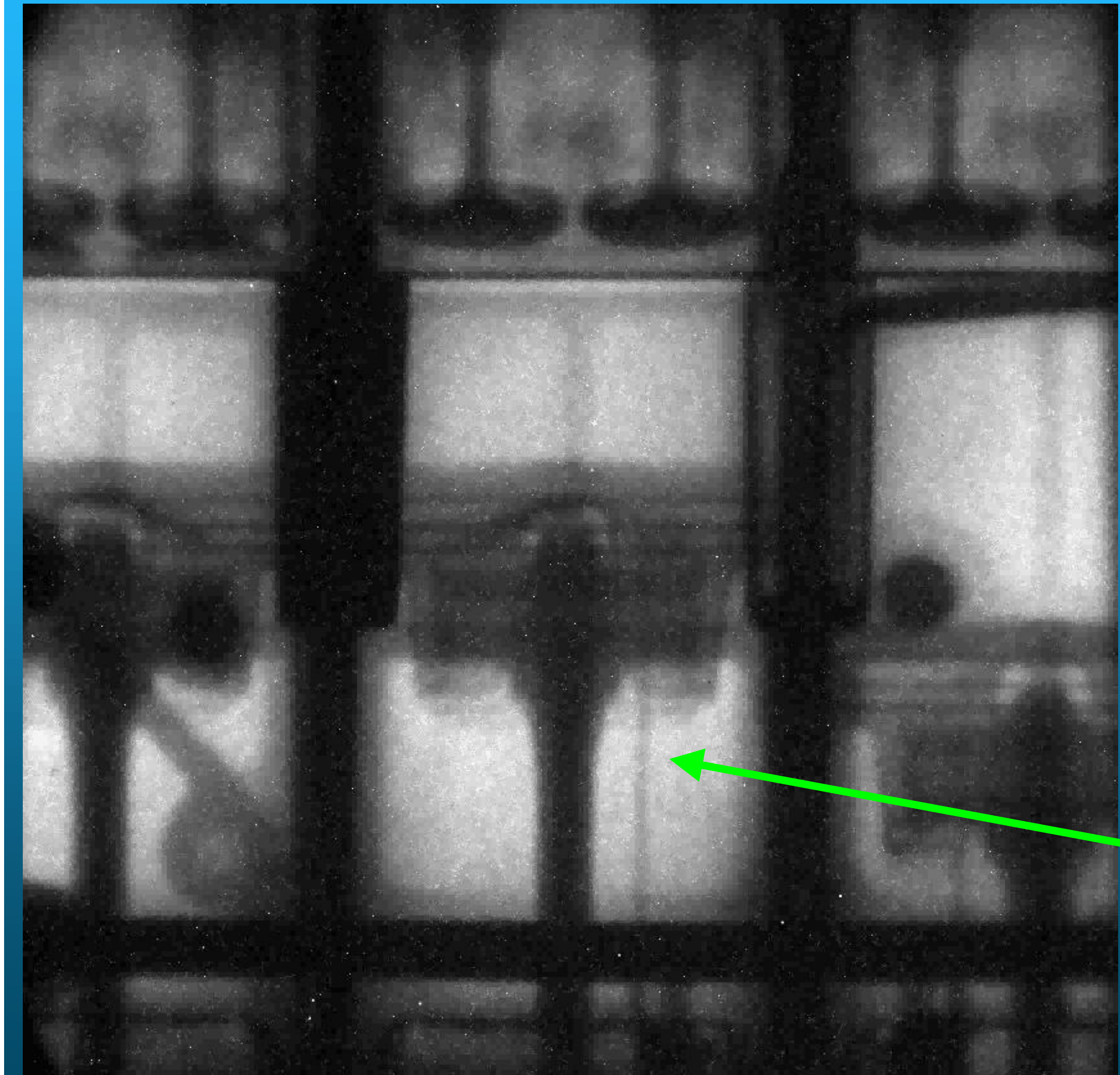
Neutrons can be transmitted like light in an optic fibre





- “Neutron guide tubes” bring the neutrons to the experiment

Neutrons are more penetrating than X-rays
And see light atoms - hydrocarbons

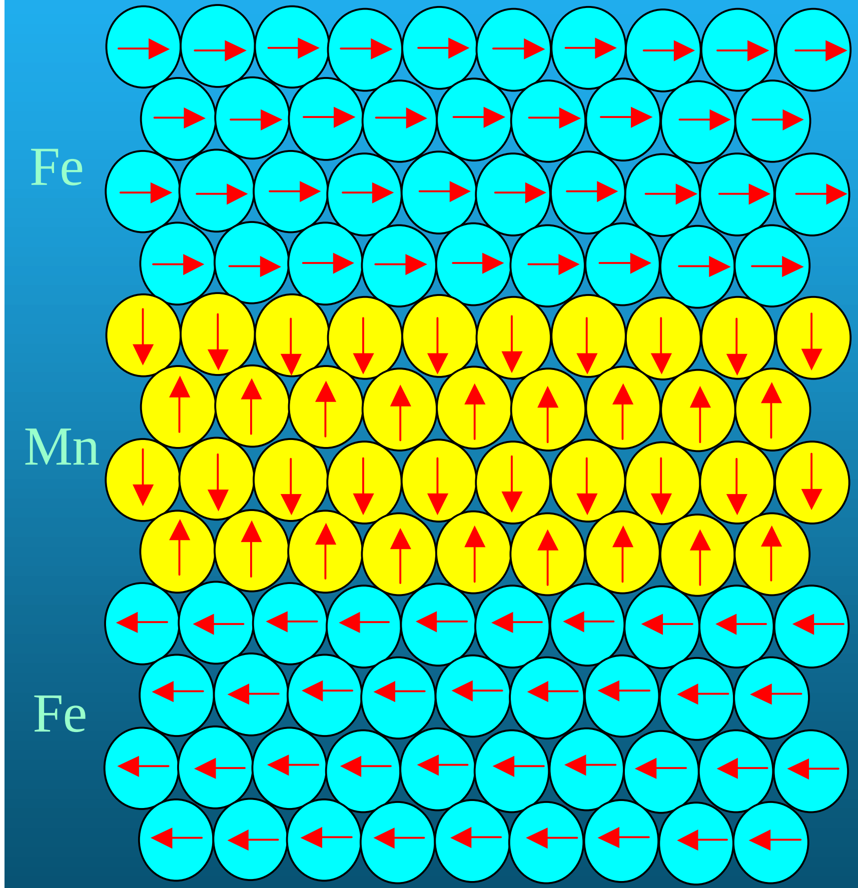


Neutron radiograph
of a real BMW engine
Time 0.5 milliseconds

Cooling oil splash

A. Hillenbach (Munich & ILL)

Magnetic multilayers

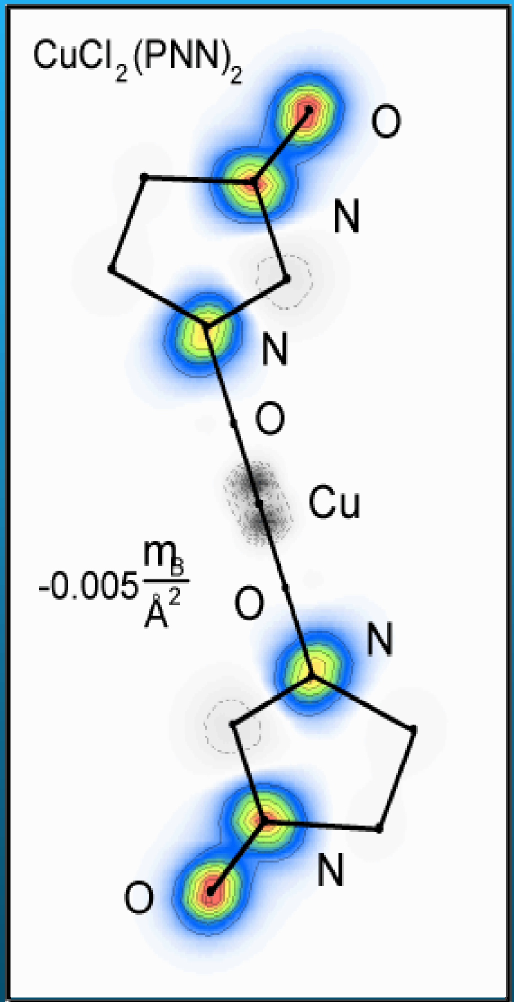


- Molecular Beam Epitaxy MBE allows us to build up layers on an atomic scale – Nano-structures
- Neutrons are tiny magnets, so can be used to probe magnetic interactions between layers – neutron reflectometry
- Devices made from magnetic multilayers include "spin valves" used for computer disks and non-volatile memory

J. Goff, S. Lee, R. Ward, M. Wells, G. McIntyre (Liverpool & ILL)

Neutrons can study magnetic materials

Molecular magnets

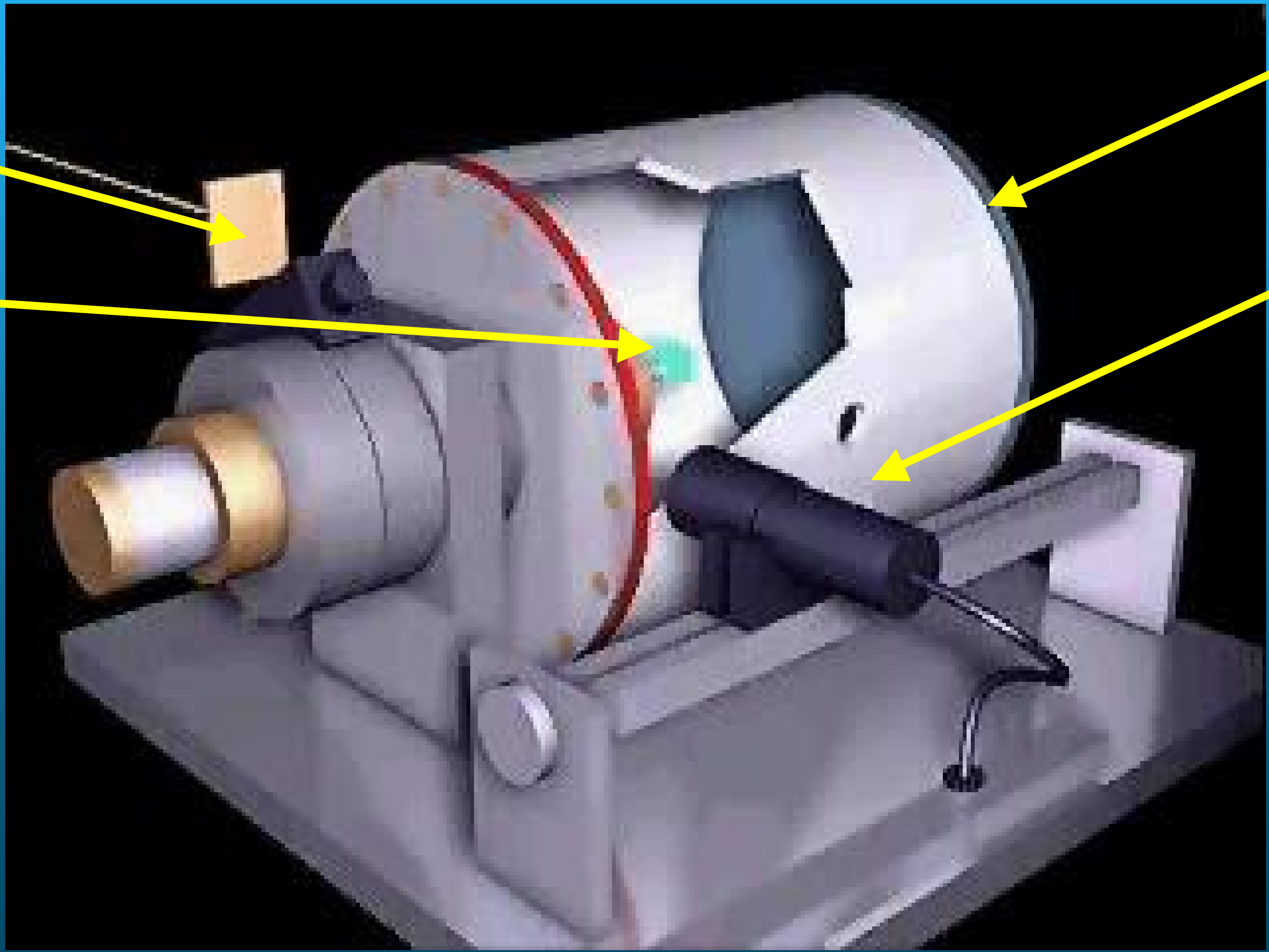


- Molecular magnets can be light, transparent, magneto-optic, bio-compatible etc…
- Neutrons are unique for mapping the magnetisation density on an atomic scale
- The first organic ferromagnet (left) - the magnetic density is on nitrogen & oxygen

E. LeLievre-Berna et al. ILL (D3 originally developed by P.J.Brown & B.Forsyth)

Neutron Image Plate Detectors – a neutron camera

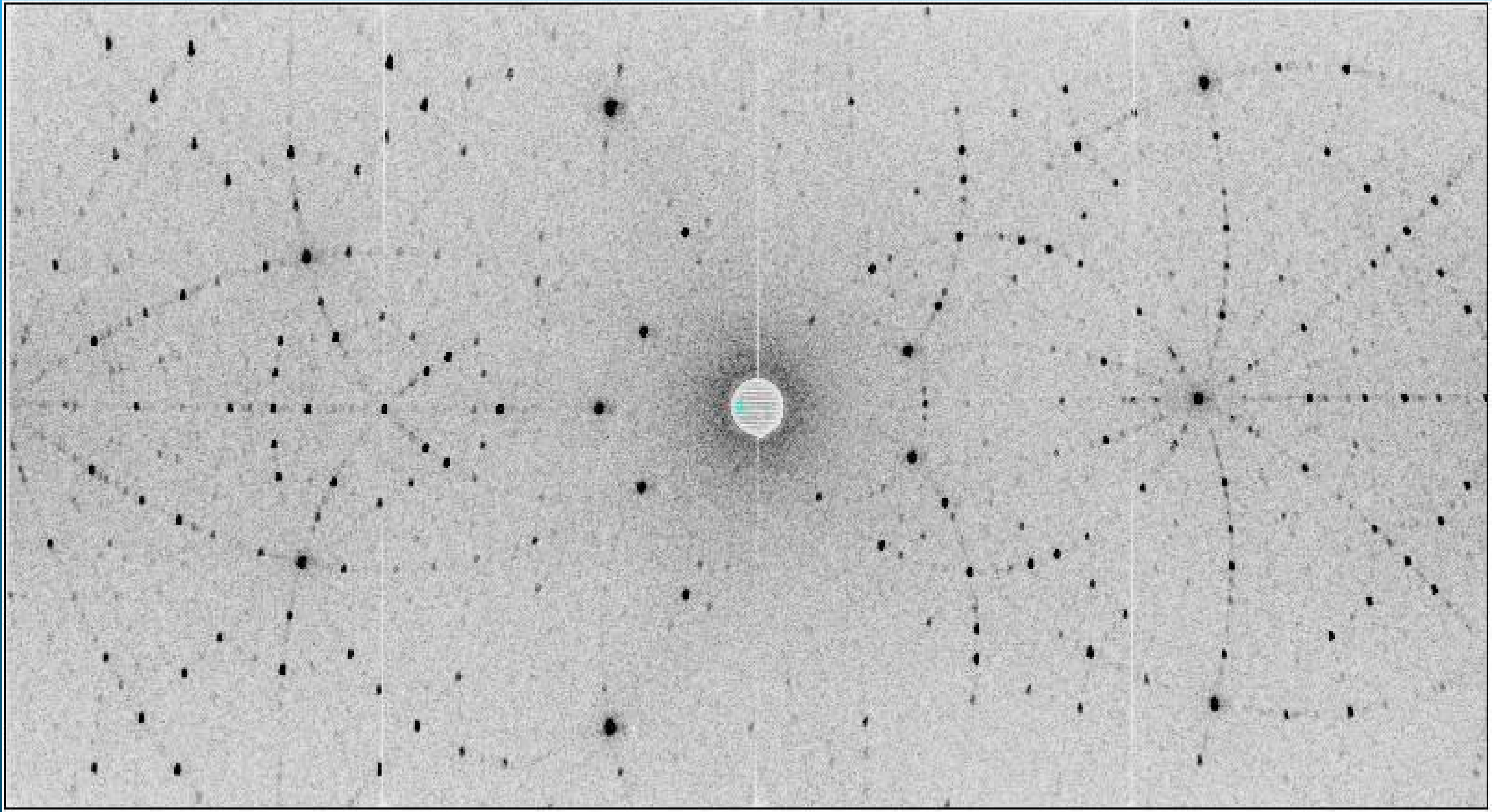
All of the scattered neutron peaks are recorded simultaneously



C.Wilkinson
M.Lehmann
D.Myles
F.Cipriani
G.McIntyre
(EMBL & ILL)

Neutron Image Plate & 5-fold symmetry of a quasi-crystal

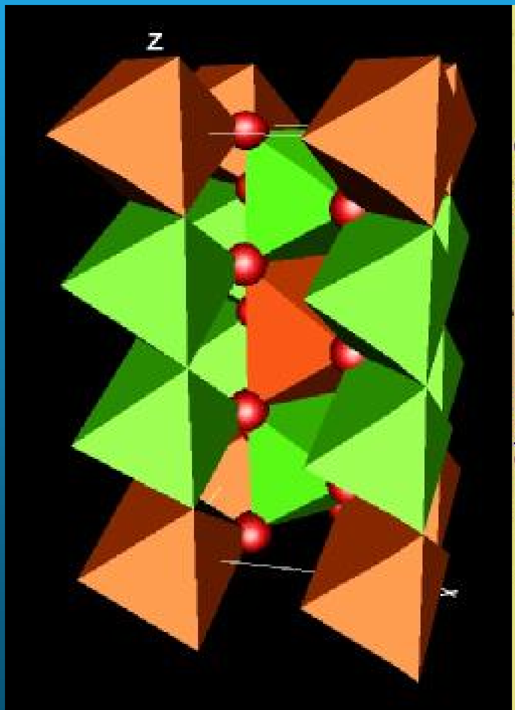
All of the scattered neutron peaks are recorded simultaneously

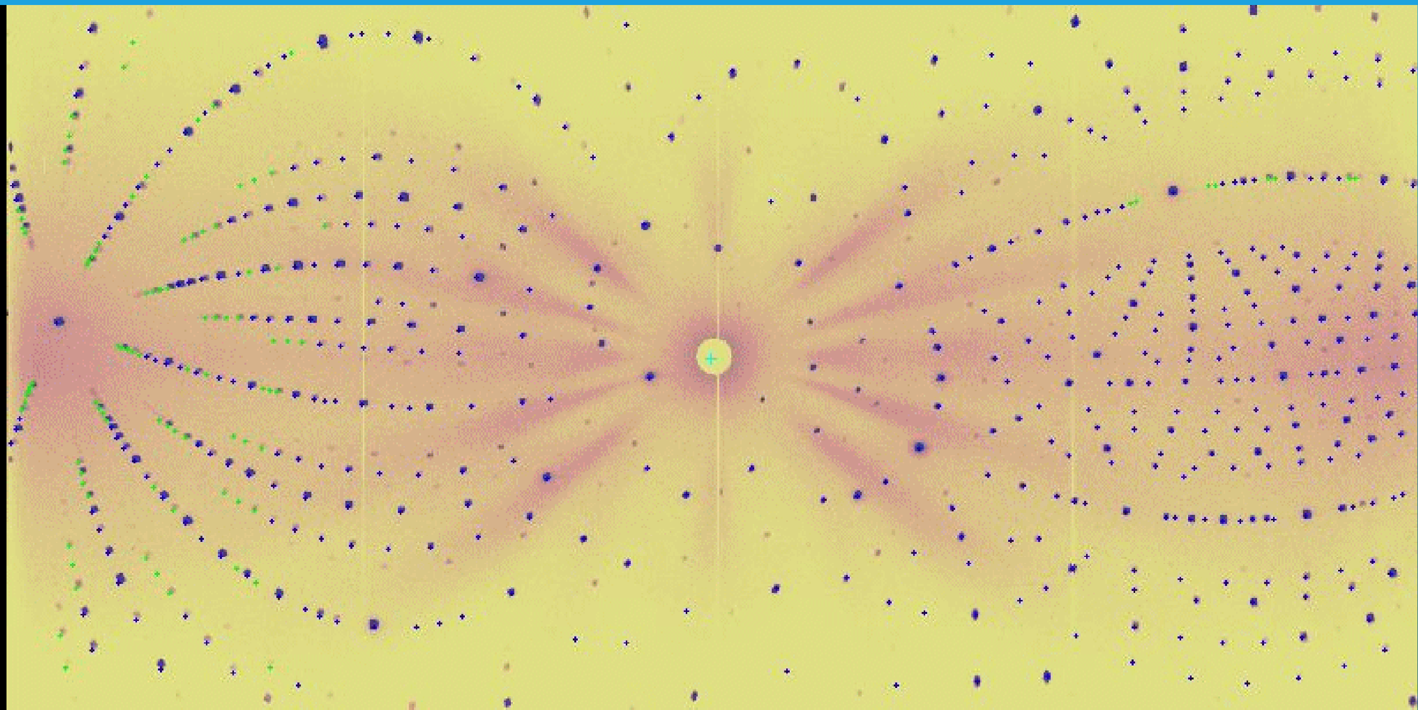


Magnetic order in Tapiolite $FeTa_2O_6$

VIVALDI image plate detector photos at 10K and 2K

Tiny 100 micron crystals, 1000's of spots in a few hours





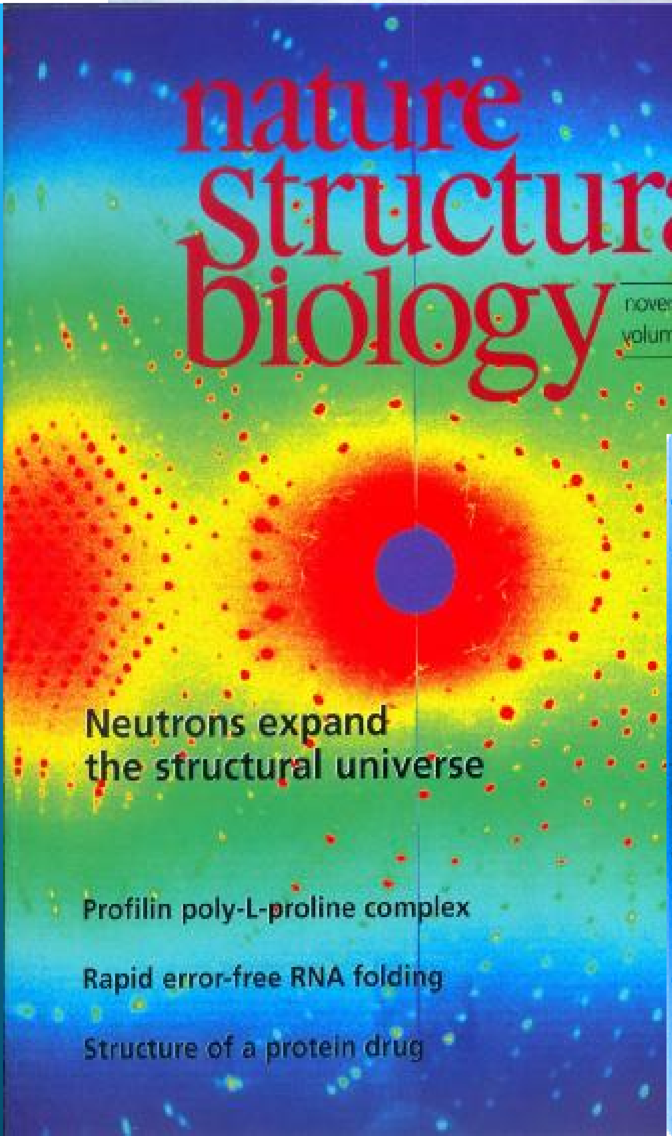
G.McIntyre, C.Wilkinson, D.Mc.Paul et al. (ILL & Warwick)

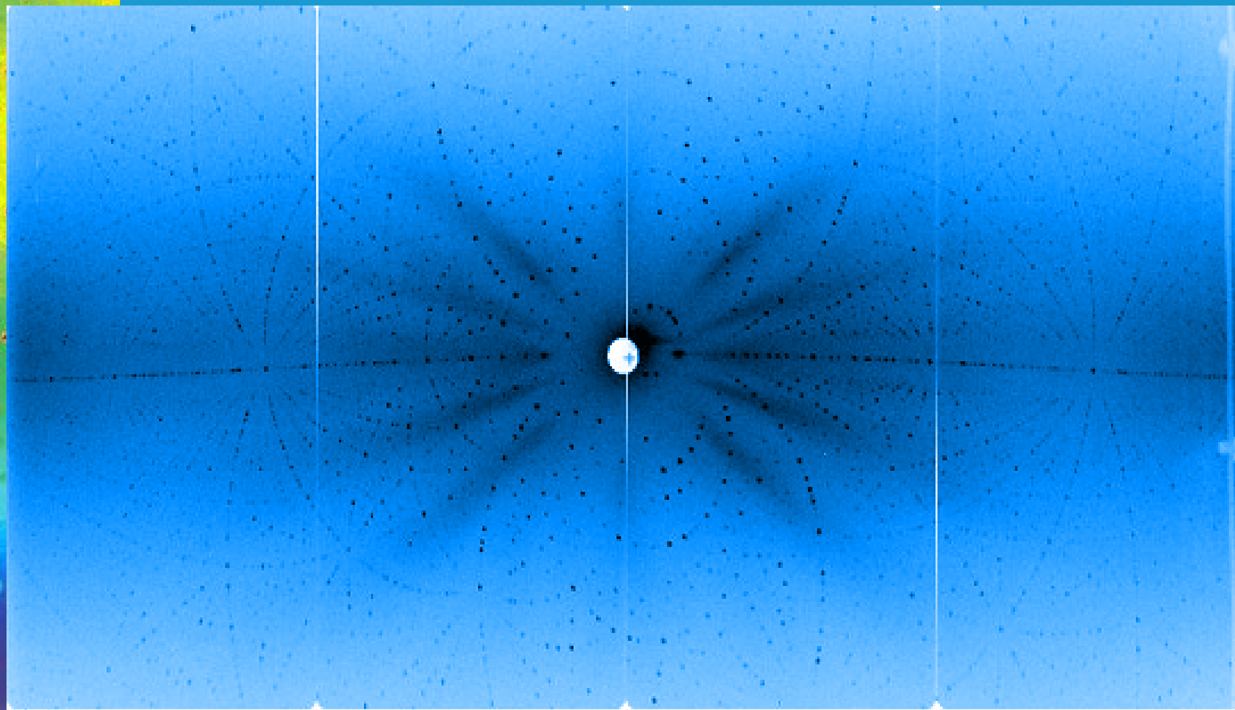
Neutrons and Life – hydrocarbons

Neutron image plate detector

Large molecules and even proteins can be studied – the role of water

C.Wilkinson et al. (ILL & King's College)





Vitamin B12 – 10,000 reflections in 8 hours from 1 mm^3 crystal

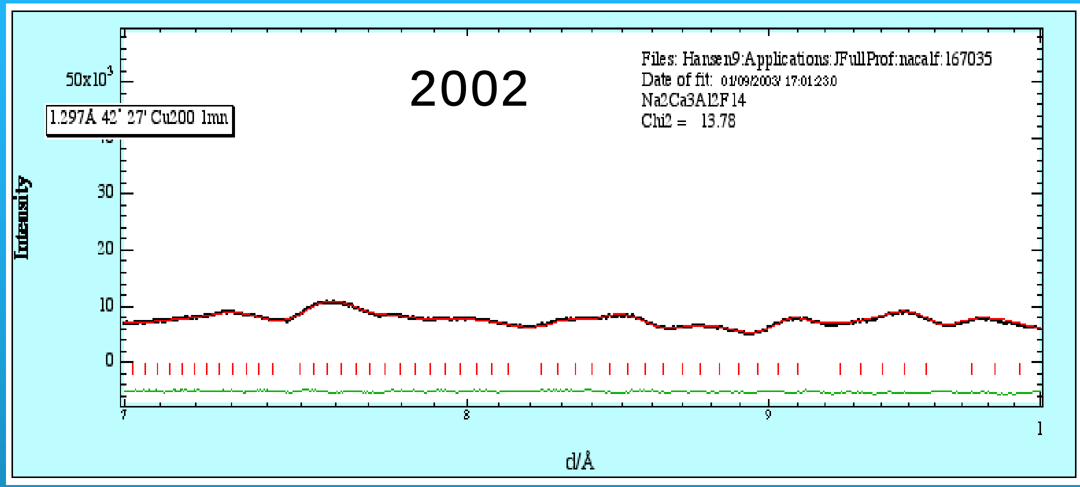
Neutrons are Expensive – Need Every Neutron

Neutron intensities are low, so large detectors are needed

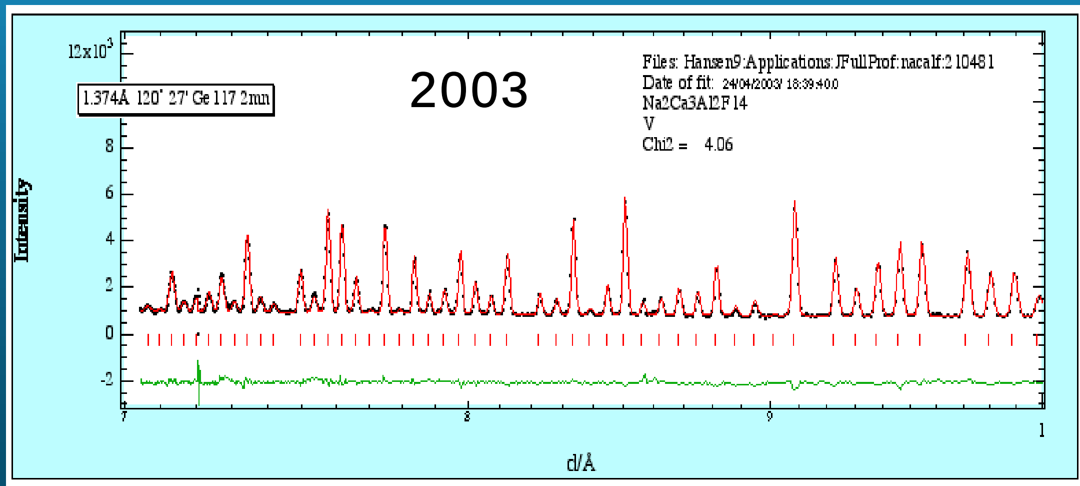
Construction of a microstrip position-sensitive detector (printed circuit)

A.Oed,
P.Convert,
T. Hansen,
et al…
(ILL)

A Continuing Fight to Improve Performance



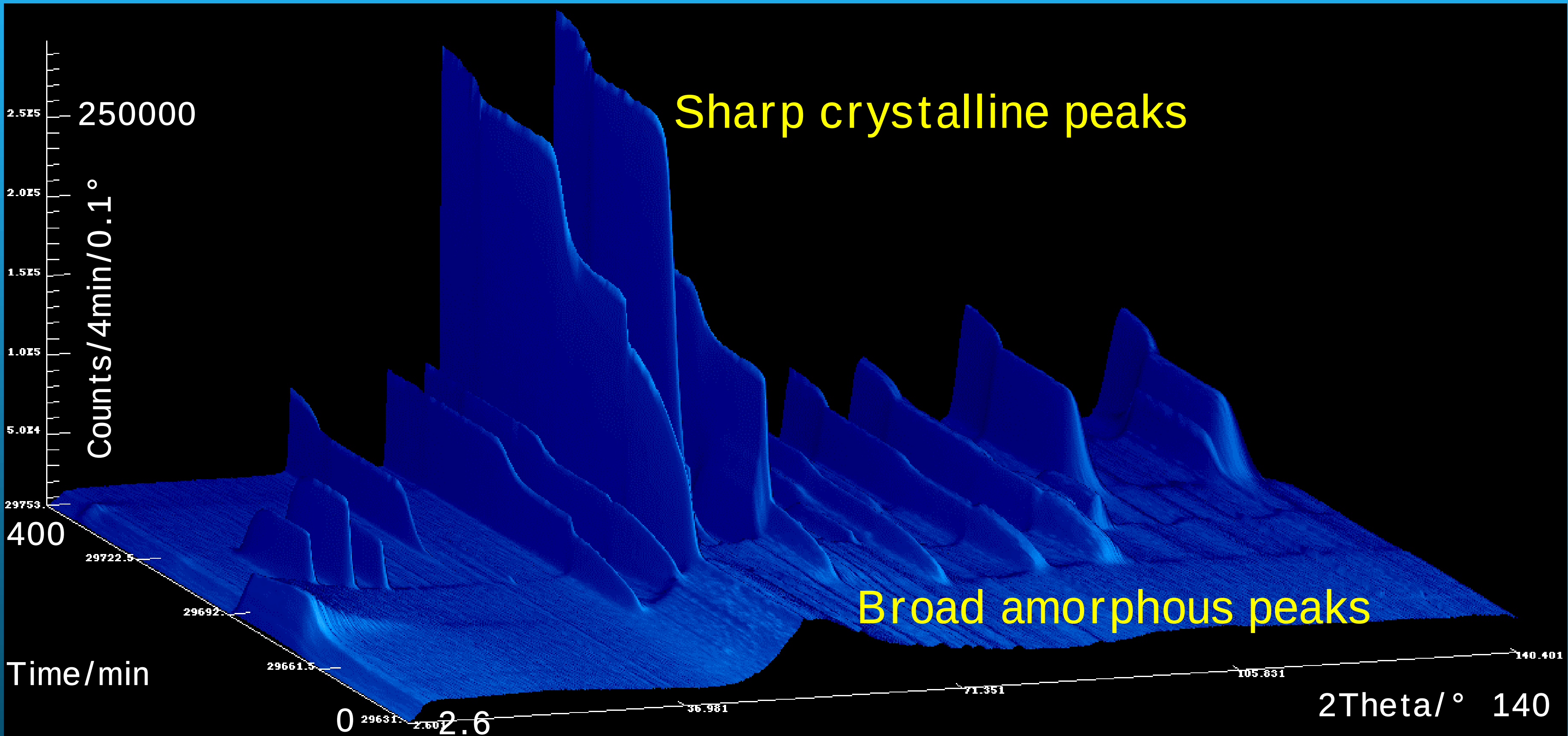
Before and After (data in 2 min.)



Higher D20 resolution since 2003

Applications of large fast detectors

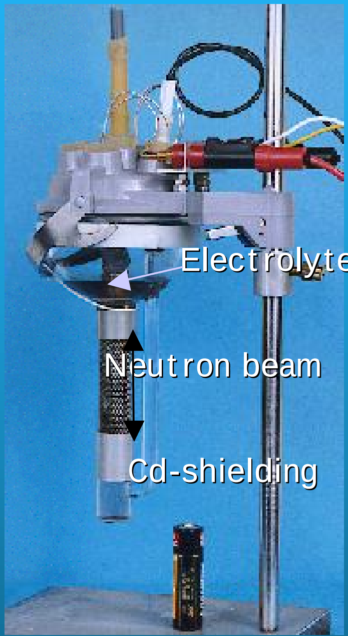
Real-time Reactions - Crystallisation of amorphous alloy $Y_{67}Fe_{33}$

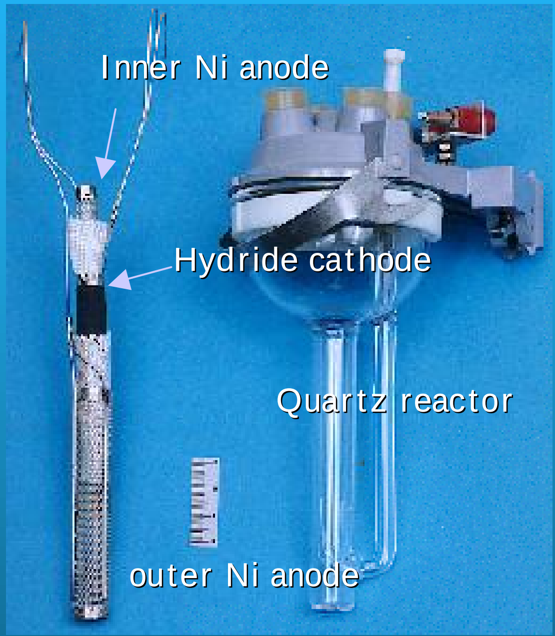


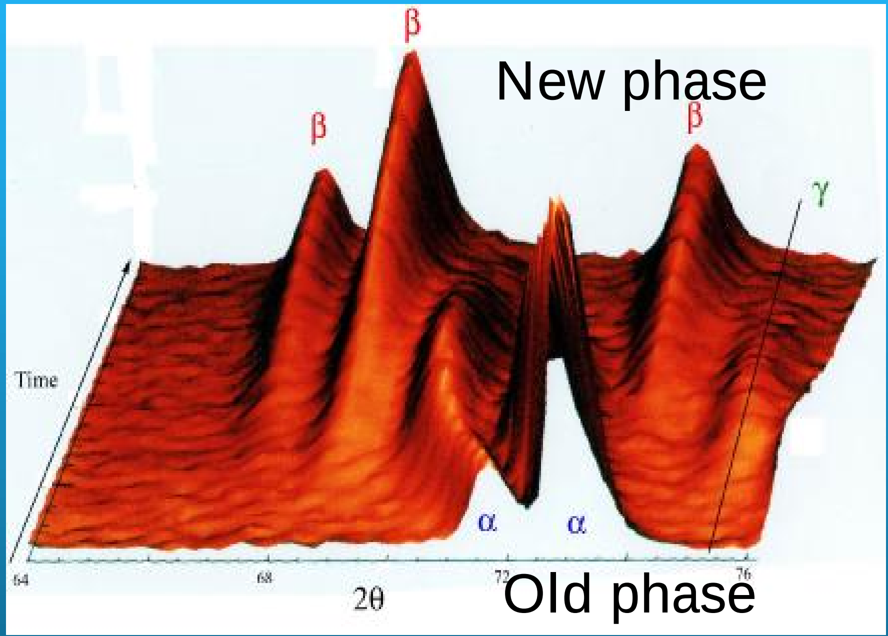
Complete diffraction pattern in minutes or seconds, scanning through temperature

R. Cywinski, S. Kilcoyne (St Andrews)

Electrochemistry of batteries & real-time neutron scattering



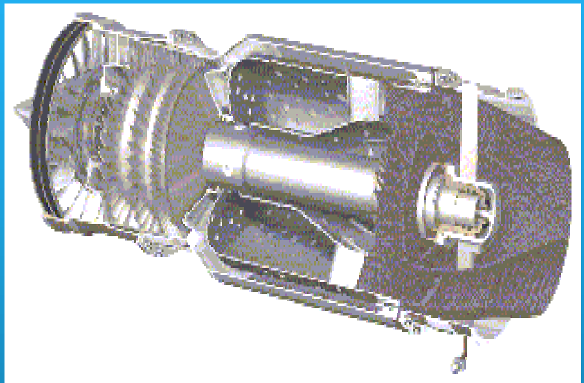


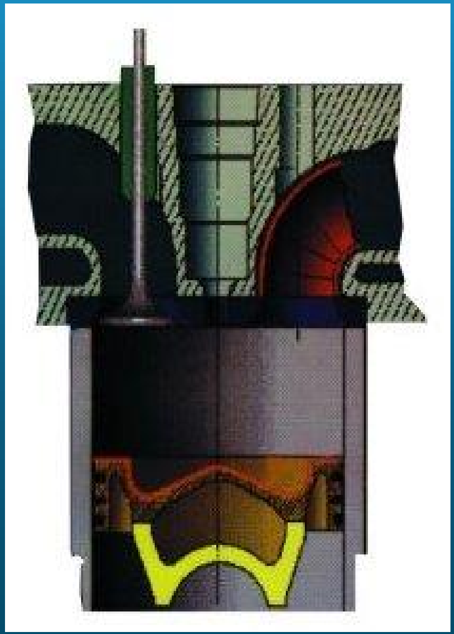


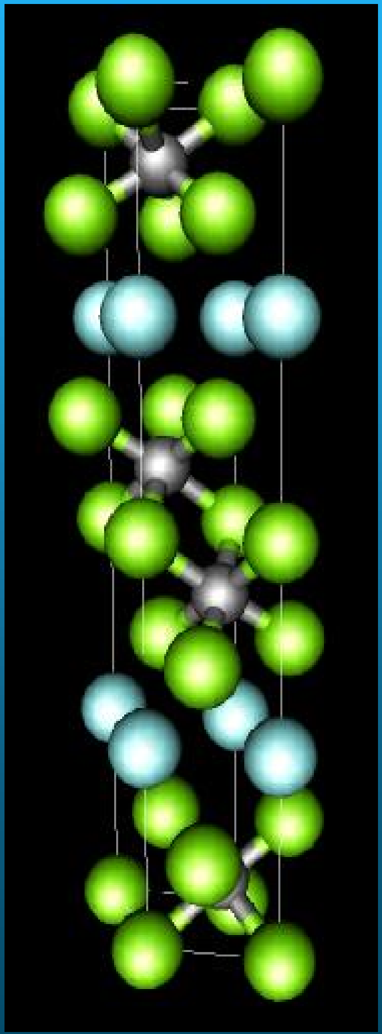
- Neutrons penetrate deep inside batteries during charge-discharge cycle
- Chemical changes due to charge-discharge can be followed in real time
- The hope is to make better batteries

Y. Chabre, M. Latroche, M.R. Palacin,
O. Isnard, G. Rousse (CNRS, CIC-Spain + ILL)

New ceramics to replace metals in engineering components







- Titanium silicon carbide Ti_3SiC_2 conducts heat and electricity
- It is tough, easily machinable
- Potential engineering applications as a light replacement for metals
- BUT, difficult to prepare pure
- Neutron diffraction was used to study Self-propagating High-temperature Synthesis – SHS

D.Riley, E.Kisi, T.Hansen, A.Hewat

Applications of large fast detectors

New ceramics to replace metals in engineering components

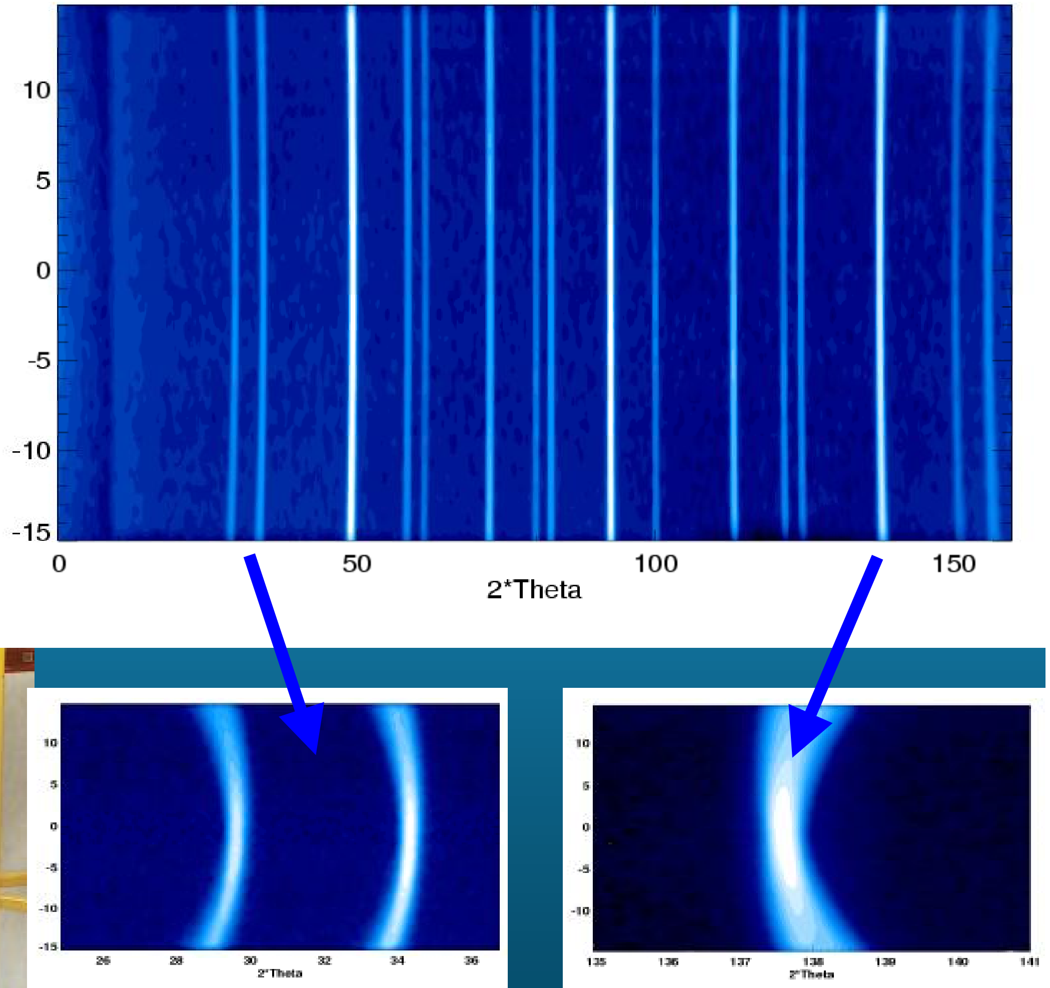
- The explosive SHS reaction was studied in real time with neutrons
- The reaction is exothermic, & heats the sample to 2200ºC in <1 sec
- The complete diffraction pattern (left) is collected at 300 ms intervals – A World Record
- Knowledge of the SHS process allows us to prepare a pure Ti_3SiC_2 product

D.Riley, E.Kisi, T.Hansen, A.Hewat

Need Every Neutron

EuroCollimators (Cheltenham)
CLRC-RAL laboratory 2003

UK-EPSRC project Super-D2B



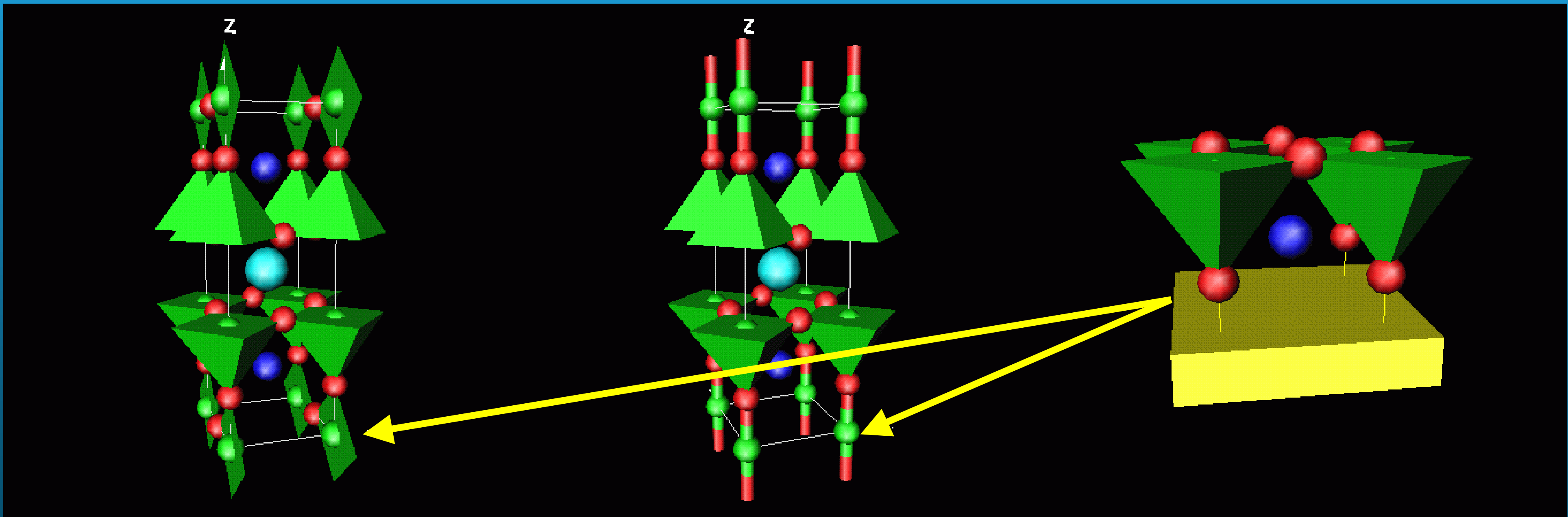
E.Suard, C.Ritter, A.Hewat, P.Attfield... (Edin.)

The importance of oxygen for high-Tc superconductors

Neutrons are sensitive to oxygen – “charge reservoir” concept

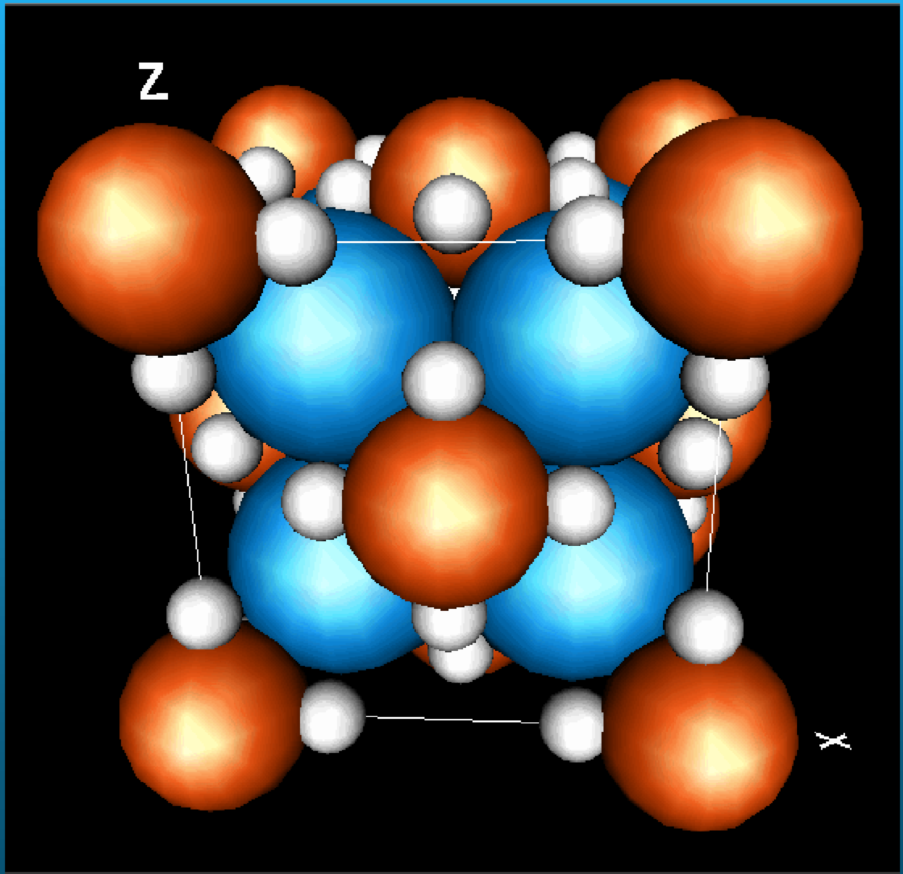
Very precise measurement of oxidation state of metal ions

Superconducting $YBa_2Cu_3O_7$ Non-supercond. $YBa_2Cu_3O_6$ Charge reservoir layer



R. Cava, A. Hewat, E. Hewat, M. Marezio et al.

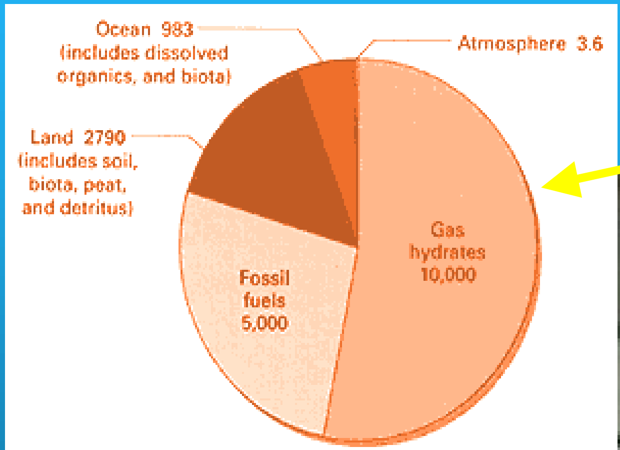
Potential Hydrogen storage materials

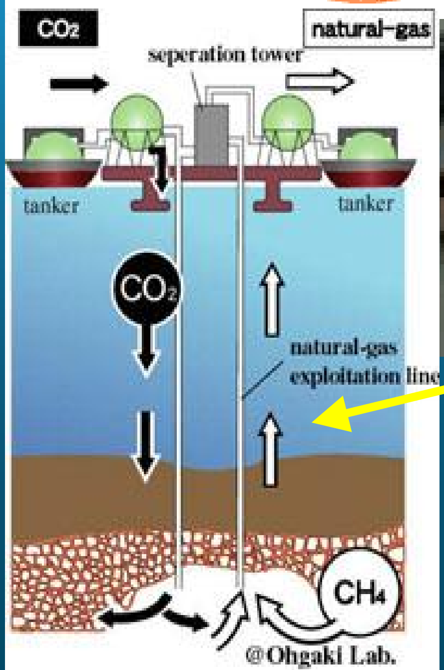


- We need a material to store hydrogen
- Mg_2FeH_6 (left) stores twice as much hydrogen as the same volume of liquid hydrogen !!!
- Neutrons are used to understand how hydrogen is absorbed
- Search for better storage materials.
- The small white hydrogen atoms fill the holes between the metal atoms

K. Yvon (Geneva)

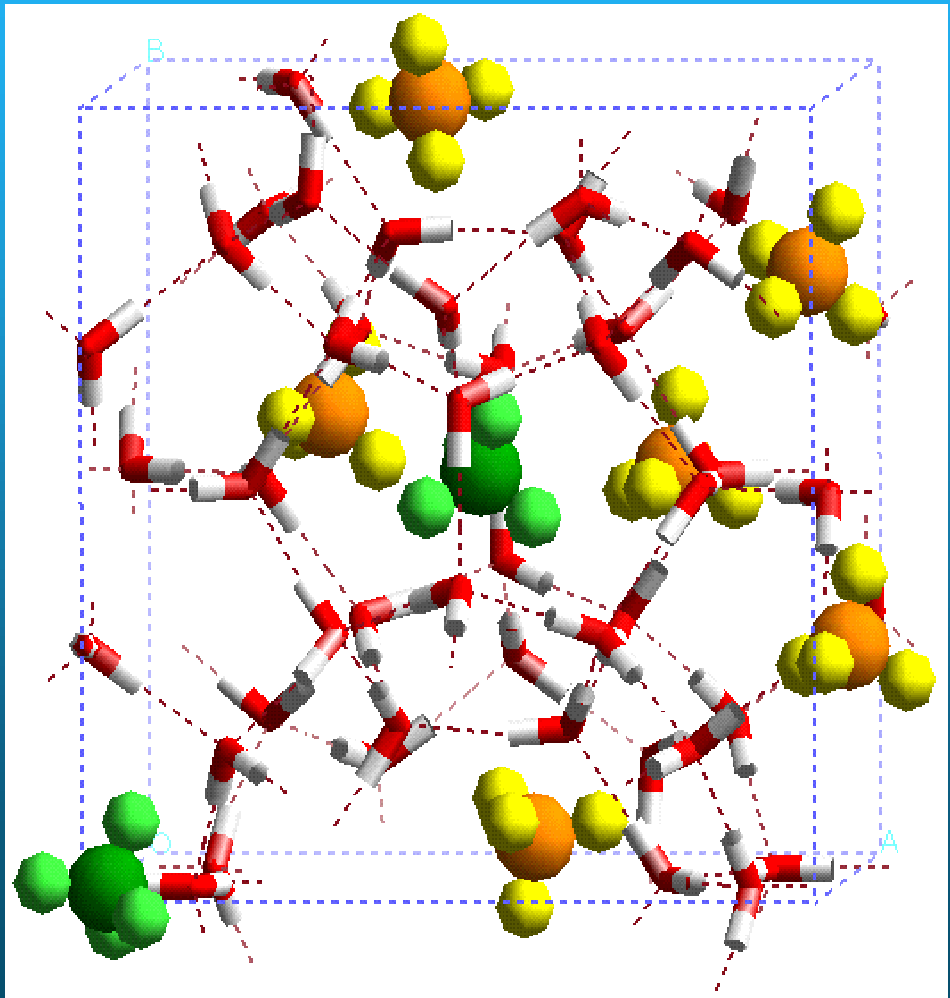
Clathrates, new gas hydrate fuel from the ocean





- Most hydrocarbons are locked in water cages at the bottom of the oceans
- These gas hydrates can be used as fuel
- A closed fuel cycle – extraction of methane and storage of CO2 in the deep ocean
- Neutrons are needed to learn more about these strange “clathrates”

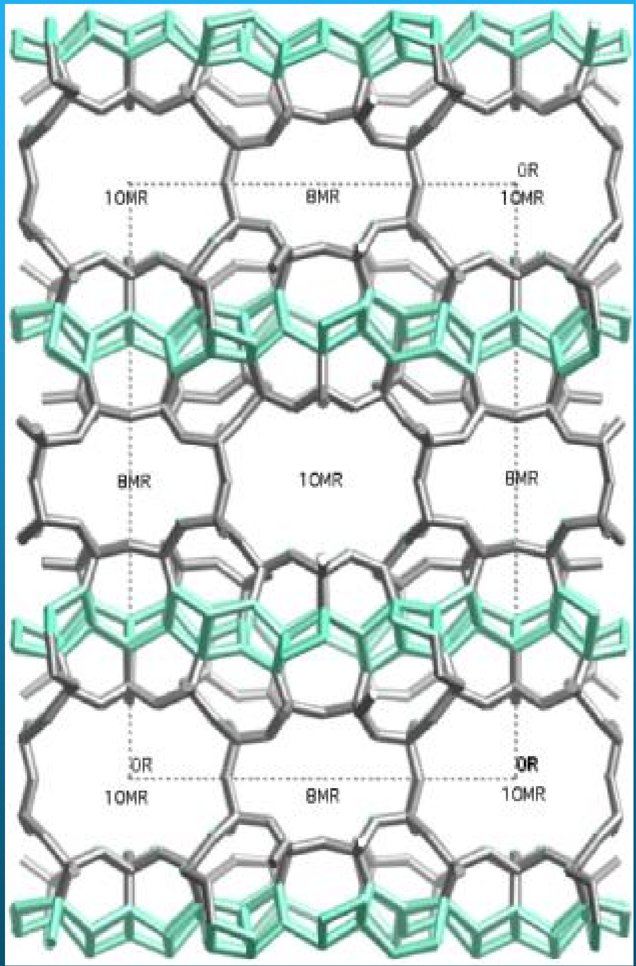
Clathrates, new gas hydrate fuel from the ocean



- Clathrates consist of molecular cages that can trap methane (spheres)
- Neutrons are important – they scatter strongly from the light methane atoms
- Compressibility was obtained, to help with seismic searches for clathrates

B.Chazallon, A.Klaproth, D.Staykova, W.Kuhs (Göttingen), John Finney (UC London)

Molecular sieves and ion exchangers



- Ion exchangers can remove toxic metals from the environment
- New types of zeolite ion-exchangers are needed to trap specific elements
- Neutrons and synchrotron radiation are used to understand ion exchange
- RUB29, a new lithium zeolite for cleaning up radioactive caesium

J.B.Parise, S-H.Park, A.Tripathi, T.Nenoff, M.Nymann (SUNY & SANDIA)

EPSRC finances very large 2D-Detector for D19

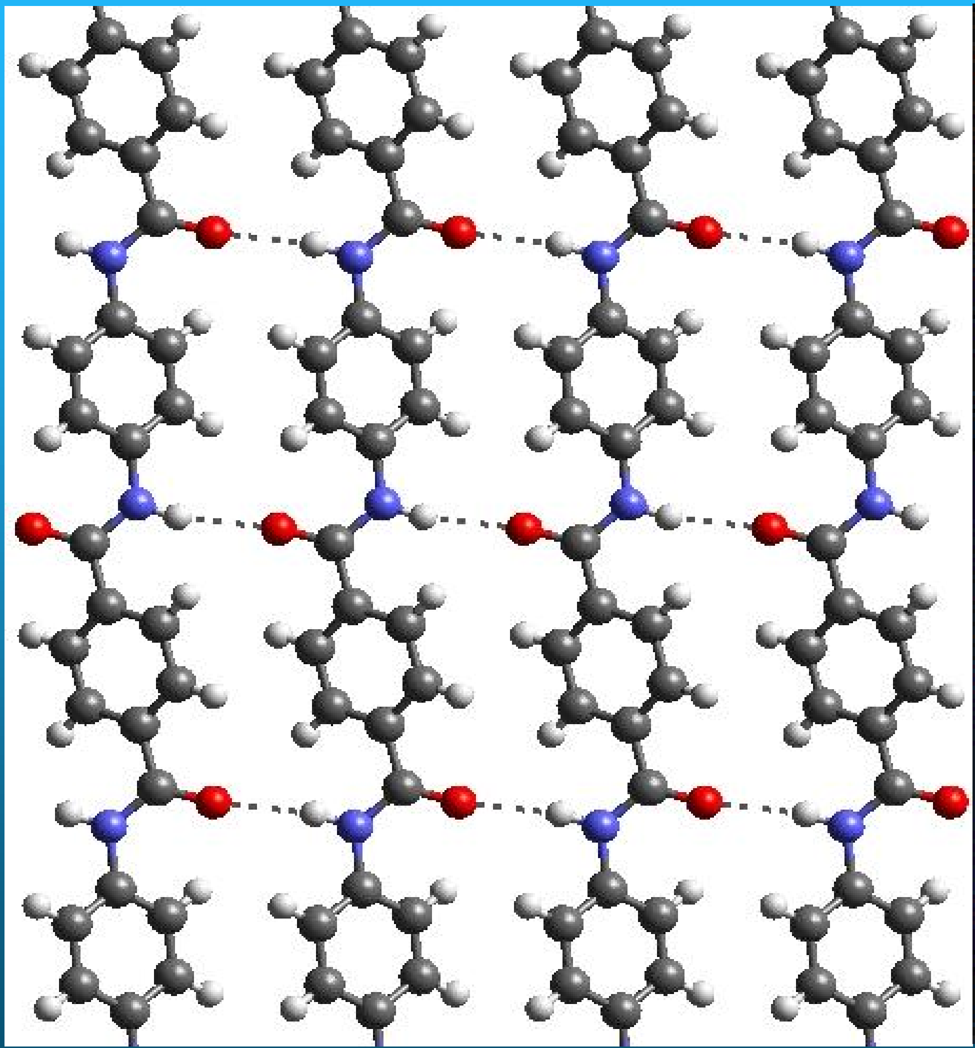
...with Judith Howard

...and Jason Green, EPSRC

T. Forsyth, S. Mason (Keel & ILL)

Neutrons and Hydrogen - Fibres

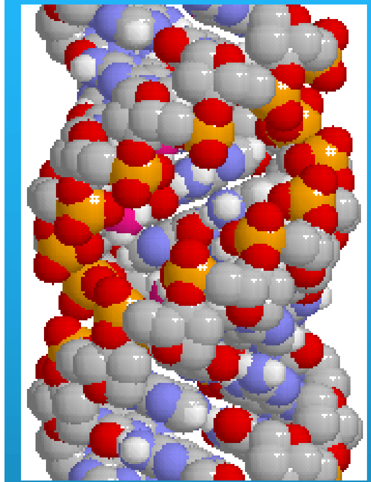
Trevor Forsyth (Keel & ILL)



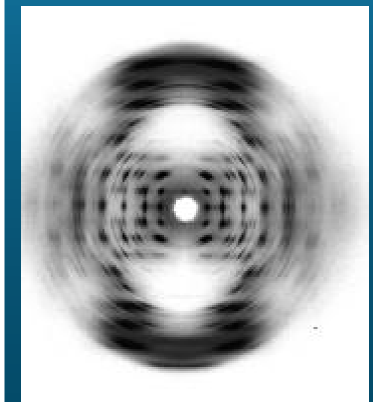
Polymer KEVLAR crystallises in hydrogen bonded sheets

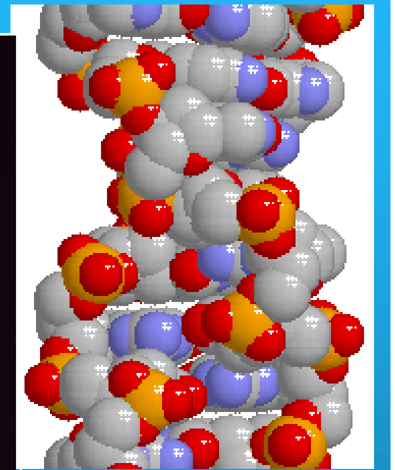
Neutrons, Water & Life – DNA

Trevor Forsyth (Keel & ILL)

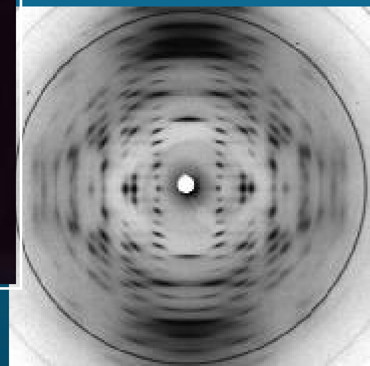


A-DNA
RH
11 bp/turn
pitch=28.2Å

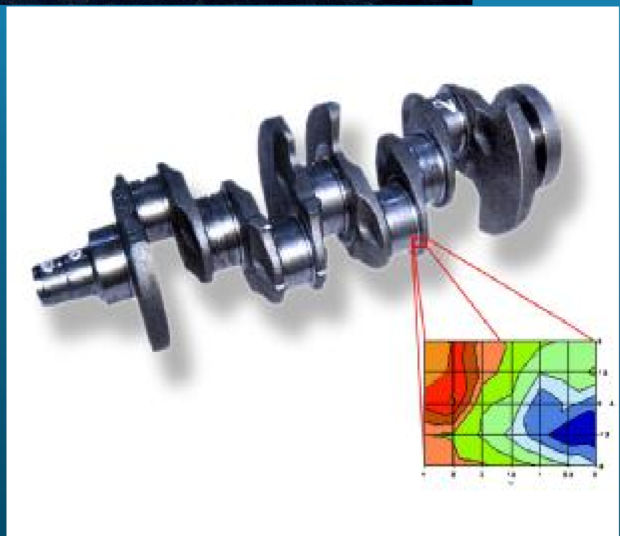




Z-DNA
LH
12 bp/turn
pitch=43Å



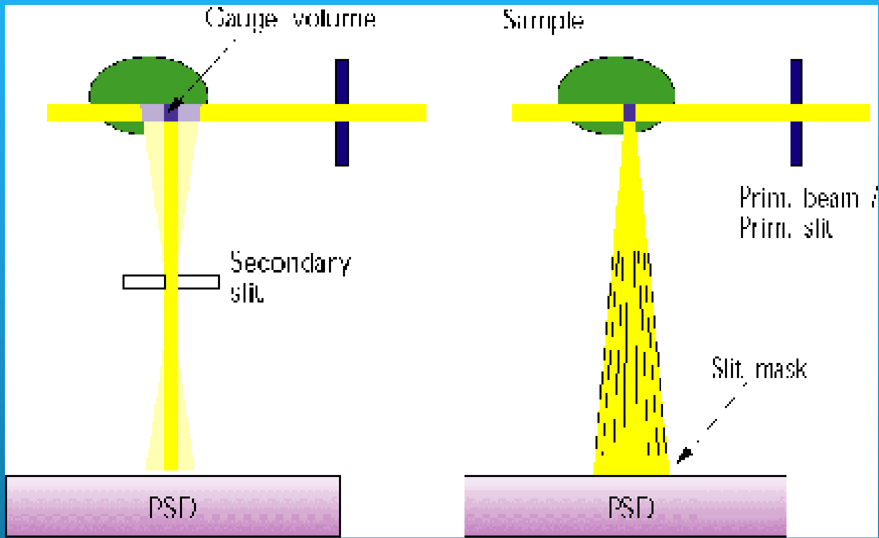
Measuring stresses deep inside engineering components



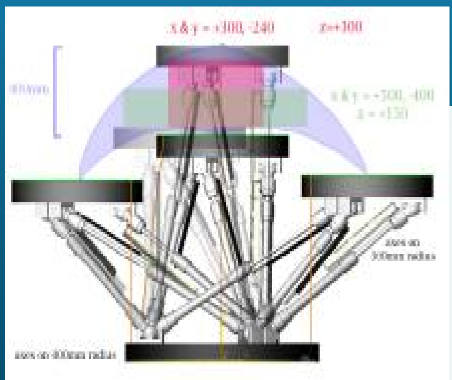
- Tensile stress can produce cracks
- Compressive stress toughens materials
- Neutrons can penetrate deep inside materials (~10cm) and measure stress by changes in atom spacings
- The compressive stress (blue) deep inside a VW crankshaft
- Design of stronger, lighter engines

T. Pirling, G. Bruno (ILL & Manchester)

Measuring stresses deep inside engineering components



- The neutron beam is collimated to a 1mm^3 "gauge volume" of measurement
- The scattered peak is measured on a position-sensitive detector (PSD)
- Small shifts in peak positions map the strain as the sample is scanned

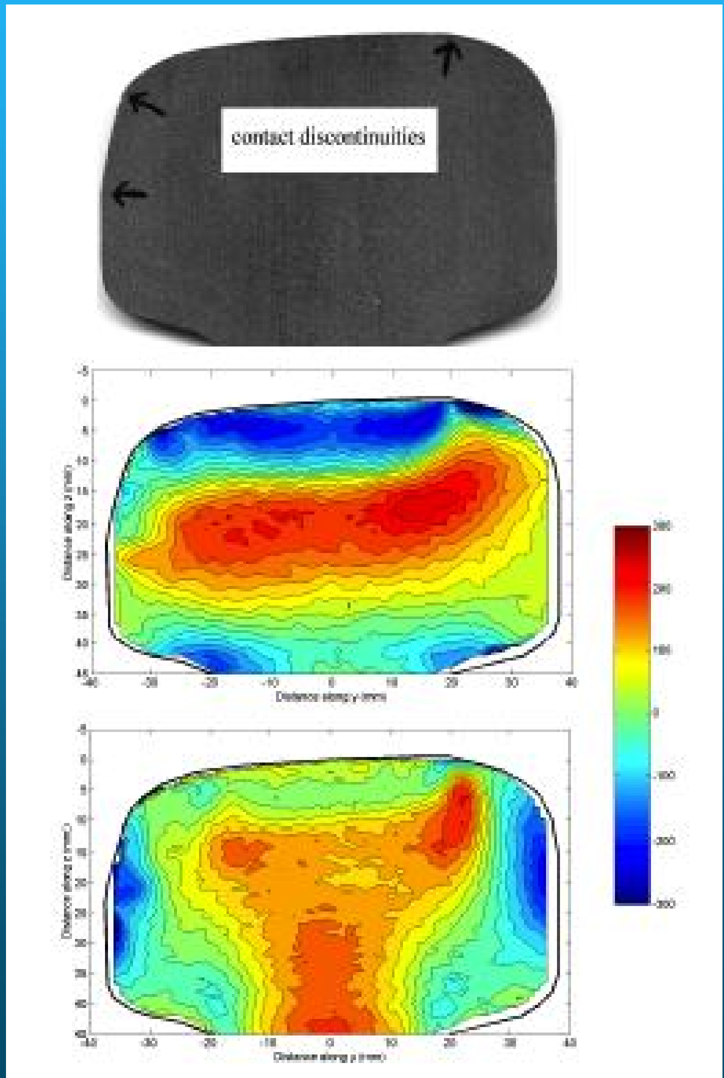


- Very large engineering components (1 tonne) can be scanned using a "hexapod" platform (similar to the platform of an aircraft flight simulator)

T. Pirling, G. Bruno (ILL & Manchester)

Giovanna, ILL Hexapod Model & British Rail

Map internal stress deep inside engineering components



The Future ? While Waiting for ESS

SNS
A U.S. Department of Energy multilaboratory project
Spallation Neutron Source

KENS
Institute of Materials Structure Science
High Energy Accelerator Research Organization
Neutron Science Laboratory (KE

ess
european
spallation
source

高エネルギー加速器研究機構物質構造科学研究所
中性子科学研究施設

ansto Replacement Research Reactor

Can we compete with the USA & Japan ?

Can we compete with the USA & Japan ?

Comparison of future US Neutron Sources

Shelter Island Workshop, N.Y.

Nuclear Instruments and Methods in Physics Research B12 (1985) 525-561

Efficiency for a given resolution = time averaged flux on sample
* sample volume
* detector solid angle

The European reactor ILL will still produce more neutrons
- on the sample !

But we need very big detectors – success of CCLRC-ISIS

Can we compete with the USA & Japan ?

Comparison of future US Neutron Sources

Shelter Island Workshop, N.Y.

Nuclear Instruments and Methods in Physics Research B12 (1985) 525-561

	D20	DRACULA	SNS
time averaged sample flux	$5x10^7$	$\sim10^8$	$\sim2.5x10^7$
detector solid angle	0.27 sr	1.5 sr*	3.0 sr
efficiency	1.7	18	9

* Based on D19 detector: R=760 mm, h=400 mm, 800 resistive wires covering 30ºx160º

We can do twice as well as the Americans, but…

A x5 bigger detector is needed for DRACULA

Already developed for the EPSRC-D19 project !

Can we already provide better service ?

14 news Research Europe, 5 February 2004

uk

UK scientists feel excluded from large research facilities

British scientists feel they are losing out to their colleagues from overseas in the use they get from the UK's large research facilities. They claim that they are failing to get the grants they need to use the facilities, and that there is confusion over which research council should fund their activities. The councils maintain that there is no problem, and that British researchers are holding their own against international competitors.

The complaint concerns the facilities run by the Council for the Central Laboratory for the Research Councils. Until April 2003, access and funding was a matter for the Engineering and Physical Sciences Research Council. However, after that date responsibility was split. CCRLC is now in charge of access to facilities, and their maintenance and development. EPSRC continues to pay for project costs, such as postgraduate participation or consumables. This transfer in responsibilities meant roughly £50 million (73m euros) moving from EPSRC's budget to CCLRC, including around £16m from EPSRC's physics programme budget.

UK researchers are unwilling to go on the record to criticise the guardians of the facilities they need for their work, but are growing increasingly vocal in private. They describe this divided situation as "crazy", "untenable" and "really messy". In particular, they say that while access to facilities is easier, it is increasingly hard for them cover the cost of the research itself.

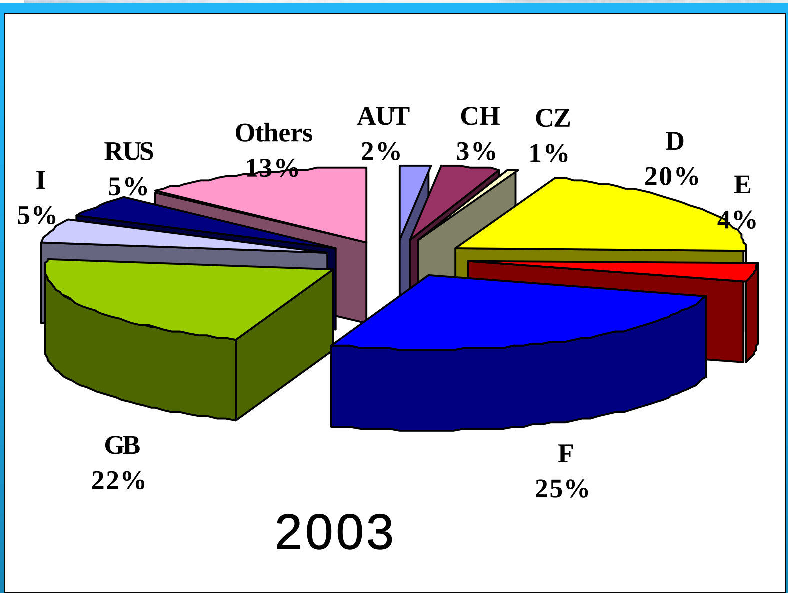
Some point
cations to EPS
fer has left the
to use [the fac
their work thr
reduced to lit

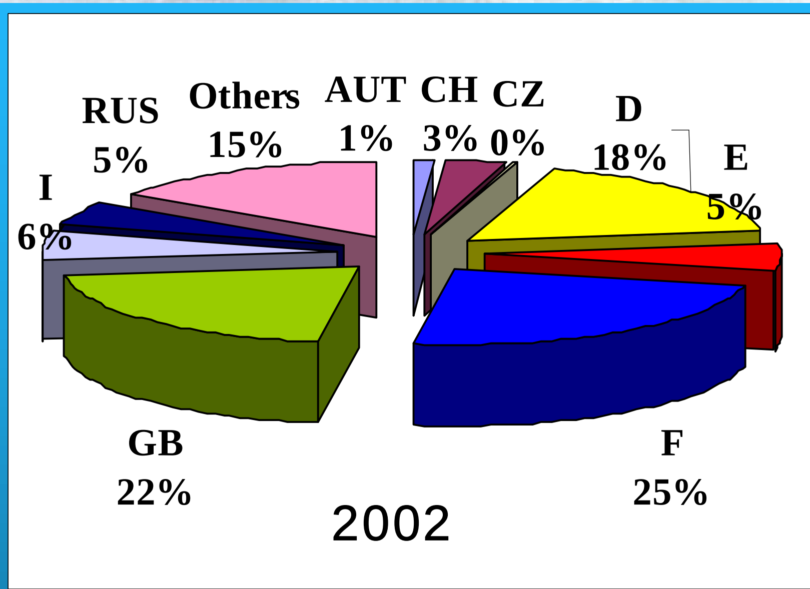
EPSRC says
changed but i
Jane Nichols
"Although th
[researchers]
[their] costs,

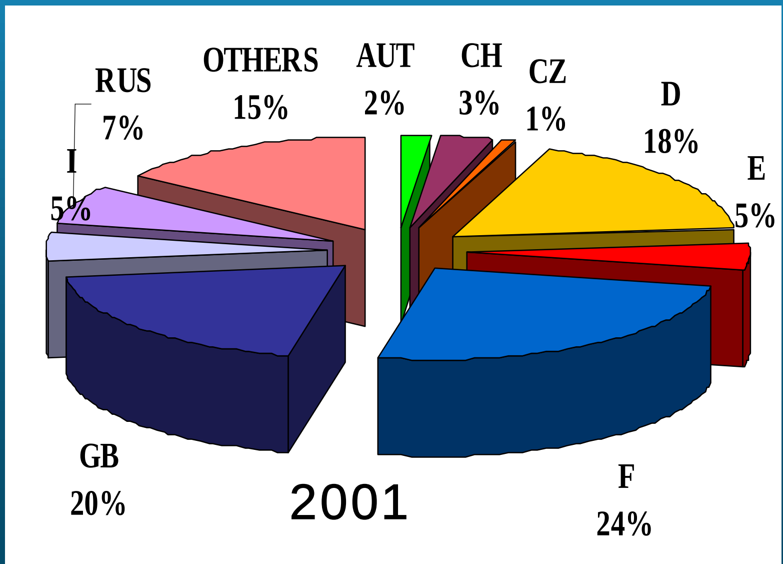
While not
funds, Nichol
other EPSRC research programme area. "We're aware that it's competitive to gain funding for physics research at the moment, but it's competitive across the whole activity that we support to gain funding and the level of competitiveness is not different in different areas. It's all about demonstrating the quality of work that you're doing in a competitive environment," she said.

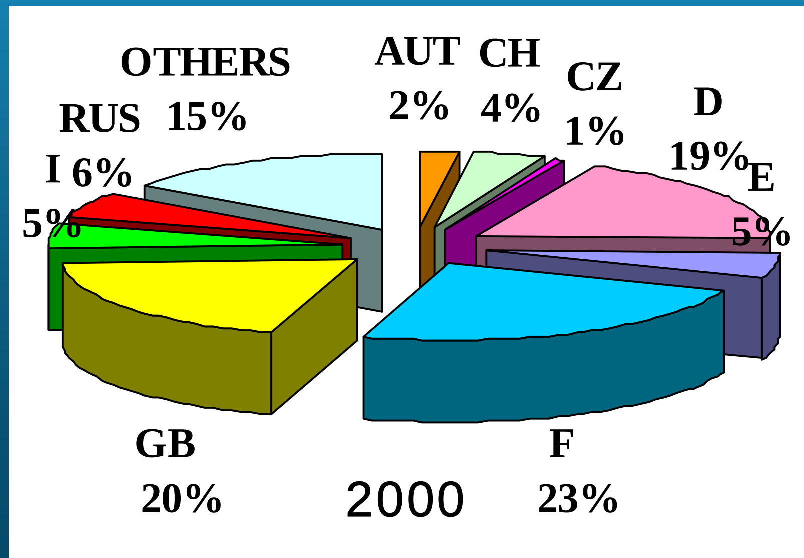
British scientists feel that they are losing out to their colleagues from overseas in the use they get from the UK's large research facilities.

Use of ILL is shared fairly – GB=D=F









ILL-CRGs (Collaborating Research Groups) French, German, Italian… but no UK-CRGs

D1B	**powder diffractometer**	**CRG-A**	**French-Spanish**
IN13	**backscattering spectrometer**	**CRG-A**	**Italian**
ADAM	**reflectometer**	**CRG-B**	**German**
BRISP	**Brillouin spectrometer**	**CRG-B**	**Italian**
D15	**single-crystal diffractometer**	**CRG-B**	**French**
D23	**single-crystal diffractometer**	**CRG-B**	**French**
EVA	**reflectometer**	**CRG-B**	**German**
IN12	**three-axis spectrometer**	**CRG-B**	**German**
IN22	**three-axis spectrometer**	**CRG-B**	**French**
S18	**interferometer**	**CRG-C**	**Austrian**
BRITTAX	**two-axis materials diffractometer**	**CRG-B**	**British ???**

BRITTAX

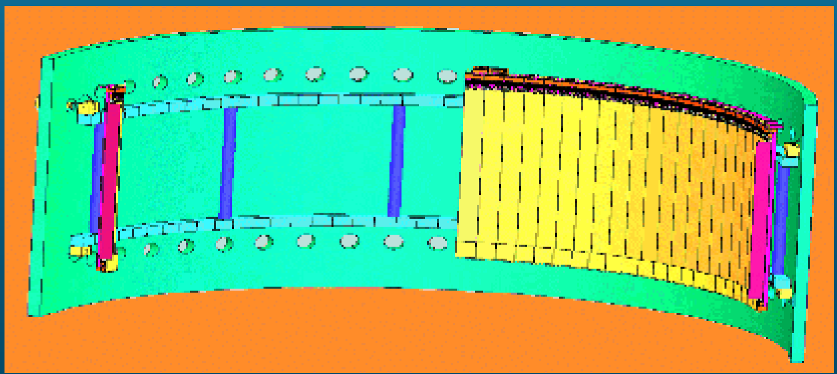
BRITish Two-AXis CRG proposal

A Proposal for a UK-CRG High Flux Diffractometer on the D1A position
See: http://icsd.ill.fr/uk-crg/

Consortium of 12 UK University Groups

We propose to capitalise on the new techniques for detectors and neutron optics, developed with recent EPSRC investment in ILL projects, to provide a unique high flux CRG diffractometer in the present D1A position.

This new CRG diffractometer will be comparable to D20 for flux, and to D1A for resolution but will also be used like D19 for single crystals.

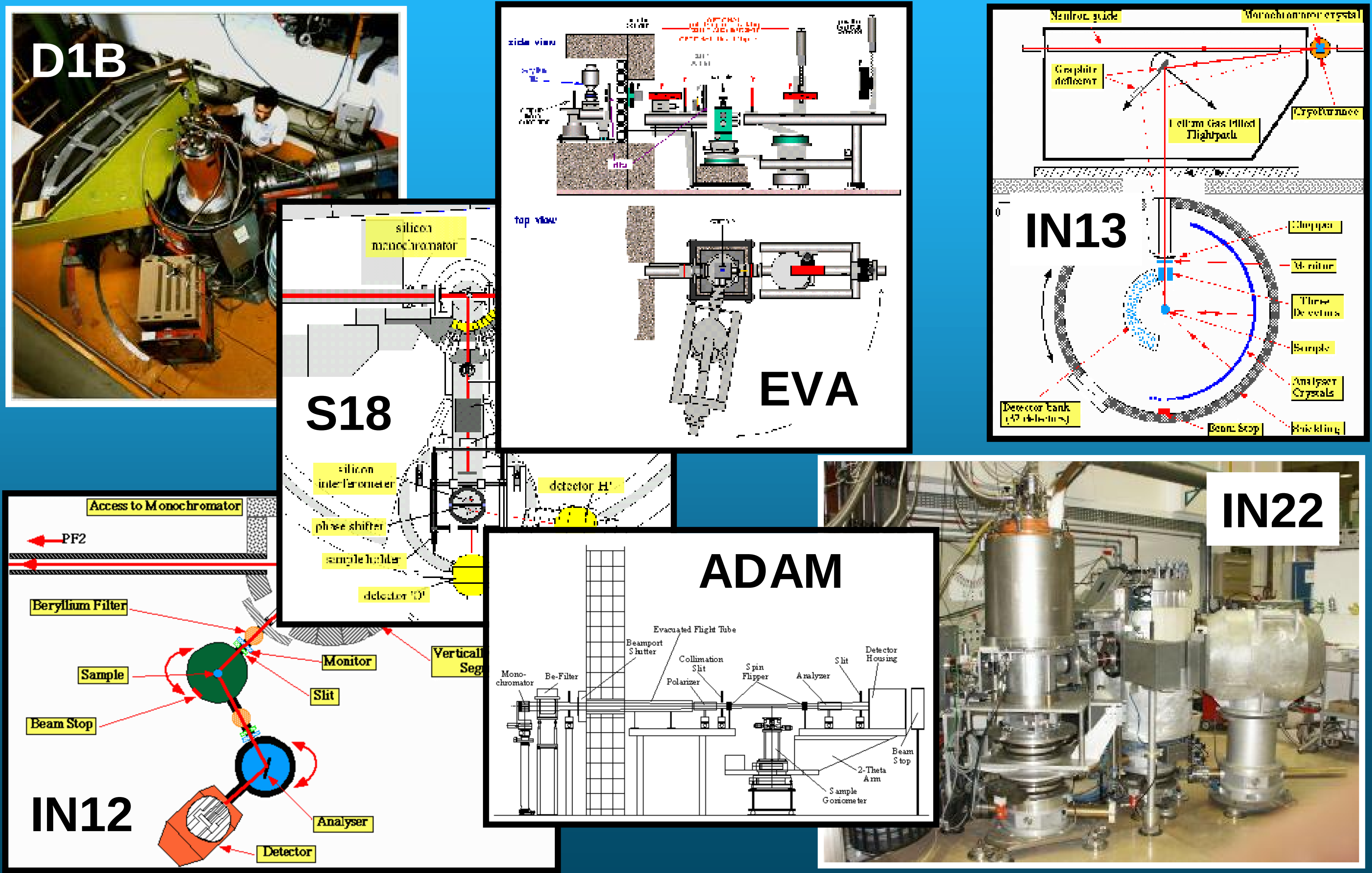


	D20	GEM	BRITTAX
time averaged flux (f)	$5x10^7$	$\sim 2x10^6$	$\sim 10^7$
detector (sr)	0.27	4.0	1.0
efficiency (f*sr)	1.7	1	1.2

Materials Problems to be addressed

- High Pressure Synthesised Materials
- High Pressure/Temperature Behaviour of Minerals
- Novel Ferromagnetic and Intermediate Valence
- Small Samples of Mixed Metal Oxides
- Transition Metal Oxides, Fluorides and Sulphides
- Structural Studies of Relaxor Ferroelectrics
- Magnetism and Polarised Neutron Diffraction
- Functional Organic Materials
- Molecular Compounds with Pharmaceutical & Photo-Optical Applications.
- Small Single Crystals & Weakly Diffracting Samples

ILL-CRGs (Collaborating Research Groups) French, German, Italian… but no UK-CRGs



Large new Italian CRG at ILL (BRISP)

Grenoble France

- World's most intense neutron source
- ~300 staff
- ~1250 visiting scientists each year
- ~500 scientific papers each year
- physics, chemistry, biology, materials

ILL member countries are shown in green

Neutrons see light atoms – eg hydrocarbons

X-ray

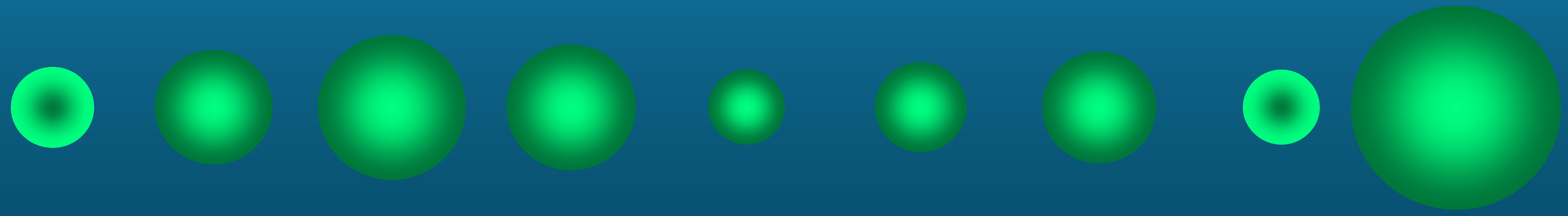
Scattering proportional to Z

Neutron

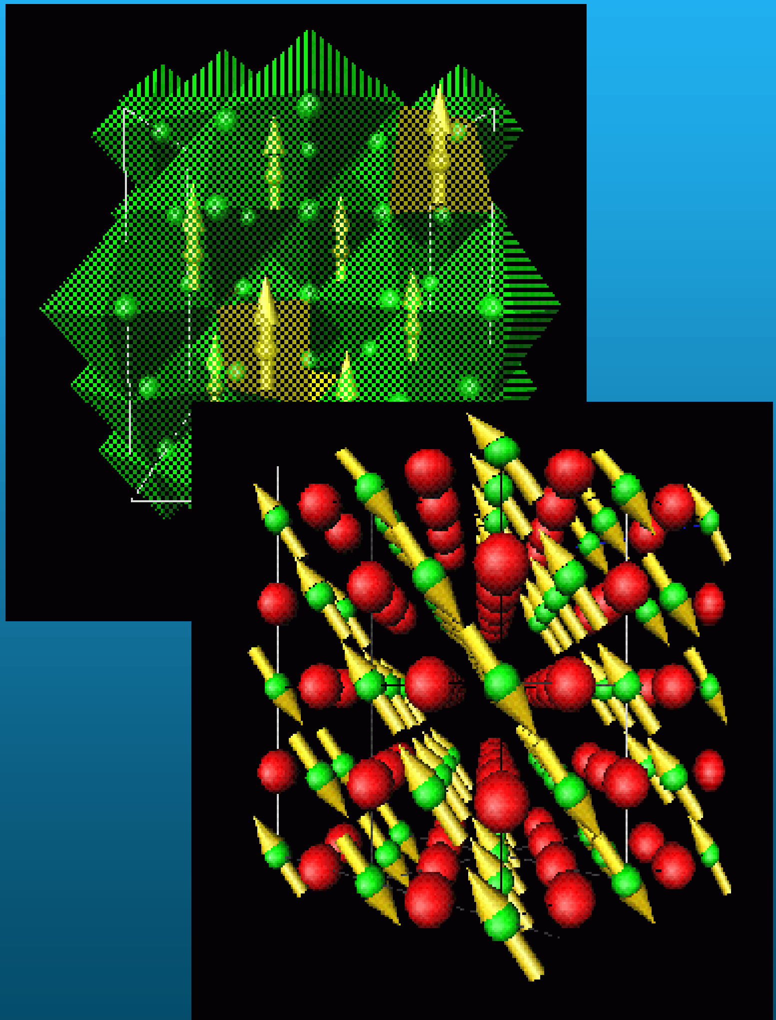
Scattering not proportional to Z

H	B	C	O	Al	Si	P	Ti	Fe
1	3	4	8	13	14	15	22	26

-3.74	5.30	6.65	5.80	3.45	4.15	5.13	-3.44	9.45



Neutrons can study magnetic materials



- Neutrons act like tiny magnets
- Interact with atomic magnetic moments
- Neutrons determine magnetic structures
- Ferromagnetic magnetite Fe_3O_4 (top)
- Antiferromagnetic manganese oxide MnO

Applications of D2B

Potential Applications of HiTc superconductors

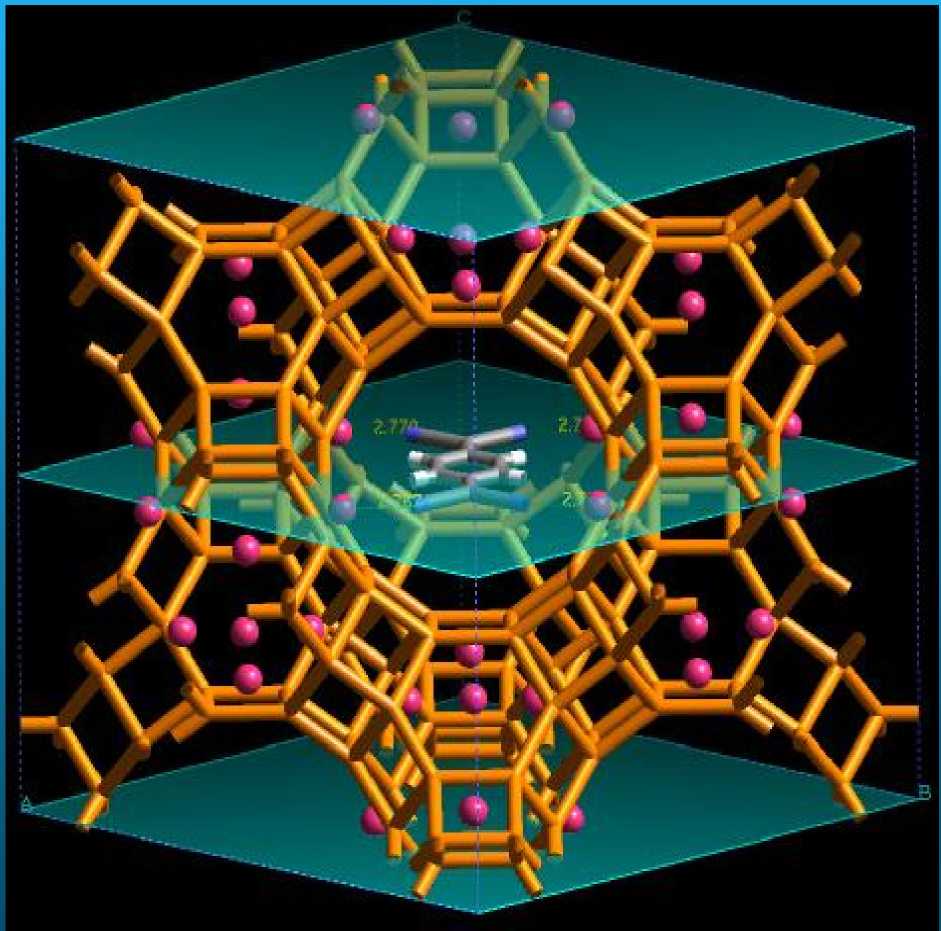
- New magnets for medical scanners & research
- Sensitive magnetometers for mapping
- Fast connections in computer microchips
- Linear motors for high speed maglev trains

Potential Hydrogen storage materials

- Hydrogen is the ideal fuel
- It can be obtained from water
- It is light & doesn't pollute !
- But - explosive & difficult to store
- A new material to store hydrogen ?
- A Swiss hydrogen fueled bus. Solar electricity is used to obtain hydrogen

K. Yvon (Geneva)

New zeolites to catalyse petro-chemical reactions



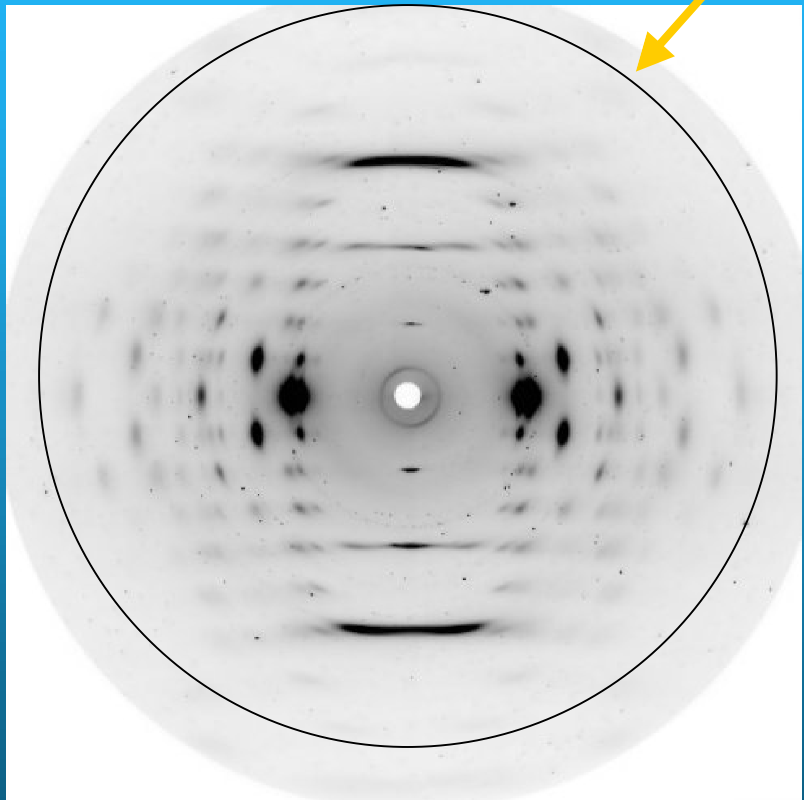
- Zeolites are very important in industry as catalysts for petro-chemicals etc
- Neutrons are used to understand how light hydrocarbon molecules interact
- Neutrons can also distinguish between silicon and aluminium in the framework
- A small organic molecule trapped inside the pore of NaY-zeolite.

C. Baehtz, H. Fuess (Darmstadt)

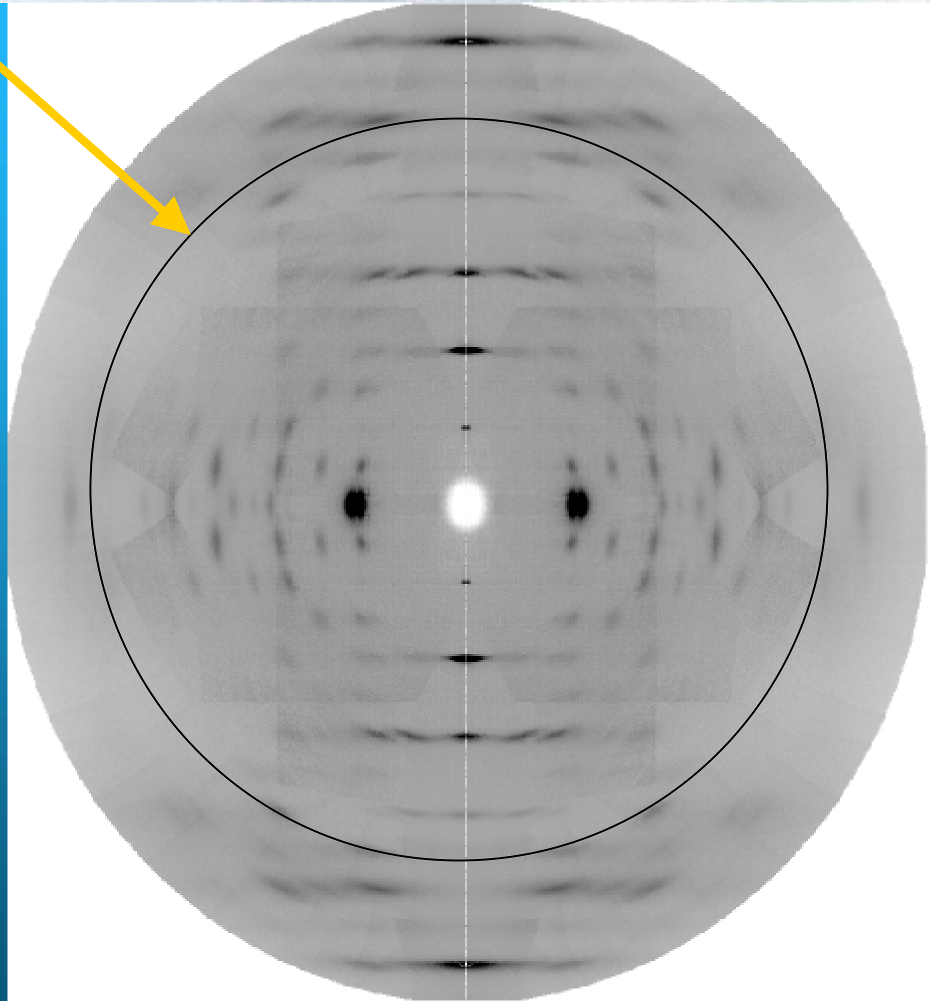
Neutrons and Hydrogen - Fibres

Trevor Forsyth (Keel & ILL)

1.4Å

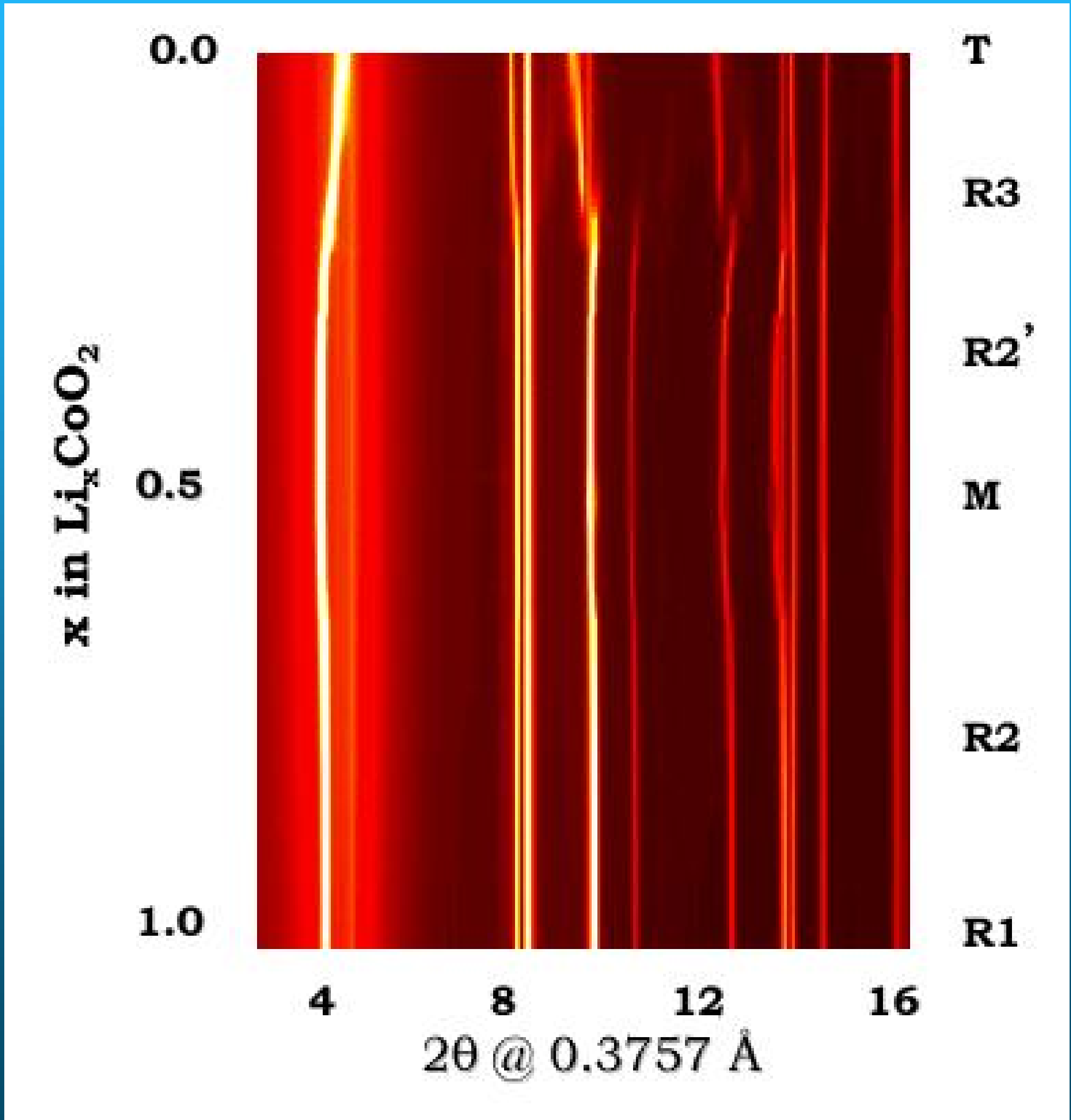


Kevla, x-ray data from APS
λ=0.8Å



Kevla, neutron data from ILL
λ=1.31Å

Applications of large fast detectors



ESRF X-ray diffraction from a Li_xCoO_2 battery

The letters to the right show different phases as a function of Li-content x

Self-Propagating Synthesis - ESRF Synchrotron Radiation