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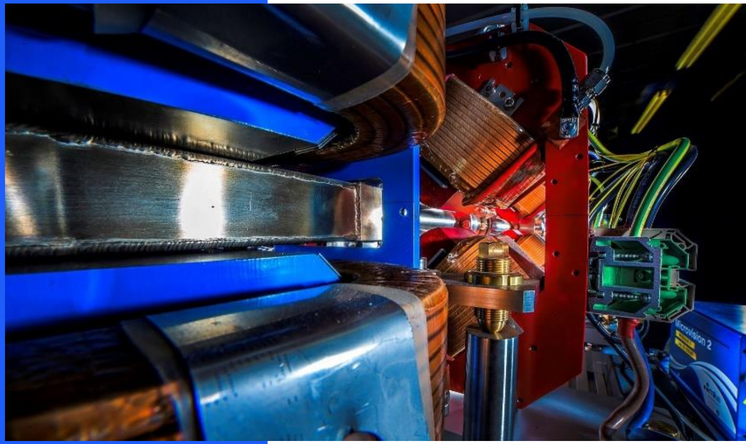
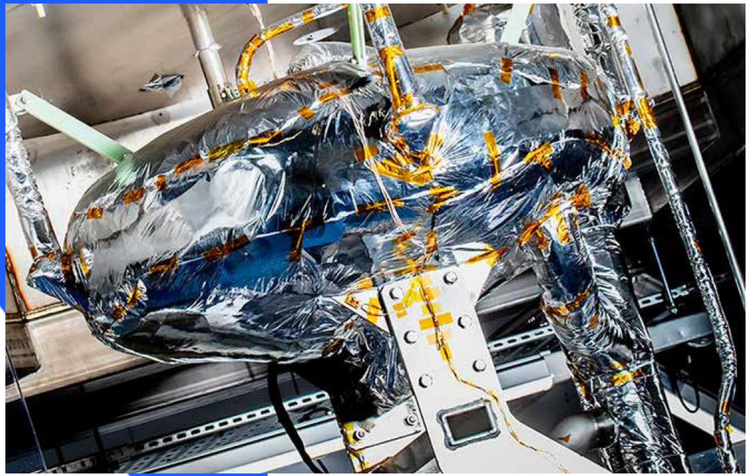
Making a brighter future through advanced accelerators

History of the SRS

Jim Clarke
Director of ASTeC
STFC Daresbury Laboratory

7th March 2023

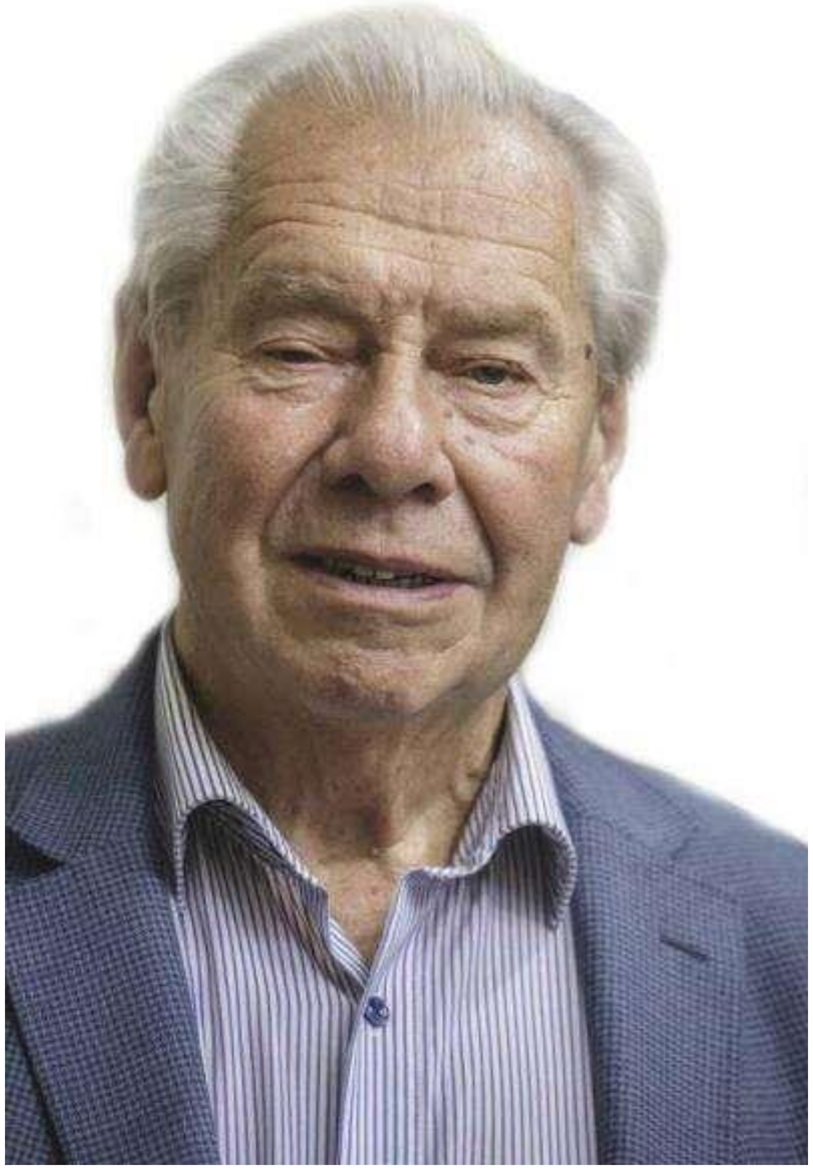




IOP Institute of Physics

Dedication to Ian Munro

- As you will hear, the story of the SRS revolves around one particular person – Ian Munro
- Sadly, he passed away in 2022
- I'd like to dedicate this lecture to Ian and publicly acknowledge his enormous contribution to synchrotron science and to Daresbury Laboratory



Ian was an Honorary Fellow of the IoP *For world recognised leadership in synchrotron radiation research and development.*
An Honorary Fellowship is the highest accolade presented by the IoP to reflect an individual's exceptional services to physics.

First a bit history and background to Daresbury Laboratory

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Approval for the Electron Laboratory

- The Minister for Science, Lord Hailsham, gave the approval for the establishment of Daresbury Laboratory to Chairman of the Governing Body of NIRNS (National Institute for Research in Nuclear Science), Lord Bridges, on 13th July 1962
- This was only financially possible by limiting the rate of growth in the CERN budget – "**On the basis of the Cockcroft report…**"

The letter from the Minister for Science, dated 13th July, 1962 is copied below:

OFFICE OF THE MINISTER FOR SCIENCE,
2, Richmond Terrace,
Whitehall, London, S.W.1.

13th July, 1962

My dear Bridges,

I am glad to be able, at last, to give authority to go-ahead with the NIRNS Electron Laboratory, subject to the conditions set out below.

On the basis of the Cockcroft report, I have agreed with the Chief Secretary that we will do our best to limit the rate of growth in CERN to 12% in 1963/64, and to 10% in each of the two following years, and that a rate of growth of 2% per annum from the present level will be applied over the next five years to our support through NIRNS and DSIR grants for currently approved schemes for research in nuclear physics. Expenditure on Atlas is not included for this purpose. I have decided that the limit of not more than 2% per annum shall apply separately to NIRNS and to DSIR grants in this field. My agreement to this is on the understanding that these limits are on the basis of current prices, that it will be permissible to seek additional funds if there is a major new scientific development not foreseen when the programme was planned, and that we leave open the question whether we will be able to afford the new projects for which a sum of £800,000 is allowed in the NIRNS forecast for 1967/68.

The way is therefore clear for NIRNS to go ahead with the Electron Laboratory, provided this is done within the limits of the 2% per annum rate of growth. I understand that this should allow to NIRNS sums within the margin of estimating error of the revised estimates you have already accepted, except for 1967/68, and that the excess over a 2% increase in that year is entirely on account of projects not currently approved.

Yours :

(signed by Lord Hailsham)

The Rt. Hon. Lord Bridges, G.C.B., G.C.V.O., M.C.,
Goodmans Furze,
Headley,
Epsom.

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Daresbury Laboratory
60 years 1962-2022

An Aside: The Role of John Cockcroft

- Cockcroft served on the Board of NIRNS from when it was established until it was absorbed into the Science Research Council in 1965
- "Largely on his advice, but with the support of most of the high energy physicists in the country, a decision was taken in 1957 to create the Rutherford High Energy Laboratory adjacent to the Harwell site. The 7 GeV proton synchrotron, Nimrod, was chosen for the laboratory, from designs already prepared by accelerator specialists at Harwell."
- "Throughout this time he was Chairman of the NIRNS Physics Committee, which was the main channel of external scientific advice to the Institute and the laboratory and, for example, generated and guided the proposals which led to the foundation of the second national high energy physics laboratory at Daresbury, in 1962."
- "He continued to take a direct interest in the work of these laboratories until his death [in 1967], by chairing consultative meetings of senior physicists and by frequent visits."

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Quotes from Biographical Memoir, MLE Oliphant, https://royalsocietypublishing.org/doi/pdf/10.1098/rsbm.1968.0007

The Electron Laboratory

- Daresbury was established to host a 4 GeV electron synchrotron (upgraded to 5 GeV) – NINA (National Institute Northern Accelerator)
- NINA began operations on 2nd December 1966, remarkable progress considering the team started with a green field only three years earlier
- "In November 1972, the [Science Research] Council decided that, as part of the price for the entry of the United Kingdom into the **SPS** programme at CERN, **NINA should be closed** within about five years." – Closedown of NINA, Alick Ashmore (Director of DL), CERN Courier Volume 17, Number 4, April 1977 https://cds.cern.ch/record/2064647/files/vol17-issue4-p101-e.pdf

NINA Construction

Feb 1964

Foundations of the ring in the foreground
Steam train in the background !

The circumference of NINA was ~220m
and the rep rate was ~50 Hz

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NINA Construction

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NINA Construction

Each dipole magnet sat on two of these pillars

Later this solution was bemoaned by the accelerator physicists since the magnets vibrated far more than if they had been installed onto a solid foundation

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NINA Construction

There were 40 dipole magnets, each 11 feet long (!) and weighing 10 tons

https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5178517

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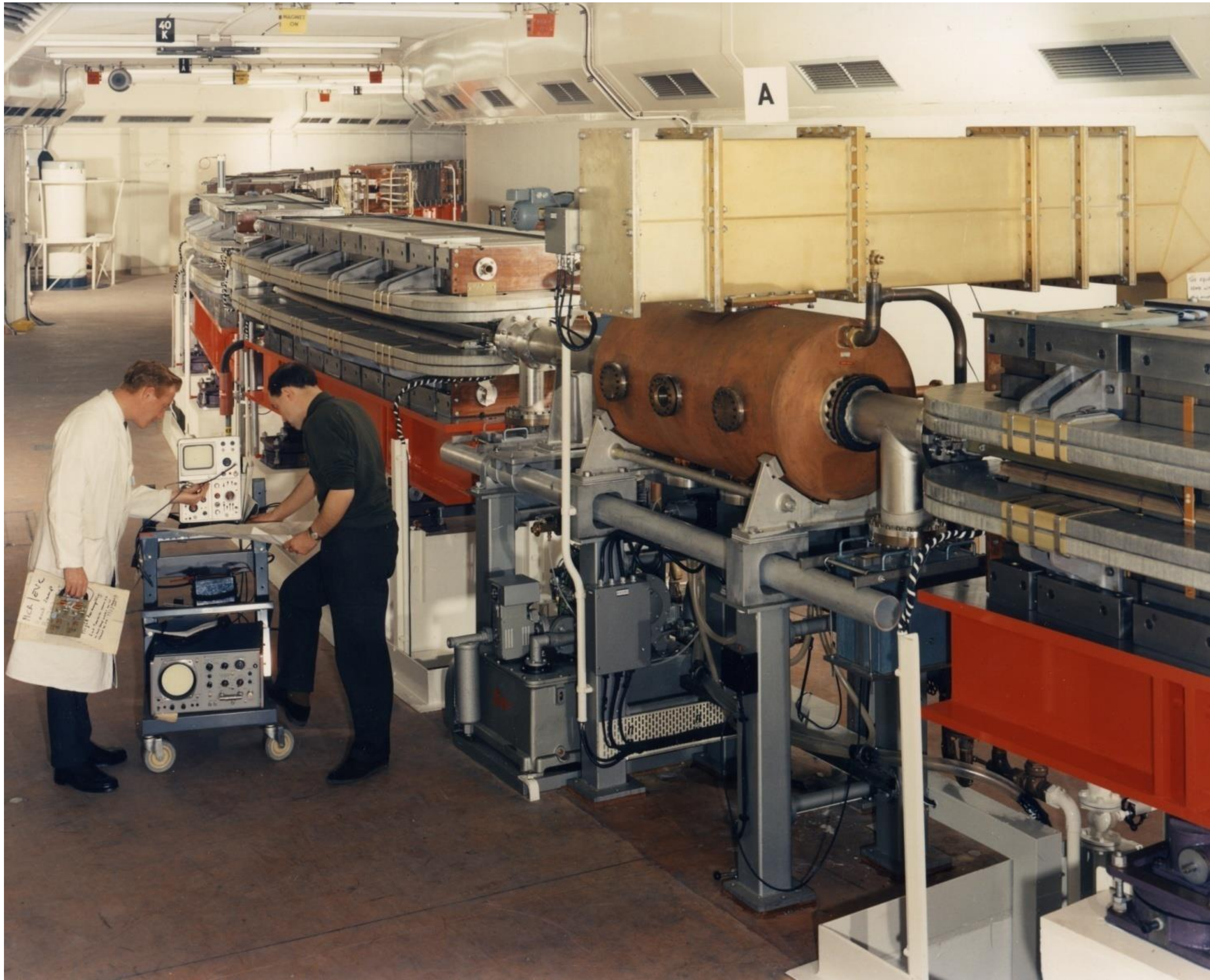
NINA Ring Tunnel

The RF ran at 408 MHz and the circumference was 300 RF cycles



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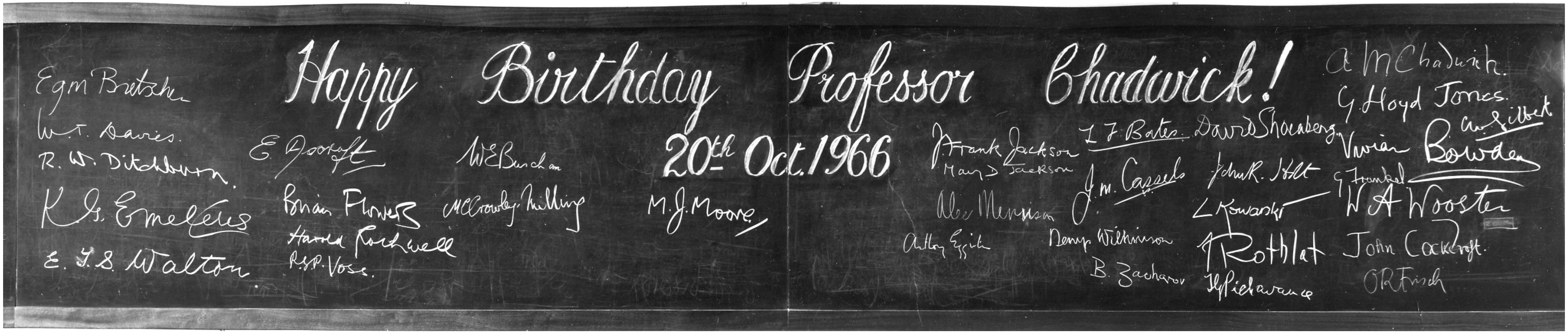

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James Chadwick, Nobel Prize winner for discovery of the neutron, celebrated his 75th birthday at Daresbury in 1966. Also present were John Cockcroft and Ernest Walton, Michael Crowley-Milling, Brian Flowers, Alec Merrison, Denys Wilkinson, John Holt, Joseph Rotblat, Egon Bretscher, Thomas Pickavance, and Otto Frisch amongst others!

An approach from Ian Munro to Alec Merrison

Ian Munro, lecturer at Manchester University, contacted the Daresbury Lab Director about making use of the synchrotron radiation from NINA even before NINA was operational

The letter was primarily to set-up a visit of the Manchester Branch of the IoP to DL

Note that the letter was sent to Merrison at Liverpool where he still had a position in the Physics Department

Atomic & Molecular Physics Group,
THE PHYSICAL LABORATORIES,
THE UNIVERSITY,
MANCHESTER, 13.
5th January, 1966.

Professor A. W. Merrison,
Department of Physics,
University of Liverpool,
LIVERPOOL.

Dear Professor Merrison,

I am writing on behalf of our Branch Committee, to ask you whether it would be possible for the Manchester Branch to hold their 1966 Summer visit at the Daresbury accelerator laboratories. Several of our Branch members have expressed interest in the accelerator and the work being carried out in the laboratories.

We have normally held our visits in July, but, of course, we would come at any time convenient for the laboratory staff. It has been suggested that there might be more to see if the visit were to be held on a day when the machine is shut down for maintenance. Would this be possible?

If you feel our visit will not cause much inconvenience, perhaps you could let me know what day, or days, would be suitable for the visit.

On a topic quite unconnected with the Institute of Physics— in the Molecular Physics Group here, we are hoping to extend our studies into the vacuum ultraviolet (from 2000 Å to 100 Å) and have some money available for equipment. One problem is to obtain an intense continuous source of radiation for excitation in this region.

Dr. Kanaris (from our Department) told me of some work he had come across when in Hamburg, concerned with the properties of the emission from centripetally accelerated electrons in a synchrotron. It sounds as though such emission might provide an ideal source of excitation for our experiments.

I am still waiting for more details from Dr. Kanaris, and have at present little idea of the experimental problems involved in extracting such emitted radiation from a large accelerator.

However, I thought I would like to write to you now to let you know what we are thinking about, and to ask what you feel about making use of the Daresbury accelerator in this way, if the project should prove feasible. Has anybody else considered a project of this nature?

Yours sincerely,

I.H. Munro

Alec Merrison’s Reply

"My attitude to such work at Daresbury is that if there is good physics in it then I would be very enthusiastic.”

“People have spoken for years about using it but nobody, so far as I know has done anything about it.”

12th January, 1966.

Dear Dr. Munro,

We should be very pleased to see the Manchester Branch in Daresbury in July. If you like to suggest a few days we shall pick one out. We shall of course be very happy to offer you tea and buns.

On synchrotron radiation. There is no doubt that this is an extremely intense source in the region you mention. People have spoken for years about using it but nobody, so far as I know has done anything about it. [illegible]aris will certainly be able to tell you all about it but if you want to calculate yourself all the necessary theory is contained in a paper by Julian Schwinger in Phys. Rev. 75 1912 (1949).

attitude to such work at Daresbury is that if there is good physics in it I would be very enthusiastic.

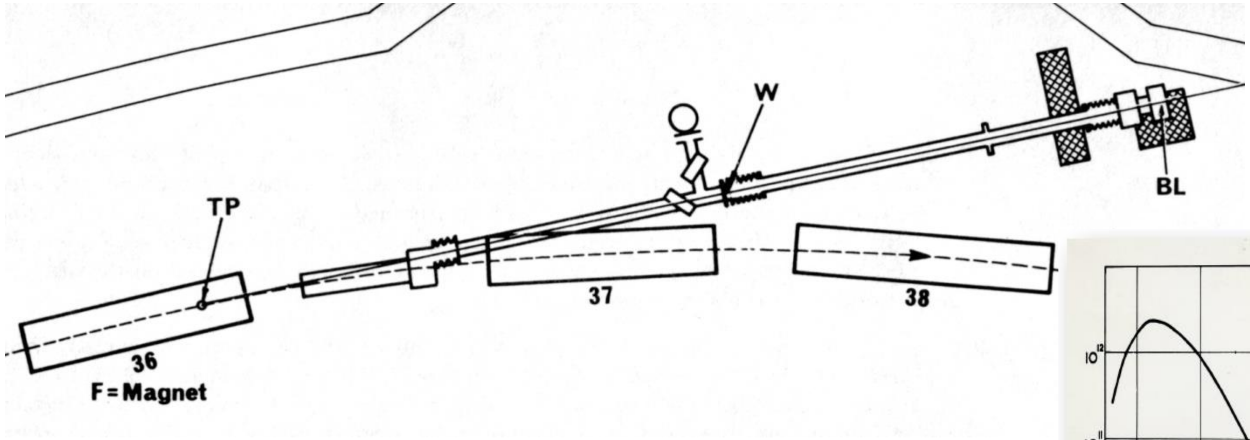
Yours sincerely,

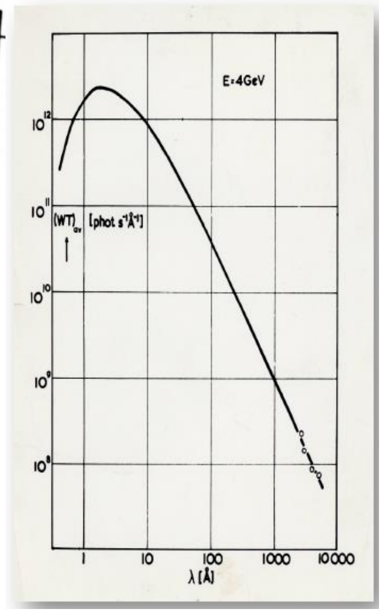
(A. W. MERRISON)

Dr. I. H. Munro,
Atomic & Molecular Physics Group,
The Physical Laboratories,
The University,
MANCHESTER, 13.

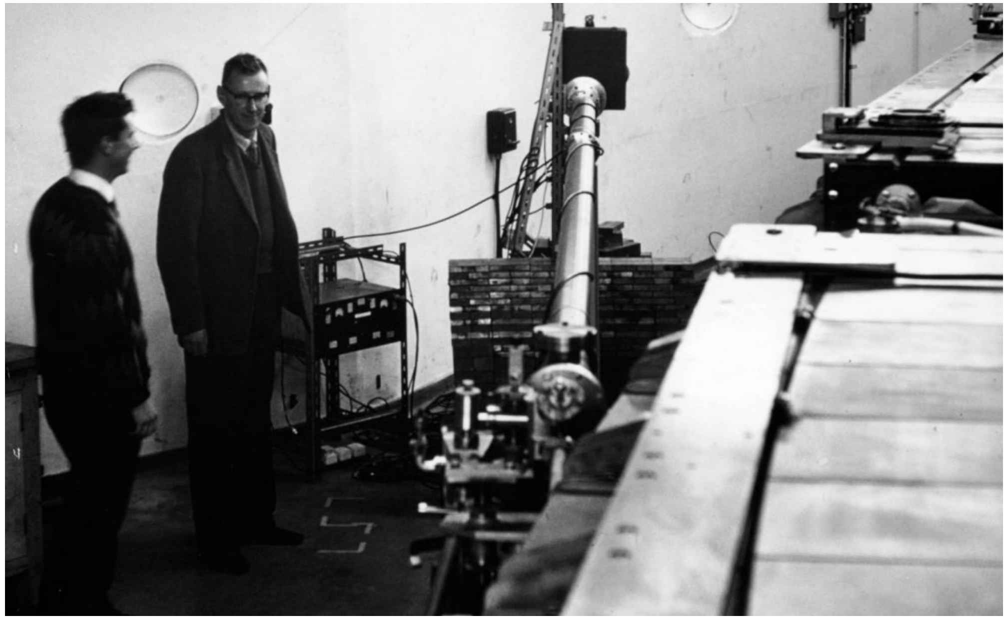
A Test Beamline was first setup to support a grant proposal

"By 1968/9 we felt that sufficient material had been acquired to justify a formal bid to the Science Board in 1970 for sufficient funds to do the job properly. This first beamline would eventually yield the rather sparse spectral data which had laboriously been gathered from NINA and which was combined with calculations on the full spectral potential of NINA if used as an absolute source of radiation, based on the paper by Schwinger."
Ian Munro, The Origins of Synchrotron Radiation research at Daresbury Laboratory, http://www.synchrotron.org.uk/





Ian Munro and Scott Hamilton (Manchester Uni)



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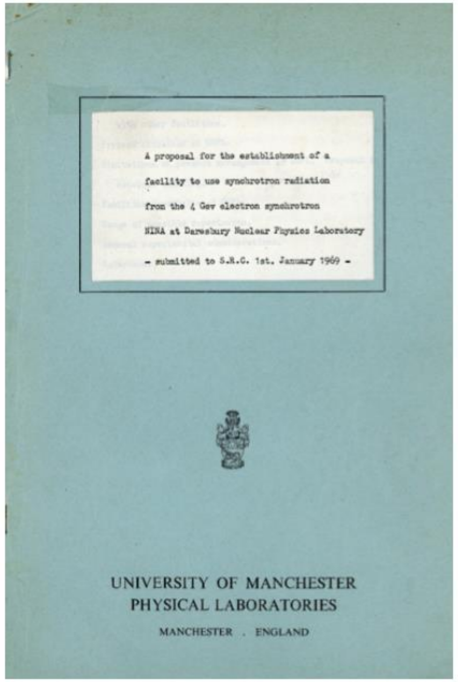
Grant Approval for the SR Facility on NINA

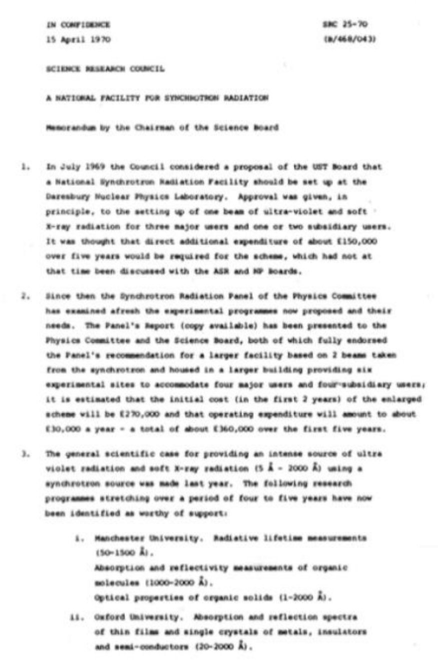
"The application was submitted to the Physics committee of the Science Board in 1969, which in 1970 took the far reaching and rapid decision to support it to the tune of £370k."

"The decision led within three years to the construction of the SRF, a 'First Generation' Synchrotron Radiation Facility on NINA which would go on to produce approximately 100 publications until NINA and therefore the SRF were both finally closed in April 1977"

Ian Munro, The Origins of Synchrotron Radiation research at Daresbury Laboratory, http://www.synchrotron.org.uk/



- The grant was submitted 1st Jan 1969.
- Approval was given in principle in July 1969 for ~£150k over 5 years.
- Formal approval was given April 1970 by which time the scope and budget had increased to ~£360k over 5 years.



IN CONFIDENCE — SRC 25-70
15 April 1970 — (B/468/043)

SCIENCE RESEARCH COUNCIL

A NATIONAL FACILITY FOR SYNCHROTRON RADIATION

Memorandum by the Chairman of the Science Board

1. In July 1969 the Council considered a proposal of the UST Board that a National Synchrotron Radiation Facility should be set up at the Daresbury Nuclear Physics Laboratory. Approval was given, in principle, to the setting up of one beam of ultra-violet and soft X-ray radiation for three major users and one or two subsidiary users. It was thought that direct additional expenditure of about £150,000 over five years would be required for the scheme, which had not at that time been discussed with the ASR and NP Boards.

2. Since then the Synchrotron Radiation Panel of the Physics Committee has examined afresh the experimental programmes now proposed and their needs. The Panel's Report (copy available) has been presented to the Physics Committee and the Science Board, both of which fully endorsed the Panel's recommendation for a larger facility based on 2 beams taken from the synchrotron and housed in a larger building providing six experimental sites to accommodate four major users and four subsidiary users; it is estimated that the initial cost (in the first 2 years) of the enlarged scheme will be £270,000 and that operating expenditure will amount to about £30,000 a year - a total of about £360,000 over the first five years.

3. The general scientific case for providing an intense source of ultra violet radiation and soft X-ray radiation (5 Å - 2000 Å) using a synchrotron source was made last year. The following research programmes stretching over a period of four to five years have now been identified as worthy of support:

   i. Manchester University. Radiative lifetime measurements (50-1500 Å).
   Absorption and reflectivity measurements of organic molecules (1000-2000 Å).
   Optical properties of organic solids (1-2000 Å).

   ii. Oxford University. Absorption and reflection spectra of thin films and single crystals of metals, insulators and semi-conductors (20-2000 Å).

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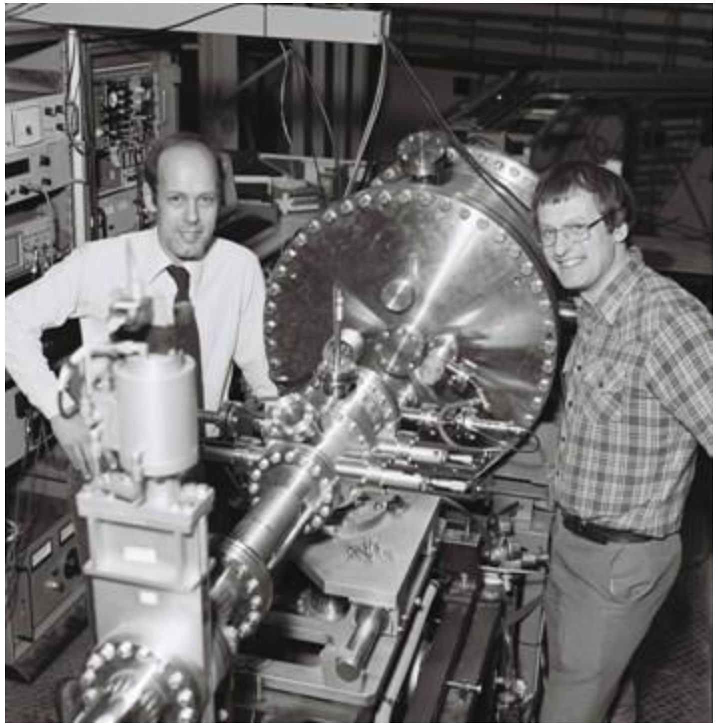
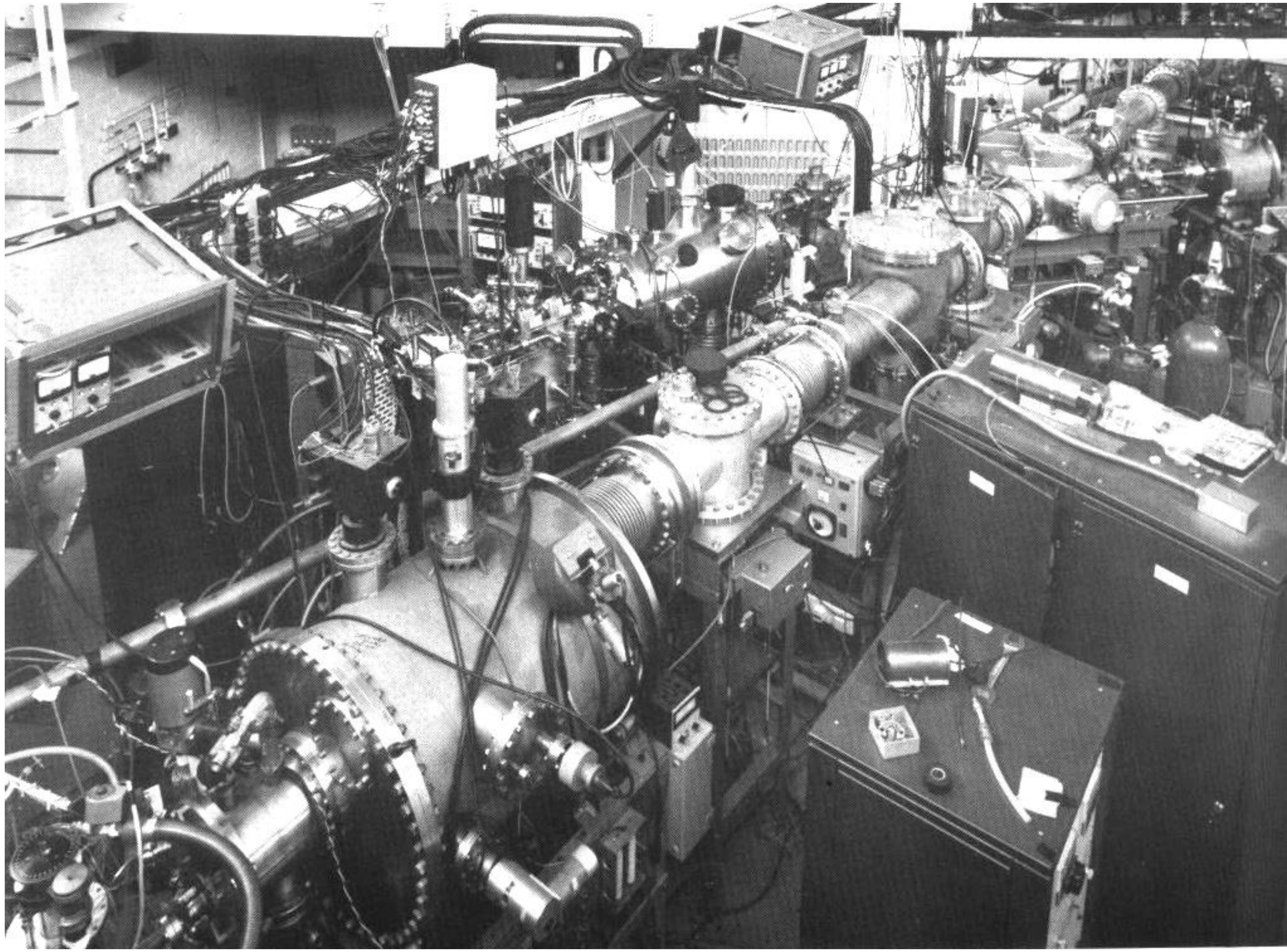
The SRF on NINA

John West and Mike Poole



The completed SRF



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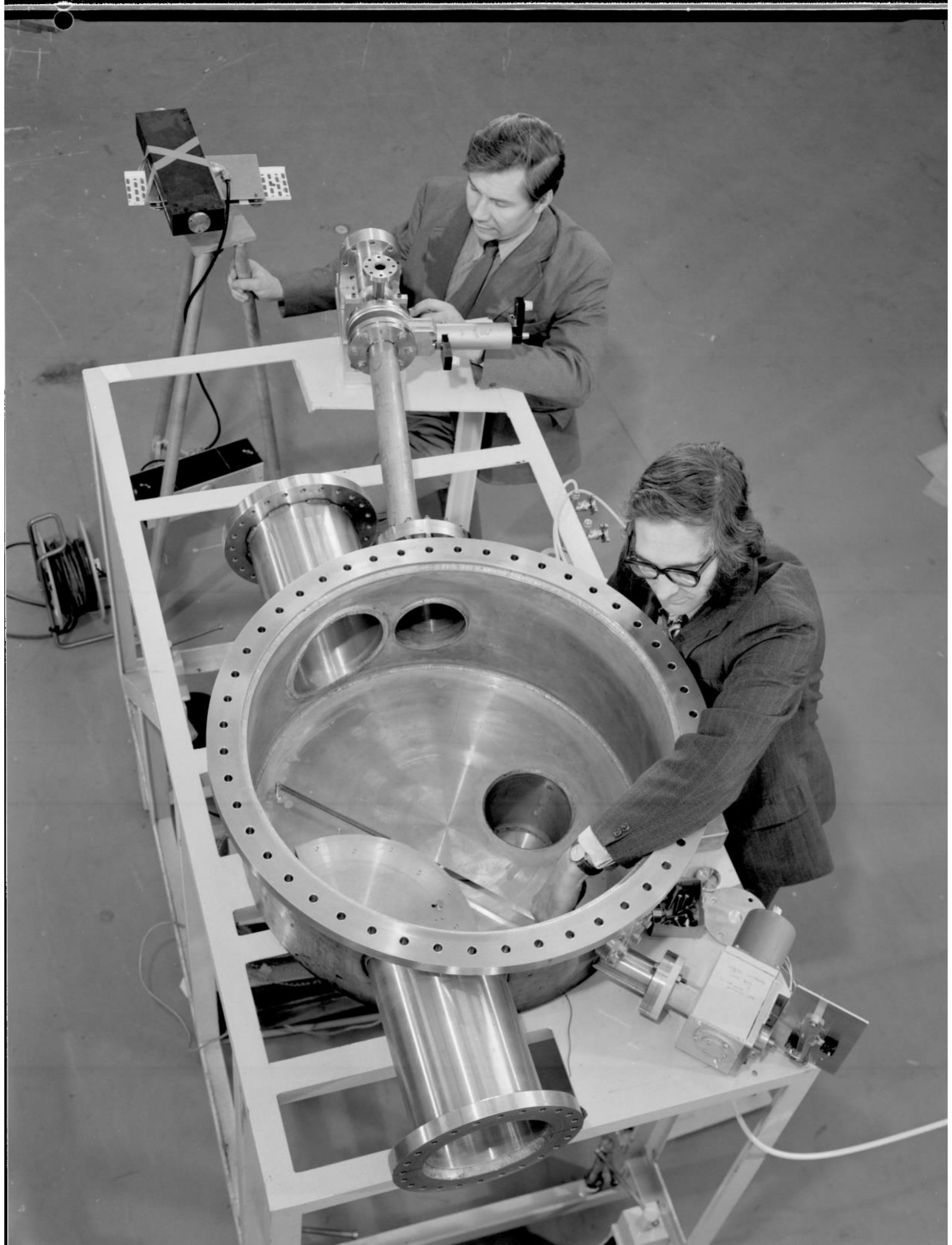
The SRF on NINA

Ian Munro and colleague (?) pretending to work on the 'Horizontal Wadsworth Monochromator'



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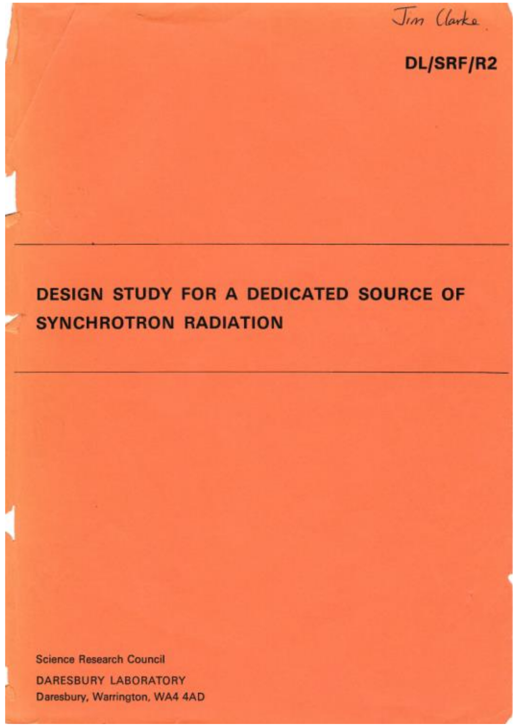
A photograph of the NINA SRF team taken a few hours before the final switch off of NINA on 31st March 1977. At the time there were 10 user groups coming from the universities of Manchester, Reading, Oxford, Coleraine, Durham, Bristol, Warwick, Leicester, Edinburgh and MRC Cambridge who successfully put the case with the wider potential users community to build the world's first dedicated SR source, the SRS. From left to right: Pat Ridley, Iggy McGovern, Bill Smith, Tony Bourdillon, John West, John Beaumont, John Morton, Ian Munro, Paul Brint, Samar Hasnain, Jeff Worgan, Robert Pettifer, Tom Short, Joan Bordas, Ken Lea and Tony Cox

The Synchrotron Radiation Source (SRS)

- Early in 1974, following completion of a feasibility study (DL Internal Report) and an assessment of the scientific justification (SRC 1974, unpublished) the Science Research Council authorized DL to carry out a Design Study for a purpose built source of SR.
- It was assumed that the source would be built at DL in the existing NINA building and that it would be a dedicated electron storage ring.
- The SRS design was published in 1975 and the facility was approved to start construction from April 1975
- The cost of the SRS was estimated to be £2.7m, plus £300k for beamlines and experimental equipment, and was expected to take four years


Jim Clarke

DL/SRF/R2

DESIGN STUDY FOR A DEDICATED SOURCE OF SYNCHROTRON RADIATION

Science Research Council
DARESBURY LABORATORY
Daresbury, Warrington, WA4 4AD

According to the Bank of England inflation calculator, goods costing £3m in 1975 would cost £21.4m in today's prices.
https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

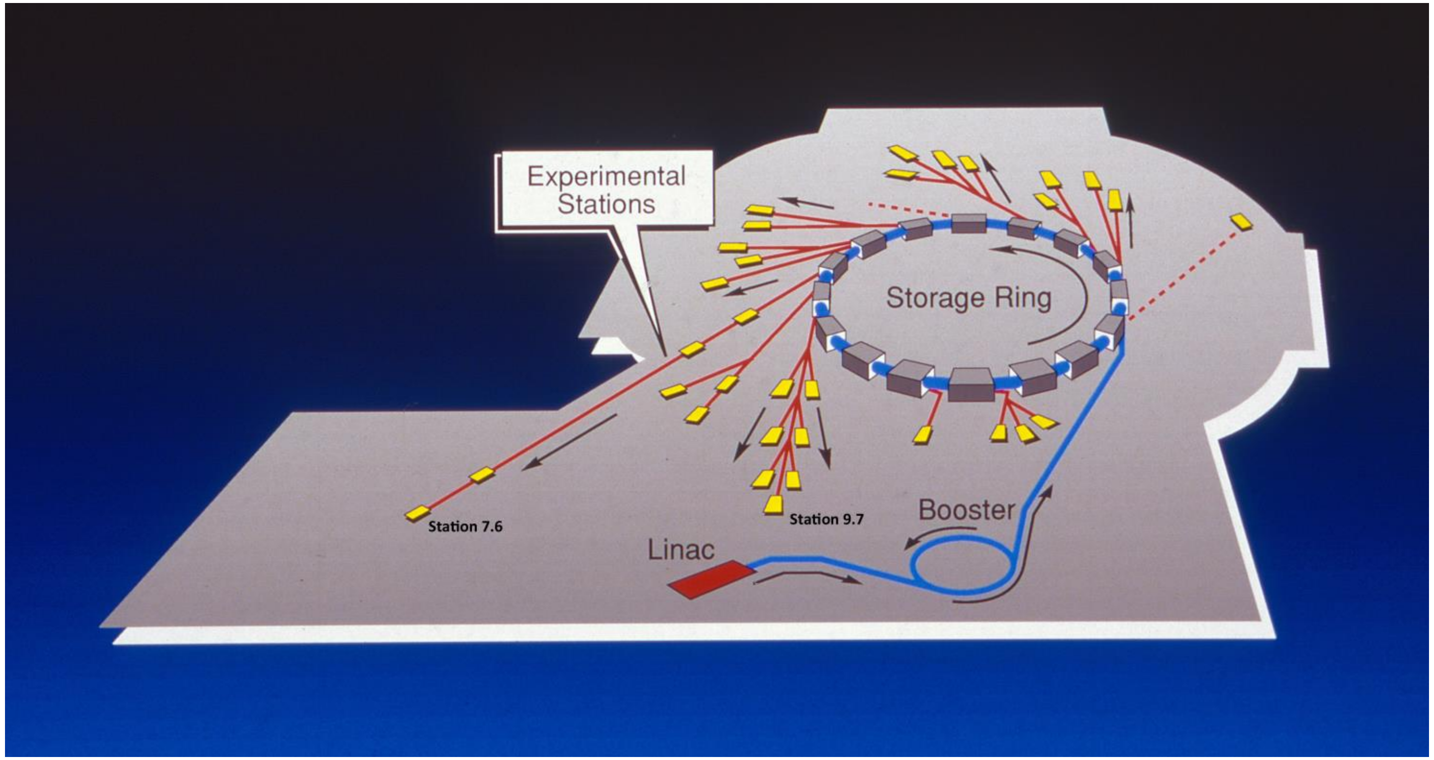
Parameter	Value	Units
Linac energy	12	MeV
Booster (injection) energy	600	MeV
Stored beam energy	2	GeV
Storage ring circumference	96	m
Lattice type	FODO	
Number of cells (2 dipoles/cell)	8	
Dipole bend radius	5.6	m
Dipole field	1.2	T
RF frequency	500	MHz
Revolution frequency	3.123	MHz

Layout & Design Considerations

- The target was to achieve a **high photon flux at 1 Angstrom** (0.1 nm) from the bending magnet sources – this set the combination of **electron energy of 2 GeV and dipole field of 1.2T**
- Users wanted safe and convenient access to their experimental equipment whilst the beam was stored – unlike the case with NINA
- The SRS was built in the NINA buildings and the injection system was outside of the storage ring – this restricted space for X-ray beamlines
- Ideas for having a low field dipole and a high field dipole to better serve the long and short wavelength communities better were rejected because the circumference of the ring would have been too large, restricting the photon beamline lengths too much – instead all of the 16 dipoles were identical so all beamlines received the same spectrum
- The lattice was a very simple FODO with only 1 quadrupole between dipoles
- The electron beam emittance was 1.5 mm mrad (1500 nm rad) with **beam sizes of ~6.2 mm (H) x 0.24 mm (V)**

Operating Concept

- Modern light sources have an injection system at the same energy as the storage ring but this was not the case for the SRS (or other similar light sources)
- The electron beam from the linac was injected into a synchrotron at 12 MeV and then accelerated to 600 MeV.
- This beam was then extracted from this ‘booster’ and injected into the storage ring at 600 MeV.
- The beam was accumulated over successive shots until sufficient beam current was stored (~350 mA).
- At this point the linac and booster were turned off and the energy in the storage ring slowly ramped over a couple of minutes to the maximum of 2 GeV.



Building the SRS –
The world's first dedicated purpose-built synchrotron light source

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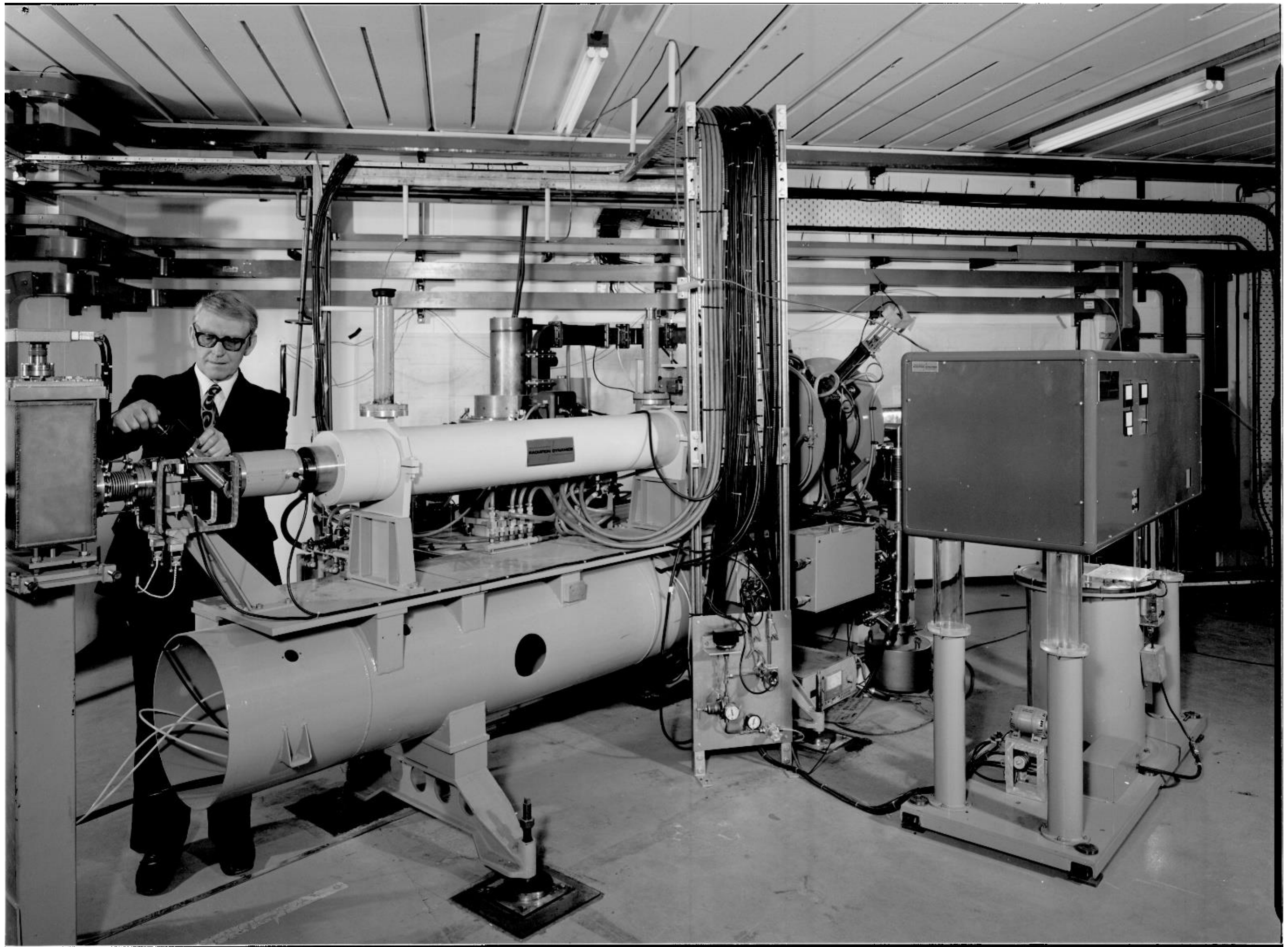
SRS Construction

The 12 MeV, 10 Hz Linac

- Medical linac repurposed as injector into the booster synchrotron
- 80kV thermionic electron gun
- 2m long travelling wave linac, 3 GHz
- 6MW klystron

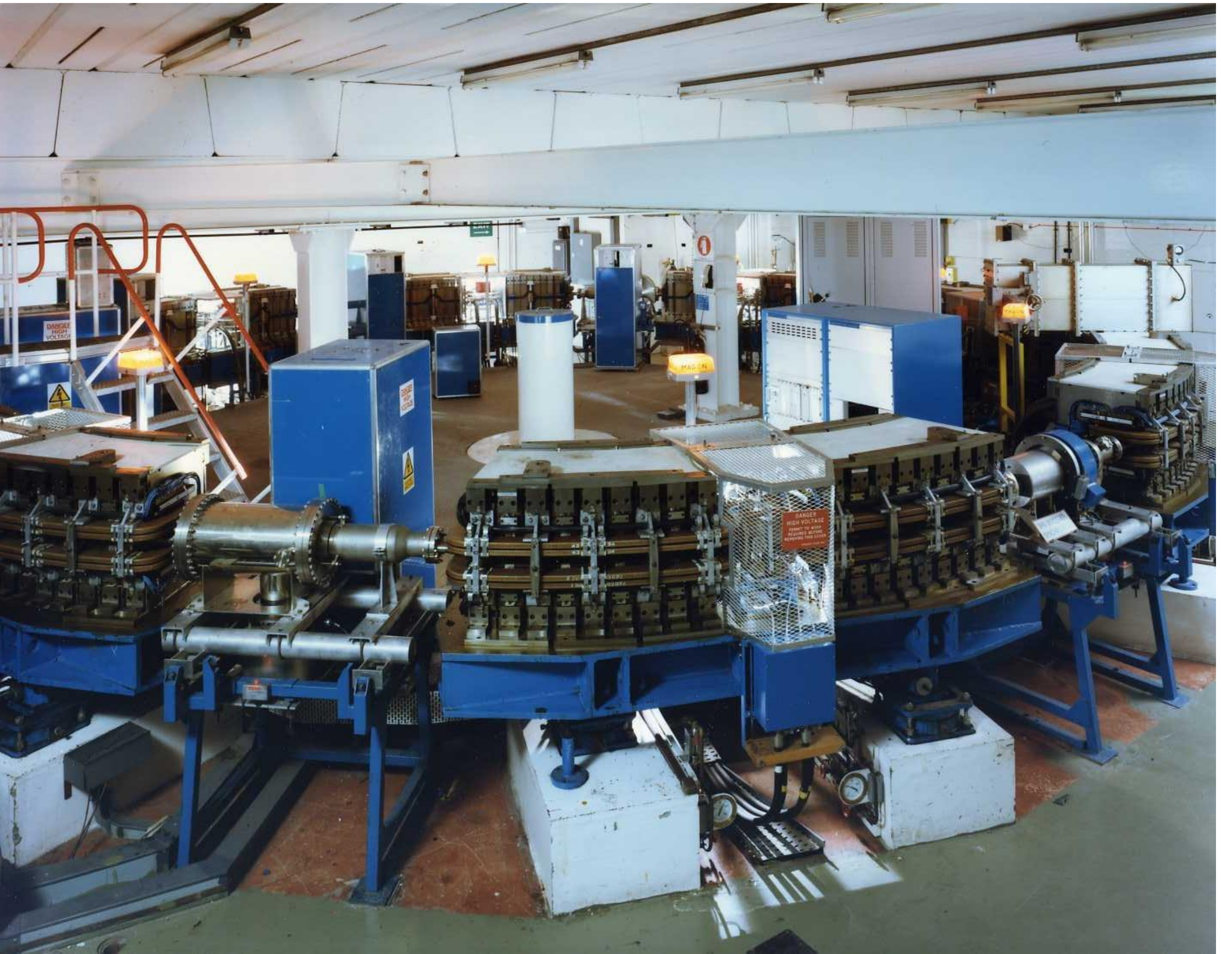


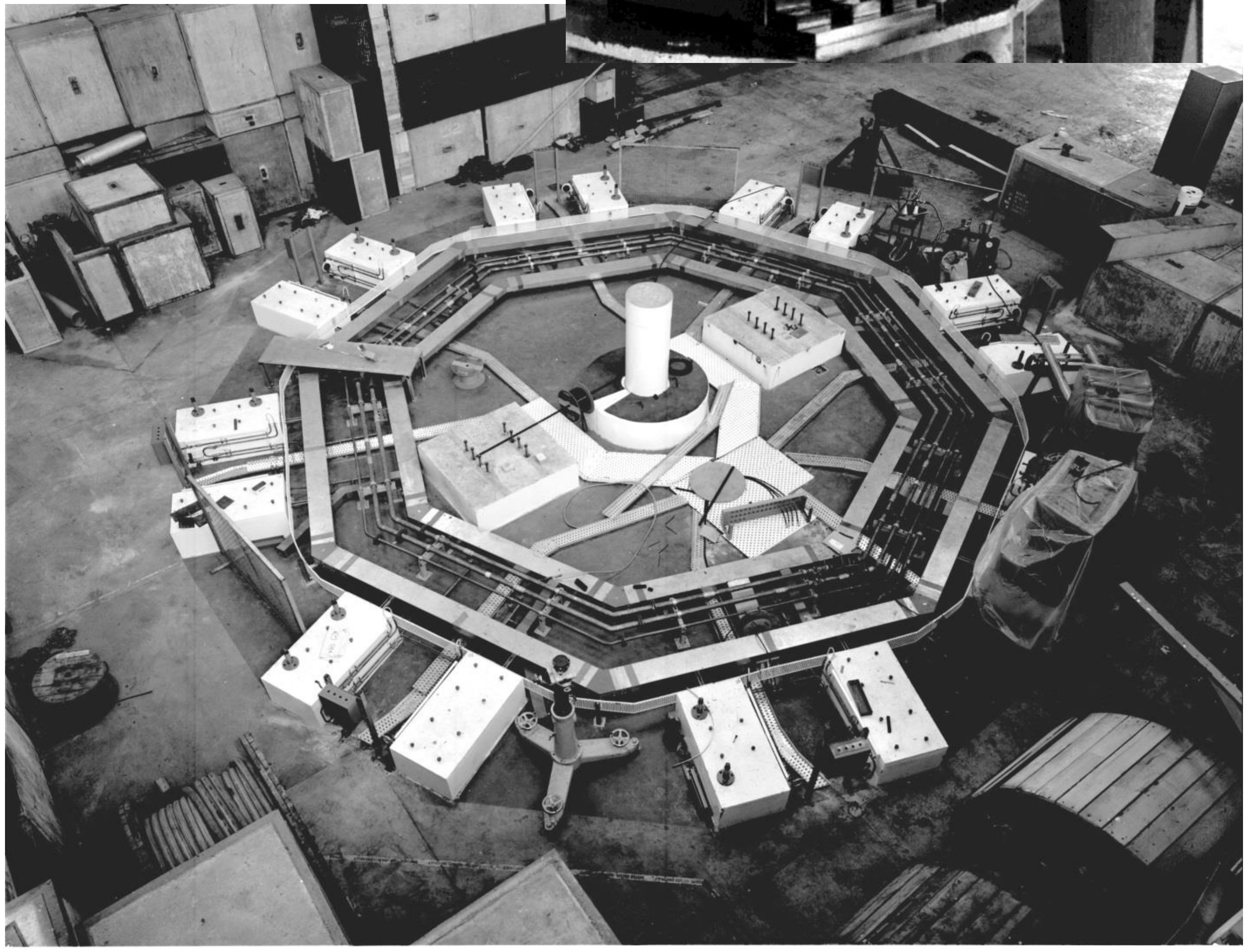
SRS Construction

The 600 MeV, 10 Hz Booster Synchrotron

- Combined function F and D dipoles, 8 cells
- Circumference 31.8m (106ns orbital period)

Richard Walker working on a booster dipole





SRS Construction

The 2 GeV Storage Ring

- Circumference of 96m (320ns), 8 cells
- The design beam current was 1 A with two klystrons installed but as only one klystron was ever installed, this limited the 2 GeV design beam current to 370 mA
- There were 4 single 500MHz RF cavities, each in a separate straight section, all powered from the single klystron

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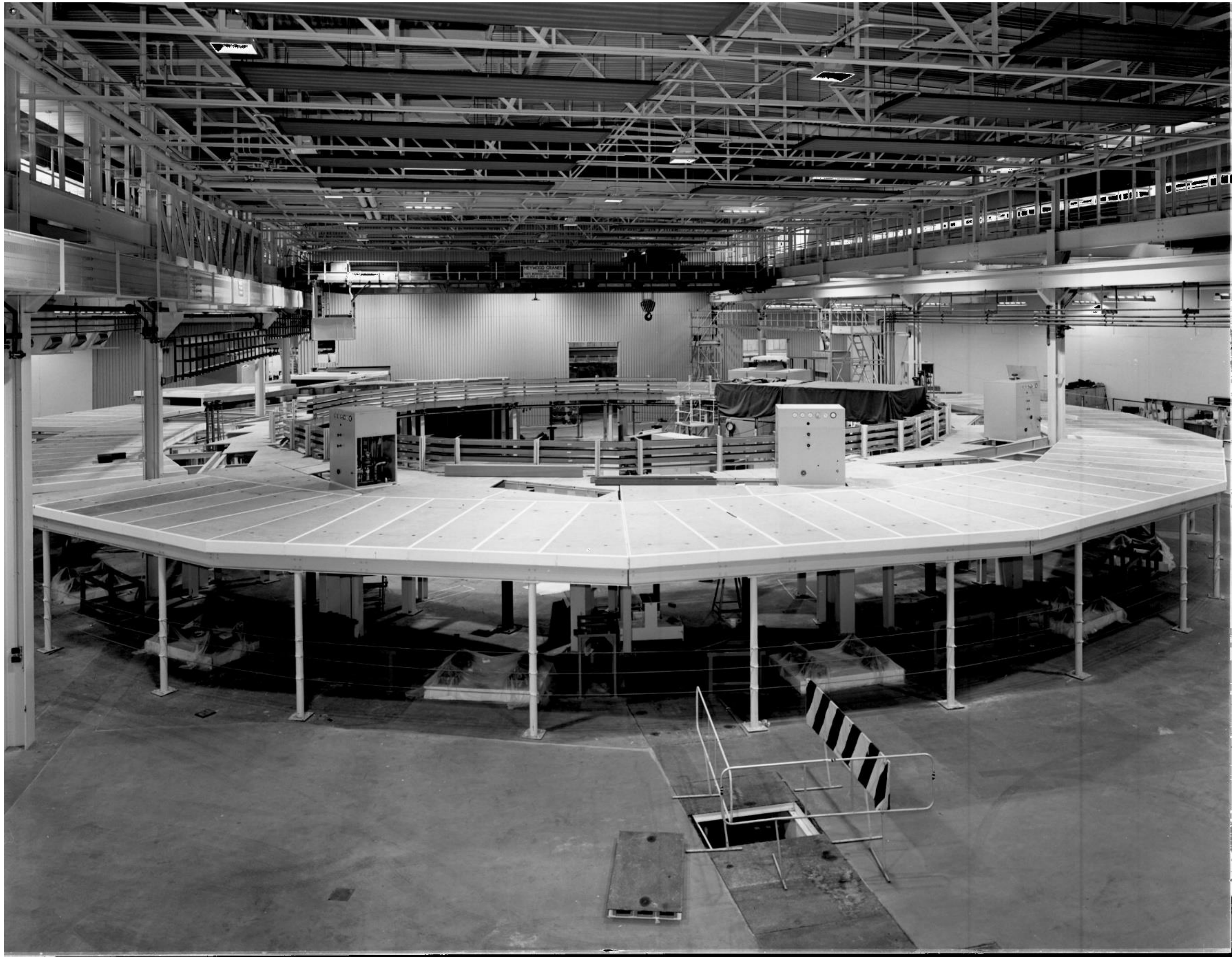
SRS Construction

The storage ring was built in the Inner Hall (currently home to the VISTA lab and DUNE APA assembly area)

The shield roof was used to house controls racks and an infra-red end station



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SRS Construction

One of the 500 MHz RF cavities fed by waveguide from above and two of the dipoles

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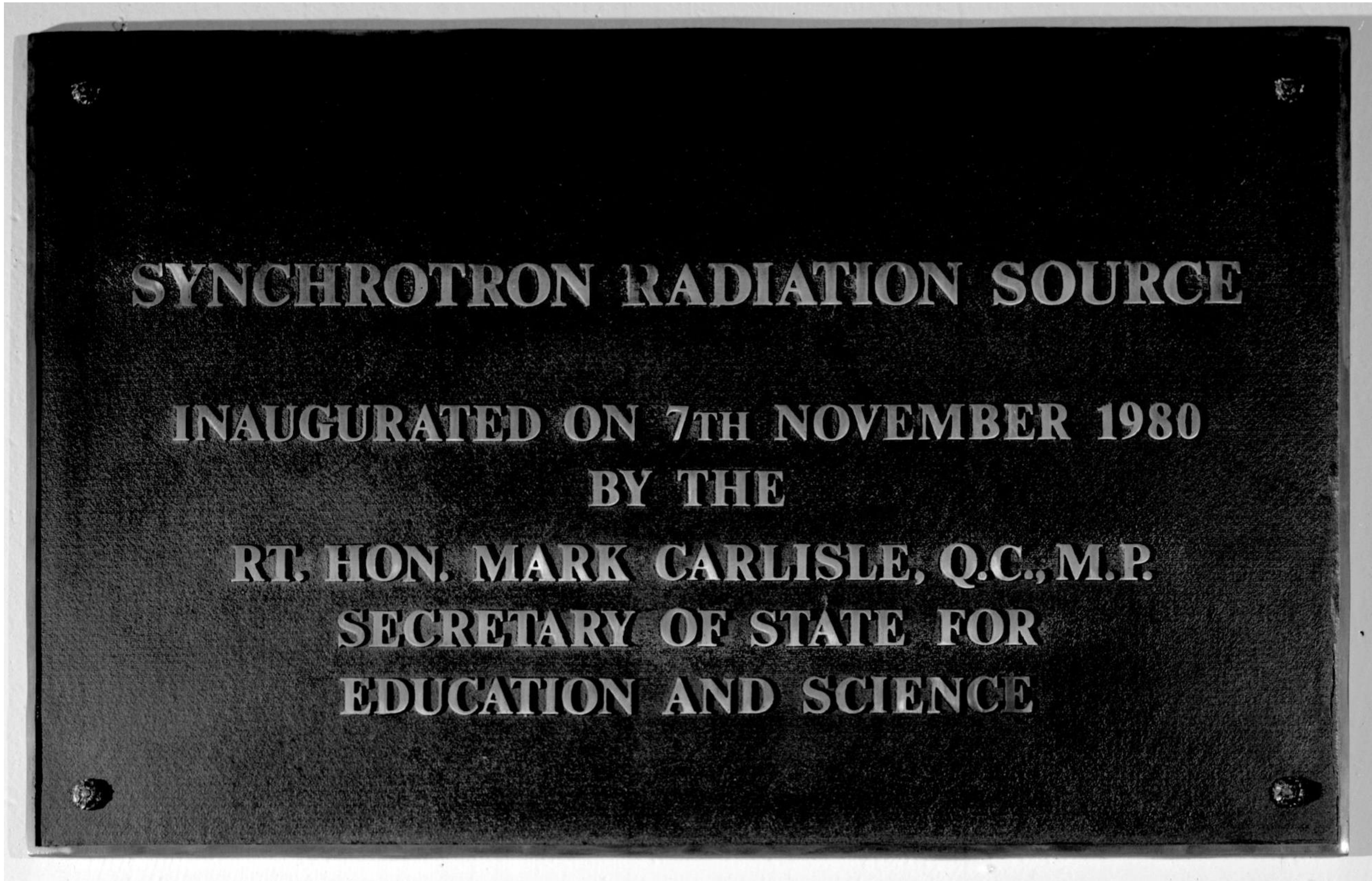
Inauguration

Mark Carlisle served as Secretary of State for Education and Science from 1979 until 1981 and also happened to be MP for Runcorn and later Warrington South



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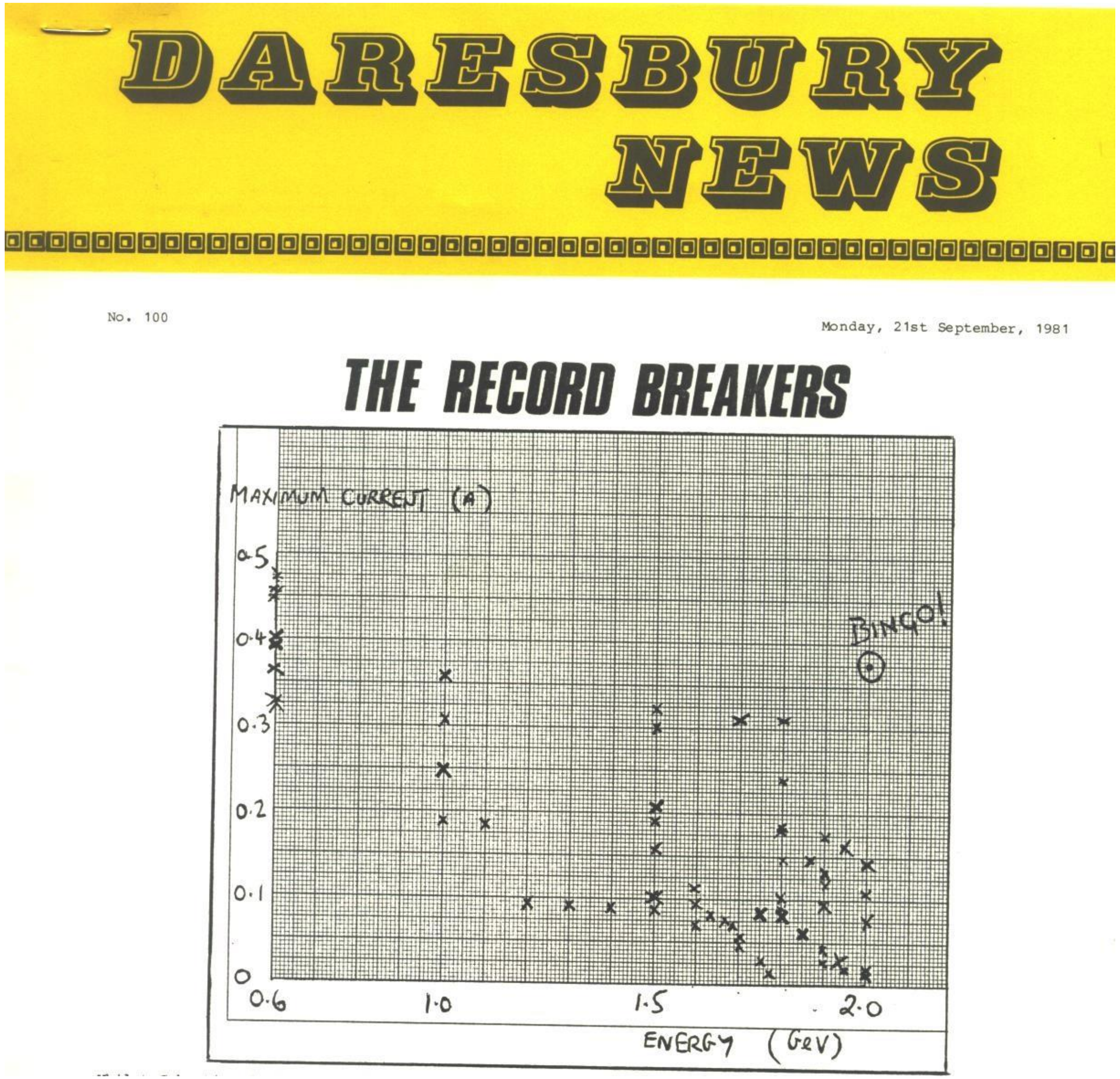
SRS Early Years of Operation

- First beam was circulated in the storage ring on **30th June 1980**
- First scheduled operations for users started in the spring of 1981, with two X-ray beamlines in operation
- The stored electron beam current at 2 GeV for users was typically around 250 mA maximum and this then decayed over the course of ~8 to 12 hours to around half this value – the decay rate depended primarily on the quality of the vacuum and as the vacuum level improved over the years so did the beam lifetime
- Single bunch operation (rather than all 160 bunches being filled with electrons) was built in from the start as this meant that users could carry out time resolved studies, with beamlines receiving a flash of X-rays every 320 ns. This mode operated at lower current of ~30 mA maximum.
- In 1983 user operations changed from 16 hours per day to 24/7 operations.

SRS Early Years of Operation



DARESBURY NEWS

No. 100

Monday, 21st September, 1981

THE RECORD BREAKERS

Jerry Thompson & Neil Marks celebrating with Godfrey Saxon explaining the right hand rule in the background!

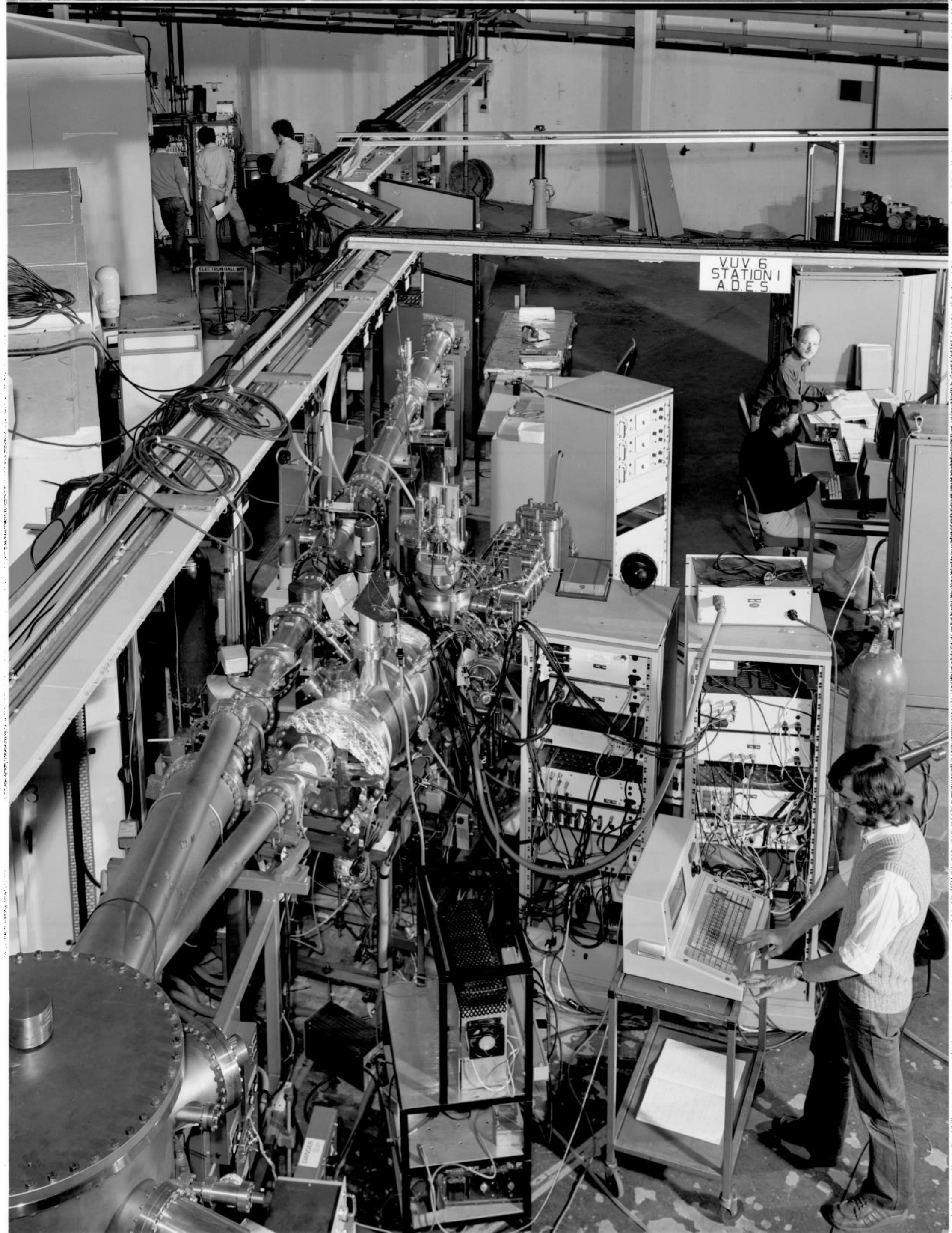
RF Problems

- The first years were affected by a number of RF window failures, mostly cracking.
- This came to a head in the last three months of 1983 when there were seven failures and no user beam!
- Failures were attributed to the growth of high conductivity areas on the windows, resulting in additional local heating and eventual thermal runaway.
- Although on-line monitoring of the ceramic temperature was introduced it was necessary to reduce the SRS operating level to 1.8 GeV to ensure adequate window lifetime.
- Known contributing factors were the proximity of the windows to the cavity fields and the quality and composition of the anti-multipactor coating.
- Following an intense period of R&D, the RF windows were physically shifted by 22mm away from the cavity and the 'copper-black' coating recipe was optimised to minimise heating – this prevented any further failures over the lifetime of the facility.

DM Dykes et al, SRS RF Cavity Windows, p2800, PAC 1985

Photon Beamlines

A typical view of one of the early beamlines. Beamline 6 had two end stations at this time. On the right is the Angular Dispersed Electron Spectroscopy station (taking vacuum ultra violet wavelengths) and straight ahead was a surface science station



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Photon Beamlines

Beamline 7 showing the typical long X-ray vacuum chamber delivering the beam to the end station or hutch.

The cabin is where the users ran the experiments from.

A lot of lead was required!

https://homepages.abdn.ac.uk/npmuseum/article/Daresburyimages/album/index.html

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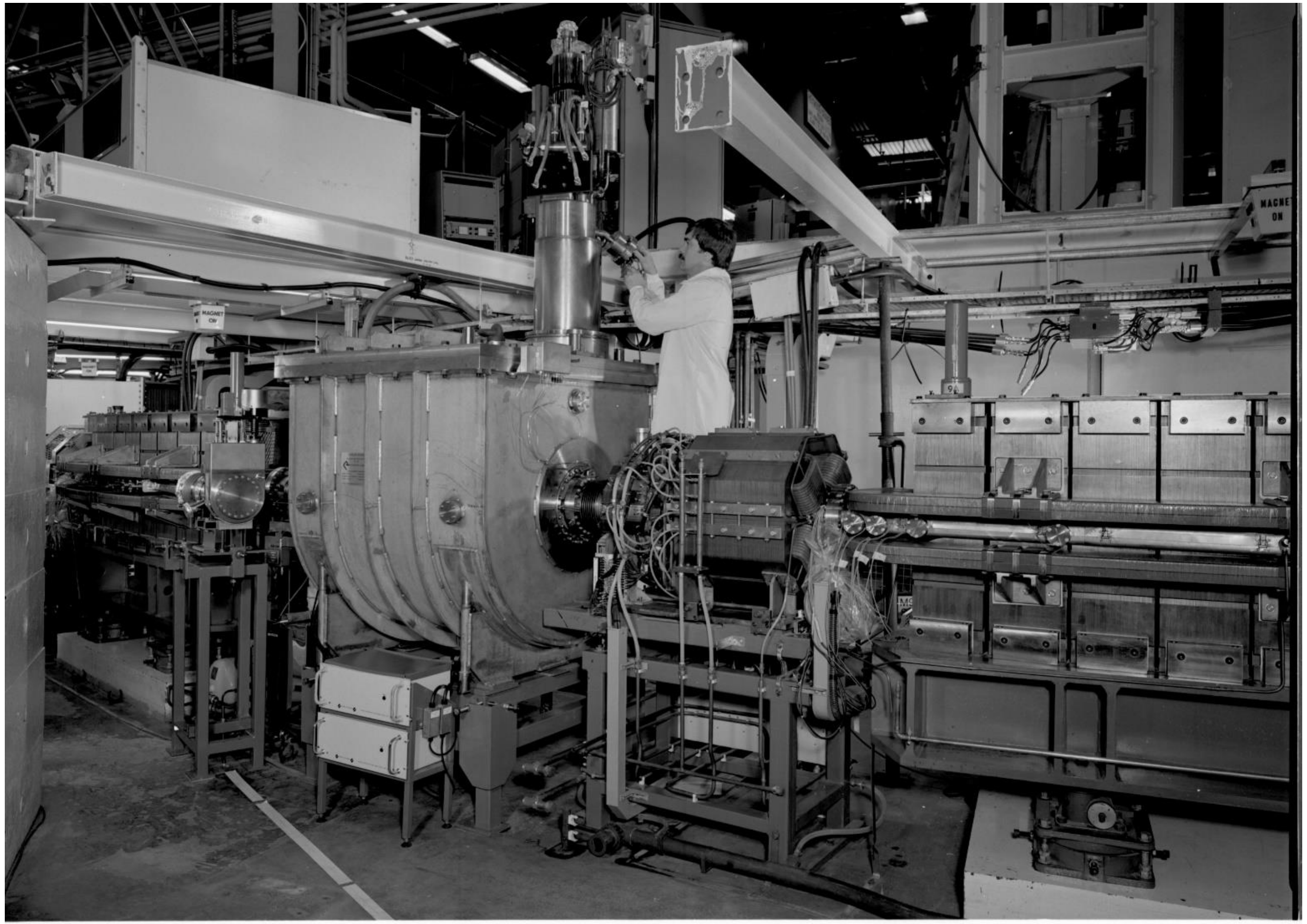
Superconducting Wiggler

To enhance the short wavelength flux for one beamline a 5T wiggler was installed

- The superconducting wiggler was designed and built by Rutherford Lab
- This generated a wide horizontal fan of X-rays that fed 7 end stations



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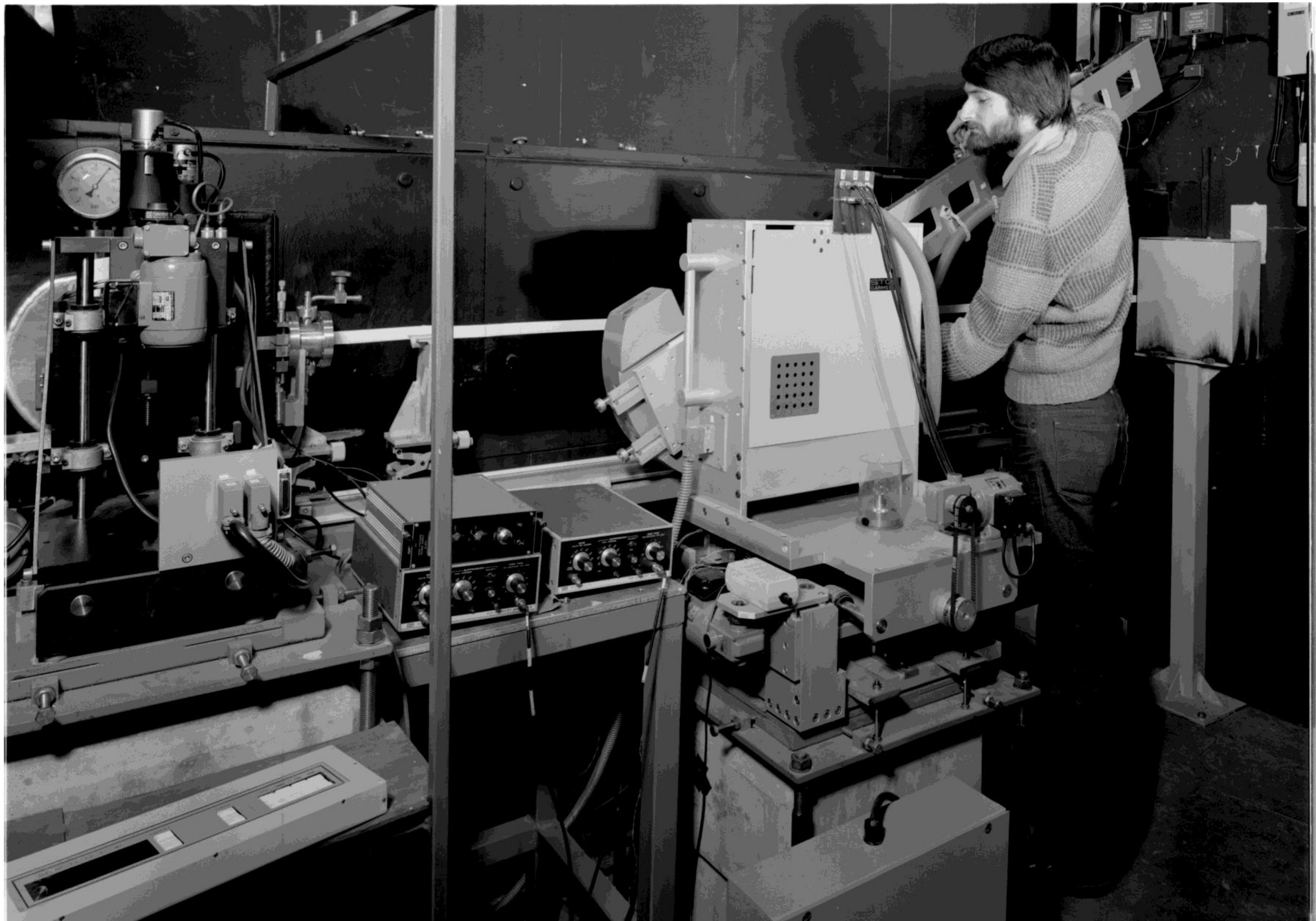
Photon Beamlines

An X-ray powder diffraction station on the superconducting wiggler beamline



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Science Impact

The first high resolution X-ray absorption near edge spectra (XANES) for copper and manganese were recorded at the SRS and published in Nature in 1981

The results were compared with theoretical calculations also made at Daresbury

The authors of the paper were G. N. Greaves, P. J. Durham, G. Diakun & P. Quinn and they were all Daresbury staff members

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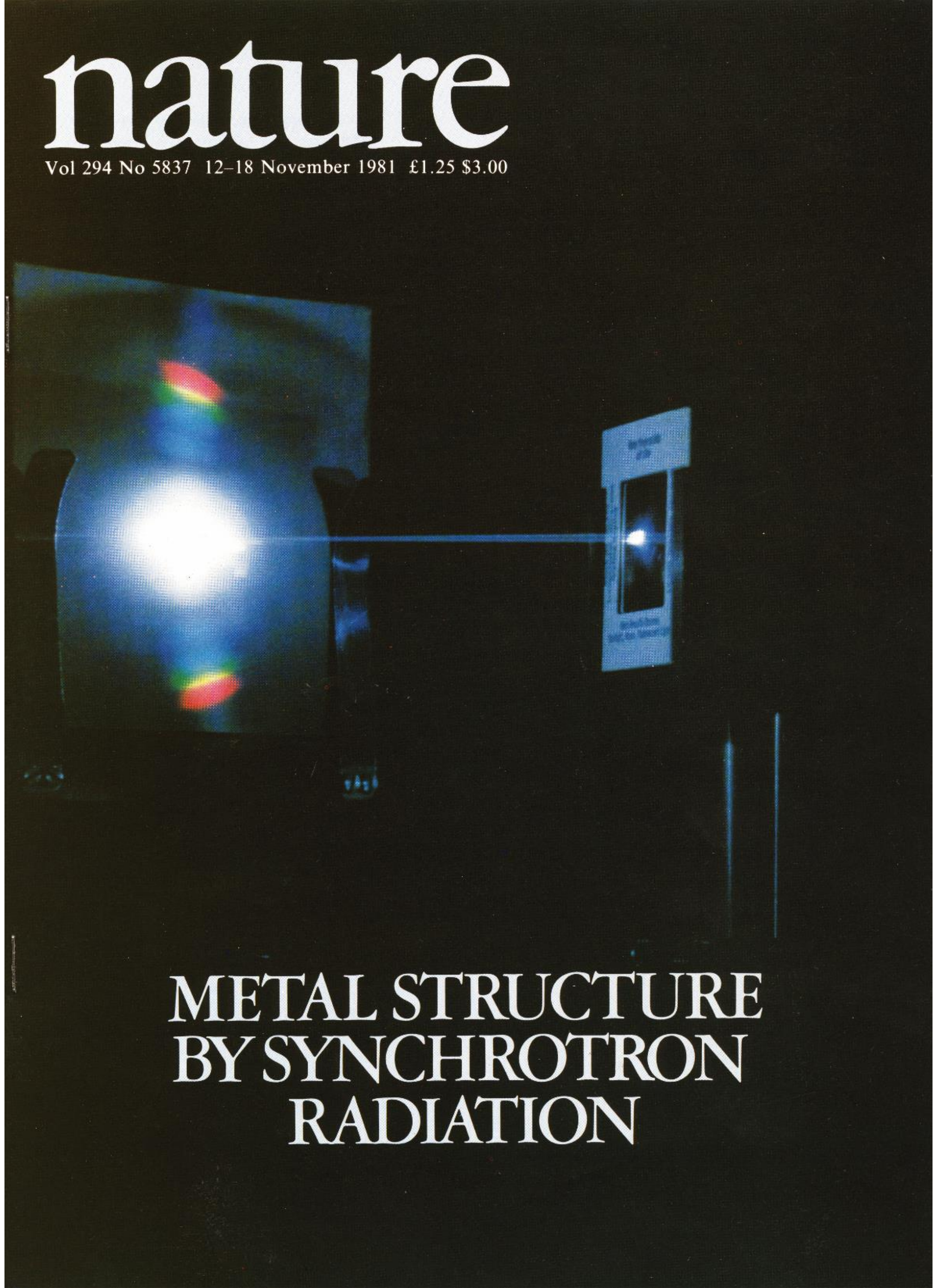
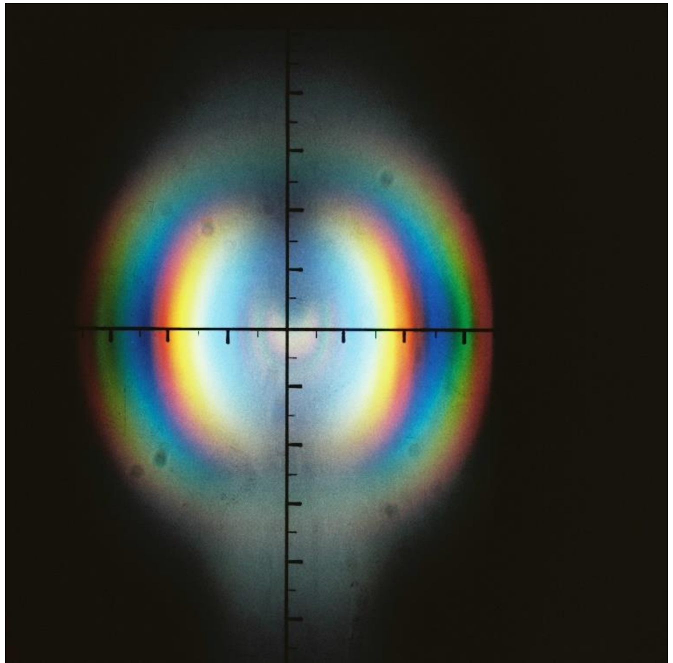
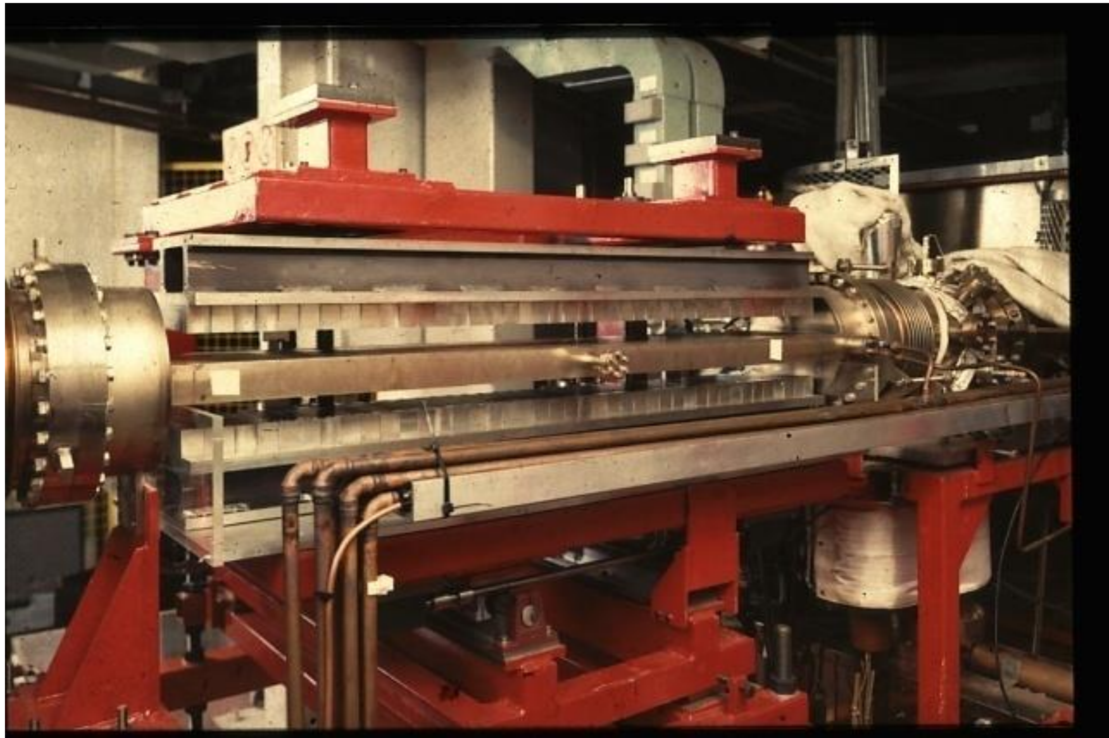


Undulator

The first undulator built in the UK was installed in October 1984

- The SRS was not intended to have undulators installed but despite this an undulator was designed and built at Daresbury and installed into the storage ring
- It was a 10 period device , built using permanent magnets, and was one of the early examples
- The engineering was very simple and the magnet gap was controlled with a switch from the Control Room. There was no choice regarding the gap it was either fully closed or fully open!
- The SR output from the undulator was observed in the visible spectrum by reducing the energy in the storage ring to 450MeV





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SRS-2 –
The Lattice Upgrade!

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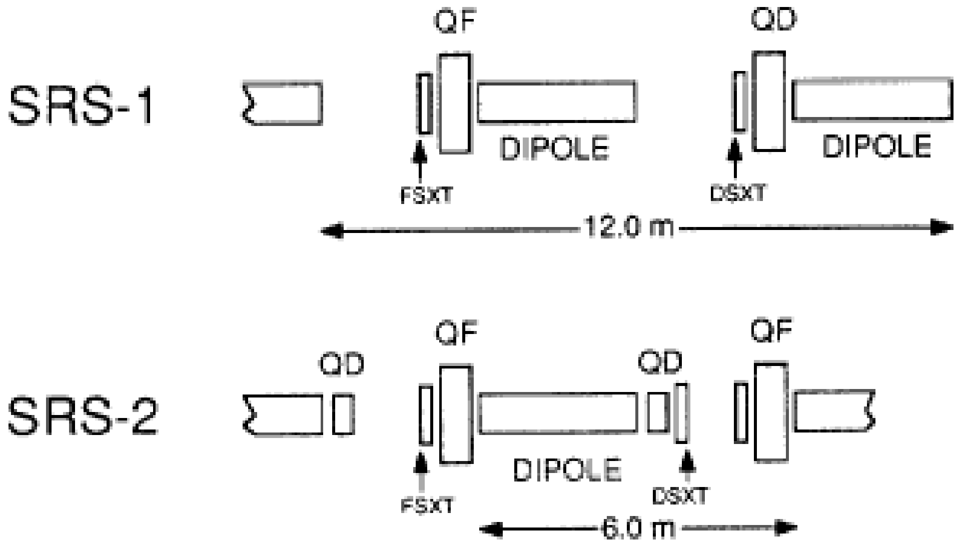
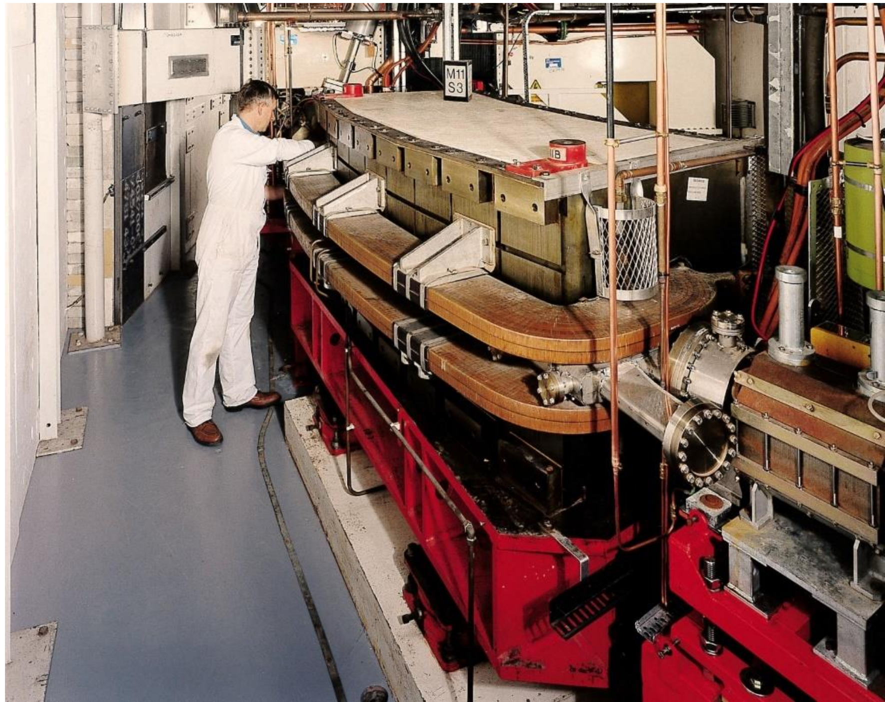
SRS-2, AKA High Brightness Lattice

The 2 GeV storage ring lattice was modified in 1986

- Options for increasing the brightness of the SRS by reducing the emittance were already **under consideration in 1981**
- The major constraint was that the dipoles and attached beamlines should not be altered or moved
- The scheme selected increased the number of cells from 8 to 16 and doubled the number of focusing quadrupoles
- This reduced the emittance by a factor of 15 (1500 nm rad to 110 nm rad, with wigglers off)
- **Approval was given in June 1983**
- Installation was deliberately delayed until Oct 1986 to allow time to complete the initial scientific programme





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SRS-2

- After a 5 month shutdown, recommissioning started in March 1987
- Routine 24/7 user beam operations were re-established by mid-June
- Beam size measurements confirmed the expected reductions with values of **~1.1 mm (H) x 0.1 mm (V)** compared to **~6.2 mm (H) x 0.24 mm (V)** previously, with the wiggler off.
- Beam lifetime increased steadily as the vacuum improved, after the major intervention, reaching ~20 hours @ 200mA

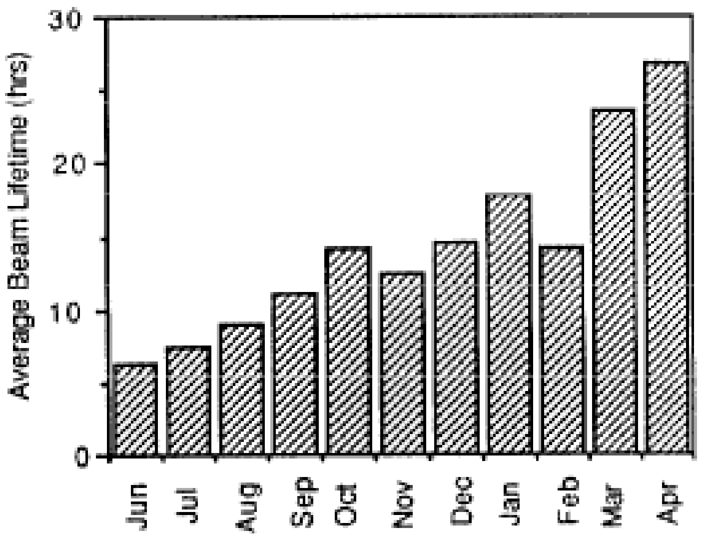

Fig. 3. Improvement in SRS-2 beam lifetime.

VP Suller et al, p418, EPAC 1988

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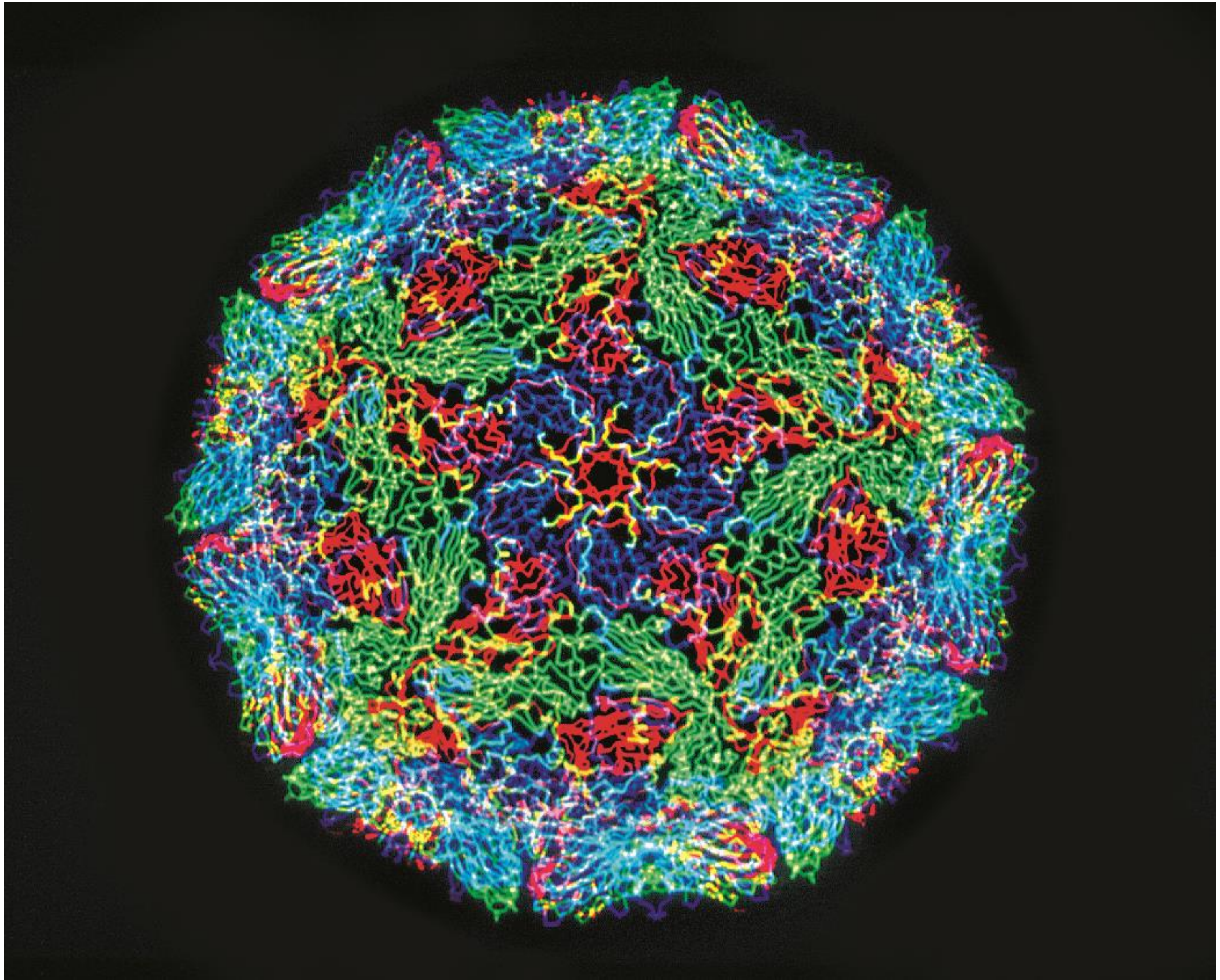
Science Impact

The structure of foot and mouth disease virus was solved using data from the SRS in the late 1980's

This was the first animal virus structure to be solved in Europe and was published in Nature

One of the authors, **Dave Stuart** (Diamond and Oxford), has gone on to lead the development of a safe and effective vaccine for the disease by making use of the capabilities of Diamond



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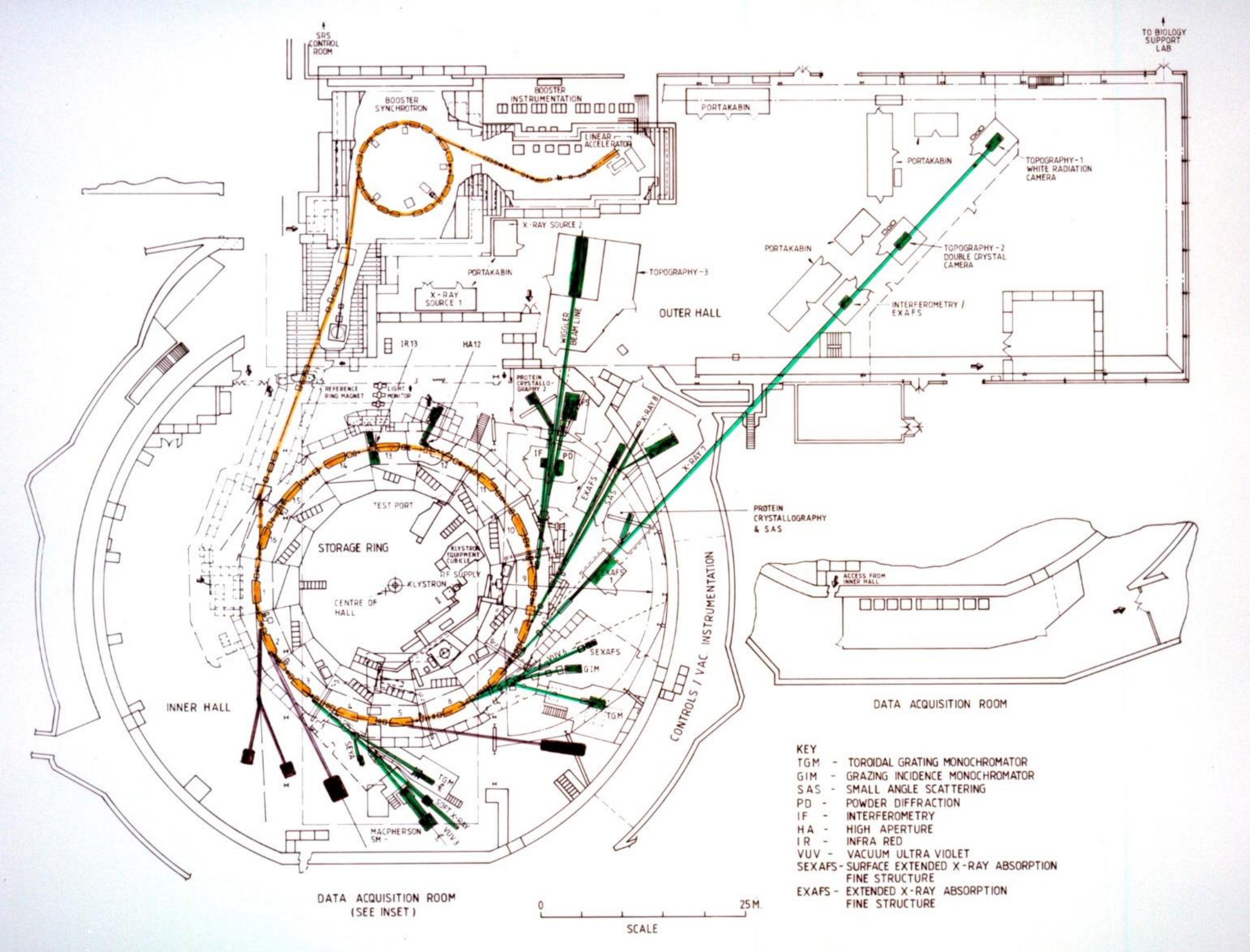
Photon Beamlines

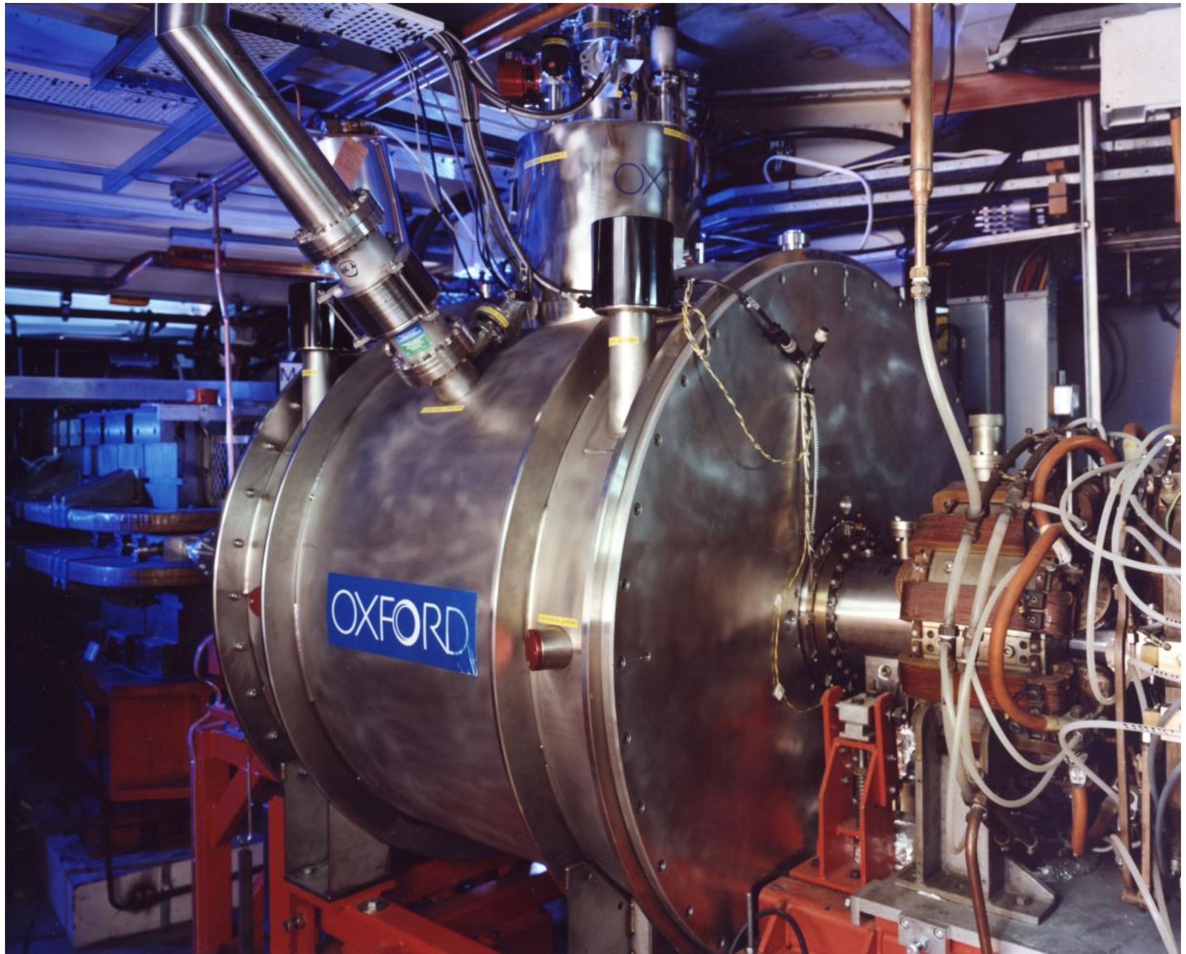
By the late 1980s there were ~20 end stations installed, this would rise to ~40 eventually.

The majority of these end stations were completely independent of each other and so could carry out experiments simultaneously



Another Wiggler…

- The 7 hard X-ray end stations on the 5T wiggler were in very high demand and so funding was secured for **a second wiggler**, this time with 5 end stations
- This second superconducting wiggler was procured directly from industry (Oxford Instruments) and had a peak field of 6T
- The contract was placed in 1989 and the magnet was installed in 1991.



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Beam Orbit Control

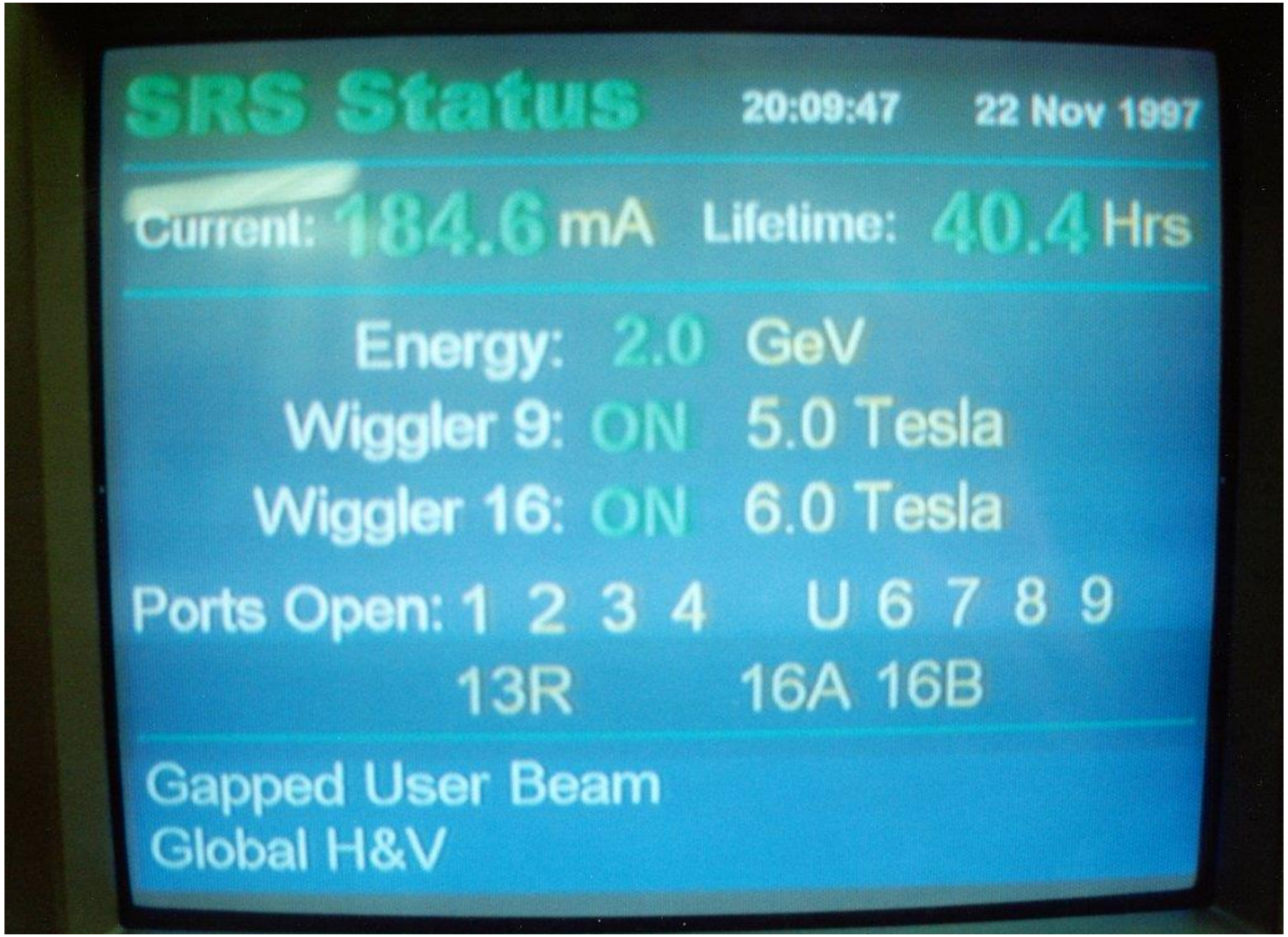
- The control of the electron beam orbit was always critical for the users as it seriously affected the performance of the beamlines and end stations
- There was no feedback on the orbit initially and it would drift over time during the course of the day
- Another drawback was that the orbit was difficult to reproduce due to the accuracy and quantity of the diagnostics
- At around the same time as the second wiggler was being developed there was a major initiative to improve the beam orbit reproducibility and control for the users
- X-ray beam position monitors were first prototyped and then rolled out to every beamline, this gave the Control Room a much better signal to optimise to and also enabled local, and later global, feedback loops to be applied
- The electron beam position monitor electronics were also fully upgraded to provide much improved performance and these were incorporated into the global feedback loops

My first ever beam shift on the SRS with Vic Suller and Jan Uythoven

Routine Operations

Around the mid 1990s the impact of ions on the stored electron beam was improved by introducing a ‘gap’ in the circulating beam. This made the day to day beam size smaller and less jittery.

The beam lifetime became sufficient that one beam a day operations became the norm.



https://homepages.abdn.ac.uk/npmuseum/article/Daresburyimages/album/index.html

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Photon Beamlines

Andy Dent and Simon Clark demonstrating how not to handle liquid nitrogen

Station 7.4 was used to develop X-ray detector systems with applications in the understanding of catalytic reactions

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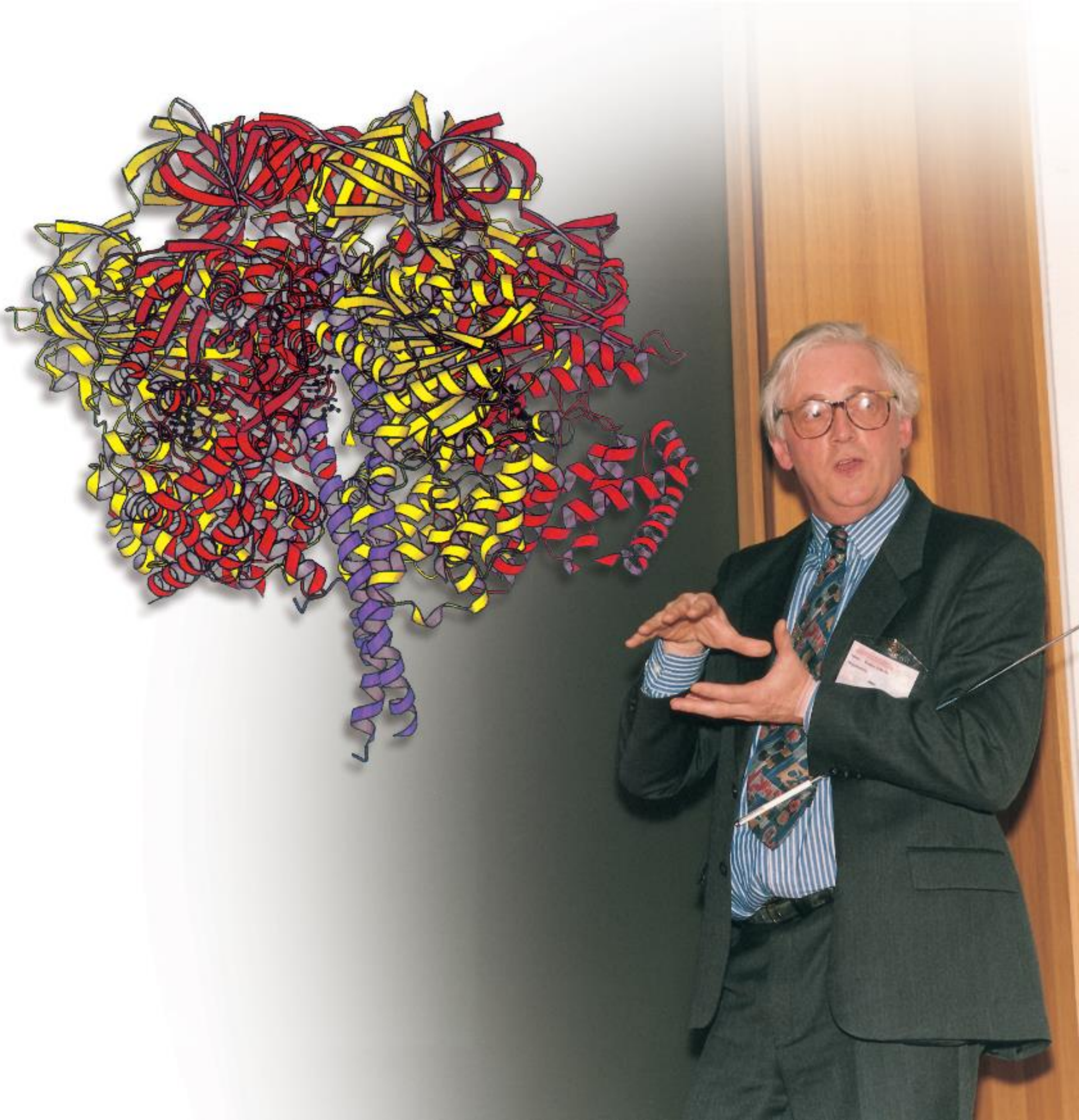
A Nobel Prize !

John Walker wins a share of the **1997 Nobel Prize for Chemistry** for solving the structure of the F1 ATPase enzyme using the SRS

In both plants and animals, energy is stored and transported by adenosine triphosphate (ATP). Photosynthesis and respiration generate a flow of hydrogen ions, which are used to build up ATP molecules with the help of ATP synthase, an enzyme that facilitates the process without being incorporated in the final product. In 1994 John Walker used X-ray crystallography to determine the structure of ATP synthase.



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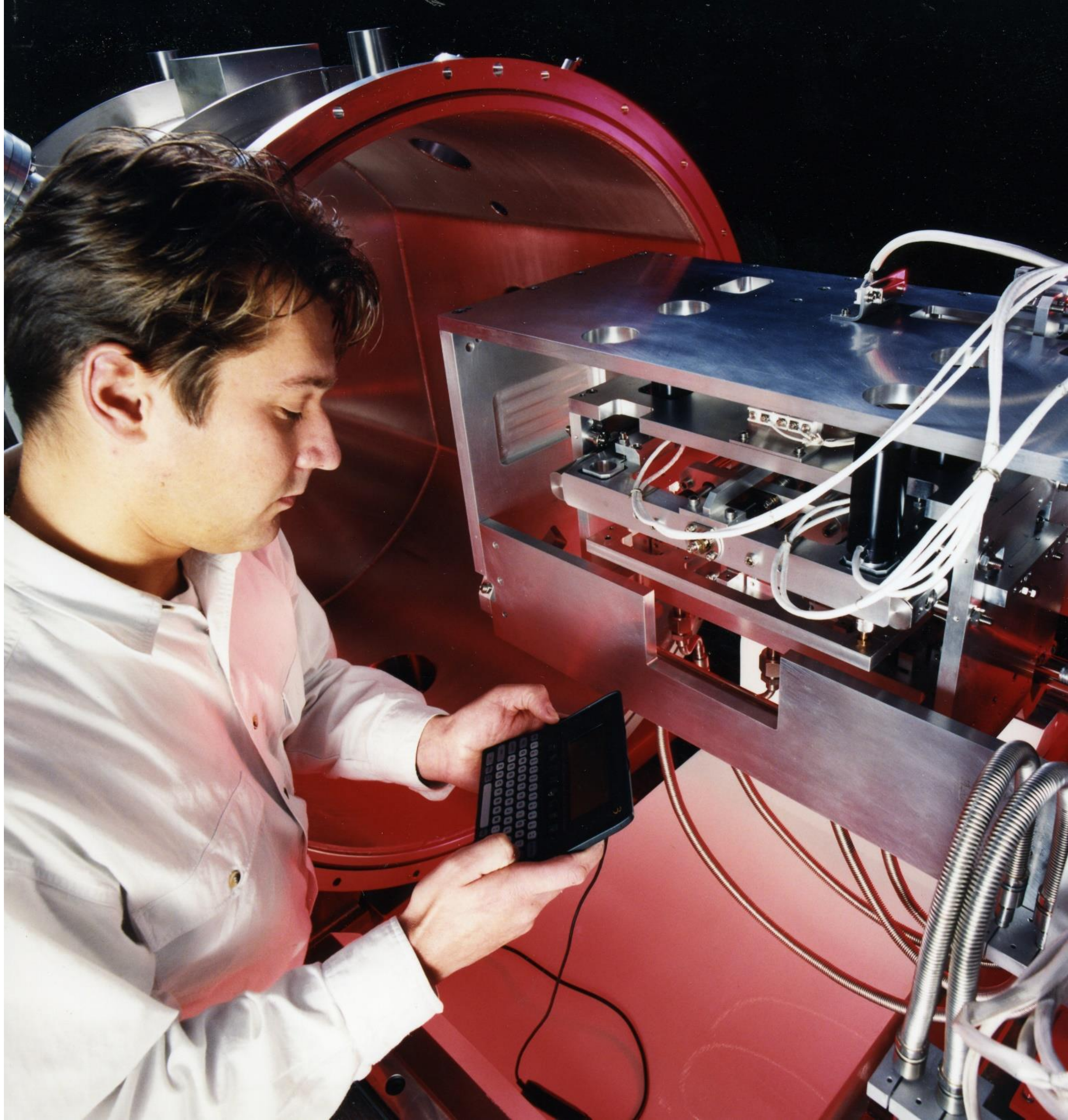
Technology Transfer

The SRS-developed technology was in regular demand from overseas facilities, especially detectors and monochromators

Here Andy Moss is commissioning an X-ray monochromator bound for Elettra in Italy



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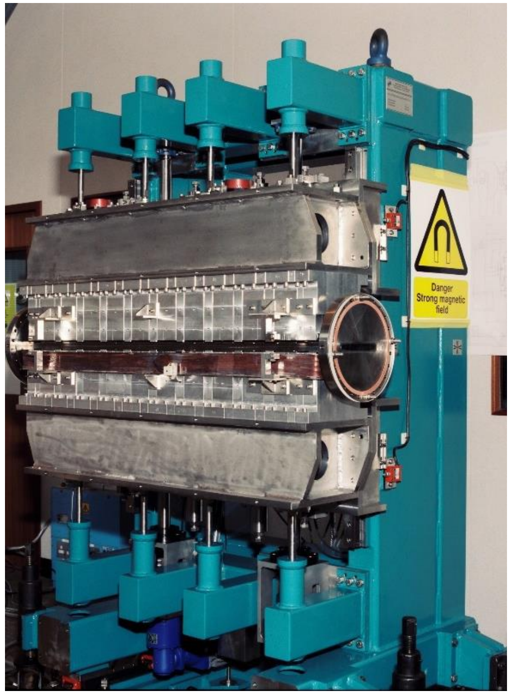
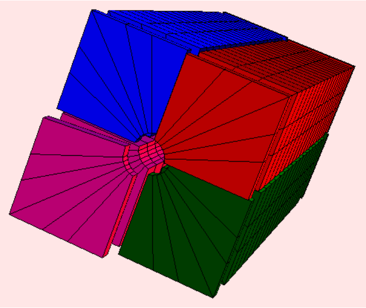
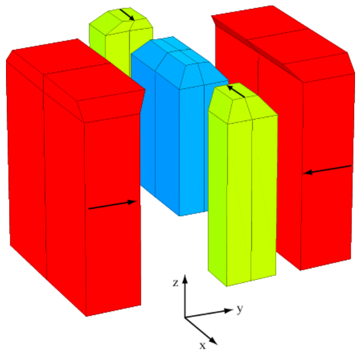
Wigglers and Undulator

- Three permanent magnet multipole wigglers (two 2T devices and later a 2.4 T device) were squeezed into three straight sections to further enhance the hard X-ray provision – this was only made possible by physically relocating all four of the RF cavities
- The final insertion device was the replacement of the original undulator with a modern APPLE-2 type undulator which provided control of the output polarization of the soft X-ray light – in this case users were given full control of the undulator settings for the first time
- These four later devices were all loaned out to various light sources after the SRS closed (Diamond, ANKA (KIT), and Thailand Light Source)







Heritage Science

Andy Smith analysing a bronze age wooden shovel from Alderley Edge copper mine using station 16.5.

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Diamond Funding

- All through the 1990s the approval was being sought to replace the SRS with a 3rd generation light source which quickly became known as Diamond
- It was clear that replacing the SRS was a 'no-brainer' but the pace of approval was very frustrating for everyone involved
- Other synchrotron light sources were being built around the world and the UK was getting left behind

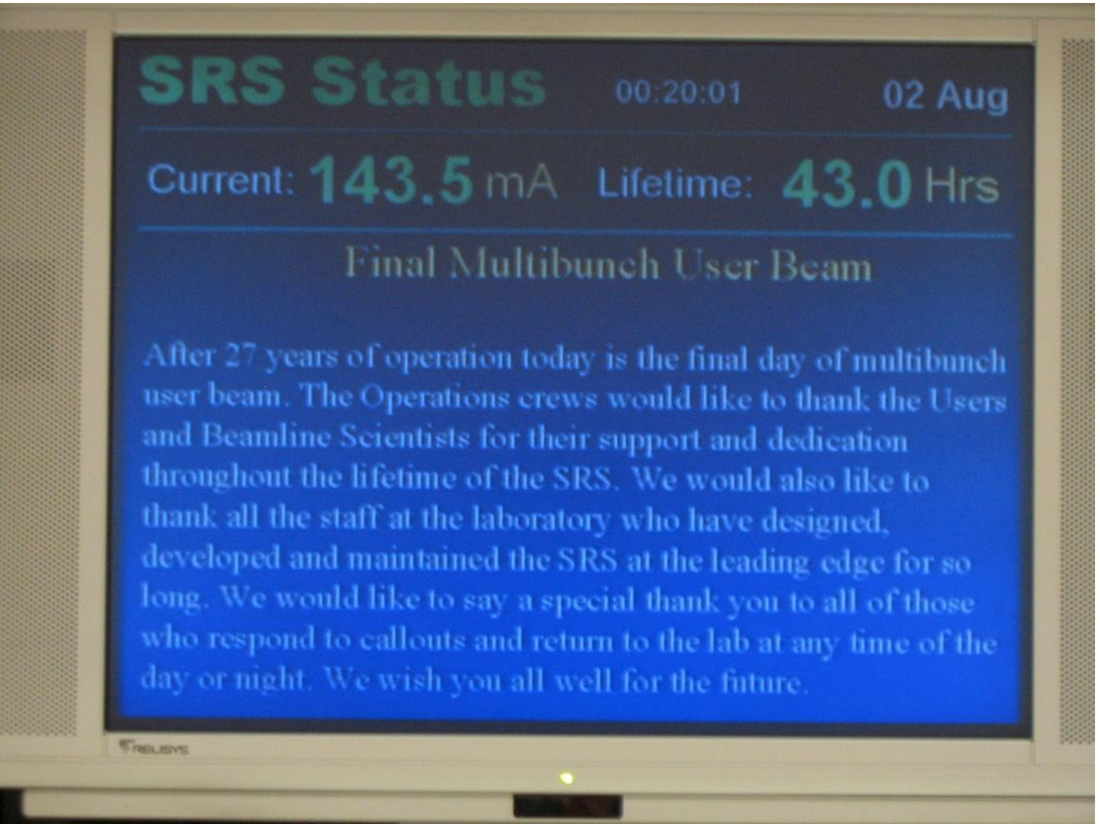
- Ian Munro applied for **Millennium Funding** to try to get the project off the ground, for which he had his wrist slapped! This example nicely sums up Ian's willingness to stick his neck out!

- **Funding was finally approved for Diamond in 1998**

- As it became known that Diamond would open for users in 2007, with seven beamlines, it was agreed that the SRS would operate until Summer 2008 so that there wouldn't be a dark period for UK users

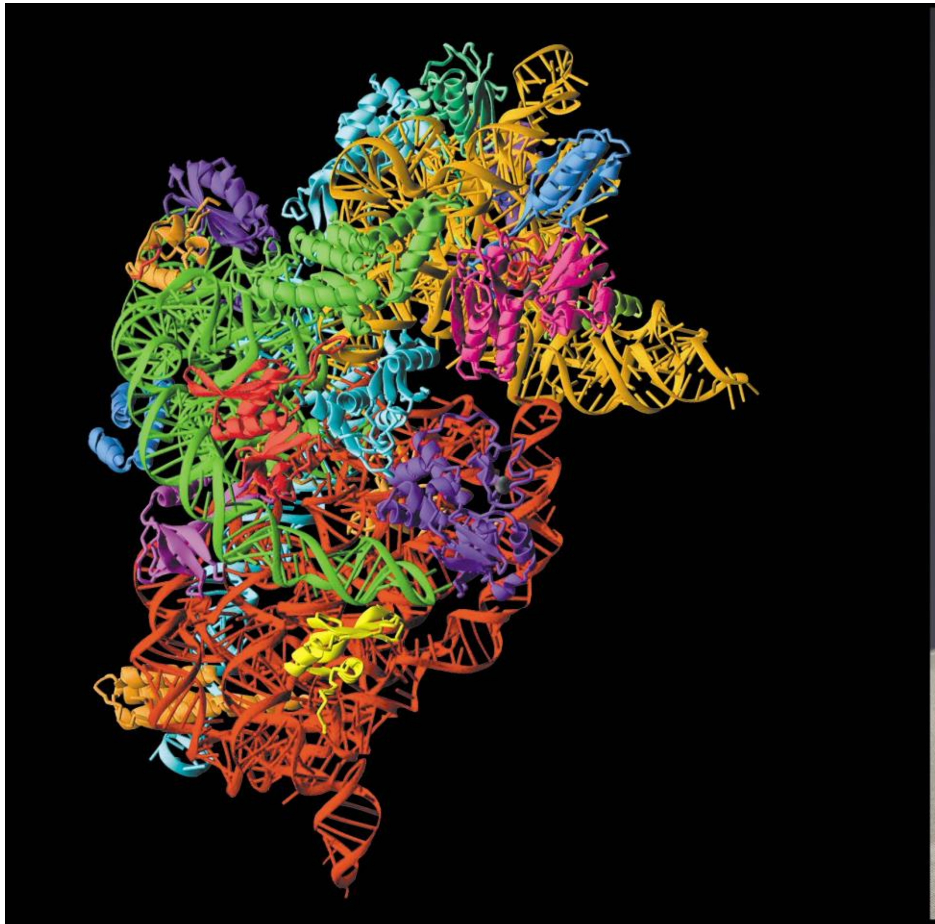
Shutdown !

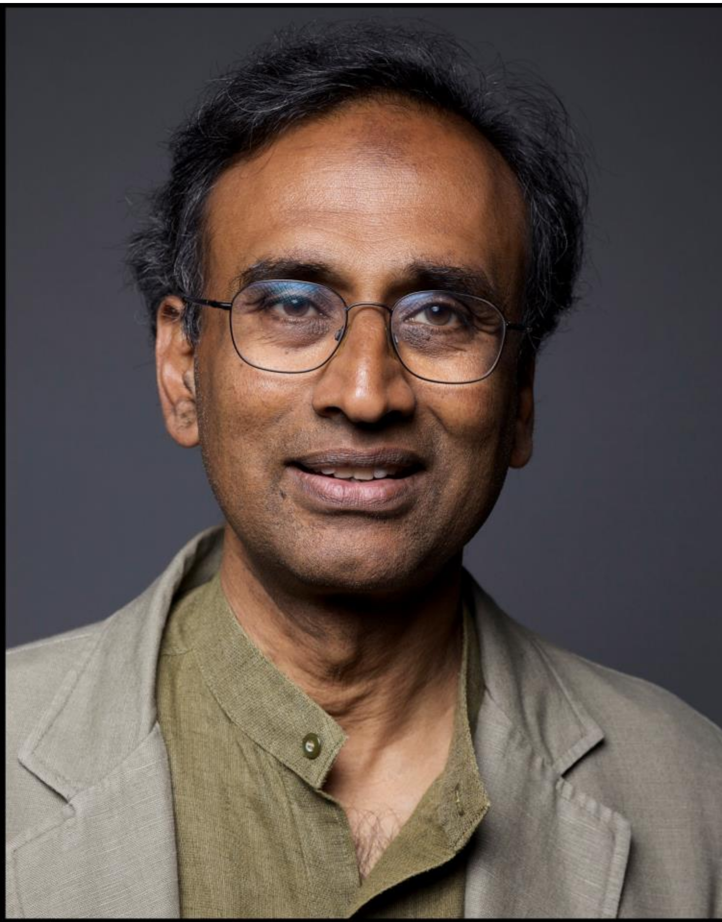
Appropriately, Ian Munro ‘dumped the beam’ for the last time in August 2008 after 28 years of successful operations by pressing the big red button !



Another Nobel Prize !

Soon after the SRS closed down we heard the news that **Venki Ramakrishnan** had won a share of the **2009 Nobel Prize for Chemistry** for solving the structure of the ribosome, the molecular machine that constructs proteins from 'instructions' coded in mRNA. Like John Walker, part of his prize winning research was carried with the SRS.





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Visit the SRS today !

Following decommissioning the buildings and infrastructure were refurbished and repurposed for CLARA, VISTA (vacuum science) lab, DUNE detector assembly area etc

Parts of the SRS were transferred to the **Manchester Science and Industry Museum** where they are on display

Dipole henge at Daresbury is made up of all the SRS storage ring dipole vacuum chambers

Watch this short film featuring Stephen Hill explaining about the excitement and inspiration he got out of working on the SRS

https://www.facebook.com/DaresburyLaboratory/videos/545409060851032

Conclusions and Personal Thoughts

- The SRS was the first 2nd generation light source in the world, as such it was bit of an act of faith by those that proposed it and those that funded it. **This appetite for risk really should be applauded.**
- The **speed of approval by the government & funding agency** for the construction and then the upgrade was **remarkable** by today's standards
- The facility was definitely of its time (obviously) and looking back it certainly had some shortcomings but this is to be expected when you are the first of a kind – **it was very exciting to be a part of it**
- There never seemed to be quite enough funding which meant the facility could have delivered even more science, been more reliable, and supported the users better
- Playing a significant part in delivering **two Nobel Prizes** is remarkable but this is only the tip of the iceberg – more than 5000 papers were published and over 1200 protein structures were solved
- There were **11,000 individual users, 4,000 PhD students and 2,000 post docs** who made use of the SRS during the 28 years of operation
- The **impact & influence** goes on with the 70+ synchrotron light sources currently operating, including Diamond which was designed by the SRS team, the new X-ray techniques that were developed, with the accelerator experts who established ASTeC and the Cockcroft Institute, with the world leading detectors that continue to be developed and delivered today, and so on
- **I would argue that the SRS is the most successful science research facility that the UK has ever built**

https://www.ukri.org/publications/new-light-on-science-socioeconomic-impact-study-of-daresbury-srs/