Welcome …

Richard P. Walker, Diamond Light Source

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… and Overview of Accelerators in the UK:

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… and Overview of Accelerators in the UK:

Past, Present and Future

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… and Overview of Accelerators in the UK:

From the dim and distant past to
the (possibly) dim and distant future…

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… and Overview of Accelerators in the UK:

A story of firsts, and near seconds …

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… and Overview of Accelerators in the UK:

Brief, and necessarily selective …

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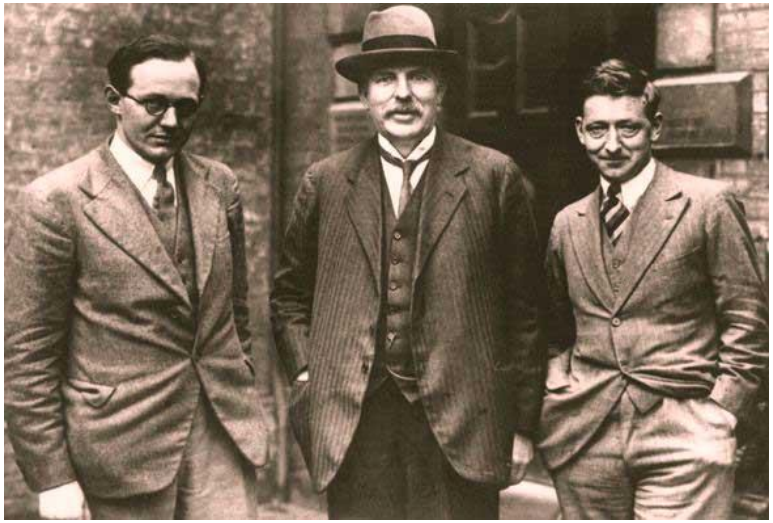
The start of particle accelerators (1927) ?

Ernest Rutherford, Director of the Cavendish Laboratory, Cambridge, in his Presidential Annual Address to the Royal Society in November 1927:

'it has long been my ambition to have available for study a copious supply of atoms and electrons which have an individual energy far transcending that of the alpha- and beta-particles from radioactive bodies.'

This statement encouraged several scientists around the world to begin work on particle acceleration.

“Splitting the Atom” (1932)



Walton, Rutherford and Cockcroft at the Cavendish Laboratory, Cambridge.

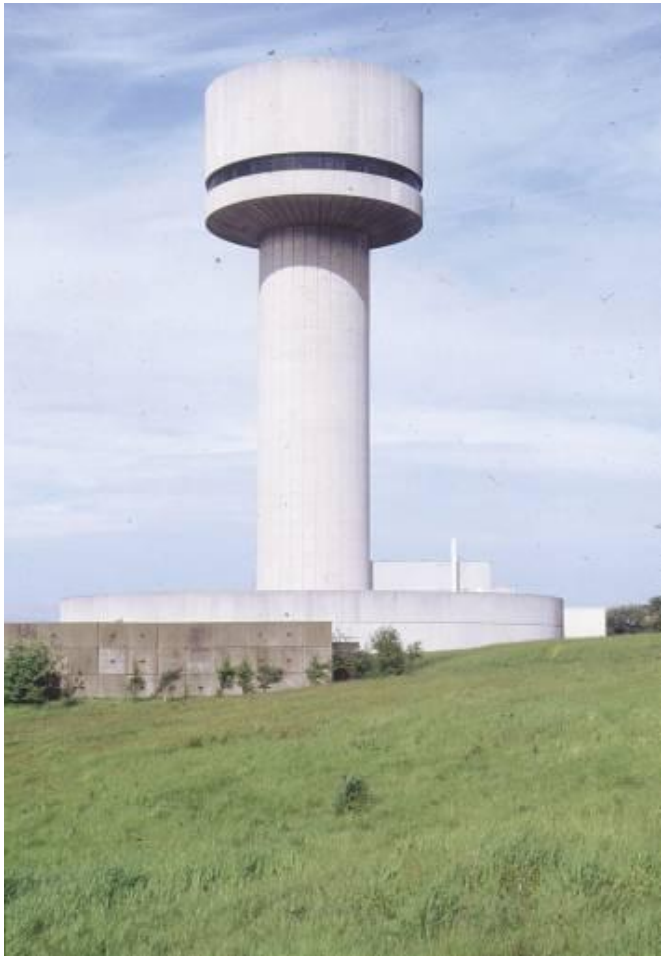
Walton and the machine used to "split the atom" (April 1932)

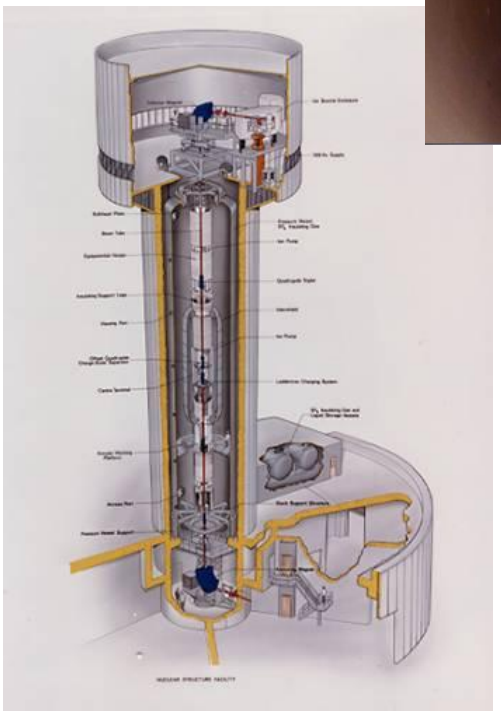
The Nobel Prize in Physics 1951 was awarded to Cockcroft and Walton *"for their pioneer work on the transmutation of atomic nuclei by artificially accelerated atomic particles"*

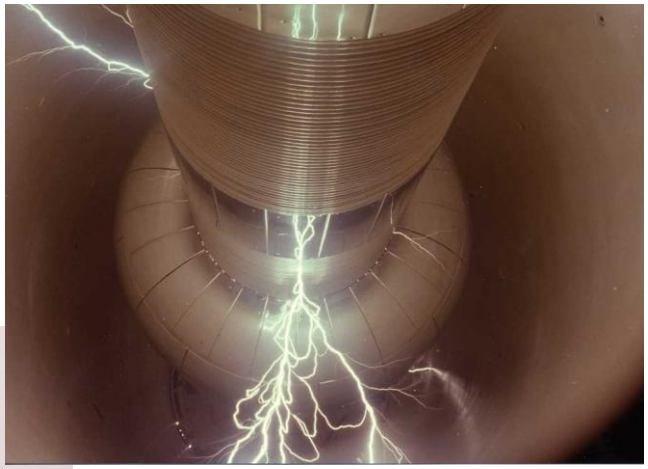
Note the Diagnostics cabin !

Nuclear Structure Facility, Daresbury Lab.

Tandem Van de Graaff, ~ 20 MV, highest voltage in the world at the time operated 1983-1993; discovery of super-deformed nuclei





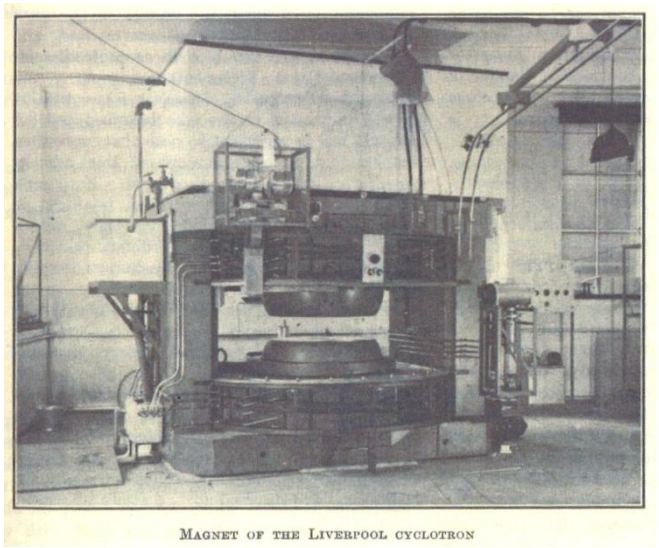


Early UK Cyclotrons

1930 – Lawrence invents the cyclotron at Berkeley

Jan. 1932 – Lawrence & Livingston achieve 1.22 MeV protons with a 11” cyclotron
(but lose the race for artificial nuclear disintegration to Cockcroft & Walton)

1935 – Chadwick (discoverer of the neutron, Nobel prize 1936) takes up a Chair at Liverpool and plans to build a cyclotron to investigate the biological effects and medical applications of neutrons and radio-isotopes.



MAGNET OF THE LIVERPOOL CYCLOTRON

The Liverpool 37” 20 MeV cyclotron first operated in 1939 ..
(along with a twin machine built by Cockcroft in Cambridge)

… but then was used for nuclear studies related to the atomic bomb until 1943, when the team was transferred to the USA as part of the “Manhattan Project”.

This was later followed by:

Birmingham	60”		(started 1938, completed 1949)	*(The “Nuffield Cyclotron”)*
Harwell	110”	180 MeV	(1949) synchro-cyclotron	*(.. which John Adams worked on)*
Liverpool	156”	400 MeV	(1954) synchro-cyclotron	

The World's First Electron Linac !

First electron acceleration in a travelling wave Linac: Nov. 1946
(Stanford Mark I, 1947, also magnetron powered)

Feb. 1948 – 4 MeV

NB] wavelength = 10.00 cm …
European S-band !

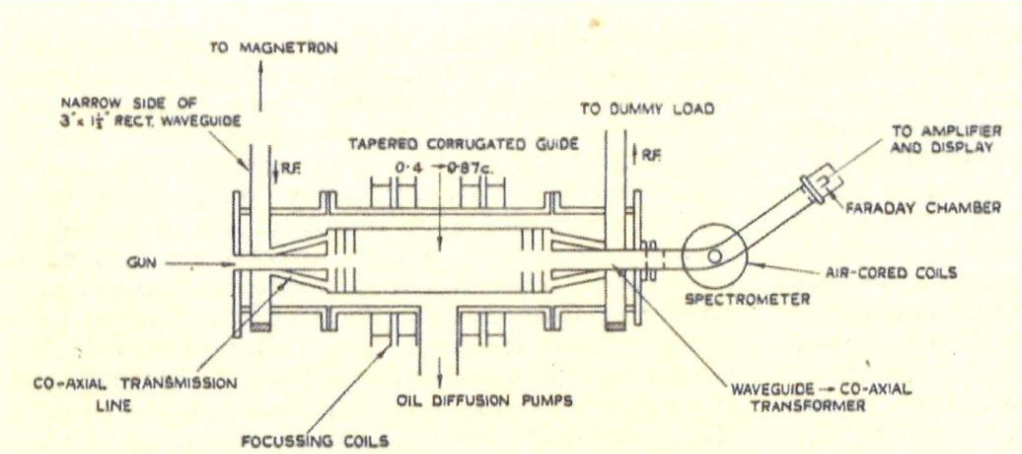
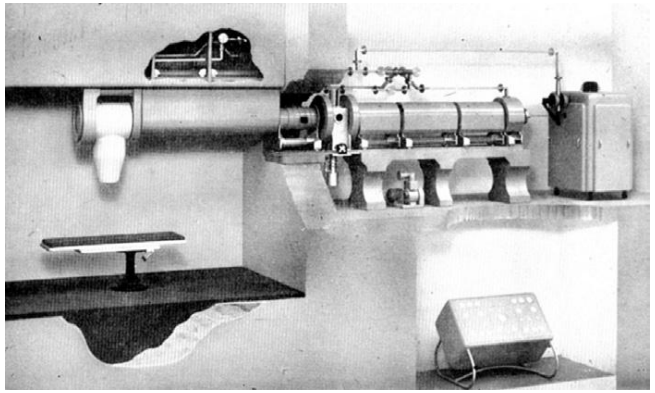


Fig. 1. SCHEMATIC DIAGRAM OF 0·5 MEV. LINEAR ELECTRON ACCELERATOR

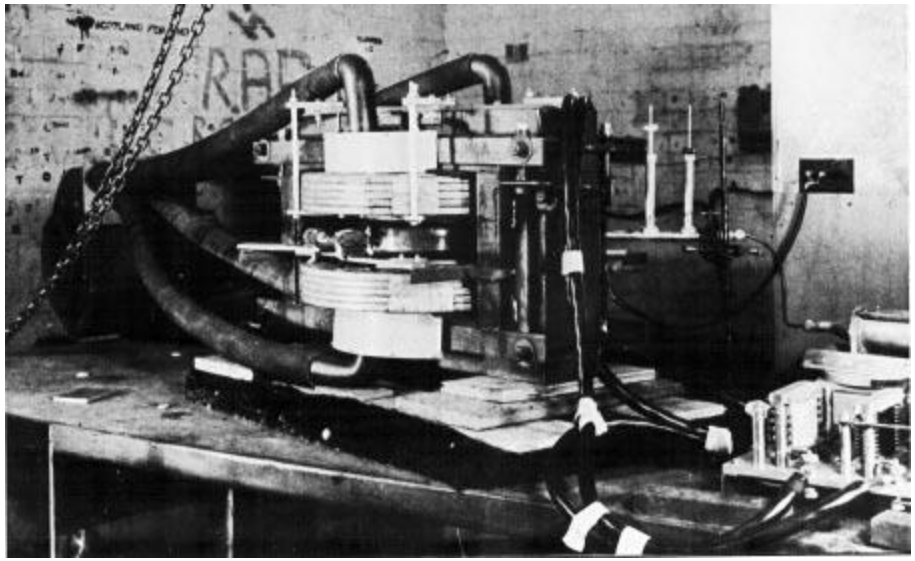
D.W. Fry et al., Nature 160 (1947) 351.

First patient treatment by a Linac:
Aug. 1953, at the Hammersmith Hospital, London
(3 m long structure, 8 MeV, 2 MW magnetron)



Model of the 8 MeV linac installation at Hammersmith Hospital

The World's First Synchrotron ! (just)



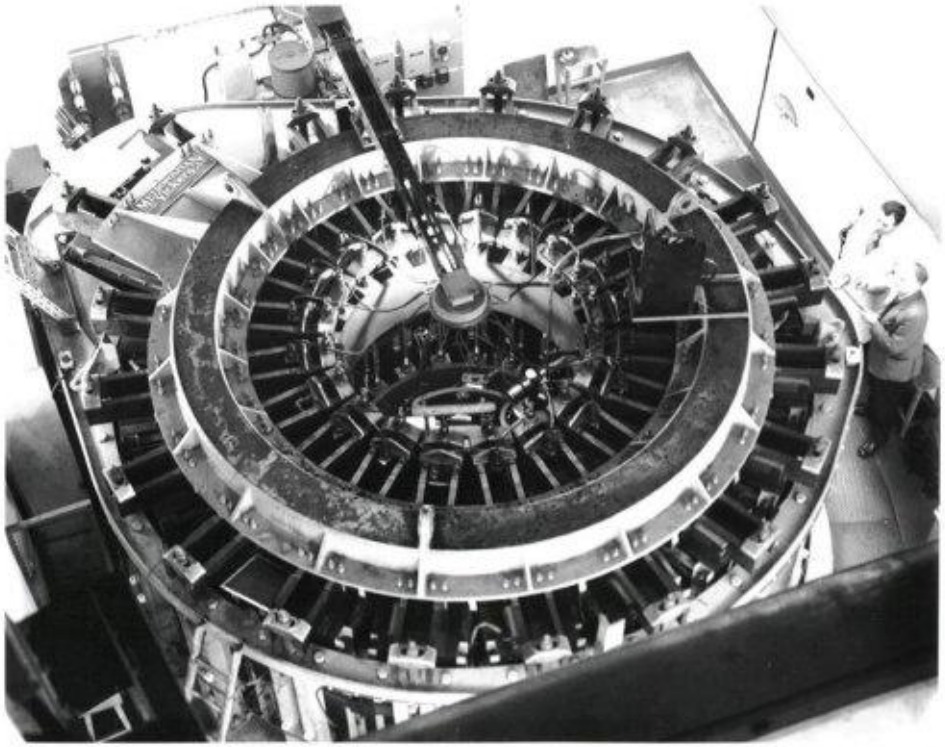
Originally a betatron built to inspect unexploded bombs during the war, it was converted to a synchrotron at the Woolwich Arsenal (London).

In **August 1946** electrons were accelerated from the maximum betatron energy of 4 MeV to 8 MeV, two months before the General Electric machine operated in the USA.

F. K. Goward & D. E. Barnes, Nature 158, Sep. 1946, p. 413.

Early UK Synchrotrons

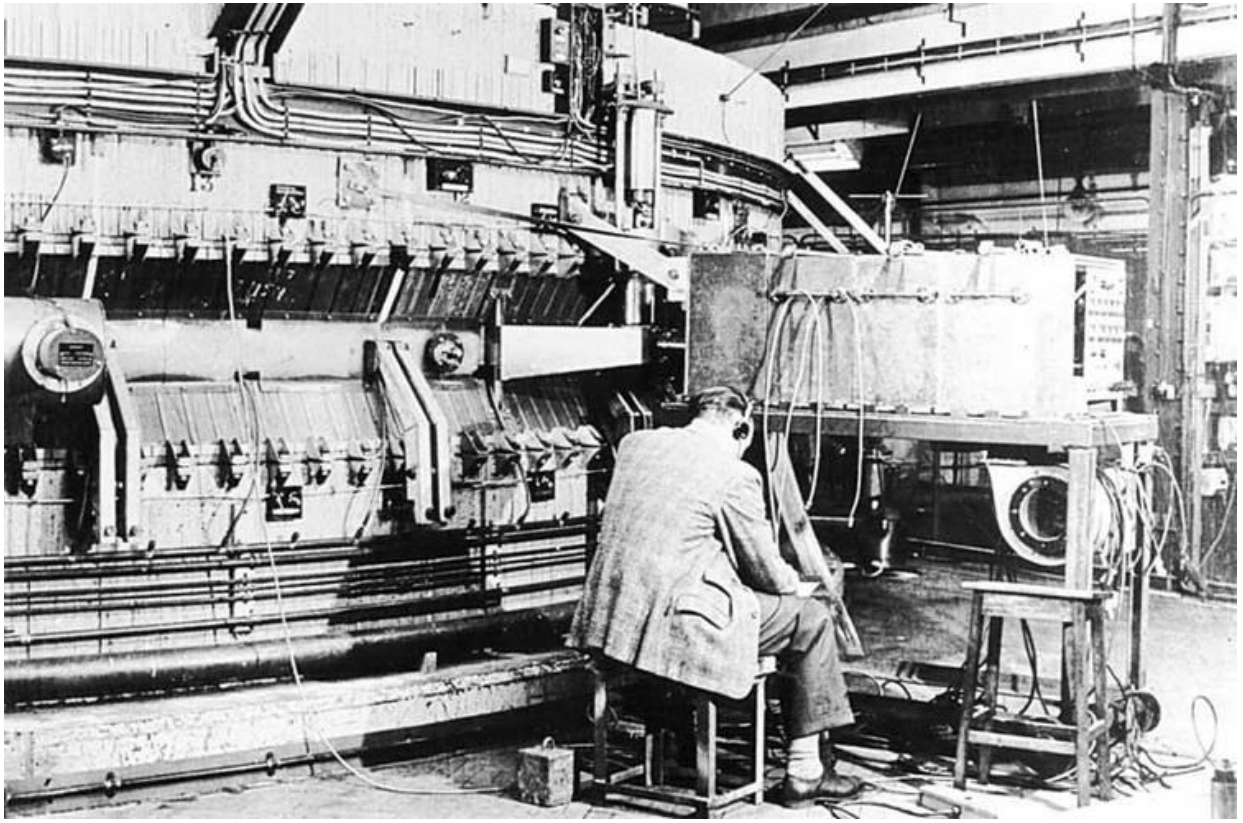
1947	30 MeV (e)	Telecommunications Research Establishment, Malvern
1949	30 MeV (e)	Radiotherapeutic Centre, Cambridge
1949	30 MeV (e)	Royal Cancer Hospital, London
1952	140 MeV (e)	Uni. Oxford
1953	1 GeV (p)	Uni. Birmingham
1954	340 MeV (e)	Uni. Glasgow
1954	400 MeV (p)	Uni. Liverpool



Glasgow electron synchrotron, (used also for synchrotron radiation experiments from 1966)

Almost the World's First Proton Synchrotron ..

The Birmingham 1 GeV proton synchrotron (July 1953-1967)



… the first proton synchrotron to be proposed†, and to start construction, but was beaten into operation by the Brookhaven Cosmotron (May 1952).

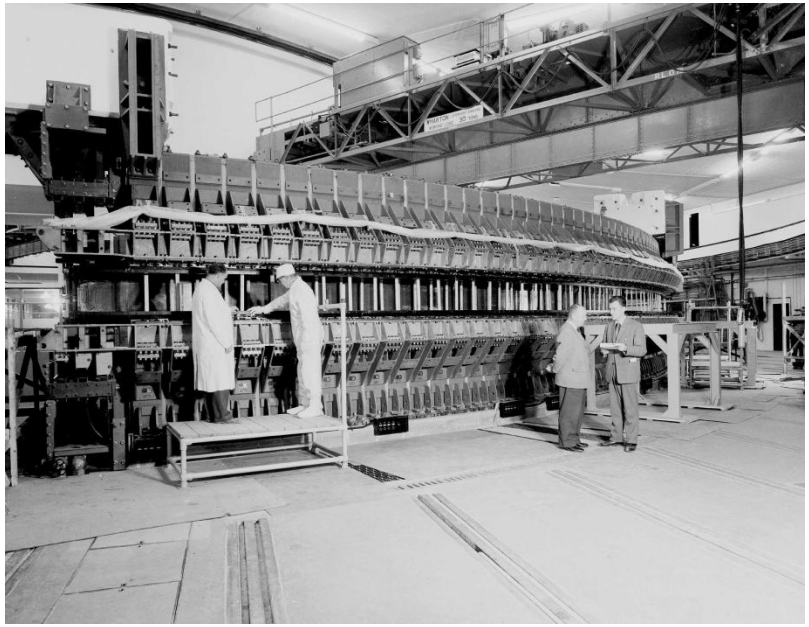
†*M.L. Oliphant (U. Birmingham), proposal submitted to the Directorate of Atomic Energy, Sep. 1943??*
M.L. Oliphant et al., Proc. Phys. Soc. March 1947, 59, p. 666

The sophisticated timing system …

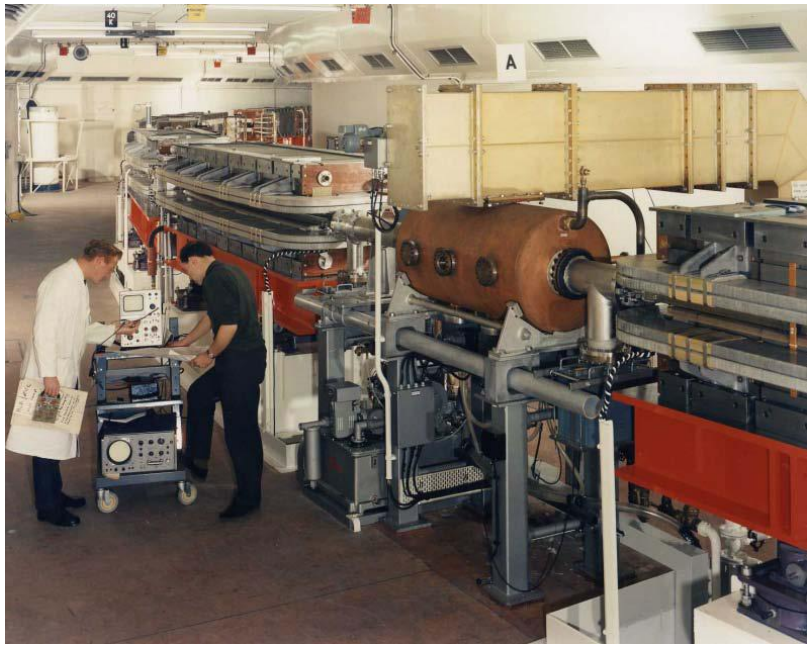
D.50197. (20). The sequence timer, which ultimately controls the linking of the radiofrequency system with the magnetic field, has been completed. Our picture shows Mr. Woodall using a test meter (on stool, right) to give the sequence timer a final circuit test. (6/5).

NIMROD and NINA

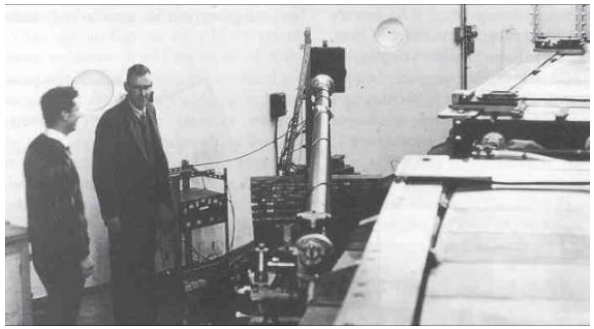
NIMROD 7 GeV proton synchrotron
Rutherford Lab., 1964-1978



NINA 5.3 GeV electron synchrotron
Daresbury Lab., 1966-1977



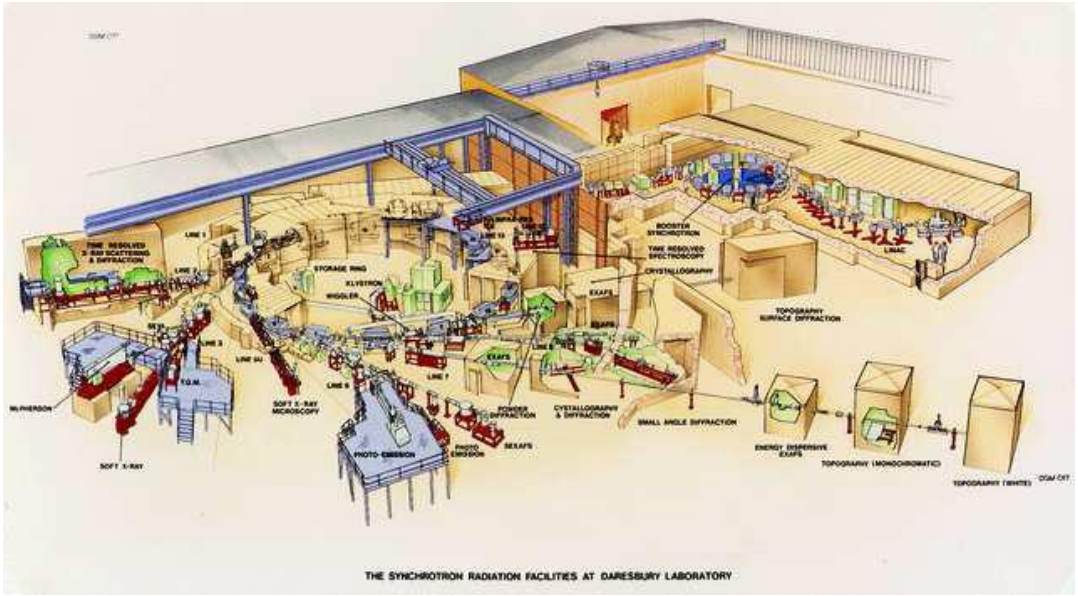
An HEP machine, but was used for Synchrotron Radiation experiments already from 1967.



The first synchrotron radiation beamline on NINA constructed in 1966/1967 by Manchester University (Department of Physics)

SRS – The World's First Dedicated High Energy Synchrotron Radiation Source

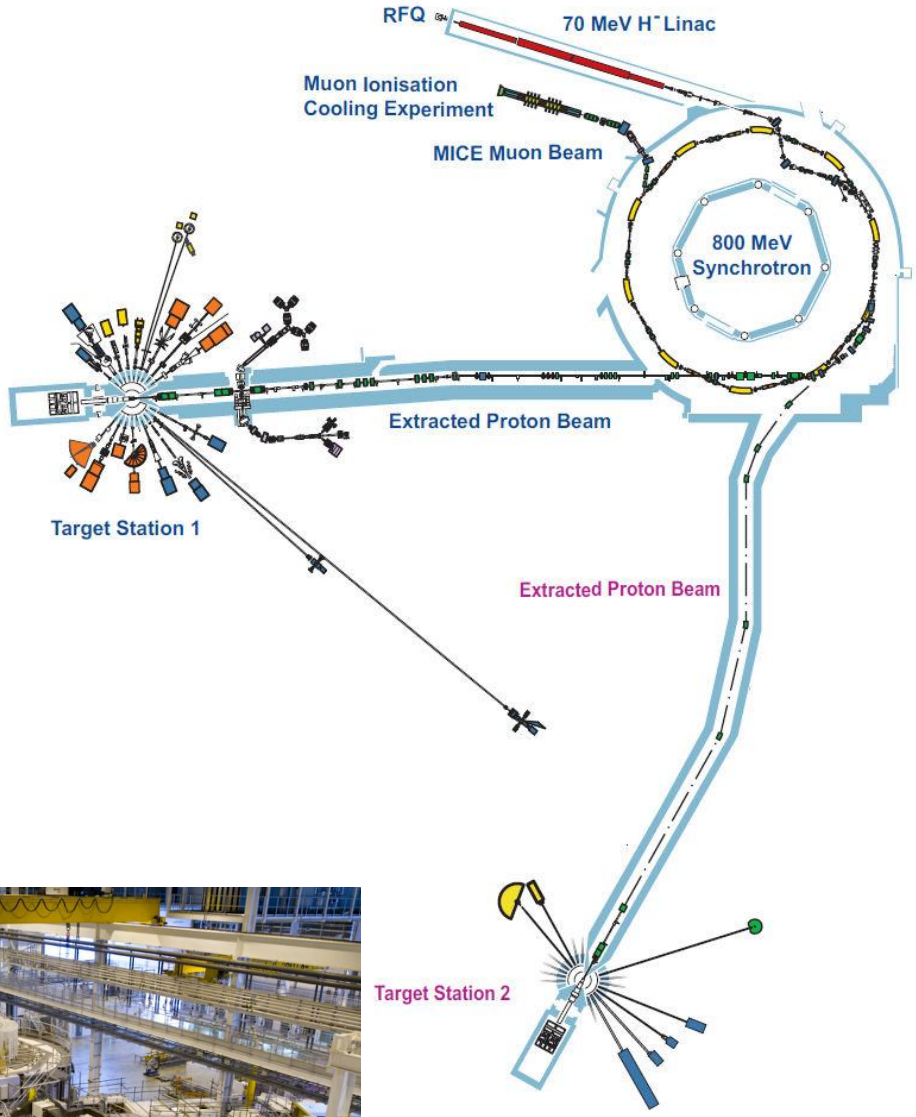
Daresbury Laboratory, 1980-2008



2 GeV electron storage ring
96 m circumference

ISIS Pulsed Neutron Source

Rutherford Appleton Laboratory



Operational since 1984
800 MeV, 220-230 μA proton synchrotron

Target Station 2
opened in 2009

Diamond Light Source

The UK's largest accelerator

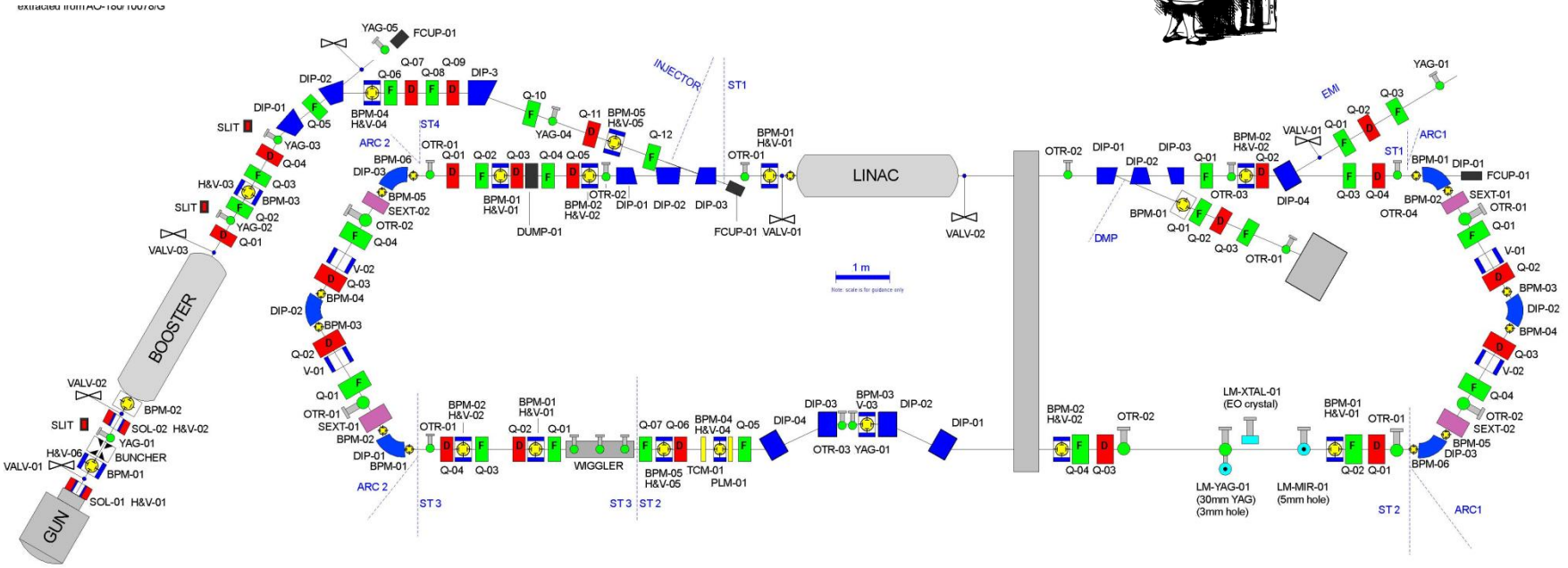
- Medium energy, 3rd Generation Light Source, replacing the SRS
- Operational since 2007
- 3 GeV, 300 mA, top-up
- 561.6 m circumference
- $\varepsilon_{x,y}$ = 2.7 nm, 8 pm
- 23 operational beamlines
- 10 beamlines under design/construction/commissioning

ALICE – Accelerators and Lasers In Combined Experiments

Daresbury Laboratory

ALICE

Accelerators and Lasers In Combined Experiments

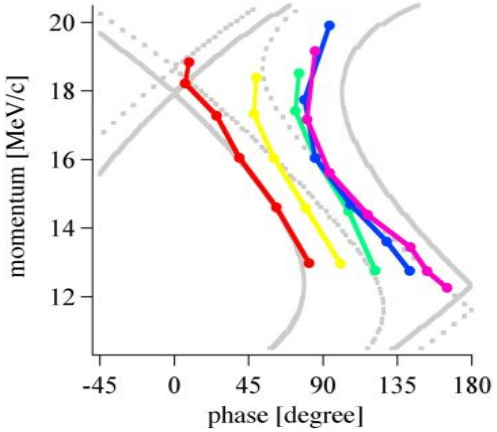


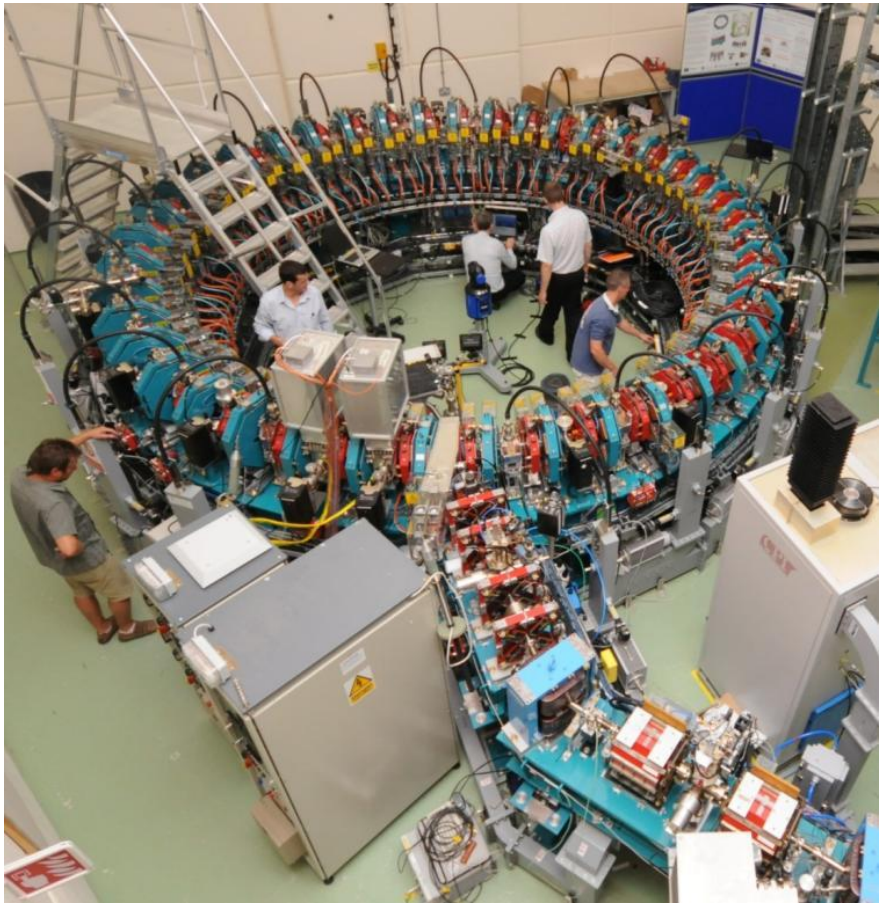
- Energy Recovery Linac prototype
- IR FEL (5.5-9 μm) and coherent THz source studies
- SNOM : IR Scanning Near-Field Microscopy (research into cancer diagnostics)
- Research into effects of THz radiation on living cells
- Bunch energy modulation with short THz pulses
- Accelerator physics studies : beam dynamics; electron beam tomography
- SRF cryomodule development (to be commissioned at the end of 2013)
- injector for EMMA

Emma – Electron Model for Multiple Applications

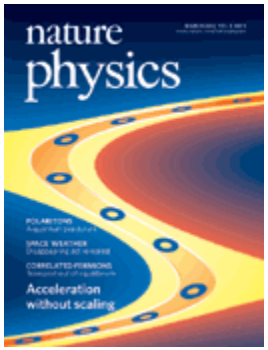
Daresbury Laboratory

World's first non-scaling FFAG!





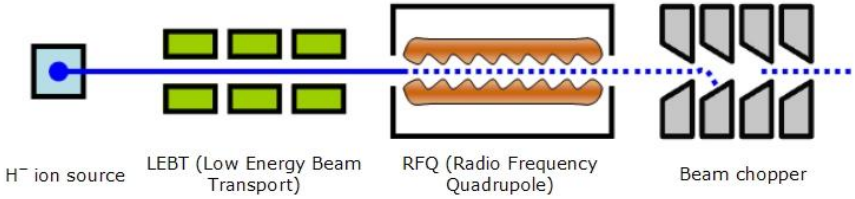
"Stable acceleration in the linear non-scaling FFAG EMMA has been successfully demonstrated… the beam is accelerated in a serpentine channel from 12 MeV/c to more than 18 MeV/c within six turns.."



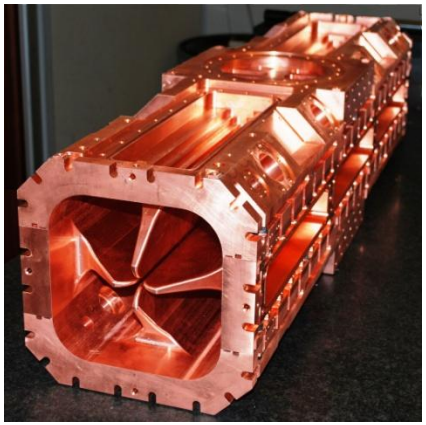
S. Machida et al., Nature Physics 8, p. 243 (2012).

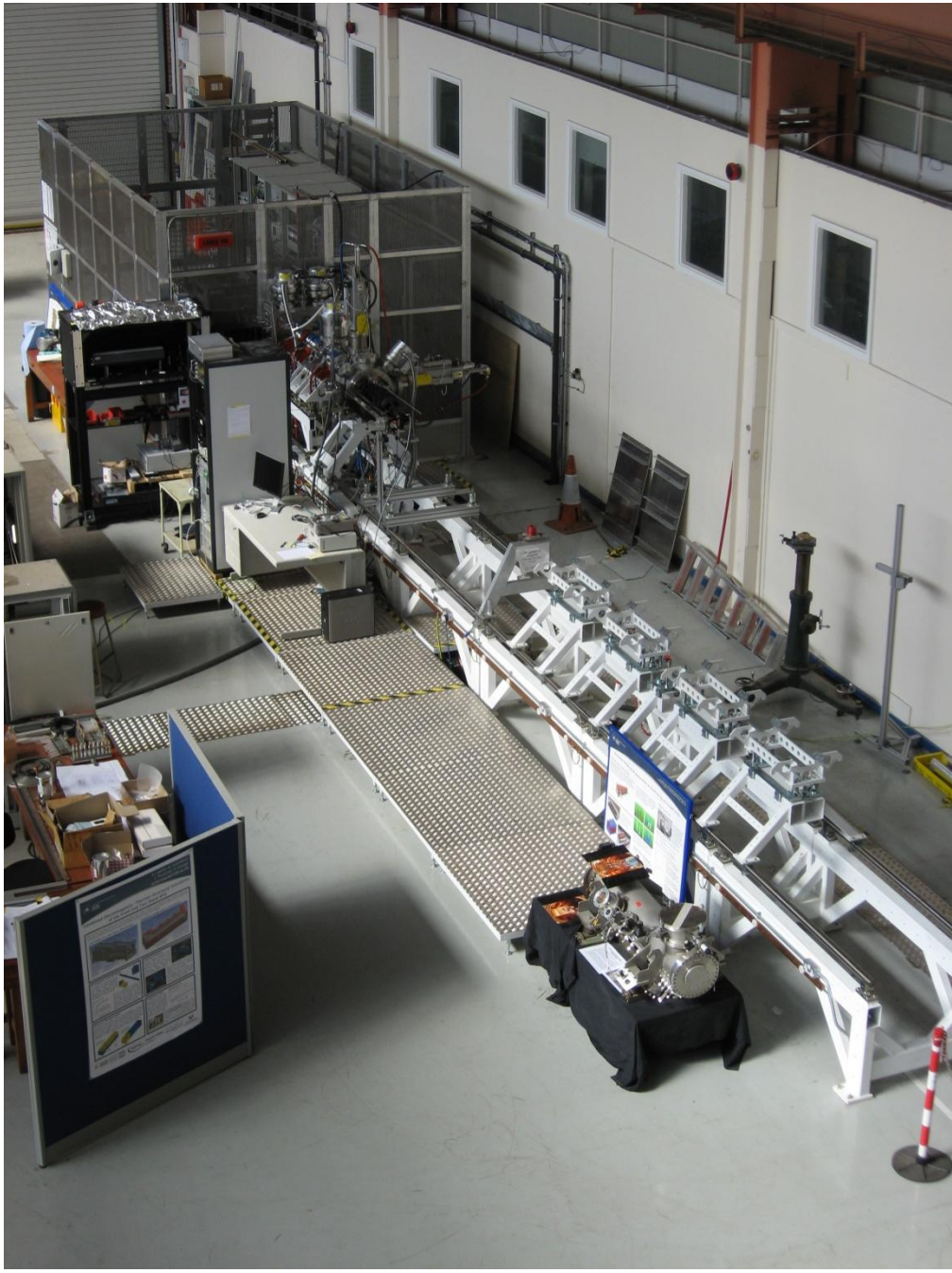
FETS – Front End Test Stand

Rutherford Appleton Laboratory



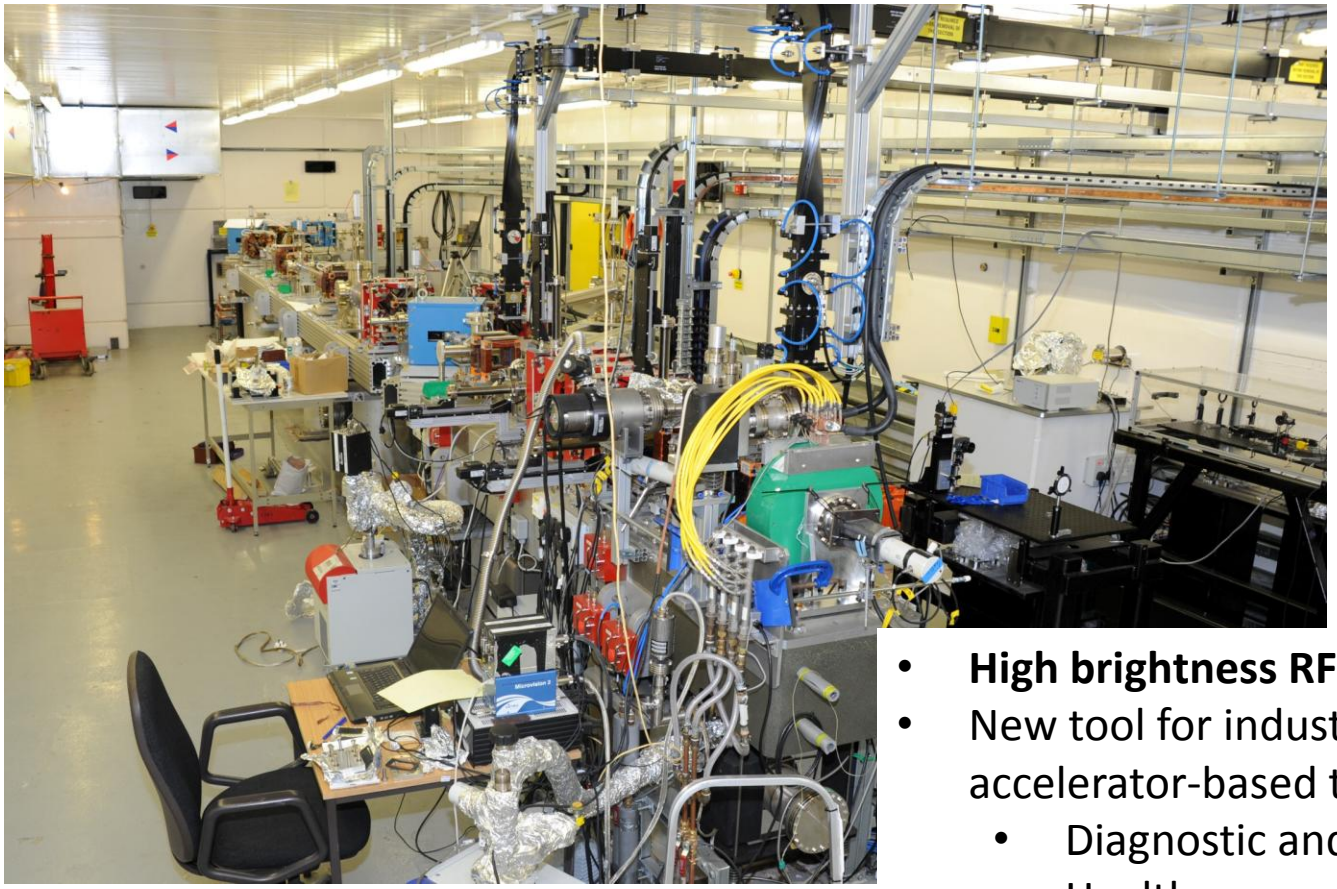
- **High Power Proton Accelerator R&D**
- Aims to produce a 60 mA H- beam at 3 MeV with 10% duty factor
- Ion source and LEBT operating, RFQ under fabrication:





VELA - Versatile Electron Linear Accelerator

Daresbury Laboratory



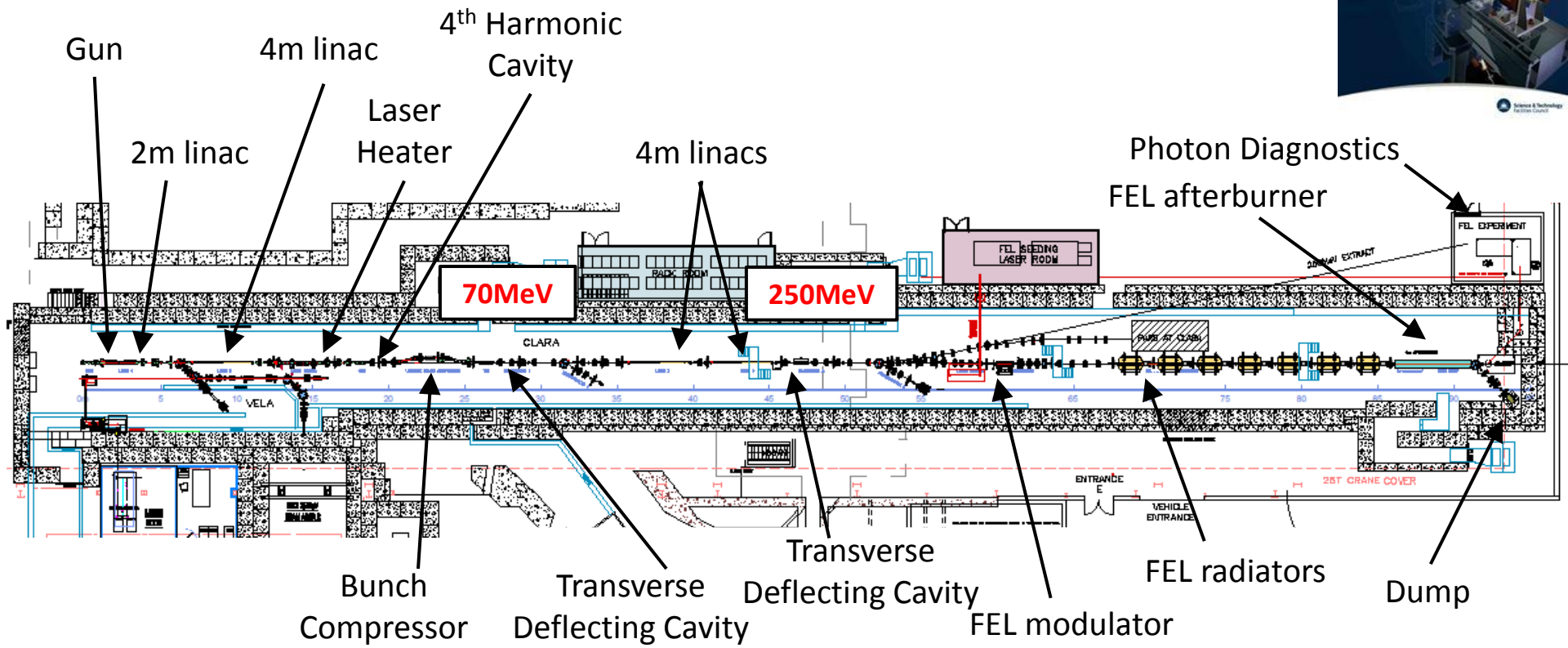
- **High brightness RF Photoinjector**
- New tool for industry to develop new accelerator-based technologies
  - Diagnostic and instrumentation testing
  - Healthcare
  - Security scanners
  - Water treatment
  - ….
- **Funded August 2011**
- **First Industrial user Autumn 2013**

The future …..

"*Prediction is very difficult, especially about the future*",
Niels Bohr, possibly.

CLARA - Compact Linear Accelerator for Research and Applications (proposal)

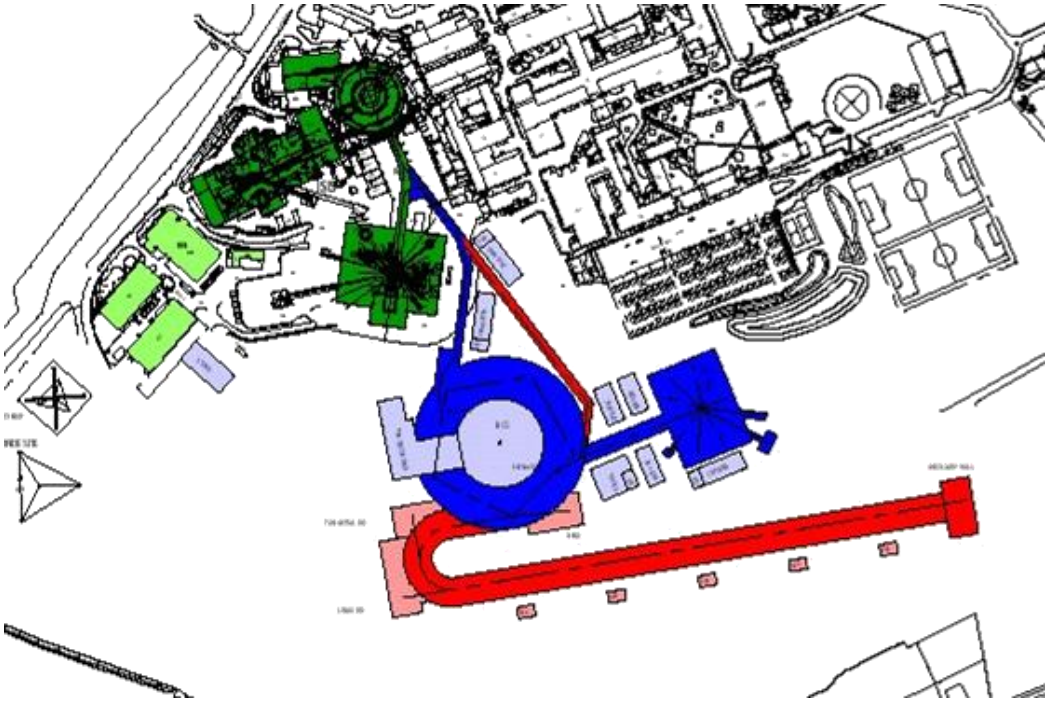
Daresbury Laboratory



To develop a normal conducting test accelerator able to generate longitudinally and transversely bright electron bunches and to use these bunches in the experimental production of **stable**, **synchronised**, **ultra short** photon pulses of coherent light from a single pass FEL with techniques directly applicable to the future generation of light source facilities.

http://www.stfc.ac.uk/ASTeC/Programmes/38749.aspx

ISIS MW Upgrade Scenarios

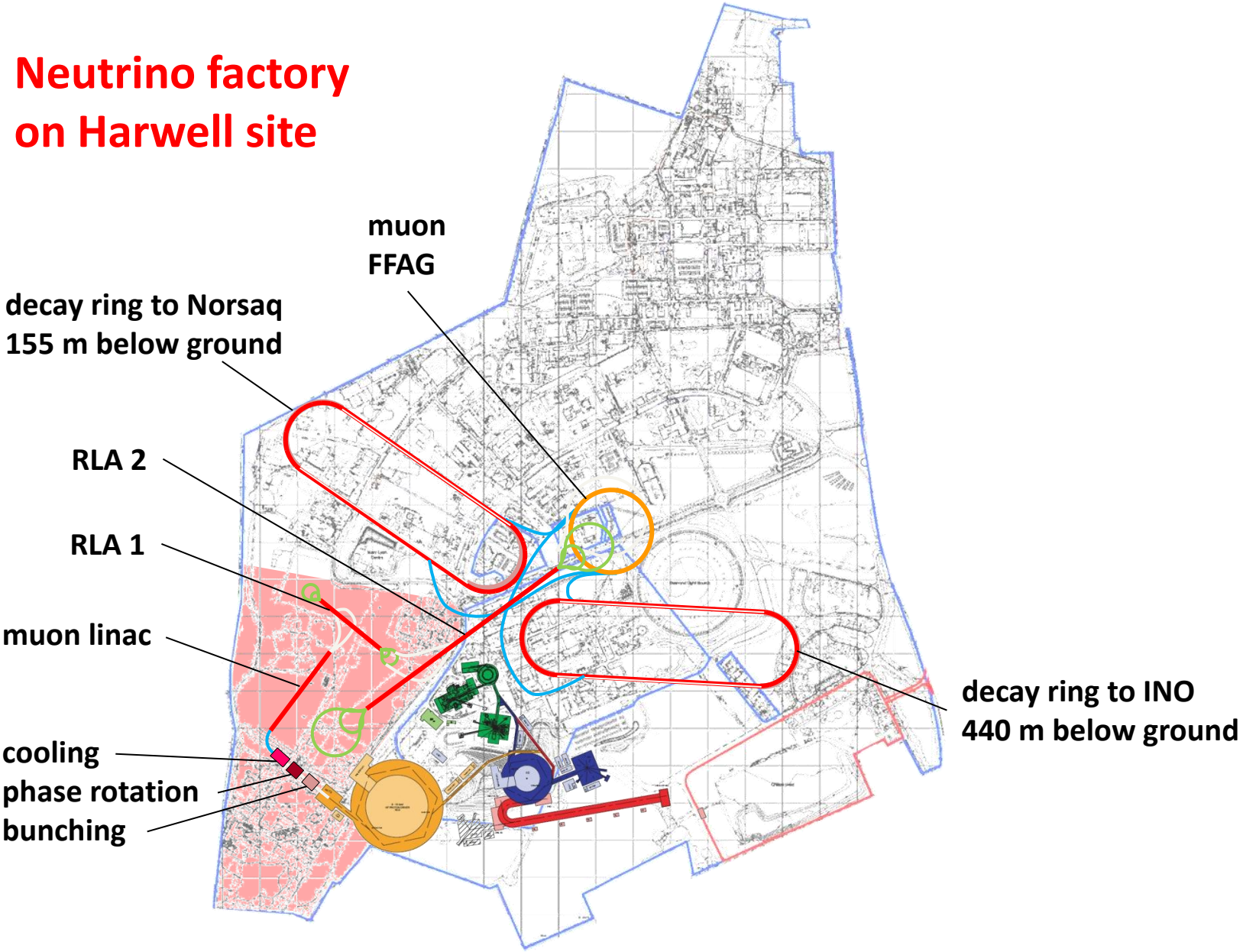


1) Replace 70 MeV ISIS linac by new ~180 MeV linac. (~0.5 MW)

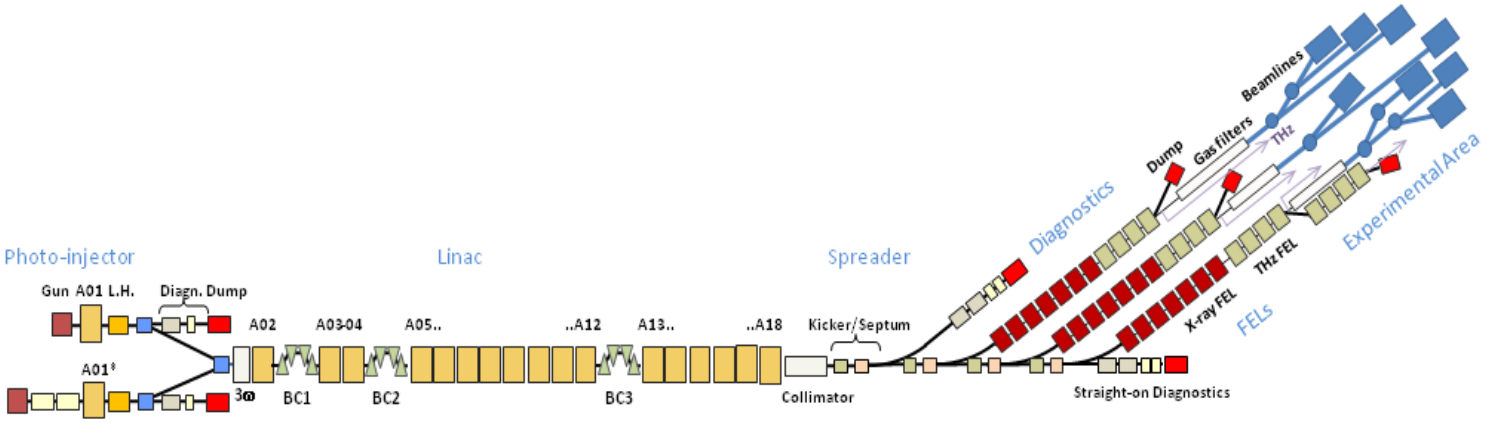
2) ~3.3 GeV Rapid Cycling Synchrotron (RCS) fed by bucket-to-bucket transfer from ISIS 800 MeV ring. (1MW, perhaps more)

3) RCS is fed directly from an 800 MeV linac with multi-turn charge exchange injection.
(2 – 5 MW)

Neutrino factory on Harwell site



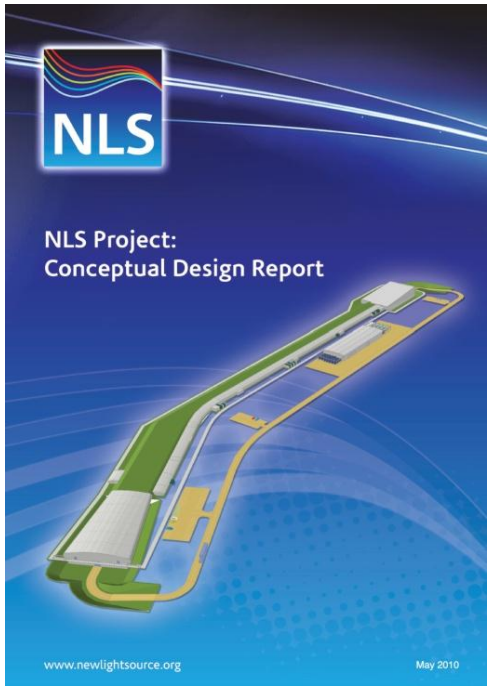
4’th Generation FEL-based Light Source



Conceptual Design Report for a “New Light Source” (NLS) completed in May 2010, but then work ceased.

However there remains a:
“***longer term aspiration to host a UK based XFEL***”,
J. Womersley, CEO Science and Technology Facilities Council, April 10th 2013

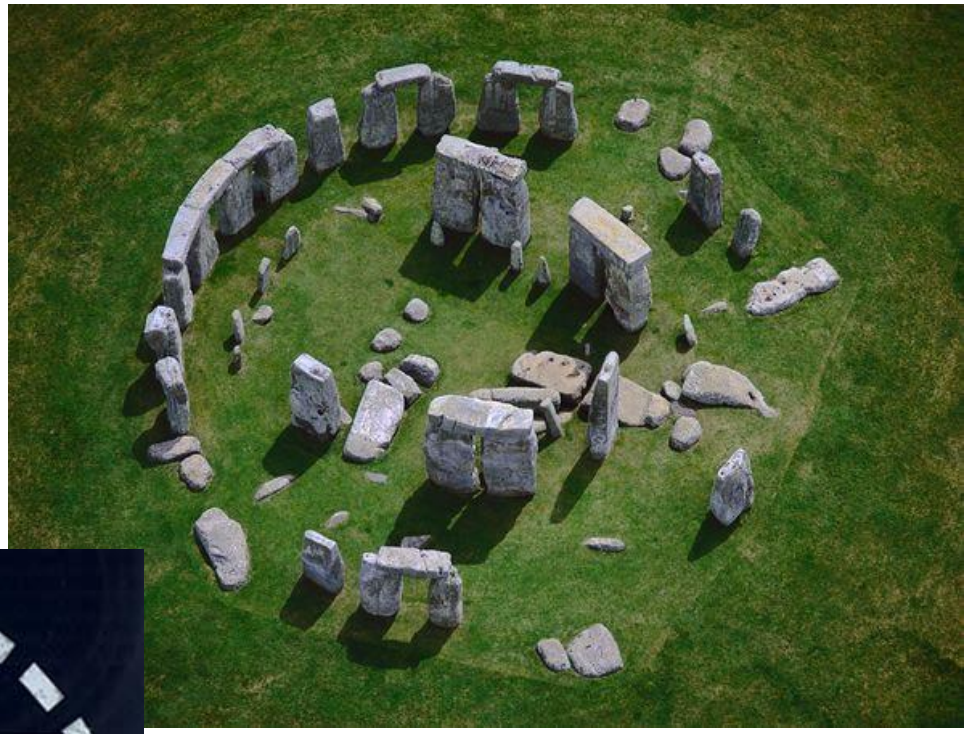
and,
“***we have included such a facility in our ten-year forward vision for capital investments, in response to a request from the minister for bold and ambitious plans***.”
J. Womersley, June 14th 2013

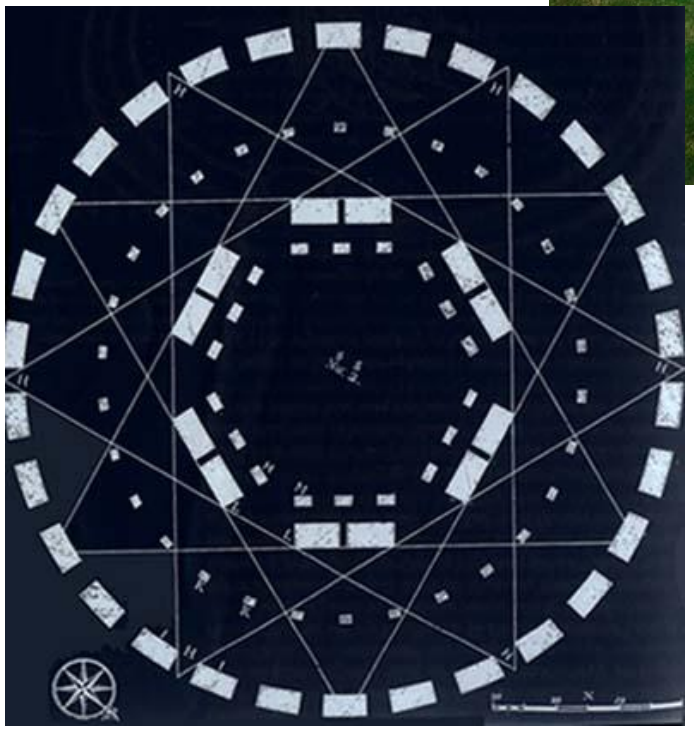


Plasma Wakefield Accelerators

Work going on at several institutes in the UK: JAI/Imperial Coll., U. Oxford, U. Strathclyde, Queens Univ. Belfast etc.

The start of particle accelerators ~ 1500 BC ?





"the STONEHENGE CONFIGURATION PATTERN which is composed of a main outer ring and an inner ring could serve as a template for the basic configuration of a particle accelerator? "

http://www.west.net/~simon/STONECIRCLESCRYSTALGRIDSandPARTICLEACCELERATORS--thePHYSICSOFPI.html

The Top 9 Clues That Stonehenge Was a Stone Age Particle Accelerator

"……. and the Number 1 Clue That Stonehenge Was a Stone Age Particle Accelerator…

Big circle? Check.
Enormously expensive? Check.
Nobody understands its true purpose? Check.
Still doesn't work? Check. We have a winner."

http://www.littlefivers.com/science/clues-that-stonehenge-was-a-stone-age-particle-accelerator/

If it didn't work …

… they obviously needed better Beam Instrumentation !

Thanks for your attention and …

… Enjoy the Conference !

diamond