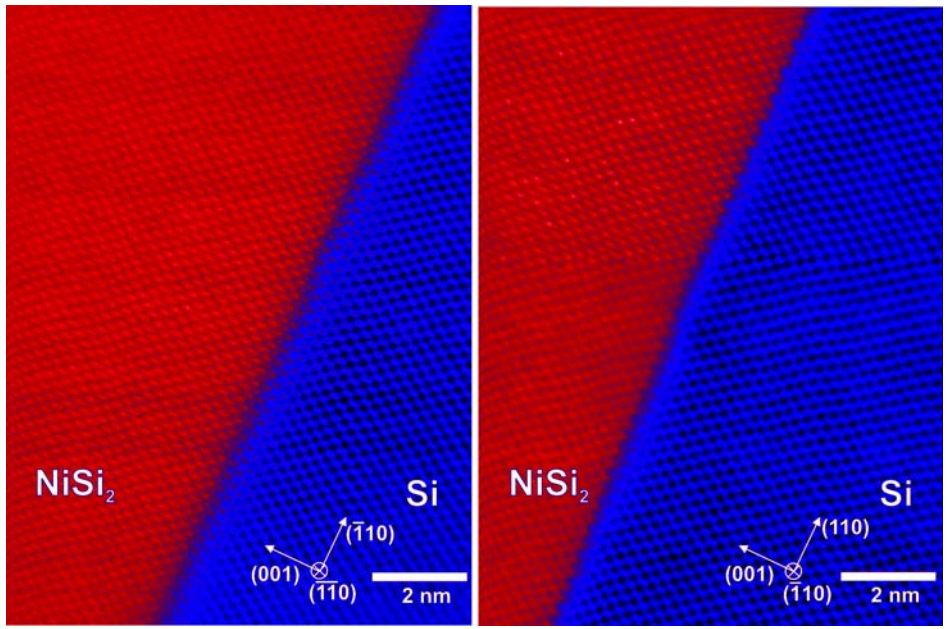
Daresbury Laboratory

SuperSTEM - Scanning Transmission Electron Microscope

- **World's highest resolution transmission electron microscope**
- **Special aberration correction to produce high resolution**
- **Super-stable building preserves it**



Silicon/Nickel disilicide

First images from SuperSTEM

www.superstem.dl.ac.uk

HPCx – Europe's Fastest Academic Computer

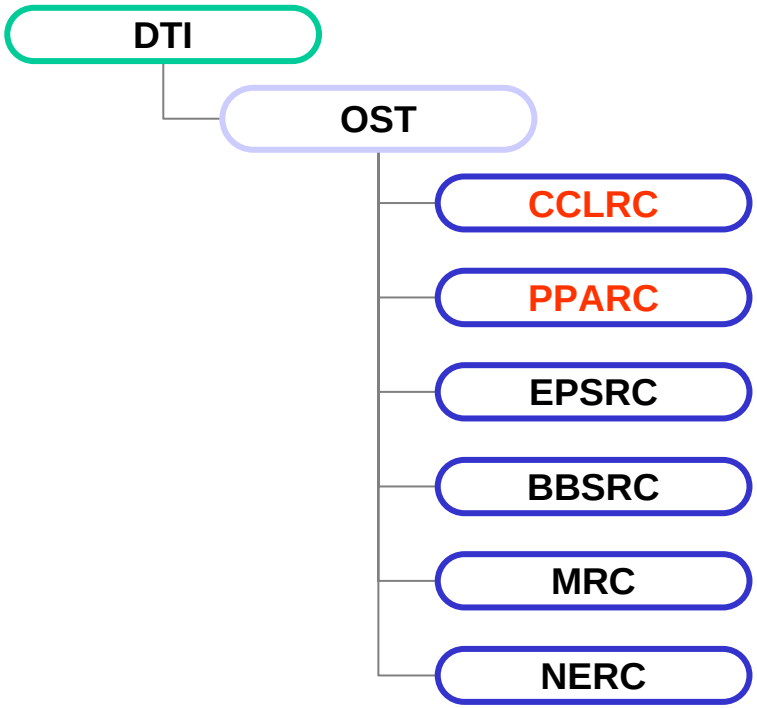
www.hpcx.ac.uk

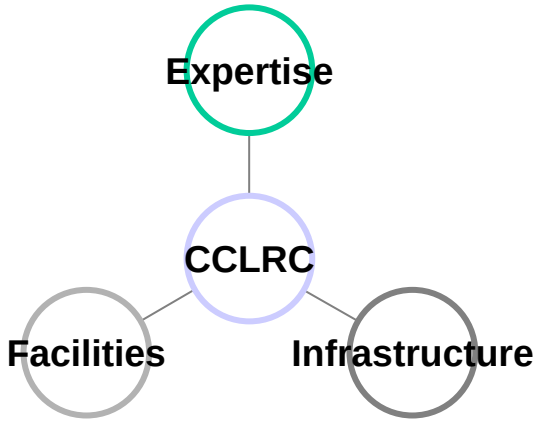
HPCx CAPABILITY COMPUTING

www.top500.org:

Rank	Manufacturer Computer/Procs	Installation Site Country/Year
1	NEC **Earth-Simulator/ 5120**	Earth Simulator Center **Japan/2002**
2	Hewlett-Packard **ASCI Q - AlphaServer SC ES45/1.25 GHz/ 4096**	Los Alamos National Laboratory **USA/2002**
3	Hewlett-Packard **ASCI Q - AlphaServer SC ES45/1.25 GHz/ 4096**	Los Alamos National Laboratory **USA/2002**
4	IBM **ASCI White, SP Power3 375 MHz/ 8192**	Lawrence Livermore National Laboratory **USA/2000**
5	Linux NetworX **MCR Linux Cluster Xeon 2.4 GHz - Quadrics/ 2304**	Lawrence Livermore National Laboratory **USA/2002**
6	Hewlett-Packard **AlphaServer SC ES45/1 GHz/ 3016**	Pittsburgh Supercomputing Center **USA/2001**
7	Hewlett-Packard **AlphaServer SC ES45/1 GHz/ 2560**	Commissariat a l'Energie Atomique (CEA) **France/2001**
8	HPTi **Aspen Systems, Dual Xeon 2.2 GHz - Myrinet2000/ 1536**	Forecast Systems Laboratory - NOAA **USA/2002**
9	IBM **pSeries 690 Turbo 1.3GHz/ 1280**	HPCx **UK/2002**
10	IBM **pSeries 690 Turbo 1.3GHz/ 1216**	NCAR (National Center for Atmospheric Research) **USA/2002**

CCLRC is a Public Sector Research Council





CCLRC has 3 sites:

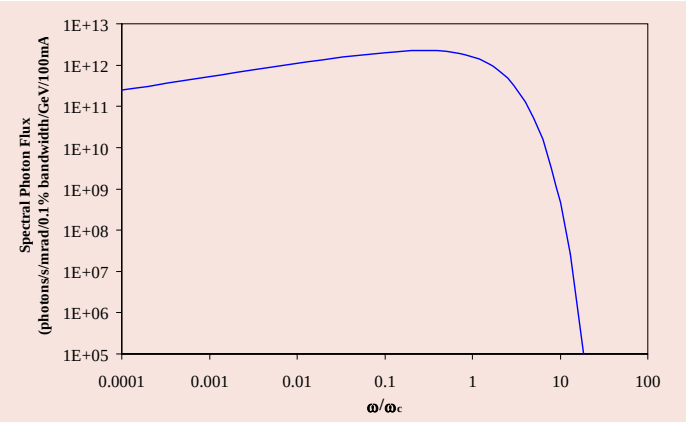
RAL
Daresbury
Chilbolton

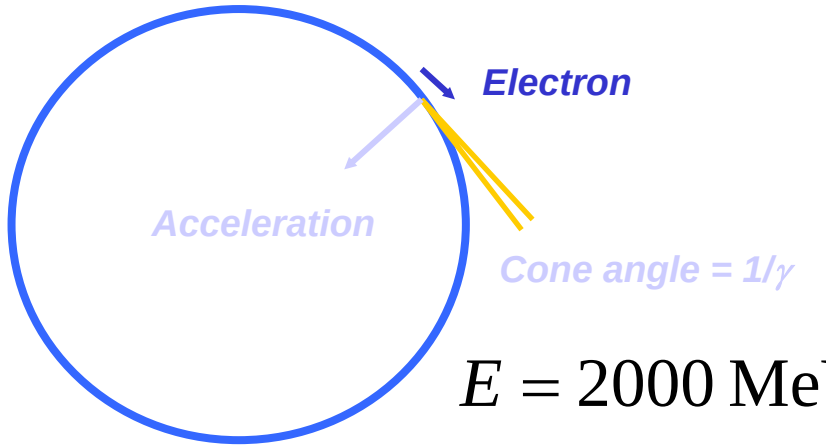
Employs over 1800 Staff
(500 at Daresbury)

History of Daresbury Accelerators

- **NINA** 5 GeV electron synchrotron (1962-1977)
- **NSF** 20 MV tandem van de Graaf (1980-1993)
- **SRS** 2 GeV electron synchrotron (1976-)
- **4GLS** 4th generation light source proposed (2002)

Synchrotron Radiation Emission

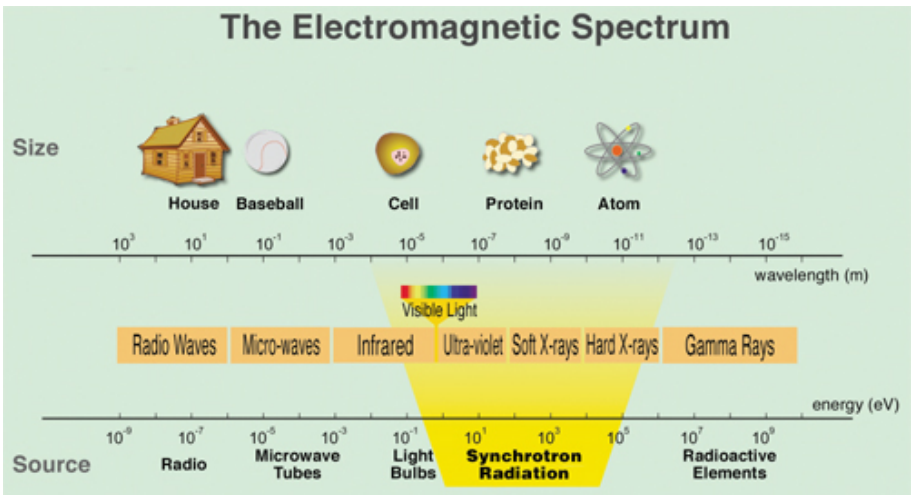


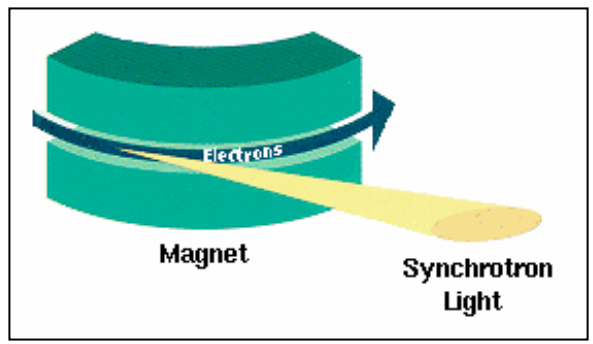


$$E = 2000\,\text{MeV}$$

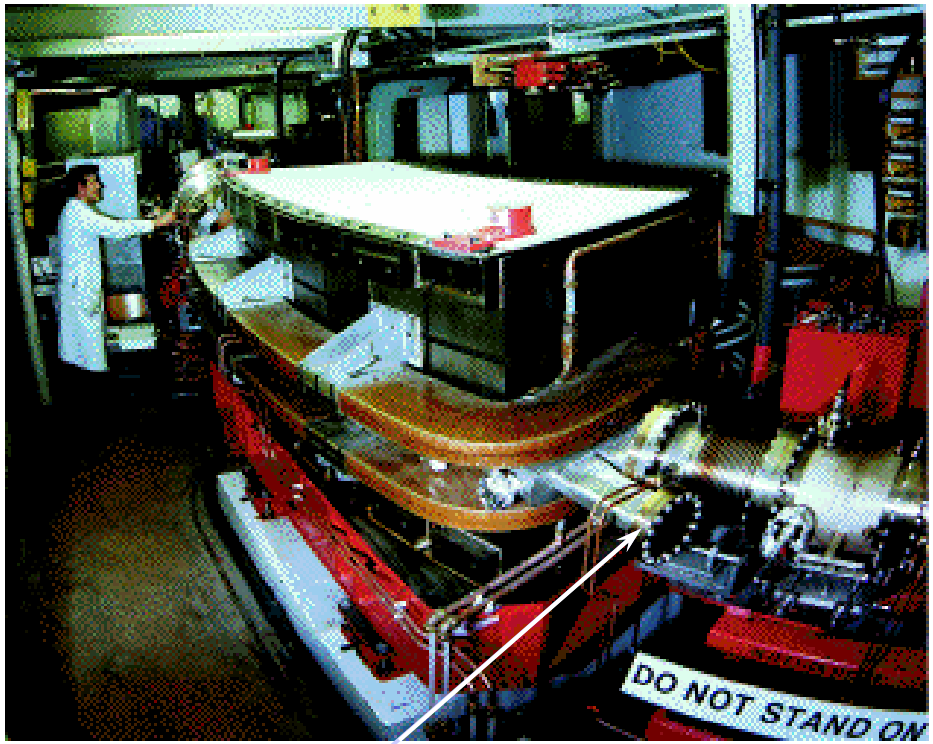
$$m_e = 0.511\,\text{MeV}$$

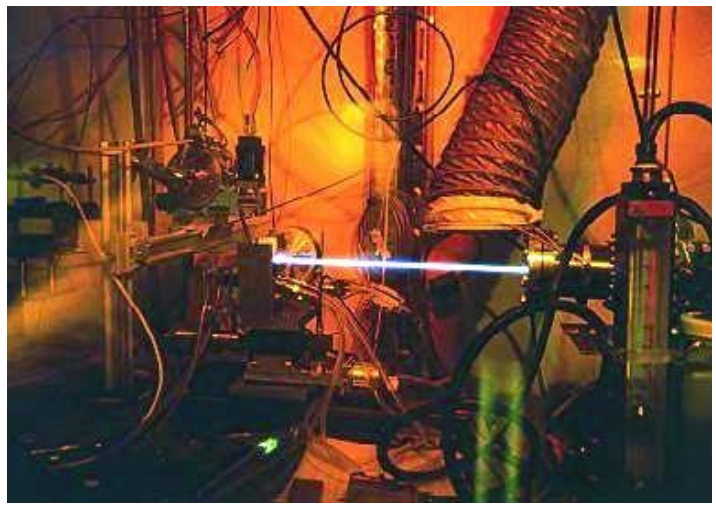
$$\gamma = 3913$$





Real Synchrotron Radiation



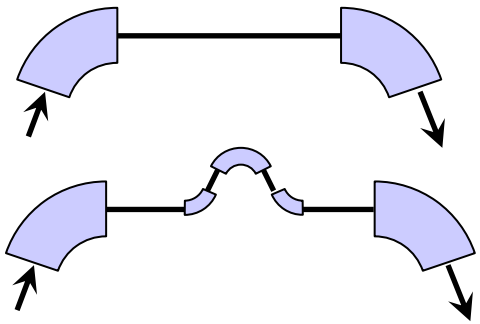


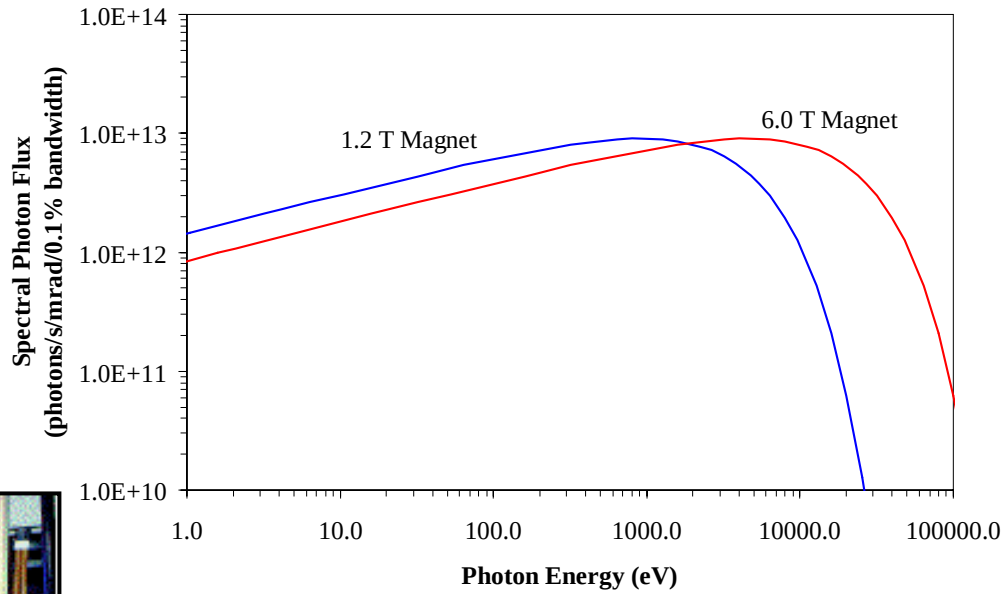
Beam port

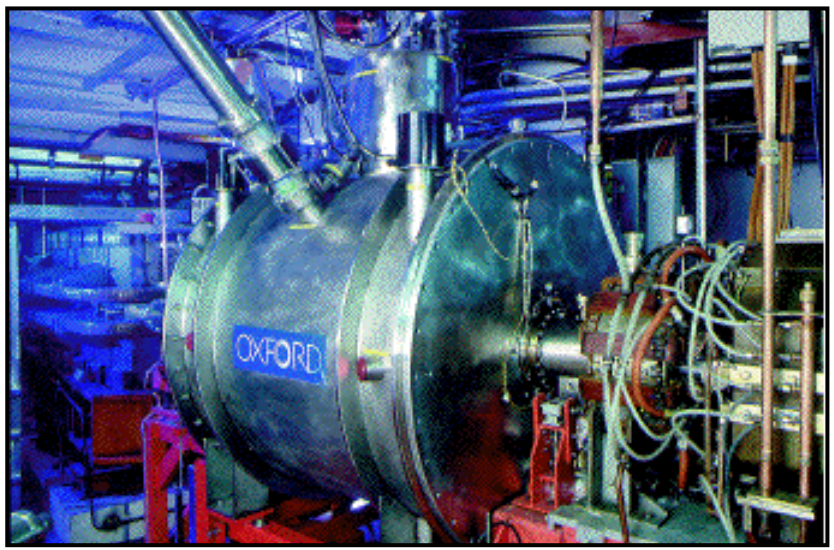
Synchrotron Radiation in Space

Crab Nebula

Insertion Devices



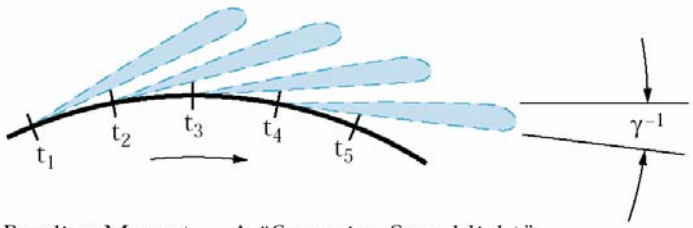




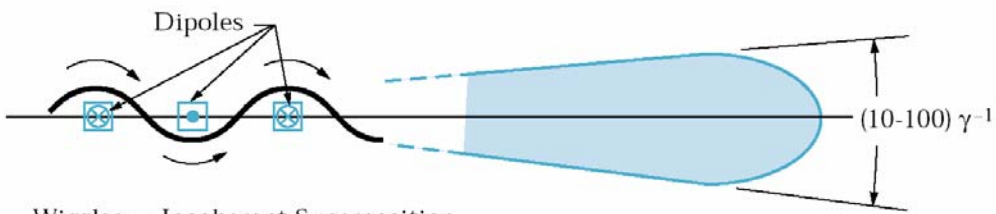
Superconducting Wavelength Shifter

6.0 Tesla

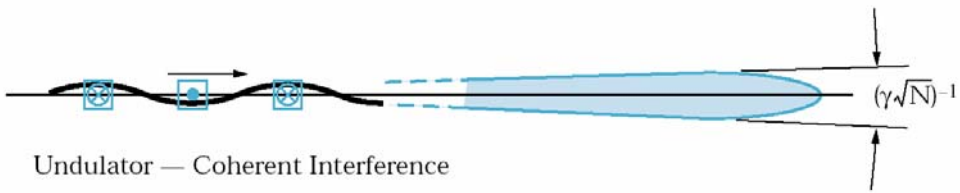
Different Kinds of SR Sources



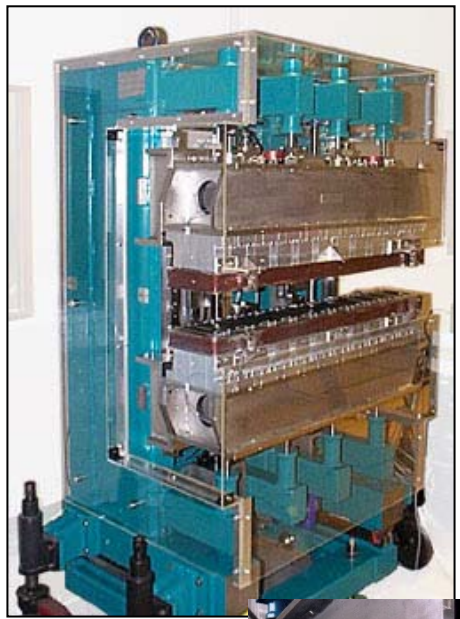
Bending Magnet — A "Sweeping Searchlight"

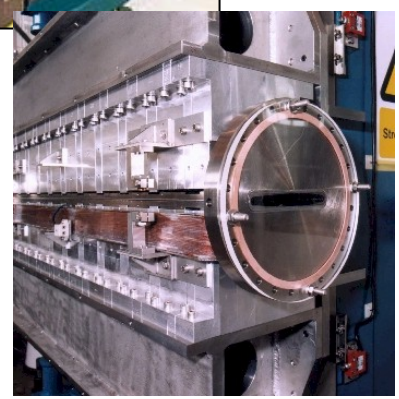


Wiggler — Incoherent Superposition



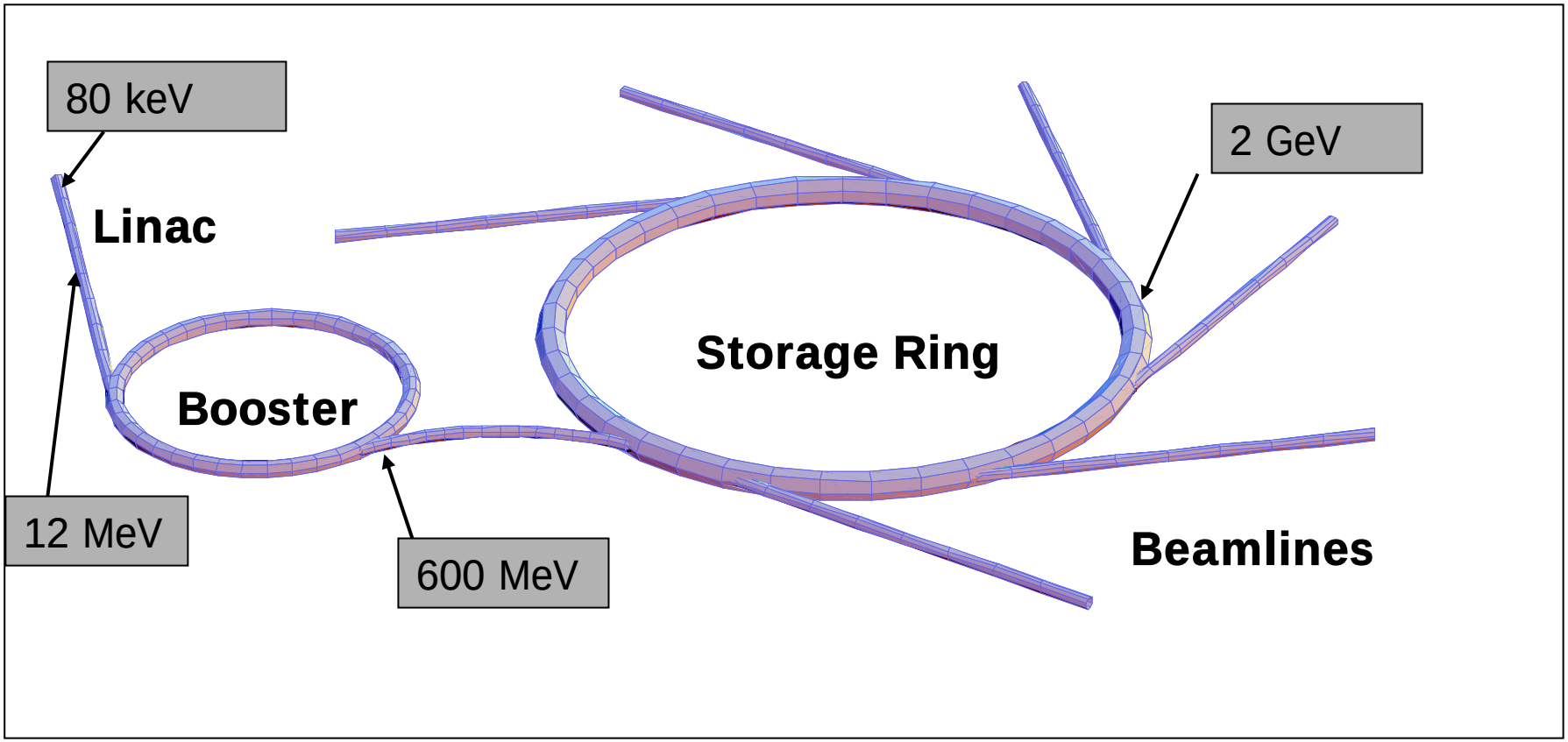
Undulator — Coherent Interference



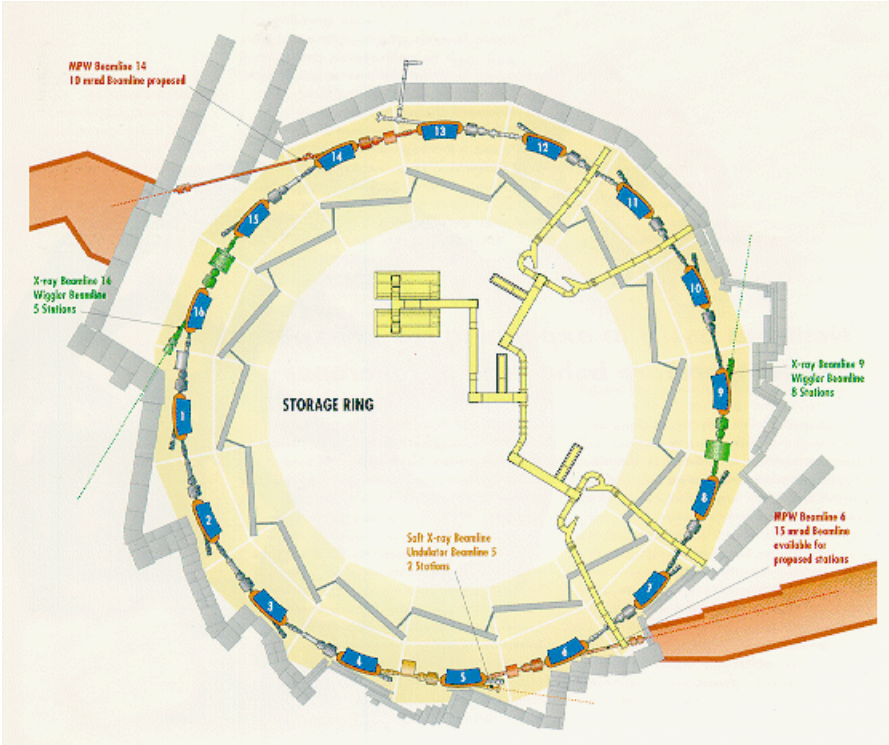


Daresbury SRS Concept

World's first dedicated x-ray source



SRS Layout



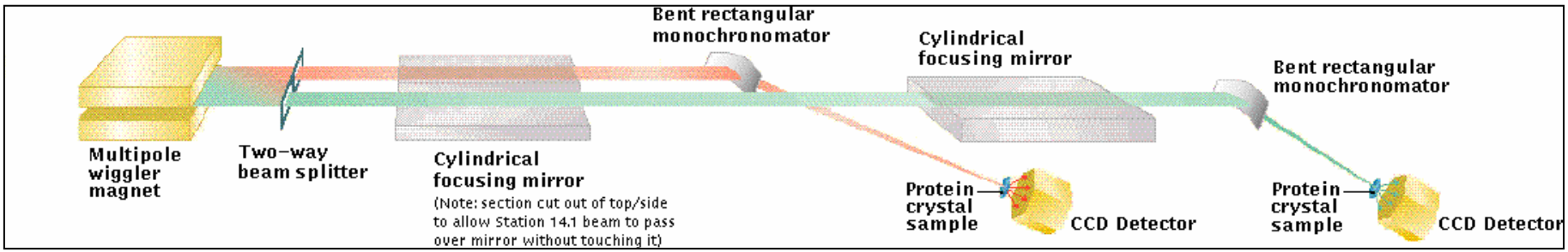
UK National Light Source operated since 1980 - to be replaced by DIAMOND

300 mA

Daily fills

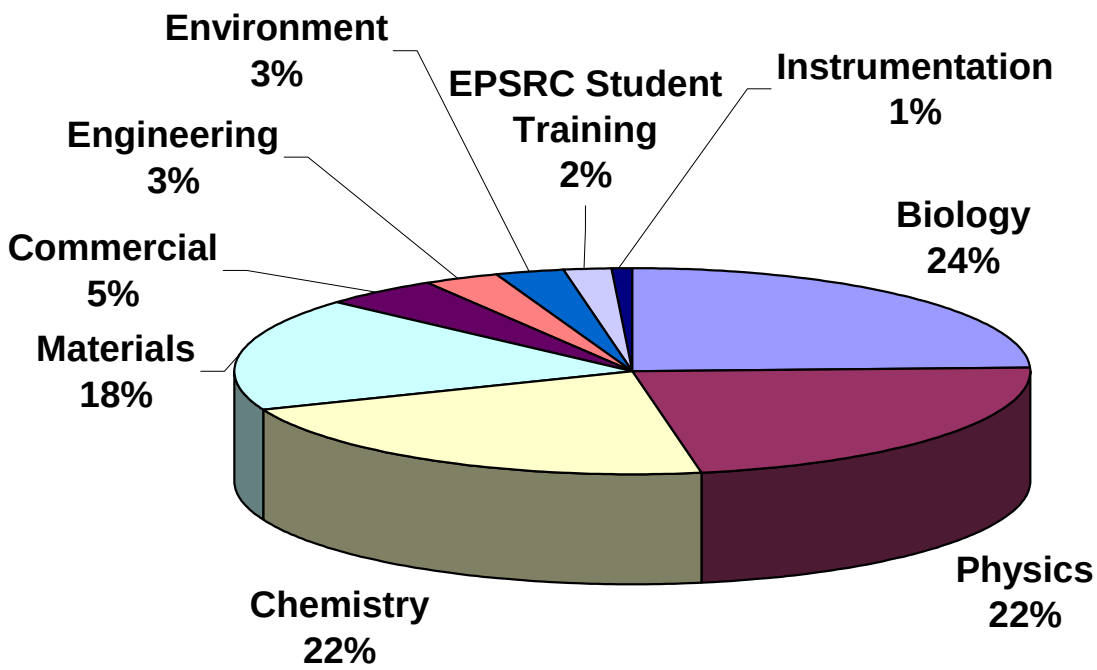
Pioneering magnetic insertion devices

From Source to Detector



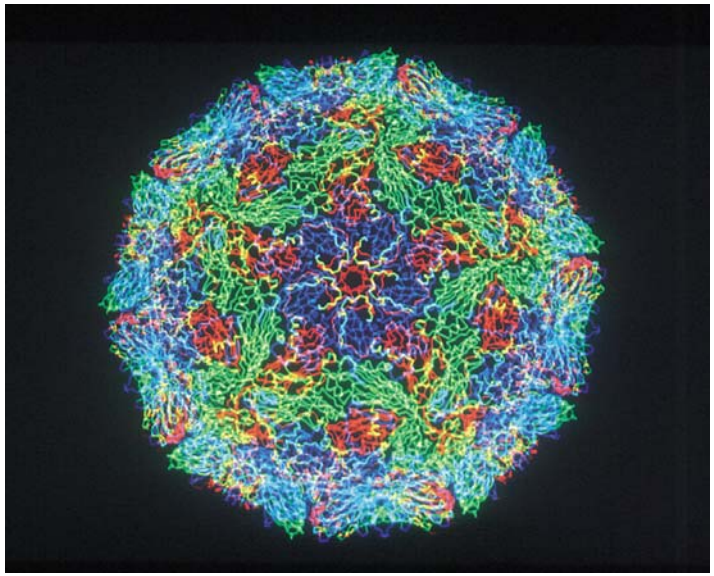
- Light from source can be split for more than one experiment
- Light focused using mirrors
- Narrow range of wavelengths selected by monochromator
- Light illuminates crystal sample and is diffracted
- Diffraction pattern observed with detector

Science on the SRS – A Snapshot



Life Science + Materials Science

Protein Crystallography

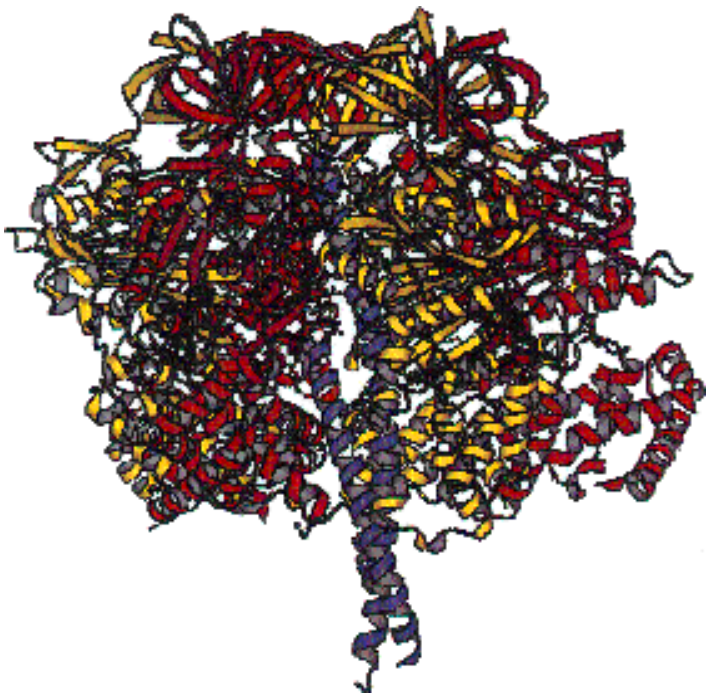


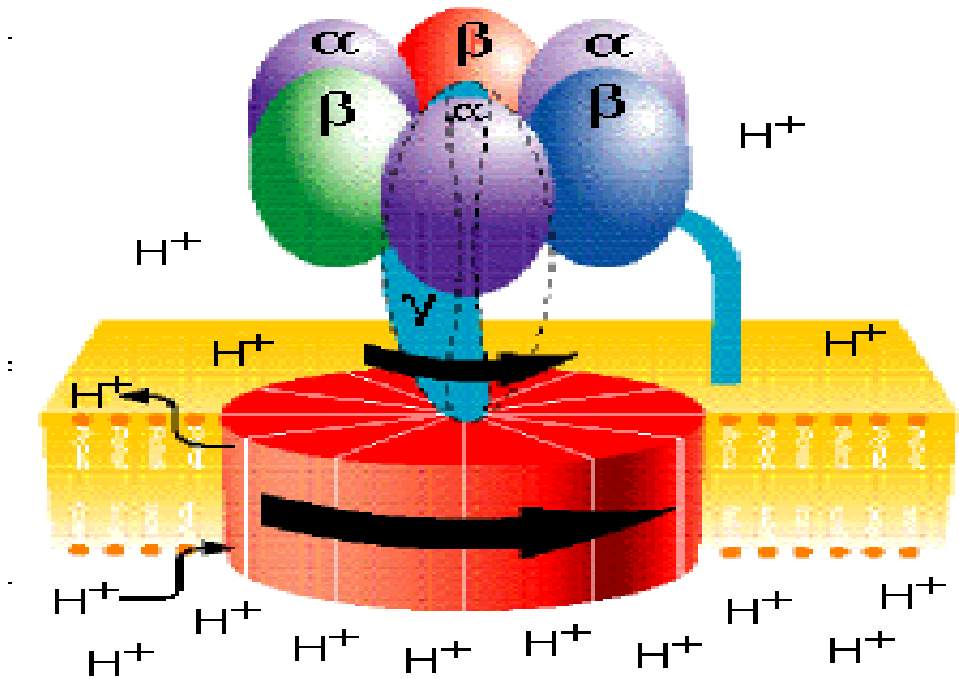
FMV Virus Structure (1990)

Light Harvesting Complex (photosynthesis)

The Nobel Prize: F1 ATPase structure

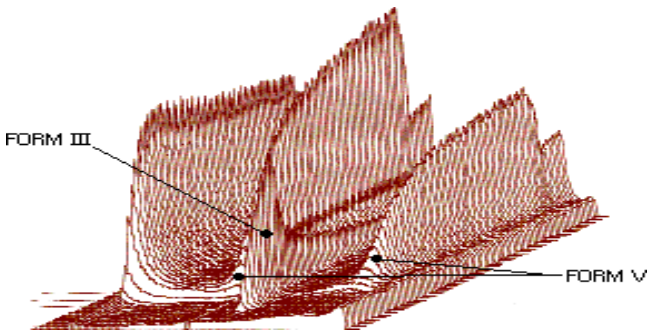
- Sir John Walker won a share of the 1997 Nobel Prize for Chemistry for solving the structure of the F1 ATPase enzyme using the SRS
- Developed an important new technique; opens the way for new insights into metabolic and degenerative disease

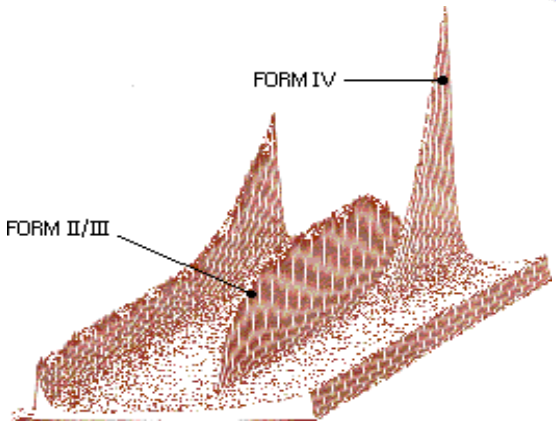




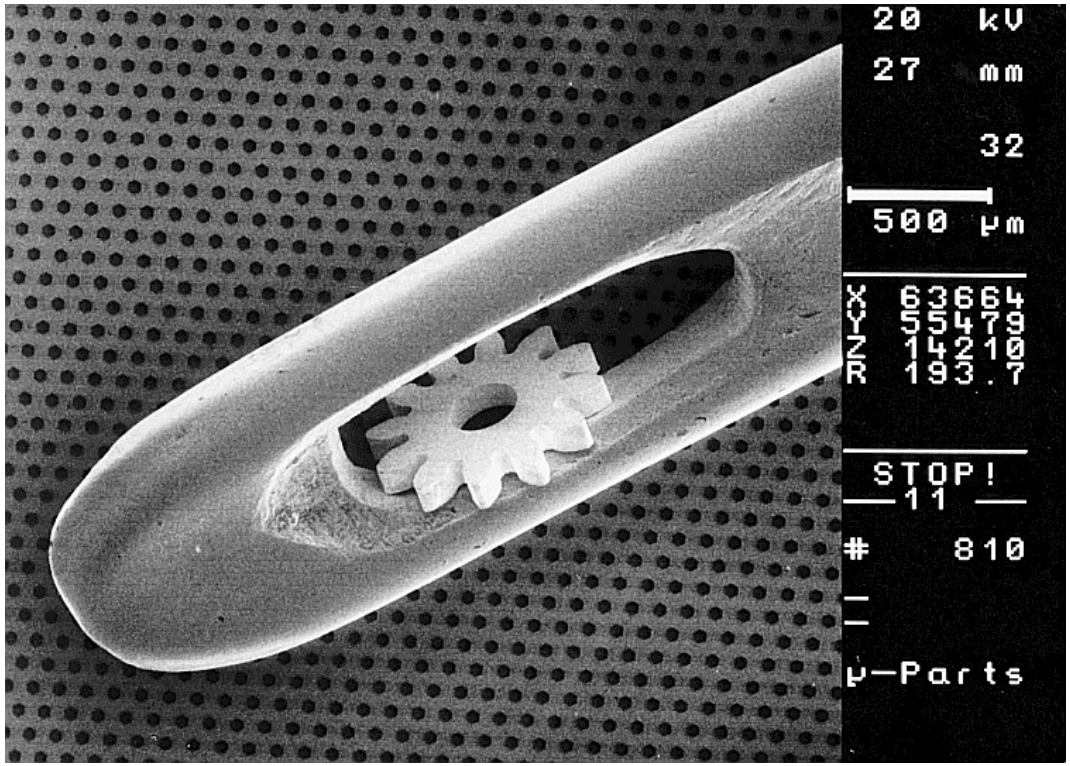
Chocolate !

- Crystallisation = chemical purification process
- Cocoa butter key to chocolate taste etc
- On-line analysis during crystallisation demonstrates conditions for best tasting chocolate (form V) - stir quickly and leave to cool at 23.86°C.
- If you don't stir, form V isn't seen.
- Analagous to other chemical processes.





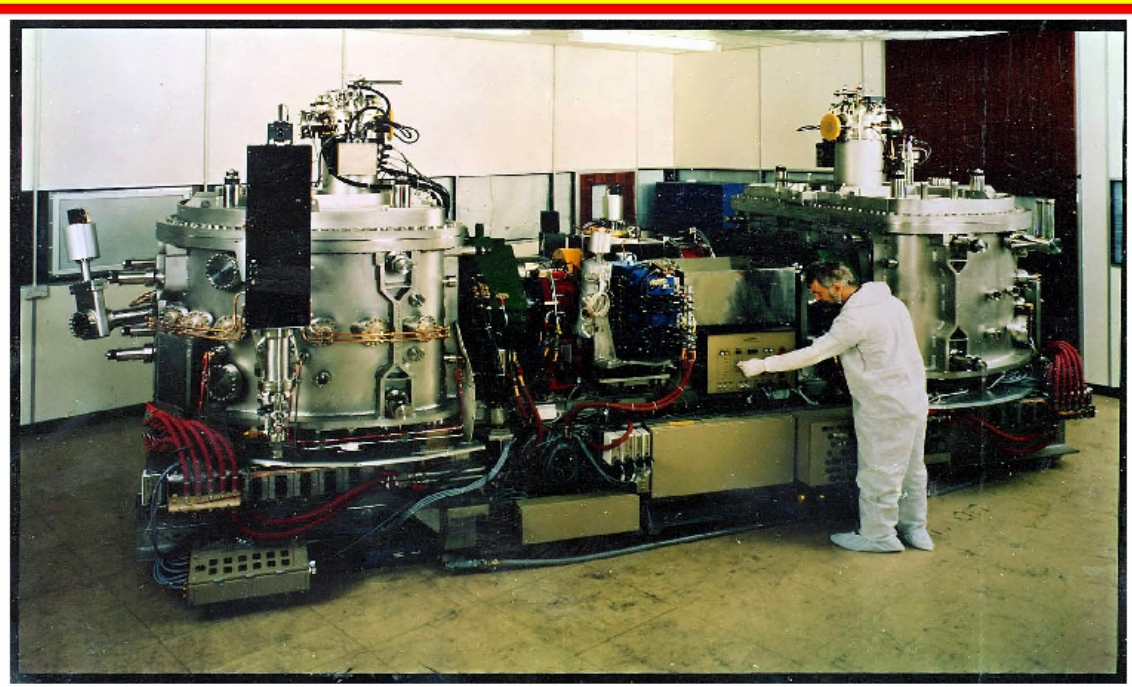
Nanotechnology (LIGA)



Alternative Compact Light Source

HELIOS at JLab

Helios Machine



Sold by Oxford Instruments to IBM in 1990
Designed at Daresbury

CCLRC Accelerator R&D Status

- **Major skill bases maintained in RAL and DL Departments but particle physics accelerator expertise (almost) lost**
- **Accelerator Science and Technology Centre (ASTeC) created in 2001 - initially 20 staff Daresbury based - now 40 staff - accelerator specialists only - £3M pa programme in 2003**
- **Major expansion underway - to £6M pa programme - mainly from CCLRC + PPARC**

Principal ASTeC Sponsored Programmes

- **Novel light sources - 4GLS, FELs, ...**
- **Linear colliders - generic (pending technology decision)**
- **Neutron sources - MW scale**
- **Neutrino factories - MICE, design concepts, proton driver**

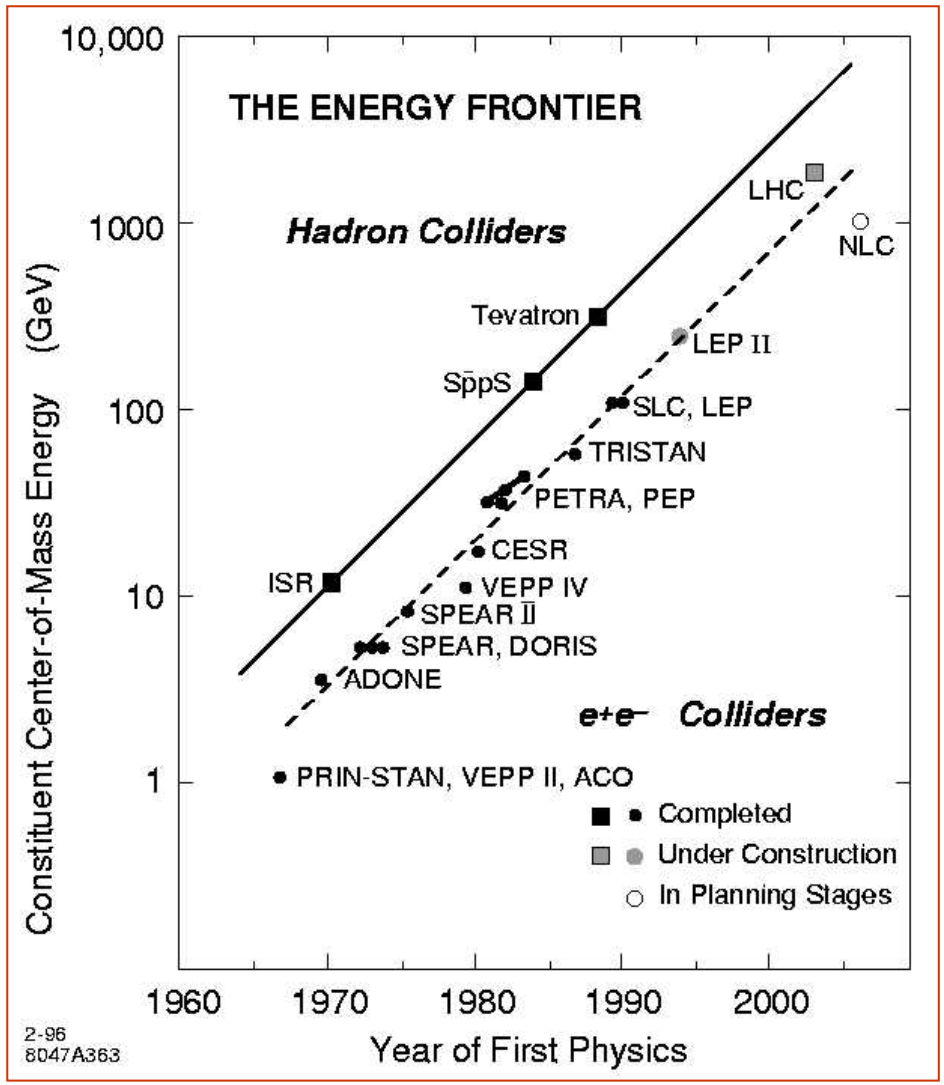
- **DIAMOND design/procurement role (will reduce but still vital)**
- **SRS support/development (hands-on role and training)**
- **'RC Basic Technology' (laser-plasma project)**
- **Underpinning technology (eg undulators, NEG pumps, RF systems etc)**

Cockcroft Institute

- **Centre funded by PPARC: £7M over next 8 years**
  - **Oxford/Holloway Centre also gets £2M from 2007-2012**
- **Lancaster/Liverpool/ Manchester: 40-50 posts**
- **Strong ASTeC integration**
- **Proposed shared premises**

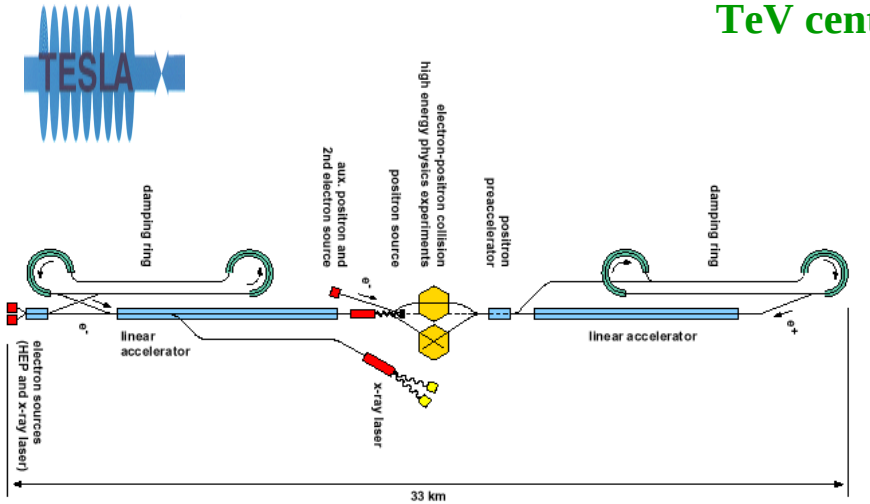
CCLRC will work with both Centres

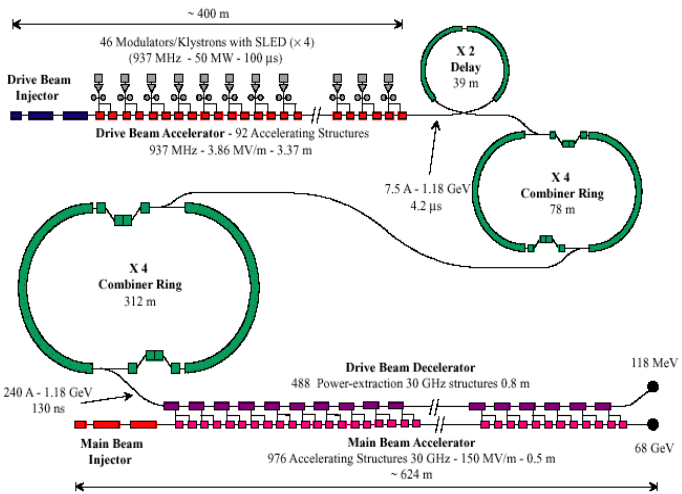
Future Electron Linear Collider

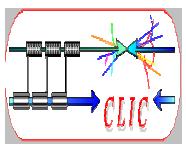


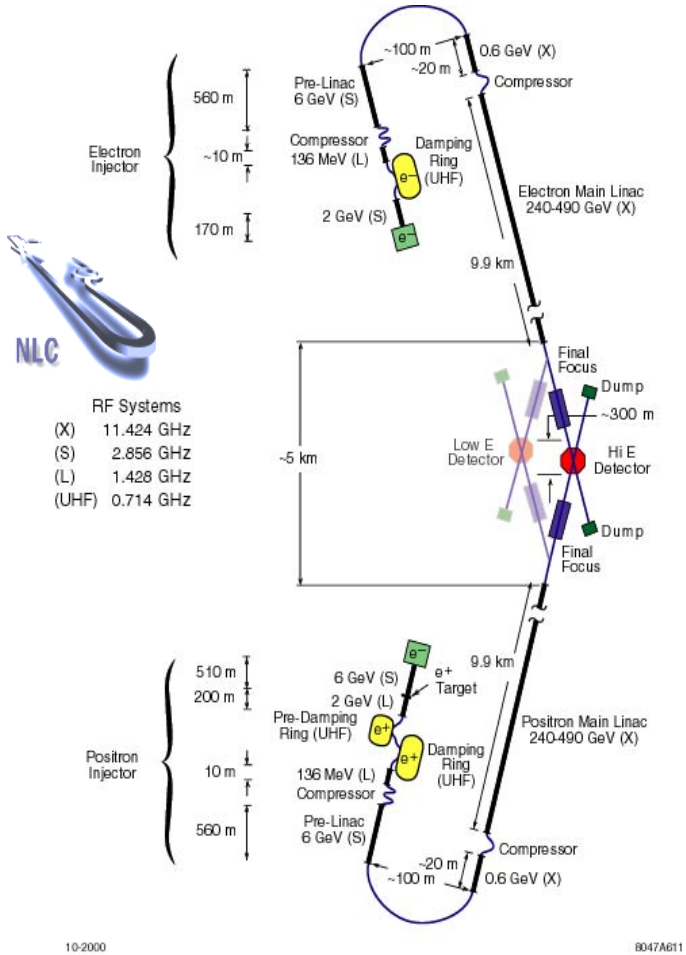
Linear Collider Schemes

TeV centre of mass





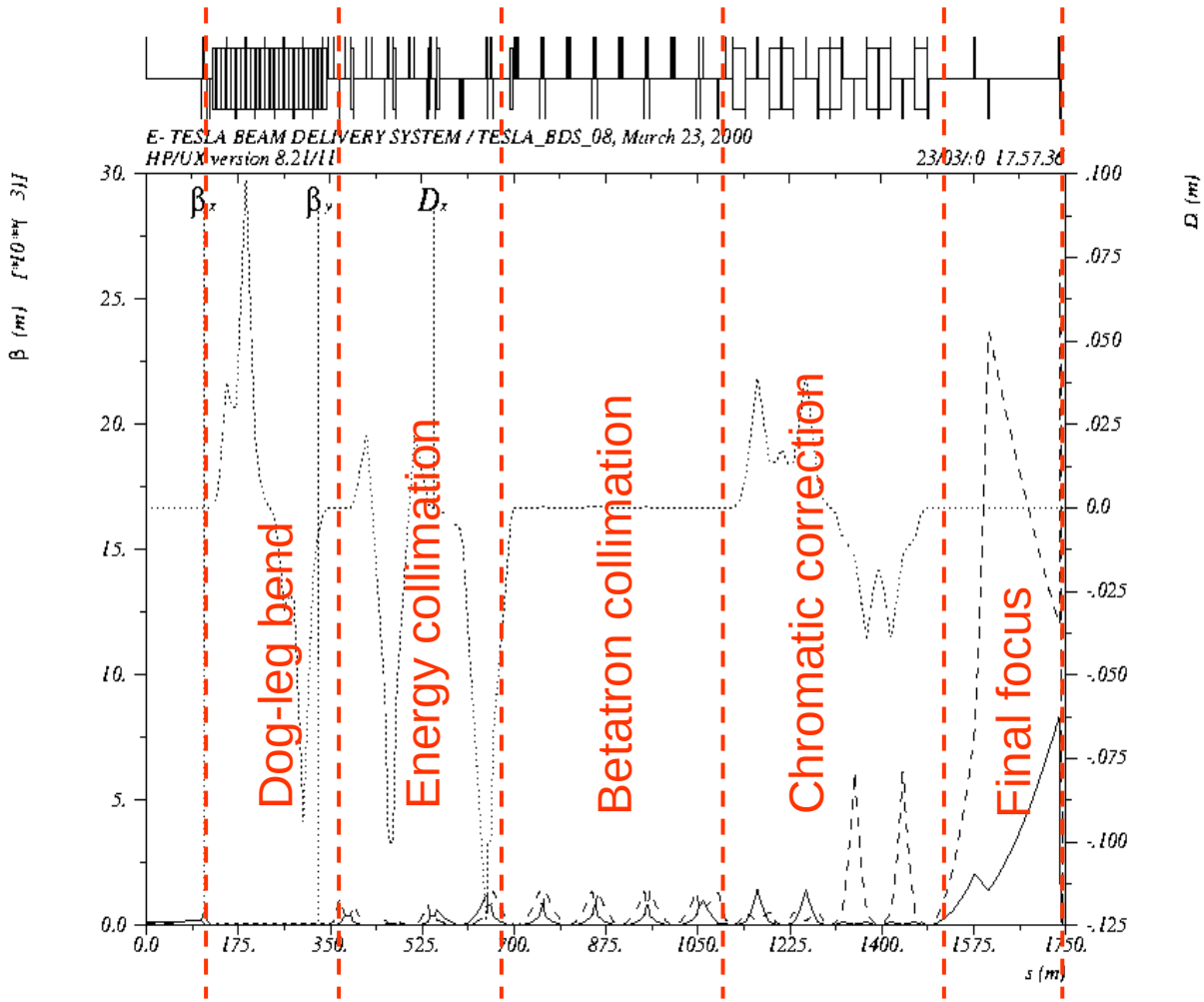




LC-ABD National Collaboration

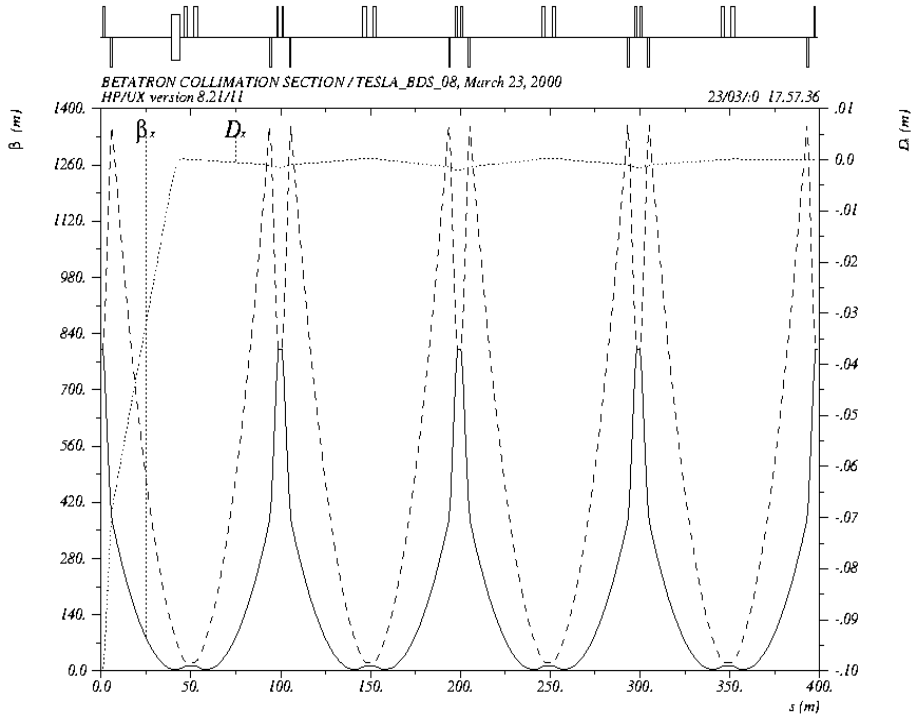
- **Linear Collider studies now organised in UK largely through LC-ABD Collaboration with HEIs**
- **Strategic decision to concentrate on Beam Delivery System**
- **Major funding initiatives (ca £10M next 3 years)**
- **ASTeC takes lead in Beam Dynamics and in Magnet and RF Technology**
- **Further major ASTeC role in Beam Diagnostics**

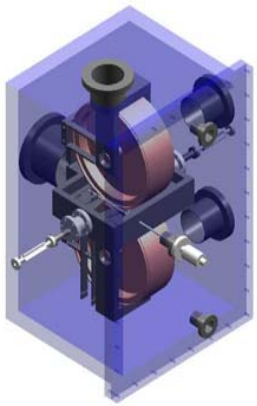
TESLA Beam Delivery System



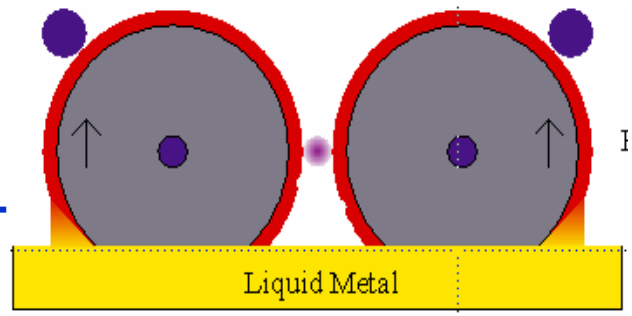
Collimation Example

- System of spoilers and absorbers used to remove particles in the beam halo
- Typical gaps of the order 1mm
- Technical challenges:
  - » wakefield reduction
  - » collimator protection
  - » secondary production





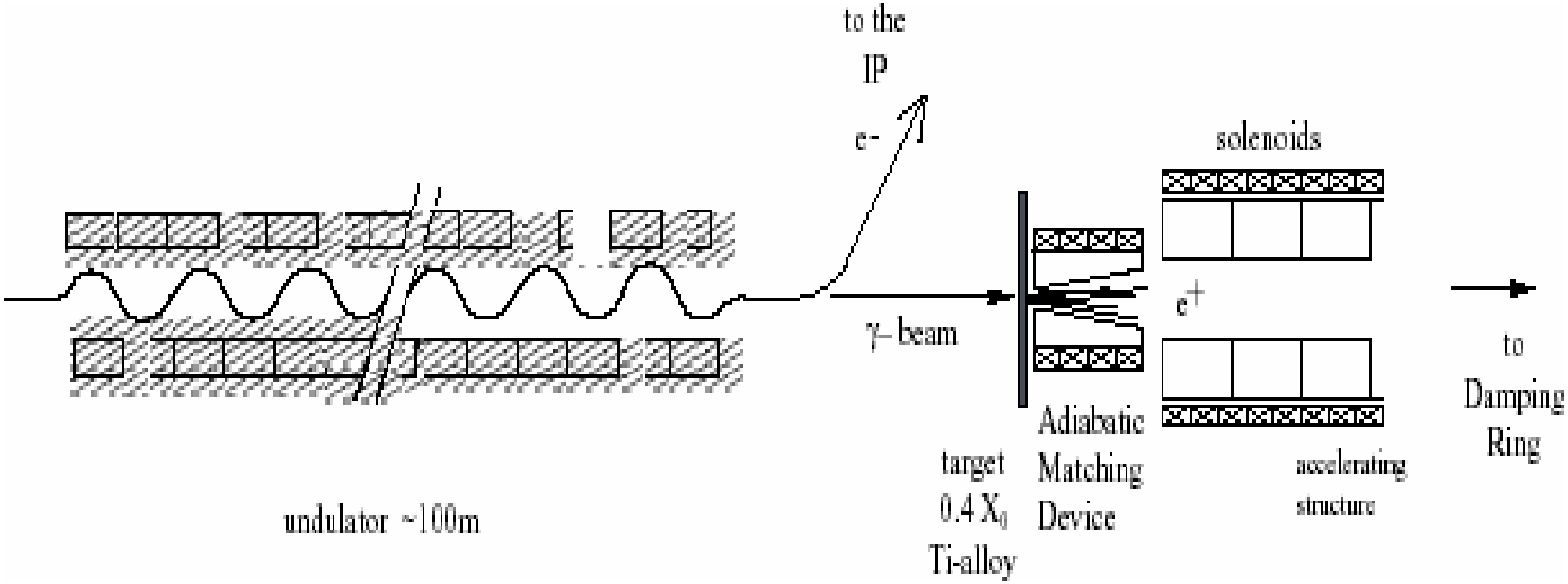
NLC collimator designs based on rotating wheels and renewable surfaces



LC Technology Work at ASTeC

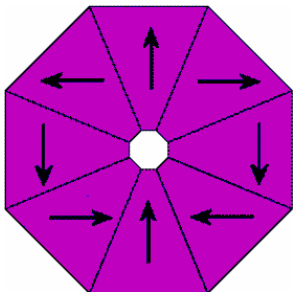
- **Polarised positron source**
- **Crab cavities**
- **Diagnostics**

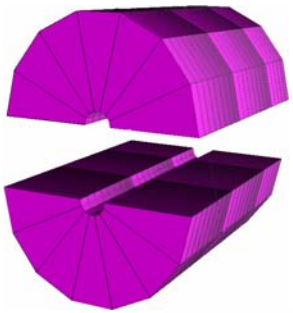
Undulator Based Polarised Positron Source

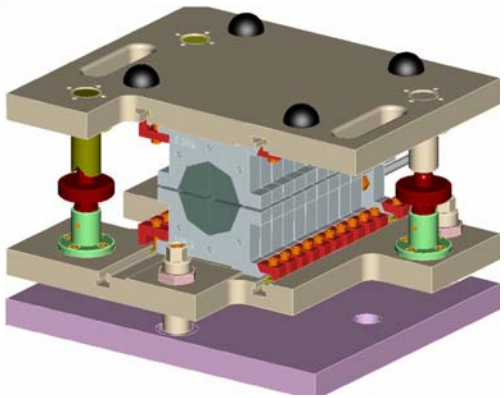


- **~250 GeV electron beam passes through 100 m undulator**
- **~20 MeV photons produced**
- **Electron-positron pairs produced in target**
- **Positrons captured**

Prototype Magnet Solutions







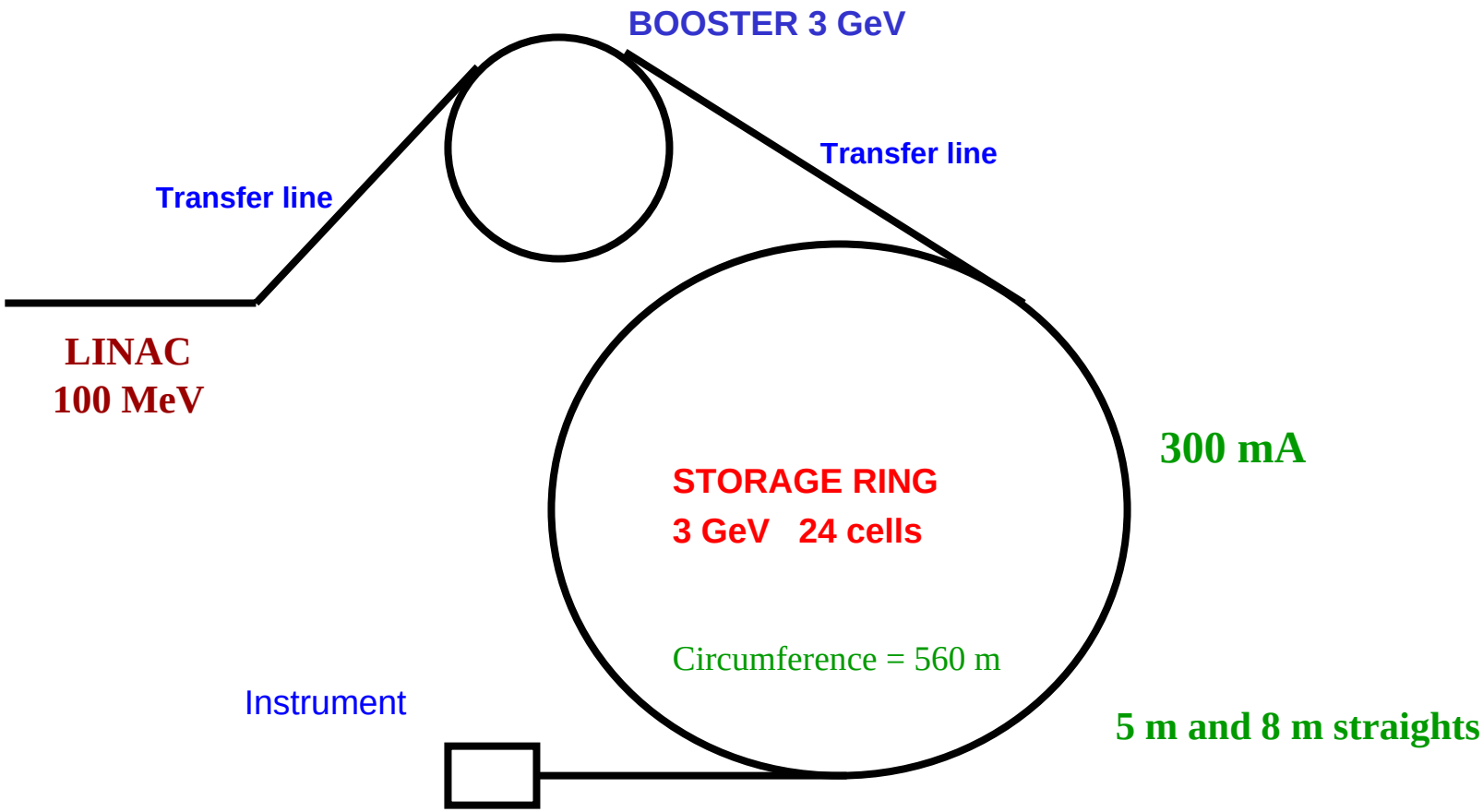
- Dipole Field Created by Rings of Permanent Magnet Blocks
- Many Rings are rotated to create Helical Field
- Two halves to allow access to vacuum vessel

Superconducting bifilar helix

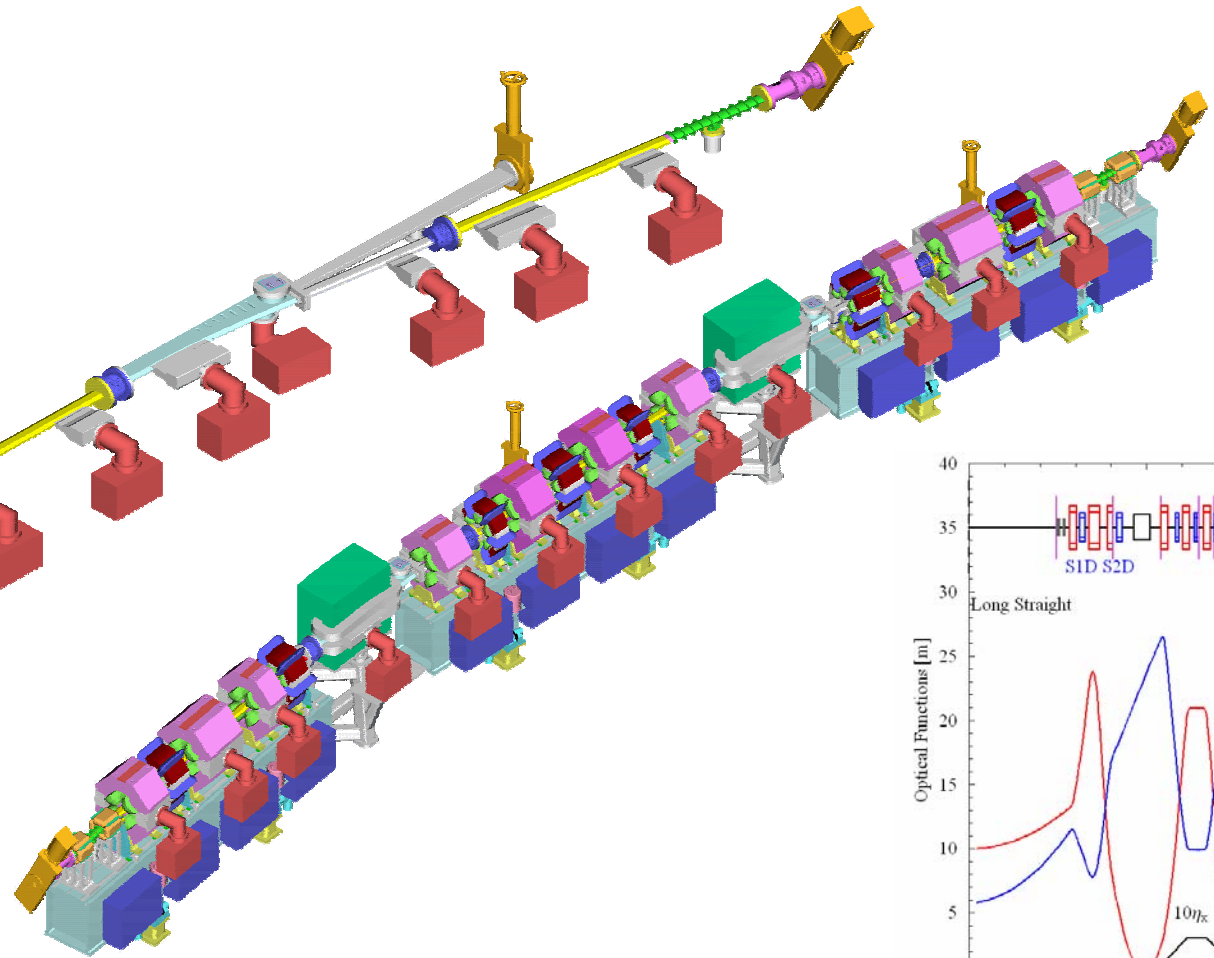
New Generation Light Source

- **Strong UK communities exploiting existing advanced storage ring and 'table top' laser facilities (SRS, ESRF, CLF)**
- **DIAMOND will serve the x-ray community from 2007**
- **Low energy (< 100 eV) requires a separately optimised source**
- **Users have identified the need to supplement transverse brightness by compression longitudinally - fs pulses**
- **Many scientific applications need multiple sources**
  - **eg pump-probe**

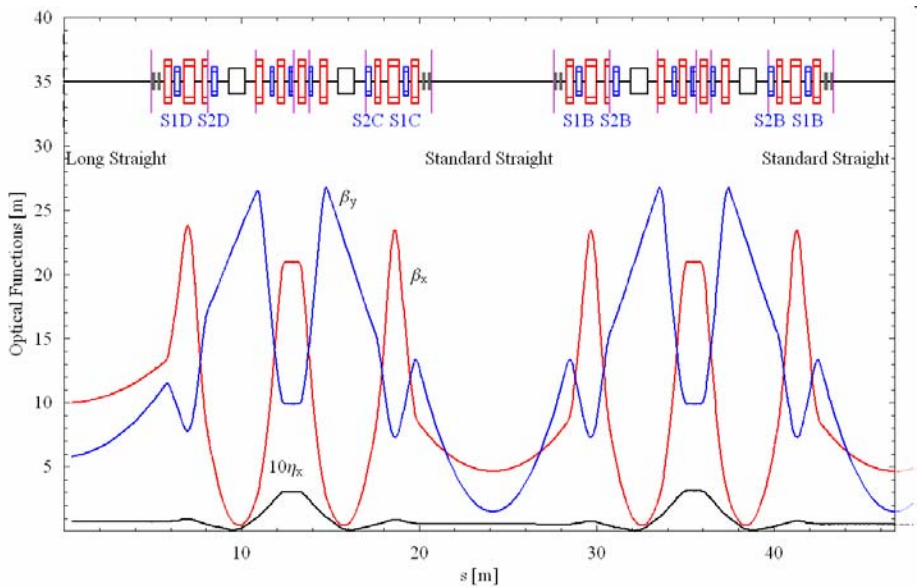
DIAMOND - A 3rd Generation Light Source (3GLS)



DIAMOND Lattice Cell



High degree of symmetry imposed



Storage Ring Problems

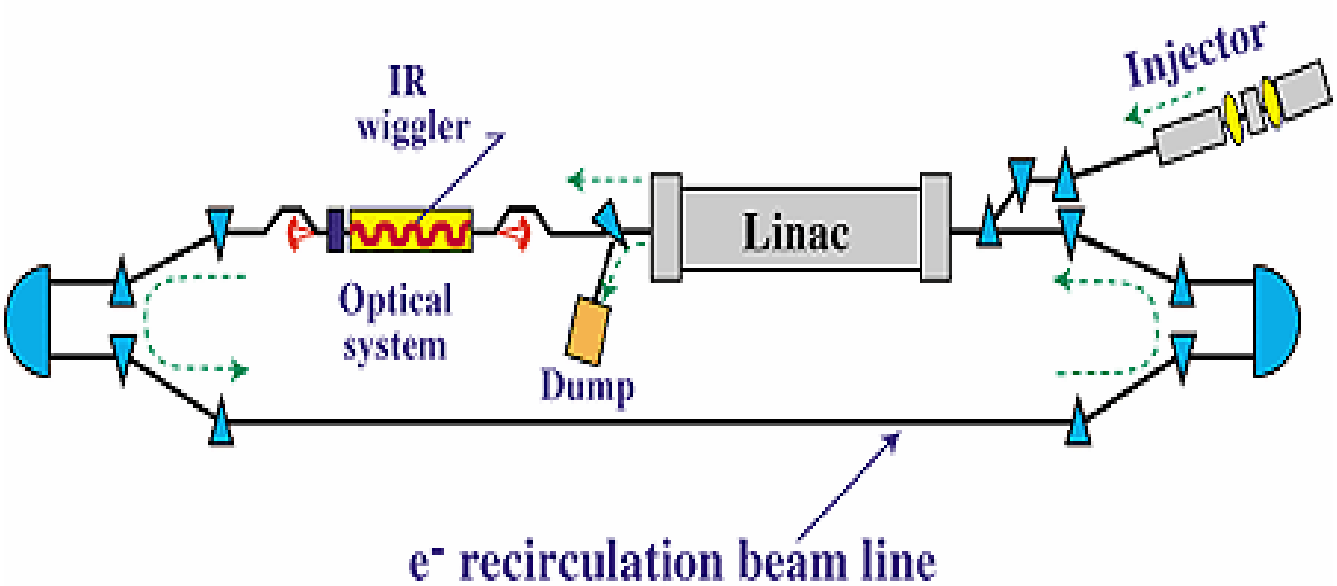
- **Equilibrium beam dimensions set by radiation emission**
- **Beam lifetime limits bunch density** **(10^{11} turns)**
- **Demanding UHV environment**
- **Undulator sources restricted**
- **Most issues worse at low energies (eg < 1 GeV)**

FUNDAMENTAL 3GLS LIMITATIONS

Linac Based Light Source

- Linacs can deliver very high quality electron beams
- Transient (< 1μs) electrons pass through all components
- Temporal pulse pattern flexibility
- High average flux requires Energy Recovery Linac (ERL)
- Superconducting RF technology can be exploited
- High average brightness gun is essential development

ERL Principle



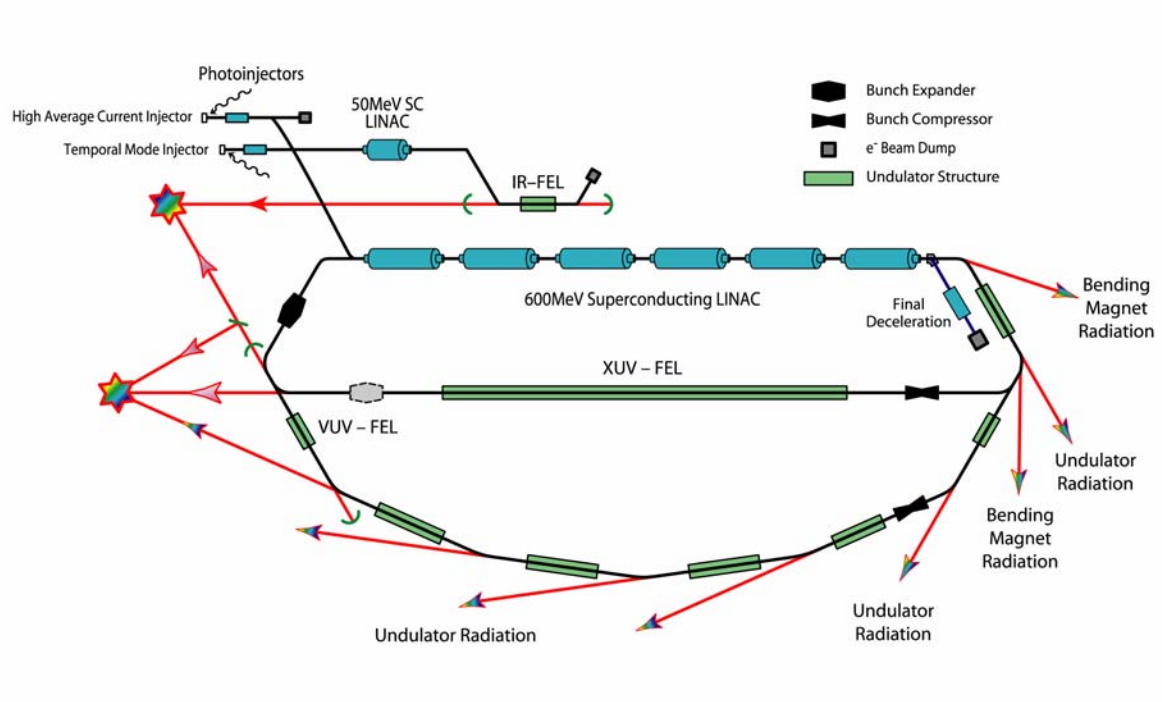
Courtesy G Neil

The 4GLS Proposal

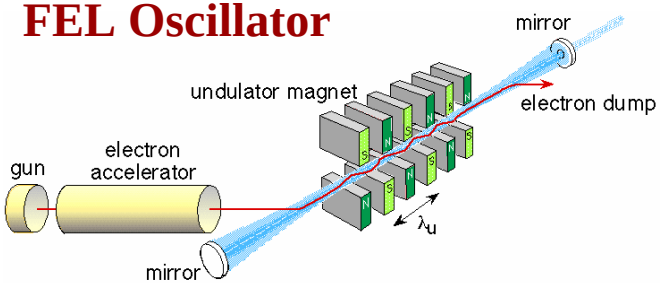
- A combined light source and FEL suite
- A superconducting 600 MeV linac
- Two photo-cathode guns: average and peak current

Emittance	<1 nm-rad
Bunch length	50 fs - 5 ps
Bunch separation	1 - 1000 ns
Target current	100 mA

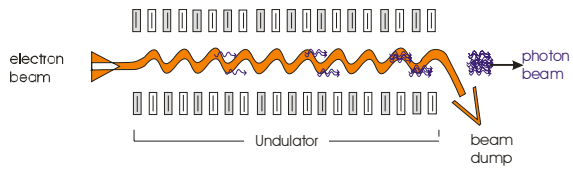
Schematic 4GLS Layout

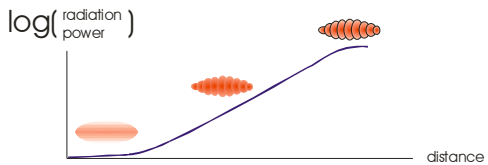


FEL Oscillator



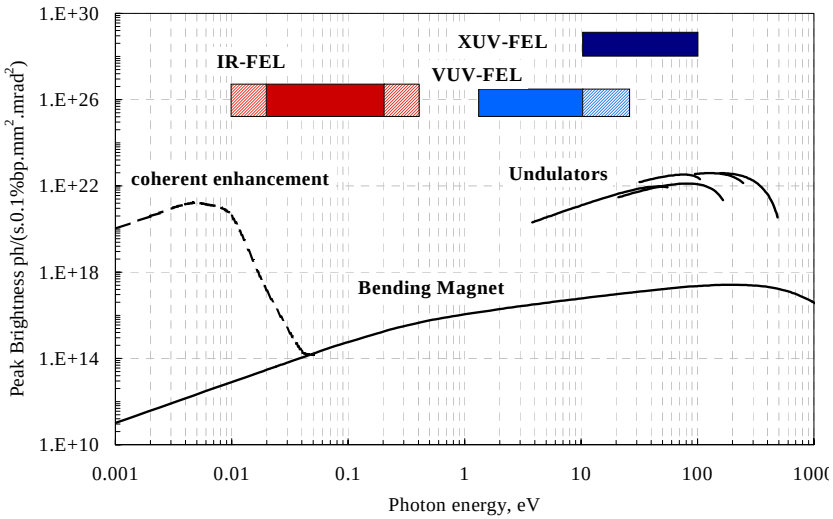
FEL Amplifier



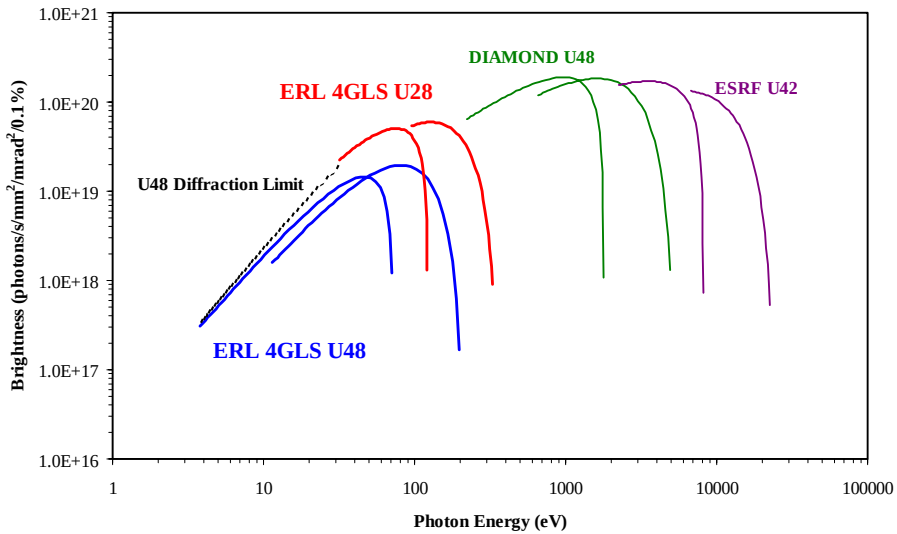


4GLS Spectral Output

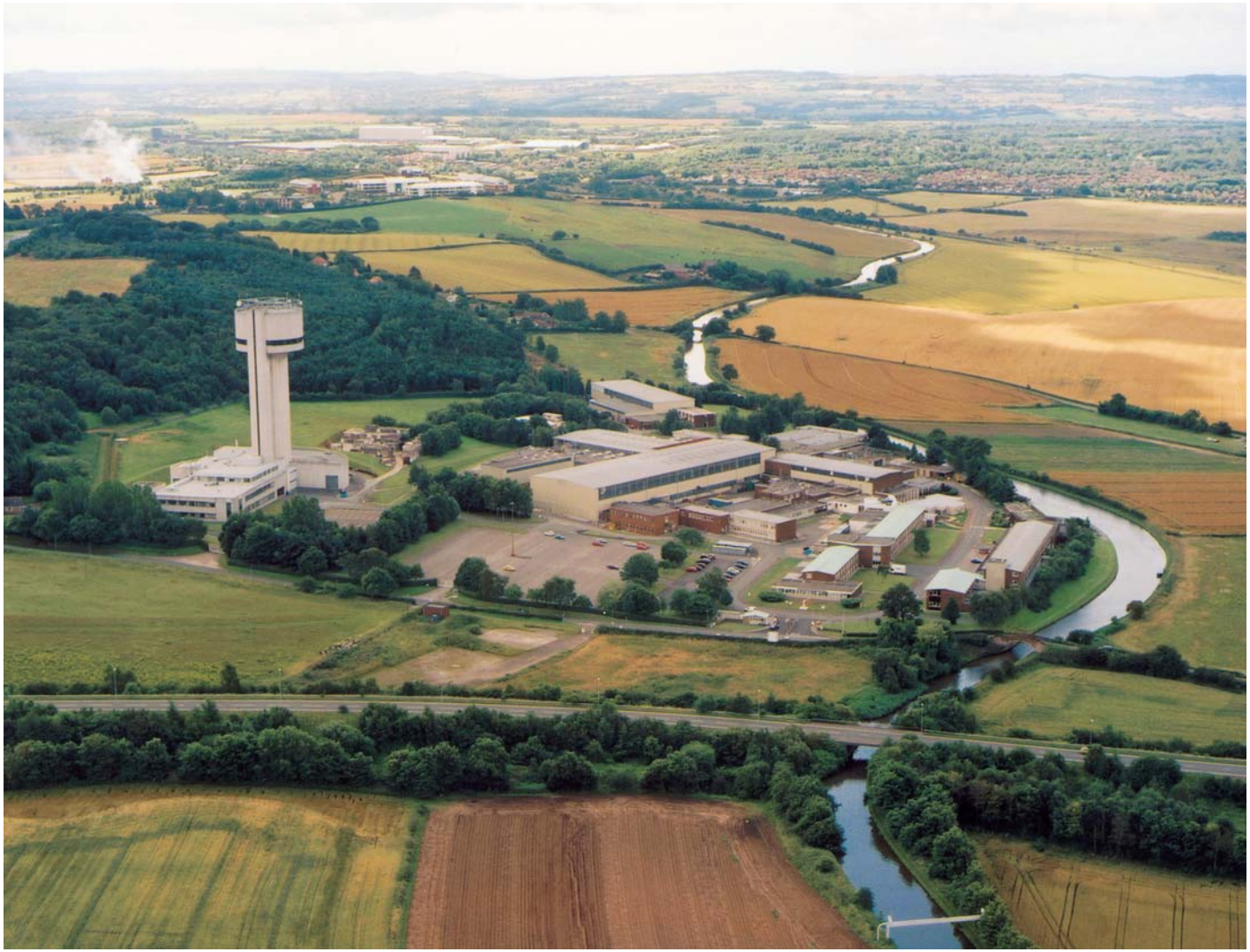
Peak Brightness



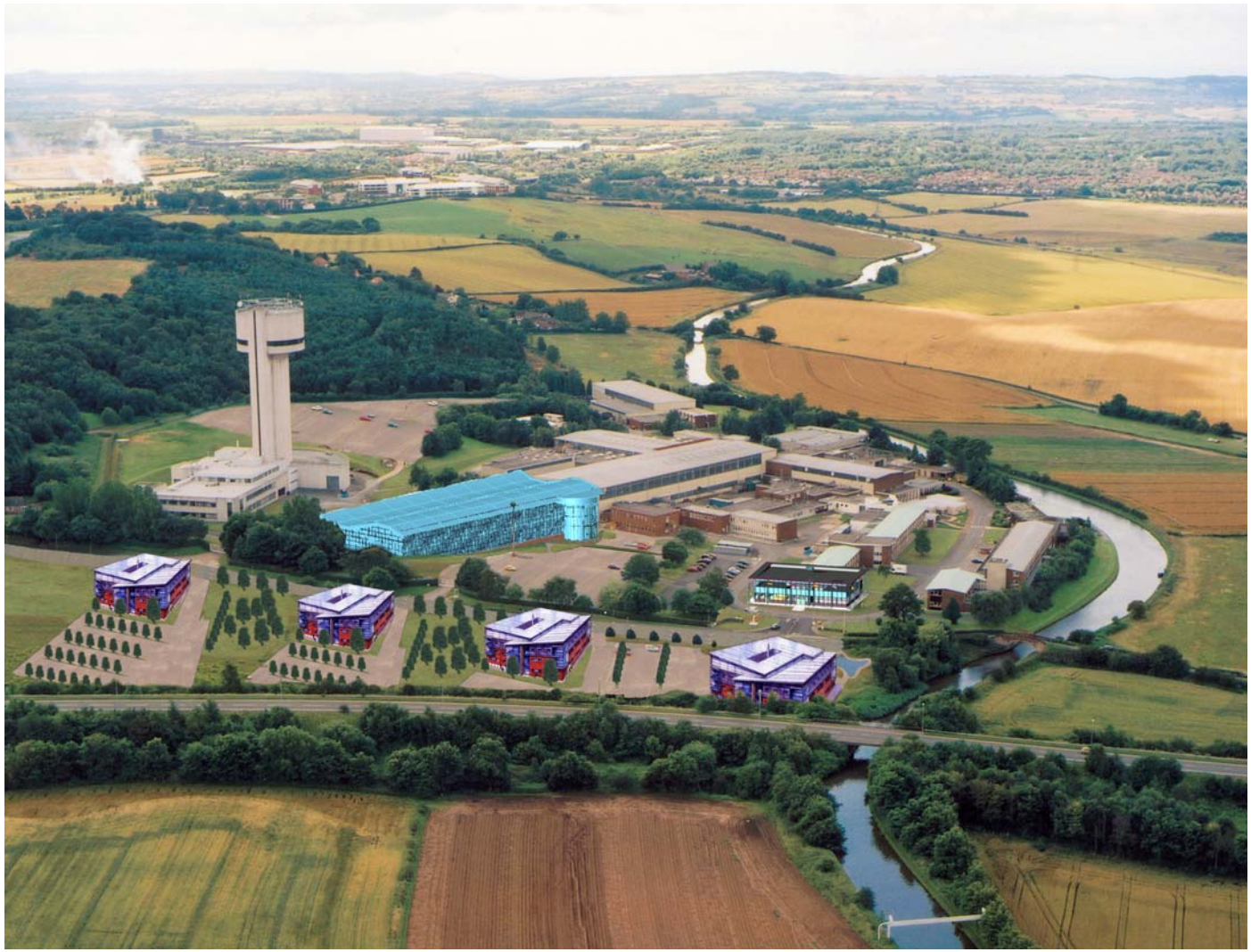
Average Brightness Comparison



Daresbury Laboratory - 2002



New 4GLS Building - Phase 1



Project Status

- **Outline feasibility studies completed**
- **Science Case accepted (May 2002)**
- **Business Case accepted (Nov 2002)**
- **R&D phase approved (Apr 2003)**

April 2003: Prototype ERL funded

ERL Prototype (ERLP) Project

Partnership:

DL (ASTeC + SRS)

RAL (CLF)

HEIs (Manchester/Liverpool/Strathclde)

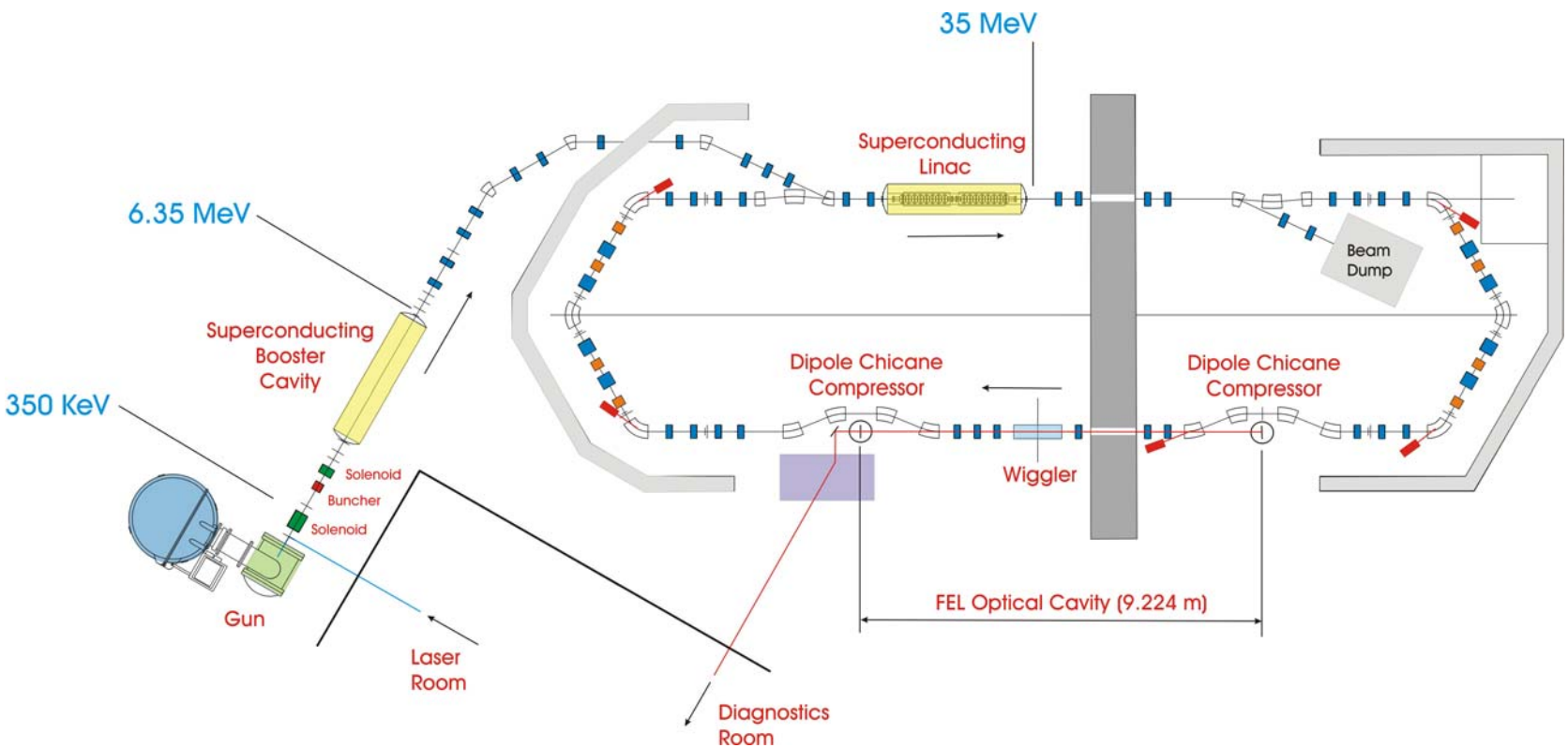
Jefferson Lab

Rossendorf

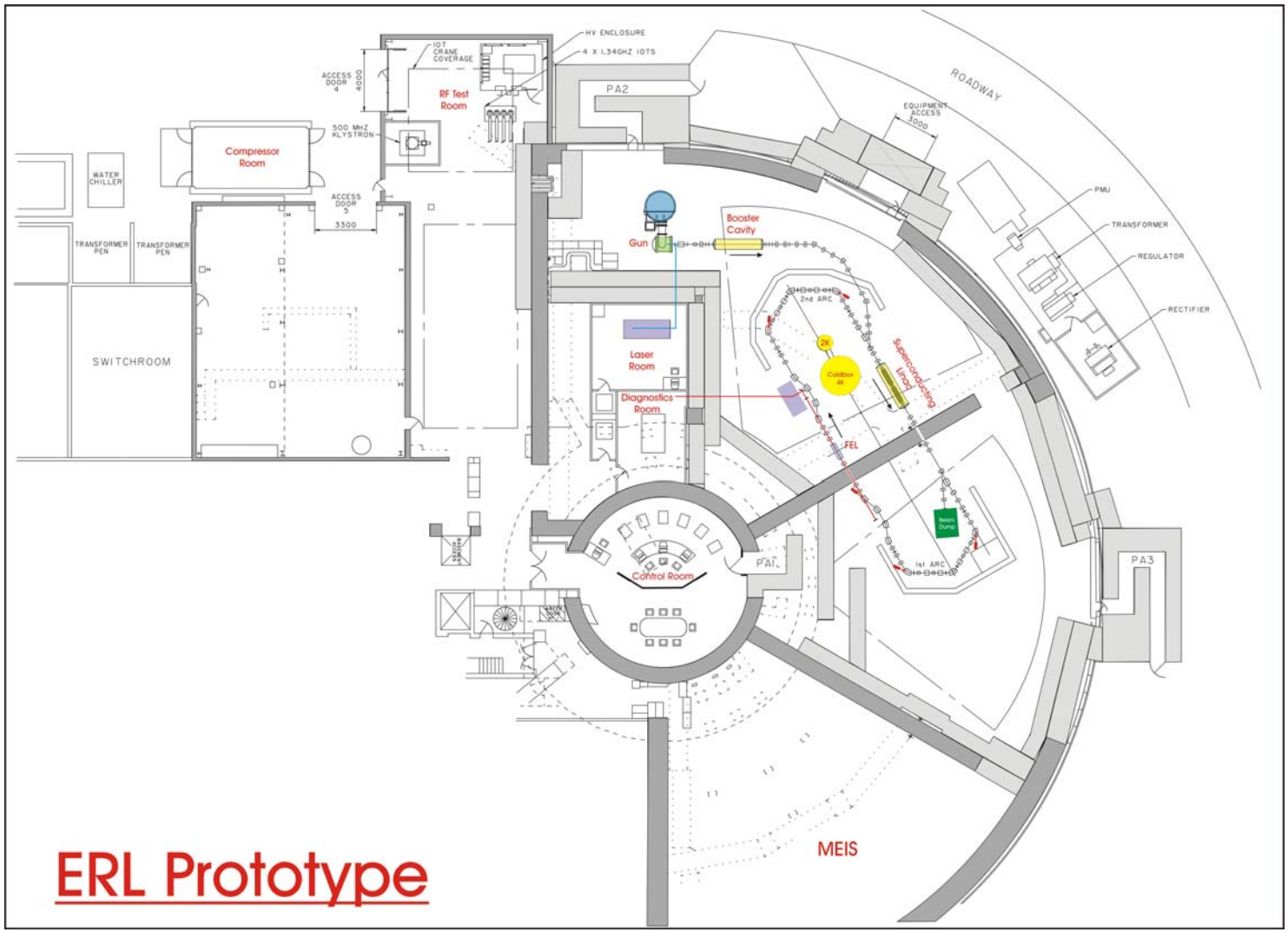
Principal challenges:

- High brightness guns
- High current superconducting linac
- Beam transport optics (bunch compression, CSR, wakes)
- Diagnostics

ERL Prototype Scheme



ERLP Planned Layout



Possible 4GLS Programme

Preliminaries	**2002/3**
ERL Prototype	**2003/7**
(Gun - Jan 2005 Booster - Oct 2005 Linac - Jan 2006 ERL - Apr 2006)	
Design studies	**2003/7**
(CDR - early 2006)	
Funding decision	**2006**
ERL operational	**2009**
FELs commissioned	**2009**
Full specification	**2010**