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Accelerator R&D and HL-LHC in the UK

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HL-LHC
11th November 2013

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History

- Starting in 2002, the UK research councils made a targeted effort to re-establish and develop a UK-based accelerator science and technology capability
- Two new Institutes established:
  - John Adams Institute
  - Cockcroft Institute
- We have succeeded in attracting internationally recognised accelerator experts (back) to the UK
- We are training a new generation of postdocs and students
  - Example: the number of PhD students in the field has gone from < 5 to over 50 in the past decade

Geography

Cockcroft Institute

Lancaster, Liverpool, Manchester, and STFC

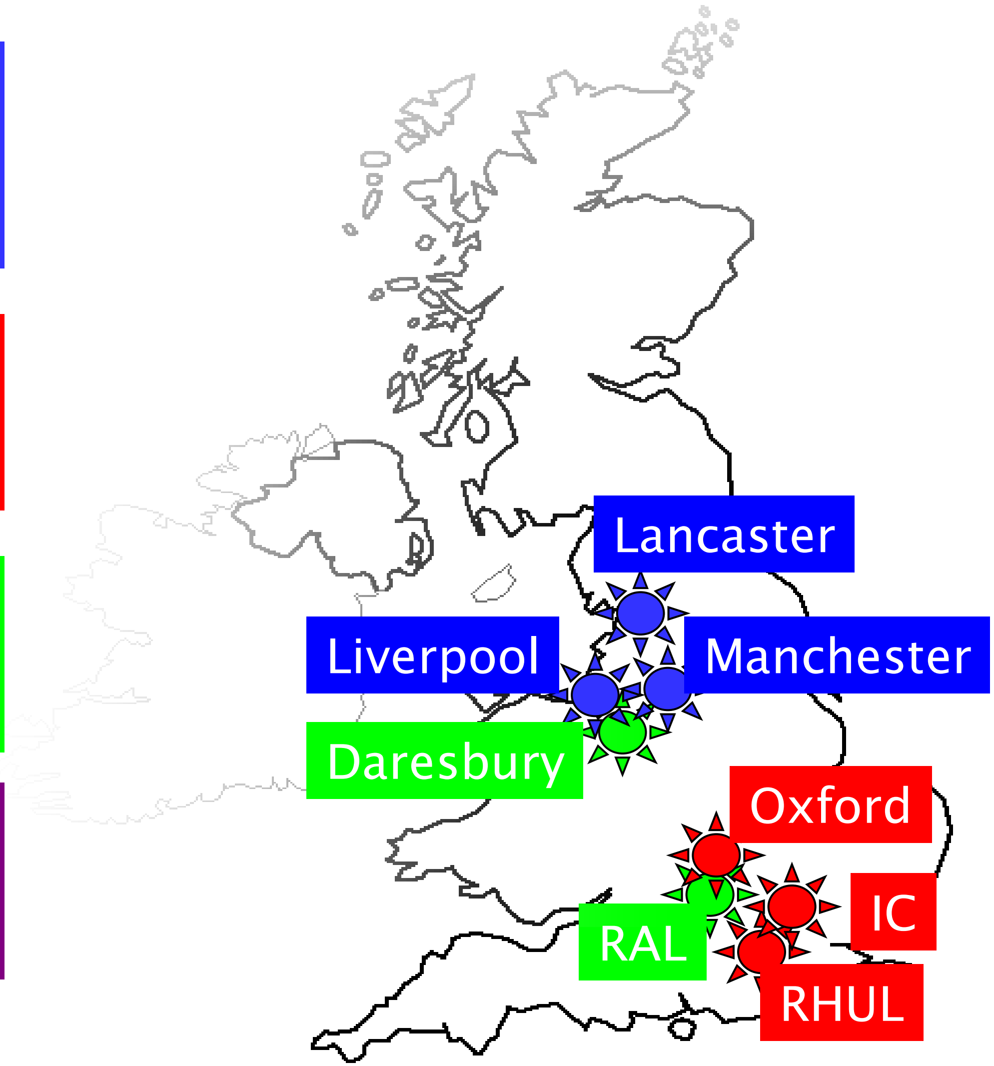
John Adams Institute

Oxford, RHUL, IC

National Laboratories

Daresbury, RAL

Other University Groups



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Funding

- The accelerator R&D programme funded though STFC Science Programmes Office is about £12M per year
- This is complemented by resources within our national laboratories
- The programme leverages additional resources from
  - International Labs
  - Universities
  - Other research councils
  - Regional development agencies
  - European Commission programmes
  - …
- Strategic input from ASB

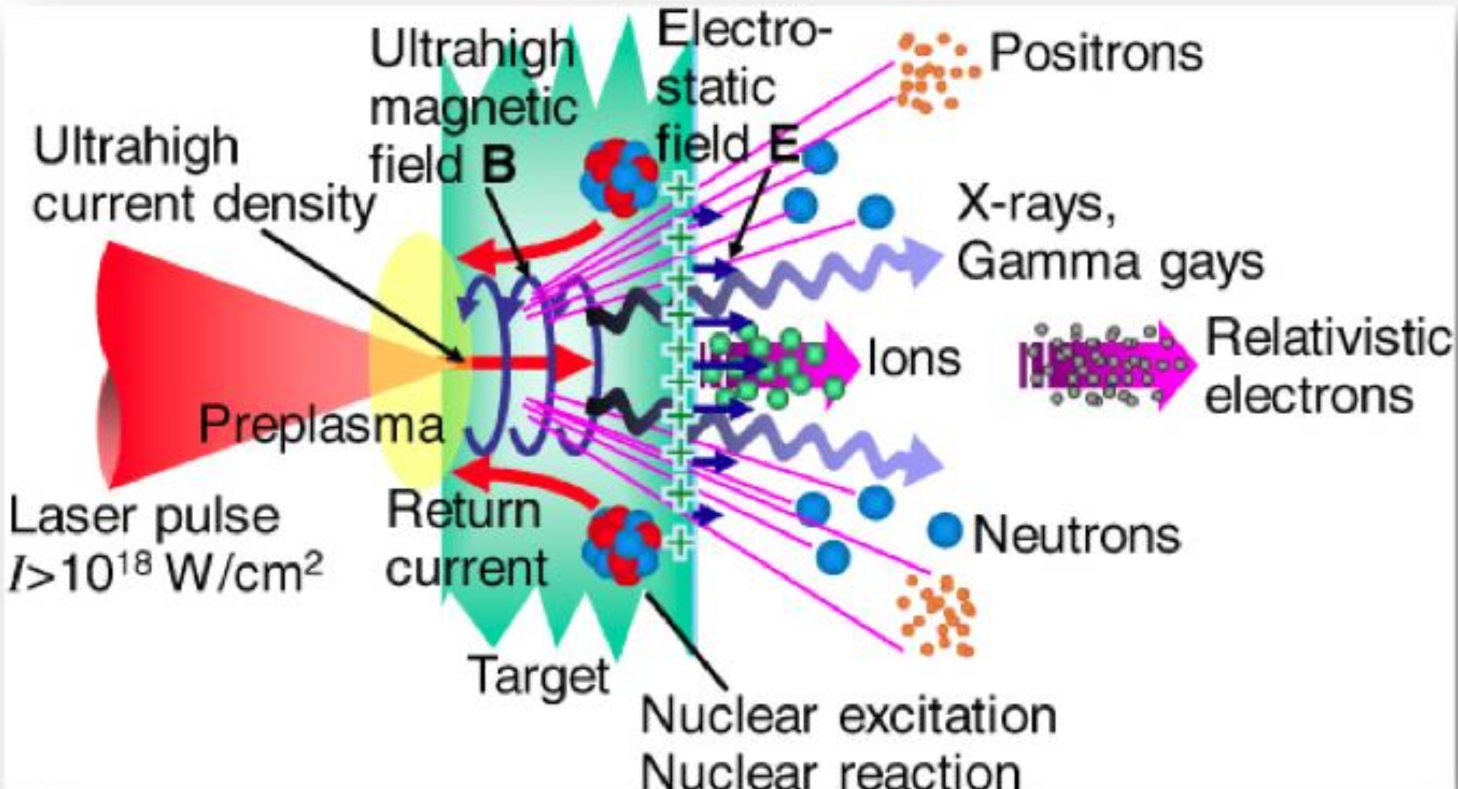
Cockcroft Institute Building at Daresbury

The programme (1)

- Support for the Cockcroft and Adams Institutes, university rolling grant effort, accelerator groups at RAL and DL + underlying technologies
- LHC and its upgrade
- ISIS
- DIAMOND
- High Power Proton Accelerators – front end test stand for MW ISIS upgrade
- Future lepton colliders (mainly CLIC with CERN, and muon accelerator contributions)
- Novel accelerator techniques (FFAG, AWAKE, Laser Plasma)

High Power Laser Interaction

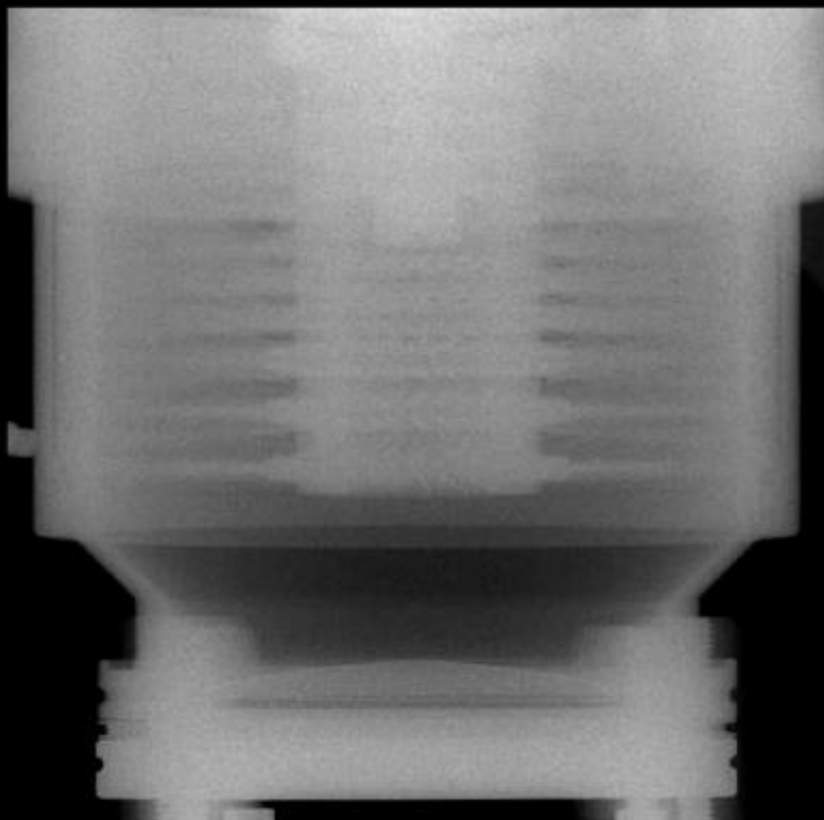
- Modest lasers can produce extreme environments

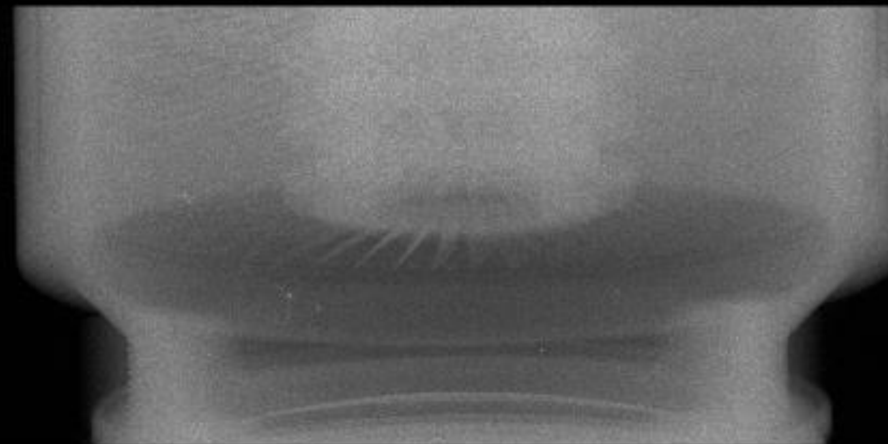


- Laser – > 10's TW drives relativistic physics > huge fields
- Extreme acceleration, over ultra short spatial and temporal extent is common place (um, mm, fs, ps)
- State of the art today is 1 PW

Courtesy J.Collier

Dynamic X-Ray Imaging





- This image shows how a 40,000 rpm turbine can be frozen using penetrating laser driven X-Rays (Vulcan)
- This is not possible any other way
- Potential applications <u>IF</u> new compact, efficient, transportable, scaleable HPL technology can be realised

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Electron Acceleration

- A High Power Laser (HPL) focussed into a gas accelerates electrons to very high energy in a short distance (cm's) – "*Wakefield Acceleration*"
- Possible to produce multi-GeV+ energies at PW powers
- Game changing
- To date, LWA electron energies produced at 1.7 GeV at CLF (cf DLS 3 GeV)

Open Workshop 31st January 2013
IoP London

Imperial College London

EPSRC
Engineering and Physical Sciences Research Council

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The programme (2)

- Laser plasma work at CLF, IC, JAI, Strathclyde and partners
- The MICE experiment at RAL
- Design studies for Neutrino Factory
- Medical applications (EMMA, ALICE…)

  Proton Therapy (Christies Hospital Manchester, UCLH London)

  Medical Diagnostic Radio-isotopes etc.

  THz imaging for diagnosis of oesophegal cancer

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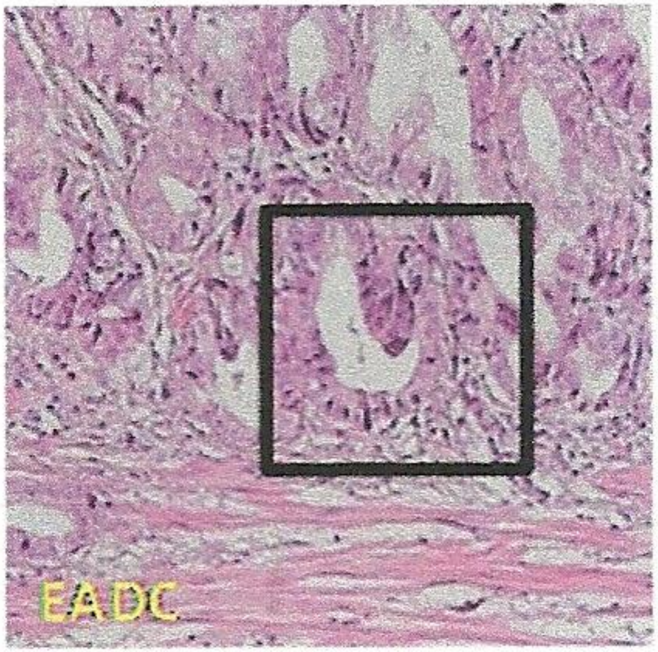
ALICE
Oesophageal Cancer Diagnosis

- **Oesophageal cancer is the fastest rising cancer in the western world.**
- Surgery is the only curative treatment and survival rates are very low.
- Condition called Barrett's oesophagus can be detected by gastrointestinal endoscopy.
- Challenge is to identify patients with Barrett's oesophagus who will develop oesophageal cancer.

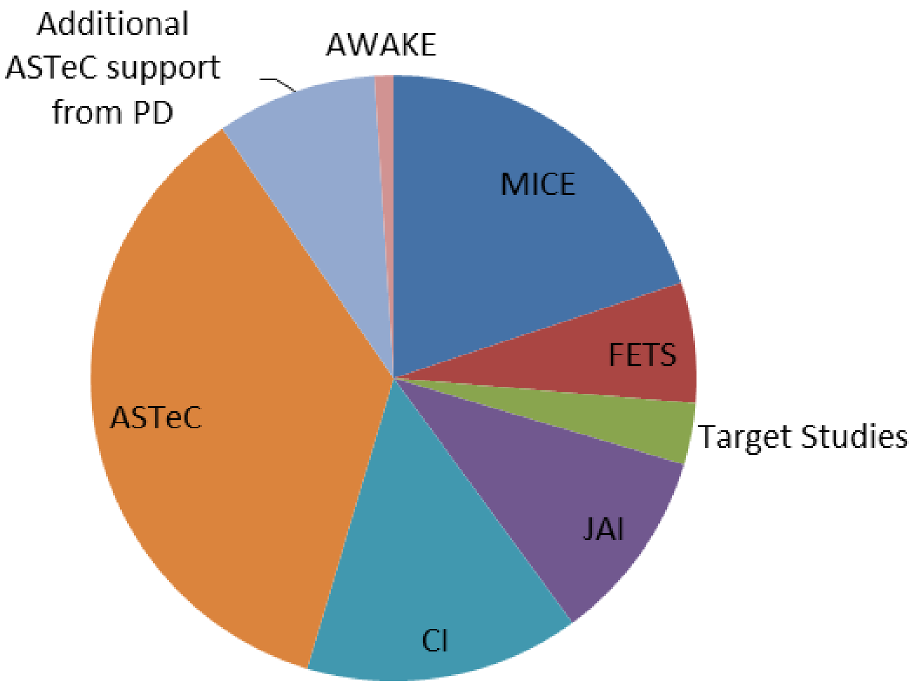
Detection Signature:

- Cancer cells surrounded by stroma made up of various (non-cancer) cell types and ExtraCellular Matrix (ECM) proteins.
- Increase in number and change of morphology and architecture, relates to the function of the cancerous DNA molecules.



Visible light image of specimen of Barrett's oesophagus.

Accelerator Programme Funding 2013/14



Initial structure has now bedded in
Now is the time to review balance and opportunities

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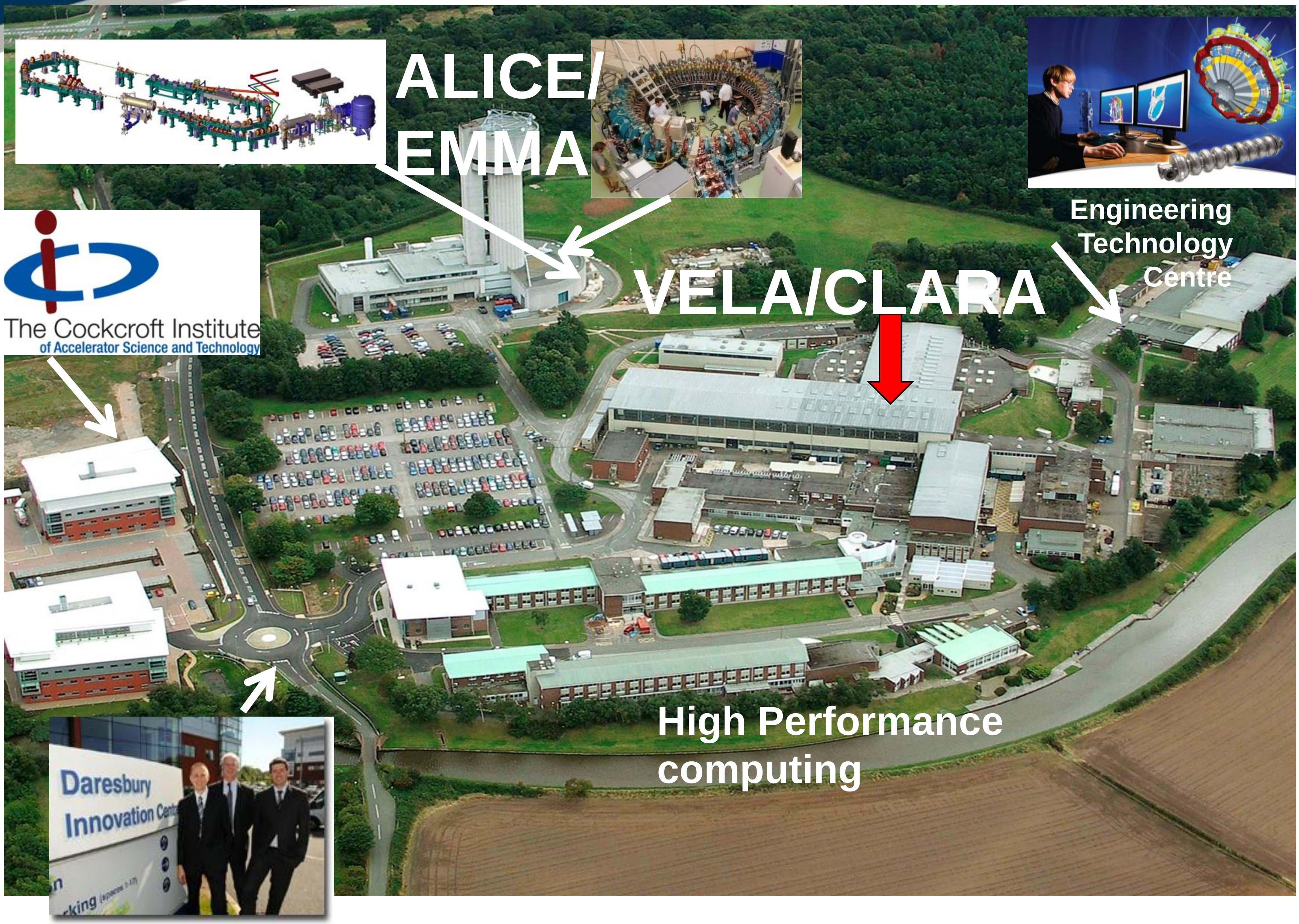
Daresbury Test Facilities: ALICE, EMMA, VELA and CLARA



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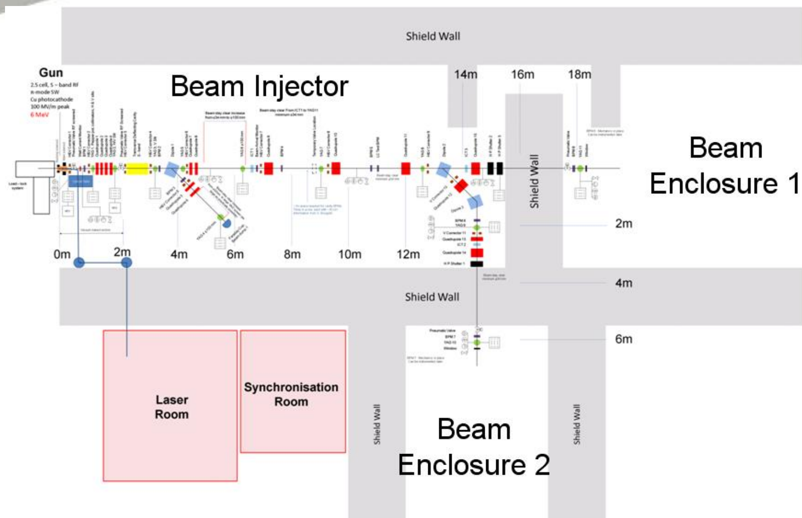
(VELA) Versatile Electron Linear Accelerator



Application Area	Energy (MeV)	Repetition Rate (Hz)	Beam Power (kW)
Security			
Cargo Scanning	1 - 6	100 - 400	≤0.1
Medical			
X-Ray Radiotherapy	5 - 25	≤500	≤2
Isotope Production	10 - 100	150	≥10
Sterilisation			
Food	5 -10	250	≤1
Medical	≤10	250	≤10

Accelerating Structures & RF Power Sources

Beam Diagnostics & Control Systems

- For the development and testing **of novel and compact accelerator technologies.**
- Through **partnership with industry and the scientific community.**
- Aimed at addressing applications **in medicine, health, security, energy, industrial processing and science.**
- Enabling research into areas of accelerator technologies which have the potential to revolutionise the **cost, compactness and efficiency** of such systems.

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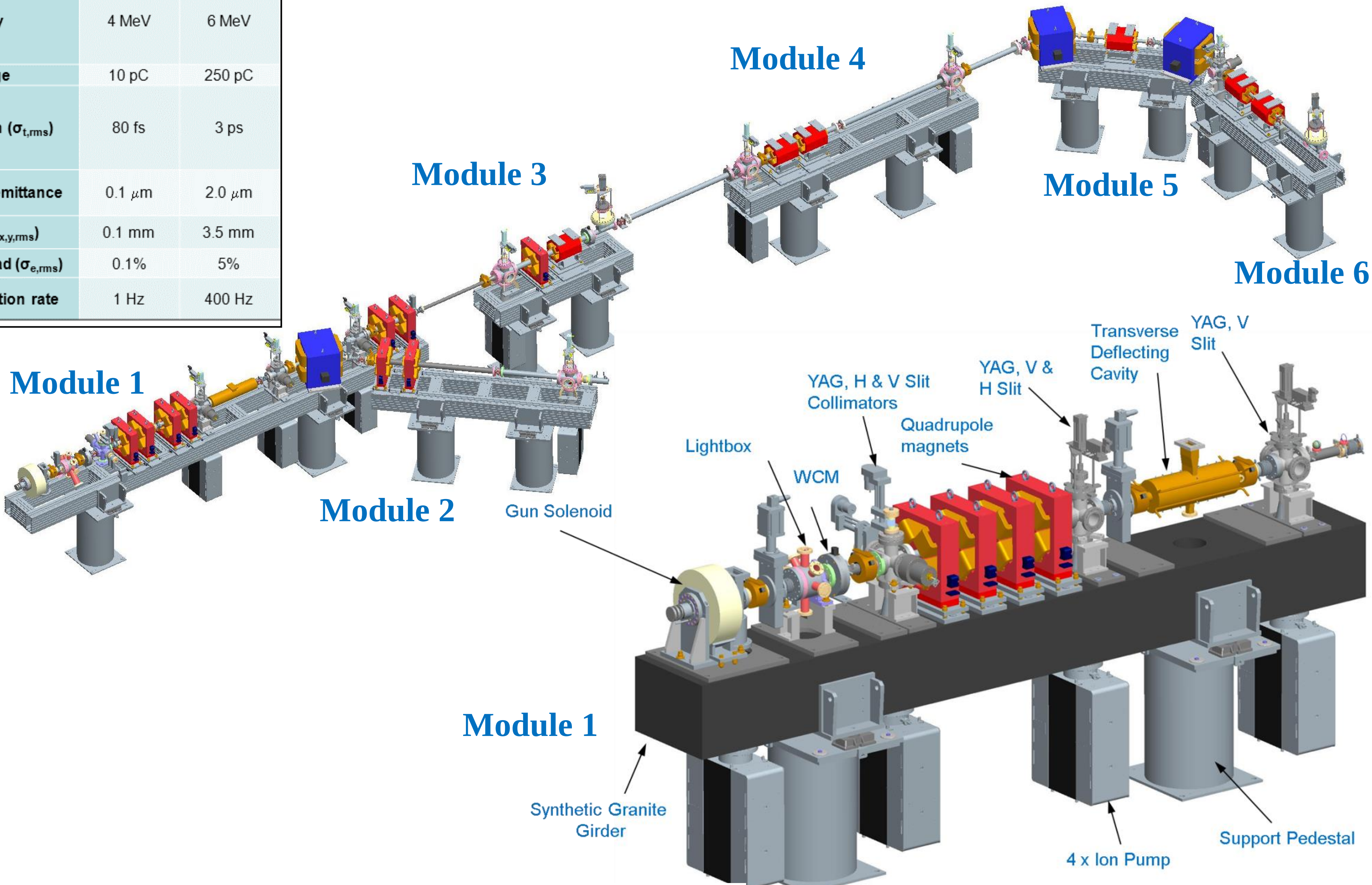
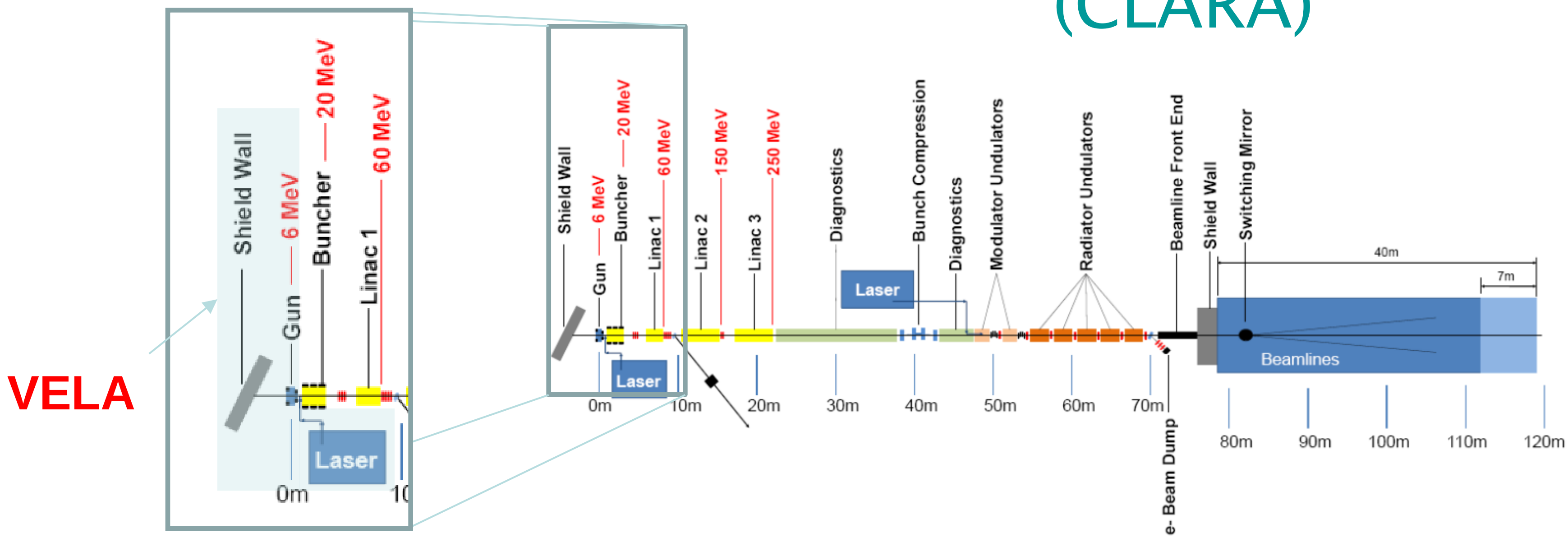
VELA Accelerator Modules

	VELA (Min)	VELA (Max)
Beam Energy	4 MeV	6 MeV
Bunch Charge	10 pC	250 pC
Bunch length ($\sigma_{t,rms}$)	80 fs	3 ps
Normalised emittance	0.1 μm	2.0 μm
Beam size ($\sigma_{x,y,rms}$)	0.1 mm	3.5 mm
Energy spread ($\sigma_{e,rms}$)	0.1%	5%
Bunch repetition rate	1 Hz	400 Hz



http://www.stfc.ac.uk/ASTeC/Programmes/VELA/38426.aspx

Compact Linear Accelerator for Research and Applications (CLARA)



- Beam Energy of 250 MeV
- Charge ranges from 10 pC – 250 pC
- <1 μm mrad beam emittance
- 300 A beam current over 300 fs bunch length for seeding schemes

Single-spike SASE, EEHG, HGHG, novel short pulse schemes

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

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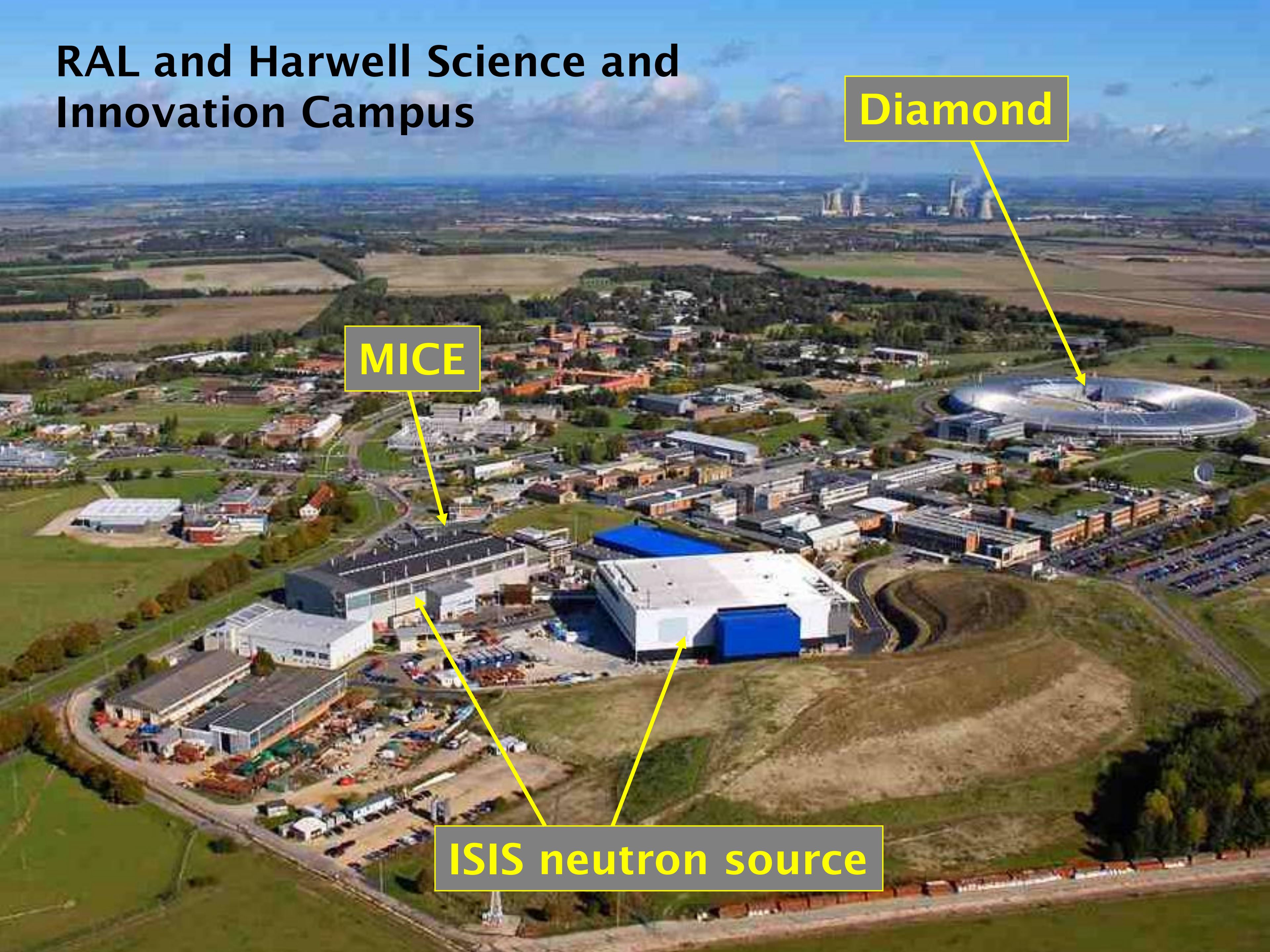
CLARA Conceptual Design

- Conceptual Design Report released July 2013 and can be found here:

http://stfc.ac.uk/ASTeC/resources/PDF/CLARA_CDRv2.pdf

RAL and Harwell Science and Innovation Campus



Diamond Light source

Energy	3 GeV
Circumference	561.6 m
No. cells	24
Symmetry	6
Straight sections	6 x 8m, 18 x 5m
Insertion devices	4 x 8m, 18 x 5m
Beam current	300 mA (500 mA)
Emittance (h, v)	2.7, 0.03 nm rad
Lifetime	> 10 h
Min. ID gap	7 mm (5 mm)
Beam size (h, v)	123, 6.4 mm
Beam divergence (h, v) *(at centre of 5 m ID)*	24, 4.2 mrad

Commissioned in 2006 and open for users in January 2007

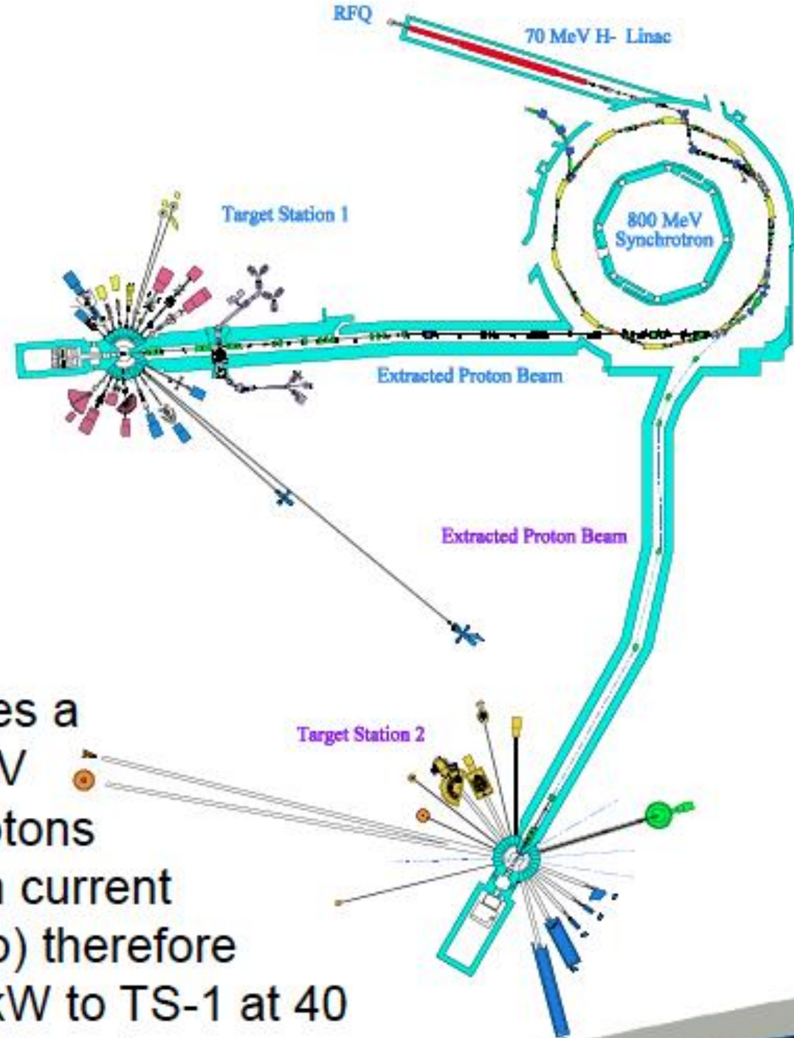
Currently operating 13 beamlines with 10 in-vacuum insertion devices

Additional beamlines planned.

A lattice upgrade being studied; similar to ESRF

ISIS Accelerators

- H^- ion source (17 kV)
- 665 kV H^- RFQ
- 70 MeV H^- linac
- 800 MeV proton synchrotron
- Extracted proton beam lines



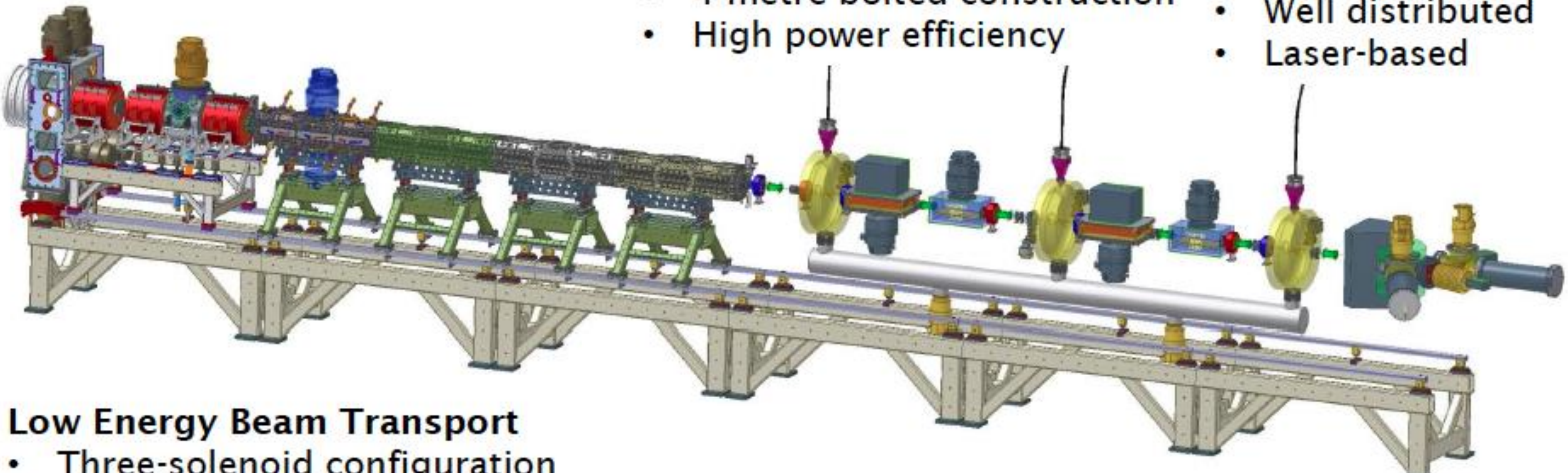
The accelerator produces a pulsed beam of 800 MeV (84% speed of light) protons at 50 Hz, average beam current is 230 μA (2.9× 10^{13} ppp) therefore 184 kW on target (148 kW to TS-1 at 40 pps, 36 kW to TS-2 at 10 pps).

Front End Test Stand (FETS)

High brightness H^- ion source
- 4 kW peak-power arc discharge
- 60 mA, 0.25 π mm mrad beam
- 2 ms, 50 Hz pulsed operation

Radio Frequency Quadrupole
- Four-vane, 324 MHz, 3 MeV
- 4 metre bolted construction
- High power efficiency

Diagnostics
- Non-interceptive
- Well distributed
- Laser-based



Low Energy Beam Transport
- Three-solenoid configuration
- Space-charge neutralisation
- 5600 Ls^{-1} total pumping speed

Medium Energy Beam Transport
- Re-buncher cavities and EM quads
- Novel 'fast-slow' perfect chopping
- Low emittance growth

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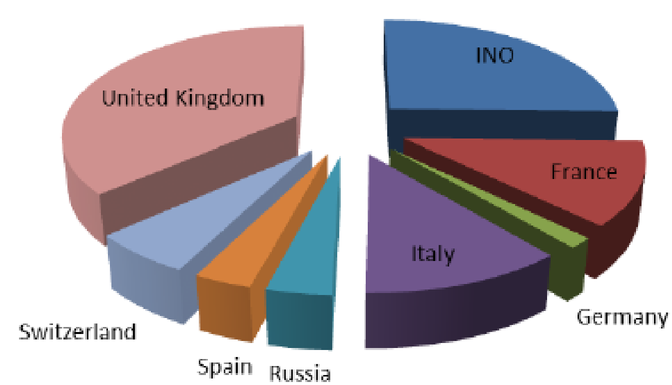
ISIS
ASTeC
JAI John Adams Institute for Accelerator Science
Imperial College London
THE UNIVERSITY OF WARWICK
Royal Holloway University of London
UCL
ESS bilbao

UK-HiLumi

Sum of pm	Column Labels						
	1	2	3	4	5	6	Grand Total
Row Labels							
CERN	114	101	90	107	123.6	58	593.6
CEA		24	48	6			78
CNRS				40.8			40.8
DESY		12					12
INFN		67.2	44			22	133.2
BINP		65					65
CSIC		24			38		62
EPFL		48					48
RHUL					64		64
SOTON						71	71
STFC		28		31			59
ULANC				70.5			70.5
UNILIV		34.8					34.8
UNIMAN		34.8			58		92.8
KEK		19.2	72	68.5			159.7
Grand Total	**114**	**458**	**254**	**323.8**	**283.6**	**151**	**1584.4**

The UK is well placed to contribute significantly to the programme

EU request (€ 4,900,000)



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UK - CERN LHC activities

Main UK activities in HL-LHC

- High Luminosity LHC optics, tracking and beam-beam
- Crab cavity design and beam dynamics
- High Luminosity LHC collimation
- LHC machine-detector interface

Strong emphasis on

- Intellectual input and design
- Computing; UK is growing in this area generally
- Some hardware.
- Additional work at Linac4, ion source, …

CLIC-UK is also a very strong partnership with CERN; many synergies and connections with the LHC work.

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Accelerator Review

- As set out in our Accelerator Strategy & roadmap STFC will be undertaking an Accelerator review.
- Purpose – To enable STFC to tension programme and make hard funding decisions so can take advantage of future opportunities
- Data collecting will be undertaken in the spring of 2014, with the review carried out in the early summer. A report will then be presented to Science Board

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HM TREASURY

Spending Review

- In the Budget (20 March) Government formally announced a Spending Review to set budgets for FY 2015/16, and the total public spending envelope for that year
- Outcome of the SR was announced on 26 June
  - *maintain resource funding for science in cash terms at £4.6 billion in*

  2015-16.
  - *increase capital funding in real terms from £0.6 billion in 2012-13 to £1.1 billion in 2015-16, and in line with inflation to 2016-17 - no news yet on how this will be allocated.*
- Announcement of the allocations to individual Councils later
  - *Expect this to be in December.*

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Programmatic Review 2013

- Overseen by Science Board with community input through the advisory panels
- Aim is to best position ourselves for next CSR and inform our programme after the 15/16 allocations are made.
- Coupling with Spending Review means the PR publication will now be in December 2013.
- The review covers the entire programme, including impact and technology; this includes the accelerator physics programme.


The UK is playing a leading role in the world's biggest scientific experiment, the Large Hadron Collider at CERN in Geneva - recreating the conditions that existed a trillionth of

Conclusions

- The UK has a vibrant accelerator programme and is committed to continued collaboration with CERN.
- STFC will continue to support innovative R&D across its accelerator programme, including making contributions at energy frontier machines.
- The Cockcroft Institute and John Adams Institute are both involved with HL-LHC and are integrating this into their R&D and training.
- Partnership with CERN is key to this and to many of our activities; we celebrated the CERN BIC this afternoon.
- Welcome to the UK.
- Have a very productive workshop!