Science & Technology Facilities Council

ALICE, EMMA & Future Directions for Accelerator R&D @ Daresbury

Susan Smith

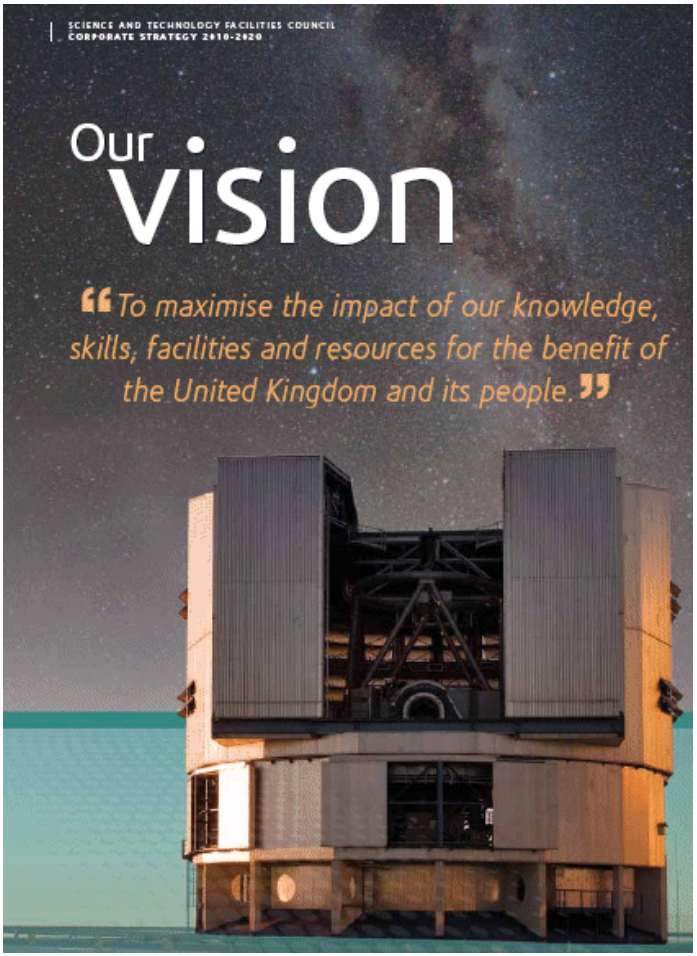
ASTeC Director STFC

DESY Dec 2011

Contents

- Introduction to ASTeC
- ASTeC Skills
- Programme
- Test facilities
  - ALICE
  - EMMA
- Underpinning R&D
- Collaborations & KE
- Summary

INTRODUCTION



Our vision

Maximising impact for the UK

Strategic goals

- World class research
- World class innovation
- World class skills

Strategic themes

- Solutions for global challanges
- Inspiring and involving
- Sustaining research excellence and leadership
- Effective knowledge exchange
- Strengthening strategic partnerships
- Building international influence

Strategic enablers

- Developing our people
- Financial sustainability
- Efficient and effective organisation

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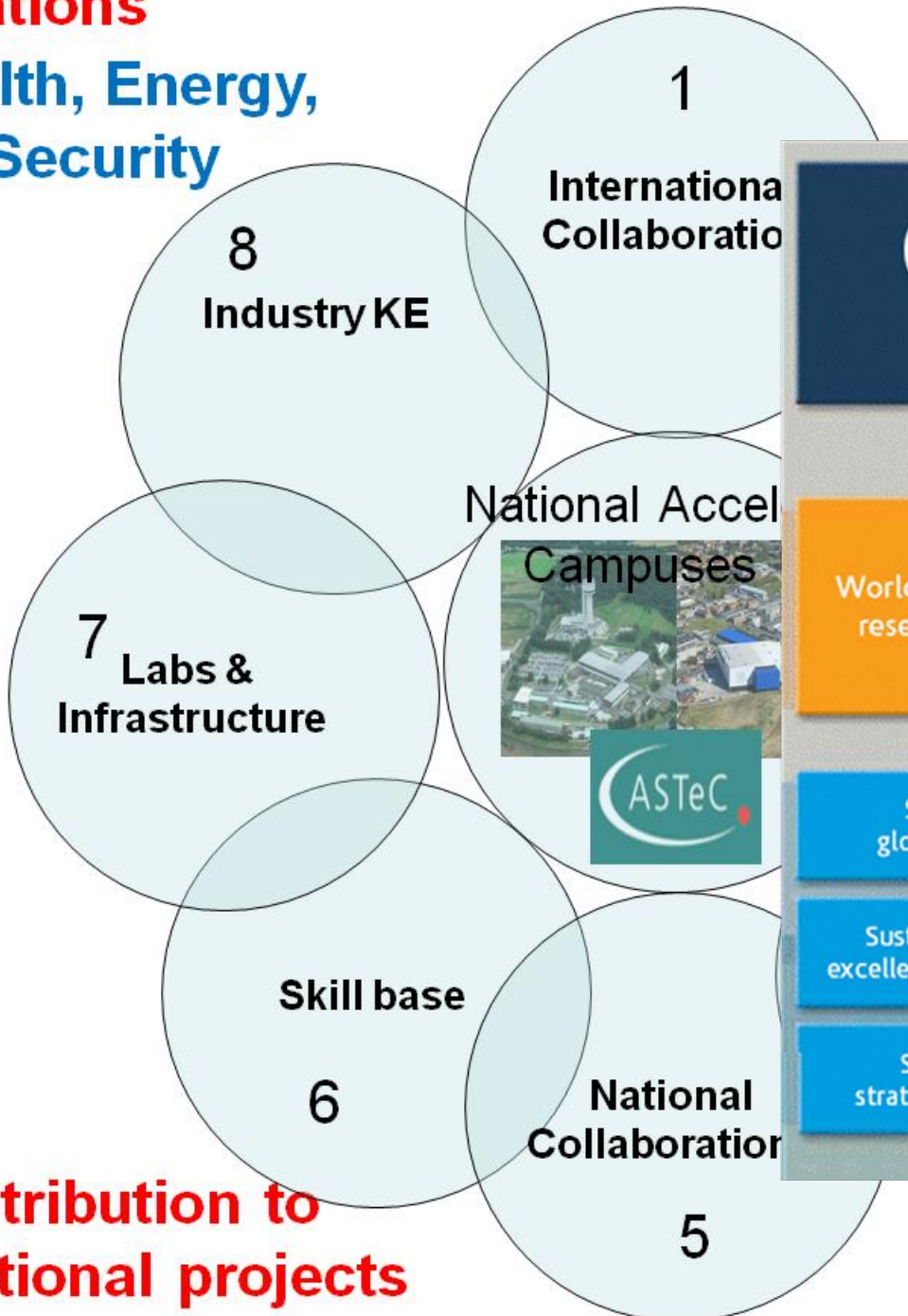
Applications

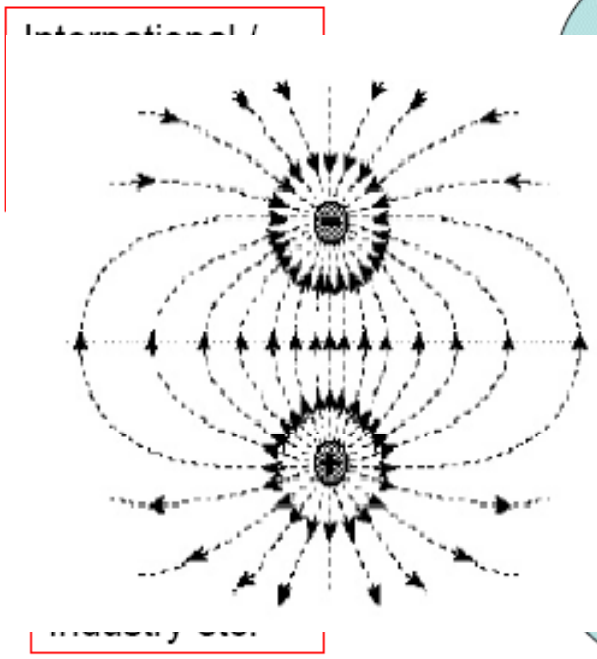
Health, Energy, Security

Future UK large scale facilities



Contribution to international projects

A ‘Dipole’ Centre Vision



esbury
entre

Regional Universities & Industry etc.

ASTeC/STFC

arwell
entre

International / National Universities & Industry etc.

ALICE/EMMA
ASTeC
Cockcroft/JAI
EBTF & CLARA
ECT
Technology Dept
CSE
Nuclear Phys...

FETs/MICE
ASTeC
Cockcroft/JAI/IC
ISIS
Diamond
Technology Dept
CLF....

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ASTeC SKILLS

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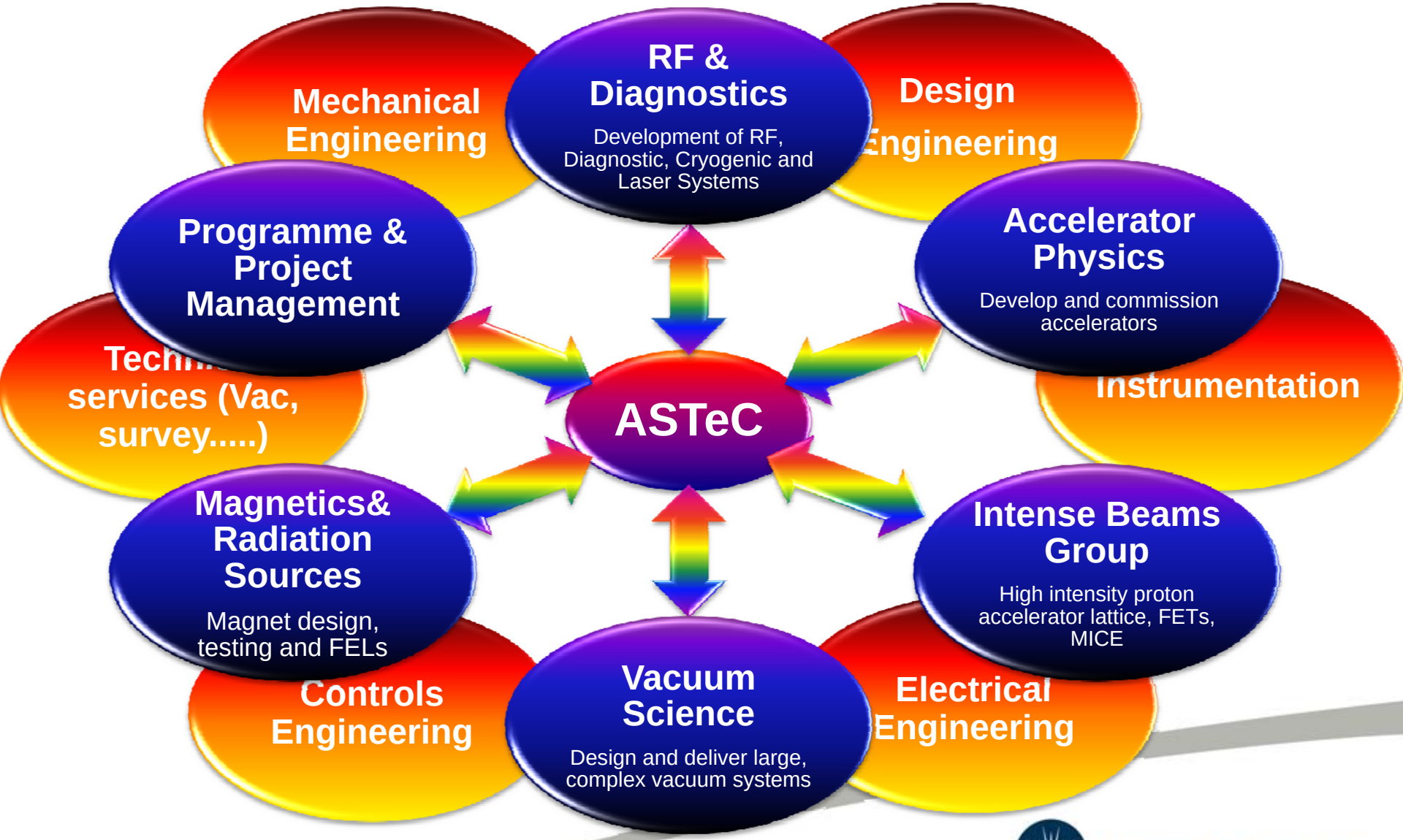
ASTeC Department Skill Base



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PROGRAMME

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Programmes @ Daresbury

- National design studies - Future light sources (4GLS, NLS, ??)
- International design studies – ILC/CLIC, LHC-HiLum, SuperB .....

- Test facilities @ Daresbury
  - ALICE → EBTF and CLARA
  - EMMA
- Underpinning R&D
  - Superconducting Radiofrequency and cryogenics
  - Injectors and high brightness electron beams
    Vacuum science
  - Magnets and free electron lasers (FELs)
- Collaboration building & Industrial and KE activities

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ALICE

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ERLP: test bed and a learning tool

New accelerator technologies for the UK

First SCRF linac operating in the UK

First DC photoinjector gun in the UK

First ERL in Europe

First IR-FEL driven by energy recovery accelerator in Europe

... lots of help from all around the world
... BIG THANKS to all and , especially, to colleagues from JLab !!

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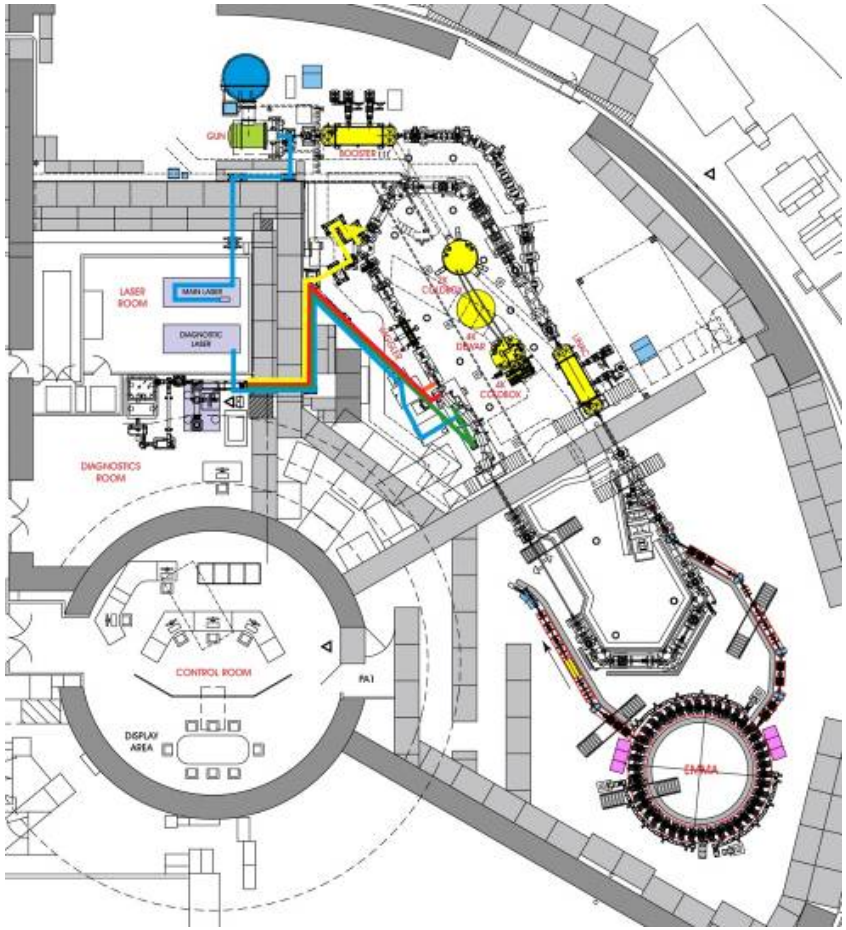
The ALICE (ERLP) Facility @ Daresbury Laboratory



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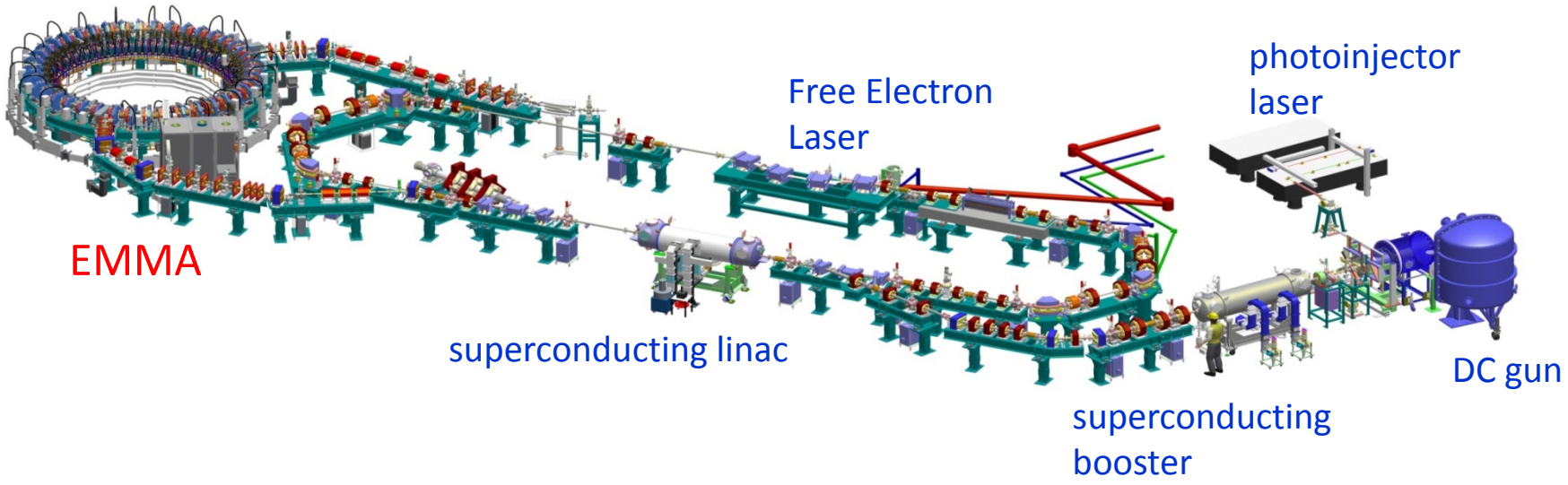
The ALICE Facility @ Daresbury Laboratory

Accelerators and Lasers In Combined Experiments

An accelerator R&D facility based on a superconducting energy recovery linac



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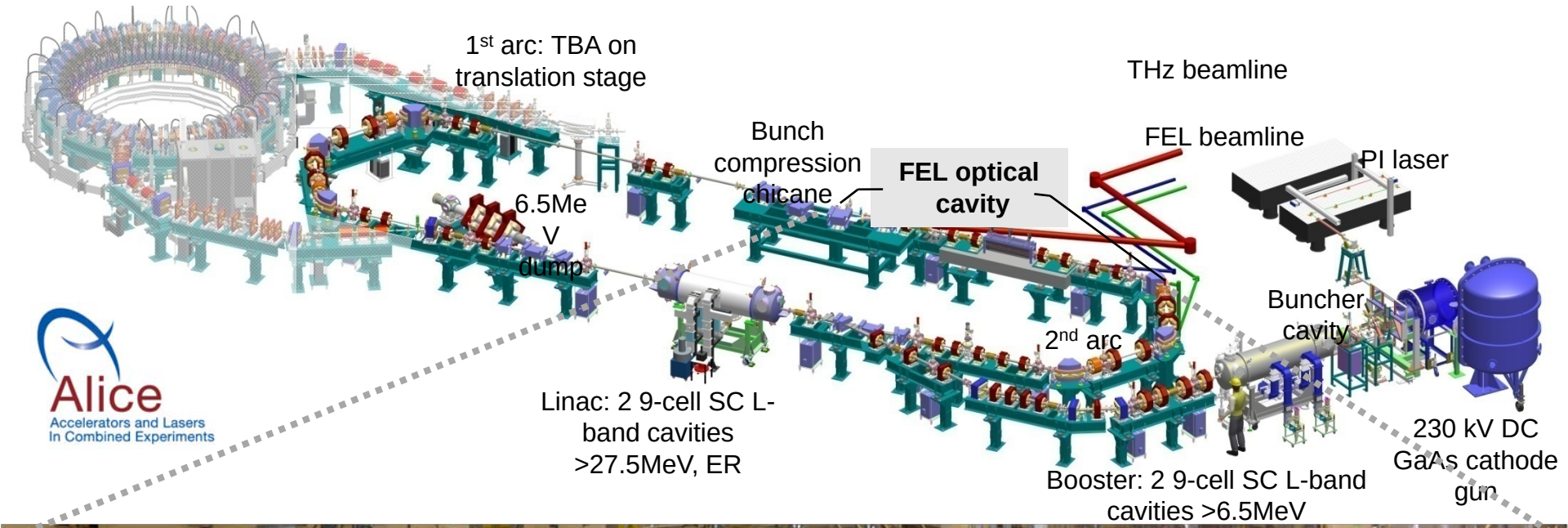
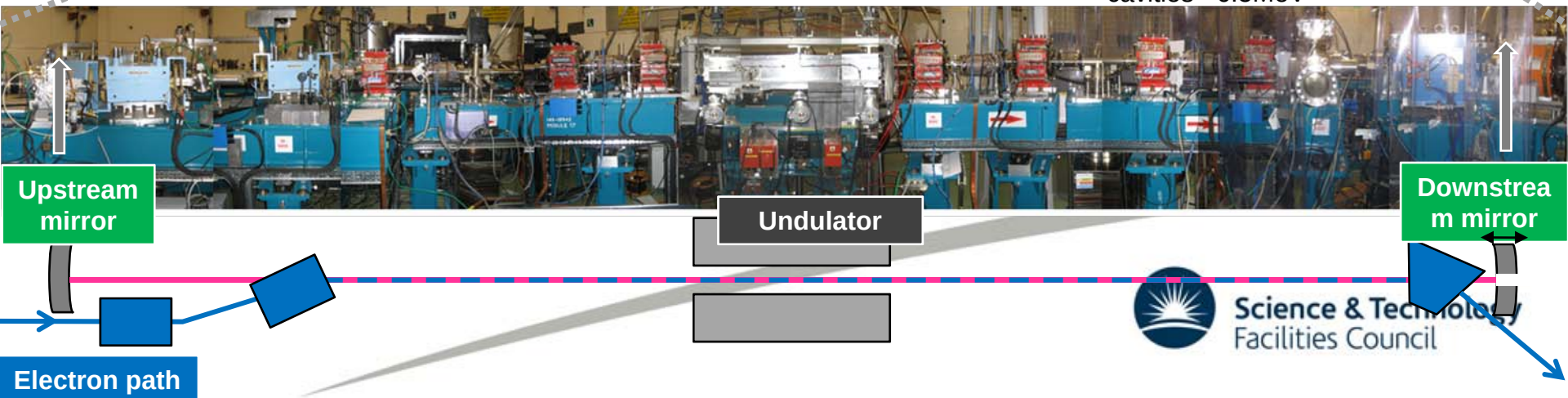
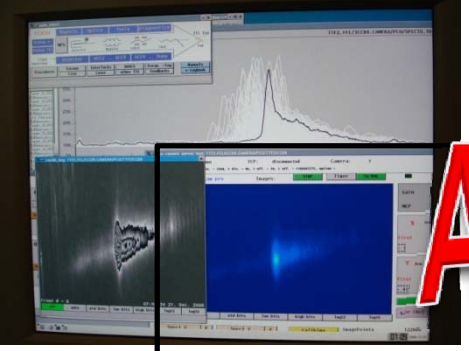
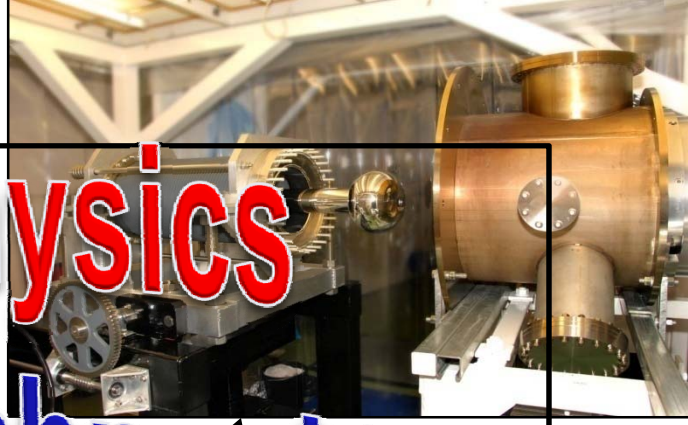
ALICE accelerator

Accelerators and Lasers In Combined Experiments









ALI [illegible]

Accelerator Physics

Ultrafast Diagnostics

[illegible] Synchronisation

Injection 350 kV

Optimisation, Benchmarking, modeling, Characterising, Understanding !

[illegible] feedback

SC RF

Laser-electron Beam Interactions

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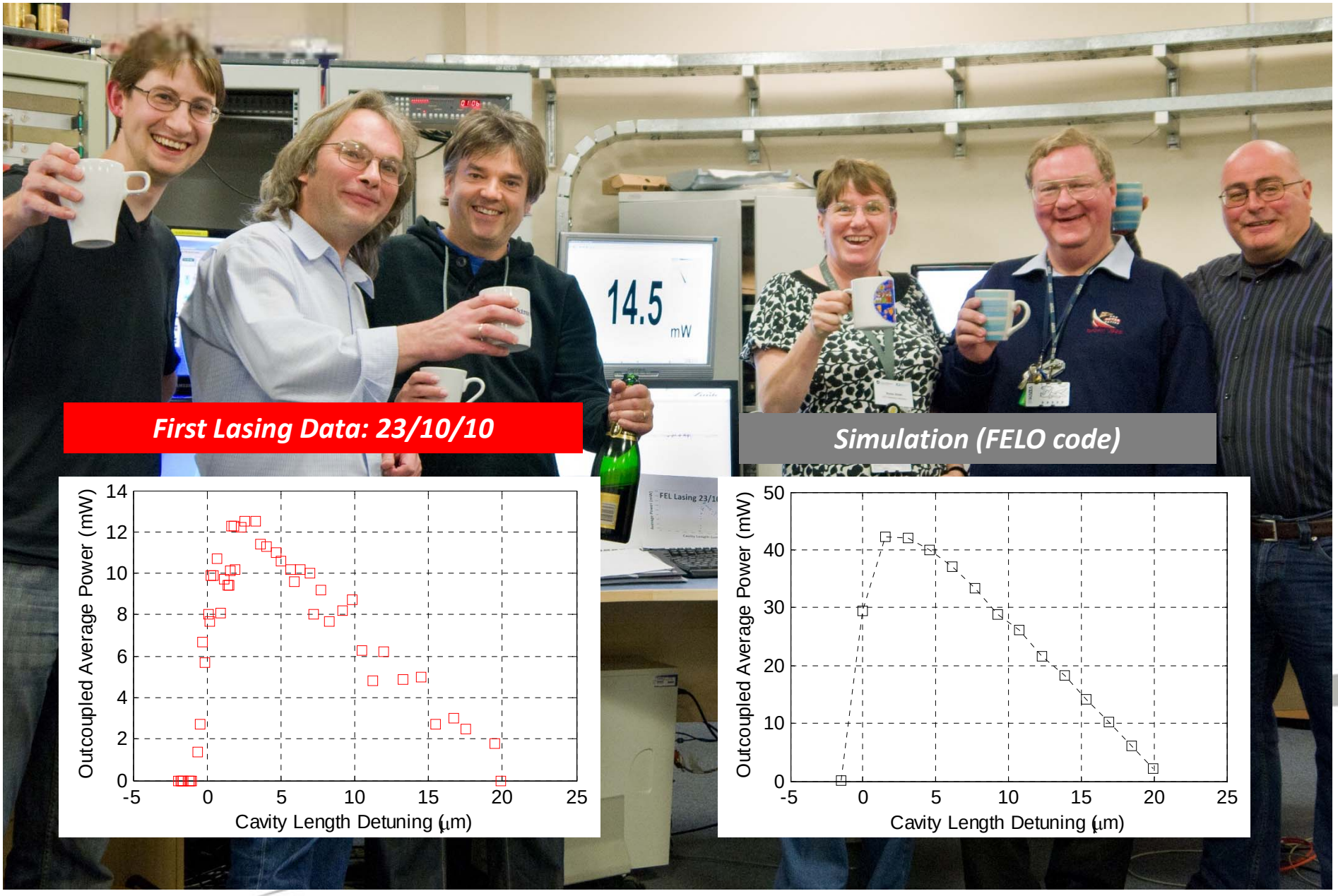
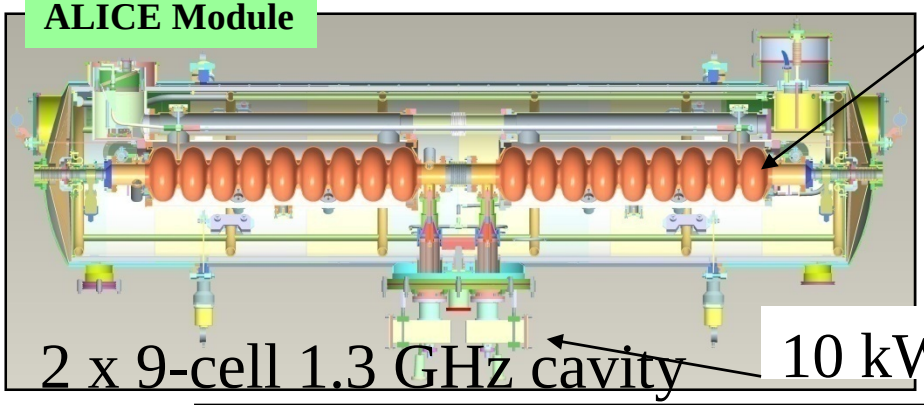
23 October 2010: First Lasing!



Cryomodule

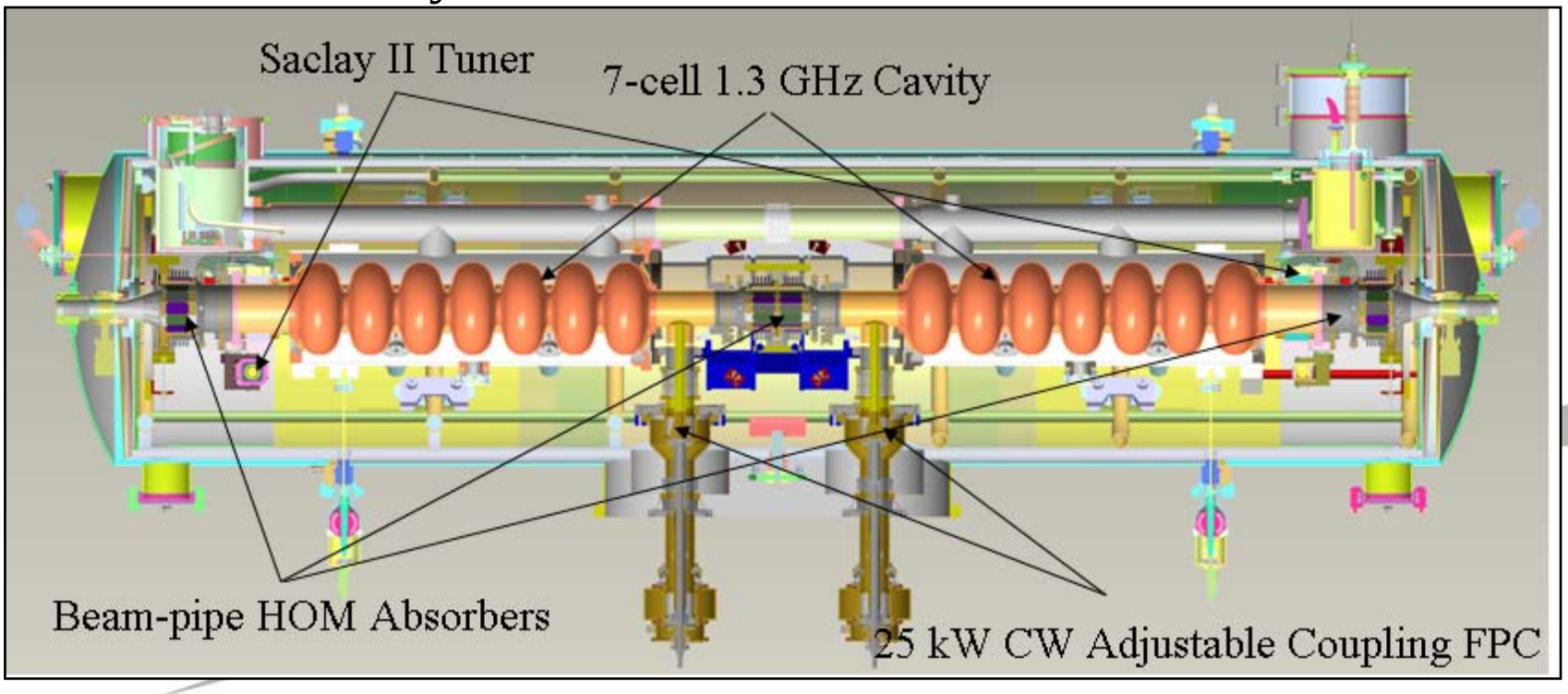
- 5 collaborating institutes
  - ASTeC (UK)
  - Cornell University (USA)
  - Stanford University (USA)
  - Lawrence Berkeley Laboratory (USA)
  - FZD Rossendorf (Germany)

ALICE Module



2 x 9-cell 1.3 GHz cavity

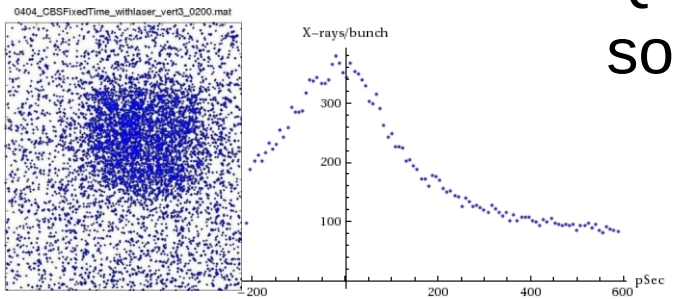
10 kW CW fixed coupling FPC

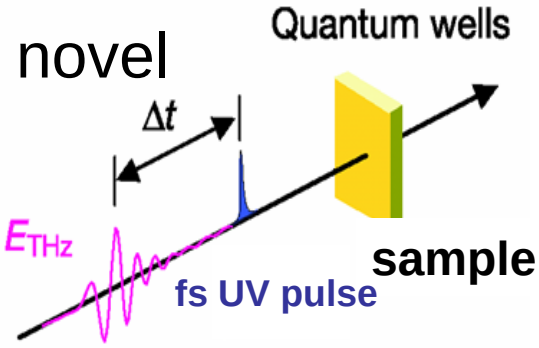


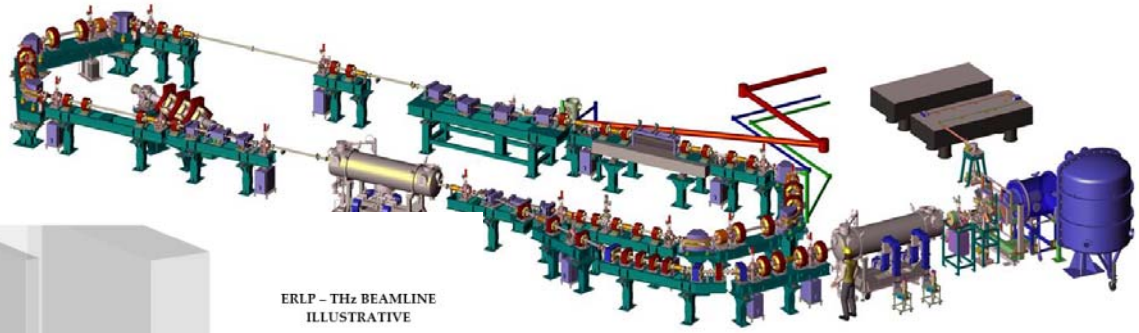
ALICE Photons

CBS

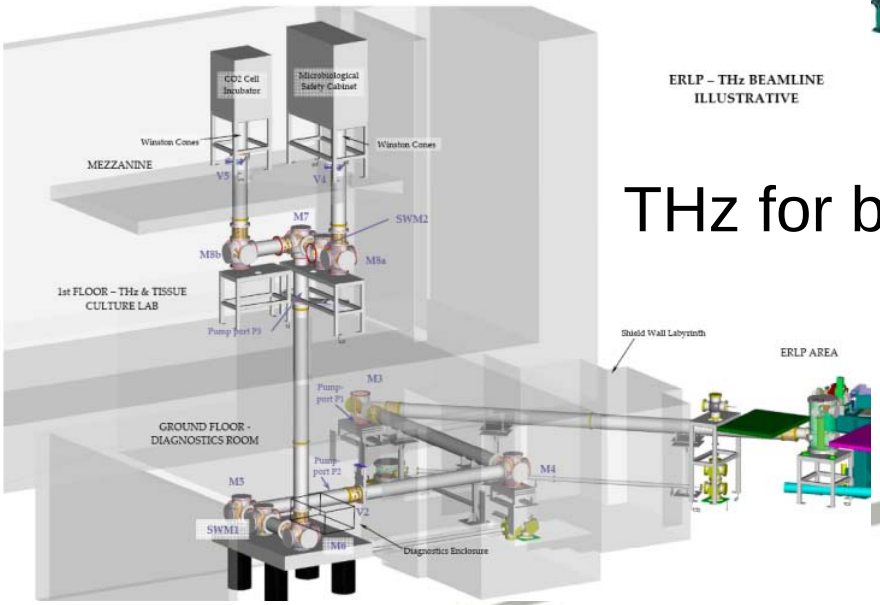
Quantum dots studies for novel solar cells

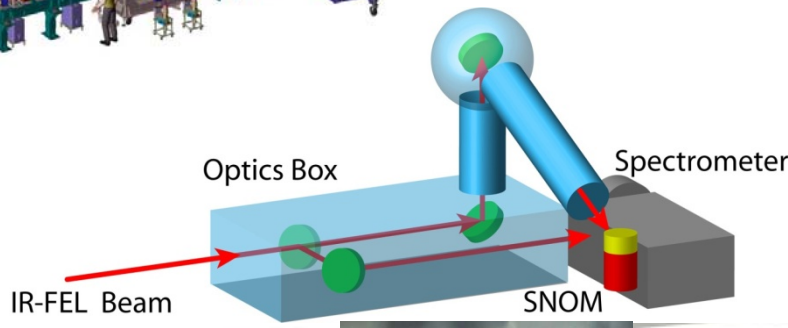






THz for biology





EMMA

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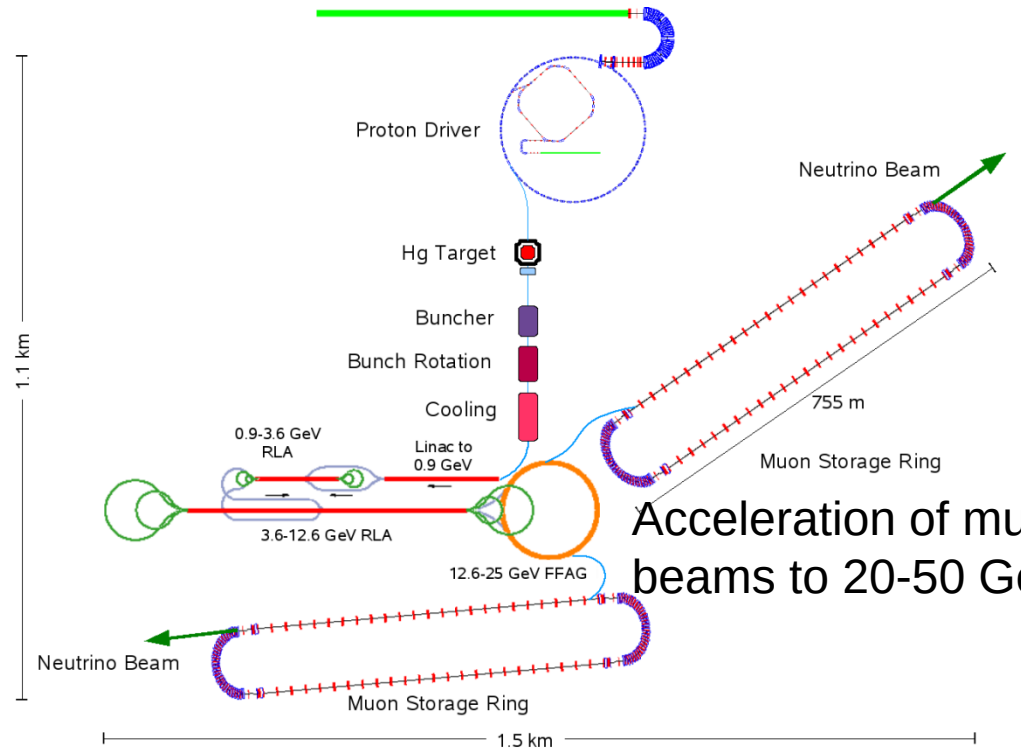
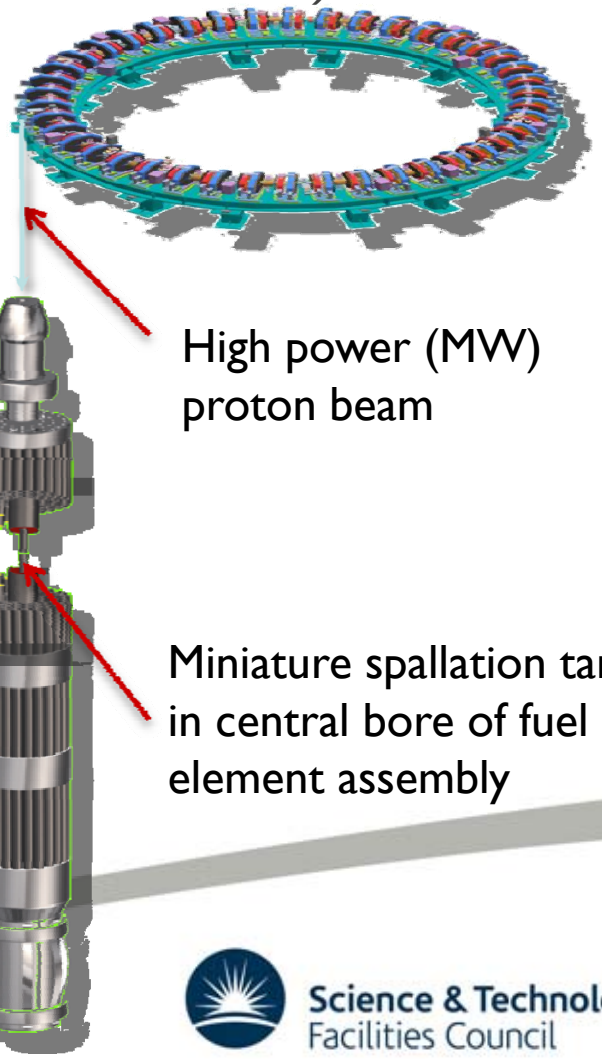
Demands for new accelerator

Neutrino Factory



Acceleration of muon beams to 20-50 GeV.

ADSR (accelerator driven subcritical reactor)



High power (MW) proton beam

Miniature spallation target in central bore of fuel element assembly

Particle therapy

Compact and flexible accelerator for particle therapy.

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What about Fixed Field Alternating Gradient accelerator?

- Fixed field magnets enables quick acceleration.
  - Beam power can be increased with high repetition.
  - Acceleration within muon lifetime is possible.
- AG focusing pushes momentum to synchrotron range.
- Fixed field magnets provide flexibility and reliability.

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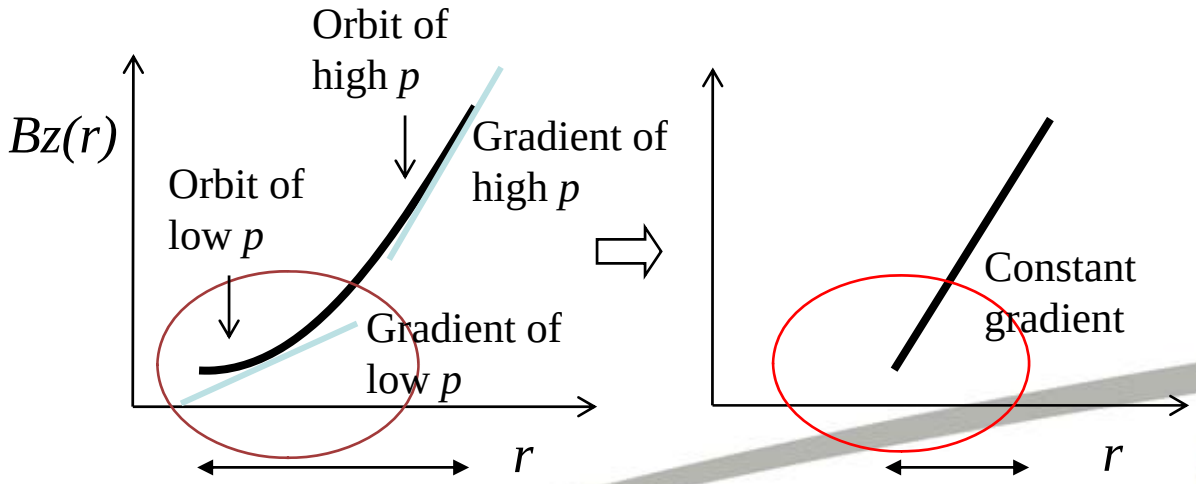
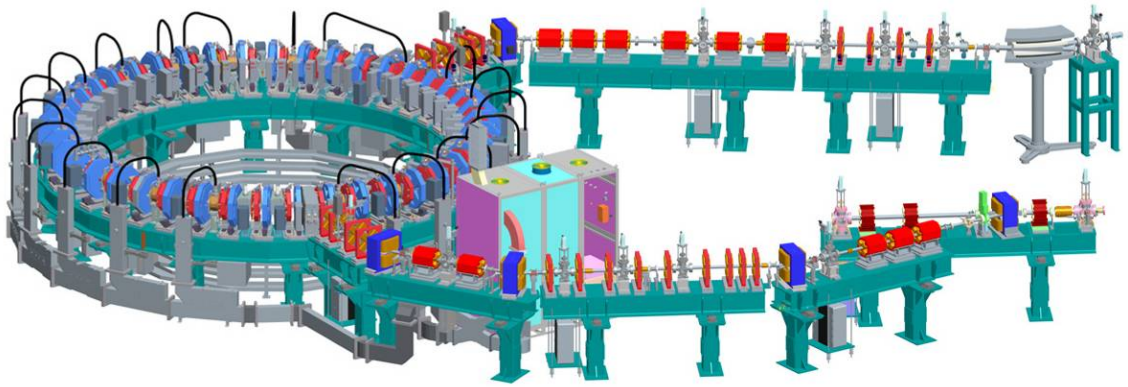
Non-scaling FFAG

- Simplified design called non-scaling FFAG strengthens the advantages.
  - Storage ring with extremely small dispersion function
- From scaling to non-scaling FFAG



ns-FFAG works as expected?

- Demonstration of a linear non-scaling Fixed Field Alternating Gradient accelerator was long waited.



- EMMA is
  - *Electron*
- Although initial experiment more focuses on
  - *Electron Model of Muon Acceleration*

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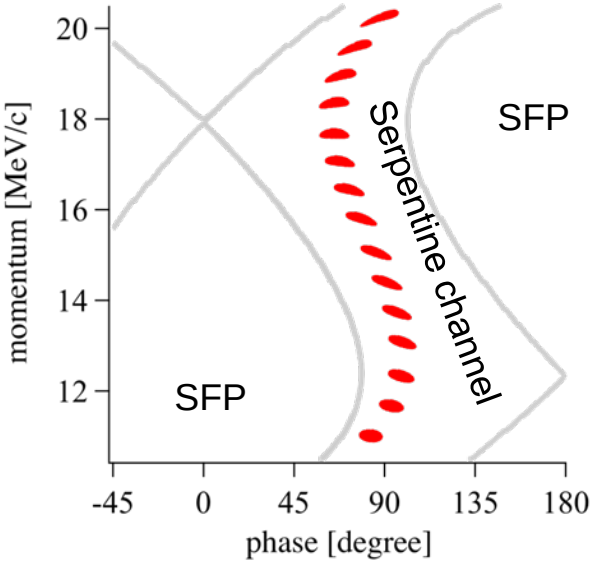
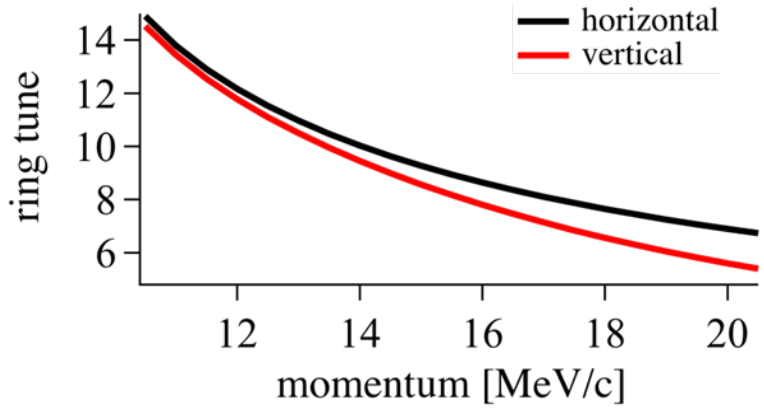
Three main goals

- Acceleration in serpentine channel (outside rf bucket) in around 10 turns.



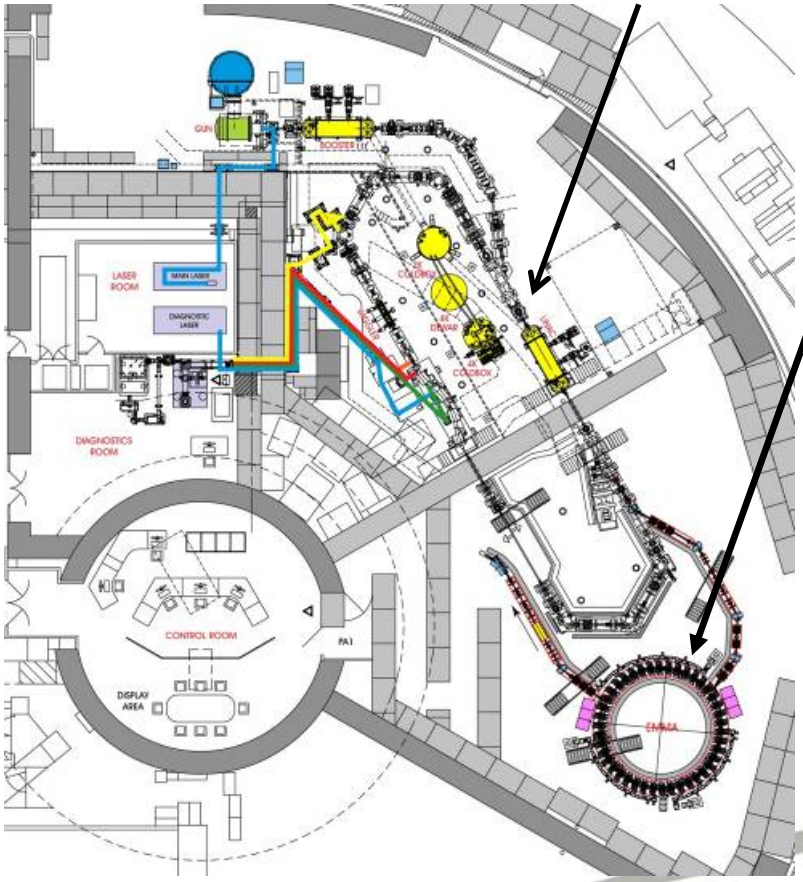


- Large tune variation due to natural chromaticity during

- Large acceptance for huge (muon) beam emittance.

EMMA

Accelerators and Lasers in Combined Experiments



Parameter	Value
Particle	electron
Momentum	10.5 to 20.5 MeV/c
Cell	42 doublet
Circumference	16.57 m
RF Frequency	1.301 GHz
RF voltage	2 MV with 19 cavities

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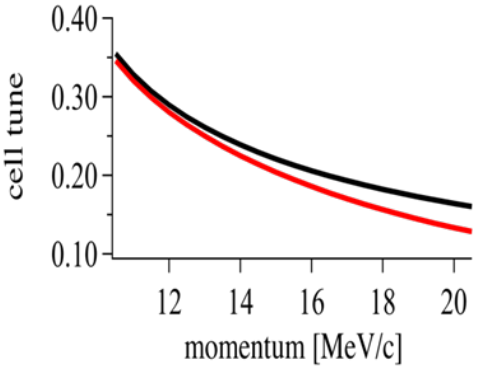
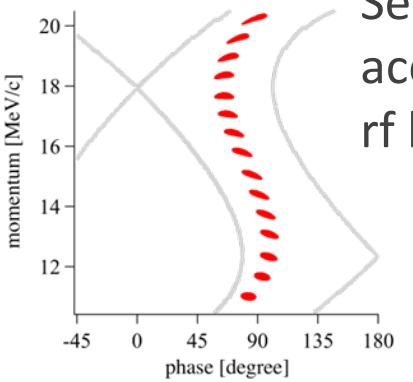
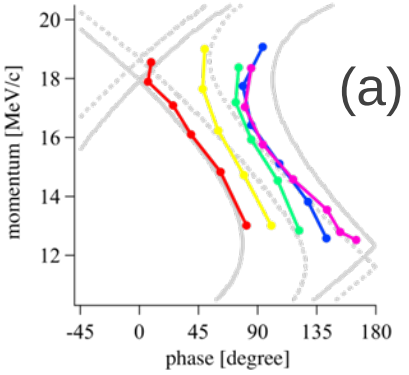
Acceleration May'11

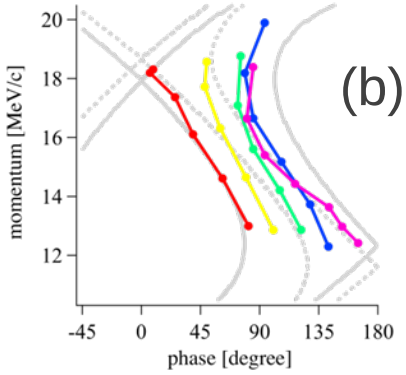


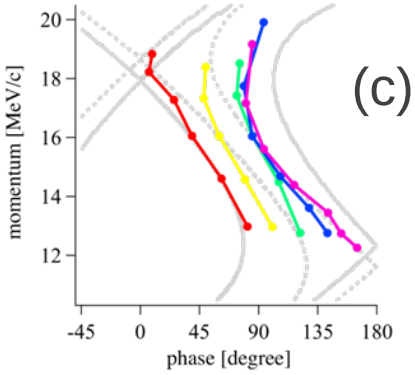


Serpentine channel acceleration outside rf bucket

All three momentum calibration methods; (a) hor. and (b) ver. tune and (c) hor. orbit shows consistent evidence of acceleration.





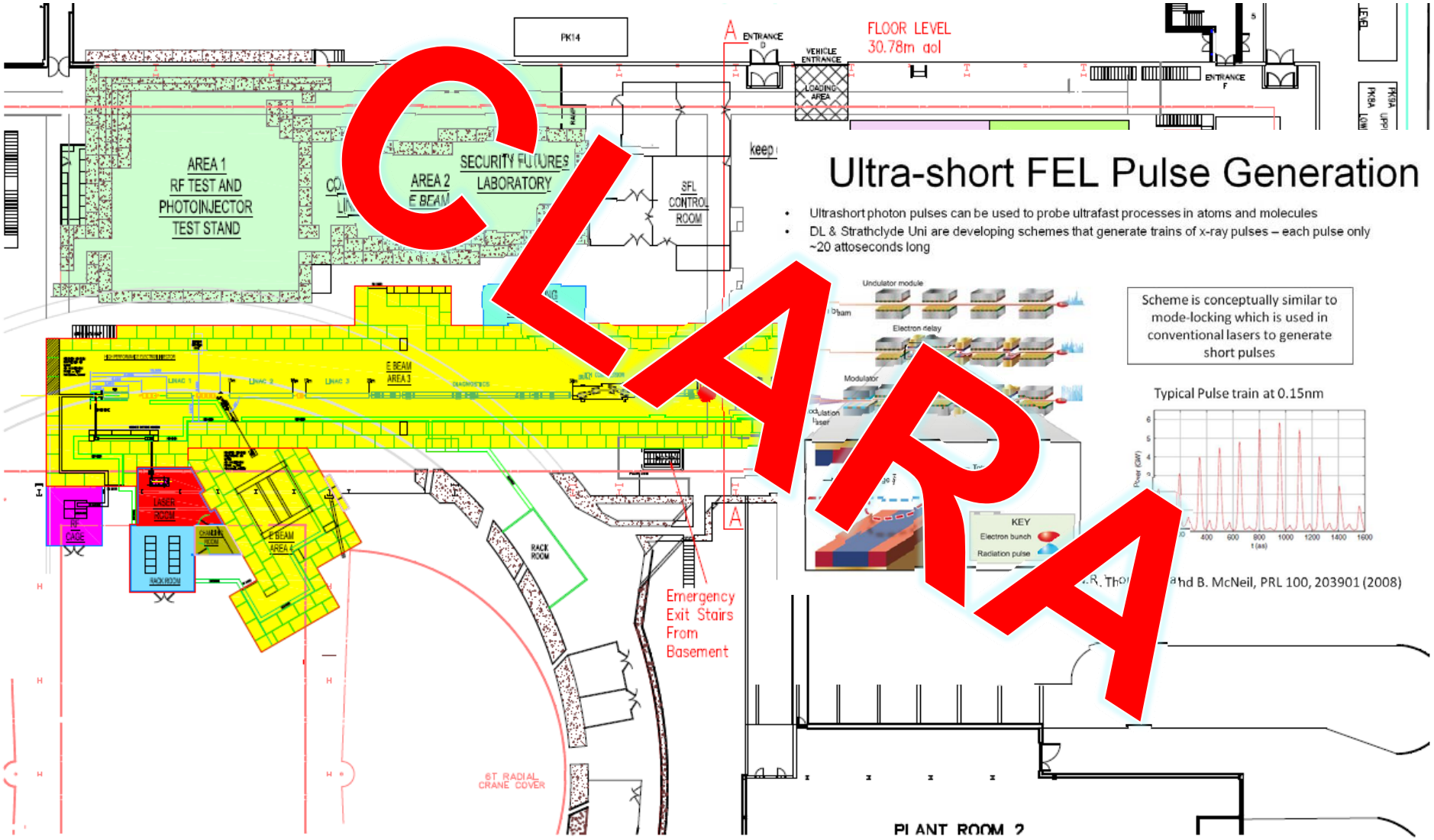


Plans for R&D Beyond ALICE & Beyond NLS

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.

- **Stable** in terms of transverse **position, angle, and intensity** from shot to shot.
- A target **synchronisation** level for the photon pulse 'arrival time' of better than 10 fs rms is proposed.
- "**ultra short**" means less than the FEL cooperation length, which is typically ~100 wavelengths long (i.e. this equates to a pulse length of 400 as at 1keV, or 40 as at 10 keV).

Compact Linear Advanced Research Accelerator



Other Aims and Prerequisites

- To lead the development of low charge single bunch **diagnostics**, **synchronisation** systems, advanced low level RF systems, and novel short period **undulators**.
- To develop skills and expertise in the technology of NC **RF photoinjectors** and **seed laser** systems.
- To develop novel techniques for the generation and control of **bright electron bunches**
  - manipulation by externally injected radiation fields
  - mitigation against unwanted short electron bunch effects (e.g. microbunching and CSR).
- To demonstrate high temporal **coherence** and wavelength **stability** of the FEL, for example through the use of external seeding or other methods.
- To develop the techniques for the generation of coherent **higher harmonics** of a seed source.
- To develop new photon **pulse diagnostic techniques** as required for single shot characterisation and arrival time monitoring.

David Cameron Confirmed £10M of investment

Prime Minister David Cameron announces new Enterprise Zones at the Daresbury Science and Innovation Campus

17 August 2011

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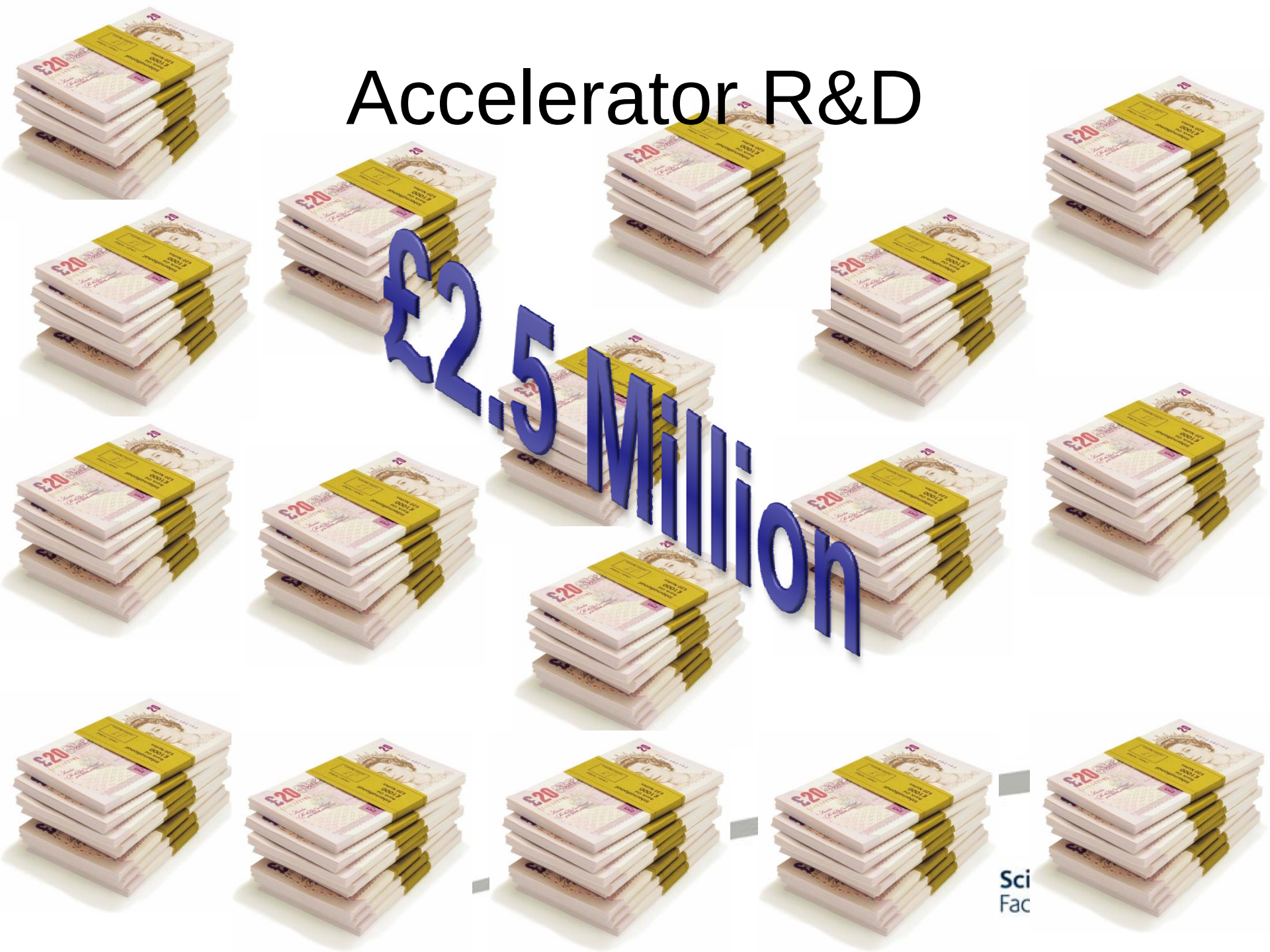
Accelerator R&D



Accelerator Investment

- **£2.5M** to implement additional enabling infrastructures
- For the development and testing **of novel and compact accelerator technologies**
- To enable **partnership with industry**
- Applications for **medicine, health, security, energy and industrial processing.**
- Revolutionise the **cost, compactness and efficiency**
- The main element of the infrastructure:-
  - **high performance and flexible electron beam injector**
  - **state-of-the-art testing enclosures** and associated support infrastructure.
- **Ongoing opportunities to bid** to expand this capability and to enhance the industrial activities it promotes on the DSIC campus in the future.

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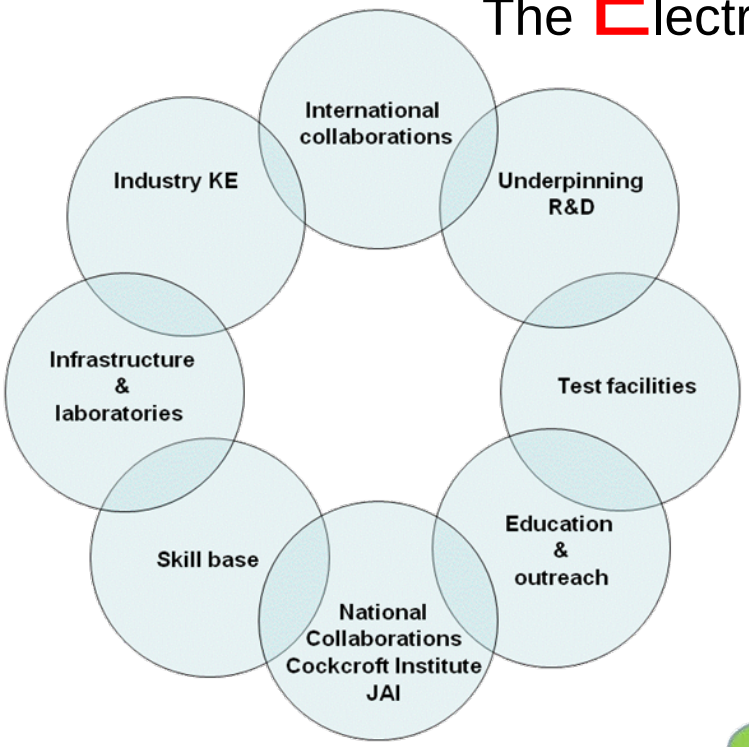
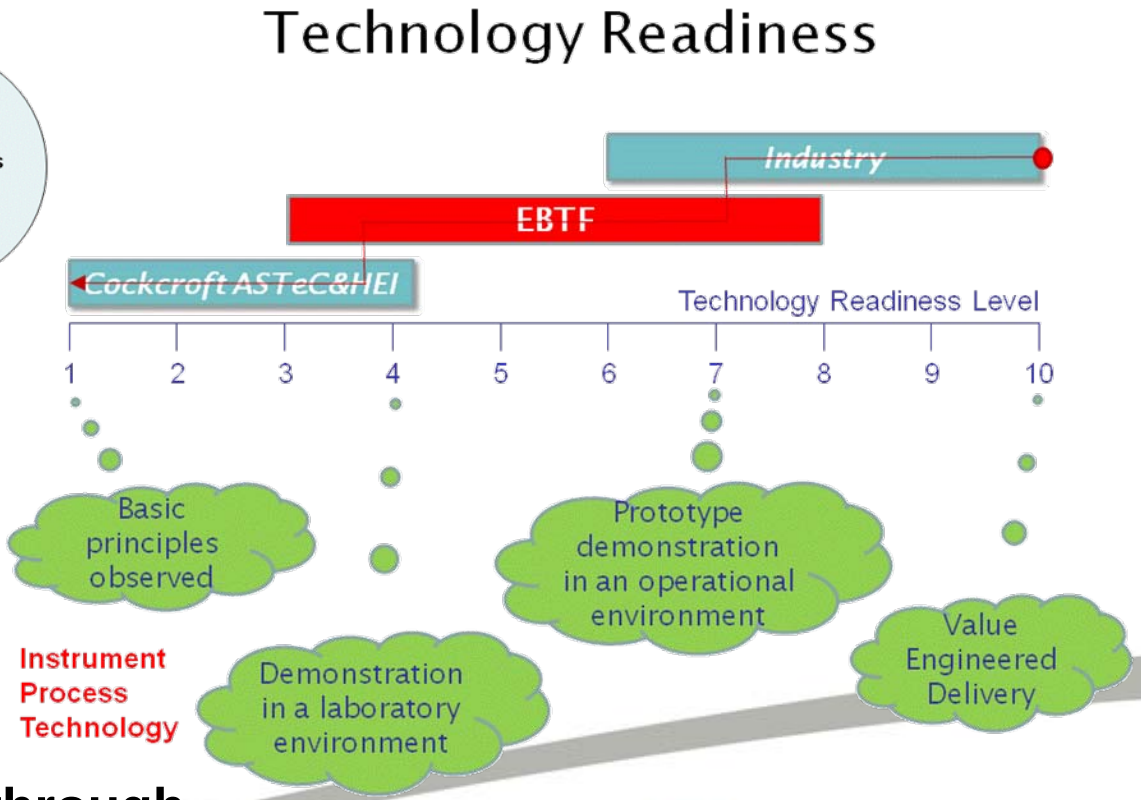
The Electron Beam Test Facility





EBTF

Accelerating Industry through Cutting Edge Facilities

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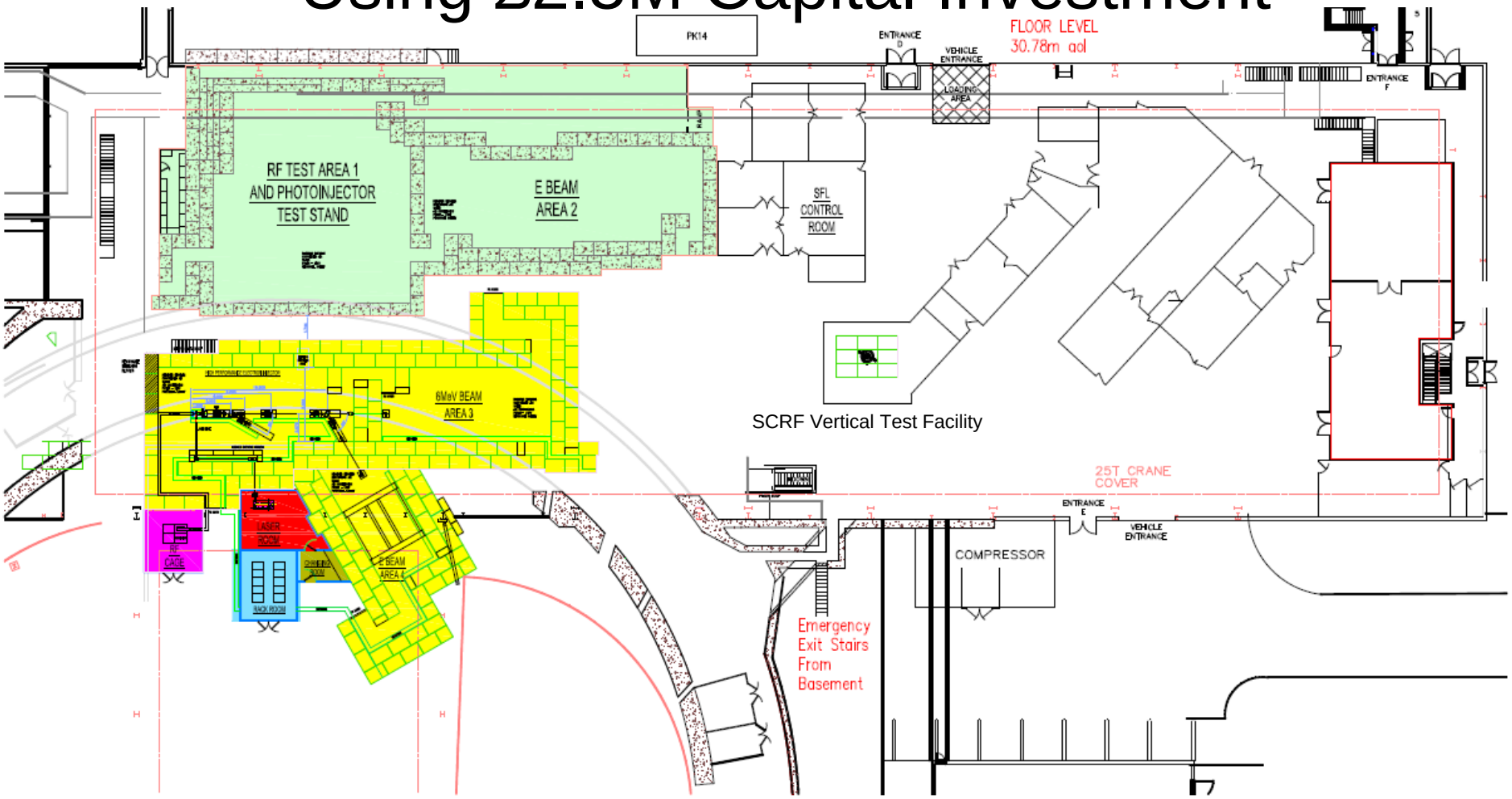
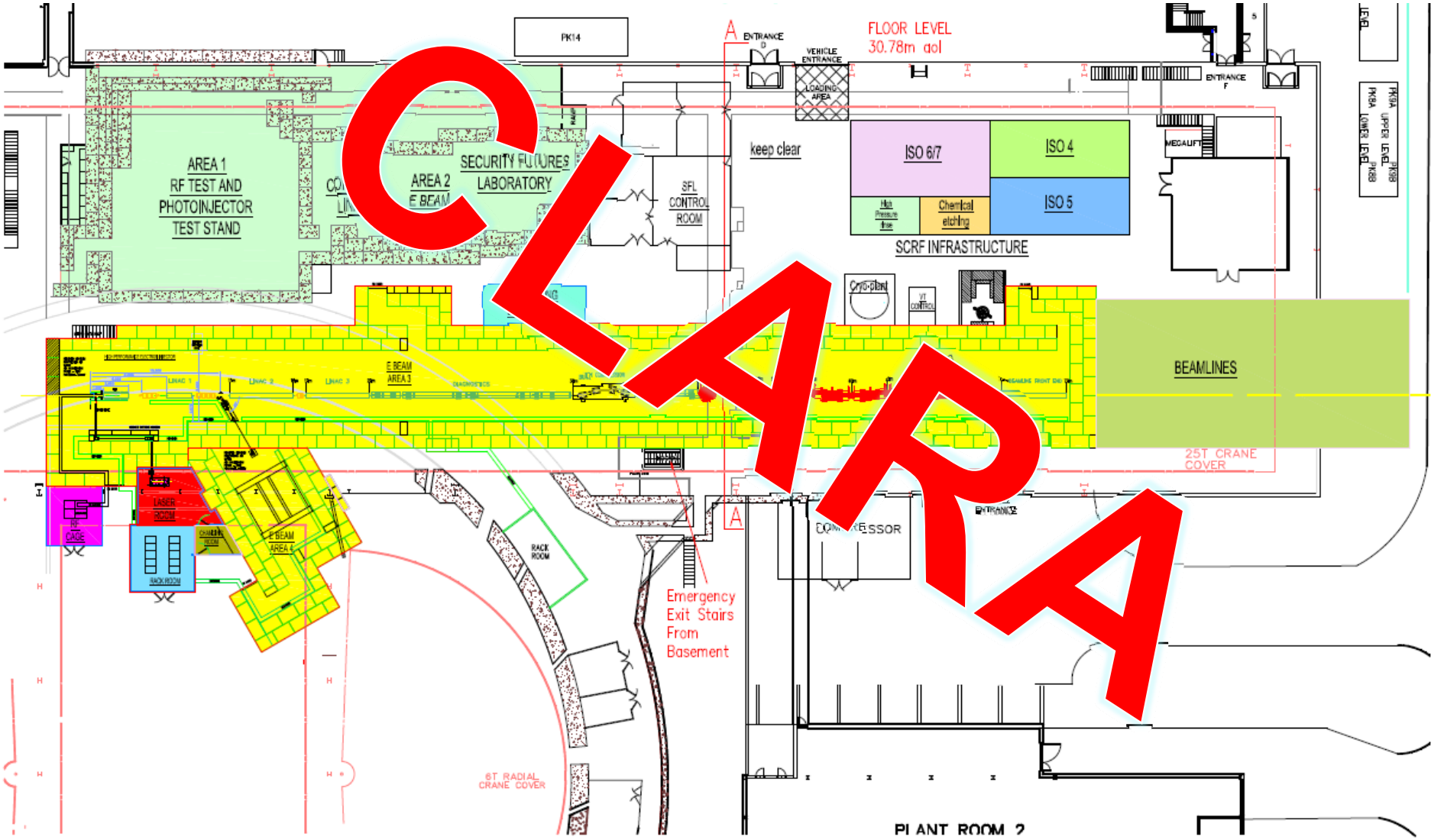
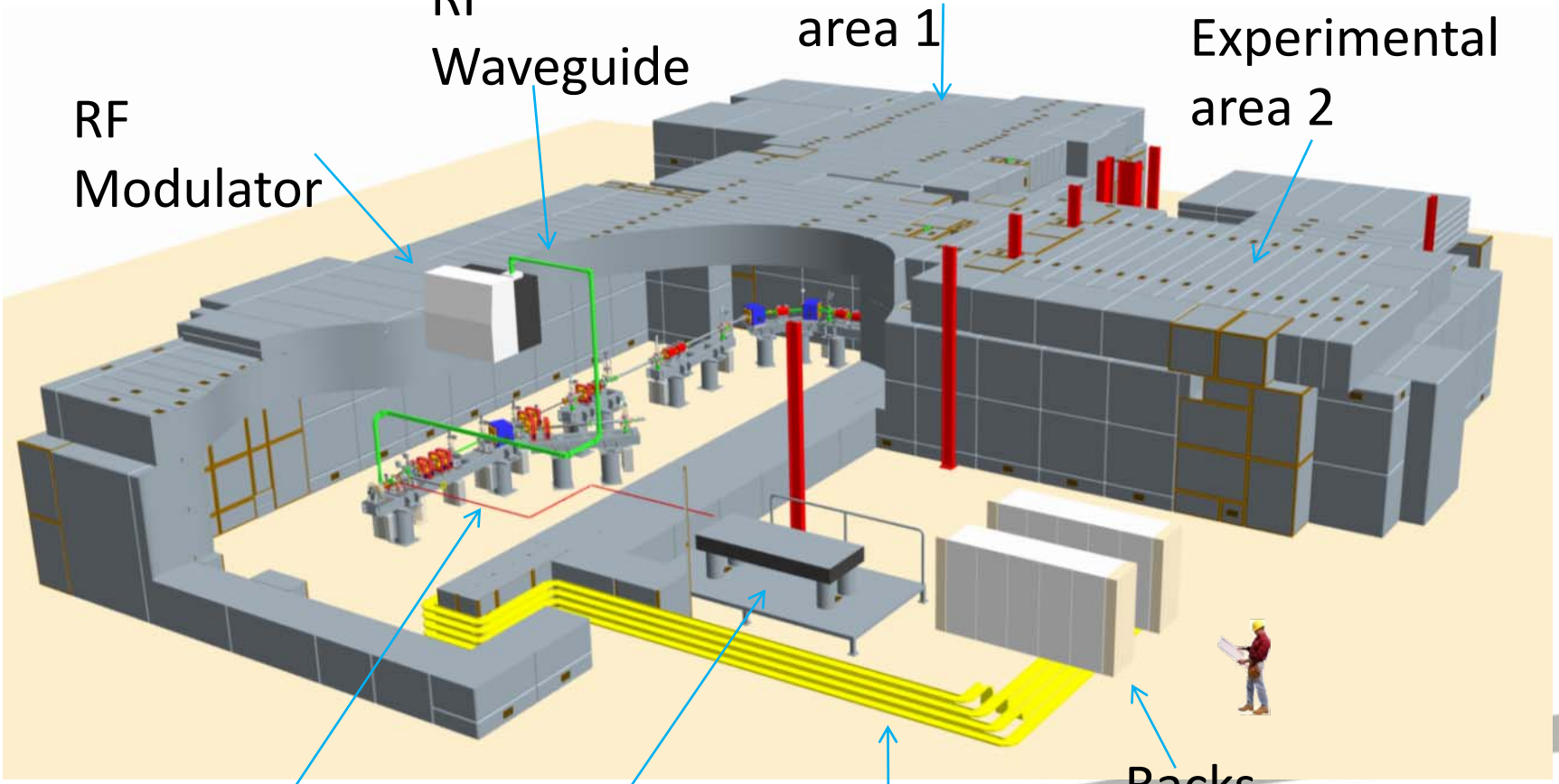
EBTF(FY 2011-12)
Using £2.5M Capital Investment



Compact Linear Advanced Research Accelerator



EBTF Accelerator Implementation



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UNDERPINNING R&D

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Underpinning R&D

- Photoinjectors
  - ALICE ceramic upgrade, short–pulse PI based on GaAs, photoemission and photo-emitter physics, metal cathodes, ultra bright guns
- Superconducting RF
  - International module collaboration, infrastructure development, Industrial collaborations
- Advanced diagnostics etc.
  - Ultrafast longitudinal diagnostics
  - Optical synchronisation tests on ALICE
  - Laser-electron beam interactions
- High power proton accelerators
  - Basic ideas for ISIS upgrades
  - FETS simulation and optimisation
  - Modelling for CERN's Linac4, Modelling J-PARC linac, Advising ESS in linac design

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Underpinning R&D

- Magnets and FELs
  - SC undulator R&D
  - CLIC drive beam quadrupoles
  - Induction Acceleration
  - Ultra short FEL pulse generation
- Vacuum science
  - Non-Evaporable Getter Coatings
    - Low Pressure Performance, Reduced Secondary Electron Emission
    - Increased Pumping Capacity, Reduced Temperature Activation
    - Coating Complex Shaped Chambers (PATENT filed)
  - Extreme high vacuum (photo injectors)
  - Ultra thin heater coatings for bakeout
  - ESD Characteristics of various materials for accelerator applications.
  - Vacuum Metrology and Instrumentation
- Targetry
  - Fluidised target studies

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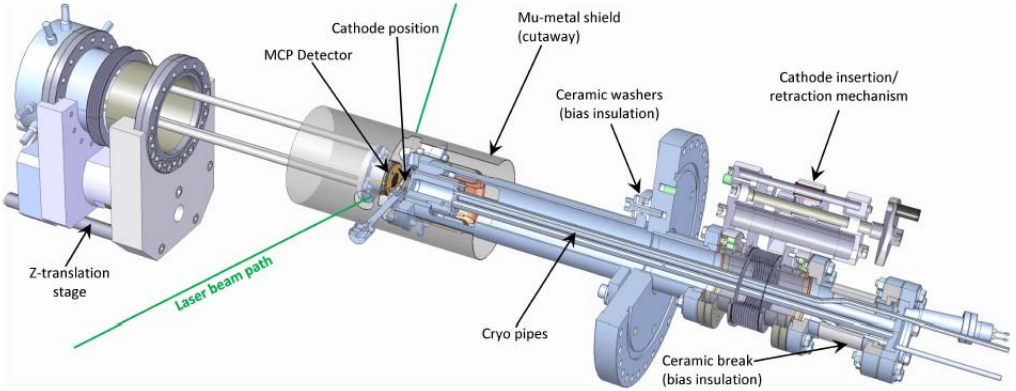
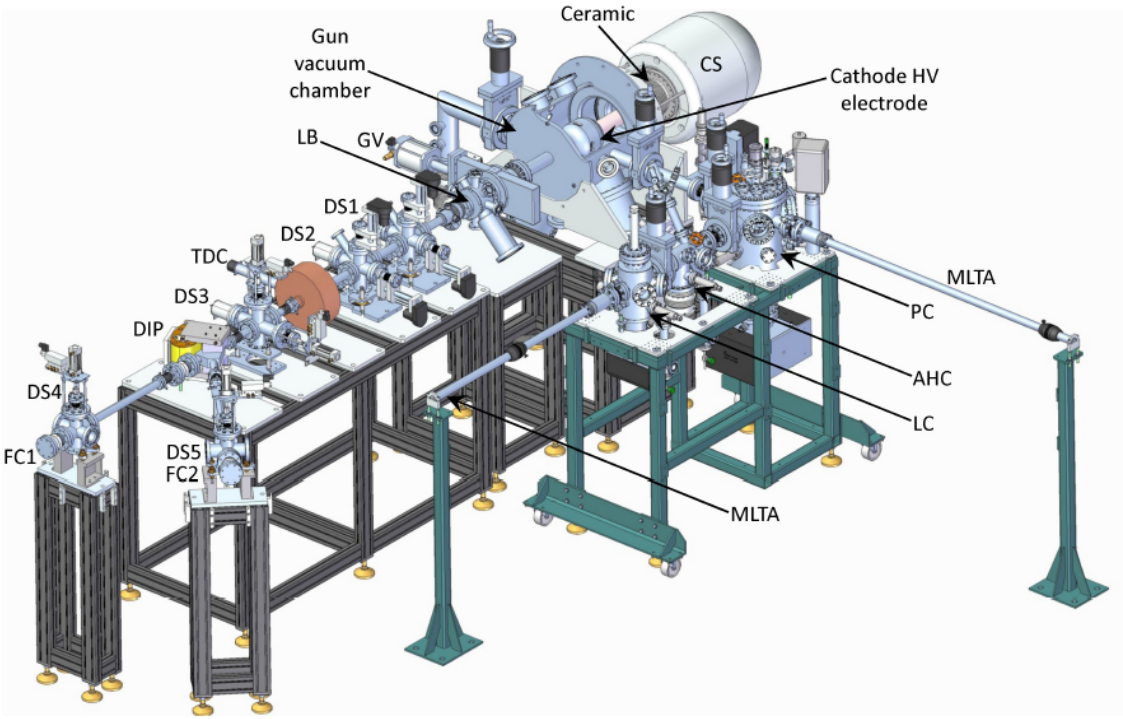
Photocathode R&D at ASTeC



Schematic of planned experimental system integrating into the loadlock photocathode preparation system developed at ASTeC to measure transverse energy spread of GaAs photocathodes as a function of QE, incident laser power and temperature.

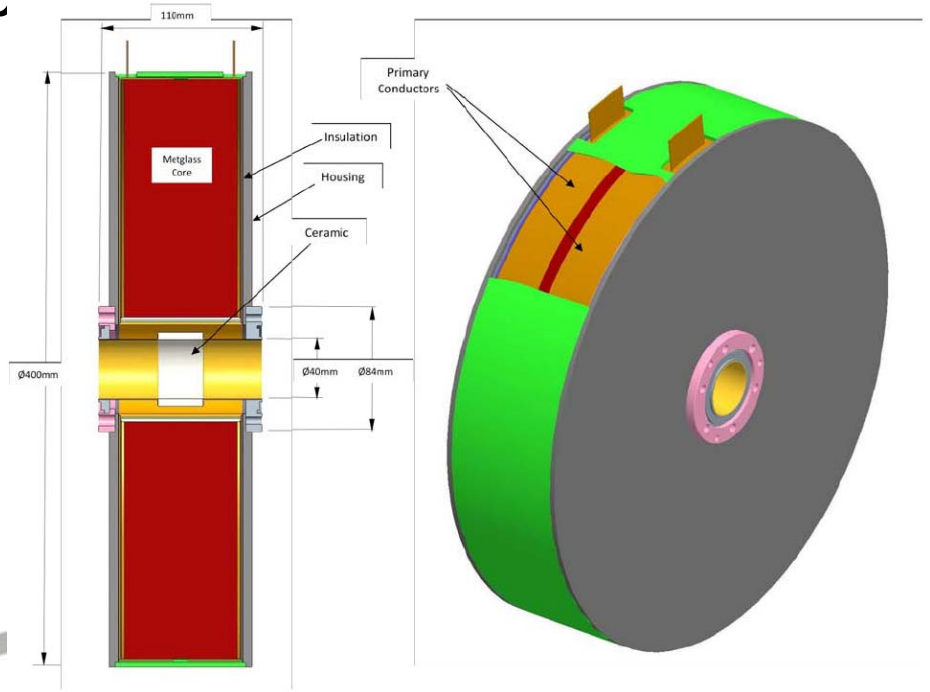
- Diagnostics beamline to characterise the performance of GaAs
- Room and cryogenic temperature
- Beam emittance and photocathode response time measurements
- Development towards a high–current, short–pulse PI based on GaAs,



With EBTF/CLARA, there will also be R&D programme of metal photocathode R&D.

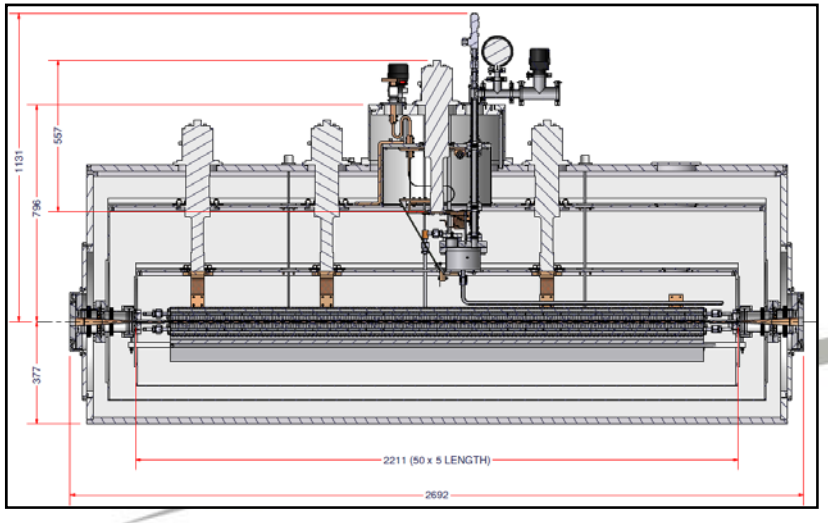
Induction acceleration

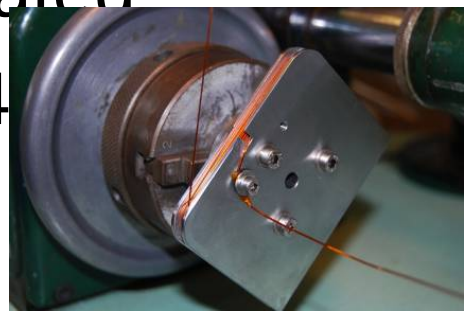
- Scoping study to gauge potential applicability
- Materials study to measure properties of high frequency steels
- Potential for high reliability accelerating system for FFAGs especially

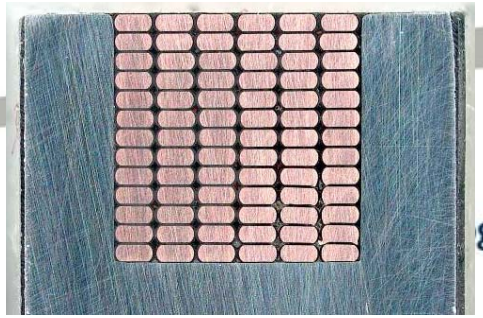


Superconducting Undulators

- Building on success of helical undulator for ILC
- Design, fabricate and test a planar undulator for light sources
- Collaboration between ASTeC, TD at RAL, DLS
- Target parameters extremely demanding and would be world leading if demonstrated
- Plan to install into Diamond in 2014

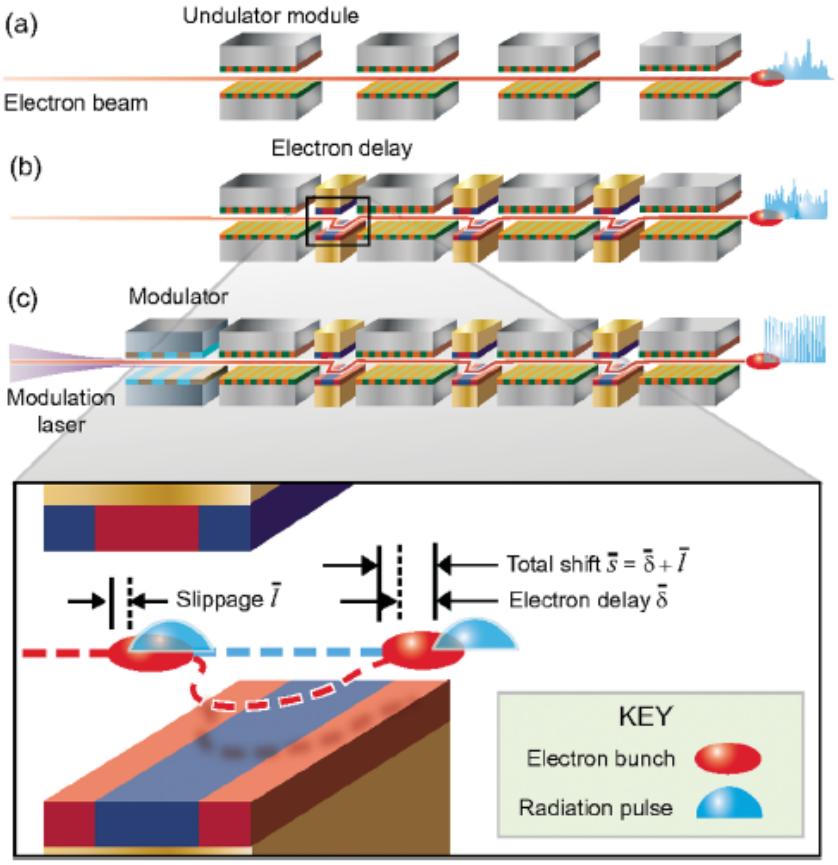






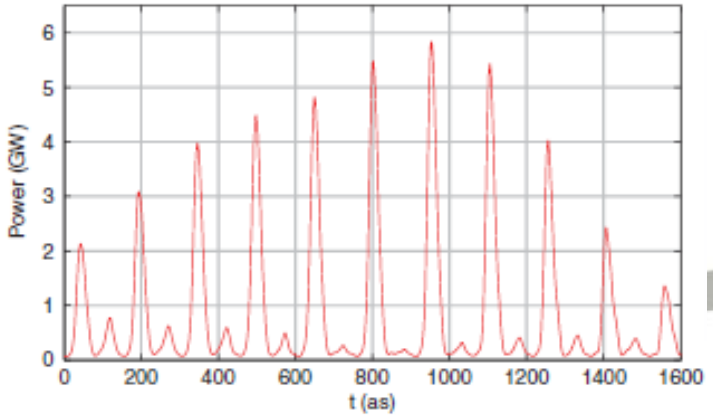
Ultra-short FEL Pulse Generation

- Ultrashort photon pulses can be used to probe ultrafast processes in atoms and molecules
- DL & Strathclyde Uni are developing schemes that generate trains of x-ray pulses – each pulse only ~20 attoseconds long



Scheme is conceptually similar to mode-locking which is used in conventional lasers to generate short pulses

Typical Pulse train at 0.15nm



N.R. Thompson and B. McNeil, PRL 100, 203901 (2008)

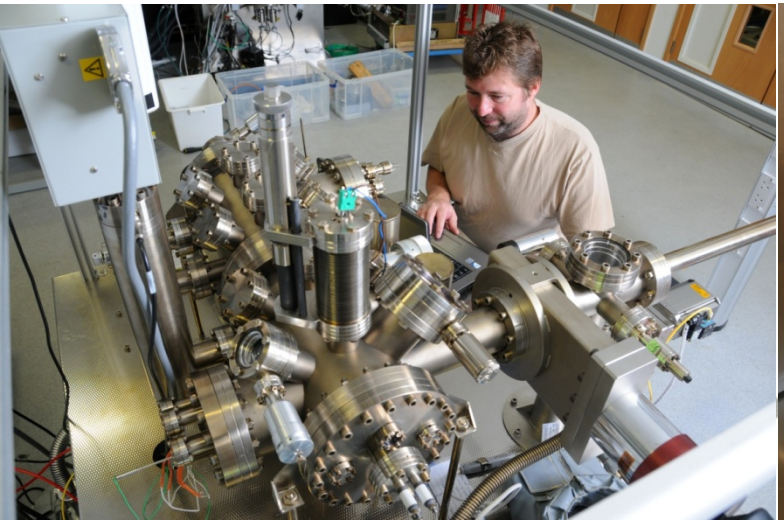
Generic Vacuum R&D

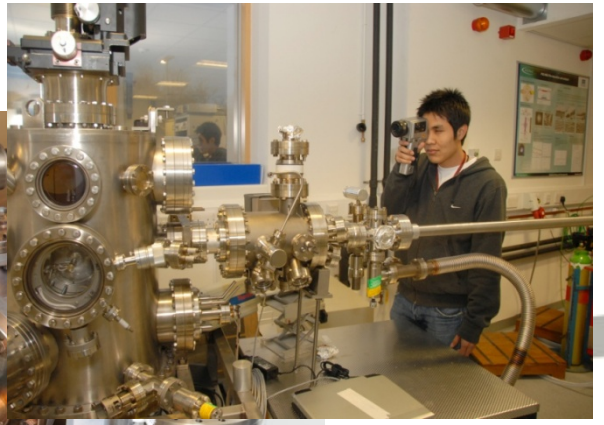
Non-Evaporable Getter Coatings

- Low Pressure Performance (Low Outgassing)
- Reduced Secondary Electron Emission
- Increased Pumping Capacity
- Reduced Temperature Activation
- Coating Complex Shaped Chambers (PATENT filed)

PVD Coating Facility

Outgassing Characterisation





XPS Surface Analysis

ilities Council

COLLABORATIONS

Science & Technology Facilities Council

Some ASTeC Collaborations

- National
  - Cockcroft, John Adams, IC, Diamond, Strathclyde, Dundee, MMU, Salford, Bath, Loughborough, Stafford, Huddersfield .....
- International
  - ALICE- HZB BERLinPRO, JLAB, KEK
  - Next Gen. Light sources-MAXIV, TRIESTIE, SwissFel
  - Injectors- LBNL, ISP Novosibrisk, PITZ, LAL, Strathclyde....
  - DICC- Cornell University, DESY, FZD-Rossendorf, LBNL, Stanford University, TRIUMF, Berkley
  - EMMA - Brookhaven, FERMI, LPSC, Grenoble
  - Protons- ESS, IDS-NF, J-PARC ,FERMI Lab
  - Vacuum- GSI,JAB
- CERN
  - CLIC Beam Delivery System, CLIC Crab cavities, CLIC drive beam quadrupoles
  - LHC upgrade crab cavities
  - LINAC4 collimation
  - HL-LHC FP7 bids: accelerator physics work, crab cavity.
- European union initiatives
  - IRUVX, EU CARD, FP7, EURONu, EUCard2, TIARA, JRP14i

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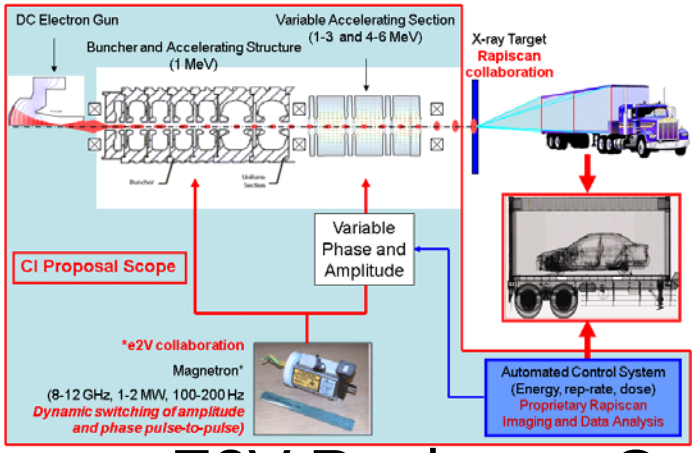
ASTeC Industrial Collaborations.

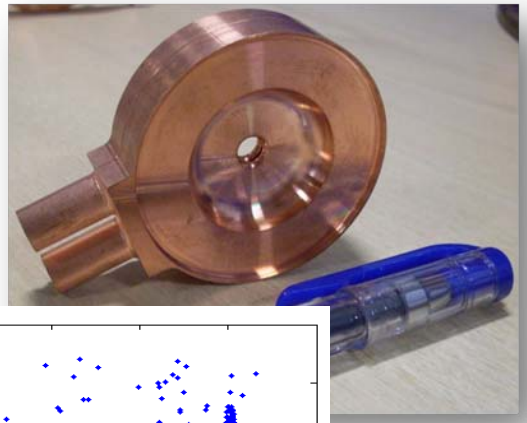
Growing industrial collaborations around technical groups expertise

- Radio frequency
  - E2V Power sources
  - Shakespeare Superconducing RF cavities
  - Rapiscan Compact linac
- Vacuum
  - Waters – Instrument Manufacturer (Mass Spectrometry) Gas flow dynamics, characterisation of dielectric breakdown
  - Vacuum Generators, Advanced XHV cleaning systems
  - CERAM, Outgassing Measurements – characterising materials
  - Nanoshell, Ultra thin heater coatings for bakeout
  - Various Opportunities – Early stage Medical applications of inert coatings
  - Henniker Scientific Plasma cleaning applications
  - Siemens Coatings
- Magnets
  - Magnet measurements
  - Programmable magnets

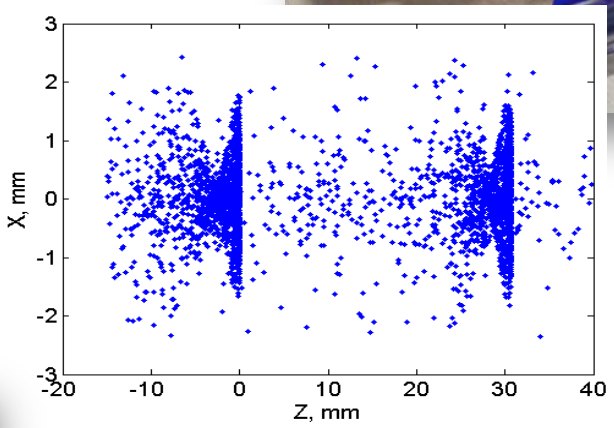
Industrial Activities

STFC Innovations (CLASP) funded activity to develop a compact linac for cargo scanning applications.

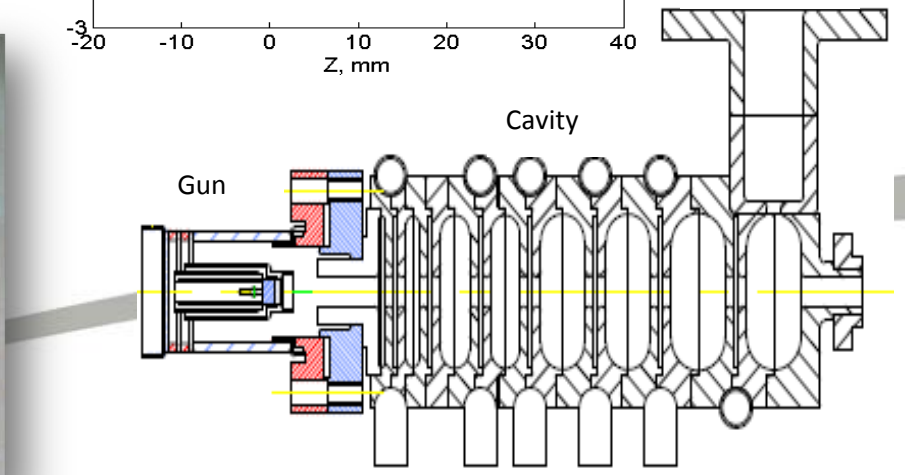


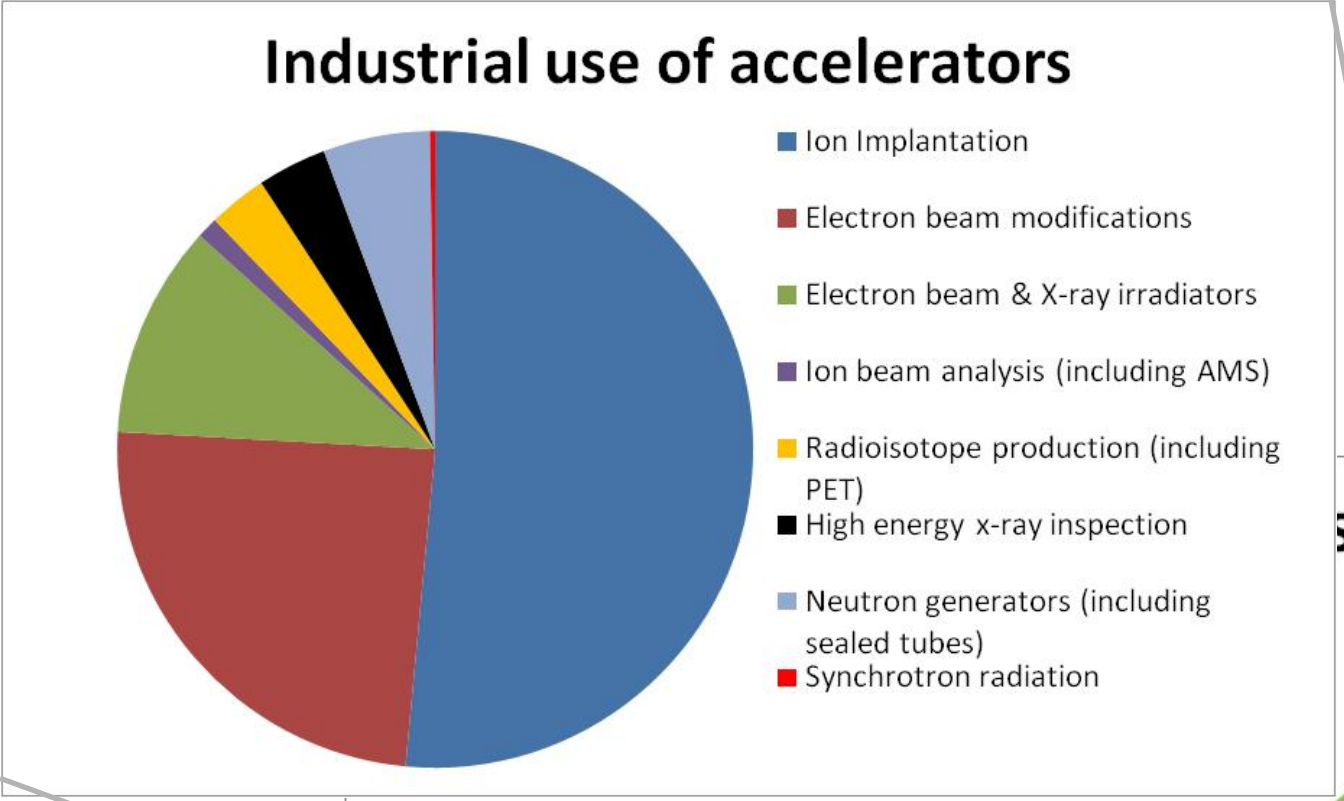


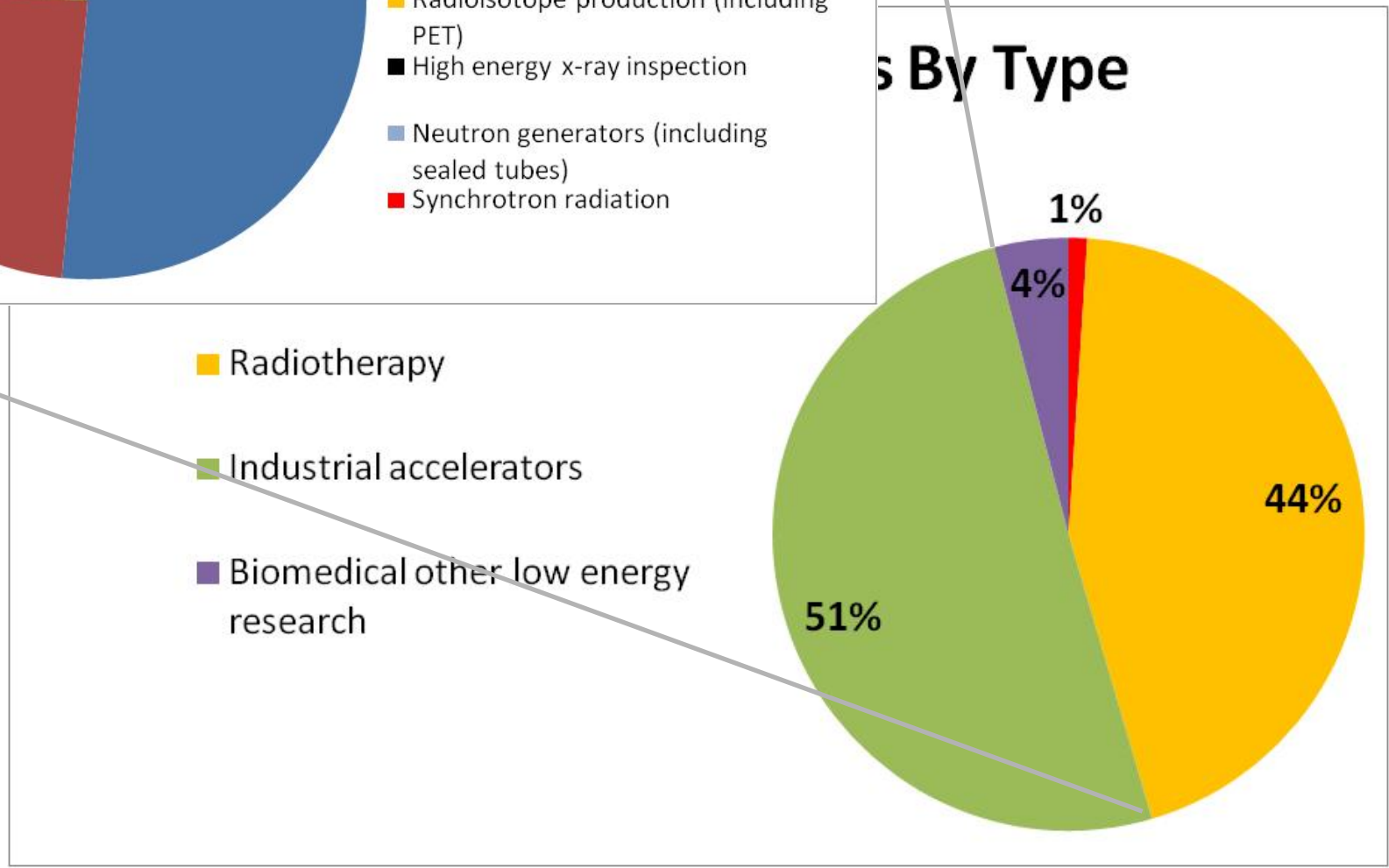
E2V Rapiscan, Cockcroft



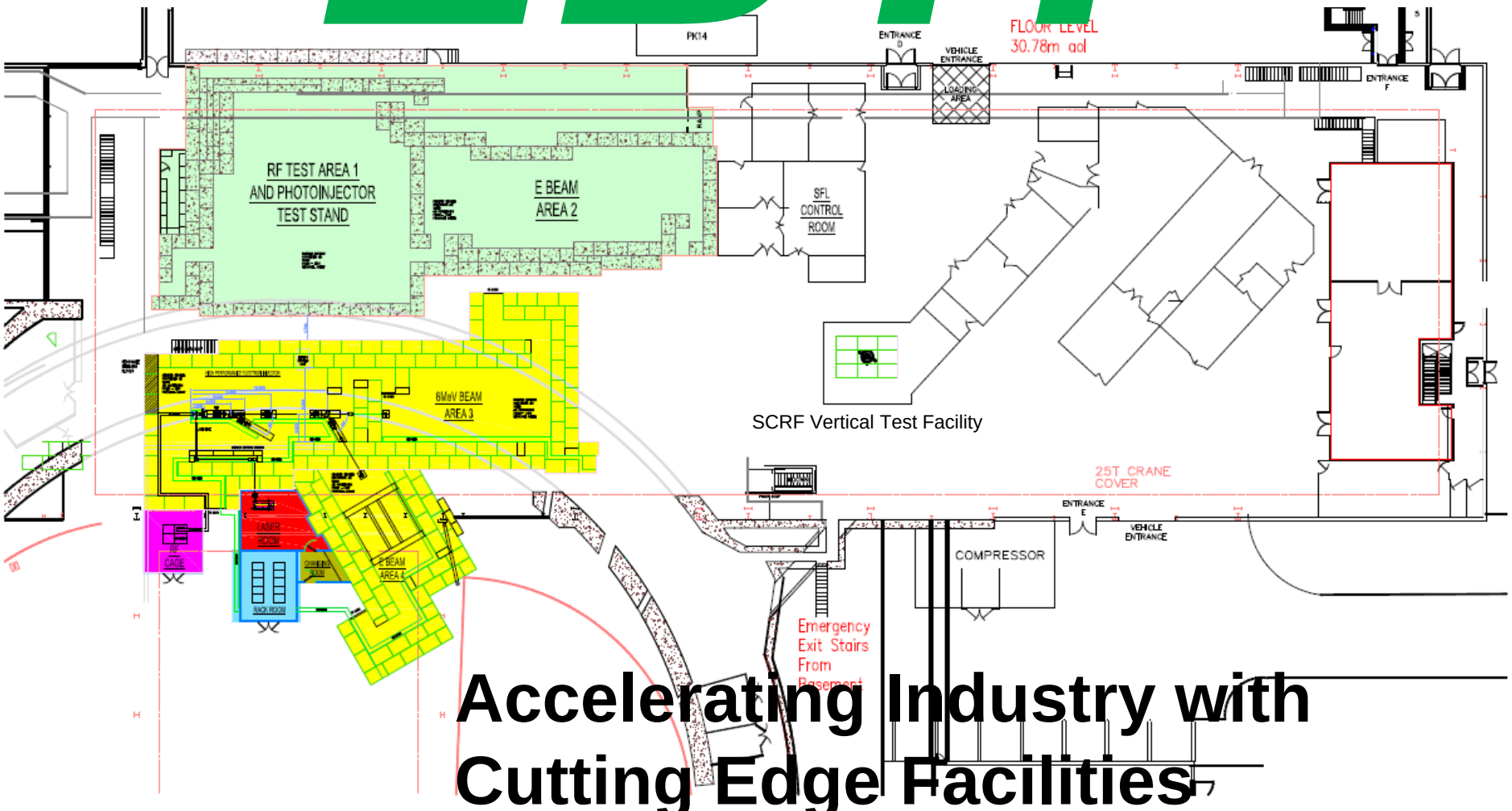
UK SRF Cavity Fabrication and Validation- Shakespeare Eng.




Industrial use of accelerators
Ion Implantation
Electron beam modifications
Electron beam & X-ray irradiators
Ion beam analysis (including AMS)
Radioisotope production (including PET)
High energy x-ray inspection
Neutron generators (including sealed tubes)
Synchrotron radiation


s By Type
1%
4%
44%
51%
Radiotherapy
Industrial accelerators
Biomedical other low energy research

EBTF



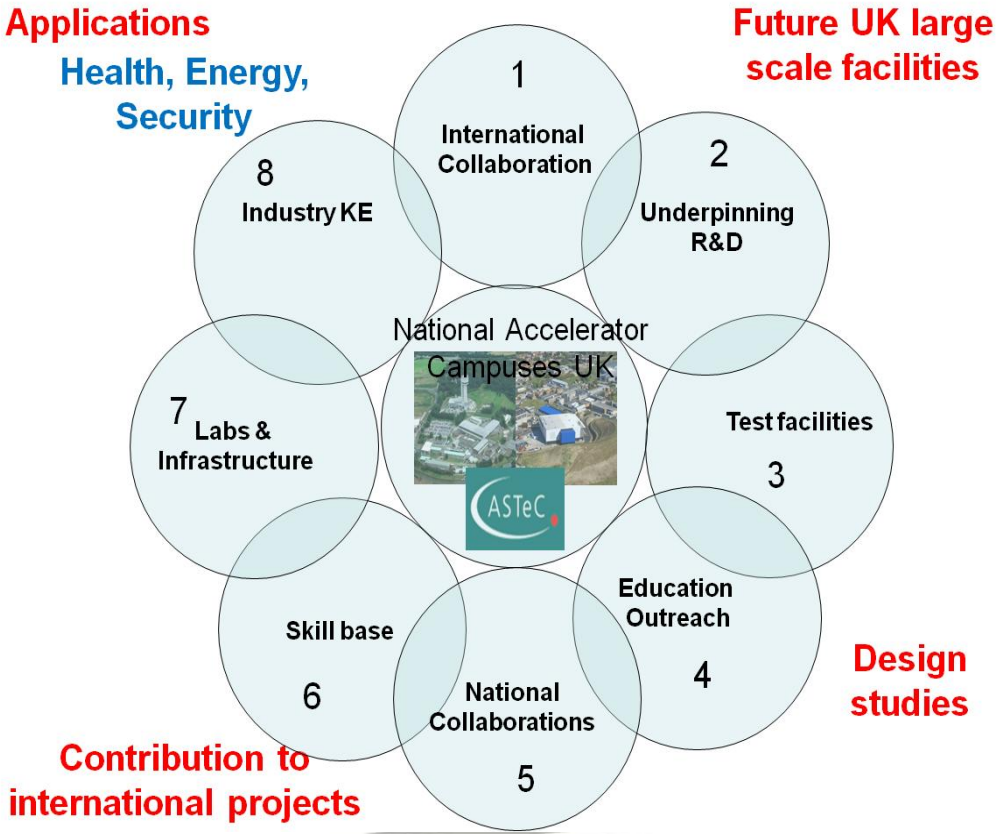
Accelerating Industry with Cutting Edge Facilities

SUMMARY

Science & Technology
Facilities Council

World Class People

World Class Test Facilities



Science & Technology Facilities Council