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# Grand Challenges

## Research Councils UK has identified the following grand challenges for research for the next 10 – 20 years;

**Healthcare:** lifelong health and well-being

**Energy Technologies:** for a low carbon future

**Climate change and environment:** living with environmental change

**Security:** for all in a changing world

**Nanotechnology and nanoscience:** through engineering to application

**Digital economy:** transforming business and society

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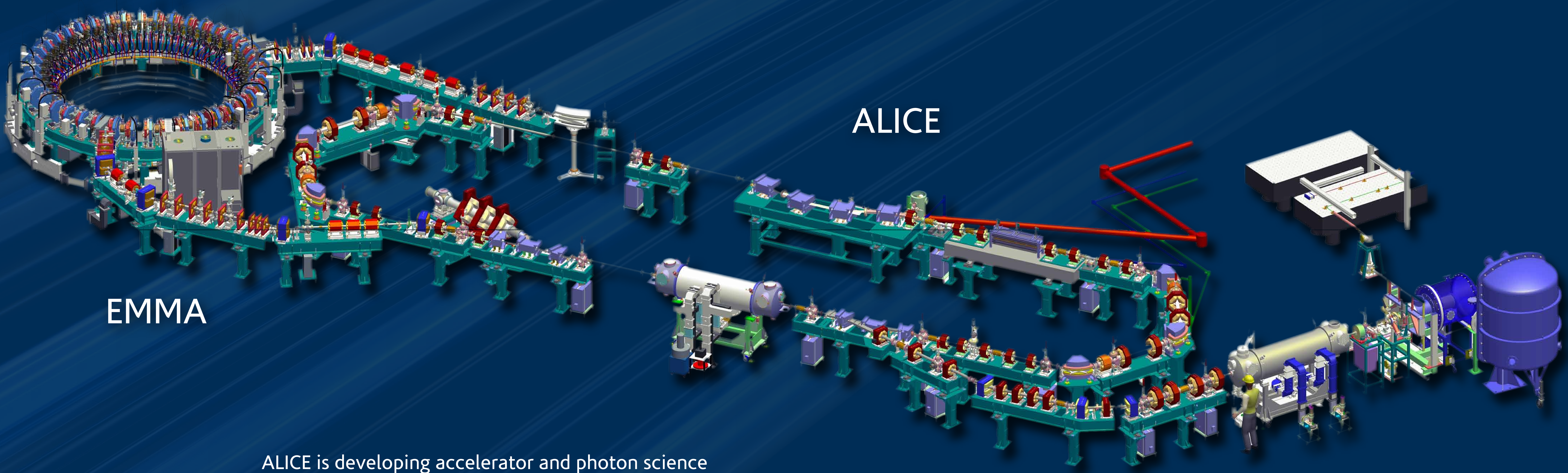
# ALICE and EMMA

To address these grand challenges we need to develop sophisticated tools that significantly extend the UK's capabilities. Particle accelerators have expanded well beyond the confines of fundamental physics to many innovative applications related to medicine, security, energy and environment.

Here at Daresbury two novel accelerators ALICE (Accelerators and lasers in Combined Experiments) and EMMA (Electron Model for Many Applications) address some of these important challenges.

ALICE and EMMA are world class research and development test facilities, which have benefited from international collaborations.

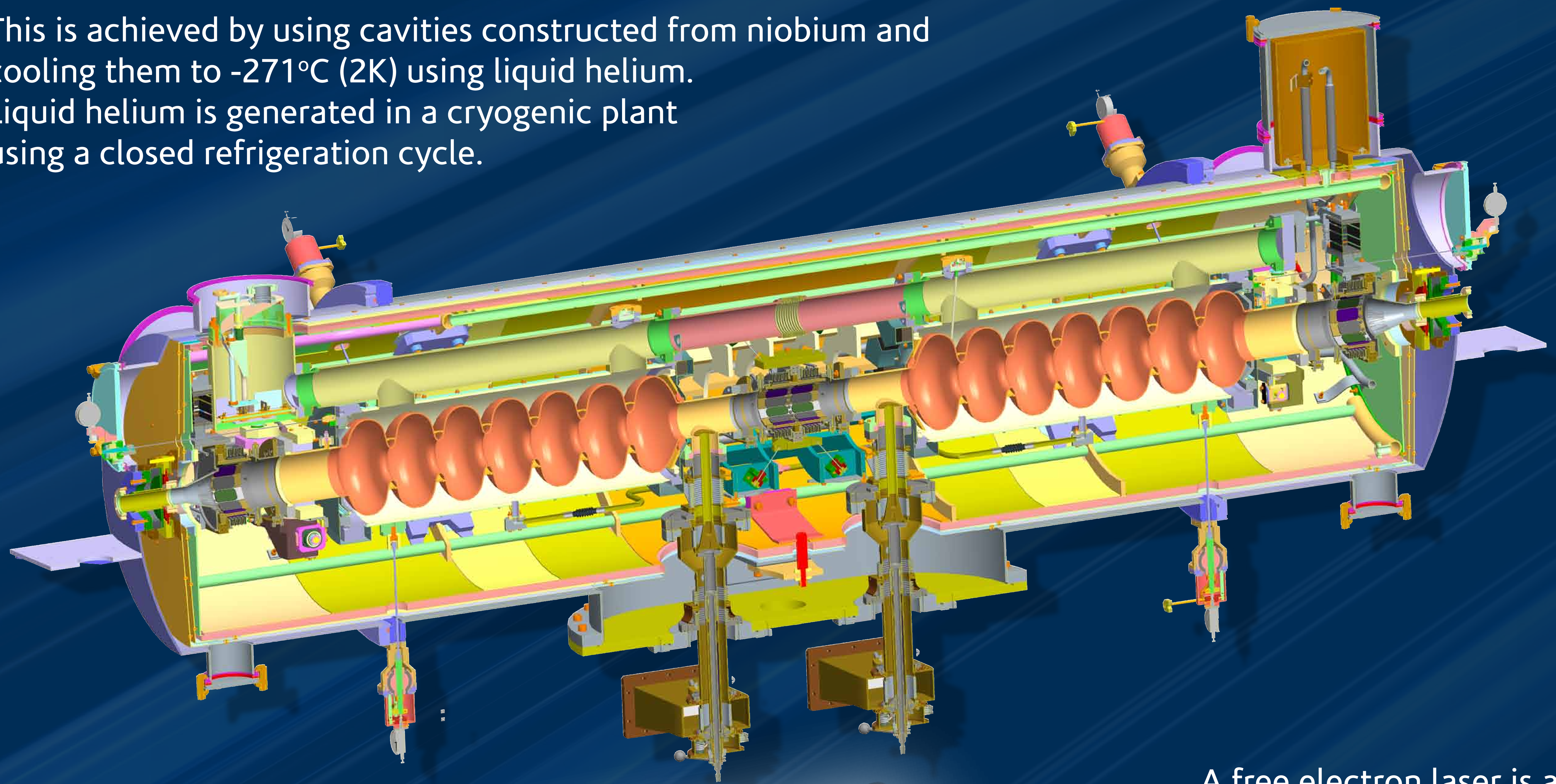


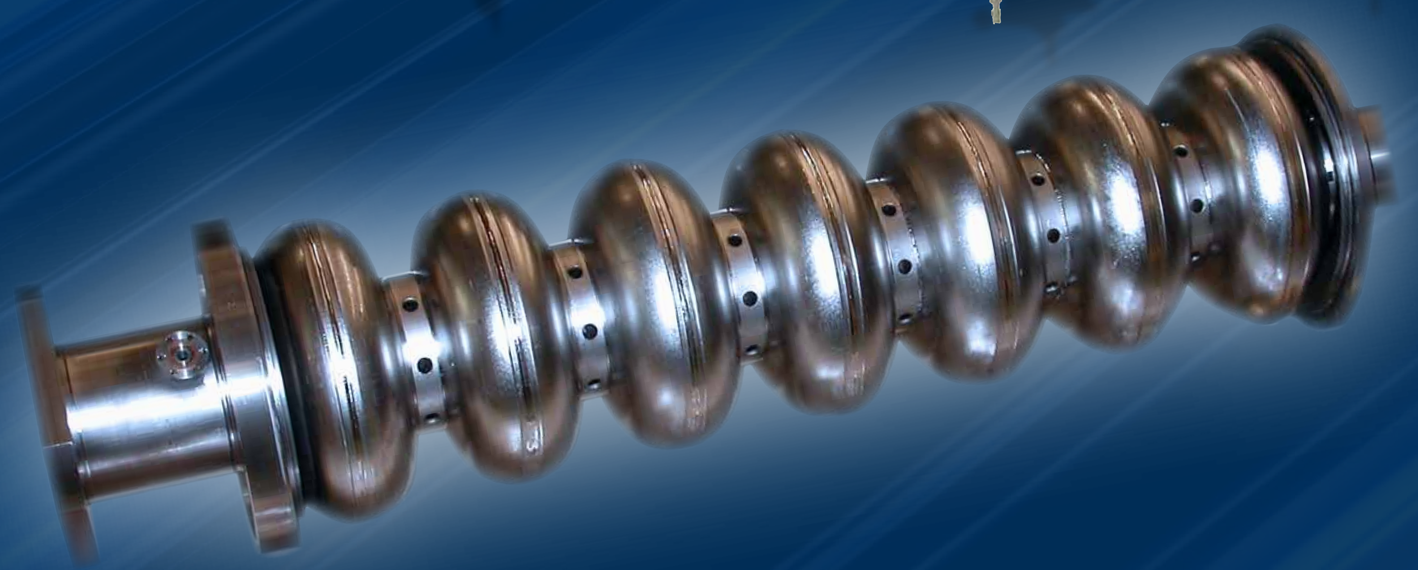

ALICE is developing accelerator and photon science technology for the next generation of light sources to enable new scientific frontiers to be explored.
ALICE is Europe's first operational energy recovery linac.
EMMA is the world's first nonscaling fixed field alternating gradient accelerator.

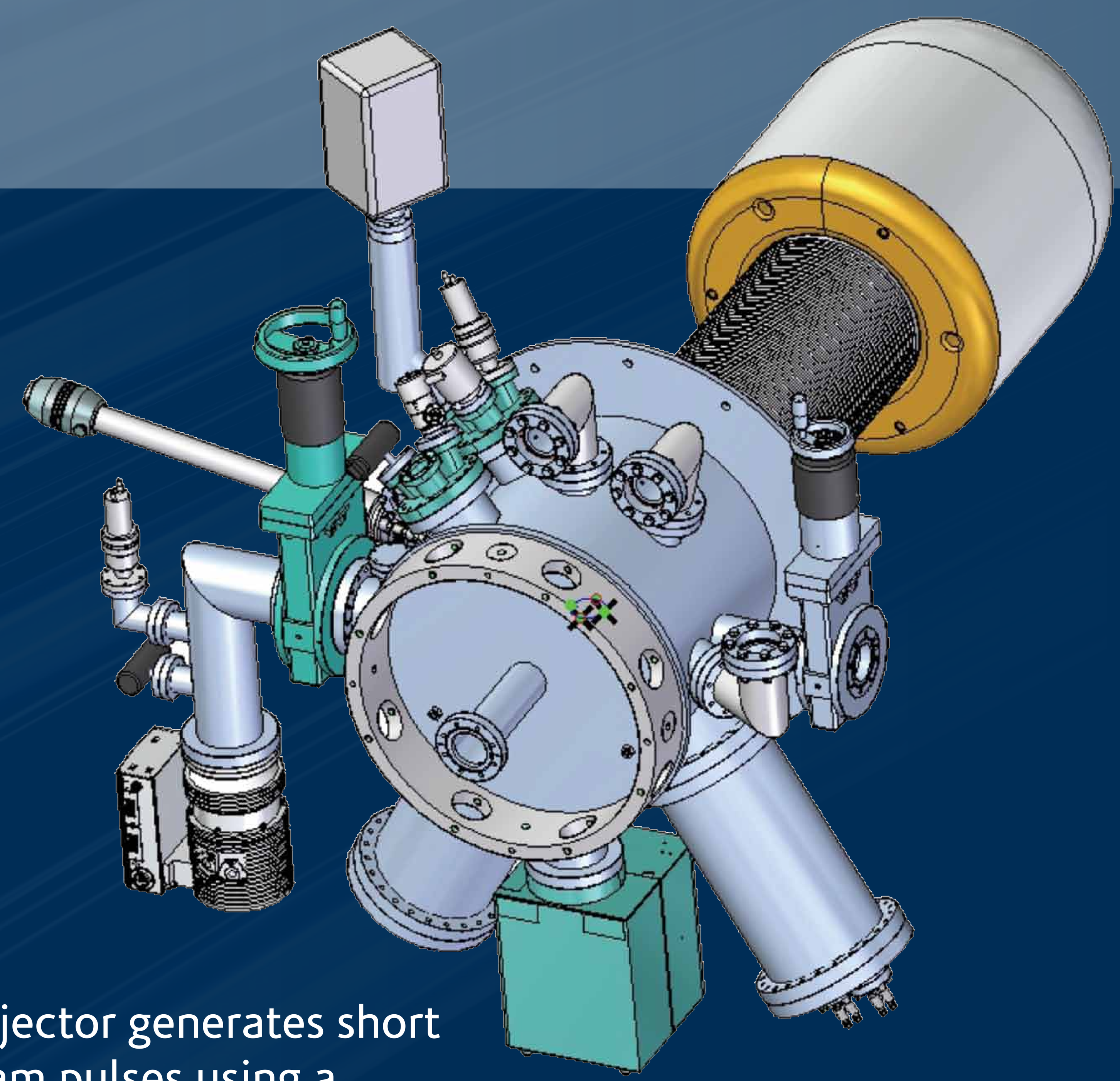
# Accelerator Technology

Electron beams can be accelerated at millions of volts per metre using superconducting radio frequency cavities. To continuously accelerate charged particles at these high voltages superconducting technology is essential.

This is achieved by using cavities constructed from niobium and cooling them to -271°C (2K) using liquid helium. Liquid helium is generated in a cryogenic plant using a closed refrigeration cycle.

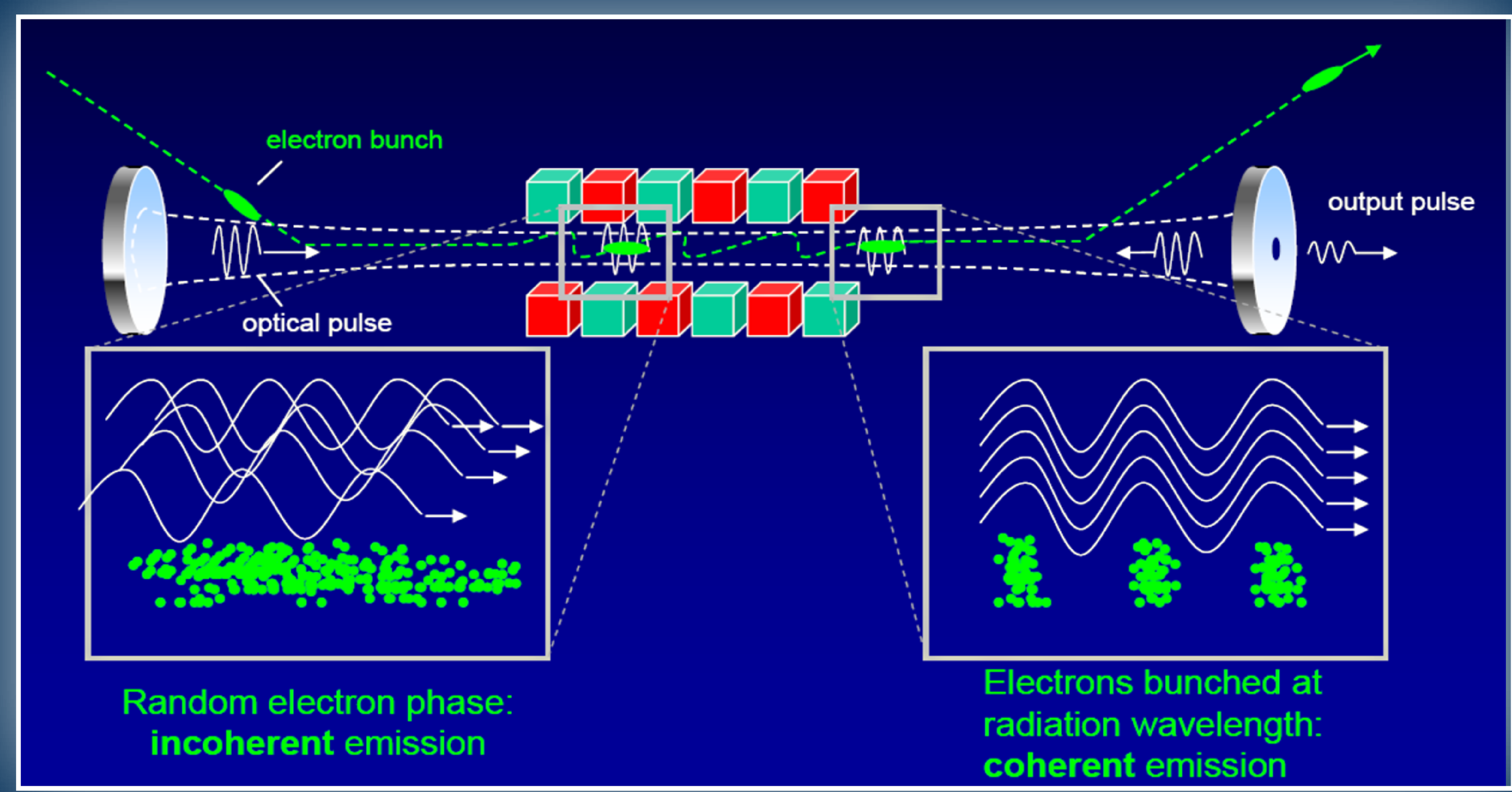






The Photoinjector generates short electron beam pulses using a laser to energise the cathode. It resides in an extreme high vacuum and high voltage environment.

A free electron laser is a 4th generation light source device that generates enhanced photon performance over a specific photon energy range, in ALICE's case infra-red light. The pulses of light can be a thousand times shorter and millions of times brighter than that generated in a synchrotron storage ring.



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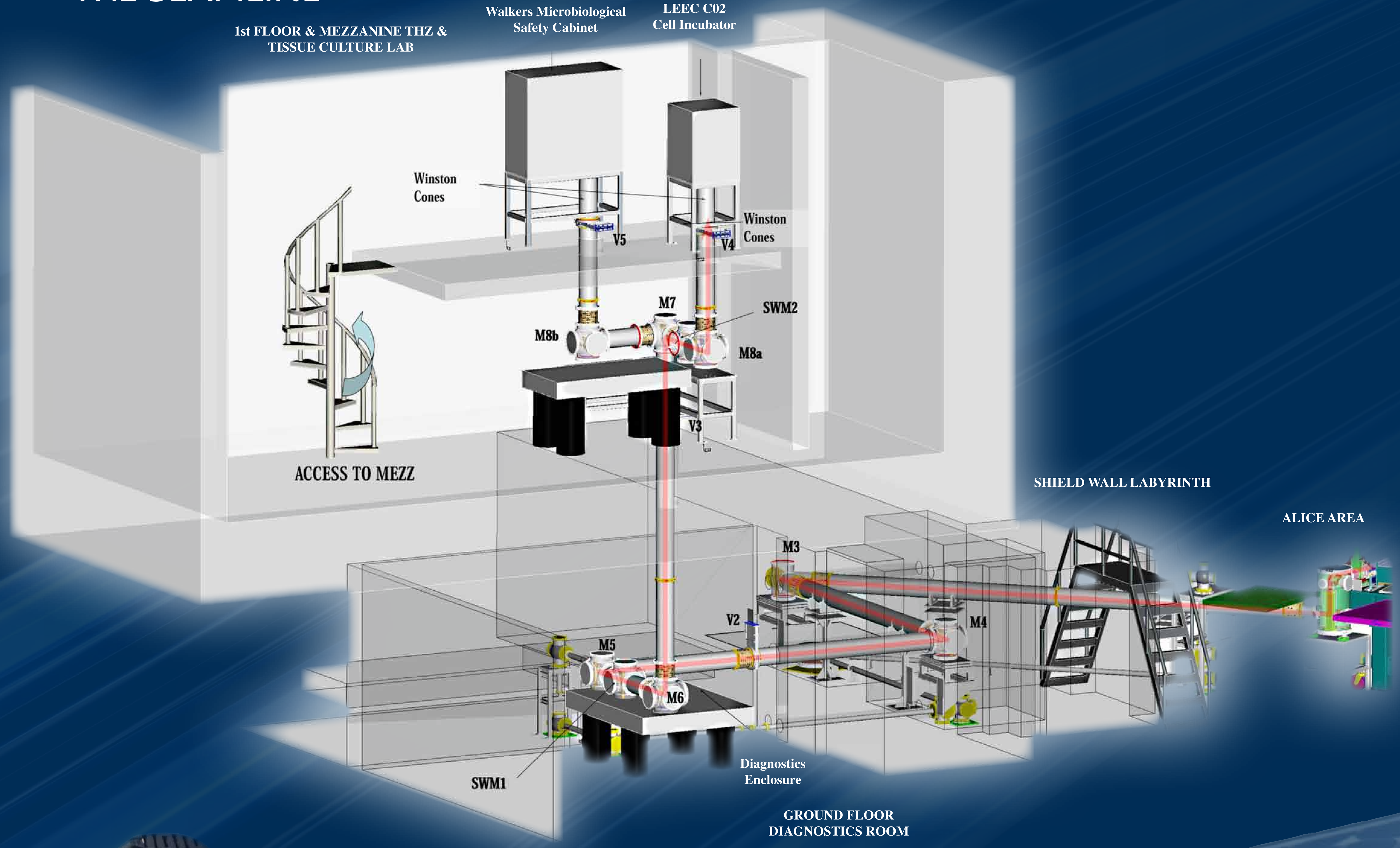
# Photon Science Applications

The Ultra-short electron bunches in ALICE emit extremely intense THz radiation due to coherent enhancement - one of the most intense sources in the world. Beamlines transport this radiation to tissue labs within the accelerator hall and on the first floor of the tower building. This enables a team of clinical scientists and physicists from the University of Liverpool to study the effect of high power THz at high rep rates on living cells under controlled environments for the first time. This research is vital in assessing the safety of high power THz sources for security screening and to unlock the secrets of biological organization.

THz BEAMLINE




ALICE is a system of integrated accelerator and laser light sources synchronized together. This is a vital tool for physicists and material scientists at Manchester University developing the next generation of more efficient solar cells. The short THz pulses from ALICE are transported to a laser laboratory where they are used to monitor the evolution of electrical carriers in novel solar cell material created with a pump laser mimicking the sun.

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# EMMA: ADVANCED ACCELERATOR APPLICATIONS

**EMMA is the world's first nonscaling fixed field alternating gradient accelerator, which has the potential to open up exciting new applications in medicine, security, energy and environment.**

This is a proof-of-principle accelerator that has been extensively modelled using computational codes to theoretically study its performance. EMMA has been constructed and experiments are in progress to benchmark the tracking and simulation codes used in its design, before its unique potential can be exploited.

Applications include the next generation of high energy proton and heavy ion accelerators for accurate and effective particle beams cancer therapy, muon accelerators for the study of the physics and chemistry of advanced materials, and inherently safe accelerator driven subcritical reactors (ADSR), in which fission is enabled by high energy proton beams spallating neutrons from a target embedded in a thorium fuelled reactor.

*Compact proton therapy machine for cancer treatment*

*Nuclear Power Plant*

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# SECURITY APPLICATIONS

The need for security in global transportation has never been more crucial. Whether protecting the public from terrorist threats, our communities from illegal drugs or our economy from counterfeiting and smuggling, the need for effective tools to monitor transported items is key to our safety.
The STFC Security Futures Laboratory (SFL), is providing a focus for this area across the Science and Innovation Campuses. Drawing together research technologies from academia, key applications in commercial security organisations and advanced engineering capability within STFC, SFL is delivering information, technologies and demonstrator systems which will form the next generation of equipment to protect our societies.

Our partnership with both commercial and academic organisations has already yielded accelerator technology which will deliver unprecedented information on container cargo at ports (with Rapiscan Cargo), engineered systems for 3-dimensional scanning of airline baggage (with CXR) and non-invasive liquid monitoring technologies for both security and counterfeiting monitoring (technology which has been spun-out into an SME business, Cobalt Light Systems)
These are but a few of the early opportunities that the STFC Security Futures Laboratory is exploring to improve the safety of our nation.


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# ALICE (Accelerators and Lasers In Combined Experiments)