UK news from CERN

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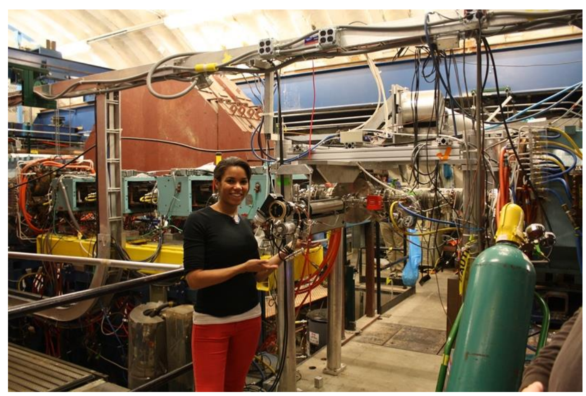
Blue sky engineering

The proposed physics goals of any new project often read like a wish list of scientific discoveries. For projects that could be built 10, 20 or 30 years in the future, achieving these goals starts with blue sky engineering; pushing technology way beyond what is currently possible. Three early career researchers from the UK are working on beam instrumentation for CLIC, the Compact Linear Collider, a possible successor to the LHC.

CLIC has been designed with two accelerator beams; a drive beam that will have high intensity but low energy, and a main beam which will have low intensity but high energy. As with any particle accelerator, the particle beam must be closely monitored to ensure it delivers the maximum design energy focussed precisely on the collision point. Understanding the properties of the beam including its size, shape and position within the beam pipe, are essential.

Lorraine Bobb is coming to the end of her PhD with RHUL in collaboration with the John Adams Institute (JAI), CERN and Cornell University. She has been developing a non-invasive, micron scale, transverse beam size monitor. The prototype that she has designed aims to measure the vertical size of the main beam to within 1 micron. Existing techniques used at other particle accelerators including the LHC are typically based on measurements taken when the beam passes through a thin screen or wire. The problem with these methods is that the interaction of the beam with the screen or wire can damage the integrity of the beam. For the high luminosities that CLIC aims to achieve, the charge density and high energy of the beam would simply destroy the beam measurement instrumentation and therefore a non-invasive technique is required.

"A non-invasive technique (the laser wire scanner) already exists," explains Lorraine, "but it's expensive and technically quite demanding. CLIC needs a cheaper and easier solution."



Lorraine testing her prototype at Cornell © L Bobb

Lorraine, with the help of her research group, designed the new instrument, chose the materials that would be used to make it and oversaw the manufacture of the prototype. "Finding a company capable of meeting the precision machining tolerances was a challenge; the instrument, which uses a target like a tuning fork, has two prongs that must have a co-

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planarity (or flatness) to within tens of nanometres [*a human hair is approximately 100,000 nm wide*]."

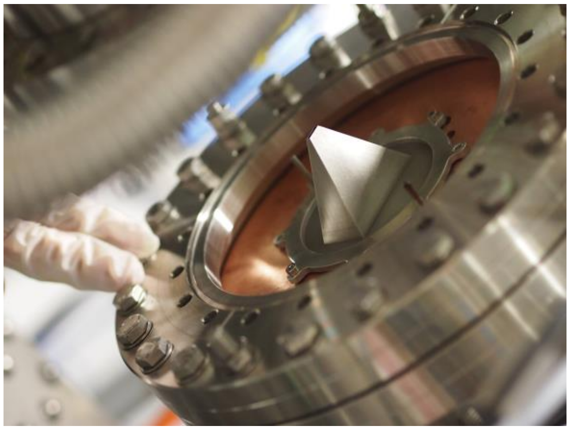
As with many prototype designs for CERN projects, the manufacturing specification challenged and extended the capabilities of the supplier.

Lorraine installed her prototype at CesrTA, the test accelerator at Cornell University and as she approaches the end of her PhD, she is now analysing the data.

"Early indications suggest that there is a lot of background noise caused by synchrotron radiation when observing shorter wavelengths, and that possibly the instrument needs to be positioned differently to minimise this background. But the project has enabled me to develop a new process for the practicalities of measuring beams non-invasively - getting the beam through the 1mm target aperture on a circular machine, without it hitting the sides, was a challenge."

Adam Jeff, a Project Associate with the University of Liverpool's Quasar Group, is developing a beam size detection monitor for the CLIC drive beam. "In terms of beam size, measuring the drive beam is less challenging than the main beam. But due to the intensity of the beam, if we passed it through a screen, the screen would melt." So Adam is also developing a non-invasive technique, this time using a gas jet monitor.

The monitor measures the beam's size and shape by detecting its interaction with gas in the beam pipe. In order not to disrupt the high vacuum, the gas will be fired across the pipe in a fine jet. "We've tested the prototype at the Cockcroft Institute and the results are promising." One year into the three year project, Adam is developing a new technique to achieve an even narrower jet – an atomic sieve. "The idea has been used previously to focus X-ray photons, but I'm adapting it for Helium atoms". According to wave-particle duality, even atoms behave like waves in some ways. The atomic sieve is a set of holes arranged such that these waves interfere constructively at a single point, effectively focusing the gas jet like a lens.



Adam's atomic sieve © A Jeff

Jack Towler, another PhD student from RHUL working in collaboration with JAI and CERN, is designing a cavity beam position monitor (BPM). Like Lorraine and Adam, his goal is to come up with a design that is as simple, easy to use and cost effective as possible.

Jack's BPM (top right) being put through its paces in the CLIC Test Facility © J Towler

When Jack started his PhD just over a year ago, a prototype had already been designed and tested. Based on the initial results, he has adapted the design and hopes to have a prototype of his instrument ready for bench testing in March.

"At certain frequencies, the beam forms patterns, known as 'modes', in the cavity. My instrument uses the amplitude of a particular mode to understand the position of the beam within the pipe. It has to have a spatial resolution of 50nm, and a time resolution of 50ns [*50 billionths of a second*].

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CLIC would require 4796 of these instruments and this brings with it a definite sense of responsibility towards getting the design right, "If I think about it, I might get scared," he says, but he's looking forward to installing the instrument on the CLIC Testing Facility and putting it through its paces.

All three young researchers are enjoying being involved in CLIC. Whether or not the project gets the go-ahead, the technology that they have developed is likely to be adopted elsewhere.

"I'm really proud that the work I have contributed could lead to similar instruments being installed in particle accelerators around the world," says Lorraine.

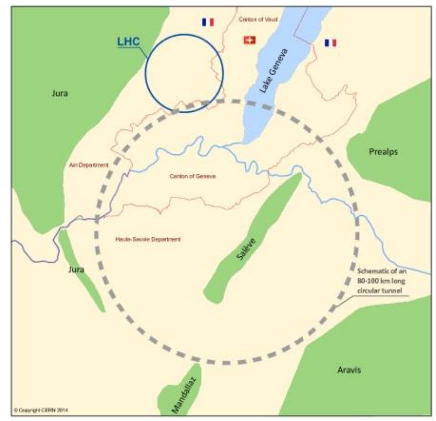
"It is a real challenge to push the beam parameters beyond what is currently possible," says Adam. "It's a great opportunity for blue sky thinking."

Tunnelling to the future

Another project has joined the list of potential successors to the LHC; the Future Circular Collider (FCC) project is looking at options for a monster of a machine for particle physics with a circumference of 80 – 100 km and collision energies of around 100TeV (the LHC has a circumference of 27km and is designed to reach collision energies of 14TeV).

Much of the planning for future projects is centred on the mechanical and electrical engineering required to deliver the physics goals, but civil engineering accounts for approximately 20% of the costs of building a facility such as FCC. John Osborne (CERN) is the civil engineer in charge of planning for future projects including the FCC, International Linear Collider and CLIC. The one thing that all three projects have in common is the need for new tunnels.

Fresh out of university, John began his career in the UK with Tarmac Construction, and it was pure chance that his first professional project was the Conwy tunnel. From there, one tunnel led to another (so to speak) and he joined CERN 16 years ago, to lead the construction of the cavern and shafts for the CMS experiment. For the past few years, he has been head of CERN's civil engineering section, with a team that looks after everything from new buildings and refurbishment of the toilets to planning for future projects.



A schematic of the proposed FCC. © CERN

"People think CERN is all about physics – but there's a lot of civil engineering too," he says. "For example, we have an 80km network of tunnels to maintain. Working here is technically interesting, and challenging."

When John was asked to produce a feasibility study for the FCC, he worked with international consulting engineers, Arup, and local geotechnical consultants, GADZ. The report focusses on the technical considerations for building an 80km tunnel that would run approximately 150m below the surface of Lake Geneva, around the Salève mountain and beneath the Swiss/French countryside.

"The initial report looked at the geology of the area, any particular risks and the depth required for the tunnel. It didn't consider the build cost – that will come later," explains John. "As part of the next step, Arup will develop a geotechnical model to explore the feasibility of all the ideas for shapes and sizes of the FCC. There are numerous proposals including inclining the tunnel with a gradient up to 2% or building two long straight sections, rather like a running track."

The work involved in planning for these proposed projects and upgrades to the LHC has

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increased to such an extent that John has set up a new section to concentrate on future projects. He is looking for an early career civil engineer to join the team as a CERN Fellow.

"Ideally, I need someone with a tunnels or geotechnical background. They'll be looking at the feasibility of the various tunnel layouts, costing and planning estimates for civil works, doing environmental impact studies, preparing reports and managing design companies. This is a unique opportunity to gain hands-on experience. CERN is an amazing place to work!"

If you're interested in applying, the closing date is 3 March.

On the final straight – LS1 update

One of the main tasks for the Long Shutdown has been to reinforce the interconnections between the superconducting magnets in the LHC. It was the failure of one of the interconnections that caused a magnet to quench just 10 days after the LHC started operating in 2008.

Celebrating the chequered flag © Michael Struik/CERN

A team of CERN engineers and technicians from Pakistan has been working its way around the 27km circumference of the LHC opening each joint, sliding a custom-built metallic bellows out of the way and removing the thermal shielding inside to reveal a series of metallic pipes linking the magnets to each other. One set of these pipes – the 'M-lines' – must then be cut open to access the splices between the superconducting cables.

The quality of the connections is checked to determine whether they need to be rewelded, before they are reinforced.

Over 1000 of the 1695 interconnections between magnets on the LHC have been rewelded and more than a quarter of the accelerator has been permanently reclosed and leak tested.

And finally…

Visitors to CERN express their appreciation in a variety of ways. John Ellis (Kings College London), Jens Vigen and Mick Storr (CERN) are now the proud recipients of some unique knitwear, thanks to two Norwegian teachers.


John, Jens and Mick wear their woollies © CERN

Inga Hanne Dokka of Kongsberg Videregående Skole and Jolanta Nylund from Akademiet Drammen presented the fruits of their labours during a recent visit by their schools.

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Diary dates

CERN Council – 17-20 March
Collider exhibition in London until 6 May
Collider in Manchester 23 May–28 September

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