CERN: The first accelerators are back in action

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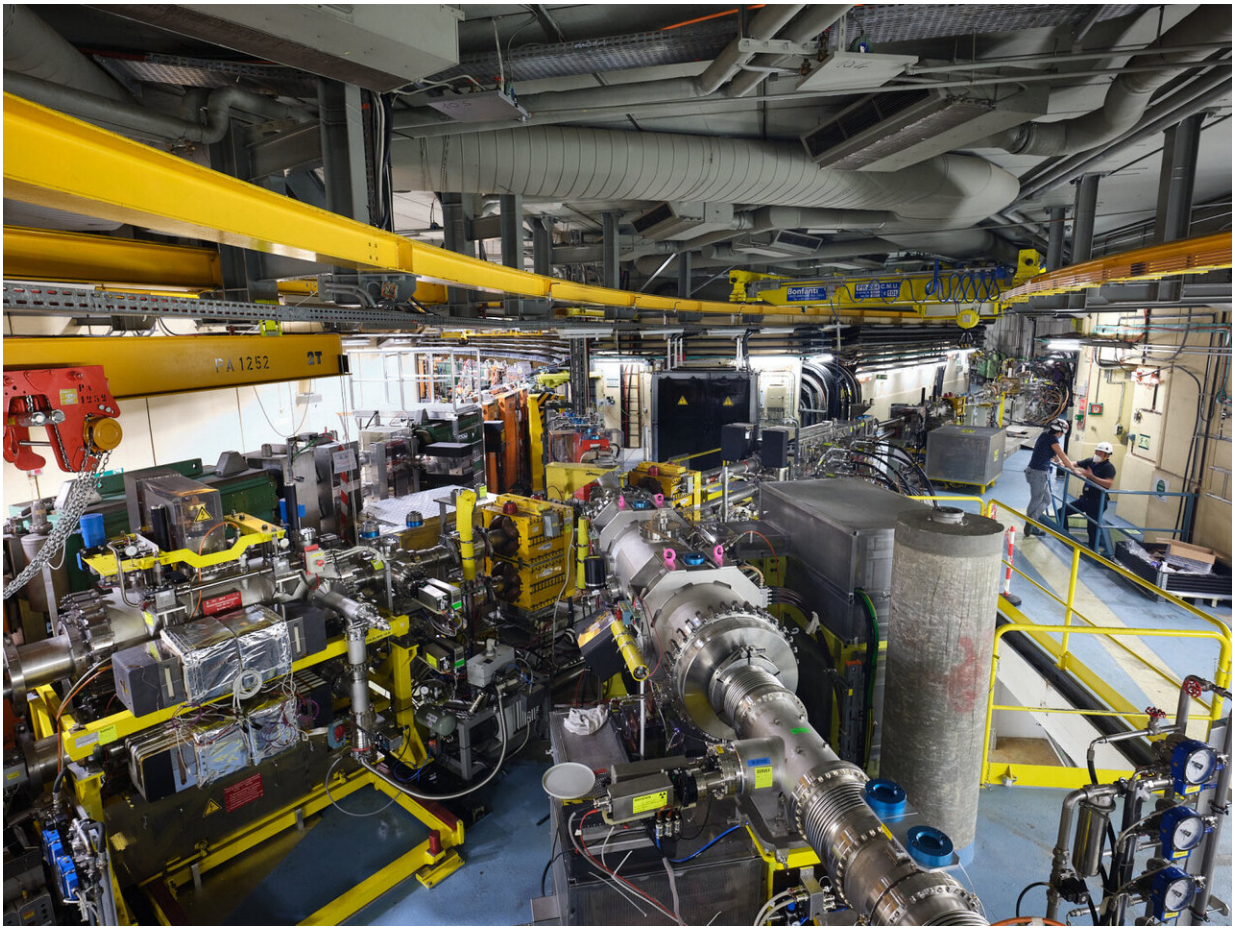

The area where the injection line to the PS Booster (on the right) and the extraction line for the PS (on the left) intersect. These two transfer lines have been completely refurbished. The ring of the Booster is visible on the left. Credit: CERN

The CERN Control Centre is back in shift work mode, with walls of screens showing the status of the beams, and coffee flowing freely day and night. On Friday, 3 July, the Long Shutdown 2 accelerator coordination team handed over the key of the PS Booster to the accelerator operators. Linac 4 and the PS Booster thus become the first two accelerators to be recommissioned, 18 months after the start of LS2.

However, recommissioning will be far more complex than simply turning a key. When the operators handed the Booster over to the LS2 teams, they were driving a model built in the last century, and now they find themselves at the wheel of a completely transformed supercar. Work has been carried out on the engine (the power supply and power converters), the accelerator (the radiofrequency cavities), the steering (the magnets), the injection, the cooling circuit, the control and safety systems... in fact, a whole host of components have been replaced or upgraded (see below). "Around 40% of the machine has been replaced," says David Hay, the "chief mechanic", or engineer in charge of the coordination of LS2 activities at the PS Booster.

The aims of the work on this nearly 50-year-old accelerator, forming part of the LHC Injector Upgrade (LIU) project, were twofold: to accelerate the particles arriving at higher energies from the brand new Linac 4 and to increase the brightness of, or the concentration of particles in, the beam.

Linac 4, the new first link in the chain, accelerates negative hydrogen ions (protons surrounded by two electrons) up to an energy of 160 MeV (compared to 50 MeV previously for the protons from Linac 2). The higher energy and the new injection system, which converts the H- ions into protons, increase the brightness by a factor of two. This means that a beam with the same dimensions will contain twice as many particles. In order to preserve this brightness in the PS, the next accelerator in the chain, the Booster will increase the energy up to 2 GeV (compared to 1.4

GeV previously), thanks to its all-new acceleration system. The electrical repulsion effect between particles of the same charge (Coulomb repulsion) lessens as the energy increases. To put it another way, higher energy helps keep the particles close together and thus contributes to maintaining the brightness. And with more brightness, comes more luminosity. "The Booster is key to increasing the luminosity of the LHC," explains Gian Piero Di Giovanni, project leader for LIU at the PS Booster, "because it effectively determines the brightness of the beam." The new injection mode with H- ions and a higher energy will also considerably reduce the particle loss rate. "We will lose only 1 to 2% at injection, compared to over 30% with the old system," says Di Giovanni.

The work at the Booster took 20 months above ground and 18 months underground. Despite the large scale of the renovations and the difficulties encountered with certain aspects of the civil-engineering work and of the cooling system for the RF cavities, not to mention lockdown, which froze activities for two months, the project has been completed on time. This achievement is down to the commitment of the teams and meticulous and proactive coordination.

Commissioning of some of the new systems started several weeks ago. The operators are now taking charge with new, cutting-edge control software. "We have spent the past two years developing the integration of these new systems," emphasises Bettina Mikulec, who supervises the operation of the Booster and Linac 4. "We now need to implement and test all the subsystems from the Control Centre and get them working in harmony." This complex commissioning process will take several months, initially without any beam. Whereas Linac 4 will resume tests with beam this summer, the first particles should be circulating in the PS Booster right at the end of the year.

The metamorphosis of the Booster

- Power supply: A new power supply system, similar to the one that was installed for the PS (POPS), based on power converters and capacitors and known as POPS-B, has been installed in a new building above ground. The power converters will supply the magnets with electrical intensities of 5500 amps, compared with 4000 amps previously. Over 95% of the Booster's power converters have been replaced since Long Shutdown 1. Some 318 new converters, ranging from 1 kW to several MW, supply all the components of the accelerator.
- Cooling: The Booster has a new cooling system, with cooling towers in two renovated buildings.
- Injection and ejection: To cope with the increase in energy and the use of negative hydrogen ions at injection, the transfer lines from Linac 4 to the Booster and from the Booster to the PS have all been replaced. This includes new magnets (kickers, septa, dipoles, quadrupoles and correctors), new instrumentation and new beam dumps. Since it comprises four superimposed rings, the Booster requires a particularly sophisticated particle distribution system.
- Acceleration: The new acceleration system is composed of three structures, each housing eight cavities built using a magnetic material known as FineMet.
- Magnets: In the transfer lines and the Booster ring itself, around 60 magnets have been replaced or renovated.
- Safety and instrumentation: A whole host of new sensors, beam position monitors, beam loss monitors, wire scanners, etc. have been installed to monitor and measure the particle beams. Devices to stop the beam or particles that stray from the trajectory have been added to the ring. Among these, a collimation system known as an "absorber/scraper", is the latest device to be installed in the Booster. The role of these devices is even more crucial now that the beam is denser.

Provided by CERN