CERN: EUROPE'S VOYAGE TO THE INFINITELY SMALL

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DOI: https://doi.org/10.1051/epn/2023506

Over the nearly 70 years of its existence as an intergovernmental scientific organisation, CERN has become a landmark of scientific research in particle physics. In a changing geopolitical and societal context, CERN is shaping its future program where large research infrastructures are the necessary cornerstones to continue to investigate the infinitesimally small.

▲ CERN Science Gateway.

It is summer at CERN, the European Organization for Nuclear Research, close to Geneva. Many young people from all over the world are talking and laughing around the tables on the cafeteria terrace in the warmth of an evening. After a pause due to Covid-19, the summer students are back! CERN's yearly summer internship programme attracts more than 300 students from over 100 countries spreading a joyful atmosphere around the site. After all, one of the core missions of CERN is to train young people, and to promote peace and international collaboration through scientific research.

Building together

It has been nearly 70 years since CERN's foundations were laid in a European landscape marked by the experience of World War II. CERN was founded to provide world-leading research infrastructures, which no European State could afford by itself, through an intergovernmental scientific organisation; to promote scientific collaboration among countries who were at war less than 10 years earlier; and to stop the scientific brain drain. Discussions among the proponents of *big science* and *traditionalists, youngsters and establishment, experimentalists and engineers* and *theorists* spanned over two years before the CERN Convention was ratified and a first research programme established. The stakes were high to build such a laboratory from scratch, on a green-field site, and the outcome was quite uncertain - it was even difficult to find a Director-General ready to take on the task. Large research infrastructures are at the heart of the CERN model: from the Synchrocyclotron in 1957 and the Proton-Synchrotron in 1959 to the first hadron collider ISR in 1971, followed by the first proton-antiproton collider $Sp\bar{p}S$, the Large Electron-Positron collider LEP, and now the Large Hadron Collider LHC. CERN's track record is filled with pioneering instruments: from construction to operation and the final physics results, working on the common goal to unravel the world of the subatomic particles has motivated many physicists, engineers and technicians to engage with CERN and to develop the necessary ground-breaking technologies. As an international treaty

organisation, CERN has established a robust framework for scientific cooperation, including financial stability, that has allowed major investments over many years.

Spreading International collaboration

The CERN model has inspired the creation of sister organisations such as ESA, ESO and EMBL, further strengthening the collaboration among the European countries in various areas. The Joint Institute for Nuclear Research, JINR, in Dubna (Russia), was the first international organisation to follow the CERN model in 1955, facilitating by then collaboration between East and West. The latest example is SESAME, the Synchrotron-light for Experimental Science and Applications in the Middle East, which has eight member states and operates a common infrastructure in Jordan since 2017. Starting with twelve founding nations, CERN's membership expanded rapidly in the 1990s towards the Eastern European Countries, and later to Israel. Today, CERN has twenty-three Member States, some 10 Associate Member States, including non-European countries such as India and Pakistan, and close to 50 international cooperation agreements with non-Member States. Nearly 12 000 users with 100 different nationalities are currently registered as CERN. About a third of the users are affiliated with institutes in non-Member States, North America accounting for the largest fraction. Yet, the geopolitical context has changed. For the first time in its history, CERN revoked the Observer Status of the Russian Federation and JINR in 2022 following the Russian invasion of Ukraine, one of CERN's Associate Member States.

Preparing the Future

Since the 2013 update of the European Strategy for Particle Physics, CERN has been working on the concept of a 100-km collider. This "Future Circular Collider" (FCC) could follow a similar development path as LEP and LHC, hosting an electron-positron collider first, FCC-ee, and later a hadron collider, FCC-hh, in an underground tunnel more than three times longer than the LHC tunnel. An accelerator R&D roadmap, coordinated by Europe's largest particle physics laboratories, has emerged as the vehicle for new technologies for the FCC and other accelerator concepts to be investigated. National laboratories in the United States, such as FNAL, BNL and SLAC, as well as KEK in Japan, are also involved in these R&D endeavours. China has started studies of a similar machine, the Chinese electron-positron Collider, or CEPC, if approved slated to start construction in the late 2020s.

Beyond Europe

Even though the LHC attracts scientists from all over the world, the facility was essentially constructed and operated with European funds. Since the FCC-ee will be about twice as expensive as the LHC, discussions about possible financial scenarios have started among the Member States of CERN: if major contributions came from outside the CERN budget, such contributors would certainly expect to have a closer involvement in CERN's governance. Are the Member States ready to invest to maintain European leadership in particle physics? Or should CERN become a "global" laboratory?

"All men by nature desire to know", said Aristotle. It is this desire that motivates us to study the intimate properties of matter and their behaviour in the earliest moments of the Universe. The question is: do we still have this desire to know in the societies of today? National science policy often extols the virtues of targeted research as a means of strengthening economies and addressing societal challenges. Physicists are as eager as anyone else to contribute to the challenges which lie ahead, but if we still want to explore unchartered territory, we need to build the necessary research infrastructures, and to continue to collaborate all over the world. ■

▲ FIG. 1: "I don't know if we were particularly lucky, but I really enjoyed every aspect of the summer student program: work, lectures and social life (a lot!)." CERN Summer Students 2023. © CERN

About the Author

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▼ FIG. 2: A scematic view of the possible implementation of the nearly 100 km FCC tunnel. © CERN