THE CERN ACCELERATOR SCHOOL – A SHINING BEACON IN THE TRAINING LANDSCAPE OF ACCELERATOR SCIENCE AND TECHNOLOGY

F. Tecker*, C. Vollinger, N. Caraban, CERN, Geneva, Switzerland

Abstract

The field of accelerator science and technology is crucial for advancements in fundamental physics, medical applications, and industrial processes, and via its technological inventions has a considerable impact on society. The specialised nature of the accelerator domain necessitates highly skilled personnel. However, the domain of accelerator science and technology is rarely taught as it requires a high specialization in the different domains. To provide training opportunities is an excellent possibility to demonstrate the diversity of the field and to attract and keep young talent in the domain of accelerator technology. The CERN Accelerator School (CAS) has played a pivotal role in addressing this need for over four decades, providing comprehensive training to a global community of scientists and engineers. This paper explores the crucial role CAS plays within the broader global training landscape for accelerator science and technology, and its contribution to the advancement of this striving field. This presentation specifically covers: an overview of the school's evolution and structure; the expansion and adaptation of CAS courses; the impact on the accelerator community; global collaborations; and addressing future needs.

INTRODUCTION

Particle accelerators have evolved from simple laboratory tools into some of the most complex scientific instruments. The LHC at CERN, being the largest scientific instrument ever built, is the backbone of high-energy physics, however, the utility of accelerators extends far beyond, into medicine through hadron therapy and radioisotope production, materials science, and industrial sterilization processes. Despite this importance, accelerator science is often underrepresented in standard university curricula.

The multidisciplinary nature of the field – requiring expertise in domains as varied as electromagnetism, radiofrequency (RF) engineering, vacuum technology, superconductivity, and accelerator physics – creates a high barrier of entry into the field. The CERN Accelerator School (CAS) was established in 1983 precisely to bridge this educational gap. By providing a structured learning environment, CAS ensures that the collective knowledge of the world's leading experts is preserved and disseminated to the next generation of scientists, engineers, and technicians.

* tecker@cern.ch

EVOLUTION AND STRUCTURE OF CAS

The CERN Accelerator School has undergone significant evolution since its founding. Initially designed in 1983 to train CERN staff for ongoing projects and to pave the way for the LEP era, it quickly expanded to accommodate the global community of accelerator science. The number of CAS courses per year has been increased from two courses to presently four courses per year, to satisfy the increasing demand for training in the expanding accelerator sector.

The Present Course Curriculum

The core of the CAS curriculum is organized around a biennial cycle of general accelerator physics and technology courses. CAS hosts a yearly ***Introduction to Accelerator Physics*** course, designed for newcomers working in the field as well as providing training in accelerator physics for experts already working in a technological domain. About every two years, CAS offers an ***Advanced Accelerator Physics*** course, which dives deeper into the mathematical foundations of beam optics and non-linear dynamics. During the advanced course, extensive Hands-on training is offered from RF measurements and simulations, Beam instrumentation and diagnostics to Beam optics design and correction (using the Xsuite programme [1]). This structured 2-level-course approach allows participants to build a solid foundation before tackling more complex challenges. In 2013, the course structure has been extended on a more conceptual level with the ***Basics of Accelerator Physics*** course offering basic-level training in General Accelerator Physics combined with an overview on core technologies used in accelerators. The course is designed mainly for engineers and technical professionals with an expert level in their domain, but who are new to accelerators. In many cases, the course participants of the Basic course later attend one of the CERN Accelerator School Introductory Physics courses.

Specialised Courses

Beyond the core curriculum of accelerator physics, CAS organises specialised schools focusing on specific technologies. These topical courses are essential for the technical staff working on subsystems of modern accelerators. Recent specialised topics included:

- **RF for Accelerators** gives a review of RF technology presently used in accelerators of different types, from dealing with power sources, beam manipulation with cavities, up to low-level RF control, including a recap of the fundamental theories. Includes Hands-on and simulation sessions on RF equipment [2] Fig. 1.

Figure 1: CAS Hands-on training on RF measurements, topical CAS on Radiofrequency [2], Berlin, 2023

- **Normal- and Superconducting Magnets:** Reviewing the magnet technology presently used in the field of particle accelerators and an overview of magnet measurement techniques. Includes Hands-on sessions with normal- and superconducting test set-ups [3] Fig. 2.
- **Mechanical & Materials Engineering for Particle Accelerators and Detectors:** Covering a wide range of mechanical engineering and material science aspects, complemented by a series of expert talks about applications in the field of accelerators [4].
- **Intensity Limitations in Hadron Beams:** Comprehensive overview of limitations which beams encounter in both linear and circular accelerators [5].
- **Beam Instrumentation:** Focus on the "eyes" of the accelerator, providing a deep understanding of how beam properties are measured, diagnostic instruments developed and monitors operated. Hands-on with real equipment from BPMs, WCT, pick-ups, and their diagnostics. Various case studies to cover different beam limitations and operational impact offered [6].

PRACTICAL HANDS-ON SESSIONS

CAS ensures that participants are not only learning the classical *Hamiltonian mechanics* of beams but are also prepared for the daily work by the integration of practical hands-on sessions. These labs are designed to transform abstract mathematical concepts into tangible physical intuition. While already the Introductory course includes Python-based practical hands-on sessions for transverse and longitudinal beam dynamics, the Advanced course and the specialised courses contain hands-on sessions with hardware labs where students spend a significant time working with real accelerator components and high-tech equipment:

- **RF Measurements:** Participants perform experiments to train general measurement techniques by utilizing Vector Network Analyzers (VNA) and Spectrum Analyzers (SA). The concepts of S-parameters, and Smith charts are taught, and spectrum measurements are carried out by the participants including performing *bead-pull* measurements for detailed cavity characterization. The practical work is complemented by RF simulations (CST [7], etc.) and longitudinal beam dynamics.
- **Beam Diagnostics:** Participants practice with physical pick-ups, RF measurements, and optical systems.

Figure 2: CAS on Normal- and Superconducting Magnets [3], left: Hands-on session, right: Lecture room.

- **Magnets:** Superconducting and resistive magnet design workshops, various magnetic measurement techniques, experiments under liquid nitrogen for measurements of high-temperature superconductor tape properties
- **Mechanical Engineering:** Workshops in mechanical design, mechanical measurements, non-destructive testing, metrology, and fabrication.

DIGITAL STRATEGY DEVELOPMENT

The learning experience is also strongly supported by a well-structured digital content. The recent communication and digital development of CAS since 2022 shows how training infrastructure now extends beyond the classroom. The updated strategy responded to a changing landscape shaped by social media, post-COVID digital habits and the growing importance of online discoverability for both educational resources and job-market access.

CAS shifted toward a more integrated communication model built around website modernisation [8], searchability, analytics, multichannel editorial publishing, newsletter automation and community tools serving the accelerator scientist community.

The strategy includes building a CAS Accelerator Community on LinkedIn [9] and WhatsApp, coordinated content on ATS News [10], Accelerating News [11], CERN channels and newsletters, together with stronger use of archives and reusable educational assets. This is important not only for visibility, but also because discoverability has become part of how specialised education institutions build reputation and reach new audiences, addressing future needs.

IMPACT ON THE COMMUNITY

CAS presently educates about 300 participants per year. However, the impact of CAS is measured not just in the number of participants trained, but in the strength of the community it builds. By providing a high-quality educational experience, CAS acts as a powerful tool for recruitment. It demonstrates the diversity and excitement of the field to young engineers and physicists who might otherwise choose more traditional sectors. The residential nature of the courses – lasting two weeks – fosters intense networking, allowing students to form professional bonds that last decades.

The various efforts had measurable effects. CAS LinkedIn followers grew from 5,000 in February 2024 to 11,312 in May 2026, equivalent to 126% growth, while the account audience remained closely aligned with the intended community, including strong shares from research services and entry-level professionals. Website traffic also increased, with visits rising from 29,411 in the 2024–2025 baseline to 33,741 in 2025–2026, unique visitors increasing from 16,056 to 18,241, and pageviews from 53,806 to 57,287. Engagement quality remained solid during this growth period, with average session duration above 2 minutes, 2.6 actions per visit, 3,482 downloads, and 25,004 outlinks clicked, reinforcing the role of the CAS site as a trusted hub that leads users to CAS proceedings, Indico content, and partner platforms.

The strategy also expanded direct community-building tools. The first CAS newsletter [12] reported 1,066 subscribers, an 87% acceptance rate, a 45.6% open rate and a 15.8% click-to-open rate, while the CAS WhatsApp community reached 660 members across 14 groups.

These tools are significant because CAS is not only a course provider; it increasingly acts as an entry point into a professional ecosystem where participants seek announcements, opportunities, collaborations and continued engagement with accelerator science.

Knowledge Preservation

The published proceedings of the CAS courses serve as the "standard textbooks" for the field. In many cases, the specialized knowledge shared by an ageing generation of experts would be lost without the documentation provided by the CAS proceedings. They are cited globally and serve as a primary reference for design studies across the world. The CAS proceedings and more then 400 videos of the lectures can be found on the CERN Document Server [13].

CAS Participants Feedback

A 2026 survey with replies of 83 participants covering seven courses, conducted 1–2 years after attendance, supports this broader interpretation of CAS as a long-term training and networking platform rather than a one-off educational event. Respondents came from more than 30 institutions worldwide, with approximately 39% from CERN, and a spread across laboratories and universities such as ALBA, CIEMAT, CNRS, DESY, ESS, GSI, INFN, ISIS, KEK, PSI, SLAC and STFC, among others; they also represented diverse backgrounds in physics, engineering and computing. The overall learning experience was rated excellent by 56.6% of respondents and very good by 39.8%, producing an overall satisfaction level of 98.8% (rating ≥ 3 on a $1-5$ scale).

The survey confirms the strong relevance of the CAS training to professional development. 41% rated course relevance to career as highly relevant and 38.6% as relevant, for a combined strong-career-relevance figure of 94.1%. Participants reported applying CAS knowledge directly to PhD work, research tasks and professional roles, particularly in beam dynamics, accelerator physics fundamentals and hands-on laboratory work that would not have been accessible in many home institutions. The long-term value of CAS learning materials is also visible in the survey: 77.6% found proceedings useful or very useful in the longer term, and 52.7% said the same for video lectures, with overall satisfaction levels of 94.8% and 82.4%, respectively.

Networking emerges as one of CAS's defining strengths. In the survey, 55.4% rated networking opportunities as excellent and 31.3% as very good, while 98.7% said they had made valuable connections. Participants linked these contacts to collaborations, mentoring, and career support, and testimonies described concrete outcomes, including collaborations with CERN groups, support during thesis writing, improved understanding of the research context, and even promotion to senior roles. These results align closely with the communication strategy's emphasis on alumni testimonials, WhatsApp groups, newsletters and LinkedIn as mechanisms to keep the CAS community active between courses.

INTERNATIONAL COLLABORATIONS

CAS is a central node in a global network of training institutions. The lecturers are selected from a variety of institutes working in the accelerator domain.
While organised by CERN, the school takes place in CERN's different member and associate member states, collaborating with local universities and laboratories who engage directly with the international expert community, this way giving strength to the accelerator field in different regions promoting their own research- and accelerator facilities.

CONCLUSION

Taking all this together, we can affirm that CAS contributes on three levels to the accelerator training landscape. First, it delivers high-quality specialised education that participants find directly relevant to their careers. Second, it sustains an international professional network that supports mobility, collaboration and long-term engagement in the field. Third, it is building the digital and archival infrastructure needed for modern scientific training: discoverable content, reusable materials and community continuity across institutions and generations.

This combination explains why CAS remains relevant more than four decades after its launch. In a field where expertise is scarce, interdisciplinary and globally distributed, CAS does more than teach courses: it creates a shared reference point for accelerator science and technology, supports the development of future specialists and strengthens the connective tissue of the international accelerator community.

ACKNOWLEDGMENTS

The authors would like to thank the CAS lecturers for their commitment and dedication to teaching the CAS, the CAS Advisory Board members, and the local organising committees of the collaborating host institutes for their tireless support to the education of the accelerator community.

REFERENCES

[1] G. Iadorola, "Xsuite: A Multiplatform Python Toolkit for Beam Dynamics", A&T Seminar at CERN, Feb. 2025, https://indico.cern.ch/event/1489714/

[2] CAS course on RF for Accelerators, Jun. 2023, Germany, https://indico.cern.ch/event/1212689/

[3] CAS course on Normal- and Superconducting Magnets, Nov. 2023, Austria, https://indico.cern.ch/event/1227234/

[4] CAS course on Mechanical & Materials Engineering for Particle Accelerators and Detectors, Jun. 2024, Netherlands, https://indico.cern.ch/event/1326947/

[5] CAS course on Intensity Limitations in Hadron Beams, Jun. 2025, Bulgaria, https://indico.cern.ch/event/1466612/

[6] CAS course on Beam Instrumentation, Nov. 2025, Croatia, https://indico.cern.ch/event/1505399/

[7] Computer Simulation Technology, CST Studio Suite, https://www.3ds.com/products-services/simulia/products/cst-studio-suite/

[8] CERN Accelerator School website, https://cas.web.cern.ch

[9] CAS LinkedIn Community, https://www.linkedin.com/in/cern-cas/

[10] CERN ATS News, https://ats-news.web.cern.ch/

[11] Accelerating News, https://acceleratingnews.eu/

[12] CAS Newsletter, https://bit.ly/4woLmFX

[13] CAS Collection on the CERN Document Server, https://cds.cern.ch/collection/CERN%20Accelerator%20School%20%28CAS%29