

Europe launches HADRON-2030 to explore the strong force that shapes visible matter

A major new European research initiative will open access to leading accelerators, experimental facilities, theoretical resources and quantum-computing technologies for the international hadron-physics community that investigates the effects of the strong force.

What holds the atomic nucleus together ? How does most of the mass of visible matter emerge from quarks and gluons ? What happens to strongly interacting matter at extreme temperatures and densities, and how precisely must its effects be understood before scientists can recognise evidence of new physics ?

These are among the questions at the heart of HADRON-2030, a new four-year Horizon Europe project beginning on 1 October 2026.

Coordinated by the French National Centre for Scientific Research, CNRS, HADRON-2030 brings together 49 beneficiary organisations from 15 countries, supported by 86 additional involved institutions. Its network connects universities, national laboratories, accelerator centres and international research organisations across Europe and beyond.

HADRON-2030 will create an integrated environment in which researchers can move between complementary facilities, combine experimental and theoretical expertise, use shared digital resources and develop the technologies required for the next generation of hadron and nuclear physics.

Understanding the strong interaction

The strong interaction binds quarks and gluons into protons, neutrons and other hadrons. It also provides the force that binds protons and neutrons together inside atomic nuclei and is therefore responsible for the structure of almost all visible matter.

Its underlying theory, quantum chromodynamics, is a fundamental part of the Standard Model of particle physics. As of today, the behaviour of the strong interaction remains extremely difficult to calculate and investigate across all relevant energy and density regimes.

Understanding it is essential for explaining the internal structure and mass of hadrons, the emergence of complex nuclear matter, and the properties of neutron stars. Precise knowledge of hadronic effects is also required to interpret collider measurements, neutrino experiments, tests of fundamental symmetries and searches for particles or interactions beyond the Standard Model.

HADRON-2030 will address these interconnected questions through a programme spanning precision physics, hadron spectroscopy, nuclear structure, strongly interacting matter under extreme conditions, nuclear astrophysics and three-dimensional studies of the internal structure of protons and other hadrons.

Some of the deepest questions in modern physics sit at the boundary between what we know about the strong interaction and what we can actually calculate or measure with sufficient precision. HADRON-2030 will bring together the facilities, technologies and scientific communities needed to move that boundary.

Opening European research infrastructures

A defining feature of HADRON-2030 is its programme of Transnational Access. Researchers will be able to apply for supported access to 15 experimental and theoretical installations, including ESFRI beam facilities at CERN, GSI/FAIR, GANIL–SPIRAL2 and MAMI/MESA, ELSA, PSI, INFN laboratories (LNF, LNS and LNL), ELI-NP, IJCLab–ALTO, JYFL-ACCLAB, IFJ, UNIWAW, BNL in Unites-States (associated) as well as the European Centre for Theoretical Studies in Nuclear Physics and Related Areas, ECT*.

The programme includes radioactive-ion beams, stable and exotic nuclei, electron and photon beams, neutron time-of-flight measurements, detector-test facilities and opportunities for intensive theoretical collaboration.

By coordinating access across borders, HADRON-2030 will allow researchers to select the facility best suited to a scientific question rather than being limited by the infrastructure available at their home institution. It will particularly benefit young scientists, emerging research groups and teams from countries without comparable facilities.

A new generation of virtual research services

Physical access will be complemented by 6 Virtual Access services. These will provide open computational tools and online environments for precision Monte Carlo calculations, partial-wave analysis, lattice quantum chromodynamics, perturbative-QCD calculations and the three-dimensional structure of hadrons.

The project will also offer remote access to quantum-computing and analogue-simulation resources through the IGFAE–CESGA infrastructure in Spain. Researchers will be able to develop and test quantum algorithms for problems in hadron physics including real-time dynamics, finite-density systems and complex quantum many-body phenomena.

Artificial intelligence and machine learning will be applied across the scientific chain, from improving accelerator operation and detector readout for reconstructing experimental events, analysing large datasets and connecting measurements with theoretical models.

Software, selected datasets, documentation and training materials will be made openly available wherever possible, following FAIR principles of findability, accessibility, interoperability and reuse.

From scientific instruments to societal applications

HADRON-2030 will develop advanced detectors, electronics, data-acquisition systems, polarized targets and computational methods. Although created for fundamental research, such technologies frequently find applications in other fields.

The project's developments will contribute to medical imaging, particle therapy and radiotherapy, radiation monitoring, security technologies, industrial inspection and high-performance computing. HADRON-2030 will encourage interaction with industry and support the transfer of promising instrumentation and software beyond their original scientific applications.

Training the scientists of the 2030s

HADRON-2030 will make a substantial investment in people. Schools, workshops, webinars, internships, exchange visits and hands-on activities related to research infrastructures will provide training for doctoral candidates, postdoctoral researchers, engineers and technical personnel.

Participants will be able to acquire experience across experimental physics, theory, detector development, data science, artificial intelligence and quantum technologies. By connecting young researchers with institutions and specialists throughout the consortium, HADRON-2030 aims to build a more integrated and resilient European scientific community.

The lasting success of HADRON-2030 will be measured not only by the discoveries it enables, but also by the researchers it prepares for the future. The next generation will need to work fluently across experiments, theory, advanced instrumentation and computing. This project will give them the opportunity to develop those skills within an international community.

Building a common future for European hadron physics

HADRON-2030 builds on the achievements of STRONG-2020 while substantially extending its scientific programme, infrastructure portfolio and technological reach. Its objectives respond directly to priorities identified in the NuPECC Long Range Plan 2024 for European nuclear physics.

Over its four-year duration, the project will coordinate research access, develop new services, support scientific collaborations and provide a common platform for communities that have often worked through separate facilities or disciplines.

By bringing these resources together, HADRON-2030 will strengthen the position of Europe at the forefront of hadron and nuclear physics and bring scientists closer to understanding the fundamental force that shapes the visible Universe.

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HADRON-2030 receives funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101292522.



Funded by the
European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.