High energy physics in Hungary

(particle and nuclear physics, astroparticles)

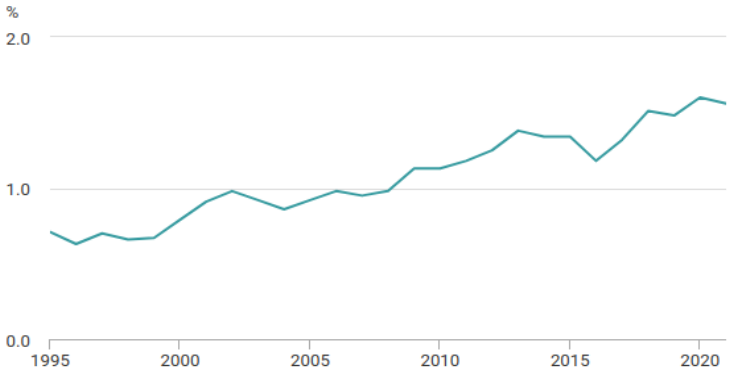
Hungary became a CERN member state in 1992.
[Thirty years of Hungarian membership of CERN]

Hungary in numbers

Parliamentary republic
Capital and largest city: Budapest
Official language: Hungarian
Area: 93,030 km^2
Population: 9.7 million
Ethnic groups: 93.5% Hungarians,
3.2% Romani (up to 8%), 1.9% Germans, etc
Joined the European Union: 2004
Currency: Hungarian forint; 1 EUR is about 400 HUF
GDP per capita: $36,848 (on purchasing power parity), $18,527 (nominal)

Some recent (2021) numbers from the Hungarian Central Statistical Office:

- R&D expenditure as a percentage of GDP: 1.56%. It continuously increased through the past decades:



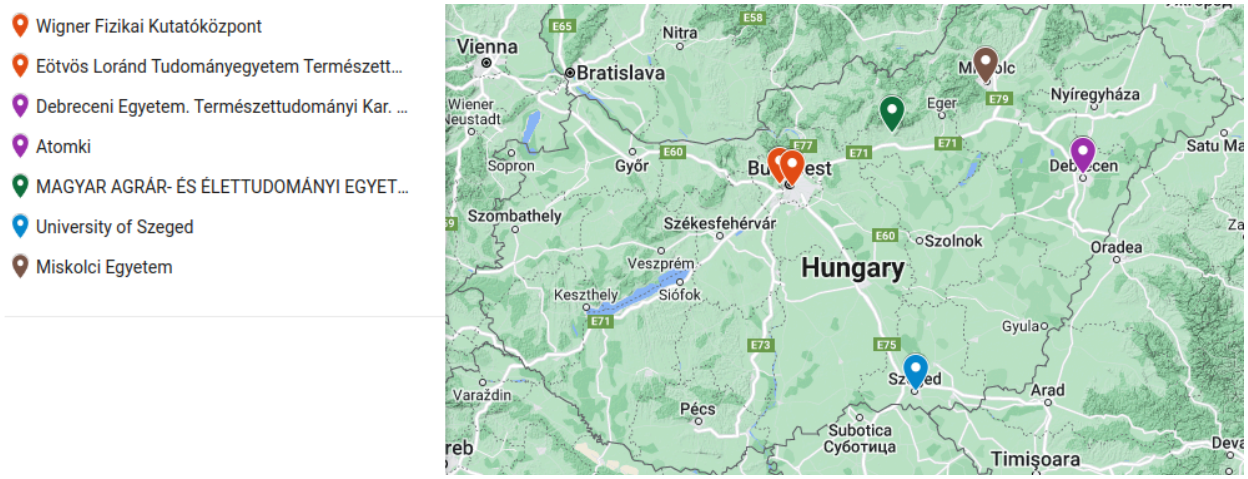
- Number of staff performing R&D activities, as a percentage of total employment: 1.09%
- R&D capital expenditure as a percentage of investments in the national economy: 0.68%
- CERN relations: the volume of Hungarian industrial deliveries fluctuates in the range of 4-7 MCHF/year. In this respect, Hungary counts as a balanced country.

Institutions

High energy physics (experiment and theory) is concentrated in Budapest, with smaller groups in Debrecen, Szeged, Pécs, and Gyöngyös [a map is below]:

- Wigner RCP, Institute for Particle and Nuclear Physics, Budapest [webpage]
- Eötvös Loránd University, Institute of Physics, Budapest [webpage]
- Institute for Nuclear Research (ATOMKI), Debrecen [webpage]
- University of Debrecen, Physics Institute, Debrecen [webpage]
- MATE Károly Róbert Campus, Gyöngyös [webpage]
- University of Szeged, Szeged
- University of Miskolc, Miskolc (associated)

The *research institutes*, formerly under the Hungarian Academy of Sciences, are since 2019 part of the Eötvös Loránd Research Network. The *universities* are controlled through asset management foundations governed by a board of trustees since 2021, with some notable exceptions: e.g. the Eötvös University is still state-owned.



Funding

Funding and support are provided through various channels, they are listed in the order of importance below.

- National Research, Development and Innovation Office (NKFIH or NRDIO) [webpage]
  - Most importantly, the funding agency disburses the CERN membership contribution (7 MCHF/year, 0.6% of total), and also supports M&O A for 16 experimentalists in CMS and ALICE (altogether 160 kCHF/year).
  - The “OTKA” (former National Scientific Research Fund) grants have calls for thematic research (30 kEUR/year for 4 years, for travel, equipment, M&O B), young researchers, and postdoctors. Usually, a thematic grant is essential to

carry out experimental research; most Hungarian experimental groups have one (or two) such grants available. One has to apply again once the 4 years term is over (there is no rolling-grant scheme available). The average success rate is quite small (20-30%), depending on the topic.
    - The Thematic Excellence Programme provides support for university knowledge centres and research centres for their research, development and innovation activities. (We have winners: application of high energy instrumentation for imaging with cosmic muons at Wigner; astro- and particle physics at Eötvös U).
    - The New National Excellence Programme provides wide support for undergraduate, graduate, PhD students, doctoral candidates and postdocs, higher education teachers and researchers with several, mostly doctoral students in the particle physics area.
    - The goal of the programme Support for summer internships for Hungarian students studying abroad is to bring back the best students from abroad (mostly from the UK) for the summer to reintegrate them into domestic research.
    - In the past years an inventory of Excellent Research Infrastructures in Hungary, a list of high-quality open laboratories, was set up with the aim to provide them with targeted support in the future. Among them are the Vesztergombi Laboratory for High Energy Physics and the Wigner Scientific Computing Laboratory (both at Wigner RCP), and the ATOMKI Accelerator Centre in Debrecen.
    - Support for the use of international and national research infrastructures to help researchers in accessing research and measurement opportunities provided by research infrastructures. Several experimental groups got additional funds for travel to CERN.
    - Under the umbrella of the funding agency, the task of the Hungarian CERN Committee is to oversee and follow the Hungary–CERN relations; it is composed of officials from the Office and researchers representing the major research institutes and universities.
- Ministry of Culture and Innovation [webpage]
    - There are 62 universities and higher education institutions in Hungary. Physics is offered in the “Bologna” system at BSc (bachelor) level (3 years), followed by the MSc (master) level (2 years), and then a PhD level (4 years). Physics teachers are educated in a separate, 5-year program. The MSc and PhD programs are often fully in English. Funding of the Universities is mainly normative: proportional to the number of students. Research is (only) supported by external grants. Physics education at the BSc level is offered by the Eötvös Loránd University (ELTE, Budapest), Technical University of Budapest (BME), University of Debrecen (DE), University of Szeged, and University of Pécs. Particle and nuclear physics are concentrated at ELTE, BME and DE. For the PhD degree, two peer-reviewed publications /and a thesis are required.
    - The number of students admitted to the first year of their BSc studies in Hungary was near 170 in the past years. Numbers of students starting in physics this year, from Eötvös U are 106 BSc, 27 MSc, 25 PhD (out of them 4 in particle physics).

    - Only 26 students have started their physics teacher studies in 2021 in Hungary (down from 108 in 2013), while the number of active physics teachers in the age group between 50-60 years is more than 120/year. Estimates say that only about half of the students finish their studies (~13/year) and among them only around 50% will indeed stay at high schools as physics teachers (~6 /year), unable to compensate for the 10-20 times larger number of retiring physics teachers.
    - Eötvös Loránd University, the flagship university in Hungary is maintained by the Hungarian state under the auspices of the Ministry of Culture and Innovation. Its particle physics program is supported by the *Excellence grant* of the Ministry, providing a yearly budget of about 600 kEUR (plus another grant also from NRDIO). It is used primarily for personnel expenses providing salaries to staff and postdocs. Other universities in Hungary, except for the Technical University of Budapest, are run by foundations whose budget is a mixture provided by state and private funds. These universities do not provide specific funds for particle physics, but there is support for space research at the University of Debrecen where hardware is being developed with contributions from colleagues in experimental HEP.
- Eötvös Loránd Research Network (ELKH) [webpage]
    - The research network currently comprises eleven research centres, seven research institutes and 116 additional supported research teams operating at universities and other public institutions, conducting basic and applied research, exploring the most varied disciplines of mathematics and natural sciences, life sciences, social sciences and the humanities. The Wigner Research Centre for Physics is one of the most highly staffed research centres of the ELKH. Its mission is to conduct exploratory research in various fields of physics and to coordinate Hungarian efforts in international projects. The Institute for Nuclear Research (ATOMKI) deals with physics (nuclear, atomic, particle, vacuum, surface and quantum physics), but also conducts research into connected fields. It has the highest number of particle accelerators in Hungary.
- The Hungarian Academy of Sciences [webpage] supports outstanding researchers in establishing new research groups but also aids excellent postdocs through extra salary.
    - The "Momentum" grants are the local equivalent of ERC Starting or Consolidator grants. On average 100 kEUR/year for 5 years is provided. There are 15-20 winners each year, 1-2 out of them are in physics. In the past decade, there were 2 winners in experimental particle physics.
    - The Bolyai research scholarship supports individuals, young researchers. There are 10-12 winners in physics each year, about 500 EUR/month extra salary for 3 years.

Experiments and people at CERN

The Hungarian experimental community concentrates on two major LHC experiments: CMS and ALICE, with small groups in TOTEM, LHCb (and CODEX-b), and individual participation in ATLAS. There is a notable activity in NA61 at SPS, while people from Szeged participate in

ISOLDE. Eötvös U recently expanded its activities to the field of neutrino physics (T2K and DUNE). In the field of research and development, and preparations for future colliders, there are groups in RD51, AWAKE, and FCC. Altogether, as of today, there are 99 participants active in CERN experiments (according to the Grey Book database; users: 73, external participants: 24, others: 2), with 24 teams and 59 authors.Recent activities of some groups are detailed below.

There are 17 Hungarian staff at CERN (0.64%), 13 researchers or engineers, 3 technicians, and 1 administrative; out of these 3 are women. On average there are 3-4 students taking part in the Technical Student Programme, one in the Doctoral Programme, while there are 3-5 active in the Summer Student Programme. Each year we have about 20 physics teachers in the Hungarian Teachers Programme, taking part in a one-week study tour at CERN.

CMS. Several physics topics, including the study of the strong interaction, hadronization, correlations, exclusive processes, double parton scattering; quantum correlations, femtoscopy; electroweak processes, anomalous couplings, search for new physics,; luminosity measurement. Taking part in high-level trigger development, Run 3 operations of the Tracker, the Muon Spectrometer, the Zero Degree Calorimeter and the Beam Radiation Instrumentation and Luminosity (BRIL) systems and the Phase-2 Upgrade:

- design and manufacture of the front-end data acquisition electronics of the Chromie test beam telescope for the CERN SPS test beam (Wigner)
- development of the FPGA-based data collection system of the CMS Phase-2 tracking detector (Wigner)
- participation in the module production of the Phase-2 Outer Tracker (Wigner)
- development of the Phase-2 BRIL luminosity measurement system (Eötvös U)
- development of the ZDC zero-angle calorimeter (Eötvös U)
- development of positioning systems for muon detectors (ATOMKI)
- testing the SiPM sensors of the MIP Timing Detector (U of Debrecen)

ALICE. Several physics topics within heavy-ion physics include jet structure, nuclear effects, heavy quarks, comparisons to elementary collisions, and modelling. The focus connected to the main feature of the ALICE detector, its excellent particle identification capabilities. Various ongoing R&D projects (Wigner):

- participation in Inner Tracking System (ITS2 and ITS3) detector developments: DAQ and cooling design
- participation in the research development of the next-generation heavy-ion physics dedicated detector, ALICE3
- construction and operation of the ALICE Analysis Facility in the Wigner Scientific Computational Laboratory (2020-)
- upgrade of the time projection chamber with GEM technology; currently developing and building GEM and multi-wire gas-filled detectors in cooperation with the Innovative Gaseous Detector Development Group (2016-2021)
- the LHC Interface Project (LHC_IF) ensures the data flow between the Large Hadron Collider (LHC) and ALICE and thus the safe operation of the experiment (2016-2022).

- data collection, compression and transmission systems: development is a new 4 TBps bandwidth data transmission system during the LS2 for data collection after 2020
- research and development of a specialised hybrid (GPU and FPGA-based) analysis system with large-scale and high data density, data-intensive computing capacity, jointly with the Wigner Scientific Computing Laboratory within the Wigner Data Centre (2021-)

NA61. Physics topics within heavy-ion physics include correlation studies such as HBT analyses; pA physics, reference measurements for the neutrino-beam community. Several hardware upgrades:

- conceptualization, design and realisation of the Forward-TPC system based on the new tandem-TPC concept, mainly for the neutrino-beam community (2015-2018, Wigner).
- conceptualization, design and realisation of the Geometry Reference Chamber system for in-situ drift velocity calibration of the large TPC system (2021-, Wigner)
- conceptualization of a new target tracker chamber with neutrino-beam physics community (2022-, Wigner)
- planning future upgrade: the low-energy beamline project (Eötvös U)

RD51. The collaboration aims at developing high-performance gaseous detectors, which are integral parts of large detector systems. The ALICE TPC Upgrade was a flagship effort facilitated by the RD51 collaboration community. Wigner RCP is among the founding members and participates in the development of new technologies and improving reliable production methods.

LHCb/CODEX-b. The group at Eötvös U focuses on exotic pentaquark and tetraquark discoveries and on the study of rare, flavour-changing neutral current decays, sensitive to new physics, through multi-body amplitude analysis tools. Intends to strongly contribute to the LHCb ECal upgrades; also a founding member of the CODEX-b proposal to install a dedicated tracking detector to probe long-lived particles.

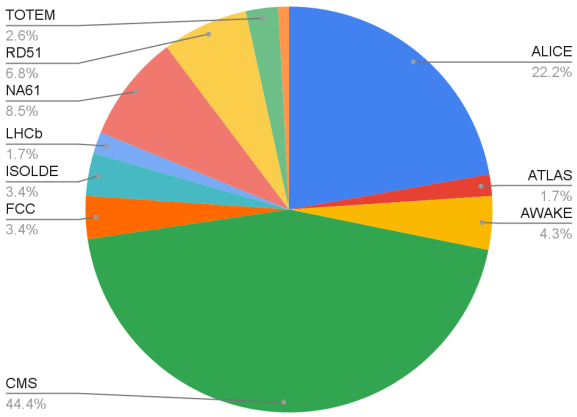
Neutrino platform. Plans at Eötvös U include improvement of vertex reconstruction software for the ND-GAr TPC using ML algorithms (DUNE); beam simulation for precise flux prediction and improved flux prediction to precision neutrino cross-section measurement utilising Near Detector (T2K).

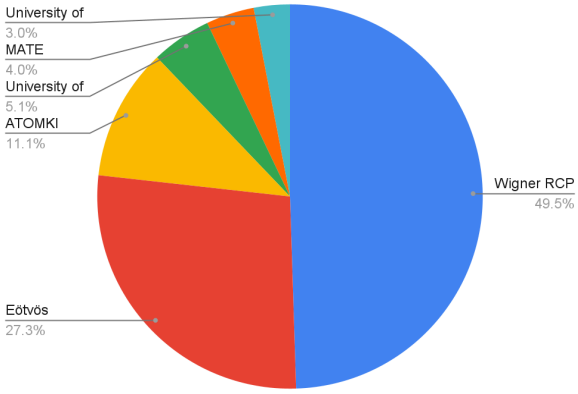
Structure of personnel

Most people are active in CMS and ALICE, followed by NA61, RD51, ISOLDE, and AWAKE. The large groups have students, while for smaller ones it is not always the case. Close to half of the people work at Wigner RCP, and more than a quarter are at Eötvös University, followed by ATOMKI, University of Szeged, MATE Gyöngyös and the University of Debrecen. About 15% of them are women, mostly students. Usually, there are 3-5% foreigners.

The following tables and charts depict the distribution of researchers in various experimental groups and institutions.

Experiment	*Sum*	As 1st exp.	As 2nd exp.	Staff	Post-doc	PhD stud.	MSc stud.	BSc stud.	Emer.
ALICE	*26*	24	2	10	2	4	5	2	2
ATLAS	*2*	2		2					
AWAKE	*5*	5		4					1
CMS	*52*	51	1	20	2	10	10	6	4
FCC	*4*	4		1	1	1		1	
ISOLDE	*4*	4		4					
LHCb/CODEX-b	*2*	2		1	1				
NA61	*10*	6	4	6		1	0	1	2
RD51	*8*	4	4	3	2	2	1		
TOTEM	*3*	3		3					
WLCG	*1*		1	1					





Institution	*Sum*	Re-searcher	PhD stud.	MSc+BSc stud.
Wigner RCP	*49*	34	9	6
Eötvös University	*27*	7	7	13
ATOMKI	*11*	10	1	
University of Debrecen	*5*	4		1
MATE Gyöngyös	*4*	4		
University of Szeged	*3*	3		

*PhD/MSc/BSc students are usually shared between universities and institutes.
‡We have students from the Budapest University of Technology and Economics (BME) as well.

Priorities and issues

- General: lack of dedicated funding for R&D, issues with stability and sustainability for basic research; heavy administration; slow public procurement.
  It is difficult to keep young people in the field and in the country.
  One of the goals of the high energy community is to establish a National Laboratory for High Energy Physics. Despite all efforts, it was not successful so far.
- As a consequence, Wigner RCP decided to continue investing at the institutional level by initiating new and developing existing infrastructures, and laboratories. Still, the priority should be collaboration at the national level.
- Eötvös University: Besides strengthening existing areas, trying to widen the scope and participation towards the flavour sector (LHCb) and neutrino physics (NA61, DUNE and others), dark sector (CODEX-b), by hiring postdocs from abroad. At the same time, Eötvös have an extensive recruiting activity country-wide to increase the number of physics students, reforming the educational material.
- ATOMKI: The stability of funding is critical. Important to keep experts.
- R&D: One needs good arguments to justify the costs of research and development for society. It is essential to provide benefits and industrial returns, but at the same time secure the possibilities to participate in cutting-edge developments for fundamental science. The establishment of Excellent Research Infrastructures by NRDIO is expected to facilitate collaboration and optimal usage of funds.

Contacts

- Council: István Szabó, Péter Lévai
- ECFA: Ferenc Siklér (restricted), Gábor Veres (plenary), Péter Major (young)
- LHC RRB: Gabriella Pásztor
- Industrial Liaison Officers: Dániel Barna, Tivadar Kiss
- Knowledge Transfer: Balázs Ujvári
- International Particle Physics Outreach Group: Dezső Horváth
- European Particle Physics Communication Network: Barbara Vizkelety