CHIPP – short outreach report, June 2024

High Schools & Students

- Masterclasses – at Bern, Geneva, EPFL and Zurich
- Workshops: Science Lab @ UZH, iLab @ PSI, Physiscope @ Geneva
- Visits at universities, CERN and schools (eg PhD students @ schools)
- Mentoring, workshops, internships, study programs for high-school students

Events

- Women and girls in science, February 11: special programs for girls in science
- Women in Physics career event at SPS (mentoring project)
- Scientifica (Zurich), Science & Nature Festival (UZH)

General public

- (Virtual) visits, talks, guided tours, videos, Youtube,…
  CHIPP members very active in (VIP) visits at CERN and inauguration of the Science Gateway
- CHIPP articles
- Science Pavilion UZH: exhibitions (LHC & Dark Matter, GW)
  well attended guided tours for schools, groups and general public
- Interviews, articles in newspapers

for extended report, see CHIPP agenda
ideas/suggestions?
→ Katharina (kmueller@physik.uzh.ch)

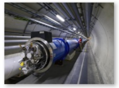
2024: 70th anniversary of CERN, SPS event 10 September with talk, panel discussion and apero
Swiss coordination: Hans Peter Beck
New set of posters on CERN and Swiss contributions for SPS (Show them locally if there is an opportunity

1954-2024
ANS / JAHRE / ANNI CERN

ATLAS, CMS & LHCb

70 years of Swiss Science at CERN

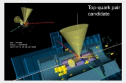
The Large Hadron Collider, LHC (start 2009)
The LHC is designed to study the origin of electroweak symmetry breaking, to search for New Physics beyond the Standard Model, and to perform precision measurements to test the Standard Model. ATLAS and CMS jointly discovered the Higgs boson in 2012, leading to the 2013 Nobel Prize in Physics.
Swiss groups have been involved in the ATLAS, CMS and LHCb projects since the mid-1990s with essential contributions to hardware, computing and physics analyses. Switzerland operates a Tier-2 computing centre at the Swiss National Supercomputing Centre (CSCS) in Lugano.



ATLAS

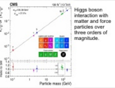
With a diameter of 25 m and a length of 46 m, ATLAS is the largest LHC experiment.
Swiss contributions to:
- Superconducting cables
- Silicon tracking detectors
- Calorimeter readout electronics
- Event building and high-level trigger
- Online data logging system
- Tier-3 data analysis facilities

Analyses:
- Searches for new physics
- Precision top measurements
- Novel physics tools and software



CMS

With 12'500 tons, CMS is the heaviest LHC experiment.
Swiss contributions to:
- Silicon pixel detectors
- Electromagnetic calorimeter
- Superconductors for the solenoid

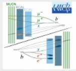


Higgs boson interaction with matter and force particles over three orders of magnitude.

Analyses:
- Higgs & Top Quark physics
- Electroweak and QCD processes
- Heavy ion physics
- Searches exotica and SUSY
- Novel physics tools and software

LHCb

LHCb searches for new forces and particles by measuring with unprecedented precision the decays of particles containing beauty or charm quarks and antiquarks.


Test of lepton flavour universality: ratio of b-meson decays to muons and electrons

Swiss contributions to:
- Silicon strip tracking detectors
- Scintillating fibres (SciFi)
- Luminometer
- On-line filter farm

Analyses
- Rare b-hadron or kaon decays
- (Semi)leptonic b-hadron decays
- Precision charm physics
- Exotica searches
- Novel physics tools and software

Particle Accelerators

70 years of Swiss Science at CERN

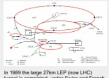
1953 CERN sur Arve


As the Meyrin site did not exist in 1953 the PS (Proton Synchrotron) division set itself up in 1953-1956 in the Institute of Physics, Quai Ansermet, on the shores of the Arve river in Geneva.

Powerful computers did not exist then and to determine the shape of magnets one had to proceed by building mock-ups.

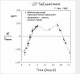

Members of the magnet group sitting on the first combined function magnet unit at the Institute of Physics in Geneva. Today, all these people have retired, **but the magnets are still pulsing.** The PS is at the heart of the CERN accelerator complex.
1st rank, left to right: R. Tinguely, C. Germain, **G. Plass**, D. Neet, B. de Raad, M. Cavallaro, K.H. Reich, G. Kuhn, J. Nilsson, C.A. Ramm, Paillard 2d rank : L. Resegotti, M. Niklaus, C.J. Zilverschoon, R. Bertolotto, Marcellin, **G. Brianti**, P. Collet Standing behind : B. Kuiper

From PS to LEP to LHC



Re-using old accelerators
The CERN accelerator complex was built successively over 60 years: each accelerator serving as injector for the following ones, each time more powerful.

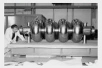
In 1989 the large 27km LEP (now LHC) tunnel is completed, under Swiss and French territories.
By 2035, this 600 MCHF infrastructure will have served the large e^+e^- collider LEP and the LHC for 50 years.



Precision measurements from LEP will remain unique for years
While measuring the mass of the Z boson with a very precise method, physicists, among them the Swiss Albert Hofmann and Jörg Wenninger, with Alain Blondel (University of Geneva), realized that the effect of terrestrial tides had to be corrected for. By changing the size and shape of the accelerator by a few hundred microns, the tides were modifying the energy of the beams!

M_Z=91.1872 ± 0.0022 GeV

Superconducting RF cavities for LEP



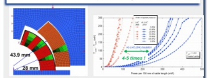
Field emission in LEP RF cavities
Superconducting cavities were used at LEP to accelerate electrons and positrons. However, when reaching high fields these cavities started emitting electrons ejected from the metal of the cavities walls, this preventing good performance.

UNIVERSITÉ DE GENÈVE
The group of Prof Oystein Fischer at University of Geneva studied this effect. A complex instrument 'ESCALAB' was built to study surfaces under various conditions. It comprised a Auger Spectrometer, a microprobe for field emission and an electronic microscope, all under extreme vacuum.
It revealed that impurities were the source of the emissions and that a high temperature treatment reduced these drastically. This method was applied to the LEP2 cavities, and has been used since for several accelerators in the world.

Superconducting magnets for LHC

1,232 superconducting dipole magnets keep the beams on their circular path, they are operated with 11,850 A and cooled to a temperature of 1.9K (-271.25 C). The magnetic field is 8.33 Tesla.

EPFL
- Characterization of heat transfer in LHC magnets operating in superfluid helium
- Finite Element Model towards the Interpretation of Magnet Quenches



Dipole cross section, finite element model
Heat transfer

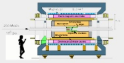
LEAR Experiments

70 years of Swiss Science at CERN

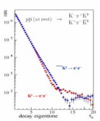
Experiments at the Low Energy Accelerator Ring (LEAR) 1982-1996

The Low Energy Antiproton Ring decelerated and stored antiprotons. LEAR delivered ~10^6 antiprotons per second onto fix targets.

CPLEAR
Test of discrete symmetries in the neutral Kaon system



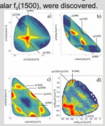
Rates for K^0 and anti-K^0 as function of decay time show a clear sign of symmetry violation between particles and antiparticles



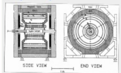
Crystal Barrel
Search for new/exotic charged and neutral states


Detector
- 1,2 Yoke
- 3 coil
- 4 CsI-crystals
- 5 drift chamber
- 6 wire chamber
- 7 hydrogen target

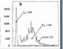
Dalitz plots of proton antiproton annihilations into three neutral pseudoscalar mesons: High event density is indicated in red. Several new mesons, among them the scalar f_0(1500), were discovered.

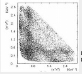


Asterix
Charged meson spectroscopy antiproton-proton annihilation



Annihilation of antiprotons with protons in liquid and gaseous targets:
Detection of x-rays from the atomic cascade allows selecting the state from which annihilation took place.
The quantum numbers of the produced states are then constrained.

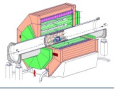



Dalitz plot for p-wave annihilation

L3 Experiment: Precision Measurements of the Standard Model

70 years of Swiss Science at CERN

LEP and the detectors ALEPH, DELPHI, L3 and OPAL were designed to measure the parameters of the Standard Model with unprecedented precision. The L3 experiment was optimized to measure photons, electrons and muons. Already in 1989, the first measurement of the Z resonance established the existence of three neutrinos. Much more precise measurements later constrained the masses of top-quark and Higgs particle, and did not show any hint of a deviation from the Standard Model predictions. LEP was stopped in the year 2000 to allow the construction of LHC in the same tunnel.



Muon Detectors
Layers of multi-wire proportional chambers were used to detect muons. ETHZ developed the laser alignment system for the barrel, and constructed the huge chambers for the forward and backward directions.

Magnet
Construction of the magnet and yoke was lead by ETHZ. Today, this magnet is part of the ALICE detector @ LHC.

L3 Cosmics
Proposed and coordinated by ETHZ, a system was added to trigger on atmospheric muons induced by cosmic rays.

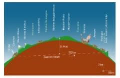
Vertex Detector
The wire chamber was designed and constructed by ETHZ, while UNIGE added a dedicated trigger system. Later, UNIGE and ETHZ contributed to an additional Si-strip microvertex detector.

Hadronic Calorimeter
ETHZ and PSI tested, assembled and calibrated the HCAL, made from depleted Uranium.

Electromagnetic Calo.
UNIL and ETHZ contributed to the ECAL made from BGO crystals. In addition, UNIL worked on the cooling system and UNIGE on the calibration device.

OPERA : Neutrino Oscillations

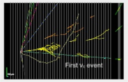
70 years of Swiss Science at CERN



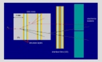
OPERA (2008-2012) is unique in studying neutrino oscillations by searching for appearance of tau-neutrinos in the CERN muon-neutrino beam to Gran Sasso.
The hybrid detector has a 1250 ton target mass composed of emulsion film-lead sandwiches complemented by electronic detectors.

First observation of neutrino oscillations

- Muon-neutrino beam from CERN to OPERA detector at 732 km distance.
- Tau-Neutrino interactions detected in lead by observing O(100 μm) long tau tracks with high resolution (1 μm).
- Target: 150000 bricks with 10 million films
- Trackers and spectrometers to trigger, point to the interaction in the target, and perform background reduction
- 19505 neutrino interactions with 10 tau-neutrino events
- 6.1σ observation of tau neutrino oscillation appearance.
- Most sensitive limits on $\nu_\mu \rightarrow \nu_\tau$
- Oscillation appearance



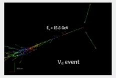
Emulsion scanning station


The detection principle of OPERA: *Signals in the trackers and interface films predict the brick "hit" by the neutrino. The interaction vertex is found by scanning the emulsions.*

- The Swiss groups had a leading role in the realization of the emulsion European Scanning System based on automatic microscopes with CMOS camera readout and robotized handling of the emulsion films.
- Bern hosted the largest emulsion scanning station in Europe, with 6 microscopes operating 24h/7d.
- ~25% of all events scanned in Bern

Swiss contributions

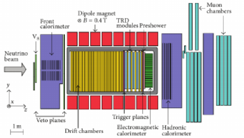
- Experiment proposal, design and construction (1998-2008)
- Management: Spokesperson
- Target tracker construction
- Lead for the target
- Development and realization of automatic microscopes
- Data taking and coordination
- Mass emulsion scanning
- Physics data analyses
- Decay search procedure
- Muon ID & momentum measurement
- Nuclear fragment identification
- Charmed particle studies
- Electron reconstruction and π^0 ID
- Kinematics of neutrino events
- Hadron re-interaction studies
- $\nu_\mu \rightarrow \nu_\tau$ oscillation analysis
- $\nu_\mu \rightarrow \nu_e$ oscillation analysis

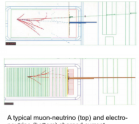


Neutrino Oscillations - NOMAD

70 years of Swiss Science at CERN

In the 1960s it was observed that only about half of the expected flux of neutrinos produced in the Sun arrives on Earth – the solar neutrino problem. A possible explanation was that the three neutrino species oscillate from one to the other with a frequency which depends on their difference in mass squared.
NOMAD (1995-1998) was an experiment searching for $\nu_{\mu(e)} \rightarrow \nu_\tau$ oscillations at the CERN SPS neutrino beam in a short base line experiment. Theoretical arguments suggested at that time that the tau-neutrinos have a mass of 1 eV/c^2 or higher and oscillating over short distances into muon-neutrinos.
The experiment was located in the CERN West Hall. It is composed of drift chambers (the target), a transition radiation detector, an electromagnetic calorimeter installed inside a magnet providing a field of 0.4 T. The muon detectors are located outside the magnet. Kinematic criteria were used to distinguish muon from tau neutrinos. No evidence for oscillations was found.




A typical muon-neutrino (top) and electro-neutrino (bottom) charged current interaction in NOMAD

We know today that muon neutrinos oscillate to tau neutrinos with an oscillation length much larger that the one available in NOMAD. NOMAD produced important results on dimuon production in neutrino interactions, and the production of Λ hyperons. These results will not be superseded before the advent of neutrino-factories.

Re-using equipment
The UA1 experiment at CERN was running from 1979-1990 it discovered the W and Z bosons. After that experiment was shut down, the magnet was used in the NOMAD neutrino experiment from 1995 to 1998. In 2008 it was shipped to Japan to be installed in the T2K neutrino experiment.

The group of Lausanne University was in charge of the construction of the **preshower detector**, in front of the electromagnetic calorimeter, and some of the drift chambers.

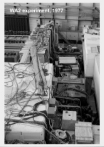
Hyperon and Drell-Yan Experiments

70 years of Swiss Science at CERN

SPS – Super Proton Synchrotron: 7 km circumference, 1976
The 400 GeV proton beam of the SPS, was extracted and used to produce secondary beams for fixed-target experiments located in the west (WA) and north area (NA). Swiss groups were involved in several WA experiments operating with charged hyperon beams between 1976 and 1982, as well as NA experiments operating with intense pion beams between 1980 and 1985. Starting in 1981, the SPS was also operated in proton-antiproton collider mode for experiments in the Underground Area (UA), leading to the discovery of the W and Z bosons in 1983.


July 1974 completion of the SPS tunnel

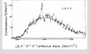
WA2, WA46
Leptonic decays of hyperons
Study of the Ω^- properties



Maurice Bourquin (1941–)
Professor at UniGE
President of CERN Council (2001–2003)

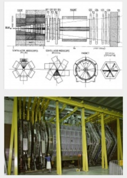
WA42, WA62
Strong interactions of charged hyperons, search for charmed strange baryons


Multi-wire proportional chambers
Liquid argon calorimeter built by Swiss groups


First observation of a charmed strange baryon, produced in Σ^-–Be interactions

NA16
Search for short-lived particles produced on nuclei with a heavy liquid mini bubble chamber

NA10 – Drell-Yan
High resolution study of inclusive production of high-mass muon pairs by intense pion beams.



Valentine Louis Telegdi (1922–2006)
Professor at ETHZ
Initiator of NA10
Chair of CERN scientific policy committee (1981–1983)

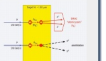
DIRAC & CLOUD

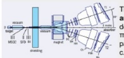
70 years of Swiss Science at CERN

Proton Synchrotron (PS): 628 m circumference, 1959
The 25 GeV Proton Synchrotron was CERN's first synchrotron, accelerating protons first time on 24 November 1959, and was for a brief period the world's highest energy particle accelerator. Ever since, the PS has accelerated protons, alpha particles, oxygen, sulphur and lead nuclei, electrons, positrons and antiprotons. Today, the PS supplies protons and lead ions in the pre-injector chain for the LHC. The PS also supplies protons to a target where antiprotons are generated for the Antiproton Decelerator. The DIRAC and CLOUD experiments use proton beams from the PS and are situated in the CERN East Hall, located adjacent to the PS.

DIRAC – Dimeson Relativistic Atom Complex
DIRAC is an experiment that measures Hydrogen-like atoms consisting of a charged meson pair at the PS. Dimesons, such as the $\pi^+\pi^-$ ($A_{2\pi}$) and the πK atom ($A_{\pi K}$) – provide a unique tool for exploring low-energy hadron-hadron interactions and understand the strong force.

$A_{2\pi}$ (pionium), produced in Ni, is detected through its breakup (ionization). Alternatively, the $A_{2\pi}$ annihilates (decays).

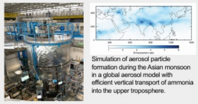




The **magnetic double-arm spectrometer** detects and identifies $\pi^+\pi^-$ (π^-K^+ and π^+K^-) pairs with small relative c.m. momentum.

DIRAC observes dimesons and measures their lifetimes. These provide information on the scattering lengths – the basic parameters in low-energy QCD, to be compared to results from Chiral Perturbation Theory and lattice QCD.

CLOUD: Cosmic Rays, 2009
The CLOUD project investigates the possible influence of galactic cosmic rays on the aerosol-cloud-climate interaction. The PS is used to produce pions to simulate atmospheric ionization conditions from ground level to the upper free troposphere. The 27 m^3 cloud chamber allows to precisely control experiments with a very low contamination background and close to atmospheric conditions.


Simulation of aerosol particle formation during the Asian monsoon in a global aerosol model with efficient vertical transport of ammonia into the upper troposphere.

CLOUD has provided an unprecedented understanding of the molecular processes involved in atmospheric particle formation and growth, and systematically measured formation and growth rates over a wide range of atmospheric conditions. It has identified key atmospheric vapors that contribute to particle formation. The parametrization of the data is implemented in models to improve the representation of aerosols, clouds and climate predictions.

Proton-Antiproton Collisions @ SppS

UA2 & UA6 Experiments

ANS / JAHRE / ANNI CERN 1954-2024

70 years of Swiss Science at CERN

SppS – the SPS converted in a proton-antiproton collider

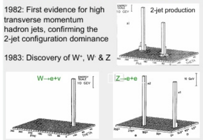
In order to study strong and electroweak interactions for the first time in the energy domain around 100 GeV, the SPS was converted in a tricky way into a proton-antiproton collider in the 1980s. The injection of stochastically cooled antiprotons into the SPS and their acceleration to 270 GeV opened up the possibility to study proton-antiproton collisions at the centre-of-mass energy of 540 GeV. The primary experimental goal was to search for the massive intermediate vector bosons W and Z postulated 1967 in the unified electroweak theory.

UA2 experiment (1981-1990)

UA2 was built around the beam pipe, it had electro-magnetic and hadronic calorimeters to detect electrons and hadrons, but could not measure particle charges except for limited regions where the W decay asymmetry was maximal. There was no muon detector.

1982: First evidence for high transverse momentum hadron jets, confirming the 2-jet configuration dominance

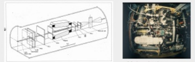
1983: Discovery of W^+, W^- & Z



UA6 experiment (1984-1990)

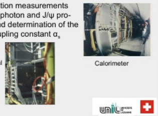
UA6 was a fixed target experiment installed at the Sp$\bar{p}$S. A jet of hydrogen molecules (H_2) was injected in the beam-line causing collisions of H_2 with protons and anti-protons in opposite directions at a cms energy of 24.3 GeV and an instantaneous luminosity of ~10^{31} $cm^{-2}s^{-1}$.

The experiment was instrumented with a two-arm magnetic spectrometer equipped with multiwire proportional chambers, an electromagnetic calorimeter, and a transition radiation detector. The Lausanne group built several MWPCs, contributed to the design and construction of the molecular jet target, and also tested the "transputer" technology to implement the trigger logic.



Molecular jet target

Results:
Cross-section measurements of prompt photon and J/ψ production and determination of the strong coupling constant α_s



Multiwire Proportional Chambers

Calorimeter

Swiss Institute of Particle Physics — Zurich, 9 – 13 September 2024 — swiss physical society

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Fixed Target Programme @ SPS (Heavy Ions)

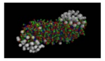
NA52 (NEWMASS) & WA98

ANS / JAHRE / ANNI CERN 1954-2024

70 years of Swiss Science at CERN

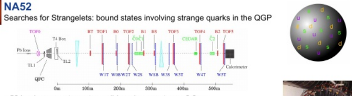
1990ies: SPS: heavy ion fixed target program searching for

- PbPb collisions
- Hot and dense state of matter
- Quark gluon plasma (QGP)
- Switzerland contributed to NA52 and WA98



NA52

Searches for Strangelets: bound states involving strange quarks in the QGP



- 524 m long spectrometer, solid angle acceptance 2.2 μsr
- @ H6 beamline in the Prevessin North Area
- Results: 10^{13} Pb+Pb collisions
  matter and antimatter (anti-helium-3) production
  confirmation of the QGP
  no evidence for Strangelets

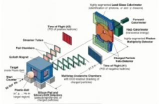
Hardware, trigger and readout electronics
3 postdocs, 3 PhDs
11 from 20 authors from Bern

Time of flight counter (100 ps resolution)

WA98

Large Acceptance Photon and Hadron Spectrometer

- High statistics study of photons, neutral hadrons and charged particles, and their correlations
- Plastic Ball detector to measure multiplicities and momenta of particles and heavier fragments
- Two spectrometers measure momenta
- Lead Glass spectrometer with 10,000 modules for high precision data on π^0 and η
- 21 institutes



Université de Genève

Swiss Institute of Particle Physics — Zurich, 9 – 13 September 2024 — swiss physical society

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Politics & Public

Early Days of CERN

ANS / JAHRE / ANNI CERN 1954-2024

70 years of Swiss Science at CERN

Timeline

- Two UNESCO conferences December 1951 (Paris) and February 1952 (Geneva) → Creation of 'Council of European representatives for the study and plans of an International Laboratory and the organization of other forms of cooperation in Nuclear research'
- 4 October 1952, Council meeting in Amsterdam: Geneva chosen by consensus from among the candidatures of Arnhem, Copenhagen, Geneva and Paris
- → This choice eliminated any possible ambiguities regarding the mission of the institution to perform work of scientific nature, and not military
- 28, 29 June 1953: initiative against the laboratory in Geneva by the workers party rejected by a popular vote
- 1 July 1953: Swiss delegation signs the convention establishing CERN, subject to ratification by the twelve signatory states.
- Work started in 1953 before the Convention was ratified and CERN was officially born. A small team of physicists and engineers worked in semi-independent groups in various institutes
- 17 May 1954: start of construction in Meyrin
- 29 September 1954: ratification by the first nine member states

The Swiss representatives, Albert Picot and Prof. Paul Scherrer brought forward Switzerland as host country

January 1952, «Tribune de Genève» reported the arguments in favour of Geneva: great scientific past, highly specialized manpower, small state, swiss neutrality.

Getting operational

While the administration setteld in a villa in Cointrin (right), the Magnet group was installed in the reactor building at the recently built Institut de Physique (below right) were technical support was provided (below)

An area in the commune of Meyrin was chosen as best site for the laboratory. Albert Picot took the members of the CERN Council in October 1953 to visit the location where the construction of the Nuclear Center would take place, and meet the local population.

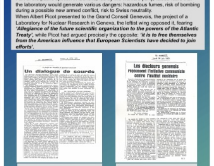
17 May 1954 : start of the construction of the first buildings in Meyrin

CERN and the region

The direct impact of CERN on Geneva is difficult to measure, but the spin-off benefits are enormous and the city is undoubtedly proud of its prestigious resident. Arriving in Geneva by road or air, CERN's presence is clearly indicated by signs.
Since 1965, CERN has expanded into the neighbouring region of the Pays de Gex in France to allow the construction of the ISR and then the SPS and LEP/LHC. This is a unique example of such duality of hosts, and CERN serves as a pioneer in legal and commercial matters.
Thanks to the neutral and peaceful nature of its host, CERN has been able to welcome physicists from all over the world, across all borders, to carry out experiments together at the frontiers of knowledge.

Opposition

Part of the public opinion in Geneva, led by the workers party, raised fears that the laboratory would generate various dangers: hazardous fumes, risk of bombing during a possible new armed conflict, risk to Swiss neutrality.
When Albert Picot presented to the Grand Conseil Genevois, the project of a Laboratory for Nuclear Research in Geneva, the leftist wing opposed it, fearing ***'Allegiance of the future scientific organization to the powers of the Atlantic Treaty'***, while Picot had argued precisely the opposite: ***'it is to free themselves from the American influence that European Scientists have decided to join efforts'.***



The workers party gathered enough signatures for a referendum proposing to prohibit establishment of any International institute performing atomic or nuclear research.

The initiative was defeated by a popular vote on 28 and 29 June 1953, after a bitterly fought campaign in which scientists took to the streets!

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Early Detectors

From Bubble to Wire Chambers

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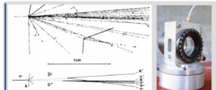
In the 1950s and 1960s, experimental particle physics made the transition to compact transistorised electronics for detector readout, allowing the speed and number of channels to increase.
Today, an LHC experiment acquires information from millions of channels every 25 ns and billions of events are recorded instead of O(100k) events for a typical bubble chamber experiment.

Bubble Chambers

give a beautiful representation of particles, they were invented by D. A. Glaser in 1952 (Nobel prize 1960): a charged particle leaves ~100 bubbles/cm that are registered by optical cameras on films. The images are projected on tables and "digitized" by visual inspection and semi-automatically recorded on data cards or (paper) tape.

Tracks in a bubble chamber showing a particle-antiparticle vertex

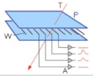


Specialized versions of bubble chambers have been used for their excellent vertex resolution: here, an event recorded with the Berne Infinitesimal Bubble Chamber (BIBC) (NA18 experiment, 1979-1989, study of charmed particles) showing two $D^{\pm}$ decays. Right: The 6.5 cm BIBC of Bern University

The photo shows two ladies at Lausanne University who inspect the images obtained with the 2m CERN bubble chamber of the experiments T173 and T210 at PS (1969-1980). The experiments measured hyperon production in pp and pn collisions at 4-5 GeV

Multi Wire Proportional Chambers (MWPCs)

In 1968 G. Charpak (Nobel 1992) presented a new detector concept: the charged particle (T) ionizes the gas in the region between cathode planes (P). The signal is collected on anode wires (W) and sent to amplifiers (A) and pulse shapers. The signals can then be digitized and stored.
In general two MWPC with orthogonal views are used to provide the (X,Y) position.



Here is a prototype built in Lausanne in 1969; it has 20 channels, but only the 4 central wires are read out on this prototype.
The MWPC was used in the SC19 experiment at CERN (1968-1973) which measured the capture π^- on p to test the isospin structure of electromagnetic current, the T symmetry in electromagnetic interactions, and the charge independence of strong interactions

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Particle Physics in Space

AMS 01 & 02 Measuring Charged Cosmic Rays

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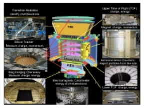
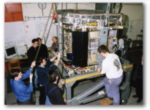
Alpha Magnetic Spectrometer (AMS) for the International Space Station (ISS)

AMS is a complex particle physics detector installed at the ISS to measure the components of charged cosmic rays with unprecedented precision. AMS-01 was a prototype detector in the Space Shuttle mission STS-91 (1998). In 2011 the highly improved AMS-02 was installed on the ISS and is successfully taking data since. It is planned to take data as long as the ISS is operational.
The AMS-02 detector contains a transition radiation detector, nine planes of silicon tracker, surrounded by an array of 16 anti-coincidence counters, an electromagnetic calorimeter, a time of flight detector with four planes of scintillating paddles and a ring image Cherenkov detector to measure and identify charged particles.

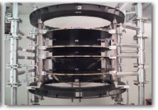


The majority of the silicon detectors for the AMS-01 and AMS-02 trackers were produced by University of Geneva and ETHZ.
ETHZ also contributed the high precision support structure for the AMS-01 tracker. This was later modified by University of Geneva for AMS-02.
The field of the permanent magnet for AMS-01 was measured by ETHZ. Originally, a superconducting magnet was built for AMS-02 where ETHZ contributed the superconducting cables and worked on the cryocooler electronics. When it was decided to significantly extend the AMS-02 operation time, it was necessary to switch back to the permanent magnet.
While AMS-01 was assembled at ETHZ, AMS-02 was assembled at CERN.
CERN also hosts the main operation center for AMS-02.



Assembly of AMS-01at ETHZ ...

and AMS-02 at CERN



Support Structure

Future Accelerators – the energy frontier

CLIC, HL-LHC, FCC

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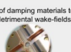
Future Accelerators at CERN

The Swiss accelerator community has been contributing to the development of CERN accelerators. Among these are the LHC complex, the HL-LHC upgrade and studies for the Compact LInear Collider (CLIC) and the Future Circular Collider (FCC) .
FCC studies a 100 km tunnel to host future circular colliders with the ultimate goal of reaching 100 TeV center-of-mass proton-proton collisions, and, as possible intermediate step, a high luminosity Z, W, H, top "factory" e^+e^- collider at energies between 90 and 365 GeV.

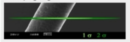
CLIC

CLIC studies have been supported by both the Paul Scherrer Institute and EPFL. Contributions have been made on the following topics:
The development of high gradient X-band accelerating structures.

- Studies of damping materials to reduce detrimental wake-fields in the linac.



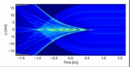
- High resolution diagnostics for beam position monitoring.
- Optics studies to reduce vertical beam emittance to 1 picometer in the damping rings.



HL-LHC

The Laboratory of Particle Accelerator Physics at EPFL in collaboration with the CERN Accelerator Physics groups worked on the high luminosity upgrade of the LHC. The team of EPFL has contributed on the following topics:

- Theoretical and numerical studies of beam-beam effects
- Studies of luminosity leveling
- Studies on electron cloud
- Collimation studies



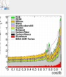
Simulation of the electron flux produced when the beam passes through the vacuum chamber. The lines show the electron flux, the colours the density of electrons. The higher the density, the brighter the colours.

FCC

- UNIGE studies the feasibility of polarized beams for FCC-ee
- EPFL studies beam-beam and collective effects for FCC-ee and FCC-hh
- UZH is developing tracking detectors and algorithms for the FCC-ee
- PSI and EPFL work on the injector concept and energy efficient high-temperature superconducting magnet solutions for FCC-ee

5cm bore solenoid 18.2 Tesla @12 K

Simulated material budget for a vertex detector at FCC



PSI, EPFL, Universität Zürich, Université de Genève

Antiproton Decelerator

Antihydrogen : ATHENA, AegIS, ALPHA-g & GBAR

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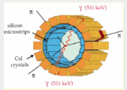
There is continuous Swiss contribution to the world-unique Antimatter Factory at CERN which provides low energy anti-protons for precision studies on antimatter. GeV antiprotons from a production target are cooled to about 5MeV in the AD-ring (Anti-proton decelerator) and further-on down to 100keV in the new ELENA facility (Extra Low ENergy Antiprotons). Main objects for precision studies are antihydrogen atoms, which are synthesised at several experiments at the lowest possible energies.

ATHENA (2002-2005)

Antihydrogen production



Antihydrogen annihilation on the trap wall. Black: trcks from the three charged pions. Red: two 511 keV annihilation photons.

The ATHENA experiment at AD demonstrated for the first time the large scale production of cold antihydrogen atoms [1] by merging antiproton and positron clouds in a nested Penning trap. The production was closely monitored by a cryogenic crystal- and tracking-detector for annihilation products of (neutral) antihydrogen atoms, which escape the trapping region and annihilate on the trap walls. The event signature is an opening angle close to 180 degrees of two detected 511keV photons (from the positron annihilation) in respect to the annihilation vertex of the pions (from the antiproton annihilation).

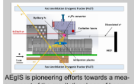
Several tens of thousands of antihydrogen atoms can be produced in nested Penning traps per mixing, the base for present high precision measurements on antihydrogen at the AD.

[1] M.Amoretti, et al., Nature 419 (2002) 456

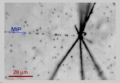
Universität Zürich

AEgIS (since 2012)

Gravity, Interferometry, Spectroscopy



AEgIS is pioneering efforts towards a measurement of the gravitational sag of beam like antihydrogen in a Moiré deflectometer. At first antihydrogen atoms are produced by collision of Rydberg state positronium and trapped antiprotons, a process confirmed in 2020. Present efforts comprise to give the produced antiatoms a forward boost and to increase the production rate.



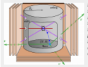
For the gravity measurement highest spatial resolutions are necessary. Nuclear emulsions can measure the annihilation vertex of antihydrogen on a surface with a precision of 1 micron. A large reduction of data taking time is achieved when combining the signal with an electronic time of flight measurement.
In 2023 the ALPHA-g experiment showed for the first time in a direct measurement that the response of gravity to antimatter has the same directional sign as for normal matter.

ETH Zürich, Universität Zürich

GBAR

Gravitational Behaviour of Antihydrogen at Rest

The GBAR experiment at ELENA is aiming to synthesise positive anti-hydrogen ions in a 2-step collision process of antiprotons with positronium atoms. Such ions consist of one antiproton and two positrons and represent the charge conjugated state to H^- ions. They can be sympathetically laser cooled with Be^+ ions, to achieve ultra low temperatures (10 μK and below), which will open a new domain for precision tests on antimatter. The main goal of GBAR is the precise determination of the acceleration of antimatter in the earth gravitational field. This should be done by laser detachment of the outer positron causing the free fall of the neutral atom. The annihilation vertex at the bottom of a UHV vessel is observed by a multilayer Micromegas tracking detector.



Principle of the free fall measurement: blue: anti-H trajectory from trap to surface; green: particles produced by the annihilation; orange:Micromega detectors

A further benefit of the 2-step production process is the copious generation of beam like antihydrogen atoms in the metastable 2S state. For this purpose a microwave excitation system and Lyman alpha photon detector was installed to measure the (field free) 2S-2P Lamb shift of antihydrogen atoms. This measurement is sensitive to the antiproton charge radius.
In 2022 first antihydrogen atoms were produced in GBAR and recently the experiment was completed with an antiproton cooling trap which is now in the commissioning phase.

ETH Zürich

Specialized Experiments

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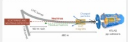
With an expanding interest in undiscovered particles - particularly long-lived and dark matter particles - and the properties of neutrinos new specialized experiments have been proposed to expand the scientific potential of CERN's accelerator complex and infrastructure. While FASER and SND@LHC are located at the LHC, NA64 and NA62 use the beams of SPS.
Swiss institutes contribute significantly to the detector's design and construction, readout, trigger, data acquisition and data analyses

FASER experiment during installation

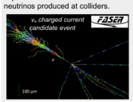
FASER & SND@LHC

The two experiments are positioned on opposite sides of the ATLAS interaction point, about 500 meters away from it and on the line-of-sight of the collision.

Sketch of the SND@LHC experiment



The experiments search for light, feebly interacting particles (FIPs) and provide a unique capability to study the properties of neutrinos created in a collider. These neutrinos are the highest-energy produced by an artificial source. In 2023 the two experiments observed the first neutrinos produced at colliders.



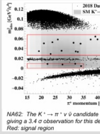
FASER: ETH Zürich, Université de Genève — SND@LHC: Universität Zürich, EPFL

NA64

Is a fixed target experiment searching for FIPs from the dark sector eg dark photons or light dark bosons. It uses the electron and the muon beam from SPS

NA62

Is a fixed target experiment to study rare kaon decays and the dark sector.

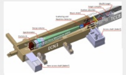


NA62: The $K^+ \to \pi^+ \nu \bar{\nu}$ candidate events giving a 3.4 σ observation for this decay. Red: signal region

NA64: ETH Zürich — NA62: EPFL

SHiP

SHiP (Search for Hidden Particles) is a future experiment that searches for new weakly interacting particles.
It is designed and optimized to search for very-weakly-interacting long-lived particles in the GeV regime, and will be located at a new SPS Beam Dump Facility at CERN.
A proton beam from SPS will be directed to hit a fixed target and produce a variety of particles, including charm mesons and photons. When these particles decay or interact with each other, they can create the hidden particles that SHiP is searching for. The experiment was approved 2024, construction is scheduled to start in 2027.



Sketch of SHiP

EPFL, Universität Zürich