CERN: 70 Years of Scientific Achievements and Innovation

BCVSPIN, 13 December 2024, Kathmandu

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CERN

CERN | 70 YEARS / ANS CERN

Peaceful scientific collaboration: a vision takes shape

1945: Europe is in ruins after World War II

1946: French proposal to the United Nations

1949: European Cultural Conference, Lausanne

Common vision of politicians and scientists

Renew peaceful collaboration following the destruction of war

Focus on fundamental scientific research at a scale beyond the capacity of any single nation

Restore scientific excellence and reverse and prevent brain drain

1940s: first proposals

Louis de Broglie proposed: "*the creation of a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the different participating states [Endowed with more resources than national facilities, such a laboratory could] undertake tasks, which, by virtue of their size and cost, were beyond the scope of individual countries*".

1950: UNESCO Conference

US Nobel laureate Isidor Rabi tables a resolution authorising UNESCO to:

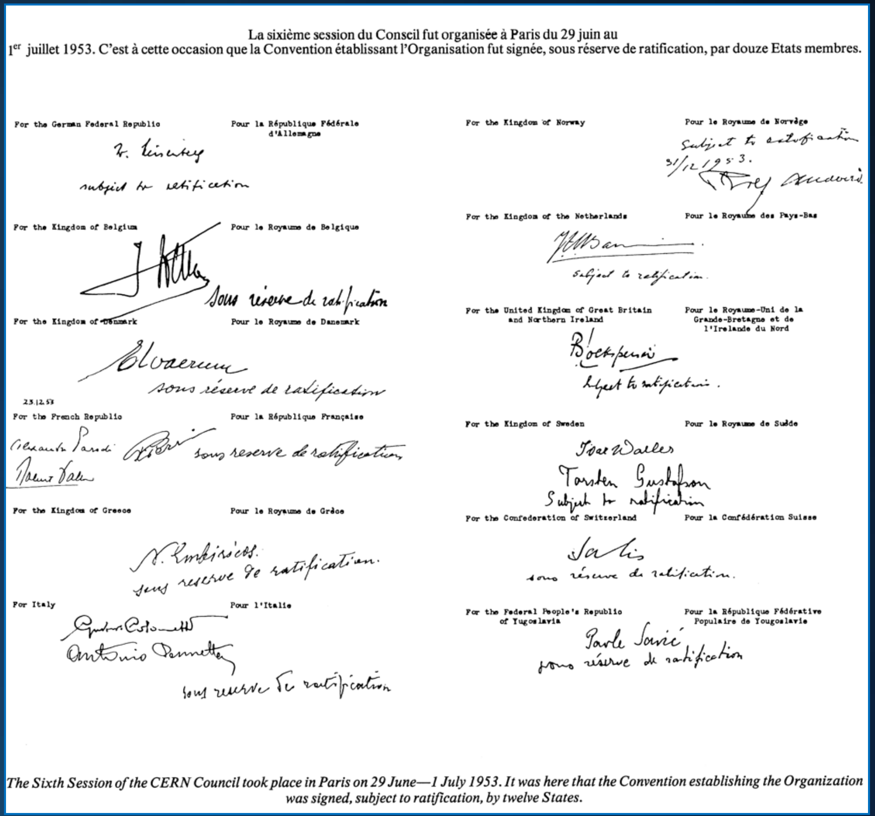
“assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration…”

1951: UNESCO Resolution

- At a meeting of UNESCO in Paris in December 1951, the first resolution concerning the establishment of a European Council for Nuclear Research was adopted.
- Two months later, 11 countries signed an agreement establishing the provisional Council – **the acronym CERN was born**. Edoardo Amaldi was made Secretary-General

1954: CERN is born

- The CERN Convention, established in July 1953, was ratified by 12 founding Member States: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the UK, and Yugoslavia.
- On 29 September 1954, the European Organization for Nuclear Research officially came into being.
- CERN was dissolved but the acronym remains.



La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

For the German Federal Republic — Pour la République Fédérale d'Allemagne

For the Kingdom of Norway — Pour le Royaume de Norvège

For the Kingdom of Belgium — Pour le Royaume de Belgique

For the Kingdom of the Netherlands — Pour le Royaume des Pays-Bas

For the Kingdom of Denmark — Pour le Royaume de Danemark

For the United Kingdom of Great Britain and Northern Ireland — Pour le Royaume-Uni de la Grande-Bretagne et de l'Irelande du Nord

23.12.53

For the French Republic — Pour la République Française

For the Kingdom of Sweden — Pour le Royaume de Suède

For the Kingdom of Greece — Pour le Royaume de Grèce

For the Confederation of Switzerland — Pour la Confédération Suisse

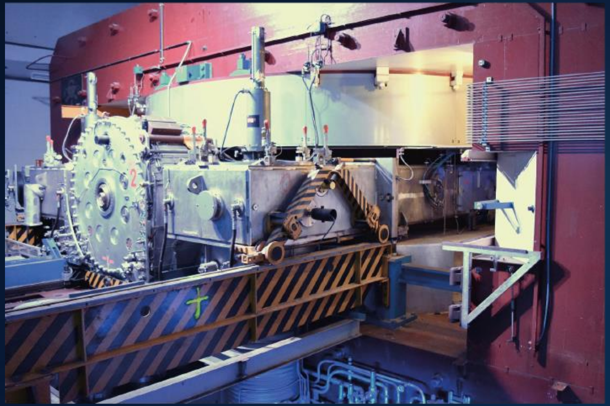
For Italy — Pour l'Italie

For the Federal People's Republic of Yugoslavia — Pour la République Fédérative Populaire de Yougoslavie

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.

The convention was signed at the Sixth session of the CERN Council in Paris on 29 June - 1 July.

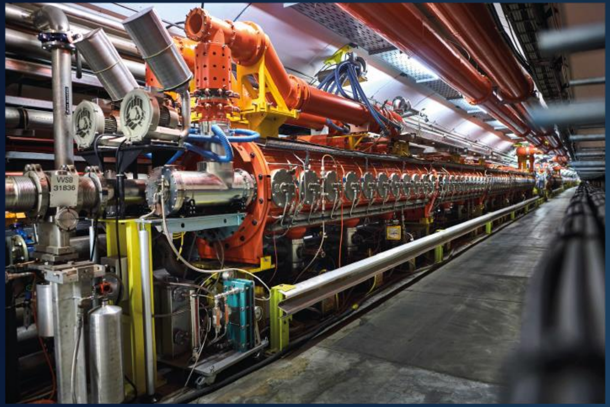
SC 0.6 GeV $\sqrt{s} \approx 1.7\ GeV$



PS – 28 GeV $\sqrt{s} \approx 7.3\ GeV$

ISR - 31.5 GeV $\sqrt{s} \approx 63\ GeV$

SPS – 630 GeV. $\sqrt{s} \approx 34.4 GeV$
(→ 1981) Sp$\bar{\text{p}}$S $\sqrt{s} \approx 540 GeV$



LEP – 104.5 GeV $\sqrt{s} \approx 209\ GeV$

LHC – 6800 GeV $\sqrt{s} \approx 13.6\ TeV$

1957 1959 1971 1976 1989 2009

1958: CERN's first discovery

1957: the **Synchrocyclotron is** CERN's first accelerator to begin operation (600 MeV proton beam)

Discovery of "rare pion decays" 1958-1962

$$R = \frac{\Gamma(\pi \rightarrow e v_e)}{\Gamma(\pi \rightarrow \mu v_\mu)} = (1.22 \pm 0.30) \times 10^{-4} \quad [1]$$

G. Fidecaro et al.

Crucial verification of a universal "weak" force with a Vector - Axial coupling

A turning point for the emerging electroweak theory

[1] Ashkin, J., Fazzini, T., Fidecaro, G. *et al*. The electron decay mode of the pion. *Nuovo Cim* **13**, 1240–1262 (1959). https://doi.org/10.1007/BF02725130

1973: the discovery of neutral currents

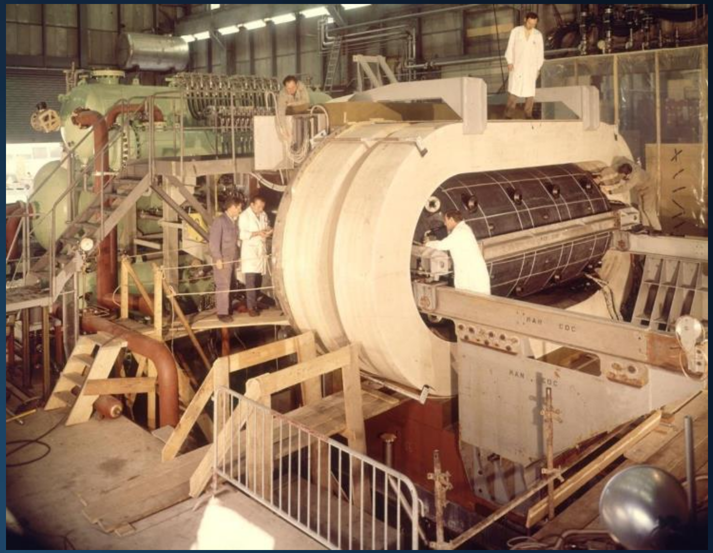
1959: the **Proton Synchrotron** (PS) begins operation
proton beam of 24 GeV (briefly the highest-energy accelerator)

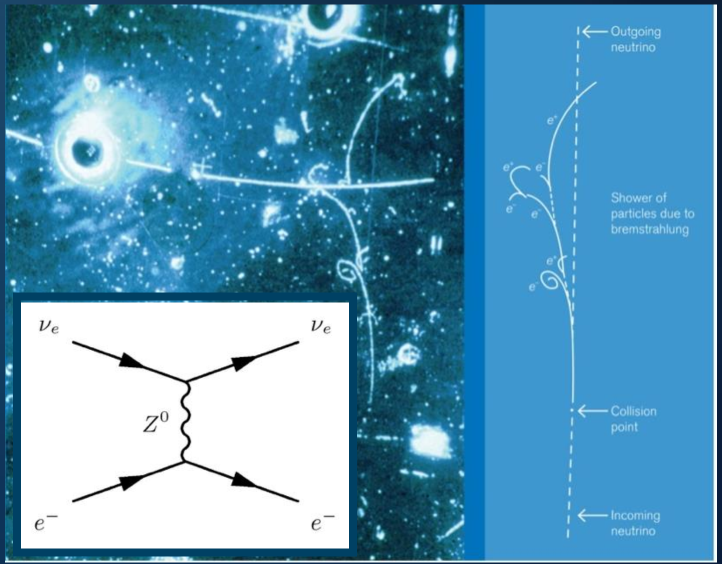
With the PS CERN entered the “high-energy neutrino beam era”

Gargamelle (4.8 m x 2 m, 1000 tonnes, 12 m^3 heavy-liquid freon)

discovery of neutral currents
⇨ establishes the electroweak theory

essential support for the quark model, and essential contributions to the confirmation of their fractional charge





Discovery of neutral currents

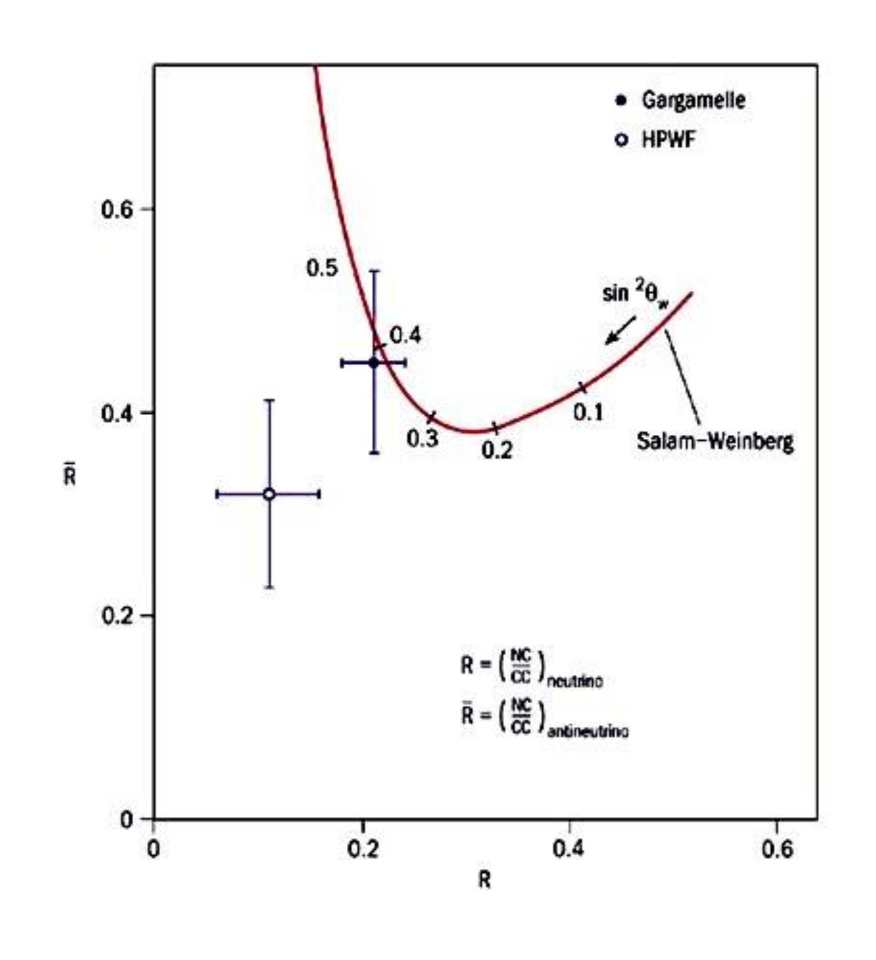
Combined rate measurement of neutral and charged current events using neutrino and anti-neutrino beams:

⇨ first direct evidence for the existence of the W and Z bosons as well as of their mass

$$M_W = \sqrt{\frac{\pi\alpha}{\sqrt{2}G_F}} \cdot \frac{1}{\sin\theta_W} = \frac{37\ GeV}{\sin\theta_W} \approx 70\ GeV$$

well before the direct observation of W and Z

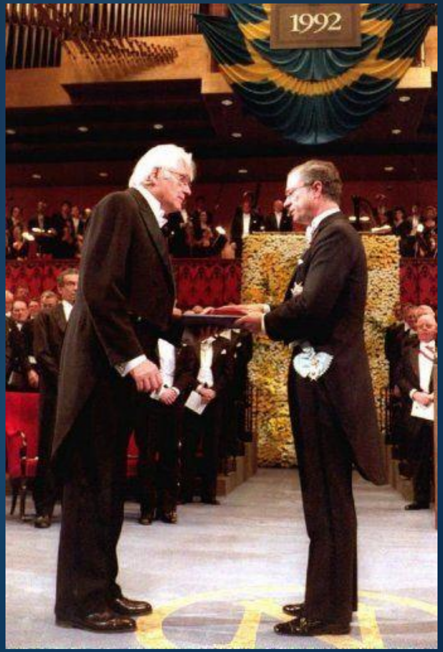
⇨ guided the CERN future accelerator path



Georges Charpak:
Revolutionizing particle detection

from “visual detectors” to “electronic detectors”

1971-1972 – Large-size Multiwire Proportional Chamber



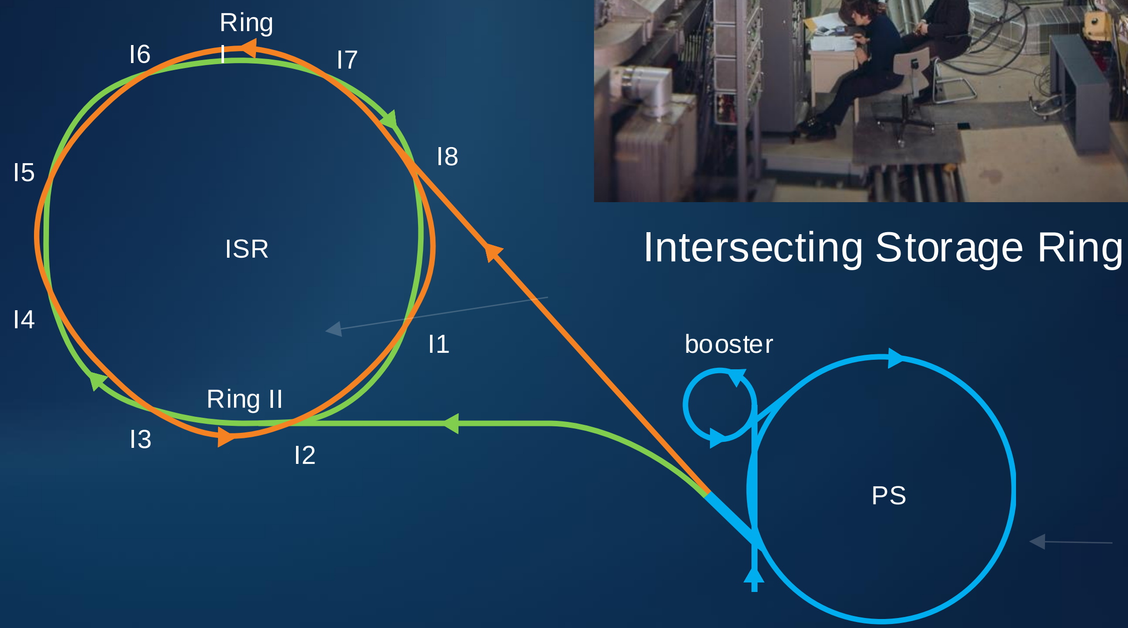
1992 Nobel award ceremony

Intersecting Storage Rings

- The **Intersecting Storage Rings** was the **World's first hadron collider** (protons, centre of mass energy of up to 62 GeV)

- The rings crossing angle and the detectors were designed to capture the forward-going debris from collisions

- Crucial contributions to QCD, the emerging theory of the strong nuclear force and the structure of hadrons, complementing the findings from the deep inelastic scattering experiments at SLAC



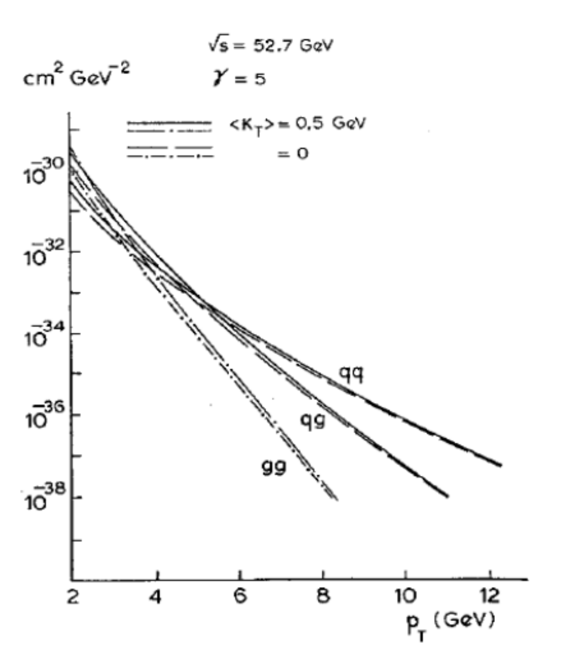
Intersecting Storage Ring

Intersecting Storage Ring

- 1972-1973: ISR announces the observation of totally unexpected production of hadrons at large transverse momentum.

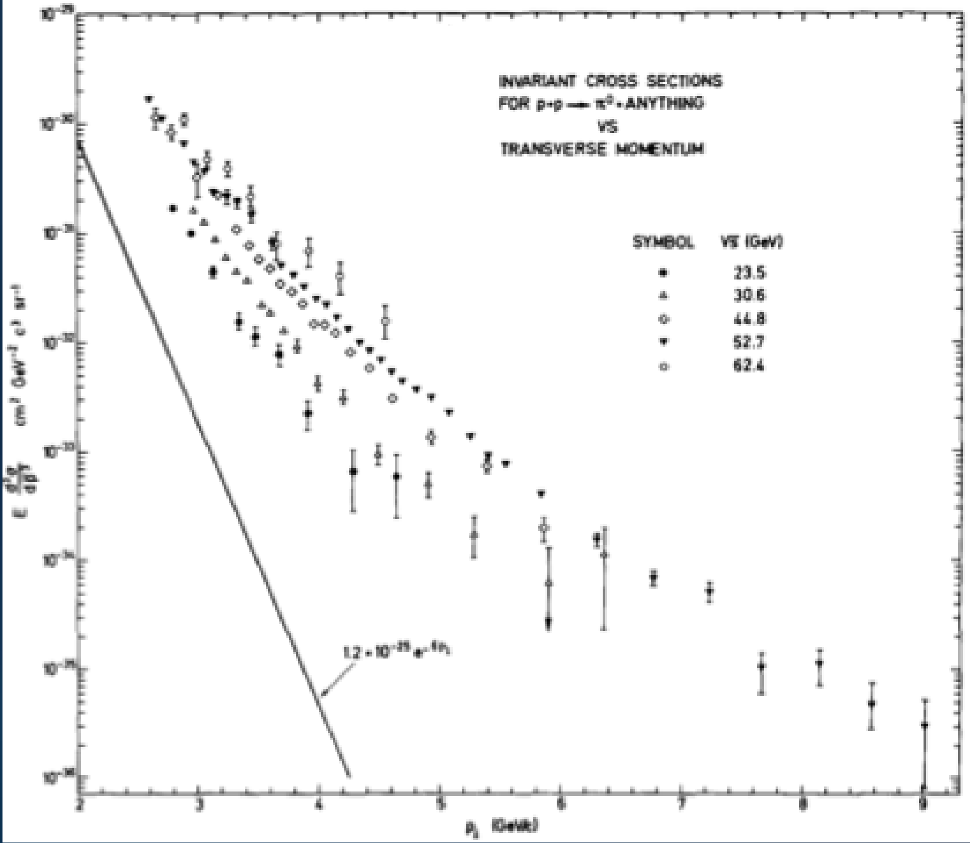
- A shocking surprise, but consistent with the emerging view (QCD) of protons made of quarks and gluons.

- New QCD predictions treating proton collisions as collisions between quarks (qq), gluons (gg) or mixed (qg)



CERN – Columbia – Rockefeller coll., Phys. Lett. B46 (1973) 471

Results presented at the 1972 Int. Conf. on High Energy Physics

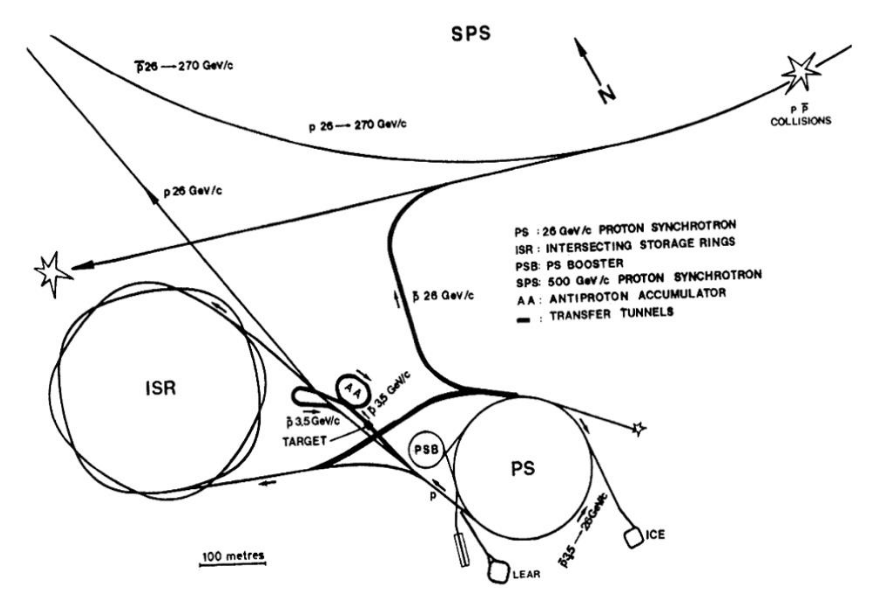


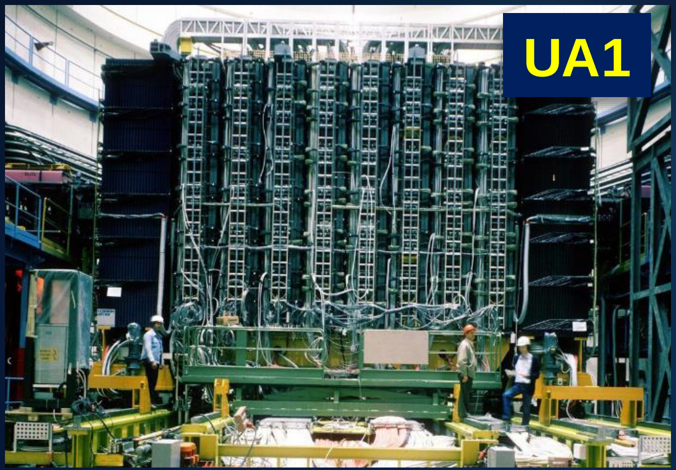
1983: discovery of the W and Z

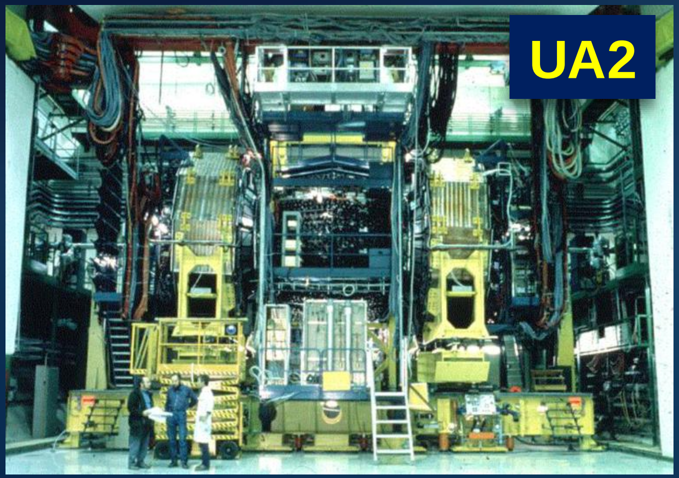
- Gargamelle and the discovery of neutral currents guided the search: look in the region 60-100 GeV

- In 1976 Rubbia proposes to modify the SpS into a collider of protons and antiprotons

- First collisions at $\sqrt{s} = 540\ \mathrm{GeV}$ were obtained in 1981



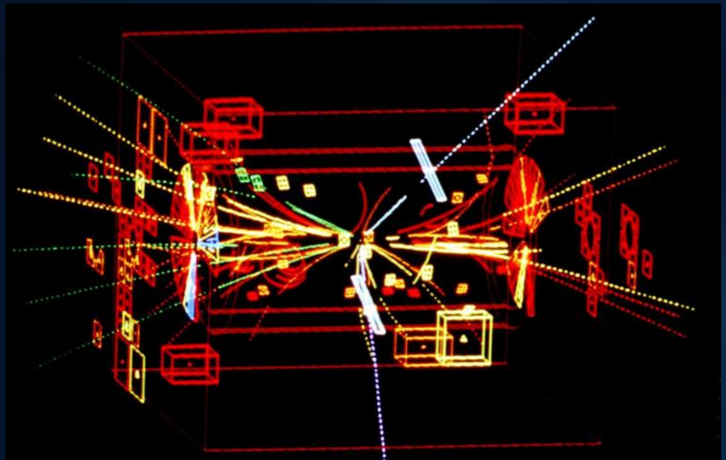




Two detectors UA1 and UA2 were built to detect the elusive W and Z through their decays into leptons.

1983: discovery of the W and Z

- UA1 and UA2 presented the first results (in two separate seminars) at CERN on 20 and 21 **January 1983**
- 6 candidates for both experiments with high energy electrons and high missing energy (i.e. neutrinos).
- **The quest for the W boson was over!**



Z^0 decay event recorded by UA1 in 1983

In **July 1983**, **clear evidence of the Z boson** was also presented.

Carlo Rubbia and Simon van der Meer were awarded the 1984 Nobel prize

Nailing down the Standard Model

In the mid-1970s the Standard Model was an attractive theory, but many aspects were still unknown:

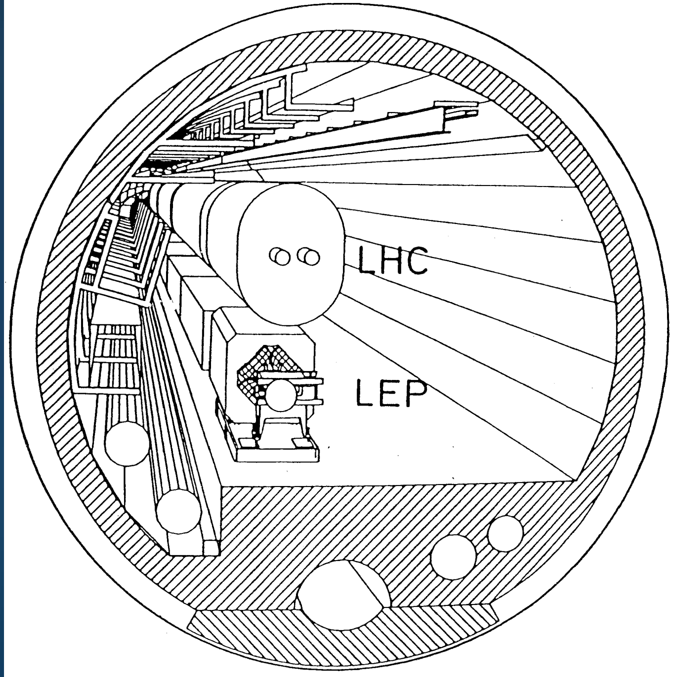
- QCD was increasingly confirmed, but the number of families (both for leptons and for quarks) was unclear. CP violation provided some clue for the quark sector, but not much for leptons.
- The vector bosons, which mediate the electroweak force, were believed to be around the corner, in the 60 - 100 GeV range.

In 1976, CERN established a study group for a Large Electron–Positron Collider (LEP) to produce and study the W and Z bosons.

LEP was approved in 1982, around the time as the discovery of the W and Z bosons.

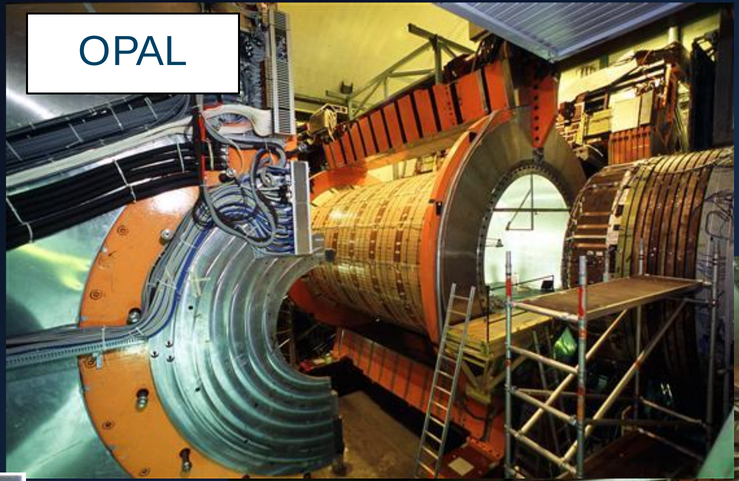
ECFA – CERN Workshop
Lausanne, 5 Sep 1984

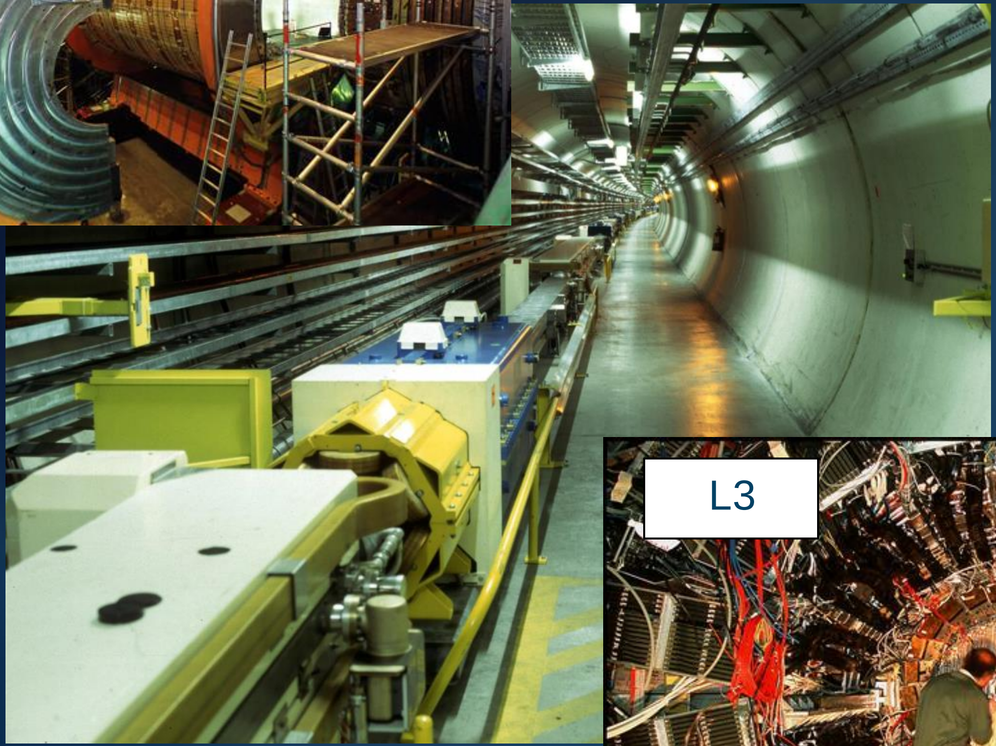
Thes possibility of hosting the LHC was one of the motivations for a 27km tunnel.

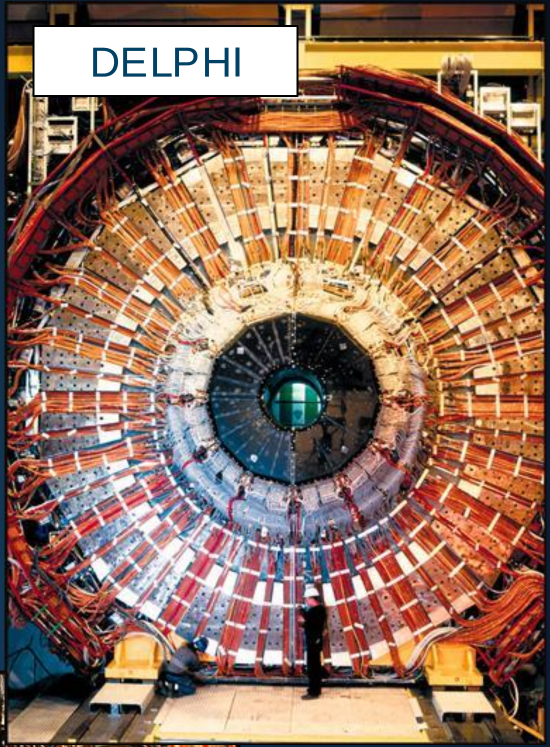


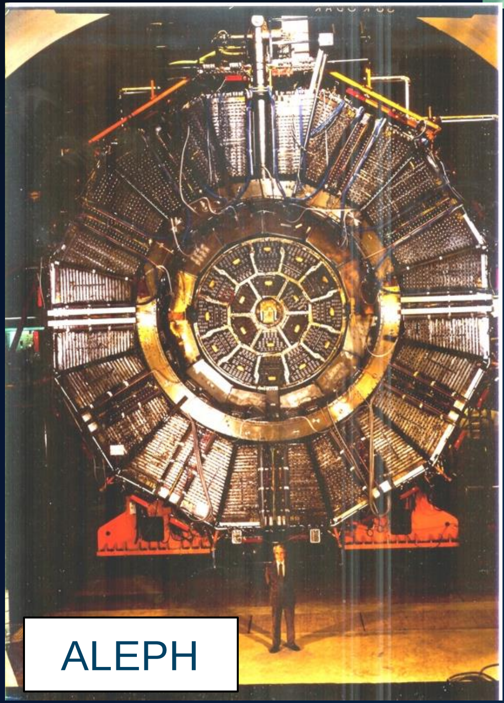
LARGE HADRON COLLIDER
IN THE LEP TUNNEL

LEP era



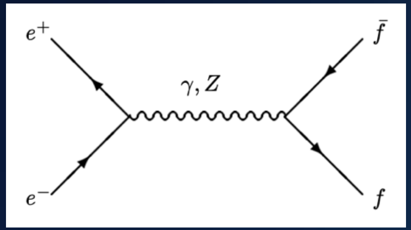




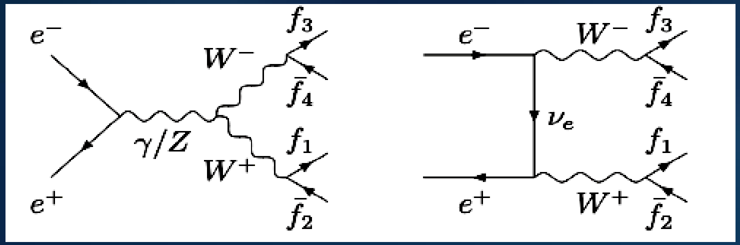


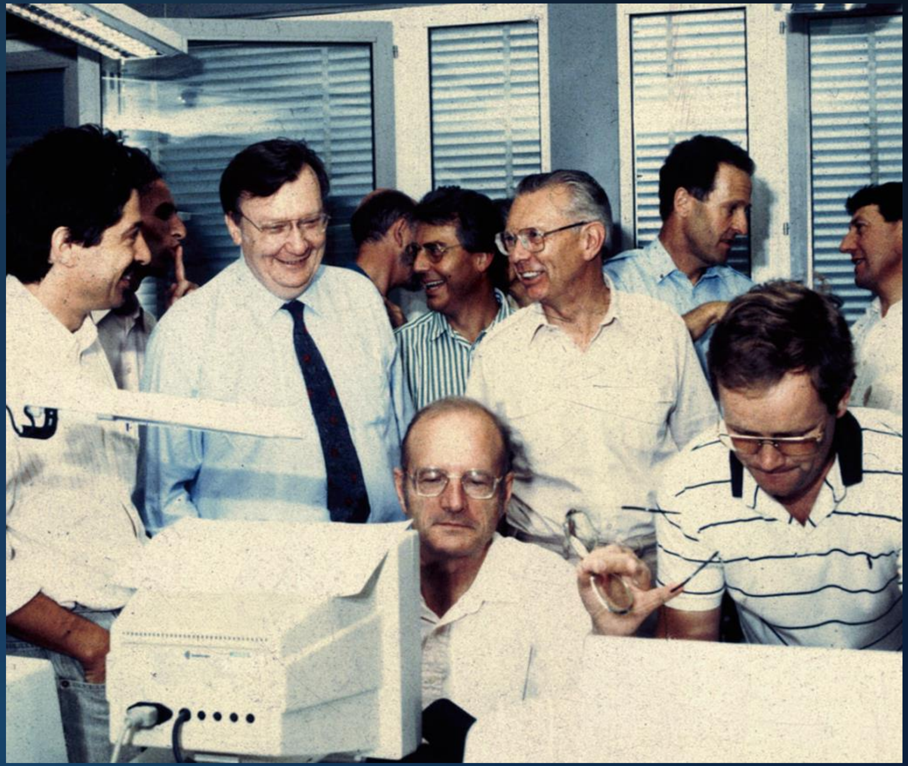
LEP era

- First beams in LEP: 15 July 1989
- LEP 1: center of mass energy around the mass of the Z boson (91 GeV) for 7 years. LEP was a Z-factory with millions of produced Z bosons.



- LEP 2: starting in 1996, energy reached and surpassed the threshold for production of 2 W boson (160 GeV). Max energy reached 209 GeV.





The World Wide Web

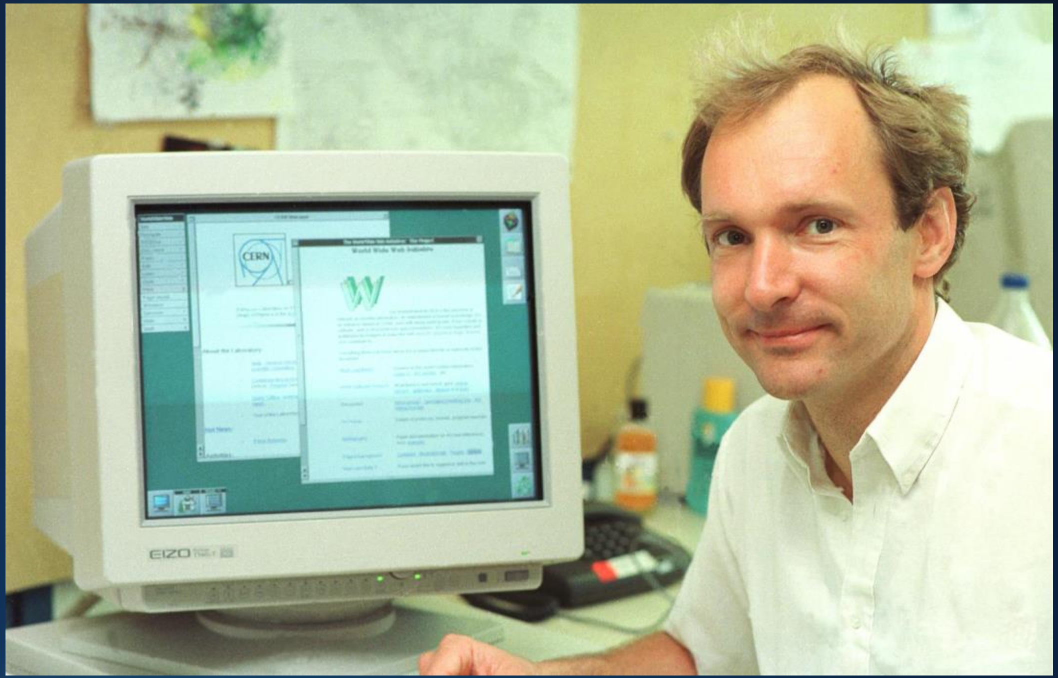
March 1989: Tim Berners Lee submits the first proposal for the World Wide Web

merge data networks and hypertext in an easy-to-use global information system

By the end of 1990, the first Web server and browser is up and running

In 1993, CERN makes the source code of the World Wide Web available on a royalty-free basis

By the end of 1994, the Web already has **10,000 servers** and **10 million users**



Tim Berners Lee displaying some of the first web pages in 1994

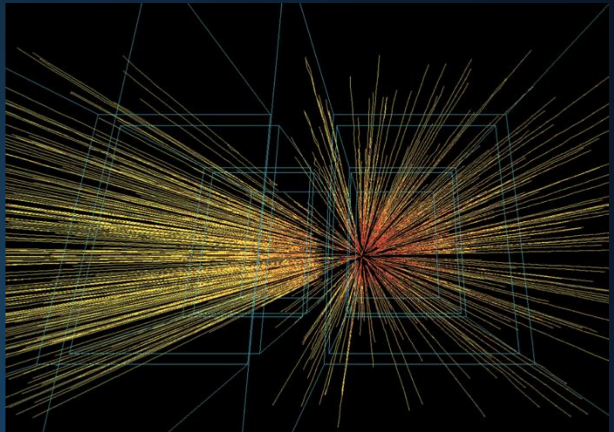
Discovery of direct CP Violation

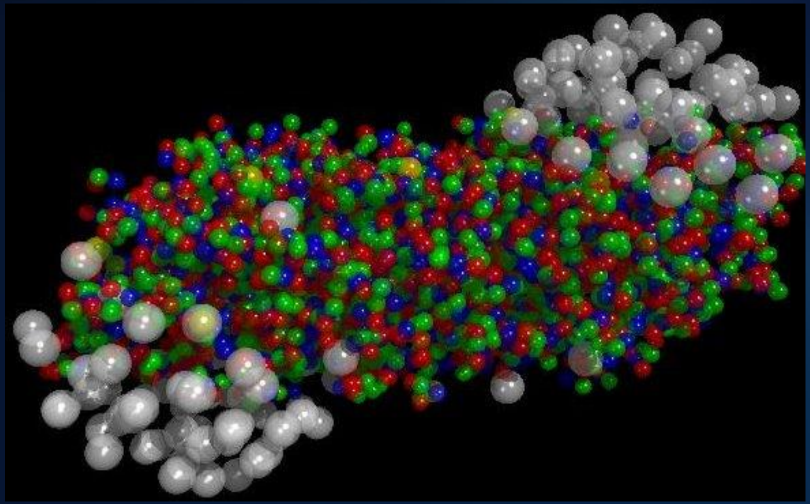
- CERN uses the powerful SPS beam to produce conspicuous yields of Kaons
- Two generations of experiments, NA31 and NA48, were setup between 1982 and 1993 to study direct CP violation through kaon decays
- NA31: first evidence of direct CP violation (a 3 standard deviation effect) in 1988.
- NA48 (final publication in 2002): observation well above 5 standard deviation.

$\varepsilon \sim 2.2 \times 10^{-3}$ indirect $\varepsilon'/\varepsilon \sim 1.7 \times 10^{-3}$ direct

CERN, February 2000: first evidence of a new state of matter, the quark-gluon plasma

- Combined data from the 7 experiments on CERN's HI programme
- Proves an important prediction of the QCD theory. An important step forward in the understanding of the early evolution of the Universe.


Event recorded by NA49 at SPS



Luciano Maiani (CERN DG): "… We now have evidence of a new state of matter where quarks and gluons are not confined. … There is still an entirely new territory to be explored concerning the physical properties of quark-gluon matter. The challenge now passes to RHIC at BNL and later to the LHC."

The Large Hadron Collider era

ATLAS

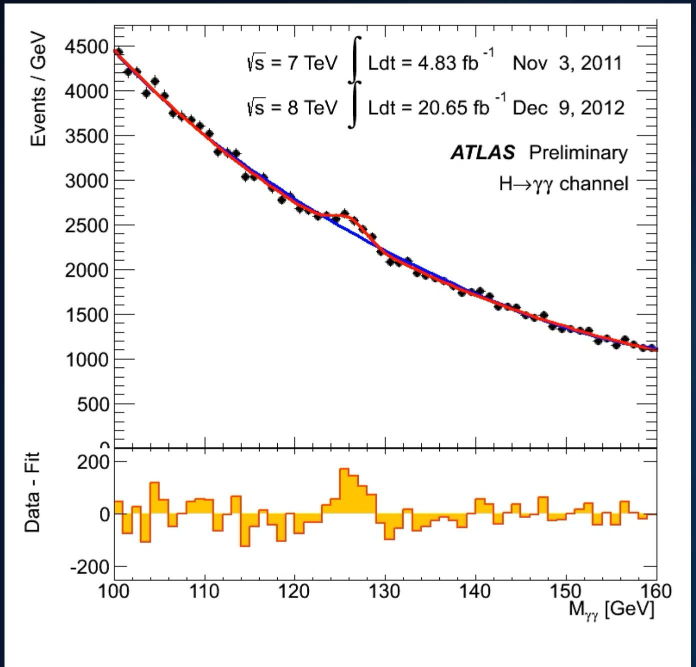
CMS

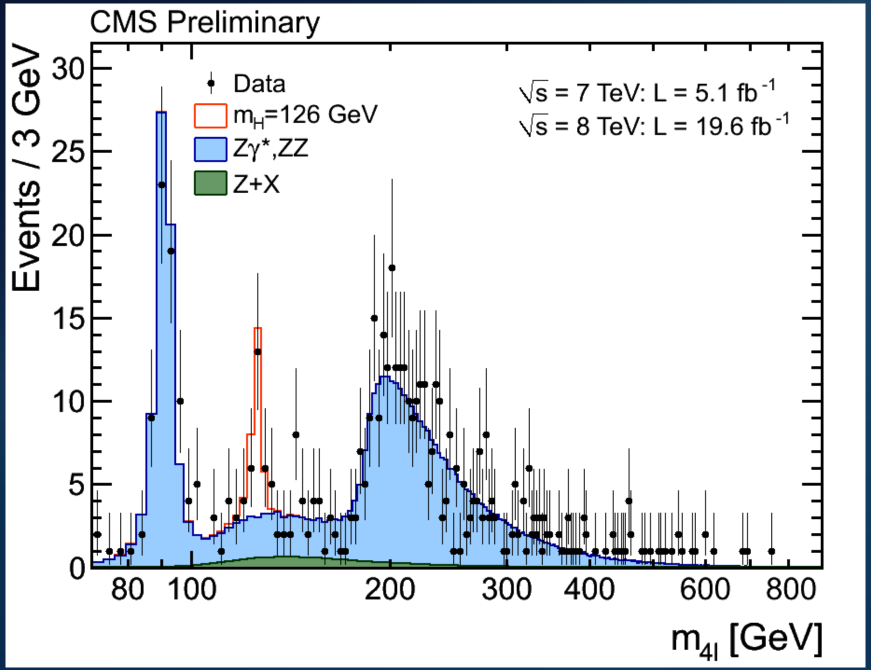
ALICE

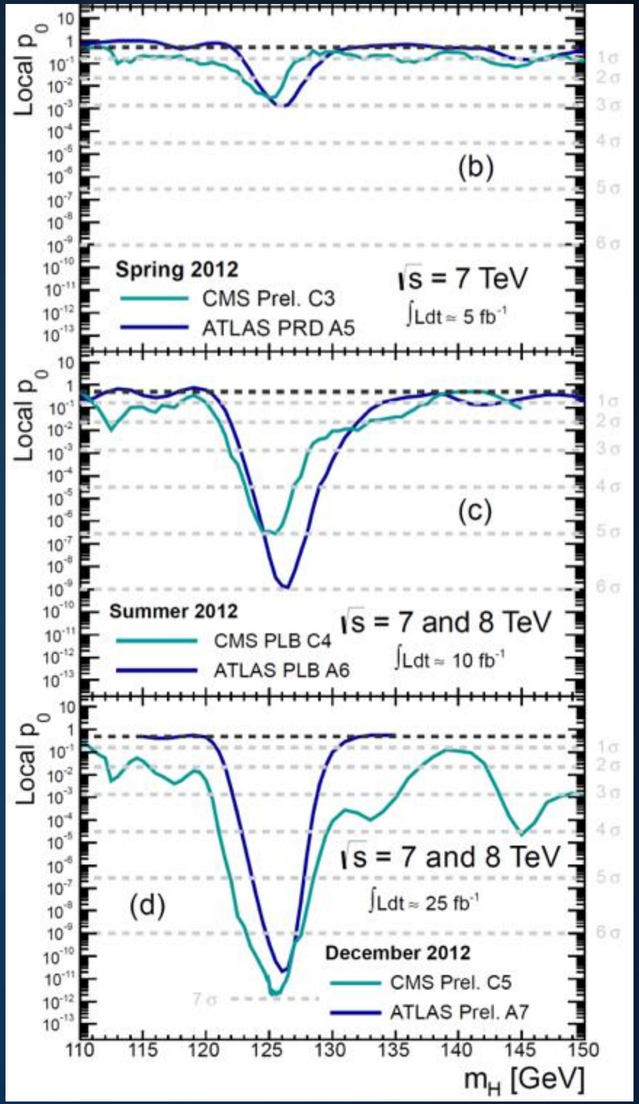
LHCb

Higgs discovery

- End of 2011: tantalizing hint, the trail begins
- Summer 2012: discovery! 5σ from both experiments
- End of 2012: confirmation! Measurement era begins







Higgs discovery … and the SM triumph

July 4th 2012 announcement

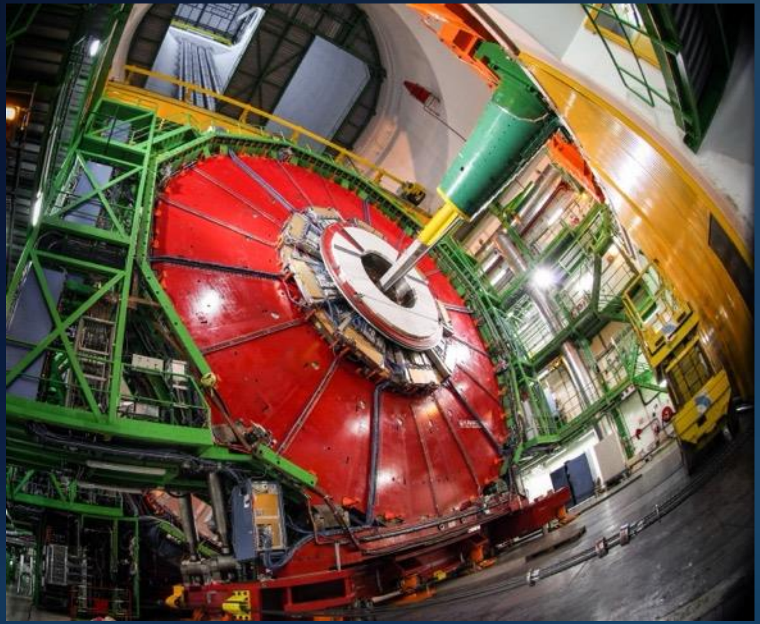

F. Gianotti (ATLAS) and J. Incandela (CMS)


F. Englert and P. Higgs

2013 Nobel Prize

CERN develops technologies in three key areas

ACCELERATORS



DETECTORS

COMPUTING

As we celebrate CERN’s 70th anniversary

we look forward to a future where CERN continues to play a pivotal role in particle physics, technology innovation and international collaboration

CERN | YEARS / ANS CERN