

# Historic perspective of 70 Years of CERN

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Future Colliders and the ESPP for Early-Career Researchers at CERN  
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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

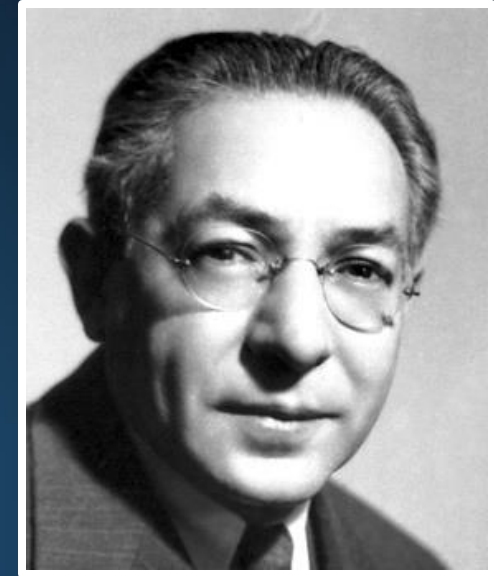
Louis de Broglie proposed: *"the creation of a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the different participating states [Endowed with more resources than national facilities, such a laboratory could] undertake tasks, which, by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

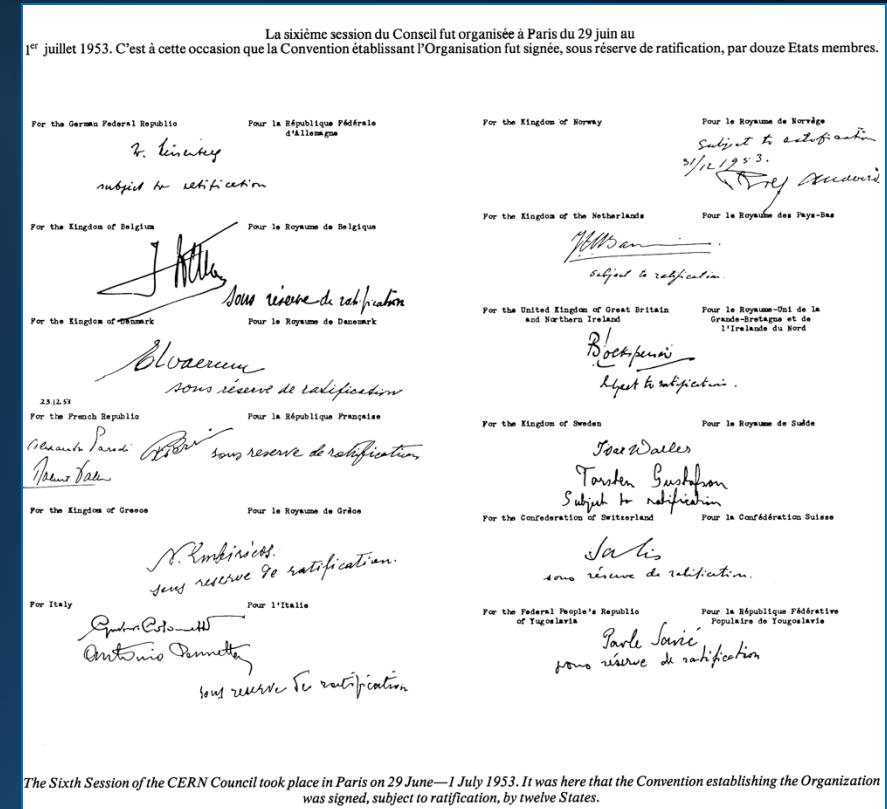


## 1951: UNESCO Resolution

- 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.



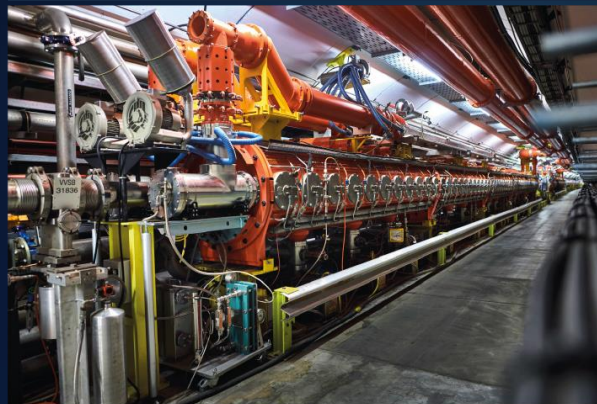
The convention was signed at the Sixth session of the CERN Council in Paris on 29 June - 1 July.

PS – 28 GeV

$$\sqrt{s} \approx 7.3 \text{ GeV}$$



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



LHC – 6800 GeV

$$\sqrt{s} \approx 13.6 \text{ TeV}$$



SC 0.6 GeV

$$\sqrt{s} \approx 1.7 \text{ GeV}$$



ISR - 31.5 GeV

$$\sqrt{s} \approx 63 \text{ GeV}$$



LEP – 104.5 GeV

$$\sqrt{s} \approx 209 \text{ GeV}$$



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

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

*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)

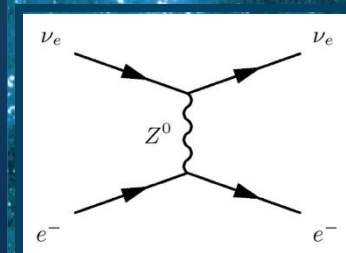
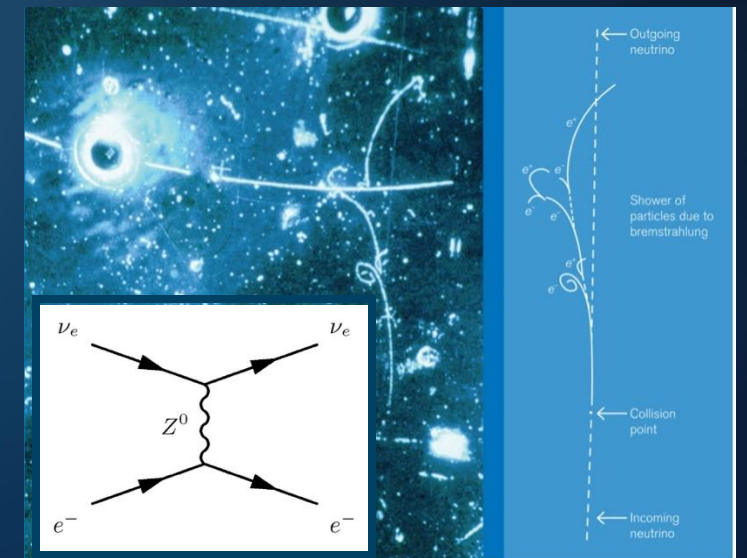
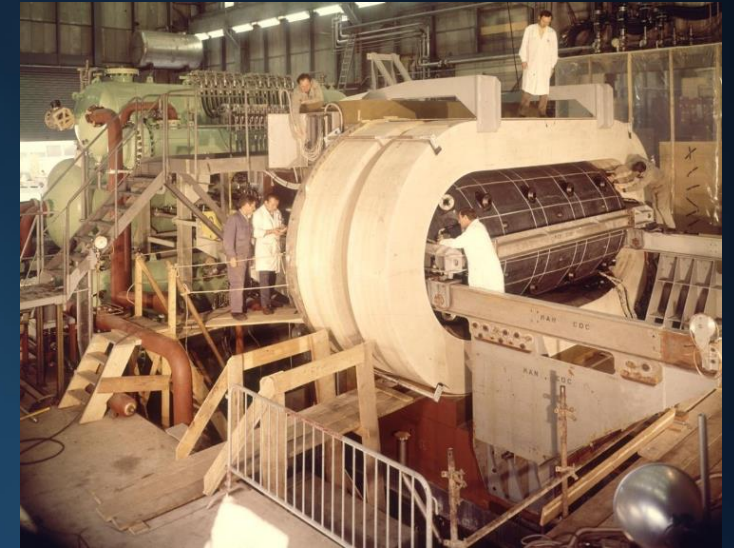
With the PS CERN entered the “high-energy neutrino beam era”

**Gargamelle** (4.8 m x 2 m, 1000 tonnes, 12 m<sup>3</sup> 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

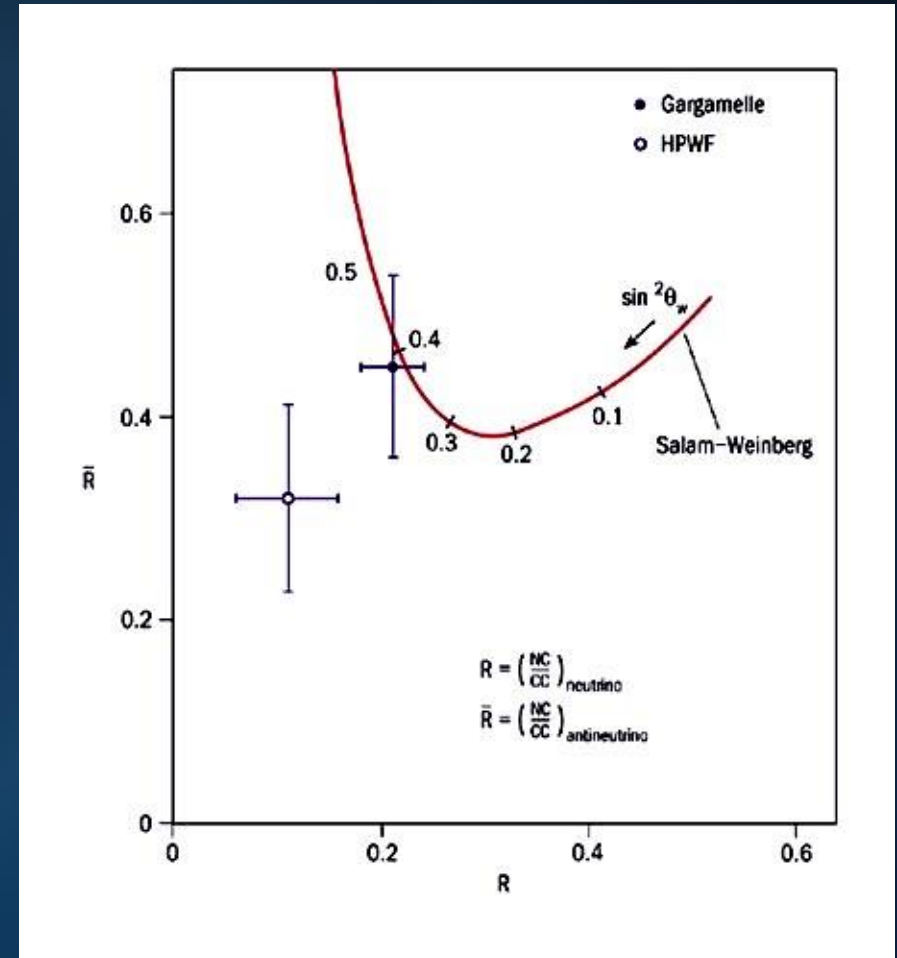
Combined rate measurement of neutral and charged current events using neutrino and anti-neutrino beams:

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

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

well before the direct observation of W and Z

⇒ guided the CERN future accelerator path

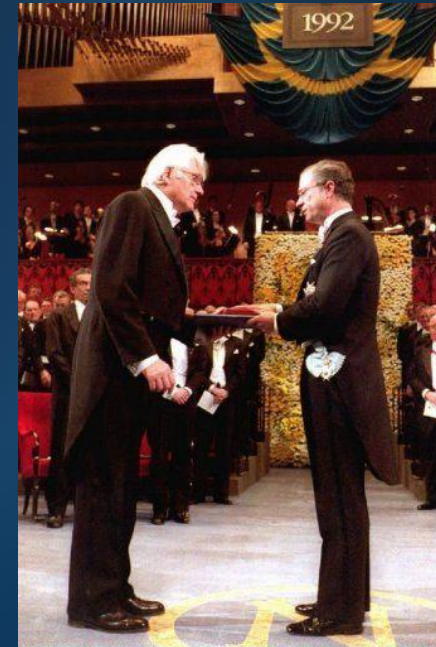


# Georges Charpak: Revolutionizing particle detection

from “visual detectors” to “electronic detectors”



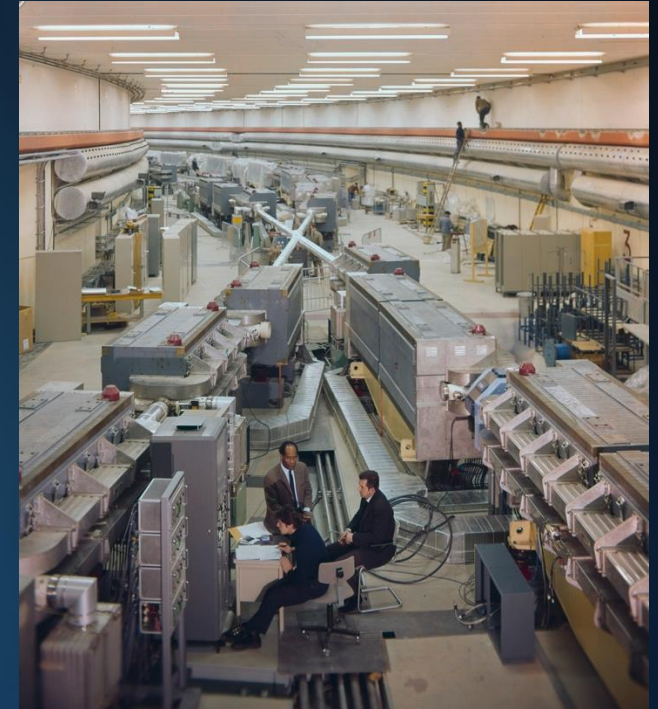
1971-1972 – Large-size Multiwire Proportional Chamber



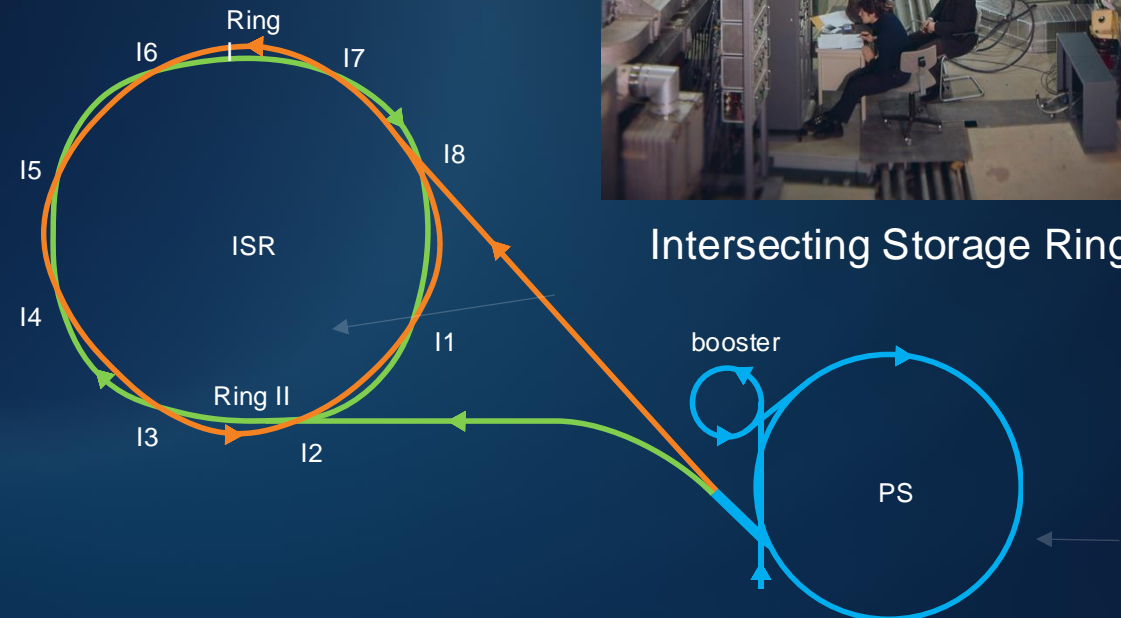
1992 Nobel award ceremony

# 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

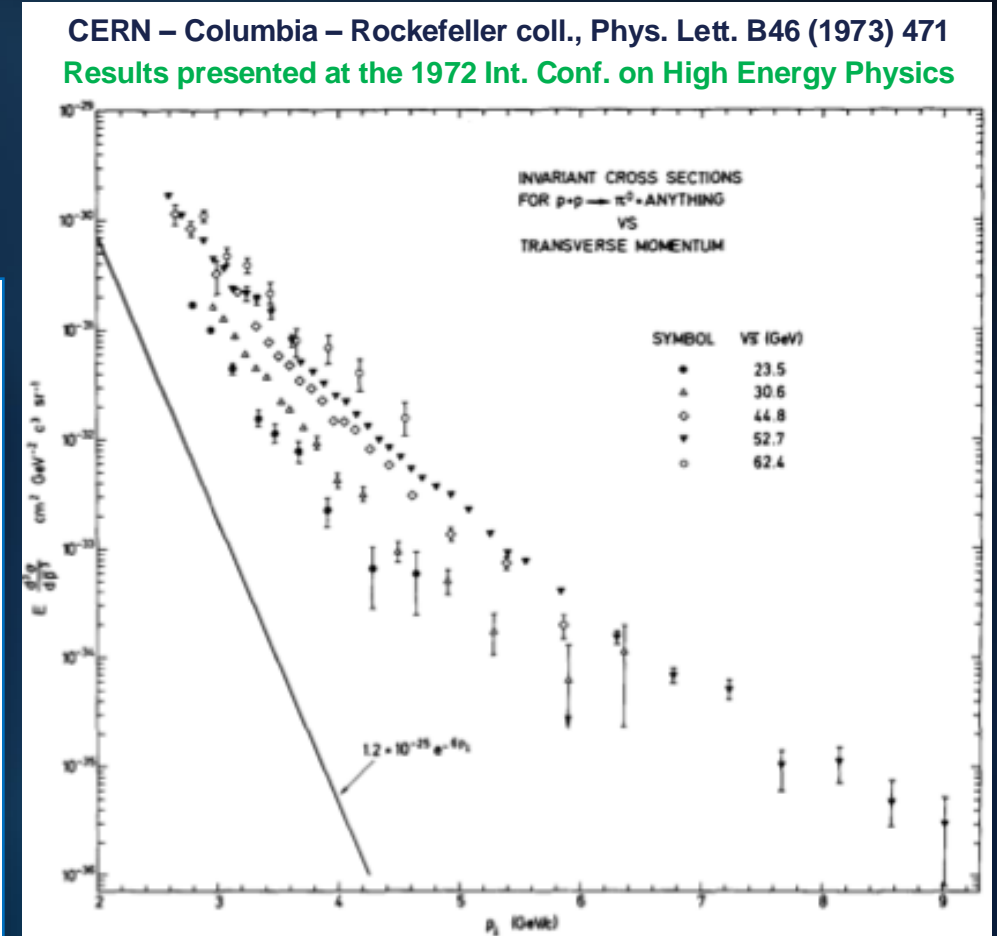
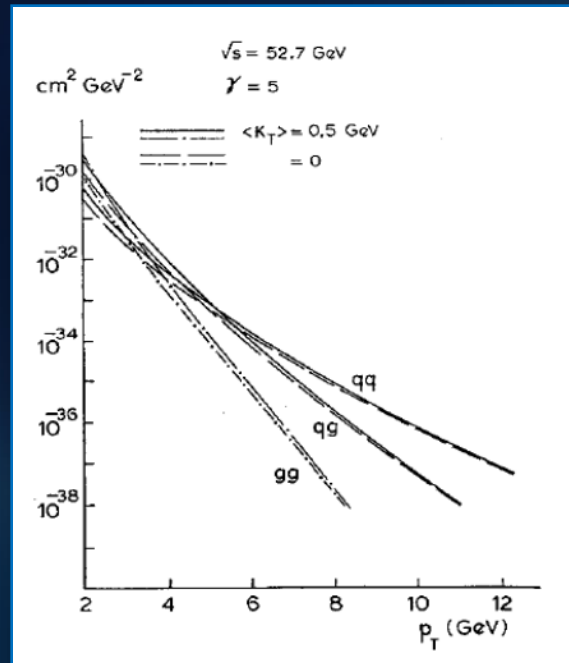


Intersecting Storage Ring



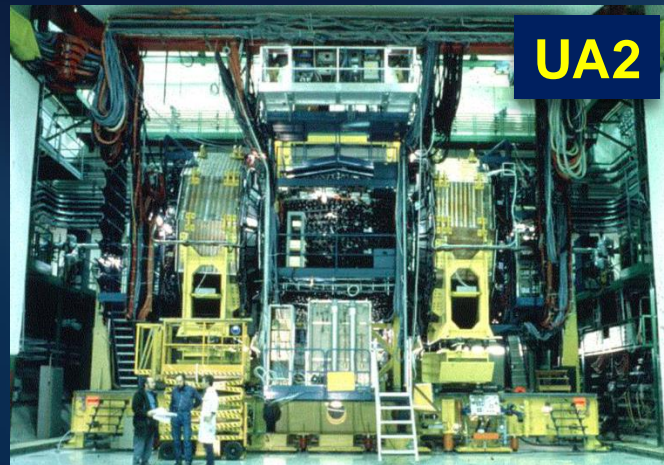
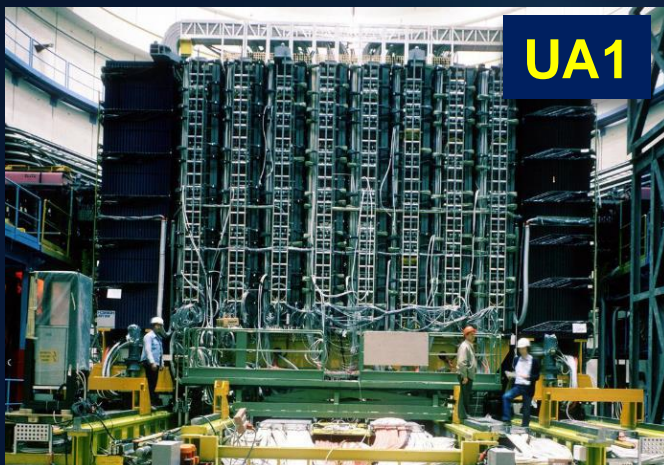
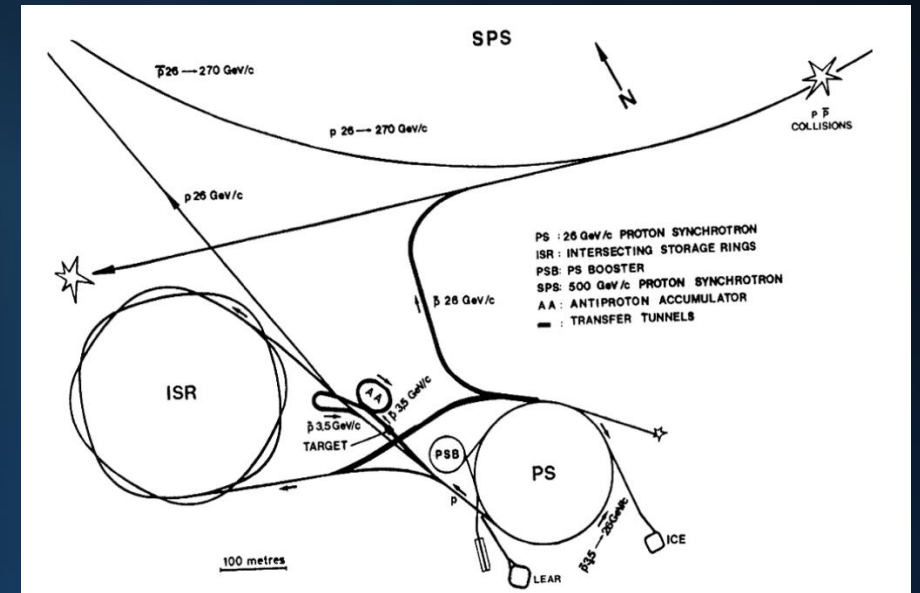
# Intersecting Storage Ring

- 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)



# 1983: discovery of the W and Z

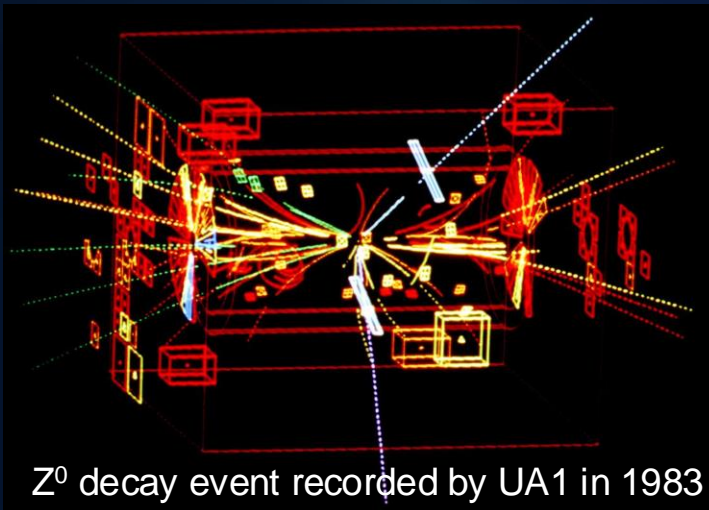
- Gargamelle and the discovery of neutral currents guided the search: look in the region 60-100 GeV
- In 1976 Rubbia proposes to modify the SpS into a collider of protons and antiprotons
- First collisions at  $\sqrt{s} = 540 \text{ GeV}$  were obtained in 1981



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!**



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:

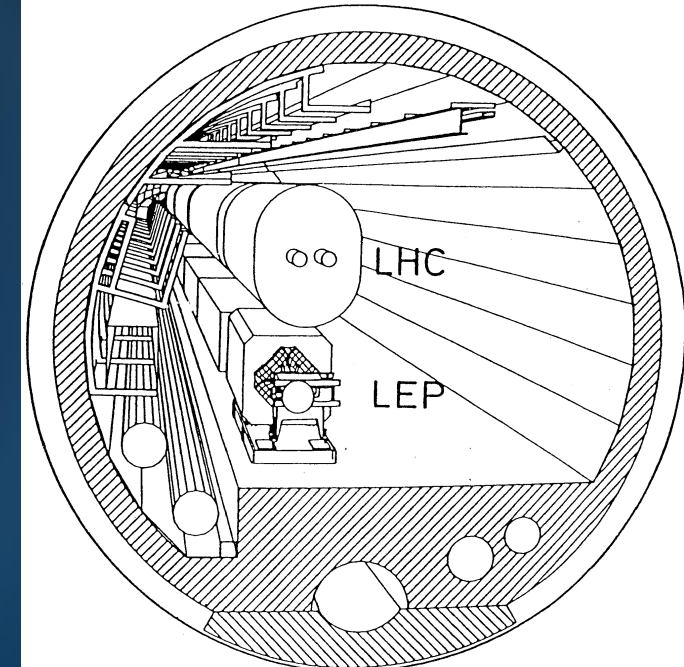
- QCD was increasingly confirmed, but the number of families (both for leptons and for quarks) was unclear. CP violation provided some clue for the quark sector, but not much for leptons.
- The vector bosons, which mediate the electroweak force, were believed to be around the corner, in the 60 - 100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

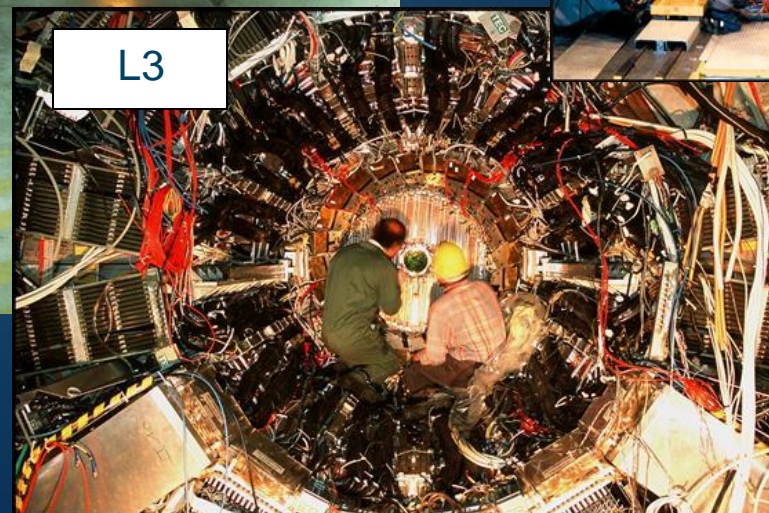
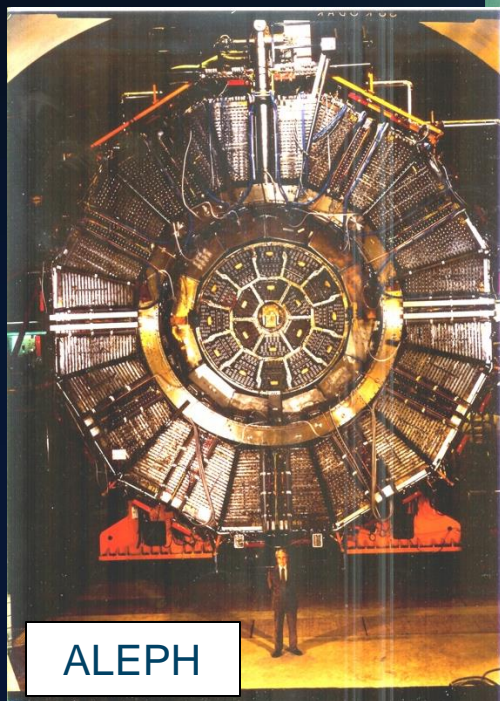
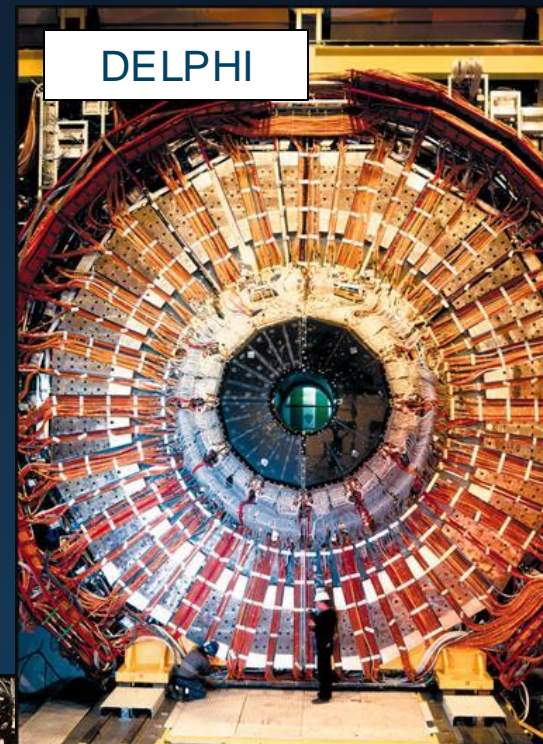
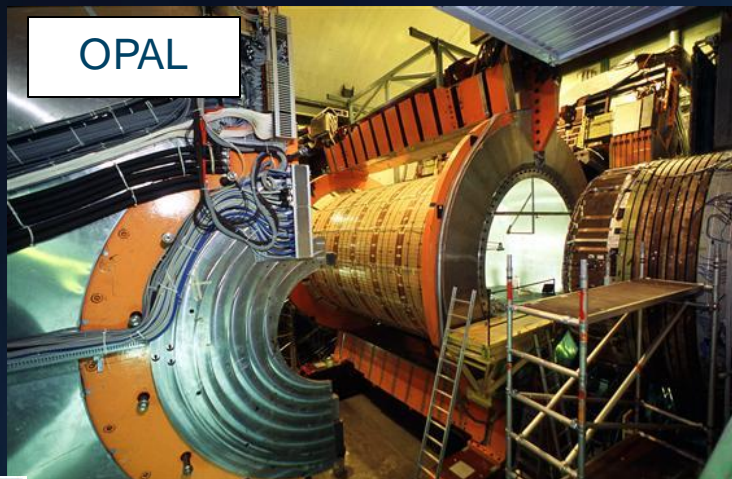
## ECFA – CERN Workshop Lausanne, 5 Sep 1984

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



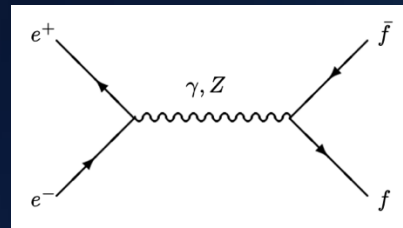
LARGE HADRON COLLIDER  
IN THE LEP TUNNEL

# LEP era

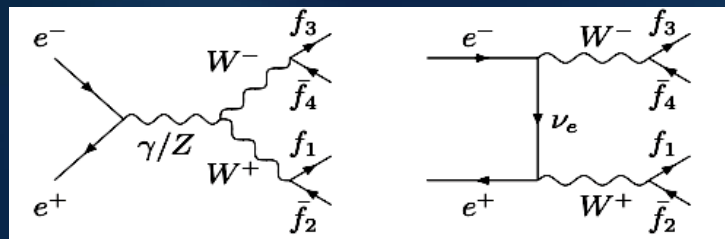


# LEP era

- 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

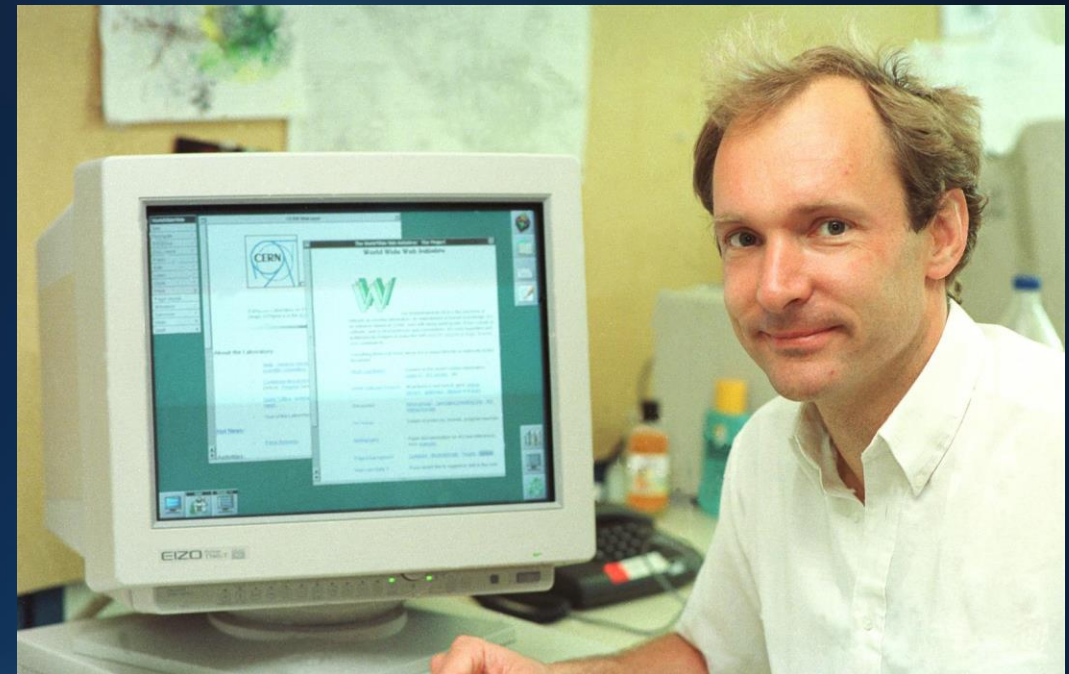
**March 1989:** Tim Berners Lee submits the first proposal for the World Wide Web

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

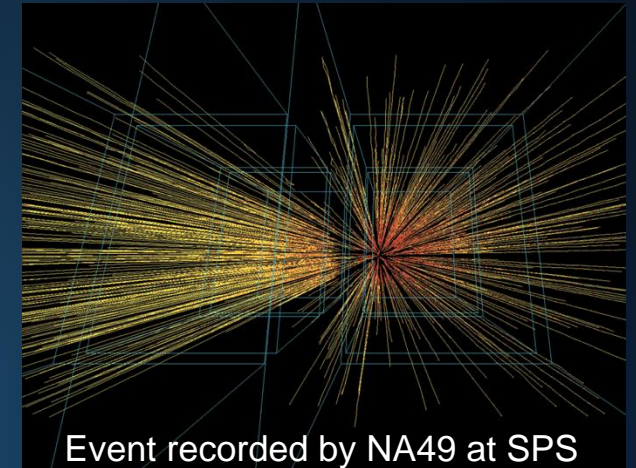
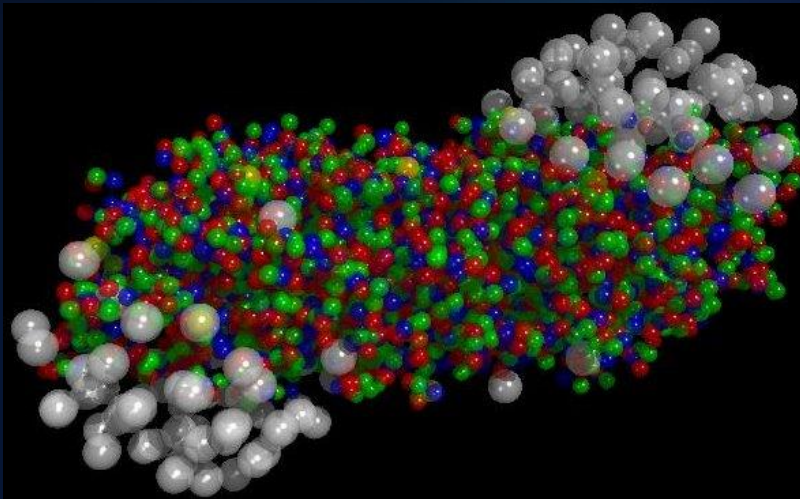
- CERN uses the powerful SPS beam to produce conspicuous yields of Kaons
- Two generations of experiments, NA31 and NA48, were setup between 1982 and 1993 to study direct CP violation through kaon decays
- NA31: first evidence of direct CP violation (a 3 standard deviation effect) in 1988.
- NA48 (final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



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

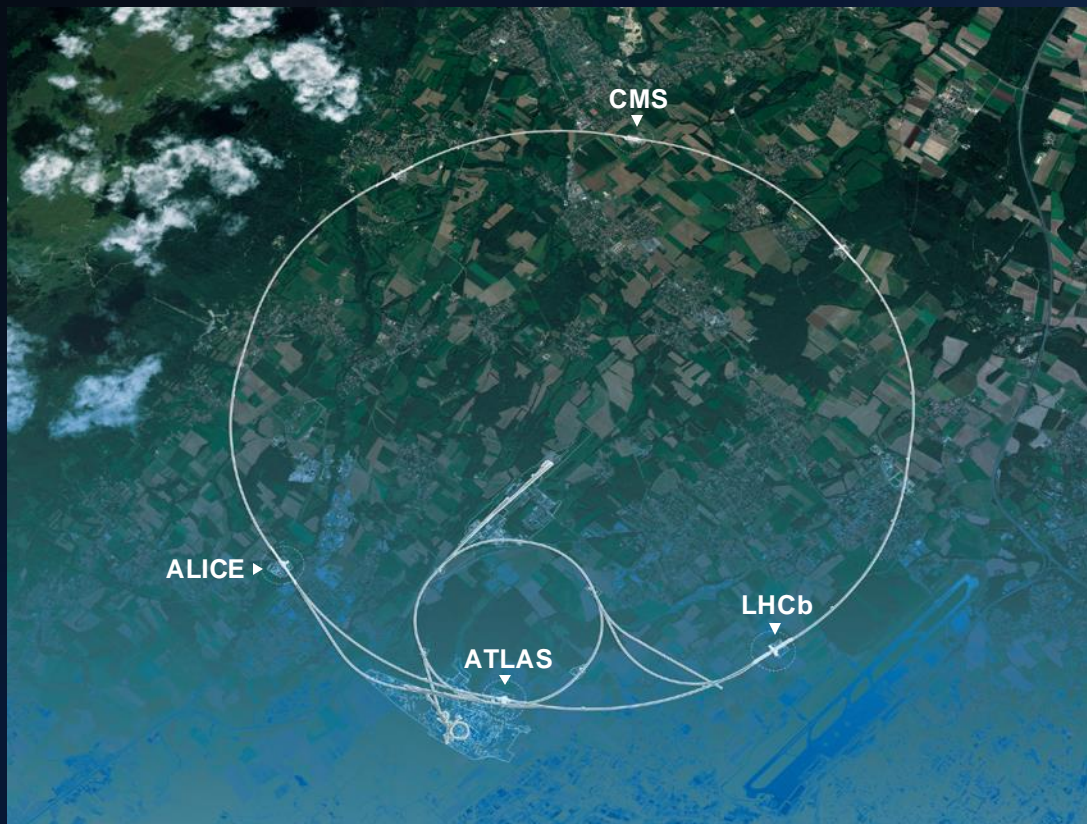
# CERN, February 2000: first evidence of a new state of matter, the quark-gluon plasma

- 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.



**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



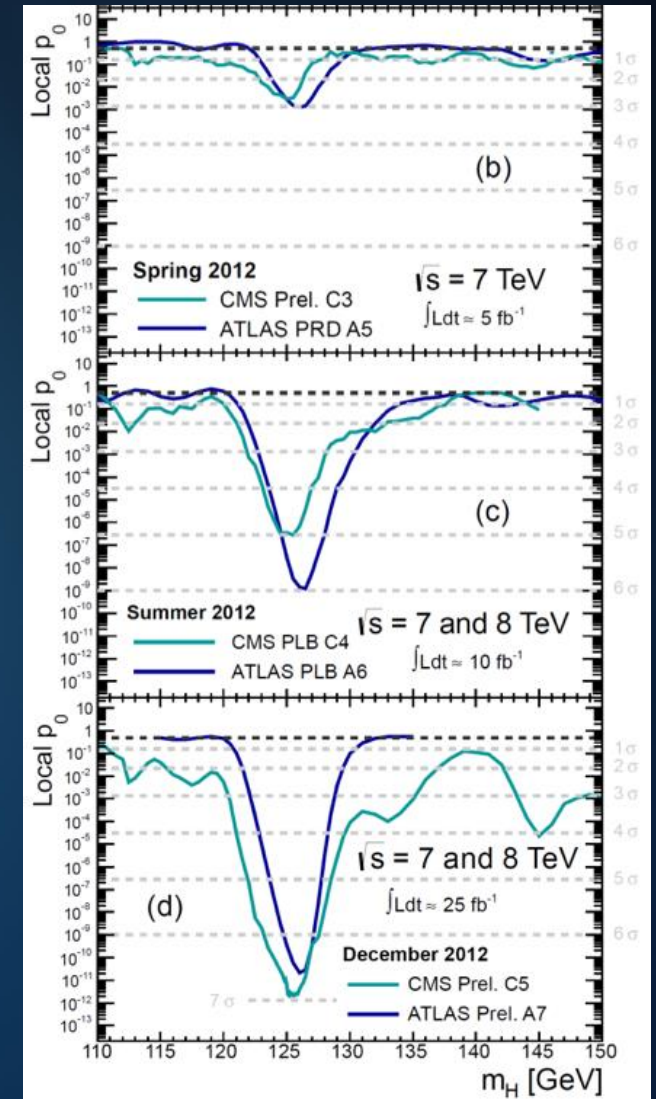
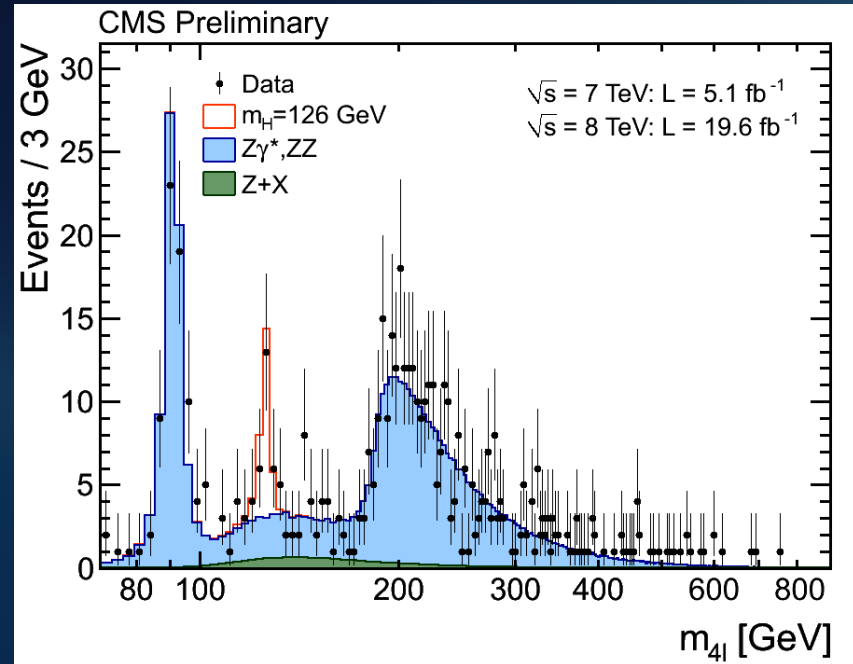
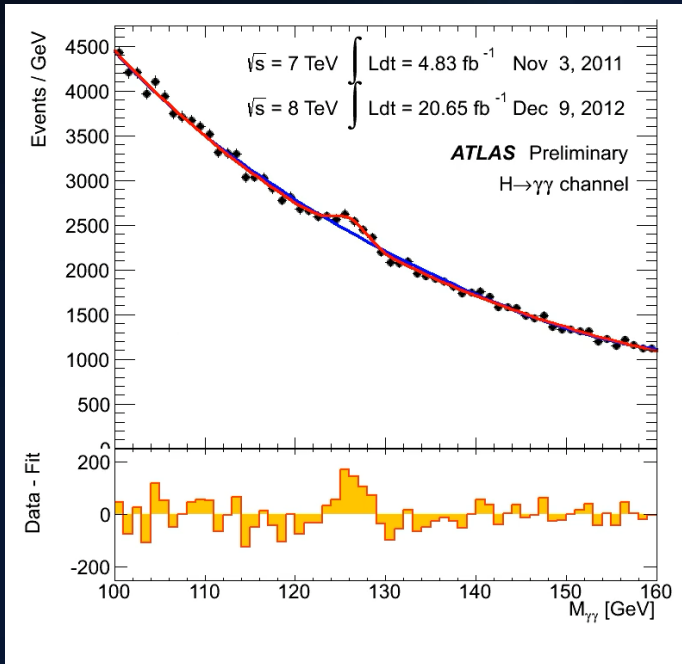
ALICE



LHCb

# Higgs discovery

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



# Higgs discovery ... and the SM triumph

July 4<sup>th</sup> 2012 announcement



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



F. Englert and P. Higgs

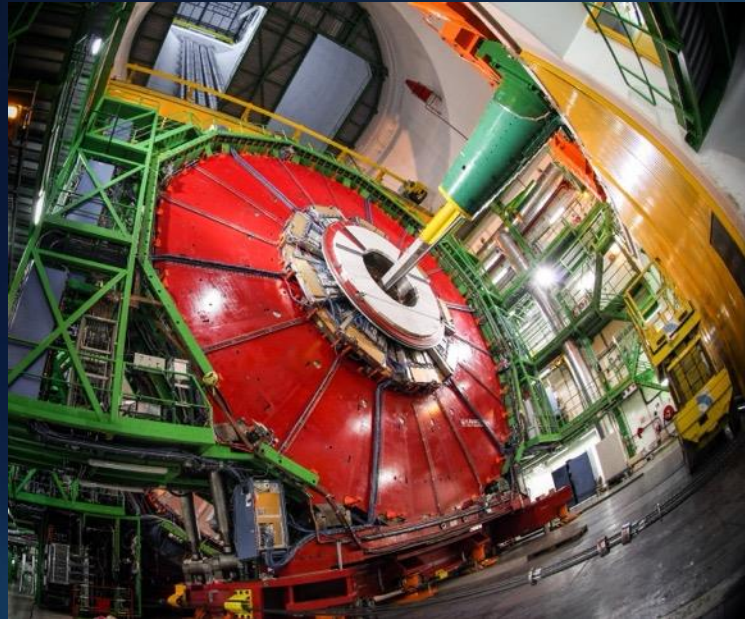
2013 Nobel Prize



# 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**

