Pioneers of Cosmic Rays

Hans Peter Beck, Universities of Bern and Fribourg, Switzerland; and CERN
25 January 2020

Early 1900's

1896 — Discovery of radioactivity

Antoine Henri Becquerel

* 15. Dezember 1852 in Paris
† 25. August 1908 in Le Croisic

Nobel Prize 1903

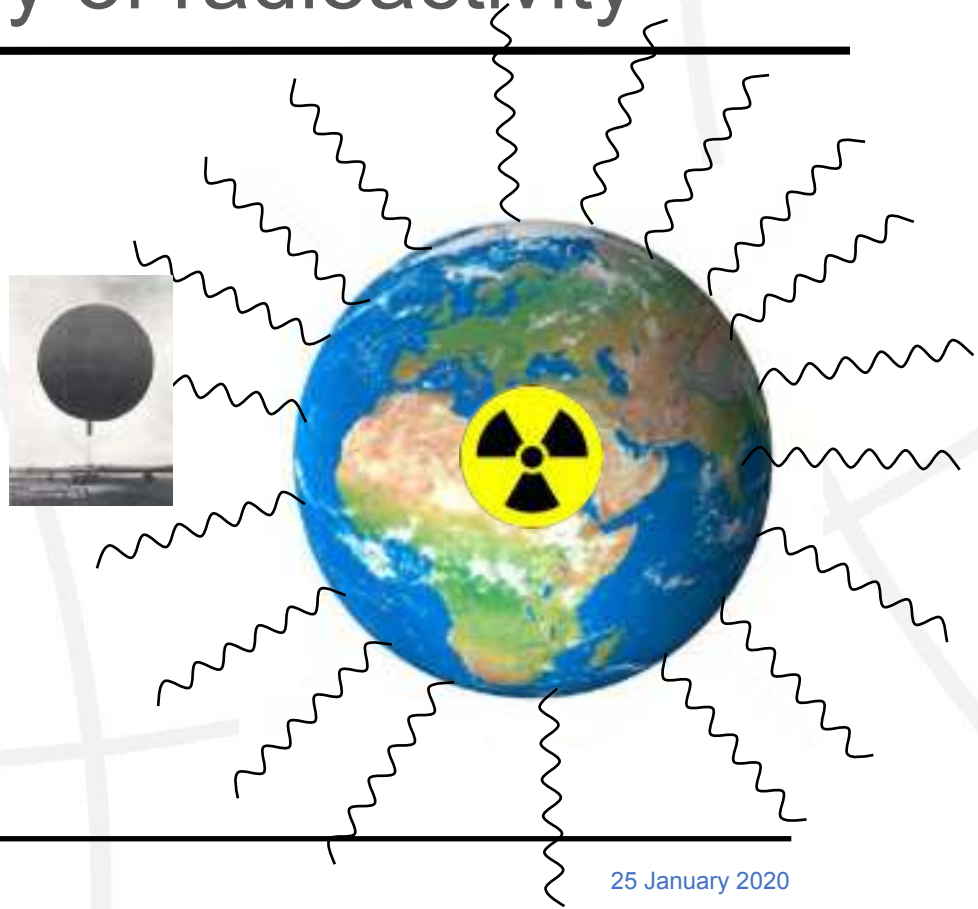
„in recognition of the extraordinary services he has rendered by his discovery of spontaneous radioactivity“

Early 1900's — Study of radioactivity

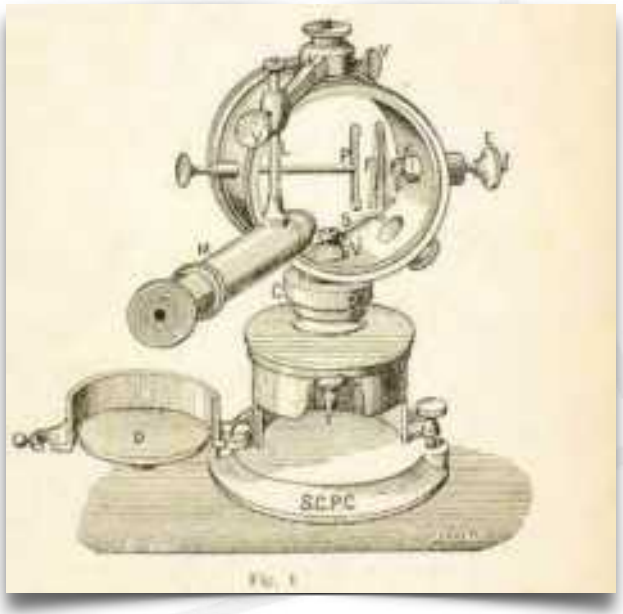
Radioactivity was discovered by **Becquerel** in **1896**, and studied further by **Marie Curie** and many others.

Earth is recognised as a **radioactive ball**.

Radioactivity measured in the atmosphere should get less when going further away from Earth.



Measuring radioactivity in the early 1900's



With an electrometer, measuring discharge between two charged wires, radioactivity was measured in that time. Painstakingly !

Pioneers of the detection of cosmic rays

Karl Bergwitz (1875-1958), Germany
Decrease of radioactivity at 1300 m to 24%

Balloon flights in 1909

Albert Gockel (1860-1927), Professor in Fribourg
No decrease, maybe increase of radioactivity at 4500m.
Introduced the term 'cosmic radiation'

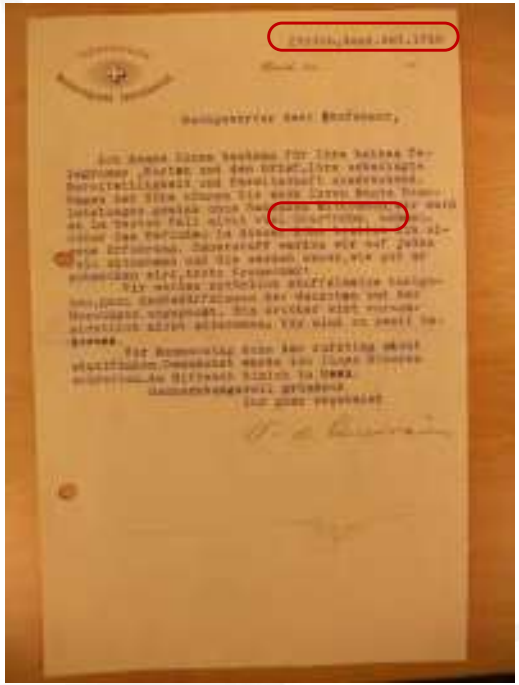
No hydrogen for Gockel to go higher

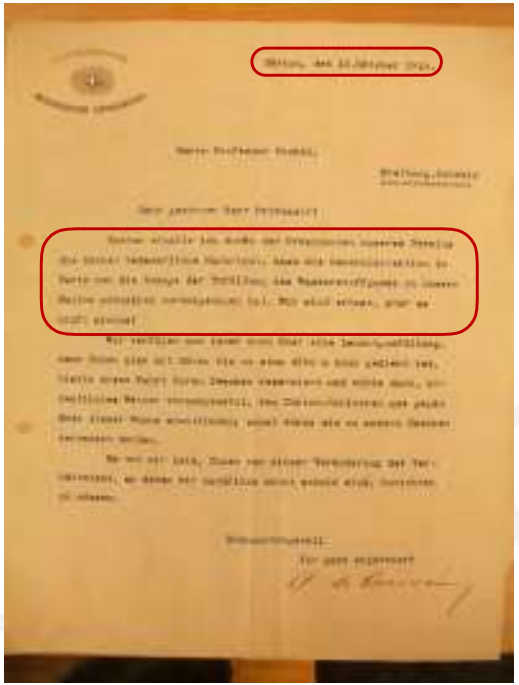
At that time,
gas balloons were used.

With methane, maximum altitude is limited.

With hydrogen, high altitudes were possible.

Gockel was first promised, then refused the hydrogen.





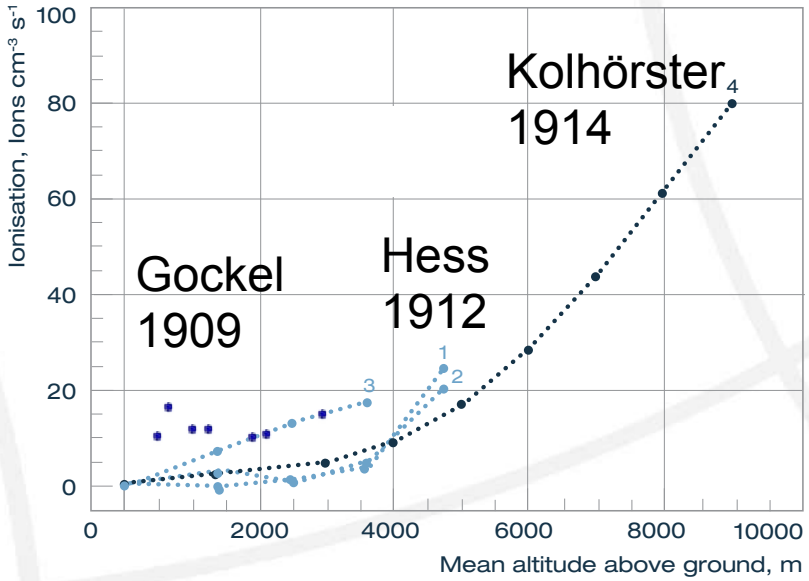
Pioneers of the detection of cosmic rays

Victor Hess (1883-1964)
Professor in Graz reached 5300 m in 1912

Werner Kolhörster (1887-1945)
Professor in Berlin reached 9300 m in 1914

Detection of cosmic rays

Ionisation of air increases with altitude.



Victor Hess with his device
Nobel prize in 1936.
Albert Gockel died already in 1927 and could not be awarded.

Commemorative balloon flight 25 January 2020

Ballon flight today with modern equipment

CAEN Electronic Instrumentation

2. General Description

The Cosmic Hunter - SP5620CH, as shown in **Fig. 2.1**; is composed of two Detection Units – SP5622 and one Coincidence Module - SP5621.

Fig. 2.1: Cosmic Hunter, the educational system to detect the cosmic rays.

Commemorative balloon flight 25 January 2020

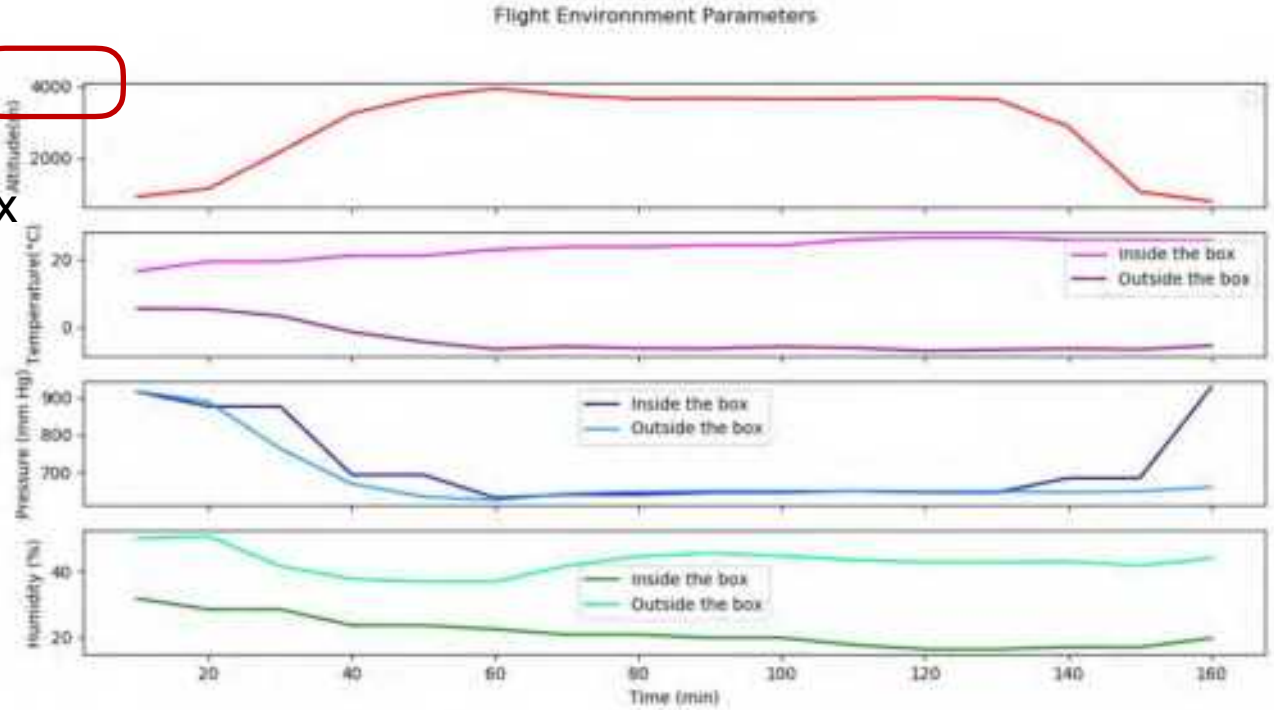
Commemorative balloon flight 25 January 2020

Commemorative balloon flight 25 January 2020

Commemorative balloon flight 25 January 2020

Chateau-d'Oex

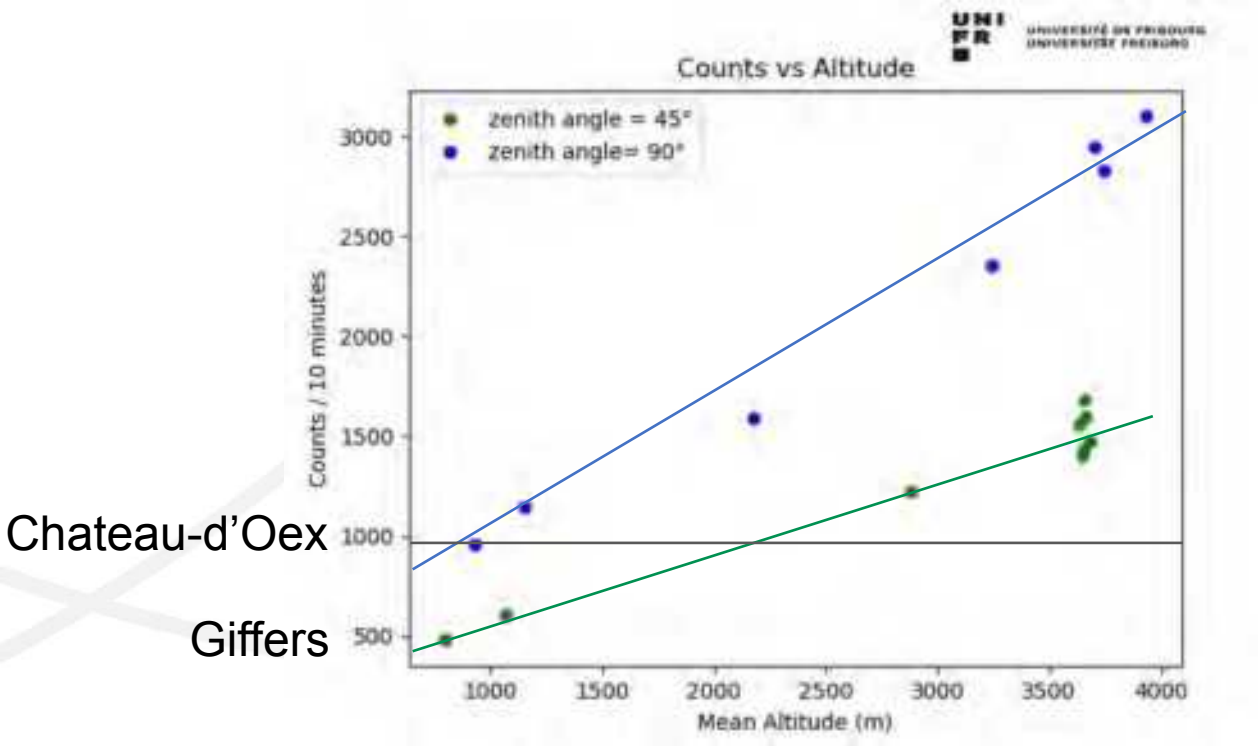
11h40



Giffers

14h15

Commemorative balloon flight 25 January 2020



cosmic rays from the top

3 times higher rate at 4000m than at 1000m

cosmic rays at 45°

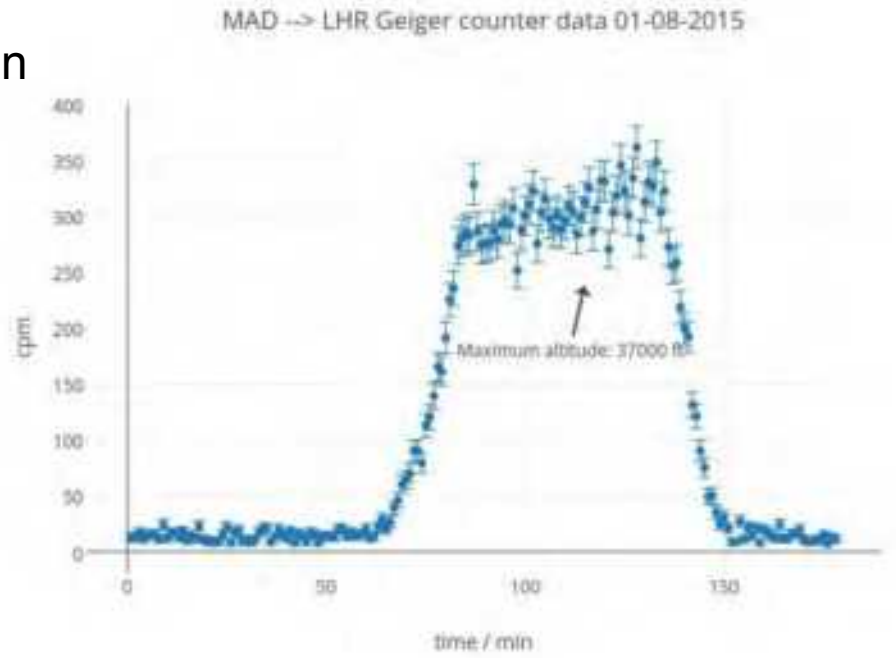
1.5 times higher rate at 4000m than at 1000m

Taking a Geiger Counter on board of an airplane

20 times higher background radiation in standard cruising altitude than at ground level.

ca 6 µS/h

Fukushima radiation map
https://jciv.iidj.net/map
Comparable to the hot zones.
E.g. Ōkuma is evacuated and has ca 4.5 µS/h



Where do cosmic rays come from?

Earth is constantly hit by particles.

Most come from the **sun**.
They have moderately **low energies**.

Active galactic nuclei, **neutron stars**, **supernovae**, deep in the **Milky Way** and **in far away galaxies**, create particles at **extremely high energies**.

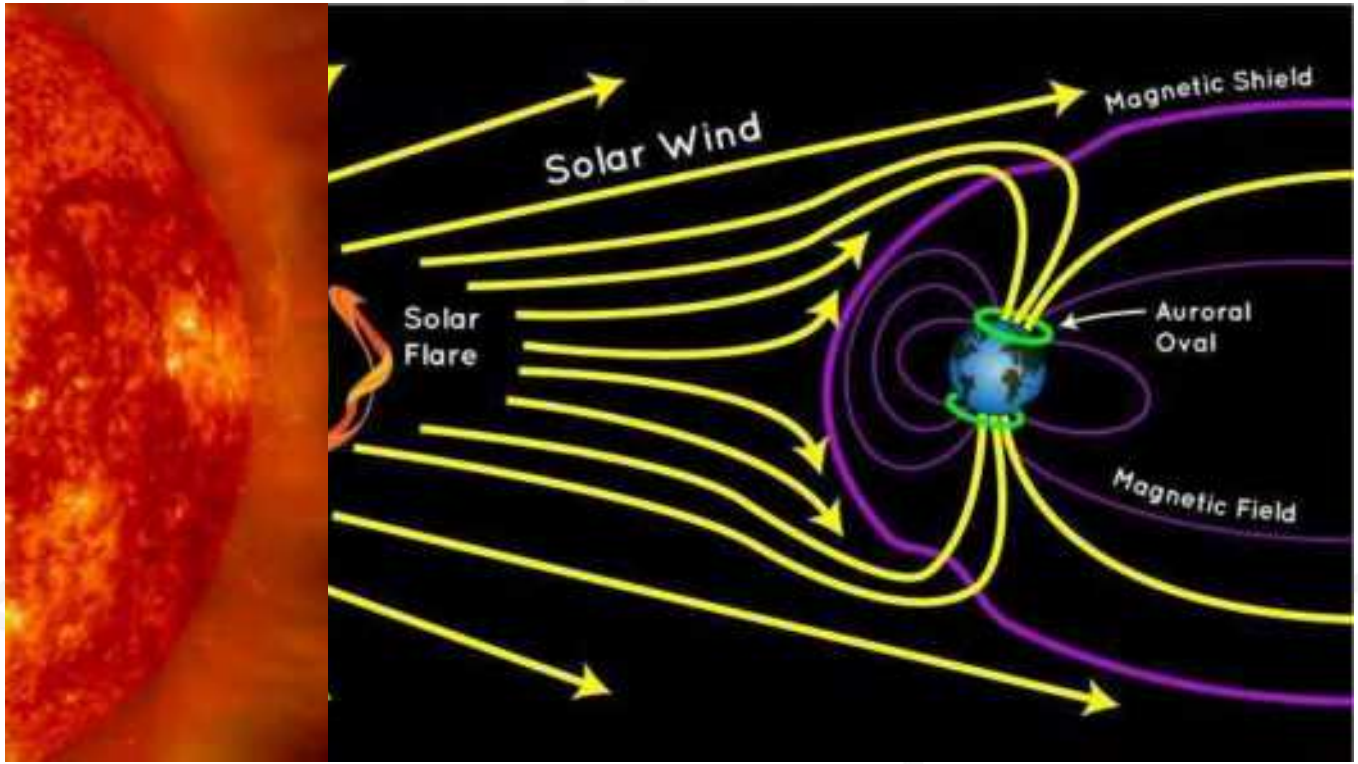
Aurora Borealis

The sun's **solar wind is composed of particles** protons, electrons, helium nuclei,…

As the energy of these is moderately low, the **Earth's magnetic field deflects** them — except in the polar regions.

When the sun is ejecting a **solar flare**, it becomes visible with the naked eye in the polar regions.

Earth’s magnetic field deflects the solar wind



Aurora Borealis (North Pole) and Australis (South Pole)

High energetic particles hit Earth everywhere

Active galactic nuclei, **neutron stars**, **supernovae**, deep in the Milky Way and **in far away galaxies**, create particles at extremely high energies.

Some of these are also hitting the Earth.

Why study Cosmic Rays ?

The **Universe** is emitting **light** - which we see with the **naked eye** and through **telescopes**.

Fascinating humankind since ever.

The **Universe** is also emitting **particles**, giving a **broader view** and **new insights**.

Fascinating even more. **Particle physics is also cosmology.**

Studying Cosmic Rays — the early days

Carl David Anderson
Discovered **anti-matter in 1932**
(the positron, which is the anti-electron)
Nobel Prize 1936

High altitude research station
at the Jungfraujoch 3500m
Since the mid 1920's.

Studying Cosmic Rays — still today

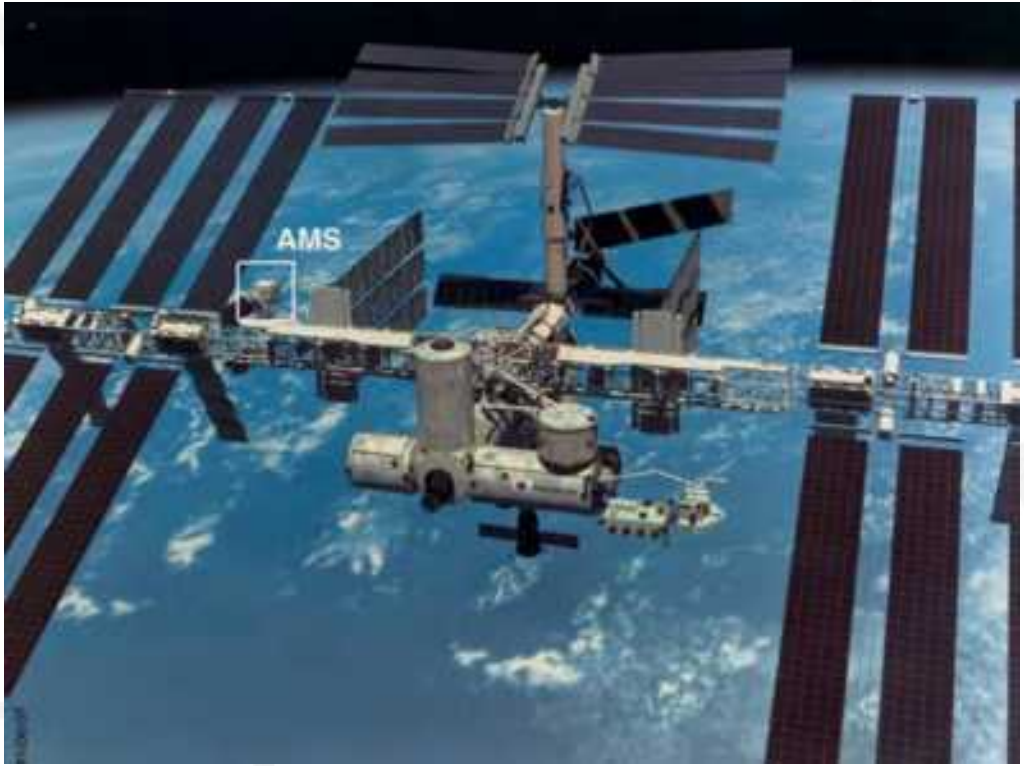
On ground

3000 km^2 array in Malargüe, Mendoza prov., Argentina

Studying Cosmic Rays — still today

In space

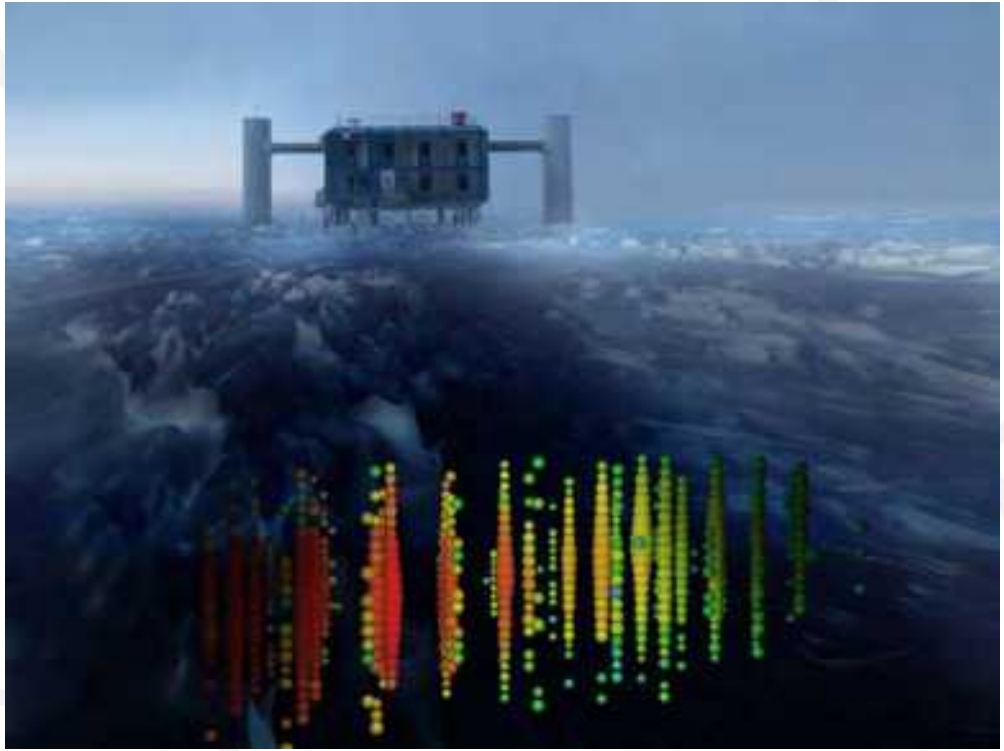
On the international space station



Studying Cosmic Rays — still today

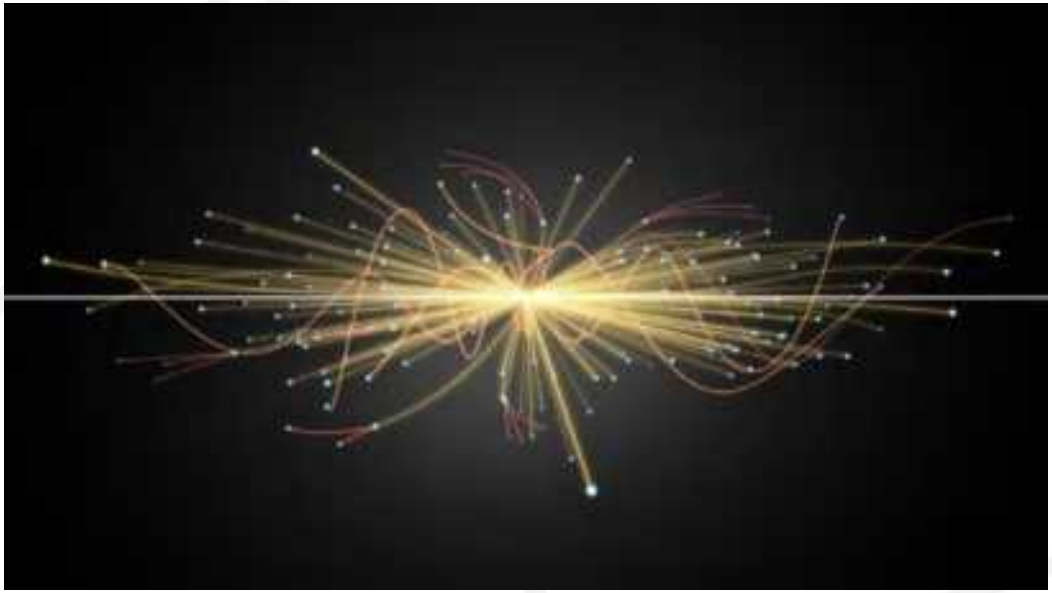
Below ground

In the ice at the South Pole



Understanding particle collisions

Proton



Proton

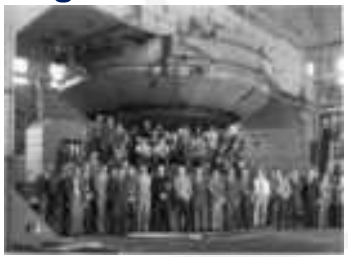
At **CERN**, particles are brought to collisions

- as cosmic rays collide with the atmosphere
- gives insight in the inner forces of matter

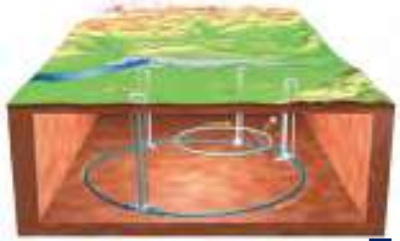
120 years of accelerating particles

1897 Accelerating electrons
Cathode ray tube
J.J. Thomson

1931 First circular accelerator
Ernest O. Lawrence & M. Stanley Livingston



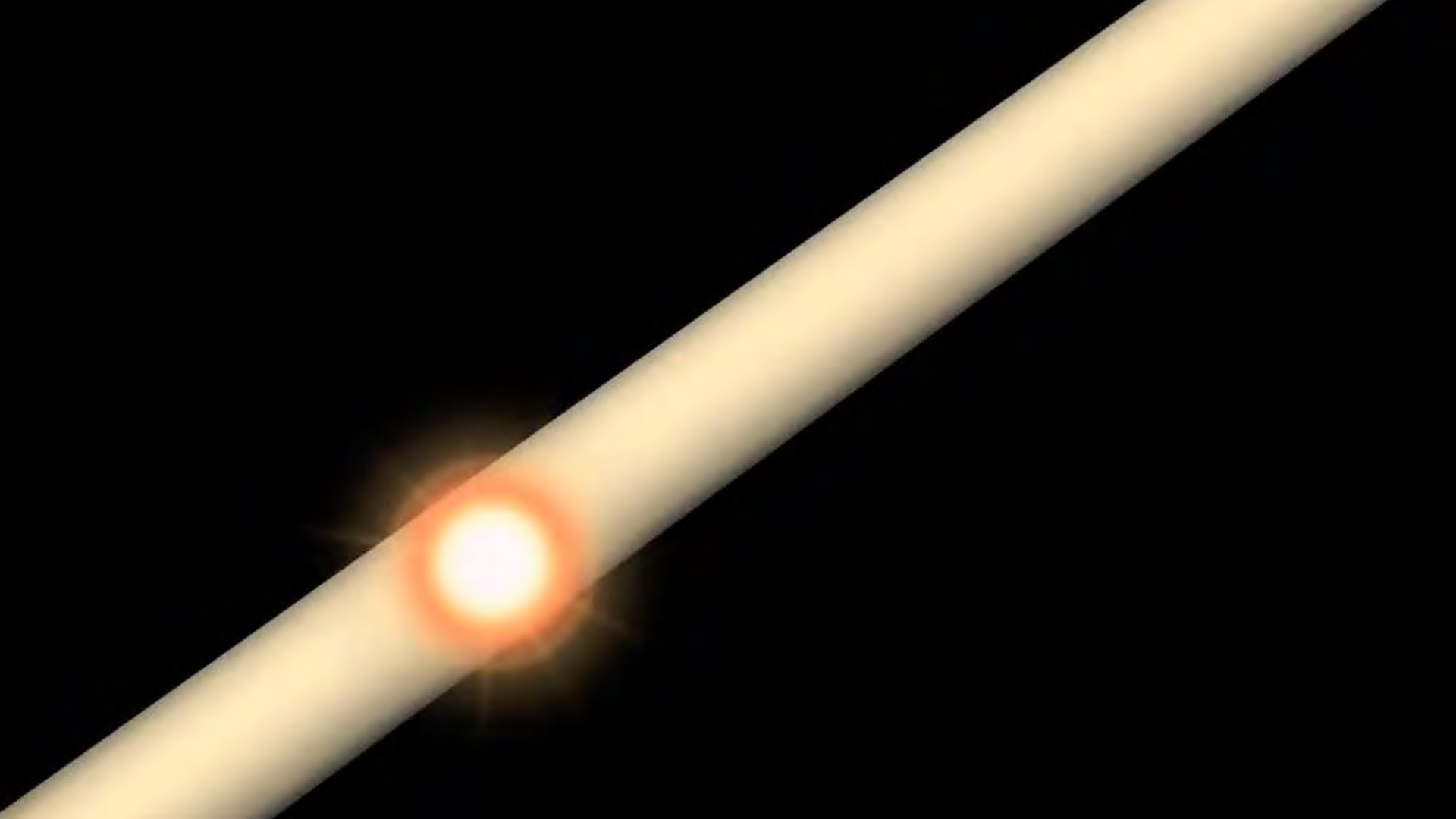
1940



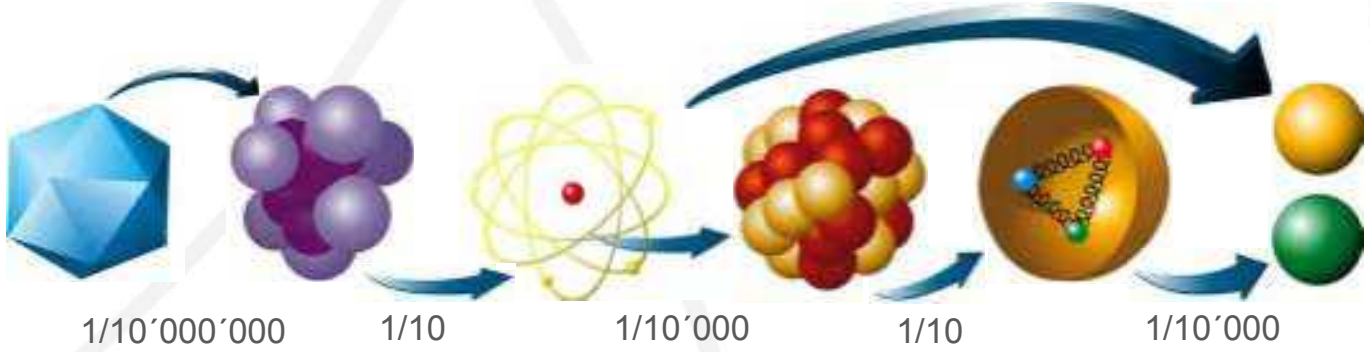
Today: LHC

CERN — Large Hadron Collider

Exploration of a new energy frontier
in p-p and Pb-Pb collisions



The structure of matter revealed



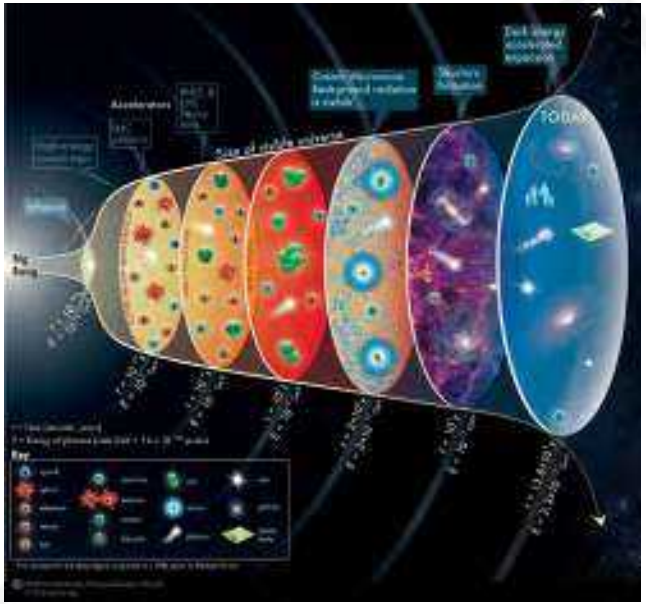
Pinhead:
10^{-3} m = 0,001 m

Atom
10^{-10} m

Electron, Quark:
< 10^{-19} m = 0,000´000´000´000´000´000´1 m
(no further inner structure ??? Who knows?)

If an atom's radius would be as large as the distance from CERN to Copenhagen, the LHC could still resolve millimetre scale objects.

The evolution of the Universe



$$\mathcal{L} = -\tfrac{1}{4}\mathcal{F}_{\mu\nu}\mathcal{F}^{\mu\nu}$$
$$+ i\bar{\psi}\not{\mathcal{D}}\psi$$
$$+ \psi_i y_{ij} \psi_j \phi + h.c.$$
$$+ \left|\mathcal{D}_\mu \phi\right|^2 - \mathcal{V}(\phi)$$

The Standard Model of Particle Physics

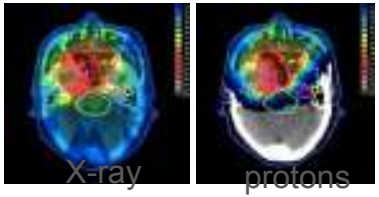
Balloons played an important role in the beginning

on the way to deeply understand the **Universe**, and with it, **who we are**, where we are **coming from**, and where we are **going to**.

Medical Application as an Example of Particle Physics Spin-off
Combining Physics, ICT, Biology and Medicine to fight cancer

Accelerating particle beams
~30'000 accelerators worldwide
~17'000 used for medicine

Hadron Therapy



Leadership in Ion Beam Therapy now in Europe and Japan

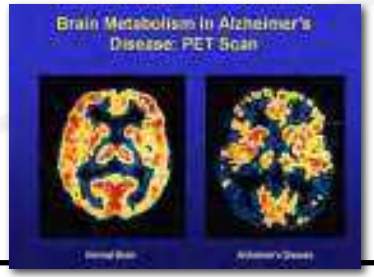
>100'000 patients treated worldwide (45 facilities)
>50'000 patients treated in Europe (14 facilities)

Detecting particles

Imaging

Clinical trial in Portugal, France and Italy for new breast imaging system (ClearPEM)

PET Scanner



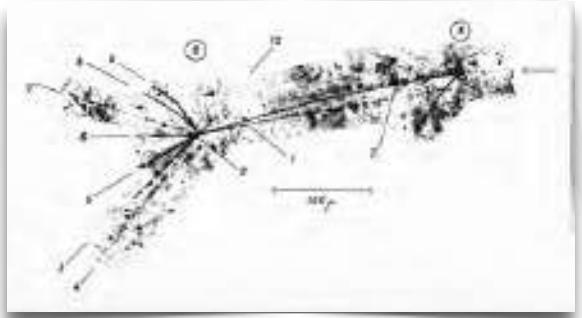
Balloon museum

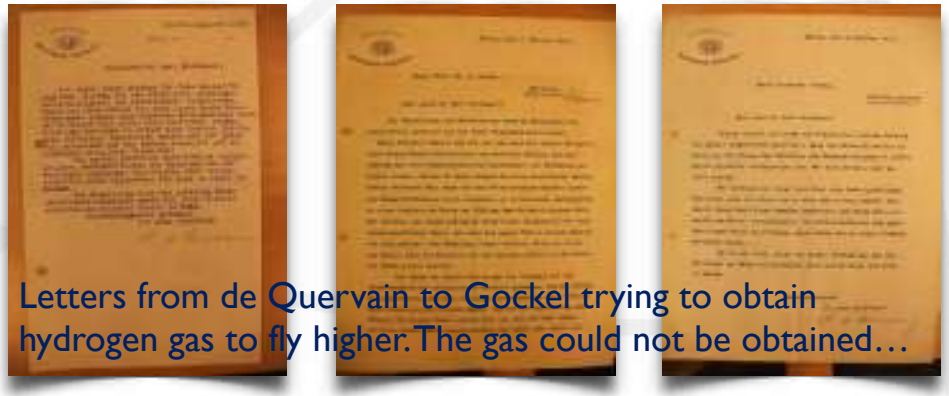
espace BALL N

Original items to show

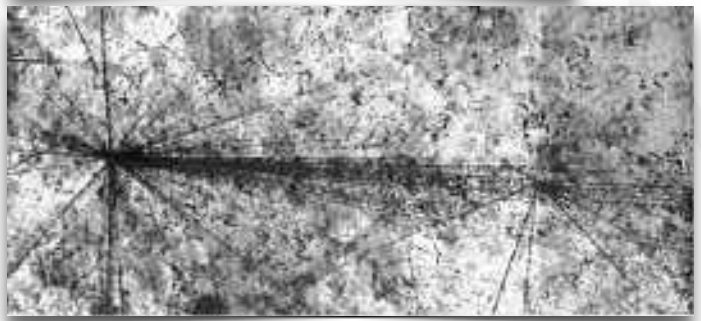
Electrometer used by Gockel around 1910

Sparkchamber





Letters from de Quervain to Gockel trying to obtain hydrogen gas to fly higher. The gas could not be obtained…



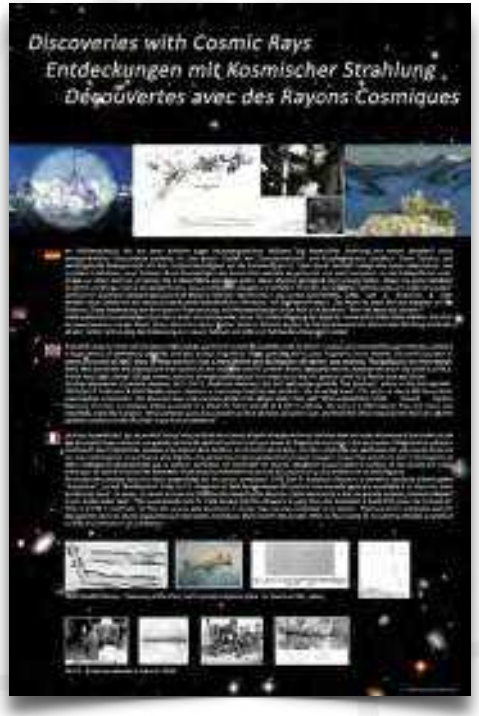
Emulsion plates from mid 1950's taken at Jungfraujoch

“Art&Science”

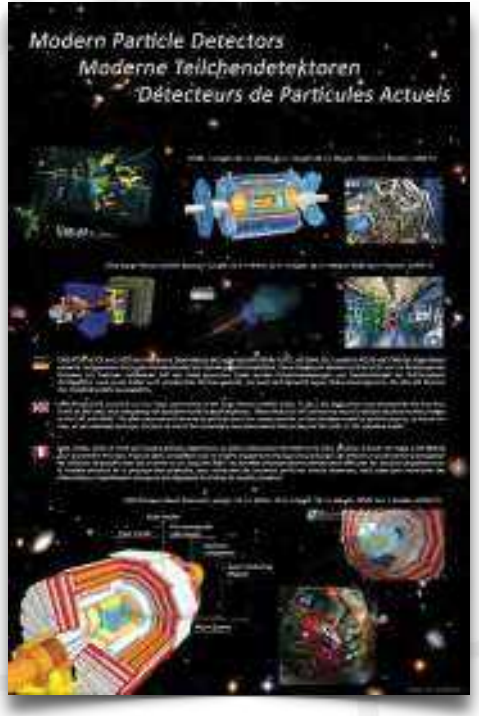
Through the opening of the exhibition:

Guided tours
Lectures
Junior Scientist booklet
https://www.espace-ballon.ch/copie-de-exposition-temporaire

Explaining Cosmic Rays



Explaining Particles



Thank you for listening

“Art&Science” - Chateau d’Oex/ CH

Balloon Museum April 2019 – March 2022

Balloon Festival January 25th Febriary 2nd 2020

photos of the CMS experiments by Michael Hoch