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# Cosmic Rays at the 42<sup>nd</sup> Hot-Air Balloon Festival in Château-d'Oex

Hans Peter Beck

The Hot Air Balloon Festival in Château-d'Oex is a well-known established event in the Swiss mountainous regions between Gstaad and Gruyère. Aeronauts from around the globe meet there every winter for their special week since 1979. It is well-known for Bertrand Piccard and Brian Jones' ascent in 1999 for their three-weeks lasting, non-stop tour around the globe, in a balloon, the Breitling Orbiter 3. In its 42<sup>nd</sup> edition, the physics of cosmic rays entered the stage of the Hot-Air Balloon Festival, end of January 2020. This is no coincidence and preparatory work was needed for it to hap-

tors means adding temporary exhibitions. General science topics, not even to speak physics, is rarely on the screen of museums curators. For the 2019 temporary exhibition, however, the theme was a mixture of art and science, as Figures 1, 2, and 7 show. In particular, it was the museum's curator, Jacqueline Trenta, who was first attracted by the art works of Michael Hoch, physicist and member of the CMS collaboration at CERN. Hoch became internationally renowned for his specific art works, rendering particle physics into art



Figure 1: Balloon museum Château-d'Oex

pen. The balloon museum in Château-d'Oex [1] is featuring historic balloon material, equipment, measuring devices, as well as modern equipment and illustrates the difficulties that needed to be mastered for the Breitling Orbiter endeavor to be a success. Keeping museums alive and attracting visi-

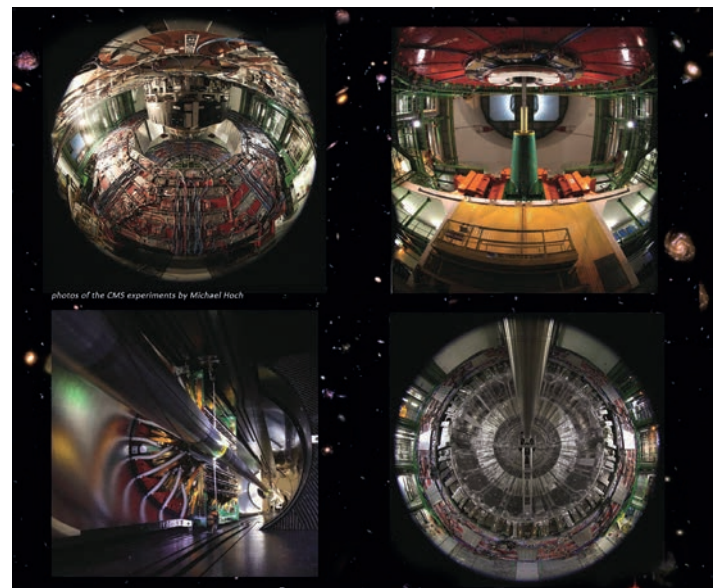


Figure 3: Photos of the CMS experiment by Michael Hoch



Figure 2: Pioneers of cosmic rays. A large-scale poster, inviting the visitors in the balloon museum to dive into a topic they wouldn't have expected at first. The historic balloon flights of Albert Gockel, Victor Hess and Werner Kohlhörster are put in context as the pioneers of a new field of research that is continued still today with

actual experiments carried on in space on the International Space Station (AMS), in high altitudes (Jungfrauoch), on ground in Argentine (Auger), La Palma (MAGIC), and below ground in Japan (Super Kamiokande) and the South Pole (IceCube).

for everybody to grasp and be indulged, for which he has been bestowed the 2017 Outreach Prize of the European Physical Society for *initiatives highlighting the conceptual and physical beauty of high-energy physics, and the inspirational qualities that are common to both art and science.*

Upon Hoch's invitation to expose his work in the balloon museum in Château-d'Oex, he contacted the author of this article, who is member of the ATLAS collaboration at CERN, telling about his invitation. With this connection, the idea was born to add the physics of cosmic rays to the exhibition. Cosmic rays were detected in the beginning of the last century in balloon flights, measuring conductivity of air with electrometers in function of altitude. The exhibition, as it stands today, is adding the narrative of cosmic ray detection in balloon flights, where the conductivity of air was measured in function of altitude by Albert Gockel in 1909, reaching 4500 m asl, followed by Victor Hess in 1912 up to 5300 m asl, and by Kolhörster in 1914 ascending as high as 9300 m asl.



Figure 4: Albert Gockel, only known photograph. Courtesy of Uni Fribourg.

Albert Gockel, professor of physics at the University of Fribourg, Switzerland, concluded that the number of ion's measured per volume of air doesn't decrease at high altitude as one would expect if radiation primarily would come from the ground [2]. He couldn't conclude on his findings as he did not get the needed hydrogen gas to reach higher altitudes of up to 7000 m asl [3,4], but it was Albert Gockel to coin the term *Kosmische Strahlung* [5]. Victor Hess' ascent to 5300 m asl, with an improved electrometer, was

conclusive and it was him to be awarded the Nobel Prize in Physics 1936 for the *discovery of cosmic radiation*, together with Carl David Anderson for the *discovery of the positron*. Gockel, who died in 1927, could not be considered, and for this reason, he is almost forgotten in the history of physics. With an original electrometer from Gockel's legacy in Fribourg and now a showcase element at the balloon museum (see Figure 5), Gockel's achievement can be grasped with admiration.

Certainly, a story that reads well by a general audience visiting the balloon museum and taken in by surprise, but this is not where it ends. Measuring cosmic rays became a hot topic of research in the decades to follow and still is today. Because of its relevance to the topic, both geographically and scientifically, the High-Altitude Research Station Jungfrauoch at 3500 m asl, was ideal to add into the narrative. Especially the emulsion plates that were exposed on the Jungfrauoch in the 1950ies, and that we received on loan, are of special value (Figure 6). These are showing the breaking up of nuclei as they were hit by a cosmic ray particle, denoted as star events. Such star events are often source where new particles emerge, in one case, the path of an antiproton



Figure 5: Electrometer from Albert Gockel's legacy, on loan from Uni Fribourg. From the *Société Centrale de Produits Chimiques*, 44 Rue des Ecoles Paris, ca. 1910. In the back, reprint from the original vending catalogue, featuring the device.

is clearly visible. A spark-chamber, on loan from Uni Bern, is operating continuously, showing how particles can be visualized and that indeed cosmic rays, in this case secondary muon tracks, are real and penetrating.

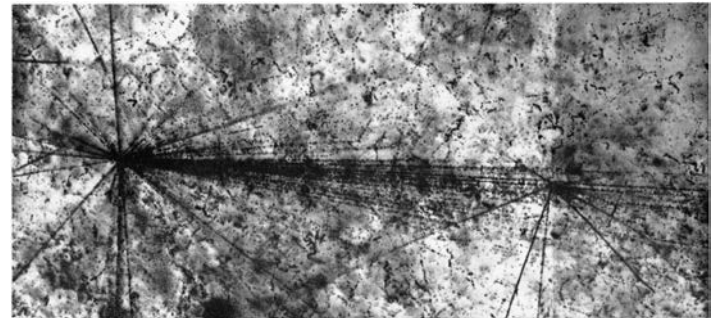


Figure 6: Star event identified at the physics institute of Uni Bern in an emulsion plate that was exposed at the Jungfrauoch, on loan from Uni Bern. A Br or Ag nucleus in the emulsion interacts with a high-energetic oxygen nucleus from cosmic radiation, where over 200 ionizing particle tracks were produced. The event was published in *Suppl. Nuovo Cimento* 12 (1954) 361.

The general audience, now fully engaged in a new world of cosmos and particles, can now be guided further to the world of accelerators, where cosmic rays are quasi-created under laboratory conditions and to the world of detectors, as particles also need to be measured. Showing Lawrence's palm-size cyclotron from 1931, and over a few steps of larger and larger-scale accelerators, guiding the audience up to the Large Hadron Collider at CERN, renders the scope and purpose of this machine in new light for most of the visitors. In parallel, the history and development of particle detectors, from early-day Geiger counters and cloud chambers up to modern devices and big detectors like ATLAS or CMS is also presented. Applications and spin-offs have not been forgotten and the link to medical diagnostic and treatment is made with PET scan and hadron therapy. The story finalizes with the Standard Model of particle physics, and Big Bang cosmology, closing the circle of what is known today about the Universe, starting from its smallest constituents.

Setting up this narrative into a balloon museum was in a certain way adventurous. It was not clear whether it will work

out, or fail. The artwork of Michael Hoch being shown in parallel, lingered this fear and is adding an emotional touch to the physics shown that pleased many.

In the end, the exhibition was counted a big success, as a substantial increase of the flow of people visiting the museum showed, and where visitors also significantly spent more time in the museum. As a result, the temporary Art & Science exhibition being planned to be open for one year from May 2019 to end of March 2020, was prolonged for another year to end in March 2021<sup>1</sup>.



Figure 7: Art & Science exhibition at the balloon museum in Château-d'Oex. The temporary exhibition, originally planned to be open to the public from May 2019 to end of March 2020 was prolonged till end of March 2021, due its success - however, the corona outbreak dictated an untimely end.

The director of the balloon festival, Fred Paulin-Getaz, excited by the exhibition, decided to make the physics of cosmic rays as a lead theme of the 42<sup>nd</sup> balloon festival, 25 January to 2 February 2020 – not without initial resistance from his local staff that he needed to overcome first. A highlight of the festival was a commemorative balloon flight on the footsteps of Albert Gockel and Victor Hess, where cosmic rays were measured with modern equipment in function of altitude over the Swiss alps.

The modern equipment used, came in form of a muon telescope that was built with two scintillating-fibre tiles of 15 cm<sup>2</sup> each and separated by 15 cm. Cosmic rays, or to be more

<sup>1</sup> However, due to the Corona outbreak, the museum had to be closed and it was decided to use this extra time of closure for a reorientation – dictating an unexpected early end of the Art & Science exhibition.



Figure 8: Group photo before ascending. The muon telescope inside its insulating box is mounted to the balloon basket. From left to right: Pierre Adatte, Augustin Muster, Nicolas Bruder, Frédéric Chassot, Hans Peter Beck, Michael Hoch, Baptiste Hildebrand.



Figure 9: Ascent of the balloon with the muon telescope attached. Hans Peter Beck (centre) and Nicolas Tièche (right), while two more students, Nicolas Bruder and Frédéric Chassot, also on board, can't be seen from this perspective. Image credit: Jean Claude Dubé

precise, mostly muons in the low atmosphere, that traverse the two tiles, cause simultaneous flashes of light in the fibres of each of the two tiles. After converting the light yield into electrical signals, the coincidence rate of both tiles firing, is obtained. The flux of muons can be measured this way in function of altitude and also in the direction in which the telescope is pointing. The CAEN Cosmic Hunter [6] was used and packed inside an insulating container, such to stabilize it from temperature drifts, avoiding condensation and freezing. A team from the University of Fribourg was readily formed, consisting of four students that all followed the author's course on particle physics and included also local staff from the physics department in Fribourg, where already Albert Gockel prepared his flights a century earlier. The insulating container was built by the Fribourg team with active heating, feedback-loop and energy supply. Further, exact GPS data and other environmental data points needed to be measured and integrated. An ideal task for young students finishing up their bachelor degree that culminated in a balloon flight up to 4000 m asl measuring cosmic rays. Figure 8 shows the students with their supervisors in the moments before the eagerly awaited ascent. Figure 9 shows an impression of the flight from Château-d'Oex to Giffers, a small village near Fribourg, reaching slightly above 4000 m asl. An increase of the cosmic ray flux by a factor of three was obtained in both configurations of the muon telescope, pointing straight to the zenith during the first half of the flight and tilted by  $45^\circ$  away from the zenith during the remaining half, as can be seen in Figure 10. With a successful flight and measured data available, their next task is to analyze and write up their report.

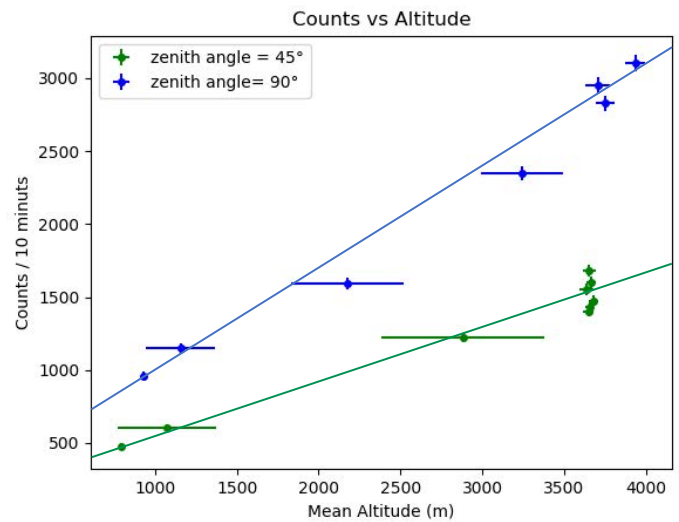


Figure 10: Coincidence rate in counts per 10 minutes interval, in function of altitude above Château-d'Oex. The rate increases by a factor of three when ascending from 1000 m to 4000 m asl, for fluxes measured under  $90^\circ$  and under  $45^\circ$ . The slopes with which the count rates increase differ by a factor of two for the two configurations measured, following a  $\cos^2 \Theta$  decrease of flux rates with the zenith angle  $\Theta$ .

[1] <https://www.espace-ballon.ch>

[2] A. Gockel, Luftelektrische Beobachtungen bei einer Ballonfahrt, Phys. Zeit. 11 (1910) 280-282.

[3] H. Völkle, "Albert Gockel und die kosmische Strahlung", SPG Mitteilungen Nr. 28 (2009) 29

[4] J. Lacki, "Albert Gockel: from atmospheric electricity to cosmic radiation", SPG Mitteilungen Nr. 38 (2012) 25

[5] A. Gockel, Th. Wulf, Beobachtungen über die Radioaktivität der Atmosphäre im Hochgebirge, Phys. Zeit. 9 (1908) 907-911.

[6] <https://www.caen.it/products/sp5620ch/>

Cern Courier featured the commemorative balloon flight in its Mar/Apr 2020 edition, of which a shorted version is re-printed here with kind permission. Full text available at <https://cerncourier.com/wp-content/uploads/2020/03/CERNCourier2020MarApr-digitaledition.pdf>

### Ascent commemorates cosmic-ray pioneers

Matthew Chalmers (CERN)

On 25 January, a muon detector, a particle physicist and a prizewinning pilot ascended 4000 m above the Swiss countryside in a hot-air balloon to commemorate the discovery of cosmic rays. The event was the highlight of the opening ceremony of the 42<sup>nd</sup> Château-d'Oex International Balloon Festival, attended by an estimated 30,000 people, and attracted significant media coverage.

ATLAS experimentalist Hans Peter Beck of the University of Bern, and a visiting professor at the University of Fribourg, along with two students from the University of Fribourg, reenacted Gockel's and Hess's pioneering flights using 21<sup>st</sup>-century technology: a muon telescope verified that the flux of cosmic rays increases as a function of al-

titude. Within two hours of landing, including a one-hour drive back to the starting point, Beck was able to present the data plots during a public talk attended by more than 250 people. A second flight up to 6000 m is planned, with oxygen supplies for passengers, when weather conditions permit.

"Relating balloons with particle physics was an easy task, given the role balloons played in the early days for the discovery of cosmic rays," says Beck. "It is a narrative that works and that touches people enormously, as the many reactions at the festival have shown."

The event – a collaboration with the universities of Bern and Fribourg, the Swiss Physical Society, and the Jungfrau research station – ran in parallel to a special exhibition about cosmic rays at the local balloon museum, organised by Beck and Michael Hoch from CMS, which was the inspiration for the festival organisers to make physics a focus of the event, says Beck: "Without this, the festival would never have had the idea to bring 'adventure, science and freedom' as this year's theme. It's really exceptional."