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Science & Art at the 42nd International Hot-Air Balloon Festival and the Balloon Museum in Château-d'Oex

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At the 42nd international balloon festival in Château-d'Oex, 25 January to 2 February, 2020, one balloon flight was special. Manned by two students from Fribourg, the speaker, and a prize-winning pilot of the international Gordon-Bennett cup 2019, a balloon ascended to 4000 m asl, commemorating a pioneering flight measuring cosmic rays. Using 21st century technology the flux of cosmic rays increasing with altitude was verified. This article tells the story behind this event and what circumstances made it possible.

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1. Château-d'Oex a special place for aeronauts

The Hot-Air Balloon Festival in Château-d'Oex [1] is a well-known established event in the Swiss mountainous regions of the canton of Vaud. 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 [2].

In its 42nd 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 happen.

2. Museums need temporary exhibitions

The balloon museum in Château-d'Oex [3] is featuring historic balloon material, equipment, measuring devices, as well as more modern equipment and is in particular exemplifying the difficulties that needed to be mastered for the Breitling Orbiter endeavour to be a success. However, keeping museums alive and attracting visitors 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, the theme was a mixture of art and science.

2.1 First contacts via art

In particular, it was the museum's curator who was first attracted by the art works of Michael Hoch, who is also at helm of the ORIGIN network [4]. Hoch became internationally renowned for his specific art works, rendering particle physics into art for everybody to grasp and be indulged. Upon Hoch's invitation to expose his work in the balloon museum in Château-d'Oex, 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 was set up, did add a full narrative of cosmic ray detection in balloon flights.

2.2 A bit of history and a narrative that leads to modern science, accelerators, detectors, applications and spin-offs

Pioneers like Albert Gockel , who ascended 4500 m asl in 1909, Victor Hess reaching 5300 m asl in 1912, and Kolhörster ascending as high as 9300 m asl in 1914 are unknown to most people, but provoke an immediate attraction to a broad audience, when their adventurous story is told. Albert Gockel, who was professor of physics at the University of Fribourg, Switzerland, is ideal for being a local hero in Château-d'Oex. Gockel in his balloon flights observed 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 [5]. However, he couldn't conclude on his findings as he did not get the needed hydrogen gas to reach high altitudes of up to 7000 m asl. Still, it was Albert Gockel to coin the term cosmic radiation, first time mentioned in a paper by Gockel and Wulf in 1908 [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. 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 a showcase element could be added to the balloon museum. Certainly, this narrative reads well by a general audience visiting the balloon museum that is taken in by surprise into the history of cosmic ray detection, 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 Jungfraujoch at 3500 m asl [6], was ideal to add into the narrative. Again, due to its scientific relevance and to it being geographically close. Especially the emulsionplates that were exposed on the Jungfraujoch in the 1950ies, and that we received on loan to be shown at the balloon museum were of special value. 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 is clearly visible. Further, a spark-chamber on loan from the University of Bern, has been operating continuously, showing how particles can be visualized and that indeed, cosmic rays, in this case secondary muon tracks, are real and penetrating.

The general audience, now fully engaged in a new world of cosmos and particles, could 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 could be put on display. 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.

2.3 Complementing with artworks

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. Further, school classes from nearby and further away were attracted and added the topic of particle physics in a way they could relate to and understand. 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. However, the COVID-19 pandemic in 2020 caused for an untimely end of the exhibition, which is now closed.

3. From a temporary exhibition to the balloon festival

The director of the balloon festival, excited by the exhibition, decided to make the physics of cosmic rays as a lead theme of the 42nd balloon festival, 25 January to 2 February 2020 – not without initial resistance from his local organizing committee 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^2 each and separated by 15 cm. Cosmic rays, or to be more precise, mostly muons in the low altitude 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 [7] has been used for this and has been 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 speaker'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. An increase of the cosmic ray flux by a factor of three was obtained in both configurations of the muon telescope, when ascending from 1000 m asl to 4000 m asl and pointing the telescope straight to the zenith during the first half of the flight and tilted by 45° away from the zenith during the remaining half. The slopes with which the count rates increase differs by a factor of two for the two configurations measured, following a $\cos^2\theta$ decrease of flux rates with the zenith angle θ. Upon the balloon landed, the data could be extracted and sent via GSM mobile phone network directly to the festival place, where a further student readily received and analyzed them. Within an hour after landing, the speaker was back at the festival place to give a well-received public talk to a public audience of about 250 who attended the festival – which included also the freshly produced data plots, showing the increase of flux with altitude. After the talk finished and many questions from the audience answered, a young girl of about 12 years of age approached the speaker in front at the podium with a big and intriguing question on her lips: *"I do want to study the Universe with particles. How can I become an astro-particle physicist myself?"*.

4. Conclusion

Modern physics can enter the stage prominently and fusing enthusiasm, even in non-science oriented museums and at festivals. What it takes is a good link that needs to be identified first and that bridges from an established local context of the non-science oriented museum or festival to modern physics. In this example, from hot-air balloons to cosmic rays, to cosmology and particles. Enlarging the context further, by adding art, allows for a well-rounded set-up, which resonates extremely well with the festival organizers, the museum director, and most importantly, the public at large over all age groups, who were all excited - even in a remote and rural place like Château-d'Oex

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