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### Behind the Scenes

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## Behind the Scenes: The Two-Weeks Stay of Beamline for Schools Winning Students at DESY

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In a previous paper<sup>1</sup> the BL4S science competition has been presented from the technical point of view. This paper focuses on the organizational aspects of the period that the winning teams spent at DESY to perform their experiments. Together with a description of the event, this paper provides the unique point of view of the participants.

*Keywords:* BL4S; DESY; CERN; high school students; science competition.

## 1. Introduction

Beamline for Schools (BL4S) is a worldwide science competition. Teams of high school students are invited to propose an experiment that can be performed within the constraints of a given beam line and pool of instruments.<sup>1</sup> Starting from 2014, for the first five years, the BL4S competition was organized and hosted by CERN, Switzerland. In order to continue the competition during the period from 2019 to 2021, when all accelerators at CERN have been turned off for maintenance and upgrade, CERN collaborated with the German accelerator laboratory DESY in Hamburg. While the project management is still rooted at CERN, DESY provides manpower for administrative and scientific support as well as access to one of their electron/positron ( $e^+/e^-$ ) beam lines. This paper focuses on the organization of the winning experiments in 2019 and 2020. The organization of the student experiments at CERN in 2014–2018 has worked in a very similar way.

At the end of each chapter, the members of the winning teams describe their experiences. These are a collection of individual contributions of students from different years. They have been minimally edited in order to preserve the opinions of the students.

## 2. Experiment Preparation

BL4S has a core team of four members; a project manager, a technical coordinator and two support scientists. This team is complemented by a large number of colleagues from CERN and DESY that support the competition in several ways.

The evaluation of the proposals takes place in April and May and the two winning teams are usually announced in June. At this time, the core team starts to have weekly meetings for the planning of the selected experiments and the organization of everything around them. First, the winning proposals are analyzed again in detail in order to look for misconceptions that have to be discussed with the winners as well as adaptations, which have to be made, in order to obtain the best results and to plan how the experiments can be realized with the pool of instrumentation<sup>1</sup> available for BL4S and the beam conditions at DESY.

As early as possible, the two support scientists get in contact with the winning teams. The goal is on the one hand to keep them as much involved

as possible in the preparation of their experiments, and on the other hand to help them to acquire skills useful for the success of their beamtime, such as computing and programming basics. The students can be as much involved as they would like to be and are encouraged to do so in order for them to get the best out of their stay at DESY.

Depending on the subject of the winning experiments, the support scientists perform simulations or contact experts. In parallel, they get an overview of equipment that has to be purchased or built for the experiments.

By late July or early August, detectors, electronics and other materials are sent from CERN to DESY for a one-week test beam. The purpose of which is to set up the experiments for the first time and to find possible improvements to the setup and potential issues that could come up when the experiments are actually performed later in the year by the students. This test is performed by the BL4S core team with the help of volunteers and staff from DESY. At this stage, the support scientists verify that the experiments can in general be run successfully by the students in autumn without actually doing all the data taking and analysis already. Usually between this test beam and the arrival of the students, additional software is developed for the analysis of the data.

### 2.1. Point of view of the students

*Shortly after we found out our proposal had been selected, we were contacted by the support scientists. They messaged us to tell us about what they had done so far and which issues still had to be solved. To actively include us in the preparation, they helped us to come up with solutions on our own, and motivated us to decide within our team what we thought was best for our experiment rather than telling us the answer straight away. They also sent us some exercises that helped us to familiarize ourselves with ROOT, the data analysis software. The preparatory work helped us to make the most out of the two weeks at DESY.*

## 3. Beamtime with the students

### 3.1. Hosting the students at DESY

On the day of their arrival, members of the BL4S team pick up the students at the airport or main railway station of Hamburg and accompany them



Fig. 1. The arrival at DESY of the “DESY Chain Team” (USA) in 2019.

to DESY (Fig. 1). The students as well as their teachers are lodged in the guest house on the DESY campus together with the other guest scientists. They receive vouchers for using the DESY canteen for breakfast, lunch and dinner, but of course they are also free to have a meal outside on their own. For this and other purposes, everyone receives a ticket for the public transport in Hamburg valid for the whole stay. In that way, the students (and the teachers/team coaches) can visit Hamburg in their free time.

### 3.2. Before the first beam

The first few days of the program are filled with activities that allow the students to acclimatize and prepare themselves for the tasks to come. Meanwhile, the BL4S team has time to set up the experiments and to prepare them for the operations by high school students.

On the arrival day, after carrying out the necessary organizational and administrative tasks at DESY, the students get their first introduction to the facility and, depending on the arrival time and jet lag, their first visit and/or a welcome reception takes place. This is the occasion to meet some of the volunteers who will help them with the data analysis during their stay.

One day is reserved for guided sightseeing in Hamburg. This social activity is very important for the two groups of students to get to know each other in a relaxed atmosphere before starting their work together on both experiments.

Another full day is dedicated to extensive safety training. On top of the courses that are mandatory for every user of the DESY beam facility, the students also follow courses of general relevance, like a fire extinguisher training (Fig. 2) and computer safety. The aim is to familiarize the students with the safety culture in High Energy Physics (HEP) research and to raise their level of awareness of potential safety hazards onsite and how to behave correctly in an emergency situation.

One day is dedicated to various lectures. First, the student teams present themselves as well as their experiments to all people involved. Then, the support scientists as well as other experts provide the participants with information on the DESY II accelerator, the detailed implementation of their experiments, the functioning of the data acquisition system and the framework for the analysis of the data. In that way, the students gain more detailed insights, which will help them conduct their experiments and analyze their data as well as understand better each others’ experiment, as they will work in mixed shift crews collecting data together for both experiments.

#### 3.2.1. Point of view of the students

*The mutual presentations are very important for us to develop an understanding of the other team’s experiment, as we will be responsible for taking data for both experiments. The lectures given by the experts from CERN and DESY serve us also as*



Fig. 2. A participant of the 2019 edition of the competition during a fire extinguisher training.

reference once we have left DESY and start to analyze our data.

### 3.3. First beam and data taking

Well prepared, the students finally experience the “first beam” event for which all team members are invited to the experimental area and which marks the start of the experiments. This is when the students see for the first time in person the detectors and electronics that have been set up for their experiments. In the following eight days, data for both experiments is taken in a time sliced manner.

Each day starts with a general meeting, during which the students and the BL4S team discuss the achievements and issues of the previous day and plan for the coming day. From the two student teams, three or four shift crews are arranged. Each crew mixes students from both teams. A shift schedule is set up that requires each crew to be present at the control room for several hours per day. The members of each crew, typically 3–5 students, run the experiments together with one or two of the support scientists. They configure and enable the beam as required, control the data acquisition system, monitor data quality, keep a detailed logbook and help with changes and adaptations in the experimental area. While the support scientists have the overall responsibility, as many activities as possible are delegated to the students. Any problems arising during data taking are addressed together.

In parallel, the students that are not on shift can work together in a room dedicated to data analysis. From the computers in this room, the members of the teams have access to the full set of data that has been taken since the first beam. For several hours every day, experienced volunteers, mainly young physicists, assist the students with the analysis of their data. They teach them the tools required, such as ROOT and Python, and help them to understand the data formats as well as the different analysis techniques. If needed they can contact the scientists in the control room at any time. Also during the data analysis, the students are motivated to come up with their own solutions. The volunteers mainly help them to ask the right questions and to learn the skills required to answer them. In 2020, a second team of volunteers for data analysis was formed to meet in person with the students from Geneva at CERN.



Fig. 3. Participants to the 2019 edition of BL4S during their beam-time at DESY.

#### 3.3.1. Point of view of the students

*We found the work in the control room both challenging and enjoyable. This was our first opportunity to work hands-on with science out of school. We had experience in classroom labs, but the beam was entirely different to any science we had been exposed to. All of us learned that decision making on experiments in real life is not always black and white, and that communication between teams and team members is crucial to achieve results. We also learned that it is impossible to completely understand everything the first time in the control room: experiments imply new results, situations, and problems outside of our expectations. The scientists were very willing to work with us even beyond the expected times. Several nights during the program, we decided to run night shifts in order to collect further data.*

*During our time at DESY, the support scientists made sure the research felt like our own, since they let us make the decisions instead of telling us what to do. This way, we felt like we had a lot of responsibility for the project and a voice to share our vision. During the data analysis, we got the opportunity to work at our own pace and combine the research with our school and university tasks.*

### 3.4. 2020 COVID Crisis

As a fortunate coincidence, the two winning teams of 2020 came from Berlin (Germany) and Geneva (Switzerland). In late September 2020, the second wave of the COVID pandemic was developing in Switzerland. A couple of weeks before the departure of the Swiss team for Hamburg, the Geneva

area was put onto the list of high risk areas by the German government and the travel of the Swiss team had to be canceled, while the German team could travel to Hamburg as planned. The BL4S team at CERN changed plans accordingly in the last minute. Although no visitors were allowed at CERN at that time, the permission was granted to the BL4S event to use CERN's S'Cool LAB<sup>7</sup> for the entire duration of the event, where the Swiss team could be supervised by one member of the BL4S team, who stayed at CERN while the other BL4S team members traveled to DESY.

With the use of videoconferencing tools, the Swiss team could participate remotely (Fig. 4), though actively, in lectures, the general morning meetings and a virtual visit to the European XFEL.

In 2020 the VIP and Sponsor Day was also organized as an online event. Officials as well as representatives of the companies and foundations that support BL4S congratulated the students on their success. Selected students, who had been members of winning teams in previous years, shared with the audience how BL4S has impacted their careers.

Videoconferencing tools had also been used for the execution of the experiment of the Swiss team, while the data to be analyzed was transmitted to the CERN computing infrastructure. The German students were very supportive and tried to learn as much as possible about the Swiss experiment so as to be able to help the other team to the best of their abilities. The Swiss team was very grateful and both teams used different channels to connect with each other — already beforehand, when it was clear that the Swiss team could not travel to DESY. After all, it was the first time in the history of BL4S that one of the winning experiments was done remotely, but successfully in the end.



Fig. 4. Set-up of the S'Cool LAB working space, where all the activities of the Swiss Team took place.



Fig. 5. The German students and members of the BL4S team in the experimental area.

At DESY the risk related to COVID was addressed by the wearing of masks and social distancing in meeting rooms as well as in the experimental area (Fig. 5).

#### 3.4.1. Point of view of the students

*The COVID-19 pandemic posed a unique challenge for the winning teams. For the first time, one group had to perform their experiment remotely. DESY and CERN tried to make the online experience as close as possible to the experience of conducting the experiments in person. Cameras were set up both in the control room and the experimental area to connect the Swiss and German teams. Even though in the end it all worked out for both teams, there were a lot of difficulties in the online experience. Particularly the first few days were very frustrating as the MicroMegas detectors<sup>1</sup> of the Swiss experiment were not working properly and they could only watch the shift groups attempting to fix the problem. Luckily, the MicroMegas could be fixed.*

*COVID-19 also affected the proposal submission. For the first time, it was not necessary to submit a video with the proposal. Since final exams in Germany were postponed from March to May and it was still uncertain if they were happening after all, we decided to use our spare time to generate a creative video. Due to the national lockdown, we were unable to meet in person. This forced us to rapidly adapt and coordinate the production over video conference tools.*

### 3.5. Other activities during the stay at DESY

One thing that the students and their teachers often ask before their arrival is what they could do in Hamburg in their free time. Once the experiments are running, this question usually does not come up again because the experience of doing research on a particle accelerator is extremely captivating. Quite frequently the students ask the support scientists to extend the day beyond the shift schedule in order to fix problems or take more data to exploit the available beamtime as much as possible.

In order to take the students out of their bubble, volunteers at DESY take them on guided tours to facilities such as the European XFEL, PETRA III and HERA. This allows the students to perceive the parallels of their work with professional research programs, and to widen their horizon.

The Swiss students that came to CERN in 2020 were given guided tours to the Antiproton Decelerator, the cryogenic test facility and the Synchro Cyclotron. In addition they were offered two activities in the CERN S’Cool lab.<sup>7</sup>

On one day, the data taking is interrupted for 3 to 4 hours for a VIP event. On the invitation of DESY, officials from the home countries of the winning teams, representatives of the sponsors, as well as officials of CERN and DESY meet with the students to celebrate their success. During this event, the teams present their experiments to the officials. In 2020, the event took place virtually due to the COVID situation. This allowed the Swiss team to participate as well, and had the additional advantage that also their parents, friends and schools could connect and follow the event.

On the last day of their stay at DESY, the students give a presentation of the results they had obtained so far.

#### 3.5.1. Point of view of the students

*The tours of the DESY facilities before the first beam were both fun and useful. Most of us had little or no exposure to physics research before taking part in BL4S. The tours allowed us to develop a taste for asking questions, an integral part of the BL4S experience. The presentations and tours of the various accelerators gave us a snapshot of life as an actual physicist or engineer, and our conversations with experts of DESY and CERN gave us context for our experiences to come.*

*During the time at DESY, we were able to have “dinner with scientists”. We discussed important issues like imposter syndrome, what it is like to be a scientist working for CERN/DESY, and how to approach science as a lifelong learner. For us, these talks made our work at the beam more fruitful, and provided mentorship when we all felt as though we had bitten off more than we could chew.*

*We did not only learn more about science but also about other cultures. We talked about the daily life of the other team and their customs. This made us grow as human beings.*

## 4. Returning Home

The BL4S experience is not over for the teams with their return home. If desired, and if the activities at school, or later at university allow, they can continue the analysis and write up their results in a publishable format. The BL4S team will be supporting them the entire way. So far five teams have taken this opportunity.<sup>2-6</sup> It took them between one and two years to fully analyze their data, and to write their papers. They all stated that it was a rewarding challenge.

CERN and DESY are organizing BL4S because they believe that such a competition can motivate high school students during a crucial moment of their career to develop an interest in STEM related subjects. The BL4S team is still in contact with many of the alumni that have won the competition in previous years. A large number of them are studying physics or engineering and some of them have returned to CERN as summer students<sup>9</sup> or even as members of one of the experimental collaborations. Many of these former students, as well as some of the students that took up studies in other subjects such as medicine, tell us that BL4S has not only been a life time experience for them, but played an important role in their career choice.

#### 4.1. Point of view of the students

*These skills of adaptability and problem solving have been necessary for our data analysis. Though we have not published any results yet, we are working on solving new problems in our code. Our issues are different from the ones we faced in the control room (i.e. we are working on classifying data rather than taking it). Still, we are trying diverse solutions to problems that we did not expect. The largest difference between data analysis and data taking*



for us is our stamina. We have found it hard to coordinate meetings around busy college schedules, and we have found holes in our knowledge of our experimental theory. As a team, we are working better than ever to face these new problems just as we learned to in the control room: by asking more questions.

BL4S has and will shape our lives. Being exposed to research at an early age and to gain first-hand experimental experience as well as the skills required for data analysis and presenting the results in meetings and publications helps a lot in the study of STEM related subjects.

After our time at DESY, two members of our team used the research at DESY for a school project. This way, normal school time was used to continue data analysis and write the first draft of a paper. During this project, we kept in touch with the BL4S support scientists. We mailed and held video meetings at least twice a month. Finishing the first draft helped us to build a basis for the following presentations and the actual paper.

On invitation from one of the support scientists, four members of our team attended an international workshop on experimental physics.<sup>10</sup> We could not only listen to the talks of the other researchers, but also present our own results to them. This has stimulated us further to ask questions and to “think on our own”. Eventhough we left DESY more than a year ago, we get the feeling that we can always contact the support scientist when we have questions, even if they are not BL4S related.

## 5. Summary and Conclusions

This paper documents the large effort that CERN and DESY are making in order to organize a worldwide, high level science competition. It shows that such an event can be organized at different research institutes even under the conditions of the COVID pandemic. It offers high school students the very rare opportunity to perform ambitious experiments at a particle beam line, gives them deep insights into the life as a scientist and can play an important role in their career choice.

### 5.1. Point of view of the students

BL4S is an amazing opportunity for students to engage in particle physics and we certainly

recommend it to anyone who is interested in physics or scientific research, in general. Even if you do not end up winning the competition you will certainly gain experience from researching and designing your own experiment.

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**S. Aretz, M. Boselli, C. Beirão da Cruz e Silva, M. Joos and P. Schütze** are the core team of *BL4S*. **E. Arce-Larreta and K. Stadermann** are coaches of winning teams. The other authors are members of the teams “*Particle Peers*”, “*DESYChain*” and “*ChDR Cheese*” that have won *BL4S* in 2019 and 2020.