PROCEEDINGS OF SCIENCE

The Beamline for Schools competition

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Abstract:
In 2014 CERN has started to organize “Beamline for Schools” (BL4S), an annual physics competition for high-school students aged 16 or more. In the competition, teams of students from all around the world are invited to propose an experiment to CERN that makes use of a secondary beam of particles with momenta of up to 10 GeV/c from CERN’s Proton Synchrotron.

In the first four years of the competition, 6900 students from all around the world have participated and in total eight winning teams have been selected and invited to CERN for ten to twelve days each.

We will describe the challenges linked to the Beamline for Schools competition, focussing on the communication with all teams in the preparatory phase of the competition, the technical implementation of the winning experiments, the operation of the experiments as well as on the support for the teams analysing the data and preparing publications of the results. We will also report on the impact of the competition on the candidate teams as well as on the winners.

Finally, we will present an outlook for the future of the BL4S competition, taking into account the shutdown of the accelerators at CERN in 2019 and 2020.

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1. Introduction

Education and outreach have always been essential values for CERN and are part of its official mission. While there are many programs for university students, doctoral students and postdocs, the offers for high-school students were so far largely limited to the visit program and a few places for internships. We believe that the last few years before leaving school are important in the lives of young people, because the decision about what to do after school has a great impact on their careers.

Looking for new ways of engaging teenagers with STEM subjects, the idea of a worldwide science competition was born back in 2009. Eventually the celebrations of the 60th anniversary of CERN in 2014 provided the right framework for the first edition of the Beamline for Schools (BL4S) project; that originally was meant to be a one-off event. Due to its success, BL4S has now become a regular event and every year CERN is inviting two teams of up to nine students and two teachers or guardians each, to perform their experiments.

The idea of BL4S is to bring high school students to CERN and to aid them with performing an experiment at one of CERN's accelerators, the Proton Synchrotron (PS). The students are using an experimental area, detectors, electronics and analysis tools identical to the ones used by "real" particle physicists. The experimental zone of the PS beam line T9 was chosen for BL4S. This area of about $50m^2$ receives a secondary beam consisting of protons, electrons, pions, kaons and muons with momenta between 0.5 GeV/c and 10 GeV/c.

Figure 1: The T9 beam line of the Proton Synchrotron. The beam enters from the right.

A document describing the properties of the particle beam is provided to the students as well as information about a number of different particle detectors that they can use to build their experiment. See [1] for reference.

However, as there is a high demand for beam time at CERN, it is not possible to bring many teams of students to CERN. In order to motivate a large number of students to learn about particle physics, the idea of a worldwide competition was born.

Within the boundary conditions set by the PS beam momentum and intensity, the available detectors and the electronic read-out system, the students are completely free to propose any kind of experiment. They may also bring their own equipment to CERN. The rules of the competition require them to form a team of at least five students that is represented by one adult (usually a teacher). The students are required to submit their proposal before they start university studies.

In order to be as inclusive as possible there is no age limit for the participation in the competition. However, due to safety regulations of CERN, only those members of the winning teams that are at least 16 years old at the time of the event can be invited to CERN.

It is obvious that teenagers usually know much too little about particle physics in order to be able to propose a sophisticated experiment. We are addressing this in two ways:

- The teams are free to use any kind of help that they can get. They may ask their teacher to guide them, get in touch with the BL4S team at CERN or the volunteers for their region [2]. They may also get in touch with local universities or other specialists.
- The teams are not required to submit a proposal that can be implemented as is. A creative, well-motivated idea is enough as long as it is feasible within the boundary conditions set by the beam and the available equipment. We do, of course, expect the students to describe, within their abilities, how the experimental set-up could look like, what difficulties they anticipate and how they would analyze the data.

The BL4S support scientists will finally develop the winning proposals into real experiments.

The experience that we have gained over the last four competitions shows that this scheme works quite well for many teams. Some students write their proposals completely by themselves, in other cases the subject of the experiment is proposed by an external person and the students have to understand the science behind it. Eventually the students have to write up their proposal in a document of at most 1000 words and complement it with a one-minute video.

In the first four years of the competition, 741 teams have submitted a proposal to CERN. Two thirds of the proposals were from member states of CERN as well as its associates. Among those, Italy (122), Spain (81), the UK (78) and Turkey (47) are the most active nations while countries such as France (8) and Germany (26) are poorly represented. The remaining third of the teams are from all around the world [3] with the USA (50) and India (30) being the most active nations amongst them. BL4S has received so far only four submissions from China and one from Japan. Our statistics also show that one third of the students are female and there are even some all-female teams entering the competition.

On average, the teams spend (according to their self-assessment) 30 hours on the elaboration of the proposal and the production of the video. The additional time spent for self-studies is difficult to estimate. Therefore, the participation in BL4S is comparable to a subject that is taught at a level of one hour per week for one school year.

In terms of the impact of BL4S, the most important figure is the number of students participating every year. Our goal is to motivate as many students as possible to dedicate some of their free time on additional studies on STEM relevant subjects and physics in particular.

Beyond that, BL4S has a huge impact on the winners. They spend ten to twelve days at CERN of which seven to eight days are dedicated to performing their experiments. Once back at school, the teams are encouraged to continue the analysis of their data and summarize their results in a scientific paper. For the writing of the paper, support is available from the BL4S team and CERN helps the students to place the paper on a publishing platform.

Financially BL4S rests on two pillars:

- CERN offers, in kind:
  - 10 days of beam time at a beam line of the Proton Synchrotron for performing the experiments of the winners as well as five to seven days of beam time for tests of detectors and preparatory studies.
  - The work force of a project leader, one administrative support person and a large number of volunteers that make small contributions
- The BL4S annual budget is primarily funded by the CERN & Society Foundation with the support of private donors (companies and charitable foundations). The budget is used to pay two support scientists, bear the cost of the stay of the winners at CERN and to develop and build detectors for use in the experiments of the winning teams. In our experience, the donors prefer to support projects for several years in a row. We are therefore trying to find solutions for bridging the gap that will be caused by the shutdown for maintenance of the accelerators at CERN in 2019 and 2020.

2. Advertising the competition

Our main challenge is making the BL4S competition known among the main target groups: high-school students in the last two to three years of their studies as well as their teachers. CERN is using its social media channels (Twitter, Facebook, etc.), the Beamline for Schools website [4] and the CERN & Society website [5] to announce the competition. In addition, the word is spread through:

- the 10.000+ alumni of the CERN teachers programs,
- high-school classes that have visited CERN,
- former participants of BL4S,
- several journals and websites for education,
- supporters' communication channels,
- as well as other channels.

Despite this effort, BL4S seems to be known by a much smaller number of schools than envisaged. In some countries (e.g. Italy and Turkey), efficient local networks exist that help to disseminate information while in other countries there are no or too little disseminators. We are actively looking for additional ways, both top down and bottom up, of spreading the word.

Surveys among the participants in 2016 and 2017 show that only 30-40% of the schools are participating regularly (mostly with new students). We believe that the main reason is the large (and often voluntary) effort that has to be made by the team coach in order to educate him or herself and to instruct the students. To this end we are encouraging and helping the teachers as much as possible by providing them with additional material and assistance or by discussing the feasibility of their ideas.

3. Selection process

In line with the commitment to treat the students in the same way as professional scientists, CERN makes a great effort with respect to the evaluation of the proposals and the selection of the winners. A team of more than 40 volunteers (physicists, engineers, communication experts) ranks the proposals. Each proposal is evaluated by at least four people. The quality of the proposals is rated according to these criteria:

- motivation of the students,
- creativity and originality of the proposal and the video,
- feasibility of the proposal,
- demonstration of ability to follow the scientific method.

After two stages of pre-selection, a short list of ten proposals is given to members of the SPS committee (i.e. the body that allocates the beam-time of the SPS and PS accelerators for professional projects) who eventually nominates the two winning teams. At the end of the selection process CERN announces the winners in a press release and notifies all teams about the result of the competition.

In addition to the two winners, every year 20 to 30 shortlisted and noteworthy teams receive a second prize, which consists of BL4S t-shirts for all members of the team as well as one low cost particle detector for the school. All participants receive by mail a printed participation certificate.

4. The role of the BL4S Support Scientists

Every year two support scientists (typically young physicists that have recently completed their PhD) are hired to work full time on BL4S for eight to nine months. The first four months are dedicated to getting familiar with the detectors and the data acquisition framework (which is based on the software that was developed for the ATLAS experiment [8]) and to the development of additional software for the read-out of the detectors as well as for the analysis of the data. Furthermore, the support scientists make substantial contributions to the development, production and testing of additional detectors that are built for BL4S in order to enlarge the spectrum of feasible experiments. In 2015/2016, three MRPC detectors have been built. In 2017, four MicroMegas detectors [6] were added to the BL4S pool of instruments.

Once the winners have been selected, the support scientists start to design and implement the successful proposals. Their work may include simulations of the experiments in order to identify potential problems or to make small modifications to the original proposals in order to correct minor misconceptions and to maximize the chance for success. The winning teams are actively participating in this process and are invited to perform part of the calculations or studies needed.

During this period, the scientists at CERN also use the beam facility at the PS to perform tests of the set-ups for the experiments.

While the winners are at CERN, the support scientists have the overall responsibility of the experiments and involve the students actively in the operation of the experiments, the data taking and the analysis of the results.

After the departure of the students from CERN, the support scientists stay at their disposal while the students complete the analysis of their data and write up the results.

During their involvement with BL4S, the support scientists have the rare opportunity of going through the full cycle of a (small) experiment from its conceptual design across the implementation to the data taking and analysis. This allows them to acquire skills that are difficult to get in any large collaboration.

5. The execution of the experiments and the data analysis

While the winners are at CERN, the main focus is laid on the experiments.
Before the students are admitted to the experimental hall they are given a full day of safety training. This includes courses on radioprotection, cryogenics, fire safety, risks related to electricity and chemicals as well as computer safety and environmental aspects.

On the day before the start of the experiments, the support scientists and other experts organize a series of lectures (three to four hours) for the students to provide them with details about the beam line, the detectors and the data acquisition system as well as the tools for data analysis. Subsequently the students of the two winning teams are assigned to four groups. Each of these four groups of students is on shift in the control room for three hours every day spanning the time from 9 AM to 9 PM. The support scientists act as shift leaders. The students on shift have to take the responsibility for a number of duties such as periodic checks of the data acquisition system, the gas supply to the gaseous detectors, the control of other operational parameters and the documentation of the progression of the experiments in an electronic logbook.

For the students that are not on shift, two analysis rooms (one per winning team) are set up. In these rooms, the students and their teachers have access to the data of their experiment and can analyze it in (almost) real time. CERN volunteers with experience in analysis and the necessary software tools (e.g. ROOT) assist them as required.

The results of the analysis as well as news from the counting room are discussed every morning in a status and planning meeting. In this meeting, the students and the support scientists also decide on the plan of the day.

The stay of the students is complemented by visits to interesting places at CERN, a meeting with the Director General, members of council and national representatives of their home countries, a meeting with representatives of the foundations and companies that provide financial support to BL4S and a dinner in Geneva.

6. Impact

Eventually the main justification for a project like BL4S is its impact among the students. We have to assess to what extent the competition manages to raise the awareness about the role of science in our society and if participation in BL4S has an effect on the career planning of the participants. A large fraction of the winners state that they will take up scientific studies after leaving school. For some, winning BL4S has changed their career plans while for others it is a positive amplification of decisions that they had taken earlier. Some of the previous winners who have been admitted to elite universities are convinced that winning BL4S has been helpful in that process. Furthermore, CERN encourages the winners to publish a scientific paper with the results of their experiments. The Dutch team “Dominicuscollege” that has won the competition in 2014 has already done so [7]. One team of 2015 and both winners of 2016 are still meeting from time to time to work on their papers. The effort that they are putting into these publications shows the level of commitment to their experiments and that the teams stay in contact even years after they had been at CERN.

It is more difficult to estimate the effect on the large number of participants that are not winning the competition. Feedback that we receive mainly from the team coaches indicates that for them BL4S is a very welcome instrument to motivate their students for extracurricular activities or project work. The average quality of the proposals shows that there are only very few teams that try to win a prize with minimum effort. Some of the teams report that their participation in BL4S was noticed at their school and that they have talked about their proposal to younger students or to classes in other schools. Some teams go as far as setting up their own web sites or contacting local newspapers or TV channels.

Finally, the organizers of BL4S share the applications from Italy with INFN and the applications from the USA with Fermilab. INFN and Fermilab re-evaluate the proposals of their national teams and try to invite one of them to one of their research facilities.

7. Outlook

In 2018, CERN will run the fifth edition of BL4S based on the by now well-established procedures.

In 2019 and 2020, CERN will be in "Long Shut-Down 2" (LS2) and all accelerators will be turned off for maintenance. Therefore, it is not possible to organize the BL4S competition at CERN during these two years. In order to perpetuate the competition, CERN is in contact with other institutes that offer a beamline with properties similar to that of the PS, in particular DESY (Germany), INFN (Italy), PSI (Switzerland) and IN2P3 (France). Our plan is to find a model of cooperation with one of these institutes that would allow using their facilities and infrastructure, complemented by work force and material provided by CERN to organize editions of BL4S in 2019 and 2020. Bridging the gap of the LS2 with the help of partner institutes has a number of advantages, the most important being that we can keep offering this competition on a yearly basis to schools around the world. In addition, it offers the partner institute new opportunities for outreach activities and finally helps to attract donators that are looking for a longer engagement with the program.

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