Operation and Improvements of PHELIX*

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General overview

PHELIX, the workhorse of the plasma physics program at GSI has performed in line with prediction in 2013. In the wake of the decision to reduce the beam time offer for users at GSI, PHELIX reduced the time dedicated to external users by 30%. Nevertheless, even under these circumstances PHELIX has shown proper performance in its fifth year of operation: 10 experiments were realized which were served in 12 beam times for external users. Three of these were performed at the Z6 area (but without ions from the UNILAC), the rest in-house in the PHELIX laser hall (PLH). Altogether, 156 shifts were delivered by the PHELIX operating team. The average duration of the preparation of an experiment at PHELIX was about 4 days, the average duration of an external beam time 6 to 7 days.

Furthermore, upgrades and improvements have been commissioned in 7 internal beam times. The longest has been the commissioning of the new target chamber (37 days) at the PLH. This and other developments are illustrated in the following.

Operation of the laser facility

In 2013, GSI has focused its activity mainly on the preparation of FAIR and, as a consequence, the accelerator was shut down. For PHELIX, which should remain in operation throughout the building phase of FAIR, this means a shift from the combined laser-ion experiments at Z6 to more stand-alone experiments. To enable this, the target area in the PHELIX building was upgraded. This, together with the decision of GSI to reduce user beam time at PHELIX by 30% had a visible impact on the beam time offer, which was set for 2013 to 170 shifts. As can be seen in fig. 1, an appreciable part of the time has been used for external beam time (29%) and the preparation (17%) of these experiments. This is - as expected - less than in 2012 where nearly 50% of the available time was spent for experiments: 2012 was, however, an unusual year, as many experiments had to be scheduled to anticipate the accelerator shut down of 2013, a necessary step in the preparation of FAIR. In addition, some maintenance tasks were delayed and took place in 2013. In 2013 also the relation between preparation and beam time changed in favor of the preparation time: PHELIX was able to offer more of this which was of advantage to set up complex experiments. Development beam time (28%) and maintenance periods (17%) also increased compared to 2012 where this portion was 22% altogether. The time of shut down (9%) did not change noteworthy due to the high operational readiness of the small operating team.

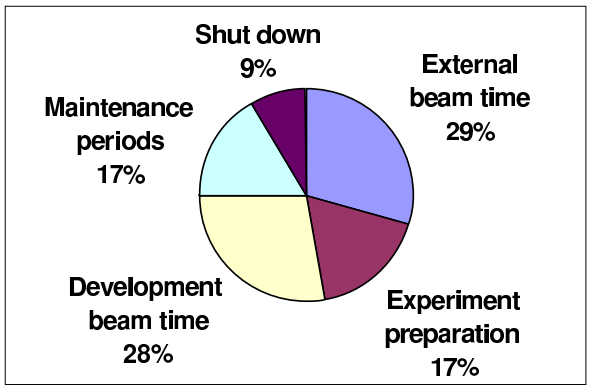

Figure 1: PHELIX usage in 2013

But the operation is not ensured by this team only: GSI supports by the help of several infrastructure departments. The PHELIX operation team is working together with these colleagues in close collaboration: To give an example, the radiation protection department is involved in nearly every beam time.

Shots are documented in the PHELIX shot database as described in the 2012 report. For 2013, 1655 shots were recorded totally in this data base. Since this includes all test shots and also the so-called snap shots (these data are taken to store actual settings of the system), the number of shots delivered for experiments is of more interest: these were 463 in 2013.

The database allows for an evaluation of failed shots: 40 of the experimental shots (8.6%) ended up with an error. One has to face the fact that this information is of less significance: On the one hand, no ”failed shot” is recorded if the laser system shows an error which forbids to shoot, on the other hand a shot can be delivered mostly shortly after the failed shot occurred. Thus, there is no severe loss of time for the experiment. But it is of interest to classify the failed shots for their reasons; it turned out that the most failures are caused by hardware (37%) as well as by the PHELIX control system (*PCS*: 45%). The increase of the last (in 2012, less than 10% of failed shots were caused by the *PCS*) is due to necessary changes made to the system which will be described in the following. These prob-

* The acronym stands for **P**etawatt **H**igh **E**nergy **L**aser for heavy **I**on E**x**periments

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lems have been solved in the meantime. Only 10% of the failed shots are caused by the operators (in 2012, the majority - 52% - happened due to this reason). This shows the high experience of those who operate the complex laser system, and also the increase of programmatically implemented help at the *PCS* in order to avoid operating errors. The last portion of 8% were caused by external reasons.

Anyhow, 423 successful experimental shots delivered in 2013 attest PHELIX to be a reliable scientific facility. It can be compared with others without any shame. The experimentalists appreciate the fact that nearly always the first shot is delivered in the early morning of the first day of the beam time - if the experimental setup is ready for operation.

Internal developments

In 2013, some modifications enabling full user service during the construction phase of FAIR have been completed with the upgrade of the high-energy target area in the PLH. By that, the experimental options have been improved while the handling of the experiments has been eased and the radiation protection was optimized. For details refer to [1].

Another goal during the ongoing preparation phase of FAIR is the development of innovative technical solutions, like the operation of high-energy lasers at higher repetition rates. A test bed has been set up in the past 18 months to tackle this issue with the particular task to upgrade the preamplifier of PHELIX to higher repetition rates and to develop the relevant diagnostics. This test bed is equipped with a separate pulsed power system. Upgrade activities in this field are described in more detail in [2].

The work on the improvement of the temporal characteristics of PHELIX has continued. First the uOPA stage (ultrafast optical parametric amplifier) in the short pulse frontend was made available to users and is rightfully documented [3]. The system is meanwhile fully integrated into the laser setup, has been used several times for experiments and is close to be operated in a daily routine. Secondly, the search and elimination of the sources of pre-pulses in the frontend and throughout the system was carried on, such that the quality of the temporal profile of PHELIX has been greatly improved. And last, a test beam time was conducted to measure the plasma expansion of the target before the main shot in order to quantify the effect of high-temporal-contrast pulses on laser-matter interactions [4].

An important component of the *PCS* has been changed during the year: the Beckhoff control bus systems have been equipped with Ethernet bus couplers. This piece of hardware connects several devices (for example nearly everything related to the pulsed power system) with the *PCS*. This change became necessary since the linear optical bus couplers used before can not easily be operated with the available hard- and software when changing the operating system of the computers from XP to WINDOWS 7. The migration of the operating system of the *PCS*-PCs was started afterwards at the end of the year.

All these improvements have been tested in several internal beam times.

Contribution to the scientific program and outreach

In 2013, seven peer-reviewed articles [5 - 11] were published on data collected at PHELIX. As seen in the past, these articles report on results often obtained during beam times which occurred longer before, since the analysis of data takes some time.

As a side effect, PHELIX was used to acquire data for the test of a new type of dosimeter which was developed by the GSI radiation protection department. Details can be found in [12].

Concerning the laser activities at FAIR, several meetings were held to understand the requirements of the different research fields. These have been written down in a project report in order to derive the parameters of a future laser facility. Finally, working on a draft of a design of such a facility has been started while in parallel resulting necessary change requests for the FAIR site management are in preparation.

Outlook for 2014

User beam time is granted at PHELIX by the scientific director of GSI after recommendation of an expert panel, the PPAC. In January 2013, the PPAC met at GSI and reviewed experiment proposals that amounted for more than 300% of the available yearly beam time.

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