Operation and improvements of PHELIX

S. Götte[1], *C. Brabetz*[1,2], *W. Cayzac*[1], *U. Eisenbarth*[1], *M. Kreutz*[1], *S. Kunzer*[1], *D. Reemts*[1], *T. Stöhlker*[1,3], *L. Tymura*[1], *F. Wagner*[1,3,4], *B. Zielbauer*[1,3], *and V. Bagnoud*[*1,3]

[1]GSI, Darmstadt, Germany; [2]Johann Wolfgang Goethe University, Frankfurt, Germany; [3]Helmholtz Institute Jena, Germany; [4]Technical University Darmstadt, Germany

The *P*etawatt *H*igh *E*nergy *L*aser for heavy *I*on E*x*periments (PHELIX) has been operating continuously since 2008. This article reports on the usage of this Helmholtz facility, recent improvements achieved in 2014 and how PHELIX contributed to the scientific program of GSI.

Overview

Figure 1 shows the usage of PHELIX in 2014 in form of a pie-chart. Ten beam times took place, distributed over 88 out of 251 working days (35%, labeled as external beam time). These experiments were prepared typically over a period of about 5 days (additional 23%, marked as experiment preparation). Thus, again more than half of the available time was spent to serve for external experimental usage. This is an increase compared to 2013 but similar to the years before.

The rest of the time, maintenance (27%; this is more than in 2013 where 17% of the time have been used for this purpose) and three development beam times (7%, which is less than in the year before) have been done. The system was shut down for 8% of the year which is the same as in 2013.

During the construction of FAIR, PHELIX is running however with a capacity reduced to 2/3 of its full possibility. This results, for example in a reduced number of beam times in which PHELIX and the UNILAC ion beam are combined. The operation of PHELIX is ongoing, but more and more affected by the set up of FAIR since GSI infrastructure departments are concentrating on their tasks to serve the different building lots at the GSI site as well as upgrading the accelerator to become the injector for the future facility.

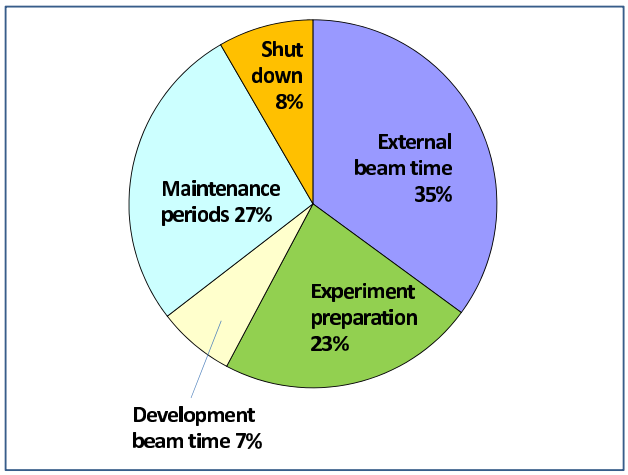

Figure 1: PHELIX usage in 2014

Operation of the laser facility

Five of the 2014 beam times were done at Z6, three of them as combined experiments of PHELIX and ions out of the UNILAC. This is less than in the years before, as mentioned above. The other five experiments were made in-house (four at the laserbay, one at the laserlab using the preamplifier only).

The PHELIX data base recorded 2310 laser shots in total. 1353 out of these were registered as experimental shots. The high amount of these is due to the beam time using the preamplifier only which can be used with a repetition rate of one shot each three minutes, while a typical experiment using the main amplifier stage gets typically six shots per day.

The number of failed experimental shots is less than a percent (in total 11 shots) which is really satisfactory; six of these failures happened due to broken hardware, mainly at the pulsed power system. They could be repaired within hours and did not cause a severe interruption of the experimental campaign. Only four shots were lost due to mistakes made by the laser crew which shows the high expertise of the operators as well as the good support of the PHELIX control system *PCS* to operate the facility. The last failed shot was due to a hardware problem not caused by PHELIX but the accelerator hardware.

The user service has been greatly formalized in the last years. After a positive evaluation, the applicant receives an information about the amount of beam time reserved for his proposal. When the experiment is scheduled and its time slot communicated by the PHELIX group leader, the experimentalist has to prepare a detailed technical design review which has to be presented and discussed at least three months before the beam time is going to happen. Within this review, all technical aspects of the planned experiment down to the screw level have to be addressed as well as the personal and machinery safety. The experimental team (up to six persons) foreseen to enter the laboratory has to be named, the roles and tasks have to be assigned and finally the shot plan has to be presented.

On the day of arrival, the external users get the necessary personal safety equipment, and after the training at the experimental site they can start to set up the experiment.

* v.bagnoud@gsi.de

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These formal aspects are normally done within one hour. On the PHELIX side, a link scientist takes care for technical aspects concerning the set up as well as an operator providing the laser in an alignment mode.

During the experiment, PHELIX is operated by a shot director who drives the shot sequence in coordination with the experiment, and an operator setting the laser parameters. The staff for these tasks is changing once per day corresponding to a shift plan prepared before. The activity of the experimentalists is steered by an experimental coordinator out of the external team. This person and the shot director communicate in the morning as well as in advance of each shot what is going to happen.

Internal Improvements

After more than ten years of operation, some of the hardware must be replaced because it is no longer supported and spares become unavailable. It is also the occasion to bring it back to the state of the art. In this view, a new fiber-based nanosecond front-end has been bought and installed at PHELIX. The performance is similar to the existing system [1] but its versatility and the service offered by the Europe based vendor (Photline Technologies) greatly improves the reliability of this subsystem. For similar reasons, a new pump laser (Verdi, manufactured by Coherent Inc.) has been bought for the femtosecond front-end. The operation modes of this subsystem have been extended over the past and reach from a free adjustable pulse contrast level by use of the uOPA system over multi-pulse generation with adjustable delays of picoseconds up to two-beam operation with different pulse durations and tunable energy ratio.

Some devices were replaced because of their lack of long-term reliability. This concerns most notably the high-capacitance Pockels-cell driver of the preamplifier. Furthermore, a new random phase plate was installed and commissioned at the Z6 experimental area to enhance the homogeneity of the laser-focus profile.

Since Microsoft stopped the support of its operating system Windows XP, all the 30 computers of the *PCS* were upgraded or renewed to run Windows 7. Additionally, LabVIEW was changed from LV 2009 to LV 2014, and accordingly the *CS* framework made a huge step from version 3.2 to 3.40.

Contribution to the scientific program

Most of the experiments done at PHELIX are planned and executed in close collaboration with the PHELIX team and the plasma physics department of GSI as mentioned above. A non exhaustive list of such experiments can be found in this report. For instance, the configuration of PHELIX in multi-beam mode allowed the generation and study of magnetic field recombination [2]. An internal beam time was devoted to the generation of Raman-shifted laser pulses for the study of a Raman-amplifier [3]. In addition, using the world-unique laser-ion setup of the Z6 area, two combined laser-ion experiments were performed on the energy loss of ions in plasma in nonlinear interaction conditions, where the ion-stopping theories are still highly incomplete [4].

In 2014, twelve articles have been published basing on experiments and laser developments done at PHELIX [5...16]. Additionally, two doctoral theses dealing with experimental and technical aspects have been finished this year in our group [17, 18]. Furthermore, a technical design report was written concerning a 100 J laser system to be set up in the APPA building at the FAIR site.

Outlook for 2015

By the help of the expert panel PPAC, PHELIX will not run out of experiments to be done in 2015; the first half of the year is scheduled already. A suggestion for a large-scale laser system (the so called Helmholtz Beamline) to be set up in an own laser building at FAIR is in an early project stage and will be continued 2015. Finally, a project is ongoing to upgrade the preamplifier stage of PHELIX in order to increase the repetition rate.

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