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# Operation of the PSI Accelerator Facilities in 2014

Andreas Lüdeke, Anton C. Mezger, Marco Schippers, Mike Seidel, Department of Large Research Facilities, PSI

**The Department of Large Research Facilities has responsibility for the operation and development of the three accelerator facilities at PSI. These are: the High-Intensity Proton Facility, the Swiss Light Source and the Proscan medical accelerator. In addition, a new injector test facility for SwissFEL, PSI's free-electron laser project, is being commissioned. This article covers operational aspects of these facilities, as well as performance highlights and new developments achieved in them.**

## High-intensity proton accelerator (HIPA)

The user operation was started in 2014 one day later as scheduled with a production current of 1900 µA. The delay was caused by a water leak in a collimator that had to be repaired. The facility was already running over two weeks before user operation with interruptions to allow us to find problems caused by shutdown-work, and to optimize the accelerator to its nominal current. After the repair the weekly availability of the facility rapidly reached values exceeding 90%. During the first service after 3 weeks of production, a water leak was detected near one of the Ring cyclotron cavities. In order to repair this leak we had to remove the cavity and during its removal the crane used for the transport was damaged. The damage of the crane could not be repaired rapidly and nearly a full week was needed to get the facility into operation again. The availability was therefore 0% in week 23 and only 48% in week 24. Several longer significant interruptions were registered for weeks 27, 29, 30, 35 and 42. Week 27 was impeded by a power failure resulting in a long setup of the facility. In the weeks 29 and 30, problems with the RF-Amplifiers for Injector-Resonator 4 and for Ring-Cavity 5 caused interruptions of several hours. In week 35 the Meson production target E had to be replaced. The drop of the availability in week 42 was caused by a longer tuning period.

The overall availability in 2014 amounted to 86.4%, a 5% better performance than in 2013. We have taken into account some shifts, scheduled for beam development, that were given back to the users for compensating the main outages. Figure 1 shows the distribution of the weekly availability over the year 2014 as well as the number of beam trips. The operational data of the facility are given in Table 1. As mentioned in the annual report of last year, we observe a steady increase of unwanted X-Ray production, originating from high voltage in the 150 MHz flattop cavity. The other problem mentioned, concerning plasma phenomena causing sparking in our extraction device is still not well understood. During the shutdown of early 2015, the flattop cavity will be removed from the cyclotron in order to find the cause of these phenomena.

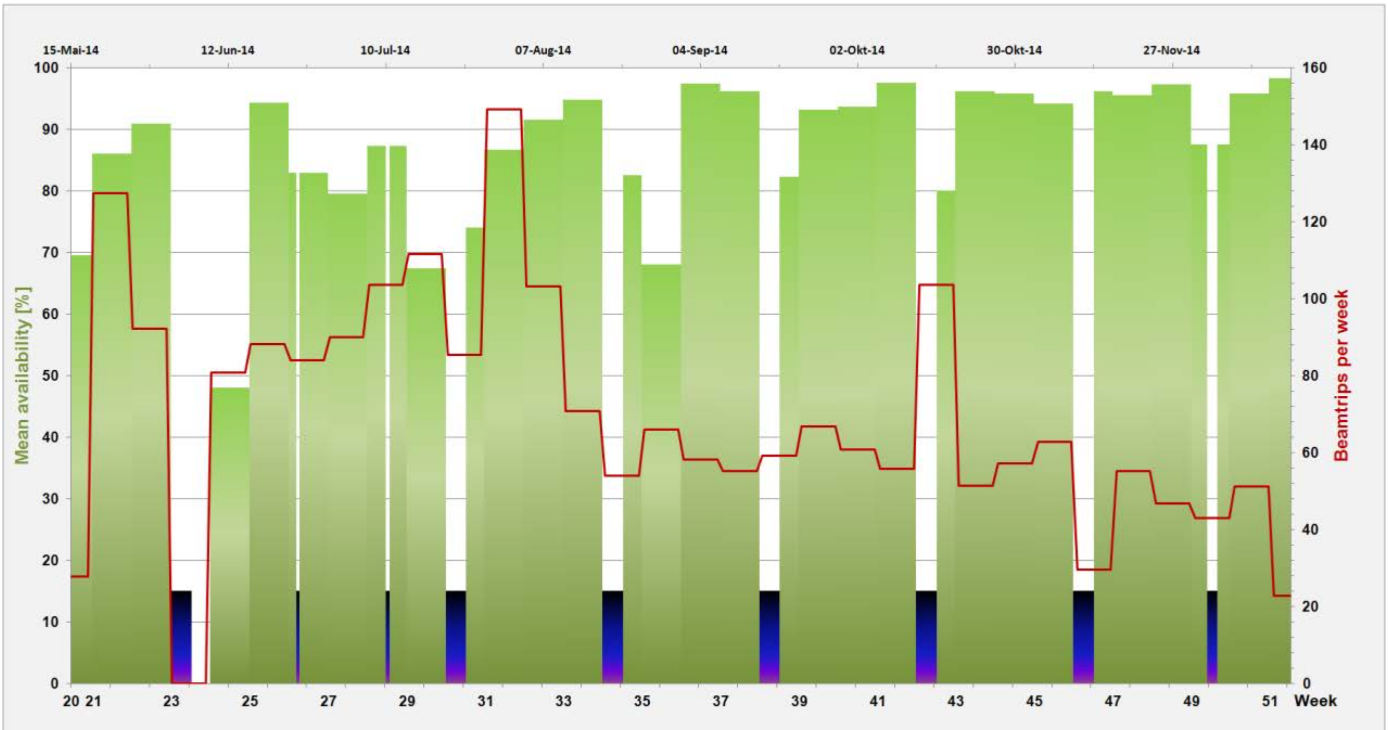


**Figure 1:** Operation of the Proton Facility: availability and beam trips.

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**Table 1:** Operational statistics for the proton facility.

| Beam-time statistics for HIPA | 2014 |
|---|---|
| **Total scheduled user beam time** | **4608 h** |
| **Compensated outage time** | **+84 h** |
| **Beam current integral** | |
| To meson production targets | 9.1 Ah |
| To SINQ | 6.0 Ah |
| To UCN | 0.02 Ah |
| To isotope production targets | 0.08 Ah |
| **Outages** | |
| Total outages (current < 1 mA) | 520 h |
| **Availability (without compensated outage)** | 86.4% |

The various relative contributions to the downtimes in 2014 are shown in Figure 2. The distribution is quite different from the previous years, due to the fact that major contributions never occurred before. The part labelled infrastructure is caused by the interruption of one week due to the necessity of repairing the crane for the re-installation of cavity 2 inside the cyclotron (mentioned above). The personnel safety item covers interruptions by failures of the personnel safety system. A technical problem of this system inhibits operation for safety reasons and introduces often a long downtime in order to diagnose the system.

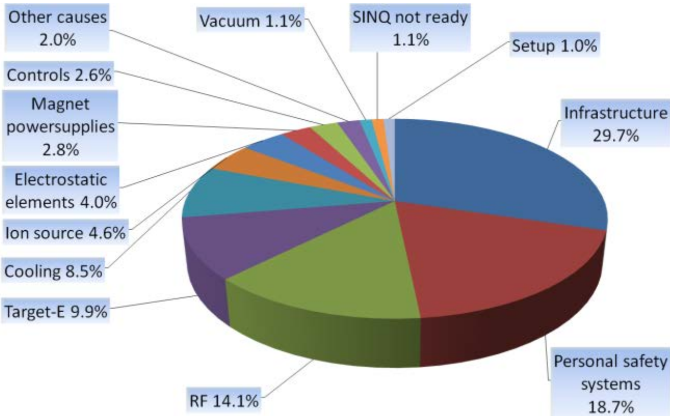


**Figure 2:** Downtime characterization for HIPA outages longer then 5 minutes (ca. 520 hours).

## PROSCAN

The cyclotron and beam lines for the proton therapy facility at PSI have worked very well in 2014. With more than 7300 operational hours, the already high availability that has been achieved in 2013, has been improved to 99.1%. This figure takes into account unscheduled downtimes in the cyclotron and beam line operation. In case of downtimes due to interlocks from the patient treatment side, these were not counted. In 2014 there were no particularly outstanding issues in the cyclotron operation that have caused the unscheduled downtimes. However, we will continue working specifically on a system that prevents frequent switch-off's of the ion-source when in full current operation. Although we have already achieved an increase of the ion source service interval to 2-4 weeks, we expect that a further reduction of the number of interlock based switch off's will increase the life time of the ion source even more. The distribution of the causes of interruptions is shown for PROSCAN in Fig. 3.

We are also continuing our work on new phase slits in the cyclotron. In order to reduce the neutron flux due to the 13 MeV protons lost at the phase slits in the cyclotron, a new phase slit system is being developed. This phase slit will be located at a smaller cyclotron radius, so that the protons (here 3 MeV) do not have enough energy to create intense neutron fluxes in the slits. Tests of a prototype are expected in 2015.

In 2015 a third gantry will be connected to the beam lines. The gantry will be connected to an extension of the beam line to the current experimental facility. A new experimental facility (PIF, Proton Irradiation Facility) will be available behind a bending magnet just before the coupling point of the new Ganty3. The beam line has been modified accordingly and taken into operation in November 2014. In December 2014 the first experiment has been performed successfully at the new PIF station. The new beam line is almost reaching the coupling point of the new Gantry3. Beam line settings for this gantry will be tested in 2015.

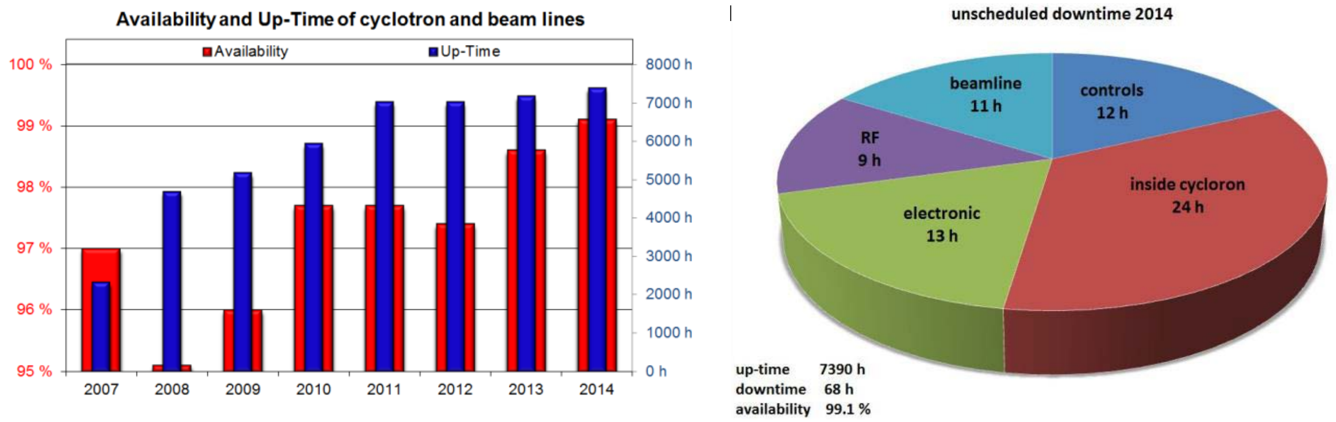


**Figure 3:** Operating hours per year, availability of PROSCAN (left) and unscheduled downtime by causes. Failures in category "Inside cyclotron" are mainly due to ion source failures.

## Development and Operation of the SLS

The operation of the Swiss Light Source for our users was running very smoothly in 2014. While the 97.5% beam availability was just an average value compared to recent years, the Mean Time Between Failures reached an outstanding value above 130 hours. Only one beam outage occurs within five and a half days during user operation. The unscheduled downtime was dominated by two incidents: one short interruption of the power grid caused – among many other things - the cryostat of the 3rd harmonic cavity to fail. The cryostat could only be restarted the next day. Since it is very time consuming to reach a stable temperature again after a warm-up, this trip alone caused a 65 hour beam outage or more than half of the downtime of the year. We now discuss the possibility to acquire a fuel-cell based uninterruptable power supply for the cryostat system that would help to avoid this kind of problem in the future.

At the beginning of the year it took 8 hours to locate the cause of a sudden beam loss. A newly injected beam only survived for three turns in the storage ring. A radiation survey eventually helped to locate the source of the problem: a 50 µm thin Nickel-Copper foil ripped and intercepted the beam path. The foil was stretched over the magnet array of the cryo-cooled permanent magnet undulator CPMU14. The total beam outage to resolve this problem was about three days. It involved locating the problem, removing the undulator from the accelerator, replacing it by a straight vacuum chamber and restarting the accelerator. Luckily most of the time was spend during the beamline development time and only 23 hours of user operation were lost. The repaired undulator was re-installed during the following shutdown. The beamline returned to user operation on the 6th of March. The time was used to redesign the fixation of the foil, in order to avoid damaging the foil during the thermal stress when cooling down the undulator.

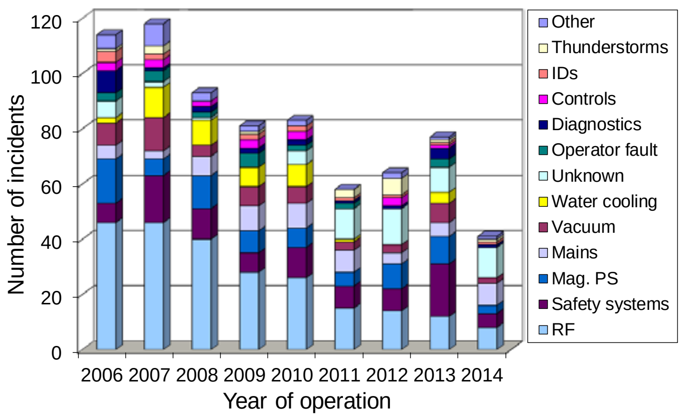


**Figure 4:** Beam outage count per failure category

Figure 4 shows the number of beam outages split by their failure category for the past years. The number of outages caused by the RF systems remains on a very low level, underlining the success of the system consolidation by the RF group over the past years. But all other groups succeeded, too, to reduce the number of outages caused by their subsystems. An upgrade of the safety system PLC helped to avoid interlocks from communication faults. The maintenance work on the magnet power supplies helped to get to an extremely low number of faults from the 600 power supplies, and all other groups succeeded to maintain their low number of subsystem faults. Only the number of power glitches of the grid appears to be constant or even increasing. While we cannot control the grid, we can reduce the effect of these power glitches on operation by putting more of the critical systems on uninterruptable power supplies. Another type of failure that remains at a constant level is the number of trips of unknown cause and we are still investigating those. The new BPM diagnostics that will be installed next year, providing turn-by-turn data from all BPM, will provide us new insights to analyse these beam losses.

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This year not only the mean time between failures reached a record-high value, the mean time between beam distortions more than doubled to 55 hours.

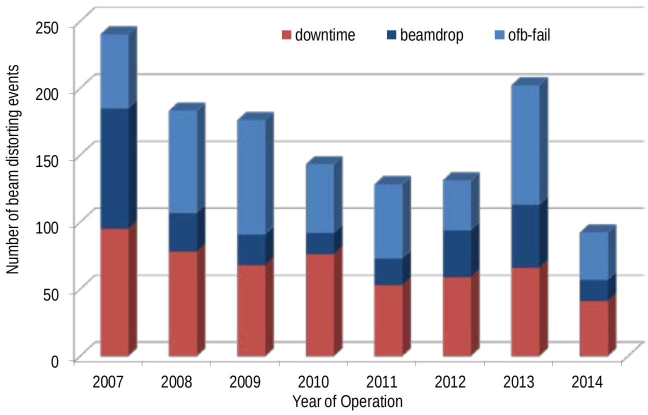


**Figure 5:** Number of beam distorting events of the past years.

Figure 5 shows the number of the different beam distortions. All types of distortions reached the lowest values in the history of the SLS: the result of the continuous and successful efforts of all subsystem groups to minimize the number of failures from each subsystem.

There was no beam outage longer than five hours in 2014, other then the two outages mentioned earlier. A water leak of cavity 4 was detected during one of the regular inspections during machine development. The repair of the leak and the restart of the accelerator took about ten hours, most of it during machine development, the rest at the following beamline shift. These regular inspections enabled us to avoid a ten hour interruption during user operation.

Figure 6 shows the duration of the beam outage events in 2014 assigned to the different failure categories.

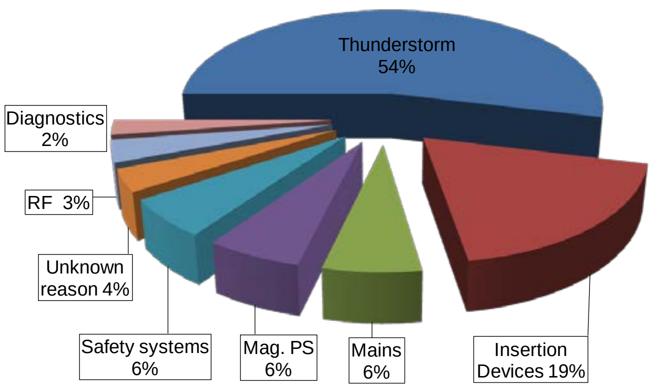


**Figure 6:** Beam outages per failure category in 2014

The operational data is summarized in Table 2.

**Table 2:** SLS Operation Statistics

| Beam Time Statistics | 2014 | | 2013 | |
|---|---|---|---|---|
| **Total beam time** | 6888 h | 78.6% | 6904 h | 78.8% |
| • user operation | 4984 h | 56.9% | 5032 h | 57.4% |
| - incl. compensation time | 160 h | 1.8% | 216 h | 2.5% |
| • beamline commissioning | 832 h | 9.5% | 816 h | 9.3% |
| • setup + beam development | 1072 h | 12.2% | 1056 h | 12.1% |
| **Shutdown** | 1880 h | 21.5% | 1864 h | 21.3% |
| **User operation downtimes** | 37 | | 66 | |
| • unscheduled outage duration | 124 h | 2.5% | 186 h | 3.7% |
| • injector outage (non top-up) | 9 h | 0.2% | 27 h | 0.5% |
| **Total beam integral** | 2455 Ah | | 2448 Ah | |
| **Availability** | 97.5% | | 96.3% | |
| Availability after Compensation | 100.8% | | 100.6% | |
| **MTBF** | 131.2 h | | 75.1 h | |
| **MTTR** (mean time to recover) | 3.3 h | | 2.8 h | |
| **MTBD** (mean time between distortions) | 55 h | | 24 h | |

The first new cavity had been installed last January and runs smoothly since then; the second has been installed this January. We schedule a long summer shutdown this year to install the third new cavity; that will allow us to finish the cavity replacement with the next January shutdown.

The upgrade plan for the storage ring to reach a much higher brilliance – the project SLS 2.0 – has been included in the Swiss Research Infrastructure Roadmap (SERI), starting in 2020. Currently we continue our efforts on the lattice design and evaluate the options for the acceleration frequency. Starting in 2017 we will get funding for a pre-project, to finalize the technical design of the SLS 2.0 project.