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Operation of the PSI Accelerator Facilities in 2013

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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 operated to prepare commissioning of the user facility. This article covers operational aspects of these facilities, as well as performance highlights and new developments achieved in them.

High-intensity proton accelerator (HIPA)

At the end of the first user operation day the production current of 2.2 mA could already be reached. A preceding commissioning period at the end of the yearly shutdown allowed optimizing the accelerator facility to the nominal current with low losses, and to achieve an efficient start into the production period. The availability rapidly reached 92% for the first user operation week and 92.1 for the first 19 weeks of operation. Only two longer interruptions were registered during this time for the weeks 27 and 28. In week 27 a water leak in a transformer caused a 28 hour interruption and in week 28 a beam-stop in Inj2 could not be opened due to a defective interface causing an interruption of 5 hours.

However, the overall availability in 2013 amounted only to 81.6%, representing the lowest availability of our facility in the last 12 years (see Fig. 2). Figure 1 shows the distribution of the availability over the year 2013 as well as the number of beam trips. Two main interruption periods are visible in this figure: weeks 39 to 41 and weeks 45 to 46. During the first period (W39-41), problems started with the RF input coupler of the ring flattop cavity. It was found that several contacts between the RF coupler and cavity were melted away (Fig. 3). After repair and installation of thermocouples in order to measure the temperatures at the RF coupler, it was observed that the temperatures below the RF coupler reached critical levels at the production voltage. In fact the temperature was depending on the strength of the magnetic bending field, a fact that could be explained if multipacting of electrons was the cause of the heat deposition. Multipacting is a cyclic emission of electron in the field of the cavity. Each accelerated electron generates new electrons when hitting the surface again, thus generating substantial currents of such stray electrons connected with heat deposition. The cavity was opened and its surface locally painted with a water-graphite colloid solved in alcohol. The surface coating reduced the emission of secondary electrons and user operation could be resumed. In the second period (W45-46) the painting had to be repeated on the complete surface of the cavity.

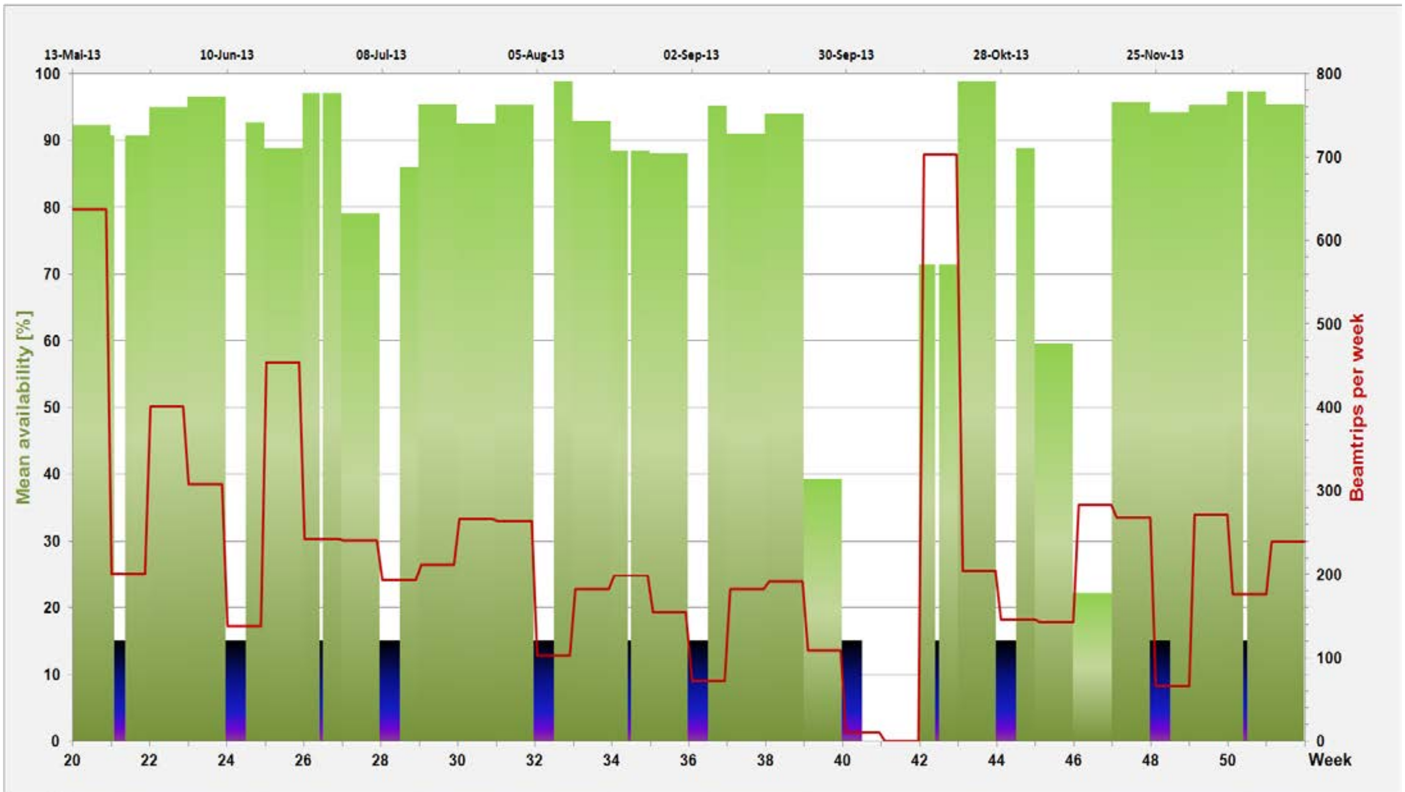

Figure 1: Operation of the Proton Facility: availability, average current, delivered charge and beam trips.

Although no elevated temperatures were observed afterwards, a steady increase of the X-Ray production in the vicinity of the cavity was recorded. These observations are not understood up to presence. One might suspect that multipacting is still going on in some regions of the cavity, and in the shutdown 2014 this has to be investigated further.

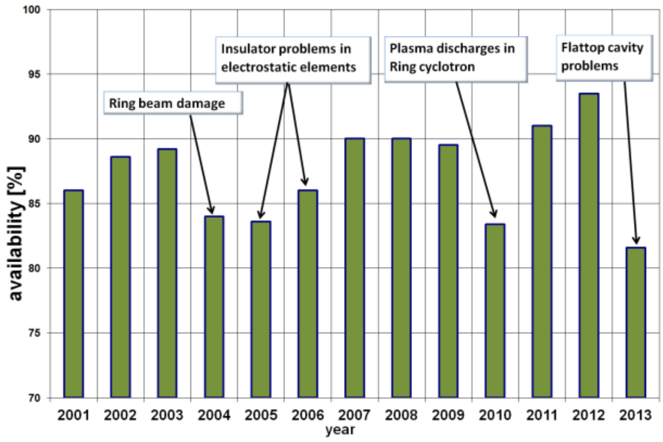

Figure 2: HIPA availability over the last 12 years.

Only a small part of the lost time could be compensated during the week 48, where originally a service was planned. With this compensation time the availability of the facility amounted to 83.5%.

Target E showed torque problems during the week 42, some days after the repair of the flattop cavity, causing a moderate interruption. The repair could be performed during a scheduled beam development period. The various relative contributions to the downtimes in 2013 are shown in Figure 4. As it is shown in the figure, the downtime is mainly caused by the above mentioned problems with the flattop cavity. The event represents almost 70% of the total downtime.

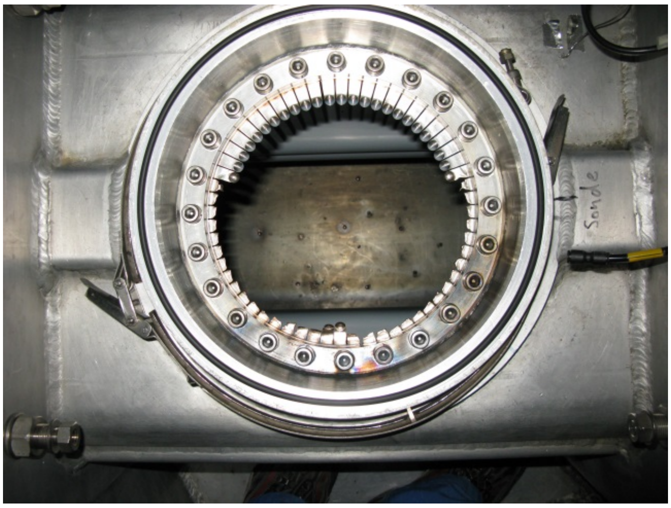

Figure 3: Burned finger contacts at the RF entrance of the ring flattop cavity

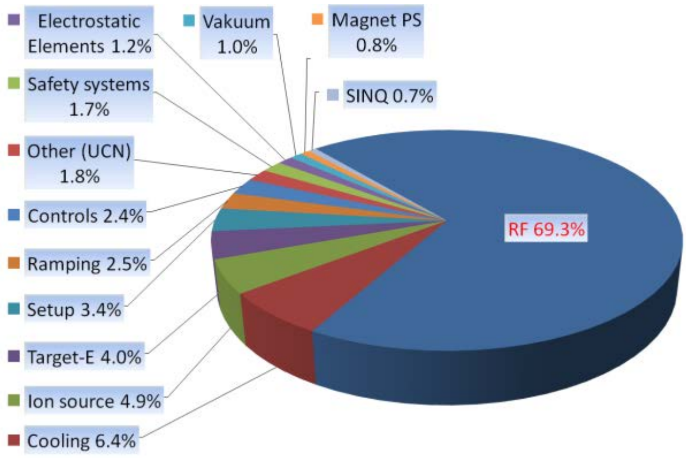

Figure 4: Downtime characterization for HIPA outages longer then 5 minutes (ca. 750 hours).

The operational statistics for 2013 is shown in Table 1.

Table 1: Operational statistics for the proton facility.

Beam-time statistics for HIPA	**2013**
Total scheduled user beam time	**4656 h**
Compensated outage time	**+112 h**
Beam current integral To meson production targets To SINQ	 9.0 Ah 6.1 Ah
To UCN	0.06 Ah
To isotope production targets	0.13 Ah
Outages Total outages (current < 1 mA)	 856.5 h
Availability (without compensated outage)	81.6%

PROSCAN

In the year 2013 it was possible to operate the medical accelerator facility about 7000 hours at improved availability of 98.5%. Compared to last year, there was much less unscheduled downtime due to problems with the RF. This could clearly be attributed to an improved cooling system of the RF amplifier. Currently most of the unscheduled downtime is related to problems in ion source. In most cases these have been caused by switch-off commands during full power operation as a result of interlocks. We are working on a solution for this problem. In parallel to the Proscan operation we are installing a test stand providing magnetic field for ion source developments and preconditioning of ion sources and extractor electrodes. Related to beam dynamics in the cyclotron we are developing a procedure to correct beam orbit variations caused by ageing effects of the ion source chimney. Due to a sputtering process the proton extraction slit in the ion source increases during the life time of the source (2-4 weeks), which causes the start position of the proton orbits to shift. We are investigating a possible correction of this off-centering by means of trimrods, mounted in the central region of 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.

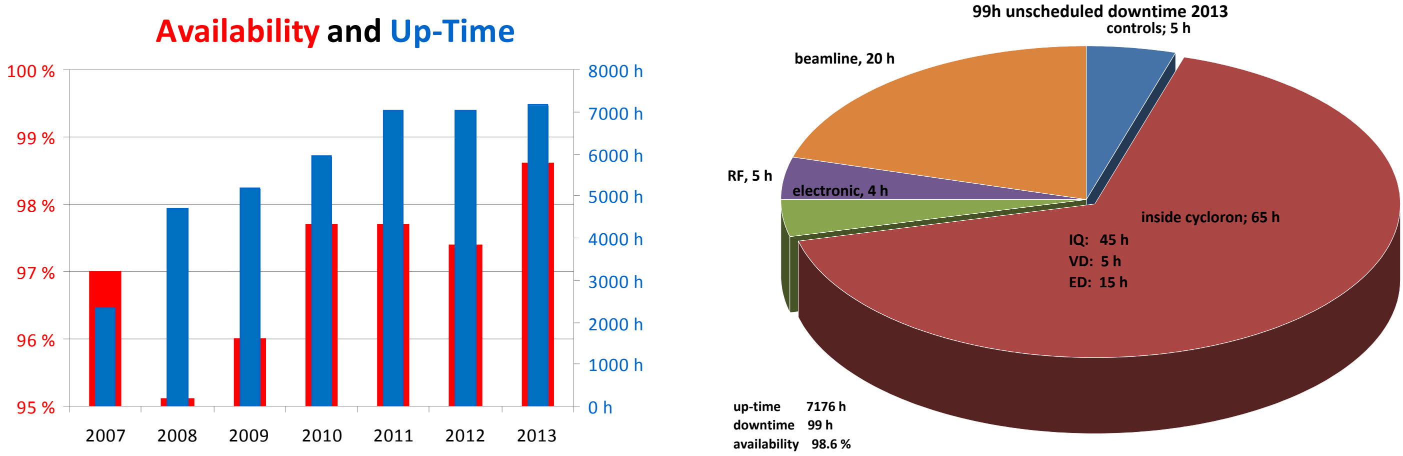

Figure 5: Operating hours per year, availability of PROSCAN (left) and unscheduled downtime by causes.

Development and Operation of the SLS

The Swiss Light Source had again a very successful year in 2013. The beam availability was 96.3%, slightly lower than in recent years. This figure was dominated by a single incident with the cryostat of the 3rd harmonic cavity, which alone caused more than half of the beam outage of the year. The length of the outage was determined by a heat-up/cool-down cycle of the cryostat. We observed a rise of the Helium pressure in the system and related that to a clogging in the cryostat – a problem that had repeatedly caused long outages over the past decade. However, it turned out not to be the origin of the problem in 2013. After the system was cooled down again and operation resumed, we soon had the same problem again: the pressure of the Helium increased in the system. This time we could exclude a clogging in the cryostat, and the whole system was carefully analyzed. A defective flow meter in the return path of the Helium turned out to be the culprit, it caused a valve to close and the system tried to compensate that by increasing the pressure. The replacement of the flow meter was done and user operation was resumed within less than 10 hours. Figure 6 shows the number of beam outages split by their failure category for the past eight 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 five years. The outages caused by the safety systems increased significantly. About 60% of these outages have been caused by the orbit-interlock that protects the primary mirror of the Infrared beamline. For several weeks we tried to find the cause for the suspected transient orbit distortions, until it was eventually discovered that an internal problem of the interlock system was the cause. A defective DAC created output noise that triggered orbit interlocks randomly. The problem has been fixed just one week before the beamline was closed down for user operation at the beginning of July.

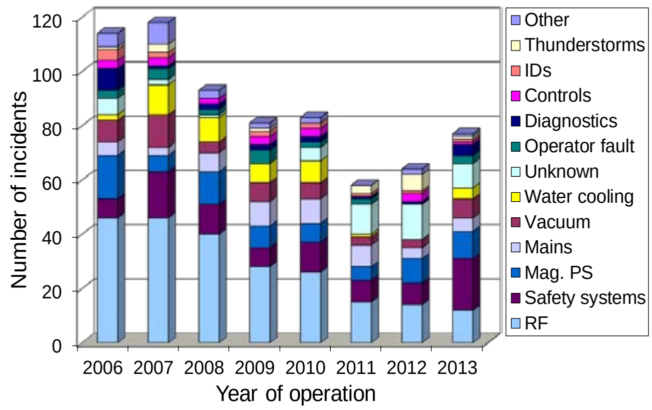

Figure 6: Beam outage count per failure category

Although the number of beam outages remained on a rather low level, the number of other beam distortions increased. The mean time between beam distortions went down to 24 hours in 2013, from above 35 hours in the three years before. That was mainly driven by a larger number of outages of the fast orbit feedback. Figure 7 shows the number of these beam distortions. The reasons for these outages were manifold. The failure rate of the BPMs increased slightly – a first indication that the old hardware should be replaced. A new BPM system is already under development and is to be deployed in 2015. Some of the problems were caused by defective VME controls hardware. And a larger number of outages had been a result of failures of corrector magnet power supplies. It turned out that the ADC cards of the magnet power supplies had capacitors that had reached the end of their lifetime. That caused the power supplies to have an increased output noise. During the course of the year the worst ADC cards had been replaced and during this winter shutdown we now reworked the ADC cards of all remaining 600 power supplies. This problem likely caused some of the beam outages that were not attributed to any failure cause in the past years. The experience of the next months will confirm or rebut this theory.

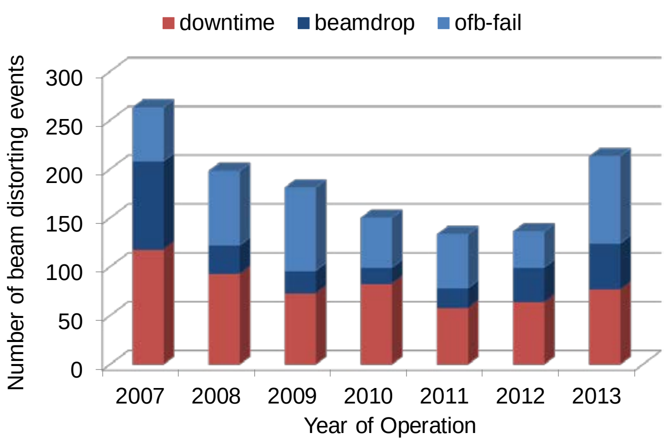

Figure 7: Mean time between beam distortions

Apart from the two outages of the 3HC cryostat system we had four more outages that had been longer than five hours in 2013. In February an outage of about seven hours was caused by a defective maxi-gauge controller of the vacuum system. It reported an interlock of the insulation vacuum to the PLC of the 3rd harmonic cavity cryostat, although the vacuum pressure was fine. It took three restarts of the cryostat to actually localize this problem, since the vacuum interlock was only detected by the cryostat PLC after the cavity had been cooled down. In fact that behavior is a logical error in the PLC that existed since the beginning, but had not been detected before. A six hour outage in June was caused by a water leak at the absorber of the VUV beamline. Two transient beam losses in July without identifiable reasons caused a total beam interruption of six hours, because a vacuum problem reduced the Linac beam current and therefore lengthened the accumulation time. In September a water leak at cavity 3 in the storage ring required a nine hour interruption to glue the leak, dry the glue and recover beam. A second water leak opened up at the very same cavity shortly after the repair; but since this leak was repaired within a machine development shift it did not affect user operation.

Figure 8 shows the duration of the beam outage events in 2013 assigned to the different failure categories. The operational data is summarized in Table 2.

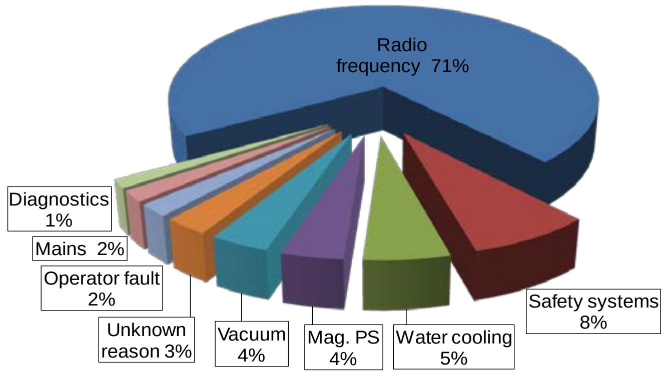

Figure 8: Beam outages per failure category in 2013

Table 2: SLS Operation Statistics

Beam Time Statistics	**2013**		**2012**	
Total beam time	6904 h	78.8%	6928 h	78.9%
• user operation	5032 h	57.4%	4968 h	56.6%
- incl. compensation time	216 h	2.5%	160 h	1.8%
• beamline commissioning	816 h	9.3%	968 h	11.0%
• setup + beam development	1056 h	12.1%	992 h	11.3%
Shutdown	1864 h	21.3%	1864 h	21.2%
User operation downtimes	66		59	
• unscheduled outage duration	186 h	3.7%	63 h	1.3%
• injector outage (non top-up)	27 h	0.5%	23 h	0.5%
Total beam integral	2448 Ah		2369 Ah	
Availability	96.3%		98.7%	
Availability after Compensation	100.6%		102.0%	
MTBF	75.1 h		84.2 h	
MTTR (mean time to recover)	2.8 h		1.1 h	
MTBD (mean time between distortions)	24 h		35 h	

The 500 MHz RF test-stand has been completed in autumn and the first of the new cavities has been commissioned to full power and is installed now in January.

The SLS is still among the top 3rd generation light sources worldwide [1]. Nevertheless we are investigating plans to upgrade the storage ring – the project is called SLS 2.0 – to a much higher brilliance, in order to stay competitive for a longer time period.

References

[1] Streun A. et al., *SLS: Pushing the Envelope Based on Stability,* Synchrotron Radiation News, 26, 4 (2013).