OPERATION OF THE PSI ACCELERATOR FACILITIES IN 2003

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OPERATION OF THE 590 MEV PROTON ACCELERATOR FACILITY

After completing the yearly shutdown in April, the proton accelerator facility was taken into operation in week 16 with a few microamperes on Target E. This test showed that the facility would be ready for the scheduled date. However during the final setup of the facility in week 17, it was found that the extraction element of the Ring cyclotron did not behave correctly and produced so many discharges that a stable beam could not be established. This component was apparently damaged by discharges occurring during the setup of the RF-cavities. It has therefore been repaired and equipped with an appropriate shielding to improve its protection against such phenomena. Due to this incident, the start up of the facility with beam currents over 1 mA was delayed by 2 days. It took as usual about one week to get a stable beam at 1.5 mA and about one month to reach the nominal value of 1.8 mA.

Very promising **highlights** in the last two production weeks deserve a special emphasis. It was possible to increase the beam current up to 1900 μA for a longer period (10 days) without a significant change in the overall losses, and during the last 24 hours a very stable operation at 2000 μA was demonstrated. This improved performance was achieved mainly through the increase of the power in the 150 MHz resonators of the injector cyclotron, by a modified beam trajectory at the Ring-cyclotron injection and, of course, by the high tuning investment done by the operation crews.

Due to the above mentioned delay the production for the users started effectively at the beginning of week 18. From then on, an average availability of 89.2 % was reached in 2003 (like in the previous year with a threshold of 1 mA, which is considered by many users as the lowest limit for an efficient data acquisition). This performance is comparable with the one achieved in the previous year. The integrated beam charge delivered to the Target E amounted to 8.1 Ah as in 2002, despite the slightly longer shutdown.

These features of the operation of the facility, as well as some additional information are presented in Figure 1.

The availability was mostly (17 weeks) higher than 90 % and dropped below 85 % only in 7 weeks. The first half year did not suffer from many interruptions, except for the one due to an insulation breakdown of a quadrupole (QHG22). The power supply of this component had to be modified to allow for floating operation in order to circumvent this problem.
In the second half year the performance was degraded by several incidents:

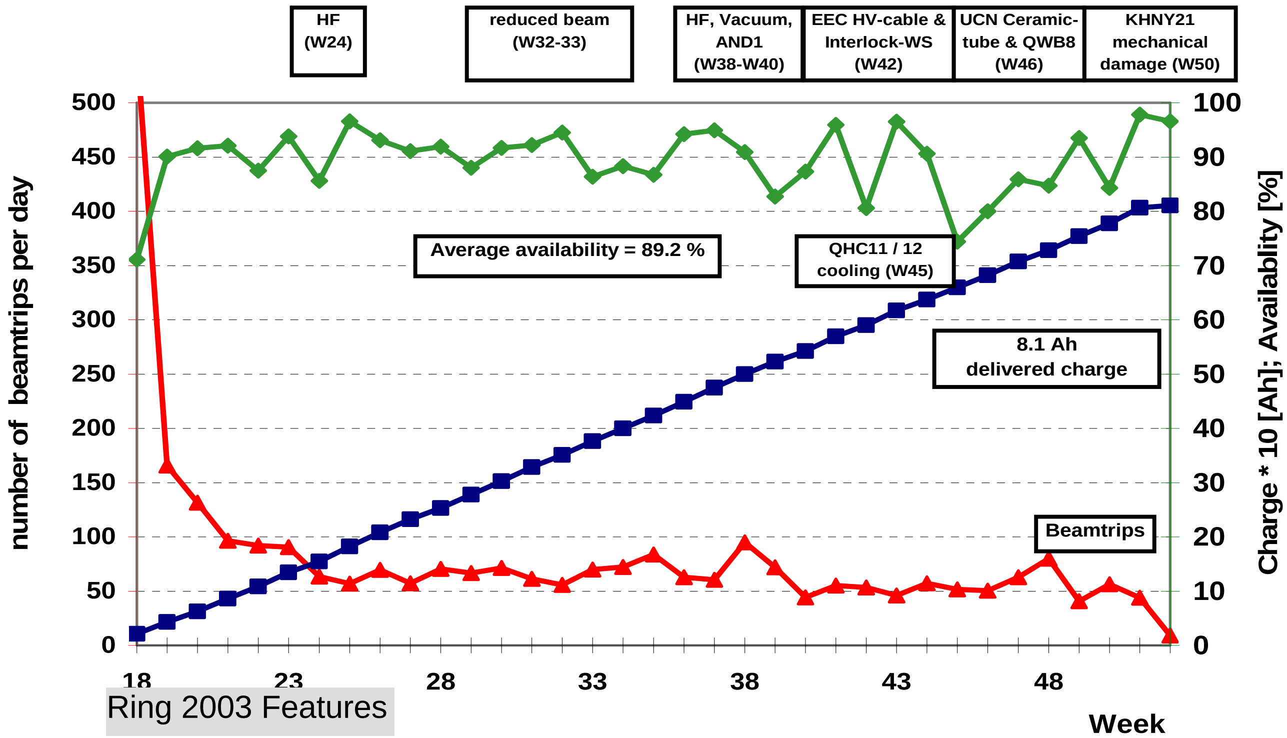

Fig. 1: Operation at the PSI High Energy Proton Accelerators: Availability, main failures, delivered charge and beam trips due to discharges in the electrostatic elements.

- In week 38-40 several smaller problems occurred, the main incident being a short circuit of one of the Ring injection magnets.
- In week 42 a short circuit occurred in the high voltage cable to the ring extraction element (EEC). Diagnostic and replacement caused a beam loss of one shift. An additional interruption of 3 hours was caused by a malfunction of the workstation handling the interlocks and the automatic beam-on procedure.
- In week 45 a coil of the quadrupole doublet QHC11 and QHC12 was water leaking and had to be repaired over the weekend. This interruption of 18 hours was the longest registered in year 2003 and the availability dropped therefore in this week down to 75 %.
- The ceramic tube of the kicker for the UCN beam installed in front of the high energy splitter was damaged and developed two times a vacuum leak. The first time this element could be provisionally repaired (6 hours of interruption in week 38), but had to be replaced in week 46 (12 hours). In the same week a cooling problem with a quadrupole in the 860 keV beam line caused 6 hours of interruption.
- The last significant problem was caused in the week 50 by a collimator in the beam transport line between target E and the SINQ target. The collimator blocked in an intermediate position, so that neither beam to SINQ nor to the Beamdump was possible. However, it could be moved manually to the appropriate position allowing beam-production on the SINQ target.

The long, exceptionally hot period in the summer caused the temperature of the Aare-river as well as that of the ground water to rise to a level such that the cooling capacity became insufficient for a normal operation of the facility. Thanks to a special permission by the responsible authorities it was possible for limited periods of time to exceed the legal temperature of the cooling water rejected to the river. Despite this fact the beam current had to be limited during the day to 1500 μA. This does not influence the statistics for the availability, but was of course an annoying disturbance for several experiments. Furthermore, the stability of the beam was definitively below average during this period, because the general air-conditioning and the heat-exchangers for the RF-systems were running above their capacity.

As shown by the steady increase of the charge deposited on the target E during the year (Fig. 1), a dip in the availability does not necessarily lead to a lack of deposited charge. This is mainly due to the fact that some compensation of the time lost was allowed on Wednesdays during service or beam development periods.

The distribution of the downtimes is again documented as in the past years, however with a new representation. One can notice some major changes in the distribution in comparison to the previous years:

- The Target E is not represented anymore, confirming that the improvement, mentioned last year was very successful.
- The electrical power for the cooling plant is now delivered from the Villigen side, so that the dependence on cumulative failure probabilities of two networks could be eliminated. Therefore we kept only one category for the cooling in the statistics.

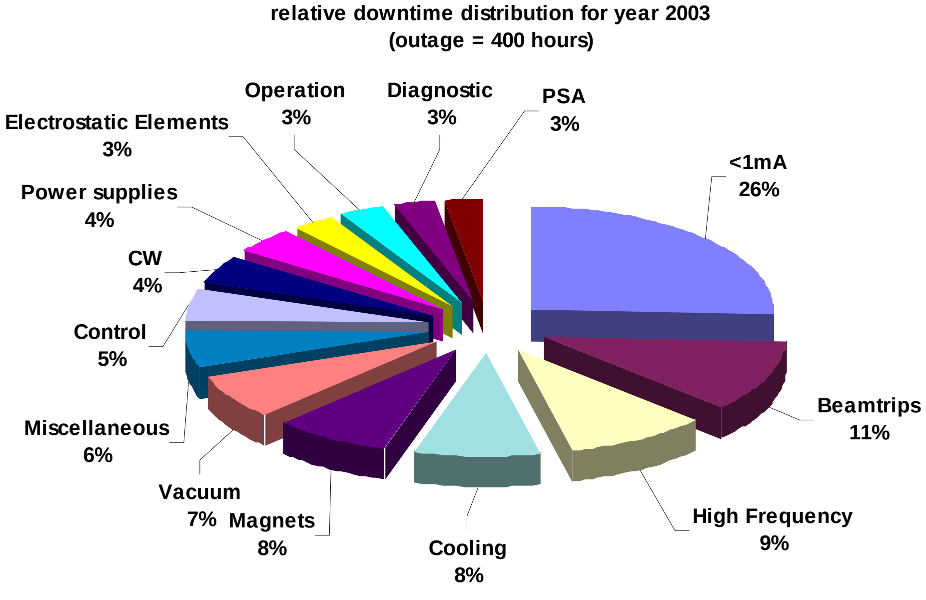

Fig. 2: Characterization of the downtimes of the 590 MeV accelerator facility.

- A new category (<1 mA) was introduced. This limit is also used in the definition of the beam availability for the users. We can therefore distinguish now between beam time loss due to beam trips and the time when the beam current is, for other reasons, below 1 mA. A beam trip causes normally an interruption of about 10 seconds after which the beam is ramped up and reaches his nominal value in another 20-30 seconds. With the <1 mA category problems while ramping to the nominal beam current after a beam trip as well as the operation of the facility below a useful current, can be accounted for in the statistics.

It is also interesting to consider the time distribution of the beam interruptions shown in Figure 3. Several things can be observed:

- As mentioned before all interruptions below 15 minutes (mainly due to beam trips) represent the 30 % of non-availability.
- Interruptions between 15 minutes and 2 hours are generally due to rapid interventions after minor failures and contribute by 30 % to the time loss.
- Interruptions longer than 2 hours caused by more significant failures represent less than 40 % of the total time loss. The predominant time to repair is lower than 6 hours.

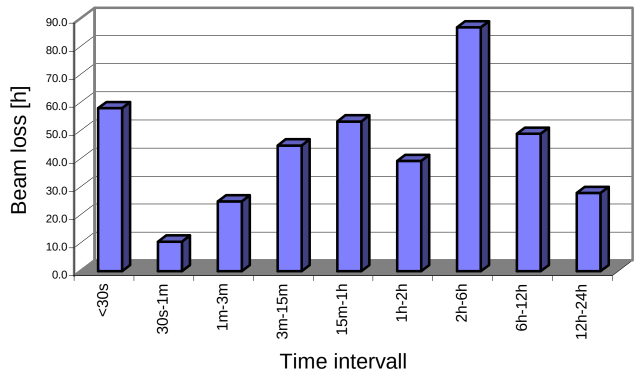

Fig. 3: Time distribution of the downtimes in 2003

These figures suggest that the increase of the availability above 90 % remains a quite difficult task. While the number of beam trips could be reduced in comparison to previous years, the reliability of the ramping procedure of the beam intensity has still to be improved. The installation of faster beam position monitors and a more sophisticated beam centering is in progress.

The reaction time of the technical support after a failure is generally short even during nights and weekends and cannot be reduced further. Therefore, the main effort has to be put on the preventive aspects with an intensification of the ongoing replacement of an increasing number of aging components.

OPERATION OF THE LOW ENERGY FACILITY (INJECTOR 1)

The Philips Cyclotron was operated on a reduced basis, with several longer shutdown and standby periods. Beam was delivered during 12 weeks to the OPTIS facility and, parasitically, for the test of electronic components for spatial research and industry. A total of 13 weeks was planned for the LISOR experiment. About half of this time was effectively used for the target irradiation. Four periods of two weeks each with Neon and Argon beams were scheduled for experiments in the field of heavy element research. The last period was however partly cancelled due to a water leak in the cyclotron. While the occasional occurrence of the well known vacuum problems in the cyclotron requested some patience from the users, the operation of the low energy facility can be considered as having been successful in 2003.

STATISTICS OF THE OPERATION

A compilation of statistical data on the operation of the facility is presented in Table 2.

Beam Time Statistic	**2003**		**2002**	
Ring Cyclotron (590 MeV)				
o production for experiments				
• meson production	4790 h	55 %	5030 h	57 %
... with SINQ	4730 h		4850 h	
... with proton therapy	1530 h		1160 h	
... with PIREX/PIF	1325 h		1334 h	
• parasitic beam programs served with direct primary beam	5 h	0 %	10 h	0 %
o setup	150 h	2 %	152 h	2 %
o beam development	120 h	1 %	272 h	3 %
o unscheduled outage	240 h	3 %	192 h	2 %
o service	320 h	4 %	248 h	3 %
o shutdown	3025 h	34 %	2784 h	32 %
o standby(incl. unscheduled outage Inj.II)	110 h	1 %	110 h	1 %
Injector II (72 MeV)				
o production for experiments				
• production for Ring cyclotron	4890 h	56 %	5100 h	58 %
... with isotope production	1960 h		1060 h	
• parasitic beam programs (IP2) served with direct primary beam	6 h	< 1 %	40 h	< 1 %
o setup	200 h	2 %	200 h	2 %
o beam development	320 h	4 %	400 h	5 %
o unscheduled outage	140 h	2 %	160 h	2 %
o service	250 h	3 %	320 h	4 %
o shutdown	2825 h	32 %	1540 h	18 %
o standby(incl. unscheduled outage Ring)	320 h	4 %	1000 h	11 %
total beam integral delivered				
o to meson production targets	8100 mAh		8100 mAh	
o to SINQ	5400 mAh		5600 mAh	
availability	89.2 %		88.6 %	
Injector I (variable energy)				
o production for experiments				
• NE-experiments	1640 h	19 %	2440 h	28 %
• OPTIS	460 h	5 %	400 h	5 %
o setup	120 h	1 %	200 h	2 %
o beam development / training	100 h	1 %	80 h	1 %
o unscheduled outage	80 h	1 %	150 h	2 %
o service	150 h	2 %	180 h	2 %
o shutdown	3530 h	40 %	2660 h	30 %
o standby	2430 h	28 %	2600 h	30 %

Table 2: Overview on the beam use

SLS OPERATION

The operation of the SLS in 2003 was in short a long series of very successful weeks interrupted by only a few very bad weeks. We increased the average beam current by a third and kept the availability well above 90 % while the Mean Time Between Failures improved drastically. Furthermore we succeeded to bring the fast orbit feedback into operation that allows us to further optimize the already excellent orbit stability and to reduce the orbit distortions generated by the operation of insertion devices. One new beamline became operational in 2003, a joint effort by the Swiss and French XAS user community for an X-ray absorption spectroscopy beamline.

One bad experience this year was that the cooling system proved to be insufficient for the extreme summer conditions. The Aare water temperature did rise to a maximum of 26°C while at the same time the outside air was exceeding 40°C. This caused a long series of problems, starting from breakdowns of the cooling compressors to instabilities in the cooling regulations and also mechanical displacements in the tunnel. An upgrade of the cooling system is now planned to be prepared for the summers to come.

The 3rd harmonic cavity was suffering again some “childhood diseases”: a leak in the isolation vacuum of the liquid helium transfer (11 h) and a breakdown of a helium compressor turbine (24 h) were major contributions to the overall downtime. Additionally to the improvements done to the system, the multibunch feedback is now in preparation that can be used as a fallback system for high current operation.

The major incident in 2003 was a moving obstacle in the vacuum chamber of sector 6. It caused more than half of the total downtime in 2003. A defective support of an absorber bar allowed the bar to move into the beam pipe and inhibited injection. Since it is impossible to completely rule out vacuum incidents with similar consequences, it was decided to schedule reserve time that can be offered to the users in such cases.

STATISTICS OF SLS OPERATION

Fig. 1 shows the development of the availability of the SLS. We succeeded to keep the availability well above 90 % in 37 out of 41 weeks and reached the average availability of 94.2 %. It was dominated by a single problem, namely the moving absorber bar. This caused in total 173 out of 307 hours downtime. Due to that the downtime was concentrated in very few weeks. This is reflected in the figure of the Mean Time Between Failures (MTBF) of the storage ring. It improved by 50 % with respect to last year operations to about 45.9 hours. The percentage of the injector outage even improved by a factor of two. Table 3 shows a summary of the operational data.

Beam Time Statistics	2003		2002	
Swiss Light Source				
o total beam time	6792 h	77%	6044 h	69%
• user operation	5288 h	60%	4472 h	51%
• beamline commissioning	696 h	8%	992 h	7%
• setup + beam development	808 h	9%	576 h	11%
o shutdown	1968 h	23%	2720 h	31%
o downtime at user operation				
• unscheduled outage	307 h	5.8%	258 h	5.7%
• injector outage (non top-up)	30 h	0.6%	54 h	1.2%
total beam integral	1567 Ah		1030 Ah	
availability	94.2%		94.3%	
MTBF	45.9 h		30 h	

Table 3: SLS Operation Statistics.

OUTLOOK

For the next year it is scheduled to bring three new beamlines into operation and to prepare the machine for the FEMTO project. Many changes to the machine are required to allow the production of femto second X-ray pulses in 2005. At the same time the standard user operation should be increased to 400 mA while keeping the excellent performance and reliability of the machine.

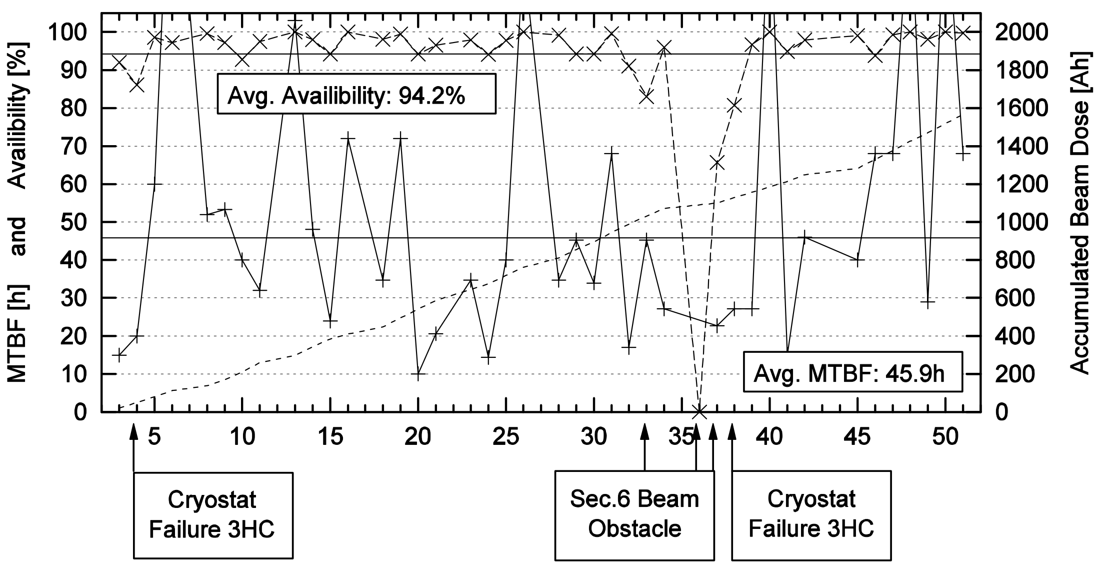

Fig. 4: SLS Operation Statistics: Weekly Availibility, Mean Time Between Failures and Accumulated Beam Dose.