OPERATION OF THE PSI ACCELERATOR FACILITIES IN 2002

A.C. Mezger, A. Lüdeke, P.A. Schmelzbach

OPERATION OF THE 590 MEV PROTON ACCELERATOR FACILITY

After a shutdown of more than 3 months (January – 18 April 2002), during which the injection line at the Ring-Cyclotron center has been reconstructed following a new modular design, the first operation with low beam currents could be started on schedule. However, anomalous values had to be used for the settings of the injection line as well as for the Ring-Cyclotron itself. As the beam current was increased, we encountered more and more difficulties in minimising the losses inside the accelerator. The limit at which they grew over the tolerated threshold was reached at a beam current of 1000 μA.

The first suspicion was indeed that the modified injection line was responsible for this behaviour. After two weeks of beam production partly interrupted by beam development periods dedicated to the investigation of the beam transport and injection parameters, it became clear that a vertically limited transmission through the accelerator was the source of the increased beam losses. The problem could be tracked back to the mechanically damaged support of a beam-stopper inside the cyclotron that did not completely move out of the beam. After dismounting this component the beam current could be increased up to its nominal value of 1800 μA.

Despite of this starting problem an average availability of 88.6 % could be reached for 2002 (defining the threshold as 1 mA, i.e. beam current lower than that = no beam). With a threshold value of 150 μA as used in preceding years the availability would exceed 90 %. Some features of the operation of the facility are presented in Fig. 1.

The integrated beam charge delivered to the targets amounted to 8.1 Ah. It was slightly lower than in 2000 (8.5 Ah) but higher than that of last year (7.1 Ah). This is mainly due to the different lengths of the shutdowns and of the scheduled interruptions.

The availability was lower than 80 % only for three weeks. Due to a vacuum degradation that was detected too late the 590 MeV beam splitter EHT was damaged and had to be replaced in week 22. In the same week, a general breakdown of the cooling system was the consequence of a power failure at the PSI-east site. In week 26 the cooling plant was flooded due to malfunctions at the restart after a further power interruption. The availability dropped in the week 29 to 56 % due to water leaks at the injection line of the Injector II Cyclotron and in a bending magnet at the injection of the Ring Cyclotron.

The insufficient water supply to the cooling plant during the repair of a leaking pipeline forced us to reduce the beam current to 1500-1700 μA during 3 weeks. Although this does not enter the statistics for the availability, several experiments could not be performed

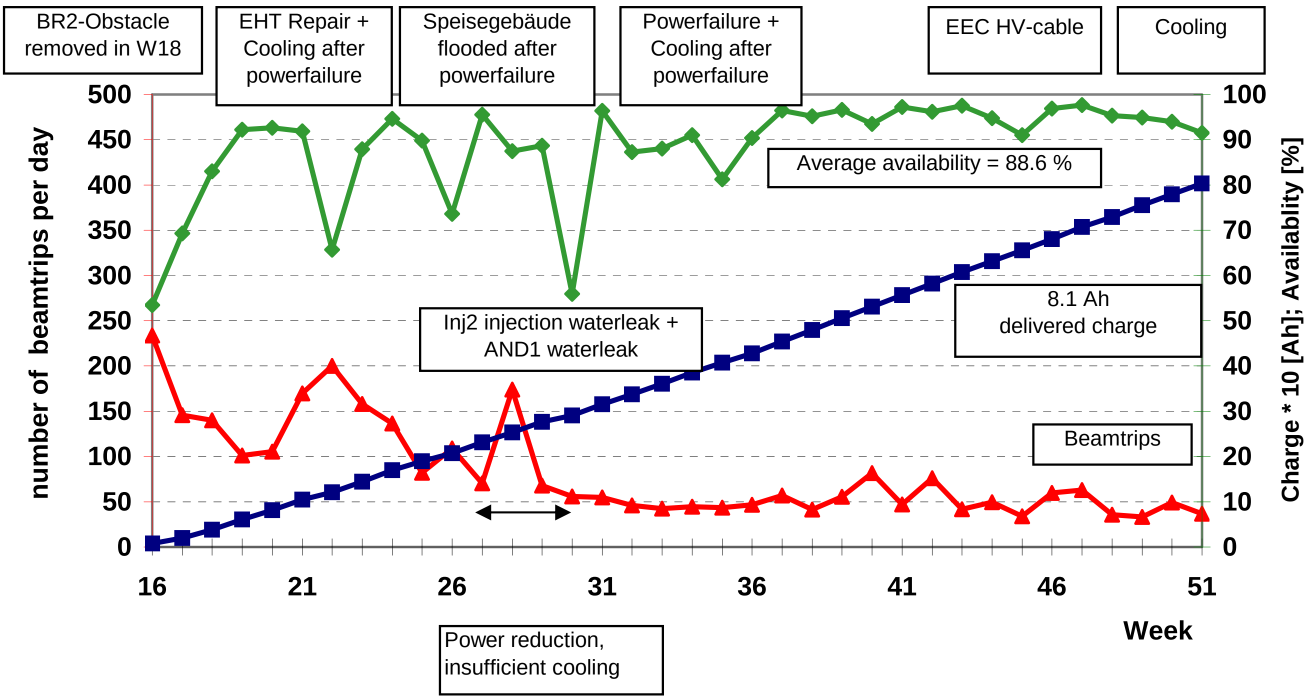

Fig. 1: Operation at the PSI High Energy Proton Accelerators: Availability, main failures, delivered charge and beam trips due to discharges in the electrostatic elements

under these unexpected conditions during this period of time. However, the performance was excellent during the last third of the year, with beam currents permanently at the 1800-1850 μA level and availabilities often exceeding 95 %.

In contrast to previous years, no replacement of the electrostatic deflectors was necessary in 2002. In the past, the vacuum in the Ring Cyclotron was broken whenever a component had to be replaced in the part of the injection line connected to the cyclotron vacuum vessel, thus causing subsequently a significant degradation of the performance of the electrostatic elements and therefore a dramatic increase in the number of the discharge related beam trips. Now, with the new design of the cyclotron center implemented in the last shutdown, the cyclotron vacuum can be isolated from that of the injection line. The behaviour of the electrostatic elements will therefore not be modified, contributing to a more stable operation of the facility. We benefited from this feature twice this year, when magnets in the Ring center had to be replaced. Another advantage of the new design was indeed the strongly reduced beam off time to perform the repairs.

Very good performance showed the operation of the pion production targets. The improved target E presently installed operated more than 6 months without any sign of performance degradation. It was therefore possible to avoid two planned preventive replacements. We expect to explore the lifetime of this type of target by running it in 2003 until it fails.

A distribution of the unscheduled down times is presented in figure 2, together with the results of the previous two years. They are ordered following their significance in 2002. However it has to be noted that the distribution differs also from those in previous analyses, since the failures of the cooling water plant are reported separately from the general cooling problems. The diagram shown in Fig. 2 reveals several striking features:

- Generally better performance can be observed for almost all topics.
- No problems with Target E were registered in 2002, which is due to improvements of the bearings and of the target wheel.
- The general implementation of the fast discharge analysis has significantly improved the performance of the RF- systems
- The beam trips, i.e. short interruptions due to discharges in the electrostatic elements in the Ring Cyclotron could be minimized to a level never achieved before.
- The occurrence of damages at the electrostatic elements (e.g. burned damping resistors or cables) diminishes with the frequency of beam trips.
- Exceptional events with high loss of beam time (like breakdown of the Freon CW cooling in 2000 or electrical short in a large magnet in 2001) didn't occur in 2002.
- The reliability of the cooling systems remains a matter of concern

Since the cooling was the main cause of major interruptions, it deserves a more detailed consideration. Failures at the cooling plant are seldom but they have severe consequences. In the least dramatic cases, they result only in the loss of 1 or 2 shifts due to the need of a new setup. When repairs are necessary, the down time increases significantly (91 hours in 2002). When looking at the causes of the main breakdowns, it appears that the damages were the consequence of power failures. Thus, the statistics in Fig. 2 is somewhat arbitrary in attributing the cause for beam loss time. It is nevertheless an open question if the controls implemented during the modernisation of the cooling plant are sufficiently failsafe for operation in such a rough environment.

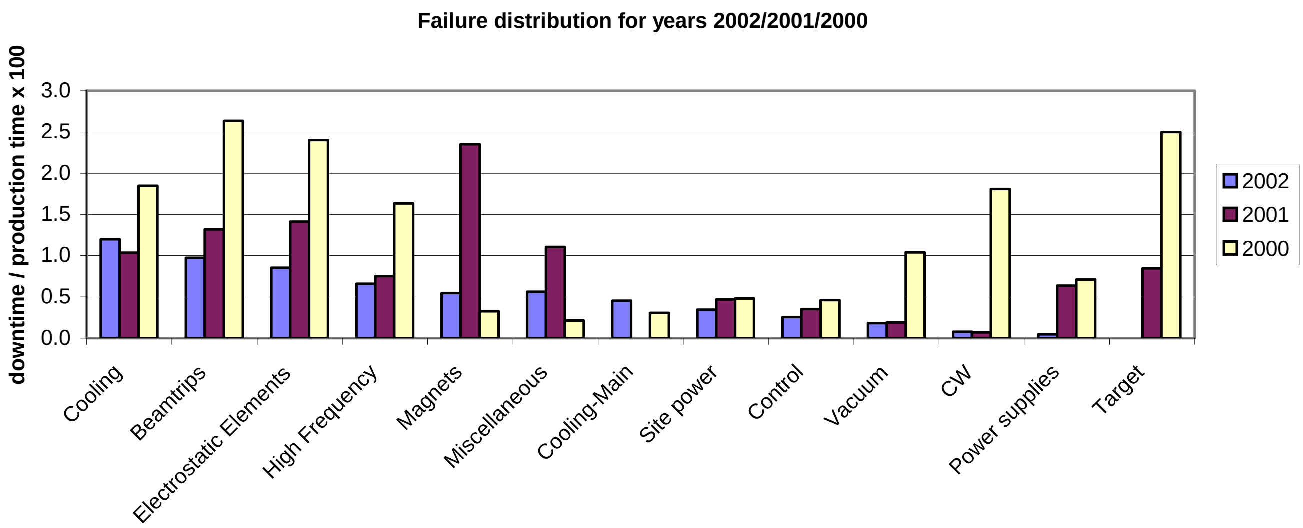

Fig. 2: Characterisation of the downtimes of the 590 MeV accelerator facility.

The (old) problems with the pumps at the Aare river will be partially solved in 2003 by revisiting the contracts with the electricity suppliers. Providing the power from the PSI-West site will reduce the cumulative effect of failure probabilities in two different networks.

The above mentioned reduction of the proton beam current due to a leaking pipeline illustrates the lack of redundancy and the emerging aging problems in almost 30 year old infrastructures. The investments to improve the reliability of these equipments are substantial and this problem will play an important role in the assessment of a reasonable balance between costs and requested performance of the facility.

The weekly and yearly average availabilities are not sufficient criteria to judge the quality of the facility. The structure of the user community has changed over the years: many experiments performed now at the Spallation Neutron Source and at the Muon Spin Resonance facilities request very short measuring periods and therefore strongly depend on the availability of the beam in the scheduled period. The same is true for the medical applications. Table 1 shows the “probability” that the beam availability for one of the referred 228 days lies in a certain range. It is seen that for 86 % of the days the experimental conditions were in the range of satisfying to good. On the other hand, two interruptions for unscheduled maintenance lasted more than 24 hours (in weeks 22 and 30, as also indicated by the dips in Fig. 1).

Availability	Number of days	Fraction of 228 days
0 = no beam	2	1 %
0 – 49 %	12	5 %
50 – 79 %	20	9 %
>= 80 %	196	86 %
>= 90 %	163	73 %
>= 95 %	128	56 %

Table 1: Distribution of single-day availabilities

TEST OF A FAST KICKER MAGNET

The projected Ultra Cold Neutron Facility on the NA-3 beam line is planned to accept every 15 minutes a 8 second long beam bunch train at full intensity. The main beam will be periodically switched to this beam line without being interrupted. For this purpose, a fast kicker magnet has been installed in the primary proton channel, just in front of the electrostatic deflector EHT. A first test of the switching procedure was performed with a 20 μA beam in the second last beam development period of 2002. The results will be discussed in another article demonstrating that a 2 mA beam could be switched with tolerable losses.

OPERATION OF THE LOW ENERGY FACILITY (INJECTOR 1)

During the first months of 2002 some beam time at the Philips Cyclotron was dedicated to the completion of a few experiments of the discontinued basic research program. The following reduced operation was characterized by long standby and shutdown periods in which the vault ventilation was renewed, new vacuum pumps were installed and the setup of the LISOR test facility was finalised. Beam was delivered for OPTIS during 11 weeks. One of the 3 heavy ion beam periods was unfortunately strongly disturbed by the well-known vacuum problems periodically arising at this accelerator.

STATISTICS OF THE OPERATION

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

Beam Time Statistic	**2002**		**2001**	
Ring Cyclotron (590 MeV)				
o production for experiments				
• meson production	5030 h	57 %	4250 h	49 %
… with SINQ	4850 h		4020 h	
… with proton therapy	1160 h		1100 h	
… with PIREX/PIF	1334 h		1270 h	
• parasitic beam programs served with direct primary beam	10 h	0 %	140 h	2 %
o setup	152 h	2 %	120 h	1 %
o beam development	272 h	3 %	210 h	2 %
o unscheduled outage	192 h	2 %	440 h	5 %
o service	248 h	3 %	190 h	2 %
o shutdown	2784 h	32 %	3360 h	38 %
o standby(incl. unscheduled outage Inj.II)	110 h	1 %	50 h	1 %
Injector II (72 MeV)				
o production for experiments				
• production for Ring cyclotron	5100 h	58 %	4310 h	49 %
… with isotope production	1060 h		942 h	
• parasitic beam programs (IP2) served with direct primary beam	40 h	< 1 %	100 h	< 1 %
o setup	200 h	2 %	230 h	3 %
o beam development	400 h	5 %	330 h	4 %
o unscheduled outage	160 h	2 %	340 h	4 %
o service	320 h	4 %	240 h	3 %
o shutdown	1540 h	18 %	3050 h	35 %
o standby(incl. unscheduled outage Ring)	1000 h	11 %	160 h	2 %
total beam integral delivered				
o to meson production targets	8100 mAh		7136 mAh	
o to SINQ	5600 mAh		4474 mAh	
availability	88.6 %		86 %	
Injector I (variable energy)				
o production for experiments				
• NE-experiments	2440 h	28 %	4170 h	48 %
• OPTIS	400 h	5 %	350 h	4 %
o setup	200 h	2 %	780 h	9 %
o beam development / training	80 h	1 %	250 h	3 %
o unscheduled outage	150 h	2 %	330 h	4 %
o service	180 h	2 %	420 h	5 %
o shutdown	2660 h	30 %	1350 h	15 %
o standby	2600 h	30 %	1110 h	13 %

Table 2: Overview of the beam use.

SLS OPERATION

The year 2002 was the first year of user operation for the SLS. We had to provide excellent performance and highest reliability in order to satisfy our synchrotron light users. Furthermore satisfied users are a prerequisite for the successful future development of the SLS: to attract highest quality science and to fund new world-class beam lines.

The main goal for the machine performance was to increase the machine current while maintaining the high beam quality reached in 2001. We started at the beginning of the year with an average beam current of 150 mA and succeeded until October to establish a reliable 300 mA Top-up mode for user operation. The final 400 mA Top-up mode was also tested, but more radiation protection measurements are required and the machine reliability at this current needs to be enhanced before this can be made the standard mode for user operation.

The key to doubling of the beam current was the successful commissioning of the superconducting third harmonic cavity in the storage ring. This cavity increases the lifetime of the stored electron beam by nearly a factor of two and at the same time reduces the problems with current related instabilities of the beam. On the other hand the very same cavity was causing us the longest single unscheduled beam interruption of the SLS in 2002 of about 30 hours. A failure of the main SLS cooling water system caused an interlock of the cryostat of the superconducting cavity that led to a warm up. We will now build a larger reservoir of cooling water for the cryostat, which will allow independent operation from the main cooling water for about one day, instead of one hour at present.

STATISTICS OF SLS OPERATION

The development of the availability of the SLS, defined by the percentage of the scheduled user beam time that was actually usable, is presented in Fig. 1. The average availability of 94 % is very good for the first year of operation, but should be surpassed in the next year. Another important figure shown in the graph is the Mean Time Between Failures (MTBF). This number is defined by the average time between two unscheduled beam losses in the storage ring. We reached an excellent value of 30 hours. It is remarkable that neither the installation of the 3rd harmonic Cavity (3HC) nor of the 5 *mm* vacuum chamber for the material science beam line caused any significant decrease in the performance.

Table 3 shows a summary of the operational data.

Beam Time Statistics	2002	2001
Swiss Light Source		
o total beam time	6044 h 69%	3576 h 41%
• user operation	4472 h 51%	1016 h 12%
• beamline commissioning	992 h 7%	256 h 3%
• setup + beam development	576 h 11%	2304 h 26%
o shutdown	2720 h 31%	5184 h 59%
o downtime at user operation		
• unscheduled outage	258 h 6%	no data
• injector outage (non top-up)	54 h 1%	no data
Total beam integral	1030 Ah	247 Ah
Availability	94%	no data
MTBF	30 h	no data

Table 3: SLS Operation Statistics.

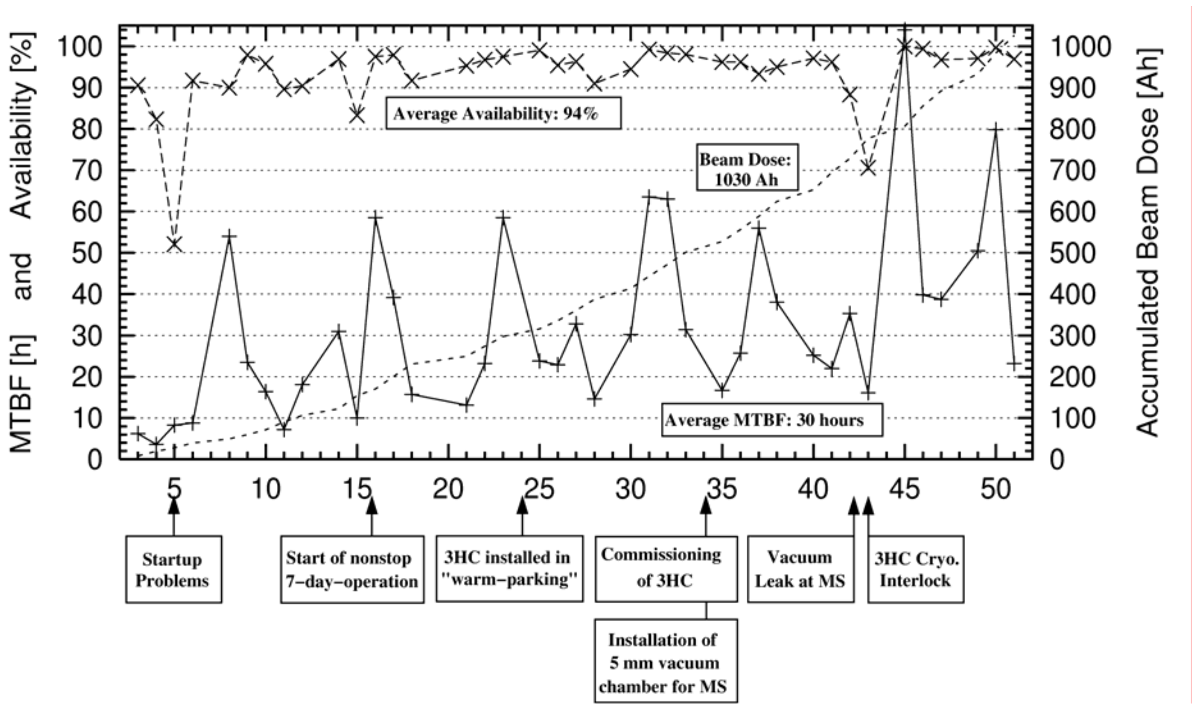

Fig. 3: Operation Figures of the SLS: Availability, Meantime Between Failures (MTBF) and Beam Dose.