# OPERATION OF THE PSI ACCELERATOR FACILITIES IN 2004

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## OPERATION OF THE 590 MEV PROTON ACCELERATOR FACILITY

After completion of the yearly shutdown the Proton Accelerator Facility was taken into operation in week 16 for the medical NA3 facility, the end of the shutdown for the experimental areas being scheduled for week 18. During the first setup the beam could not be brought into the Ring Cyclotron and the beam pipe had to be opened for inspection. However no obstacle could be detected and after pumping the beam line again, the beam was successfully set up and delivered to the biomedical facility. At that moment the origin of the problem was not understood and only several months later the cause of this failure could be detected. We will come back later to this point. Due to this problem the start of the facility was delayed by one day.

In week 18, without delay in the schedule of the high energy shutdown, stable operation with 1500 μA could be obtained over the weekend of May 1st. A production current of 1700 μA was already obtained in week 20 and in week 26 the nominal current of 1800 μA could be reached.

The facility ran this year with an average availability of 84.2 % (based on the threshold of 1 mA). This is significantly lower than in the three previous years, as shown in Fig. 1 where the availability of the past 10 years is presented. In order to judge the evolution over this period, two curves are shown: one with the availability with the previously used threshold at 150 μA and one with the 1 mA limit used in the last four years. While the lower performance in 2004 is clearly a step backward in our effort to increase the availability, it remains within the long term average. This is nevertheless a signal that our goal to raise the availability over 90 % is a very difficult task and that a routine operation at this level cannot be guaranteed.

To compensate for longer interruptions, four machine development days were re-scheduled for production. This has not been accounted for in the statistics, and would increase the availability from 84.2 % to 85.5 %.

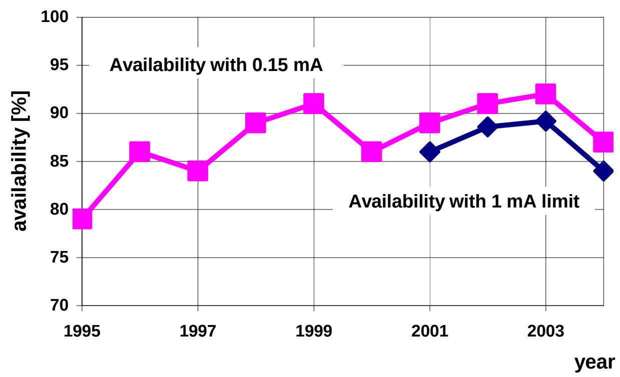


**Fig. 1:** Availability of the high energy facility for currents over 1500 μA.

The integrated beam charge delivered to the Target E amounted to 7.1 Ah compared with 8.1 Ah for the same time period in 2003 and reflects also the smaller availability. These features, as well as some additional information on the operation of the facility are presented in Fig. 2. About half of the production weeks are characterized by availabilities of 90 % or higher with a rather stable period in the weeks 34 to 47, interrupted however in the weeks 43 and 44 by a

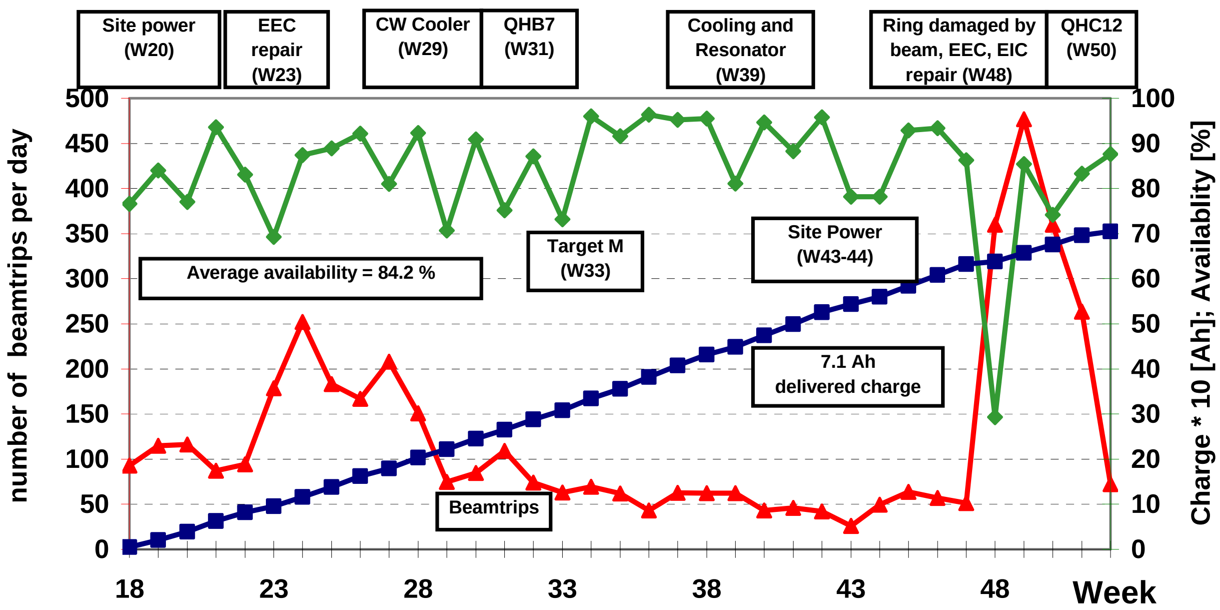


**Fig. 2:** Operation at the PSI High Energy Proton Accelerators: Availability, main failures, delivered charge and beam trips due to discharges in the electrostatic elements.

failure in the supply of the electrical power to the facility and in the week 39 by a manipulation error in the Injector 2 cooling, which caused problems to get a resonator back into operation.

The other half of the production weeks was marked, besides short interruptions, by the following major events:

- In week 20 two site power interruptions due to lightnings caused an interruption of 17 hours.
- In week 23 the Ring extraction element (EEC) and its high voltage cable had to be replaced, causing an interruption of 24 hours and an unstable operation during about one week.
- In week 27 problems with the site cooling caused an interruption of 5 hours.
- In week 29 a heat exchanger in the CW that had been replaced three years ago, had to be replaced again and led to an interruption of 20 hours.
- In week 31, a defective quadrupole in the p-channel had to be replaced. This costed us 10 hours of high energy production. The NA3 beam branch with the medical facility was not affected by this incident.
- In week 33, due to a defective pump unit in a secondary beam line the vacuum of the p-channel was broken during the beam production. The target M suffered from this breakdown and had to be replaced, causing an interruption of 30 hours.
- In week 39, a manipulation error caused an interruption of the cooling of Injector 2 leading to a series of secondary problems resulting in the loss of 20 hours of beam time.
- In the weeks 43 and 44 (Sunday and Monday) the breakdown of an insulator at the power transformer station switched off the accelerators twice, thus causing an interruption of 42 hours.

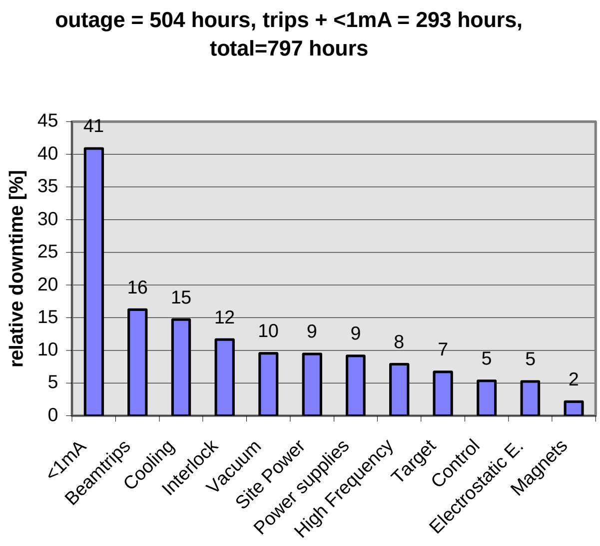


**Fig. 3:** Characterization of the downtimes of the 590 MeV accelerator facility.

- In week 48 a severe damage to the Ring Cyclotron was caused by a malfunction of the machine interlock system. Due to a defective module the beam was not turned off at the time of a voltage breakdown in a HF-cavity. As a consequence, holes were burned in a protection collimator and in a vacuum valve. Metallic deposits originating from the melting of these components led to malfunctions of the electrostatic elements which had to be replaced, too. The total length of the interruption amounted to 60 hours.

  When taking the facility into operation after this repair, we experienced the same problem as during the setup after the shutdown. Again, it was not possible to inject the beam into the Ring Cyclotron. The problem was identified as a forgotten cleaning rag, lying at a hidden position but eventually moving into the beam path as the beam line was evacuated.

  Due to the increased sparking of the electrostatic elements, the number of trips was significantly increased during the subsequent weeks.

  This event was the longest registered in year 2004. The availability dropped in this week to 30 % giving a negative contribution to the average availability of over 1.5 %.

- The last significant problem was caused in week 50 by the power supply of a quadrupole in the p-channel. Due to the stochastic character of the failure the problem could not be located easily and it took up to 16 hours to get the power supply repaired. The medical program was not affected by this interruption.

The distribution of the downtimes is documented in Fig. 3. In comparison to last year no major differences exist in the general outage distribution, except that some items disappear (PSA, Diagnostic, Operation) and some other items (Target, Power system, Interlock failure causing beam damage) (re)appear. For clarity we have to comment the following items:

- The Target M is mentioned here as outage source, but the failure was caused by a vacuum breakdown in an experimental beam line. Improvements in the vacuum system should prevent this from happening in the future.
- The power system interruptions, generally caused by lightnings, were dominated this year by the failure of a ceramic insulator at the power transformer station. This is likely to be a unique event in the lifetime of the facility.
- The increase of the contribution due to the power supplies is caused by the fact that many of these devices are getting old and should be replaced. This could evolve to a severe problem since only a limited number of power supplies can be replaced each year.

- The contribution of the cooling is not only due to a few major interruptions, but also to the increasing occurrence of pipe clogging in the quadrupoles in the 870 KeV beam line. The water pipes have often to be cleaned, thus causing interruptions of the production for several hours. The installation of the necessary equipment to improve the water quality is in preparation.
- The Interlock failure leading to the above mentioned damage of the Ring Cyclotron was the first event that could be attributed to this system in the last 20 years. Other damages of similar severity took place in the past, but were caused by insufficient diagnostics. While over the years, the situation has improved in this respect, the observed failure of the run permit system itself creates a new situation and calls for immediate action. The replacement of older components will be accelerated and additional redundancies will be implemented during the 2005 shutdown.

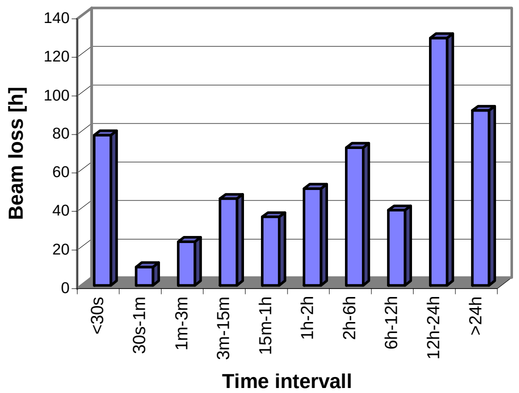


**Fig. 4:** Time distribution of the downtimes in 2004.

Comparing the distribution of the length of the beam interruptions displayed in Fig. 4 with last year record, one can draw the following conclusions:

- The distribution of the interruptions smaller than 6 hours is essentially the same. They are responsible for about half of the outage time. A large part of the time loss originating from short trips are due to the unstable beam periods after replacement of electrostatic elements.
- The last three bars in the histogram represent the other half of the outage time and illustrate a negative feature of the 2004 production period. Since the loss of a full day is already critical for numerous short experiments performed at the µSr and at the SINQ facilities an intensified effort is due to reduce the occurrence of this type of outage.

## OPERATION OF THE LOW ENERGY FACILITY (INJECTOR 1)

The Philips Cyclotron was operated on a reduced basis for 12 OPTIS periods, for test of electronic components (mostly as parasitic use during the OPTIS weeks), and for the LISOR and the Heavy Elements programmes. While the proton beam could be delivered without major difficulties, experiments with the heavy ion beams had to be cancelled or rescheduled because of a breakdown of the ECR source and problems with the acquisition of replacement parts. At the accelerator itself, repairs of water leaks and the elimination of instabilities of the rf-system dominated the significant effort needed to maintain the machine in an operational stage.

## STATISTICS OF THE OPERATION

A compilation of statistical data on the operation of the facility is presented in Table 1. Since in the present operating mode of Injector 1 an arbitrary distinction of the periods without beam production in shut-down, service or standby is not meaningful, the time not attributed to the effective use of the machine or for operator training is now recorded in one item:

| Beam Time Statistic | 2004 | | 2003 | |
|---|---|---|---|---|
| ***Ring Cyclotron (590 MeV)*** | | | | |
| o production for experiments | | | | |
| • meson production | 4710 h | 54 % | 4790 h | 55 % |
| … with SINQ | 4460 h | | 4730 h | |
| … with proton therapy | 1480 h | | 1530 h | |
| … with PIREX/PIF | 0 h | | 1325 h | |
| • parasitic beam programs served with direct primary beam | 80 h | 1 % | 5 h | 0 % |
| o setup | 160 h | 2 % | 150 h | 2 % |
| o beam development | 120 h | 1 % | 120 h | 1 % |
| o unscheduled outage | 282 h | 3 % | 240 h | 3 % |
| o service | 320 h | 4 % | 320 h | 4 % |
| o shutdown | 3380 h | 38 % | 3025 h | 34 % |
| ***Injector II (72 MeV)*** | | | | |
| o production for experiments | | | | |
| • production for Ring cyclotron | 4800 h | 55 % | 4890 h | 56 % |
| … with isotope production | 1680 h | | 1960 h | |
| • parasitic beam programs (IP2) served with direct primary beam | 210 h | 2 % | 6 h | < 1 % |
| o setup | 200 h | 2 % | 200 h | 2 % |
| o beam development | 300 h | 3 % | 320 h | 4 % |
| o unscheduled outage | 206 h | 2 % | 140 h | 2 % |
| o service | 250 h | 3 % | 250 h | 3 % |
| o shutdown | 3180 h | 36 % | 2825 h | 32 % |
| **total beam integral delivered** | | | | |
| o to meson production targets | 7100 mAh | | 8100 mAh | |
| o to SINQ | 5100 mAh | | 5400 mAh | |
| **availability** | 84.2 % | | 89.2 % | |
| ***Injector I (variable energy)*** | | | | |
| o production for experiments | | | | |
| • NE-experiments | 1140 h | 13 % | 1640 h | 19 % |
| • OPTIS | 360 h | 4 % | 460 h | 5 % |
| o setup | 240 h | 3 % | 120 h | 1 % |
| o beam development / training | 350 h | 4 % | 100 h | 1 % |
| o no production | 6770 h | 77 % | 100 h | 1 % |

**Table 1**: Overview of the beam uses.

## SLS OPERATION

The year 2004 was very successful for the operation of the SLS. Availability and Mean Time Between Failures were further considerably improved and the newly scheduled reserve time for the compensation of downtime during user operation allowed us to deliver 99.7% of the originally scheduled user beam time.

Two new beamlines started commissioning in 2004: the microXAS beamline for X-Ray absorption spectroscopy and the second protein crystallography beamline PX-II, funded by a collaboration of the Max-Planck-Gesellschaft and the Swiss pharmaceutical industries Roche and Novartis.

The main reason for downtime stemmed from a rather unexpected source: a defective insulator of a main transformer caused a power cut of about one hour affecting the entire PSI west area. Several minor power cuts subsequently followed, before the main transformer was finally repaired. In total 57 hours or 30% of the downtime of the year was caused by those failures of the mains.

The fast-orbit-feedback (FOFB) was one of the highlights for operation in 2004. We succeeded in reaching world-leading orbit stability down to a sub-micron level. The FOFB usage started already in Nov. 2003, but performance and reliability of the system were steadily improved on throughout the year [1].

A filling-pattern-feedback on the beam charge distribution was brought into operation [2]. It measures the filling pattern utilizing a fast photo diode in the synchrotron light beam. The feedback is necessary to safely run a hybrid mode, with an isolated single bunch within the beam gap of the standard 80 % filling. This hybrid mode is required for time resolved measurements and is extensively used for the surface interface microscopy beamline. The feedback also serves to further improve the orbit stability, since it reduces the effect of the filling-pattern dependency of the beam position measurement [1].

## SLS OPERATION STATISTICS

Fig. 5 shows the development of the availability of the SLS. We reached the average availability of 96.3 % during the delivered user beam time. About 175 hours of reserve time was used for the compensation of downtime during user operation. Together with some single machine shifts given to the users, we succeeded to compensate for nearly all of the unscheduled downtime. The Mean Time Between Failures (MTBF) of the storage ring improved again this year to 59.5 hours. The injector outage increased to 46 hours. This was mainly due to a defective pre-amplifier, causing phase drifts. Table 2 shows a summary of the operational data.

| **Beam Time Statistics** | **2004** | | **2003** | |
|---|---|---|---|---|
| ***Swiss Light Source*** | | | | |
| o total beam time | 6616 h | 75% | 6792 h | 77% |
| • user operation | 5116 h | 58% | 5288 h | 60% |
| - incl. compensation time | 175 h | 2% | - | |
| • beamline commissioning | 696 h | 8% | 696 h | 8% |
| • setup + beam development | 804 h | 9% | 808 h | 9% |
| o shutdown | 2168 h | 25% | 1968 h | 23% |
| o downtime at user operation | | | | |
| • unscheduled outage | 190 h | 3.7% | 307 h | 5.8% |
| • injector outage (non top-up) | 46 h | 0.9% | 30 h | 0.6% |
| **Total beam integral** | 1845 Ah | | 1567 Ah | |
| **Availability** | 96.3% | | 94.2% | |
| Availability after Compensation | 99.7% | | - | |
| **MTBF** | 59.5 h | | 45.9 h | |

**Table 2:** SLS Operation Statistics.

## OUTLOOK

Two more beamlines will deliver beam to users in the next year: the PX-II beamline, which already started commissioning and the Infrared Dipole beamline. But the major tasks will be the commissioning of the FEMTO project and the installation of the super-bends. Both will require major changes to the machine settings and will be a challenge for the SLS operation.

## REFERENCES

[1] M. Böge et al., *Beam dynamics activities at SLS*, this report.

[2] B. Kalantari et al., *Bunch Pattern in Top-up Mode at the SLS*, this report.

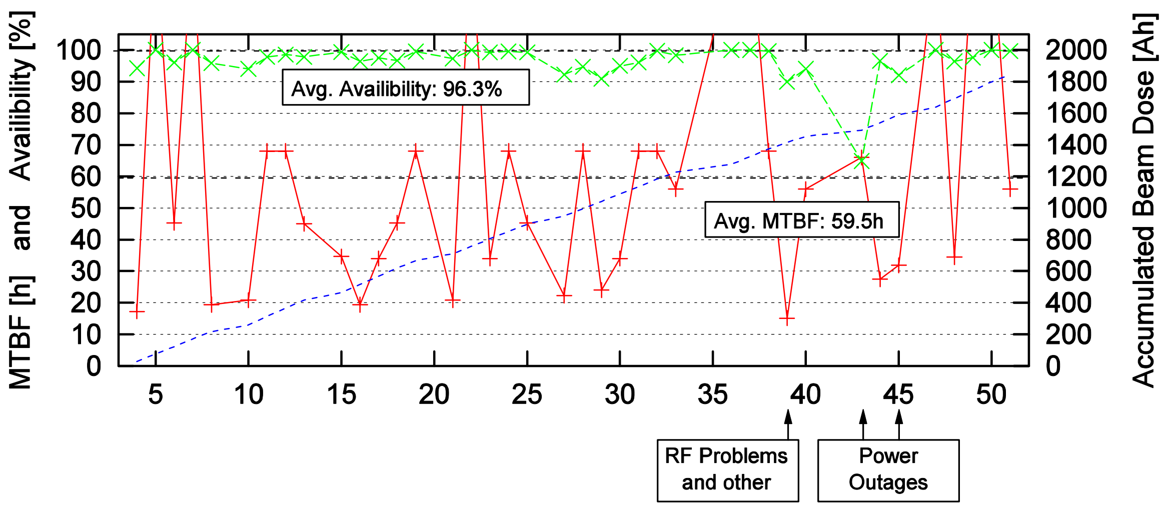


**Fig. 5:** SLS Operation Statistics: Weekly Availability, Mean Time Between Failures and Accumulated Beam Dose.