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## 2.6
# SINQ 2000
## Status report

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**Abstract**

SINQ, in its fourth year of operation is fully committed to serving a large community of users from all over the world. It experienced significant improvements of performance through both, an increase in proton current on target and the replacement of Zircaloy by lead as target material. The present service life of a target is two years with the highest charge accumulated being 6.8 Ah on the last Zircaloy target and 5.8 Ah on the present lead target after its first year of service. This makes SINQ the most powerful spallation neutron source by a large margin and this fact is taken advantage of in an extensive materials irradiation program with a large number of specimens placed inside the target. The results will be of significance not only for future research neutron sources but also for accelerator driven systems (ADS) which are expected to play a role in the future of nuclear technology. At present a liquid metal target is under development at SINQ in collaboration with the ADS community. The anticipated gain in neutron flux is about a factor of 1.5.

### SINQ as a Neutron Source for Users

Since the last ICANS meeting, when SINQ was looking back at its first 500 mAh of beam on target, the facility has matured into a neutron source with a full user program. Currently eight neutron scattering instruments are fully operational (2 triple axis spectrometers -one of them with polarization analysis-, 1 high resolution time of flight spectrometer, 4 diffractometers and one small angle scattering machine). Two more, a reflectometer and a strain diffractometer are in the process of commissioning. Non-diffractive uses of SINQ include two radiography facilities, a prompt gamma analysis machine, a nuclear physics installation with cold neutrons, two isotope production rigs, two installations for neutron activation analysis and a fission product extraction facility.

SINQ is operated as a user facility with proposals being evaluated and beam time allocated twice a year by the SINQ Science Committee. On an average, some 60 % of the total beam time is assigned to experiments proposed by Swiss scientists (including PSI's strong in-house group), the remainder being split in roughly equal shares between proposals coming from the rest of Europe and from outside Europe. Beam time requests run at roughly twice the available instrument time, with the degree of overbooking varying among the different types of instruments. Although SINQ serves the traditional reactor clientele, the users are coping well with the particularities of an accelerator based spallation source.

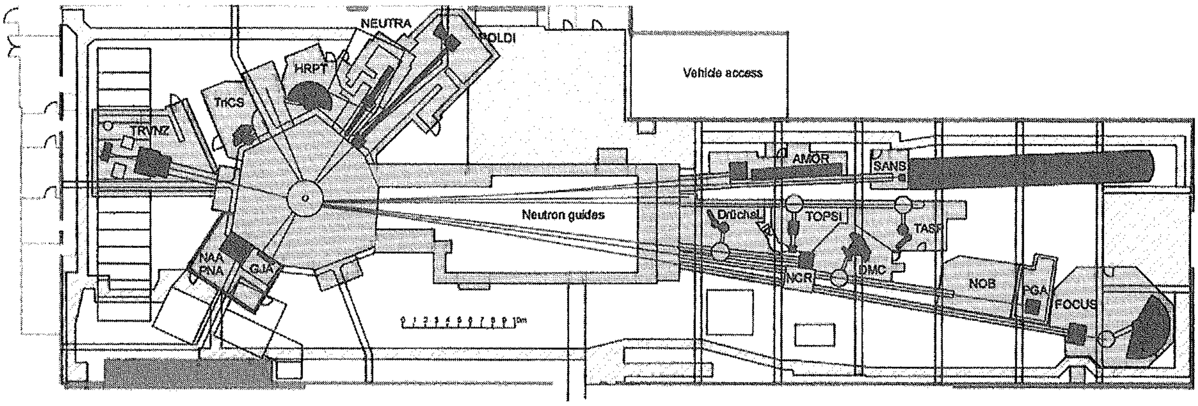


**Figure 1** *Floor plan of the SINQ halls showing instrument layout, instrument floor space and shielding*

**Facility Operations**

In general the performance of the PSI accelerator system was highly satisfactory during most of the past two years with a steady increase in charge delivered per week. However, even on good days (an example is shown in Fig. 2) the number of short beam trips runs at roughly 50 per day. In Fig. 2 the current has been averaged over 3 minutes, which results in trips seemingly not going all the way to zero. This is, however an artefact because the shortest trips are only 20 sec long. This duration has been set for the rise time of the beam after a trip in order to avoid too rapid heating on the rotating, radiation cooled graphite target "E" upstream of the SINQ target.

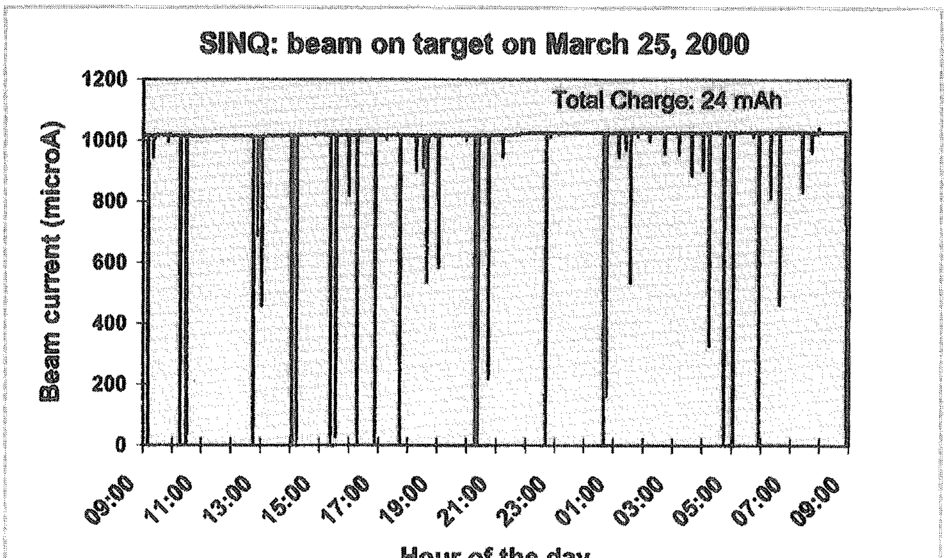


**Figure 2:** *Beam current recording for the SINQ target on a good day. Each dip indicates a total loss of beam for 20 sec or more (the plot shows an average over 3 min).*

During the past years the proton current delivered to the SINQ target has been continuously raised from its value of 800 μA in 1997. This was due to ongoing improvements of the accelerator current on the one hand and to a reduction of the length of Target "E" from 6 cm to 4 cm on the other. This shortening of the graphite target upstream of SINQ in October 1999 (week 44) resulted in a 25% increase of the current on SINQ and an even higher increase of the peak current density, which is now about 30 ($\mu A/cm^2$)/mA.

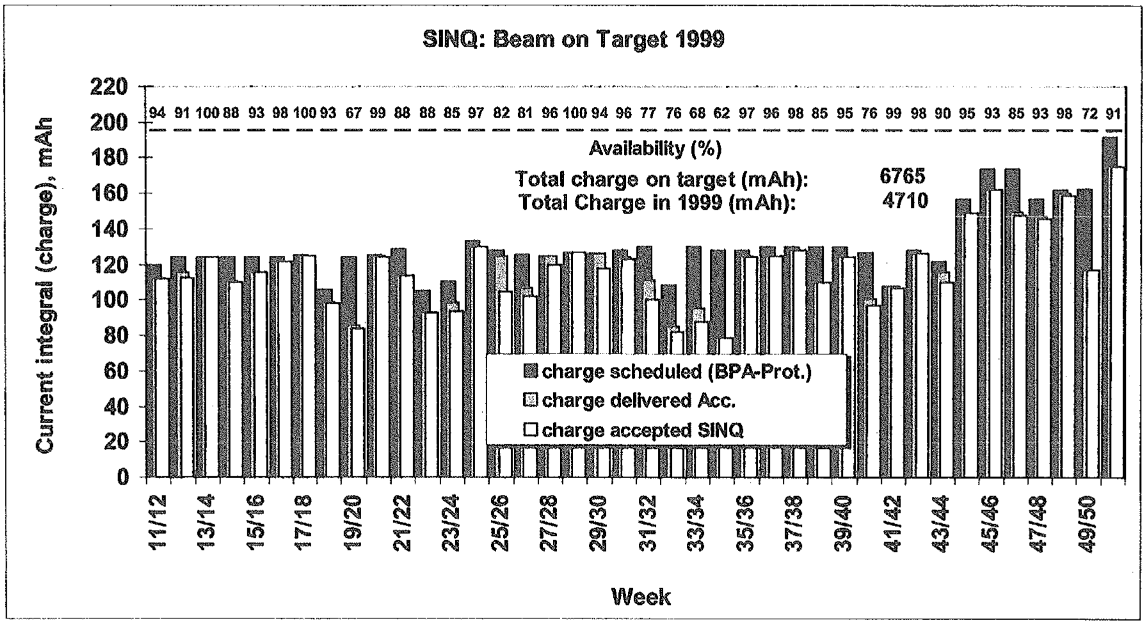


**Figure 3** *Charge history of the SINQ target in 1999. The target was removed after the end of this period having received a total of 6.76 Ah of protons, 4.7 of which were delivered in 1999.*

As can be seen from Fig. 3, the overall reliability of the facility was quite satisfactory, averaging at 91% for the charge delivered by the accelerator and at 89 % for the charge accepted by SINQ (ratio scheduled/actual). This shows that the availability of the SINQ target and moderator system was as high as 98%. Periods of increased non-availability were either caused by external events (e.g. river flooding in the spring wiping out the heat sink) or failure of highly loaded beam line components such as a splitter used to peel off about 20 μA for the use in PSI's medical facilities.

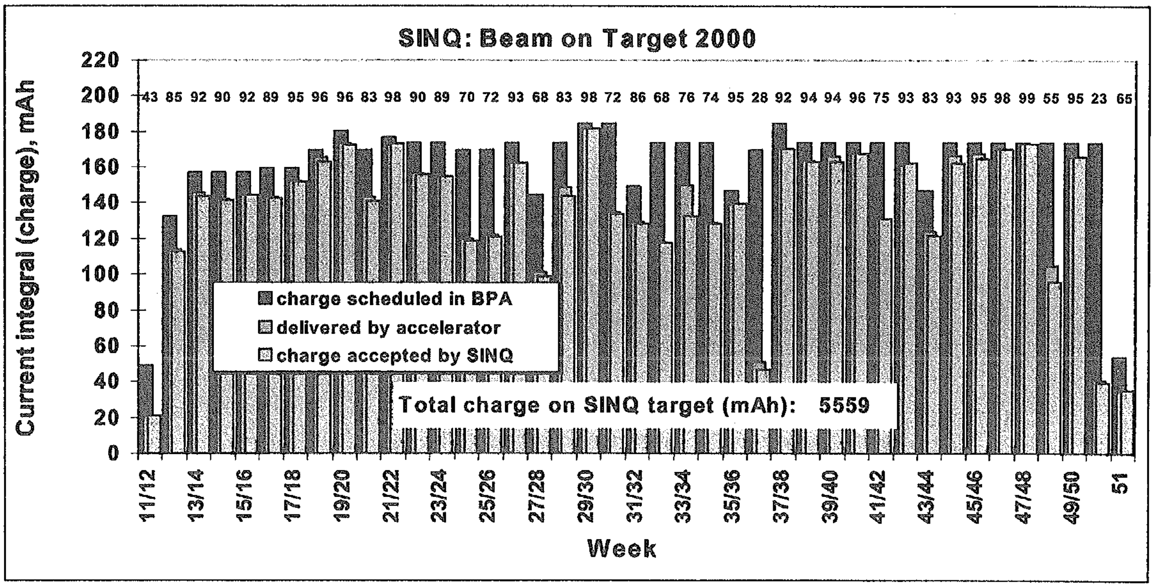


**Figure 4** *Charge history of the SINQ target in 2000. The total charge delivered was 5.6 Ah. The target will remain in operation through 2001, unless some problem is detected*

In the last week of 1999 the current integral scored the record value of 180mAh. Although this value was scheduled in several weeks in 2000, it was only exceeded once, in week 29/30, with the all time high of 181.6 mAh so far (Fig. 4). Although the total charge delivered to the target in 2000 was the highest ever (5.6 Ah), the average availability (86%) was down from 1999. Much of this is attributed to the high "stress" some of the components are subject to when the accelerator is run at a current level above 1.8 mA, which is what is needed to reach 1.2 mA on SINQ. Yet again, the availability of the SINQ systems was as high as 98%.

It is worth noting that, while the accelerator control room is manned in permanence, the SINQ facility including its cold source is running fully automated, with a member of the operations crew being on call outside normal working hours.

## Facility Development

While an important improvement in the neutron flux and fluence offered to the users resulted from the increase in proton current on target, an equally important contribution came from the ongoing target development efforts. After a Zircaloy rod target had been used up to the end of 1999, the target inserted in the beginning of 2000 is of a different design.

The Zircaloy rods had been welded into a hexagonal Zircaloy case - with the exception of those that contained test samples, which were held in place by wires. With the more concentrated beam profile resulting from the reduced length of Target E, it was not deemed necessary anymore to have a hexagonal target cross section. Advantage could be taken of the easier and cheaper fabrication of a square cross section target. At the same tine the Zircaloy rods were replaced by lead filled steel tubes, which had been successfully tested in the second target. Furthermore, the material of the case was changed to an aluminium alloy (AlMg3), the same material from which the target container shells are made. All rods of Target Mark 3 are held in place by wire locks, and hence are much easier to remove for post use examinations.

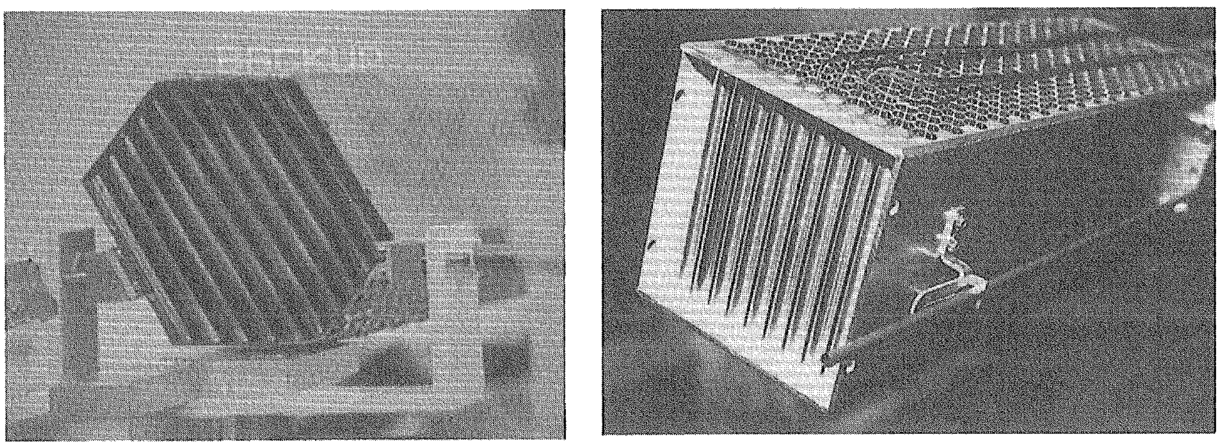

**Figure 5**: *The second (Mark 2, left, after use) and third (Mark 3, right) targets used in SINQ. The footprint of the beam is clearly visible on the second target.*

As before, a large number of test specimens were incorporated in some of the target rods and thermocouples were introduced to monitor the temperature in the rods. The gain in neutron flux at the instruments from the new target was a factor of 1.45. Accounting for the fact that, for reasons of availability austeitic stainless steel was used for the tubes rather than the originally foreseen martensitic 9% Cr steel, this agrees well with theoretical expectations.

Apart from the specimens included to build a materials database for future spallation target design, there are also test rods in the target, again, which directly aim at the development of the next generation spallation target, using liquid heavy metals. One test rod contains specimens immersed in mercury for the SNS and ESS projects, and two more contain molten PbBi in preparation for a liquid metal target experiment to be carried out at SINQ in 2004 (MEGAPIE, see separate paper in these proceedings). A liquid metal target is expected to yield another flux increase in the order of a factor of 1.5 over the present lead rods in steel tubes. In parallel, we are busy examining the question whether Zircaloy tubes can be used instead of the steel tubes. This would yield some 25 to 30 % flux gain, according to calculations. The problem might be that, while the hydrogen generated in the lead most likely diffuses through the steel tubes, it might lead to the formation of hydride lenses in the Zircaloy. Indications for this to happen were found when examining steel rods that had been irradiated in Zircaloy tubes in Target Mark 2 by neutron radiography.

Apart from improvements on the target side, we are presently also working on a cold moderator container with a re-entrant hole, which should improve the cold neutron flux in our guide system by a factor between 1.3 and 2.5, depending on wavelength. This new cold moderator is expected to replace the old one starting in 2003.

## Conclusions and Acknowledgements

During the past two years we were able to increase the neutron flux in SINQ by a factor of 2.2 and to provide neutrons to the users with high reliability. Further improvements are in the pipeline. SINQ has thus shown that continuously operating spallation neutron sources can be competitive with research reactors on virtually all accounts. This success is the result of a dedicated operations and development crew on both, the accelerator and the target systems side. It is a pleasure to thank everyone involved for their continuous efforts and readiness to put in extra work whenever necessary, and to appreciate the ongoing support by the PSI management, whose encouragement was the trigger to embark on the MEGAPIE project as a real step forward.