Proceedings of the 1999 Particle Accelerator Conference, New York, 1999

A 0.5 MW / 10 Hz OPTION OF THE SPALLATION SOURCE AUSTRON

Ph. Bryant[1], E. Griesmayer[2], E. Jericha[3], H. Rauch[4], M. Regler[5], H. Schönauer[1]

[1] CERN, PS Division, Geneva, Switzerland, [2] Fachhochschule Wiener Neustadt, Austria, [3] Institut für Kernphysik, Technische Universität Wien, Austria, [4] Atominstitut der Österreichischen Universitäten, Wien, Austria, [5] Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, Wien, Austria

Abstract

In 1993-94 a feasibility study for AUSTRON, a neutron spallation source, was made on behalf of the Austrian Ministry of Science and Research. At that time, the machine was a synchrotron cycling at 25 Hz and delivering an average beam power of 205 kW at 1.6 GeV. An option to double the power by doubling the frequency was foreseen. Now a more ambitious development of the original concept is proposed that aims at 0.5 MW at 1.6 GeV, pulsed at either 50 Hz or 10 Hz. The slow repetition rate is achieved by the addition of a storage ring holding four consecutive (single bunch) pulses from the 50 Hz synchrotron until a fifth pulse is accelerated and transferred to the target with the four stored ones. In this way, an energy per pulse of 50 kJ (one half of the pulse energy of the 5 MW ESS) is obtained, yielding about 3.5×10^{16} thermal neutrons /(s cm^2). This peak flux matches well a number of innovative instruments and allows unprecedented resolution for some more conventional ones.

On August 20, 1998, the Austrian Government has unanimously decided to contribute one third of the total cost of the facility and invites international partners to participate.

1 HISTORY OF THE PROJECT

The history of AUSTRON begins in the years 1991 - 92, where a number of politicians and scientists contemplated the creation of a large-scale research facility in the eastern part of Austria that would radiate into and attract scientific potential from the now accessible East European Countries. In 1991, Prof. C. Rubbia advised the government that a pulsed spallation neutron source would be the most attractive and useful ‘centre of excellence’ (at that time the concept proposed for ‘Pentagonale’ – a loose collaboration of Italy, Austria and its three eastern neighbours). The basic parameters and the scenario were fixed in a meeting gathering nuclear, material structure, instrumentation and accelerator physicists at CERN, and proposed to the Austrian government [1],[2],[3] which subsequently financed a feasibility study [4],[5] for the project. Target and infrastructure was studied at the Atominstitut of the Austrian Universities while the accelerator study group was based at CERN. From the beginning, the machine was designed to be realised in stages (I - III).

2 AUSTRON I, II, III

In view of the philosophy of building the accelerator with conventional technology and to fully profit from existing experience, in particular at ISIS [6], the scenario of a low-energy linac injecting in a Rapid Cycling Synchrotron (RCS) was adopted. Based on considerations on target optimisation the top energy of the RCS was chosen to 1.6 GeV. The basic machine (I) aimed at a beam power of 100 kW onto a single target, the first upgrade (II) would double the the beam intensity and hence the delivered power by augmenting the linac energy, and the second upgrade (III) doubles the repetition rate from 25 Hz to 50 Hz so that two target stations can be served.

Table 1: The Stages of AUSTRON

AUSTRON Stage	**Pulse rate** [Hz]	**Inject. energy** [MeV]	**Nr. of protons** p / pulse	**Av. Beam power** [kW]
I	25	70	1.6×10^{13}	102
II	25	130	3.2×10^{13}	205
III	50	130	3.2×10^{13}	410
0.5 MW	50	130	0.4×10^{13}	500
0.5 MW	10	130	2.0×10^{13}	500

The feasibility study deals in most details with stages I and II, while stage III was anticipated by rating the hardware components to meet its specifications.

The lattice of the 213 m circumference RCS uses FDF triplets and a superperiodicity of three like the ESS reference design. H^- Injection is taking place at the end of the fall of the magnet field in a finite-dispersion section with the foil on the inside of the circulating beam, which is traversed by the H^- beam in the combining bending. The RF acelerating system operates at harmonic number $h=2$ and requires a peak voltage of 160 kV (Stage I, II) and 246 kV (III), respectively.

---

1) Email: Horst.Schonauer@cern.ch

0-7803-5573-3/99/$10.00@1999 IEEE.

3 AUSTRON 0.5 MW

Some smaller complementary studies have been made after the Feasibility Study, such as the optimisation of the RF voltage program for trapping and acceleration [7]. It turned out that the longitudinal losses of the 50 Hz-cycling AUSTRON III could not be reduced to below ≤10% while the 25 Hz stages lost far less than 1%. As a consequence, the magnet cycle had to be modified to a dual-frequency (33 Hz rise / 100 Hz fall) cycle with short flat bottom clamping in order to match the loss figures of the 25 Hz cycle, at 0.41 and also at 0.5 MW. The augmented power entails a more marked peak space-charge tune shift of -0.42 at 1.5 ms in the cycle [8]. This means that particles will cross a third-order stopband for 2 ms. The best way to cope with possible adverse effects depends on details of the real machine and should be studied there. A second-harmonic RF system and/or an advanced collimator system are part of the options. Simulation of an advanced loss collimator in the AUSTRON lattice yielded a collimation efficiency of injection and RF trapping losses of 97.2% to be compared with 94.7% for a three-stage graphite collimator array [9].

4 AUSTRON 0.5 MW AT 10 HZ

In order to reduce the pulse frequency from 50 to 10 Hz, while maintaining the average beam power, the only economic issue is the addition of a storage ring (SR). The latter must be able to hold four consecutive pulses from the RCS along its circumference until a fifth pulse is accelerated and all the five can be sent to the target. Holding four RCS pulses side by side in a ring of comparable size is only possible if a single bunch is accelerated there (harmonic number *h=1*). Its length at extraction must be short enough to leave comfortable gaps for rise and fall of the injection kicker of the storage ring. This is possible indeed with a RF voltage of the *h=1* system of the RCS raised to 250 kV at the end of the cycle, shortening the bunch to a length of 76 ns or 36 RF degrees. In the storage ring the four bucket centres are separated by 191 ns, leaving a gap of 115 ns between neighbouring bunches. In the *h=4* system of the SR bunches are 144 degrees long. To match the bucket to the bunch shape only 65 kV RF voltage are needed at 5.23 MHz.

Fig. 1 shows a SR of the same shape as but mirror symmetric to the RCS of the Feasibility Study [3]. This geometry allows the probably shortest possible transfer beam line between the two rings. The original extraction outward from the RCS is just turned inward. Note that the lattice structure of the SR is slightly different from the RCS: The quadrupole triplets of the long straight sections of the RCS have been replaced by quadruplets in the SR, in order to free the centre for the symmetric injection/extraction/direct-pass array of two septum magnets plus a kicker. Every fifth RCS cycle the accelerated bunch is sent straight to the target before or after the row of the four bunches extracted from the SR. This configuration allows these bunches coming directly from the RCS to pass straight through the septa to the extraction line, the kicker being deactivated during their pass. A further simplification requiring a modification of the RCS lattice would be to make both rings intersecting in the same plane.

Dipoles and quadrupoles of the SR are smaller than those of the RCS as the beam dimensions at 1.6 GeV are less than half those at injection, and the fields of the d.c. magnets can be raised to 1.5 T. The very long free straight section of the SR appears well suited for accommodation of an efficient loss collimation system capable to cope with residual loss at 1.6 GeV.

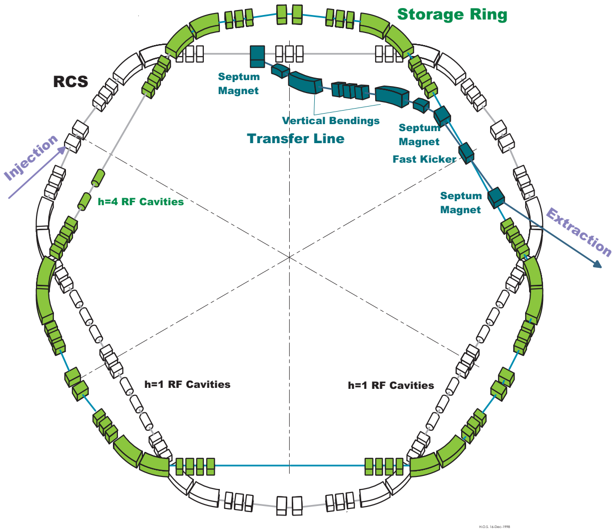

Figure 1: The Storage Ring above the RCS with the transfer line.

5 TARGET AND INSTRUMENTATION

According to the present concept of AUSTRON it is planned to start with one single target station. The target station houses the spallation target, the moderators and several beam tailoring elements like in-pile collimators or background suppression and bandwidth choppers, accessible via separate access hatches for the various beam lines. The proposed spallation target in flat target geometry [10, 11] consists of one block of solid tungsten-rhenium (W-5%Re). The target temperature at 0.5 MW - 10 Hz operation is expected to reach some 1300 °C which can be controlled by an advantageous edge-cooling technique. In the current design, the target is surrounded by 4 moderators. Following the requirements for the proposed neutron instrumentation, one moderator at ambient or intermediate temperature and 3 cold moderators are needed. This clearly reflects the increasing importance of cold neutrons for condensed matter research. In 1998 a suite of 21 instruments was proposed for AUSTRON [12, 13]. The corresponding layout is shown in fig. 2.

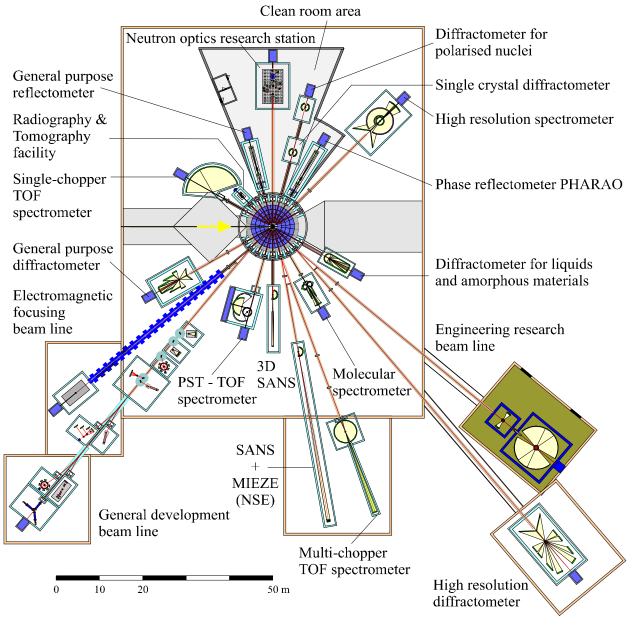

Figure 2: Schematic layout of the proposed AUSTRON instrumentation.

Most of these instruments will highly gain from the slow repetition rate of the neutron source. With total flight path distances ranging from 12 m to more than 100 m, the AUSTRON instruments aim at high resolution by TOF analysis. Owing to the repetition rate of the source a large wavelength band (up to 30 Å) can be used in one frame of the source without having to deal with overlapping neutron from subsequent pulses. This is of particular importance for the proposed diffractometers which cover momentum transfer regions for the investigation of liquids and amorphous substances, powder crystallography, and single crystal studies under special environmental conditions, for the reflectometers and the small-angle scattering instruments. This also holds for the crystal analyser spectrometers, especially the high resolution spectrometer.

Advanced environmental control is one of the unique features of the AUSTRON facility. A part of the experimental hall will be covered by a special vibration-isolated area under clean room conditions. This has become an issue since neutron research has reached a level of sensitivity where environmental effects can influence the results of an experiment considerably. The reflectometers, single crystal diffractometers and the neutron optics research station will profit from these conditions, unprecedented at any other neutron source.

Several instruments are based on experimental methods which are still under development and will be unique at AUSTRON. These innovative instrument concepts are the neutron spin echo instrument for pulsed sources, the phase reflectometer, the spin echo small-angle scattering instrument, the diffractometer for polarised nuclei, the phase space transformation spectrometer and the pulsed neutron optics instruments.

6 CONCLUSIONS

By modifying the magnet cycle, the beam power of AUSTRON III can be raised to 0.5 MW (one tenth of the ESS goal of 5 MW). By integrating a storage ring capable of holding four consecutive 50 Hz pulses, a repetition frequency of 10 Hz without loss of average power can be achieved. In this way, an energy per pulse of 50 kJ (one half of the pulse energy of the ESS) is obtained, yielding a peak flux of 3.5×10^{16} thermal neutrons per sec and cm^2.

7 ACKNOWLEDGEMENTS

The authors would like to thank the Austrian Ministry of Science and Transport and in particular Dr A. Stoklaska for their continuing support and faith in the project. The help and encouragement of the CERN Directorate, and especially from K. Hübner, and the hospitality extended to the study team by the PS Division and its Leader D. J. Simon over several years are all gratefully acknowledged. The authors would also like to thank the International Scientific Council of the AUSTRON Project under Prof. A. Furrer whose advice and wisdom has always been very much appreciated. Finally to mention Dr H. Weber who has recently agreed to take on the difficult, but vital, task of Project Management.

8 REFERENCES

[1] H. Aiginger et al. (editors), ”AUSTRON, an Interdisciplinary Research Centre”, Vienna, January 1992.
[2] AUSTRON Machine Study Team: “A Pulsed Spallation Source in Central Europe”, Proc. of the 3rd EPAC, Berlin, March 1992, p. 432 .
[3] P. Bryant, M. Regler, M. Schuster (editors), “The AUSTRON Feasibility Study” , Austrian Ministry for Science and Research, Vienna, Nov. 1994.
[4] F. Baumann et al., “The Accelerator Complex for the AUSTRON Neutron Spallation Source and Light-Ion Cancer Therapy Facility”, Int. Rept. CERN/PS 95-48 (DI), December 1995 .
[5] P. Bryant et al., ”The Accelerators for the AUSTRON Spallation Source“, Proc. of the 4th EPAC, London, June 1994, p. 2677 .
[6] C.W. Planner, “Reaching 200 µA at ISIS”, Proc. of the ICANS-XII Meeting, Abingdon, May 1993, RAL Report 94-025, Vol.2, p. A-4 .
[7] E.Griesmayer, “RF Trapping and Acceleration in AUSTRON”, Int. Rept. CERN/PS 95-10 (DI), May 1995.
[8] E.Griesmayer, “RF Trapping and Acceleration in the 500 kW AUSTRON Rapid-Cycling Synchrotron”, Int. Note CERN PS/CA 98-18, July 1998 .
[9] H. Schönauer, “Loss Concentration and Evacuation by Mini-Wire-Septa”, Proc. of the 1995 PAC, Dallas, May 1995, p.1894 .
[10] M. Schuster, “Status of the AUSTRON-Project”, ICANS XIII, PSI-Proc. 95-02, Villigen, October 1995, p. 831 .
[11] M. Schuster et al, “Material and geometry studies for the AUSTRON target”, Physica B 234-236 (1997) 1224
[12] E. Jericha et al, “AUSTRON progress report”, ICANS XIV, Starved Rock Lodge, Utica, Illinois, June 1998 (in print)
[13] AUSTRON Project Team, “AUSTRON project study 1998” (Part 2), Vienna, September 1998