

A Pulsed Spallation Source in Central Europe

The "AUSTRON" Machine Study Team¹

reported by K.Schindl and H.Schönauer

CERN-PS

CH - 1211 Geneva 23

Abstract

A pulsed spallation neutron source, satisfying the increasing needs of material sciences, life sciences and medical research, has been considered by a study group of potential users and accelerator experts¹. Beams for other disciplines, notably nuclear physics, medium energy physics, and detector R&D would be provided as well. The accelerator specifications for the spallation source are: proton beam power on target 200 kW; repetition rate ≤ 25 Hz; pulse length ≤ 1 μ s. A number of scenarios were contemplated with proton beam energies ranging from 0.8 to 5 GeV. The accelerator configuration preferred consists of two stages where Stage 1 is an H- Linac and a rapid-cycling (25 Hz) synchrotron in the GeV range providing an average beam power of 100 kW on the target. A number of upgrading possibilities with a view to reaching the design beam power is discussed for Stage 2 of the project. The possibility of "parasitic" light ion acceleration for basic medical research is explored.

1. INTRODUCTION

The "AUSTRON" project [1] - the name is provisional - is a concept for a major international research centre offering research facilities for a wide range of users, the majority of them from fields other than physics. This initiative is supported by the "Hexagonale" Group (A, CS, H, I, PL, Slovenia, Croatia) which recommends "AUSTRON" as one of the projected regional research centres. A panel of experts representing over 50 institutes in this region unanimously favoured the construction of a pulsed neutron spallation source. Building this facility in Austria, near to the Czechoslovakian and Hungarian borders, is under consideration by Austrian authorities.

2. USER REQUIREMENTS

The Working Group "Scientific Case" [2], representing a broad community of potential users, came up with the following specifications and priorities:

1) A pulsed spallation neutron source, yielding neutrons in the sub-eV and eV range, for material science, structural chemistry, molecular biophysics, life sciences, with:

- average beam power on target 200 kW
- repetition rate ≤ 25 Hz
- pulse length < 1 μ s.

The short pulse length is required to enable time-of-flight measurements: combined with a low repetition rate it yields a high peak neutron flux and reduces overlap of consecutive pulses in time-of-flight measurements with sub-eV neutrons. The yardstick for these figures is the ISIS synchrotron [3,4] featuring 120 kW beam power, at present the world's top performing pulsed spallation neutron source.

All the following requests are of much lower priority and to be considered for parasitic use only:

2) Neutrons in the few 100 keV range (emerging from the spallation target in the forward direction): The required time structure differs from the one given above:

- repetition rate several 100 Hz
- pulse length (r.m.s) ≤ 2.5 ns

3) Light ions for basic medical research (no treatment), supported by a growing number of institutes. Tentative requirements:

- light ions up to Ne
- energy up to 250 MeV/nucleon
- some 10^9 ions/s, any time structure.

4) Secondary beams, in particular for detector development.

Due to present capacity limits of spallation neutron sources, potential users wish to have the facility built as fast as possible, which precludes extensive R&D work on novel accelerator concepts and technology. Moreover, the cost of the complex (including tunnels and specific equipment, but not the target station and general infrastructure) should not exceed 100 MECU (about 180 MCHF).

3. ACCELERATOR CONFIGURATIONS CONSIDERED

The machine options evaluated are summarised in Table 1, where

LIN means Linear accelerator, of drift tube (< 150 MeV) or coupled-cavity (> 150 MeV) type. In all cases they accelerate H⁺ ions so as to allow charge exchange injection into the synchrotron(s).

RCS means Rapid Cycling Synchrotron.

SR, CR Storage Ring, Compressor Ring, respectively.

FFAG stands for Fixed Field Alternating Gradient accelerator, which combines features of cyclotrons and synchrotrons. As yet no reference machine of this type has been built.

Since cost is one of the selection criteria, the machine team had to assign rough price tags to the options considered; very likely they will undergo significant changes when studied more thoroughly.

¹ H.Aiginger, W.H.Breunlich, K.Hübner, M.Regler, G.H.Rees, K.Schindl, H.Schönauer, A.Wrulich

Table 1: Options considered

| | | p beam power (kW) | average current (μ A) | repetition rate (Hz) |
|---|--|-------------------------|----------------------------------|----------------------------|
| 1 | 70 MeV LIN 1.6 GeV RCS | 100 | 63 | 25 |
| 2 | 800 MeV LIN 800 MeV CR | 200 | 250 | 10 |
| 3 | 120 MeV LIN 5 GeV RCS | 100 | 20 | 25 |
| 4 | 160 MeV LIN 50 Hz 1.2 GeV RCS 1.2 GeV SR | 200 | 167 | 10 |
| 5 | 100 MeV LIN 50 Hz 1.6 GeV FFAG | 200 | 125 | 10 |
| 6 | 100 MeV LIN 1 GeV Helical synchrotron | 200 | 200 | 8.33 |

Option 1, reminiscent of ISIS, is the preferred configuration, because it fits into the price tag and has a broad upgrading potential. Its additional merit is the possibility to accelerate light ions.

Option 2, reminiscent of LAMPF/PSR [5], is attractive with its low repetition rate, but much too expensive.

Option 3, at about the same cost as Option 1, could be readily upgraded to 200 kW by increasing the Linac energy to 400 MeV. Some R&D on the accelerating cavities (combination of high voltage and large frequency swing) would be required.

Option 4: advantages and drawbacks similar to option 2.

Option 5 would exploit a novel accelerator design requiring major R&D effort. It is under serious consideration by KFA Jülich [6].

Option 6, initially proposed for another application [7,8], would ask for considerable R&D work and does not appear compatible with the project time scale.

4. ACCELERATOR CONFIGURATION PROPOSED

The proposed accelerator complex is sketched in Fig. 1, and a possible set of main parameters is listed in Table 2. It is planned to build AUSTRON in two stages. Stage 1 (Option 1 of Table 1) will consist of a 70 MeV H^- Linac and a 25 Hz, 1.6 GeV RCS. Although its average p beam power on target is slightly below most recent figures of ISIS (120 kW) [9], its peak power will exceed the (50Hz) ISIS by a factor ~ 1.7 as AUSTRON will operate at 25 Hz. Thus even this first stage will be competitive to existing pulsed neutron sources. No doubt the AUSTRON team may profit from the wealth of experience accumulated at ISIS, auguring well for a reasonably short construction time.

H^- ions are needed because charge-exchange injection is the only known way to inject such high beam intensities per pulse while keeping the beam within the design emittance. This is by now the widely-used standard technique to

generate bright beams and has the additional merit of keeping injection losses and thus irradiation of machine components manageable. An injection energy of 70 MeV turns out to be the minimum compatible with an acceptable space-charge defocusing of $\Delta Q \sim 0.3 - 0.4$.

Table 2: AUSTRON, Stage 1, tentative parameters

| Synchrotron | | |
|--|---------------------|---------------|
| Output energy | 1.6 | GeV |
| average current | 63 | μ A |
| repetition rate | 25 | Hz |
| beam power | 100 | kW |
| number of p per pulse | $1.6 \cdot 10^{13}$ | |
| transv. emittance (invariant, 86%) | 150 | π mm mrad |
| pulse length (2 bunches of 50 ns each, 350 ns spacing) | 420 | ns |
| circumference | 200 | m |
| injection energy | 70 | MeV |
| RF frequency | 1.1 - 2.8 | MHz |
| peak RF voltage | 170 | kV |
| harmonic number | 2 | |
| bunch area | 0.5 | eVs |

Injector (H^- source, R.F.

Quadrupole, Drift Tube Linac)

| | | |
|----------------------------------|------------|---------|
| Linac output energy | 70 | MeV |
| repetition rate | 25 | Hz |
| pulse length | ~ 100 | μ s |
| beam current during pulse | 30 | mA |
| numb. of turns injected into RCS | ~ 60 | turns |

5. LIGHT IONS?

The proposed Stage 1 of the AUSTRON accelerator complex does not a priori exclude light ion acceleration. This option would lead to a considerable enlargement of the users community. They would require some 10^9 light ions per second, up to ${}_{20}\text{Ne}^{10+}$, at ~ 250 MeV/nucleon, for $\sim 10\%$ of the machine operation.

AUSTRON Stage 1 could be upgraded for parasitic light ion operation at fairly modest investment as follows (see also Figure 1):

(1) Addition of a second pre-injector: an Electron Cyclotron Resonance (ECR) source and an ion RFQ;

(2) a second injector system to the RCS, as the ions have to be injected with betatron stacking which is rather incompatible with charge-exchange injection;

(3) upgrading of the RF acceleration system in the RCS to a larger frequency swing: 1.1 - 3.7 MHz; four bunches are accelerated. Alternatively, a more complex main magnet power supply could enable the RCS to cycle slowly and change its RF harmonic number from 4 to 2 during the cycle. Note that the ion travelling speed in the drift tube linac is half the one of protons, thus the ions would be accelerated in the " $2\beta\lambda$ " - mode.

6. UPGRADING POTENTIAL

Not the least of the criteria which guided the choice of AUSTRON Stage 1 is the variety of upgrading options it offers. These "Stage 2" add-on options are sketched in Figure 1, and their merits are commented upon below:

Stage 2, Option 1: A second 1.6 GeV RCS, which would cycle synchronised with the first one, both sending the protons on the target simultaneously. In this way, both mean and peak neutron flux are doubled with respect to Stage 1.

Stage 2, Option 2: A 1.6 GeV storage ring. Every other pulse from the RCS would be stored in the SR and would be ejected together with the following pulse from the RCS, thus halving the repetition rate to 12.5 Hz. The peak neutron flux is doubled with respect to stage 1, whereas the average remains unchanged. Moreover, this low repetition rate is very much favoured by users of sub-eV neutrons. The storage ring may also satisfy the particular time structure needed by the fast neutron users mentioned earlier: as only a fairly modest proton beam intensity is requested, the short bunches (a few ns) as well as the high repetition rate (several 100 Hz) may be generated in the SR by RF manipulations involving fixed-frequency cavities with a harmonic number 12 (~17 MHz, 200 kV), and bunch-by-bunch extraction from the SR with 300 Hz during the 40 ms cycle time of the RCS.

Stage 2, Option 3: A general-purpose 5 GeV RCS, at moderate intensity (5 μ A), for nuclear physics; the performance in terms of neutron flux remains unchanged.

7. OUTLOOK

The selection of one particular accelerator complex out of six configurations contemplated is not to be considered as closed. The final choice will depend on the outcome of a design study which will more thoroughly deal with the merits, cost, upgrading potential (Stage 2), broadness of

potential user community, etc. of the configurations competing for AUSTRON Stage 1. Thus the next step is the setting-up (and ensuring the financing) of a concept team of experts from various fields who would be due to come up with a design proposal within ~18 months from the approval in principle.

8. ACKNOWLEDGEMENT

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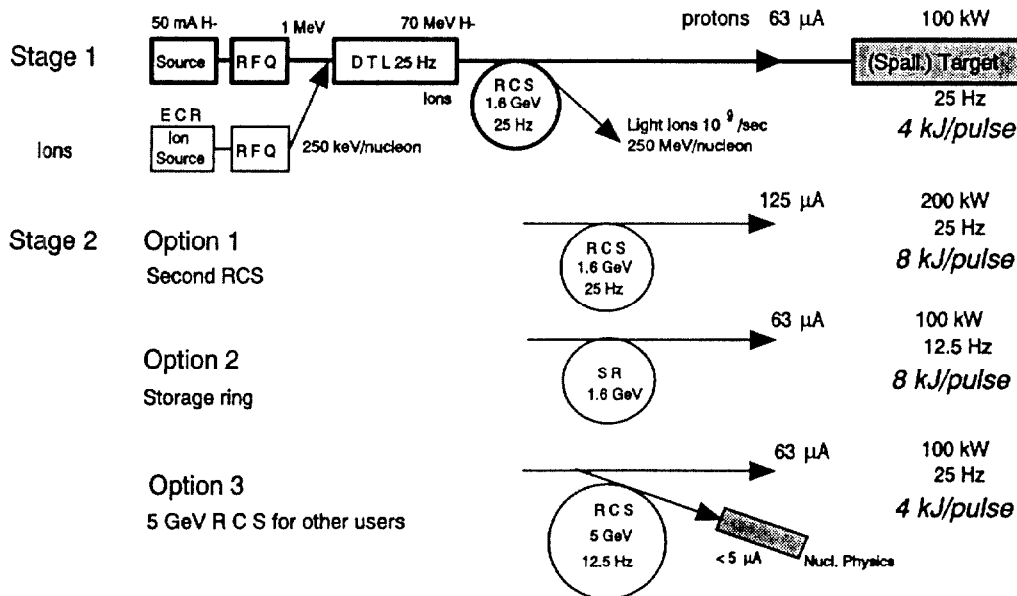


Fig. 1: AUSTRON, preferred Stage 1 accelerator complex, with options for Stage 2