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STATUS REPORT ON THE SIN-NEUTRON SOURCE
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ABSTRACT

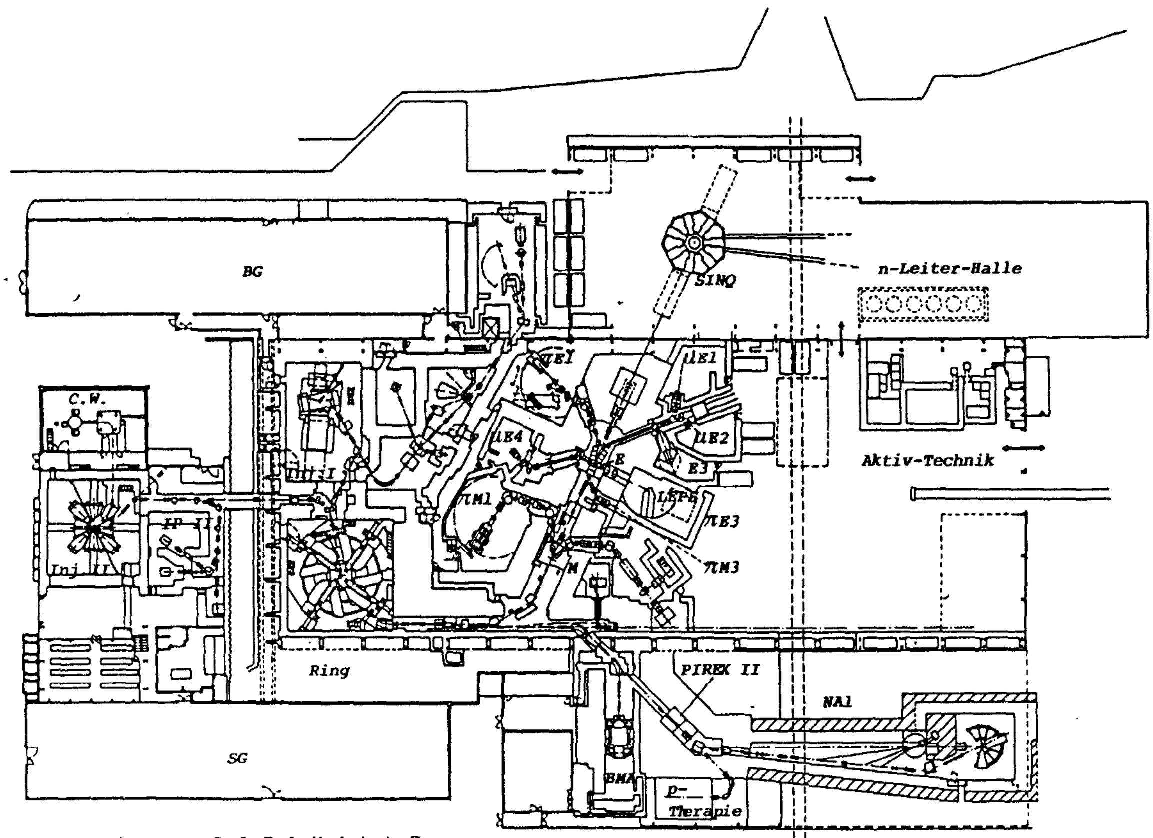
SINQ is a continuous spallation neutron source which is planned to be attached to the existing accelerator at SIN after its upgrading to higher currents. The overall project aims to provide the Swiss neutron user community with the facilities necessary to carry out scattering experiments in the wavelength range 1 to 10 Å; that is, the neutron source itself, experimental areas, sample conditioning apparatus, sample preparation areas and scattering instruments. Construction is planned to start in 1987, with the first neutron expected in early 1990. Total costs (excluding spectrometers) are estimated to be 27 Mio. SFr.

1. INTRODUCTION

The Swiss Institute for Nuclear Research (SIN) operates a cyclotron system that produces a high-intensity proton beam of 592 MeV. The beam intensity available at present is about 150 μA, and mainly used for meson production at two special target stations. The secondary meson beams are used for nuclear and particle physics. This research forms the main activity for SIN, although some condensed matter physics is done at a muon beam.

After having passed through the meson target, about 70 % of the power of the original primary proton beam is still left. This beam is at present stopped in a beam dump.

A new injector system is now being commissioned to allow routine operation of the SIN experimental programme with a proton current in excess of 1 mA. With such beam current, the construction of a spallation neutron source with a performance comparable to that of a medium-flux reactor becomes feasible. Owing to the absence of any macro-pulse structure in the extracted proton beam this neutron source will be of the continuous type.



EXPERIMENTIERHALLE DER ZUKUNFT

Fig. 1 Layout of the SIN-accelerator system and the experimental facilities. The location of the neutron hall, containing SINQ, and the guide hall is at the upper right of the picture.

The layout of the accelerator system and experimental facilities, following completion of the upgrade programme and including SINQ, is shown in Fig. 1. The major components of SINQ are (I) an extension of the present proton channel, (II) the neutron source itself, (III) the building for the source and neutron beam-tube experimental area, (IV) the neutron guide hall, and (V) the scattering instruments.

2. STATUS OF INJECTOR II

The pre-accelerator (Cockcroft-Walton) of Injector II contains a multi-cusp ion source with an extraction voltage of 60 keV. A short beam line, where the H^+ beam is cleared of other hydrogen ions, is followed by an acceleration tube of 800 keV. The 860 keV beam is then axially injected into the injector cyclotron, which is - like the main ring accelerator - of the isochronous type. Approximately 10 % of the injected DC-beam is accepted by the RF-system of the cyclotron for further acceleration up to 72 MeV. A view of Injector II with the 860 keV beam line, axial injection and the extraction for the 72 MeV beam is presented in Fig. 2.

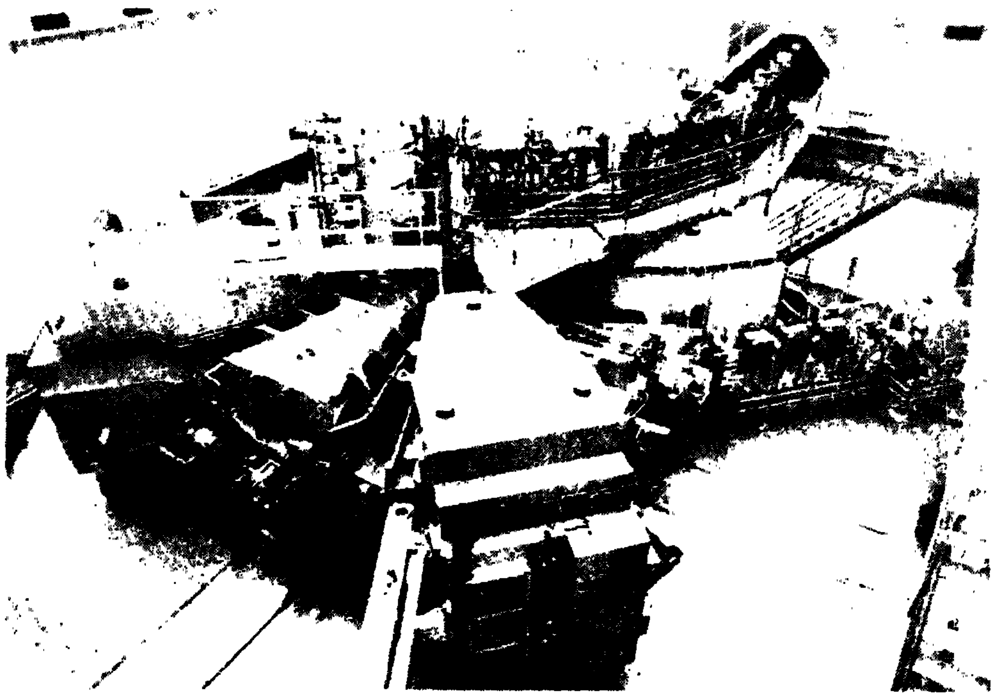


Fig. 2 A view of Injector II with the 860 keV beam line, axial injection and the extraction region for the 72 MeV beam line.

The status of this accelerator is as follows:

I) A maximum current of Ø.55 mA has been extracted. Beam losses were smaller than Ø.1 %. For a high extraction efficiency, a good separation of the final turns is essential. Fig. 3 shows the pattern of the last turns before extraction.

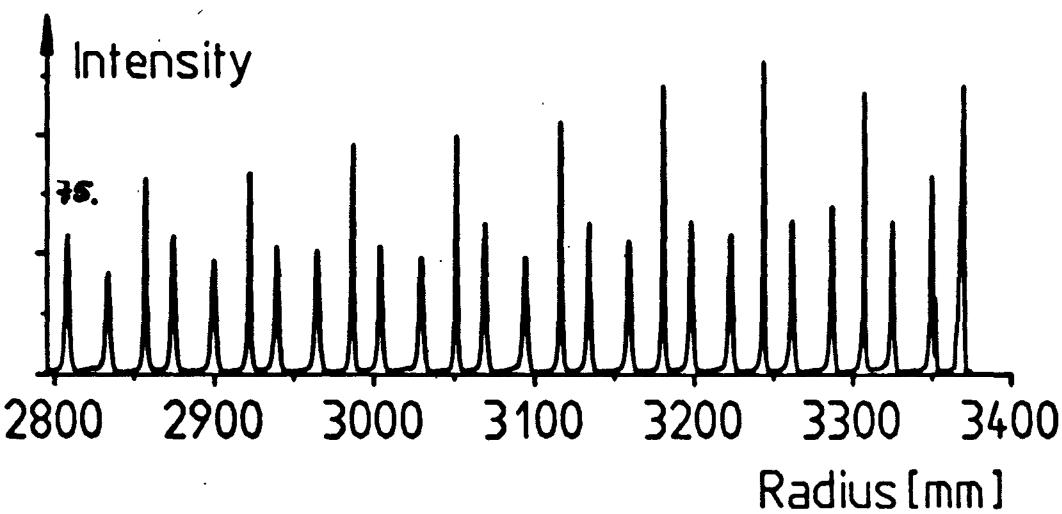


Fig. 3 Pattern of the last turns in Injector II before extraction. A superperiod of three turns (due to a small phase space mismatch) and the horizontal focusing frequency close to Q=4/3 is clearly visible.

II) In order to investigate space charge effects, a 1 : 6 pulse suppression system has been installed. By suppression of 5 out of 6 micropulses, the space charge effects of high currents can be produced at only 1/6-th of the corresponding beam power. In this mode, a current which corresponds to 72Ø μA has been extracted.

III) During 1985, Injector II will be used for routine operation at currents of circa 2ØØ μA. This limitation is given by the second meson target station which has not yet been upgraded for higher currents.

The ultimate intensity limit will probably be determined by longitudinal space charge effects at the low energy orbits (7 MeV) just after injection into this machine /1/. It is of vital interest to show soon the feasibility of currents of the order of 1.5 mA, since both the spallation neutron source project as well as the possible extension of the SIN facilities towards higher energies /2/ rely on this beam current.

3. THE SPALLATION SOURCE - SINQ

a) Principle

The source is to be mounted on an extension of the present proton channel beyond target 'E' in a new building on the east side of the experimental hall. This building is to contain the source itself and the experimental area for instruments requiring beam tubes. The non-interacting part of the proton beam will be collected beyond target 'E', deflected downwards to pass under the beam-tube area, hence to the centre of the source and finally pitched vertically upwards to the spallation target.

The proton energy at the spallation target will range from 560 to 590 MeV (depending on the thickness of target 'E') with an initial intensity of 1 mA.

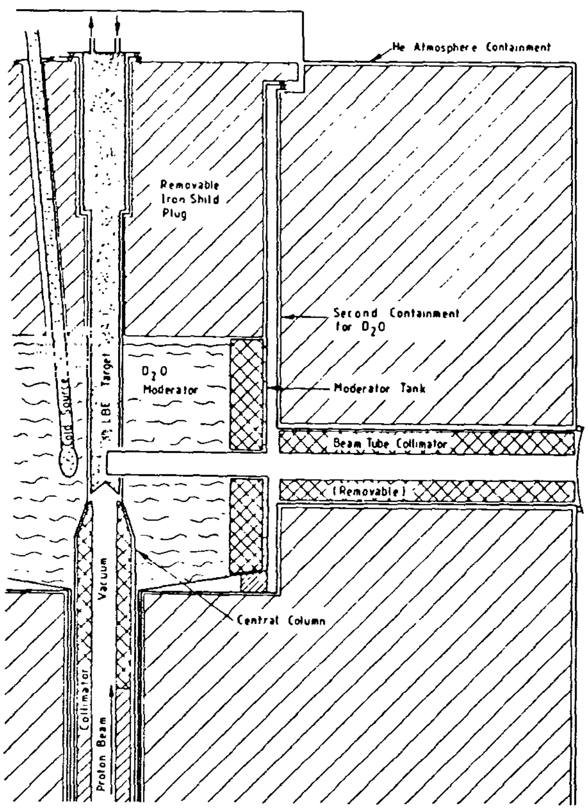


Fig. 4 Schematic view of the vertical section through the central region of the source.

A vertical section through the central region of the source is shown in Fig. 4. The target consists of a 'pot' of Pb/Bi eutectic mixture (molten) of inner diameter about 15 cm and 2 to 4 m high. Most of the beam power is deposited in the bottom 30 cm of the target. Natural convection is to be used to transport this heat to an exchanger mounted at the top of the target and hence away from the source /3/. The 'active' region of the target (the bottom 30 cm) is located at the centre of a tank of D_2O with a diameter and height of about 2 m. The D_2O thermalizes the fast neutrons resulting from high-energy proton interactions with the Pb/Bi in the target.

Design work is presently particularly active for

I) The target plug including the heat exchanger and the cold traps for volatile spallation products /4/. This whole system is being designed as an entity and to have a lifetime of more than one operational year.

II) The beam entrance collimator system in front of the spallation target.

III) Flasks for the exchange and disposal of the target plug and the collimator system

IV) The D_2O-system.

V) The proton beam extension to the spallation target.

Since in many projects for spallation neutron sources the primary proton beam is also to be exploited for other purposes, e.g. μSR, it might be of general interest to describe our beam transport line after the last meson target in more detail.

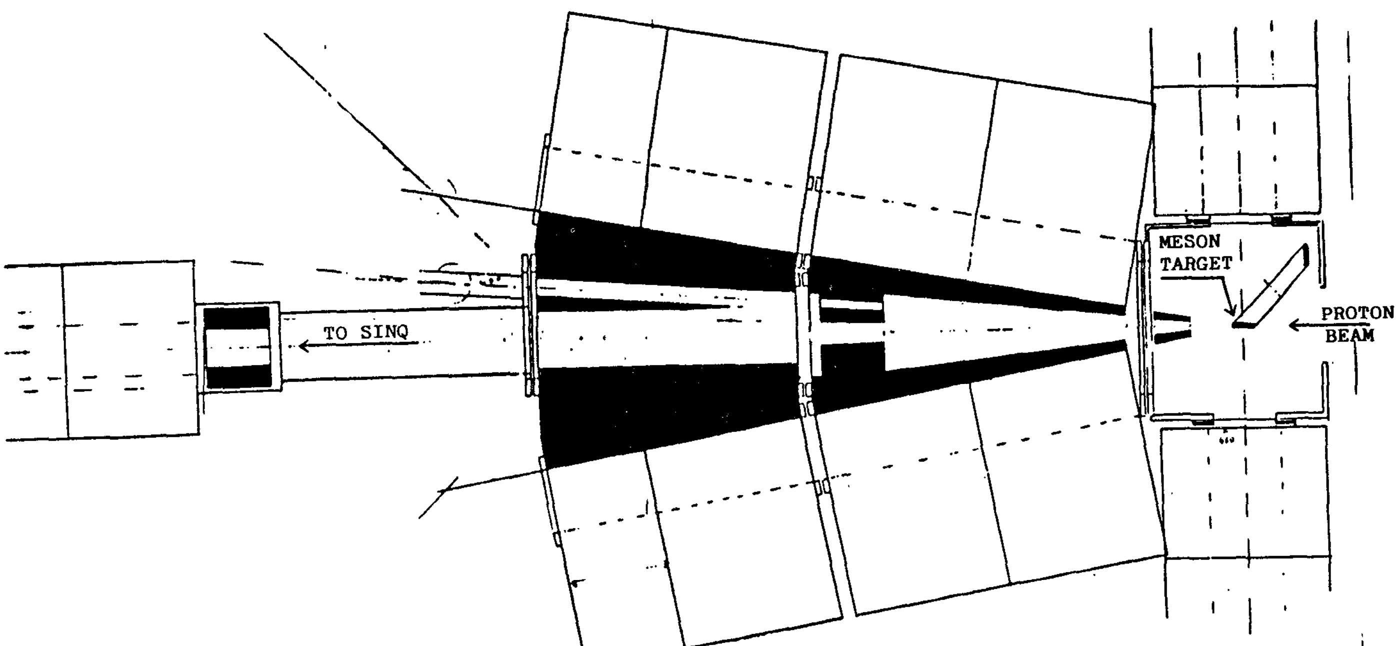


Fig. 5 The collimator system for cleaning up the transmitted proton beam at the last meson-target station.

b) Proton Beam Injection

Fig. 5 shows the collimator system which has to remove the halo of the proton beam, produced by scattering in the meson target. The transport of the proton beam through the target and the collimator system leads to the beam losses listed in Table I. The thickness of the target used for this estimate corresponds to 12 g Carbon, which is certainly an upper limit for a meson target bombarded by a proton beam with a power larger then 1 Mw:. The feasibility of a recovery of the proton beam under these extreme conditions gives us confidence in the chosen concept.

Table I

	loss (% of primary beam intensity)
Meson Target	11
Collimator I	6
II	14
III	1
Total	32

After passing through the meson target, the beam has a somewhat peculiar energy structure: Those parts which have missed the target, passing on its left or right side, have the original energy of 590 MeV, but the main part has been degraded by the target material to the range 570 -540 MeV.

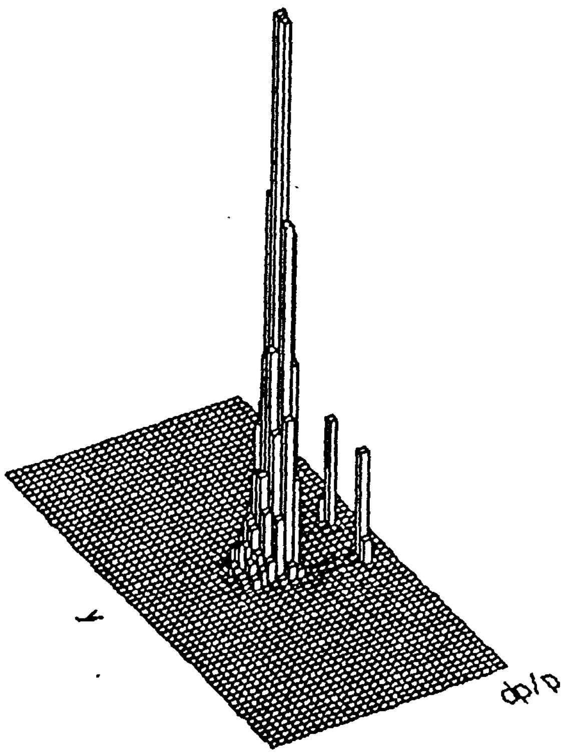


Fig. 6 Energy distribution of the proton beam after the meson target. A small part of the beam is passing to the left and right side of the target without interaction.

This distribution is shown in Fig. 6. Due to the relatively large energy spread, the beam line to the spallation target has to be of the achromatic type.

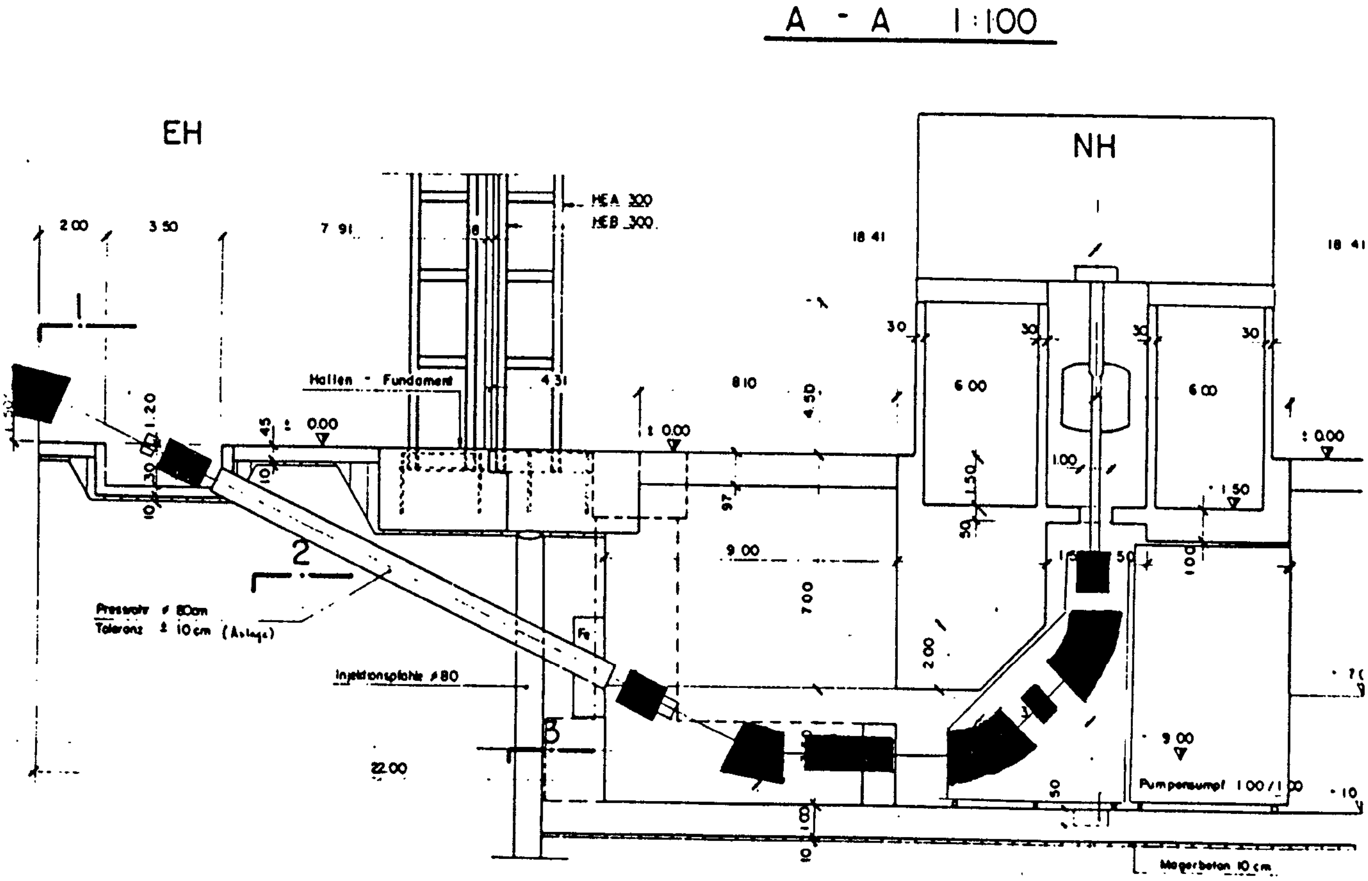


Fig. 7 Beam transport line between the meson target and the spallation source target. The sloping drift section passes the beam under the foundations of the present experimental hall. This concept also avoids excavating in the position where the present beam dump is located.

The present layout for the beam line is shown in Fig. 7. The proton beam will be refocused by a pair of quadrupoles placed after the collimator region, deflected downwards to pass under the neutron hall and hence into the cave below the centre of the source and finally pitched vertically upwards to the spallation target.

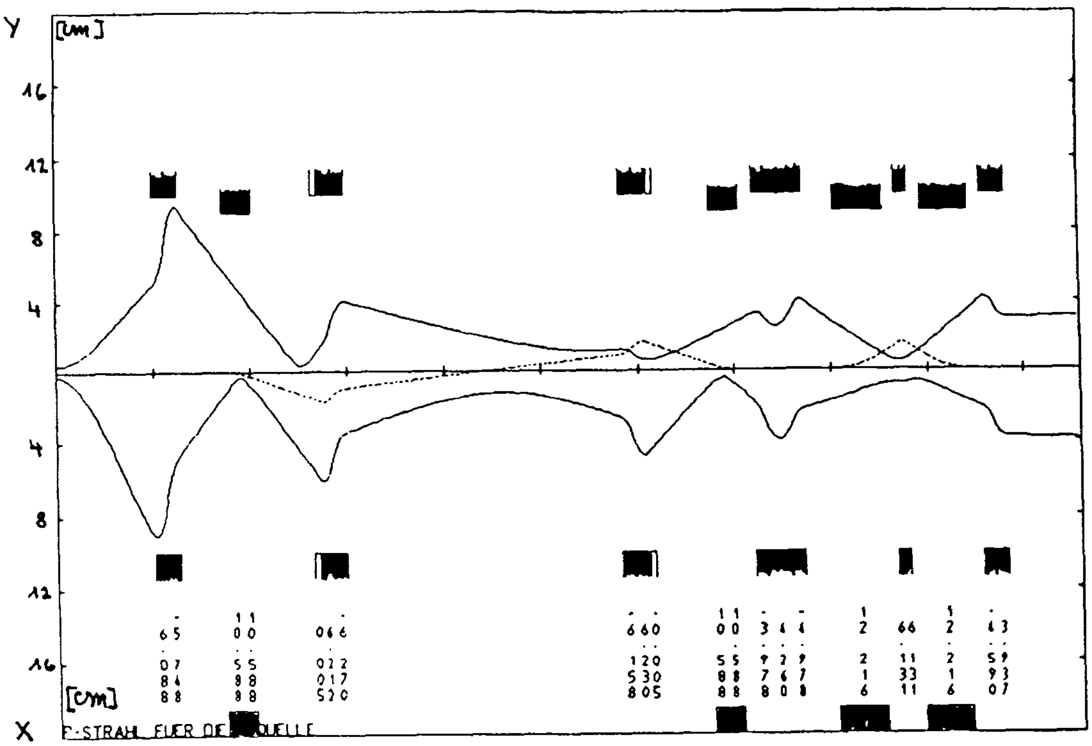


Fig. 8 Proton beam envelope and dispersion path for the injection line. This envelope contains the whole energy width of the beam indicated in Fig. 6.

The horizontal and vertical beam envelope as well as the dispersion path through the transport system are shown in Fig. 8. Beam losses are predicted to be less than 10^{-4} and located mainly in the region of the quadrupole doublet after the long drift tube, where the beam dispersion is rather high. This low beam loss gives us the possibility to design the undersource cave as a region with limited access and avoid an expensive remote handling system.

The beam spot on the target is relatively large, with a diameter of 6-8 cm. This size is a compromise between the following demands:

I) Optimal neutron production in the target

II) Efficient driving of the natural convection of the liquid metal in the target

III) Limitation of the power density in the material of the target window.

A collimator system in the vertical part of the beam line will protect equipment in this region (vacuum system, magnets etc.) against beam mis-steering. Special precautions will have to be taken to prevent incorrect focusing onto the beam window.

c) Neutron Flux and Source Performance

The design and performance of SINQ are based on results from an experimental programme for the investigation of the neutronics. This programme has been realized by a Julich-SIN collaboration on a secondary proton beam at SIN with a one-to-one mock-up model of the source /5/.

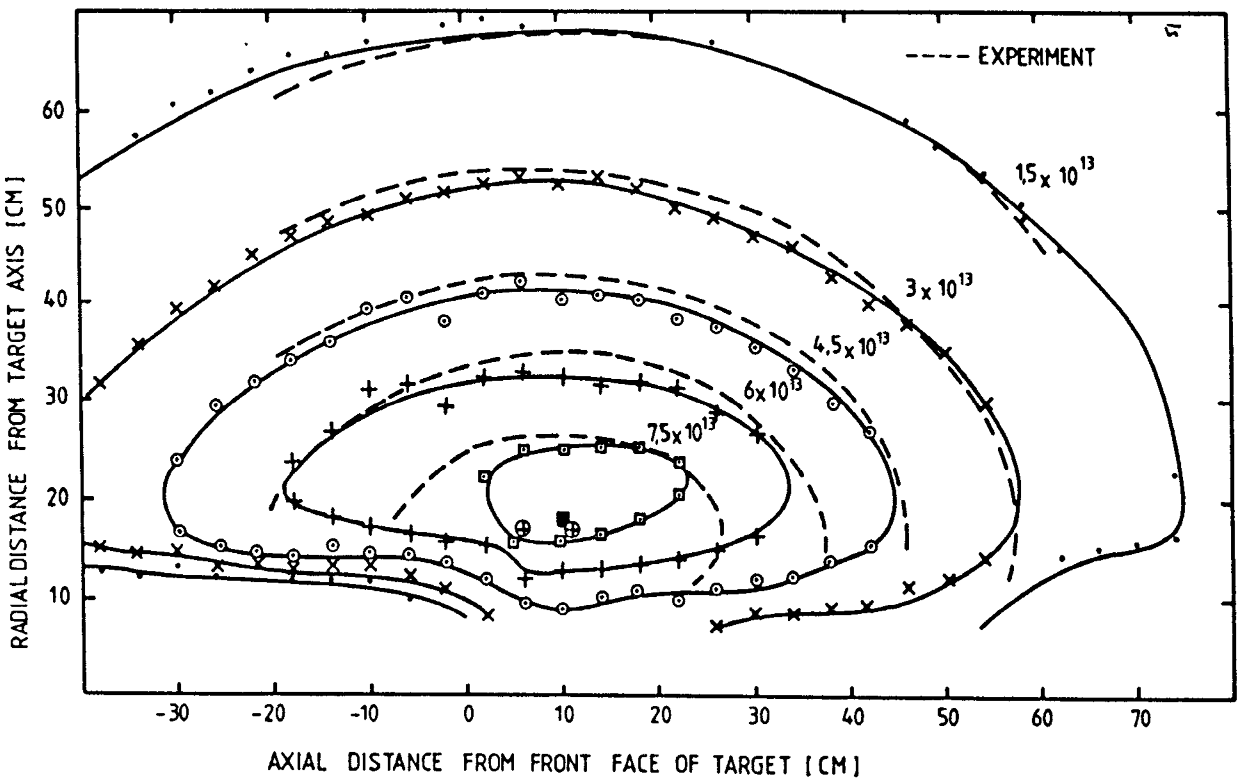


Fig. 9 Flux map for thermal neutrons in the D2O-moderator for 1 mA proton beam current.

Dashed lines: Mock up experiment

Solid lines: Monte Carlo simulation.

One of the flux maps, relevant to the planned SIN source, is shown together with its comparison with a Monte-Carlo simulation in Fig. 9. By means of flux distributions such as these, the optimal position of the cold source as well as the position and size of the beam tubes, may be determined. The last experiments at the mock-up model examined several configurations of cold hydrogen sources and their spectra /6/.

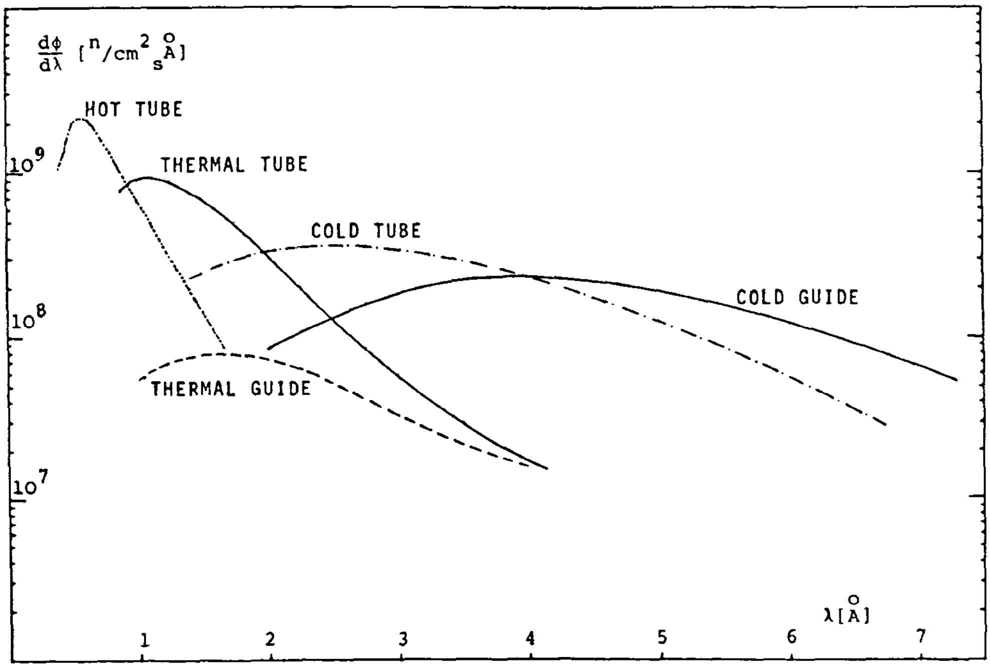


Fig. 10 Spectral fluxes at monochromator positions of SINQ for tubes and guides. The primary proton beam current is 1.5 mA.

From these data we can estimate the spectral fluxes at monochromator (or velocity selector) positions of beam tubes and neutron guides. The spectral fluxes shown in Fig. 10 are based on the following tube and guide cross sections and a primary beam current of 1.5 mA (1 Mw beam power):

height $h = 10$ cm width $d = 5$ cm

Furthermore the guides are assumed to be straight and plated with ^{58}Ni. For background /7/ suppression, we will need to install benders into the guides; as a result, the flux at the guides of the actual source will be somewhat lower and the spectrum will cut off at short wavelength. It is evident from Fig. 10 that experiments using a wavelength region of 2Å – 4Å should be installed at beam tubes viewing one of the cold sources: For wavelength above 4Å, the guides give a higher flux.

The flux at a thermal guide is given for reference only; it is not planned to install these at SINQ.

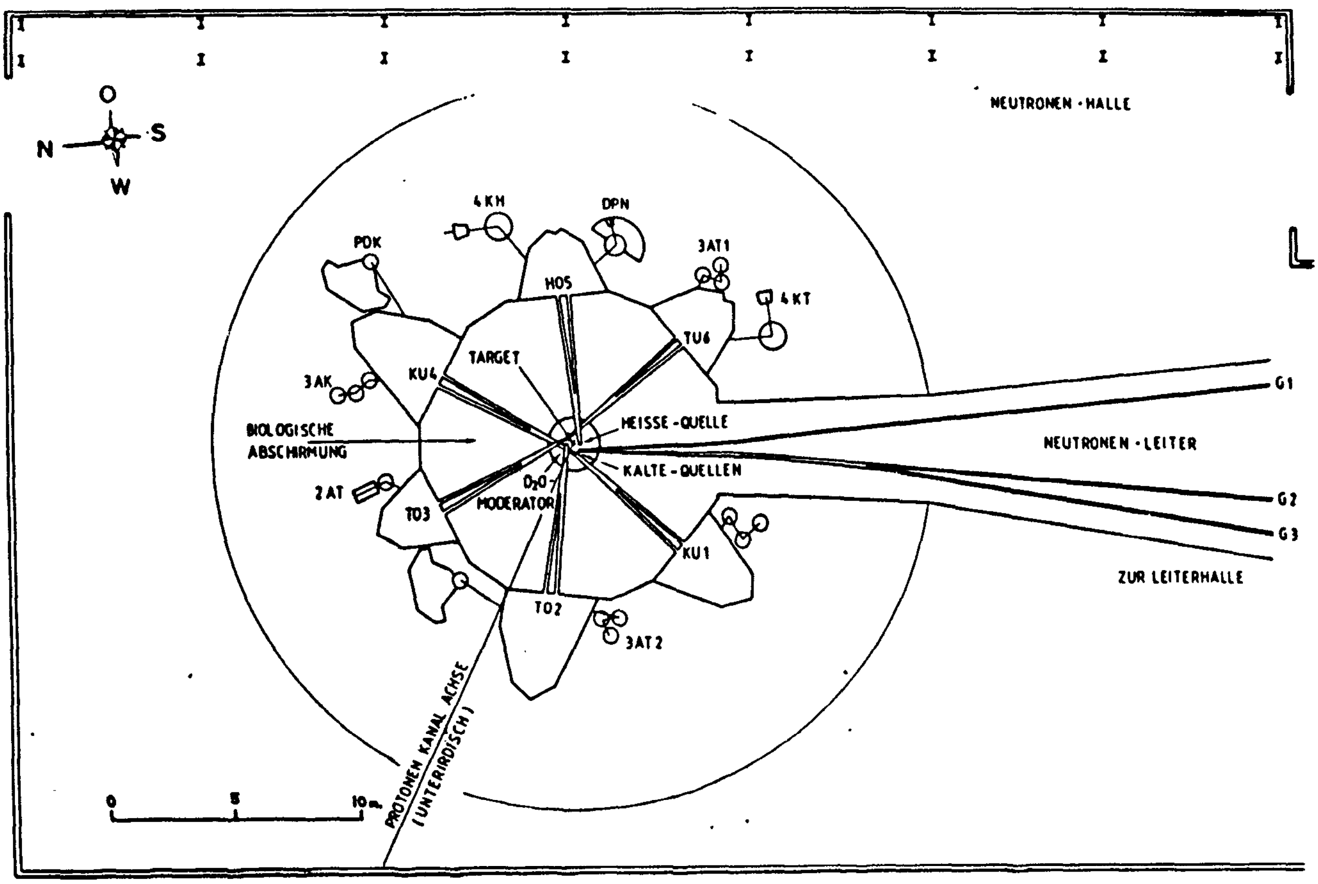


Fig. 11 Horizontal cut through the source, showing the layout for beam tubes and instruments.

d) Beam Tube Lay-out and Instrumentation

A horizontal cut through the source, showing the layout for the beam-tubes is shown in Fig. 11. The truncated heptagon is the fixed part of the source but with the shielding around the beam tubes mounted in boxes to allow this to be rearranged as the source develops during operation. External to the source will be mounted monochromators; these will require shielding which is more easily constructed onto flat faces (hence the heptagon).

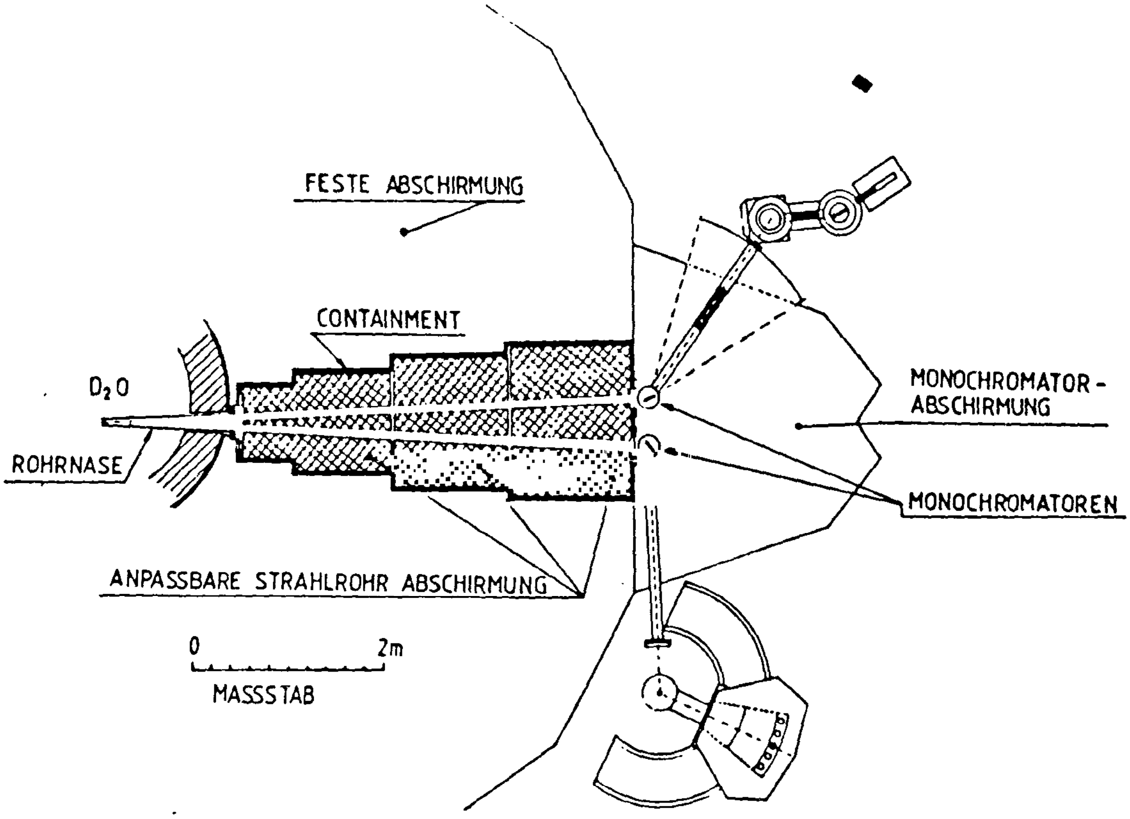


Fig. 12 Beam tube pair with monochromator shield and instruments.

A schematic picture of a beam-tube pair with their monochromators, external shielding and instruments is shown in Fig. 12.

A list of instruments, divided between thermal, hot and cold tubes and cold guides, is given in Table II.

Table II Neutron Scattering Instruments for SINC

1. Thermal-neutron beam tube
   - Two-axis spectrometer with adjustable detector
   - Multidetector powder diffractometer
   - Two-off three-axis spectrometers
   - Four-circle goniometer

2. Hot-neutron beam tubes
   - Polarized-neutron spectrometer
   - Three-axis spectrometer for high energy-transfer

3. Cold-neutron beam tubes
   - Three-axis spectrometer
   - High energy-resolution three-axis spectrometer (with neutron turbine)

4. Cold-neutron guides
   - High resolution powder-spectrometer
   - Small angle scattering spectrometer for biological applications
   - Small angle scattering spectrometer for materials and polymer science
   - High resolution three-axis spectrometer
   - Spin-echo spectrometer

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