Layout of the Target Station for the German High Power Spallation Neutron Source Project

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1. Introduction

The spallation neutron source presently under study in West Germany is designed to be competitive with a conventional high flux reactor in all fields of neutron scattering applications and to provide added flexibility not obtainable with a reactor in some respects. Since a fair number of well established experimental techniques with a high scientific potential such as triple axis spectroscopy essentially depend on the time average flux, the goal was reach $\phi_{av}^{th} = 6 \cdot 10^{14}$ cm^{-2} sec^{-1} to be within a factor of 2 of modern high flux reactors. Similarly, much emphasis was on the use of thermal and cold neutrons. The main reasons, why a neutron source, based on spallation rather than fission is considered are:

1.) The spallation neutron source, being driven by a linac /1/ can be operated with a time structure imposed on the neutron flux which gives a potential for significant advantages in its utilization /2/, /3/.
2.) In principle a proton compressor ring can be added which would even further shorten the proton pulses and allow a truly pulsed neutron source, opening up the epithermal neutron energy range.
3.) The spallation source will operate without a critical assembly and hence has an inherent safety potential which, in the case of a reactor, has to be provided for by a complex control system.
4.) There is no highly enriched uranium needed which may become more and more difficult to obtain in the future.
5.) There seems to be a potential to obtain significantly higher neutron fluxes with a spallation source relative to a reactor.

This paper describes the layout of the target station proposed for such a source. Separate papers will deal with the accelerator /1/, the scientific instrumentation /2/, /3/, the technical aspects /4/, specific materials problems /5/ and with the details of neutronics calculations /6/.

2. Time structure and neutron scattering experiments

For the experimentalist, a time structure imposed on the neutron flux is of interest for various reasons:

- Instruments traditionally using the average neutron flux can benefit by gating the detector to the time interval of interest and thereby suppress background and higher order contamination from the monochromator. For this purpose, the neutron pulses should be of the order of 0.5 ms long or less. (Since all of the useful intensity is compressed in this interval, instantaneous count rates may become very high and the pulse should not be made shorter than necessary).
- Instruments traditionally using time of flight for energy discrimination can be synchronized to the time structure of the source and thus benefit in full from the peak neutron flux.

For this reason the peak flux should be as high as possible. Considering also other aspects such as technical limits of accelerator components and flight path lengths resulting from the necessary thickness of the shield, the following parameters for the operation of the accelerator were chosen:

Pulse repetition rate	100 sec^{-1}
Pulse duration	0.5 ms
Maximum beam current	100 mA
Proton energy	1100 MeV

This results in a duty cycle of 1/20 and in an average beam power of 5.5 MW.

Both the high beam power and the time structure pose significant problems in the target design.

3. The target

3.1. Choice of target material

It is known from the literature (see e.g. /7/) that the neutron yield Y depends on the proton energy E, and the mass number A, of the target nucleus according to

$$Y = a \cdot (A + b) \cdot (E - c)$$

For a target of 10 cm diameter and 60 cm length the constants are: $a = 0.1\ \mathrm{GeV}^{-1}$ for non-actinides and $a = 0.2\ \mathrm{GeV}^{-1}$ for depleted uranium; $b = 20$ and $c = 0.12$ GeV.

This shows that depleted uranium would be the best choice for a high neutron yield. Yet, building a uranium target is technically more complicated than building a target from e.g. Pb, due to the cladding requirements and the higher heat output in uranium. No uranium will therefore be foreseen in the initial design but the target concept should allow its later use if sufficient experience has been gained.

3.2. Choice of target geometry

It was assumed that the proton beam hitting the target would have a Gaussian intensity distribution with a FWHM of 4 cm and truncated at 4 cm radius. For a lead target, this results in a time average heat deposition at the hot spot of 6 kW/cm^3 or of 120 kW/cm^3 during the proton pulse /6/. The corresponding heating rate in an uncooled target is $4 \cdot 10^3$ K/sec. In order to cool such a target the only choice is to move the target through the proton beam and let it cool down elsewhere. An elegant way is to use a liquid target of Pb-Bi eutectic (melting point 123°C) and let the beam hit the flowing liquid, as originally proposed for the Canadian ING /8/. It is also investigated within the German study project /9/. Most likely, the beam would hit the vertically streaming liquid from above in order to avoid the need for a window under a mechanical load. The target geometry is essentially cylindrical, providing the possibility of building a neutron source which resembles closely that of a reactor: A large D_2O tank is used as a moderator with the beam tubes running tangentially to the target. While having a potential for a high time average neutron flux such a concept gives only moderately high peak fluxes and precludes the use of uranium.

A different target concept, which has been selected as the reference design is depicted in Fig. 1. It is a rotating disc of 2.5 m diameter with the target material mounted on its circumference and the proton beam coming in at right angles to the axis of rotation. In this case the target has essentially slab geometry, i.e. it is extended in two dimensions, with the upper and lower half space available for independent moderators. Experimentally it has been found that the leakage of fast neutrons from a slab target in the direction normal to the slab is increased by a factor of 1.4 relative to a cylindrical target of the same diameter. This is probably due to scattering of fast neutrons in the "wings". This enables a more efficient coupling of moderators into the target under otherwise similar circumstances. The distribution of fast leakage neutrons on the surface is shown in Fig. 2.

3.3. The target reference design

There is a large number of different possibilities to arrange the target material and cooling channels in a rotating target, which allows room for optimization. The approach to start with is chosen to minimize operational hazards. The target material is subdivided into 9128 individually canned pins, arranged in close packing. The coolant water is brought in through the shaft of the wheel and flows outward between the target pins. Channels are provided in the upper and lower support structure to return the coolant to the shaft.

The speed of rotation of the target is 0.5 rps which is adjusted such that consecutive proton pulses hit adjacent areas of the outer window whose centres are one FWHM apart. If a target pin is fully hit by the proton pulse, its mid-plane temperature distribution is as shown in Fig. 3a /10/. The peak temperature of 113°C is considered a safe temperature. The temperature of the Al can after the shot is 73°C. After a full revolution the peak temperature has fallen to 76°C and the temperature of the Al-can is 57°C. It is obvious that the temperature variation in the Al is fairly modest even for the most heavily loaded pins. The tensile stresses in the Al due to the higher thermal expansion coefficient of Pb superimpose on the compressive stress from water pressure.

Since each pin is exposed to the proton beam only once every two seconds, the radiation damage rate is reasonably low.

Also the operating temperature is a favourable one for Al with respect to void formation and helium mobility /5/. A minimum lifetime of 15000 to 20000 hours of actual operation at full power is expected. This holds also for the outer beam window.

The problem which might arise for an Al canning with a Pb-target is the production of mercury in the spallation process. A preliminary upper limit estimate yielded an average of 130 ppm of mercury over the whole target with the peak concentration being as high as 1300 ppm after one year of continuous operation /11/. The actual production should be lower than that. Nevertheless this might become a problem if significant diffusion takes place. On the other hand, up to 25% of mercury appears to be soluble in lead /12/. This means that small amounts would not tend to diffuse out of the solid target pins. This problem will be considered in more detail, in particular also for the case of an accidential melting of the lead in the Al-can. Of course, if necessary a different canning will have to be chosen or a suitable coating provided on the inside.

4. Moderators and Reflectors

With the average neutron flux of the proposed facility matching that of a reactor, uses other than neutron scattering are also being considered, such as fast and thermal neutron irradiation. For this reason it is desirable not only to have a high neutron flux but also a large volume of high flux. This is, at a first glance, a contradiction to the requirement of a short neutron pulse. However, with the two locations above and below the target being available for independent moderator design, a hybrid moderator concept has been conceived with a fast H_2O moderator with a reflector below the target (for good pulse structure) and a D_2O tank (for a large volume of high flux) above the target. Experiments on a mock-up of such a system at SIN /13/ showed that even in the case of a Pb-target very little cross talk will occur with respect to time structure between moderators, even if used without a decoupler.

4.1. The fast moderator for thermal neutrons

4.1.1 Geometry of the moderator

In order to obtain the above mentioned time structure of some 500 μs FWHM, an H_2O moderator is necessary. This pulse width does not require any decoupler or poison and the moderator geometry can therefore be trimmed for highest neutron leakage. It was found /14/ that adding fins to the moderator surface leads to a considerable increase of neutron leakage. The best results were obtained with a moderator as shown in Fig. 4a with 6 to 9 cm long fins (or, alternatively, 6 cm deep grooves) of 0.5 to 1 cm thickness /15/*. The experiments also showed that, in a well reflected geometry, H_2O and polyethylene are equivalent with respect to intensity. H_2O must be used because an estimated 20 kW of heat /11/ have to be removed from the moderator.

4.1.2 The reflector

The moderator will be surrounded by a reflector for fast neutrons which, as shown in Fig. 4b, is designed for minimum losses. It was found experimentally /18/ that, while giving nearly the same overall intensity**, a Pb-reflector produces less strong tails on the neutron pulses than a Be-reflector does. Therefore, the reflector will probably be of Pb, which is also a significant advantage from the point of view of shielding.

4.2. The D_2O-moderator

To facilitate the installation of cryogenic and irradiation equipment, it was decided to place the D_2O-moderator above the target. The dimensions of the tank would be 1 m radius by 1 m high.

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* Such grooved moderators, although with less deep grooves have also been investigated with respect to their time structure at the CERN booster Synchrotron /16/ and at the ZING-P'-facility at Argonne /17/. It is found that there is some but little pulse broadening and such moderators may even be useful for pulsed sources. At the same time the neutron spectrum is considerably softer for the grooved moderator.

** This result has also been confirmed by computer simulation /19/.

Its main purpose is to serve as a reflector for the cold neutron source and as a volume to locate irradiation facilities.

The thermal neutron flux distribution measured in such a tank for 600 MeV protons on a Pb and a U-238 slab target with 10% polyethylene in the volume and with 6 mm polyethylene and 30 mm Al between the target and the D_2O is shown in Fig. 5 /20/. At 1100 MeV a somewhat flatter gradient along to the proton beam would be expected. The volume of high flux, although being smaller than in a reactor, is still sufficient to accomodate an efficient cold neutron source and a few irradiation thimbles.

The fast neutron flux above the target will be of the order of 10^{15} cm^{-2} sec^{-1}. Therefore it has been conceived to avoid the risk of a leak developing in the D_2O tank by a design as shown in Fig. 6, where the most heavily radiation loaded structural part does not serve as D_2O containment.

4.3. The cold neutron source

With the D_2O constituting a long-life time neutron reflector, the choice for the cold neutron source will probably be D_2 for maximum cold neutron leakage. However, no final decision has been made yet and other possibilities are being considered /21/. The cold source would be inserted into the D_2O tank in a separate pipe of aluminium or zircaloy (Fig. 6). The bottom part of this tube would contain a light water cooled plate of lead or bismuth for γ-shielding and pre-moderation to avoid excessive heat load on the cold source. It is believed that a detailed calculation will show that the cold neutron leakage from this source should almost match that of the HFR Grenoble where the cold source could not be placed at the peak flux position due to heating problems.

This design will also reduce the fast neutron load on the containment of the cold source considerably.

4.4. Expected performance of the moderators

Considerable experimental and computational work has gone into the assessment of the expected performance of the moderators with respect to thermal neutron leakage and time structure. A list of expected performance data is given in Table 1. Listed are the peak thermal neutron flux, the peak-to-average ratio, the

decay constants and the fractions of the flux decaying with the respective parameters. The data are inferred from measurements at SIN /13/ (600 MeV, scaled to 10 mA which is roughly equivalent to 5 mA, 1.1 GeV). Some allowance has been made for added losses in a real design.

For the case of a Pb-target the time-dependent thermal neutron flux is shown in Fig. 7. In the H_2O-moderator, which has a decay constant of 200 μs, 92% of the stationary flux is reached 500 μs after the proton pulse is switched on. This shows that the proton pulse of 500 μs is the maximum that should be chosen, because for longer pulses the neutron flux would not increase further. Although a pulse of 250 μs with twice the intensity would yield a higher neutron flux, 500 μs is considered a good choice for the reasons mentioned in section 2.

In the D_2O-tank - and likewise in the cold source - a FWHM of the neutron pulse of 850 μs is expected for a Pb-target with a significant tail at long times. Nevertheless this pulse structure is still sufficiently pronounced to be taken advantage of in some slow neutron applications /3/.

5. Shielding and beam holes

5.1. Bulk shielding

In order to be able to accept as large a solid angle as possible, and to avoid frame overlap with the background of the following pulse when working with relatively slow neutrons (e.g. 4 Å) the shield should be not too thick. For this reason an attempt will be made to provide as efficient a shield as possible. The moderators and reflectors will be surrounded by water cooled lead with possibly some dense metal shot embedded in it. The problem is particularly serious at the D_2O tank since the D_2O itself has practically no shielding effect for thigh energy neutrons. Fortunately the rotating target provides good lateral shielding itself and also the Pb-reflector would be helpful in this respect. It is foreseen that only two beam tubes penetrate the shield at the level of the D_2O tank in addition to the neutron guides. All thermal neutron beams ending in the target hall will view the lower moderator. The diameter of the beam tubes will be 10 cm at the moderator and increase to 20 cm at the outside of the shield. The exact composition of the shield has not yet been determined, but probably it will consist mostly of cast iron.

5.2. Neutron guides

Use of the cold neutrons will be mainly made by neutron guides leading into a separate neutron guide hall. Two bundles of 6 guides each will view the cold source in such a way that the reflector displacement is minimized (Fig. 8). The neutron guides will be tailored for different wavelengths by their curvature with the longest-wavelength guides ending close to the target hall. The guides will be shielded to twice the length of direct sight. A list of the characteristic parameters of the guides is given in Table 2. The cross section will be 20 x 3 cm^2 to allow multiple use by splitting the height.

5.3. The shutters

The shutters should provide sufficient protection when closed to allow at least temporary work on the neutron beam lines while the source is operating. It has been assumed (with proof still to be provided) that for a beam hole not looking directly at the target, some 3 m of shielding are sufficient. Since the shutters, when closed, should not weaken the nearby shielding unduely, a system has been chosen which consists of 3 m diameter discs with horizontal axes of rotation and with the beam hole running in the disc (Fig. 9). When rotated away from the open position, these discs close the beam hole very quickly, without opening up a new hole in the shield. When fully closed, the beam hole in the shield points vertically and beam hole inserts can be changed from above with the shutter safely closed. The beam hole does not run through the centre of the disc which, in principle, allows to put the hole at the level of the upper or the lower moderator without changing the disc's position in the shield *. It is even conceivable to use shutters with two beam holes to bring out two beams on top of one another. For the purpose of maintenance the shutters can be lifted out of the shield if required /4/.

Wells for the installation of choppers running in phase with the source are provided behind the shutters. The outer part of the shield is designed to be easily changable to retain maximum flexibility for the installation of monochromators etc.

The shutters for the neutron guides are designed differently, since the diameter of the disc shutters would force the front end of the neutron guides too far away from the cold neutron source. Since the neutron guides can be shut off individually for routine work on the experiments, the task of these shutters is mainly to shut off the whole bundle of guides when work on the neutron guides themselves is necessary. This will be done only when the source is not operating and therefore the shutters only have to suppress the decay radiation from the target. They are designed as lift- and lower shutters operated from above.

6. Experimental Areas and Facilities

6.1. The target hall

The target shield will be located in a 40 m diameter hall which will be occupied by the thermal neutron scattering instruments. There will be conventional instruments adopted to the intensity modulated source such as triple axes spectrometers, diffractometers and time-of-flight spectrometers (with a chopper) as well as newly conceived instruments especially designed to take advantage of the time structure /2/. The target hall will be equipped with a 20 t crane able to reach almost every point in the hall. Air conditioned cabins for the electronis are foreseen along the outer wall. The possibility will be provided to extract certain beams to locations outside the hall for long flight path instruments.

6.2. The neutron guide hall

The two bundles of 6 neutron guides are separated by an angle of 30^0. In this way it becomes possible to make very efficient use of the space in the neutron guide hall (Fig. 10), because four lines of instruments can be installed. Preference

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* This feature might become of interest if, upon addition of a proton compressor ring, the source should ever be converted into a pulsed source (see section 7.2).

has been given to a larger number of neutron guides rather than a higher cross sections because the guides are easier to build and excessive length (resulting in higher losses) is avoided. Two parallel cranes with a capacity of 10 t each will serve the two halves of the neutron guide hall. Similar to the target hall, air conditioned cabins for the electronic equipment will be arranged along the walls.

6.3. The neutrino cavern

Since the spallation source provides an intense source of neutrinos it is conceived that a cavern for neutrino experiments should be located under the target station (Fig. 11). It should be shielded from the target by some 8 m of iron and subtend a solid angle of one steradian relative to the target.

6.4. Irradiation facilities

6.4.1 Low temperature irradiation facility

Low temperature irradiation of solids is an important method to obtain information on defects caused by energetic particles in solids. It is of particular interest to be able to select between a thermal neutron spectrum to produce radiation damage from recoil nuclei after neutron capture and a fast neutron spectrum to produce the damage by direct knock-on processes. It has been shown /22/ that the spectrum produced by a spallation target with a Pb-reflector is well suited to study the radiation damage by a fission spectrum. For this reason an attempt has been made to provide an irradiation thimble which allows selection of the type of spectrum by the irradiation position. As shown in Figs. 6 and 8 there is a tube running through the D_2O-tank which holds the low temperature irradiation thimble. A hole in the lateral Pb-shield of the target is foreseen under this tube such that samples to be irradiated can be pushed down into the Pb-shield for fast neutron irradiation. Thermal neutron irradiation is possible if the samples are lifted to a level inside the D_2O tank. The fast flux in the lead is estimated to be $1\cdot10^{14}cm^{-2}sec^{-1}$ the maximum thermal flux accessible will be $3\cdot10^{14}cm^{-2}sec^{-1}$.

6.4.2 Room temperature irradiation

A second irradiation position, mainly for chemical applications has been proposed. However, so far no detailed design has been worked out. A vertical tube of 10 $cm^{\varnothing}$ ending in the D_2O tank is foreseen for this purpose.

6.5. Ultra cold neutrons

The possibilities of building an efficient source of ultra cold neutrons, especially by taking advantage of the time structure of the fast neutron pulses are being considered in detail. So far no decision has been made as to the type of ultra cold neutron source. Extraction of suitable cold neutron beams through a horizontal beam tube or a vertical one looking directly on the cold neutron source are, in principle, possible. In the last case the beam tube would penetrate the Be-reflector above the cold source (see Fig. 6) and be equipped with a curved vertical neutron guide.

7. Options and extensions

The question, what could be done later to further improve the performance of the source, is obviously an important one in the process of decision making. Basicly three possibilities have been considered, which are outlined briefly in the following sections.

7.1. Increase of average proton current

Since the peak proton current is an important design feature of the accelerator /1/, the only realistic possibility would be to increase the duty factor by lengthening the proton pulses. This would have an adverse effect on the time structure of the source and might even be a disadvantage with respect to high energy neutron shielding. At the same time the load on the accelerator components would be increased.

7.2. Use of uranium as target material

Some experimental work has gone into the problem of a possible gain in neutron flux by using depleted uranium as target material. As can be seen from Fig. 5 and Table 1, the expected gain is roughly a factor of 2 with no degradation of time performance. Therefore the possibility of changing to a uranium target later on remains very interesting. Although the design of the target would allow to use depleted uranium rather than lead, the larger heat output and different thermal expansion may make it necessary to provide means for an improved thermal contact ot the canning material and to compensate differential expansion, e.g. by immersing the U-238 in a Pb-Bi eutectic which would melt when the target is in operation. Whether Al could then still be used for canning will be investigated in detail, but also using stainless steel canning seems feasible. In this case it might be of advantage to fabricate also the wheel itself from stainless steel to avoid water corrosion problems. The extra heat output in the uranium could be handled by slightly increasing the water flow through the target. There would probably also result a higher γ-flux from the use of uranium but this could be handled in the case of the cold source by increasing the thickness of the Bi-shield, if necessary. Since the number of fast cascade particles produced is essentially the same for Pb and U-238, no significant effect on the background situation or bulk shielding is expected.

7.3. Pulsed source with a compressor ring

One unique feature of spallation neutron sources is the fact that the epithermal neutron energy range can be made accessible to experimental research, which is practically not possible on reactors. For this the proton pulses have to be considerably shorter than foreseen in the facility as described above. A conceptual design has been worked out for a compressor ring which could be added to the facility /23/. The idea is to accumulate protons on a circular orbit whose length is such that the time of revolution of the protons corresponds to the desired pulse length. When the accumulation is completed, all protons are extracted from the ring in one single turn and directed onto the target. The diameter of such a ring would be 65 m with 4/5 of the circumference filled with protons, allowing for a gap to activate the extraction magnet. Up to $3 \cdot 10^{14}$ protons can be accumulated circulating in the ring at the transition energy. This

mode of operation ensures isochronism which keeps the bunch together without rf-equipment. Instabilities occuring are slow enough to be of no importance during the short accumulation period of 500 μs. A pulse compression by a factor of 600 should thus be achievable.

Obviously, in order to utilize the shorter proton pulse, suitably designed moderator-reflector geometries are needed. The simplest way to provide these would be to replace only the H_2O moderator and retain the D_2O tank with the cold source for conventional use. With the fast moderator-reflector assembly mounted on the target trolly /4/ it is relatively easy to replace this part with a differently designed one with, say two smaller and decoupled moderators. These could be viewed by some of the beam tubes without changes, whereas others would perhaps have somewhat unfavourable glancing angles. These tubes might be shifted to the upper level for use with the D_2O tank. Suitable provisions will be made in the design of the shield, but the D_2O tank itself would probably have to be exchanged for a differently designed one. This solution would, of course, impose serious restrictions on the possibility of thermal neutron work. Therefore, the optimum solution would be to build a second target station for pulsed neutron work. This would make the facility an unprecedented tool for neutron scattering research.

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Target	Moderator	Reflector	$\hat{\phi}$ $10^{14}cm^{-2}sec^{-1}$	$\frac{\hat{\phi}}{\bar{\phi}}$	α_1 (μs^{-1})	α_2 $(\mu s)^{-1}$	$\frac{\phi(\alpha_1)}{\phi(\alpha_2)}$
Pb	H_2O	Pb	130	18.4	$(200)^{-1}$	-	-
	D_2O	D_2O	50	7.9	$(759)^{-1}$	$(3333)^{-1}$	13.3
U-238	H_2O	Pb	290	18.4	$(200)^{-1}$	-	-
	D_2O	D_2O	125	10.2	$(440)^{-1}$	$(5000)^{-1}$	32.3

Table 1 Flux data and decay parameters inferred from measured data /13/ for the hybrid moderator concept with targets of Pb and U-238. In the D_2O-tank a 15% depression due to structural parts and beam tubes has been allowed for. All values may be about 10% lower in the real design due to a larger coolant volume fraction.

guide	(m)	λ_{nom} (Å)	λ_{min} (Å)	L_{II}(m)
1	1151	6	4.2	33
2	2591	4	2.8	50
3	4606	3	2.1	67
4	2591	4	2.8	50
5	1658	5	3.5	40
6	414	10	7	20

Table 2 Characteristic data of the neutron guides.

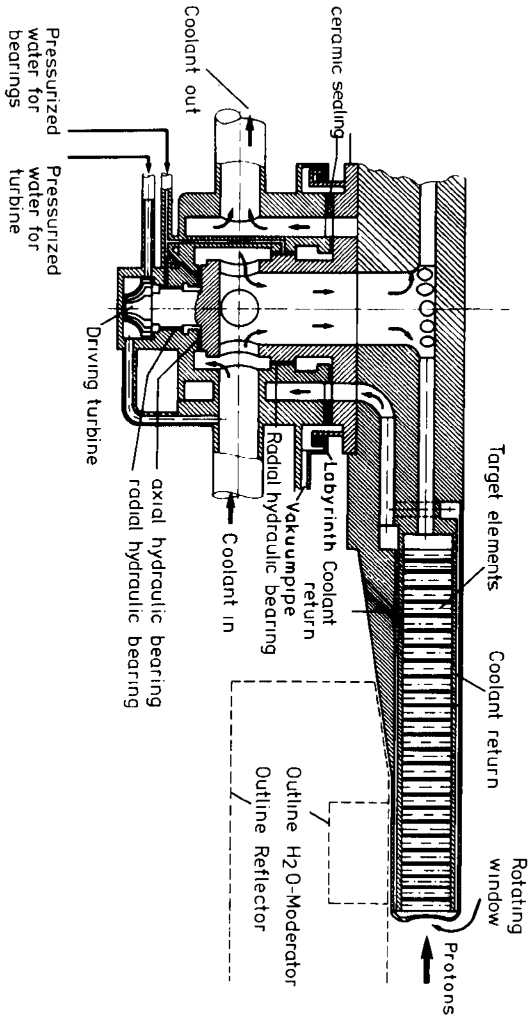


Fig. 1 Rotating target proposed for the German high power spallation neutron source. About 9000 Pb zylinders of 18 to 24 mm diameter and canned in aluminium are arranged on the circumference of a 2.5 m diameter wheel and cooled by water flowing between them. Only one half of a section through the wheel is shown.

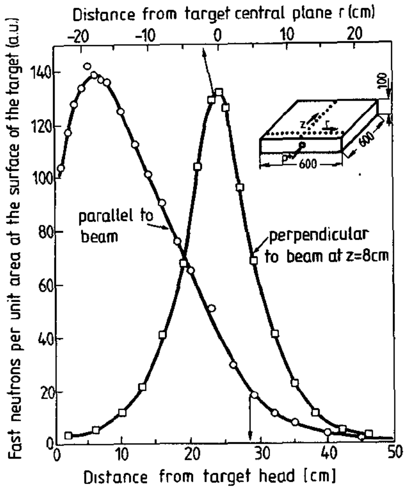
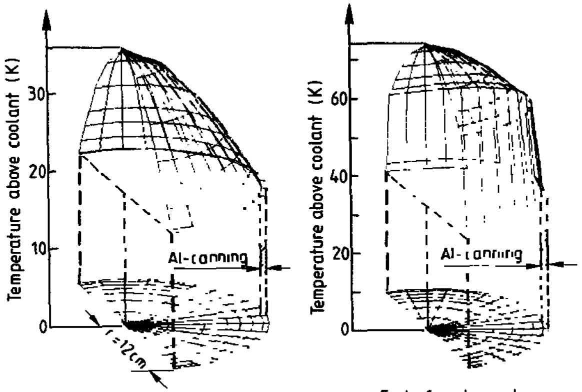


Fig. 2

Distribution of fast neutron leakage at the surface of a Pb-slab target as measured by Rh-activation for 600 MeV protons impinging on the target. The foils were arranged as indicated on the inset.



End of cooling period

End of proton pulse

Fig. 3 Temperature distribution in the mid-plane of the most heavily loaded target pin of 24 mm diameter.

a) Temperature distribution directly before the proton pulse

b) Temperature distribution directly after the proton pulse

The network of finite elements used for the calculation is shown at the bottom of each Figure. Temperature scales are different in both graphs!

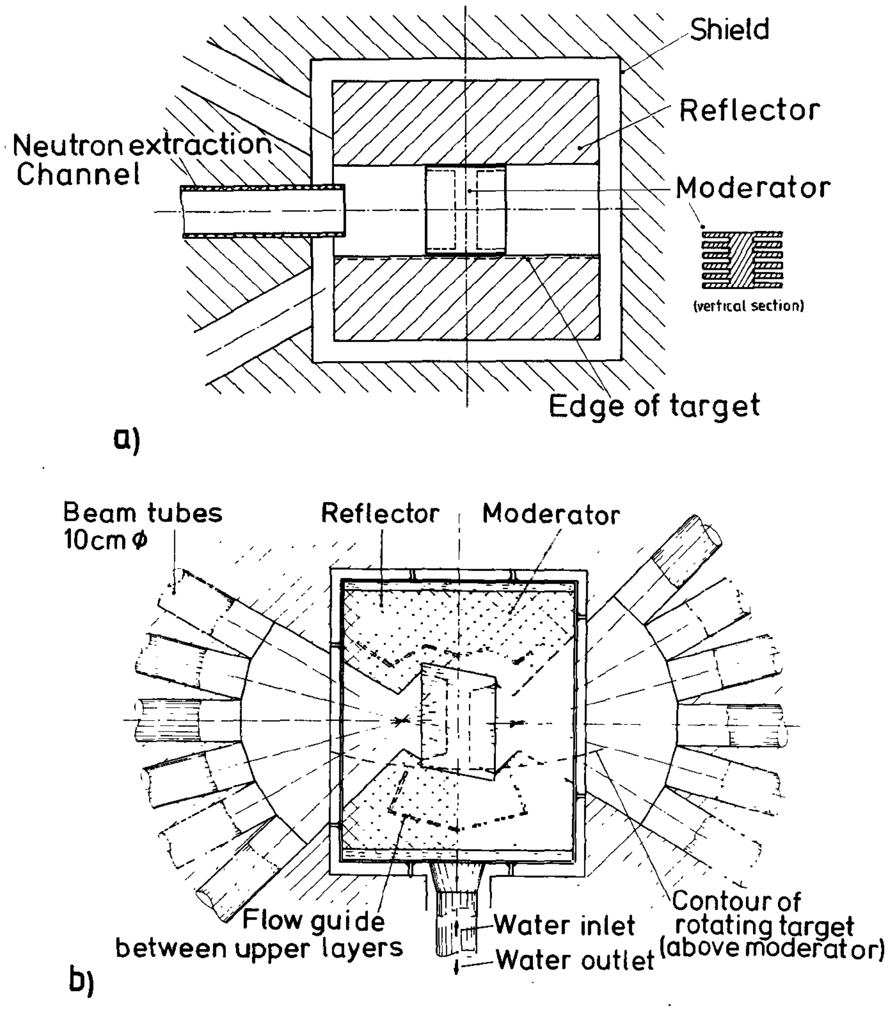


Fig. 4 Moderator-reflector arrangement for the spallation neutron source.

a) Polyethylene moderator used in a straight reflector tunnel in the measurements.

b) Proposed moderator-reflector arrangement for the reference design.

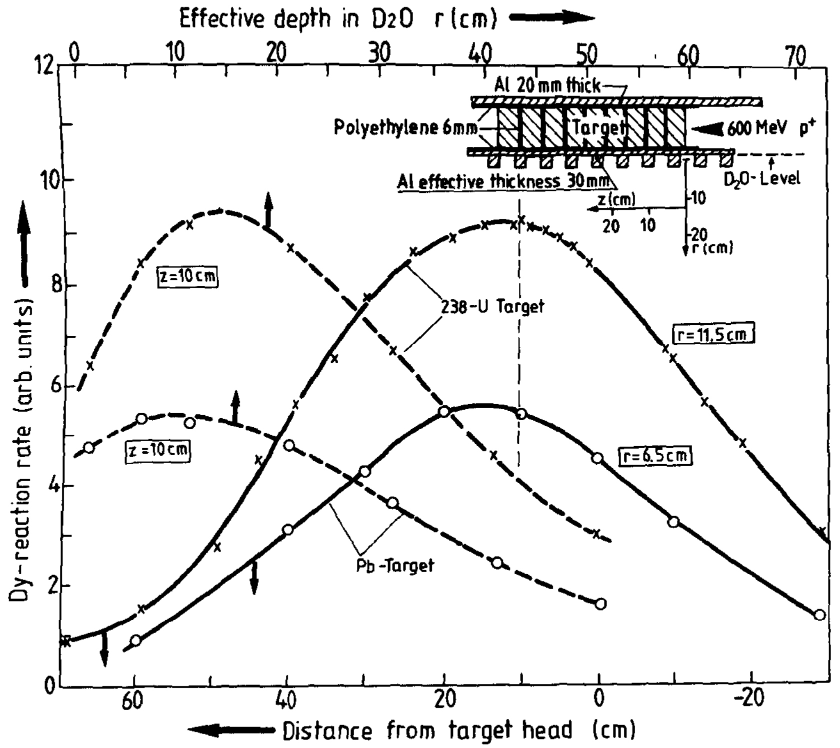


Fig. 5 Thermal neutron flux distributions measured in the D_2O of a hybrid moderator arrangement for slab targets of Pb and U-238. A schematic diagram of the arrangement used is given in the inset.

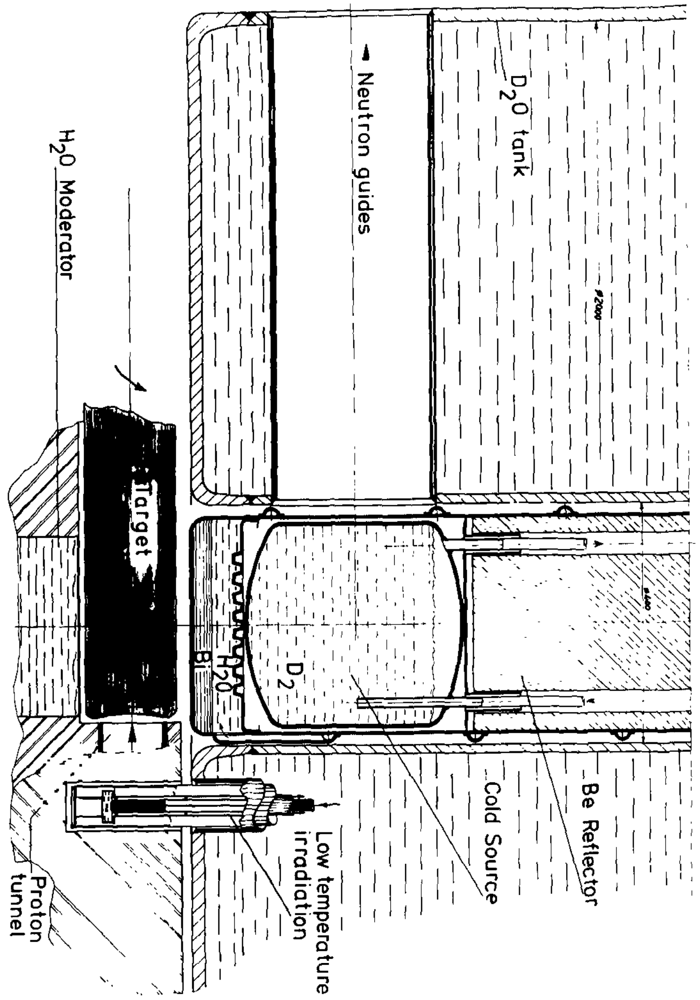


Fig. 6 Schematic representation of a possible design for a cold neutron source in conjunction with a rotating target.

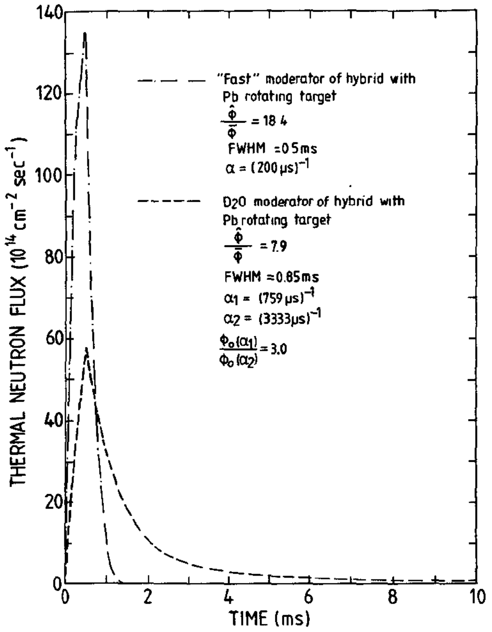


Fig. 7

Expected time dependent neutron flux for the moderators of the hybrid system (unperturbed in the case of the D_2O).

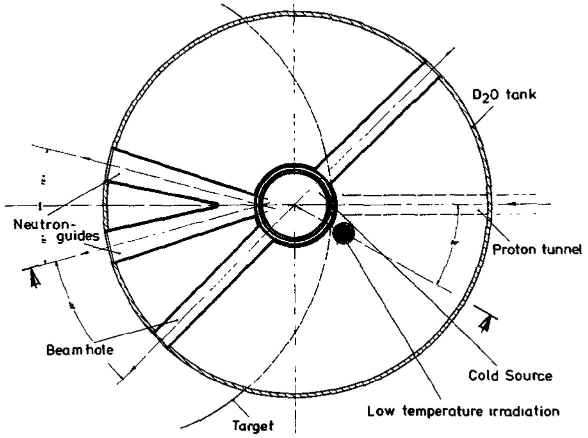
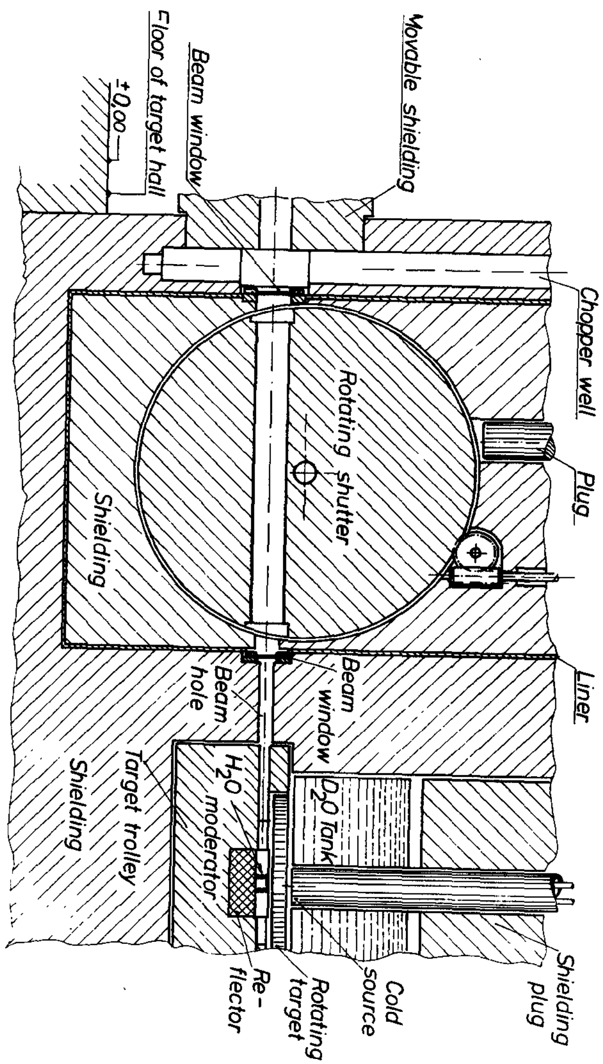


Fig. 8 Schematic horizontal cut through the D_2O tank at the level of the cold neutron source.

Fig. 9 Schematic of beam hole layout with disc shutter. Rotating the shutter through 90^0 will allow replacement of beam hole inserts (collimators) while the beam hole is closed. Rotating through 180^0 brings the beam hole to the level of the upper moderator (cold source).



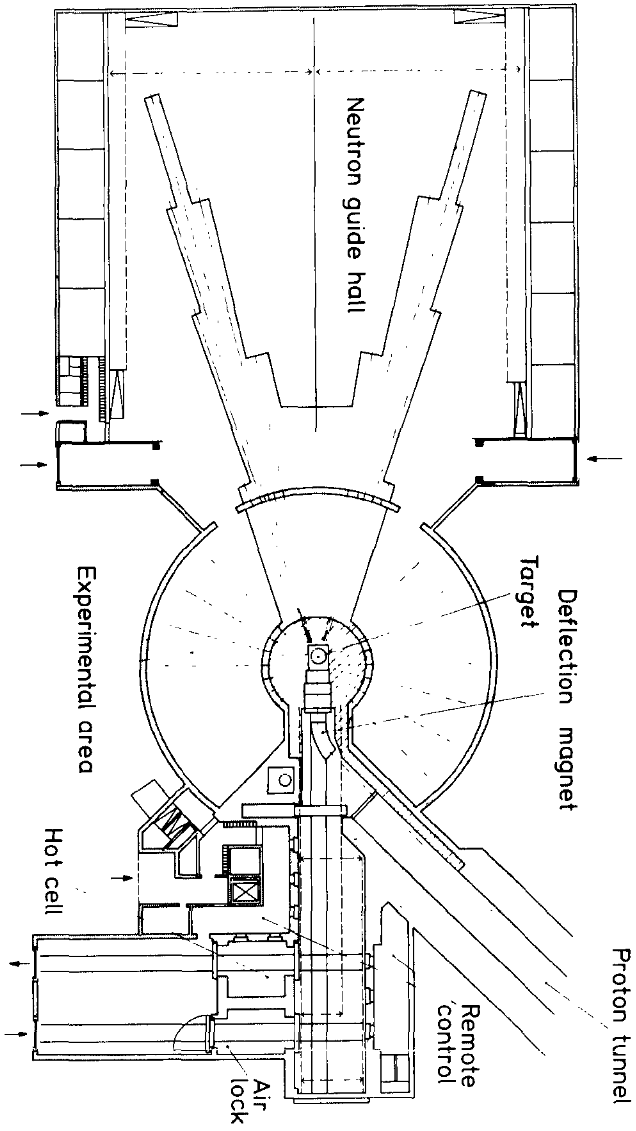


Fig. 10 Horizontal cut through the target complex showing the circular target hall with the adjacent target service area and the neutron guide hall. Two bundles of neutron guides separated by 30^0 are looking at the cold neutron source.

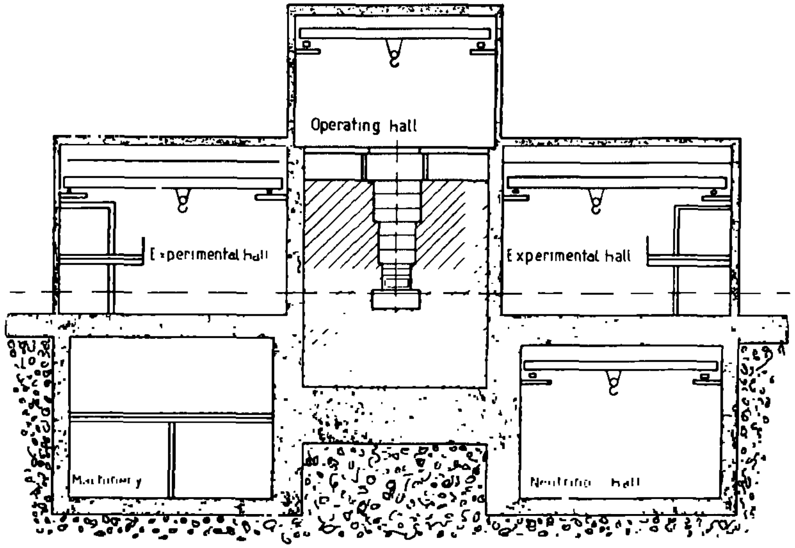


Fig. 11 Vertical cut through target building. Above the experimental area a service area is located which holds the cryogenic equipment for the cold neutron source and the low temperature irradiation facility and eventually the sample processing station for the room temperature irradiation facilities. Below the target and shielded by 8 m of iron there is, laterally displaced, the neutrino cavern.

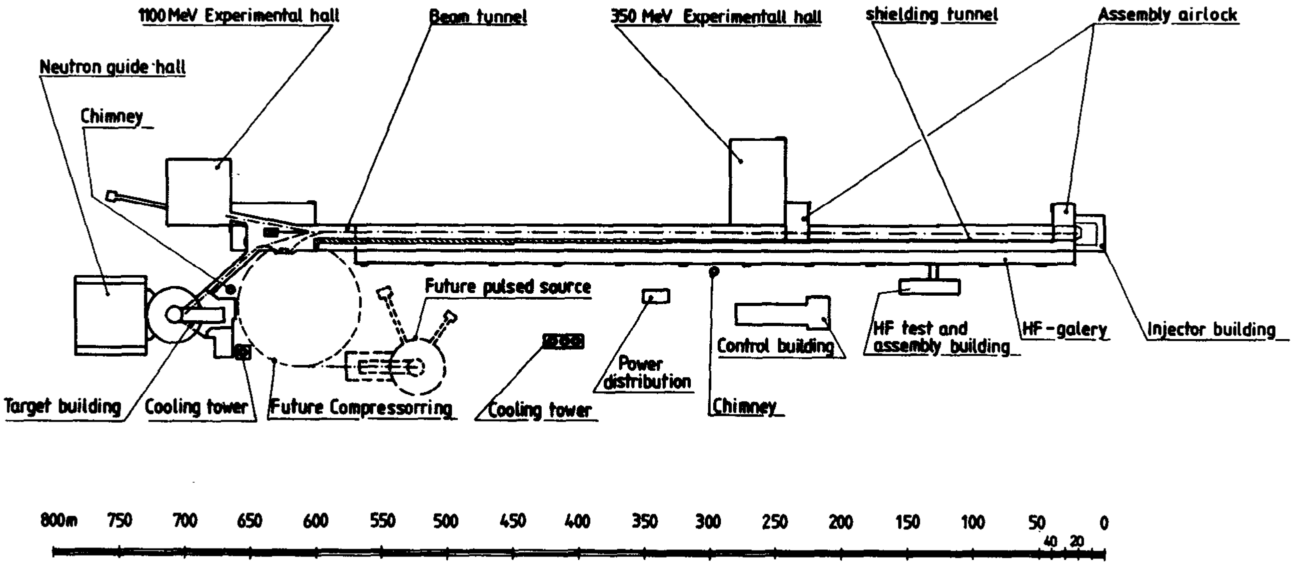


Fig. 12 Ensemble of buildings for the proposed spallation neutron source. The options of a compressor ring and a second (pulsed) target station are shown dashed to emphasize that the location of these buildings may change in the course of a detailed planing.