User Dedicated Neutron Guide System at SINQ

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Abstract:

The neutron guide system for the Swiss continuous spallation source SINQ is now specified in detail and entered the period of manufacturing. The design of the guide system was dominated by the intention to provide an optimum supply for dedicated types of instruments by simultaneously considering the best possible conditions for future users. It consists of seven individual guides, starting at a distance of 150 cm from the 20 l liquid D_2-moderator. All guides are curved to prevent the direct view to the source within a 25 m shielding bunker, thus filtering the high energy neutrons and other disturbing radiation. Supermirror coating of five guides, combined with a shallow curvature, will allow access to even thermal neutrons up to 36 meV in energy or down to 1.5 Å in wavelength, respectively.

Introduction

The concept of the new Swiss spallation Source SINQ is that of a steady state neutron source, driven by a 590 MeV proton beam from the PSI-ring cyclotron. The time structure (51 MHz) of the proton beam is lost after hitting the spallation target and releasing the neutrons into the moderating D_2O surrounding the target. The thermal flux expected in the D_2O-tank near the target is in the 10^{14} $cm^{-2}s^{-1}$ range [1]. At a distance of about 10 cm from the target surface, a 20 litre liquid D_2-cold moderator will be placed inside a T-shaped beam tube, as illustrated in Fig. 1. The one of the T-wings directing south will feed the neutron guide system of SINQ. The guide entrance is located at a distance of 1,50 m from the cold moderator surface, viewing a moderator cross section ("entrance window") of 135 x 80 mm^2. In their angular arrangement, all guides are directed towards this window to ensure optimum illumination.

The in-shielding section

The first section of the guide system with a length of roughly 4.5 m is located inside the target shielding block . It consists of two separate bundles of guides, containing three guides each, with angular inclinations between 4° to 6° towards both sides of the central axis (cf. Fig. 1). This 4,5 m-section is enclosed in a gas-tight casing, filled with Helium (HeII) at a pressure of about 1.1 bar, which circulates by forced ventilation and is backcooled outside the plug to ensure the necessary heat removal from the guide entrance section.

Each of the two guide bundles is adjusted inside of a steel casing. Both casings together are mounted on a plug wagon (Fig. 2) which carries supporting and adjustment devices for the casings. All open space is filled with steel shielding. The wagon is set up on a high precision railway system which allows removal and reproducible re-installation of the entire plug insert with a remotely controlled handling device, attaining the correct alignment even after years of operation and severe activation of the components.

Out-of-shielding section

Outside the plug insert the guides are continued individually, self sealed and evacuated. Following the PSI-numbering system (PKS), the guides are numbered (cf. Fig. 2) =1RNR11 to 16 inside the plug. Outside, guide =1RNR16 ist splitted horizontally into two separate guides, than numbered =1RNR16 and 17. The seven guides cross two shielding bunkers at a length of about 24 m before they penetrate a three meter thick shielding wall and exit into the guide hall. Inside these bunkers, all guides are curved to prevent the direct view to the in-shielding section and to the source.

Fig. 3 shows schematically the guide cross sections, the geometric arrangement and envisaged coating of the curved section inside the guide bunker. Fig. 4 gives an overview of the entire guide system showing the floorplan of the source, the bunkers and the guide hall.

Characteristic data and performance

The characteristic guide data are given in Table 1 together with a list of proposed instruments for the initial operation period. These data result from the combination of various considerations with the aim to obtain a user dedicated but still universal guide system of excellent total performance:

- The **inclinations** against the central axis were chosen as the result of the consideration of an optimum illumination from the source, flux depression, available space and geometric arrangement.

- The **dimensions in height** were determined by the height of the entrance window at the source (135 mm), combinded with the aim of an optimum illumination. These considerations led to a uniform height of 120 mm for all guides. After splitting guide =1RNR16, a square cross section of 50 x 50 mm^2 resulted for both subunits.

- The choice of the **width** of each guide was based on the combination and optimization of various considerations: first of all the instrument requirements on Q-resolution, useful beam divergence, characteristic wavelength and instrument position. Further, the requirement on a sufficient guide curvature to prevent the direct view to the source, and finally the given building geometry. A considerable role in this optimization process played

- the choice of **coating**: After the successful in-house development of large-scale supermirror production [2], PSI had the possibility of an ab-initio design of the guide system using supermirror (SM) coating. Thus, the maximum reflection angle for neutrons could be increased considerably compared to the critical angle of conventional single-layer coating with Ni. For the SINQ-guide system, either twice the critical angle of Ni (SM2), or a 20% increase (SM 1.2), simulating (isotopically enriched) Ni-58 coating, was taken into consideration.

The choice of coating affects two important performance parameters of the system: the transmitted **beam divergence** and the **characteristic wavelength**.

Regarding the former, a higher beam divergence of a supermirror coated guide yields on intensity gain, for SM2 by a (theoretical) factor 4 for ideal reflectivity; for realistic reflectivities one obtains a factor of 2.5 to 3. The usefulness is obvious except for instruments of high Q-resolution (e.g. SANS, high resolution powder diffractometer) where the neutrons of high divergence disturbe the resolution. For those instruments dedicated guides are foreseen coated with natural Ni, at least in the straight section, in order to suppress the unwanted high divergencies at the instrument entrance.

Regarding the latter, SM coating shifts the characteristic wavelength of a curved guide towards smaller values, proportional to the inverse of the maximum angle of reflection. This shift in wavelength yields a real spectral gain of neutrons compared to conventional coatings, allowing the approach to the range of thermal neutrons with rather comfortable or conventional geometric characteristics of the guides (cf. Table 1). For example, all guides except =1RNR11 and 16 transport neutrons of wavelengths down to 2 Å and below, the guides =1RNR13 and 15 even to 1.5 Å.

The spectral gain is achieved even if the SM-coating is made only in the curved section, and there even if only the outer (concave) guide wall carries SM-coating. Such a choice is made for =1RNR12 and 17 (cf. Fig. 3 and Table 1) where the spectral gain is wanted but not the higher divergence. Guide =1RNR17 has, in addition to the SM-coating, a vertical division of the guide along the curved section to transmit 2 Å neutrons without reducing the useful width from 50 mm.

Filtering high energy neutrons

Compared to a fission reactor a spallation source has (besides many advantages) the disadvantage that part of the initially produced neutrons are of high energy ($E \geq 10$ MeV) which requires massive shielding. Special precautions have to be taken to prevent that those neutrons come down the beam line and penetrate into the experimenal area. For the SINQ-guide system, the precautions foreseen combine the guide curvature with high energy collimators. The collimators consist of steped steel casings tightly enclosing the guides (gap $\leq$ 3 mm) on lengths of about 3 m each. They will consequently be installe i) inside the guide insert, ii) in the 3 meter exit wall from the bunker to the guidehall, and iii) approximately half way in between inside the bunkers. Calculations prove a more-than-sufficient attenuation of the high-energy neutrons by this collimator arrangement. It must not be mentioned that other unwanted radiation, from Gammas to epithermal or fast neutrons is also very efficiently eliminated by this precaution.

References

[1] G.S. Bauer, Status Report SINQ, ICANS XII (1993)

[2] P. Böni, I.S. Anderson, P. Buffat, O. Elsenhans, H.P. Friedli, H. Grimmer, R. Hauert, K. Leifer, A. Menelle, J. Penfold and J. Söchtig , this volume (1993)

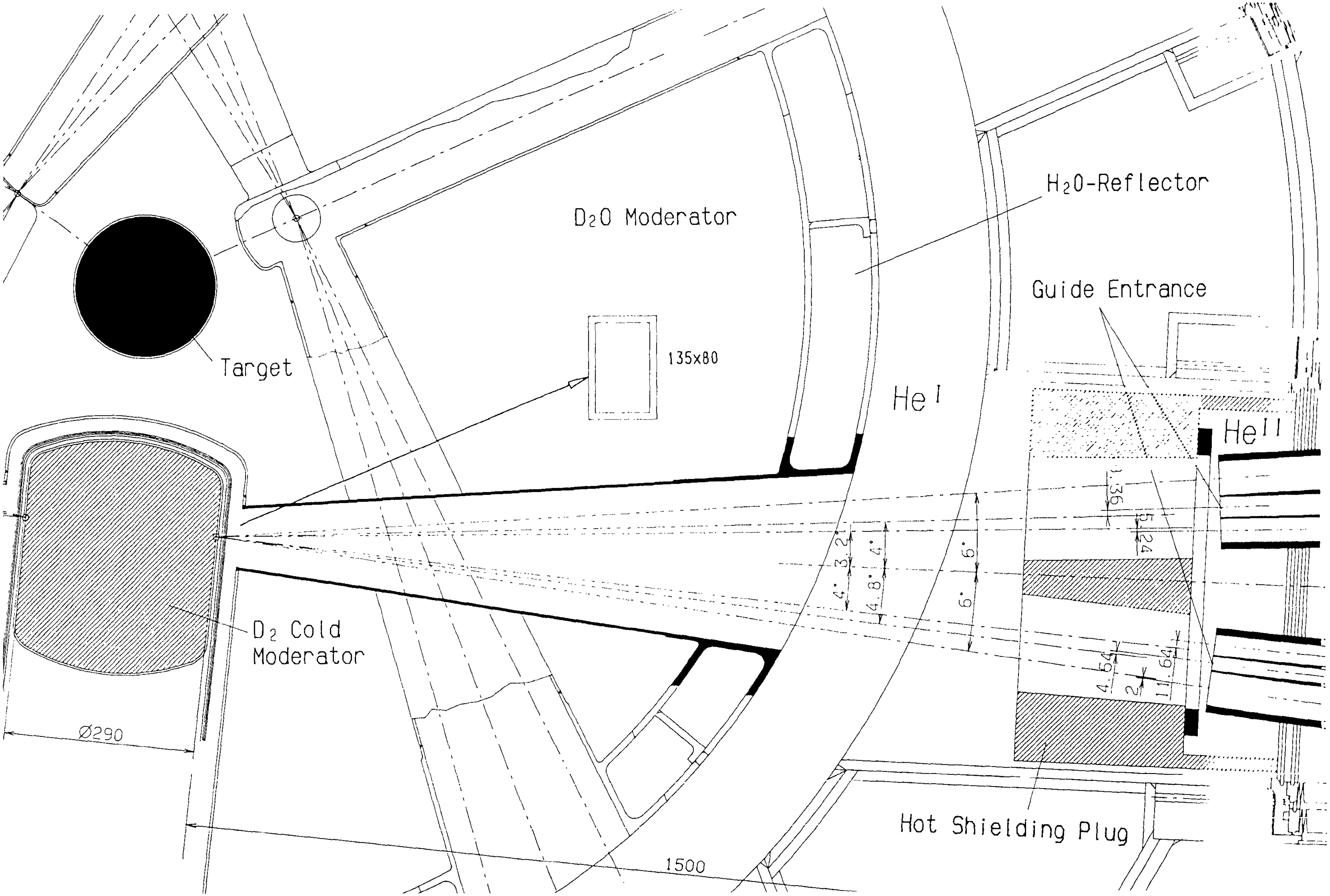

Figure 1: Schematic horizontal cross section through the SINQ target and D_2O moderator tank at the height of the D_2-cold moderator vessel and the beam tube feeding the guide system.

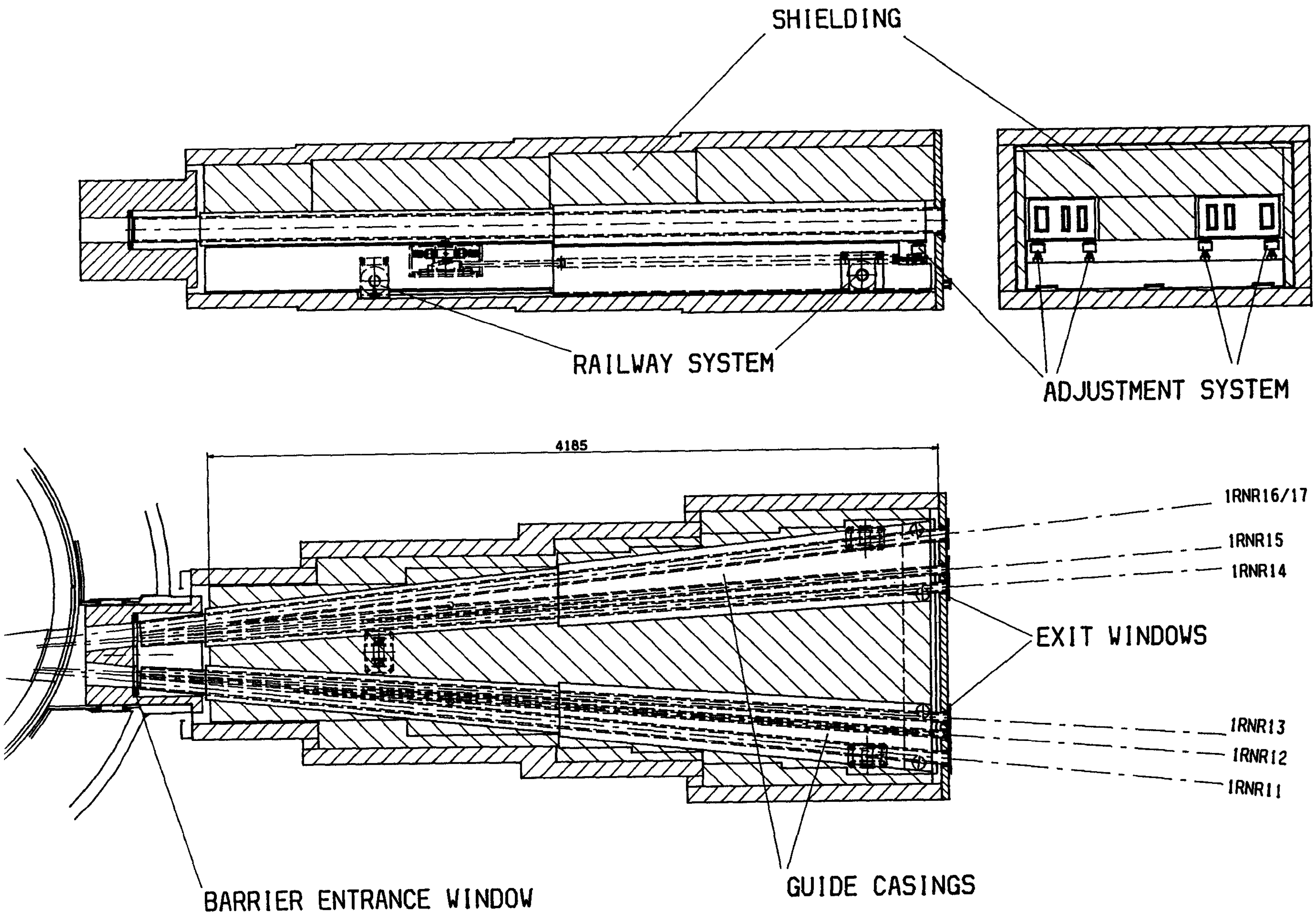

Figure 2: Triple-view of the neutron guide insert in the main shielding, showing the position of the two guide bundles and their casings, the plug wagon with railway and adjustment systems.

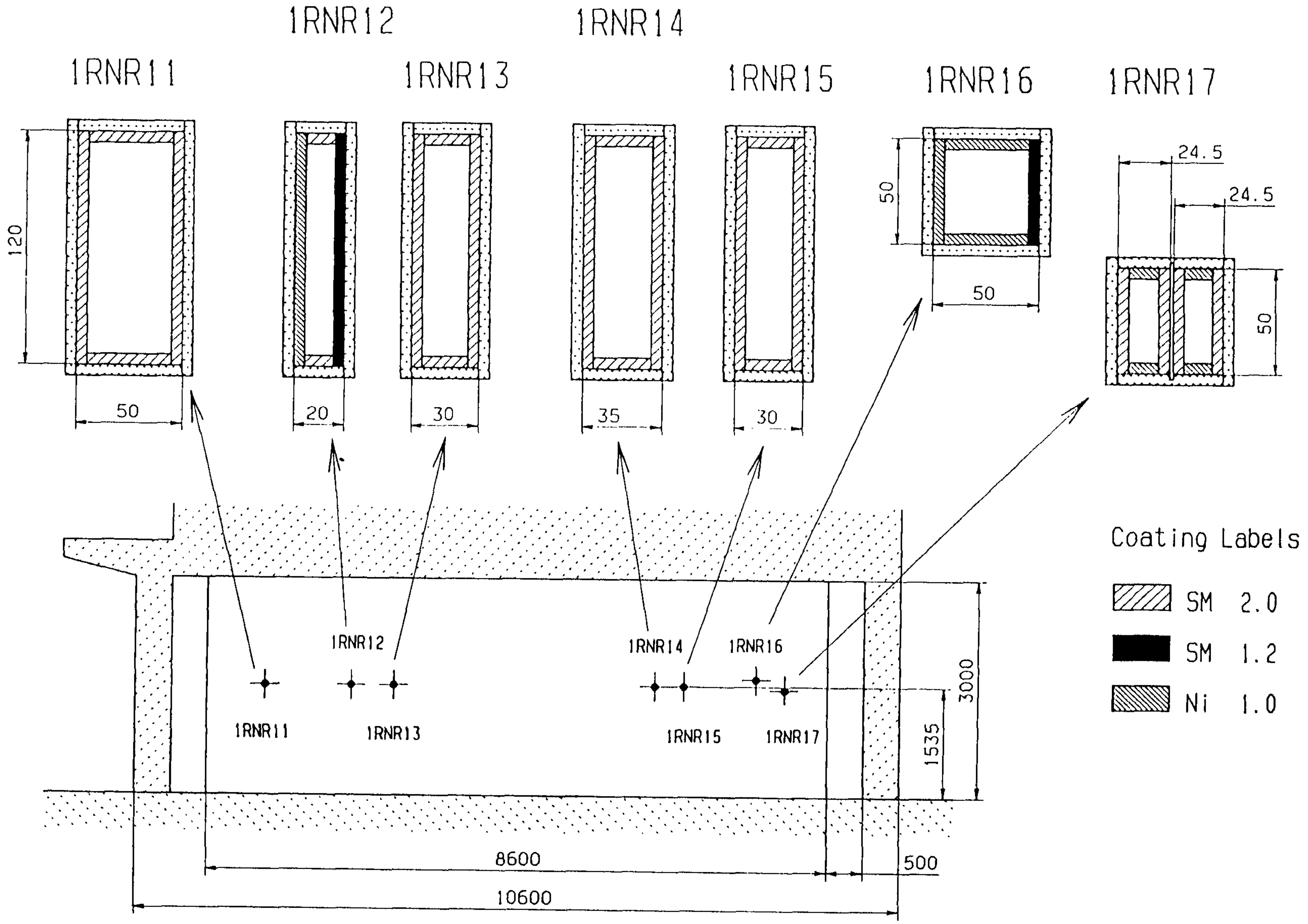

Figure 3: Guide cross sections, geometric arrangment and coating foreseen for the curved section inside the guide bunker (viewing to the source).

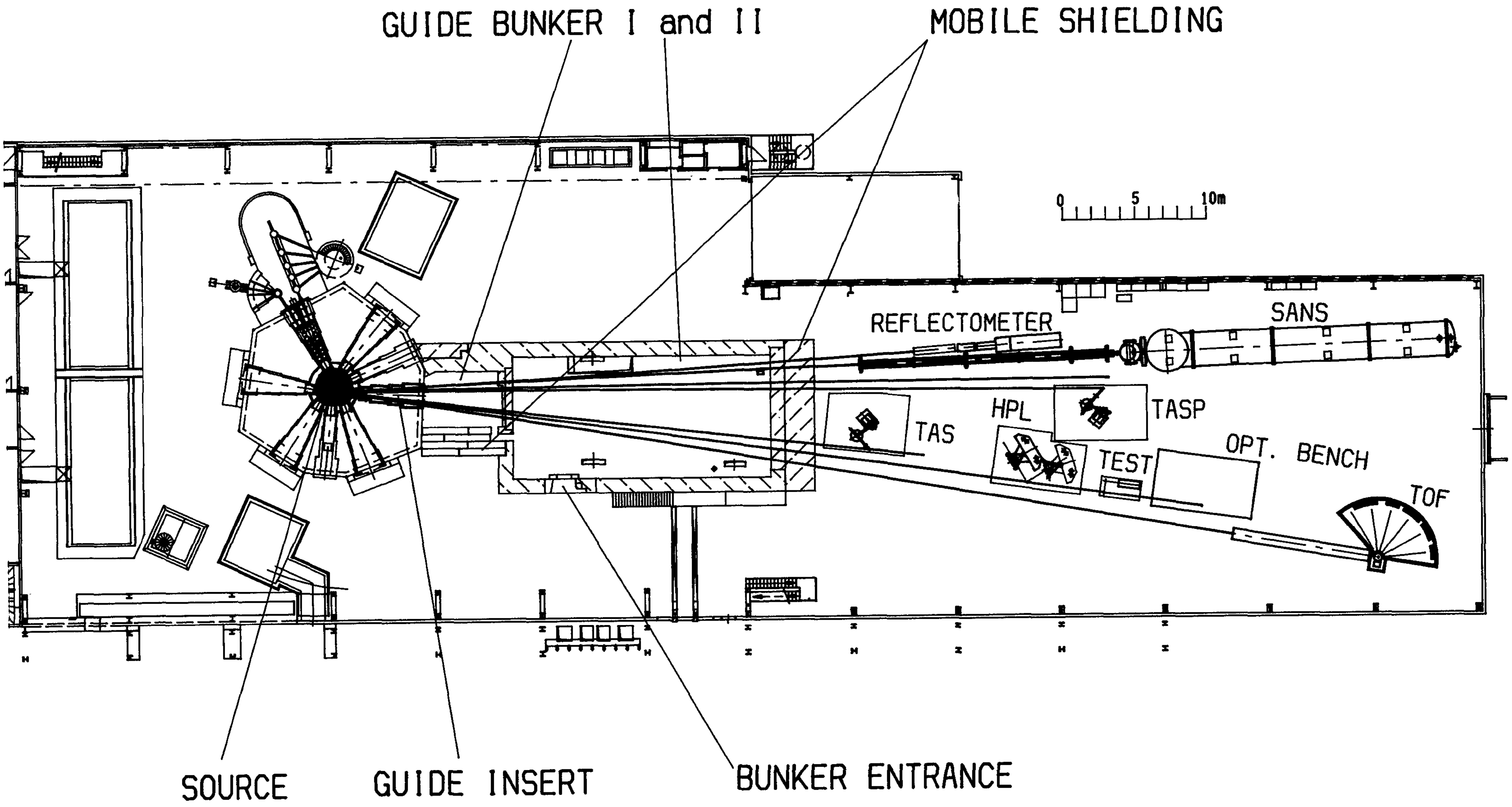

Figure 4: Floorplan of the SINQ-hall , showing the location of the source with the main shielding, the guide bunkers, the lines of the seven neutron guides and the instruments proposed for the first operation period.

Guide (PKS)	Inclination against central axis	Dimensions width x height (mm^2)	L_{CURV} (m)	R_{CURV} (m)	Charact. wavelength λ * (Å)			Proposed instruments		
					Ni	SM1.2	SM2.0			
1RNR11	-6°	50 x 120	20	1445 ↘	4.9	4.2	2.4	BSS	NN	TOF
1RNR12	-4.8°	20 x 120	20	3612 ↘	2.0	1.7	1.0	Powder Diffr.	Test	Opt. bench
1RNR13	-4.0°	30 x 120	20	2408 ↗	2.9	2.5	1.5	TAS	NN	NN
1RNR14	+3.2°	35 x 120	20	2063 ↘	3.4	2.9	1.7		NN	TASP
1RNR15	+4°	30 x 120	20	2408 ↘	2.9	2.5	1.5	NN	NN	NN
1RNR16	+6°	50 x 50	20	1445 ↘	4.9	4.2	2.4			SANS
1RNR17	+6°	2x24.5 x 50	24	1234 ↗	3.7	3.2	1.9	Reflectometer		

↘ Curvature westward

↗ Curvature eastward

▣ Day-One-Instrumentation

☐ Options ready to realize

Table 1: Characteristic data of the SINQ neutron guide system, giving geometry and curvature parameters, the calculated characteristic wavelengths for three types of coatings with the decided choices labeled, and the proposed instruments for the initial operation period.