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PROGRESS ON THE SNS TARGET STATION

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1 Introduction

This progress report is a continuation of reports given in the previous ICANS meetings. In particular, the report given at ICANS IV (1) was a definitive statement of the overall Target Station, containing the expected performance parameters. This review gives progress and modifications covering the last eighteen months, under the five broad areas of Target, Target Assembly, Control System, Bulk Shield and Remote Handling. Finally a discussion of additional facilities to the SNS is presented.

2 Target

(i) The general description of the target was given at the ICANS IV meeting. Since that time a full description of the theoretical study on the whole target assembly, based on a modified HETC code package, has been produced (2).

A study of the cooling tests on target plate models has shown that the cooling is mainly forced convective and that the expected uranium centreline temperatures would be as low as 290°C. Accordingly new uranium thicknesses have been obtained based on a centreline temperature of 380°C and assuming a reduction of up to 10% in thermal conductivity due to uranium burn-up. The choice of temperature allows a greater mechanical strength and a margin of error in reduction of beam size (~ 10%) or in beam intensity (~ 20%) whilst keeping below the cavitational swelling regime of radiation damage. The new target will have 23 plates in 4 batches of uranium thickness 7.7mm (8), 9.7mm (8), 16.8mm (4) and 26.2mm (3), as shown in the schematic diagram, figure 1.

(ii) Fabrication of the zircaloy-2 clad uranium plates has been under development with the Fulmer Research Institute in the UK. The HIP bonding technique is used in which the assembly of uranium disk and zircaloy cover plates are subjected to an isostatic pressure of 2000 bars in an argon atmosphere furnace at 800°C for 3 hours. Two successful test plates have been obtained with complete bonding; however, β-quenching to refine grain size resulted in some small areas of de-bond at the corners. This problem is being investigated, along with mounting of thermocouple wells.

3 Target Assembly

(i) The four moderators discussed in reference (1) have been confirmed and their basic geometries fixed, as shown in Table 1. Of the two lower, cryogenic, moderators one will be liquid methane at 95 - 97K and the second will be para-hydrogen at 25K. The moderators will be single phase to give uniform density and flow, requiring operating pressures of 4 atmospheres (ie. subcooled with $T_B \sim$ 131K) for methane and 15 atmosphere (ie. supercritical) for hydrogen. New estimates of the total energy deposition in the moderators indicate values of about 665W for the methane and 520W hydrogen moderators for an assumed 200μA on target. These new figures have been based on references (3) and (4) and are about two times the previous estimates. Further details of the moderators are given elsewhere in this meeting (5).

(ii) The moderators will be surrounded on all but the exit faces by decoupler using a boron loaded laminate containing 35% of natural B_4C, to give an effective decoupling energy of about 3eV. No decoupler is proposed for the hydrogen moderator, high intensity of the long wavelength neutrons being required rather than pulse shape. The beam ports through the reflector will also contain decoupler of the same type. The total energy desposition is expected to be about 4KW, to be removed through thermal contact with the reflector vessels.

4 Control System

The target station control system has three tasks: to set up and monitor the operation of the plant, to provide an interlock system to ensure safe operation and to provide an emergency shutdown system whilst maintaining cooling of the target at all times. The system itself is composed of 4 parts; (i) a Minicomputer Control System (MINICS) using a GEC 4070 minicomputer to provide the overall control function and to carry out routine monitoring, (ii) a Microcomputer Control System (MCS), using an Intel iSBC microprocessor, to monitor the vital parameters related to the condition and safety of the target station components (eg. target temperatures, coolant presssures and flow) and to provide the facility for a software-generated beam trip under monitored faults, (iii) a Target Beam Trip (TBT) to provide a hard-wired interlock operating independently of the computers, (iv) Coolant Control Logic (CCL) to ensure adequate cooling to the target in the event of plant or computer failure. Each of the first three parts is capable of turning off the proton beam in the event of a fault thus providing a three-fold heirarchy of safety monitoring and operation: the last part ensures continued target safety under all circumstances, eg. against decay heating which has a maximum value of about 9KW. The CCL is implemented using programmed logic controllers (PLCs) in a triple redundant configuration such that a single failure within a PLC will not cause CCL malfunction.

Sensors (eg. temperature, pressure, position) are standard radiation-hard commercial devices connected to standard panel meters which interface directly to the data acquisition system. Modular design is maintained to allow rapid servicing and simple alignment and calibration. This basically simple system is designed to make commissioning and trouble shooting as straight forward as possible and to enhance reliability.

The system is designed so that the target station, once set-up, can be left unattended during normal operation with monitoring and control exercised remotely via the main SNS control system.

5 Bulk Shield

Major components of the bulk shield have been designed and have been delivered or are under construction.

The shielding inserts provide local supports into which the collimated neutron beams and their shielding are placed. The arrangement makes the mounting of the neutron beams independent of the bulk shield and so allows flexibility in any future instrument layouts. The inserts, in 6 modules, have been delivered and figure 2 shows the mounting of a set of three in the bulk shield. The second set will be mounted in July/August of this year. The datum base plates and the central pillar, acting as the target station central datum and the eventual emergency drain pipe, can also be seen in this figure.

The shutter "vessels" contain triangular shielding wedges and the neutron beam shutters. The shielding wedges are in production, with completion expected by the end of November 1982. The shutters themselves are designed and the order for manufacture will be placed in September 1982. The centre section of the shutter incorporates a cast-lead collimator with its own helium atmosphere.

The target void vessel provides a contained atmosphere of helium, at 4.5mbar below ambient, around the target assembly. The helium gas performs several functions: at 95% concentration it guarantees there is no risk of burning or detonation with complete leakage of either or both cryogenic moderators; when circulated it provides cooling for the 5KW energy deposition in the vessel walls; it serves as a low attenuation transport medium for thermal neutrons. The void vessel is some 3.2m diameter and 3.2m high. Its walls contain eighteen neutron beam double windows each of size 190 x 190mm^2 of 2 x 0.5mm thick aluminium. Pressure cycling tests of a single 0.5mm sheet from ambient to vacuum to ambient, with 207mbar on the other side, have shown a distortion of less than 10mm over a 1000 cycles without failure. The number of cycles is an order of magnitude greater than ever likely in operation. The vessel has been designed, is being constructed under the ASME III category 'A' regulations and is due for delivery in April 1983.

Figure 3 shows the void vessel. In this figure can also be seen the tubes for the proposed Fusion Materials Irradiation Test Facility, which will sample the backward flux of fast and high energy neutrons escaping from the target assembly. At the location shown, fluxes of 4×10^{11} ncm^{-2}sec^{-1} for En $\geqslant$ 1 MeV and 4×10^{10} ncm^{-2}sec^{-1} for En $\geqslant$ 10MeV are expected for a 200μA input proton beam.

6 Remote Handling

The dimensions of the remote handling cell have been fixed at 3.3m (L) by 4m (W) by 5.5m (H). The walls and roof are respectively 1.6m and 1m thick. The wall thickness will reduce the radiation dose rate at the outside of the shielding to less than 10μSv/hr and so allow prolonged use of the manipulators. Detail design is underway for installation, together with the rail and drainage systems, in the second half of this year. The overall ventilation system has been specified according to the appropriate UK codes of practice.

A full scale mock-up remote handling cell has been built to start the testing and development of the tools and techniques for handling all the components of the Target Assembly. The major task is removal and replacement of the target. The alignment and lifting frames and the mechanism for rotating the target from horizontal to vertical prior to placing it in the storage wells have been built. The overall operation of removing a (dummy) target, rotating it and placing it ready for storage takes about 1½ hours. Various fasteners for the target flange have been examined, with captive swing bolts appearing to be the best. Coolant seals for this flange (and others) have also been studied, with silver-plated stainless steel ("Corruseals") giving the best seals with minimum corrosion.

Figure 4 shows part of the target removal operation showing the lifting frames around the dummy target. More details of remote handling are given elsewhere in this meeting (6).

7 Other Facilities

The use of an irradiation test facility in the target station has already been mentioned: there are further major facilities additional to the SNS based on an intermediate transmission target located in the extracted proton beam some 20m upstream of the main SNS target. These facilities consist of a negative pion beam for medical applications and a surface μ^+ beam for studies in solid state and chemistry using the μSR technique. The pion beam will rely on the high intensity of the proton beam and will complement the existing facilities at SIN, LANL and TRIUMF. The surface muon beam will be unique in that it will be pulsed, give useful μ^+ stopping rates up to 100 times greater than existing facilities and give wide flexibility in available operating modes. Figure 5 shows a general layout of the Experimental Hall with the intermediate target station, pion and muon beams.

(i) The target itself will have a variety of geometries with graphite thicknesses up to 50mm in the proton beam direction, resulting in a reduction of thermal neutron flux from the main SNS target of up to about 16%. Various tunes of the proton beam are available to produce different waist sizes (horizontal and vertical) at the target as required by the pion and muon beams whilst still satisfying the main optics requirement of transmitting good beam onto the neutron production target. Local steel shielding will be installed around the target to reduce the external radiation dose rate to the same value as elsewhere for the EPB shielding, ie. less than 7μSv/hr. Further shielding may be added as necessary to ensure low time-independent backgrounds for the neutron instruments.

(ii) The biomedical pion beam will be a conventional low momentum (up to 210 MeV/c) negative pion beam of large acceptance (285 msr %Δp/p), which combined with the 200μA incident proton beam will generate dose rates in the pion stopping region (volume 120 x 80 x 70mm^3, 0.67 litres, depth 285 - 375mm in tissue) of 0.11 Gy/min (10.9 Rads/min). The primary task of this beam will be radiological experiments and eventually radiotherapy on human patients. A comprehensive programme of research with this beam has been proposed by groups from UK universities and medical institutions.

(iii) The 28MeV/c pulsed surface muon beam facility will be one of the only two pulsed μ^+ sources in existence, the other being the low current (I_p = 2μA) source at KEK. The advantages of a pulsed μ^+ source will be combined with those of a surface muon beam to achieve increases of up to a factor 100 of the useful μ^+ stopping rates for μSR studies. The beam will incorporate two fast kicker magnets, the first separates the individual muon bursts generated by the intrinsic pulse structure of the SNS proton beam (2 x 100ns bursts separated by 230ns, repeated at 50Hz) and the second to shorten each pulse down to ~10ns FWHM when required. The use of Soller-type collimators before the second kicker might allow a decrease of the final pulse width down to 1 - 2ns. Beam intensities of $10^7 \mu^+$/s total, ie. $10^5 \mu^+$/burst will be available with the full time width of each burst. This intensity decreases linearly with pulse width down to the 1 - 2ns available. The beam will include a crossed-field electrostatic velocity selector which, at 10% rating, will eliminate electron contamination, and at full rating (E = 5MV/m, B = 6.5 x 10^{-2}T, L = 2.3m) will rotate the muon polarisation from 100% longitudinal to 100% transverse.

The beam can also be operated with the pulse separation facility for cloud muons of both charge signs of momentum up to 50MeV/c and as a conventional high momentum pion beam ($\pi\pm$) up to 200MeV/c.

The principal use of this beam will be for μSR, channeling experiments in solid state and a wide spectrum of pure research with pions and muons.

The status of this work is that funds have been provided to allow the modification of the EPB for the future implementation of these proposals. The proton beam line has been redesigned and includes the use of large aperture quadrupoles (which already exist); the mechanical support systems for the quadrupoles and a rail system have been designed to overcome the restricted access due to the presence of the intermediate target; the EPB shielding has been modified to allow the installation of either or both beams; detail work is starting on the intermediate target itself. No further committment has yet been made on the biomedical beam; but for the μSR beam work is going ahead to prepare a full proposal for presentation at the end of this year with the possibility of installation ready for SNS "Day One" in 1984.

8 Acknowledgements

This report gratefully acknowledges the work of the members of the SNS Target and Utilisation Group, in particular Tim Broome, Dave Clarke, Brian Diplock, Gordon Eaton, John Hogston, Mike Holding, Bernard Poulten, Ken Moye, Ken Roberts and Eddie Fitzharris and Colin Thomas, also the collaboration with members of Neutron Division.

9 References

(1) A Carne, "Review of SNS Target Station". Proceedings of ICANS IV, KEK Tsukuba, Japan, October 1980.

(2) F Atchison, "A Theoretical Study of a Target Reflector and Moderator Assembly for SNS". Report RL-81-006, April 1981.

(3) N Watanabe and K Boning, "Summary of Energy Deposition and Cryogenic Equipment". Proceedings of ICANS V, Julich, West Germany, June 1981.

(4) E Karls, K Hain, W Leiling, "Technisches Konzept einer Kalten Neutronen-Quelle fur die SNQ". SNQ Study Teil III KfA Julich/Karlsruhe, June 1981.

(5) B R Diplock, "Cryogenic Moderator Design". This Conference.

(6) B H Poulten, "Remote Handling Equipment For SNS". This Conference.

TABLE 1

SNS Moderators

A	B	C	D
H_2O	CH_4	p-H_2	H_2O
316 K ± 1 K	95 - 97 K ± 1 K	25 K ± 1 K	316 K ± 1 K
High Intensity at expense of resolution	High Resolution slowing down spectrum	Long wavelength	(as required)
dimensions of moderator material, mm			
w 120 h 120 d $\left.\begin{array}{l}15\\30\end{array}\right\}45$	120 115 45 (at centre)	110 120 80 (at centre)	120 120 $\left.\begin{array}{l}22.5\\22.5\end{array}\right\}45$
Poison: 0.05mm Gd. Clad	Poison: provision for future incorporation	Poison: None	Poison: 0.05 mm Gd. Clad
Decoupler: 6mm boron loaded laminate, 35% natural B_4C	Decoupler: 6mm boron loaded laminate, 35% natural B_4C	Decoupler: None	Decoupler: As 'A'
Void Liner: As for decoupler (shared with 'D')	Void Liner: As decoupler preferred (shared with 'C')	Void Liner: 1mm Cd preferred (shared with 'B')	Void Liner: As for decoupler (shared with 'A')

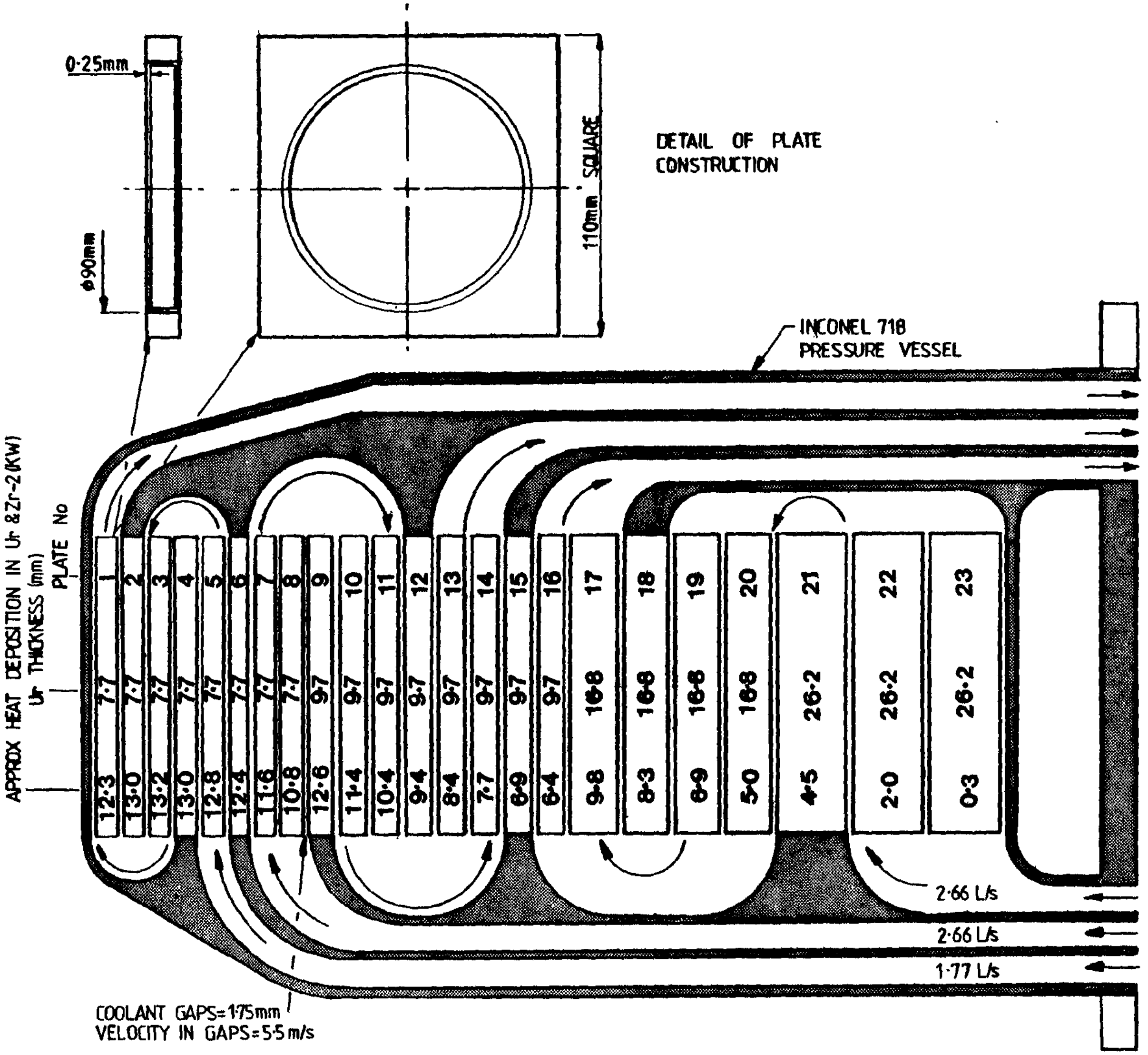

PLATE No	Ur THICKNESS (mm)	APPROX HEAT DEPOSITION IN Ur &Zr-2 (KW)
1	7·7	12·3
2	7·7	13·0
3	7·7	13·2
4	7·7	13·0
5	7·7	12·8
6	7·7	12·4
7	7·7	11·6
8	7·7	10·8
9	9·7	12·6
10	9·7	11·4
11	9·7	10·4
12	9·7	9·4
13	9·7	8·4
14	9·7	7·7
15	9·7	6·9
16	9·7	6·4
17	16·8	9·8
18	16·8	8·3
19	16·8	6·9
20	16·8	5·0
21	26·2	4·5
22	26·2	2·0
23	26·2	0·3

T_{cl} (max) = 380°C

W max = 300 W cm^{-2}

T (Zr) ~ 120°C

BULK OUTLET TEMPERATURE 50°C

OUTLET PRESSURE 3·4 BARS

HEAT DEPOSITED IN TARGET	KW
a) In ^{238}U including decay	209
b) In Zircaloy-2 cladding	6
c) In Inconel Vessel including Window	7
d) In Heavy Water Coolant	5
TOTAL	227

INLET PRESSURE 4·76 BARS

HEAVY WATER COOLANT

AT 43°C

FIG:1 TARGET COOLING PARAMETERS AND TEMPERATURE DISTRIBUTION (FULL INTENSITY PROTON BEAM)

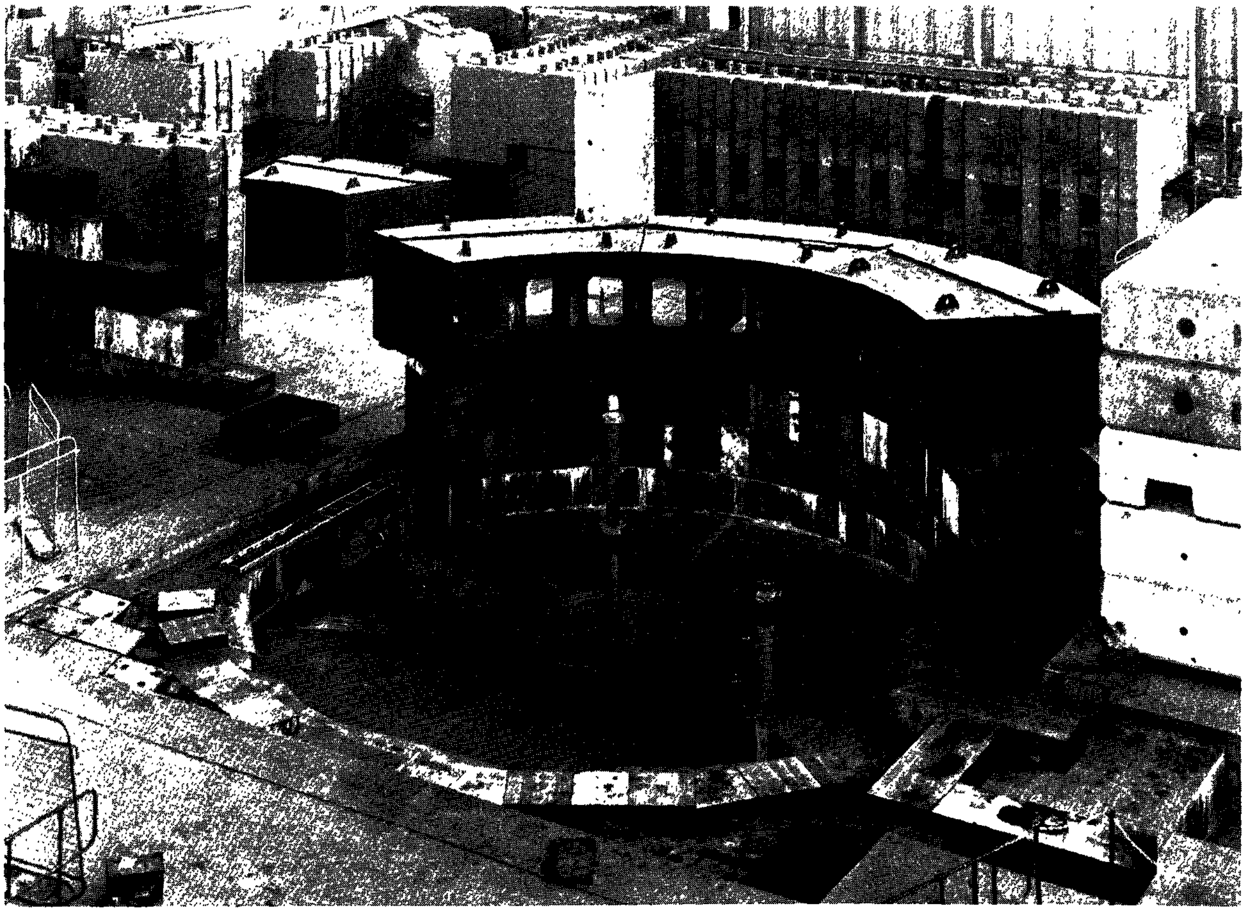

Fig. 2. Installation of first set of shielding inserts.

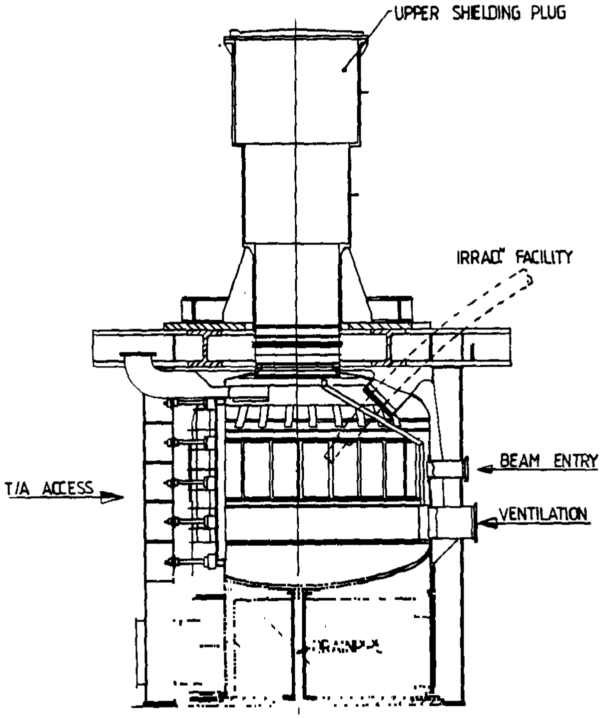

Fig. 3

Target station void vessel (vertical section)

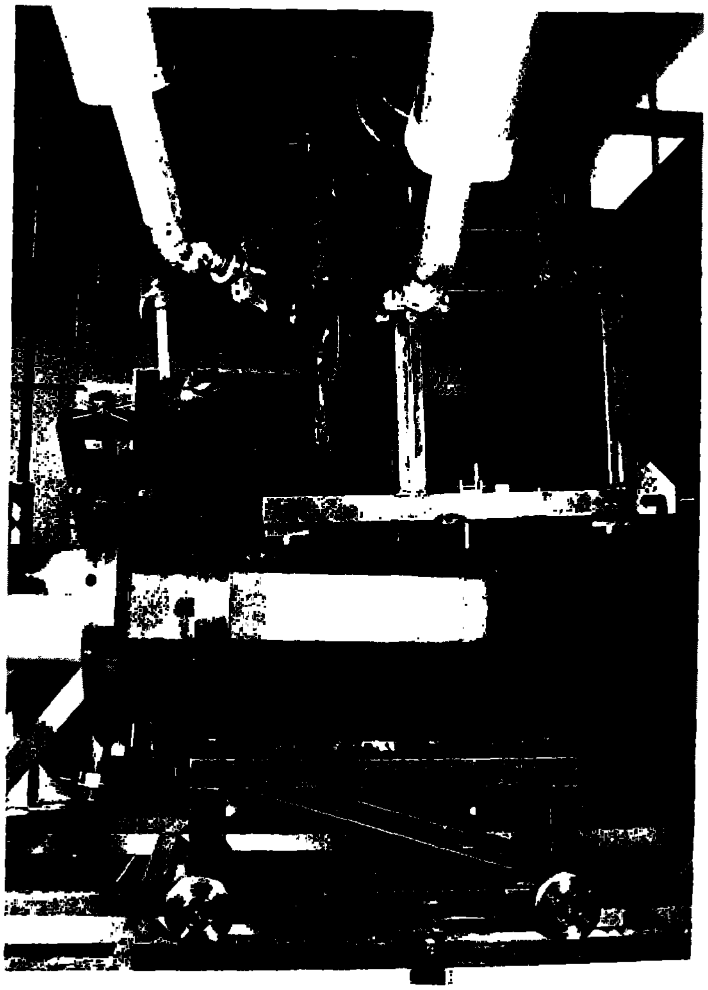

Fig. 4

Target removal operation in mock-up RHC.

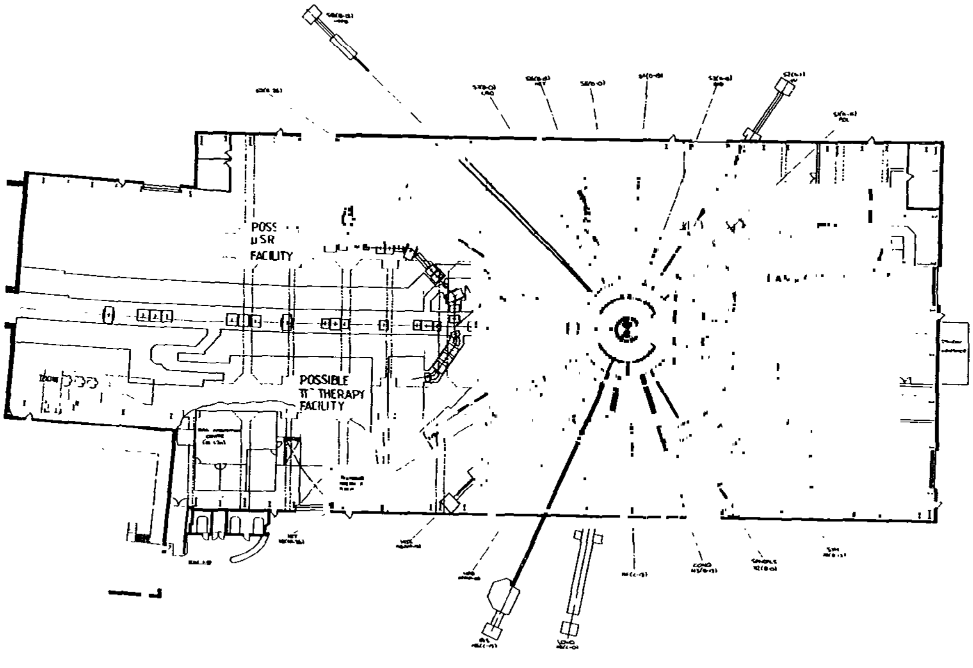

Fig. 5. General layout of experimental hall including intermediate target, pion and muon beams.