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PRESENT STATUS AND FUTURE PROJECT OF KENS FACILITY

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1. Introduction

The KENS facility restarted the operation on 17 June 1985 after a long shut down of more than one year. Although no neutron scattering researches were carried out in our facility during the last fiscal year, many efforts have been paid for realization of the KENS-I', the second phase of KENS, in this period. A number of new spectrometers has also been installed and there is now no vacant beam hole left unused in our facility. Fig. 1 is the latest version of the layout of the KENS facility. The machine groups worked to improve the spectrometers, particularly their data acquisition systems, while the users were busy for analyzing the data they accumulated before the shut-down. Therefore many papers on the scientific yields from KENS-I have been or are going to be published. A publication list will be distributed in the ICANS meeting. This report summarizes the present status of the KENS-I' as well as the point of improvement of each spectrometer.

The future project of the Booster Synchrotron Utilization Facility, GEMINI, has started to be discussed formally as one of the important candidate of the next projects of our laboratory, KEK, which is discussed in the last section.

2. KENS-I' Facility

The KENS-I' is a project which aims to increase the neutron beam intensity by one order of magnitude by upgrading the present accelerator and converting the tungsten target to a depleted uranium target for neutron production. The project is now underway as described below.

2.1 Increase of 500 MeV proton beam intensity

The increase of the proton beam intensity was planned to be achieved (i) by converting the 20 MeV injection system from the original multi-turn injection to the H^- charge-exchange injection system 1),2) and (ii) by increasing the injection energy from 20 MeV to 40 MeV3). The final beam current we can expect by this modification is about four times of the original intensity in an ideal situation.

H^- charge-exchange injection

The first trial on the H^- charge-exchange injection at the Booster Synchrotron had been carried out during three weeks from the end of September 1983 preceding the long shut-down of the 12 GeV Proton Synchrotron through 1984. More than 20 mA H^- ion beam was extracted from a newly developed multi-cusp ion source, and 18 mA was injected into the 20 MeV linac. At the end of the test period, the H^- ion beam delivered from the linac reached 8 mA. The maximum stacked beam intensity of 2.1×10^{12} protons just after completion of the injection process has been attained by the new injection method with a 8 mA, 100 μs wide H^- ion beam and a 120 $\mu g/cm^2$ thick carbon stripper while the stacked beam by the original multi-turn injection method with proton beam was at around 1.4×10^{12} protons in the typical operation. The maximum output intensity of 7.1×10^{11} protons per pulse was recorded, which was a new record in the booster. The test experiment proved that in spite of such low injection energy as 20 MeV this injection method appeared to be quite promising for increasing the beam intensity of the Booster Synchrotron.

Operation of the 12 GeV Proton Synchrotron has reopened in the early of this June with commissioning of the new H^- charge-exchange injection system in place of the original system for the proton multi-turn injection. The intensity record of the Booster Synchrotron has been rewritten and reached more than 9×10^{11} proton per pulse at the end of the last June, which is up about 50 % from the original case of the proton beam injection.

Upgrading of the injector linac

Extension of the present injector linac from 20 MeV to 40 MeV was undertaken. Construction of an additional Alvarez linac is under way. By this upgrading, the space-charge limit of the Booster Synchrotron is raised by a factor of two. Furthermore, it is beneficial to the H^- charge-exchange injection scheme applied to the booster. Energy loss and multiple scattering caused by passing through a charge stripping foil are considerably reduced. Especially the multiple scattering will be reduced to about a half when the proton energy increases from 20 MeV to 40 MeV. Thus, combining the charge-exchange injection with the linac upgrading, higher beam intensity of the booster can be attained with lower beam loss at injection.

Parameters of the new Alvarez linac are listed in Table 1.

The new linac will be installed by the end of this October, and come into operation in November.

2.2 Conversion to U target

The uranium target we finally got for KENS-I' consists of four blocks of Zircaloy-2 cladded depleted uranium metal which were fabricated at Argonne National Laboratory. Figure 2 shows a photography of the target blocks with an illustration of the designed target assembly. The traditional rectangular shape of KENS-I target is inherited to keep the better target-moderator coupling. A new target cooling system has been manufactured, a photograph of which is shown in Fig. 3. A mock-up experiment of the new target system proved that the flow rate of cooling water 60 ℓ/min can keep the maximum temperature at the center of uranium block at about 230°C for heat generation of 7.5 kW (500 MeV, 10 μA). The target-moderator-reflector assembly will be modified slightly in order to install the new target, but the overall configuration will be maintained. A lead cask to handle the irradiated uranium target, which is located in front of the target shielding will be renewed. The air filled target environment as well as the last two meters section of the proton beam line will be replaced by helium atmosphere in order to protect the uranium target from serious erosion caused by NO_x produced by the proton beam, on which we have a bitter experience. The new uranium target system is now under severe examination and the installation of the system will be completed at the end of this October.

2.3 Target Shielding

Shielding power of the existing bulk shield for the target station is very close to the upper limit of the dose rate regulation for accepting the upgraded proten beam of 10 μA, but still within allowable level. Preshielding around the exits of the neutron beam holes is, however, not sufficient and a substantial improvement of the preshielding is indispensable. In addition to it, most of spectrometers have hitherto been operated without overhead shields for convenience sakes, which should be inhibited in KENS-I'. Neutrons scattered upward from the spectrometers will not only give serious radiation level inside the experimental hall, particularly at the position of the second floor of 2 m high, newly installed for easy access to the spectrometers, but also contribute significantly to the neutron skyshine at the nearest site boundary. It has been proved that the overhead shield reduces the radiation level within an allowable level. The experimental hall was surrounded by 1 meter thick concrete wall up to 4 m height. For the wall which borders the Particle Radiation Medical Science Center (PRMSC), the height was extended to 5 m to reduce the radiation level at the control room of PRMSC.

Quite recently with the new start of our facility, we encountered a serious problem of the unexpected increase of radiation level around the bulk shield. The increase of the proton beam was about by 1.5 times, but the radiation level at the top of the overhead shield of the entrance to the target station attained already to 26 mrem/hr. We expect it due to the unexpected proton beam loss around the entrance the target shielding (about 1.6 m up-stream of the target).

It is not clear whether it is due to the increase of proton beam size or other reasons and a careful survey of the origins is now under way. This is the first difficulty we have had since the construction of KENS-I, but should be overcome in order to accomplish the KENS-I'.

2.4 Cold Moderator of KENS-I'

Since the intensity of neutron will increase about by a factor 8 in KENS-I', the new cold moderator should have a cooling power to remove the heat deposit of the order of 15 W (flat moderator) to 50 W (grooved moderator). (We should note here that our previous report[4)] on the heat deposit in the KENS-I cold moderator may not be accurate enough because we have now an indication that the tail of proton beams hits the cold moderator at the end of the KENS-I operation , which was clearly not the case at the beginning). Therefore mock-up experiments were carried out for the KENS-I' cold moderator and the details are discussed in a separate paper presented in this ICANS meeting . Here we briefly summarizes the results obtained.

The mock-up experiments were practiced with a flat moderator (12 x 5 x 15 cm^3) of solid methane using the cooling system of the KENS-I. Heat generation by neutrons was simulated by a heater of resistive wire embedded inside solid methane so that the same temperature distribution as the neutron heating could be attained. The results of the experiments are shown in Figs 4(a) and (b). It is clear from these figures that the increase of heat deposit to 15 W in the present cold moderator results in increasing the maximum temperature to 60 K, but the temperature increase can be reduced by introducing 1 mmϕ Aℓ wire lattice (1 x 1 cm^2) inside solid methane as shown in Fig. 4(b). We also found a significant temperature difference between the cooling head and the wall of the moderator case for the 15 W heating. A simple three dimensional calculation based on the differential equation of heat transportation was found to give a good agreement with the observation. After making a series of simulation calculation as displayed in Fig. 5 and also by taking into account curious phenomena ("Burp") Argonne cold moderator exhibits, we attained to the following conclusions.

1) The best way to cool the moderator is to insert Aℓ plates (0.5 mm thin at the distance of 10 mm). Aℓ sponge would not be recommended because it has a possibility to promote the H_2 decomposition.

2) The moderator case should be cooled directly by coolant of refrigerator, instead of adopting the indirect method we used for KENS-I, but the present refrigerator (PGH 105, 40 W cooling power at 20 K) can be employed even for KENS-I'.

3) We need to give up the grooved moderator mainly because of lack of cooling power with the present refrigerator as well as for the difficulty of cooling effectively solid methane. In addition to it, it was found that the grooved moderator does not give benefits to the high resolution powder spectroscopy. The decrease of the intensity by adopting the flat moderator can be partly compensated by improving the reflector system.

Finally we should note that in KENS-I' both thermal and cold neutron intensities on the sample position will be significantly larger than the equivalent neutron sources because of its tight configuration.

3. Installation and Improvement of Spectrometers

The total number of spectrometers installed at KENS reaches to fifteen as is shown in Fig. 1. Two new spectrometers, WIT and INC which were approved to be installed after the last ICANS meeting is still under construction. All other spectrometers are under operation for the users. We have now six elastic scattering machines (FOX, WIT, HIT, MRP, HRP), seven inelastic scattering spectrometers (MAX, LAM-80, LAM-40, LAM-D, CAT, RAT, INC) and two spectrometers for polarized neutron scattering (PEN, TOP). The characteristics or recent progress of these spectrometers will be discussed briefly below.

3.1 Four Circle Single Crystal Diffractometer FOX

A new one dimensional ^{6}Li loaded glass scintillation position sensitive detector using encode method was developed for the FOX, was attached to the diffractometer. A preliminary measurement detected Bragg reflections with a good S/N ratio, but still high back ground level.

3.2 Thermal Neutron Small Angle Scattering Instrument WIT

The WIT is a new type small angle scattering instrument installed at the thermal neutron beam hole in order to increase the total machine time of neutron small angle scattering. The instrument is equipped with a two dimensional converging grid collimator and 14 ring ^{6}Li loaded glass scintillation detectors. The spectrometer is particularly suitable for the simultaneous measurement of the wide range of momentum transfers Q between 0.01 A^{-1} and 25 A^{-1} from isotropic scattering media. A recent preliminary measurement indicates that the converging grid collimator works satisfactorily. We are particularly interested in the back ground level of our glass scintillators.

3.3 Liquid and Amorphous Diffractometer HIT

It is well known that the HIT has made a significant contribution to the structural determination of a number of liquid and amorphous materials. The recent interest is focussed on glass transition$^{5)}$.

As the second stage, two improvements are now in progress, one is a development of the electrical hardware focussing and another is a scintillation detector system introduced as lower angle counters. In the first stage, we adopted a traditional geometrical focussing for high angle counters and off-line focussing was performed on analysis for lower angle counters. This was because the instantaneous counting rate exceeded the processing time of the computer for the programmed forcusing. Recently, however, we have developed a new CAMAC module which enables us to accumulate the high counting rate of neutron signals, 170 ns in separation with the time focussing. Block diagram of the module is shown in Fig. 6.

For the measurements of S(Q) from liquids and amorphous solids containing light atoms such as water (D_2O) solution, lower angle counters, say $2\ \Theta < 30°$, becomes indispensable to avoid enormous Placzek corrections, Sometimes S(Q) up to 70 A^{-1} is required with $2\ \Theta \simeq 30°$. This means that epithermal neutrons up to 37 eV must be detected with a reasonable efficiency. A scintillation detector system using ^{6}Li loaded glass, 5 to 10 mm thick is now under development for this purpose. In addition to these counters, three scintillation rings are going to be installed at $2\Theta = 2.6° \sim 4°$ in order to extend the momentum transfers range down to $Q = 0.05\ A^{-1}$.

3.4 Powder Diffractometers HRP/MRP

Two powder diffractometers have been in operation since 1983. The HRP is a high resolution diffractometer realized by utilizing narrow thermal neutron pulses from the solid methane moderator, having a 20 meters long flight path and backward counters. Resolution $\Delta d/d$ achieved by HRP is almost the same as that of GPPD at IPNS ($\Delta d/d \sim 0.3$ %). Fig. 7 shows a typical example of the result obtained for Bi_2O_3 at room temperature with the Rietveld profile$^{6)}$. Counting time was one day which is adequate for Rietveld refinement. A problem we need to resolve now is how to describe the burst shape of neutrons from the grooved solid methane moderator by a simple set of parameters, covering an entire range of neutron wavelength from cold Maxwellian to epithermal region, which is now under consideration.

3.5 Small Angle Cold Neutron Scattering Instrument SAN

The SAN is a cold neutron small angle scattering machine, having made an important contribution to various problems as phase separation$^{7)}$, spin glass, polymer science and structural studies of biological substances because of its unique characteristics of wide dynamical range of Q measurements and of employing neutrons with a band of wavelength. The characteristics of the spectrometer as well as the design principle are discussed in detail in a separate paper presented in this meeting$^{8)}$. A very recent progress we made is that the minimum Q range which was designed to be $3 \times 10^{-3}\ A^{-1}$ by employing the wave lengths between 3 to 11 A is now extended to $2 \times 10^{-3}\ A^{-1}$ by shifting the employing wavelength region from 3 to 9 A to 9 to 15 A as shown in Fig. 7. Another important result we got is that the magnon scattering can now be separated from small angle scattering of static origin without making energy analysis. The technique is found to be quite promissing for studying the ferromagnetic system.

3.6 Coherent Inelastic Scattering Spectrometer MAX

The MAX was most successfully used to study the low energy spin dynamics in a quasi-2D antiferromagnet, $MnTiO_3$ 9) and has proved that the anisotropic magnon dispersions can be measured with almost the same efficiency and resolution as our triple axis spectrometer TUNS at JRR-2 (10 MW Reactor). However for the high energy excitation studies the resolution problem is much more severe in the MAX than the three axis spectrometer in the reactor and we need further technical development for it. One of the important progresses we made was the development of Si wafer monochromators 10). By employing commercially available Si wafers, we fabricated bent packet Si wafer monochromators having the reflectivity more than 70 % of PG (200). Since the monochromator does not suffer from higher order contamination and a good number of large monochromators can be obtained with a reasonable price, the Si wafer monochromator would give a promissing aspect for the MAX type spectrometer.

3.7 Incoherent Inelastic Scattering Spectrometers LAM-80, LAM-40, LAM-D

Three LAM-Type spectrometers with different dynamical range of measurements have finally been installed at KENS which were found quite useful for studying the molecular dynamics in various chemical compounds by covering a wide range of energy transfers between 100 meV and 1 μeV. If combined further with CAT, the dynamical range of measurements for the incoherent inelastic scattering can be extended up to 1 eV. The LAM type spectrometer is characterized by (i) its simple structure, (ii) easy to modify the energy resolution, (iii) a good scattering intensity profile for the quasi-elastic scattering which makes easy the profile analysis and particularly (iv) the wide dynamical range of measurement for the inelastic scattering. The detailed discussions of the characteristics are found in a separate paper[11)]. We can conclude that the LAM is quite suitable for the pulsed neutron source. Fig. 9 displays an example of the energy spectra measured with LAM-40 and LAM-80.

3.8 eV Spectrometer RAT

Resonance Detector Spectrometer RAT attracted a world wide attention because of its clear detection of Bose condensation state in superfluid helium[12)]. The measurements of momentum distribution from solids and liquids including superfluid ^{4}He will be continued for coming months with an improvement for increasing statistics, but a developing study for low Q and high energy transfer measurements with RAT will soon be started, for which the development of the sum coincidence method is indispensable, which is now in progress.

3.9 Epithermal Neutron Polarizer PEN

The PEN, the spectrometer to polarize epithermal neutrons by means of polarized proton filter is a unique machine which continued the operation even in the shut-down period. The most significant progress we made during this period is the success of cooling the polarized proton filter by liquid ^{4}He which were cooled by pumped liquid ^{3}He down to 0.4 K (^{3}He/^{4}He Heat Exchange Method)[13)]. This success overcame a difficulty of presence of ^{3}He in the neutron path and enabled us to enlarge the filter area. The maximum proton polarization of the filter of $30 \times 40 \times 15$ mm^3 attained by means of dynamical polarization was 50 %, which can polarize the neutrons of 1 eV to 75 %. A higher proton polarization would be obtained if the cooling power is improved, which is now under examination. In Fig. 10 is plotted the quality factor η of the polarized proton filter defined as $\eta = P^2 TA$ (P=neutron polarization, T=neutron transmission, A=neutron beam area) determined experimentally for different filters against the year of measurement, indicating a continuous improvement of the factor. A more detailed description will be given in a separate paper presented in this meeting.

3.10 Cold Polarized Neutron Spectrometer TOP

The TOP is the cold neutron scattering spectrometer with polarization analyzer employing polarized neutrons with λ ranging from 3 to 9 A. Recent interests have been focussed on the transmission measurements where the wavelength dependence of the depolarization was found to give new information on domain sizes in the ferromagnetic materials[14). A peculiar phenomenon of damped oscillation type depolarization was observed in the re-entrant spin glass system as $Fe_{0.7}A\ell_{0.3}$ or $Fe_{0.22}Cr_{0.78}$. In order to pursue further these phenomena, a three dimensional polarization analyzer is installed to the spectrometer. Fig. 11 displays a preliminary result we got with this analyzer. A frame shape sample of $Fe_{0.7}A\ell_{0.3}$ was used for the measurement. No oscillatory depolarization was found for the Z-Z polarization in a magnetic field of 100 Oe.

4. Future Project - KENS-II

The GEMINI project consisting of the projects of intense neutron scattering facility, KENS-II and intense pulsed meson facility Super BOOM was officially proposed to KEK in 1984 as the next project of the Booster Synchrotron Utilization Facility.

The GEMINI (Generator of Meson Intense and Neutron Intense Beam) is an 800 MeV rapid-cycling proton synchrotron with two bunched beams, each of which is planed to be delivered to each facility. The total time averaged current is aimed to be 500 μA and the KENS-II will get the proton beams of 250 μA in time average continuously. Layout of the GEMINI project is displayed in Fig. 12.

The project has been discussed in various places including among the neutron scattering community or nuclear physicist group. On the other hand, the KEK started the discussions on the post TRISTAN project and the GEMINI is considered as a good candidate for it. The neutron scattering committee agrees that the pulsed spallation neutron source would be the next national project of neutron source in Japan and the GEMINI-KENS-II project satisfies their requirements. However the nuclear and high energy physics groups consider that the GEMINI should have a potential to link to a higher energy accelerator so as to promote the hadron project as a Kaon factory. In this connection, a project to increase a current intensity of the existing 12 GeV Proton Synchrotron (PS) has also been discussed in KEK and the combination of the GEMINI with the future project of the 12 GeV proton accelerator is one possibility to realize the GEMINI in KEK. These projects are going to be discussed in some authorized committees from more general stand point of view.

Under these circumstances the GEMINI project is planed to be modified to satisfy the severe requirements imposed by muon group coupled with the nuclear and high energy physics groups; the increase of the beam energy to higher than 1 GeV, the decrease of the beam emittance in addition to the sharp bunched beam. Since it is difficult to compromise these requirements with those of neutron group by upgrading the original GEMINI accelerator itself, accelerator group made an interesting proposal to add a 1.5 GeV FFAG synchrotron to the GEMINI project, whose average radius at injection is just a half of the original synchrotron's. One of the bunches accelerated by the 800 MeV synchrotron is injected into the FFAG synchrotron, and is accelerated up to 1.5 GeV. The preliminary design parameters are listed in Table 2. The circumference of the extraction orbit is larger than that of the injection only by 5 %. The extracted beam can be injected into the present 12 GeV PS at KEK, which makes possible to increase the beam intensity of the PS by fifteen times of the present intensity. Moreover, the beam from the FFAG synchrotron may also be a source of kaon and anti-proton factory, which might be built in future. Additional cost of the GEMINI project due to the construction of the FFAG synchrotron is estimated to be 25 to 30 % up of the construction money of the 800 MeV rapid-cycling synchrotron.

One of the recent topics in the GEMINI design study is the development of a world highest field permanent quadrupole magnet, and the development of a stranded cable for the exciting coil of the rapid-cycling GEMINI magnet. The segmented ring-shaped quadrupole magnet, whose bore radius is 6 mm, will be set in the drift tube of a 400 MHz, 100 MeV Alvarez injector linac. It has been realized that the maximum field gradient and pole-tip field are 160T/m and 1.2T with core material of SmCo, and 260T/m and 1.6T with Nd-Fe-B, respectively. The transverse acceptance of the linac will be considerably increased by using those permanent magnets. A proto-type bending magnet for the

GEMINI synchrotron has been completed. In place of conventional hollow conductor, a stranded cable with a water-cooling pipe is used as an exciting coil. The cross section of the cable is 30 mm x 30 mm. The cable consists of 84 Al-wires of 3 mm in diameter and a 14 mm dia. and 1.5 mm thick copper pipe, carrying 1,650 A DC current and 880 A peak AC current (50 Hz). By applying such a stranded cable, the rapid-cycling magnet is completely free from the power dissipation due to the induced eddy current in coil conductor. Fig. 18 and 19 show the ring-shaped quadrupole magnet made of Nd-Fe-B and the cross sectional view of the stranded cable for exciting GEMINI synchrotron magnet respectively.

We would express our sincere thanks to Prof. T. Nishikawa, Director General of National Laboratory for High Energy Physics for his continuous interests and encouragement.

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Table 1. Parameters of new linac

Kinetic Energy	20.60 - 40.46 MeV
Frequency	201.070 MHz
Tank	Copper-plated steel
Length	12.84 m
Inside diameter	0.90 m
Number of cells	35
Drift tube	Copper-plated stainless steel
Length	23.32 - 28.79 cm
Outer diameter	16 cm
Bore diameter	3 cm
Stem diameter	3.6 cm
Quadrupole magnet	Permanent (ALNICO-9)
Aperture	3.4 cm
Length	16 cm
Outer diameter	13.5 cm
Field gradient	2.0 - 2.05 kG/cm
Synchronous phase	-30°
Average axial field	2.1 MV/m
Shunt impedance	70.33 - 68.71 MΩ/m
Transit time factor	0.8699 - 0.8143
Effective shunt impedance	53.22 - 45.56 MΩ/m
RF System	
Excitation power	1.078 MW
Coupling	Loop, two feeds
Stabilizer	Post couplers
Post diameter	3.0 cm
Vacuum system	
Main pump	Ion pump (1.000 l/s x 7)
Roughing pump	Turbomolecular pump (500 l/s x 1)

Table 2. A 1.5 GeV FFAG Synchrotron

Max. kinetic energy	1.5 GeV
Max. intensity	3x10^{13} p/p
Max. repetition rate	50 Hz
Average beam current	250 μA
Injection energy	800 MeV
Number of sectors	16
Circumference factor	2.5
Pole radius	
at injection	13.49 m
at max. energy	14.15 m
Injection field	0.904 T
Max. field	1.324 T
Spiral angle	64.6°
Field index	8.0
Radial betatron oscillation frequency	
horizontal	3.24
vertical	3.25
Max. beta-function over radius of curvature	
holizontal	1.4
vertical	1.6
Momentum compaction factor	0.111
Max. momentum dispersion over radius of curvature	0.34
Beam emittance	
at 800 MeV	290 x 160 (mm•mrad)^2
at 1.5 GeV	190 x 100 (mm•mrad)^2
Frequency range of RF acceleration	2.98-3.11 MHZ
Harmonic number	1
RF bucket area at injection	4.1 ev•sec
Peak RF voltage	40 kV
RF voltage at injection	21 kV
Number of cavities	2
Transition energy over rest mass energy	3.0
Weight of sector magnets	
iron	590 tons
copper	24 tons

KENS NEUTRON SCATTERING FACILITY

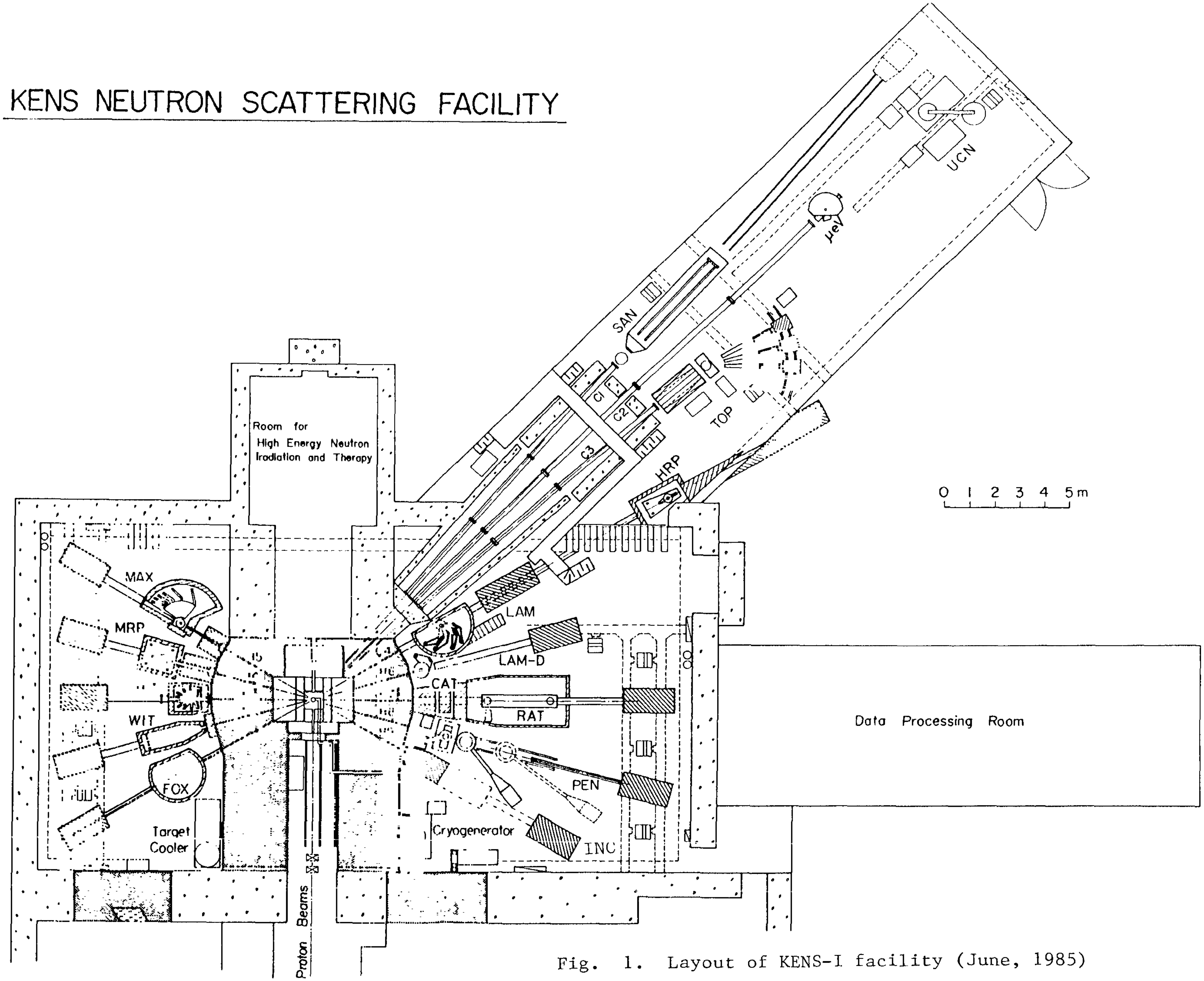

Fig. 1. Layout of KENS-I facility (June, 1985)

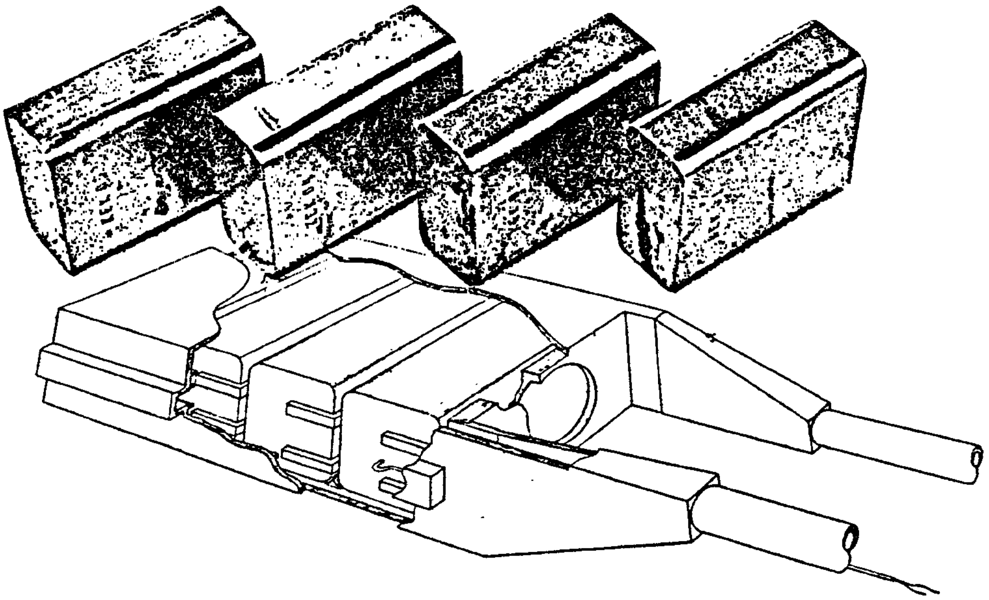

Fig. 2. Uranium target blocks for KENS-I' with an illustration of target assembly

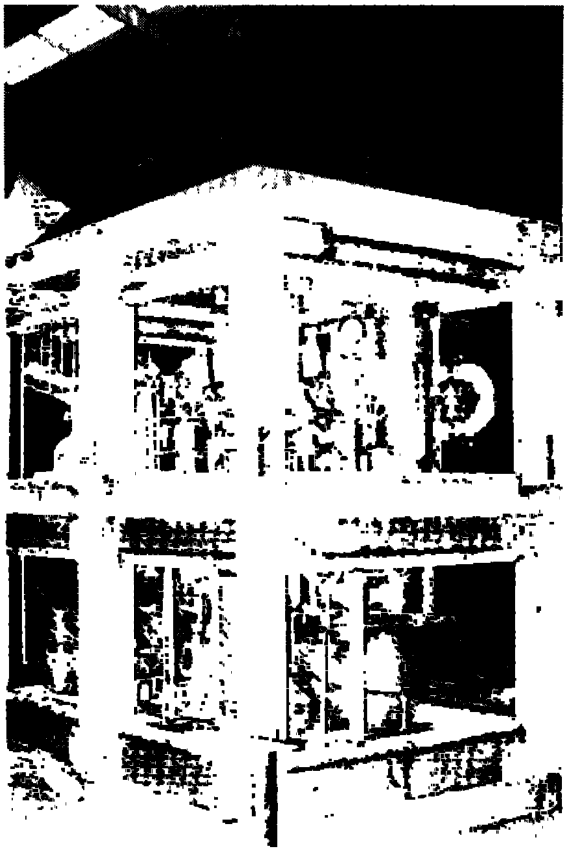

Fig. 3. Photograph of target cooling system

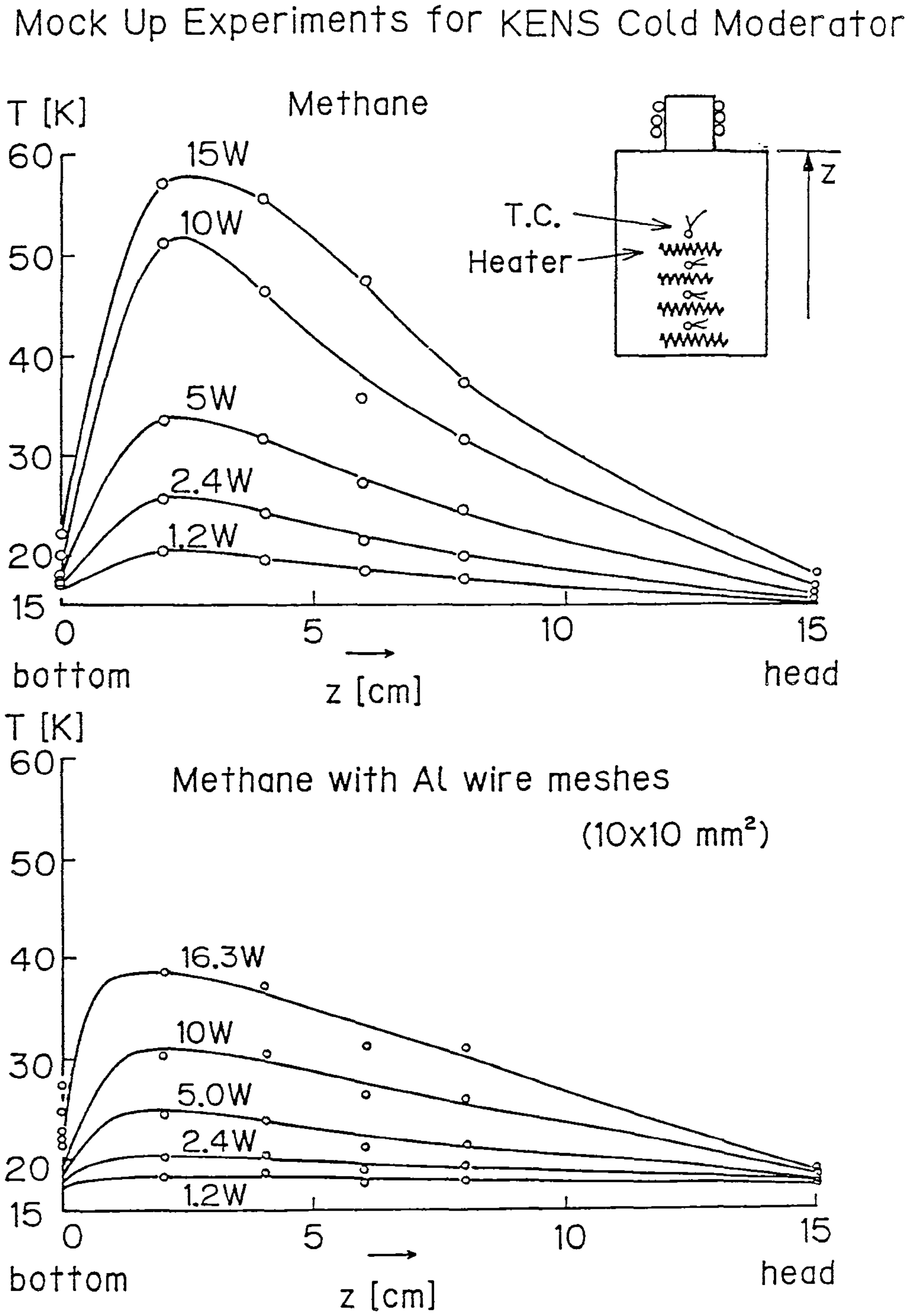

Fig. 4. Temperature distribution inside KENS-I methane cold moderator in case of higher heat deposit (a) without Aℓ wires. (b) with 1 mm ϕ Aℓ wire lattice (10 x 10 mm^2)

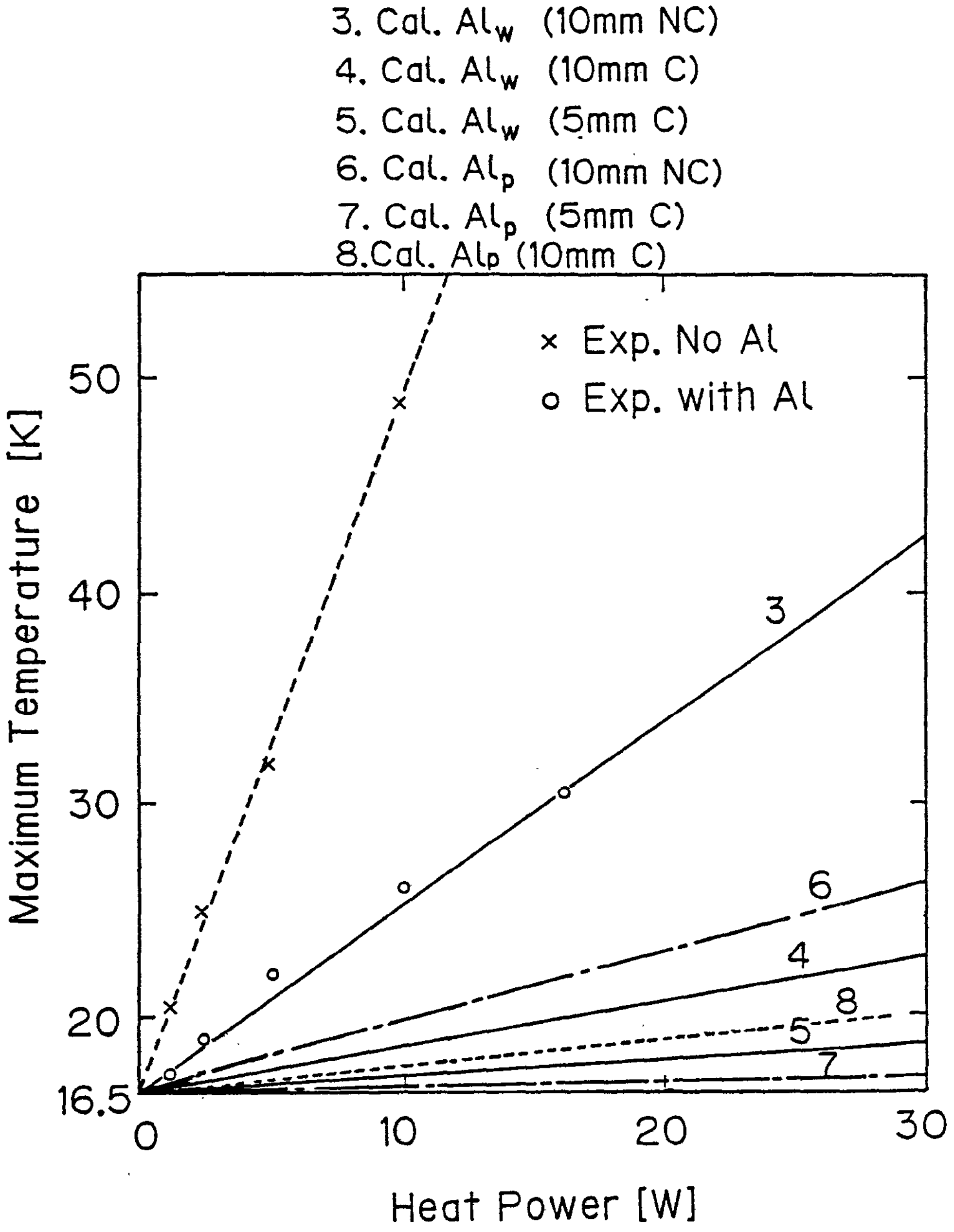

Fig. 5. Simulation calculation of maximum temperature inside solid methane for several different cases and comparison with the experimental results
Aℓw (10 mm NC): 1 mm ϕ Aℓ wires lattice 10 x 10 mm^2 with poor thermal contact with the refrigerator
Aℓ P (5 mm C) 0.5 mm thick Aℓ plate lattice 5 mm apart with good contact with the refrigerator

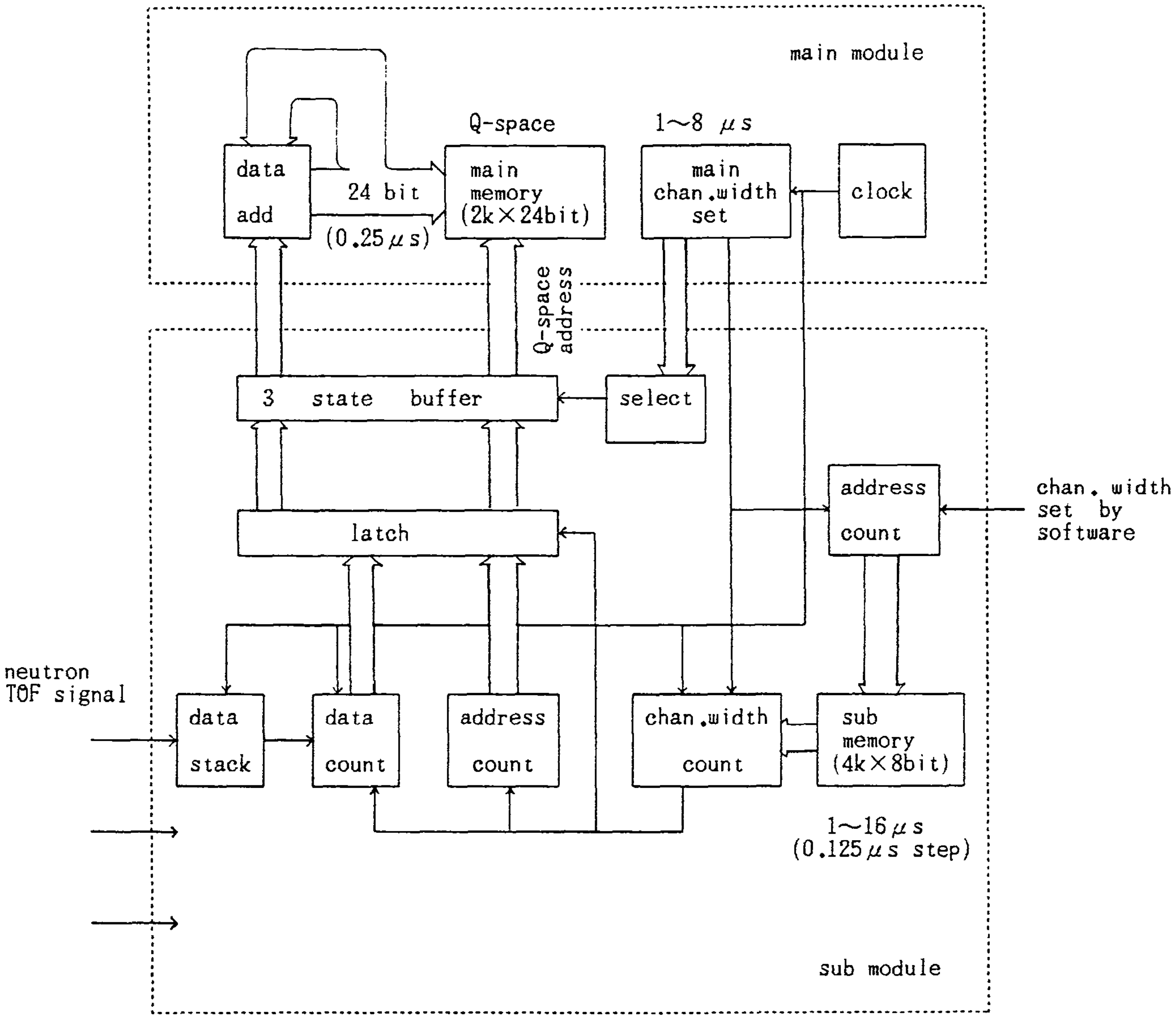

Fig. 6. Block diagram of CAMAC module for hardware time-focussing

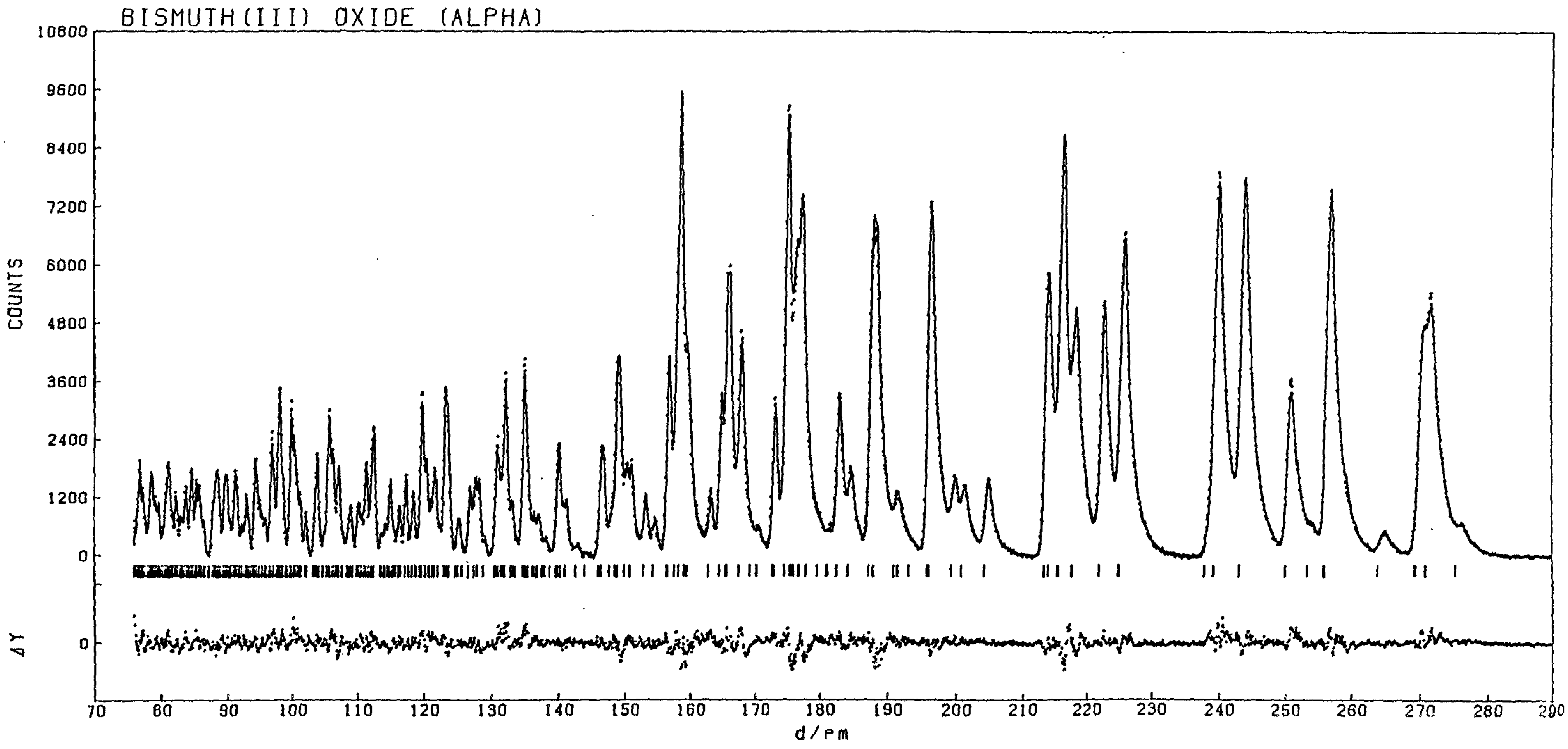

Fig. 7. Powder diffraction patterns taken by HRP with Riesvelt profile

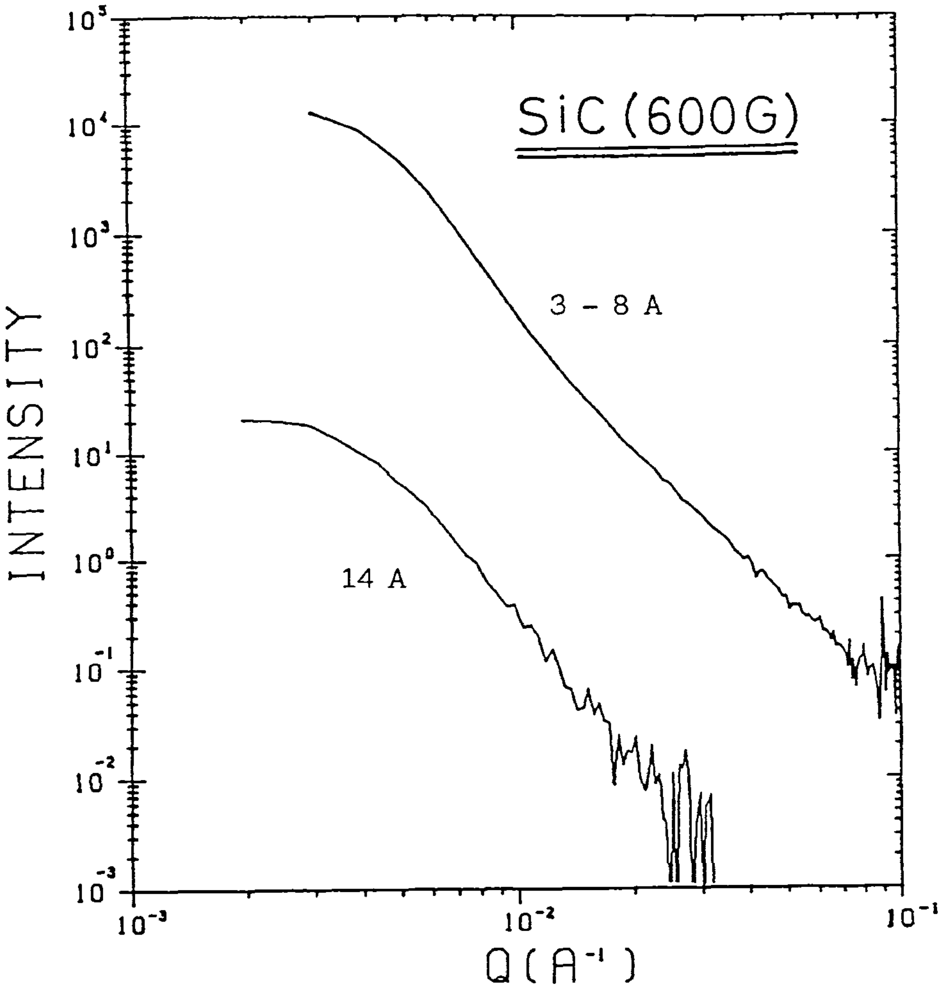

Fig. 8. A preliminary result of small angle scattering from SiC (600 G) measured by employing a band of wavelength between 9 and 15 A can comparison with a previous measurement

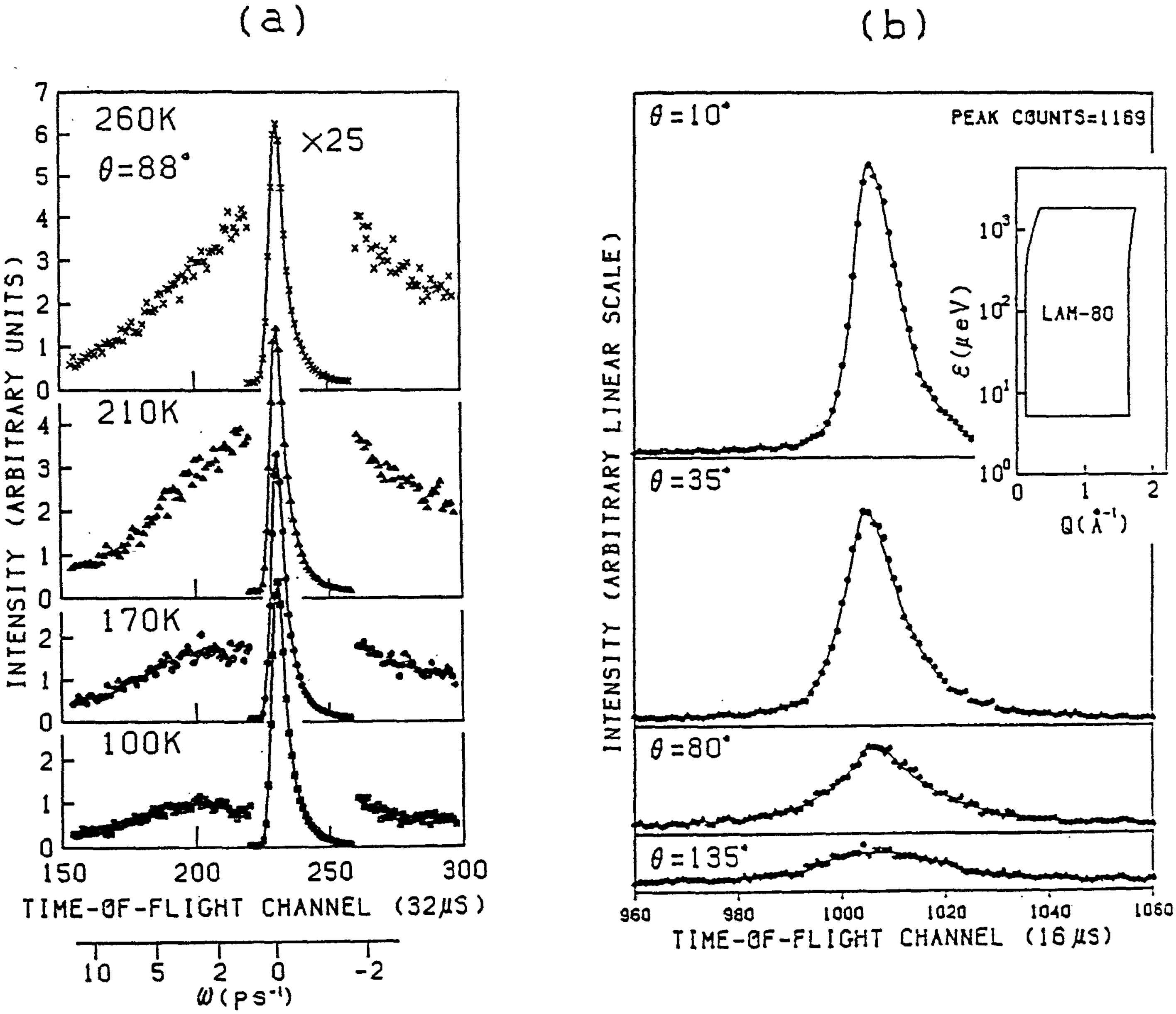

Fig. 9. Time of flight spectra from poly (butadience), measured (a) with LAM-40 at various temperatures, and (b) with LAM-80 at a temperature below meeting point

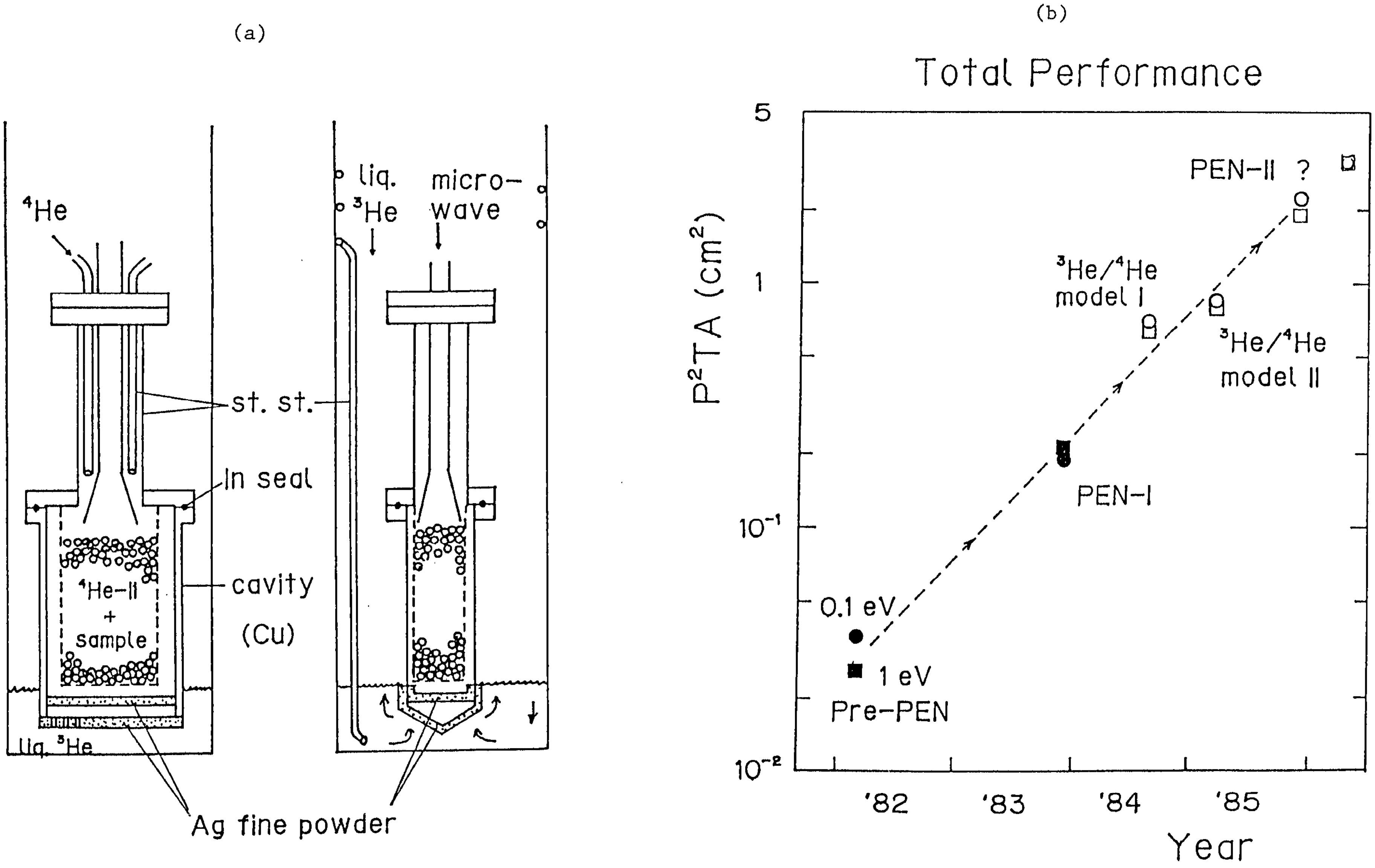

Fig. 10. ^{3}He/^{4}He heat exchange cooling system newly adopted for polarizing proton filter of PEN (a) and improvement of quality factor $\eta = P^2TA$ of polarizing proton filter plotted against the year of measurement (b)

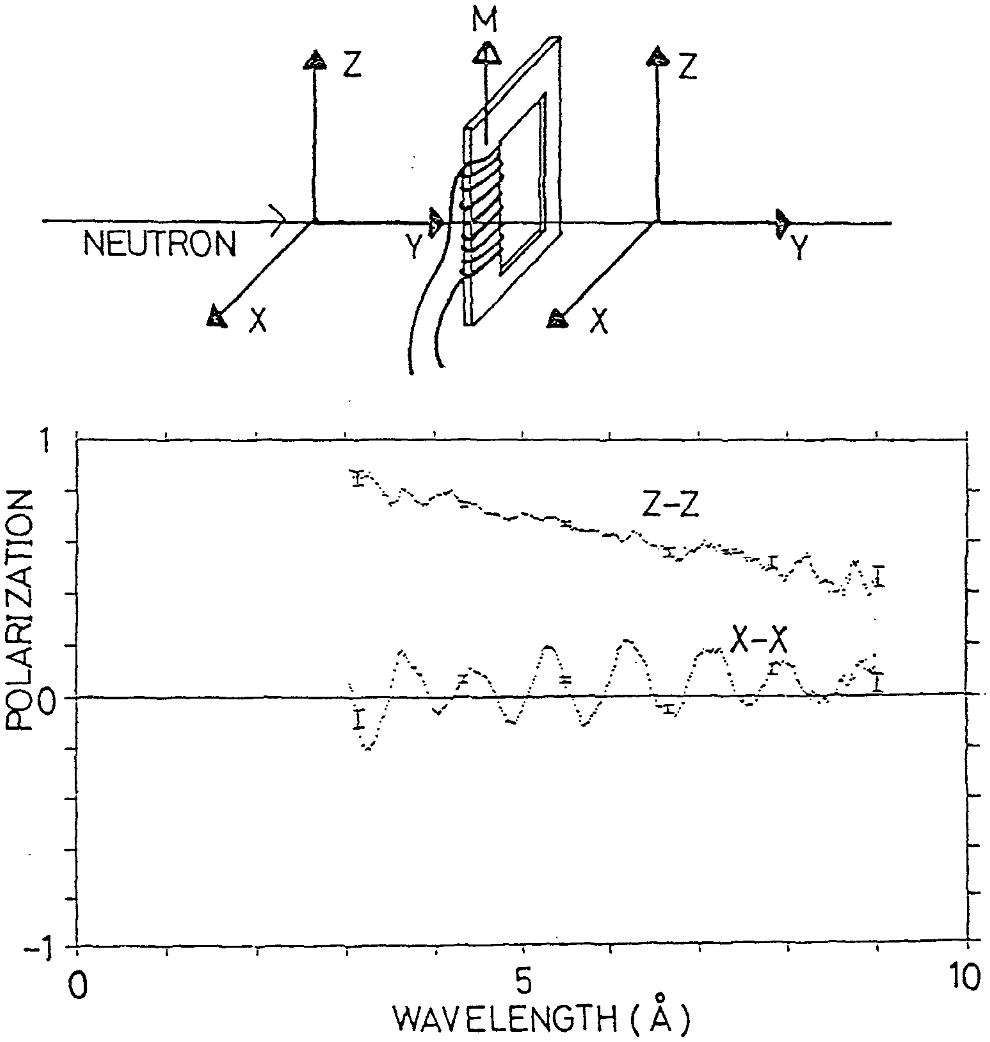

Fig. 11. A preliminary result of three dimensional polarization analyses of polarized neutrons transmitted through the frame shape re-entrant spin glass $Fe_{0.7}Al_{0.3}$

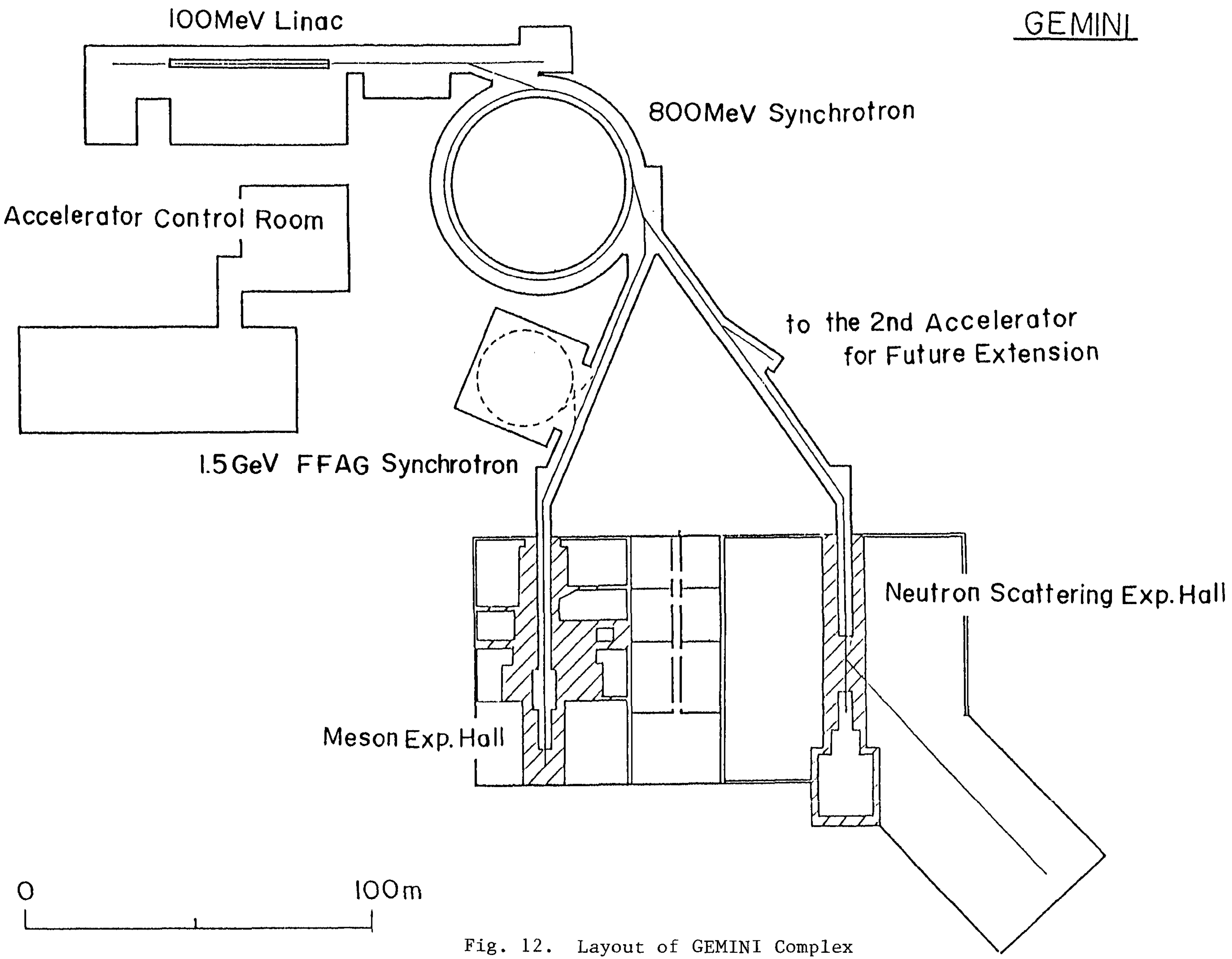

Fig. 12. Layout of GEMINI Complex

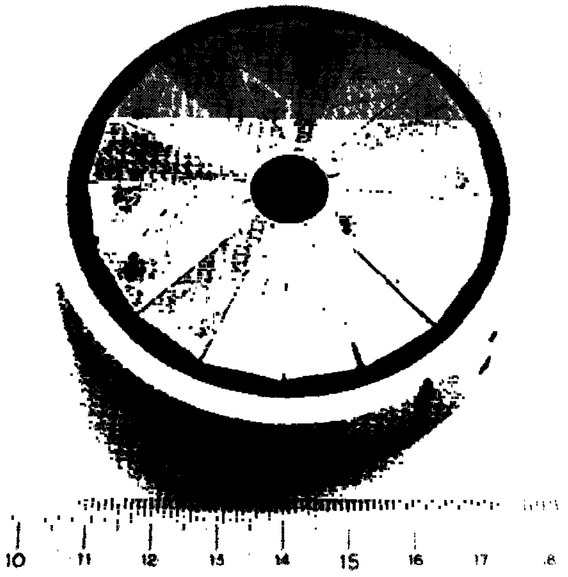

Fig. 13. A segmented ring-shaped permanent quadrupole magnet built in the drift tube of the 400 MHz 100 MeV injector linac

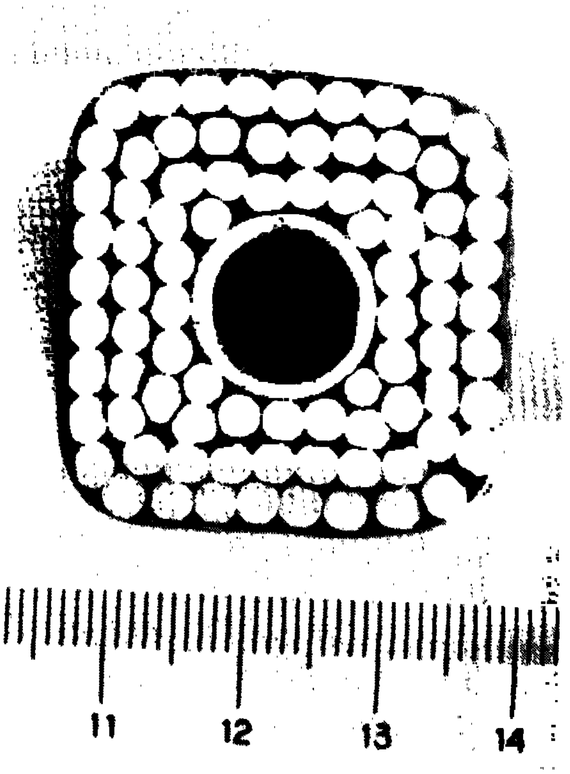

Fig. 14. Cross sectional view of the stranded cable for exciting GEMINI synchrotron magnet