Edited by A Carne

1. INTRODUCTION

The overall programme for the Workshop on Target Assembly/Target Station
had been presented to the participants prior to the Workshop. It had the
form of an organogram showing the links between the main areas, with final
links to a) Instrument and b) Operational Requirements. This programme
was largely followed, as the timetable, figure 1. shows.

The aims of the sessions were:

   i)   to recognise problems that could be studied within the
         timescale of the week.

  ii)   To recognise problems that could be resolved during the
         weeks and months immediately after the workshop.

 iii)   To exchange information and experiences on the various
         aspects and to compare solutions to common problems.

An Action Sheet shows the work recognised under points i) and ii) above.
It shows two problems were resolved during the week, also the many more
to be dealt with in the near future. The main purpose of the Action Sheet,
however, is to help maintain the momentum that was generated during the
week and to keep this area of ICANS a continuing collaboration.

As far as point iii) is concerned, a Report list is provided of the reports
made available during the meeting. (Participants requiring individual reports
are advised to obtain them from the Authors.) In the following sections are
presented summaries of the various sessions.

2 CODES

2.1 Neutronic

a) TIMOC. RL uses the TIMOC[1] neutron transport code which was originally developed at Ispra for the design of the SORA pulsed reactor. It has been installed on the Rutherford Laboratory IBM 360/195 computer. The code used cross-section data from the ENDF/B library (via the CODAC code) and may be used for time-independent or time-dependent neutron flux calculations.

A code validation exercise was carried out in August 1977, when the code was used to predict the ϕ (1eV) flux for various geometries used in the MUSTA benchmark experiments. The detailed results for the 10 separate geometries are given in the MUSTA description. Overall the fluxes predicted by TIMOC appeared to be systematically 15% higher than those observed, and had a random variation, $\delta \sim 15\%$.

Recently a new code, THERMAL[2], has been written which calculates the matrix of scattering probabilities between the thermal region energy groups (for H_2O or $(CH_2)_n$). This matrix may be included in the cross-sections used by TIMOC to produce more realistic neutron transport in the thermal region. The results for ϕ (ε,t) obtained by this method are presently being compared with expected energy and time distributions.

[1] H RIEF, R JAARSMA, EUR 5016e.
[2] M W JOHNSON, Unpublished work.

b) NMTC + MCNG. LASL (WNR) uses the NMTC + MCNG program package. Results from the package are described in the Report list, nos 6 and 7. The package includes time dependence in neutron transport, also gamma transport and energy deposition. Thermalisation is not included. NMTC is used as a source for MCNG. Future work to be done includes the effects on the neutron time pulse of reflector and decoupler. Generally the codes are due for updating.

c) Comparison of NMTC/MCNG with TIMOC. The results of the two cases were compared during the meeting, the TIMOC code using the RL IBM 360/195. The WNR target geometry was used, for which the neutron fluxes

time dependence in the epithermal energy range were compared.
The results are satisfactorily similar. The comparison is described
in the Report list, no.20, and appended to this report (pp 24-28).

2.2 Target

a) HETC. RL uses the HETC program package which, although working, is
not fully operational as it cannot, yet, satisfactorily reproduce
experimental data.

A flow-diagram for the package is shown in Fig. 2. The boxes at
the bottom of the figure indicate the general areas where results
are wanted. The two main-line codes HET and O5R share a common
geometry package which allows simulation of layouts in a realistic
way. Gamma transport is not implemented yet, and is included with
dashed lines to show its relationship with the overall calculation.

The major changes introduced are:

A.   fission into HET
B.   a revision of the fission treatment
      in O5R
C.   the use of ENDF/B IV neutron cross-section
      data with O5R

Fission is modelled in HET by allowing competition with neutron
emission at all stages of the evaporation, that is fission occurs
after the high energy intranuclear cascade is complete. Computation
with the model is made by using the systematics of fission in the
literature for both probability and post fission parameters. The
significance of including fission may be judged from the following
results (Note: that all refer to production at the HET stage and
require the transport to the target surface by O5R for completion);
the neutron spectrum contained an overall increase of 30%, with an
increase of $\sim$ 60% for those above 2 MeV. The average total fragment
recoil energy is $\sim$ 160 MeV and leads to a factor of $2\frac{1}{2} \rightarrow 3$ on energy
deposition.

For O5R a modified weighting scheme is used for fission neutrons,
plus the following of the whole 'fission-cascade' in a single run.
The records for the history tape have been extended to carry extra
information particularly to allow energy density analysis.

The cross-section group averaging code XSECT has been replaced with a new code, XSCEND, developed at the Rutherford Laboratory. This allows use of ENDF/B cross-section data. Much of the data is in resonance parameter form, these are unfolded before group averaging. We note that we need to introduce Doppler broadening to this data.

The code gives excellent agreement with experiment for nucleon-nucleon scattering (Table 1 and Figs 3 and 4).

First checks with nucleon nucleus data shows significant disagreement; for the ^{59}Co (p, spallation) system at 370 MeV the code seems to evaporate $\sim$ 20% too many nucleons. The isobaric yield curves are displaced significantly from the experimentally determined systematic of Rudstam[1] (Fig. 5).

The conclusion at this stage of checking, is that the evaporation parameters used in our version of the code do not form a matched set and will need correcting. The effect of altering the coulomb barrier penetrability (to 75% and 60% of the programs current value) and the level density parameter from A/8 to A/14 is also shown in Fig. 5. This conclusion ties in with the suggestion by Russell (LASL) that the predicted neutron spectra seems too soft.

[1] G RUDSTAM, Z Naturforschung 21A, 1027 (1966).

b) HETC + VEGAS CODES on Mass Distribution. During discussion on codes it was suggested that the BNL intranuclear cascade/evaporation code VEGAS was better than that of HET.

In 1972, the results of a 'code-battle' were published[2]. Comparative calculations on two systems, ^{27}Al(p, spallation) and ^{181}Ta (p, spallation) at 150 and 300 MeV were made using VEGAS, the Bertini code (used by HET) and a third code from Dubna.

The conclusions of this study were that despite model differences these codes gave results which were in good agreement with each other. Particularly the residual mass distribution agreed well despite excitation and prompt particle energy differences.

The conclusion must be that there is (up to 1972) no reason for expecting the VEGAS code to be better than HET.

It was agreed that LASL try and find out if any subsequent modifications have been made which alter this conclusion.

[1] K CHEN et al., Phys. Rev. 166, 949 (1968); 176, 1208 (1968); C4, 2234 (1971).

[2] W S BARASHENKOV et al., Nucl. Phys. A187, 53 (1972).

c) NMTC + MCNG. LASL (WNR) uses this package as described above.

3. PHYSICS DESIGN OF TARGET/MODERATOR/REFLECTOR ASSEMBLY

3.1 Target Assembly Studies for SNS at RL

Several candidate geometries exist for the SNS target assembly. A four moderator Wing geometry utilising the reference target design was described. Calculations have shown that a penalty $\sim$ 2 is found between a moderator viewing the front and rear of the target in a reflected geometry. Losses of only $\sim$ 10% in the intensity of a single faced front moderator are incurred by:

a) opening up both faces of the moderator

b) replacing downstream reflector by a rear moderator.

The decoupling energy in these calculations was 170 eV. This configuration provides considerable flexibility, eg 4 moderator types and 8 moderator faces are available to match to the 18 proposed beamlines; orientation of the moderators with respect to the proton beam allows maximum utilisation of the experimental hall. Other geometries are possible, including a slab system ($\sim$ 50% gain in intensity but with less flexibility) and a Slab/Wing combination. The choice of the final system is yet to be made.

WNR reported no instrumental difficulties in viewing their target through the moderator. They will report the effect of going to an offset beam.

3.2 Cold Moderator Studies for KENS

Several tests have been performed to obtain the optimum cold moderator and cooling system geometry, using an electron linac and lead target. A solid mesitylene moderator (similar to solid methane at 20K) was placed 5 cm above the target and the neutron flux density was measured as a function of vertical distance h. The results, for 3 different moderators,

are given in the Report list, no.1, showing that the neutron peak intensity is insensitive to h (at about 4 cm) when the moderator broad dimensions exceed 10 cm. However the distance between target and moderator is very important.

A solid mesitylene moderator at 20K, 3 cm thick by 10 x 10 cm^2 gave a neutron flux with a peak at about 3 meV with $E(\phi)_{max}/E|_{1ev} \sim 10^3$. The pulse width was 80 μsec (FWHM) at 4 Å. The moderator was surrounded by Be, and Cd decoupler was used.

4. TARGET/MODERATOR/REFLECTOR. BENCHMARKS AND EXPERIMENTAL RESULTS

4.1 Mock-Up Experiments at RL

Static measurements have been made using a small Ac-Be source on reflected and unreflected moderator configurations. A full description is given in the RL report RL-77-140/A.

A full scale dynamic mock-up experiment on Nimrod, MUSTA, has been performed, the main details of which are given in the Report list, no.18. A comparison with TIMOC shows good agreement and establishes TIMOC as an operational code in SNS design optimisation. Details of fast neutron production in uranium and lead targets are given. Pulse widths extracted by diffraction from the (220) planes of beryllium were found to be in agreement with data from a poisoned moderator on the Harwell linac.

4.2 LASL-WNR Operation, Development and Experiments

The emphasis of effort at the WNR facility is moving away from major construction to reliable facility operation. The fast kicker system is in the shakedown phase. The target/moderator cooling and borated water decoupling systems for target 1 have been recently implemented. Two types of moderators are available for experimenters:

a) the low-power water cooled CH_2 moderators have been used successfully when the energy deposition in each of the two pieces is $\leq$ 20 watts; this corresponds to 0.2% of LAMPF, at design intensity, striking the WNR Ta target.

b) high-power Al canned H_2O moderators have also been built to accept higher fractions of the LAMPF current on the WNR target.

The vacuum inside the target 1 crypt is routinely kept at $\sim$ 30 microns. The fast chopper system is being modified to enable the selection of a single LAMPF micropulse every microsecond. For high-energy (bare target) neutron experiments this could mean a proton repetition rate as high as 4000 Hz.

The WNR has been operated routinely at 1.6 μA average current which is about a factor of 6 below design level. The proton current will be increased as rapidly as possible.

WNR Development and Experiments

An attempt will be made to simplify the design of the WNR target canister. Measurements are in progress to obtain absolute thermal and epithermal neutron flux distributions from the WNR moderator. The angular distribution of thermal neutrons from the WNR moderator will also be measured.

The objectives of the Fertile-to-Fissile Conversion (FERFICON) program using LAMPF/WNR is as follows:

- Measure neutron leakage from Pb, Th, and U targets
- Measure fertile-to-fissile conversion efficiency in Th and U targets
- Measure energy deposition in Th and U targets
- Compare experimental results with calculated predictions.

Neutron/proton measurements have been made on a 9.85 cm dia. by 40.7 cm long Pb and 10.0 cm dia. by 40.7 cm long depleted U targets; data reduction and analysis are proceeding. See Report list nos. 8,9.

Work on cold moderators should be started in the near future.

4.3   ZING-P'. A summary of the measurements taken on ZING-P' is given in the Report list, no. 10.

4.4   Target-Moderator-Reflector Mock-up Experiments for KENS. Several Target-Moderator configurations were tested both for bare and reflected systems. Moderators used were of polyethylene; Cd was used as decoupler (though future measurement will use B_4C); the reflector used has graphite, though a small amount (about 6 litres) of BeO was used close to the target and moderators. The "target" was an Am-Be source. The results and comparison with similar measurements made elsewhere are given in the Report list, no. 3.

The values of $E\phi(E)$ at 1eV measured by KENS, IPNS and RL(SNS) give the following values for target-moderator-reflector coupling efficiency (n ster^{-1}n$_p$$^{-1}$ per 100 cm^2 moderator face):

(KENS) 8×10^{-4}; (IPNS) 4×10^{-4}; (SNS) 2.5×10^{-4}

The high value given by KENS is partially accounted for by the use of Cadmium as a decoupler (E_d = 0.5 eV). Details of the IPNS calculation were not available and the discrepancy was not resolved.

5. BULK SHIELDING, BEAM PORTS AND PLUGS

The various pulsed neutron source projects are at differing stages of development and the states of the bulk shield designs reflect this. The WNR shield is complete and neutron experiments are in progress. The performance of the shield has been measured and has demonstrated that the design method - of using Monte Carlo neutron cascade calculations - has been highly successful. The detailed design of the KENS shield is complete and includes some work on the performance of the shield close to the beam tubes. These effects were not included in the WNR design. The SNS bulk shield design is in its early stages and preliminary calculations have been made on the gross dimensions of the shield. Shielding layouts for IPNS-1 show the neutron scattering and irradiation effects target to be within the same shielding assembly.

5.1 Bulk Shield at LASL

Detailed Monte-Carlo calculations were done for various configurations and materials. Codes used were the NMTC intra-nuclear cascade model transport code for particle energies above 20 MeV, and MCN, the standard code used for neutron transport at Los Alamos for energies below 20 MeV. Changes were made in the codes to make them more compatible, but extensive experimental tests of the codes were not performed. Statistical uncertainty in dosage results is $\sim$ 20%, but no estimate of accuracy is claimed beyond a qualitative "factor of two".

a) Choice of Material

Iron and lead were compared, and found to have nearly the same attenuation length. Iron was chosen as the most cost-effective high density material for the bulk shield. Because of cross-section windows, especially at 26 keV, there must be some other element as well. Calculations for the ING had recommended a hydrogen content of 0.008×10^{24}/cm^3; LASL considered

various ratios of H/Fe, and settled on a smaller value to keep the average density higher. From construction considerations, a mix was used of 64 parts steel to 9 parts heavy concrete to 1 part void (by volume), for a net H content of $0.00073 \times 10^{24}/cm^3$ and an average density of $7.22 \ g/cm^3$. The outer 30 cm layer of the shield is heavy concrete containing boron glass frit.

b)   Shape of Shield

The WNR proton beam is directed vertically downward, striking a heavy metal target viewed by horizontal beam tubes. The shielding is therefore a vertical cylinder. Calculations immediately showed that leakage under the floor would be a major source of radiation in the experimental area. The essentially forward-directed high-energy neutrons diffuse outwards readily. The iron cylinder is therefore extended 0.75 m below floor level, and a plinth of heavy concrete 3 m thick extends below that.

c)   "Get-Lost" Hole

Three forms of forward neutron beam stop were calculated:

1)   a 91 cm diameter x 2.8 m deep hole, lined by 55 cm of iron;

2)   a naval gun barrel of diameter 41 cm and length 2.8 m; and

3)   a solid plug of Fe/concrete mix.

The difference in dose rates in the experimental area were not statistically significant. The third case - no "get lost" hole - was chosen as easiest to build. This case also minimises the possibility of radiation reaching ground water under the facility (not a problem at Los Alamos), and minimise the total amount of dense material needed. As constructed, the volume below the target is lead instead of iron.

d)   Beam-tube penetrations

The penetrations were not included in the calculations. At WNR, the beam tubes are large but generally well filled with steel, so that the actual penetrations are "small". The pipes are stepped, and the volume around the pipes was filled with poured lead.

e) Measurements

Radiation dose measurements with WNR running at about $^1/_3$ of design power have not shown measurable levels on the face of the shield, on the floor, near a closed beam path, nor near a properly shielded experiment. Levels near an unshielded open port of about 4 cm diameter were above tolerance. To date, we have not observed any discrepancies with the calculations.

5.2 KENS Shielding

The biological shield was designed so as to satisfy the following conditions:

a) The maximum dose equivalent rate at the surface of the shield in the horizontal direction is less than 0.8 mrem/hr.

b) The annual dose equivalent at the nearest site boundary should be a small fraction of the natural background radiation.

c) The maximum distance from the target to the surface of the shield should be less than 4 m; the height of the shield should not be greater than 4 m.

d) The total budget was limited.

Details of the design are given in the papers, Report list nos.4 and 5.

5.3 SNS Bulk Shield Design

Preliminary calculations have been made for the bulk shield around the SNS target. The design goal is to reduce the radiation level at the surface of the bulk shield to 0.75 mrem/hr. It may be possible to relax this requirement on the top and bottom faces of the shield when the consequences to experiments of "skyshine" and "ground shine" have been further evaluated.

The shield thickness was calculated using a neutron spectrum calculated by Fullwood et al[1]. This neutron spectrum was converted to a dose equivalent spectrum. The angular dependence of the high energy neutron spectrum was also taken from reference (1). It was found that the shield must provide an attenuation of $\sim 3 \times 10^8$ in the forward direction and $\sim 10^8$ in the sideways directions, the difference being due to the greater penetration of the high energy component which is peaked forward.

Due to the "windows" in neutron cross-sections for iron a composite
structure is envisaged for the shield with layers of iron alternating
with layers of iron loaded or boron loaded concrete. The precise details
of the composition of this sandwich will be established using the HETC
package but preliminary figures for the shield thickness is 5.3m in the
forward direction and 4.9 m in the sideways direction.

The shield will probably be constructed in two main parts. The inner
3.0 → 3.5 m being permanently cast shielding and the outer layer being
made from blocks. This may then allow easier access to collimators,
shutters etc. in the beam tubes. An attempt is being made to design
the shield in such a way that it will be possible in the future to change
the neutron beam tube layout. The most promising way of achieving this
is to have the beam tubes contained in an insert into the main shielding.
A geometry somewhat like a "pill box" is envisaged.

At present detailed design work is underway using the HETC package
investigating the following problems.

a) Details of the shield materials

b) 'Weakening' of the shield due to the beam holes

c) Energy deposition in the inner layers of the shield - is cooling
   required?

d) Incorporation of choppers, shutters and collimators

e) Skyshine and groundshine

f) The overall geometry of the shield

In addition the design will recognise the possible requirements of
facilities for non-thermal neutron users of the SNS. eg fast neutron
beams, charged particle beams, etc.

[1] "Neutron Production by Medium-Energy Protons on Heavy Metal Targets".
    R R Fullwood et al. LASL Report LA4789 (1972).

6. TARGET/MODERATOR/REFLECTOR ENGINEERING

6.1 KENS Cold Moderator

For KENS it is proposed to use a solid methane cold moderator of 130^W x
50^D x 150^H mm^3 placed 19 mm above the target. The moderator will operate
around $20^{\circ}K$, cooled by helium gas from a 40W Phillips PG105 Cryogenerator.
The heat load is not yet known in detail, but because of geometry will be
due to neutrons rather than γ-heating. Container will be of pure

aluminium (high k at 20°K), and a window will allow inspection of the methane. Cooling will be arranged to give a lower temperature at the bottom of the moderator rather than at the top to avoid deep boiling problems. A safety pump system will be installed to remove gaseous CH_4 in an emergency.

More details of the KENS proposal and the mock-up experiments are given in Report list no.1. Though methane is regarded as the best material for cold neutrons it was pointed out that for SNS intensities the lifetime of the methane would be too short.

6.2   IPNS-I Engineering System

The engineering design for IPNS-I is scheduled to begin in full in October 1978. The target will have 7 "Savannah River Modified Alloy" uranium discs, diameter 10 cm and 2.2 cm thick. The plates will be clad in Zircaloy-2, 0.254 mm thick. Coolant will be by water flowing at 1m/sec. The maximum centreline temperature will be 275°C. A tantalum target will also be built as a back-up. A status report and a summary report on target design are given in the Report list, nos.13 and 14; detailed considerations are given in reports no.12 and 16.

The neutron scattering target will have 3 moderators, but no cold moderat The radiation effects and neutron scattering targets will be the same to allow easy interchange. The cooling systems will be redundant for each other. A layout drawing was presented (see Report list, no.17).

In operation, it is proposed not to shut-off Booster II in the event of a target fault, but to divert the beam to a beam dump.

6.3   SNS Target System

The proposed SNS target will use "Springfields Adjusted" uranium, in plates of thicknesses in 4 batches of 5 mm to 10 mm. Cladding will be Zircaloy-2, 0.254 mm thick. The coolant will be D_2O so that the target containment vessel cooling wings can also serve as reflector. The cooling gaps will be 2 mm wide, but will be allowed to reduce to 1.5 mm under plate irradiation swelling. The target plates will be curved to a large radius to resolve non-uniform buckling throughout the pack. The target containment vessel will be of Inconel 718 to resolve radiation damage to the window.

A series of nucleate boiling tests have shown burn-out safety factors greater than 3 on the proposed nucleate boiling regime, of static pressure 2.6 bars, bulk temperature $30^{\circ}C$, flow rate 12 m/sec.

In view of potential problems of quasi-static and cyclic stress the target parameters are under review - including the type of uranium alloy and centre-line temperature.

6.4 Hybrid Moderator Systems

Kley (Ispra) proposed a hybrid moderator system in slab geometry. The beam and target would be "flattened" to ensure strong coupling to the moderators. The proposed beam profile is $10(v) \times 1(h)$ cm^2; the target dimensions roughly $12(v) \times 2(h)$ cm^2 by 20 cm long. The target would be a stainless-steel walled vessel packed with uranium plates, cooling by vertical flow of water. Above and below the assembly would be Be reflector 4-5 cm thick, at each end would be Be and H_2O (poisoned ?) agai 4-5 cm thick. Two moderators are proposed:

a) Thermal and cold neutron source. The moderator would have a water section with a curved face, plan dimensions 12×4 cm^2, and a true cold section with hydrogen at 20K. This combination is then faced with a large Be or C single crystal also at $20^{\circ}K$. Beam ports viewing the moderator would have diameter 15-20 cm normal to the moderator:at other angles 10 cm diameter. The combination of large coupling and thin cold section maximises the ratio of flux to pulse width. A practical feature is the reduction of cryogenic heat load sincethe major part of thermalisation is taken by the water part of the moderator.

b) Epithermal-thermal neutron source. In this case the water section is considerably reduced and the true moderator consists of 4-5 cm thickness of (A) Titanium hydride at $600^{\circ}C$, or (B) Zirconium hydride at $850^{\circ}C$, or (C) Yttrium hydride at $1200^{\circ}C$. The moderators are held under 1-4 atmospheres pressure of hydrogen: cooling is by hydrogen plus helium gas flow. Beam ports viewing the moderator are as in (a).

Bauer (Jülich) suggested a slab geometry system for the SNS. The target would be similar to that proposed by Kley and using vertical flow cooling. On each side of the target would be one parallel slab and two angled slab moderators. The advantages of such a system are:

1.   3 beam lines per moderator giving the planned 18 beam lines
2.   Easy horizontal target removal
3.   Good coupling to give good neutron beam intensities.

7.   SAFETY, OPERATION AND DISPOSAL

Overall safety studies of all of the systems at the various laboratories will be required as the designs become firm. All systems, in part or as a whole, will require appropriate formal safety assessments and documentation. Though the laboratories have different approaches to particular areas, it was agreed that for reference purposes safety related documents should be exchanged amongst ICANS members.

Disposal was not discussed in any detailed way.

7.1 IPNS-1

Conceptual designs for the removal and insertion of targets are being evaluated. Basic requirements include:

i)   ability to change targets and moderator/reflector assemblies independently
ii)   need for a single system to permit rapid change to enhance operating efficiency.

The latter requirement is necessary since target assembly optimisation to match experimenter's needs may not be readily possible through calculations. Failures can be expected; and experimentation with different configurations will be needed for future optimisation studies.

Diagrams were presented of several target and T/A removal schemes, the preferred target removal system using linked discs, horizontal

at the target becoming vertical through a tube of generous radius, as detailed in Report list, no.17.

The work expended on IPNS-I is expected to establish a precedent for IPNS-II and similar systems.

7.2 WNR

Some aspects of WNR operation have been discussed in 2.3 (b) above. Difficulties have been experienced with the final HARP monitor. At present a thermocouple embedded in the Ta target is being used as a beam monitor where the beam is tuned for maximum temperature. There has not been sufficient running time to see deterioration in the performance of the thermocouple.

Details of the existing WNR handling system are shown in the Report list, no.21. It is hoped to replace the present system by having disposable targets rather than just individual parts.

7.3 SNS

It is proposed to cantilever the Target Assembly from a massive removable shielding door. By withdrawing the shielding door in a downstream direction the target assembly is brought within a Hot-cell equipped with remote manipulators. The aim is to build the target assembly in as "standard" way as possible with all functions compatible with the requirements for remote handling. At shutdown target activity is expected to be of the order of 10^5 curies.

A full scale model of the target assembly was presented, showing the stages of breakdown to give access to the separate components.

ACTIONS ARISING FROM TARGET ASSEMBLY/TARGET STATION WORKSHOP:
ICANS MEETING 10-14 JULY, 1978

	ACTION	TITLE
1.	RL	Use TIMOC code on LASL Target/Moderator geometry to compare with NMTC/MCNG results.
2.	RL	Time dependence calculations on polythene moderator, rather than H_2O, to check time dependence given by G Russell as standard deviation $\sigma(ns) \sim 654/E^{0.457}$ with E in eV. (These two actions were completed during the ICANS meeting.)
3.	LASL	To repeat calculations on LASL Target Assembly with decoupler to check effects of decoupler strength on time pulses in reflected system.
4.	RL/LASL	RL to obtain a version of MCNG code for gamma transport and comparison purposes.
5.	LASL	To transmit information on recent LASL FERFICON MEASUREMENTS also on future thin target measurements, for code checking.
6.	RL/LASL	Mass split predictions of HETC to compare with LASL VEGAS code.
7.	LASL	NMTC/MCNG check on HETC prediction for evaporation neutrons for $^{54}Co(p,$ spallation) at 370 MeV.
8.	LASL	Experimental determination of thermal neutron distribution over face of moderators.
9.	LASL	Send data on latest radiation survey to RL, including effects of mis-steer of the beam ($7\frac{1}{2}$ nA lost).
10.	LASL	Information on Beam Plug design to RL.
11.	LASL	To provide information on neutrino fluxes from beam dump experiment.
12.	KENS	To seek to obtain Cascade neutron spectra 800 MeV p on W, Ta (also possible ^{238}U ?), (Watanabe).
13.	ANL/LASL/ RL	Exchange Safety Analysis Reports or Functional Specifications as mutual aids in developing safe operational systems for Target Stations.

REPORTS AVAILABLE AND/OR RECEIVED AT TARGET ASSEMBLY/TARGET STATION SESSIONS

1. "KEK Neutron Source and Neutron Scattering Research Facility", Y Ishikawa and N Watanabe, Tohoku University, Japan. July 1978.

2. "Application of 500 MeV Proton Beam from KEK Booster Synchrotron to Neutron and Meson Physics and Medical Use", H Sasaki, Natl. Lab. for High Energy Physics, Japan. July 1978.

3. "Target-Moderator-Reflector Mock-Up Experiments for KENS", N Watanabe, M Misawa and S Yamaguchi, Tohoku University, Japan.

4. "Shielding Design for KENS", N Watanabe, K Katoh and R H Thomas. Note 6, KEK-78-7, July 1978.

5. "Transverse Shielding for KENS:II", R H Thomas, Note 5 KEK78-7, 1978.

6. "Initial Target/Moderator Configuration, WNR Facility", G J Russell, Trans. Amer. Nucl. Soc. 27, Pbl. 1977.

7. "Calculated Neutron Leakage Characteristics for WNR (as built) Ta Target", Office Memo. G Russell, LASL, May 1978.

8. "Status of FERFICON using LAMPF/WNR", G J Russell, LASL, May 1978.

9. "Accelerator Breeder Target Neutronics AECL's Underlying Research Program", P M Garvey et al. (1978).

10. "The ZING-P' Neutron Source", K Crawford, ANL.

11. "IPNS Target Optimisation Studies", S Das and T Worlton, ANL, June 1978.

12. "Evaluation of Target Materials and REcommendations for IPNS-1", B A Loomis, ANL, 1978.

13. "Target Design: Introduction and Objectives", (notes of) N Swanson, ANL, July 19

14. "Target Station Status, IPNS", (notes of) N Swanson, ANL, July 1978.

15. "IPNS Design: Health Physics on Booster II", R L Mundis, ANL, June 1978.

16. "IPNS-1 Target Cooling Conceptual Design", L Carlson, ANL, June 1978.

17. "IPNS-1 Target Handling Concept Drawings, 1st set", N Swanson, ANL, July 1978.

18. "Spallation Target-Moderator-Reflector Studies on Nimrod", RL, July 1978.

19. "Sketches for Proposed Hybrid Moderators for SNS", W Kley (Ispra) July 1978.

20. "Comparison of WNR Proton/Neutron Transport Codes with TIMOC", M W Johnson and A Taylor. ICANS Meeting, July 1978.

21. "Characteristics of WNR and Target System", Transparencies, G J Russell, LASL.

	1000 MeV		380 MeV	
	HET	EXPT.	HET	EXPT.
σ_{TOT}	47.8	47.55	23.5	24.4
$\sigma_{el.}$	26.5	$\left\{\begin{array}{l}26.8\\28.2\end{array}\right.$	22.2	?
$\sigma_{pp\pi^{o}}$	3.4	3.7	0.02	0.05 (?)
$\sigma_{pn\pi^{+}}$	17.9	17.2	0.26	0.3→0.4
$\sigma_{pp\pi^{o}\pi^{o}}$	~ .02	?	0.0	0.0

p-p Scattering cross-sections

	630 MeV		200 MeV	
	HET	EXPT.	HET	EXPT.
σ_{TOT}	39.1	37	41.6	$\left.\begin{array}{l}\\ \\\end{array}\right\}$42.7
$\sigma_{el.}$	27.6	26 ± 3 @ 576	41.6	
$\sigma_{np\pi^{o}}$	7.4	?		
$\sigma_{nn\pi^{+}}$	1.9	?		
$\sigma_{pp\pi^{-}}$	2.2	1.68 @ 600 ~ 2.4 @ 780		

n-p Scattering cross-sections

[Hydrogen target: 2 cms dia. x 10 cms:0.04264 nuclei $\mathring{A}^{-3}$, axially illuminated.]

TABLE 1 : COMPARISON OF HET RESULTS WITH EXPERIMENT

	TUESDAY 11th	WEDNESDAY 12th	THURSDAY 13th	FRIDAY 14th
MORNING	TARGET — HETC αVARIANTS SPECIFIC EFFECTS (h e fission) CODES TARGET, REFLECTOR, MODERATOR CODES (i) TIMOC (ii) MORSE (iii) VIM (iv) MCMP	TARGET/MOD/REFLECTOR BENCHMARKS (EXPERIMENTAL RESULTS) (I) MUSTA — A Taylor (II) WNR — G Russell (FERFICON) (III) ZING-P' — N Swanson (IV) KENS — N Watanabe (V) OTHER EXPERIMENTS	TARGET/MOD/REFLECTOR HARDWARE ENGINEERING (MOD/REFL) (I) COLD MODERATOR (En Dep) Y ISHIKAWA (KENS) G RUSSELL (LASL) R WIMBLETT (RL) TARGET ENGINEERING TEMP, STRESS, GROWTH (N SWANSON)	VISIT — AERE LINAC
AFTERNOON	TARGET ASSEMBLY PHYSICS DESIGN FAST NEUTRON → THERMAL NEUTRON MODERATOR → INSTRUMENTS (OPTIMISATION)	BULK SHIELDING etc (I) SNS — T Broome (II) WNR — P Seeger (III) KENS — N Watanabe	SAFETY, OPERATION & DISPOSAL (I) ANL — N SWANSON (II) LASL — G RUSSELL	(1) SUMMARIES (II) FUTURE COLLABORATION
ODDITIES AND SPECIAL REQUIREMENTS			4.30 AERE LINAC DESCRIPTION p.m. BEAM LAYOUT → INSTRS REQUIREMENTS	

FIG: I TARGET ASSEMBLY/TARGET STATION PROGRAM
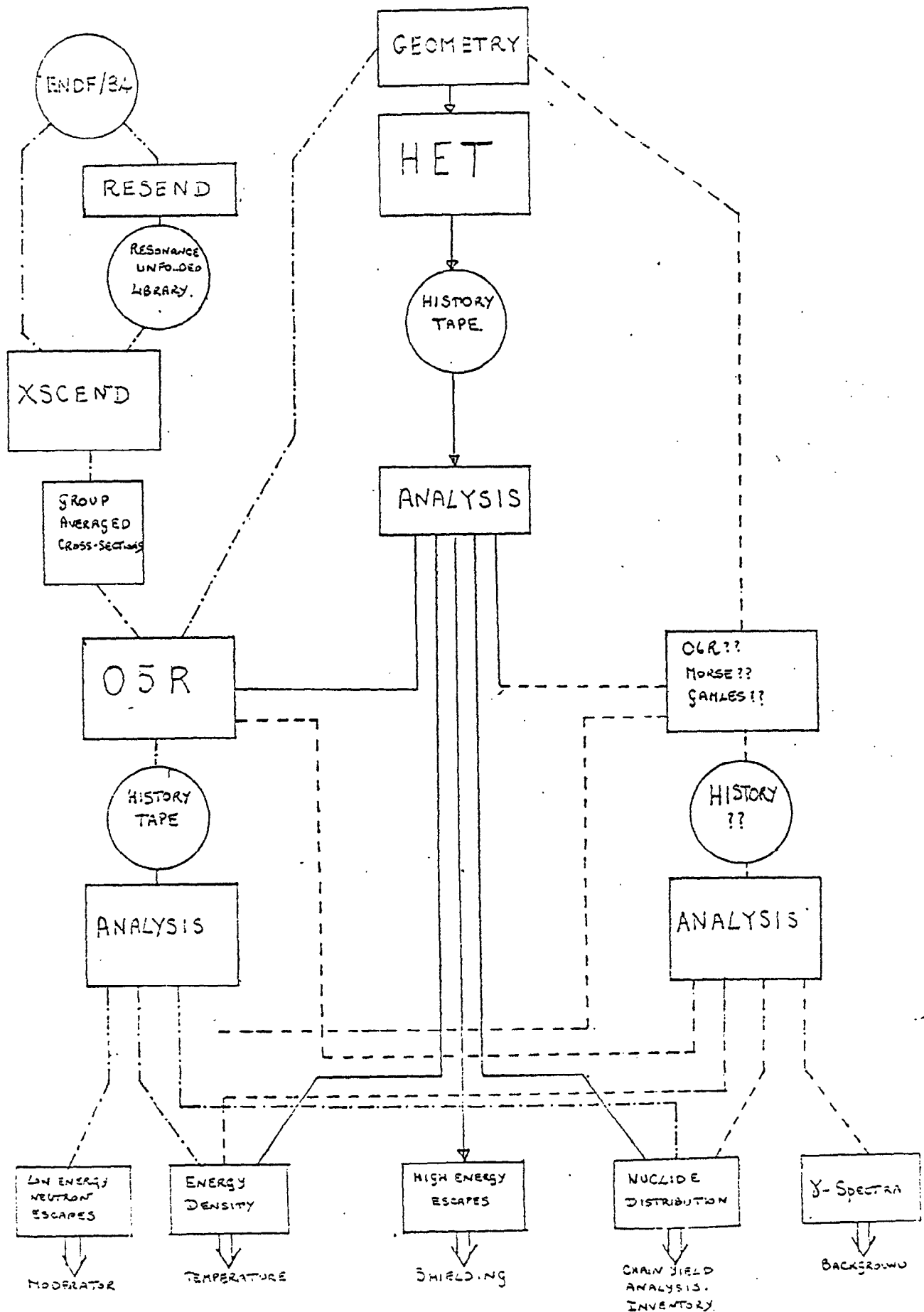
19.

FIG.2: HETC Program, Flow Diagram for Target Calculations
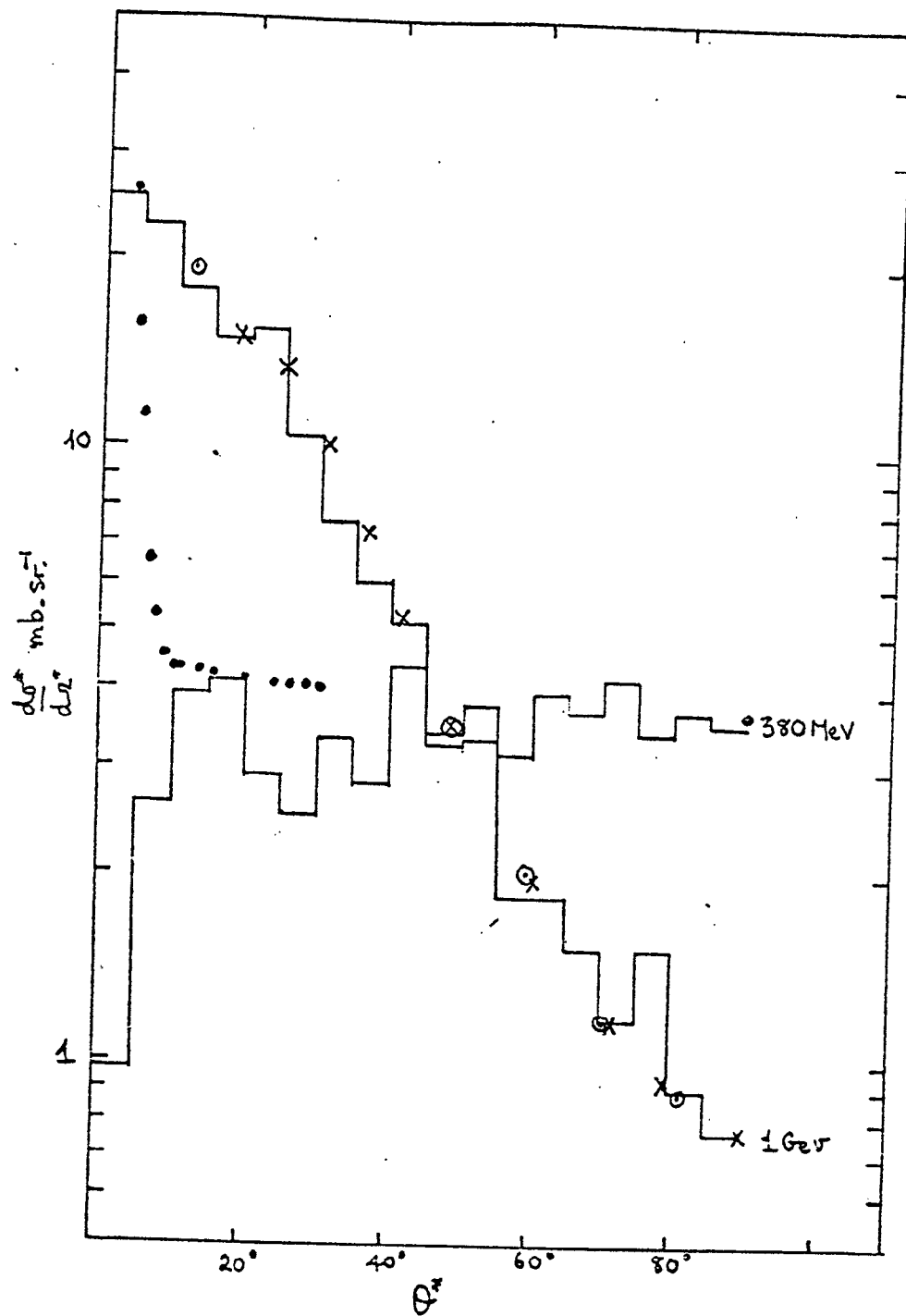
FIG.3: <u>P-P Elastic scattering from HET</u>. The experimental results are from: ⊙ McFarlane et al., Nuovo. Cim. <u>28</u>, 943 (1963) at .97 GeV; X Dowell et al. Nuovo. Cim. <u>18</u>, 818 (1960) at 1 GeV; ● Holt et al., Proc. Phys. Soc. <u>71</u>, 781 (1958); Harting et al., Proc. Phys. Soc. <u>71</u>, 770 (1958) at 380 MeV.
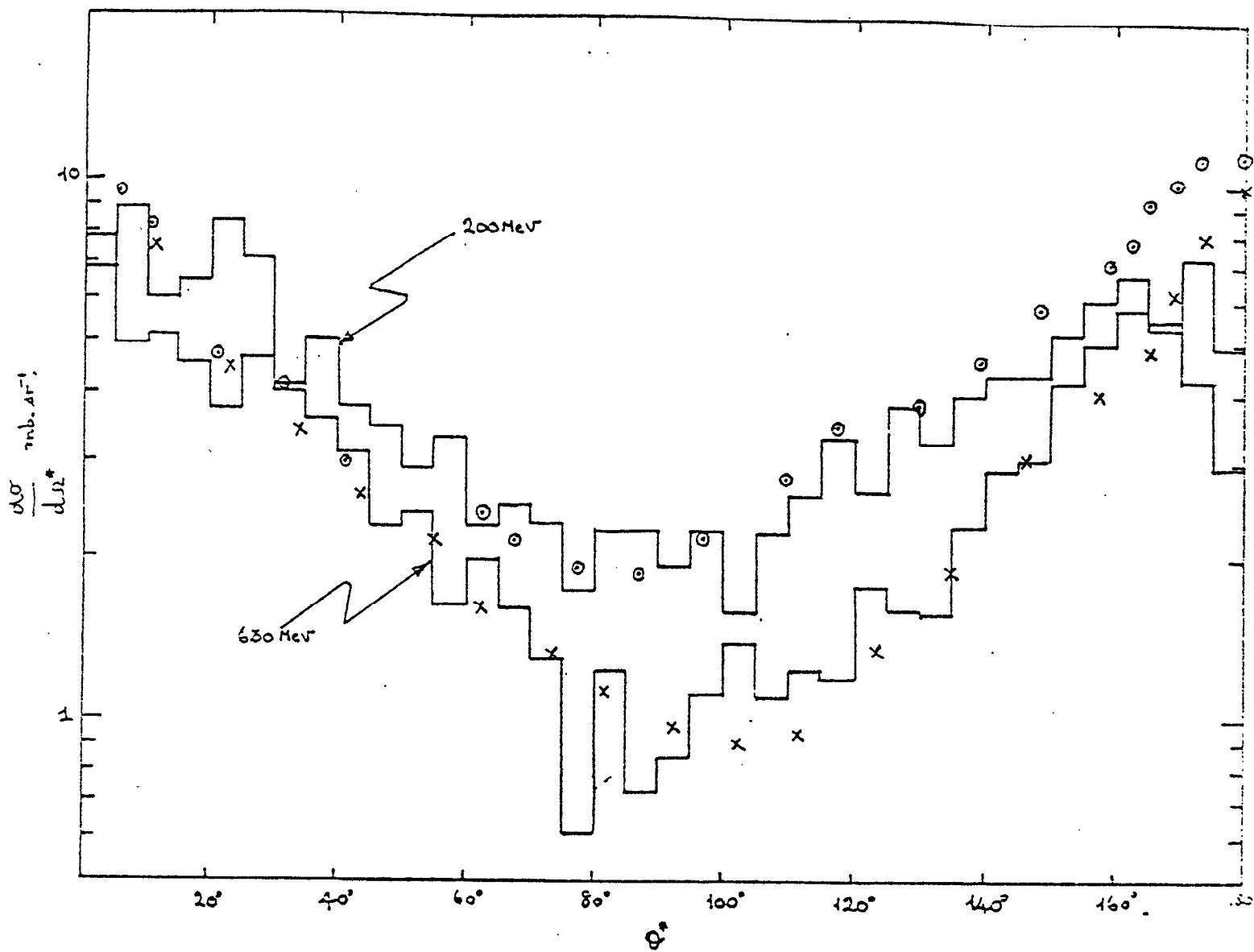
FIG.4: η-p elastic scattering from HET. The experimental points are from:
X   Kazarinov and Simonov, Sov. J. Nucl. Phys. 4, 100 (1967) at 630 MeV;
⊙   Kazarinov and Simonov, Zh. Eksperim. Teor. Phys. 43, 35 (1962) at
    200 MeV as reported in Thomas et al., Phys. Rev. 67, 1240 (1968).
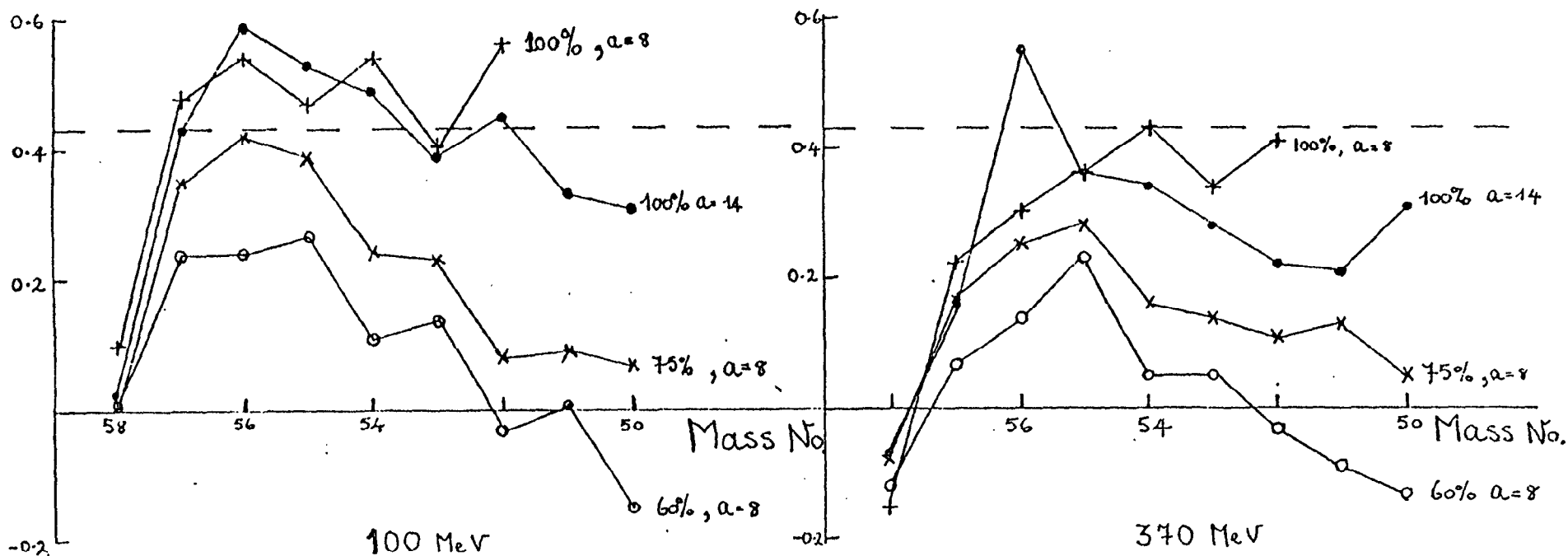
FIG.5: Deviation ΔZ of the mean charge for Isobaric yields of HET from the predictions of Rudstam[1].

The results are for 100 and 370 MeV proton bombardment of ^{59}Co. Also shown is the effect of (arbitrary) changes to the level density parameter a and the coulomb penetrability (% of value in current version of HET). The dashed line at $\Delta Z \doteq 0.43$ is the mean separation between adjacent masses. The lines connecting the points are to serve as a guide to the eye.

APPENDIX 1

Comparison of WNR Proton/Neutron Transport Codes with TIMOC

The geometry used in the comparison is shown in Figure 1.

Neutron Flux Intensity

The results obtained by the WNR Monte Carlo codes, which transport both protons
and neutrons may be succinctly expressed:

$$\Phi(E) = 0.00962 \ E^{0.0961} \quad \text{n/p.lethargy.st}$$

where $\Phi(E)$ is the epithermal neutron flux averaged over a 0.5 st conical solid
angle emerging from the 15 cm diameter central area of the polythene moderator
shown in Fig.1. This flux is shown as the lower line in Fig.2.

The flux obtained by the TIMOC (Rutherford Laboratory) code for the same geometry
is shown as the upper line in Fig.2. The two results have the same energy
dependence but the absolute value at 1 eV is

$$\Phi(1 \ eV)_{WNR} = 0.00962 \quad)$$
$$\Phi(1 \ eV)_{TIMOC} = 0.0110 \quad) \quad \text{n/p.eV.st}$$

Note 1: Since TIMOC only transports neutrons, and not protons, the effect of the
proton beam was simulated by incorporating a quasi fast neutron source,
within the Ta target and suitably distributed along it. This quasi source
was given an energy distribution:

$$\chi(E) \ \alpha \ \sqrt{E} \ \exp \{-E/A\}$$

where $A = 1.4$ MeV

which was found to reproduce the observed neutron energy distribution on
the surface of a bare Ta target.

2: WNR results are expressed in units of neutrons/proton whereas TIMOC results
are in neutrons/n_f. For the purposes of the comparison a ratio of
$n_f/p = 10$ has been assumed.

Neutron Time Dependence

In the epithermal region the WNR codes predicted a variance in the leakage pulse of

$$\delta_{WNR} = 654 \times E^{-0.457} \quad (ns)$$

This is shown as the straight line in Fig.3. The TIMOC results, for the same geometry, are shown as the histogram on Fig.3. It will be seen that at $\sim$ 100 eV they appear to differ by $\sim$ 20%.
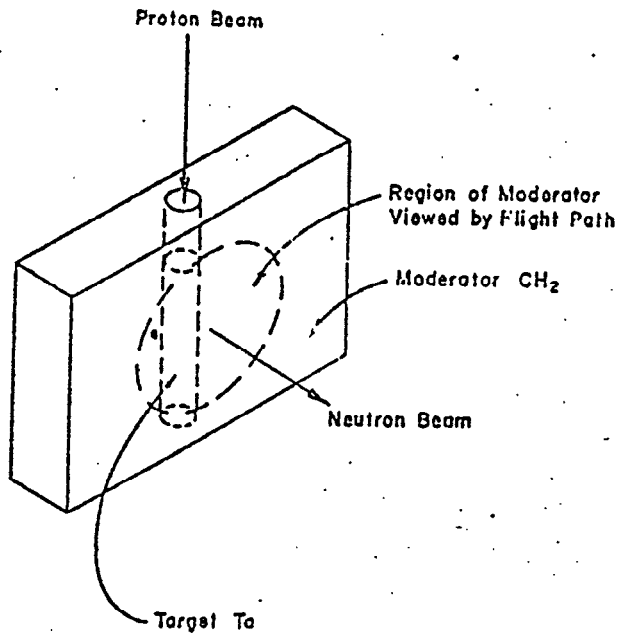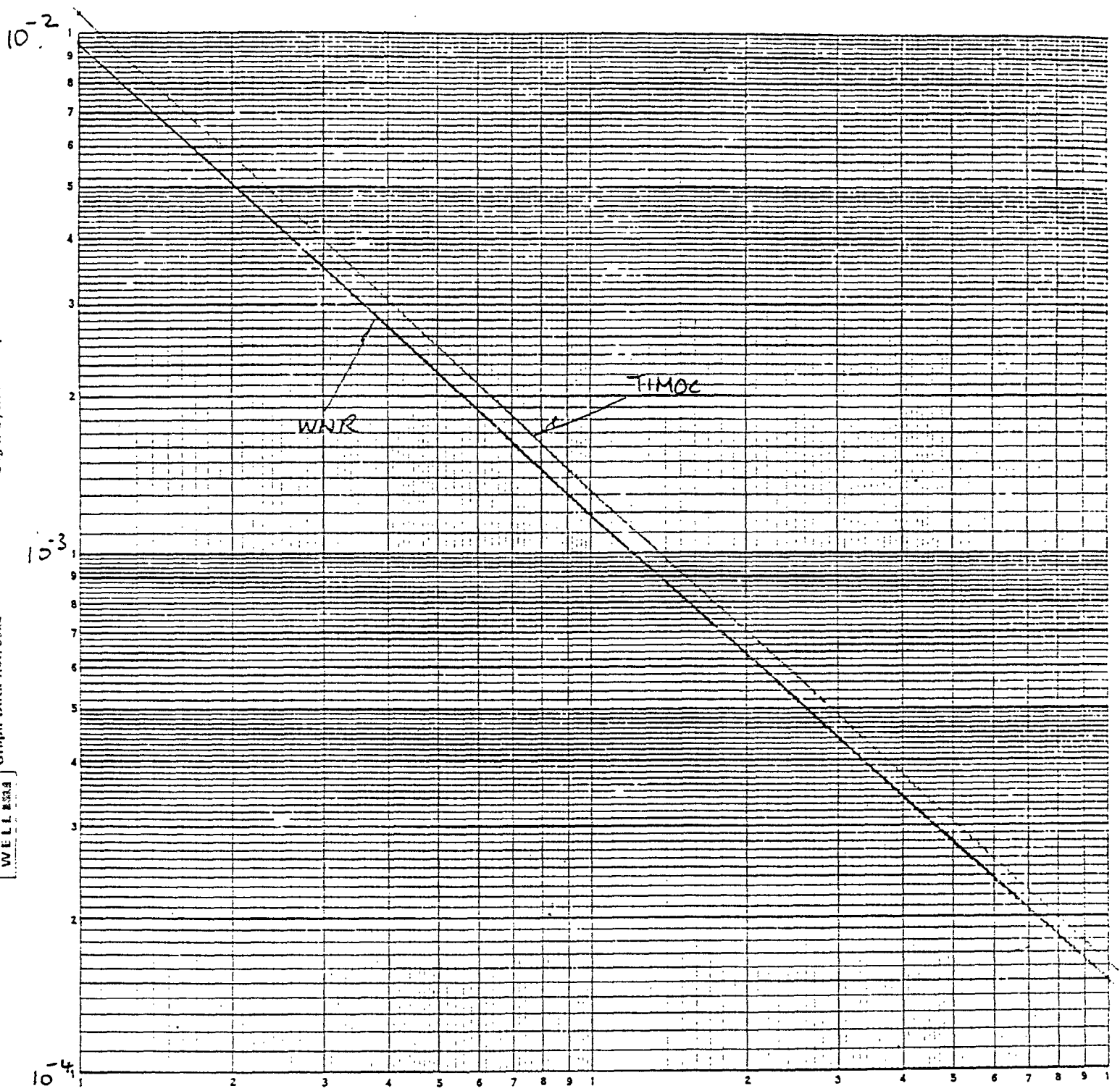
M W Johnson
A D Taylor

Fig. 1. The initial WNR target/moderator configuration.
The top of the target is below the top of the
moderator.

Fig 2

Fig 3.