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MULTICHANNEL SYSTEM FOR ANGULAR DISTRIBUTION MEASUREMENTS

ЧЕХОСЛОВАЦКАЯ АКАДЕМИЯ НАУК

ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ

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1. Introduction

The measuring spectrometric apparatus described in this work serves for the measurement of angular distributions of particle spectra obtained from nuclear reactions studied with the aid of the electrostatic accelerator and the U-120 M cyclotron both operating in the Nuclear Physics Institute of the Czechoslovak Academy of Sciences at Řež. Special attention was given to attaining maximum energy resolution at a high measurement efficiency. This was accomplished by installing 8 independent spectrometric chains which enable a measurement of the angular distributions in eight points simultaneously. In this way not only the measuring cycle is significantly reduced but the information on the angular distribution in the reaction studies becomes more accurate at the same time. Individual semiconductor detectors are cooled from $-40^{o}C$ down to $-60^{o}C$, which decreases essentially the level of the inherent detector noise and it also makes it possible to apply a higher operational voltage and thus to obtain deeper barriers. An energy resolution of 13keV has been attained with the detectors Tesla at 11 MeV of particle energy. In Fig. 1 the spectrum of protons from the $^{29}Si(d,p)^{30}Si$ reaction is shown for illustration. The energy of deuterons accelerated with the Van de Graaff accelerator was 3050 keV.

In the next paragraphs the function of the whole apparatus is explained in detail. Description of the measuring method, treatment of the information obtained and a brief outline of individual electronic assemblies of the apparatus is presented. Finally a short review of corresponding software applicable to the measurement in question is given.

2. Functional scheme of the apparatus

Fig. 2 shows a block diagram of the experimental set-up for the study of excitation curves in low-energy (d,p) reactions. The angular distribution is measured at 8 angles simultaneously in dependence on input particle energy. The basic part of the apparatus is the target chamber, which contains 8 detectors in two groups of four detectors each placed in two opposite quadrants. In this way the whole angular distribution can be measured at a single target position (rotation angle). The beam of accelerated particles enters the chamber via a collimation system the apperture of which can be varied from outside without vacuum breaking . After passing through the target the beam is captured in the Faraday cup and its charge is measured. A monitoring target can be also inserted into the path of the beam. The beam direction with respect to the chamber axis can be accurately checked by two measuring probes.

Analog outputs from individual detectors are fed to chargesensitive preamplifiers fixed directly on the chamber and from there to the input of linear amplifiers. After amplification the signals are applied to a linear mixer. This circuit generates a code characterizing the path (angular channel) of the registered particle. Moreover it generates control pulses for a pulse - height converter the ...

which receives the mixer signals. The conversion gain can be selected up to maximum 4096 channels. Parallel information from the converter is fed to a multiplexer, which transmits the angular and pulse-height code to a data storage device selectable by means of a front panel adress switch. An interface card corresponds to each external unit and the address of information transfer can be selected on it. In the case shown in Fig. 2 the address of the magnetic tape unit is chosen. Fifteen - bit information (12 bits for the address + 3 bits for the angular channel code) goes out from the multiplexer which information is then recorded on a magnetic tape through the buffer memory. The whole measurement is monitored with the charge measuring apparatus. The Faraday cup is provided on its input with a protective insulating ring kept at a voltage of -600V to eliminate the escape of secondary electrons from the Faraday cup. The information on the charge is fed to the scaler in the form of pulse sequence. The necessary exposure length (charge magnitude) is present in the scaler which then controls converter blocking. The second monitoring circuit consists of a special detector positioned in the target chamber at a fixed angle. The pulses from this detector are applied to a single-channel analyzer connected to another scaler. The purpose of the monitor is to check the state of the target or to find a correction for its loss.

The whole measurement is controlled by the computer HP 2100 A. One of the methods of experiment control used in measuring of excitation functions is shown in Fig. 2 and in the block diagram in Fig. 3. In this case the tape recorder, the scaler and the converter are directly controlled by the computer, the remote control switch (RCS) is situated in the accelerator control room.

After starting the program the scaler is reset to zero, the converter is blocked and the tape transport is switched on. After decoiling empty gap, separating the data of individual expositions, the converter and the scaler are started. The exposition lasts as long as the desired charge passes through the target. When the presetting is attained the converter is blocked again. Then the tape transport stops, and the RCS in the accelerator control room demands to input a new value of energy. After setting the accelerator conditions the whole cycle is repeated. The program can be interrupted at any phase by "the end of tape" condition. This sends a message for tape exchange and the whole program is stopped. During the measurement one angular channel is always monitored by a 4096-channel analyzer connected to the multiplex system. The angular channel selection is enabled by a digital selector, which is a part of the magnetic tape unit.

The spectra recorded on the tape are processed with the computer and stored on a disc memory for an off-line processing. Because of the size of the operational memory only two spectra out of eight are read when processing the tape by the computer. Hence each tape must be read four times. Total number of 4000-channel spectra stored on one disc may be as high as 245.

3. Description of blocks of the measuring apparatus

a) Target chamber

The chamber, the main assembly of which is shown in Fig. 4, is made from Al alloy and it is formed by a cylinder /1/ having inner diameter 650mm and two covers equipped with turn tables/2/. The upper cover can be tilted by approximately 100° with a hoist mechanism /3/. The distance of the tables in operational position is 150mm. Each table is provided with radial grooves, into which detector holders and or calibration sources are mounted. Along the table perimeter a scale /4/ is engraved. By means of the verniers /5/ attached to the cover the angle of the tables can be read on the scale. The accuracy of the angle setting is 0.1°. The tables can be rotated by ± 180° using two motors which are fixed to the chamber covers /6/. The angular position can be read at the place of the measuring apparatus by means of a closed TV system. Fixed annuli are mounted in the central part of the covers, which bear coaxial rotation connectors for connecting detector tables. Each cover is provided with 10 connectors /7/ which are vacuum-tightly jointed with inner connectors. A device for the target shift and rotation is positioned on the lower cover in the vertical chamber axis. The target holder itself consists of a frame holder /8/ and of a bar /9/, which can be moved vertically and in this way one of the targets can be positioned in the beam axis. This bar can be displaced into a small chamber /10/ on the upper cover which is vacuum-tightly connected with inner target chamber volume. By inserting the bar into the chamber the two volumes are vacuum-tightly separated so that, after admitting air inside, the cover can be removed and the target can be exchanged. After covering it again and prepumping by the valve /11/ the bar can be displaced back into the target chamber. Hence the target exchange can be carried out without vacuum breaking inside the chamber.

The beam of accelerated particles enters the chamber through a collimation system, which is rigidly connected to the chamber. The collimator /12/ consists of three carroussels/13/, which contain 6 collimation diaphragms. These diaphragms can be also inserted without breaking the vacuum. After adjusting the diaphragms the position is fixed and in this way the transparency of all diaphragms is secured. An antiscattering slit /14/ can also be inserted into the collimator.

The chamber output is provided with a monitoring system/15/, which carries two adjustable probes with semiconductor detectors/16/ positioned at an angle of 30° with respect to the longitudinal axis of the chamber. To study the elastic scattering a monitoring target /17/ can be inserted into the axis . The intensity difference in both channels indicates the geometrical asymmetry of the measurement. The system is ended with a Faraday cup /18/ with electrode /19/ protecting against secondary electrons.

An optical adjustment of the chamber axis is enabled by a small chamber with a removable screen at the collimator input /20/. The screen is positioned in a ball joint/21/ in which the whole chamber and also the collimation system can be rotated. The vacuum system and other equipment of the chamber is not shown in the figure.

Table rotation and target displacement can be controlled both from the chamber place and remotely.

A cooling system for the semiconductor detectors is a special accessory of the chamber. It comprises a heat exchanger in an isolated vessel with ethylalcohol. The ethylalcohol filling can be even cooled down to -70^{o} C when using liquid nitrogen vapours. The required temperature can be adjusted on a thermostat. The cooling medium is pumped with a pump into a tombac distribution tubing mounted in the chamber under the turn tables. The whole distribution tubing is vacuum tight and thermally insulated from the chamber body. The cooling liquid is led on the tables to the holders of detectors (Fig. 5) connected in series. Temperature sensing probes within the detector holders permit a continuous measurement of their respective temperatures. A second system circuit with preheated ethylalcohol serves to a quicker heating back to the room temperature.

b) Charge - sensitive preamplifiers

The inherent noise FWHM is 3,5 keV, the charge conversion gain is 30 mV/MeV. The preamplifiers are mounted directly on the chamber to minimize stray capacity. The amplification can be selected to be 1 or 5.

c) Linear amplifiers

The maximum linear output pulse voltage is +12V. The amplification can be selected either in steps 64 ÷ 2048 or continuously. Derivation and integration constants are 0,15; 0,5; 1; 2; 5 μsec respectively. Simple and double derivation or integration can be selected. The inherent noise of the amplifier is 6 μV at the maximum gain and at shaping constants of 1 μsec.

d) Linear mixing circuit

In Fig. 6 a block scheme of the mixer is shown. It has 4 essential parts: a linear gate, pulse - height discriminators, a mixing circuit and a coding circuit. The input signal is fed to the closed linear gate and to the discriminator at the same time. The discrimination level can be set in the range of 0.1 ÷ 5V, which enables to separate noise and other perturbing signals in individual angular channels. If the pulse-height of the input pulse exceeds the discrimination level the linear gate in the corresponding input opens and a 3-bit code is generated in the code circuit. From the gate the pulse is fed to a resistor mixing circuit, the attenuation of which is compensated by the input amplifier. The analog pulse on the output is thus accompanied with a 3-bit code. Each of the inputs of the mixing circuit can be gated, if necessary, with an external pulse.

e) Pulse-height converter

It transforms the input analog pulse in the range of 0.1 ÷ 10 V to a 12-bit parallel code. The internal transformation frequency is 10 MHz. The conversion gain, the upper and lower discriminators, and the possibility of zero suppression up to 2000 channels can be adjusted. The integral linearity is as low as ± 0.01%, the differential one 0.5%. The output 12-bit code is obtained in the TTL. Blocking of the converter is accomplished by the computer through the multiplexer.

f) Multiplex transfer system

It enables the transfer of numerical data and of control signals between various sources and destinations, e.g. from an ADC to a magnetic tape unit or from a computer to an external memory (Fig.7). The transfer direction and the connection can be selected either by push-buttons on the apparatus front panel or by a computer program. Each device connected to the multiplexer has its own interface card and address. Besides it, each device itself can call another device. The arrangement enables a parallel transfer of a 16-bit word. To transfer more bits (e.g. from a magnetic recorder) the transfer must be carried out in two or more steps.

g) Magnetic tape unit

It is provided with a buffer memory, a digital selector and the tape recorder itself [1]. It uses a 25.4 mm wide tape. The speed can be selected from 24 mm/sec to 5 m/sec. The tape recorder has 23 recording and 1 synchronization tracks. The buffer memory sets the record density to about 12 pulses/mm. The record is parallel, in the application given in Fig. 2, there are used 12 bits for recording pulse-heights from the converter and 3 bits for the address of the corresponding detector. The magnetic tape 1000 m long is provided on both ends with transparent windows for a phototube, which indicates the tape end. Individual expositions are separated with record-free gaps. These gaps are indicated by an electronic circuit and they announce the record end to the computer. Magnetic tapes can be also read by means of the multiplexer to the pulse-height analyzer. The angular channel code is then selected with the digital selector.

h) 4096 - channel analyzer

It is controlled directly by the multiplexer, which enables to control its start, zero setting, and the transfer of memory content to the computer.

i) Current integrator

It measures the current and charge in the Farady cup. The measured current is transformed to frequency, so that the total number of output pulses is proportional to the collected charge.

j) 8 - channel pulse scaler

It comprises 8 independent scalers with a common switchable display. Each scaler has 5 decades and also a counting rate divider 1:10 and 1:100 at the input. The input is +/-10 V, maximum input frequency is 10 MHz. Each scaler has an adjustable presetting of pulse number and a common testing generator. Start and reset can be carried out either independently or simultaneously. Through the multiplexer all the functions can be controlled by the computer and the state of any scaler can be read.

k) HP 2100 A computer [2]

The computer assembly consists of a processor, a disc memory, a display, a punch tape reader, a punching device, and a teletype. The operation memory capacity is 16 kwords, word length 16 bits, disc memory capacity 4.7 Mbytes, mean access time 30 msec. The disc operating system enables to use programming languages FORTRAN IV, ALGOL, ASSEMBLER. Graphic and alphanumeric display is equipped with a light pen. The measuring apparatus described in preceding paragraphs is connected with the computer through the multiplex with two interface cards placed in the computer.

4. A brief review of software

1) Basic program block

This block is controlled from the display with light pen in the course of spectra processing. In Fig. 8 an example is given with the screen and the spectrum on it as well as a table of symbols. In the left upper corner the spectrum code is shown, in the right upper corner the number of represented channels, number of which can be selected. By contacting the table symbols with the light pen the individual functions of the control program can be selected. The selected symbols remain then illuminated. By a repeated contact these functions can be cleared.

Following functions can be performed:

[illegible], [illegible], [illegible] – the number of displayed channels is selected

[illegible] – spectrum shift in both directions either continuously or step by step

[illegible] – channel number and its content or also the corresponding energy, if the calibration is accomplished, are represented in the spectrum in the upper screen part by subsequent contacting

[illegible] – search for all peaks in the spectrum and printing the list of them

[illegible] – determination of the peak area between two boundaries defined by pen contacting in the spectrum. The result is displayed again in the upper screen part.

[illegible] – storing the peak without background

ULZ - storing the peak with background

ZRV - clearing the last record and peak position

TSK - printing the table of peak areas and positions (or energies)

KAL - spectrum calibration after inserting the calibration data from TTY

SVS - representation of the measured reference spectrum (its code is given by the teletype) at the same time. Return to the main program is accomplished by contacting the symbol " ÷" in the symbol table. Then following programs can be called by the teletype:

- classification and transfer of the measured spectra from the tape recorder
- transfer of the spectra from the analyzer to the computer
- storing the spectra on the disc
- finding a selected spectrum on the disc
- reading spectra from the punch tape
- punching the selected spectrum
- check on the disc status
- printing the spectrum list
- deleting a spectrum
- change of the spectrum code

2) Control programs for independent use

- transfer of the spectra from the analyzer to the computer memory with the control of the analyzer functions
- transfer of the data from the computer memory to the analyzer

- transfer of parallel information from the pulse-height converter to the computer including the selected chain and converter function control.

3. <u>Programs for further processing</u>

- accurate spectrum calibration. The calibration is carried out using Chebyshev polynomials by energies given. Optimum degree of the polynomials is found [3].
- expansion of angular distributions by Legendre polynomials (up to 4-th degree)
- decompositions of the doublet by gaussians, representing the resulting fit by the display
- determination of the accurate peak position by an asymmetric gaussian
- automatic determination of areas and peak positions in the spectrum read from the punch tape
- determination of the peak areas on the display by a light pen, the data may be printed
- non relativistic kinematics; the energy of the emitted particle and of the final nucleus in the laboratory system is calculated, the emitted particle angle in the center - of - mass system, the transformation of the solid angle from the laboratory to the center - of - mass system are calculated
- relativistic kinematics. Calculations are carried out (at a double precission) for: the particle energy in laboratory system, emission angles in the center - of - mass system, energy losses of the impacting and the emitted particle in the target, energy and angle derivatives of the emitted particle energy, the transformation coefficient for the cross section, the

optimum target angle, the reaction Q value etc. [4]

- optimalization of kinematic parameters. Up to 5 kinematic parameters - particle masses, the impacting particle energy and reaction Q values can be determined from the angular dependence of the emitted particle energy.
- analysis of cross-section fluctuations. An analysis in the frame work of Ericson theory [5] is carried out, autocorrelation functions, correlations at different angles and in different channels are calculated as well mean values are replaced by the non-periodic Fourier expansion.

5. Conclusion

The described method of measurement and processing has been checked on the beam of the electrostatic accelerator of the Nuclear Physics Institute of the Czechoslovak Academy of Sciences by a longterm operation. Angular distributions and excitation functions in (d,p) reaction on several nuclei of the s-d shell have been studied. A high efficiency and a high operational reliability has been confirmed during the entire measurement.

R e f e r e n c e s

1. EMIDATA INSTRUMENTATION TAPE TRANSPORT AND CONTROL UNIT,
   TYPE RD3A/SA, INSTRUCTION MANUAL
   EMI ELECTRONICS LTD, HAYES, MIDDLESEX, ENGLAND

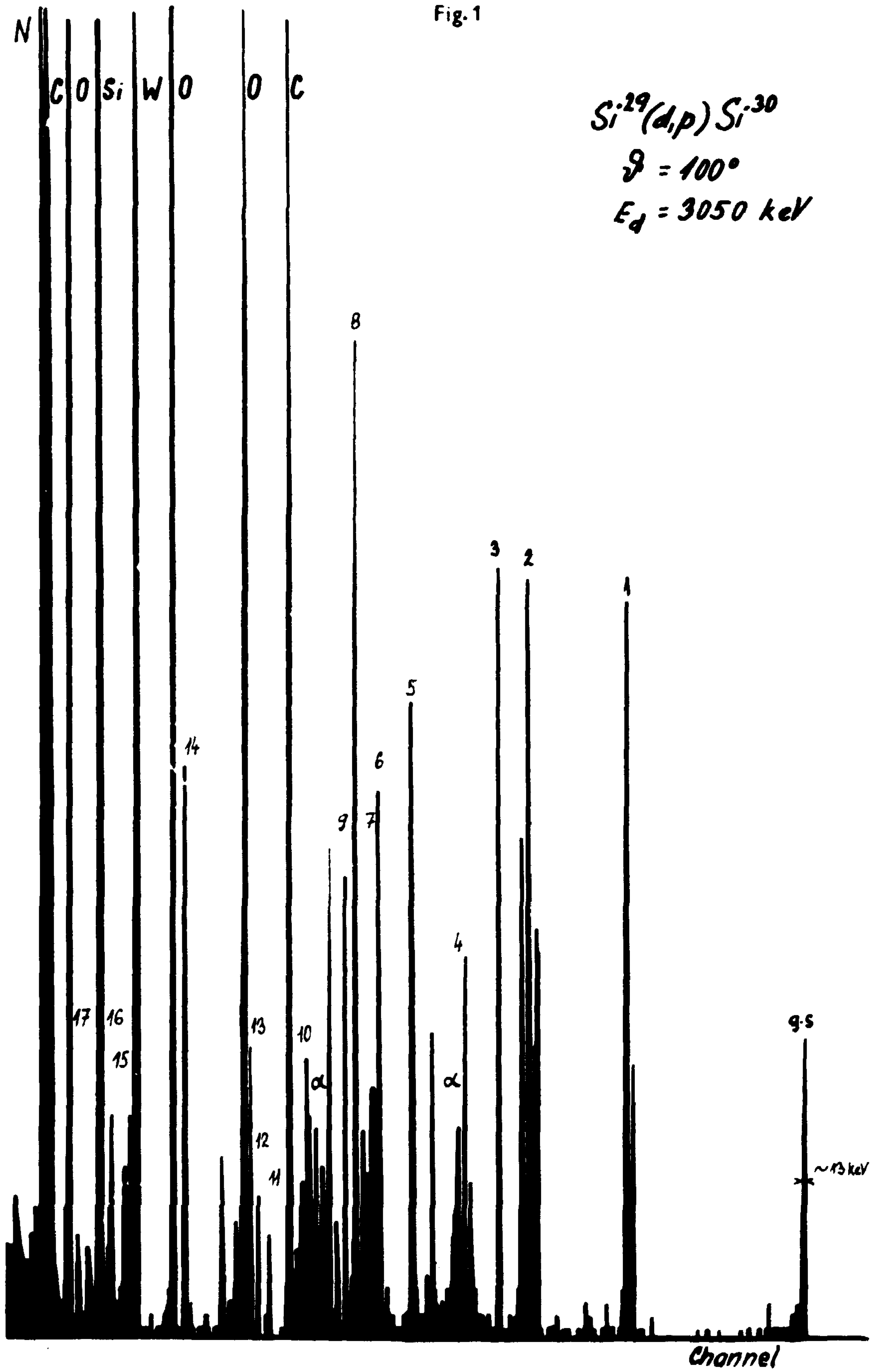
2. HP 2100 A COMPUTER
   REFERENCE MANUAL, 1971

3. R. S. GUTER, B. V. OVCHINSKI,
   ELEMENTY CHISLENOVO ANALYZA, MATEMATICHESKOI OBRABOTKY
   REZULTATOV OPYTA
   GIFML MOSKVA, 1962

4. J. ŘÍKOVSKÁ, V. KROHA
   RELATIVISTICKÁ KINEMATIKA V JADERNÝCH REAKCÍCH
   REPORT ÚJV 2067.F, 1968

5. ERICSON T.: ANN. PHYS. 23 (1963) 390

Fig. 1


N
C
O
Si
W
O
O
C
$Si^{29}(d,p)Si^{30}$
$\vartheta = 100°$
$E_d = 3050$ keV
8
14
6
9
7
5
3
2
1
4
17
16
15
13
12
11
10
α
α
g.s
~13 keV
Channel

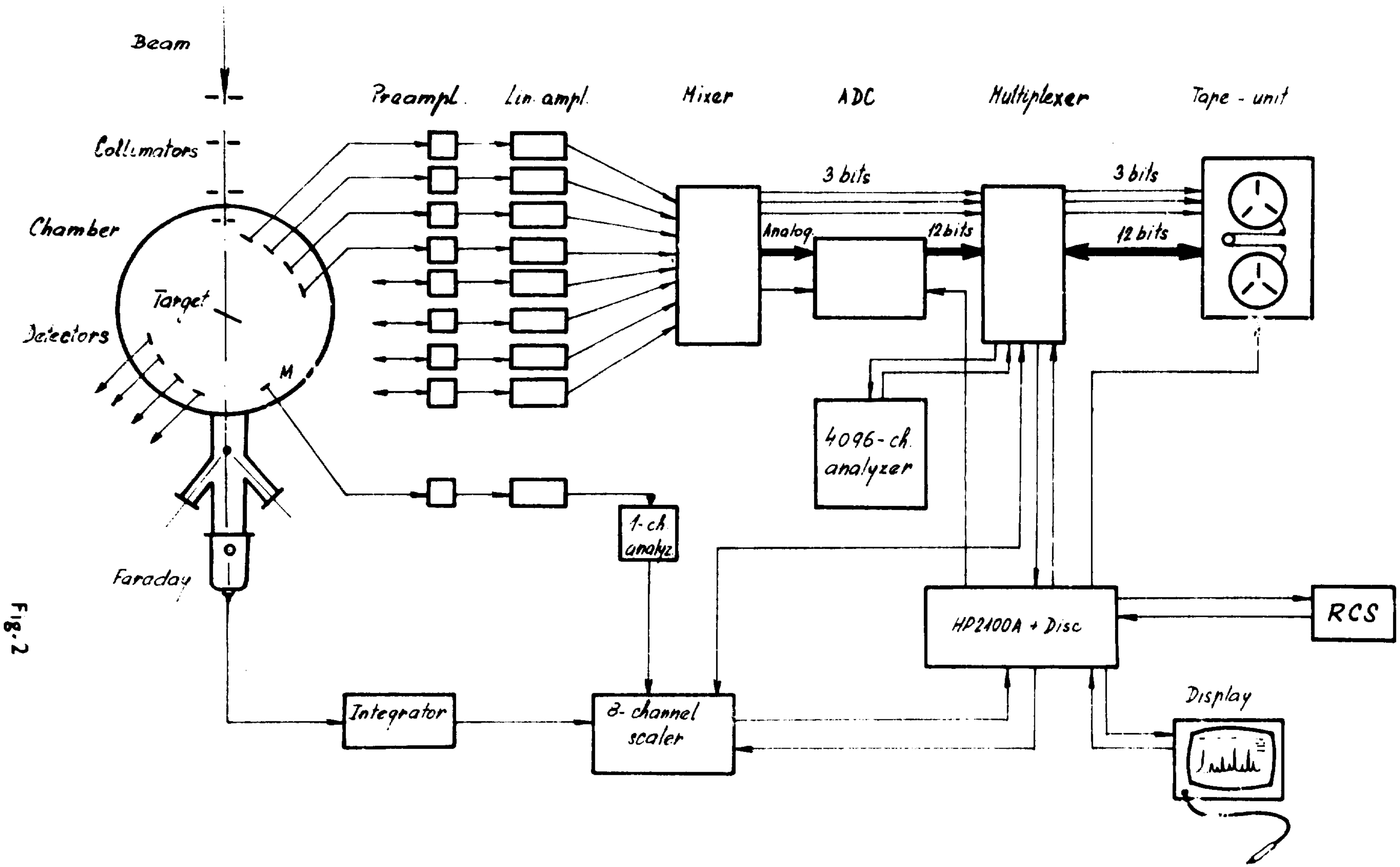

Beam
Collimators
Chamber
Target
Detectors
M
Faraday
Preampl.
Lin. ampl.
Mixer
ADC
Multiplexer
Tape - unit
3 bits
Analog
12 bits
3 bits
12 bits
4096-ch.
analyzer
1-ch.
analyz.
HP2100A + Disc
RCS
Display
Integrator
8-channel
scaler

Fig.2

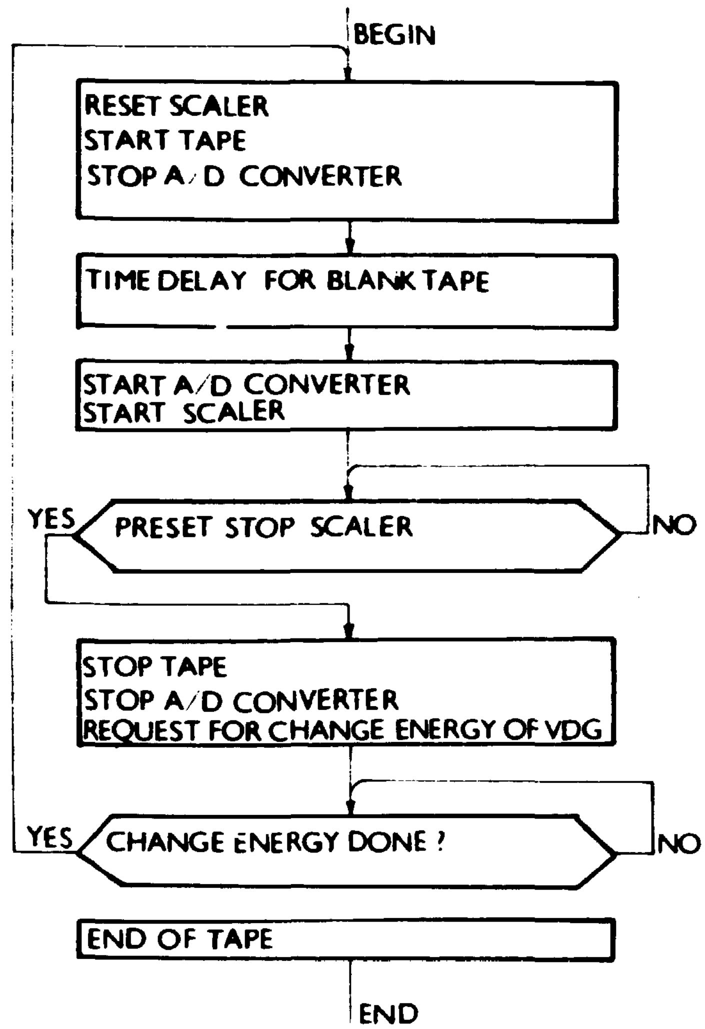

BEGIN
RESET SCALER
START TAPE
STOP A/D CONVERTER
TIME DELAY FOR BLANK TAPE
START A/D CONVERTER
START SCALER
YES
PRESET STOP SCALER
NO
STOP TAPE
STOP A/D CONVERTER
REQUEST FOR CHANGE ENERGY OF VDG
YES
CHANGE ENERGY DONE ?
NO
END OF TAPE
END

Fig. 3

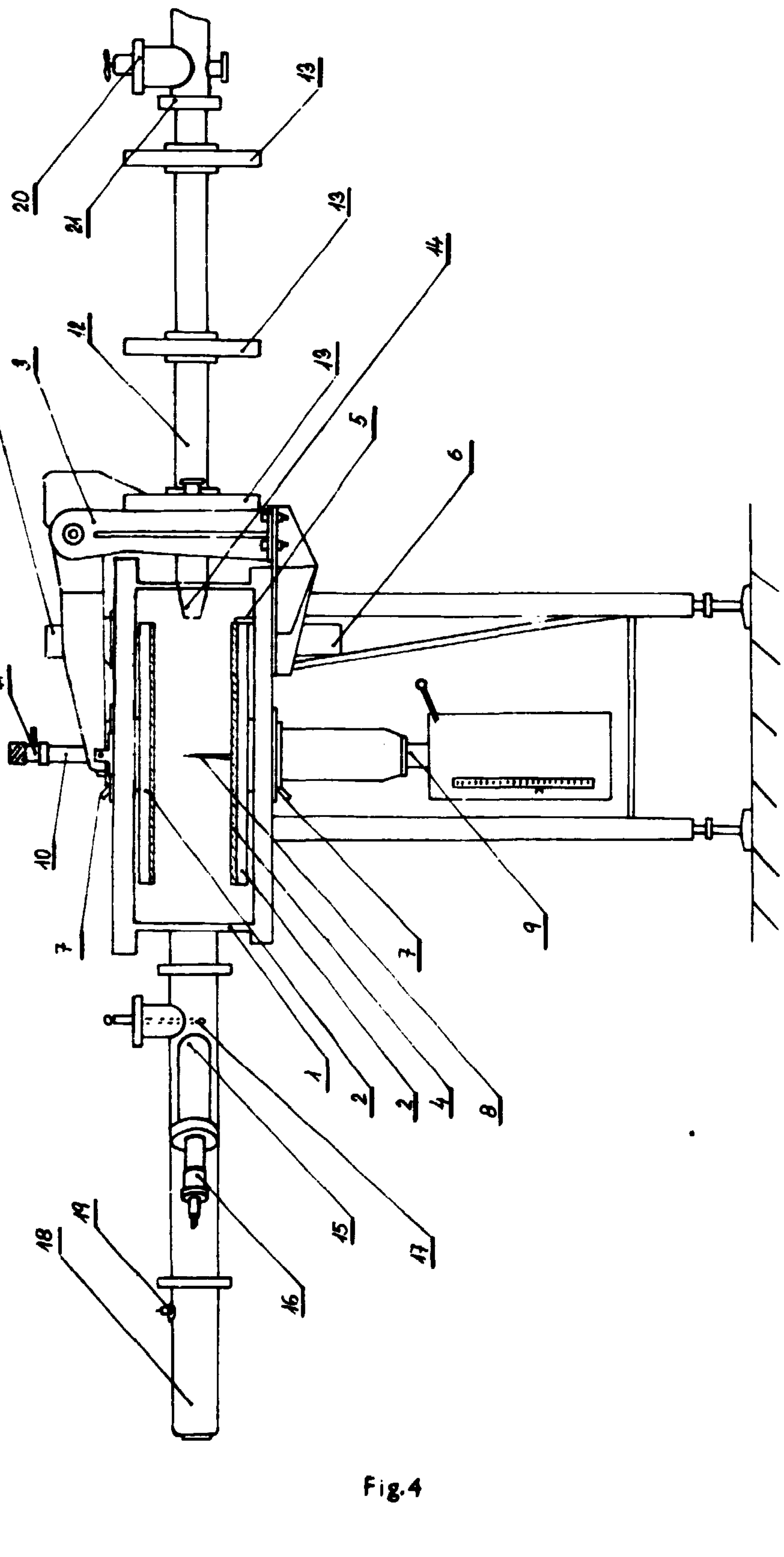


Fig.4

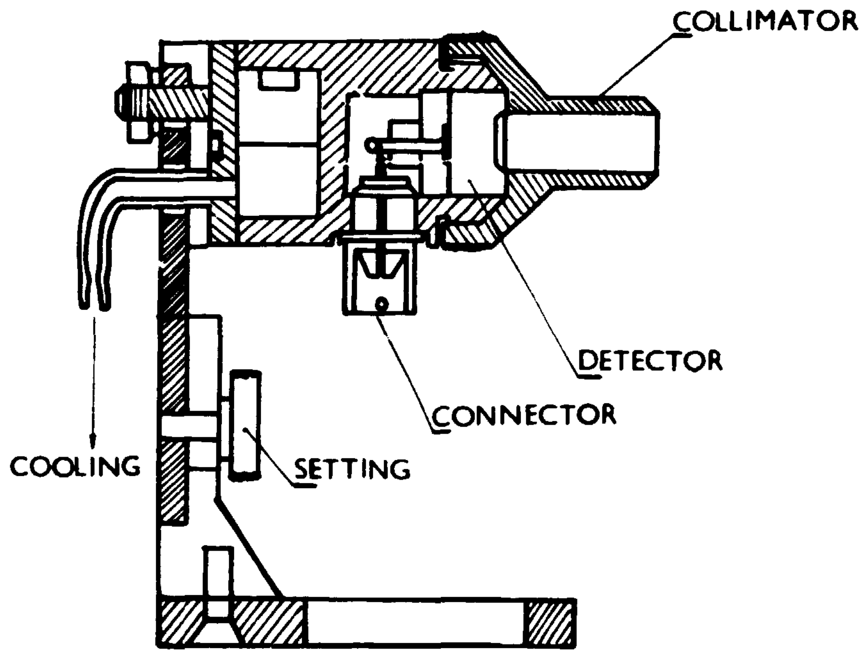


Fig. 5

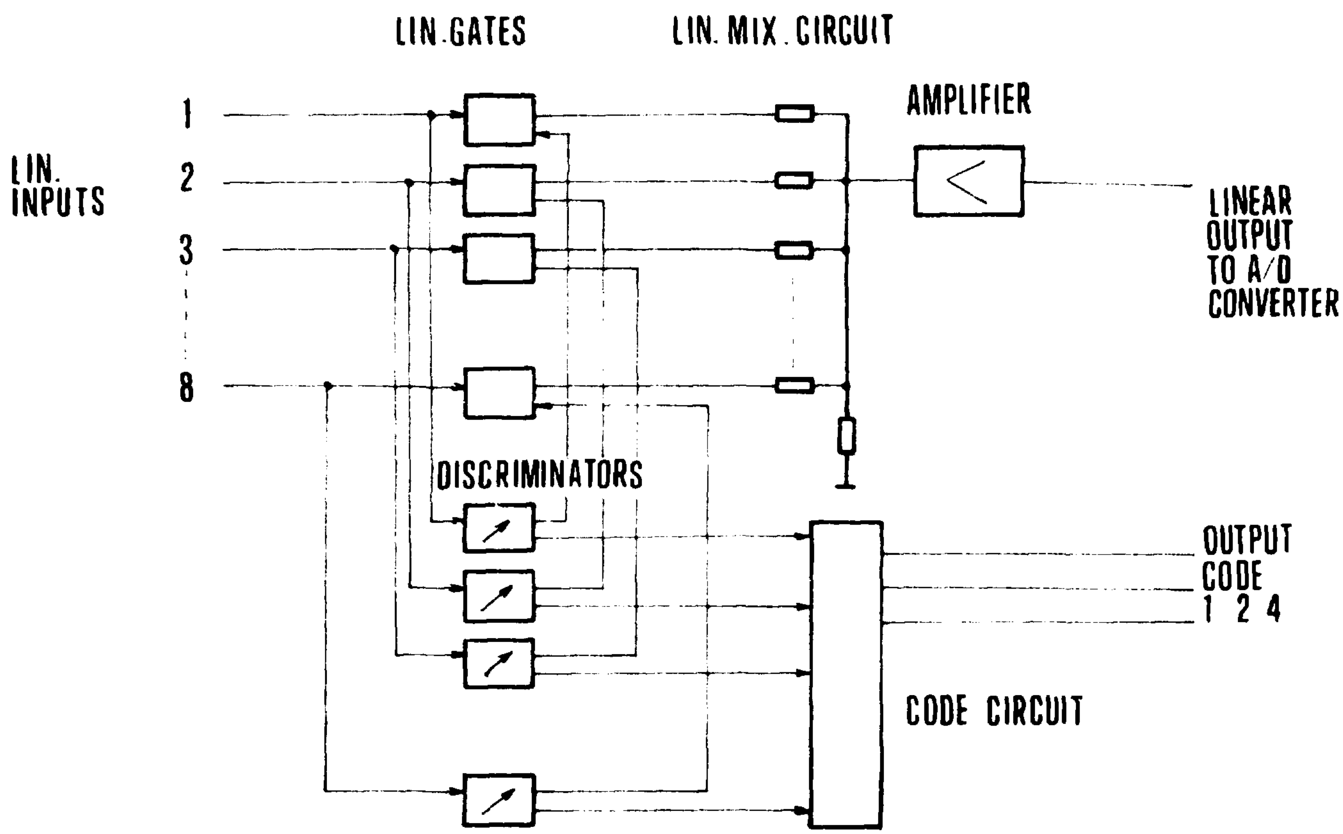

LIN. GATES
LIN. MIX. CIRCUIT
AMPLIFIER
LIN. INPUTS
1
2
3
8
LINEAR OUTPUT TO A/D CONVERTER
DISCRIMINATORS
OUTPUT CODE
1 2 4
CODE CIRCUIT

Fig. 6

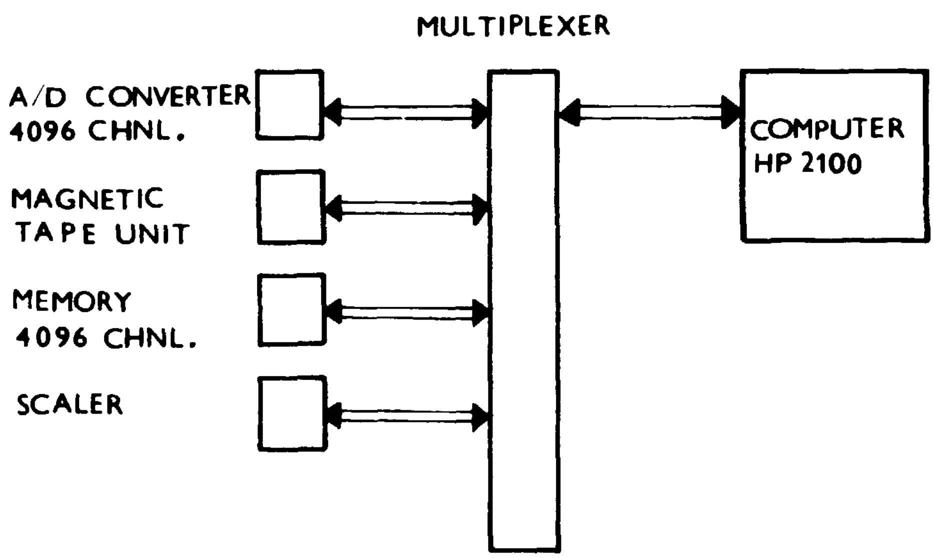

MULTIPLEXER
A/D CONVERTER
4096 CHNL.
MAGNETIC
TAPE UNIT
MEMORY
4096 CHNL.
SCALER
COMPUTER
HP 2100

Fig. 7

SCREEN OF DISPLAY PROGRAM

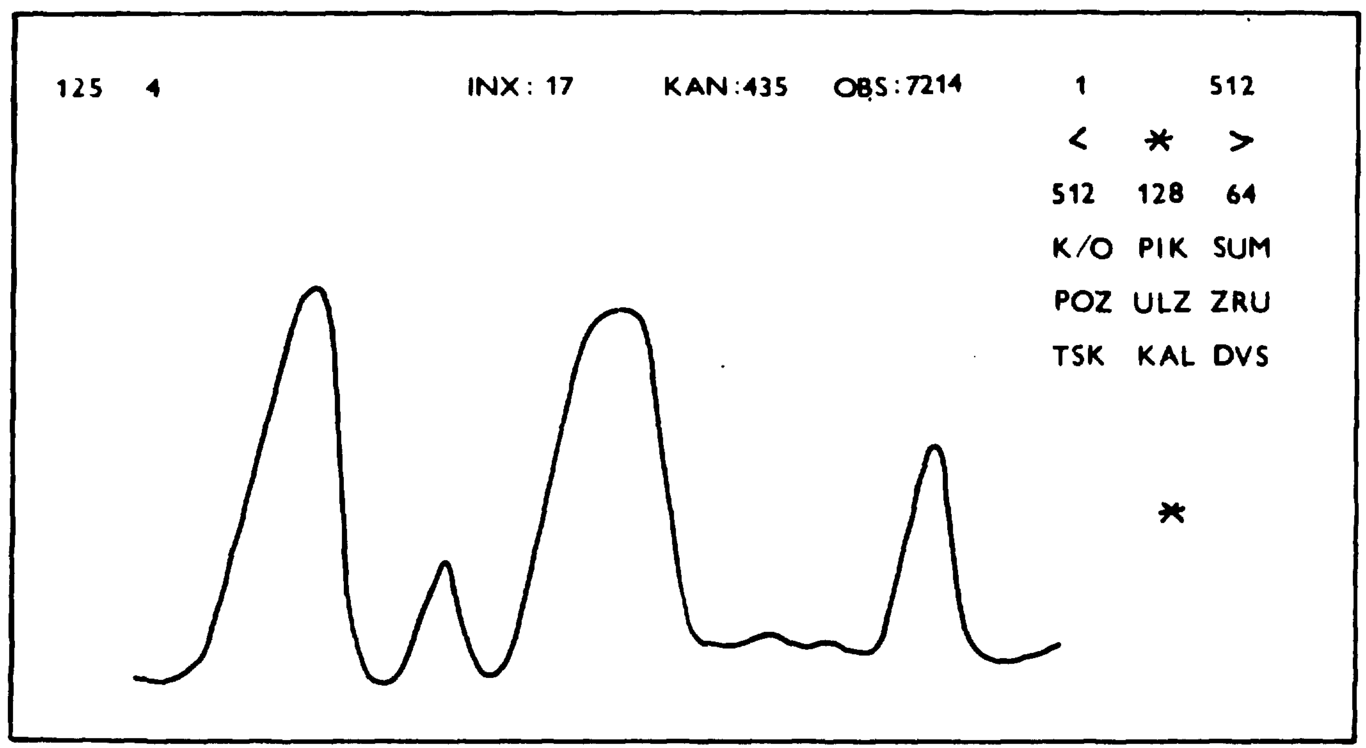


Fig.8