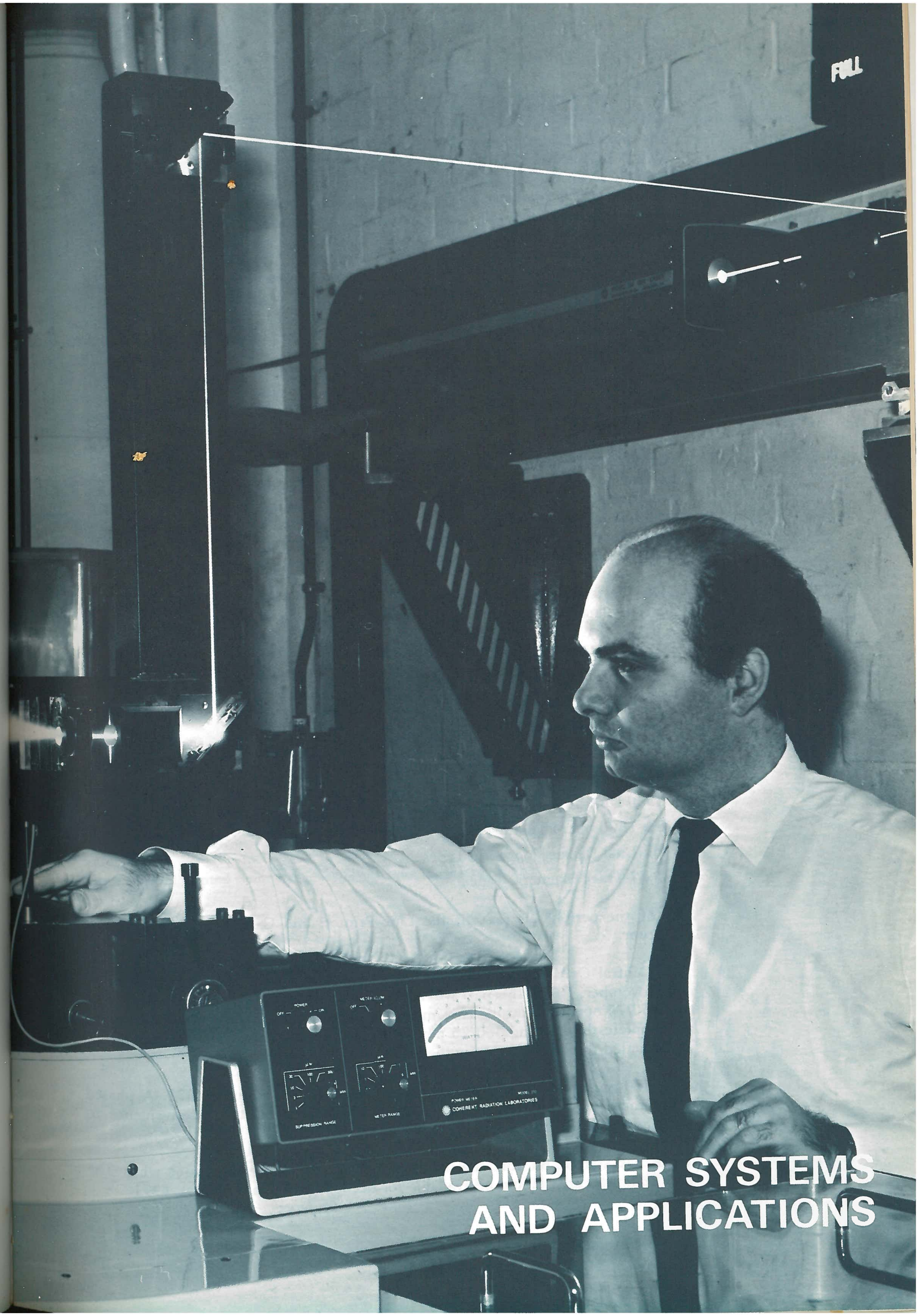


COMPUTER SYSTEMS AND APPLICATIONS

Part of the automatic film measuring machine (HPD II) showing the laser beam used as a light source for the flying spot.

Computer Systems And Applications

THE NEW CENTRAL COMPUTER–IBM 360/195

(*Ref: 178*)

Approval was received on 10th November 1970 for the purchase of an IBM 360/195 computer, with peripheral equipment, at a total cost of £3·6M. This sum includes the cost of the building extension estimated at £122K.

An Advisory Committee has been formed to advise the Director of the Rutherford Laboratory on Computer Policy. Membership of the Committee represents the respective interests of the Rutherford, Daresbury and Atlas Laboratories. The computer will be available not only to the Rutherford Laboratory but will also be used for off-loading work from the Daresbury Laboratory and computers used at universities for bubble chamber film analysis. Computing facilities for nuclear structure groups and Elementary Particle Theorists will be authorized through the Rutherford or Daresbury Laboratories. A small proportion of time (10 to 20%) will be authorized through the Atlas Laboratory for its own users.

At its first meeting on 18th January 1971, the Advisory Committee approved the following configuration for the computer:

IBM 360/195 CPU + 2 Mega-byte Store
4 Line Printers
Card Reader/Punch
Block Multiplexor
Fixed Head File
2314 Disk Store
3330 Disk Store
8 × 1600 bpi Magnetic Tapes
2 × Dual Density Magnetic Tapes
2 × 7-Track Magnetic Tapes

All of the peripherals (except the Line Printers and Card Reader) are of IBM 370-type.

The Central Computer (CPU, Store, Multiplexors) is scheduled for delivery on 1st November, 1971. This part will be installed and tested without interruption of the 360/75 operation during November and early December. When commissioning is complete the existing 360/75 peripherals will be switched over. The down-time is estimated to be 5 days during the latter part of December.

The 370-type peripherals will not be available until February 1972. A phased programme of installation has been prepared causing as little inconvenience to users as possible during the period February to April 1972.

Work has started on the new southern extension to the computer wing. The new computer area should be available for occupation by mid-August, 1971.

THE IBM 360/75 CENTRAL COMPUTER

Hardware Changes

The small 2311 disks have been replaced by two 8-drive 2314 disk sets. This change has eased maintenance and development, and given better throughput and better facilities for user data. A second console (1052 plus 2150) has been added, primarily to facilitate tape and disk mounting. Additional parallel data adaptors have been put in the two 2701 data control units, for attachment of the terminal IBM 1130 and DDP 516 computers as extra satellites. An IBM 2702 Multiplexor to be commissioned shortly will provide another 12 access points to the 360/75. Six of these will go through the Rowstock Telephone Exchange. The IBM 1130 has been delivered and accepted, and communication between the 360/75 central computer and all its satellites is now reliable. Two visual display units (Tektronix storage tubes) have been attached to the DDP 224 satellite. The data-link to the London Institute of Computer Science has been made bi-synchronous.

Operations

Four-shift working is now normal and 4,000 jobs per week were being done by the end of the year. During the last quarter the overall machine efficiency was about 98%, with CPU utilisation of 88%; 9-track magnetic tapes were mounted 33,000 times. Performance during 1970 is shown in figures 128(a) and (b).

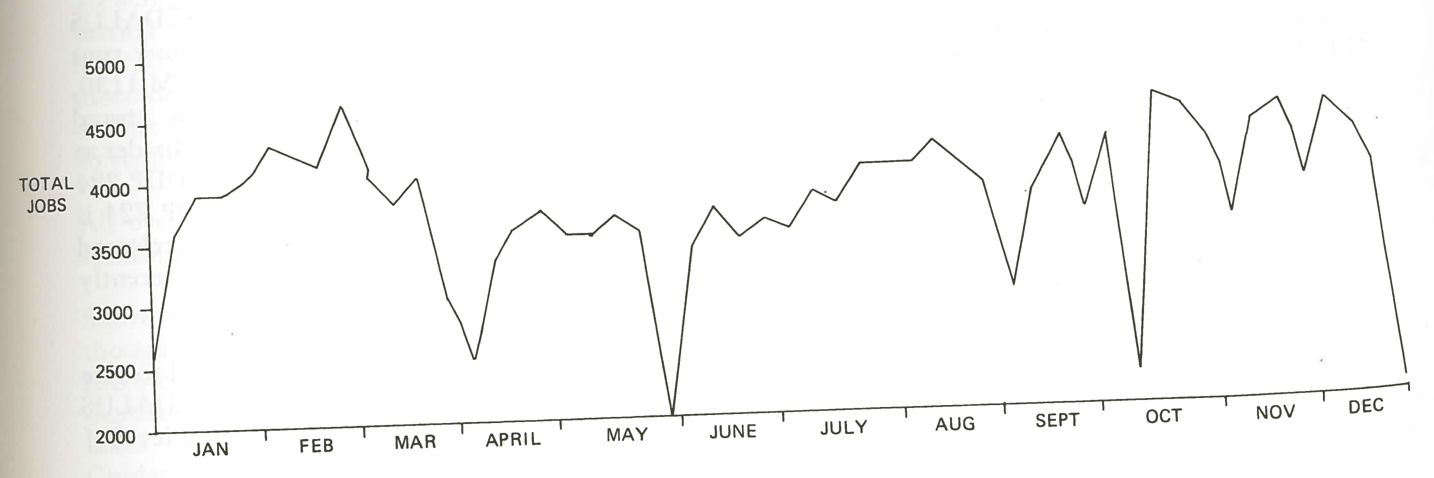
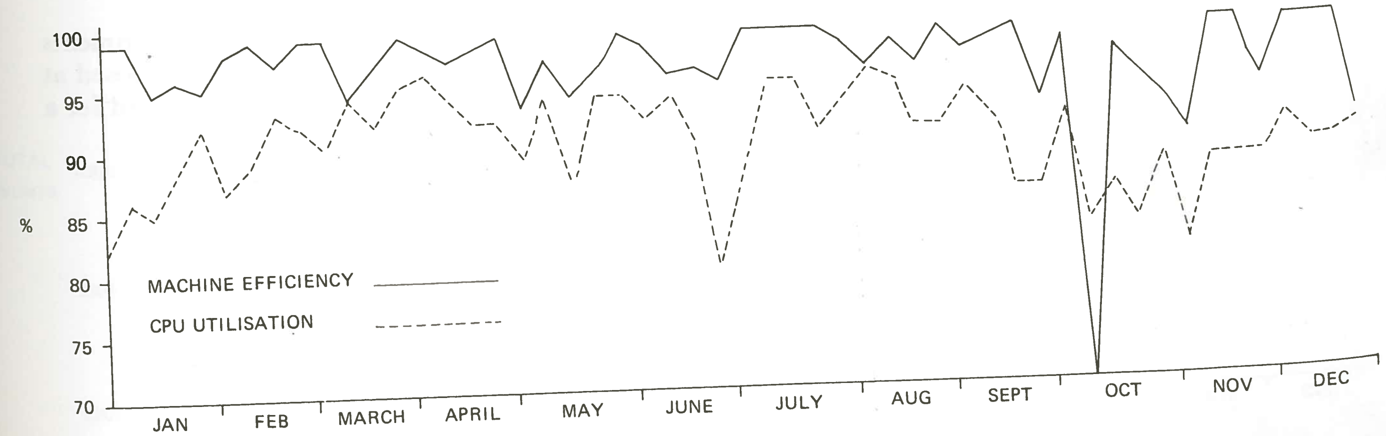


Figure 128(a). Total number of Jobs on Central Computer during 1970.

Figure 128(b). Central Computer machine statistics during 1970.



System Software

Release 18·6 of the IBM Operating System was installed in September. After some initial troubles and insertion of PTF's (Program Temporary Fixes), it was decided to obtain in advance some modules of release 19 and retain some of 17, and the resulting system is very reliable. The main reason for introducing 18·6 was software support for the second control console. The sub-system HASP-2 was introduced in December, mainly because of its facility for remote job submission from the interactive terminals controlled by the ELECTRIC program.

Studies on changing the operating system from multi-programming with a fixed number of tasks (MFT) to multi-programming with a variable number of tasks (MVT) are well advanced, and methods of avoiding memory fragmentation (aggravated by very long jobs such as on-line automatic measuring machines) have been developed.

Program Libraries

The CERN and AERE libraries of programs and subprograms have been made available, and facilities developed whereby users can incorporate items from these libraries in their programs. Hitherto subprograms of general use written at the Rutherford Laboratory had been incorporated in the Fortran automatic-call library and the IBM Scientific Subroutine Package. These latter have now been left as they are issued and the Rutherford-written routines form a new library on their own.

The Multi-Satellite Control Program MAST-DAEDALUS

The MAST program, for controlling several satellite computers by the DAEDALUS method, was written during the year and installed in December. It now runs whenever the computer is on, at present handling 3 satellites (DDP 224, IBM 1130, DDP 516. The control program that runs in the DDP 224 satellite is now stored in relocatable form in the 360 disk store, whence it is fetched by a small loader as required. The programs which control the various devices attached to the DDP 224 are also stored in this way, and the space occupied by them in the DDP 224 is freed when the user goes off-line. Data buffer-space is also acquired and released dynamically. Messages destined for fast or slow devices are now handled differently and output data can be buffered if requested.

The present version of MAST is designed to be secure against misuse, and to give the various concurrent users complete protection from each other. DAEDALUS code in the DDP 224 and IBM 1130 is virtually complete for the present level of design, and is being written for the DDP 516.

On-Line Computer Applications

AUTOMATIC FILM MEASURING

HPD I

During 1970 HPD I measured 210,000 events on film from four experiments undertaken by the Bubble Chamber Research Group. The film was exposed at CERN 2 metre chamber (some as long ago as 1966, but originally intended for a different experiment). The total is made up as follows:—

Experiment	Events
$\bar{p}$ p (Momentum range 1·23 to 1·43 GeV/c)	26,000
K^-p (14 GeV/c)	92,000
K^-p (Momentum range 0·96 to 1·36 GeV/c)	90,000
π^+d (4 GeV/c)	2,000
Total	210,000

Over 90,000 antiproton events had already been measured at the start of the year, and the remaining 26,000 were added by the summer to complete this experiment.

A few high energy K^-p events, from film exposed in February to April 1969, were measured last year; and this year saw the remainder done. Early in 1971, however, a further large exposure for this experiment will be made at CERN.

The low energy K^-p experiment over a range of incident momenta is an extension with much better statistics of the first experiment put on HPD I (in 1968) from the Saclay 82 cm chamber in operation at Nimrod. With 90,000 events measured this experiment is well under way.

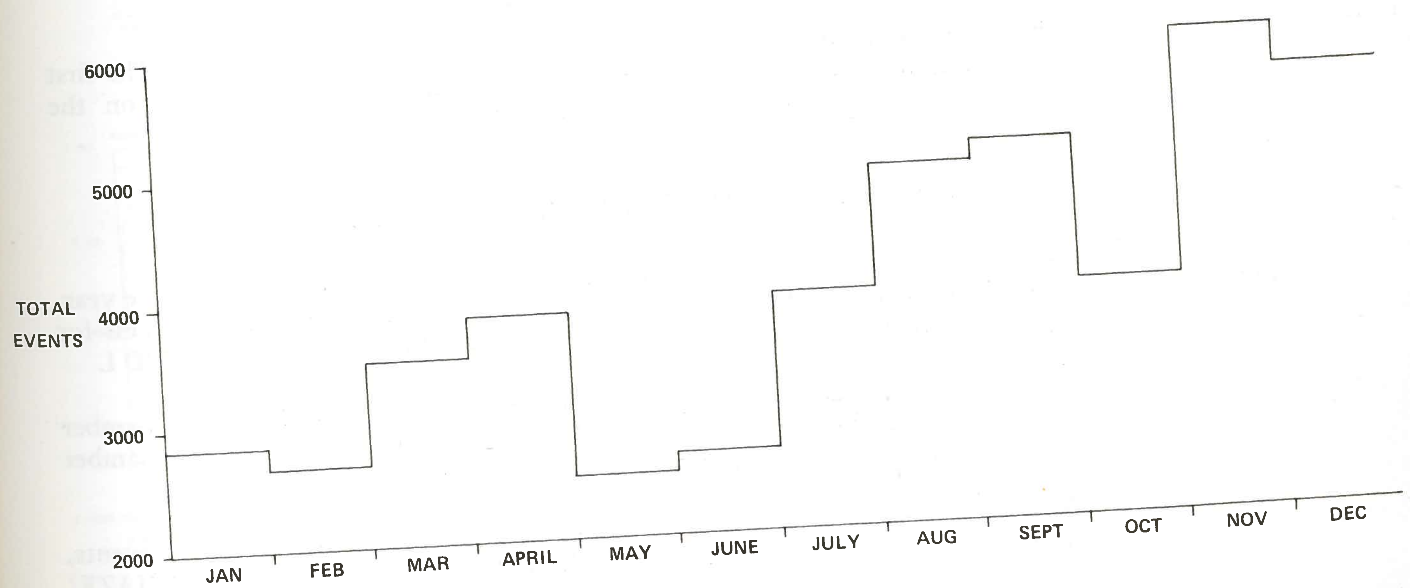
Film of pion interactions in deuterium was taken in the summer of this year and measurement has barely started. University Groups at Birmingham and Durham are collaborating in this experiment, and the HPD will be used to measure film scanned at Durham.

With some fluctuations the measuring rate has improved during the year to reach 68,000 events in the final quarter, with a peak of over 10,000 events in one week. The average weekly totals of measurements are shown for each month in figure 129 To achieve these figures a regular maintenance schedule has been formulated and carried out. In addition, improvements have been made in the hardware, particularly to the measuring stage hydraulic control and the film transport, which is now more dependable and easier to operate. There has been some development of the on-line control program in the IBM 360/75, mainly for ease of operation but also to reduce the core space occupied (from 160k-bytes to 130k-bytes).

All events measured were first scanned and pre-digitised and the yield from the scanning laboratory has corresponded closely with this progress.

Short test runs have been made with the Minimum Guidance pre-digitising system, though the cost in extra computing time prohibits its regular use on the IBM 360/75 for our present rate of measuring. The normal Road Guidance system from pre-digitising through to HAZE filtering, but excluding KINEMATICS and SUMX, etc. takes some 10 seconds CPU time for four-pronged events, and the Minimum Guidance system nearly twice as much.

Figure 129. Average weekly totals of events measured on HPD I during 1970.



CYCLOPS Film from two spark chamber experiments was measured on CYCLOPS during 1970. During the first half, 120,000 more events were measured from the Cambridge /Rutherford Laboratory experiment begun last year (Experiment 13). In the last quarter, half of the 500,000 events exposed at the Daresbury Laboratory for a π^0 photo-production study by a Glasgow/Sheffield University group were measured. The rates achieved were about 300 events per hour in the first case, and 600 in the second (due to the small format, with two events on every frame measured).

The combined total of 245,000 frames is well below the capacity of CYCLOPS. The measuring time was less than 720 hours in the year and was due to lack of film. The machine is, however, expected to be fully occupied next year.

A side-line, taking a few hours of CYCLOPS time, was the measurement of film showing action potentials in nerve cells. This arose from an investigation being carried out in the University Pathology Department at Oxford.

HPD II While sharing most of its operating principles with HPD I, the new machine incorporates many improvements made possible by advances in technology. Taken together, these are expected to facilitate measurement of low-contrast film from the new generation of large bubble chambers (using fish-eye optics and Scotchlite illumination) on films up to 70 mm wide, and to improve the measuring rate by up to a factor of two.

The new light source is a 200 milli-watt Argon laser (blue-green) which provides a spot at the film 300 times as bright as in HPD I, with a width of only 3 μm and excellent signal/noise ratio. This was developed in collaboration with Imperial College London and is expected to be the model for other laboratories, both within the UK and outside.

The disk speed in HPD II is 6,000 rev/min and the possibility of operating at 9,000 rev/min is under investigation. This compares with the 3,000 rev/min speed of HPD I, and is faster than any other in Europe. The film transport system will handle the new standard 300-metre spools, and position individual frames with respect to Brenner marks or perforations.

A dedicated DDP 516 satellite computer, linked to the central IBM 360/75 and running under the MAST-DAEDALUS system, has been fully exploited in designing the HPD II circuits. Data checking, formatting and some data reduction is carried out by the DDP 516, which also supports a graphics unit comprising two Tektronix 611 storage cathode ray tubes, a keyboard, and interactive tracker-ball. This is a very flexible system, with much scope for development.

HPD II digitised its first frame of bubble chamber film in December. The first production measurements of spark chamber film from an experiment on the CERN Intersecting Storage Rings are expected in Autumn 1971.

VISUAL DISPLAY SYSTEMS—'COMPUTER GRAPHICS'

IDI Display and Light Pen (Ref: 157) Operation of the IDI display and light pen system continued throughout the year. Apart from a little tidying-up, there was no change to the patch-up process for bubble chamber events measured, with pre-digitised Road Guidance, on HPD I.

Two new programs were developed, the first for patching-up failed spark chamber events from CYCLOPS, and the second (not yet complete) for bubble chamber events measured with Minimum Guidance.

The main users were the Bubble Chamber Group. Tracks from over 40,000 events, measured on HPD I, which had failed the criteria set in the subsequent HAZE/

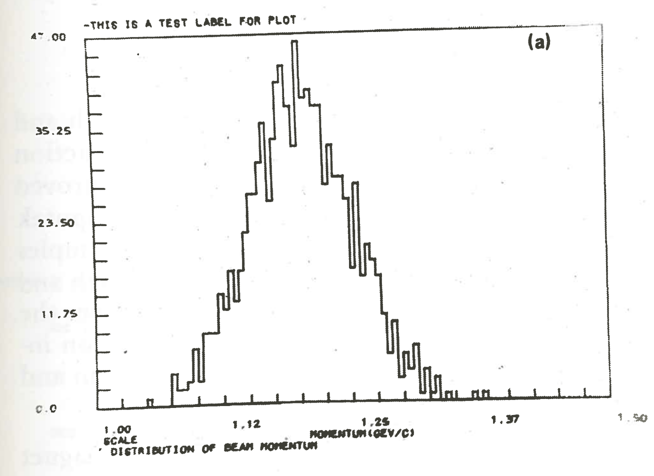
GEOMETRY processing were patched-up. Up to 50 hours per week were used, and usually about 60% of the faulty events were rescued.

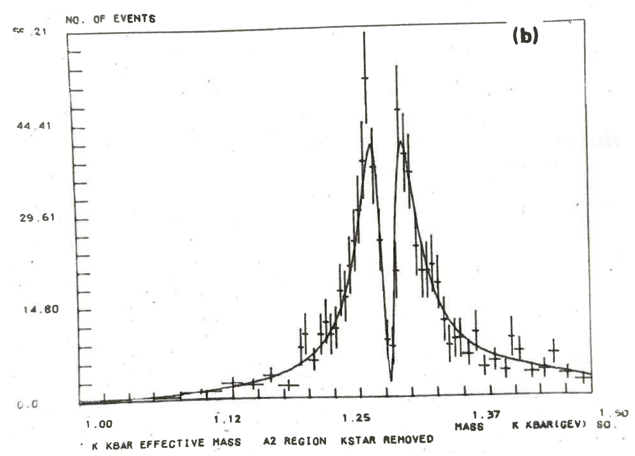
The IDI system was also used to rescue 2,000 failed events from spark chamber film measured on CYCLOPS, and to display events from a non-visual spark chamber experiment for viewing and labelling tracks. Both of these applications were subsequently transferred to the DDP 516 graphics terminal.

Computek Display The Computek display system has been developed to provide easy and immediate visual access, initially on a Computek 400 storage display, to data generated in the IBM 360/75 computer. Files of pictures (which may be line drawings, scatter plots, text or a mixture of all three) are created by batch programs, incorporating standard graphics routines, running in the 360/75.

The files are stored on disk and can be displayed at any linked graphics terminal by a standard program, now part of the ELECTRIC system and permanently loaded and available.

The system has already been widely used: some examples by High Energy Physics groups are the display of SUMX output while Applied Physics groups have utilised the facilities as an aid to design of bubble chambers and superconducting magnets. The Beams Theory group is using the display in developing an interactive beam-design program based on TRAMP. Figure 130 shows some applications.





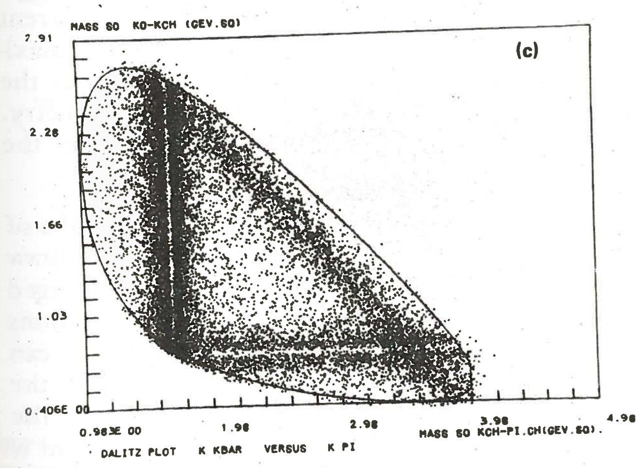


Figure 130. Examples of Computek Display output. Monte-Carlo simulation of $\bar{p}p \rightarrow K^0 K^{\pm} \pi^{\mp}$ at 1·2 GeV/c with a matrix element imposing approximately equal amounts of $K^*(890)$ and A_2, both described by a dipole model.
(a) Distribution of beam momentum.
(b) $K\bar{K}$ effective mass plot, with a dipole fit to the A_2 superimposed.
(c) Dalitz plot for the $K\bar{K}\pi$ system.

Other developments include the 'interception' of data intended for the Atlas Laboratory's Stromberg-Carlson plotter, or for the line-printer on the IBM 1130 terminal computer, with the object of providing immediately a 'first look' at data.

SUMX–Graphics Package

The statistics program SUMX has been modified for use with the graphics display facilities. Histograms and scatter plots produced by SUMX can now be viewed at the graphics terminal, and examples are shown in figures 130a, b and c.

A routine to minimise functions of several variables has been added to this SUMX-Graphics package, so that analytic functions can be fitted to histograms of experimental date at the end of the SUMX run. The fitted function is displayed superimposed on the data, and figure 130b, shows an application.

DDP 516 Graphics Terminal (Ref: 142)

A stand-alone interactive graphics system has been developed. It consists of an 8k DDP 516 computer, a tape drive, a disk unit and two consoles each comprising a Tektronix 611 storage tube, a keyboard and an interactive tracker-ball. An operating system has been written which permits simultaneous operation of all the peripherals.

At present, the facility is used for Experiments 1 (page 26), 13 (page 44) and 14 (page 45). An example of the interactive feature is shown in figure 131, where the CYCLOPS digitisings of an event from Experiment 13 are displayed. The crosses indicate the patch-up points supplied by the operator (using the tracker-ball). The event reconstruction program in the 360/75 uses these points for guidance. About 30 events may be patched-up per hour.

Possible developments of the system include expansion of the computer memory, a data link to the IBM 360/75, and acquisition of additional graphics consoles.

COMPUTER GRAPHICS AS AN AID TO DESIGN

Design of Bubble Chambers and Superconducting Magnets

A wide variety of computer programs have been written to aid the research and design of bubble chambers and superconducting magnets. A substantial reduction in the amount of work involved in studying computer output and in improved understanding of results can be achieved by use of graphical output. The Computek display system has been applied to several applied physics problems, some examples of these applications are now given. In figure 132 is shown the predicted growth and recondensation of a bubble compared with experimental measurements from the DESY bubble chamber operating under the same conditions. The prediction incorporates vapour expansion and compression and heat transfer by conduction and convection.

Figure 133 shows the geometry and field prediction of a superconducting magnet for a polarized target experiment. In this design the coil shape had to be optimised to give maximum magnetic field at the centre whilst maintaining a wide angle aperture for experiments. Because of the dependence of superconductor current density on magnetic field, the performance of the magnet is limited by the maximum field at the coil windings. It is a feature of this program to search for the peak field and display the results on the screen immediately below the geometry. Further shapes can be tried by resubmitting the program remotely from the terminal.

Finally in figure 134 is shown a picture of a beam entry optimisation. The results of a trajectory plotting program called TOPIC are shown, this program will draw the geometry of a magnetic device and compute and plot the path of charged particles in a non uniform magnetic field. The user stipulates the initial conditions and submits the job remotely. After processing by the 360 batch the pictures can be retrieved, studied and new initial conditions decided in order to improve the beam entry. Special features include loss of energy by ionisation whereby the position along the track at which the beam reaches a prescribed momentum is flagged.

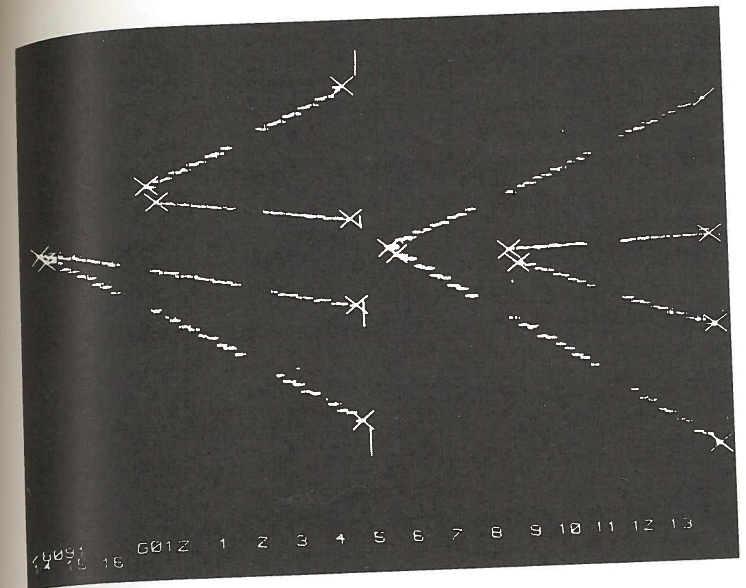


Figure 131. An example of the interactive graphics display showing the CYCLOPS digitisings of an event from Experiment 13.

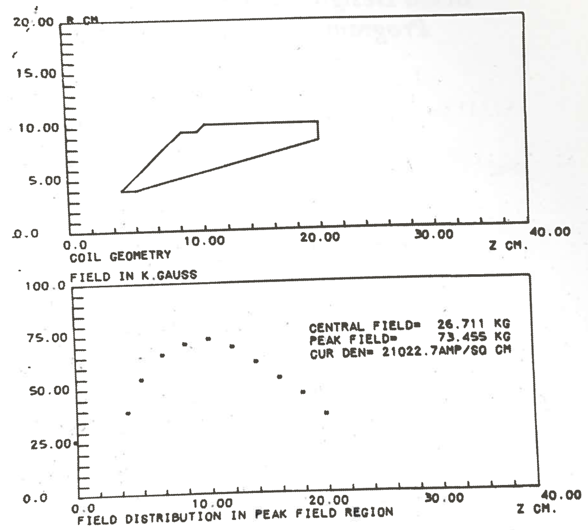


Figure 133. Optimisation of superconducting coil geometry.

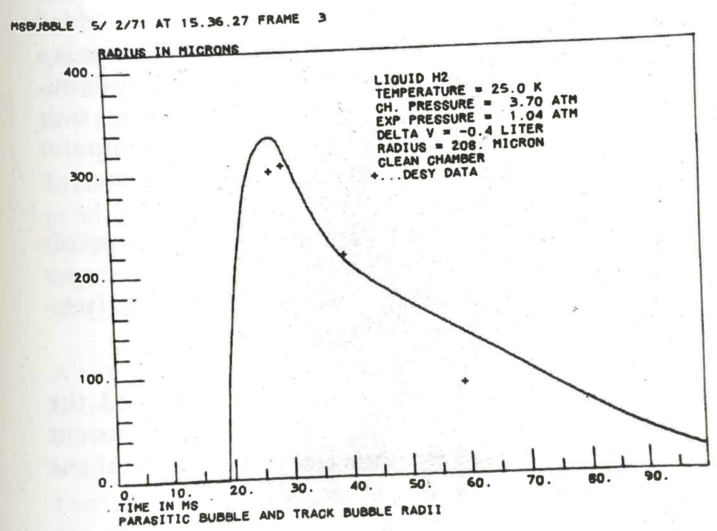


Figure 132. Predicted growth and recondensation of a bubble compared with experimental measurements.

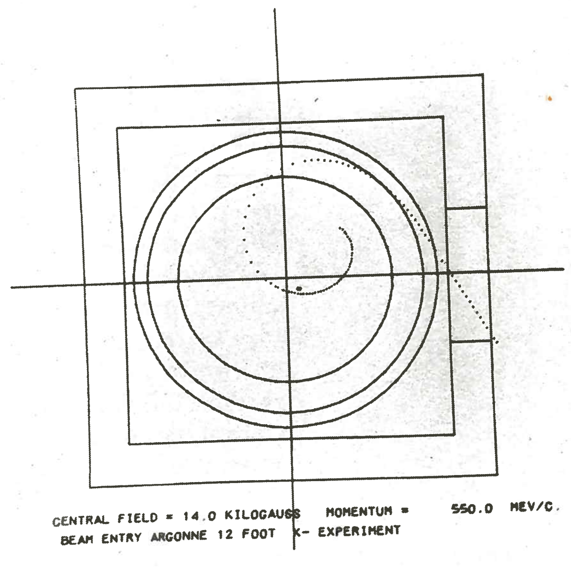


Figure 134. Tracking program for optimising beam entry.

Beam Design Programs

An interactive visual-display (graphics) program is being developed to complement the existing and widely used beam optics programs, TRAMP and IPSO FACTO. Initial definition of the beam is based on TRAMP, but thereafter the flow of the program has been completely changed to simplify the task of adding extra facilities as their need becomes apparent.

Output is routed via the DDP224 satellite computer either to the Computek display for graphical output, or to an adjacent typewriter. Communication with the program is via the typewriter keyboard. Modifications to the beam-line or automatic numerical matching can be performed and the resultant effect on stored particle trajectories can be displayed rapidly. This interactive aspect of the program is its key feature and should greatly facilitate the task of beam design, and the development of tuning procedures for existing beam-lines. An example of graphic output from the program is shown in figures 101 and 102 referring to the stopping K beam described on page 130.

EXTENSION OF ON-LINE SYSTEMS

New Satellite Computers

In addition to the DDP 224, through which all on-line users have communicated with the central computer so far, two new satellites will soon be in full operation. They are a DDP 516 dedicated to HPD II, and an IBM 1130, which will be situated in the Nimrod Experimental Area, and function as a remote terminal. In due course the IBM 1130 used for gathering data from the scanning and pre-digitising machines will also be linked to the central computer.

A new multiplexor is being built for the DDP 224, to allow simultaneous operation of the existing typewriter consoles and connection of up to a total of 16 similar devices.

The terminal IBM 1130 is at present connected to the 360/75 by a short distance link, and the magnetic tape unit, line printer and card reader are being commissioned using an operating system similar to that on the DDP 224. A unit has been added to the terminal computer to allow connection of a further eight devices. One is a multiplexor, connecting users in the Experimental Area via their CAMAC systems. Another is an 880 kilo-bit per second 'serial' link, capable of operating over distances exceeding half a mile, which will be used when the terminal computer reaches its site in the Experimental Area (500 yards from the central computer).

Once established there, the terminal will allow users to submit jobs or data (cards or 7-track magnetic tape) to the 360/75 and receive back output on an 80 lines per minute printer. It will also be possible to connect various user terminals (typewriters, small computers, or visual displays).

A direct link between the DDP 516 computer (controlling HPD II) and the central computer has been established and is operating satisfactorily. Current hardware, including a newly-built multiplexor for the direct control feature of the IBM 360/75, allows the connection of up to six satellite computers.

The ELECTRIC Program

A program named ELECTRIC has been developed to provide remote job entry to the central computer from typewriter consoles which will be distributed around the Laboratory. It operates under the DAEDALUS message switching system and gives a general service. A user may create and edit files containing the text of programs, job control statements or data, and may submit a file as a job for batch execution. The program also allows monitoring of the subsequent progress of the job.

In addition to these normal facilities for conversational remote job submission, the program allows the user to hold files in the form of text with associated editing instructions. The files can then be used in their original text form or as updated by their associated edit instructions (or sub-sets of these instructions). A comprehensive set of manipulations of both text and edit instructions is available.

ELECTRIC is also intended to help in the following problem situations which often arise in computing:

(i) Keeping several slightly different versions of the same big basic program.

(ii) Supplying new versions of programs to outside users who have themselves modified the previous version.

(iii) Difficulties when more than one person is working on a program.

The system has been in use with a limited number of typewriter consoles since mid-1970.

DATA ANALYSIS SOFTWARE

Bubble Chamber Programs

Maintenance and modifications of the existing Road Guidance system, and development of the Minimum Guidance system, have been the main activities this year.

Automatic Track Matching was introduced early in 1970, and has been used in processing all of the three experiments measured since. No other changes of principle have been made to the production version of the date processing program, though there have been numerous small changes.

Data safety has been considerably improved by an automatic file protection program now in regular use. Tapes containing data accumulate at several stages of HPD production measurement, e.g. digitisings prior to week-end HAZE runs, and geometry input prior to merging with output from the patch-up system, which may not be available for a week or two. To prevent tapes being accidentally overwritten a record is held (on disk) of the current use of each HPD tape, and programs which output data to tape have been modified to check that the tape is available for use, and to update the record. A list of free tapes can be generated at any time.

In the Minimum Guidance system, two major problems are the number of digitisings produced (two to six times as many as in Road Guidance) and the CPU time taken by the filter program (about three times Road Guidance). A method under test would reduce the digitisings by defining, at the measuring stage, a cone containing all tracks of an event, and gating-out other digitisings.

A sample of events from the low-energy K^-p experiment is being used for Minimum Guidance tests. The main problems arising in matching tracks found in the three views have been due to non-interacting beam tracks close to the production vertex, and (in multi-vertex events) tracks being picked up by the filter program at more than one vertex. For example, the track from a Σ decay may well be picked up at the production vertex and at the decay vertex.

A patch-up system using the IDI display and light pen has been developed, and has been successfully applied to 'rescue' more than half of the failed events in a test batch. The region of the picture close to the vertex is displayed, but without digitisings of tracks already successfully matched. The operator marks three points on tracks chosen (as in Road Guidance), and filtering then proceeds as in Road Guidance.

Spark Chamber Programs

The general filtering program, which finds tracks from CYCLOPS digitisings, has been modified to search for curved tracks by performing a parabolic fit for each track. A version of the program is being used to find tracks and fiducial centres from digitisings of film taken at the Daresbury Laboratory for a Glasgow/Sheffield University photoproduction experiment. The program is now in a production state for this experiment and runs will start soon. Tape output will go to the Daresbury Laboratory for final processing and analysis.

Production runs on automatically measured events in Experiment 13 (page 44) ended in June 1970, and all remaining runs use information from events patched-up, either on the DDP 516 Graphics terminal, or on digitising tables. In future experiments, it appears desirable to reconstruct sparks from CYCLOPS digitisings, and then link sparks together to form tracks.

A program used in an earlier experiment has been developed, and tests with K13 data have shown the method is faster (by a factor of two) than the direct linking of digitisings to form tracks. It also facilitates correlation of tracks between different views. However, the direct method is more successful in finding tracks, and further work is being done on the two-stage program to improve its success rate.

Many spark chamber experiments require momentum determination from particle trajectories through regions of non-uniform magnetic field. To minimise computing time for such analysis, it has proved valuable to express the momentum as a function of entry and exit parameters. A program has been written to find appropriate functions for Experiment No. 16 (page 48) and tests on data generated by a Monte Carlo program have been satisfactory. A program for expressing inhomogeneous magnetic fields in terms of Chebyshev polynomials is under development, and should be widely applicable.

USE OF SMALL COMPUTERS

Small computers are in extensive use in the Laboratory. Their application ranges from routine data-logging for complex apparatus to control of sophisticated devices such as the 'flying spot' film measuring machines. Some of these computers have been referred to in various chapters of this Report and those in use as on-line satellites to the central 360 computer are described in the immediately preceding sections of this chapter. The use of other computers are briefly described below and a complete summary is presented in Table 18.

High Energy Physics Experiments using electronic techniques

The most common application is in the recording of raw data and continuous monitoring of the performance of counters and spark chambers. These functions are carried out in parallel. Without such a service most modern experiments requiring large statistics and high data collecting rates, and using large numbers of detectors, would be impossible. Some experiments are able to analyse, at least partially, their raw data in between each beam pulse from Nimrod, e.g. reconstruct the topology of an event to see if it is of the required category. This speeds up the data analysis time considerably.

The advent of the CAMAC electronic system will enable control and data-logging of beam line magnet currents to be included in the computer duties. This will further increase the data-collection efficiency.

Beam line Control

The extracted proton beam X3 was set up using a computer to perform magnet scans to optimise the beam. This proved to be a very efficient operation and plans are in progress to enable a similar procedure to be used for the K9 beam.

Bubble Chamber Control

A computer system is being developed for data-logging and to control the chamber operation.

Film Analysis

Scanning and road-making of bubble chamber events is carried out on-line to a small computer which checks and records the data. A future development may be the direct connection of this computer to the central computer so as to perform a more detailed quality-control of the data.

Table 18

SUMMARY OF THE USE OF SMALL COMPUTERS

Computer	Application
DDP 224 (360 satellite)	HPD I; CYCLOPS; IDI light pen and visual display; COMPUTEK display; typewriter consoles, etc.
DDP 516 (360 satellite)	HPD II system.
IBM 1130 (360 satellite)	Terminal computer to be located in experimental area. Typewriter consoles; direct data-links between central computer and experiments.
IBM 1130	Bubble chamber film scanning and pre-digitising machines.
DDP 516	Graphics device for spark chamber film analysis.
PDP 8LA	Control of conventional bubble chamber film-plane measuring machines (not yet operational).
PDP 5	Development in Nimrod area.
PDP 8	Control of X3 beam (also linked to PDP 5).
PDP 8	Control of K9 beam.
PDP 8–I	Data-logging and control of 1·5 m hydrogen bubble chamber.
DDP 516	K12A (experiment 9, page 38).
DDP 516	K13 (experiment 13, page 44)
DDP 516	π9 (setting up).
DDP 516	Intermediate Boson Experiment, to be run at the ISR, CERN (experiment 18, page 51).
Ferranti Argus 400	K15 (experiment 8, page 36).
PDP 8	π10 (experiment 32, page 68).
IBM 1130	π8 (experiment 16 and 17, pages 48 to 50).
PDP 9L	$\bar{p}p$, at CERN (experiment 10, page 39).
Modular 1	Electronics: testing of CAMAC modules and CAMAC systems used in experiments.