STATUS REPORT OF THE CERN-LSD SYSTEM

CERN-LSD Group
(presented by J.-C. Gouache)

1. INTRODUCTION

This first paper is intended to serve as a general frame for the following reports. It gives an overall view of the construction of the LSD (short for "Lecteur à Spirale Digitisée") and of the operation of the whole system at CERN. Most of the points and figures just mentioned here will be dealt with in detail in the next papers.

No attempt is made to give a precise description of the machines - this can be found in references 1, 2, 3 and 4 - we simply emphasize the main differences with the other devices of this type.

Before we go into the details of this status report we would like to stress the following point: experiments at CERN are carried out in two departments; the Department of Physics II concentrates on bubble chamber physics and half of the events measured there are processed on the LSD's. This already gives an idea of their importance in the CERN production systems.

2. HISTORICAL SURVEY

The studies for the construction of a Spiral Reader at CERN as a joint project with the Collège de France began in November 1966. The design of the LSD was intended to be as close as possible to the Berkeley machine but finally evolved into the complete redesign of the following items:

- the cone-periscope system was put vertical instead of horizontal and the photomultiplier outside the periscope assembly;
- the system for automatic measurement of fiducial marks was designed to measure 4 marks/picture instead of 2;
- the PDP-4 was replaced by a PDP-9;
- the spiral scan radius was increased from 40 cm in space to 72 cm;
- the optical path was simplified in the sense that the light did not go through any plane parallel plate (except film gate) on the main path from film to cone-periscope;
- the film transport had to accomodate film from the 2 m or 80 cm HBC's, i.e. 50 or 35 mm unperforated film (measurement of 70 mm film was not required);
- the electronics was entirely redesigned for integrated circuits.

In April 1969 the LSD 1 (fig. 1) produced its first event digitizings and test production could be started. The digitizing logic and pulse analysis system were closely derived from the Berkeley machine and the periscope slit dimensions were then 260 x 17 μ^2 in the

film plane. The first experiment to be measured was Exp. 30, $\pi^- p$ at 3.9 GeV/c, topologies 200 and 400 only. At the end of April 1970, this first experiment was successfully completed with the measurement of 33,000 events. A detailed account of this first year of production, of the difficulties encountered and their solutions is given in ref. 5. In the meantime, in November 1969, the autofiducial system had been put into operation and this increased the measuring rate by a factor 3 (from 20 to 60 events/hour). This first experiment consisted partially of events already measured on manual machines (IEP) and was essentially intended to assess the quality of LSD data.

The second experiment was started in May 1970 (Exp. 36, again $\pi^- p$ at 3.9 GeV/c, but all topologies except 200) and until June 1971, 120,000 events (out of which 40,000 were measured twice) had been processed, corresponding to the measurement of 200,000 vertices. This experiment was originally intended to investigate the alleged split of the A2 meson, to study the $\omega\rho$ interference and the B meson, but finally extended its scope to a general study of production mechanisms. In the meantime, towards March 1971, the very first investigations to get ionization information from the pulse height measurements were initiated on selected event samples using the method then currently in use at Berkeley and at the Weizmann Institute. This study was carried further with the next experiment to convince ourselves of the reliability of pulse height measurements. The study was sufficiently well advanced to use ionization in production for the second half of the experiment.

This third experiment was Exp. 28, a formation experiment, $K^- p$ between 1.45 and 1.86 GeV/c, all topologies. It lasted from July to December 1971 and yielded 68,000 events (out of which 12,000 were measured twice) corresponding to the measurement of 115,000 vertices. It was intended essentially for phase shift analysis, hence the large amount of remeasurements.

The last experiment started in February 1972 ($K^- p$ at 4.2 GeV/c, all topologies except 200 and 400). It is intended to be the first very large statistics K^- experiment. One expects to obtain a total of 3 million photographs (the exposure would then correspond to 200 events/μb) which should lead to the measurement of a total of 1,500,000 events on LSD's. Besides the study of the Ξ^* resonance ($\sim$ 50,000 strangeness-2 final states expected) one intends to perform all K induced physics in the intermediate region. At this date (May 1972) 40,000 events are already on DST, corresponding to the measurement of 75,000 vertices.

Since we have mentioned the existence of two LSD's, let us review briefly the construction of LSD 2 (fig. 2).

Already in the fall 1969 the spare parts for LSD 1 were being used to perform different tests which had proven to be necessary from the experience gained with the first machine and the difficulties encountered. Since this set-up essentially consisted of the machine framework carrying a cone-periscope assembly, it was, in some early reports, referred to as "Test C-P" (Cone-Periscope).

The first item to be tested was a new type of Automatic Gain Control referred to as AGC 2 (as opposed to AGC 1 on the LSD 1). It could accept background variations in a ratio 1:50 (resp. 1:10 for AGC 1).

The second item was an integrator, primarily intended to replace the pulse height by a pulse area estimate to improve the ionization information. It turned out to be extremely useful in the treatment of broad pulses, as encountered during calibration and with highly curved tracks but its influence on ionization estimate still remains to be investigated.

Other pieces of hardware, such as a new type of analog-to-digital converter, a new pulse discrimination logic, a new photomultiplier etc. were also tested. At the same time, studies to increase the amount of light coming to the periscope in order to be able to reduce the slit width (thus improving ionization measurement) without deteriorating the signal to noise ratio, led to the replacement of both semi-transparent mirrors. All these results are discussed in detail in the next reports on hardware improvements.

In the meantime, in June 1971, an X-Y stage was added to "Test C-P" and, in August 1971, a slow film transport. After the completion of the system for automatic measurement of the fiducial marks and debugging of the control program towards the beginning of 1972, it was then officially labelled LSD 2.

Up to now, it has measured a total of 15,000 events from Exp. 42. These events have already been measured on LSD 1 and are intended to check the consistency between both machines. This comparison is still under way but everything seems to indicate that LSD 2 will be in a position to take over the full production load when LSD 1 is turned off for a long maintenance in July 1972. From October 1972 onwards, both machines are expected to be run together.

3. PERFORMANCE

3.1 Production

Fig. 3 shows the overall production of LSD 1 since April 1969. Based on 1971 production and extrapolating the figure for the beginning of 1972, the typical yearly production should now amount to 200,000 to 250,000 vertices. The speed has also constantly increased; it seems to level off at 70 vertices/hour but it is obviously correlated to the topologies measured, to the beam density and to the operator's performance. The maximum speed obtained up to now on a 2 hour shift is 120 vertices/hour. To appreciate this figure one should keep in mind that the absolute maximum velocity of the machine lies between 150 and 180 vertices/hour. The total number of events processed on LSD 1 at this date is 320,000 (resp. 430,000 vertices).

Fig. 4 shows the actual measuring time, i.e. the time during which one actually measures events (thus excluding breakdowns, film and magnetic tape handling, calibration, tests etc.). Again a typical yearly figure can be estimated to lie between 3,500 and 4,000 hours of measuring time on a total of 5,000 hours foreseen (corresponding to a typical percentage of 75%). The LSD 1 has been measuring events during 8,000 hours but the machine has been running during 11,000 hours since April 1969.

The difference between foreseen time and measuring time can be accounted according to the following table (typical values):

- film and magnetic tape change calibration, etc.	7%
- preventive maintenance	4%
- test (including title measurements)	7%
- breakdown	7%
Total	25%

3.2 Quality

For the current experiment (Exp. 42; all events, except 600's are multi-vertex events) one can give the following figures:

- passed events (i.e. go directly onto DST)	40%
- check events (i.e. come back to the scanning table because of ambiguous kinematical hypotheses)	40%
- failed events:	
geometry	13%
kinematics	7%

One should note that these numbers are obtained without using ionization. Preliminary results for Exp. 42 seem to indicate that ionization should reduce the number of check events by a factor 2 and the number of hypotheses for the remaining check events by a factor 3.

4. PRODUCTION OPERATION

Fig. 5 shows a flow diagram of the production operation of LSD 1 for Exp. 42. Its most characteristic feature is the time scale. As can be seen, a complete measurement cycle does not take more than 60 hours. In other words, within 3 days, a film is measured, the output tapes are processed through THRESH-GRIND-SLICE on the CDC 65-6600, the CHECK events are identified, the remeasurements are prepared and the physicist gets a pre-DST. At this stage already, most of the tests on physical quantities can be carried out.

The procedure has become necessary by the very type of experiment performed namely the processing of 1,500,000 events out of 3,000,000 photographs. It allows to split the whole experiment into a series of "sub-experiments", not longer than 8 weeks, corresponding to the standard interval between two long maintenance periods on the LSD. Remeasurements are typically performed during the last $1\frac{1}{2}$ week of this period. At this level real physics analysis can already be started and then proceed in parallel with the measurements.

This procedure has been implemented and operated up to now with the direct participation of programmers and physicists. We are now in the process of delegating more and more of this responsibility to assistant staff and are making efforts to get a smooth and well

coordinated operation of the whole chain, in order to leave the physicists free for other tasks.

4.1 Preparation of input

The high processing rates reached by 2 LSD's in production are such that the classical scanning had to be given up and a more efficient system implemented. Recently (May 1972), 6 Shiva scanning tables have been connected on-line to a PDP-11 computer. The data (roll, frame, topology) are entered via a keyboard and the grid is replaced by a line of 24 push-buttons located on the table about 30 cm in front of the operator. These buttons have dimensions corresponding to the size of the TV screen on the LSD, thus ensuring a good positionning for the measurement.

After different consistency checks, the data are output onto a DEC-tape which is used to produce the usual INDEX tape and the LSD input tape. Paper, pencil and scan-cards have thus been entirely eliminated.

The scanning operation itself has been simplified as much as possible. The only item which has been added to the usual information is the number of kinks.

Besides the improvement in reliability and the reduction in cost, the scanning speed has increased by a factor of 2 (from 32 to 60 events/hour, thus almost reaching the average speed of one LSD).

4.2 Organization of measurements

4.2.1 LSD operation

A typical measuring period lasts 8 weeks between two maintenance periods of 1 week. One measures 5 days/week, 24 hours/day. Each week, a preventive maintenance is performed, typically during 5 hours.

The measurement is presently organized in 2 hour shifts. The operators are the same as for scanning and identification, and are supervised in all their activities by the same coordinators.

The maintenance is performed by one electronics technician "on call", 24 hours a day.

4.2.2 Measuring sequence

A detailed description of the measuring sequence is given in ref. 1 We would simply like to mention here that the number of "special" buttons has been cut down to a minimum in order to increase the speed and to reduce the number of operator errors.

Three "special" buttons are left:

- Button A : this point must be reconstructed in space
- Button B : this point is a help to the filter program
- Button C : ignore the digitizings beyond this point.

4.3 Quality control of the output

4.3.1 Hardware checks

During the weekly preventive maintenance all the standard test programs are run before the machine is delivered to the production. These programs cover the PDP-9, the magnetic tape units and the LSD hardware. The production control program also performs, on-line, a series of consistency checks.

Some parameters computed by the calibration program have been shown to be particularly sensitive to the machine status. Their behaviour is carefully registered and the engineers are informed whenever their value reaches a given threshold. As an example, we might mention the average RMS deviation of the digitizings for all crosses, the reconstruction of a radial line on the square grid, and the average pulse width and pulse height on individual crosses.

4.3.2 Check of the operator's measurements

After one week, the number of events measured by each operator is sufficient to perform a statistics on his performance. For instance, the speed, the percentage of tracks lost per topology, the ratio of the number of useful crutch points to their total number etc.

At the sub-experiment level (8 weeks) one computes the operator's effective speed expressed in "good" events/hour. A "good" event is defined as an event which has passed the whole program chain (geometry and kinematics). This latter figure really expresses the operator's performance.

4.3.3 Check of the measurement quality

The geometry output allows to verify several quantities such as the residuals on the fiducial marks, the track residuals and the beam parameters ($1/p$, λ, ϕ).

The kinematics output serves to produce the plot shown on fig. 6. It should be emphasized that this plot is updated each week and thus ensures that the whole chain, from film to DST, is working properly.

5. CREDITS AND ACKNOWLEDGEMENTS

The LSD system is the result of a group effort and this is why all the papers presented at this Symposium are signed "CERN-LSD Group".

Although the present development and maintenance team consists of about 12 persons, here is the list of people who have either participated at some stage in the construction or have contributed in some fashion to the success of the LSD system at CERN:

G. Bain	Ph. Gavillet	E. Pagiola
P. Berge	K. Geissler	G. Pichon
C. Bertuzzi	J.-C. Gouache	R. Platteaux
R.-K. Böck	G. Guillou	H. Ponssen
M.-H. Bovard	R. Hemingway	G. Regad
G. Brandon	H. Klein	S. Reynaud
R. Budde	W. Krischer	E. Riipinen
V. Chaloupka	J.-C. Legrand	E. Rossa
L. Dobrzynski	J.-C. Marin	E. Rosso
J. Domeniconi	F. Martin	A. Scharding
J. Dupont	L. Montanet	J. Trembley
E. Eichmann	D. Moreno	C. Vollerin
H. Frederiksen	P. Nappey	P. Wellstead
J.-L. Garavel	G. Ososkov	L. Zanello

Finally one should not forget to pay the proper credit to the continued efforts of our operators and their supervisors to achieve a high rate of measurement and to develop both machines into an efficient production system.

REFERENCES

1) The LSD Project (Spiral Reader), CERN-Collège de France, by J.C. Gouache and J. Trembley, CERN/D.Ph.II/INSTR 68-2, 14 August 1968, Paper presented at the Summer School on "Use of Computers in Experimental Physics" held in Alushta, Crimea, USSR, May 1968.

2) Project LSD (Spiral Reader) Electronique by P. Nappey, CERN/D.Ph.II/INSTR 69-5, 28 April 1969.

3) Description and Performance of the CERN Spiral Reader (LSD), by G. Brandon, R. Budde, K. Geissler, J.C. Gouache, P. Nappey, H. Ponssen, G. Regad, E. Rossa and J. Trembley, CERN Yellow Report 70-21, 24 July 1970, Proceedings of the International Conference on Data Handling Systems in High Energy Physics held at Cavendish Laboratory, Cambridge, England, in March 1970.

4) Cartes d'Electronique du Lecteur en Spirale Digitisée (LSD), by J. Domeniconi, J.C. Legrand and R. Platteaux, CERN/D.Ph.II/INSTR 71-1, 4 January 1971.

5) First Working Year of the CERN Spiral Reader, by L. Dobrzynski, CERN/D.Ph.II/INSTR 71-7, 28 September 1971.

FIGURE CAPTIONS

Fig. 1 Overall view of LSD 1

Fig. 2 Overall view of LSD 2

Fig. 3 Production of LSD 1

Fig. 4 Measuring time on LSD 1

Fig. 5 Flow diagram of production operation for Exp. 42

Fig. 6 Physical distributions for the system's quality control.

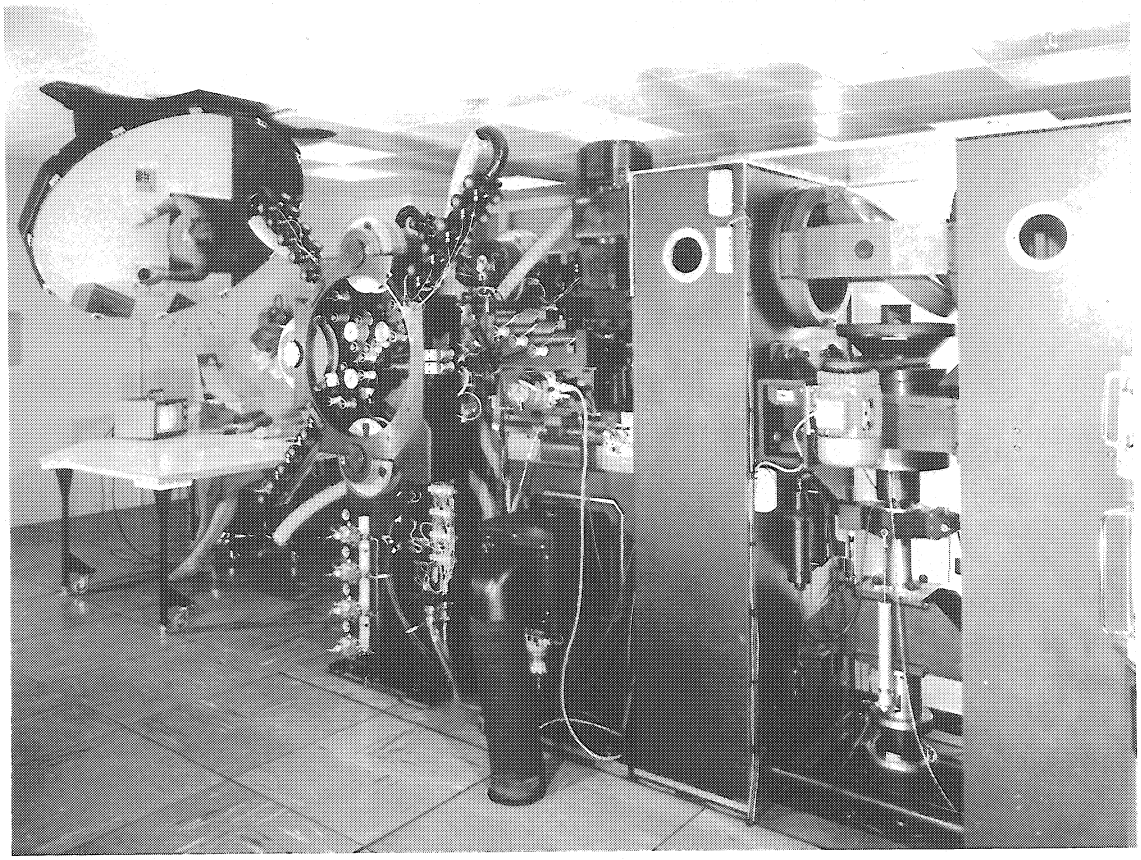

Fig. 1

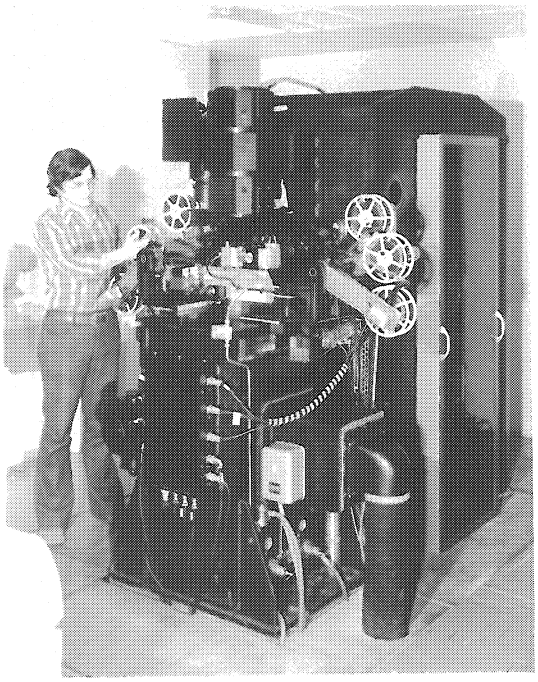

Fig. 2

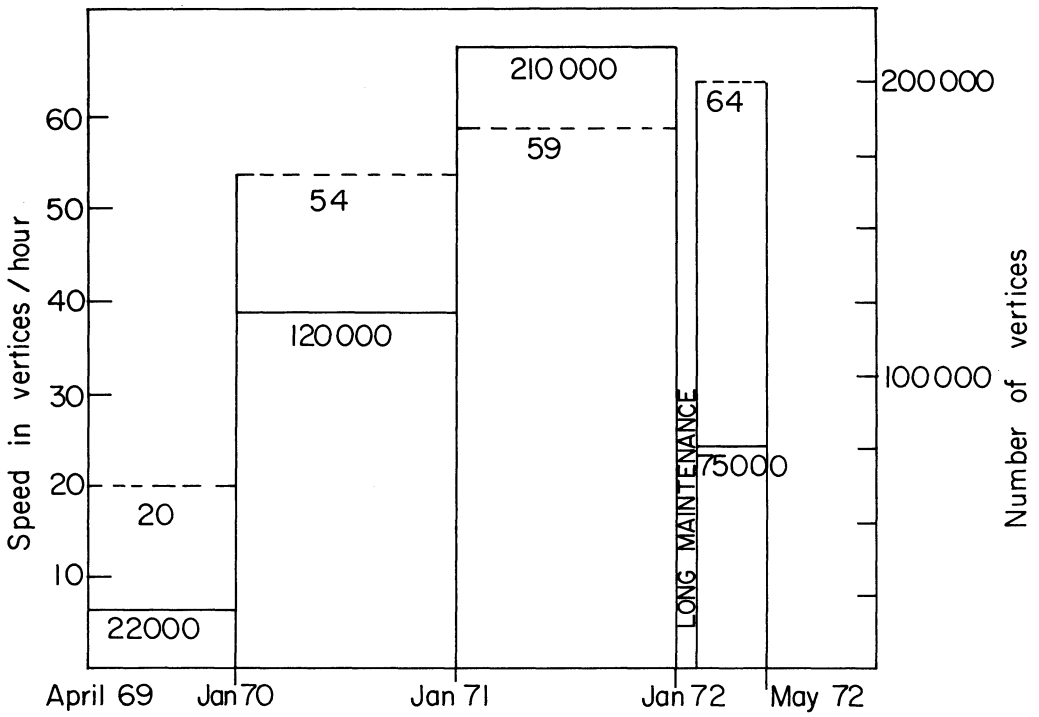
Speed in vertices / hour
60
50
40
30
20
10
210 000
64
59
54
120000
20
22000
LONG MAINTENANCE
75000
200000
100000
Number of vertices
April 69
Jan 70
Jan 71
Jan 72
May 72

Fig. 3

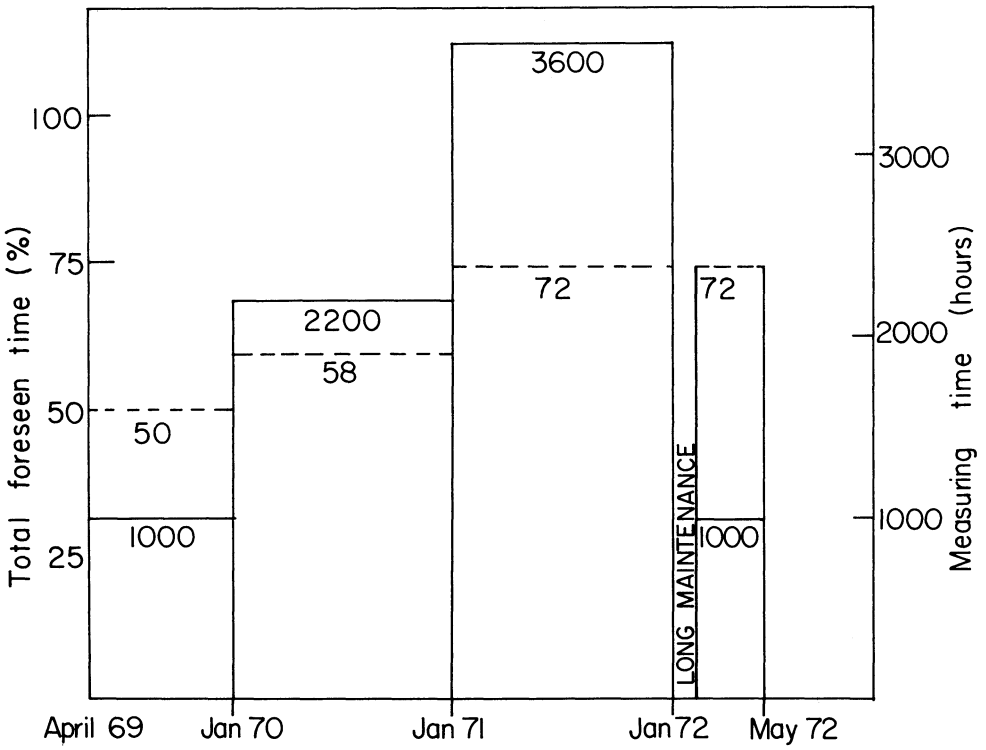
Total foreseen time (%)
100
75
50
25
3600
72
72
2200
58
50
1000
1000
LONG MAINTENANCE
3000
2000
1000
Measuring time (hours)
April 69
Jan 70
Jan 71
Jan 72
May 72

Fig. 4

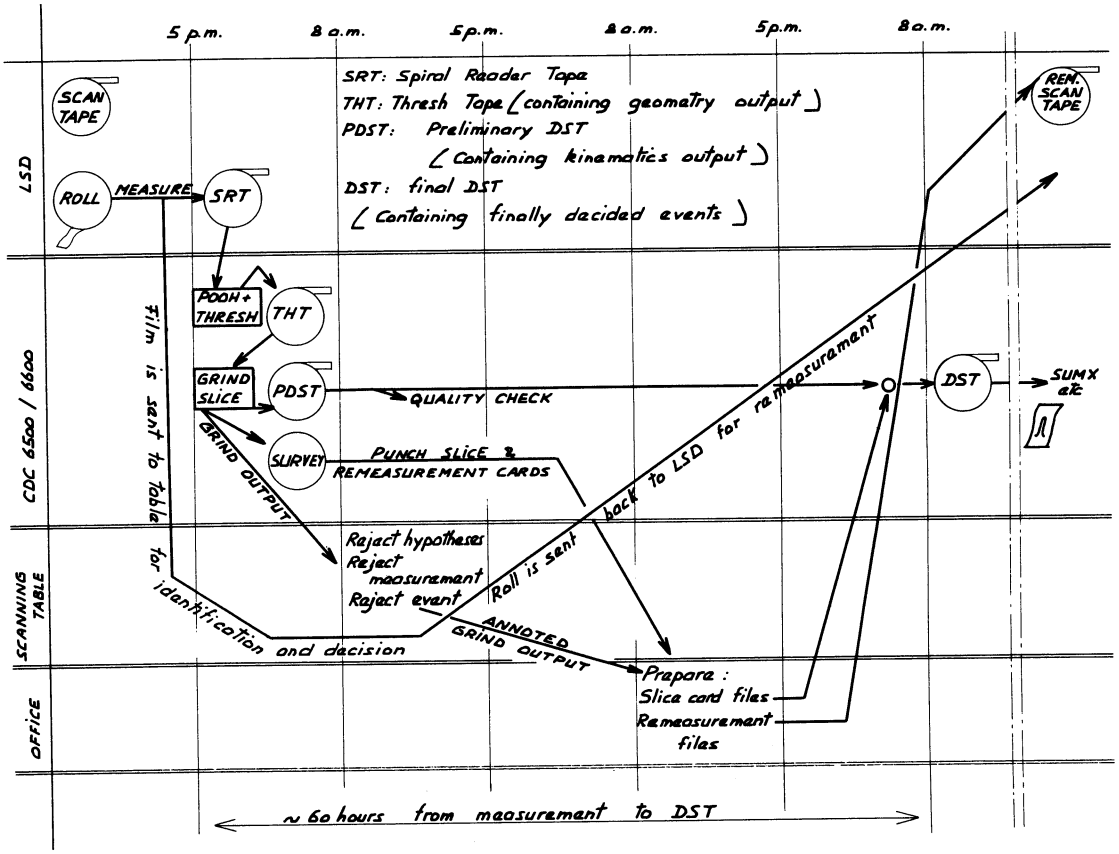
5 p.m.
8 a.m.
5 p.m.
8 a.m.
5 p.m.
8 a.m.
LSD
CDC 6500 / 6600
SCANNING TABLE
OFFICE
SCAN TAPE
ROLL
MEASURE
SRT
SRT: Spiral Reader Tape
THT: Thresh Tape (containing geometry output)
PDST: Preliminary DST
(Containing kinematics output)
DST: final DST
(Containing finally decided events)
REM. SCAN TAPE
POOH + THRESH
THT
GRIND SLICE
PDST
QUALITY CHECK
DST
SUMX etc
SURVEY
PUNCH SLICE & REMEASUREMENT CARDS
GRIND OUTPUT
Film is sent to table for identification and decision
Reject hypotheses
Reject measurement
Reject event
Roll is sent back to LSD for remeasurament
ANNOTED GRIND OUTPUT
Prepare :
Slice card files
Remeasurement files
~ 60 hours from measurement to DST

Fig. 5

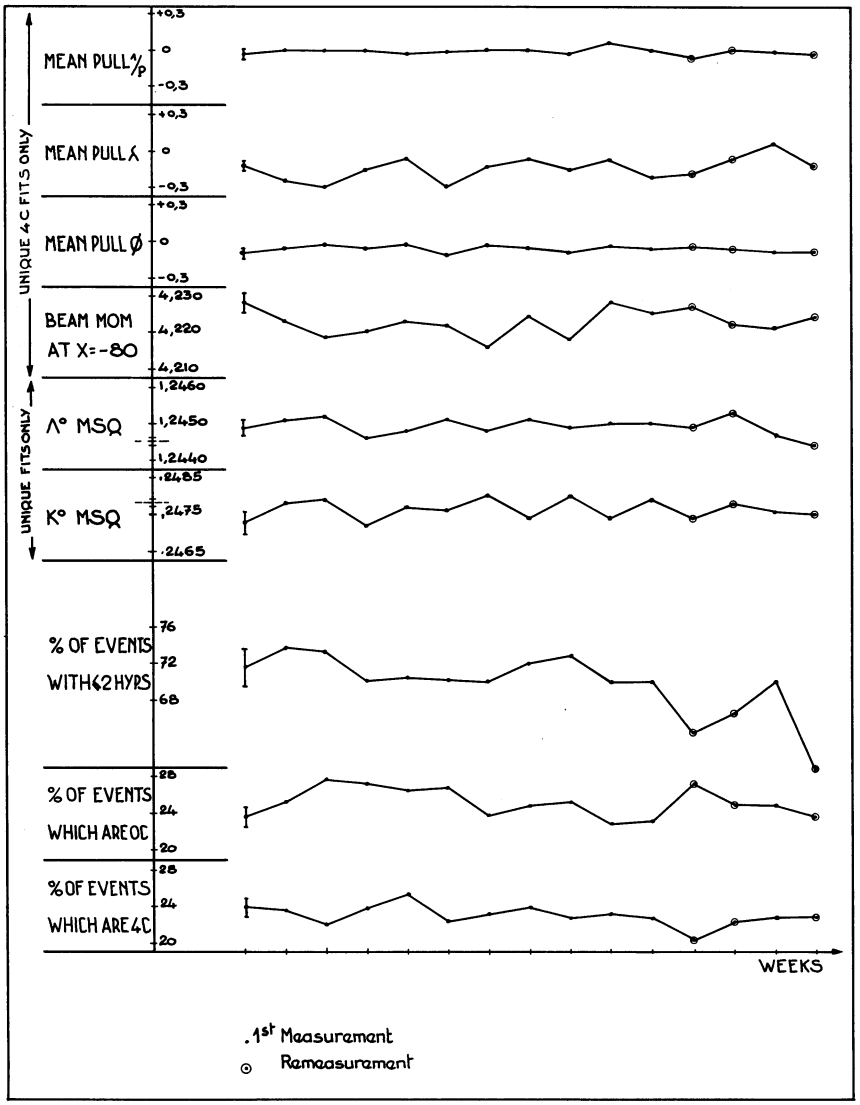
UNIQUE 4C FITS ONLY
UNIQUE FITS ONLY
MEAN PULL p
+0,3
0
-0,3
MEAN PULL Λ
MEAN PULL Ø
BEAM MOM AT X=-80
4,230
4,220
4,210
Λ° MSQ
1,2460
1,2450
1,2440
K° MSQ
.2485
.2475
.2465
% OF EVENTS WITH ≤2 HYPS
76
72
68
% OF EVENTS WHICH ARE OC
28
24
20
% OF EVENTS WHICH ARE 4C
WEEKS
. 1st Measurement
⊙ Remeasurement

Fig. 6