Proceedings of the HPD Collaboration Meeting
Held on September 27th, 1971
PREFACE

The HPD Collaboration Meeting held on September 27, 1971 at CERN was almost entirely devoted to the problems of measuring film from the future Big European Bubble Chamber (BEBC). Nearly all the papers presented at the meeting are duplicated in this report. It could have been published earlier, in less complete form, but it was felt that some of the reports which were slow in arriving were well worth waiting for.

The general conclusion of the discussion held at the end of the meeting was that, while the work on hardware, such as installation of laser light sources and improvement of detector circuits, was well under way, there was very little effort yet committed to the study of the computer programming problems. However, the work on Mirabelle film, at Saclay using Minimum Guidance, and at Imperial College using Full Guidance is very relevant.

Laser light sources were installed at RHEL and Liverpool, and were approved for installation at Amsterdam, Birmingham, and Imperial College. The nucleus of the work on track detection circuits is the collaboration between RHEL and Amsterdam; R. Lawes, RHEL, will coordinate the distribution of information. Munich have specialised in building filters. It was also agreed that it would be desirable to have standard gratings and test patterns on film and this would be coordinated through Saclay.

W.G. Moorhead
15.3.1972
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HPD 2 DEVELOPMENT AT THE RUTHERFORD LABORATORY

R. Lawez

1. Introduction

HPD1 at the Rutherford Laboratory has been in regular production since 1969. The machine operates at 3000 rpm and is capable of measuring 2 m chamber film at a rate in excess of 100 events/hour. Development work has been concentrated on HPD 2 and the main programme has been to implement the integral computer proposal previously described (1). The computer used is a 12K, 0.96µs DDP 516 and was chosen from a survey carried out at the beginning of the project (2).

The problems presented by B.E.B.C. resulted in a proposal to use a laser as a light source and this was implemented on the RHEL HPD2 in late 1970 (in collaboration with W T Welford from Imperial College ) (3).

A major diversion from the main construction programme has been to convert HPD2 from a 50mm to a 70mm scanline. This will be required for the first two experiments (optical spark chambers) to be measured and eventually, of course, for B.E.B.C. itself.

During these modifications a number of mechanical improvements have been made to the machine including a film gate, stage brakes and film transport.

A review of the hardware changes and recent results from the laser optical system is presented.

2. Optical/Mechanical Improvements

The following changes have been satisfactorily concluded:

2.1 70mm Optics

The conversion package offered by Sogénique has been installed. It involves lifting the optical bench of the machine by 6 cms and using CERN 3 Wray lenses and holders in the track channel only. This gives rise to a number of changes in HPD parameters:

<table>
<thead>
<tr>
<th>Item</th>
<th>50mm HPD Nominal</th>
<th>70mm HPD Nominal</th>
<th>70mm HPD Measured</th>
</tr>
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<tbody>
<tr>
<td>Disc Speed (RPM)</td>
<td>3000</td>
<td>6000</td>
<td>5910</td>
</tr>
<tr>
<td>Period (mS)</td>
<td>2.5</td>
<td>1.25</td>
<td>1.28</td>
</tr>
<tr>
<td>Spot Velocity (µ/µsec)</td>
<td>24</td>
<td>48</td>
<td>47.3</td>
</tr>
<tr>
<td>Grating (µ/µsec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot Velocity Track</td>
<td>24</td>
<td>62</td>
<td>61</td>
</tr>
<tr>
<td>(µ/µsec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least Count (µ)</td>
<td>1.59</td>
<td>2.05</td>
<td>2.058</td>
</tr>
<tr>
<td>Lens Aperture</td>
<td>f/4.0</td>
<td>f/4.15</td>
<td>f/4.13</td>
</tr>
<tr>
<td>Focal Length (mm)</td>
<td>91.5</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Demagnification</td>
<td>1:53</td>
<td>1:68.4</td>
<td></td>
</tr>
<tr>
<td>Scanline length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual (mm)</td>
<td>53</td>
<td>68.4</td>
<td></td>
</tr>
<tr>
<td>Digitized</td>
<td>50</td>
<td>64.5</td>
<td>64.8</td>
</tr>
<tr>
<td>Film Gate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass (mm)</td>
<td>83.2</td>
<td>83.2</td>
<td>105.6</td>
</tr>
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The machine has produced calibration constants but as yet of insufficient stability. (For further comments on performance see section 4).

2.2 70mm Film Gate

A new film gate has been commissioned on HFD 2. (Fig. 1) It was constructed for the following reasons:

(i) CERN 3 lenses require an extra 22.4 mm of glass. Although the optical bench has been raised the new lens holders take up most of the available space.

(ii) The sprocket holes in CERN standard 70mm film (e.g. BEBC) would cause trouble for our existing gate employing a vacuum groove for suckdown and an air blast frame.

(iii) The existing film gate took 1-2 secs to clamp the film flat enough for measurement. If full advantage of 6000 rpm disc speed is to be taken then fixed overheads of this type must be reduced.

The new gate is available from Sogneique and has the following design parameters:

(i) It will accept all film formats without any modification and provides the maximum viewing area available from the machine i.e. 70 x 207 mm.

(ii) In order to speed up clamping and unclamping, the film has vacuum/air applied to both sides at the same time. A moving glass plate also clamps the film to the prism. This acts both to bring the film close to the vacuum groove and to seal the "chamber" containing the film. NB: The vacuum groove is outside of all film widths including sprocket holes.

(iii) All control of air/vacuum is done with a spool valve integral with the body of the film gate.

(iv) The degree of flatness of the film appears to be exceptional. For example, the interference pattern produced when the film is flat on the prism completely covers the viewing area and is still produced when the gate is operated at 3-5 cycles/sec. A single clamp or unclamp operation takes approximately 100 ms.

2.3 Stage Brakes

The Moog valve hydraulic servo system developed at RHUL has intermittently suffered from stage creep. The fixed brakes previously used to provide some friction have been removed and replaced by on/off hydraulically operated brakes. These are integral (i.e. inside) with the hydraulic rams and operate in approximately 10-20 ms. A pressure of 300 psi produces a braking force of 200 kg.

2.4 Film Transport

HFD 2 is designed to accommodate CERN 300m film spools and a suitable film transport is under development. The existing vacuum boxes have
been modified to provide a voltage equivalent to continuous indication of the position of film in the box.

3. The Laser Illumination System

The laser system was reported at the last meeting (3) and more details are now available (4). Comments will therefore be limited to new information:

(i) Theoretical spot dimensions now change due to the 70mm optical changes.

For 50mm optics

| Diameter of Airy Disc | = 6.6μ |
| Diameter of Spot at 50% Intensity | = 3μ |

Now for 70mm optics

| Diameter of Airy Disc | = 8.3μ |
| Diameter of Spot at 50% Intensity | = 4μ |

(ii) We have experienced some operational problems with the laser. In conjunction with the manufacturers (Coherent Radiation) the problems have been shown to originate in the wavelength selector's mechanical assembly. This item appears to have hysteresis during thermal cycling demanding an irritating amount of adjustment during operation. As the movement takes place, the laser power output drops but the more significant change is that the position of the laser beam shifts. The laser system is unfortunately not tolerant of such beam movements.

The problem however has at least two solutions. Firstly, the manufacturers have changed the design of the selector to combat this problem. Secondly, the laser can be operated at "all wavelengths", predominantly 488nm and 514.5nm. This has several advantages:

(a) The 200 mw output power specified for HPD can be obtained for relatively low plasma current and thereby presumably prolonging laser life (?).

(b) The beam is very stable, reproducible and in every way operationally acceptable.

However, there may be one disadvantage and that is slight spot degradation (see next section).

(iii) Apart from these problems, experience generally with system is excellent. In particular, stability and dust problems with the optics itself are virtually non-existent. The RHEL laser has operated for approximately 1100 hours with no detectable deterioration in its output characteristics.

The laser modification is available from Jogenique both according to the RHEL scheme (laser mounted on an external support, e.g. a wall) and with the laser mounted on the disc box. To date, the groups committed to a laser system are RHEL, Imperial College, Birmingham and Liverpool.
4. Preliminary Results with the laser system

The results reported in this paper are from two investigations:

(i) Investigation of Spot characteristics
(ii) Tests with brightfield chamber film.

4.1 Measuring Spot Characteristics

HPD2 has been fitted with an accurate assembly to view the measuring spot. This consists of a microscope solidly attached to the W stage and a spot viewing prism assembly made to the accuracy of the film gate and offering a 70 x 70mm viewing area. With this assembly it has been a relatively easy task to inspect the measuring spots at any point in the scan lines.

There are several indications of the nominal spot size.

(i) The spot is seen to be diffraction limited so that theory indicates spot diameter $\theta = 8\mu$.

(ii) Rough calibration of the microscope gives $\theta \approx 8\mu$.

(iii) Modulation in the grating channel is high (>90%) and the individual grating pulses are square rather than sinusoidal.

NB: The clear gap between dark grating lines is 12.5\mu. Risetimes are consistent with $\theta = 8\mu$.

(iv) Modulation with traditional sources of data is high, e.g. 15\mu gratings and 2m chamber film. Indeed, despite the non-uniform background and the absence of AGC on HPD2, it has been possible to get excellent results from 2m chamber film with relatively high discrimination levels e.g. 25%. NB: Judgement of excellence was limited to visual inspection, on a computer display, between HPD1 and HPD2 results.

However, the Saclay Group provided a film copy of some gratings with lines down to 2\mu. Although it should be stressed that the quality of the copy was seen, under a microscope, to be inadequate for a rigorous analysis of performance with $<15\mu$ lines, it nevertheless has provided encouraging results. A precision grating is on order from Heidenhain and more accurate measurements will be made. In the meantime the results obtained from the Saclay copy are given below.

The test grating was carefully aligned in the machine to ensure that all lines were being scanned. The focus of the Wray lens was then checked to provide maximum modulation. This modulation was expressed as:

$$\text{Modulation} = \frac{\text{Track Height}}{\text{Local Background}}$$

The results for different line widths (averaged over several lines) are shown in Figure 2. Note that the film covered the central part
of the scanline hopefully minimizing the effect of spot astigmatism. As a comparison the results from the Saclay HPD (interpreted from a photograph) are also given. The line contrast was unknown.

There are perhaps two reasons why the performance of the laser system is not even better with narrow lines.

(i) Spot astigmatism may still be a factor. (See below)

(ii) The film copy both in line width and contrast may not have been sufficiently accurate.

A series of observations was made through the microscope on both the scan lines. There appears to be no noticeable difference between scan lines so that the results are given only for the normal scan.

It should be clear that at most positions in a scan line it is possible by adjusting the fixed fibre to get a good round spot. In fact the impression is that the spot with the new 70mm optics is better, when adjusted, than previously obtained.

The survey documented here was as follows:

(i) The fibre system was adjusted to give a good spot in the centre of the scan line. The laser was set to output only at 488nm.

(ii) The laser was then changed to all wavelengths.

(iii) With the laser set back to 488nm only, the fixed fibre was adjusted to give a good spot at a point approximately 20mm from the centre of the scan line.

The interpretation of spot degradation in various positions in the scan line was difficult. However, it is at least possible to see when the Airy disc has distorted and merged with the first ring etc. In this way the degree of astigmatism can very approximately be identified at 8μ, 16μ, 24μ etc. A somewhat idealized interpretation of such results is shown in Figure 3.

At present it is believed that the degree of astigmatism shown by the Wray lenses is excessive and the manufacturer is to be consulted.

4.2 Tests with Brightfield Chamber film

Apart from looking at conventional reverse developed film, two sources of film have been used:

(i) Argonne 12 foot chamber
(ii) BEBC model

To date little work has been possible due partly to the commissioning programme for the project and partly to the lack of an AGC system. However, preliminary results are encouraging although the remarks at present must be qualitative only. The tests were done with the laser at all wavelengths.
The HRD 2 is certainly able to see the tracks in the Argonne chamber and still, even without AGC, not flood the system with too many digitizings. As the discrimination level is lowered tracks become much clearer but unfortunately background in other areas of the film cause saturation. A conventional AGC system will eliminate this and work has started on such a system.

It has also been possible to see bubbles with black centres and to see the triangular shaped pulses expected from the high gamma film used. The contrast of the tracks was not measured directly.

Similarly film from the BEBC model (distributed by Reinhard June 1971) has been examined. The same problems arise and again it is possible to detect the 50Ou threads in the chamber. It is understood that the background density was D = 1 or 10% transmission and that the track density range was D = 0.6 - 0.8 or 16-25% transmission. It would therefore appear that track contrasts below 2:1 are detectable.

Photographs from a computer display of both types of film are shown in Figure 4.

Conclusions

The engineering changes necessary to enable an HPD 2 to handle BEBC format film are commercially available and appear to be entirely satisfactory. The laser system also appears to be operationally acceptable.

Quantitative results on film from brightfield chambers are minimal at present. However, it is perfectly possible to detect tracks of relatively low contrast in both the Argonne and BEBC model chambers. A subjective view is therefore that track detectability is good and that the early results are encouraging.

REFERENCES

1. H J Down, R A Lawes - I Proposal for a Computer Based HPD
   DD/DA/68/11
2. H J Down, R A Lawes - II Selection of a Computer
   DD/DA/68/11
3. R A Lawes. A Laser Illumination System for an HPD
   HPD Collaboration Meeting, Paris, October 1970
4. R A Lawes, W T Welford. A Laser Illumination System for an HPD.
   Rutherford Laboratory Report No. RHEL/R 212.
CONDITIONS

No AGC
A/C coupling R=10K, C=100pF.

ARGONNE 12 FOOT CHAMBER TRACKS

NOV 1970 RUN - WITH MASK

REEINAHRD - BEBC/OP-37 JUNE 1971

R.H.E.L. HPD LASER SYSTEM

Fig. 4
Requirements

In an HPD system it is necessary to improve the signal-to-noise ratio of the track channel by a lowpass filter. Noise should be suppressed, whereas track pulses are not to be distorted.

Possible Solutions

It is well known that in RADAR techniques and in TV circuits, where similar problems arise, the Thomson filter is often used. It has a flat envelope delay and therefore produces no overshoot, but has a slow rise time. From the mathematical view point, it is related to the Butterworth filter, which delivers overshoot but has a faster rise time when compared to the Thomson filter. The different characteristics of these two types of filters depend on different pole locations of the transfer function in the complex frequency plane.

A new type with characteristics lying between the Butterworth and Thomson filters has been introduced by Y. Peless, and is called the Transitional Butterworth Thomson filter (TBT). It may be applied in circuits where, in the interest of fast rise time, small overshoot shall be tolerated.

The poles of its transfer function are located on paths between the poles of the corresponding Butterworth and Thomson filters. The exact positions on these paths are to be chosen depending on the desired characteristics. They are defined by the parameter $M (0 \leq M \leq +1)$, where $M = 0$ corresponds to the Butterworth and $M = +1$ to the Thomson case.
Calculations of Pole Locations and Filter Characteristics

We wanted to study the characteristics of these three types of filters. In Ref. 1 data are presented for filters of order 2 to 5 (M values in steps of 0.2). Information on transient response is given for step functions only. We wished to have information for other input signals and also for filters of higher order. This was the reason for the author to write computer programs for the calculation of pole locations and filter response. The calculations have been carried out for orders 2 to 12 and M values of 0, 0.25, 0.5, 0.75 and 1.0 (that is, for 55 different filters). Pole locations are given in printed form. Plots of the output signals for each filter are given for three different kinds of input: step function, sin^2-waves (8 different frequencies), and sin^2-pulses (8 different pulse widths). Another set of plots is given for the non-transmitting-range attenuation of sin^2-waves (steady state), for single sin^2-pulses, and also for the normalized time delay of these single pulses.

Publication of all the data is forseen, together with explanations and practical hints for the calculations of the hardware filter components.

Comparison of the different Filters

Filters with M = 0 have fast rise times and give overshoot for step function and small sin^2-pulses. For M = 1, filters have slower rise times when compared to the case where M = 0, but have no overshoot.

Sin^2-pulses at the input give output signals similar to bell shapes. The symmetry of these pulse shapes depend on N and M. It is worse for small N and M = 1 and improves for either N higher or M smaller.

The nominal value of attenuation for sin^2-waves is about N \cdot 20 dB/Dekade. The delay time (time from the maximum of the input pulse to the maximum of the output pulse) for sin^2-pulses is equal to the envelope delay for the range approximately 0 < \omega_0 < 1 and differs for \omega_0 > 1. The delay never is absolutely constant. For small N, it is best with M = 0.5, for medium N with M = 0.75, and for high N with M = 1.0.
Realizable Filters

A realizable network cannot satisfy all requirements, but includes compromises. Let us first state the requirements:

1) Constant pulse delay
   (to avoid errors when measuring tracks of different width)

2) No overshoot
   (to avoid difficulties with small pulses and double pulses)

3) Symmetry of output pulses
   (important for track center detection)

4) High "pulse damping" in the stop band
   (suppression of small disturbing pulses)

5) High rate of increase in "pulse damping" above the cutoff frequency
   (good discrimination between small track pulses and still smaller disturbing pulses)

6) High attenuation in the steady state ("wave damping")
   (suppression of periodic disturbing signals like clocks, radio frequencies etc.)

7) Low N
   (small number of components)

Now we consider a compromise.

Points 4 and 5 cannot be performed because the low pulse damping
(20 dB/Dekade) is not to be affected by the order of the filter.
Points 3 and 6 require a high N in contrast to point 7. This last point is no serious restriction but is just a matter of cost and convenience.

We now choose a certain N and look for a value of M in the pulse delay diagram which gives a maximally flat pulse delay. Then we determine the overshoot for this filter and decide whether it can be accepted. If not, we must choose a higher M (to reduce overshoot) and therefore a higher N (in order that the pulse delay remains flat.)
Example

Lowpass filter  TBT  N10  M + 0.75

normalized pulse delay 7.3 ± 0.05
max. overshoot 3% for ω₀ = 1
max. overshoot smaller for other pulses
symmetry can be accepted
pulse damping 20 dB/Dekade
wave damping very high
N not too high (5 coils, 5 condensors)

Conclusion

Our considerations show that the Thomson filter is not the best solution for all pulse applications, as is very often assumed. By use of TBT filters, better results can be achieved especially for low order filters.

If it should nevertheless be desirable to use a Thomson filter for some reason (perhaps one has no data for TBT available or does not want to calculate anything), it is recommendable to use a high order. Then delay time errors will remain small and symmetry of output signals remains good.
A set of plots is included at the end of this paper.

Figure 1 shows the normalized delay times for all filters. Figures 2, 3 and 4 present the transient and steady state characteristics of a TBT N10 M + 0.75 filter.

The normalization used and the input pulse shapes are described below.

Normalization

The usual frequency normalization is used. The normalized angular frequency is

$$\omega = \frac{\Omega}{\Omega_c}$$

where $$\Omega = 2\pi F$$ and $$\Omega_c = 2\pi F_c$$.

$F$ is the frequency and $F_c$ is the characteristic frequency or cutoff frequency of the network.

This normalization leads to the following time normalization. The period of one oscillation is $T = \frac{1}{F}$ or $T = \frac{2\pi}{\Omega}$. For the characteristic frequency, $T_c = \frac{2\pi}{\Omega_c}$.

The normalized time is

$$t = \frac{2\pi}{\omega}$$

This leads to

$$t = \frac{2\pi}{\Omega} \cdot \Omega_c \quad \text{and} \quad T = t \cdot \frac{1}{\Omega_c}$$

For the calculation of the actual values from the normalized values, we use the equations

$$\Omega = \omega \cdot \Omega_c \quad \text{for frequencies and}$$

$$T = t \cdot \frac{1}{\Omega_c} \quad \text{for times.}$$
Definition of pulses

A \( \sin^2 \)-pulse can be understood as one cycle of a \( \sin^2 \)-wave. It is described by the function

\[
u(t) = \begin{cases} 
0, & t < 0 \\
\sin^2(\frac{\omega_0}{2}t), & 0 < t < t_0 \\
0, & t > t_0
\end{cases}
\]

where \( \omega_0 \) is the normalized angular frequency of the oscillation.

\[t_0 = \frac{2\pi}{\omega_0}\]

is the pulse width measured at the bottom line. The width at 50% of the pulse amplitude is \( \frac{t_0}{2} = \frac{\pi}{\omega_0} \).

Reference

1) YONA PELESS and T. MURAKAMI

"Analysis and Synthesis of Transitional Butterworth - Thomson filters and Bandpass Amplifiers."

RCA Review, March 1957
TBT-FILTER

Normalized Pulse Delay as Function of $\omega_0$

with $N$ and $M$ as Parameters

(normalized pulse width $t_0 = \frac{2\pi}{\omega_0}$)
TBT LOW-PASSFILTER N10 M+0.75

DAMPING

$\sin^2$-WAVES (---) $\sin^2$-PULSES (—)
TBT LOW-PASSFILTER N10 M+0.75

PULSE RESPONSE

STEPFUNCTION AND SIN²- PULSES \( \omega = \frac{1}{8}, \frac{1}{4}, \frac{1}{2}, 1, 2, 4, 8, 16 \)
EXPLOITATION DES CLIQUES "IRABELLE" SUR IRDO

== A l'aide du "INSUR GUIDANCE" ==

B. Mathieu

Quelques clichés de l'expérience faite auprès de Saturne utilisant "irabelle" sont passés au travers de 10 filtres. La qualité médiocre des photos et le bruit de fond considérable dans la chambre firent, seules les traces fortement ionisées sortirent correctement, les autres étant novées dans les divers bruits parasites. Aussi a-t-on cherché plus à se rendre compte des problèmes auxquels on allait devoir faire face qu'à exploiter de manière quelconque un événement.

Le passage au travers du filtre a été fait brutalement, sans aucune adaptation de celui-ci. Il s'agissait simplement de connaître les réactions du programme devant les quelques différences suivantes qu'un examen de quelques détails des clichés faisait ressortir par rapport à la chambre 2 m.

- dispersion plus grande des points autour de la trace (30 à 15 μ) (fig. 1 et 2)
- difficultés éventuelles dues à la présence des ombres (fig. 3 et 4)
- zones de mélange des traces beaucoup plus importantes (30 à 120 μ) (fig. 5 et 6)
- absence de points sur des zones relativement importantes : raccords de scotch-lite ou taches de tous ordres sur le fond.

Les premiers résultats sont relativement encourageants. Le problème de la dispersion des points nécessiterait une adaptation des paramètres du filtre. Les ombres ne sont pas sèches tant que la trace est isolée. Eventuellement on obtiendrait simplement quelques éléments parallèles à la trace.

Restent deux problèmes à résoudre :

- la présence de trous importants : on compte sur une amélioration de la qualité des clichés (les premiers films venus de SERPHICOU donnent bon espoir de ce côté).
- le problème des zones de mélange.
On peut penser que l'élargissement de ces zones est dû à la présence des ombres qui élargissent le signal du photo-multiplicateur et il est peu probable de voir alors une amélioration de ce fait.

Ceci produit, surtout à haute énergie où on a une accumulation de traces vers l'avant, une confusion dans la zone du vertex visible sur le film et accentuée par le HPD. On ne peut obtenir de résultat correct qu'en ayant une bonne connaissance de la trace avant de pénétrer dans la zone confuse ce qui est d'autant plus délicat que moins la trace est nette, contrastée, plus la zone confuse est importante.

Le problème d'ombre de la trace rencontrée la première par le spot du HPD sur la suivante, classique avec la chambre de 2 m., est ici remplacé par un autre, moins avantageux pour le filtre : la trace la plus noire l'emporte toujours (fig. 5, en bas).

Il semble qu'il sera nécessaire de prévoir une préméasure adaptée et de chercher les traces en les remontant vers le vertex plutôt qu'à partir de ce dernier.

Les figures 7, 8 et 9 montrent un cliché du run technique sans champ et ce que voit le HPD à des réglages différents du photo-multiplicateur.

On remarque combien le bruit de fond devient important dès qu'on cherche à sortir le maximum de trace, mais aussi une nette amélioration de la qualité des clichés et une meilleure maîtrise du HPD pour leur exploitation.

S'il reste encore beaucoup de travail pour obtenir les améliorations souhaitables, on peut espérer atteindre des résultats honorables.
VISUALISATION 1 LIGNE SUR 1,1 POINT SUR 1

Fig. 1
VISUALISATION 1 LIGNE SUR 1,1 POINT SUR 1.

Fig. 2
VISUALISATION 1 LIGNE SUR 1, 1 POINT SUR 1

Fig. 3
VISUALISATION 1 LIGNE SUR 1,1 POINT SUR 1

Fig. 4
VISUALISATION 1, LIGNE SUR 1, 1 POINT SUR 1

Fig. 5
VISUALISATION 1 • LIGNE SUR 1, 1 POINT SUR 1

Fig. 6
EXPLOITATION DES ClichÉS DE MIRABELLE SUR HPD

B. Mathieu

Il s'agit de se rendre compte des possibilités de mesure des clichés de Mirabelle au moyen d'un appareil de mesure automatique tel que le HPD. On peut décomposer l'opération en deux stades :

- approchement de l'information continue sur le cliché au moyen du HPD. Le problème étant de récupérer toute l'information avec le minimum de bruit ;

- utilisation du filtre minimum guidance pour ne garder sous forme résumée que l'information intéressante relative à chaque événement.

Les premières mesures sur HPD ont été faites en Mars-Avril 1971 sur quelques clichés de l'expérience faite auprès de Saturne utilisant Mirabelle. L'importance du bruit de fond dû à des phénomènes parasites autour de Saturne, la présence d'une grille dans la chambre, et le manque d'homogénéité du fond, firent que seules les traces fortement ionisées sortirent correctement, les autres étant noyées dans les divers bruits parasites. On put se rendre compte, cependant, des problèmes auxquels il allait falloir faire face :

- dispersion plus grande des points autour de la trace que pour des clichés de la chambre de 2 m.

- zone de mélange des traces beaucoup plus importantes : lorsque deux traces se croisent sous un angle faible, les points sortis par le HPD ne sont plus situés sur chacune des traces. On a classiquement la figure suivante :

![Figure](image)

ici bien souvent on continue à voir plus longtemps la trace la plus contrastée et non pas la première que rencontre le HPD.

C'est donc la trace la moins visible qui présentera le plus long trou. D'autre part, la longueur de cette zone est beaucoup plus grande.

- enfin, même sur des traces contrastées et fortement ionisées, la présence des trous était fréquente.
Fin septembre, on mesura au HPD, un des clichés du run technique sans champ. Ceci mit en évidence les améliorations apportées dans le circuit de détection du HPD et l'amélioration de l'homogénéité du fond et du contraste des clichés bien que, pour une exploitation correcte, beaucoup de progrès doivent encore être faits. On peut remarquer sur les photos prises sur le scope HPD combien le bruit de fond devient important dès qu'on cherche à sortir le maximum de traces (Fig. 1). La mesure des grandes croix, au HPD, ne devait désormais plus poser de problèmes.

En octobre, on mesura quelques clichés de l'expérience à 70 GeV en choisissant les vues les plus correctes mais aucun des clichés n'atteignait la qualité du précédent. Si les ombres des traces avaient pratiquement disparu, sauf pour les traces proches de l'objectif, on remarquait des zones extrêmement peu contrastées où le HPD ne voyait rien et où l'œil, même, ne pouvait rien voir si on isolait cette zone de cliché. Les agrandissements de ce que voit le HPD pour un événement type le montraient clairement. En fait là où il y a une information sur le film, le HPD la restituait presque intégralement mais il ne fait aucun doute qu'un filtre, quel qu'il soit, ne pourra pas reconstruire de nombreuses traces avec aussi peu de données. On mit en évidence aussi l'impossibilité d'exploiter la zone du vertex et, dans la plupart des cas, de mesurer celui-ci avec précision (Fig. 2, 3, 4).

Le 8 novembre 1971, on passa en HPD un cliché de la dernière expérience (Fig. 5). Les zénaies verticales, le long des raccords de scotchlithe, ont disparu et le fond est, semble-t-il, beaucoup plus homogène. Mais une zone claire horizontale est apparue dans laquelle on ne peut pratiquement rien voir, divisant le cliché en deux parties, la partie supérieure claire et relativement contrastée et la partie inférieure plus sombre. Si le HPD voit dans une des deux zénaies, il ne distingue rien dans l'autre s'il voit dans la zénaie claire, il ne voit rien dans la zéne sombre et, s'il voit dans la zénaie sombre, on ne distingue plus rien entre les traces et le bruit de fond dans la zénaie claire. Même une régulation très poussée du circuit de détection permettrait très difficilement de s'en sortir car on est obligé de faire fonctionner le PM à la limite de ses possibilités et ceci serait difficilement tolérable dans une exploitation dont on exigerait un minimum de rendement.

Le 12, on reprit le même cliché, d'assez loin, un des meilleurs dont on disposait et on le mesura au HPD en vitesse 1/2, densité 1, avec un diamètre du spot diminué de moitié. C'est-à-dire que la distance entre deux ligne de balayage était passée de 64 à 32 µ et le diamètre du spot de 25 à 18µ. On avait en effet remarqué qu'on rencontrait assez souvent le long des traces des bulles isolées de très faible diamètre et on risquait de perdre cette information si la ligne de balayage ne passait pas précisément au milieu de la bulle. La réduction de l'interligne comme du diastre du spot permettait effectivement de récupérer une grande partie de cette information. Par ailleurs, on améliorait la largeur des traces qui passait de 30-35µ à 20-30µ et surtout l'intervalle minimum entre deux traces en dessous duquel le HPD donne un mélange des deux traces qui passait de 80-120µ à 40-60µ. Les photos de ce que voit le HPD prises à partir d'un plot de chaine fine (fig 6 et 7) montrent qu'avec des clichés de cette qualité, tout au moins pour la zone claire, on est capable de sortir une information correcte, indépendamment de problèmes filtre sérieux dus aux traces longtemps confondues et à l'impossibilité de mesure dans la zénaie du vertex.
On a passé au travers du filtre uniquement jusque-ici des clichés pris auprès de Saturne. Dans la mesure où la trace existait à la sortie HPD, c'est-à-dire était fortement ionisée, le suivage de la trace ne posait pas de problèmes majeurs. Les ombres, dans la mesure où elles existent, ne sont pas gênantes tant que la trace est isolée. La dispersion plus grande des points nécessiterait simplement une adaptation des paramètres du filtre. Si on suppose que le problème des trous le long de la trace sera résolu petit à petit par une meilleure connaissance de la chambre et une amélioration des clichés, le problème le plus grave est celui du croisement des traces sous un angle relativement faible car il est probable que la zone de mélange restera toujours grande comparativement à la chambre de 2 mètres, car l'image des bulles sur le film restera entourée d'une zone claire dûe au principe même d'éclaircissement de la chambre. Ceci nécessitera, pour arriver à une solution correcte, une bonne connaissance de la trace avant de pénétrer dans cette zone incertaine, donc éventuellement une adaptation du filtre à ce problème spécifique.

Ce même problème se pose lors de l'initialisation des traces car la zone du vertex à très haute énergie est pratiquement toujours une zone confuse, beaucoup de traces partant vers l'avant sous un angle faible. Une solution sûre mais manquant peut-être d'élegance est de prêmesurer sur chaque trace deux points proches (un point et sa tangente) dans une zone claire et de reconstruire la trace, non pas à partir du vertex, mais à partir de ces deux points. C'est de toute façon dans ce sens que le travail sera d'abord fait.

Le problème n°1 semble être, pour l'instant, celui de l'amélioration des clichés. En effet, dans la mesure où l'information existe sur le film où le fond est relativement homogène, le HPD restitue dès maintenant cette information. Quant au filtre, à moins de reconsidérer totalement la question, et d'un investissement considérable, il exige une information relativement dense avec un minimum de "trous". Si cette information existe, il y a toute probabilité pour qu'il donne de bons résultats.
The Status of MG at CERN

M. Ferran

PERFORMANCE

In a recent test on events at 10 GeV/c, MG was seen to give the same success rate (70% instead of 73%) as FG on the first pass. An MG light-pen recovery station can "patch up" virtually all events which fail the first pass. An operator takes 5 minutes to "patch up" an event, on average. This recovery system is at present being used on its first production batch, the residue from 6,000 events.

COMPUTER COST

FILTER, the special part of MG, has the following characteristics when running in the CDC 6600:

- 10 sec. CPTIME / 4-prong
- 38K program. Realtime is ~ 4-5 times CPTIME.

CURRENT DEVELOPMENTS

Present effort is being directed towards cutting computer cost. Recently it has been shown that the enormous digital image may be thinned out without affecting the program performance.

A device called "gear-changing" already existed in FILTER: when a track is well known, only 1 scanline in 2 is used from the available data. This caused considerable saving in CPTIME. Input tapes to FILTER were edited to look as though only 1 scanline in 2 had been taken from HPD, except for a region around the vertex where all scanlines were taken for use in track detection. Using this data gave essentially the same results as having all scanlines available and skipping some of them. The CPTIME is not affected but the Real time is considerably reduced.

The HPD control program is being adapted to write digitizings on disk, rather than tape, for input to FILTER. Thus the data will move faster through the chain with less man and machine time lost in tape handling.

Inside the FILTER program a modification which looks promising is to use a double length "moved area" along the beam directions, but taking 1 scanline in 2. This permits the resolution of "slowly separating" or "slowly crossing" tracks in a region where tracks often look alike and are very close together. The modification is being evaluated.

DIFFICULTIES

MG does not follow all tracks to the end. About 20% of tracks are followed so that the last measured point is around 12 cm from the end of the track. This effect is being investigated. MG does rather less well on short tracks than on long tracks.

It has been observed that HPD can produce twice as many digitizings from a given frame with an old lamp as with the same lamp when new, all other things being equal. This is being studied.
Status and future plans for HPD system in Bologna at JNAR

M. Masetti

We have in Bologna an HPD on line to the IBM 360/44 working with Road Guidance programs. The system's analysis rate is about 100 ev/h. Thresh rejection rate is about 8% for two prong events. The Gate processing is performed on-line while Filter, the views merging program, and Thresh are executed on the CDC 6600 in one step.

Now we are working on a second HPD which will be connected in parallel to the previous one to double the production rate in the Road Guidance system: as one HPD is measuring, the other one is executing the orders to start measuring the next picture as soon as the first HPD has finished. It is foreseen to have this new system in production at the end of this year.

At the beginning of the next year we plan to start on the problem of measuring and processing BEBC pictures. We do not expect to have serious problems in measuring BEBC pictures with HPD. The main decision is whether to process BEBC pictures using Minimum Guidance philosophy. From our point of view, Minimum Guidance processing is still too expensive for pictures from the 2m chamber, and too many tapes must be handled.

One solution could be to have an electronic device able to reduce the HPD digitizings to track elements or weighted points as in the Prush system or in the Line Element Recognition device proposed at CERN. In this way the data to be processed by a Minimum Guidance program will be reduced and as a consequence the computing time and the number of tapes necessary, too. We plan to follow this idea starting at the beginning of the next year.
BRUSH Status Report, September 1971

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Introduction

This report of BRUSH begins with a discussion of recent tests with 2m chamber films.

For lack of man power, we were not yet able to rewrite the simulation program for a fast computer, so we can test the operation of BRUSH and the geometry program only with limited numbers of events.

Geometry Program

a) Results of a Blind Test

The geometry program was further developed, using a first set of 21 pictures over and over again.

Recently a blind test was performed on a second set of 65 pictures. This sample was selected by our own bubble chamber group according to criteria unknown to us. In zero guidance fashion, 3 abnormal scans were made in each view to cover the whole picture.

The results became available 10 days ago, and only a rough analysis was possible in the meantime. Of the 105 primary events inside the fiducial volume, 75 events, that is 71%, were correctly reconstructed by the geometry program. The THRESH and GRIND runs have not yet been carried out, but we know from experience that practically no further rejects are to be expected. (This has been confirmed by the later analysis, the results of which are given in ref.1). The yield in this single BRUSH run was comparable to the yield of full guidance after remeasurements.

b) Discussion of Failures

The following break-down of the 30 failures (29%) shows that we are still in a learning process as far as proper settings of thresholds or treatment of particular difficulties are concerned.

A relatively frequent cause of failures was incorrect combination of tracks to vertices (8 cases). This turned out to be caused mainly by tolerances chosen too wide. On the whole, some more sophistication in the vertex construction is called for.

In 3 cases a beam-like secondary track followed too far beyond the vertex and was therefore not correctly assigned. Using the beam title in addition to the BRUSH beam flags will prevent following tracks into the incoming beam track.

A more serious type of failures is short tracks (9).

Fig. 1 gives an indication of our efficiency as a function of track length. The outer contour shows the total of short tracks in our sample. The shaded areas indicate how many of these were found by
the geometry program. At present, of these short tracks found, only those are accepted which have a terminal point, that is an abrupt ending of digitizings in at least two views. These accepted track elements are shown cross-hatched.

We note a rapid drop in efficiency for tracks shorter than 1 mm on film. For detecting a short track, track elements must have been found by BRUSH in all three views. A modification in the geometry program seems possible which in the vicinity of a vertex searches for track elements pointing toward this vertex, and perhaps a coincidence in only two views might be considered sufficient. This has not yet been tried, however.

4 events failed due to great confusion. In each case, a rather short track was lost, and in two cases these short tracks coincided within HPD resolution with some other track in one view. Here again, a two view search for track elements pointing to the vertex might have brought these tracks back to life.

Finally, there was an assortment of less frequent failures (6). One comforting aspect of the unavoidable failures is that (at least in a hydrogen chamber) most of them can be detected automatically with the aid of a charge conservation check. With some easily implemented additional checks, only three of the 36 failures would have remained undetected.

c) Computer Requirements

Our BRUSH geometry program can only be run on a computer large enough to hold all track elements for all three views of a picture in core memory. On a byte-oriented computer, it takes about 400 k bytes for both program and data. If we consider a CDC computer, this would correspond to about 20 k words of fast core memory for program and about 50 k words of ECS for data.

Of even greater importance for the feasibility of the BRUSH method is the CPU time on this large computer. The average CPU time per primary event inside the fiducial volume was 1.9 sec/event on the IBM 360/91 for the present state of the program. This program is entirely written in FORTRAN, and no particular effort has gone into optimizing the CPU time. The CPU time can certainly be brought down further, but even now it compares quite favourably with Minimum Guidance.

BRUSH On-Line Program

The test run also allowed some estimate of efficiency and time consumption of the actual BRUSH on-line data processing.

As the geometry CPU time rises sharply with the number of BRUSH track elements, the question arises whether all of these track elements are worthwhile. Some statistical figures and inspection of track element plots have convinced us that the overwhelming majority of the track elements are parts of genuine tracks.
With only 4 k words to buffer the digitizings, BRUSH is required to analyse the HPD data on-line. The basic unit of analysis is the slice (16 scan lines), and we wish to analyse each slice (even the crowded ones) within one slice time.

For a 3000 rpm HPD the time for one slice is 40 msec. In the BRUSH simulations, a slice-by-slice count was kept of the number of times certain routines were used. Multiplied with estimated execution times for these individual routines, we get an estimate of BRUSH time consumption per slice.

As it turned out, the lion's share of BRUSH time is used in those two routines which handle the individual digitizings. These are the mapping routine for the digitizings, and the least squares fit which handles the digitizings of a track element candidate. Both these routines have been programmed in BRUSH computer language in all detail, and their execution time can be calculated precisely.

The majority of slices would have taken between 3 and 10 of the allowed 40 msec. Only 0.7% of the slices would have taken more than 16 msec, so an on-line operation with even a 6000 rpm HPD is easily possible.

BRUSH Hardware

Since last year's Paris meeting, the configuration of the BRUSH hardware has changed in one important point. This is the recent addition of a PDP-02 to service all of our "slow" peripherals. These are a teletype, fast paper tape reader and punch, the 611 display, and two magnetic tape units.

This scheme will allow us to have the input-output system working by the time we have to test the hardware of BRUSH proper.

Data transfer with the fast peripherals must be controlled by BRUSH itself. These fast peripherals are the HPD, the magnetic drum to store the track elements slice by slice, and a fast link to the disc of a large computer.

Status

The PDP-0 and all peripherals are delivered, the teletype interface is already being used. The design of the other three interfaces is completed, construction has just begun.

Large parts of the BRUSH hardware are already completed. These are the track detection unit, the fast flip-flop registers, and the program memory.

Of the CPU, about one half is completed, in particular the units for arithmetic and logical operations, and the special arithmetic unit for multiplication, division, and square root.

Yet to be completed are instruction register and instruction decoder, the index registers plus index adders, and the instruction control. Furthermore, the interfaces with HPD and drum have yet to be made.
Schedule
The CPU and all interfaces may be completed in about 6 months. It is not until that time that detailed hardware tests can be started. Allowing some time for these tests, an off-line test of the BRUSH method might be started in the middle of next year, using digitizings on tape to simulate the HPD.

Future Use of BRUSH
Possible first experiments with BRUSH should use hydrogen chamber film, because of the absence of spectator tracks and the possibility of making charge conservation tests. Certainly we will also try HYBUC and BEBC pictures, where BRUSH seems especially suited for survey experiments.

The local procedures in BRUSH and the direct three-dimensional geometry approach let BRUSH appear an appropriate method to cope with many of the large bubble chamber difficulties.

Reference

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**Fig. 1**

- Frequency
- 20
- 15
- 10
- 5
- 0

- Total of short tracks in pictures
- Tracks found
- Tracks accepted

Length of track on film

0 1 2 3 4 5

[mm]
The Birmingham VAST Project

H.R. Shaylor

VAST is a semi-automatic scanning and rough digitising machine based upon a precision CRT flying spot system. It is an open ended project, and later developments should bring it accuracy up to measuring standards.

The use of an enlarged T.V. type display under program control should avoid the problems of referring to the optical display when the track following program requires operator assistance.

It has been decided to add an optical film display to the machine as an insurance against the possibility that a Tektronix 611 storage display will be inadequate for initially finding events.

Glitch problems which arise when the deflection DAC\(^5\) cross a high significant bit boundary have been overcome by using a secondary DAC with a limited range for generating the slice scan (which is used in the rough digitisation and track following modes). The slice is positioned by the primary DAC\(^5\) which then remain static during the scan. Any glitches or errors from the secondary DAC\(^5\) are reduced in proportion to their reduction in scan range as compared with the primary DAC\(^5\). Glitches are no problem in the complete picture or enlarged T.V. viewing modes since they are easily distinguished visually and do not cause confusion.

The enlarged T.V. viewing mode, with its differential X and Y enlargement and steerable viewing area has been tested. The results (on 2m film) are comparable with good optical projection.

The slice scan generator circuits have been built and tested, so have the complete picture display scan circuits.

The control computer, a DEC PDP-11 with 12K core, has had a 1.2m word disk and a Tektronix 4002A visual terminal added.
This makes for an extremely powerful interactive DOS system. This has led to a considerable amount of use of the computer for the development of POLLY types of programs (and contention over computer use for hardware development). The interfacing of the PDP-ll to the group's main computer, an IBM 360/44 is complete. This makes it practicable to run DOS on the PDP-ll without DEC tapes or a high-speed reader-punch.

H.R. Shaylor,
**LIST OF EXTERNAL PARTICIPANTS**

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It cannot be guaranteed that there are no errors in this list which is taken from the sheet of paper circulated during the meeting.