CERN DD/DA/65/5
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Summary on present performance of the cathode-ray tube used in Luciole 66 and proposal for a device with increased scan area

1. Luciole I, as used on-line to the IBM 7090, is essentially a prototype device thought as being a first step into the field of using a CRT for digitizing track chamber pictures. Its specifications were based on information gathered from physicists working with sampling spark chambers. In particular at that time a measuring precision of about 1:2000 was considered as being satisfactory for the physicists and accessible to the engineer. Since its completion the device has proved to be very reliable and processed some 100,000 events successfuly with a maximum speed of over 2,000 events per hour.

2. The change-over from the IBM 7090 to the CDC 6600 made a number of modifications of the device necessary. These were due to the entirely different input and output specifications of the new computer. Based on the experience made with Luciole I it has been preferred, however, not only to modify the existing scanner but to re-design the digitizing logic and a part of the CRT control circuitry. This practically new device was called Luciole 66. Apart from modifications originating from the particularities of the computer*) (like format change, idle feature, etc.) the experience with the CRT control has influenced the new design from two points of view:

a) It has been seen that the scanning pattern is more stable, i.e. more precise, than hoped originally, over 1 - 2 hours a r.m.s. stability of $1 \cdot 10^{-4}$ has been obtained in the "fast" and of $2 \cdot 10^{-4}$ in the "slow" direction.

b) The "slow" (1 μs) P24 phosphor combined with some compensation circuitry following the photomultiplier (PM) output can, without difficulty, be used for a scanning speed higher than on Luciole I.

Consequently, the (digital) resolution on Luciole 66 has been chosen four times, the scanning speed twice faster compared to Luciole I.

3. It seems to be valuable to summarize the features of the present CRT system so as to give some basis for further discussion.

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*) For a full description of the Luciole 66 operation mode, see report DD/DA/65/1 of T. Lingjaerde.

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a)	Scan area on the CRT screen (Ferranti 5/29 AM)	:	60×60 mm^2
b)	Spot size over the whole scan area (half intensity width)	:	$\lesssim 35$ μm
c)	Pincushion distortion, theoretical value for 22° deflection	:	4.1%
	actual value with static correction	:	1%
d)	r.m.s. stability of the raster scan pattern over over 1 - 2 hours, "fast" direction	:	$1 \cdot 10^{-4}$
	"slow" direction	:	$2 \cdot 10^{-4}$

The raster scan is controlled by a 5 Mc/s clock, it is characterized by:

a)	Number of digitized positions per scan,	:	7160
	i.e. on the screen	:	8.4 μm/digit
b)	Number of scan lines normal,	:	768
	i.e. distance of scan lines on the screen	:	78 μm
	idem double precision,	:	1536
	i.e. distance of scan lines on the screen	:	39 μm
c)	Total duration of fast scan cycle	:	819.2 μsec
	of which flyback period	:	100.8 μsec
	Total duration of slow scan cycle normal	:	838.9 msec
	of which flyback period	:	209.7 msec
	idem double precision	:	1677.7 msec
		:	419.4 msec

The above-mentioned dimensions have to be multiplied by the optical reduction factor to get the corresponding values on the scanned film. For instance, the format of the pictures for the "Lundby I" experiment was 25×25 mm^2, which leads there to a factor of 0.42.

4. Hitherto the discussion has been confined to square rasters. For a given point size (i.e. optical resolution) because of the circular limitation of the usable field on the CRT screen, these obviously contain the maximum number of separable points. Of course, electrically the shape of the scanned area can be changed easily by simply varying the maximum values of the deflection currents. But for a rectangle with a ratio of the side lengths of 1:1.5 the loss is 7%, for 1:2 20% of the total field compared to the square. This consideration is of preponderant importance as soon as one tries to evaluate long-shaped pictures. For a 1:3 side ratio the CRT would already be used very uneconomically.

5. A way out of this difficulty (offering in addition a substantial increase in resolution) consists of projecting several CRT scan patterns onto the picture to be evaluated, covering in this manner its whole field. With some obvious preference a side ratio of 3:1 of the rectangular picture format is used in track chambers working at CERN. An array of three square scan patterns would therefore be adequate*). In particular, this method offers a possibility of extending the application of CRT's to the scanning of bubble-chamber pictures that are constantly (i.e. with the development of bigger and bigger chambers) increasing in size.

Some analogy of this proposal to the HPD set-up is obvious. For the HPD the optical problems are solved as soon as a satisfactory line scan has been obtained which covers the shorter dimension of the picture. The longer dimension is taken care of by the mechanical movement of the precision stage. In the proposed CRT system, similarly, the optical problem is solved as soon as a sufficiently precise pattern is available that covers a square with the side length of the short dimension of the picture; the full length is obtained by adding additional rasters until the whole picture is fitted. In principle, of course, the short dimension could also be divided into several sub-patterns.

6. To produce this multi-pattern set-up several elements of the chain CRT, projection lens, field lens, photomultiplier (PM) have to be multiplied. Here, this shall be discussed for the above-mentioned example of three sub-patterns. The most straightforward solution using only well-known elements would be to use three CRT's and three projection lenses (see Fig. 1), a common field lens and three (or even only one) PM's.

Another possibility would be to project the same CRT screen with three projection lenses onto the film, merely keeping the same set-up behind the film. But there the use of three PM's cannot be avoided, otherwise the information from the three different paths of the picture could not be separated. Furthermore, the asymmetric use of the two outer lenses asks for a wider usable field angle which might be difficult to obtain. By these facts the advantage of having only one CRT is partly balanced. Extrapolating from the data enumerated under point 3 (i.e. without taking into account further improvements of stability, resolution, etc.), a scheme of this type should scan a picture of 35×105 mm^2 with 45 μm line spacing and 5 μm digital resolution in 2.5 sec (including flyback time) if one part after the other has to be scanned, and within 0.84 sec when the output of the three PM channels can be merged. (This high speed would clearly make the use of a very elaborate film transport a necessity.)

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*) Similar set-ups have already been discussed by D. Maeder in Nucl. Inst. and Meths. 20 (1963) 407-412.

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7. Additional remarks

a) The 3 CRT solution of Fig. 1 could reasonably use common deflection amplifiers for the three coils connected in series, and common generators for correction voltages.

b) A small overlap of the scan regions should exist ($\approx$ 0.5 mm). An over-all calibration programme (in principle, similar to that one used in Luciole I) has to be developed that also assures the liaison between the sub-patterns.

c) There are no special difficulties expected for the mechanical adjustments. Furthermore, the experience with Luciole I gives much confidence in the reliability of such a device.

d) Some minor progress can be hoped for from the use of a bigger CRT (i.e. passing from a 5" to a 7" screen). The main advantage lies in smaller screen noise and lesser significance of blemishes, both originating from the scaled-up spot size.

e) An increase in resolution of about 30% can be obtained by using a tetrode CRT instead of a triode. Unfortunately, this gain is coupled with a reduction of the light output by a factor 4 that in turn decreases the signal to noise ratio by a factor 2.

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REFERENCES

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3) H. Anders, T. Lingjaerde, J.A. Wilson and D. Wiskott, "Luciole", CERN 63- 34, 259 (October, 1963).

4) H. Anders, D. Maeder and D. Wiskott, Nucl.Instr. and Meths. 20, 414 (1963).

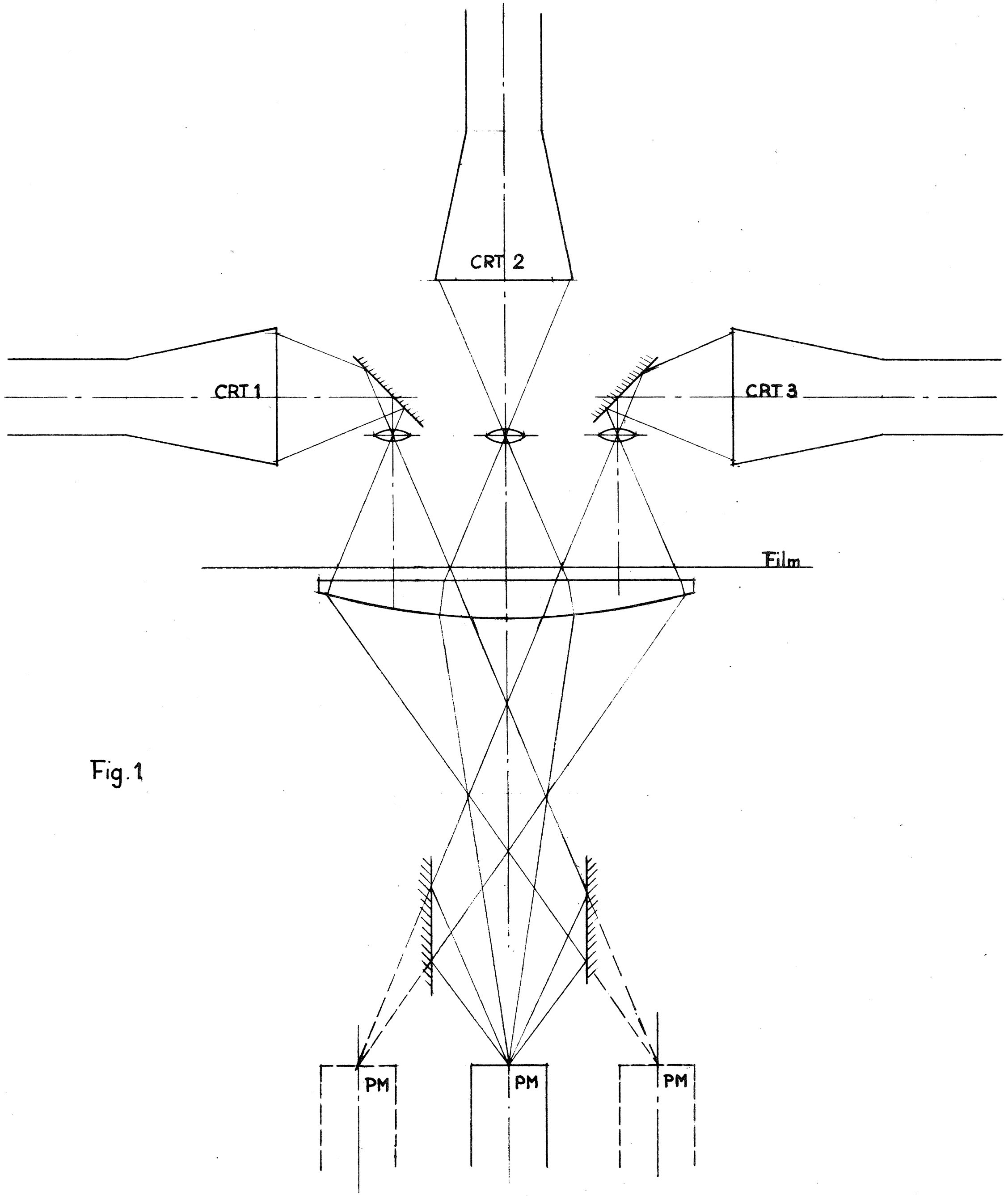

Fig. 1

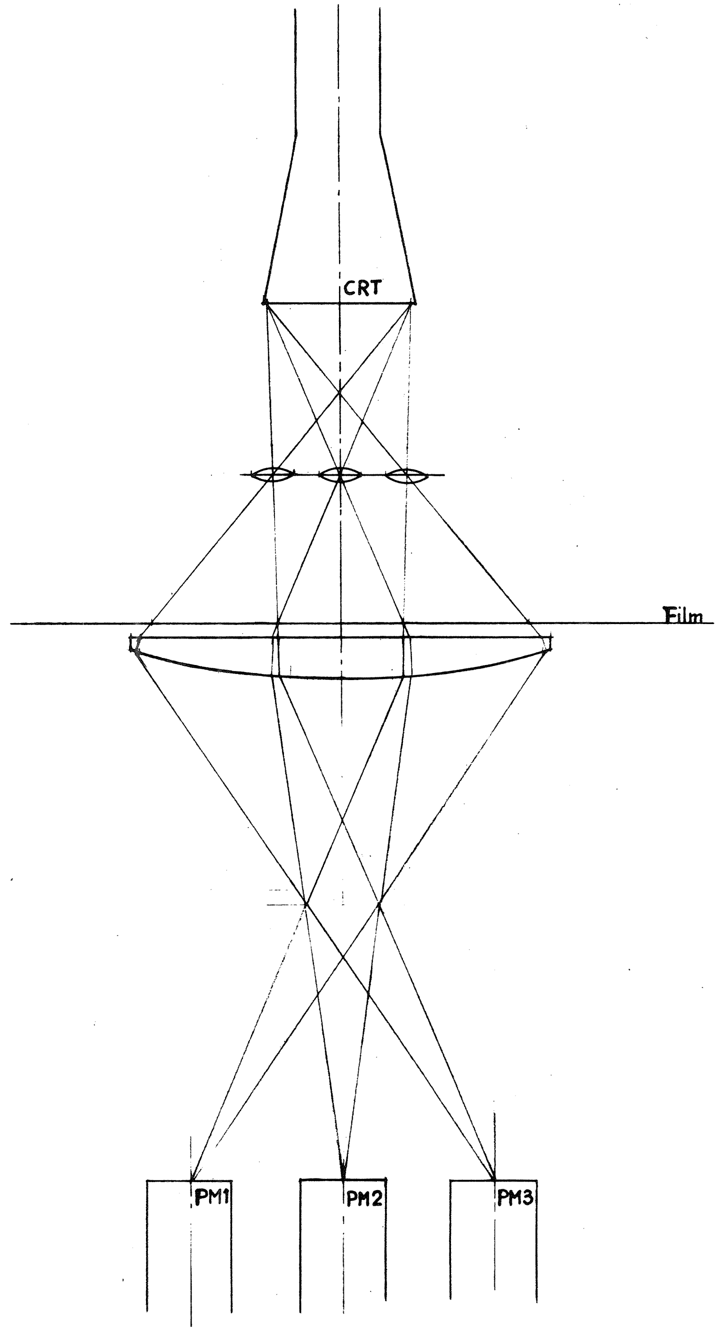

Fig. 2