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A MATRIX CALORIMETER FOR BEBC

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1. INTRODUCTION

It is generally agreed among the groups studying ν, $\bar{\nu}$ physics with bubble chambers, especially in H_2, that the limit to further progress in the study of structure functions, QCD effects, and even cross sections, is the lack of knowledge of the true neutrino energy. There have been many methods proposed to estimate the missing neutral energy in ν interactions, kinematical or even pure empirical parametrizations. All these methods have been shown to introduce systematic biases in terms of Q^2 dependences. In the study of QCD effects these biases wash out the small log Q^2 dependence expected at high energy. The only possible way to further progress is to provide in the bubble chamber some possibility to measure directly the missing neutral electromagnetic energy.

Most discussion up till now on putting an electromagnetic calorimeter into BEBC has been based on the idea of adapting a standard counter technique, scintillator or liquid argon, etc. to the hostile environment of the bubble chamber. Perhaps a better approach is to use the potential of the bubble chamber itself to develop a new type of detector.

The first thoughts on such a detector are described in the following note. The principle of the device can only be proven by a fairly extensive set of tests in a working bubble chamber.

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2. LAYOUT

As has been discussed previously [1] any calorimeter has to be placed in the liquid itself due to the thick chamber body and the lack of access between the coils. The sensitive surface area proposed is $2.4 \times 2.0\ m^2$ and a thickness of 25 radiation lengths, i.e. $\sim$ 30 cm in total, if lead is used as converter. Unlike a typical calorimeter layout of sheets of converter, it is proposed in this case to use rods of lead or tungsten $3 \times 3\ mm^2$ cross section to form a checker-board pattern, as shown in fig. 1(b). Sheets of metal, 0.5 mm thick would be placed between each row for strength and to improve the heat flow through the detector. The sensitive element of the calorimeter is the bubble chamber liquid itself in the $3 \times 3\ mm^2$ spaces between the lead/tungsten rods. The whole assembly, 6.8 t of lead and 7.8 t of support structure would be fixed to the exit wall of the chamber and enclosed in a lexan box of a construction similar to the TST recently used in BEBC. At least the sides of this box would be covered with Scotchlite to replace that on the chamber body.

A simple calculation [2] shows that a column of heavy NeH_2 mixture 2 m long would be sensitive, i.e. give tracks, for a reasonable, 2-3 cm, movement of the upper and lower surfaces of the lexan. Two main questions are, would the whole array spontaneously boil?, and is it possible to remove the heat and recompress the bubbles between expansions? Clean antiboiling surfaces of extruded lexan could be used to surround the columns of liquid, fig. 1(c) which might help. However, it is clear that only a large scale test in a working bubble chamber could prove that the device is sensitive, before boiling spontaneously.

It has been assumed in the following note that the $3 \times 3\ mm^2$ column of liquid will cavitate, i.e. form a single large bubble at the position of the track. In effect, there will be no information about the number of tracks in each cell after the cell has "fired".

3. READ-OUT

One of the features of this "matrix calorimeter" is the very high spatial resolution $\sim \pm 3$ mm, available and the correspondingly high number of channels e.g., 33 600 in the layout described. It will be shown in the next section that this resolution is essential for the work in a bubble chamber to resolve individual gammas and electrons.

This very large number of channels demands that the read-out system must be very simple and reliable. The most obvious technique would be to photograph the cells, which would perhaps require the use of a cylindrical lens and a flash devoted to the detector. Other methods could be to use a system of fibre optics driven by a laser to illuminate the cells and a second set to collect the reflected light from the bubbles. A purely electrical signal could be obtained by measuring the change in capacity between insulated conductive surfaces on two faces of the column of liquid. If this was sufficiently sensitive it might even give a measure of the number of tracks on each cell. Clearly little thought has been given to a read-out system, however, there are several possibilities.

4. PERFORMANCE

An extensive Monte-Carlo simulation has been made of ν events in BEBC filled with H_2 and the matrix calorimeter in an attempt to answer the following questions:

(a) What is the cell size required to allow a good pattern recognition for single electron and gamma interactions and discrimination against hadron interactions?

(b) What is the expected linearity and energy resolution of the calorimeters, and how do they depend on the cell size ?

(a) As the problems of pattern recognition tend to be very subjective and difficult to quantify, typical 200 GeV ν events have been generated in the bubble chamber with the corresponding hit patterns on the calorimeter.

The neutrino events have been simulated on data based on the present νH_2 experiment in BEBC (WA21). The program used is described in [3]. All tracks are followed in the BEBC liquid and allowed to interact or cascade in the liquid or in the calorimeter. Fig. 2 shows the hit patterns in the calorimeter from an isolated 10 GeV/c electron or gamma. Each 3×3 mm^2 cell which has at least one track is marked by a cross. The energy of the incoming particle is directly proportional to the number of crosses. It can also be seen that the 25 radiation lengths of the calorimeter provide adequate containment of the shower.

The problems of pattern recognition of the electromagnetic part of the shower are shown in the examples of events displayed in figs 3-5. Figs 4 and 5 show typical high energy events, in each of the displays of the hit pattern on the calorimeter several high energy gammas and electrons can be seen to cascade. It is clear that only with the very high spatial resolution available it is possible to resolve individual gammas or electrons. Fig. 3 shows an event with no π^0's produced, and a hadronic interaction in the calorimeter. From the different starting points of the shower there is clear separation between electrons and hadrons.

(b) Fig. 6 shows the dependence on the number of cells fired and the incident gamma energy. The number of cells fired rises more steeply than the dashed curved, which corresponds to the true energy deposited in the calorimeter, and then tends to saturate at higher energies as there are more and more multiple hits in each cell. The shape of this curve is reflected in the energy resolution, σ r.m.s. number of cells, as shown in fig. 7. The Monte-Carlo prediction is compared at low energy with the data of [4].

At low energies the resolution obtained just by counting cells is in fact better than that obtained by measuring pulse height, but because of the saturation effect it does not fall with the expected $1/\sqrt{E}$ behaviour, but tends to level out with $\Delta E/E \sim 8\%$.

The variation of $\Delta E/E$ with the size of the cells is shown in fig. 8 at fixed gamma energy of 1 GeV. The variation in $\Delta E/E$ has the expected form with a dependence on $\sqrt{t}$, where t is the sampling thickness in radiation lengths.

5. CONCLUSION

From the Monte-Carlo study it is clear that a calorimeter of the type described with a cell size of 3×3 mm^2 would give adequate energy resolution and a spatial resolution superior to any other type of calorimeter proposed. The spatial resolution is such that individual gamma conversions can be easily seen and separated from hadron interactions.

The only remaining questions are those mentioned in the introduction: will the matrix calorimeter spontaneously boil before being sensitive to individual tracks? and the question of the recompression of the large number of bubbles produced.

This can only be answered by a fairly major test in a large working bubble chamber.

REFERENCES

[1] G. Myatt, Report of working group on BEBC hybridisation, 9 February 1979.

[2] G. Harigel, private communication.

[3] A.L. Grant, Monte-Carlo generation of neutrino events, Internal Note CERN/EP/NPC-N 79-8.

[4] M. Conversi et al., CERN/EP 76-20 (1976).

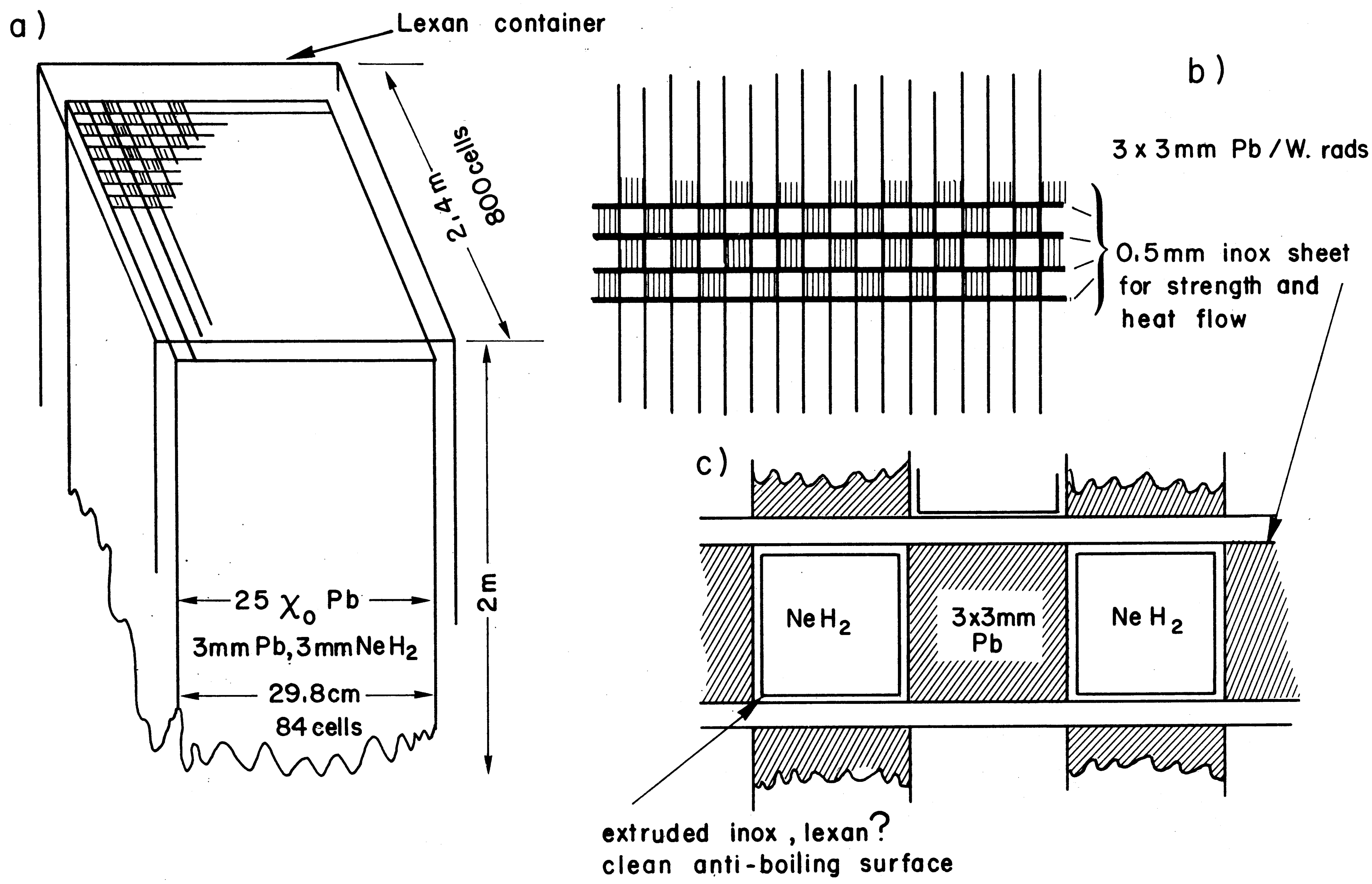

a)
Lexan container
2,4 m
800 cells
2 m
25 X0 Pb
3mm Pb, 3mm NeH2
29.8cm
84 cells
b)
3 x 3mm Pb / W. rads
0.5mm inox sheet
for strength and
heat flow
c)
NeH2
3x3mm
Pb
NeH2
extruded inox, lexan?
clean anti-boiling surface

Fig. 1

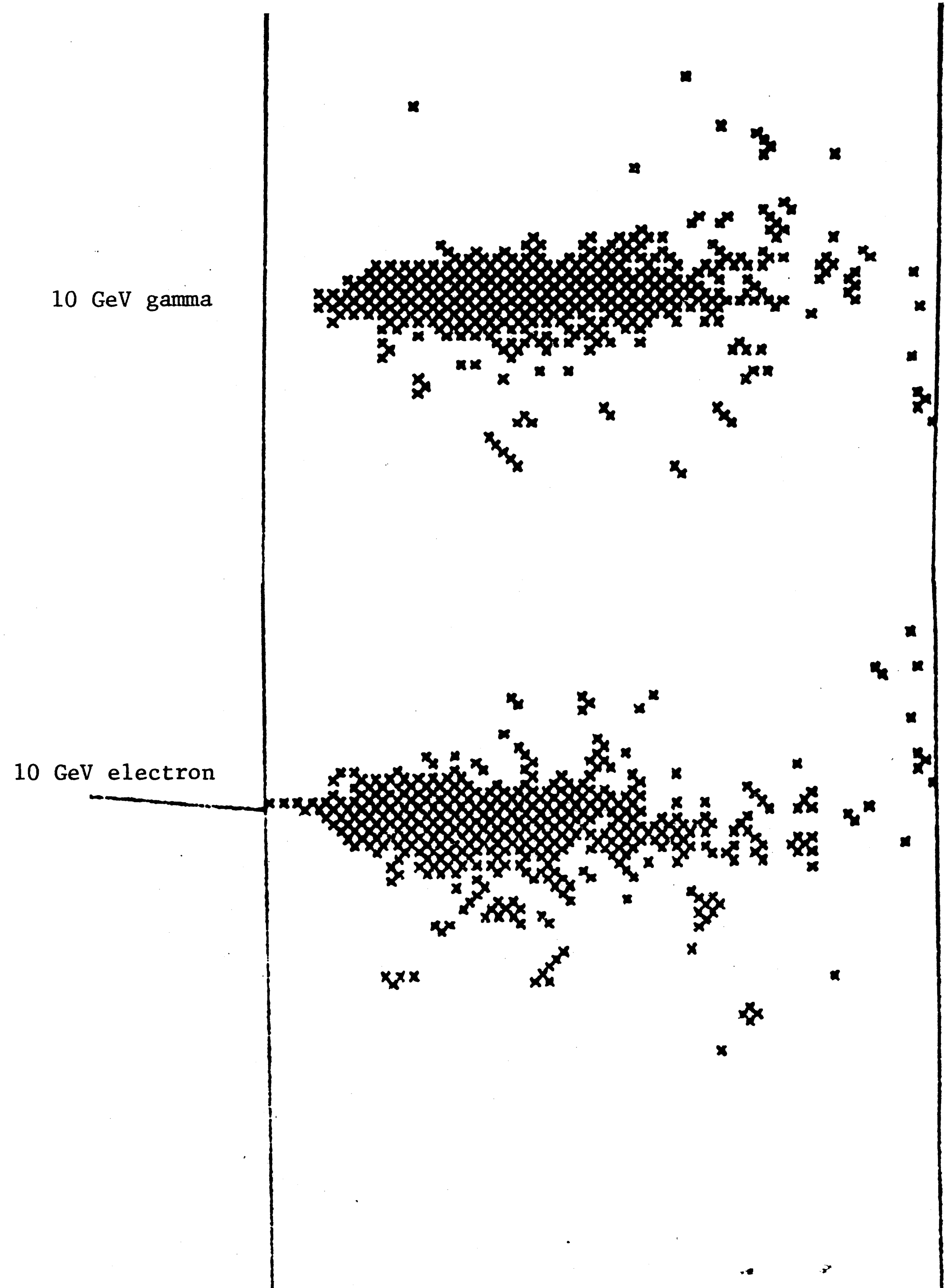


Fig. 2

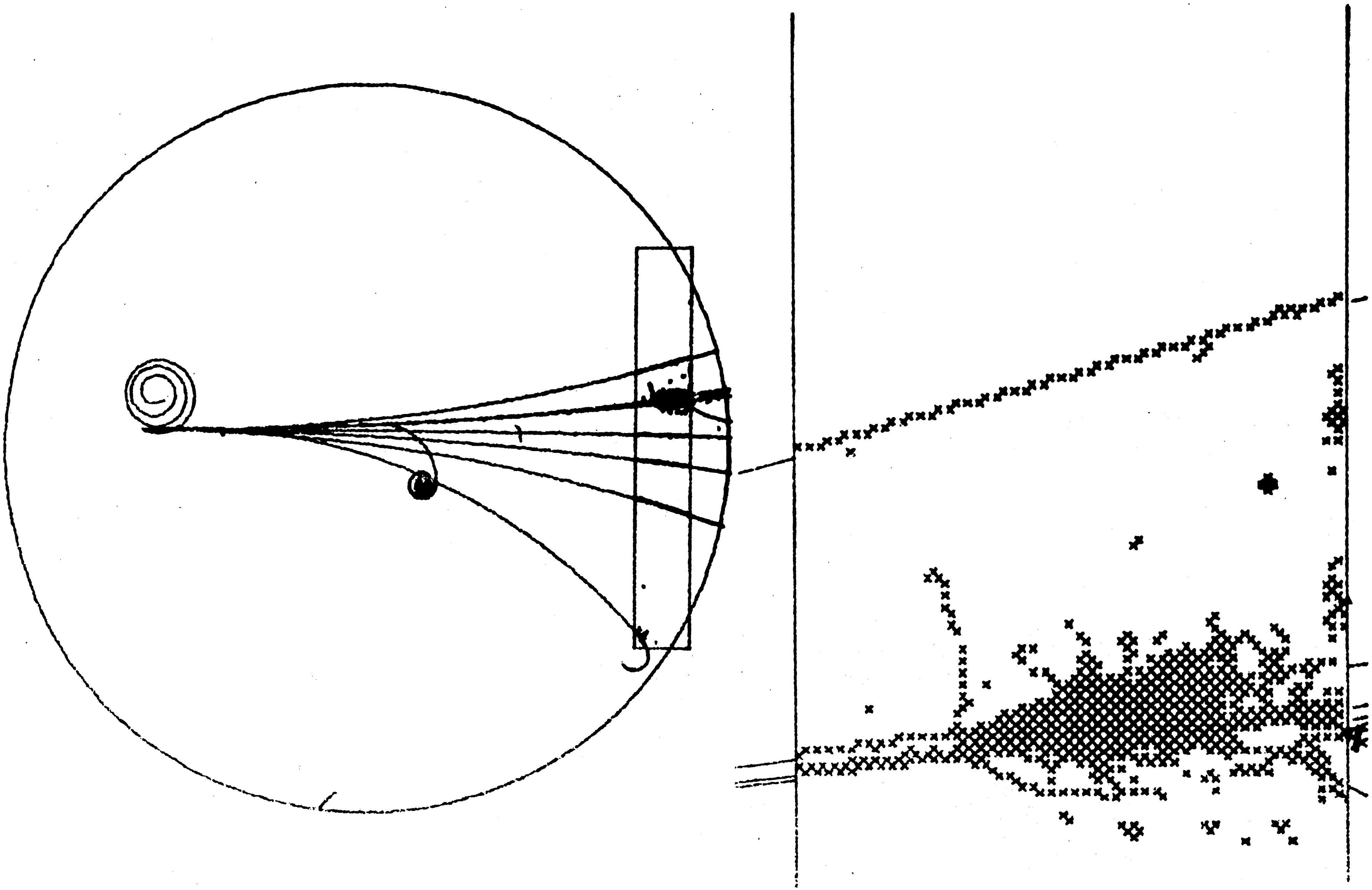


Fig. 3

Hadron interaction in calorimeter

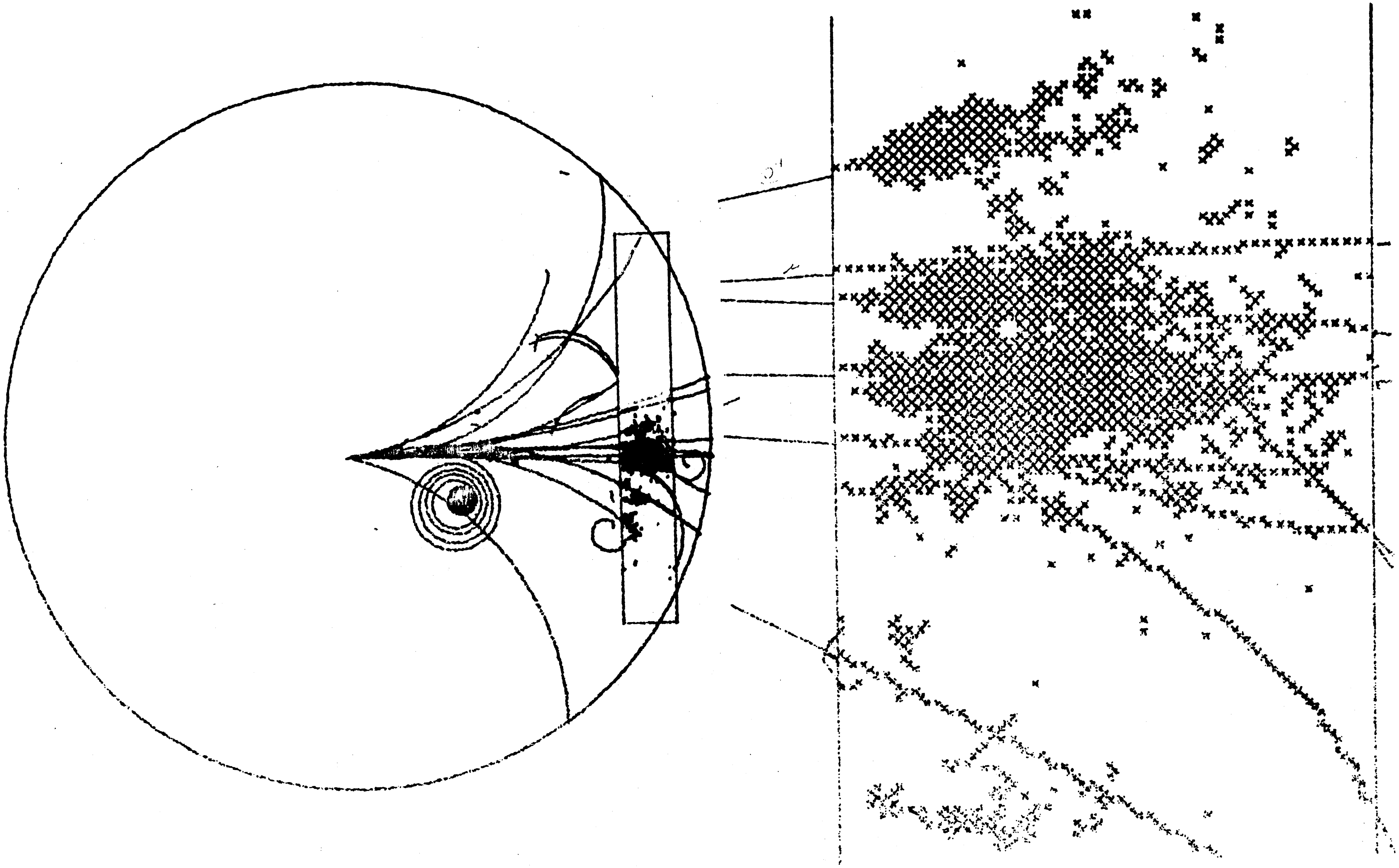


Fig. 4

Electron and gamma showers

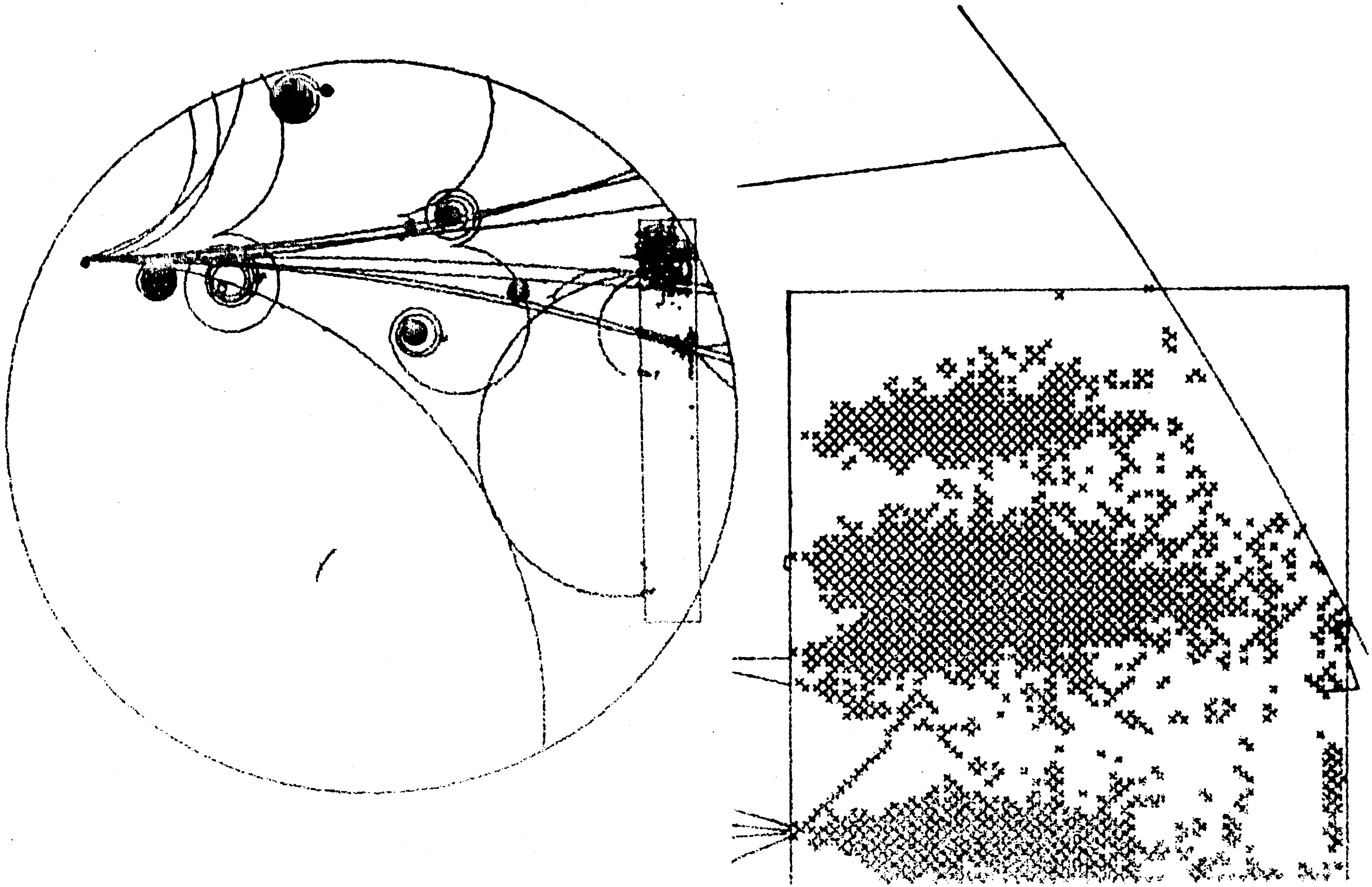
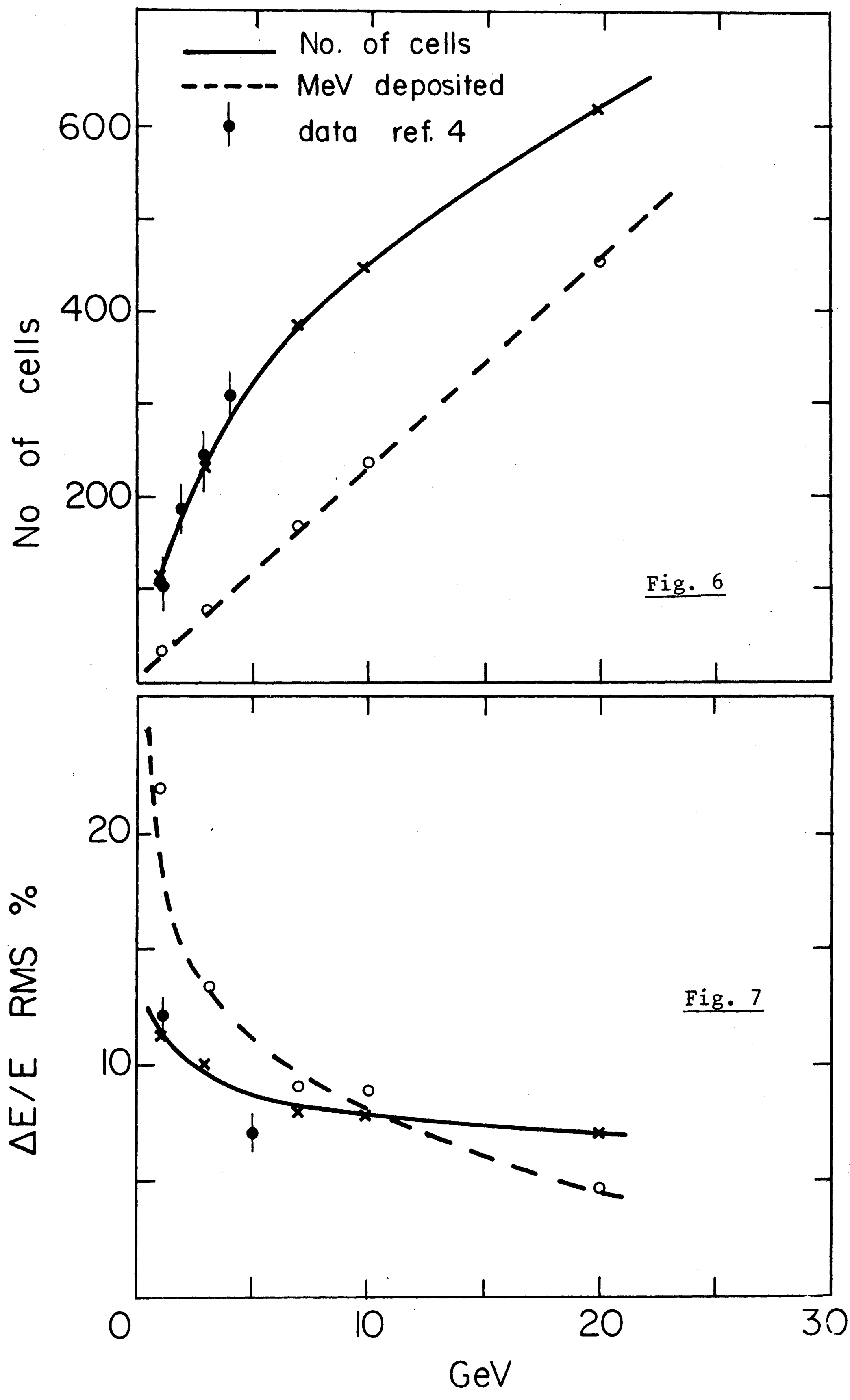


Fig. 5

Electron and gamma showers


No. of cells
MeV deposited
data ref. 4
600
400
200
No of cells
Fig. 6
20
10
ΔE/E RMS %
Fig. 7
0
10
20
30
GeV

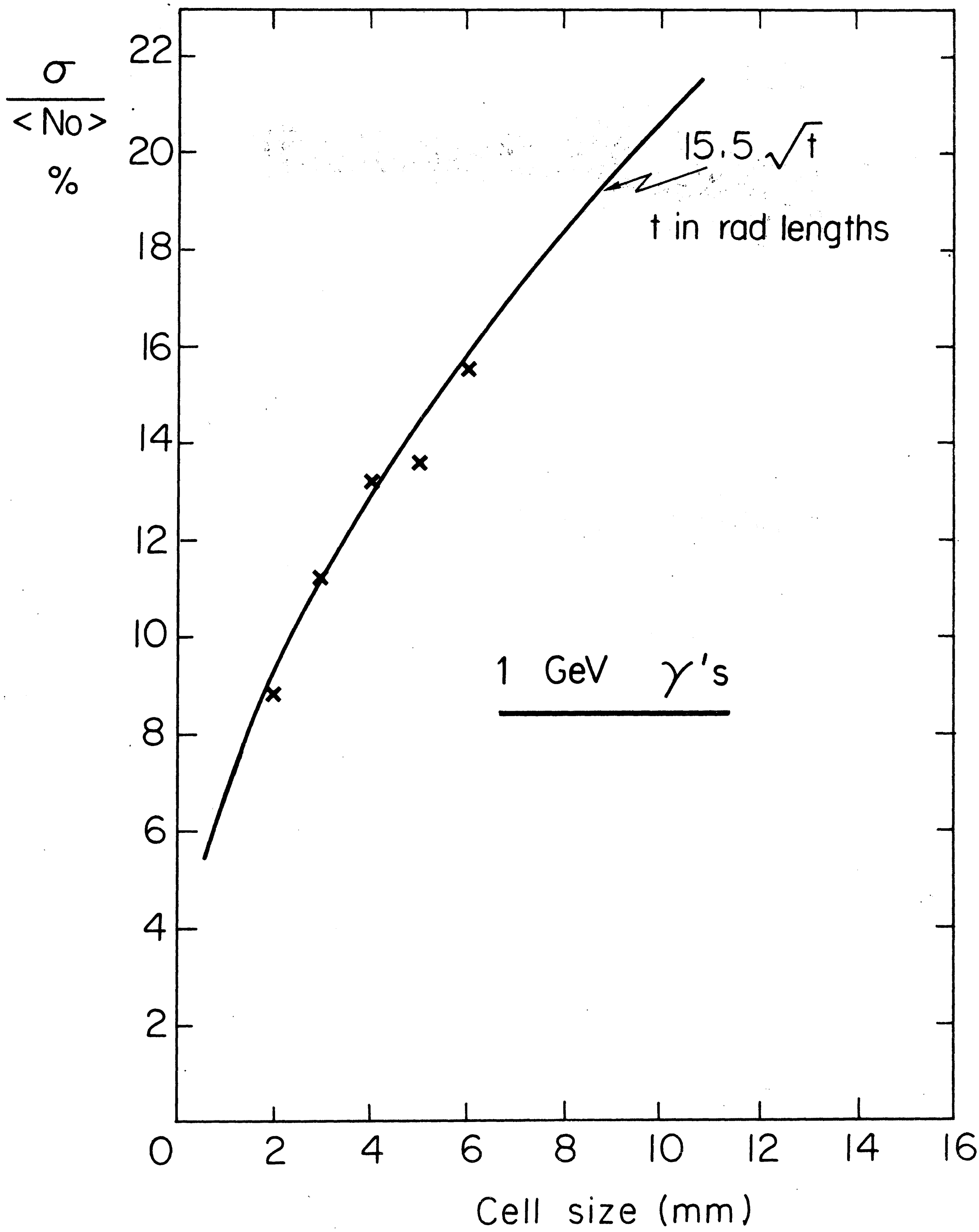

σ / <No> %
22
20
18
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
Cell size (mm)
15.5 √t
t in rad lengths
1 GeV γ's

Fig. 8