EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

EmC 65/D
31.3.1965

PREPARATION OF THE EXPERIMENT ON FRAGMENT PRODUCTION*

(CERN-Valencia-Warsaw collaboration)

* *
*

1. Preparation of May exposure (CERN - 1 technician, 1 physicist)

Make a drawing of the arrangement and start its construction (see Hoffmann for the space available in the beam).

Targets: ^{9}Be, C (20 - 100μm) and heavier nuclei.

Position of the emulsion: distance from the target and angles covered; take into account the solid angle effect and the differential cross-section to get an as uniform intensity of irradiation as possible in all the emulsions.

Possibility of using two targets in the same arrangement; be careful about the background produced by the first target in the emulsions corresponding to the second target.

Secondary particles entering the edge or the surface of tilted emulsion (5-10°) ? The exposure will be made in the air and the emulsions should be protected against light by thin Mylar foil (5-20μ). Estimate the minimum energy which can be recorded for a typical fragment like ^{8}Li or carbon.

Type of plates to be used. Probably a set of sensitivity (K2, KO, K-1, K-2).

Order them. One dozen of each sensitivity. Size ? 3"x3". Volume : about 150 ccs; cost: Frs. 800.-

Intensity of the beam to use (for safety try to place emulsions at various distances for a given angle).

How to monitor the beam ? A rough estimate of the circulating proton beam ejected should do.

---

* See proposals EmC 64/4, 65/1, 65/1 Addendum I.

65/634/5/ar

2. **Experiment to be made in the magnetic field of a 2-metre PS bending magnet, at the end of the summer.**

i) General arrangement (target, magnetic field, detector)

The type of magnet which is available to us (a 2-metre PS bending magnet) forces us to accept some geometrical limitations in the set-up. These limitations are summarized by the drawing of Fig. 1; they are essentially given by the volume of the field (50 x 200 x 15 cm) and the angle of the beam with the detector line (about 15° or less). One can envisage to use simultaneously two targets, T_1, T_2 and two detector lines for getting more information in one exposure. The advantages and the disadvantages of such an arrangement have to be considered (how confusing tracks like T_2M_1 will be amongst the tracks like T_1C_1, what accuracy on Q (see definition of Q in EmC 65/1) can be reached in trajectories like T_2M_1 ...). The use of two targets T_1 and T_2 will make the intensity along the detector line $C_1'' C_1'$ more uniform. For both emission angle and solid angle T_1 will contribute more to the intensity of tracks in region C_1'' and less in the region C_1'; it will be reverse for target T_2.

N.B. It is not excluded a priori that a different arrangement in the way of combining the target, the beam and the detector line could, for some particular types of exposures, be better adapted for recording fragments. In this respect it should be interesting to devote some thoughts to the arrangement consisting of only one target placed at the centre of the magnetic field volume and of the two detector lines $C_1'' C_1'$ and $C_2' C_2''$.

ii) Define a choice of exposures to be made in an allocated machine time of three shifts (assuming that the PS gives about 5×10^{11} protons every 3 seconds).

An exposure will be defined by the target used (nature and thickness), the angles, the nature, the energy and the number of the fragments in

which one is interested. It would be wise to foresee something like 6 to 10 different exposures and to make some kind of a list of priorities.
That way of doing will give us a clear picture of what we want to do during the three shifts and help us in taking quick decisions according to the time we will have available in the course of the exposure. In this respect, it would be useful to prepare a set of curves summarizing what can be expected. Fig. 2 gives an example of such a type of curves. Normalize the curves for 10^{12} incident protons falling on a target of 1 mgr/cm^2. The y axis gives the number of fragments falling on an area of one cm^2 normal to the direction of the fragments. On the x axis is represented the distance $T_1C_1 = x$ which could vary in principle from 0 to 200 cm.
The curves should be made for several fragments (say, protons, deuterons, He, Li, Be, B, C and O) and several target elements (namely a typical light element A and a heavy element B). The protons must appear on these curves also, as they are going to be rather numerous and probably troublesome if some exposure has to be made with G5 emulsions.
In addition, one can draw another useful set of curves (Fig. 3a and 3b) which shows at a given position x_1 of the detector the number of particles (p, d, α, Li ...) per cm^2 of area normal to the fragment direction reaching this point as a function of the energy (Fig. 3a) and of the range (Fig. 3b) of the particle.
These curves are interesting mainly for light particles (protons, deuterons, α) for which one can expect a large number contributing to produce a heavy background in sensitive plates like G5 or K2. Such curves can be made for several positions x_1 (e.g. x_1 = 40 cm, x_2 = 100 cm, x_3 = 150 cm). On each curve (see Fig. 3b, for example) one should indicate the angle θ (defined in Fig. 1) corresponding to different values of the energies (Fig. 3a) or of the ranges (Fig. 3b).
All these indications, even roughly calculated, are intended to give information on the repartition of the intensity of the various groups of particles along the detector line and to help in the estimate of the amount and the nature of the background (protons mainly) in various places at the surface or inside the emulsion layers.
65/634/5/ar

It is obvious that the test exposure will give the final statement of the problem, but all this preparatory work should help in preparing in the best manner the questions which the test exposure will be asked to answer.

N.B. In computing the data for the above mentioned curves one can go slightly further and give the formula translating the experimental results (mainly number of fragments of a given type per unit area normal to the fragment direction found at a given x in certain range $d\theta$ and dE around θ and E) in a function like $\frac{d\sigma}{d\Omega dE} = f(\theta)$ which will be the final form for plotting the results.

iii) Plates to be used in each exposure

This point needs the knowledge of the properties of each type of emulsion (G5, K2, K0, K-1, K-2) like for example, the energy for a track to be visible as a function of the charge of the particle, the possibilities of identification from the aspect of the track (width of the track, thinning down length, etc. ...). These properties have to be, as much as possible, determined experimentally.

In practice, the determination of Q (see EmC 65/1) by the point of entry of the track, its angle and its range will give in most cases (that will depend, of course, of the type of fragments one is looking at) a good identification of the fragment. When the separation is doubtful, it should be possible, with some training, to make in some cases a decision just by a quick inspection of the track (like, for example, a distinction between charge 1 and 2 on G5 or K2 emulsions). In the remaining difficult cases more elaborated ways of identification like the width of the track and its thinning down length will have to be used. This procedure assumes that one must find, when a track has been just measured (x, θ, R) a way of knowing whether this particular track has to be considered more carefully or not. This implies suitable curves to be drawn or small computing devices to be adapted in order to make the decision quickly. This way of doing should be, in principle, preferred to the one which consists in coming back to the doubtful tracks after one has made a lot of scanning, computed it and decided afterwards of a choice of tracks to be considered again for additional measurements.

Furthermore, if would be useful to have some information on the accuracy to be expected in the measurement of the track length (case where the track is entering the surface of a tilted emulsion, 10° for example, or in the case where the track is entering the edge of the emulsion). If the fragments are made entering the surface, there will be a surface blackening produced by short range particles coming with them which will disturb the scanning for longer range tracks. This disadvantage will be avoided in exposures for which the fragments are entering the edge of the emulsion, but it seems that on the other hand this arrangement would in general lead to less accurate range measurements.

One could nevertheless imagine that the fragments are still accepted through the surface which will be protected against this short range background by a suitable known thickness of Mylar. The Mylar foil will at the same time protect the emulsion surface against light blackening.

Several types of emulsions can be used in the same exposure in order to gain flexibility for overcoming more easily the various difficulties which can arise.

iv) Construction of the vacuum tank and of the associated equipment

a) Vacuum tank itself. Rough drawing and specification in the framework described in (i). From that, a final drawing will be made by the CERN drawing office and the construction of the tank by the CERN workshops. Some points have to be borne in mind as needing more thoughts and careful studies.

- Connection with the proton beam pipes (avoid as much as possible windows). This part should be discussed in detail with L. Hoffmann, the future users of the fast ejected proton beam in the South Hall and the PS co-ordinator.
- Foresee a fast operation for removing and placing the emulsion stacks.
- Positioning and handling of the targets.
- Protection of the emulsions against light. (That can be solved by an independent protection of the stack itself, for example by a thin enough

(5μ or so) sheet of Mylar covering the top emulsion of the stack (see the end of paragraph 2(iii).

- Estimate of the maximum air pressure to be accepted inside the vacuum tank in order to get a negligible background produced by the beam during its path through the tank. It must be pointed out that the scanning should be able to reject any particle which is not coming from the region of T_1 or T_2.

b) Stack holder. Fast and precise positioning of the stack holder with respect to the target, and precise positioning of the emulsion with respect to the stack holder. How many layers of emulsion must we put in each position ?

c) Targets. A choice of targets has to be decided. After that one has to inquire and make sure that they are available in a form suitable for the experiment. This point is especially relevant to targets of light elements such as lithium, beryllium, boron, etc..

d) Measurement of the field. To know its uniformity and the exact limits of the volume available. Some shimming is certainly to be forseen for a better uniformity of the field on the edges. Specialized people at PS are certainly able and willing to take care of these points.

e) Beam and beam monitoring. A rather close contact has to be kept with people building the fast ejected proton beam in the South Hall and with the future users. L. Hoffmann is willing to assume the responsibility of taking care of the various points connected to beam problems. The monitoring seems easy if no absolute measurements of cross-sections are needed. To go down to less than 5% will raise some problems. Emulsions placed somewhere on the side of the incident proton beam (especially after a window if there is one) can be used as a monitor for relative intensity measurements.

v) Tests before the main exposure

This exposure is made for the determination of the optimum intensity of the final exposure and for a check of the behaviour of the various sensitivities of emulsion. It must be, if possible, a full test exposure with one target at least. For this reason the test and the main exposure should be separated by at least one month, leaving enough time to process the plates and to make necessary measurements on the tracks recorded. In particular, the accuracy of the determination of Q as a function of x and θ will be tested in using the tracks of ^{8}Li which can be identified independently by their typical "hammers". The total uncertainty on Q will then result of the sum of the errors on x, θ and the range R. An attempt should be made to get an experimental estimate of the contribution of each of them to the total error. The errors coming from the measurements of θ and R are expected to be the most contributing ones. This test exposure should in addition be used for a check of the speed at which are made the various operations taking place during one exposure.

vi) Order of the plates

Must be made two month before the date foreseen for the test exposure. Thickness, size, sensitivity, number to be decided.

vii) Gridding, processing

Made at CERN. Accurate gridding has to be foreseen.

viii) Scanning

This point will be discussed later, but it would be wise to consider it now in a somewhat detailed manner, since it could show up that some of its requirements will influence in one way or another some details in the preparation of the exposure (see for example the points raised in 2(iii) about the successive steps to be used for complete track identification).

(ix) Organisation of the work

a) Manpower. These notes are intended to be a framework for the preparation of the exposure which could be made at the end of the summer. They are circulated to the people who have participated in the proposal (EmC 64/4, 65/1 and 65/1 Addendum I) or who have shown interest in the type of studies involved in it. They are:

For CERN : J.C. Combe, L. Hoffmann
For CERN-Valencia : R. Llosa
For Strasbourg : R. Pfohl, R. Stein
For Warsaw : P. Zielinski.

Furthermore, these notes should be a working document on which everybody has first to make criticisms, comments and suggestions, and secondly to decide how to take part in the solution of the various points mentioned. For practical reasons I would propose to subdivide the work in the following way:

CERN: More responsible for 1., 2(iv) which will involve one physicist (R. Llosa) in average during about three months and a technician for two months. It could be that at a certain stage of the preparation of 2(iv) outside technical help would be desirable. Furthermore, 2 or 3 outside physicists are needed during the exposure period starting one month before the date fixed for the test exposure.

Outside participants: should deal mainly with points 2(i), 2(ii), 2(v) for Warsaw and with 2(iii), 2(vi) for Strasbourg with a possible overlapping between the two labs which they can organize as they want, provided they let know everybody how they divide their duties and responsibilities.

b) Time scale. The design and the construction of the vacuum tank which has to start now could take about 3 to 4 months before being ready to be put inside the 2-metre bending magnet with the stack holder completed and fitted into the tank.

The calculations and the various experimental checks on the emulsions should in principle be ready when the full tank test takes place.

One should even be in a position to produce an as uniform magnetic field as possible and to monitor the beam. At this stage about a fortnight should be enough for assembling everything in the beam and making the preliminary technical checks before the exposure.

c) Financial aspect.. As far as it is possible to foresee the development of the situation the cost of the experiment could be estimated as follows:

- Construction of the vacuum tank in the CERN main workshop: about 10,000 Swiss Frs. (material and working hours).
- Emulsion: about one litre, 4,000 Sw.Frs.

d) Immediate action. The most urgent point is certainly the design and the construction of the vacuum tank and its associated equipment. The other problems to be solved can be made clear and studied while the construction stage develops. Nevertheless, it would be desirable to have at the beginning of May a reply of the groups involved, containing their comments on the actual programme, their detailed plans for participating in the preparation of the experiment and eventually the results already obtained on the points raised in this report.

J.C. Combe R. Llosa

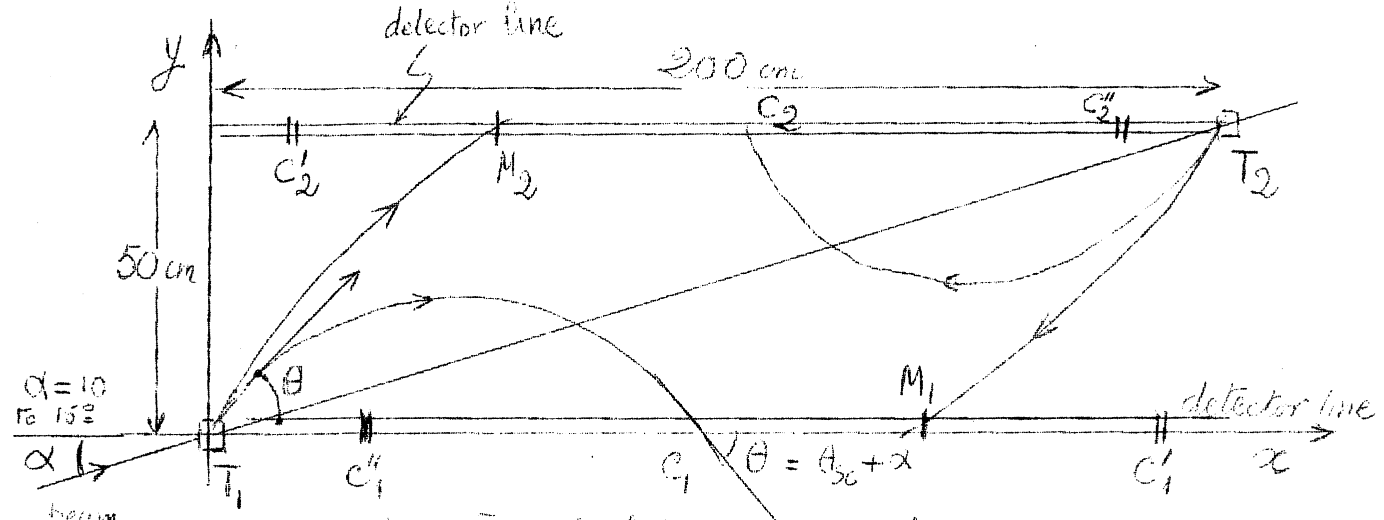

Fig. 1 . For calculations take a field of 16.7 kilogauss

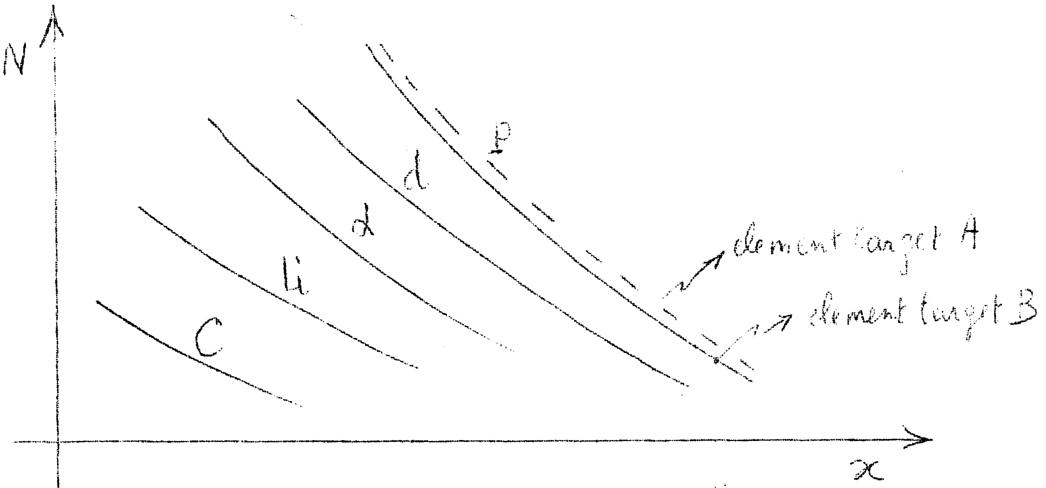

Fig 2 (see text for explanation)

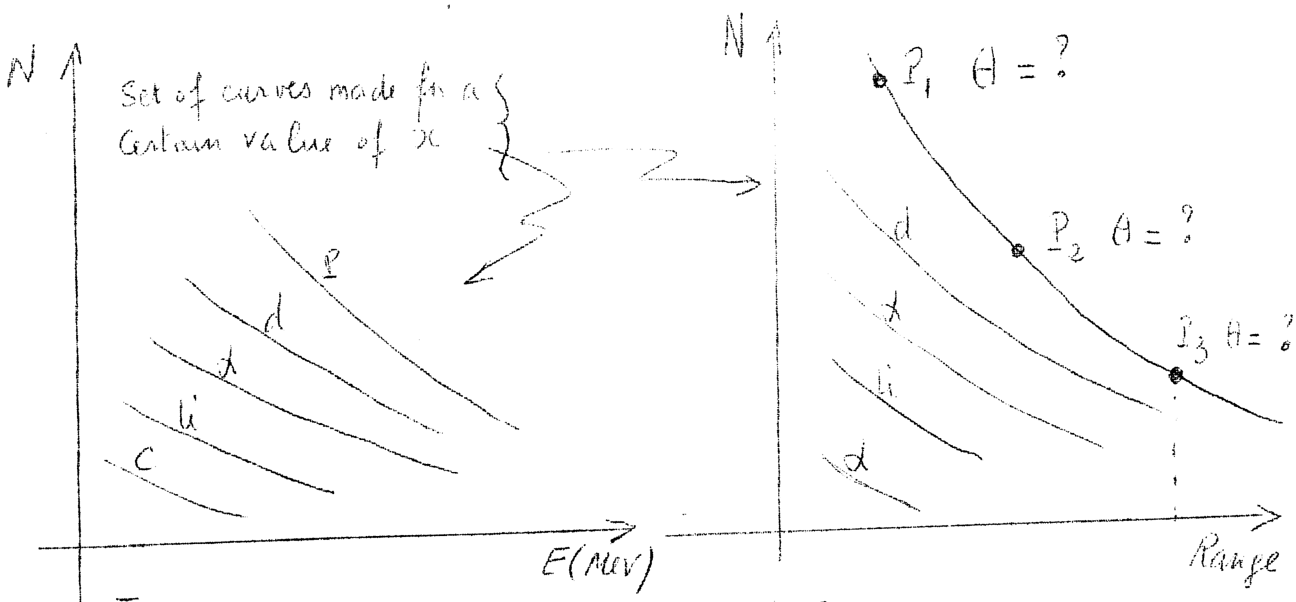

Fig 3a
(see text for explanation)

Fig 3b