CERN/PSCC/81-20
PSCC/M80
12 March, 1981

STATUS REPORT FOR EXPERIMENT SC 84 (MARCH 81)

R. BIMBOT, B. BORDERIE, I. FOREST, J. GALIN, D. GARDES, B. GATTY, H. GUILLEMOT, M. LEFORT, H. OESCHLER, M.F. RIVET, S. SONG, B. TAMAIN, X. TARRAGO and P. VOLKOV.

In this first experiment at the S.C. at C.E.R.N., our main goal was to follow the evolution with bombarding energy of the highly dissipative processes between two massive nuclei. The data are far from being completely reduced, nevertheless the on line analysis allows to consider this first attempt as being successful.

THE BEAM.

As far as the beam is concerned we can distinguish two periods. Before Christmas due to some deficiencies of the ROTCO the beam was unstable (numerous discharges and low intensity) and finally the machine broke down leading to a loss of about 6 shifts. In January, the beam had become very stable and the intensity satisfactory. Three energies were used : 86, 60 and 30 MeV/nucleon. The beam transport onto the targets was easily achieved with relatively low intensity losses.

THE RESULTS.

The investigation of momentum transfer and energy deposit was conducted in two different ways.

1°/ On the one hand on heavy targets (Au, U, Th) the transferred momentum can be easily deduced, as the subsequent fission process "converts" this quantity into the angle between the fission fragments. This is a trivial kinematical effect : the more recoil is given to the target-like nucleus, the smaller is the relative angle between the two fission fragments.

For very small momentum transfers the fragments are emitted 180° apart in the lab system, whereas for full projectile momentum transfer to the system the relative angle is minimum (fig. 1).

On U and Th targets, a few MeV are needed to overcome the fission barrier and consequently all the reaction channels end up by fission. Therefore, we observe a very broad angular correlation extending from zero the the maximum possible momentum transfer. There is a definite evolution with bombarding energy. At 30 MeV/u the most probable momentum transfer corresponds roughly to 8/10 of the maximum allowed transfer, whereas at 60 MeV/u the peak is shifted down to approximately 2/10 of the maximum.* Nevertheless, at 60 MeV/u, it is shown that still a few percents of the total cross section imply full momentum transfer.

As far as the gold target is concerned (fig. 2) it is worth noticing the absence of fission at small momentum transfers as expected due to the large static fission barrier for nuclei close to gold. Only a large amount of angular momentum could allow fission, and we hope to use these properties to make estimates of the impact parameters which are involved.

Before concluding this section, we'd like to mention that the collected data for protons and α particles detected in coincidence with one or two fission fragments have not yet been analyzed. The properties of these light particles are expected to help understanding how the energy is dissipated as a function of the amount of transferred momentum. In addition, high energy fragments of the projectile (B, Be, Li) have been recorded in coincidence with the fission fragments and may also shed some light on the reaction mechanism.

---

* A similar evolution has been clearly seen by Klapisch et al. when investigating the isotopic distributions of fission fragments.

2°/ The second part of the experiment was devoted to a study of the dissipative phenomena on light targets (Ni) which deexcite mostly by particle emission leading to a bunch of residual nuclei. The latters could be easily isolated from particles of low mass (below the projectile mass) by using very thin solid states Si detectors mounted in telescopes (as shown in fig. 3.a). Their angular distribution is forward peaked but gently decreasing as expected for a nucleus after evaporation of numerous particles.

In coincidence events with light particles the time-of-flight difference was measured (fig. 3.b) and the mass of the fragment could be deduced. From a very priliminary analysis it seems that the most probable masses are very similar at 86 MeV/u, 60 MeV/u and 30 MeV/u. This is consistent with the data observed on heavy targets : the higher the bombarding energy, the lower the fraction of transferred momentum. If we assume this effect to be due to a reduction of the number of transferred nucleons from the projectile to the target (but at full velocity), then the energy deposit would be very similar at high and low energy and consequently the residual masses close to each other as shown in the schematic diagram of fig. 4. Our preliminary analysis seems to indicate such conclusions. As for the fission experiment, the characteristics of the light charged particles detected in coincidence with the massive residues will help investigating further, but the analysis is much longer and more complex so we cannot give any precise result for the moment.

CONCLUSION AND BEAM REQUIREMENTS FOR THE FUTURE.

The investigation of momentum transfer and energy deposit on light and heavy targets by two different methods seems to give consistent results. It is expected that the analysis of light particles emitted in coincidence with the fusion residues and the fission fragments will allow us to precise the reaction mechanism : to which extent a thermal equilibrium has been reached ? Emphasis in the present experiment was put onto the evolution with incident energy. An important point to investigate next is the influence of the projectile structure on the momentum transfer probability. The strong structure of ^{12}C in three α may lead to a peculiar situation. Thus, we'd like in a second run to shoot the same targets with Ne at 3 energies (about 30, 50 and 70 MeV/u). Similar experiments have been done at Orsay and Berkeley with Ne at 13 MeV/u, which will give a low energy reference. Furthermore, the experiment will be pursued at 100 MeV/u as soon as GANIL starts delivering Ne.

The experimental apparatus will be very similar to the one already used (fig. 5) and 40 shifts are necessary to get reasonable statistics. Fall 81 would be a convenient period for us to get the beam, till then we hope to have analysed the major part of the data. Our setting up with tests and calibrations required ten days before starting up with the beam.

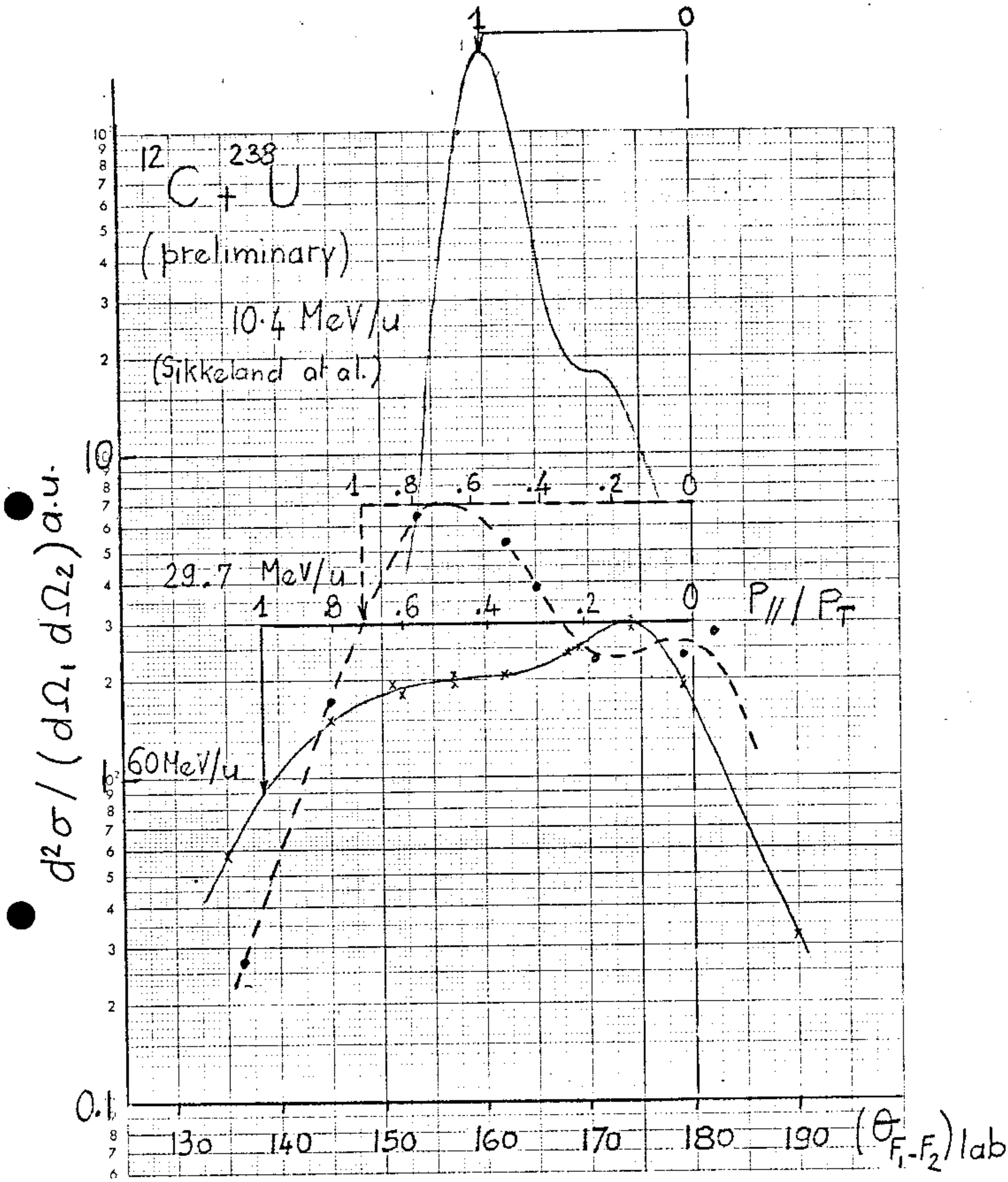


Figure 1 : Angular correlation between the two fission fragments issued from the bombardment of a ^{238}U target by ^{12}C at different energies. At 29.7 MeV/u and 60 MeV/u the cross sections are directly comparable. For each energy a relative momentum scale ($P_{//}/P_T$) is given on top of the angular distribution (with $P_{//}$ and P_T standing for the transferred parallel momentum and P_T the total momentum).

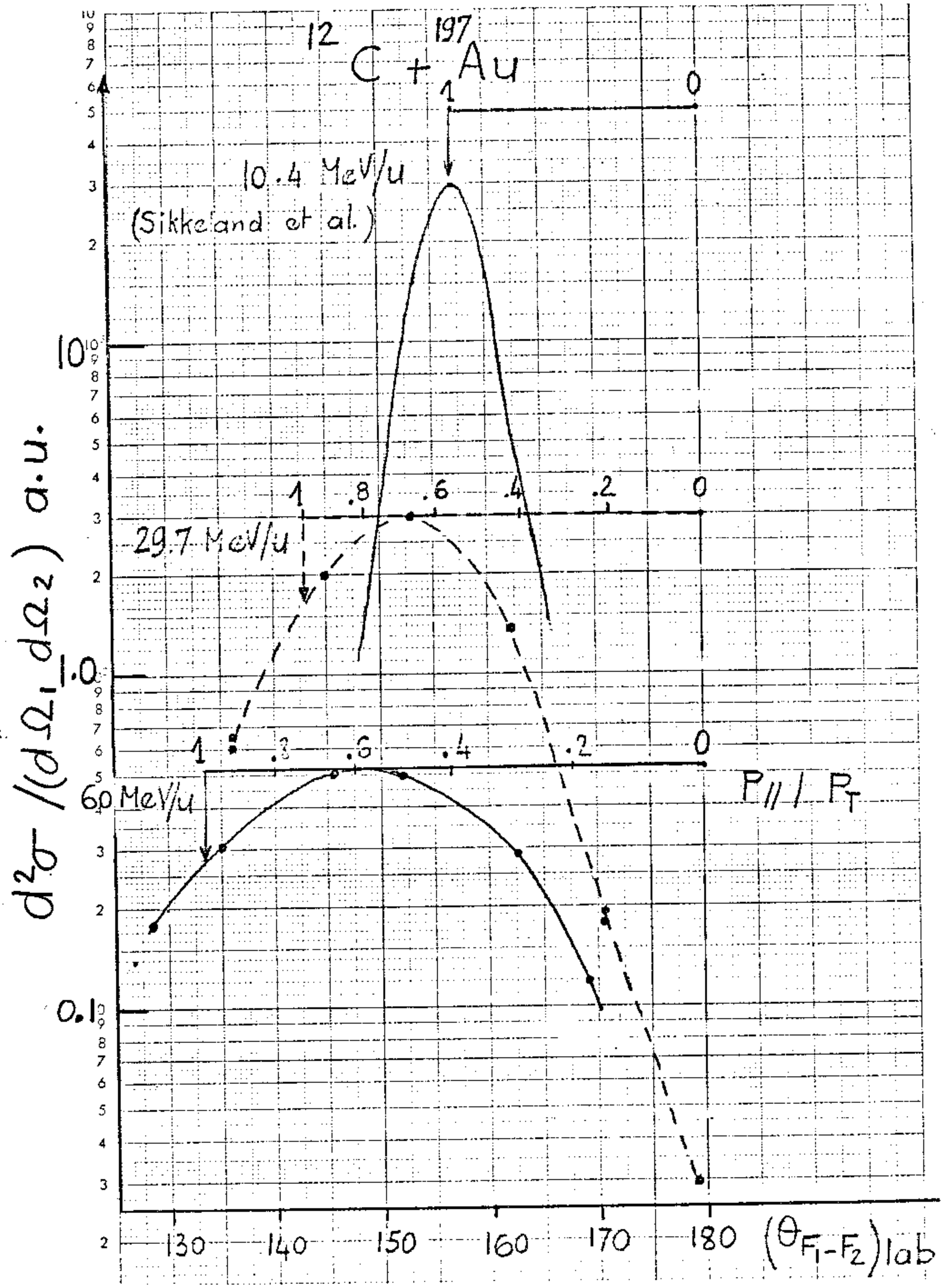
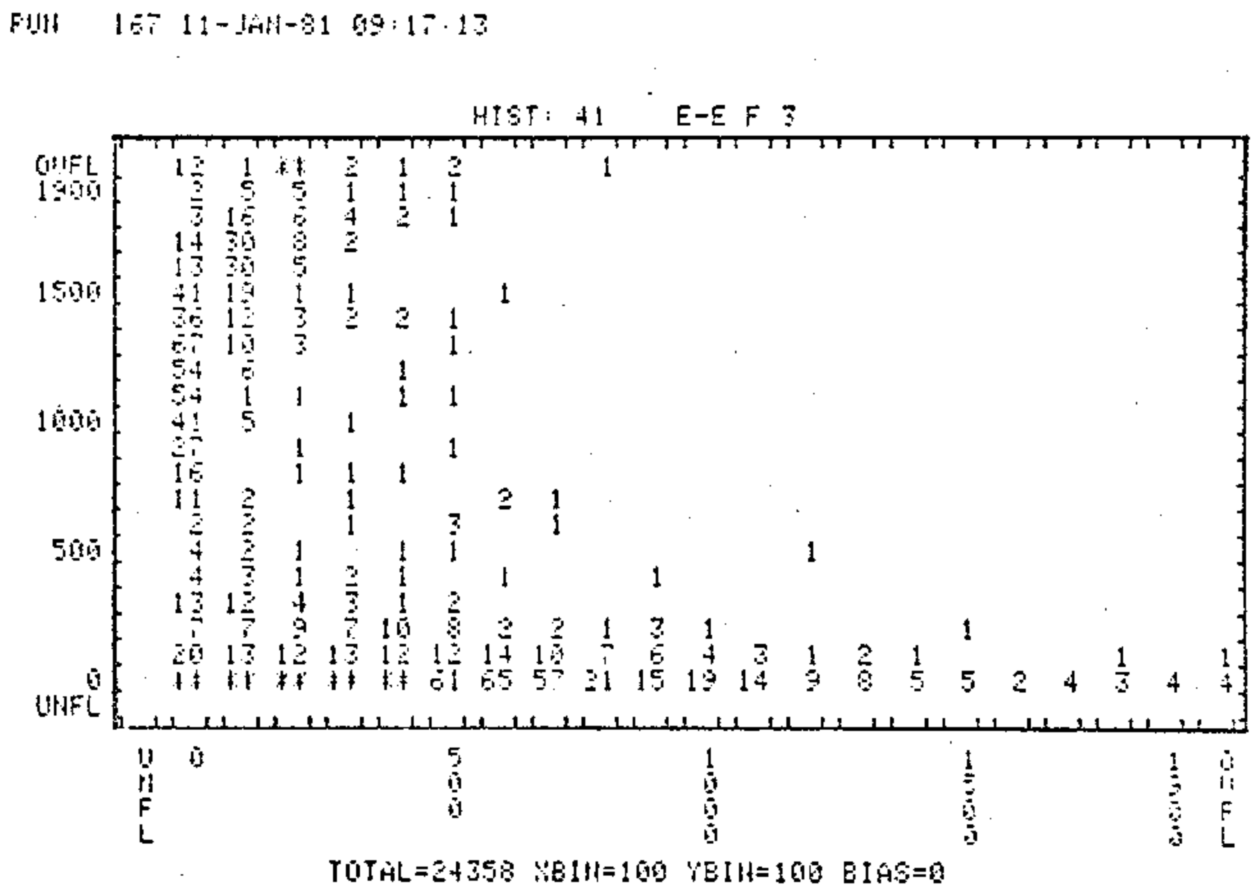


Figure 2 : *Angular correlation between the two fission fragments issued from the bombardment of a ^{197}Au target by ^{12}C at different energies. At 297 MeV/u and 60 MeV/u the cross sections are directly comparable. For each energy a relative momentum scale ($P_{//}/P_T$) is given on top of the angular distribution (with $P_{//}$ and P_T standing for*



*<u>Figure 3.a</u> : Distribution of the reaction products of ^{12}C + ^{nat}Ni at 30 MeV/u in a ΔE*E space (where ΔE represents the energy deposit in a 4 µm thick transmission Si detector and E the residual energy). The heaviest residues are located in the upper left hand side of the matrix and can be easily isolated from the projectile like fragments.*

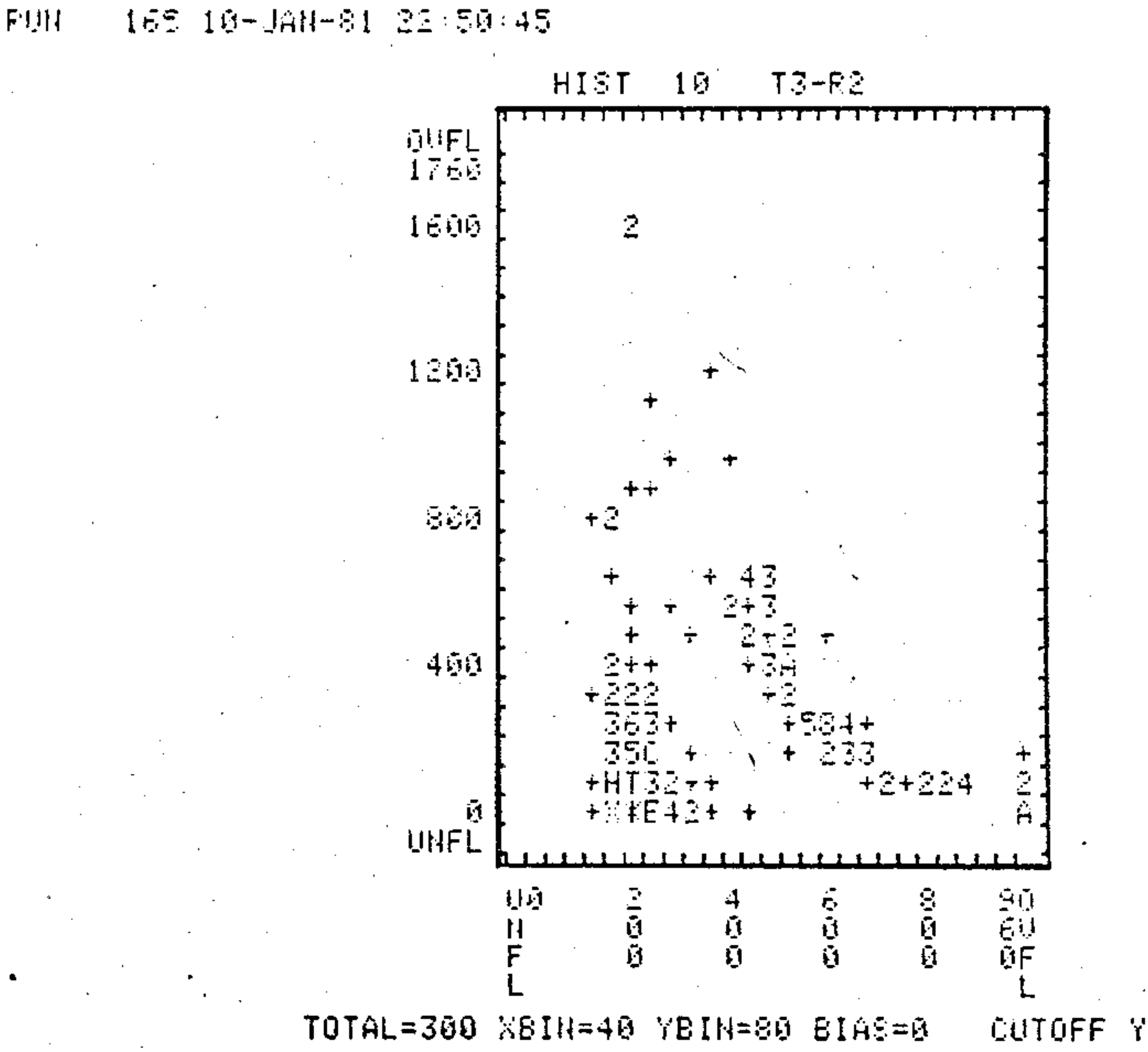


Figure 3.b : *Distribution of reaction products in a E * t space (where E represents the total energy of a reaction product and t the time of flight difference between this product and a light particle detected in coincidence). The right hand side contribution originates from the heavy residues whereas the left hand side component is due to protons and α particles essentially.*

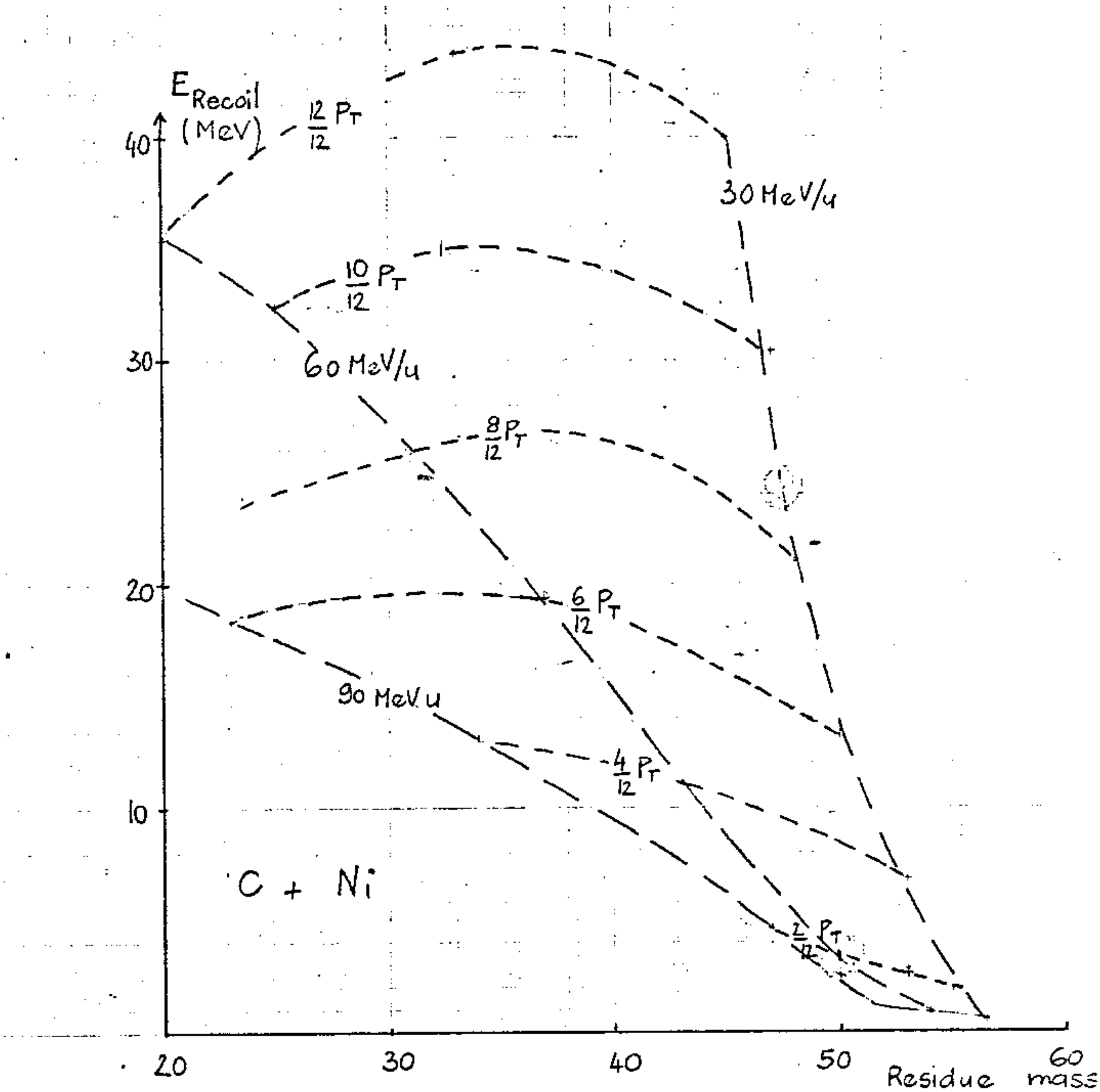


Figure 4 : In a simple model we try to predict two main characteristics i.e. mass of the residual products (in abscissa) and associated recoil kinetic energy (in ordinate) as a function of bombarding energy (long dashed line) and fraction of transferred momentum (short dashed line).

The underlying picture is the following : from the transferred momentum (i.e. transferred mass) the recoil velocity of the target like resulting nucleus is computed neglecting the transverse momentum. Then, the excitation energy is simply calculated and the number of emitted nucleons roughly estimated assuming thermal equilibration and that 12 MeV are needed on the average for each nucleon emission. The resulting mass residue is deduced and the kinetic energy computed assuming that isotropic evaporation does not modify on the average the initial recoil velocity of the target like nucleus.

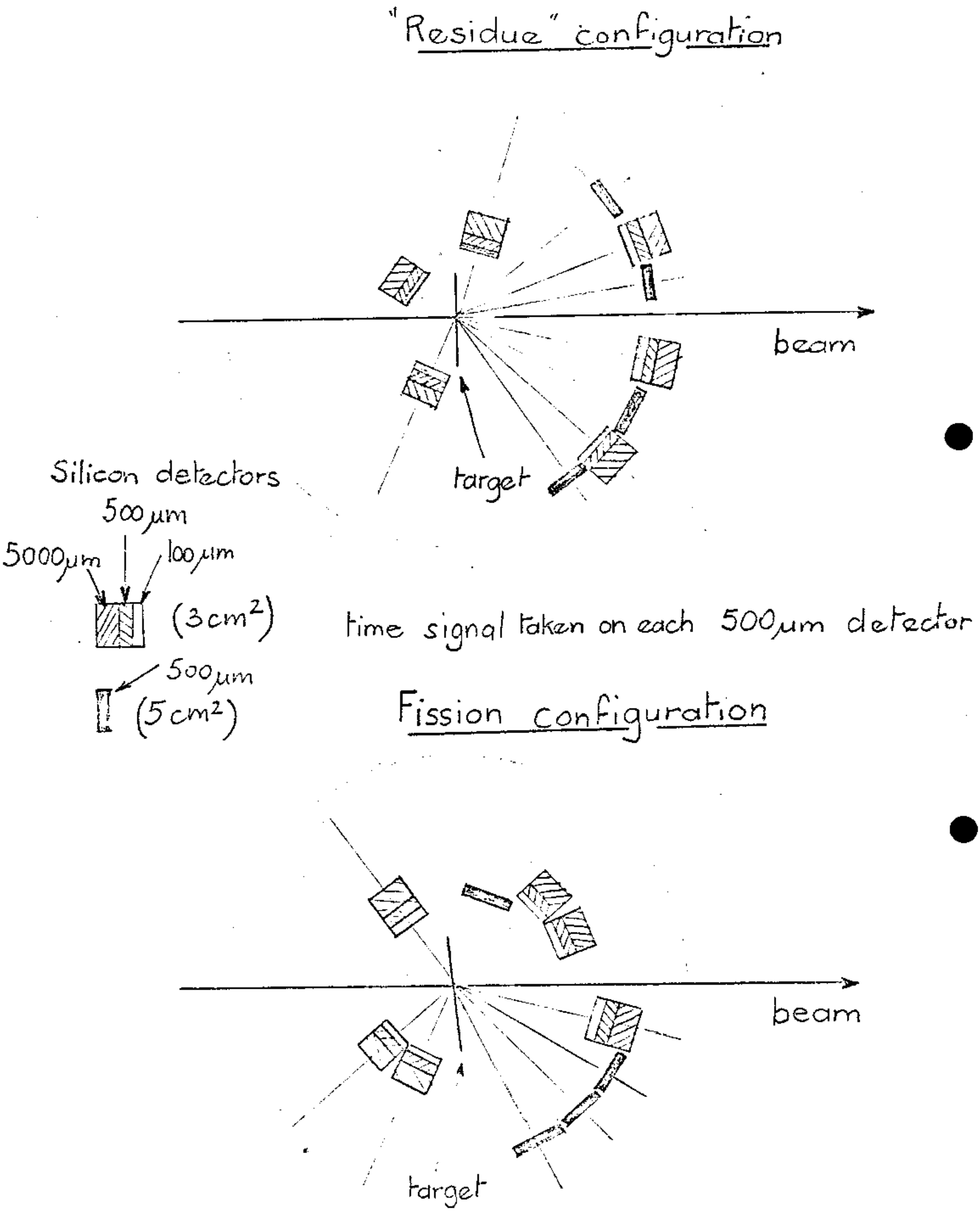


Figure 5 : Scheme of the detection system.