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PATTERN RECOGNITION PROGRAM FOR THE PICTORIAL DRIFT CHAMBER DIOGENE

M. POITOU

DPh-N, CEN Saclay, 91191 Gif-sur-Yvette Cedex, France.

The rather small size of the Diogène pictorial drift chamber has several unfavourable consequences : not more than 16-18 points to define even the best isolated tracks ; high track density and hence missed points due to double hit resolution ; strongly bent trajectories and thus many track crossings. In spite of these difficulties, the events can be analyzed. The program takes advantage of the fact that the vertex position is known. Two different methods are used : the first one selects out rather quickly most of the tracks by a simple strategy ; the remaining tracks are then searched by a more global but much more time consuming method.

Diogène is a 4π drift chamber which is designed to measure large multiplicity events in relativistic heavy ion collisions. The measured particles will be $\pi^{\pm}$, p,d,t,^{3}He,α... Multiplicities larger than 40 are expected to be measured. This detector is a strongly down scaled and adapted copy of the jet chamber of the JADE detector at DESY [1]. It consists [2] of a cylindrical drift chamber divided into 10 sectors, each of them having 16 anode wires. The size of Diogène is 80 cm in length and ∿ 70 cm in diameter. Each anode wire is connected at both ends to a multiple hit electronics again copied from JADE [3] which registers up to 8 hits per wire in a single event. The recorded data per hit are the wire number, the drift time of the electrons, the amplitudes of the signal measured at both ends of the wire. These informations allow to calculate the hit location, with however a left right ambiguity due to the fact that the drift time is the same whether the hit is on the left or the right hand side of the wire. The Z coordinate is obtained by charge division at both ends of the wire. The double hit resolution introduced by the electronics is 7 mm in drift distance and applies irrespective of the polar angle θ. In case of a double hit within the 7 mm, the drift time of the hit which is closest to the wire is correctly measured. However the amplitudes are combinations of the amplitudes from both hits, which implies a wrong Z determination. The chamber is located in a magnet whith a magnetic field of 1 tesla. This rather high value is necessary in order to get a reasonable accuracy on the particle momentum. As a consequence the trajectories, and especially the low momentum ones, are rather strongly bent, giving rise to track crossings and to tracks going over from one sector to the next one. The track crossings together with the double hit resolution always lead to loss of at least one hit for one of the tracks, and bad amplitude measurement resulting in wrong Z coordinate for the other one. The magnetic field is parallel to the beam axis, and perpendicular to the electric field giving thus rise to a drift direction tilted by 23° with respect to the electric field direction.

The geometrical resolutions are the followings : 400 μm (FWHM) for the drift distance, 16 mm (FWHM) for the Z coordinate.

The detector will be used with a beam colliding a small target, the location of which is known and hence gives a starting point for all trajectories. However the beam is flying in a vacuum pipe while the chamber is filled with a 4 atm. pressure gas. In order to stand the pressure difference the beam pipe has to be rather thick (1.3 mm of steel, which shall be changed for a 1.3 mm carbon fiber tube). There can thus be important multiple scatterings in the tube so that the track in the chamber may not always be prolungated with the same geometrical parameters down to the target. The target size is also not infinitely small.

The frame in which the particles will be detected is now well defined. The multiplicity of particles can be rather high. A particle giving a signal on all wires of a sector will thus be measured at 16 different points giving rise to 32 a priori possible geometrical points. The electronics is capable of measuring

256 such possible points in a sector out of which only 128 can be correct, the others being the left right symmetrical of the true ones. A complete event may thus consist of up to 1280 true points (or 2560 possible points) which are to be connected appropriately together ; the left right ambiguity has also to be solved. With the expected particle multiplicities (about 40), one has thus to analyse events of about 1200 possible points.

The program RATRADI (Reconstruction and Analysis of TRAjectories in DIogène) which will be described here was developed in parallel to the design of Diogène (thus leading to modifications in the detector such as the shift of the wire plane with respect to the target). It was tested with simulated events. The detection of these events in Diogène according to our current knowledge of the detector was simulated in a Monte-Carlo code by Denis L'Hôte from the Diogène collaboration.

The first thing one has to try and do in such a code is to reduce the number of points one has to deal with at any time in the event analysis. For this purpose all points assigned to a track as well as their left right symmetrical ones will be removed from the list of available points as soon as the track is found.

A few wrong points (symmetrical to the true ones) will be eliminated a priori just because they geometrically fall out of the sector in which they are supposed to be measured. This applies however only to points which are detected in the vicinity of the edge of a sector, only on one side of it.

Due to the curvature of the trajectories, it is not possible to treat one sector independently of the neighbouring ones. Indeed one must always consider 3 sectors together. One restricts thus the problem to the analysis of a maximum of 768 points.

The next step to reduce the number of points is to use the fact that the target point is known. A trajectory in Diogène will be an helix with its axis parallel to the magnetic field (and to the beam). In a projection on a plane perpendicular to the beam axis, a track will be a circle (at least as long as we can neglect the effects of energy loss on the rigidity of the particle). In a (r,Z) representation where r is the distance of the point to the beam axis and Z the coordinate along the beam axis, the projection of the helix is a sine curve. However for all particles coming from the target and passing through the inner tube, the portion of sine curve inside the chamber is to a very good approximation a straight line. Indeed the deviation from the straight line is always hidden by the poor Z resolution. A track can thus be defined as a set of points having all the same polar angle θ. If in a sector (or a group of 3 sectors) one builds the histogram of θ, each track should define a peak. However it is not so simple to extract a peak for three reasons : 1) there may be several tracks at θ values which are not very different from each other so that the peaks overlap ; 2) the resolution in θ will broaden the peaks ; 3) on the first wires (which are not far away from the target) the density of tracks is higher, which leads to a larger probability for piled up hits and hence wrong θ values. However if one considers only the 6 outer wires, then there are less tracks, less problems with double hit resolution, and it is much easier to define "peaks" on the histogram A peak would better be called an accumulation region. Left and right symmetrical points have not the same θ value. Their "peaks" can be separated from each other by a few degrees.

So the basic selection made by the program is to build the θ histogram for all points measured in *one* sector on the outermost wires. Each peak of the histogram is representative of one or several tracks. Taking into account the poor Z resolution of the detector, the program defines a θr range which is broader by several degrees than the peak of the histogram. Then all points in this sector and its two neighbouring ones, which have a polar angle in the calculated range, are selected out for further treatment. This kind of selection will be repeated a lot of times throughout the program.

The selected points must now be further analysed in order to find out tracks. Since the drift time and hence x,y coordinate resolution is 40 times better than the Z resolution, most of the subsequent treatment for the track finding will be done in the x,y coordinates (projection of the track on a plane perpendicular to the beam axis).

In the first part of the treatment, a simple strategy will be used in order to find very quickly the easiest tracks.

The wires are arbitrarily classified in three sets : an outer one, an intermediate one, an inner one. The class of each wire will be varied during the analysis. The program selects an outer wire with the largest number of hits, and an intermediate wire with also the largest number of hits. The outer wire is as outer as possible and the intermediate one is as inner as possible.

Now the program selects the first point of the outer wire and the first point of the intermediate one. These two points together with the target point define a circle. The program checks whether this circle can be a track or not. If it is not, then the next point on the intermediate wire is selected ; etc. In order to be a possible track, the circle must have a radius which is not too small. If so the program looks for points from the list built according to θ, which are close to this circle (typically $\lesssim$ 1 mm). If there are enough of these points and if they are reasonably aligned in the (r,Z) plane, they are assumed to belong to a possible track. Now the whole set of points is fitted by a circle which has to stand tests of χ^2, and of distance to the target. This later test allows to eliminate the left right symmetrical of the true track : since the wire plane is shifted from the target, the symmetrical "circle" cannot come from the target. If those tests are successful the program searches again for points close to this circle and aligned in the r,Z plane ; these points may be different from the first ones that included the target point due to multiple scattering in the beam pipe). The points, if different from the previous ones are again fitted by a circle. If all conditions are fulfilled to define a track, then the program decides that a track has been found, and assigns the points to the track, thus removing them and their left right symmetrical from the list of available points. Points which are on the circle in the x,y plane (but not in Z) are also assigned to the track. In case of double hit in the integration time of the electronics, the time of the first hit, and hence the x,y coordinates are correctly measured, however the Z and hence the θ values are wrong. The point thus belongs to the track. However it cannot be used to determine neither the polar angle nor the energy loss of the particle in the gas.

The program then continues with the remaining points from the two wires. When all the pairs of these points have been selected, the program looks for the next "peak" in the θ histogram.

This procedure is repeated for the 10 sectors of Diogène.

After the whole detector has been checked once the criteria to define the angular range or to accept the tracks are slightly weakened and the procedure starts again.

This of course does not allow to measure tracks in a rather forward or backward direction since they do not reach the outermost wires. So the whole procedure has to be repeated with new definitions of the outer, intermediate and inner wires, in order to cover the whole angular range of Diogène. Since the tracks which have a small $p_\perp$ can be more scattered in the tube than the other ones, the criteria to define a track must also become weaker and weaker. One must also have special criteria for tracks which are close to other ones on a long path in the chamber : only a reduced number of wires detect them, which leads to special rejection conditions.

With this rather simple strategy it is possible to find very fast most of the tracks. The only point is to have adequate rejection rules : one should of course accept the largest possible number of tracks, but one must be careful not to build wrong tracks by assigning together points which do not belong to the same tracks : if wrong tracks are generated by the program they will cause trouble first because they are wrong and second because their points cannot be used in the subsequent search of the program to determine the true tracks to which they belong.

Typically the program takes about 5 ms (on IBM 3081) for each track which is found by this procedure ; this time includes also service routines which calculate geometrical corrections to apply to the track, refits the track with the corrected points and calculate the physical parameters of the track (direction, momentum, mean energy loss...).

However this simple strategy is not enough to find all the tracks : due to double hit resolution and to background, it may happen that a track has not a point on both selected wires. It then cannot be found by this strategy. One has thus to find another way of selecting the points of a track ; this other way should be more global (include as little strategy as possible). However in the absence of a strong selection of points the number of cases which one has to consider involves a lot of different possibilities so that the computing time may increase considerably. This method has thus to be used rather late in the analysis, when there are not too many points left to be analysed.

The method which is used till now is the following : after the selection of points in a θ range, the program checks all possible couples of two points measured on two different wires. The two points together with the target define a circle. If the radius is not too small, then the program looks for points close to this circle. Some condition on the (r,Z) alignment of the points is required. The χ^2 of the fit of the points by a circle may not be too large. With all these conditions, the program selects the couple of points giving rise to a circle with the highest number of points close to it. If there are several such couples, the program selects the one (or the first one) with the smallest χ^2 value for the fit. This technique allows to find tracks which are not detected by the usual strategy. But of course it costs a lot of computing time especially when there is some background.

An alternative method to find tracks globally has been developed by the Strasbourg [4] part of the Diogène collaboration. It takes also advantage of the fact that the (x,y) projection of the track is a circle coming from the target. Then the geometrical inverse of the circle is a straight line which may be easier to identify. This procedure might be introduced in the present code to replace the global analysis one which was just described, since it should be much faster, because it involves no combinatorial analysis of the points.

Another approach has also been tried by the Clermont-Ferrand part of the collaboration [5], in the spirit of the method used at Tasso [6]. However the geometry of Diogène is so different from that of Tasso that this latter method does not seem to give good results for the tracks which do not reach the outer wires of Diogène.

About 90 % of the tracks are correctly reconstructed by the program. Fig.1 shows an event from the first run performed with the whole detector (fig. 1 a) and the results of the analysis by the program (fig. 1 b). The actual performances of the program are the following : from 5 ms to 30 ms per track depending on the complexity of the events and the stage where the track is recognized with a storage required of about 260 kbytes in an IBM 3081. The speed of the program can be increased especially for complex events by adjusting the rejection parameters. The parameters used by now mainly come from the analysis of the simulated events. The true events slightly differ from the simulated ones. However this adjustment cannot be performed as long as the detector is not completely studied in its true running conditions.

References

[1] J. Heintze, Nucl. Instr. Meth. 156 (1978) 227.

[2] J.P. Alard, J. Augerat, R. Babinet, F. Brochard, Y. Cassagnou, J.P. Costilhes L. Fraysse, J. Girard, P. Gorodetzky, J. Gosset, J. Julien, C. Laspalles, M.-C. Lemaire, D.L'Hôte, B. Lucas, G. Montarou, A.P. Papineau, M.J. Parizet, J. Poitou, C. Racca, M. Suffert, J.C. Tamain and Y. Terrien, Letter of intent n° 8 and Proposal n° 43, Laboratoire National Saturne.

[3] W. Farr and J. Heintze, Nucl. Instr. Meth. 156 (1978) 301.

[4] C. Racca, CRN Strasbourg (France). Private communication

[5] D.G. Cassel and H. Kowalski, Nucl. Instr. Meth. 185 (1981) 235.

[6] G. Montarou, LPC Clermont (France). Private communication.

Figure captions

Fig. 1. a) An event from the reaction of 3.2 GeV α with ^{208}Pb. Top : projection on a plane perpendicular to the beam axis. Bottom : projection on the r,Z plane, r is the distance to the beam axis, Z is the coordinate along the beam axis. For each hit the two *a priori* possible points (due to left-right ambiguity) are plotted. b) Result of the analysis of this event by RATRADI.

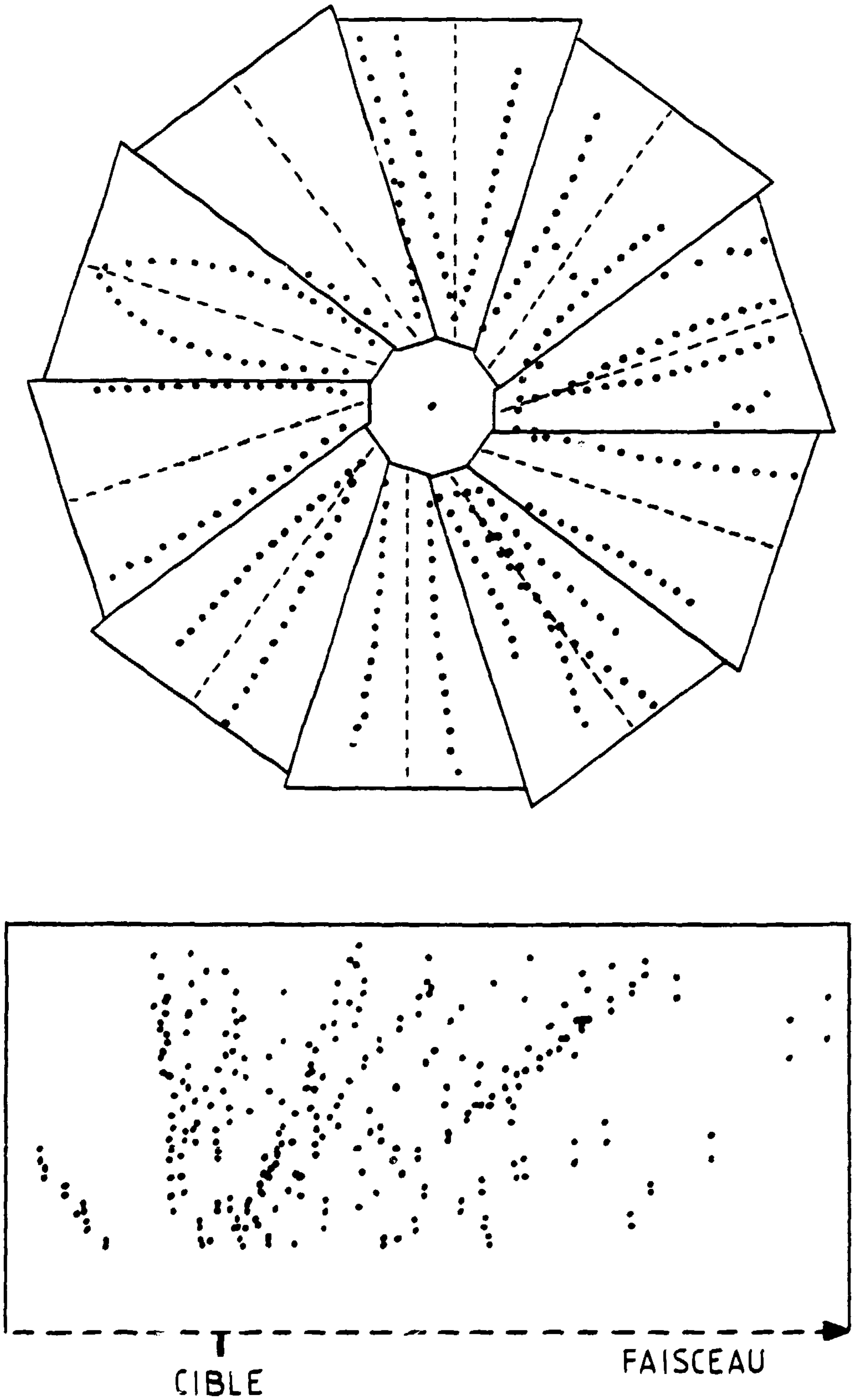

Fig.1a

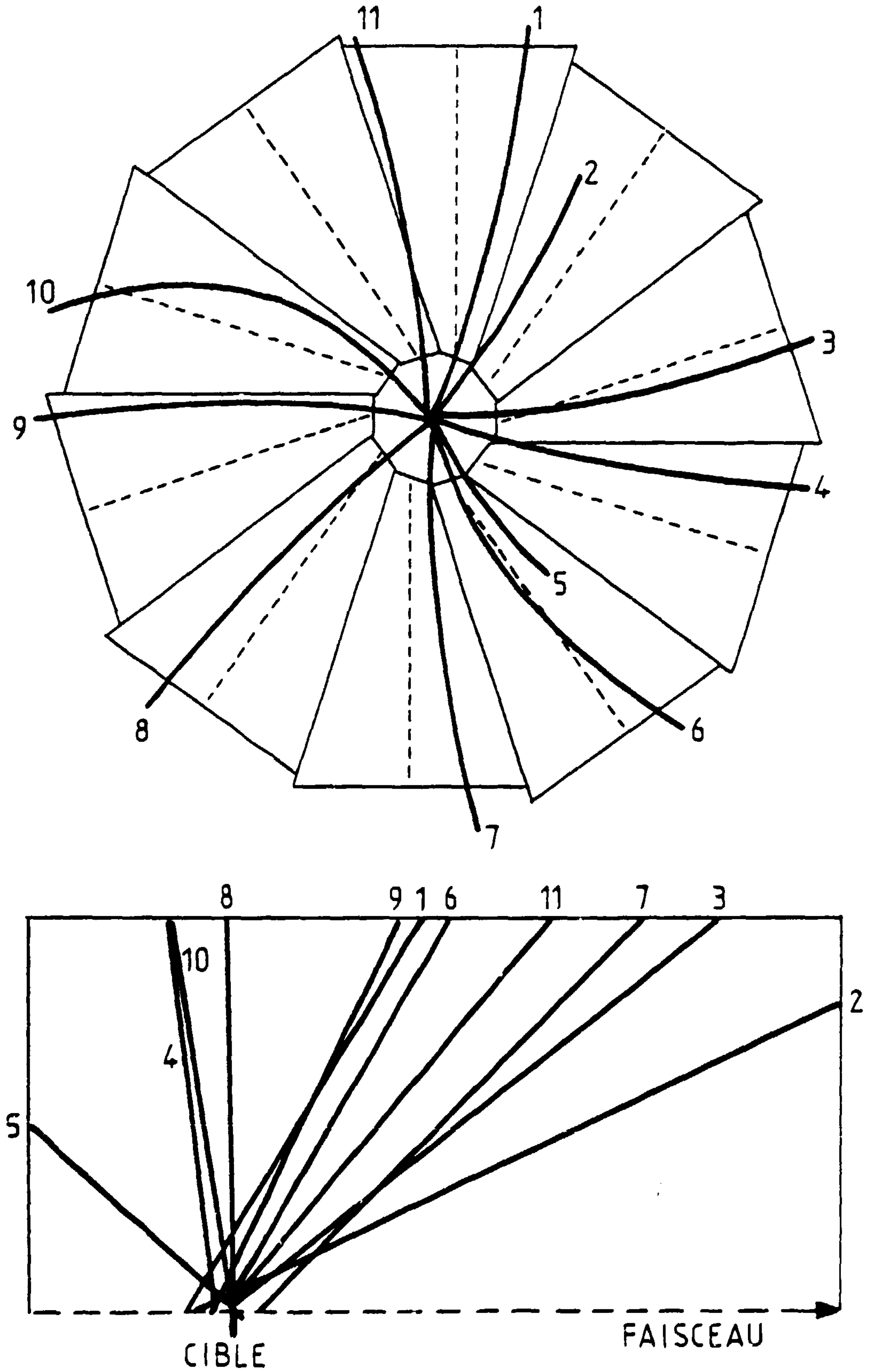

Fig.1b