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A NOTE ON THE VERTEX PROGRAM

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A NOTE ON THE VERTEX PROGRAM

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ABSTRACT

The geometrical reconstruction program written to fulfil particular needs of the vertex detector in the FRAMM spectrometer is presented.

In this program a fast and effective nevertheless simple method was used to treat events with high combinatorial background in space reconstruction.

At the end some results from experimental data processing are commented.

1. - INTRODUCTION

Nowadays simultaneously with the fast progress of experimental techniques in high energy physics, the old complaints about quality of experimental data are still persisting. Poor statistics and inconsistence between measurements derived from different experiments are undoubtly the most pronounced.

The CERN-NA1 experiment, done by the FRAMM collaboration in 1980, with its program of systematic studies of hadron-nucleus collisions is an example of how to succeed in overcoming the mentioned difficulties. This experiment supplies interesting collection of data taken by the same apparatus with different beam-nuclear target configurations, thus providing decent statistics.

In this note we will limit our interest to the large angle production events from the vertex detector. In order to elaborate these data independently of the pattern recognition in the forward spectrometer, the program VERTEX has been developed.

The aim of VERTEX is the geometrical reconstruction of multiprong events with charged particles emitted over a wide range of solid angle.

The present version of this program has been tested and put in operation on the IBM mainframe at CERN.

2. - APPARATUS CHARACTERISTICS

The FRAMM experimental set-up has been presented earlier(1), so for the purpose of this report, only the vertex detector built to study multihadron production will be briefly reminded.

This autonomous part of the whole FRAMM spectrometer consists of a box of 8 drift chambers and 2 cylindrical multiwire proportional chambers (MWPC) - Fig. 1.

2.1. - DRIFT CHAMBERS

The technical description and parameters of these drift chambers are given elsewhere(2). The box structure of four pairs of drift chambers covering 80% of 2π polar angle surrounds 2 cylindrical multiwire proportional chambers and the target. The drift chamber wires are perpendicular to the beam direction (roughly coinciding with the z-axis in FRAMM reference system) and supply precise measurement of the drift z-ccordinate.

For every signal the drift chambers provide also simultaneous read-out (by delay lines) of the second coordinate i.e. the one along the wire. The measured resolution for delay (x or y) and drift (z) coordinates are respectively:

σ (x or y) = 0.7 cm

σ (z) = 0.02 cm

2.2. - MWPC

Details about the MWPC construction and operation are given in(3). Chamber operation tests and calibration runs have been done with a ^{55}Fe source.

The applied proportional region of chamber operation is guaranteed as far as the energy deposit left by charge passage in the chamber is smaller then 15 keV. Using the particle velocity variable ($\beta = v/c$) this limit corresponds to β about 0.4. The nuclear emulsion terminology nominate the particles in question as shower and grey ones.

The impulse amplitude registered by the MWPC is a function of energy loss (i.e. velocity) and can be subject of further investigations. We know also the space coordinates of the particle path in a cylindrical system: the z-coordinate with an average resolution σ (z) = 2 cm (by charge division method) and the azimuthal angle ϕ with σ (ϕ) = 0.056 rad.

Also slow particles ("black" particles, $\beta < 0.4$) can be detected by the MWPC, but they develop the saturation of the chambers. Exactly on this uniform behaviour of MWPC with respect to the large class of slow particles and nuclear elements, we based our definition of "slow" or "black" particles.

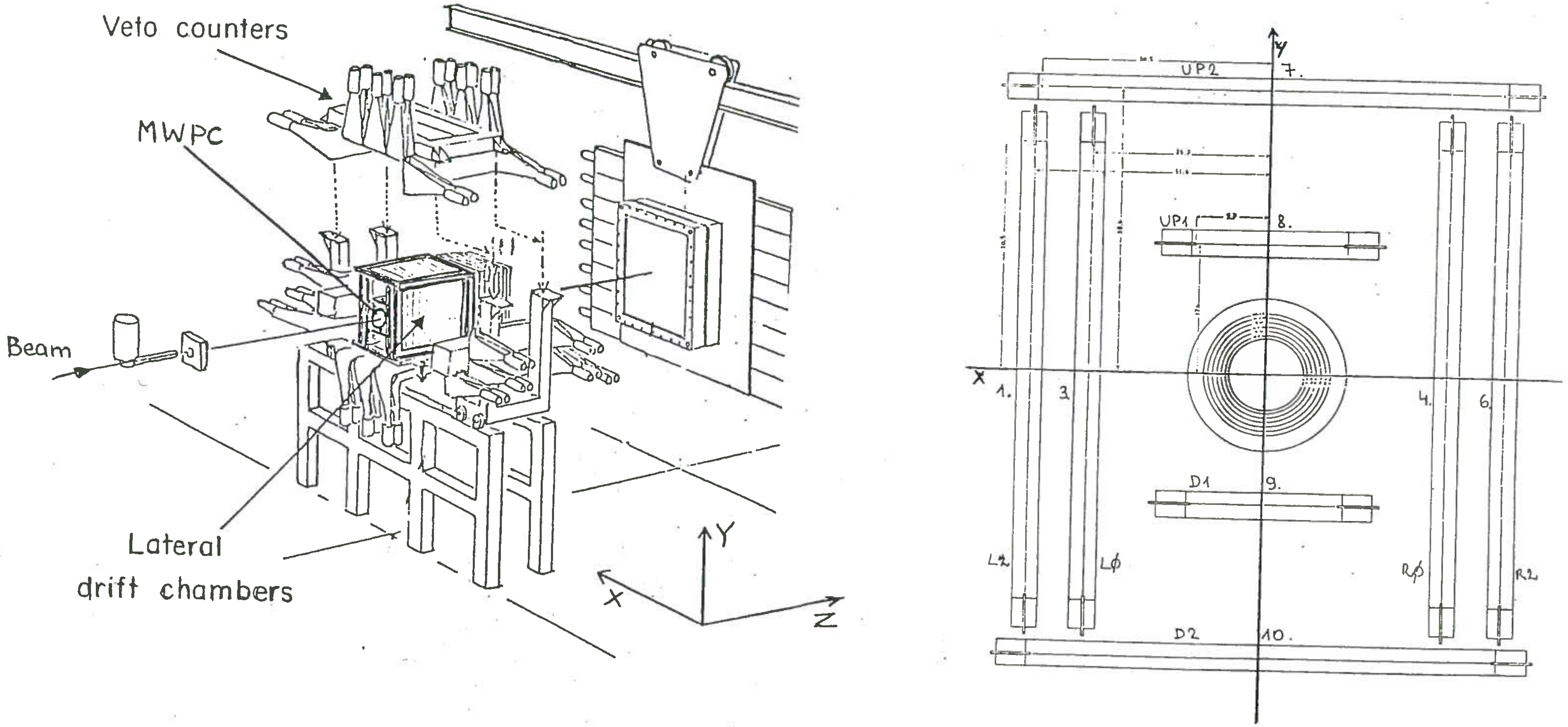


Fig. 1

1a) The general view on FRAMM vertex detector.

1b) The XY view of the vertex detector.

For this class, from the signal left in the chamber, twofold read-out for azimuthal angle ϕ and $(\phi+0.45)$ rad can be extracted, while there is no indication for the z-coordinate.

2.3. - TARGET AND BEAM

Each of the four nuclear targets (Al, Cu, Ag, Pb) used in the FRAMM experiment is made of 30 identical slices of radius 1.5 cm and thickness 100 μm distributed every 1 cm along the axis of the cylindrical chamber (z-axis).

The SPS charged hadron beam (π^+, π^-, K^+, p) was focused into the target by a system of quadrupol lenses. The position of the beam can be reconstructed from a beam spectrometer in about 20% of the events. For the rest of the sample the average beam position (approximated as an average position of the reconstructed vertices) was used. The slight inclination of the beam respect to the z-axis (in the FRAMM reference system) results in a shift of the beam-target cross point between the first and the last target much smaller than the beam systematic error originating from uncertainty of the alignment algorithm and is neglected.

3. - THE VETREX PROGRAM

VERTEX is a program intended to reconstruct inelastic hadron-nucleus events starting from experimental data taken by the FRAMM vertex set-up.

The main problem encountered during reconstruction is the high level of combinatorial background with relatively weak constraint conditions (reflection of evident simplicity of apparatus), requesting long and time consuming procedures in the traditional, scrupulous approach. The necessity to reduce calculation time leads to application of non-standard algorithms. The proposed method including numerical values of applied cuts is justified by efficient results of Monte Carlo data reconstruction.

3.1. - PROGRAM PRESENTATION

The program has a modular structure, processing the experimental data by a chain of modules with optional external input and output. The organization of the program makes possible to re-process/execute, with new conditions, only certain parts of elaboration.

The main modules, briefly described below, are the following:

DECOD:
-BEAM
-DRIFT
-MWPC
→ PATREC → I - ST SPACE → REFIT → CLASSIF

3.2. - DECOD

Purpose: to transform electronical response of the apparatus to explicity significant variables (like space coordinates of signals) using automatically updated set of calibration parameters and constants.

There are 3 independent processors BEAM, DRIFT and MWPC for corresponding detector decoding.

3.3 - PATREC

Purpose: to recognize events using only drift chamber signals in XY projection i.e. in the plane perpendicular to the beam direction. The signals from drift chambers associated in pairs are considered candidates for tracks originating from interaction in the target. Two points build a "track" if their impact parameter to the beam direction fulfil acceptance conditions. The cuts on impact parameters (different in X and Y direction) are ones of important selection parameters.

In Fig. 2 the X- and Y- projection of discussed variables are presented. The distinction between horizontal and vertical chambers as well as differentiated X and Y distributions are a simple consequence of geometry.

The output of PATREC contains list of drift signal associations. Each association (track) represents in fact, as a result of ambiguity of the drift signal, 4 possible space solutions - subtracks. Every solution is a 5 -parameter straight line.

The additional information about the track (accessible from MWPC, known with poor resolution and frequently incomplete) concerning track space localization was not satisfactory enough to be used as a universal criterion to resolve the mentioned ambiguity.

3.4. - I -ST SPACE FIT

Purpose: to determine in first approximation, groups of tracks belonging to the same event and estimate possible vertex position. The procedure to search for the best vertex fit (i.e. with smallest space dispertion) between all possible combinations of all tracks and subtracks is very inefficient (even for modest multiplicity of order 5-6 it would require over 10^3 attempts for 1 event).

The radical reduction of number of possible combinations (named simply "groups") containing different sets of subtracks, each representing different track, can be achieved by a following simple procedure.

The main idea is to restrict the number of groups only to collections of subtracks mostly concentrated along the direction in which the track position is known with the best experimental resolution. The choice of this direction was decided analyzing the Monte Carlo distribution of vertex fitted from track belonging to generated events smeared by experimental errors. On Fig. 3 the vertex projections on the XY plane and the Z axis of reference system are given. The well peaked z-distribution indicates the suitable direction. In general, by this pass the number of possible groups undergoes substantial decrease from $4^n \rightarrow 4n$, where n is the multiplicity of the event.

The new variables introduced by this approach are:

- z_{ij} -coordinate of track-beam impact distance - to characterize the i-th subtrack of j-th track;
- the average $\langle z\rangle_k = (\sum_{ij} z_{ij})/n$ - to characterize the k-th group
  k-th group $G_k = \{T_{ij}\}$ of subtracks T_{ij}
- the dispersion σ_k of the average $\langle z\rangle_k$.

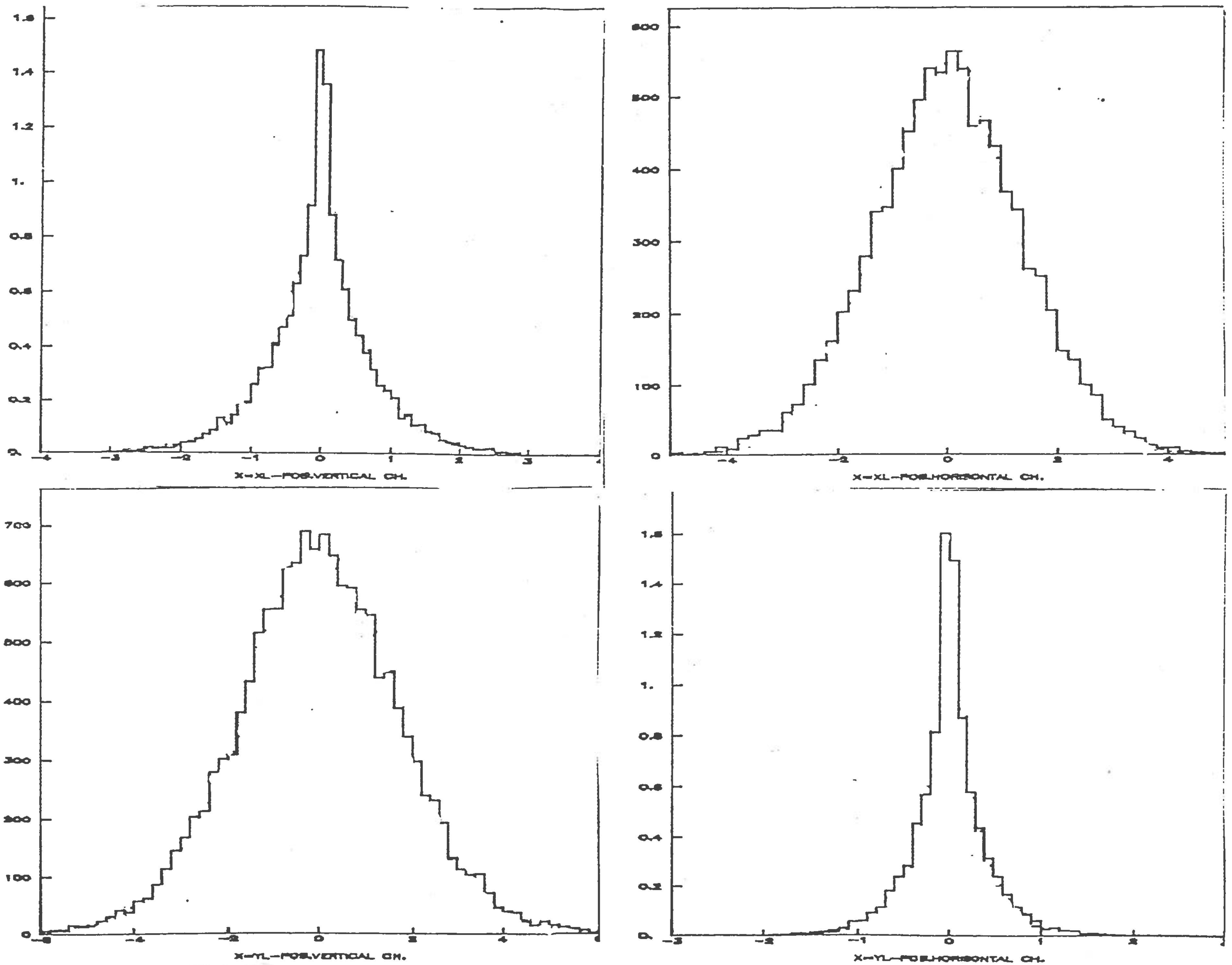


Fig. 2. The X and Y component of the track - beam impact parameter.

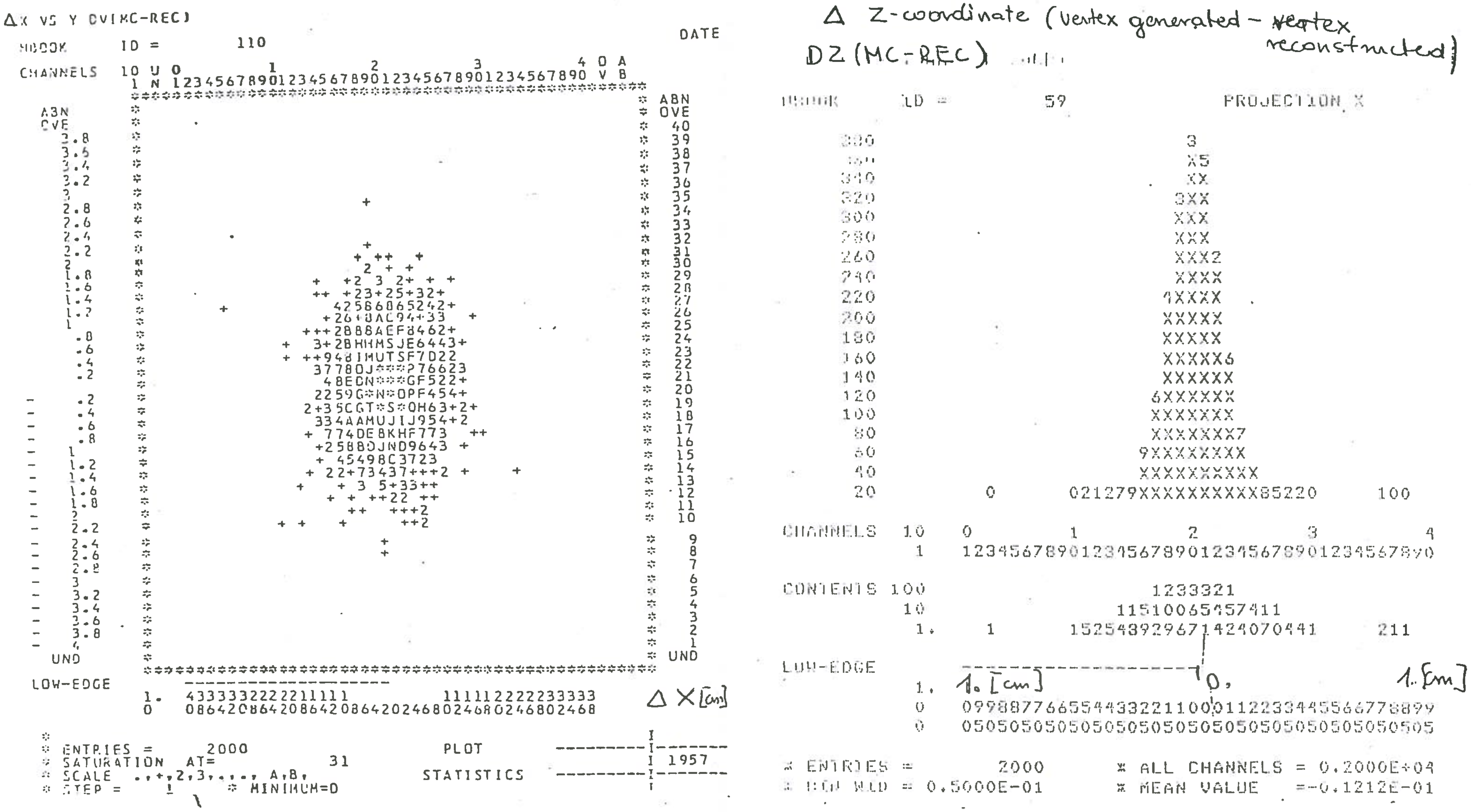


Fig. 3. The distributions of the reconstructed vertex - generated vertex discrepancy in the XY-plane and in the beam direction (Z-coordinate).

The group dispersion $\sigma(\langle z\rangle)$ for the right combination of subtracks determined by the experimental errors is used to eliminate evidently faulty groups.

In fact to establish the cut value for $\sigma(\langle z\rangle)$ also other factors have been taken into account. Let's list them in order of importance:

- limited precision of beam position (for consistency of elaboration always the average values were used),
- correlations with other cuts,
- equilibrate level of true/spurious track rejections.

It was proved with MC tests that this procedure is not very sensitive to the exact position of the beam and the application of the average beam position instead of the exact one does not influence quantitatively the results.

The effect of mixing background tracks with true ones can be easily noticed by an artificially large $\sigma(\langle z\rangle)$ value, overflowing the acceptance limit (Fig. 4). The tracks responsible for this overflow are eliminated until at least one subgroup is found with a $\sigma(\langle z\rangle)$ inside the cut limits.

The cut value for $\sigma(\langle z\rangle)$ is an important parameter of the procedure and its value used in the first fit approach is more restrictive than the one in the final fit in order to optimize false track rejection.

3.5. - REFIT

Purpose: to recover the tracks belonging to the event lost in the primary approach (by application of sharp cuts) and terminate current event elaboration. Now the z-position of the vertex found in the previous step is considered a new important binding condition. The stream of pattern recognition and space fit is repeated with the following modifications:

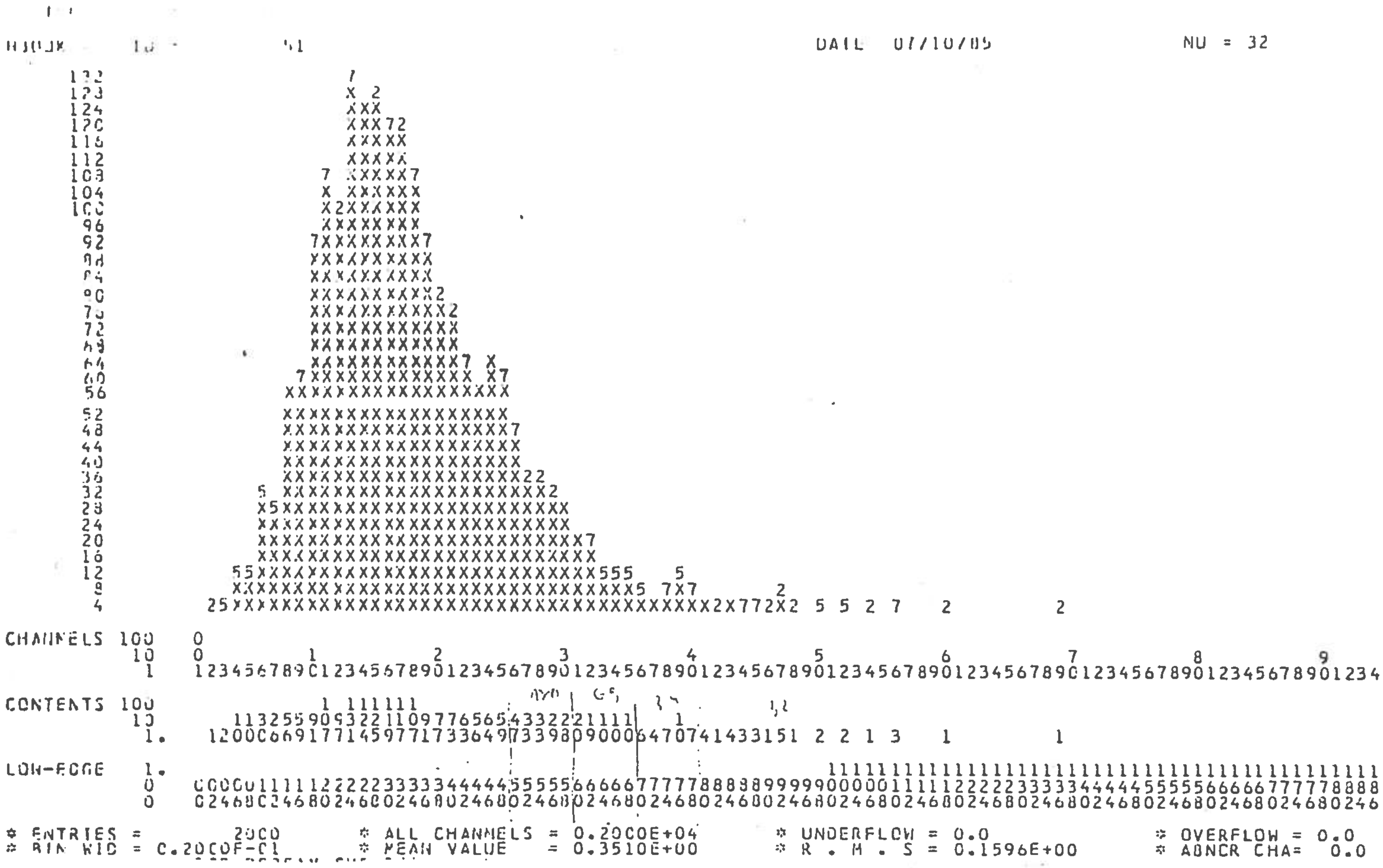
i) only drift chamber signals not used in the first fit track associations are considered;
ii) more tolerant acceptation limits are applied on impact parameter;
iii) the newly linked tracks in pattern recognition step (PATREC) should now pass near pro-vertex (provisory vertex position) found in the first fit;
iv) the z-dispersion limit for new groups is enlarged.

The final result of REFIT is the space image of the event, the image based purely on drift chamber information. For every event the information bank has been updated at the end of each step of elaboration and recorded on Data Summary Tapes (DST). In the majority of cases (90%) the described algorithm leads to unambiguous, one-vertex solution. For the multi-vertex events all concurrent solutions are kept on DST for further analysis.

After the last stage, the auxiliary information from MWPC can be utilized and for this purpose the CLASSIF subprogram was developed.

3.6. - CLASSIF

Once we have the space reconstructed event, we start the matching of drift tracks with MW ones. In spite of the difficulty in establishing the drift tracks belonging to the event, it is relatively easy, taking advantage σ(<z>) generated by MC



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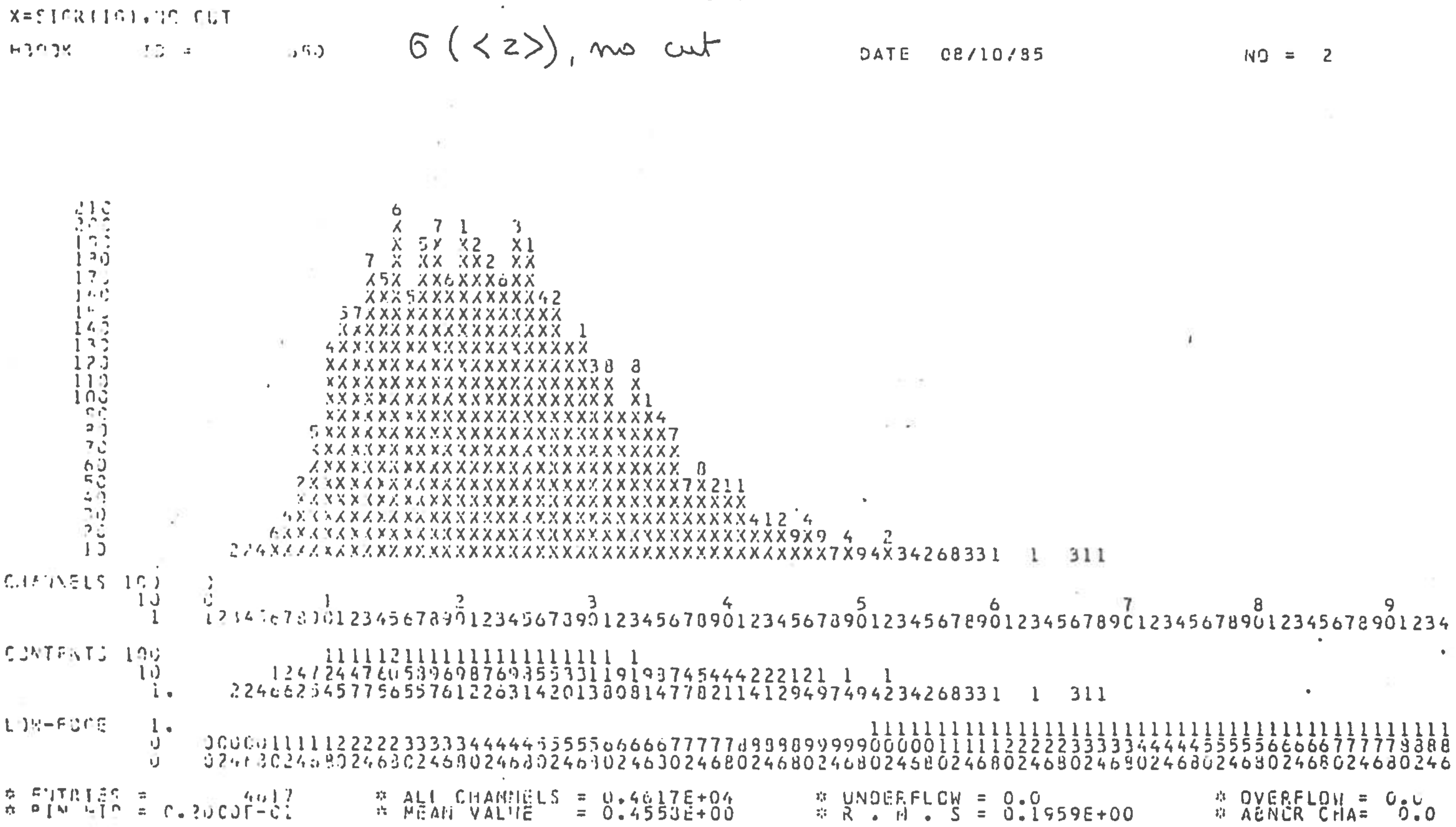
* ENTRIES =        2000      * ALL CHANNELS = 0.2000E+04      * UNDERFLOW = 0.0           * OVERFLOW = 0.0
* BIN WID = 0.2000E-01       * MEAN VALUE   = 0.3510E+00      * R . M . S = 0.1596E+00    * ABNCR CHA=  0.0
```

σ(<z>), no cut



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* ENTRIES =        4617      * ALL CHANNELS = 0.4617E+04      * UNDERFLOW = 0.0           * OVERFLOW = 0.0
* BIN WID = 0.2000E-01       * MEAN VALUE   = 0.4553E+00      * R . M . S = 0.1959E+00    * ABNCR CHA=  0.0
```

Fig. 4. The distribution of the σ(<z>)-variable for the final true line configuration and in the first space fit approach before any cut.

of the expected central position of the interaction point, to connect signals from both chambers in "MW tracks". In the best case such "track" is composed of a couple of single hits with consistent information about its space localization and energy loss allowing to classify the particle. The crossed multi-linking between "MW-" and "drift-tracks" encountered often during the match procedure leads to unique ordering by methods of statistical weight analysis. It is possible to draw from energy loss some additional conclusions for particles. Since the approach to this point depends on future physics program, we refrain - at the present DST level - from any precocious classification.

3.7. - REMARKS ON SIGNAL BACKGROUND

In order to relate experimental results with theoretical predictions and with results of other experiments it is necessary to have a good understanding of the distorsions of the physics distributions introduced by the apparatus. These can arise both from apparatus and procedural effects.

For what concerns the efficiency of reconstruction program it depends in general on the ratio true signal - background signal and in particular on parameters and cuts used in the program (some of which mentioned during the presentation of the program). The numerical cut values were established as a result of tests performed with MC data assuming simplified background. We abstain for the moment from the attempt to deepen the difficult problem of the nature of the background because of its insufficient 'a priori' knowledge, easier to approach once the raw data processing is completed. If we pass a simulated event by the data analysis chain in the same way as a real event, we enable the fitting program effects on the track reconstruction to be accounted for. And the more realistic background component we used, the best estimation of correction factors we are able to gain. Summarizing, the importance of background analysis, not so crucial at the application program level becomes essential during the correction procedure and should not be underestimated.

4. - ELABORATION RESULTS

The hadron-nucleus collision data for multihadron produciton studies has been taken

- at 3 energies: 80, 150, 300 GeV;
- with different hadron beam: p, K, π^+, π^-;
- on 4 nuclear targets: Al, Cu, Ag, Pb.

About 2 million triggers were written on 100 tapes.

The initial selection of an interesting sample of events with interaction in the target relies on rough elimination of pure beam events triggered by σ-electrons, requesting at least one signal in the vertex drift chamber system. This reduces the raw data roughly by a factor 2.

The next filter, with request of at least 2 track associations seen by the drift chamber system in the XY-projection, reduces to 20% the previous value of real triggers.

The final and decisive stage of geometrical reconstruction reject another 20-30% of later quantity leading to 200.000 events.

The statistics of survived data is shown in Table I.

Table I. The statistics of the experimental sample (in thousands) - only the reconstructed events with the charged multiplicity in the vertex detector ≥ 2 are included in the table.

Target	Al	Cu	Ag	Pb
beam				
	80 GeV			
π^-	2.97	3.91	9.30	6.10
π^+	2.66	4.19	4.04	8.40
	150 GeV			
π^-	2.65	3.29	5.27	6.85
π^+	7.88	14.18	5.46	27.04
K^+	1.41	3.91	4.58	7.45
P	5.04	5.49	7.78	10.19
	300 GeV			
π^-	2.66	4.05	5.39	7.11
π^+	1.61	3.54	6.33	7.90

REFERENCES

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(2) S.R. Amendolia, "A set of drift chambers built for the FRAMM-NA1 spectrometer" Nucl. Instr. and Methods 176 (1980) 461-468.
(3) E. Albini,"A vertex detector working as an active target in multihadron production on nuclei" , Nucl. Instr. and Methods 178 (1980) 49-54.