

**MASTER**

IS-2231

Physics (UC-34)  
TID-4500

UNITED STATES ATOMIC ENERGY COMMISSION  
Research and Development Report

PHYSICS USE OF THE AMES LABORATORY  
ON-LINE MEASURING SYSTEM  
FOR BUBBLE CHAMBER EVENTS

by

T. L. Schalk and W. J. Kernan

December 1969

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National Bureau of Standards, U. S. Department of Commerce  
Springfield, Virginia 22151  
Price; Printed Copy \$3.00; Microfiche \$0.65

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ABSTRACT

The use of the Ames Laboratory on-line measuring system for bubble chamber events is described using the measurement of "Vee" events in  $\bar{p}p$  experiments at 2.4 and 2.9 GeV/c as an illustration. Simplified flow charts of the control routines and systems are presented. The physics basis of the design is shown and discussed.





## INTRODUCTION

Several reports have been written describing various aspects of the Ames Laboratory on-line measuring system for bubble chamber events.<sup>1-3</sup> This report will concentrate on the design of how to use the system for effective interaction with the final physics results.

We will not attempt to describe all of the uses which have been tried for the Ames Laboratory on-line measuring system, but will confine ourselves to the control for one specific experiment. The particular experiment we have chosen to describe is the most complicated on-line control experiment we have attempted up to the present. The film was from  $\bar{p}p$  exposures in the 31-in. Brookhaven National Laboratory hydrogen bubble chamber at momenta of 2.4 and 2.9 GeV/c. The particular work described in this report involved the measurement of all Vee events, that is, the production of a neutral particle followed by its decay into two charged particles. The standard measurement for such events on conventional measuring machines not under computer control always has a difficult re-measure problem. The sources of the remeasures can be classified as follows: (1) events that fail to reconstruct; (2) events that pass reconstruction but fail to have an acceptable one-constraint fit to the Vee decay (we exclude from this category events where the "Vee" recorded by the scanner is clearly not the decay of a  $K^0$ ,  $\Lambda^0$ , or  $\bar{\Lambda}^0$ ); (3) events where the one-constraint Vee-fit is successful, but the three-constraint fit assuming production at the measured "production vertex" recorded by the scanner is not successful; (4) events where both Vee-fits (one- and three-constraint) are successful, but the overall fit at the production vertex is unsuccessful and indicates the desirability of a remeasure.

Any on-line reconstruction system can eliminate category (1) problems. Of the remaining categories, our experience in past experiments<sup>4,5</sup> of this type had indicated that number (3) was by far the most troublesome. A solution to this can be found that does not involve the use of on-line kinematics. However, the on-line kinematical fitting procedure will clearly allow the solution of this problem and can be used to eliminate problem events in category (2) as well. We chose to ignore the problems of category (4) for this particular experiment.

The design for this experiment made use of some general facility routines which were already available. These routines were in both KERTRAN and FORTRAN. They used a local version of HGEOM for the measurement of fiducials, vertices, and tracks. Part of this has already been documented in a prior report on this system.<sup>1</sup>

#### SIMPLIFIED DESIGN OF EXPERIMENTAL CONTROL

The general control program is greatly complicated by the possibility of events with two Vees. In this general case much of the logic is devoted to handling the two-Vee possibility. To begin with, this description will be simplified to consider only one Vee as possible. The general logic changes to allow for multiple Vees will be discussed later.

The major problems that one has to face at the beginning of a particular experiment are "what do you want the operator to do in a particular order, what information do you wish to display to her, and where do you want her to be able to interact with the program?" The particular

control program which actually operates the procedure at the table is known locally as a TAWTA. This is a local acronym for task word table. The particular TAWTA designed for this experiment began by reading a scan card, initializing all the variables for the event, and displaying to the operator the frame number, description of the topology in terms of the number of prongs, decays, and Vee's, and a grid location inside the frame where the event was to be found. After acknowledging the instruction to measure fiducials, the operator proceeded to measure all the fiducials in all views. These were immediately reconstructed and tested for a satisfactory measurement. Upon completion of this step the operator was instructed to measure the vertex of the Vee. When that had been reconstructed in three-dimensional space and had passed the criteria against which it is tested, the instruction to the operator was to measure the tracks of the Vee.

This part of the control is conceptually flowcharted in Figure 1. In this figure and throughout this report X and Y stand for the digitizer readings defining the stage position of the measuring machine. In all of the descriptions and flowcharts we will ignore the operator's ability to interact with the control program via her button board. Although this is a necessary and important feature of the system, it complicates the description too much to be included.

Since this is a simplified conceptual flowchart (for example, no operator intervention in the order is allowed as shown), an effort has been made to show the logic in a consistent, workable and clear fashion even at the expense of exact correspondence between the flowchart and the program. For example, in Figure 1, if the vertex measurement is not

satisfactory, the program displays a message "REMS VERT" (remeasure vertex) and then transfers to a proceed on "ACK" (acknowledge from the operator) that is in a different chain of logic. In practice each display message of this type would have its own proceed and would then branch in after the position shown in the flowchart. But clearly this change does not affect the understanding of the design. Similarly, in the loop for fixing unsatisfactory fiducial measurements, whether View 1 is lighted before or after the "REMS FID" (remeasure fiducials) message is immaterial to understanding the design.

After acknowledging the tracks message, the operator then began to measure the negative track, measuring it in all three views, and then proceeded to measure the positive track in all three views. At the completion of each view measurement of one track, a circle fit to the track in that view was carried out, tests were made against the r.m.s. deviations of the point around the fitted curve, and only upon satisfactory completion of these tests did she go to the next view. At the end of the third view of the track, the prior two-view data were called back in and all three views were fitted in three-dimensional space. Again tests were made on the r.m.s. deviation of the points about the fitted curves. In addition to these tests, tests on the uncertainty in the reconstructed angles of the track were carried out. Completion of all of these tests allowed the operator to proceed. Failure at any test caused her to be given the instruction to immediately redo the step at which she had failed. Conceptually this part of the control program is outline in Figure 2.

Completing both tracks of the Vee automatically generated an attempt to carry out a one-constraint kinematic fit to the Vee. The hypotheses tried were  $\gamma \rightarrow e^+e^-$ ,  $K^0 \rightarrow \pi^+\pi^-$ ,  $\Lambda^0 \rightarrow p\pi^-$ ,  $\bar{\Lambda}^0 \rightarrow \bar{p}\pi^+$ . A one-constraint fit of the  $\gamma$  decay to  $e^+e^-$  automatically eliminated the event immediately. Successful one-constraint fits to either a  $K^0$ ,  $\Lambda^0$ , or  $\bar{\Lambda}^0$  hypothesis would cause the program to proceed. An attempted fit to one of these which produced a fit, but for a chi-squared value which was considered too large, would immediately generate an instruction to the operator to remeasure all tracks of the Vee before proceeding further. Then it would go through the procedure of a one-constraint kinematical fit again.

When a successful one-constraint fit had been achieved, the operator was instructed to proceed to measure the production vertex that had been associated with this Vee by the scanner. She measured that vertex in all three views. When it successfully reconstructed and passed tests, the information on the tracks of the Vee was immediately recalled, and the Vee fit was tried over again, now as a three-constraint fit involving the known directions of the Vee; that is, it should originate at the production vertex and travel to the decay vertex. If this three-constraint fit was successful, that is, it had a reasonable value of chi-squared, the operator then proceeded to measure all of the tracks at the production vertex. If, however, this three-constraint fit was not successful, the operator was then instructed to search for other possible production vertices that might be present in this frame. This part of the program is shown conceptually in Figure 3.

In this experiment, the search for additional possible production vertices is quite important because reactions such as  $\bar{p}p \rightarrow \Lambda^0 \Lambda^0$  involve no charge tracks originating from the production vertex; that is, they are 0-prong events. The scanning for 0-prong events has a very poor efficiency, and one eliminates this part of the problem in the overall experiment by being able to catch it at this point, forcing the operator to search through the frame looking for other vertices including the possibilities of a 0-prong vertex.

Once the operator had found the vertex from which the Vee originated, she then proceeded with the event, except she had to have control over the topological description of the event inside the computer. The reason for this can be seen from a simple example. Suppose that the scanner had recorded the event as a 2-prong 1-Vee; the Vee had reconstructed as a  $\Lambda$ , but would not fit from the originally associated 2-prong vertex and had now been found to be associated with a 0-prong event. One had to renumber all of the tracks. It was found to be easier to systematically allow the operator to comment on the topology. At the point where the operator was to begin measuring of all the tracks at the production vertex the computer asked a question on the topology. If she then hit "ENTER" with no buttons on her data board depressed, it assumed that the topology it had received from the scan card was correct and that all tracks were correctly numbered. She could use buttons on her data board to change the number of prongs, the number of decays, or the number of Vee's. Any change in this would automatically generate a renumbering of all vertex numbers and all track numbers associated with the event to correspond to the present description of the topology. For example, consider the misidentified

2-prong 1-Vee which was mentioned before and which should be measured as a 0-prong 1-Vee. In the original measurement the Vee tracks would have been tracks number 4 and 5. The ENTER of the description that this was a 0-prong 1-Vee would cause those tracks to be automatically renumbered to tracks 2 and 3.

#### ACTUAL CONTROL PROGRAM

Because the physics is actually more complicated than the simple 1-Vee topologies described above and flowcharted in Figure 3, the control program is significantly more complicated also. One of the features which was designed into the control program was an attempt to force the operators at the measuring machine to do a verification of the scan to make sure that other Vee's had not been missed with the event. This design feature was such that the operator always had to signal that the last Vee measured was the last one available for that event. Because of the possibility of multiple Vee's and the testing of these Vee's against different production vertices in the same frame, the control procedure became quite complicated. The actual flowchart of the program used is shown in Figure 4. This figure also shows that once an event was begun, an output tape record was written even if no Vee was successfully found in the event. This is a bookkeeping procedure to assure us that we knew the eventual disposition of every "Vee" found in the scan. So for rejected events, program information on the reason for the reject plus any operator comments associated with the rejection (entered by the operator through her button board) were written in the output record.

The first three boxes of this flowchart (through the box labeled "Measure Vee") correspond to Figures 1 and 2. The remainder of Figure 4 corresponds to an accurate description of the program flow which was shown in simplified form in Figure 3.

#### RESULTS OF THIS EXPERIMENTAL CONTROL

While this was a complicated control program to design and to implement, we feel that the features that we have attempted to design into this have been very successful. We achieved a significant increase in the throughput of the system. Compared to an earlier experiment of this group at 2.7 GeV/c,<sup>4,5</sup> where the data were measured off-line, our best estimate is that the measuring time per event decreased in this system by a factor of almost three. We also achieved a higher quality of data, particularly with the design features of forcing the operator to cross-check the film for any other associated Vee's, as well as the quality control on the momenta, the errors in the momenta, the angles, and the errors in the angles. We significantly decreased the bookkeeping problems that are associated with remeasuring. For example, in the off-line system an event that had been measured once and had a successful Vee-fit was remeasured if it did not seem to be associated with the production vertex with which it had been measured. After remeasuring, the same Vee was now in the sample twice; one had to be careful that for lifetime measurements, etc., that Vee was only allowed through the system once. In the present system all problems of association are cleared up before a record of the event is ever written, so the event gets into the record-keeping part of the system only once, and then is clearly associated with



one production vertex. Even without the increase in the throughput of the system, the reduced bookkeeping problems would have justified the effort that went into the design and implementation of the control procedure for this experiment.

#### ACKNOWLEDGMENTS

The authors express appreciation to Mr. W. Higby, Mr. A. Klein, and Mrs. R. Wagstaff, without whose work on other aspects of the system this control program could never have been implemented or tried.

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- Figure 2. Flowchart of the control for measuring the tracks of the Vee.
- Figure 3. Flowchart of the control for trying the kinematical fits and determining the production vertex.
- Figure 4. Flowchart of the control for the on-line measuring of Vee events in the  $\bar{p}p$  experiments.

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\*Throughout the figures the following abbreviations are used: "FIDS" for fiducials, "VERT" for vertex, "REMS" for remeasure, and "ACK" for acknowledge.

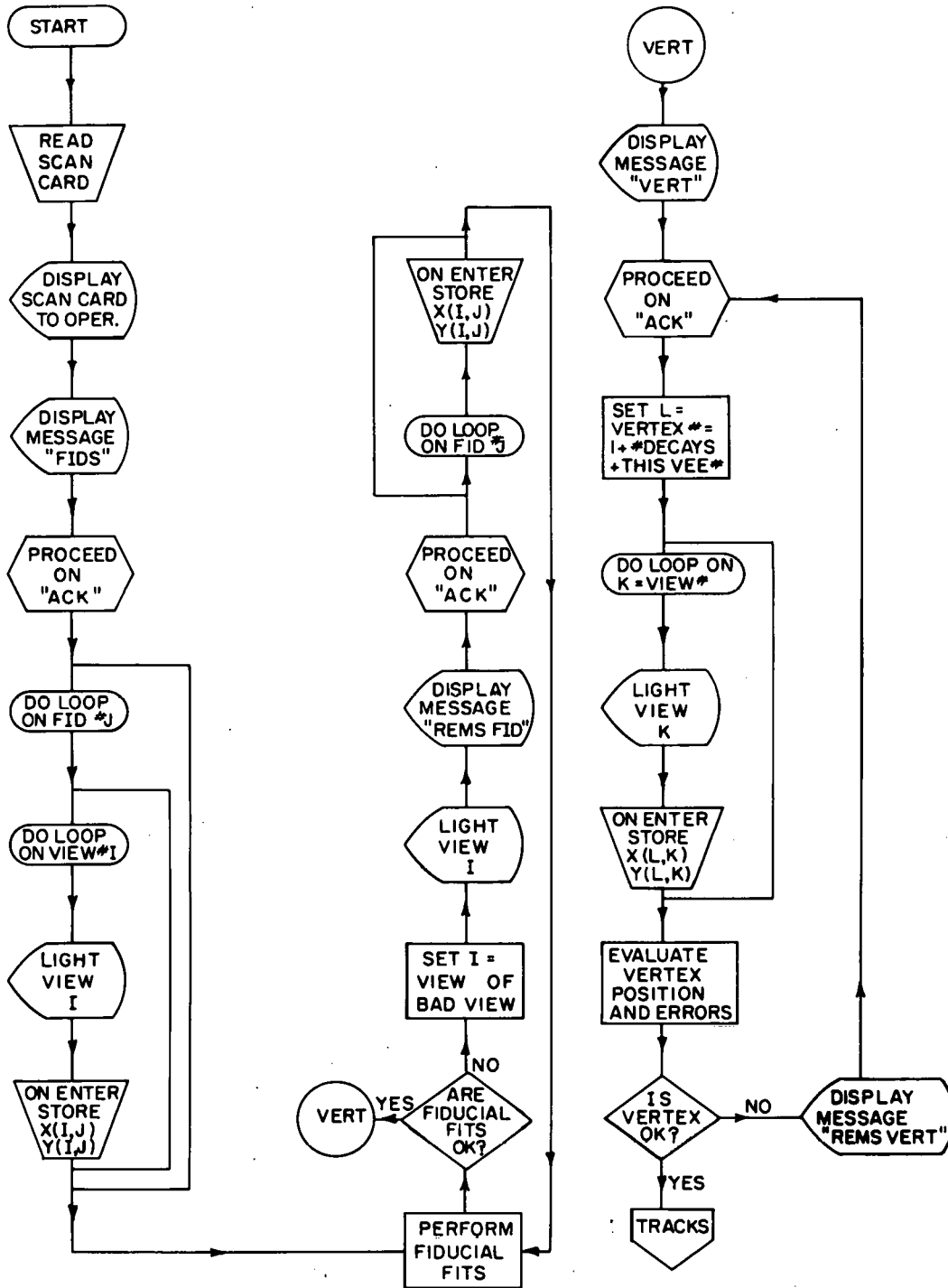


FIGURE 1. Flowchart showing the control for the initialization of an event and the measuring of the fiducials and the Vee vertex.

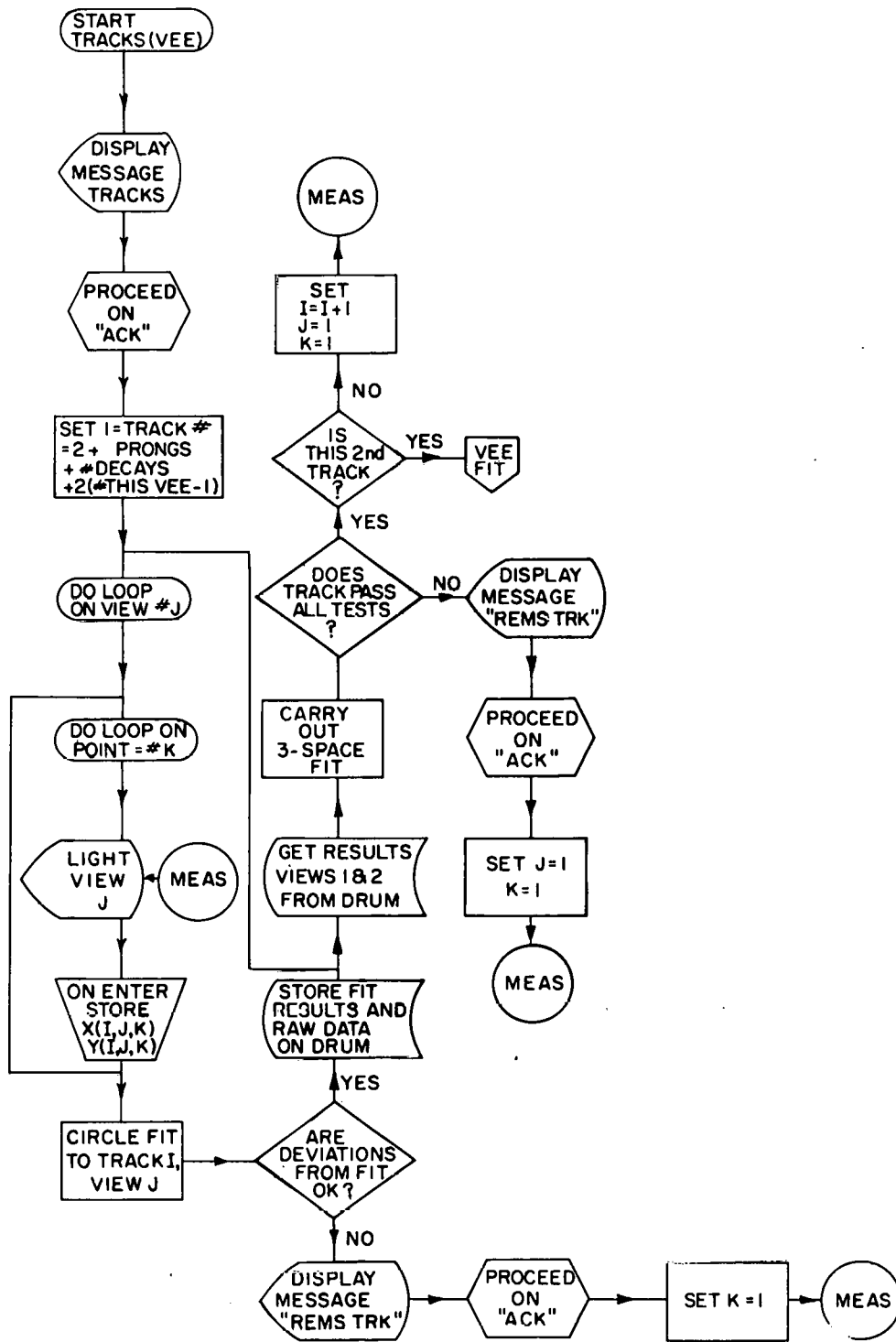


FIGURE 2. Flowchart of the control for measuring the tracks of the Vee.

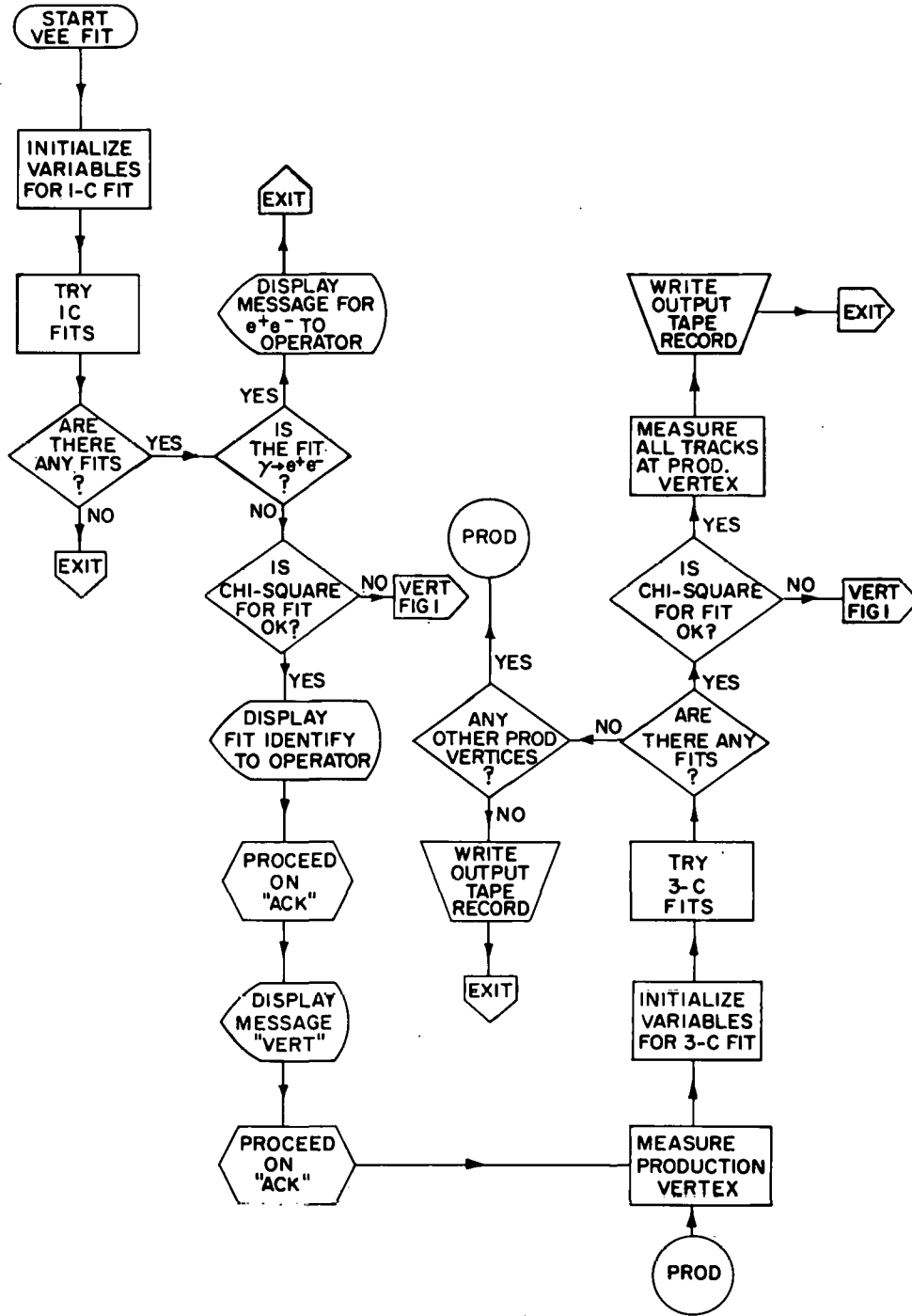


FIGURE 3. Flowchart of the control for trying the kinematical fits and determining the production vertex.

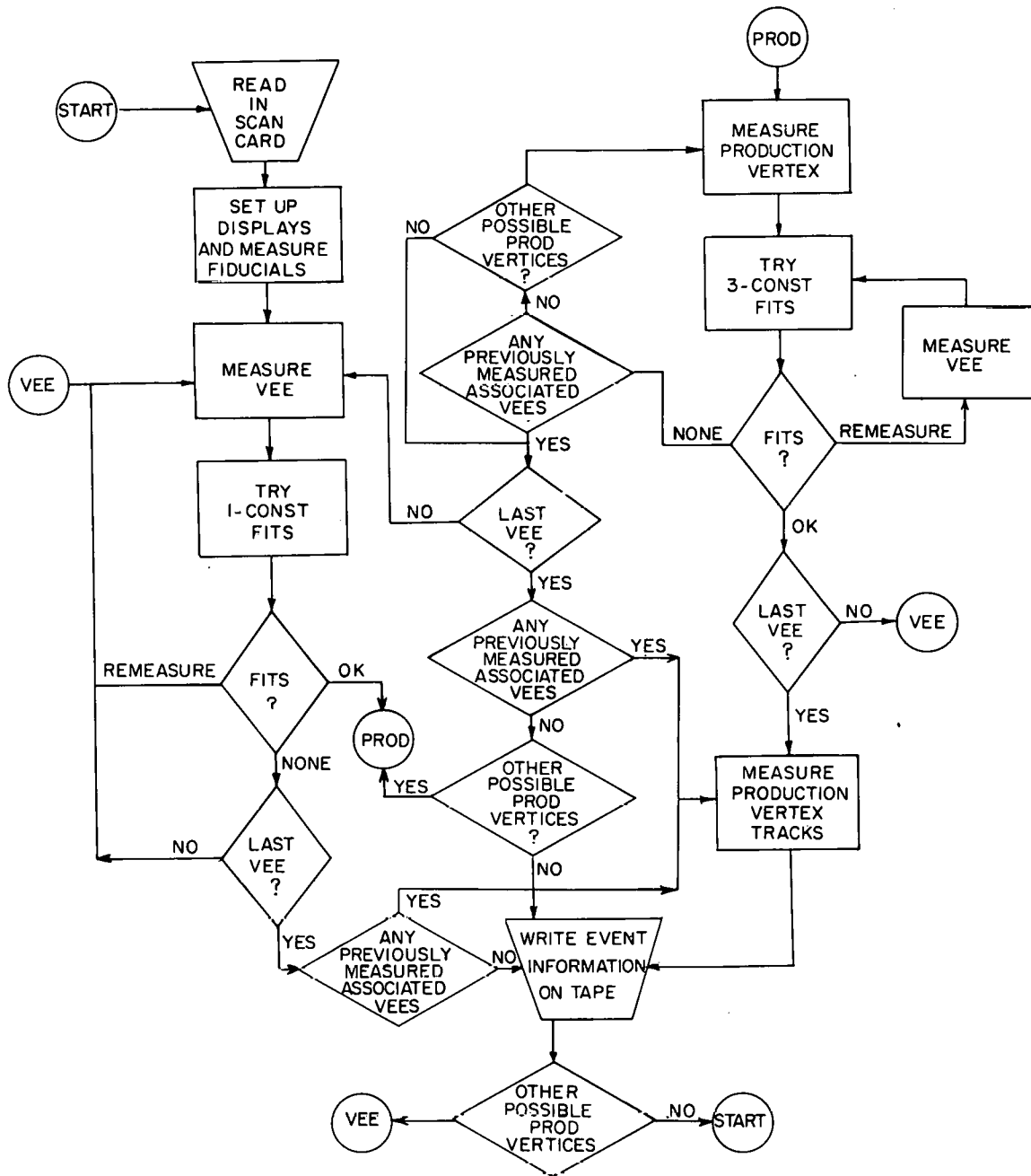


FIGURE 4. Flowchart of the control for the on-line measuring of Vee events in the  $\bar{p}p$  experiments.