Fermi National Accelerator Laboratory

FERMILAB-Pub-77/14-EXP
7200.311

(Submitted to Nucl. Instrum. Methods)

A SEMI-AUTOMATIC BUBBLE MATCHING METHOD FOR BUBBLE CHAMBER TRACKS

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January 1977

Operated by Universities Research Association Inc. under contract with the Energy Research and Development Administration

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January 1977

ABSTRACT

A method is described that enables one to bubble match semi-automatically tracks produced in liquid hydrogen bubble chambers of simple geometry by high energy hadron interactions. The method is especially suitable for high multiplicity (>6 prongs) final state events where conventional track matching programs have difficulty. Event match rates of ~ 30 events/hour have been achieved using this technique on SAMM, the semi-automatic CRT measuring machine at Fermilab.

I. INTRODUCTION

In order to reconstruct the trajectories of particles from an interaction in a bubble chamber, three stereo views are usually employed. Typical three view reconstruction programs, such as TVGP, expect the measurements of the tracks on all three views to be in the same order. If the tracks are ordered in each view according to their curvatures, a large majority of slow tracks reconstruct without difficulty. For high energy interactions, however, tracks occur in jets and curvature ordering alone fails to track match fast forward tracks in the jet, since these tracks have very small curvatures. In a small chamber such as the 30" chamber at Fermilab, even if one were to take all possible permutations of the tracks in three views and reconstruct the tracks using TVGP it is found that in a large percentage of the cases the track triplet with the least helix fit error is not the correct triplet. Evidently, bare bubble chamber curvature information is insufficient to resolve the ambiguities and additional data is required on the tracks. Two separate approaches have been used to obtain this additional information, the first being to use data from wire chambers placed downstream of the bubble chamber[1]. The second method is to compare the bubble patterns of the tracks and will be the subject of this paper.

II. SEMI-AUTOMATIC BUBBLE MATCHING

Track matching using bubble patterns consists of three stages:

(a) SAMM measurement of unmatched tracks.

(b) Prematching: A computer program matches all the obvious triplets and prepares a list of ambiguous triplets to be bubble matched.

(c) SAMM bubble matching: Using a split screen television small segments of track are displayed side by side from two different stereo views.

(a) SAMM measurement: SAMM is a semiautomatic cathode ray tube (CRT) bubble chamber measuring machine[2]. In the road guidance mode, track and vertex information is provided to it in the form of predigitisations prepared at the scan table. The three views are measured in three separate bays, each bay possessing its own CRT. This feature is crucial in bubble matching. The tracks are predigitised in a clockwise order at the scan table, no effort being wasted to match charges or curvatures. The resulting unmatched roads are passed through SAMM which measures the tracks in the same order.

(b) Prematching: A computer program (named STMCH) processes the SAMM output to prematch the events. Its functions are:

(1) To order the tracks in each view in increasing curvature. negative tracks being given negative curvatures. This results in charge ordering as well.

(2) To employ the technique of Stereosearch[3] to produce allowed doublets for views 1 and 2 and views 1 and 3. (The stereo axis for the 30" chamber for views 2 and 3 is along the beam direction and this provides little information for the forward jet.) The stereosearch formulae predict the angle change in a track between a given point on one view and the corresponding point on the second view as a function of dip of the track. Only the doublets passing the Stereosearch test are taken for further consideration.

(3) to combine the doublets into triplets and to output triplets in the order of increasing ambiguity. The doublet selection procedure gives an estimate of the dip of the doublet. Doublets from views 1 and 2 are combined with doublets from views 1 and 3 to produce a list of triplets. A triplet is formed only if the two dip estimates are compatible within errors. As an example. let track 5 on view 1 satisfy the stereosearch criterion with track 6 on view 2.(The track numbers are assigned according to curvature ordering.) .Let track 5 satisfy the Stereosearch criterion with track 7 on view 3. Then the doublets are 56 for views 1 and 2 and 57 for views 1 and 3. If the dip

estimates for 56 and 57 are compatible, a triplet 567 is formed. Most of the tracks going backward in the center of mass are uniquely assigned as triplets in this fashion and need not be matched further. Triplets are output in the order of increasing ambiguity by STMCH. The triplet list from STMCH is further reduced by using TVGP to reconstruct those track triplets present in the list. Triplets with helix fit error greater than 30 microns are deleted The remaining triplets are grouped into sets, each of which is a possible way of matching the whole event. If the sum of helix fit errors for a set is 4 microns less than its nearest rival, then the event is declared uniquely matched. The remaining events are passed on for bubble matching by SAMM.

(c) Bubble Matching by SAMM: The reduced triplet list from prematching is input into the SAMM program TVMCH that compares tracks between views 1 and 2 , and views 1 and 3. In order to do the comparison, a region of the view 1 track half way along the measured length is chosen and displayed on the Television screen. The SAMM slice scan was modified to simulate a TV raster for this purpose. By choosing various lengths of scans, different magnifications could be obtained. If the region chosen on view 1 proved to be unclear due to background tracks, the tracker ball was used to move along to a clearer region. Since the view 1 track radius is accurately known from the SAMM measurement. the program locks the tracker ball on to the track and moves the center of the slice scan along the track only. This prevents unnecessary wastage of time due to track derailment.

The view 2 track that is ambiguous with the view 1 track is displayed on the lower half of the picture. (see Figure 1.). The point at which the view 2 track is displayed is chosen as follows. The center bubble on the view 1 track is transformed to the view 2 co-ordinate system under the assumption that the track has no dip. This point. for simple optics, bears the same relation to the view 2 vertex that the view 1 bubble bears to the view 1 vertex . The intersection of the view 1-view 2 stereo-axis passing through the transformed point and the view 2 track is found and the view 2 slice scan center is positioned at the intersection. It was found that this simple computational algorithm was sufficient to get within half a mean gap length of the corresponding bubble on the view 2 image. Figure 1 is a photograph of the split screen images for a positive match.

If the track images do not match. the next match candidate on view 2 is tried. retaining the view 1 track until a match is found. This procedure is repeated for all ambiguous view 1 tracks. Each time a match is found on view 2. all triplets containing that view 2 track other than the match triplet are eliminated from further consideration.

If a track proves too difficult to match, the operator can suspend further consideration on it till after the other tracks are matched. Very often. by the time the others are matched, the difficult track becomes part of a unique triplet. When all view 1 tracks are matched with those on view 2, the procedure is repeated between views 1 and 3. In practice, by the time view 3 is to be matched, most of the triplets become unique and the number of comparisons between views 1 and 3 are much smaller than those between 1 and 2 Figure 2 shows a case when the tracks do not match.

To illustrate further, consider the triplet list 222,232,323,333 in which the tracks 2 and 3 are ambiguous with each other. The first triplet is 222, so view1 track 2 is compared with view 2 track 2. Suppose the two tracks do not match.. At this point all ambiguities are in principle resolved, since view 1 track 2 must match with view 2 track 3. i.e the second triplet 232 is correct. The program however allows you to test this. Since view 1 track 2 match with view 2 track 3, the third triplet 323 must be correct as well. The triplet 333 is deleted from the triplet list and 323 is declared unique. The program then moves on to the next ambiguous track.

Results: Table I gives the results obtained for events in which all the tracks were measured correctly by SAMM. The average time/event to bubble match is 2.07 minutes, giving an overall rate of 30 events/hour.

Conclusions:- We have devoloped a fast effective way of eliminating track matching ambiguities in bubble chamber events. The method works equally for any energy of interaction and for any multiplicities within the range of current accelerators. The method does not rely on any down stream information and therefore has a wider range of applicability than those that do. Finally, the bubble patterns now being visually matched may be capable of being matched automatically by SAMM, by comparing the gap lengths locally in the region of corresponding bubbles. The method described thus lends itself to further automation.

The authors would like to extend their thanks to the personnel of the Film Analysis Facility at Fermilab, particularly D.Bogert, for their help towards this work.

REFERENCES

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TABLE I

prong	no.of events	no. to bubble match	average no. of triplets	average time (mins.)
8	244	91	18.9	1.62
10	139	76	22.7	2.04
12	68	44	25.6	2.12
14	23	17	38.8	3.16
16	8	5	51.4	5.01
18	3	3	44.0	4.88
overall			23.8	2.07

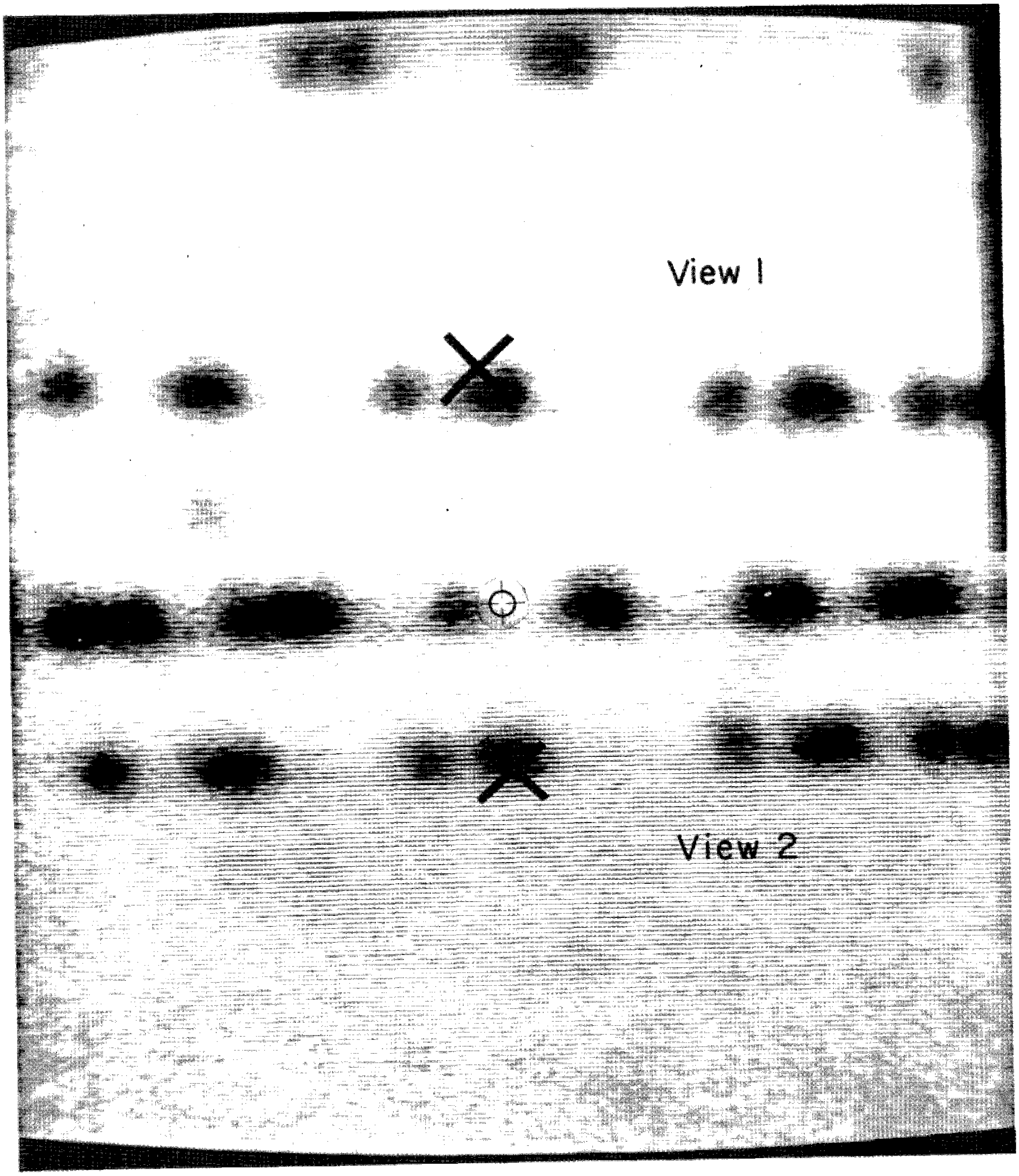

Figure I

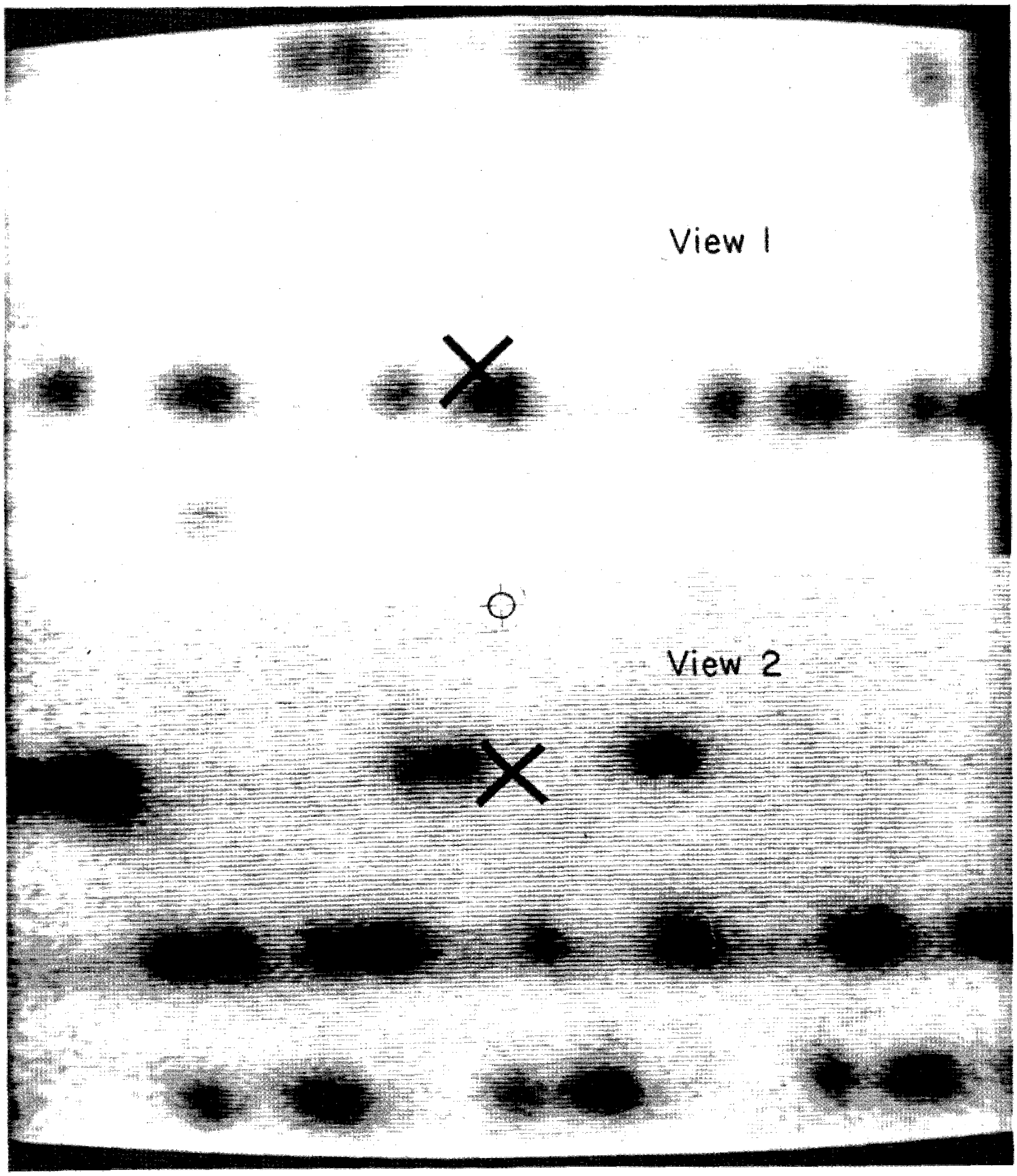

Figure 2