CERN/TC/PHYSICS 66-27
19.10.1966

SCANNING OF 10 GeV/c K^- PHOTOGRAPHS IN 2-METRE H.B.C.

1. Object

It is intended to measure on the photographs of 10 GeV/c K^- taken in the 2-metre CERN hydrogen bubble chamber, the following event types:

(a) Two and four prongs with no strange particles

(b) Zero, two and four-prong events with a single V^o

(c) Events with two or more strange particle decays (charged or neutral), for all prong multiplicities. This includes a search for Ω^- particles.

To obtain absolute cross-sections, we scan for, but do not measure all other event types.

2. General Scanning Conventions

We scan on views 1,3 and 4. The fiducial regions are determined on view 1. In the first scan we use view 1 (bacause it has better optics) and view 4 is used as a reference in the case of difficult events. In the rescan, we look at view 3 and then look at view 1 to determine the grid and ionization.

If a frame is not acceptable (flash does not work, bad development, less then three cameras) comments may be made (with an 'R' to show event is rejected and a comment to explain why), but they are NOT in general necessary and it is simpler not to make them. To make the writing on the scan sheet more easily distinguishable, please write with a red pen. If the writing of an event is not clear, because of score outs etc., please score out entire line and start on a fresh line.

3. Angular Acceptance of Beam Track

The incident beam track is accepted at the scanning table if it is within about one degree of the angle of the other beam track. To be precise, we require a beam track to have a displacement from the general beam direction of less than 5 mm over a 30 cm length.

4. Width of Fiducial Region

The width of the fiducial regions is defined by lines joining the inner fiducial marks as shown in the Figure. This is on view one.

PS/5677/jc

5. Length of Fiducial Regions

As shown in the Figure, the chamber is divided into four regions. Firstly there is a small region near the beam entry which is used only to determine the direction of the beam track and hence we do NOT scan in this region. Secondly there is a long fiducial region in which we scan for all events types (we only measure types (a), (b) and (c) of paragraph (1), but record the other event types - 6, 8 prongs etc. - for determination of cross-sections from counter experiments). Thirdly there is a region in which we scan only for events with 2 or more strange particles (type (c) of paragraph (1)). Fourthly there is a small region at the end of the chamber which we do not scan for interactions, but only use to reject V^o decays whose outgoing tracks would be too short to give useful measurements, that is if the apex of a V^o lies in this fourth region the V^o should not be considered in the topology column, but it should be noted in the comments column as "VO TOO SHORT". Thus a 2 prong event with a V^o in the fourth region should be described as a 2 prong and measured as such. The information "VO TOO SHORT" will be printed on the Event List and may be used to check the choice of the correct GRIND hypothesis. This is necessary because we correct for the probability of decay of V^o's outside of the illuminated region of the chamber.

6. Acceptance of Neutral and Charged V's

To be accepted for measurement, the sum of the lengths of the prongs of V^o should be greater than 15 cm (in chamber space) on at least one view. For a charged V, the sum of the length of the charged V and of its secondary must be greater than 15 cm in at least one view. If a V^o or $V^{\pm}$ is shorter than required, the event should be recorded in the "Comments" column (this is to help the comparison of scans and the checking of GRIND hypothesis). Also if the V^o apex occurs downstream from the last pair of fiducial marks, it should be ignored (see drawing). This is due to the fact that the most difficult events are high energy V^o's with short prongs and such events tend to occur only at the end of the chamber. It should be noted that V^o's can come from a decay point (Ξ^- or Ω^-) - such a V^o should be written down in the scan sheet as a normal V^o - GRIND will try to fit the V^o to the apex and to the decay point. If a V^o can come from two apexes, then one should write SV (for same V^o) in the "Comments" column for both events.

7. Electron Pairs

If an electron pair comes from a gamma ray produced in an interaction, it is important to note it in the scanning list (although it is not measured, it is used later to distinguish between events with a missing neutron or a missing π^o).

To distinguish between electron pairs and K^o or Λ^o decay we use three pieces of information,

1) The angle between the two prongs of an electron pair is always zero. The angle between the two prongs of a K^o or Λ^o is usually not zero, but can be zero (a) on one camera only because of chance, (b) if the V^o disintegration is along the line of flight of the V^o, that is, there is one high energy prong and one low energy prong.

2) An electron has always minimum bubble density (apart from question of dip). A pion of less than 100 MeV/c has at least 3 times minimum bubble density. Hence, if a track has a curvature of less than 20 cm radius (100 MeV/c) it can be decided if it is a pion or an electron.

3) If a V^o has zero decay angle, then if the prong with lower momentum has more than 100 MeV/c, then the other prong cannot have a momentum less than 1.5 GeV/c. For example, one cannot have momenta of 100 MeV/c and 700 MeV/c for the prongs, or 200 MeV/c and 400 MeV/c, etc. and still have zero angle between the prongs of the V^o. No such restriction applies to electron pairs.

Hence, if one finds a V^o with zero angle between the prongs,

1) Check on a second view that the angle is also zero.
2) If the lower momentum prong has a radius of curvature of 20 cm or less, look at bubble density - if it is more than 3 times it is a V^o and the event should be measured - if it is about minimum then it is an electron pair, it should <u>not</u> be measured but should be recorded 'G' for gamma.
3) If both tracks have a curvature of less than 200 cm, then the event is an electron pair.
4) If one track has a curvature greater than 200 cm, it may be a V^o and should be measured (we take 200 cm radius ≡ 1.0 GeV/c instead of 1.5 GeV/c to correct for dip etc.). One should write on the scan sheet the topology number assuming it is a V^o, and in the "Comments" column one should write 'VO/G'. See Example No. 14.

8. Dalitz Pairs

If a gamma is converted to an electron pair at the interaction point these electrons are called a Dalitz pair. These will cause the number of prongs to be two more than desired. Hence if one of the prongs can be identified as electron, then it should be assumed that there exists a second electron track even though it cannot be identified. The event should be recorded as the number of non-electron prongs and 'D' should be written in the "Comments" column. Thus a visual 4-prong would be recorded as "2 + Dalitz Pair". It may be noted that the angle between the Dalitz pair is in general not zero, though small angles have the highest probability. If only one electron can be identified, the other being too fast, the event should be rejected.

9. Odd Number of Prongs

There are several possible causes of events with an odd number of prongs, one of which is that the proton has a momentum of less than 50 MeV/c and so has too short a range to be visible. Hence these events should be recorded if they occur in the fiducial Region so that an upper limit may be obtained to their frequency of occurence.

9a. Tau Decays

The K^- of the beam may sometimes decay into three charged pions ($\pi^-\pi^-\pi^+$). Hence, three-prong events should be noted and "T-decay" written in the "Comments" column. These τ-decays will have two negative tracks and one positive (which cannot be a proton).

9b. One-prong Events

In general, one-prong events will be K^- decays in flight. As the bias due to undetectable small angles decays is large, there is no point in recording them, an effort, however, must be made by looking at the kink-point to verify that there is no short recoil, hence that the event is not a small angle elastic scatter.

10. Identification and Labelling of Proton Tracks

If a positive track stops in the chamber and does not emit a decay particle, then it must be a proton. Such a track is given a special label which is interpreted in the program as a proton.

- If a track is stopping and curved, the end point is called F, G or H.
- " " " " " " straight, the end point is called W or H.
- If a secondary scatters and gives a zero range proton, the point is called Z.

Further mass assignments by labelling may often be performed successfully, but are liable to be sufficiently frequently in error, that they should not be used for the present.

11. Visual Ionisation Estimation

An attempt is made for each event which will be measured to estimate the density of bubbles on the tracks. This is an overall estimate and contains mass, momentum, dip angle and choice of camera. Here we choose camera ONE. Corrections for dip and choice of camera will be made by the program. Hence we write down the bubble density that we see.

We only write down ionisation estimates for those tracks where it will be useful. This means we only write down ionisation estimates for the tracks having the interaction vertex of two and four prong events whether or not there are V^{o+-}. (The reasoning is as follows: when there are $\geqslant 2\,V^{o+-}$, we will have to look later at the event plus GRIND output on the scanning table anyway to decide the hypothesis. Since charged V's are only taken if there are at least 2 V's, we do not need to note the ionisation of the decay track. For V^o's, kinematic fitting normally allows one to decide whether the V^o is a Λ^o or a K^o, but when the V^o gives a fit to both Λ^o and K^o, then the tracks from the V^o are of such high momentum that it will be necessary to study the event plus GRIND output later. Also secondary scatters are not written down since they give 3 or 4 constraint fits in GRIND).

For each track, we use an "ionisation number" for the ionisation estimate defined as below.

Visual estimate times minimum	Ionisation number
$\approx$ 1 (minimum)	1
$\approx$ 1.5	5
$\approx$ 2	2
$\approx$ 3	3
$\geqslant$ 4	4
certain pion e.g. $\pi - \mu - \varepsilon$ decay	6
NOT SURE OR FORGOTTEN	0

Beam tracks should be taken as minimum. An estimate of two times minimum may be obtained by looking at two overlapping beam tracks. In estimating ionisation, it is better to look for the frequency of long gaps (rather than trying to count individually bubbles).

The order of writing down the ionisation is important. The ordering is done clockwise on camera one, that is, is done in the order in which one would measure on I.E.P.

In estimating ionisation one cannot be sure, but one makes one's best estimate. The category "not sure", number zero, should be very very rarely used.

12. Secondary Interactions

If a track makes a secondary interaction then one must decide whether the track length before this interaction is long enough to allow a good measurement - this we decide by measuring whether or not the sagitta is greater than 2 mm. The measurement may be made using the two parallel lines spaced 2 mm apart. If the sagitta is greater than 2 mm, we ignore the secondary interaction. The IEP operator is informed by writing the name of the track and the letter 'C' for cut e.g. 'A3C' in the "on-line Comments" column.

If the sagitta is less than 2 mm, then some information can sometimes be gained by measuring the secondary interaction, but it has been found that, in general, only information from two-prong secondaries which are elastic scatters is useful. Hence if the secondary is a two-prong it is measured and one writes the track name and the letter 'S' for the interaction point SS in the "on-line Comments" column e.g. 'A3S' . If the secondary interaction is a two prong event which is clearly inelastic (both tracks on same side), it should not be measured. If the secondary interaction is anything other than a two-prong, (and the sagitta 2 mm) then the event should be rejected by writing 'R' in the reject column and 'Sec.Int.' in the "Comments" column.

13. Rejection of Events

Since we scan twice, it is important for the comparison of scans that we write that an event is rejected and explain why. Thus if a beam track is very obviously non-beam, we write nothing, but if it is only just non-beam from curvature or angle, then it is better to write the frame number and topology and to write 'R' in the reject column and "non-beam" in the "Comments" column.

14. Topology

The topology of an event is defined as a 3 figure number, the first figure is the number of prongs (tracks), the second the number of charged V's and the third is the number of V^0's to be measured. For example, a 2-prong + V^0 + V^+ is 211, a 4-prong + V^0/ep is 401.

15. Grid

To assist the on-line IEP's, a grid, based mainly on the fiducial marks, is marked on the scanning table. The position of the apex of the interaction on the grid is written on the scanning sheet. It need not be too exact - a small error (one place) will not be controlled in the comparison of scans.

16. On-Line Comments

These are essentially instructions to the IEP operator and each instruction consists of 3 symbols - 2 to define the track and one for the instructions. These are F or G; W or X; and Z for curved, straight and zero range proton tracks, S, T or U for secondary two prong to be measured, C for a track to be cut - because of a secondary interaction, $\pi - \mu - e$ decay or sometimes for energy loss, though in general the IEP operators are asked to cut the track if the sagitta is greater than 2 cm. Thus instructions might be 'A2F' 'A4C' 'A3S' 'S2Z' 'A2Q'. The label for a charged V decay is P, Q or R.

17. $V^{\pm}$, V^{o}

In this column, divided into blocks of 4 columns, one writes the charge of V and then the approximate distance in cm of the V from the apex, e.g. for V^{+} V^{o} V^{-} event one might write +5 b b, 30 b b, -15 b (where 'b' stands for blank column).

18. Charged V or Scatter without Recoil

Quite often a secondary makes an elastic scatter in which the recoil proton has a momentum of less than 50 MeV/c so that the proton range is less than one bubble diameter. Such an event is often called a charged V. This happens particularly often with low energy pion tracks when one can sometimes say from the bubble density that the track is a pion and not a K or Σ. However, if the transverse momentum of decay particle is large, (appreciably greater than 50 MeV/c) or if the change in bubble density is noticeable, then the event should be considered as a charged V. If however it could be a scatter with a zero range proton, then it should be so measured - for example, one might write in the "On-line comments" column 'A3S S3Z'.

19. Neutral Stars

If a neutral star, 3-prong, 5-prong etc., which might come from an interaction is noticed, it should be recorded in the "Comments" column as N3, N5 etc.

20. Zero Prong and Elastic Scatters

From the results of the first 10 GeV/c K^{-} experiment, there is a suspicion that the scanning efficiency for zero prong and for small angle elastic scatters. We do not scan directly for zero prong events - we scan for zero prong + V^{o} events and then calculate the number of zero prong events with no V^{o} observed. Hence the best way to scan, is to look for V^{o} events and then, having found one, to try and see if there is a zero prong from which it could have come (note there exists a background of zero prong events which are not associated with an interaction point in the visible region of the chamber - they may, for instance, come from an interaction in the steel wall of the bubble chamber). To detect small angle elastic scatters, it is necessary to look along the beam tracks at a glancing angle to the table.

21. Prints - Sketches

If an event is exceptionally difficult (e.g. Dalitz Pairs) one can ask for a print to be made to help the IEP operator, and one writes 'P' in the "Comments" column. As the making of prints requires transferring the film to another scanning table, it is often simpler to make a sketch in the book beside the scanning table and these sketches will then be given to the IEP operator.

22. Labels

Primary interaction point	A, B, C, D, E	
Beam particle (second label)	1	
Decay vertex of a V^o	M, N, O,	L
Decay vertex of a $V^{\pm}$	P, Q, R,	I
Stopping point	F, G, H,	W
Secondary interaction point	S, T, U,	
Zero length track	Z	

23. Deciding between V^o and Gamma

Angle between Tracks		Momentum of Tracks		Ion^n of Lower Mom^m Track	Decision
View 1	View 4	Lower	Higher		
> 0	> 0	-	-	-	V^o
0	> 0	-	-	-	V^o
> 0	0	-	-	-	V^o
0	0	< 100 MeV/c	-	> 3	V^o
0	0	< 100 MeV/c	-	≈ 1	G
0	0	> 100 MeV/c	< 1 GeV/c	-	G
0	0	> 100 MeV/c	> 1 GeV/c	-	V^o/G

24. General Procedure

We scan views 1 and 4 and a scan card is punched repeating the information on the scanning sheet - since the punching is often done by the punching pool who are not familiar with scanning, it is important that the writing sheet be clear and unambiguous e.g. V^o must be written VO. A second scan on views 1 and 3 is made and a second scan card is punched. From these two sets of scan cards, three lists are prepared.

(1) Comparison of Scans

The computer compares the first and second scans and if for an event there is a significant difference, the two cards are pointed out on the "Comparison List". If the event has been found on one scan and not on the other, this is also pointed out. The film is then put on the scanning table for a third time and those events where there was a significant difference are then checked and a decision as to the correct solution is made.

At the same time as the computer produces the comparison list, it also produces a combined scan card for each event (where there is a significant difference, two combined scan cards are produced). After the comparison of scans has been made, a correct combined scan card is produced and the two provisional cards are thrown away.

For an event to be looked at in the Comparison of Scans, it must be significantly different in the two scans. For ionisation estimate, one requires a difference of two steps, e.g. 2 is different from 1, 3 is different from 1.5, 4 is different from 2 but 1.5 is not different from 1, 2 is not different from 1.5 etc. But the combination of 1211 is different from 1121 where two tracks have probably been interchanged, perhaps because view 3 or 4 were used instead of view 1 in the re-scan. In the grid positions, one allows a tolerance of one unit, e.g. B3 is not different from A3, C2 is not different from B2, but B2 is different from B4, C3 is different from E3 and B3 is different from C4.

This combined scan card differs from the normal scan card in three respects (a) it indicates whether the event was found in the first scan only, the second scan only or both, (b) the initials of the person making each scan is given (probably using a code), (c) the ionisation estimate is a combined number.

First Scan	Second Scan	Combined	GRIND
1121	1121	11211121	1,1,2,1
11	15	1115	1,1.25
13	14	1314	1,3.5
1321	1455	13211455	1,3.5,1.75,1.25

The ionisation estimates are combined and the average value is given to GRIND (as shown in 4th column above) where it is used as a guide to the checking of hypotheses.

(2) Measurement List

From the combined scan cards, a measurement list is made out where the necessary information is given to the IEP operator. The IEP operator is also asked to type out the combined ionisation estimate (reduced to a 4 digit number) - this is the means by which the ionisation estimate enters GRIND.

(3) Event List

From the combined scan cards, a list of the events to be measured is made. This list contains the "on-line comments", "Comments", ionisation and scanning efficiency information. It is used in two ways. Firstly to control the number of IEP measurements. Secondly to help in the deciding on the correct GRIND hypothesis and it is also used to record the decision. This decision is then used to select the correct SLICE card.

D.R.O. Morrison