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SCANNING OF 8 GeV/c π^+

1. Object

To measure in the photographs of 8 GeV/c positive pions in the 2-metre hydrogen bubble chamber, the following event types :-

(a) four-prong events with no strange particles

(b) two-prong events with at least one V^o, (i.e. types 201, 211, 202)

We do however, scan for, but not measure, other event types - see below.

2. General Scanning Conventions

We scan on views 1 and 4. The fiducial regions are determined on view 1. In the first scan we use view 1 (because it has the better optics) and view 4 is used as a reference in the case of difficult events. In the rescan, we look at view 4 and use view 1 for checking - e.g. fiducial region.

If a frame is not acceptable (flash does not work, bad development, less than three cameras) comments may be made (with an 'R' to show event is rejected), but they are NOT in general necessary. 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, due to 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

On view 1, a width of 34 cm on the CERN 2-metre scanning tables is accepted, 9.5cm to the right of the first cross on the entry side and 24.5 cm to the left of it. This 34 cm corresponds to about 27 cm in chamber space - See attached drawing.

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5. Length of Fiducial Regions

For simplicity we define only two regions as shown in drawing. In region 1, all events are recorded. In region 2, only 2-prong + V^o events are recorded. If the region is not written down in the scanning sheet it is assumed to be region 1. If the event lies in region 2, then this must be noted on the scan sheet. Although all events are recorded in region 1, only 4-prong and 2-prong + V^o events will be measured, the others being required for cross section measurements or for some future experiment.

The dividing line between region 1 and region 2 is the central line of the image. As there is no convenient fiducial mark there, we have chosen the shadow of a thermocouple on the glass window which appears as a circle heavier on the downstream side and this side is taken as the dividing line.

6. Acceptance of Neutral V's

It is required in general, that the sum of the lengths of the two prongs of the V^o should be greater than 15 cm. In addition, 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.

7. Electron Pairs

If an electron pair comes from a gamma ray from 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 decays, 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 due to 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 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 not 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.13.

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. If the electron of the Dalitz pair is positive then the other electron must be the negative track in a 4-prong event. If the electron is negative, then there are 3 positive tracks and it may be best to reject the event.

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 region 1 so that an upper limit may be obtained to their frequency of occurence.

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, H or I
- " " " " " " straight, the end point is called W or X.
- 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 to 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.

Following the emulsion system of calling tracks white, grey or black, we have also 3 classes and in addition a fourth - "don't know".

The division between white and grey has been chosen to be two times minimum since this is easy to identify as it can be standardised by looking at two overlapping beam tracks. The GRIND program will use the ionisation information, in a generous manner, to try and decide which hypotheses are possible.

Visual Estimate times minimum	Label	Program favours .....x Min^m.
<2.0	1	1.0 to P
= 2.0 - 4.0	2	Q to R
>4.0	3	Greater than S
Not sure or forgotten	0	All hypotheses equally favoured

The choice of P, Q, R and S will be made later when we have more experience, but might for instance be P = 2.0, Q = 1.5, R = 5.0, S = 3.0. The category "not sure" should be avoided as much as possible.

The order of writing down the ionisation number is important. The ordering is done clockwise on camera one, and is done in the order in which one would measure on IEP. Thus scatters on prongs are recorded as they occur. If there are two V^o's, they should be written down in the order of their x-coordinate, that is the upstream one before the downstream one. The ionisation of the beam track is not recorded.

In addition to writing down the ionisation for the events we intend to measure now (4-prong, 2-prong V^o) we should also write down the ionisation for 2-prong events since we may measure them in the future.

12. Secondary Interactions

If a track makes a secondary interaction then one must decide whether the track is long enough before this interaction 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 then 2 mm, then some information can sometimes be gained by measuring the secondary interaction, but it has been found that, in general, information from two-prong secondaries only is useful. Hence if the secondary is a two-prong it is measured and one writes the track name and the letter 'K' for the interaction point KK in the "on-line Comments" column e.g. 'A3K'. 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^o's to be measured. For example, a 2-prong + V^o + $V^{\pm}$ is 211, a 4-prong + V^o/ep is 401. Thus we will expect to measure only 400, 401, 402, 201, 211, 202, 212 and 203 event types. Here we measure 401 and 402 events only when the V^o is V^o/ep.

15. Apex

In the Apex column, R = Region, L = Label of apex. R is taken to be 1, unless the event lies in region 2. The label is taken to be A unless there are 2 or more events in which case we write B or C or D etc. For example, if there is a 6-prong and then a 4-prong, the 4-prong should be called B.

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, K or L for secondary two prong to be measured, C for a track to be cut - due to 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''A3K''K2Z''A2Q'

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 'A3K K3Z'

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. 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.

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

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