Identification of Positive Hadrons

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Abstract

In this short document, the procedure for identifying positively charged hadrons is described. We take as an example the E1-F dataset.

1 Introduction

Particle identification is the process of combining detector level information, as well as higher level information from the results of reconstruction (charge, momentum, and time of flight) to catagorize each track as a known particle. These particles can then be corrected and used in physics analyses.

In this note, the authors describe their methodology used to identify positively charged tracks as one of three common species (pion, kaon, proton). Cuts are applied to remove tracks in geometrically poorly understood regions of the detector, followed by a maximum likelihood ratio based identifiation using time-of-flight information. An additional cut is used for our analyses which restricts the vertex of the positive track to be close to that of the electron. Such a cut should be removed to study processes with detached vertex positions (arising from the decay of other produced hadrons).

The methodology described in this note is based on the discussion provided by (reference the BESIII paper on likelihood based particle identification).

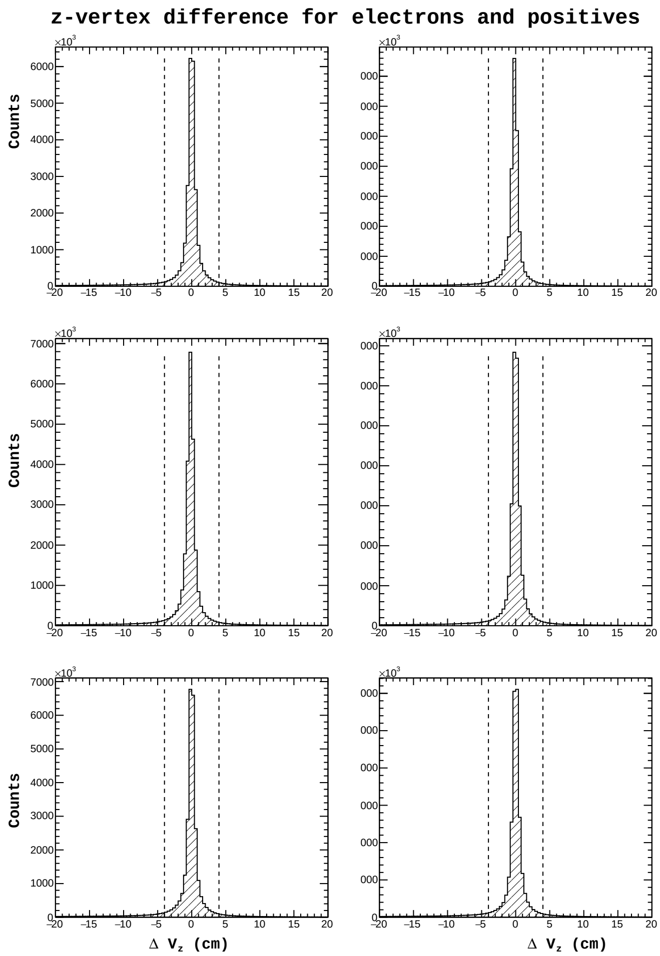

Figure 1: Shown above: The difference between the z-vertex position between detected electrons and positive tracks.

2 Preliminary Cuts

All positive tracks are subject to two constraints before being classified by the likelihood method. First, events which pass close to the torus coils are removed by cutting on the hit positias reported by the region 1 drift chambers. Such events are often poorly reconstructed or have poorly understood acceptances and are regarded from analyses. Finally, the distance between the electron vertex and the positive track vertex is computed ($\delta v_z = v_z^e - v_z^+$). This distance is constrained to be within the length of the target (5 cm). As stated above, if the analyst desires to look at events where the pion, kaon, or proton is produced as the result of a decaying hadron, this cut should be removed.

- drift chamber fiducial
- vertex difference

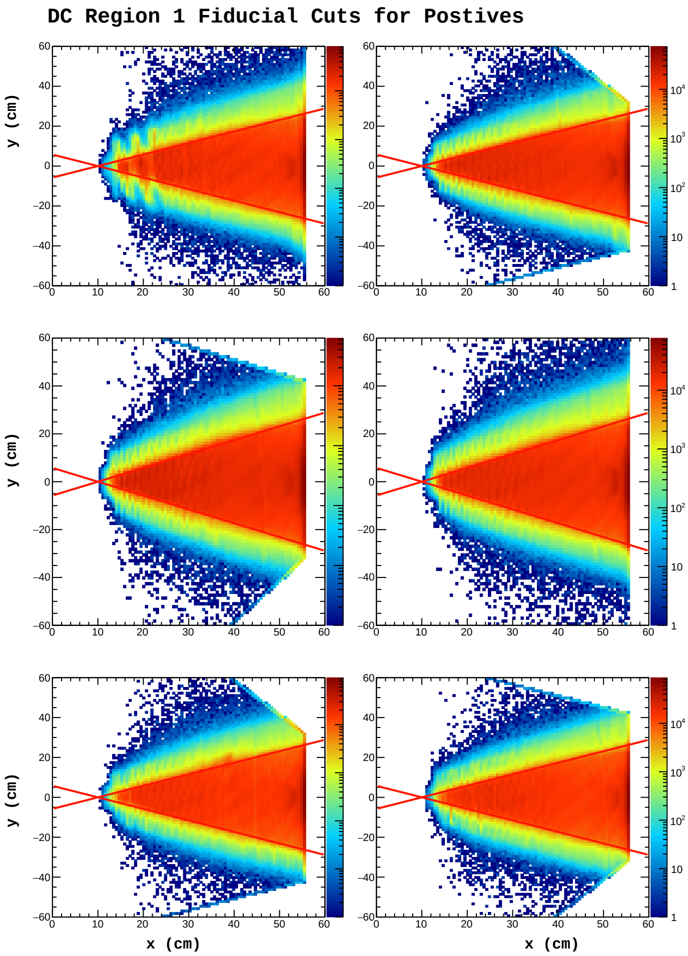

Figure 2: Shown above: Positive track hits on the region 1 drift chamber, events falling between the red lines are kept for analysis.

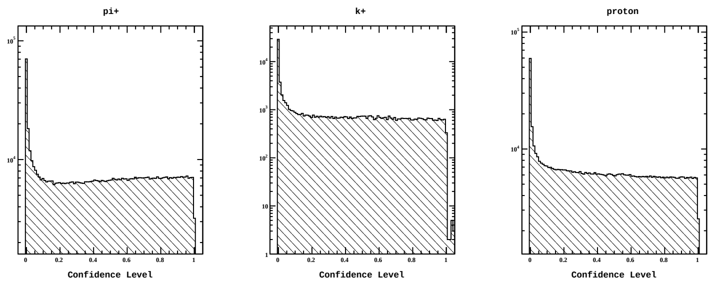

Figure 3: Shown above:

3 Likelihood Method

In this section timing cuts for discriminating between pion, kaon, and proton tracks are described. Each positive track is assigned an identity based on the largest likelihood ratio of the three candidates. There may be times when although a track is categorized as one particle species, it is very unlikely (all likelihood values were small). The analyst can use a consistency test to discard such events. The calculation of significance levels for this purpose will also be discussed.

3.1 Likelihood Functions

For each particle species considered, a normalized probability density function $P(x; p, h)$ is constructed for each input into the likelihood analysis. Here, x corresponds to the feature being used to catagorize different particles (x could be delta-beta, time of flight, or energy deposition etc.), p is the particle momentum, and h is the hadron being hypothesized (eg: in our case the possible values for h are pion, kaon, proton). If one uses a set of N variables $x = (x_1, x_2, ..., x_N)$, the likelihood for a hypothesis h can be defined as shown below.

$$\mathcal{L}_h = \prod_{N}^{i=1} P_i(x_i; p, h) \tag{1}$$

In many cases, it is possible to use a Gaussian PDF for the variable x_i, and fixed values of p, h.

$$P(x_i; p, h) = \frac{1}{\sqrt{2\pi}\sigma_i(p,h)} exp\left\{ -\frac{1}{2}\left(\frac{x_i - \mu_i(p,h)}{\sigma_i(p,h)}\right)^2 \right\} \tag{2}$$

The identity is assigned by choosing the particle hypothesis h which maximizes the likelihood ratio. Using this method, every positive track is assigned a particle identification. However, at times the likelihood value is quite small when compared with the maximum likelihood for that species. This is the case for positrons which are classified by this method as positive pions, because they are the closest particle for which a hypothesis has been provided. To avoid these situations, the significance level of each track is calculated and a cut is placed on the minumum significance. The effect of this cut on the analysis can be easily measured as significance level is bound between 0 and 1.

$$S = 1 - \int_{\mu - x_{obs}}^{\mu - x_{obs}} P(x_i; p, h) dx_i \tag{3}$$

This quantity represents the probability to observe a value of x as far from the mean as x_{obs}. Significance levels of 0 then correspond to tracks which are poorly identified as the class h. In the case that the PDF is Gaussian, the standard 1, 2, and 3 sigma cuts can be understood simply as significance levels of approximately 0.32 = 1-0.68, 0.05 = 1-0.95, and 0.01 = 1-0.99.

$$\frac{\mathcal{L}_h}{\mathcal{L}_{\pi^+} + \mathcal{L}_{K^+} + \mathcal{L}_p} \tag{4}$$

- theory

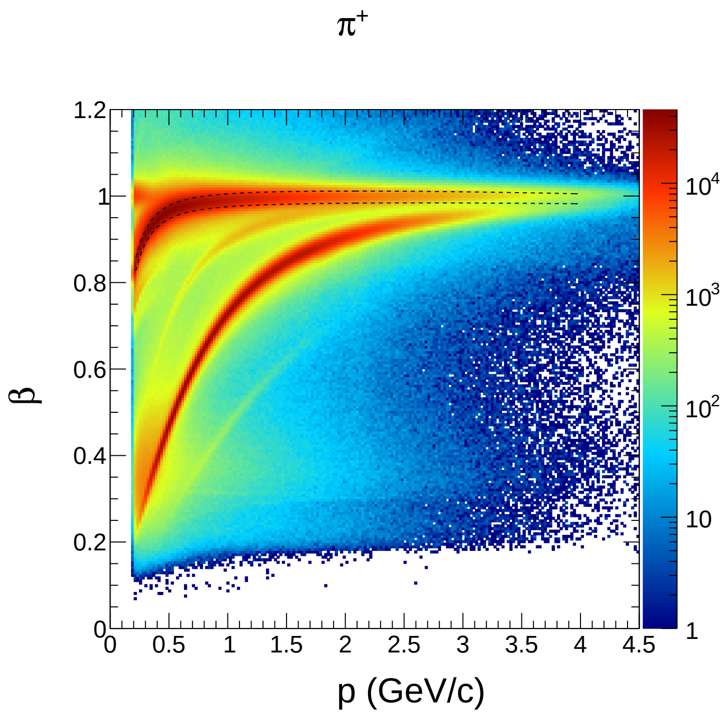

Figure 4: Shown above:

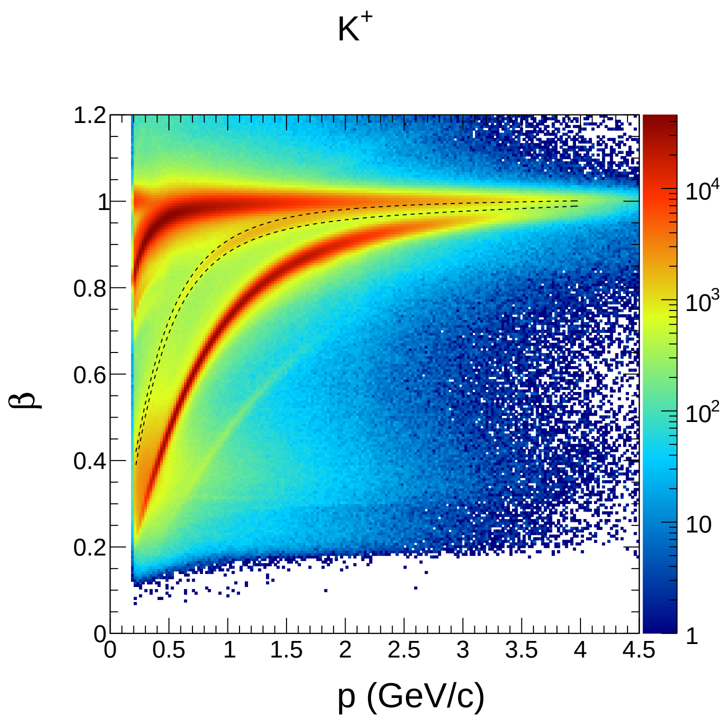

Figure 5: Shown above:

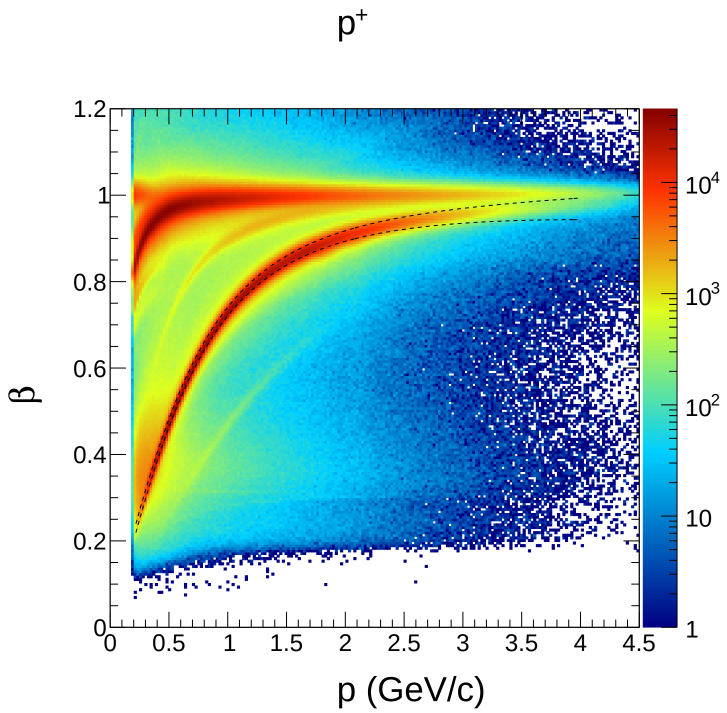

Figure 6: Shown above:

- resolution fits
- confidence level plots