CB-Note 201

Version 1

Hadronic Splitoffs

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1 Introduction

There is the problem in the analysis of charged events that the charged particles pass through the crystal calorimeter. The primary shower signal (PED) associated with this passage, is flagged by GTRACK, and not considered a photon candidate (see GTRACK writeup in CB-Memo 118). **All such PEDs are excluded from the results presented in this memo.** However, it is found that a single charged track can give more than one PED, and these extra PEDs mean that the observed number of PEDs is not equal to the number of detected photons in an event.

In this memo I give the frequency of such extra PEDs, and describe their general characteristics. I do this by using events of the type $\bar{p}p \to \pi^+\pi^-$ or $\bar{p}p \to K^+K^-$ which should contain no photons, therefore all un-matched PEDs are charged splitoffs. Note that a PED must have at least 20 MeV of energy.

2 Data Set

I use as the events a clean set of collinears from Nov 90. These are selected as described in CB-Memo 185, but with tighter cuts on some criteria. These tight cuts are designed to give a very good signal/background. I require that my single collinear fit through the two tracks in the event have a prob. $> 1\%$, that the opening angle between the two tracks be greater than 175.6 degrees, and that there be at least 18 hits per track (i.e. long, well measured collinear tracks). The resulting momentum from the single fit to the event is shown in figure 1. There is clearly a minimal background under the two types of collinear events ($\bar{p}p \to \pi^+\pi^-$ and $\bar{p}p \to K^+K^-$). I then select events with momentum in the range 740 to 810 MeV/c as K^+K^-(403 events), and with momentum in the range 860 to 1000 MeV/c as $\pi^+\pi^-$(1124). These give me pure samples of the two event types, with little feedthrough from one to the other.

In my event samples I find a total of 1261 un-matched PEDs (showers) in the 1124 pion events, and 569 showers in the 403 kaon events.

3 Shower Characteristics

The first quantity I look at is the number of showers per event. This is shown in figures 2 a) and b). There is a difference between pions and kaons. The average 2 track pion event has 1.17 showers, and the average 2 track kaon event 1.38, that is 0.56 showers/pion, and 0.69/kaon. One simple criteria is to suppress all PEDs that are found in the same cluster as a PED that is matched to a charged track (such clusters are called 'charged clusters'). The surviving showers per event are shown in figure 2 c) and d). This leaves 0.34 showers/pion, and 0.45/kaon. What is also of interest, is the fraction of events with 0, 1, 2... split-offs. Therefore in table 1 I give the fraction of events with 0, 1, 2... showers.

Next I look at the energy of the showers. Figure 3 shows the energy of all showers in kaon and pion events (figures 3 a and b respectively). Several features are evident. For the pions there is a small minimum ionizing peak, indicating that the matching criteria is not perfect (see the GTRACK memo where for long well measured tracks the matching efficiency is estimated to be 98%). In general the shower energies contain a peak just above 20 MeV (which I find is correlated with showers not in charged clusters, see fig 4), and a broader distribution that extends above 100, 200... MeV (coming mainly from showers in charged clusters). The average energy of a shower in a kaon event (124 MeV) is slightly larger than that in pion events (113 MeV). In table 2 I show the fraction of showers above 50 and 100 MeV.

The separation of showers from the nearest track is shown in figures 5 a and b. The angle plotted is the angle between two straight lines which are drawn from the centre of the detector,

No. of showers	π Events	K Events
0	67%	61%
1	20%	21%
2	5%	5%
≥ 2	8%	13%

Table 1: Percentage of events with n split-offs

E > x MeV	π Events	K Events
50	66%	72%
100	43%	53%

Table 2: % of Showers Above a Given Energy

and which terminate at the impact of the track on the surface of the barrel and the centre of the reconstructed shower on the barrel surface. Note that the angle is given to the nearest track in the event (there are two back-to-back tracks per event). A clear peak is visible for showers clustering around the track. However, about half the showers are randomly distributed in space, with no correlation to the direction of the parent track. This is true for both kaon and pion events.

In figure 5 I also show the number of showers per cluster in the events. I find that the 1 shower/cluster showers are the isolated showers, with no 'memory' of the parent tracks location. The multiple shower/cluster showers are almost all located close to the parent track, usually in a charged cluster.

As well as position, energy, etc, we keep information on other shower characteristics. In figures 6 and 7 I show several of these. In figures 6 a and b, I show E1/E9. This is the energy in the central crystal of a shower, divided by the energy sum of the 3x3 crystal matrix centred on this crystal. One crystal showers show up clearly, but the remaining distribution covers the whole possible range of values. In figure 6 c and d I show the number of crystals per shower, for those showers which are in clusters by themselves (i.e. only 1 PED in the cluster, this parameter does not really make sense when there is more than one shower in the cluster). The distribution extends up to 10 crystals/shower, with a tail to even higher values. The average is 7 crystals/shower. No real difference between kaon and pion events is evident.

In figure 7 I show the second moment and invariant shower mass of the showers. Unfortunately, the range shown for the showers covers the range where one finds genuine photon showers. These parameters are sensitive to shower shape, so it appears no special shape is associated with split-off showers. The spikes in these distributions are associated with minimum ionizing showers that were not matched to the parent track. These occur in odd clusters where there are exactly 2 PEDs, neither of which is matched, the total energy of the cluster being 360 MeV, and the cluster contains approximately 60 crystals. It is not clear how these clusters arise or if they will occur in all run periods.

4 Split-off Suppression

The aim of split-off suppression should be to remove split-off showers from events, but to keep all photon showers. However, the distributions shown for split-offs in this memo, overlap the equivalent distributions for photons. Thus criteria need to be found that minimize splitoffs, maximize photons, and are reproduceable in the Monte-Carlo (essential if efficiencies are to be known, crucial not just for BR studies but also for Dalitz plot analyses). It is thus essential that the MC produces split-offs with the same characteristics as in real data. Up until now this has not been true. The solution is thus to use cuts that minimize split-offs and whose effect on real photons can be simulated, combined with analysis methods that are not sensitive to the presence of split-offs. Such a cut could be on shower energy, you could for example suppress all showers less than say 50 MeV. This reduces the number of splitoffs per pion from 0.56 to 0.37 (0.69 to 0.50 for kaons). Then in analysis you need to do 4c fits to events which contain the same number of showers as required photons, plus fits to events with more than enough showers (n+1, n+2, n+3....) until you obtain no more good signal events. This is essentially the philosophy of USDROP.

It has been suggested that all showers in a charged cluster should be dropped from analysis. This reduces the number of splitoffs by some 50% or so. It thus looks attractive. But it should be remembered that the charged clusters can subtend an opening angle around a track of up to 35°, so an event with several tracks and such cuts will have a greatly reduced photon acceptance. Also, since in MC the number of splitoffs is not well reproduced, and the size of splitoff PEDs has never been checked properly, such a cut will be very difficult to reproduce accurately for efficiency calculations. Thus although attractive at first glance, such a cut has major drawbacks.

5 Conclusions

Split-off showers from charged tracks occur with great frequency. (In reports at monthly meetings, various people doing analysis with lower momentum tracks than the collinears used here, report similar frequencies). There is no nice parameter than can flag these split-offs. Analysis will have to be done on events containing split-offs. There is a need for caution, and a clear need for a MC that reproduces the split-offs.

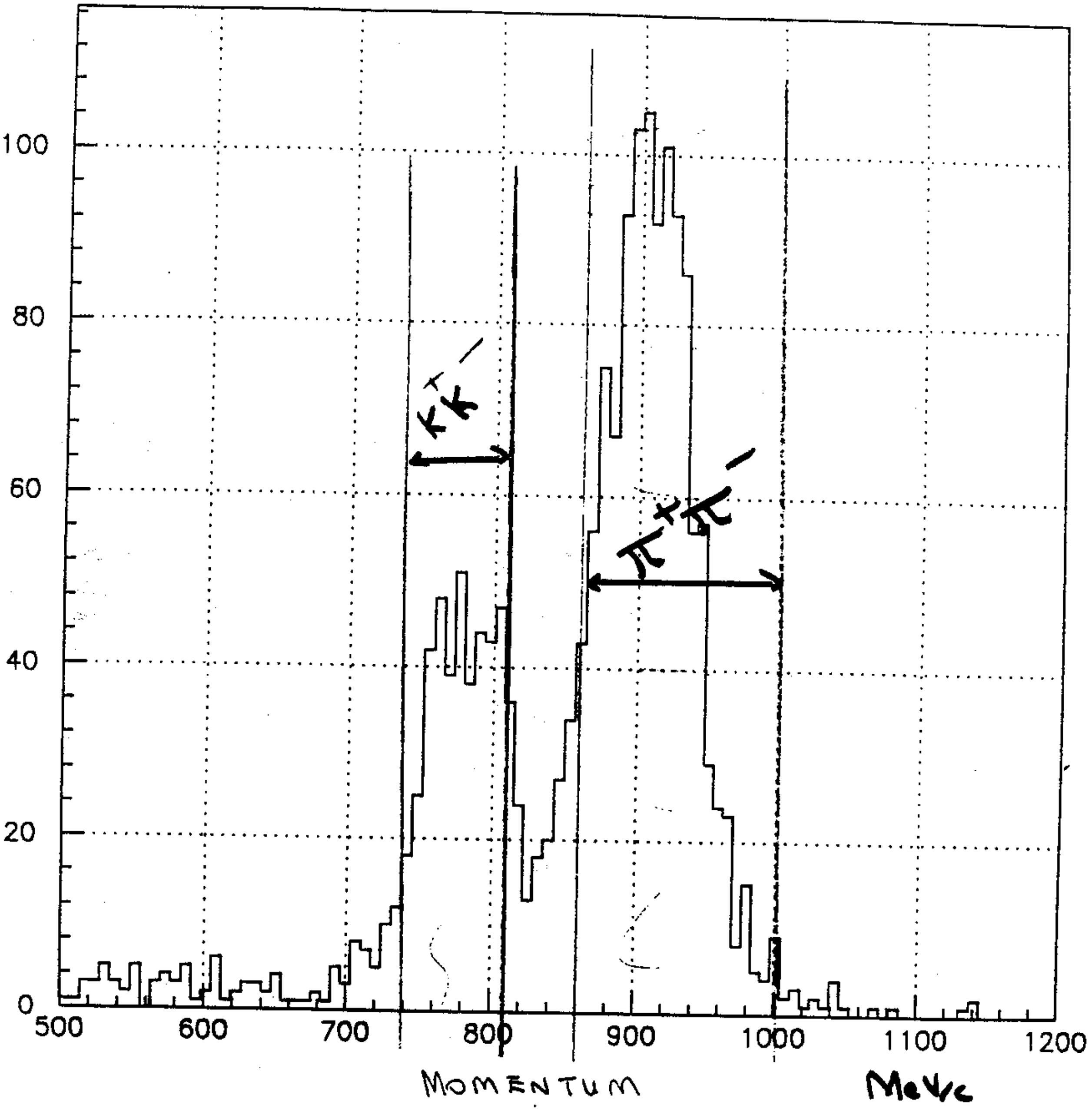

Fig 1: Results of single fit to all hits in collinear events

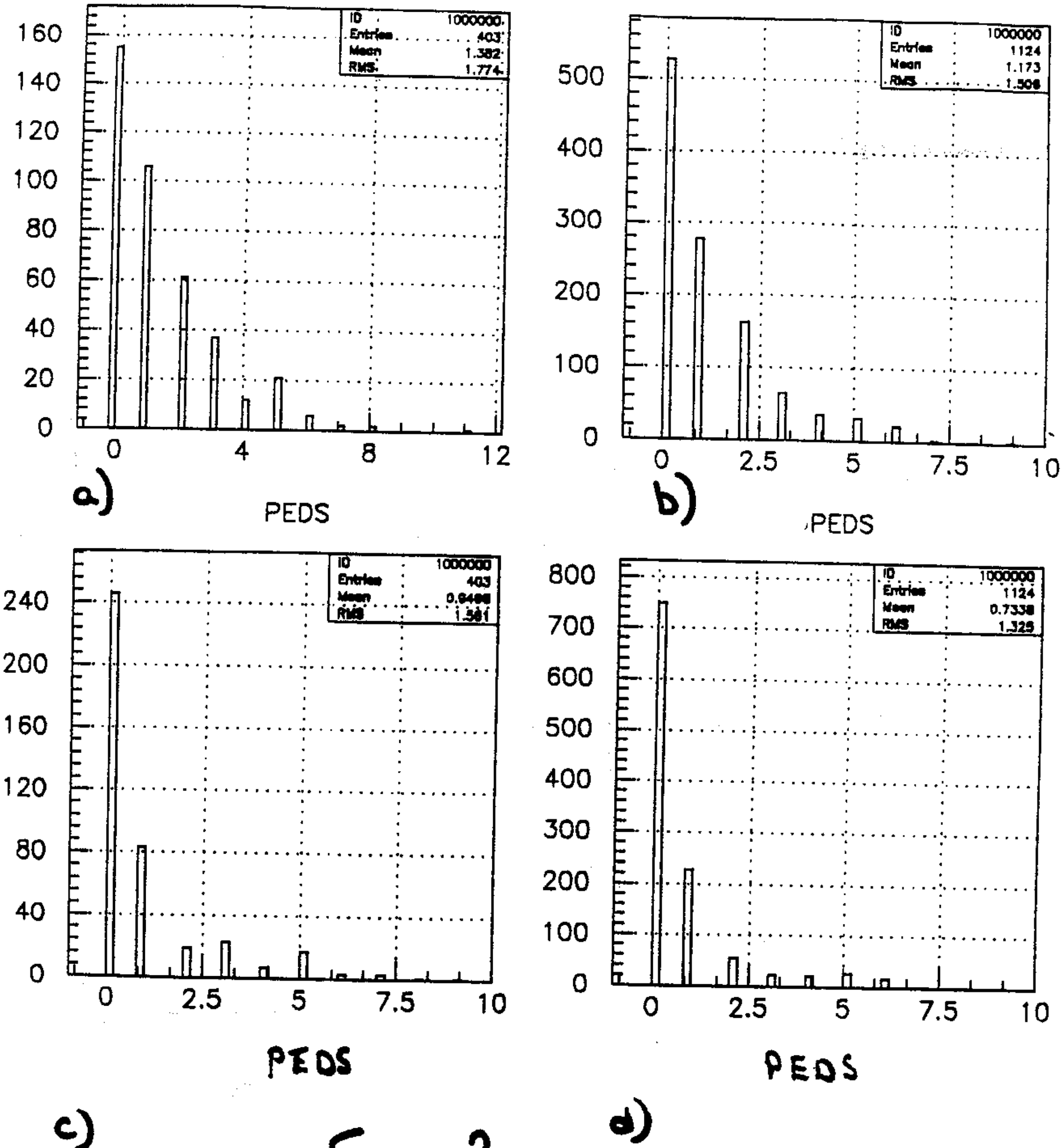

Figure 2

a), b) Are number of showers per event

c), d) Are number of showers/evt which are not in a cluster hit by a charged track

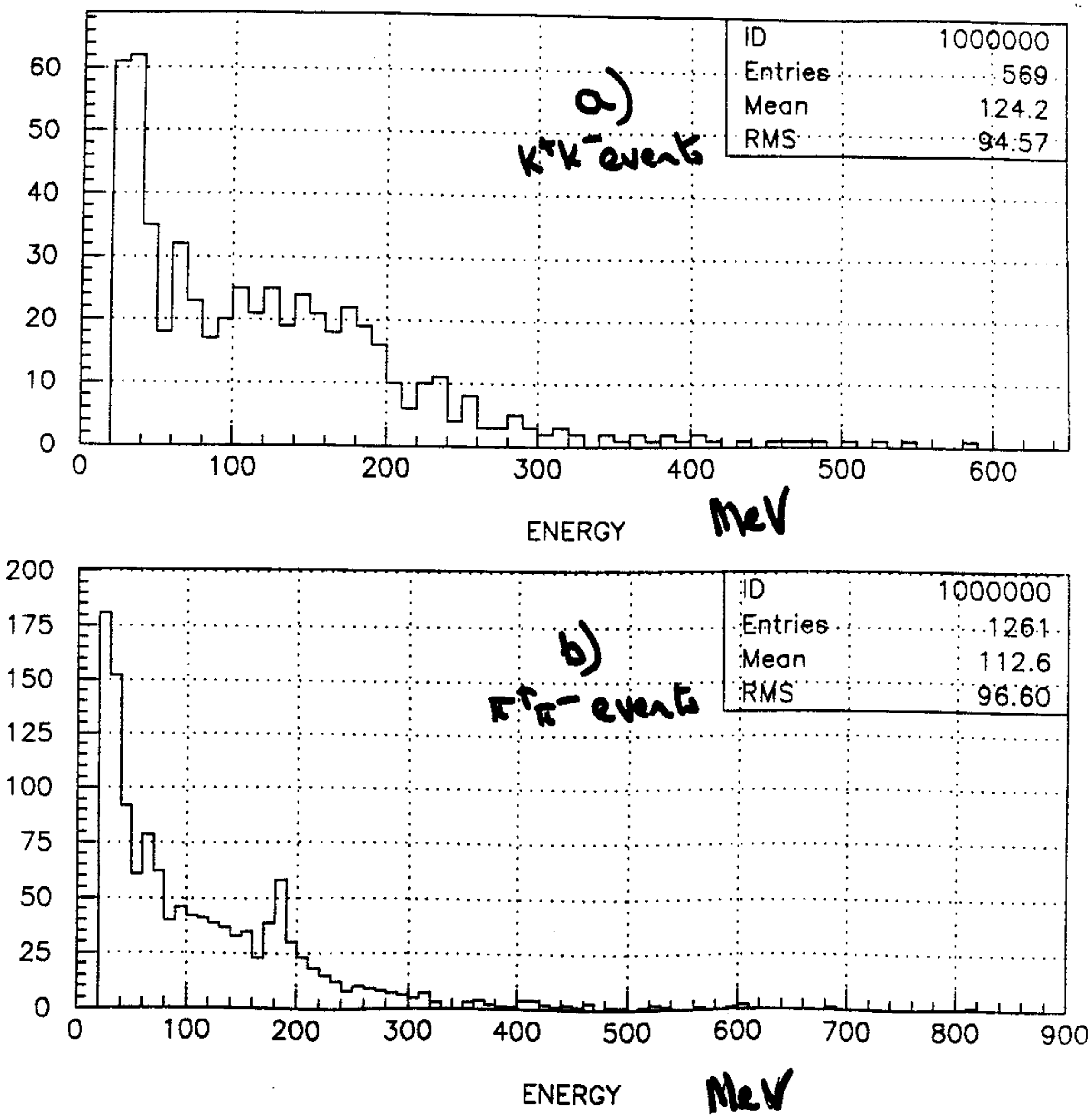

Figure 3 Energy of showers
a) K^+K^- events
b) $\pi^+\pi^-$ events

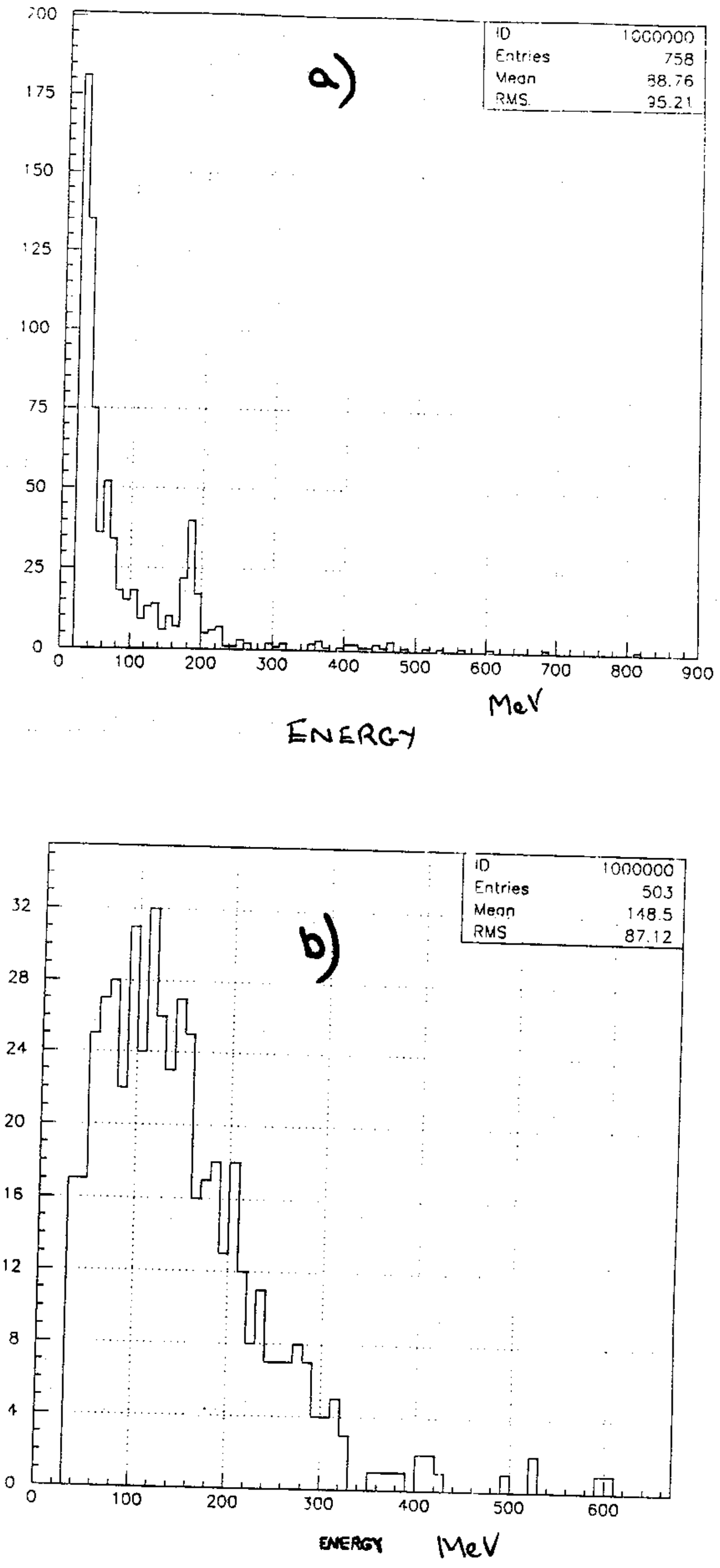

Figure 4 $\pi^+\pi^-$ Events: Shower energies
a) If not in charged cluster
b) If in a charged cluster

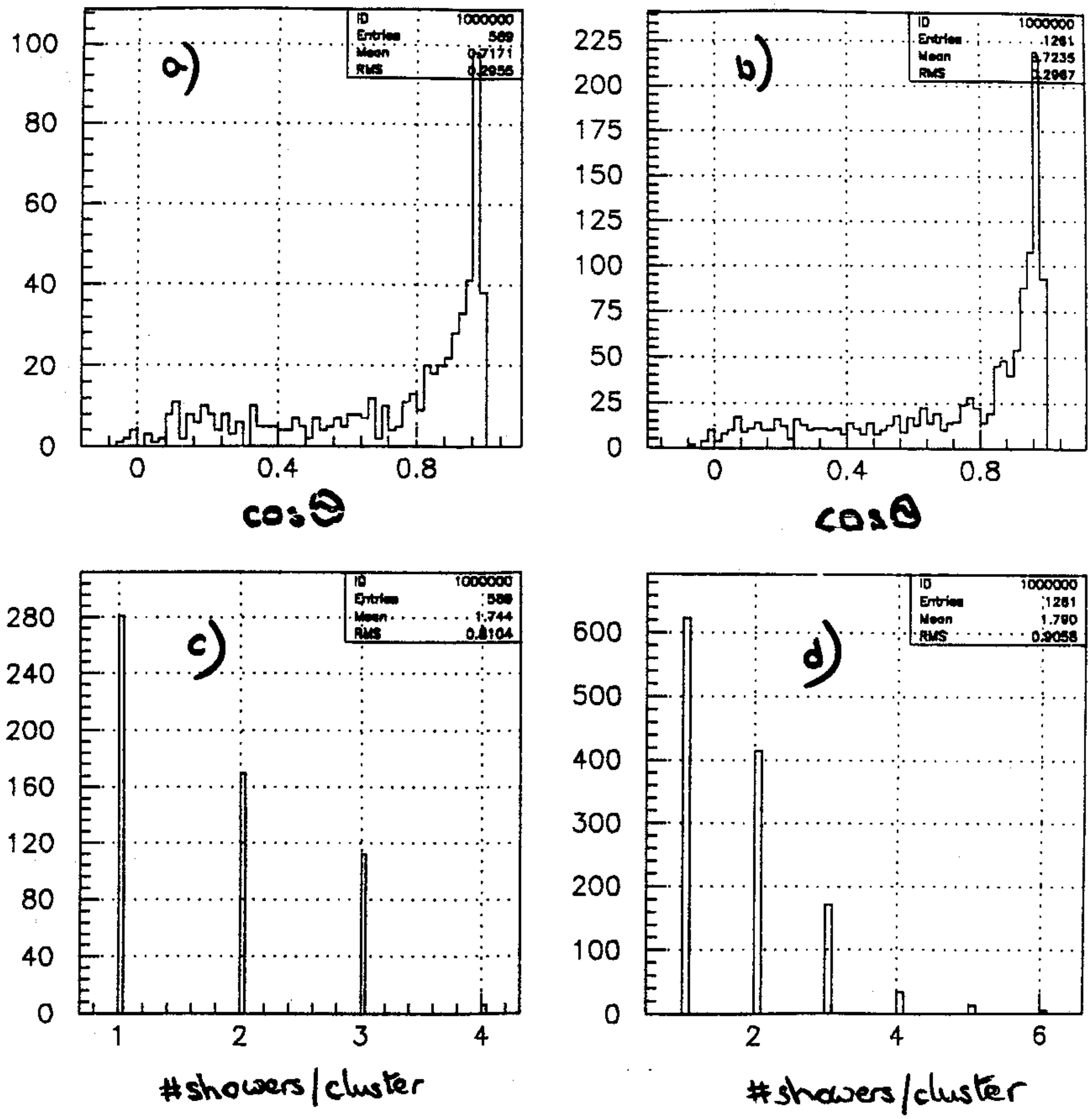

Figure 5

a),b) Angular separation of showers and nearest charged track

c),d) Number of showers per cluster in an event

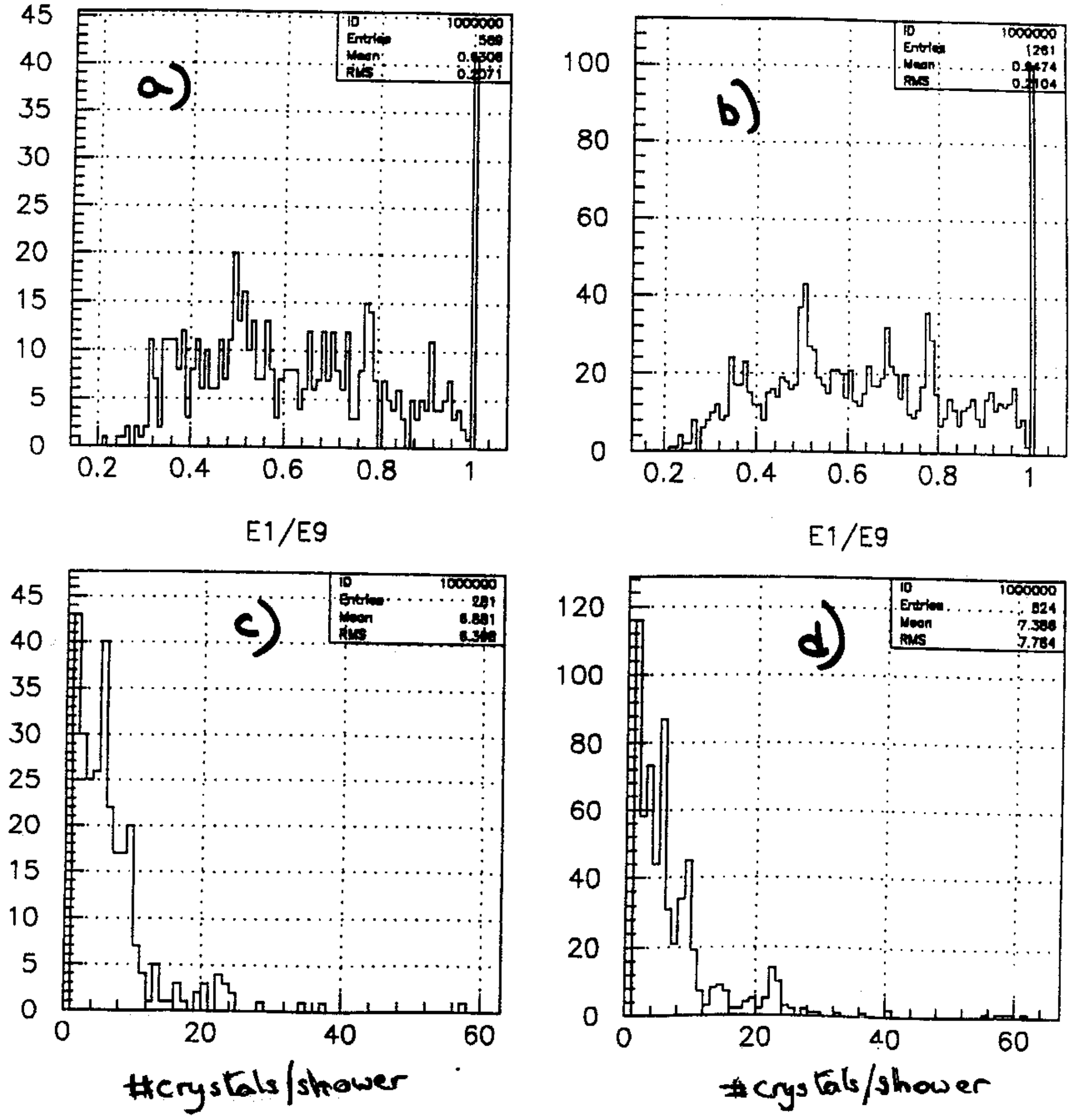

Figure 6 a), b) E1/E9 per shower
c), d) #crystals/shower for
1 PED/cluster showers

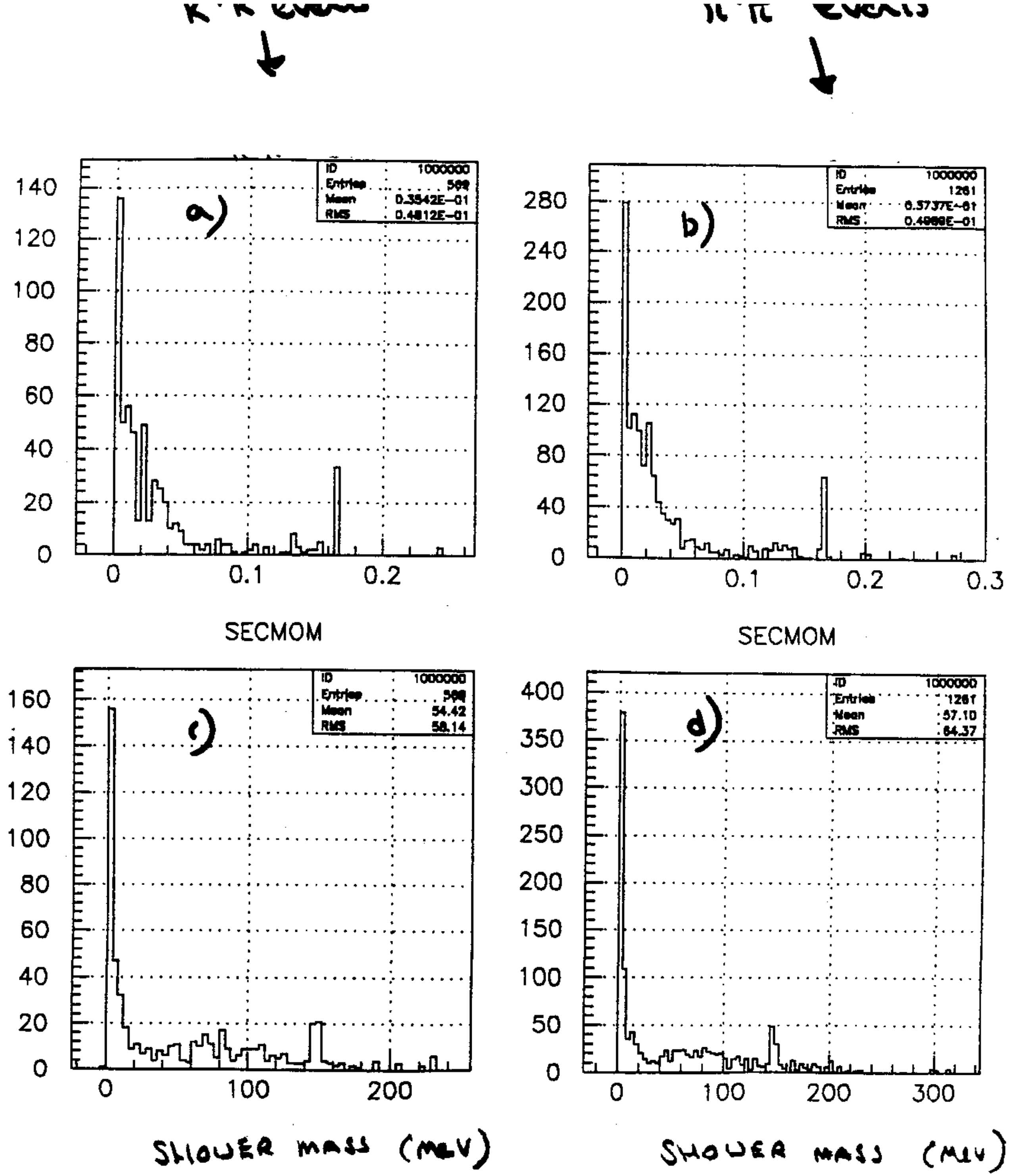

Figure 7

a), b) 2nd moment of shower

c), d) Invariant shower mass