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An Update of Tau Polarisation in the Pion Channel

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Contents

- The pion analysis used for the tau polaraisation paper is applied to all '89, '90 and '91 data.
- Another analysis is described which uses the ECAL pads to separate single pions from pions accompanied by π^0s.
- The systematic errors of both analyses are evaluated and the final results are compared.
- The polarisation is measured as a function of polar angle.

The final measured values of the tau polarisation, averaged over polar angle, are -0.084 ± 0.044(stat.) $\pm$ 0.027(syst.) with the old analysis and -0.106 ± 0.038(stat.) $\pm$ 0.024(syst.) with the new. A fit to the polarisation as a function of polar angle, assuming lepton unversality and using the new analysis, gives $P_l = -0.097 \pm 0.031$ (stat.) $\pm$ 0.016 (syst.) which shows that there is a worthwhile gain in both statistical and systematic errors when this method is used.

1. Introduction. Why Another Analysis ?

The difficult part of $\tau \rightarrow \pi\nu$ decay selection is to reject events containing photons while preserving a high and known acceptance for the wanted events. The original analysis achieves this by making a cut on the depth at which a shower starts to develop in ECAL. The depth is measured using only the wire plane data. Three consecutive planes, each with energy greater then 2.5 × that expected from a minimum ionising particle, is taken to be the signal for a shower. Tau decays containing photons or electrons are rejected by requiring that the depth of the shower be greater than five radiation lengths (L_R). The advantages of this cut are;

- The wire readout has negligible noise, few and well-known dead channels.
- A single, simple cut removes nearly all the background.

But it has the disadvantages that;

- About 30% of pions are lost.
- There is significant disagreement between data and Monte Carlo in the distribution of the shower depth for both hadronic and electromagnetic showers.

When the analysis was developed in early '90 the first advantage was decisive. But now that ECAL pad data is a lot cleaner and clustering algorithms which make full use of ECAL's granularity are available it may be better to recognise photons as clusters which are not aligned with the track impact point. This possiblity was investigated a long time ago [3] and it was shown that pion acceptance around 95% was possible.

2. The Old (Longitudinal) Analysis

2.1 Shower Depth: Data vs. Monte Carlo

I do not want to abandon the analysis based on shower depth so it is a good idea to understand why the Monte Carlo does not agree with the data and whether this has a serious effect on the final results. Figures 1 a,b show the shower depth of electrons from $\tau \rightarrow e\nu\nu$ decays in two ECAL energy bins. The points with error bars are the real data and the dashed line is Monte Carlo data normalised to the real data. Figure 2 shows the same thing for the ρ test sample defined in section 4.1.1 . Figure 3 shows data taken with a pion test beam and special Monte Carlo data which simulates the test beam conditions.

From figures 1 and 2 I conclude that the devlopment of an electromagnetic shower in the first few radiation lengths is not quite correctly simulated. The Monte Carlo produces showers which develop more slowly than real ones. This could be because the Monte Carlo uses a shower parameterisation instead of the time-consuming EGS. Does this discrepancy matter? It will slightly affect the amount of background which the Monte Carlo predicts to be in the pion candidates. In figure 1 I have indicated that the difference in the position of the falling edge is about 0.4 radiation lengths. The cut is placed rather safely in the data at 5 L_R but the equivalent position in the Monte Carlo might be at 5.4 L_R. Therefore I have varied the cut used in the analysis of the Monte Carlo to 5.4 L_R and the background changes by 0.4 % which changes the polarisation by 0.004 . This is taken to be the systematic error due to this effect.

Figure 3 shows that there is a slight disagreement in the depth profile of pion showers. The spike in the first bin is certainly larger in the test beam data than in the Monte Carlo. I guess that this spike must be caused by pions backscattered from interactions deep inside ECAL which pass right back to the front layers and out of the front face of ECAL. The probability of this happening seems to be underestimated by the Monte Carlo by about 5% at high energy. We can use the test beam data to correct for this difference. This is fine except that it has a statistical error which introduces an error of $\pm$ 0.019 to the polarisation measurement which can not be reduced without going back to the test beam.

So the conclusion is that the longitudinal method has an unavoidable systematic error of $\pm$0.02 which is acceptable when compared with the statistical error of $\pm$0.04 which we expect from all data taken up to now.

2.2 Summary of Cuts

For details see ref [2].

1. The event must be in the lepton class 15.

2. The hemisphere of the pion candidate must contain one good track ($|d0| < 2$ cm , $|z0| < 10$ cm , $|\cos\theta| < 0.9$, TPC hits > 4) and no bad tracks (2 cm $< |d0| < 20$ cm , $|z0| < 20$ cm , TPC hits > 4).

3. The track must not extrapolate to an ECAL crack or overlap region.

4. The depth of the shower start must be greater than 5 L_R.

5. The mean distance from the extrapolated track to the hits in the last 5 planes of HCAL must be greater than 3 $\times$ the expected multiple scattering distance. If a plane has more than one hit, the one farthest from the track within a $\pm$30 cm road is used. If there are no hits in the last 5 planes then the track passes this cut.

6. EITHER the stack 2+3 energy of the four towers of ECAL closest to the track must be greater than 1.2 GeV OR (number of HCAL planes with hits separated by >6 cm) / (total hit HCAL planes) must be greater than 0.18 .

7. The sum of all calorimeter energy (E_{calo} = ECAL wires + HCAL towers) must be less than twice the track momentum.

2.3 One new cut

One additional cut has been introduced to remove high energy muons. Figure 4b shows the track momentum vs. E_{calo} for pion candidates which pass all of the previous cuts but which have a muon of more than $0.8\times E_{beam}$ in the opposite hemisphere. Similar pion candidates without a high energy muon opposite are shown in figure 4a. It is obvious that some pion candidates are really muons from $Z \rightarrow \mu\mu$ events and that they can be removed with a cut on the corner of figure 4. In order to make the cut fairly independent of energy for real pions it requires that;

$$E_{calo.} > P_{track} - 5\sqrt{P_{track}}$$

The 1σ error on E_{calo} is approximately equal to $sqrt(P)$, so this cut is at 5σ from the expected energy.

2.4 Cuts against non-tau events

We keep the same cuts as were used last year. The aim is to remove Bhabha and muon-pair background each with a single cut on the hemisphere opposite to the pion candidate. This has the advantage that it is possible to measure the level of remaining background without relying on the Monte Carlo. For example figure 5b shows the ECAL wire distribution that cut 2 below is applied to. It can be seen that there is some Bhabha background in the pions and its level can be measured by fitting the bump around 1 . We can use real Bhabha events to measure the shape of this bump and calculate the number of Bhabhas in the tail below the cut at 0.9 .

1. To remove $Z\rightarrow ee$ events, the ECAL wire energy in the hemisphere opposite the pion must be less than $0.9\times E_{beam}$.

2. To remove $Z\rightarrow\mu\mu$ events, the momentum of any muon-like track opposite the pion must be less than $0.75\times E_{beam}$.

3. To remove two photon events, the sum of the track momenta in one of the hemispheres must be more than 5 GeV.

2.5 Results

The overall acceptance of these pion selection cuts is shown as a function of pion energy in figure 6. It can be seen that the acceptance is almost flat at 45% above $X_\pi = 0.1$ and this is the region used for the polarisation fit. Figure 7 shows the various backgrounds from other tau decay channels. They are peaked at low X_π but at no energy are they greater than 10% of the pion signal and on average they are 4.3%.

When this analyis is applied to all data taken by ALPEH up to the end of 1991 it finds 2105 events with $X_\pi > 0.1$. By using the method described in section 2.4 we calculate that the background from Bhabhas in our final sample is 0.04 ± 0.1 % and the background from muon pairs is 0.14 ± 0.1 %. These backgrounds are subtracted. The measured momentum spectrum is then fitted to a mixture of Monte Carlo events generated with positive and negative helicity, so that the ratio of the mixture gives the measured tau polarisation. Figure 8 summarises the fit, it shows that the χ^2 is good. The fitted value of the polarisation, before any systematic corrections, is -0.084 ± 0.044 .

3. The New (Transverse) Analysis

All cuts are identical to those of the old analysis except that the shower depth cut, 2.2(4), is replaced by ECAL pad based cuts agains photons and electrons. The GAMPEC algorithm is used to break down julia clusters (PECO) into smaller clusters which may correspond to individual photons or π^0s. This gives the advantage that photons may be found even if they are mixed up with the hadronic shower, a situation which often occurs in $\tau \rightarrow \rho\nu$ decays. A slightly modified version of GAMPEC is used which returns the distance between each cluster and the nearest charged track but which does not cut on this distance. Apart from this, the other cuts in GAMPEC are at their default values which are;

- The storey energy needed to start a cluster is 75 MeV in stack 1, 150 MeV in stack 2, or 200 MeV in stack 3.
- The cluster must have energy in stacks 1&2 or 2&3 or 1&2&3.
- The total energy in stacks 1 and 2 must be greater than 250 MeV.

The clusters returned from GAMPEC are sorted into those in the front stacks of ECAL, which could possibly be photons, and those at the back which could not. If the fraction of energy in the first two stacks, F_{12}, is greater than 0.7 or if the cluster is in an ECAL crack then it is called a "front" cluster. Otherwise it is called a "back" cluster. The back clusters are mainly satellites of hadronic showers and they are used later to measure the accuracy of the Monte Carlo shower simulation. Figure 9 shows (energy) vs. (distance to the charged track) of the front clusters with energy greater than 0.4 GeV. If there is more than one such cluster the farthest one is plotted. The data is Monte Carlo, generated without radiation so as to avoid confusing the picture with radiative photons. The events shown in figure 9 have already passed all of the other pion selection cuts. Figure 9a shows $\tau \rightarrow \pi\nu$ decays and 9b shows decays containing a single π and one or more π^0s. It can be seen that a cut can provide good rejection of decays with π^0s. The photon definition was chosen to be ; energy $>$ 0.4 GeV, distance $>$ 5cm and energy $>$ 2.8 $-$ 0.2$\times$distance.

As well as the above cut against photons a cut against electrons is needed. A cut on R2, the estimator which measures the balance between track momentum and the energy in the four closest ECAL towers to the track impact, is sufficient to remove $\tau \rightarrow e\nu\nu$ events. However there is also the background from Bhabhas to consider. If the track fit suffers from a fluctuation towards higher momentum then it will not balance with the ECAL energy and the electron will pass the R2 cut. This happens often enough in Bhabha events to lead to a high background in the pion sample. So a cut is applied to the energy of the four central ECAL towers at 0.6$\times$ E_{beam}. Figure 10 illustrates this cut.

To summarise, cut 2.2(4) in the old analysis is replaced by;

1. No photons
2. R2 $<$ -3.5
3. $E_{4\_towers} < 0.6\ E_{beam}$

3.1 Results

The cuts against non-tau events and the polarisation fit are exactly the same as described for the old analysis. In this case the acceptance (figure 11) is 60% where it was 45% before and the background (figure 12) is now 7.7% where it was 4.3%. So this analysis achieves it's aim of a higher acceptance without much more background. The background from Bhabhas is 0.6 ± 0.1 % and from μ-pairs is 0.1 ± 0.1 %. More importantly, it uses a cut which is in some sense orthogonal to the old one, so if both methods agree we can have a lot of confidence that they are both right. 3047 events are found and the polarisation fit, before any systematic corrections, gives $P = -0.107 \pm 0.038$ (Figure 13).

4. Systematics.

4.1 Acceptance

The acceptance can be divided into the geometrical part due to cuts 2.2(1) to 2.2(3) and the remaining part due to particle identification. The geometrical part has an acceptance of 73% , independent of momentum above $X_\pi = 0.1$ (figure 14). The geometry of Aleph, the efficiency of track reconstruction and the topology of τ events are very accurately described by the Monte Carlo so their contribution to the systematic errors can be ignored.

4.1.1 Cuts against muons

The acceptance of the anti-muon cuts, 2.2(5) and 2.2(6), is measured with the charged pions from ρ events. The ρs are defined by using photons selected with the same cuts as described in section 3. If a tau decay passes the geometrical cuts and has two photons with an invariant mass in the range 100 to 180 MeV and the track + photons invariant mass is in the range 400 to 1000 MeV then it is called a ρ (figure 15). The Monte Carlo shows that this selection produces a sample of decays which are 95.5% real ρ or $K\pi^0$ and the remaining events are almost entirely $\pi\pi^0\pi^0$. The probability that the charged track in this ρ sample will pass the anti-muon cuts is plotted as a function of track momentum in figure 16. There is good agreement between data and Monte Carlo. The ratio of acceptances is consistent with 1 and a straight line fit to the ratio yields a correction to the τ polarisation of $\Delta P = -0.021 \pm 0.015$. Thus, this systematic error is much smaller than the statistical error on the polarisation and since it is measured with real data it will always be smaller. The only possible criticism is that one of the anti-muon cuts involves ECAL and in 4.5% of the test sample there are extra photons, which have not been found by GAMPEC and which might be biassing this cut. However we know that the acceptance of these cuts for isolated pions is already 90% and the presence of extra photons can only increase this acceptance. So at worst the acceptance measured with the ρ sample could be 0.5% above the acceptance of isolated pions, and this small bias should be present in both real data and Monte Carlo so its effect is completely negligible.

4.1.2 The ECAL cuts

The acceptance of both longitudinal and transverse ECAL cuts has been measured with the test beam data. The results are shown in figures 17 and 18. There is some disagreement between test beam and Monte Carlo for both types of cut, but the disagreement is smaller and more accurately measured with the transverse cut. The test beam data is concenterated at low energy so we must make some assumption about the extrapolation to higher energies. The features of a shower generally evolve as some less-than-linear function of energy, eg sqrt(E) or log(E), so we assume that the acceptance of these cuts will not change sigificantly between the highest measured point (30 GeV) and 45 GeV . The correction factors, and the range that they cover, are shown on figures 17b and 18b by the squares with horizontal error bars. These corrections change the polarisation measured with the old analysis by $\Delta P = +0.016 \pm 0.016$ and the new analysis by $\Delta P = +0.016 \pm 0.009$.

Another way to measure the accuracy of the Monte Carlo simulation of hadronic showers in ECAL is to look at the "back" clusters defined in section 3. We know that these clusters are not photons because of their large energy fraction in stack 3. We then make the reasonable assumption that to a hadron the front and back of ECAL are not very different because they are only separated by 0.6 interaction lengths. Figure 19 shows the energy vs. distance plot of back clusters which are found with pion candidates in real and Monte Carlo data. There is qualitative agreement between them and they have a strong resemblance to figure 9a. Figure 20 shows the fraction of pion candidates which have no back clusters outside the same energy/distance cuts as were applied to the front clusters. The fact that there is agreement here implies that the Monte Carlo is correctly simulating this type of hadronic satellite shower. A polarisation correction could be derived with a straight line fit to the ratio data/MC which would give $+0.006 \pm 0.007$. This is consistent with the number coming from the test beam data. The test beam result is preferred because it does not use any assumptions.

4.2 Backgrounds from other tau channels

The systematic error due to these backgrounds can be divided into two parts;

4.2.1 Branching Ratio Uncertainties

There is uncertainty in the relative branching ratios of the background channel and the pion channel. This is easily dealt with by reweighting Monte Carlo events with the ratio of measured to input branching ratios. The results are summarised in Table 1 below. The measured numbers come from from the Aleph note [4], except for the K* which is from the particle data tables. Both analyses are affected by approximately the same amount by a change in background level because, although the new analysis has twice as much background it has a flatter X distribution.

4.2.2 Cut Uncertainties

It is possible that a cut has a different efficiency at removing background in real data from that predicted by the Monte Carlo.

The efficiency of the cut agains muons has been measured with μ pair events. A muon is tagged with kinematic cuts and by identifying a muon on the opposite side. The probability of a real muon being identified as a pion is 1.1% , while the same probability measured with Monte Carlo μ pairs is 0.5%. Thus a correction of $B(\tau\rightarrow\mu\nu\nu)$ / $B(\tau\rightarrow\pi\nu)$ × (0.6 ±0.1) % is applied to the muon background in the pion sample.

The uncertainties in all of the other cuts are estimated by varying the cuts within a range corresponding to the possible discrepancy between data and Monte Carlo. The program is then re-run on the Monte Carlo with the changed cuts but the position of the cuts is not changed for real data.

Figure 21 shows E_{calo}/P_{track} of tau decays which have passed all of the pion selection cuts. It can be seen that the peak is slightly narrower in Monte Carlo than in real data. So the cut which was

TABLE 1

Decay Mode	Branching Ratio measured	Branching Ratio in M.C.	Polarisation Change old analysis	Polarisation Change new analysis
pion	12.49 +- 0.53	12.0	-0.003+-0.003	-0.002+-0.002
electron	18.02 +- 0.52	18.5	negligible	negligible
muon	17.28 +- 0.53	18.0	negligible	negligible
rho	24.48 +- 1.03	23.0	+0.001+-0.001	+0.001+-0.001
K*	1.39 +- 0.20	1.5	-0.003+-0.005	-0.002+-0.005
Total			-0.005+-0.006	-0.004+-0.006

applied at 2.0 is 3.5 R.M.S. deviations from the mean in the data and 3.8 deviations in the Monte Carlo. The effect of this difference on the polarisation is estimated by varying the cut position from 2.0 to 1.9 in the analysis of Monte Carlo data.

The shower depth cut is varied by 0.4 L_R for the reason described in section 2.1 .

The transverse analysis uses cuts on both the energy of possible photons and their distance from the charged track. The distance cut, at 5cm, is very large compared to the possible errors in alignment of components within ALEPH. So it is not a possible source of error. However, the energy cut at 400 MeV in the raw energy is at a position where little is known about the reliability of the Monte Carlo. The best data that I know of is the study done by Rob Edgecock et al. for the single photon paper [5]. This uses low energy electrons from two photon interactions to measure the energy scale of ECAL clusters down to 500 MeV in corrected energy, equivalent to 400 MeV in raw energy. They demonstrate that there is agreement between data and Monte Carlo at the level of 4% or better in their lowest energy bin. In order to be very safe we double this uncertainty and vary the energy cut from 340 to 460 MeV.

TABLE 2

Cut	Measurement Method	Background Change	Polarisation Change
anti-muon	Use real muons	+1.0+-0.2 %	+0.010 +-0.002
showr depth	variation 5.0 to 5.4	+-0.4 %	+-0.004
min. gam. E	variation 340 to 460 MeV	+-0.3 %	+-0.007
R2 and E_4_tower	variation -3.3 to -3.7 variation 0.59 to 0.61	+-0.2 %	+-0.002
E balance	variation 2.1 to 1.9	+-0.3 %	+-0.002
Total effect on	old analysis		+0.010 +-0.005
	new analysis		+0.010 +-0.008

5. Final Results

Table 3 summarises the systematic corrections and errors. The systemtaic errors are added together in quadrature to give the final results; $P = -0.084 \pm 0.044 \pm 0.027$ from the old analysis and $P = -0.106 \pm 0.038 \pm 0.024$ from the new. The only important systematic errors which are not common to both methods are those due to the different ECAL cuts and they can account for a difference of $\pm$ 0.019 . There are 1970 events which are common to both selection procedures. The expected statistical difference due to the events which are not in common between the two analyses is ± 0.026 . So the results of the two methods of analysis are consistent with each other.

If one calculates the total number of pions found by each analysis, corrected with the Monte Carlo for acceptance and backgrounds, one finds N_{old} = 4652 pions and N_{new} = 4831 pions . The statistical error due to events not in common is expected to be $\pm$ 60. So at first sight there is a 3 sigma discrepancy. But figures 17b and 18b show that the ratio (Test Beam acceptance) / (Monte Carlo acceptance) has an offset from 1. which is different for the old and new ECAL cuts. This difference is around 3% which agrees with the difference seen in the number of events above and shows that the test beam and the real data are self consistent.

TABLE 3

Systematic	Effect on old Analysis	Effect on new Analysis
ECAL Acceptance	+0.016 +- 0.016	+0.016 +- 0.009
HCAL Acceptance	-0.021 +- 0.015	-0.021 +- 0.015
Branching Ratios	-0.005 +- 0.006	-0.004 +- 0.006
Background Cuts	+0.010 +- 0.005	+0.010 +- 0.008
Monte Carlo Statistics	0 +- 0.013	0 +- 0.011
Track Momentum Scale	0 +- 0.004	0 +- 0.004
Total	0 +- 0.027	+0.001 +- 0.024

6. Polarisation vs. Polar Angle

The tau polarisation is expected to vary as a function of polar angle, θ, where θ is the angle between the tau and the beam particle of the same sign;

$$P(cos\theta) = \frac{P_\tau + P_Z \frac{2cos\theta}{1+\cos^2\theta}}{1 + P_\tau P_Z \frac{2cos\theta}{1+\cos^2\theta}} \qquad (1)$$

where $P_\tau = -2v_\tau a_\tau/(v_\tau^2 + a_\tau^2)$ is the polarisation of the taus coming from decay of an unpolarised Z and $P_Z = -2v_e a_e/(v_e^2 + a_e^2)$ is the polarisation of a Z produced with unpolarised beams. If this expression is integrated over a range of cosθ which is symmetrical about 0 , the result only depends on P_τ and this is the measurement that has been favoured by the tau group. Now the polarisation is measured in several cosθ bins so it is also sensitive to the electron couplings. However, if lepton universality is assumed, a more accurate measurement of v/a can be made because the forward taus, which are expected to be more polarised, are weighted more heavily.

The events have been divided into bins in cosθ as shown in table 4. The data has been divided into nine bins because we do not wish to lose the cosθ information. The polarisation fits work well even with a small sample of real data but they do need a large sample of Monte Carlo data. Therefore the acceptance, background from other tau channels and background from μ-pairs is divided into three bins corresponding to the barrel, overlaps and endcaps. This utilises the fact that that these quantities do not vary with cosθ in the barrel and that they are foreward-backward symmetric. The background from Bhabha events is divided into six bins which allow for forward-backward asymmetry.

Within these bins the analysis is carried out exactly as described in the previous sections, using the new pion definition. For example the real events in bin D8 have the Bhabha background from bin B5 subtracted and the remaining corrections and fit are done with μ-pair background and Monte carlo data from bin A2. The corrections for the Branching Ratios and Background Cuts (Table 3) are applied independently to each cosθ bin because they depend on the level of background. The same ECAL and HCAL systematic correction factors are applied to all bins because these corrections are thought to be due to imperfect simulation of hadronic showers in the calorimeters and are not strongly dependent on the angle between the hadron and the calorimeters. The result of this analysis is shown in table 4 and figures 22 and 23. The curve in figure 22 is the result of a fit to the function (1) which finds $P_l = -0.097 \pm 0.031$ (stat.) . Where lepton universality is assumed ; $P_l = P_\tau = P_Z$.

A nice feature of the fit vs. polar angle is that the same systematic uncertainties have less effect on the polarisation. For example, if 0.024 is added to each bin then the fitted value of P increases by 0.016. This is because the fit is effectively measuring the polarisation of the forward taus and dividing by some factor to get the average polarisation, so any systematic error is divided by the same factor.

TABLE 4

Cosine Theta	Real Data bin	Accept & Bkg. bin	Bhabha Bkg bin	Fit Result	Total Bkg level
-0.9					
	D1	A1	B1	0.04+-0.15	10.4 %
-0.8					
	D2	A2	B2	0.01+-0.13	8.5 %
-0.63					
	D3	A3	B3	-0.07+-0.11	8.1 %
-0.4					
	D4	A3	B3	-0.15+-0.11	8.0 %
-0.15					
	D5	A3	B3	-0.13+-0.11	8.0 %
0.15					
	D6	A3	B3	-0.09+-0.10	8.0 %
0.4					
	D7	A3	B4	-0.18+-0.10	8.0 %
0.63					
	D8	A2	B5	0.02+-0.12	9.1 %
0.8					
	D9	A1	B6	-0.46+-0.14	14.1 %
0.9					

References

1. ALEPH Collaboration *Measurement of the polarisation of τ leptons produced in Z decays* Phys. Lett. B256 (1991) 430

2. S.W.Snow *A measurement of the polarisation of the τ in $\tau \to \pi\nu$ decays.* ALEPH 90 – 158

3. S.W.Snow *Position Resolution of Pion showers in ECAL.* ALEPH 89 – 50

4. M.Davier & Z.Zhang *Measurement of tau branching ratios* ALEPH 91 – 094

5. R.Edgecock et al. *A Direct Measurement of the Invisible Width of the Z from Single Photon Counting* ALEPH 91 – 135

Figures 1 and 2

The distribution of shower starting depth for electrons and rhos in two energy bins. The points with error bars are real data and the dashed line is Monte carlo. On each plot the approximate shift in the position of the upper edge between data and Monte Carlo is indicated.

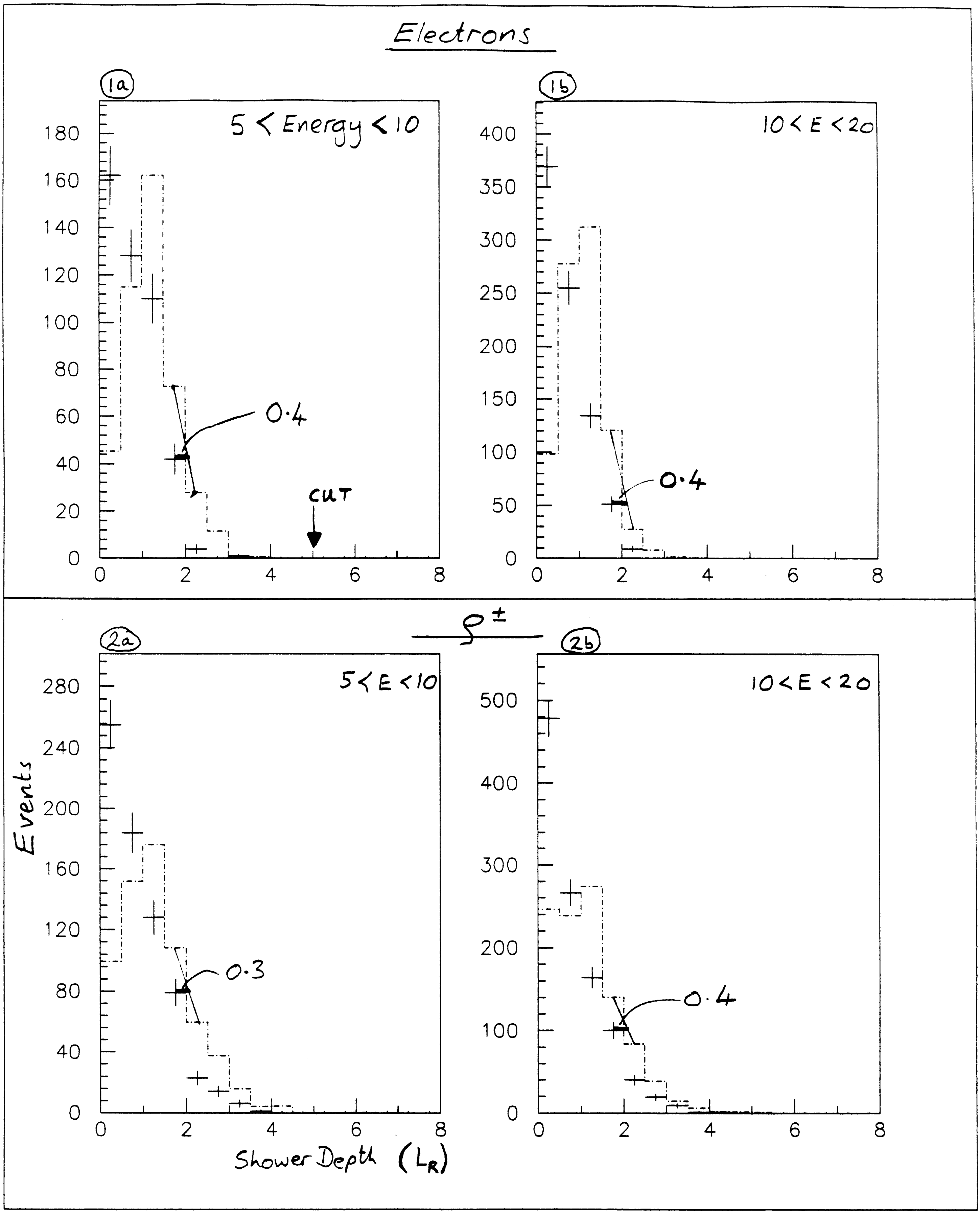


Figure 3

Shower starting depth distribution of pions measured with the test beam and simulated with the Monte Carlo.

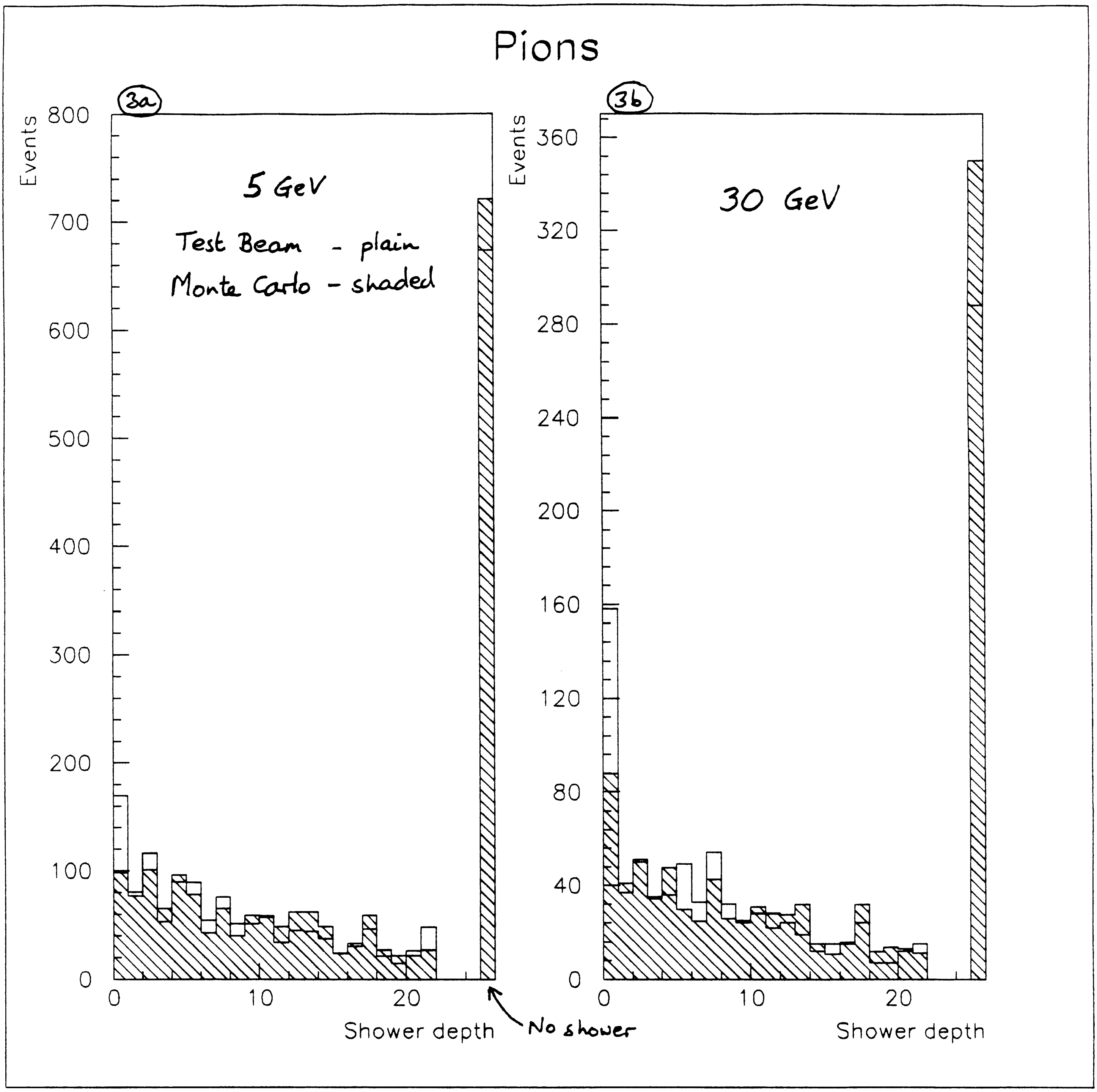
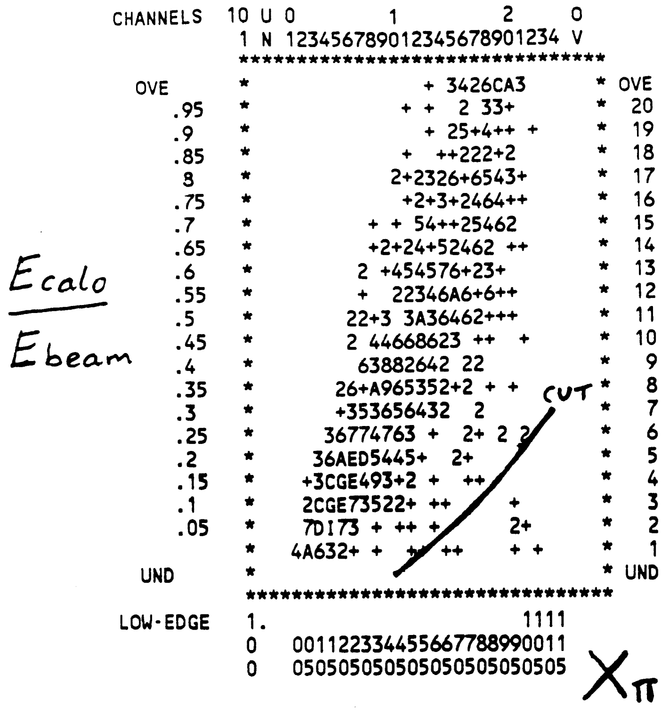
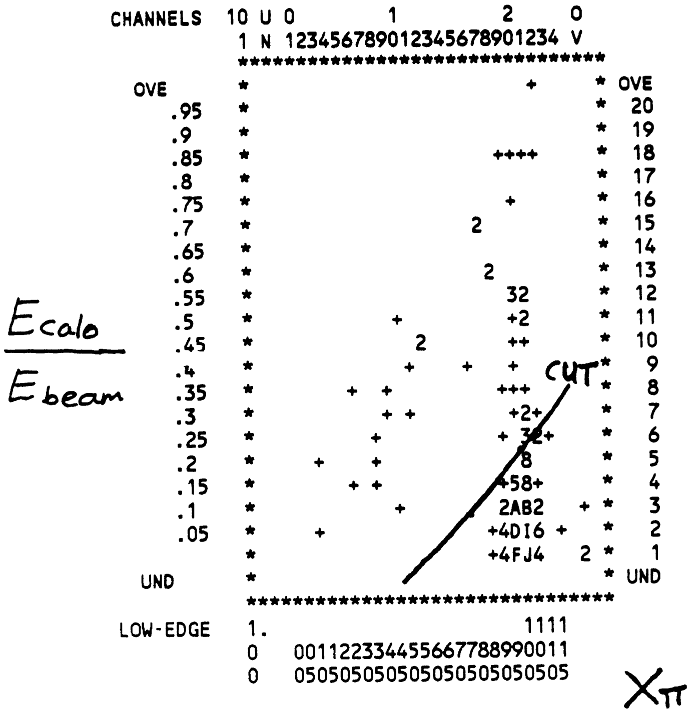


Figure 4

Shows the cut which rejects muon background on the basis of its high track momentum combined with low calorimeter energy.



Mainly real pions

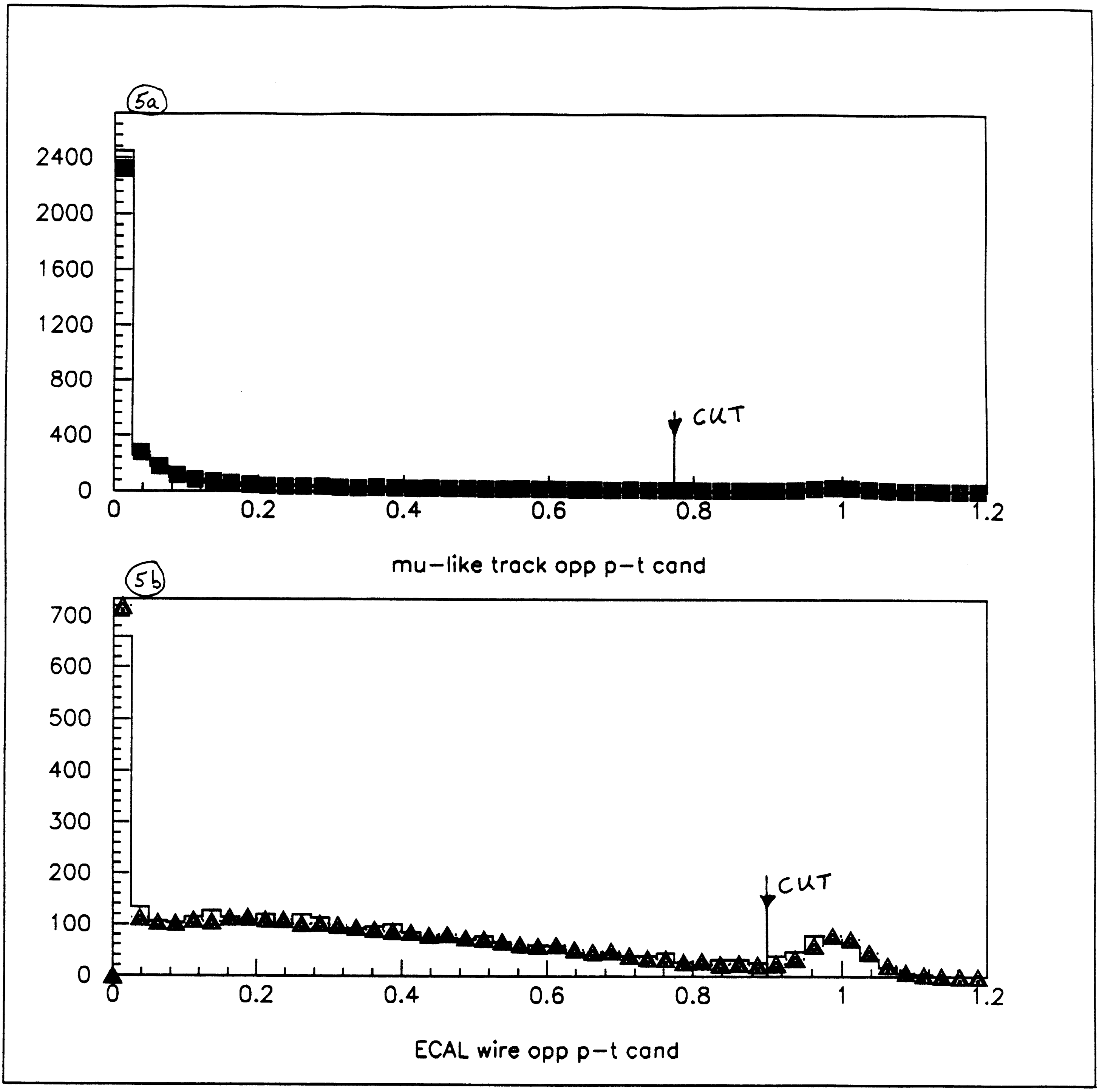


Mainly muons mistaken for pions

Tracks selected as "pions" for which the track opposite is a muon with $X_\mu > 0.8$

Figure 5

The cuts which are made on the hemisphere opposite the pion candidate to reject the residual Bhabha and mu-pair background. The histograms show the real pion data while the solid points are a combination of tau Monte Carlo and real Bhabhas (or muons) weighted to fit the data.



Figures 6 and 7

The acceptance of the old analysis for pions and the background in the pion sample from other tau decay channels.

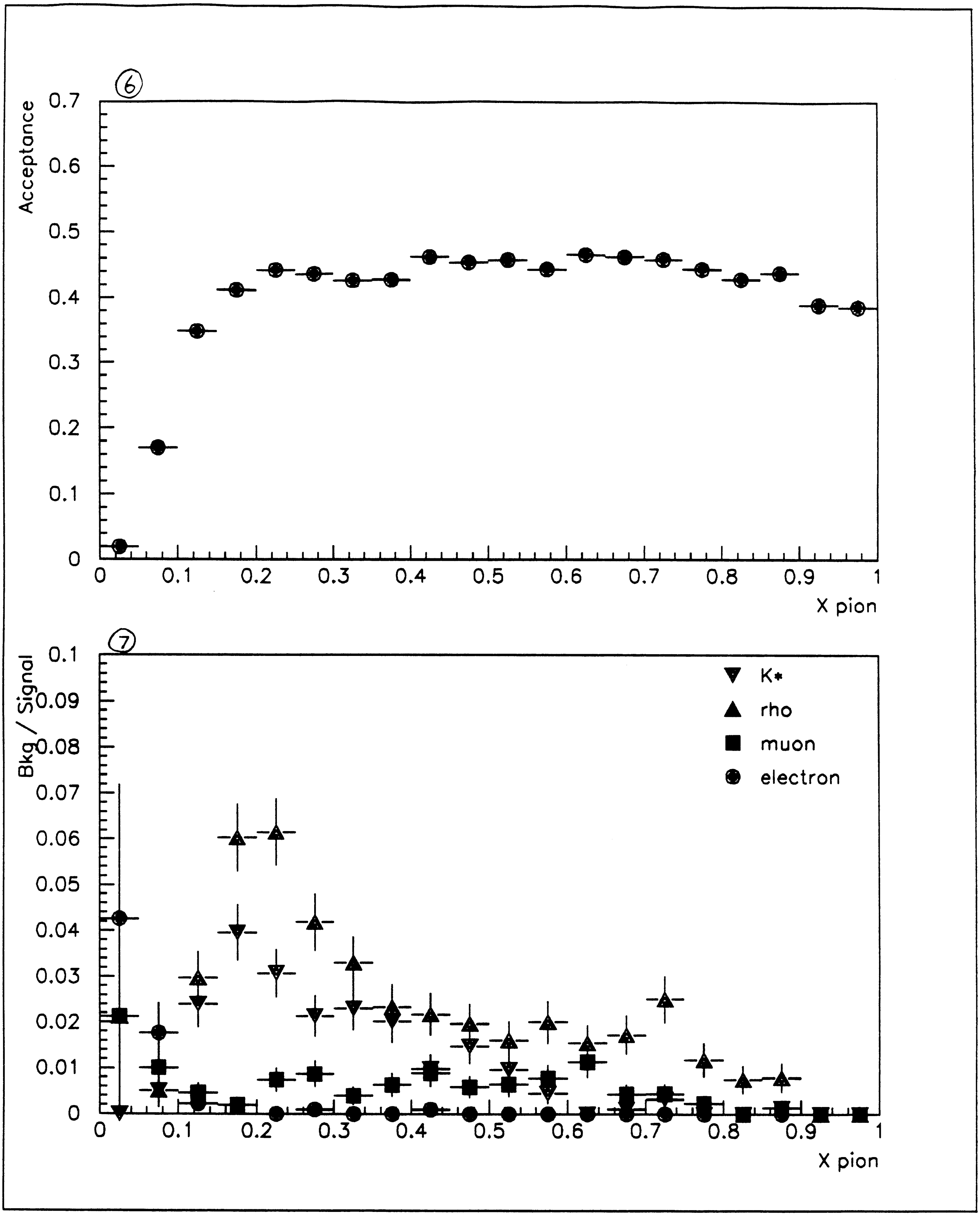


Figure 8

The result of the helicity fit with the old analysis.

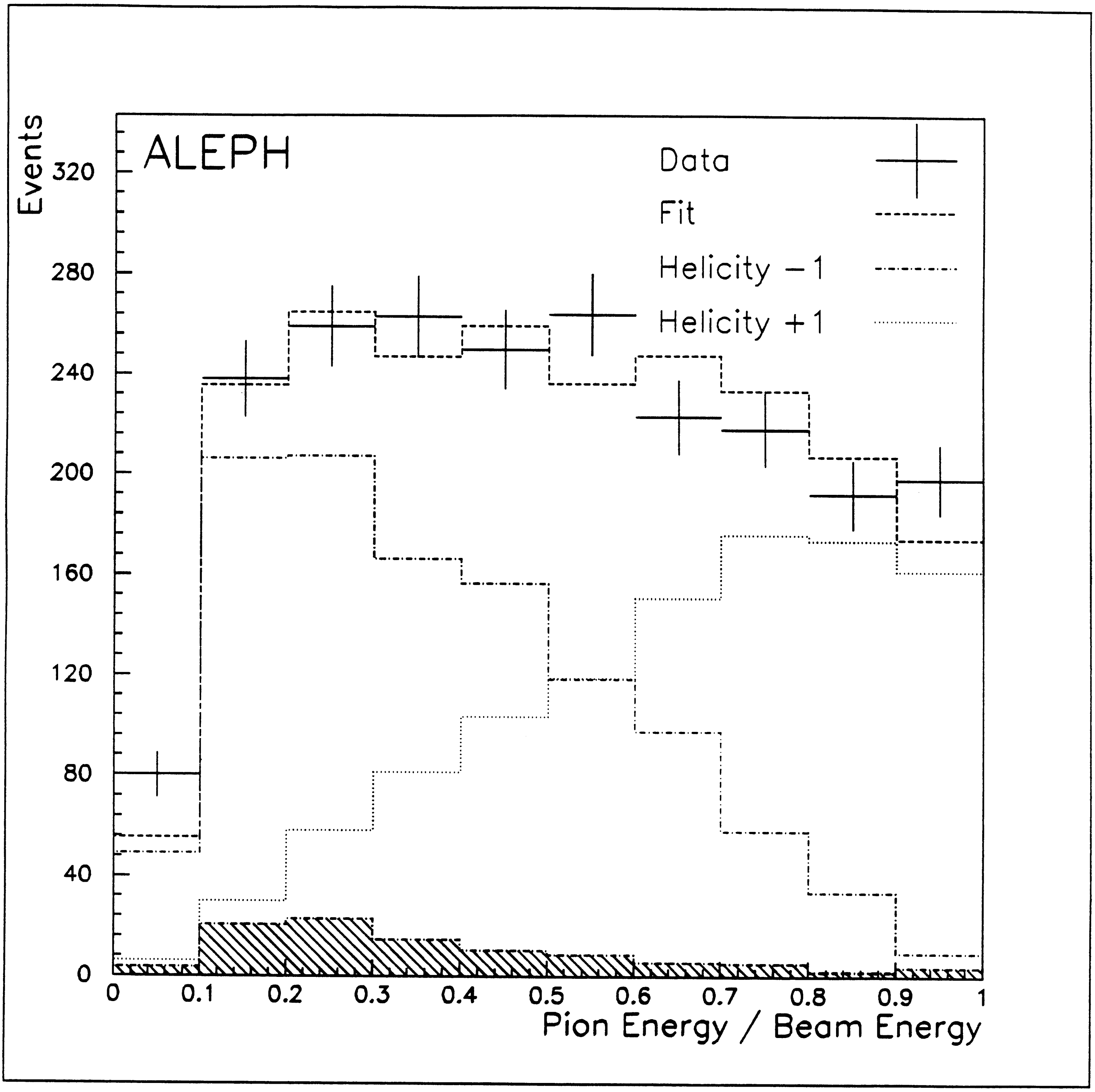


Figure 9

The distribution of GAMPEC "front" clusters in energy versus distance from the charged track impact. If there is more than one cluster, the one which is at the greatest distance from the track is plotted.

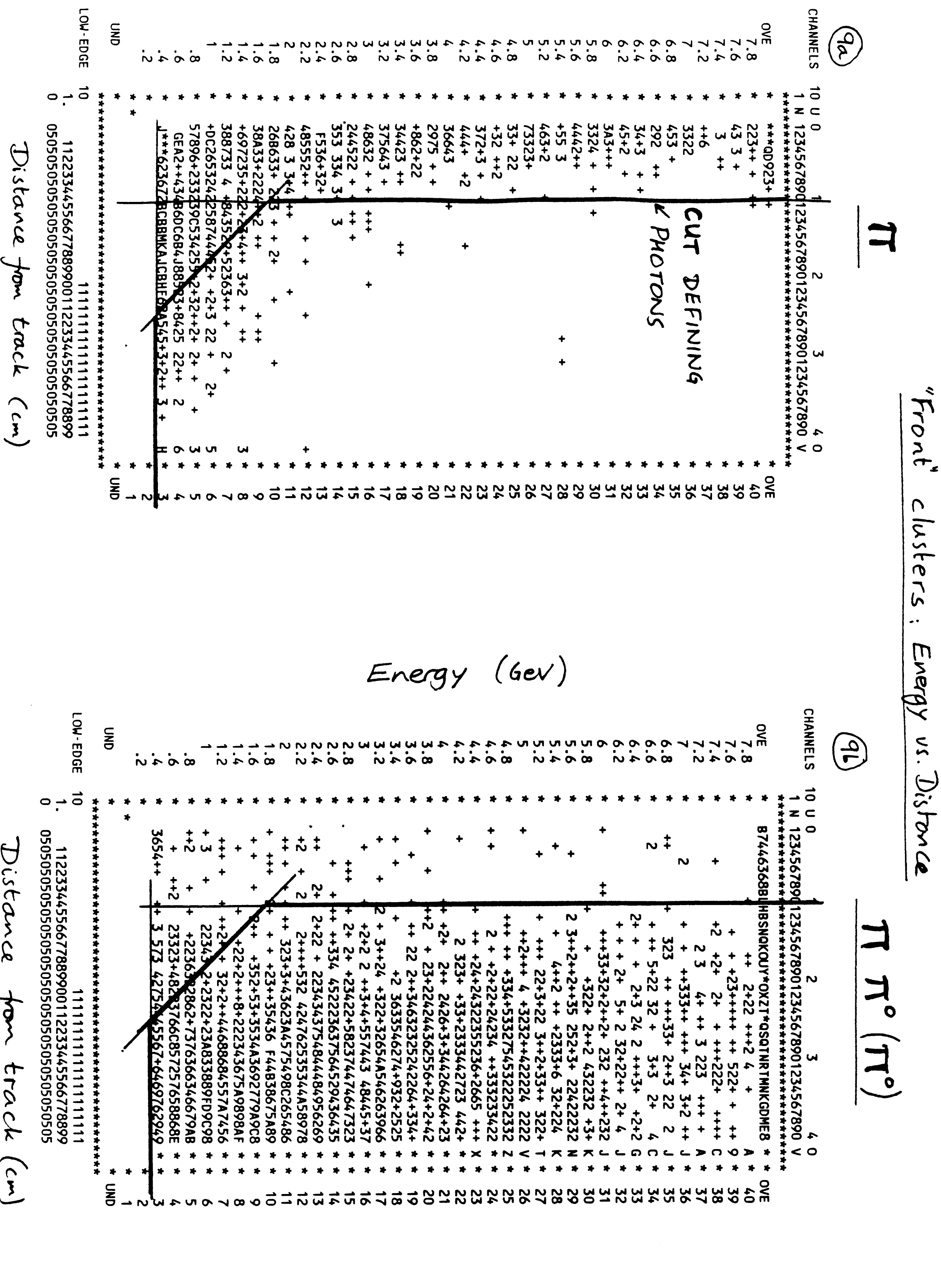
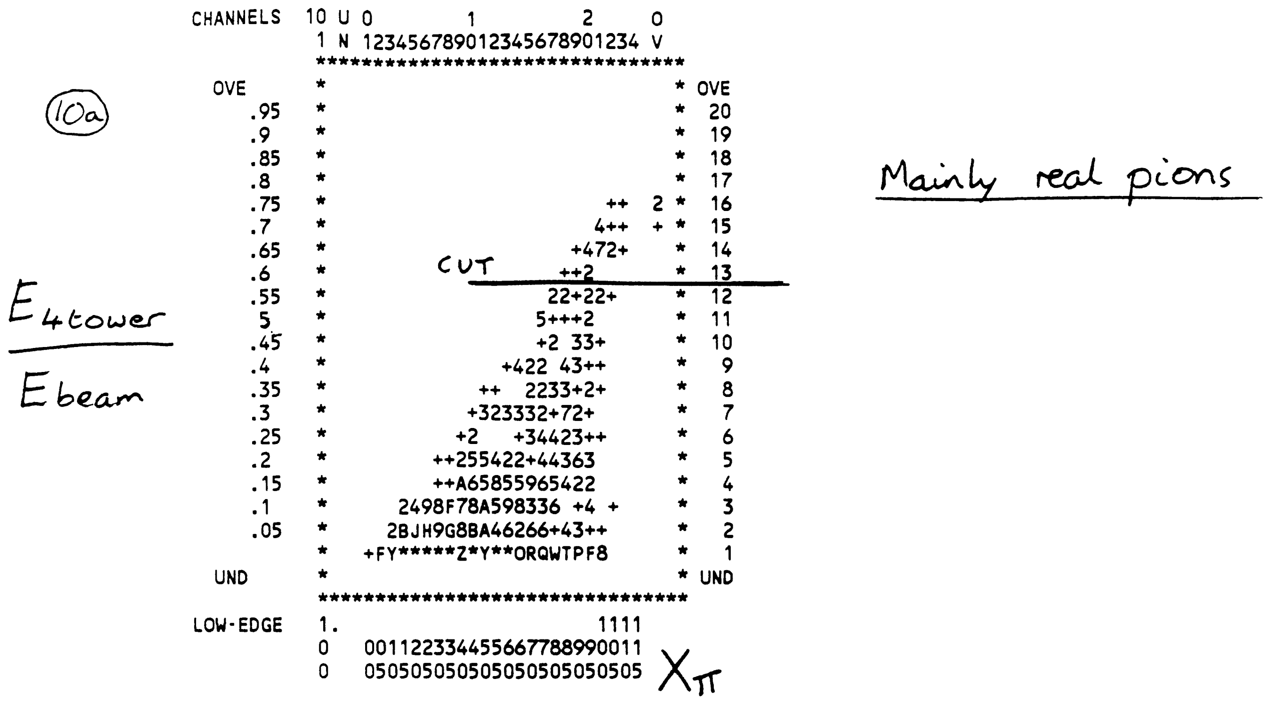
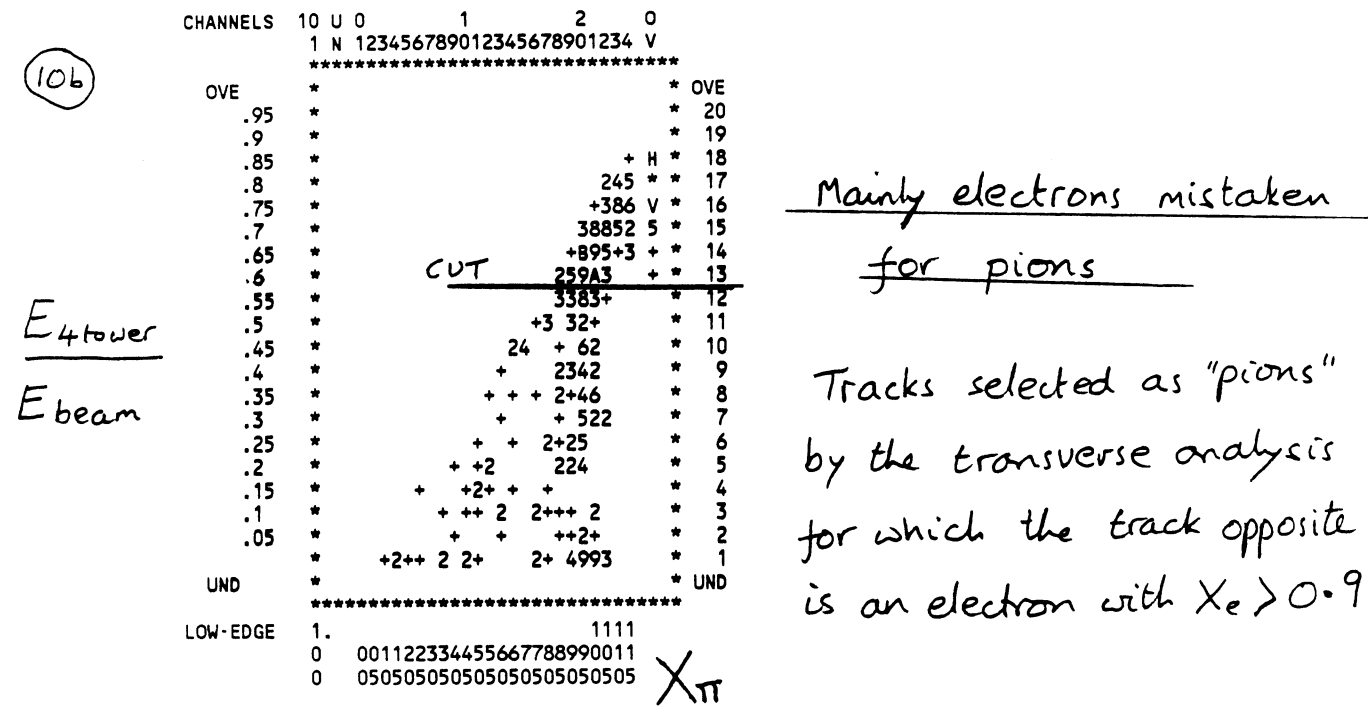


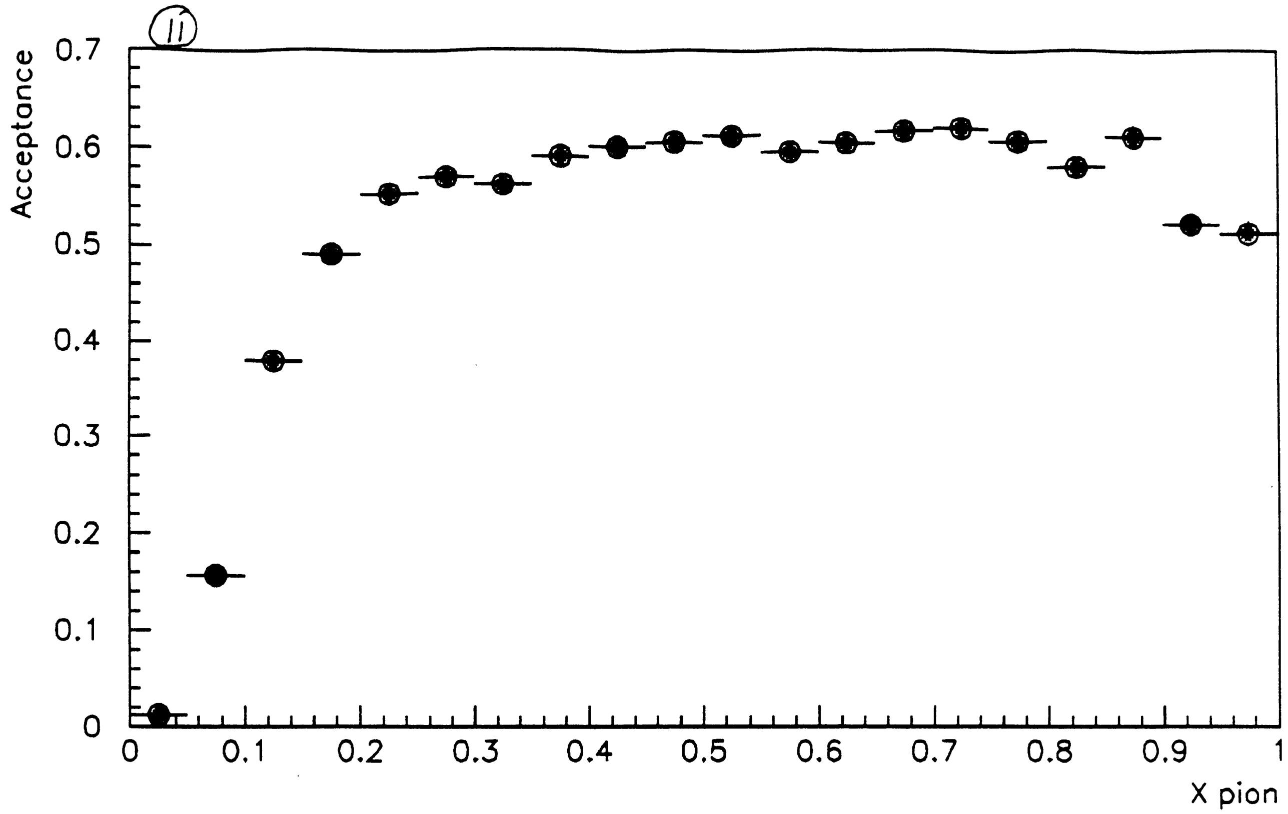
Figure 10 The cut on 4_tower energy / beam energy which is used to strengthen the rejection of Bhabhas from the pion candidates in the new analysis.





Figures 11 and 12

The acceptance of the new analysis for pion alysis + and the background in the pion sample from other tau decay channels.



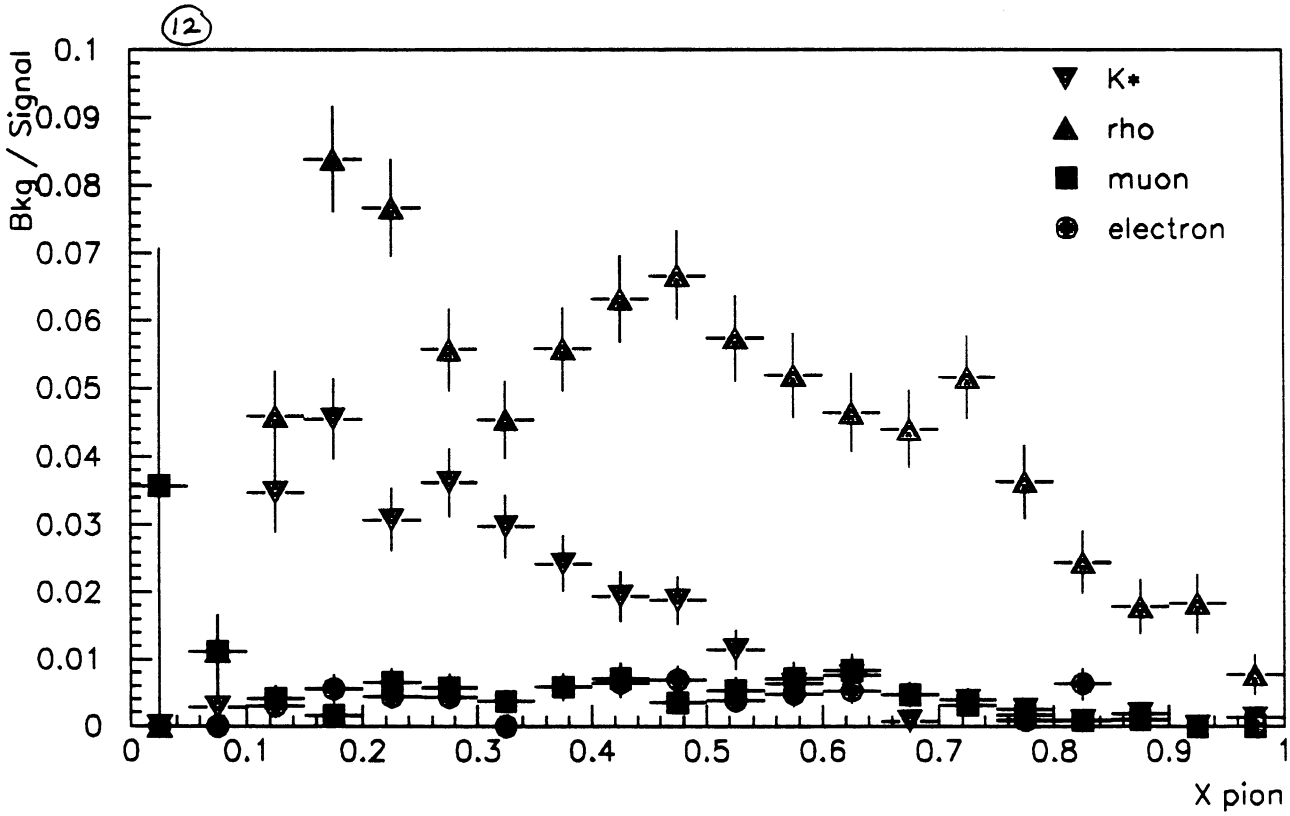


Figure 13

The result of the helicity fit with the new analysis.

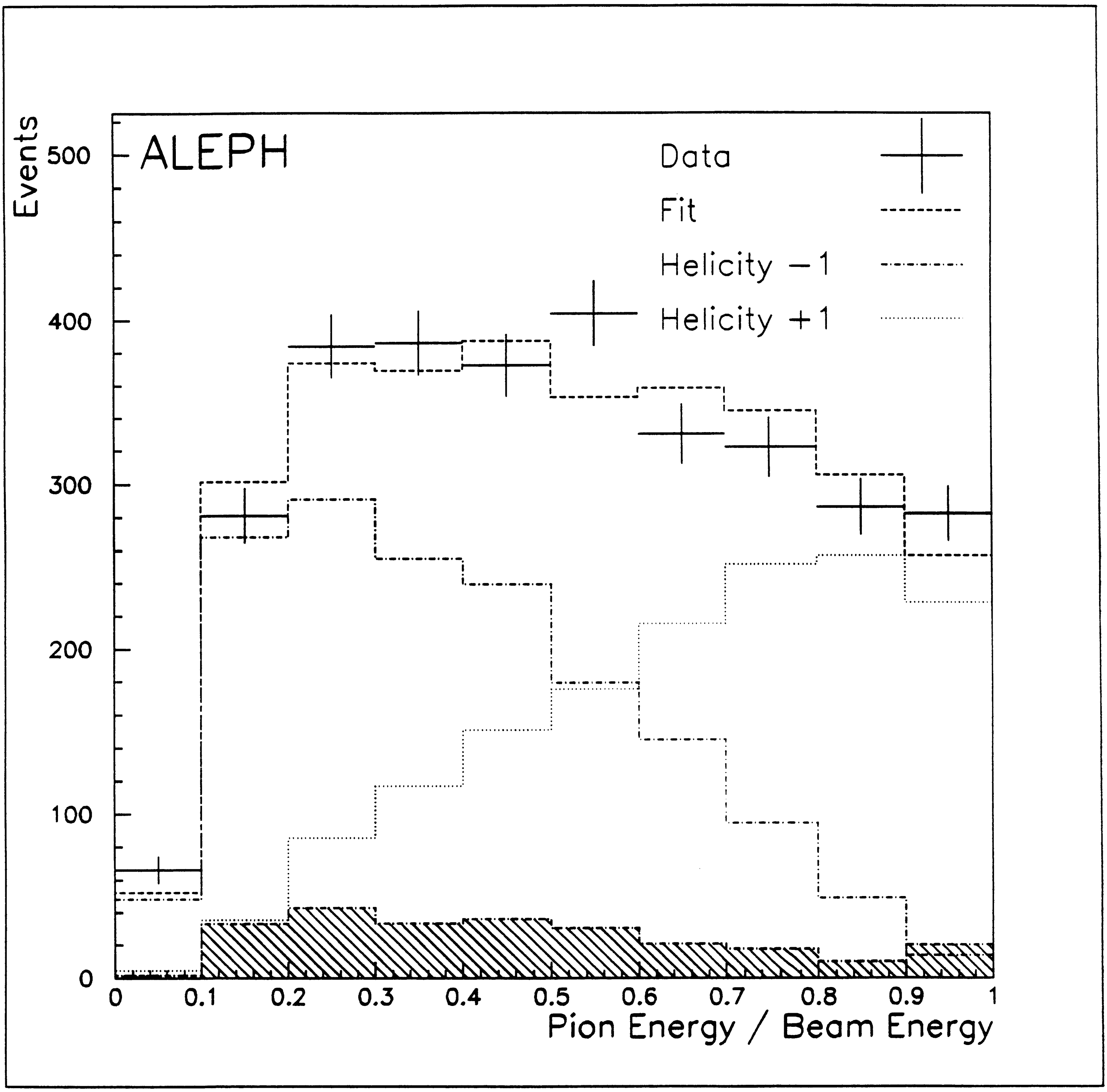


Figure 14

The probability that a pion will pass the geometrical and track quality cuts, as a function of pion energy.

Figure 15

The cuts used to define the rho test sample.

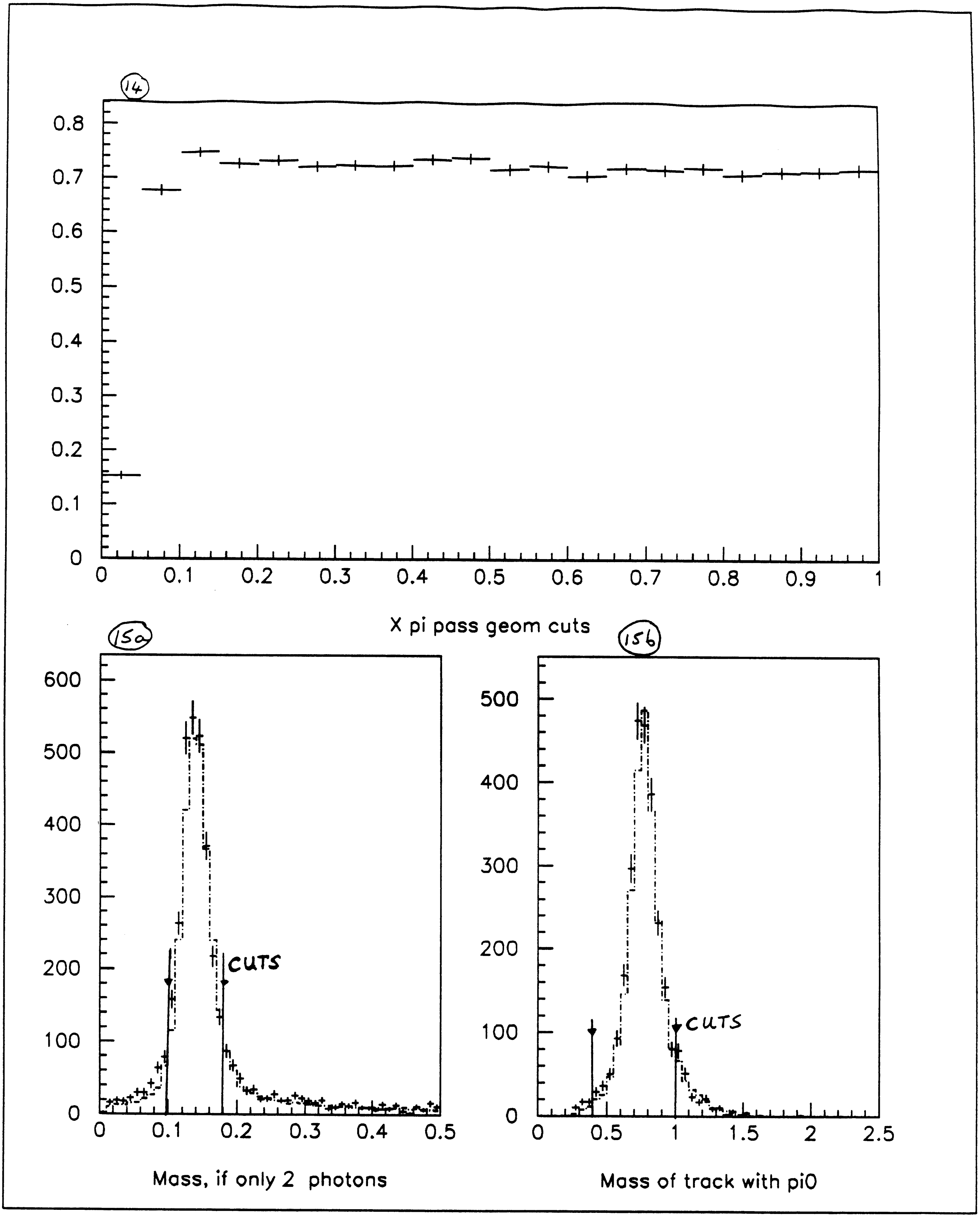


Figure 16

The acceptance for pions of the anti-muon cuts. Measured with the rho sample in both data and Monte Carlo. The straight line fit to the ratio data/MC (excluding the lowest bin) give a correction which must be applied to the polarisation.

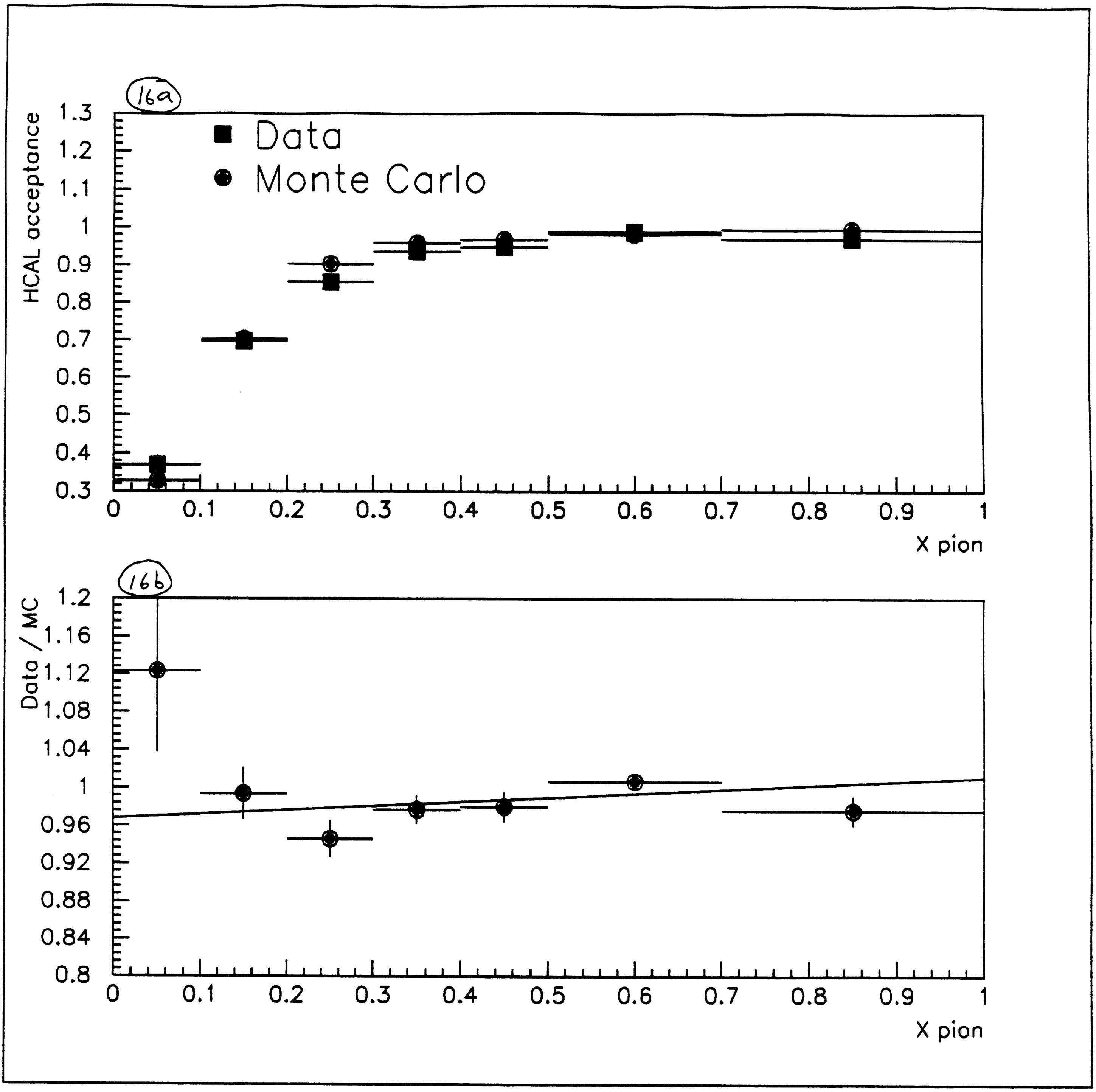


Figure 17

The acceptance of the old ECAL cut in test beam and Monte Carlo. The squares with horizontal error bars show how the data is re-binned to cover the whole X range.

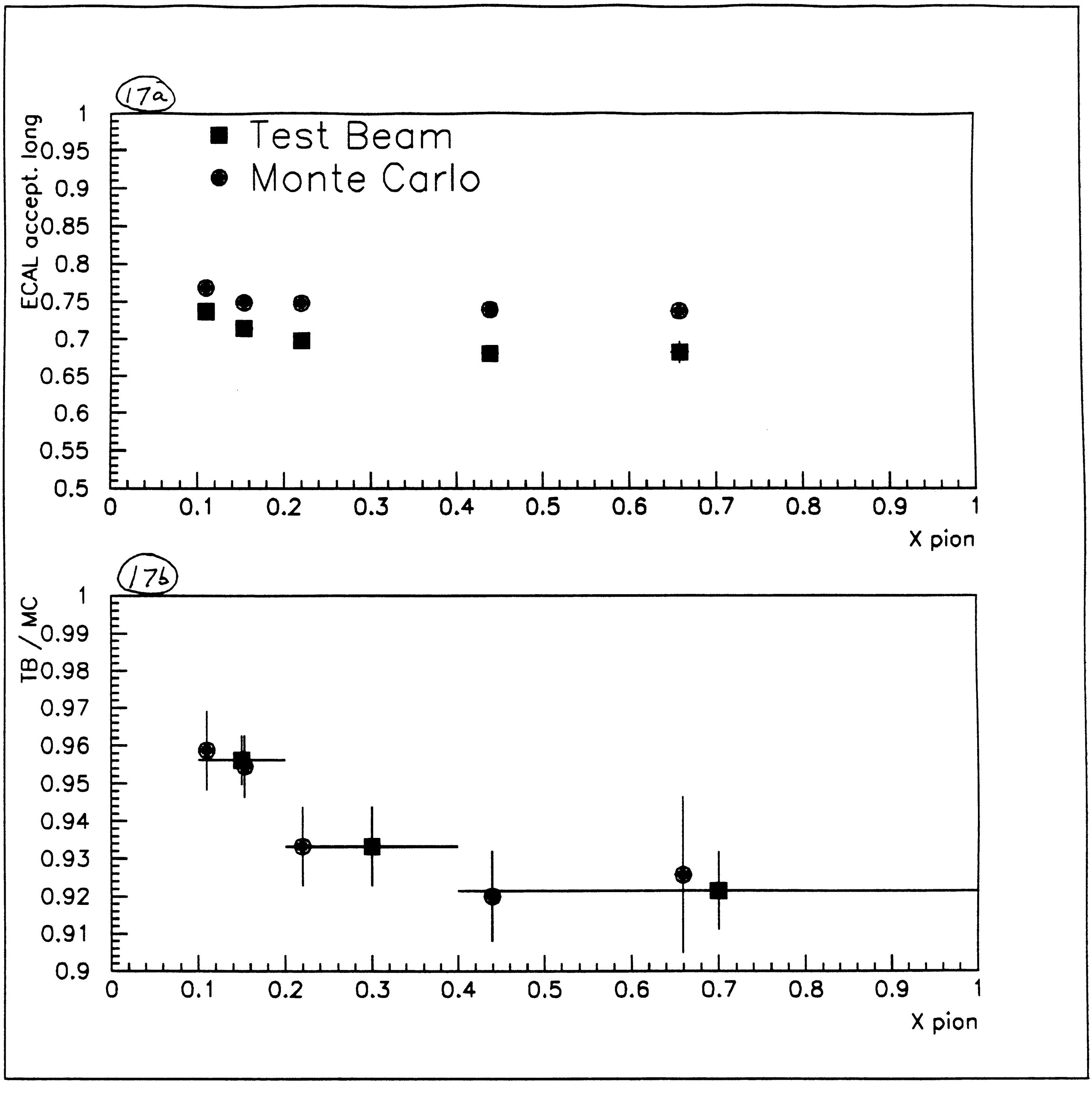


Figure 18

The acceptance of the new ECAL cut in test beam and Monte Carlo. The squares with horizontal error bars show how the data is re-binned to cover the whole X range.

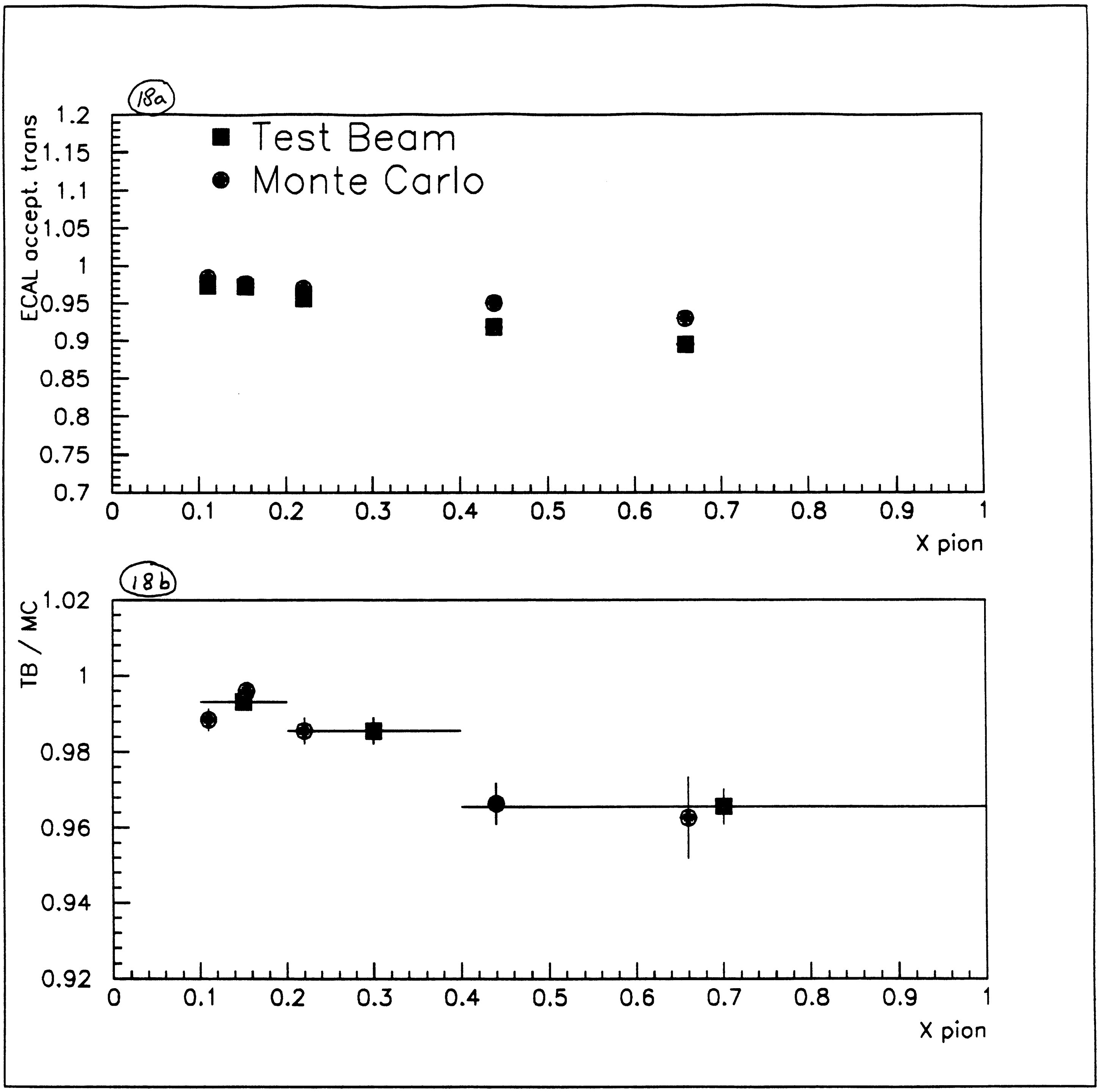


Figure 19

The distribution of GAMPEC "back" clusters in energy versus distance from the charged track impact. If there is more than one cluster, the one which is at the greatest distance from the track is plotted.

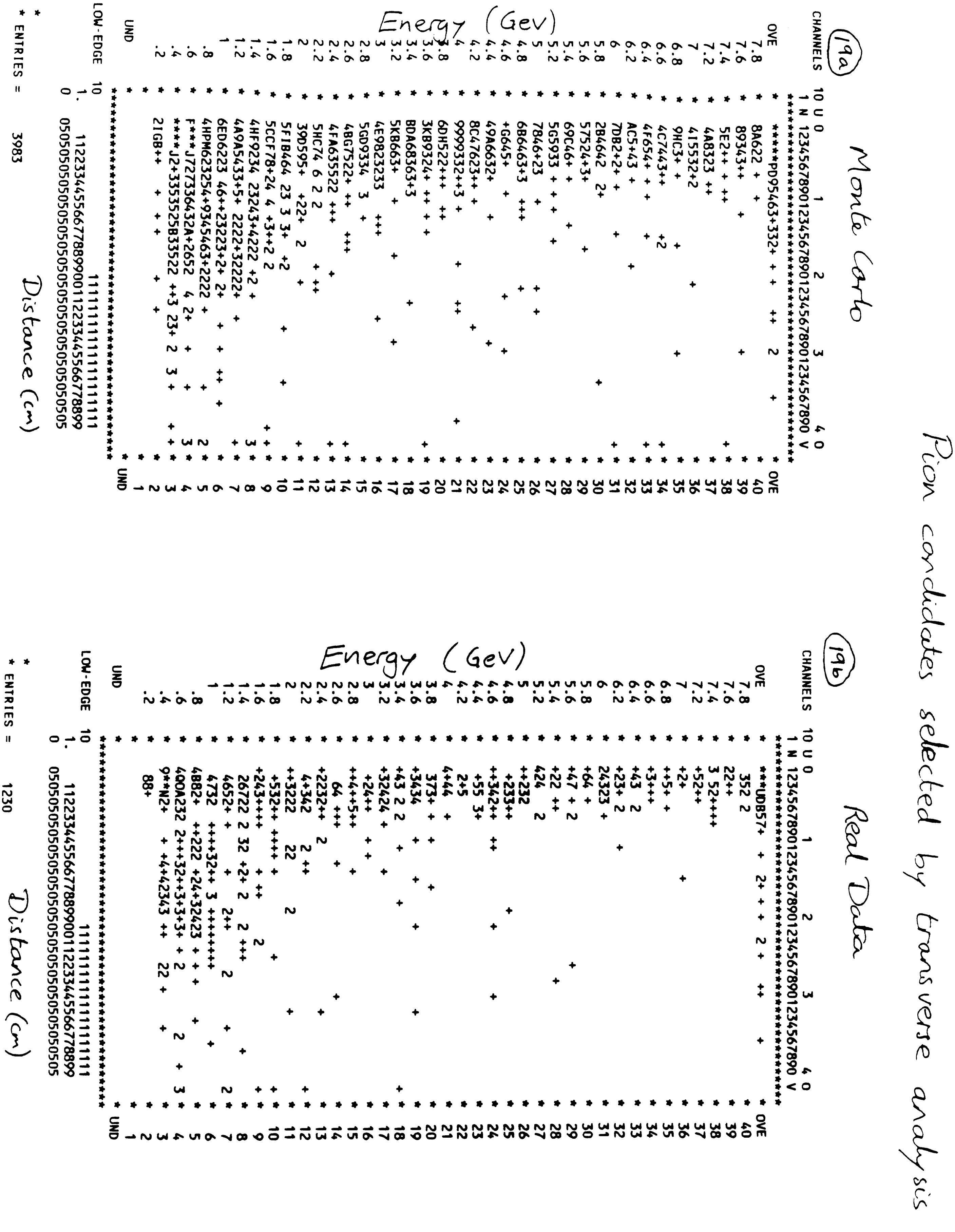


Figure 20

The amount by which pion acceptance would change if "back" clusters were considered to be possible photons.

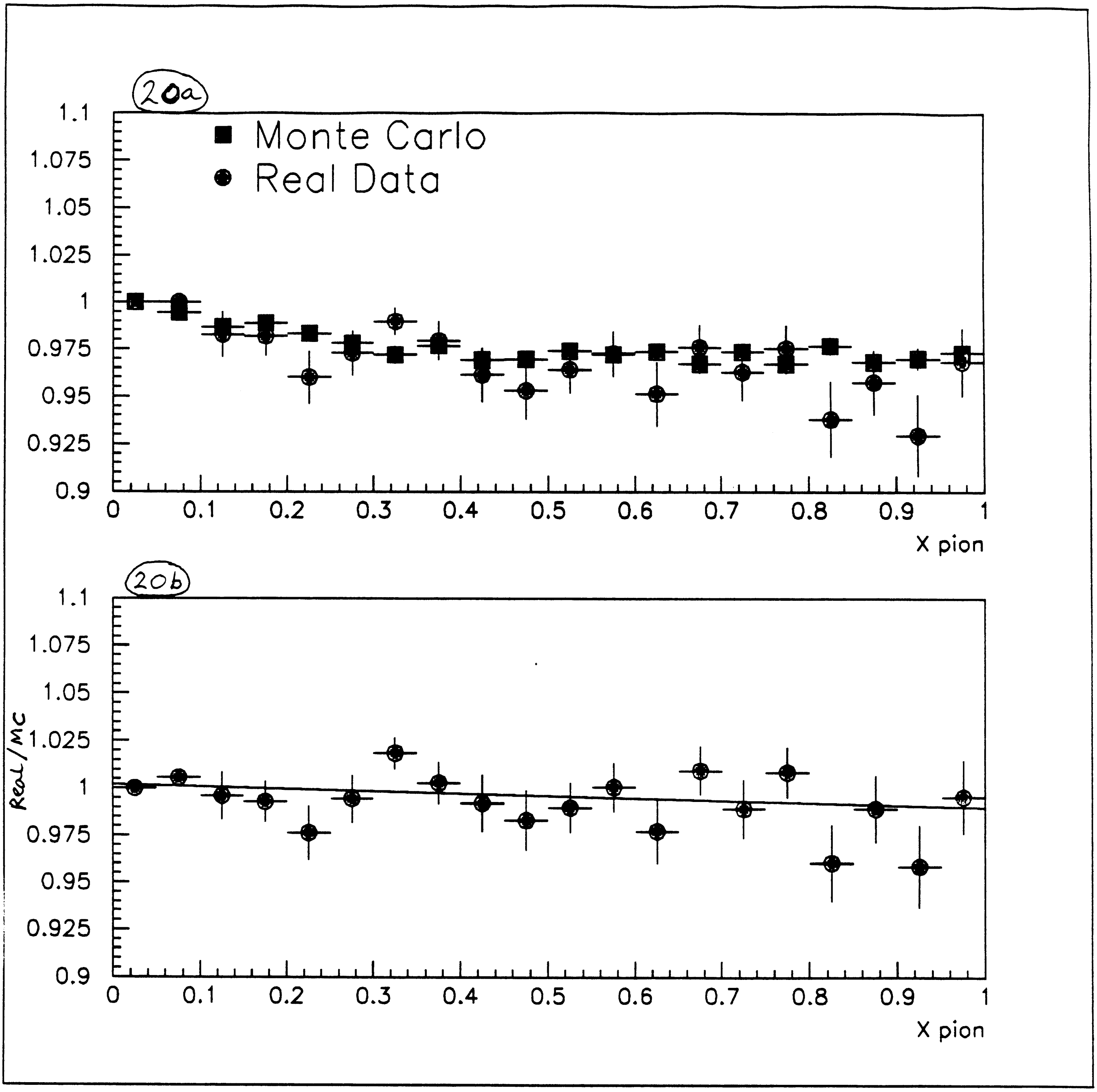


Figure 21

The E_calo / track momentum distribution of pion candidates selected from real data and from Monte Carlo.

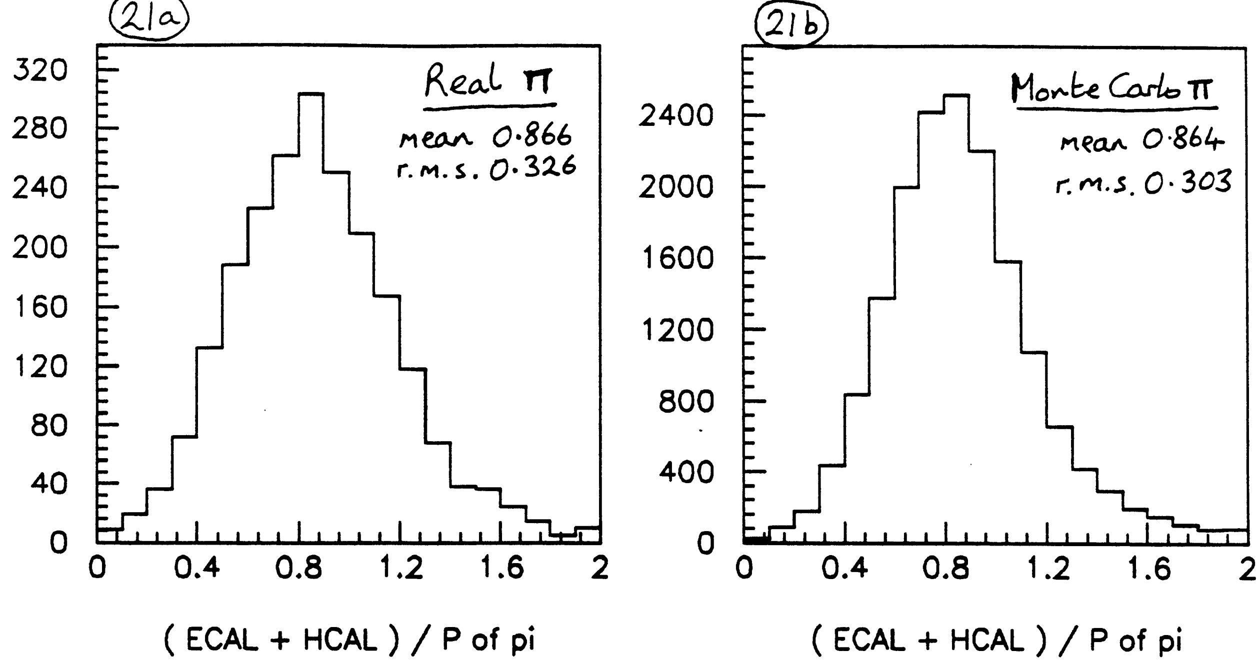


Figure 22

Polarisation as a function of polar angle.

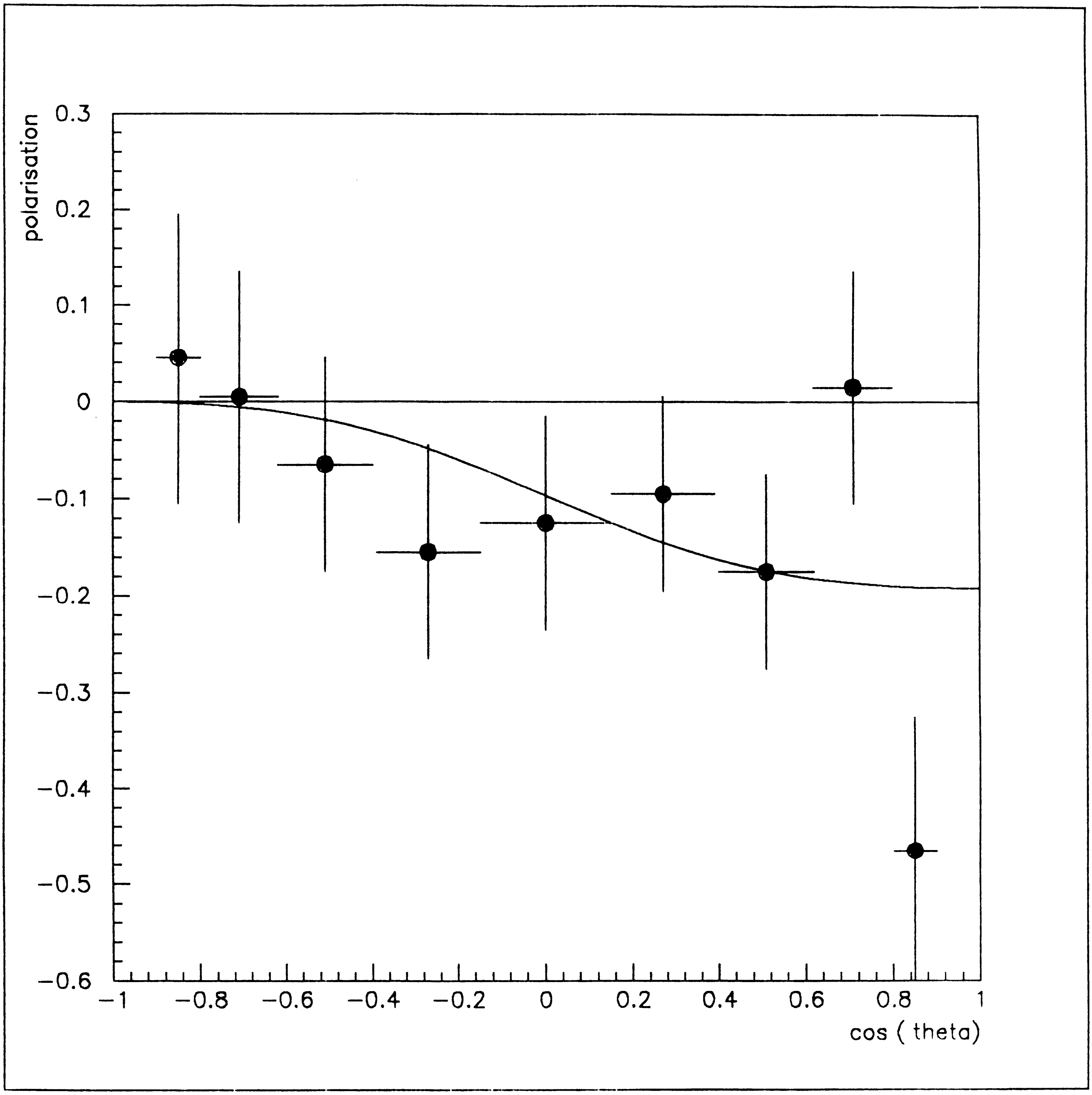
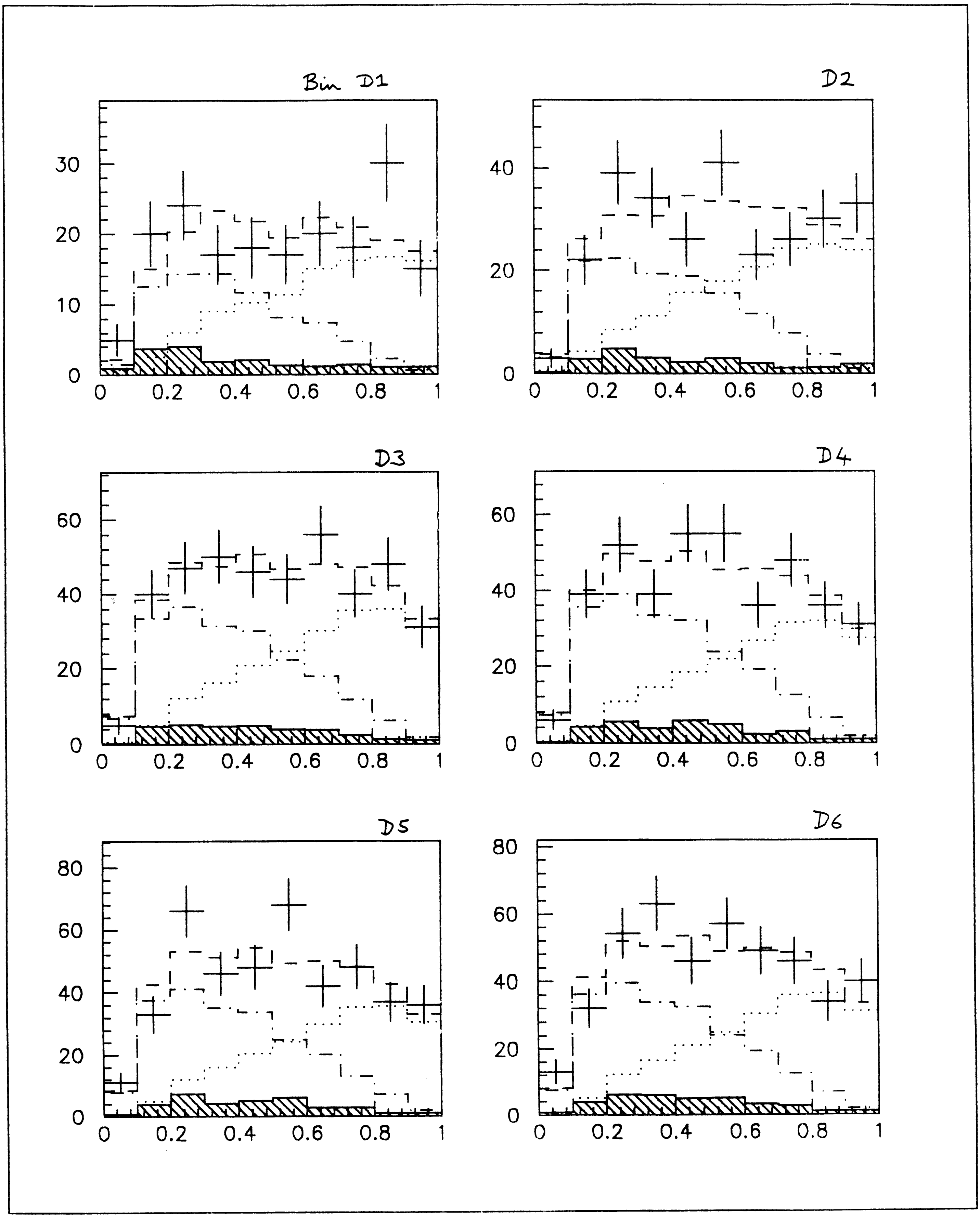
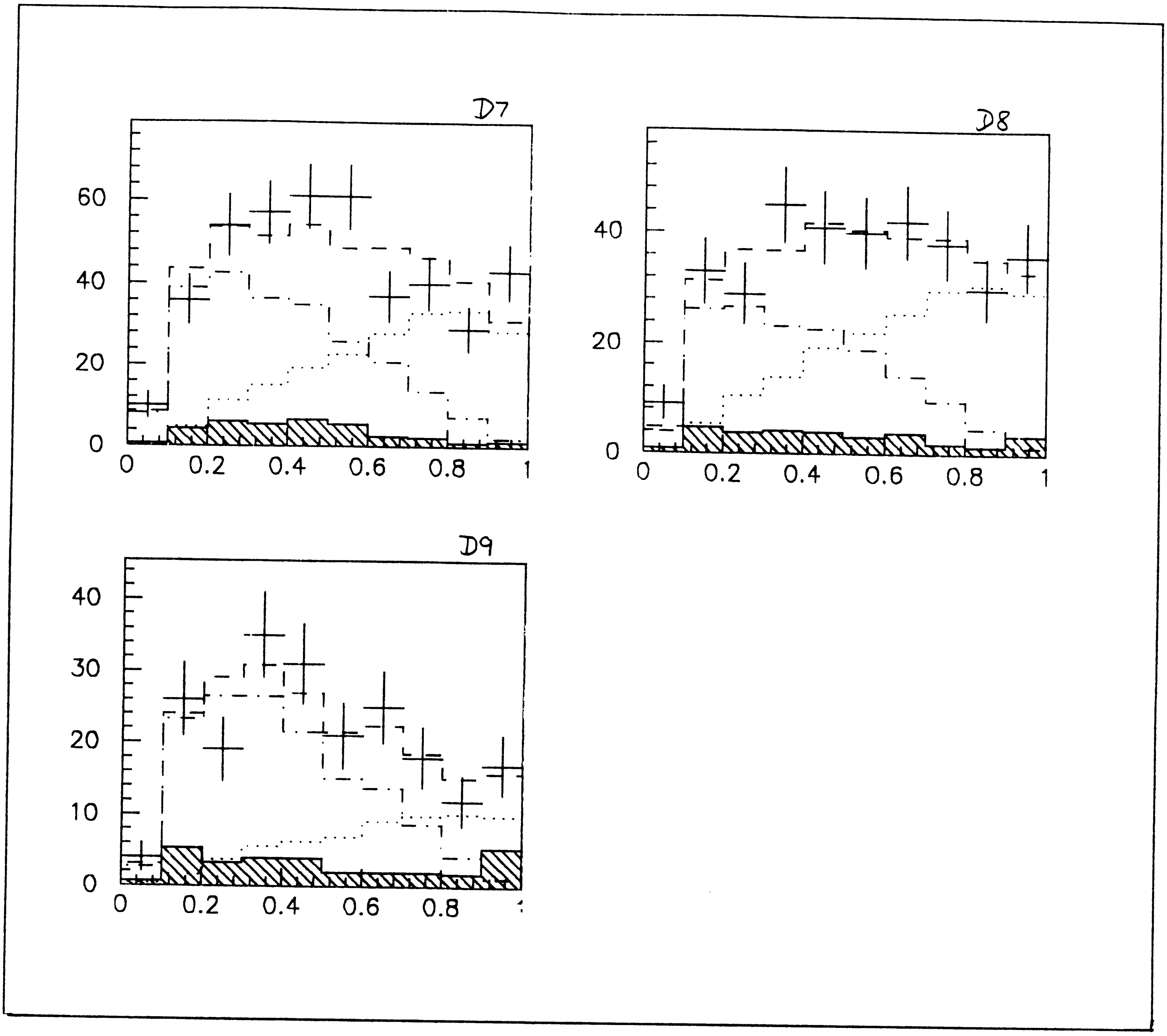


Figure 23

The polarisation fits in each of the nine bins.




D7
0
20
40
60
0.2
0.4
0.6
0.8
1
D8
0
20
40
0.2
0.4
0.6
0.8
1
D9
0
10
20
30
40
0.2
0.4
0.6
0.8