Chapter 4

Background from non-heavy flavors

In the previous chapter we described the selection criteria to make the sample of the $b\bar{b}$ production candidates. We will call this sample as a "whole electron sample". Although we have applied tight electron cuts, we still have three types of backgrounds in the whole electron sample: (i) charged hadrons faking electron, (ii) electrons from photon conversions and (iii) electrons from c-quarks. In the latter two backgrounds, we have real electrons. We estimate the residual number of photon conversions using the efficiency of the method used to reject conversions. The third background, electron from c-quarks, are difficult to estimate. The method to estimate this background is described in the next chapter.

In this chapter, we describe how to estimate the non-heavy quark backgrounds, hadrons faking electrons and photon conversions.

4.1 Hadrons faking electrons

The electron quality cuts which we have applied to the data mainly use the shower shape of the electrons and thus it is effective for removing the events with multi-photon and hadron overlapping. However, this method has a difficulty to remove the hadrons faking electrons because the shower shape of those hadrons is similar to that of the real electrons. In order to estimate the fraction of those hadrons, we use the CPR charge distribution. At first we make the templates for real electrons and hadrons using the control samples as described below.

4.1.1 Control sample for CPR templates

Real electron sample

A real electron sample is made from a sample of events with photon conversion identified using the conversion finding method as described in Sec. 3.1.3. We apply the following selection criteria to make this sample:

- Apply all electron identification cuts shown in Table 3.1, except for the requirements of CPR, conversion rejection and SVX hit
- Identify a conversion using the conversion finding method: $|\delta S| < 0.2(\mathrm{cm})$ and $|\delta \cot\theta| < 0.06$
- Require the conversion to occur in the CTC inner wall: $30 > R_{e^+e^-} > 20$ cm
- Require the measured Q_{CTC} (see Sec. 2.2) for the conversion partner track to be larger than the predicted value for an electron track by one sigma
- $VTX_{occ} < 0.2$

The CPR distribution for this "pure" electrons are shown in Fig. 4.1(a). In order to parameterize the distribution, we fit this distribution to the following empirical function:

$$f(x) = P_1 x^{P_2} exp\left[P_3 x^{P_4}\right] + \frac{P_5}{P_7} exp\left[-\frac{1}{2}\left(\frac{x-P_6}{P_7}\right)^2\right].$$

The obtained fit function is used as a template for the real electrons.

Hadron-rich sample

A hadron-rich sample is selected by removing the events satisfying the HAD/EM requirement for electron selection in Table 3.1. We assume that the energy deposition of hadrons in the CPR can be fitted to a Landau distribution since the CPR is a gas proportional chamber. We fit the hadron-rich sample to a Landau distributions plus the electron template. We practically use a sum of two Landau distributions to make a better fit. The fit results are shown in Fig. 4.1(b). The sum of two Landau distribution is used as a template for the hadrons faking electrons.

4.1.2 Results of CPR fit

The amount of the hadrons faking electrons in the whole electron sample is estimated by fitting the CPR charge distribution to the sum of electron and hadron templates. The CPR charge cut listed in Table 3.1 is not applied to this sample. The fit results for the whole electron sample and the diffractive candidates are shown in Fig. 4.2 and Fig. 4.3, respectively. The hadron fraction of the sample after applying the CPR charge cut is calculated using the cut efficiency for hadrons and electrons, 46% and 93%. We obtain the hadron fraction of 25.8±0.2(stat)±0.6(syst)% for the whole electron sample, and 30.4±5.1(stat)±0.8(syst)% for the diffractive candidates. The systematic uncertainty is estimated by changing the template shapes according to their uncertainties.

4.2 Photon conversion electrons

The method to reject the photon conversion events is based on finding the partner track of the trigger electron. Once the conversion finding efficiency

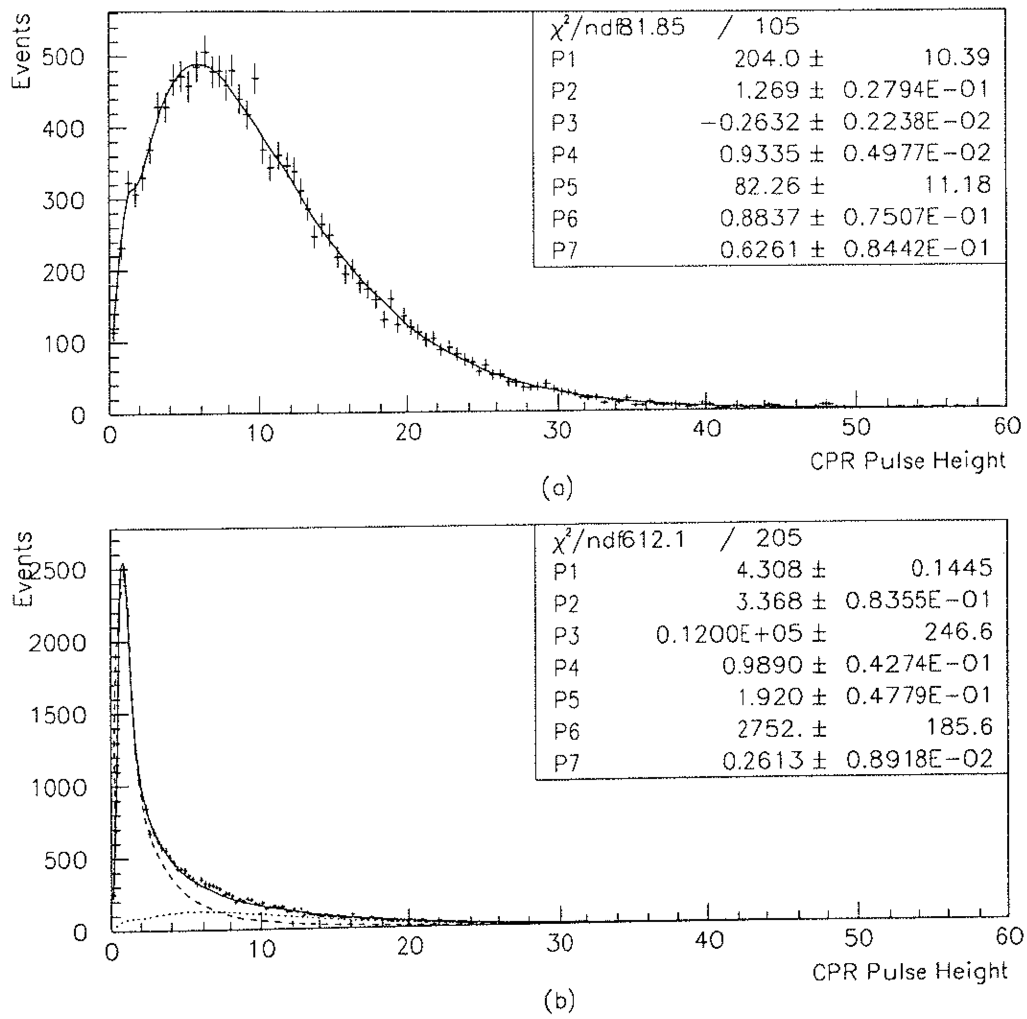


Figure 4.1: (a) The CPR charge distribution of the control sample for the real electrons. (b) The CPR charge distribution of the control sample for the hadron-rich events.

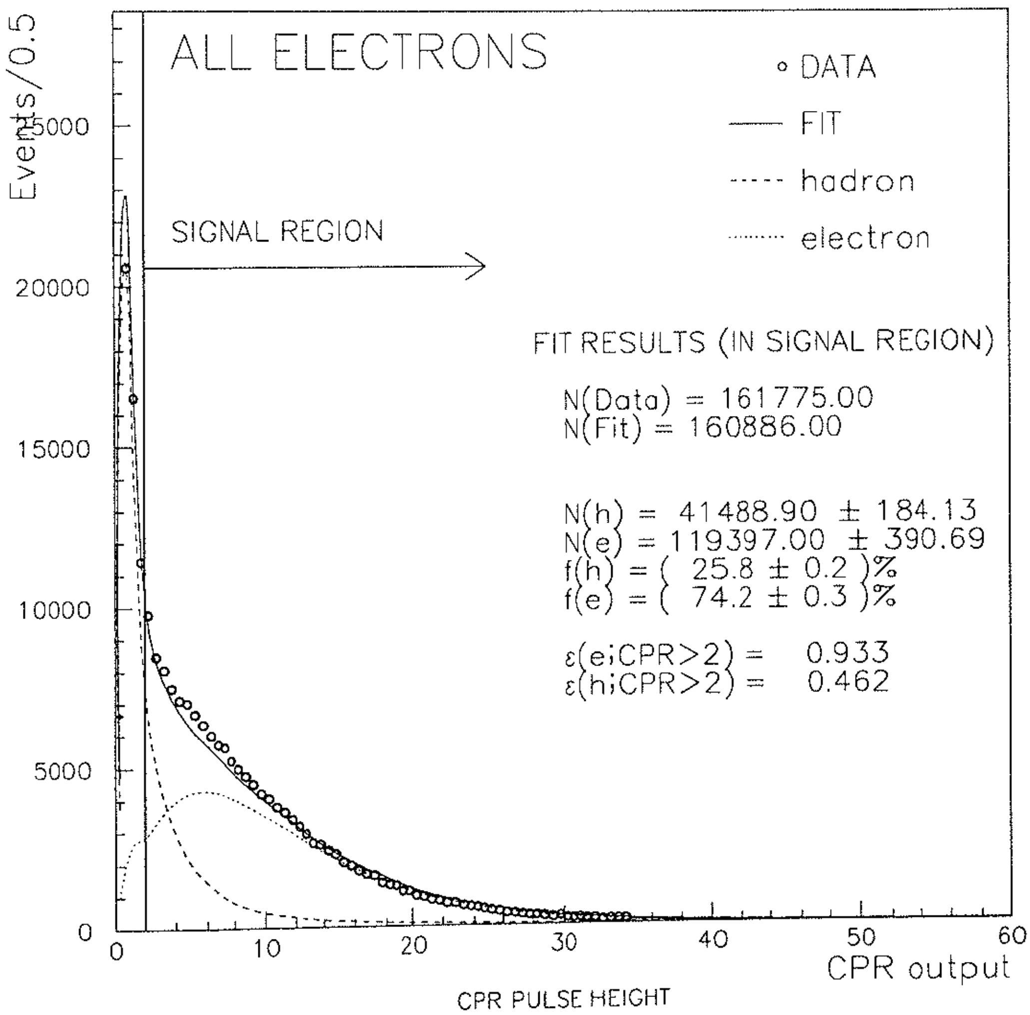


Figure 4.2: The CPR charge distribution for the whole electron sample. Open circle represents the CDF data. The solid curve shows the fit to a sum of the two templates, the electron (dotted) and the hadron (dashed).

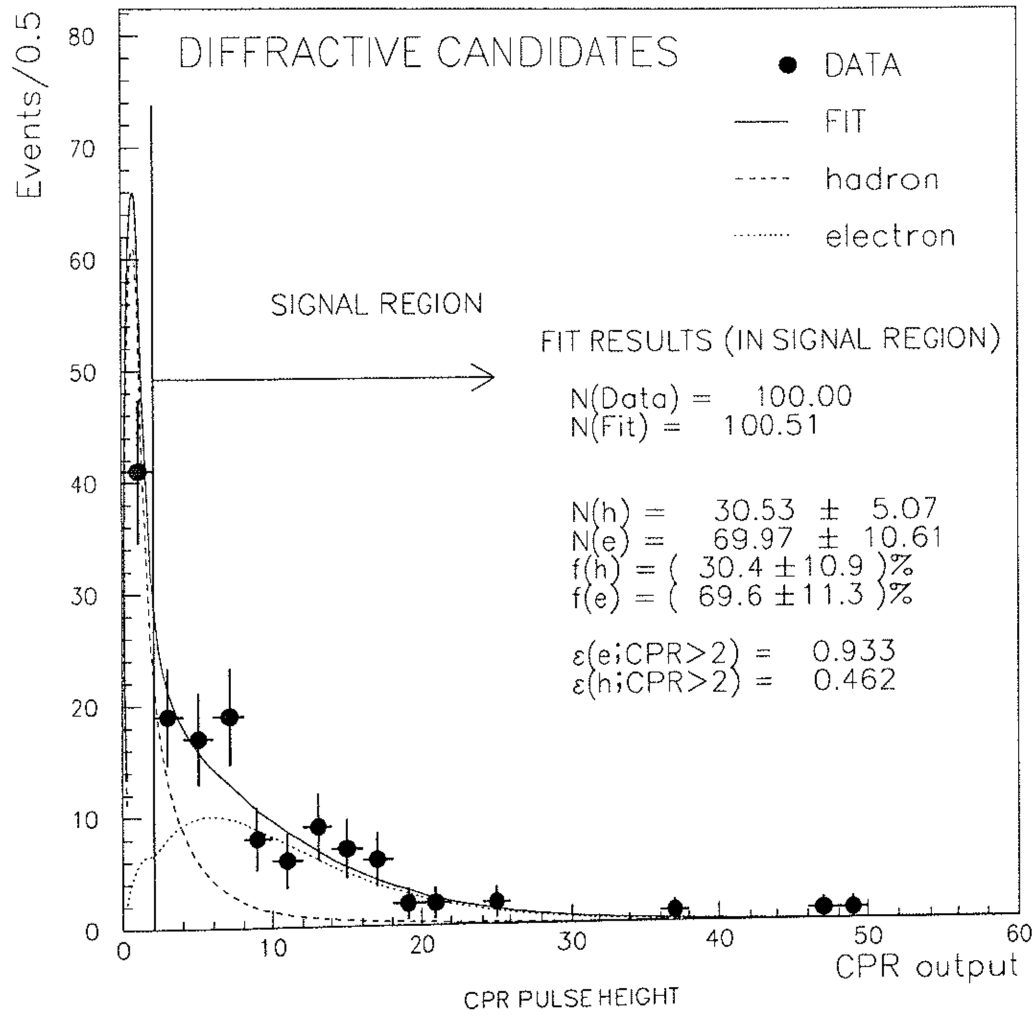


Figure 4.3: The CPR charge distribution for the diffractive candidates. The solid circle represents the CDF data. The solid curve shows the fit to a sum of the two templates, the electron (dotted) and the hadron (dashed).

is known, the residual number of the conversions is calculated by,

$$N_{conv}^{resid} = (1 - \varepsilon_{conv}) \times \frac{P \times N_{conv}^{tag}}{\varepsilon_{conv}} \tag{4.1}$$

where ε_{conv} is the conversion finding efficiency, N_{conv}^{tag} is the number of conversions tagged by the method and P is a fraction of the conversions.

In the following sections, we describe the conversion finding efficiency and the estimation of the residual conversion in the sample.

4.2.1 Conversion finding efficiency

The conversion finding efficiency is studied using the control sample obtained by the VTX occupancy method. The VTX occupancy method identify conversion electrons created outside the VTX ("outside-conversion"). So this method is independent of the conversion finding method described in the preceding section. The "outside-conversion" leaves no tracks in the VTX and thus the VTX_{occ} become low. We select those kind of conversions by requiring the VTX_{occ} to be less than 0.2 and also required no SVX hit for the track to ensure the outside-conversion.

The conversion fraction in this sample is measured using the CPR charge distribution. The CPR distribution for the VTX conversion sample is shown in Fig. 4.4. We categorize this sample into two components: (i) outside-conversions correctly tagged with the VTX and (ii) any events accidentally tagged with the VTX. Assuming that a probability of the accidental tagging is independent of a physical process which produces a trigger electron, we use the CPR distribution for the VTX-untagged events as the accidental tagging component. In order to estimate the fraction of correctly tagged conversions, we fit the CPR distribution with a sum of the two templates, real electron and untagged events. The fit results are also shown in Fig. 4.4. The CPR fit yields that the fraction of real conversion in this sample is 93%. We further apply a tighter CPR requirement (CPR>6.0) to this sample and obtain the control sample of outside-conversions with 95% purity.

Estimation from tagging rate

The conversion finding method tags 79.5 ± 1.0% of the conversions in the control sample. Thus the conversion finding efficiency is found as ε^{conv}=79.5 ± 1.0(stat)%. The starting point of the conversion pair is obtained with the conversion finding method as shown in Fig. 4.5 in the radial coordinate. A peak around the radius of 20~30 cm corresponds to conversions occurring in the wall between the CTC and the VTX as expected from the method to make this sample.

Estimation from ε^{trk} and ε^{cut}

The efficiency of the conversion finding method is also estimated with a different approach using the same control sample. We divide the efficiency into two factors, the efficiency of the CTC to accept the partner track (=ε^{trk}) and the efficiency of the topological cut used in the algorithm (=ε^{cut}).

In order to estimate the tracking efficiency ε^{trk}, we plot the p_T spectrum of the partner track as shown in Fig. 4.6. We further require the radial conversion point to be in the CTC wall (20< $R_{e^+e^-}$ <30cm) to increase a purity. A lack of events in a low momentum region below ~400 MeV/c is due to the limited acceptance of the CTC for low momentum particles. We fit the distribution to an exponential function in the p_T range of 0.5< p_T < 3.0 GeV/c to determine the number of events lack in the p_T region below 0.5 GeV/c. The tracking efficiency obtained by the fit is ε^{trk}=81.0±0.7%.

In order to estimate the topological cut efficiency ε^{cut}, we select conversion partner tracks with sufficiently high p_T for the reconstruction in the CTC (p_T >0.5 GeV/c). The distributions of δS and $\delta \cot\theta$ used in the conversion finding method are shown in Figs. 4.7(a) and (b). The topological cut efficiency is ε^{cut}=94.7±0.9%. By multiplying the above two efficiencies, ε^{trk} and ε^{cut}, the total efficiency of the conversion finding method is found as ε^{conv} = 76.7±1.0(stat)%.

Combined results

The agreement between the two estimations are fairly well. However, in the second estimation we assumed that the partner track p_T distribution has an exponential for without any proof. Therefore we used the first estimation and take the difference between the two estimations for the systematic uncertainty. The conversion finding efficiency is $\varepsilon^{conv} = 79.5 \pm 1.0(\text{stat}) \pm 2.7(\text{syst})$ %.

4.2.2 Residual conversions

Purity of the conversion-tagged sample

We have 161775 electrons in the whole electron sample after rejecting 25630 electrons as conversions using the conversion finding method. In order to estimate the residual conversions, we study the purity of the conversions tagged by the conversion finding method. The CPR distribution is used to estimate the purity of the conversions in the same way as described in the previous section by assuming that the accidental tagging probability is independent of the physical process. We thus fit the CPR distribution for the conversion-tagged sample with a sum of the two templates: (i) electrons as correctly tagged conversions and (ii) conversion-untagged sample as accidentally tagged events. The CPR distribution is shown together with a fit curve in Fig. 4.8. The fit yields 19092±284 conversions in the 25630 tagged events. The purity of the conversion tagged sample is 74.5±1.2%.

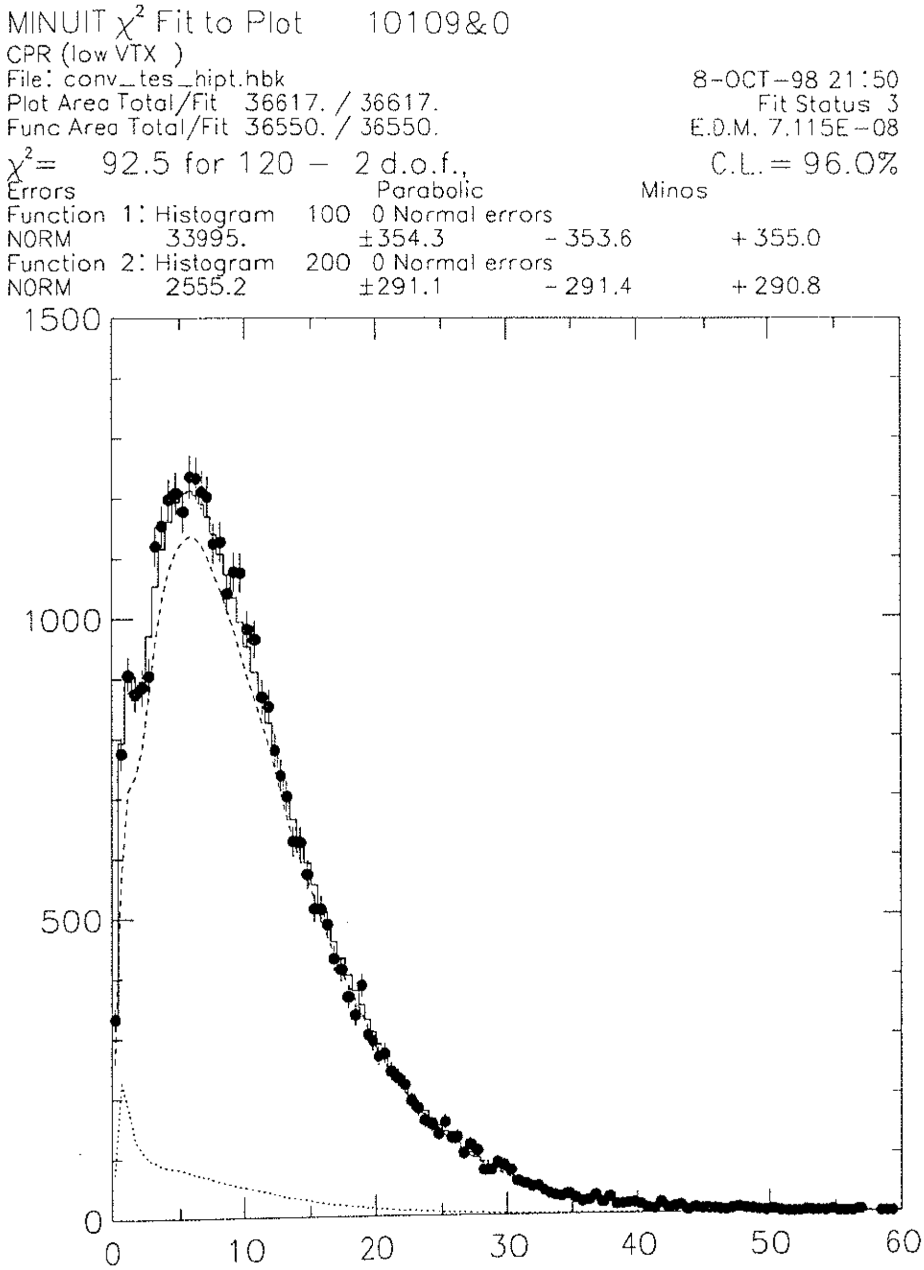


Figure 4.4: The CPR charge distribution for the VTX tagged conversion sample overlayed with the fit result. The dashed curve shows the contribution of pure conversion events. The dotted curve shows the contribution of accidentally tagged events.

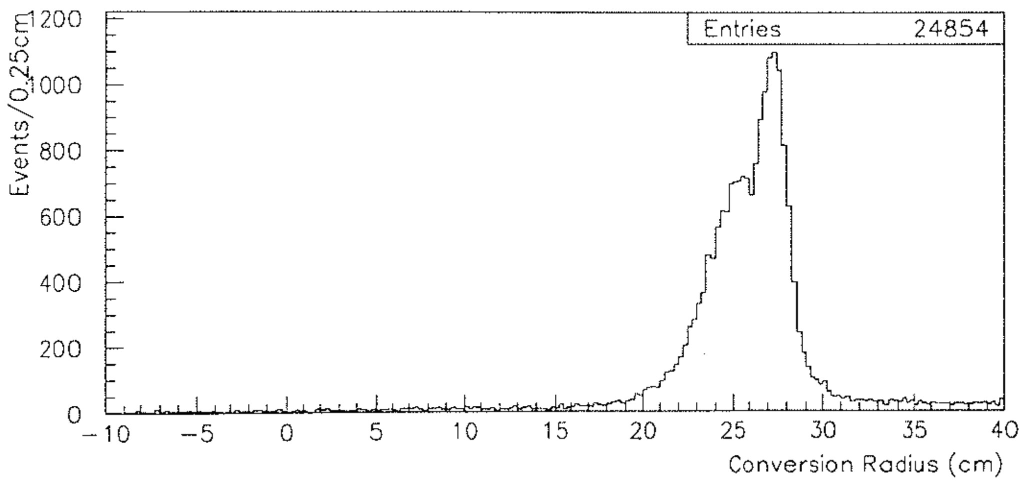


Figure 4.5: The radius where the conversion occurs in the detector. A peak corresponds to the thick material which forms the wall of the VTX and the CTC.

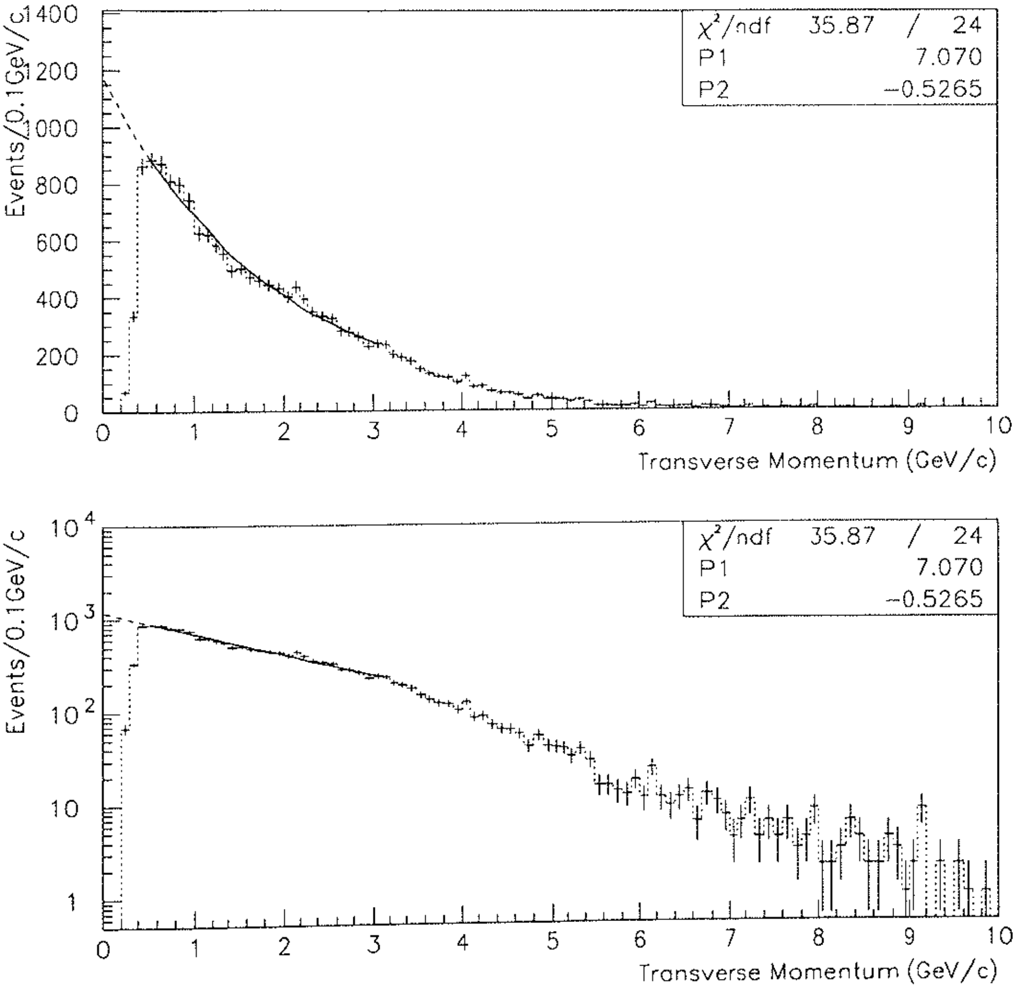
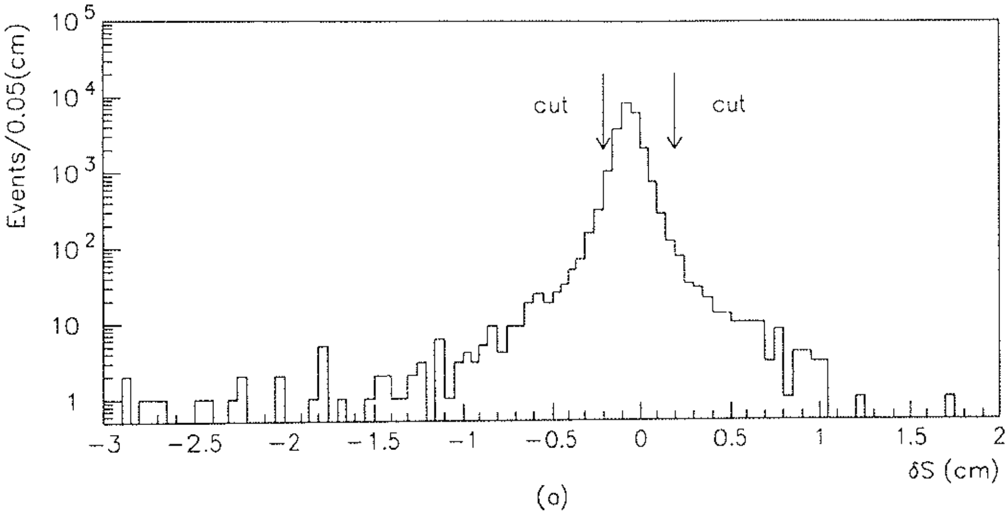


Figure 4.6: Transverse momentum of the conversion partner track.



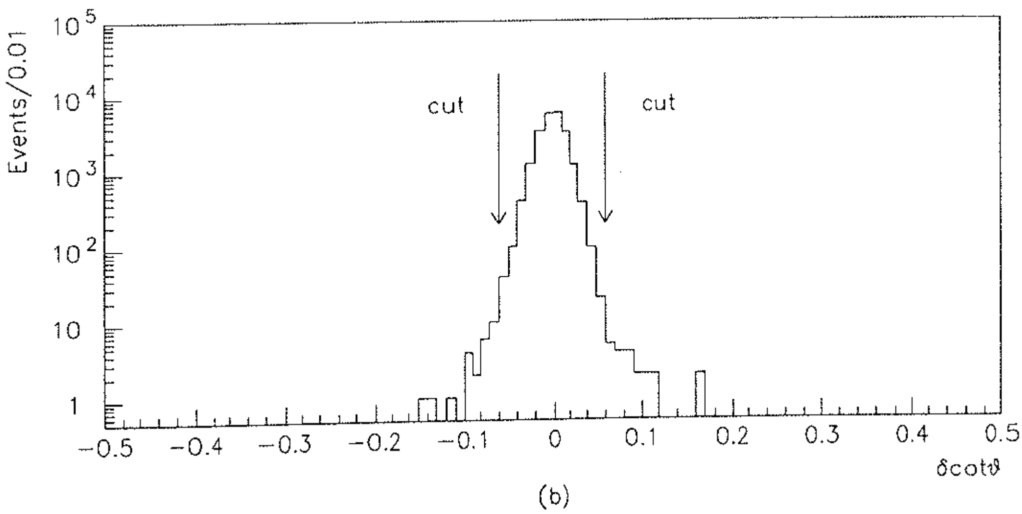


Figure 4.7: Distribution of the cut variable for conversion rejection. (a) separation of the two trajectory in the r-ϕ plane. (b) $\delta \cot\theta$ of the two track.

Residual conversions in the whole electron sample

The number of residual conversions are calculated with Eq. 4.1.

$$\begin{aligned} N_{conv}^{resid}(all) &= (1 - \varepsilon_{conv}) \times \frac{P \times N_{conv}^{tag}(all)}{\varepsilon_{conv}} \\ &= (1 - (0.795 \pm 0.029)) \times \frac{(0.745 \pm 0.012) \times 25630}{0.795 \pm 0.029} \\ &= 4924 \pm 172 \text{ events.} \end{aligned}$$

This results in a fraction of residual conversions of 3.0±0.1(stat+syst)%.

Residual conversions in the diffractive candidates

We have 100 electrons in the diffractive candidates, after rejecting 11 electrons as conversions using the conversion finding method. In order to calculate the number of residual conversions in the diffractive candidates, we use the same conversion efficiency and purity as in the whole electron sample. The number of residual conversions in the diffractive candidates is 2.1±0.7(syst+stat) events. The corresponding fraction in the diffractive candidates is 2.1±0.7(syst+stat)%.

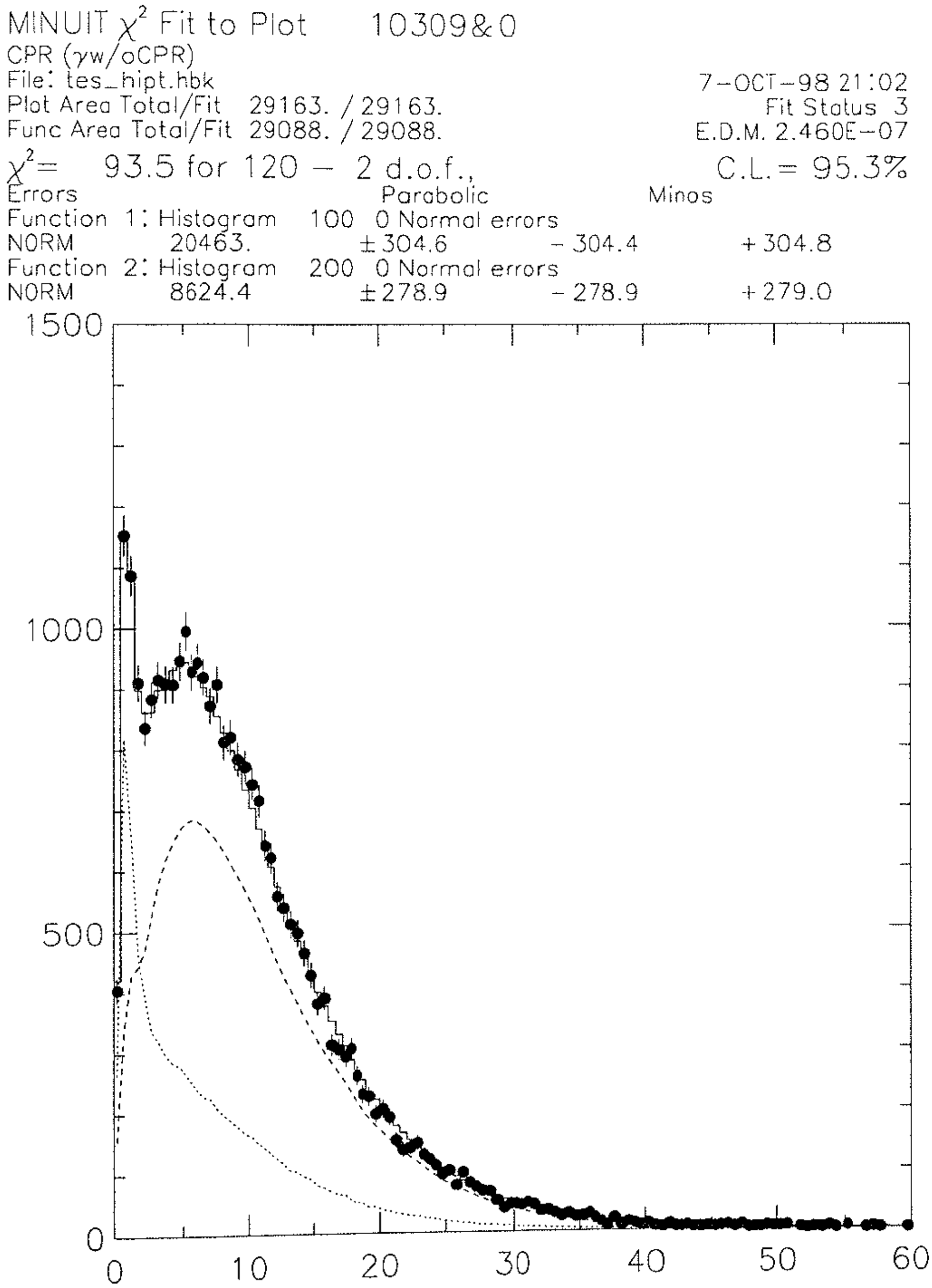


Figure 4.8: The CPR charge distribution for the conversions rejected from the whole electron sample. The fit result is overlayed. The dashed curve shows a contribution of correctly tagged conversions. The dotted curve shows a contribution of accidentally tagged events.