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PILEUP ISSUES ON THE ELECTRON IDENTIFICATION

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Pileup Issues on the Electron Identification

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ABSTRACT

The effect of pileup on the electron identification has been studied taking into account the time evolution of the realistic detector signal. The emphasis is placed on the effect to the electron isolation requirement. The study shows effect due to the pulse length can be greatly reduced by the wave form measurement using neighboring two bunches.

INTRODUCTION

At the SSC, the interaction rate of 10^8 Hz is expected from the total p-p cross section of about 100 mb at $\sqrt{s}$ = 40 TeV and designed luminosity of L = 10^{33}cm^{-2}sec^{-1}. Therefore, it is generally thought that the pileup effect is important at the SSC. There are two different sources for so called 'pileup', which are sometimes mixed and treated together.

1) Due to multi-interactions at single beam crossing: Since the rate of beam crossing of SSC accelerator is 60 MHz, an average of 1.6 interactions is expected for interaction rate of 10^8 Hz. This indicates that a considerable fraction of beam crossing have 2 or more interactions overlapped together.

2) Due to detector signal time response: If detector signal is much longer than a beam crossing interval (16 nsec), a signal contributes to several beam crossings. For example, effectively events from 6 beam crossings would contribute in case of 100 nsec wide signal. This effect would be important for calorimeter.

Generally, the detector with faster signal is preferred considering item 2). If signal width is less than 16 nsec, then the detector is free from the effect of the

item 2), but still the effect from item 1) can not be avoided.

The effect of pileup will show up in various aspects, such as trigger rates, jet reconstruction, track pattern recognition etc. Here, the effect on electron analysis is considered. An electron in most of the interesting physics is an 'isolated electron'. An isolation requirement usually imposes a small energy around an electron and would be affected by pileup. Also, electron identification itself would be affected by pileup. In the following, the effect of pile up on above two aspects is discussed.

EFFECT ON ELECTRON ISOLATION

Recently, a study of effect of pileup on electron isolation for top event selection was done by F.Page.[1] He studied isolation of electron originated from top with mass of 140 GeV by looking a sum of E_T of particles within cone of $\Delta R = \sqrt{\Delta y^2 + \Delta\phi^2} < 0.2$ or 0.4 around an electron. He superimposed 10 minimum bias events (1.6 interactions $\times$ 6 crossings) onto top events and compared E_T sum distributions for pileup and no pileup cases. He found the contribution from superimposed events to E_T within cone is considerably large and concluded that the pileup was serious problem. (He used minimum bias events only, but it is considered that the two jet events with low P_t are also taken into account as 'pileup' events.[2] In this case, the pileup effect would be even larger.) However, in reality some events are coming from different crossings and contribution would be different. This effect is not taken into account in above study. In order to take this into account, one needs to study a time evolution of signal and interactions at each beam crossing.

Simulation of Time Evolution of Signal with Pileup

Here, Liq. Ar calorimeter is considered, since wave form of the Liq. Ar detector signal can be analytically calculated and Liq. Ar has slower signal than other detectors. However, the discussion holds for any type of detectors in principle. The wave form of shaper amplifier for impulse signal can be written with parameters of peaking time (τ_p), number of differentiation (n), and number

of integration (m). A parameter n = 1, 2, 3 gives Poisson, bipolar, and three lobe shaping, respectively. The wave form for Liq. Ar detector signal can be obtained by convoluting an impulse wave form with Liq. Ar signal $A \cdot (T_d - t)$, where T_d is a maximum drift time of electron between Liq. Ar gap. Fig. 1 shows some examples of wave form. Note that the peak position of convoluted signal with $T_d = 400$ nsec is about twice of τ_p.

The pileup effect on the wave form of signal has been studied by several people.[3,4] They generated the minimum bias/Low P_t tow-jet events at each crossing according to Poisson distribution of average 1.6 events and superimposed wave forms for calorimeter cell which has actual signal. An example of wave form superimposed with pileup signals studied by T.Kondo[4] is shown in Fig. 2.

Effect of Pileup on Electron Isolation with Wave Form Simulation

The effect of pileup to electron isolation has been studied incorporating Liq. Ar calorimeter wave form analysis mentioned above. Higgs events with decay channel of Higgs $\rightarrow W^+W^- \rightarrow e\nu +$jets are used for study. Events are generated using ISAJET[5] program and Higgs mass is chosen at 400 GeV. For pileup events, TWOJET events with $3 < P_t < 200$ GeV are generated using ISAJET program. Calorimeter segmentation is assumed to be $\Delta y \times \Delta\phi = 0.05 \times 0.05$ and all particles are assumed to deposit all energy into one calorimeter tower which they hit. Electrons, photons, π^0's, and η^0's deposit all energy into EM part with energy resolution of $\sigma_E/E = 15\%/\sqrt{E}$, while hadrons deposit all energy into hadron part with $\sigma_E/E = 50\%/\sqrt{E}$. Muons are assumed to deposit 3 GeV in hadron part.

For wave form analysis, bipolar shaping with 3 integration (n=2 and m=3), $\tau_p = 50$ nsec, and $T_d = 400$ nsec are chosen here. This gives peak position of output signal around 100 nsec. The calorimeter signal is assumed to be sampled at every beam crossing (via either analog memory or FADC). The beam crossing for Higgs event is assumed to be (at least roughly) determined at the trigger stage and the data for several beam crossings around Higgs event are read out.

Electron isolation is studied in the same way as done by F.Page: Distributions are compared for a sum of E_T of calorimeter towers within cone of $\Delta R =$

$\sqrt{\Delta y^2 + \Delta\phi^2} < 0.2$ or 0.4 around the tower which an electron from W hits. For wave form simulation case, energy deposit of calorimeter is calculated with two different ways:

A) Use sampled pulse hight for beam crossing of Higgs event. Towers with negative energy are not used for sum assuming the data below pedestals are suppressed in the readout.

B) Use sampled pulse hight for three beam crossings (± 1 around Higgs event crossing) and fit them with parabola to get peak pulse hight and timing as done by T.Kondo's study. Towers with peak timing inconsistent with Higgs event crossing ($|\Delta T| > 10$ nsec) are rejected from sum.

Fig. 3 shows distribution of fitted peak time for towers within cone of $\Delta R < 0.4$. Clear peaks corresponding beam crossings can be seen. The intervals of peaks different from beam crossing interval reflects the fact that the pulse shape is not parabola. Most of signal from different crossings can be rejected by a requirement of $|\Delta T| < 10$ nsec. Fig. 4 (a) shows E_T sum distributions within $\Delta R < 0.4$ for cases of no pileup, average 1.6 events superimposed, and average 10 events superimposed. In this case, TWOJET events are just superimposed according to Poisson distribution and no wave form simulation is done. Fig. 4 (b) shows corresponding distribution with wave form simulation for calorimeter energy calculated by methods A and B, respectively. Superimposing average 1.6 events has only small effect but superimposing average 10 events gives quite large effect and the isolation requirement will be seriously damaged as pointed out previously. With wave form simulation, energy calculation by method A gives similar result as superimposition of average 10 events and superimposition method seems good approximation for this case. However, energy calculation by method B eliminates most of the effects by signals from different beam crossing and the distribution is almost same as one with average 1.6 events superimposed, which can not be avoid in any case. Fig. 5 (a) and (b) show corresponding distributions for $\Delta R < 0.2$ case and show same effect as $\Delta R < 0.4$ case.

Therefore, it is essential to record the wave form information of the calorimeter signal in order to avoid the pileup effect on isolation for slow signal detector

such as Liq. Ar. However, sampling 3 beam crossings and simple parabola fitting is good enough to eliminate the pileup effect from different crossings.

Effect of Pileup to Efficiency and Background Rejection

With presence of pileup effect, one has to increase a threshold of E_T sum cut for isolation in order to keep the efficiency for signal events. Increasing threshold usually decreases the rejection power for background. However, the background events also suffers the pileup effect with same way as signal events. Therefore, the above effects tend to cancel each other.

The effect of pileup to the efficiency and background rejection has been studied by H.Yamamoto.[6] He used Higgs $\rightarrow ZZ \rightarrow 4e$ events for signal and $t\bar{t} \rightarrow 4e$ + jets events as background. He studied the efficiency for Higgs and background rejection as a function of E_T sum cut value with no pileup and with pileup case. His result shows some tendency of cancellation when the background rejection is fixed.

EFFECT ON ELECTRON IDENTIFICATION

Pileup may also cause an effect on the electron identification itself. Here, the effect of pileup for electron identification has been studied in two cases:

1) One of the most effective electron identification is matching of energy deposit in EM calorimeter and momentum measured by tracking system. Fig. 6 shows distribution of $(E_{EM} - p)/\sqrt{p}$ for no pileup and average 10 events superimposed case. (a factor $1/\sqrt{p}$ is to cancel the energy dependence of resolution.) Here, E_{EM} is a sum of energy in 3×3 EM towers ($\Delta\eta \times \Delta y = 0.15 \times 0.15$) around the electron decayed from W in Higgs events studied above. p is momentum of electron which is supposed to be measured by tracking system, but here generated momentum was taken for simplicity. The effect of pileup is small even with average 10 events superimposed case (no wave form simulation).

2) Another way of identifying electron is to require the most energy being deposited in EM part of the calorimeter and only small energy deposit in hadronic

part. Fig. 7 shows distribution of $E_T(HAD)/E_T(EM)$ for 3×3 calorimeter towers around the electron decayed from W. Again, the effect of pileup is small enough even with average 10 events superimposed case.

Therefore, the effect of pileup to the electron identification is small enough with studied calorimeter segmentation even with higher luminosity ($L \sim 10^{34}$ $cm^{-2}sec^{-1}$).

SUMMARY

The effect of pileup to electron identification is studied in the following aspects:

The effect on electron isolation has been studied with realistic detector signal wave form simulation. The effect due to slow time response of signal can be reduced to insignificant level if the wave form of the signal is recorded (three beam crossing samples are enough). The effect of multi-interactions in same beam crossing can not be avoided. This effect is not serious at luminosity of 10^{33} $cm^{-2}sec^{-1}$. At high luminosity ($L = 10^{34}$ $cm^{-2}sec^{-1}$), this effect will be quite serious. One hope is that we may be able to find the isolation requirement which is insensitive to pileup effect. For example, in summing E_T within cone, one may sum up towers inly with $E_T > 1$ GeV. This reduces the pileup effect considerably as shown in Fig. 8, but need more study including background rejection. Another hope is that pileup effect cancels in some extent considering the efficiency vs background rejection. We need further study for these aspects.

On the other hand, pileup effect on electron ID itself seems to be small even for high luminosity.

The author wishes to thank Prof. T.Kondo and Dr. H.Iwasaki for providing a information of their study and their programs.

REFERENCES

1) F.Page, talk given at Workshop on Simulation for SSC, Jan 1990, Dallas.

2) A.Bay *et al.*, in proceedings of Snowmass '88, p882; J.Freeman and C.Newman-Holmes, in proceedings of Workshop on Experiments, Detectors, and Experimental areas for the Supercollider, Berkeley, 1987.

3) E.Stern, talk given at Workshop on Simulation for SSC, Jan 1990, Dallas.

4) Study done by T.Kondo and H.Iwasaki, mentioned in T.Kondo, "ACS Detector", KEK Preprint 89-191, JSD-NOTE-1990-005.

5) F.E.Paige and S.D.Protopopescu, BNL-37066 (1985).

6) H.Yamamoto, talk given at Workshop on Simulation for SSC, Jan 1990, Dallas.

FIGURE CAPTIONS

Fig. 1. Wave forms for different parameters for shaping. Solid, dashed, and dot-dashed lines shows Poisson, bipolar, and three-lobe shaping.

Fig. 2. Time evolution of simulated Liq. Ar signals with pileup events.

Fig. 3. Time distribution of fitted peak for calorimeter towers within cone of ΔR of 0.4 around electron.

Fig. 4. E_T sum distribution for $\Delta R < 0.4$ case: (a) no wave form analysis. Solid line shows no pileup case, dashed line shows average 1.6 events superimposed, and dot-dashed line shows average 10 events superimposed. (b) with wave form simulation. Dashed line shows energy calculated by method A and dotted line shows energy calculated by method B (see text).

Fig. 5. E_T sum distribution for $\Delta R < 0.2$ case: (a) no wave form analysis. Solid line shows no pileup case, dashed line shows average 1.6 events superimposed, and dot-dashed line shows average 10 events superimposed. (b) with wave form simulation. Dashed line shows energy calculated by method A and dotted line shows energy calculated by method B (see text).

Fig. 6. $(E_{EM} - p)/\sqrt{p}$ distribution for no pileup case (solid line) and for average 10 events superimposed case.

Fig. 7. $(E_T(HAD)/E_T(EM)$ distribution for no pileup case (solid line) and for average 10 events superimposed case.

Fig. 8. E_T sum distribution for $\Delta R < 0.4$ case: Towers only with $E_T > 1$ GeV are used in sum. Solid line shows no pileup case, dashed line shows average 1.6 events superimposed, and dot-dashed line shows average 10 events superimposed.

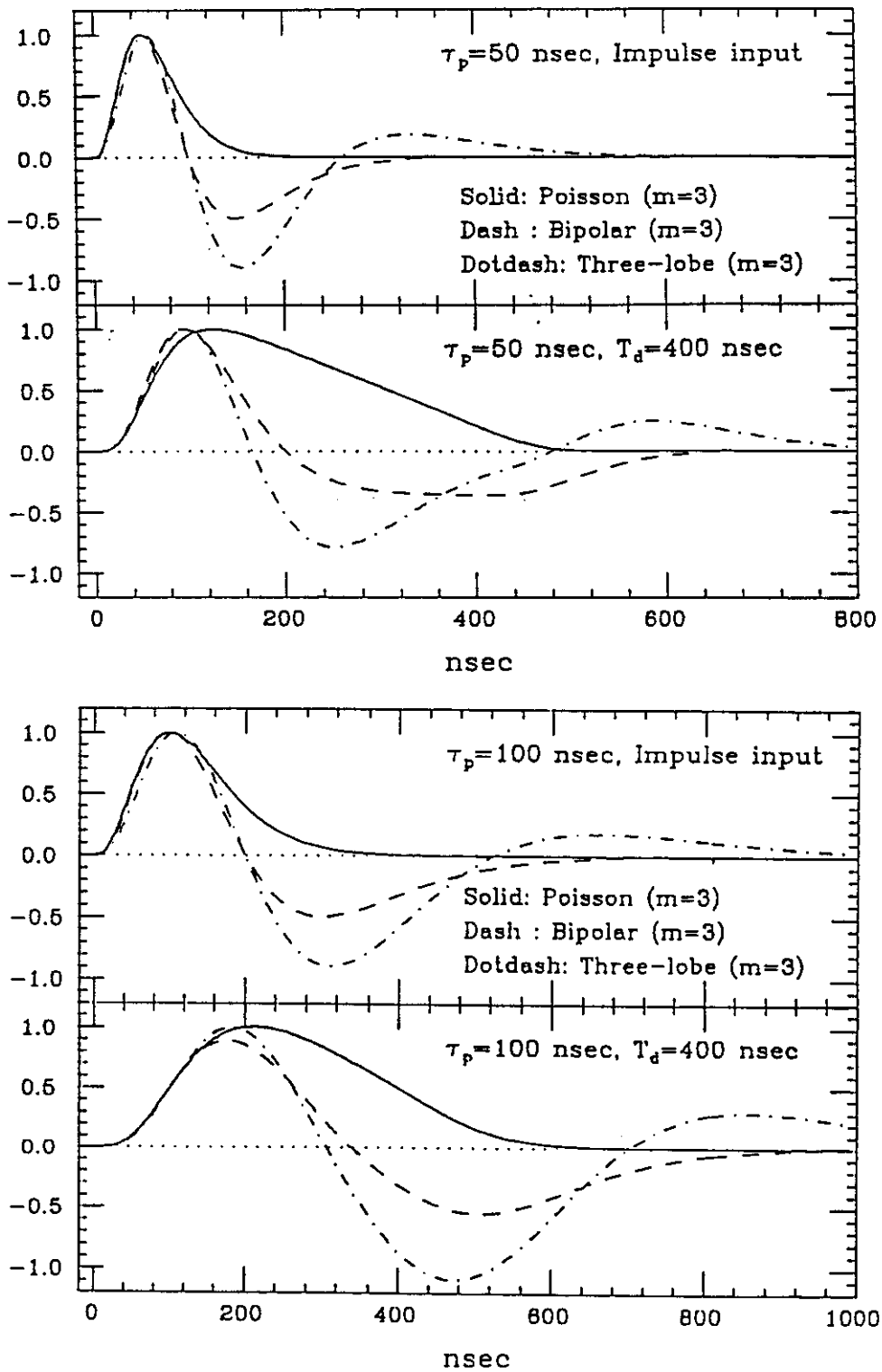

τ_p=50 nsec, Impulse input
Solid: Poisson (m=3)
Dash : Bipolar (m=3)
Dotdash: Three-lobe (m=3)
τ_p=50 nsec, T_d=400 nsec
1.0
0.5
0.0
−0.5
−1.0
0
200
400
600
800
nsec
τ_p=100 nsec, Impulse input
Solid: Poisson (m=3)
Dash : Bipolar (m=3)
Dotdash: Three-lobe (m=3)
τ_p=100 nsec, T_d=400 nsec
1000

Fig. 1

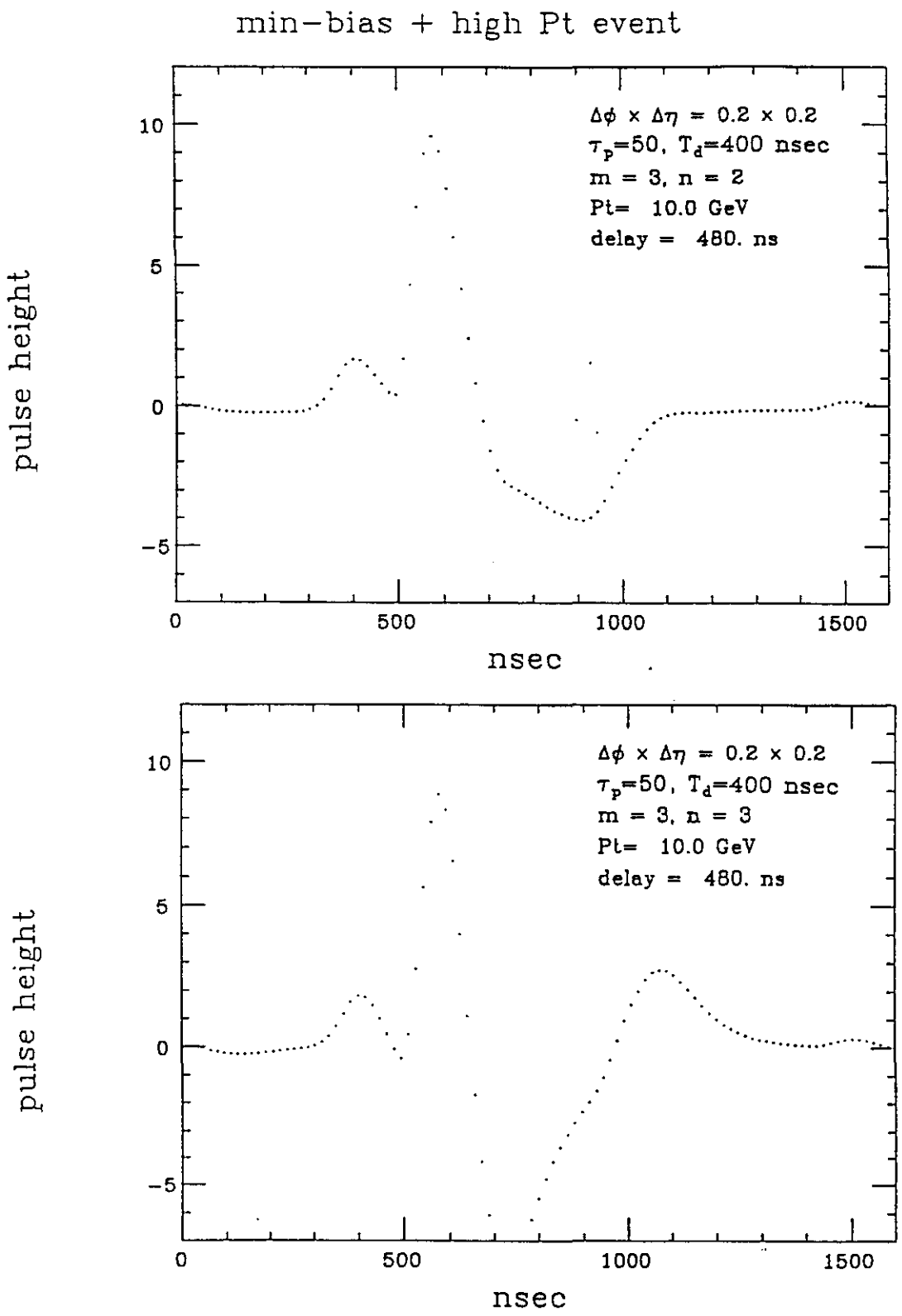

min−bias + high Pt event
Δφ × Δη = 0.2 × 0.2
τp=50, Td=400 nsec
m = 3, n = 2
Pt= 10.0 GeV
delay = 480. ns
pulse height
nsec
Δφ × Δη = 0.2 × 0.2
τp=50, Td=400 nsec
m = 3, n = 3
Pt= 10.0 GeV
delay = 480. ns
pulse height
nsec

Fig. 2

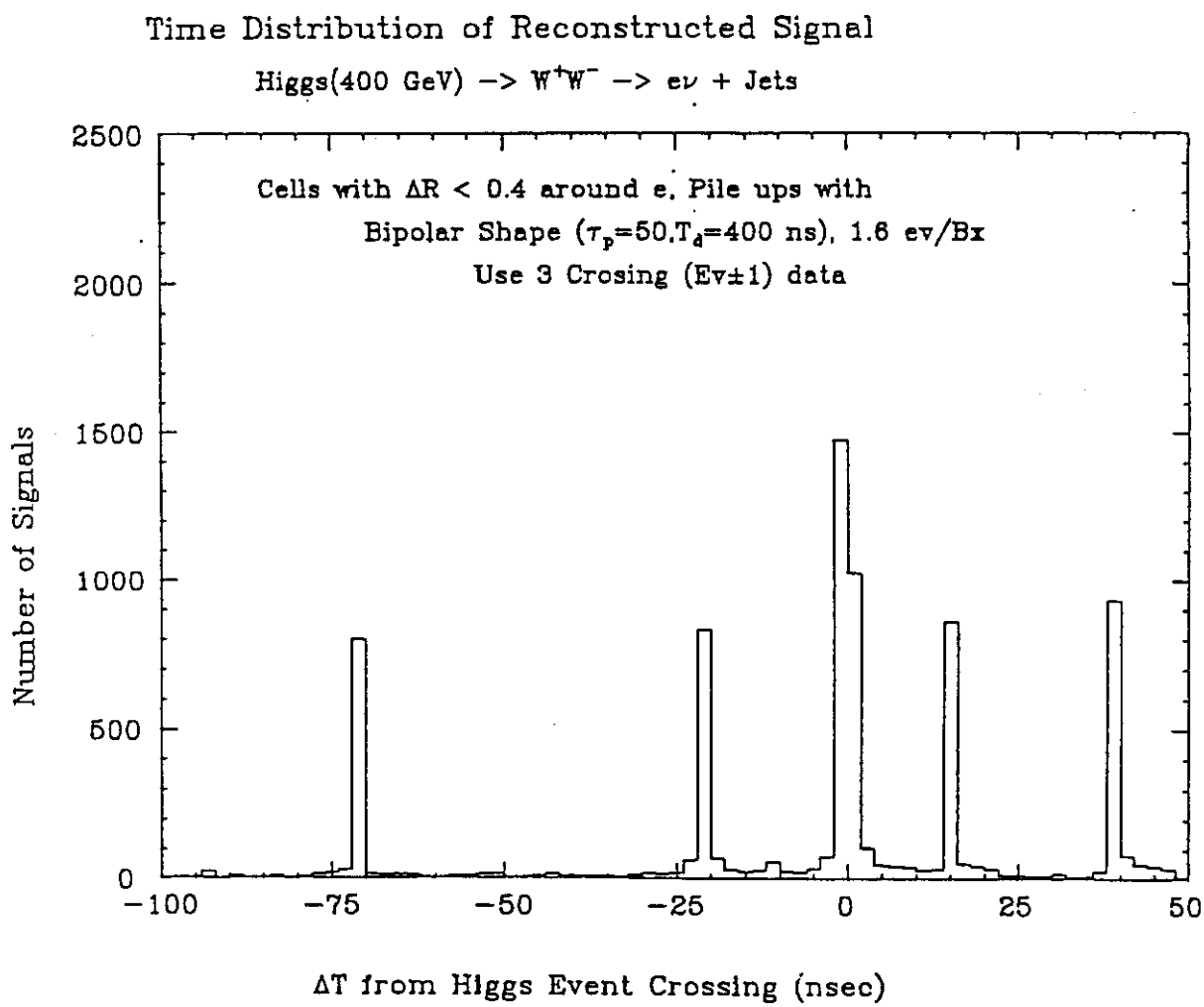
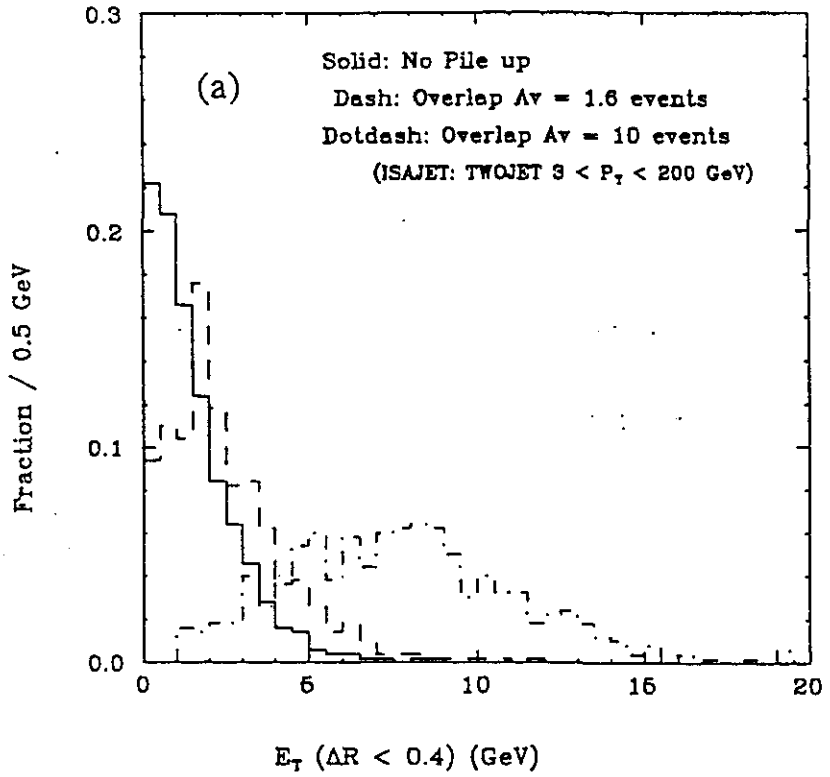

Time Distribution of Reconstructed Signal
Higgs(400 GeV) -> W+W- -> eν + Jets
Cells with ΔR < 0.4 around e, Pile ups with
Bipolar Shape (τp=50,Td=400 ns), 1.6 ev/Bx
Use 3 Crosing (Ev±1) data
Number of Signals
2500
2000
1500
1000
500
0
−100
−75
−50
−25
0
25
50
ΔT from Higgs Event Crossing (nsec)

Fig. 3

Pile up Effect on Isolated Electron

Higgs(400 GeV) -> W^+W^- -> $e\nu$ + Jets



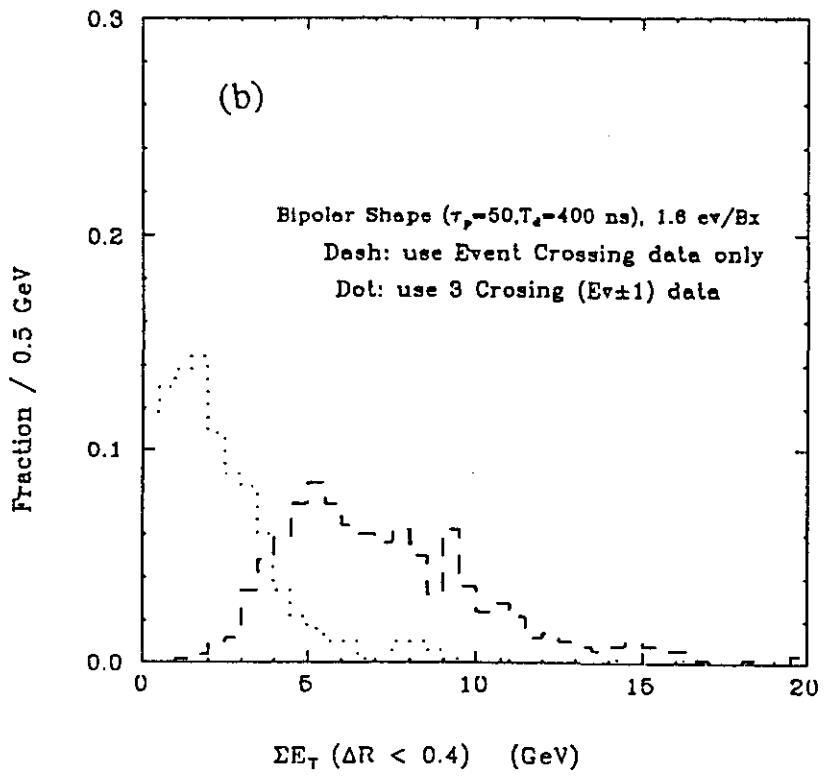


Fig. 4

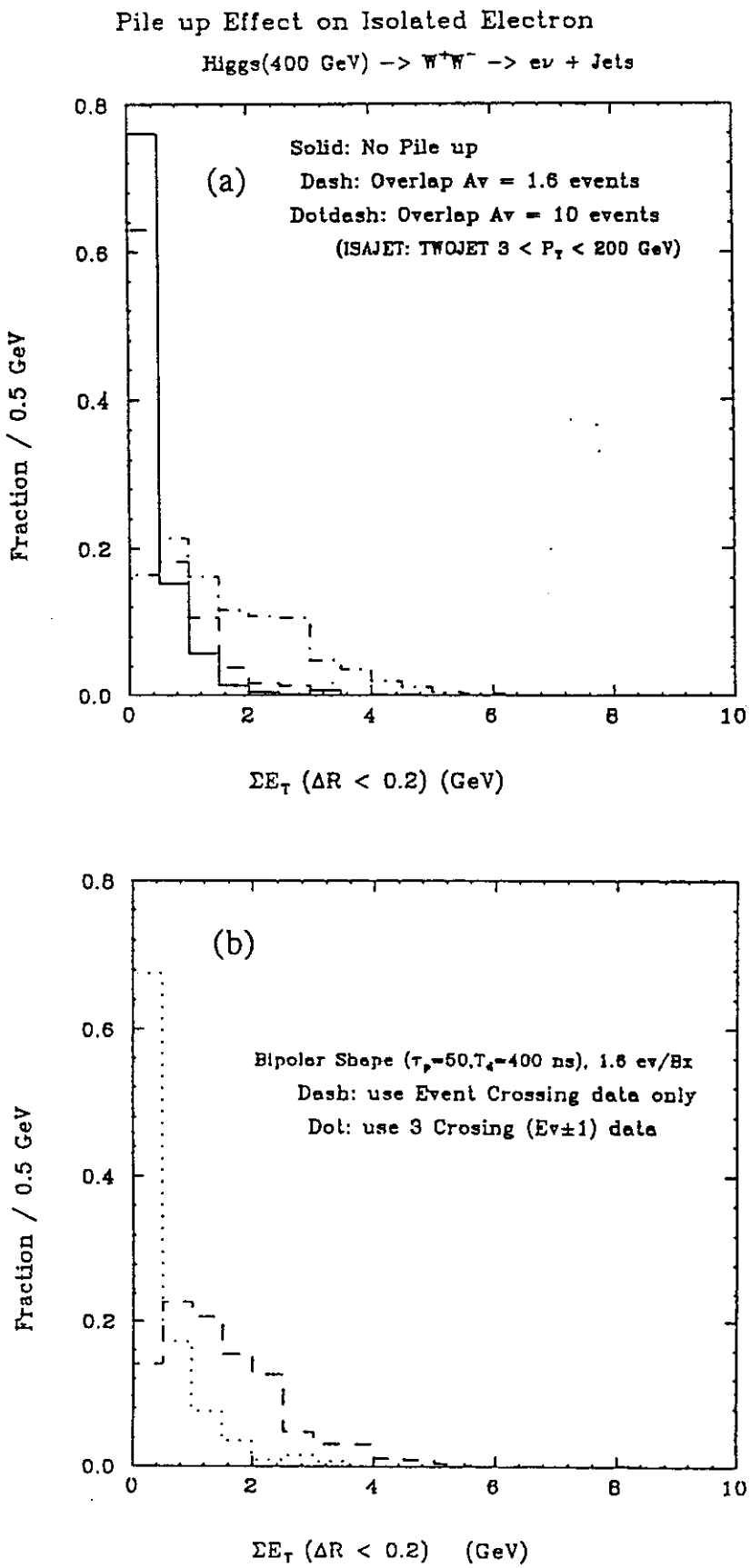

Pile up Effect on Isolated Electron
Higgs(400 GeV) -> W+W- -> eν + Jets
(a)
Solid: No Pile up
Dash: Overlap Av = 1.6 events
Dotdash: Overlap Av = 10 events
(ISAJET: TWOJET 3 < P_T < 200 GeV)
Fraction / 0.5 GeV
ΣE_T (ΔR < 0.2) (GeV)
(b)
Bipolar Shape (τ_p=50,T_d=400 ns), 1.6 ev/Bx
Dash: use Event Crossing data only
Dot: use 3 Crosing (Ev±1) data
Fraction / 0.5 GeV
ΣE_T (ΔR < 0.2) (GeV)

Fig. 5

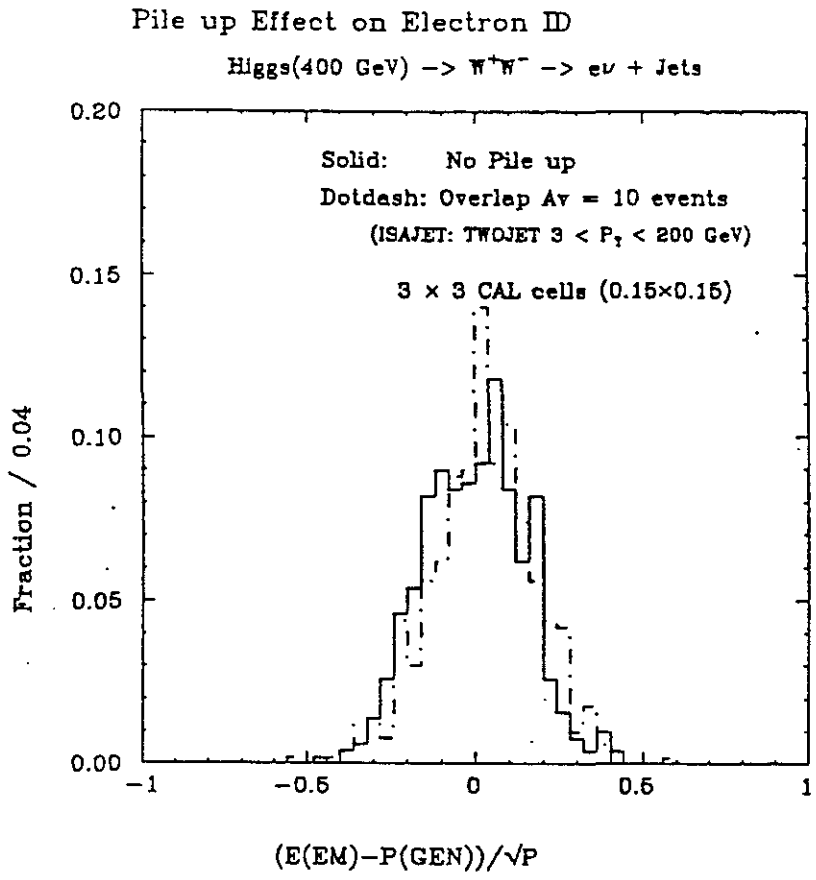

Pile up Effect on Electron ID
Higgs(400 GeV) -> W+W- -> eν + Jets
Solid: No Pile up
Doldash: Overlap Av = 10 events
(ISAJET: TWOJET 3 < P_T < 200 GeV)
3 × 3 CAL cells (0.15×0.15)
Fraction / 0.04
0.20
0.15
0.10
0.05
0.00
−1
−0.5
0
0.5
1
(E(EM)−P(GEN))/√P

Fig. 6

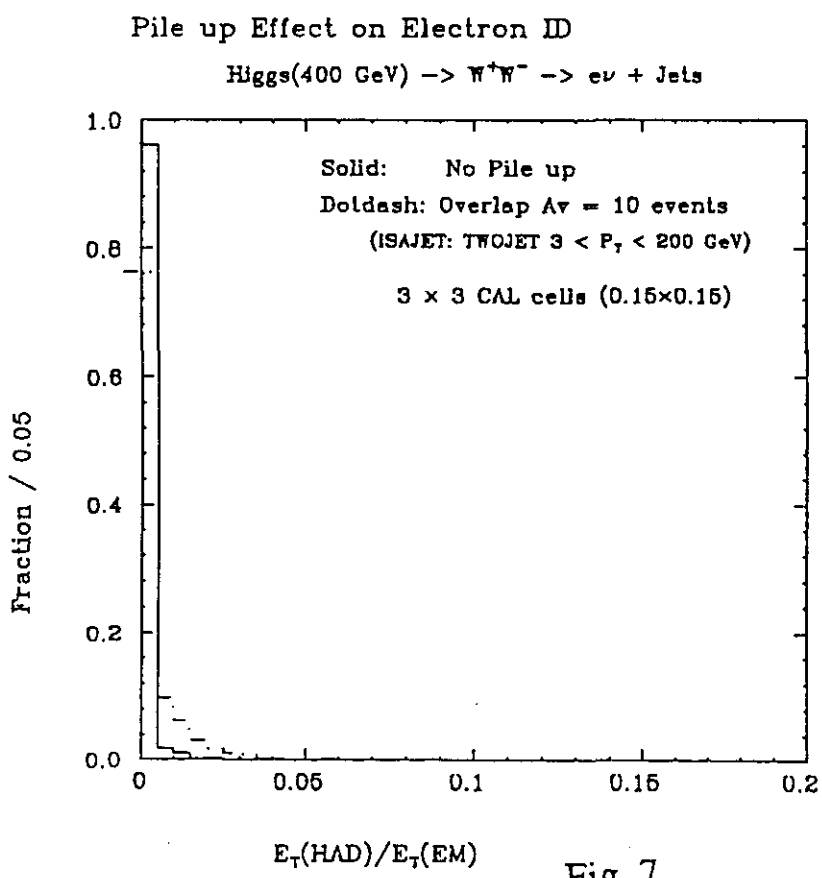

Pile up Effect on Electron ID
Higgs(400 GeV) -> W+W- -> eν + Jets
Solid: No Pile up
Doldash: Overlap Av = 10 events
(ISAJET: TWOJET 3 < P_T < 200 GeV)
3 × 3 CAL cells (0.15×0.15)
Fraction / 0.05
1.0
0.8
0.6
0.4
0.2
0.0
0
0.05
0.1
0.15
0.2
E_T(HAD)/E_T(EM)

Fig. 7