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Lepton Fake Estimate Using 320 pb^{-1} CDF Run II Data

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abstract

In this note we describe the lepton fake rate estimate and the fake background estimate for HWW dilepton signal search in 5.3.3. We have found good agreement over the estimated fake rates among the analyzed jet samples, including the lepton fake rates, the strong p_t dependence of them and the cross-sample predicted numbers of faked leptons.

1 Introduction

This note is to document the estimate of the probability of jet/track objects faking leptons (lepton fake rates) and the estimate of fake background for the HWW dilepton analysis using cdfsoft2 release 5.3.3. The fake background in the 4.11.2 version analysis accounted for about 10% of total background with both final-state leptons required $E_t > 20$ GeV. The fake background is expected to increase due to the lepton E_t lowering strategy in the 5.3.3 version. So it is desirable to estimate the fakes with best achievable systematic uncertainty.

2 Datasets

We ntuplized the inclusive jet samples as described in Table 1 using top_533_nt5 executable for the estimate.

dataset ID	trigger	trigger requirement
`gjt10d`	Jet20	at least a raw jet with $E_t > 20$ GeV
`gjt20d`	Jet50	at least a raw jet with $E_t > 50$ GeV
`gjt30d`	Jet70	at least a raw jet with $E_t > 70$ GeV
`gjt40d`	Jet100	at least a raw jet with $E_t > 100$ GeV

Table 1: The jet datasets and trigger requirements used for the lepton fake rate estimate.

We applied DQM's good run list version 7.0 for top/ewk/exotics electron/muon (CMU & CMP & CMX... CMX bit ignored for run < 150145) and silicon. The total offline integrated luminosity after applying the good run list would be 320 pb^{-1}.

3 Fake Rate Definitions

The lepton fake rate is defined as the probability for a fakeable object to pass the lepton identification criteria. Such a fake rate is highly dependent on the definition for a fakeable object [1] and, since object composition varies from sample to sample, balance should be sought between generalization of fakeable object definition and consistency of fake rate among samples.

For electrons the fakeable objects are electromagnetic clusters loosely selected from CdfEmObjects, which in comparison to generic jets

- ◇ have higher E_{had}/E_{em} and hence higher chance to fake electrons;
- ◇ have more reliable energy measurement;
- ◇ no quark/gluon-like substructure to complicate the study.

For muons the fakeable objects are minimum ionizing particles (MIP) loosely selected from CdfMuons. These kinds of fakeable objects cover all the real or fake lepton sources and allow easy p_t parameterization.

Mathematically the lepton fake rate can be written as the number of fakeable objects passing the lepton cuts divided by the number of fakeable objects, as in Equation 1 and Equation 2.

$$\mathrm{FR}_{\mathrm{TCE/PHX}} \equiv \frac{\text{!leading-jet-wrapped TCE/PHX electrons}}{\text{central/plug emObjects}} \tag{1}$$

$$\mathrm{FR}_{\mathrm{CMUP/X/U/P/IO}} \equiv \frac{\text{!leading-jet-wrapped CMUP/X/U/P/IO muons}}{\text{CMUP/X/U/P/IO MIPs}} \tag{2}$$

4 Lepton Selection

The lepton selection cuts for **numerator** are listed in Table 2, Table 4 and Table 5. The lepton selection cuts are the same as for the main HWW dilepton analysis [8].

5 Fakeable Object Selection

The selection cuts for **denominator** fakeable objects are listed in Table 3 and Table 6.

CdfEmObjects from higher jet E_t trigger tend to have larger hadronic fraction due to the difference on trigger and offline clustering algorithms. So the requirement of $E_{had}/E_{em} < 0.125$ improves the consistency of electron fake rate denominator composition from different jet samples. The effect of requiring electron fake rate denominators $E_{had}/E_{em} < 0.125$ is shown with the CdfEmObject E_{had}/E_{em} profile *vs* calorimetric isolation in Figure 2.

CdfMuons can include electrons, conversions, hadronic punches-through and decays-in-flight etc., which generally deposit more energies in the calorimeters than MIP as there is no minimum ionizing requirement. So the requirement of $E_{em+had}/p < 1$ improves the consistency of muon fake rate denominator composition from different jet samples. The effect of requiring muon fake rate denominators $E_{had+em}/p < 1$ is shown with the MIP E_{em+had}/p profile *vs* calorimetric isolation in Figure 3.

Our signal samples for the HWW dilepton analysis, bhel0d+bpel0d+bhmu0d, are primarily composed of W+jets, which tend to have good calorimetric isolation. So requiring all the fake rate denominators to have calorimetric isolation < 0.2, we further improve the consistency of especially electron fake rate denominator composition from different jet samples while keeping the applicability of estimated lepton fake rates to the fakeable objects found in the signal samples. The fake rate denominator calorimetric isolation profiles vs E_t before and after such a requirement for each type of lepton are shown in Figure 4 and 5.

Improving the fake rate denominator composition consistency among jet samples improves the fake rate consistency among jet samples.

6 Trigger Bias Reduction

To reduce trigger bias, we removed the highest E_t (a.k.a. leading) jet (default CdfJet, cone size $R = 0.4$) and all the numerator and denominator objects within a cone of $\Delta R(\eta, \phi) < 0.4$ around it per event. We did not completely remove trigger bias, Figure 1. However, the remnant trigger bias propagates little into the denominator fakeable objects, as shown in Figure 7. So the rates are not too disturbed by the trigger bias.

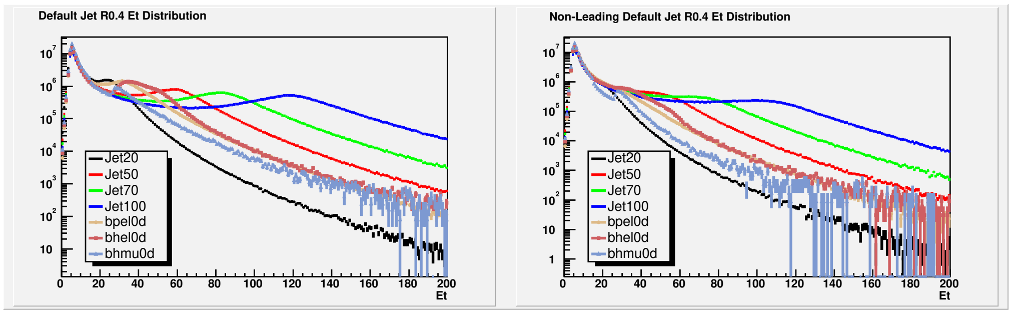

Figure 1: Jet20/50/70/100 and bhel/pel/hmu0d jet E_t distributions before (L) and after (R) removing the leading jet.

7 Fake Rate Results

The distributions of numerator lepton p_t and denominator object E_t from the jet samples are shown in Figure 6 and Figure 7. The fake rate results are shown in Figure 8. We have included Bayesian errors for the bins lack of numerator statistics [2].

We have compared the number of leptons observed in each jet sample with the number of leptons predicted using Jet20/50/70/100 fake rates and found overall agreement, as shown in Table 7 and Table 8.

For the estimate of fake background in the HWW dilepton analysis we use the statistics-weighed average lepton fake rates and quote the largest difference between samples as systematic uncertainty.

8 Conclusion

Our lepton fake rate estimate has been done and the fake rate consistency across samples has been obtained. The fake background estimate for the HWW dilepton analysis is described in Appendix A.

A Fake Background Estimate for the HWW Dilepton Analysis

We estimated fake background for the HWW dilepton analysis [8] in the following way.

- ◇ We first found the denominator fakeable objects in signal data samples, `bhel0d`, `bpel0d` and `bhmu0d` that pass event selection together with an identified lepton or another fakeable object and hence form fakeable dileptons;
- ◇ then weighed the fakeable dileptons with the combined fake rate of corresponding type(s) and p_t(s);
- ◇ finally summed up these weighed fakeable dileptons as total fake background.

Lepton selection cuts are listed in Table 2, Table 4 and Table 5. Denominator fakeable object selection cuts are listed in Table 3 and Table 6. Event selection cuts are available in the main analysis note [8].

Double fake background, with both leptons faked by denominator objects, is included but does not have any significance because the lepton fake rates in most lepton-populated p_t region are around $10^{-2\sim-1}$.

The estimated fake background is included in all the plots in the main analysis note [8]. The estimated fake background together with MC-predicted background expectation is in agreement with observation.

We performed an interesting cross-check by changing the electron fake rate denominators from *em* objects to generic jets ($|\eta| < 1.1$ for TCE and $1.2 < |\eta| < 2$ for PHX; half and half charge sign probabilities) and we found the change of fake background integral numbers within 15%. The shapes can be found in Figure 9.

As seen in the result tables and figures such as Table 7, Table 8, Figure 8 and Figure 9, this lepton fake estimate works out with very good agreement. Nevertheless we quote 50% uncertainty from sample dependence on the estimated fake background, just to be conservative and consistent with other CDF lepton fake estimates.

References

[1] A Second Determination of the Fake Lepton Background for the Summer 2003 Top Dilepton Analysis, M. Coca, A. Ivanov, R. Eusebi, E. Halkiadakis, A. Hocker, P. Tipton, CDF6742.

[2] Efficiency Uncertainties: A Bayesian Prescription, John Conway, CDF5894.

[3] Electron Identification in Offline Release 5.3, C.Hill, J.Incandela, C.Mills, CDF7309.

[4] High p_t Muons, Recommended Cuts and Efficiencies for Release 5.3.1, Victoria Martin, CDF7367.

[5] Reconstructing the Plug Electron Energy in 5.3.3, G. Manca, S. Harper, CDF7687.

[6] Search for Production of Chargino and Neutralino in ee+lepton Final States, G. Manca, M. Griffiths, B. Heinemann, CDF7499.

[7] Search for the Associated Production of Chargino and Neutralino in $\mu\mu$+lepton Events, D. Bortoletto, A. Canepa, O. Gonzalez, E. Lytken, CDF7714.

[8] Search for SM Higgs Bosons in the $gg \to H \to W^*W^* \to \ell\nu\ell\nu$ Channel with 360/pb CDF Run II Data, S. Chuang, M. Coca and M. Kruse, CDF7708.

CollType==DefEm
region==0 (central)
$E_t > 10$ GeV
$E_{had}/E_{em} < 0.055 + 0.00045 \cdot E$
$E/p < 2$ or track $p_t > 50$ GeV
$L_{shr} < 0.2$
$-3 < Q \cdot \Delta x < 1.5$ cm
$\|\Delta z_{\text{CES}}\| < 3$ cm
$\|z_0\| < 60$ cm
$\chi^2_{strip} < 10$
number of good axial SL segments ≥ 3
number of good stereo SL segments ≥ 2
conversion != 1
fiducial==1
calorimetric isolation < 0.1
track isolation < 0.1

Table 2: The selection cuts for tight central electrons (TCE) [3, 6].

CollType==DefEm	CollType==DefEm
region==0 (central)	region==1 (plugs)
$E_t > 10$ GeV	$E_t > 10$ GeV
$E_{had}/E_{em} < 0.125$	$E_{had}/E_{em} < 0.125$
track $p_t > 0$	$\|$PES 2D $\eta\| > 1.2$
conversion != 1	$\|$PES 2D $\eta\| < 2.0$
calorimetric isolation < 0.2	calorimetric isolation < 0.2

Table 3: The selection cuts for central (L) and plug (R) fakeable em objects ($\text{FR}_{\text{TCE/PHX}}$ denominators).

CollType==Phoenix
region==1 (plugs)
$E_t > 10$ GeV
$E_{had}/E_{em} < 0.05$
PEM 3×3 fit tower != 0
PEM 3×3 $\chi^2 < 10$
PES 2D 5×9 U > 0.65
PES 2D 5×9 V > 0.65
$1.2 <$ |PES 2D η| < 2.0
calorimetric isolation < 0.1
phxMatch TRUE
number of silicon hits for PHX track ≥ 3
$\|z_0$(PHX track)$\| < 60$ cm
ΔR(PHX track, PES cluster) < 3 cm

Table 4: The selection cuts for phoenix electrons (PHX) [3]; energies scaled up to bring the Z mass peak back to 91 GeV [5].

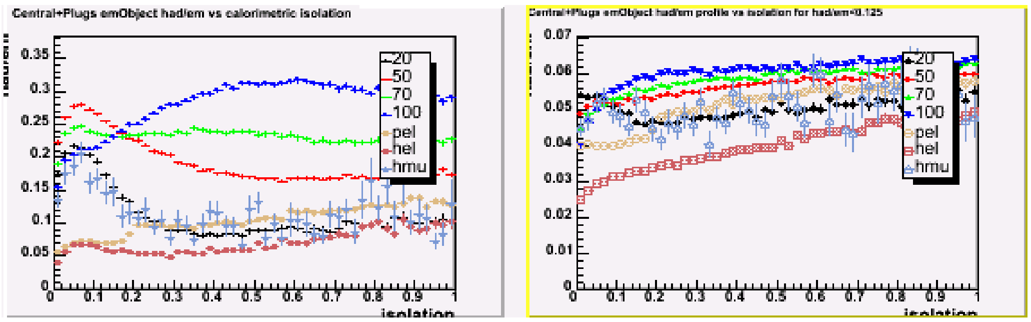

Figure 2: E_{had}/E_{em} profiles *vs* calorimetric isolation before (L) and after (R) requiring $E_{had}/E_{em} < 0.125$ of the *em* objects from Jet20/50/70/100 and bhel/pel/hmu0d.

for CMUP/CMX/CMIO	$p_t > 10$ GeV
for CMU/CMP	$p_t > 20$ GeV
for all muons	non-cosmic
	$E_{em} < 2 + (p_t > 20$ GeV$) \times \max(0, 0.0115(p - 100))$ GeV
	$E_{had} < 6 - (p_t < 20$ GeV$) \times (2.5 - p_t/8)$ $+ (p_t > 20$ GeV$) \times \max(0, 0.028(p - 100))$ GeV
	$\|d_0\| < 0.02$ cm for tracks with si hits attached $\|d_0\| < 0.2$ cm for tracks without si hits attached
	$\|z_0\| < 60$ cm
	calorimetric isolation < 0.1
	track isolation < 0.1
	number of good axial SL segments ≥ 3
for CMUP/CMX	number of good stereo SL segments ≥ 2
for CMU/CMP/CMIO	number of good stereo SL segments ≥ 3
for CMUP/CMU/CMP	run number ≥ 154449 or not in bluebeam
for CMUP/CMU	$\Delta x_{\text{CMU}} < 3$ cm
for CMUP/CMP	$\Delta x_{\text{CMP}} < 5$ cm
for CMUP/CMP	x-fid(CMP) < 0 and z-fid(CMP) < -3 cm
for CMX	run number > 150145
	run > 186598 or not from miniskirt or keystone
	$\Delta x_{\text{CMX}} < 6$ cm
	x-fid(CMX) < 0 and z-fid(CMX) < -3 cm
for $\text{CMX}_{\text{triggerable}}$/CMIO	COT-exit radius > 140 cm
for CMIO	non-CMUP/CMX/CMU/CMP/BMU
	track fiducial==4
	$E_{em} + E_{had} > 0.1$ GeV

Table 5: The selection cuts for CMUP/CMX/CMU/CMP/CMIO muons [4, 7].

for $\text{MIP}_{\text{CMUP/CMX/CMIO}}$	$p_t > 10$ GeV
for $\text{MIP}_{\text{CMU/CMP}}$	$p_t > 20$ GeV
for all MIP	non-cosmic
	$\|d_0\| < 0.02$ cm for tracks with si hits attached
	$\|d_0\| < 0.2$ cm for tracks without si hits attached
	$\|z_0\| < 60$ cm
	$(E_{em} + E_{had})/p < 1$
	calorimetric isolation < 0.2
for $\text{MIP}_{\text{CMUP/CMU/CMP}}$	run number ≥ 154449 or not in bluebeam
for $\text{MIP}_{\text{CMUP/CMP}}$	x-fid(CMP) < 0 and z-fid(CMP) < -3 cm
for MIP_{CMX}	run number > 150145
	run > 186598 or not from miniskirt or keystone
	x-fid(CMX) < 0 and z-fid(CMX) < -3 cm
for $\text{MIP}_{\text{CMX}_{\text{triggerable}}\text{/CMIO}}$	COT-exit radius > 140 cm
for MIP_{CMIO}	non-$\text{MIP}_{\text{CMUP/CMX/CMU/CMP/BMU}}$

Table 6: The selection cuts for CMUP/CMX/CMU/CMP/CMIO fakeable MIP tracks ($\text{FR}_{\text{CMUP/CMX/CMU/CMP/CMIO}}$ denominators).

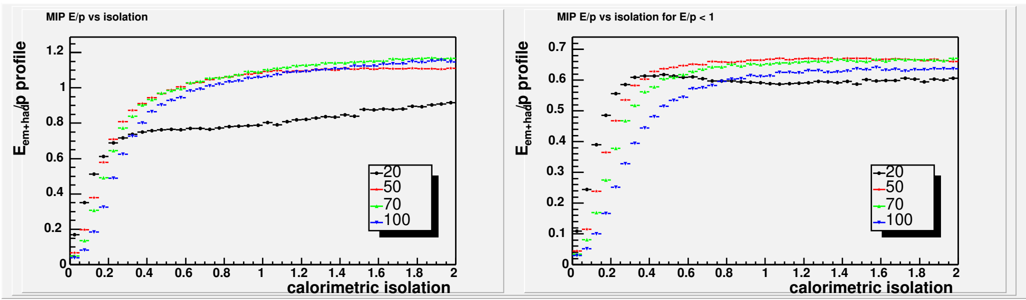

Figure 3: E_{em+had}/p profiles *vs* calorimetric isolation before (L) and after (R) requiring $E_{em+had}/p < 1$ of the minimum ionizing particles from Jet20/50/70/100.

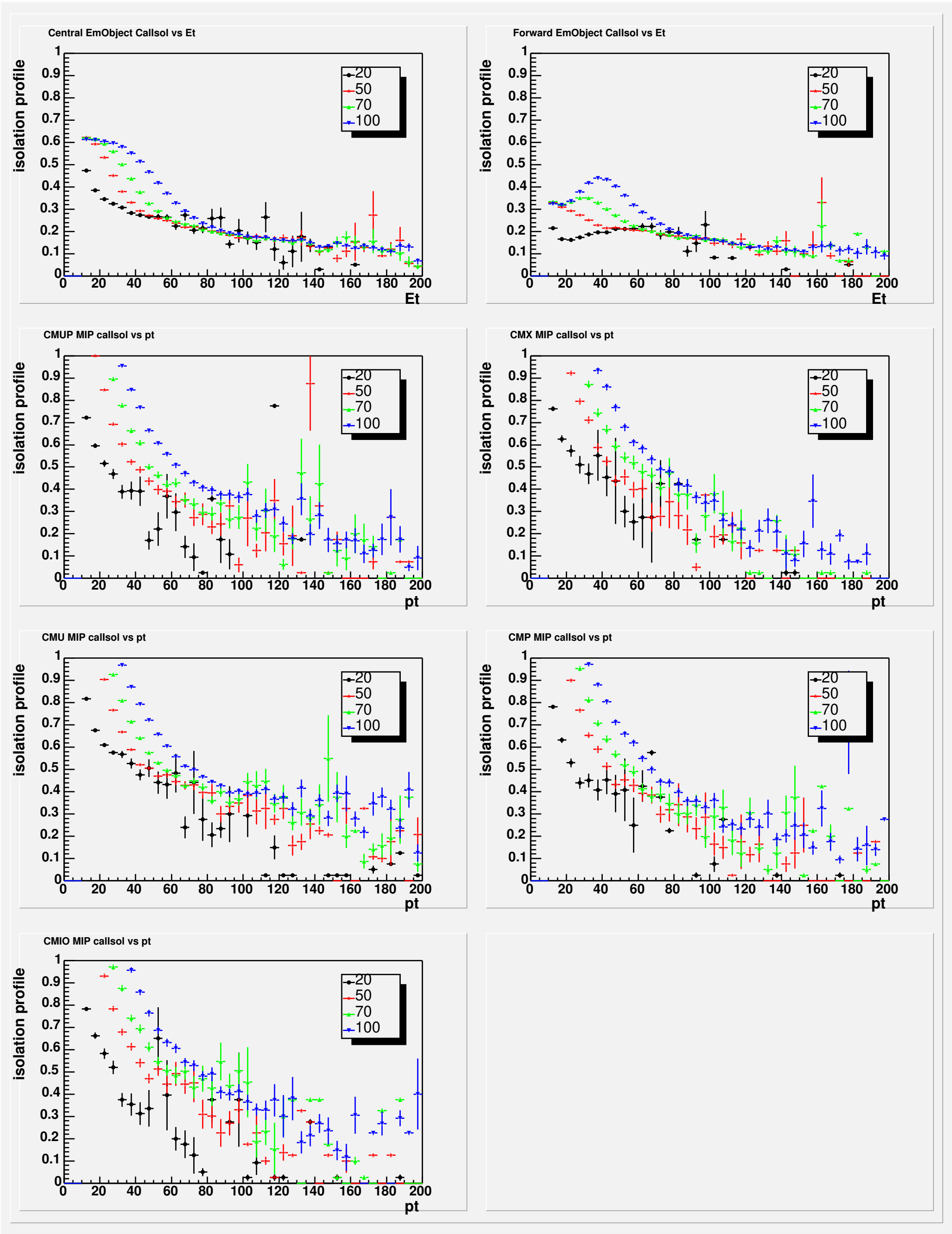

Figure 4: Fakeable object calorimetric isolation profiles *vs* E_t from Jet20/50/70/100.

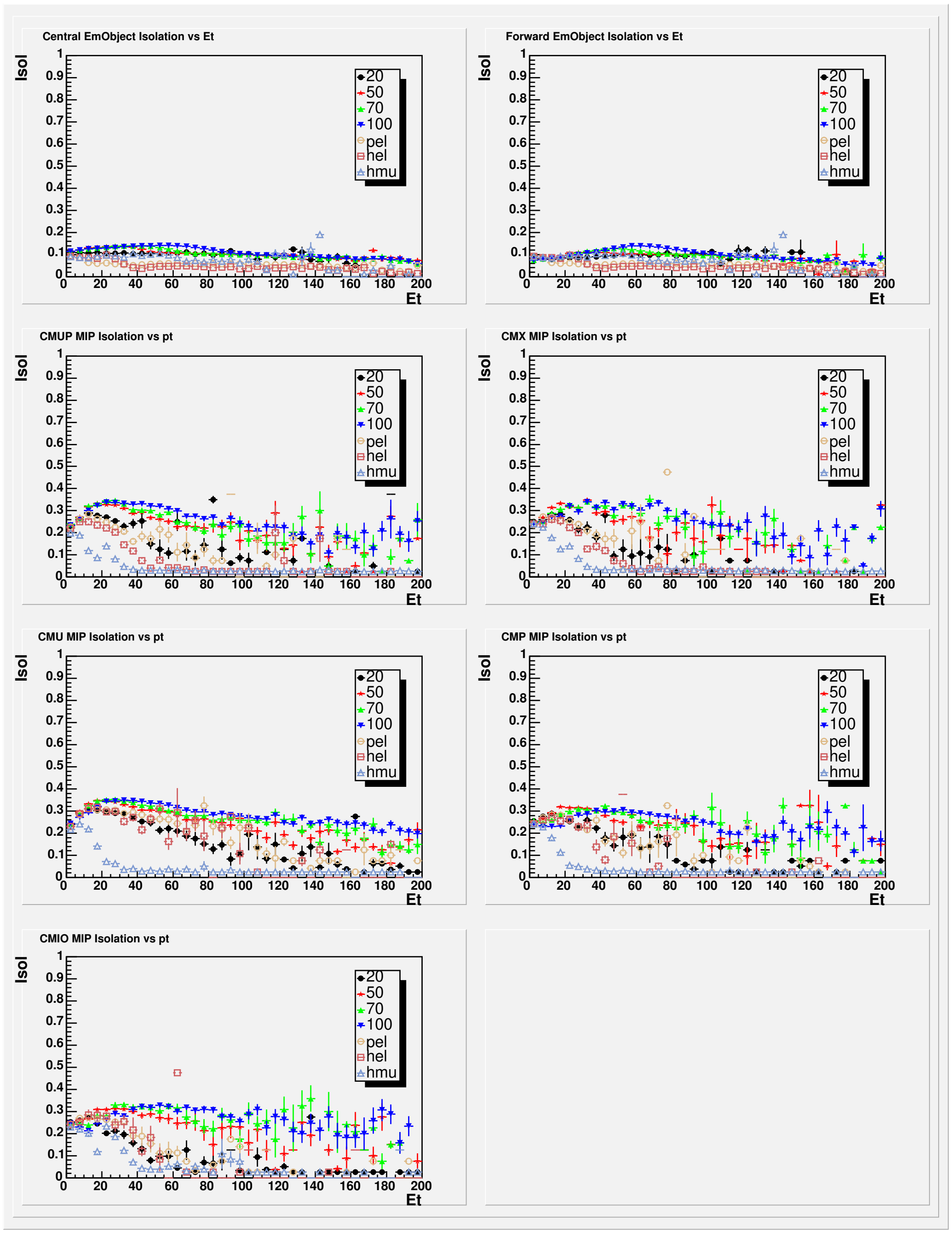

Figure 5: Fakeable object calorimetric isolation profiles *vs* E_t from Jet20/50/70/100 and bhel/pel/hmu0d after requiring calorimetric isolation < 0.2.

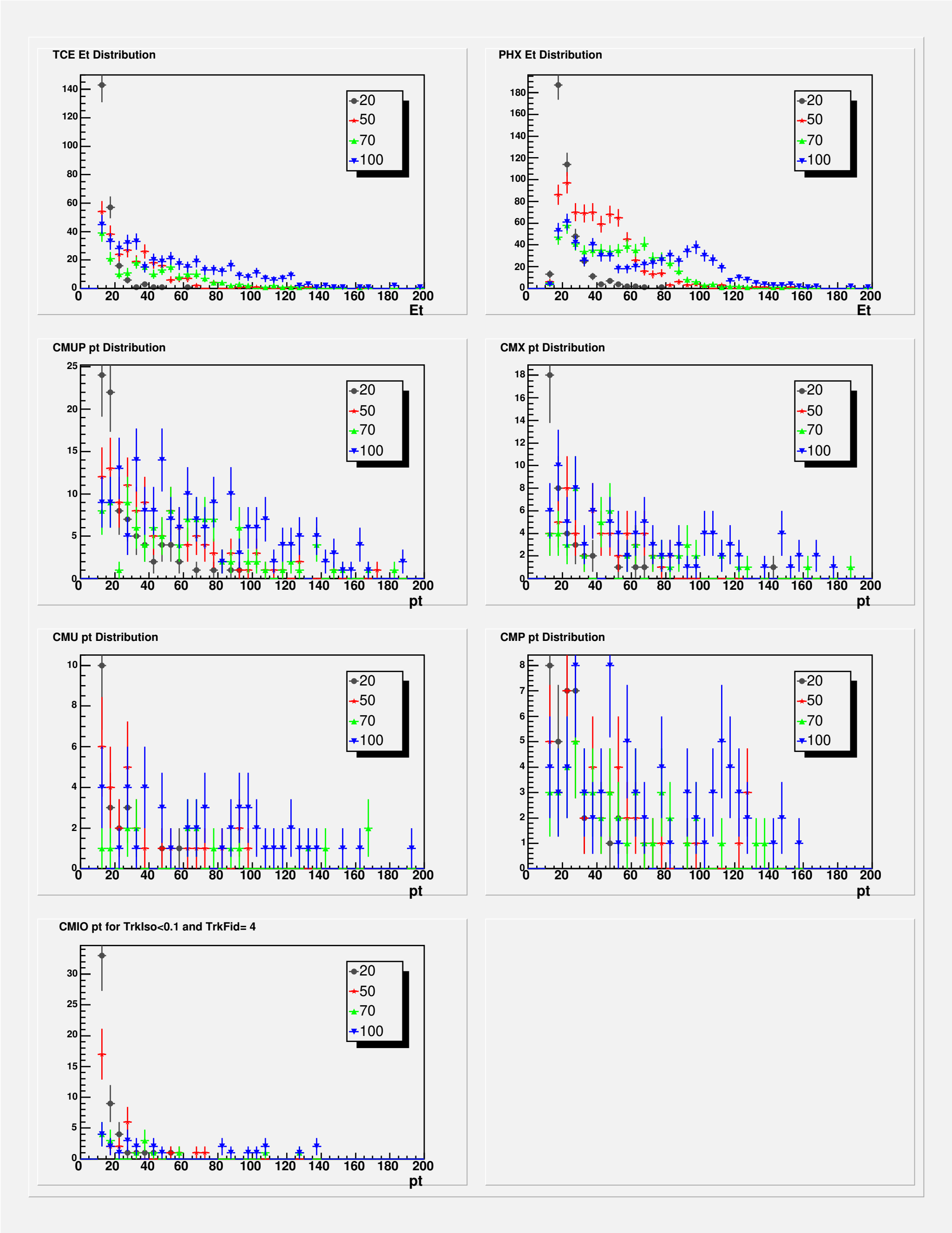

Figure 6: Lepton p_t distributions from Jet20/50/70/100.

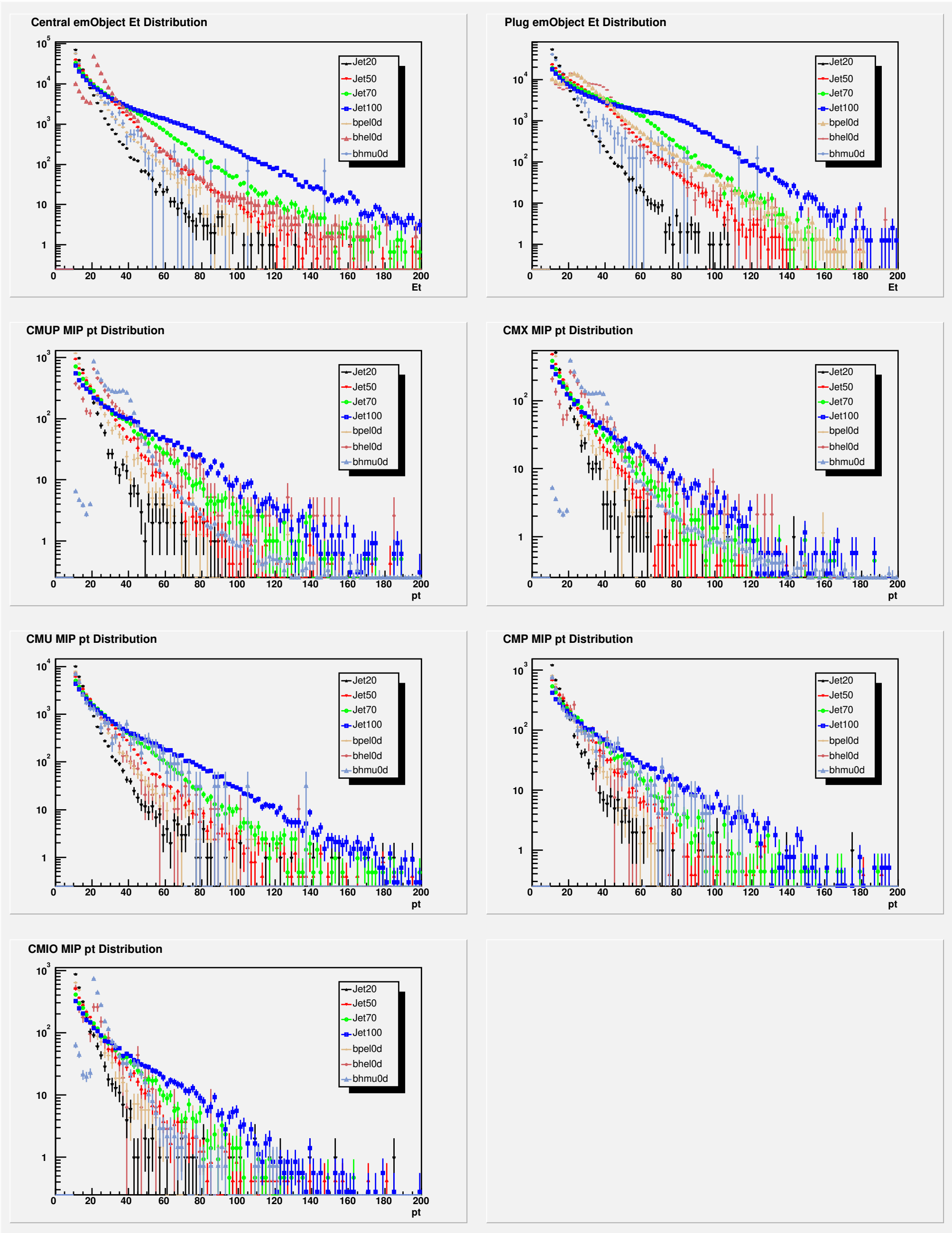

Figure 7: Normalized fakeable object E_t distributions from Jet20/50/70/100 and bhel/pel/hmu0d.

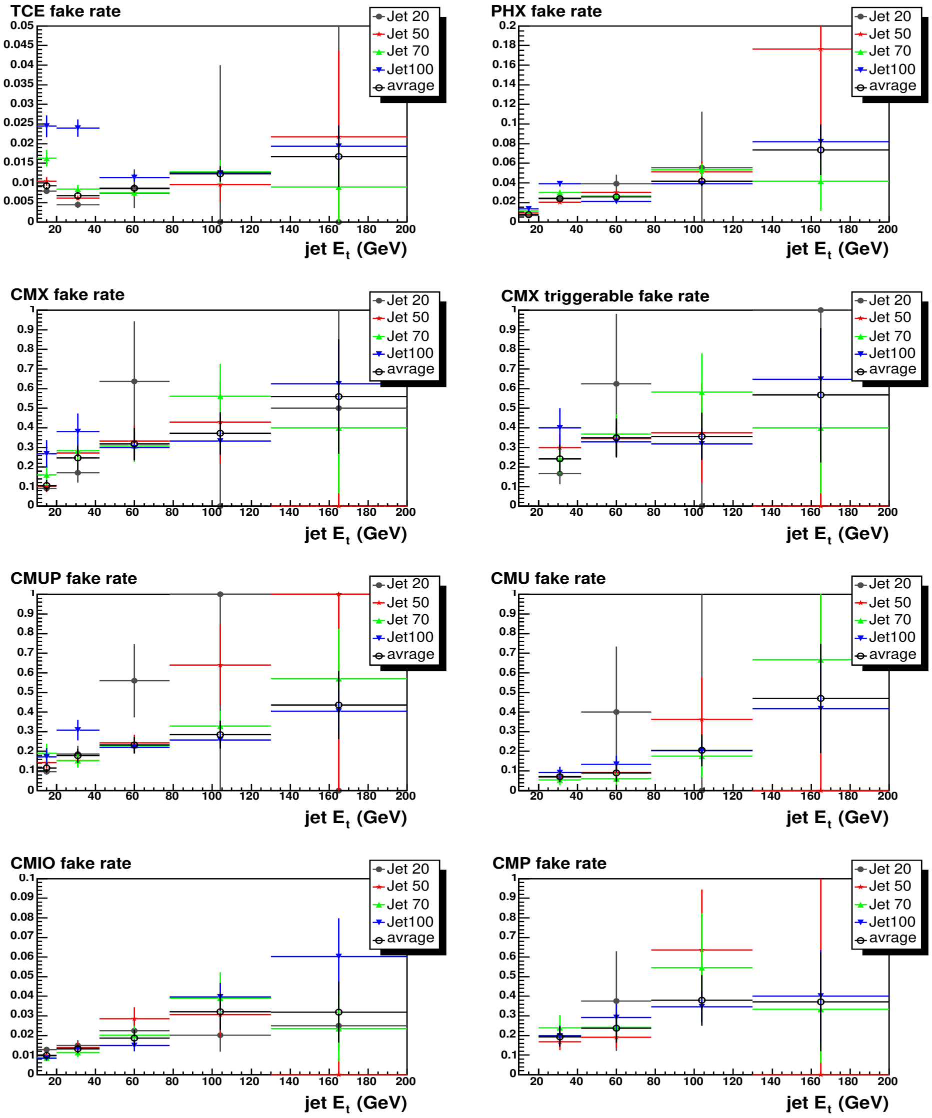

Figure 8: Lepton fake rates estimated using rebinned Figure 6 and Figure 7, including the averages over jet20/50/70/100.

lepton	*fakrat*	*densrc*	number predicted	lepton	*fakrat*	*densrc*	number predicted
TCE	Jet 20	Jet 20	229.00 ± 15.31	PHX	Jet 20	Jet 20	420.00 ± 20.83
TCE	Jet 50	Jet 20	301.47 ± 27.80	PHX	Jet 50	Jet 20	468.97 ± 31.79
TCE	Jet 70	Jet 20	464.15 ± 54.10	PHX	Jet 70	Jet 20	609.97 ± 52.36
TCE	Jet100	Jet 20	762.59 ± 72.16	PHX	Jet100	Jet 20	739.02 ± 59.08
TCE	Jet 20	Jet 50	204.25 ± 45.64	PHX	Jet 20	Jet 50	847.53 ± 91.53
TCE	Jet 50	Jet 50	253.00 ± 16.03	PHX	Jet 50	Jet 50	728.00 ± 27.63
TCE	Jet 70	Jet 50	344.55 ± 27.31	PHX	Jet 70	Jet 50	876.33 ± 43.61
TCE	Jet100	Jet 50	707.25 ± 46.04	PHX	Jet100	Jet 50	990.82 ± 53.90
TCE	Jet 20	Jet 70	142.63 ± 82.99	PHX	Jet 20	Jet 70	628.15 ± 115.99
TCE	Jet 50	Jet 70	168.22 ± 13.37	PHX	Jet 50	Jet 70	533.17 ± 25.07
TCE	Jet 70	Jet 70	209.00 ± 14.61	PHX	Jet 70	Jet 70	563.00 ± 24.42
TCE	Jet100	Jet 70	384.96 ± 21.36	PHX	Jet100	Jet 70	560.09 ± 25.92
TCE	Jet 20	Jet100	140.71 ± 372.10	PHX	Jet 20	Jet100	780.98 ± 349.08
TCE	Jet 50	Jet100	228.92 ± 36.93	PHX	Jet 50	Jet100	730.38 ± 73.81
TCE	Jet 70	Jet100	274.04 ± 26.45	PHX	Jet 70	Jet100	730.41 ± 44.41
TCE	Jet100	Jet100	423.00 ± 20.93	PHX	Jet100	Jet100	668.00 ± 26.71

leptype	*fakrat*	*densrc*	number predicted	lepton	*fakrat*	*densrc*	number predicted
CMX	Jet 20	Jet 20	51.00 ± 8.48	CMX_{trg}	Jet 20	Jet 20	17.00 ± 5.47
CMX	Jet 50	Jet 20	59.61 ± 11.58	CMX_{trg}	Jet 50	Jet 20	23.22 ± 5.49
CMX	Jet 70	Jet 20	80.00 ± 19.03	CMX_{trg}	Jet 70	Jet 20	20.39 ± 5.55
CMX	Jet100	Jet 20	121.82 ± 24.08	CMX_{trg}	Jet100	Jet 20	30.32 ± 7.54
CMX	Jet 20	Jet 50	75.86 ± 24.73	CMX_{trg}	Jet 20	Jet 50	51.08 ± 22.26
CMX	Jet 50	Jet 50	69.00 ± 10.41	CMX_{trg}	Jet 50	Jet 50	46.00 ± 8.76
CMX	Jet 70	Jet 50	78.89 ± 12.62	CMX_{trg}	Jet 70	Jet 50	45.31 ± 9.25
CMX	Jet100	Jet 50	98.42 ± 14.22	CMX_{trg}	Jet100	Jet 50	53.72 ± 10.03
CMX	Jet 20	Jet 70	59.03 ± 25.89	CMX_{trg}	Jet 20	Jet 70	44.62 ± 23.09
CMX	Jet 50	Jet 70	59.01 ± 10.36	CMX_{trg}	Jet 50	Jet 70	42.03 ± 9.55
CMX	Jet 70	Jet 70	68.00 ± 10.75	CMX_{trg}	Jet 70	Jet 70	47.00 ± 9.19
CMX	Jet100	Jet 70	74.51 ± 10.11	CMX_{trg}	Jet100	Jet 70	48.61 ± 8.19
CMX	Jet 20	Jet100	92.85 ± 56.99	CMX_{trg}	Jet 20	Jet100	73.67 ± 50.58
CMX	Jet 50	Jet100	96.37 ± 22.16	CMX_{trg}	Jet 50	Jet100	68.51 ± 21.54
CMX	Jet 70	Jet100	120.19 ± 20.90	CMX_{trg}	Jet 70	Jet100	88.21 ± 18.20
CMX	Jet100	Jet100	118.00 ± 14.25	CMX_{trg}	Jet100	Jet100	80.00 ± 11.93

Table 7: TCE/PHX/CMX/$CMX_{triggerable}$ lepton number predictons with Jet20/50/70/100 *fak*e *rat*e applied to the *den*ominators in *s*ou*rc*e jet sample, showing overall agreement. The true numbers of leptons in the *densrc* jet sample are retained when applied the fakerates from the same jet sample.

lepton	*fakrat*	*densrc*	number predicted	lepton	*fakrat*	*densrc*	number predicted
CMUP	Jet 20	Jet 20	86.00 ± 11.15	CMU	Jet 20	Jet 20	7.00 ± 3.21
CMUP	Jet 50	Jet 20	96.23 ± 15.06	CMU	Jet 50	Jet 20	5.69 ± 1.77
CMUP	Jet 70	Jet 20	117.64 ± 24.31	CMU	Jet 70	Jet 20	4.37 ± 2.07
CMUP	Jet100	Jet 20	128.45 ± 22.70	CMU	Jet100	Jet 20	7.39 ± 2.33
CMUP	Jet 20	Jet 50	177.45 ± 41.10	CMU	Jet 20	Jet 50	31.88 ± 21.90
CMUP	Jet 50	Jet 50	121.00 ± 13.53	CMU	Jet 50	Jet 50	19.00 ± 5.02
CMUP	Jet 70	Jet 50	119.28 ± 15.10	CMU	Jet 70	Jet 50	13.88 ± 4.78
CMUP	Jet100	Jet 50	151.03 ± 17.45	CMU	Jet100	Jet 50	23.28 ± 5.31
CMUP	Jet 20	Jet 70	217.71 ± 81.82	CMU	Jet 20	Jet 70	31.54 ± 28.17
CMUP	Jet 50	Jet 70	142.10 ± 23.67	CMU	Jet 50	Jet 70	17.29 ± 7.94
CMUP	Jet 70	Jet 70	116.00 ± 13.21	CMU	Jet 70	Jet 70	15.00 ± 4.72
CMUP	Jet100	Jet 70	126.59 ± 12.35	CMU	Jet100	Jet 70	21.49 ± 4.37
CMUP	Jet 20	Jet100	388.87 ± 213.23	CMU	Jet 20	Jet100	40.48 ± 88.52
CMUP	Jet 50	Jet100	277.95 ± 64.95	CMU	Jet 50	Jet100	45.60 ± 22.20
CMUP	Jet 70	Jet100	196.43 ± 24.61	CMU	Jet 70	Jet100	33.77 ± 11.72
CMUP	Jet100	Jet100	193.00 ± 17.18	CMU	Jet100	Jet100	43.00 ± 7.67
lepton	*fakrat*	*densrc*	number predicted	lepton	*fakrat*	*densrc*	number predicted
CMIO	Jet 20	Jet 20	188.00 ± 13.90	CMP	Jet 20	Jet 20	19.00 ± 5.26
CMIO	Jet 50	Jet 20	154.54 ± 15.34	CMP	Jet 50	Jet 20	14.99 ± 3.73
CMIO	Jet 70	Jet 20	139.06 ± 16.14	CMP	Jet 70	Jet 20	21.09 ± 5.67
CMIO	Jet100	Jet 20	144.53 ± 12.36	CMP	Jet100	Jet 20	18.17 ± 4.56
CMIO	Jet 20	Jet 50	140.80 ± 11.56	CMP	Jet 20	Jet 50	49.98 ± 19.91
CMIO	Jet 50	Jet 50	124.00 ± 11.35	CMP	Jet 50	Jet 50	40.00 ± 7.85
CMIO	Jet 70	Jet 50	108.23 ± 11.34	CMP	Jet 70	Jet 50	51.01 ± 10.22
CMIO	Jet100	Jet 50	112.52 ± 8.49	CMP	Jet100	Jet 50	47.94 ± 8.42
CMIO	Jet 20	Jet 70	121.05 ± 10.52	CMP	Jet 20	Jet 70	35.95 ± 15.59
CMIO	Jet 50	Jet 70	110.05 ± 10.18	CMP	Jet 50	Jet 70	30.06 ± 8.68
CMIO	Jet 70	Jet 70	95.00 ± 9.89	CMP	Jet 70	Jet 70	39.00 ± 7.86
CMIO	Jet100	Jet 70	97.01 ± 7.20	CMP	Jet100	Jet 70	37.24 ± 6.44
CMIO	Jet 20	Jet100	233.43 ± 21.29	CMP	Jet 20	Jet100	48.95 ± 21.76
CMIO	Jet 50	Jet100	218.69 ± 20.88	CMP	Jet 50	Jet100	76.85 ± 25.71
CMIO	Jet 70	Jet100	193.02 ± 20.72	CMP	Jet 70	Jet100	84.19 ± 22.51
CMIO	Jet100	Jet100	199.00 ± 14.36	CMP	Jet100	Jet100	71.00 ± 10.62

Table 8: CMUP/CMU/CMP/CMIO lepton number predictons with Jet20/50/70/100 *fak*e *rat*e applied to the *den*ominators in *s*ou*rc*e jet sample, showing overall agreement. The true numbers of leptons in the *densrc* jet sample are retained when applied the fakerates from the same jet sample.

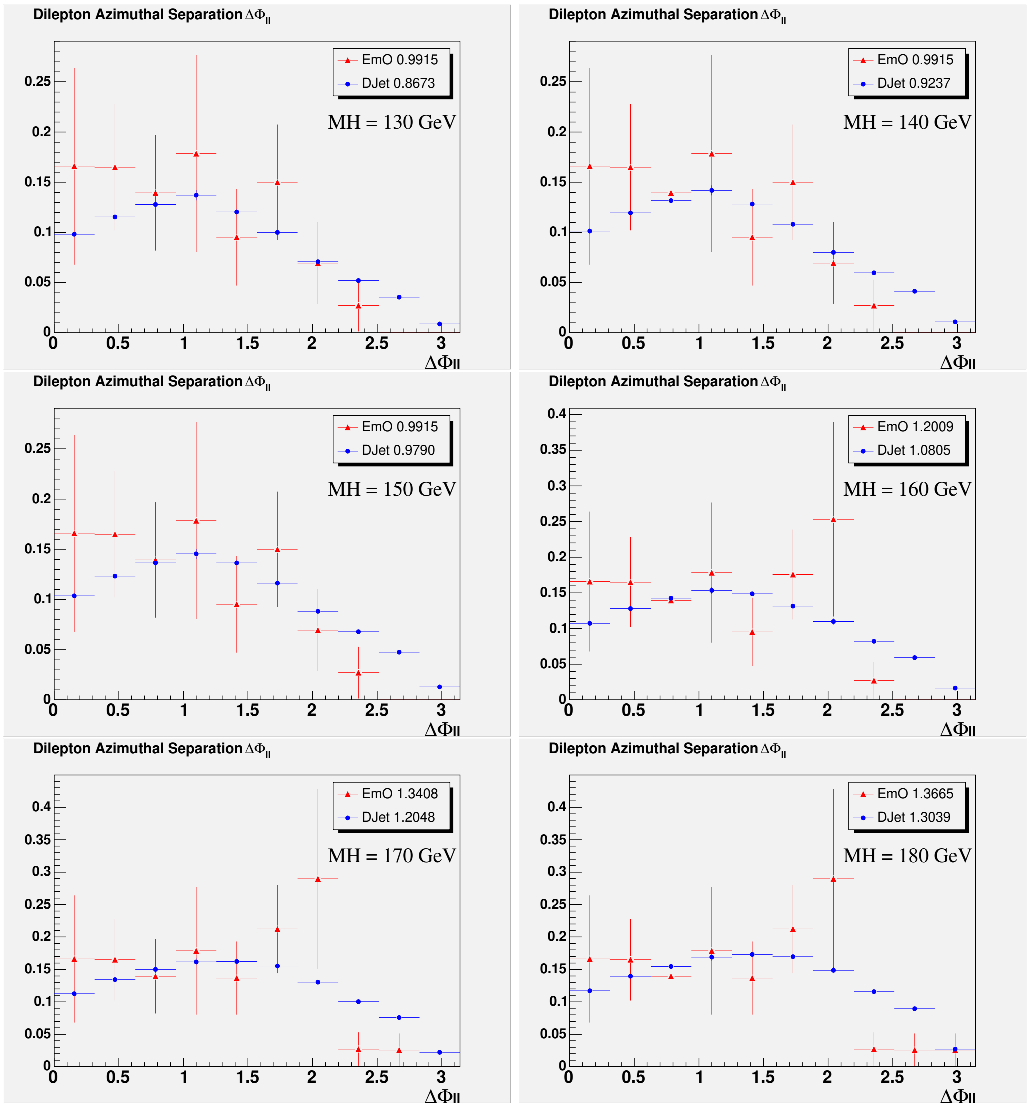

Figure 9: The dilepton azimuthal angular separation $\Delta\phi_{\ell\ell}$ distributions of the fake background estimated with either em objects (EmO) or generic jets (DJet) as electron fake rate denominators and minimum ionizing particles (MIP) as muon fake rate denominators. The numbers in the legends are the integrals of the corresponding histograms, which means also the total fake backrgrounds. The shapes agree reasonably well although the EmO errors are much larger than DJet because the statistics (and the CPU consumption) are much smaller.