WW→lνlν : Final Numbers

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- Drell−Yan background :
  - updated data−based estimate
  - updated systematic uncertainty
- Fake background :
  - use of full statistics
  - more careful W/Z contamination removal
  - P_T dependence
- Diboson backgrounds :
  - ZZ
  - W(Z/γ*) normalization
- Signal estimates :
  - updated WW yield calculations
  - PDF acceptance systematic

Not covered :

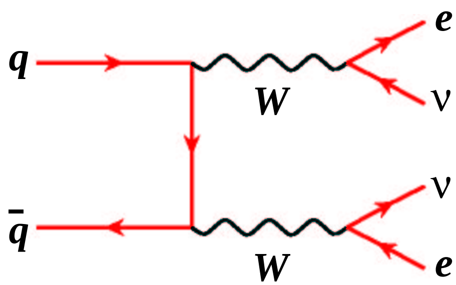
- Updated MET_PEM trigger efficiency
- Updates on heavy flavour background
- Many other minor changes and cross−checks.

See :

CDF−6909

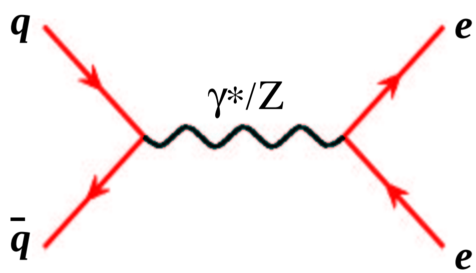
http://www−cdf.fnal.gov/internal/physics/WW

The Big Picture



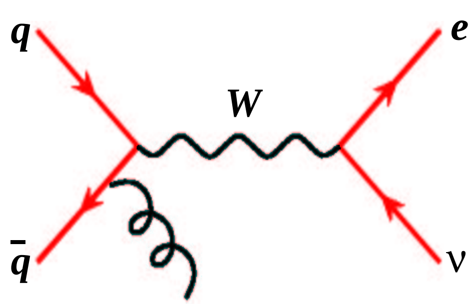
<u>Signal:</u>
$\sigma(p\bar{p}\to WW \to e\nu e\nu) \sim 0.15$ pb

MC



<u>Drell−Yan :</u>
$\sigma(p\bar{p}\to \gamma^*/Z \to ee) \sim 250$ pb
Must have "fake" missing−E_T.

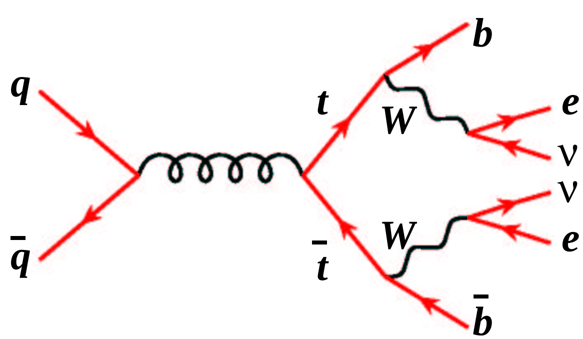
MC ?



<u>W+jets :</u>
$\sigma(p\bar{p}\to W(\to e\nu)+\geq 1\text{−jet}) \sim 500$ pb
Jet must fake a lepton.

DATA

e.g.



<u>$t\bar{t}$, WZ, ZZ, Wγ:</u>

$\sigma(p\bar{p}\to t\bar{t} \to e\nu e\nu b\bar{b}) \sim 0.1$ pb
$\sigma(pp\to WZ \to e\nu ee) \sim 0.01$pb
$\sigma(pp\to ZZ \to ee\nu\nu) \sim 0.02$ pb
$\sigma(pp\to W\gamma \to e\nu\gamma) \sim 50$ pb

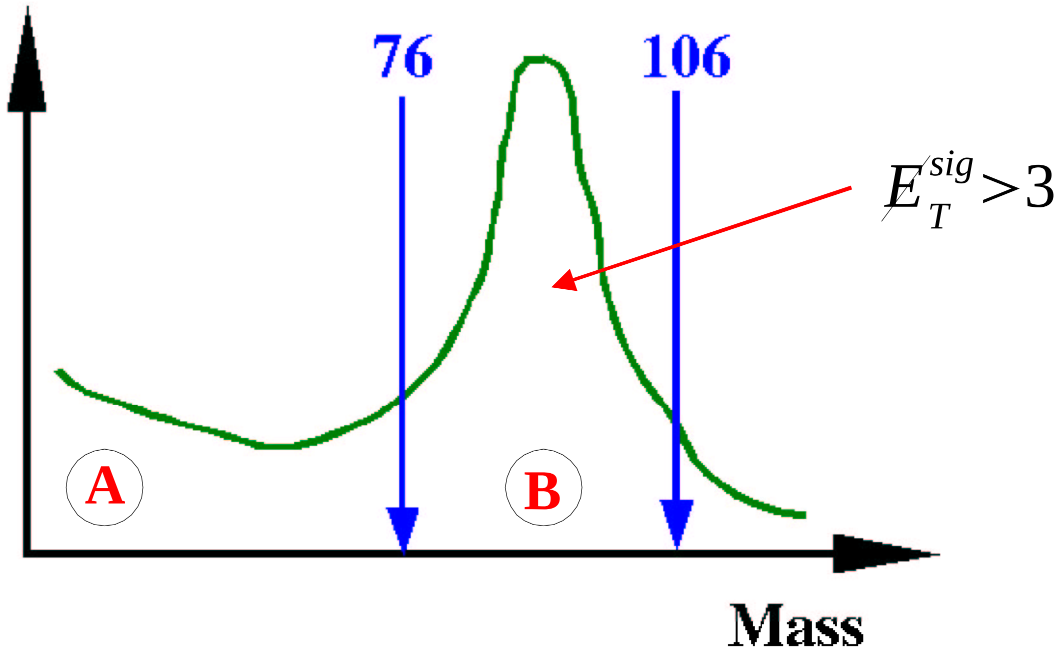
MC

Diboson Backgrounds

SOMETHING HERE ON ZZ AND W/GAMMA* CONCERNS

Drell−Yan Background

Data−based method :



A (outside Z window) :

$$N_{DY}^{\text{out}} = n_{WW}^{\text{in}} \times R_{\frac{\text{out}}{\text{in}}}$$

events in **B** passing **A** cuts

ratio of DY events in **A** to DY events in **B**

Drell−Yan Background : Outside Z Window

	ee		$\mu\mu$	
	Data	MC ($\not{E}_T > 25GeV$)	Data	MC ($\not{E}_T > 25GeV$)
Outside Window	577	242	604	219
Inside window	5459	471	4934	385
$R_{\frac{out}{in}}$	0.106 ± 0.001	0.51 ± 0.02	0.122 ± 0.001	0.57 ± 0.01

ratio very correlated with cuts : take from MC

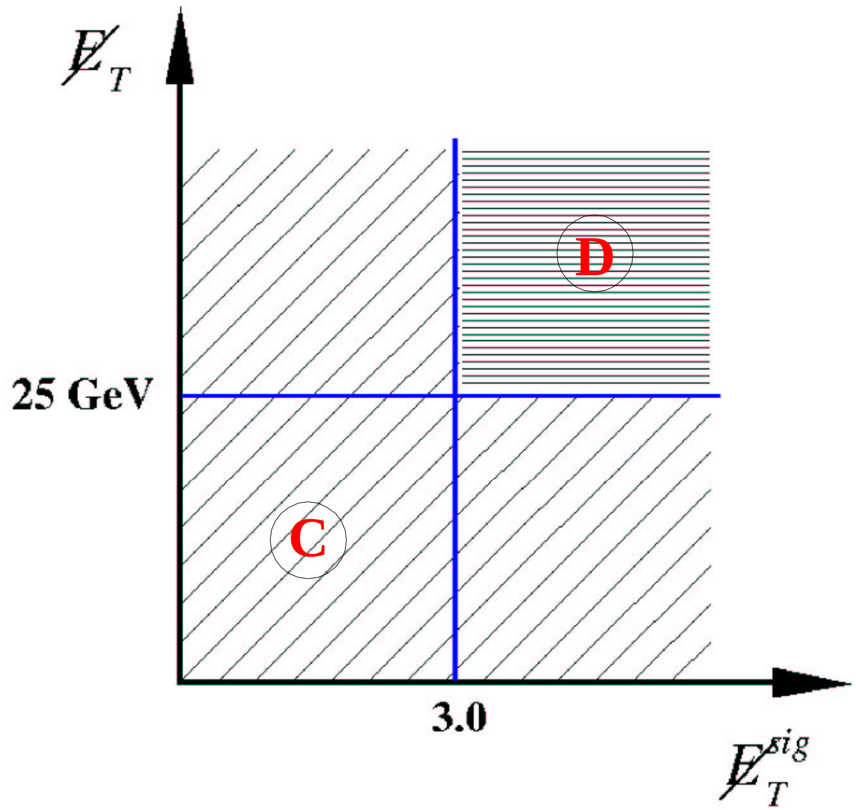
Number of events in Z mass window passing WW cuts heavily contaminated :

	WW	$t\bar{t}$	WZ	Fake	$Z \rightarrow \tau\tau$	ZZ	$W\gamma$	Total (n^{in}_{other})
ee	0.70	0.007	0.28	0.114	0.012	0.38	0.06	1.55
$\mu\mu$	0.65	0.0	0.28	0.086	0.007	0.39	0.0	1.41

Drell−Yan Background : Outside Z Window

Background Estimate	ee	$\mu\mu$
n_{ww}^{in}	2	1
$(n_{ww}^{in} - n_{other}^{in})$	$(2 - 1.55)$	$(1 - 1.41)$
$(n_{ww}^{in} - n_{other}^{in}) \times R_{\frac{out}{in}}$	$(2 - 1.55) \times 0.51$ $= 0.23 \pm 0.61$	$(1 - 1.41) \times 0.57$ $= -0.23 \pm 0.68$

Drell−Yan Background : Inside Z Window



C : $\not{E}_T < 25 \vee \not{E}_T^{sig} < 3$

D : $\not{E}_T > 25 \wedge \not{E}_T^{sig} > 3$

B (inside Z window) :

$$N_{DY}^{\text{in}} = \hat{n}_{WW}^{\text{in}} \times R_{\frac{\hat{DY}}{DY}}$$

events in **C** passing **D** cuts

ratio of DY events in **D** to DY events in **C**

Drell−Yan Background : Inside Z Window

	ee	$\mu\mu$
Numerator Denominator	3 5456	3 4931
$R_{\frac{\hat{DY}}{DY}} = \frac{Numerator - \hat{n}^{in}_{other}}{Denominator}$	$\frac{3-2.75}{5456}$ $= 4.55 \times 10^{-5} \pm 0.0003$	$\frac{3-2.26}{4931}$ $= 0.00015 \pm 0.00035$

Numerator is *mainly* non−DY.

	WW	$t\bar{t}$	WZ	Fake	$Z \to \tau\tau$	ZZ	$W\gamma$	Total $\hat{n}^{in}_{other}$
ee	0.74	0.56	0.59	0.09	0.06	0.47	0.23	2.75
$\mu\mu$	0.65	0.51	0.53	0.06	0.05	0.47	0.0	2.26

Drell−Yan Background : Inside Z Window

Background Estimate	ee	$\mu\mu$
$\hat{n}_{ww}^{in}$	3160	3107
$\hat{n}_{ww}^{in} \times R_{\frac{\hat{DY}}{DY}}$	$3160 \times (4.55 \times 10^{-05})$ $= 0.14 \pm 1.00$	3107×0.00015 0.46 ± 1.09

Drell−Yan Background : Summary

Channel	Inside	Outside	Total
ee	0.14 ± 1.00	0.23 ± 0.61	0.37 ± 1.18
$\mu\mu$	0.46 ± 1.09	-0.23 ± 0.68	0.46 ± 1.28

MC
0.75 ± 0.34
0.61 ± 0.27

Comments on data cross−check :

- It is not independent of the assumed WW cross−section due to the contamination corrections. Turning off WW in the contamination estimate :

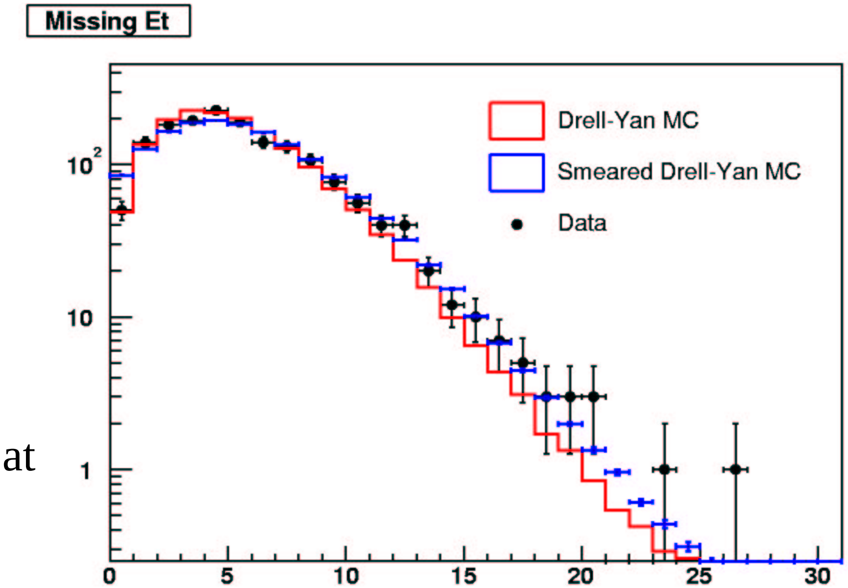
DATA (w/WW)	**DATA (wo/WW)**
0.37 ± 1.18	**1.2 ± 0.3**
0.46 ± 1.28	**1.0 ± 0.3**

Iterative solution would be close to estimate with WW.

- Still dependent on MC in several ways.
- Considered a consistency check only.

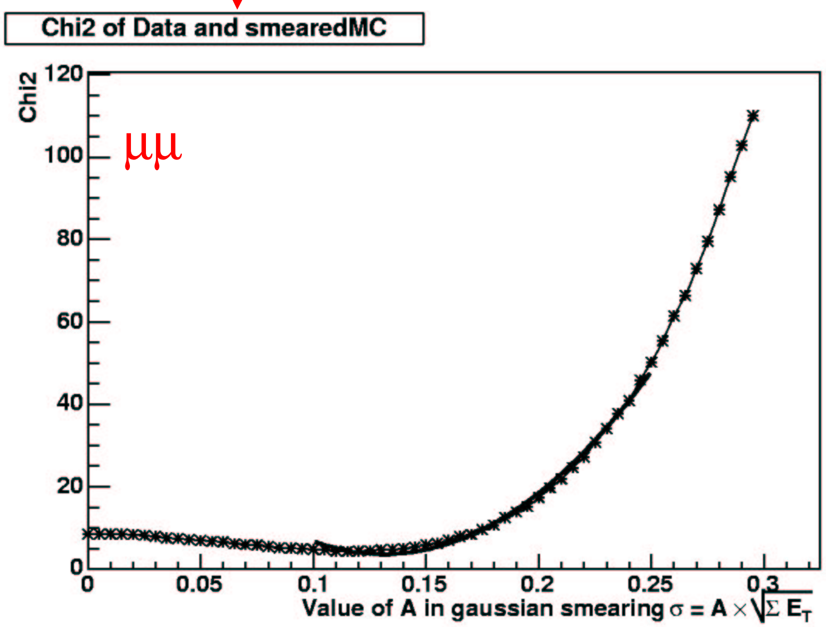
Drell−Yan Systematic

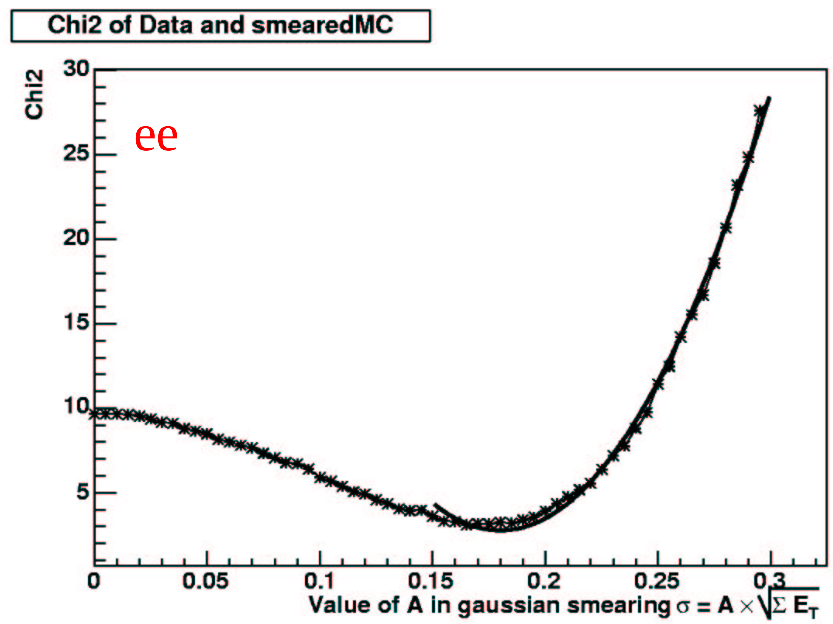
- Previously done by "eye".
- Now smear $\propto \sqrt{\Sigma E_T}$ and fit $\not\!E_T$ distribution between 10 and 20 GeV where contamination small.



no clear evidence for additional smearing required (minumum covered by systematic)

additional smearing does much better job at intermediate $\not\!E_T$





Fakes

$$R_{TCE\,(PHX)} = \frac{\text{Number of isolated TCE}\,(\text{PHX})}{\text{Number of jets with}\,|\eta|<1.1\,(1.2<|\eta|<2.5)}$$

raw $E_T > 20$ GeV

No tight $\not{E}_T$ cut to remove W contamination (worry about bias of this cut)

$$R_{\mu} = \frac{\text{Number of isolated}\,\mu}{\text{Number of tracks consistent with MIP's}}$$

corrected track $P_T > 20$ GeV

$E/P < 1.0$

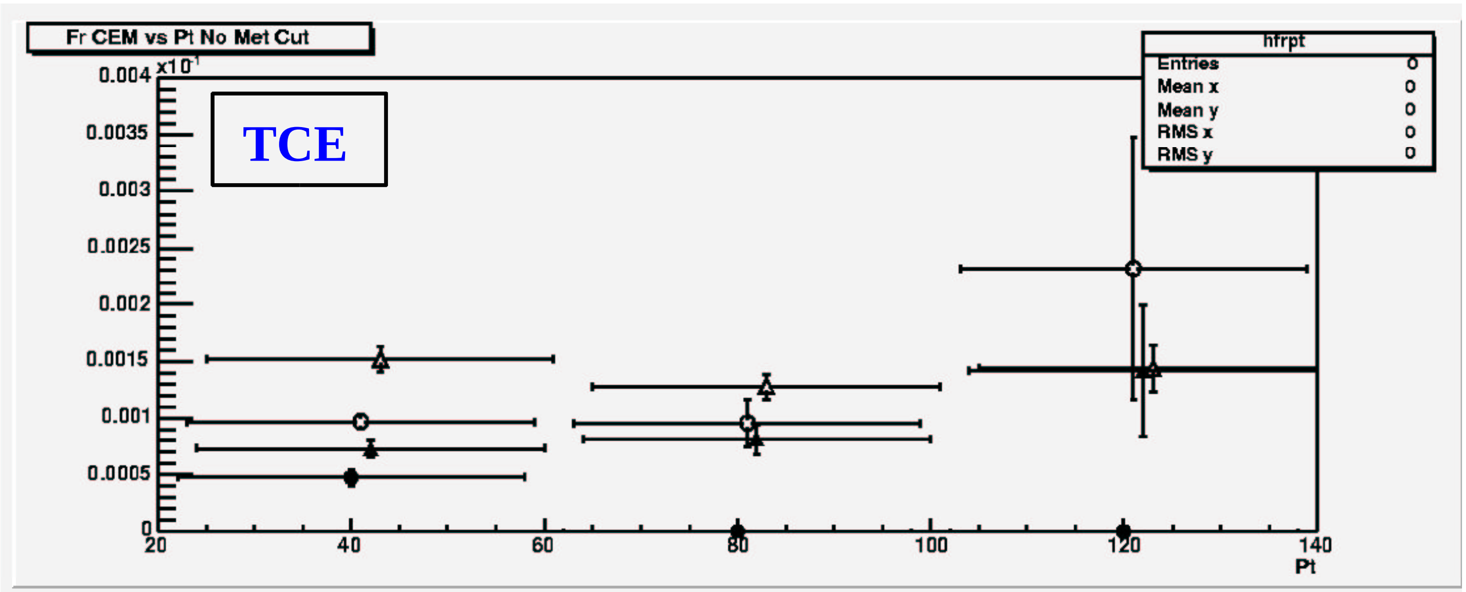
track $|z_0| < 60.0$ cm

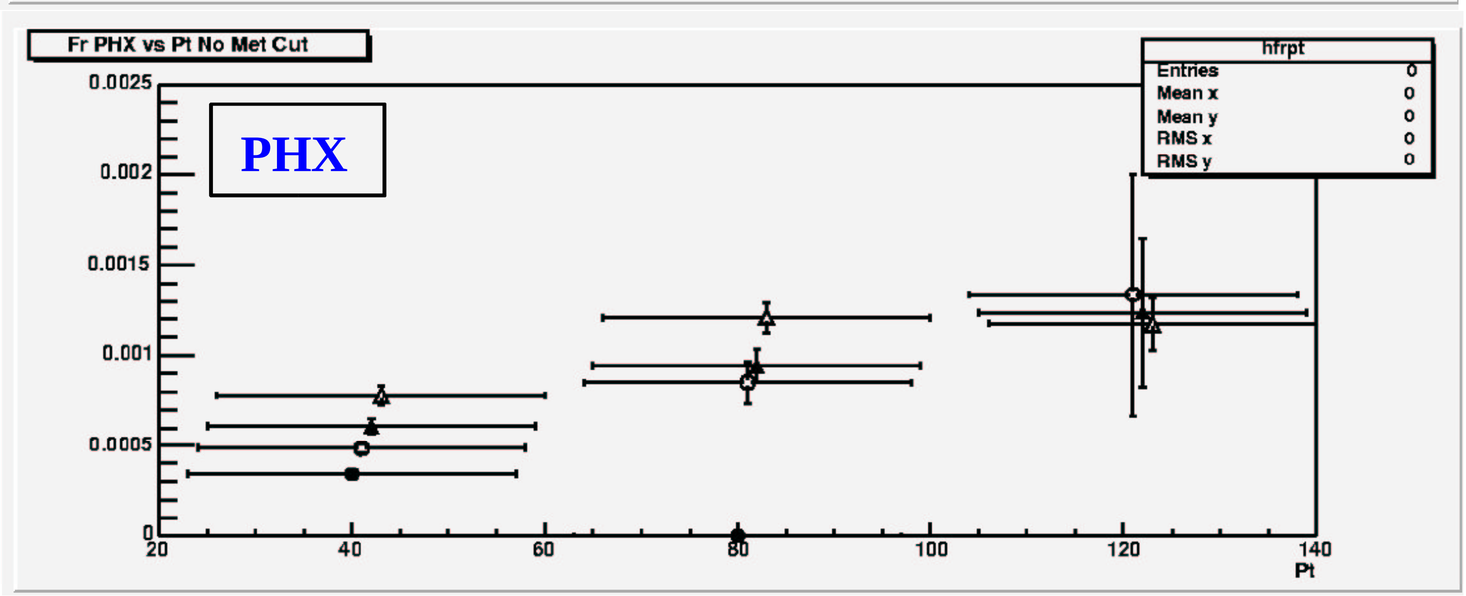
track $|d_0| < 0.2$ cm, < 0.02 cm if SI hits

non$-$cosmic

(CMUP, CMU, CMP, CMX, CMIO) based on muon fiducial tool

Fakes : P_T Dependence

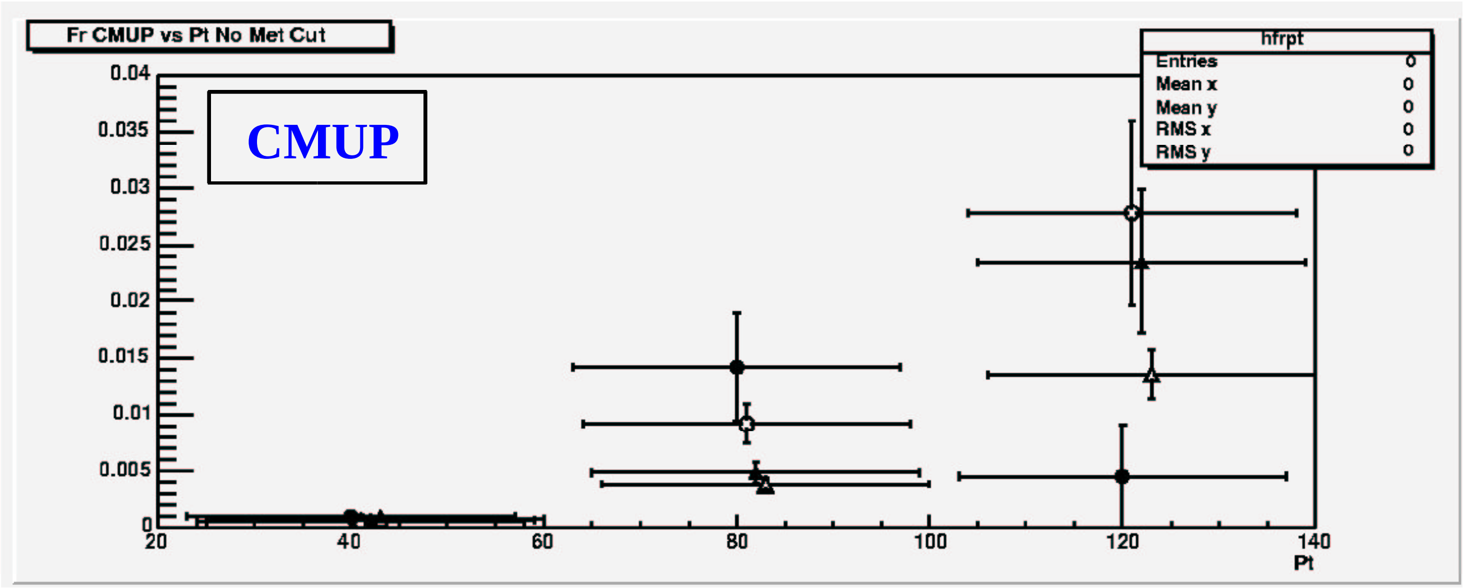


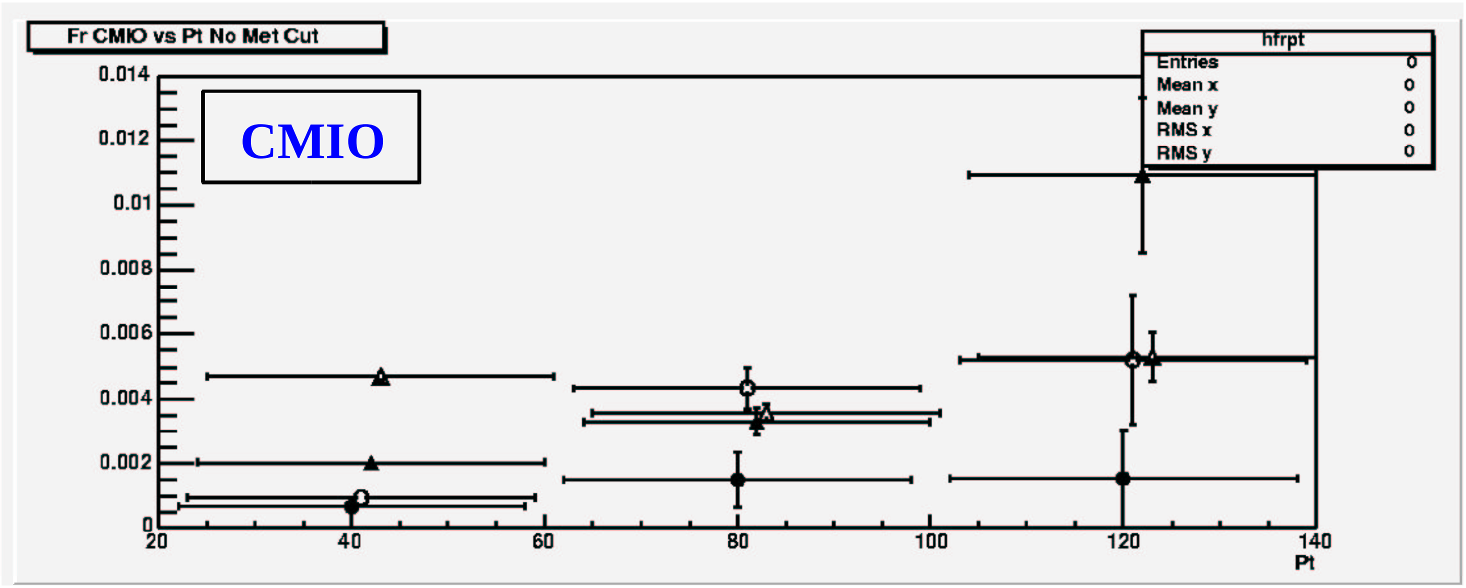


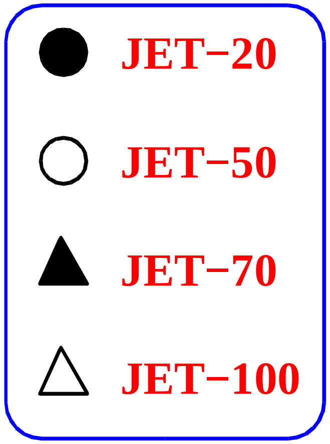
- ● JET−20
- ○ JET−50
- ▲ JET−70
- △ JET−100

- Fake rates applied as a function of denominator P_T.
- Final fake estimate changes very little compared to applying an average value.

Fakes : P_T Dependence







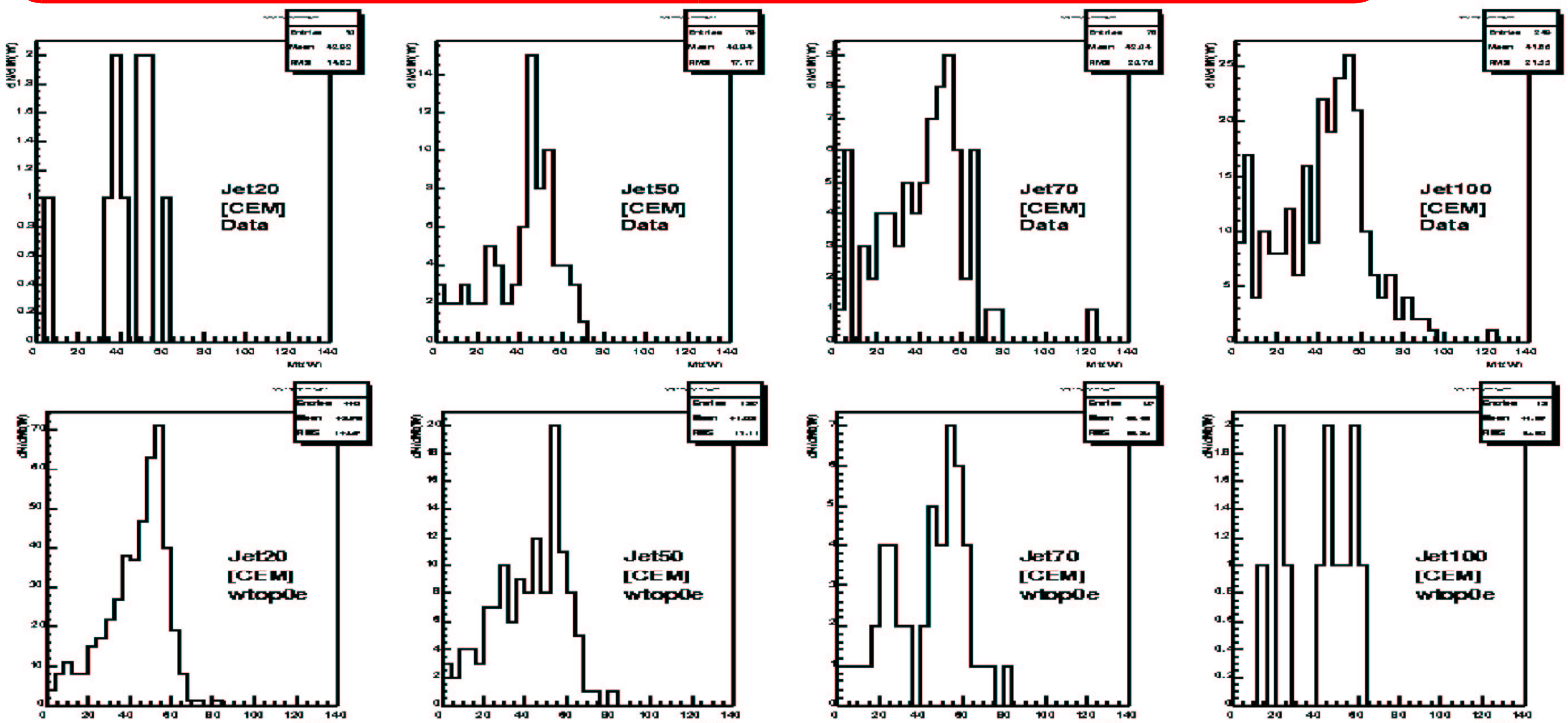
Fakes : W Contamination Correction

- Want to remove leptons from W decay from fake ratio numerator.
- Previously done by applying a harsh and potentially biasing cut : $\not\!\!E_T < 10\ \text{GeV}$
- New strategy is to select W events in the lepton (signal) sample and directly count how many will have entered the fake ratio numerator.
- Double check using Monte Carlo that the events we remove are "W−like".

Isolated lepton, $\not\!\!E_T > 20\ \text{GeV}$, must be in FR numerator (trigger bit, leading jet) :

DATA

PYTHIA



P_T	$20 < P_T < 60$	$60 < P_T < 100$	$100 < P_T < 140$
JET20 CEM	0.00004 ± 0.00001	0. ± 0.	0. ± 0.
JET50 CEM	0.00007 ± 0.00001	0.00006 ± 0.00002	0.00006 ± 0.00006
JET70 CEM	0.00003 ± 0.00001	0.00004 ± 0.00001	0.00010 ± 0.00005
JET100 CEM	0.00005 ± 0.00001	0.00004 ± 0.00001	0.00007 ± 0.00001
CEM	0.00005 ± 0.00002	0.00003 ± 0.00003	0.00006 ± 0.00005
JET20 PHX	0.00033 ± 0.00003	0. ± 0.	0.00658 ± 0.00660
JET50 PHX	0.00044 ± 0.00002	0.00068 ± 0.00010	0.00102 ± 0.00058
JET70 PHX	0.00043 ± 0.00004	0.00084 ± 0.00008	0.00111 ± 0.00039
JET100 PHX	0.00036 ± 0.00004	0.00085 ± 0.00007	0.00100 ± 0.00014
PHX	0.00039 ± 0.00005	0.00059 ± 0.00042	0.00243 ± 0.00279
JET20 CMUP	0.00081 ± 0.00015	0.01136 ± 0.00426	0.00452 ± 0.00454
JET50 CMUP	0.00021 ± 0.00005	0.00375 ± 0.00115	0.01944 ± 0.00678
JET70 CMUP	0.00031 ± 0.00007	0.00223 ± 0.00066	0.00983 ± 0.00408
JET100 CMUP	0.00036 ± 0.00007	0.00118 ± 0.00030	0.00743 ± 0.00159
CMUP	0.00042 ± 0.00030	0.00463 ± 0.00509	0.01031 ± 0.00746
JET20 CMU	0.00046 ± 0.00022	0. ± 0.	0. ± 0.
JET50 CMU	0.00024 ± 0.00010	0.00051 ± 0.00082	0. ± 0.
JET70 CMU	0.00015 ± 0.00010	0.00288 ± 0.00141	0. ± 0. (*)
JET100 CMU	0.00023 ± 0.00010	0.00001 ± 0.00005	0. ± 0. (*)
CMU	0.00027 ± 0.00016	0.00085 ± 0.00144	0. ± 0.
JET20 CMP	0.00117 ± 0.00030	0. ± 0.	0. ± 0.
JET50 CMP	0.00043 ± 0.00010	0.00063 ± 0.00073	0.02415 ± 0.01412
JET70 CMP	0.00028 ± 0.00009	0.00101 ± 0.00070	0. ± 0. (*)
JET100 CMP	0.00025 ± 0.00007	0.00032 ± 0.00022	0.01272 ± 0.00342
CMP	0.00053 ± 0.00046	0.00049 ± 0.00050	0.00922 ± 0.01208
JET20 CMX	0.00065 ± 0.00019	0.00056 ± 0.00130	0. ± 0.
JET50 CMX	0.00020 ± 0.00006	0.00264 ± 0.00123	0. ± 0. (*)
JET70 CMX	0.00028 ± 0.00008	0.00225 ± 0.00085	0.00140 ± 0.00206
JET100 CMX	0.00034 ± 0.00008	0.00024 ± 0.00017	0.00350 ± 0.00144
CMX	0.00037 ± 0.00022	0.00142 ± 0.00120	0.00123 ± 0.00175
JET20 CMIO	0.00062 ± 0.00007	0.00086 ± 0.00066	0.00152 ± 0.00152
JET50 CMIO	0.00088 ± 0.00005	0.00340 ± 0.00057	0.00350 ± 0.00162
JET70 CMIO	0.00194 ± 0.00009	0.00281 ± 0.00040	0.00822 ± 0.00208
JET100 CMIO	0.00461 ± 0.00012	0.00308 ± 0.00025	0.00396 ± 0.00065
CMIO	0.00201 ± 0.00199	0.00254 ± 0.00127	0.00430 ± 0.00335
JET20 CMIOFIDELE	0.00046 ± 0.00008	0.00099 ± 0.00084	0.00214 ± 0.00214
JET50 CMIOFIDELE	0.00099 ± 0.00007	0.00393 ± 0.00079	0.00557 ± 0.00251
JET70 CMIOFIDELE	0.00263 ± 0.00014	0.00364 ± 0.00057	0.00882 ± 0.00270
JET100 CMIOFIDELE	0.00610 ± 0.00018	0.00410 ± 0.00037	0.00490 ± 0.00089
CMIOFIDELE	0.00255 ± 0.00282	0.00316 ± 0.00155	0.00536 ± 0.00334

Fakes

- Full statistics in the jet samples used to compute fake ratios.
- Same run range as signal samples.
- Far fewer zero bins (consistent with statistics).
- CMUP/CMX fake rates very similar.
- Same systematics considered as before.
- Blessed fake number :

1.08 ± 0.49

- Updated number :

1.34 ± 0.66

WW Acceptance Systematics

- Largely unchanged.
- Additional cross−check of 0−jet efficiency scale factor. It's not a strong function of selection cuts for the signal − covered by existing 6% error.
- Revisit Pythia/Herwig difference, taking properly into account different assumptions for BR($W \to l\nu$) built into each generator − slightly reduced systematic of 4%.
- New systematic due to PDF variation −1% :

Cuts	*ee* events	Acceptance	Uncertainty Range (%)
–	113.48	–	–
$\|\eta\| < 1$	40.48	0.36	(-1.0 , 1.2)
$P_T > 20$	31.05	0.77	(-0.4 , 0.4)
$\not{E}_T > 25$	21.84	0.70	(-0.3 , 0.3)
overall	21.84	0.19	(-1.0 , 1.1)

- Apply cuts (at generator level) on all 40 CTEQ6 PDF sets. Monitor acceptance range.
- Conservative since we have wider acceptance than $|\eta|<1$

- Combined acceptance uncertainty 10% (unchanged).

WW : Summary of Expectations

	CDF Run II Preliminary			
Source	ee	$\mu\mu$	$e\mu$	$\ell\ell$
Drell-Yan e^+e^-	0.75 ± 0.34	0.00 ± 0.00	0.052 ± 0.043	0.80 ± 0.34
Drell-Yan $\mu^+\mu^-$	0.00 ± 0.00	0.61 ± 0.27	0.28 ± 0.13	0.89 ± 0.30
Drell-Yan $\tau^+\tau^-$	0.047 ± 0.021	0.046 ± 0.020	0.099 ± 0.041	0.19 ± 0.05
WZ	0.29 ± 0.03	0.33 ± 0.03	0.15 ± 0.02	0.76 ± 0.06
ZZ	0.35 ± 0.04	0.34 ± 0.04	0.011 ± 0.002	0.70 ± 0.07
$W+\gamma$	0.48 ± 0.13	0.00 ± 0.00	0.57 ± 0.13	1.06 ± 0.19
$t\bar{t}$	0.021 ± 0.011	0.012 ± 0.007	0.046 ± 0.018	0.078 ± 0.023
Fake	0.52 ± 0.19	0.17 ± 0.16	0.65 ± 0.37	1.34 ± 0.66
Total Background	2.46 ± 0.42	1.51 ± 0.33	1.86 ± 0.43	5.82 ± 0.86
$WW \to$ dileptons	2.61 ± 0.31	2.48 ± 0.29	5.11 ± 0.60	10.20 ± 1.19
Total Expectation	5.07 ± 0.56	3.99 ± 0.46	6.97 ± 0.76	16.0 ± 1.6
Run 2 Data	6	6	5	17

⇐ **updated** (Drell-Yan)

⇐ **new** (ZZ)

⇐ **updated** (Fake)

⇐ **new σ(WW)**

WW Cross Section Extraction

$$\sigma^{WW}_{meas} = \frac{(N_{obs} - N_{bk})}{\epsilon_{tot} \times \mathcal{L}} = \frac{(N_{obs} - N_{bk})}{\epsilon_{lep} \times [3 \times \mathrm{BR}(W \to l\nu)]^2 \times \mathcal{L}}$$

- Previously using 0.11043 (Campbell & Ellis LO EWK)
- Switch to using Standard Model value 0.1080

Updated :

$$\sigma^{WW}_{meas} = 13.6^{+5.8}_{-5.1} \text{ (stat)} \pm 1.7 \text{ (syst)} \pm 0.8 \text{ (lum) pb}$$

Blessed :

$$\sigma^{WW}_{meas}\text{(blessed)} = 14.3^{+5.6}_{-4.9} \text{ (stat)} \pm 1.6 \text{ (syst)} \pm 0.9 \text{ (lum) pb}$$

Backup Slides

WW Cross−Section X−Checks

Using old value for BR(W→lν)=0.11043 :

$$\sigma^{WW}_{meas}(\text{old BR}) \;=\; 13.0^{+5.6}_{-4.9}\;(\text{stat})\;\pm\;1.6\;(\text{syst})\;\pm\;0.8\;(\text{lum})\;\text{pb}$$

Using data−based DY background numbers :

$$\sigma^{WW}_{meas}(\text{cross check}) \;=\; 14.2^{+5.8}_{-5.1}\;(\text{stat})\;\pm\;2.7\;(\text{syst})\;\pm\;0.9\;(\text{lum})\;\text{pb}$$

WW : Grand Summary Table Blessed Winter'04

	CDF Run II Preliminary, 200 pb^{-1}			
Source	ee	$\mu\mu$	$e\mu$	$\ell\ell$
Drell-Yan e^+e^-	0.69 ± 0.31	0.00 ± 0.00	0.048 ± 0.039	0.74 ± 0.31
Drell-Yan $\mu^+\mu^-$	0.00 ± 0.00	0.61 ± 0.24	0.28 ± 0.12	0.89 ± 0.27
Drell-Yan $\tau^+\tau^-$	0.047 ± 0.018	0.046 ± 0.018	0.098 ± 0.037	0.19 ± 0.05
WZ	0.29 ± 0.03	0.32 ± 0.03	0.15 ± 0.02	0.76 ± 0.06
$W\gamma$	0.48 ± 0.13	0.00 ± 0.00	0.57 ± 0.13	1.05 ± 0.19
$t\bar{t}$	0.013 ± 0.008	0.008 ± 0.005	0.033 ± 0.014	0.053 ± 0.017
Fake	0.45 ± 0.20	0.15 ± 0.13	0.48 ± 0.23	1.08 ± 0.49
Total Background	1.97 ± 0.40	1.14 ± 0.28	1.66 ± 0.31	4.77 ± 0.70
$WW \rightarrow$ dileptons	2.90 ± 0.34	2.75 ± 0.32	5.69 ± 0.66	11.3 ± 1.3
Total Expectation	4.87 ± 0.55	3.89 ± 0.45	7.35 ± 0.76	16.1 ± 1.6
Run 2 Data	6	6	5	17

WW : Updated Plots

WILL PUT UPDATED PLOTS HERE ...