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Update to *Search for New Physics in the Missing Transverse Energy + Dijet Channel at CDF*

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1 Introduction

This document lists the changes made to the analysis described in the thesis *Search for New Physics in the Missing Transverse Energy + Dijet Channel at CDF* [1] after its defense and submission, but before the submission of its results for publication (see CDF Note 9329 [2] for the latest publication draft.) Updated scalar leptoquark cross-section numbers have been used for the final analysis.

More information on this analysis can be found in CDF Note 9170 [3].

2 Background Predictions

Table 1 shows the total background predictions, and replaces Table 5.10 in the thesis. In response to questions asked during talks at CDF, the background predictions for events in the high kinematic region are reported with a precision of 0.1 events for clarity instead of being rounded to the nearest whole event as in the thesis. The background predictions are otherwise unchanged. In the low kinematic region, a total background of 2443 ± 145 events is predicted, while 2506 events are observed in the data (a $0.43\,\sigma$ deficiency.) For the high kinematic region, a total background of 211.2 ± 29.8 events is predicted, while 186 events are observed in data (a $0.34\ \sigma$ deficiency).

With no changes in the background prediction, the kinematic comparison histograms do not need to be updated.

Background	$H_T > 125, \not\!\!E_T > 80$	$H_T > 225, \not\!\!E_T > 100$
$Z \to \nu\overline{\nu}$	888 ± 54	86.4 ± 12.7
$W \to \tau\nu$	669 ± 42	50.6 ± 8.0
$W \to \mu\nu$	399 ± 25	32.9 ± 5.2
$W \to e\nu$	256 ± 16	14.0 ± 2.2
$Z \to \ell\ell$	29 ± 4	1.7 ± 0.2
Top Quark Production	74 ± 9	10.8 ± 1.7
QCD	49 ± 30	9.0 ± 9.0
γ+jet	75 ± 11	4.8 ± 1.1
Non-collision	4 ± 4	1.0 ± 1.0
Total predicted	2443 ± 145	211.2 ± 29.8
Data observed	2506	186

Table 1: Summary of estimated Standard Model background contributions to the dijet plus missing E_T candidate samples along with the number of observed events in data. This table replaces Table 5.10 in the thesis.

3 Leptoquarks

A recent DØ analysis set a 95% C.L. mass lower limit of 205 GeV/c^2 for first and second generation scalar leptoquarks decaying exclusively to $q + \nu$ [5]. The DØ analysis used NLO cross-sections for leptoquark pair production which took into account not only variations in renormalization scale, but uncertainty on the cross-section calculations due to choice of PDF. For publication, this analysis does the same. Updated NLO cross-sections from Krämer [6] are used.

3.1 New Cross-sections

In order to take both sources of uncertainty in cross-section into consideration, the relative uncertainties on the "nominal" cross-section (at $\mu = M_{LQ}$) from PDF choice are added in quadrature to the uncertainties from varying μ from $0.5M_{LQ}$ to $2M_{LQ}$. The relative PDF and μ uncertainties are given in Table 2. The relative μ uncertainties are the same as those used in the thesis, but the nominal values for $\mu = M_{LQ}$ are recalculated. The PDF uncertainties are added in quadrature to the uncertainty on the nominal cross-section due to the cross-section difference when μ goes from M_{LQ} to $0.5M_{LQ}$. This relative uncertainty is added to the nominal value to get a high-end value for the NLO cross-section. The PDF uncertainties are also added in quadrature to the uncertainty on the nominal cross-section due to the cross-section difference when μ goes from M_{LQ} to $2M_{LQ}$. This relative

uncertainty is subtracted from the nominal value to get a low-end value for the NLO cross-section. Table 3 shows the final set of cross-sections used in this analysis. Again, the lowest cross-section is used in order to obtain the most conservative limits. Together, Tables 2 and 3 replace Table 6.3 in the thesis.

M_{LQ} (GeV/c^2)	PDF choice (%)	$\mu = \frac{1}{2}M_{LQ}$ (%)	$\mu = 2M_{LQ}$ (%)
60	7.19	16.9	16.9
70	8.45	15.5	16.1
80	9.46	14.6	15.9
90	10.3	13.8	15.6
100	10.9	12.6	15.2
110	11.3	11.8	14.8
120	11.6	11.3	14.4
130	11.7	11.0	14.4
140	11.7	9.7	14.2
150	11.7	9.9	13.9
160	11.6	9.7	13.9
170	11.4	9.5	13.9
180	11.2	9.4	13.8
190	11.0	9.3	13.8
200	10.8	9.0	13.7

Table 2: Calculated relative uncertainties on NLO cross-sections for different values of the leptoquark mass due to choice of PDF and renormalization scale μ.

M_{LQ} (GeV/c^2)	High σ (pb)	Nominal (pb)	Low σ (pb)
60	265.3	224.2	183.1
70	118.0	100.3	82.0
80	58.03	49.44	40.27
90	30.73	26.22	21.32
100	17.22	14.76	12.00
110	10.141	8.718	7.094
120	6.220	5.352	4.361
130	3.945	3.400	2.769
140	2.558	2.220	1.812
150	1.712	1.484	1.214
160	1.166	1.013	0.830
170	0.806	0.702	0.576
180	0.5654	0.4933	0.4057
190	0.4015	0.3510	0.2892
200	0.2877	0.2522	0.2082

Table 3: Calculated NLO cross-sections for different values of the leptoquark mass, taking into account variation on the renormalization scale μ and choice of PDF.

3.2 Updated Results and Figures

While the acceptances and efficiencies for leptoquark pair production remain unchanged, the changes to both background prediction and leptoquark pair production NLO cross-section require recalculation of the results. The final number of expected signal events for both the low and high kinematic regions as a function of the leptoquark mass is shown in Table 4, which replaces Table 8.4 in the thesis.

Table 5 and Figure 1, replacing the thesis' Table 8.9 and Figure 8.1 respectively, give the resulting limits. The 95% C.L. lower mass limits are now 187 GeV/c^2 for 1st and 2nd generation leptoquarks, and 175 GeV/c^2 for 3rd generation. The cross-section 95% upper limits are also changed. The kinematic comparison histograms, Figures 2 to 4, replace Figures 8.2 to 8.4 in the thesis.

M_{LQ}(GeV/c^2)	$H_T > 125, \not\!\!E_T > 80$	$H_T > 225, \not\!\!E_T > 100$
60	794	68
70	970	103
80	1002	105
90	965	126
100	920	117
110	813	116
120	699	116
130	564	107
140	443	97
150	341	87
160	263	79
170	200	69
180	147	56
190	113	49
200	84	40

Table 4: Expected number of signal events in both the low and high kinematic regions defined for the dijet plus missing E_T analysis as a function of leptoquark mass. Replaces Table 8.4 in the thesis.

4 Supersymmetry

No changes are made to the process for the supersymmetric interpretation of these results, or to the 95% C.L. upper limits and kinematic comparison

LQ Model	Lower M_{LQ} Limit (GeV/c^2)	Upper σ Limit (pb)
1st Generation	187	0.325
2nd Generation	187	0.325
3rd Generation	175	0.486

Table 5: 95% C.L. lower limits on scalar leptoquark mass for the different generations along with the corresponding upper limits on the leptoquark production cross sections. Replaces Table 8.9 in the thesis.

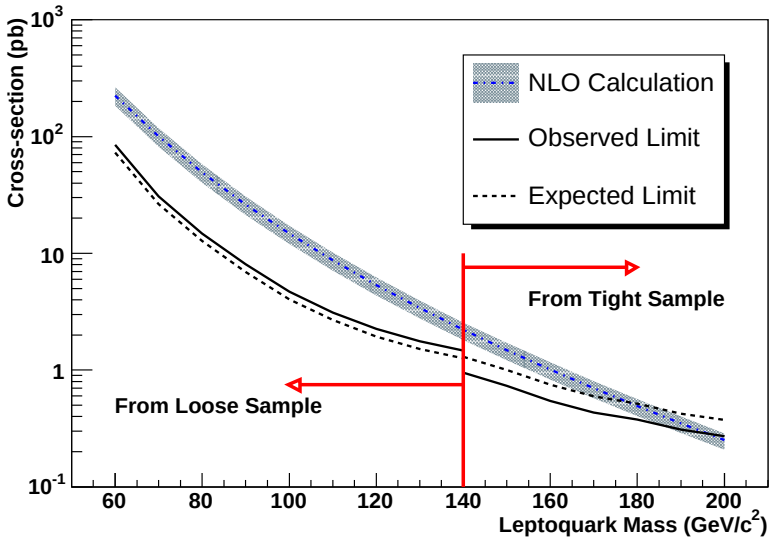

Figure 1: 95% cross-section limits for 1st and 2nd generation leptoquark pair production as a function of M_{LQ}. Replaces Figure 8.1 in the thesis.

histograms. For clarity, Table 6, which repeats the information in Table 8.25 of the thesis, is show below.

5 Conclusion

The analysis described in the thesis *Search for New Physics in the Missing Transverse Energy + Dijet Channel at CDF* set limits on new physics in the dijet + $\not\!\!E_T$ channel at CDF. The final limits set are slightly changed from those set in the thesis, due to changes in the leptoquark NLO cross-section and cross-section uncertainties used.

For the leptoquark interpretation, the 95% C.L. lower mass limits are 187 GeV/c^2 for 1st and 2nd generation leptoquarks, and 175 GeV/c^2 for 3rd generation. For the MSSM interpretation, mass spectra S2 and S3 are still

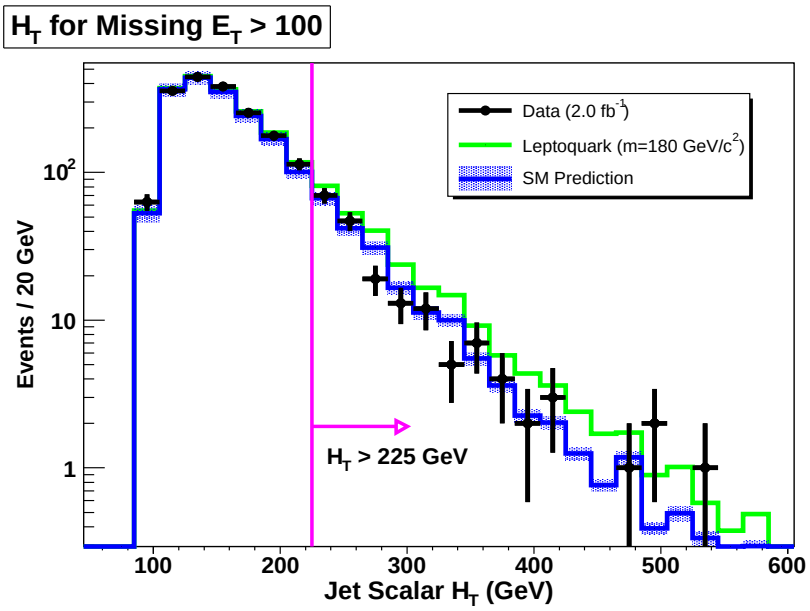

Figure 2: H_T data, background prediction, and signal prediction after missing $E_T > 100$ GeV cut. The signal is leptoquark pair production at $M_{LQ} = 180$ GeV/c^2, and is graphed assuming the σ at $\mu = 2M_{LQ}$ of 0.406 pb. The region to the right of the vertical line at 225 GeV represents the high kinematic region. Replaces Figure 8.2 in the thesis.

ruled out to leading order.

References

[1] Daniel M. MacQueen, *Search for New Physics in the Missing Transverse Energy + Dijet Channel at CDF*, Ph.D. Thesis, University of Toronto, 2009 (CDF Note 9330).

[2] T. Aaltonen *et al.* (CDF Collaboration), *Search for New Physics with a Dijet plus Missing E_T Signature in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV*, to be submitted to Phys. Rev. Lett., 2009 (CDF Note 9329)

[3] K. Burkett, E. James, P.-H. Beauchemin, P.-O. Devivieros, D. MacQueen, and P. Savard, *Searches for New Physics in the exclusive Dijet plus Missing E_T Event Sample using 2 fb^{-1} and extracted Limits on Scalar Leptoquark Production*, CDF Note 9170, updated June 29, 2009.

[4] J. M. Campbell and R. K. Ellis, *Update of vector boson pair production at hadron colliders*, Phys. Rev. D 60, 113006 (1999).

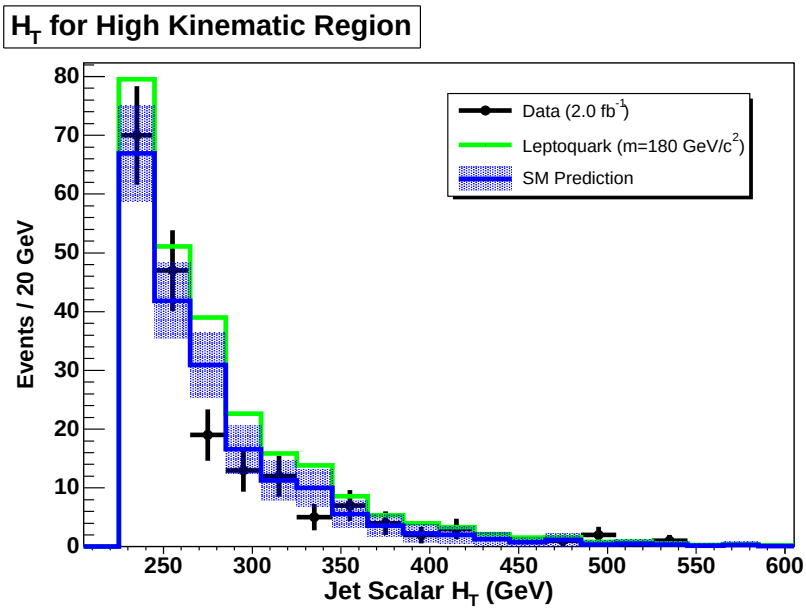

Figure 3: H_T data, background prediction, and signal prediction for the high kinematic region. The signal is leptoquark pair production at $M_{LQ} = 180$ GeV/c^2, and is graphed assuming the σ at $\mu = 2M_{LQ}$ of 0.406 pb. Replaces Figure 8.3 in the thesis.

[5] V. M. Abazov *et al.* (DØ Collaboration), *Search for scalar leptoquarks and T-odd quarks in the acoplanar jet topology using 2.5 fb^{-1} of $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV*, Phys. Lett. 668, 357 (2008).

[6] M. Krämer, private communications, 2008 and 2009.

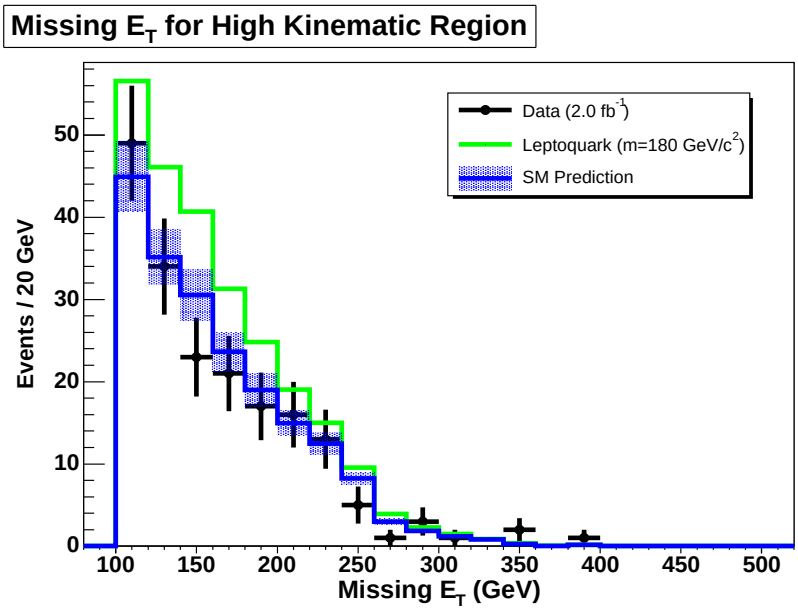

Figure 4: Missing E_T data, background prediction, and signal prediction for the high kinematic region. The signal is leptoquark pair production at $M_{LQ} = 180$ GeV/c^2, and is graphed assuming the σ at $\mu = 2M_{LQ}$ of 0.406 pb. Replaces Figure 8.4 in the thesis.

SUSY spectrum	A priori (pb)	Observed (pb)	PYTHIA (pb)	Ratio
Right-handed $\tilde{q}$				
S1	0.15	0.11	0.045	2.41
S2	0.26	0.19	0.28	0.68
S3	0.51	0.37	0.61	0.61
S4	86.1	100.5	18.0	5.57
Inclusive				
S1	0.53	0.39	0.36	1.09
S2	0.90	0.65	1.73	0.38
S3	1.93	1.40	3.21	0.44
S4	78.5	91.6	57.4	1.60

Table 6: Cross-section 95% C.L. a priori and observed upper limits for all four SUSY spectra, compared to PYTHIA leading order cross-sections. The final column is the observed 95% C.L. upper limit divided by the PYTHIA cross-sections. Identical to Table 8.25 in the thesis.