The LSD Experience at CDF Run I

Search for Like-sign Dileptons

• The LSD (like-sign dilepton) experience at CDF Run I is a signature-driven, blind-box search for physics beyond the Standard Model. The analysis:

  • requires a like-sign lepton pair in the CDF Run I detector central region (necessary for charge identification)

  $e^{\pm}e^{\pm}$ $e^{\pm}\mu^{\pm}$ $\mu^{\pm}\mu^{\pm}$

  • uses the standard lepton ID cuts from CDF Run I

• Goal: to reduce SM physics while keeping LSD requirements as simple as possible.

  • Basic cuts: like-sign, lepton isolation, minimum transverse momentum ($p_T > 11$ GeV) on *both* leptons

  • This purposefully keeps the LSD analysis open to as much exotic physics as possible.

Standard Model Backgrounds

• The following table shows how the SM backgrounds are removed

• a √ mark indicates the cut is effective in removing that SM process

Process	Like-sign	Isolation	$p_T > 11$ GeV
WW	√		
$t\bar{t}$	√	√	
Drell-Yan	√		√
$b\bar{b}$,$c\bar{c}$	√	√	√
WZ,ZZ	√		
W + jets		√	√
"Fake + fake"		√	√

• Z events are rejected with an invariant mass window on any opposite sign lepton pairs in the event: $M_{OS} < 81$ or $M_{OS} > 101$ GeV/c^2

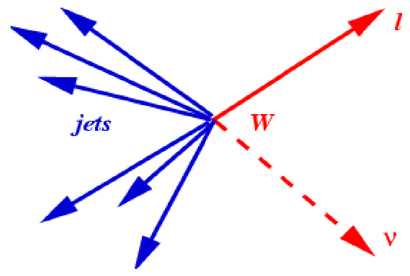
• Events identified as cosmic rays and electron conversions are also rejected

Fake Lepton Background

• The largest background comes from isolated non-leptonic tracks that pass all of the lepton ID cuts, thus faking a real lepton.

W + jets →

The real lepton from the W decay combined with a track faking a lepton from one of the jets can pass the LSD signal cuts.



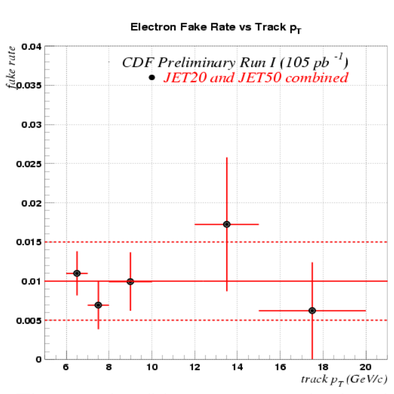
• To estimate this background we need to know

  • the **fake rate**: the probability that a single isolated track fakes a real lepton

  • the **isolated track rate**: the number of isolated tracks per event as a function of p_T

Multiplying the number of W + jet events in the dataset by the fake rate and the isolated track rate yields the expected background from W + jets.

Fake Rate



The e and μ fake rates are calculated independently, then summed to get the total fake rate per isolated track:

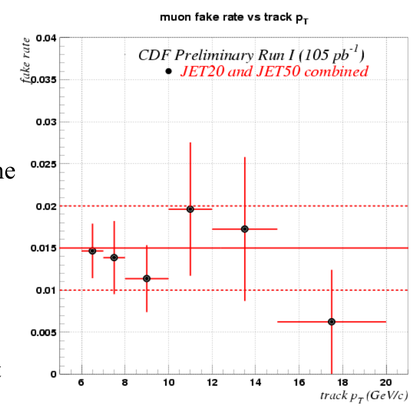
$$F_{rate} = N_{fake} / N_{isolated\ tracks}$$

as a function of p_T.

The combined e and μ fake rate was found to be **(2.5±0.7) %** independent of lepton p_T

• The fake rate is calculated from jet control samples with 20 and 50 GeV thresholds (JET20 and JET50).

• After removing real leptons from W and Z decays from the samples, any track which passes *all* of the lepton ID cuts is considered a fake: N_{fake}



Isolated Track Rate

The isolated track rate per event is found by selecting $Z \rightarrow \ell^+\ell^-$ events and dividing the number of isolated tracks (excluding the two high-p_T tracks from the Z legs!) by the total number of events in the sample.

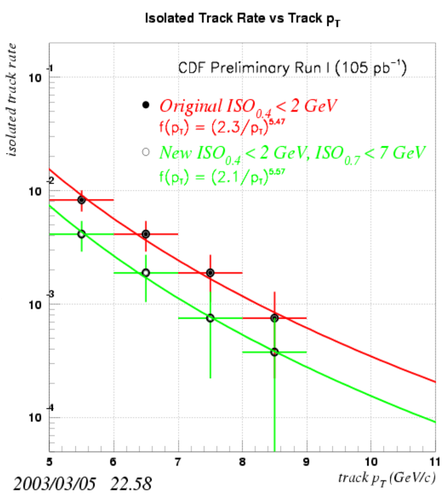
From the Z dilepton events:

$$R_{isotrk} = N_{isotrk} / N_{events}$$

as a function of track p_T.

The R_{isotrk} result is plotted to the right and fit with a falling power spectrum as a function of track p_T to extrapolate the isolated track rate to higher values of p_T.

Note the lower, green curve labeled **New ISO**: this is from our improved isolation cut described to the right! →

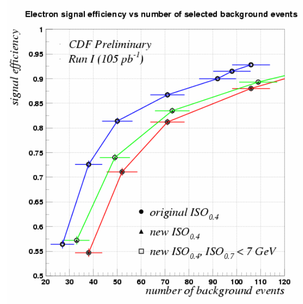


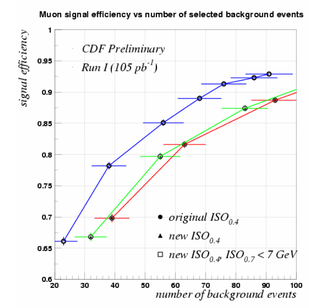
Improved Isolation!

As you probably noticed from the green curve on the isolated track rate plot, we use a new, improved (over the original CDF Run I) definition of isolation for this analysis. This includes:

• A new reclustering of the lepton energy in the ISO cone

• A double cone cut at radius R=0.4 (standard) *and* R=0.7 (new)





The plots above show the improvement in signal efficiency as a function of background events for both e and μ after the reclustering (green curve) and double cone (blue curve) improvements. For a fixed signal efficiency we found a **factor of 2 improvement in background rejection** with the new isolation for e and μ combined.

Monte Carlo

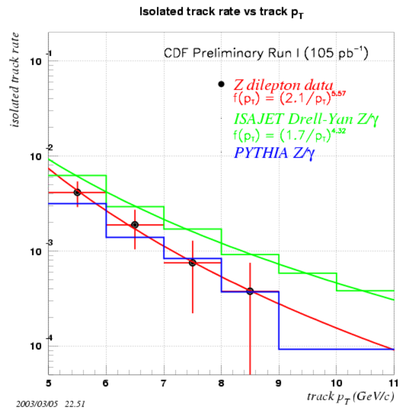
• Large backgrounds are generated with PYTHIA v6.1

  • Backgrounds: Drell-Yan, W + jets, WZ, and ZZ

  • Includes off-shell Z mass

• Small backgrounds are generated with ISAJET v7.20

  • Backgrounds: WW, all heavy flavor

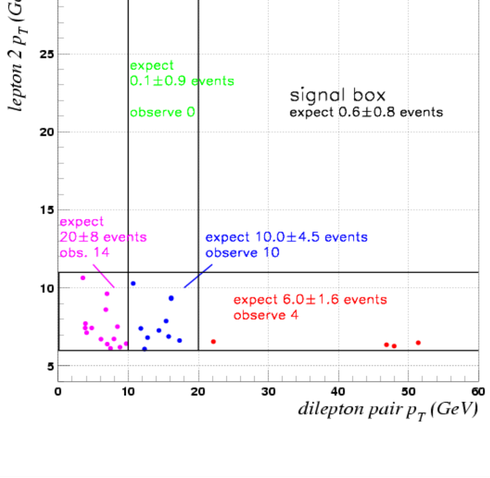


Because our largest background is lepton + fake, it is important that the Monte Carlo correctly models the rate of isolated tracks.

The comparison of the data (red points) to the PYTHIA (blue) and ISAJET (green) isolated track rates shows good agreement between data and PYTHIA. Scaling as a function of track p_T is necessary for ISAJET background estimates, based on the fits shown in the plot.

Around the Box Comparisons

In order to remain unbiased when selecting the LSD analysis cuts, the search is done blind, so that we can not look at the data in our signal region, or box, until the analysis cuts are finalized.



Before "opening the box," we look at regions around the box defined by one or more analysis cuts to confirm that the Monte Carlo correctly predicts the expected SM and fake lepton background events in each region.

This plot of the 2nd lepton p_T vs. dilepton pair p_T shows good agreement between observed and MC predicted events in the p_T-space around the signal box.

Expected Background

The table below gives the expected background from all processes in the signal region. The largest background contributions are from WZ (from off-shell Z production) and W + jets (from fakes).

Process	expected events
Drell-Yan (γ^*/Z)	$0.03^{+0.10}_{-0.01}$
WW	$0.0003^{+0.0003}_{-0.0002}$
WZ	0.229 ± 0.004
ZZ	0.061 ± 0.001
W + jets	0.30 ± 0.07
$t\bar{t}$	$0.008^{+0.006}_{-0.004}$
$b\bar{b}$, $c\bar{c}$	$0.0^{+0.001}_{-0.0}$
fake-fake	$0.0^{+0.83}_{-0.0}$
total	$0.63^{+0.84}_{-0.07}$

Observed in the data: 0 events in 107 pb^{-1}

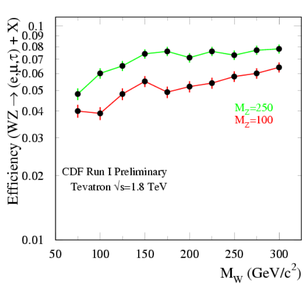
→ No new discovery from Run I ←

Signature-based Search Results

Because this analysis was not done within a specific exotic physics model, we can evaluate the results in terms of as-yet unpredicted exotic particles which decay to a LSD pair.

WZ pairs are produced with PYTHIA (standard WZ spin, coupling) with leptonic decay required. By varying the "WZ" masses we produce limits for exotic, heavy "WZ-like" particles.

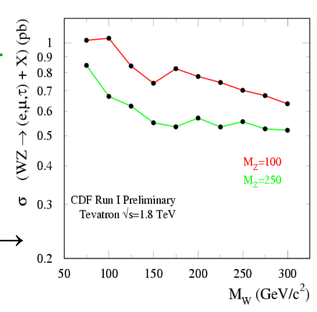
WZ-like Signal Efficiency: M_Z = 100, 250 GeV



← efficiency

95% CL limit →

WZ-like 95% CL Excl. Limit: M_Z = 100, 250 GeV

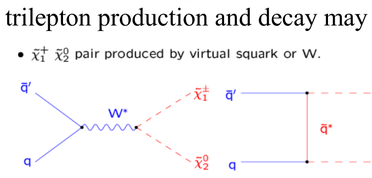


This technique can be used to produce limits on any theory which has a pair of isolated like-sign leptons in the final state.

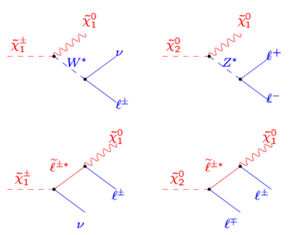
Supersymmetry Search Results

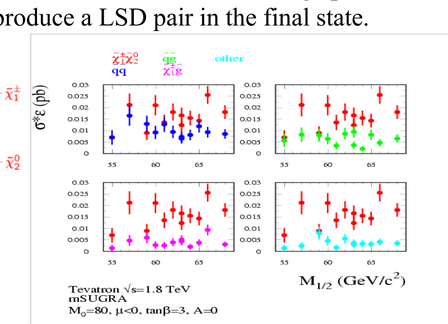
In addition to the signature-based interpretation, the LSD search has sensitivity to SUSY particle production. For example, chargino-neutralino ($\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$) trilepton production and decay may produce a LSD pair in the final state.

• $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ pair produced by virtual squark or W.



• $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ decay via virtual W/Z or virtual slepton to trileptons + neutrino + lightest neutralino (LSP).

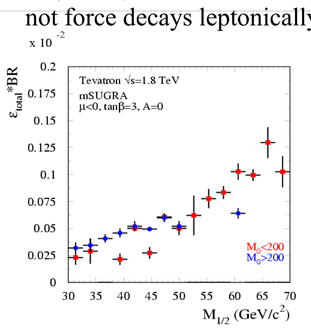




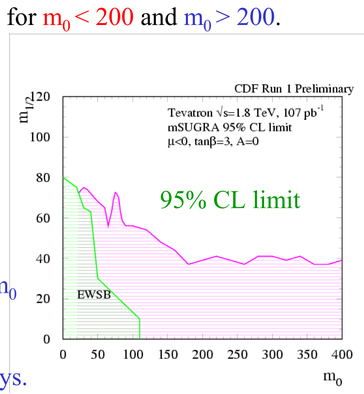
In addition, the cross-section * efficiency plot above shows that at m_0 = 80 LSD has sensitivity for other mSUGRA sparticle production modes as well as $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, allowing an inclusive, multi-process search.

mSUGRA Limits

We interpret the LSD search result in the mSUGRA model with tanβ = 3, μ < 0, and A = 0. We use inclusive production and do not force decays leptonically.



← LSD efficiency as a function of $m_{1/2}$ for $m_0 < 200$ and $m_0 > 200$.



For large values of m_0, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ dominates, but the features at low m_0 come both from contributions from other processes ($\tilde{q}\,\tilde{g}$, etc) and from efficiency losses to invisible $\tilde{\nu}$ decays.

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