Search for Anomalous Kinematics in Top Dilepton Events at CDF

- Motivations and Goals
- Method
- Data Sample and Event Selection
- Results
- Conclusions

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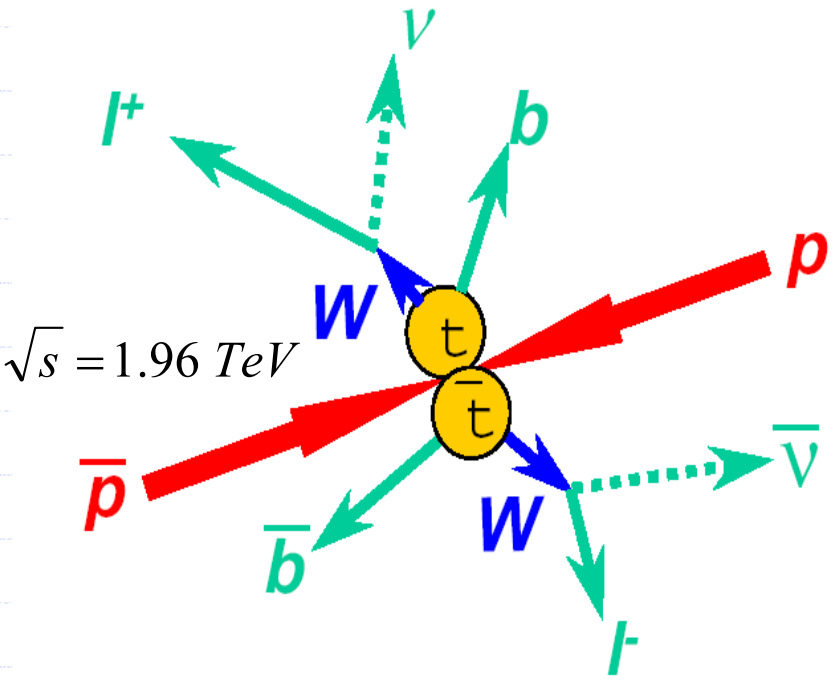
DPF Meeting
August 31, 2004

Top Dilepton Decay Chain



Event Signature:

2 high-E_T leptons (e or μ),

at least 2 high-E_T jets

(b-jets + ISR/FSR),

large missing transverse energy due to neutrinos.

l = e or μ

BR = 5 %

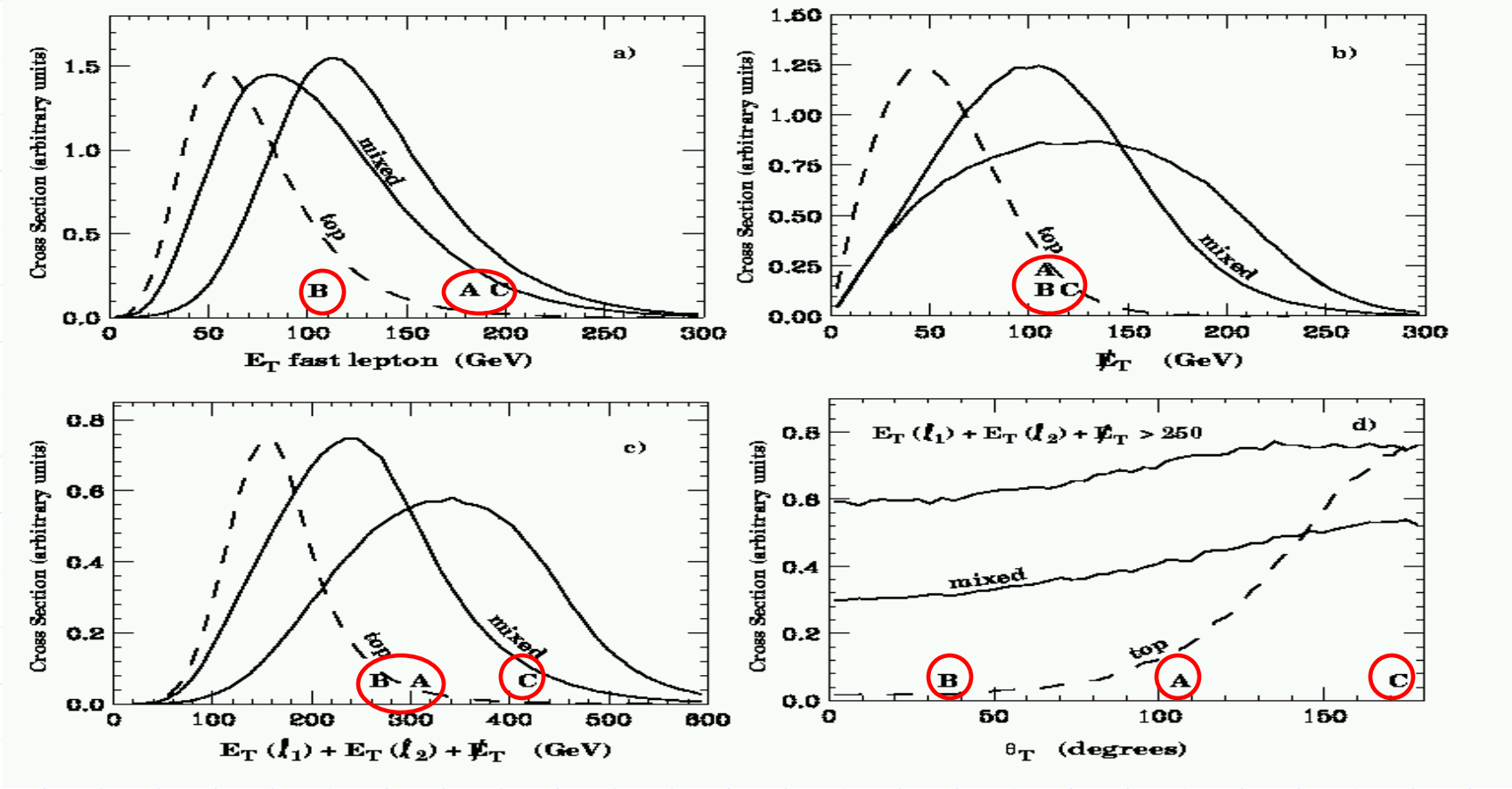
Motivation: ***Observed 9 events in Tevatron Run I, several events had kinematics that was incompatible with the Standard Model expectations.***

- In hep-ph/9607342 ***Barnett and Hall*** argue that some of the Run I Top Dilepton events have characteristics that are better accounted for by decays of supersymmetric quarks :

with

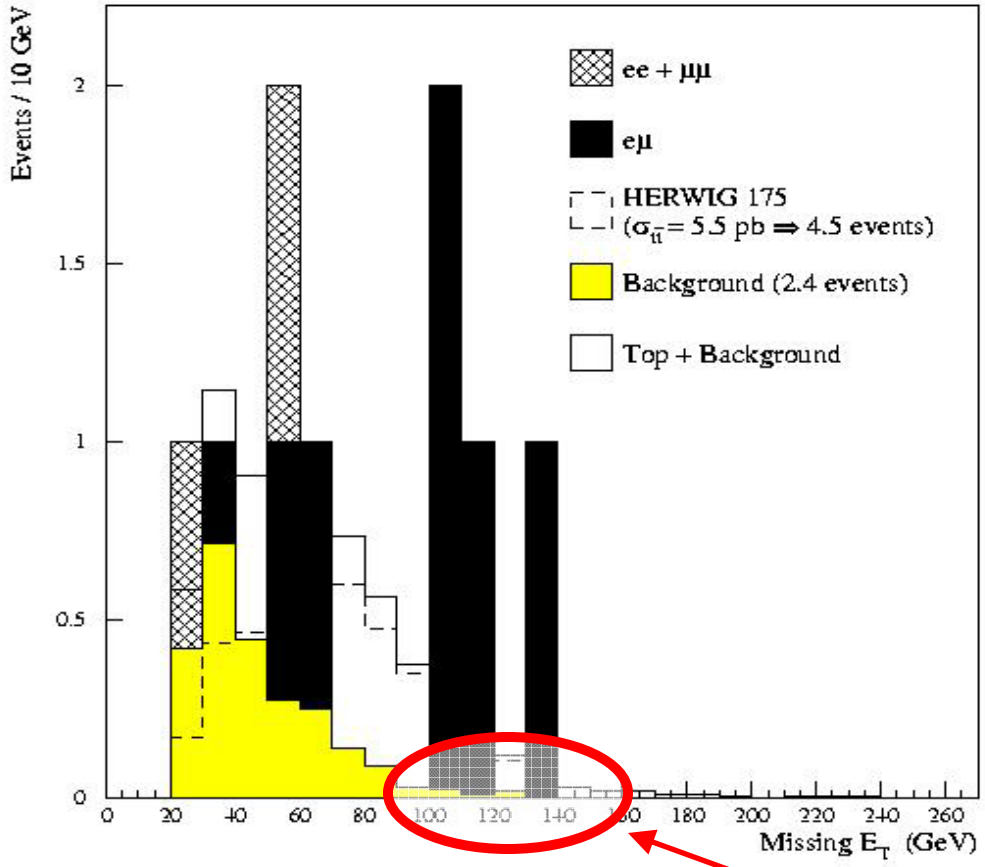
$$\tilde{q} \rightarrow q\tilde{\chi},\ \tilde{\chi} \rightarrow \nu\tilde{\ell},\ \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0.$$

Masses: 310 260 130 50 GeV



Goals of the Analysis

(motivated by peculiarities seen in Run I Top Dilepton Sample



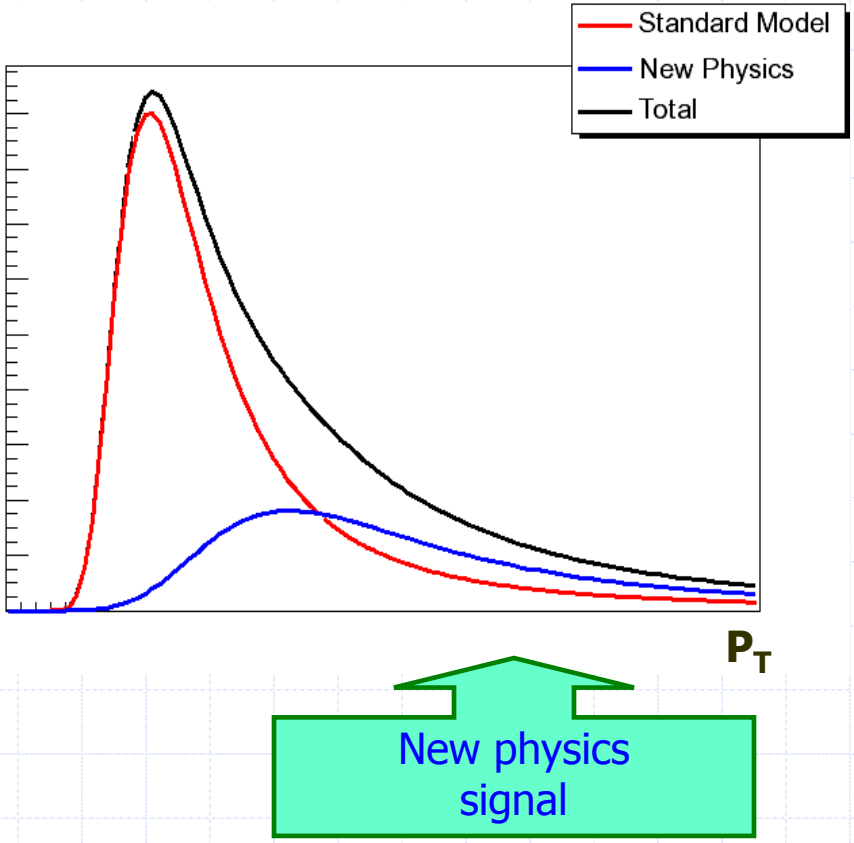
Missing E_T distribution
Run I dilepton sample

1: Determine how consistent the kinematic features of the dilepton events are with the SM.

2: Isolate events in a data sample with possible non-SM decays and quantify departure of those events from the SM.

What kind of distortions in kinematic distributions are we looking for?

- Expect new physics to reveal itself in the high Pt region.



- We design a statistical technique (goodness-of-fit) for a generic search for new physics especially sensitive to the tails of kinematic distributions.
- Method is

a) data-driven;

b) defined a-priori;

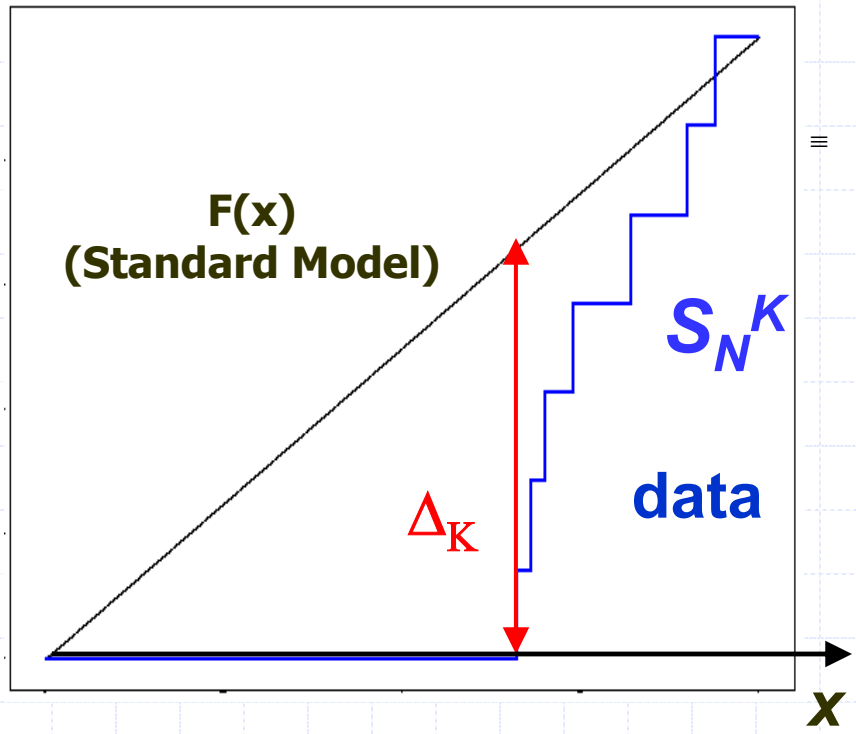
c) designed to isolate a subset of events most inconsistent with the SM and to assess significance of the deviation

Kolmogorov-Smirnov test

Adopt KS test for comparison of kinematic distributions

$$\Delta = max_i | F(x_i) - S_N^K(x_i) |$$

Example: single variable x

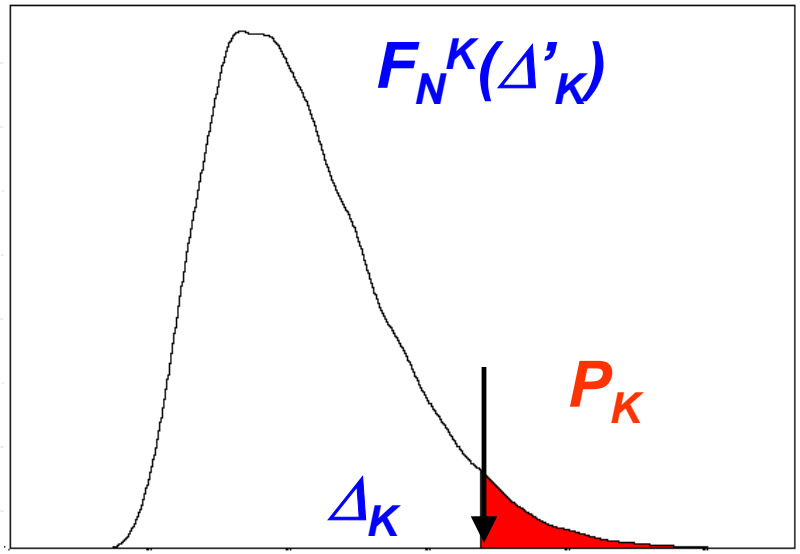


- Randomly populate N events – this is a pseudo-experiment S_N
- Construct subset of events S_N^K -- from the K events at the right tail.
- Find the KS distance Δ_K between Standard Model distribution **F(x)** and data $S_N^K(x)$
- Construct probability distribution functions $F_N^K(\Delta_K)$ for each K:

$$1 \le K \le N$$

by generating a large number of pseudo-experiments

Isolating the most unlikely subset and quantifying significance of deviation



$$P_K = \int_{\Delta_K}^{\infty} F_K^N(\Delta'_K) d\Delta'_K$$

Determines probability of consistency for subset of K events

Define Statistic: $P = \min_{0<K<N} P_K$

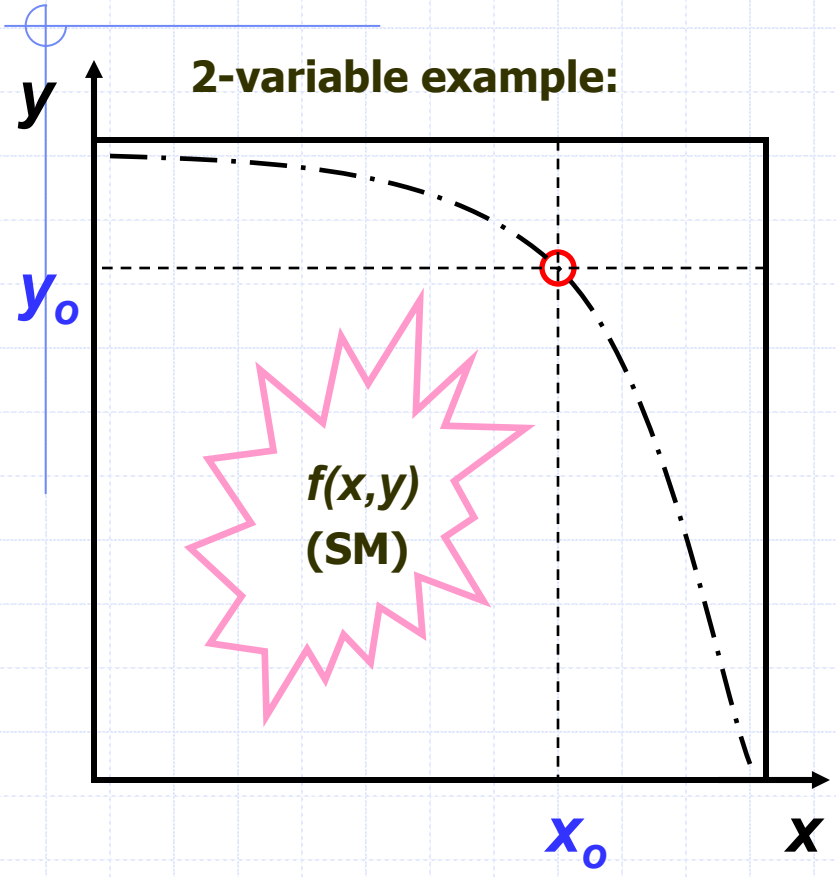
Determines a subset revealing the largest discrepancy from the Standard Model (a subset of possible new physics events ?!)

Next, generate pseudo-experiments and calculate

α = **Prob** ($P < P_{data}$)

which quantifies significance level of departure of the most unlikely subset from the SM

Multi-Variate test



- We choose a statistic (Product KS)

$$P = (P_x \cdot P_y)^{1/2}$$

- geometrical mean of 1D-KS probabilities P.

- Assign a weight to each event – measure of 'unlikeness'.
- $w = (w_x \cdot w_y)^{1/2}$, where

$$w_x = \int_{x_0}^{1} f(x,y)dx$$

- Construct unlikely K-subset from K events with smallest weights.
- Proceed as in 1D-case.

Choice of kinematic variables

New physics is likely to reveal itself in various kinematic distributions. Need to include many variables, but not too many – we don't want to dilute the result.

New physics scenario:

1. Decay of heavy particles leads to large transverse momenta objects with at least one hard lepton and a large missing Et.

(Missing E_T, P_T of the leading lepton)

2. Conservation laws require large quantities to be back to back.

($\Delta\phi$ leading lepton, met - angle between them)

3. Final state quantities of a new physics event most likely do not satisfy the system of kinematic equations for the SM top quark decay. *(topological variable)*

Topological weight of an event

- $(P_l + P_\nu + P_b)^2 = M_t^2$
- $(P_l + P_\nu)^2 = M_W^2$

- Solve system of kinematic equations for neutrino momenta.
- Enhance neutrino solution phase space by accounting for ambiguities in two lepton-b-jets pairings, detector resolution and uncertainty in top mass.
- Integrate over enhanced phase space and get a topological weight per each event.

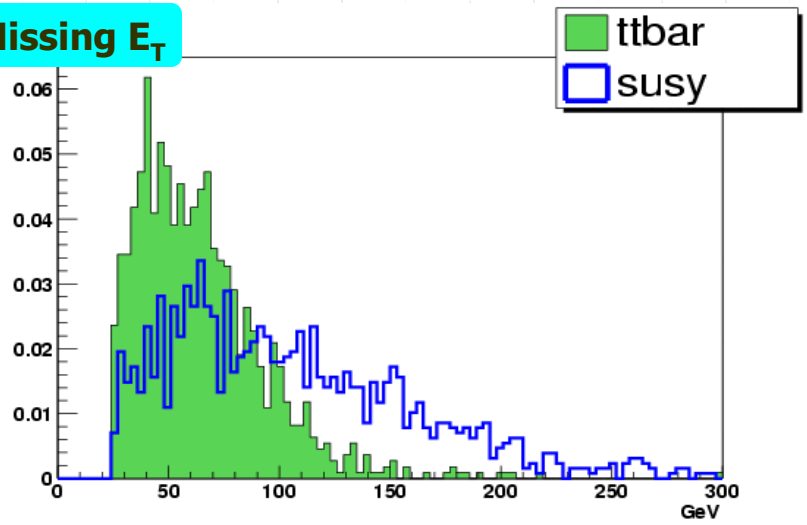
$$T_w = \int \exp\left\{ -\frac{(\not\vec{E}_T^{\,predicted} - \not\vec{E}_T^{\,measured})^2}{2\sigma^2_{\not E_T}} \right\} d\not\vec{E}_T^{\,predicted}$$

Top dilepton events have on average larger T than non-top SM background and new physics events

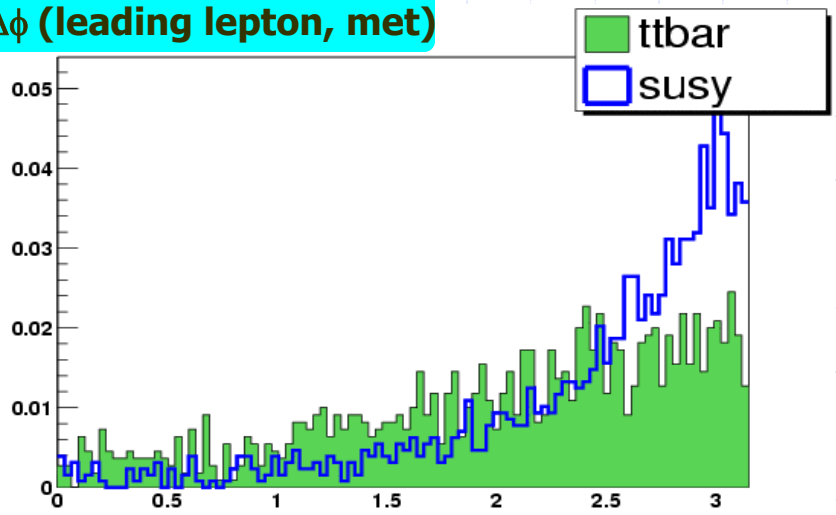
MC comparison of ttbar with Barnett & Hall SUSY model

Assuming 50 % dilepton candidates from this SUSY model, the PKS method would find less than 1% consistency 60% of the time with 13 events sample.

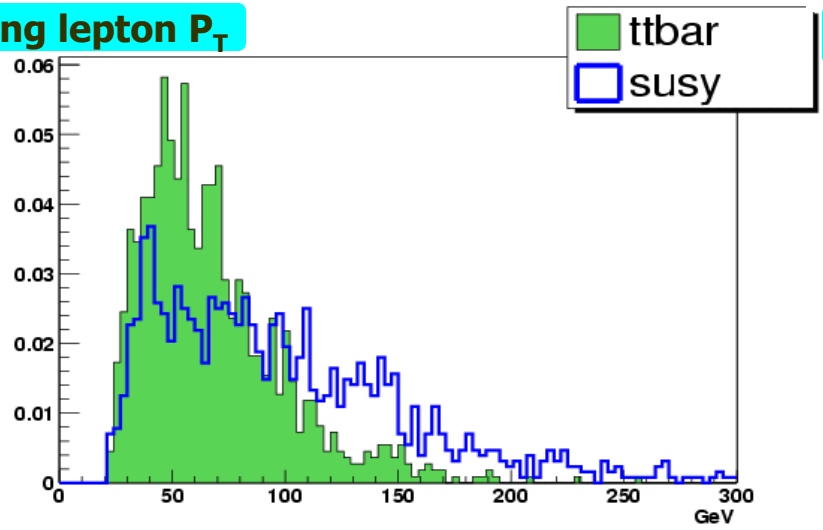
Missing E_T



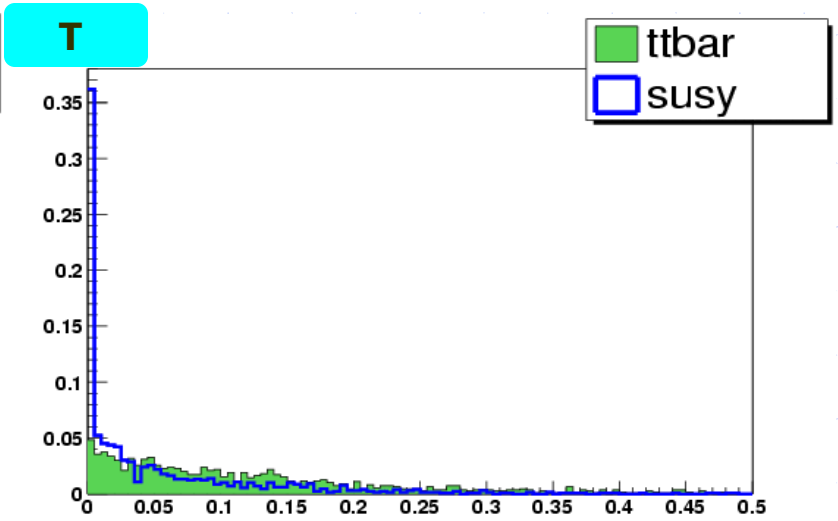
$\Delta\phi$ (leading lepton, met)



Leading lepton P_T



T



Run II Top Dilepton Selection

- Event Selection used in Run II top cross section measurement named 'DIL' (hep-ex/0404036 accepted to PRL)
- Two leptons E_T > 20 GeV (at least one isolated);
- Opposite charge;
- Two jets E_T > 15 GeV, $|\eta|$ < 2.5
- Reduce Drell-Yan events and other SM backgrounds:

Missing E_T > 25 GeV;

$|\Delta\phi_{(\mathbf{lepton,Met})}|$ > 20deg if Met < 50 GeV;

in Z mass region - 76 GeV < Mll < 106 GeV:

jet Significance > 8;

$|\Delta\phi_{(\mathbf{jet\ OR\ lepton,Met})}|$ > 20deg

H_T (scalar energy sum of all objects) > 200 GeV.

Observe 13 events;

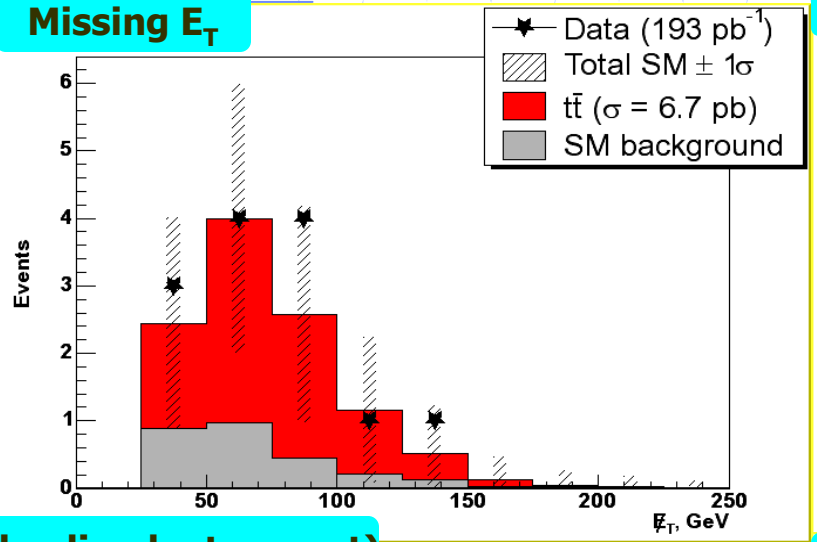
expect 2.7+/- 0.7 from non-top backgrounds,

8.2 +/- 1.1 from ttbar (σ = 6.7 pb)

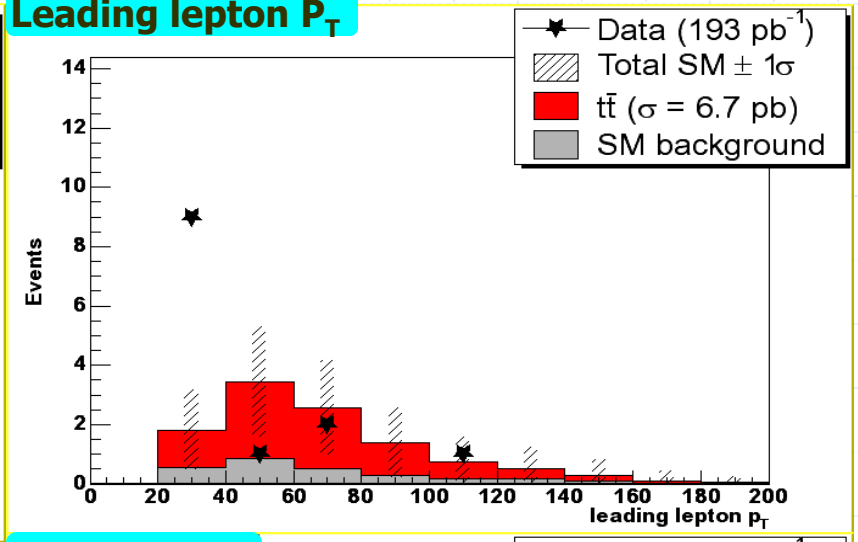
Kinematics in Run II Top Dilepton Sample

Observe most unlikely subset of all 13 events, which is α = 1.6% consistent with SM primarily due to an excess of low P_T leptons

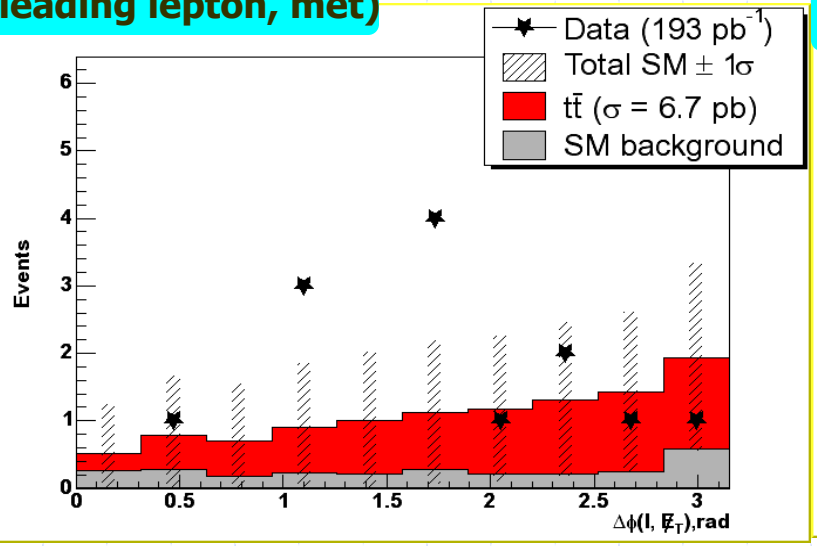
Missing E_T



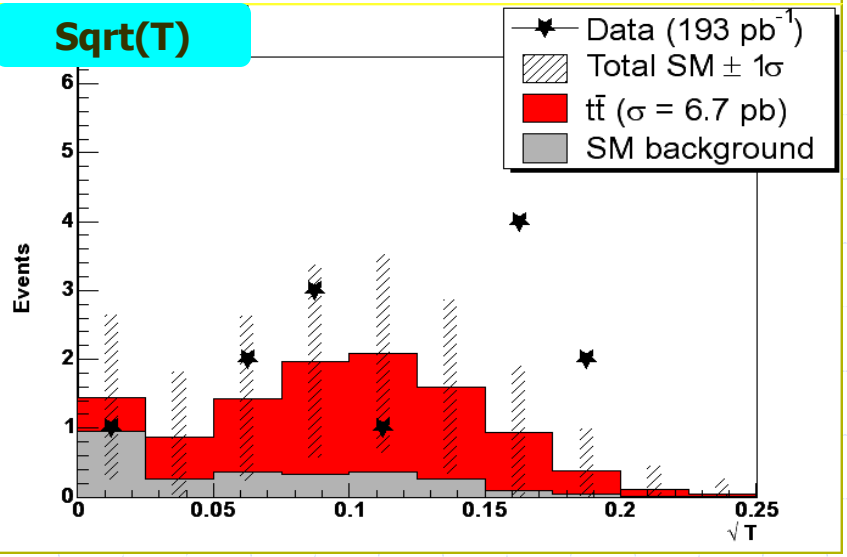
Leading lepton P_T



$\Delta\phi$ (leading lepton, met)

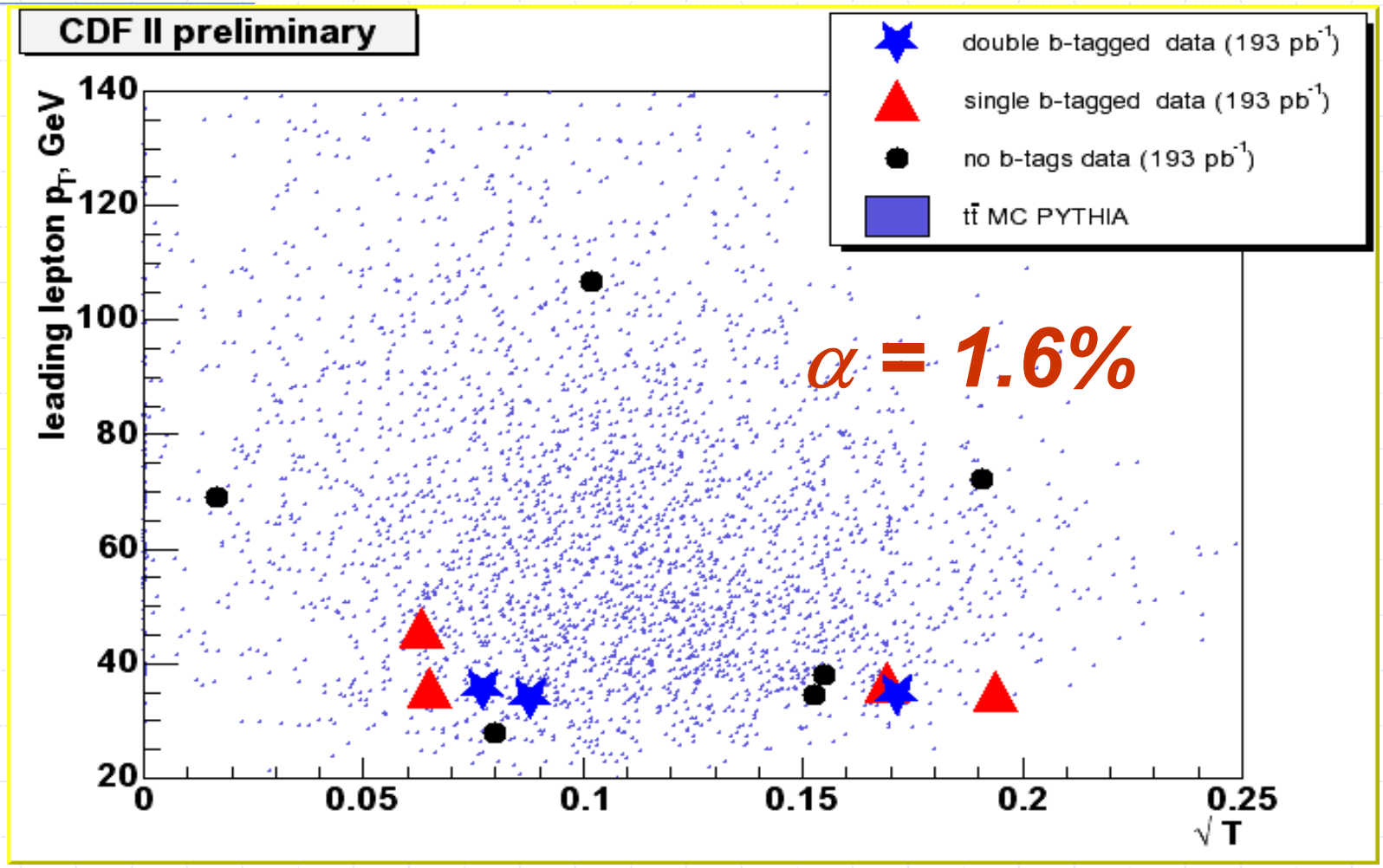


Sqrt(T)



Dilepton events in (Ptl,T) –plane

Low P_T-lepton events are accompanied with b-jets - likely being from ttbar



Systematic Uncertainties

Make Use of +,- 1 σ templates

Source	α '
Background Estimates	0.010-0.027
Jet Energy Scale	0.021-0.026
ISR/FSR	0.012-0.016
PDFs	0.019
Top Mass	0.014-0.021
MC Generator	0.016
Combined	0.010-0.045

- Procedure:

  Find α'□ for each systematic uncertainty.
- For combining all systematic effects use combinations of the worst scenarios.

Conclusions

- We have assessed the top dilepton sample's consistency with the Standard Model in the four-variable space (missing E_T, P_T of the leading lepton, $\Delta\phi$ between these quantities and T) and find a probability of consistency 1.0 – 4.5 %.
- The distributions are consistent with the SM expectations. The lepton P_T distribution exhibits a mild excess at low P_T consistent with a statistical fluctuation of SM top.
- No anomalies are seen in the kinematic regions expected to be populated by events containing new heavy particles. New physics scenarios invoked by Run I events are not favored by the Run II data.
- This analysis is based on 193 pb^{-1},
  another ~ 200 pb^{-1} are collected,
  expect ~ 4000 – 9000 pb^{-1} with Run II by 2009

Backup Slides

Validation of MC simulation on the sample of W + 3 jets events

- Event Selection:
- one high P_T > 20 GeV electron or muon (trigger) ;
- At least three jets (Et > 15 GeV, $|\eta| < 2.5$)
- Met > 25 GeV

(QCD removal: if Met < 35 GeV, 0.5 < $\Delta\Phi$(Met,leading jet) < 2.5)

- $|Z_{\text{primary vertex}} - Z_{0,\text{lepton}}| < 5.0$ cm

- Observe: 973 events. Main Backgrounds: QCD ~ 8.8%; ttbar ~ 11.2%

- Require 4 – th jet to "simulate" T:
  – treat the first two jets as b-jets and the other two jets as a second lepton and neutrino;
  - reconstruct an event if it was top dilepton.

‘W+Jets’ kinematic distributions