New TeVatron searches in BSM physics

Michel Jaffré

on behalf of the CDF and D0 collaborations
Motivations

In BSM models, new physics will manifest in similar event topology

➢ Take a given final state and try to constrain several models at once

Tevatron assets in BSM physics searches: large accumulated datasets and well understood detectors and reconstructed objects

➢ Search in more complex final state

Outline

Dilepton/diphoton resonances
Diboson resonances
More complex signatures

Delivered/Recorded luminosity

6.0 fb$^{-1}$
9.4
10.5
ee/μμ mass spectra

- Large datasets CDF(D0) : 5.7 (5.4) fb⁻¹
- Well understood electron/muon objects
- μμ practice new ME likelihood method
- Good agreement with SM predictions

M. Jaffré         Moriond EW March 13-20, 2011
ee/\mu\mu\ resonance\ search

- Mass limits for various Z' models, contraints on couplings
  - SSM, string E6, Stuekelberg extension models
- Mass limits for RS graviton for \( k / \bar{M}_{Pl} = [0.01, 0.1] \) using mass dependent K factor
Diphoton mass distribution

No significant deviation from expectation

RS graviton $M_G > 963$ GeV for $k/\bar{M}_{Pl} = 0.1$ using a mass dependent K factor for the signal cross section
Combined dielectron/diphoton resonance search

Improved limits on RS graviton mass by combining ee and $\gamma\gamma$ analysis

- **D0**: 560-1050 GeV for $0.01 \leq k/M_{Pl} \leq 0.1$ (fixed k-factor)
- **CDF**: 604-1055 GeV (mass dependent k-factor)

PRL 104, 241802 (2010)

CDF public note 10405
W' → eν

- Simple final state: high pT electron and high mET
- Reaching Tevatron phase space limits: PDF at large x
- Xsection limit interpreted within the left-right symmetric model
- W' → WZ decay mode suppressed

CDF 5.3 fb⁻¹

- D0 1 fb⁻¹ : PRL 100, 031804 (2008) 1 fb⁻¹ : M > 1 TeV

PRD 83 031102 (2011)
Di boson resonances : WW/WZ

- Resonance decaying to on shell vector bosons
- \( W' \rightarrow WZ \rightarrow lll'+m_{ET} \) 4.1 fb\(^{-1} \) PRL 104, 061801 (2010)
- \( W'/Z'/G^* \rightarrow WZ/WW \rightarrow e/\mu + m_{ET} + 1(+1)\) jets
- \( W' \rightarrow WZ \rightarrow ee/\mu\mu + 1(+1) \) jets
- Kinematic cuts use the fact that bosons from decay are highly boosted, 2 jets from decay may even merge
  \( \Rightarrow \) Jet mass > 60 (70) GeV comes from \( W(Z) \) decay

\[ \begin{align*}
\text{PRL 104, 241801 (2010)} \\
\end{align*} \]

\[ \begin{align*}
\text{754 GeV} \\
\text{690 GeV} \\
\text{754 GeV} \\
\end{align*} \]
\[ \gamma + \text{jets (+ mET)} \]

CZF public note 10355

- Method independent and signature based analysis on \textbf{4.8 fb-1}
- Searching for excess of events in lot of distributions
  - Photon $E_T > 30$ GeV
  - Jet $E_T > 15$ GeV
- Importance to model QCD background from data

All plots compatible with expectations.
follow-up of PRD 80, 011102 (2009) with 6fb$^{-1}$

$E_T^{\text{lepton}} > 20 \text{ GeV}$, $E_T^\gamma > 10 \text{ GeV}$

$mET > 20 \text{ GeV}$, $E_T^{\text{jet}} > 15 \text{ GeV}$

85 events vs 99.1 ± 9.3 expected

Isolate the $tt\gamma$ contribution by

$\geq 3$ jets and $H_T > 200 \text{ GeV}$

30 events vs 26.9 ± 3.4 expected

Searching for a deviation to SM leads to a SM Xsection measurement

$\sigma(tt\gamma) = 0.18 \pm 0.07 \pm 0.04 \text{ pb}$

$\sigma(tt\gamma)/\sigma(tt) = 0.024 \pm 0.009 \pm 0.001$
Single vector-like quarks

Q\textsubscript{L} and Q\textsubscript{R} same transformation under SU(3)xSU(2)xU(1)

\[(M_{T}^{Q})^{2} = (\sqrt{p_{T}^{2} + M_{W}^{2} + p_{T_{\perp}}^{2}})^{2} - (\vec{p}_{T_{w}} + \vec{p}_{T_{\perp}})^{2}\]

2 scenarios:

- no coupling to d quark
  \[\tilde{K}_{uD} = 1, \tilde{K}_{uU} = \sqrt{2}, \tilde{K}_{dQ} = 0\]

- no coupling to u quark
  \[\tilde{K}_{dU} = 1, \tilde{K}_{dD} = \sqrt{2}, \tilde{K}_{uQ} = 0\]
3-jet resonance

Model indep. search \( q\bar{q} \rightarrow Q\bar{Q} \rightarrow 3j+3j \)

\( \geq 6 \) jets( \( p_T > 13 \) GeV), \( m_{ET} < 50 \) GeV,

\[ \sum p_T \geq 250 \text{GeV} \]

- Diagonal cut adjusted for each mass to isolate object decaying into 3 jets

Landau shape from 5-jet events

Largest excess seen around the top mass
New fermions “Quirks”

A new unbroken SU(N) gauge group (scale $\Lambda \ll M_Q = 0.1-1\text{TeV}$)

If new fermions Q are charged they can be pair produced.

But no hadronization will occur; QQ pair will stay connected as with a rubber band ($L \sim M_Q/\Lambda^2 \approx 1-100\mu m$)

And be reconstructed as a highly ionizing straight track

dE/dx distribution as expected

95%CL $M_Q > 107$ GeV for SU(2)

PRL 105, 211803 (2010)
Leptonic jets + mET

Exotic SUSY model: ∃ hidden sector weakly coupled to SM particles

Dark photon $\gamma_D$ is light $\rightarrow$ collimated lepton pair

Darkino $\tilde{\chi}$ escapes detection $\rightarrow$ mET

Ask for a track of opposite charge close to lepton candidate

Change the isolation criteria in lepton definition

![Graphs showing event counts and cross section limits](image)

- Inclusive limit
- Observed in $\gamma_D$ mass window
- Expected in $\gamma_D$ mass window

Approximate range of possible SUSY cross-sections for

- DI-electron mass (GeV)
- DI-muon mass (GeV)

5.8 fb$^{-1}$
Search for a 4\textsuperscript{th} generation down type quark

- Current limits push $M_{b'} > M_{\text{top}} + M_W$
- $q\bar{q} \rightarrow b'\bar{b}' \rightarrow t\bar{t} WW \rightarrow b\bar{b}WWWW \rightarrow l + mET + \geq 5 \text{ jets} (\geq 1 \text{ b-jet})$
- 2D-analysis performed: $N_{\text{jets}}$ and $H_T = \sum_{\text{jets},\text{lepton},mET} E_T$

\begin{itemize}
  \item Data
  \item Bkg. + b'
  \item Total Bkg.
  \item $t\bar{t}$
  \item $W, Z, t$
  \item QCD
  \item Di-boson
\end{itemize}

\begin{itemize}
  \item Obs. - Exp.
  \item Bkg. Unc.
  \item b'
\end{itemize}

4.8 fb\(^{-1}\)  372 GeV

95\% C.L. cross section limit [fb]
Dark matter search

Exotic $T' \rightarrow tX$ ($300 < M_{T'} < 600$ GeV); $T' \rightarrow Wb$

Signal: $l + \geq 4$ jets + mET > [100-160] GeV

Background: ttbar and W + jets under control

95% C.L. cross section limits for $(M_{T'}, M_X)$ points

Limits for $M < 300$ GeV valid for $\tilde{s} \rightarrow t\chi_1^0$

Background regions

- njets=3, $E_T^{miss} > 100$ GeV/GeV
- njets>4, $E_T^{miss} < 100$ GeV/GeV

CDF Run II Preliminary $L=4.8$ fb$^{-1}$

Events

$m_T$ [GeV/c$^2$]

$M_{T'} < 360$ GeV for $M_X < 100$ GeV

4.8 fb$^{-1}$
Summary and Outlook

✓ No excess of events over SM expectations in $\rightarrow 6 \text{ fb}^{-1}$

✓ Hints in B sector (dimuon charge asymmetry) and Top sector (FB Asymmetry)

✓ Performances of the Tevatron has brought limits on BSM physics beyond one could have expected.

   Search for BSM physics is now in the ballpark of LHC

✓ Given the large datasets, searches at the Tevatron will concentrate on more complex final states;

   Exercise more advanced techniques of use also at LHC

All CDF and D0 results are available on:

http://www-cdf.fnal.gov/physics/exotic/exotic.html
http://www-d0.fnal.gov/Run2Physics/WWW/results,np.htm
Backup
Dielectron highest mass event

$M_{ee} = 960 \text{ GeV}$

$E_T = 482 \text{ GeV}$

$E_T = 468 \text{ GeV}$
$\gamma + m\text{ET} + \text{jets}$