Search for Quirks and Hidden Valleys at the Tevatron

Yunhe Xie
Fermilab

On behalf of D0 collaboration

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Outline

❖ Tevatron performs well
❖ Large amount of data already in the can
❖ Keep searching for new physics beyond Standard Model
❖ Will cover in my talk two unique signatures:
   ‣ quirks
   ‣ hidden valley models (lepton-jet signature)
❖ Very first exploration of those models at hadron colliders
❖ Analysis done with data up to 5.8fb⁻¹
Tevatron @Fermilab

- Was the most energetic collider in the world until recently
- @ $\sqrt{s}=1.96$ TeV

- Delivered 9 fb$^{-1}$
- Recorded 8 fb$^{-1}$/experiment
- Deliver rate ~ 2 fb$^{-1}$/year now
- Expect 11~12 fb$^{-1}$ by end of 2011
Multi-purpose detector

- Tracking system: primary vertex, track, $p_T$, $dE/dx$, etc..
- Calorimeter: $E$, $E_T$,
- Muon system: muon detection
Quirks

- One possible minimal extension of the SM: new fermions are introduced $Q$ and $\overline{Q}$: quirks
- Two parameters: $m_Q$ and $\Lambda$ (new Gauge coupling)
- Pair-produced if $Q$ carries some SM charges ($e$ only, no SM color)
- Bounded state when $\Lambda << m_Q \approx 0.1-1$ TeV
- Unique signature: a high $E_T$ track with large $dE/dx$, a jet and $E_T$ aligned with track

$$L \approx \frac{m_Q}{\Lambda^2}$$

$$\approx 1 \text{ } \mu m \left( \frac{m_Q}{100 \text{ GeV}} \right) \left( \frac{\Lambda}{100 \text{ keV}} \right)^{-2}$$
Quirks -- II

- Background estimated with data
  - Lepton background (e and µ); multi-jet background; noise-like background
- Signal simulated with MadGraph+PYTHIA processed with GEANT3 D0 detector simulation
  - dE/dx is calculated separately for quirks with detector resolutions and instrumental noise from data

![Graph showing dE/dx distribution for various backgrounds and signal processes](image_url)

- Lepton background (e and µ)
- Multi-jet background
- Noise-like background
- Hadrons, multijets
- Fake tracks

![Graph showing comparison between data and background](image_url)
- Find no signs of new physics

- Set an upper limits on the quirk production cross section for various quirk masses at 95% C.L.

- Exclude charged electro-weakly interacting quirks with mass up to 107 GeV at 95% C.L.

- This is the first experimental search for quirks

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**Quirks -- III**

**D0, 2.4 fb^{-1}**

<table>
<thead>
<tr>
<th>Quirk Mass (GeV)</th>
<th>Observed Limit</th>
<th>Expected Limit ±1 s.d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>80</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>120</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>140</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>160</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

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**Preliminary**

- **theory**, MadGraph
- Expected Limit
- Observed Limit
- Expected ±1 s.d.
Hidden Valleys

❖ **Hidden Valley models:**

❖ introduce a new, hidden sector

❖ weak couplings to SM sector

❖ new interpretation of astrophysics and dark matter?

❖ **Unique detector signature:**

❖ At least two isolated leptonic jets (l-jets) from the dark photon:

❖ high lepton content of the jets (muons and/or electrons)

❖ lepton matched to a central track together with a companion track of opposite charge within a 0.2 cone

❖ Large Missing Transverse Energy ($E_T$) from the LSP in the hidden sector
Hidden Valleys -- II

- Search in three channels: ee, eμ, and μμ
- Background estimated with data
  - Multi-jet events (all three channels) and photon conversions for electron l-jet (ee only)
  - Control region: low MET, non-isolated region, extrapolate to signal region
- Signal simulated with MadGraph+PYTHIA processed with GEANT3 D0 detector simulation

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**Preliminary**

- **μμ data**
- **signal**
- **background**
- **normalization error**

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**Preliminary**

- **muon l-jets**
- **background**
  - m(γD)=0.3 GeV
  - m(γD)=0.9 GeV
  - m(γD)=1.3 GeV

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**TABLE I**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Events / 1 GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ee</td>
<td></td>
</tr>
<tr>
<td>eμ</td>
<td></td>
</tr>
<tr>
<td>μμ</td>
<td></td>
</tr>
</tbody>
</table>

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Hidden Valleys -- III

- Consistent with SM prediction
- Set an upper limit on the production cross section of SUSY events decaying into 2 l-jets with $E_T$ as a function of $m(\gamma_D)$

Run 248074 Evt 24810582 Wed Dec 17 03:49:03 2008
ET scale: 52 GeV

D0, 5.8 fb⁻¹ Preliminary

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Hidden Valleys -- IV

- Hidden Valley models -- Dark photons:
  - detector signature:
    - a photon ($\gamma$)
    - a pair of collimated leptons from the dark photon ($\gamma_D$)
  - Large MET ($E_T$) from the LSP in the hidden sector

- Backgrounds estimated from data:
  - QCD + $\gamma$, $W \rightarrow e/\mu \nu + \gamma$, $W \rightarrow \tau \nu \rightarrow 3h^{\pm} \nu + \gamma$

Conclusion

- Tevatron performs well
- Experiments continue to search for evidence of new physics beyond SM
- Two analysis were presented with unique signatures
- Exploring new models/signatures with good knowledge of detectors and data
- Keep updating results with more data
  - 9fb\(^{-1}\) has been delivered with 8fb\(^{-1}\) recorded
  - 11-12fb\(^{-1}\) expected by the end of 2011
- Stay tuned for more coming new results
Back-up
Massive Long Lived Particles

- **D0 (CMSP) results (1 fb⁻¹)**
  - [Graph A](image)
  - [Graph B](image)
  - [Graph C](image)

- **CDF (Champs) results (1 fb⁻¹)**
  - [Graph D](image)

In conclusion, we have used the wIZ II TOz and wOT...
Hidden Valleys -- ee channel

**Preliminary**

- **Missing E_T (GeV)**
  - Events / 1 GeV
  - ee data
  - signal
  - background
  - normalization error

- **cross-section limit (fb)**
  - 0
  - 1
  - 0.5
  - 1.5
  - 2
  - 2.5
  - dark photon mass (GeV)
  - di-electron channel
  - electron-muon channel
  - di-muon channel
  - combined limit

- **Events / 1 GeV**
  - 0
  - 10
  - 10^2
  - 10^3
  - Missing E_T (GeV)

- **Run 248074 Evt 24810582 Wed Dec 17 03:49:03 2008**
  - ET scale: 52 GeV

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