Searches at CDF

Ray Culbertson, FNAL  August 4, 2004
Status of CDF Detector

New plug Calorimeter
• working well

New SVX detector
• on about 90% of the time
• 5/12% loss radiation, resonance
• L00 is being used right now
• Has to last until LHC (OK)
• SVT working well

New COT tracker
• working well in general
• showed some aging, loss of gain
• inner layers off for a period
• back on, higher flow, O₂
• Recovery looks good

Most analysis now: 200pb
This Fall: 500pb
Trigger Scale at CDF

**Most searches:**
- Inclusive central $e$ at 18 GeV
- Inclusive central $\mu$ at 18 GeV
- $e+e$, $\mu+\mu$, or $e+\mu$ at 4 GeV
- Inclusive $\gamma$ at 25 GeV
- Diphoton at 12 GeV
- Central b-jet at 2x20 GeV
- Inclusive single jet at 100 GeV
- 3 jets at 10 GeV, $\text{SumEt}>100$
- Missing Et at 45 GeV
- $\tau+$Missing Et at 10/20 GeV
- $e/\mu+$track at 8/5 GeV

**Also:**
- $\mu\mu$ J/$\psi$ at 1.5 GeV
- All 6-track
- $e/\mu+$track+SVT
- diffractive
  - some prescale...
- ee J/$\Psi$ at 1.5 GeV
- 2 tracks with SVT, Pt>2.5
Search for Z' → e e

**Sample**
- Based on high-Et electron triggers
- Loose cuts for good S/N sample
  - Iso Et/Et < 0.2
  - Pt > 15 GeV
- Add Plug
  - Iso Et/Et < 0.1
  - No track requirement

- Backgrounds
  - jet → e - est. from data iso dist. shape from loose cuts
  - Drell-Yan MC, incl ττ
  - Electroweak MC

CDF Run II Preliminary (200 pb⁻¹)

![Dielectron Mass Distribution](chart.png)
Search for $Z' \rightarrow \mu\mu$

**Selection**
- 2 muons
  - central or no-stub (2nd)
- isolated
- reject cosmic rays
  - examining COT fit,
  - looking for exiting trk
  - matching i.p. and z

**Background**
- Above 200 GeV in Mass
  - $18.7 \pm 0.9$ Drell Yan from MC
  - $2.2 \pm 0.5$ fakes (from same sign)
Observed: 18
Search for $Z' \rightarrow \tau\tau$

**Tau Selection - hadronic decays**
- Narrow jet of tracks/energy
- Isolated from nearby tracks/energy (shrinks for high Et)
- Reconstruct $\pi^0$'s in shower max
- $\tau$ mass < 1.8 GeV

**Z' Selection**
- Require $e + \tau$, $\mu + \tau$, or $\tau \tau$ (trigger on same)
- MEt > 15 GeV
- MEt along lepton (2 $\nu$'s)
- $Z'$ Mass from l, $\tau$ and MEt
Search for Z' $\rightarrow \tau\tau$

**Backgrounds**
- jets fake $\tau$'s at level of 1%
  - create fake rates from jets,
  - multiply e/µ + jet sample
- Use Z as a control sample check
- Mass $> 120$ GeV is signal region

**Results**
- D.Y. $2.08 \pm 0.33$
- Fakes $0.75 \pm 0.19$
- Total $2.83 \pm 0.38$

Observed: 4
- signal acceptance*efficiency = 3%
Z' Limits

Models
- SM, E6, Littlest Higgs, Technicolor

<table>
<thead>
<tr>
<th></th>
<th>ee</th>
<th>µµ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z'</td>
<td>750</td>
<td>735</td>
</tr>
<tr>
<td>Z'Ψ</td>
<td>625</td>
<td>600</td>
</tr>
<tr>
<td>Z'χ</td>
<td>610</td>
<td>580</td>
</tr>
<tr>
<td>Z'η</td>
<td>650</td>
<td>635</td>
</tr>
<tr>
<td>Z'I</td>
<td>570</td>
<td>530</td>
</tr>
<tr>
<td>RPV ν</td>
<td>660</td>
<td>665</td>
</tr>
<tr>
<td>Z_H</td>
<td>~800</td>
<td>775</td>
</tr>
</tbody>
</table>

ρ_T, ω_T no limit

Z' → τ τ alone: ~400GeV
Search for Diphoton Peaks

Sample
- diphoton triggers
- checked with backup high-Et trigger

Analysis
- Selection similar to electrons but with track rejection
- losing 6% per leg to conversions!
- could be combined with electrons, plug added

CDF Run II Preliminary 202 pb$^{-1}$

$\gamma\gamma$ Mass in bins of 1$\sigma$ mass resolution
Search for Diphoton Peaks

**SM background**
- NLO Diphox calculation
- normalized to $\mathcal{L}$

**Jets Faking Photons**
- Usually a high-Et $\pi^0$
- extremes of fragmentation
  usually from $q$, not $g$
- shape from a sample
  of loose photons
- normalize to low Mass

- Variable bins for statistical comparison to BG prediction
Randall-Sundrum Graviton Limits

**Model**
- S-channel Graviton
- Warp factor is curvature in extra dimension
- Small warp values predict narrow peaks

**Limits**
- $ee$, $\mu\mu$ and $\gamma\gamma$
- All about 200pb
- $\gamma\gamma$ has larger BR
- $\gamma\gamma$ spin factors improve acceptance

![Graviton Mass (GeV/c^2) vs k/M_{Pl}]

CDF Run II Preliminary (200 pb^{-1})

RS graviton model
95 % C.L. Excluded Regions

Decay mode
- dimuon
- dielectron
- diphoton
"Very Exotic" Searches

- $Z'$ $ee, \mu\mu, \tau\tau, jj, bb, tt$
- $W'$ $ev, \mu\nu, \tau\nu, jj, tb$
- RS Graviton $ee, \mu\mu, \tau\tau, \gamma\gamma, ZZ, WW, jj$
- ADD Graviton $ee, \mu\mu, \tau\tau, \gamma\gamma, ZZ, WW, j\nu, \gamma\nu$
- Axion - $jj, \gamma\gamma$
- Excited l/q $e\gamma, \mu\gamma, \tau\gamma, qg, b\gamma, jj, bZ, t\gamma$
- LQ 1, 2, 3 gen
- Monopoles
- CHAMPS
- Technicolor $\rho_T \rightarrow W bb$
- $b'$ long-lived $Z, b\gamma$
- $t'$ high-mass $t, t\gamma$
- Technicolor $Wb, \gamma bb$
Search for SBottom

B-tagging
- SVX tracks in jets, w/large i.p.
- cluster into vertices
- eff ~40% per b jet
  (~55% → ~65%+ per top event)

Selection
- MEt not along jets, no leptons
- 3 jets+1 or 2 tags
- Optimized MEt > 80 GeV

CDF Data
QCD-multijet
Top
W/Z+jets,Diboson

Exclusive Single B-Tagged Events
CDF Run II Preliminary, 156pb⁻¹

Inclusive Double B-Tagged Events
CDF Run II Preliminary, 156pb⁻¹
Search for SBottom

**Backgrounds**
- QCD light-\(q\) jets, fake tags
  use non-tagged jets \(X\) fake rate
- QCD heavy flavor
  Monte Carlo, norm to low MEt
- \(W/Z\) ... , \(t\ t\) - Monte Carlo
- Several checks in control regions

**One tag**
16.4 ± 3.7 expected  21 observed

**Two tags**
2.6 ± 0.7 expected  4 observed
SUSY Searches

**MSSM**
- squark: jj MEt
- stop: cc MEt, lbbb MEt, lbbjj MEt, jjjjbb MEt, stable
- sbottom: bb MEt, bbbb MEt
- stau: stable
- chargino-neutralino: lll MEt, $\tau\tau\tau$ MEt
- gluino: bbb MEt, jjjj MEt, LS ll
- indirect: Bs $\rightarrow$ $\mu\mu$

**Other Scenarios**
- RPV sneutrino: dilepton modes
- RPV stop: $\tau\tau$bb, bb MEt, t MEt
- RPV chargino-neutralino: llll
- RPV squark: lljj, ljjMEt, qqMEt
- GMSB: $\gamma\gamma$
- GMSB stop: $\gamma\gamma$jj, W$\gamma$, Wb
- GMSB stau: $\tau\tau\tau\nu$
SM Higgs → Wbb

Selection
- central e or µ with Pt >20 GeV
- MEt > 20 GeV
- 2 jets with Et>15 GeV, |η|<2 (optimized)
- 1 SVX b-tag
- veto events with extra jets
- veto loose second lepton
- total eff ~ 1.8%
  (including W BR)

Mass Resolution
- 17% here
- 10% possible, in progress
Search for SM Higgs

**Background**
- Fakes from mistag matrix
- Wbb from Data/MC
- Fake lepton from MEt vs Iso
- DiBoson, tt, t from MC

**Background Totals**

<table>
<thead>
<tr>
<th>Source</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fake b-tags</td>
<td>14 ± 2.6</td>
</tr>
<tr>
<td>Wbb</td>
<td>33 ± 6.4</td>
</tr>
<tr>
<td>DiBoson</td>
<td>2.5 ± 0.6</td>
</tr>
<tr>
<td>Fake lepton</td>
<td>8.5 ± 1.2</td>
</tr>
<tr>
<td>tt</td>
<td>4.3 ± 1.4</td>
</tr>
<tr>
<td>single t</td>
<td>3.8 ± 0.5</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td>66 ± 9</td>
</tr>
</tbody>
</table>

**Observed Events:** 62
Notes on Higgs

Available Searches
- SM \ Wbb
  - plug leptons, better mass meas
  - other taggers, high-\(\eta\) tagging
- SM \( h \rightarrow WW \rightarrow ll\nu\nu \)
- \( H^{++}, \) including long-lived

Ongoing Searches
- most modes of \( Wh, Zh \)
- most modes of \( h \rightarrow WW, ZZ \)
- \( hbb \) at high \( \tan\beta \)
- \( A \rightarrow \tau\tau \)
- \( H^+ \) direct and indirect
- several more

Future
For probable 95\% exclusions on \(<120\ GeV\ SM\ Higgs\) - need 2fb
For probable 3\(\sigma\) evidence - need \(~5\)fb
Restricting SUSY Higgs using Vbb: starting 1-2 fb
Setting limits on SUSY at high \(\tan\beta\) now
Thoughts on Searches

**Historically Model-based**
- One student, one model, one publication
- Models expire or are excluded - shouldn't change search results
- How do we select models? No limit = not interesting?
- We are too focused on models - inefficient, creates blinders
- The good part is that it is precise, optimized, and tells a story

**Increasingly (?)**
- Models treated as nominal examples, benchmarks
- Several searches published without a model
- Trying to spend more time investigating data
- Publish more variations on data selection
- Investigate virtually every signature
  (we covered essentially all primary signatures in Run I!)
- Automated searches - DØ Sleuth proponents moved to CDF
- Trying to preserve results to apply to new models
### Run I CDF Anomaly Scorecard

<table>
<thead>
<tr>
<th>Effect</th>
<th>Run II Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>- high-mass dijet excess</td>
<td>accomodated by PDF</td>
</tr>
<tr>
<td>- top dilepton event kinematics</td>
<td>pattern not reinforced, need more definitive statement</td>
</tr>
<tr>
<td>- $\mu$-$\gamma$ event excess</td>
<td>excess at this level is excluded in Run II</td>
</tr>
<tr>
<td>- $e e \gamma \gamma ME_T$ candidate</td>
<td>no event yet (note $D\emptyset$ e $\gamma \gamma E_T$)</td>
</tr>
<tr>
<td>- Wbb superjets</td>
<td>no result yet, tools need more development</td>
</tr>
</tbody>
</table>

*Where are the Run II anomalies?*
Last Slide

Operations
- COT back in full operations
- Biggest problem is tuning trigger table to high luminosity!

Searches
- We are hemorraging results! More for ICHEP..
- Will comment on SM/SUSY Higgs by LHC era
- Still plenty of time for even bigger discovery
- Always looking for new ideas