W+jj, the Tevatron, and Technicolor

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the CDF bump

4.3 fb\(^{-1}\) data: central l(e/µ), MET > 25 GeV,
2 jets \(p_T > 30.0\) GeV, \(p_{T,jj} > 40.0\) GeV

look in dijet mass spectrum

![Graphs showing dijet mass spectrum with 3.2 sigma excess.](image)
what it’s not

• an artifact of LO (ALPGEN) W+jets:
  NLO has a steeper spectrum, excess grows (3.4σ) while improving fit tail and W/Z peak

• from ttbar mismodeling (theory): (J. Campbell, AM, C. Williams in progress)
  has a feature at ~150 GeV, only modeled with PYTHIA by CDF...
  BUT: too small, CDF relative background rates are consistent with NLO (MCFM), ttbar K factor w/ CDF cuts is < 1

• the overall JES (“can’t I just shift all the data to the left...?”)
  NO! change of jet energy = change in acceptance, have to redo cuts, fits, etc.
  JES(p_T, η) known to % level for light quarks (from ttbar)
  varying within JES systematics, excess stays over 3σ
what it’s not

JES best known for light quarks, what about gluons?

Could a possible mis-modeling detector response to gluon-jets be behind it?

(AM, S. Mrenna, H. Wolfe in progress)
what it's not

Well...
- at large $M_{jj}$, mostly quark `jets' (at LO parton level)
- some cross-over from QQbar to QG in region of interest
- but Q/G mis-modeling would show up in other places ($\gamma$ + jets, dijets) and crossover has the wrong behavior as you change jet $p_T$ cuts

(AM, S. Mrenna, H. Wolfe in progress)
what about D0?

has a task force looking into this now.. will repeat CDF analysis + variations. timescale??

existing l + nu + jj analysis relies on ‘reweighting’ = disagreement between data & MC fixed by

**rescaling MC to data** (in **multiple** variables)

reweighting driven by regions where fixed-order MC can’t work (low $p_{TW}$) .. (CDF takes $p_{Tjj} > 40$ GeV to avoid this)

not clear (to me) why this is a good idea, does appear to have an effect.. especially $\Delta R_{jj}$ reweight
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Figure 44: Dijet mass before (left) and after (right) $\Delta R_{jj}$ weighting in the muon channel.

what (new physics) it could be...

needs to have a relatively large cross section $\sigma(p\bar{p} \to Wjj) \sim 2-4$ pb

one resonance...

(Matt’s talk)

two resonances...

pair production...

more?
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this talk

more?
$W + jj$ from two resonances

- **Small coupling**
- **Large coupling**
- **Resonant production**

- Needed to avoid direct $Z'/W'$ constraints

- Light parent resonance with narrow width, large BR to $W jj$

- Mass $m \sim 150-160$ GeV
**W + jj from two techni-resonances**

mass scales, resonance properties fit in with Low-Scale technicolor model of Eichten & Lane

**Main idea:** there are two sources of dynamical EWSB

\[
\langle \bar{T}_{1L} T_{1R} \rangle \propto 2\pi v_1^3 \quad \text{...for example, } T_1, T_2 \text{ in different TC reps.}
\]

\[
\langle \bar{T}_{2L} T_{2R} \rangle \propto 2\pi v_2^3 \quad \sin \chi = v_2 / v_1 \ll 1
\]

resonances (\(\rho_T, a_T, \omega_T\) ..) associated with the \(v_2\) scale are light

two vevs \(\rightarrow\) extra NGBs = technipions (similar to \(H^\pm/A\))
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the TC version of a 2HDM!

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deconstructed version

\[ U_1 = e^{i\pi_1/v_1} \quad \text{and} \quad U_2 = e^{i\pi_2/v_2} \]

spectrum

\[ \nu_1 \text{ res.} \]

\[ \nu_2 \text{ res.} \]

fermion - $\rho_T$ coupling suppressed by

\[ \frac{M_W}{M_{\rho_T}} \sin \chi \ll 1 \]

(Lane, AM '09)
Does it fit: $W + \ell\ell$

signal parameters: $M_{\rho_T} \cong 290$ GeV, $M_{\pi_T} \cong 160$ GeV

$\sigma(p\bar{p} \to \rho_T^{\pm};0 \to W + \ell\ell) \sim 2.4$ pb

CDF cuts:

- $M_{\ell\ell}$

ALPGEN, MLM matched

PYTHIA 6.4

granularity

$\delta\eta \times \delta\phi = 0.1 \times 0.1$
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CDF cuts:

extra cuts: $\Delta \phi_{jj} > 1.75$, $p_{T,W} > 60 \text{ GeV}$

ALPGEN, MLM matched

PYTHIA 6.4

granularity $\delta \eta \times \delta \phi = 0.1 \times 0.1$

(ELM '11)
1.) on one hand, just a 'simplified model' involving two resonances few inputs \((M_\rho T, \sin \chi)\) --> Wjj, correlated signals, forget UV for now

2.) on the other hand, parameters that fit are motivated by TC lore

   ex.) \(M_\rho T < 2 M_{\pi T}\) if TC is near-conformal, \(<\bar{T}T>\) can have a large anomalous dimension, which effects \(M_{\pi T}\), not \(M_\rho T\)
wait a minute... **technicolor?!!?!**

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also means QCD-based estimates of PEW do not apply

*note, using LEP measurements alone, value of \( \sin^2 \theta_w \rightarrow S = 0.45 \) !

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(Marciano, Chanowitz)

• $m_{top}$, flavor?? subject of another talk
Does it fit: $W + jj$

For the two resonance story to make sense there must be a peak in the total $Wjj$ invariant mass near $\sim 300$ GeV.

with CDF cuts alone, $p_T$ peak sits on top of sculpted background

(V. Cavaliere thesis)
Extracting the techni-signal

Wjj simulation for 4.3 fb  (no b-tag!)

CDF cuts
S/B = 235/3400

CDF+ELM cuts
S/B = 215/1215
Extracting the techni-signal

What else can be done to reveal $\rho_T$? **angular distributions**

e.g.) $\sigma(q\bar{q} \rightarrow \rho_T \rightarrow W \pi_T) \propto \sin^2 \theta$

back off $p_T$ cut on $W$ to 40 GeV, cut right around $M_{\rho_T}$, subtract a fit of $W$+jets
Extracting the techni-signal

Correlated signals:

\[
\sigma(\rho_T^\pm \rightarrow Z\pi_T^\pm) \simeq 0.5 \text{ pb}
\]
\[
\sigma(\rho_T^0 \rightarrow e^+ e^-) \simeq 12 \text{ fb}
\]

for other states not directly behind Wjj...

\[
\sigma(\omega_T \rightarrow \gamma\pi_T^0 \rightarrow \gamma\bar{b}b) \simeq 80 \text{ fb}
\]
\[
\sigma(a_T^\pm \rightarrow \gamma\pi_T^\pm \rightarrow \gamma\bar{b}q) \simeq 185 \text{ fb}
\]

LHC signals:

Wjj?... signal increases by \( \sim 4 \), W+jets increases by \( \sim 10 \)

better bet: \( \rho_T^\pm \rightarrow W^\pm Z, W^\pm \gamma \), dileptons

(see 2007, 2009 LesHouches reports)
Conclusions

the CDF bump is absolutely not “wrong”: may be new physics ...

.. but if not, it exposes a mismodeling/misunderstanding in QCD/detectors that is necessary to understand for future searches.

why reweight?

two resonance topology:
• large rate in $Wjj$ with small fermion-resonance coupling
• must see peak in total $M_{Wjj}$, related signals in $Zjj, \bar{f}f$

parameters from Low-Scale Technicolor fit surprisingly well:
• multiple EWSB scales -> light resonances
• coupling to SM suppressed by $v_2/v_1 \ll 1$

should be an exciting summer! THANK YOU
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BACKUP
Requiring AT LEAST Two Jets

Excess still in place. Statistical significance $3.5\sigma$.

$M_{jj}$ events/(8 GeV/c$^2$)

CDF data (4.3 fb$^{-1}$)
- WW+WZ 4.3%
- W+Jets 73.0%
- Top 13.8%
- Z+jets 2.7%
- QCD 5.6%

Bkg Sub Data (4.3 fb$^{-1}$)
- WW+WZ

P. Catastini, CERN seminar 5/3/11
incorporating some NLO

more NLO background checks coming soon