The CDF Excess: Discovery or Fluctuation?

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Outline

- The TEVATRON at Fermilab
- The Collider Detector at Fermilab
- The Excess in Wjj Events
- Reactions of the HEP Community
- Tests at Other Experiments?
- Prospects
**The Zoo of the Standard Model**

<table>
<thead>
<tr>
<th>Quarks</th>
<th>Leptons</th>
<th>Bosons</th>
</tr>
</thead>
<tbody>
<tr>
<td>up</td>
<td>electron</td>
<td>photon</td>
</tr>
<tr>
<td>down</td>
<td>neutrino $e$</td>
<td>gluon</td>
</tr>
<tr>
<td>charm</td>
<td>muon</td>
<td>$Z^0$</td>
</tr>
<tr>
<td>strange</td>
<td>neutrino $\mu$</td>
<td>$W^\pm$</td>
</tr>
<tr>
<td>top</td>
<td>tau</td>
<td>Higgs</td>
</tr>
<tr>
<td>beauty</td>
<td>neutrino $\tau$</td>
<td></td>
</tr>
</tbody>
</table>

**colored quarks $\Rightarrow$ colorless composite hadrons**

hadrons = mesons $(q\bar{q})$ + baryons $(qqq)$

Nucleons ($I = \frac{1}{2}$):

- $p = (uud)$
- $n = (udd)$
- $\bar{p} = (u\bar{u}\bar{d})$
## Glory Road of the Standard Model

### Status 2010

Includes hundreds of measurements of all experiments

\[ \frac{|\text{Expt} - \text{theory}|}{\text{expt. uncertainty}} \]

During LEP the slightly deviating quantity kept changing.

Now: forward-backward asymmetry of
\[ e^+e^- \rightarrow Z \rightarrow b\bar{b} \]

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \alpha^{(5)}_{\text{had}}(m_Z)$</td>
<td>0.02758 ± 0.00035</td>
</tr>
<tr>
<td>$m_Z$ [GeV]</td>
<td>91.1875 ± 0.0021</td>
</tr>
<tr>
<td>$\Gamma_Z$ [GeV]</td>
<td>2.4952 ± 0.0023</td>
</tr>
<tr>
<td>$\sigma^0_{\text{had}}$ [nb]</td>
<td>41.540 ± 0.037</td>
</tr>
<tr>
<td>$R_l$</td>
<td>20.767 ± 0.025</td>
</tr>
<tr>
<td>$A_{t,b}^{0,l}$</td>
<td>0.01714 ± 0.00095</td>
</tr>
<tr>
<td>$A_l(P_t)$</td>
<td>0.1465 ± 0.0032</td>
</tr>
<tr>
<td>$R_b$</td>
<td>0.21629 ± 0.00066</td>
</tr>
<tr>
<td>$R_c$</td>
<td>0.1721 ± 0.0030</td>
</tr>
<tr>
<td>$A_{t,b}^{0,b}$</td>
<td>0.0992 ± 0.0016</td>
</tr>
<tr>
<td>$A_{t,b}^{0,c}$</td>
<td>0.0707 ± 0.0035</td>
</tr>
<tr>
<td>$A_b$</td>
<td>0.923 ± 0.020</td>
</tr>
<tr>
<td>$A_c$</td>
<td>0.670 ± 0.027</td>
</tr>
<tr>
<td>$A_l$(SLD)</td>
<td>0.1513 ± 0.0021</td>
</tr>
<tr>
<td>$\sin^2\theta_{\text{eff}}(Q_{fb})$</td>
<td>0.2324 ± 0.0012</td>
</tr>
<tr>
<td>$m_W$ [GeV]</td>
<td>80.399 ± 0.023</td>
</tr>
<tr>
<td>$\Gamma_W$ [GeV]</td>
<td>2.085 ± 0.042</td>
</tr>
<tr>
<td>$m_t$ [GeV]</td>
<td>173.3 ± 1.1</td>
</tr>
</tbody>
</table>

LEP Electroweak Working Group:
http://lepewwg.web.cern.ch/

July 2010
TEVATRON at FERMILAB

1 TeV + 1 TeV $p\bar{p}$ collider
Collider Detector at Fermilab (CDF)
We report a study of the invariant mass distribution of jet pairs produced in association with a W boson using data collected with the CDF detector which correspond to an integrated luminosity of 4.3 fb\(^{-1}\). The observed distribution has an excess in the 120-160 GeV/c\(^2\) mass range which is not described by current theoretical predictions within the statistical and systematic uncertainties. In this letter we report studies of the properties of this excess.
WX $\rightarrow \ell^\pm \nu jj$: main selection cuts

- 1 isolated muon or electron, $p_T > 20$ GeV/c, $\not{E}_T > 25$ GeV
  remove 2-lepton events even if 2nd lepton weaker

- 2 jets: cone alg.,
  $\Delta R = \sqrt{\left(\Delta \eta\right)^2 + \left(\Delta \Phi\right)^2} < 0.4,$
  $E_T > 30$ GeV, $\eta < 2.4$

- For the jj-system ($E(j_1) > E(j_2)$):
  $p_T(jj) > 40$ GeV/c, $\Delta \eta(jj) < 2.5$

- Jet energy correction for 30 GeV jets.

- Transverse mass ($M_T^2 = M^2 + p_x^2 + p_y^2$)
  $M_T(W) = M_T(\ell^\pm + \not{E}_T) > 25$ GeV

- $|\Delta \Phi(p_T,j_1)| > 0.4$
The measured spectrum \((4.3 \text{ fb}^{-1})\)

Fitting

- SM background only
  - \(\chi^2/\text{ndf} = 77.1/84\)
  - SM Wjj: Alpgen + Pythia

- SM background + Gaussian peak
  - \(\chi^2/\text{ndf} = 56.7/81\)
The CDF bump fitted (4.3 fb$^{-1}$)

Validity of analysis: 
WV peak at 80 GeV

Excess events:
\[ e^{\pm}: 156 \pm 42 \]
\[ \mu^{\pm}: 97 \pm 38 \]

SM background + Gaussian peak:
\[ M_{jj} = 144 \pm 5 \text{ GeV}/c^2 \]
\[ \chi^2/\text{ndf} = 10.9/20 \]
Interpretation of the CDF result

- No parent SM particle decaying, CDF studied \( M(\ell^{\pm}, \nu, jj) \)

- Not a Standard Model Higgs-boson (Flip Tanedo):
  - no excess in \( \ell\nu b\bar{b} \) at \( M_H \sim 120 - 160 \) GeV;
  - cross sections:
    - \( \sigma(\text{bump}) \sim 4 \text{ pb} \), \( \sigma(150 \text{ GeV Higgs} \rightarrow jj) \sim 12 \text{ fb} \).

- Assuming an excess with Gaussian distribution with the experimental dijet mass resolution in the 120–160 GeV \( M(jj) \) range gives a significance of \( 3.2\sigma \) for new physics.

- No excess in Z + jets, although non-SM particles may couple to both Z and W
Strange CDF events: photon + jet

"Halloween event", 1994
CDF, 1996: $p \bar{p} \rightarrow e^+ e^- \gamma \gamma!!$

An avalanche of theoretical papers tried to explain it.
Low energy supersymmetry with a neutralino LSP and the CDF $ee\gamma\gamma + \slashed{E}_T$ event

S. Ambrosanio, G. L. Kane, Graham D. Kribs, Stephen P. Martin
Randall Physics Laboratory, University of Michigan, Ann Arbor, MI 48109–1120

S. Mrenna
High Energy Physics Division, Argonne National Laboratory, Argonne, IL 60439

Theoretical paper, 57 pages
CDF, 2002: $Z'(M \sim 371 \text{ GeV}) \rightarrow e^+e^-$?
Wow. That is really cool! I’d like to offer my congratulations to the Tevatron experiments! That would be, of course, CDF and DZERO! Wait. I’m on DZERO. Why don’t I know about this discovery!? All sarcasm aside, I’ve seen the DZERO results and, yeah, there is a bump. But there is a reason we aren’t really talking about it: we don’t trust it yet. We see lots of these bumps. Most of them don’t stick around very long: we can easily identify their (non-new-physics) sources and remove them. Some stick around longer than others.

..., there is a long history of bumps that appear and then go away — especially in something that involves jets (ala the ALEPH 4-jet bump). Both of these analyses are 4-jet bumps.
CDF and D0, 2008: Z' (?) → e^+e^-

\[ M(e^+e^-) = 240 \text{ GeV/c}^2 \]

CDF: 50 events – 27.5 MC bgrd

Significance \(\sim 3.2\sigma\)

CDF + D0: 60 events – 40.2 MC bgrd

Significance \(\sim 3.3\sigma\)

By Tommaso Dorigo (CDF and CMS)
ALEPH vs. DELPHI, L3 and OPAL

In 1995 ALEPH saw a lot of non-SM 4-jet events at LEP at $E_{CM} \sim 133$ GeV, the other 3 expts did not and later ALEPH neither, although the original finding was very significant statistically.

In 2000 ALEPH saw a very significant SM Higgs signal ($e^+e^- \rightarrow HZ \rightarrow b\bar{b}jj$) in 4-jet events at $M_H = 115$ GeV/$c^2$. No such Higgs was seen in any other channel or by any other LEP experiment. The number of ALEPH Higgs events was much higher than the SM expectation.
Prompt comments on the CDF bump

- Dennis Overbye, New York Times: *At Particle Lab, a Tantalizing Glimpse Has Physicists Holding Their Breaths*
  The results, if they hold up, could be a spectacular last hurrah for Fermilab’s Tevatron, once the world’s most powerful particle accelerator and now slated to go dark forever in September or earlier, whenever Fermilab runs out of money to operate it.

- Résonaances (Paris), 6 April 2011: *Another 3 sigma from CDF*

- Florian Freistetter (Vienna), Astrodicticum-simplex, 8 April 2011: *Entdeckung am Tevatron: neue Physik oder viel Lärm um Nichts?*

- Hamish Johnston, Physics World: *Big noises about a little bump at Fermilab*
What about D0 and LHC?

D0 is busily analysing, they will make an announcement in a week or so

CMS: Hot discussion on Internet, a lot of scepticism. As an example it was shown that a 6% rescaling of $M_{jj}$ can erase the effect and even improve the overall fit of the WV peak of the background.
LHC will decide about the validity of this effect, but we are \( \sim 1 \) year away in luminosity. For now we should wait for D0-s announcement.