Would We Believe A Discovery Based Solely On Boosted Objects?

A Springboard for Discussion

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Discovery and Limits

- We have published limits on boosted objects
- Could we discover something? And have the community believe us?
  - By “discovery” I mean something really surprising: BSM

- Some people argue that you shouldn’t claim a limit if you wouldn’t claim a discovery had the outcome gone the other way.
  - I like the idea behind this.
  - However, our tests tend to be asymmetric (95% CL vs. $5\sigma$)
    - The practical vs. the philosophical
The Kind of Discovery You Usually Don’t Get

- This is the ATLAS discovery of the $\chi_b(3P)$. This is the n=3, l=1 state of bottomonium.
  - It is expected to be there

- It appears in two channels $\chi \rightarrow Y(1S,2S)$
  - With either converted or unconverted photons

- The significance is in excess of six sigma
  - “Six” in words to emphasize that it’s really hard to quantify significances with $p < 2 \times 10^{-9}$.
    - PRL changed it to “6”. <sigh>

- Known states show up with
Sigmas Aren’t Everything

- DAMA and DAMA/LIBRA have a $9\sigma$ signal, showing 10+ cycles – yet the majority of scientists remain unconvinced.

- The null hypothesis is not “there is no dark matter”. It is “there is no dark matter and we understand the experiment perfectly”.

- Which option we believe is a matter of scientific judgment, not number of sigmas.
Priors and Prejudice

- I asked about two dozen people if they would believe a result only on a boosted signature
  - Nobody gave an unqualified “yes”
  - Everyone said “it would depend what it was”
  - There was a desire for a confirming result
    - A second channel
    - Interestingly, the same thing from the other experiment was viewed as weak confirmation. The concern is that there is some common systematic.

- There is no simple standard of proof
  - People will accept weaker evidence for things that they feel are likely than things that they feel are unlikely
  - What would you need to believe that a new, predicted, hadron was discovered?
  - What would you need to believe that charge non-conservation has been discovered?

- My prejudice: I would not believe a discovery based on an excess above a calculation. I would want to see an excess over something
Q-Jets

I liked the idea.
I think it could be “sold” based on the following argument:
- “If you had a signal with $R=0.6$ but nor $R=0.59$ or $R=0.61$ would you believe it?”*
- It’s value (as I see it) is mot so much as a statistical trick to improve significance as something that protects you from background fluctuations.

Familiarity is always an issue
- The more “new stuff” you need to swallow to understand the discovery, the more resistant the community will be
  - Both the top and the Higgs techniques were well-exposed before their respective discoveries.

* I know Q-jets don’t vary $R$, but this was too good to pass up.
Case Study: A $t\bar{t}$ resonance at 2 TeV

- Example: a KK gluon
- A nice feature: this is top – lots of people are studying top who are not looking for this particular phenomenon.
Case Study: A $t$-$t\bar{t}$ resonance at 2 TeV

- Example: a KK gluon
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We are starting to measure the data points; I have not ever seen them on the same plot.
Case Study: A t-tbar resonance at 2 TeV II

- Additionally, we have leptons:
  - Single lepton branching fraction is 2/9 of the all-hadronic
    - I’m ignoring taus
  - A convincing all-hadronic signal should have at least a unconvincing (by itself) single-lepton signal.

- In principle, one even has a mass measurement
  - There are two solutions for m(W), but we have two constraints: top mass, and jet pT balance.
  - However, for these boosted objects, the energy resolution is not very good: at ATLAS it would be around 25 GeV.

- A supporting channel does not have to be as strong as the discovery channel
  - Remember H → ZZ*. On July 4th, this didn’t look particularly compelling by itself. And this is the channel where the Higgs nature of the “X(125)” is manifest.
Case Study: A Non-resonant Excess of WW events at high $M$

- Model: electroweak interaction becomes strong at short distances.
- Signature: lepton, MET aligned with it, recoiling off a fat jet.

- Even though this is topless, the “partially resolved” category will add confidence that this is sensible.
- Dileptons could provide a confirming channel
  - There is no mass information
  - $m(\ell\ell)$ depends on the details of this interaction; it could get washed out
Case Study: New Particle Pair Production

$pp \rightarrow X\overline{X}; X \rightarrow jj$

Signature: two jets with substructure and a common mass. Possible displaced vertices.

- Analysis strategy: tag jets as “special” (substructure, mass, possibly b-tagging)
  - Measure mistag rate from data

Under the null hypothesis

$$N_0 = N(1 - f)^2$$

$$N_1 = 2Nf(1 - f)$$

$$N_2 = Nf^2$$

$$f = \frac{1}{1 + 2N_0 / N_1}$$

$$\Delta N_2 = N_2 - \left( N_0 + N_1 + N_2 \right) \left[ \frac{1}{1 + 2N_0 / N_1} \right]^2$$
Case Study: New Particle Pair Production II

\[ \Delta N_2 = N_2 - \left( N_0 + N_1 + N_2 \right) \left[ \frac{1}{1 + 2 \frac{N_0}{N_1}} \right]^2 \]

- A million dijets, \( f = 0.1\% \) and this is sensitive (5\( \sigma \)) at the 5 event level
- Make the fake rate 1\% and now you need 50.
- Anyone can run their own numbers

- One way to confirm the effect is to take your tagger and split it into two independent (as far as background is concerned) taggers. Both need to show the effect.
  - A fake rate of 0.1\% means each tagger has \( f = 3.1\% \), and the 5\( \sigma \) effect becomes two 0.9\( \sigma \) effects. So this essentially kills your statistics.
- A second way to confirm the effect is to divide the tagging into loose and tight, and do a 3x3 \( \chi^2 \) with 4 degrees of freedom.
  - Making “loose” looser provides little or no information (reverts to the above case)
  - Making “tight” tighter makes the \( \chi^2 \) dependent on the exact distribution of the 5 events.
New Particle Thoughts

- We’re not going to improve the credibility of such a result with more and/or better statistics.

- The “credible sensitivity” is probably substantially worse than the $5\sigma$ sigma sensitivity.
  - If one could see a $5\sigma$ signal in each of the N samples with N–1 cuts applied, that would be helpful (but would it be enough?)
  - It would certainly help to show there is no signal in a sample where a signal is not expected: $\gamma$+jet, for example.
  - At some level, I fear we’re going to have to live with reduced sensitivity.
Confirmation, Comfort and Credibility

- The credibility of a boosted discovery depends on what the discovery is
  - We can argue whether this should be this way or not, but I believe it is true.

- Even weak confirmation goes a long way towards credibility
  - This is essentially DAMA/LIBRA’s problem
  - Both top and Higgs had this

- Better integration of the “boosted community” in the experiments can only help
  - People need to get comfortable with these new ideas, and this is one way to do this
  - A parade of SM results using boostology would be helpful
  - Top Group sociology enters into this in non-trivial ways