Blackbox A: Analysis, Unveiling, and kT/cone Jet Comparison

Jonathan Walsh

University of Washington

Analysis: Kyle Armour, Matt Bowen, Amanda Gray, Andrew Larkowski, Rob Schabinger, Dan Ventura

Advisers: Steve Ellis and Matt Strassler

Blackbox Author: Matt Strassler

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Motivations behind Blackbox A

- A simple model with interesting features
- Ideal for novices
- Motivates development of analysis techniques
- Allows for investigation of detector effects and reconstruction algorithms

The First Look: Cuts

- Objects in the detector below a PT cut have low resolution and may be inaccurate, so are excluded from analysis
- For our analysis, the following cuts were applied:
  - MET: no cut
  - Leptons, Photons: 25 GeV
  - Jets: 50 GeV

Basic Lepton and Photon Counters

Dilepton Events

2l	e-	e+	μ-	μ+	τ-	τ+
e-	0	450	3	24	3	14
e+		1	20	1	9	2
μ-			2	471	1	11
μ+				0	17	0
τ-					0	6
τ+						0

number of leptons	number of events
0	15480
1	1436
2	1035
3	37
4	20
5	0

number of photons	number of events
0	17744
1	226
2	38

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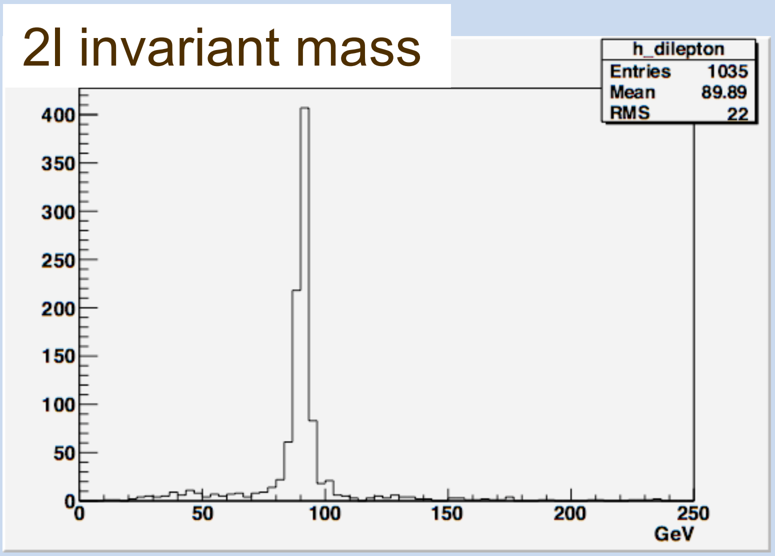
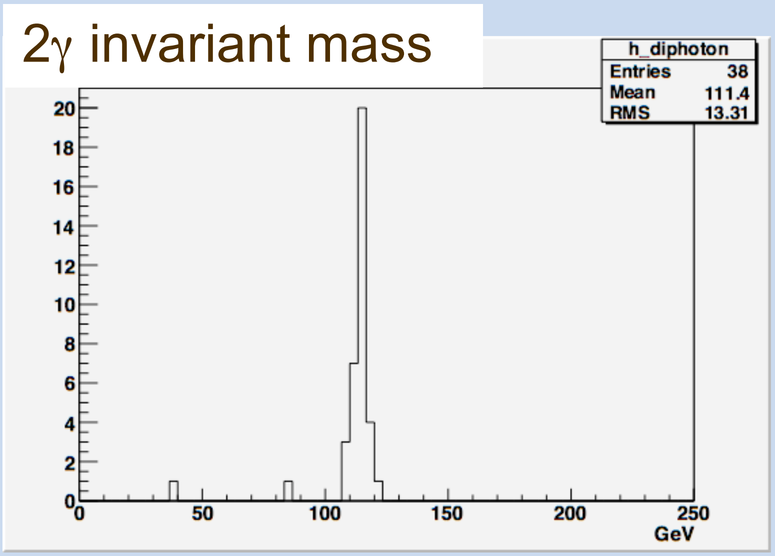
Standard Model products from the basic counters

Z

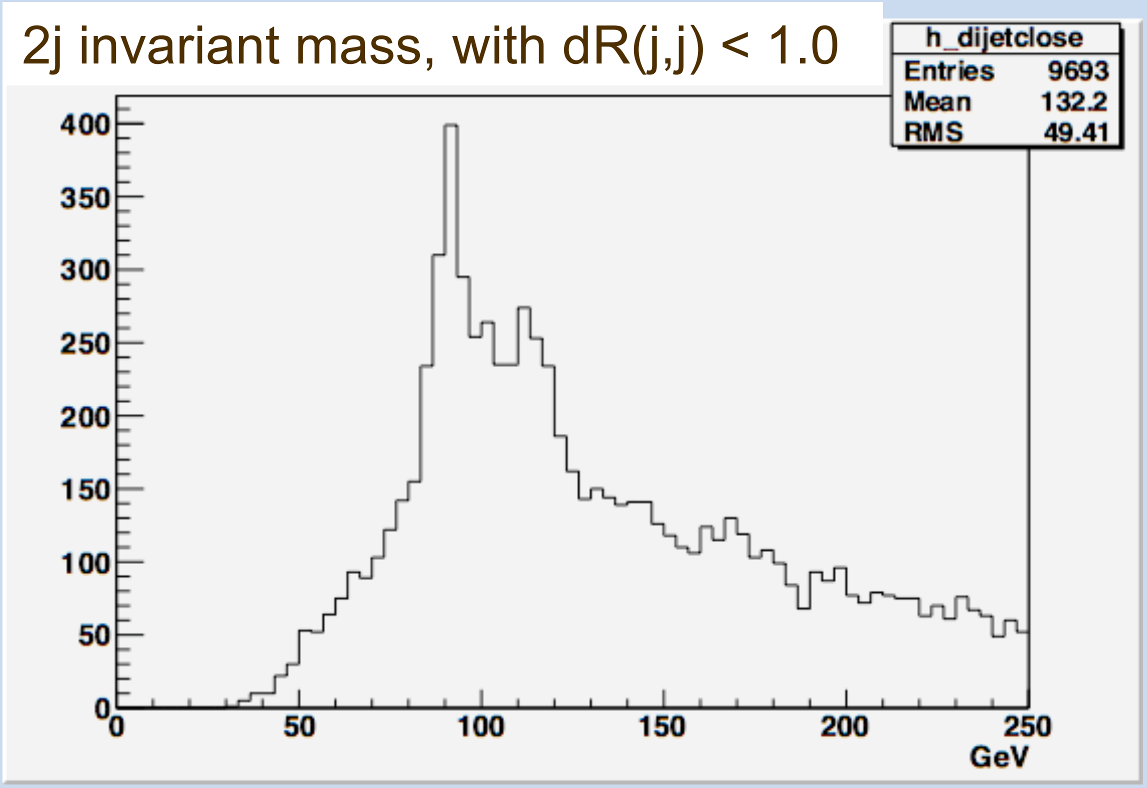
h: mass near 115 GeV





Note: transverse mass plots and the dilepton counters do not indicate evidence of W production

We can see the higgs and Z in jets



From this plot, the rate of higgs and Z production is roughly the same

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Let's look at the jets

- Large number of jets in the box (average of 1 b-tagged and 3 untagged per event)
- Many events with multiple jets

number of objects	b-tagged jets	non b-jets
0	7590	141
1	7013	1208
2	2797	3777
3	543	5359
4	58	4305
5	7	2250
6	0	711
7	0	210
8	0	39

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Features to look for

- A new physics signal could involve standard model decay products, so we should look for features in ZZ, hZ, Z + jets, h + jets, and in combinations of jets
- For example, we could look at the invariant mass of Z + jets, a higgs and Z, etc.
  – We see no features in these plots except…

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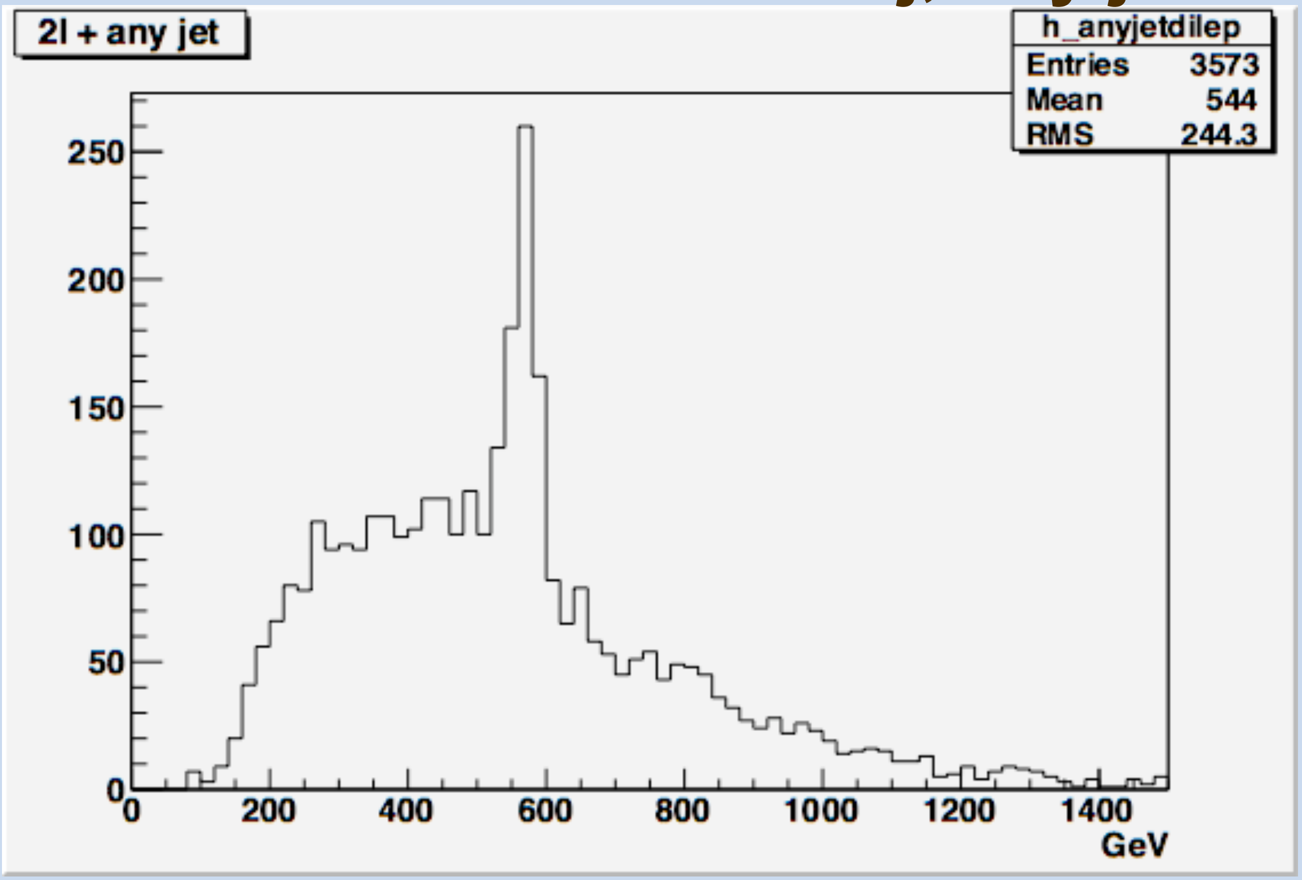
A new physics signal! Resonance near 575 GeV

Invariant mass of 2l + j, any jet



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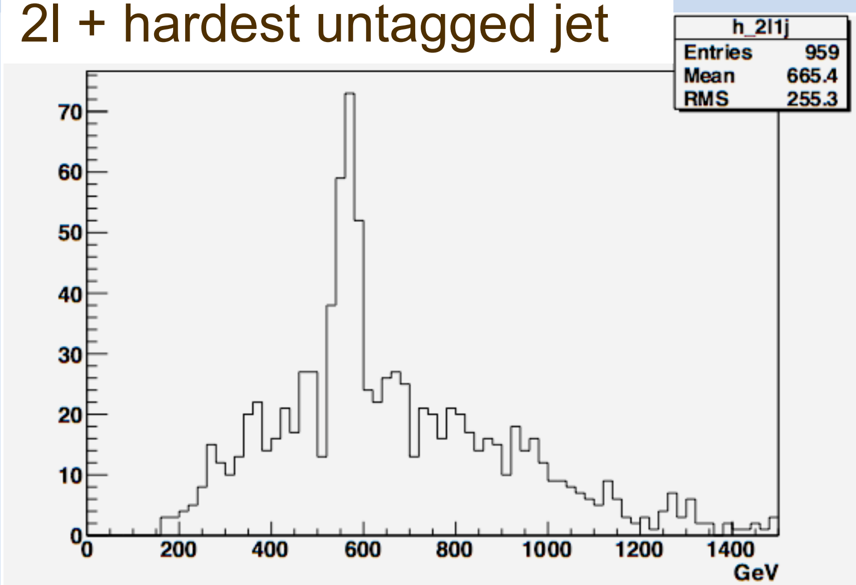
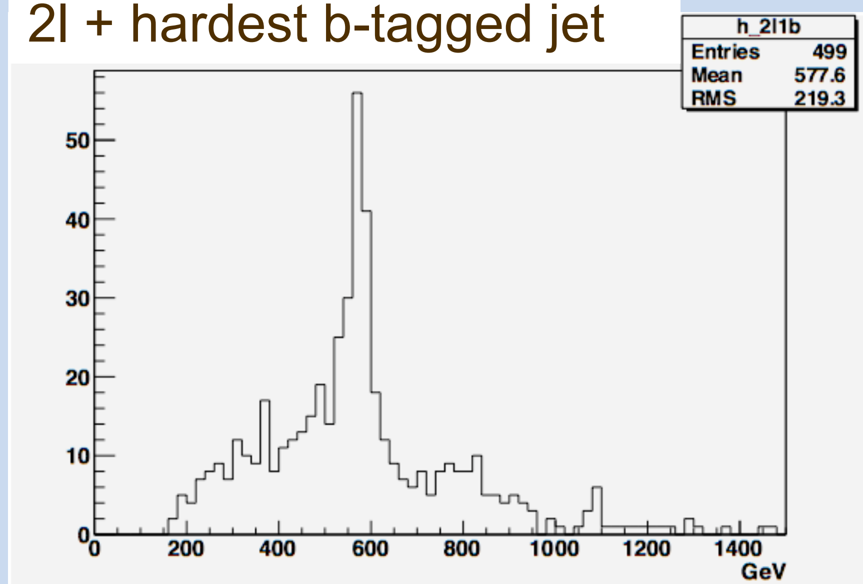
X → 2l + b gives a clearer peak

This leads us to believe the X has the decay X → Z + b, where the b jet may not be tagged

2l + hardest untagged jet

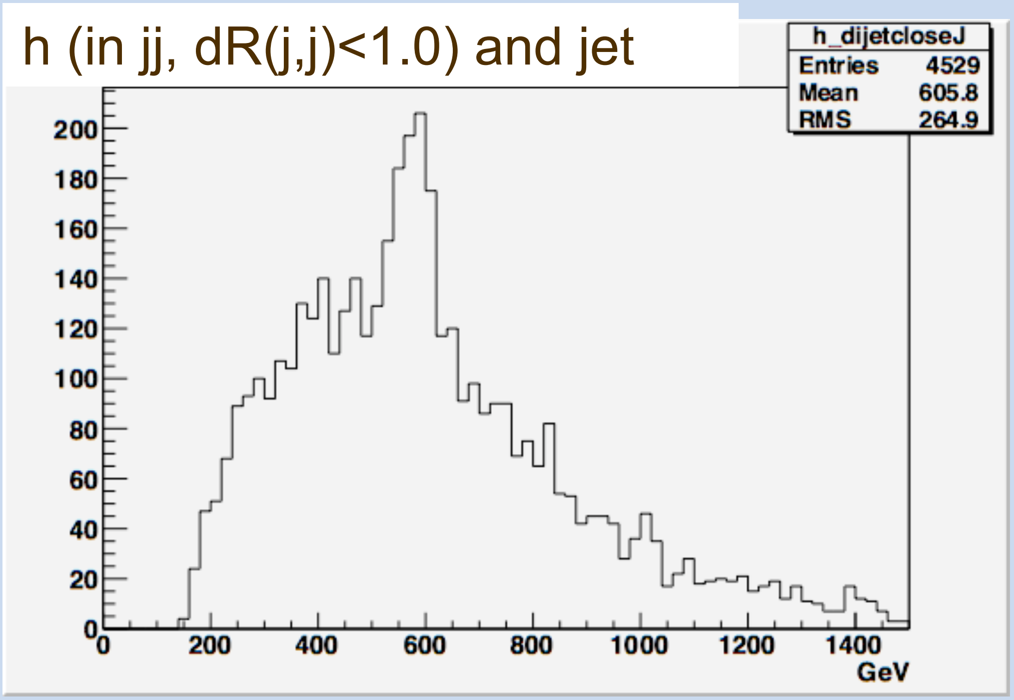


2l + hardest b-tagged jet



X → h + j is also seen

• The higgs is from 2 jets within dR = 1.0 and 10 GeV of the higgs mass
• These jets + any other jet gives a resonance at the X mass



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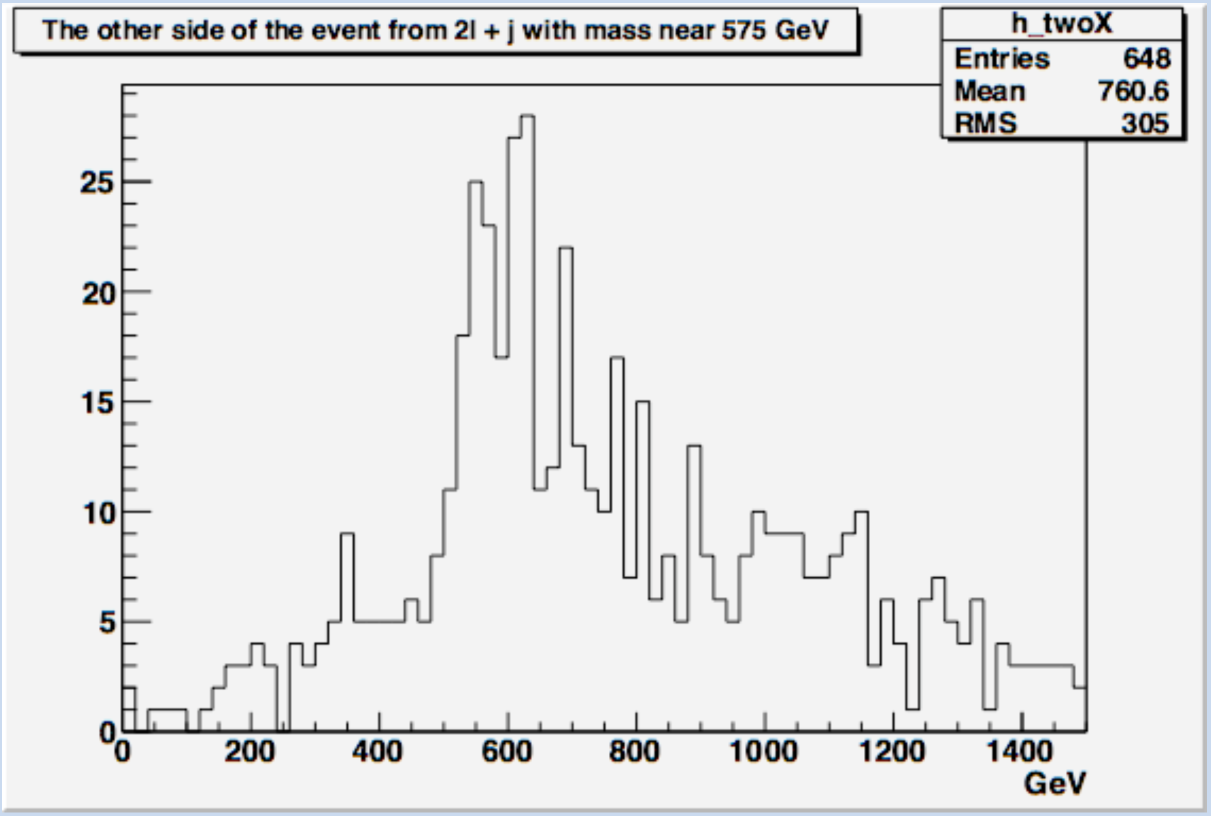
X pair production

When we see X → Z (2l) + b, the invariant mass of the rest of the event has a peak at the X mass



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So, we have a basic model

- X pair production with $m_X = 575 \pm 15$ GeV
- X decays seen: $X \rightarrow Z + b$ and $X \rightarrow h + b$
- This could be everything in the box
  - No other resonances are seen (SM or otherwise)
- The next steps are to come up with a model for what the X is, estimate the X branching ratios, and simulate this process to compare to the box

What is the X?

- We know X decays into a b quark plus a colorless and neutral object, so the X must carry b quantum numbers
- The dilepton counters indicate that the decay $X \rightarrow W^- + t$ is suppressed
  - If multi W events were in the box, we would see events with structures like $e\mu$, l^+l^+, or 3l
- The simplest model is that in which the X is a new quark, which we will call the b'

What features does this model have?

quark	SU(2)	U(1)	SU(3)
$\begin{pmatrix} t_L \\ b_L \end{pmatrix}$	2	$+\frac{1}{6}$	3
$\bar{b}_L$	1	$+\frac{1}{3}$	$\overline{3}$
$\bar{t}_L$	1	$-\frac{2}{3}$	$\overline{3}$

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What features does this model have?

quark	SU(2)	U(1)	SU(3)
$\begin{pmatrix} t_L \\ b_L \end{pmatrix}$	2	$+\frac{1}{6}$	3
$\overline{b}_L$	1	$+\frac{1}{3}$	$\overline{3}$
$\overline{t}_L$	1	$-\frac{2}{3}$	$\overline{3}$
b'_L	1	$-\frac{1}{3}$	3
$\overline{b'_L}$	1	$+\frac{1}{3}$	$\overline{3}$

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Method to estimate the b' branching ratio

- h→γγ is easily distinguishable, but very sensitive to new physics
- h→bb is less sensitive to new physics, so it is ideal for determining the branching ratios of the b'
- The decay Z → 2l gives a lower bound on the rate b' → Z + b
- The ratio of the hadronic decays of the Z and h provide an upper bound on the b' → Z + b rate

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A lower bound on b' → Z + b

We can use:

- the number of events (18008)
- the number of dilepton Z's (686)
- the decay rate of Z→2l (.077)
- and the probability for missing a lepton (.39)
  - Derived from the ratio of 1l to 2l events: $\frac{N_{1l}}{N_{2l}} = \frac{2p_l}{1-p_l}$

to get a lower bound on the rate r_Z of b' → Z + b:

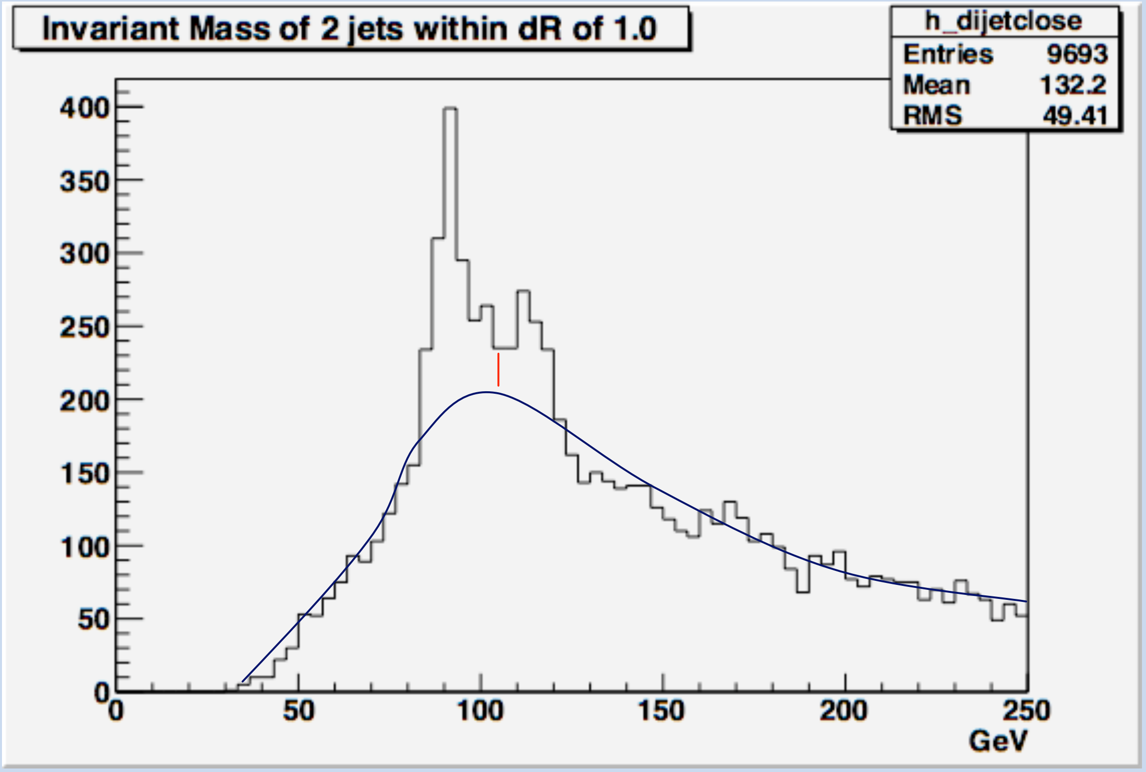
$r_Z > .70 \pm .19$

X branching ratio estimates

Z and h in 2 jet events, any jets with delta R < 1.0

Events in the Z peak: 530

Events in the higgs peak: 270



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An upper bound on b’ → Z + b

- Assuming Br(h→jj) = 100%, the ratio of higgs to Zs in the 2j events gives an upper bound on the rate r_Z:

$$r_Z < 0.78 \pm 0.10$$

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b’ branching fractions

- We have Br(b’→Z+b) between 51% and 88%
- The primary conclusion is that the branching fractions of the b’ to Zs and higgs are on the same order
- The best way to test our model is through a simulation in PYTHIA and PGS

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The Blackbox A PYTHIA card

Available at:
staff.washington.edu/jrwalsh/BlackboxA/card

Blackbox A as a study tool

- Now that we understand the model in the box, we can utilize it to study differences between kT and cone jet algorithms
- These kinds of comparisons are needed to characterize the difficulties we may encounter at the LHC with the different jet algorithms

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kT and cone jet algorithm comparison

- This box is the perfect setting to test differences between the two algorithms as it provides 3 things:
  - Events with many jets
  - Hard jets (from the b' decay)
  - Softer jets (from h and Z hadronic decays)
- PGS 3 uses the cone jet algorithm, while PGS 4 implements the kT jet algorithm

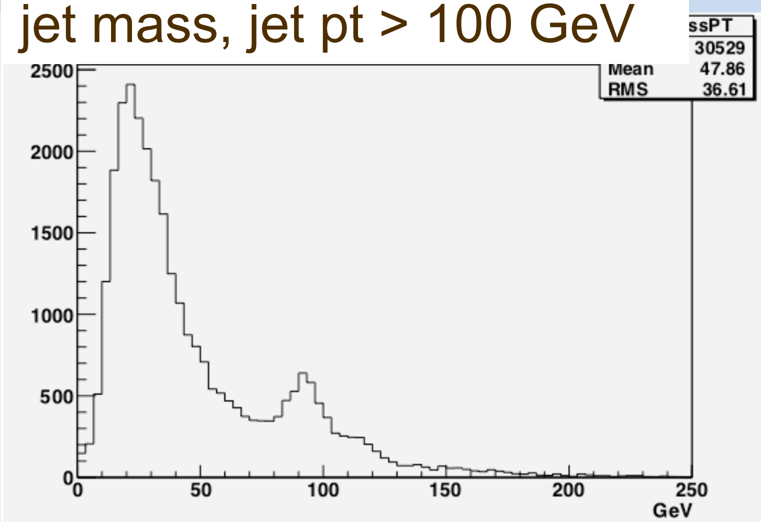
Caveat! The transition from PGS 3 to 4 must be kept in mind in considering this analysis!

Single jet invariant mass spectrum shows the kT smearing

• The kT algorithm smears the jet mass distribution higher, increasing the background at larger mass and making the Z (and higgs shoulder) less visible

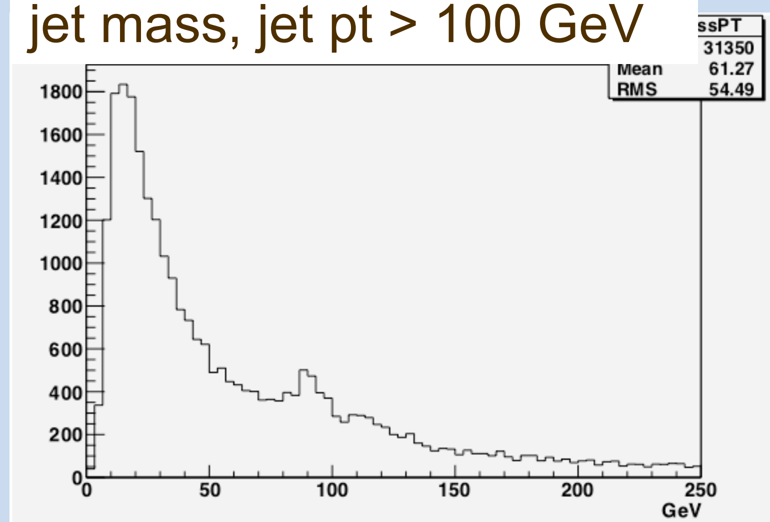
cone jet algorithm
resolution parameter R = 0.7

jet mass, jet pt > 100 GeV



kT jet algorithm
resolution parameter D = 0.5

jet mass, jet pt > 100 GeV



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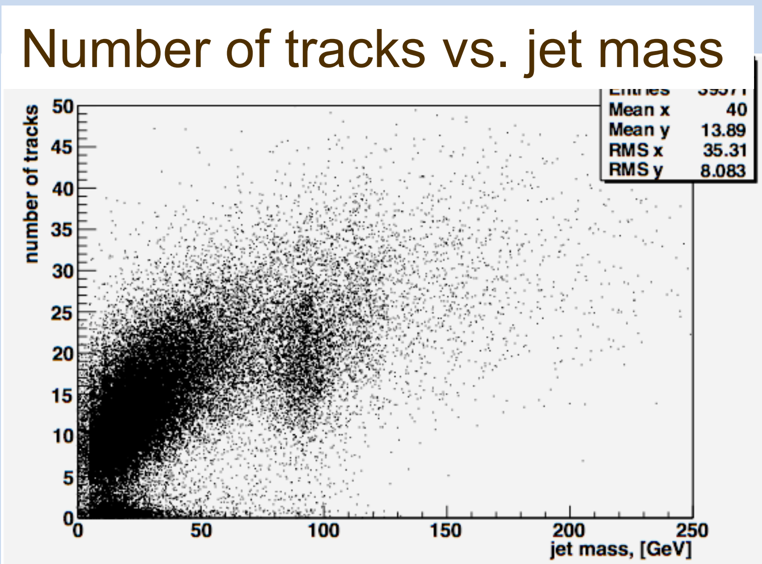
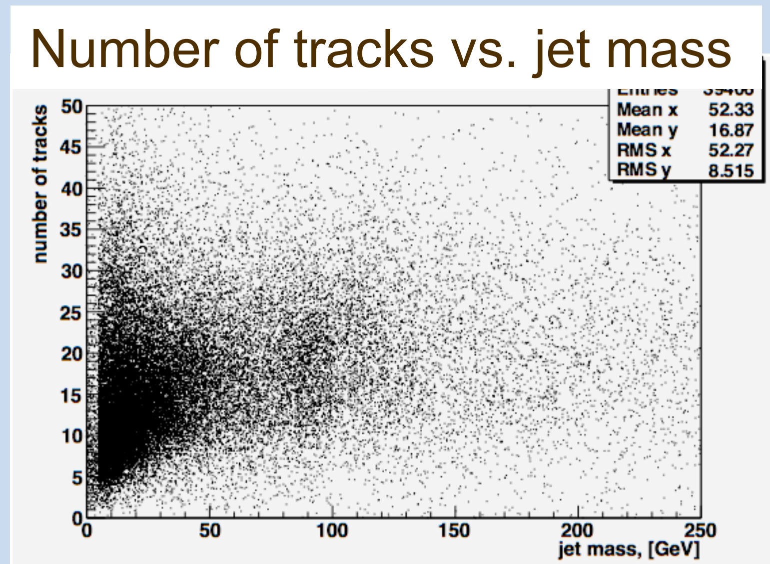
Number of tracks in the cone and kT algorithms

cone jet algorithm



kT jet algorithm



Many more high track jets in the kT algorithm

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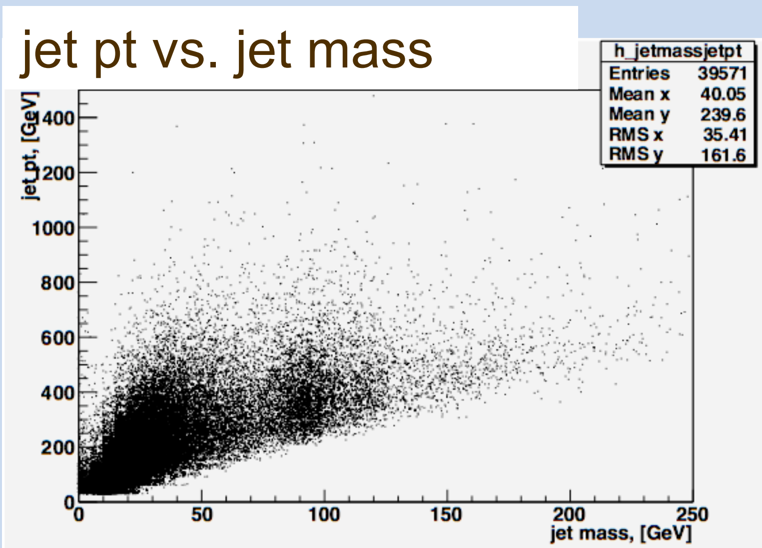
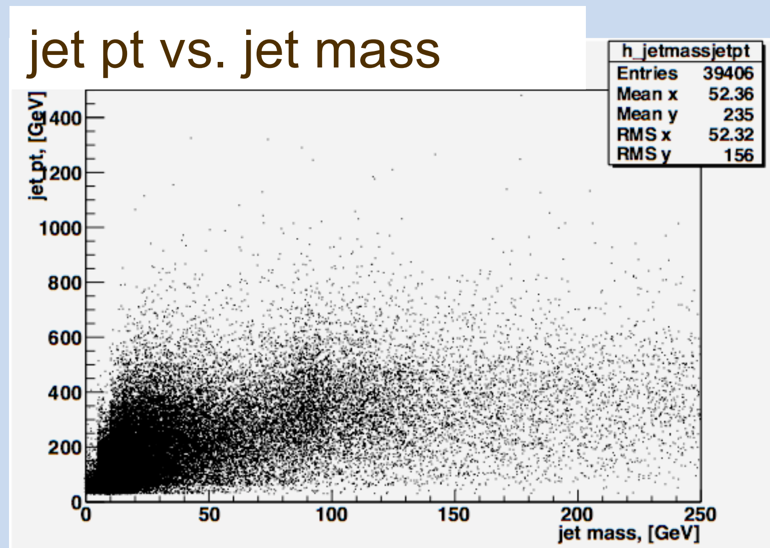
Jet resolution decrease can lead to missing a physics signal

cone jet algorithm with identifiable Z and higgs



kT jet algorithm with a less identifiable Z and a smeared out higgs



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cone and kT jet algorithm differences

cone jets (PGS 3)

1l	number
e-	133
e+	127
μ-	131
μ+	107
τ-	228
τ+	228

total number of jets	39571
total number of bjets	11499

kT jets (PGS 4)

1l	number
e-	171
e+	169
μ-	171
μ+	165
τ-	43
τ+	46

total number of jets	39406
total number of bjets	7796

number of events = 9582

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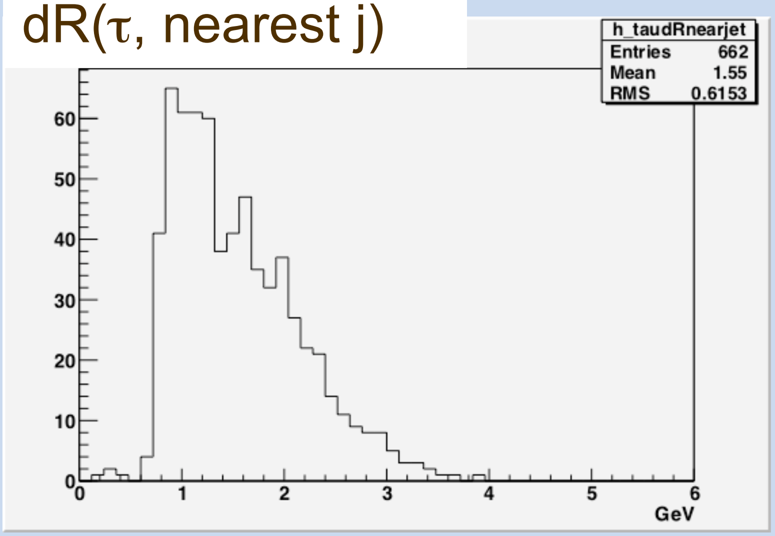
Are the taus not lonely enough?

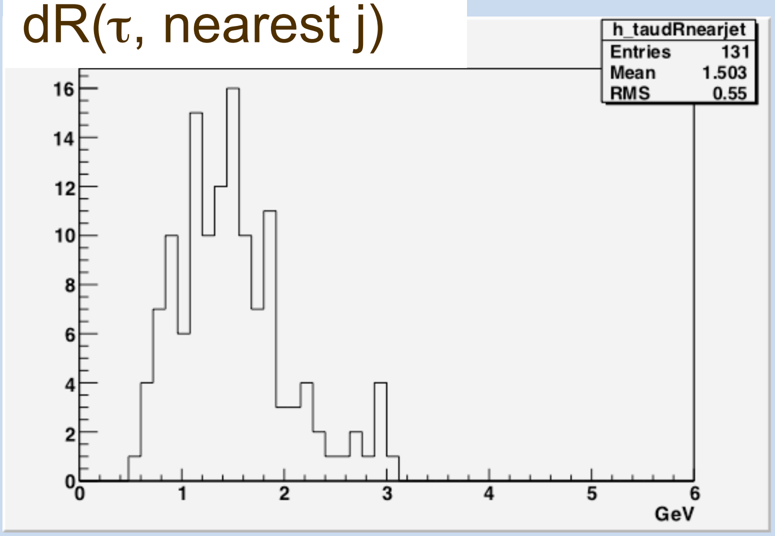
cone jet algorithm (PGS 3)
resolution parameter R = 0.7

dR(τ, nearest j)



kT jet algorithm (PGS 4)
resolution parameter D = 0.5

dR(τ, nearest j)



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Conclusions about the kT and cone algorithm comparison study

- kT jet characteristics tend to vary much more than cone jet
  - kT jets can have low pT and high mass (over merging)
  - Expect a larger number of tracks per jet with the kT algorithm, and very few jets with low numbers of tracks
  - Expect poor reconstruction of resonances and other features
- Jet pT and mass spectra are smeared out more in the kT algorithm than the cone
- Tau reconstruction may be very poor in the kT algorithm due to pencil jet absorption into jets
  - Is this is a PGS 3→4 effect or a kT algorithm effect? More study is needed

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