Non standard objects
for/from Higgs

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Jet substructure techniques in Higgs physics can be really useful! (even for early LHC)

\[ pp \rightarrow V \ h \]

\[ \mathcal{L} = 30 \ \text{fb}^{-1} \]
Hidden agenda

Jet substructure techniques in Higgs physics can be really useful! (even for early LHC)

\[ pp \rightarrow V h \]

\[ \sqrt{s} = 14 \text{ TeV}, \mathcal{L} = 10 \text{ fb}^{-1} \]

\[ M_T = 800 \text{ GeV} \]

Butterworth, Davison, Rubin, Salam

0802.2470

Kribs, Martin, TSR

1012.2866
Hidden agenda

Jet substructure techniques in Higgs physics can be really useful! (even for early LHC)

production is non standard

h \rightarrow bb
decay is standard
Jet substructure techniques in Higgs physics can be really useful!
(even for early LHC)

- production of Higgs is standard
- decay is non-standard
Non-standard objects from Higgs

\[ m_h = 120 \text{ GeV} \quad \text{and} \quad m_A = 10 \text{ GeV}. \]

\[ h \rightarrow a \ a \rightarrow (\tau \tau) (\tau \tau) \]
Non-standard objects from Higgs

\[ m_h = 120 \text{ GeV} \quad \text{and} \quad m_A = 10 \text{ GeV}. \]
Non-standard objects from Higgs
Non-standard objects from Higgs

Photon jets

Yavin, Toro
arXiv:1202.6377
Non-standard objects from Higgs

di-tau jets
Englert, TSR, Spannowsky
arXiv:1106.4545

Photon jets
Scholtz, TSR
preliminary studies
this is how my detector looks like!
particles $\rightarrow$ calorimeter cells $\rightarrow$ 4vectors

find the total energy deposited by the particles with same ($\eta$, $\phi$) cell
find the total energy deposited by the particles with same \((\eta, \varphi)\) cell

check if \(E_{\text{deposited}} > E_{\text{threshold}}\)
particles → calorimeter cells → 4vectors

check if $E_{\text{deposited}} > E_{\text{threshold}}$

find the total energy deposited by the particles with same $(\eta, \varphi)$ cell

construct massless four-vectors with $(E_{\text{deposited}}, \eta, \varphi)$
4vectors -> objects

make anti-kT jets of size 0.4 with em cells

$p_T > p_T^{\text{min}} \& \text{hcal energy/em-jet energy} < 0.1$

charge track inside the em-jet

- yes
  - isolated electron
- No
  - isolated photon

add the constituents of em-jet to the list of hcal four vectors

- make anti-kT jets with $R = 0.7$
**di-tau jets vs. qcd jets**

- **di-tau jets**: jets from gg -> h -> a a -> (ττ) (ττ) events
- **qcd jets**: jets from dijet events

Jets were made with $p_T^{\text{min}} > 30, 50, 100$ GeV
di-tau jets vs. qcd jets

conventional calorimeter based tau-taggers are not that useful in tagging di-tau jets

\[
R_{\text{em}}^j = \frac{\sum_\alpha p_{T,\alpha} \Delta R(\alpha, j)}{\sum_\alpha p_{T,\alpha}}
\]

\[
E_{\text{iso}}^j = \frac{\sum_{r_1 \leq \Delta R(\alpha, j) \leq r_2} p_{T,\alpha}}{\sum_\alpha p_{T,\alpha}}
\]
**di-tau jets vs. qcd jets**

Information from tracker still helps

Note the 2 prong structure

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Saturday, April 7, 2012
di-tau jets vs. qcd jets

NSubjettiness can be useful

\[ \tau_N = \frac{\sum_k p_{T,k} \min (\Delta R(1,k), \ldots, \Delta R(N,k))}{\sum_j p_{T,j} R} \]

**di-tau jets vs. qcd jets**

NSubjettiness can be useful
di-tau jets vs. qcd jets

Simple cut helps a lot
Higgs with di-tau jets
Higgs with di-tau jets

- two leptons that reconstruct a Z
- two jets with at least one passing di-tau selection cut.
- missing energy
DITAU TAGGING

Cuts and efficiencies

<table>
<thead>
<tr>
<th>Condition</th>
<th>ditaus</th>
<th>ZZj</th>
<th>WZj</th>
<th>WWj</th>
<th>t\bar{t}</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_\ell = 2 ), ( Z ) mass reconstruction with ( e^+e^- ) or ( \mu^+\mu^- )</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>( \max(p_T^\ell, p_T^{\ell'}) \geq 80 \text{ GeV}, p_T^Z \geq 150 \text{ GeV} )</td>
<td>0.416</td>
<td>0.217</td>
<td>0.130</td>
<td>0.011</td>
<td>0.026</td>
</tr>
<tr>
<td>( n_j \geq 2 ) with ( p_T^j \geq 30 \text{ GeV}, \Delta R(j_{50}, Z) \leq 1.5 )</td>
<td>0.216</td>
<td>0.048</td>
<td>0.035</td>
<td>0.00019</td>
<td>3.9 \times 10^{-4}</td>
</tr>
<tr>
<td>( p_T \geq 50 \text{ GeV},</td>
<td>\Delta\phi(p, Z)</td>
<td>\geq 2 )</td>
<td>0.199</td>
<td>0.0402</td>
<td>0.029</td>
</tr>
<tr>
<td>( \tau_3/\tau_1</td>
<td>_{\text{ecal}} \leq 0.5 ) (leading jet)</td>
<td>0.172</td>
<td>0.033</td>
<td>0.021</td>
<td>0.00015</td>
</tr>
<tr>
<td>( p_T^j/m_j \geq 7 ) (leading jet)</td>
<td>0.125</td>
<td>0.011</td>
<td>0.0084</td>
<td>5.4 \times 10^{-5}</td>
<td>2.1 \times 10^{-5}</td>
</tr>
<tr>
<td>cross section [fb]</td>
<td>0.083</td>
<td>0.0018</td>
<td>0.0020</td>
<td>3.0 \times 10^{-6}</td>
<td>7.2 \times 10^{-6}</td>
</tr>
<tr>
<td></td>
<td>1.32</td>
<td>0.45</td>
<td>1.83</td>
<td>0.18</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Higgs with di-tau jets

\[ m_T^{\text{cluster}}(j_1j_2) < 160 \text{ GeV} \]

\[ \sigma(\text{signal}) = 0.50 \text{ fb} \]

\[ \sigma(\text{background}) = 0.12 \text{ fb} \]

\[ S/\sqrt{B} \gtrsim 5 \]

\[ \mathcal{L} = 12 \text{ fb}^{-1} \]

\[ [m_T^{\text{cluster}}(j_1j_2)]^2 = \left( \sqrt{m^2(j_1j_2) + p_T^2(j_1j_2) + |\slashed{p}_T|} \right)^2 \]

\[ - \left( p_T(j_1j_2) + \slashed{p}_T \right)^2. \]
combine observables to a likelihood

\[ L = f(\tau_3/\tau_1|_{\text{ecal}}) \times f(p_T^j/m_j) \times f(\text{charged tracks}) \]

d > 0.7 gives tagging efficiency of 66\%(58\%) for mistagging probability of 7\%(6\%)
photon jet tagger
photon jet tagger

but before anything else - one slide about how Jakub destroyed my detector
photon jet tagger

my nice em-cal

Jakub’s crazy em-cal
photon jet tagger

the usual suspects
Photon jet tagger

NSubjettiness

![NSubjettiness distribution for photon jets and QCD jets](image-url)
photon jet tagger

Analysis with 3/5 exclusive subjets
photon jet tagger

TMVA response for classifier: Fisher

BDTD response
photon jet tagger
photon jet tagger
Higgs as a di-diphoton-jet resonance