AEACuS
Algorithmic Event Arbiter and Cut Selector

A Universal Meta Language for the Specification of Event Selection Cuts (and a general software tool for their implementation)

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With: Jesse Cantu, William Ellsworth
"Then spake Zeus: ... ‘The cases are now indeed judged ill and it is because ... many ... who have wicked souls are clad in fair bodies and ancestry and wealth, and ... the judges are confounded ..., having their own soul muffled in the veil of eyes and ears and the whole body. ... They must be stripped bare of all those things ..., beholding with very soul the very soul of each immediately. ... [I] have appointed sons of my own to be judges; two from Asia, Minos and Rhadamanthus, and one from Europe, Aeacus. These ... shall give judgement in the meadow at the dividing of the road, whence are the two ways leading, one to the Isles of the Blest ..., and the other to Tartaros.’

– Plato, Gorgias (trans. Lamb)
Motivations

AEACuS: The Software Tool

❖ Automate model comparison against LHC data
❖ Replicate most current search strategies for new physics
❖ Link to MadGraph/Event - Pythia - PGS/Delphes chain
❖ Embody lightweight, consumer-level, standalone design
Functionality

AEACuS: The Software Tool

- Reads from standardized LHCO format input
- Filters kinematics, geometry, isolation, charge & flavor
- Dilepton pair assembly (by like/unlike charge & flavor)
- Jet clustering (KT, C/A, Anti-KT) & Hemispheres (Lund, etc.)
- Missing $E_T$, scalar $H_T$, effective & invariant mass, ratios & products
- Transverse mass, 1- & 2-step asymmetric $M_{T2}$ (with combinatorics), Tri-jet mass, $\alpha_T$, Razor & $\alpha_R$, Dilepton Z-balance, Lepton W-projection, $\Delta\phi$ (& biased $\Delta\phi^*$), Shape Variables (thrust & minor, sphericity, F)
Motivations

AEACuS: The Meta Control Language

❖ Decouple specific usage from general functionality
❖ Render event cut strategies compactly & unambiguously
❖ Merge power & flexibility with uniformity & simplicity
❖ Decouple phenomenology from software maintenance
Event Selection Case Study

ATLAS: 3 Jets & 1 Lepton (CONF 2012.041)

```plaintext
1  ***** cut_card.dat 3.0 *****
2  * ATLAS Jets and Lepton (3J1L)
3  * ATLAS-CONF-2012-041
4  *** Object Reconstruction ***
5  OBJ_ALL = PRM:[0.0,4.9]
6  OBJ_ELE = PTM:10, PRM:[0.0,2.47]
7  OBJ_MUO = PTM:10, PRM:[0.0,2.4]
8  OBJ_LEP_001 = SRC:+000, EMT:+1, PTM:25
9  OBJ_LEP_002 = SRC:+000, EMT:+2, PTM:20
10 OBJ_JET_002 = SRC:+000, CMP:+001, PTM:20, PRM:[0.0,4.5], CDR:0.2
11 OBJ_LEP_003 = SRC:[+001,+002], CMP:+002, CDR:0.4, CUT:[1,1]
12 OBJ_JET_003 = SRC:+002, PTM:25, PRM:[0.0,2.5], CUT:3
13 OBJ_LEP_004 = SRC:[+000,-003], EMT:-3, CUT:[0,0]
14 OBJ_JET_004 = SRC:+003, CUT:[3,UNDEF,-1]
15 OBJ_JET_005 = SRC:+003, PTM:80, CUT:[0,3]
16 OBJ_JET_006 = SRC:+005, PTM:100, CUT:1
17  ***** Event Selection *****
18  EVT_MET = CUT:250
19  EVT_MHT_001 = LEP:003, JET:004
20  EVT_MEF_001 = MET:000, MHT:001
21  EVT_REF_001 = NUM:000, DEN:001, CUT:0.3
22  EVT_LTM_001 = LEP:003, MET:000, CUT:100
23  EVT_MHT_002 = LEP:003, JET:003
24  EVT_MEF_002 = MET:000, MHT:002, CUT:1200
25  ***********************
```
Event Selection Case Study

ATLAS: 3 Jets & 1 Lepton (CONF 2012.041)

- 5: Enforce pseudorapidity ($\eta < 4.9$) on all objects
- 6,7: Clip electron and muon transverse momentum ($P_T > 10$ GeV) & $\eta$
- 8,9: Define a harder $P_T$ variant of the $e, \mu$ populations

```
1 ***** cut_card.dat 3.0 ****
2 * ATLAS Jets and Lepton (3J1L)
3 * ATLAS-CONF-2012-041
4 *** Object Reconstruction ***
5 OBJ_ALL = PRM:[0.0,4.9]
6 OBJ_ELE = PTM:10, PRM:[0.0,2.47]
7 OBJ_MUO = PTM:10, PRM:[0.0,2.4]
8 OBJ_LEP_001 = SRC:+000, EMT:+1, PTM:25
9 OBJ_LEP_002 = SRC:+000, EMT:+2, PTM:20
10 OBJ_JET_002 = SRC:+000, CMP:+001, PTM:20, PRM:[0.0,4.5], CDR:0.2
```
Event Selection Case Study

ATLAS: 3 Jets & 1 Lepton (CONF 2012.041)

• 10: Limit jet $P_T$ & $\eta$, enforcing isolation ($\Delta R_{lep} > 0.2$) from leptons
• 11: Rejoin $e/\mu$ forks & demand exactly one isolated ($\Delta R_{jet} > 0.4$) object
• 12: Source harder, central jet group “003” with at least three objects

<table>
<thead>
<tr>
<th>Event ID</th>
<th>Source</th>
<th>EMT</th>
<th>PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>OBJ_LEP_002 = SRC:+000, EMT:+2, PTM:20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>OBJ_JET_002 = SRC:+000, CMP:+001, PTM:20, PRM:[0.0,4.5], CDR:0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>OBJ_LEP_003 = SRC:[+001,+002], CMP:+002, CDR:0.4, CUT:[1,1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>OBJ_JET_003 = SRC:+002, PTM:25, PRM:[0.0,2.5], CUT:3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>OBJ_LEP_004 = SRC:[+000,-003], EMT:-3, CUT:[0,0]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>OBJ_JET_004 = SRC:+003, CUT:[3,UNDEF,-1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>OBJ_JET_005 = SRC:+003, PTM:80, CUT:[0,3]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>OBJ_JET_006 = SRC:+005, PTM:100, CUT:1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• 13: Reject events with soft (non tau) leptons (those not in group “003”)
• 14: Source a new grouping “004” of only the three hardest jets
• 15: Reject events with more than three hard jets ($P_T > 80$ GeV)
• 16: Demand at least one hard jet with ($P_T > 100$ GeV)
Event Selection Case Study

ATLAS: 3 Jets & 1 Lepton (CONF 2012.041)

• 18: Cut on inclusive missing $E_T < 250$ GeV
• 19: Source scalar $H_T$ from lepton plus three group “004” jets
• 20: Source effective mass $M_{\text{EFF}}$ from inclusive missing $E_T$ & 3J+L $H_T$
• 21: Cut on ratio of missing $E_T$ to $M_{\text{EFF}} < 0.3$
• 22: Cut transverse mass of lepton & missing $E_T$ below 100 GeV
• 23: Source inclusive scalar $H_T$ from lepton plus all group “003” jets
• 24: Source inclusive effective mass $M_{\text{EFF}}$ & cut below 1200 GeV

17  ***** Event Selection  ******
18  EVT_MET = CUT:250
19  EVT_MHT_001 = LEP:003, JET:004
20  EVT_MEF_001 = MET:000, MHT:001
21  EVT_REF_001 = NUM:000, DEN:001, CUT:0.3
22  EVT_LTM_001 = LEP:003, MET:000, CUT:100
23  EVT_MHT_002 = LEP:003, JET:003
24  EVT_MEF_002 = MET:000, MHT:002, CUT:1200
25  ************************************
Event Selection Case Study

CMS: Razor ELE Box SR6 (PAS-SUS 2012.005)

```plaintext
1  ***** cut_card.dat 3.0 *****
2  * CMS Razor ELE Box (SR6)
3  * CMS PAS SUS-12-005
4  *** Object Reconstruction ***
5  OBJ_ELE = PRM:[1.566,1.422]
6  OBJ_MUO = PRM:[0.0,2.4]
7  OBJ_LEP = EMT:-3, PTM:10, PRM:[0.0,2.5]
8  OBJ_JET = PTM:60, PRM:[0.0,3.0]
9  OBJ_LEP_001 = SRC:+000, EMT:+1
10 OBJ_LEP_002 = SRC:+000, EMT:+2
11 OBJ_LEP_003 = SRC:+002, ETR:[0.00,0.27], PRM:[0.0,2.1]
12  # OBJ_LEP_004 = SRC:+003, PTM:12, CUT:[0,0]
13  # OBJ_LEP_005 = SRC:+001, PTM:20, CUT:[0,0], ANY:004
14  OBJ_LEP_006 = SRC:+003, CUT:[0,0]
15  OBJ_LEP_007 = SRC:+002, PTM:15, CUT:[0,0]
16  OBJ_LEP_008 = SRC:+002, CUT:[0,1], ANY:[006,007]
17  # OBJ_LEP_009 = SRC:+001, PTM:20, CUT:[0,0]
18  OBJ_LEP_010 = SRC:+001, CUT:[0,1], ANY:009
19  OBJ_LEP_011 = SRC:+003, PTM:12, CUT:[0,0]
20  OBJ_LEP_012 = SRC:+001, PTM:20, CUT:1
21  ***** Event Selection ******
22  EVT_JRM_001 = LEP:000, JET:000, CUT:[450,1000]
23  EVT_ALR_001 = LEP:000, JET:000, MET:000, CUT:[0.30,0.50]
24  ****************************************
```
AEACuS
Algorithmic Event Arbiter and Cut Selector

- The software version 3.2 may be downloaded now!
  http://joelwalker.net/code/aeacus.tar.gz
- The meta control language is documented in arXiv:1207.3383
  (to appear in Comp. Phys. Comm D, pending revision)
The AEACuS meta language is an ideal mechanism for large experiments (CMS/ATLAS) & small phenomenology groups to unambiguously propagate an approximate rendering of internal event selection strategies.

The AEACuS software tool is an ideal agent for the rapid and uniform projection of sophisticated event cut workflows onto new physics models.
RHADAManTHUS?

Relational Heuristic Analysis, Display, And Manipulation: The Histogram Utility Suite

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