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)**

Joel W. Walker

Sam Houston State University

KITP Particlegenesis Workshop 2014

With: Jesse Cantu, William Ellsworth

AEACuS

Algorithmic Event Arbiter and Cut Selector

> " 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)

AEACuS

"You should have gone with Rhadamanthus"

cestry and wealth,
founded …, having
the veil of eyes and
… They must be stri[p]
…, beholding with
each immediately. …
my own to be judge[s]
Rhadamanthus, and
These … shall give
at the dividing of th[e]
ways leading, one to
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

- ❖ 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, α_T, Razor & α_R, Dilepton Z-balance, Lepton W-projection, $\Delta\phi$ (& biased $\Delta\phi^*$), Shape Variables (thrust & minor, spheri[o]city, F)
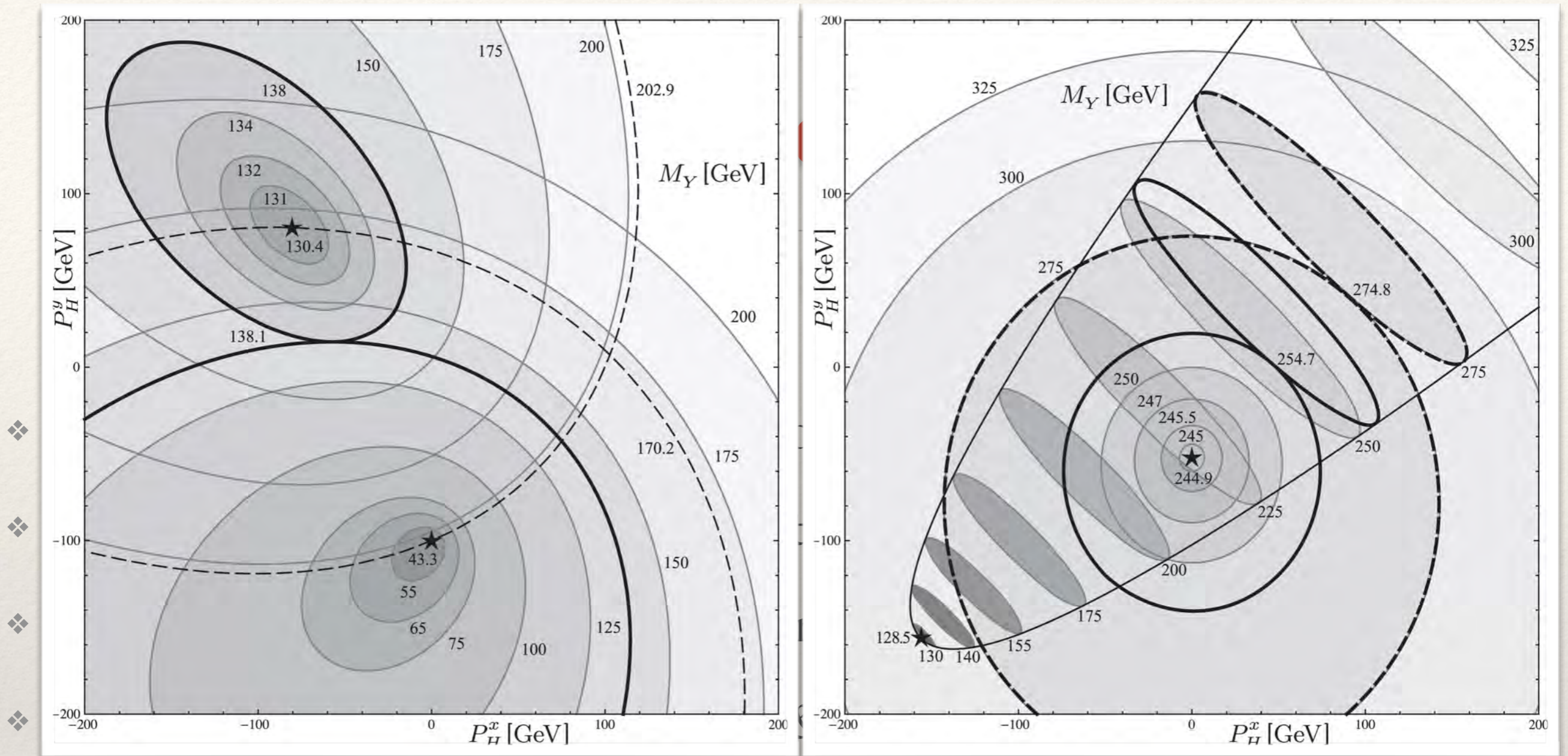
- Missing E_T, scalar H_T, effective & invariant mass, ratios & products

- Transverse mass, 1- & 2-step asymmetric M_{T2} (with combinatorics), Tri-jet mass, α_T, Razor & α_R, Dilepton Z-balance, Lepton W-projection, $\Delta\phi$ (& biased $\Delta\phi^*$), Shape Variables (thrust & minor, spheri[o]city, F)

Functionality
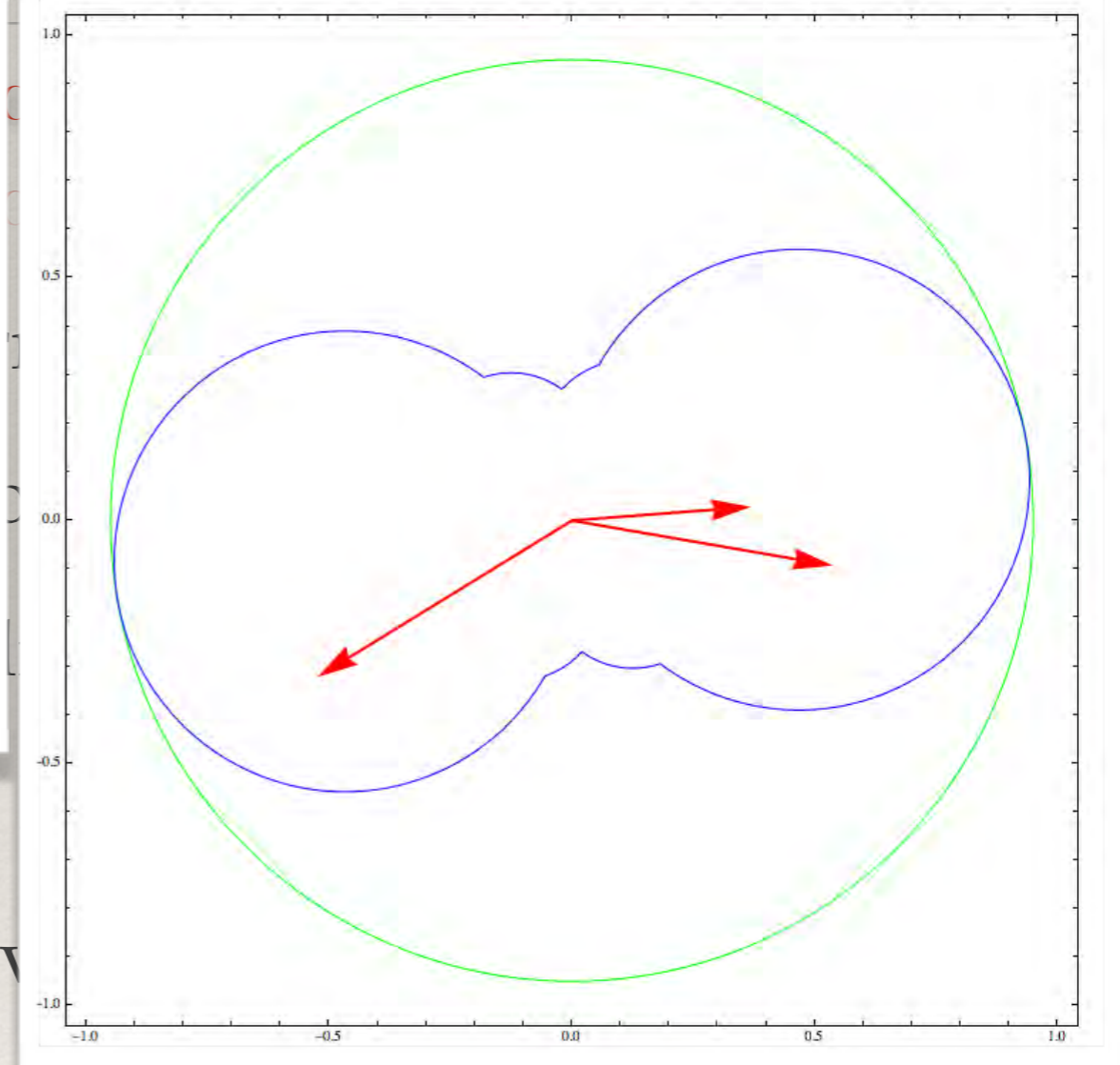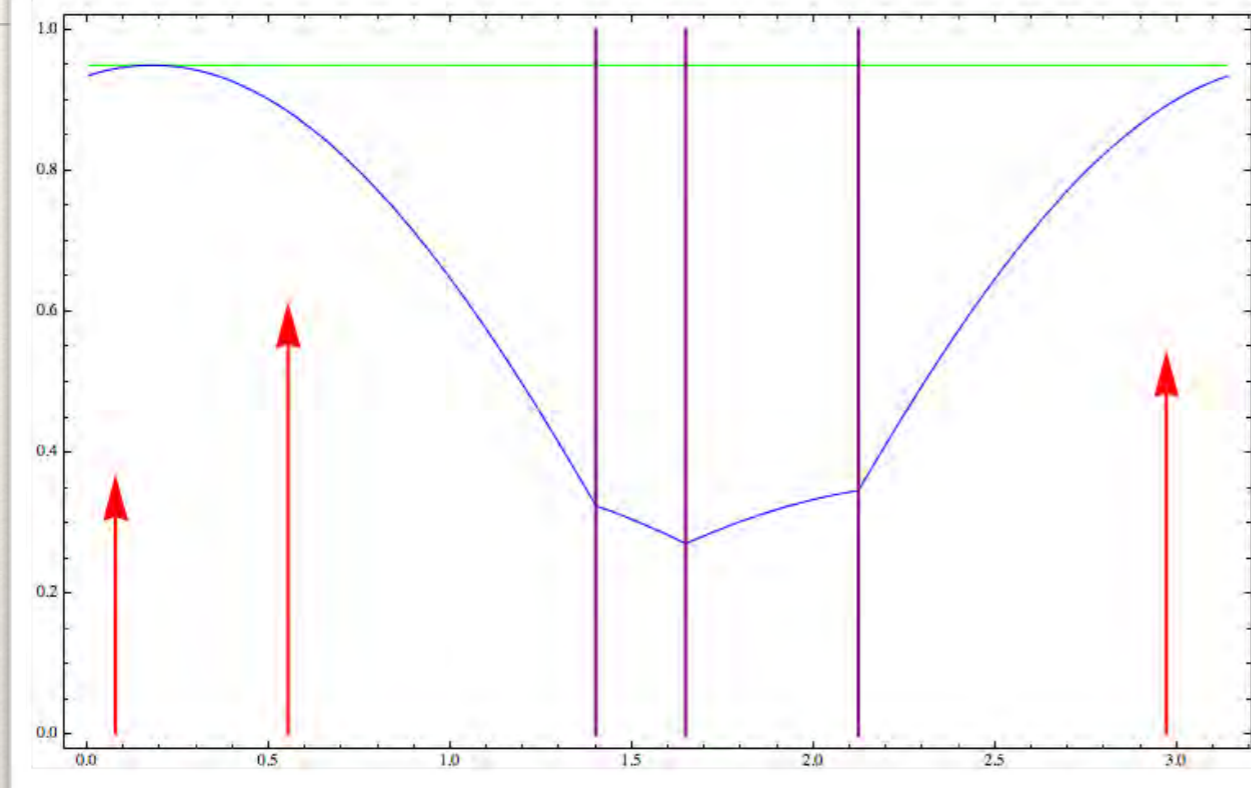
* Jet clustering (KT, C/A, Anti-KT) &

* Missing E_T, scalar H_T, effective & inv

* Transverse mass, 1- & 2-step asymmetric M_{T2} (with combinatorics), Tri-jet mass, α_T, Razor & α_R, Dilepton Z-balance, Lepton W-projection, $\Delta\phi$ (& biased $\Delta\phi^*$), Shape Variables (thrust & minor, spheri[o]city, 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)

```
 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)

```
 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
```

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

```
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)

- 10: Limit jet P_T & η, enforcing isolation ($\Delta R_{LEP} > 0.2$) from leptons
- 11: Rejoin e/μ forks & demand exactly one isolated ($\Delta R_{JET} > 0.4$) object
- 12: Source harder, central jet group "003" with at least three objects

```
 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 *******
```

- 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_{EFF} from inclusive missing E_T & 3J+L H_T**

- **21: Cut on ratio of missing E_T to M_{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_{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)

```
 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

  (expected to appear in Comp. Phys. Comm. D post revision)

Final Thoughts

Rethinking the Communication & Automation of Event Selection

* 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

* Future development may focus on:
  i) recursively cascaded event sub-selection
  ii) display, analysis, and manipulation of compound user-defined event heuristics
  iii) automated card-based histogram generation (integrate with MadAnalysis 5?)

RHADAManTHUS ?

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

- Heuristic *adjective* \hyü-'ris-tik\ (www.merriam-webster.com)

  : using experience to learn and improve :

  involving or serving as an aid to learning, discovery, or problem-solving by experimental and especially trial-and-error methods <*heuristic* techniques> <a *heuristic* assumption>; *also* :
  of or relating to exploratory problem-solving techniques that utilize self-educating techniques (as the evaluation of feedback) to improve performance <a *heuristic* computer program>

- Stay Tuned …