Searching for Supersymmetric Top Quarks at the LHC

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Why are we doing this?

- LHC: Higgs mass in 125 GeV region
- Standard model: higher loop corrections to Higgs mass diverge quadratically
  - "Fine-tuning problem"
- Subtracting two very large numbers
  - Another way?

Supersymmetry (SUSY)

- Main idea: Fermion-boson pairs with same mass, quantum numbers (except spin)
  - Partner for boson: -ino
  - Partner for fermion: s-
- Higher loops cancel partially
  - Logarithmic divergence instead of quadratic
- Interesting note: supersymmetry came from string theory
  - Stands on its own as an idea

Using SUSY

- If supersymmetric partner for top quark exists, higher-order corrections cancel
- Feasibility
  - Can only cover some of the parameter space at the current energy level
  - Gluinos and heavier stop quarks cannot be detected
- No supersymmetric particle has been discovered yet!
  - Searching in the dark
  - Not clear that you can ever rule out supersymmetry

The top squark

- Squark, stop quark = supersymmetric top quark
- Expected decay mode
  - $\tilde{t} \rightarrow t + \tilde{\chi}_1^0$
  - $\tilde{\chi}_1^0$ = lightest supersymmetric particle
- Goal: use machine learning to optimize the search for this particular decay mode

Proposed ML Techniques

- So far: SVMs, LDA, kernel methods
  - Not particularly successful
- Boosted decision trees
  - Solution to classification problem: selecting important data from noise/background
  - Jets: representation of collision; each corresponding to a different final particle
  - Particularly good for Higgs searches among other CMS experiments
- Phenomenological data from Dutta et. al.
  - Proposed search mechanism for squarks
  - Test viability of these ML techniques

Sorting through the noise

- PGS4
  - Translating data from PYTHIA to objects and jets
  - Creates objects by simulating the detector
- M3
  - Separating top-top events from background
  - Pick 3 jets with largest vectorially summed transverse momentum, compute invariant mass
  - Most effective with 4+ jets; data has 6
- Transverse energy analysis
  - Separating QCD events
  - Most effective with 3 jets
  - Data is grouped into two systems

What We've Done So Far

- Received phenomenological data from Dutta et. al. (Texas A&M)
- Used PYTHIA and ROOT to do basic data analysis on particle collisions
- Isolated jets and observed energy distribution

Current Task

Trying to separate the signal into two top quark systems.

- 2 bjj combinations with two largest P_T
  - $t \to b + W \to b + 2j$
- Calculate M3 for both
- Calculate M2 for both (due to jets only)
- Combined chi-squared test
  - M3 for top quark, M2 for W boson
- Better combination = top quark A; rest = top quark B

Potential

If this project succeeds we can:

- Strongly suggest the evidence of a supersymmetric particle
- Detect it **now** within the current parameter space
- Provide a possible partial solution to the fine-tuning problem in the Higgs context

References

- DOI:10.1103/PhysRevD.86.075004
  - Proposed search mechanism by Dutta et. al.
  - arXiv:1207.1873 [hep-ex]
- arXiv:1106.0902 [hep-ex]
  - Describes M3 approach to isolating top-top events
- DOI:10.1103/PhysRevD.81.114027
  - Instance of using PGS4 to process data
  - arxiv:1002.3366 [hep-ph]
- Boosted Decision Trees as Event Classifiers

Questions?