Searching for Ultra Rare Processes With the Large Hadron Collider

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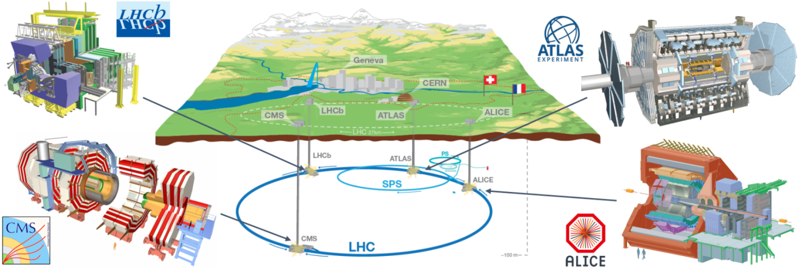
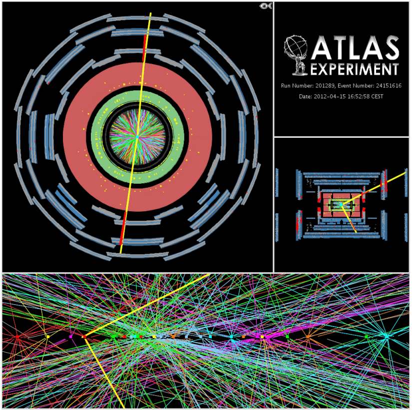
Overview

The Large Hadron Collider



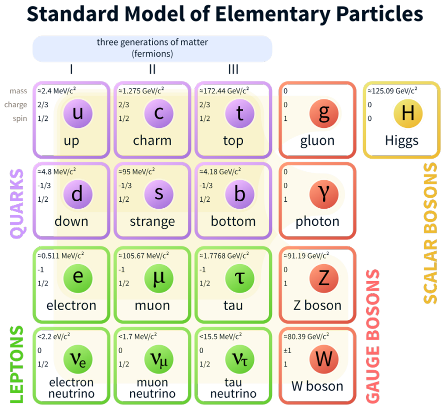
- 27km ring beneath Franco-Swiss Border
- 4 Major Experiments
- Collides protons at center of mass energy 13TeV
- Over 10 Quadrillion (10^{15}) events produced within the ATLAS detector so far

Events in ATLAS



- LHC Provides around 600 million interactions/second
- Save compelling events
- Extremely large, messy data sets
- Detector well modeled for Monte Carlo event generation

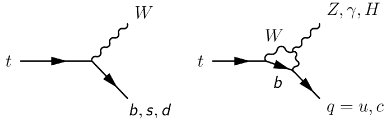
The Standard Model of Particle Physics



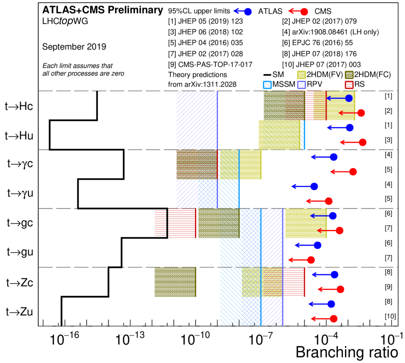
- Our current theory that attempts to explain everything
  - Experimentally precise and well behaved
  - Very few exceptions (i.e. Neutrino Mass, Dark Matter Abundance)

The Top Quark and Flavor Changing Neutral Currents

- Heaviest fundamental particle
- Lifetime 5×10^{-25}s
  - Allows study of single quark decay
- Top decays to bW essentially 100% of the time
- Expect $\approx 10^8$ top pair events



(a) (b)



Neural Networks

- Advanced pattern recognition used to classify events
- A dense neural network is used with various low and high level variable inputs
- Supervised learning used to approximate any multidimensional function

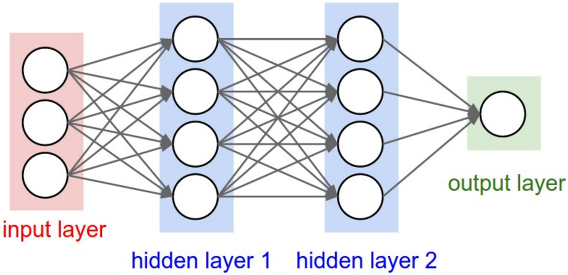
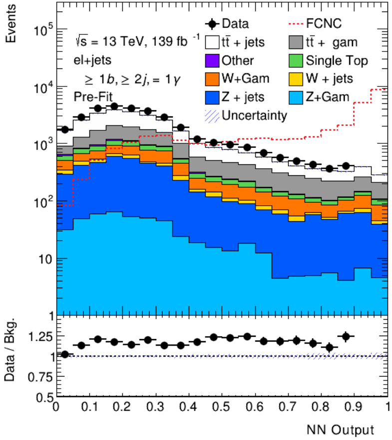


Figure: [Ref: Neural Network]

Neural Network Outputs

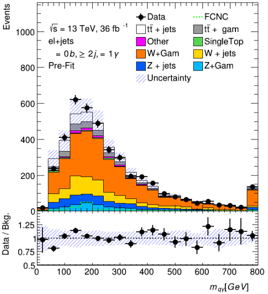


Monte Carlo isnt perfect - Use data driven backgrounds to compensate!

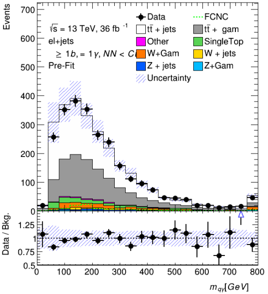
Work In Progress - Results

Regions to check background modeling behavior compared with data while not unblinding the signal region are used

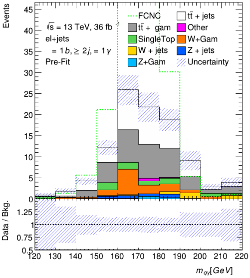
- Background Enriched Region 1



- Background Enriched Region 2



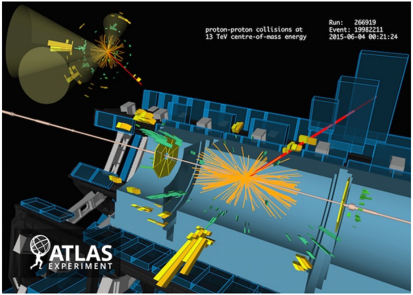
- Signal Enriched Region



Statistics only limit BR$(t \to q\gamma) \leq 4 \times 10^{-5}$

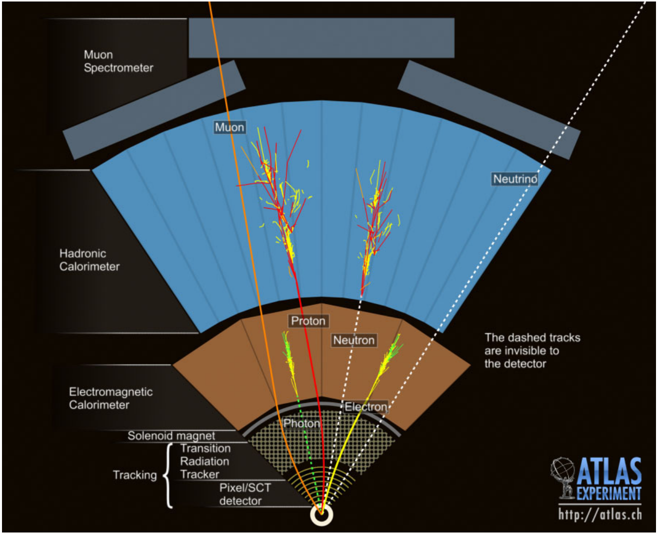
Conclusions

- I have created model independent signal samples to search for new physics with flavor changing neutral current decays in top pair events
- Developed and implemented a neural network for signal classification
- Currently working to ensure well modeled backgrounds and account for systematic errors
- After unblinding if I find any excess in signal data events it is a strong indication of physics beyond the Standard Model

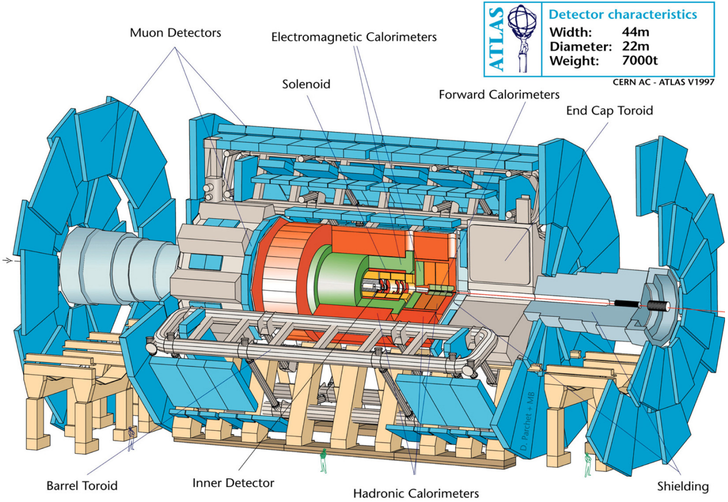


Backup

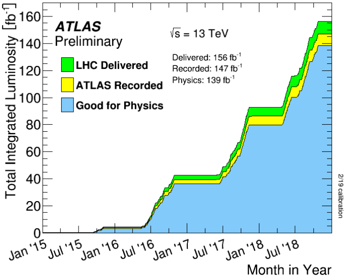
Particles in ATLAS

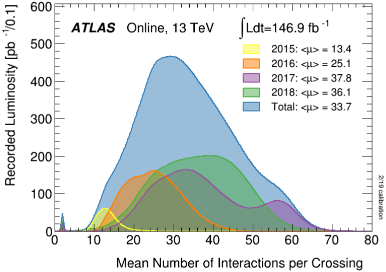


The ATLAS Detector

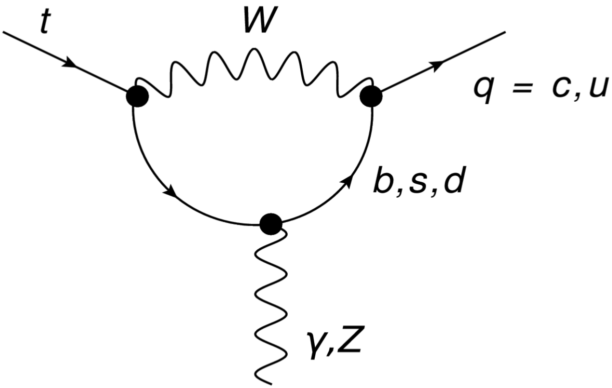


Luminosity and Pile-up





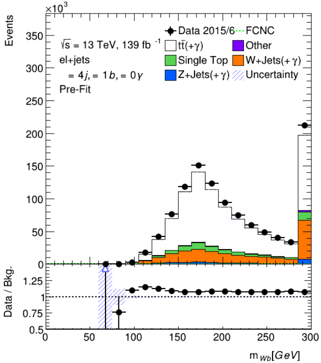
FCNC Diagrams



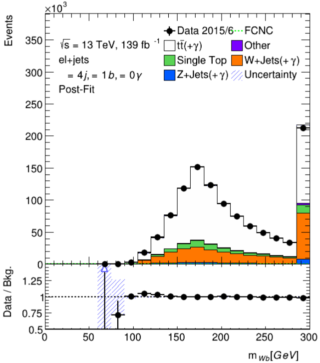
Data Driven Backgrounds

- Various physics processes are known to be poorly modeled, especially at the high energies and interaction rates of the LHC

Before Scaling



After Scaling



Neural Network Model Inputs

$$\text{Separation} = \sum_i^{bins} \frac{n_{si} - n_{bi}}{n_{si} + n_{bi}}$$

mu+jets channel

Variable	Separation
photon0iso	41.18
mqgam	28.27
photon0pt	24.07
mtSM	11.60
mlgam	7.56
deltaRjgam	5.64
deltaRbl	4.42
MWT	3.34
ST	3.30
nuchi2	3.12
jet0pt	2.81
njets	2.07
smchi2	1.89
wchi2	1.87
jet0e	1.52
deltaRlgam	1.17
leptone	0.87
deltaRjb	0.86
met	0.68
bjet0pt	0.52
leptoniso	0.27

e+jets channel

Variable	Separation
photon0pt	23.14
mqgam	22.73
photon0iso	18.70
mtSM	11.02
mlgam	9.53
deltaRbl	5.00
deltaRjgam	4.60
ST	3.83
MWT	3.16
jet0pt	2.47
njets	1.70
nuchi2	1.59
deltaRlgam	1.40
wchi2	1.33
smchi2	1.09
deltaRjb	0.88
leptone	0.85
leptoniso	0.56
bjet0pt	0.50
met	0.47