Thesis Outline

Title: Search for New Physics in final states with a Z Boson, Jets, and MET with 35.9 fb^{-1} of LHC data with sqrt(s) = 13 TeV.

Section 1 — Introduction

1. The standard model of particle physics
    1. The Std. Model has been used to predict all the phenomenology we've seen in particle colliders. It is built on QFT which has been proven to work in CM physics and Particle Physics. The latest prediction is the Higgs and it's couplings.
        1. Brief description of QFT (show Lagrangian, point out W/Z couplings)
        2. Show Feynman Rules for SM, give brief description of how they work.
    2. There are very fine numerical quantities which have been predicted by the (parts of) SM, in that sense, it is one of the best tested theories the world has ever known.
        1. Fine structure constant
        2. W/Z/Higgs prediction
        3. Higgs couplings w.r.t mass
    3. The standard model has some issues which shows it likely is not the final theory. To Wit: Dark Matter, Dark Energy, Neutrino Masses, and the gravitational interaction.
    4. Other oddities also exist: Why 3 generations? Hierarchy Problem/Naturalness?
2. SUSY as a solution
    1. "SUSY is a general enough theory that you can have any phenomenology" -FKW
    2. GUT coupling
    3. Brief description of Coleman-Mandula theorem
    4. R-parity for proton lifetime —> Take S.M. vertices and replace two legs with SUSY partners
    5. Electroweak scale SUSY, SUSY-breaking
3. Why the ZMET final state?
    1. The Electroweak sector was tested by LEP where electroweak bosons were first produced. At LEP cross sections for the decays of massive electroweak bosons were measured to great precision. Knowing these decay cross sections helps tremendously in setting limits for the production of new particles in simulation.
    2. All fermions have some chiral component which couples to the massive electroweak particles. This creates some precedent to believe that new particles should have some coupling.
    3. Various supersymmetry models predict that some supersymmetric particles will couple to the Z boson.
    4. It is a clean signature.
    5. CMS is excellent at detecting electrons and muons (henceforth 'light leptons') with high fidelity for their momentum and energy.
4. Past ZMET Results.

Section 2 — The Acquisition of Data

1. The LHC
    1. "The LHC is a large PP accelerator in Geneva," show stats about energy and luminosity.
    2. Show PP collision cross sections, point out production of Z boson.
2. The CMS Detector
    1. Short intro to CMS (size, fiducial area, general construction paradigm, magnetic field)

    2. Description of the tracking system
    3. Description ECAL
    4. Description of HCAL
    5. Event Triggering pipeline (L1 and HLT system)
3. Physics Objects
    1. Particle flow and jet clustering
    2. Vertex Selection
    3. B-tagging
    4. Electron measurement pipeline (how are tracks turned into momentum)
    5. Muon measurement pipeline
    6. Photon measurement pipeline
    7. Lepton selection and Isolation
    8. Isolated Tracks
    9. MET reconstruction
        1. Sources of MET
        2. Type 1 MET
    10. MET filters, beam halo, ect…
4. Monte Carlo

Section 3 — Search for New Physics in events with a Z Boson, MET, and jets.

1. Restate search motivation (outlined above in 1.2.2-1.2.4)
2. Analysis strategy
    1. Use leptonic decays on Z mass —> Reduce hadronic BGs
    2. Reduction of the DY background —> Jets+MET
    3. Breakdown of remaining backgrounds, TTBar and Z+ν
    4. Background Elimination Handles:
        1. TTBar has high number of jets —> split into high and low jet multiplicity
        2. MT2 helps reduce TTBar
        3. Low jet multiplicity selects DY —> ask for high HT (select for heavy crap at the primary vertex)
        4. Bin in MET as different signal models likely will have an excess in a particular MET bin.
        5. Btagging splits TTBar and Z+ν from Z+Jets.
3. Object and Event Selection
    1. Lepton Selection
        1. Trigger Requirements
        2. Lepton ID and Isolation requirements
    2. Search Regions
        1. Motivated by SUSY models
        2. Hadronic SUSY models targeted by HT binned regions
        3. EW SUSY models targeted by VZ and HZ regions
4. Background Estimation Methods and Uncertainties:
    1. The MET Templates method for fake MET
        1. Closure Test
        2. Electroweak Subtraction
            1. Closure in $\gamma\mu$ region
        3. Normalization to low MET region
    2. The Flavor Symmetric BGs
        1. Derivation of RSFOF

3. Z+ν
    1. Samples considered
    2. Closure tests in 4L (ZZ) and 3L (TTZ/WZ) regions
5. Results
    1. Show Signal Region results tables and plots
    2. No significant excesses
6. Signal Interpretations
    1. Breakdown of Uncertainties
    2. Temperature plots, “limits up by X GeV” for Y model
7. Electroweak Combination Results

Section 4 — Conclusions

1. Standard model continues to pass all tests
2. Outlook for future searches in leptonic final states, higgs physics, electroweak searches (maybe hint at WWW here?)
3. The state of SUSY