ABSTRACT

SEARCH FOR CHARGED HIGGS BOSONS IN THE $\tau + \ell$ FINAL STATE WITH 36.1 fb^{-1}OF pp COLLISION DATA AT $\sqrt{s} = 13$ WITH THE ATLAS EXPERIMENT

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This dissertation uses 139 fb^{-1}of ppcollision data collected at a center of mass energy of $\sqrt{s} = 13$ by the ATLAS detector to search for charged Higgs bosons decaying to a tau lepton and a neutrino ($H^{\pm} \to \tau^{\pm}\nu_{\tau}$) in association with a leptonically decaying top quark. No significant excess was found, therefore limits are set at the 95% confidence level on the charged Higgs production cross section times the branching fraction into the $\tau^{\pm}\nu_{\tau}$ranging from XX pb to XX fb. These limits are interpreted in the hMSSM benchmark scenario as an exclusion at 95% confidence on tanas a function of $m_{H^{\pm}}$. In this scenario, for $tan = 60$, the $H^{\pm}$mass range up to $XXXXGeV$ is excluded, with all values of tanexcluded for $m_{H^{\pm}} \leq XXXGeV$

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DEDICATION

To Dr. Dhiman Chakraborty. Thank you for everything.

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THEORY

In this chapter, the theoretical motivation of a search for $H^\pm \to \tau^\pm\nu_\tau$is described. Firstly, a review of the Standard Model of particle physics (SM) is laid out, then a brief overview of Supersymmetry focusing on the Minimal Supersymmetric Standard Model (MSSM). Finally, the Type II 2-Higgs Doublet Model's (2HDM) relation to the $H^\pm$production cross section and subsequent branching ratio into SM particles is described as motivation for the choice of studying $H^\pm \to \tau^\pm\nu_\tau$.

2.1 The Standard Model

The Standard Model of particle physics is a quantum field theory that describes all known matter and forces. The Standard Model is built upon a gauge group of type $SU(3)_C \times SU(2)_L \times U(1)_Y$. The $SU(3)_C$ term dictates the strong interaction while the $SU(2)_L \times U(1)_Y$ term describes the electroweak interaction. These interactions occur between fundamental particles called fermions that comprise the known matter of the universe. The interactions, or forces, are mediated by fundamental particles called bosons.

2.1.1 Particles

The particles that make up the Standard Model are separated into two groups according to their intrinsic angular momentum charge, or spin. Fermions are those that carry half-integer spin while Bosons carry full integer spin values.

2.1.1.1 Fermions

The matter we encounter in everyday life is comprised of fermions that obey Fermi-Dirac statistics. Fermions are subdivided into two groups, quarks and leptons. The quarks participate in the strong interaction via their color charge. Quarks cannot exist as a singular particle and thus combine into hadrons in a process called hadronization; the bound states they form are colorless. Leptons carry no color charge and therefore do not participate in strong force interactions. The fermions in the standard model all participate in the electroweak interaction. However, the electromagnetic interaction is limited to those fermions that carry an electromagnetic charge.

Fermions can then be further divided into three generations, each lepton has an electrically neutral weak force partner in the form of a neutrino. Table 2.1 lists all the SM fermions and their properties.

Check these numbers with current PDG

Table 2.1: Standard Model fermions and their properties [1]

	1^{st} Generation	2^{nd} Generation	3^{rd} Generation	Spin	EM Charge	Color	Mass
Quarks	Up (u)	Charm (c)	Top (t)	$\frac{1}{2}$	$+\frac{2}{3}$	✓	$m_u = 2.3^{+0.7}_{-0.5}$ MeV $m_c = 1.275 \pm 0.025$ M $m_t = 173.2 \pm 0.7$ Ge
	Down (d)	Strange (s)	Bottom (b)	$\frac{1}{2}$	$-\frac{1}{3}$	✓	$m_d = 4.8^{+0.5}_{-0.3}$ MeV $m_s = 95 \pm 5$ MeV $m_b = 4.18 \pm 0.03$ Ge
Leptons	Electron (e^-)	Muon (μ^-)	Tau (τ^-)	$\frac{1}{2}$	-1	X	$m_{e^-} = 511$ keV $m_{\mu^-} = 105.7$ MeV $m_{\tau^-} = 1.8$ GeV
	Electron Neutrino (ν_e)	Muon Neutrino (ν_μ)	Tau Neutrino (ν_τ)	$\frac{1}{2}$	0	X	$m_{\nu_e} < 1.1$ eV $m_{\nu_\mu} < 0.19$ MeV $m_{\nu_\tau} < 18.2$ MeV

2.1.1.2 Bosons

Bosons are colloquially referred to as force-carriers in that the fundamental forces act via an exchanging gauge bosons. This means that each force has an associated boson which is described by a field theory, which has a set scale on which it operates.

Table 2.2: Standard Model bosons and their properties [1]

Field Theory	Boson	Spin	EM Charge	Color	Mass
Quantum Chromodynamics	Gluon (g)	1	0	✓	0
ElectroWeak Theory	Photon (γ)	1	0	X	$< 1 \text{x} 10^{-18}$ eV
	$W^{\pm}$	1	± 1	X	80.377 ± 0.012 GeV
	Z	1	0	X	91.1876 ± 0.0021 GeV

2.1.2 Interactions

At its core, the SM relies upon symmetries. From these symmetries, conservation laws follow. It is these laws of conservation, and the breaking of said symmetries, that dictate the allowed interactions of matter. The first, being a symmetry under charge conjugation, mirror reflection, and time reversal is known as CPT symmetry. The symmetry between charge conjugation and mirror reflection (CP) can be broken in certain circumstances, but holds in strong and electromagnetic interactions. This breaking of CP symmetry occurs in the weak interaction and implies a non-symmetry between matter and antimatter. Since this symmetry holds for strong and electromagnetic interactions, baryon number ($B = \frac{1}{3}(n_q - n_{\bar{q}})$) and lepton number are conserved in SM interactions. Lepton generation number [1], electric charge, color charge, 4-momentum ($p = (E, \vec{p})$), and angular momentum are all conserved in the SM.

2.1.2.1 Electromagnetic Interaction

NEEDS TO BE DONE

2.1.2.2 Weak Interaction

NEEDS TO BE DONE

[1] Ignoring neutrino oscillations

2.1.2.3 Strong Interaction

NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

2.2.2 R-Parity

NEEDS TO BE DONE

2.2.3 The MSSM Higgs Sector

NEEDS TO BE DONE

2.3 Charged Higgs Bosons

NEEDS TO BE DONE

2.3.1 Previous Result

NEEDS TO BE DONE

CHAPTER 3

THE LHC AND ATLAS EXPERIMENT

3.1 The Large Hadron Collider

In order to study the Standard Model,the Higgs boson, and hints of new physics, the Large Hadron Collider (LHC) was built outside of Geneva, Switzerland. At 27 km in circumference with a center of mass energy of 13.6 TeV, the LHC is the largest and highest energy particle accelerator ever built. It consists of NUM SECTORS magnet sectors split between dipole and quadrupole magnets.

3.2 The ATLAS Detector

NEEDS TO BE DONE [2]

3.2.1 Inner Detector

NEEDS TO BE DONE

3.2.1.1 Pixel

NEEDS TO BE DONE

3.2.1.2 Semiconductor Tracker

NEEDS TO BE DONE

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NEEDS TO BE DONE

3.2.2 Calorimeters

NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

3.2.3.4 Thin Gap Chambers

NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

5.2 Datasets

NEEDS TO BE DONE

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NEEDS TO BE DONE

5.3 Background Modeling

NEEDS TO BE DONE

5.4 Analysis Strategy

NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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NEEDS TO BE DONE

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