



Northern Illinois
University

Search for Charged Higgs Bosons in the $\tau + \ell$ Final State with 139 fb^{-1} of pp Collision Data at $\sqrt{s} = 13\text{ TeV}$ with the ATLAS Experiment

Dissertation Defense

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Introduction

Theory

The Standard Model

Higgs Mechanism

Supersymmetry

Charged Higgs Bosons

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LHC

The ATLAS Detector

Simulation

Event Reconstruction

$$H^\pm \rightarrow \tau^\pm \nu_\tau$$

Signature

Event Selection

Datasets

Background Modeling

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Conclusion

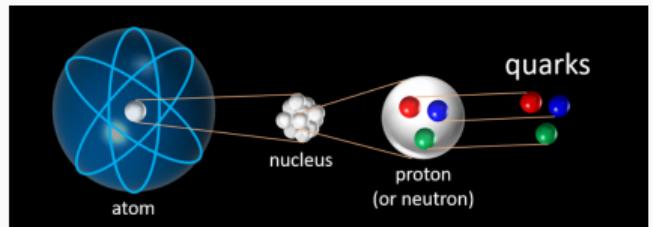
Introduction

- This defense will take ~ 1 hour
 - I will walk you through the work that is contained in my PhD dissertation
 - After the presentation is complete, the committee and I will address comments privately
 - When we are done, I will return, the committee will discuss among themselves then return
- General Guidelines
 - Please remain muted unless you are speaking
 - There will be time at the end for questions, but feel free to interrupt if there is something urgent
- Thank you for attending!

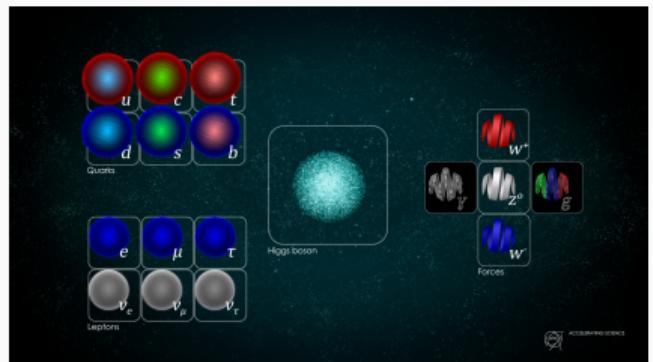
Theory

What are we made of?

- The scientific field of particle physics seeks to explain the building blocks of the universe
 - How many fundamental particles are there?
 - How do they interact with each other
- The Standard Model of Particle Physics (SM)
 - Matter is comprised of fermions
 - Half-integer spin ($s = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, etc.)
 - Anti-matter is identical to matter except for opposite electromagnetic charge
 - Forces are carried by an exchange of bosons
 - Integer spin ($s = 0, 1, 2$, etc.)
 - Gluon (g) → Strong force
 - Photon (γ) → Electromagnetism
 - W^\pm, Z^0 → Weak force

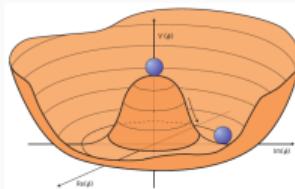


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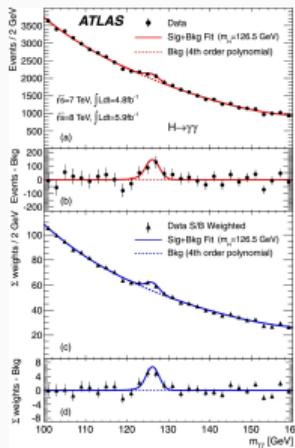


The Higgs Mechanism

- Theorized by Higgs, Englert, and Brout in 1964
 - Complex scalar doublet ($s = 0$)
 - Non-zero vacuum expectation value
- Interactions with Higgs field give particles mass
- Discovered jointly by the ATLAS and CMS collaborations in 2012



Higgs potential [2]

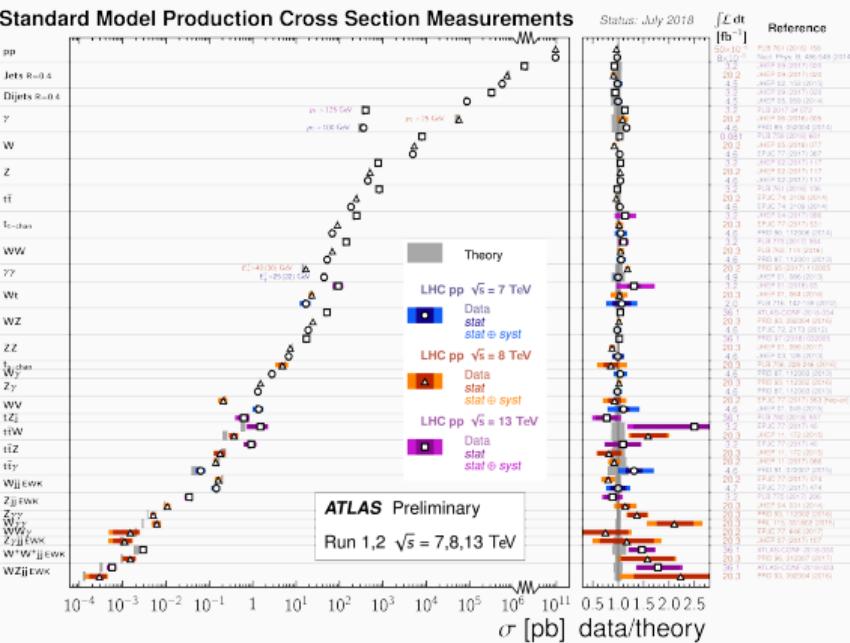


Higgs discovery [3]

The Standard Model



- Predicts the probabilities of particles decaying to others (among many other things)
 - Has been thoroughly tested
 - Measurements agree to a high degree of accuracy
 - Not a complete theory
 - Gravity
 - Matter-antimatter asymmetry in the universe
 - Predicted neutrino masses are 0
 - Observed neutrino mixing says otherwise



- Hierarchy problem, “unnaturalness”
 - Electroweak scale is ~ 100 GeV
 - Planck scale is $\sim 2.4 \times 10^{18}$ GeV
 - Supersymmetry (SUSY) offers many new particles to occupy the intermediate range
- SUSY proposes a symmetry between fermions and bosons (spin)
 - $Q|Fermion\rangle = |Boson\rangle$
 - $Q|Boson\rangle = |Fermion\rangle$
- SUSY is a large group of theories
 - Minimal Supersymmetric Standard Model (MSSM) is the smallest SUSY extension to the SM
 - 2 Higgs Doublet Models have two complex doublet scalar fields
 - Two relevant free parameters, $\tan\beta$ and m_{H^\pm}
 - $\tan\beta$ is the ratio of the vacuum expectation values of H^\pm

light neutral scalar	h^0
heavy neutral scalar	H^0
neutral pseudoscalar	A^0
two charged scalars	H^\pm

Experimental Apparatus

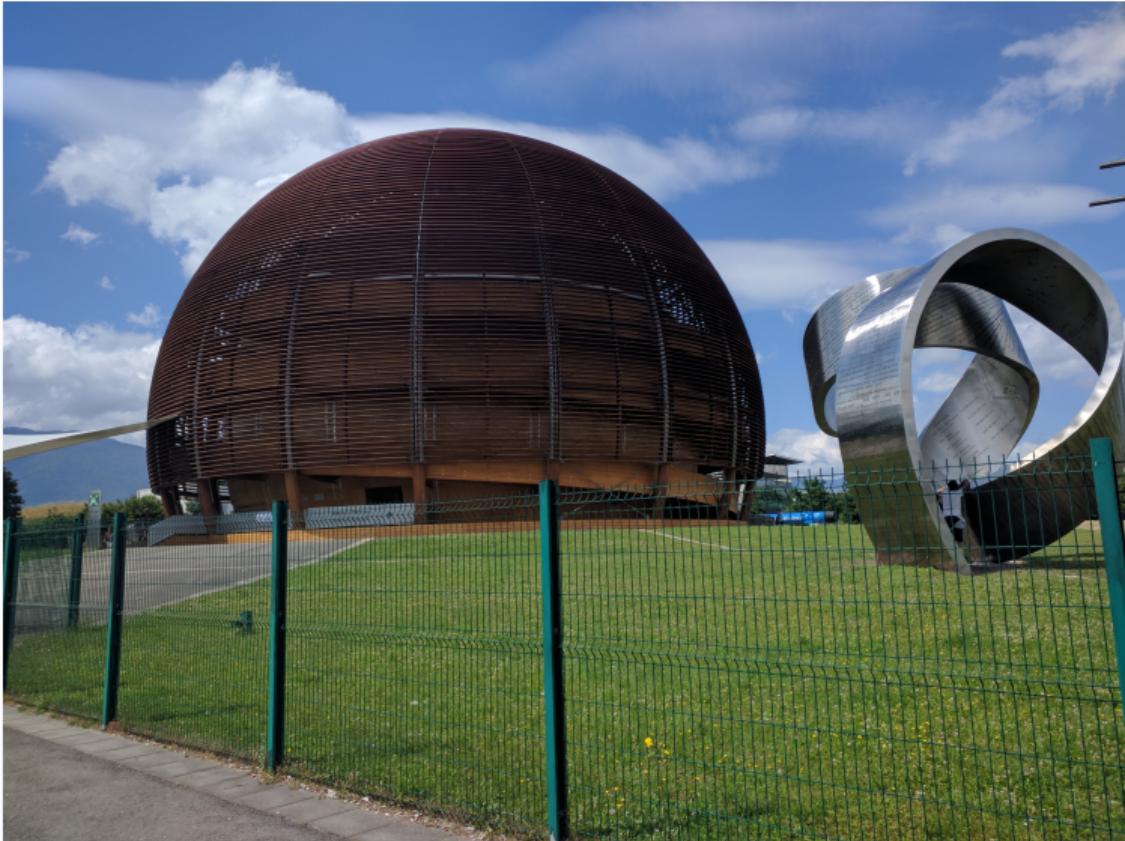
Simulation

Event Reconstruction

$$H^\pm \rightarrow \tau^\pm \nu_\tau$$

Conclusion

Thank You



Bibliography

References i

- [1] D. Hemphill, *The behavior of the primordial universe*, Apr. 2020. [Online]. Available:
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- [2] J. Ellis, “Higgs Physics,” , 117–168. 52 p, Dec. 2013, 52 pages, 45 figures, Lectures presented at the ESHEP 2013 School of High-Energy Physics, to appear as part of the proceedings in a CERN Yellow Report. DOI:
10.5170/CERN-2015-004.117. arXiv: 1312.5672. [Online]. Available:
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- [3] ATLAS Collaboration, “Observation of a new particle in the search for the standard model higgs boson with the atlas detector at the lhc,” *Physics Letters B*, vol. 716, no. 1, pp. 1–29, 2012.

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