A SEARCH FOR LONG-LIVED, CHARGED, SUPERSYMMETRIC PARTICLES USING IONIZATION WITH THE ATLAS DETECTOR

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Bradley Axen: *A Search for Long-Lived, Charged, Supersymmetric Particles using Ionization with the ATLAS Detector,* Subtitle, © September 2016

Usually a quotation.

Dedicated to.

ABSTRACT

How to write a good abstract:

https://plg.uwaterloo.ca/~migod/research/beckOOPSLA.html

PUBLICATIONS

Some ideas and figures have appeared previously in the following publications:

Put your publications from the thesis here. The packages `multibib` or `bibtopic` etc. can be used to handle multiple different bibliographies in your document.

optional quotation

ACKNOWLEDGEMENTS

Put your acknowledgements here.

And potentially a second round.

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LISTINGS

ACRONYMS

EG Example

PART I

INTRODUCTION

You can put some informational part preamble text here.

1 INTRODUCTION

PART II

THEORETICAL CONTEXT

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2 STANDARD MODEL

The Standard Model of particle physics seeks to explain the symmetries and interactions of all currently discovered fundamental particles. It has been tested by several generations of experiments and no significant deviations have been found. The Standard Model provides predictions in particle physics for interactions up to the Planck scale (10^{15}-10^{19} GeV).

The theory itself is a quantum field theory grown from an underlying $SU(3) \times SU(2) \times U(1)$ that requires the particle content and quantum numbers consistent with experimental observations (see Section 2.1). Each postulated symmetry is accompanied by an interaction between particles through gauge invariance. These interactions are referred to as the Strong, Weak, and Electromagnetic forces, which are discussed in Section 2.2.

Although this model has been very succesful historically, the theory is incomplete; for example, it is not able to describe gravity or astronomically observed dark matter. These limitations are discussed in more detail in Section 2.3.

2.1 PARTICLES

The most familiar matter in the universe is made up of protons, neutrons, and electrons. Protons and neutrons are composite particles, however, and are made up in turn by particles called quarks. Quarks carry both electric charge and color charge, and are bound in color-neutral combinations called baryons. The electron is an example of a lepton, and carries only electric charge. Another type of particle, the neutrino, does not form atomic structures in the same way that quarks and leptons do because it carries no color or electric charge. Collectively, these types of particles are known as fermions, which are defined as particles with half-integer spin.

There are three generations of fermions, although familiar matter is formed predominantly by the first generation. The generations are identical except for their masses, which increase in each generation by convention. And each of these particles is accompanied by an antiparticle, with opposite-sign quantum numbers but the same mass.

The fermions compromise what is typically considered matter, but there are additionally particles that are mediators ofinteractions between those fermions. These mediators are known as the gauge bosons, gauge in that their existance is required by gauge invariance (discussed further in Section 2.2 and bosons in that they have integer spin. The boson which mediates the electromagnetic force is the photon, the first boson to be discovered, which has no electric charge, no mass, and a spin of 1. There are three spin-1 mediators of the weak force, the two W bosons and the Z boson. The W bosons have electric charge of $\pm$ 1 and a mass of 80.385 ± 0.015 GeV, while the Z boson is neutral and has a mass of

91.1876 ± 0.0021 GeV. The strong force is mediated by eight particles called gluons, which are massless and electrically neutral but do carry color charge.

The final particle present in the Standard Model is the Higgs boson, which was recently observed for the first time by experiments at CERN in 2012. It is electrically neutral, has a mass of 125.7 ± 0.4 Gev, and is the only spin-0 particle yet to be observed. The Higgs boson is the gauge boson associated with the mechanism that gives a mass to the W and Z bosons.

Together these particles form the entire content of the Standard Model, and are summarized in Figure **??**. These are the particles that constitute the observable universe and all the so-far-observed interactions within it.

2.2 INTERACTIONS

The interactions predicted and described by the Standard Model are fundamentally tied to the particles within it, both in that they describe the way those particles can influence each other and also in that the existence of the interactions requires the existence of some particles (the gauge bosons).

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The ATLAS experiment combines measurements in the subdetectors to form a cohesive picture of each physics event.

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[August 2, 2016 at 15:35 – Version 0.13]

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Examples: *Italics*, Small Caps, ALL CAPS [1]. Acronym testing: **UML!** (**UML!**) – **UML!** – **UML!** (**UML!**) – **UML!s**

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B.1 APPENDIX SECTION TEST

Random text that should take up a few lines. The purpose is to see how sections and subsections flow with some actual context. Without some body copy between each heading it can be difficult to tell if the weight of the fonts, styles, and sizes use work well together.

B.1.1 APPENDIX SUBECTION TEST

Random text that should take up a few lines. The purpose is to see how sections and subsections flow with some actual context. Without some body copy between each heading it can be difficult to tell if the weight of the fonts, styles, and sizes use work well together.

B.2 A TABLE AND LISTING

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There is also a Python listing below Listing 1.

1 Footnote example.

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fastidii ea ius	germano	demonstratea
suscipit instructior	titulo	personas
quaestio philosophia	facto	demonstrated

Table 1: Autem usu id.

B.3 SOME FORMULAS

Due to the statistical nature of ionisation energy loss, large fluctuations can occur in the amount of energy deposited by a particle traversing an absorber element[2]. Continuous processes such as multiple scattering and energy loss play a relevant role in the longitudinal and lateral development of electromagnetic and hadronic showers, and in the case of sampling calorimeters the measured resolution can be significantly affected by such fluctuations in their active layers. The description of ionisation fluctuations is characterised by the significance parameter κ, which is proportional to the ratio of mean energy loss to the maximum allowed energy transfer in a single collision with an atomic electron:

You might get unexpected results using math in chapter or section heads. Consider the `pdfspacing` option.

$$\kappa = \frac{\xi}{E_{\mathrm{max}}} \tag{1}$$

E_{max} is the maximum transferable energy in a single collision with an atomic electron.

$$E_{\mathrm{max}} = \frac{2m_{\mathrm{e}}\beta^2\gamma^2}{1 + 2\gamma m_{\mathrm{e}}/m_{\mathrm{x}} + (m_{\mathrm{e}}/m_{\mathrm{x}})^2},$$

where $\gamma = E/m_{\mathrm{x}}$, E is energy and m_{x} the mass of the incident particle, $\beta^2 = 1 - 1/\gamma^2$ and m_{e} is the electron mass. ξ comes from the Rutherford scattering cross section and is defined as:

$$\xi = \frac{2\pi z^2 e^4 N_{\mathrm{Av}} Z\rho\delta x}{m_{\mathrm{e}}\beta^2 c^2 A} = 153.4\frac{z^2}{\beta^2}\frac{Z}{A}\rho\delta x \quad \mathrm{keV},$$

where

z	charge of the incident particle
N_{Av}	Avogadro's number
Z	atomic number of the material
A	atomic weight of the material
ρ	density
δx	thickness of the material

κ measures the contribution of the collisions with energy transfer close to E_{max}. For a given absorber, κ tends towards large values if δx is large and/or if β is small. Likewise, κ tends towards zero if δx is small and/or if β approaches 1.

2 Examples taken from Walter Schmidt's great gallery: http://home.vrweb.de/~was/mathfonts.html

Listing 1: A floating example (`listings` manual)

```
for i in xrange(10):
    print i, i*i, i*i*i
print "done"
```

The value of κ distinguishes two regimes which occur in the description of ionisation fluctuations:

1. A large number of collisions involving the loss of all or most of the incident particle energy during the traversal of an absorber.

   As the total energy transfer is composed of a multitude of small energy losses, we can apply the central limit theorem and describe the fluctuations by a Gaussian distribution. This case is applicable to non-relativistic particles and is described by the inequality $\kappa > 10$ (i. e., when the mean energy loss in the absorber is greater than the maximum energy transfer in a single collision).

2. Particles traversing thin counters and incident electrons under any conditions.

   The relevant inequalities and distributions are $0.01 < \kappa < 10$, Vavilov distribution, and $\kappa < 0.01$, Landau distribution.

DECLARATION

Put your declaration here.

Berkeley, CA, September 2016

Bradley Axen

COLOPHON

Not sure that this is necessary.