The Noble Prize in 2013 was awarded to François Englert and Peter W. Higgs “for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN’s Large Hadron Collider.” The announcement by the ATLAS and CMS experiments took place on 4 July, 2012.

The mechanism was first proposed by those authors in 1964 in two papers published independently. It explains how the force responsible for the decay of atom nuclei is much weaker than electromagnetism, but it is better known as the mechanism that endows fundamental particles with mass. The new idea forms an essential part of the Standard Model of particle physics. As was pointed out by Higgs, a key prediction of the idea is the existence of a massive, so-called Higgs boson. The Standard Model describes the fundamental particles from which we, and all the visible matter in the Universe, are made, along with the interactions that govern their behavior. It is a remarkably successful theory that has been thoroughly tested by experiment over many years, and the Higgs particle was the last remaining piece of the model to be experimentally verified. Nevertheless, the theory does not immediately apply to energies that exceed those of the LHC but were certainly involved during the evolution of the Universe (Big Bang). An obvious reason could be that not-yet discovered forces with their own new particles exist. Furthermore, the Standard Model does not deal with the gravitational force. Some models including the gravitational force actually predict that Micro-Black Holes could even be produced in the particle accelerator.

The way to probe such shortcomings is to either observe behavior in particle reactions different from the one as predicted by the Standard Model, or to explicitly create those new particles at higher and higher energies. As such effects and appearances are expected to be rare the initial particle beam needs to have higher and higher intensity, and the rate at which collisions occur needs to increase. This presents new challenges on the particle detectors: they have to be very radiation hard and fast, and provide with high efficiency location and energy of reaction products. The detectors closest to the LHC beam provide essential measurements of charged particle trajectories and are particularly exposed to the radiation from the LHC.

Studying detectors that have these key characteristics is the focus of my research. More specifically, Chemical Vapor Deposition (CVD) diamonds show promising results for the next-generation detectors needed closest to the LHC beam. In coordination with the High Energy Physics Group of the University and Dr. Stefan Spanier, I have spent the last several months studying several of our own CVD diamonds on a test-stand I calibrated and personally assembled in our laboratory. Using this test-stand and several diamonds of various irradiation levels, I have collected and analyzed a substantial amount of data that has revealed much about the radiation hardness of diamonds when damaged with proton irradiation. Presented here are the results of this research.


# Studies of Charge Collection in Diamond-Based Particle Detectors at the LHC

Jared Smith, First-Year Undergraduate University of Pennsylvania, Department of Physics and Astronomy

## Background

### Introduction

The noble gas Ar in 2015 was awarded to Francisco Ing And Peter W. Wegner for "The theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, which we call: the physics of the Higgs boson."

The mechanism explains how the force responsible for the decay of subatomic particles, the Higgs boson, is responsible for interactions between particles and forces. However, the mechanism that explains the force responsible for the decay of subatomic particles, the Higgs boson, is responsible for interactions between particles and forces. The mechanism explains how the force responsible for the decay of subatomic particles, the Higgs boson, is responsible for interactions between particles and forces.

### CVD Diamond Detectors

In my work, I am studying the effect of charge collection on diamond-based particle detectors. The process of charge collection is a complex one, involving the interaction of charged particles with the lattice structure of the diamond. However, the mechanism that explains the force responsible for the decay of subatomic particles, the Higgs boson, is responsible for interactions between particles and forces.

### Experiment

#### Objectives

1. Analyze charge collection of both non-damaged and damaged diamonds.
2. Determine Charge Collection efficiencies in various conditions.
3. Establish a reliable test stand for diamond detector.
4. Eventually, measure rate dependence and light dependence of diamonds.

#### Apparatus

One of the primary goals of my research is to set up a reliable test stand for measuring the properties of diamonds.

The following materials are primarily the test stand:

- **NTSR Diode IrDian:** used to study the effect of high-voltage radiation on diamond and its impact on charge collection efficiency.
- **NTSR Diode RD42:** used to study the effect of radiation damage on diamond and its impact on charge collection efficiency.

#### Results

- **NTSR Diode IrDian:** used to study the effect of high-voltage radiation on diamond and its impact on charge collection efficiency.
- **NTSR Diode RD42:** used to study the effect of radiation damage on diamond and its impact on charge collection efficiency.

#### Conclusion

- Overall, it's clear that a diamond is more heavily ionizing and charge collection efficiencies are lowered.

#### Bibliography

- R. J. Kopf and Diamond Detectors on Particle Physics in High-Energy Physics, Particle Detectors, 2002
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