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Dark Matter And Super Symmetry: Exploring And Explaining The Universe With Simulations At The LHC

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ABSTRACT

The Large Hadron Collider (LHC) at CERN in Geneva, Switzerland, is one of the largest machines on this planet. It is built to smash protons into each other at unprecedented energies to reveal the fundamental constituents of our universe. The 4 detectors at the LHC record multi-Petabyte datasets every year. The scientific analysis of this data requires equally large simulation datasets of the collisions based on the theory of particle physics, the Standard Model. The goal is to verify the validity of the Standard Model or of theories that extend the Model like the concepts of Super Symmetry and an explanation of Dark Matter. I will give an overview of the nature of simulations needed to discover new particles like the Higgs Boson in 2012, and review the different areas where simulations are indispensable: from the actual recording of the collisions to the extraction of scientific results to the conceptual design of improvements to the LHC and its experiments.

1 INTRODUCTION

High Energy Physics (HEP) strives to develop a detailed mathematical understanding of nature at the smallest elementary level. Its science is based on the interplay between the theory framework that describes elementary particles and elementary forces between them; and the experimental detection of particles and measurements of their interactions. It calls for probing nature at ever increasing detail to unlock the last mysteries of our universe.

The theory of particle physics is called the Standard Model and describes the universe through 12 particles and their anti-particles, and 4 fundamental forces represented by their own force particles. Particles are called fermions and have half-integer spins (one of fundamental properties or quantum numbers of particles) and respect the Pauli exclusion principle (not two particles can be identical in all their quantum numbers). There are 12 fermions, separated into 6 leptons (electron, electron neutrino, muon, muon neutrino, tau, tau neutrino), and 6 quarks (up, down, charm, strange, bottom, top). The hydrogen atom consists of an electron orbiting a proton, which consist of 2 up and 1 down quark.

Force particles are bosons with integer spin and describe the fundamental forces: the electro-magnetic force represented by the photon, the weak force represented by the W and Z bosons, the strong force represented by the gluon, and gravitation which is the least known fundamental force and believed to be represented by the graviton, but this is not yet proven.

Also called elementary particle physics, its experimental results are based on the analysis of many individual detector measurements in comparison to corresponding simulations that are based on the current understanding of the theory. Because of this, HEP was and is traditionally a very data intensive and trivially parallelizable science discipline.

The LHC (Evans and Bryant 2008)

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Place the acknowledgments section, if needed, after the main text, but before any appendices and the references. The section heading is not numbered. These instructions are adapted from instructions that have been updated and improved by proceedings editors and several other individuals, who are too numerous to name separately (our apologies, but it is necessary), since the first set of instructions were written by Barry Nelson for the 1991 WSC.

REFERENCES

Evans, L., and P. Bryant. 2008. "LHC Machine". *Journal of Instrumentation* 3 (08): S08001.

AUTHOR BIOGRAPHIES

Oliver Gutsche is a staff scientist at the Fermi National Accelerator Laboratory and member of the CMS collaboration of 2,500 physicists, which is operating one of the 4 detectors at the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland. After the Higgs Boson discovery in 2012, his research is focusing on new physics beyond the established theory of particle physics called the Standard Model, especially in the areas of Super Symmetry and Dark Matter. In his role as Assistant Head of the Scientific Computing Division, Dr. Gutsche coordinates the computing needs of the High Energy, Neutrino and Muon Particle Physics experiments at the laboratory. He has intimate knowledge of the large scale computing solutions used for the LHC experiments to analyze multi-Petabyte size datasets on distributed computing infrastructures of many 100,000 cores, having architected many of the used systems and leading the computing operations team of CMS during the first running period of the LHC. His email address is gutsche@fnal.gov.