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# First Measurement of the Differential Inclusive Cross Section for Jet Production at DØ Run II

by

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For my dedication, I cannot improve upon Exodus 20:12.

# Curriculum Vitae

The author was born in New York, NY, on October 16, 1975. He attended Kenyon College from 1993 to 1997, and graduated with a Bachelor of Arts degree in 1997. He came to the University of Rochester in the Summer of 1997 and began graduate studies in Physics. While at Rochester, he received the Department of Education Graduate Assistance in Area of National Need Fellowship. He pursued his research in Experimental High Energy Physics under the direction of Professor Tom Ferbel and received a Master of Arts degree from the University of Rochester in 1999. In 1999, the author moved to Fermi National Accelerator Laboratory (Fermilab) where he joined the University of Rochester's group at the DØ experiment.

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I also wish to thank my father Michael Davis who took an adult astronomy class with me while I was in grade school and my mother Madelyn Ollendorff Davis whose advice I have always prized.

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# Abstract

The differential inclusive jet cross section in proton-antiproton collisions at a center of mass energy of 1.96 TeV reaches the smallest distances or equivalently the highest momentum transfers ever probed. We present a preliminary measurement of jet production from the DØ experiment at Run II of the Tevatron. Next-to-leading-order QCD calculations of the cross section are consistent with the data over seven orders of magnitude.

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# Chapter 1

# The Energy Frontier

One of the most basic questions a scientist can ask about almost anything is: "what is this made of?" Modern science has answered this to a remarkable degree. By the beginning of the twentieth century, scientists had determined that all visible matter in the universe was made of atoms, and they formulated the periodic table of elements. While the table did not list every element that can be found in nature, and new ones have since been manufactured, this was a major success that lead to great progress in answering the above fundamental question. Some scientists believed that atoms were entirely indivisible, but nobody had yet applied enough energy to completely rip them apart and see what they were made of. Chemical reactions typically involve energies of no more than a few eV (electron Volts) per atom, not enough to break them apart.

Early x-ray work reached energies of keV ($10^3$ eV) but this too was insufficient to break atoms.

There were hints that atoms might be divisible. The electron and other forms of radiation were discovered before the end of the nineteenth century. In the early part of the twentieth century, scientists learned that atoms contained electrons and a positively charged nucleus. The discovery of the nucleus required hitting atoms with other particles that had kinetic energies of several MeV ($10^6$ eV). Doing this experiment required the use of energetic natural radiation that was also discovered near the turn of the century.

By the mid 1930s, scientists determined that matter was made of three types of particles: electrons, protons, and neutrons. Much of this knowledge came from scattering experiments, the most famous of which was done in Ernest Rutherford's laboratory in 1911. By scattering naturally occurring $\alpha$ particles off thin gold foil, his group discovered that gold atoms have hard cores at their centers. The energy of the naturally occurring $\alpha$ particles was about 6 MeV. With this energy, they could easily penetrate the atom, but not the nucleus. Discovering protons and neutrons in the nucleus required similar energies, but smaller target nuclei. To dig any deeper required higher energies, far beyond the reach of natural radiation.

To probe the nature of electrons, protons, and neutrons requires accelerators.[1] Using primarily accelerator-based experiments, physicists in the twentieth century have constructed the Standard Model of particle physics. In the Standard Model, the electron is a fundamental particle, but the neutron and proton are composites made of indivisible quarks and gluons. As the energy frontier moves forward, we will probe these particles at even smaller distance scales always asking: "what is this made of?" References to all of these discoveries and much more can be found in Ref. [1].

This thesis reports research performed at Fermi National Accelerator Laboratory's Tevatron, currently the world's highest-energy accelerator, where we study the highest energy $p\bar{p}$ collisions. The name Tevatron comes from TeV.

$$1 \text{ TeV} = 1000 \text{ GeV} = 10^{12} \text{ eV} \tag{1.1}$$

We are following the tradition of Rutherford, probing the structure of the proton at the smallest distances we can attain.

[1]Cosmic rays come to earth from space and they can have extremely high energies. These have been used for studying many issues in particle physics, but, unlike particle beams from accelerators, they constitute a poorly controlled laboratory. Accelerators can provide many collisions at a fixed energy; with cosmic rays, you get what comes.