Summary of Key Concepts

Intro to Particle Physics

Week of April 7th, 2024

Resources

Note: All of these resources are free and created with high school students in mind!

- For an introduction to the type of physics and detectors we use in experimental particle physics, check out the Lancaster Particle Physics Package:
  - http://lppp.lancs.ac.uk/index_en-GB.html?LPPPSession=1706906039556
- For an in-depth exploration of the data analysis tools used in experimental particle physics, the detectors used in famous particle physics experiments, and modern particle identification methods, check out Particle Identification Playground:
  - https://duberii.github.io/pid-playground/
- To work with real data from particle physics experiments and an exploration of the reconstruction process in particle physics data analysis, check out Particle Physics Playground:
  - https://sites.google.com/siena.edu/particle-physics-playground/home

Key Terms

Key Term	Definition
The Standard Model	The theory that describes a set of particles that are the fundamental building blocks of the world around us.
Quarks	The particles that are inside protons and neutrons. There are a total of 6 quarks (and 6 antiquarks). These particles are all charged and experience the strong force.
Leptons	A type of fundamental particles that include electrons, muons, and neutrinos. Unlike quarks, they do not experience the strong force.
Strong Interaction	The interaction described by the standard model that holds together quarks. The strong interaction is carried by the gluon.
Electromagnetic Force	The interaction that holds electrons in an atom. It is carried by the photon.
Weak Interaction	The interaction that causes the decay of nuclei and fundamental particles. It is carried by the W and Z bosons.
Gravity	The interaction that causes planets to orbit. It is the only known fundamental force that cannot be described by the standard model.
Boson	A particle in the standard model that mediates an interaction. Examples are photons, gluons, W and Z bosons, and the Higgs boson.
Charge	A property of particles that determines how strongly it is affected by an interaction. The best examples of charges are electrical charge and color charge.
Antimatter	Particles that have the same properties as particles in the standard model, but with opposite charges. When a particle comes in contact with its antiparticle, they annihilate and release a ton of energy!
Hadron	A collection of quarks held together by gluons.
Color Confinement	The name for the observation that particles we observe have no net color charge. In other words, all free particles must be color neutral.
Baryon	A hadron made of 3 quarks of different colors. Its antiparticle is an antibaryon.

Meson	A hadron made of one quark and one antiquark of opposite colors. The antiparticle of a meson is another meson.
Detector and Beam Physics	The field of particle physics that studies how to design and improve the detectors we use in particle physics experiments.
Standard Model Physics	The field of particle physics that studies the forces described by the standard model.
Beyond the Standard Model Physics	The field of particle physics that is looking for particles and interactions that cannot be described by the standard model.
Particle Identification	The process of figuring out what particles we detected in the various detectors used in particle physics. This is the first stage of data analysis in experimental particle physics.
Reconstruction	The process of figuring out what happened to produce the particles identified using particle identification. Reconstruction is the part of data analysis where we would answer our questions about the interactions we are trying to study.

Lecture

Learning Objectives

1. Recognize the Standard Model and describe its role in particle physics
2. Recognize how composite particles are built from the standard model
3. Recognize major branches of particles physics research

Key Ideas

1. The Standard Model is the periodic table of particle physics!
    a. It describes matter (quarks and leptons) and how they interact (through bosons)
    b. There are theories that build on the Standard Model, but we have yet to find evidence to support those other theories.
2. Most composite particles are held together by the strong force. These particles are called hadrons.
    a. Hadrons are categorized based on their structure: Baryons, AntiBaryons, and Mesons. The quarks in these particles can also be in superposition, which affects the properties of the particle.
3. Research in experimental particle physics mostly fits into 3 branches:
    a. Detector and Beam Physics
        i. Studying how we can detect different kinds of particles in particle colliders
    b. Standard Model Physics
        i. Studying the forces and interactions described by the Standard Model
    c. Beyond the Standard Model Physics
        i. Searching for particles that cannot be described by the Standard Model

Lab

Lab will be used to host a Capstone Project Office Hour in which you can share your project progress and questions with your classmates and TA.