PARTICLE TRANSFORMATIONS
TEACHER NOTES

DESCRIPTION
This activity enables students to discover some basic rules of particle transformations and to interpret simple particle transformation diagrams, commonly known as Feynman diagrams. The student guide addresses the class as members of the *Student Research Committee* (SRC) in the imaginary *Particle Decay Observation Facility* (PDOF), where they analyze observations of particle transformations (decays) to make conclusions about the rules which govern them. There are three sets of eight interactions in the form of Feynman diagrams. Each set shows transformations of a particular class of particles—gauge boson, meson, or lepton— into other particles. Working in teams and using reference materials, students figure out the conservation rules which govern these transformations. Then, lead a discussion in which students synthesize team conclusions into a system of rules. Students can take their interpretations to the next level with an optional "zoo" set of more difficult but interesting interactions.

STANDARDS ADDRESSED
Next Generation Science Standards

Science Practices
1. Asking questions
2. Developing and using models
4. Analyzing and interpreting data
6. Constructing explanations
7. Engaging in argument from evidence

Disciplinary Core Ideas – Physical Science
PS1.A: Structure and Properties of Matter
PS2.B: Types of Interactions
PS3.B: Conservation of Energy and Energy Transfer

Crosscutting Concepts
1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity

Common Core Literacy Standards

Reading
9-12.4 Determine the meaning of symbols, key terms . . .
9-12.7 Translate quantitative or technical information . . .

Common Core Mathematics Standards

MP7. Look for and make use of structure.

IB Physics Standard 7: The Structure of Matter

7.3 The structure of matter

ENDURING UNDERSTANDING
The Standard Model provides a framework for our understanding of matter at its most fundamental level.

LEARNING OBJECTIVES
The students will be able to:
- Identify conservation rules that govern particle transformations.

- Interpret a simple particle transformation (Feynman) diagram.

PRIOR KNOWLEDGE

Students should understand the concept of conservation laws in physics.

RESOURCES

1. Reference materials for students
   1.1. Table of particles
   1.2. Standard Model chart
   1.3. Student guide
   1.4. Particle cards from *Shuffling the Particle Deck* activity (Optional)
2. Particle transformation examples for students:
   2.1. Gauge bosons
   2.2. Mesons
   2.3. Leptons
   2.4. Zoo (Optional)
3. Teacher reference:
   3.1. Annotated article transformations

All resources are available in the QuarkNet Data Activities Portfolio.

IMPLEMENTATION

Divide your students into groups of two or three. There are three different classes of interactions in this activity. Ideally, the class should consider all three interaction classes. You can save the zoo as an extension. Give each team a set of particle transformations, a Standard Model chart, and a particle table. The main tasks for each team include:

- Studying the diagram and writing a description for the first particle transformation. (Check to be sure they can make a one-to-one correspondence between the diagram and the description.)
- Using the pattern from the first transformation to write descriptions for the remaining transformations and using reference materials when necessary to identify the particles depicted in the diagram. (You have a set of annotated particle transformations to check student interpretations of the diagrams.)
- Using the reference materials to look up the quantities associated with each particle in the transformation, totaling each quantity before and after the transformation in the space provided and noting which quantities increase, decrease, or stay constant.
  Looking for general rules based on before and after results and recording the rules they claim along with their evidence and reasoning.

After 15–30 minutes, you can lead a discussion in which each team reports the rules they claim. The class resolves disagreements and decides which rules are generally applicable by using evidence and reasoning.

QUESTIONS

During a general discussion in which teams share their results, address the following questions:

1. Which quantities are conserved for meson transformations?
2. Which quantities are conserved for lepton transformations?
3. Which quantities are conserved for gauge boson transformations?
4. Which quantities are conserved for all transformations?
5. Are there other patterns that students can observe?
6. If there is an exception to a rule, can it still be a valid rule? If so, how?

- *Electric charge, lepton number, electron number, and tau number are all conserved in the interactions. In question 5, mass remains the same or decreases as a result of the transformation. The generation number should go down in lepton transformations. In question 6, are there any rules that applied to one class of interactions but not to all?*

ASSESSMENT

Assessment may be based upon:

- Team-written transformation descriptions.
- Team conclusions regarding transformation rules.
- Quality of discussions.