![QuarkNet logo]

Data Portfolio Sample Pathways for Each Data Strand

LHC: Understanding Colliders

Level 0	Level 1	Level 2	Level 3	Level 4
Dice, Histograms and Probability	Rolling with Rutherford	4 Masterclasses	**CMS e-Lab**	
Making it 'Round the Bend	**Calculate the Top Quark Mass**	**CMS Data Express**	Cosmic Ray e- Lab	
Mass of U.S. Pennies	**LHC Discovery**	**ATLAS Data Express**	LIGO e-Lab	
Quark Workbench	Calculate the Z Mass			
	Seismology			

In *Making it 'Round the Bend*, students learn that magnets can bend a beam of charged particles in a circular path. The *Top Quark* activity allows students to discover how conservation of energy and conservation of momentum work in relativistic systems focusing on a single event. In the *LHC Discovery* activity, students gather data using both CMS event data and ATLAS event data. Then, choose between the *CMS Data Express* or *ATLAS Data Express* so students analyze a larger dataset. The *CMS e-Lab* is the culminating activity.

LHC ATLAS: ATLAS Masterclass Preparation

Level 0	Level 1	Level 2	Level 3	Level 4
Dice, Histograms and Probability	**Calculate the Top Quark Mass**	ATLAS Masterclass	CMS e-Lab	
Making it 'Round the Bend	Calculate the Z Mass	**ATLAS Data Express**	Cosmic Ray e- Lab	
Mass of U.S. Pennies	LHC Discovery	CMS Data Express	LIGO e-Lab	
Quark Workbench	**Rolling with Rutherford**	TOTEM Data Express		
	Seismology			

Preparation for a masterclass is an essential step to ensure that students have a positive learning experience. Starting with the *Penny Mass,* this activity allows students to practice making and interpreting histograms to provide the evidence for claims. In the *Rolling with Rutherford* activity, students practice making claims from indirect evidence. In the *Top Quark Activity*, students discover how conservation of energy and conservation of momentum work in relativistic systems. *ATLAS Data Express a*llows students to practice using the ATLAS event viewer to determine which particles are present in a given event.

LHC CMS: Focus on Special Relativity

Level 0	Level 1	Level 2	Level 3	Level 4
Dice, Histograms and Probability	**Calculate the Top Quark Mass**	CMS Masterclass	**CMS e-Lab**	
Making it 'Round the Bend	**Calculate the Z Mass**	**CMS Data Express**	Cosmic Ray e- Lab	
Mass of U.S. Pennies	LHC Discovery	ATLAS Data Express	LIGO e-Lab	
Quark Workbench	Rolling with Rutherford	TOTEM Data Express		
	Seismology			

The *Top Quark* activity allows students to discover how conservation of energy and conservation of momentum work in relativistic systems focusing on a single event. The *Z Mass* activity applies the same problem-solving techniques to a larger dataset. The *CMS Data Express* is a logical choice for extended study, and the *CMS e-Lab* is the culminating activity.

LHC TOTEM: Interference Patterns

Level 0	Level 1	Level 2	Level 3	Level 4
Dice, Histograms and Probability	Calculate the Top Quark Mass	4 Masterclasses	CMS e-Lab	
Making it 'Round the Bend	Calculate the Z Mass	CMS Data Express	Cosmic Ray e- Lab	
Mass of U.S. Pennies	LHC Discovery	ATLAS Data Express	LIGO e-Lab	
Quark Workbench	**Rolling with Rutherford**	**TOTEM Data Express**		
	Seismology			

The *Dice and Histogram* activity allows students to learn the basics of constructing and interpreting histograms. In the *Rolling with Rutherford* activity, students practice making claims from indirect evidence. The TOTEM detector is a subdetector of the CMS detector designed to find the elastic scattering angle of protons colliding in the CMS detector. These data, when plotted in a histogram, result in an interference pattern which demonstrates the wave nature of protons.

Cosmic Ray Studies

Level 0	Level 1	Level 2	Level 3	Level 4
Dice, Histograms and Probability	Calculate the Top Quark Mass	4 Masterclasses	CMS e-Lab	
Making it 'Round the Bend	Calculate the Z Mass	3 Data Express	**Cosmic Ray e- Lab**	
Mass of U.S. Pennies	LHC Discovery	**Cosmic Rays and the Sun**	LIGO e-Lab	
Quark Workbench	**Rolling with Rutherford**	**Muon Lifetime**		

	Seismology			

The *Dice and Histogram* activity allows students to learn the basics of constructing and interpreting histograms. The *Penny Mass* activity allows the students to practice making and interpreting histograms to provide the evidence for claims. The *Quark Workbench* activity allows students to better understand the properties of particles and how the particles are organized in the Standard Model. In the *Rolling with Rutherford* activity, students practice making claims from indirect evidence. The *Muon Lifetime* activity allows the students to determine the difference between half-life and lifetime. The students also use cosmic ray data to determine the lifetime of cosmic ray muons. The *Cosmic Rays and the Sun* activity allows students to use cosmic ray data to provide evidence for a claim about the origin of cosmic rays. The Cosmic Ray e-Lab is the culminating activity.

LIGO:

Level 0	Level 1	Level 2	Level 3	Level 4
Dice, Histograms and Probability	Calculate the Top Quark Mass	4 Masterclasses	CMS e-Lab	
Making it 'Round the Bend	Calculate the Z Mass	3 Data Express	Cosmic Ray e- Lab	
Mass of U.S. Pennies	LHC Discovery	Cosmic Rays and the Sun	**LIGO e-Lab**	
Quark Workbench	Rolling with Rutherford	Muon Lifetime		
	Seismology			