A view from Australia

CoEPP

ARC Centre of Excellence for Particle Physics at the Terascale

Paul Jackson
University of Adelaide

IPPOG meeting - Nov 2nd 2017

Overview

Masterclass

- Masterclass in High Schools – New South Wales.
- Uta, Ken, Barbora, Christine and Steve have been in regular contact with the NSW masterclass group - primarily Shantha Liyanage (who initiated this project and brought it to the attention of NSW dept of education)
- The online resource has been developed and was trialed earlier in the year, it ended with an ATLAS virtual visit.
- Continued discussions with NSW department of education show that teachers need to be trained up, that it can't be "just left to the students to engage" because they need support
- In contact with Ben Garrard, Business Relationship Office with NSW DET.
- Needs effort to follow this up.

Outreach in Schools

- Continuing effort to engage school children at various age groups through local /national initiatives.
- Will touch on one example during this talk.

Particle physics masterclass

- **Disclaimer**

We offer this draft resource for schools as part of our user testing process. Whilst every effort has been made to ensure that this resource is accessible, it has not been through final quality checks to ensure that it meets appropriate WCAG accessibility standards. If you have feedback on the resource let us know how we can make it better using the **Particle physics masterclass feedback form**.

- **Overview**
- **Inside the Large Hadron Collider**
- **Standard Model of particle physics**
- **Carriers of the weak force and the maker of mass**
- **Analyse Atlas data**
- **Information for teachers**

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NSW Government | Education Public Schools

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Currently being trialed in high schools in New South Wales. Run nationally in association with the International Particle Physics Outreach Group (IPPOG). We've presented this information to school teachers in other states – no time or support to follow up at the moment.

Particle physics masterclass

Disclaimer

Overview

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The Large Hadron Collider (LHC) is the largest, most complex machine ever built. Producing high energy collisions between subatomic particles to investigate matter, force and energy at the most fundamental level, it gives us a deeper understanding of the fabric of the universe.

This resource enables you to:

- get inside the workings of the LHC and investigate how charged particles are accelerated to almost the speed of light
- understand key terms and concepts about the physics of the fundamental particles that make up matter—particle physics
- complete tasks that complement the NSW Physics Syllabus
- analyse real data collected by the LHC ATLAS detector
- visit virtually CERN scientists working at the ATLAS detector on the Large Hadron Collider, CERN—Particle physics with the masters at ATLAS CERN.

Get organised

Inside the Large Hadron Collider

Standard Model of particle physics

Carriers of the weak force and the maker of mass

Analyse Atlas data

Information for teachers

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Particle physics masterclass

- Disclaimer
- Overview
- Inside the Large Hadron Collider

LHC | Equivalence | Electric fields | Magnetic fields | Special relativity | Superconducting

Particle physicists want to better understand the universe and the fundamental particles and forces of the basic makeup of matter.

In the mid-twentieth century physicists developed hypotheses about the mechanism that gives mass to particles. Like, why do particles have the measured mass, and why do some not have mass? The best explanation was given in 1964 by **Peter Higgs**, who assumed the existence of a particle, the boson which bears his name, which is the mediating particle of the Higgs field. This field gives mass to each particle it interacts with.

To test this and other hypotheses they built the **Large Hadron Collider** (LHC).

With this machine scientists can probe deeply into the origin of mass, dark matter, and new phenomena such as supersymmetry or extra dimensions.

Watch the **CERN Experiment** to get an overview of the LHC, and then view the Large Hadron Rap for a creative explanation of the collider.

+ **Accelerators and detectors**

− **Note the position of detecting structures comprising ATLAS**

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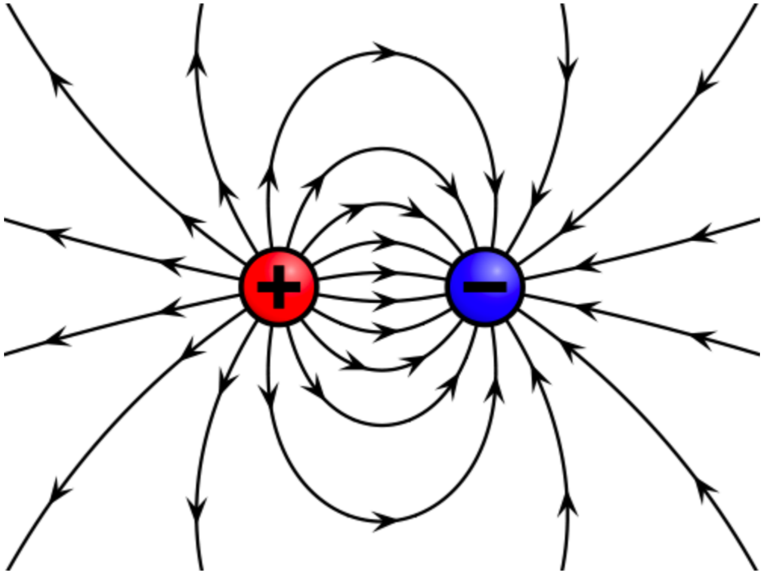
The LHC uses electric fields to accelerate particles to velocities close to the speed of light.

View this video on **'Electric fields'**.



The electric field around a positive and negative charge. **Geek3** | **CC BY SA 3.0**

Lines of electric force

Electric fields surround charged objects

Simple charge accelerator

Accelerating charges between parallel plates

When a charge is accelerated across a voltage (V) the energy gained by the charge is given by:

Energy = qV

Particle physics masterclass

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- Standard Model of particle physics

In the last 50 years scientists have made a giant leap with the age old questions:

- What are the ultimate building blocks of reality?
- What are the forces that govern it?

Our modern understanding of what underpins the universe has been able to explain phenomena from the behaviour of atoms to how stars form. The name for this understanding is called the Standard Model of particle physics.

Task: Discuss key features of the Standard Model

Standard Model | Fundamental particles | Fundamental forces | New physics

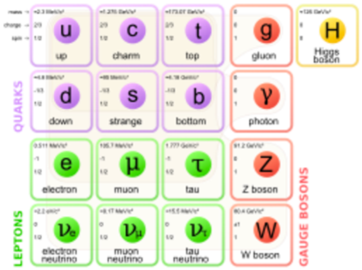
The Standard Model of particle physics describes the fundamental particles and forces of nature. Fascinatingly, ordinary matter is made up of only a few—electrons and 'up' and 'down' quarks.

The model includes many particles that only exist for tiny amounts of time.

Replacement models?

Learn more about the Standard Model by watching these videos:

- Don Lincoln (Fermilab) The Standard Model
- Tobias Golling (CERN) The Standard Model of Particle Physics
- Theory of everything (The Standard Model)
- Every force in nature (Theory of everything, part III) (forces).



The Standard Model MissMJ | CC BY 3.0

Particle physics masterclass

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- Carriers of the weak force and the maker of mass

Many fundamental (indivisible) particles were discovered when larger particles collided inside particle accelerators, including the particles that carry/bring-about/mediate the weak force—W and Z bosons. And the one that gives all particles their mass — the Higgs boson.

Some particles are very short-lived and decay almost immediately to more stable particles.

Track massive particles when they are produced

Feynman diagrams | W boson | Z boson | Higgs boson | **Identifying particles**

When protons travel at almost the speed of light, as they do in the LHC, they gain very large energies. Because of these large energies, when the protons collide all types of particles are emitted and also created:

Q: What is emitted or created?

The ATLAS detector is a sort of digital camera, recording what happens when protons collide (events). After collision, as the spat-out particles cross the ATLAS detector, they leave electronic signals or footprints.

To analyse data collected by the ATLAS detector we need to analyse these footprints to identify short-lived particles like the Z boson and Higgs boson.

Select the two video simulations on the **'Identifying Events page'** to see how the ATLAS detector 'sees' proton collisions.

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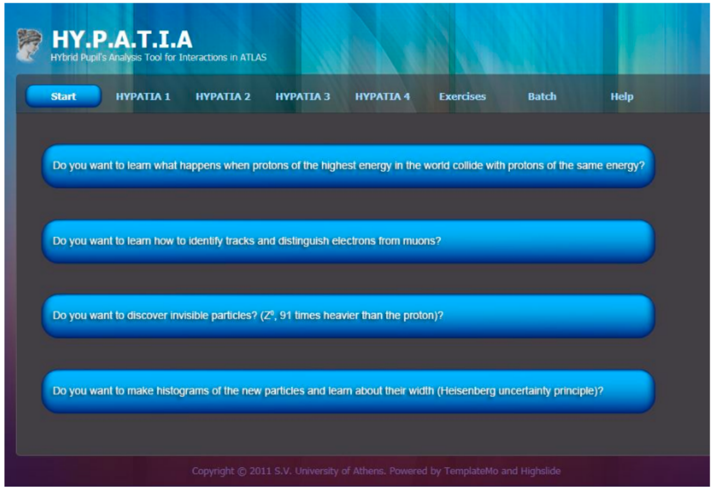
The dark Higgs?

Analyse Atlas data



HY.P.A.T.I.A software tool Screenshot **© 2011 S.V University of Athens**

If you are committed to participating in the Particle physics with the masters at ATLAS CERN be sure to make your booking at least two weeks in advance. See **Information for teachers** section.

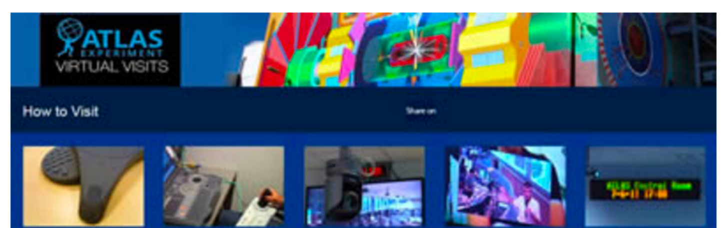
TASK:

Join the HY.P.A.T.I.A Q&A forum

Use **HY.P.A.T.I.A** online to identify tracks of particular particles that are produced when hadrons collide at high energies in the ATLAS detector:

- Access help via the **HY.P.A.T.I.A help guide** for each exercise.
- Use the **Start** page of HY.P.A.T.I.A online to guide you through the activities.

To join Particle physics with the masters at ATLAS CERN work with your teacher to **set up the Masterclass**.



Screenshot **© CERN**

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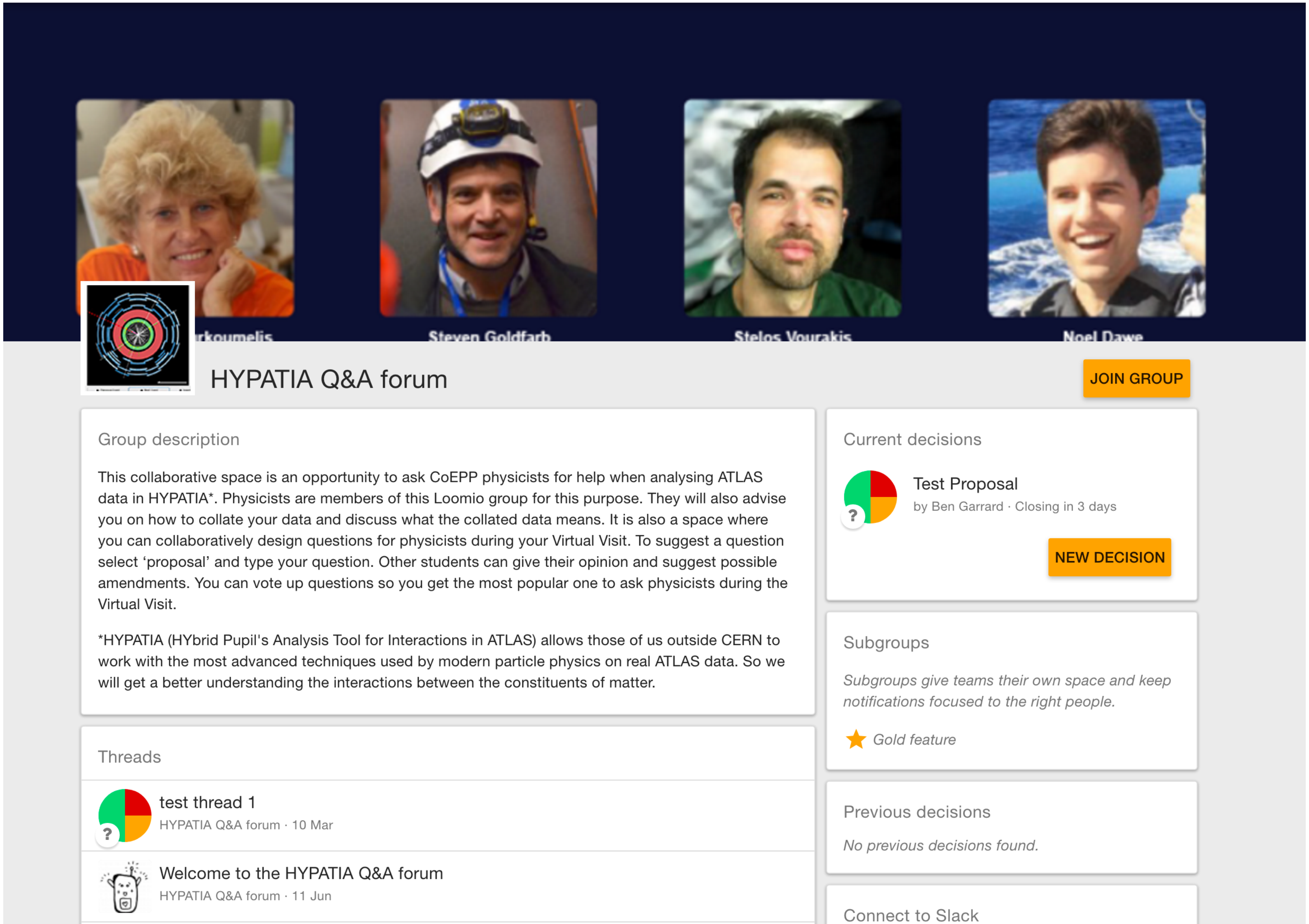

Chat rooms available where students can ask questions to physicists about particle physics in general or specifically about the data analysis tools. Obviously unrealistic that these be continuously available resources…..

Chat rooms available where students can ask questions to physicists about particle physics in general or specifically about the data analysis tools

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SABRE

A new experimental facility in Australia to search for Dark Matter in a low background environment – also good for outreach ☺

5.5 hours from Adelaide
3 hours from Melbourne

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SABRE

In early October representatives from CoEPP (M. Dolan, N. Dawe, I. Bigaran, G. Busoni, S. De La Motte, T. Corbett and M. McDonald) ***held a science camp at 'Halls Gap' for students in the Stawell area*** – it was aimed at year 9-11 students.

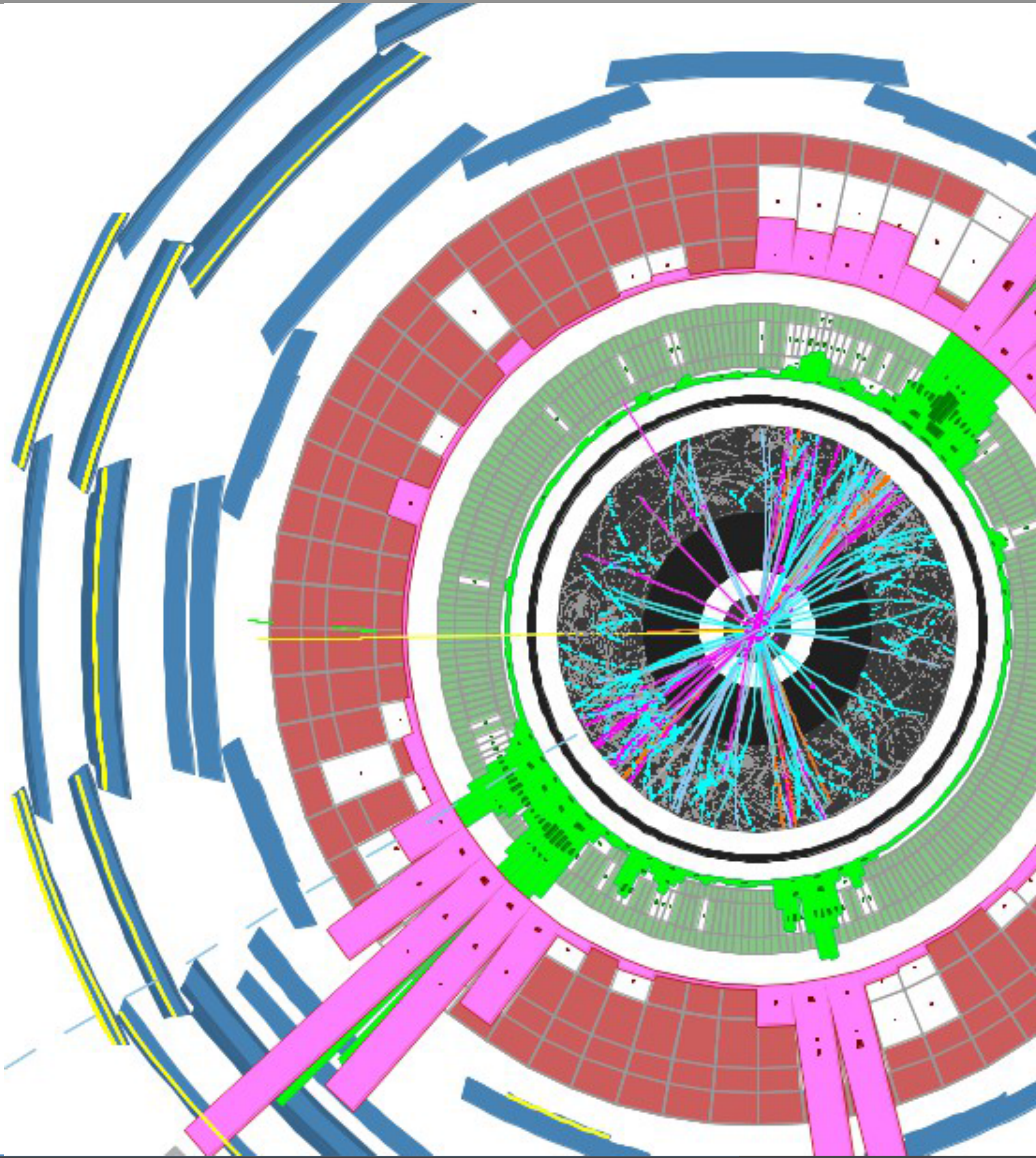
3 days of talks, workshops and activities - with particular focus on the new Stawell Underground Physics Laboratory (SUPL)

Students built models of the LHC with Lego, constructed cloud chambers to detect subatomic particle tracks, students were given a hands on experience of the sort of physics soon-to-be conducted directly underneath them.

- IPPOG members have been crucial in helping push the particle physics MC to NSW schools.
- Resources to support teachers are limited.
- Hoping for progress in future.

- Continued effort to engage school children of all ages in particle physics.

- As budgets tighten outreach opportunities may suffer.



Thanks! Some backup slides may follow

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Subtopic 3.4: Standard Model

In this subtopic students explore theories that describe the composition of subatomic particles and how interactions between those particles can then be used to describe phenomena such as electrostatic repulsion, beta decay, and positron–electron annihilation.

Science Understanding

The Standard Model suggests that there are three fundamental types of particles: gauge bosons, leptons, and quarks.

The Standard Model identifies four fundamental forces: electromagnetic, weak nuclear, strong nuclear, and gravitational.

Gauge bosons are particles which mediate the four fundamental forces. They are often called 'exchange particles'.

Force	Gauge Boson
Electromagnetic	photon
Weak nuclear	W, Z
Strong nuclear	gluon
Gravitational	graviton

The gauge boson for gravitational forces, the graviton, is still to be discovered.

- Describe the electromagnetic, weak nuclear, and strong nuclear forces in terms of gauge bosons.

Leptons, such as electrons, are particles that are not affected by the strong nuclear force.

Quarks are fractionally charged particles that are affected by all of the fundamental forces.

Quarks combine to form composite particles and are never directly observed or found in isolation.

- Distinguish between the three types of fundamental particles.

Possible Contexts

This uses the concept of the nucleus developed in Stage 1, Subtopics 6.1: The Nucleus, and 6.2: Radioactive Decay.

Use the online interactive from the Particle Data Group at Lawrence Berkeley National Laboratory to develop an understanding of the Standard Model.

http://www.particleadventure.org/

Use the following resource on quarks:

http://neutrinoscience.blogspot.co.uk/2015/07/pentaquark-series-what-are-quarks.html

Discuss the research using the Large Hadron Collider which has found that some particles are formed from combinations of four and five quarks:

http://www.symmetrymagazine.org/article/july-2015/lhc-physicists-discover-five-quark-particle

Discuss the adaptation of the Standard Model to include the Higgs boson, to account for the finite masses of various leptons and quarks.

Feynman diagrams can show how gauge bosons mediate the fundamental forces.

Explore the change in understanding of the Standard Model in the light of new information using, for example, high-energy particle accelerators.

Explore the benefits and limitations of using positron–electron annihilation in PET scanners, including for the production of gamma rays.

Research the economic and social impacts of using the cyclotron at SAHMRI to produce radioisotopes for PET scanning.

DRAFT – for teaching in 2018

Science Understanding	Possible Contexts

Science Understanding

There are six types of quark, with different properties, such as mass and charge. Each quark has a charge of either +2/3 or −1/3.

Quark	Symbol	Charge (e)
Up	u	2/3
Down	d	−1/3
Strange	s	−1/3
Charm	c	2/3
Top	t	2/3
Bottom	b	−1/3

All other composite matter particles, such as atoms, are thought to be combinations of quarks and leptons.

Baryons are composite particles that consist of a combination of three quarks.

- Describe how protons, neutrons, and other baryons can be formed from different combinations of quarks.

Each particle is assigned a lepton number and a baryon number.

Lepton numbers can be one of three types:

- electronic lepton number, L_e
- muonic lepton number, L_μ
- tauonic lepton number, L_τ.

The lepton number, regardless of type, for a lepton is 1. All other particles have a lepton number of 0.

The baryon number of a quark is 1/3. All other particles have a baryon number of 0.

For every matter particle there exists an antimatter particle equivalent.

Antiquarks have a baryon number of −1/3 and antileptons have a lepton number of −1. Antiquarks have the opposite charge to their quark equivalent. Quarks and antiquarks can form particles called mesons.

Possible Contexts

Explore how beta minus decay involves the conversion of a neutron to a proton accompanied by the production of an electron and an antineutrino.

Explore how beta plus decay involves the conversion of a proton to a neutron, accompanied by the production of an electron and an antineutrino.

Explore how beta decay can be explained in terms of the conversion of quarks.

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