

Theoretical Physics and Higgs Physics

Dana Jančinová


Joseph Hortezuela

Martina Obdržálková

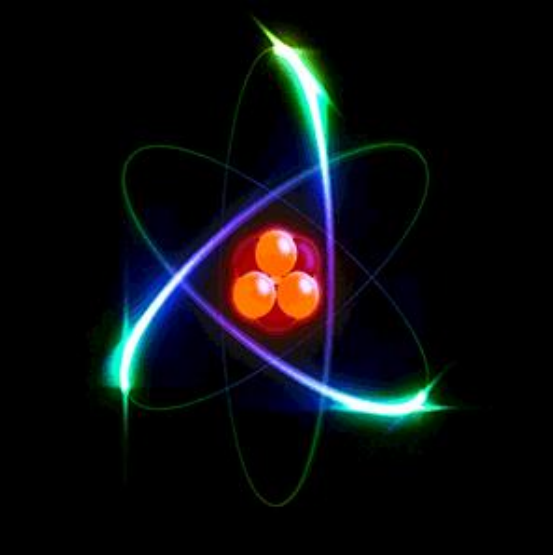
Mary Fisher

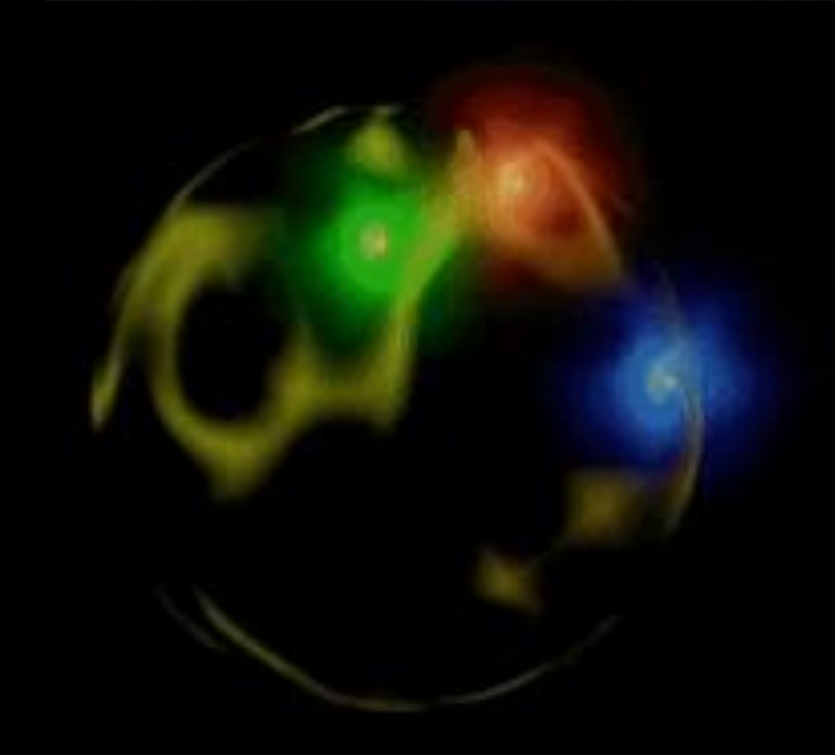
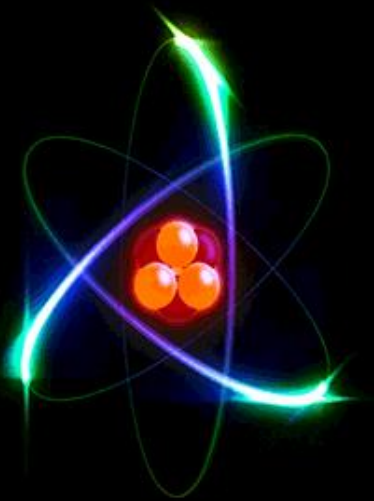
Miljan Rupar

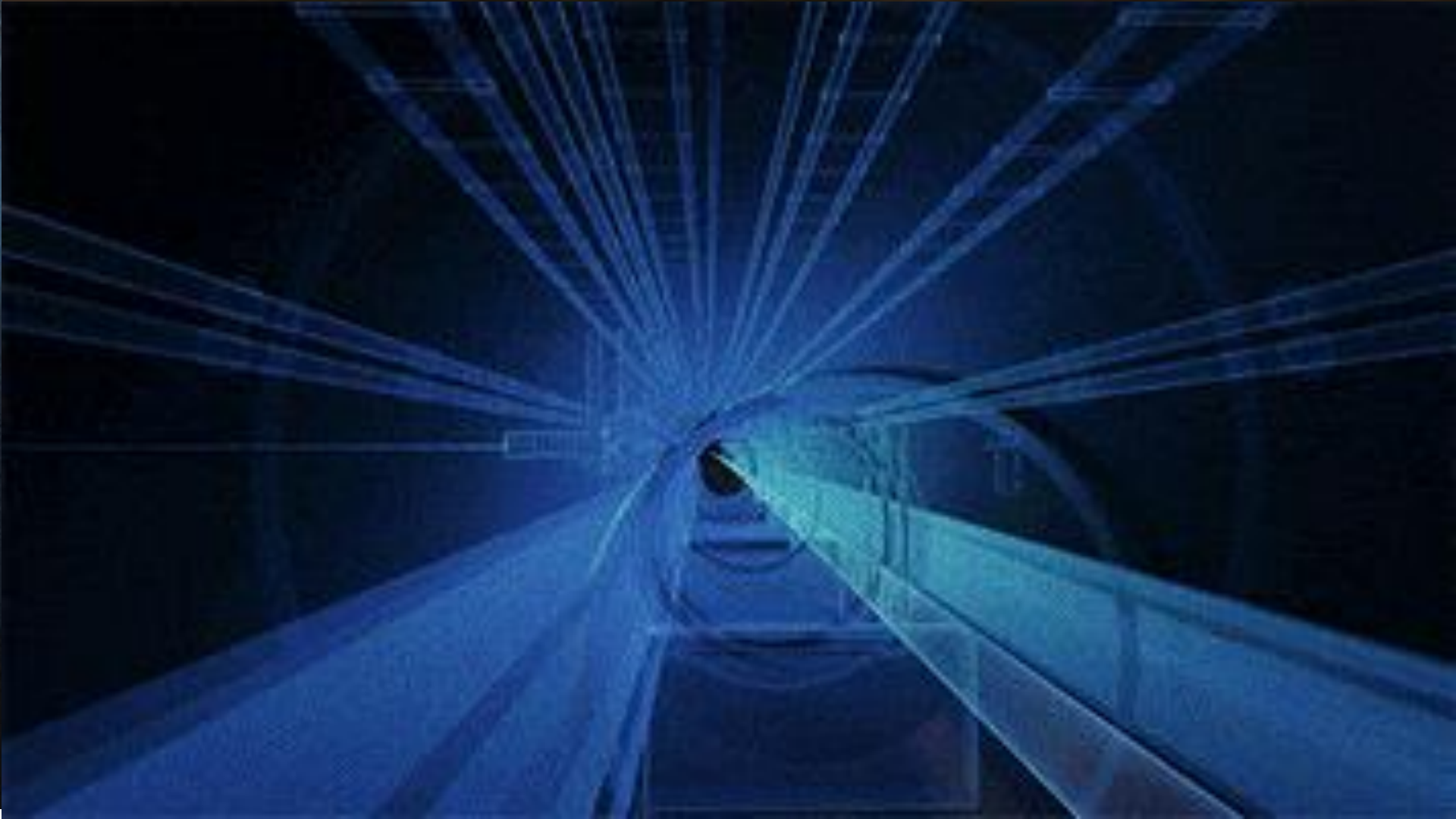




Space: the final frontier









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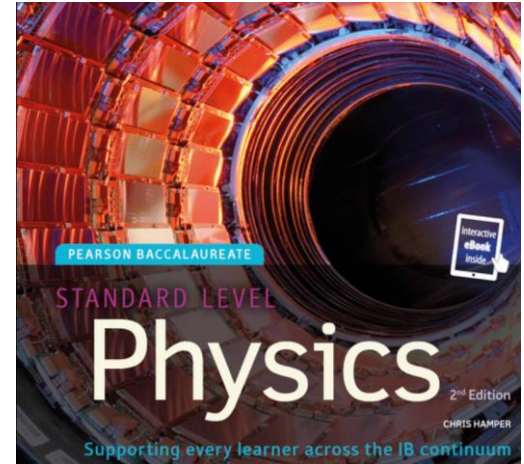
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Curriculum and Classroom Connections

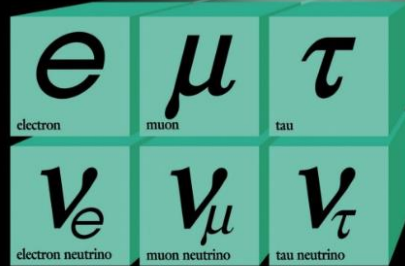
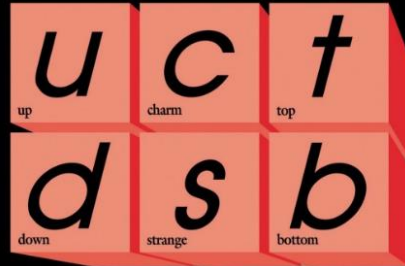
- Concept of **Energy** in Classical Physics Framework
 - **Mass**: result of a dynamic effect of the interaction with a scalar field.
- Next Generation Science Standards (NGSS)
 - **HS-PS3**: *Design, build, and refine a device to convert one form of energy into another form.*
- IB Physics SL and HL
 - **Topic 7.3**: *Structure of Matter*



The structure of matter	7.3	<ul style="list-style-type: none">• Quarks, leptons and their antiparticles• Hadrons, baryons and mesons• The conservation laws of charge, baryon number, lepton number and strangeness• The nature and range of the strong nuclear force, weak nuclear force and electromagnetic force• Exchange particles• Feynman diagrams• Confinement• The Higgs boson
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Fermions: spin = 1/2 particles

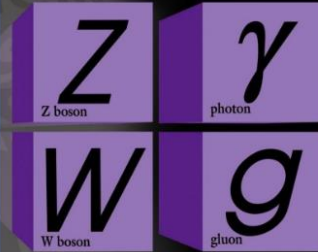
Quarks



Leptons

Vector Bosons: spin = 1 particles

Forces



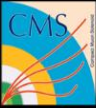
Higgs Boson:
spin = 0
fundamental
scalar particle

Key ideas

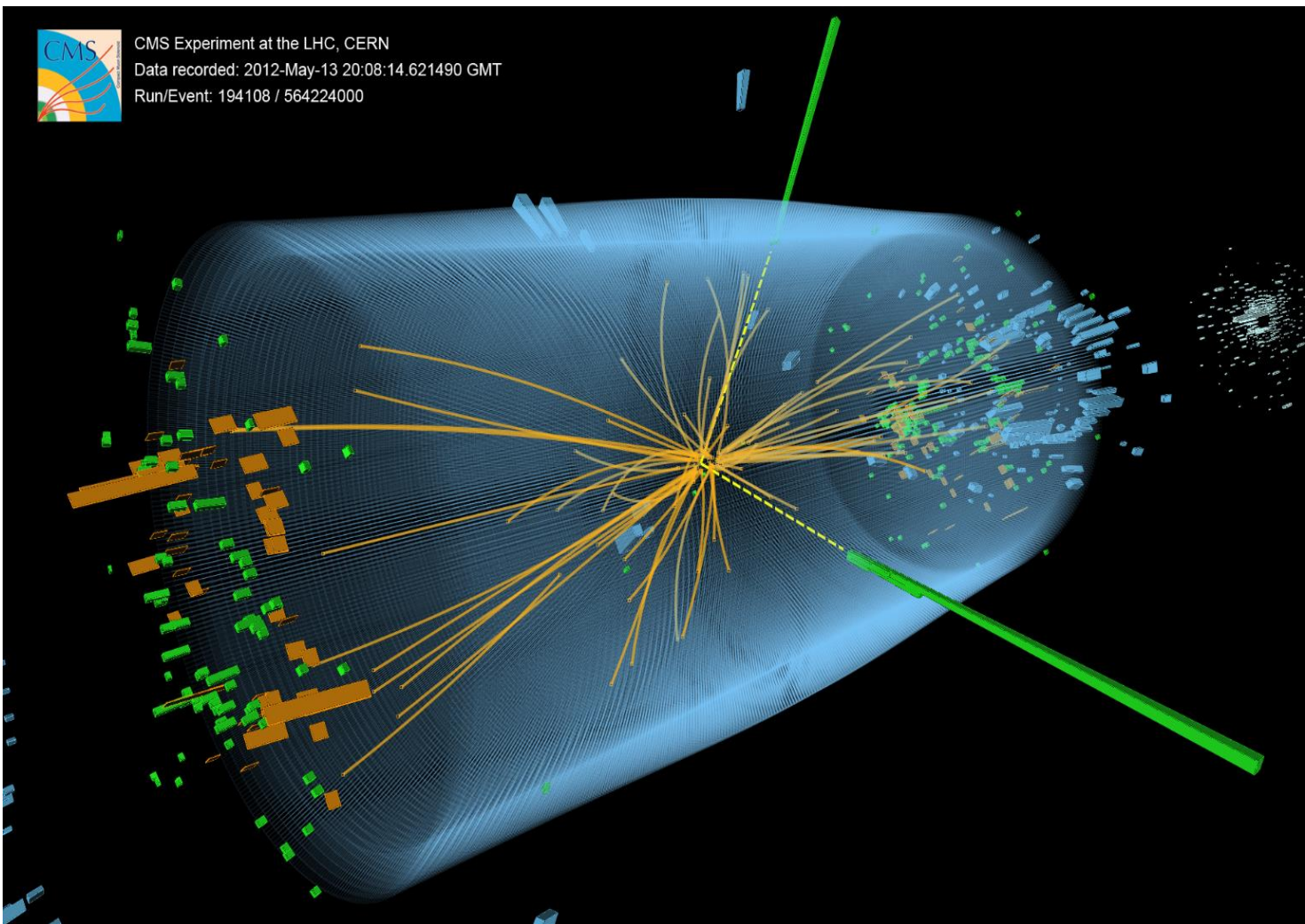
- 1964 - THEORY - Peter Higgs suggested an existence of a new field
- 2012 - EXPERIMENT - the Higgs boson associated with the Higgs field has been detected at Cern and announced to general public
- 2013 - NOBEL PRIZE - for Peter Higgs and Francois Englert

First question:

Why there has been so much excitement and delight about Higgs boson?

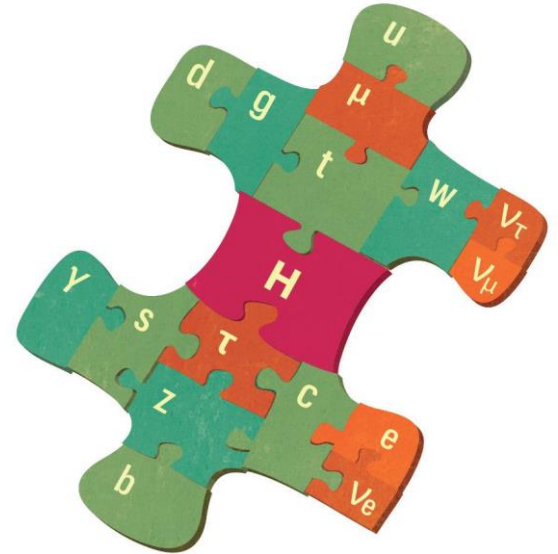
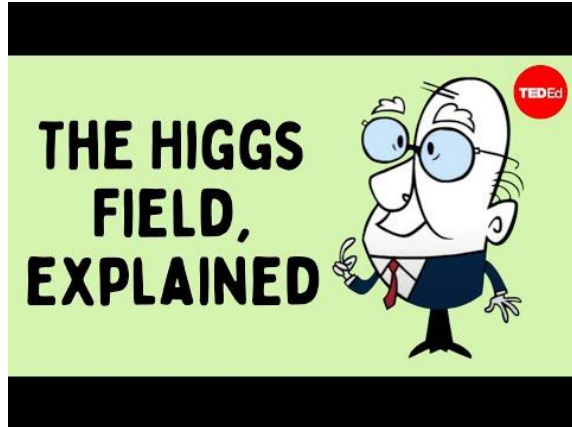


CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000



Higgs field and Higgs particle/boson

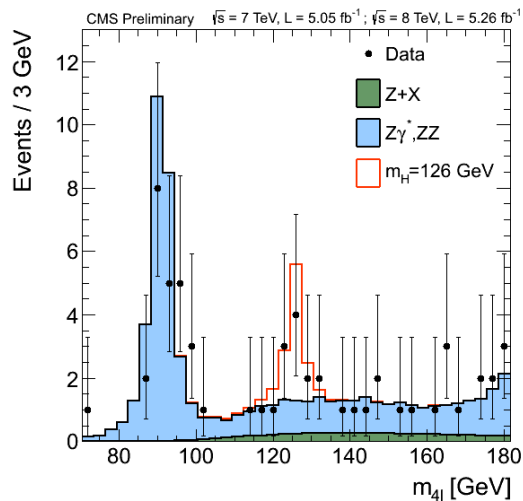
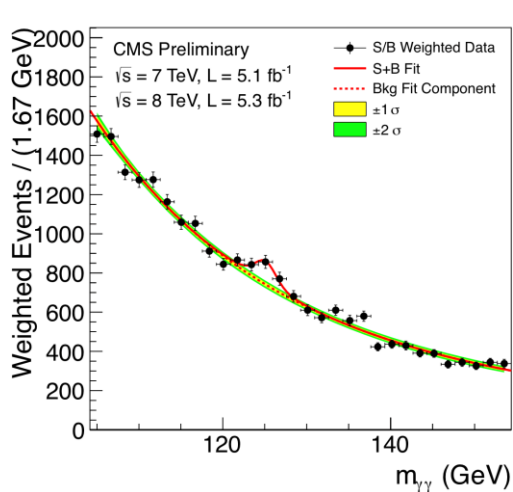
- Last piece of puzzle to standard model
- Answer to the very basic question
 - What gives the particles their mass
- On the cutting-edge of Physics research
- Best analogy so far - room filled with people



Texas A&M University

How does the research work:

1. Theory - expectations
2. Experiment - real data
3. Do the experimental data correspond with theoretical expectations?



An Alternative approach

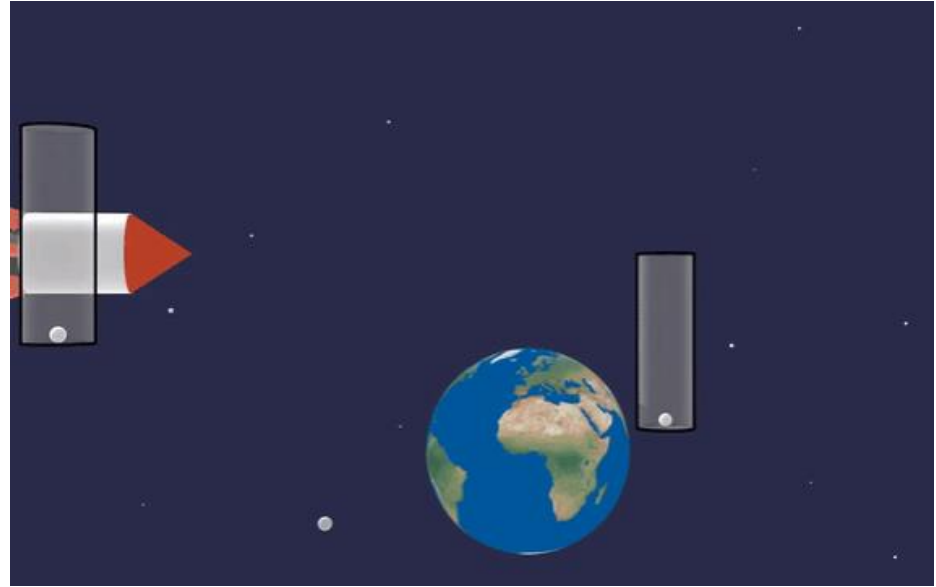
1. Experiment(s) which does not match with current theory
2. Theory explaining it
3. Predictions
4. Can the predictions of the theory be proven by an experiment?

Potential students' conceptions & challenges



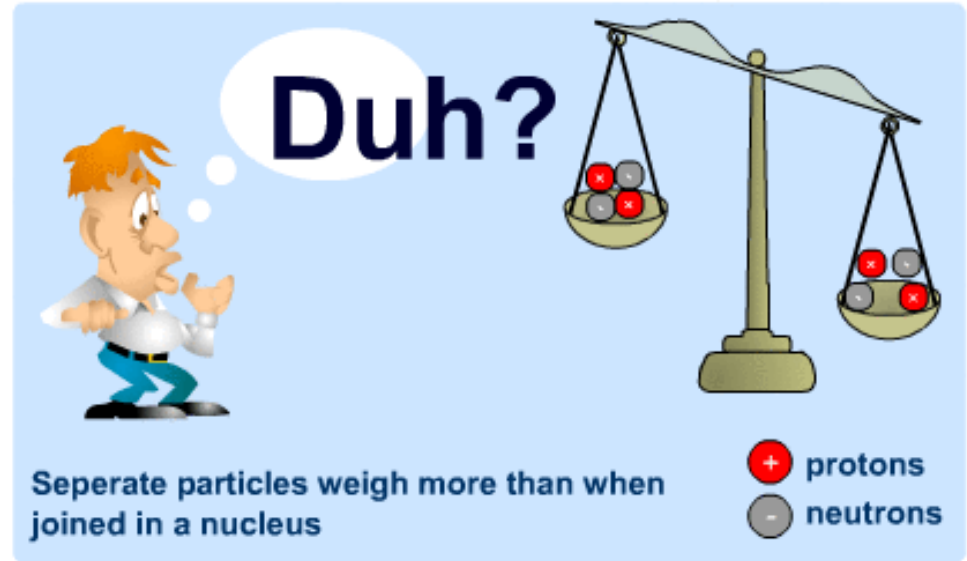
Potential students' conceptions & challenges

- Relativistic physics - time dilation.
- Nuclear physics - mass defect
- Particle physics - annihilation, creation oscillation



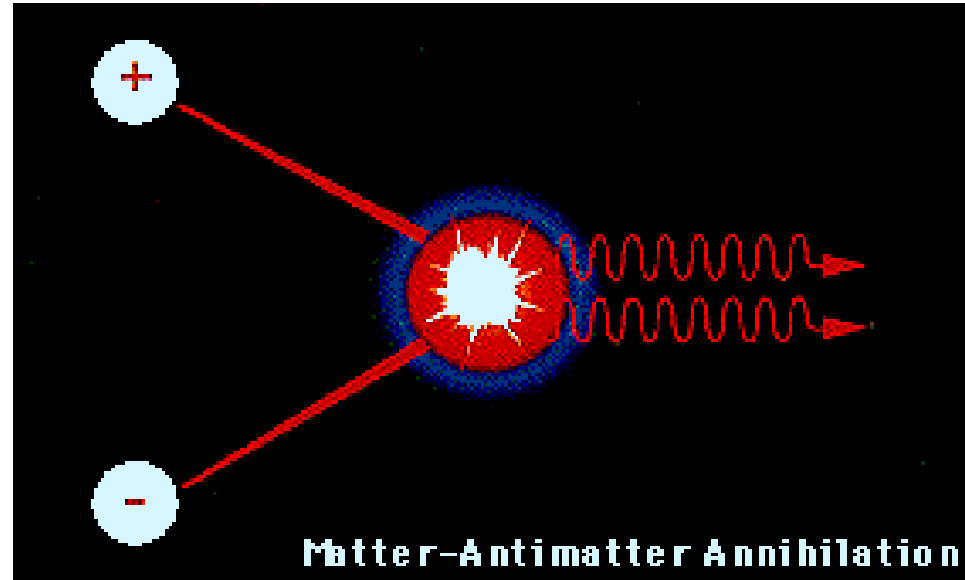
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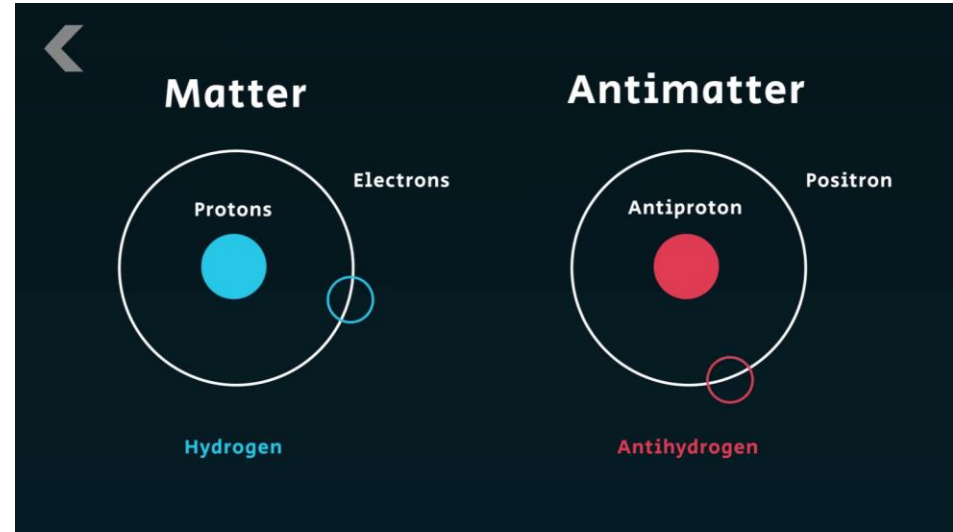
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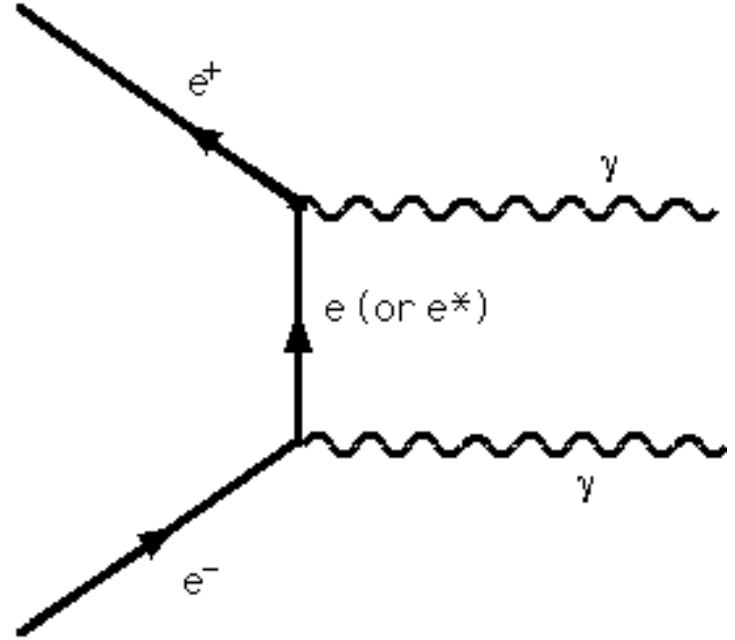
Potential students' conceptions & challenges

- Antimatter
- Opposite of timeflow direction of antimatter



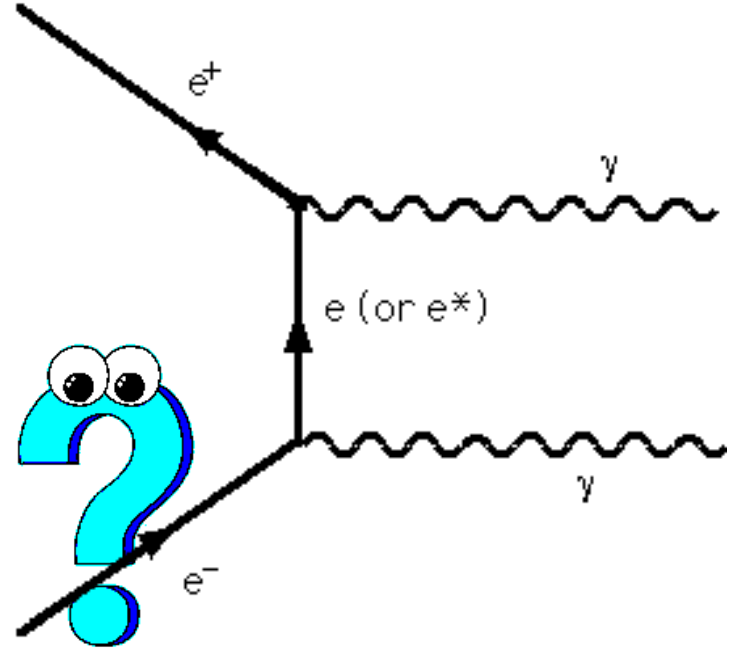
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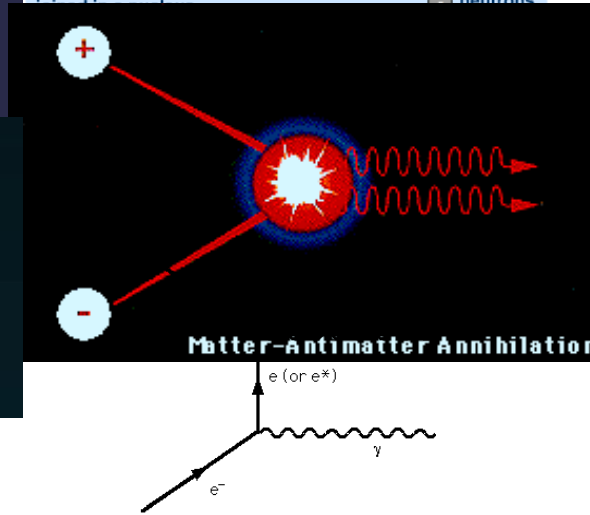
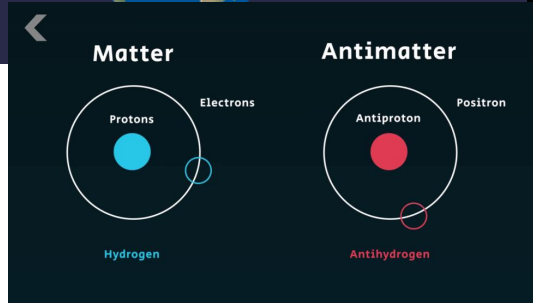
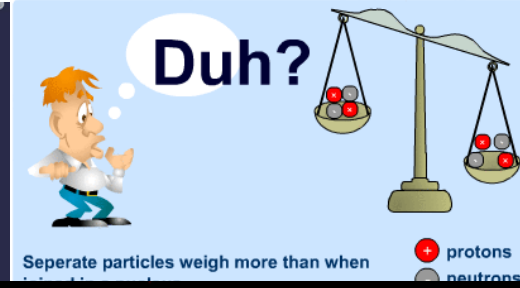
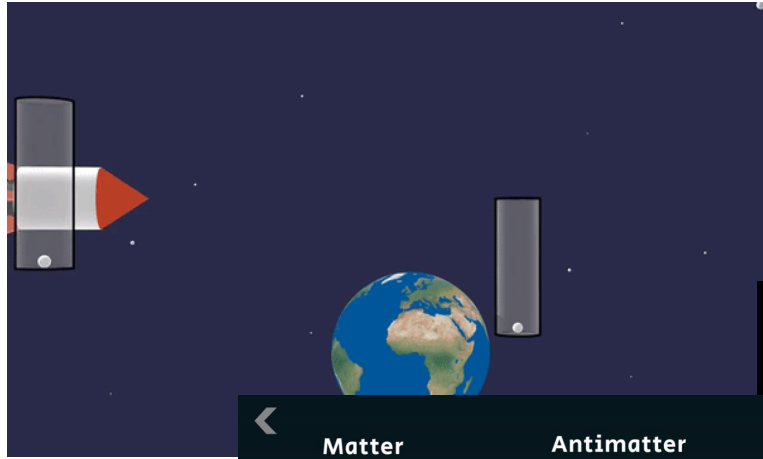


Potential students' conceptions & challenges

- Antimatter
- Opposite of timeflow direction of antimatter



Potential students' conceptions & challenges



Potential students' conceptions & challenges

The collage consists of several overlapping images and diagrams:

- Top Left:** A rocket launching from Earth into space.
- Top Center:** A large blue question mark with eyes, set against a white background.
- Top Right:** A balance scale with two pans. The left pan is higher and contains three red spheres (protons) and one grey sphere (neutron). The right pan is lower and contains two red spheres and two grey spheres. Text below reads "uh?" and "igh more than when". A legend indicates a red circle is a proton and a grey circle is a neutron.
- Center:** A glowing blue brain.
- Bottom Left:** A diagram titled "Matter" showing a central blue circle labeled "Protons" surrounded by a larger white circle labeled "Electrons". Below it is the word "Hydrogen".
- Bottom Center:** A plus sign (+) in a white circle.
- Bottom Right:** A diagram titled "Matter-Antimatter Annihilation" showing a central red and white explosion with red wavy lines radiating outwards. Below it, a diagram shows an electron (e^-) and a positron (e^+ or e^{*}) colliding to produce a gamma ray (γ).

Helpful resources



The W^+ boson has a positive electric charge. It is the mediator of the weak interaction, which allows particles to transform into other particles. The W^+ boson is therefore very important in the nuclear fusion reactions that power our sun, where protons transform into neutrons.



The anti-muon neutrino is the ant-particle of the muon-neutrino. Neutrinos are extremely light particles that almost never interact with other particles. Every second more than 100 trillion neutrinos pass through your body and you don't even notice them!



PARTICLE IDENTITIES



https://scoollab.web.cern.ch/sites/default/files/Particle_v2/index.html

Helpful resources

The Quark Puzzle

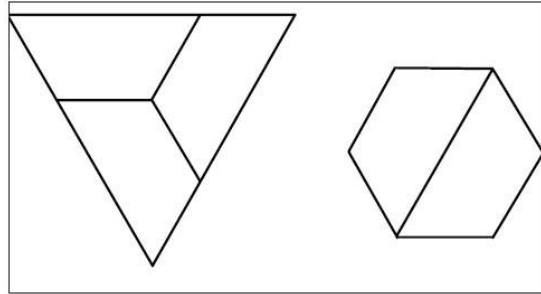


Fig. 1. Primitive three-quark baryon and a two-quark meson.

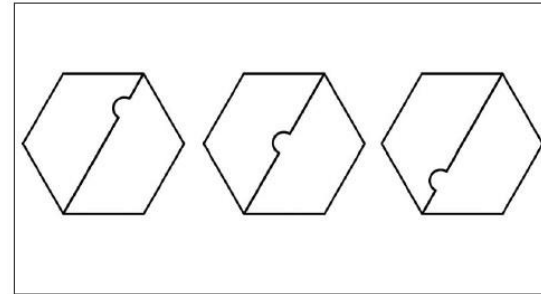


Fig. 2. The addition of lobes that control quark conot/anit-color pairings in mesons.

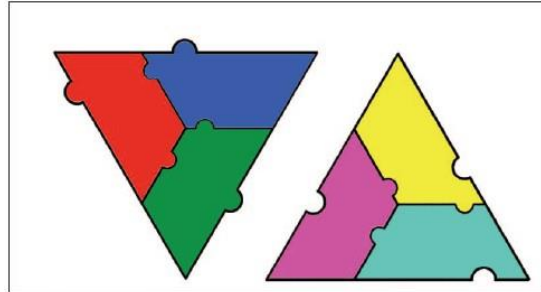


Fig. 3. A matter baryon and an anti-matter baryon.

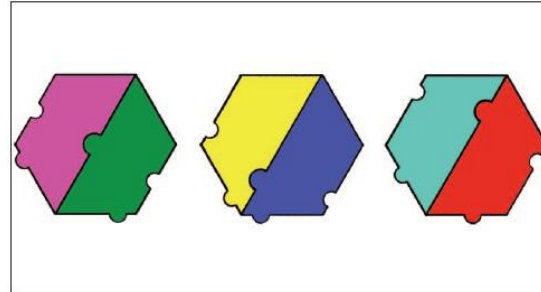
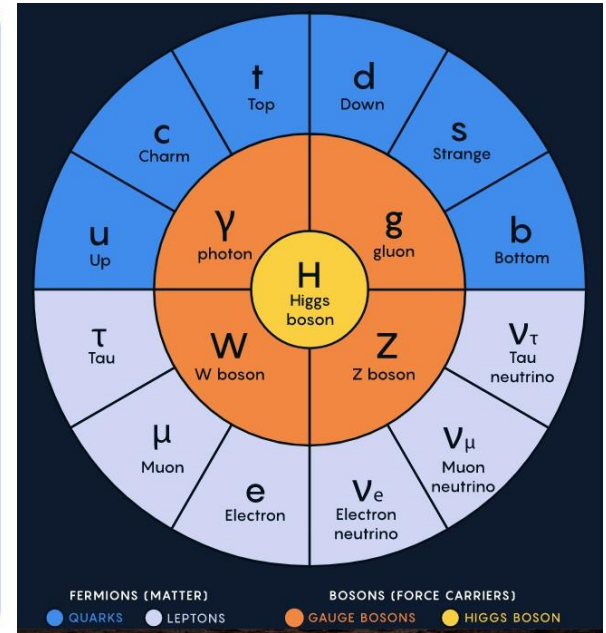
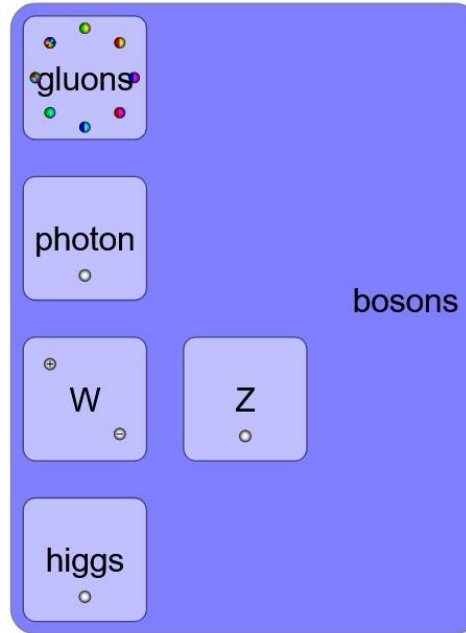
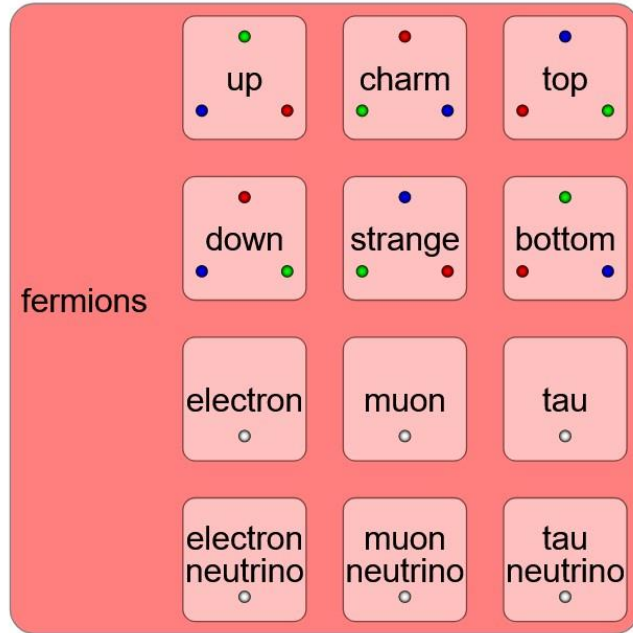


Fig. 4. The three possible color pairings for mesons.

<https://aapt.scitation.org/doi/10.1119/1.3393062>

Helpful resources

The Table of Particles



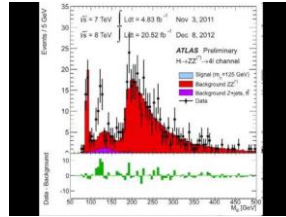
<https://physics.info/standard/>

<https://www.quantamagazine.org/a-new-map-of-the-standard-model-of-particle-physics-20201022/>

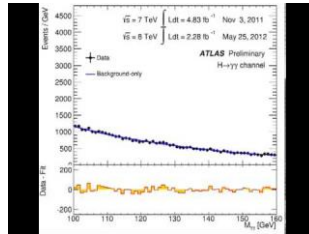
Helpful resources

Finding the Higgs Boson

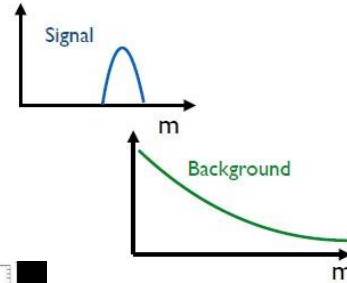
The animation of signal accumulation in the Higgs boson decaying to four leptons channel



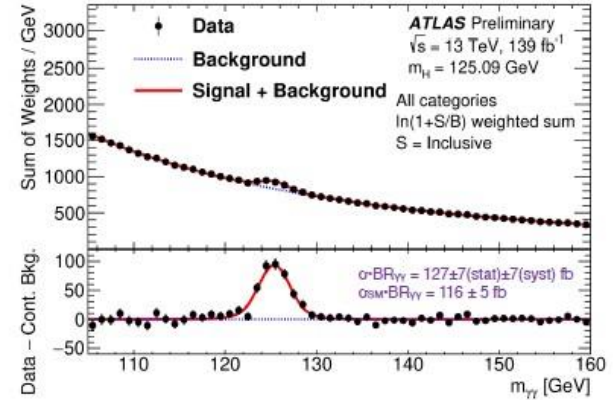
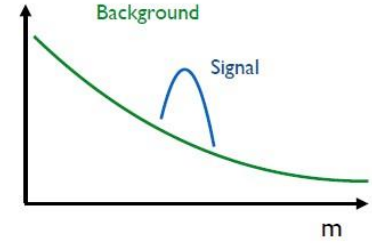
The animation of signal accumulation in the Higgs boson decaying to two-photon channel



Step 2



Step 3



Best Practice - an Idea - Higgs Day

Higgs Day - How could it look - Or could be a sequence of lessons

Approx 2 hours that would be 'off timetable' for around 14 years old students

20 mins Discussion - what is mass, what are we made of?

10 mins - measure the mass of different tins as they would feel on the different planets?

10 mins demo the magnetic fields with ironing filings - link to Higgs field

How scientists work - discovery process

40 mins Modelling the discovery of the Higgs field using dice and plotting graph

Modelling the Discovery of the Higgs boson

Do the 'half life' experiment to get an exponential decay curve first of all

Then explain that one student will steal and add to different groups - students make prediction

One/two student is the 'naughty one' who you release part way through the exercise to steal and add cubes to the different groups.

Should see a different graph

