Theoretical Physics and Higgs Physics

Dana Jančinová

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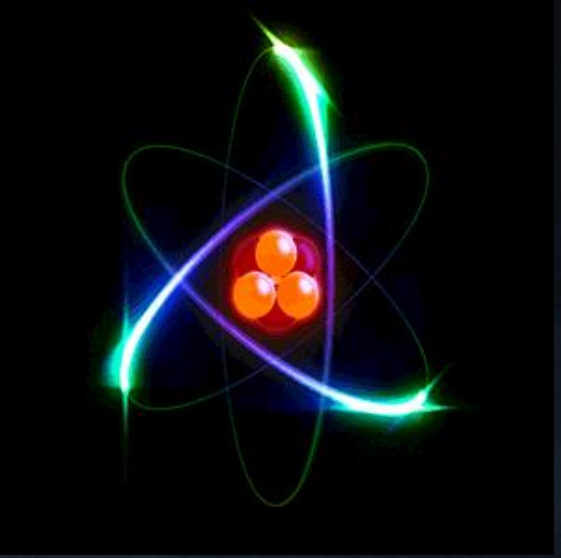
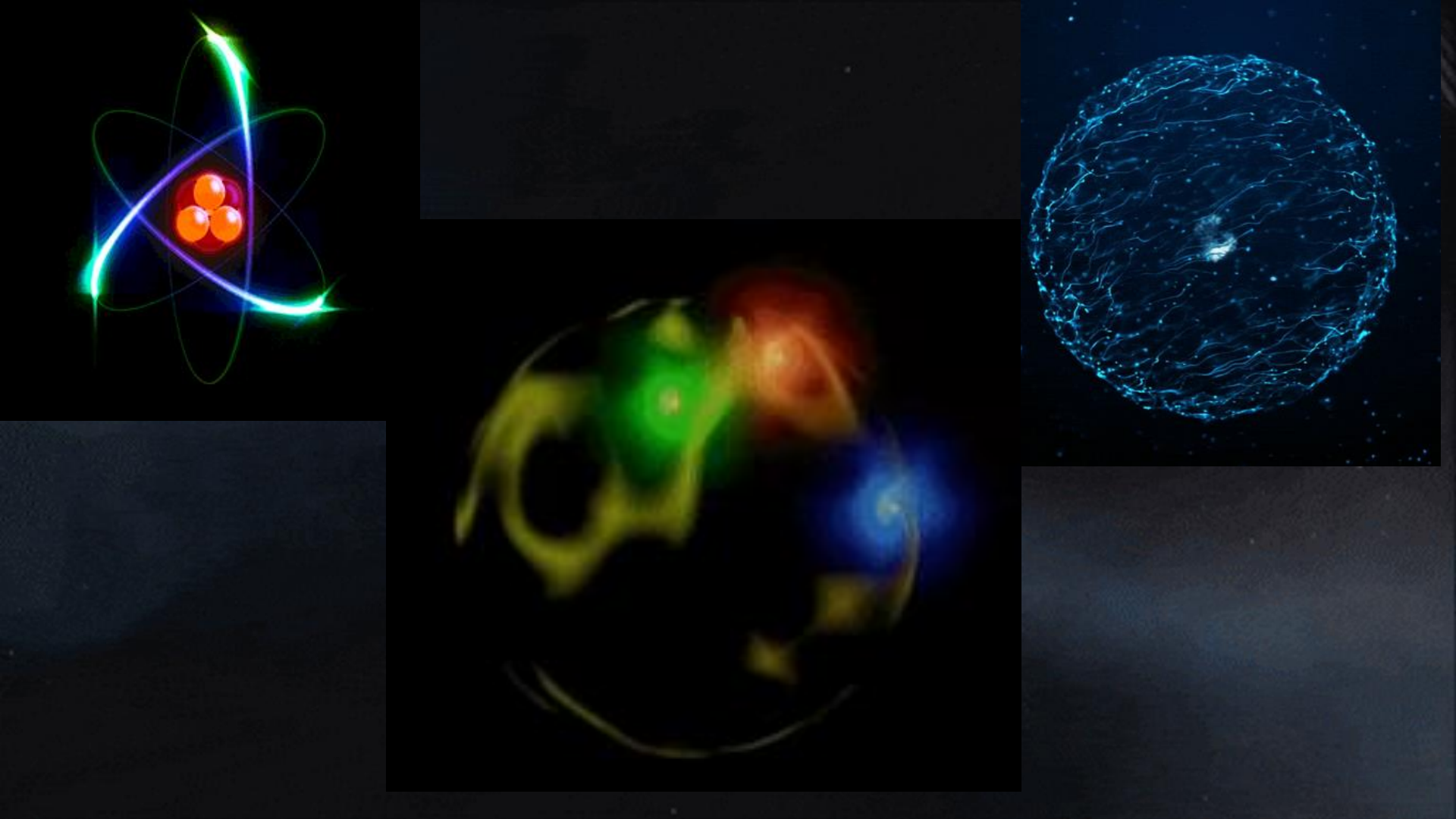
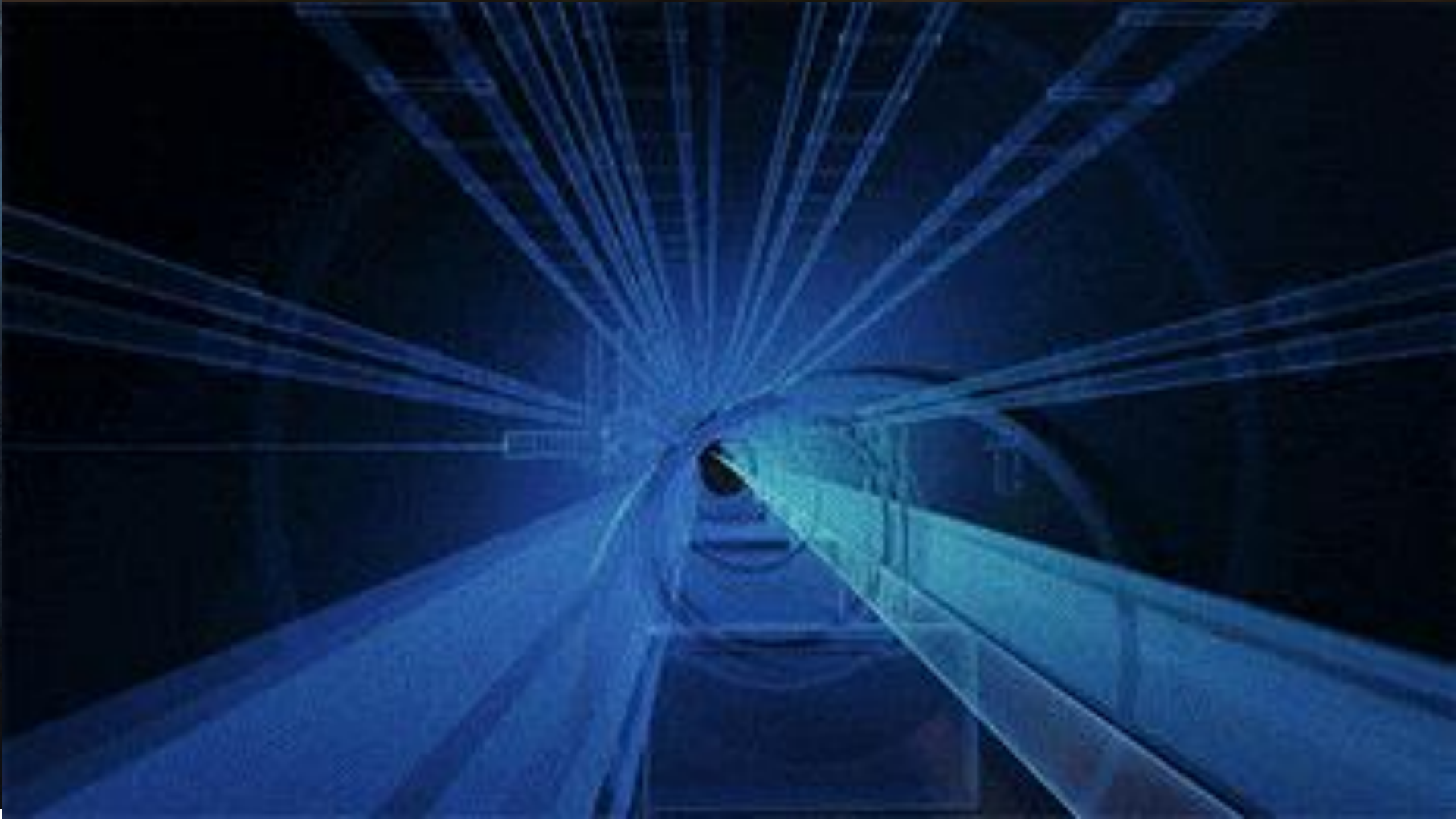
Space: the final frontier







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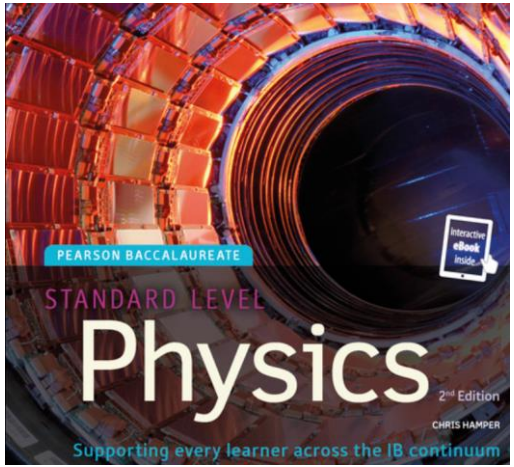
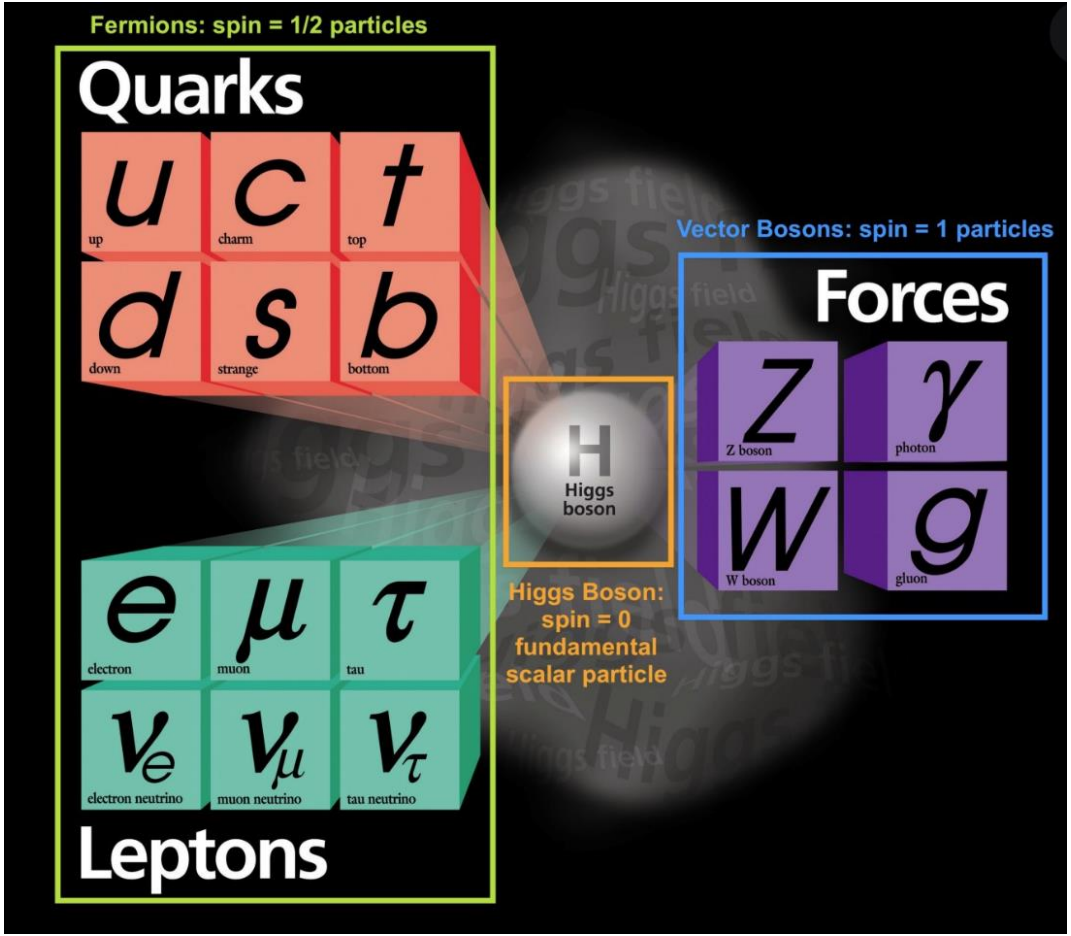
Curriculum and Classroom Connections

- 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	• 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


Fermions: spin = 1/2 particles
Quarks
u
up
c
charm
t
top
d
down
s
strange
b
bottom
e
electron
μ
muon
τ
tau
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
Leptons
H
Higgs boson
Higgs Boson: spin = 0 fundamental scalar particle
Vector Bosons: spin = 1 particles
Forces
Z
Z boson
γ
photon
W
W boson
g
gluon

Key ideas

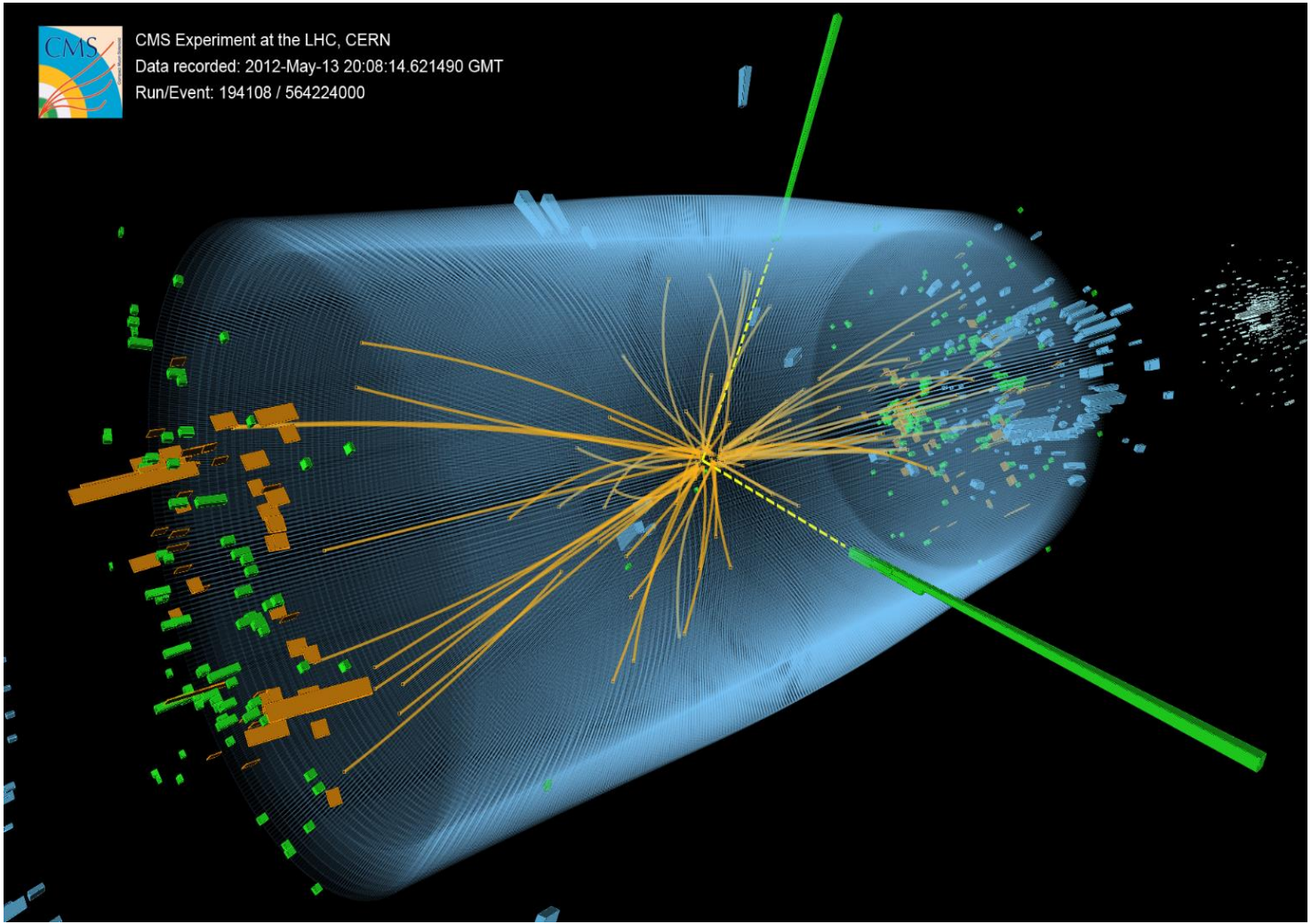
- 1964 - THEORY - Peter Higgs suggested an existence of a new field

- 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

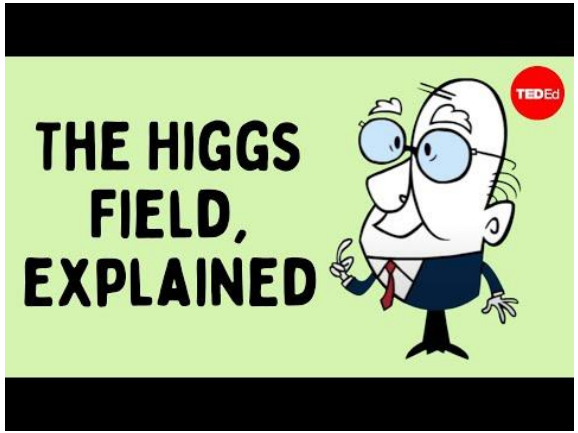
First question:

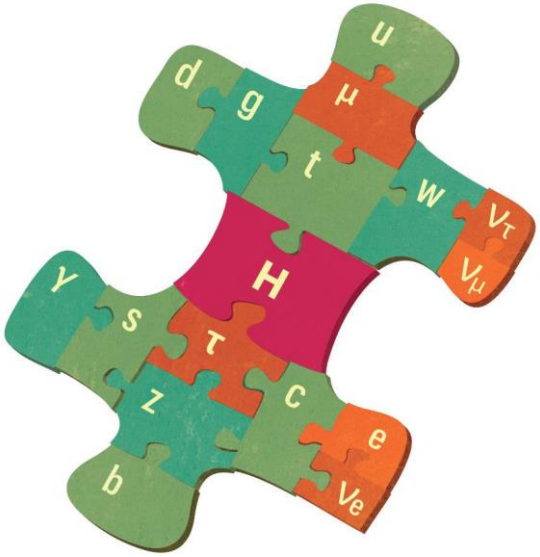
Why there has been so much excitement and delight about Higgs boson?


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

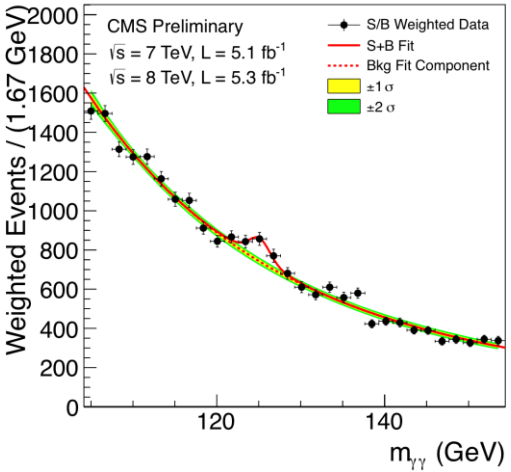
- Last piece of puzzle to standard model
- Answer to the very basic question
  - What gives the particles their mass
- On the cutting-edge of Physics research
- Best analogy so far - room filled with people

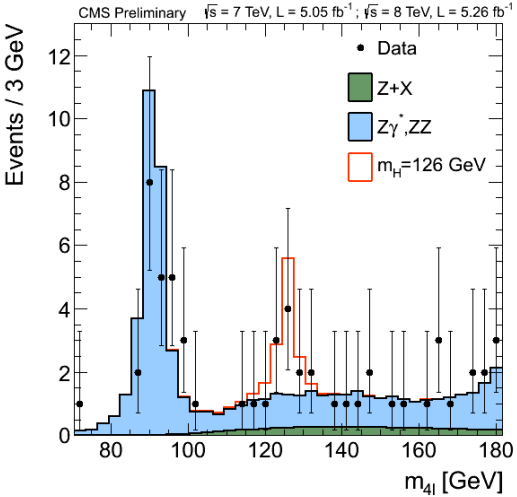




How does the research work:

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

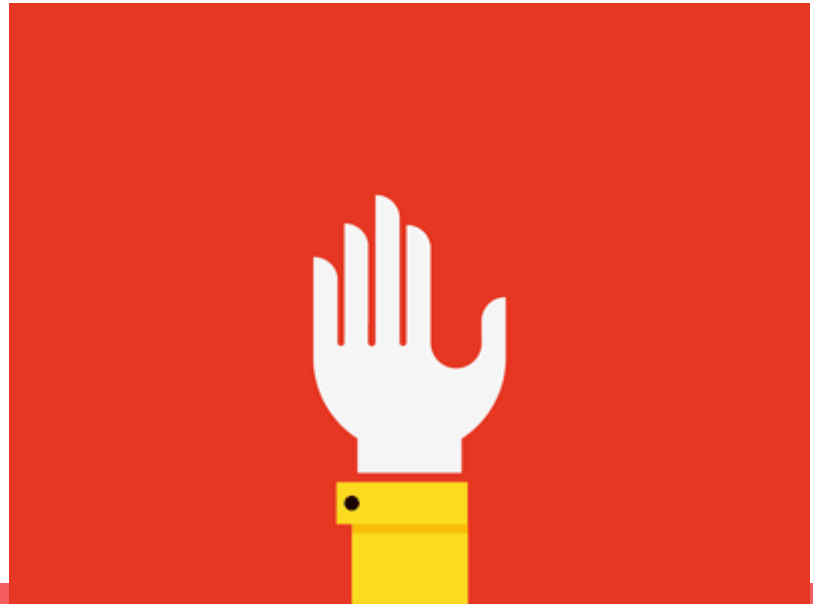




An Alternative approach

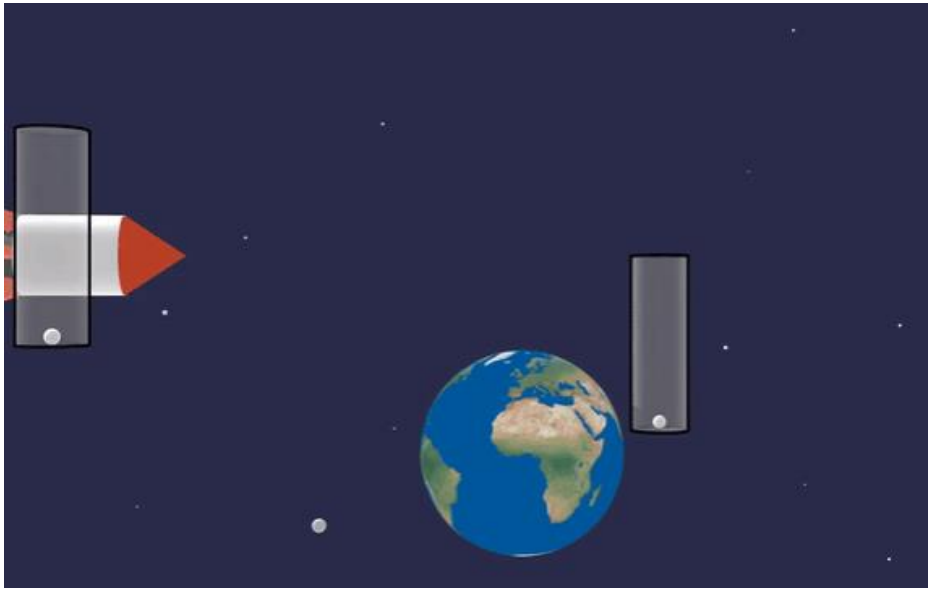
1. Experiment(s) which does not match with current theory
2. Theory explaining it
3. Predictions
4. Can the predictions of the theory be proven by an experiment?

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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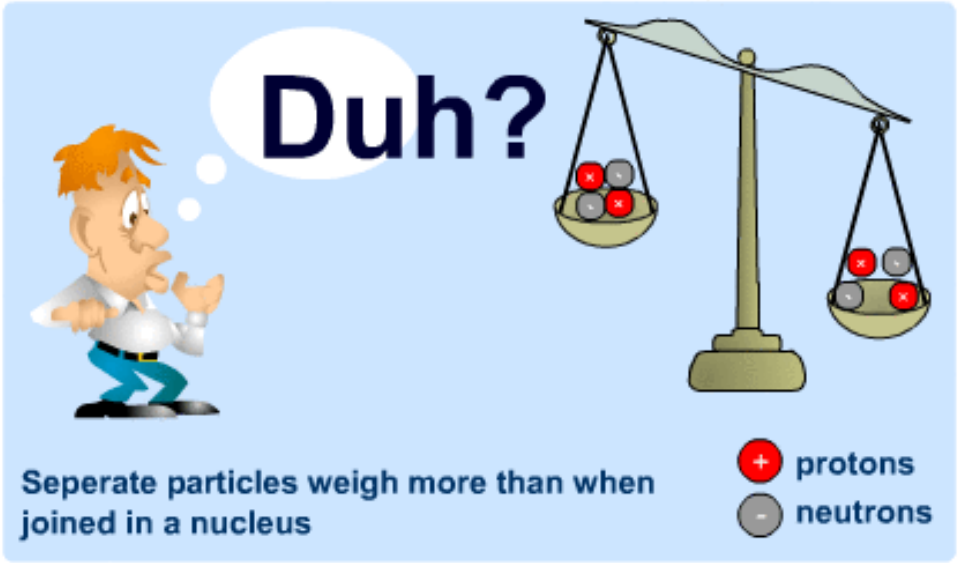

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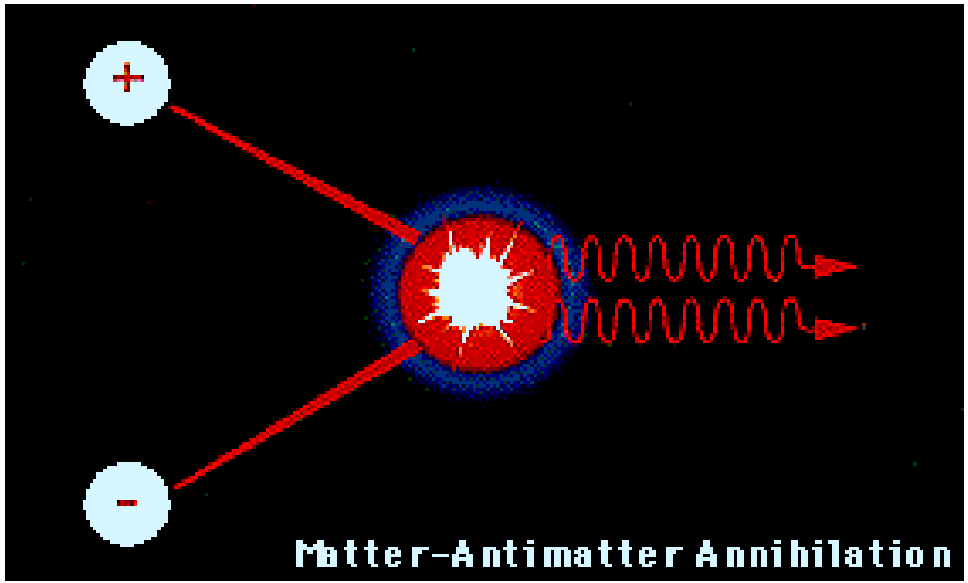
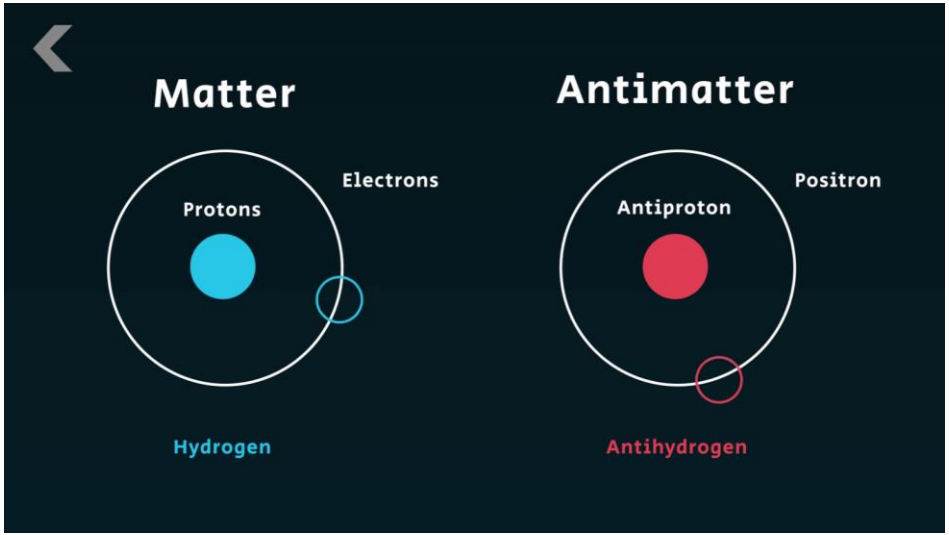


Potential students' conceptions & challenges

- Antimatter

- Opposite of timeflow direction of antimatter



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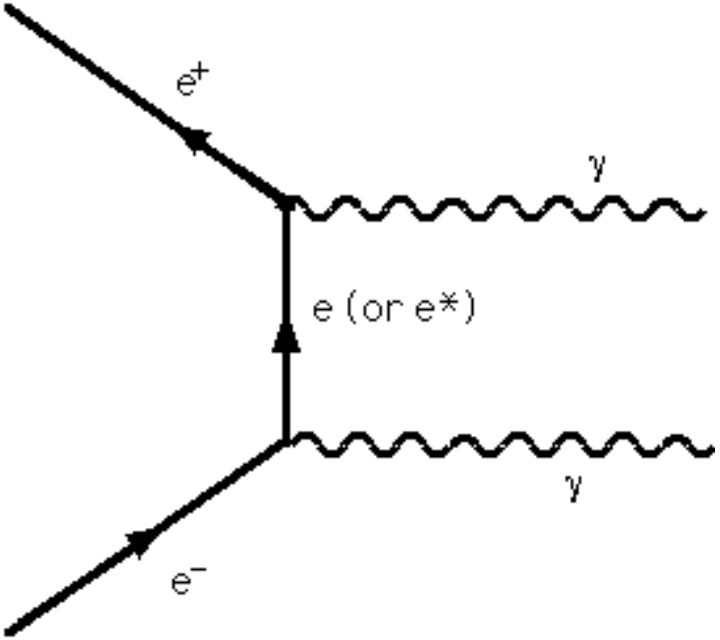

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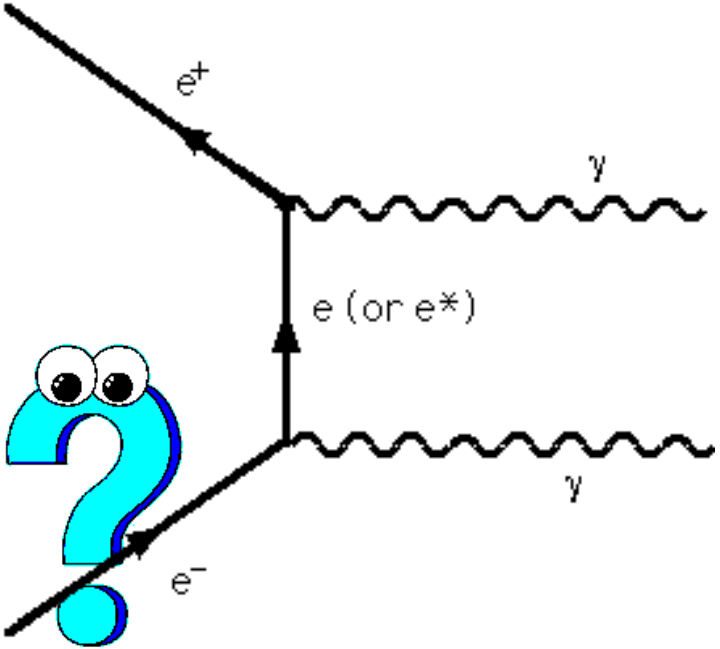

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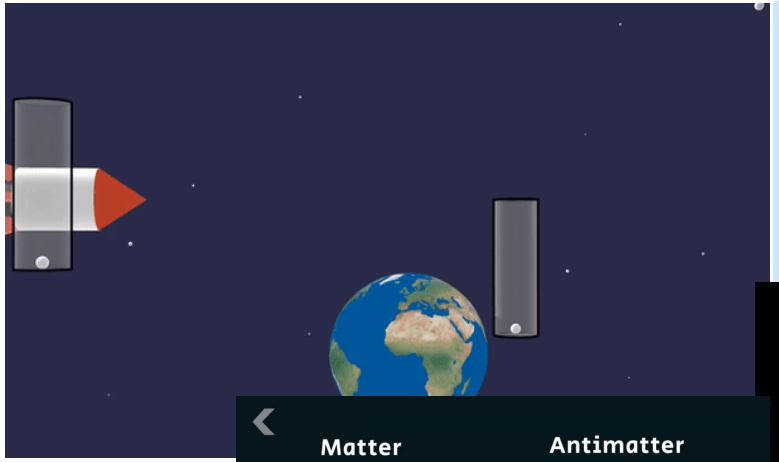

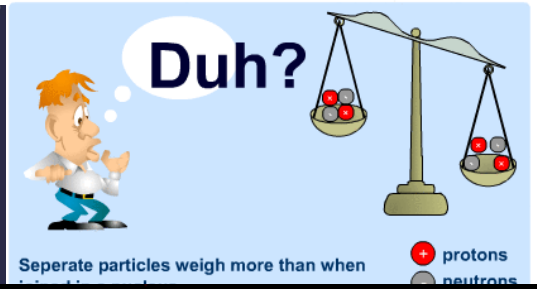

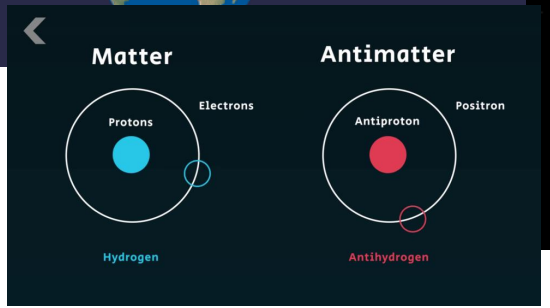

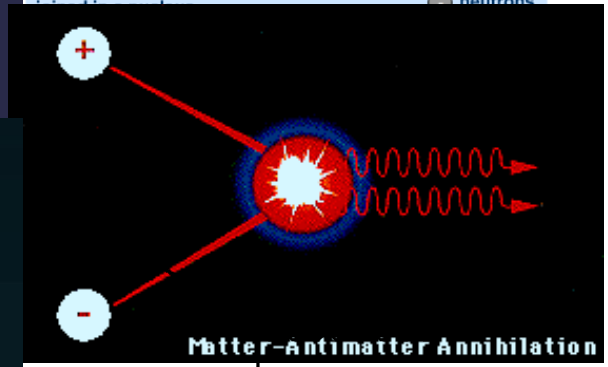

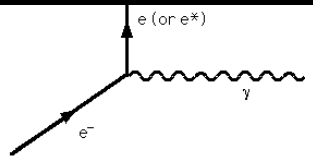

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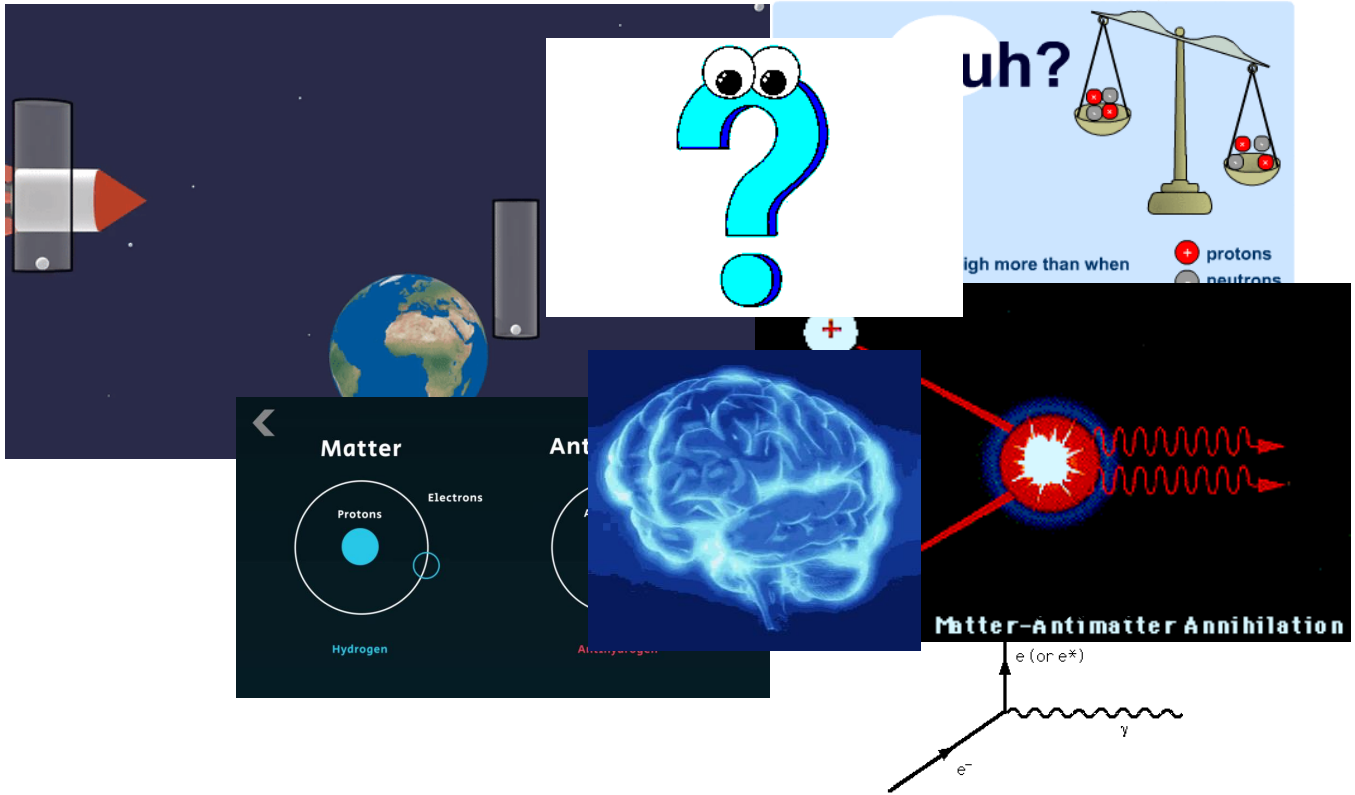


Helpful resources

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

Helpful resources

The Quark Puzzle

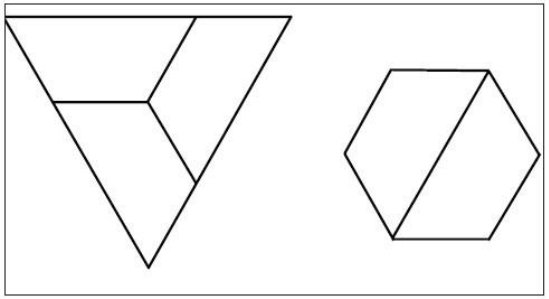


Fig. 1. Primitive three-quark baryon and a two-quark meson.

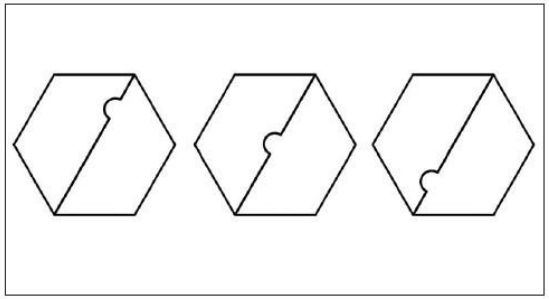


Fig. 2. The addition of lobes that control quark conot/anit-color pairings in mesons.

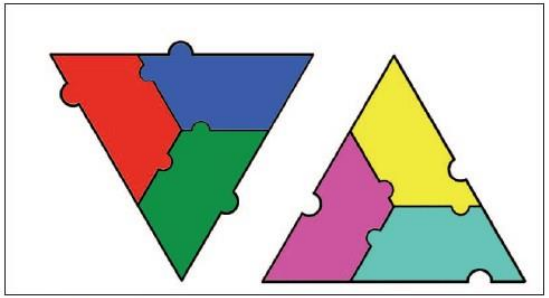


Fig. 3. A matter baryon and an anti-matter baryon.

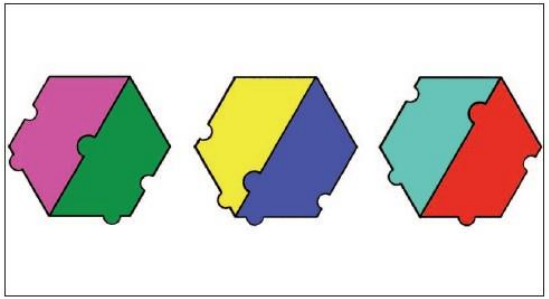
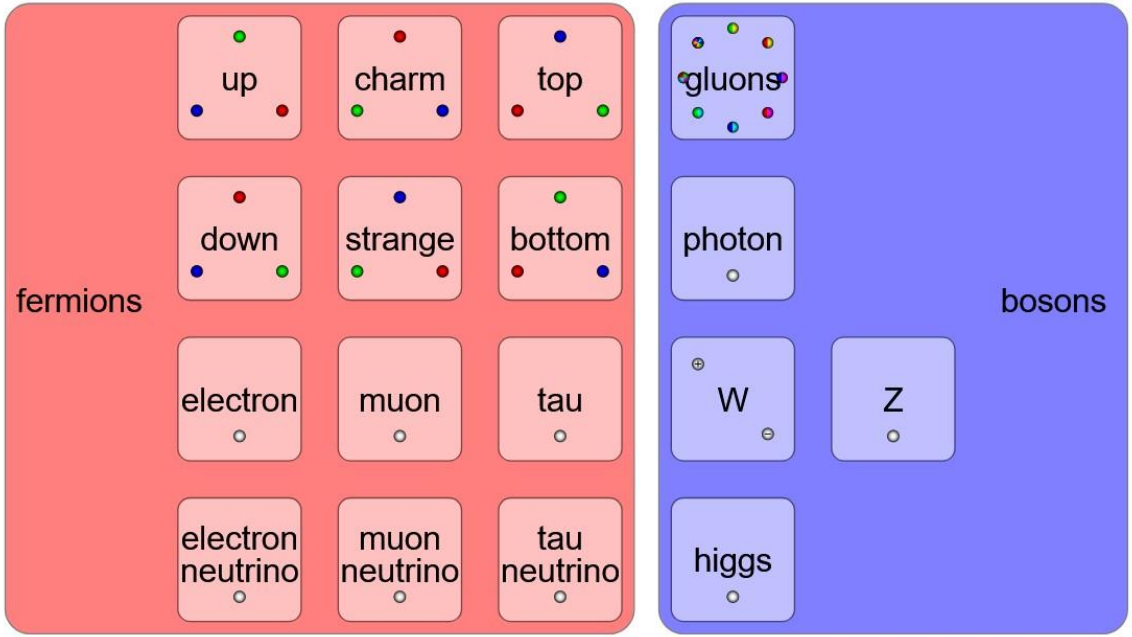


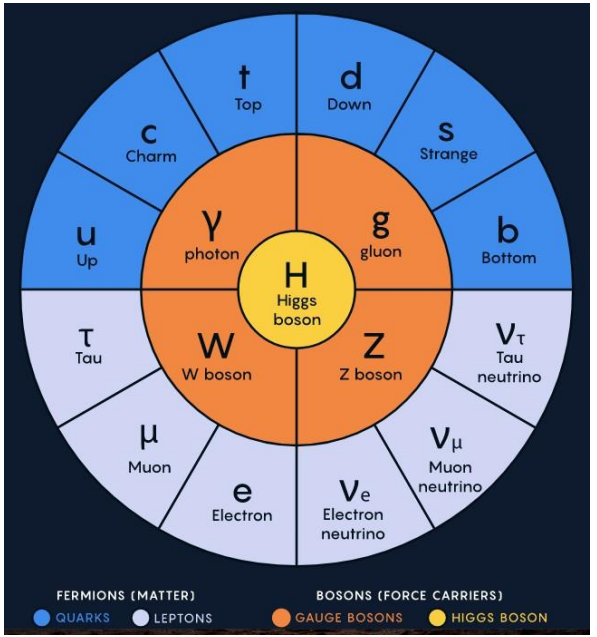
Fig. 4. The three possible color pairings for mesons.

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

Helpful resources

The Table of Particles

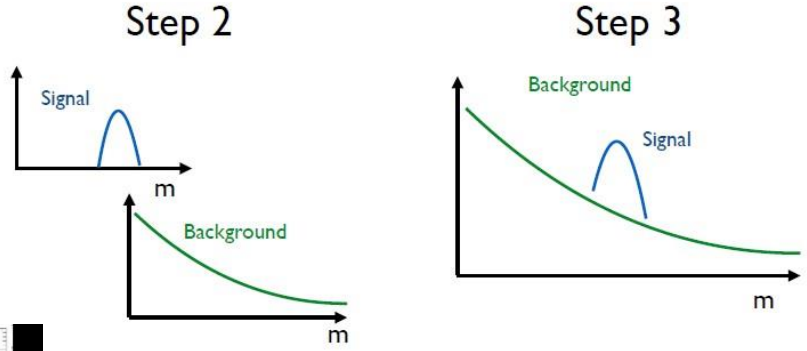




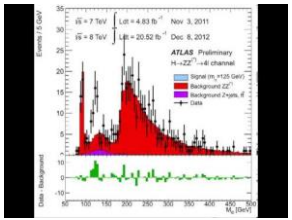
https://physics.info/standard/

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

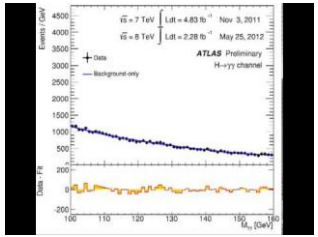
Helpful resources
Finding the Higgs Boson

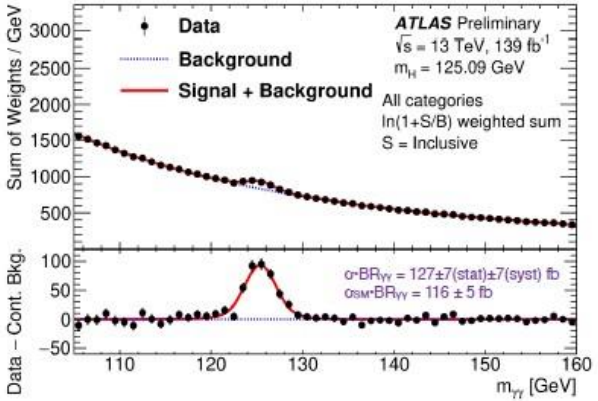


The animation of signal accumulation in the Higgs boson decaying to four leptons channel



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





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