Particle Physics - Welcome
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International Student Science Fair 2015
Monash University
About 100 years ago, Mendeleev proposed the periodic table. Today, we know it can be reduced to just a few ultra-fundamental constituents and the forces that act between them.
Abstractly, we think of an idealised “pointlike” particle

But could we ever really see “a point”?

How do we see, in the quantum world?

To see something small, we scatter waves off it

➔ Heisenberg’s uncertainty principle.

To resolve “a point”, we would need infinitely short wavelengths

Heisenberg would then give it an infinitely hard kick
Kick it as hard as we can

The Large Hadron Collider
CERN, Geneva, Switzerland
“Stable beams” for run 2: June 3rd, 2015

What are we really colliding?
Take a look at the quantum level

Quantum fluctuations inside fluctuations inside fluctuations ...

u d u

proton
Kick it as hard as we can

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Hadrons are composite, with time-dependent structure:

\[ u_u d_u g_u p_f(x, Q^2) = \text{number density of protons at momentu} \]

\[ \text{protons} \]

\[ \text{protons} \]

Linguistics (example):

\[ F_2(x, Q^2) = \sum_i e^2_i x f_i(x, Q^2) \]

\[ \text{structure function proton distributions} \]
What we see when we look at the quarks inside the proton

- An ever-repeating self-similar pattern of quantum fluctuations
- At increasingly smaller distance scales: *scaling*
- To our best knowledge, this is what a fundamental (‘elementary’) particle really looks like
What we see when we look at the quarks inside the proton

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Nature makes copious use of such structures

Called **Fractals**

Note: this is not an elementary particle, but a different fractal, illustrating the principle
The Meaning of Fundamental

Similar phenomenon when you kick/hit particles:
   Accelerated charges radiate
   ➔ Self-similar pattern of bremsstrahlung; “jets”

Any deviation from this ever-repeating scaling behaviour
   Would indicate “substructure”
   A new level of fundamental

Superstring theory?
   Probably beyond our reach

Still, the fundamental content of the universe is …

Expect we could resolve something like this at the “Planck Scale” > billion times LHC energies …
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This Morning

• Play “Quantum Tic-Tac-Toe” to learn hands-on the weird rules of Quantum Mechanical “superpositions”

• Play “Virtual Atom Smasher” to adjust the parameters of a real-world particle-physics simulation to agree with data

• Listen to brief presentations by our scientists about favourite research topics of theirs

• Ask questions about anything from antimatter to relativity, what we know about dark matter, what the difference is between the Higgs field and the Higgs boson, or anything else you want to know about particles, the fundamental laws of nature, or relativistic quantum theory

Welcome to Monash University