What’s Inside the Neutron?

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“The Periodic Table”
What Do We Know?

From the Edge of the Universe to $10^{26}$ m

the Earth to ...

hominids to ...

the Atom to...

the nucleus to...

Protons and ...

... are made of quarks.

neutrons ...

$10^{-10}$ m

$10^{-15}$ m

$10^7$ m

$10^{-15}$ m
The Periodic Chart
What Do We Know?

- The Universe is made of quarks and leptons and the force carriers.

- The atomic nucleus is made of protons and neutrons bound by the strong force.

- The quarks are confined inside the protons and neutrons.

- Protons and neutrons are NOT confined.
What is the Force?

- Quantum chromodynamics (QCD) looks like the right way to get the force at high energy (Nobel Prize in 2004).

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How Well Do We Know It?

- We have a working theory of strong interactions: quantum chromodynamics or QCD (B. Abbott, et al., Phys. Rev. Lett., 86, 1707 (2001)).

- The coherent hadronic model (the standard model of nuclear physics) works too (L. C. Alexa, et al., Phys. Rev. Lett., 82, 1374 (1999)).
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What Don’t We Know?

1. We can’t get QCD and the hadronic model to line up.

2. NEED TO FIGURE OUT QCD AT THE ENERGIES OF NUCLEI!!!
What We Knew and Now Know About the Neutron.
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![Diagram showing charge distribution of neutron, proton, core, vector cloud, and scalar cloud.](image1)

![Graph showing neutron charge density with different visualization ideas.](image2)

![Graph showing charge density of the neutron.](image3)
Results - Comparison with Existing Data and Theory

$G_M^p / \mu_n G_D$

$Q^2(\text{GeV}^2)$
Results - Comparison with Existing Data and Theory

![Graph showing comparisons between different models and data sets. The graph plots $G_M^n/\mu_n G_D$ against $Q^2(\text{GeV}^2)$ with various symbols and colors representing different theoretical predictions and data sets. The x-axis represents $Q^2$ values ranging from 0 to 5, and the y-axis represents the ratio of $G_M^n/\mu_n G_D$ ranging from 0.7 to 1.3. The graph includes symbols for CLAS, Kubon, Bartel, Anklin, Arnold, Xu, Anderson, Green band, Solid, Miller, and Dashed Guidal. A horizontal red shaded area indicates the systematic uncertainty.]
Experiments at Jefferson Lab
The CEBAF Large Acceptance Spectrometer (CLAS)
Life on the Frontiers of Knowledge
**More Life on the Frontier - the Large Hadron Collider**

1. The Large Hadron Collider (LHC) is the largest and highest-energy particle accelerator, colliding opposing beams of protons at 99.999999% of the speed of light.

2. Will test various predictions of high-energy physics, including the existence of the Higgs boson and other new particles.

3. 27 kilometres around, beneath the Franco-Swiss border, built by over 10,000 scientists and engineers from over 100 countries and hundreds of universities and laboratories.

4. On 10 September 2008, the proton beams were successfully circulated in the main ring of the LHC for the first time.
• Saying this is nuclear and particle physics.
The LHC - What It’s Really About.

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- Is like saying this is Beethoven’s Fifth Symphony.
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- The Standard Model of particle physics has been superbly successful, but is now looking a bit frayed around the edges. Asking ‘What is the LHC for?’ will give you different answers from different people.
The LHC - It Won’t Eat You!

- No danger of creating a black hole that will suck in the Earth despite what some people say.

- It may be responsible for other surprising effects.
The LHC - Why should YOU pay for it?

1. Over the last 100 years, at least 50% of the growth in our standard of living is due to technological change.

2. Technological spinoffs: NMR → MRI, WWW, transistors, computers, ...

3. Production of trained scientists, engineers, technicians. ...
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In Paris in 1783 Benjamin Franklin watched with amazement one of the first hot-air balloon flights. The following exchange was said to occur.

Unknown questioner to Franklin: Sir, what’s the use of flying in the air?

Ben Franklin’s answer: Sir, what’s the use of a newborn baby?
The LHC - It Won’t Eat You!

It may be responsible for other surprising effects.

http://www.youtube.com/watch?v=j50ZssEojtM