What's Inside the Neutron?
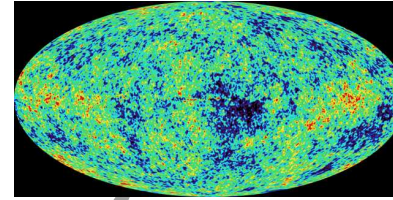
Jerry Gilfoyle, University of Richmond

"The Periodic Table"

What Do We Know?

From the Edge of the Universe to

10^{26}m

the Earth to ...

10^7 m

hominids to ...

10^1m

10^{-10}m

the Atom to...

the nucleus to...

10^{-15} m

Protons and ...

neutrons ...

... are made
of quarks.

?

The Periodic Chart

NIST Physics Laboratory Holdings by Element

What Do We Know?

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

BOSONS	force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1			Strong (color) spin = 1		
Name	Mass GeV/c^2	Electric charge	Name	Mass GeV/c^2	Electric charge
γ photon	0	0	g gluon	0	0
W^-	80.4	−1			
W^+	80.4	+1			
Z^0	91.187	0			

FERMIONS	matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c^2	Electric charge	Flavor	Approx. Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0	u up	0.003	2/3
e electron	0.000511	−1	d down	0.006	−1/3
ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3
μ muon	0.106	−1	s strange	0.1	−1/3
ν_τ tau neutrino	<0.02	0	t top	175	2/3
τ tau	1.7771	−1	b bottom	4.3	−1/3

- 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.
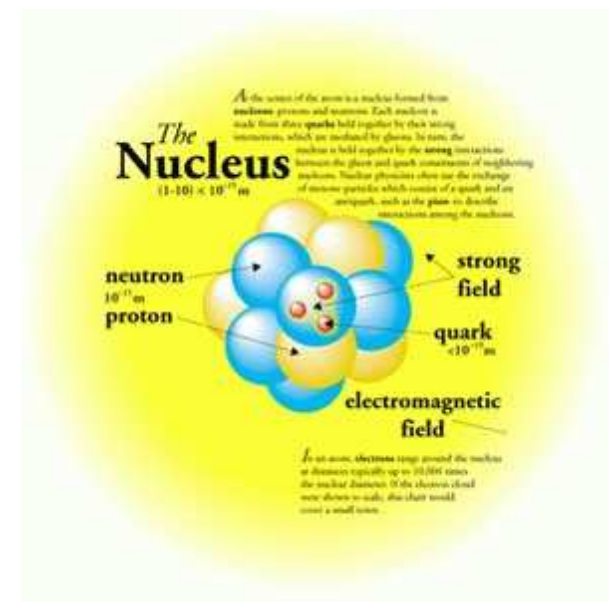
What is the Force?

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

- The hadronic model uses a phenomenological force fitted to data at low energy. This 'strong' force is the residual force between quarks.
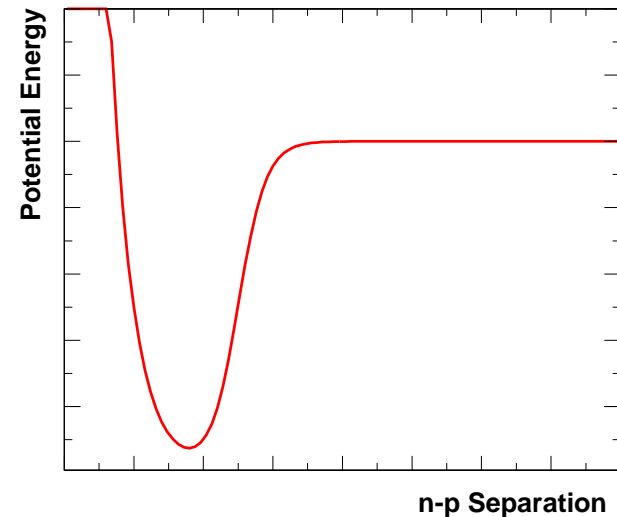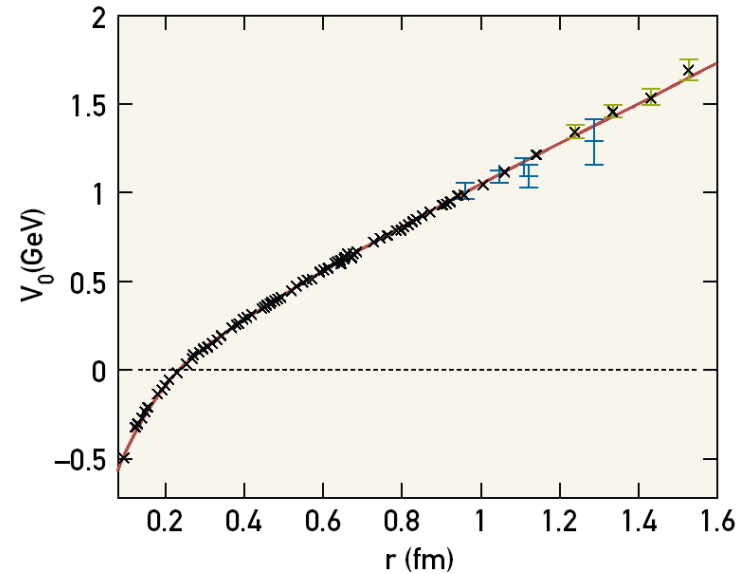
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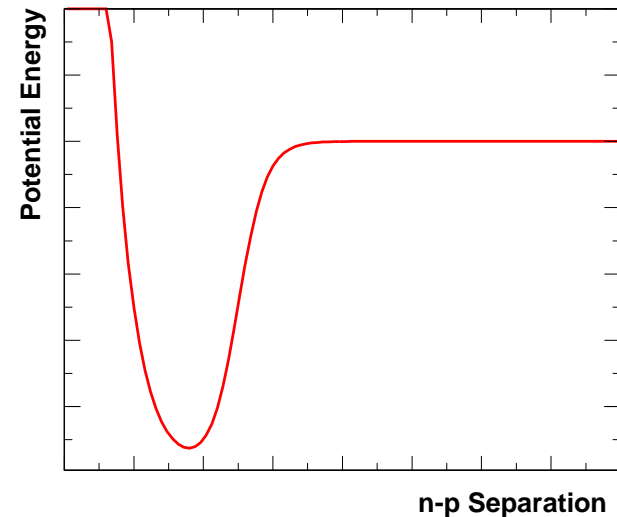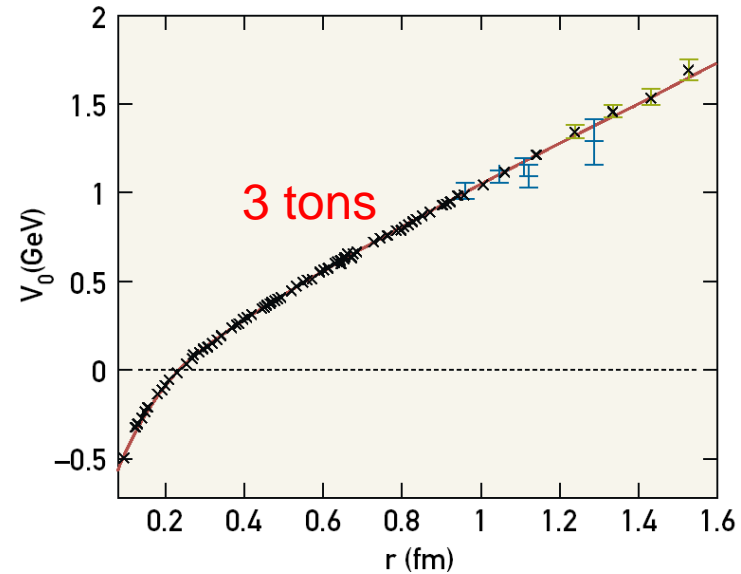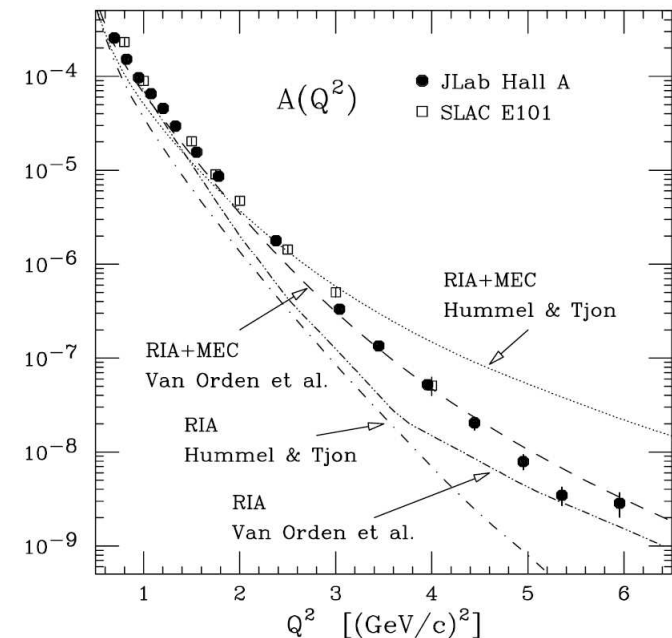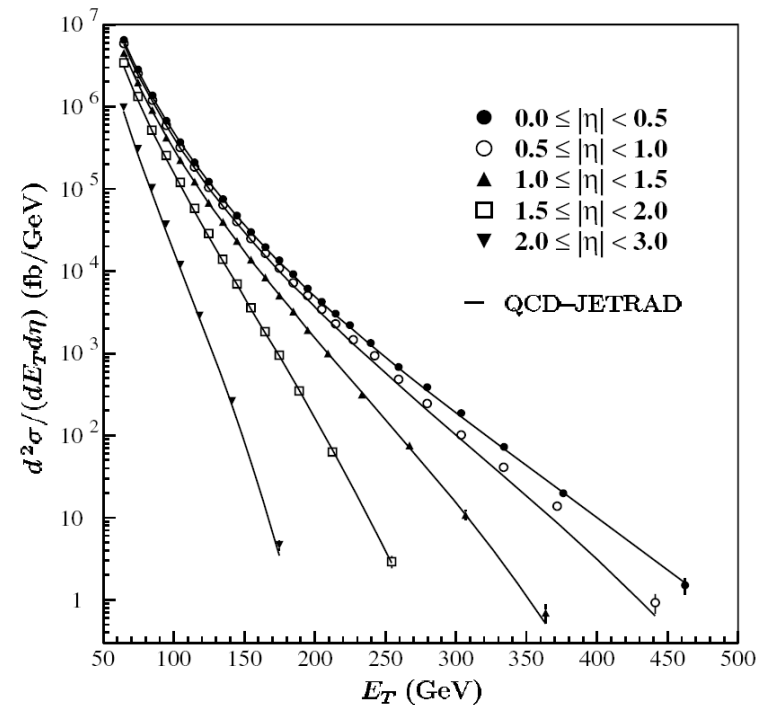
How Well Do We Know It?

- 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)).
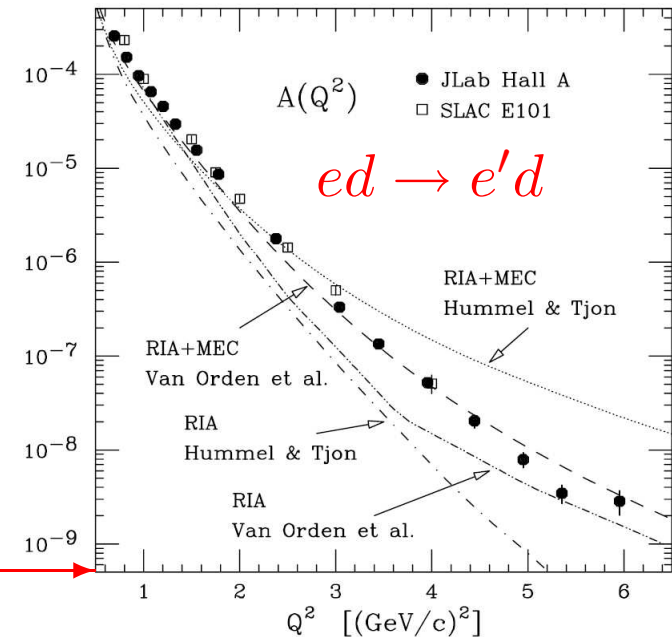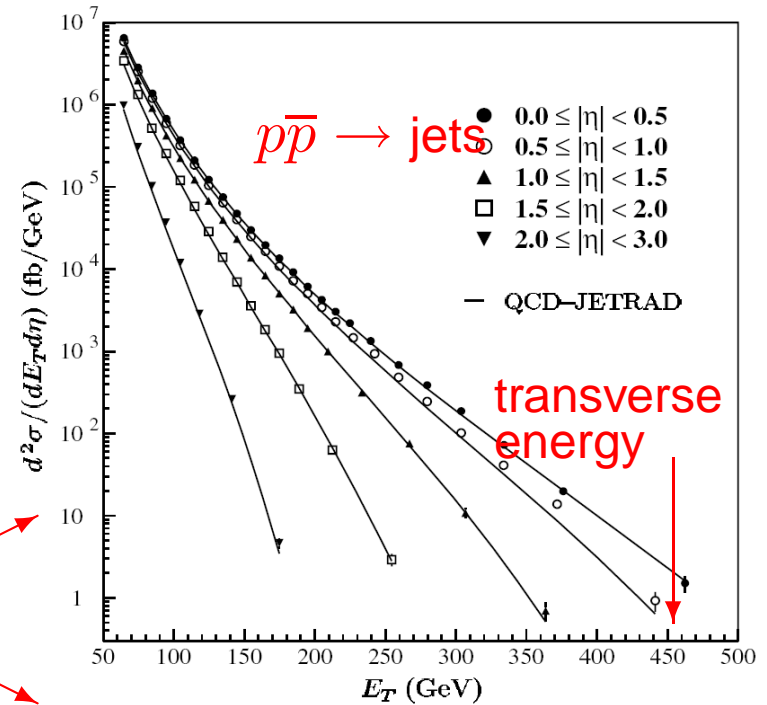
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  effective target area

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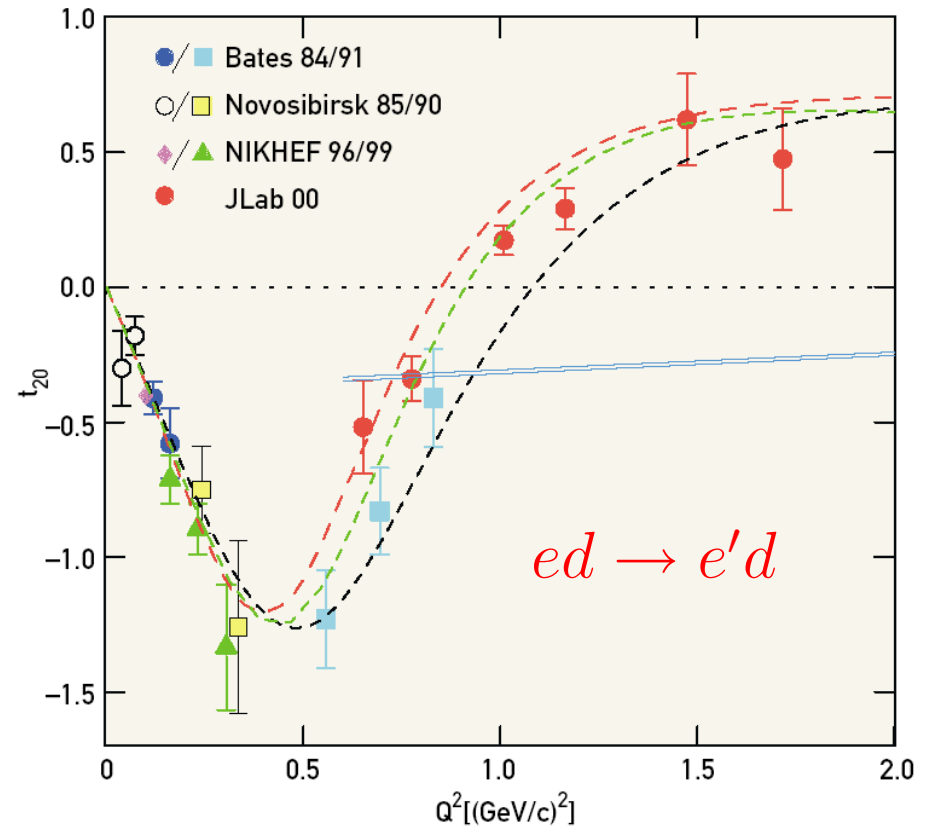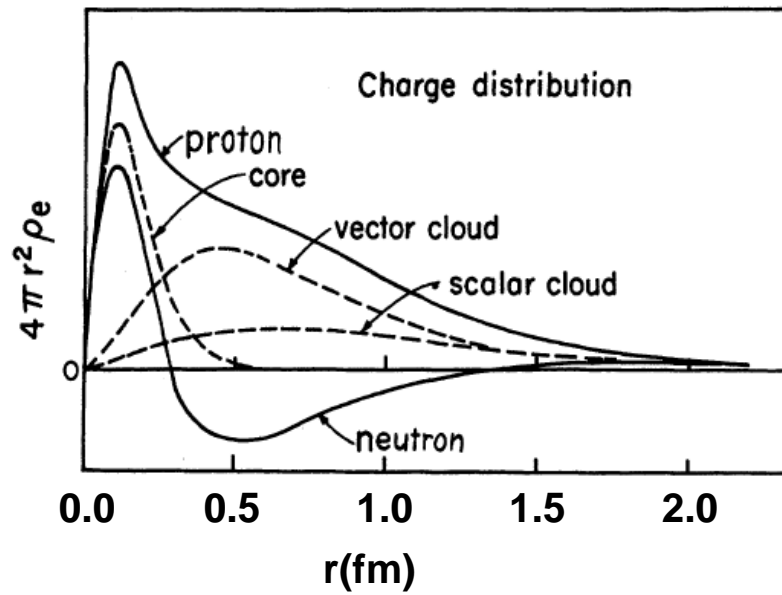
  4-momentum transfer squared

$p\overline{p} \to$ jets

- $0.0 \leq |\eta| < 0.5$
- $0.5 \leq |\eta| < 1.0$
- $1.0 \leq |\eta| < 1.5$
- $1.5 \leq |\eta| < 2.0$
- $2.0 \leq |\eta| < 3.0$
- QCD–JETRAD

transverse energy

$\frac{d^2\sigma}{dE_T d\eta}$ (fb/GeV)

E_T (GeV)

$A(Q^2)$

- JLab Hall A
- SLAC E101

$ed \to e'd$

RIA+MEC
Hummel & Tjon

RIA+MEC
Van Orden et al.

RIA
Hummel & Tjon

RIA
Van Orden et al.

Q^2 [(GeV/c)^2]
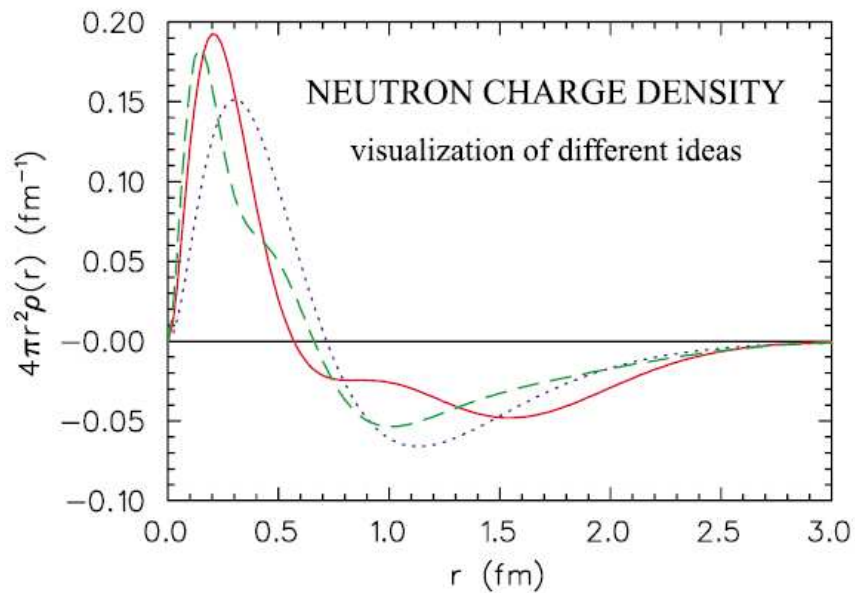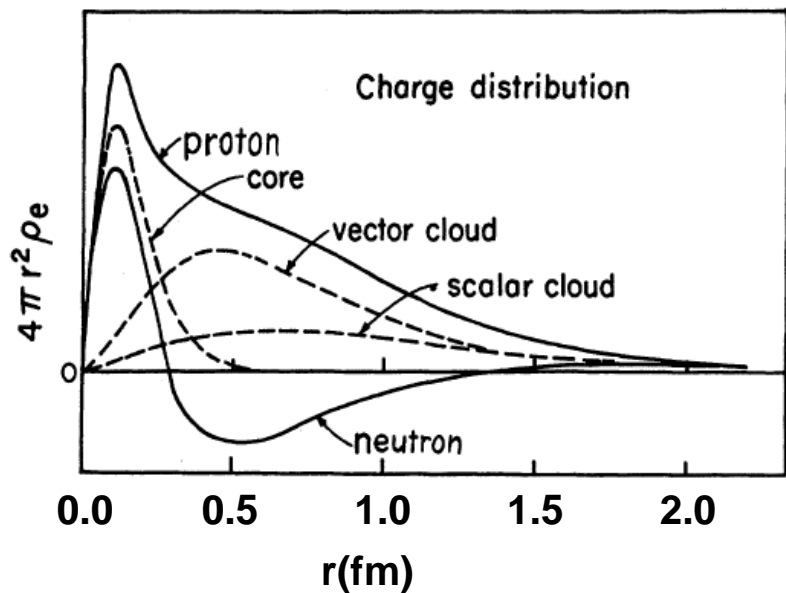
What Don't We Know?

1. We can't get QCD and the hadronic model to line up. D. Abbott, *et al.*, Phys. Rev Lett. **84**, 5053 (2000).

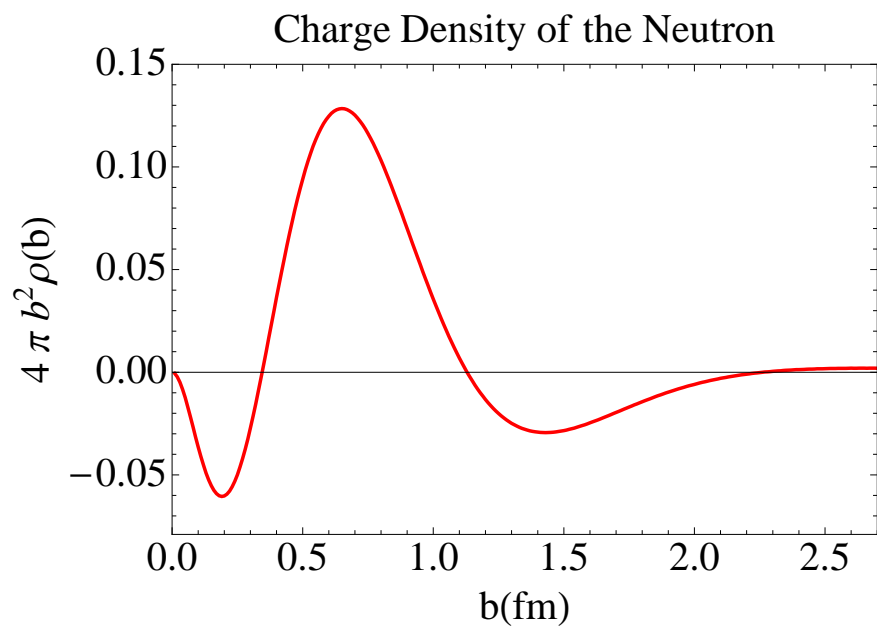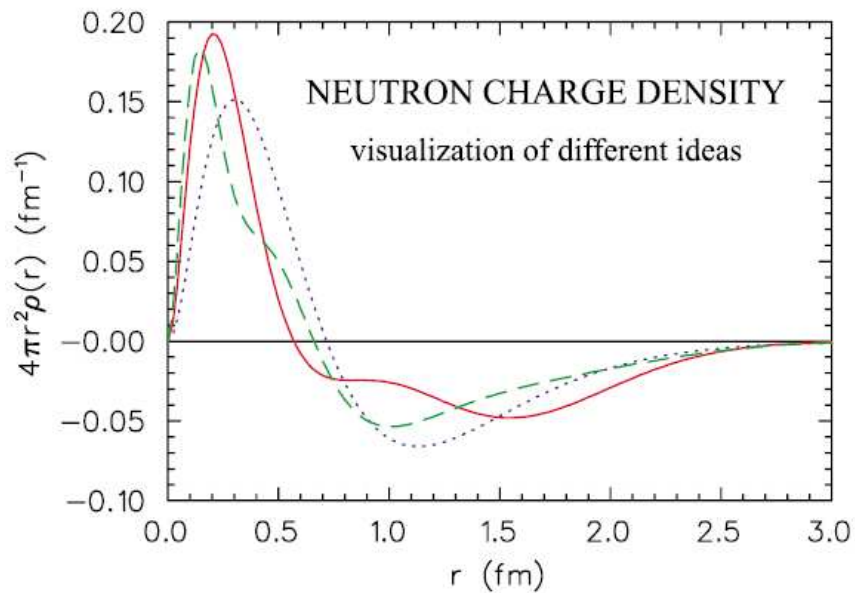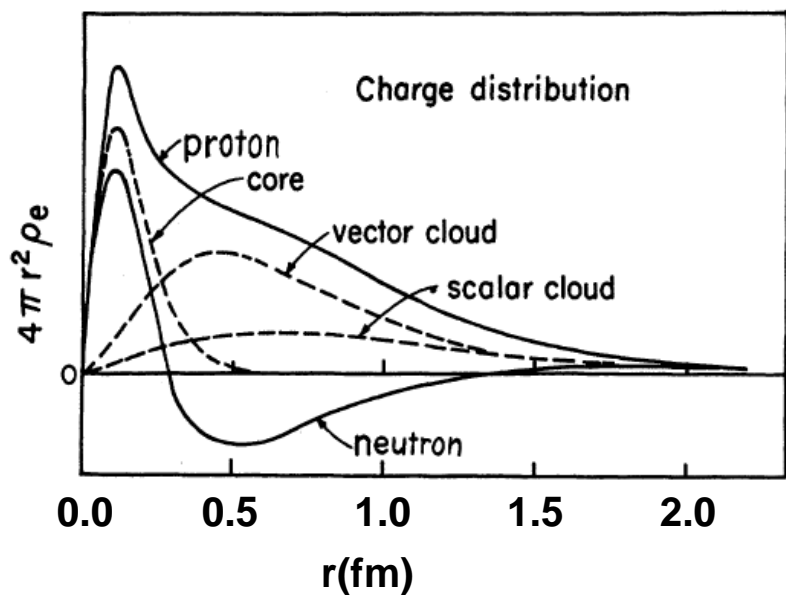2. NEED TO FIGURE OUT QCD AT THE ENERGIES OF NUCLEI!!

What We Knew and Now Know About the Neutron.

Charge distribution

proton
core
vector cloud
scalar cloud

$4\pi r^2 \rho e$

O

neutron

0.0   0.5   1.0   1.5   2.0

r(fm)

What We Knew and Now Know About the Neutron.

Charge distribution

proton
core
vector cloud
scalar cloud
neutron

$4\pi r^2 \rho_e$

r(fm)

NEUTRON CHARGE DENSITY
visualization of different ideas

$4\pi r^2 \rho(r)$ (fm^{-1})

r (fm)

What We Knew and Now Know About the Neutron.

Charge distribution

proton
core
vector cloud
scalar cloud
neutron

$4\pi r^2 \rho_e$

r(fm)

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r (fm)

Charge Density of the Neutron
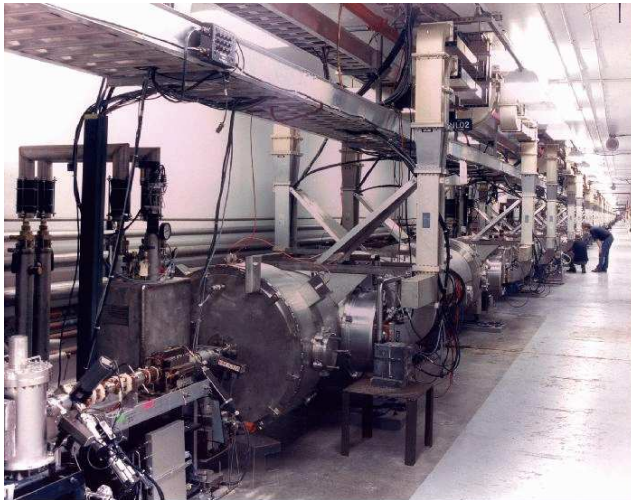
$4\pi b^2 \rho(b)$

b(fm)

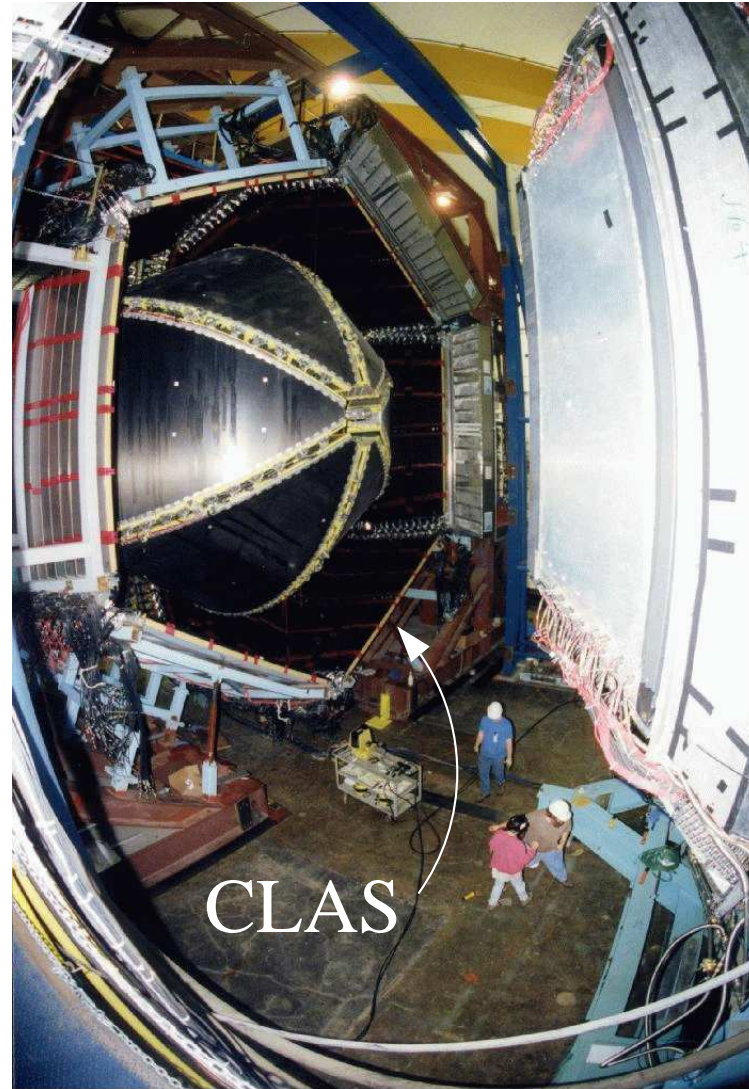# Results - Comparison with Existing Data and Theory
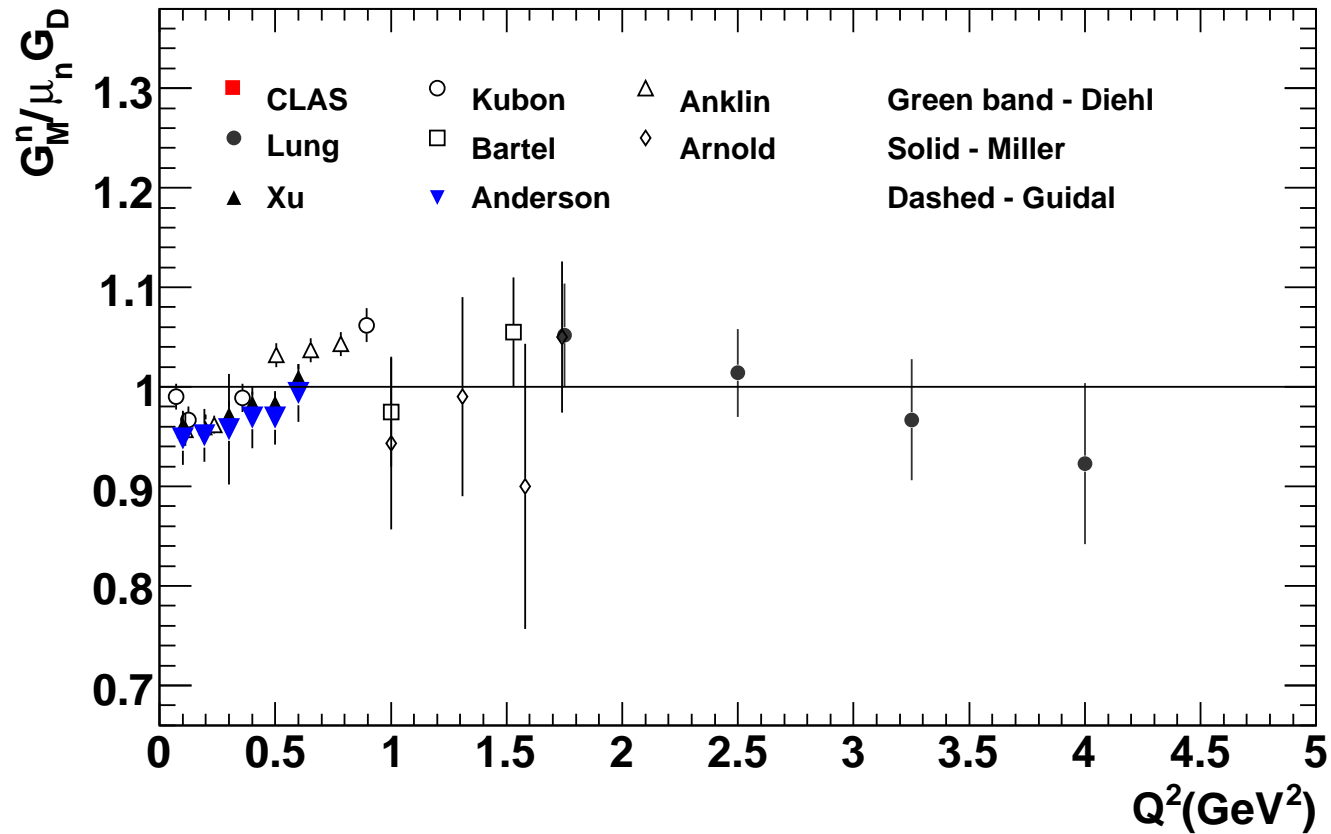
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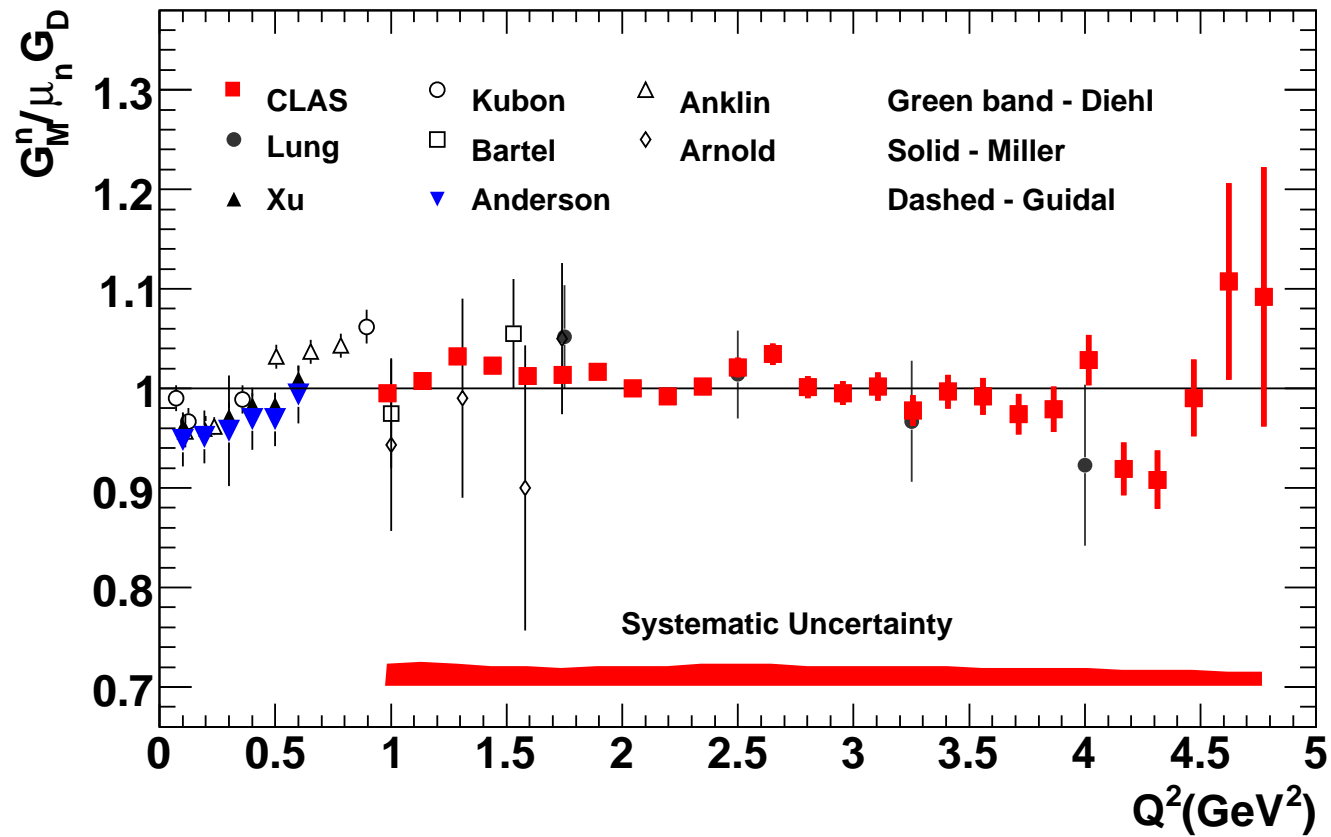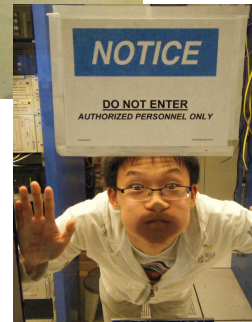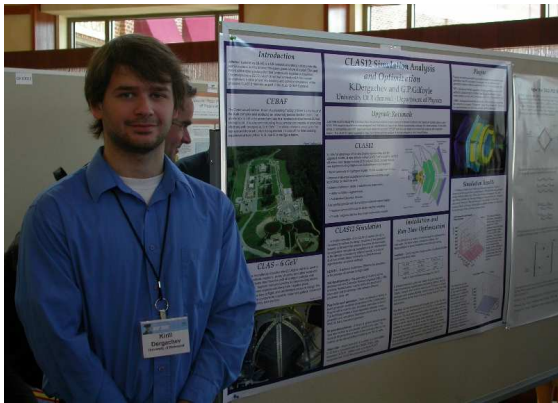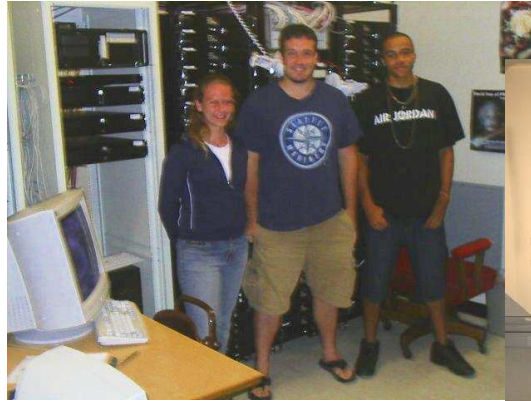
Experiments at Jefferson Lab

The CEBAF Large Acceptance Spectrometer (CLAS)

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.

The LHC - What It's Really About.
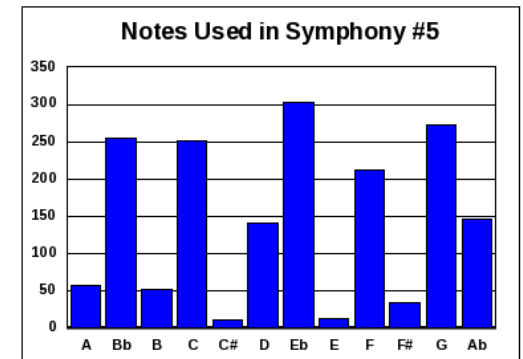
- Saying this is nuclear and particle physics. $\longrightarrow$

The LHC - What It's Really About.

- Saying this is nuclear and particle physics. ————————→

- Is like saying this is Beethoven's Fifth Symphony. ————→

The LHC - What It's Really About.

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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.

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Lawsuit: Huge Atom Smasher Could Destroy World

Monday, March 31, 2008
By Paul Wagenseil
FOX NEWS

E-Mail   Print

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Stop the scientists before they destroy us all!

That's what a Hawaii man with a background in nuclear physics is asking a court to do.

Walter F. Wagner and his colleague Luis Sancho have filed a federal lawsuit seeking to stop work on the Large Hadron Collider, a gigantic atom smasher on the Franco-Swiss border that's set to start operations in May.

• Click here to visit FOXNews.com's Natural Science Center.

Physicists hope its incredible energies will form briefly-lived new particles that could shed light on the origins of the universe, among other

AP

Black holes can be such a drag.

marvels.

- 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.comedycentral.com/colbertreport/full-episodes/index.jhtml?episodeId=209851`

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