Hunting for Quarks

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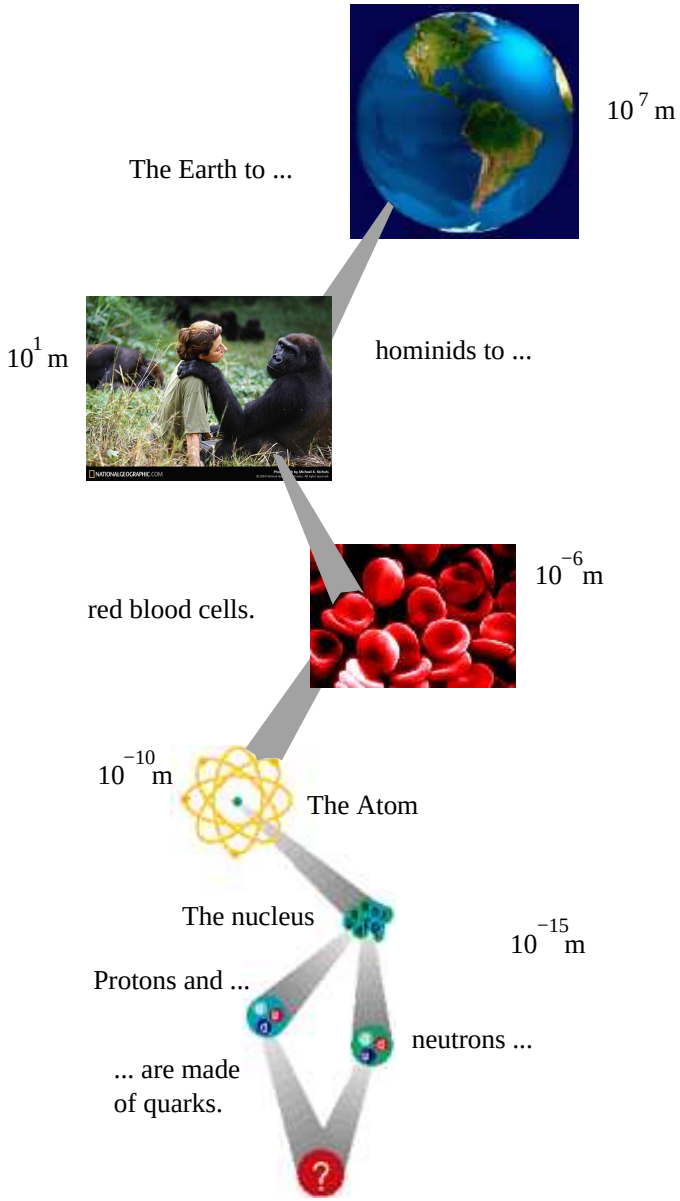
"The Periodic Table"

What Do We Know?



What Else 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		
Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	−1
W^+	80.4	+1
Z^0	91.187	0

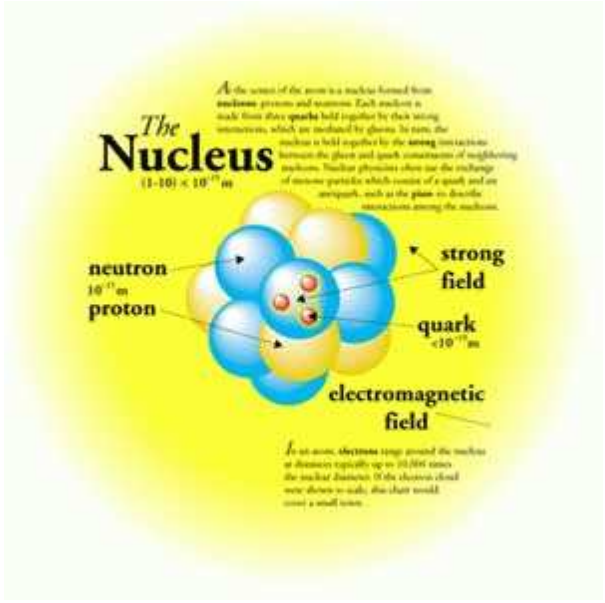
Strong (color) spin = 1		
Name	Mass GeV/c^2	Electric charge
g gluon	0	0

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

Leptons spin = 1/2		
Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	−1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	−1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	−1

Quarks spin = 1/2		
Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	175	2/3
b bottom	4.3	−1/3

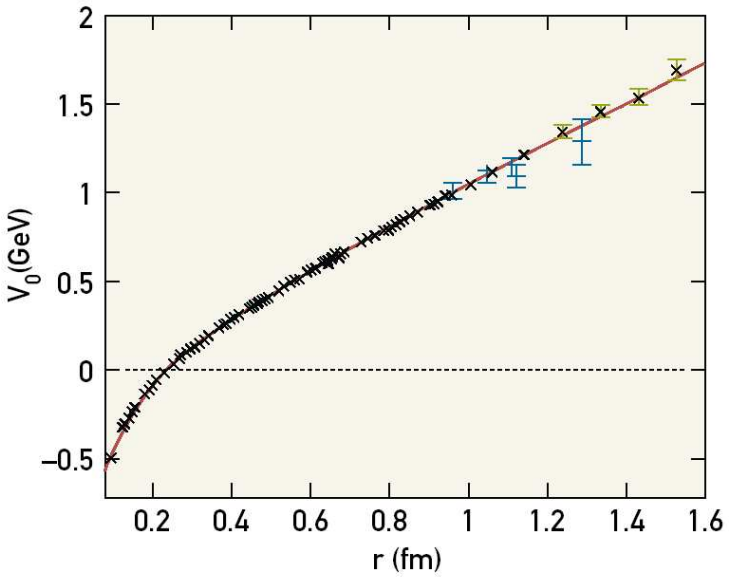
- The atomic nucleus is made of protons and neutrons bound by the strong force.



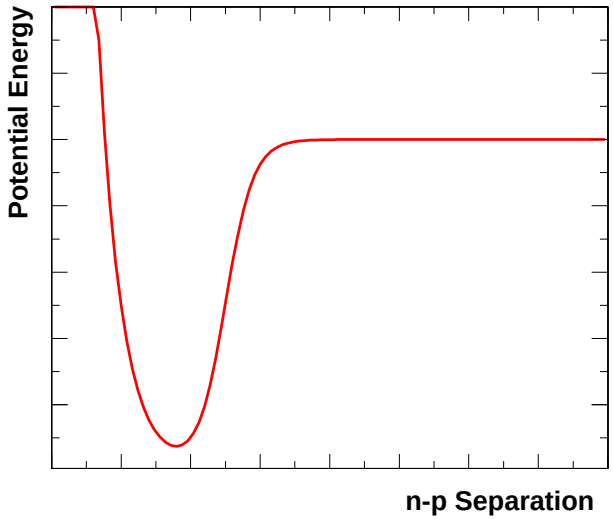
- The quarks are confined inside the protons and neutrons.
- Protons and neutrons are NOT confined.

What is the Force?

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



- 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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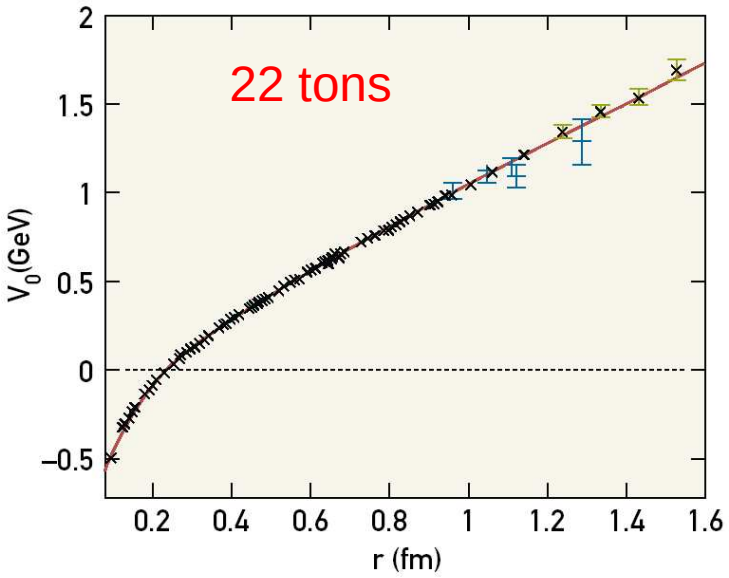

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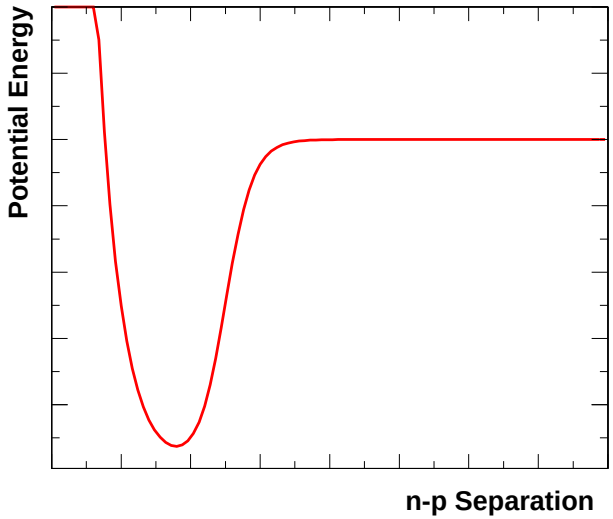
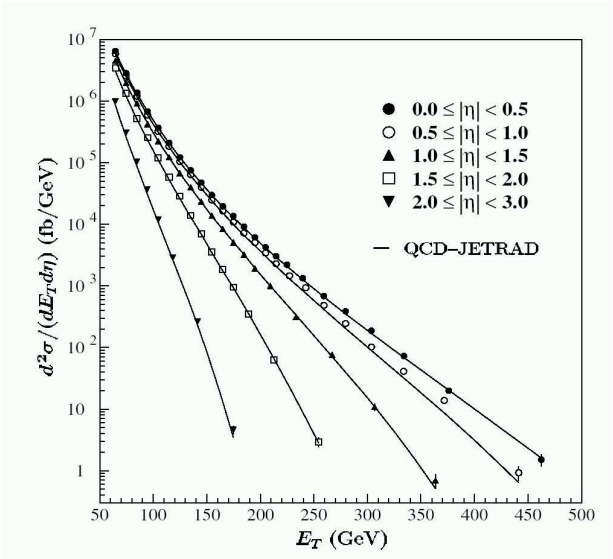


How Well Do We Know It?

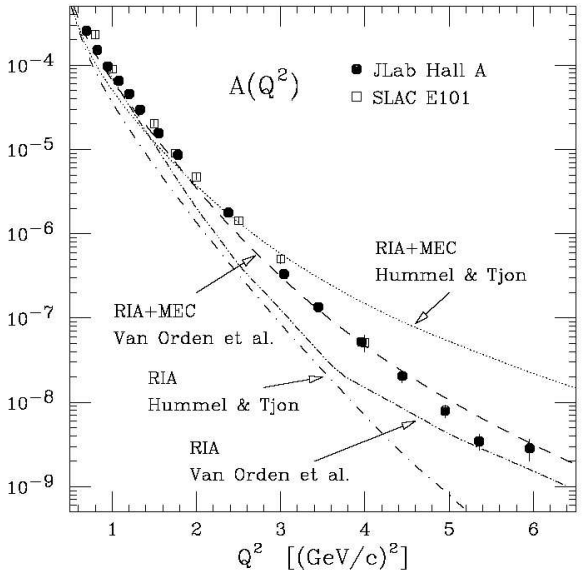
- We have a working theory of strong interactions: quantum chromodynamics or QCD.

  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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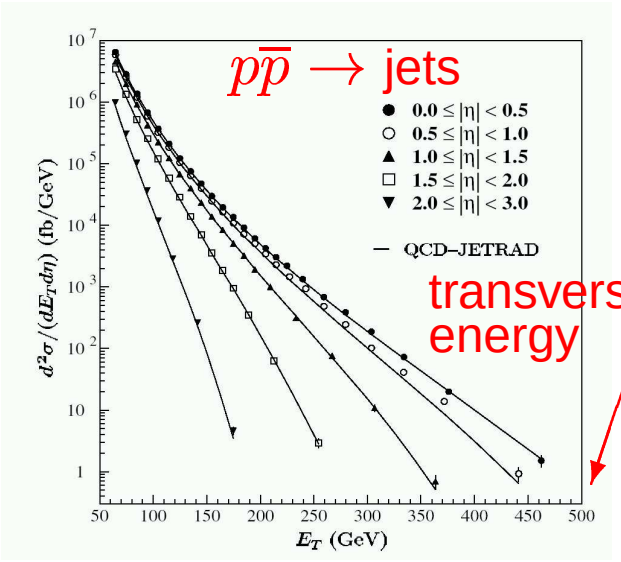

effective area of the target

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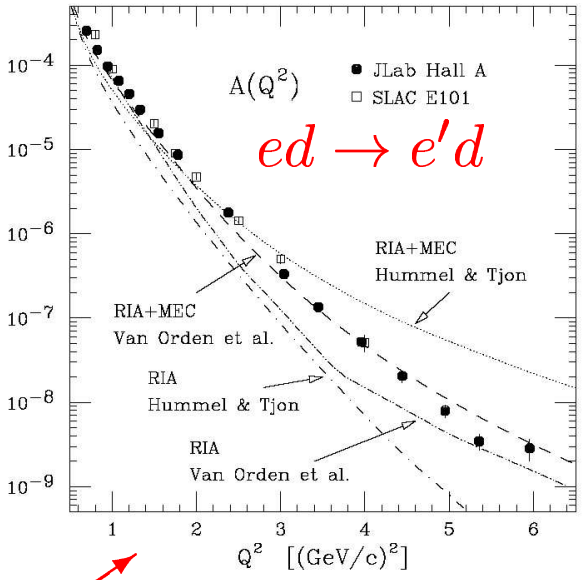


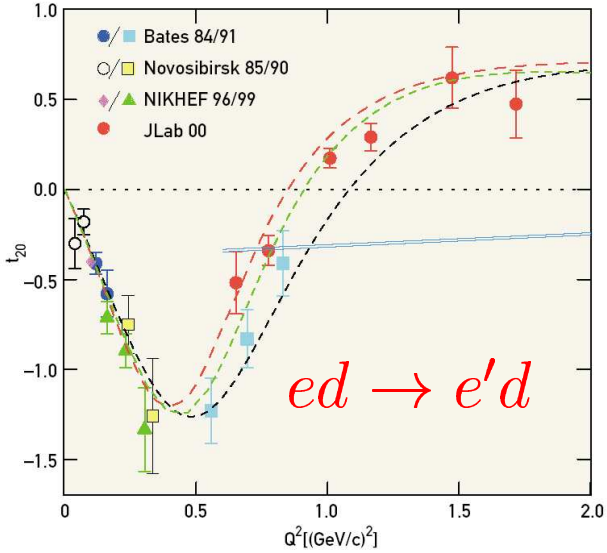
4-momentum transfer squared

What Don't We Know?

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

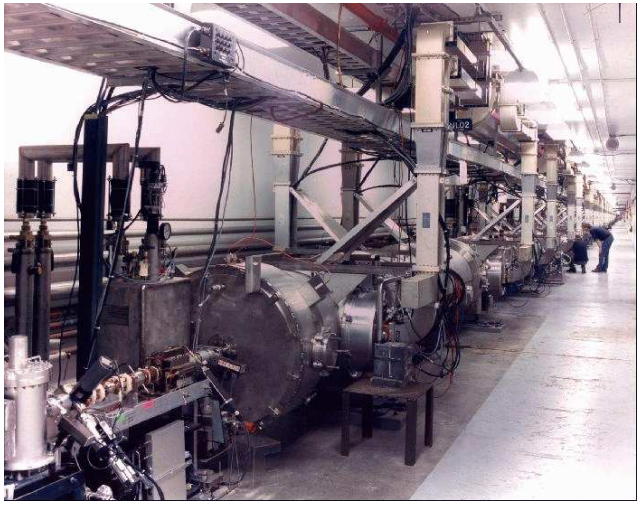
   D. Abbott, *et al.*, Phys. Rev Lett. **84**, 5053 (2000).

2. We have to find the hadronic model 'baseline' to see the transition to QCD.



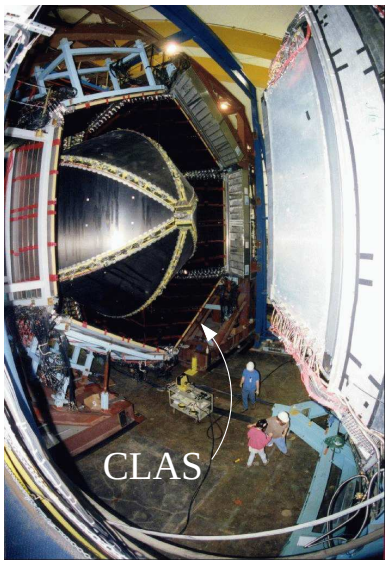
Experiments at Jefferson Lab

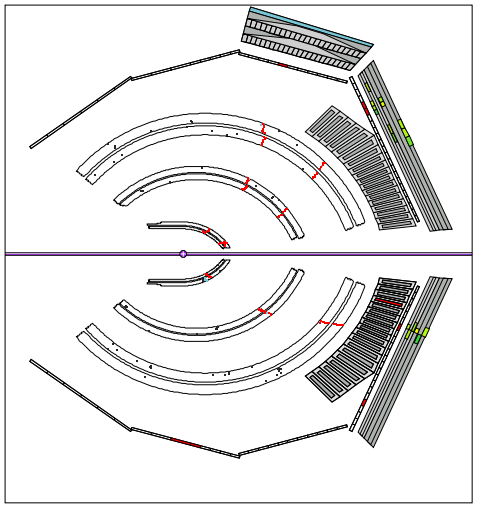
- Jefferson Lab is a US Department of Energy national laboratory and the newest ‘crown jewel’ of the US.
- The centerpiece is a 7/8-mile-long, racetrack-shaped electron accelerator that produces unrivaled beams.
- The electrons do up to five laps around the Continuous Electron Beam Accelerator Facility (CEBAF) and are then extracted and sent to one of three experimental halls.
- All three halls can run simultaneously.



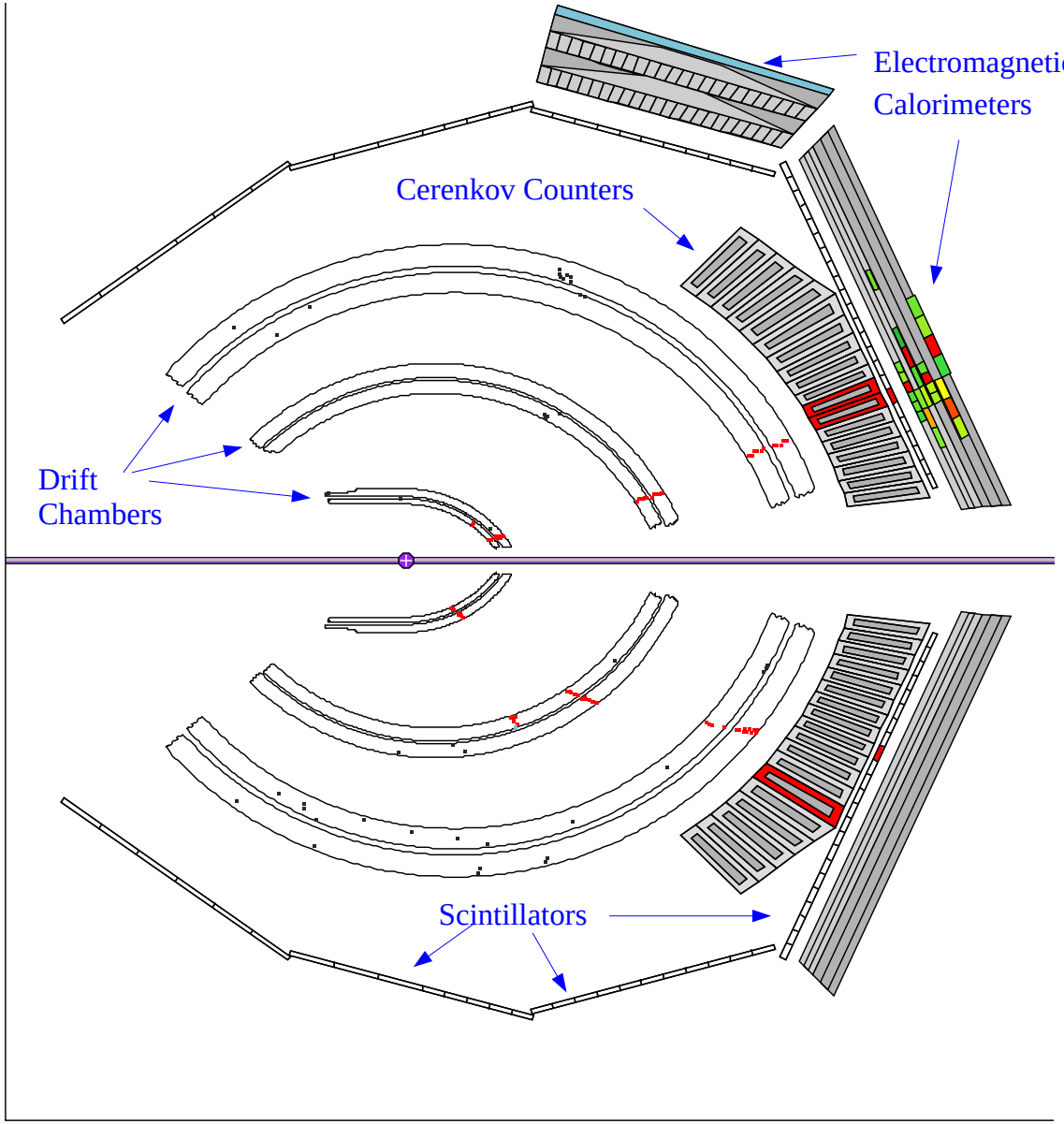
The CEBAF Large Acceptance Spectrometer (CLAS)

- CLAS is a 45-ton, $50-million radiation detector.
- It covers almost all angles.
- It has about 40,000 detecting elements in about 40 layers.
- Drift chambers map the trajectory of the collision. A toroidal magnetic field bends the trajectory to measure momentum.
- Other layers measure energy, time-of-flight, and particle identification.
- Each collision is reconstructed and the intensity pattern reveals the forces and structure of the colliding particles.





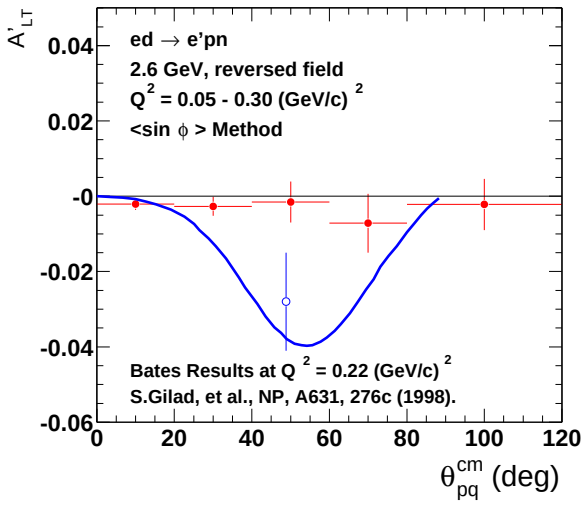
A CLAS Event

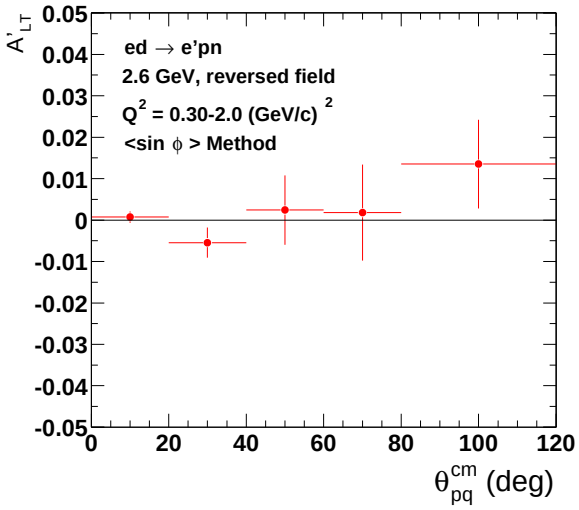

Electromagnetic
Calorimeters
Cerenkov Counters
Drift
Chambers
Scintillators

Life on the Frontiers of Knowledge

Some Results and Conclusions

- Measuring the deuteron wave function.





- We are hunting for quarks (and gluons) hidden inside the nucleus.
- Strong physics motivation to test the nuclear ‘coherent hadronic model’ in a new energy range and push it past its limits and break it.