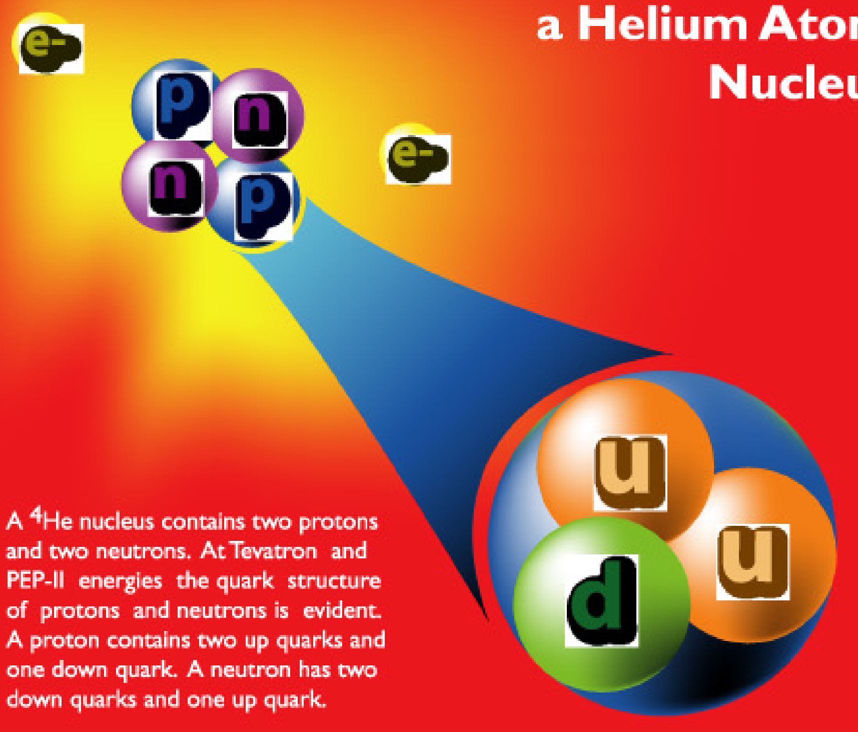
Quantum Field Theory

Quantum field theories describe the interactions of the subatomic particles observed in experiments at Fermilab and SLAC. Physicists validate these theories by checking predictions against experimental measurements. New theoretical predictions resulting from high precision experiments drive requirements of future experiments.

Quark Structure Inside a Helium Atom Nucleus



A ^{4}He nucleus contains two protons and two neutrons. At Tevatron and PEP-II energies the quark structure of protons and neutrons is evident. A proton contains two up quarks and one down quark. A neutron has two down quarks and one up quark.

How Much Computing Power Is Required?

Examples of Past Successes:

"Proof" of quark confinement	(pencil and paper) (1974)
Light-hadron spectrum	10s of Gflops-years (early '90s)
Glueball spectrum	10s of Gflops-years (mid '90s)
Determination of α_s to 4-5%	10s of Gflops-years (1995)

Examples of Ongoing and Future Work:

Accurate light-hadron spectrum	100s of Gflops-years
α_s to 1-2%	100s of Gflops-years
B and D meson matrix elements to 5%	1000s of Gflops-years
$\varepsilon' / \varepsilon$ (CP violation)	1000s of Gflops-years
Quark-gluon plasma equation of state	1000s of Gflops-years

A 2.0 GHz Pentium 4 desktop computer produces 0.8 Gflops-year for Lattice QCD code. Hundreds to 1000's of commodity computers must work together in a cluster to sustain the terascale calculations.

Fermilab Lattice QCD Facilities

The Department of Energy, through its Office of Science, supports lattice field theory research via the Scientific Discovery through Advanced Computing (SciDAC) initiative. SciDAC provides funding for hardware (both commodity clusters and purpose built supercomputers) and for the design and implementation of a common software base for the entire lattice community.

Elementary Particles

Quantum Chromodynamics

The field theory describing the interaction of quarks and gluons, Quantum Chromodynamics (QCD), is part of the Standard Model of particle physics. Understanding QCD is crucial, since most of the visible matter in the universe is composed of quarks and gluons. Obtaining theoretical predictions having the same level of precision as experimental measurements requires the numerical techniques of lattice field theory (Lattice QCD).