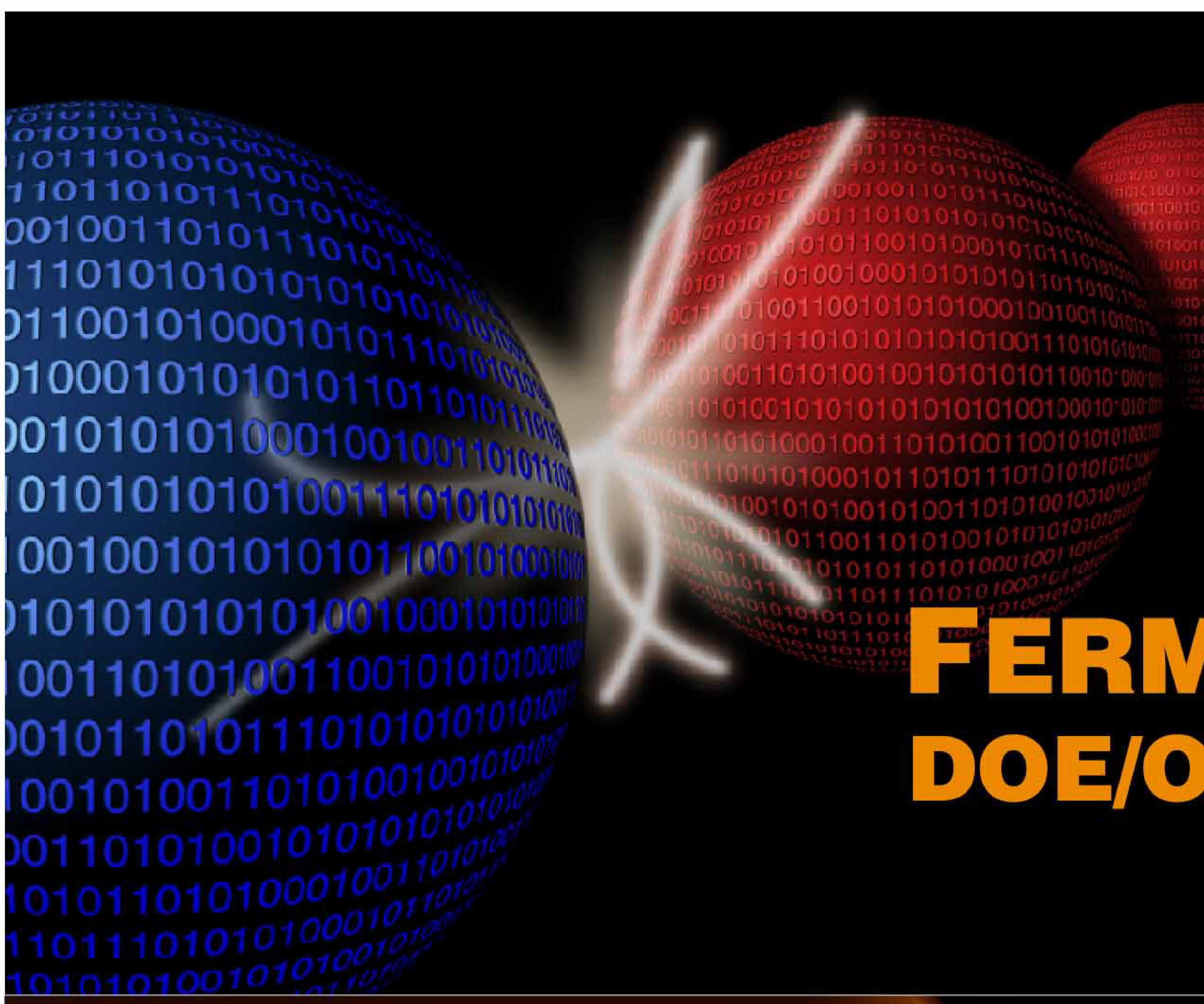

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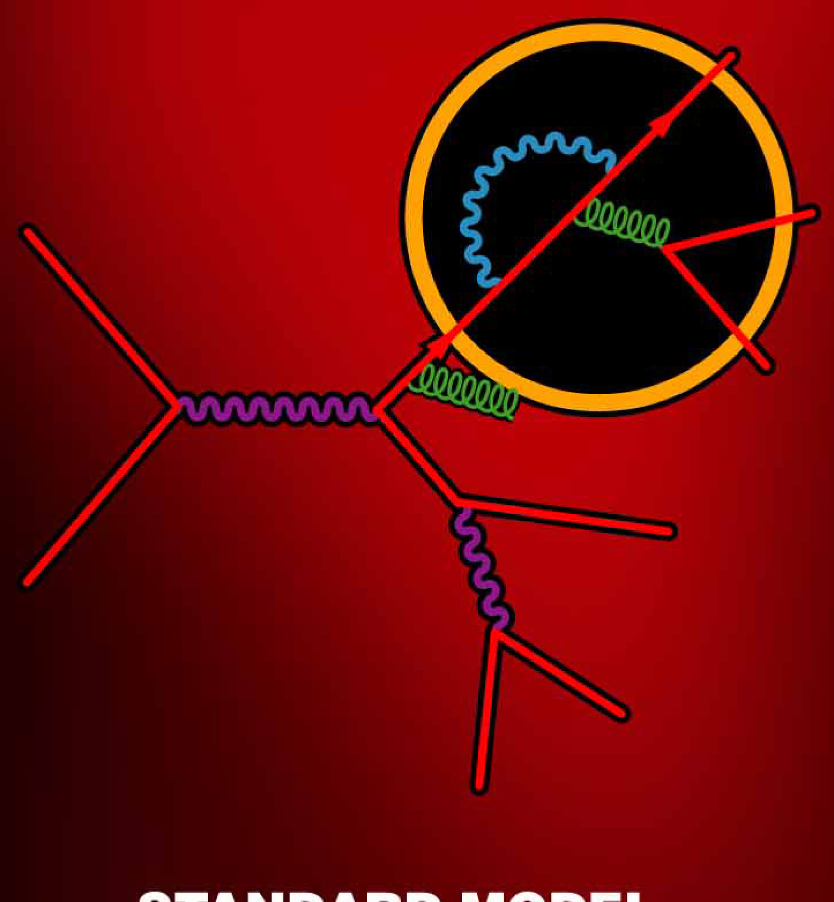
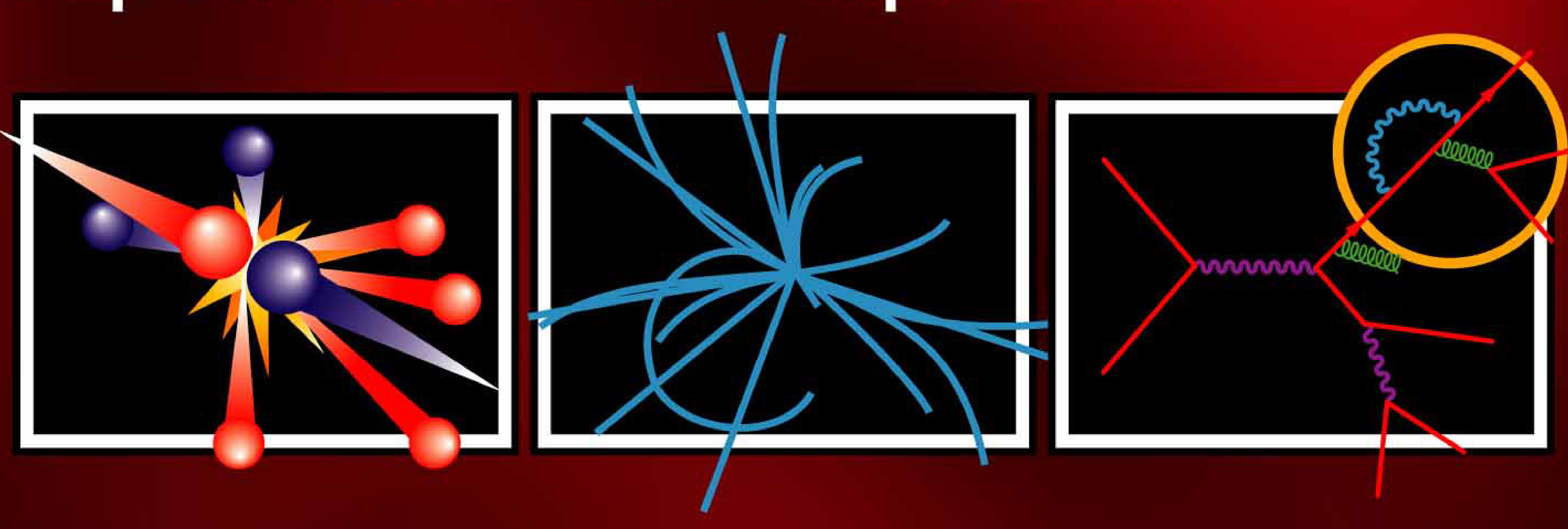
INTERPLAY OF THEORY AND EXPERIMENT

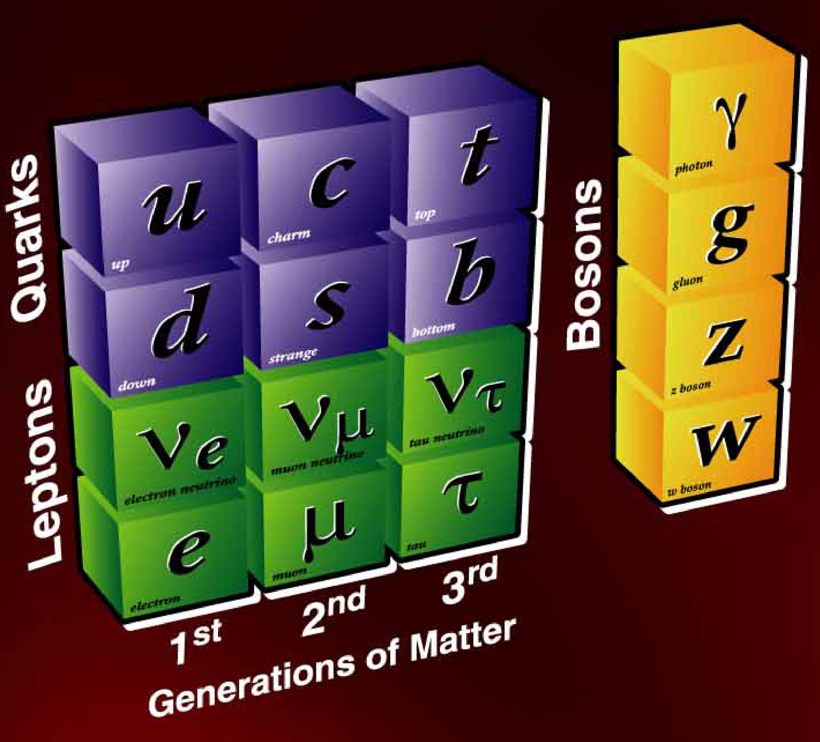


Physicists validate theories by checking predictions against experimental measurements — do the error bars of one fall within the error bars of the other. New theoretical predictions resulting from new high precision experiments drive the requirements of future experiments.



STANDARD MODEL

The twentieth century was an era of striking progress towards comprehending the fundamental structure of matter, beginning with the discovery of quantum mechanics and atomic physics, progressing to nuclear physics, and culminating with the Standard Model of elementary particle physics.



The standard model of leptons and bosons has been spectacularly successful in its predictions. For example, compare the predicted value and experimental measurement of the muon (μ) magnetic moment:

Predicted: 116,591,597 $\pm$ 67 X 10^{-11}

Measured: 116,592,023 $\pm$ 151 X 10^{-11}

These values are determined to a precision of about one part in a million. They differ, however, at the level of four parts in a million. Refining such precision checks of theory against experiment may lead physicists to new discoveries beyond the Standard Model.

For the muon, analytic methods yield a theoretical prediction near the same level of precision as the experiment. In other quantum theories, obtaining a level of theoretical precision comparable to experiment is sometimes far beyond known analytic methods. Physicists then consider numerical techniques.

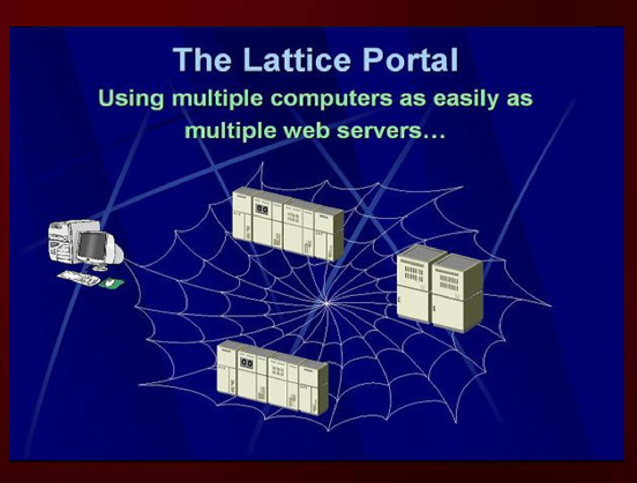
One such theory is Quantum Chromodynamics (QCD)– the standard model of quarks and gluons. Understanding QCD is crucial since quarks and gluons comprise most of the visible matter in the universe. Analytic methods are often not sufficient for QCD, hence, physicists use the numerical techniques of Lattice QCD to make predictions.

COMPUTATIONAL CHALLENGE

The only known method to extract many predictions from QCD with controlled errors is through the large scale numerical simulations of lattice gauge theory. Recent refinements of numerical algorithms, coupled with major increases in the capabilities of parallel computers, have brought these simulations to a new level.

Reaching the precision demanded by new experiments will require even better algorithms and multi-terascale computational facilities.

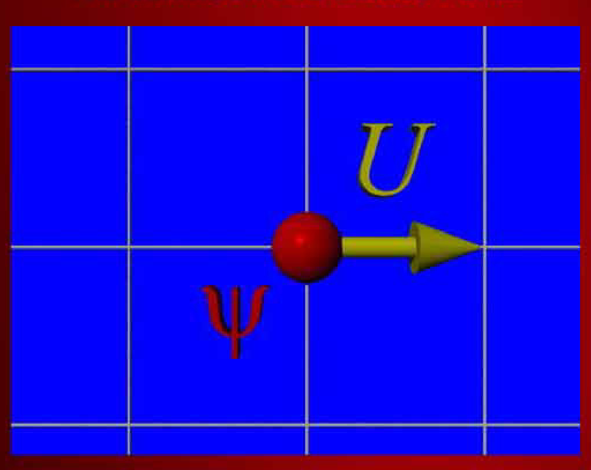
To build these facilities, we look to clustering technologies as one of the most cost effective in the marketplace. To exploit clusters, it is essential to build and test large examples and to develop and exercise software that exploits their advantages. The Department of Energy's Scientific Discovery through Advanced Computing (SciDAC) initiative has provided funding, guidance, and a framework for cooperation among the U.S. lattice gauge community to pursue this work.



Fermilab Lattice Gauge Theory Computational Facility

Fermilab operates a prototype cluster of 80 dual processor systems that provides a peak performance of 112 GFlops. Funded in part by SciDAQ, scientists use this cluster to develop and run lattice QCD codes and to develop tools and techniques to be applied to larger clusters. This year, SciDAQ funding will also provide approximately 175 new computers for a gain of more than 700 GFlops in peak performance.

The Jefferson Lab Lattice Portal



Jefferson Lab (JLab) is developing a set of web services to facilitate access to computational resources for Lattice QCD. The prototype portal is already being used to monitor and manipulate the batch system and data storage for a cluster of 40 alpha processors at JLab and 48 at MIT, and will soon be used for a cluster of 256 Pentium 4 processors at JLab. Supported by SciDAC funding, the lab is also developing optimized communications and linear algebra routines for the Pentium 4.