TRAC @ Fermilab, 2013

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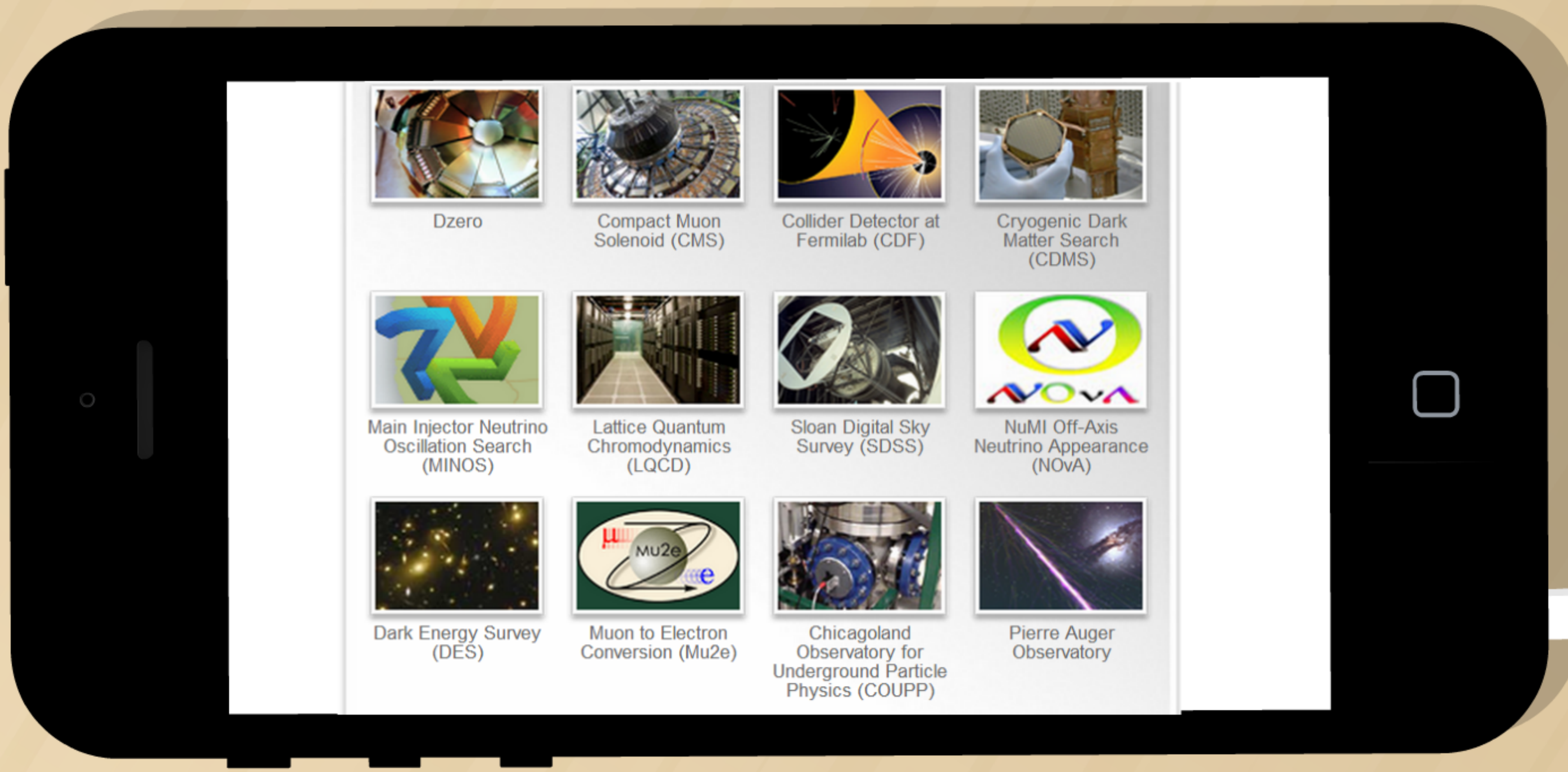
Notes

The Computing Sector

I spent this summer working in the computing sector under my mentor James Simone. The computing sector plays a role in almost every major experiment here at Fermilab. For example...

My first task was to figure out what "Lattice Quantum Chromodynamics" was, so I hit the books, one word at


Dzero
Compact Muon Solenoid (CMS)
Collider Detector at Fermilab (CDF)
Cryogenic Dark Matter Search (CDMS)
Main Injector Neutrino Oscillation Search (MINOS)
Lattice Quantum Chromodynamics (LQCD)
Sloan Digital Sky Survey (SDSS)
NuMI Off-Axis Neutrino Appearance (NOvA)
Dark Energy Survey (DES)
Muon to Electron Conversion (Mu2e)
Chicagoland Observatory for Underground Particle Physics (COUPP)
Pierre Auger Observatory

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Lattice Quantum Chromodynamics (LQCD)

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Quantum Chromodynamics

Protons and neutrons (as well as other subatomic particles collectively known as hadrons) are made up of smaller particles called quarks, which are in turn held together by particles called gluons. QCD is a theory that describes the strong force interactions between the quarks and gluons.

Quarks

Quarks come in six different varieties, as given in the

The manner in which the up and down quarks are

In addition to the six varieties, quarks possess one

Quarks

Quarks come in six different varieties, as given in the standard model of particle

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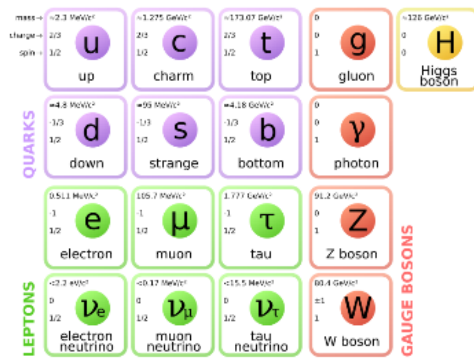
Quarks come in six different varieties, as given in the standard model of particle physics.



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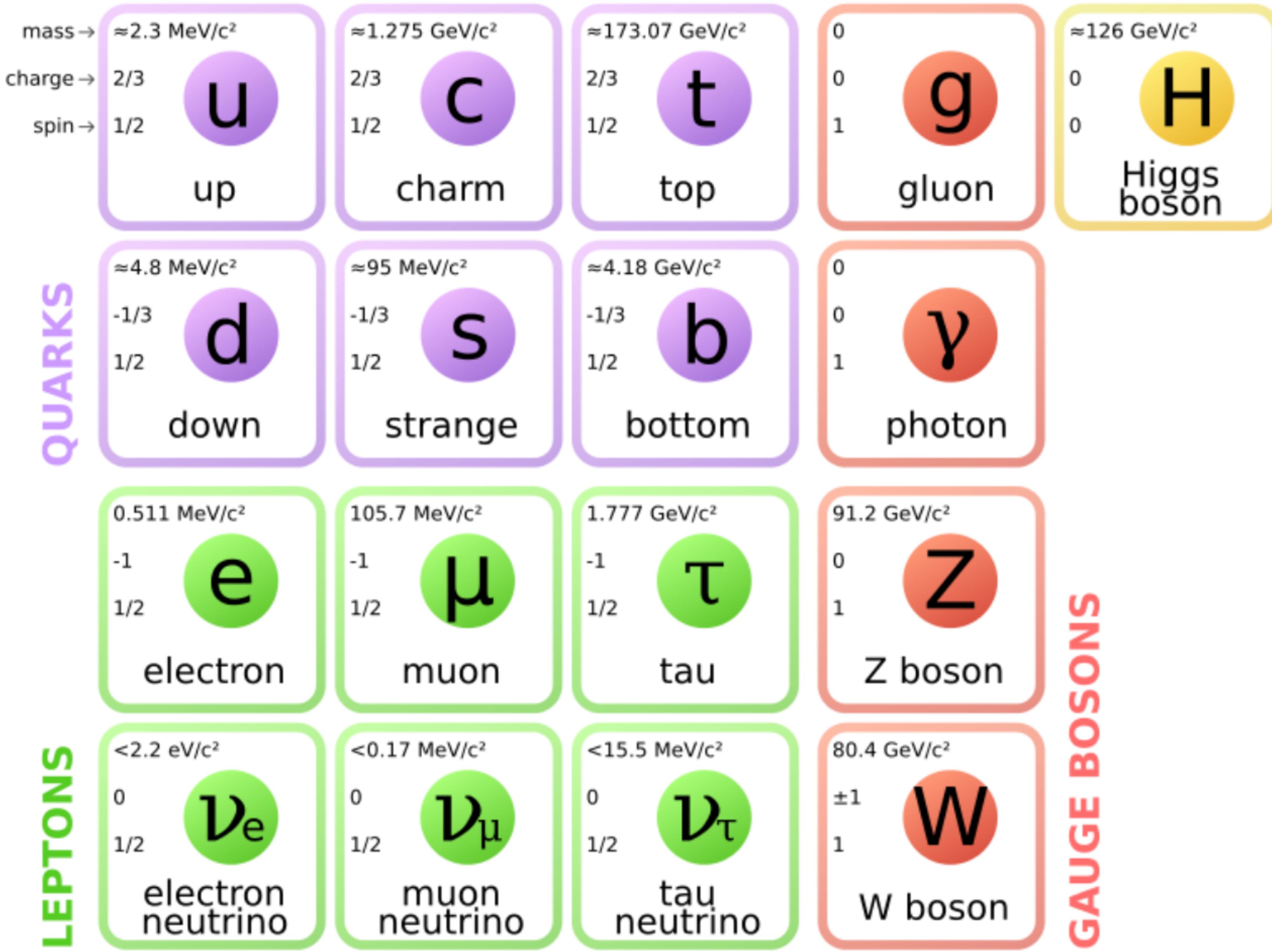
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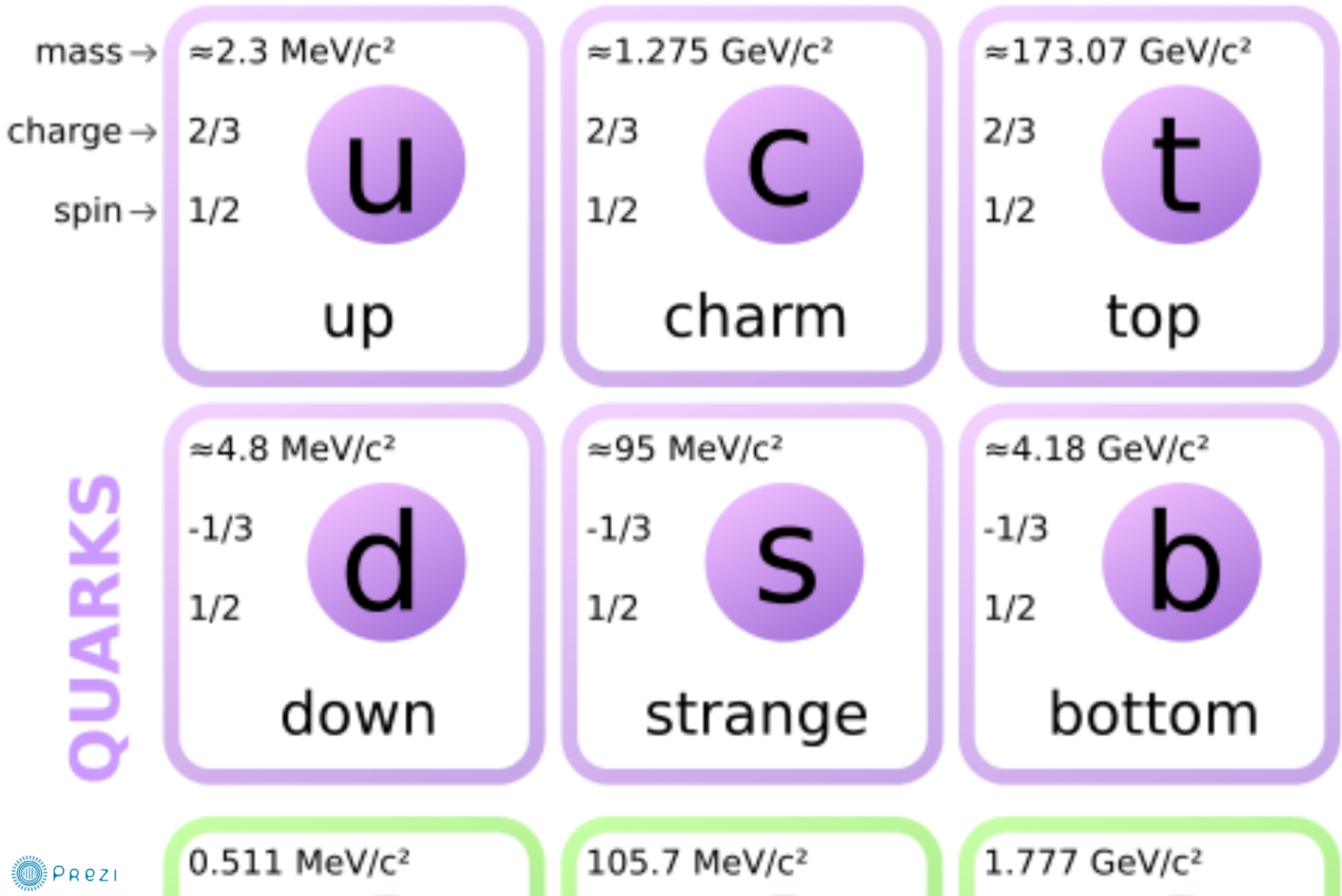
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SPECIAL EDITION

FermiNews

The Newsletter of the Fermi National Accelerator Laboratory

IS IT THE TOP QUARK? YES!!!

Physicists at Fermilab today announced the discovery of a subatomic particle known as the top quark, the last undiscovered quark of the six predicted to exist by current scientific theory. Scientists worldwide had sought the top quark since the discovery of the bottom quark at Fermilab in 1977.

Two research papers, submitted simultaneously on Friday, February 24, to *Physical Review Letters* by the CDF and DZero experiment collaborations respectively, describe the observation of top quarks produced in high-energy collisions between protons and antiprotons, their antimatter counterparts, at Fermilab's Tevatron, the world's highest energy particle accelerator. The collaborations, each with about 450 members, will present their results at seminars held at Fermilab today.

"Last April, CDF announced the first direct experimental evidence for the top quark," said WILLIAM CARITHERS, JR., cospokesman for the CDF experiment, "but at that time we stopped short of claiming a discovery. Now, the analysis of about three times as much data confirms our previous evidence and establishes the discovery of the top quark."

The DZero collaboration has discovered the top quark in an independent investigation. "The DZero observation

continued to page two

In this artist's representation of a particle collision, a proton and antiproton collide at nearly the speed of light.

Events of the Day

Thursday, March 2, 1995 • Volume 18, Number 4

CDF Seminar .... 1:30 p.m., Ramsey Auditorium

DZero Seminar .... 2:30 p.m., Ramsey Auditorium

Media Opportunity, pass required .... 4:00 p.m., 1 West Conference Room

The CDF & DZero preprints, the top quark press release and background information is available via WWW on the Fermilab home page. The URL is http://www.fnal.gov/ Paper copies of the preprints can be obtained from the Publications Office, WH15SW.

TRAC TEACHER BRINGS HIGH-ENERGY PHYSICS TO CLASSROOM

Jeff Rylander's physics classroom at Main East High School in Park Ridge, Illinois looks like many laboratory classrooms in the U.S.—tables and chairs are scattered about along with some lab equipment and a computer or two. But if you look closer in his room, you can see something not many other high schools have. Adjacent to a personal computer is a 4'x3'x1' box, or "coffin," as Jeff calls it.

This "coffin" is not for bidding laboratory mice adieu, rather it's used for a sophisticated experiment to measure the lifetime of a muon, a charged particle produced when cosmic rays collide with atoms in the earth's upper atmosphere. Modeled after similar equipment at Fermilab, this box will offer Jeff and his students a unique opportunity—an opportunity to explore high-energy physics much in the same way as it is done at Fermilab and other high-energy physics labs.

Jeff, a junior honors and introduction to physics teacher, built this muon detector while at Fermilab last summer as part of the Education Office's Teacher Research Associates Program (TRAC). He received help from DANE SKOW of the Physics Section as his program mentor and KAREN KEPHART, also of the Physics Section.

Jeff Rylander (lower l) with five students from his junior honors physics class and Dane Skow (lower r) in front of their muon detector. Jeff brought his students to the Lab in December for the test run of the equipment. "It was exciting for the students to see an experiment take its first data," said Jeff.

As part of the TRAC program, participating teachers are given a stipend to purchase equipment to help them bring their "research experience" back to their schools. After some consideration, Jeff and Dane decided on building a muon experiment. They modeled it after a similiar lab

continued to page seven

BE SAFE THIS SPRING: TORNADO AWARENESS TIPS

The week of March 6, 1995 has been designated as Tornado Preparedness Week by the Illinois Emergency Management Agency. As we approach the tornado season, it is important to become familiar with the unique character and weather terms that will be used throughout the season.

A tornado is a violent storm with whirling winds of up to 300 miles per hour. It appears as a rotating, funnel-shaped cloud, from gray to black in color, that extends toward the ground from the base of a thunderstorm. A tornado spins like a top and may sound like a roaring airplane or train. These short-lived storms are the most violent of all atmospheric phenomena, and over a small area, the most destructive.

According to the National Oceanic and Atmospheric Administration (NOAA), the peak month for tornado activity in Illinois is April. However, tornadoes have occurred as late as November.

The National Weather Service issues two types of tornado-related alarms, a tornado watch and a tornado warning. For your safety, familiarize yourself with both alarms.

A tornado WATCH means that conditions are favorable for tornadoes to develop. Listen to local radio, television or NOAA weather radio. Be alert for changes in the weather and be prepared to move to a place of safety quickly.

A tornado WARNING means that a tornado has been sighted and confirmed in the area. When a warning is issued, take cover immediately in a designated shelter. Stay away from outside walls and windows.

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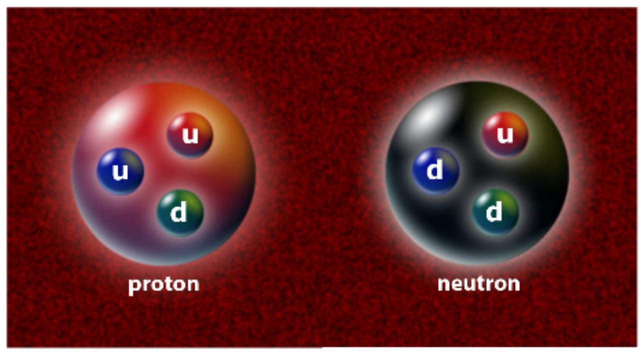
The manner in which the up and down quarks are combined determine what type of particle is created.



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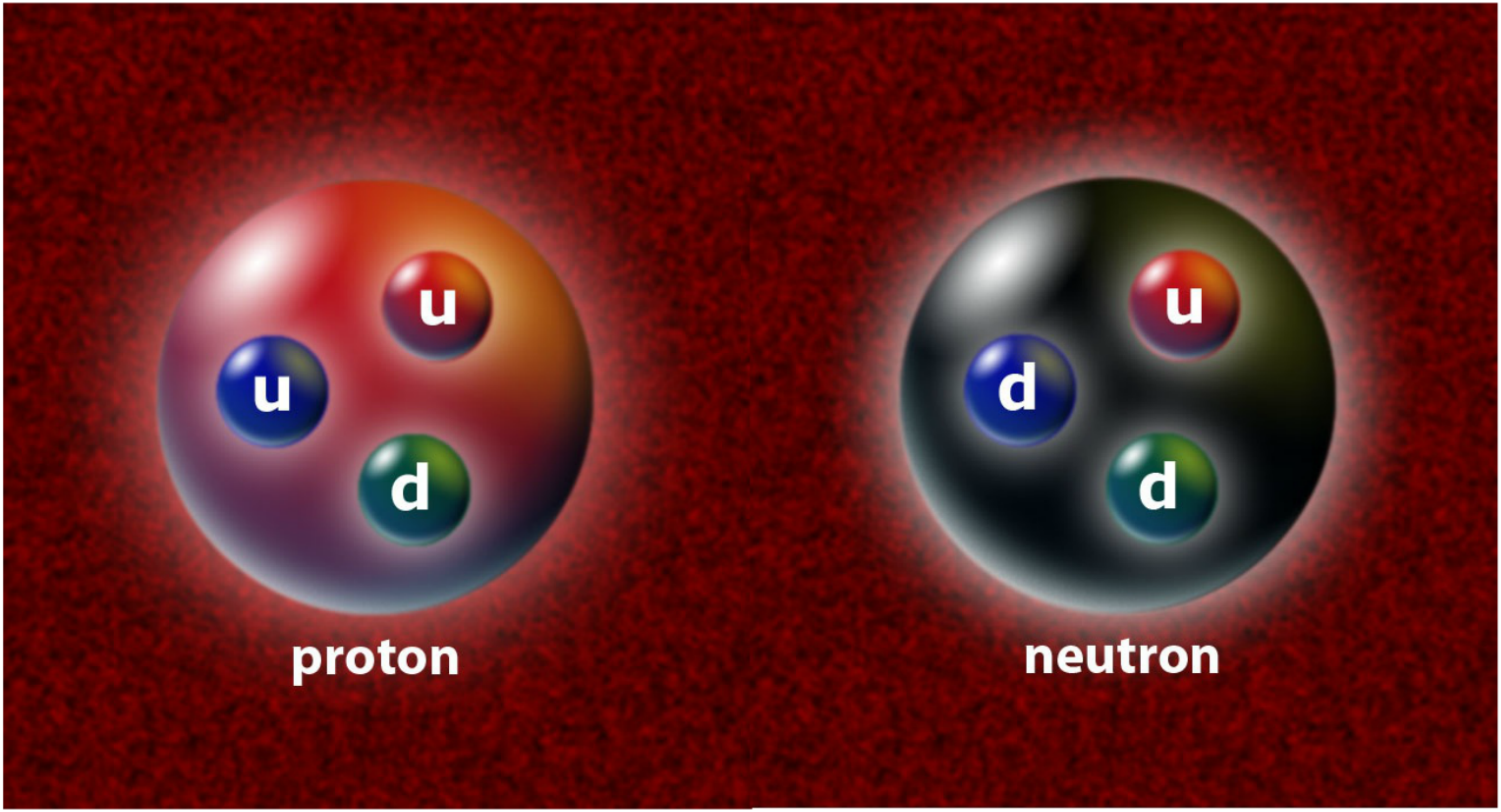
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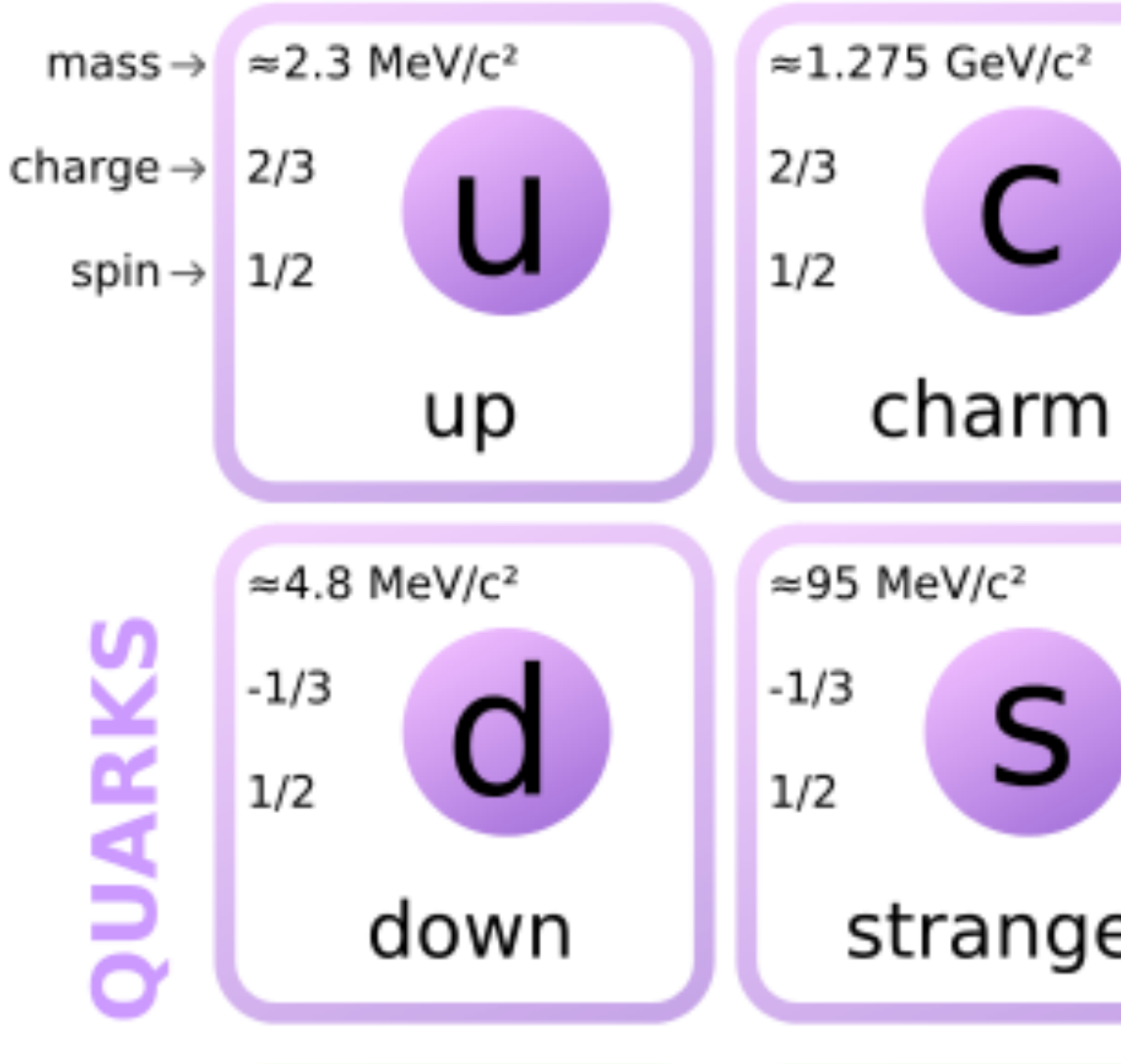
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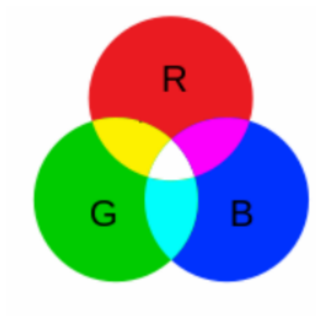
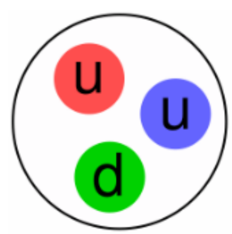
In addition to the six varieties, quarks possess one of three different "color charges": red, green, or blue.

This is not color in the visual since, but rather a handy classification system.

Just like the +1 and -1 charge of protons and electrons cancel out when combined, the three quark colors cancel out (turn white) when combined.





Any hadron with three quarks will always consist of one green, one blue, and one red quark. Thus, all hadrons are colorless.

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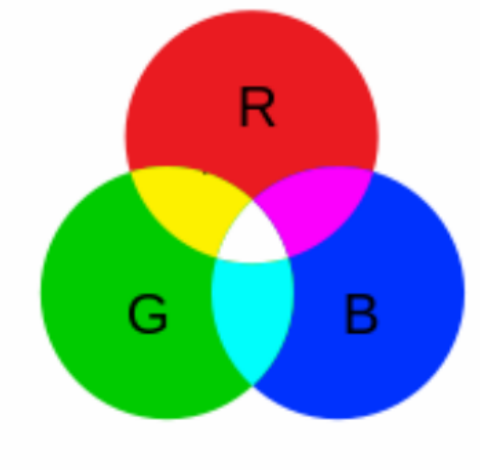

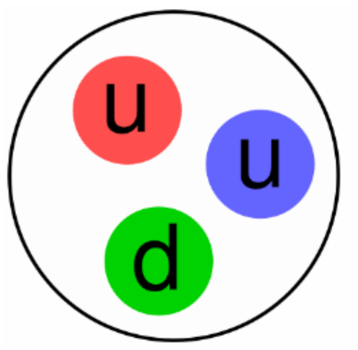

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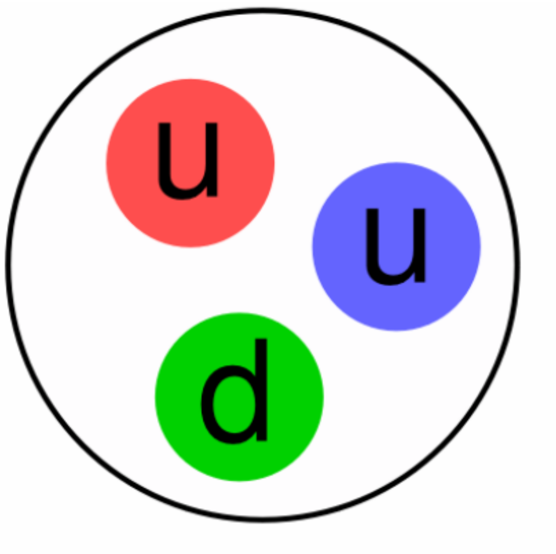


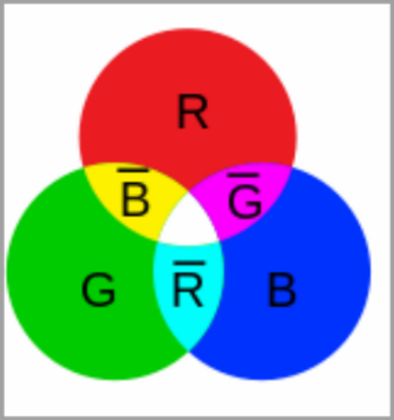
Any hadron with three quarks will always consist of one green, one blue, and one red quark. Thus, all hadrons are colorless.

Some hadrons are comprised of one quark and one anti-quark. These are known as mesons.
Even mesons are neutral in color.
Anti-quarks are colored anti-red, anti-blue, and anti-green.

Anti-protons & anti-neutrons are composed of up anti-quarks & down anti-quarks.

Anti-quarks are colored anti-red, anti-blue, and anti-green.

Also known as cyan, yellow, and purple.



Hadrons made up of 3 quarks (such as protons and neutrons) are called baryons.

Some hadrons are comprised of one quark and one anti-quark. These are known as mesons.

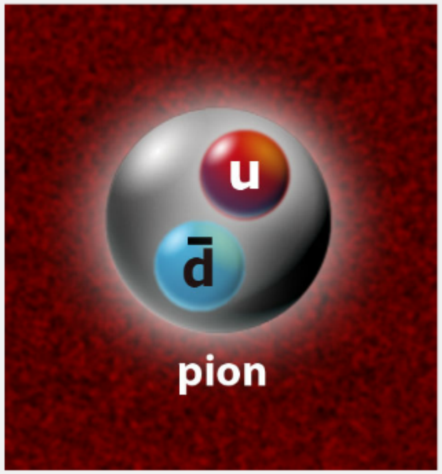
For example, there are the four pions:

p+ : U*D'

p0 : U*U' or D*D'

p- : D*U'

Even mesons are neutral in color:



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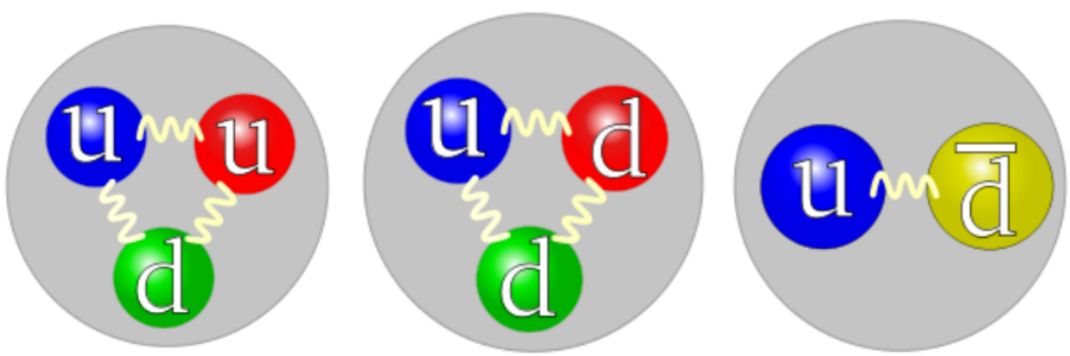
Gluons

Gluons are the force carriers that transmit the strong force between quarks and hold them together.



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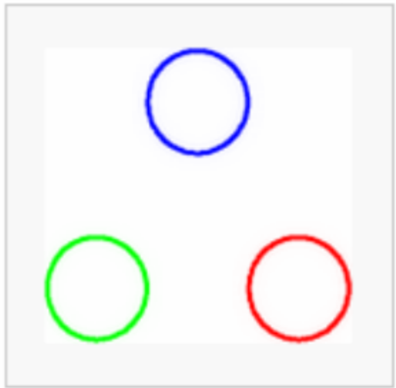

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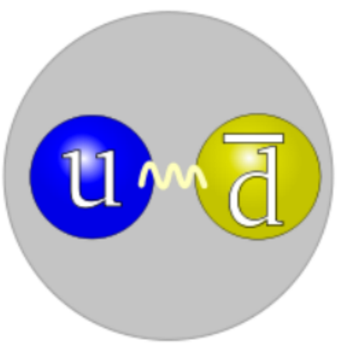
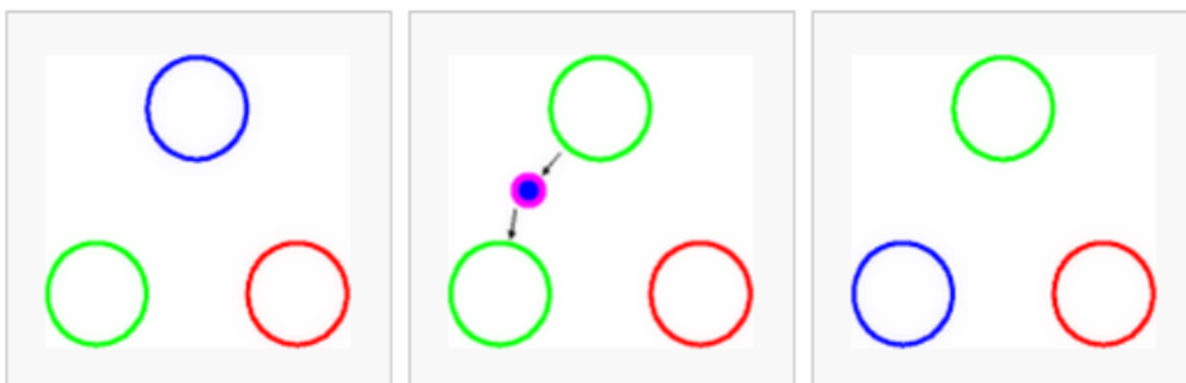


The gluons follow color field lines (analogous to magnetic field lines) between quarks.



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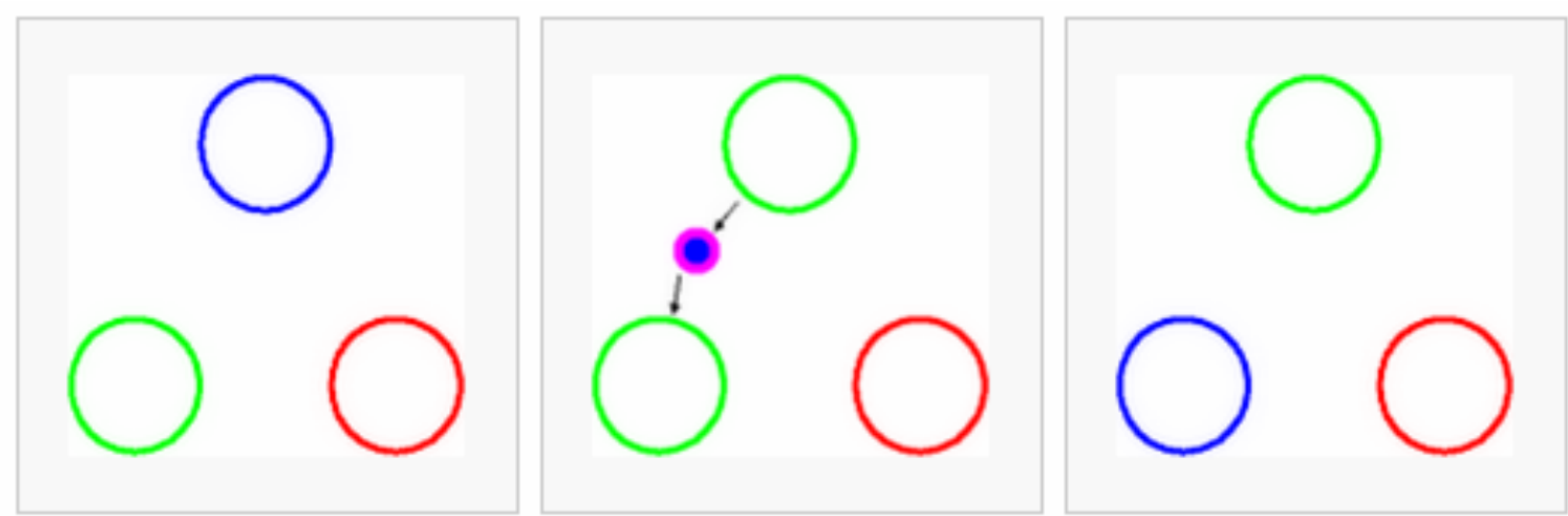
magnetic field lines) between quarks.



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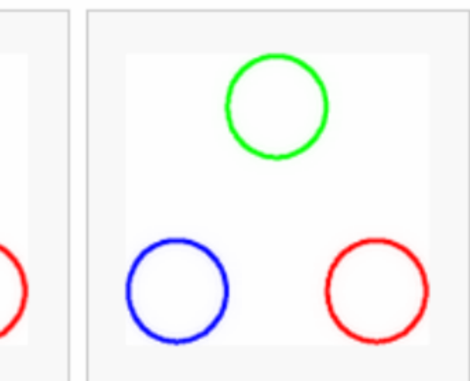

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In addition to being much stronger than gravitational and electromagnetic forces, it also gets stronger as distances increase, like a spring or a rubber band.

http://upload.wikimedia.org/wikipedia/commons/6/64/Gluon_tube-color_confinement_animation.gif

Lattice Quantum Chromodynamics

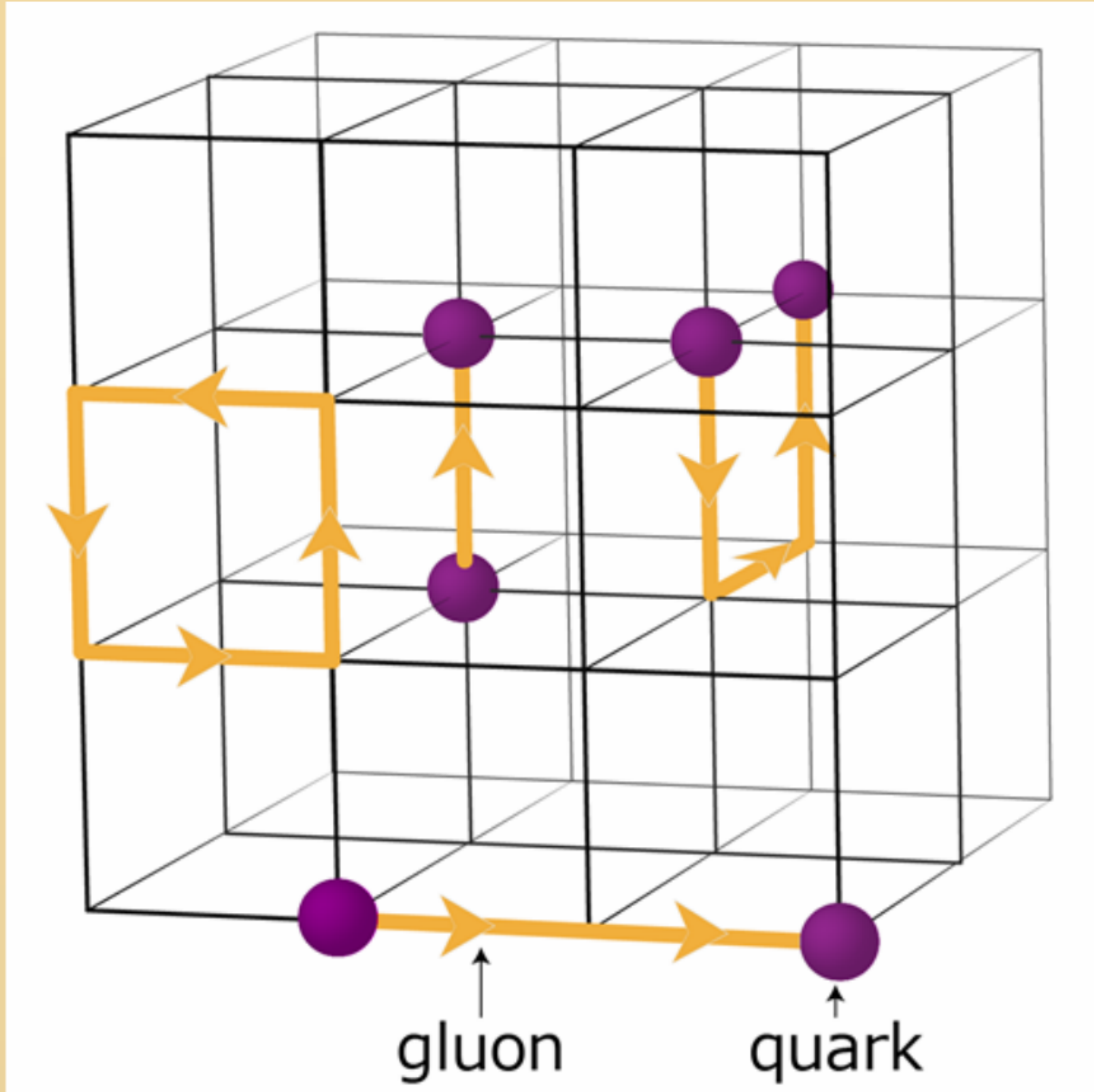
That all explained the "QCD" part of Lattice QCD.

Next, it was time to figure out what the "Lattice" portion meant.

Instead of treating the space-time the quarks and gluons inhabit as continuous, it is divided into a lattice of regularly-spaced points in space time.

A single slice of the lattice for a particular point in time would look something like this:

A single slice of the lattice for a particular point in time would look something like this:



In 4D, the lattice looks more like this:

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The benefits of such a discretizations of space time are

- Analyzing on the continuum is hard to impossible because of the non-linear nature of the string force.
- The spacing between the lattice can be allowed to approach zero, allowing the lattice to approach continuity.
- The methods used to analyze discretized space-time are very similar to those used in regular statistical analysees.

I wish I could say more about Lattice QCD, but

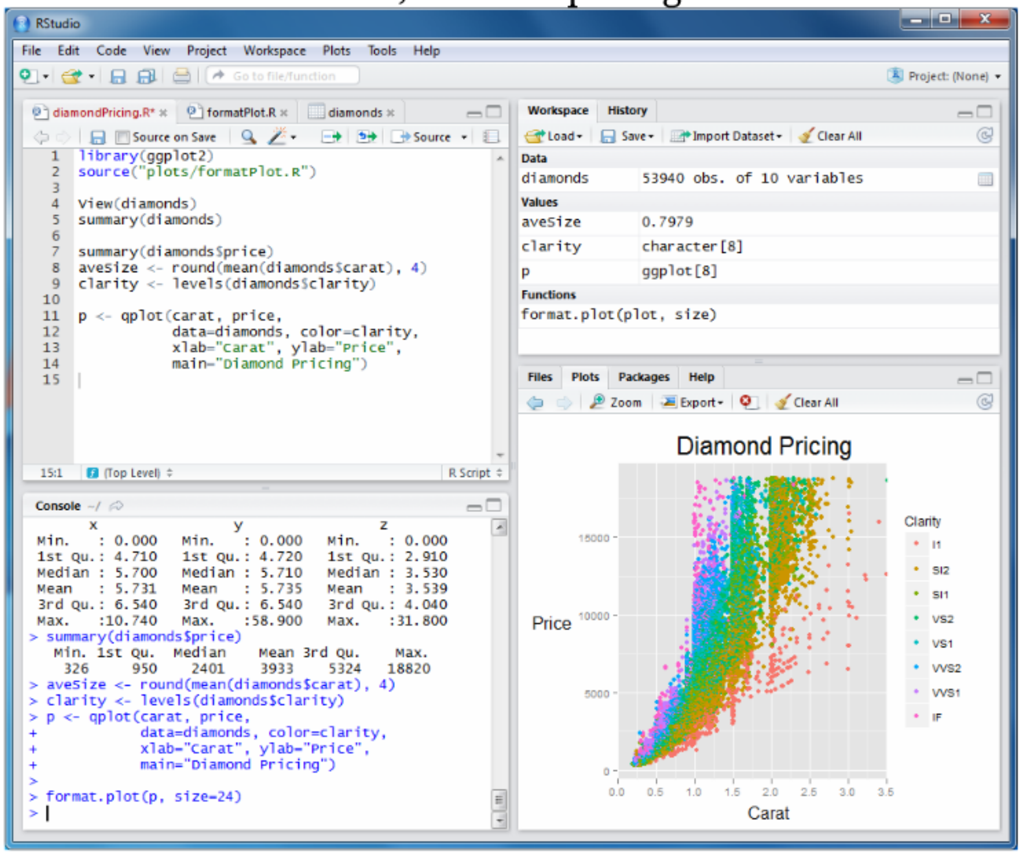
continuity.
The methods used to analyze discretized space-time are very similar to those used in regular statistical analysees.

I wish I could say more about Lattice QCD, but unfortunately, the first equation in a book titled "Basics of Lattice Quantum Chromodynamics" looked like this:

$$\frac{d\sigma}{dQ^2dy} = \sum_{i,j} \int_0^1 d\vartheta_a \int_0^1 d\vartheta_b f_{i/H_a}(\vartheta_a) f_{i/H_b}(\vartheta_b) \frac{d\hat{\sigma}(\vartheta_a, \vartheta_b, i, j)}{dQ^2dy}$$

Analyzing data

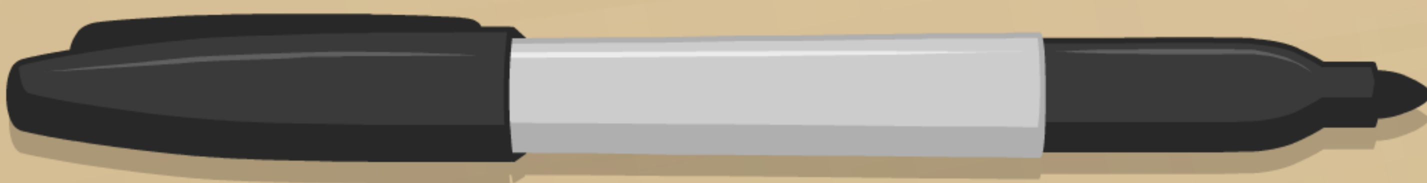
I used the R programming language to analyze data, both real and theoretical, and comparing the results.



What am I taking back with me?


Improved knowledge of particle physics
Renewed interest in programming
Fermilab itself
Humility

Any questions?



Thank you