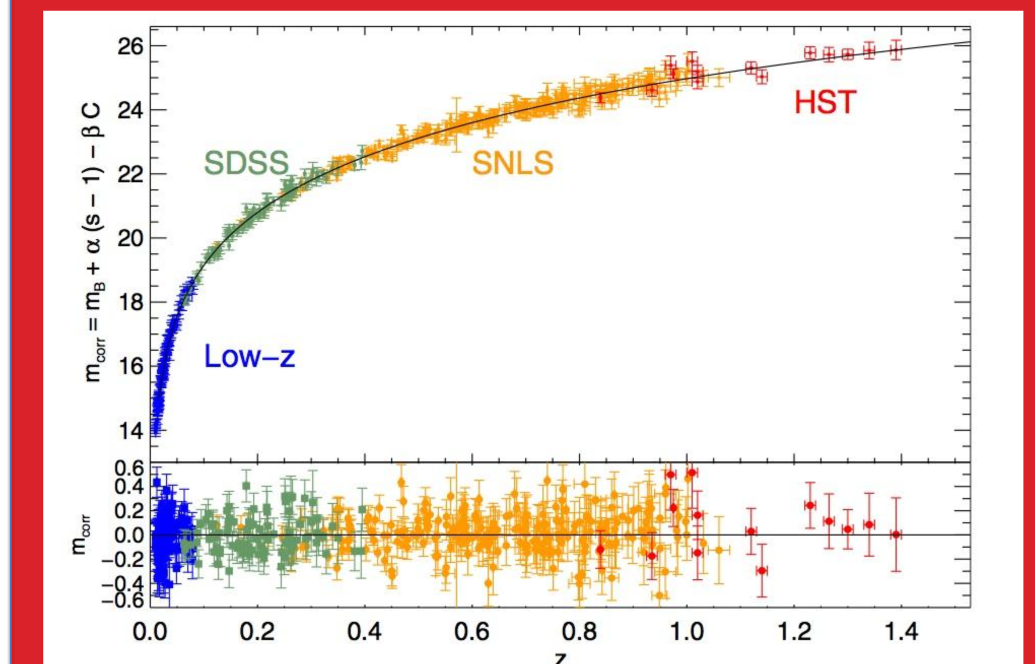
The Cosmic Frontier at Fermilab

Dark Energy



Hubble diagram

Measurements of the distant cosmos, such as the Hubble diagram shown at left, reveal a mysterious new force – *dark energy* - that appears to *accelerate* the expansion of the universe and makes up most of its total energy content. *Dark energy* can be studied through large-scale precision measurements of the expansion and structure of the universe using massive surveys.

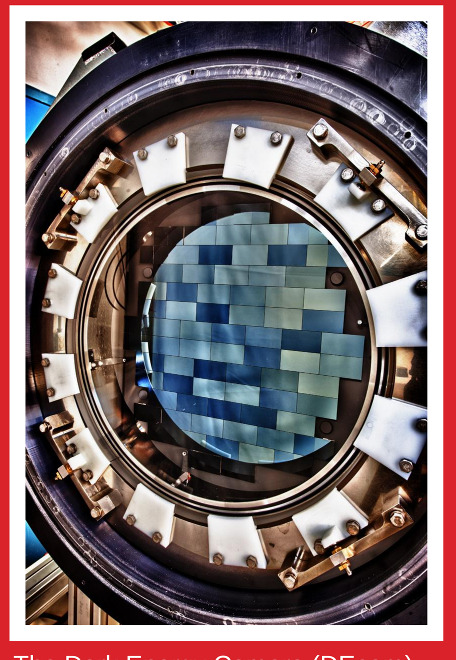
Sloan Digital Sky Survey (SDSS)


Sky catalogue: Galaxy Clusters

Fermilab's connection to dark energy research began with its role as the anchor laboratory for the Sloan Digital Sky Survey. SDSS was the world's first large, deep digital survey of the universe.

Fermilab now leads a supernova survey with SDSS that sets new standards for precision and error calibration in the use of supernovae to measure very large cosmic distances.

The Dark Energy Survey (DES)

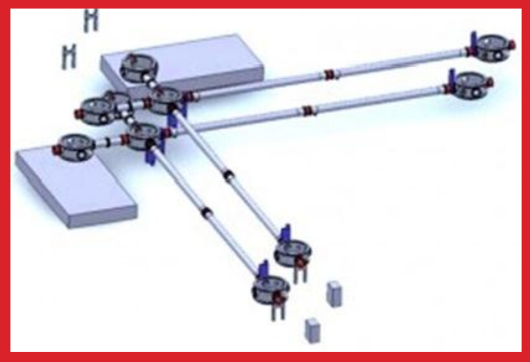

The Dark Energy Camera (DEcam)

The Dark Energy Survey will be a deeper, more precise successor to SDSS. Fermilab leads the international DES collaboration, which is deploying the Dark Energy Camera on the 4-meter telescope at the Cerro Tololo Inter-American Observatory (CTIO) in the Chilean Andes.

The final petabyte-scale survey database will comprise about 300 million galaxies and will look back in time over more than half of the age of the universe.

Quantum Spacetime

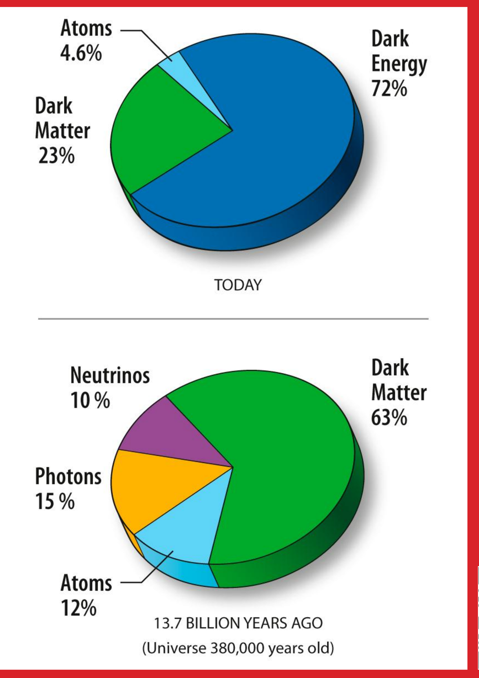
The length scale at which two important theories - general relativity and quantum field theory - are unified was first calculated by Max Plank and is known as the Planck Length (1.6×10^{-35} m).


Fermilab Holometer (conceptual design)

The holographic theories constructed to unify the theories predict subtle macroscopic effects. If there is a minimum interval of time, or a maximum frequency in nature, there is a corresponding limit on a on the fidelity of space and time ("quantum spacetime")

Using the technologies introduced in gravitational wave interferometers, the Fermilab Holometer will attempt to measure the holographic noise (blurriness) that would be caused by this limit. It will be the first direct experimental access to the Planck scale.

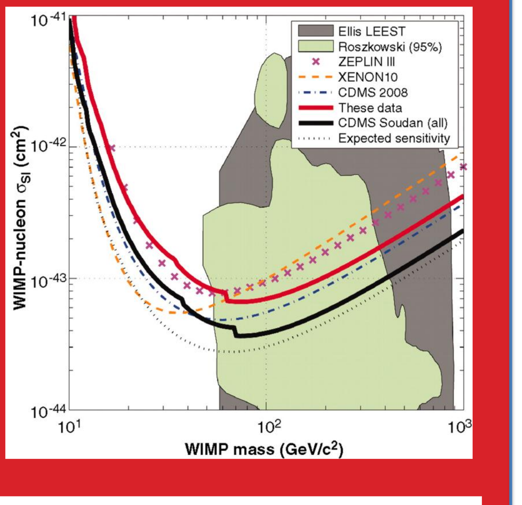
Dark Matter



Since the 1930s, astronomers have accumulated evidence that the mass that holds galaxies and clusters together with its gravity far exceeds the amount of mass in normal atoms in any detectable form. Scientists suspect this gravity comes from an invisible *dark matter* made of some new kind of elementary particle left over from the early universe. Fermilab is a leader in the worldwide hunt for dark-matter particles, playing a leading role in three kinds of experimental searches.

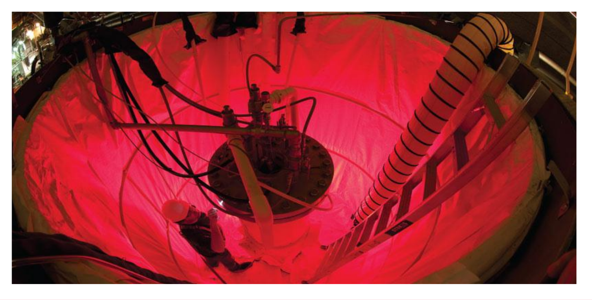
CDMS

The Cryogenic Dark Matter Search uses germanium crystals cooled to 0.04 degrees above absolute zero. CDMS data place the strongest current constraints on the properties of WIMPs (Weakly Interacting Massive Particles).



COUPP

The Chicagoland Observatory for Underground Particle Physics uses bubble chambers – dusting off this older particle physics technology in a new, powerful way – to search for nuclear recoils caused by collisions with dark matter.

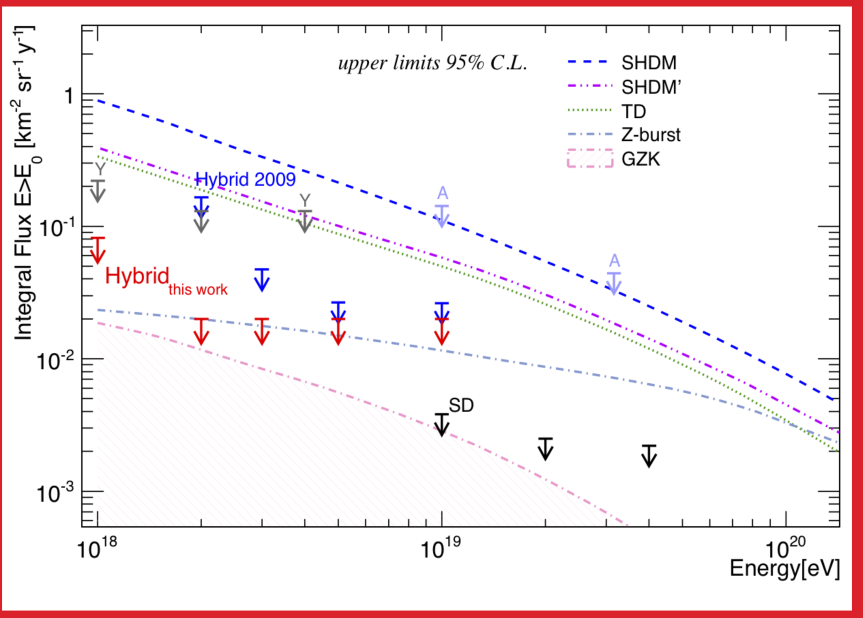


Darkside

Darkside (Depleted Argon cryogenic Scintillation and Ionization Detection) will place a liquid-argon detector in the Gran Sasso National Laboratory in Italy. The 50 kg detector will improve sensitivity by 10x over current experiments.

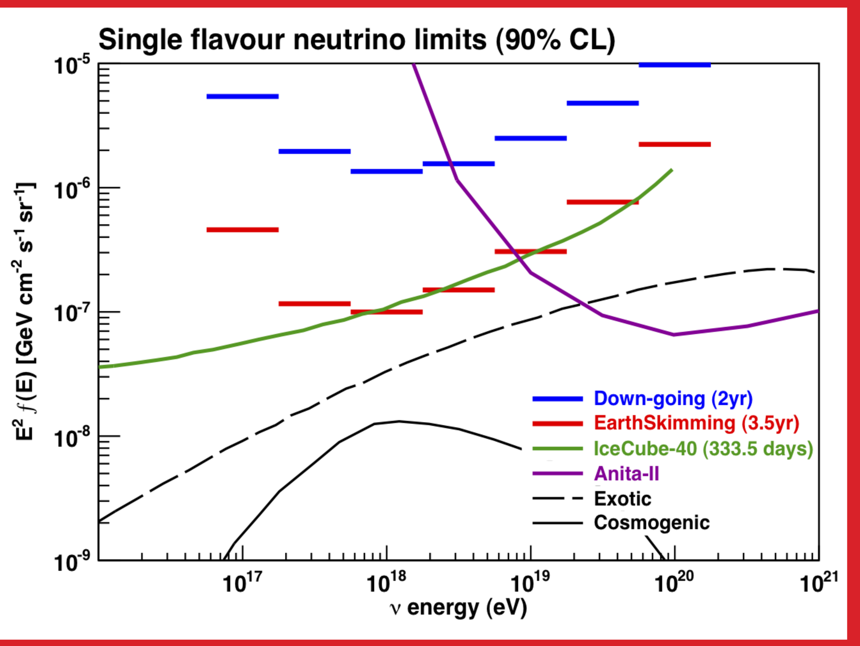
High-Energy Cosmic Particles

The universe accelerates particles to energies far greater than human-made accelerators can, more than 10 million times more energetic than protons in the Large Hadron Collider.



Fermilab is the lead laboratory supporting the Pierre Auger Cosmic Ray Observatory in Argentina, the premier facility for studying the highest energy cosmic rays. The Observatory consists of a surface array of 1600 water tanks (like the tank in the photo above) overlooked by four fluorescence detector telescopes. It covers 3000 km^2, roughly the area of the state of Rhode Island.

Auger currently has the most stringent limit on photon primaries, ruling out many top-down scenarios for ultra-high-energy cosmic ray production.



The best limits on a neutrino flux can be set by looking for deeply penetrating horizontal air (down-going) showers for all flavors via charged and neutral current interaction, and with Earth-penetrating (up-going) showers for tau neutrinos via decay into tau leptons. No neutrino candidates were observed.