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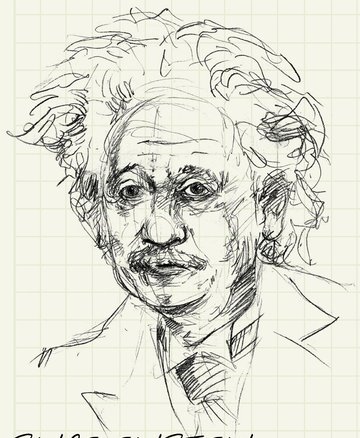


SINCE EINSTEIN, PHYSICISTS HAVE SOUGHT A UNIFIED THEORY TO EXPLAIN ALL THE FUNDAMENTAL FORCES AND PARTICLES IN THE UNIVERSE. THE RESULT IS A STUNNINGLY SUCCESSFUL THEORY THAT REDUCES THE COMPLEXITY OF MICROSCOPIC PHYSICS TO A SET OF CONCISE LAWS...

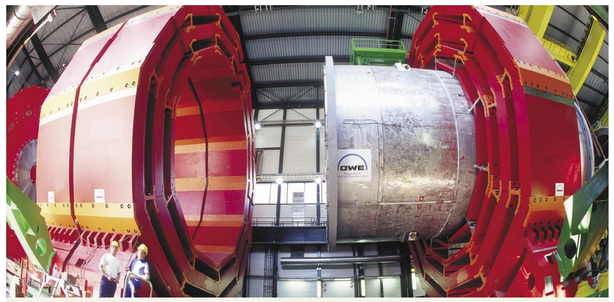
EINSTEIN'S DREAM OF UNIFIED FORCES

1
ARE THERE UNDISCOVERED PRINCIPLES OF NATURE : NEW SYMMETRIES, NEW PHYSICAL LAWS?

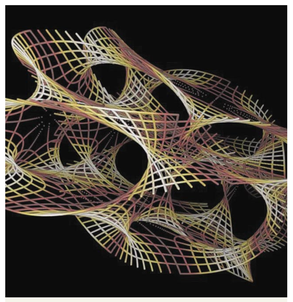
2
HOW CAN WE SOLVE THE MYSTERY OF DARK ENERGY?

3
ARE THERE EXTRA DIMENSIONS OF SPACE?

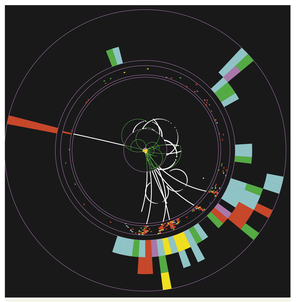
4
DO ALL THE FORCES BECOME ONE?



CMS DETECTOR AT THE LARGE HADRON COLLIDER The LHC, currently under construction in Geneva, Switzerland, should have enough energy to produce all or most of the superpartner particles, either directly or through the decays of other superpatners, to determine the pattern of superpartner masses and decays. *Credit: CERN*

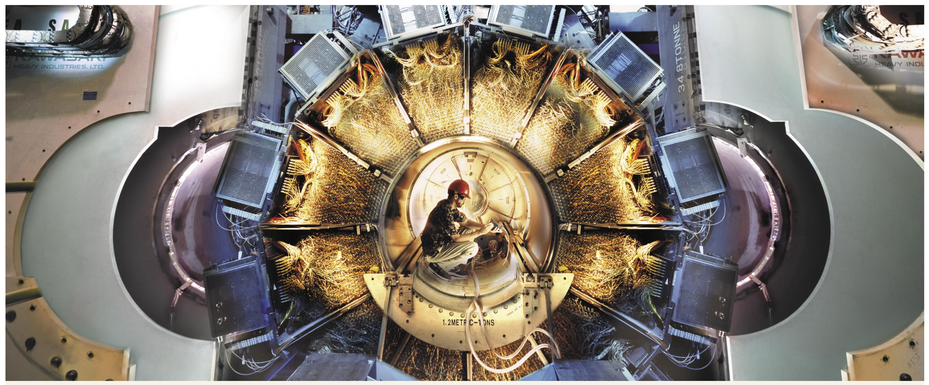


SUPERSTRINGS A computer's graphical representation of multi-dimensional spacetime. *Credit: Jean-Francois Colonna*



SUPERSYMMETRY Simulated response of linear collider detector to supersymmetry displaying the characteristic signature of a lepton, a hadronic jet and missing transverse energy. *Credit: Norman Graf*

THE FERMILAB TEVATRON may have enough energy to produce detectable signals of the lightest superpartners. *Credit: Fermilab*



BABAR (DETECTOR) at Stanford Linear Accelerator Center already constrains theoretical models for the physical mechanism that breaks supersymmetry. Future precision studies will allow physicists to disentangle the flavor structure of supersymmetry through subtle changes to decays of B mesons.
Credit : Stanford Linear Accelerator Center

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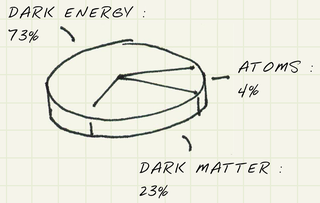
...BUT THESE SAME QUANTUM IDEAS FAIL WHEN APPLIED TO COSMIC PHYSICS. SOME FUNDAMENTAL PIECE IS MISSING; GRAVITY, DARK MATTER AND DARK ENERGY MUST HAVE QUANTUM EXPLANATIONS.

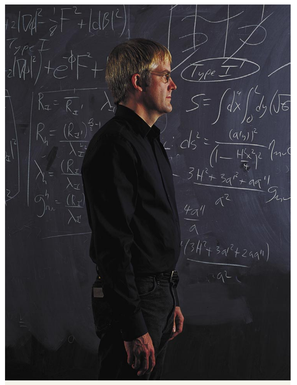


INVESTIGATIONS OF THE MICROWAVE BACKGROUND RADIATION HAVE SHOWN THAT NORMAL VISIBLE MATTER PLUS COLD DARK MATTER CAN ACCOUNT FOR ONLY ABOUT 30% OF THE CONTENT OF OUR UNIVERSE. THE REMAINING 70% IS DARK ENERGY.

THE LAWS OF NATURE DERIVE FROM NATURE'S SYMMETRIES; SEARCHING FOR NEW PARTICLES AND FORCES MEANS SEARCHING FOR NEW SYMMETRIES. ONE SUCH SYMMETRY MIGHT BE SUPERSYMMETRY, WHICH PREDICTS THAT FOR EVERY KNOWN PARTICLE THERE EXISTS A SUPERPARTNER PARTICLE OF THE SAME MASS.

THEORY THINK TANK AT SLAC
Credit: Peter Ginter

AN INTERNATIONAL SCIENCE Fermilab's DZero collaboration.
Credit: Fermilab



THEORIST JOE LYKKEN
Credit: Chicago Tribune Magazine

EXPERIMENTS ARE SEARCHING FOR SUPERSYMMETRY NOW; DIRECTLY AT THE TEVATRON AND INDIRECTLY AT THE B-FACTORIES BELLE AND BABAR.

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COMPUTING THE QUANTUM UNIVERSE

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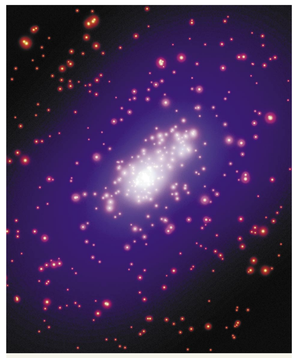
PHYSICISTS HAVE IDENTIFIED 57 DISTINCT SPECIES OF ELEMENTARY PARTICLES AND HAVE DETERMINED MANY OF THEIR PROPERTIES IN EXQUISITE DETAIL. WHAT ARE THEIR ROLES? HOW WILL WE KNOW WHEN WE HAVE FOUND THEM ALL?

THE PARTICLE WORLD

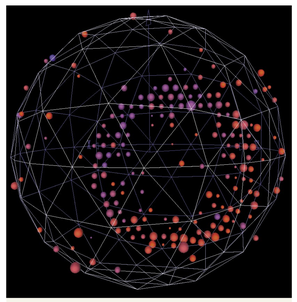
5
WHY ARE THERE SO MANY KINDS OF PARTICLES?

6
WHAT IS DARK MATTER?
HOW CAN WE MAKE IT IN THE LABORATORY?

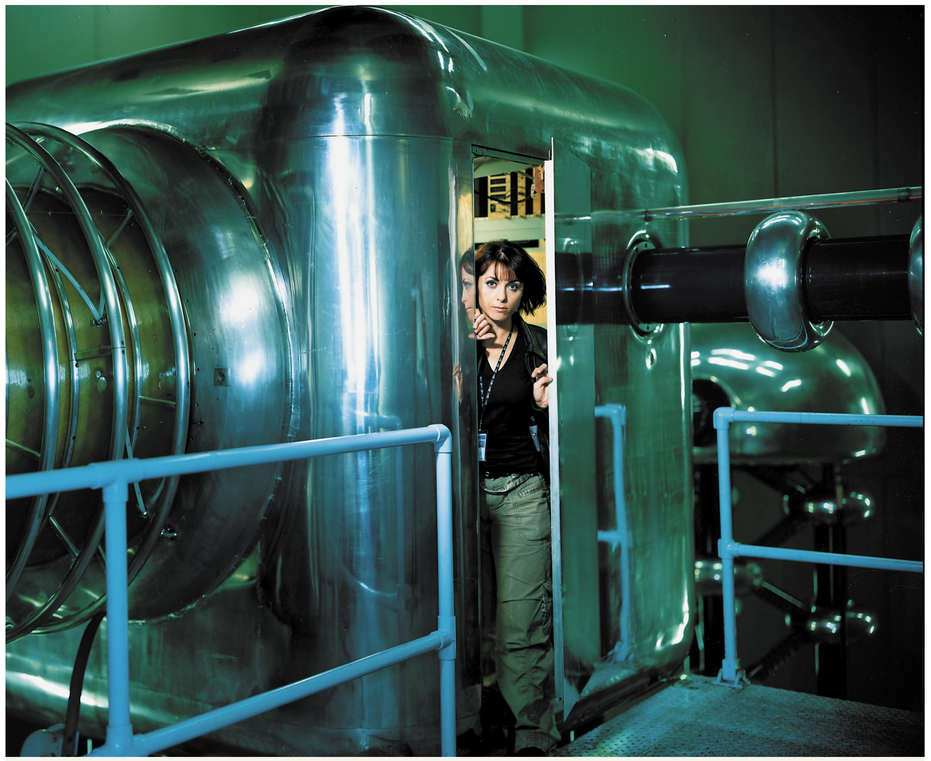
7
WHAT ARE NEUTRINOS TELLING US?



DARK MATTER MAP The total mass within giant galaxy cluster CL0025+1654 is the sum of the galaxies themselves, seen in yellow as ordinary luminous matter, plus the cluster's invisible dark matter shown in blue. The cluster's dark matter is not evenly distributed, but follows the clumps of luminous matter closely. *Credit: J.-P. Kneib Observatoire Midi-Pyrenees, Caltech. ESA, NASA*



NEUTRINO EVENT in the MiniBooNE experiment at Fermilab. The ring of light, registered by some of more than one thousand light sensors inside the detector, indicates the collision of a muon neutrino with an atomic nuclei. *Credit: Fermilab*



INSERT CAPTION *Credit: Fermilab*

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UBIQUITOUS, ELUSIVE AND FULL OF SURPRISES, NEUTRINOS ARE THE MOST MYSTERIOUS OF THE KNOWN PARTICLES IN THE UNIVERSE.

ν_μ ν_τ ν_e

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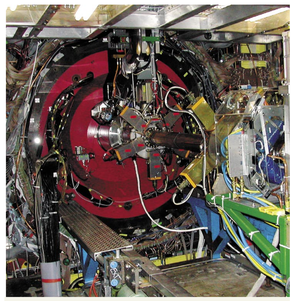
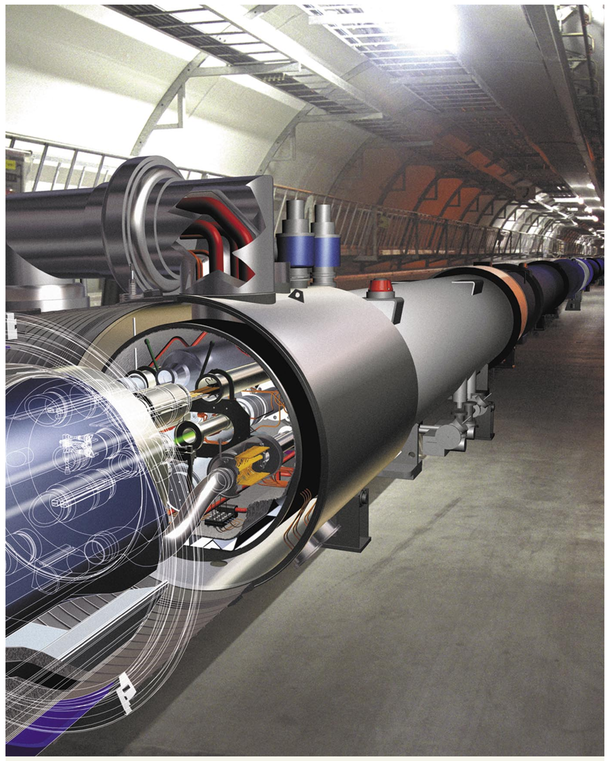
IN PARTICLE PHYSICS, ELEMENTARY PARTICLES ARE THE MESSENGERS OF NEW PHENOMENA, INCLUDING NEW FORCES AND NEW FORMS OF MATTER.



CLEO DETECTOR CLEO detects, measures and analyzes electron-positron collision events generated by CESR. *Credit: Cornell–Wilson Laboratory*

CAPTION



LARGE HADRON COLLIDER *Credit: CERN*

THE MILKY WAY GALAXY
Credit: Allan Morton / Dennis Millon / SPL

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QUANTUM MECHANICS DICTATES THAT EVEN HIDDEN DIMENSIONS SHOW UP AS ELEMENTARY PARTICLES. BY MEASURING THEIR PROPERTIES, PHYSICISTS CAN INFER THE SHAPES AND SIZES OF THE HIDDEN DIMENSIONS.

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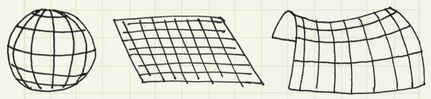
WHAT STARTED THE BIG BANG? HOW DID SPACE, TIME, MATTER AND ENERGY TAKE THE FORMS THAT WE SEE TODAY? CAN WE WORK BACKWARD TO UNRAVEL THE HISTORY OF THE UNIVERSE?

POSSIBLE GEOMETRY OF UNIVERSE



CLOSED FLAT OPEN

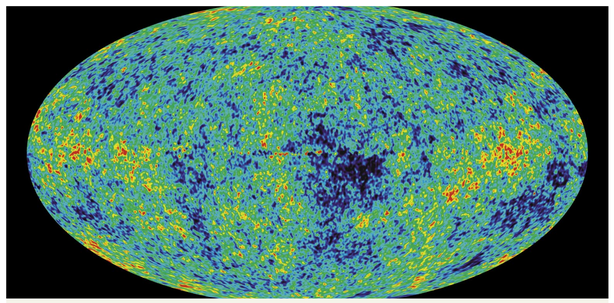
THE BIRTH OF THE UNIVERSE

8

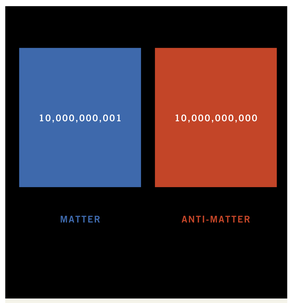
HOW DID THE UNIVERSE COME TO BE?

9

WHAT HAPPENED TO THE ANTIMATTER?

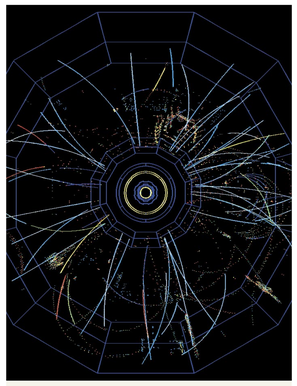


THE MICROWAVE SKY The first detailed, all-sky picture of the infant universe. The WMAP image reveals 13 billion+ year old temperature fluctuations (shown as color differences) that correspond to the seeds that grew to become the galaxies. Encoded in the patterns are the answers to many age-old questions, such as the age and geometry of the Universe. *Credit: NASA / WMAP Science Team*

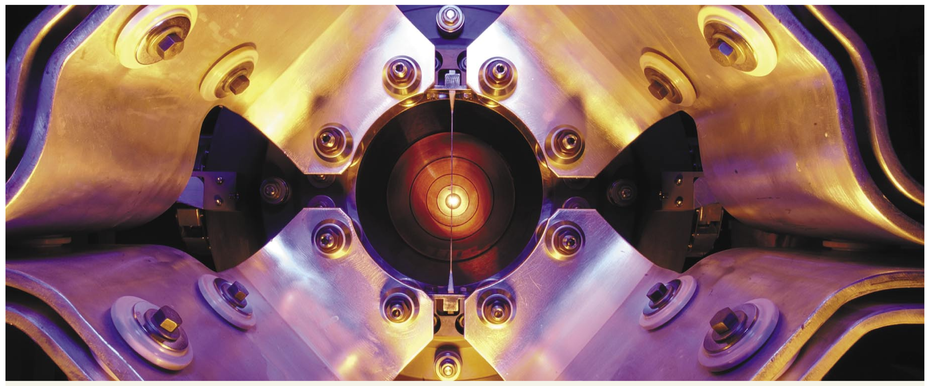


THE EARLY UNIVERSE
When matter and antimatter annihilated at the big bang, some tiny asymmetry...

TODAY'S UNIVERSE ...produced our universe, made entirely of matter. *Credit: Hitoshi Murayama*



RHIC An end view of a collision between deuterons and gold ions captured by the STAR detector at Brookhaven's Relativistic Heavy Ion Collider, which will help study QCD phase transition. *Credit: Brookhaven National Laboratory*



NUMI Horn for focusing particles at the NuMI experiment, which will search for neutrino mass. Neutrino mass can, in principle, turn matter into antimatter and back, and can change the balance between them. *Credit: Fermilab*

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AFTER THE BIG BANG EXPLODED WITH ENORMOUS ENERGY, THE UNIVERSE BEGAN THE COOL-DOWN THAT HAS LASTED UNTIL OUR OWN TIME. THE RESULTING CHAIN OF EVENTS IS A COSMIC DRAMA WITH MANY ACTS, DRAMATIC TRANSITIONS AND A HOST OF ACTORS APPEARING AND DISAPPEARING ALONG THE WAY. THE EARLY SCENES PLAYED OUT AT UNIMAGINABLE TEMPERATURES AND DENSITIES, THE STAGE SET BY THE FUNDAMENTAL PROPERTIES OF PARTICLE PHYSICS.

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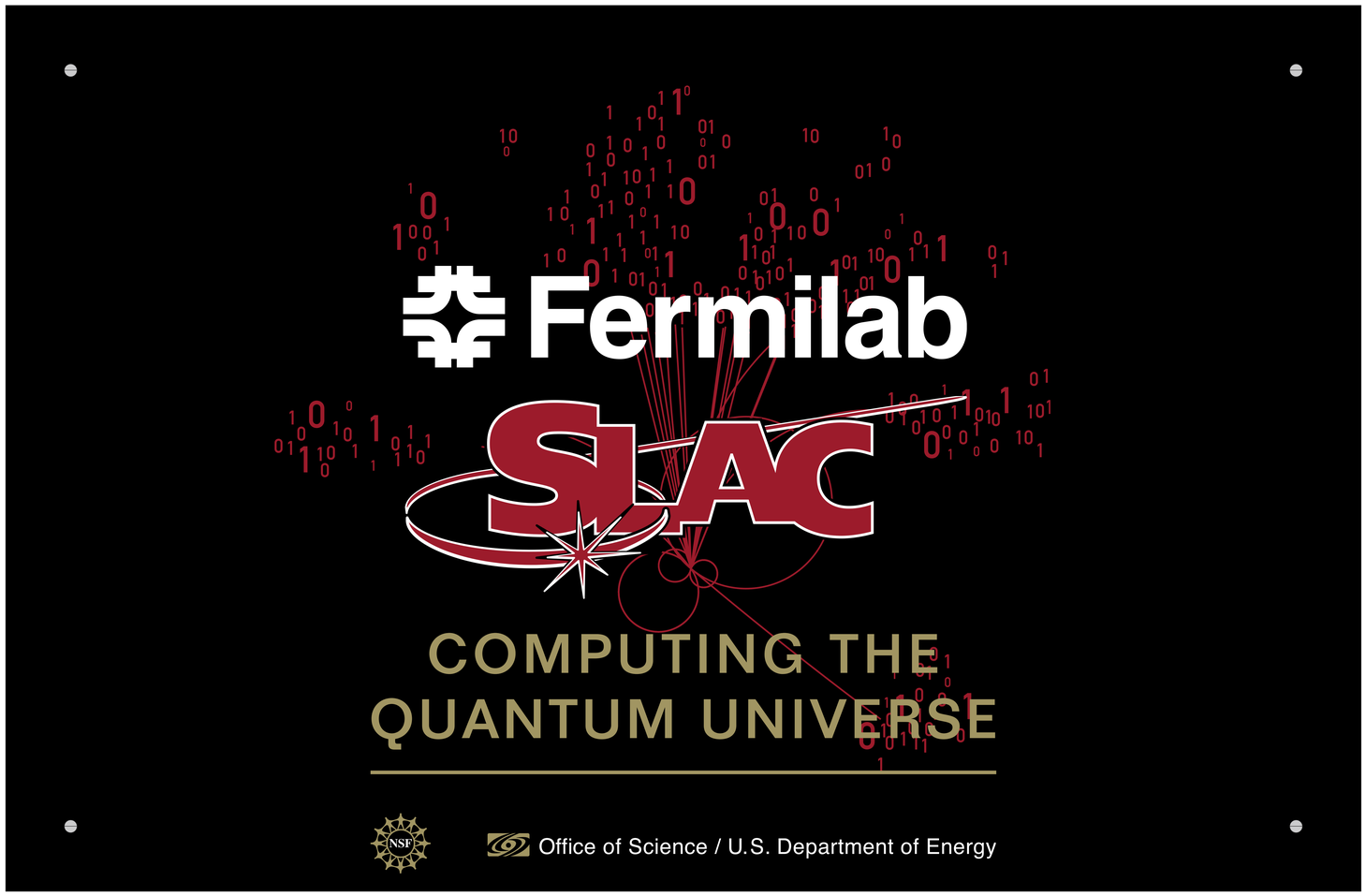
TO RECONSTRUCT THE COSMIC STORY, TELESCOPES AND SPACE PROBES DETECT THE RELICS FROM THE EARLY UNIVERSE, AND PARTICLE ACCELERATORS RECREATE AND STUDY THE EXTREME PHYSICS THAT CHARACTERIZED THE STAGES OF DEVELOPMENT AND THE TRANSITIONS BETWEEN THEM. AS WE BEGIN TO UNDERSTAND THE COSMIC PAST, WE CAN LOOK TO THE FUTURE OF THE UNIVERSE AND PREDICT ITS ULTIMATE FATE.

WORKING LATE Fermilab physicist Brenna Flaugher. *Credit: Fermilab*



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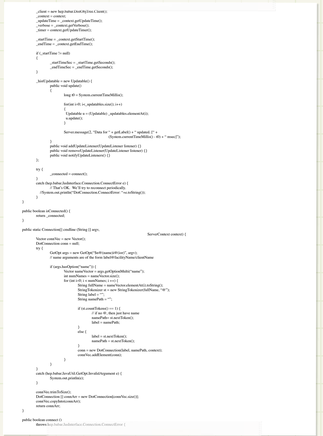
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