

# NEUTRINOS AND DARK MATTER IN THE CLASSROOM



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North Dakota

South Dakota

Nebraska

Wyoming

Minnesota



- Buffalo
- Lemmon
- Mobridge
- Aberdeen
- Gettysburg
- Redfield
- Watertown
- Dupree
- Pierre
- Brookings
- Rapid City
- Philip
- Chamberlain
- Mitchell
- Sioux Falls
- Hot Springs
- Winner
- Pine Ridge
- Lake Andes
- Lead

# SANFORD LAB EDUCATION AND OUTREACH



We strive to introduce students at all grade levels to what is happening in their state/region with:

1. CLASSROOM PROGRAMS - <http://www.sanfordlab.org/education/assembly-programs>
2. FIELD TRIPS - <http://www.sanfordlab.org/education/request-visit>
3. CURRICULUM UNITS - <http://www.sanfordlab.org/education/curriculum-modules>

Engineering



# Deep Science

Biology

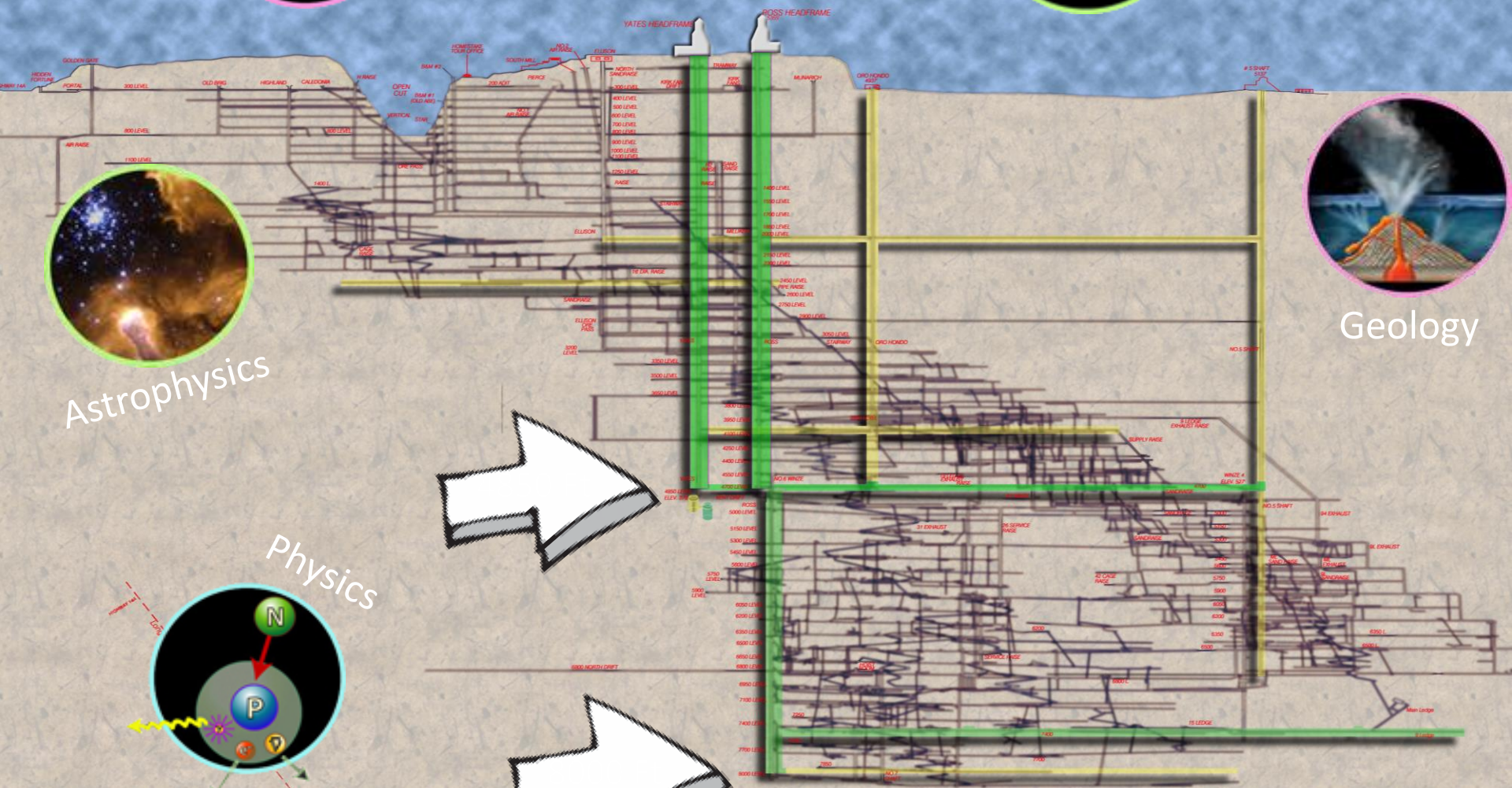
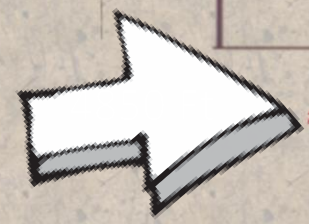
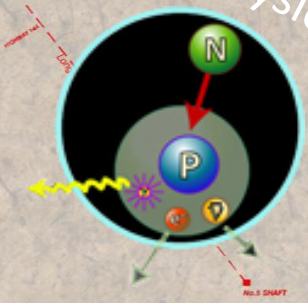


Astrophysics

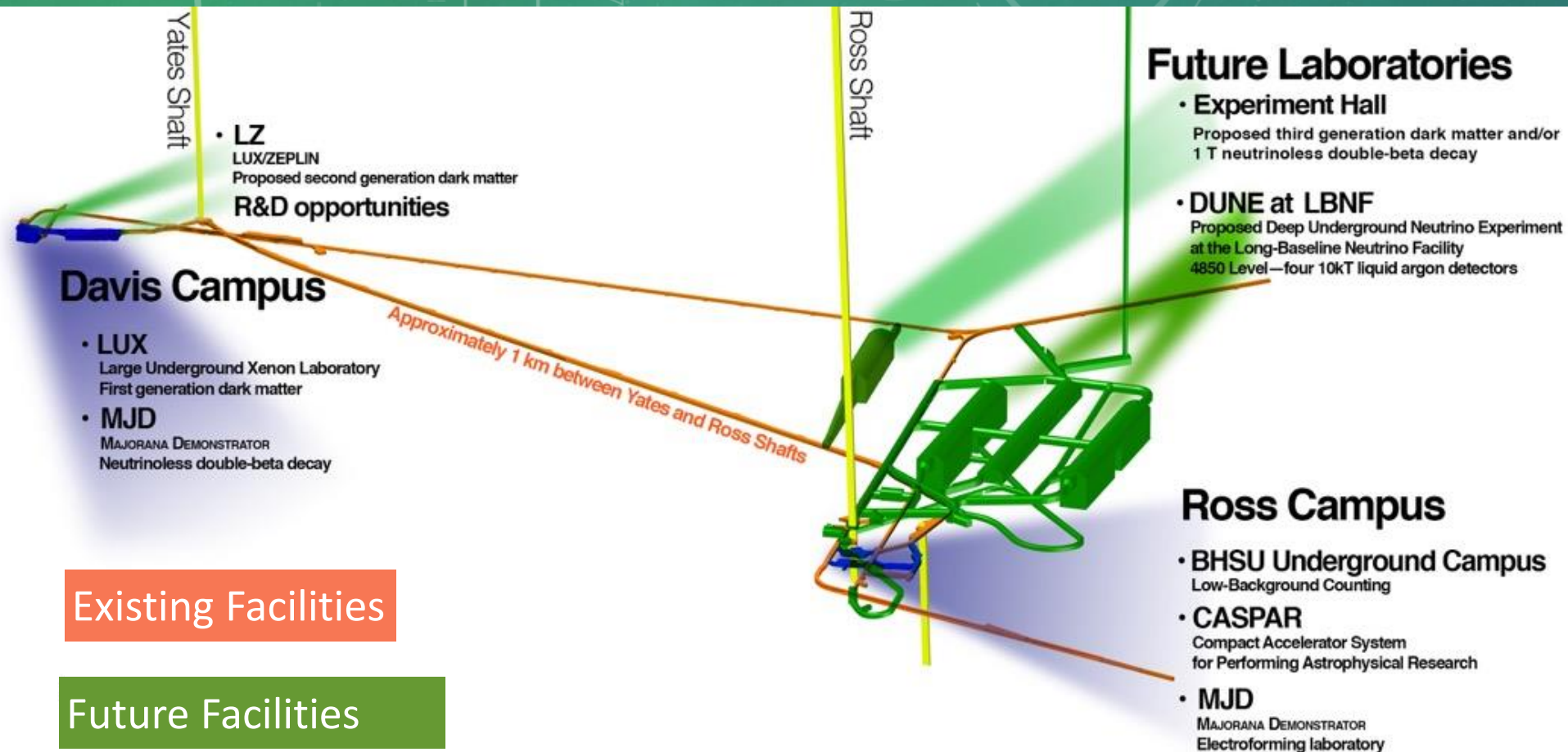


Geology

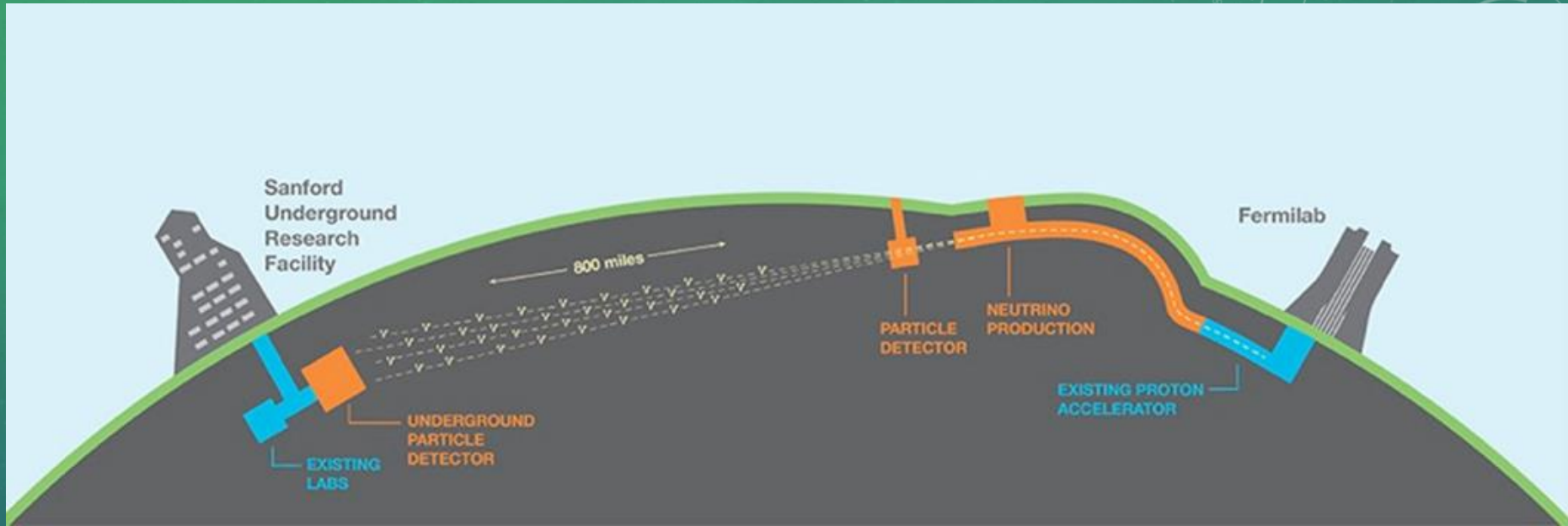
Physics



# 4850L HEP FACILITIES



# LBNF AND DUNE



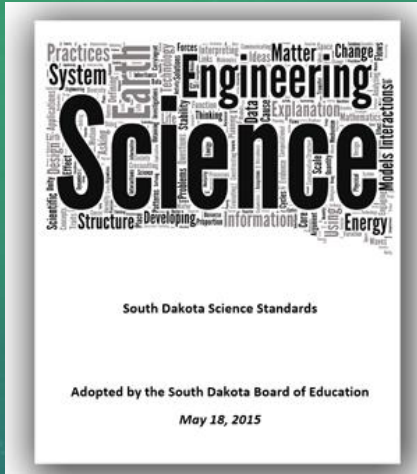
- LBNF: provides facilities at two locations to support DUNE

- Near Site: Fermilab, Batavia, IL - facilities to create a neutrino beam
- Far Site: Sanford Underground Research Facility, Lead, SD - facilities for DUNE detectors

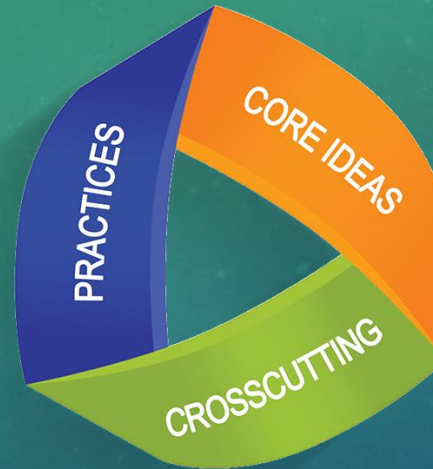
- DUNE: large liquid argon detectors to study neutrino oscillations

- Near and Far Site neutrino detectors: U.S. as partner in international project
- DUNE Collaboration includes 150 institutions, 28 countries, over 840 collaborators

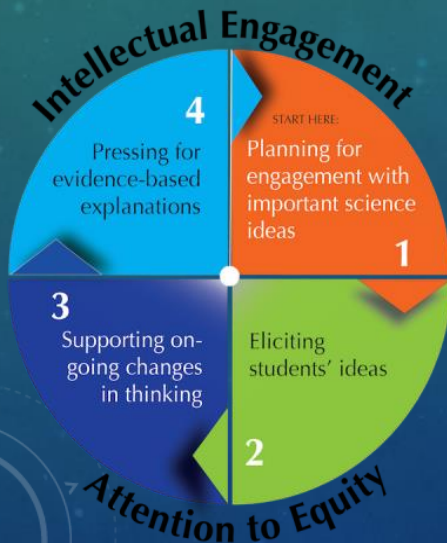
# ALL CURRICULUM UNITS



Are aligned with South Dakota (i.e. NGSS) science standards



Feature science and engineering practices from the Framework



Designed around an anchoring phenomenon ([www.ambitiousscience Teaching.com](http://www.ambitiousscience Teaching.com))



Connects with the science and engineering happening at Sanford Lab

# LOGISTICS

- All units come with a materials kit for hands-on activities
- Schools schedule a unit through an online form:
  - We ship out materials kits ahead of start date (available within South Dakota).
  - The school is responsible for returning material in good shape.
- All students are given a pre- and post-assessment associated with the unit.
- In 2015-2016, NASA funds enabled us to provide teacher stipends for substantial feedback during the pilot phase.
  - The combination of the teacher feedbacks and assessments were used in revising units for 2016-2017

OFFERINGS	TARGETED GRADES	STATUS
Exploring the Unseen	3-5	Piloted in 2015-2016; Revised for 2016-2017; Teacher training 2016
May the Force be With You		
Science and Measurement		New for 2016-2017
Seismic Science	6-8	Piloted in 2015-2016; Revised for 2016-2017; Teacher Training 2016
The Search for Dark Matter		
Waterworks		New for 2016-2017
'We are Made of Starstuff'	9-12	Piloted in 2015-2016; Revised for 2016-2017; Teacher Training 2016
Perplexing Puddles		

<http://www.sanfordlab.org/education/curriculum-modules>

# THE SEARCH FOR DARK MATTER

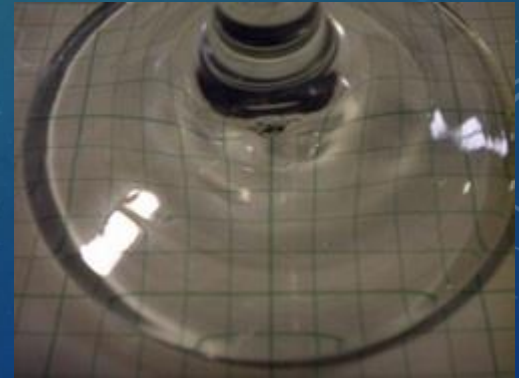


Science Focus:  
What is dark matter, what is the evidence for its existence and how are scientists searching for it.

	Lesson Title	Science	Scientist Featured	Technology
1	Our Modern Universe	The Scale of the Universe	Early Astronomers	Eyes
2	Exploring the Universe through Light	Atomic Spectroscopy	Galileo; Fritz Zwicky	Telescopes
3	The Role of Gravity	Gravity and Orbital Motion	Vera Rubin	Telescopes/ Spectroscopy
4	Exploring the Unseen	Indirect Evidence	Ray Davis	Underground Detectors
5	Gravity and Light: Evidence of Dark Matter	Gravitational Lensing	Albert Einstein	Hubble Space Telescope
6	Going Deep for Dark Matter: The LUX Detector at SURF	How LUX Works / Video-conference with Davis campus	LUX Graduate Student	Cryogenic underground Detectors

# SAMPLE HANDS-ON ACTIVITIES

- LESSON 2
  - Exploring Light - Atomic Spectroscopy
- LESSON 4
  - Indirect Evidence - Black Boxes with 3-D graphing
- LESSON 5
  - Gravitational Lensing - using goblets
- LESSON 6
  - Modeling the LUX Detector - a WIMP tag game



# ONLINE INTERACTIVE RESOURCES UTILIZED

- LESSON 1

- The Scale of the Universe Website (<http://www.htwins.net/scale2/>) - students explore using a graphic organizer as a guide

- LESSON 3

- Gravity Launch Simulator (<http://sciencenetlinks.com/interactives/gravity.html>) - students use the simulator to explore the parameters that allow an object to be captured in an orbit
- Rotating Galaxy Interactive ([http://highereducation.com/olcweb/cgi/pluginpop.cgi?it=swf::100%::100%::/sites/dl/free/0072482621/78778/DarkMatter\\_Nav.swf::Dark%20Matter%20Interactive](http://highereducation.com/olcweb/cgi/pluginpop.cgi?it=swf::100%::100%::/sites/dl/free/0072482621/78778/DarkMatter_Nav.swf::Dark%20Matter%20Interactive)) - students can explore what happens to the orbits of stars in a galaxy as they change the amount of dark matter

- LESSON 4

- Quarked Website ([www.quarked.org](http://www.quarked.org)) - students are guided through using online games to explore the particle universe.

# CLASSROOM\* PROGRAMS - SPRING 2016

OFFERINGS	RECOMMENDED FOR GRADES	TIME NEEDED	CONNECTION TO SURF
A Day in the Life of a Sanford Lab Scientist	K-5	30 minutes	Working underground
Nerds Searching for WIMPs	3-5	30-minutes	Dark Matter and LUX Experiment
Discover Exciting Career Possibilities	Middle School (6-8)	45 minutes	STEM Careers
Neutrinos – Matter or Not?	High School (9-12)	50 – 90 minutes (will fit to size of class period)	LBNF / DUNE

\*can be done in single classrooms or with several grades or classes together

- reached 8588 students in 60 schools in 2015-2016

<http://www.sanfordlab.org/education/assembly-programs>

# NEUTRINOS - MATTER OR NOT?

- Introduces the standard model, matter and antimatter and interactions
- What's special about neutrinos?
- The Solar Neutrino Problem and how it was resolved
- The future - how to make a neutrino beam
- Engineering the underground for DUNE
- Timeline (in student terms)



SPIN = 1/2

## Properties

mass= 2.3 MeV  
charge= +2/3  
flavor = yes  
color = yes

interaction?

# ACKNOWLEDGEMENTS

- The Sanford Lab Education and Outreach Group
  - Dr. June Apaza, Julie Dahl, Dr. Peggy Norris, Dr. Ben Sayler
- Our master teacher helpers
  - Lynn Arnold, Ann Hast, John McEnelly, Brenda Murphey, Chad Ronish, Deb Thorp, Kim Weber, Kristin Wheaton
- Our funders (alphabetical)
  - Black Hills State University
  - Great Plains Foundation
  - NASA South Dakota Space Grant Consortium
  - National Science Foundation (NSF) Office of Mathematics and Physical Sciences
  - South Dakota Governor's Office of Economic Development
  - South Dakota NSF Experimental Program to Stimulate Competitive Research
  - South Dakota Science and Technology Authority