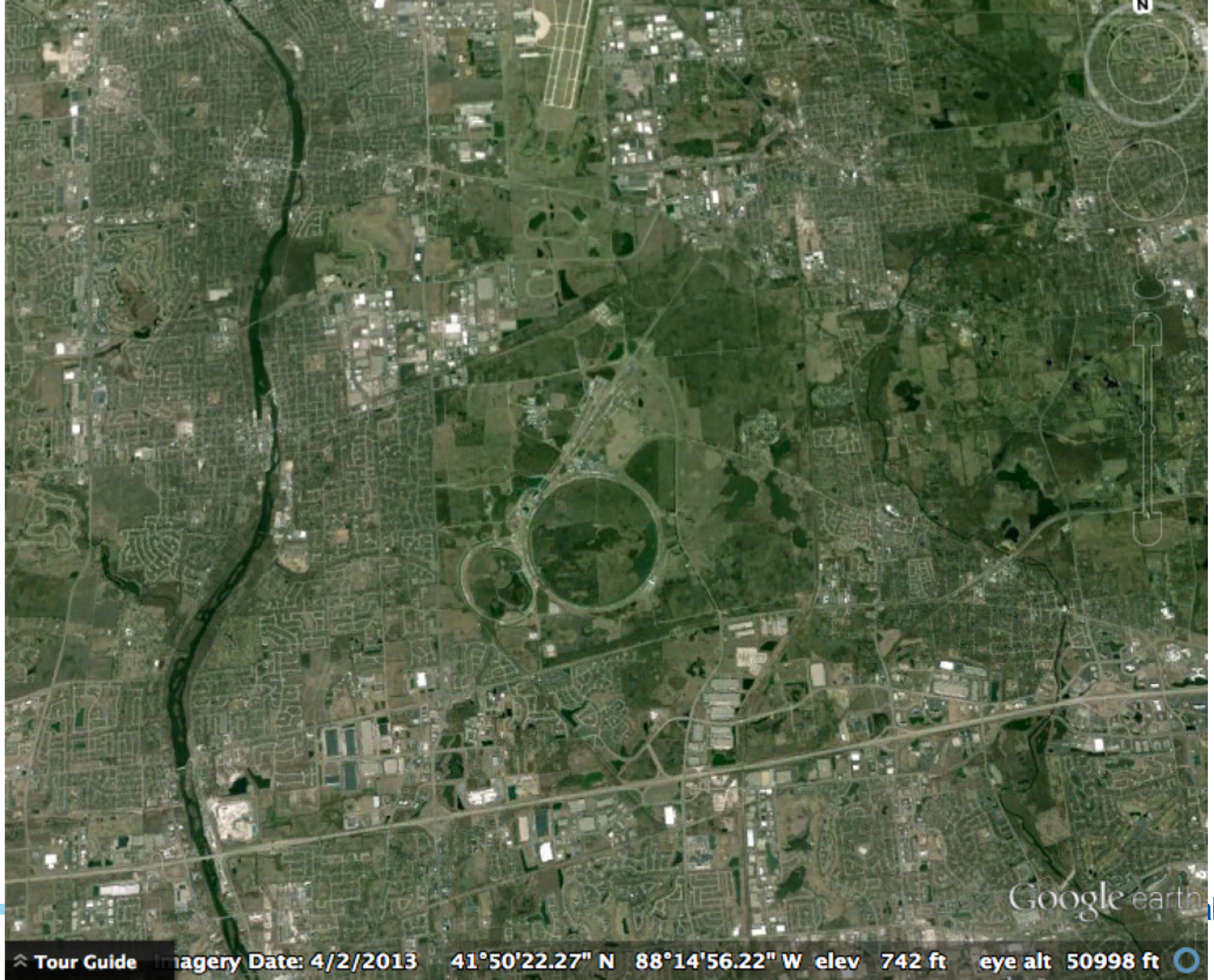
Fermilab U.S. DEPARTMENT OF ENERGY | Office of Science

Introduction to Fermilab

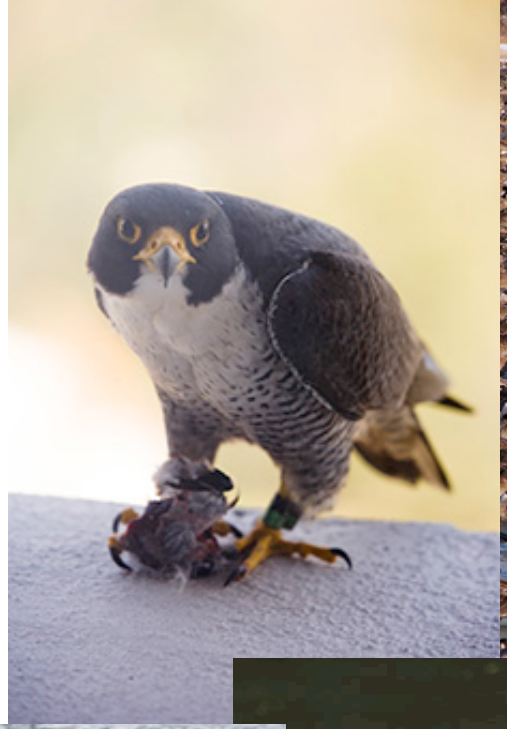
Joe Lykken

March 2018

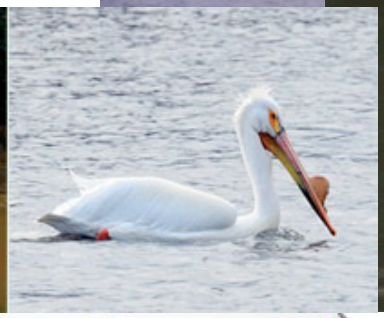
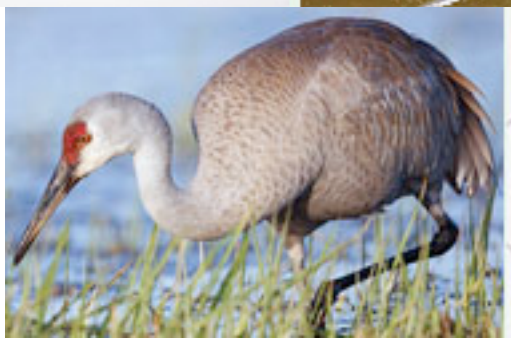
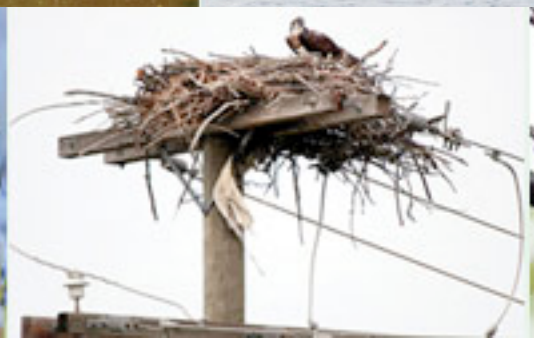
50 years of Fermilab


N
Google earth
Tour Guide
Imagery Date: 4/2/2013 41°50'22.27" N 88°14'56.22" W elev 742 ft eye alt 50998 ft

Fermilab is a good place to be if you are a Bird…





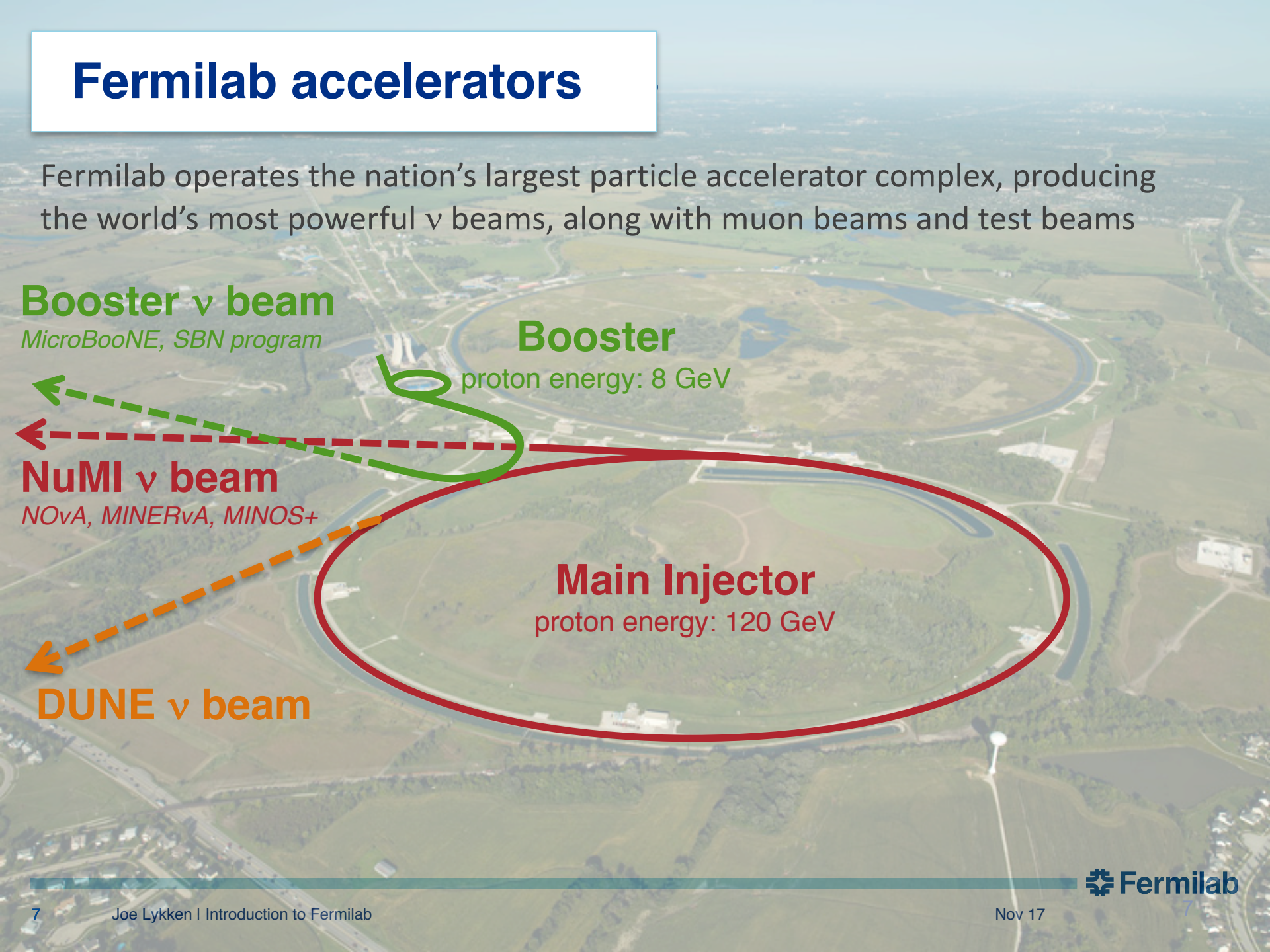
Fermilab

…or a Bison…

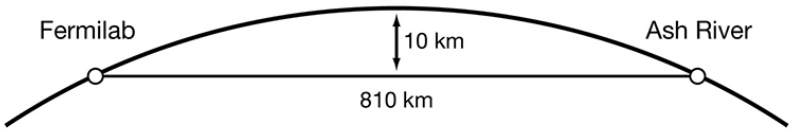
…or a Neutrino…

Fermilab accelerators

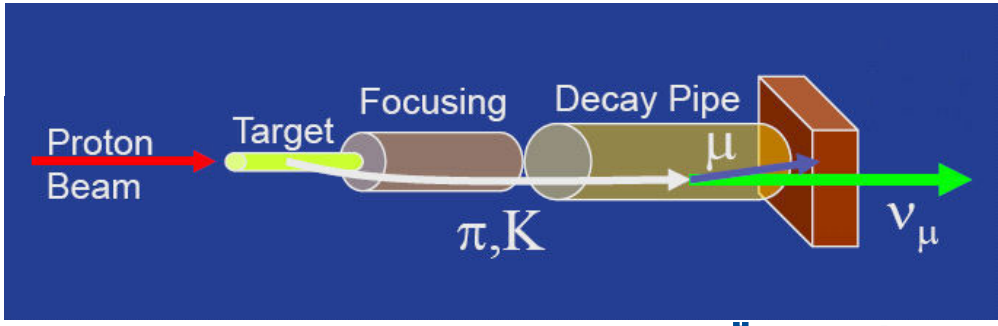
Fermilab operates the nation's largest particle accelerator complex, producing the world's most powerful ν beams, along with muon beams and test beams



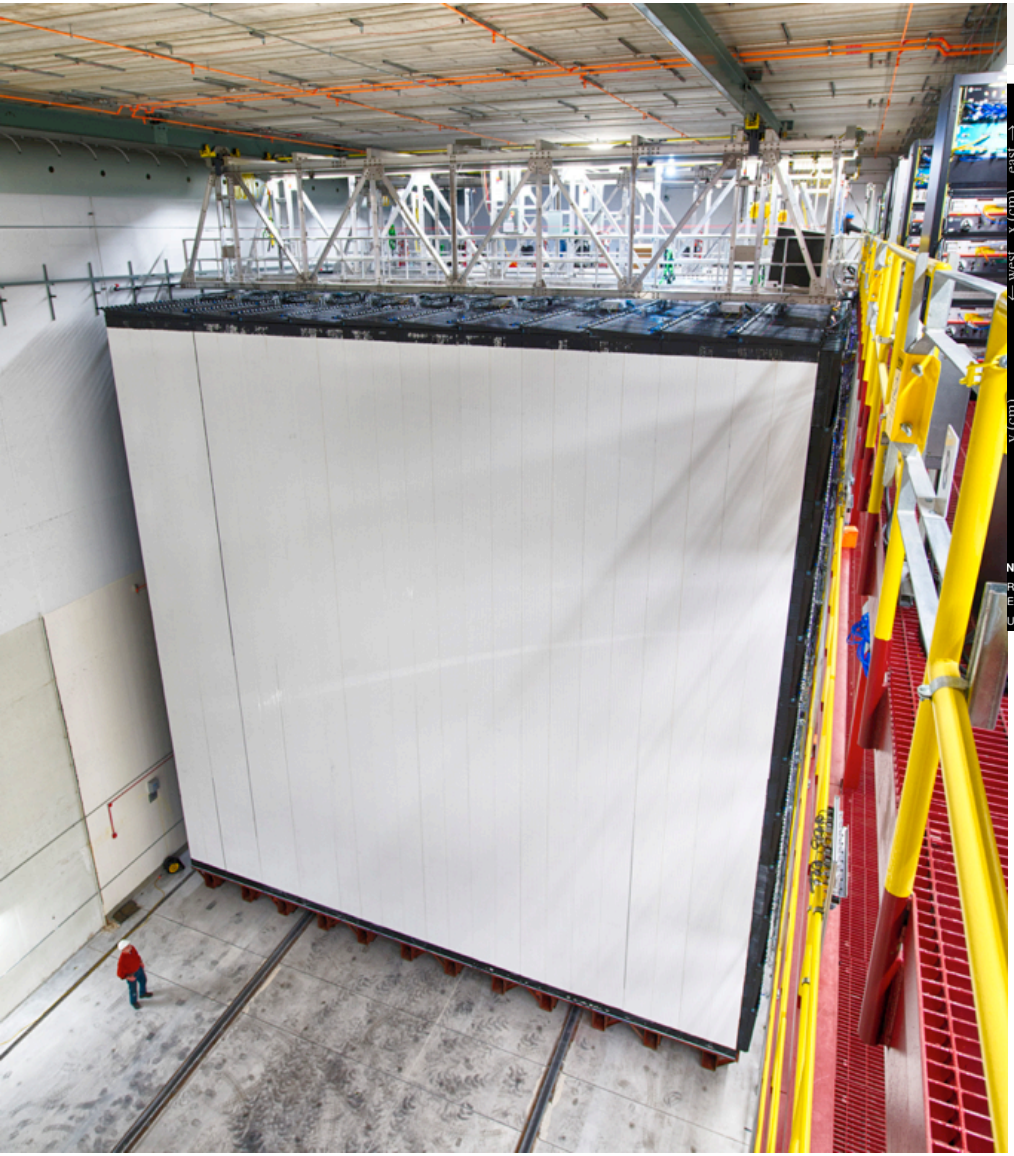
Neutrino beam to NOvA



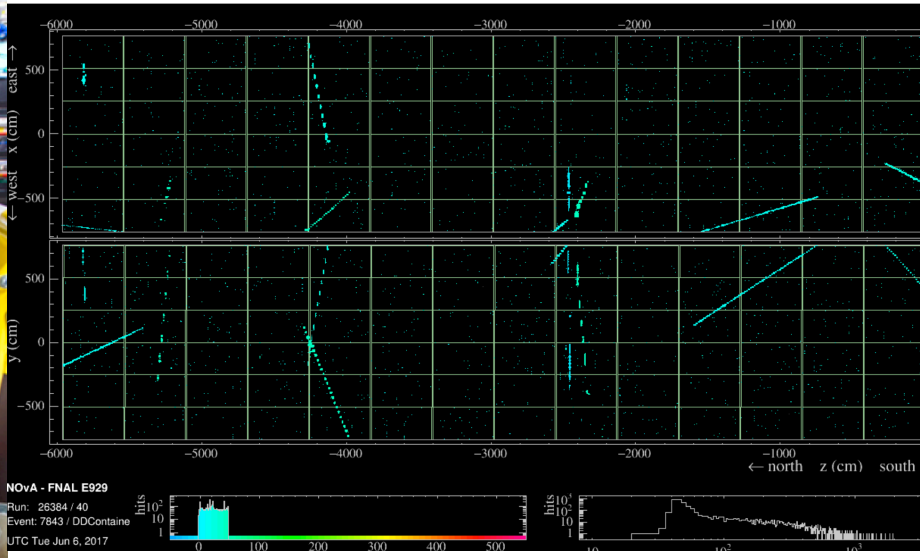
- We are shooting high energy neutrinos 500 miles through the Earth to Minnesota
- 1/400 of a second later, some of them interact with the 15,000 ton NOvA far detector



NOvA is currently Fermilab's flagship experiment



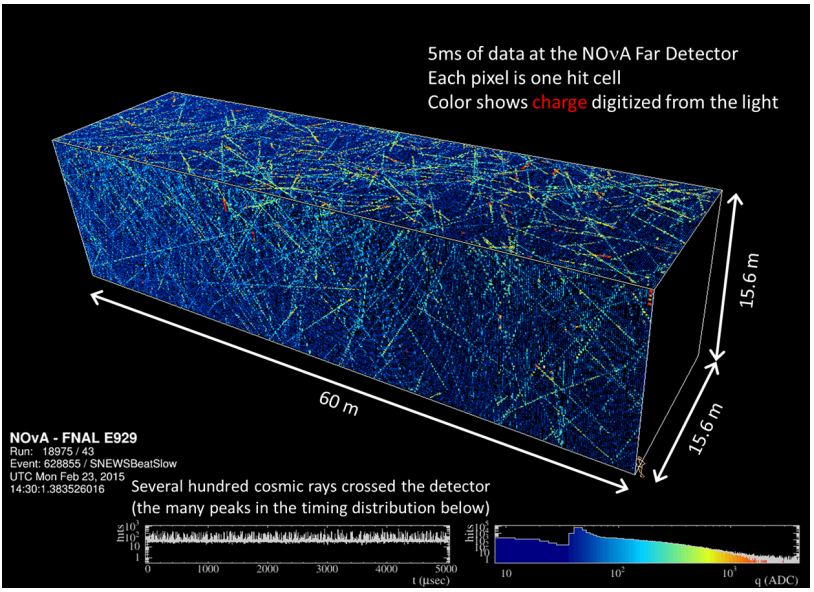
The Far Detector at Ash River

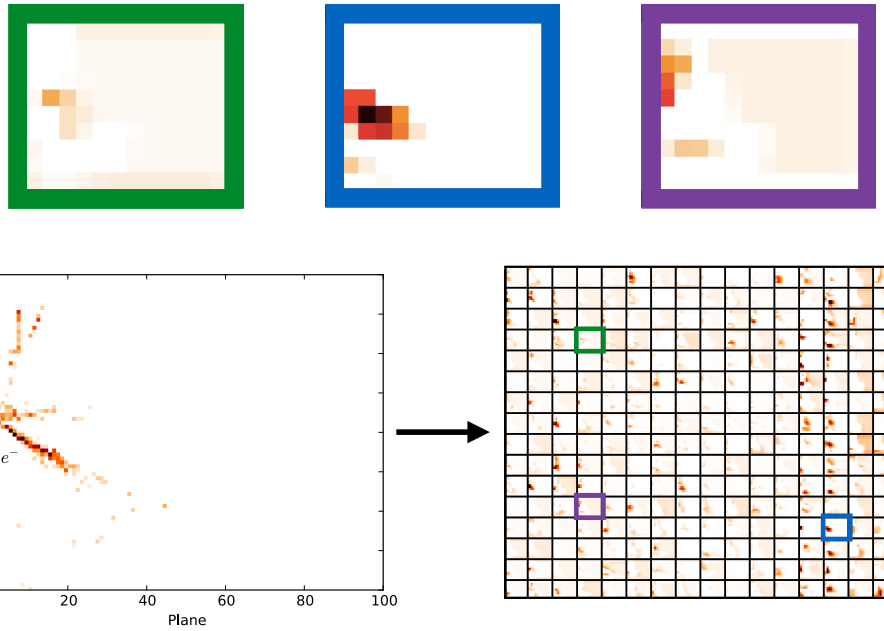


Fermilab

NOvA deep learning

- This analysis features a new event selection technique based on ideas from computer vision and deep learning



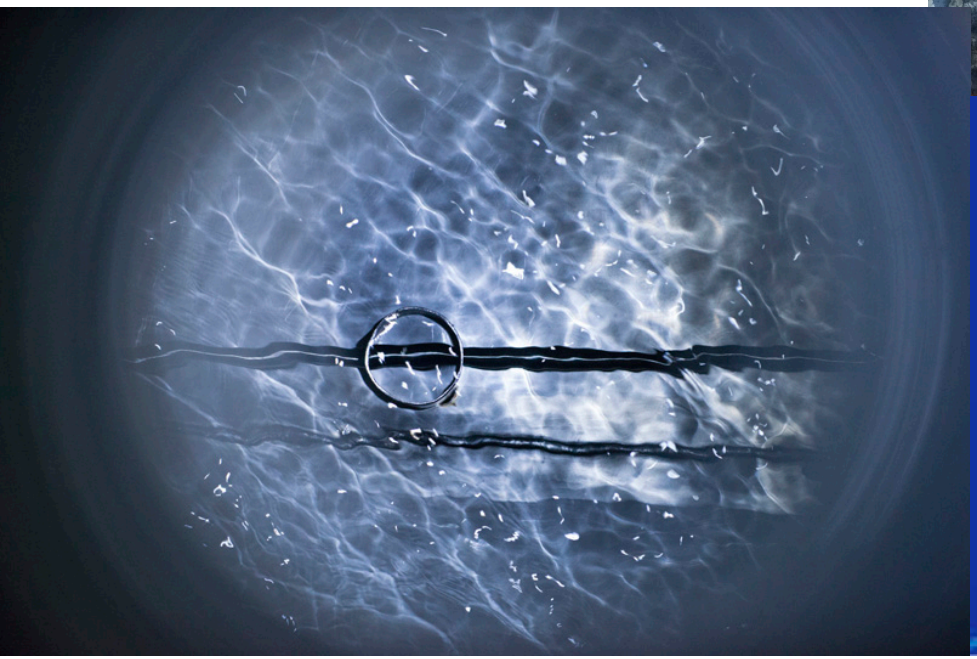


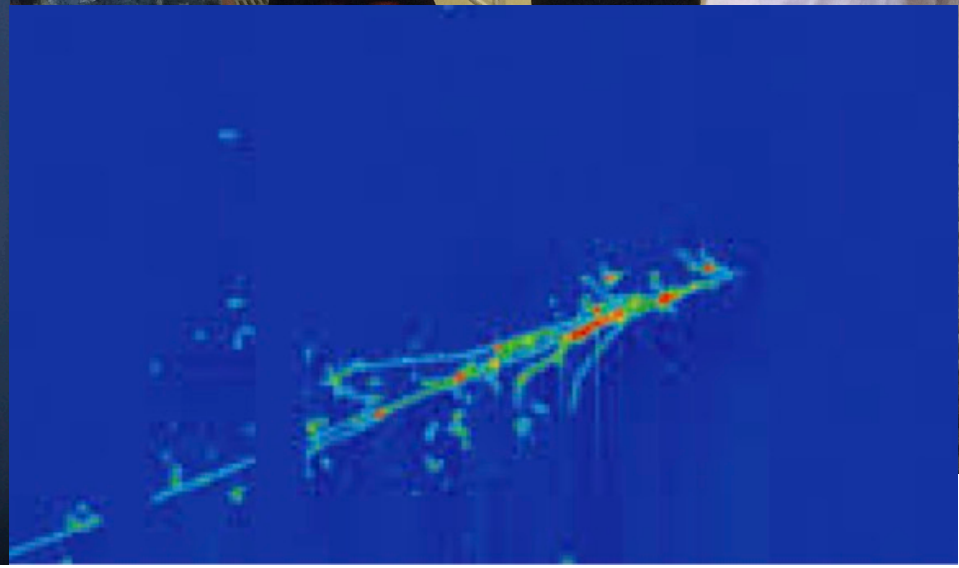
Like adding 5,000 tons of detector!

Improvement in sensitivity from CVN equivalent to 30% more exposure

A new technology for detecting neutrinos : liquid argon (87^0K = -303^0 F)

Bonnie Fleming of Yale standing on top of the ~200 ton MicroBooNE liquid argon neutrino detector at Fermilab

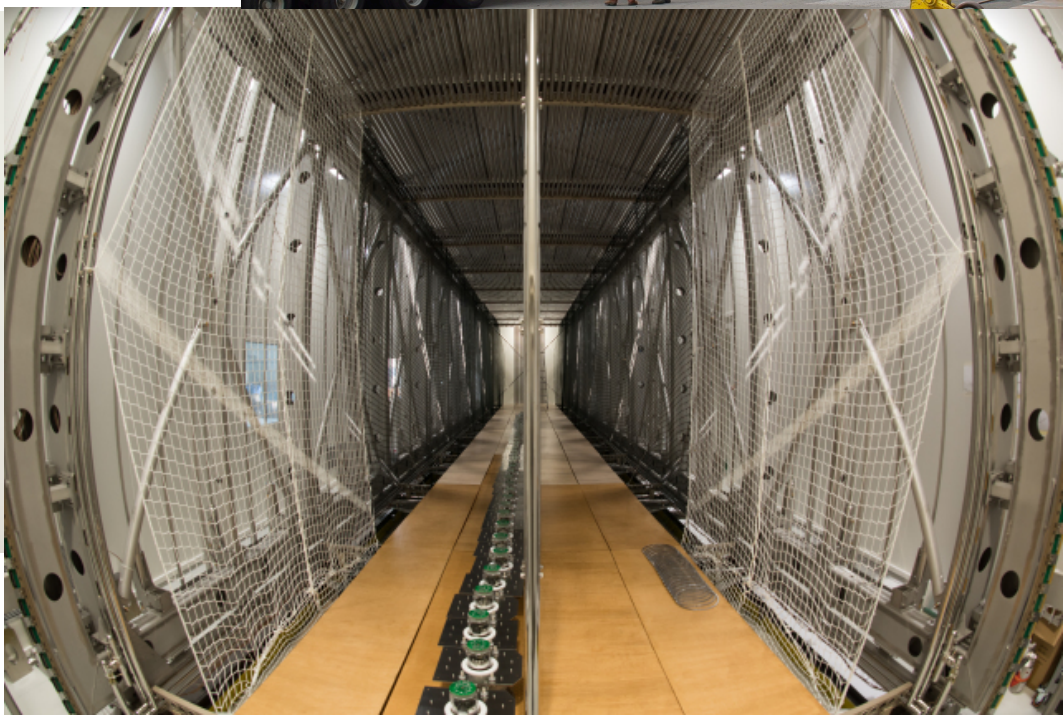




ICARUS!

ICARUS, the world's largest liquid argon time projection chamber (600 tons), was upgraded at CERN and shipped to Fermilab

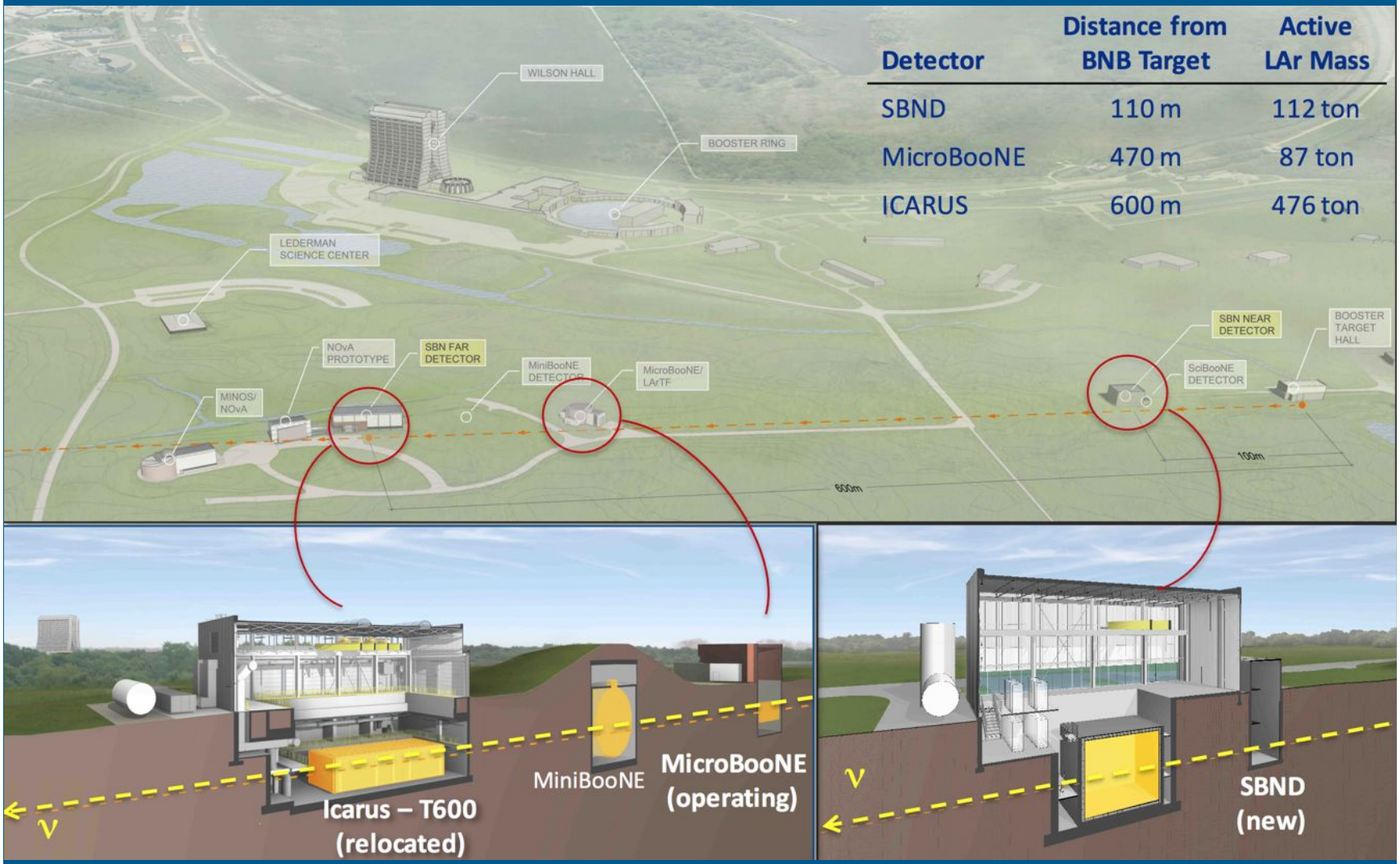
Senator Carlo Rubbia, Nobel Laureate, former CERN Director-General, etc etc



Fermilab

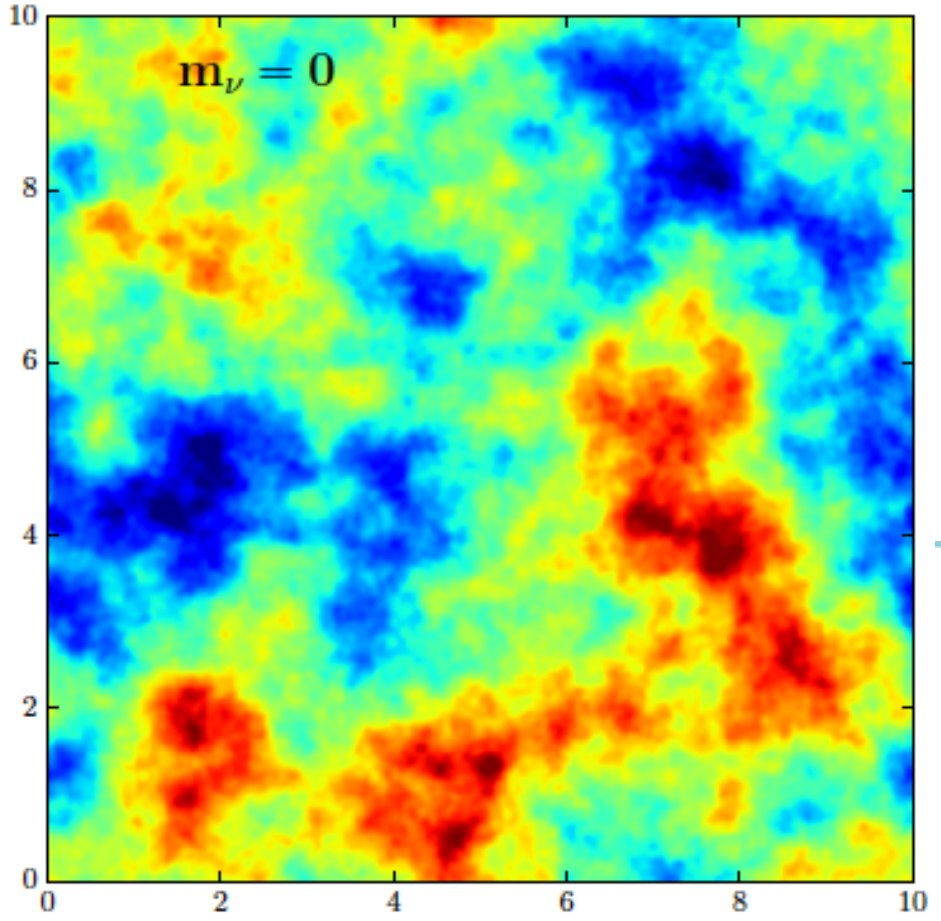
ICARUS@Fermilab

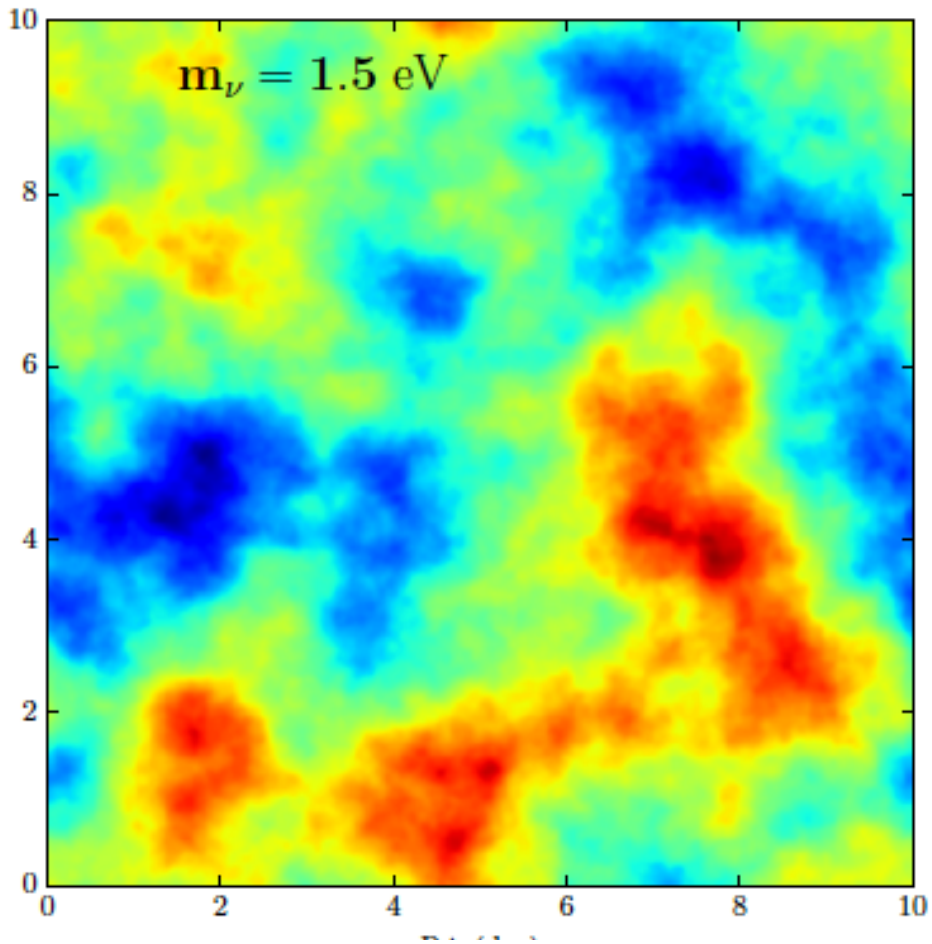
Arrived safely and will be installed soon



SBN Program Detectors – LAr TPCs

neutrino mass affects the shape of the universe



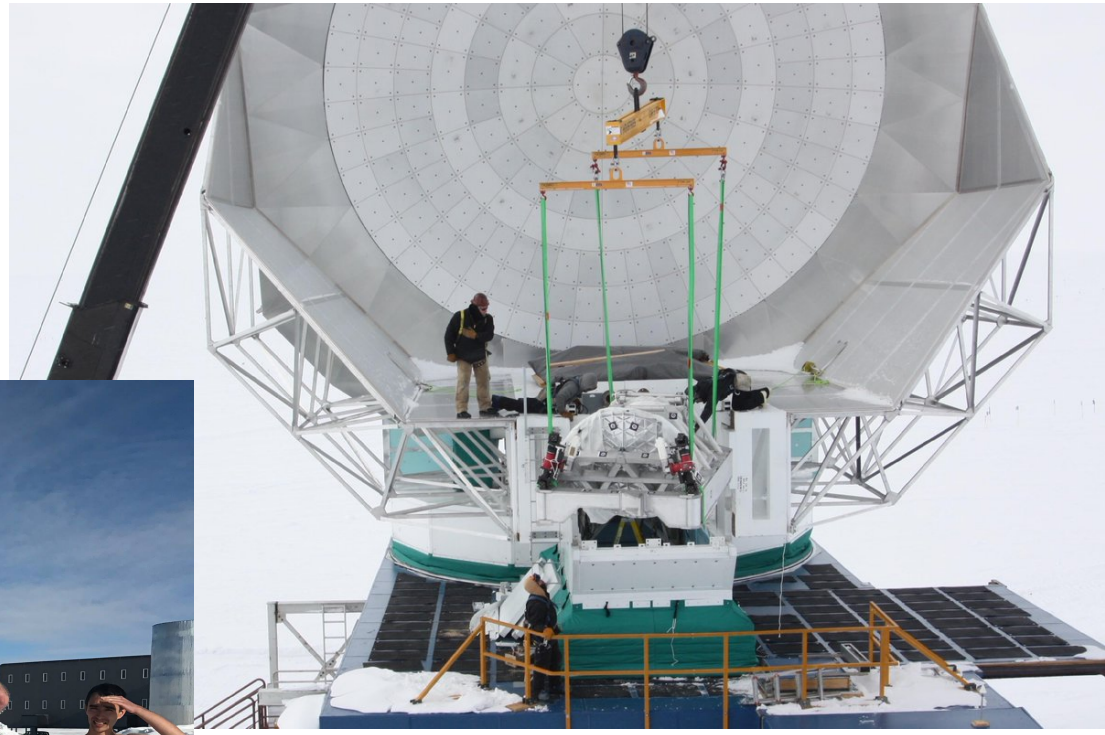


Simulated maps of distortions produced by gravitational lensing of cosmic microwave background (CMB) radiation

South Pole Telescope

- Microwave “camera” was designed by Fermilab scientist Brad Benson, integrated and tested at Fermilab’s SiDet facility
- Shipped to the South Pole from Fermilab in 2016

South Pole Telescope 3G up and running



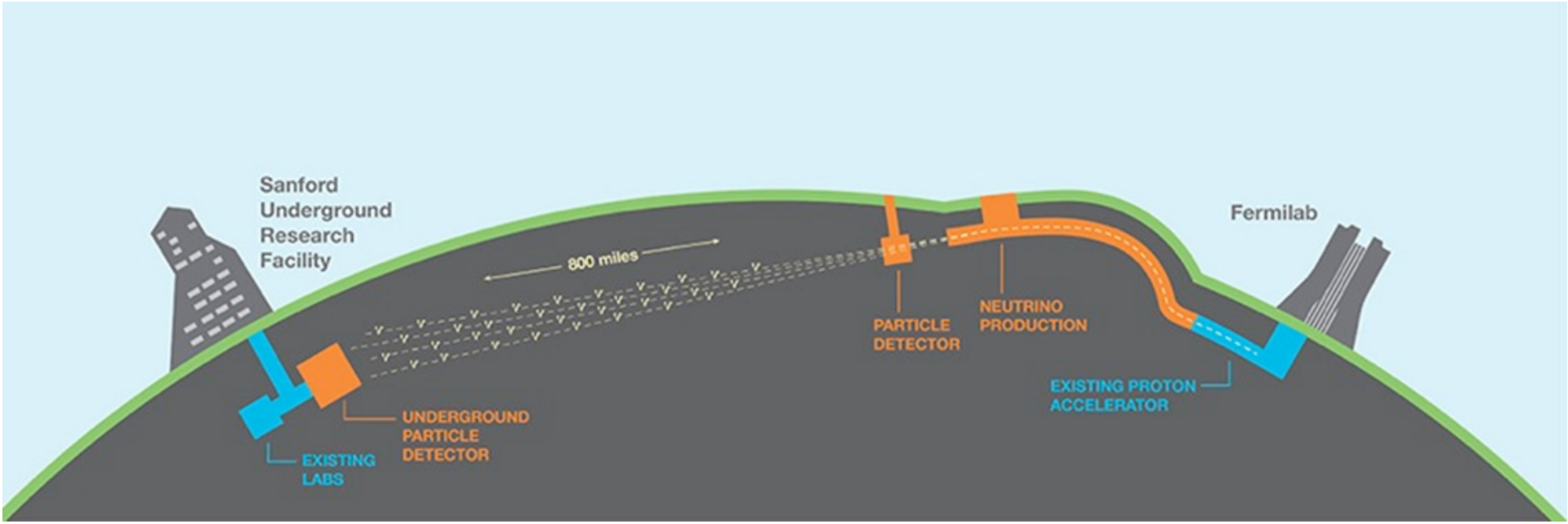
5 years of observation will tell us about neutrino mass

Fermilab

LBNF Facility and DUNE Experiment

Long Baseline Neutrino Facility: infrastructure at two locations:

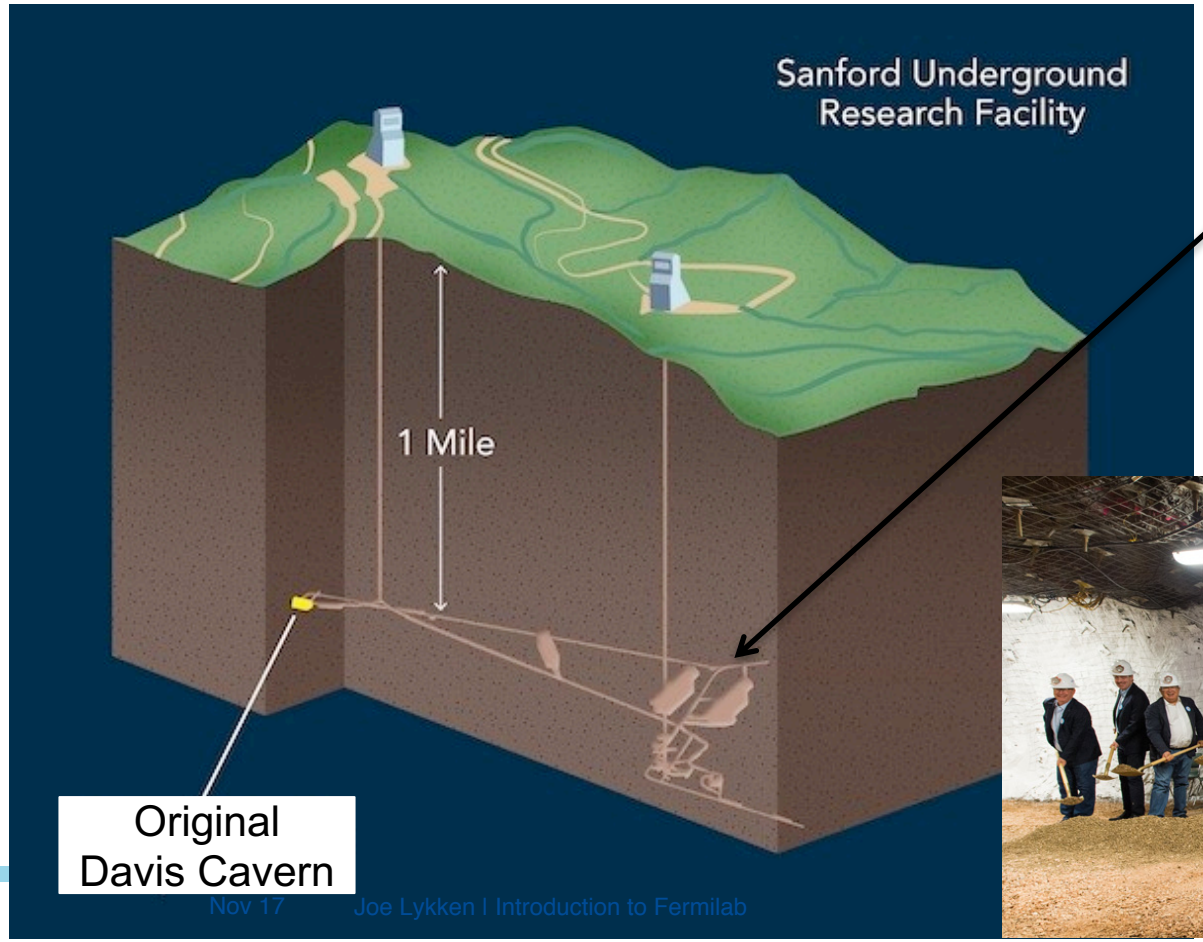
- **Near site**: Fermilab – facilities to create neutrino beam, support a near detector
- **Far site**: Sanford Underground Research Facility, Lead, SD – facilities to support 70,000 tons of **DUNE** liquid argon TPC detectors



The ultimate neutrino oscillation experiment needs:

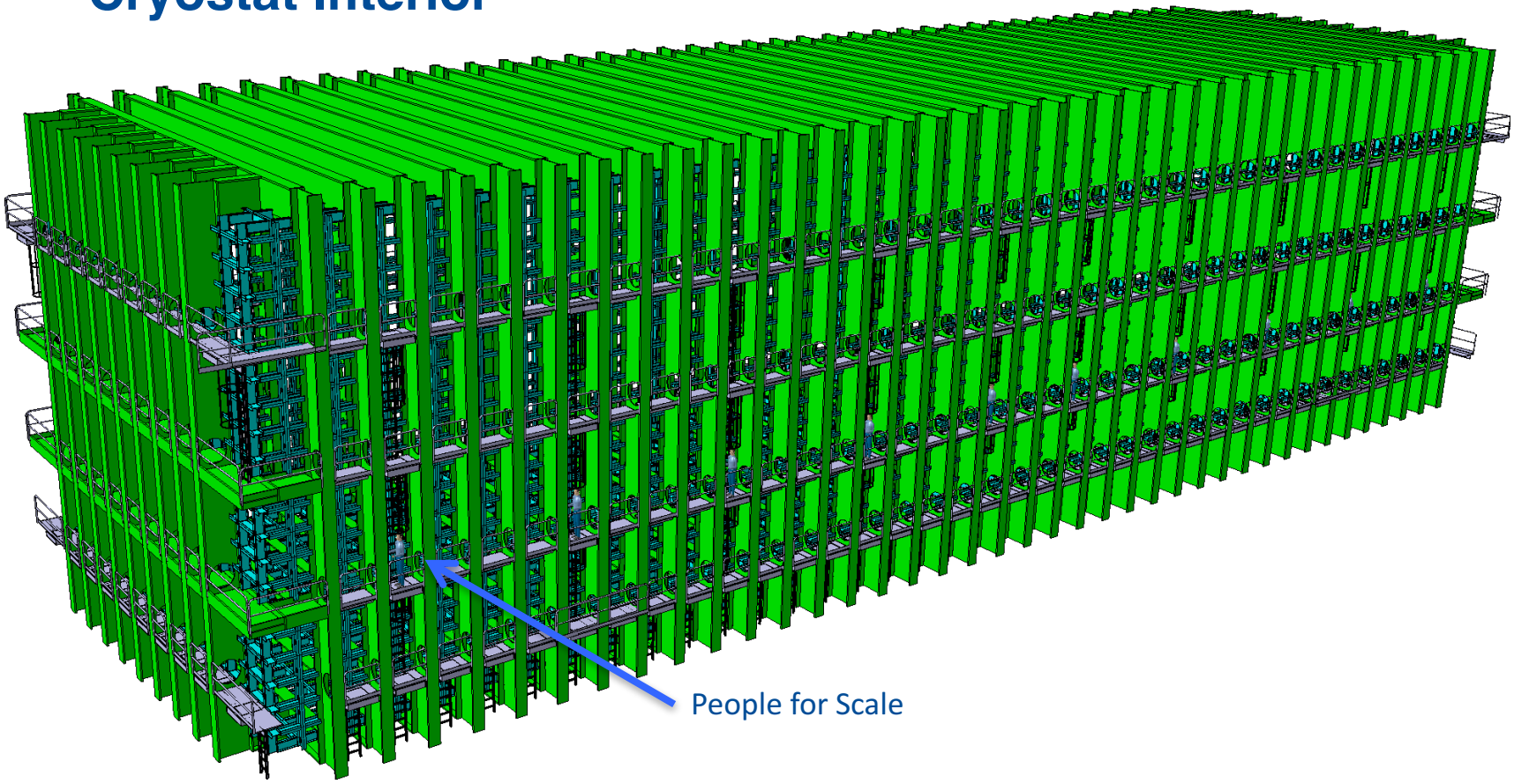
1. Intense controlled neutrino beam
2. Not so much cosmic background
3. Lots of detector mass
4. Advanced detectors

LBNF/DUNE has all of these!



Need to excavate 800,000 tons of rock for DUNE caverns

CERN Design for Free-Standing Steel Cryostat with Membrane Cryostat Interior



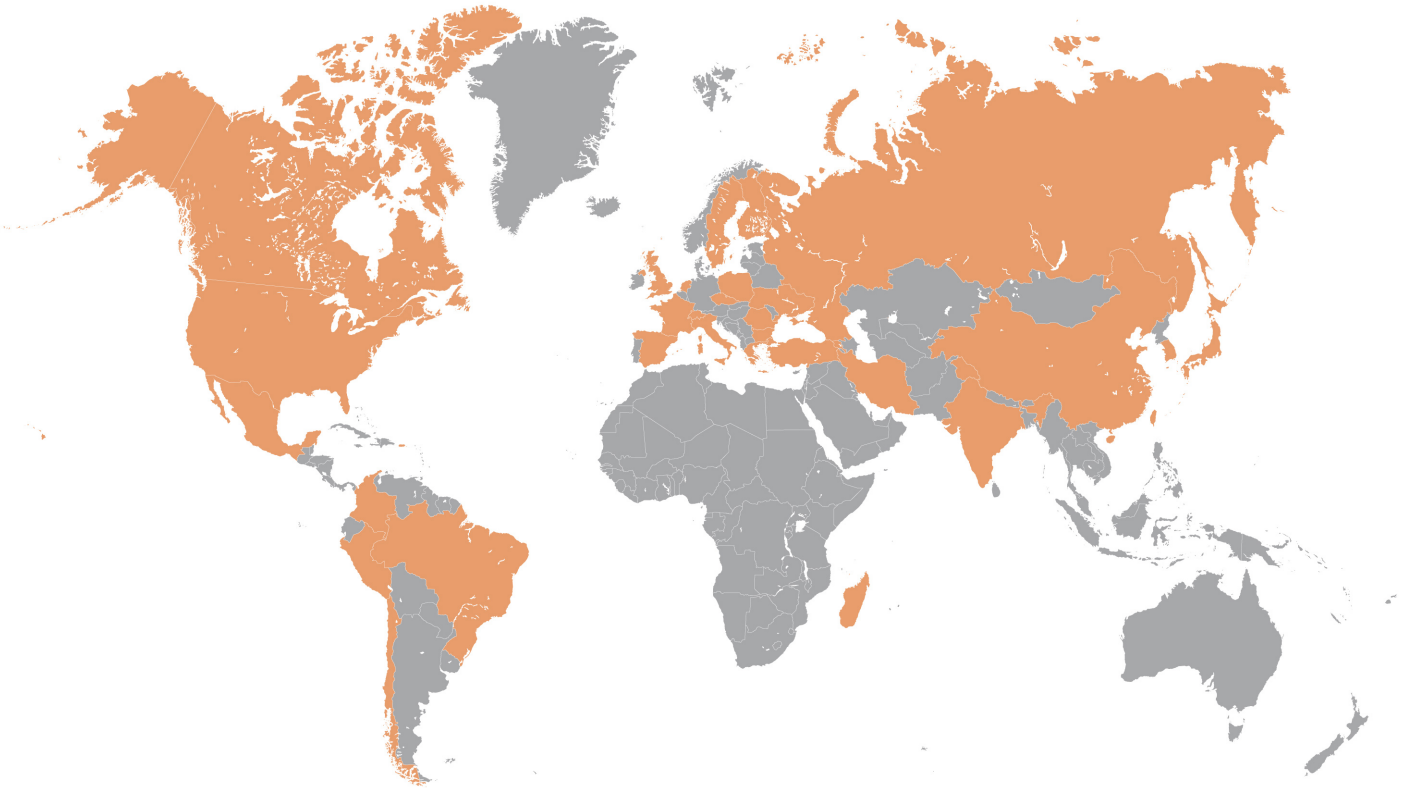
DUNE collaboration

1,064 scientists

from 176 institutes

in 31 countries

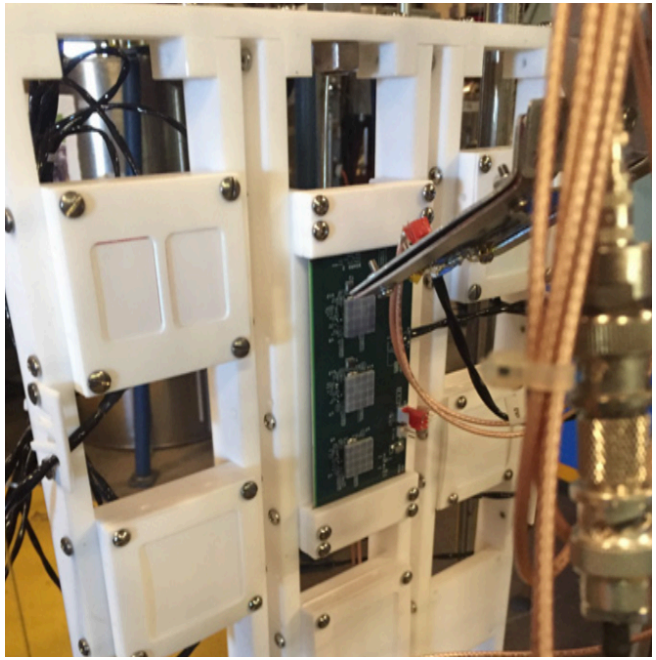
and growing steadily



DUNE collaboration

- DUNE is building a regional collaborative effort in Latin America that focuses on leadership roles in high speed electronics, advanced computing, and a novel light detection technology: ARAPUCA

- ARAPUCA in the language of native Brazilian means a trap for birds; the new detector technology concept was invented by two Brazilian physicists



Fermilab and Latin America: A long-standing partnership gets even stronger

Latin American Neutrino Physicist meeting at Fermilab, April 2016

Mark Thomson and Marcela Carena at SILAFAE 2016, Guatemala, Nov 2016

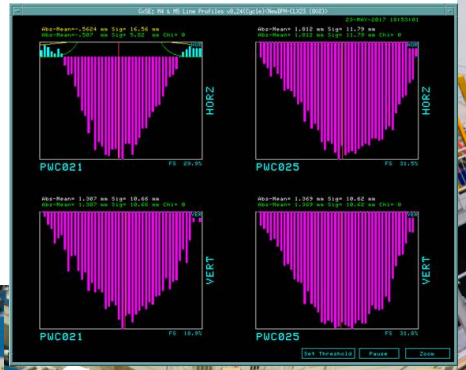
Marcela Carena with President of Cuban Physical Society and Director of CEADEN, Havana, July 2016

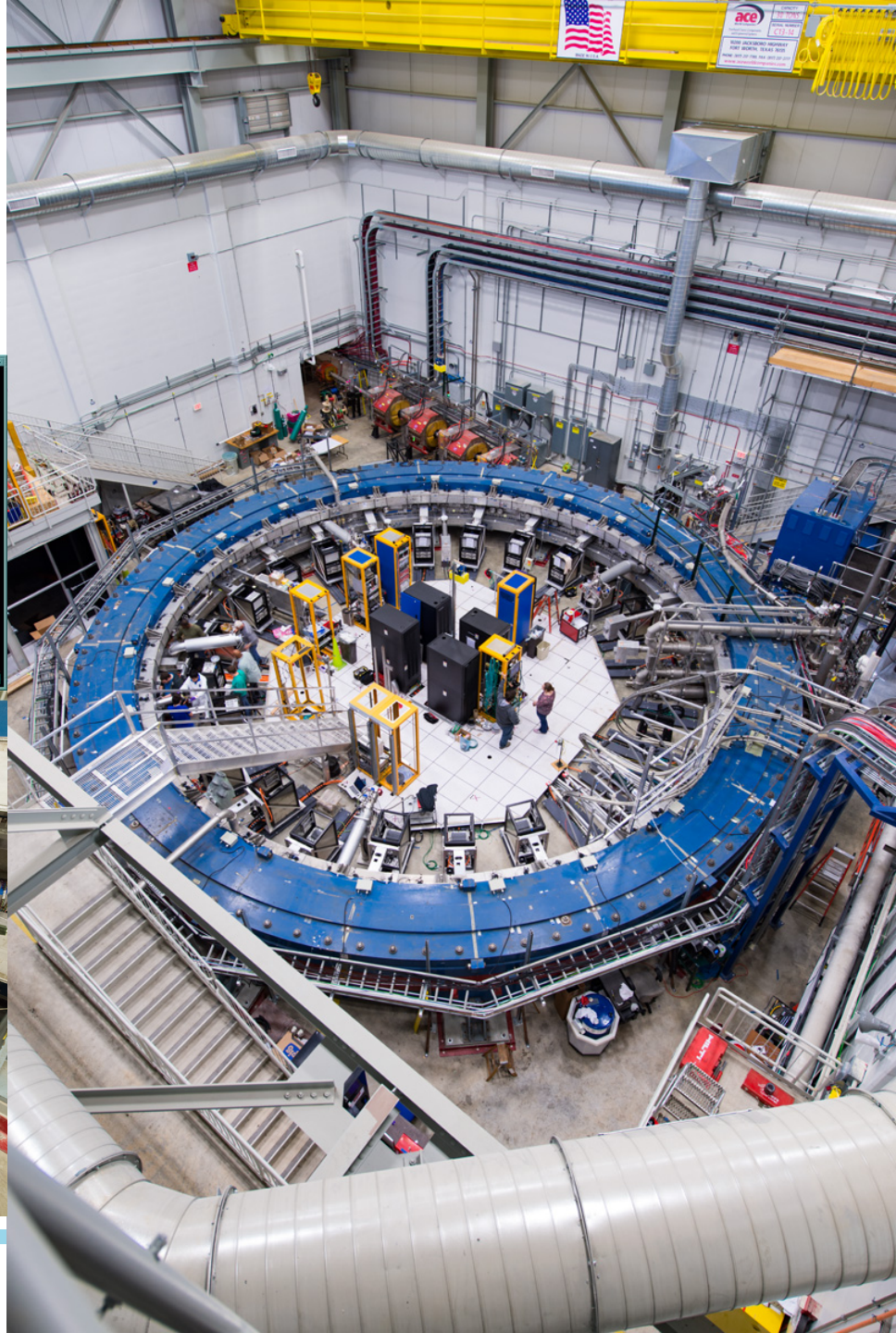
Fermilab Muon g-2 experiment

Precision Science

Confirming an anomaly in the magnetic moment of the muon would imply new particles and/or new interactions beyond the Standard Model of particle physics

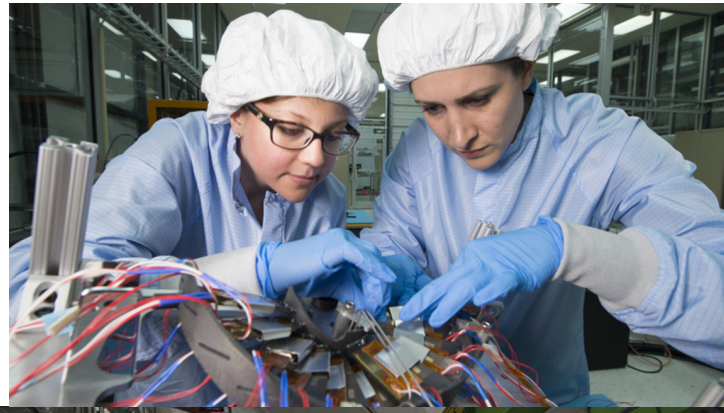
Muon g-2 experiment is starting now!

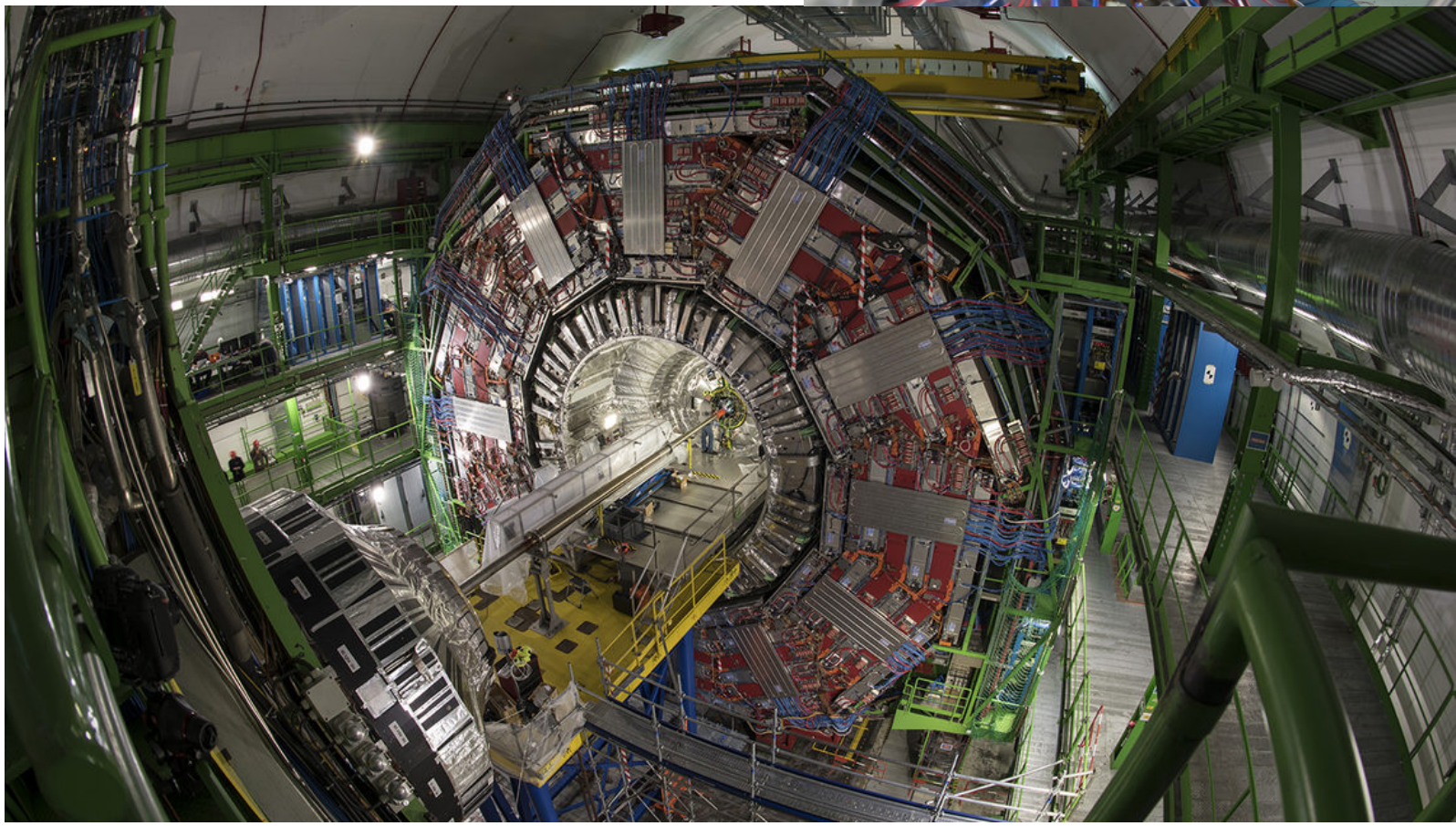




Upgraded CMS experiment running now at CERN

CMS Phase 1 upgrade forward pixels installed



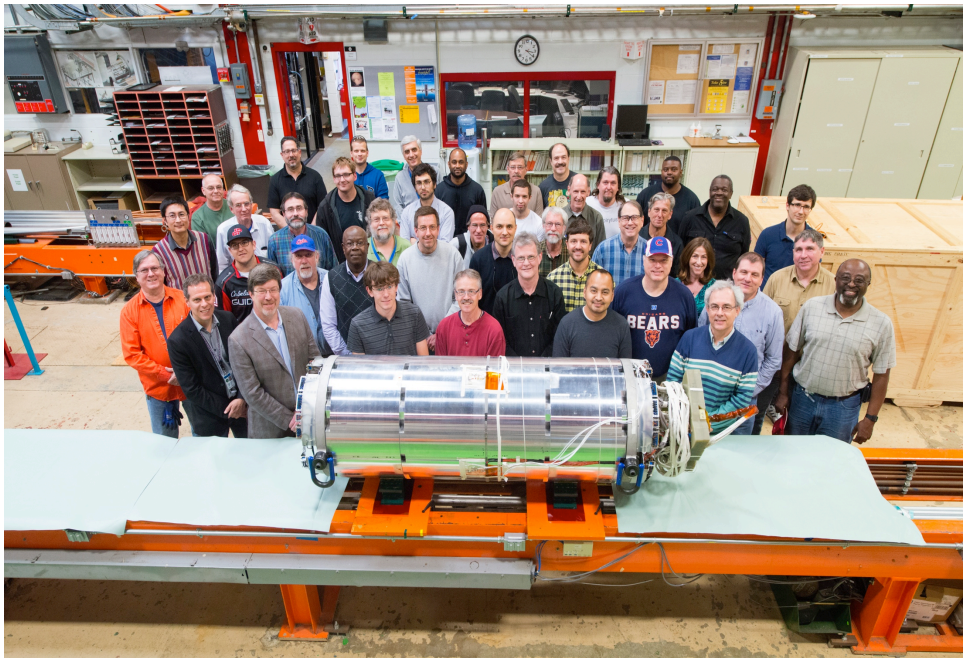


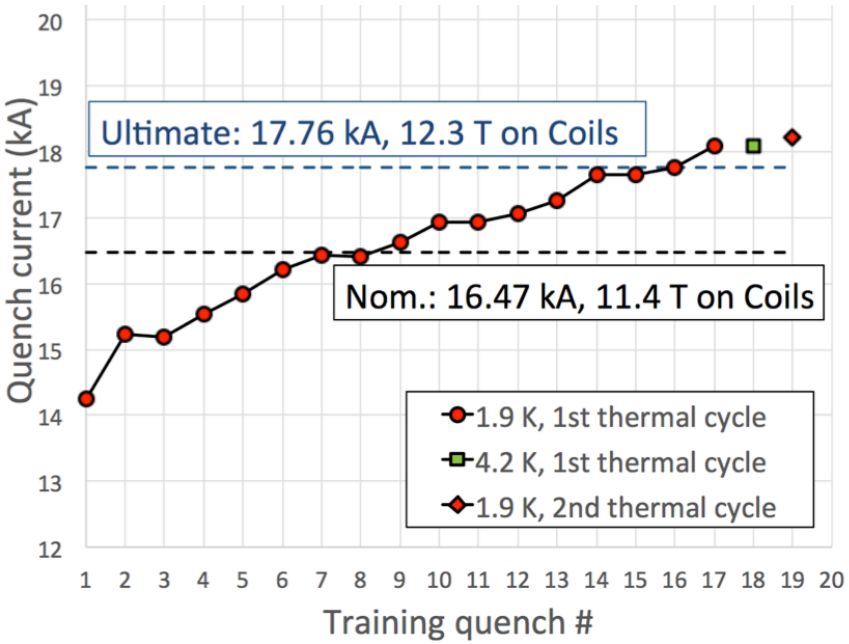
Higgs connections

- Does the Higgs destabilize the vacuum?
- Is there a Higgs portal to dark matter?
- How does the Higgs boson talk to neutrinos?
- Is the Higgs responsible for the genesis of matter in the early universe?
- Extra credit: is the Higgs related to cosmic inflation or dark energy?

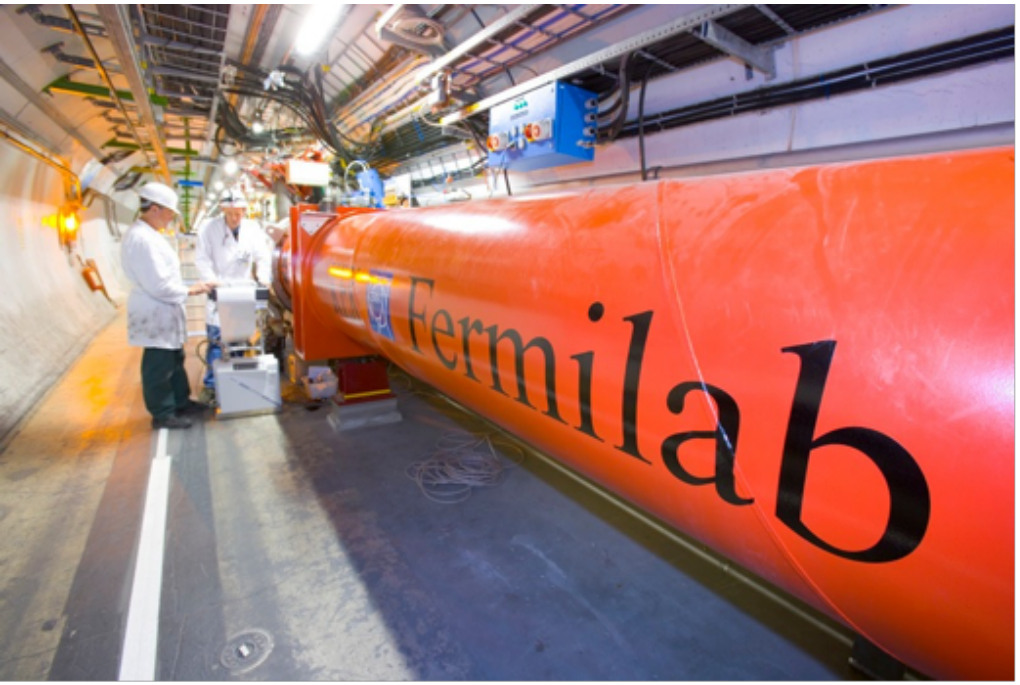
Fermilab

Fermilab is building high-field superconducting magnets for High-Luminosity LHC



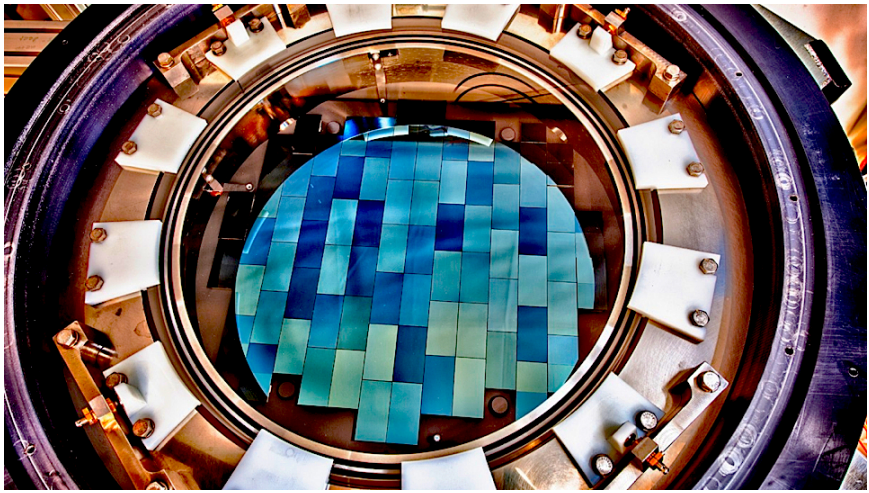


There are already Fermilab magnets in the LHC…



DARK ENERGY SURVEY

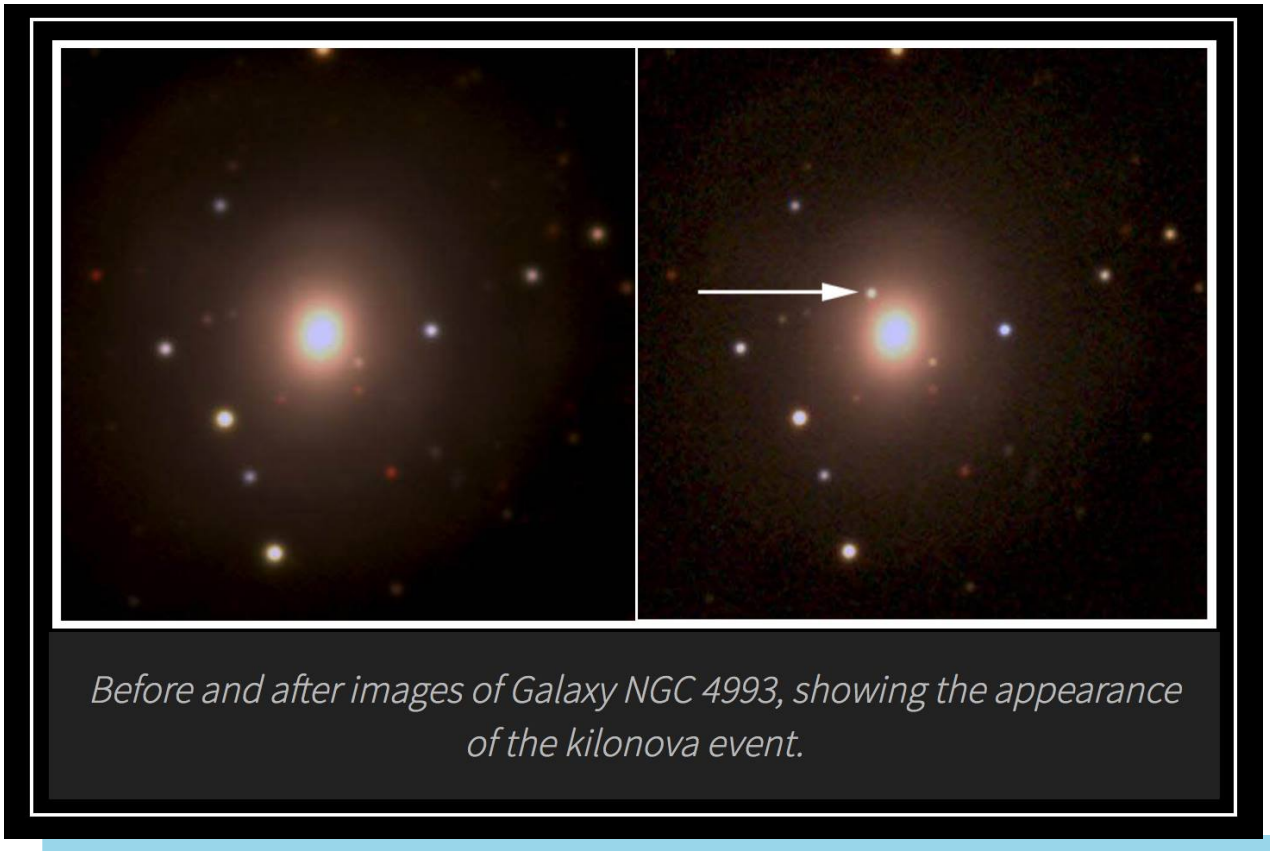
- Dark Energy Camera in Chile
- Finished Year 4 of 5
- Survey of 300 million galaxies
- Will tell us a lot the effects of dark matter and dark energy
- Experiment designed and operated by Fermilab scientists



Kilonova discovery from the Dark Energy Survey

LIGO and VIRGO gravity wave detectors saw signal of a merger of two neutron stars 130 million light years away

DES saw the “kilonova” caused by a large fraction of the neutron star masses being converted to light during the catastrophic merger event

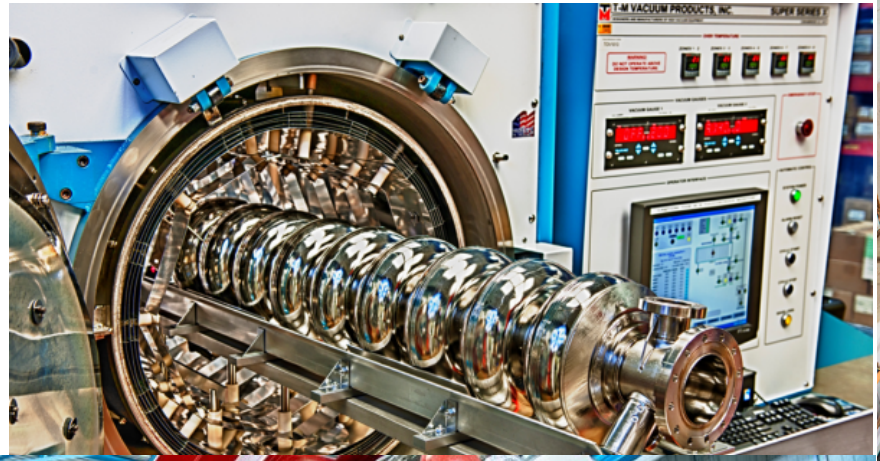


Before and after images of Galaxy NGC 4993, showing the appearance of the kilonova event.

Marcelle Soares-Santos

Fermilab builds cutting edge accelerators

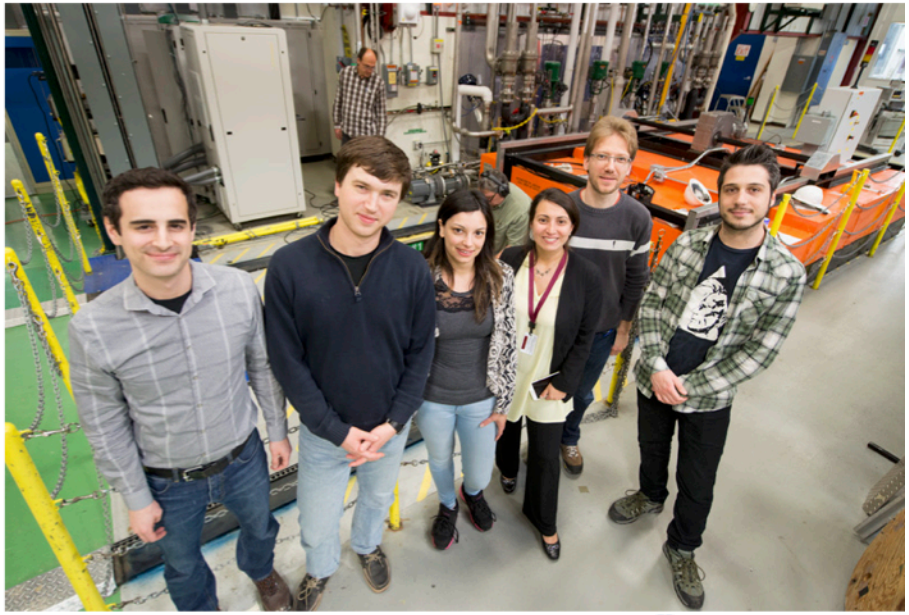
Assembly and testing of cryomodules for the LCLS-II XFEL accelerator



Quantum Computing & Quantum Sensors @ Fermilab

- In collaboration with the Univ. of Chicago and supported by the Heising-Simons Foundation, currently building and operating qubits coupled to superconducting cavities storing single microwave photons
- Fermilab has produced world-record ultra-low noise ultra-high efficiency superconducting microwave cavity systems, implemented on large scales
- We can simultaneously push technology for quantum computers and sensors for dark matter detection

Photo of Fermilab SRF team includes 3 DOE Early Career Awardees and a 2017 Presidential Early Career Awardee



From PIP-2, LCLS-2 to Quantum Computing

Quantum Communications

- Quantum teleportation and secure communication using entangled photons to link quantum computers over large distances with telecom fiber and quantum repeaters

- Caltech and AT&T have formed a strategic 5-year partnership for co-design, systems engineering and integration of **IN**telligent **Q**uantum **NE**tworks & **T**echnologies, i.e. the **INQNET**

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Beyond Quantum Computing: AT&T Foundry and Caltech Leading the Charge on Quantum Networking Technologies

INNOVATION / Palo Alto, California, May 31, 2017

Share

Alliance for Quantum Technologies (AQT) to Harness the Power of Networked Quantum Computing Technologies

The AT&T Foundry innovation center in Palo Alto, California is joining the California Institute of Technology to form the Alliance for Quantum Technologies (AQT). The Alliance aims to bring industry, government, and academia together to speed quantum technology development and emerging practical applications.

INQNET Program

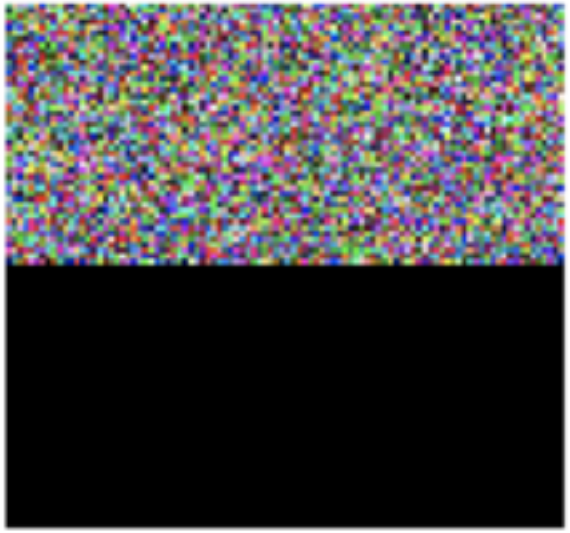
AT&T CEO John Donovan
at Fermilab May 12

Alice-Bob-Charlie-Eve

```
0.000s: Charlie distributing bell pairs...
4.703s: Alice encoding her data and sending to Bob, intercepted by Eve...
12.354s: Bob disentangling and reading out quantum data...
21.194s: Simulation of 216384-bit transmission complete.
```

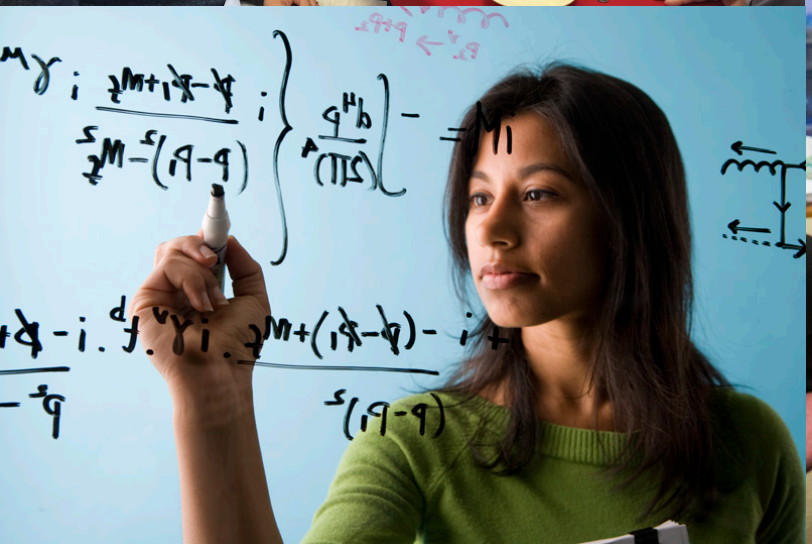
Original image

Eve's image

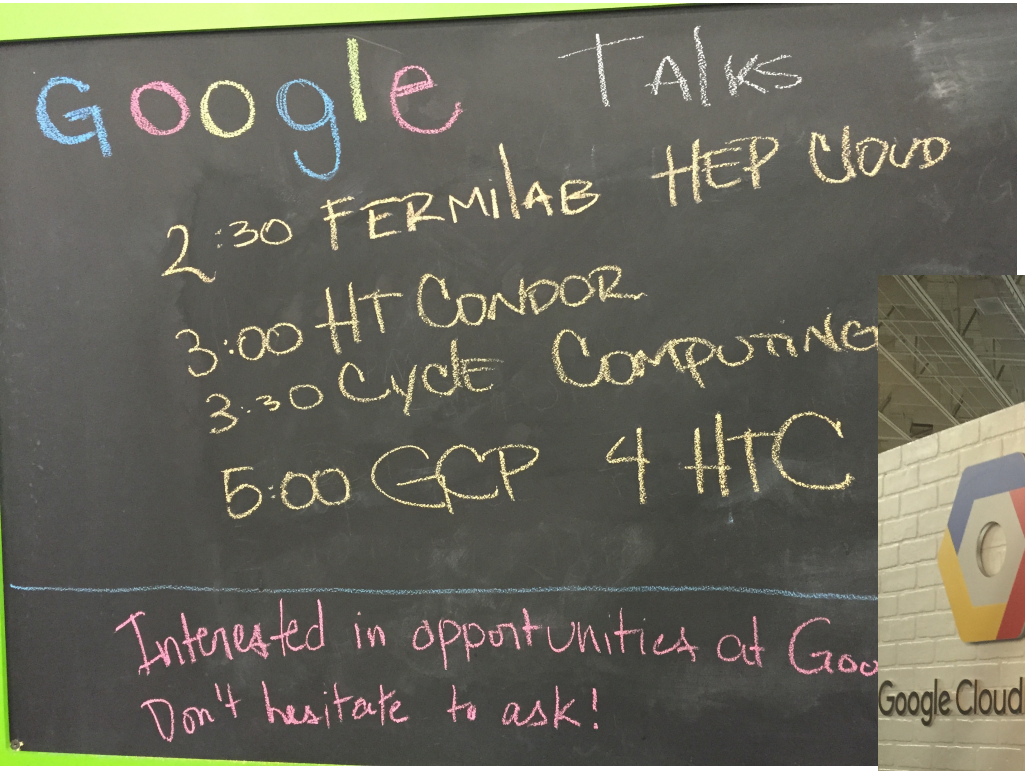


Bob's image

We have a smart vibrant theory group



HEPCloud @ Google @ Supercomputing 2016



Enjoy your time at Fermilab

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