

The New Frontier on the Great Plains:

Fermilab and the future of particle physics

*Young-Kee Kim
Deputy Director, Fermilab*

*Fermilab Public Lecture
October 21, 2011*

Welcome to Fermilab

6,800 acres
park-like site
with prairies



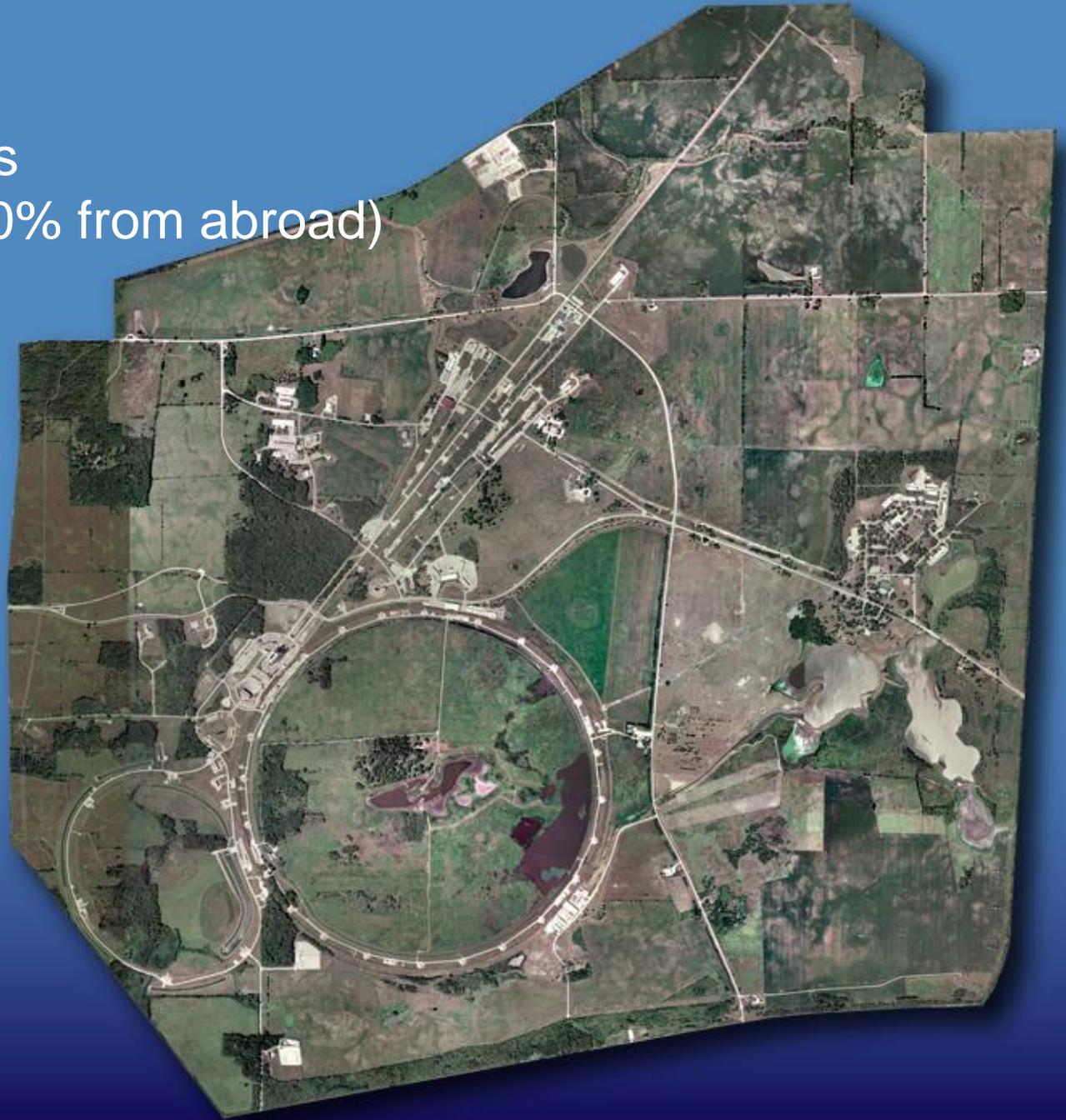


A herd of American bison,
symbolizing

Fermilab's presence on the frontiers of particle physics
and the connection to its prairie origins

Fermilab

- 1,900 employees
- 2,300 users (~50% from abroad)



What is the world made of?
What holds it together?
Where did we come from?

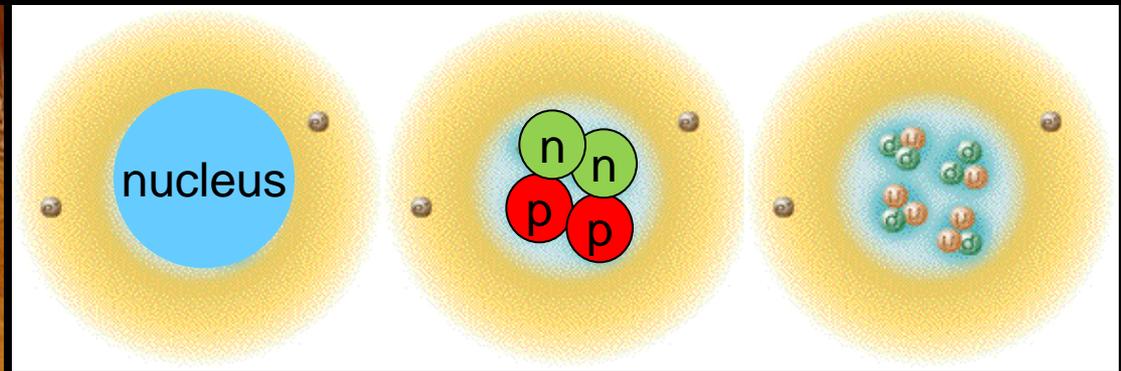


Accelerators are **Ultimate Microscopes.**

What is the world made of?



up, down quarks, electrons



Gravitational force

Electromagnetic force

Weak and Strong forces

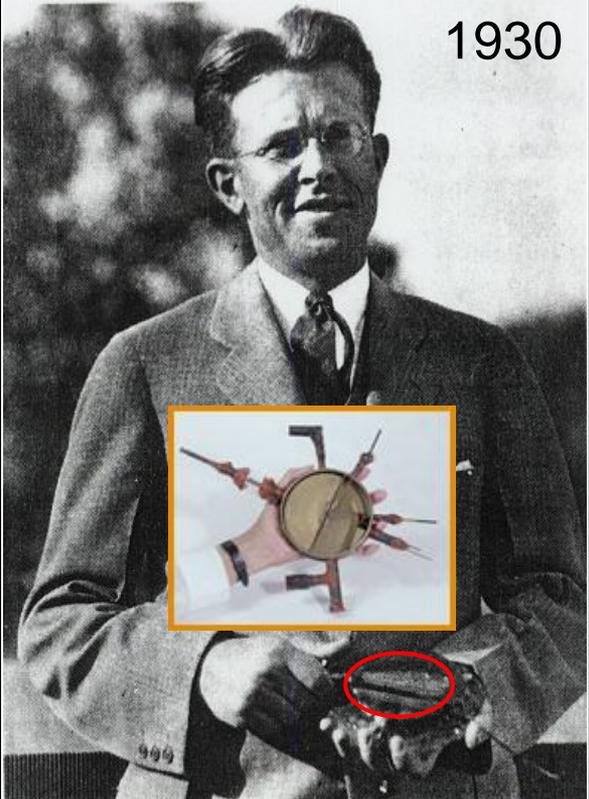


What holds it together?



1930

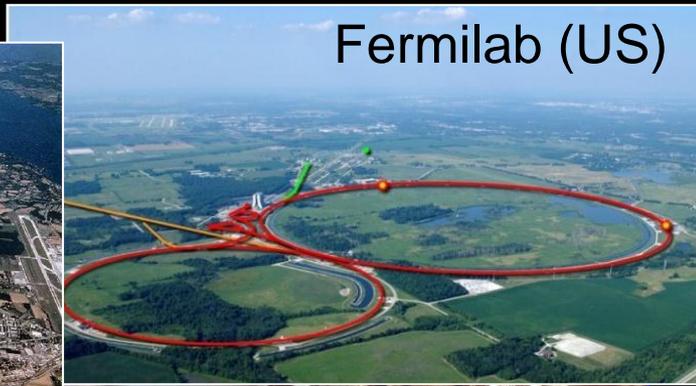
Today's accelerators for particle physics



Ernest Lawrence
(1901-1958)



CERN (Europe)



Fermilab (US)



KEK/J-PARC (Japan)



IHEP (China)

Accelerators at Fermilab



Today, ~30,000 accelerators are in operation around world

- Discovery science



- Manufacturing and material science



- National security



- Energy and the environment



- Medical treatments and science

Fermilab and Industry Partnerships

Proton Cancer Therapy



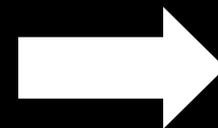
Loma Linda Proton Therapy
and Treatment Center

World's 1st proton accelerator
built specifically for proton therapy

Designed and built at Fermilab



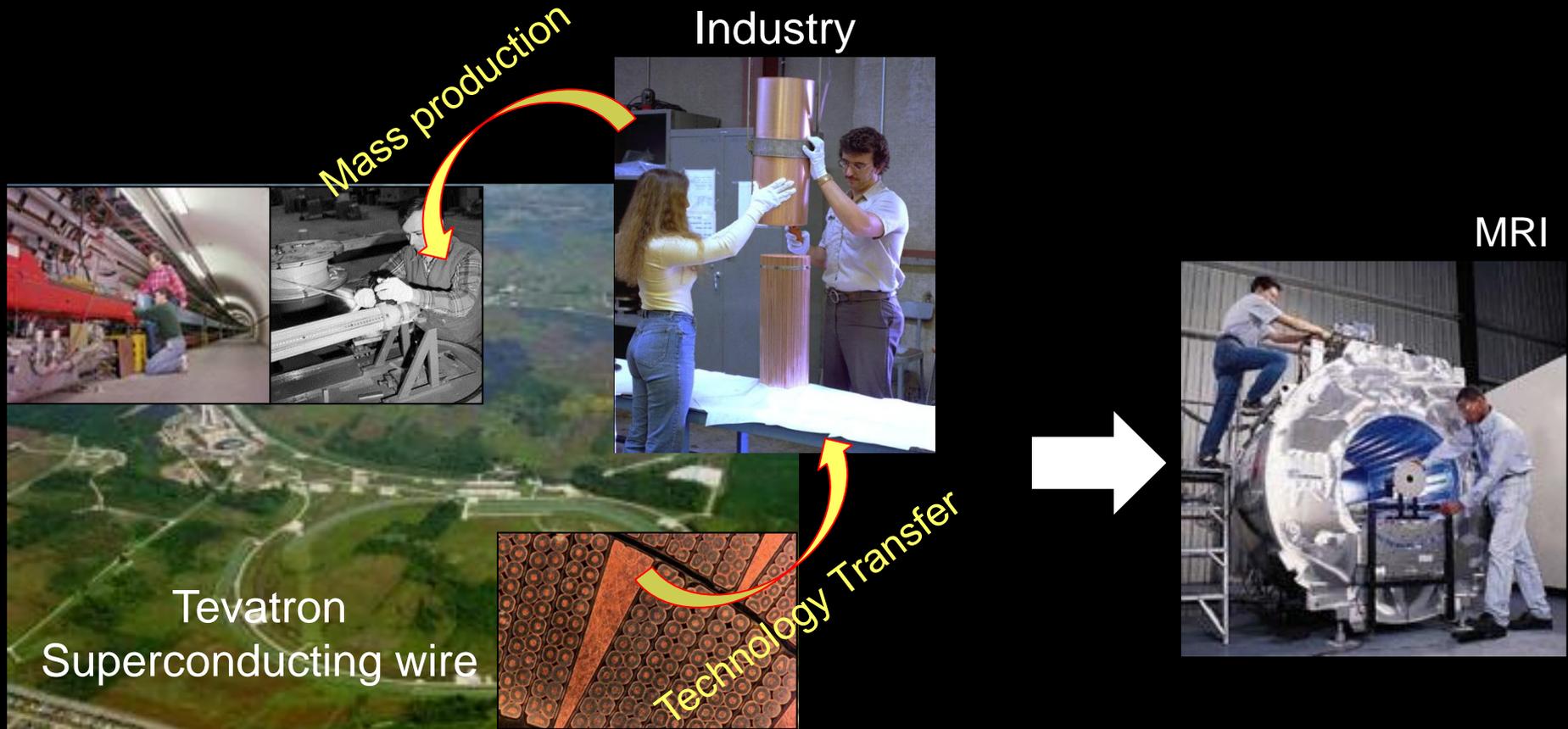
Technology
Demonstration



Industry

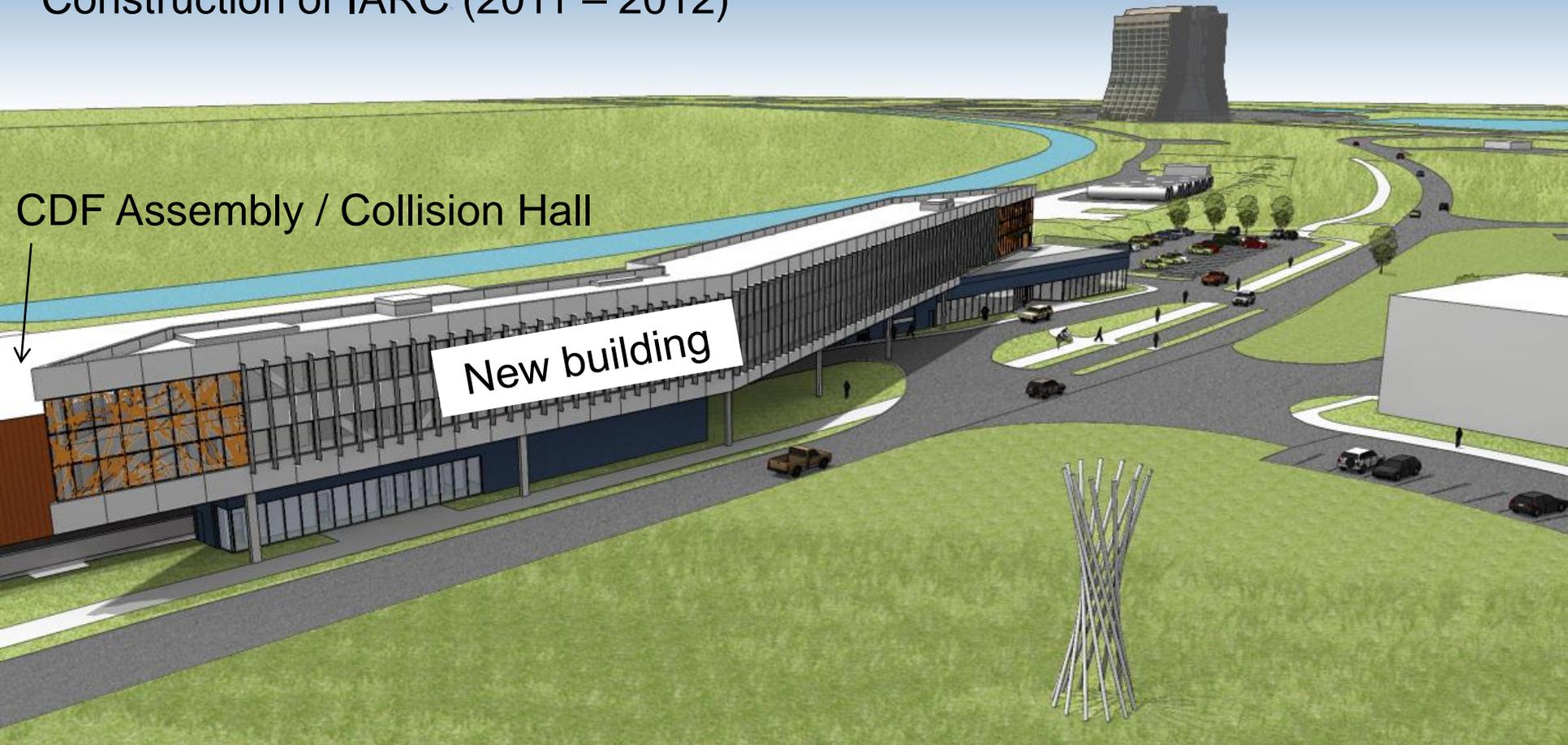
Fermilab and Industry Partnerships

Tevatron Superconducting Wire → MRI



Illinois Accelerator Research Center

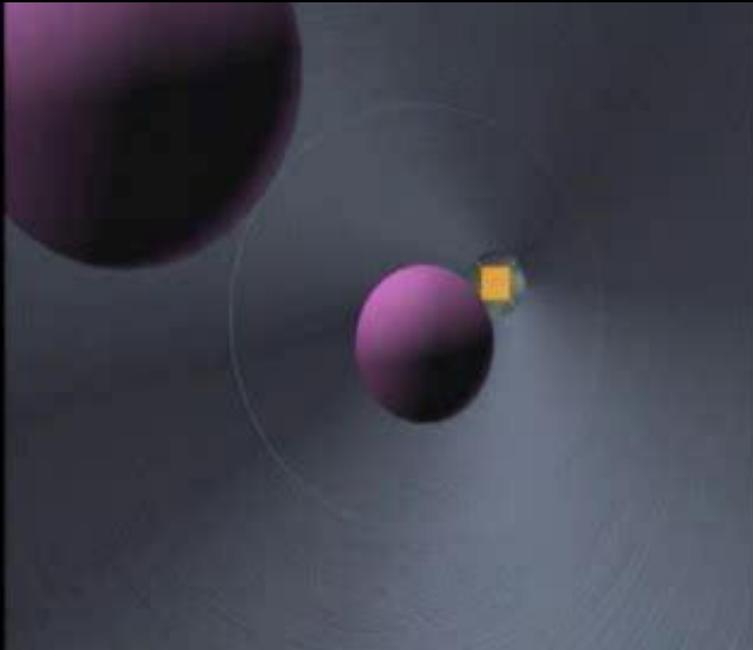
Construction of IARC (2011 – 2012)



Accelerator science, technology, education, partnerships with industry

Accelerators are like **Time Machines**.

They make particles last seen
in the earliest moments of the universe.



kaons

pions

neutrinos

muons

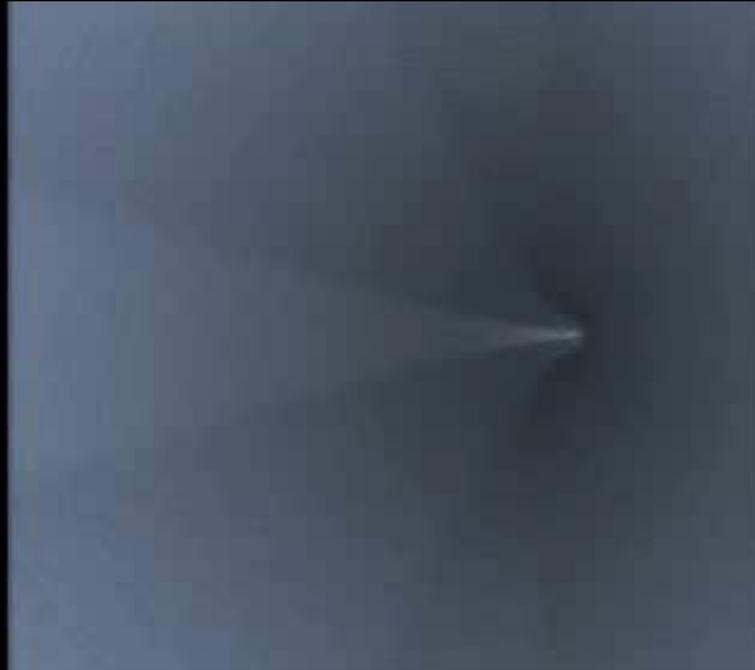
....

anti protons

.....

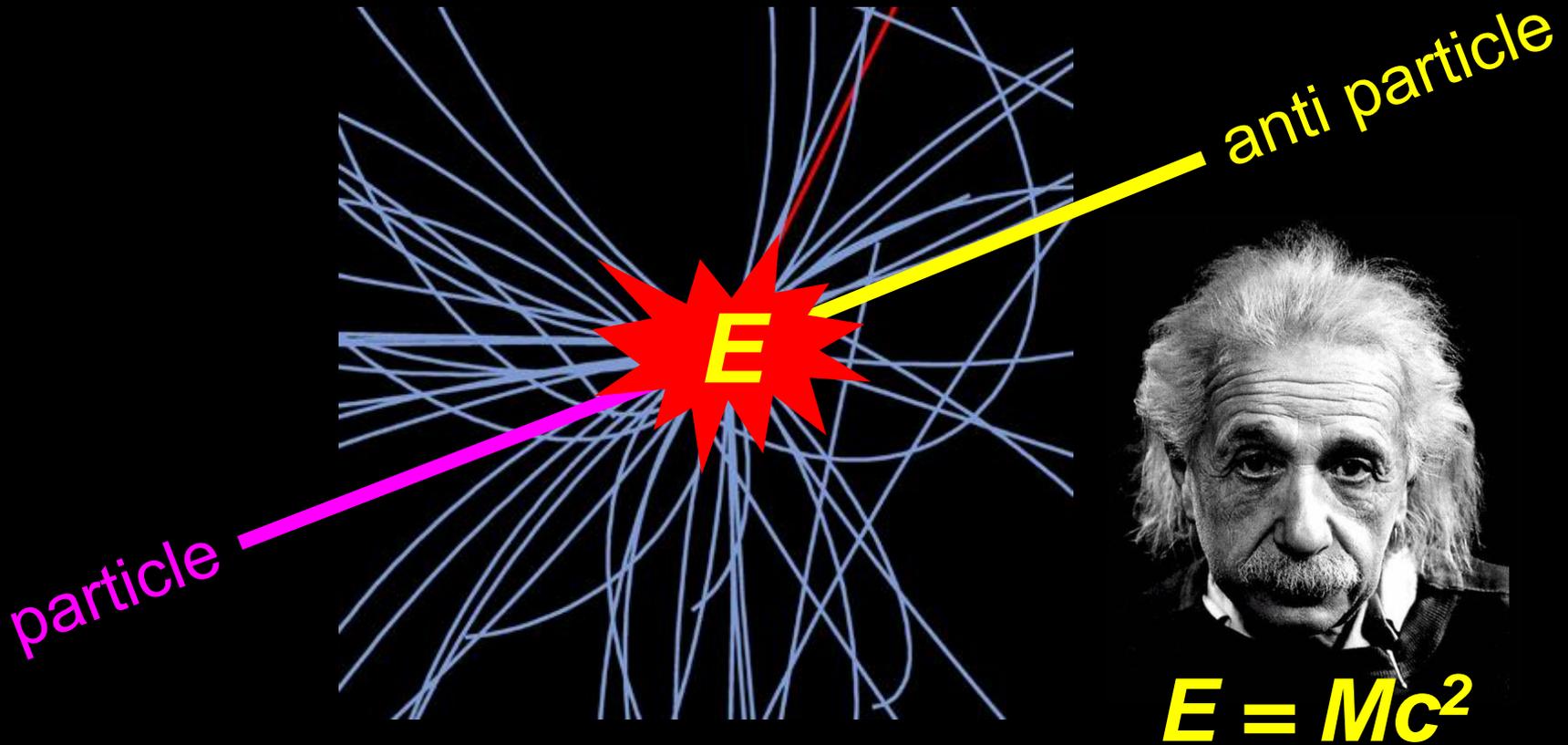
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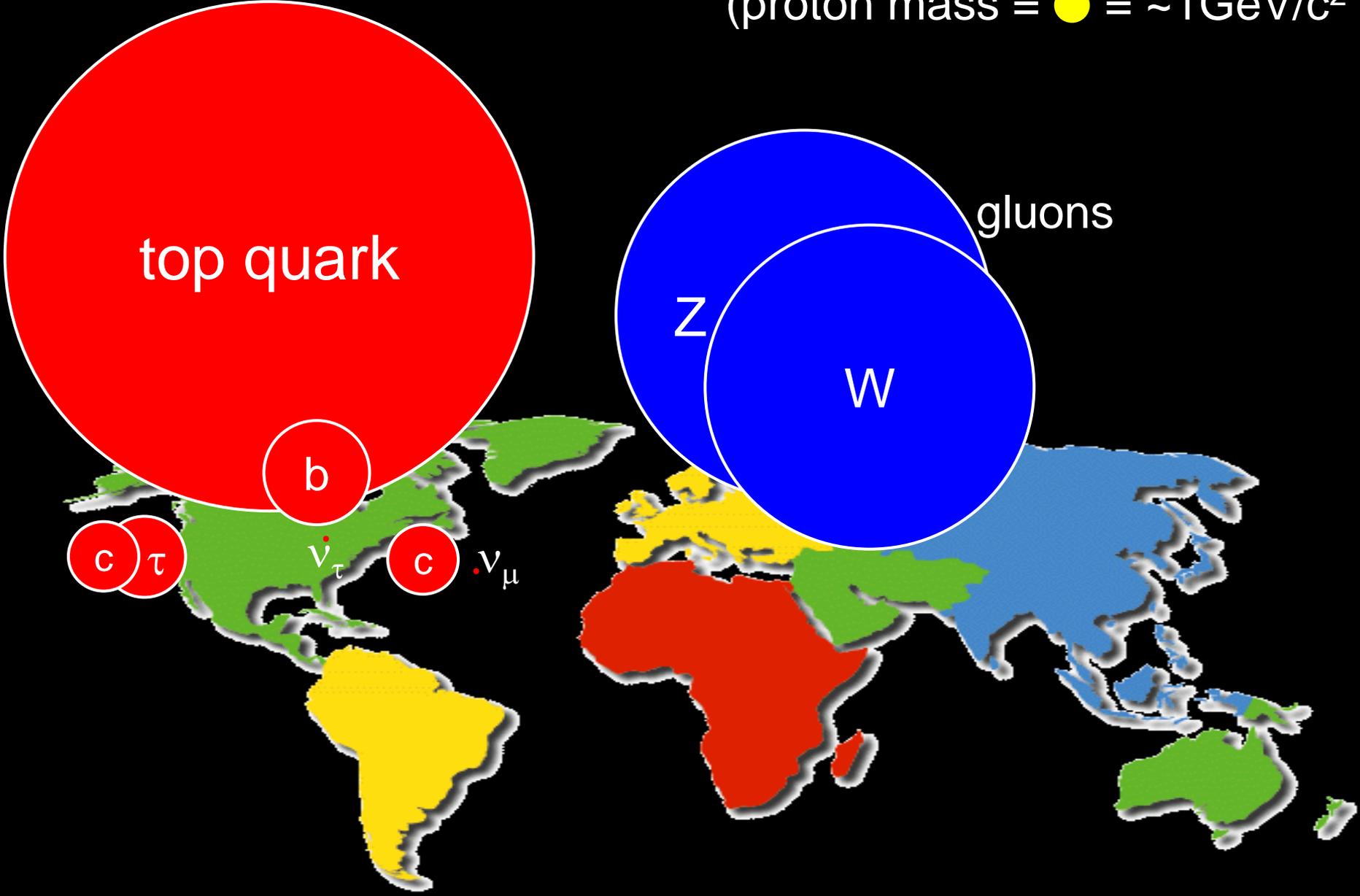


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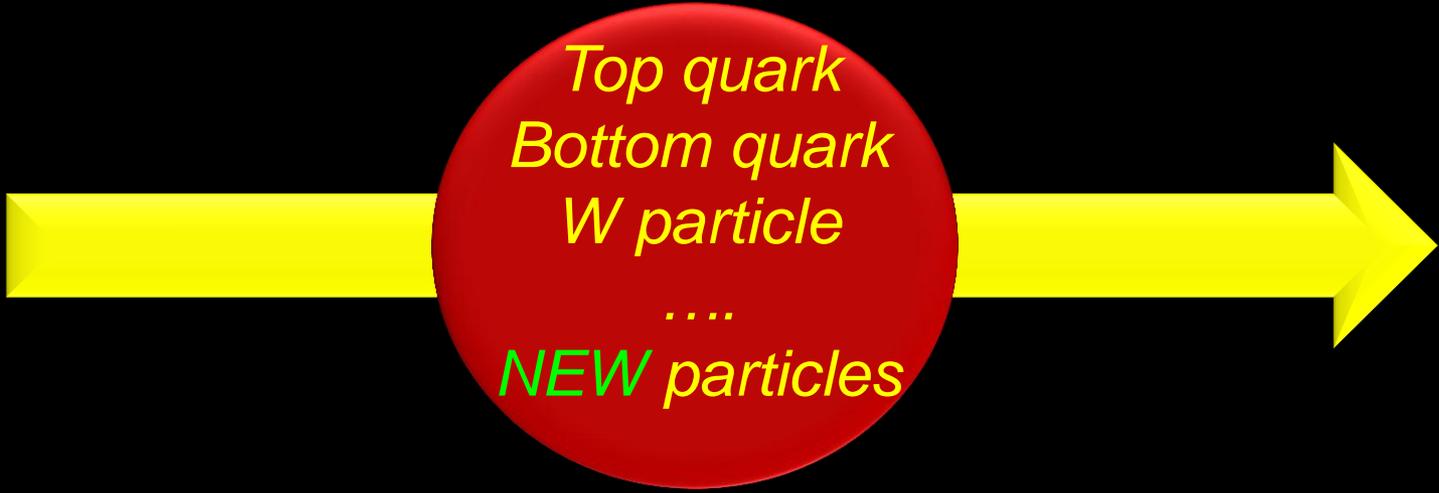
They make particles last seen
in the earliest moments of the universe.



(proton mass = ● = $\sim 1\text{GeV}/c^2$)



Discover the nature of these particles and **NEW** particles



by intense beams
of neutrinos, muons, kaons and nuclei

Accomplishment of the 20th Century

Table of Elementary Particles Standard Model



Quarks

u up	c charm	t top
d down	s strange	b bottom

e electron	μ muon	τ tau
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino

Leptons

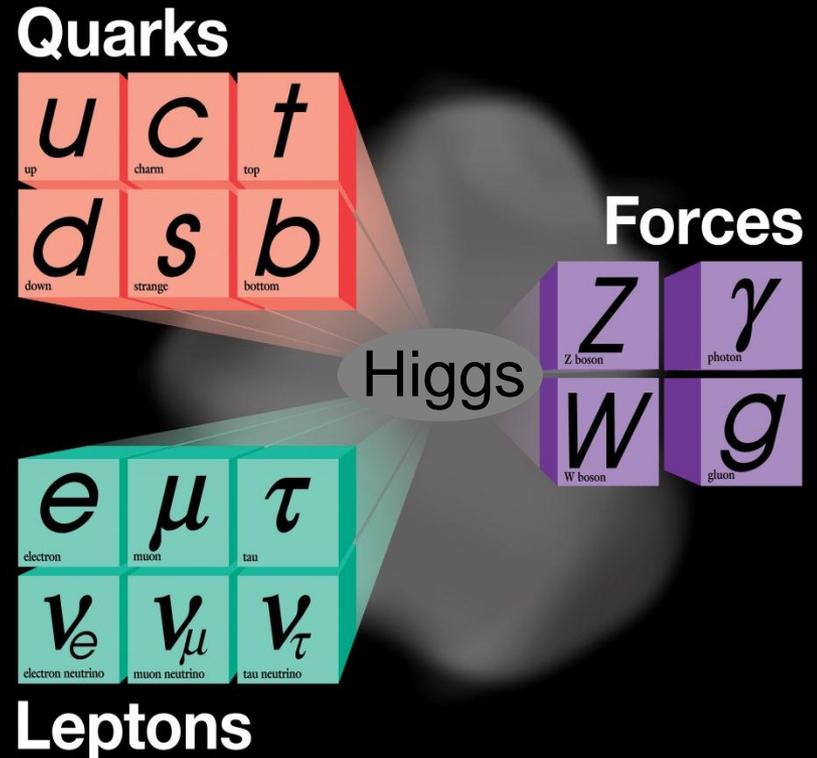
Forces

Z Z boson	γ photon
W W boson	g gluon

Higgs

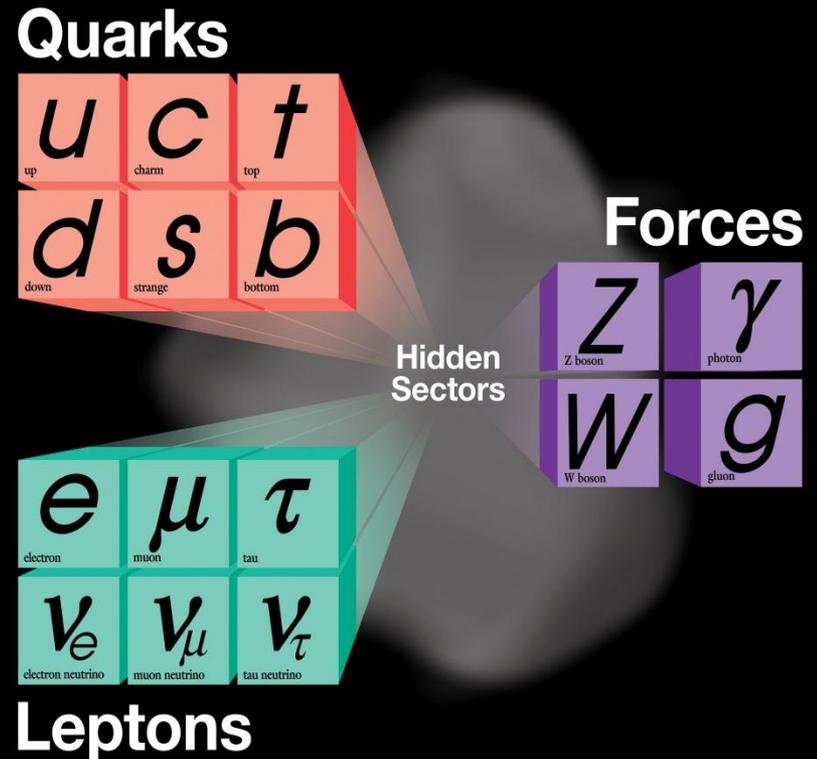
The triumphs.....

- The present theory is a remarkable intellectual construction
- Particle experimental results beautifully fit in this framework



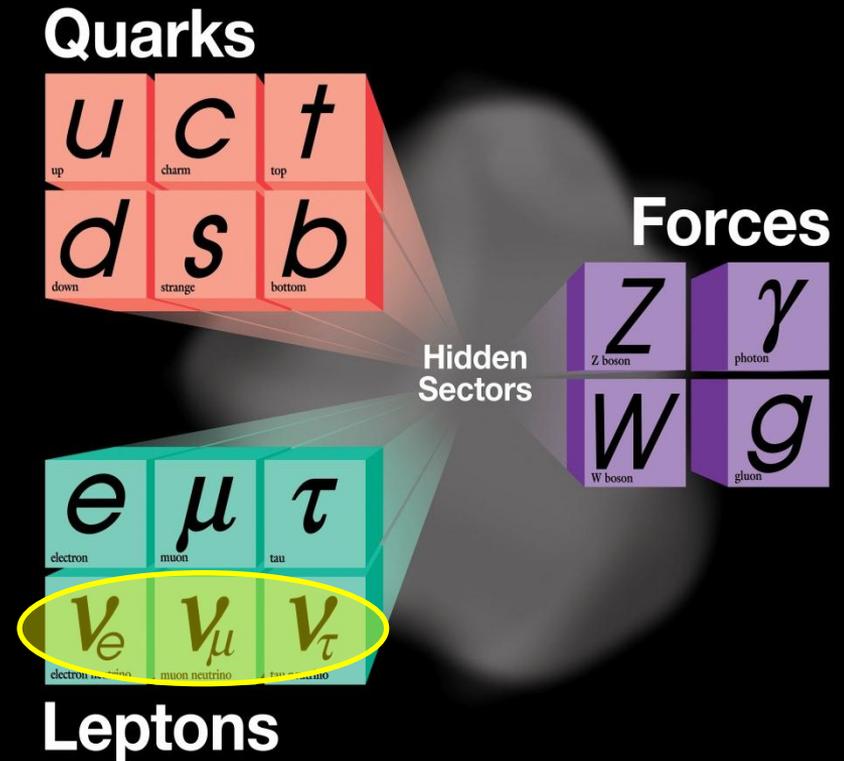
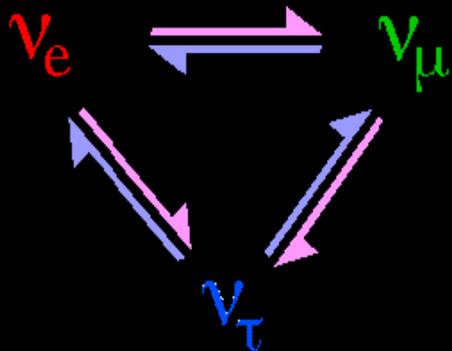
..... and the mysteries

- Origin of mass?
- Why so many kinds of particles? Why three families?
- Do all forces become one?



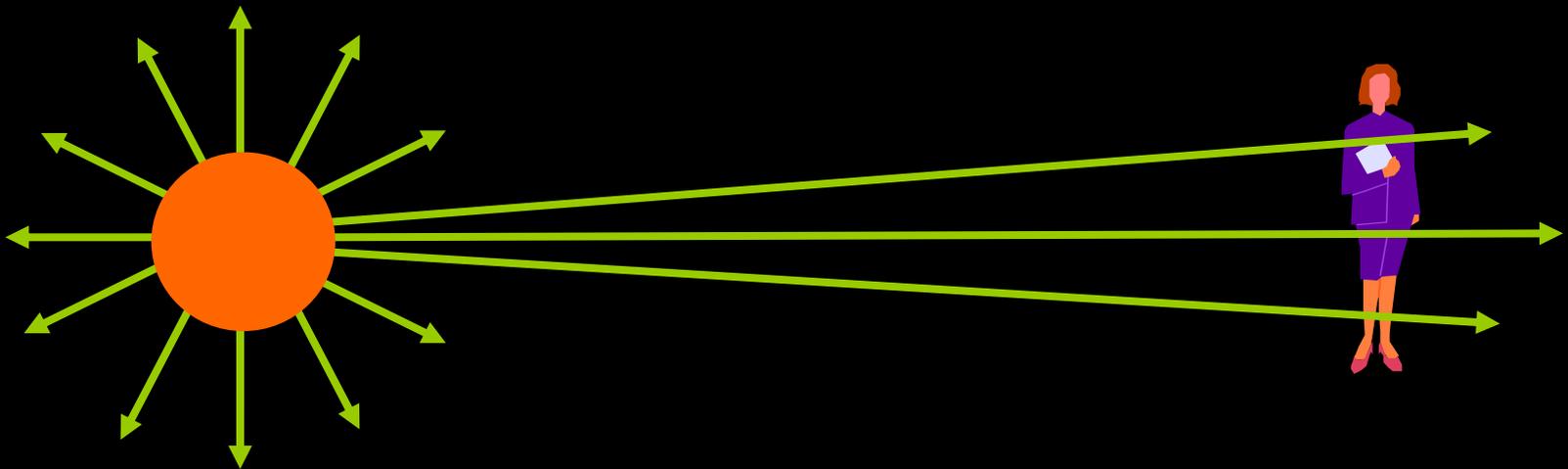
..... and the mysteries

- What do neutrinos tell us?



Neutrinos are under our skin

~100 trillion neutrinos zip through each person every second.

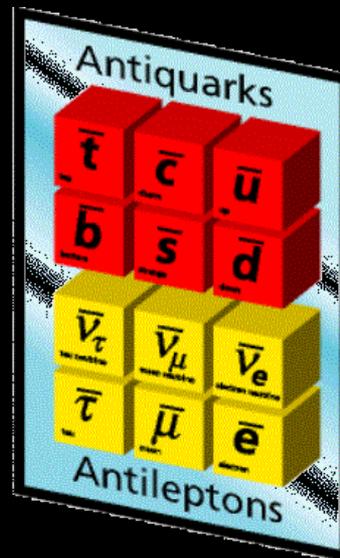
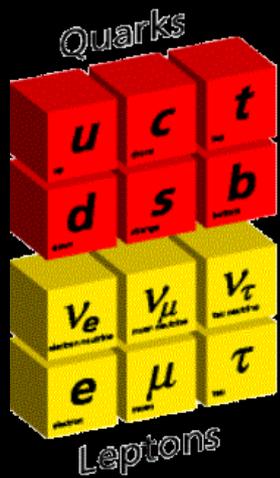


One billion neutrinos for each proton or electron in the universe

If we wish to understand the universe,
we must understand neutrinos

..... and the mysteries

Where did all antimatter go?



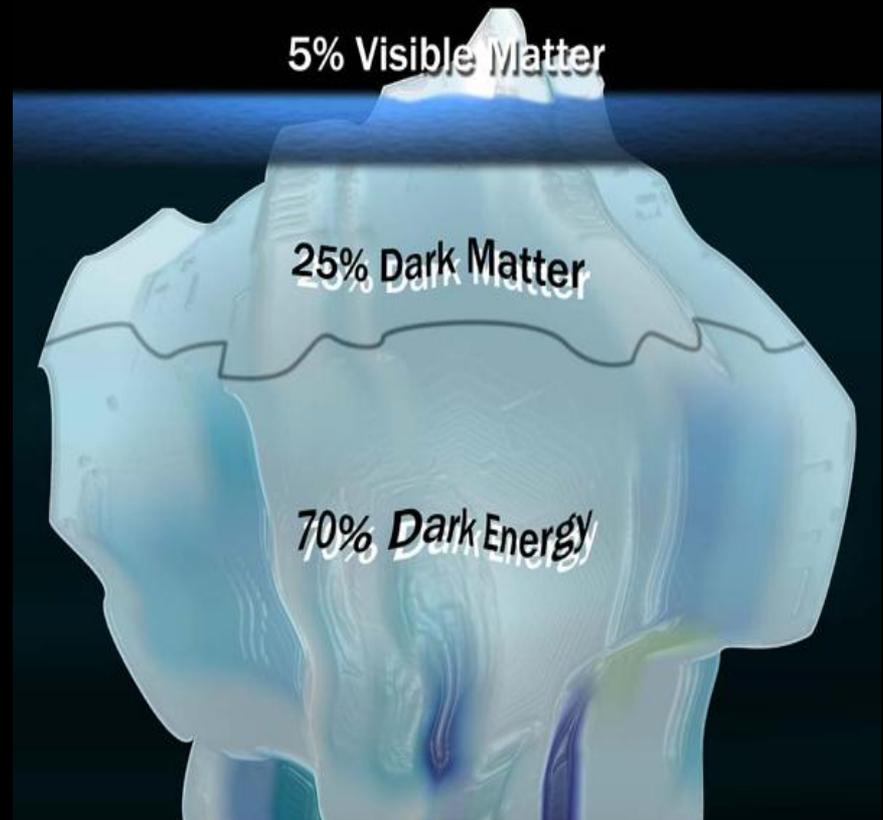
..... and the mysteries

- What is dark matter?
- It is everywhere, it is five times more abundant than matter.



..... and the mysteries

- Not only is the universe expanding, it is accelerating.
- What is dark energy?
Not a clue!



What is the world made of?
What holds it together?
Where did we come from?

Primitive Thinker



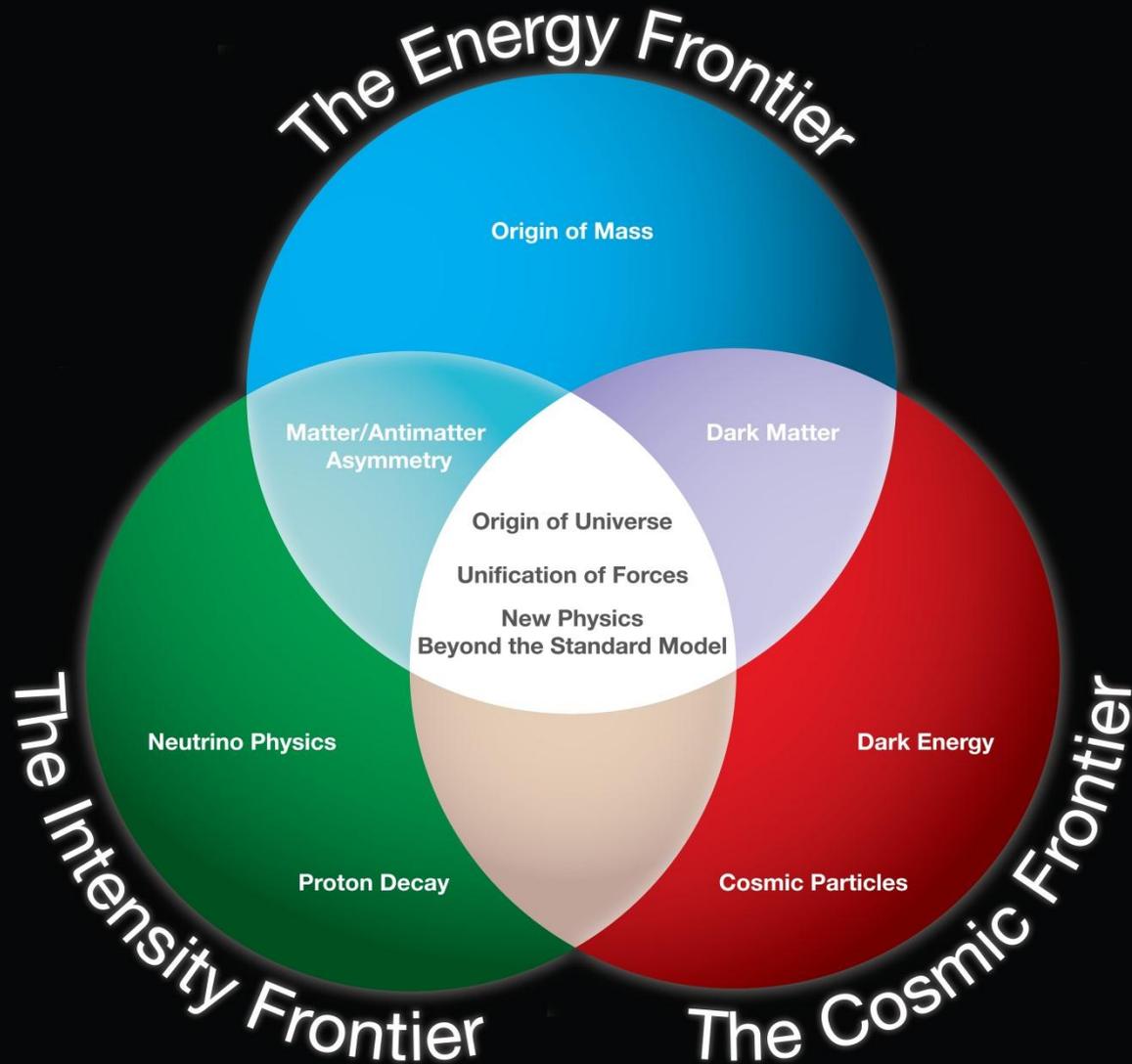
21st Century Questions in Particle Physics

- Origin of mass?
- Why so many kinds of particles?
- Do all forces become one?
- What do neutrinos tell us?
- What happened to antimatter?
- What is dark matter?
- Mystery of dark energy?
-

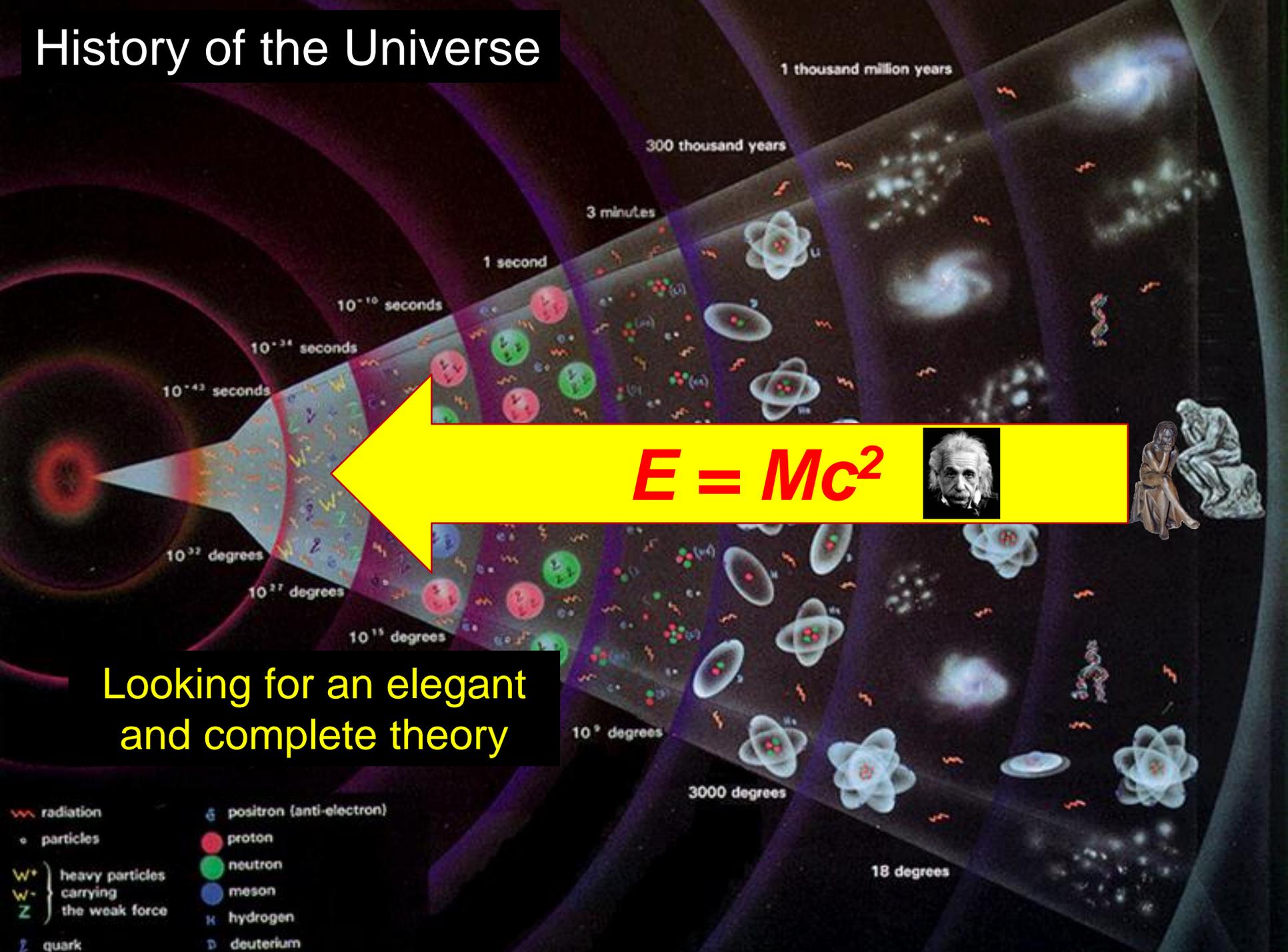
Evolved Thinker



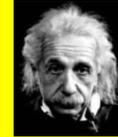
Tools for the Future



History of the Universe



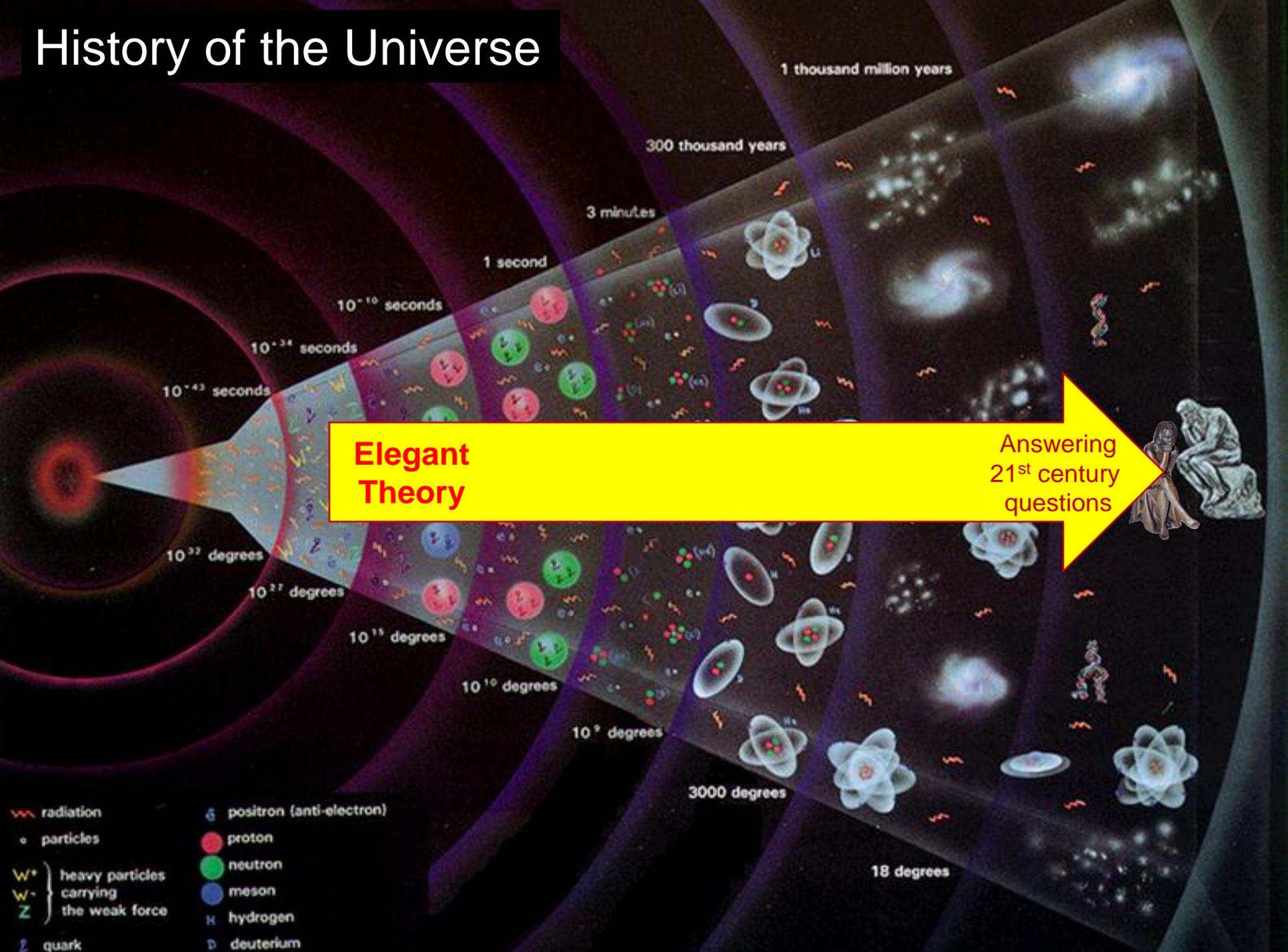
$$E = Mc^2$$



Looking for an elegant and complete theory

- radiation
- particles
- W^+ heavy particles carrying the weak force
- W^-
- Z
- quark
- positron (anti-electron)
- proton
- neutron
- meson
- hydrogen
- deuterium

History of the Universe



- radiation
- particles
- W^+ heavy particles carrying the weak force
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Current Experimental Programs at Fermilab (Collaborative Efforts)

Energy Frontier: 27 countries



Intensity Frontier: 17 countries



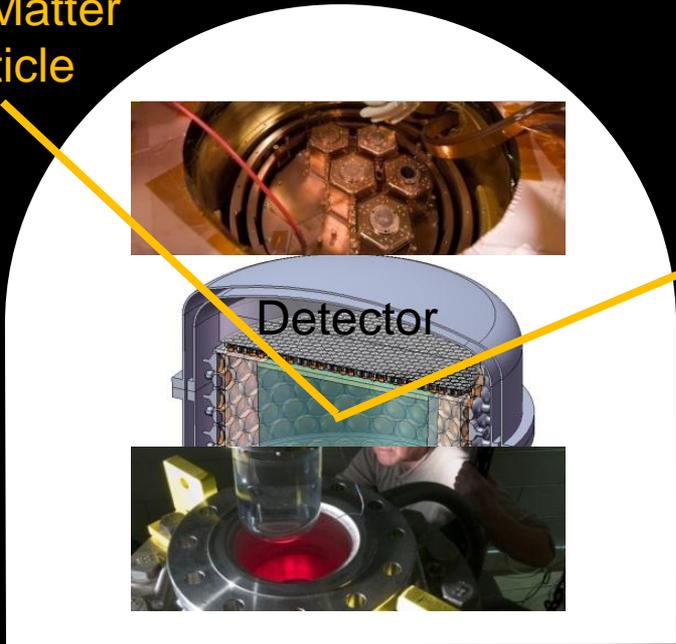
Cosmic Frontier: 24 countries



Cosmic Frontier

Dark Matter Detector

Dark Matter Particle



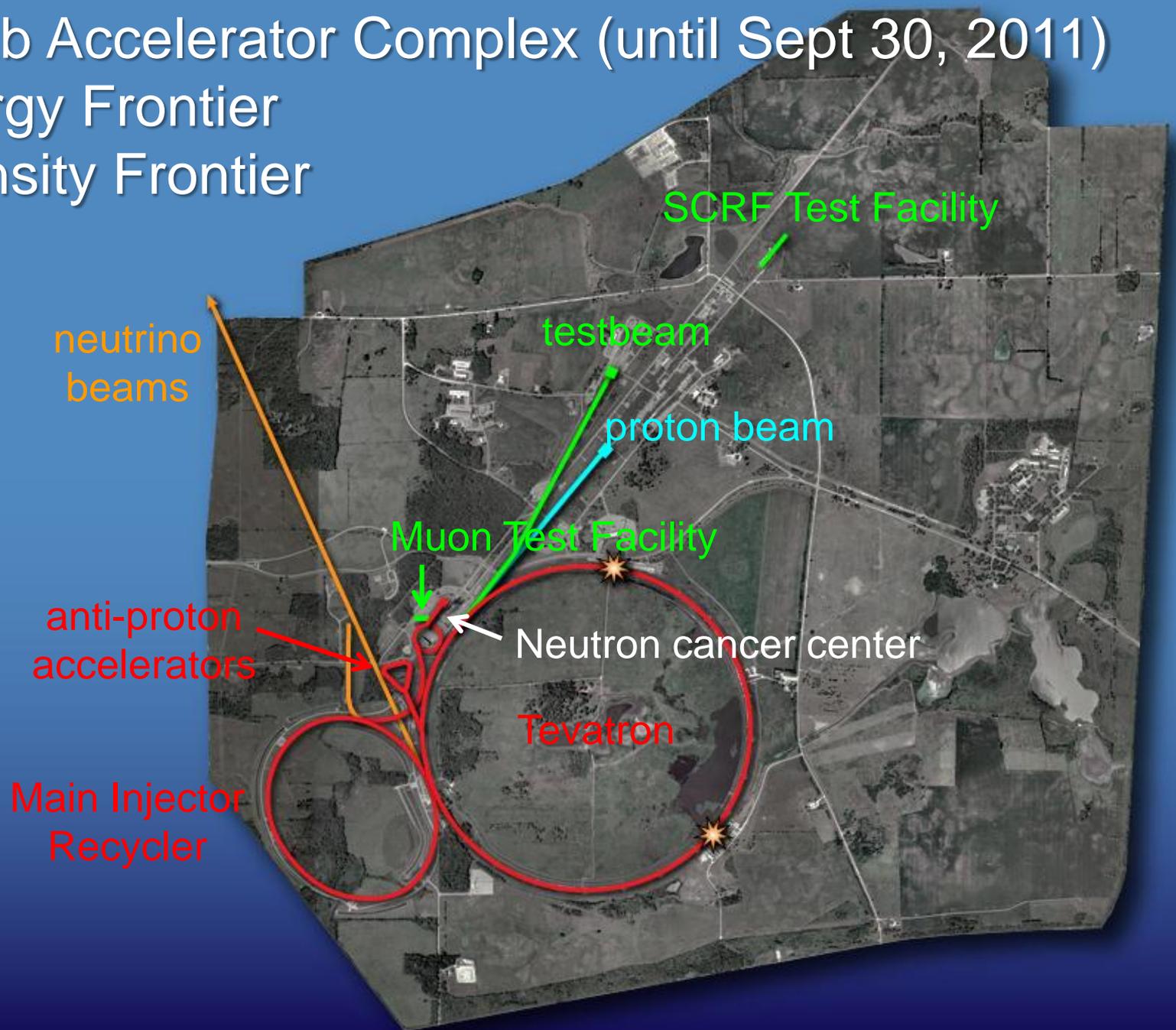
Dark Energy Camera



Detectors in underground facilities

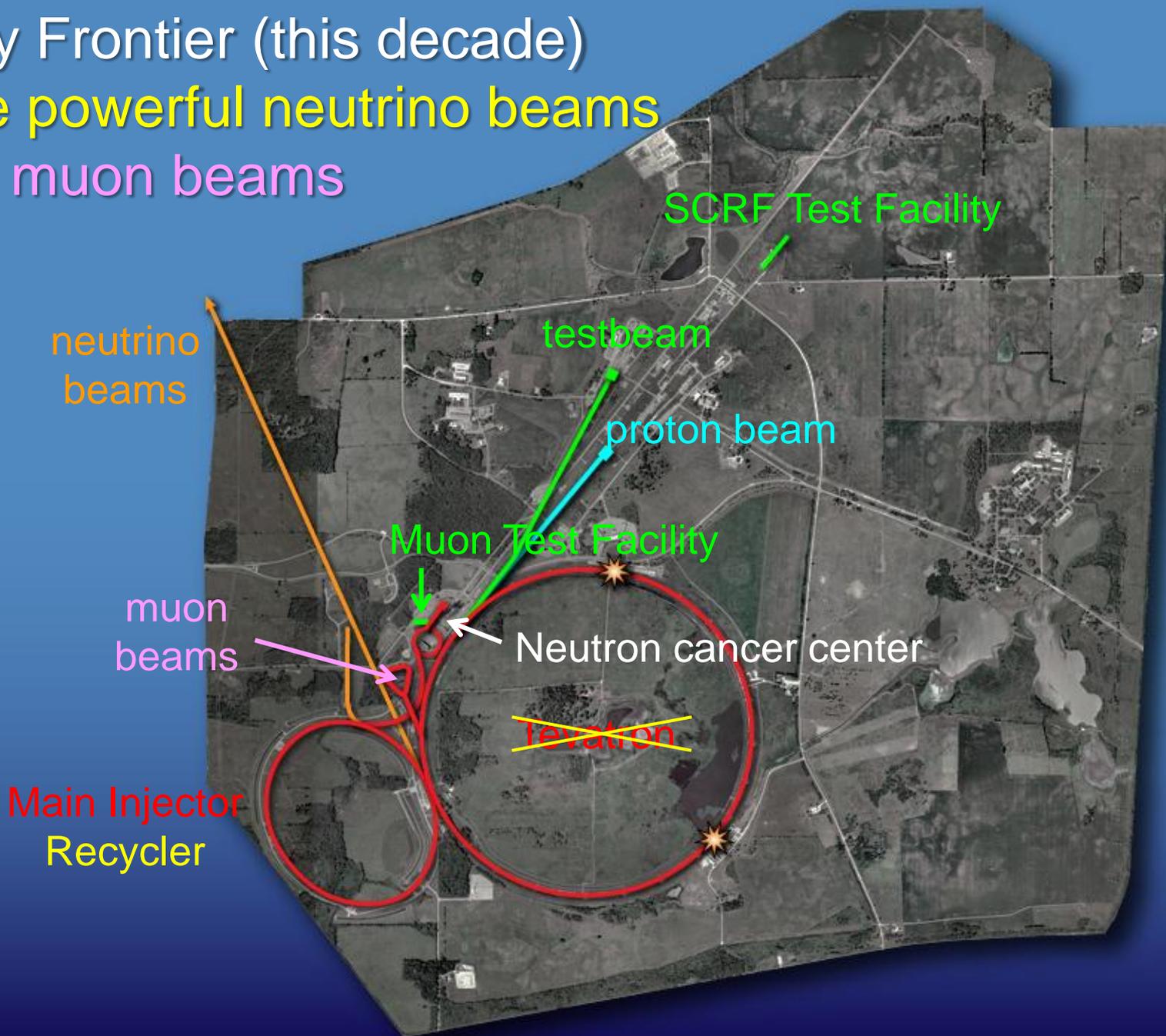
Fermilab Accelerator Complex (until Sept 30, 2011)

- Energy Frontier
- Intensity Frontier



Intensity Frontier (this decade)

- More powerful neutrino beams
- New muon beams



Energy Frontier: Fermilab and LHC



Fermilab ★

★ CERN

Tevatron

LHC

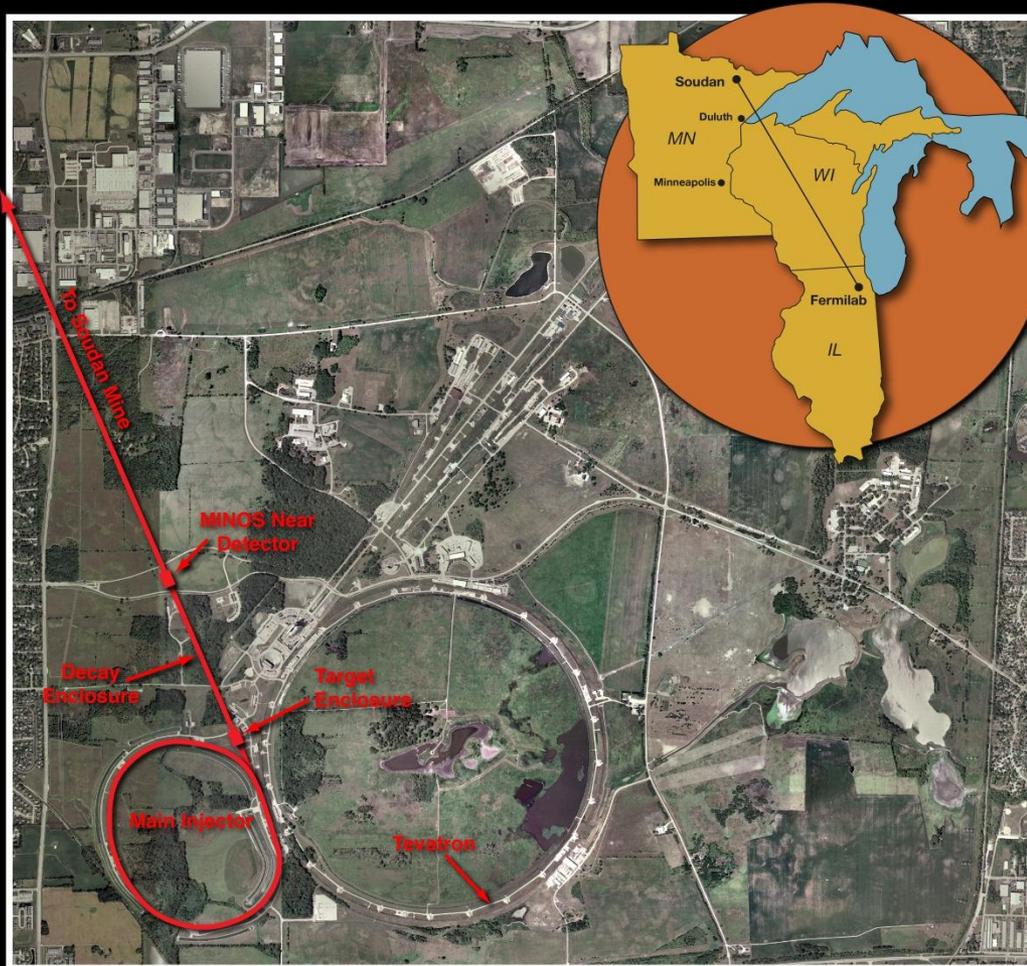
Intensity Frontier probes

- Origin of mass?
- Why so many kinds of particles?
- Do all forces become one?
- What do neutrinos tell us?
- What happened to antimatter?
- What is dark matter?
- Mystery of dark energy?
-

Evolved Thinker



Intensity Frontier: Neutrino Experiments (now)



MINOS (Soudan Mine)



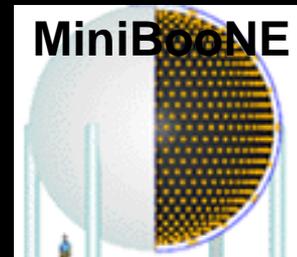
**MINOS detector
at Fermilab**



MINERvA

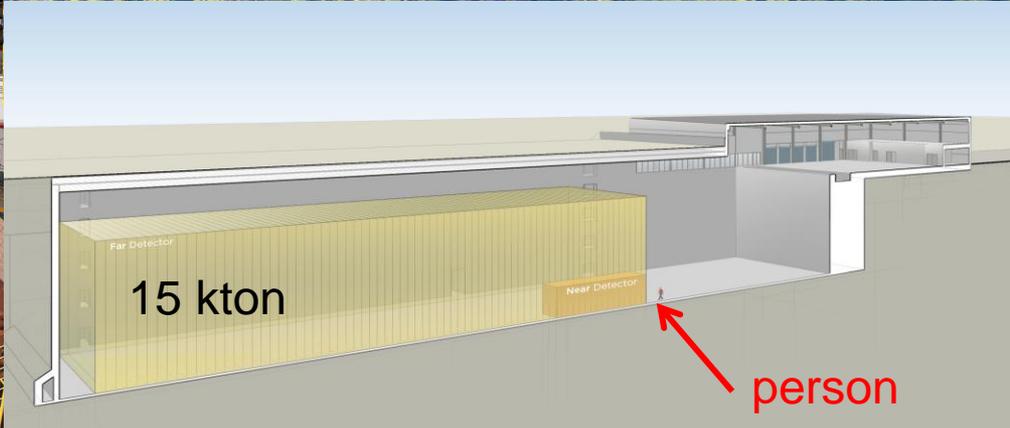


MiniBooNE

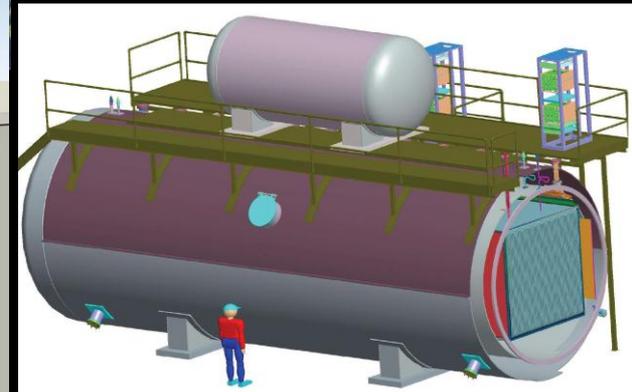


Intensity Frontier (this decade) new generation neutrino detectors

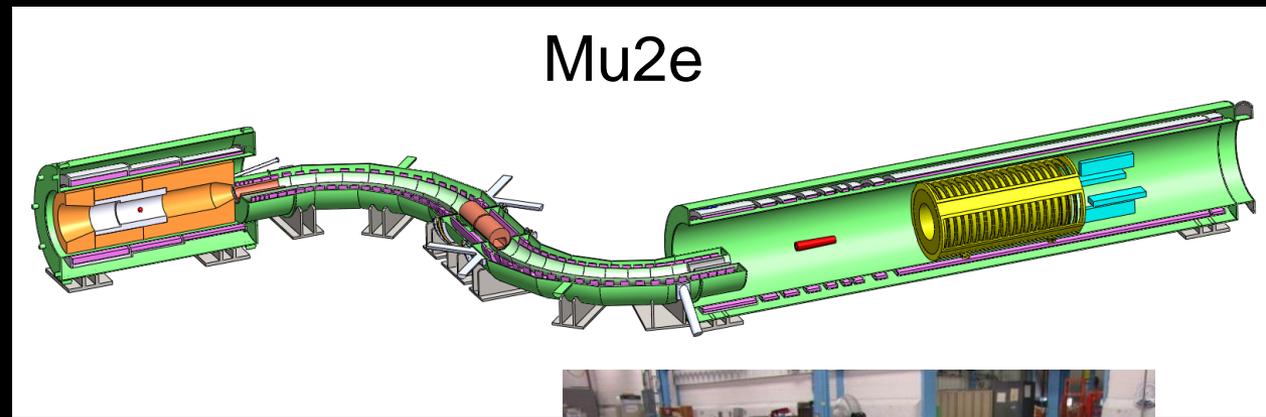
NOvA under construction
Minnesota site & Fermilab site



MicroBooNE
under construction
Fermilab site



Intensity Frontier (this decade) new muon experiments at Fermilab

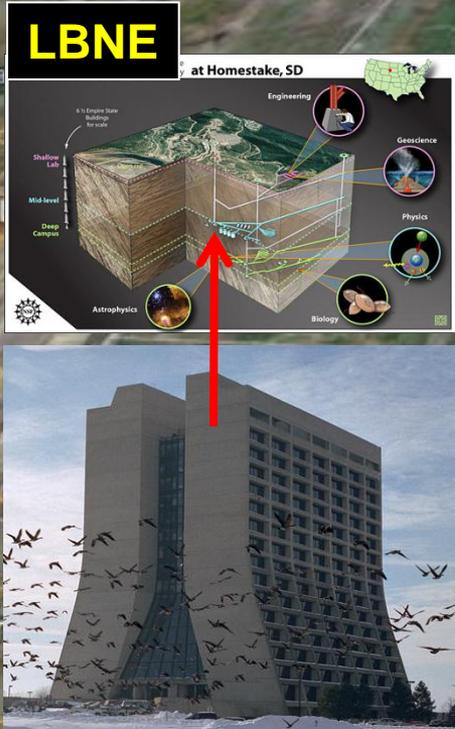


Intensity Frontier: Developing programs for 2020s and beyond

LBNE
(Long Baseline Neutrino Experiment)

Project X

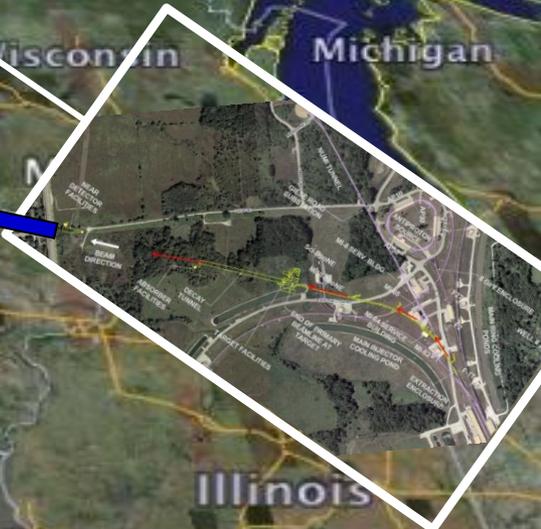
Long Baseline Neutrino Experiment



NOvA
MINOS

735 km
450 miles

1300 km
808 miles



Collaboration: 318 members
58 institutions (6 US labs) and 5 countries (India, Italy, Japan, UK, US)
Continues to grow!



Soul Mate



Image NASA
© 2008 Tele Atlas
Image © 2008 TerraMetrics
© 2008 Europa Technologies

Google

Pointer 43°03'56.44" N 95°10'42.53" W Streaming 100%

Eye alt 1108.62 km

Project X

will be the world's most powerful proton source

will make the world's most powerful beams of neutrinos, muons, kaons and nuclei to explore new physics in unprecedented breadth and depth

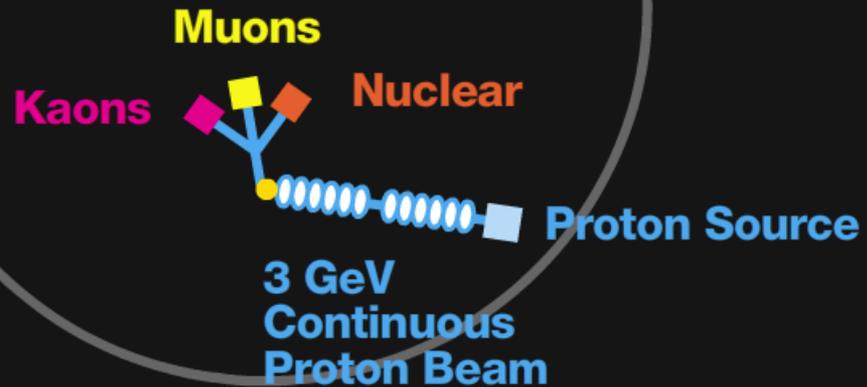


will establish a versatile technical foundation for future accelerators

Project X: Low-energy Program

Highest-intensity proton accelerator in the world

Proposed Experimental Areas



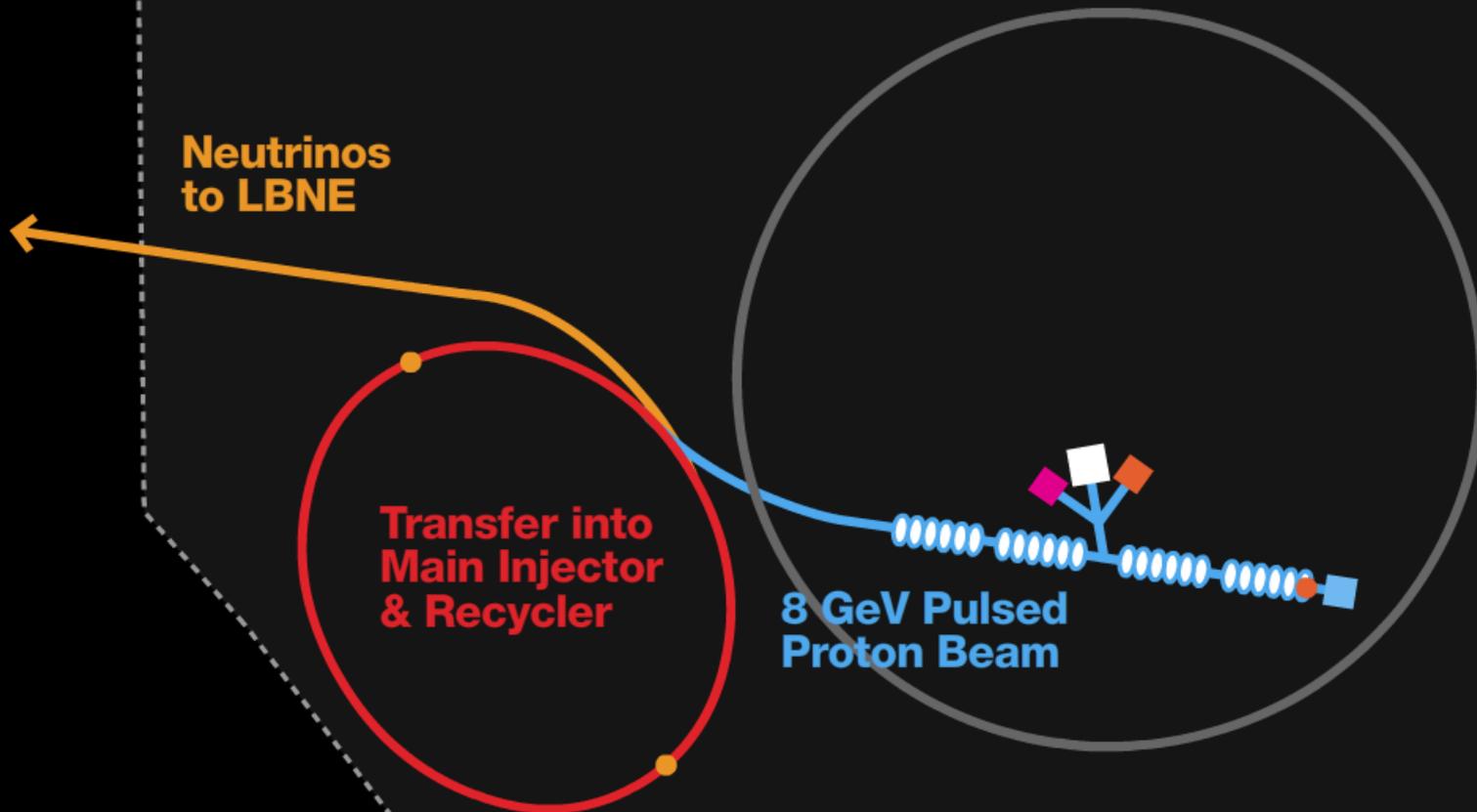
Proposed location of Project X 3-GeV experimental campus at Fermilab

- 
- 1 Proton beam from 3-GeV linac
 - 2 Switchyard: beam distribution
 - 3 Charged kaon decay experiment
 - 4 Neutral kaon decay experiment
 - 5 Experiments with atomic nuclei
 - 6 Advanced muon-to-electron conversion experiment
 - 7 Wilson Hall and existing buildings

Project X would provide a 3-GeV proton beam for experiments with kaons, muons, and atomic nuclei. Energy applications

Project X: High-energy Program

More beam for high-intensity neutrino experiments



Intensity Frontier probes

- Origin of mass?
- Why so many kinds of particles?
- Do all forces become one?
- What do neutrinos tell us?
- What happened to antimatter?
- What is dark matter?
- Mystery of dark energy?
-

Evolved Thinker



Vision of Fermilab

- Fermilab is going after the most exciting questions in particle physics, the most interesting questions about the nature and future of our universe.
- Fermilab continues to operate most of its existing accelerators with enhanced capabilities and next generation experiments (2010s)
- Fermilab will build new accelerators and experiments for the future (2020s and beyond)

The Great Plains were once a frontier
for the expanding United States.



It is now a frontier
for expanding our knowledge of the universe.