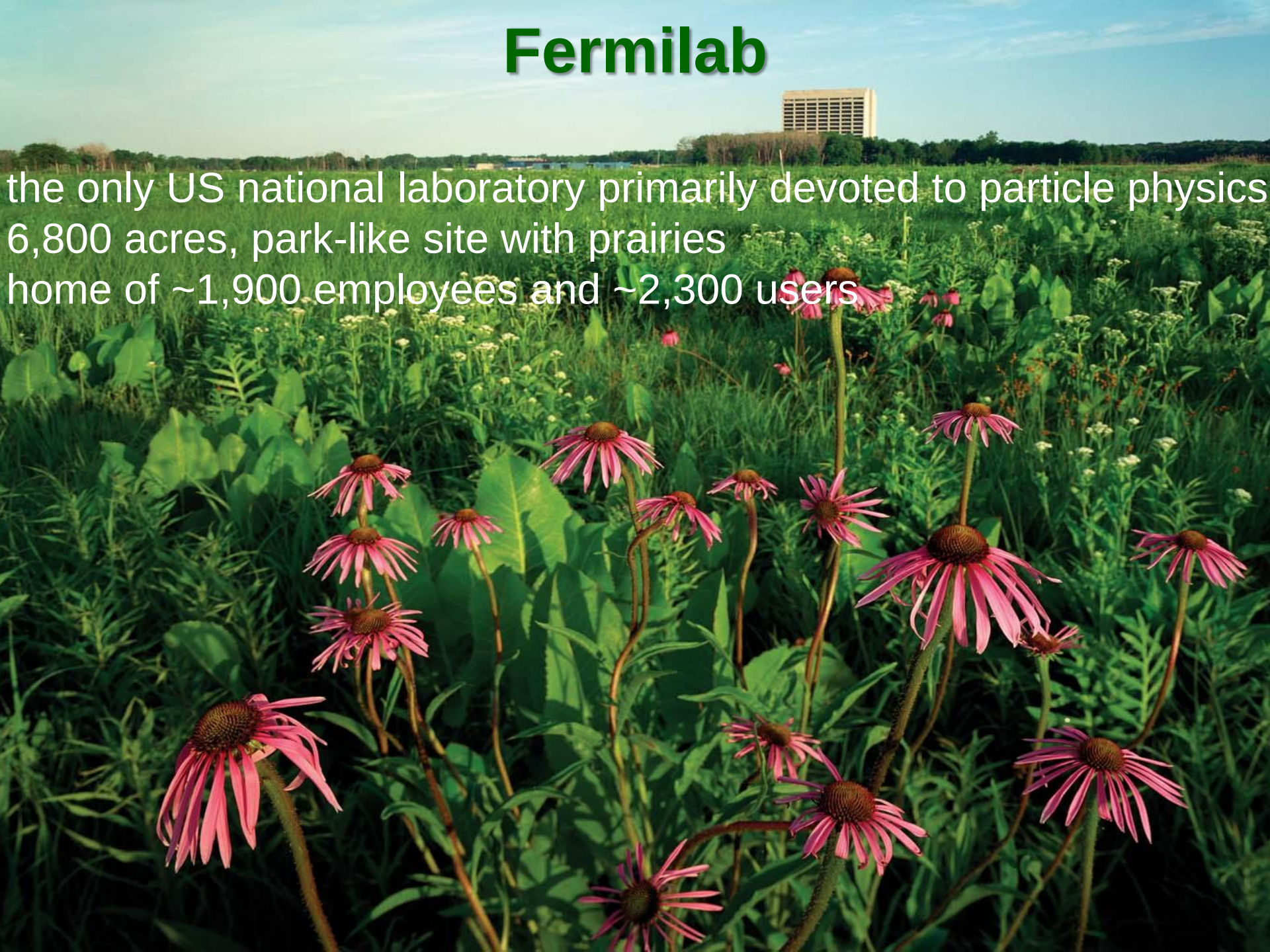
The New Frontier on the Great Plains:

Fermilab and the future of particle physics

Young-Kee Kim
Deputy Director, Fermilab

Physics for Everyone:
a non-technical lecture series about Fermilab science and culture
November 16, 2011

Fermilab



the only US national laboratory primarily devoted to particle physics
6,800 acres, park-like site with prairies
home of ~1,900 employees and ~2,300 users

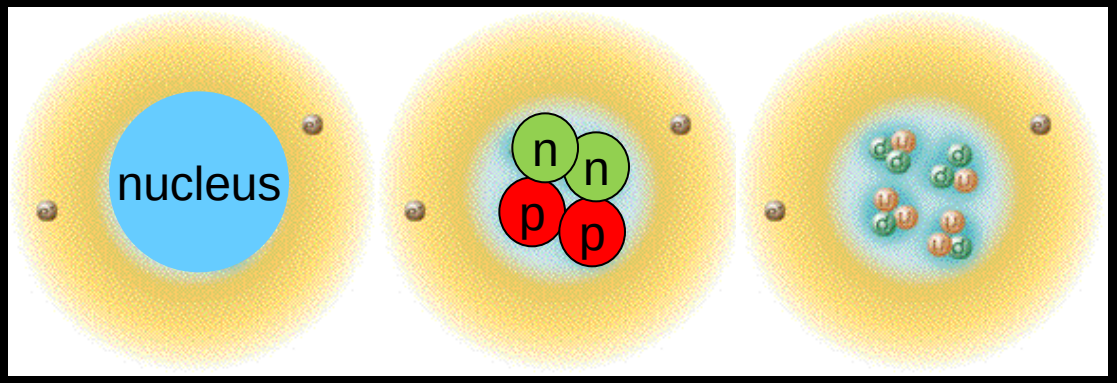
A herd of American bison,
symbolizing
Fermilab's presence on the frontiers of particle physics
and the connection to its prairie origins


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

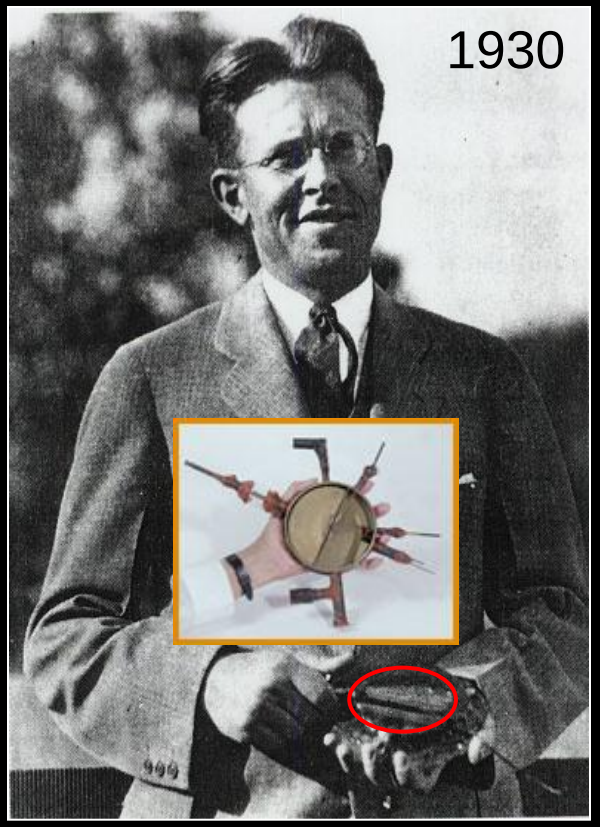


Gravitational force

Electromagnetic force

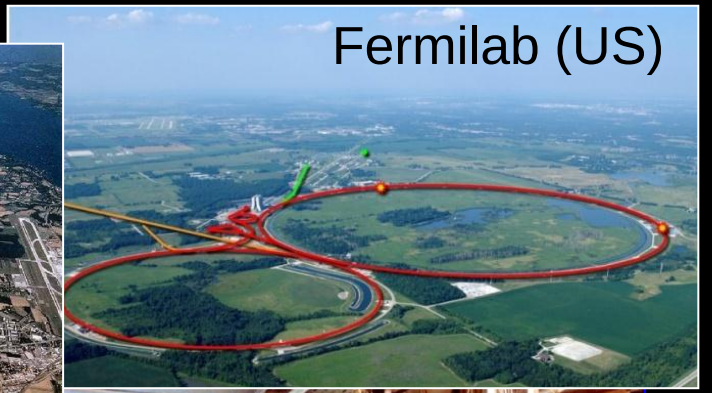
Weak and Strong forces

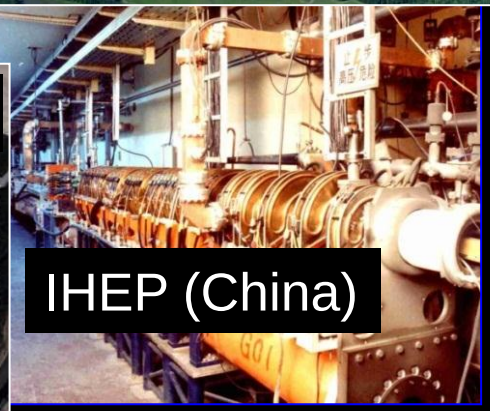
What holds it together?



Ernest Lawrence
(1901-1958)

Today's accelerators for particle physics





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

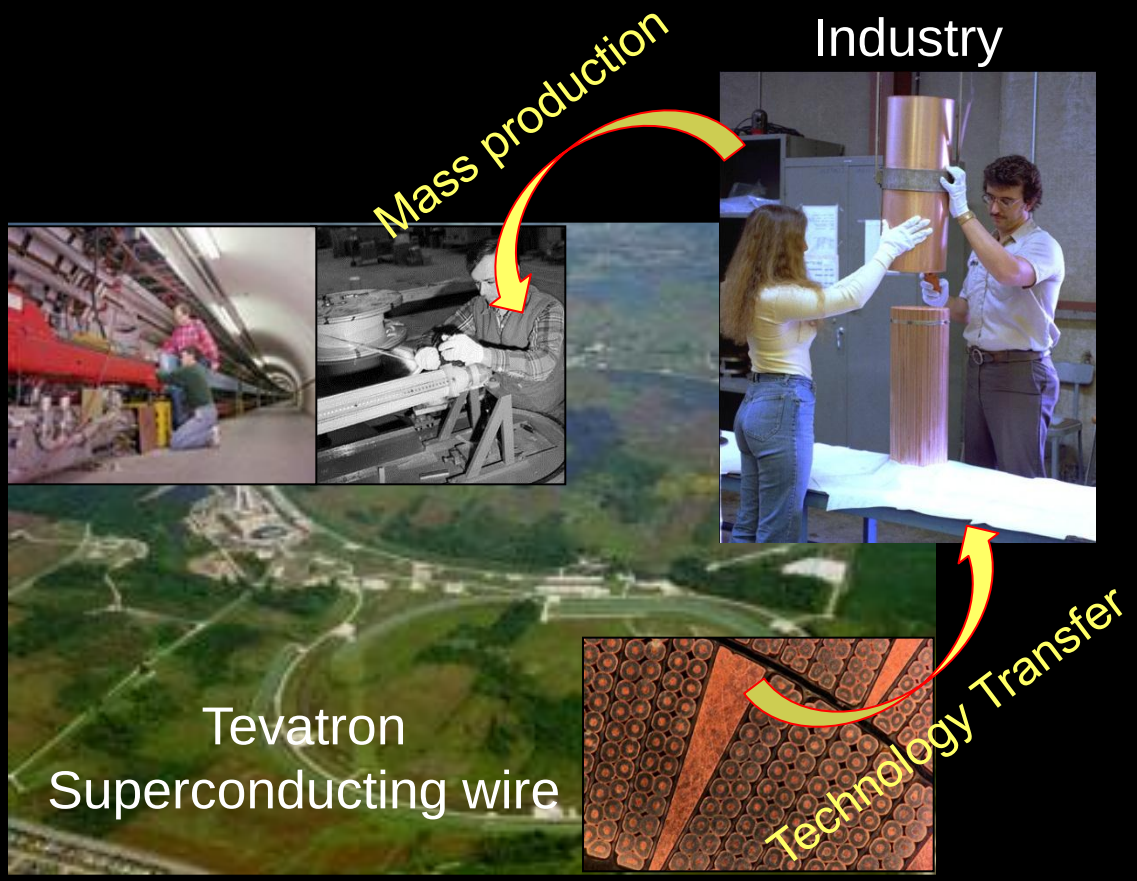
World's 1st proton accelerator built specifically for proton therapy

Designed and built at Fermilab

Technology Demonstration → Industry

Fermilab and Industry Partnerships

Tevatron Superconducting Wire → MRI

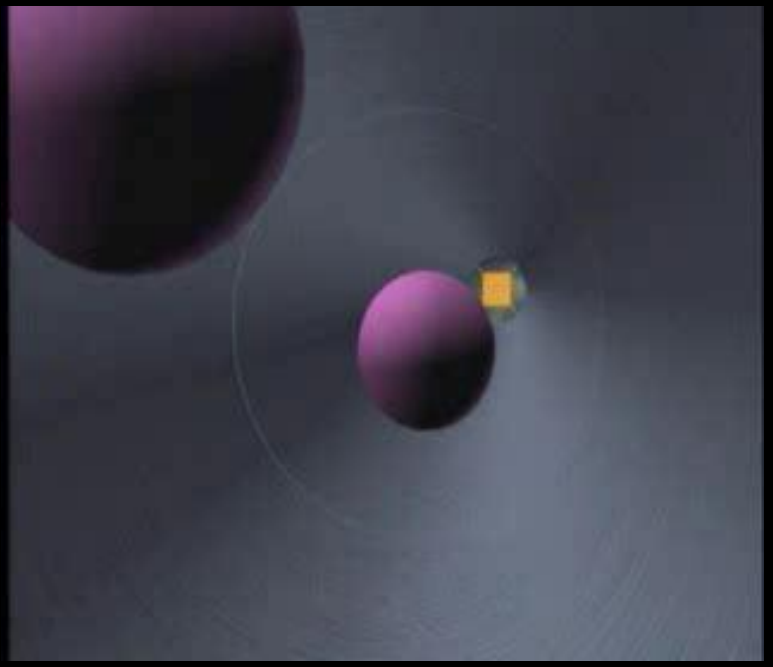


Illinois Accelerator Research Center

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
…..

Accelerators are like Time Machines.

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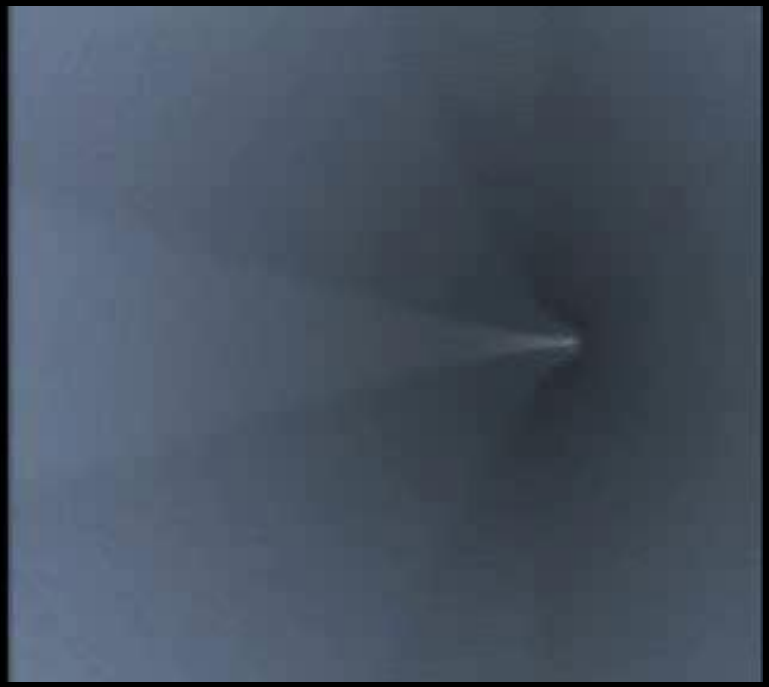
in the earliest moments of the universe.



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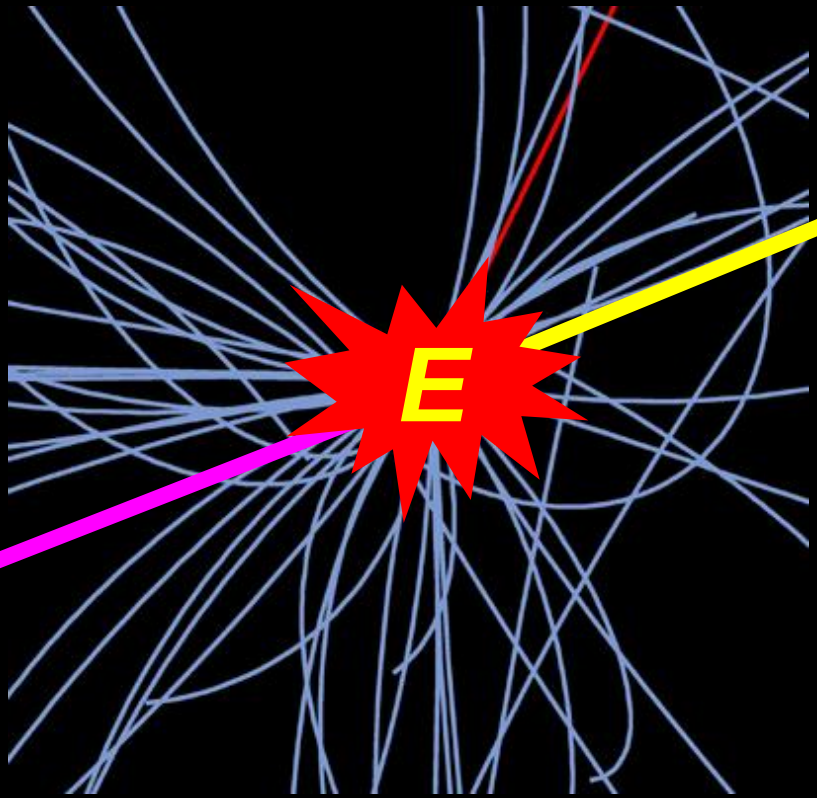
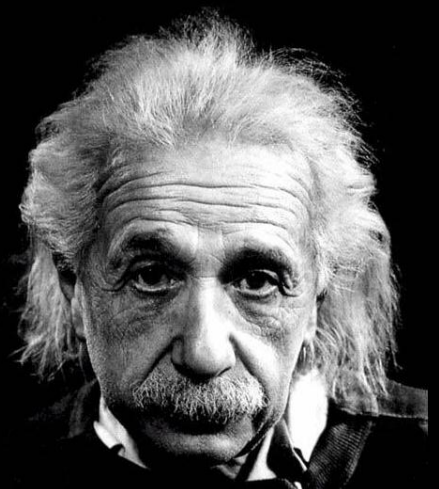


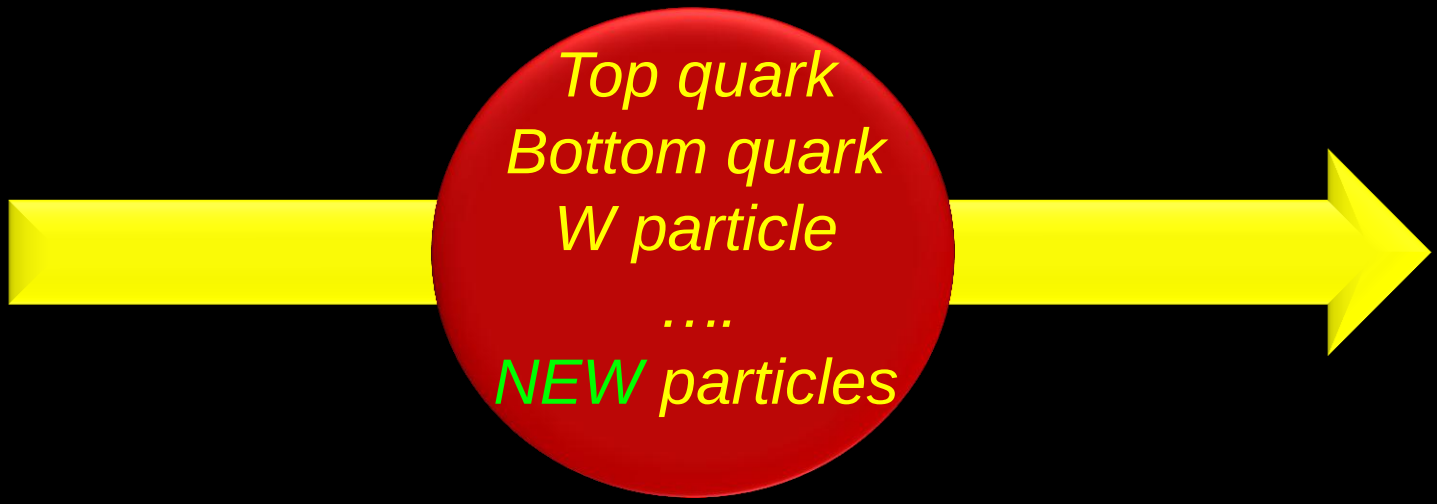
anti particle

particle



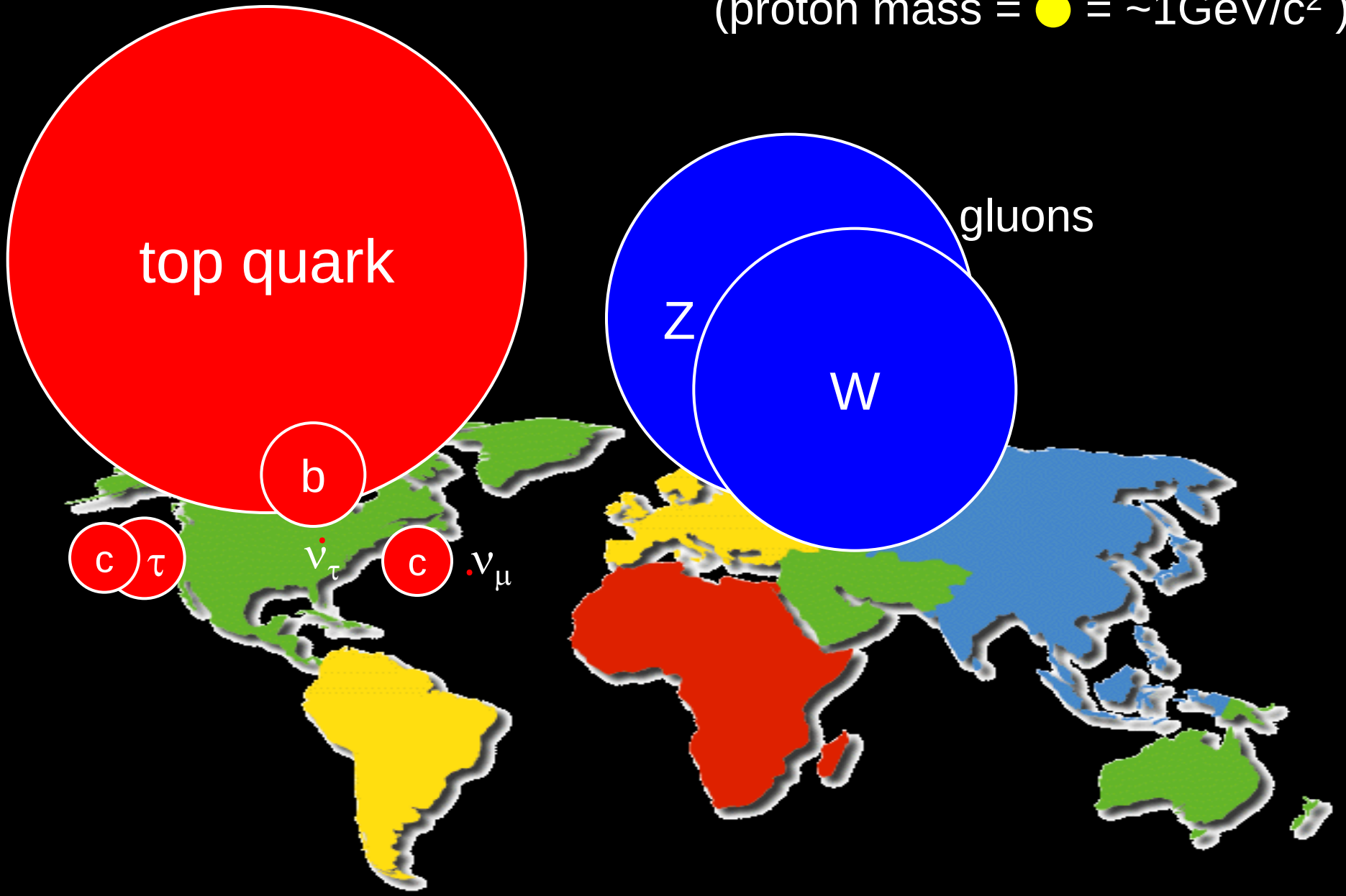
$E = Mc^2$

Discover the nature of these particles and NEW particles



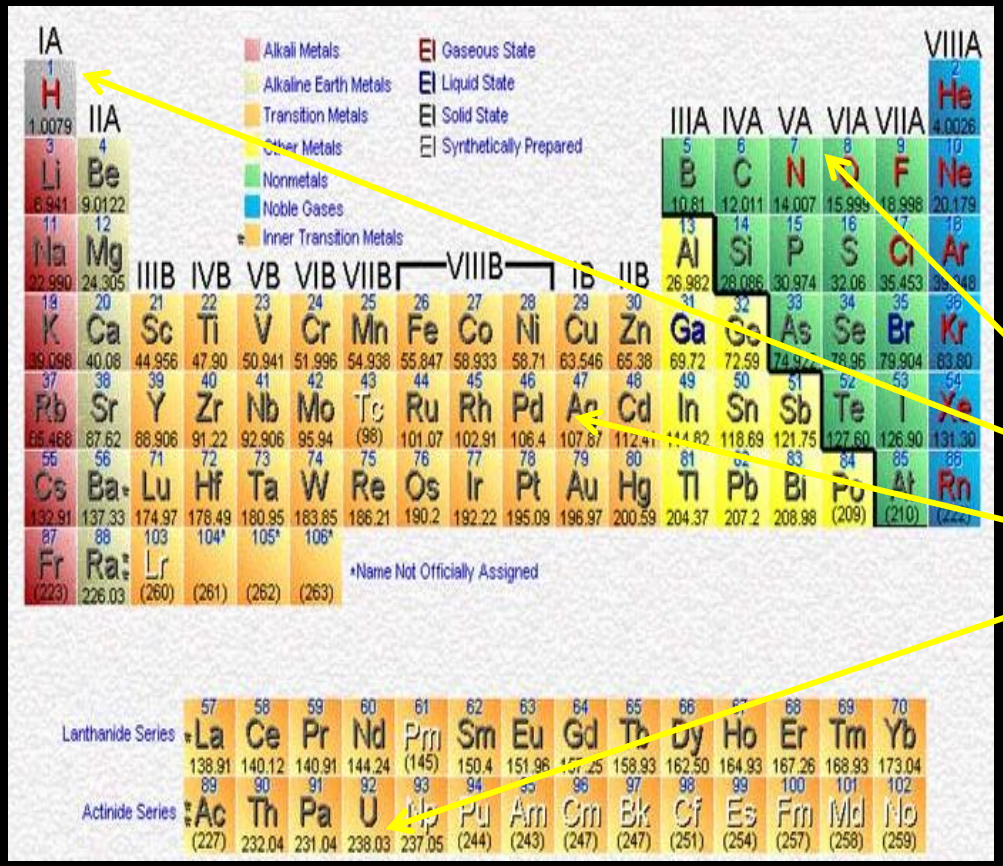
by intense beams
of neutrinos, muons, kaons and nuclei

(proton mass = ● = ~1GeV/c^2)



Accomplishment of the 19th Century

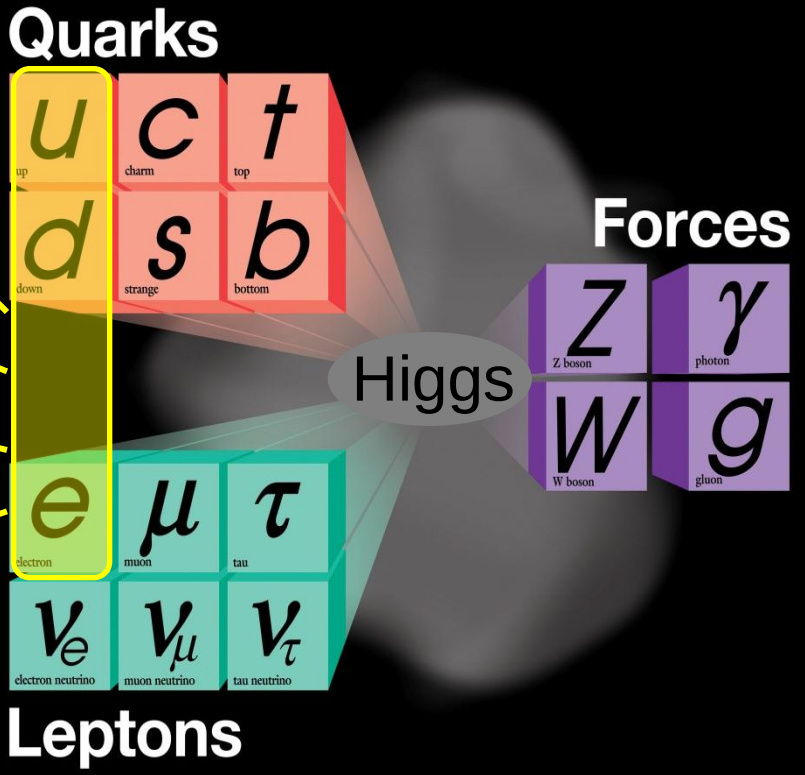
Periodic Table of Elements



Accomplishment of the 20th Century

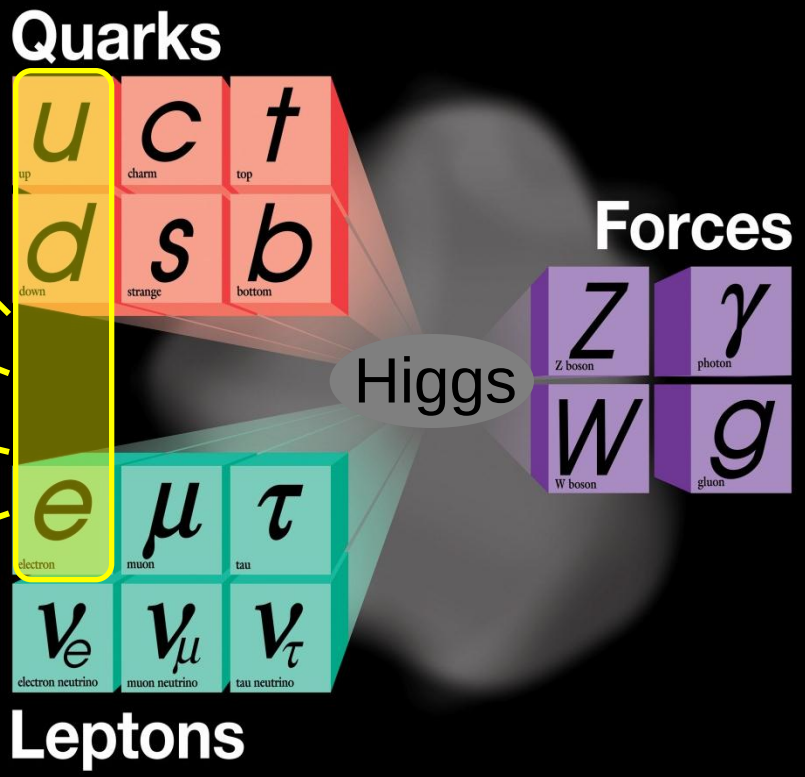
Table of Elementary Particles

Standard Model



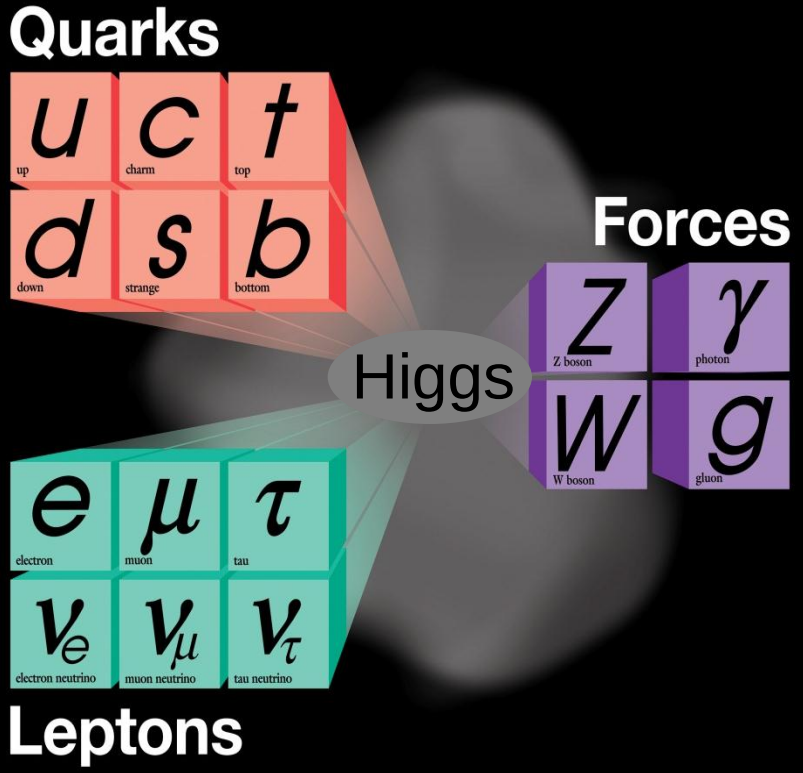
Accomplishment of the 20th Century

Table of Elementary Particles
Standard Model



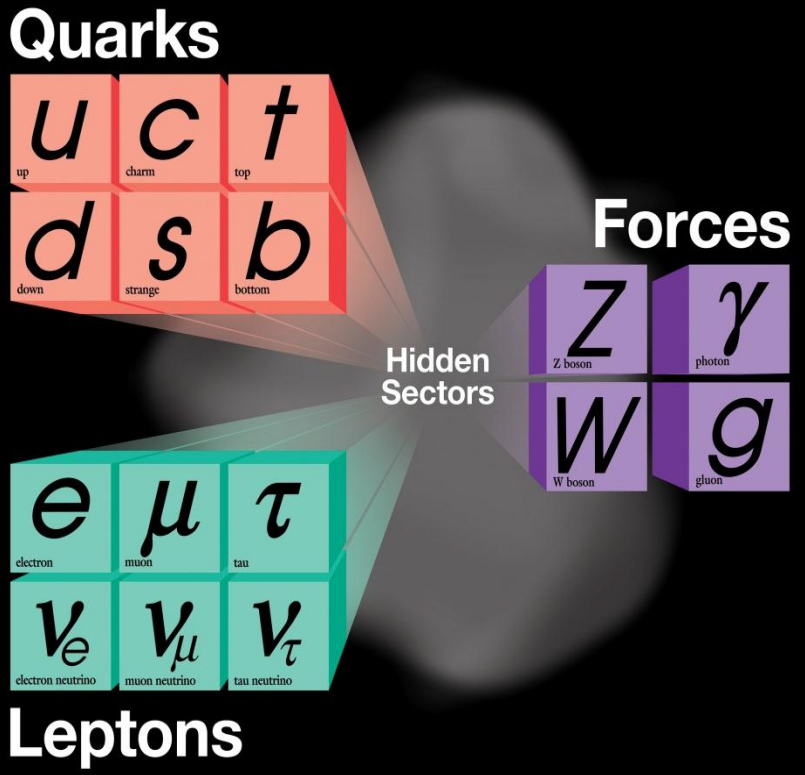
The triumphs……

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



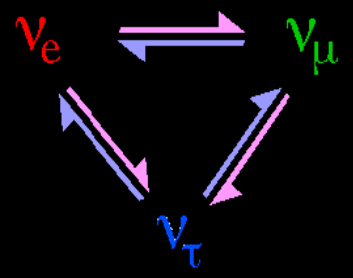
..... and the mysteries

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

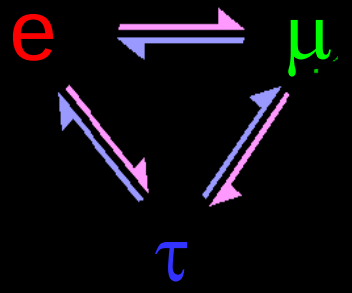


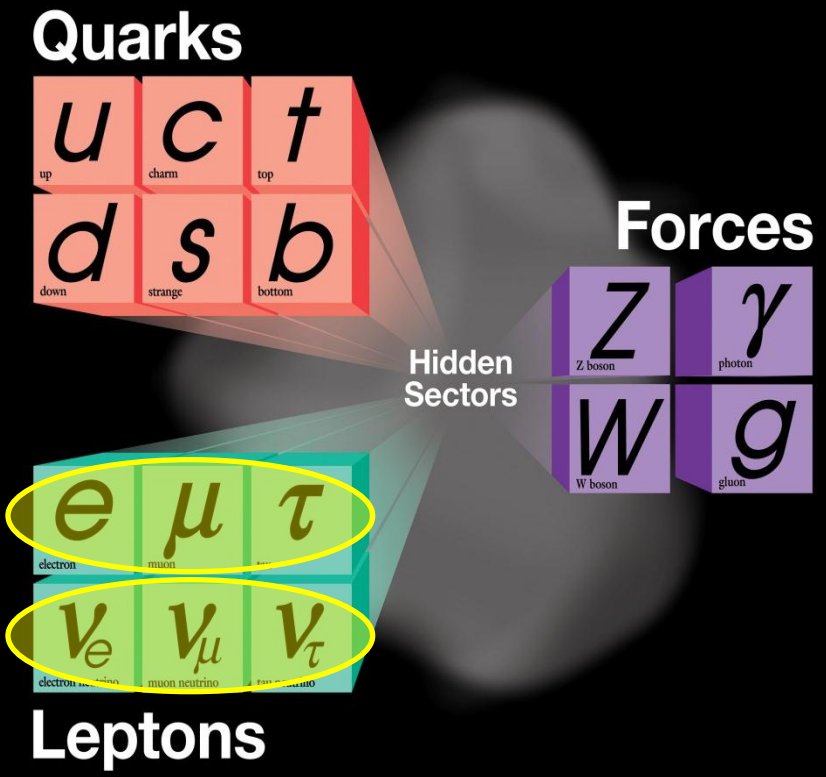
..... and the mysteries

- What do neutrinos tell us?



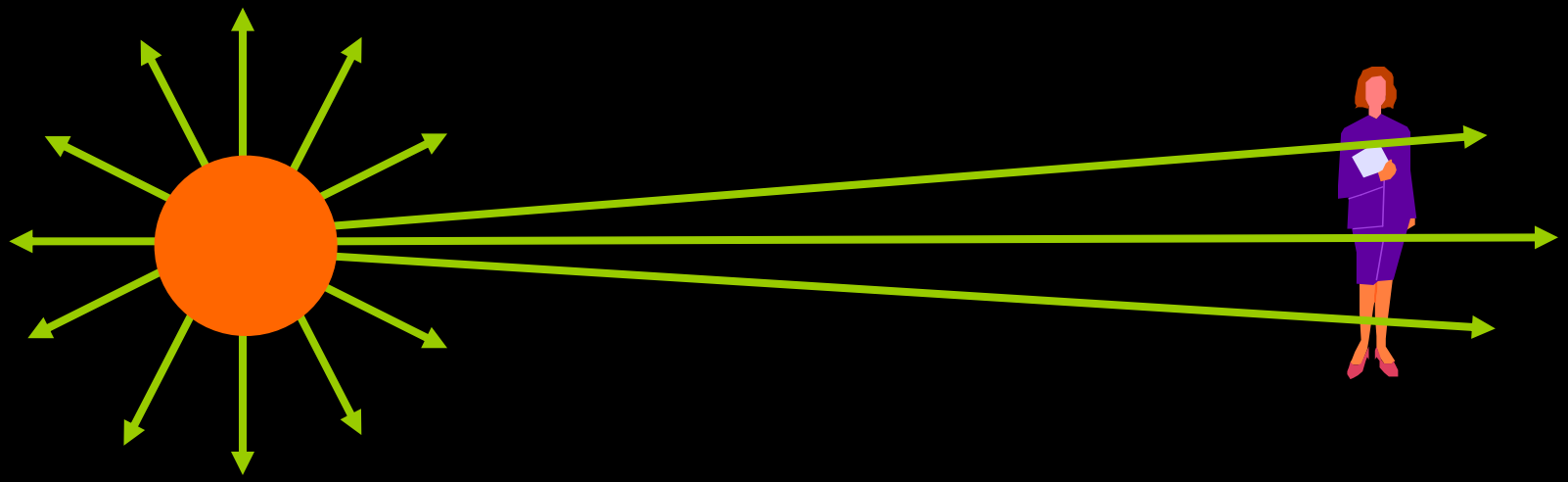
- Will charged leptons change from one kind to another?





Neutrinos are under our skin

~100 trillion neutrinos zip through each person every second.



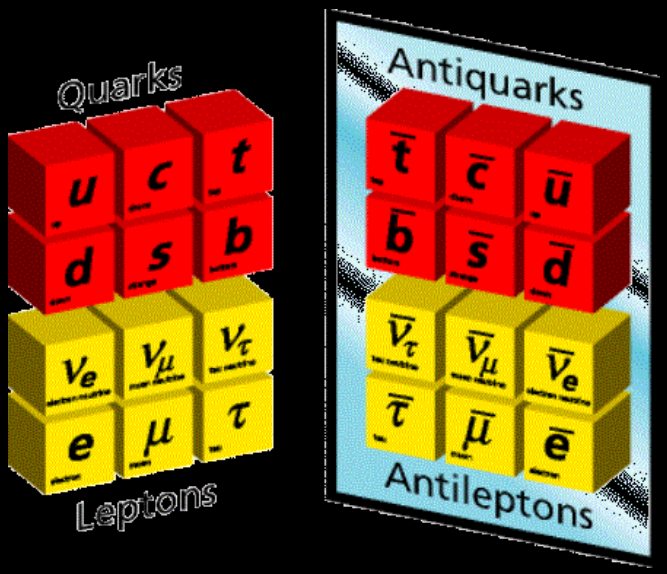
One billion neutrinos for each proton or electron in the universe

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.

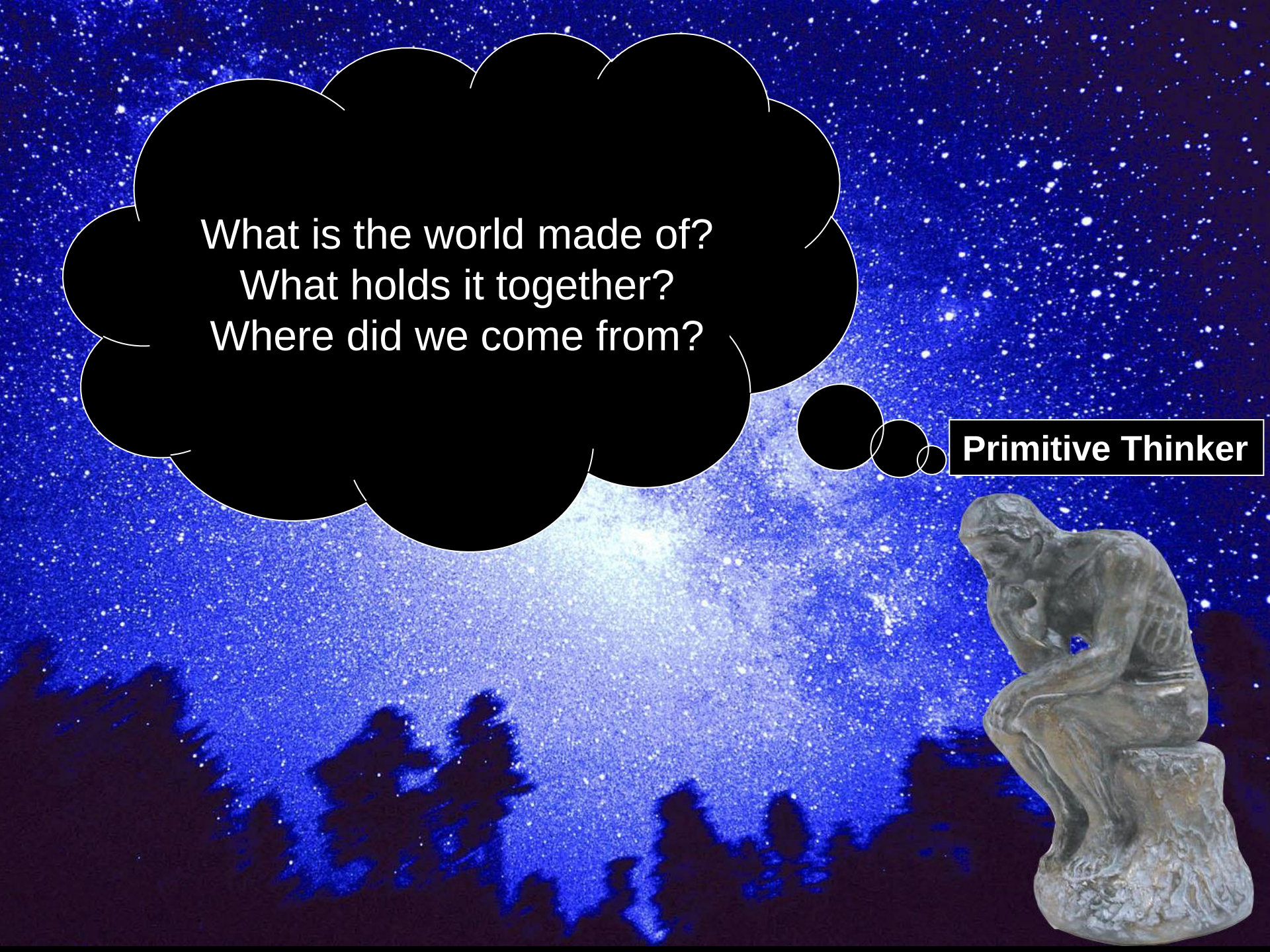
Galaxies are spinning too fast to be held together by gravity of the stars

……. and the mysteries

- Not only is the universe expanding, it is accelerating.

- What is dark energy?

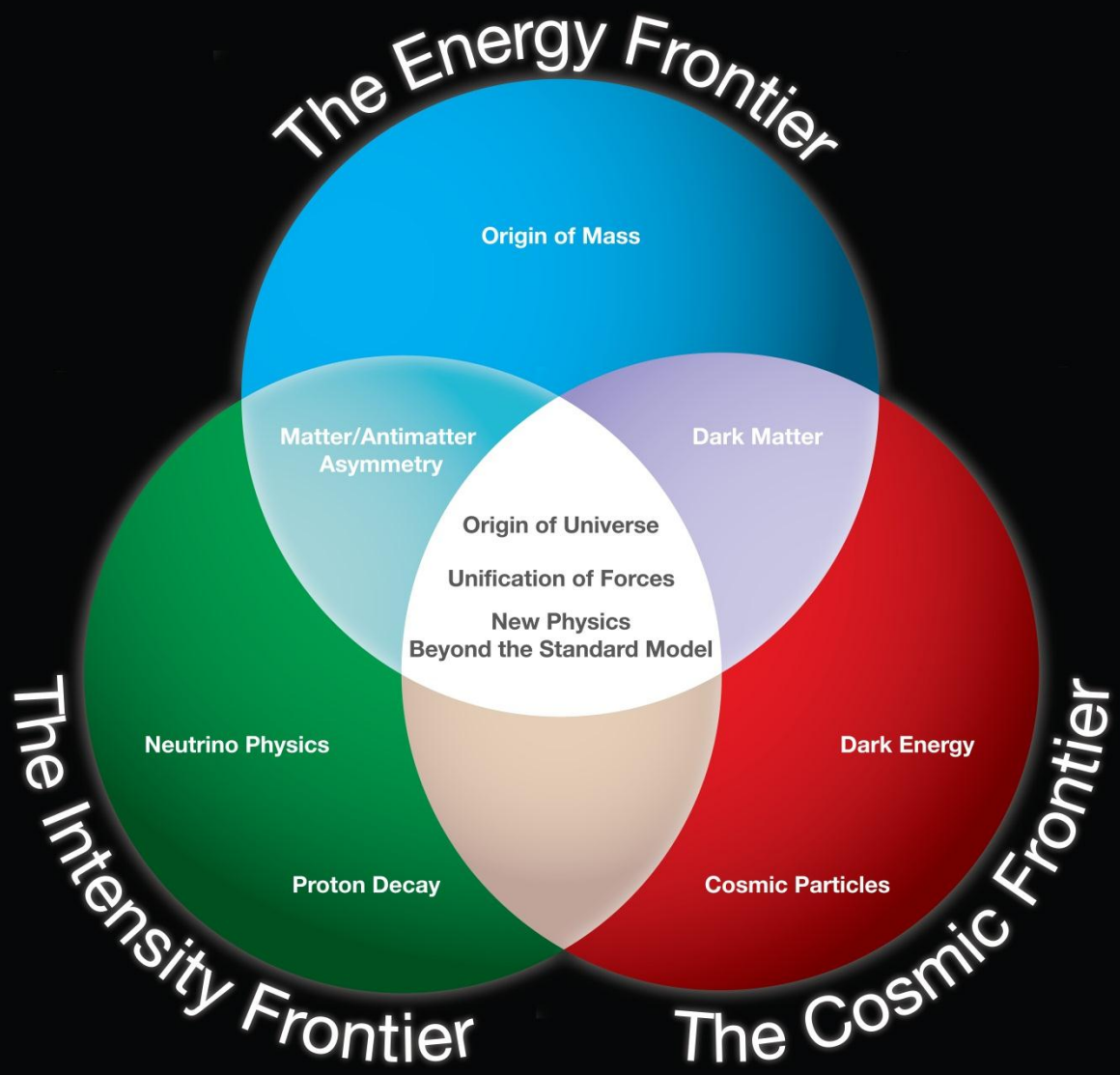
  Not a clue!


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

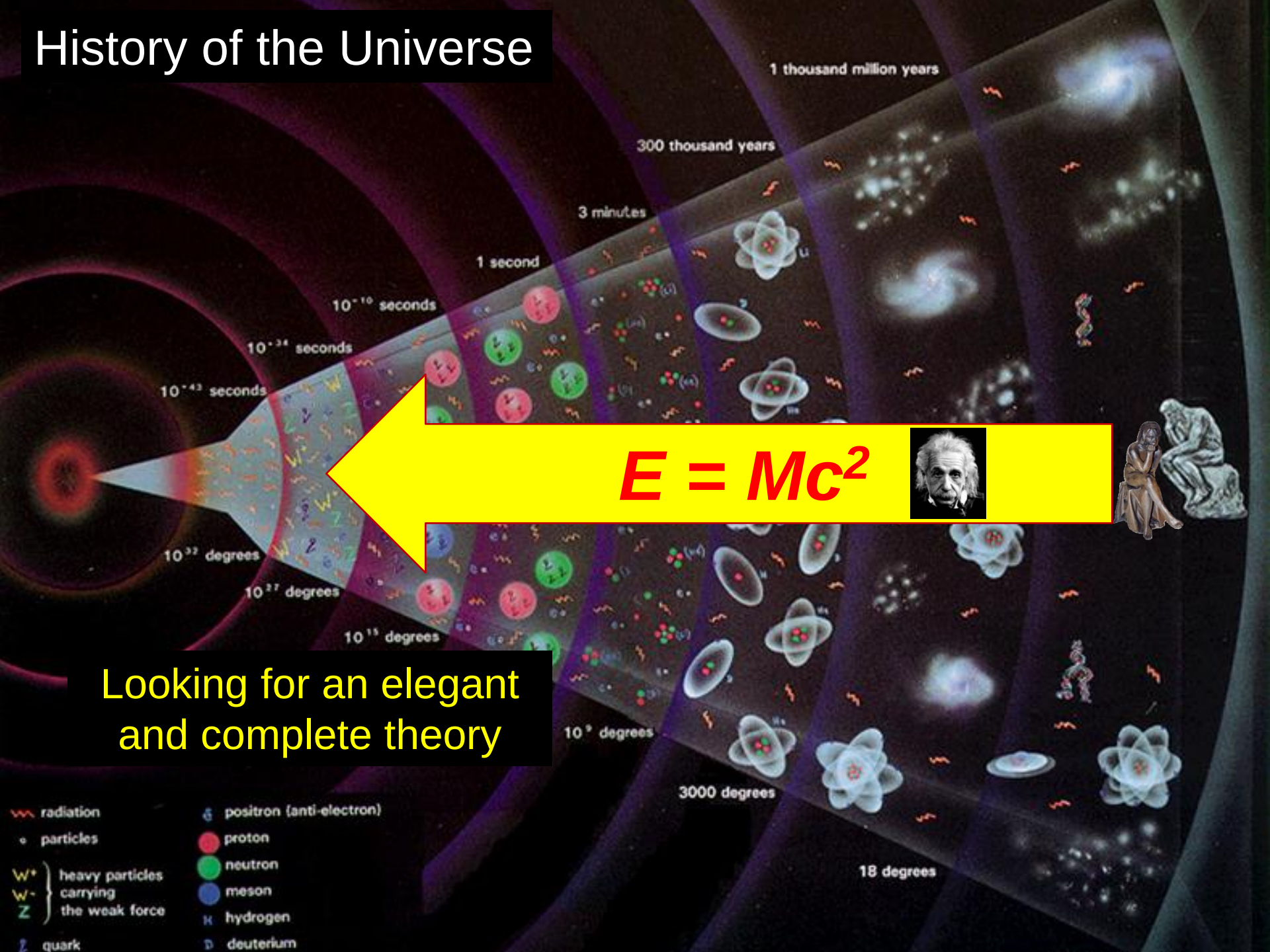
21st Century Questions in Particle Physics

- 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?
- ……

Tools for the Future

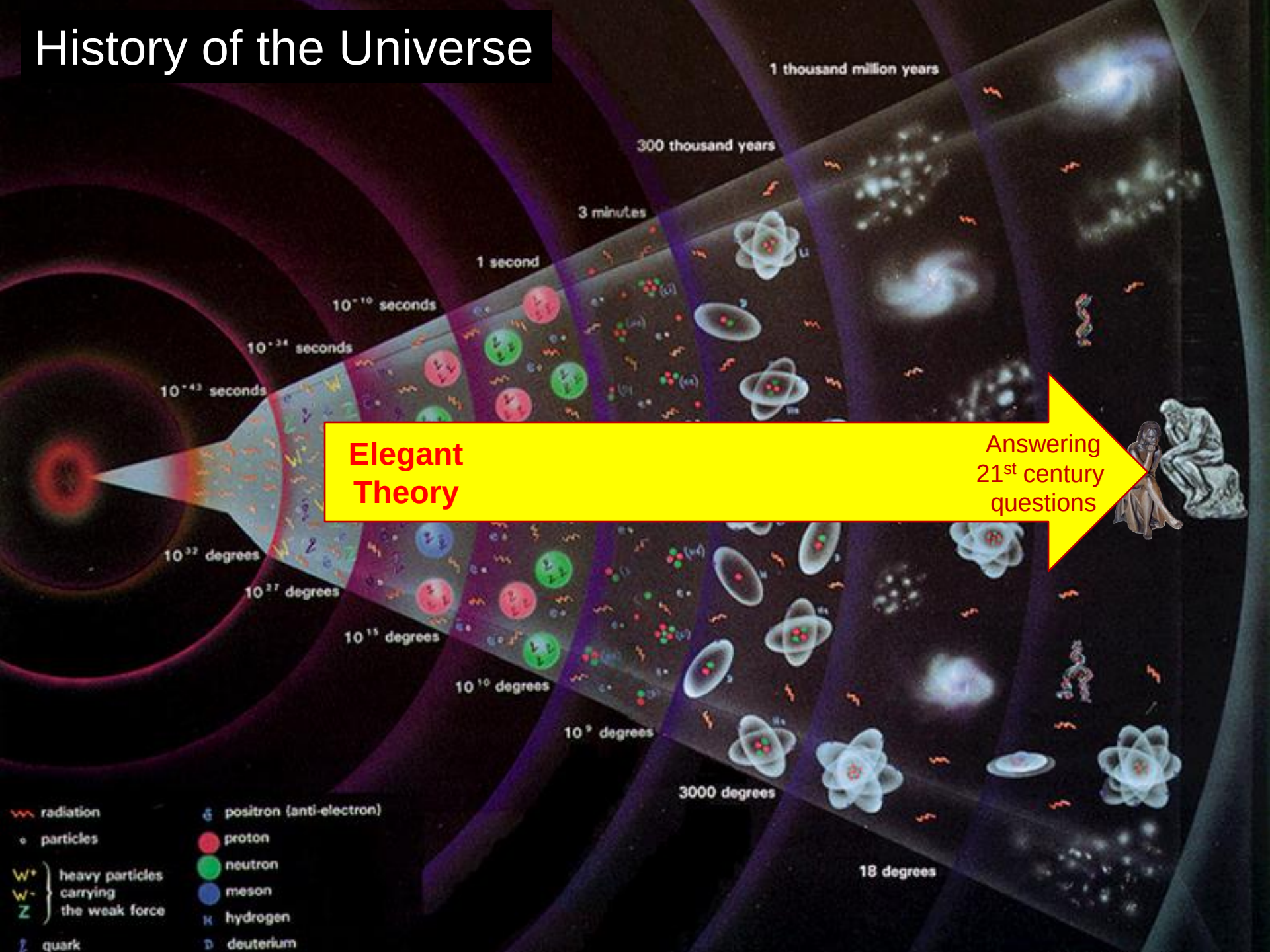


History of the Universe



Looking for an elegant and complete theory

History of the Universe



Current Experimental Programs at Fermilab
(Collaborative Efforts)

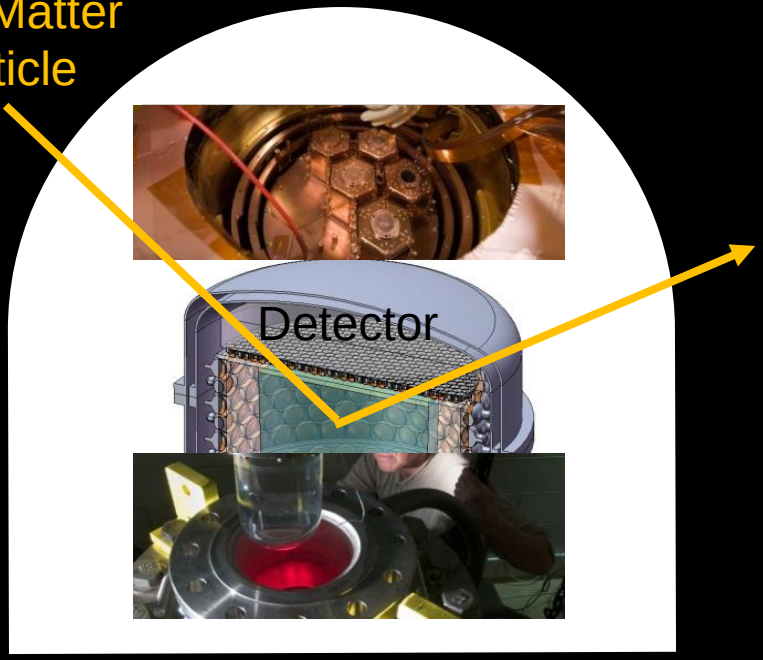
Energy Frontier: 27 countries

Intensity Frontier: 17 countries

Cosmic Frontier: 24 countries

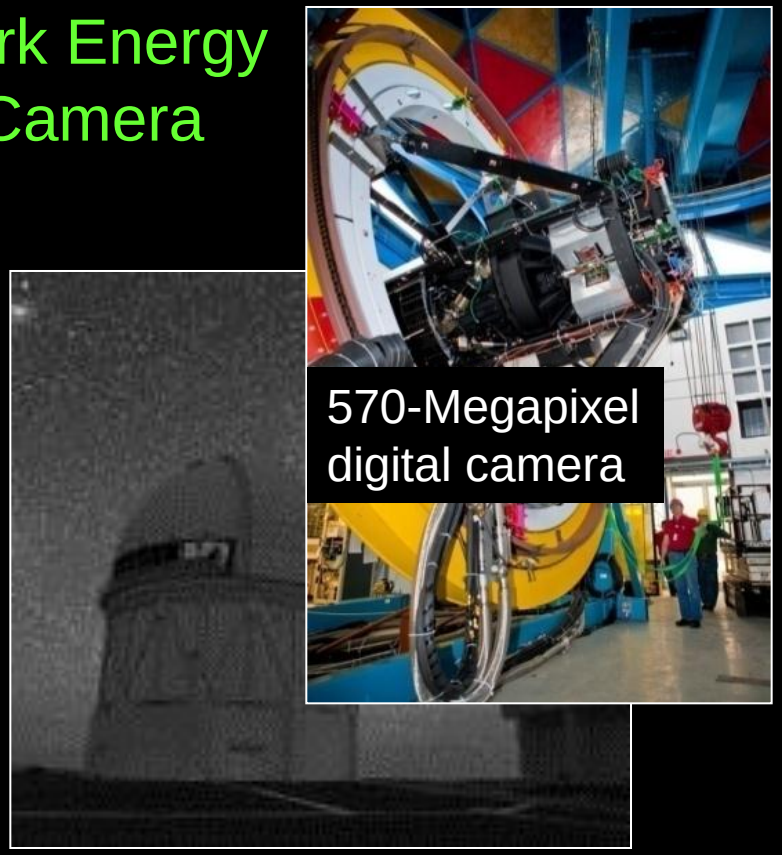
Cosmic Frontier

Dark Matter Detector



Detectors in underground facilities

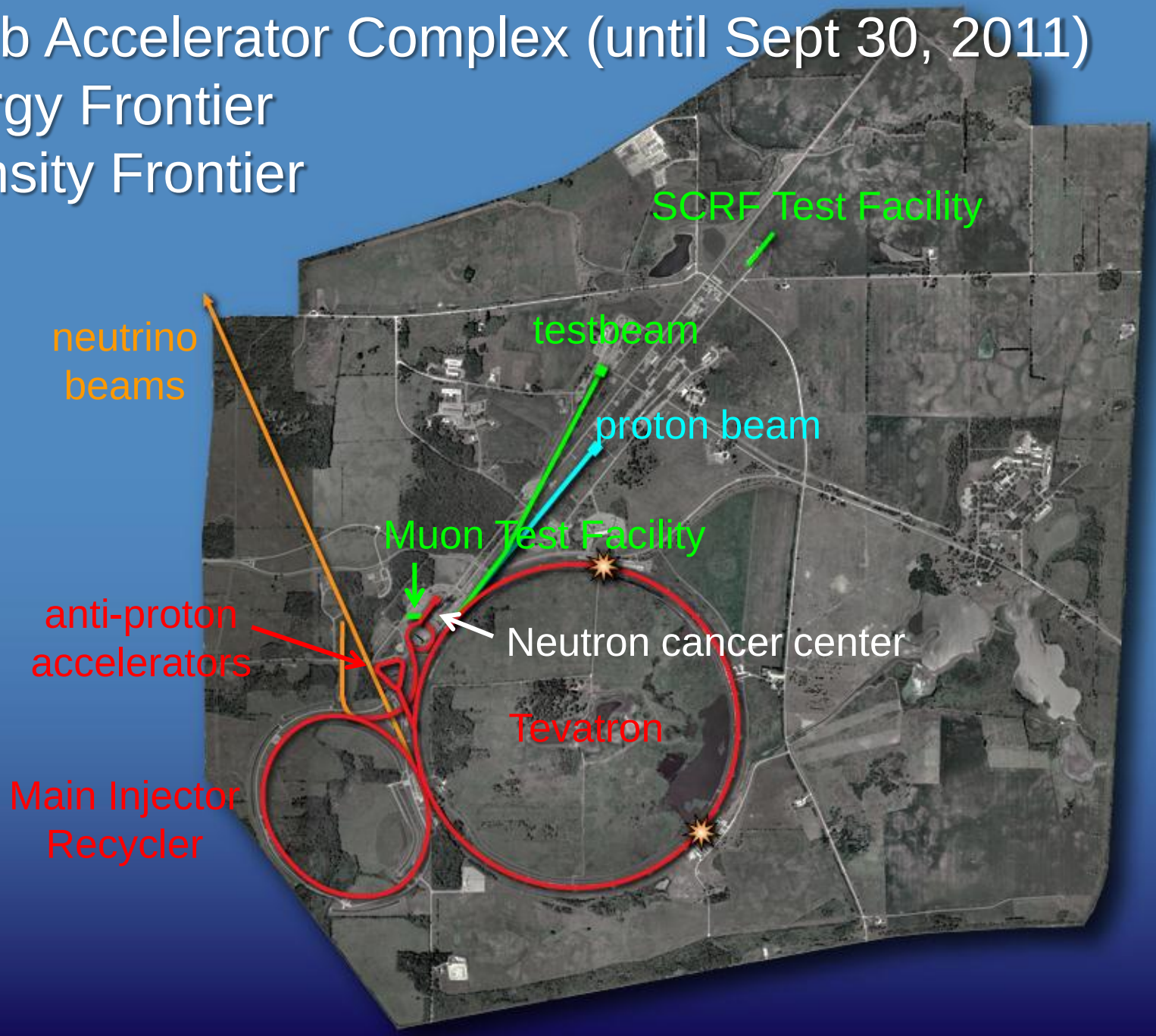
Dark Energy Camera



Exploring Highest Cosmic Ray Particles
Exploring Quantum Space-time

Fermilab Accelerator Complex (until Sept 30, 2011)

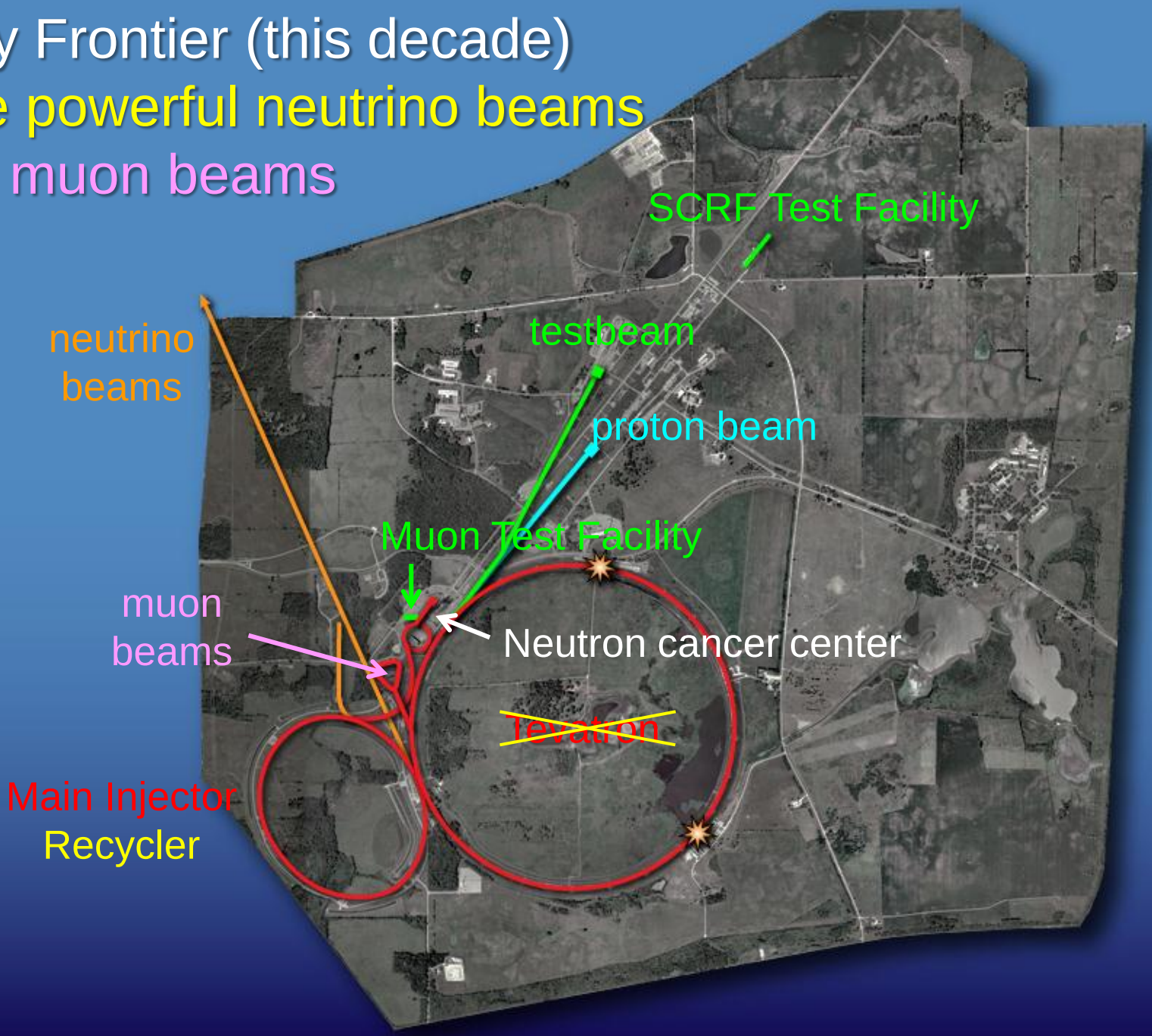
- Energy Frontier
- Intensity Frontier



Energy Frontier: Fermilab and LHC

Intensity Frontier (this decade)

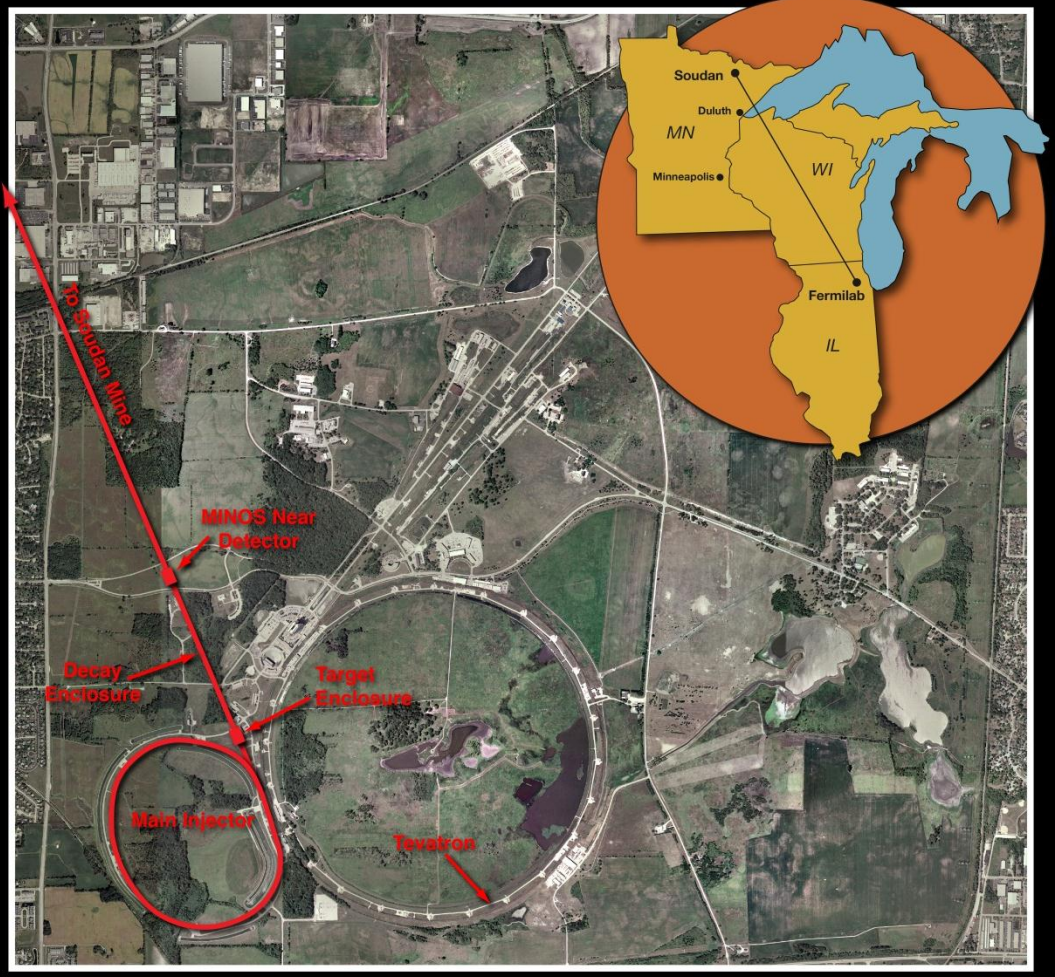
- More powerful neutrino beams
- New muon beams

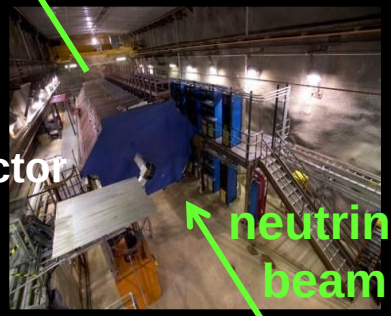


Intensity Frontier probes

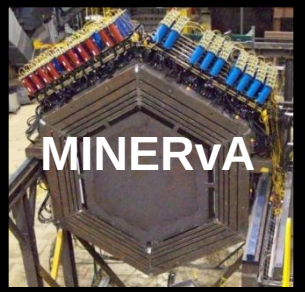
- Origin of mass?
- Why so many kinds of particles?
- Do all forces become one?
- What do neutrinos tell us?
- What happened to antimatter?
- What is dark matter?
- Mystery of dark energy?
- ……

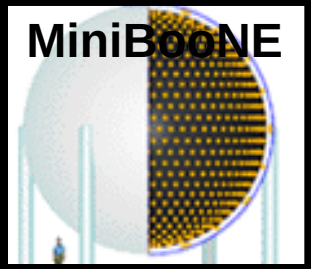
Intensity Frontier: Neutrino Experiments (now)





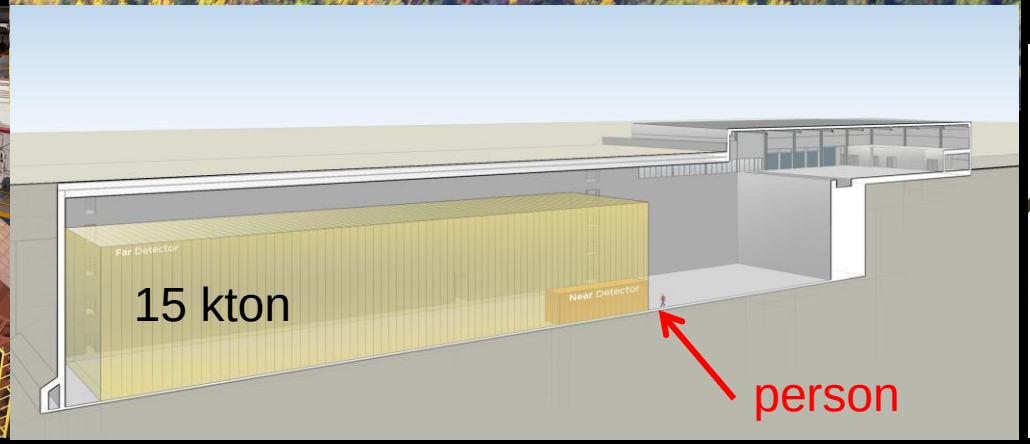
MINOS detector at Fermilab



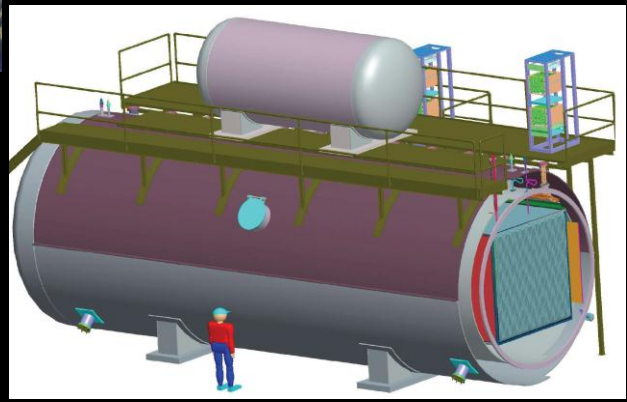


Intensity Frontier (this decade)
new generation neutrino detectors

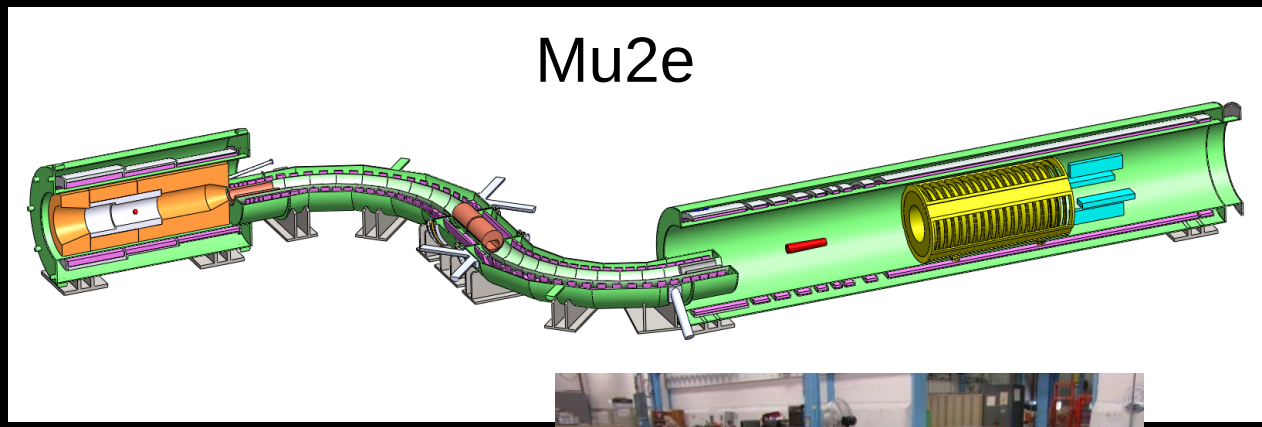
NOvA under construction
Minnesota site & Fermilab site

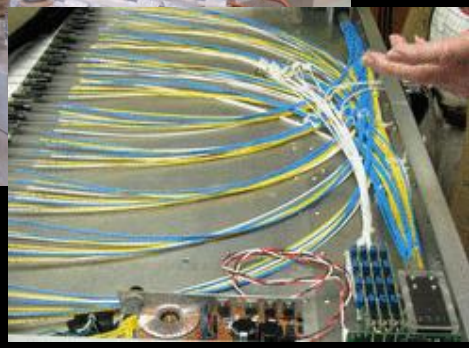


MicroBooNE
under construction
Fermilab site



Intensity Frontier (this decade)
new muon experiments at Fermilab



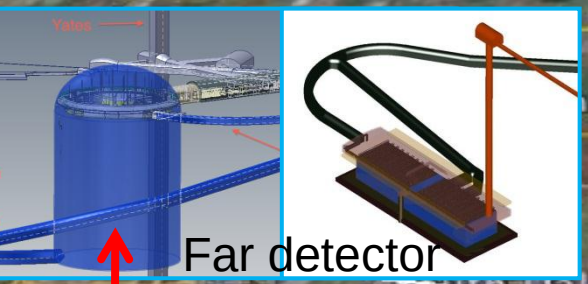


Intensity Frontier:
Developing programs for 2020s and beyond

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!

Ontario

Minnesota

Lead, SD

South Dakota

Wisconsin

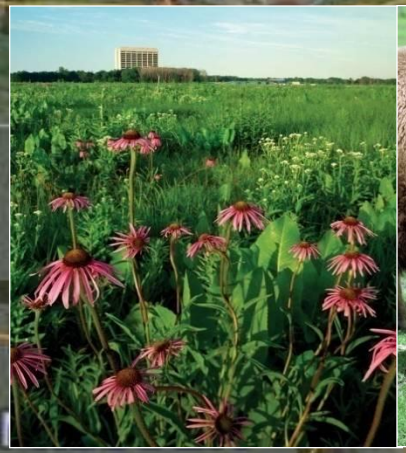
Michigan

Soul Mate

Milwaukee

Iowa

Nebraska



Kansas

Image NASA
© 2008 Tele Atlas
Image © 2008 TerraMetrics
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Google

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

Eye alt 1108.62 km

Project X

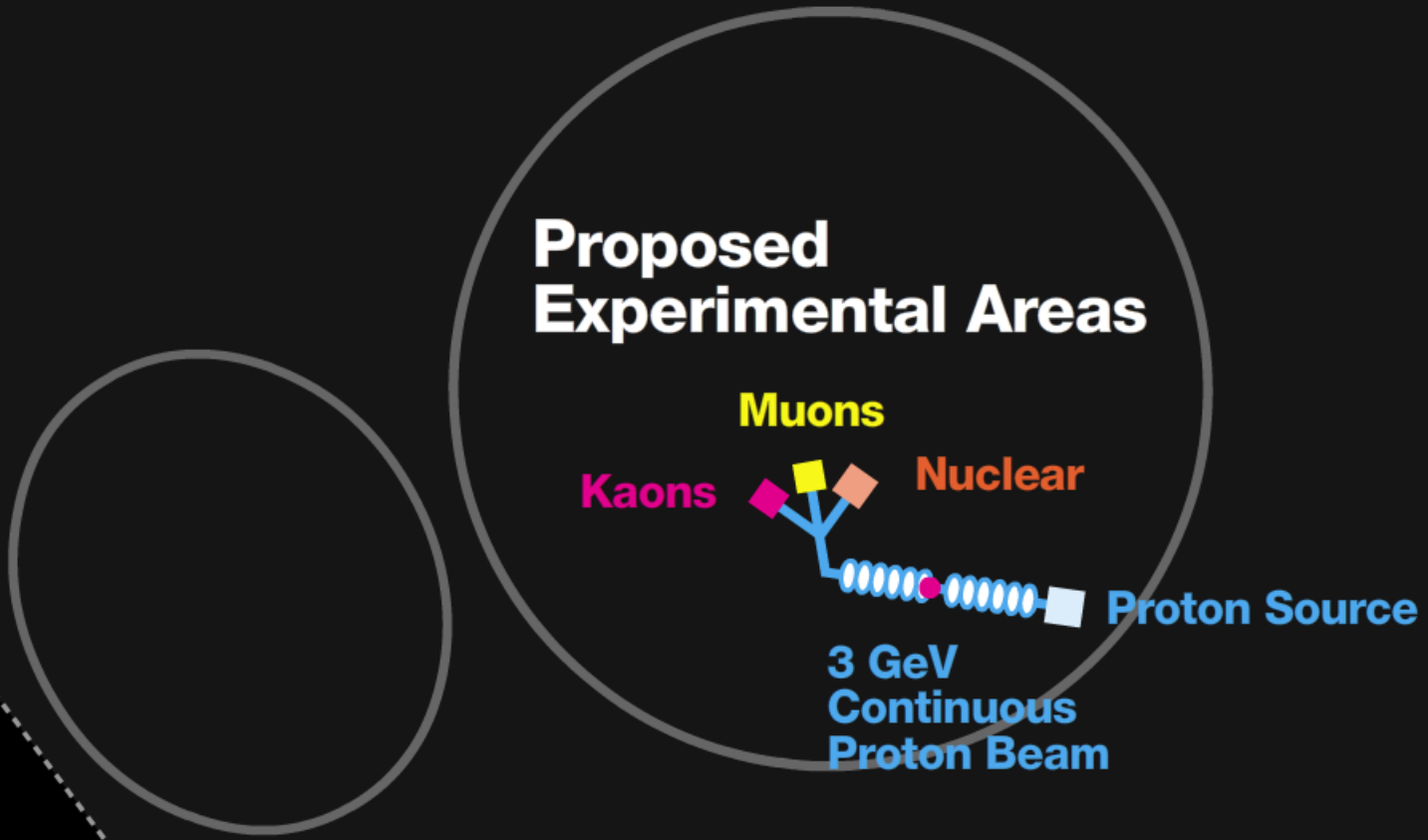
will be the world's most powerful proton source

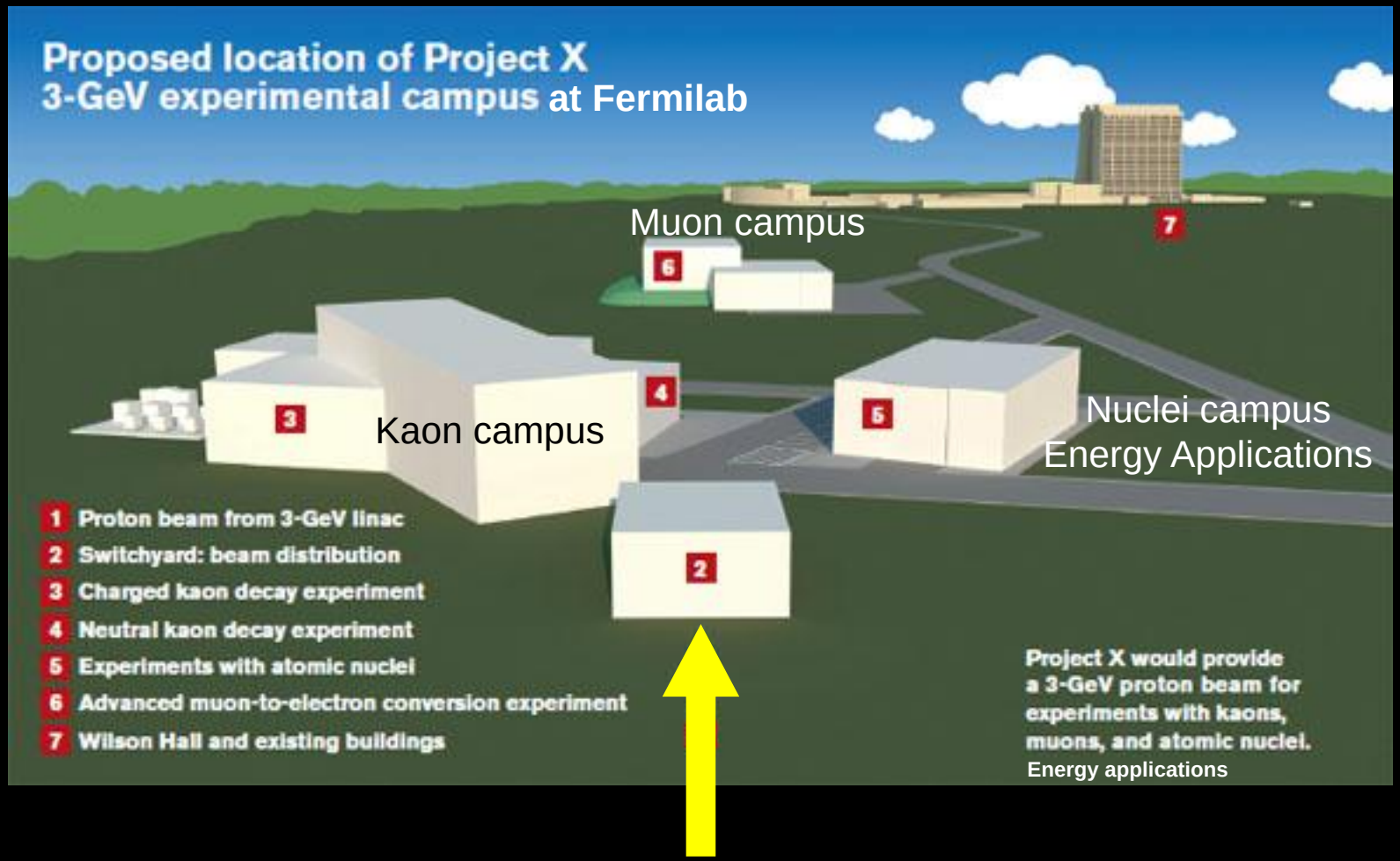
will make the world's most powerful beams of neutrinos, muons, kaons and nuclei to explore new physics in unprecedented breadth and depth

will establish a versatile technical foundation for future accelerators

Project X: Low-energy Program

Highest-intensity proton accelerator in the world

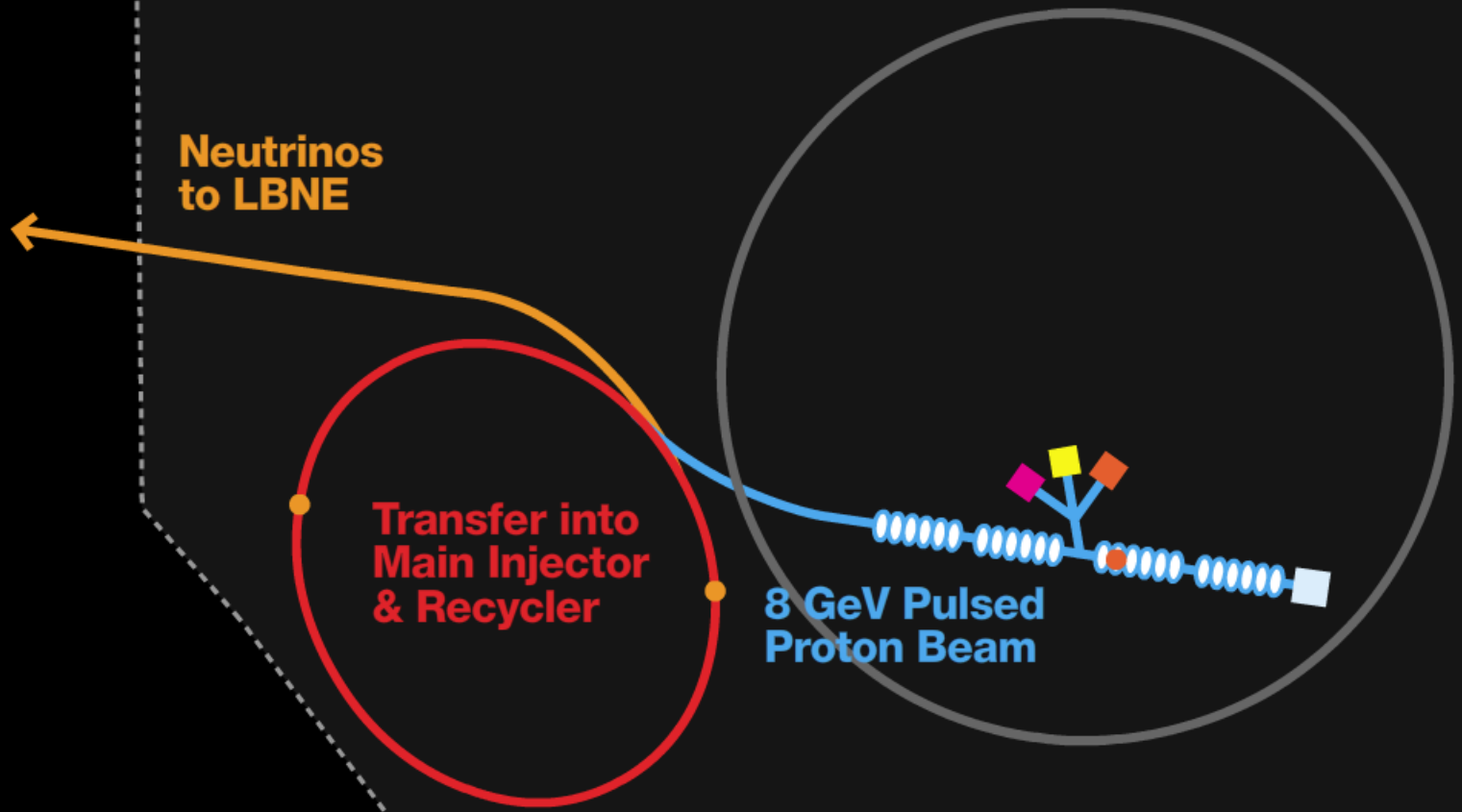




3 GeV, 3 MW Proton beam

Project X: High-energy Program

More beam for high-intensity neutrino experiments



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.