My Challenges in Particle Physics

Conference for Undergraduate Women in Physics at Yale
January 16, 2010

Young-Kee Kim
Fermilab and the University of Chicago
ykkim@fnal.gov

Spokesperson of CDF Experiment
(June 2004 – June 2006)

Deputy Director of Fermilab
(July 2006 – Present)

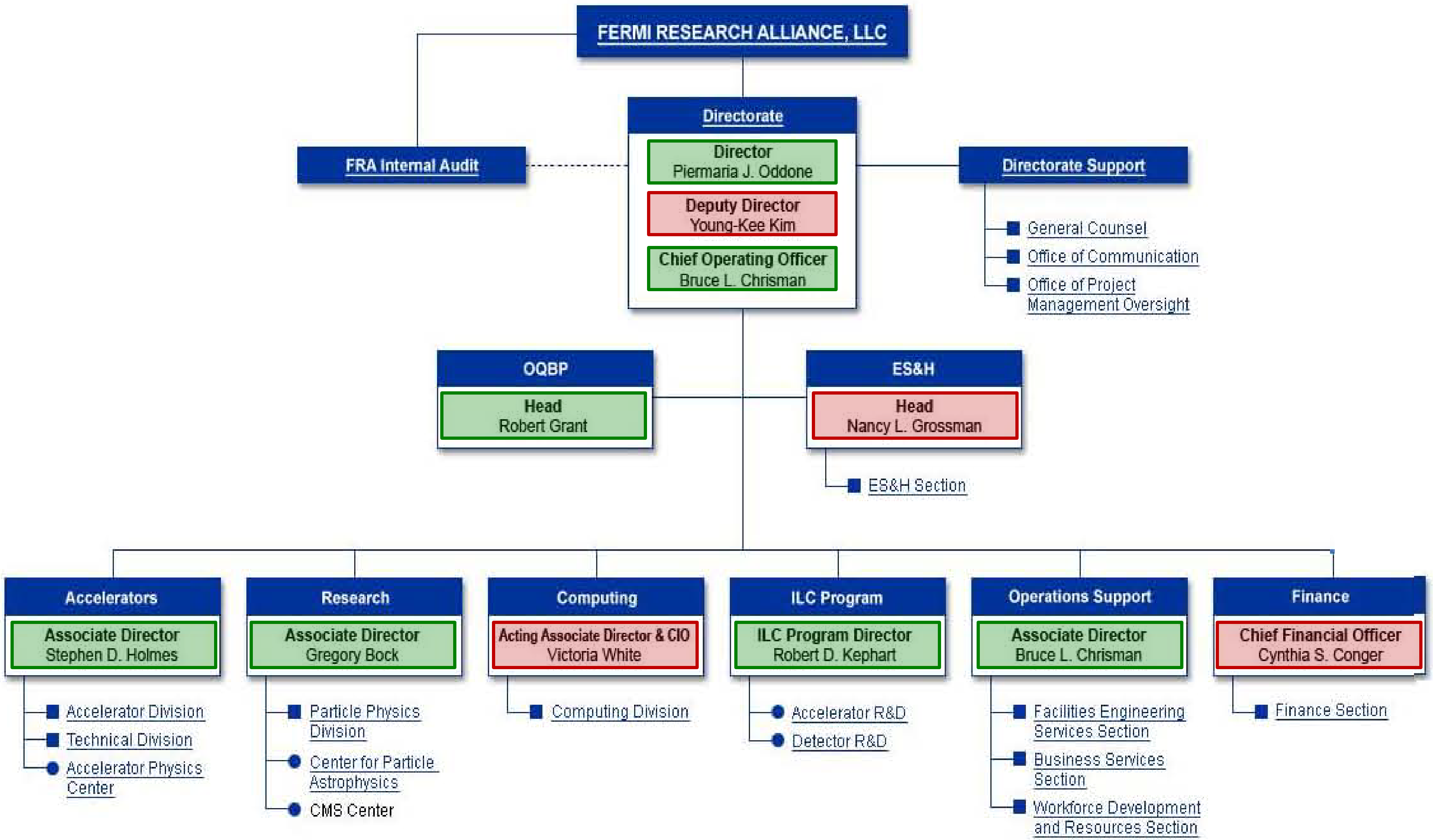
Fermilab

- ~2,000 employees
- ~2,300 researchers
  from around the world
- 6800 acres, park-like site
- like a small village

- High energy collider (Tevatron)
- High intensity ν beams
- Particle Astrophysics programs
- Particle / Particle Astro Theory
- Computation

Fermilab

Fermilab Organization



my father's calligraphy

Respect

the Universe
(Laws of Nature),

Love

People


International Conference on Women in Physics (Oct 2008, Korea)
Conf. for Undergraduate Women in Physics at Yale
Networking
Networking
APS Committee on WIP
http://www.aps.org/
Women Physicist Luncheon at Fermilab
Greater Chicago
GREATER CHICAGO
HERC
Higher Education Recruitment Consortium

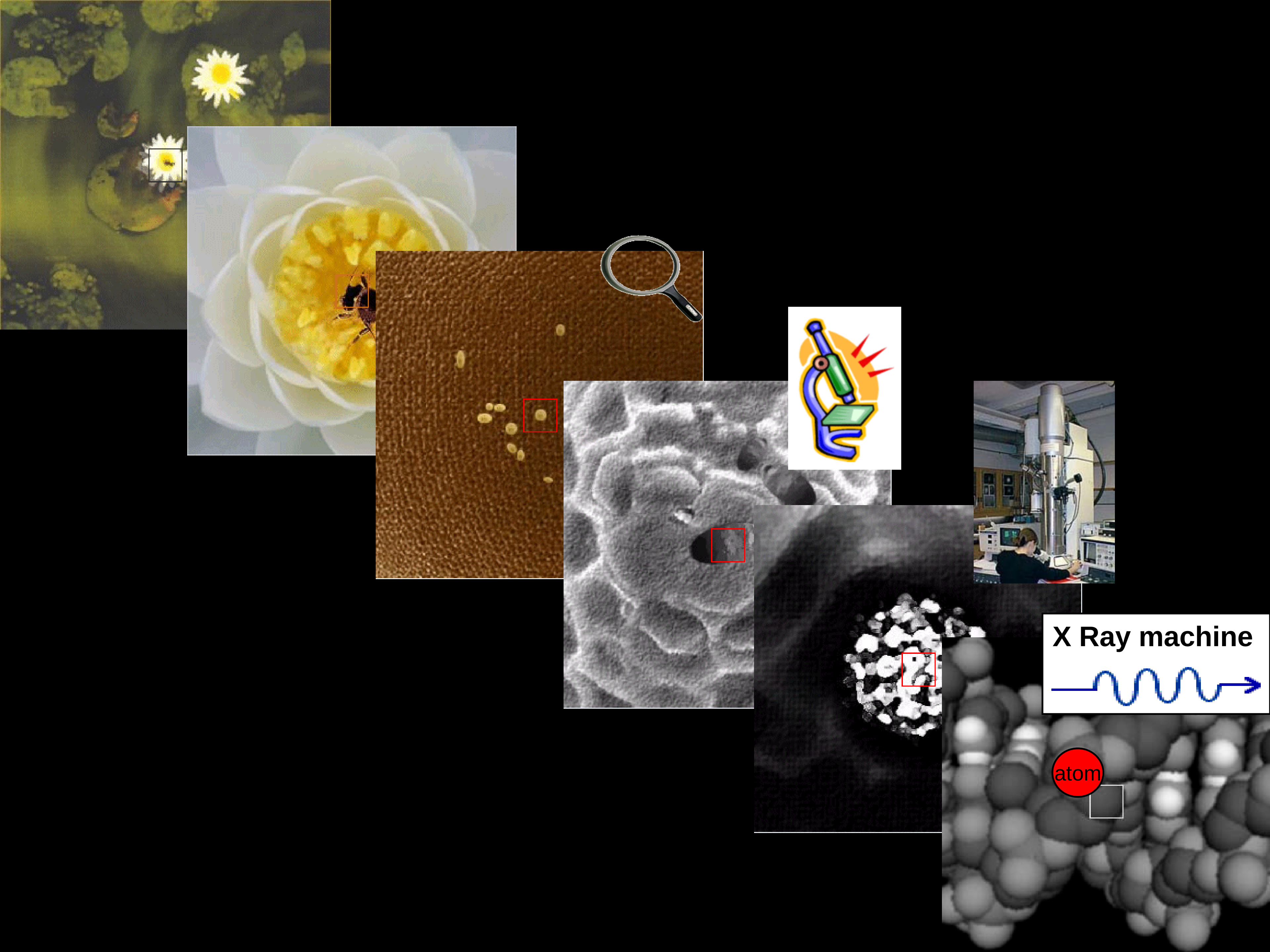
Particle Physics

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

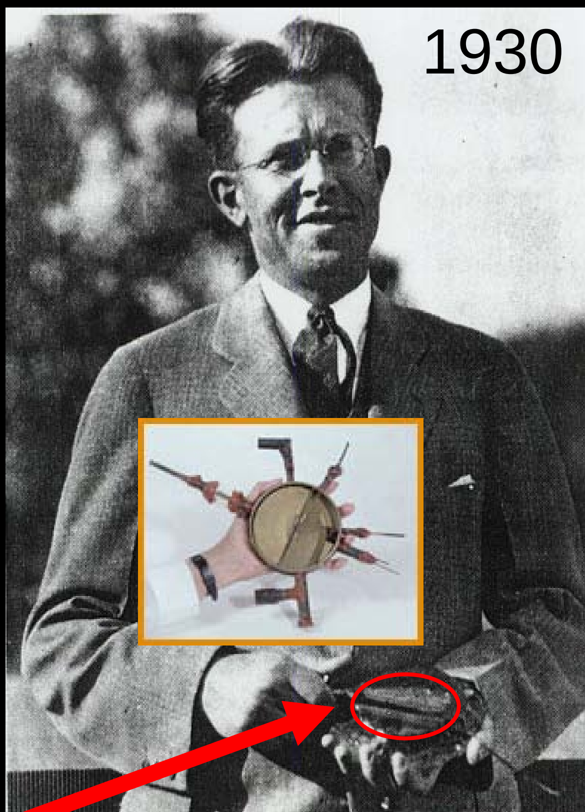
Tools ?

the smallest things in the world
interactions (forces) between them
the Universe's past, present, and future

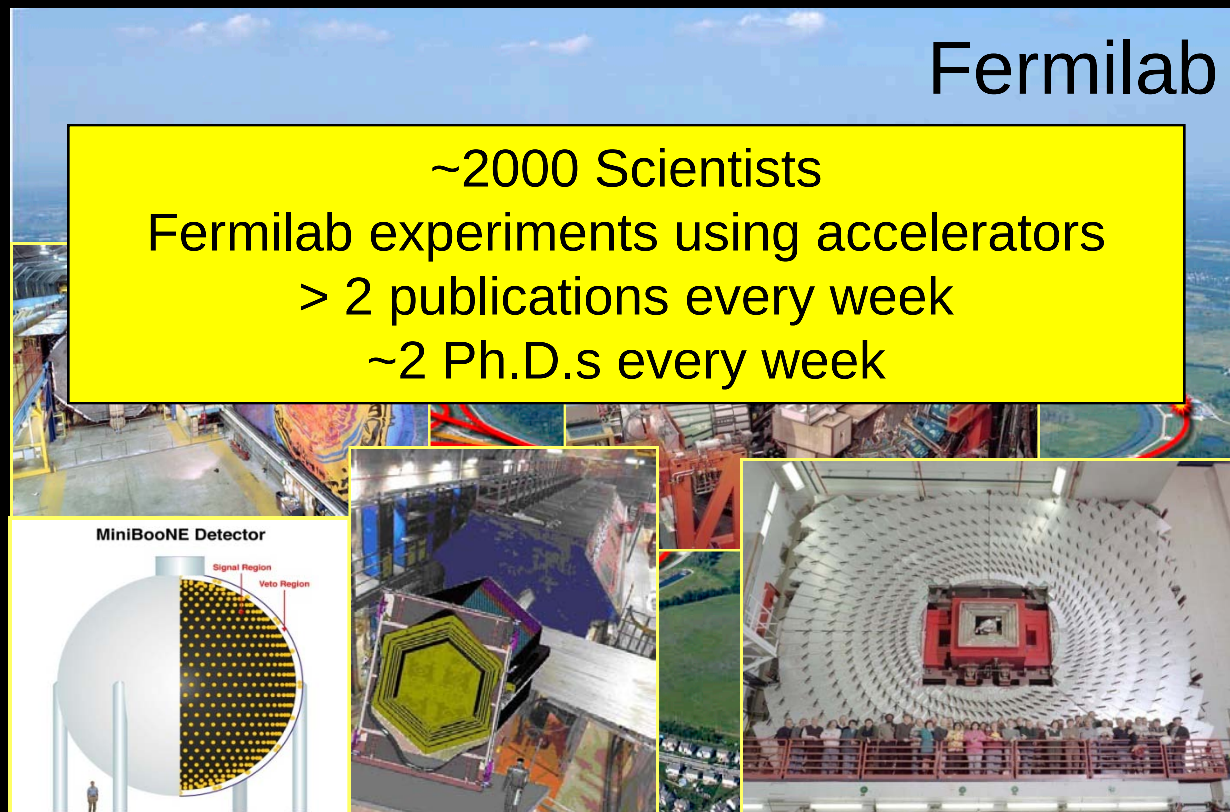
Particle Physics: physics where
small and big things meet,
inner and outer space meet


X Ray machine
atom

Many generations of Accelerators created
with higher and higher energy and intensity beams



Ernest Lawrence
(1901 - 1958)

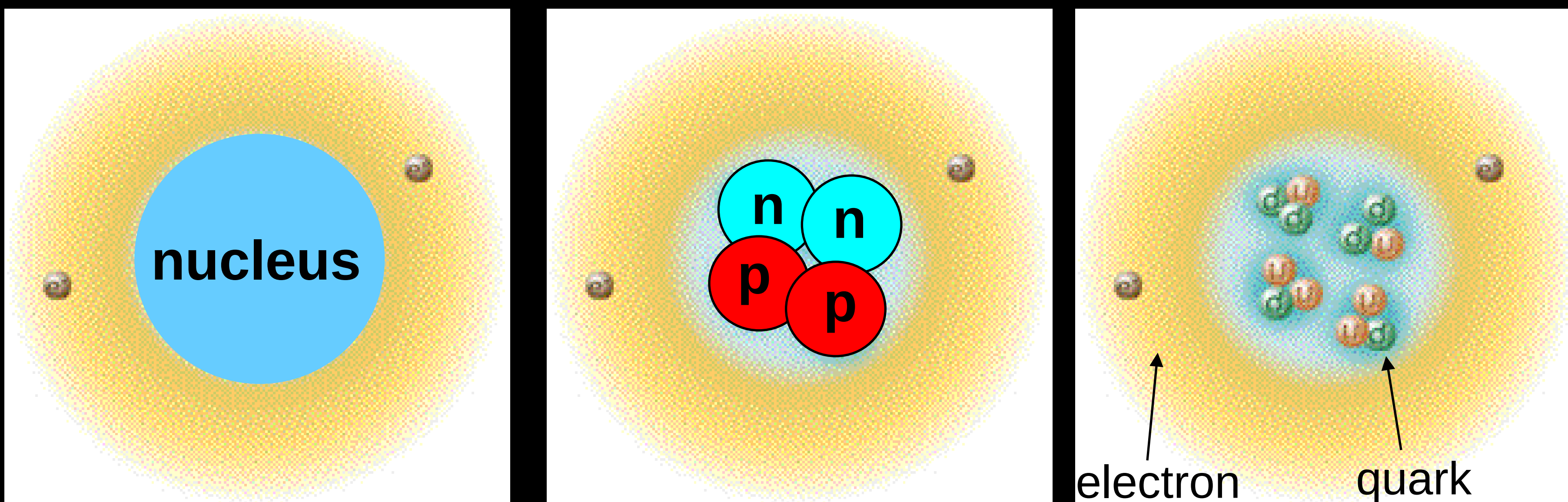


$\times 10^4$ bigger
$\times 10^6$ higher energy, higher intensity beam

Accelerators are Powerful Microscopes.

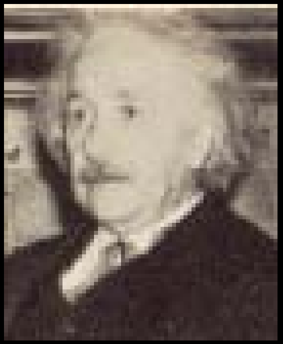
higher energy beam particle = smaller wavelength $\longrightarrow$ $\lambda = \frac{h}{p}$

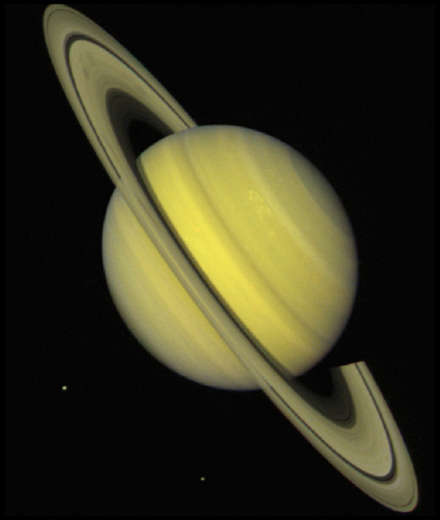
What is the universe made of?



10^{-18} m
0.000000000000000001 m
nana nano meter

Everything is made of electrons, up quarks and down quarks.



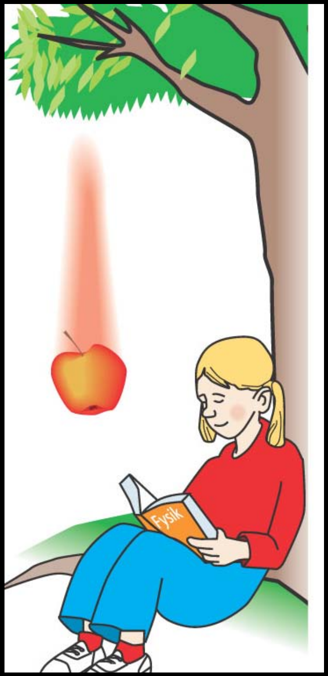


What holds the world together?

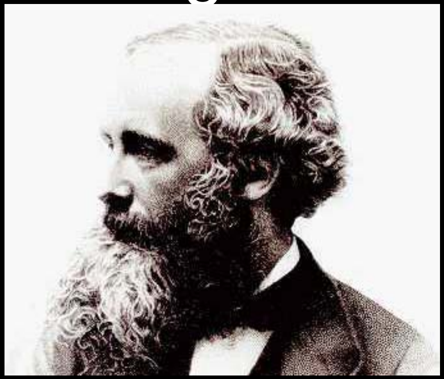
Beginnings of Unification

Gravitational Force

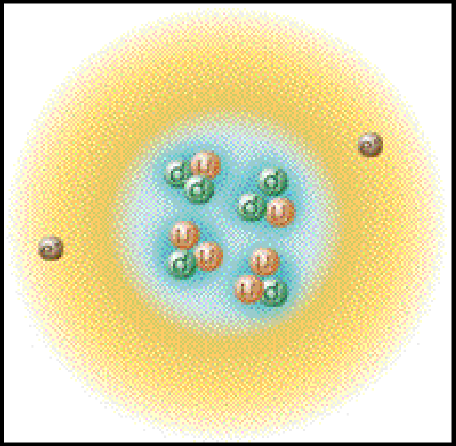
Issac Newton
(1642 - 1727)



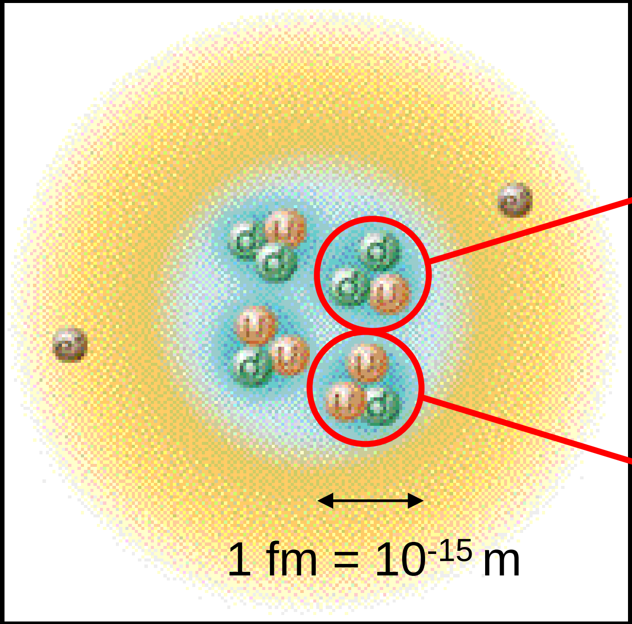
Electromagnetic Force



James Clerk Maxwell
(1831 - 1879)

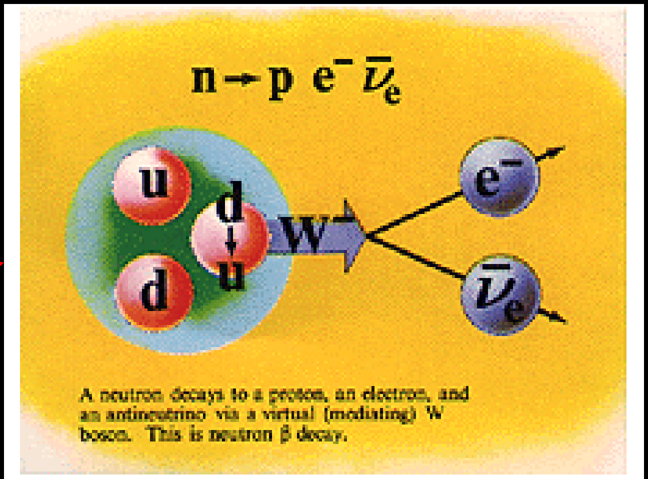


Enrico Fermi
(1901 - 1954)



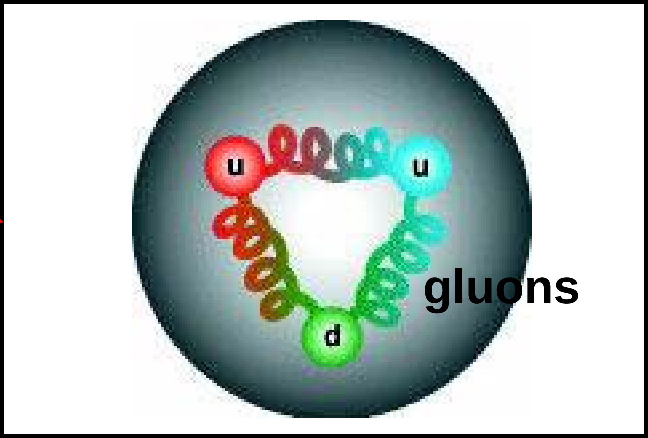
Weak Force

radioactive decays



Strong Force

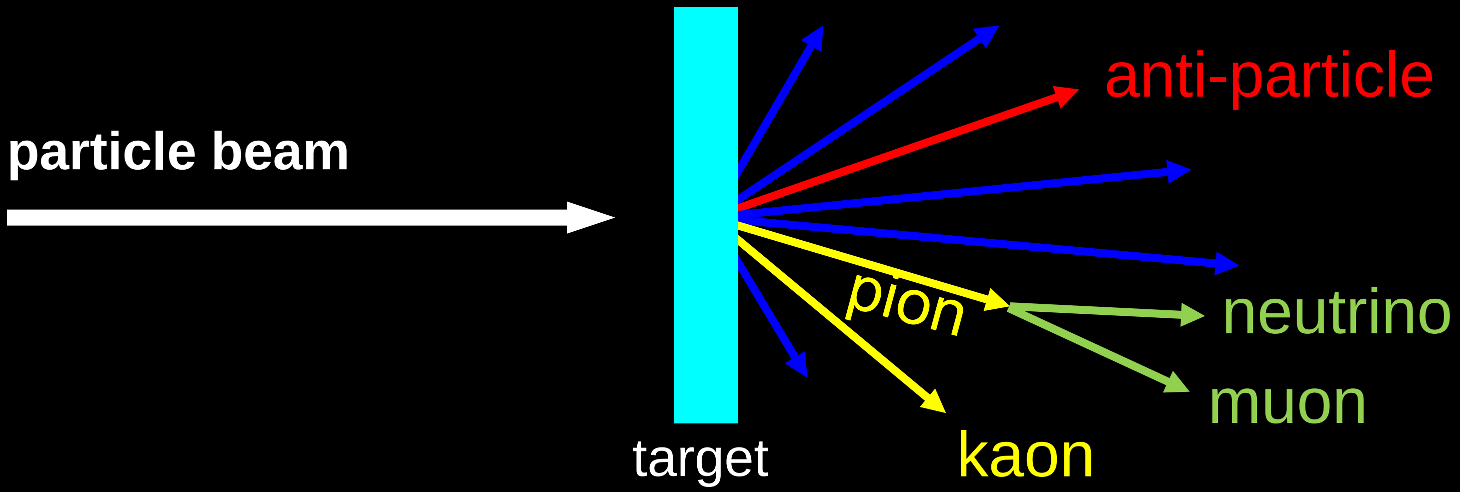
holding proton, nucleus

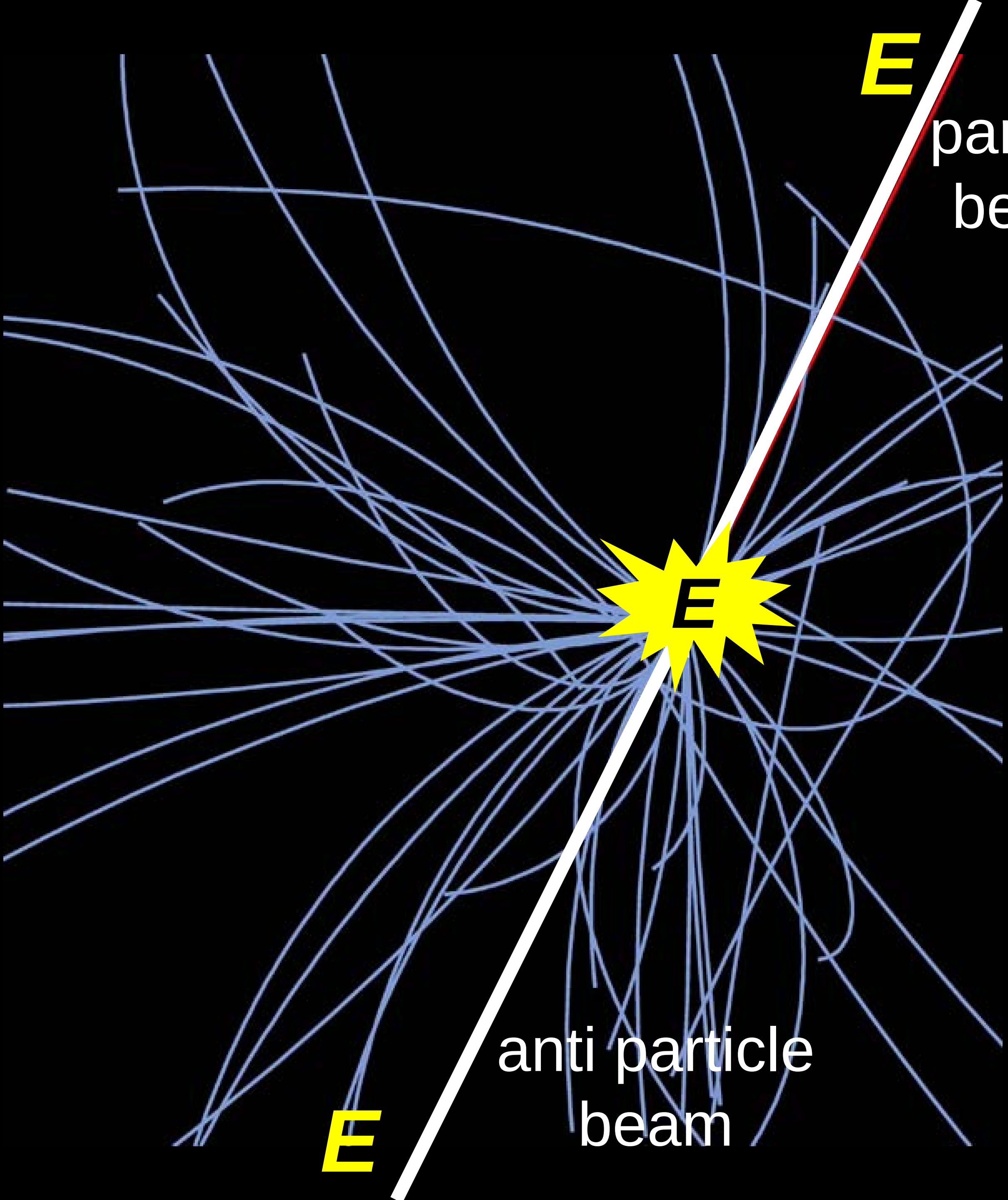


Accelerators as tools to study weak and strong forces

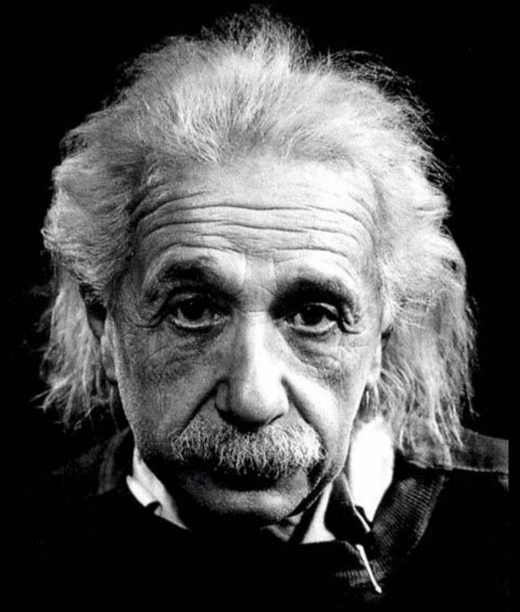
Accelerators are like Time Machines

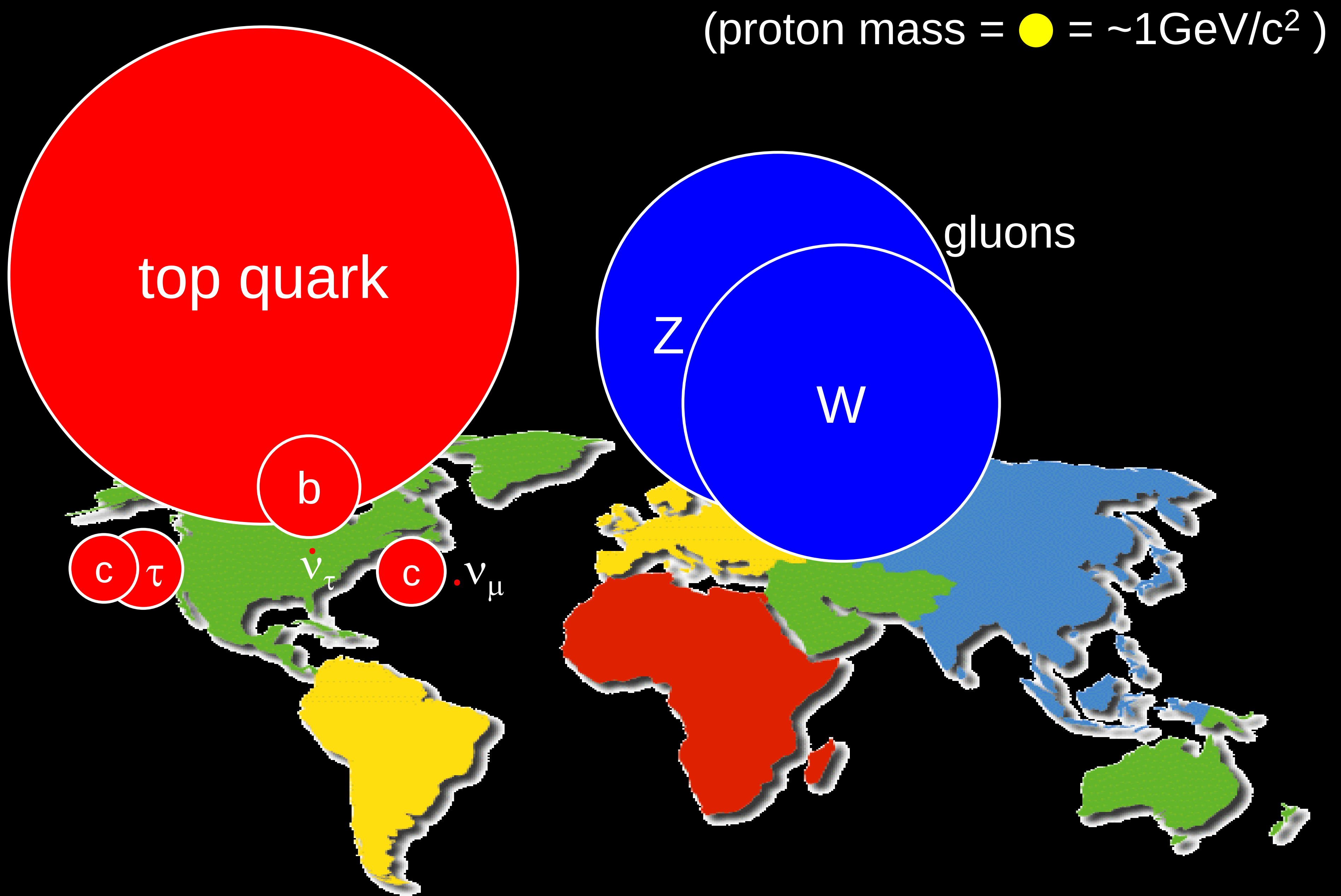
because they make particles last seen
in the earliest moments of the universe.





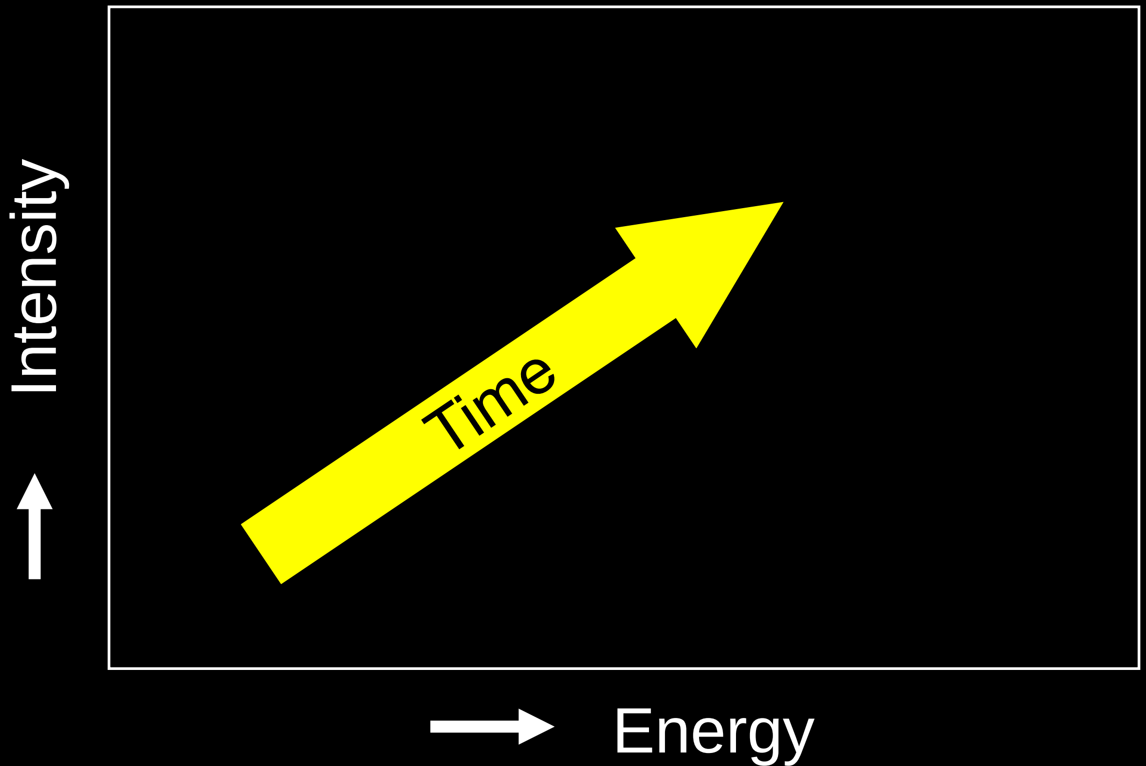
$E = mc^2$





(proton mass = = ~1GeV/c^2)
top quark
gluons
Z
W
b
c
τ
ν_τ
c
ν_μ

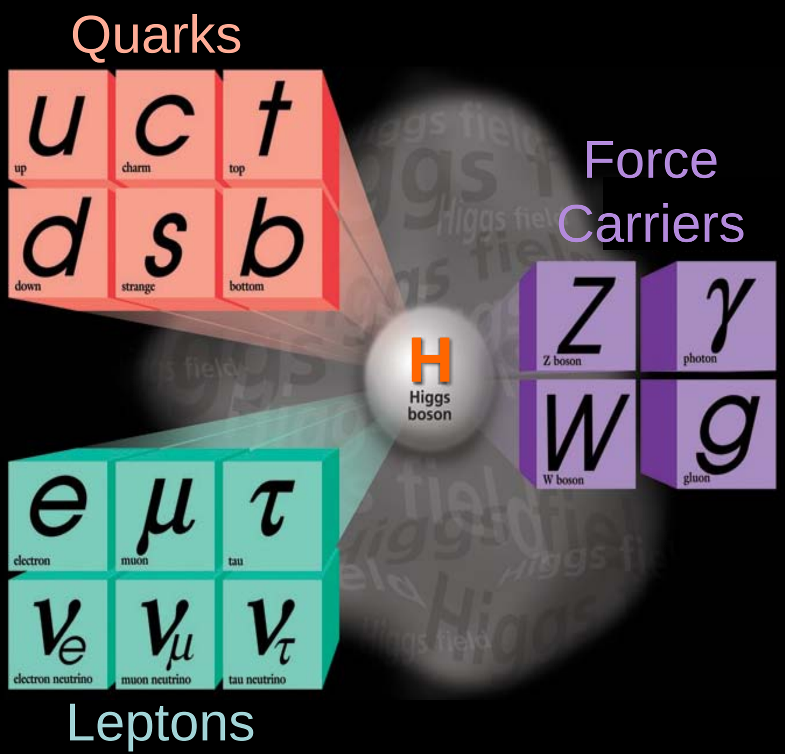
With advances in accelerators, we discovered many surprises.



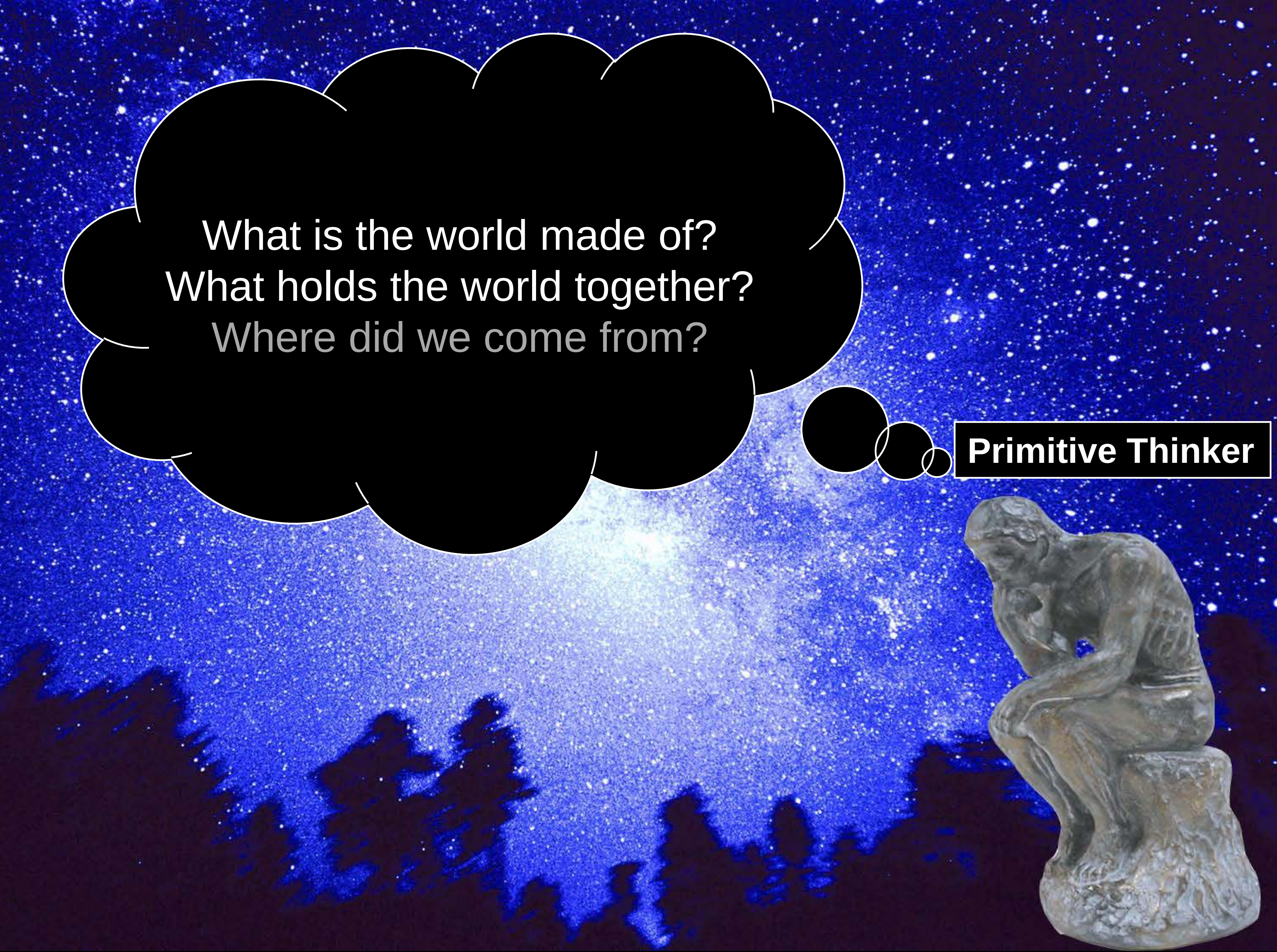
The field of Particle Physics has been tremendously successful in creating and establishing "Standard Model of Particle Physics" answering "what the universe is made of" and "how it works"

Standard Model of Particle Physics

- Standard Model is a remarkable intellectual construction
- Every particle experiment ever done at the lab (except Neutrino experiments. Nobel Prize in 2002) fits in the framework
- But huge questions remain unanswered. New physics (e.g. Supersymmetric extension of SM, extra dimensions, …) is required to answer.



Higgs yet to be discovered


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

21st Century Questions in Particle Physics

1. What is the origin of mass for fundamental particles?
2. Why are there so many kinds of particles?
3. Do all the forces become one?
4. Are there extra dimensions of space?
5. What are neutrinos telling us?
6. Are there undiscovered principles of nature:
   new symmetries, new physical laws?

Evolved Thinker

Where did we come from?

Understanding our Universe!

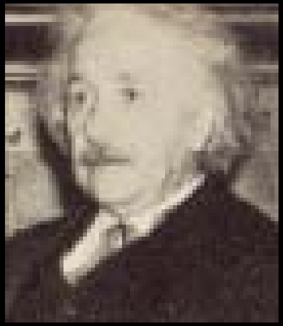
Particle Physics and Cosmology Questions from Astrophysical Observations

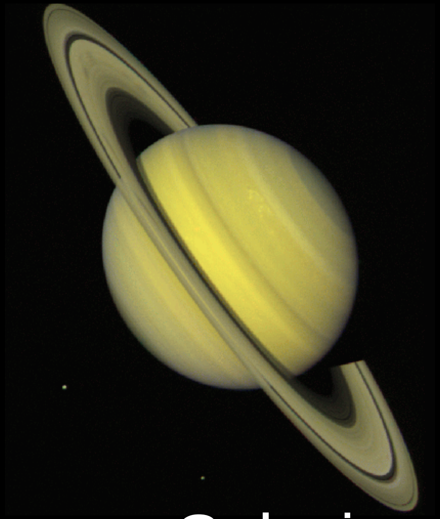
~~Everything~~ is made of electrons, up quarks and down quarks.

Everything that we can see








Galaxies are held together by mass far bigger (x5) than all stars combined.

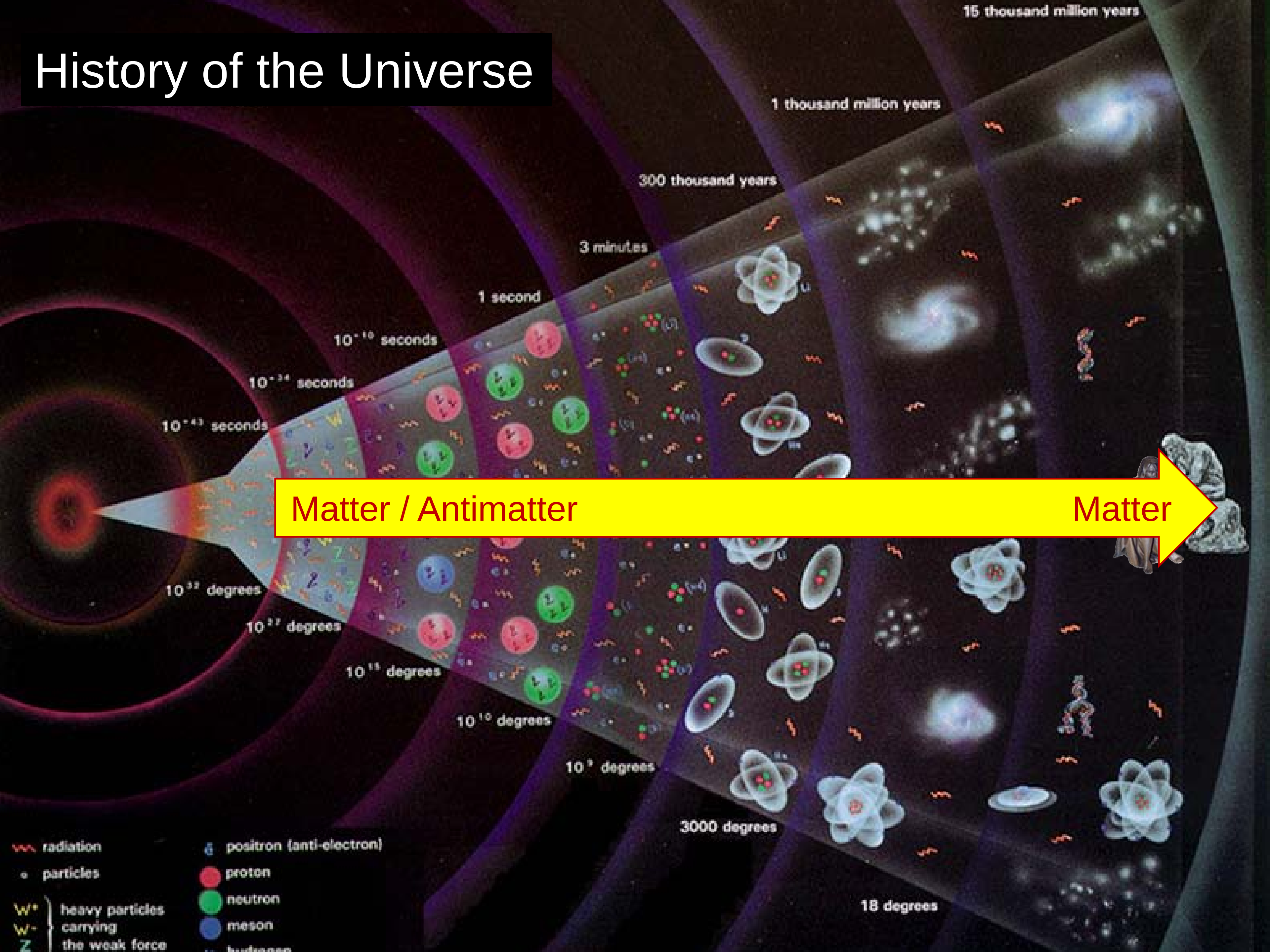
Dark Matter - What is it?

Not only is the Universe expanding, it is

Accelerating!!

Where does energy come from?
Dark Energy

History of the Universe



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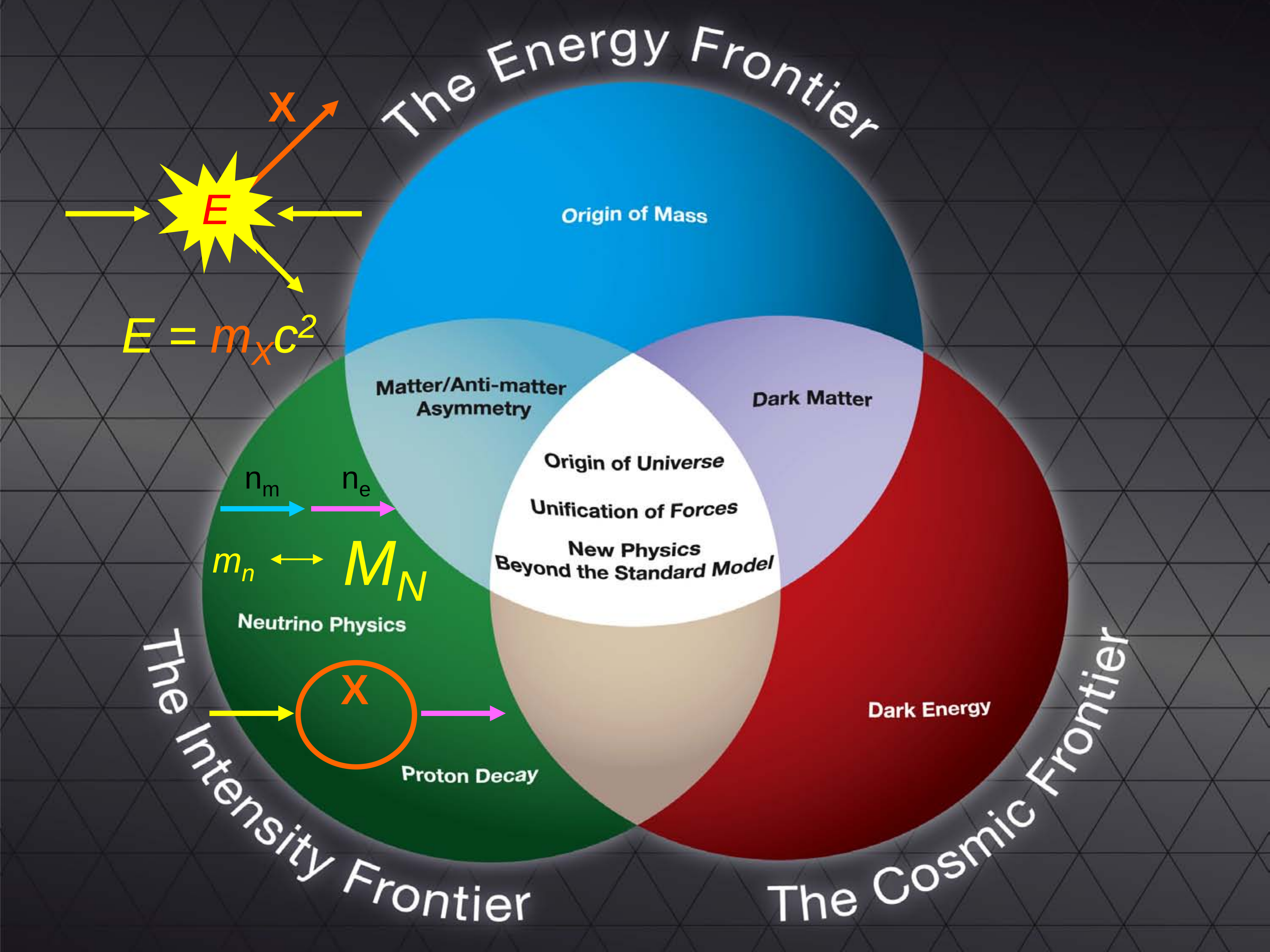
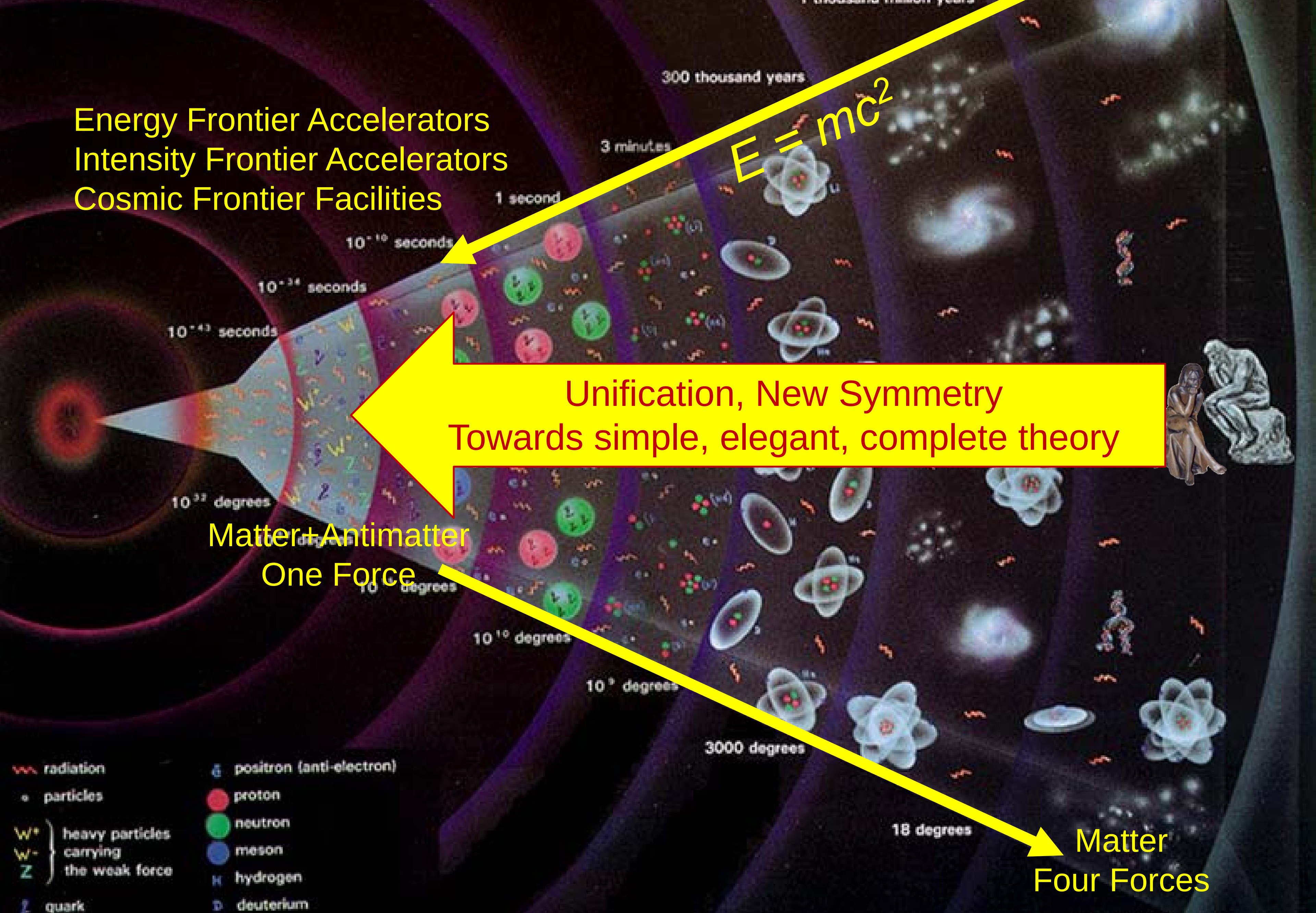
9. How can we solve the mystery of dark energy?
10. How did the universe come to be?

Evolved Thinker

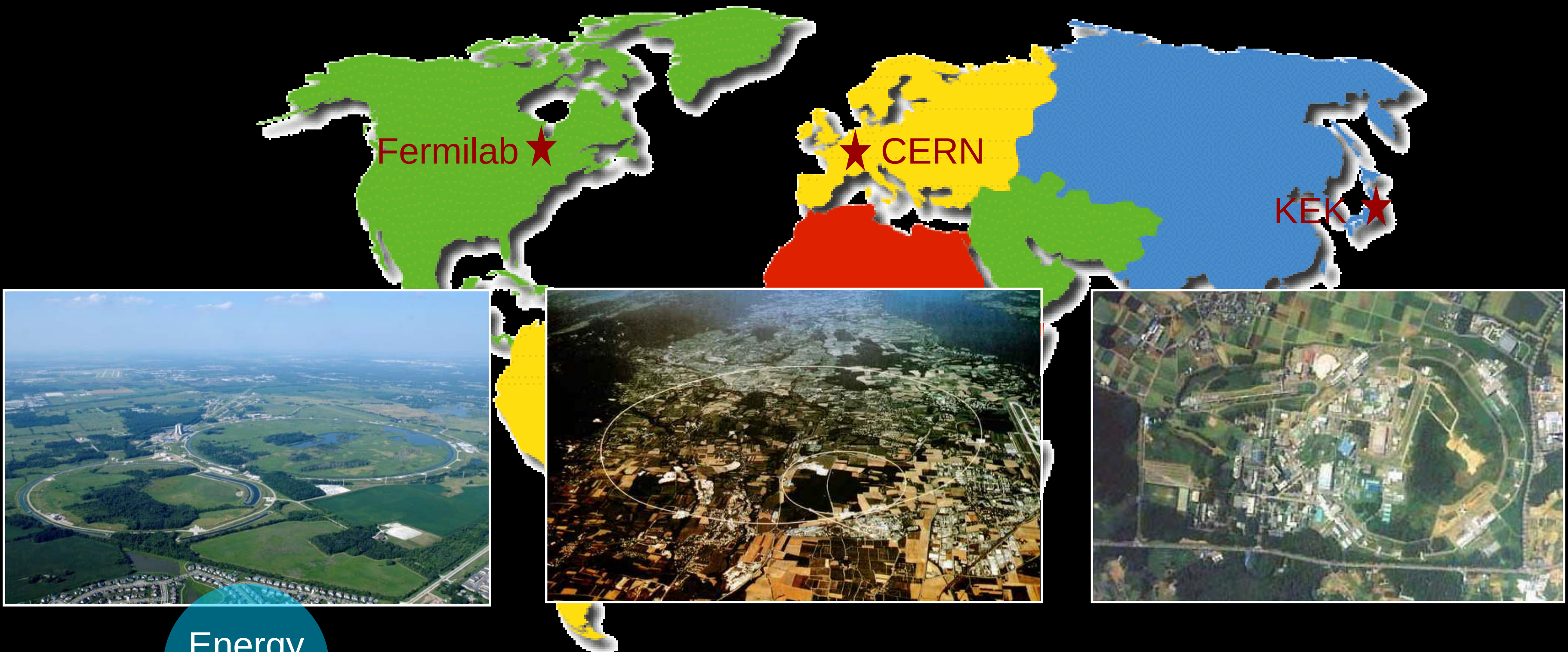


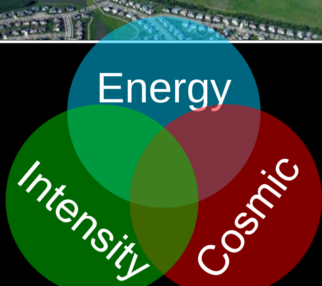
The Energy Frontier
The Intensity Frontier
The Cosmic Frontier
Origin of Mass
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
Neutrino Physics
Proton Decay
Dark Energy
X
E
$E = m_X c^2$
n_m
n_e
$m_n \longleftrightarrow M_N$
X

History of the Universe

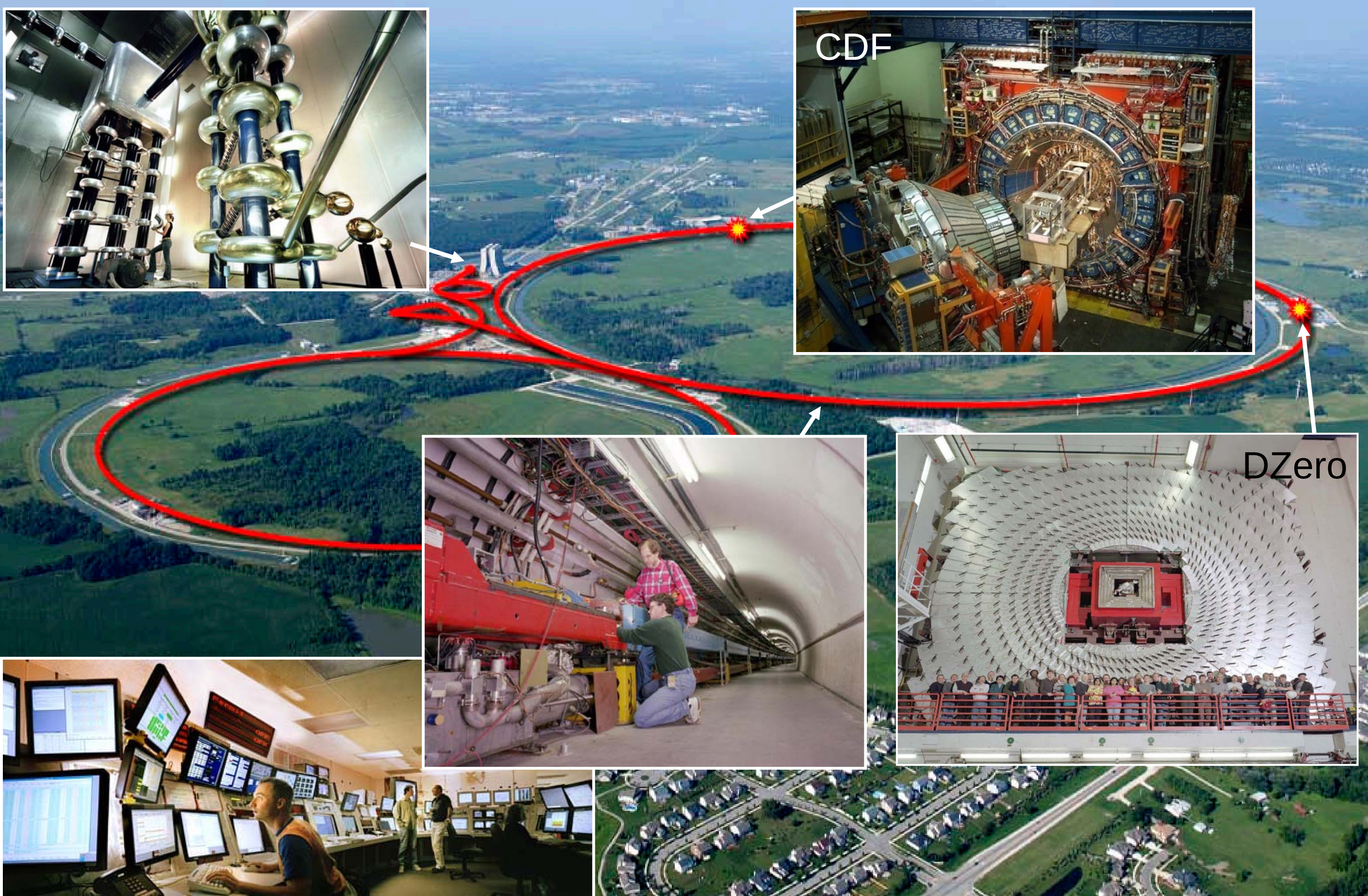


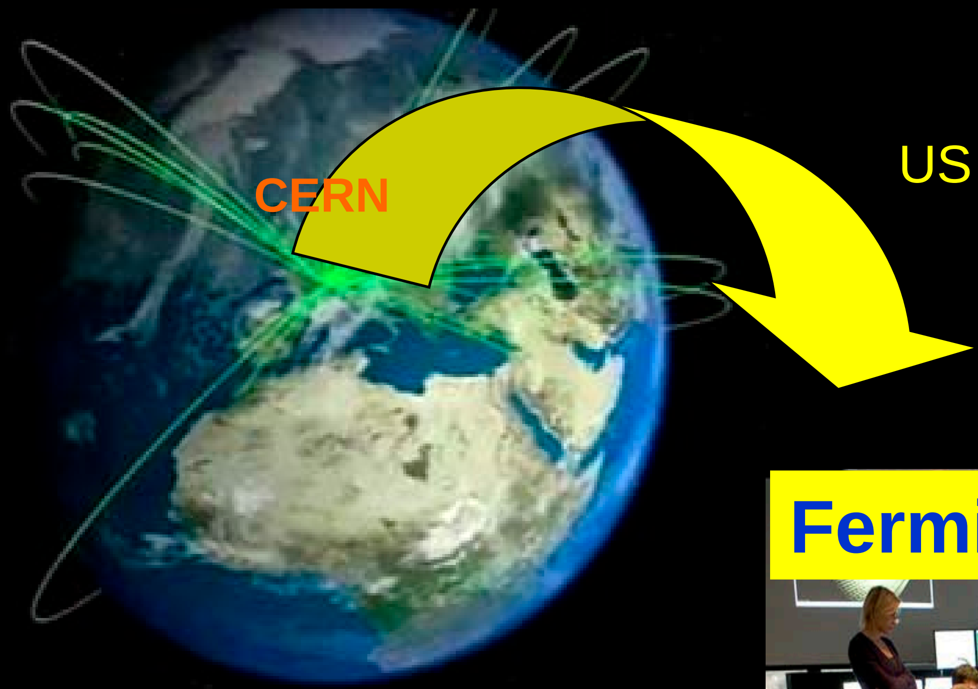
Particle Physics in the World





The Energy Frontier: The Tevatron





US CMS Host Lab; the only US CMS Lab

CMS Tier-1 Computing Center
LHC Physics Center
Support US CMS Community

To make being at Fermilab as good as being at CERN.
Requires critical mass (~100 Fermilab + University Scientists at Fermilab).

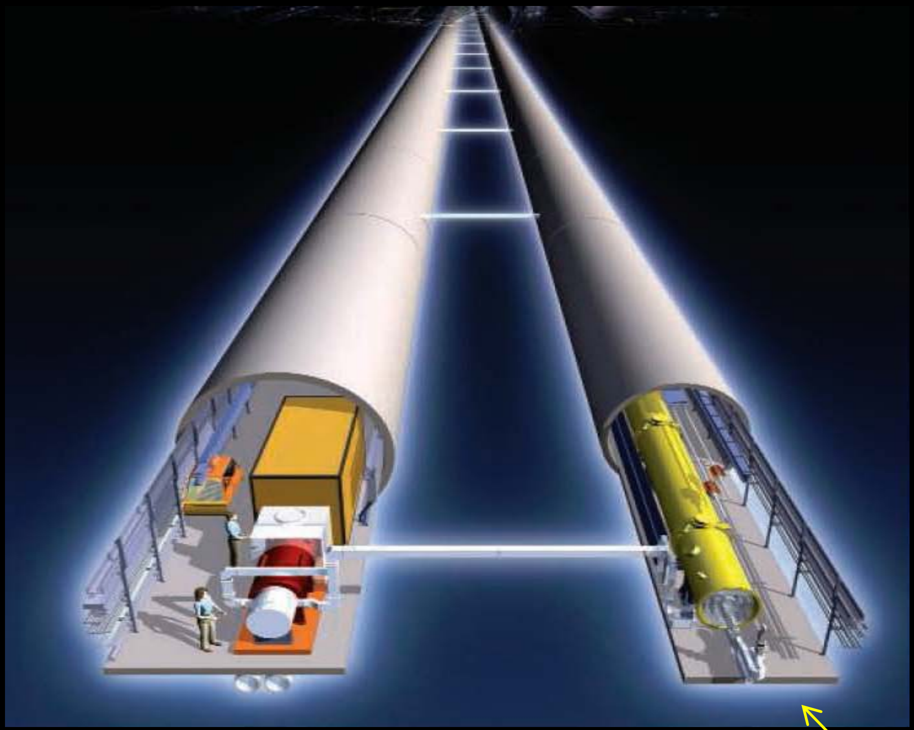
Supporting the LHC Community

CERN-Fermilab Hadron Collider Physics Summer School

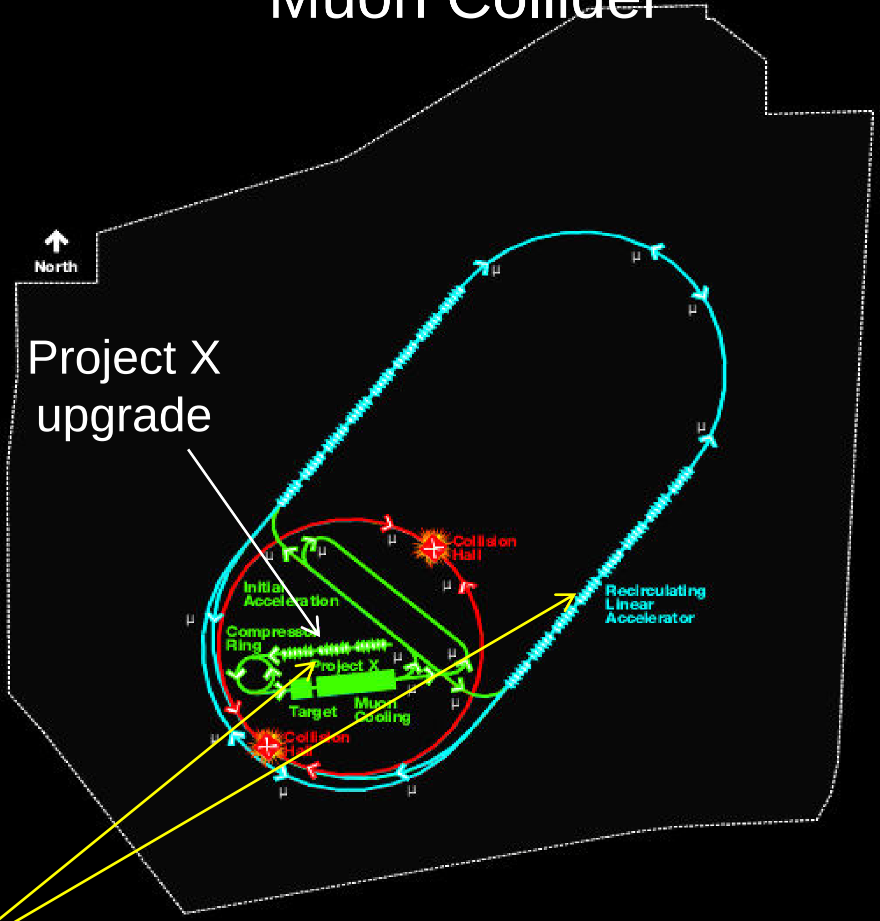
1st	Fermilab	August 9-18, 2006
2nd	CERN	June 6-15, 2007
3rd	Fermilab	August 12-22, 2008
4th	CERN	June 8-17, 2009
5th	Fermilab	Summer 2010

Energy Frontier: Beyond LHC (Future Options)

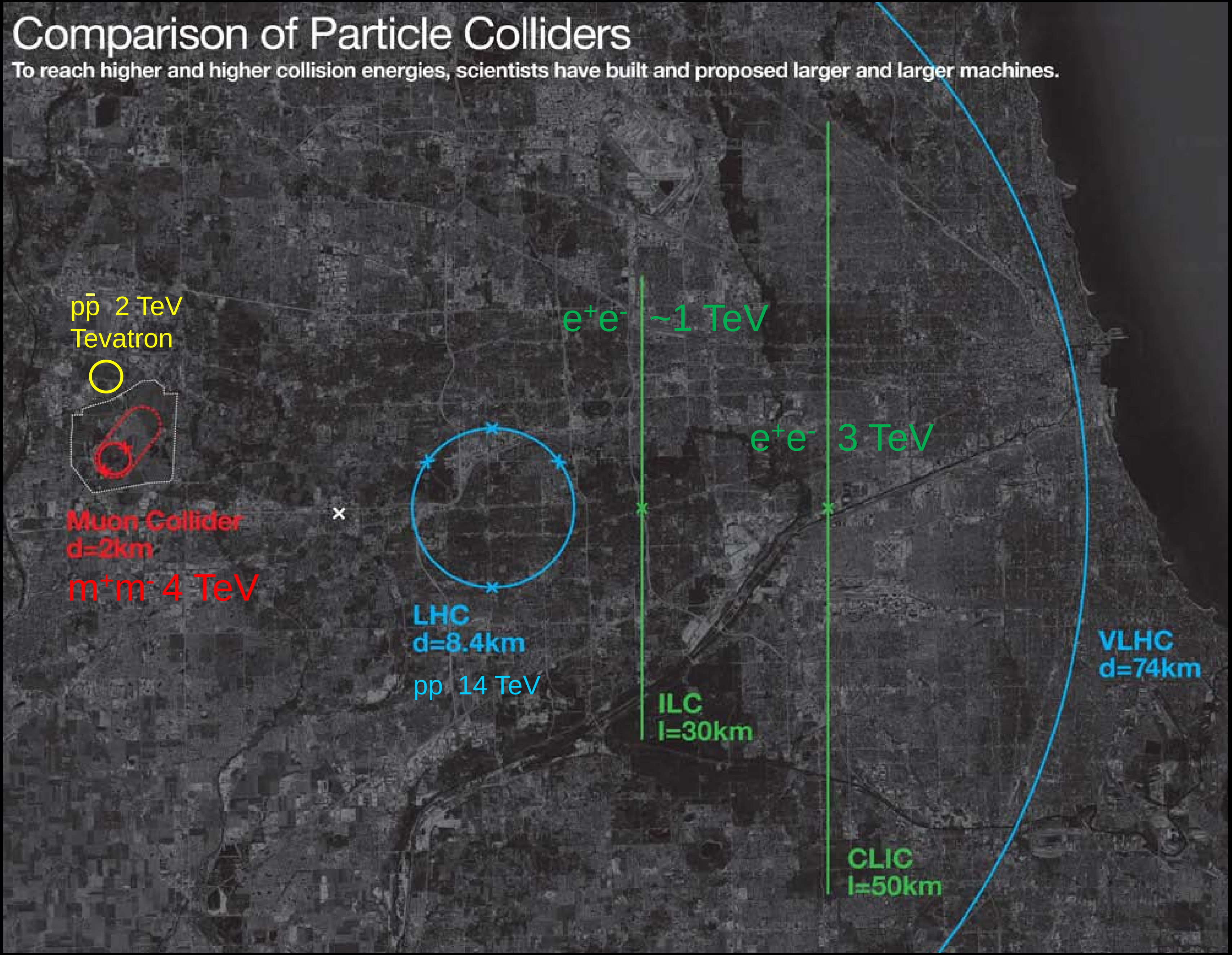
International Linear Collider



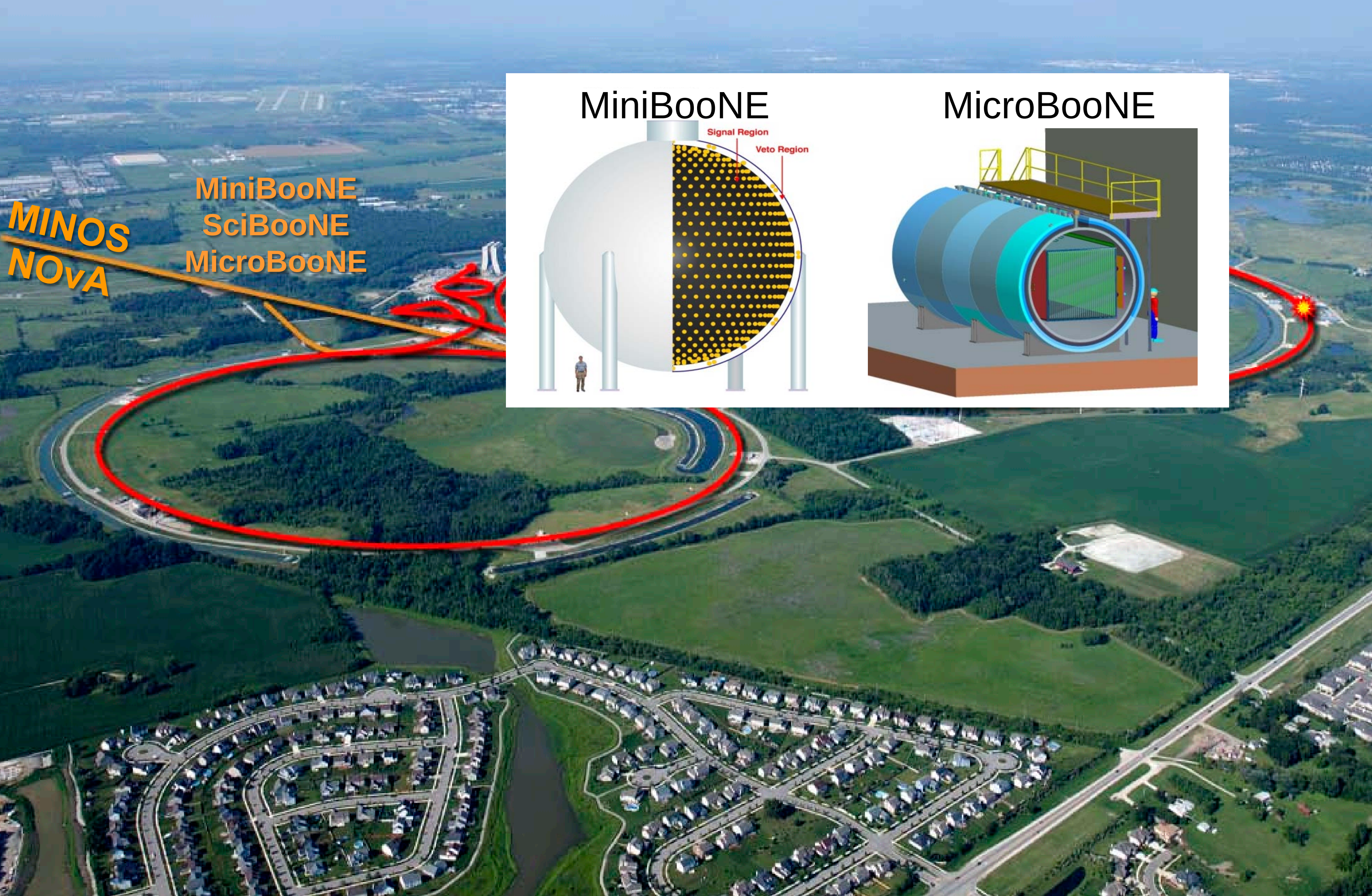
Muon Collider

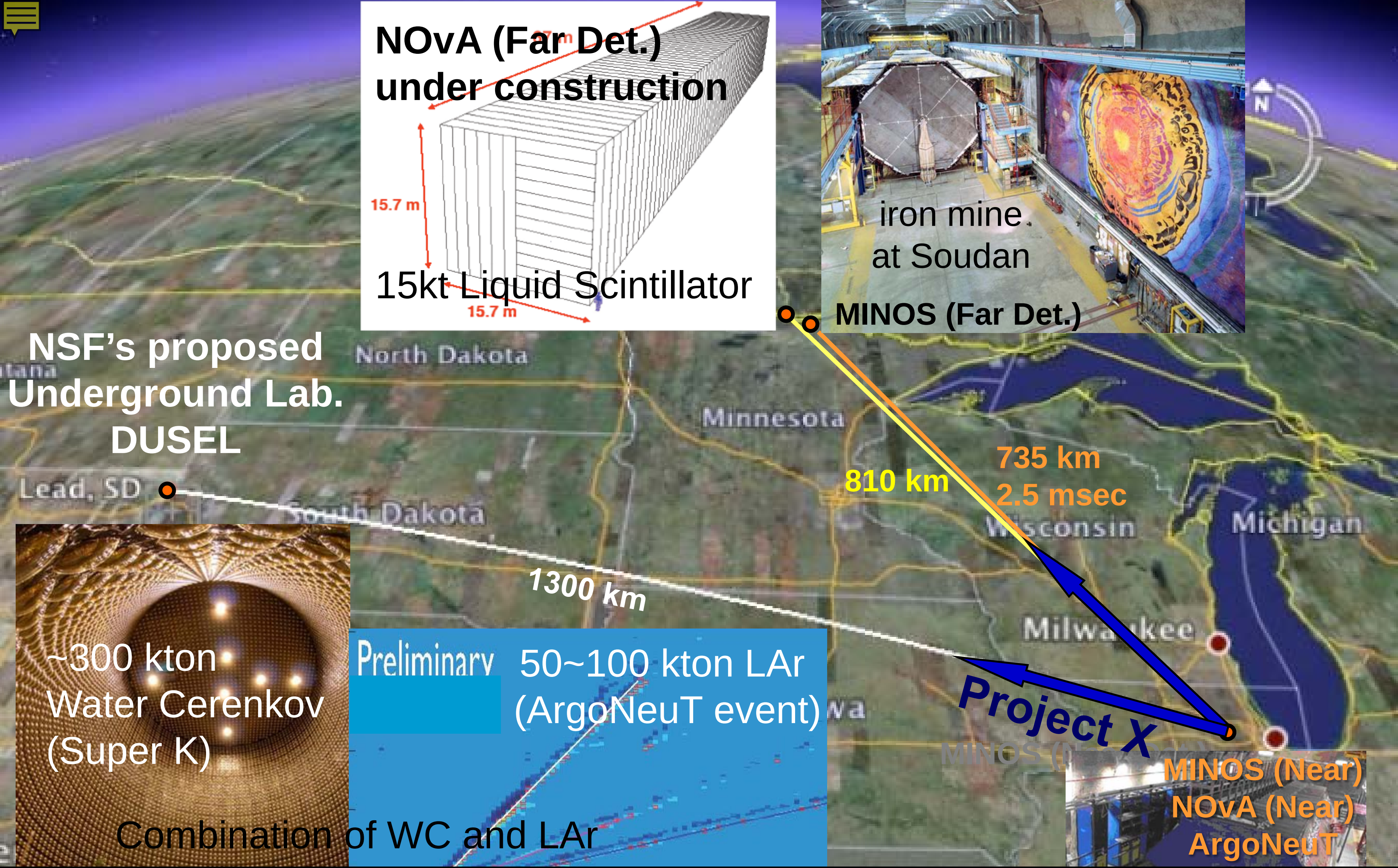


Superconducting RF Technology


Comparison of Particle Colliders
To reach higher and higher collision energies, scientists have built and proposed larger and larger machines.
$p\bar{p}$ 2 TeV
Tevatron
Muon Collider
d=2km
m^+m^- 4 TeV
LHC
d=8.4km
pp 14 TeV
e^+e^- ~1 TeV
ILC
l=30km
e^+e^- 3 TeV
CLIC
l=50km
VLHC
d=74km

The Intensity Frontier: Neutrino Beams





Matter – Antimatter Asymmetry with Neutrinos

Proton Decay

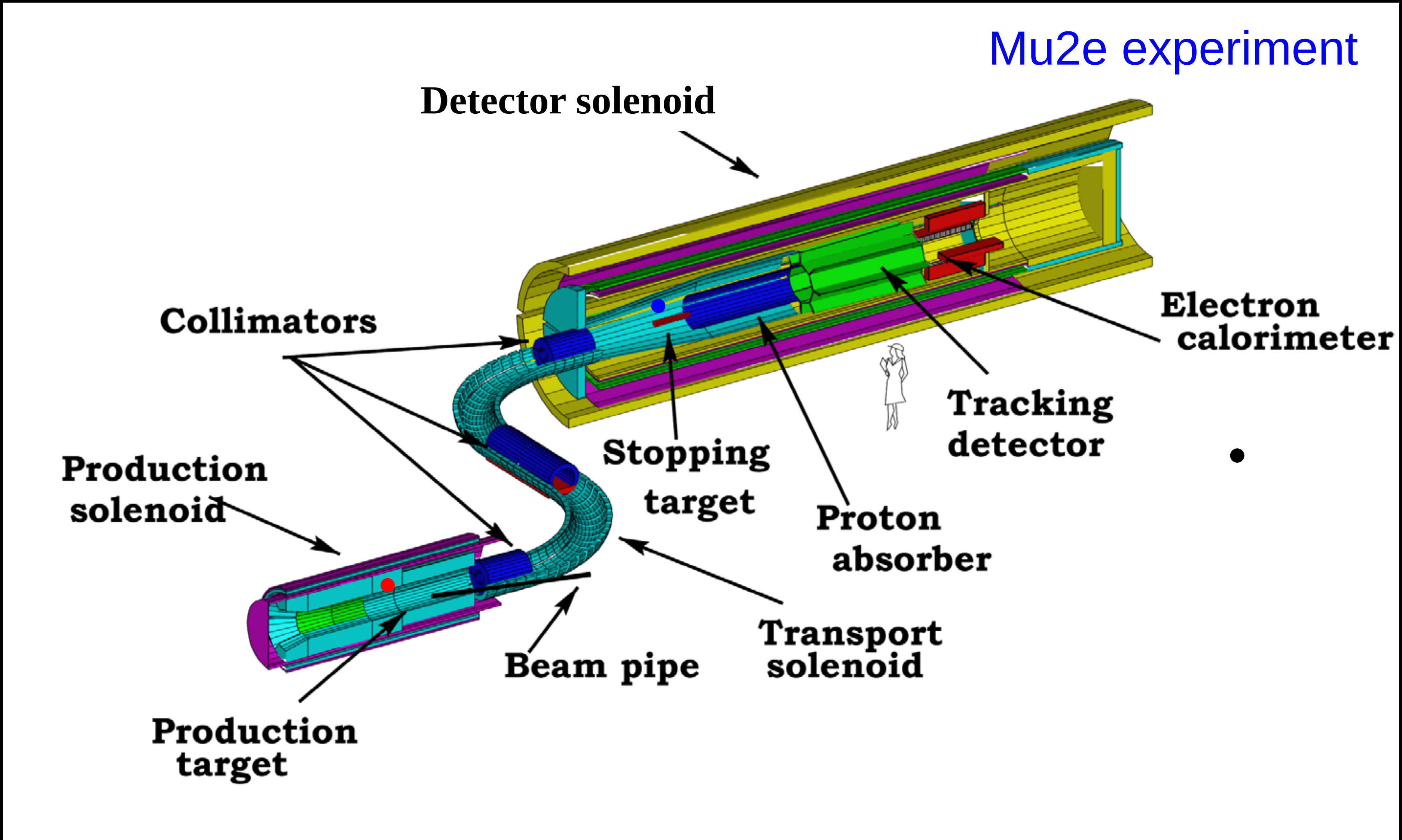
Supernovae Neutrinos

International Neutrino Summer School

Merging various neutrino schools into one coherent school
Rotating in three regions

1st	Fermilab	July 6-18, 2009
2nd	KEK	2010
3rd	Europe	2011

Intensity Frontier: μ to e Conversion (μN → eN)



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The Cosmic Frontier: Dark Matter Searches

Underground Experiments using underground neutrino detector halls

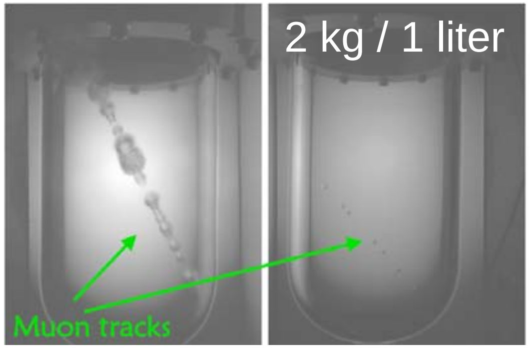
CDMS

Low temp. Ge / Si crystals

World's Best Limits

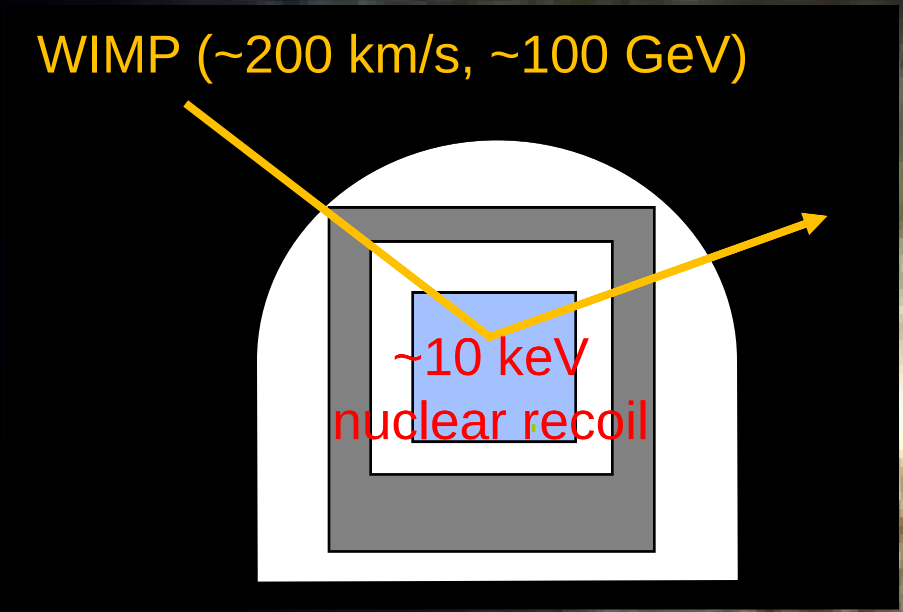
COUPP

Room temp. CF_3I Bubble Chamber



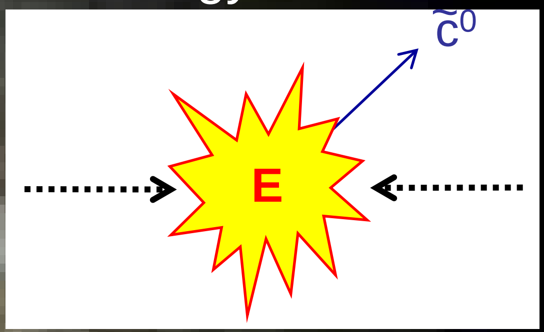
Cosmic Frontier: Dark Matter

Underground experiments may detect Dark Matter candidates.

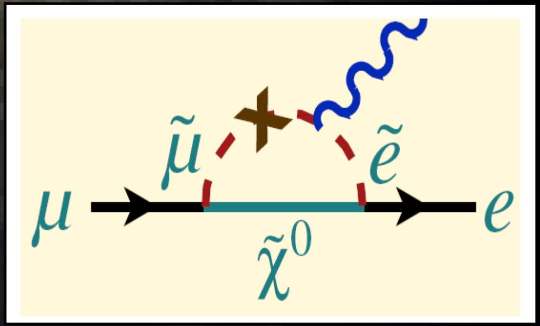


Cosmic Frontier

Energy Frontier



Intensity Frontier



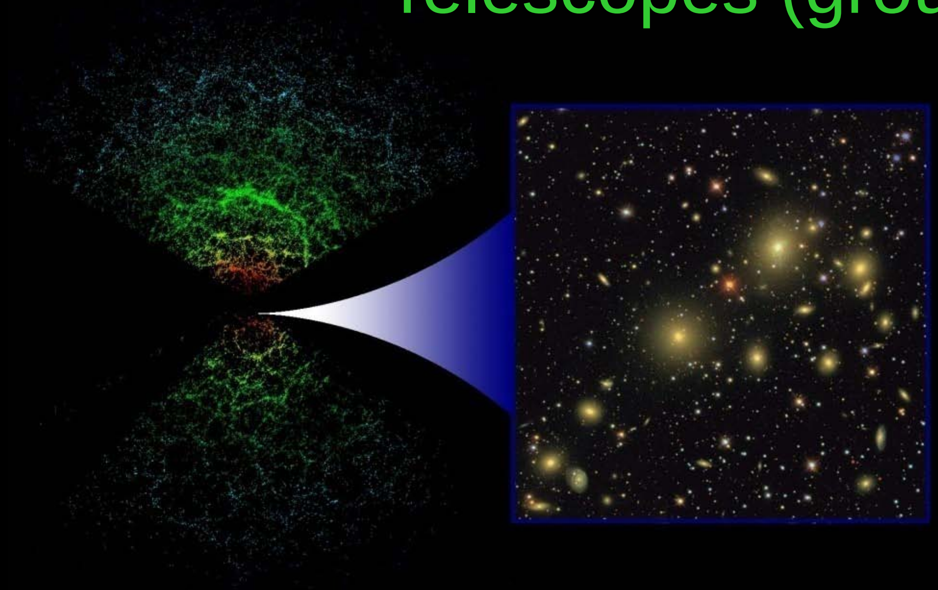
Interplay:

Cosmic – Energy – Intensity Frontiers

Accelerators can produce dark matter in the lab and understand exactly what it is.

The Cosmic Frontier: Probing Dark Energy

Telescopes (ground, space)



Sloan Digital Sky Survey
(SDSS)

Dark Energy Survey
(DES)

Joint Dark Energy Mission
(JDEM)

How does  fit

into this grand picture?

21st Century Questions in Particle Physics

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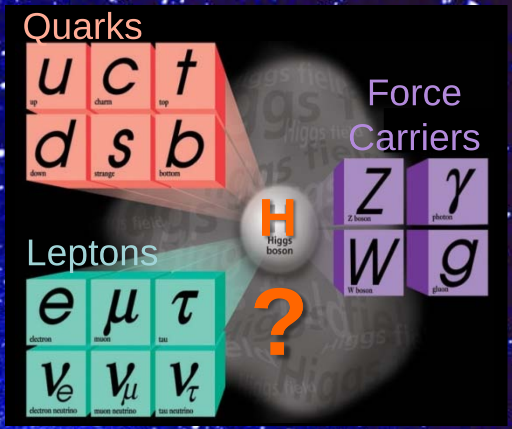
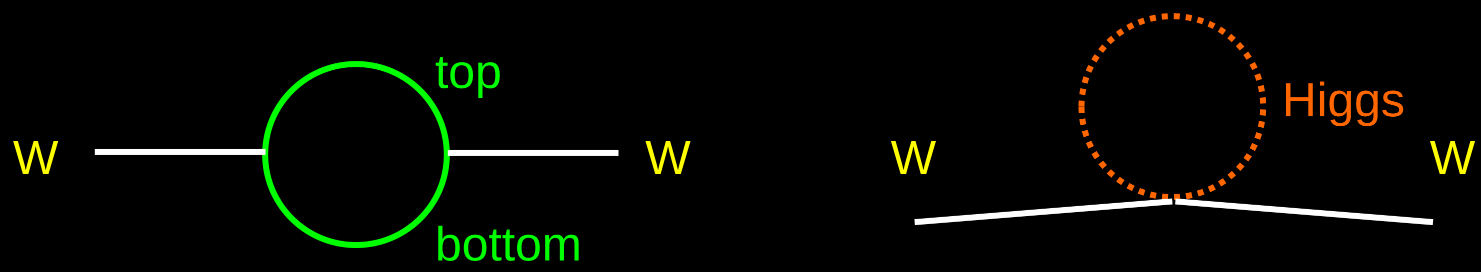


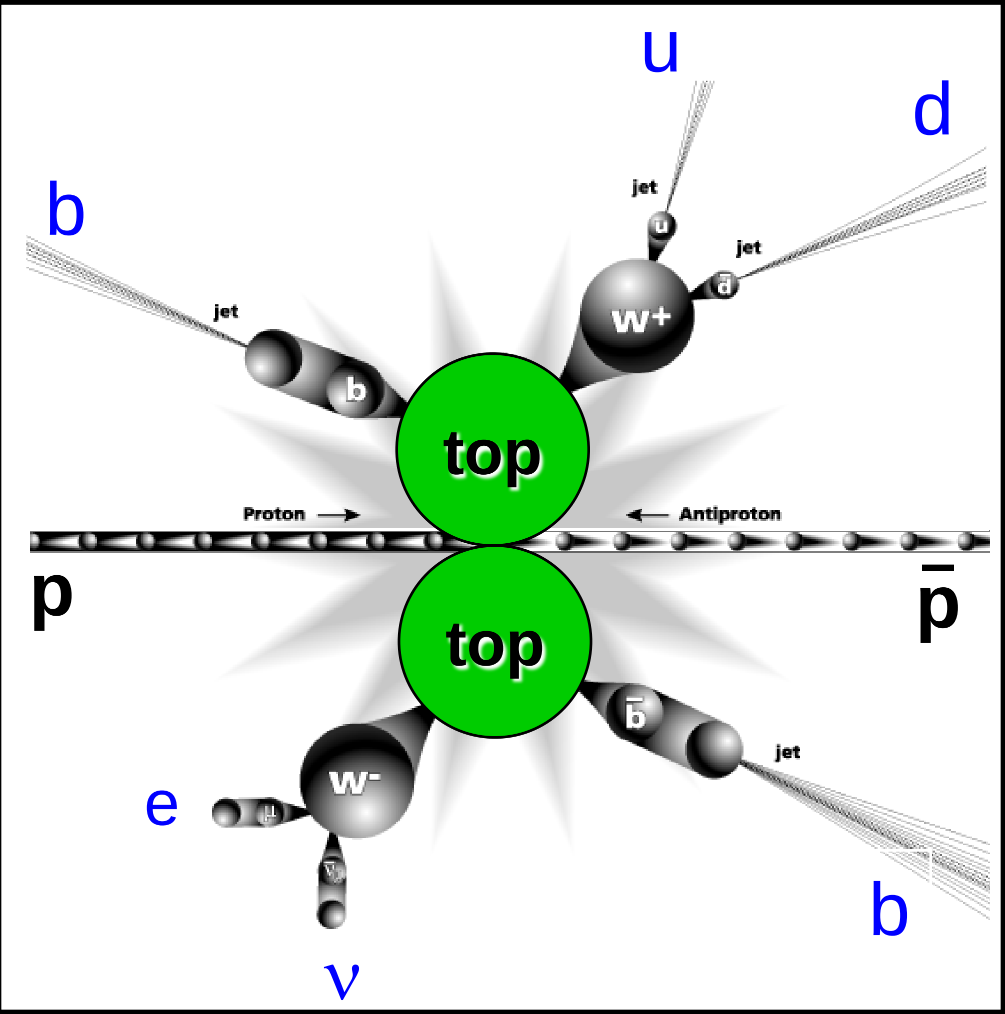
Young-Kee Kim

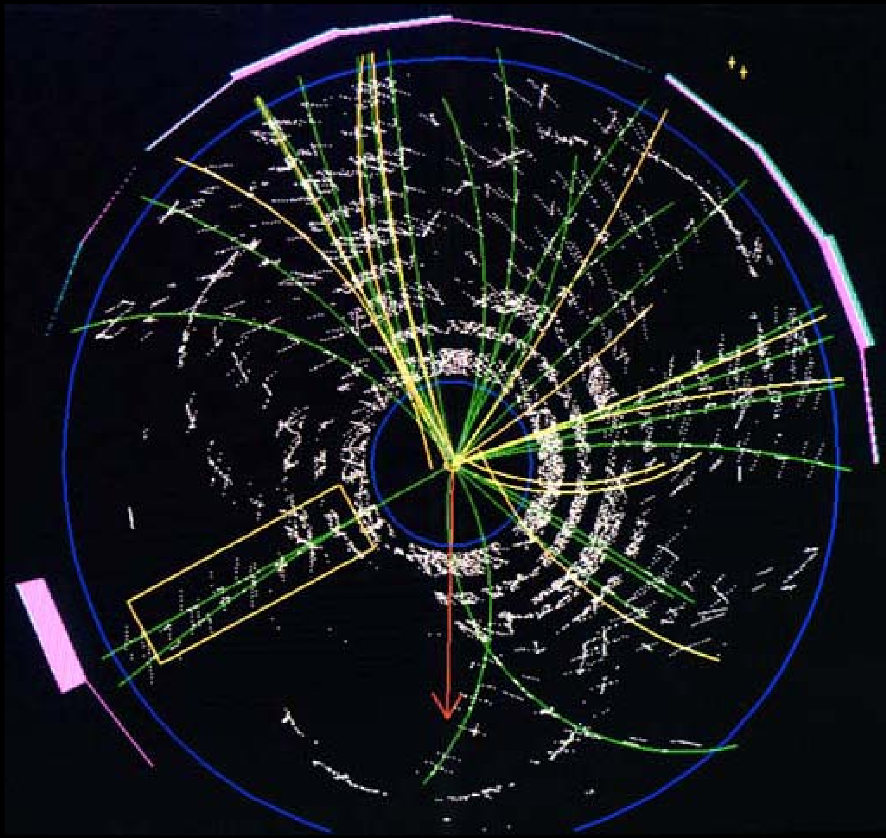
Through Quantum Fluctuations,

Top quark mass and W boson mass carry information about the Higgs Boson.



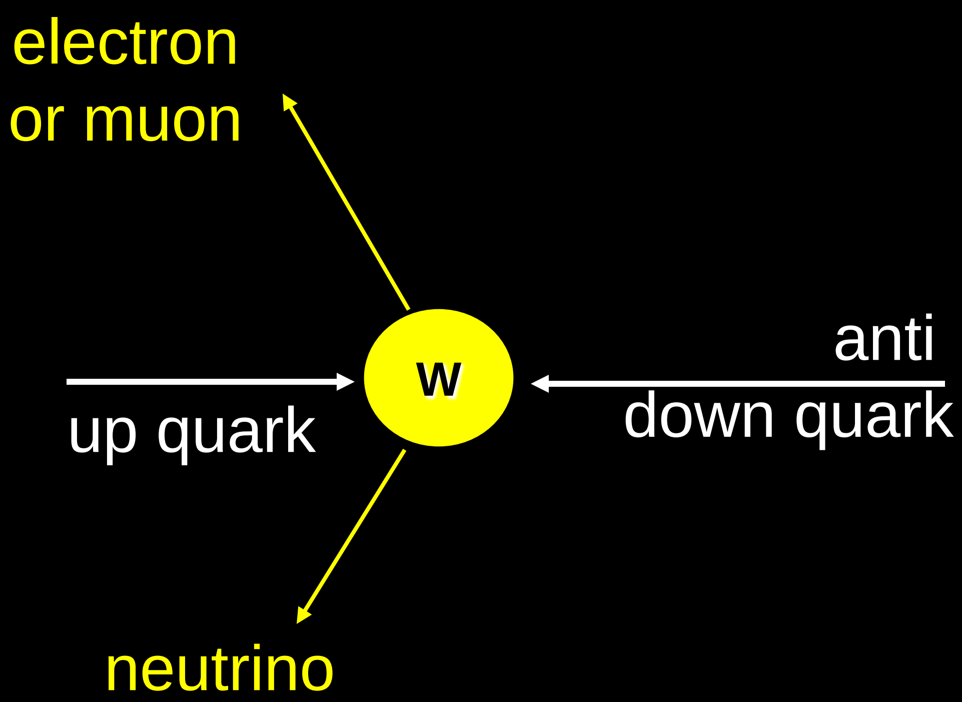
Top Quark Mass





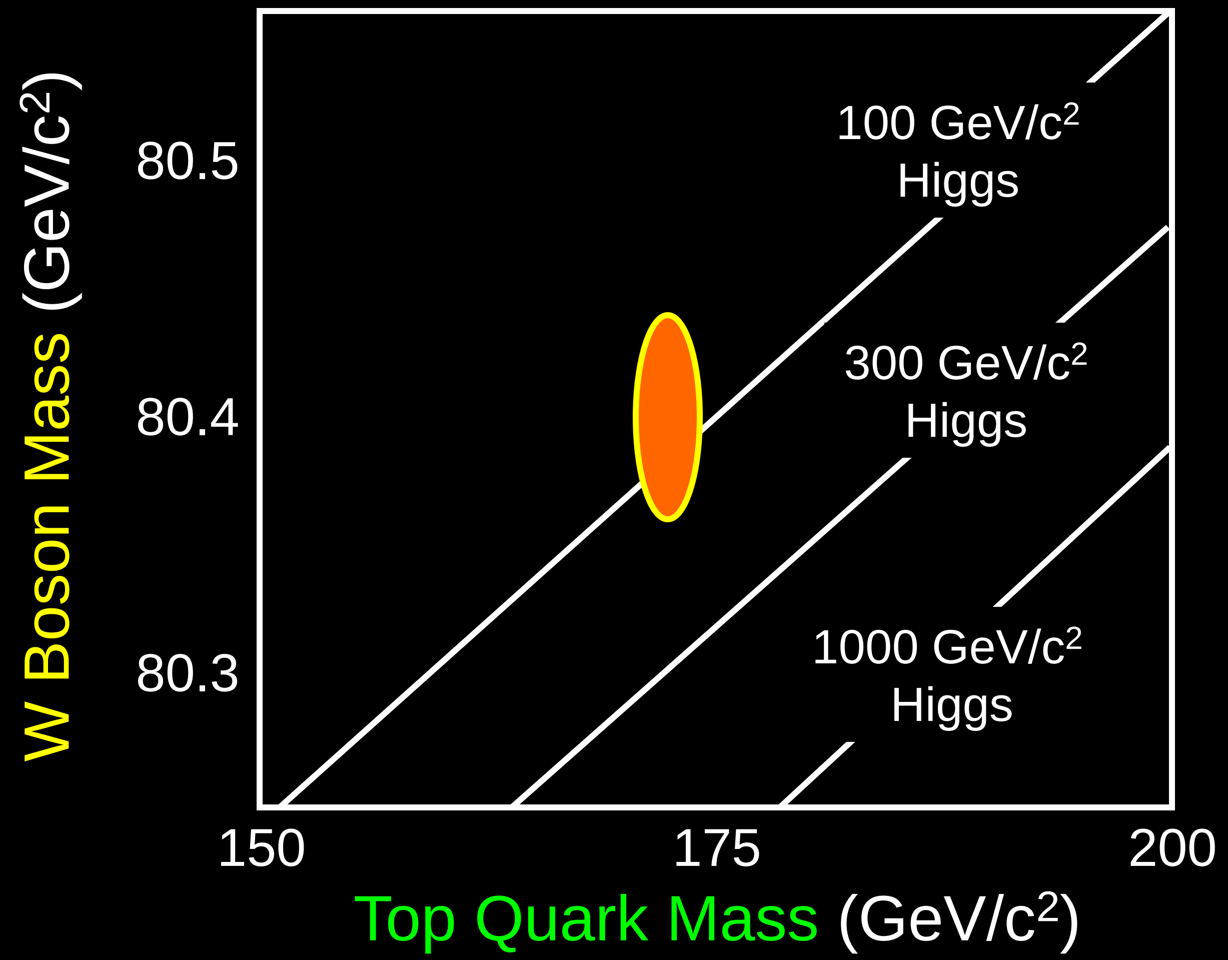
better than 1 % Accuracy

W Boson Mass



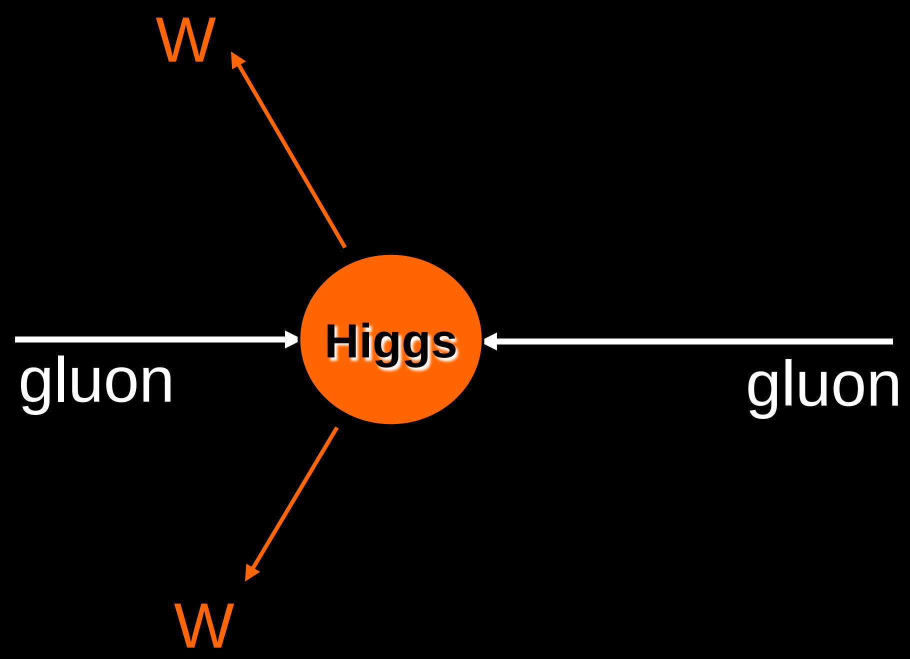
0.05 % Accuracy

What did we learn from Top and W masses?



114 GeV/c^2 < Higgs Mass < ~Top Quark Mass (172 GeV/c^2)
SM Higgs (if it exists) is being produced NOW at the Tevatron!
Challenging – Just not that often & it's buried in "backgrounds"

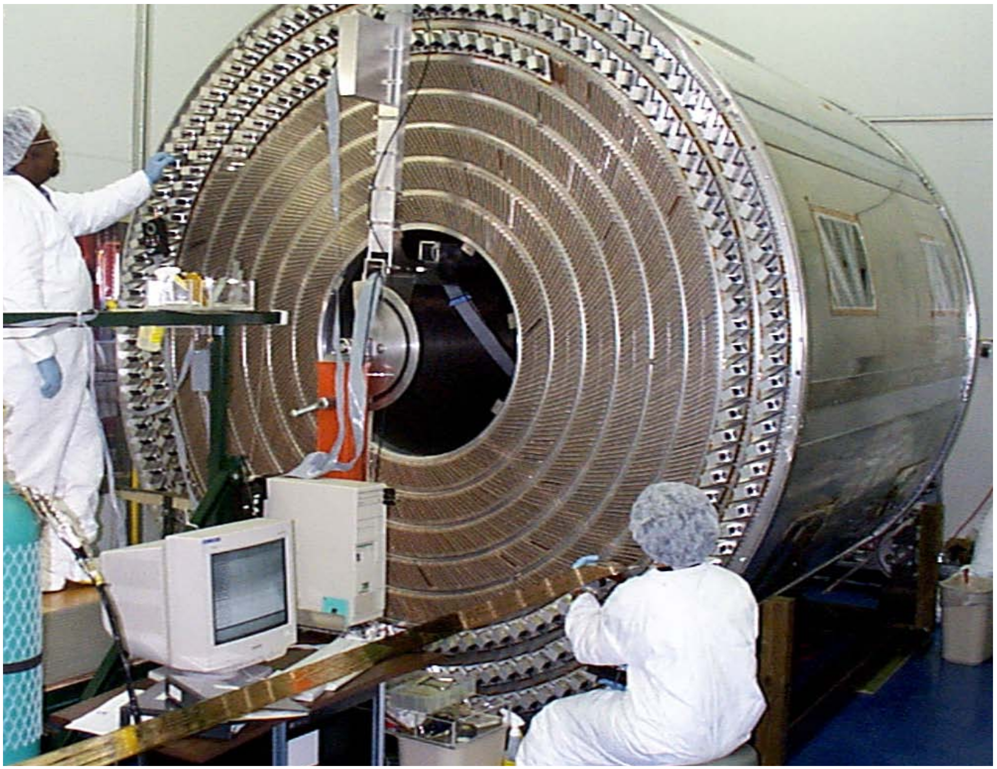
Searching for Higgs
at Fermilab's Tevatron and CERN's LHC

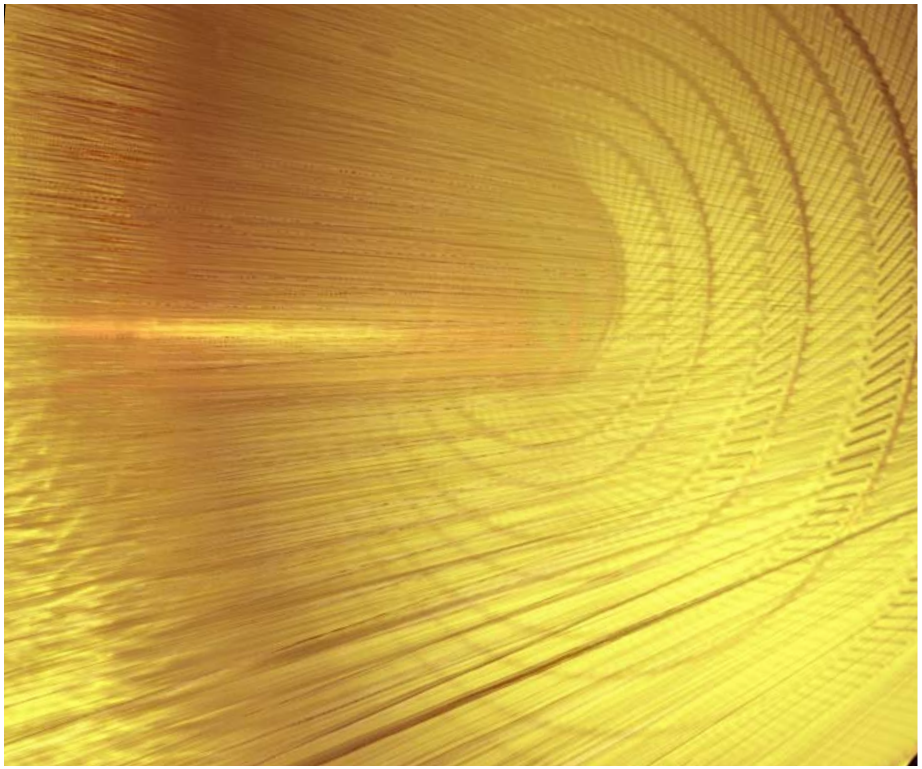


114 GeV/c^2 < Higgs Mass < ~Top Quark Mass (172 GeV/c^2)
Fermilab could exclude this range if Higgs is not there.

CERN's LHC is the ultimate accelerator for finding Higgs.

Building Detectors and Triggers





Completion of CDF Detector Construction: Sept. 13, 2000

I can NOT do anything without my students and postdocs

My current group

Undergraduate Students	Graduate Students	Postdoctoral Fellows
Jake Whitaker	Satomi Shiraishi	HyunSu Lee
Richard Ruiz	Wesley Ketchum	
	Jian Tang	
(~5 undergrad students during Summer including REU students)	Yangyang Cheng	
	Ho Ling Li	
	Robert Lanza	