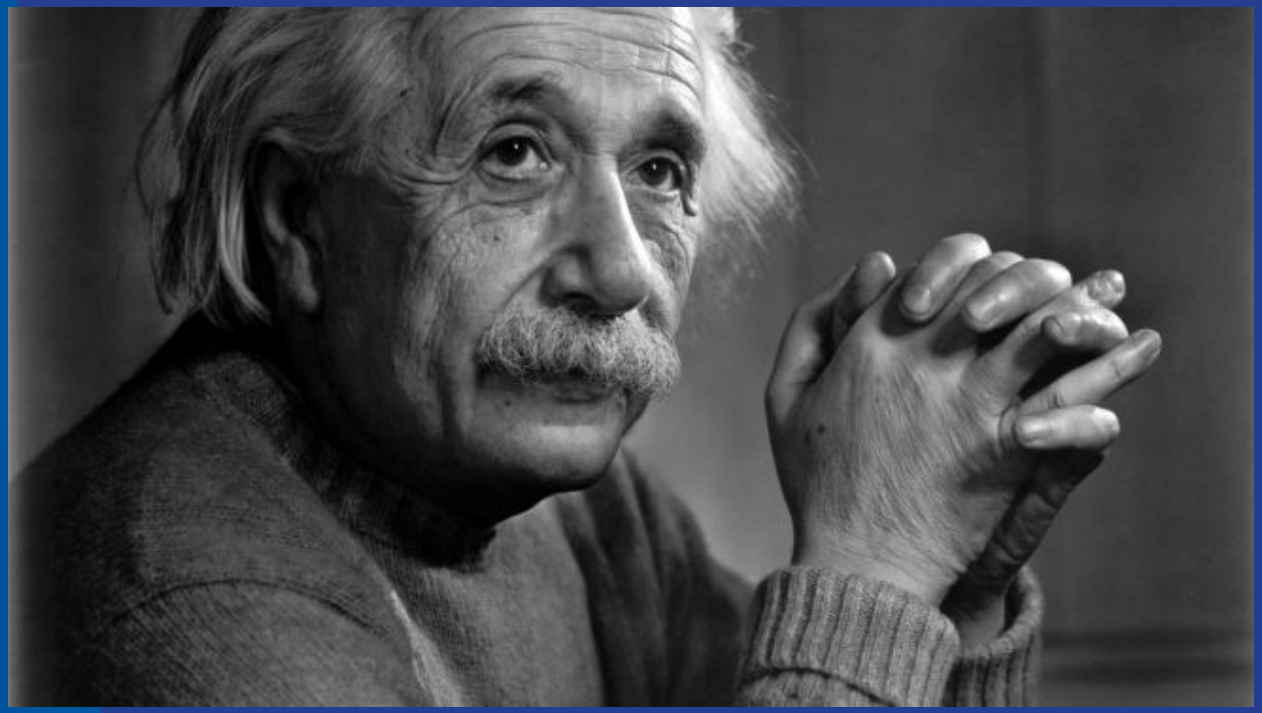
The future of Fermilab

P. Oddone

Tevatron Symposium

June 11, 2012

It is the best of times!

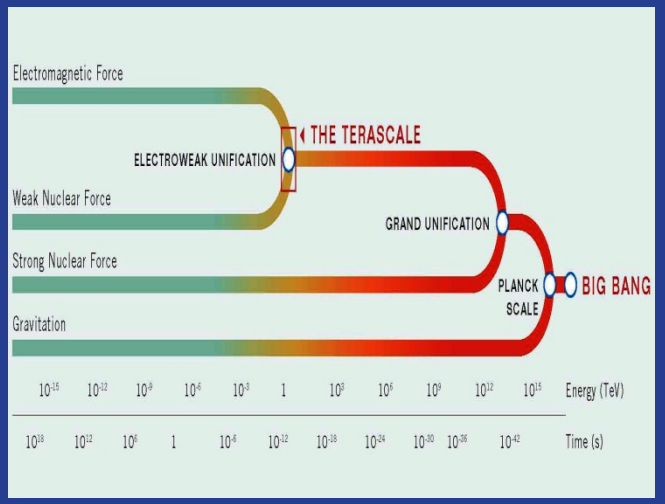


"The most beautiful experience we can have is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science"

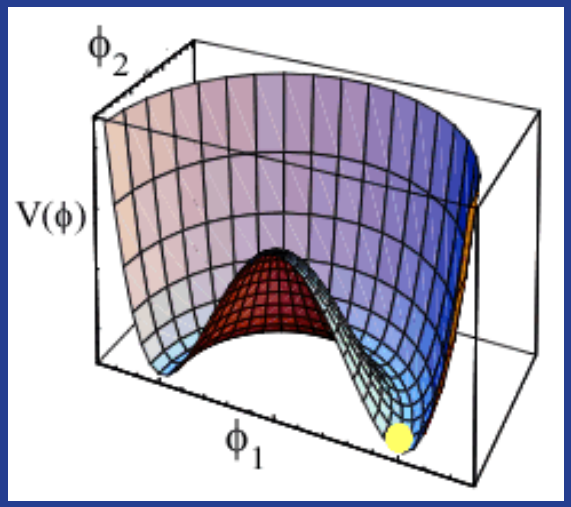
The sense mystery has never been greater!

The sense of mystery….

Why are we not a soup of red photons?



Do all forces unify?



How do elementary particles get their mass?

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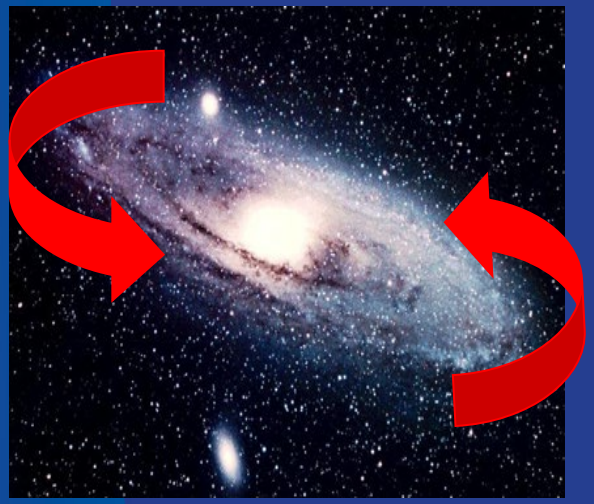
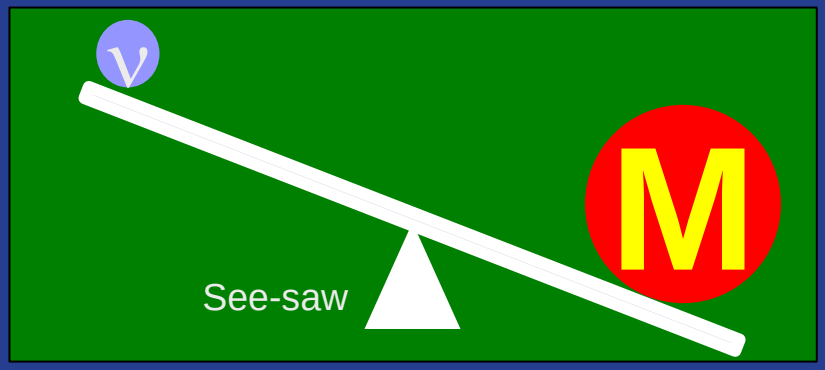
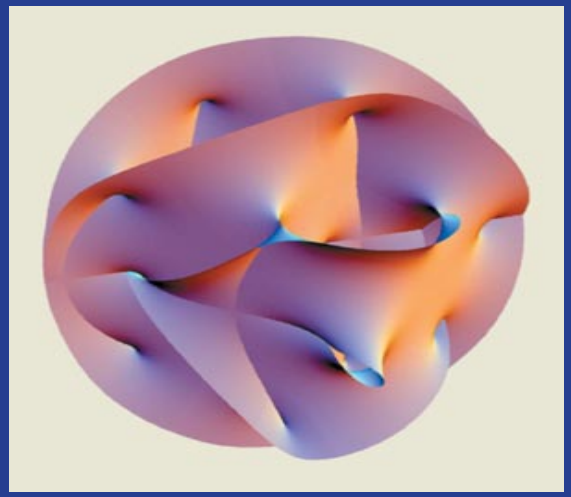
The sense of mystery….



What is dark matter?

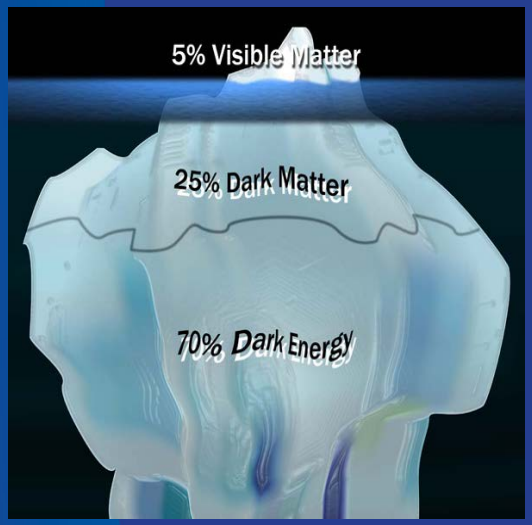


Why are neutrinos so light?



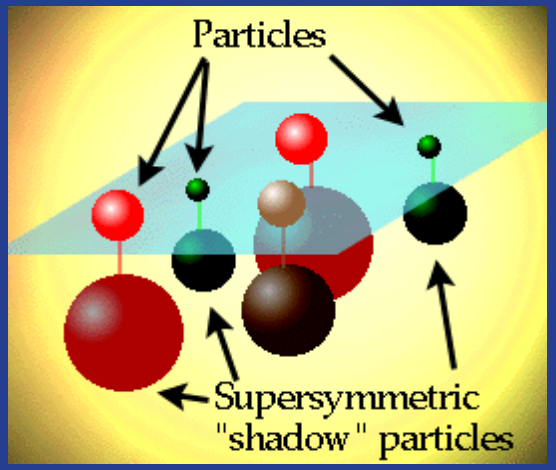
Are there extra dimensions of space?

The sense of mystery….



What is dark energy?

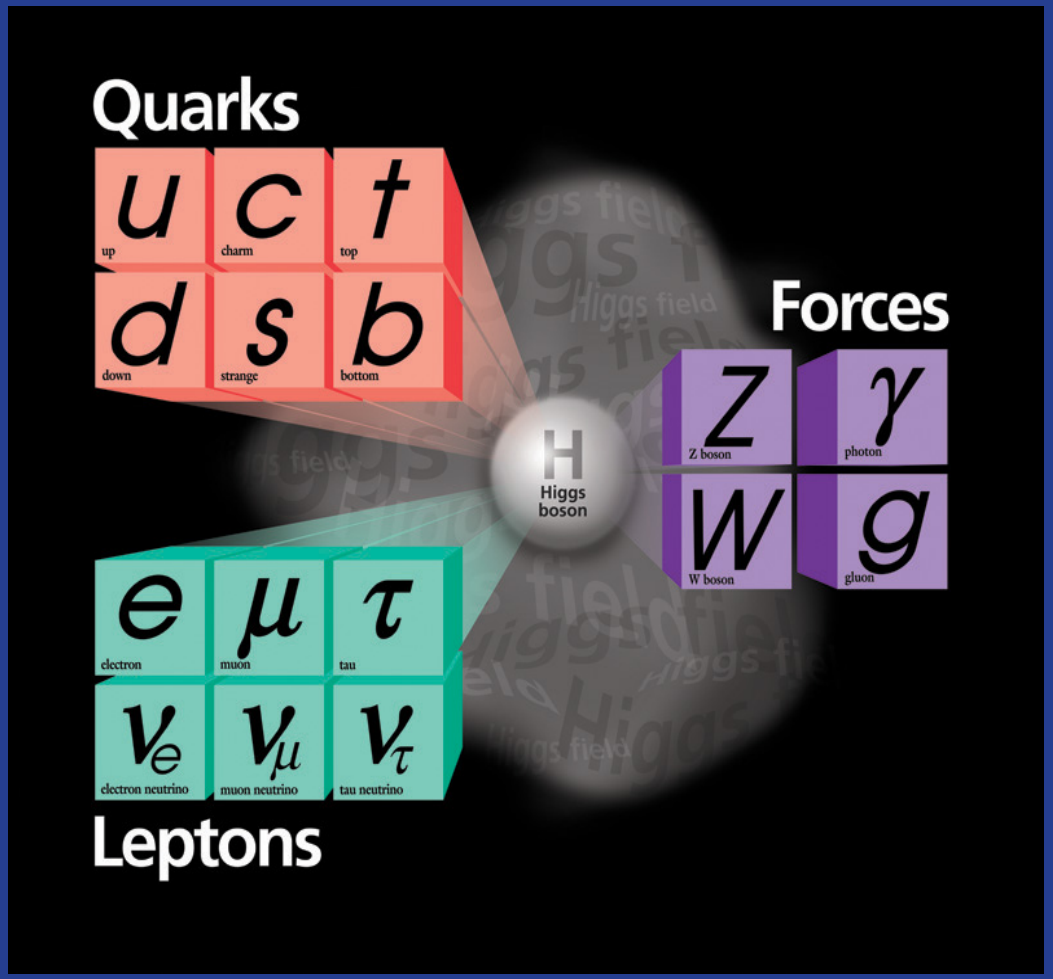
Why three families of quarks and leptong?



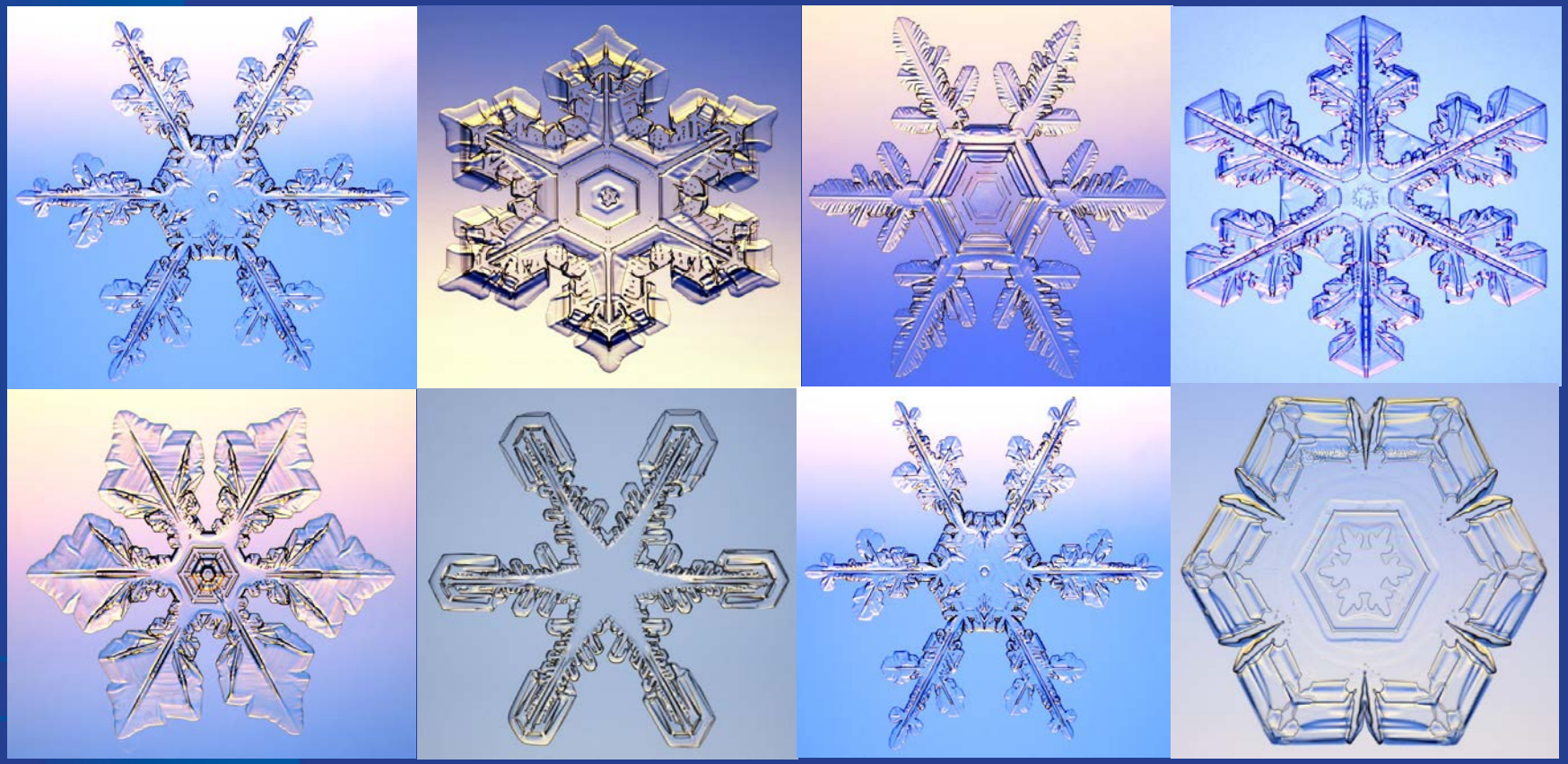
Is there supersymmetry? Where?

Why are we so puzzled?

- The present theory is a remarkable intellectual construction
- Every particle experiment ever done fits in the framework
- It allows us to define what is incomplete in our understanding, and there is much we are missing



The quest to put it all together!

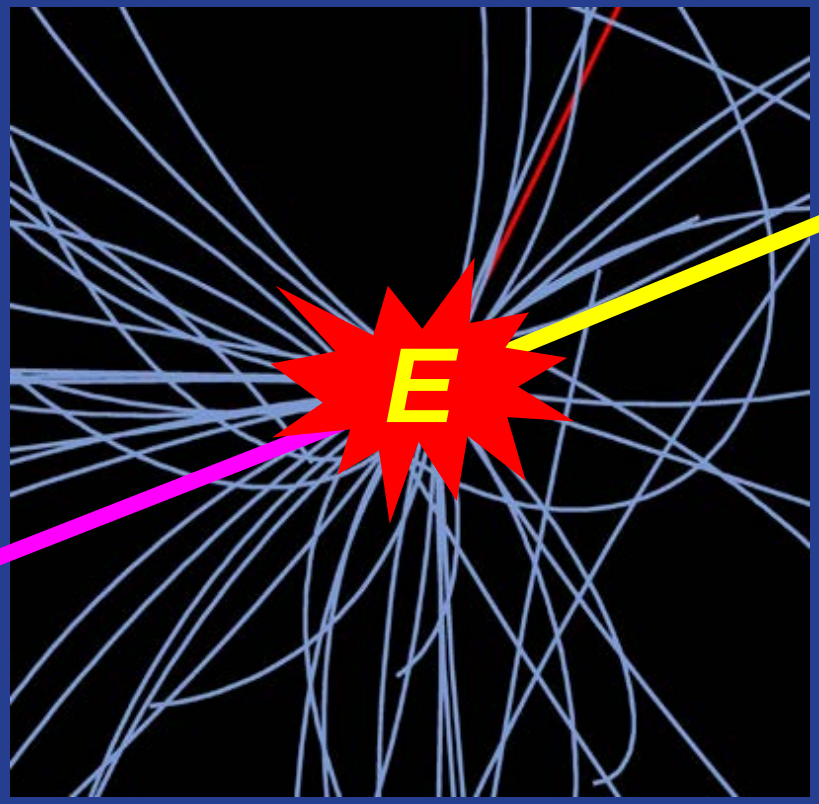


Is there an underlying simplicity?

- The world has now a remarkable set of tools to try to answer these questions, and more in construction and in the planning stages. A global vision articulated by ICFA in *Beacons of Discovery*

- Fermilab is an integral part of this global vision, with a unique set of tools and contributions to the world's program

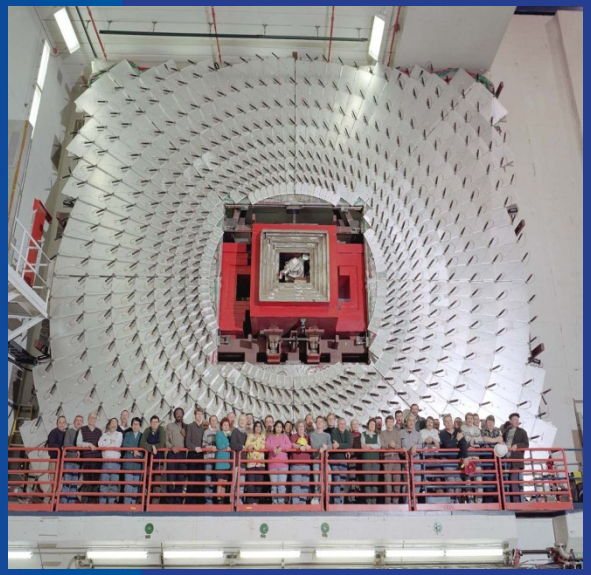
Energy Frontier



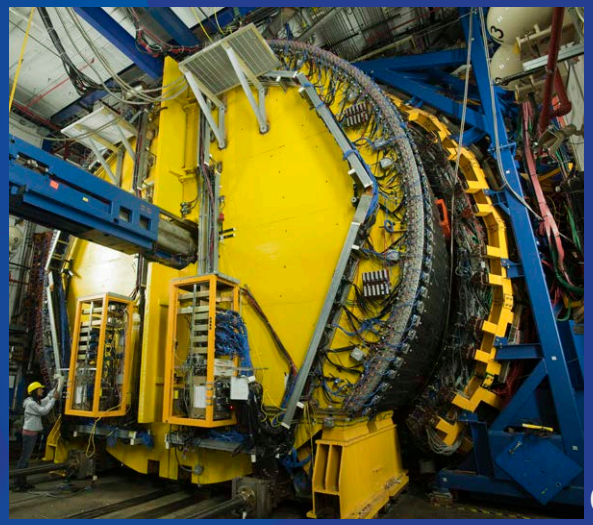
$E = Mc^2$

Limit: a few TeV

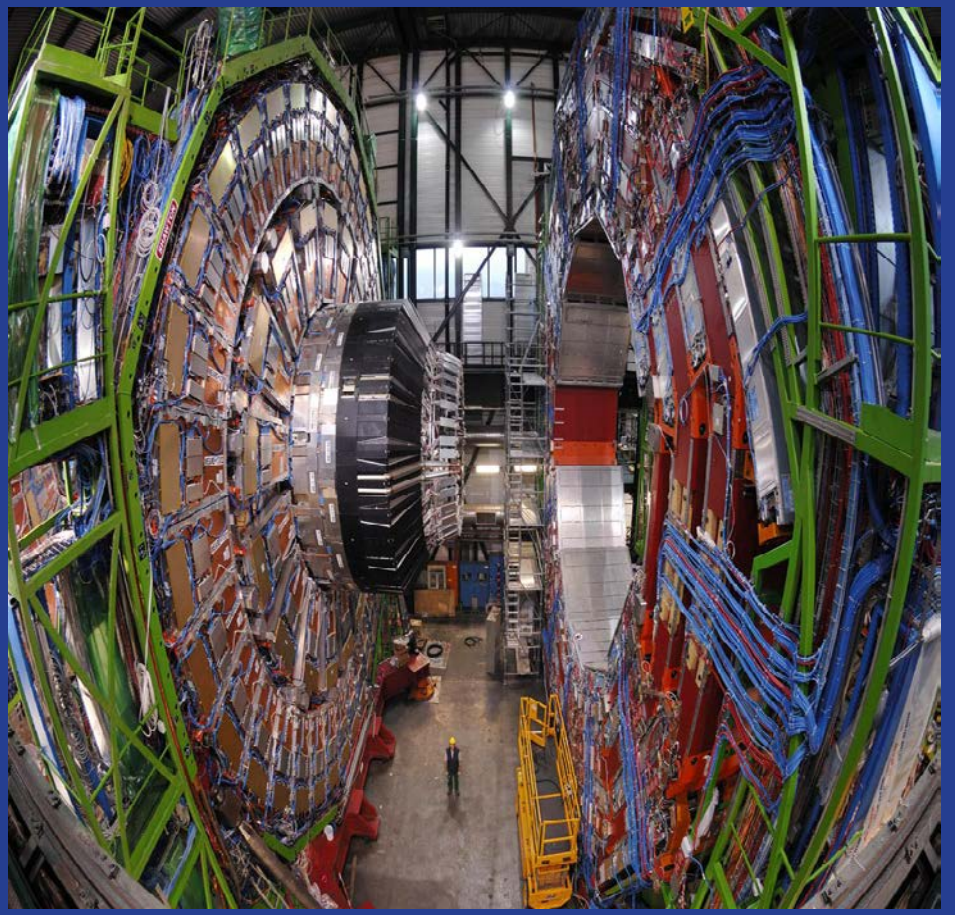
At the energy frontier….. now



DZero



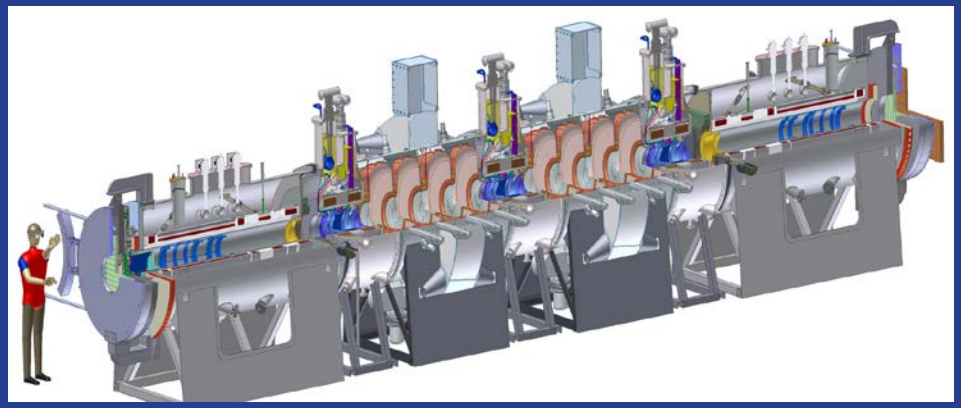
CDF



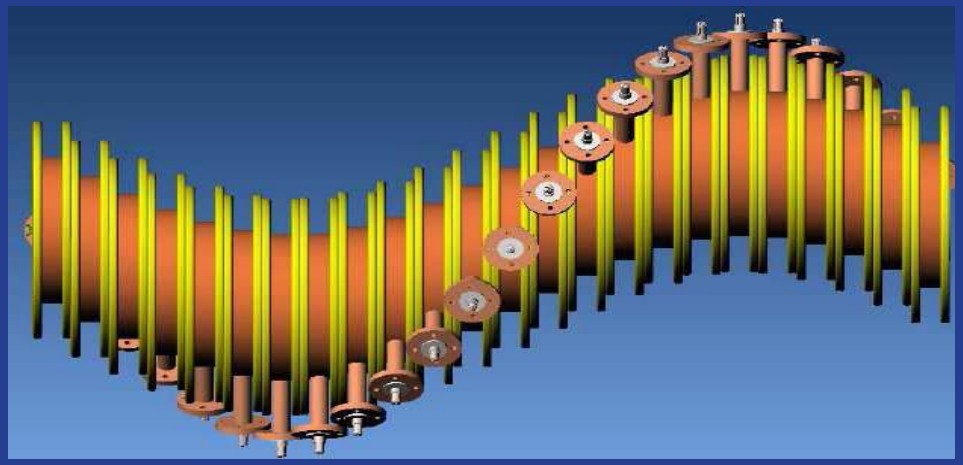
CMS physics and LHC and CMS upgrades

At the energy frontier….. future

ILC



Muon cooling and muon collider

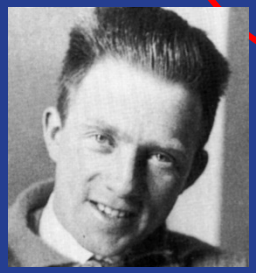


At the Intensity Frontier

Discover the nature of massive known & NEW particles indirectly by intense beams of charged leptons and quarks

Quantum Fluctuation

High-intensity particle beam → *Top, W, Z, …. NEW* → **Rate for rare transition**

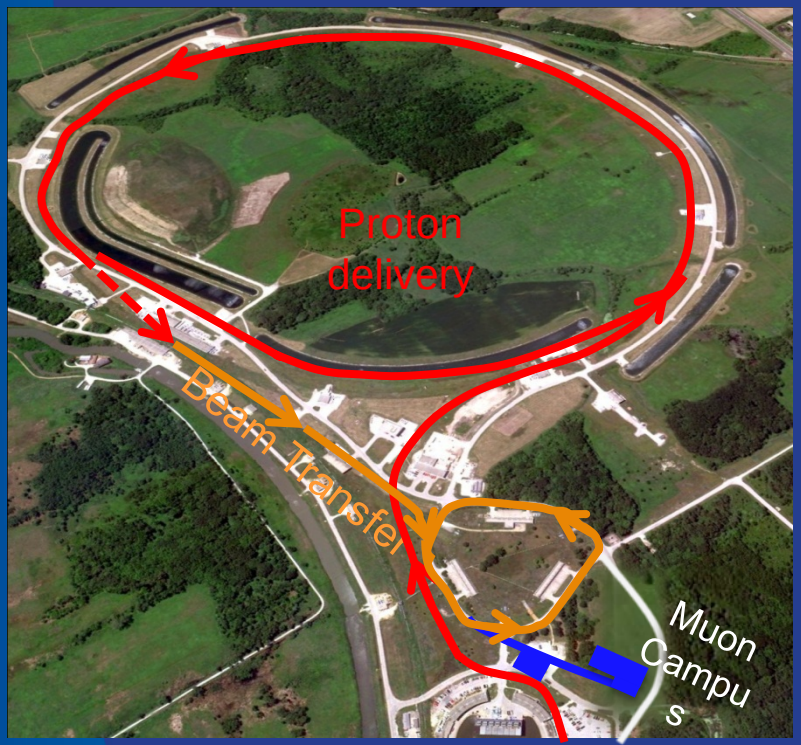


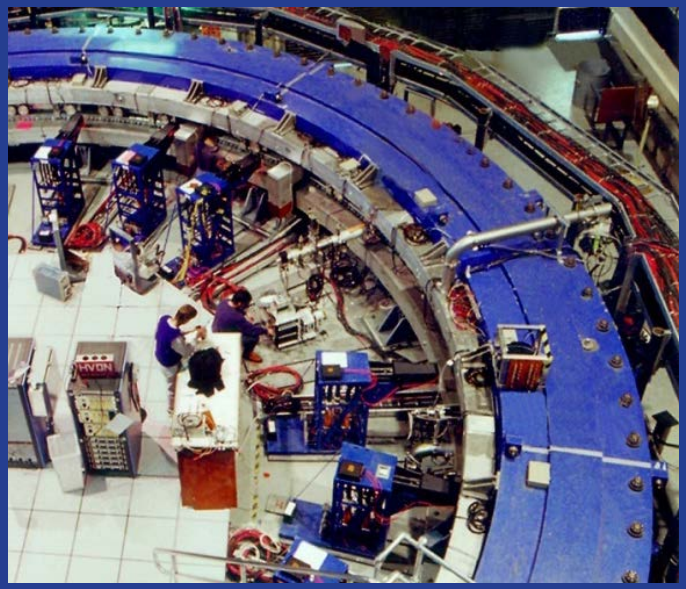
Uncertainty Principle

$E = Mc^2$

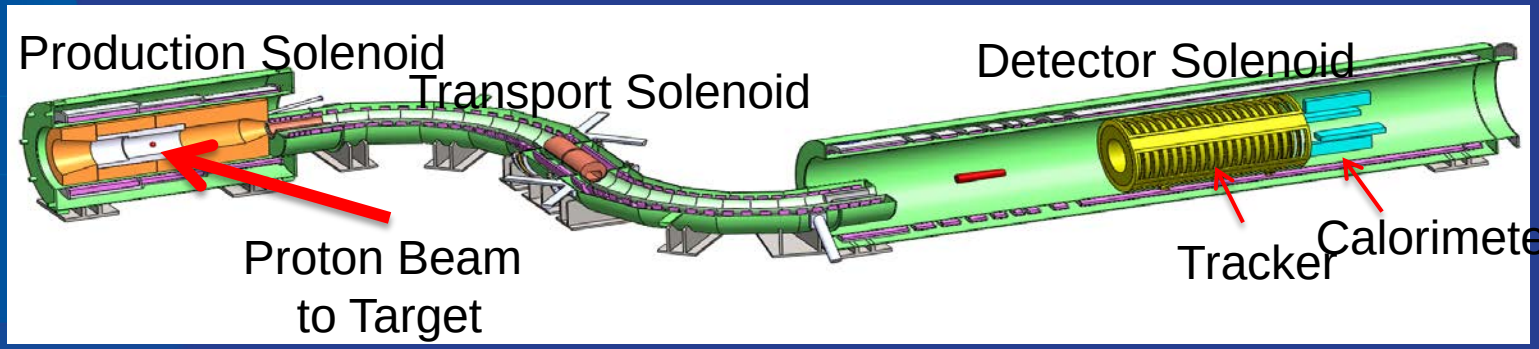
Limit ~10^4 TeV

Intensity Frontier at Fermilab: Muon Campus





Muon g-2



Mu2e

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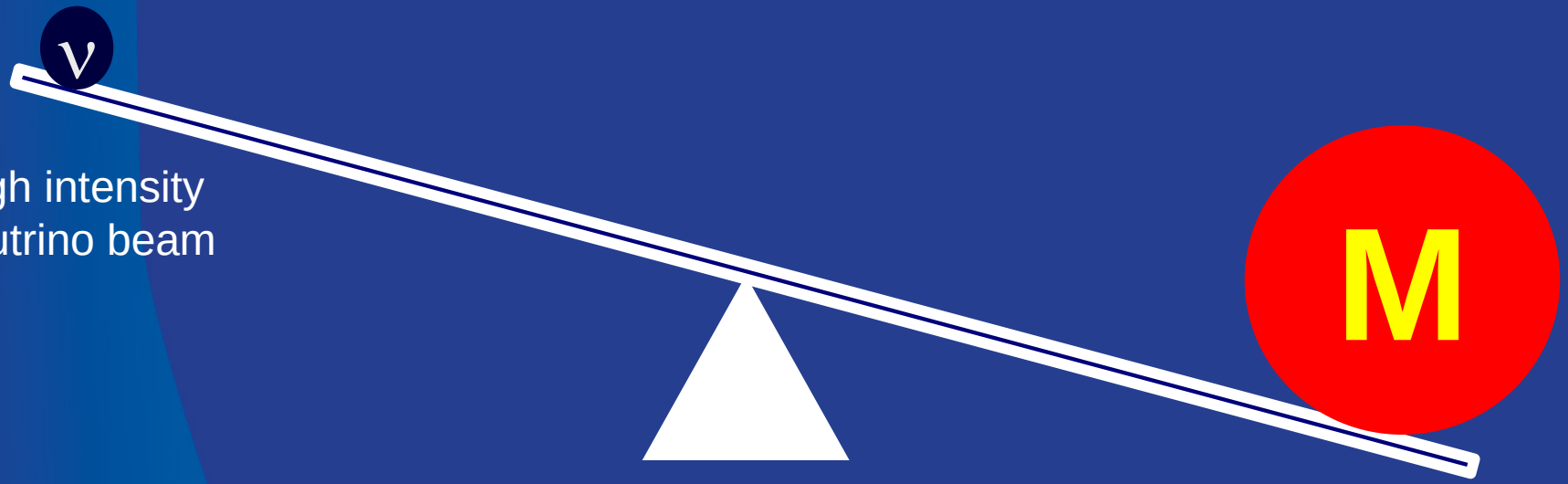
Intensity Frontier

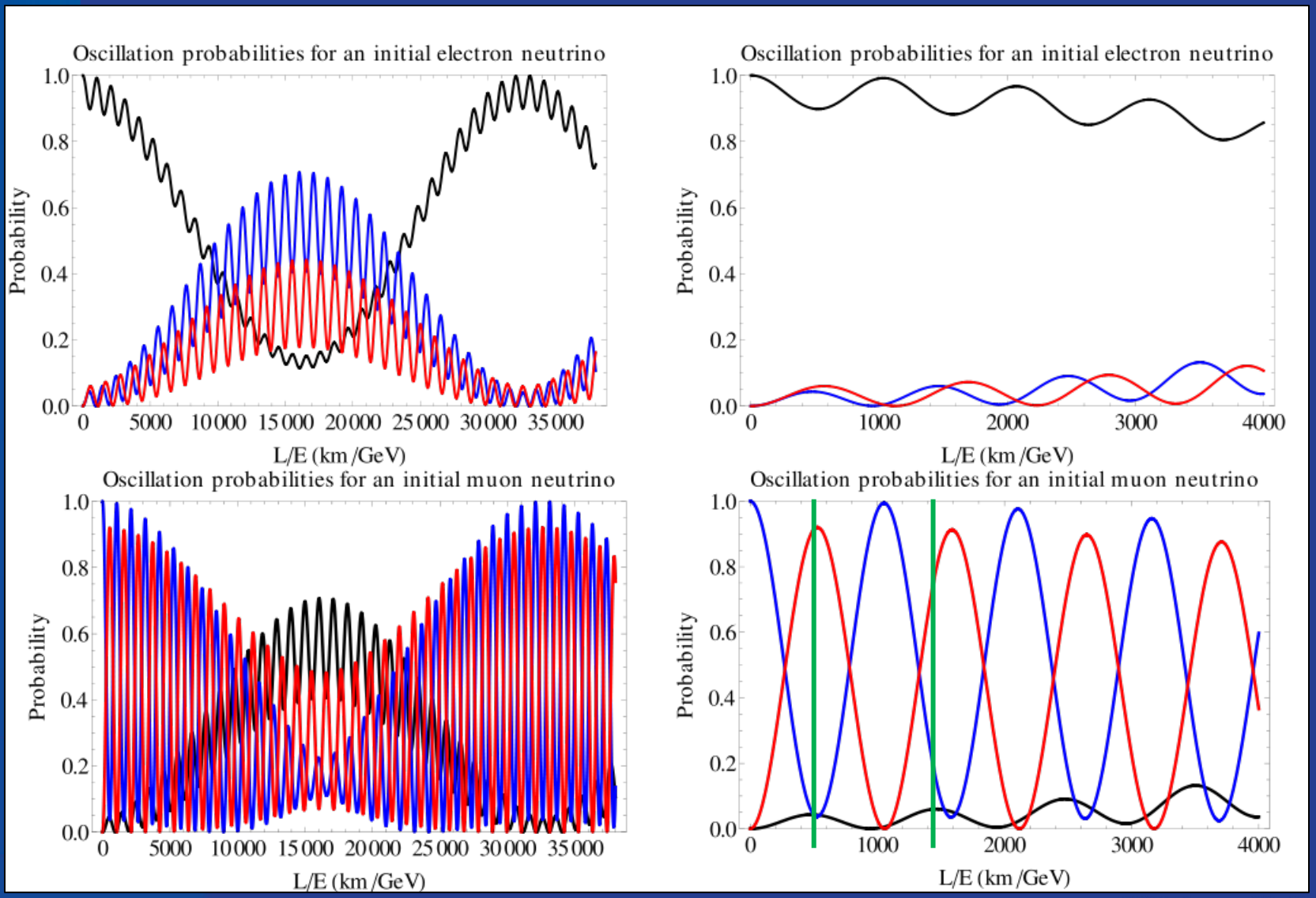
Probe even more massive NEW particles and dark sector particles by intense neutrino beams



Why multiple neutrino experiments?

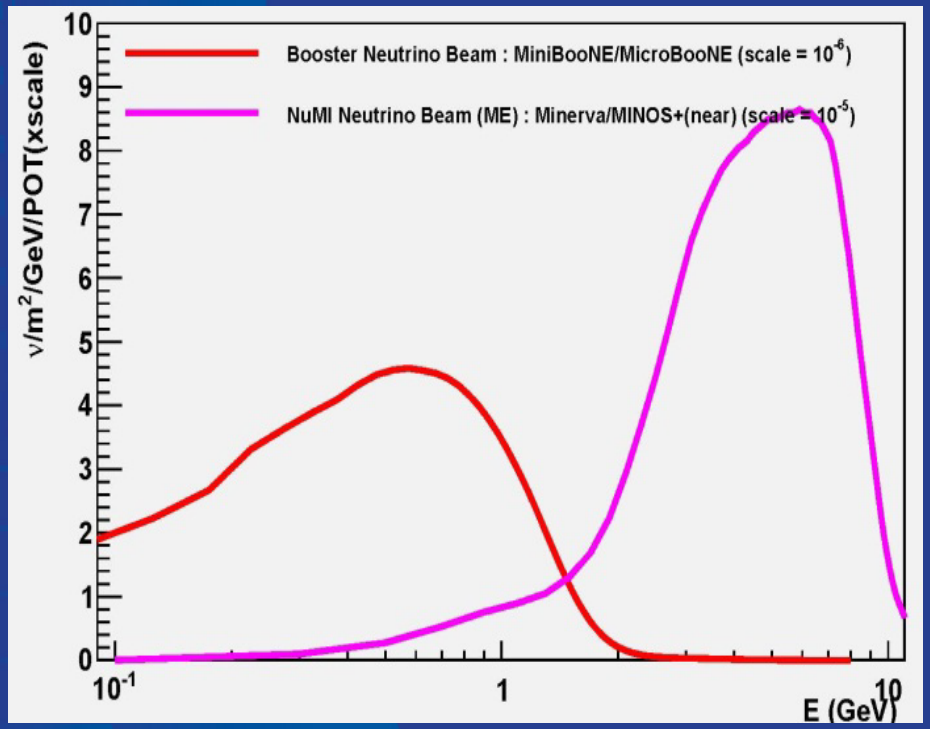
- Different aspects of neutrino physics drive different experiments; each limited by having to operate at one distance and one energy. Beams not used up!!
  - Long baseline:
    - MINOS (disapearance; broad energy spectrum, on-axis; high rate)
    - NOVA (electron appearance, off-axis, narrow energy spectrum; low rate)
    - LBNE (appearance and disappearance; on-axis high rate, best positioned to add second oscillation maximum)
  - Short baseline
    - MINERvA: cross sections different nuclei
    - MiniBOONE and MicroBOONE: anomalies

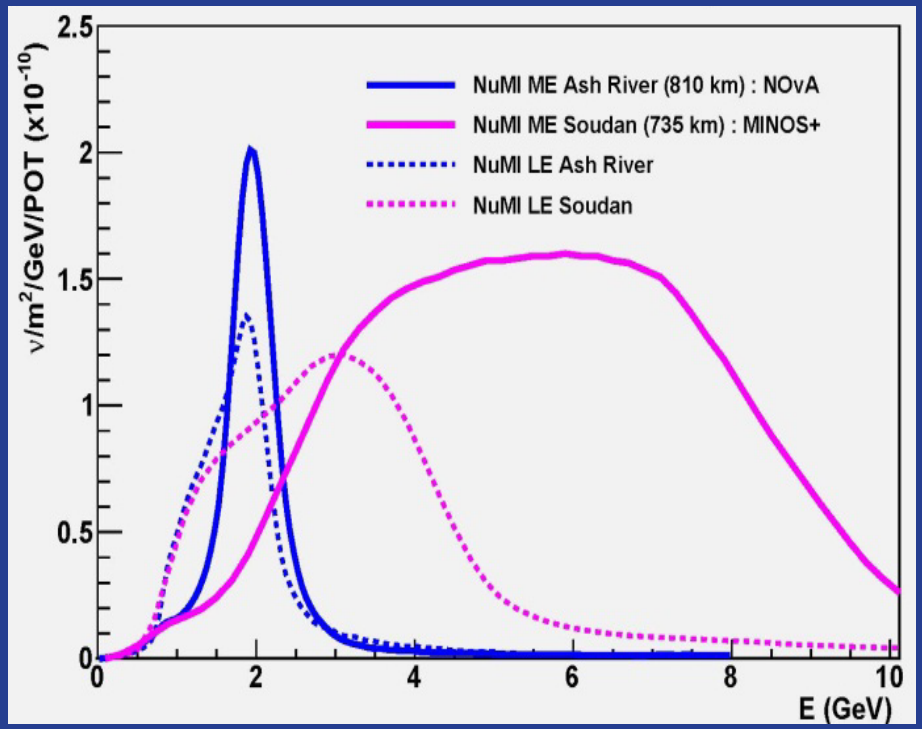
Neutrino oscillations



Neutrino beams

Diverse and intense beams: Unmatched in the world





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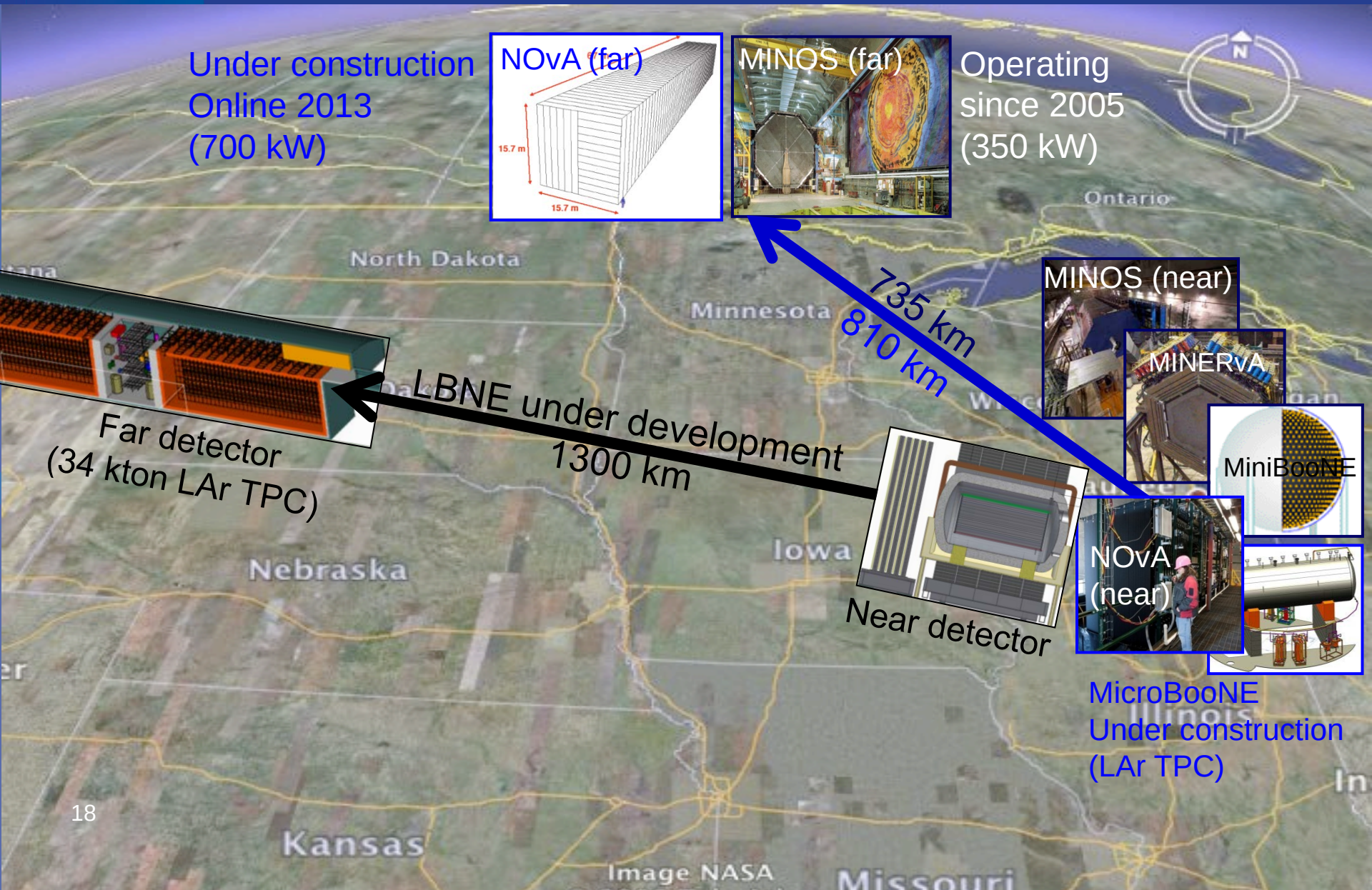
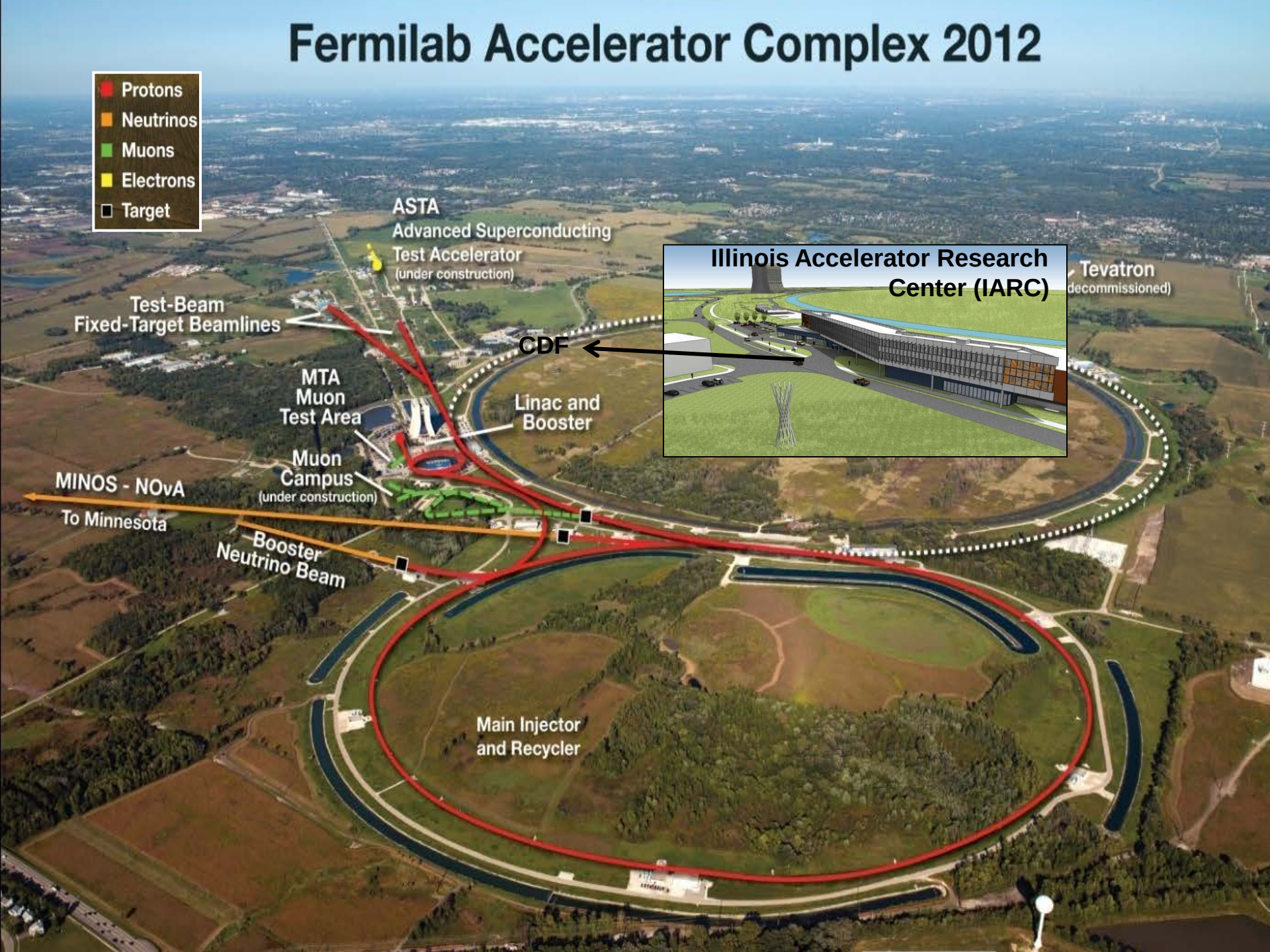
Neutrino program



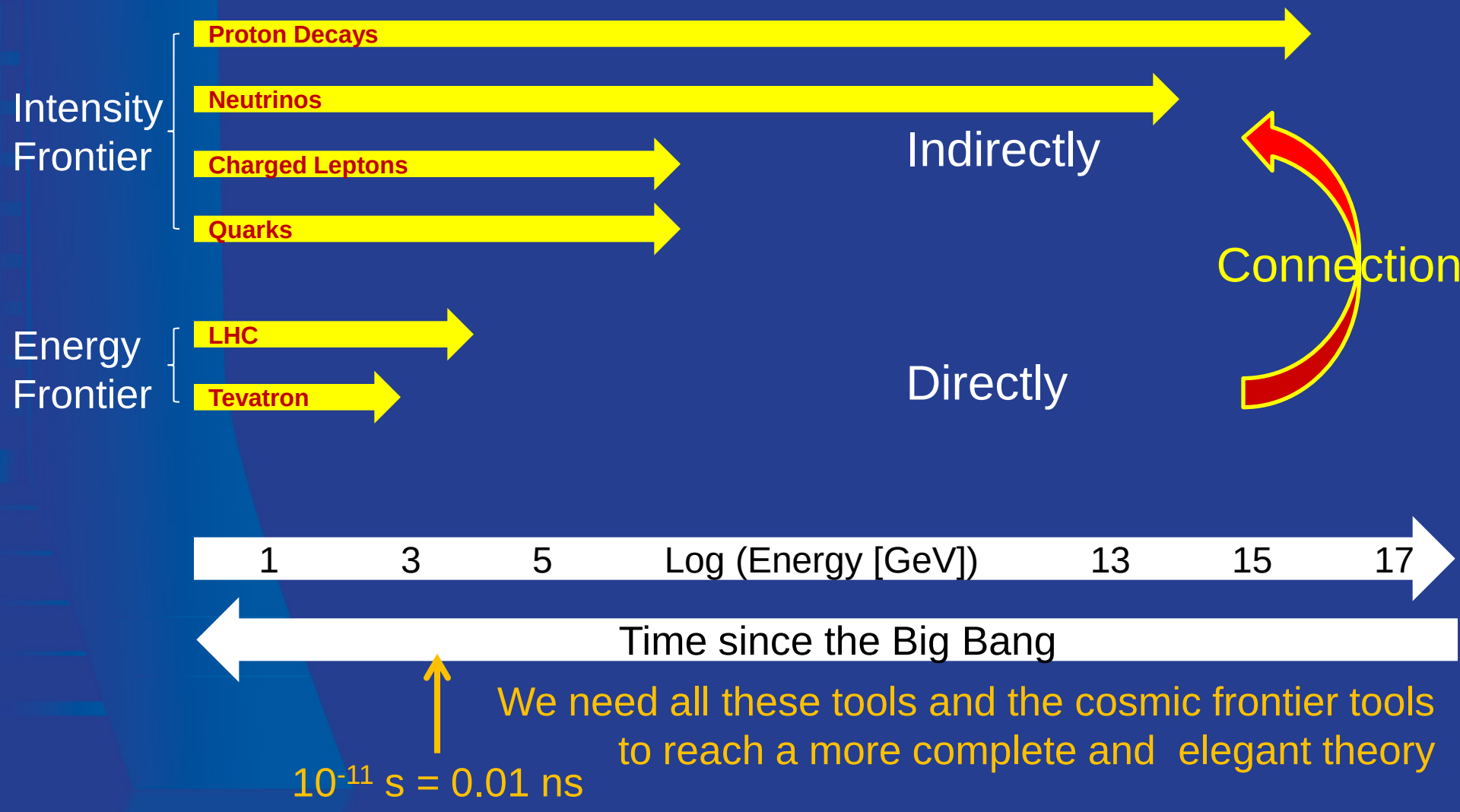
Fermilab Accelerator Complex 2012



Accelerator stewardship: IARC

Funding from the State of Illinois for new building; reconditioning of CDF assembly hall and provision of utilities thanks to DOE. IARC to act as a) portal to Fermilab accelerator facilities b) collaborative space for universities and industries c) training ground for accelerator technologists

The strategy and experimental reach

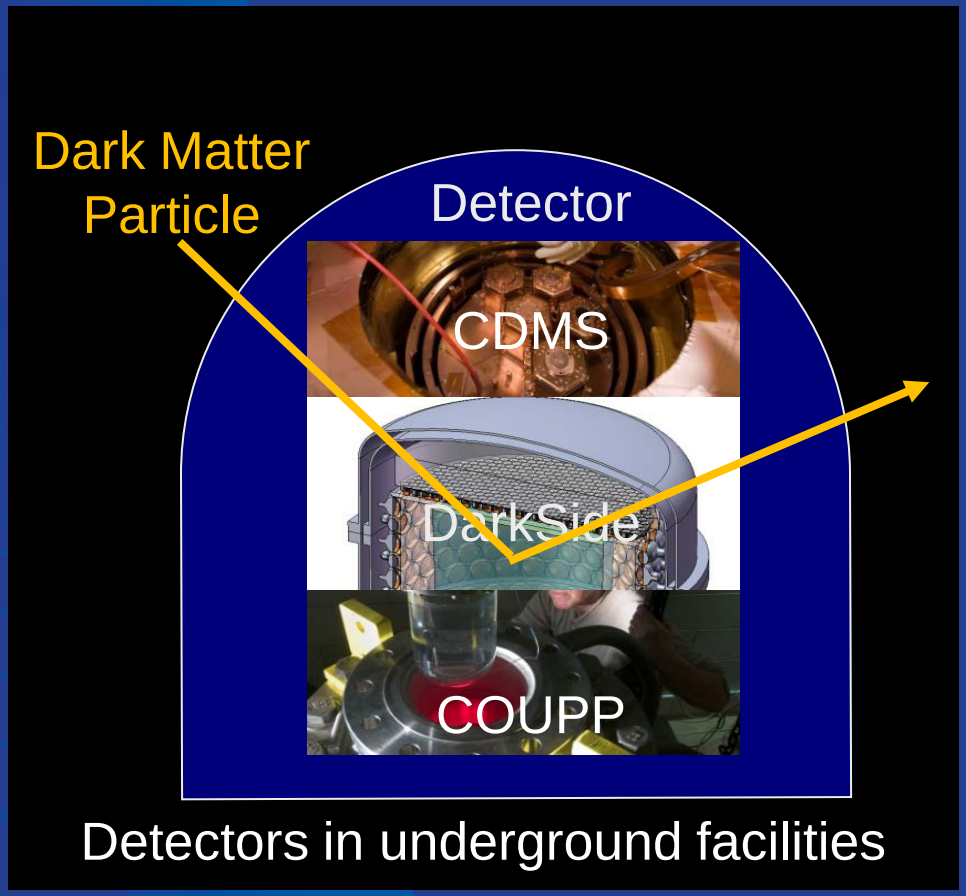


Cosmic Frontier at Fermilab

- Pioneering role starting three decades ago in establishing the connection between cosmology and particle physics: David Schramm, Rocky Kolb, Michael Turner…
- Leader of the Sloan Digital Sky Survey: established large surveys as cosmological tools (progenitor of DES, LSST, BigBOSS….)
- Pioneering work in dark-matter searches and the study of ultra-high-energy cosmic rays

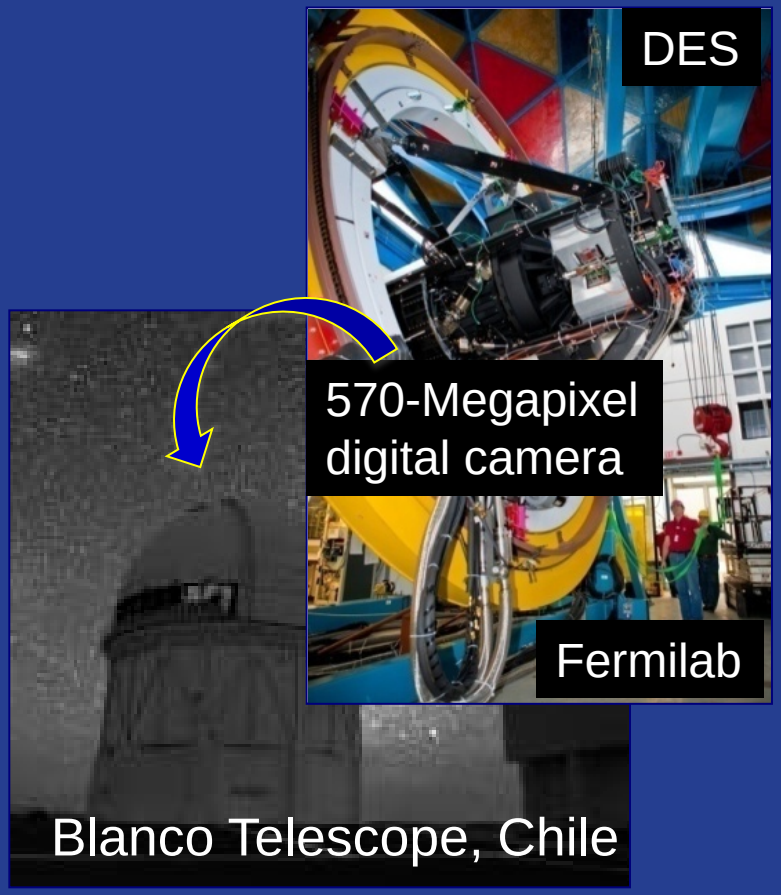
Cosmic Frontier at Fermilab

Dark Matter Detector



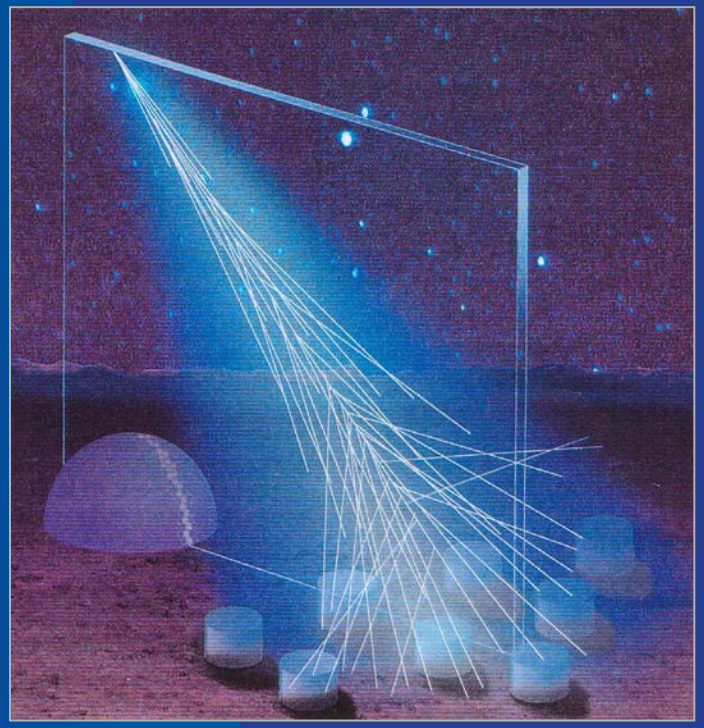
Detectors in underground facilities

Dark Energy Camera

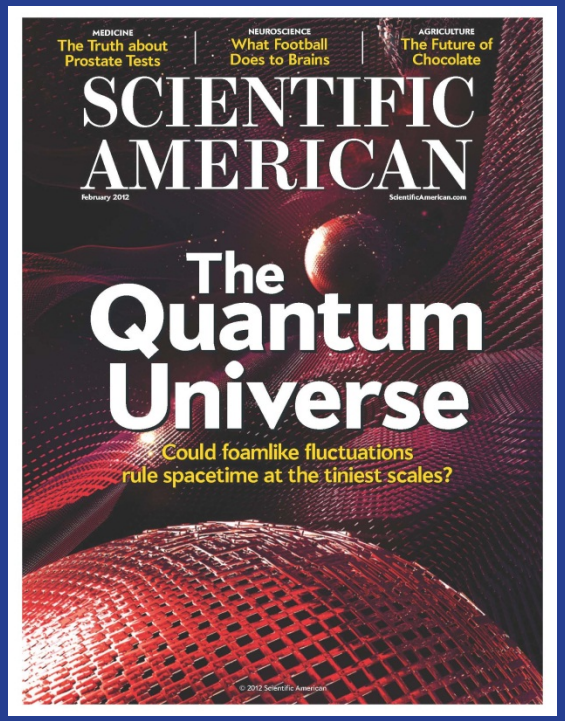


Cosmic Frontier at Fermilab

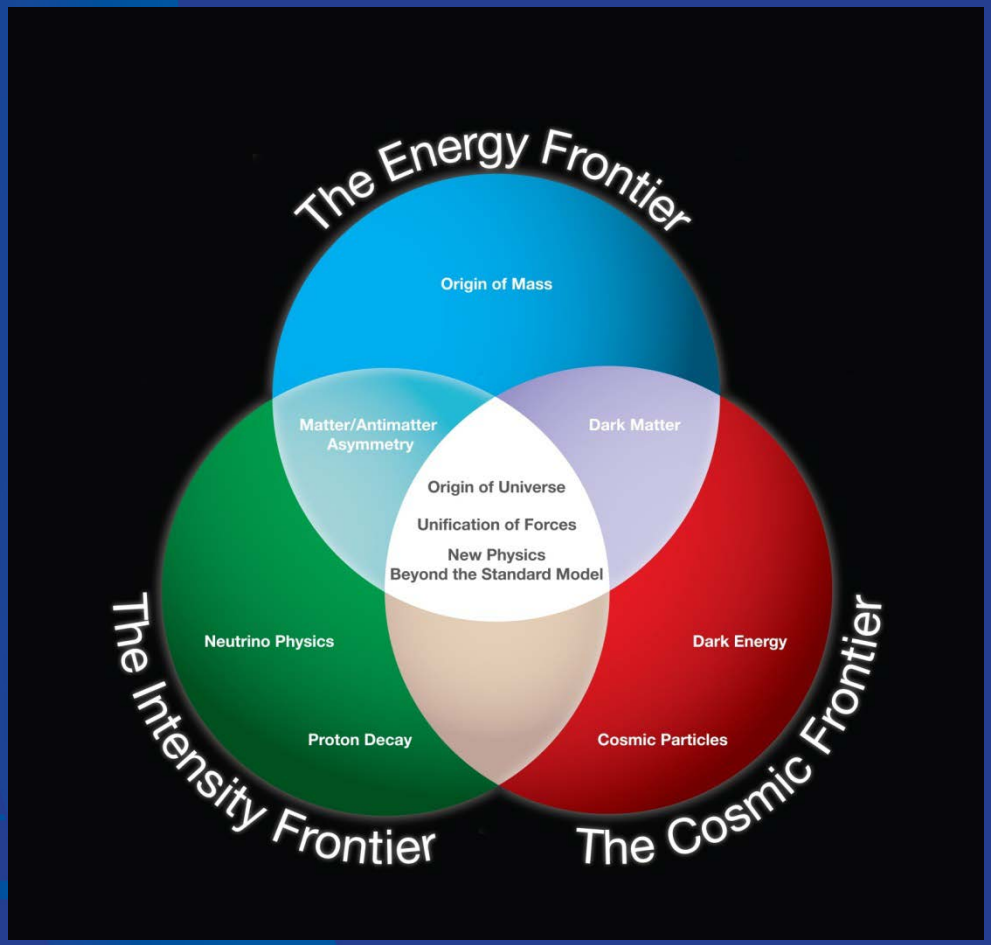
Exploring
Highest-Energy Cosmic-Ray Particles
(Auger)



Exploring
Quantum Space-time
(Fermilab Holometer)



Recent results and Fermilab's strategy

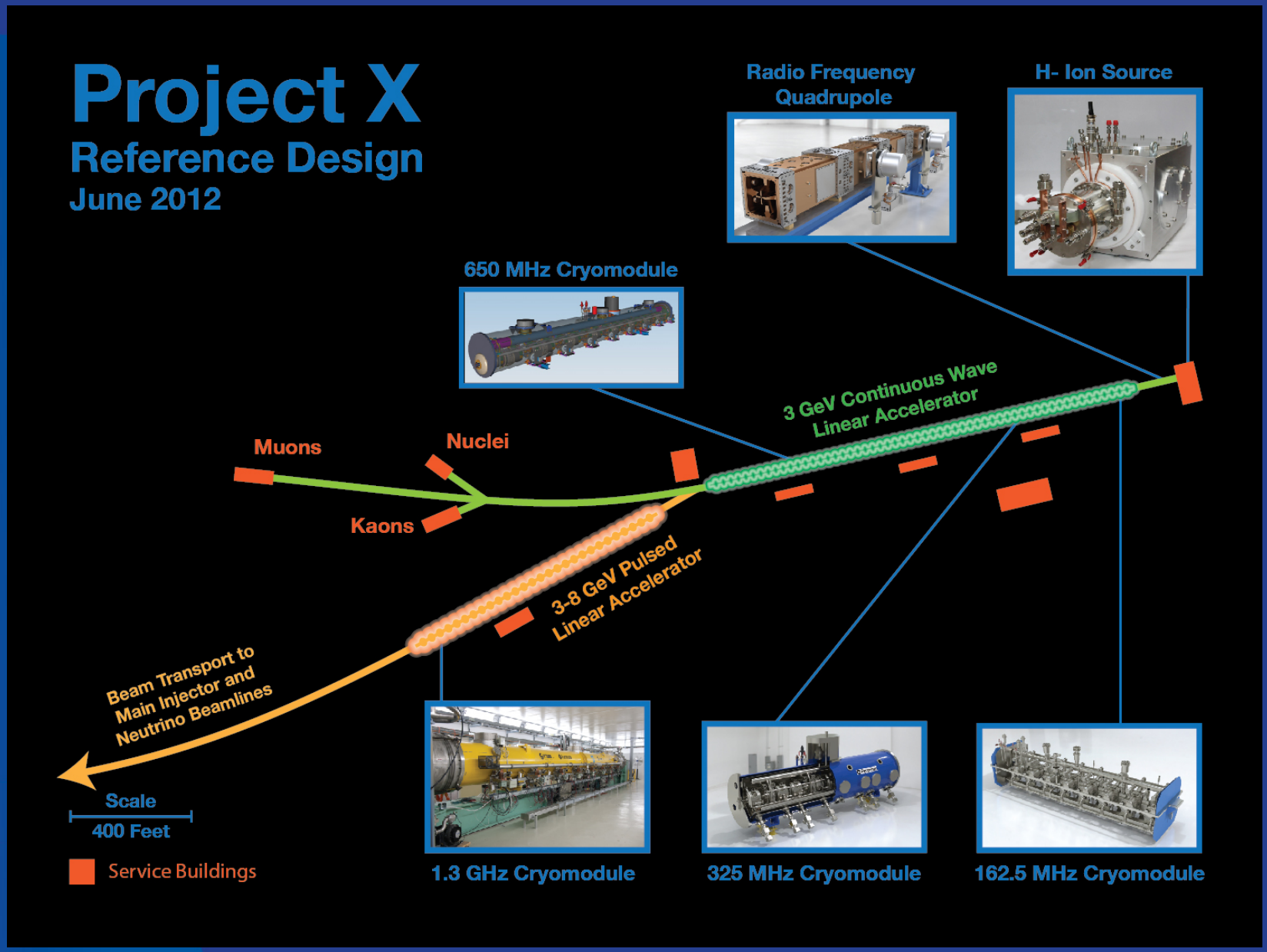


Recent results on θ_{13} and the LHC further validate our strategy:

- The gate for great neutrino physics is now wide open
- No low-energy structures at LHC (other than possibly the Higgs) → makes indirect intensity frontier methods more urgent
- If there are new structures they are likely to be at higher energies → a boost to muon collider R&D
- The cosmic frontier always critical: the right mathematical equations "remember" the history of the Universe

Program next decade

- LBNE: will have completed Phase 1 of the project and we would be running a 700kW beam to Homestake (or alternative). Assuming a detector on the surface, the second phase of LBNE would be to add mass underground to enlarge the program to proton decay and SN collapse in addition to better neutrino measurements
- Project X: a broad program with megawatts of continuous beam, ideal to lead at the Intensity Frontier
  - Neutrino, long/short base-lines, more than 2 MW to LBNE
  - Kaons where the Standard Model backgrounds are minimal and we are sensitive to many models
  - Rare muon decay with sensitivity to masses 10000 TeV
  - Symmetry violations through electric dipole moments in nuclei
  - Applications to transmutation, spallation targets, ADS



Argonne National Laboratory • Brookhaven National Laboratory • Fermi National Accelerator Laboratory • Lawrence Berkeley National Laboratory
Pacific Northwest National Laboratory • Oak Ridge National Laboratory / SNS • SLAC National Accelerator Laboratory • Thomas Jefferson National Accelerator Facility
Bhaba Atomic Research Center • Raja Ramanna Center of Advanced Technology • Variable Energy Cyclotron Center • Inter University Accelerator Center

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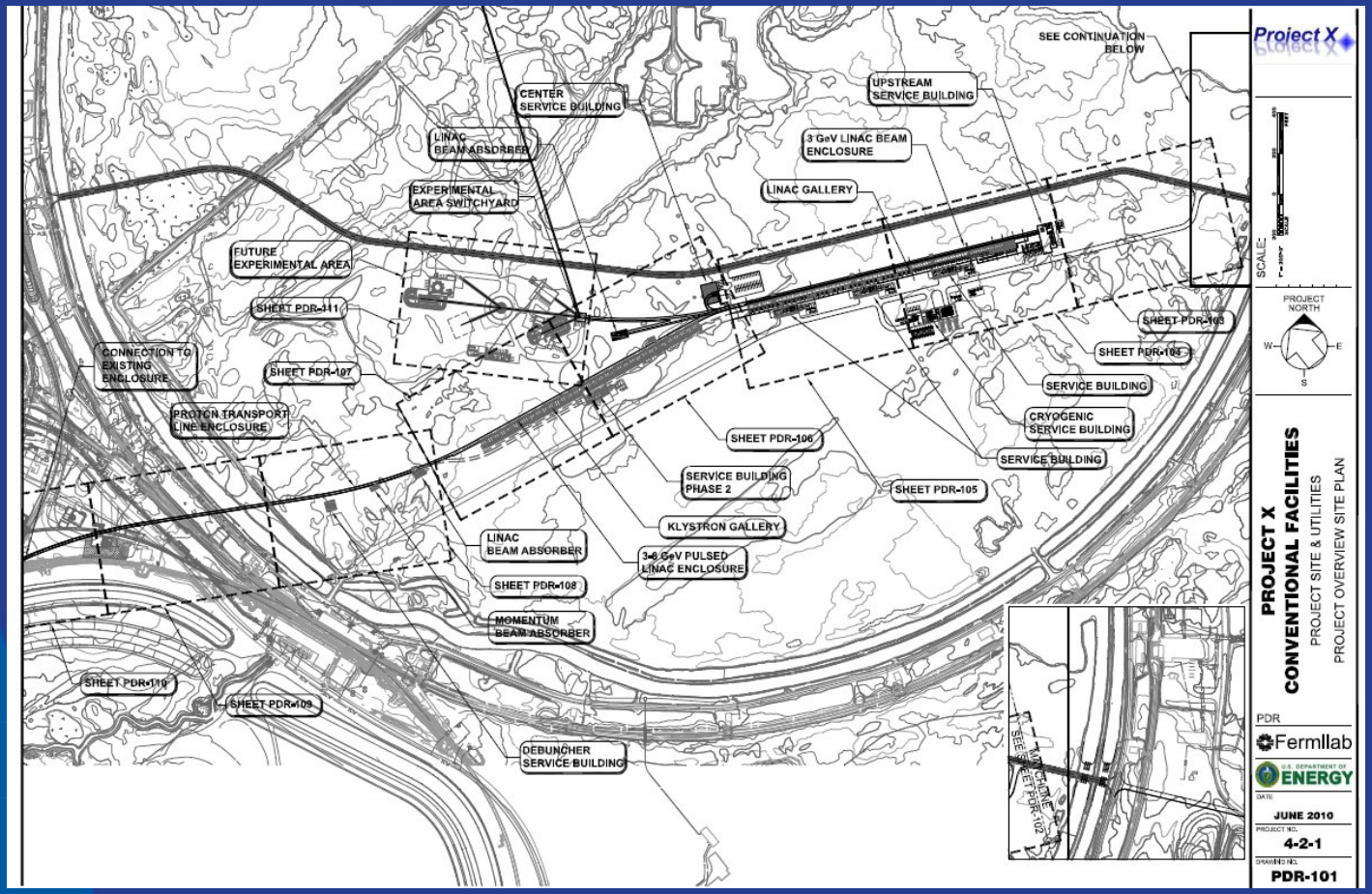
Project X Siting



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Project X

- Unique facility with a 3 MW at 3 GeV continuous-wave (CW) linac. Multiplies low-energy flux of protons at Fermilab by 100 with flexible timing patterns, ideal for rare decays
- Solves “proton economics”. Experiments run simultaneously at 3 GeV, 8 Gev and 60-120 GeV at high power
- Delivers 2+ MW to LBNE
- To be developed consistently to serve as front end of neutrino factory or muon collider
- Very strong partnership with India in the development of Project X and Intensity Frontier Program

Phased approach to Project X

- Project X can be broken into three phases, each for about a third of the cost
  - Phase 1: Up to 1 GeV. Retires old linac, increases flux of neutrinos x1.7, enhances existing Mu2e by x10, starts EDM, nuclear-physics and nuclear-material studies
  - Phase 2: Up to 3 GeV. Starts powerful Intensity Frontier experiments with kaons and short baseline neutrino programs
  - Phase 3: Up to 8 GeV; Multiplies power to LBNE by factor of 3; power at 8 GeV by several fold for short-baseline neutrino experiments
- Decision on when these phases should start can wait to much later in the decade

We value our many international partners: thank you for coming!

17 countries

27 countries

24 countries

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