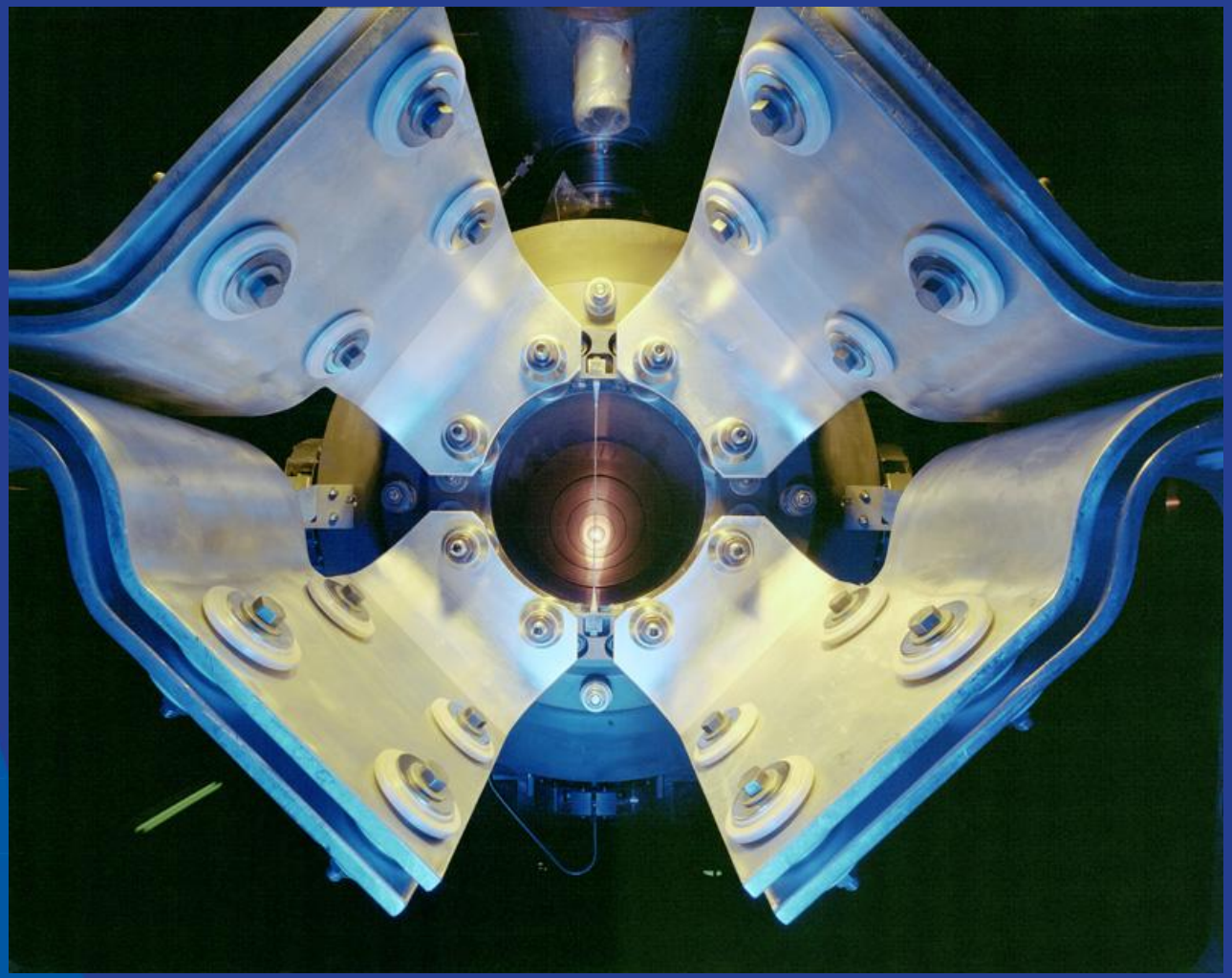
Introduction to Fermilab

Indian Delegation Visit, July 29th, 2011



U.S. DEPARTMENT OF ENERGY

Fermilab

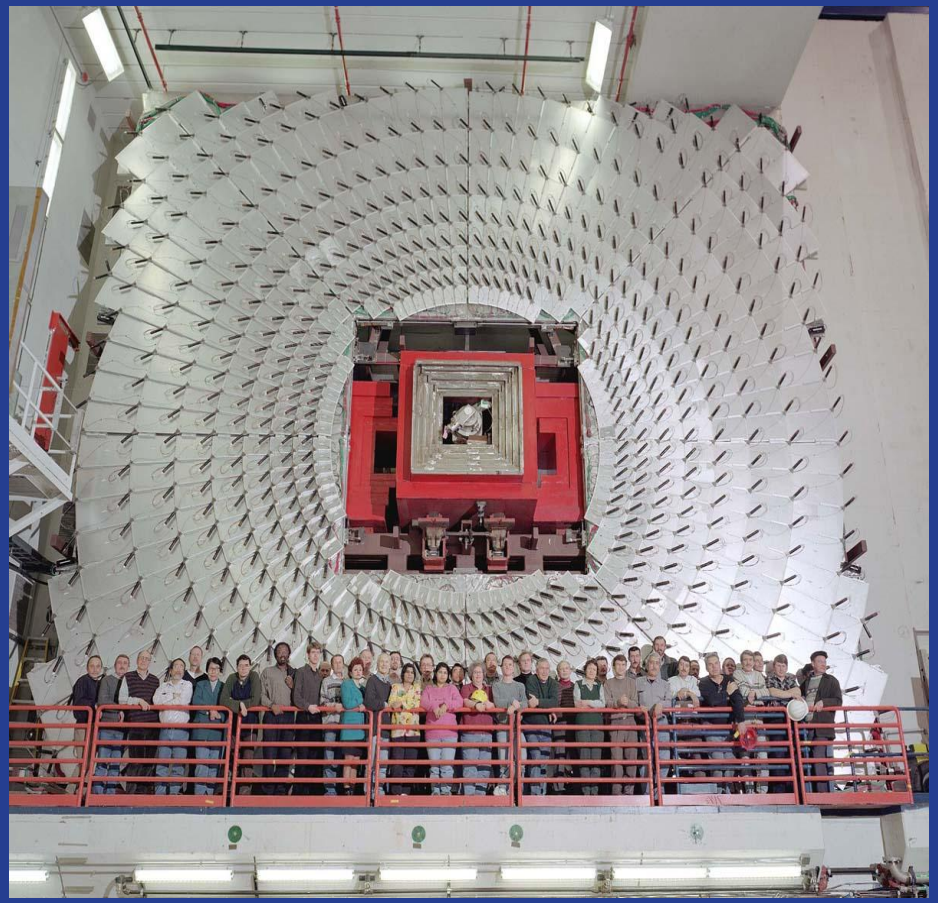
Fermilab characteristics (FY2010)

- 1925 employees; $ 399M
- 2300 users and visiting scientists
- 6800 acres, park-like site
- Tevatron: the only p-$\bar{p}$ collider through FY 2011

- Highest intensity neutrino beams (low and high energy)
- A world class particle astrophysics, particle theory and computation programs
- Advanced detector and accelerator technology

Mission: the national particle physics lab

- Enable the US community to tackle the most fundamental physics questions of our era
- Interdependence: integrate the universities and other laboratories fully into national and international programs

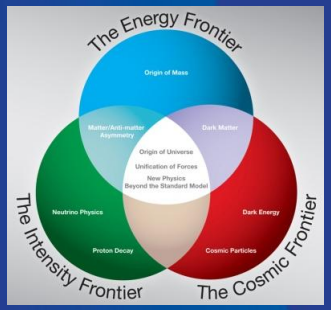


Program drivers: science

- The sense of mystery has never been more acute and evident
  - Where does mass come from?
  - Are there extra dimensions of space?
  - Why only three families of quarks and lepton?
  - Why is matter dominant?
  - What are the neutrino masses and what do they say?
  - Where are the heavy neutrino partners?
  - Does nature use supersymmetry?
  - Do the forces unify?
  - What is dark matter?
  - What is dark energy?

Program drivers: science

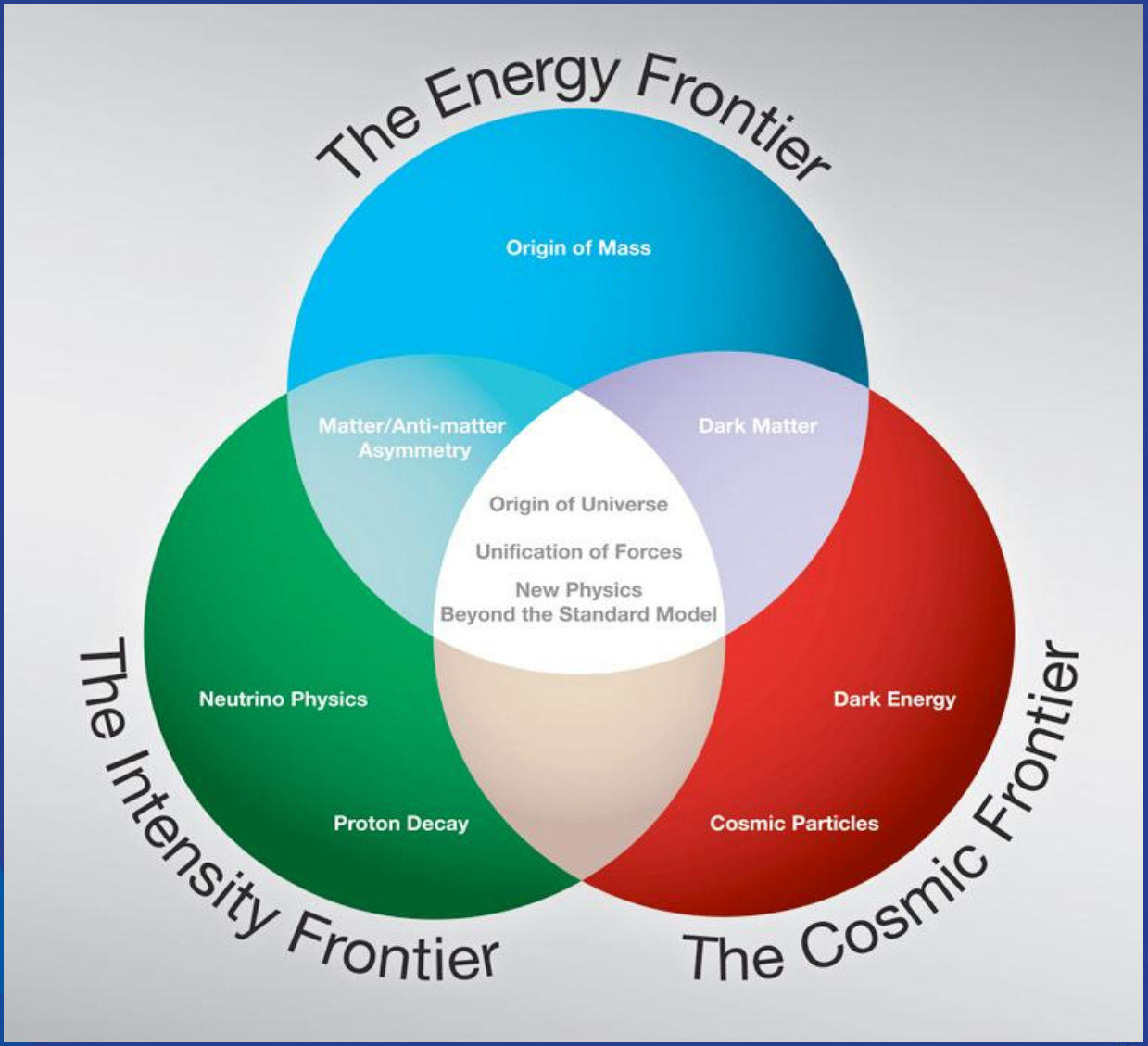
- These questions fire the imagination of the public and the press
- As the national laboratory for particle physics, we place the US in a leadership position in the world



Most elements are in place: exciting opportunities and national strategic plan at each of the three frontiers of particle physics: energy, intensity and cosmic frontiers

- Historically many applications in society through development of accelerator, detector and computational technology

Future program: at the three frontiers



Collaborative Efforts

- International collaborations for our programs

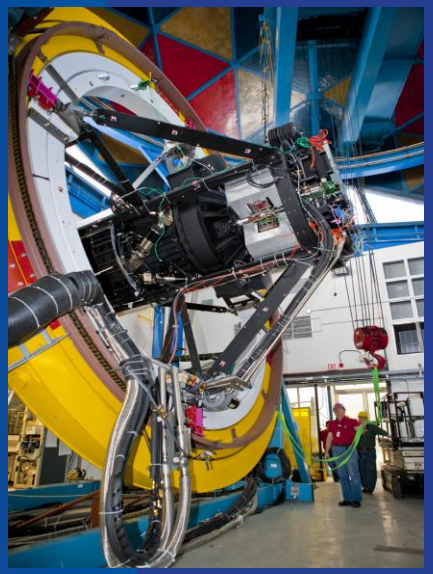
27 countries

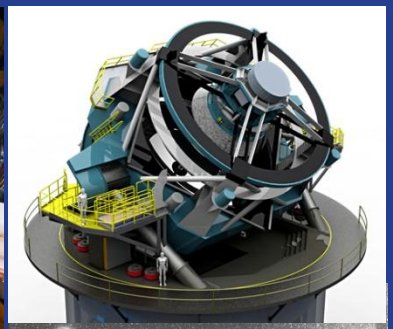
17 countries

24 countries

- Collaboration among DOE laboratories
  - Project X, ILC/SRF, Muon collider, neutrino factory, LHC Accelerator, many particle experiments, …
- Work for other DOE laboratories
- Argonne-UChicago-Fermilab Collaboration

Fermilab and the cosmic frontier

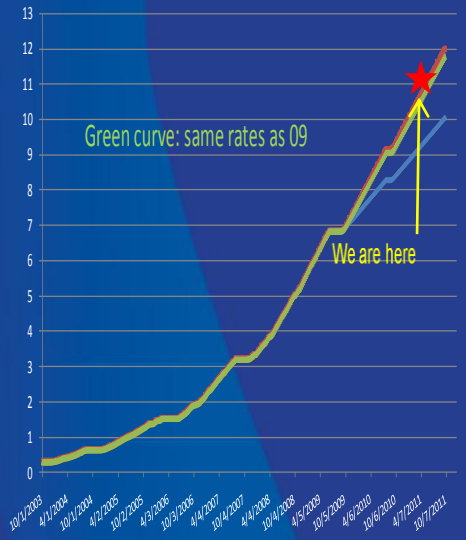



The principal thrust is the study of dark matter and dark energy through a series progressively more sensitive experiments

Fermilab and the energy frontier

Tevatron LHC	LHC	LHC Upgrades ILC??	LHC ILC, CLIC or Muon Collider



Energy frontier: the legendary Tevatron

Accelerator Innovations

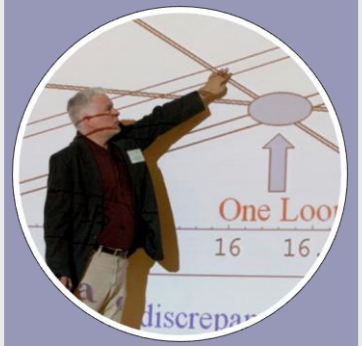
- First major SC synchrotron
- Industrial production of SC cable (MRI)
- Electron cooling
- New RF manipulation techniques

Detector innovations

- Silicon vertex detectors in hadron environment
- LAr-U238 hadron calorimetry
- Advanced triggering

Analysis Innovations

- Data mining from Petabytes of data
- Use of neural networks, boosted decision trees
- Major impact on LHC planning and developing
- GRID pioneers



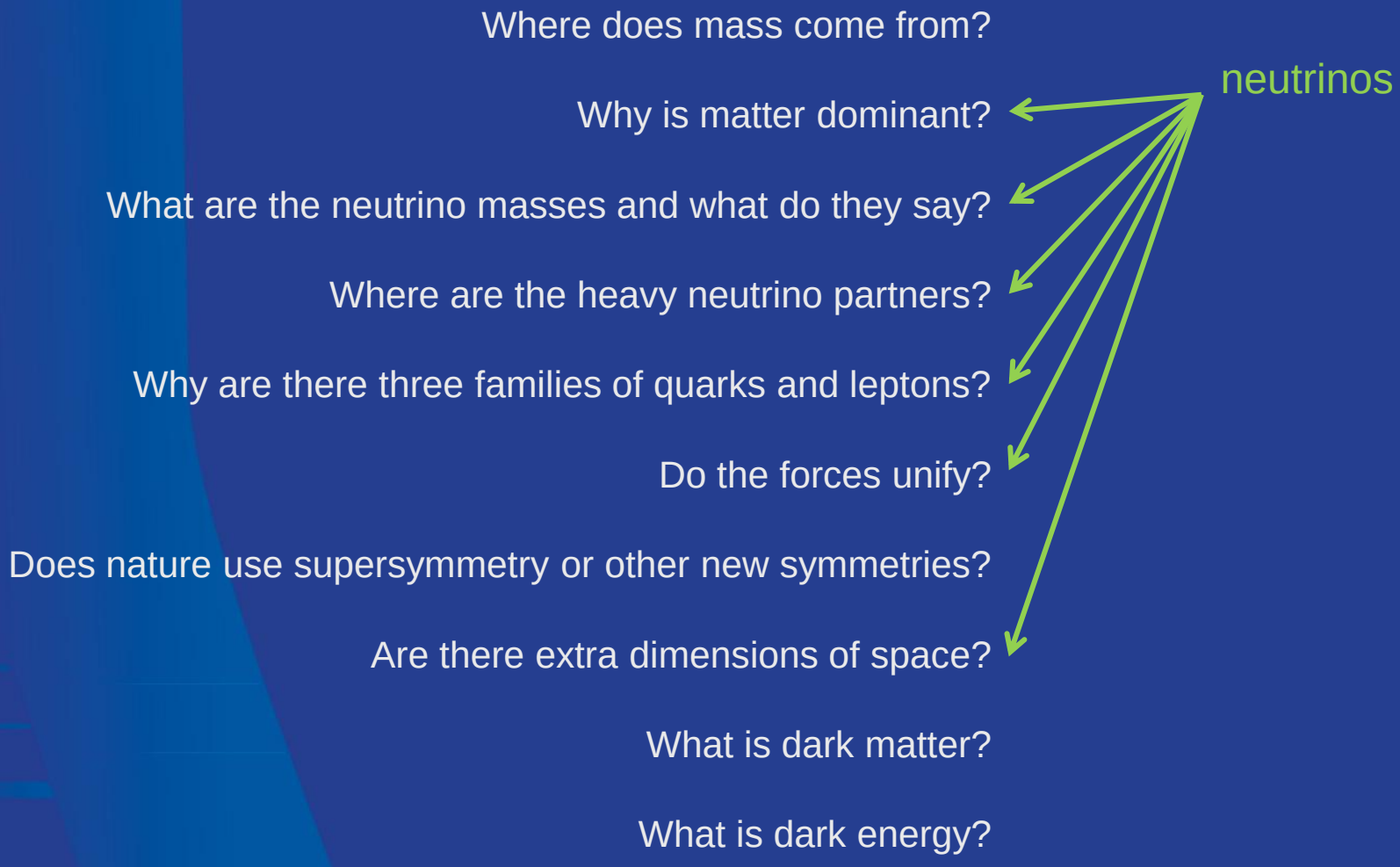
Major discoveries

- Top quark
- B_s mixing
- Precision W and Top mass → Higgs mass prediction
- Direct Higgs searches
- Ruled out many exotica

The next generation

- Fantastic training ground for next generation
- More than 500 Ph.D.s
- Produced critical personnel for the next steps, especially LHC

Neutrinos and the big questions



Neutrinos this decade

ν SM: Pattern of neutrino masses and mixings

- Long baseline experiments: MINOS → NOvA → (LBNE)

Beyond ν SM: Explore cracks in our understanding: sterile neutrinos? Anomalous interactions?

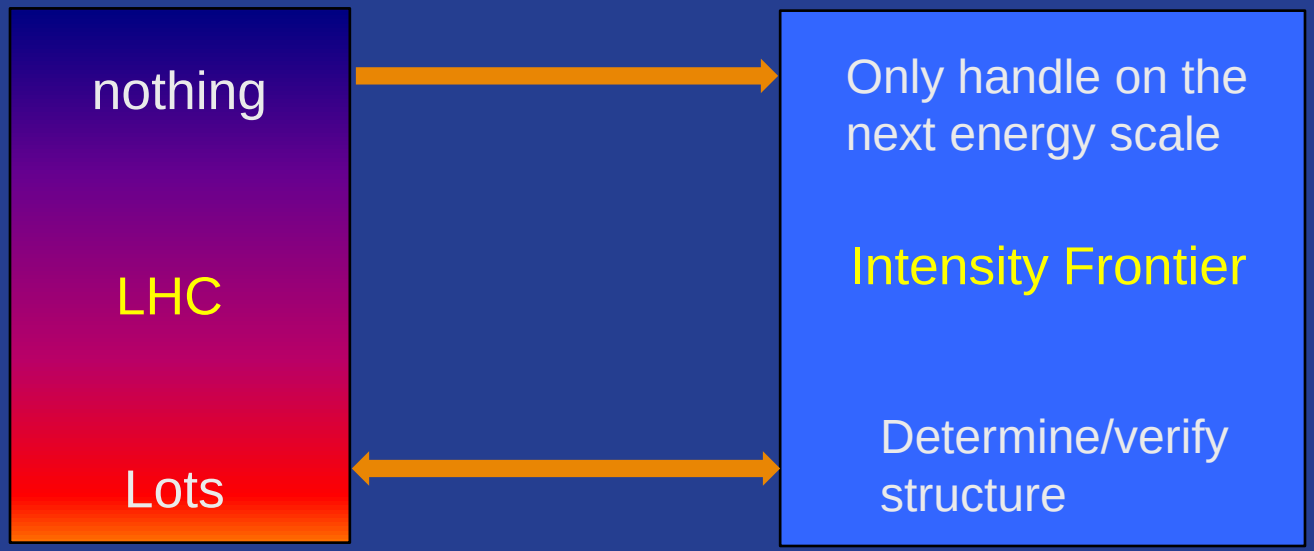
- Short baseline experiments: MiniBooNE → MicroBooNE
- Long baseline experiments: MINOS → MINOS+

Neutrino physics measurements as a probe of nuclear structure and support of oscillation experiments

- Dedicated experiment: MINERvA

Program this decade

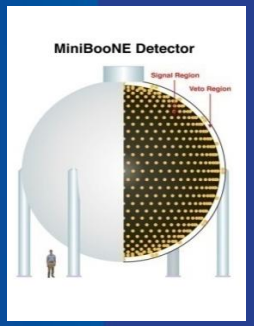
- Also in the intermediate term, a series of world-class experiments exploiting the intense beams:
  - g-2: anomalous magnetic moment of the muon
  - Mu2e: direct muon to electron conversion
  - SeaQuest: nuclear physics Drell-Yan process to study the structure of the nucleon in the nuclear environment

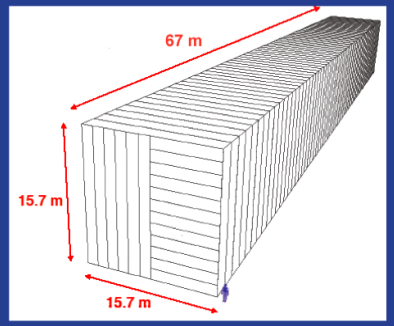


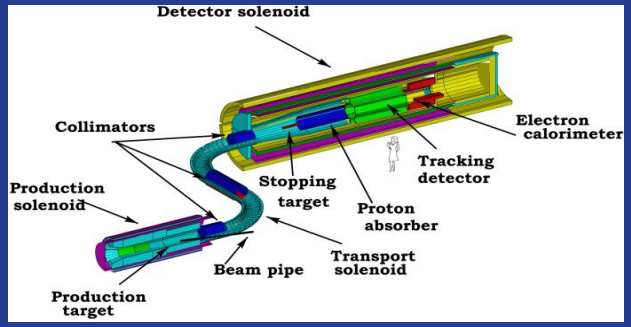
Program next decade

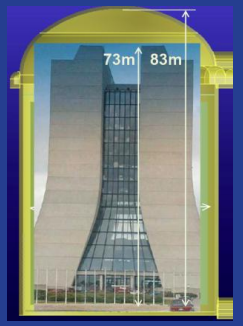
- LBNE (2+ MW): the long-base line experiment
  - Neutrino mass spectrum (mass hierarchy)
  - Matter-antimatter symmetry
  - Neutrino/antineutrino differences
  - Anomalous interactions
- Project X: a broad program with megawatts of continuous beam, ideal to lead at the intensity frontier
  - Neutrino, 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 including supersymmetry
  - Rare muon decay with sensitivity to masses 1000 TeV
  - Symmetry violations through electric dipole moments in nuclei
  - Applications to transmutation, spallation targets, ADS

Fermilab and the intensity frontier

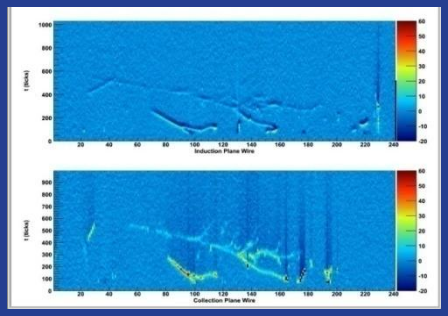


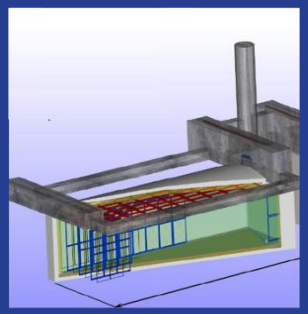






MINOS MiniBooNE MINERvA SeaQuest	NOvA MicroBooNE g-2 MINERvA MINOS SeaQuest	NOvA g-2 LBNE Mu2e	Project X+LBNE μ, K, nuclear, … ν Factory ??



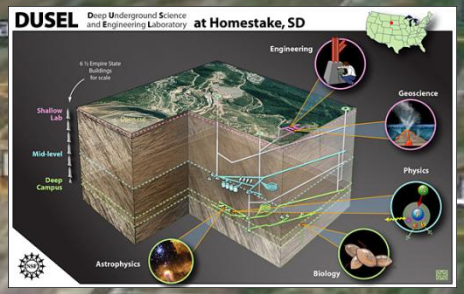


In the long term: LBNE

- LBNE is a key experiment in the neutrino area and already engages a very broad collaboration
- It can start with the 700kW beam developed for NOvA (facilities have to be built towards the DUSEL direction)
- It would ultimately use over >2000kW in the *Project X* era

Long Baseline Neutrino Experiment

CD 0: January 2010



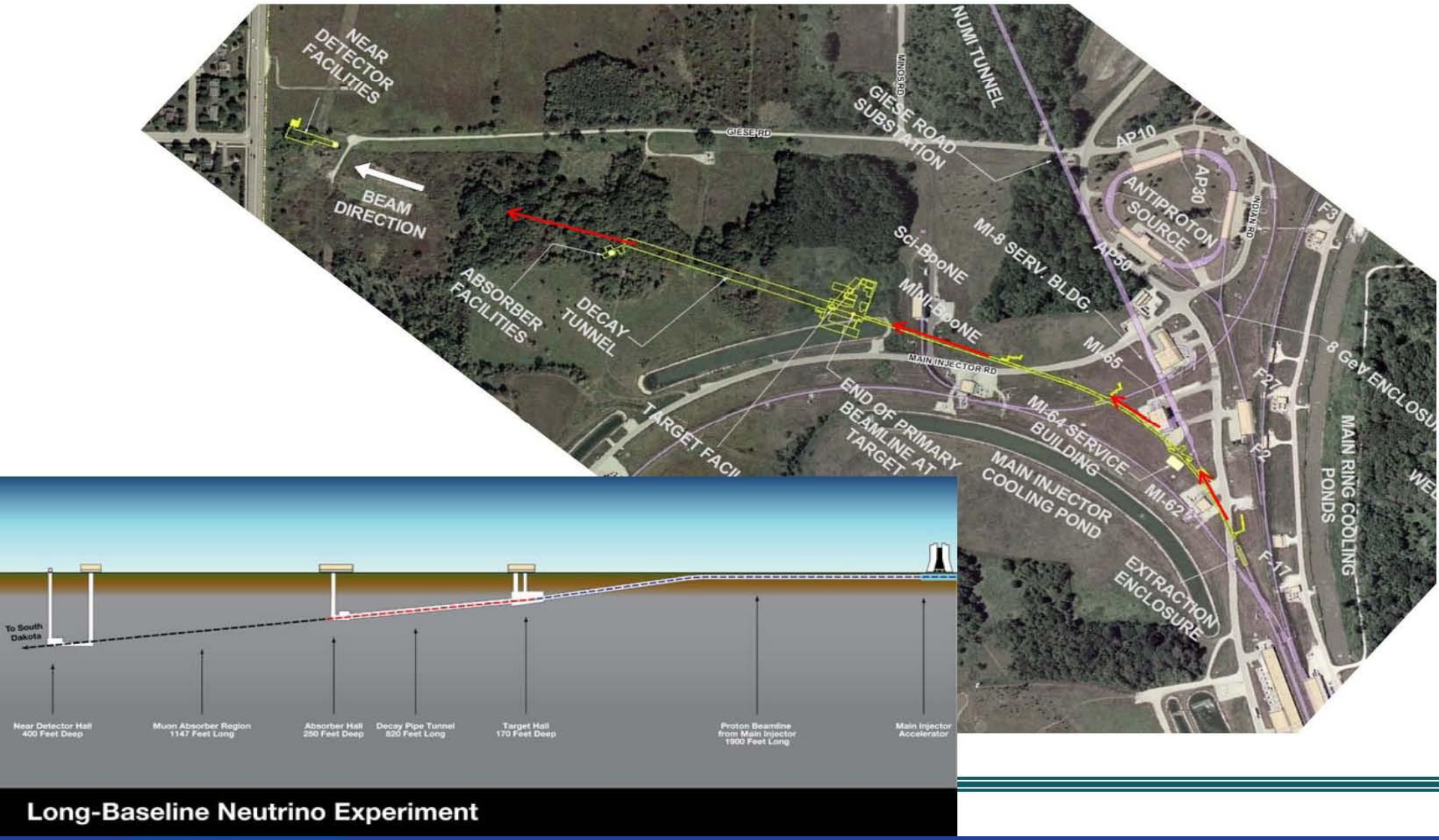
1300 km

Collaboration: 306 members

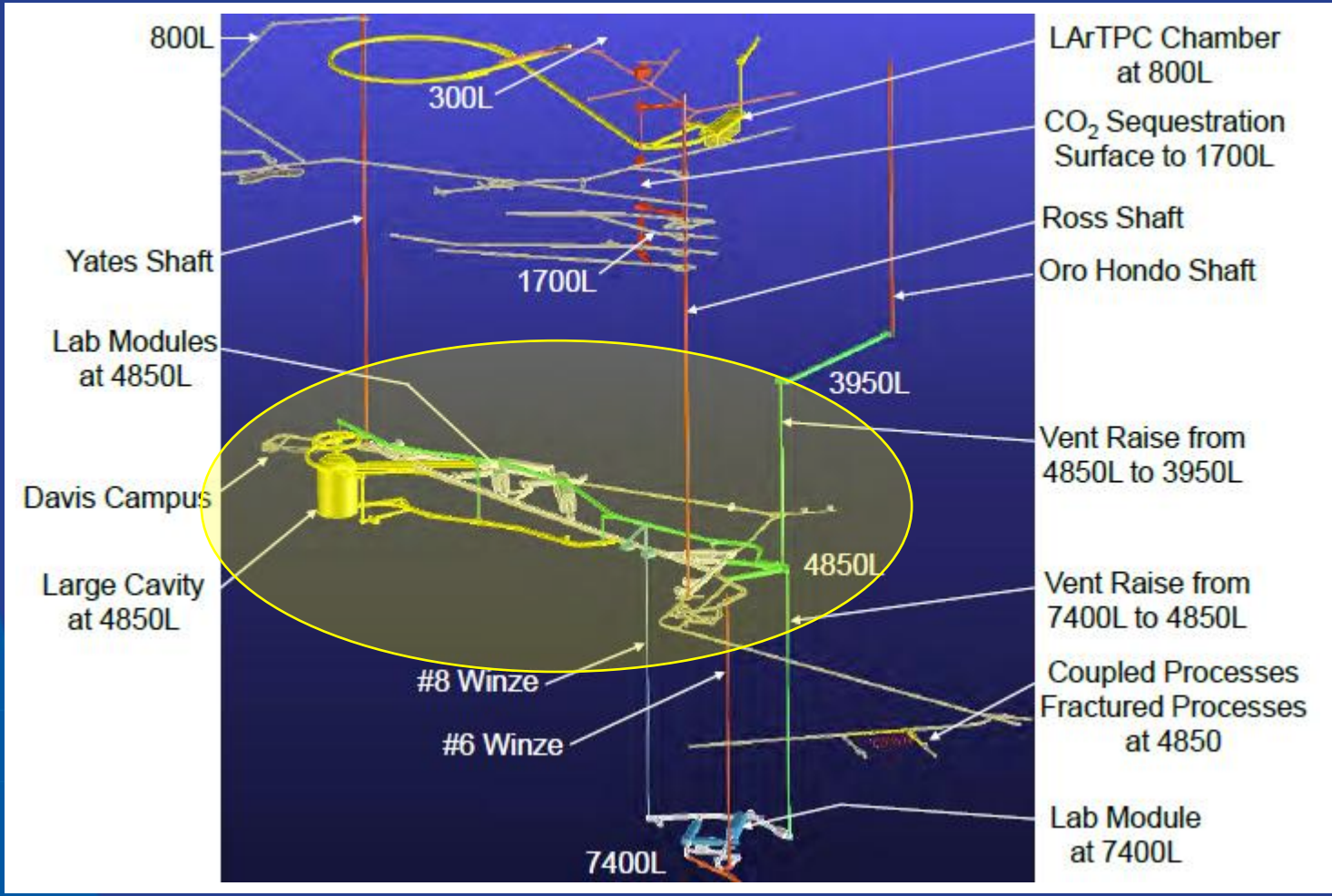
58 institutions (6 US labs) and 5 countries (India, Italy, Japan, UK, US)

Continue to grow!

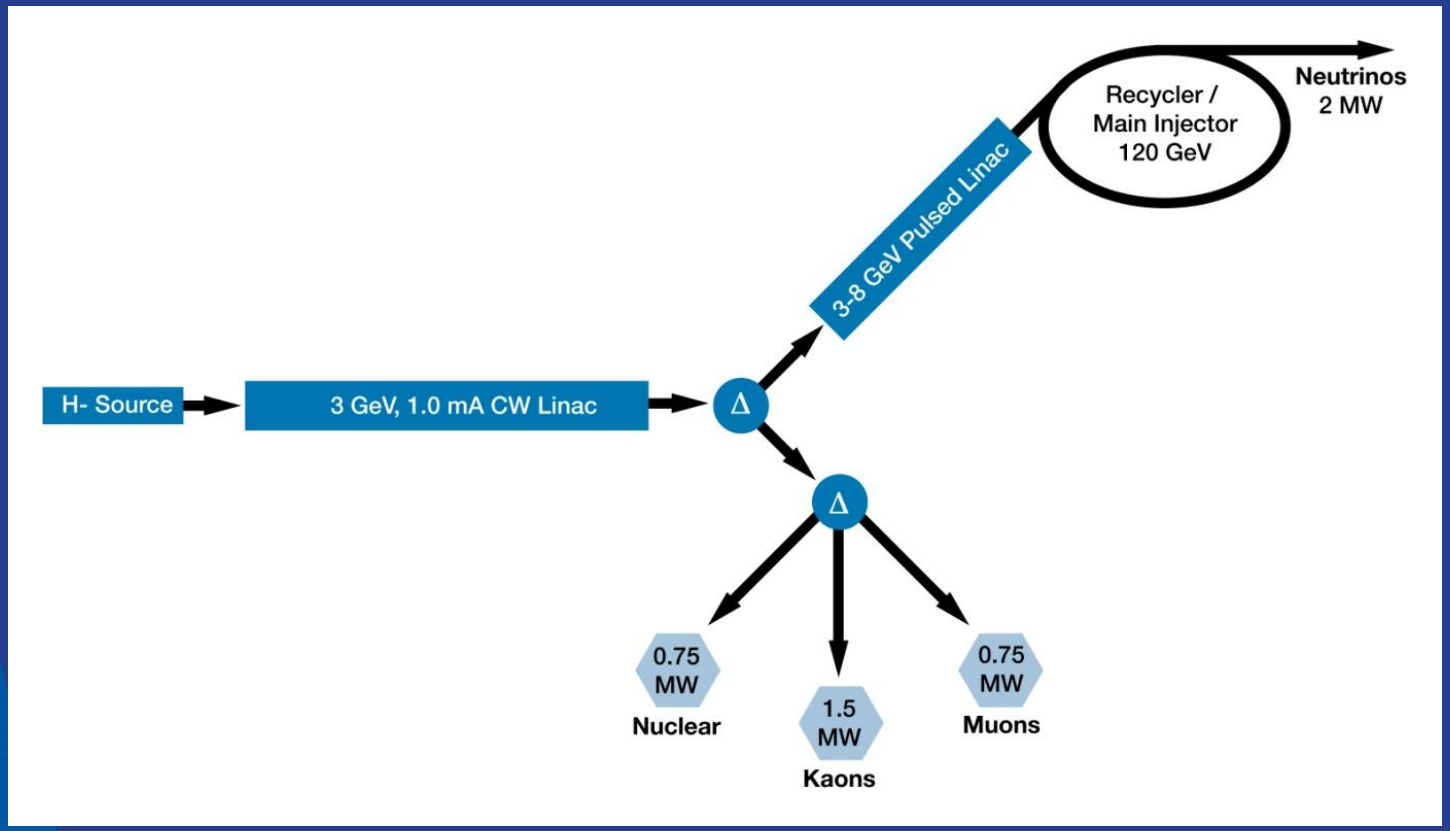
Conceptual Design Overview – Neutrino Beam



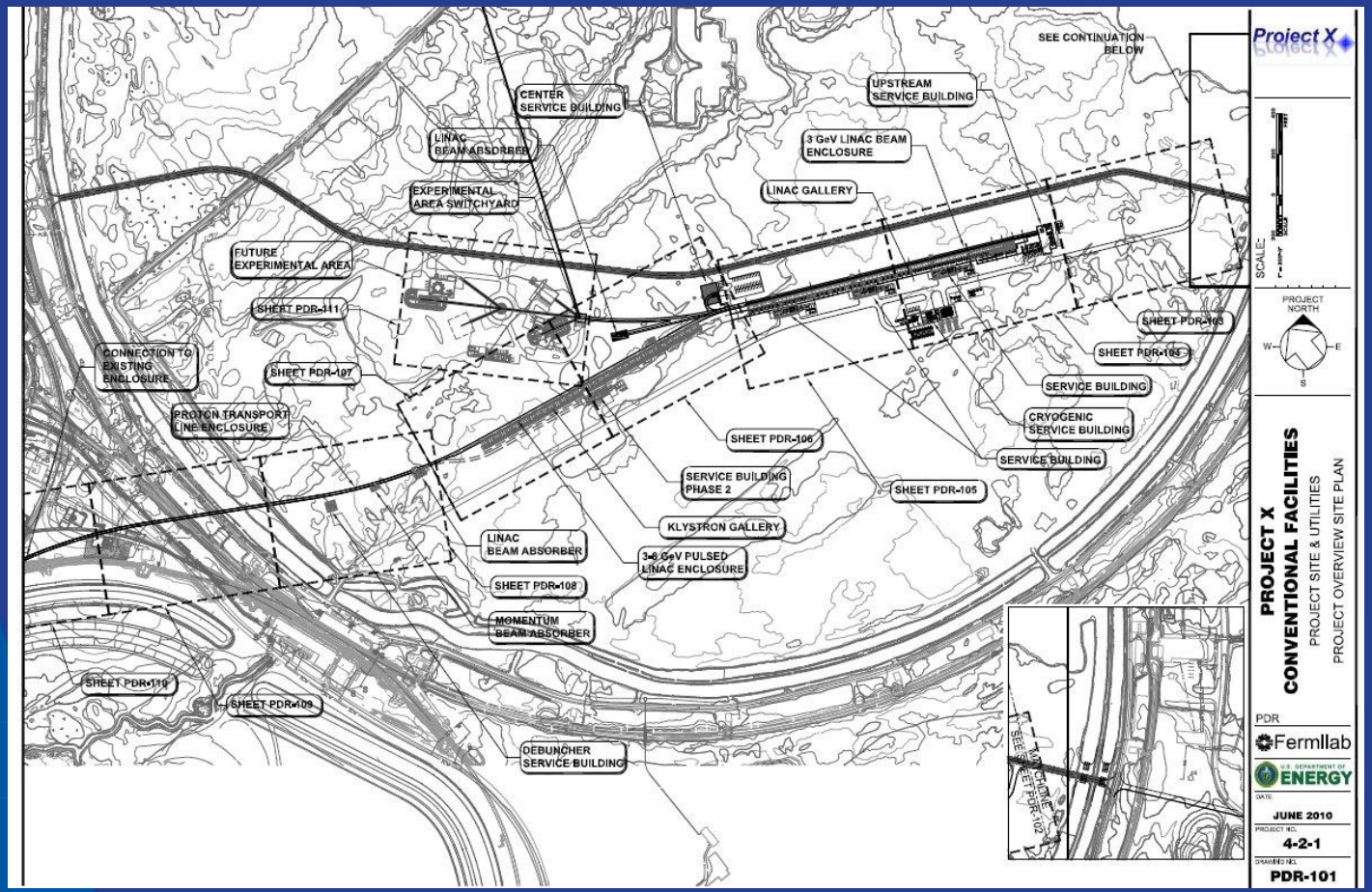
Homestake Lab Layout



Project X Reference Design



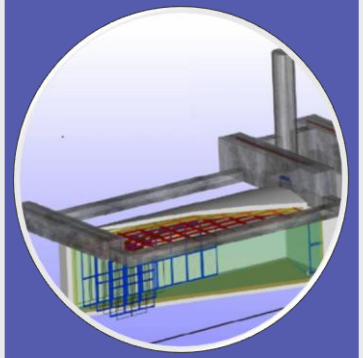
Project X Siting



Project X: International Collaboration

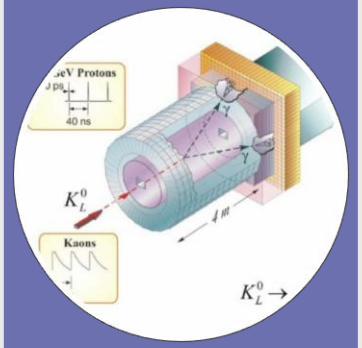
- India is the major partner in the R&D phase and we hope the major partner during the construction
- We have worked with Indian Laboratories for the last several years and have built an extremely valuable collaboration for both partners
- The collaboration long range goals are Project X in the US, including the physics program, and development of superconducting linacs in India

Project X: new experiments



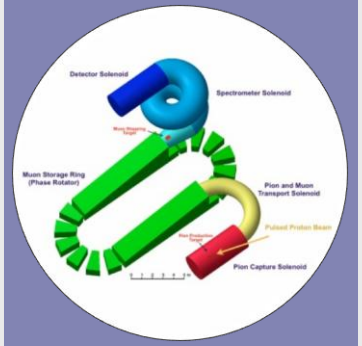
Neutrinos

- Matter-antimatter asymmetry
- Neutrino mass spectrum
- Neutrino-antineutrino differences
- Anomalous interactions
- Proton decay
- SuperNova bursts



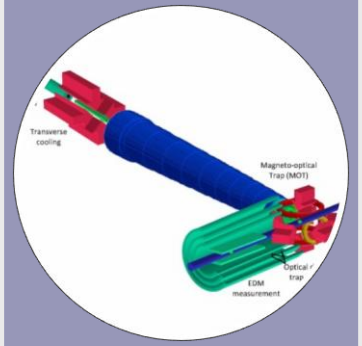
Kaons

- Physics beyond the Standard Model
- Minimally flavor violating supersymmetry
- Elucidation of LHC discoveries
- Two to three orders of magnitude increase in sensitivity



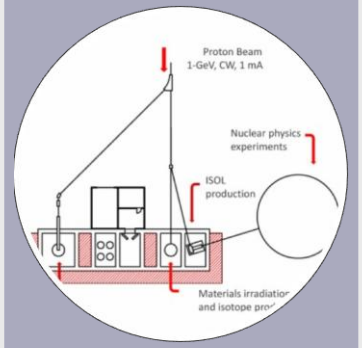
Muons

- Oscillation in charged leptons
- Physics beyond the Standard Model
- Elucidation of LHC physics
- Sensitive to energy/mass scales three orders of magnitude beyond LHC



Nuclei

- New generation of symmetry-test experiments
- Electric Dipole Moments
- Three or more orders of magnitude increase in Francium, Radium, Actinium isotopes



Energy Applications

- Transmutation experiments with nuclear waste
- Spallation target configurations
- Materials test under high irradiation
- Neutron fluxes under various configurations relevant to ADS

Project X: technology innovation

CW Linac Design

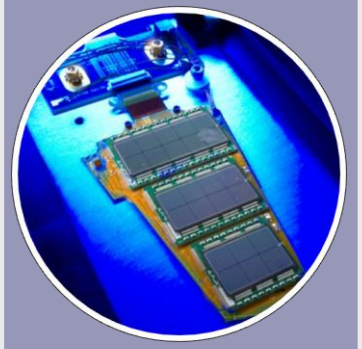
- Multi-MW/high duty factor (continuous wave) proton linac
- First of a kind, all superconducting RF design
- Low beam loss/high reliability

SRF Accelerating Modules

- State-of-the-art performance
- High Q_0/high gradient
- Low-β spoke resonators
- Medium-β elliptical resonators
- U.S. industrial development

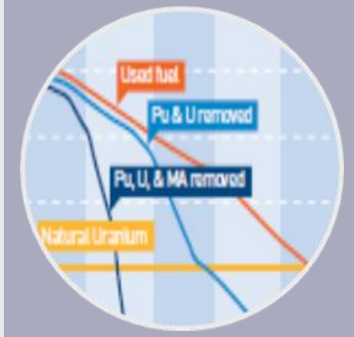
Fast Chopper

- Revolutionary concept
- Programmable bunch patterns at 162 MHz
- Applications beyond HEP



Detector Development

- High speed electronics & triggering
- Rad hard detectors
- Large Liquid Argon Time Projection Chambers
- Cryo-electronics
- High power targeting



Transmutation

- MW-class CW beams at 1 GeV
- Technology demonstration
- Benchmarking experiments to validate concepts

Project X and the big questions

Where does mass come from?

Why is matter dominant?

What are the neutrino masses and what do they say?

Where are the heavy neutrino partners?

Why are there three families of quarks and leptons?

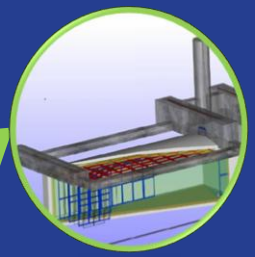
Do the forces unify?

Does nature use supersymmetry or other new symmetries?

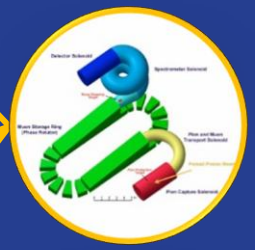
Are there extra dimensions of space?

What is dark matter?

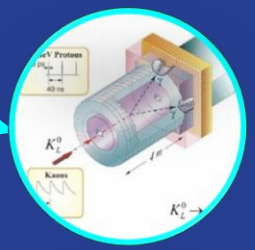
What is dark energy?



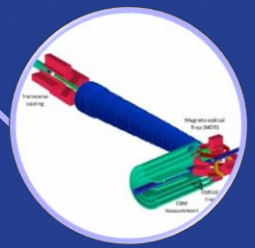
neutrinos



muons



kaons



Nuclei (EDMs..)

Education (K-12, undergrads, public)

http://www.fnal.gov/pub/education/k-12_programs.html

- NSF, DOE, Fermilab Friends, Fee-based cost recovery
- Typical per year: about 45,000 teachers, students, and general public touched by Fermilab
  - Regular teacher workshop: 100
  - Summer interns: 50
  - Summer teachers: 20
  - Students field trip: 8,500
  - Science adventure classes: 1,600
  - Visitors to science center: 3,000
  - Tours: 3,300 students;120 teachers;7,700 public
  - Classroom presentation: 15,000
  - Science Chicago Fest: 6,000
  - …..