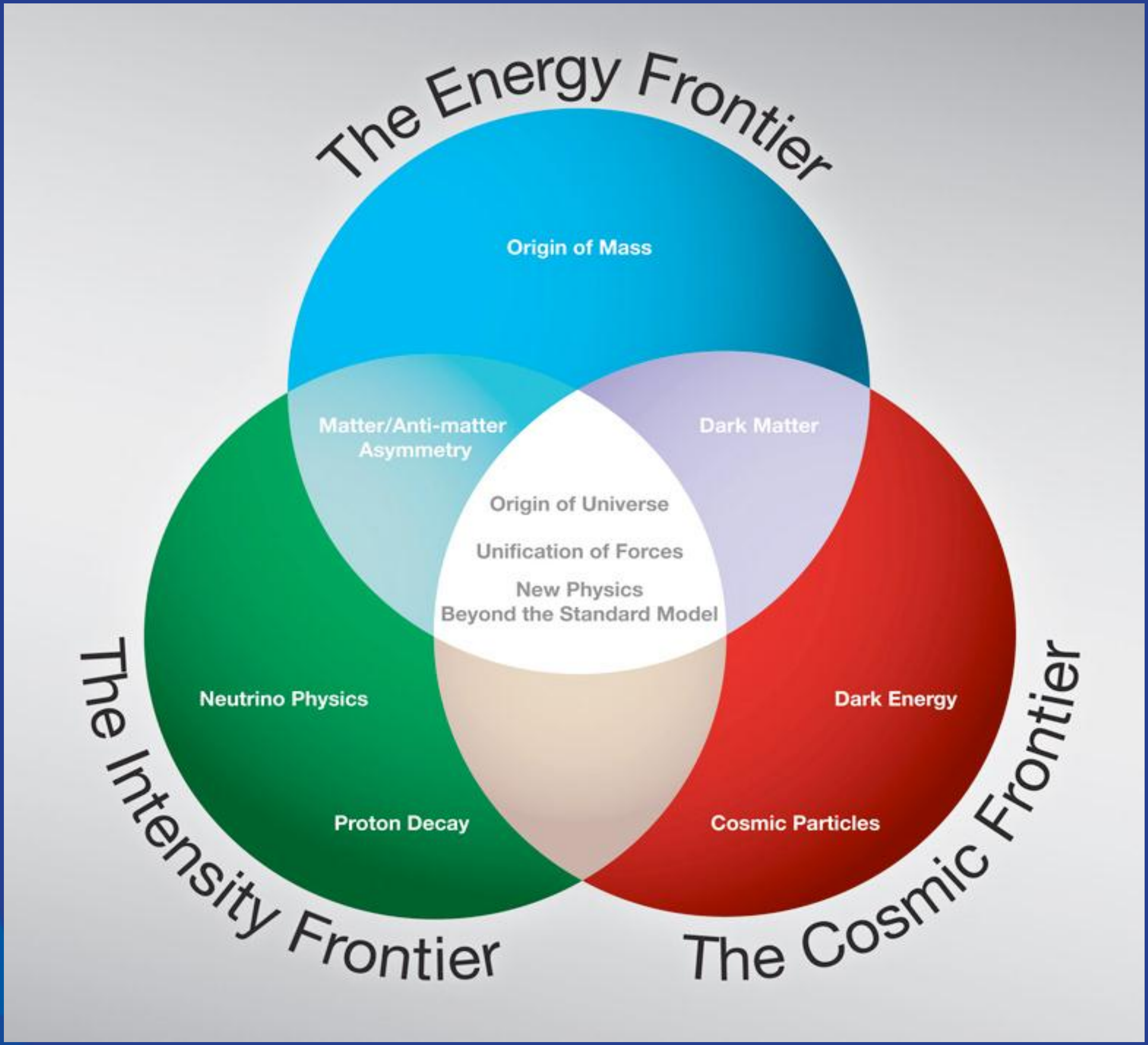
News from the US

P. Oddone, Evolution of the US program

EPS-HEP2011, Grenoble, July 27th, 2011

[Photo: fountain on Blvd. Gambetta, Grenoble]

Program expressed in three frontiers



The cosmic frontier

- Principal thrusts are the study of dark energy and the study of dark matter
- Dark energy:
  - DES being installed in the Blanco (4m) telescope, Cerro Tololo, Chile; supported by DOE and NSF
  - LSST (8m) in process of approval. First priority of the Decadal Survey for ground telescopes. Supported by DOE and NSF
  - BigBOSS proposed for the Mayall (4m) telescope to carry out a spectrographic survey. In process of approval

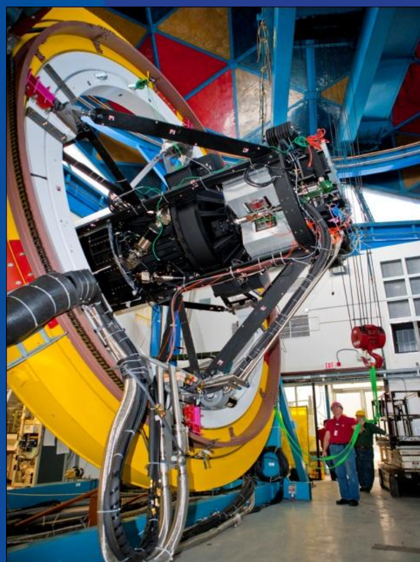
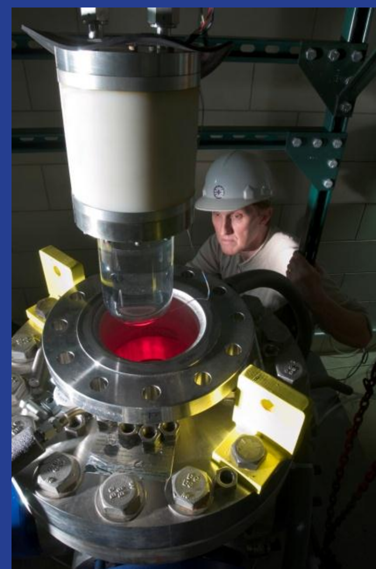
The cosmic frontier

- Dark energy:
  - CMB: relevant to dark energy, dark matter and inflation; large number of approaches supported mostly by NSF: Atacama Cosmic Telescope, South Pole Telescope, QUIET, POLARBEAR……
  - WFIRST, a wide field IR survey, is the first priority of Decadal Survey for space; delayed due to NASA's budget restrictions while building the James Webb Telescope

The cosmic frontier: dark matter

- Direct detection: many efforts trying to achieve “zero background”, i.e. discriminating against electromagnetic backgrounds, alpha particles and shielding against neutrons. Examples:
  - CDMS in various versions (Ge bolometers)
  - LUX (liquid Xenon)
  - MAX (depleted liquid Argon)
  - COUPP (bubble chamber)……
- Indirect detection: look for annihilation products such as in Fermi-GLAST and AMS

Cosmic Frontier


DDM: ~10 kg IDM: Fermi, AMS DE: BOSS, CMB P. Auger	DDM: ~100 kg IDM: Fermi, AMS DE: DES, CMB P. Auger	DDM: 1+ ton DE: LSST DE: BigBOSS??	DDM: 1+ ton DE: LSST DE: WFIRST??

The US at the energy frontier

- We will shut down the Tevatron down on September 30, 2011; the analysis will continue for several years
- Next is the exploitation of the LHC. The LHC (accelerator and detectors) has been the largest investment made by the US since the 70s !!
- The next steps will be to contribute to the High Luminosity LHC. Imperative to keep the doubling time short or life becomes boring. US will contribute to accelerator and detector upgrades
- The biggest unknown is what follows the LHC?

The US at the energy frontier

- By far the simplest machine is ILC. Issues are cost and maximum energy. US plans to continue R&D through 2012. Alignment of technology with Project X allows US to be ready beyond 2012

- If we need several TeV, we will need either CLIC or a Muon Collider. Most US effort is on studying the feasibility of the muon collider (MAP program). Both are formidable enterprises

- If the basis for lepton colliders is not established by the LHC, a natural extension will be the “energy doubler” for LHC. US program is carrying out the R&D program on Nb_3Sb in collaboration with CERN

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

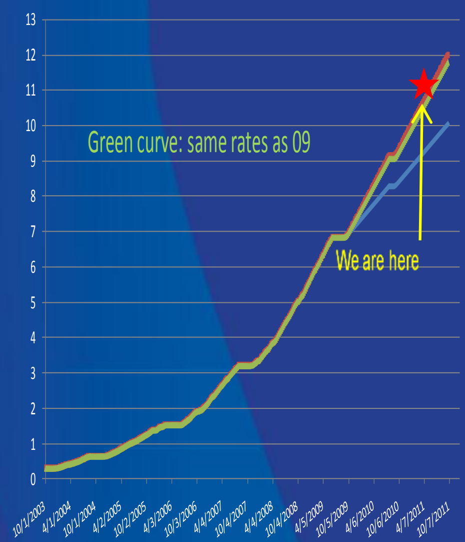
- Top quark
- B_s mixing
- Precision W and Top mass → Higgs mass prediction
- Direct Higgs searches
- Ruled out many exotica

The next generation

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

The US at the energy frontier

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



Fermilab facilities → intensity frontier Neutrinos

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

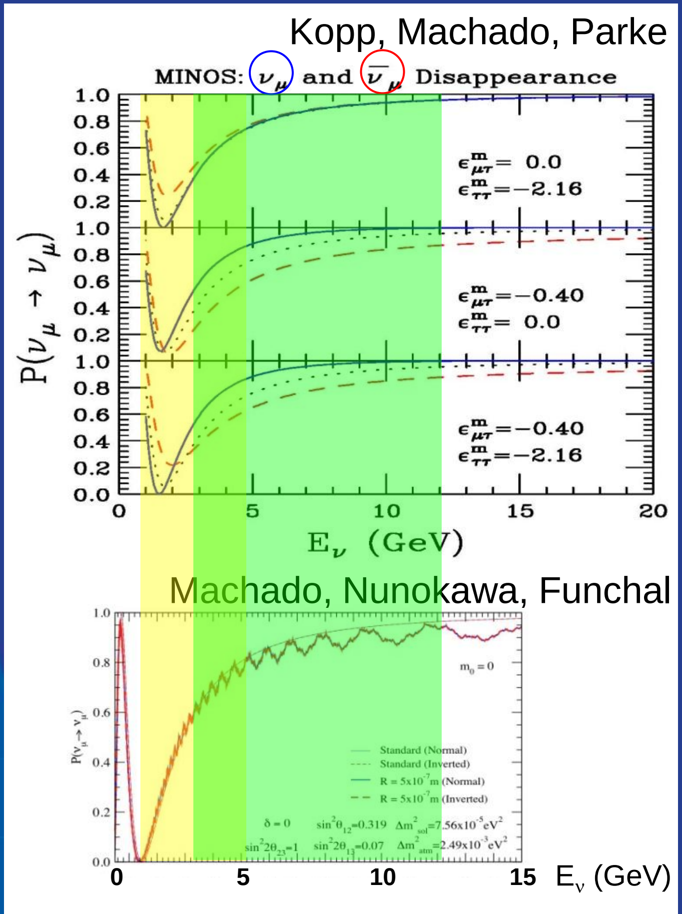
- Dedicated experiment: MINERvA

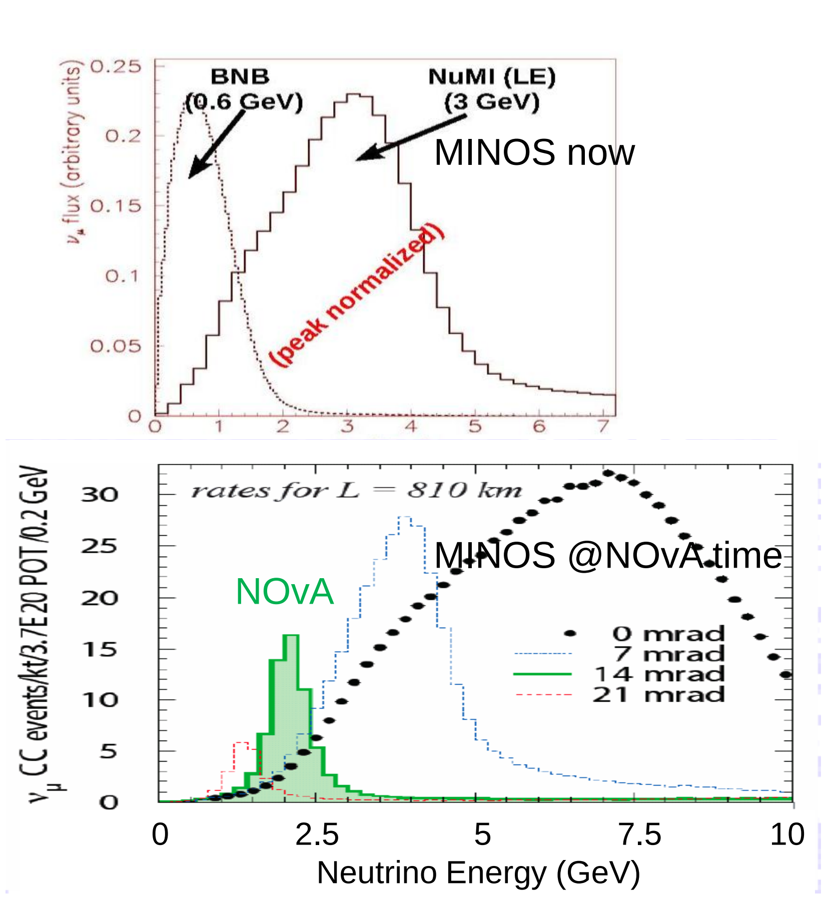
Fermilab facilities → intensity frontier Rare Decays

- Also in the intermediate term, a series of world-class experiments exploiting the present beams:
  - g-2: anomalous magnetic moment of the muon x20 statistics
  - Mu2e: direct muon to electron conversion - huge sensitivity to NP
  - SeaQuest: nuclear physics Drell-Yan process to study the structure of the nucleon in the nuclear environment

MINOS + (FY13-14)

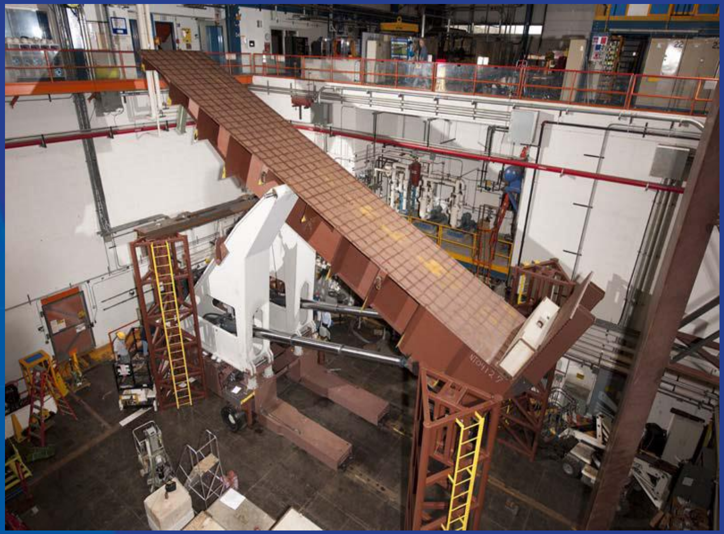
Sensitivities to new physics

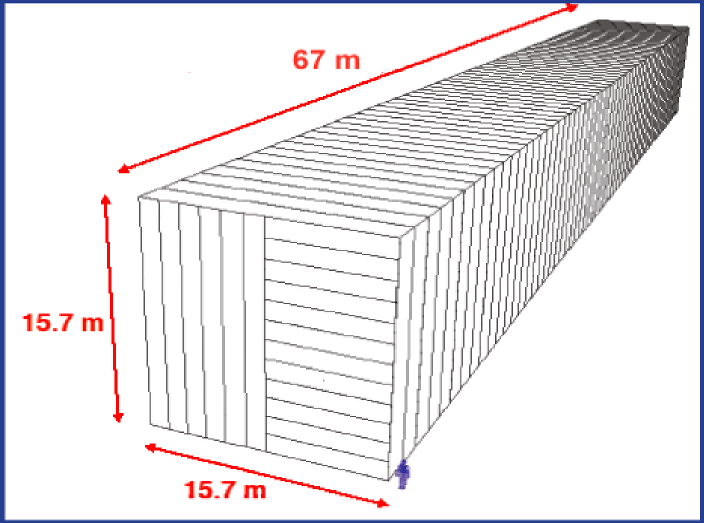




NOvA

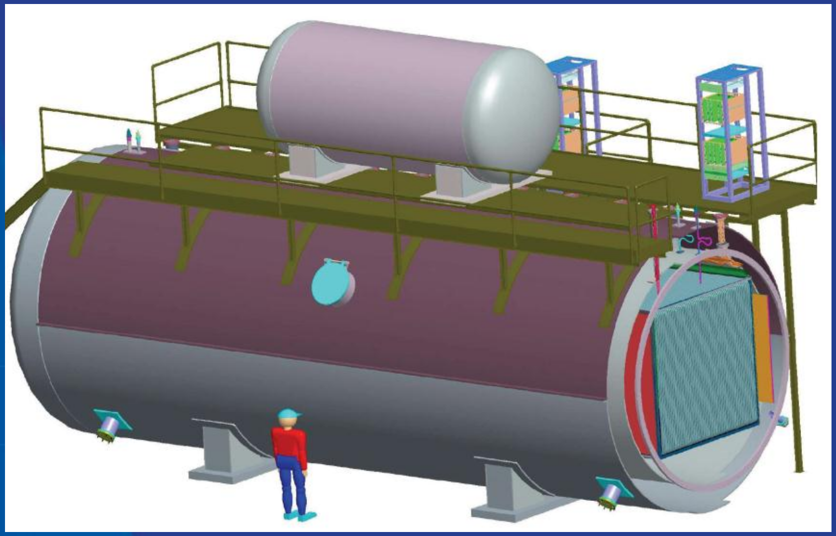
- Electron appearance and next step in oscillation parameters. Neutrinos vs. antineutrinos: different parameters?

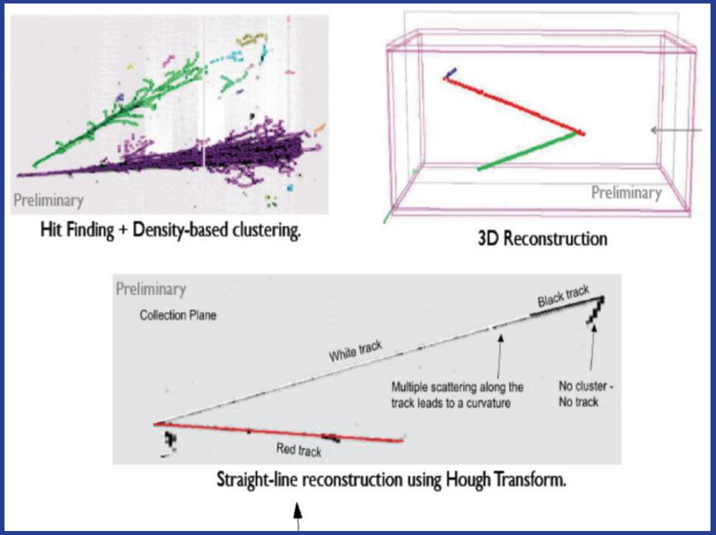




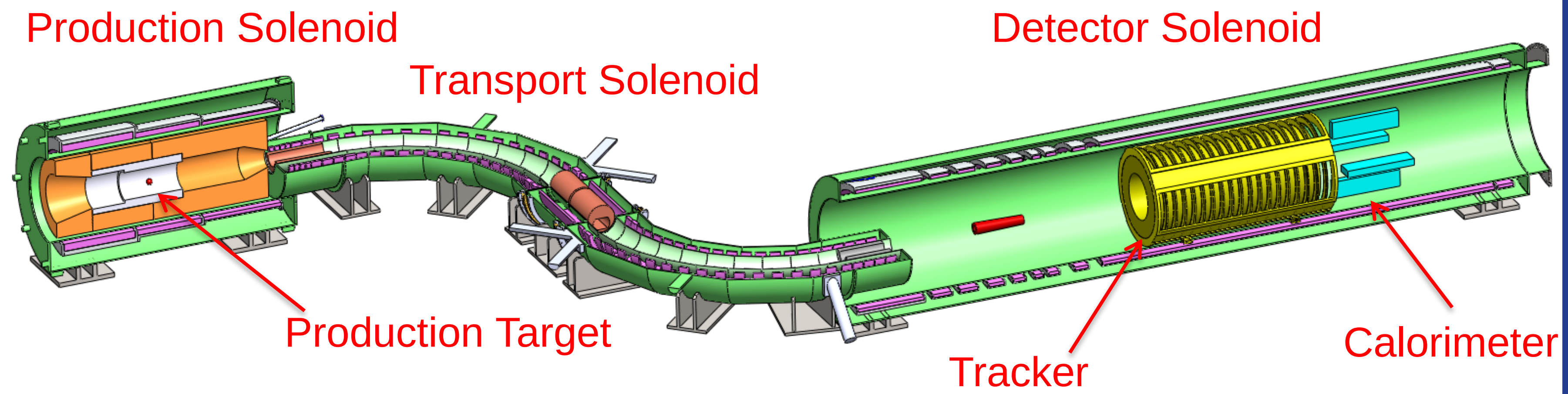
MicroBooNE

- Follow excess in MicroBooNE data. Critical to determine is it electrons or photons?
- Use Liquid Argon TPC: physics + further development of the technology



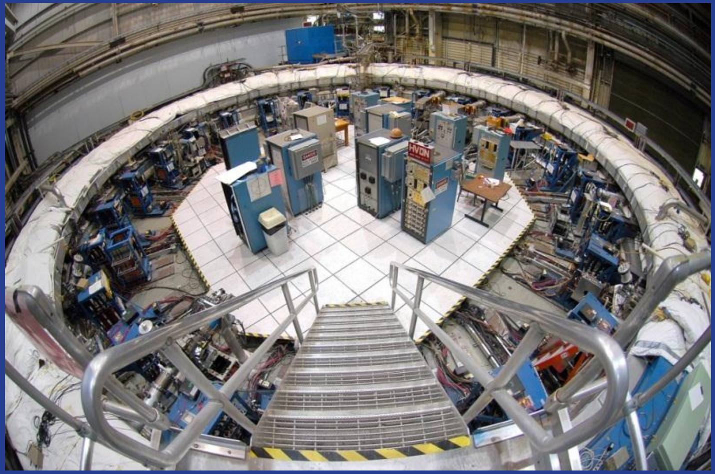


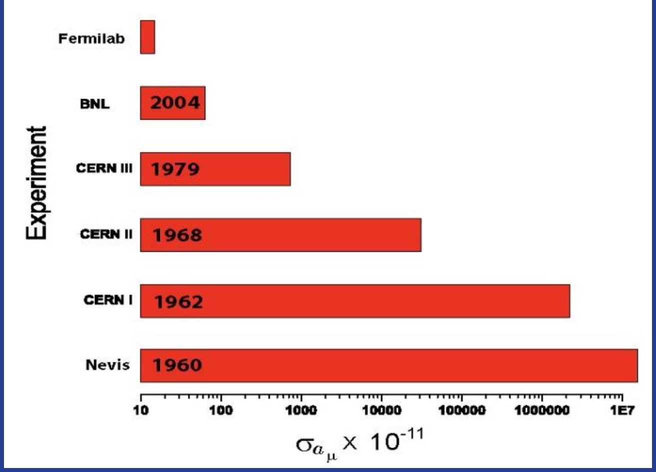
Some examples: Mu2e….

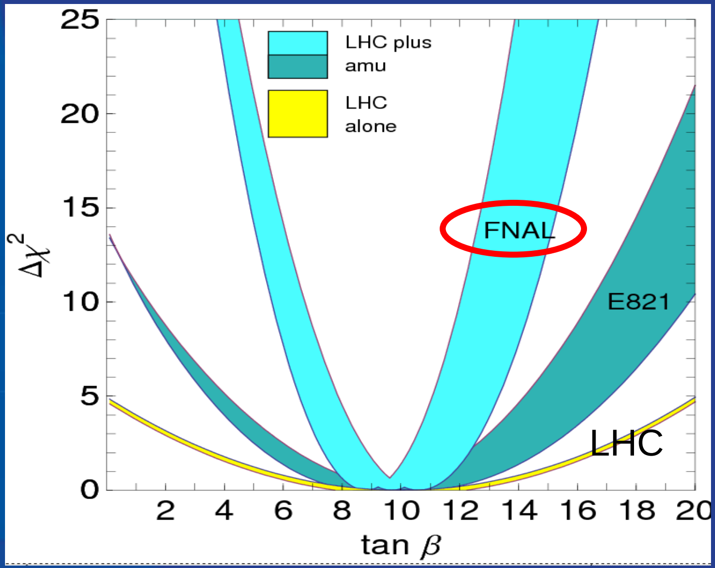


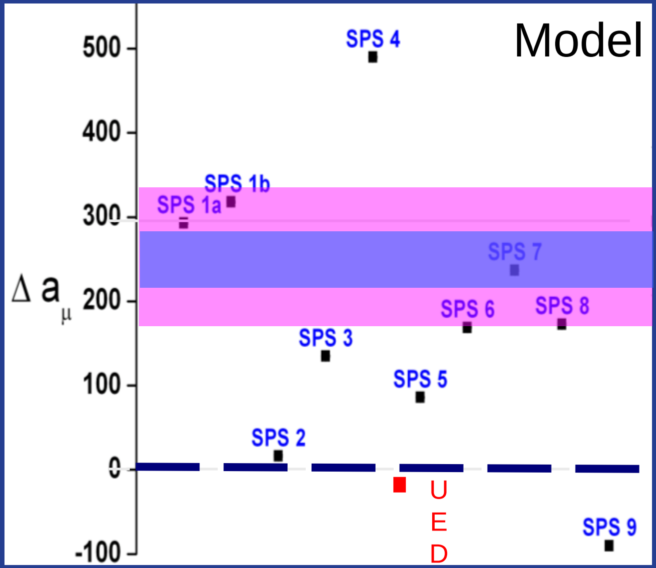
Conversion of a muon into an electron in the field of a nucleus: negligible rate in the SM and measurable in almost any extension of the SM

A new (g-2) to uncertainty $0.14 * 10^{-11}$









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
  - Rare muon decay with sensitivity to masses 10000 TeV
  - Symmetry violations through electric dipole moments in nuclei
  - Applications to transmutation, spallation targets, ADS

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

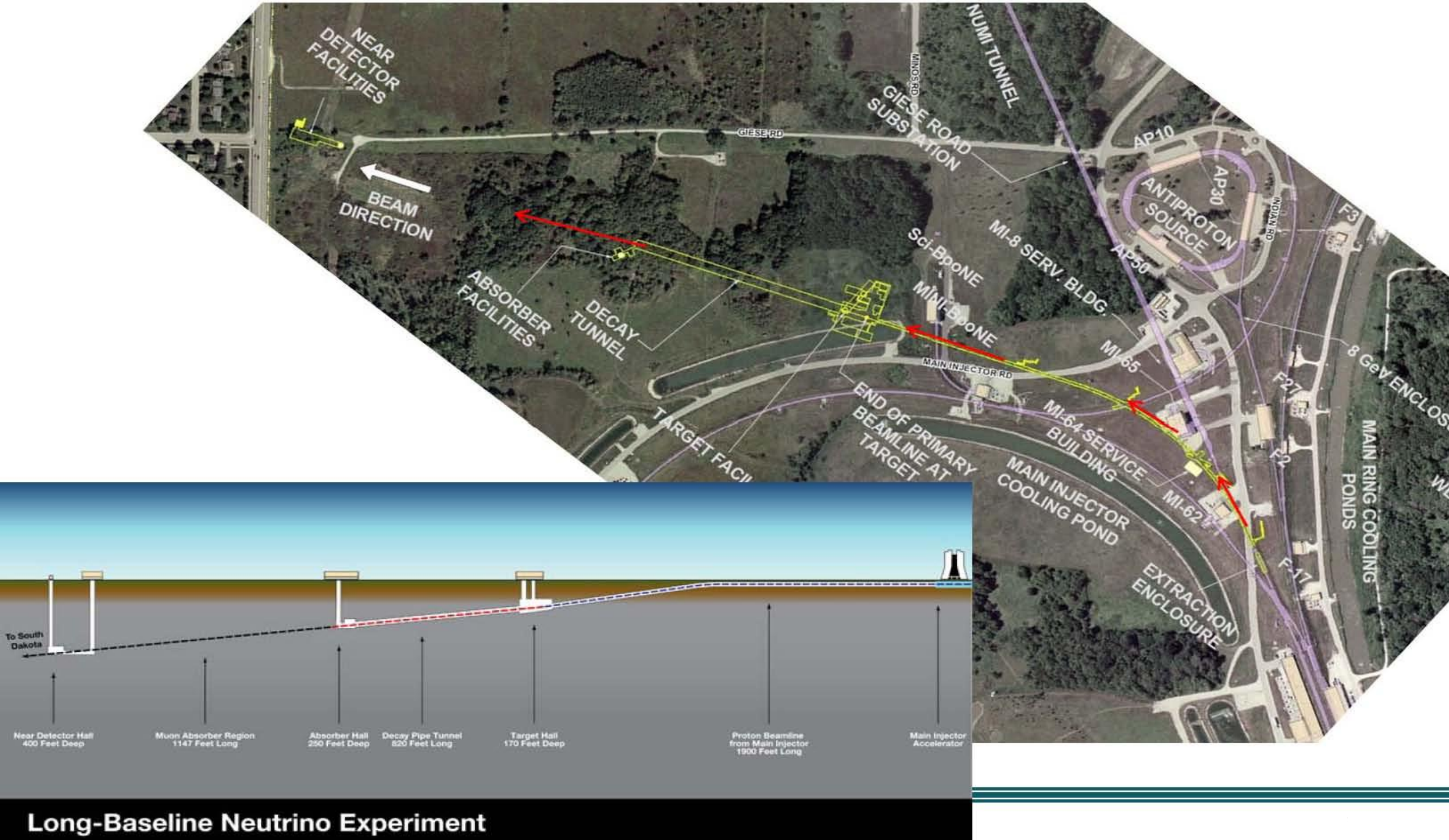
Collaboration: 306 members

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

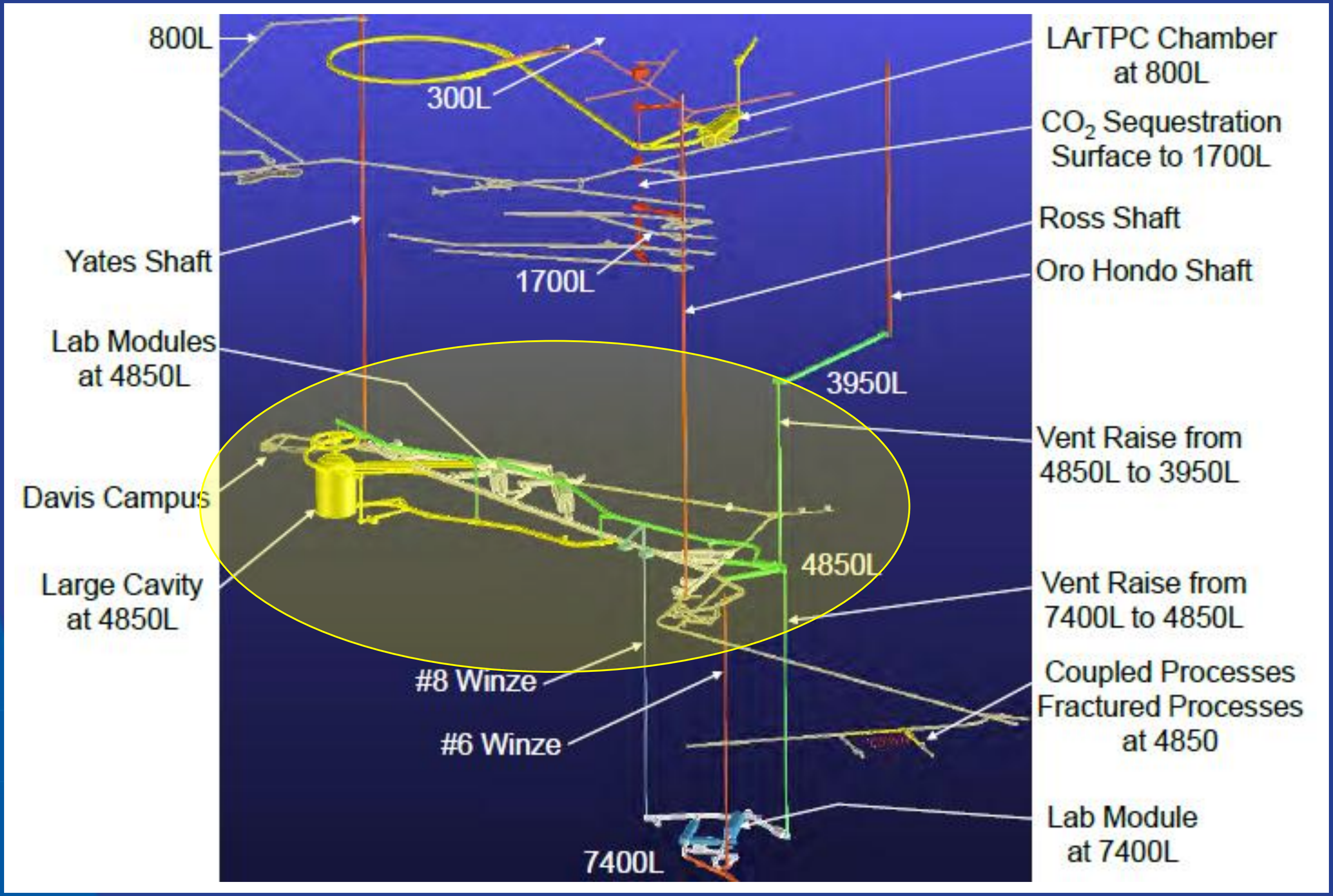
Continue to grow!

Pointer 43°03'56.44" N 95°10'42.53" W Streaming ||||||||||100% Eye alt 1108.62 km

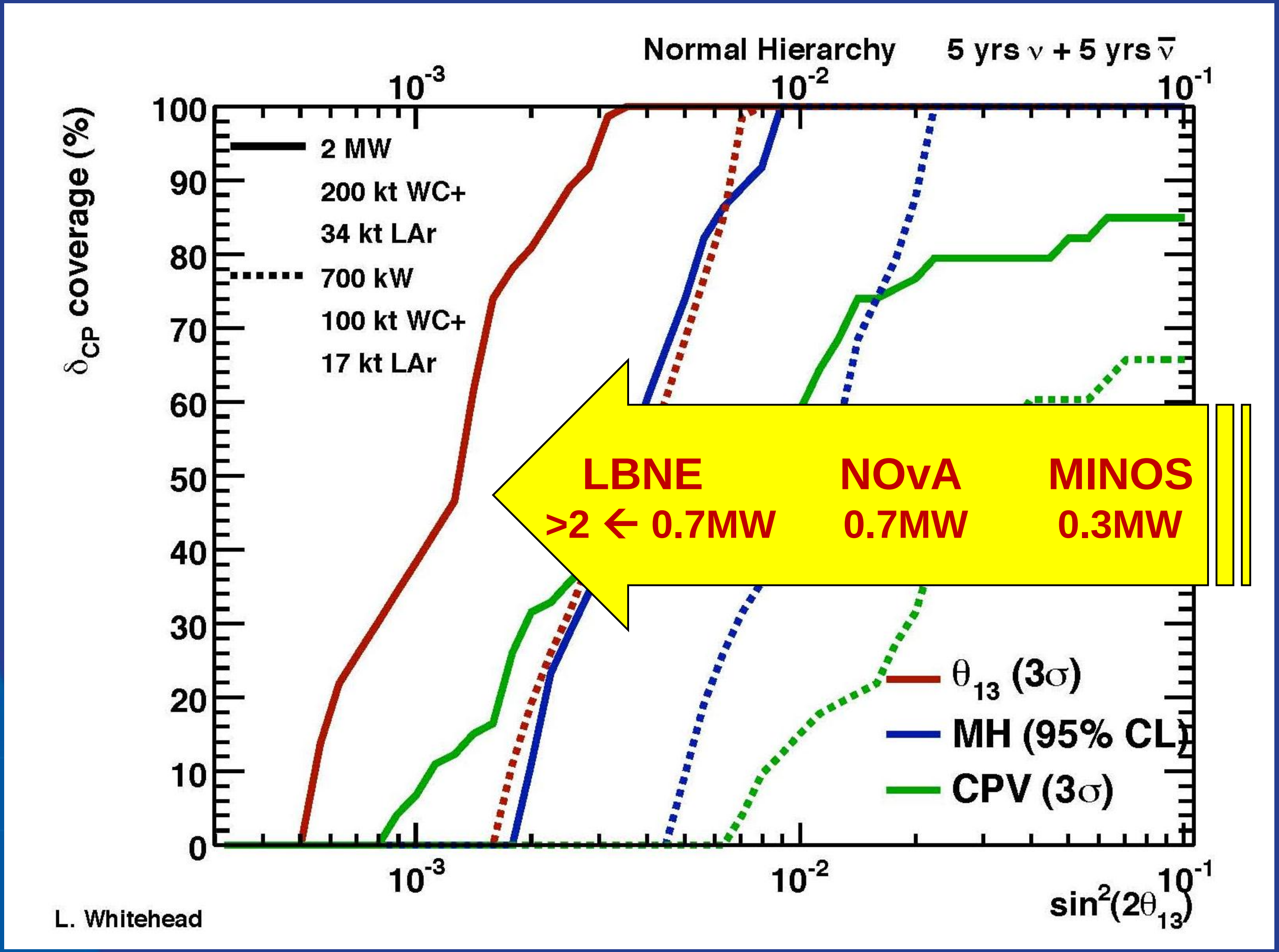
Conceptual Design Overview – Neutrino Beam



Homestake Lab Layout



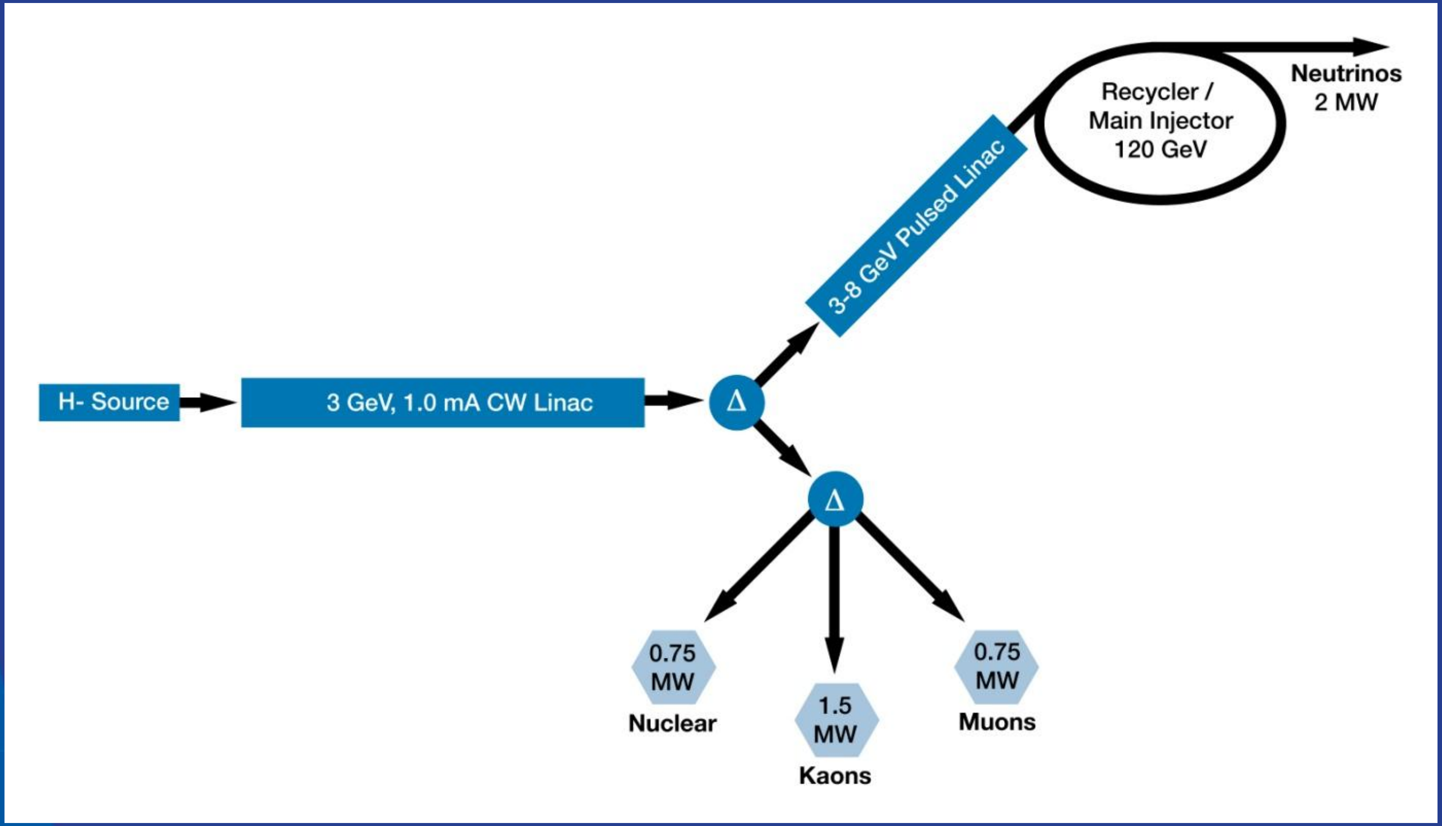
Evolution of Neutrino Sensitivities



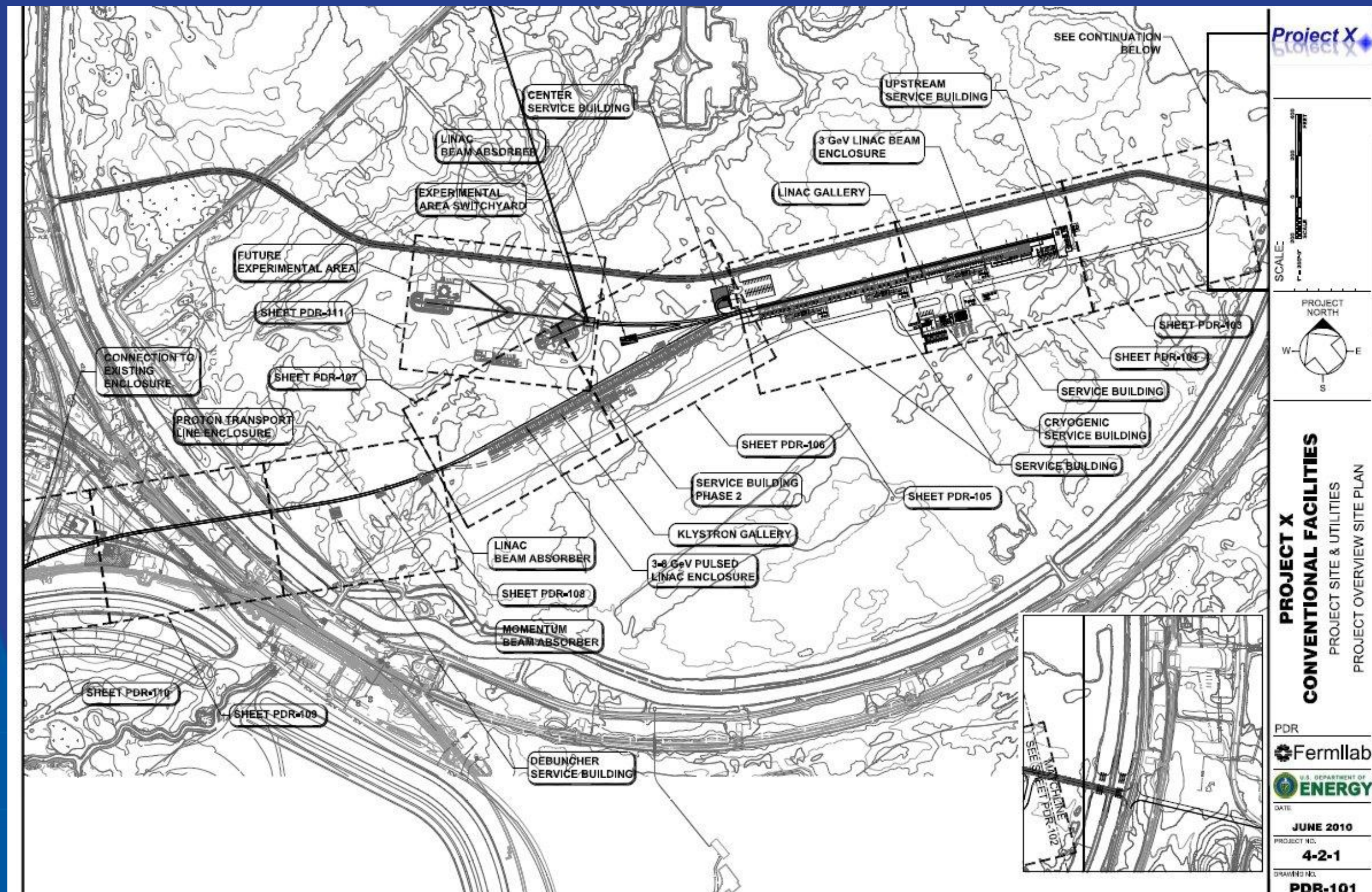
Status of Homestake facility

- NSF stopped funding the development of the deep underground laboratory in DUSEL: not appropriate for NSF
- DOE will support the facility through 2012 to allow for re-configuration
- Recent NRC Report strongly supports the scientific objectives: LBNE, DBD, DM
- Marx/Reichtanadter Report supported joint development, but dependent on LBNE
- DOE is supporting design, down-select on technology for LBNE. Final decision depends on costs and budgets……

Project X Reference Design



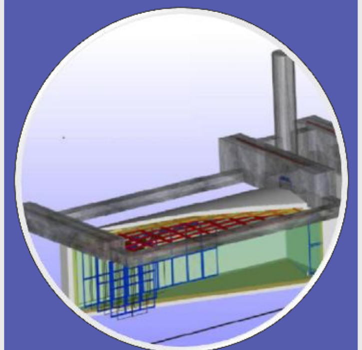
Project X Siting



Project X

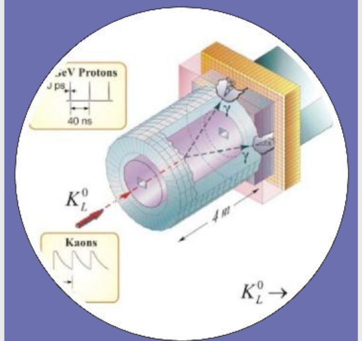
- Unique facility with 3 MW, continuous wave (CW) linac. Multiplies low energy flux of protons at Fermilab by 100 with flexible timing patterns, ideal for rare decays
- Solves “proton economics”. Experiments run simultaneously at 3 GeV, 8 Gev and 60-120 GeV at high power
- Delivers 2+ MW to LBNE
- To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

Project X: new experiments



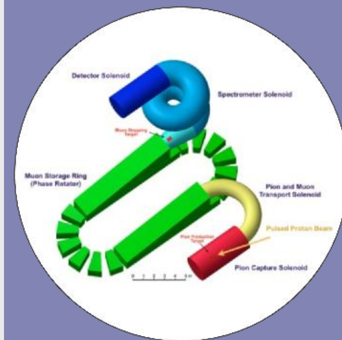
Neutrinos

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



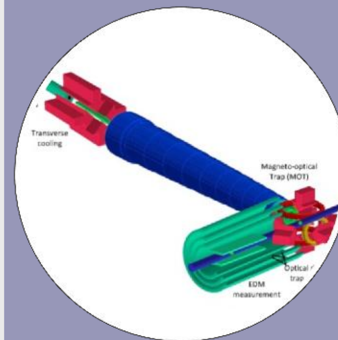
Kaons

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



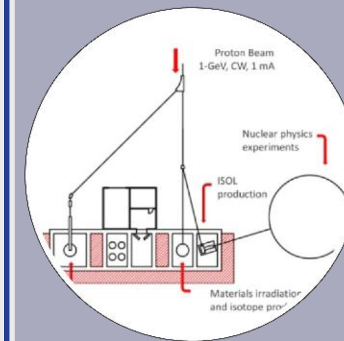
Muons

- 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

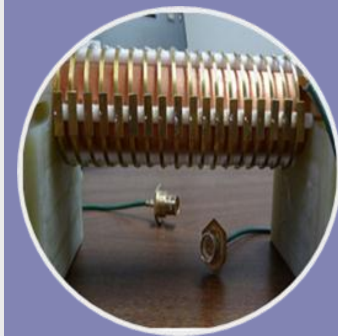
Project X: technology innovation

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

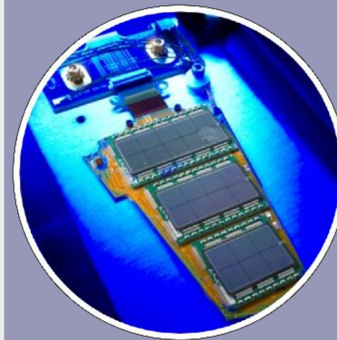
SRF Accelerating Modules

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



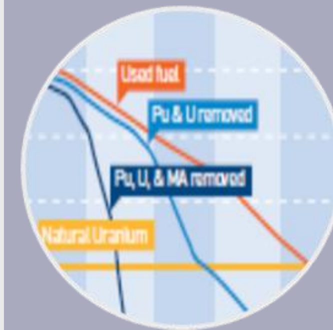
Fast Chopper

- 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?

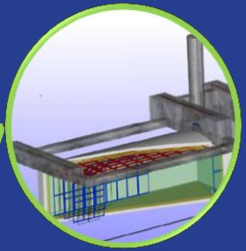
Do the forces unify?

Does nature use supersymmetry or other new symmetries?

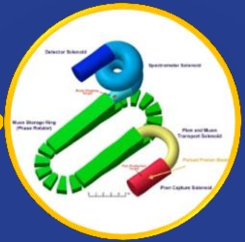
Are there extra dimensions of space?

What is dark matter?

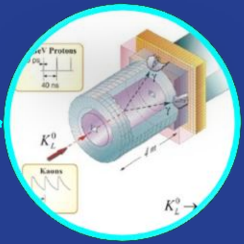
What is dark energy?



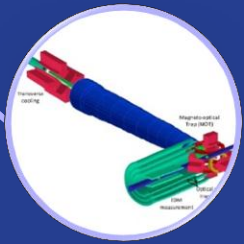
neutrinos



muons



kaons



Nuclei
(EDMs..)

From *Project X* to Neutrino Factory and Muon Collider

Project X
Accelerate hydrogen ions to 8 GeV using SRF technology.

Compressor Ring
Reduce size of beam.

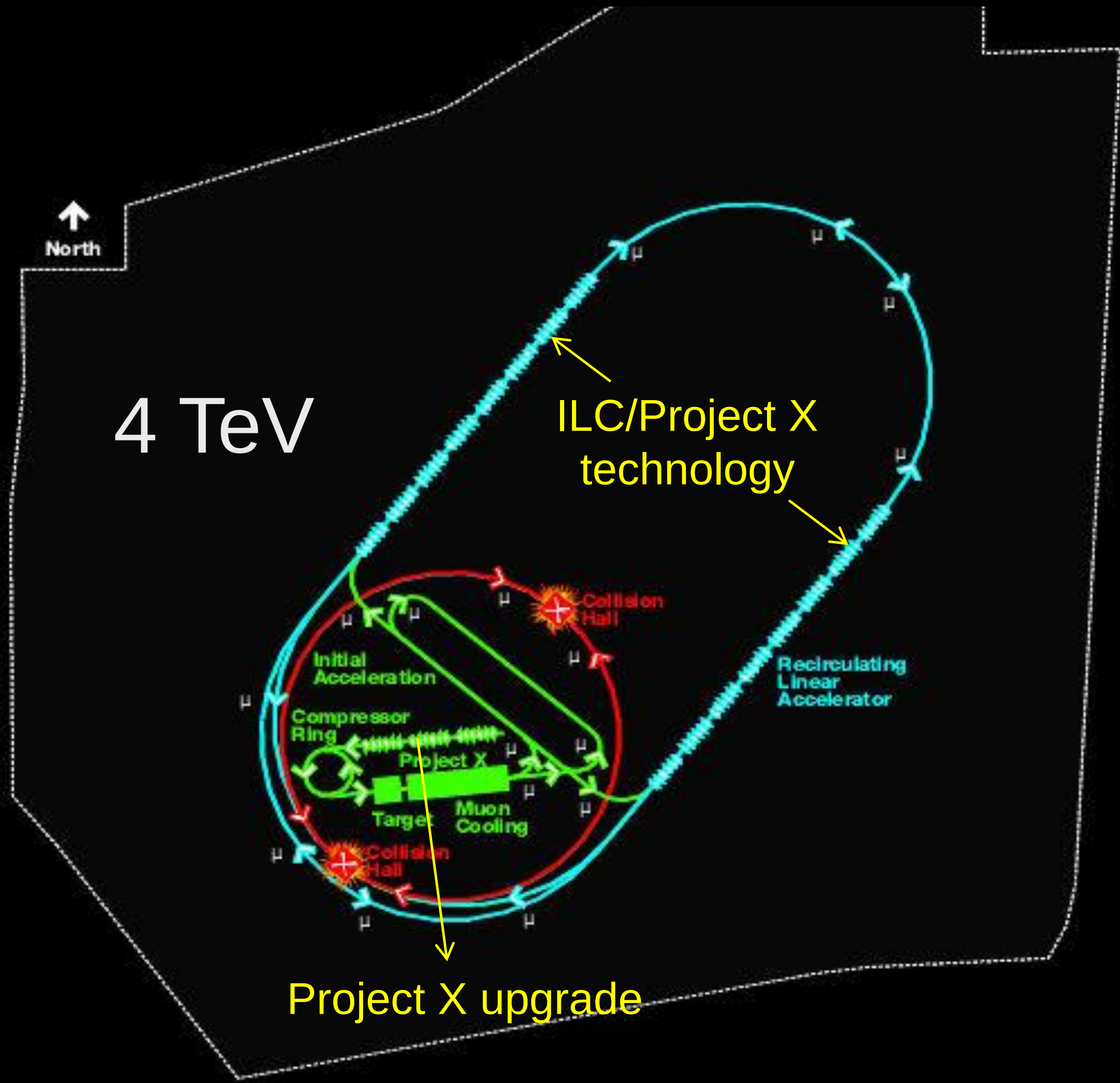
Target
Collisions lead to muons with energy of about 200 MeV.

Muon Cooling
Reduce the transverse motion of the muons and create a tight beam.

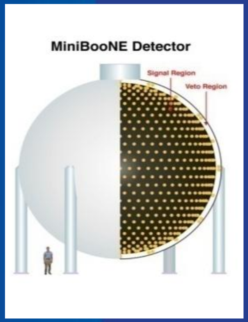
Initial Acceleration
In a dozen turns, accelerate muons to 20 GeV.

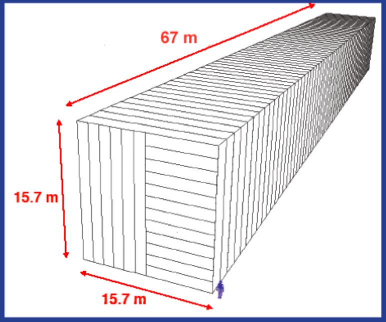
Recirculating Linear Accelerator
In a number of turns, accelerate muons up to 2 TeV using SRF technology.

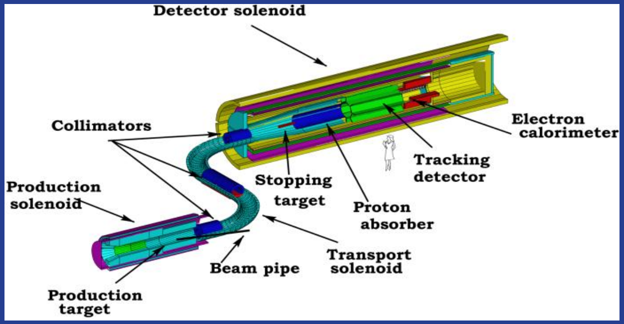
Collider Ring
Located 100 meters underground. Muons live long enough to make about 1000 turns.



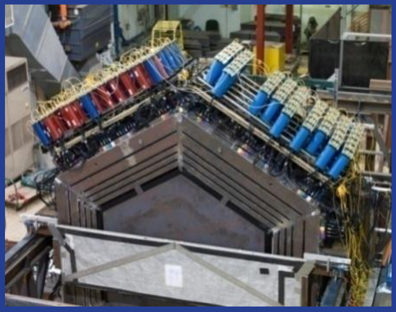
Fermilab and the intensity frontier

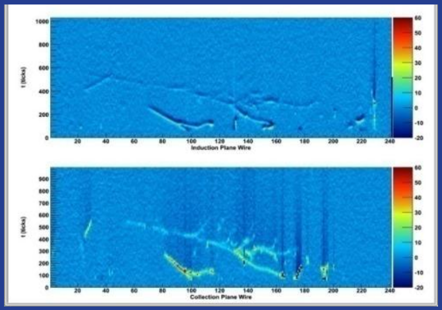


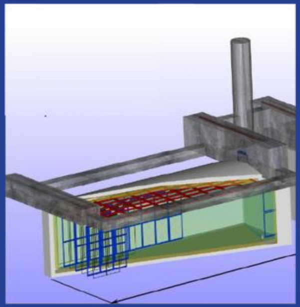




MINOS MiniBooNE MINERvA SeaQuest	NOvA MicroBooNE g-2 MINERvA MINOS+ SeaQuest	NOvA g-2 LBNE Mu2e	Project X+LBNE μ, K, nuclear, … ν Factory ??







Fermilab