Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

# Fermilab Report…post 2014 P5 report Fiscal Year 2014

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HEPAP

29 September 2014

# Fermilab is America's particle physics & accelerator lab

6,800 acres

1,720 FTEs  2,097 facility users

Our vision is to solve the mysteries of matter, energy, space and time for the benefit of all. We strive to:

Lead the world in neutrino science with particle accelerators
Lead the nation in the development of particle colliders and their use for scientific discovery
Advance PP through measurements of the cosmos

# Mission/Overview/Lab-at-a-Glance

- Aligning with Particle Physics Project Prioritization Panel (P5)
- Exciting and demanding transition for Fermilab
  - from Tevatron ops to hosting an international neutrino program
  - from operations-based to project & ops-based laboratory
- Organizational changes to effectively meet the new direction
  - Creation of a Neutrino Division and Chief Project Officer
- Several large projects at various stages of CD process
- International interest and participation is increasing
- Staff is stretched but motivated and encouraged
- Near-term budget challenges for research, ops and projects
- Implementing Master Campus Plan
- OHEP & FSO relationships and support are excellent

# Fermilab's Input to P5…Guiding Criteria

- Principles adhered to:
  - Launch the best accelerator-based neutrino program possible
  - Strengthen the accelerator complex because this is what we provide to the community…beams including muons
    - Develop high-power neutrino target capabilities
    - Advance high-intensity beam dynamics understanding (IOTA)
  - Provide a platform for LHC Reserach & future colliders
    - High-field magnet technology ($Nb_3Sn$ and HTS)
    - Advance SRF technology (big strides recently)
  - Pursue dark matter & dark energy
  - Provide scientific computing big data tools for community
  - Strengthen core detector infrastructure
  - Partner with Office of Science labs, universities, international

# Today

- HEP went through a community-planning process (Snowmass) and P5 prioritization process and came up with a roadmap
- Community is behind P5 report – a letter of endorsement with >2,200 signatures from HEP community exists
- P5 plan has Fermilab as world-leading neutrino program for the next two plus decades
- Many proposed projects no longer part of the P5 plan forward
- Field made tough choices based on its scientific priorities

# The Post P5 Field Today…much greater focus

- Muons: Mu2e, Muon g-2
- DESI
- ~~LBNE:~~ Recast as international LBNF & coherent SBN
- PIP-II
- ~~Project X~~
- ~~ORKA~~
- LSST
- ~~EDMs~~
- Generation 2&3 Dark Matter Experiments
- LHC upgrades (accelerator and detector)
- ~~MAP/MICE~~
- ~~NuSTORM (neutrino factory)~~
- ~~Muon Collider~~
- ILC (awaiting Japanese green light)
- ~~Materials and irradiation facility~~

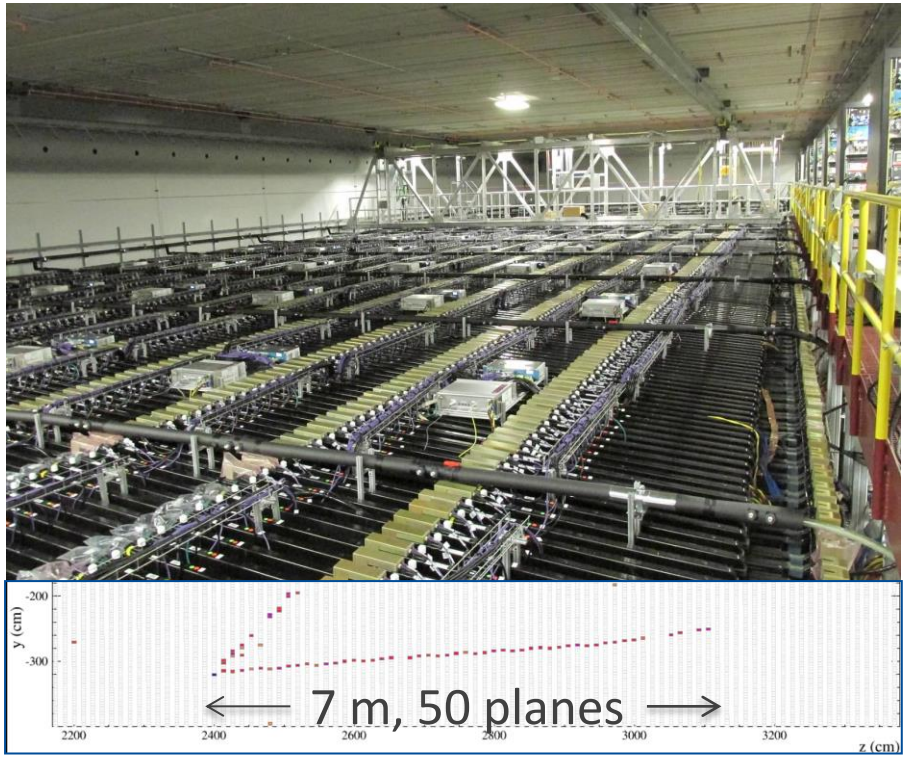
# Additional Focus

- The Tevatron research program, both CDF and D0 are scheduled to be complete by end of FY15…still about 20 students each to graduate
- In the cosmic area, DAMIC, Dark-side, PICO, and Holometer will wind down and complete by end of FY15.
- Ended neutron therapy treatments….R&D Loyola?
- Minos+ ends FY16….operational funds move to NOVA
- A Tevatron decommissioning task force is being assembled
  - Goal is to reduce cost of maintaining infrastructure
    - tunnel HVAC, roof repairs, security, alarms,
  - Plan is to start decommissioning FY16
  - Likely remove all SC magnets and ship to offsite storage
  - Demolish some of the 24 support buildings

# NOvA…has begun data taking



- **Science goal:** For different $\delta_{CP}$ ranges: determine mass hierarchy, determine $\theta_{23}$ octant, constrain allowed range of $\delta_{CP}$ . Measure $sin^2(2\theta_{23})$ to ~4%.
- **Technical challenge:** Finish outfitting detectors with APDs.
- **FY14 highlights:** 14 kiloton far & 294 ton near detector assembly done, filled with 2.7 M gal liquid scintillator. Commissioning now.




TPC: $278M

Status: CD-4 complete

Operations start: Aug 2014 w/full det.

Run duration: 6 years @ 700 kW

Partnerships

DOE labs: ANL

U.S. universities: 19

International: 6 countries, 14 institutes



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# MicroBooNE…about to start in fall



- **Science goal:** Determine the nature of the MiniBooNE low energy excess of electron neutrinos
- **Technical challenge:** Operate a LArTPC with 2.5m drift, cold electronics, and purity without evacuation
- **FY14 highlights:** Completed construction of the TPC, electronics, and cryogenics


TPC: $19.9M

Status: CD-3 (Commissioning fall)

Operations start: Jan 2015

Run duration: 3+ years

Partnerships

DOE labs: BNL, LANL, SLAC

U.S. universities: 13

International: 3 countries, 5 institutes

# LBNE Becoming LBNF



- **Science goal:** Neutrino CP violation and mass ordering; nucleon decay; supernova neutrinos.
- **Technical challenge:** Massive LAr TPC deep underground; targeting MW proton beam
- **FY14 highlights:** Science book; internationalization; 35 t LAr cryostat prototype; geotech investigation at 4850L at Sanford

Status: CD-1 (2012), CD-3a (≥2017)

Operations start: ≥2024

Run duration: ≥20 years

Goal: Reformulate collaboration with substantial international partnerships

Partnerships

DOE labs: ANL, BNL, LANL, LLNL, SLAC

U.S. universities: 48

International: 7 countries, 34 institutes



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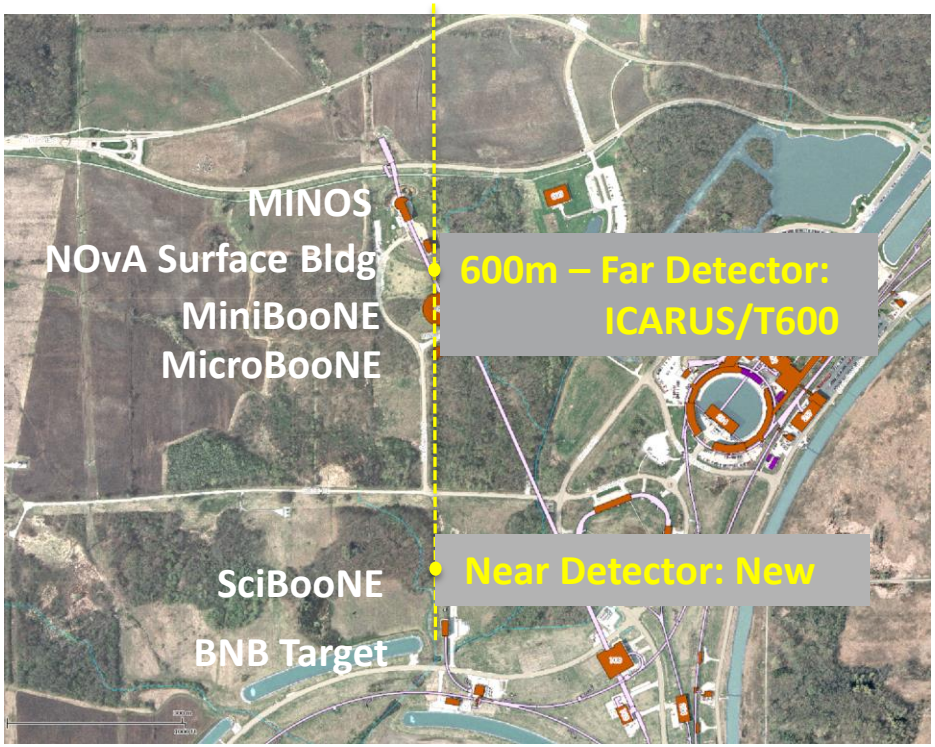
# Short-Baseline Neutrino Program



- **Science goal:** Search for sterile neutrinos; definitive resolution of LSND and MiniBooNE anomalies. **Technical challenge:** Design and construct near detector in <3yrs, refurbish and transport T600.
- Align R&D with LBNF needs
- **FY14 highlights:** Prepare joint (LAr1-ND, MicroBooNE, ICARUS) report for Jan FNAL PAC. Establish framework for coordination between experiments




TPC: ~$24M (DOE only)

Status: July 23, 2014 Fermilab PAC

Operations start: 2018

Run duration: 3+ years

Partnerships: NSF, DOE, STFC, INFN

DOE labs: LANL, BNL, SLAC

U.S. universities: 17

International: 24 institutes (incl. CERN)



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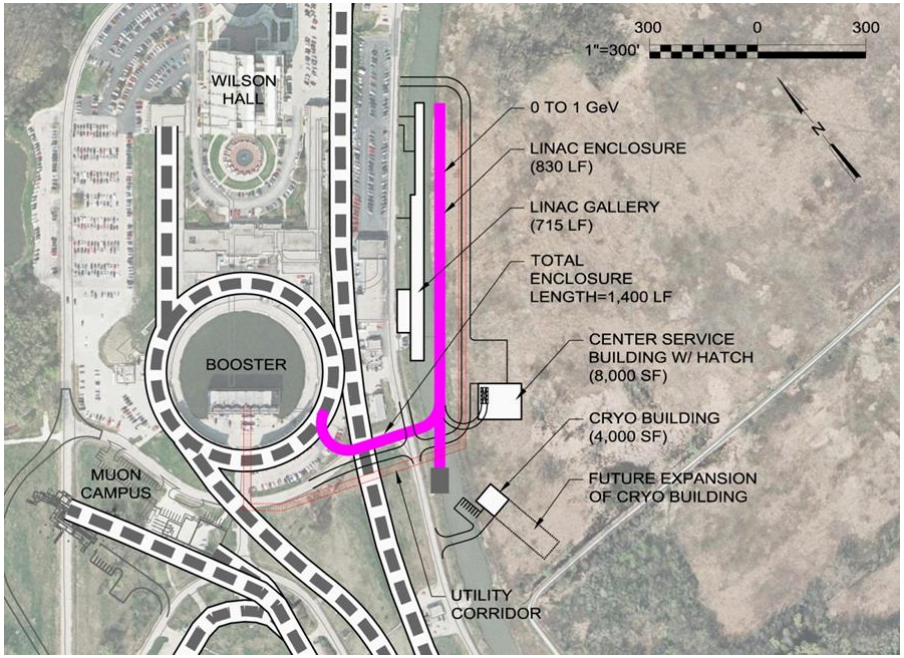
# Upgrading the Accelerator Complex to Meet Future Needs

- Fermilab is transforming its accelerator facilities, making the use of existing assets freed up by the end of Tevatron collider operations.
- The existing Fermilab accelerator complex, including the Main Injector synchrotron, Recycler storage ring, and NuMI neutrino beam line and target, have been upgraded and are on the path to supplying 700 kW proton beams by 2016
- The Proton Improvement Plans (PIP-I, PIP-II), are designed to support the operation of Fermilab's suite of neutrino and muon experiments through 2030.

# PIP-II…India Annex I approved

Neutrinos, Explore the Unknown

- **Science goal:** Provide >1 MW of beam power at LBNF startup; provide a platform for future high power/high duty factor capabilities (e.g. Mu2e up to 100 kW)
- **Technical challenge:** High-performance beam source; high-efficiency SRF acceleration
- **FY14 highlights:** Ion source commissioned; very high $Q_0$ processing protocols developed




TPC: $400M-500M (DOE only)

Status: Pre-CD-0

Operations start: FY2024

Run duration: >20 years

Partnerships: India, CERN

DOE labs: ANL, LBNL, ORNL

U.S. universities: Cornell, NIU

International: 2 countries, 5 labs



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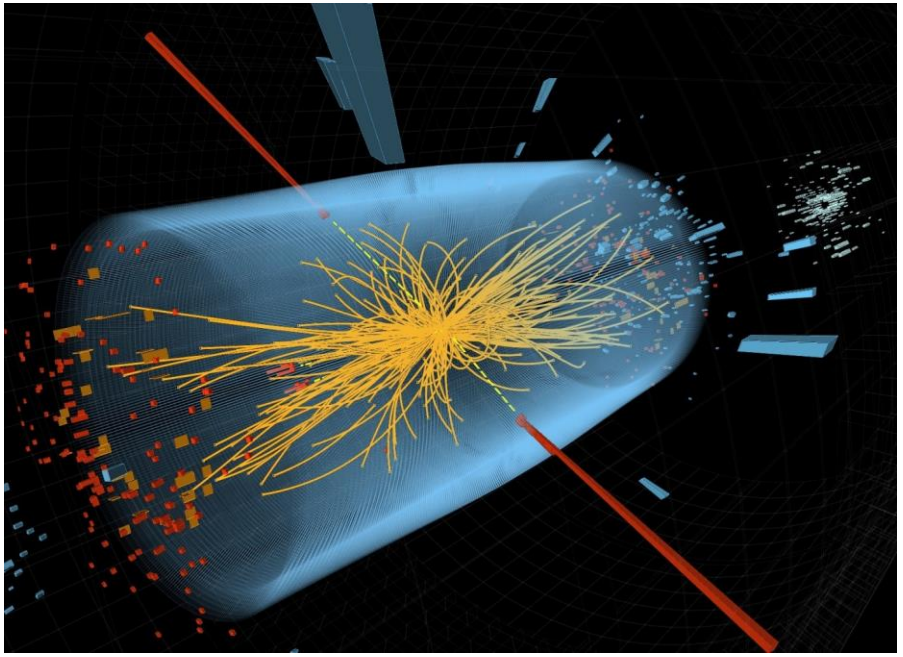
# Driving Large Hadron Collider Research and Upgrades

- Fermilab is responsible for operational, organizational, technical and computing support for the 627-member U.S. CMS community
- Support Fermilab scientists, postdocs, and engineers to operate and analyze data from the CMS detector and provide the upgrades of the detector and the LHC accelerator complex

# US CMS

Higgs boson, Dark matter, Explore the unknown

- **Science goal:** Measure Higgs properties; search for new particles and forces
- **Recent publications:** Higgs width, dark matter and supersymmetry searches, Top mass measurement, $B_s$->$\mu\mu$
- **Upcoming milestones:** LHC startup in 2015 at higher energy



Status: Run 1 completed and many analyses published; LHC in shutdown period; Run 2 to start in 2015

Run duration: LHC Run 2 from 2015 through mid-2018

Partnerships: DOE/NSF program

U.S. universities: 47

International: CERN + 130 institutes

LHC Physics Center

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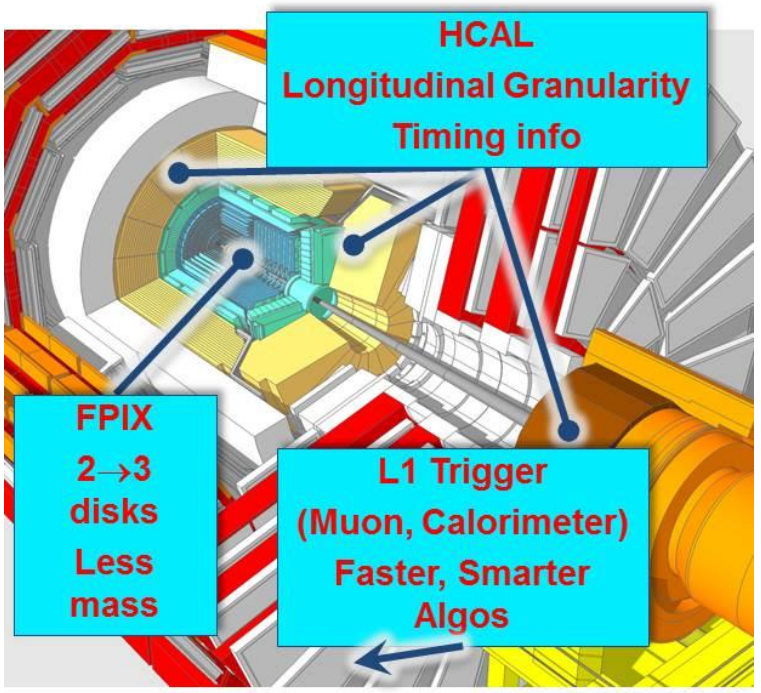
# US CMS Phase I Upgrades



- **Science goal:** Exploit the opportunity at the LHC to explore the Energy Frontier
- **Technical challenge:** Create new HCAL front end and backend, Forward Pixel, and L1 Trigger system within the constraints of the LHC schedule while simultaneously operating the current detector
- **FY14 highlights:** Completion of design/prototype phase and Initiation of the fabrication phase




TPC: $42.7M

Status: CD-2/3 Review complete

Operations start: 2015-2018

Run duration: ~10 yrs (then HL-LHC)

Agencies: DOE, NSF

DOE labs: FNAL

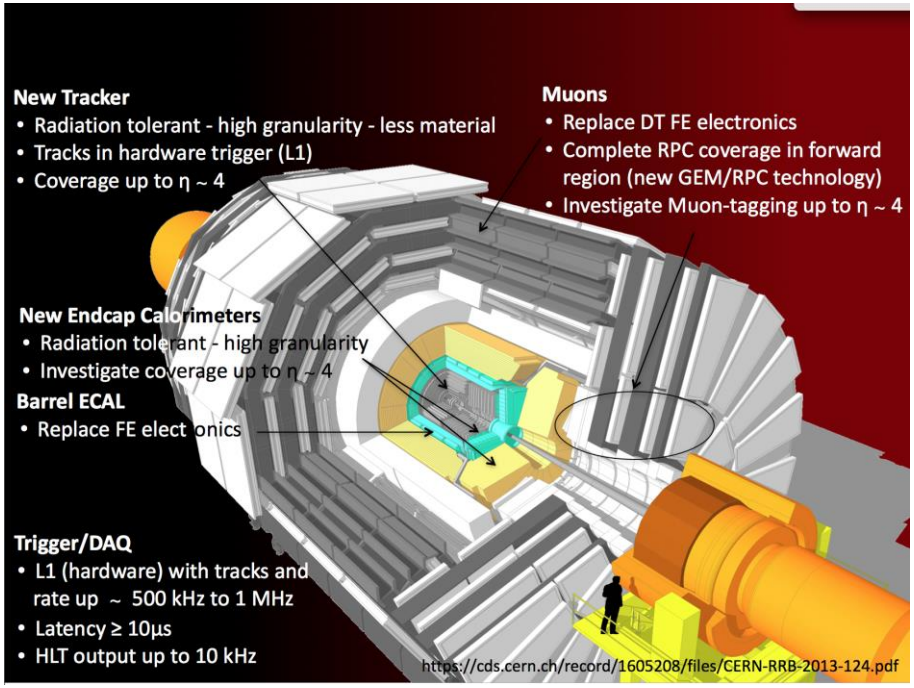
U.S. universities: 30

International: CERN + 130 institutes

# US CMS Phase 2 Upgrades

Higgs Boson, Explore the unknown

- **Science goal:** Discovery of new physics, measurement of Higgs boson properties
- **Technical challenge:** Design of a silicon tracker integrated with a L1 trigger and an endcap calorimeter to operate in the high luminosity environment of the HL-LHC.
- **FY14 highlights:** Start up of the Phase 2 R&D program.




TPC: Scope to be negotiated

Status: R&D begun; CD-0 in FY16 and aim for construction start in FY18

Operations start: 2025 (after LHC Long Shutdown 3)

Run duration: HL-LHC run 10 years

Partnerships: DOE, NSF (proposed)

DOE Labs: FNAL

U.S. universities: 47

International: CERN + 130 institutes

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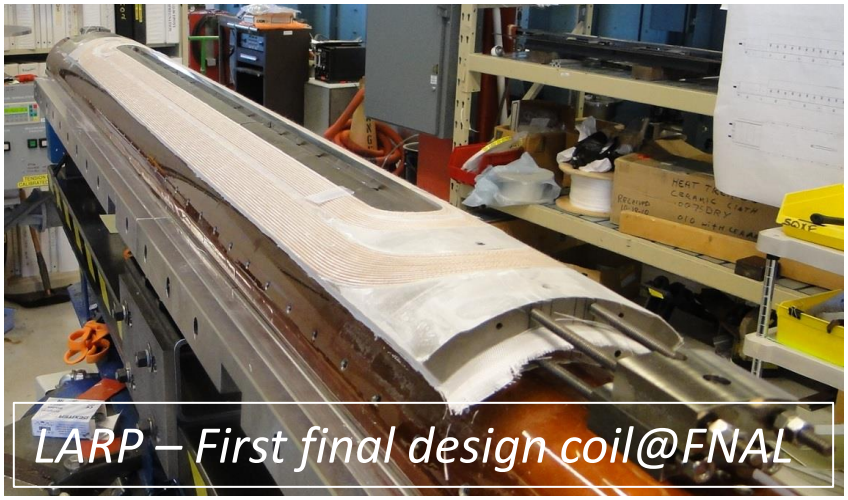
- **Science goal:** Contribute with leading-edge technology ($Nb_3Sn$ magnets and possibly crab cavities) to the HL-LHC (3,000 $fb^{-1}$ per experiment)
- **Technical challenge:** Develop first accelerator-quality $Nb_3Sn$ focusing quadrupoles.
- **FY14 highlights**: Consistently reached 170 T/m in recent models. Essential means to high luminosity for LHC.


LARP – First final design coil@FNAL

TPC: LARP $48M

HL-LHC scope to be negotiated

Status: pre-CD-0 (LARP/HL-LHC Phase)

Operations start: 2019, 2025

Run duration: ~10 years

Partnerships

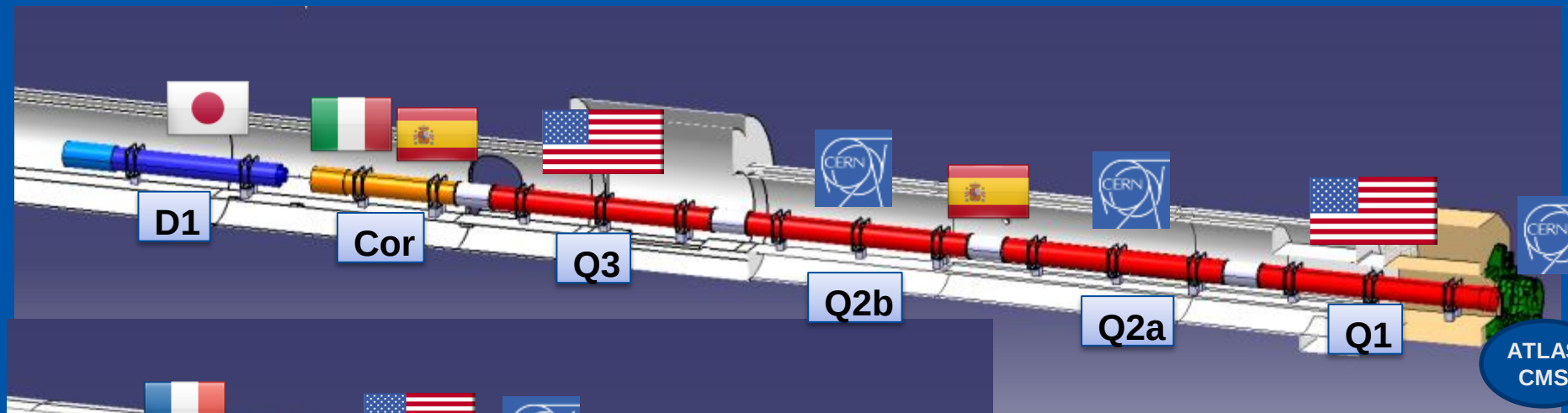
DOE labs: BNL, LBL, SLAC

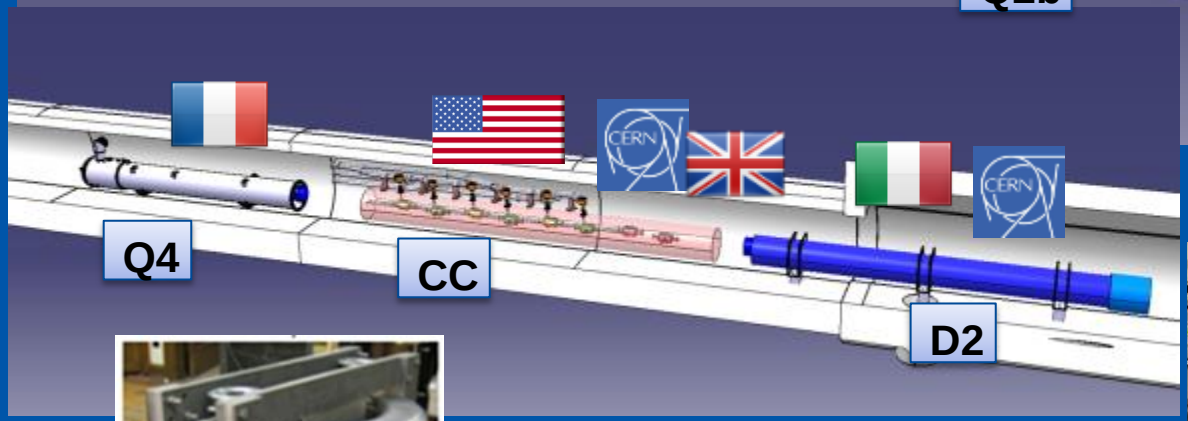
U.S. universities: ODU (JLab)

International: CERN

# USA for HL-LHC : LARP for R&D

**8 IT quadrupoles Q1 and Q3 (16 single magnets + 4 spares)**
**32 Crab Cavities (dressed cavity no cryomod) + 4-8 spares**




LARP ¼ wave proto single Crab Cavity


1st LARP quadrupole short coil in $Nb_3Sn$

# US HL-LHC Cost Estimate
## (from February 2014 DOE review of LARP)

| | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | LARP TOTAL | PROJECT TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| LARP funding | $16M | $16M | $16M | | | | | | | $48M | |
| LLI (pre-Project funding) | | $10M | $23M | | | | | | | | $33M |
| Project funding (MIE) | | | | $34M | $51M | $43M | $31M | $17M | $6M | | $182M |
| TOTAL | $16M | $26M | $39M | $34M | $51M | $43M | $31M | $17M | $6M | $48M | $215M |

TPC = 215 M$

- Observation #1: TPC includes elements (Cryomodules for CC, Wide Band Feedback System) which have recently been re-negotiated and are probably going to be supported by CERN for HL-LHC
  - New cost estimate coming by early FY15, expected below 200 M$
- Observation #2: In order to start Quadrupole production in earnest in FY18 to meet CERN LS3 schedule, some funding for LLI (Long Lead Items) is needed in F16-FY17:
  - M&S: ~ $13M for SC Strand and Cable (50% of full needs), tooling and Magnet parts. Forward Funding for even a fraction of this M&S will insure success of US-HL-LHC. Buy-back with OH expenses once CD-3 is achieved (FY18)
  - Labor (SWF) and Contingency (35%) account for the remaining LLI funds
- Observation #3: Continuation of LARP until CD-3 for US-HL-LHC (FY18) is essential to complete magnet prototyping program

# Muon g-2



- **Science goal:** Measure g-2 of the muon four times more precisely than previous experiments to search for new physics
- **Technical challenge:** Obtaining high field uniformity, delivering new muon beam, measuring muon spin precession to sub-ppm
- **FY14 highlights:** Ring transport from BNL; building complete; cryo plant began construction


TPC: $46.4M

Status: CD-2 review complete (expect in spring after ring cooled down & turned on)

Operations start: March 2017

Initial run duration: 2-3 years

Partnerships

DOE labs: ANL, BNL

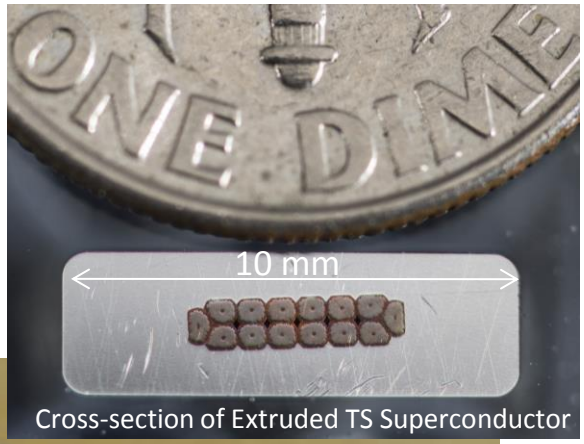
U.S. universities: 16

International: 8 countries, 17 institutions

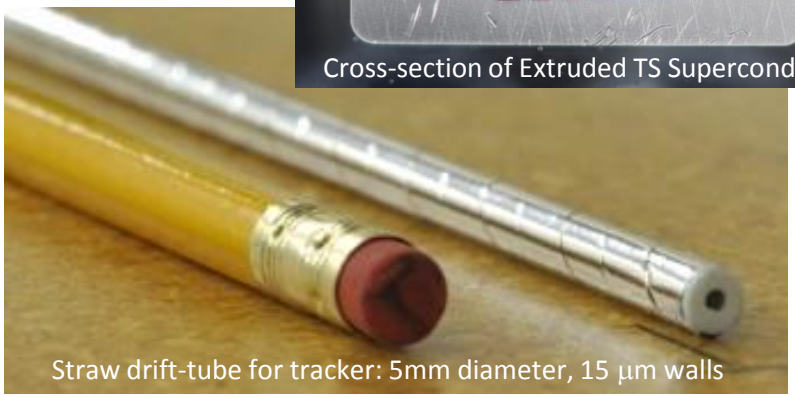
# Mu2e



- **Science goal:** Discover charged-lepton-flavor-violation by improving sensitivity by $10^4$
- **Technical challenge:** Design and fabricate unique superconducting solenoid system and world's most intense muon beam
- **FY14 highlights:** Completed conductor R&D for procurement (CD-3a), solenoid reference designs, and specified detector technologies



Cross-section of Extruded TS Superconductor


Straw drift-tube for tracker: 5mm diameter, 15 μm walls

TPC: $271M

Status: Seeking CD-2/3b approval Nov. 2014

Operations & Commissioning: 2020

Initial run duration: 5 years

Partnerships

DOE labs: ANL, BNL, LBNL

U.S. universities: 16

International: 3 countries, 8 institutions

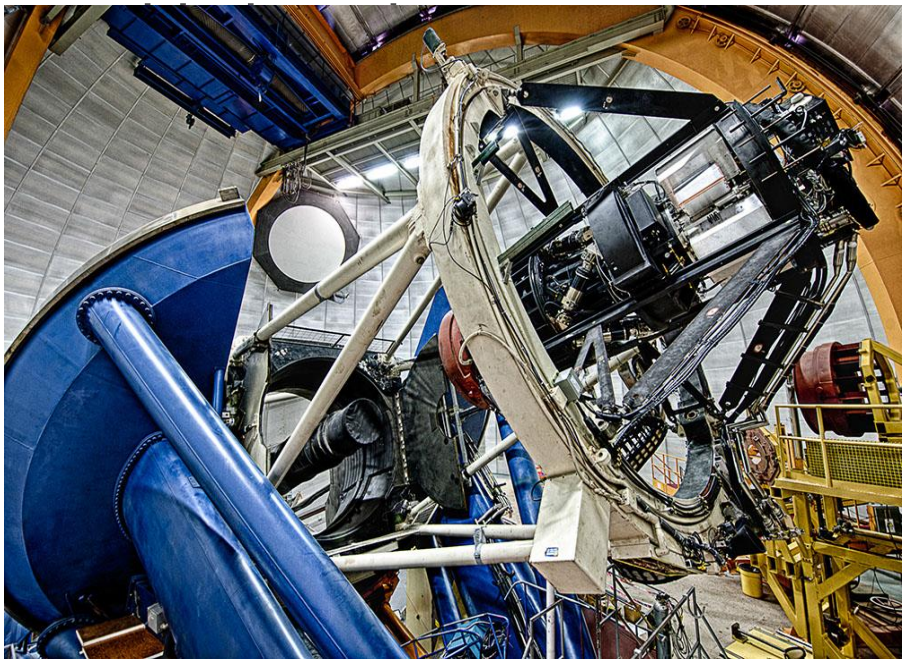
# Dark Energy Survey

Cosmic acceleration, Neutrinos, Dark Matter

- **Science goal:** Probe dark energy via clusters, lensing, supernovae, large-scale structure
- **Recent publications:** Weak lensing cluster masses, photometric redshifts, superluminous supernova, cross-correlation with CMB
- **Upcoming milestones:** papers on discovery of high-redshift clusters, supernovae, large-scale weak lensing in coming months

Status: 1st season completed Feb. 2014; 2nd season started Aug. 2014

Run duration: at least through Feb. 2018 (Five 105-night seasons)



Partnerships

DOE labs: FNAL, ANL, SLAC, LBNL

NSF, NOAO, NCSA

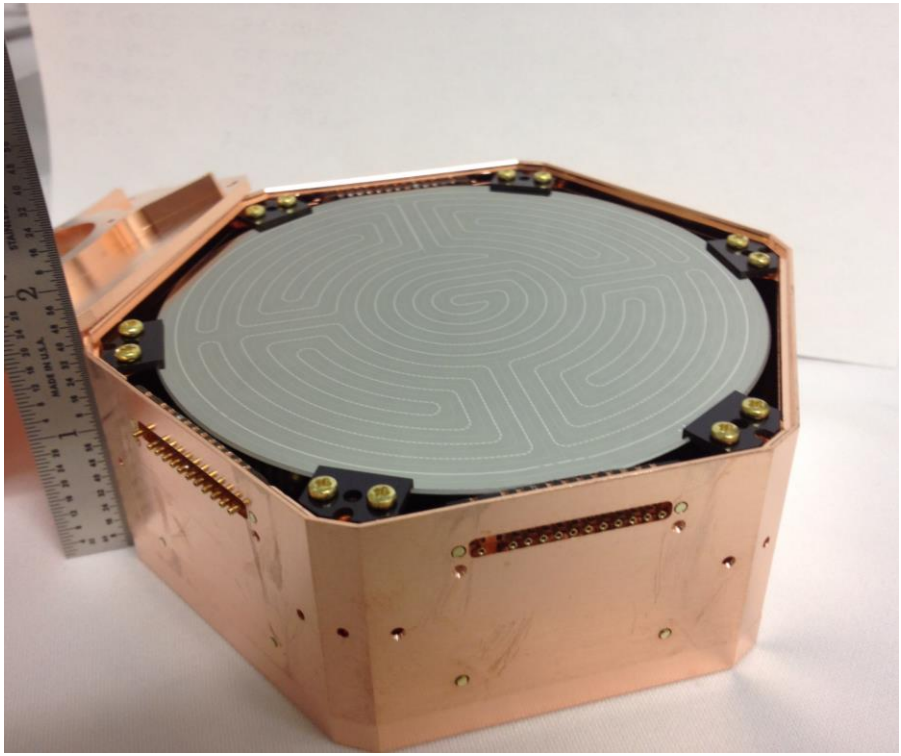
U.S. universities: 9

International: 5 countries, 12 institutes

# SuperCDMS



- **Science goal:** Directly detect dark matter particles, search for non-standard particles
- **Recent publications:** Background performance of SuperCDMS iZIPs; low-mass dark matter limits with CDMSlite and with iZIPs
- **Upcoming milestones:** Background-free dark matter search from SuperCDMS Soudan



Status: Operating SuperCDMS Soudan; designing SuperCDMS SNOLAB (G2 dark matter)

Run duration: Soudan (2015), SNOLAB (2020)

Partnerships

National Laboratories: 3

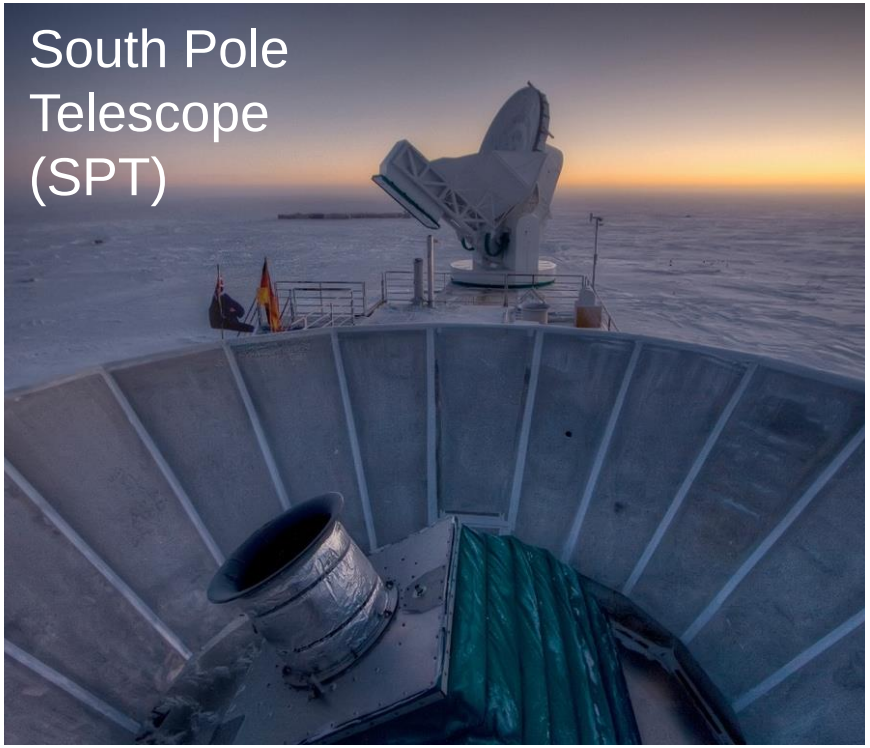
U.S. universities: 13

International: 4

# CMB-S4



- **Science goal:** Probe ~$10^{16}$ GeV physics during cosmic Inflation; measure sum of the neutrino masses; constrain dark radiation
- **Technical challenge:** Scaling of superconducting detector arrays to ~500,000 pixels
- **FY14 highlights:** Endorsement by P5 and HEPAP; CMB B-mode polarization detected by Stage 2 experiments




TPC: ~$100M

Status: Seeking CD-0 approval

Operations start: ~2022

Run duration: ~5 years

Partnerships

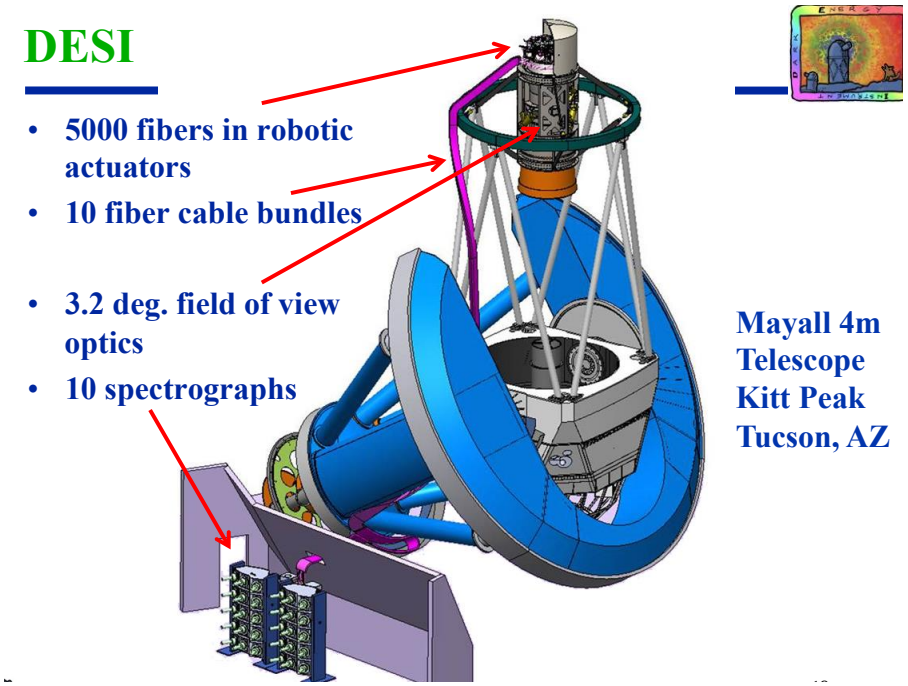
DOE labs: ANL, FNAL, SLAC, LBNL

U.S. universities: ~20

International: ~6

# Dark Energy Spectrographic Instrument (DESI)

- **Science goal:** measure the cosmic distance scale over nearly the entire age of the Universe, constrain neutrino masses and inflation.
- **Technical challenge:** 1m diameter lenses, 5000 robotic fiber positioners
- **FY14 highlights:** 1st spectrograph ordered, optical design finalized, 1st lens orders placed, fiber positioner selected




TPC: $42M DOE

Status: CD-1 Review Sept. 2014 (Ready for FY15 MIE start)

Operations start: 12/2018

Run duration: 5 years

Partnerships (currently forming):

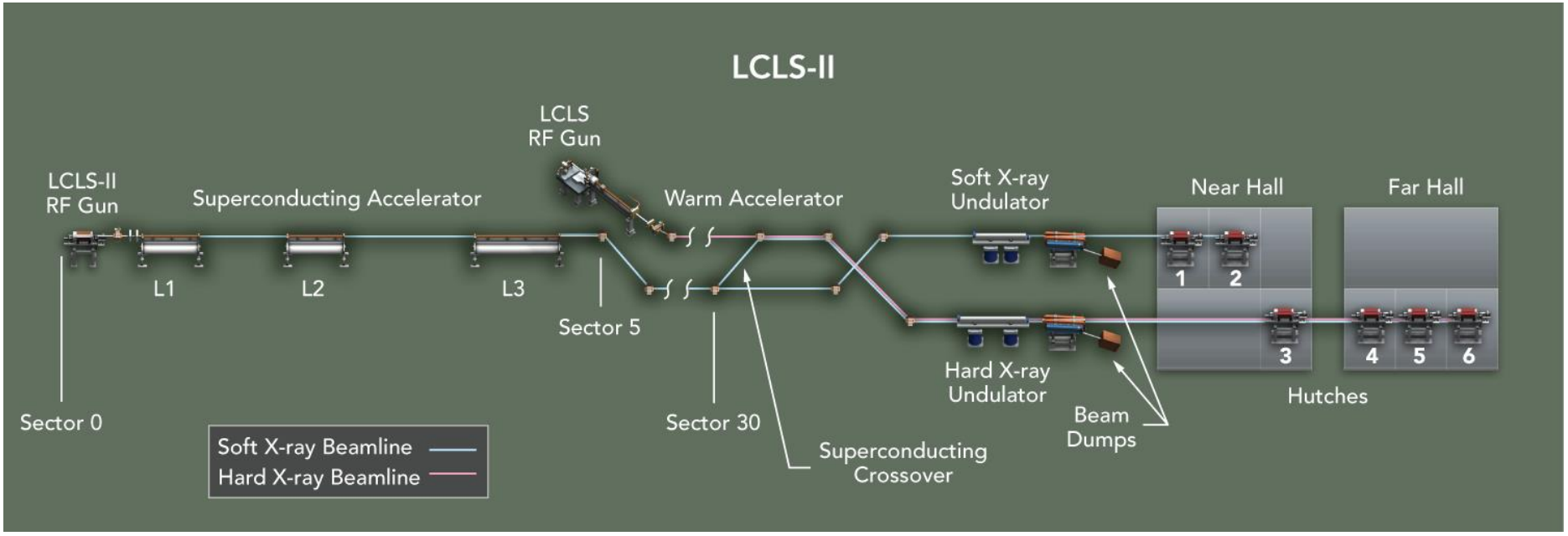
DOE Labs: LBNL (Lead Lab), FNAL, SLAC, ANL, BNL

U.S. Universities: 21

International Institutions: 19

# LCLS-II Activities at FNAL

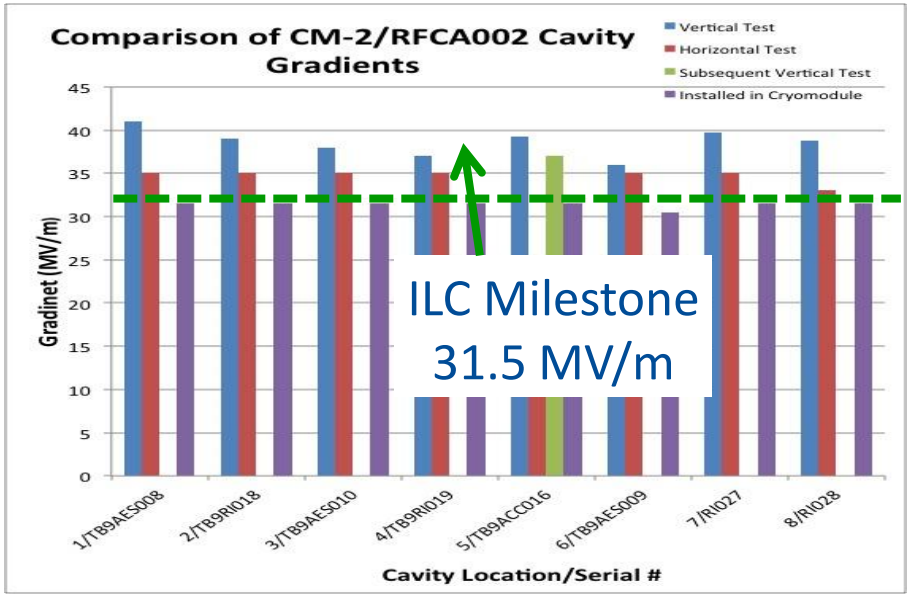
- Work on High Q0 development
  - Goal is to establish that the parameter choice of 2.7 E10 (in production) is valid, and that the cryoplant design capacity is adequate
  - Breakthrough for SRF-based accelerators (lowers cost to operate)
- Design, fabricate, test 17 1.3 GHz + two 3.9 GHz cryomodules
  - Fermilab has sole responsibility for 3.9 GHz cryomodule
- Design & fabricate cryogenic distribution system
- Partners: JLAB, ANL, Cornell, SLAC, LBNL, FNAL



# Superconducting RF Cryomodule



- **Science goal:** Experimentally demonstrate high-gradient high-efficiency beam acceleration with an SRF ILC-type cryomodule
- **Technical challenges:** Nb cavity surface quality via series of processing steps; high-Q resonance control in presence of microphonics noise; beam loading compensation
- **FY14 highlights:** 8 cavity 1.3GHz SRF cryomodule commissioned at world record 31.5 MV/m gradient




Status: System tests without beam

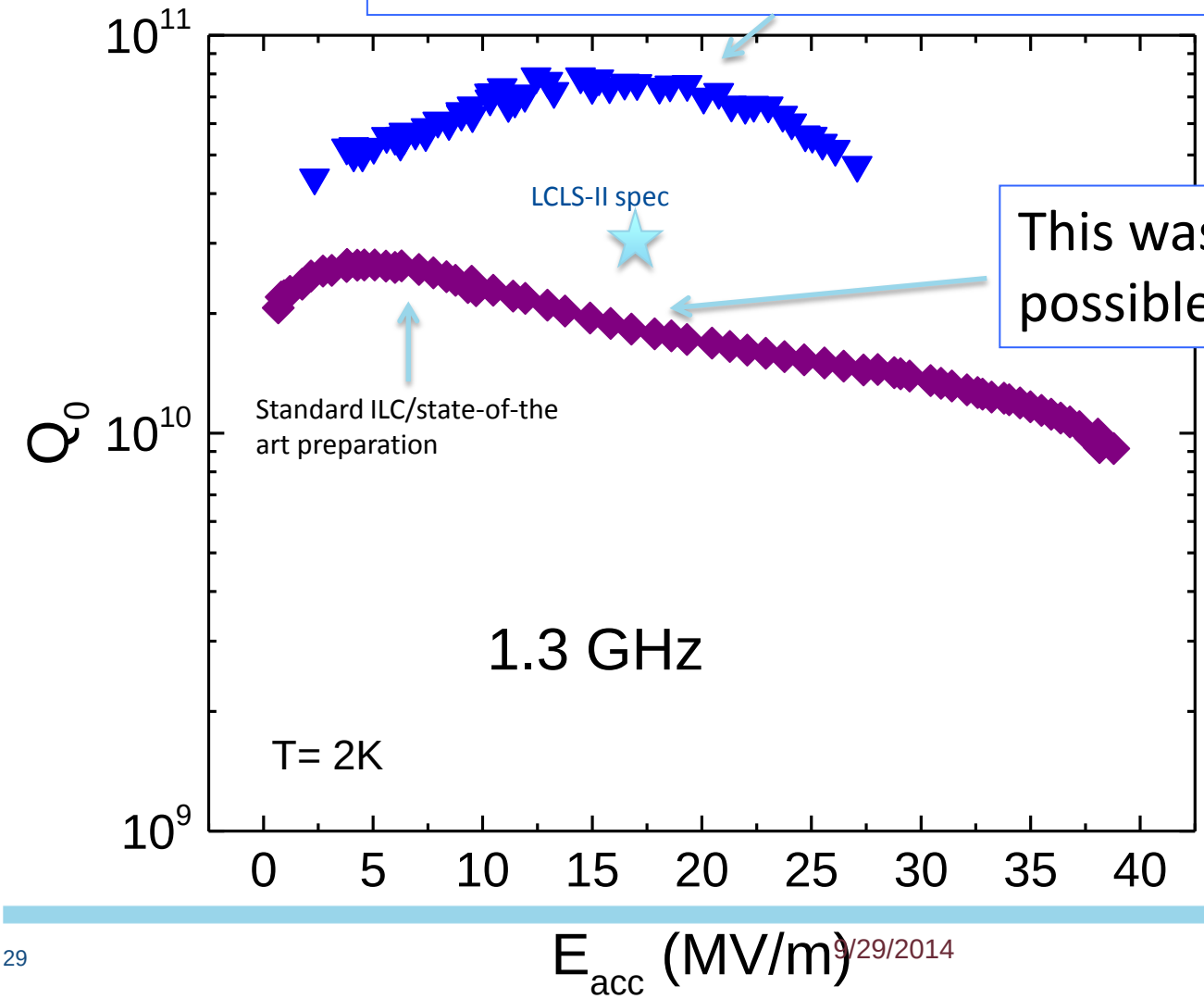
Operations start: late 2015 (with beam)

Run duration: 3-5 years

Partnerships: SLAC, ANL, JLab

# Nitrogen doping: Discovery: First breakthrough results in High Q :

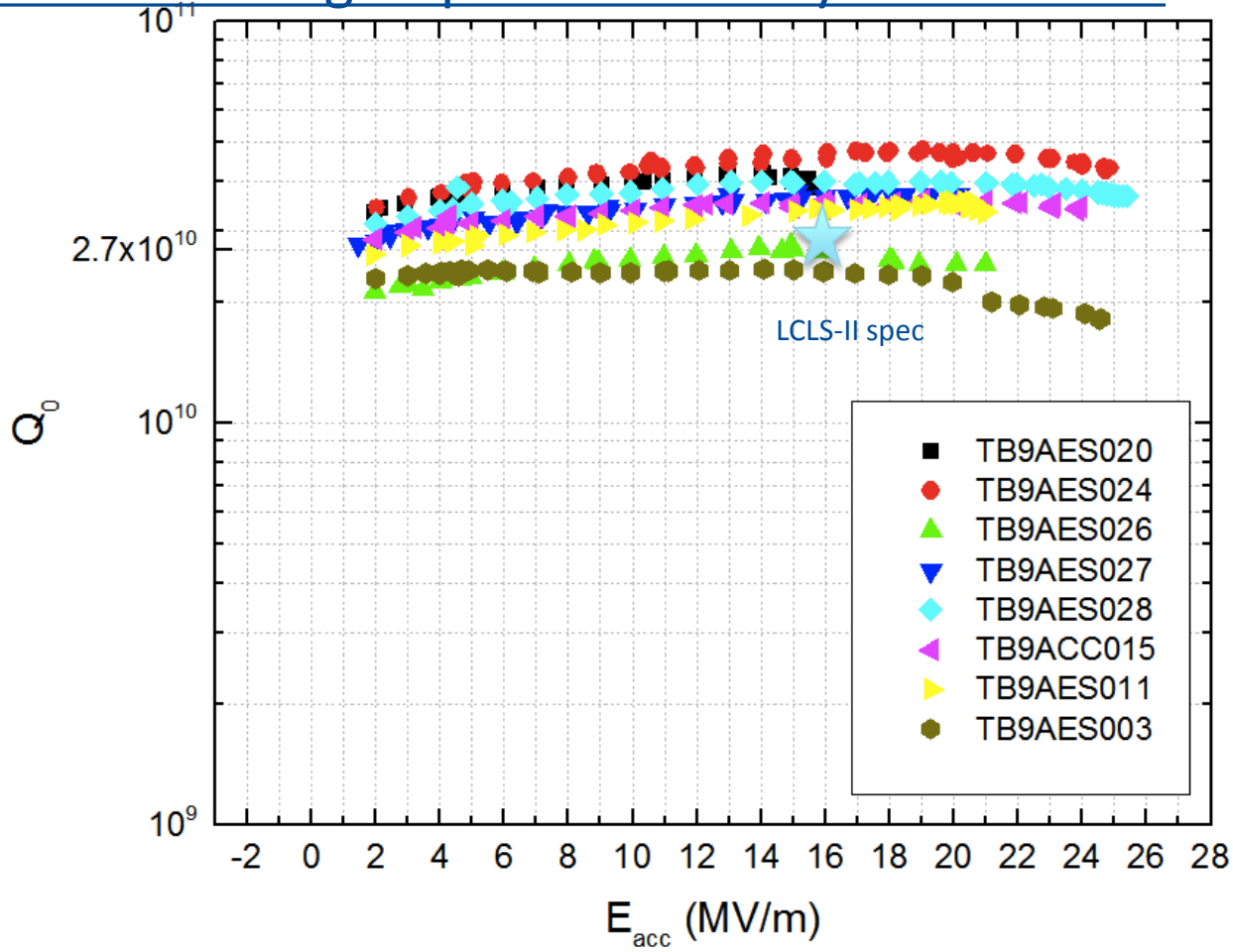
Record quality factors after nitrogen doping – up to 4 times higher Q!




This was the highest Q possible up to last year

# FNAL – Consistent nine cell results with optimized recipe– one LCLS-II cryomodule milestone

New Discovery: If optimal cooling is achieved in cryomodule, magnetic shielding requirements may be reduced!



# Recent Highlights from Experiments

- CMS, working with FNAL theorists, places a direct upper bound on the width of the Higgs boson at 22 MeV, more than two orders of magnitude better than previous bound and better than expected.
- DECam enables discovery by astronomers of a new planetoid
- SuperCDMS result on dark-matter search extends WIMP exclusion to very low mass.
- Stebbins et al. work in 1998 point way to possible observation of gravitational waves from inflation in CMB B-polarization
- Recent analysis of data from Fermi Gamma-Ray Space Telescope provides the strongest evidence to date of dark-matter particles annihilating in the region of the Galactic Center (Hooper et al.)

# Recent Highlights (cont.)

- MINOS combines neutrino, anti-neutrino, beam and atmospheric data in a three-flavor oscillation paper
- S-channel single top production discovered at Tevatron
- Joint Tevatron-LHC precision measurement of the top mass
- Theory results include:
  - Definition of the effective delta m squared measured in neutrino disappearance experiments. Used by the Daya Bay experiment.
  - Co-authorship of PDG review on Higgs
  - Lattice calculations have led to the world's best determinations of the CKM matrix elements |Vus| and |Vcb|, with similar work well underway for |Vub|

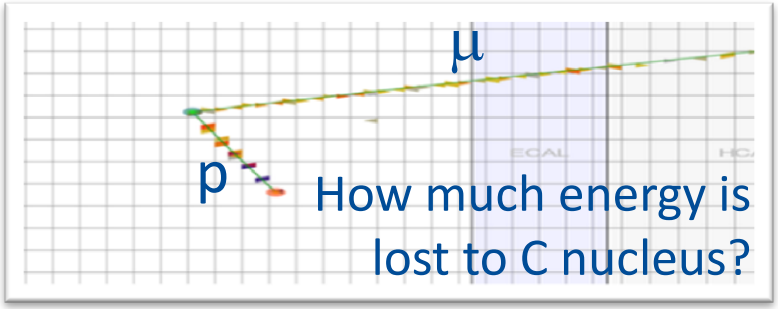
# MINERvA

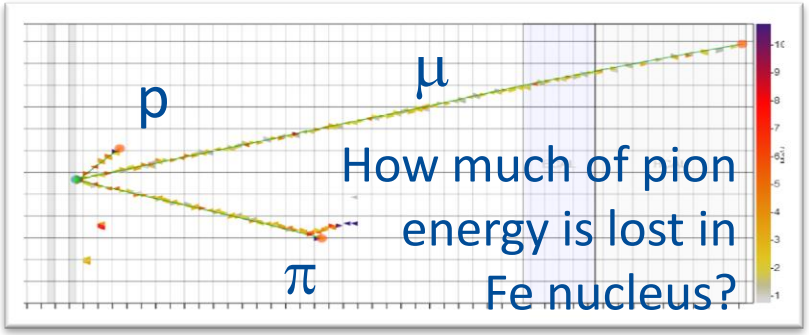


- **Science goal:** Measure neutrino interactions on various nuclei as input to oscillation experiments. Understand transition from free (n,p) to light (C, O) to heavy (Fe, Ar) nuclei
- **Recent publications:** $\nu$ and anti-$\nu$ quasi-elastic scattering, first $\nu$ measurement of "EMC effect"
- **Upcoming milestones:** publications on $\pi^{\pm}$ and $\pi^{0}$ production, Medium Energy data set soon to surpass Low Energy

Status: running in NuMI

Run duration: $6 \times 10^{20}$ POT in $\nu$ mode: $12 \times 10^{20}$ POT in anti-$\nu$ mode (FY18)




Partnerships:

U.S. universities: 13

International: 6 (5 from Latin America)

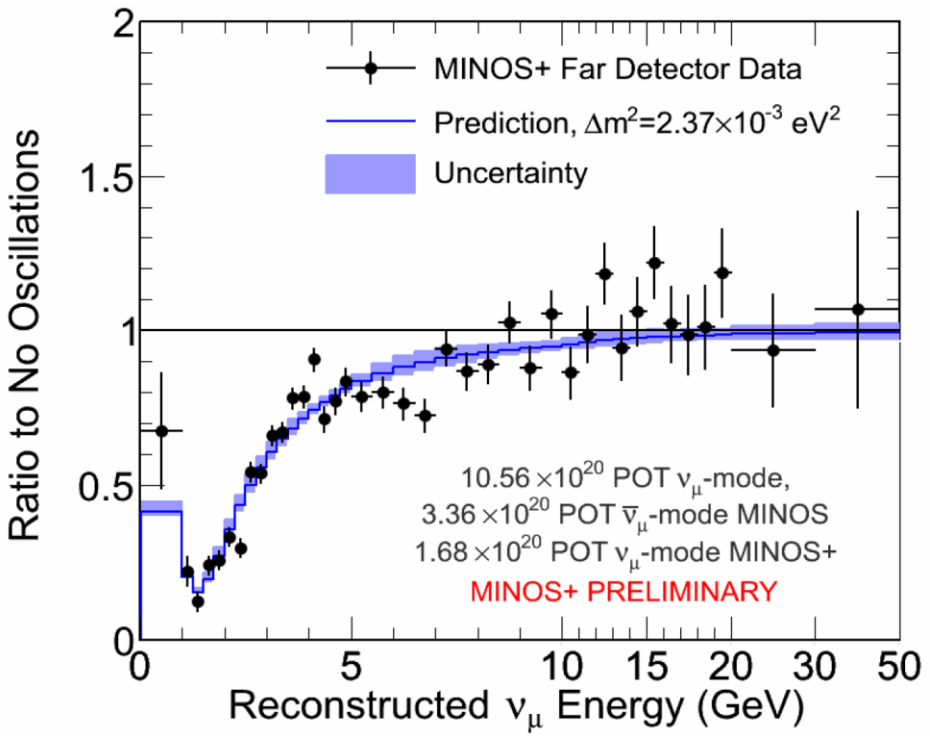
Oscillation experiments (T2K, NOvA)

Neutrino Event Generators (GENIE)

# MINOS+



- **Science goal:** Precision measurement of oscillation spectrum; sterile neutrino search; standard oscillation parameter measurements
- **Recent publications:** $\theta_{13}$ measurement; PRL (2013); appearance and disappearance combined analysis; PRL (2014)
- **Upcoming milestones:** Complete refutation of all non-PMNS effects (or not!). Combination with NOνA on standard parameters




Status: Running in NuMI beam line, 2.5x10$^{20}$ POT so far

Run duration: Through shutdown 2016 (unless new physics)

Partnerships

DOE labs: FNAL, BNL, LANL

U.S. universities: 15

International: 9



Fermilab

# Fermilab Holometer



**Science goal:** Discover or constrain quantum spacetime fluctuations with spectral density = Planck time

**Upcoming milestones:**

July 2014: commissioning complete, operations begin

Summer 2015: Planck sensitivity science results expected

Status: Dual, correlated, power-recycled, >MHz-band, 40 meter Michelson interferometers operating

Duration: Through 2015


Partnerships

DOE labs: FNAL

U.S. universities: 4

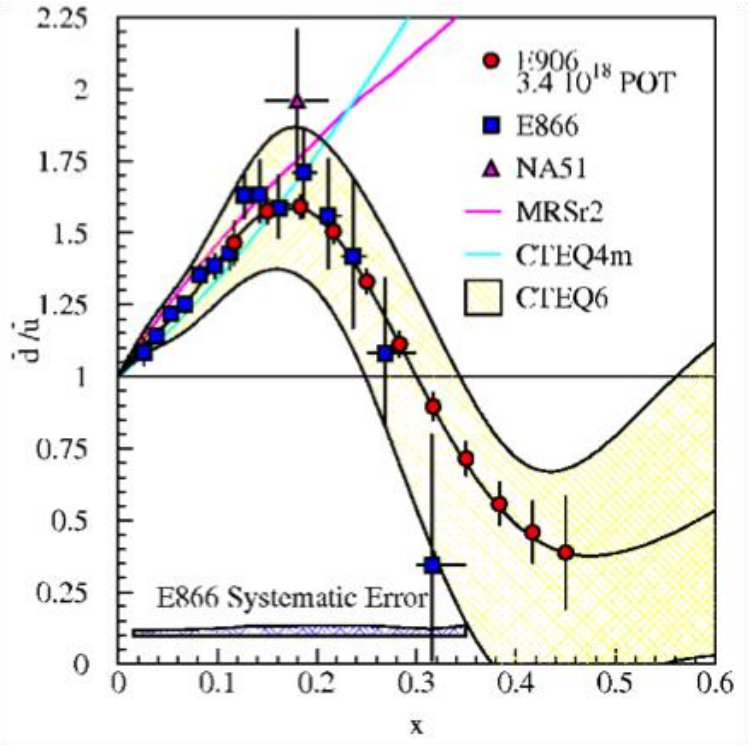
# SeaQuest (E906)



- **Science goal:** Measure the flavor asymmetry of the nucleon antiquark sea; understand the origin of the antiquark sea and how it is modified in cold nuclear matter.
- **Upcoming milestones:** Initial publication based on data collected by Sept. 2014; installation of new wire chamber to increase acceptance for large target antiquark $x_F$.

Status: Physics run started Feb. 2014. Drell-Yan yield increasing as spill uniformity increases.

Run duration: Current run ends late 2015, plan to follow up with polarized target.




Partnerships: Nuclear Physics

DOE labs: ANL, FNAL, LANL

U.S. universities: 6

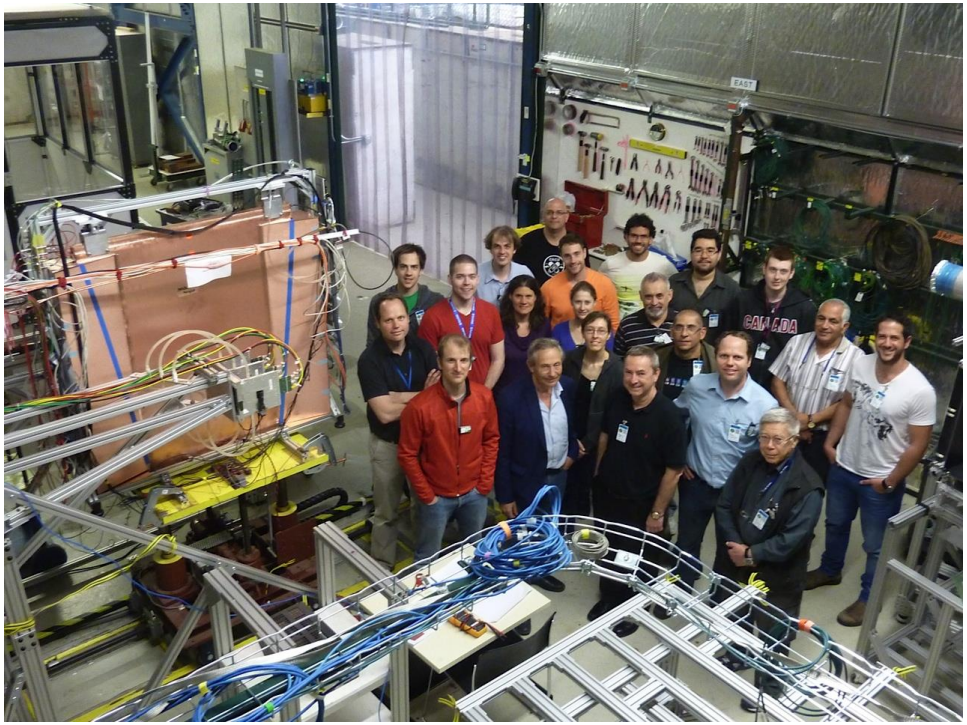
International: 6

# Test Beam Facility



- **Science goal:** provide test beams for all detector tests, with relatively low bureaucratic overhead.
- **Recent achievements:** Restarted Operations of MCenter line. New High-Rate Area for tracking detectors
- **FY14 highlights:** In FY 2014 FTBF served 17 experiments with 319 collaborators from 84 institutions in 20 countries.

Status: Two operating beam lines



Users in 2014:

DOE labs: FNAL, ANL, BNL, ORNL, SLAC

U.S. universities: 34

International: 45

# Cost of Doing Business – Balancing Priorities

Initiatives and Trade-offs

New senior management team highly engaged in assessment of issues, risks and investments

- Standing working group focuses cost reduction and improvement opportunities

High-priority indirect initiatives receiving funding in FY14 include:

- New LDRD program
- WorkDay – a modern Human Capital Management system; first lab to implement
- Growing the Office of Partnerships & Technology Transfer and supporting related business development efforts
- Strengthening the procurement function to provide optimum support for large capital projects
- Revitalization of the Wilson Hall atrium to represent a new direction driven by Master Plan
- Repurposing former collider facilities supporting new operations (Muon Campus)
- Reuse of former Tevatron equipment for new experiments
- Enhanced computing experience for users – internet connectivity, identity management

# Improving Performance – Refocusing to Implement P5

- "Building for Discovery" emphasizes tightly managed portfolio of projects at Fermilab
  - Strengthen and promote project management across portfolio and in concert with emphasis on operations: Chief Project Officer Mike Lindgren
  - Regina Rameika to Head Neutrino Division
    - provides visible organizational home for short- and long-baseline programs
  - Patty McBride to Head Particle Physics Division
- Reconfigure senior management team to enhance communication and clarify line management
  - Closer connections between employees across all divisions and departments ("One Lab")

# Long-Baseline Program Process

- June 16: CERN Science Policy Committee (SPC) presentation…US situation and plans post-P5
  - Chairs of CERN Council & Finance Committee present
- CERN Medium-Term Plan (MTP) approved…5 year plan with next year's budget defined…$60M for neutrinos
  - Aimed at neutrino platform to assist with program in US
  - Investment in infrastructure outside CERN allowed
  - No funds for a CERN neutrino beam for at least 5 years
- June 21-22: APPEC Paris meeting…European neutrino physicists & agencies met to discuss future post-mTP
  - World program represented
  - Strong support for accelerator-based neutrinos in US & Japan
  - Next meeting at Fermilab in spring

# Long-Baseline Program Process (2)

- July 14: Siegrist hosted a meeting at Fermilab of funding agencies….UK, Italy, CERN, India, Brazil, Japan
  - Governance (three box model: PAC, OEB, IJOG)
  - Project management (embed international components in Lehman-like process)
  - Launch steering committee to develop international PMP
- Now commencing a broader-team building process…
  - July 21-22 “Summit” is beginning (Ken Long & Rob Roser Co-Chairs)
- iIEB first meeting at Fermilab September 23-24
  - iIEB interim International Executive Board
- Next steps….keep working on baseline issue & LOI draft
  - LOI to PAC for January meeting
  - “new” collaboration CDR will go to PAC for summer 2015

# Fermilab recommendation for National GARD Program

1. High-field magnets and materials
2. Multi-MW beams and targets
3. Cost-Effective SRF Technology
4. Advanced Accelerator Concepts
5. Accelerator Science, Modeling & Design
6. Core Accelerator Competencies

# Rationale and Goals

1. High-field magnets and materials
   - Long-term; maintain US leadership in SC magnets; $Nb_3Sn$, HTS
   - Significant T*m cost reduction, modest support of global design
2. Novel techniques for multi-MW beams and targets

PIP-II Beyond PIP-II (mid-term)

| | 1st 10 years | 2nd 10 years | | |
|---|---|---|---|---|
| To Achieve : | 100 kT-MW-year | 500 kT-MW-year | | |
| We combine : | | Option 1 | Option 2 | Option 3 |
| Mass | 10 kT | 50 kT | 20 kT | 10 kT |
| Power | 1 MW | 1 MW | 2.5 MW | 5 MW |

   - Mid-term strategy after PIP-II depends on the technical feasibility of each option and the analysis of costs/kiloton versus costs/MW
   - R&D on effective control of beam losses in proton machines with significantly higher currents ($Q_{SC}$) and on multi-MW targets

# Rationale and Goals (2)

3. Cost-Effective SRF Technology
   - Crucial enabling technology for accelerators
   - Aim at a substantial reduction in construction and operation costs
   - Improve gradients, increase Q-factor, study new materials;
   - Affects both far- and mid-term accelerators

4. Advanced Accelerator Concepts
   - Conceptual and technical feasibility of advanced collider concepts; aim at HEP applications and significant **total** cost reduction
   - Intense secondary beams for next-generation precisions experiments (such as “beyond mu2e”, “beyond g-2” and a NF)
   - Both long- and mid-term

# Rationale and Goals (3)

5. Accelerator Science, Modeling and Design
   - Conceptual design and modeling of new machines
   - Cross-cutting accelerator theory and experiments
   - Excellence in high-performance high-fidelity computer modeling
   - Combination of both mid-term and long-term efforts

6. Core Accelerator Competencies
   - Accelerator training and education for HEP and beyond
     - Jointly - Universities and National Labs
   - Novel particle sources; Advanced beam instrumentation
   - NC rf and cost-effective rf sources
   - Both mid-term and long-term efforts

# Conclusion

- Aligning with Particle Physics Project Prioritization Panel (P5)
- Exciting and demanding transition period for Fermilab
- Several large projects at various stages of CD process
- International interest and participation is increasing
- Neutrinos are coming together
- Staff is stretched but motivated and encouraged
- Near-term budget challenges for research, ops and projects
- Excited about implementing campus master plan
- Continue to develop a vision for longer term future in conjunction with the world program