A Look from the Present into the Future

with an emphasis on experimental opportunities to resolve big scientific questions

or

Building a Particle Physics Program to Address the Most Compelling Scientific Questions of the Field

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Aspen - Winter 2014

Compelling Scientific Questions

from the *The Quantum Universe*

ARE THERE UNDISCOVERED PRINCIPLES OF NATURE:
NEW SYMMETRIES, NEW PHYSICAL LAWS?

HOW CAN WE SOLVE THE MYSTERY OF DARK ENERGY?

ARE THERE EXTRA DIMENSIONS OF SPACE?

DO ALL THE FORCES BECOME ONE?

WHY ARE THERE SO MANY KINDS OF PARTICLES?

WHAT IS DARK MATTER?
HOW CAN WE MAKE IT IN THE LABORATORY?

WHAT ARE NEUTRINOS TELLING US?

HOW DID THE UNIVERSE COME TO BE?

WHAT HAPPENED TO THE ANTIMATTER?

http://www.interactions.org/quantumuniverse/qu/index.html

Compelling Scientific Questions
from Snowmass CSS 2013

1. **How do we understand the Higgs boson? What principle determines its couplings to quarks and leptons? Why does it condense and acquire a vacuum value throughout the universe? Is there one Higgs particle or many? Is the Higgs particle elementary or composite?**
2. **What principle determines the masses and mixings of quarks and leptons? Why is the mixing pattern apparently different for quarks and leptons? Why is the CKM CP phase nonzero? Is there CP violation in the lepton sector?**
3. **Why are neutrinos so light compared to other matter particles? Are neutrinos their own antiparticles? Are their small masses connected to the presence of a very high mass scale? Are there new interactions invisible except through their role in neutrino physics?**
4. **What mechanism produced the excess of matter over anti-matter that we see in the universe? Why are the interactions of particles and antiparticles not exactly mirror opposites?**
5. **Dark matter is the dominant component of mass in the universe. What is the dark matter made of? Is it composed of one type of new particle or several? What principle determined the current density of dark matter in the universe? Are the dark matter particles connected to the particles of the Standard Model, or are they part of an entirely new dark sector of particles?**
6. **What is dark energy? Is it a static energy per unit volume of the vacuum, or is it dynamical and evolving with the universe? What principle determines its value?**
7. **What did the universe look like in its earliest moments, and how did it evolve to contain the structures we observe today? The inflationary universe model requires new fields active in the early universe. Where did these come from, and how can we probe them today?**
8. **Are there additional forces that we have not yet observed? Are there additional quantum numbers associated with new fundamental symmetries? Are the four known forces unified at very short distances? What principles are involved in this unification?**
9. **Are there new particles at the TeV energy scale? Such particles are motivated by the problem of the Higgs boson, and by ideas about space-time symmetry such as supersymmetry and extra dimensions. If they exist, how do they acquire mass, and what is their mass spectrum? Do they carry new sources of quark and lepton mixing and CP violation.**
10. **Are there new particles that are light and extremely weakly interacting? Such particles are motivated by many issues, including the strong CP problem, dark matter, dark energy, inflation, and attempts to unify the microscopic forces with gravity. What experiments can be used to find evidence for these particles.**
11. **Are there extremely massive particles to which we can only couple indirectly at currently accessible energies? Examples of such particles are seesaw heavy neutrinos or GUT scale particles mediating proton decay.**

Compelling Scientific Questions

from Snowmass via Chip Brock

Big Questions

1. How do we understand the Higgs boson?

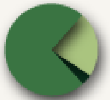
2. How do we understand the multiplicity of quarks and leptons?

3. How do we understand the neutrinos?

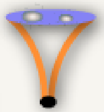
4. How do we understand the matter-antimatter asymmetry of the universe?

5. How do we understand the substance of dark matter?

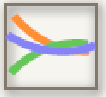
6. How do we understand the dark energy?



7. How do we understand the origin of structure in the universe?



8. How do we understand the multiplicity of forces?



9. Are there new particles at the TeV energy scale?

10. Are there new particles that are light and extremely weakly interacting?

11. Are there extremely massive particles to which we can only couple indirectly at currently accessible energies?

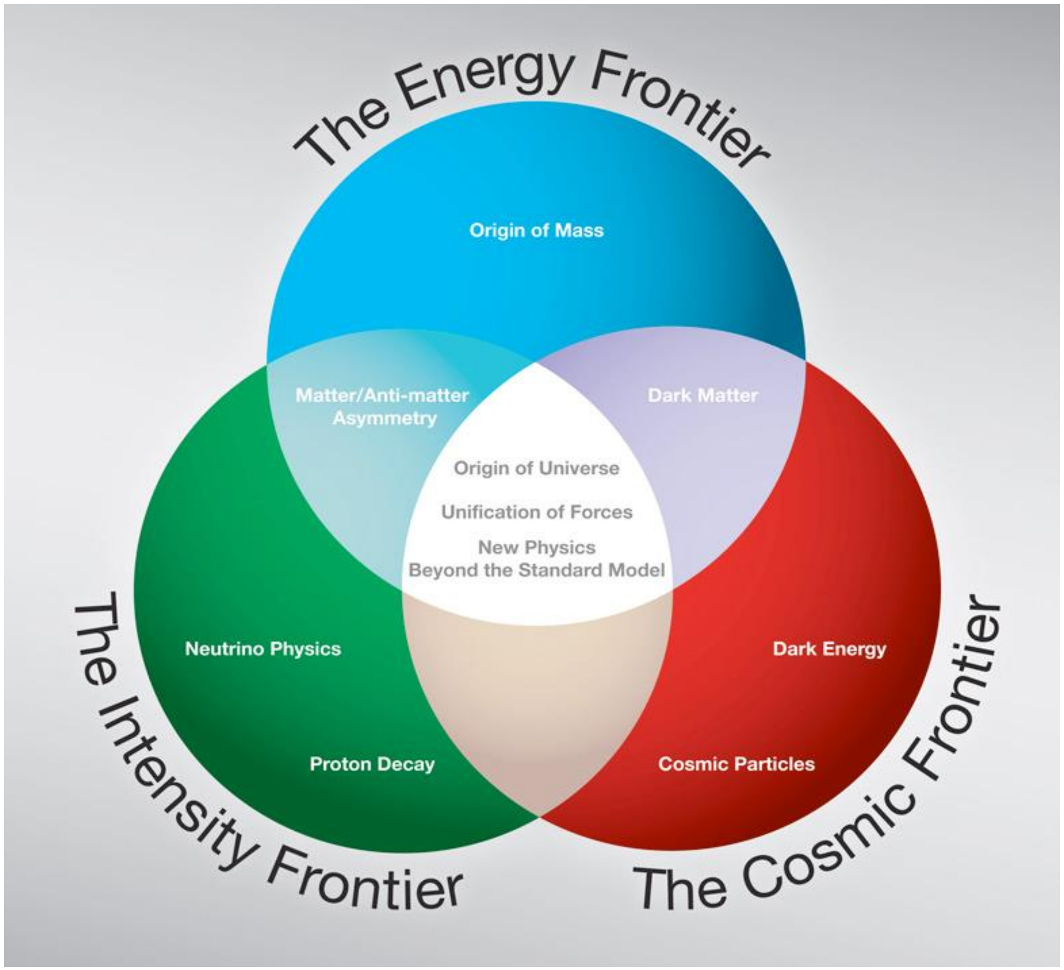
The Departure Point

2008 P5 Strategic Plan

Vision of 2008 Strategic Plan :

Address fundamental questions about the laws of nature & the cosmos

through a strong, integrated program at the 3 frontiers



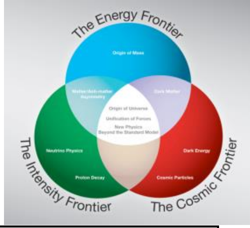
The three frontiers of research form an interlocking framework.

"The panel recommends a strong, integrated research program at the three frontiers of the field: the Energy Frontier, the Intensity Frontier and the Cosmic Frontier."

A program that:

- **continuously produces important results on each frontier**
- **harmonizes with the worldwide program**

Major Recommendations of 2008 P5



- A strong, integrated research program at the three frontiers of the field: the Energy Frontier, the Intensity Frontier, and the Cosmic Frontier.
- Energy Frontier: Support for the US LHC program, including US involvement in the planned detector and accelerator upgrades. (highest priority)
- Intensity Frontier: A world-class neutrino program as a core component of the US program, with the long-term vision of a large detector in the proposed DUSEL and a high-intensity neutrino source at Fermilab.
- Intensity Frontier: Funding for measurements of rare processes to an extent depending on the funding levels available… (Mu2e in all scenarios)
- Cosmic Frontier: Support for the study of dark matter and dark energy as an integral part of the US particle physics program.
- A broad strategic program in accelerator R&D, … along with support of basic accelerator science.

Sketches of the facets of the present program
and
Some opportunities for the future program

Some emphasis on U.S. program

Opportunities are generally those identified by the Snowmass study

Organized by frontier, but note interplay between frontiers

ENERGY FRONTIER

Energy Frontier Status – Overview

- U.S.-based **Tevatron** stopped operations in 2011.
- CERN-based **LHC** operational since ~ 2010.
  - Preparations for **upgrades to LHC accelerator & experiments** in two phases
- Japanese-hosted **ILC** under consideration.
  - Preparations for **ILC accelerator & experiments** have been long in the making, foreseeing a global project.
- R&D for **future options** underway – lepton colliders, hadron colliders

My subsequent EF status slides will focus on U.S. role.

U.S. at the Energy Frontier – Status I

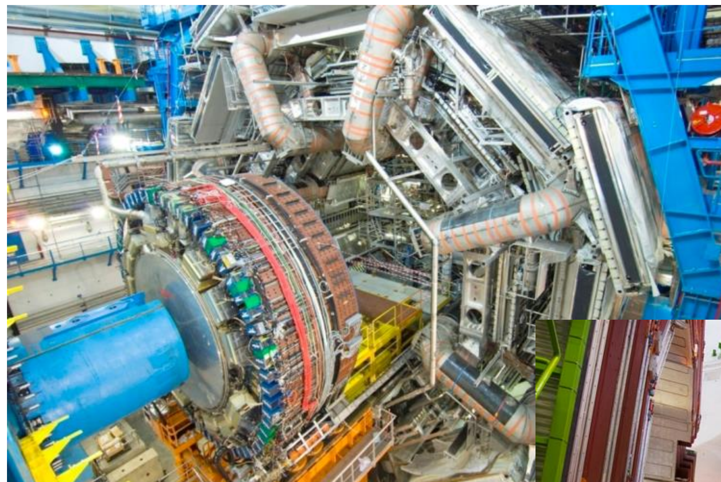
Exploiting the LHC

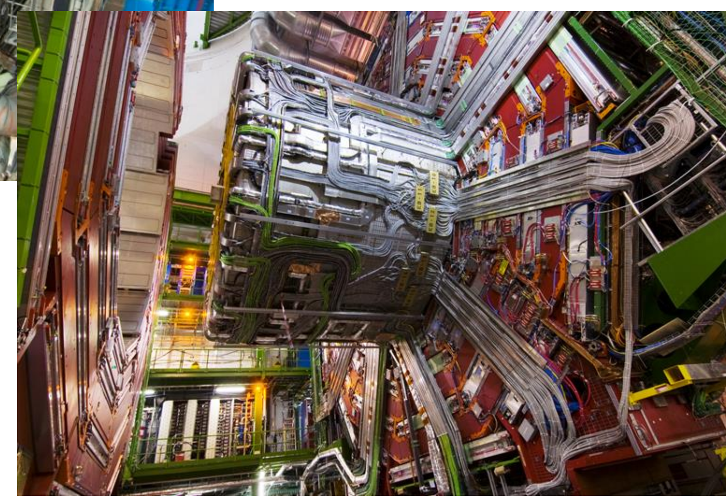
- LHC has been one of largest investments of U.S. in HEP ever.
- U.S. participation in ATLAS, CMS, LHCb, ALICE & accelerator

35-40% of HEP research

US ATLAS
- 44 institutions
- 376 PhD authors (21%)
- 175 students

US CMS
- 49 institutions
- 426 PhD authors (32%)
- 247 students





Recent research successes have been dramatic.

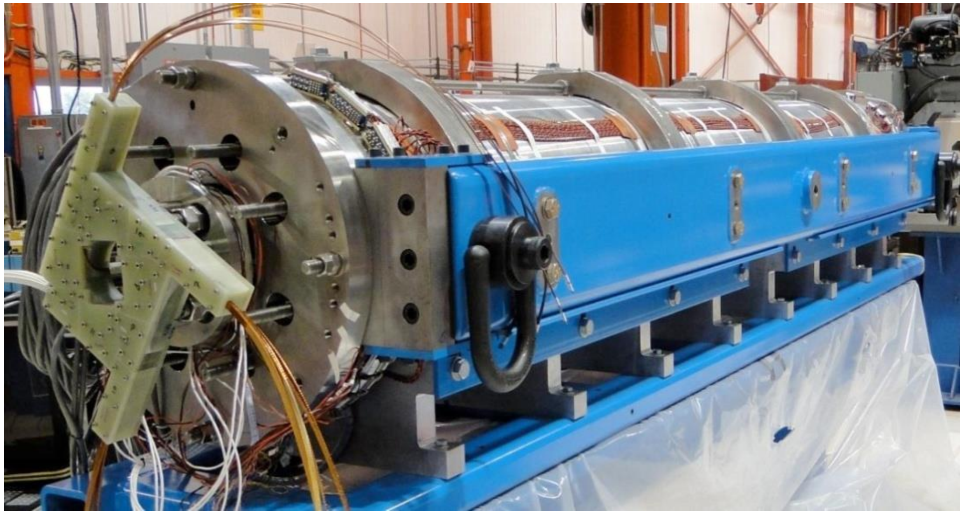
U.S. at the Energy Frontier – Status II

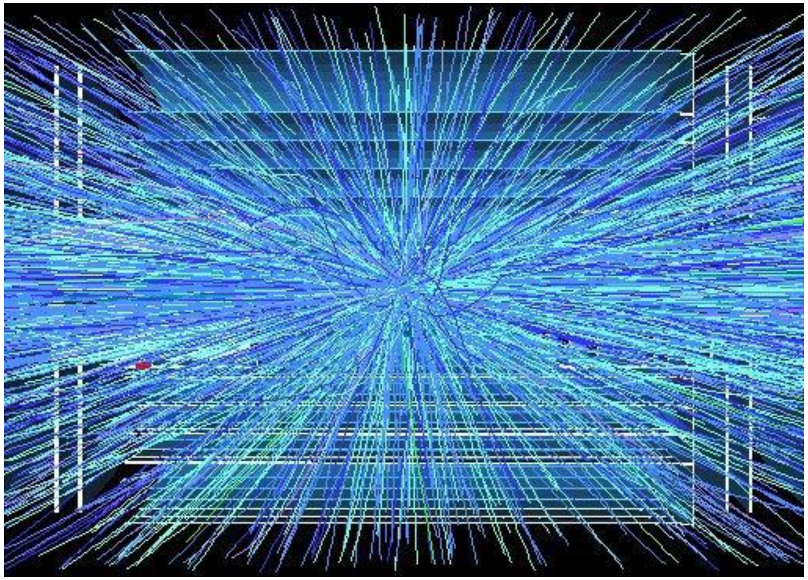
Preparing for LHC upgrades

- Physics capabilities are promising
- Phase I - detector upgrades

  U.S. transitioning from R&D to Construction
- Phase II: HL-LHC - accelerator & detector upgrades

  U.S. in active R&D on greatest technical challenges
  - ***E.g.,*** **accelerator – Nb_3Sn quadrupole magnets**
  - ***E.g.,*** **experiments – silicon trackers**

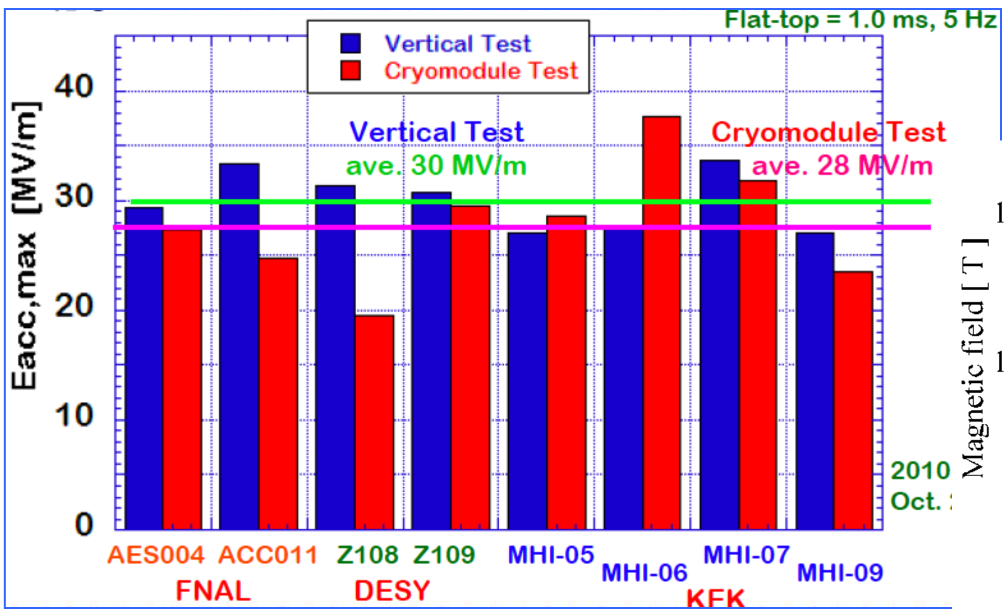


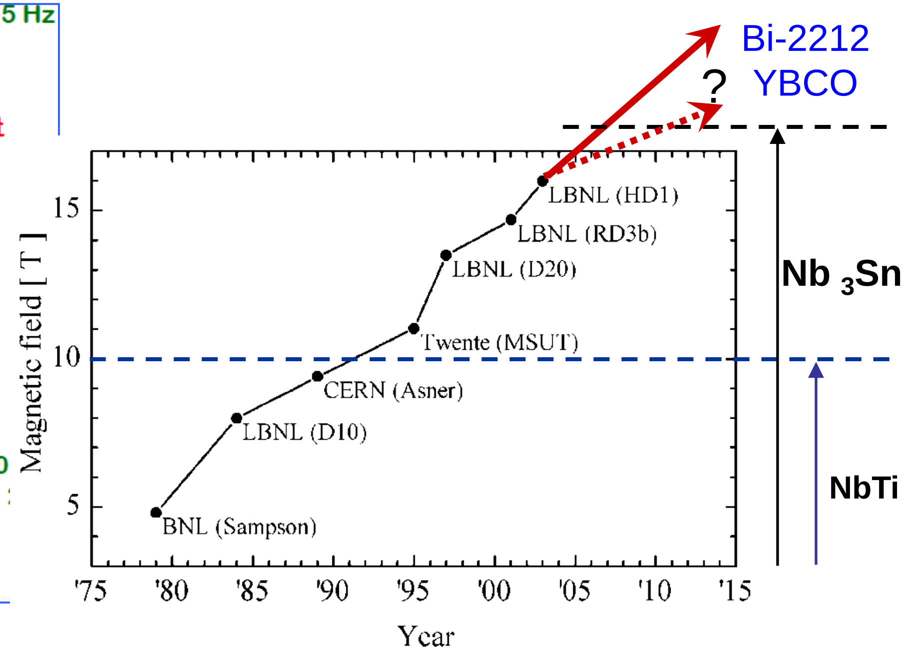


Accelerator R&D for Future EF Options

Performing a broad range of R&D for variety of future accelerator options

- **Superconducting RF (ILC)** – bottom left
- **Muon cooling (muon collider)** - right
- **Superconducting dipoles (HE-LHC, VLHC)** – bottom right





Energy Frontier – Snowmass Vision - I

Discovery of the Higgs boson calls for a three-pronged research program:

1. **Determine the properties of the Higgs boson as accurately as possible.**
    - **This will guide large parts of the future particle physics program.**
2. **Make precise measurements of the heavy particles W, Z, t, which can carry the imprint of the Higgs field.**
3. **Search for new particles predicted by models of the H boson and EWSB.**

LHC → HL-LHC **will drive the EF program forward for next 15-20 yrs**

- **Precision study of Higgs properties at the few percent level**
- **Search for new particles**
- **Probe for new dynamics of W, Z, H at TeV energies**
- **Study rare decays using billions of top quarks**

ILC **continuing the EF program with a lepton collider**

- **Sub-percent, model-independent study of Higgs properties**
- **Improved precision in knowledge of W, Z, t, well enough to allow discovery of new physics effects**
- **New particle searches complementary to LHC**

Energy Frontier – Snowmass Vision - II

Other options for high-energy colliders – a look beyond the LHC & ILC

- **Circular e+e- colliders**
- **Muon colliders**
- **Photon colliders**
- **100-TeV class hadron collider**
  - **A large step in energy**
  - **Great potential for new insights into EWSB and DM**
- **Accelerator and Detector capabilities to enable**

Large circular colliders are (once again) attracting much interest worldwide.

- **Studies are being initiated for e+e- and pp options.**
  - **VLHC - Snowmass**
  - **FCC study – Europe**
  - **CEPC + SppC - China**
- **Identify & address R&D on enabling technologies in a global effort.**

Energy Frontier - Facilities

Hadron colliders:

- Tevatron – closed 2011
- LHC operational since ~2010; Phase I LHC expt. upgrades being initiated
- **High Luminosity LHC (HL-LHC) - in research and development - ~2023 install**
- More distant options for higher energy being explored (e.g. HE-LHC, VLHC)

Lepton colliders:

- **International Linear Collider (ILC hosted in Japan) – TDR complete; initiative from Japan to host; allows staged approach to E_{cm}**
- More distant options for higher energy being explored (e.g. CLIC, μ collider, TLEP)

HEP Energy Frontier Experiments

Experiment	Location	CM Energy; Status	Description	# Institutions; # Countries	#U.S. Institutions	#U.S. Coll.
DØ (DZero)	Fermilab Tevatron Collider [Batavia, Illinois, USA]	1.96 TeV; Operations ended: Sept. 30, 2011	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	74 Institutions; 18 Countries	33 Univ., 1 National Lab	192
CDF (Collider Detector at Fermilab)	Fermilab Tevatron Collider [Batavia, Illinois, USA]	1.96 TeV; Operations ended: Sept. 30, 2011	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	55 Institutions; 14 Countries	26 Univ., 1 National Lab	224
ATLAS (A Toroidal LHC ApparatuS)	CERN, Large Hadron Collider [Geneva, Switzerland / Meyrin, Switzerland]	7-8 TeV; 13-14 TeV Run 1 ended: Dec. 2012 Run 2 start: 2015	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics, and Heavy-Ion	169 Institutions; 37 Countries	40 Univ., 4 National Labs	583
CMS (Compact Muon Solenoid)	CERN, Large Hadron Collider [Geneva, Switzerland / Cessy, France]	7-8 TeV; 13-14 TeV Run 1 ended: Dec. 2012 Run 2 start: 2015	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics, and Heavy-Ion	179 Institutions; 41 Countries	48 Univ., 1 National Lab	678

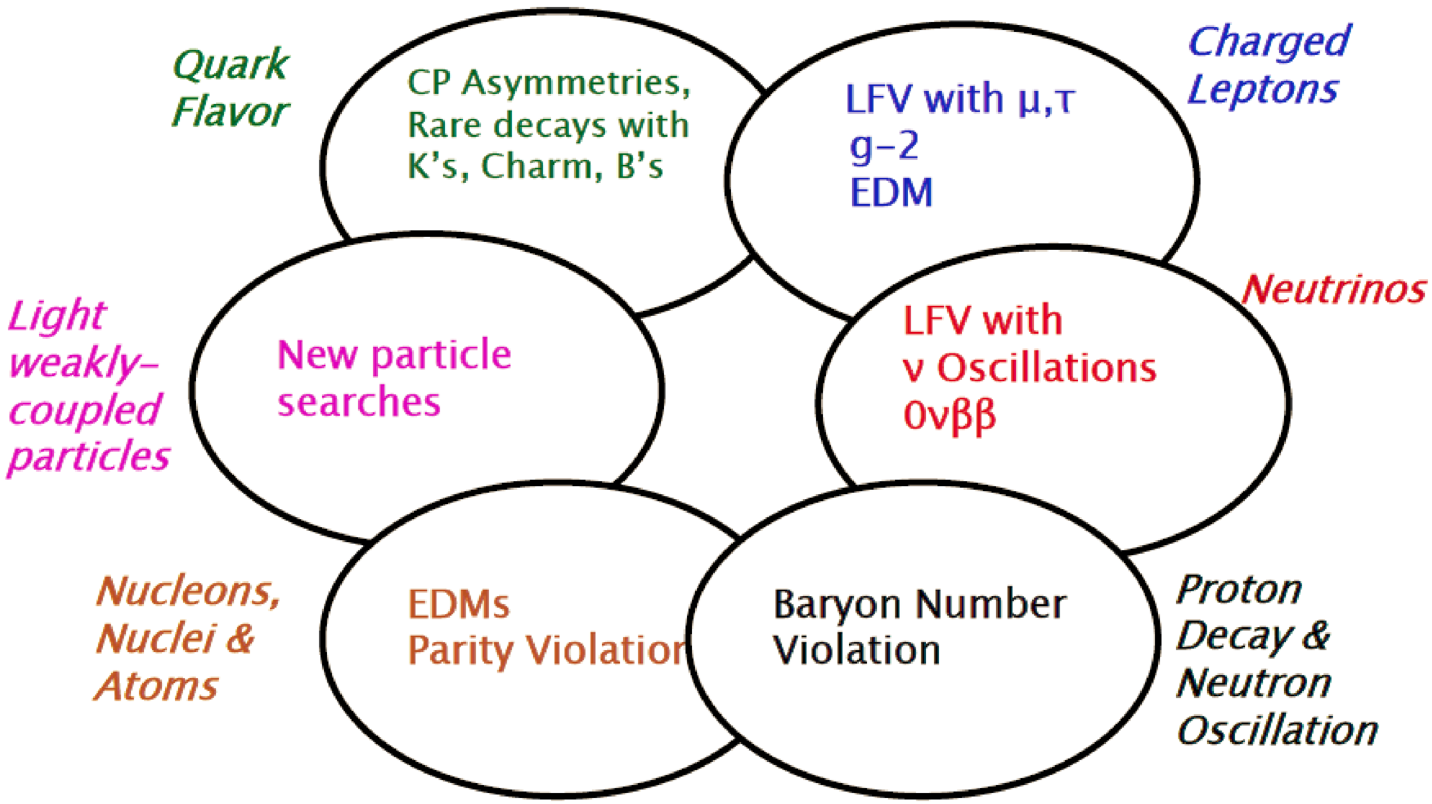
Collaboration data as of August 2013.

- Two main scientific thrusts
  - Tevatron at Fermilab (pp collider): DØ Collaboration, CDF Collaboration
  - LHC at CERN (pp collider): CMS Collaboration, ATLAS Collaboration
- U.S. is single biggest collaborator in both ATLAS and CMS experiments at LHC
  - US-ATLAS: ~23% of the international ATLAS Collaboration
    - — 175 U.S. graduate students
  - US-CMS: ~33% of the international CMS Collaboration
    - — 247 U.S. graduate students

INTENSITY FRONTIER

The Intensity Frontier Program

The Intensity Frontier is a broad and diverse, yet connected, set of science opportunities

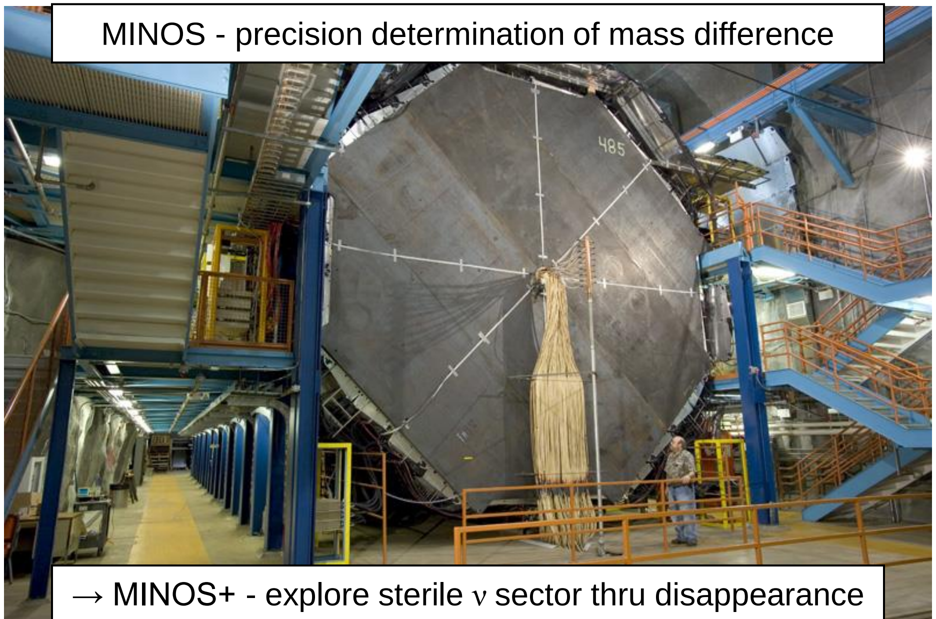


from Hewett & Weerts

Intensity Frontier

NEUTRINO PROGRAM

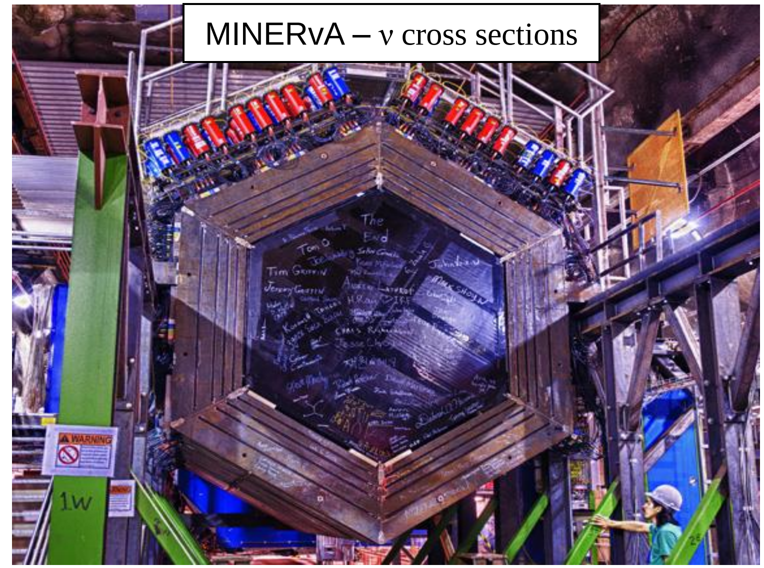
Ongoing Neutrino Program at Fermilab



MINOS - precision determination of mass difference

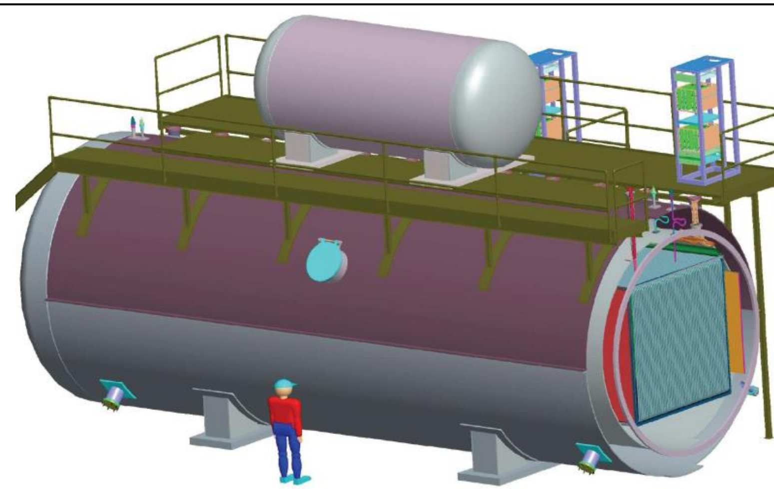
→ MINOS+ - explore sterile ν sector thru disappearance

NOvA – confirm θ_{13} thru appearance; determine mass hierarchy



MINERvA – ν cross sections

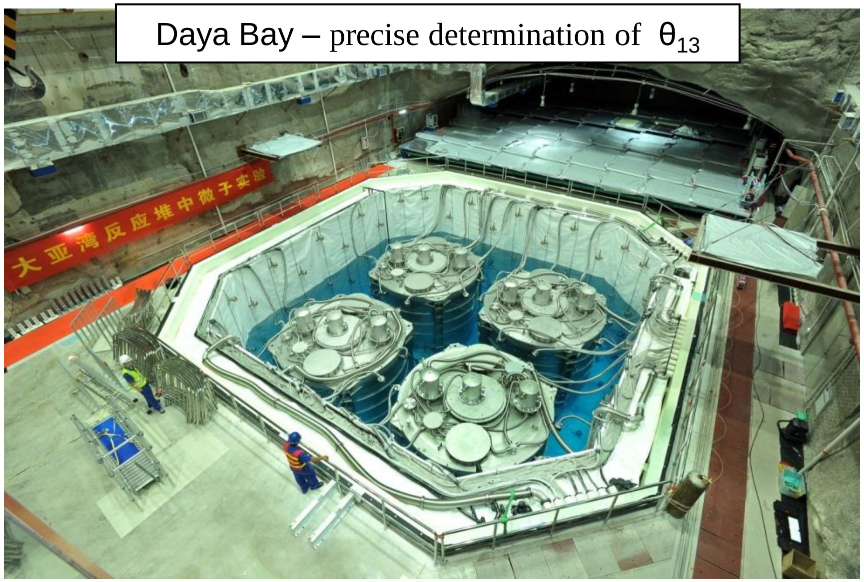
MicroBooNE - explore sterile ν sector thru appearance



Ongoing Neutrino Program beyond Fermilab

with U.S. participation

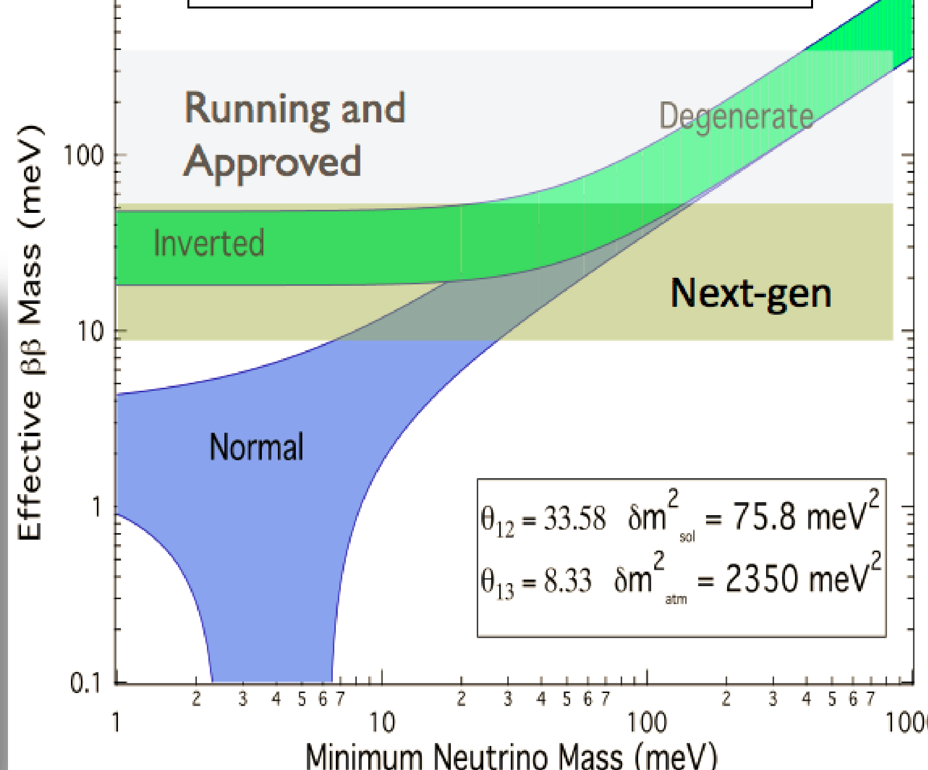
Daya Bay – precise determination of θ_{13}



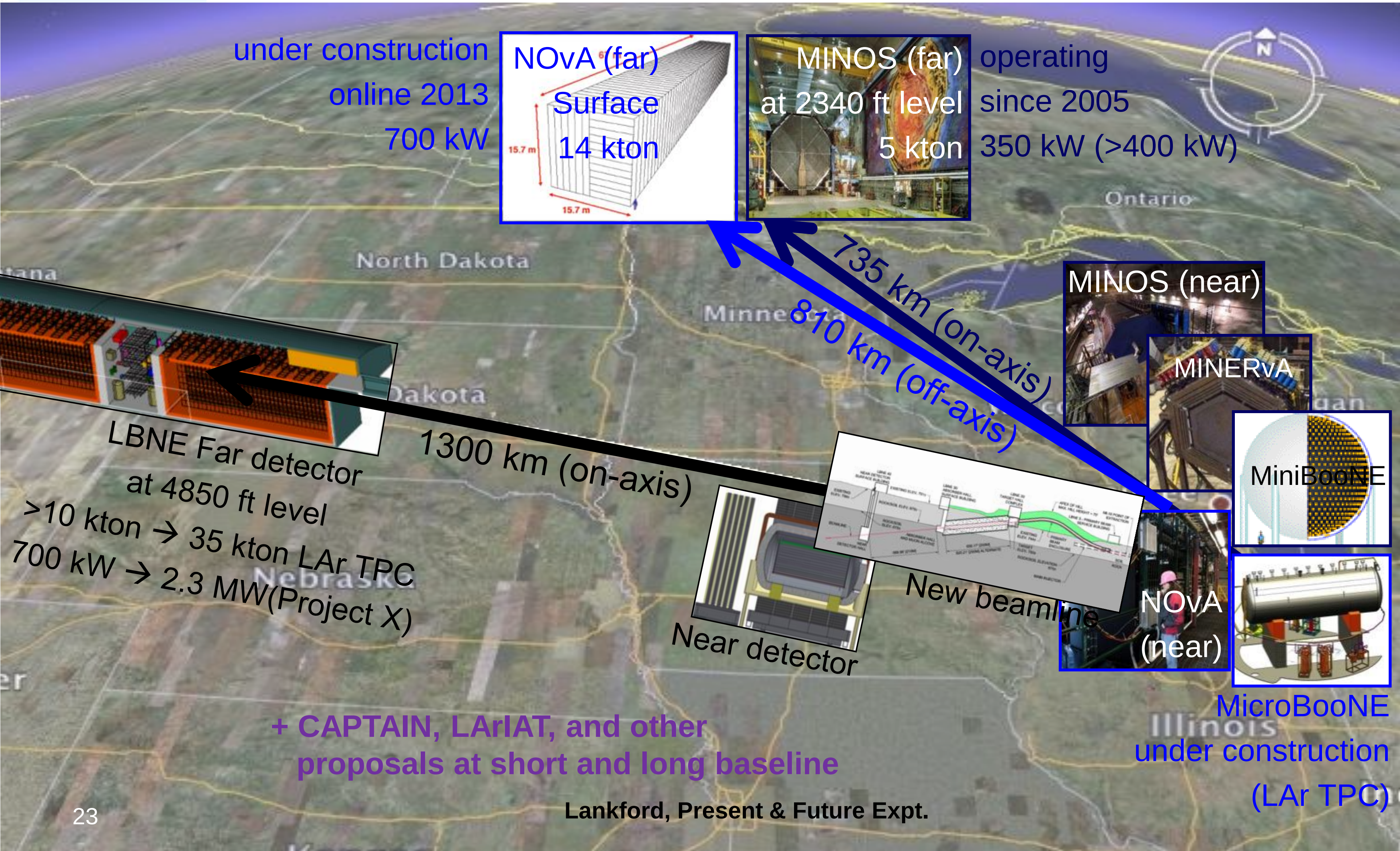
SuperK/T2K:
long-baseline oscillations
atmospheric neutrinos
+ proton decay
+ supernova search

Neutrino mixing/masses, Lepton number non-conservation…

EXO-200 & Majorana Demonstrator:
neutrinoless double-beta decay



Evolution of U.S. Neutrino Experiments



Neutrino Program – Snowmass Vision

Measurement of θ_{13} tells us that determination of two fundamental properties of neutrinos is within reach:

- **Neutrino mass hierarchy (MH)**
- **Whether CP is violated**

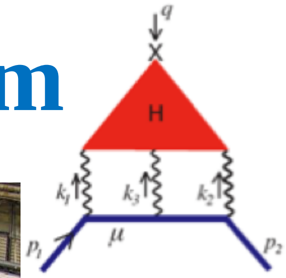
- **LBNE**
  - **MH, uniquely positioned to determine if CPV**
  - **w/ multi-megawatt beam, study CPV with conclusive accuracy**
  - **Atmospheric neutrinos, proton decay, supernova measurement**
- **Experiments in Antarctic ice PINGU/IceCube to explore MH**
- **Reactor experiments for precision measurement of θ_{13} and explore MH**
- **Testing 3 neutrino flavor paradigm w/ short-baseline experiments + LBNE**
- **Neutrinos have left their imprint on the history of evolution of the universe. Cosmic surveys shed light on neutrinos, e.g. absolute mass scale and number of neutrino species.**
- **Neutrinoless double-beta decay**
  - **Reaching to determine whether neutrinos are Dirac or Majorana**

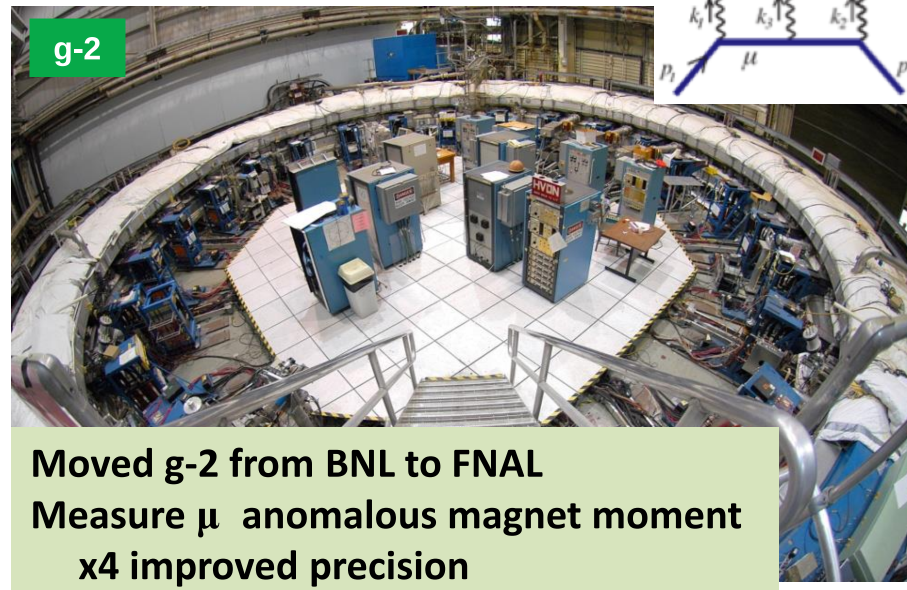
Intensity Frontier

Flavor Physics:

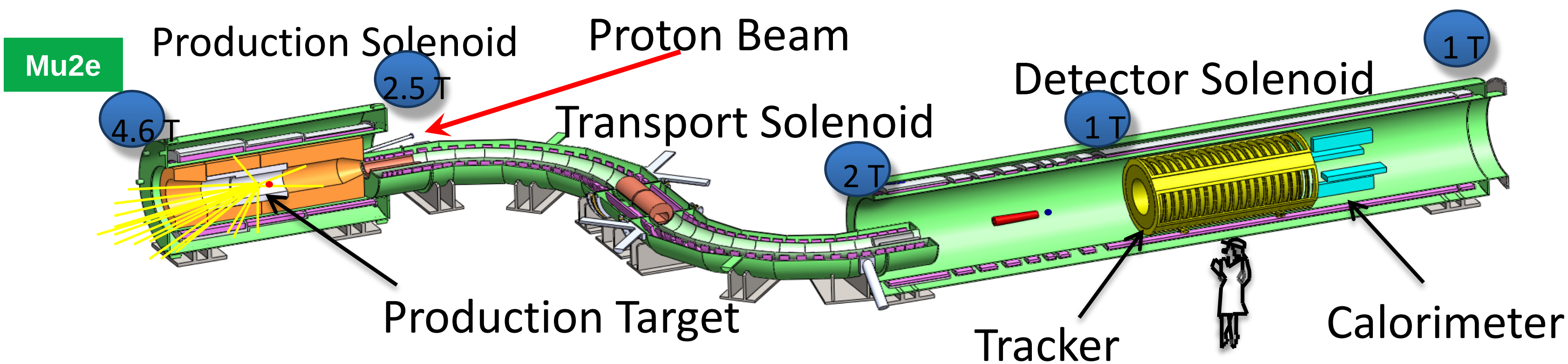
Quarks & Leptons

Emerging Fermilab Muon Program





Moved g-2 from BNL to FNAL
Measure μ anomalous magnet moment
x4 improved precision

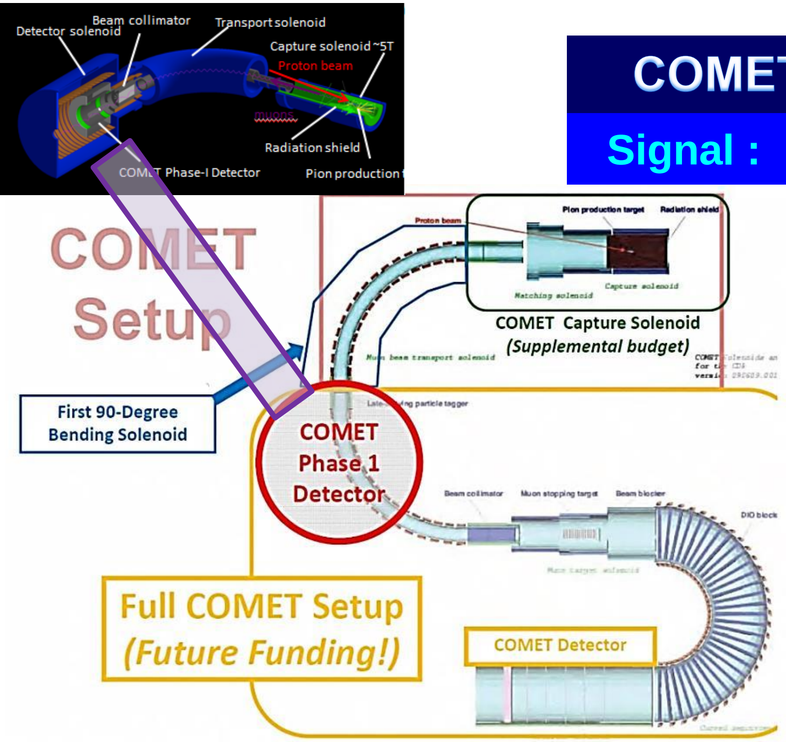


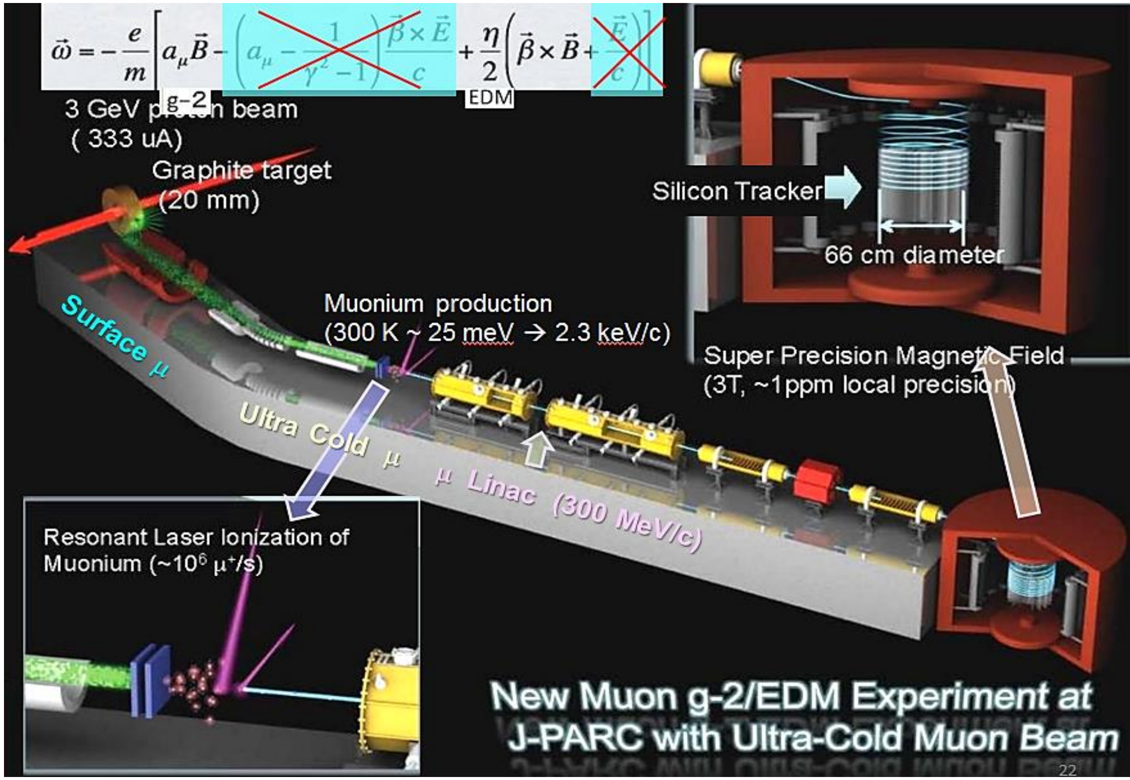
Mu2e to explore charged lepton mixing via conversion of μ → e in field of nucleus

Muon Flavor Physics in Japan

COMET: μ → e Conversion

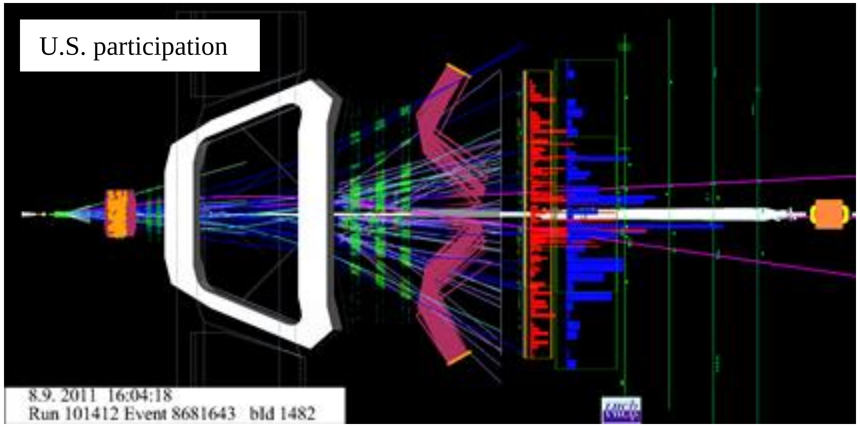
Signal : μ- + (A,Z) → e- + (A,Z)



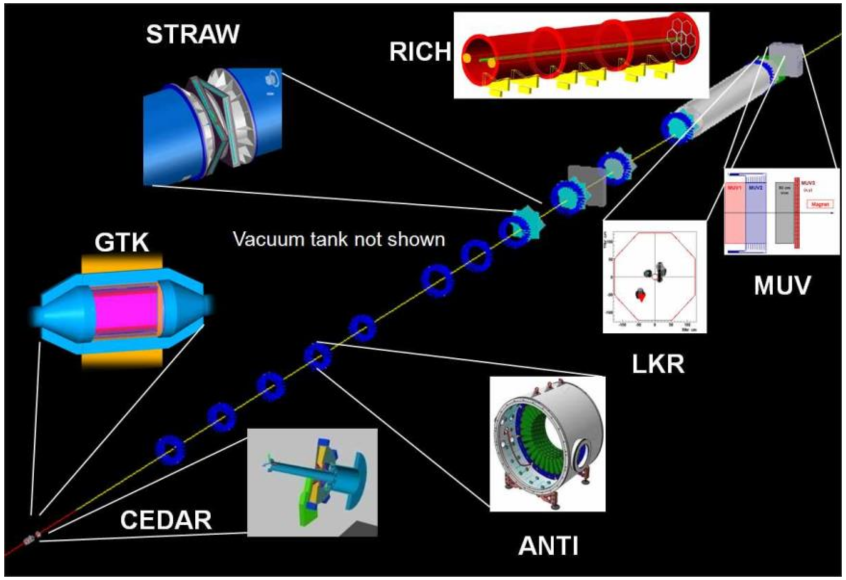


Flavor Physics in Europe

B physics at CERN - *LHCb*

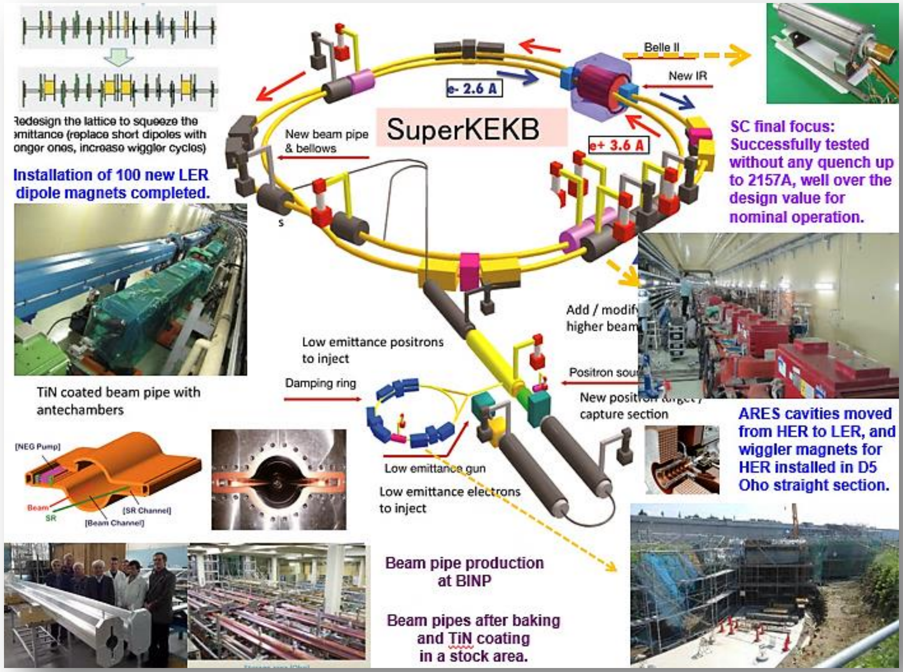


Kaon physics at CERN – *NA62*

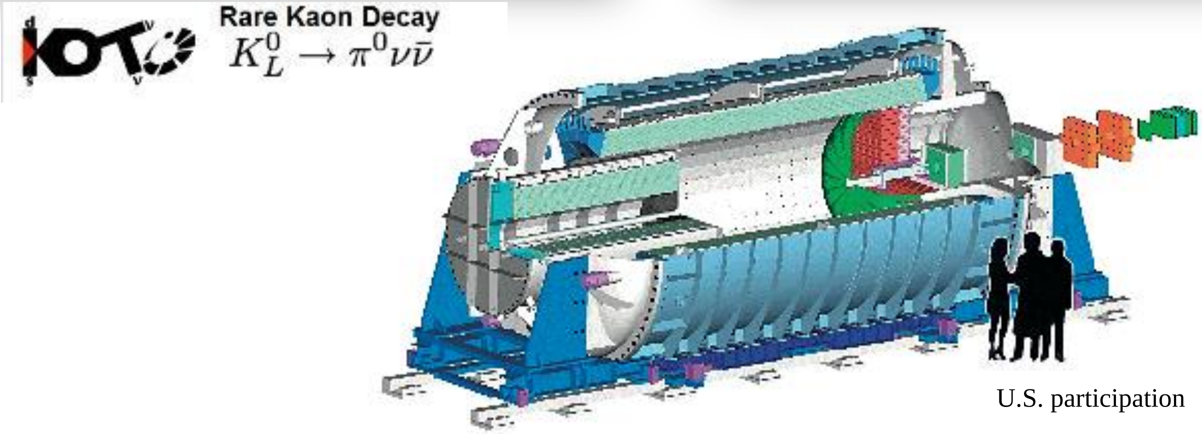


Muon physics at PSI - *MEG*

Quark Flavor Physics in Japan



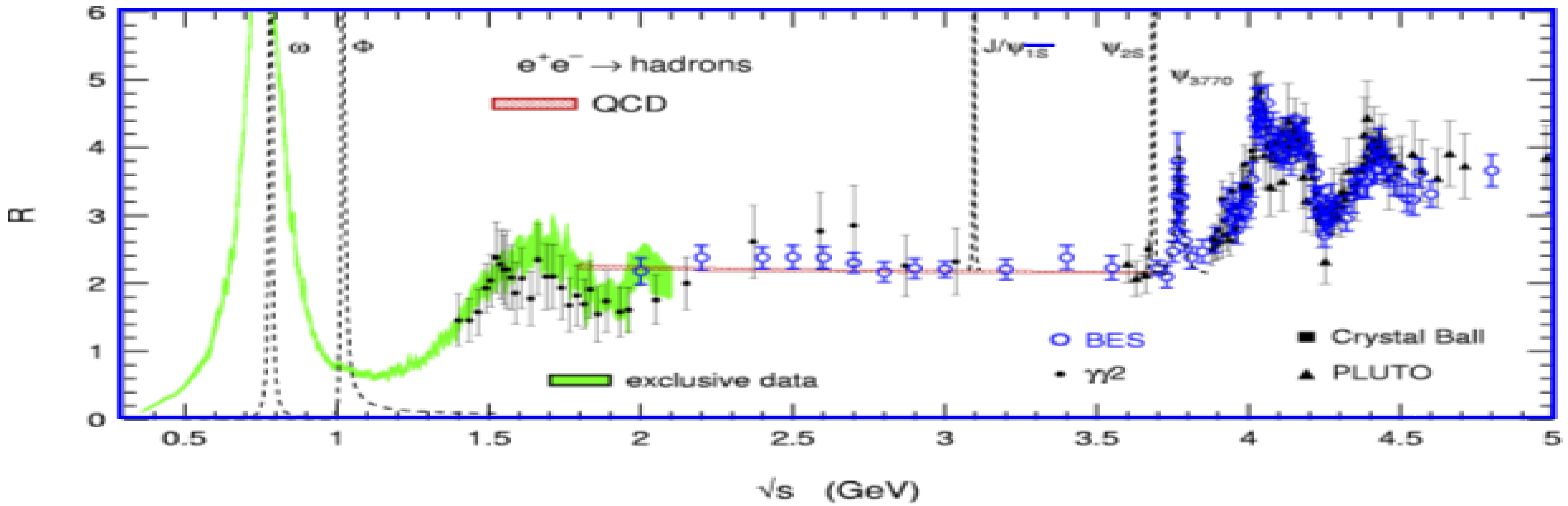
U.S. participation



U.S. participation

Quark Flavor Physics in China

BESIII



U.S. participation

Precision Physics – Snowmass Vision

Flavor physics: quarks & leptons

- probes of new physics at very high energy scales

- Fermilab accelerator complex
  - Muon anomalous magnetic moment g-2
  - Search for muon-to-electron conversion Mu2e
  - Rare K decays - ORKA proposal
- International opportunities at colliders
  - LHCb at LHC
  - Belle II at KEK
  - BES III at IHEP Beijing

Electric dipole moments (EDMs)

- would violate CP

- A recent renewed focus

Light, weakly coupled particles

- theoretically inspired, DM

- Searches possible with modest experiments in existing intense beams

Fermilab Proton Improvement Plan II

Summary

- The Fermilab accelerator complex can be upgraded to establish LBNE as the leading long-baseline program in the world, with >1 MW at startup (2025)
- The Proton Improvement Plan-II (PIP-II) is a complete, integrated, cost effective concept, that meets this goal, while
  - leveraging U.S. superconducting rf investment,
  - attracting international partners,
  - providing a platform for the long-term future
- PIP-II retains flexibility to eventually realize the full potential of the Fermilab complex
  - LBNE >2 MW
  - Mu2e sensitivity x10
  - MW-class, high duty factor beams for rare processes experiments
- We look forward to a positive recommendation from P5, and are in a position to move forward expeditiously.

18 S. Holmes, P5/BNL, Dec. 16, 2013 Fermilab

HEP Intensity Frontier Experiments

Experiment	Location	Status	Description	#US Inst.	#US Coll.
Belle II	KEK, Tsukuba, Japan	Physics run 2016	Heavy flavor physics, CP asymmetries, new matter states	10 Univ., 1 Lab	55
CAPTAIN	Los Alamos, NM, USA	R&D; Neutron run 2015	Cryogenic apparatus for precision tests of argon interactions with neutrinos	5 Univ., 1 Lab	20
Daya Bay	Dapeng Penisula, China	Running	Precise determination of θ_{13}	13 Univ., 2 Lab	76
Heavy Photon Search	Jefferson Lab, Newport News, VA, USA	Physics run 2015	Search for massive vector gauge bosons which may be evidence of dark matter or explain g-2 anomaly	8 Univ., 2 Lab	47
K0TO	J-PARC, Tokai , Japan	Running	Discover and measure $K_L \rightarrow \pi^0 \nu\nu$ to search for CP violation	3 Univ.	12
LArIAT	Fermilab, Batavia, IL	R&D; Phase I 2013	LArTPC in a testbeam; develop particle ID & reconstruction	11 Univ., 3 Lab	38
LBNE	Fermilab, Batavia, IL & Homestake Mine, SD, USA	CD1 Dec 2012; First data 2023	Discover and characterize CP violation in the neutrino sector; comprehensive program to measure neutrino oscillations	48 Univ., 6 Lab	336
MicroBooNE	Fermilab, Batavia, IL, USA	Physics run 2014	Address MiniBooNE low energy excess; measure neutrino cross sections in LArTPC	15 Univ., 2 Lab	101
MINERνA	Fermilab, Batavia, IL, USA	Med. Energy Run 2013	Precise measurements of neutrino-nuclear effects and cross sections at 2-20 GeV	13 Univ., 1 Lab	48
MINOS+	Fermilab, Batavia, IL & Soudan Mine, MN, USA	NuMI start-up 2013	Search for sterile neutrinos, non-standard interactions and exotic phenomena	15 Univ., 3 Lab	53
Mu2e	Fermilab, Batavia, IL, USA	First data 2019	Charged lepton flavor violation search for $\mu N \rightarrow eN$	15 Univ., 4 Lab	106
Muon g-2	Fermilab, Batavia, IL, USA	First data 2016	Definitively measure muon anomalous magnetic moment	13 Univ., 3 Lab, 1 SBIR	75
NOνA	Fermilab, Batavia, IL & Ash River, MN, USA	Physics run 2014	Measure ν_μ-ν_e and ν_μ-ν_μ oscillations; resolve the neutrino mass hierarchy; first information about value of δ_{cp} (with T2K)	18 Univ., 2 Lab	114
ORKA	Fermilab, Batavia, IL, USA	R&D; CD0 2017+	Precision measurement of $K^+ \rightarrow \pi^+ \nu\nu$ to search for new physics	6 Univ., 2 Lab	26
Super-K	Mozumi Mine, Gifu, Japan	Running	Long-baseline neutrino oscillation with T2K, nucleon decay, supernova neutrinos, atmospheric neutrinos	7 Univ.	29
T2K	J-PARC, Tokai & Mozumi Mine, Gifu, Japan	Running; Linac upgrade 2014	Measure ν_μ-ν_e and ν_μ-ν_μ oscillations; resolve the neutrino mass hierarchy; first information about value of δ_{cp} (with NOvA)	10 Univ.	70
US-NA61	CERN, Geneva, Switzerland	Target runs 2014-15	Measure hadron production cross sections crucial for neutrino beam flux estimations needed for NOνA, LBNE	4 Univ., 1 Lab	15
US Short-Baseline Reactor	Site(s) TBD	R&D; First data 2016	Short-baseline sterile neutrino oscillation search	6 Univ., 5 Lab	28

Intensity Frontier - Facilities

Neutrino physics:

- Long baseline:
  - NOvA – physics in 2014; MINOS+
  - LBNE – CD-1 approval with flexible scope, with enhancements from international collaboration
- Short baseline:
  - MINERvA, MicroBooNE
  - nuSTORM – conceptual stage

Flavor physics in the quark sector:

- LHCb – small but important US participation
- BES III, BELLE-II
- ORKA - proposed

Muon physics:

- g-2 – CD-1 approved
- Mu2e – CD-1 approved

Proton Improvement Plan:

- PIP - underway; includes 700kw to NuMI beamline
- PIP II – recent idea to deliver >1 MW to LBNE on Day 1
- Further proton complex improvements

COSMIC FRONTIER

Cosmic Frontier - Overview & Status

Overview:

- Discover (or rule out) the particle(s) that make up Dark Matter.
- Advance the understanding of the physics of Dark Energy.
- Understand the high-energy universe: HE particle messengers
  - Cosmic rays, gamma rays, neutrinos, gravitational waves
- Probe the physics of inflation with Cosmic Microwave Background.

Status – current scope:

Dark Matter: ADMX-II, COUPP-60, DarkSide-50, LUX, Super-CDMS-Soudan,
CoGeNT, DRIFT-II, DMTPCino, MiniCLEAN, PICASSO, XENON100/1T

Dark Energy: BOSS, DES, DESI, LSST

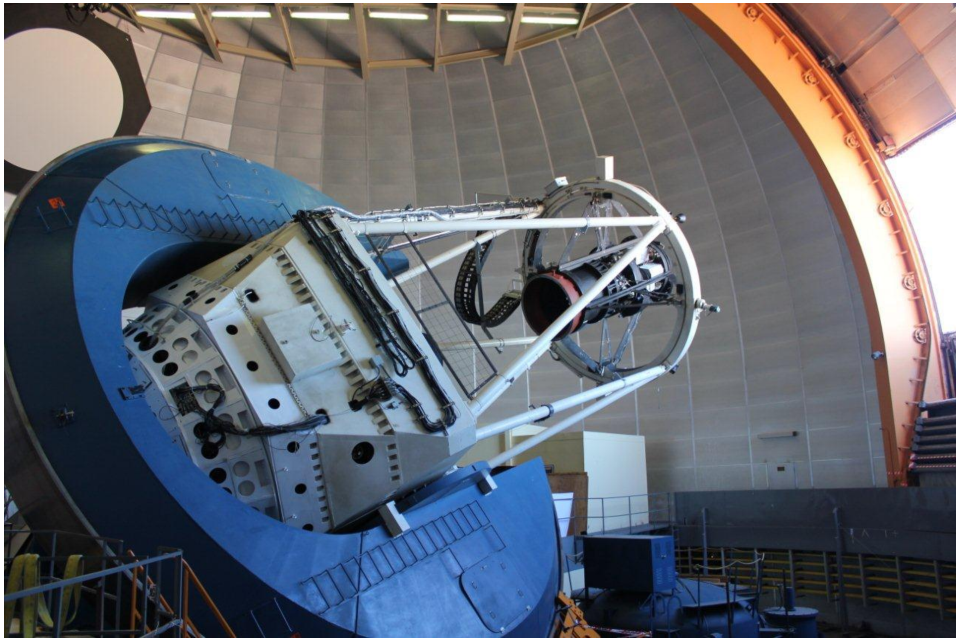
Particle astrophysics: CR: Pierre Auger, Telescope Array;
GR: AMS-02, FGST-LAT, HAWC, VERITAS; ν: IceCube

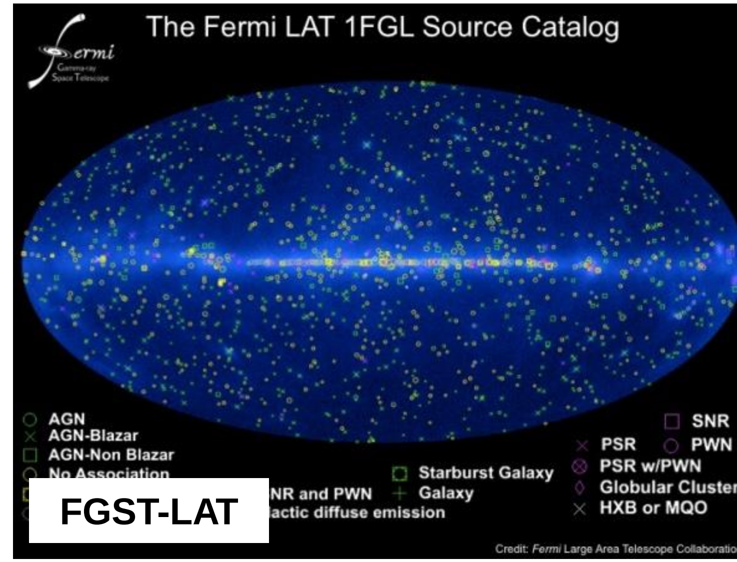
CMB: ACTPol, POLARBEAR

Note significant interagency partnerships at this frontier.

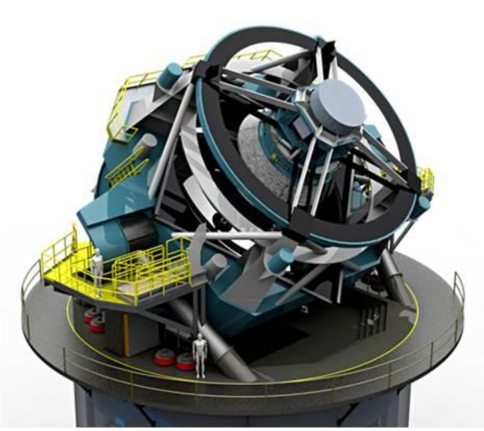
- For example, LSST
  - Highest priority for ground-based in ASTRO2010 decadal survey
  - NSF – telescope and data management
  - DOE – (advanced CCD) camera

Some Cosmic Frontier Experiments



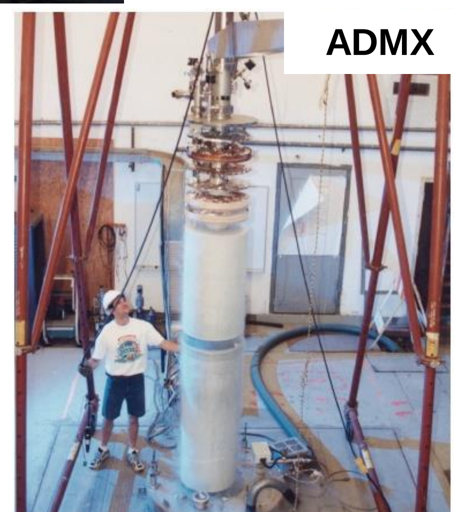


FGST-LAT

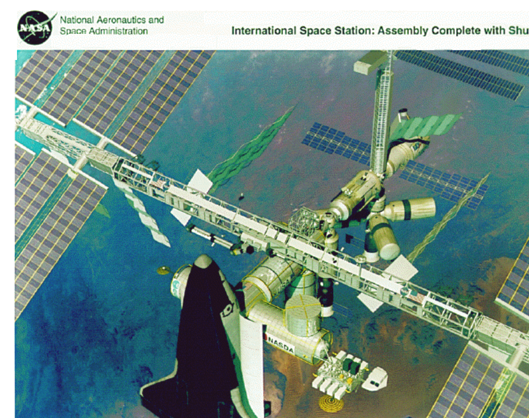


LSST

CDMS



ADMX



AMS

Cosmic Frontier – Snowmass Vision

Dark matter program

- Complementary techniques for a comprehensive campaign:
  - Direct detection
  - Indirect detection (gamma rays, neutrinos, antimatter)
  - Accelerator-based searches
  - Astrophysical surveys
- An active program in the U.S. and other regions
- Search for first non-gravitational signals of dark universe; open door to exploring particle properties of DM

Cosmic surveys

- Dark energy
  - New tests of the behavior of dark energy & general relativity over a wide range of distance and cosmic time scales
- Cosmic microwave background
  - Probe the physics of inflation
- Shed light on neutrino MH, sum of masses, # of light neutrinos

Cosmic particles

- Proton interactions at energies beyond the LHC
- Neutrinos produced in interactions of cosmic rays with CMB

Cosmic Frontier - Facilities

Dark Matter:

- Generation 2 DM initiated recently; downselect in progress
- Generation 3 DM to follow, late in 10-yr period

Dark Energy:

- LSST progressing (CD-1, NSB approved)
- DESI (mid-scale spectroscopic) being initiated
- Possible next generation DE facilities under discussion

CMB:

- Stage 2 - now
- Stage 3 - in development
- CMB-S4 - in concept

HEP Cosmic Frontier Experiments

Experiment	Location	Description	Current Status	# Collaborators (# US, HEP)	# Institutions (# US, HEP)	# Countries
Baryon Oscillation Spectrosopic Survey (BOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	operating through FY14	160 (36 HEP)	(15 US, 8 HEP)	6
Dark Energy Survey (DES)	CTIO in Chile	dark energy stage III (imaging)	operations started Sept. 2013	300	25 (13 US, 9 HEP)	6
Large Synoptic Survey Telescope (LSST), including Dark Energy Science Collaboration (DESC)	Cerro Pachon in Chile	dark energy stage IV (imaging)	CD1 for LSSTcam approved; FY14 Fabrication start requested	232 (201 US)	55 (43 US, 16 HEP)	3
Dark Energy Spectroscopic Instrument (DESI)	expected to be at KPNO in AZ	dark energy stage IV (spectroscopic)	CD0 approved Sept 2012; planning CD1 in FY14	180 (95 US, 72 HEP)	42 (23 US, 18 HEP)	13
Axion Dark Matter eXperiment (ADMX-IIa)	Univ Washington	dark matter - axion search	Operating	24 (20 US, 17 HEP)	7 (6 US, 3 HEP)	2
Chicagoland Observatory for Underground Particle Physics (COUPP-60) → PICO	SNOLab in Canada	dark matter - WIMP search	Operating	60 (26 US, 8 HEP)	14 (6 US, 1 HEP)	5
DarkSide-50	LNGS in Italy	dark matter - WIMP search	Operating	122 (66 US, 12 HEP)	26 (12 US, 3 HEP)	7
Large Underground Xenon (LUX)	SURF in South Dakota	dark matter - WIMP search	Operating	102 (86 US, 56 HEP)	17 (13 US, 9 HEP)	3
Super Cryogenic Dark Matter Search (SuperCDMS-Soudan)	Soudan in Minnesota	dark matter - WIMP search	Operating	83 (70 US, 38 HEP)	19 (16 US, 6 HEP)	3
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	FLWO in AZ	gamma-ray survey	Operating	92 (74 US, 32 HEP)	20 (15 US, 5 HEP)	4
Pierre Auger Observatory	Argentina	cosmic-ray	Operating	463 (51 US, 12 HEP)	100 (20 US, 5 HEP)	18
Fermi Gamma-ray Space Telescope (FGST) Large Area Telescope (LAT)	space-based	gamma-ray survey	June 2008 launch; operating	319 (157 US, 73 HEP)	49 (14 US, 3 HEP)	9
Alpha Magnetic Spectrometer (AMS-02)	space-based (on ISS)	cosmic-ray	May 2011 launch; operating	600	60 (6 US, 2 HEP)	16
High Altitude Water Cherenkov (HAWC)	Mexico	gamma-ray survey	Fabrication; Operations starts summer 2014 in Mexico	111 (54 US, 8 HEP)	31 (16 US, 2 HEP)	2

PLANNING

The future of US HEP

Goal: Identify compelling HEP science opportunities over an approximately 20-yr time frame

Community-driven (APS DPF)

Not a prioritization, but can make scientific judgments

Deliverables:

"White papers"

Input to working group write-ups

Report:

- ***7x* 30-page group write-ups + theory report**

  w/ executive summaries input to overview

- **30-page Overview**

Analogous to Briefing Book of European Strategy Update

Initiating P5: Context

- **DOE OHEP & NSF MPS have charged the HEPAP Chair to "constitute a new P5 panel to develop an updated strategic plan for U.S. high energy physics that can be executed over a 10-year timescale, in the context of a 20-year global vision for the field."**

- **Particle Physics Project Prioritization Panel (P5)**
  - HEPAP subpanel, appointed by HEPAP Chair
  - 24 members, chosen for their combination of expertise and broad view of field
  - Chaired by Steve Ritz (UC Santa Cruz)
  - Reports to HEPAP, which reviews & approves report and submits to agencies

- **Much has changed since the 2008 P5 report** (from the charge) **:**
  - "… a need to understand the priorities, … under more stringent budgets …"
  - "the recent discovery of what appears to be the long-sought Standard Model Higgs boson and the observation of mixing between all three known neutrino types at unexpectedly large rates have opened up the possibility of new experiments and facilities that can address key scientific questions about the fundamental nature of the universe in new and incisive ways."

- **Preliminary comments – March; Report - May**

P5 Budget Scenarios

Charge to P5 contains 3 budget scenarios for consideration

- "… consider these scenarios not as literal guidance but as an opportunity to identify priorities and make high-level recommendations."

A. FY2013 budget baseline: flat for 3 years, the +2% per year

B. FY2014 President's budget request baseline: flat for 3 years, the +3% per year

C. "Unconstrained" budget scenario

Beyond A and B, prioritize projects "… needed to mount a leadership program addressing the scientific opportunities identified by the research community."

Identify opportunities.

Note that P5 <u>must</u> address budget scenarios A & B. The current fiscal climate may change in the future though. The P5 plan should allow the field to benefit from realizing more of its ambitions sooner if the climate changes.

P5 Process

http://www.usparticlephysics.org/p5

- **P5 teleconferences**
- **Face-to-face P5 meetings during "input phase"** - all with open sessions and town hall meetings
  - **Nov 2-4: FNAL** Snowmass, international context , neutrino program
  - **Dec 2-5: SLAC** Cosmic Frontier, theory. computing
  - **Dec 15-18: BNL** Energy Frontier, precision physics, 'proton driver', accelerator R&D, detector R&D
- **Face-to-face meetings during "deliberation phase"** ~ 3-4 week intervals

- **Please note:**
  - **P5 will build on the investment in the Snowmass process and outcomes.**
  - **P5 will continue interactions with the community: public meetings, town halls, further input, communications. Note that website with RSS feed set up.**
  - **P5 will strive for transparency & present the rationale for its recommendations.**
  - **HEPAP will perform an independent review of the draft P5 report.**

Some Challenges to Strategic Planning

Scientific opportunities & project concepts exceed budget constraints.

- Prioritization is required

National/regional planning occurs in a global context.

- Program is global; funding is national/regional.
- Optimal progress in HEP requires:
  - US access and intellectual contributions to science facilities overseas.
  - Offering facilities in the U.S. that fit the global program and that serve the worldwide scientific community, while providing intellectual opportunity within the U.S.
- Planning must define US role as a participant in the global HEP program,
  - As a participant in international experiments/facilities overseas
  - As a host of international experiments/facilities in US
  - This model has worked in the past, but is more challenging now w/ big facilities.

Proper balance is needed between short-term achievements & long-term goals.

- Steady achievement demanded by decision makers; required for training/career development.
- Ongoing investment in R&D and in construction required for long haul.

Conclusion

U.S. has a broad and vibrant program

- 3 frontiers of research, supported by theory, accelerator R&D, computing
- Partnerships with other agencies and nations
- Experiments in the U.S. and abroad

Recent HEP results ⇨ An exciting time, of momentous opportunity
Significant, fundamental scientific questions to be addressed
Concepts and technologies exist to address these questions

Strategic planning for U.S. HEP program is in progress.

- Community study of scientific opportunities has culminated.
- Roadmap (P5) step is in preparation; will complete by Summer 2014.

The challenge (the biggest challenge) is fiscal.

How to mount a program of significant experiments and significant opportunity within funding constraints?

A well-formulated global vision/program needed to address this challenge.

US planning discusses US facilities and international participation in the context of worldwide program.