U.S. DEPARTMENT OF ENERGY

OFFICE OF SCIENCE

DOE Program Status

HEPAP Meeting
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Outline

The Year of Discovery in Particle Physics

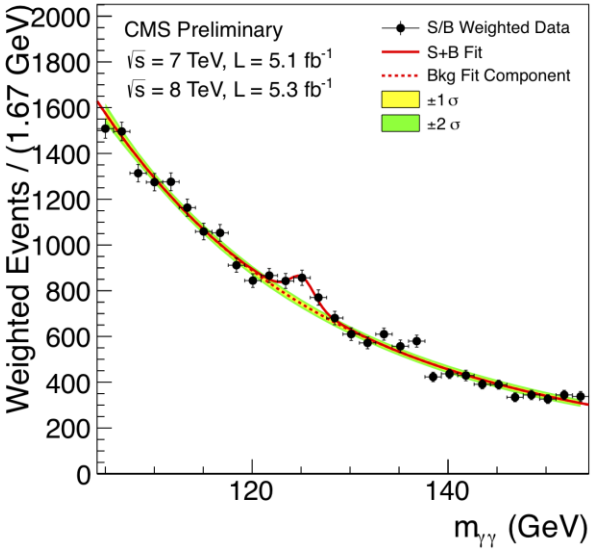
New HEP Budget Structure

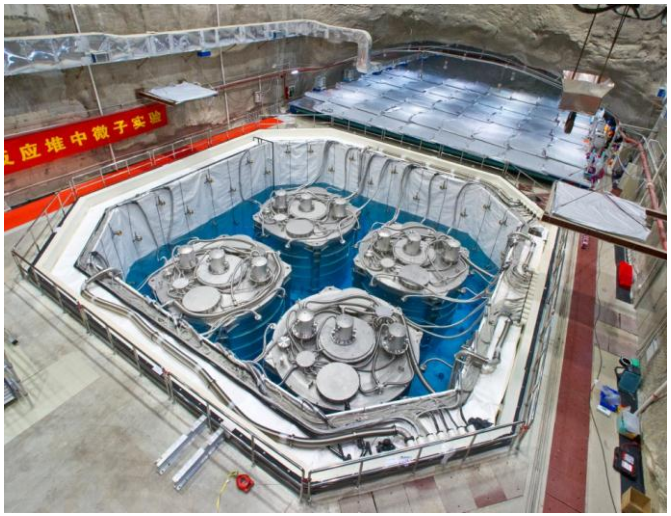
Status by Frontier

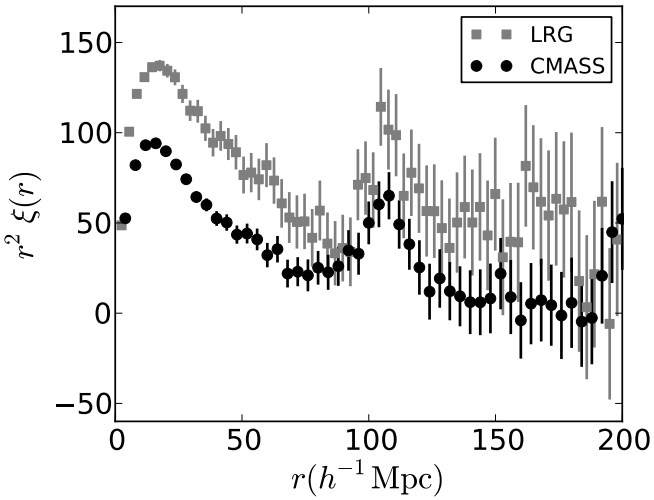
Strategic Planning and Community Process

2012 : The Year of Discovery

- **A particle that looks a lot like the SM Higgs Boson has been discovered at CERN**
  - Seen by both experiments each in multiple decay modes.
- **Daya Bay reactor neutrino experiment definitively shows that the unmeasured neutrino mixing is large (of order 10%)**
- **BOSS has measured the characteristic length scale of the universe.**







Year of Discovery: Fruit of Investments

- **The U.S. began involvement in the LHC in 1994 and real investments started in 1997.**
  - "Higgs" discovery (if it's the Higgs boson predicted by the Standard Model) culminates a 48 year search for the mechanism that gives mass to fundamental particles.
- **The Daya Bay project started in 2006.**
  - It was designed to provide guidance for the development neutrino program by being sensitive to values of θ_{13} at the 1% level.
  - The very rapid result was a consequence of nature's choice of $\theta_{13,}$ providing further evidence that neutrinos have very unusual properties – and a signal of their importance
- **The discovery of dark energy in the late 90s has completely changed the field of cosmology.**
  - Many new tools have been developed to study the problem.
    - BOSS started operations in 2009 and has now firmly established the predicted presence of a "standard ruler" for cosmology.

This discoveries are important in their own right, but also point us to new measurements to better understand the universe.

HEP Strategic Plan

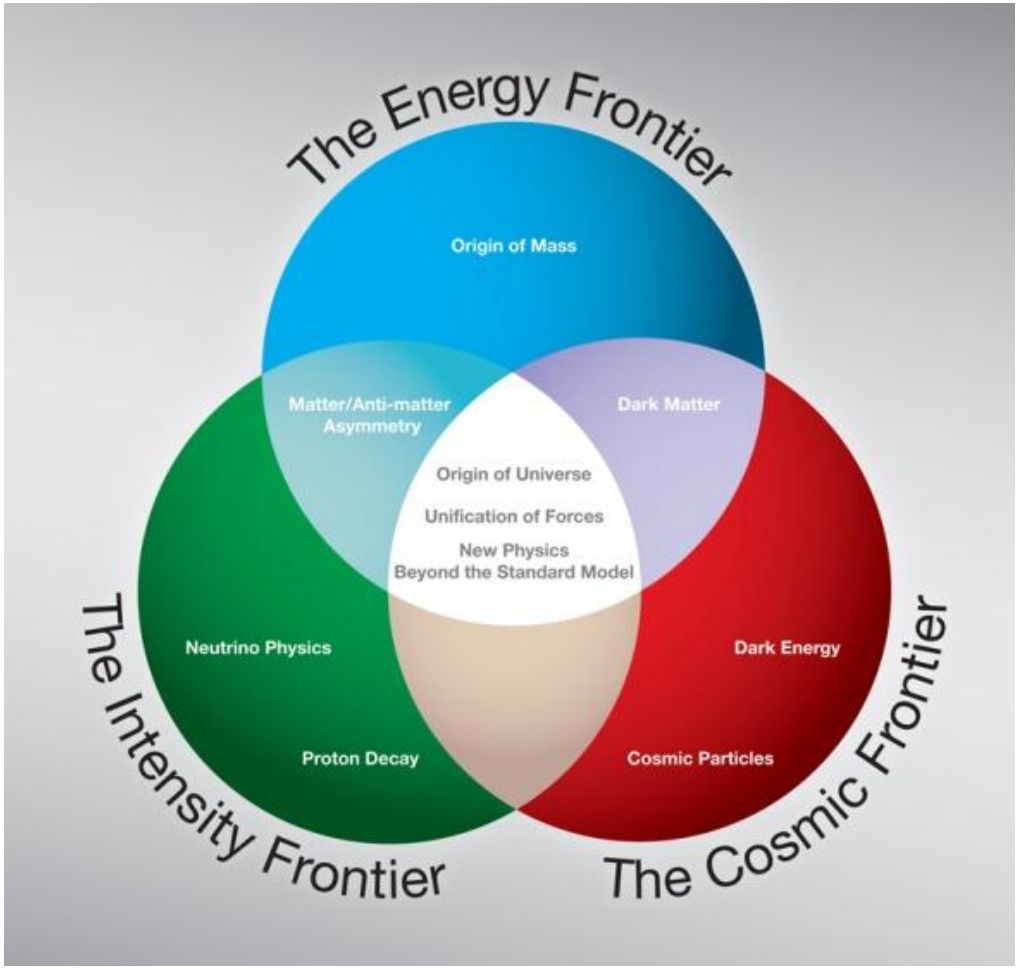
Plan is based on the HEPAP (P5) report from 2008, which was affirmed and updated in 2009 and 2010. This plan has not changed.

Progress in achieving the goals of particle physics requires advancements at the

- Energy, Intensity and Cosmic Frontiers
- Each provides a unique window for insight about the fundamental forces and particles of nature
- The U.S. should have a strong, integrated research program at all three frontiers.

HEP at its core is an accelerator-based experimental science.

- Support accelerator and detector R&D to develop new technologies
  - that are needed by the field
  - that benefit the nation



Major Recommendations of P5

- The panel recommends that the US maintain a leadership role in world-wide particle physics. 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.
- The panel recommends support for the US LHC program, including US involvement in the planned detector and accelerator upgrades. (highest priority)
- The panel recommends 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.
- The panel recommends funding for measurements of rare processes to an extent depending on the funding levels available… (Mu2e)
- The panel recommends support for the study of dark matter and dark energy as an integral part of the US particle physics program.
- The panel recommends a broad strategic program in accelerator R&D, including work …, along with support of basic accelerator science.

Making New Investments

- **HEP has finished three projects in FY 2012.**
  - Daya Bay, Dark Energy Survey, and FACET have all received CD-4 and are operating.
  - BELLA will be completed this calendar year.
- **Balance the investments across the three frontiers.**
- **Five new MIEs received Mission Need approval in September**
  - all are in the $20-40 million range.
  - Energy Frontier: ATLAS Detector Upgrade; CMS Detector Upgrade
  - Intensity Frontier: New Muon g−2 Experiment
  - Cosmic Frontier: Second-generation Dark Matter Experiments
    Midscale Dark Energy Spectroscopic Instrument
- **Should carry us through FY 2017-2018**
  - Need to have case for new projects ready in the 2015-2016 timeframe.

New HEP Budget Structure

Old Structure (FY2003-2012)

- **Proton Accelerator-Based Physics**
- **Electron Accelerator-Based Physics**
- **Non-Accelerator Physics**
- **Theoretical Physics**
- **Advanced Technology R&D**
- **SBIR/STTR**
- **Construction**

- "Tools-based" structure a compromise between Facilities and Research thrusts
- Became unbalanced with the end of B-Factory program in 2008

New Structure (FY2013+…)

- **Energy Frontier Experimental Physics**
- **Intensity Frontier Experimental Physics**
- **Cosmic Frontier Experimental Physics**
- **Theoretical and Computational HEP**
- **Advanced Technology R&D**
- **SBIR/STTR**
- **Construction**

- "Science-based" structure better balanced, aligned with strategic plan
- Substructure now more consistent and transparent

New High Energy Physics Budget Structure
(Data recast in new structure, dollars in thousands)

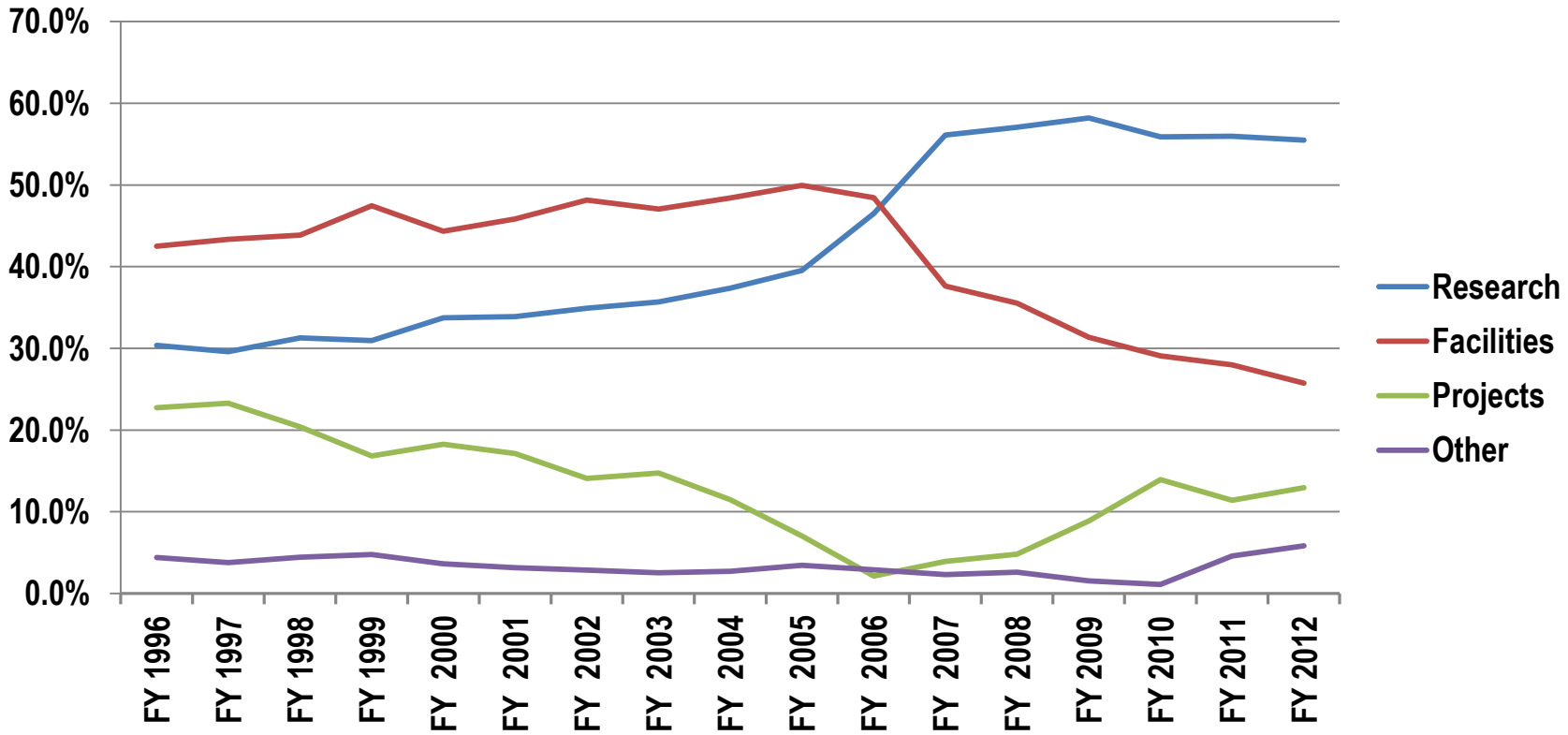
Description	FY 2012 actual	FY 2013 Request	FY 2013 - FY 2012	% change
Energy Frontier	159,130	160,736	+1,606	+1.0
Intensity Frontier	284,048	280,743	-3,305	-1.2
Cosmic Frontier	72,390	84,946	+12,556	+17.3
Theoretical and Computational HEP	67,031	65,018	-2,013	-3.0
Advanced Technology R&D	159,934	144,488	-15,446	-9.7
SBIR/STTR	20,327	20,590	+263	+1.3
Construction (Line Item)	28,000	20,000	-8,000	-28.6
Total, High Energy Physics	**790,860**	**776,521**	**-14,339**	**-1.8**
Office of Science	**4,873,634**	**5,001,156**	**+127,522**	**+2.6**

HEP Physics Funding by Activity

Funding (in $K)	**FY12 actual**	**FY13 request**	**comment**
Research	**391,871**	**383,607**	-2.0% reduction
Facility Operations and Exp't Support	**248,954**	**262,024**	Intensity Frontier Ops
Projects	**129,708**	**110,300**	
Energy Frontier	0	0	
Intensity Frontier	86,570	61,337	NOvA ramp-down
Cosmic Frontier	12,638	26,263	LSST + G2 DM ramp-up
Other	2,500	2,500	LQCD hardware
Construction	28,000	20,000	Mu2e and LBNE
TOTAL HEP	**770,533**	**755,931**	**Not incl SBIR/STTR**

All subprograms except SBIR/STTR and Construction have same substructure, makes roll-ups (such as this) much easier

Budget trends



Lack of new facilities for science threatens the future of the program

→ Need to fully exploit current research efforts but also develop new facilities and experiments to maintain a healthy & leadership program.

Energy Frontier Status

Fermilab Tevatron (DØ and CDF)

- Operations ended Sep 2011
- Working with D0 and CDF collaborations on orderly completion of key analyses within the next year

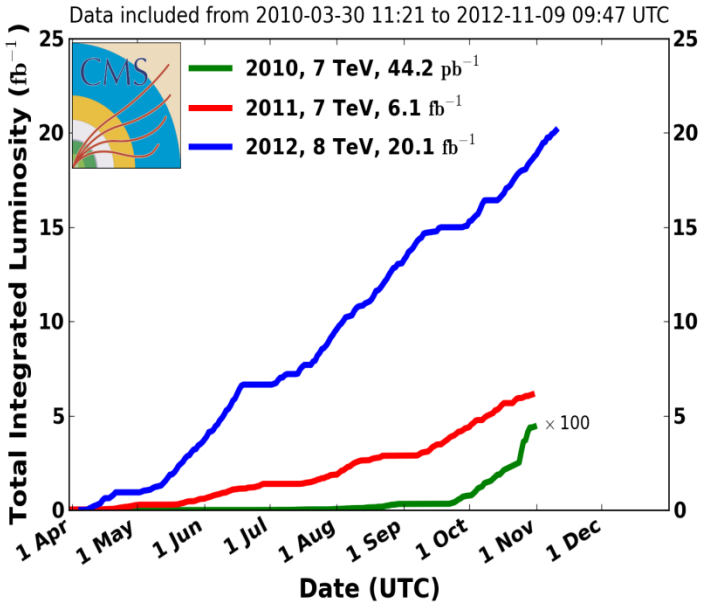
Large Hadron Collider (LHC) at CERN

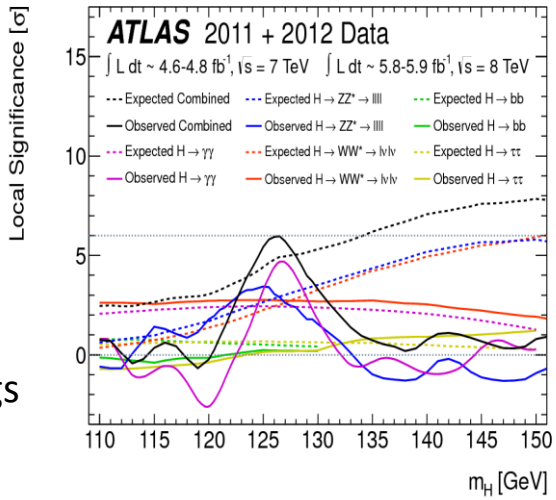
- Working with experiments to develop plan for contributions to "Phase-1" upgrades (scheduled for installation in ~2017)
- In discussions with CERN management on longer-term upgrade options.
  - US scope for later upgrades TBD

Physics Status

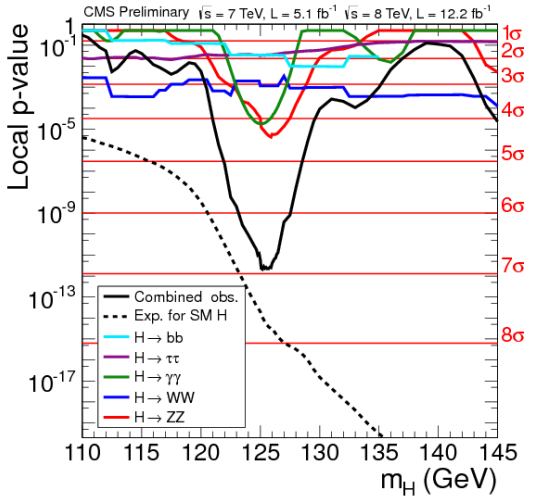
- Experiments are now shifting from a search-based strategy to a measurement-based program to address if particle is truly consistent with Standard Model Higgs
- Still no smoking guns for physics beyond the SM
  - What will 14 TeV running tell us?

Projected by end-2012: ~25 fb^{-1} per CMS & ATLAS





ATLAS Observed Result (July 2012)



CMS Observed Result (as of HCP 2012)

Energy Frontier Issues

- **What are key elements in the decision tree for the energy frontier?**
  - What is the strongest physics case we can make now in light of the LHC results?
  - Do we wait for 14 TeV running at LHC before deciding our position?
  - Are there significant "opportunity costs" to waiting?
  - Can we think of any scenario in which it would make sense to stop running the LHC in ~2022 (once 300 fb^{-1} has been collected)? (see T. Wyatt, Cracow 2012…)
- **What is the physics case for the HL-LHC upgrade? What are the key physics issues that must be emphasized?**
  - Higgs
    - What is the expected precision on Higgs properties that LHC will deliver? How much better would a proposed Japan-hosted ILC machine (or other Higgs factory alternatives) perform?
  - BSM
    - Higgs as a window to new physics
    - Saving SUSY ?
    - Dark Matter
      - What can we expect for Dark Matter particle limits from LHC?

Intensity Frontier Status

Current program: Minerva, NOvA, T2K, MicroBoone, Daya Bay, EXO-200

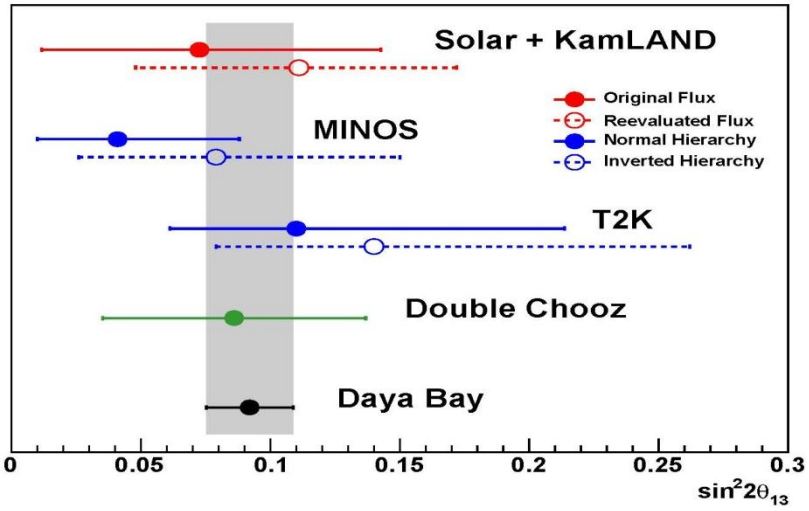
- **NOvA** and **MicroBoone** will complete construction in FY 2014
- Others taking data

Planned program: projects in design/R&D phase; fabrication not approved yet

- **Belle-II** follows up successful B-factory program with 10-100x more data on flavor physics in quark sector (CD-1 approved)
- **Mu2e** to explore charged lepton mixing (CD-1 approved)
- **LBNE** to make definitive measurements of neutrino properties (CD-1 review successful, decision next week)
- **Muon g-2** pursues one of the few indications of physics beyond the SM, reducing errors by a factor of ~4 (CD-0 approved)

Physics Status

- Daya Bay, T2K, NOvA, et al. will usher in the era of precision neutrino physics with few % measurements
  - 1st steps in a comprehensive program



Intensity Frontier Issues

- **We must have long-term goals for the precision with which we need to measure the neutrino mixing matrix elements.**
  - This is an essential element that will guide the development of the neutrino program.
  - What error do we need to achieve on the matrix elements? Why?
- **This question is very important since it enables us to explain to all our stakeholders why we need a wide variety of neutrino experiments.**
  - It also guides our investment strategy on R&D to support neutrino factories since small errors may require higher beam intensities than can be reached with conventional targets/beamlines.
- **Many other important areas of investigation were well summarized in last year's intensity frontier workshop. We need to turn that into a situation analysis for each of the main areas.**
  - What are the capability gaps?
  - Can we demonstrate a steady flow of results on a range of topics?
  - Are there projects or pilots needed to fill out the program?

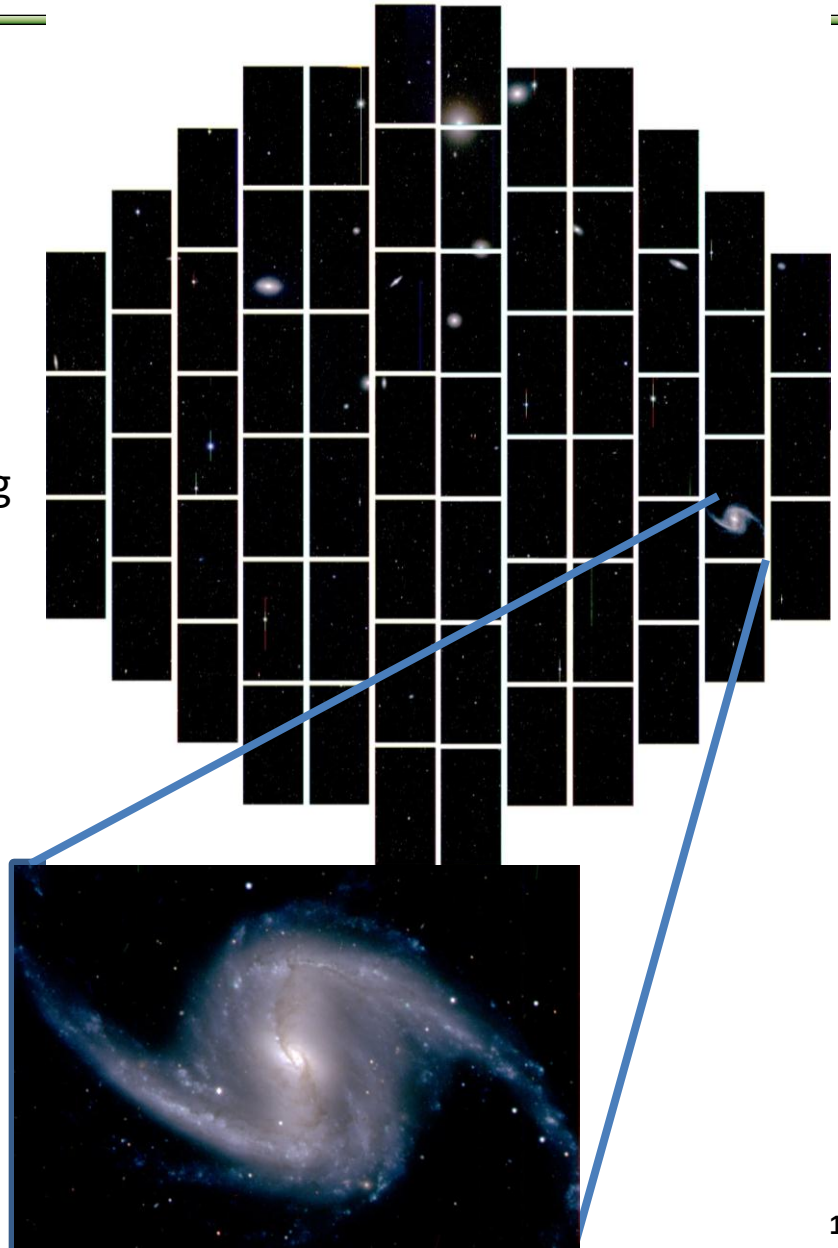
Cosmic Frontier Status

Current program

- Several operating experiments studying high-energy cosmic and gamma rays
  - **Fermi/GLAST, Veritas, Auger, AMS**
- Several 1st generation (G1) dark matter direct detection experiments operating
- Several dark energy programs underway using existing telescopes and cameras
- **Dark Energy Survey** commissioning

Planned program

- **2nd-Generation Dark Matter** experiments to probe most of preferred WIMP, axion phase space
- **Mid-scale Dark Energy Spectroscopic instrument** to complement DES/LSST
- **Large Synoptic Survey Telescope** will make definitive ground-based Dark Energy measurements using "weak lensing"



Cosmic Frontier Status – Next Steps

Dark Energy

- HEP physics strategy is delineated in "Rocky III" report.
  - Excellent example for SnowMiss convenors
- DOE project strategy is DES → MS-DESI → LSST
- Very limited involvement in alternative approaches
- Actively discussing implementation strategy with NSF Astronomy

Dark Matter

- Proposals for FY13 R&D funding reviewed in Sep. Results out early 2013.
- Anticipate further selection after this phase
  - Downselect which project(s) move to fabrication phase in about a year
  - Project(s) start fabrication no earlier than FY14
- Critical Decision 0 for DM-G2 experiment(s) was signed in Sep.
- G3 R&D and planning continues at a low level

High Energy Gamma Rays

- DOE/HEP recently gave guidance to the US CTA collaboration:
  - Following Astro2010, we consider NSF to be the lead for considering the project.
  - We have no funding identified for a contribution to CTA in the foreseeable future and therefore don't plan to fund R&D towards it.

Cosmic Frontier Issues

- **Dark Energy well covered by the task force chaired by Rocky Kolb.**
  - DES → Mid scale Spectroscopic Instrument → LSST
- **Dark matter direct detection: what is the community position on the necessity of G3 WIMP search experiments, possibly in multiple isotopes?**
  - Do we need to reach the irreducible neutrino floor?
  - Is our enthusiasm for WIMP searches modulated by LHC results? Should it be?
  - What about other dark matter candidates and methods?
  - What does the decision tree for this area look like? What are key results and outcomes?
  - What would be the impact of an LHC or indirect detection discovery?
- **The role of other particle astro areas in the HEP program needs to be better articulated: Gamma Ray experiments, cosmic ray experiments, CMB, etc.**
  - We have a number of experiments running, including FERMI/GLAST, AMS, Pierre Auger, etc. What is their impact on HEP?
  - Why do we need more, what gaps should be filled, etc. Are any pilot projects needed?
  - Astronomy and astrophysics are wonderful science but not in the DOE mission.

Current and Upcoming Reviews

Research Reviews

- Comparative university grant review panels held in Nov., decisions in Jan., grants start May 1
  - FY13 requests are 2-3x the available funding for most programs
  - HEP research planned to decrease ~ 2%/year for next few years
  - Further discussion tomorrow
- Comparative lab research reviews held summer 2012, reports out soon (Energy, Det. R&D)
  - 2013 Reviews: Accelerator R&D (March), Intensity (May), Cosmic (tbd)
- Office of Science Early Career review panels in Jan.
  - Expect ~10 HEP awards (lab + univ), announced late spring/early summer

Operations Reviews

- Plan to institute reviews of operating (or near-operating) experiments on a regular schedule
  - Already do this for LHC experiments annually, also Fermilab operations review
  - Cosmic frontier ops review Sep 2012, Intensity frontier ops review Jan 2013
    - Review each experiment individually (i.e. didn't rank/prioritize against each other)
    - For experiments that don't already have an agreed-upon operations phase, we will use this as an opportunity to set the operations budget & schedule
    - Results will inform future program planning

Project Reviews

- Well established CD process continues

Strategic Planning

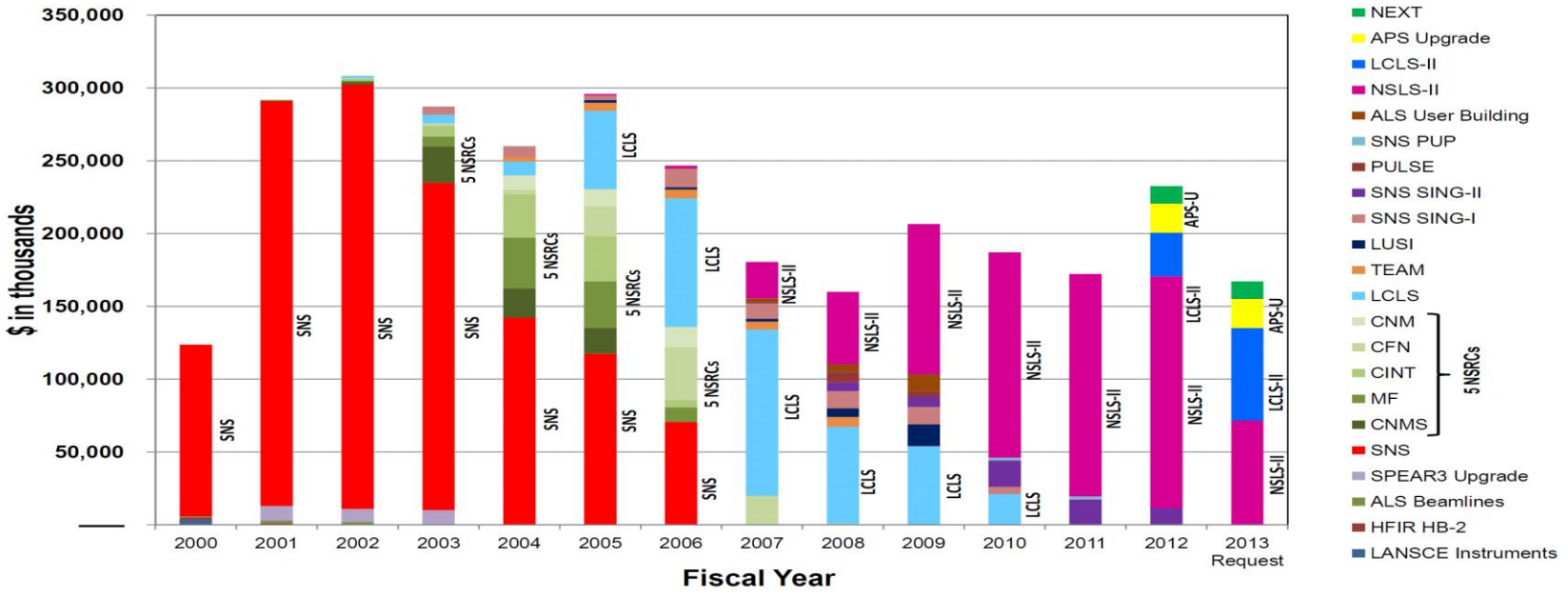
- **The HEP budget puts in place a comprehensive program across the three frontiers.**
  - In five years,
    - NOvA,Mu2e, g-2 will be running on the Intensity Frontier.
    - The CMS and ATLAS detector upgrades will be installed at CERN.
    - DES will have completed its science program and new mid-scale spectroscopic instrument should begin operation
    - The two big initiatives, LSST and LBNE, will be well underway.
- **Need to start planning now for what comes next.**
  - Have held an Intensity Frontier workshop already
  - Engaging the DPF in a community planning process that will conclude next summer.
  - Will set up a prioritization process (a la P5) using that input.
  - Start the agency process to propose new initiatives as the current initiatives finish.

Boundary Conditions

- **"Physics comes first." However there are important real-world considerations.**
- **Note that a 'brute force' approach that seeks to spend vast sums in order to build some facility/physics capability simply will not work in today's fiscal environment. This has been empirically demonstrated.**
  - Most recently, via our discussions on LBNE, we have confirmed that single project expenditures must be somewhat smaller than $1B per stage.
- **CSS2013 participants are encouraged to think about whatever physics you think is most relevant and important to progress in HEP, but the effort you put in should be tempered with a realistic assessment of funding possibilities.**
  - Many ideas can be staged to provide new physics capability at each step, but some cannot.
- **Projects that build upon previous investments either scientifically or through recycling of infrastructure are generally well received.**
- **A plan that can produce a steady flow of scientific results is also highly desirable/required.**

Prioritization Process

- After CSS2013 process completes, we plan to re-establish a Particle Physics Project Prioritization Panel (P5) to take the study output as input to the next round of prioritization, including budget projections.
- We expect to have an updated plan sometime in calendar 2014 that will shape the program going forward.
- Note that we need more projects in the pipeline than we have budget to support, since we need to move construction money continuously from one project to the next, as BES has done (see below)



Questions for the Community (from CPM 2012)

- **Energy Frontier science plan will require high-energy LHC running**
  - What is the **real** physics of the TeV scale?
  - Do we need to probe at both "low" (~ 0.2TeV) and high (multi-TeV) energies?
- **Intensity Frontier plans will be informed by experiments now taking data or under construction**
  - What will Daya Bay, NOvA, T2K tell us about the neutrino matrix? About the neutrino mass hierarchy?
  - Can the precision/rare flavor (quark, lepton) experiments see something beyond the SM? If so, how does it relate to new physics at the LHC?
  - What is the "decision tree" that will lead us to the next experiments?
- **Cosmic Frontier plans : selecting the best technology/techniques**
  - We have a process for G2 Dark Matter experiments. Whither G3?
  - Do all the various dark energy techniques agree about the scale and time dependence of this phenomena? Are space-based missions needed?
- **This will likely take a few years to sort itself out**
  - US "Snowmass" process is an important element, along with European and Asian HEP strategies

Planning Summary

- **A lot of work about physics and technology remains to be done to flesh out what we need to know to guide the program successfully.**
  - We should regard CSS2013 as the first real step in this process, which is open ended.
- **One of the organizational change issues we have to adapt to are the new rules around conference attendance – a traditional 'Snowmass' type working meeting does not fit within the new rules without severe restrictions in participation, which we do not want.**
  - We can still achieve our goals, but in a somewhat modified format.
  - Lots of homework will need to be done ahead of time
- **We look forward to a vigorous discussion of the science opportunities and options**
  - This must be done in a realistic context that considers timescales, resources, and technology maturity
- **The written reports from the CSS2013 working groups will provide important input to the next P5 planning process.**

Sermonette

- **The HEPAP/P5 strategic plan has been very successful at**
  - Developing a prioritized, executable program plan that has been sufficiently flexible to respond to major changes
  - Conveying the interest and importance of HEP to non-HEP audiences
  - Framing the program in an easy-to-understand context
- **And yet…**
  - Some members of the community do not seem to know what the plan is, much less communicate it effectively to non-HEP types
  - Worse, other members of the community will gladly substitute their personal vision for the community plan with little or no prompting
  - This does not convey the impression that we as a community know what we want, which makes implementation of **anything** very challenging
  - It also undermines our international standing
- **For example**
  - Implementation of reconfigured LBNE seems to suffer from this phenomenon. This does no credit to US HEP at an important fiscal juncture

Summary

- **It has been a very good year physics-wise for HEP. We are trying to capitalize on that.**
  - Exciting times on all three experimental frontiers
- **We are still on track to implement most of the elements of the 2008 HEPAP/P5 strategic plan, albeit at lower budget levels**
  - Maintained priorities (eg. LHC) but some items have been de-scoped or abandoned (eg. JDEM, DUSEL)
  - Enabling new projects while maintaining facilities in flat budgets necessitates reducing research
  - HEP budget now transparently reflects strategic choices and priorities
- **We support the DPF community process for future planning**
  - Good kickoff at Fermilab in Oct., now need to execute
  - Many important physics questions to be addressed
- **We will start a new P5 process after the conclusion of the DPF study**
  - The community needs to get on board

BACKUP

LBNE Implementation Strategy

- **Office of Science has chosen a path forward for Long Baseline Neutrino Experiment**
  - Project chose liquid argon technology for the detector.
    - The cost estimate for the full project (detector + beamline) was $1.6 billion.
  - Fermilab and the project were advised to take a phased approach.
    - Lower peak costs and more timely science results
    - Sought community input on phasing plan
      - Experiments using the NuMI beamline to Minnesota were evaluated.
      - 10 kton liquid argon detector on the surface at Homestake was preferred choice
      - New neutrino beamline at Fermilab
      - Provides the foundation for a long-term world-leading neutrino program
  - CD-1 Review held Oct 30, 2012.