US Department of Energy
Office of High Energy Physics (HEP)
Program Status Report
to APPEC

April 7, 2016 in Paris

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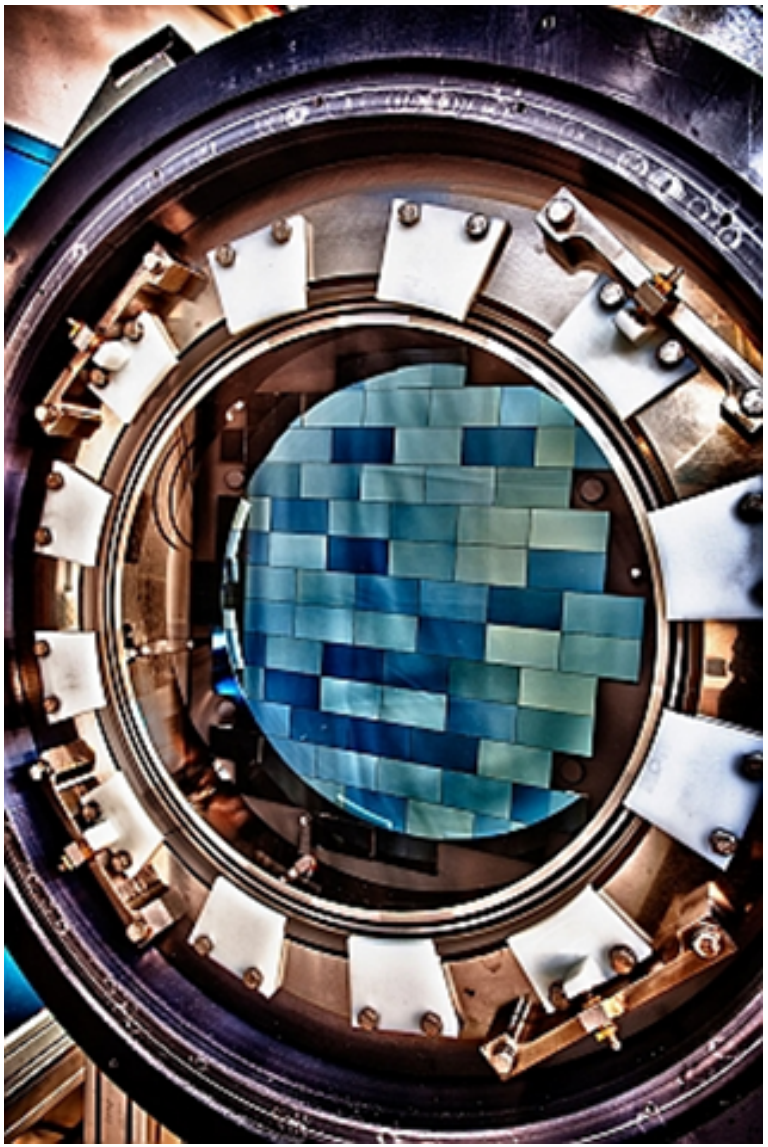


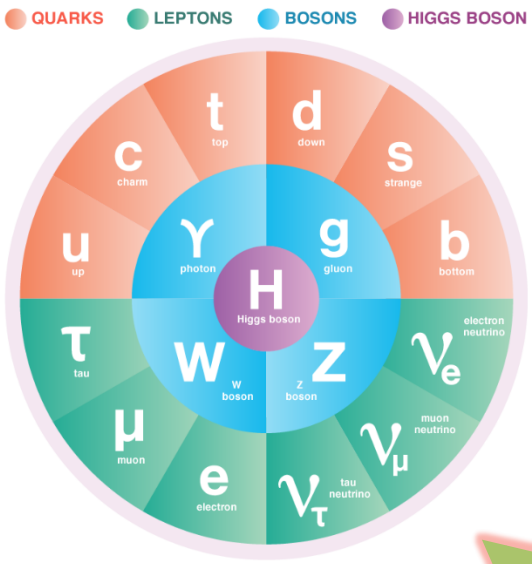
HEP PROGRAM – MISSION, GUIDANCE, STRATEGIC PLANNING, BUDGET

HEP PROGRAM – STATUS

The Office High Energy Physics (HEP) Program Mission

…is to understand how the universe works at its most fundamental level:

- **Discover the most elementary constituents of matter and energy**
- **Probe the interactions between them**
- **Explore the basic nature of space and time**



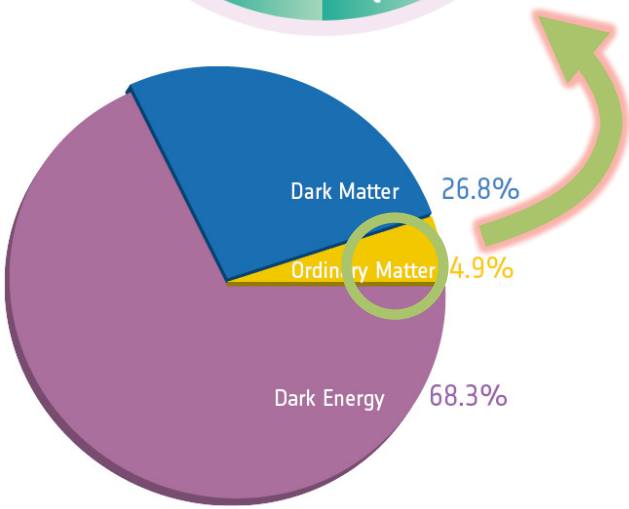
HEP is part of a "Mission" Agency

- Provides science leadership & support to enable significant advances in specific science areas
- **Strategic planning process with community input to develop science drivers and a portfolio of facilities & experiments**
- Laboratory System with comprehensive resources & infrastructure to build and operate this portfolio.
- **Interagency & International partnerships to maximize science**.

HEP fulfills its mission by:

- **Building projects that enable discovery science**
- **Operating facilities that provide the capability to perform discovery science**
- **Supporting a balanced research program to produce discovery science**

➔Support scientific collaborations to participate in all phases of experiment in order to produce the best possible science results.



HEP Program Guidance

FACA (Federal Advisory Committee Act) panels & subpanels provide official advice:

→High Energy Physics Advisory Panel (HEPAP) - Reports to DOE and NSF

- **Provides the primary advice for the program**
  - Subpanels for detailed studies, e.g.
    - **Particle Physics Project Prioritization Panel ("P5") – Strategic Planning Process**

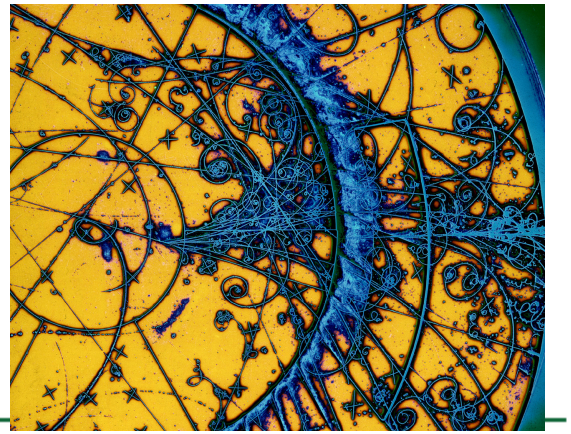
→Astronomy and Astrophysics Advisory Committee (AAAC)

  - Reports to NASA, NSF and DOE on areas of overlap

National Academy of Sciences

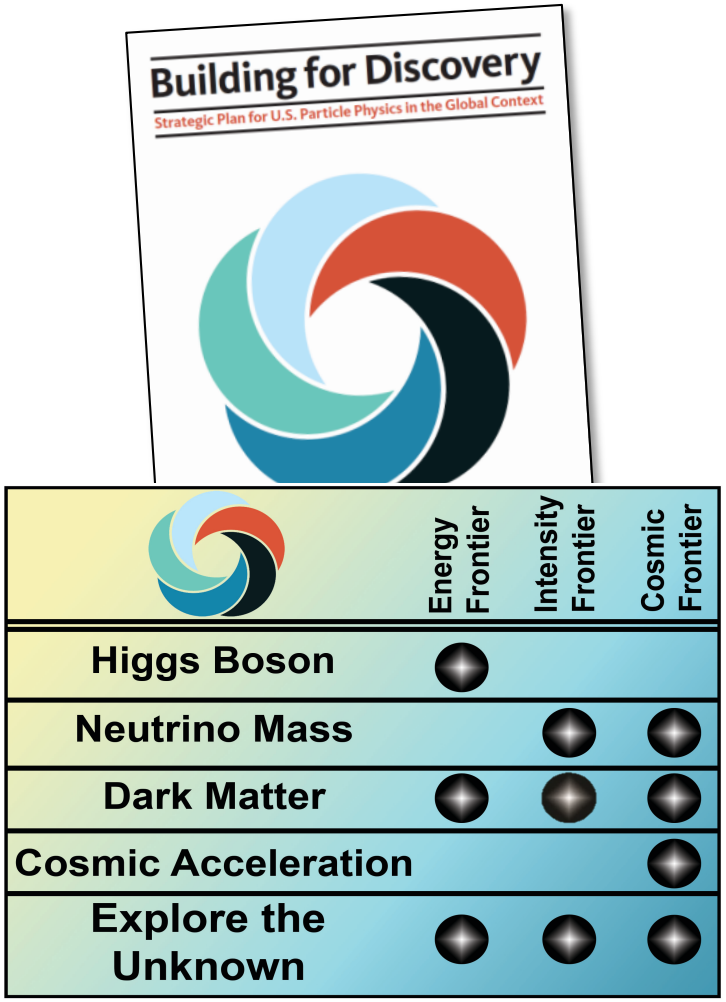
- Reports: New Worlds New Horizons (2010), "Mid-decade review" in astronomy/astrophysics
- Ongoing: Board on Physics & Astronomy (BPA), Committee on Astronomy & Astrophysics (CAA)

Other: community science studies, reviews, DPF input, etc.



Enabling the Next Discovery – 2014 P5 Strategic Plan

Science drivers identify the scientific motivation while the Research Frontiers provide a useful categorization of experimental techniques



HEP is working with NSF in implementing the strategy detailed in the P5 report in the context of a global vision for the field

- **HEP Addresses the five compelling science drivers with research in three frontiers and related efforts in theory, computing and advanced technology R&D**
- **Increasing emphasis on international partnerships to achieve critical physics goals**

P5 report suggests increasing the project budget fraction to 20%–25%

- "Addressing the [science] Drivers in the coming & subsequent decades requires renewed investment in projects."

HEP program status & planning in FY16 and going forward → building upon the P5 plan

Energy Frontier: Continue to support leadership roles in highly successful LHC program → Phase 1 and Phase 2.

Intensity Frontier: Solidify international partnerships for U.S.-hosted LBNF/DUNE while continuing accelerator complex improvements and current & near-term suite of experiments

Cosmic Frontier: Advance our understanding of dark matter and dark energy

- Fabrication funding ramp up supports key P5 recommended Cosmic Frontier projects to study dark matter and dark energy: LSSTcam, DESI, SuperCDMS-SNOLab, LZ
- Planning for future CMB-S4 ground-based project

Advanced Accelerator R&D

Continued R&D in the promising area of beam-driven plasma wakefield acceleration

Accelerator Stewardship

Broader applications of accelerator technologies, e.g. to enable ion-beam cancer therapy and R&D for high-power ultrafast laser.

Theory & Computational Physics

Continued support following the P5 report which recognized the importance of theory and computing as important to maintaining thriving program.

FY 2017 HEP Funding by Activity

HEP Funding Category ($ in K)	FY 2015 Current	FY 2016 Enacted	FY 2017 Request	Explanation of Changes (FY17 vs. FY16)
Research	334,225	327,389	331,123	Sustain support for research program
Facilities	264,634	254,979	252,037	Overall operations support reductions due to scheduled completion of projects
Projects	99,373	107,620	108,516	***Other Project Costs (OPC) includes CDR, project-specific R&D, prototyping and testing, installation and commissioning/pre-operations before CD-4***
Energy Frontier Projects	*15,000*	*19,000*	*18,967*	*Initial ATLAS/CMS upgrades complete in FY17; OPC* begins for HL-LHC detector upgrades*
Intensity Frontier Projects	*48,170*	*17,685*	*9,349*	*Reduction from ramp down of g-2 & end of LBNF/DUNE OPC*; SBN Program increases*
Cosmic Frontier Projects	*45,203*	*66,835*	*70,200*	*Planned ramp up supports fabrication of LSSTcam, DESI, SuperCDMS-SNOLab, LZ*
Other Projects	*1,000*	*4,100*	*10,000*	*Increase to support the FACET-II project*
Construction (Line Item)	37,000	84,115	103,741	Request engineering design, site preparation and long-lead procurement for the LBNF/ DUNE; planned profile for Mu2e
SBIR/STTR	20,768*	20,897	22,580	
Total	**766,000***	**795,000**	**817,997**	

**** SBIR/STTR added to FY 2015 for comparison to FY 2016/2017***

HEP - Energy Frontier Status

Strategy

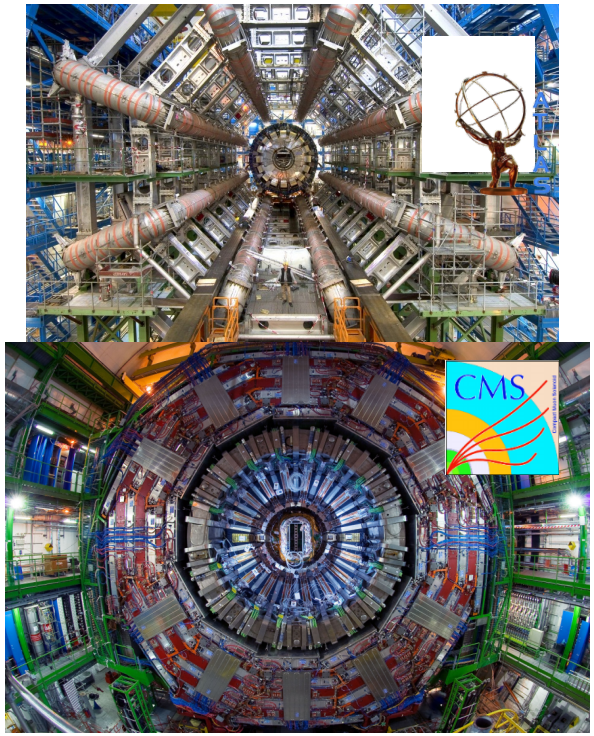
- **P5 report identified LHC upgrades as the highest priority near-term large project and specifically recommends:**
  - Complete "Phase-1" (2019) upgrades of ATLAS and CMS experiments
  - Continue collaborations with the "Phase-2" (High-Luminosity LHC, 2024-26) upgrades of the accelerator and the ATLAS and CMS experiments to extend discovery potential

Current program

- **The U.S. will continue to play a leadership role in LHC discoveries (Run II) and is actively executing the initial detector upgrades (Phase-1)**

Planned program

- **High-luminosity LHC upgrades in 2024-2026 will extend the discovery reach (Phase 2)**
  - **DOE/HEP actively working with US-CMS and US-ATLAS to begin mounting upgrade projects in FY17**
  - **Next important step for HL-LHC is finalizing the international scope of accelerator and detector upgrades and determining the U.S. contributions**



HEP - Intensity Frontier Status

Exploring the unknown through precision measurements – muon-beams,

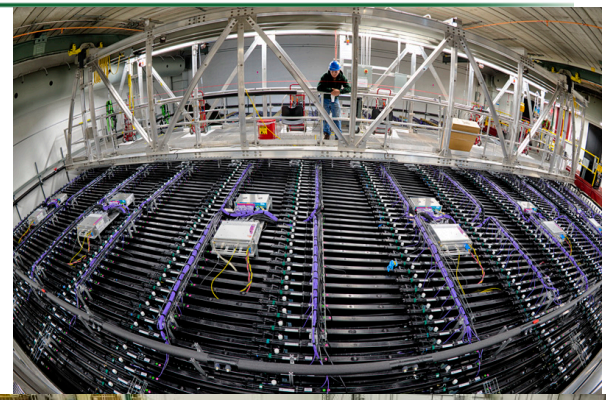
- **P5 recommended muon-beam based program at Fermilab: *Muon g-2 & Mu2e***
- **Collaborating w/Japan on *K* meson, *c/b* quark, and *τ* lepton precision studies: *Belle II & K0TO* (J-PARC)**

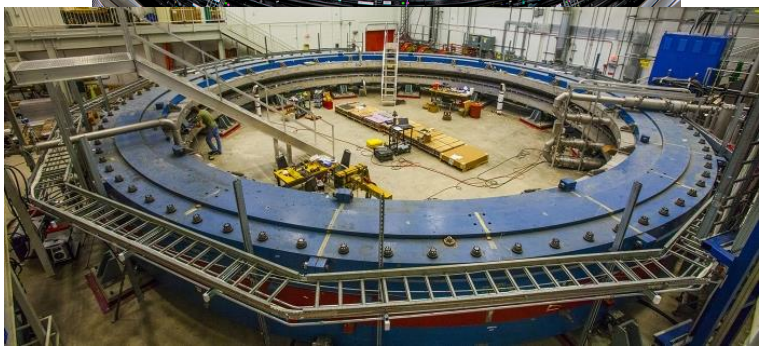
Identify the physics of dark matter

- ***APEX* and *Heavy Photon Search (HPS)* performing particle beam based searches for DM particles**

Pursuing the physics associated with neutrino mass

- **Mass hierarchy & *ν* properties studied at Fermilab, Japan, China, and underground:**
  - ***Daya Bay, MicroBooNE, MINERvA, MINOS+, NOvA, Super-K, T2K***
- **Sterile neutrino search and neutrino CP violation program continues to evolve with P5 recommendations for short-baseline neutrino (SBN) and long baseline neutrino programs**





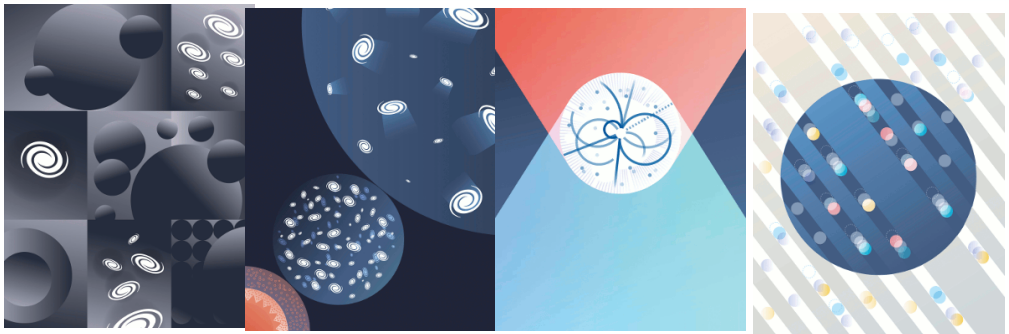
Planned program

LBNF/DUNE is a key element of the global vision presented in the P5 report, and a major domestic milestone as the first international science ground-based facility hosted in the U.S.

- **The swift establishment of the international Deep Underground Neutrino Experiment (DUNE) is a strong indication of the high level of interest from the neutrino community in achieving this global vision**
- **The international effort on LBNF/DUNE made impressive progress**

Aim to solidify international partnerships for LBNF/DUNE with FY 2017 investments in site preparation and excavation of caverns in FY17

HEP Cosmic Frontier - Status



Dark Matter | Cosmic Acceleration | Explore the Unknown | Neutrino Mass

Cosmic Frontier: Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

Program thrusts:

- Study the nature of **Dark Energy**
- Direct Detection searches for **Dark Matter** particles
- **Cosmic-ray & Gamma-ray studi**es – particle properties, high energy acceleration mechanisms, indirect searches for dark matter particles
- **CMB –** current minor efforts planned to expand
- **Other**: computational cosmology; + related Theory, Detector development, computational, etc.

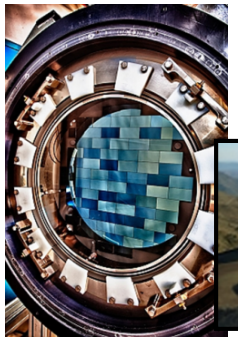
Status & Path Forward

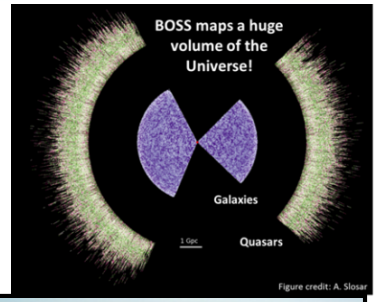
- Continue development near term projects recommended by P5 → Dark Energy, Dark Matter
- Planning activities to support P5 recommendations later in the decade → CMB-S4

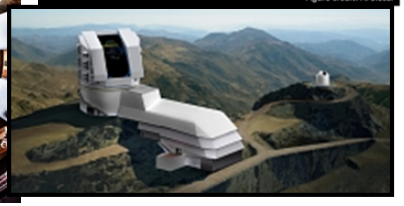
Cosmic Frontier – Dark Energy

Precision measurements to differentiate between Cosmological Constant and new fields or modification to General Relativity

- staged, complementary suite of imaging, spectroscopy and supernova survey experiments







Operating/Completed:

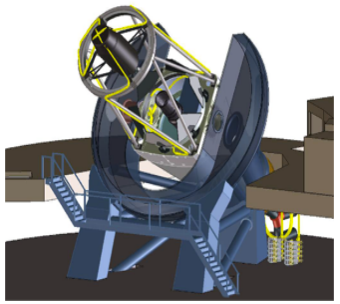
– ***BOSS* (spectroscopic)** ended in FY14; **eBOSS (spectroscopic)** started in 2015

– ***DES* (imaging)** started 5-year survey in late FY13; partner with NSF-AST

Design, Fabrication:

– ***Large Synoptic Survey Telescope* (LSST, Stage IV imaging)**

- HEP and NSF-AST (lead agency) partnership; LSST Project status review Feb. 2016
- HEP responsible for the LSST camera; started fabrication in FY14, CD-3 (full fabrication approved) Aug. 2015
  - Significant international contributions on LSST camera
- LSST Facility Operations phase planning starting (NSF, DOE)
  - Planned support by NSF, DOE and significant international contributions
- LSST Dark Energy Science Collaboration (DESC) Operations needs being developed.



– ***Dark Energy Spectroscopic Instrument* (DESI, Stage IV spectroscopic)**

- "HEP experiment" with LBNL managing:
  - build DESI instrumentation & data management system for use on Mayall telescope
- HEP coordinating with NSF-AST to use ("lease") the Mayall telescope
  - NSF and DOE support Mayall during FY16-18; HEP fully supporting Mayall for dark energy operations starting in FY19
  - Status: CD-3 review (ready for full fabrication phase) in May 2016
- Plan: Mayall shutdown, ready for DESI 1QFY18; DESI+Mayall commissioning complete & data-taking starts 1QFY20

Research: In addition to above, HEP has research-only activities on **Euclid, WFIRST,** & **supernova surveys**

Cosmic Frontier:
Direct Detection Dark Matter (DDDM)

→Learn the identity and nature of Dark Matter with staged program of experiments with multiple technologies & methods

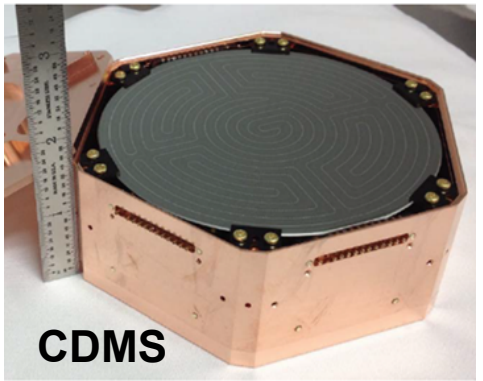
Operating:

DM-Generation 1 (DM-G1): **ADMX-II, LUX, CDMS-Soudan, DarkSide-50, COUPP/PICO, DAMIC** – completing operations efforts by FY 2016

Design, Fabrication:

-- Progress continues on DM-G2's selected by HEP & NSF-PHY in July 2014; with international contributions

- **ADMX-G2** axion search at Univ of Washington (HEP); operations start end 2016
- **LZ** at Homestake Mine in South Dakota
  - WIMP dark matter search through dual phase liquid Xe – higher mass range
  - HEP leads, LBNL Project Office
    - Fabrication start (CD-1/3a) in FY15; CD-2/3 review in April 2016.
- **SuperCDMS-SNOLab** at Sudbury Neutrino Observatory in Canada
  - WIMP search using cryogenic solid-state crystals – lower mass range
  - HEP+NSF-PHY partnership, SLAC Project Office
    - CD-1 approval in Dec. 2015; CD-2 planned for FY17


CDMS


LUX

HEP plans for future (P5)

- HEP concentrating on getting the DM-G2 experiment(s) successfully started
- Limited R&D support planned in FY16+ for
  - Near term off-project efforts to support the DM-G2's and continuing focused technology studies for the future

Cosmic Frontier: CMB

In Atacama: CLASS, ACT, PolarBear/Simons

Gain insight into **inflationary epoch** at the beginning of the universe, **dark energy,** and **neutrino properties** by studying the oldest visible light.

HEP has been involved at a low level in CMB for decades (1977 LBNL measures CMB dipole; 1992 COBE → 2006 Nobel Prize), esp. in technology and computing - Planck computing (NERSC), SPTpol, SPT-3G, Research-only efforts in PolarBear, Bicep…

South Pole Telescope (SPT) and BICEP/Keck Array

→As recommended by P5, HEP is planning to participate in a CMB Stage 4 (CMB-S4) experiment, which would start later in P5 decade

- **HEP will coordinate efforts within HEP program and consider possible HEP roles**
- **Working with NSF to coordinate planning and a path forward**

***Cosmology with CMB-S4 Collaboration Workshop* was held March 7-9, 2016, at LBNL (~180 participants) - Produced first draft Science Book (149 pages) - https://cosmo.uchicago.edu/CMB-S4workshops/index.php/Main_Page**

CMB-S4 Collaboration Community-based planning aiming towards ground-based experiment to:

- **Gain insight into the inflationary epoch, Probe dark energy and neutrino properties from CMB lensing, Map B-mode polarization power spectrum, Probe high energy environment of early universe**

Notional CMB-S4 experiment is array of several telescopes with on the order of 0.5 M detectors in several locations

- **Partnership may include NSF-AST, NSF-PLR, NSF-PHY, international agencies**
- **Technology ready, but needs scale-up of detector fabrication, testing, and readout**
- **Science case and strawman concepts being developed; Investigate international partners!**

→ HEP labs – ANL, FNAL, LBNL, SLAC already have efforts using Lab Directed R&D funds

Cosmic Frontier – Cosmic-ray, Gamma-ray

Use ground-based arrays, space telescopes, and an experiment on the International Space Station to perform indirect searches for dark matter, fundamental physics

→ Significant inter-agency & international partnerships

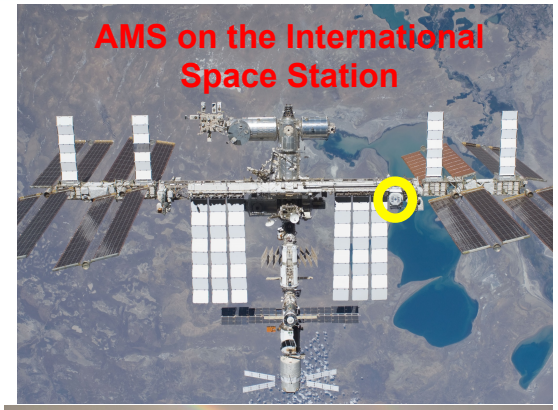
Operating/Analysis:

- ***Fermi/GLAST*** *(w/NASA)*
  - HEP participation in coordination with NASA ;HEP is supporting the Large Area Telescope Instrument Science Ops Center at SLAC
- ***VERITAS*** *(w/NSF)*
  - HEP participation ramping down; their current funds should allow them to operate through ~ FY17
- ***Auger*** *(w/NSF-PHY)*
  - HEP participation in operations & research ramping down in FY16; no participation planned on upgrade
- ***AMS*** *(w/NASA)*
  - operations continuing
- ***HAWC*** *(w/NSF)*
  - 5 year operations started early 2015

P5 Recommendation **- Cherenkov Telescope Array (CTA)**

HEP response to P5 recommendation, funding availability & programmatic priorities:

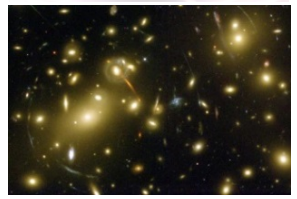
→HEP not continuing support of research, planning, R&D efforts on CTA.

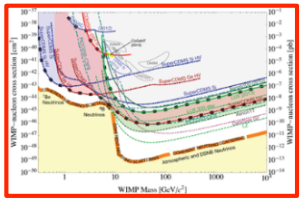


Cosmic Visions – looking towards the future

Following P5, HEP Labs & Community are redirecting programs to align with P5 priorities

- **Considerable LDRD effort directed at CMB, dark energy, dark matter future technologies**





HEP has started "Cosmic Visions (CV)" groups in several areas

- Allows interactions with small HEP community groups (~ monthly) as a 2-way line of communication
- CV groups can collect, coordinate HEP community status and HEP funded efforts for R&D, planning, studies & options for future datasets, experiments, projects
- HEP can use this information to help coordinate and focus our planning and efforts.

NOTE: Of course, any HEP-funded R&D/technology plans need to be in the context of the larger non-HEP and global community (so as not to duplicate efforts or go off in directions that don't make sense)

CV Groups:

CV-CMB

Coordinate HEP technology R&D and other efforts as input for future CMB-S4 planning

CV-DE

Plan future directions in dark energy research, datasets, experiments, or facilities following the end of construction of DESI and LSST; complement, build on or extend these experiments in investigating the physics of dark energy.

CV-DM (Dark Matter Direct Detection)

Coordinate HEP technology R&D and other efforts as input for planning current technology needs and studies &as input to future DM-G3 planning

Summary

- **An exciting time for the HEP Program!**
- **Close coordination with the other agencies; significant partnerships.**

P5 developed compelling, realistic strategic plan with a community consensus vision →HEP is moving forward with NSF to implement it.

The HEP FY2016 Budget & FY 2017 Budget Request continues the implementation of the P5 global vision for particle physics

- Our strategy is to implement P5's plan for Funding Scenario B while pursuing an opportunity to accelerate the establishment of the first U.S.-hosted international science facility, LBNF/DUNE (has received strong support from the Administration, Congress, and interested international partners)