



U.S. DEPARTMENT OF
ENERGY

OFFICE OF
SCIENCE

DOE Office of High Energy Physics (HEP) Status Report to the NAS March 4, 2014

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From Deep Underground to the Tops of Mountains, HEP pushes the Frontiers of Research

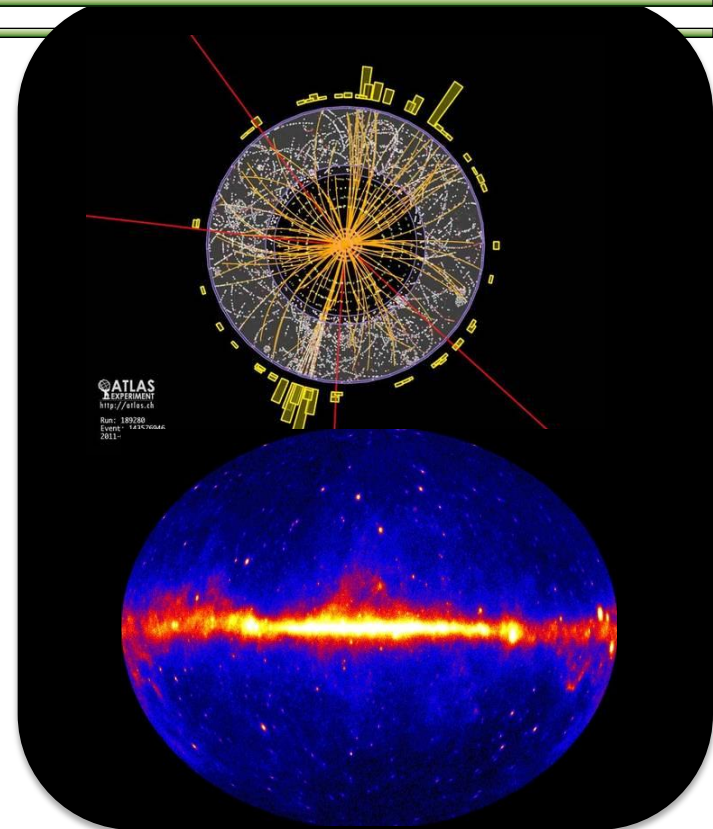
RESEARCH AT THE ENERGY FRONTIER — HEP supports research where powerful accelerators such as the LHC are used to create new particles, reveal their interactions, and investigate fundamental forces, and where experiments such as ATLAS and CMS explore these phenomena.

RESEARCH AT THE INTENSITY FRONTIER — Reactor and beam-based neutrino physics experiments such as Daya Bay and LBNE may ultimately answer some of the fundamental questions of our time: why does the Universe seem to be composed of matter and not anti-matter?

RESEARCH AT THE 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.

THEORY AND COMPUTATION — Essential to the lifeblood of High Energy Physics, the interplay between theory, computation, and experiment drive the science forward. Computational sciences and resources enhance both data analysis and model building.

ACCELERATOR SCIENCE — Supports R&D at national labs and universities in beam physics, novel acceleration concepts, beam instrumentation and control, high gradient research, particle and RF sources, superconducting magnets and materials, and superconducting RF technology.



HEP Program Guidance

FACA panels & subpanels – 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. PASAG, P5)

➤ **Astronomy and Astrophysics Advisory Committee (AAAC)**

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

Other:

e.g. National Academies of Science studies, community science studies, reviews, etc.

Strategic Program Planning → Have been following the 2008 P5 program plan

→ Recently embarked on new strategic planning process:

Snowmass + P5 (May 2014 reports)

HEP Program Model

DOE Office of Science: We are a science mission agency

- Provide science leadership and support to enable significant advances in specific science areas
- Lab environment with a variety of resources needed to design, build, operate selected facilities & projects
- Lab infrastructure, including computing facilities (NERSC, SCiDAC program etc)
- Encourage scientific teams with expertise in required areas to participate in all phases → science results.
- Partnerships as needed to leverage additional science and expertise (e.g. use other agency's facilities)

High Energy Physics

- **We develop and support a specific portfolio of selected facilities & experiments to obtain the science**
- support a science collaboration in all stages, leading to the best possible science results

Model has been very successful:

See <http://science.energy.gov/about/honors-and-awards/doe-nobel-laureates/>

Customized Implementation Strategies

■ Energy Frontier

- US has a leading role in LHC physics collaborations but is not the **driver**
 - The issue is the scope and scale of US involvement. Requires US-CERN negotiation.
 - Could also be true for Japanese-hosted ILC but requires *deus ex machina*

■ Intensity Frontier

- US is a (the?) world leader and needs new facilities and/or upgrades of existing facilities to maintain its position
 - Has the potential to attract new partners to US-led projects if we can get going
 - Portfolio of experiments and science case is diverse. This complicates the case. The scale of the projected investments is a big challenge

■ Cosmic Frontier

- US HEP has a leading role in a competitive, multidisciplinary environment
 - Technologies are diverse but HEP physics case is simple and compelling. Only question is how far one needs to go in precision/setting limits.
 - DOE is a technology enabler, not a facilities provider (see NSF, NASA)
 - Analogous to LHC but the HEP physics goals are not those of the facility owners
 - DOE supports particle physics goals and HEP-style collaborations
 - Astronomy and astrophysics is not in our mission nor our *modus operandi*

Budget

FY14 HEP Budget Overview + FY15 President' Request

	FY2012	FY2013	FY2014	FY2014	FY2014	FY2014	FY2014	FY2015
			Initial President's request	plan in CR	House mark	Senate mark	Final Approp.	President's request (3/4/14)
Budget in \$M	actual	actual	s request	CR	mark	mark	Approp.	(3/4/14)
HEP available	770.5	727.5						
SBIR/STTR (~ 3%)	20.3	20.8						
HEP Total	790.8	748.3	776.5	748.3	772.5	806.6	797.5	744
Office of Science	4,874.60	4,621.10	5,152.70		4,663.00	5,152.7	5,071.00	5,721.00

The FY2014 HEP budget has been approved and is up \$21M from the President's Request (with specific guidance for the \$21M).

The FY2015 HEP President's Request budget was released on 3/4/15; down significantly from FY 2014 appropriation.

➔ Program planning in this budget environment is very difficult due to not having a stable budget.

FY14 HEP Budget

In the last few years, the HEP budget philosophy has been to enable new world-leading HEP capabilities in the U.S. through investments on all three frontiers

- To be accomplished through ramp-down Research (~ -6%) & existing Project operations

FY 2013 Budget:

We were not able to start new Major Item of Equipment (MIE) projects, including the Large Synoptic Survey Telescope camera project (LSST-camera) or Belle-II.

FY 2014 Budget Appropriations & Guidance:

Projects Approved:

- LSST-camera MIE-fabrication start - we can provide full planned funding (\$22M in FY14)
- Belle-II MIE-fabrication start
- Muon g-2 MIE-fabrication start
- Muon to Electron conversion (m2e) experiment Project Engineering & Design (PED) and Construction funds approved

Other

Specific guidance in approved Budget for the additional \$21M provided over the Request:

- Long Baseline Neutrino Experiment (LBNE) – \$26M in R&D & PED funds (**\$16M in PED over Request**)
- Homestake Mine Operations - \$15M provided (**specific guidance was \$5M over Request**)

HEP Budget - Cosmic Frontier

	FY2012	FY2013	FY2014	FY2014	FY2015
			President's	Approp. – current	President's
Cosmic Frontier (in \$K)	actual	actual	request	plan	request (3/4/14)
Research – university + labs			46840	49271	
Research - university	12881	12233			
Research - labs	34962	36448			
Experimental Operations	8505	10111	7500	9615	
Future project R&D (includes DM-G2, DESI, etc)		9659	13494	8900	
Small project fabrication	5891		1200		
MIE R&D - LSST camera	5500	8000		3000	
MIE fabrication - LSST camera			22000*	19000	
MIE fabrication – HAWC (ended in FY13)	1500	1500			
TOTAL	69239	77951	91034	89786	
* This is a REQUEST					

Strategic Planning

Strategic Plan & Budget

- **The U.S. HEP program is following the strategic plan laid out by the previous HEPAP/P5 studies (2008)**
 - Recent results provide compelling evidence that the science focus is shifting “Beyond the Standard Model.”
 - We are adapting the program to the science opportunities.
- **Though some of the boundary conditions have changed, we are still trying to implement the 2008 strategic plan within the current constraints**
- **We are currently actively engaged with community in developing new strategic plan through Snowmass/P5 process (2013-2014)**
- **Increased emphasis on broader impacts via accelerator stewardship**
- **Maintain leadership**
 - Focus on areas where US can have leadership
 - High impact science as opposed to incremental advances
- **P5 report will come out in May 2014**

Program Status → Cosmic Frontier



HEP Program Model – Cosmic Frontier

Cosmic Frontier:

Design and build instrumentation; led by scientific collaborations; bring other resources (e.g. computing, operations) & use other agency's facilities (e.g. telescopes) when needed.

→ Our model also brings significant new capabilities in terms of instrumentation, and coordinated computing, simulation and analysis efforts that provide impacts & resources to the astronomy community.

Considerations for Research Support

- Priority is to support efforts in our program, where we have responsibility for experiment
- People working in HEP collaboration model – long term commitments, responsibilities, % effort
- Increasing university involvement in dark energy, dark matter
- Change distribution between thrusts as we go forward to support changing program

Cosmic Frontier – Planning

At the Cosmic Frontier: US HEP has a leading role in a competitive, multidisciplinary environment.

→ We follow PASAG criteria: Make contributions to select, high impact experiments:

- That directly address HEP science goals
- That will make a significant, visible or leadership contribution
- Where HEP community contributions /expertise is needed – instrumentation, collaborations, analysis techniques etc.

PASAG criteria - Used for considering projects as well as research activities

Current Planning - Projects

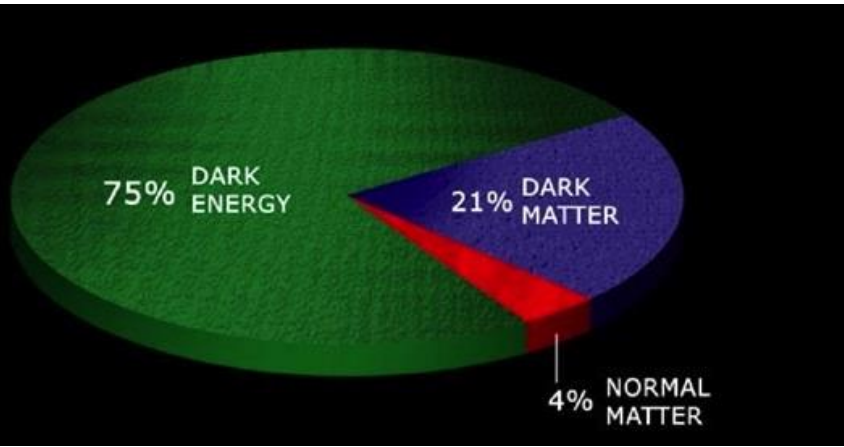
- Dark Matter: working with NSF-PHY on planning one or more DM-G2 experiments
- Dark Energy: LSST camera fabrication project approved in FY14 (partnership NSF-AST); planning DESI (in coordination w/NSF-AST)
- Cosmic-ray, Gamma-ray: HAWC ending fabrication and full operations starts in FY14 (w/NSF-PHY); considering SPT-3G

Path Forward – Awaiting guidance from P5 on projects currently in the planning phase as well as other possibilities

- DM-G2, DESI
- Cherenkov Telescope Array (CTA) contributions, Stage 4 CMB experiment (CMB-S4)

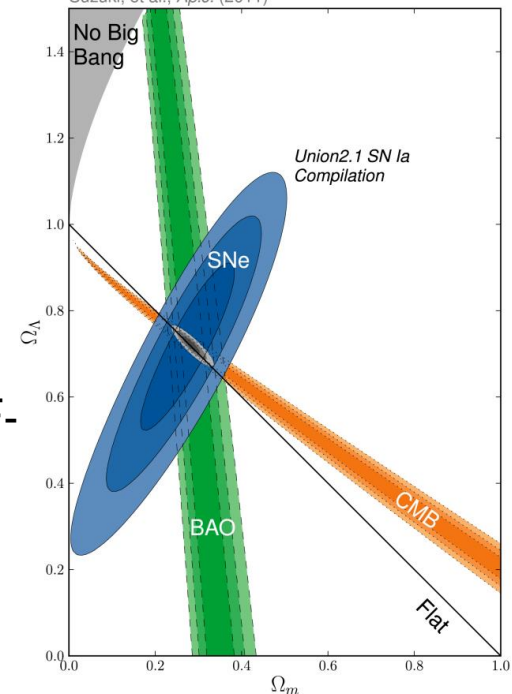
→ Will further develop and optimize program following the Snowmass/P5 process.

Dark Energy Program - status



Have continuing balanced, staged program of Stage III → Stage IV experiments that use imaging or spectroscopic surveys to explore the nature of dark energy using complementary methods. Different methods probe different parameter space. Weak lensing will allow differentiation between cosmological constant or modification to General Relativity.

Supernova Cosmology Project
Suzuki, et al., *Ap.J.* (2011)



Operating

- Baryon Oscillation Spectroscopic Survey (**BOSS**)

Stage III spectroscopic survey using Baryon Acoustic Oscillation (BAO) method; 5 year operations completes in FY14

- Dark Energy Survey (**DES**)

Stage III imaging survey; 5 year ops started Sept 2013; partnership with NSF-AST; Joint Oversight Group (JOG) meets monthly

- Supernova surveys continue operations



Dark Energy Program - planning

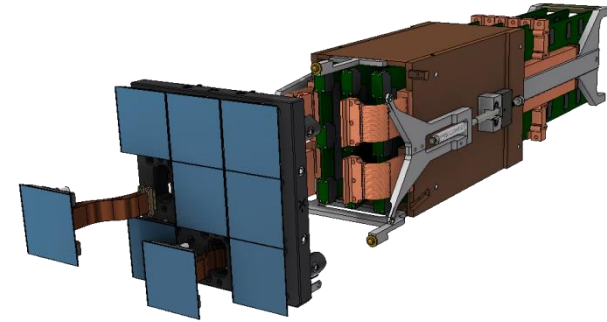
Fabrication phase

- Large Synoptic Survey Telescope (**LSST**)

Stage IV imaging survey

→ FY14 fabrication start for LSST-camera **approved!**

- Partnership with NSF-AST; MOU in place
- JOG meets weekly; brief OSTP regularly
- CD-3a review in May 2014; CD-2 review in Nov. 2014



LSST - Science Raft Tower,
Part of the DOE deliverables

Planning

- Dark Energy Spectroscopic Instrument (**DESI**)

Stage IV spectroscopic survey to use BAO and Redshift Space Distortion (RSD) methods

- planning in coordination with NSF-AST
- Sept. 2012 CD-0 approved
- Jan. 2013 statement of agency principles signed
- April 2014 CD-1 review scheduled
- FY14 R&D support continuing
- extended BOSS (**eBOSS**) operations being considered

Science effort, but no
“project” plans:

- WFIRST NASA Science Definition Team
- Euclid (ESA/NASA) space mission

Baryon Oscillation Spectroscopic Survey (BOSS)

Dark Energy using Baryon Acoustic Oscillation (BAO) method

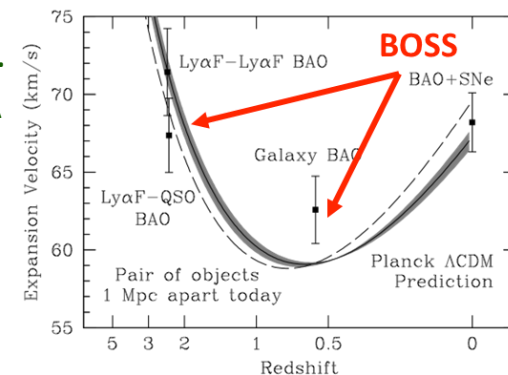
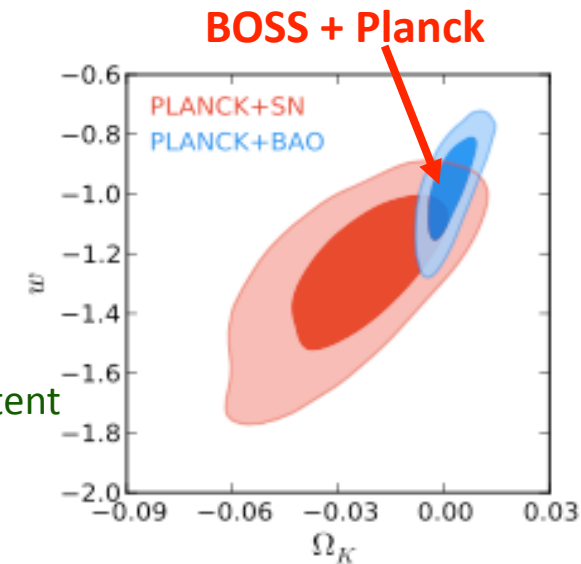
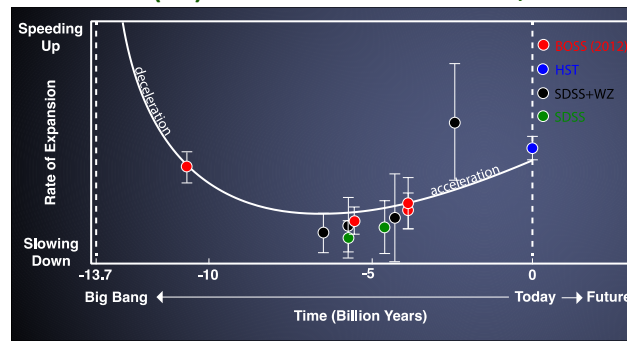
- first Stage-III dark energy experiment; 5 year survey completes in July 2014
- flagship survey on Sloan Digital Sky Survey (SDSS) Phase III at Apache Point Observatory in New Mexico; DOE funded spectrograph upgrade
- Mapping 3-D positions of 1.5 million galaxies & line-of-sight to 160,000 quasars using Lyman-alpha forest.
- Pending proposal for extended-BOSS (eBOSS) survey

January 2014: 1.0% distance measure from galaxy survey at $z=0.55$ is consistent with Einstein's Λ

- Supersedes all previous BAO results combined
- better than the accuracy of local measurements of the Hubble constant

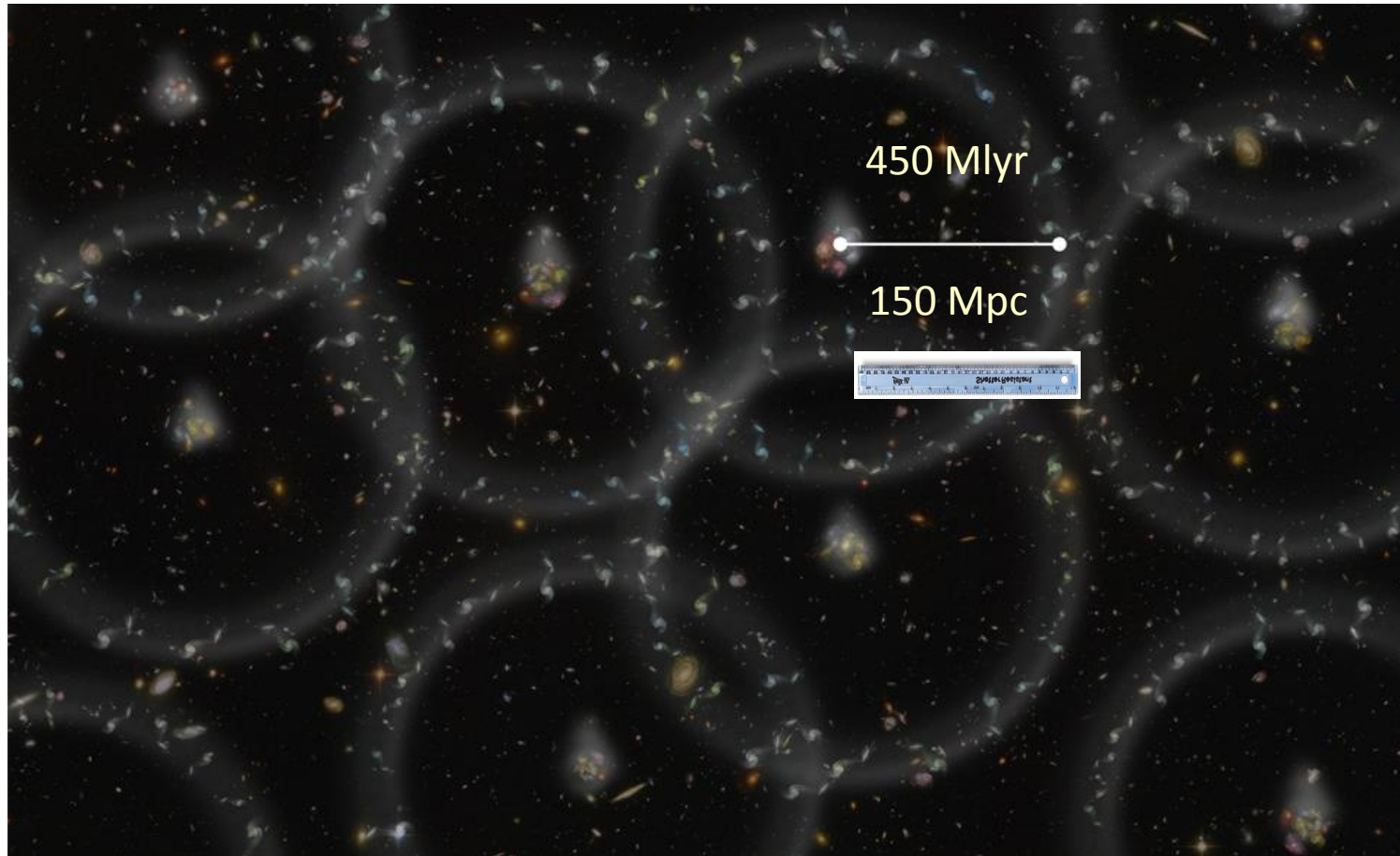
November 2012: 3% distance measure at $z=2.3$ from newly-demonstrated Lyman-alpha technique from distant quasars; results from 3X more data in prep. for **April 2014**

- First measurement showing the universe is decelerating ~ 10 billion years ago.
- Dark energy equation of state (w) measured to 10%, consistent w/Einstein's Λ



Baryon Oscillation Spectroscopic Survey (BOSS)

“BOSS measures the universe to 1% accuracy” using the BAO standard ruler
Pairs of galaxies more likely to be separated by 450 million light-years



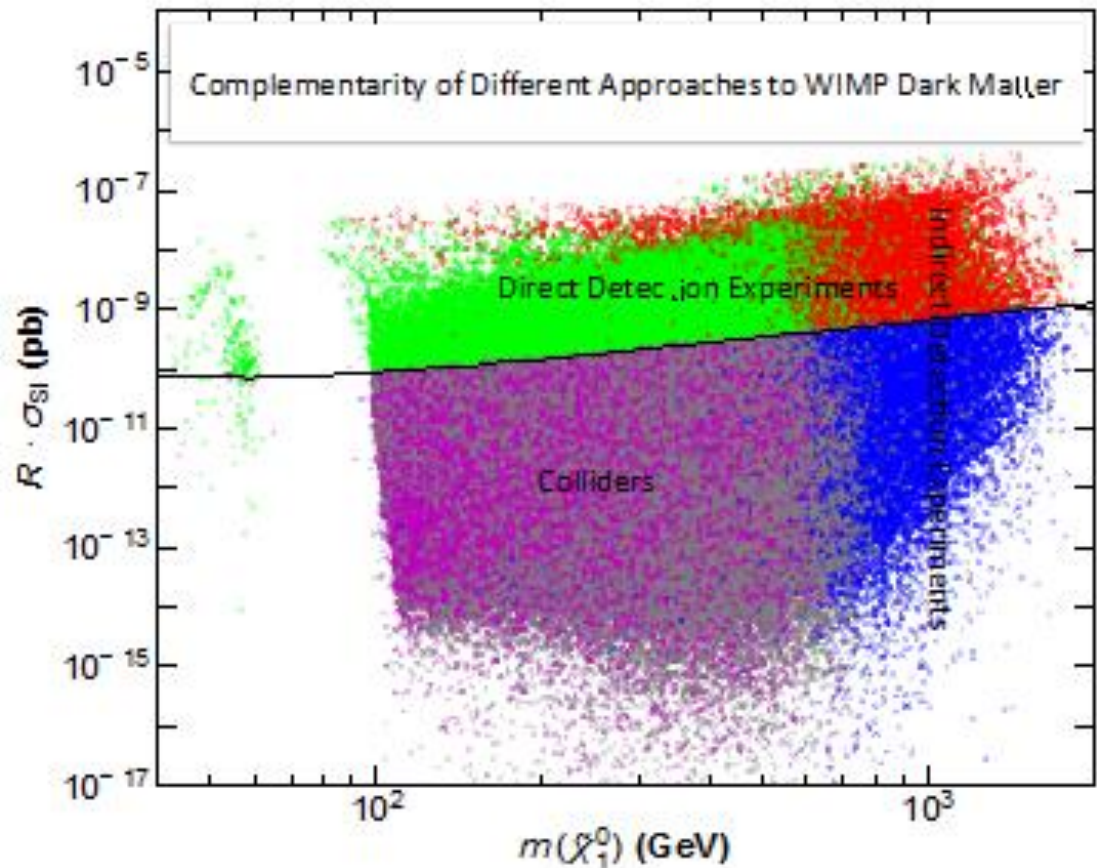
Artist conception of baryon acoustic oscillations (BAO) from the early universe, imprinted on the distribution of galaxies. Credit: Z. Rostomian; Jan 2014 press release, <http://www.interactions.org/cms/?pid=1033541>

Complementary Methods for Dark Matter Detection

Direct Detection: Deep underground experiments directly measure interactions with DM WIMPs. These provide the most information on the nature of DM if detected.

Indirect Detection: Measure cosmic-ray byproducts of WIMP annihilation in the Galaxy.

Particle Accelerators: Production of new particle species in collisions; cannot determine if they are the DM, however.



These three methods cover all the possible ways of detecting WIMP dark matter.

Dark Matter – Direct Detection Program Status

→ Have balanced, staged program of experiments w/multiple technologies in the near term.

- Done in coordination with NSF-PHY

Dark Matter “Generation 1” (DM-G1)

→ current generation of commissioning or operating experiments will determine which of several promising technologies are best for larger searches.

Weakly Interacting Massive Particle (WIMP) searches:

- SuperCDMS-Soudan: cryogenic germanium
- LUX: liquid xenon
- DarkSide-50: liquid argon
- COUPP-60: bubble chamber fluids

Nature Magazine - 2013 in Review → LUX was rated the top story of the year.

Axion search:

- ADMX-2a: search for axions – dark matter candidates predicted in certain QCD models; would interact with strong magnetic fields to produce detectable photons

Dark Matter – Direct Detection Program Planning

➔ Have a path forward for next phase of direct detection dark matter experiments

Dark Matter Generation 2 (DM-G2) experiments

Select the best technologies for dark matter searches that will be over an order of magnitude more powerful than those of Generation-1.

Sept. 2012 – approved Critical Decision 0 (CD-0) for DM-G2 experiment(s)

FY2013 (and continuing part-way through FY14)

– based on Sept 2012 review, R&D funding provided to:

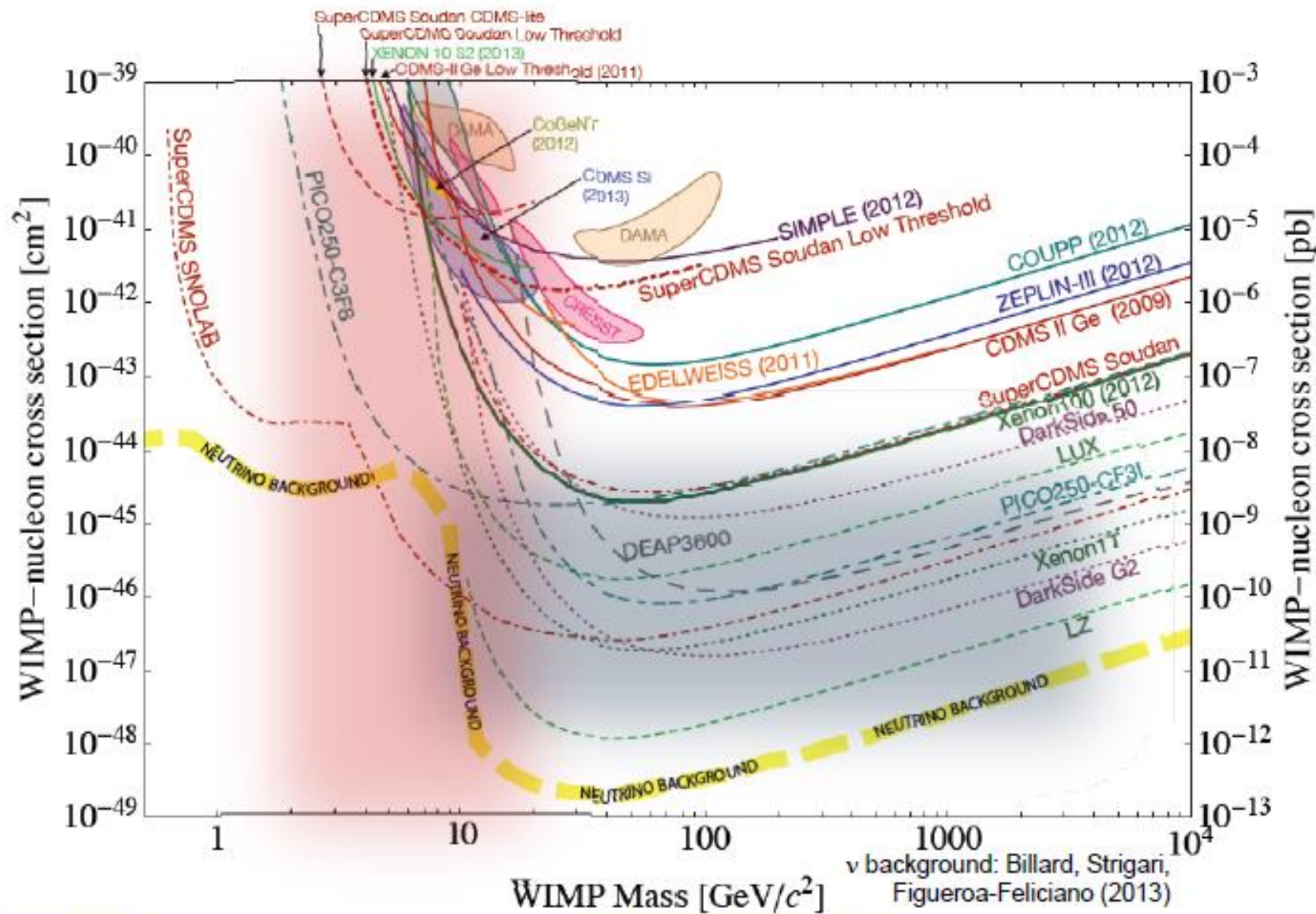
SuperCDMS-SNOLab, LZ, DarkSide-G2, PICO-250, ADMX-G2

Dec. 2013 - down-select review for 1 or more DM-G2 experiments to move to the fabrication phase – results will be announced later in 2014

DM-G3 experiments

- G3 R&D and planning continues at a low level

CURRENT STATUS AND FUTURE PROSPECTS



High Energy Cosmic-ray, Gamma-ray experiments

➔ Experiments measuring properties of high energy cosmic-rays & gamma rays; can also explore acceleration mechanisms and do indirect searches for dark matter candidates.

Operating

Alpha Magnetic Spectrometer – cosmic ray observatory in space

Pierre Auger - cosmic ray observatory in Argentina

Fermi Gamma-ray Space Telescope – gamma-ray observatory in space

- Origin of Cosmic Rays (FGST) one of Science magazine's Top 10 Science Breakthroughs of the Year

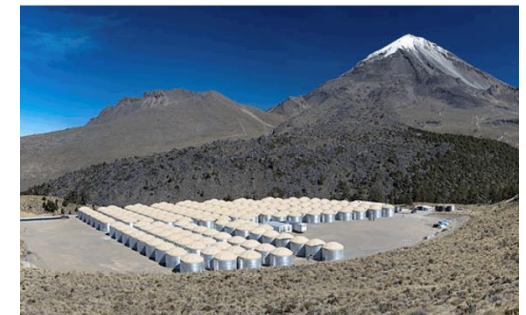
VERITAS – gamma-ray array in Arizona

Fabrication

HAWC – gamma ray array in Mexico; now partial operations with full operations starting August 2014

Future Planning:

- community planning on Cherenkov Telescope Array (CTA); will be considered by P5



Construction on schedule and on budget:
194 of ~300 tanks are constructed (2/1/14)

Cosmic Frontier – Cosmic Microwave Background (CMB)

CMB experiments:

HEP currently has small contributions to:

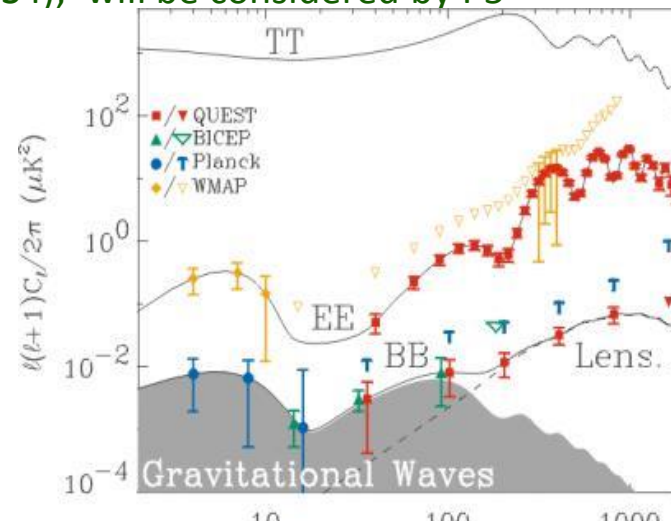
- South Pole Telescope polarization (SPTpol)
 - HEP provided outer-ring detectors
- Planck
 - supercomputing resources for data analysis at NERSC (DOE & NASA MOU)

Planck →

Future Planning

SPTpol-3G – HEP considering participation in major upgrade to replace the camera with a larger focal plane with 2539 multi-chroic pixels (total of 15,234 detectors) to greatly increase sensitivity

CMB Future: Community is developing science case and concept for a Stage-IV CMB experiment (CMB-S4); will be considered by P5



SPT is the first CMB telescope to measure “B-mode” polarization in the CMB



Summary

Cosmic Frontier: Lots of results coming out or expected soon in all areas.

Have plan forward & working to implement it:

- Dark Energy: LSST-camera (approved!), DESI
- Dark Matter: DM-G2
- Other possibilities: awaiting P5 report (May 2014)