AAAC-Related Programs in the NSF/Physics Division

AAAC Meeting

November 12, 2015

Brad Keister

Deputy Division Director

Jean Cottam & Jim Whitmore

Program Directors for Particle Astrophysics

Keith Dienes

Program Director for Particle Astrophysics and Cosmology Theory

Pedro Marronetti & Mark Coles

Program Directors for Gravitational Physics

Division of Physics – 2015

Denise Caldwell, DD

Brad Keister, DDD

Atomic, Molecular, Optical & Plasma Physics
Gillaspy (F); Lukin (T); Gitomer (E)

Interactive Activities in Physics
(REU Sites, MRI, CAREER, BP org) McCloud (F)

Elementary Particle Physics; LHC
Shank (I); Gonzalez (F); Meadows (I); Coles (F)

Particle Astrophysics; IceCube
Whitmore (F); Cottam (F)

Physics at the Information Frontier
(QIS, Computational Physics, CDS&E)
Orel (I); Mihaila (F)

Gravitational Physics; LIGO, AdvLIGO
Marronetti (F); Coles (F)

Nuclear Physics; NSCL
Opper (F); Hicks (I)

Theoretical Physics
(AMO, Nuclear, EPP, AC)
Orel (I); Mihaila (F); Dienes (V)

Physics of Living Systems
Blagoev (F)

Physics Frontiers Centers
Cottam (F); McCloud (F)

Accelerator Science
Shank (I); Gonzalez (F); Lukin (T)

Midscale Instrumentation, Coles, Science Advisor

Particle Astrophysics Programs

Particle Astrophysics lies at the intersection of particle physics, astronomy and cosmology. Formerly separate questions in cosmology (the universe on the largest scales) and quantum phenomena (the universe on the smallest scales) become connected through our understanding that the early universe can be explored through the techniques of particle physics.

- The experimental **Particle Astrophysics (PA)** program supports university research that uses astrophysical sources and particle physics techniques to study fundamental physics, research that locates experiments in low background environments, and research that utilizes the facilities of IceCube at the South Pole. Currently supported activities include: Astrophysical sources of gamma-rays, cosmic-rays, and neutrinos; studies of solar, underground, and reactor neutrinos; neutrino mass measurements; searches for the direct detection of Dark Matter; and the study of ultra-high energy neutrinos and the properties of neutrinos with IceCube.
- The **Theoretical Particle Astrophysics and Cosmology** program supports proposals that primarily are involved with theoretical particle astrophysics and big-bang cosmology as well as more speculative string theory inspired cosmologies. Understanding the quarks to cosmos connection has been a recent focus of the program as well as better understanding the implications of the fluctuation spectra of the cosmic microwave background. The cosmology and astrophysics research supported by the program is usually associated with people with training in particle theory and encompasses dark matter, dark energy, high energy cosmic rays as well as exotic cosmologies arising from Brane-world and String Theory scenarios.

PA Program Scope & Currently Supported Projects

- Direct Dark Matter Detection – WIMP and non-WIMP experiments

  SuperCDMS, XENON, LUX, DArkSide, PICO, DRIFT, ADMX-HF, DM-Ice, SABRE, ALPS2, DAMIC and DM-GPS

- Indirect Dark Matter Detection

  VERITAS, HAWC, IceCube

- Cosmic Ray, Gamma Ray, and UHE Neutrino Observatories

  IceCube, VERITAS, HAWC, Auger, Telescope Array, ARA, ARIANNA

- Dark Energy

  LSST

- Cosmic Microwave Background

  SPT, ACT-Pol (w/ Gravity)

- Neutrino Properties

  Double Chooz, Daya Bay, Project 8

- Solar Neutrinos

  Borexino, SNEWS

AST

Polar Programs

Theory Program Scope & Currently Supported Projects

- Dark Matter - direct detection
  - Limits of direct detection experiments due to neutrino backgrounds
  - Flavor symmetry effects on signatures
  - Studies of DM interactions with various nuclei
  - Computational resources for dark matter density simulations
- Dark Matter - indirect detection (decay or annihilation of DM)
  - Studies of photons and positrons from dwarf galaxies (such as LMC,SMC)
  - Cosmic ray flux predictions as backgrounds for indirect DM signals.
  - Effects of cosmic variance on astrophysical indirect DM signals
  - Effects of resonant DM annihilation and effects from various DM candidates
- Dark Matter - galactic structure
  - Simulations of various DM candidates
  - Search for microstructures due to DM
- Inflation
  - Non-Gaussian perturbations in inflation and effects on CMB and Large Scale Structure
  - Alternative models to inflation
- Cosmic Strings
  - Effects on CMB and Large Scale Structure
  - Observational signatures
  - Theoretical evolution of string networks.

Gravitational Physics Programs

The Gravitational Physics program supports research at the frontiers of science aimed towards answering questions about the nature of space and time, the gravitational attraction at atomically small and cosmological large distances and the use of gravitational waves to explore the universe.

- The **Experimental Gravitational Physics** program supports research that includes tests on the inverse distance square law of gravitational attraction, Lorentz invariance and Equivalence Principle as well as the direct detection of gravitational waves. This program oversees the management of the construction, commissioning, and operation of the Laser Interferometer Gravity Wave Observatory (LIGO), and provides support for LIGO users and other experimental investigations in gravitational physics and related areas. This includes tasks that range from instrument science, data analysis and detector characterization to source population calculations and the connection between the gravitational waves and the electromagnetic and neutrino signatures of astrophysical events.

- The **Theoretical Gravitational Physics** program supports research on classical and quantum gravity theory, including gravitational wave source simulations and other phenomena associated with strong field gravity and the interface between gravitation and quantum mechanics. This includes formulating new approaches for theoretical, computational, and experimental research that explore the fundamental laws of physics and the behavior of physical systems and, in some cases, interpreting the results of experiments. The effort also includes a considerable number of interdisciplinary grants.

Gravitational Physics Scope & Currently Supported Projects

Theory

- Structure of General Relativity (GR)

  Mathematical GR, Classical Field Theory, Properties of horizons and singularities, Stability of Einstein Field Equations (EFE) solutions

- Alternative Theories of Gravity

  Extensions of GR, Scalar-Tensor Theories, Testing of Alternative Theories using current and future Gravitational Wave (GW) detectors

- Unified Theories

  Unification of Quantum Mechanics and Gravity: Loop Quantum Gravity (not String Theory), Approximations to Unified Theories, Semi-classical field theories

- Astrophysics

  Numerical Relativity (NR) as a tool to find solutions of the EFE with astrophysical relevance. Modeling of black holes, neutrons stars, quark stars (in binaries or in isolation). Generation of GW signals for LIGO searches

Experiments

- Short Range Experiments

  Deviations from Inverse Square Law, Weak Equivalence Principle tests, Search for Lorentz Symmetry violations

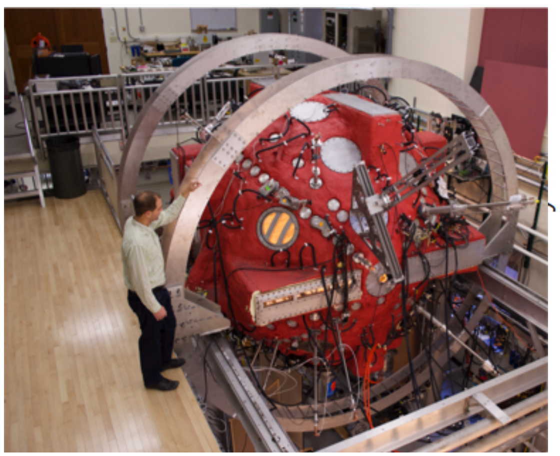
- Long Range Experiments

  Lunar Laser Ranging, Detection of relic GWs in the Cosmic Microwave Background (Atacama Cosmology Telescope)

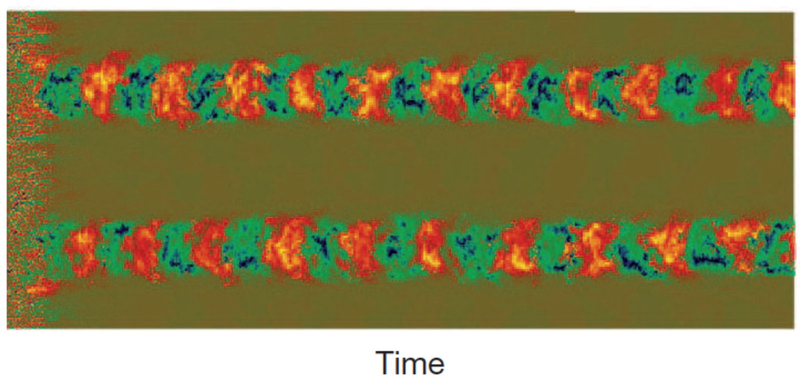
- LIGO
  - Instrument Science: Mirror Coatings, Laser Interferometry, Squeezed Light, Noise Isolation
  - Data Analysis: Sky Localization, Connection with EM and Particle observations (Multi-messenger Astronomy), Search Algorithm Development, GW Template Construction. GW Sources Synthesis
  - Outreach: LIGO Science Education Center (Livingston, LA)

Plasma Astrophysics & Heliophysics

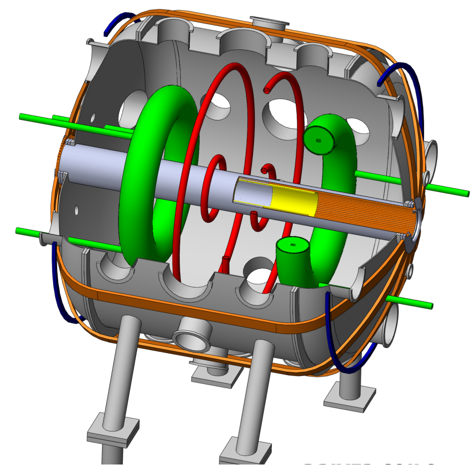
- 99.9% of the visible Universe is thought to consist of fully or partially ionized plasmas. The collective behavior in plasmas leads to phenomena as varied as magnetization from cosmic to planetary scales, particle energization throughout the Universe, and light shows from extragalactic gamma ray bursts to aurorae here on Earth.
- Synergetic observation, theory, modeling and experiments transform our understanding of the generation of magnetic fields in astrophysical dynamos; explosive release of magnetic energy in GRBs, solar/stellar flares and planetary magnetospheric sub-storms; thermal and non-thermal particle acceleration in astrophysical shocks and jets.



FY09 PHY MRI award: Madison Plasma Dynamo Experiment to study the generation & evolution of magnetic fields in plasma flow driven environments.



Physics Frontiers Center for Magnetic Self-Organization: First numerical demonstration of large-scale, fast dynamo by sheared, helical flows [Tobias & Cattaneo, Nature (2013)]



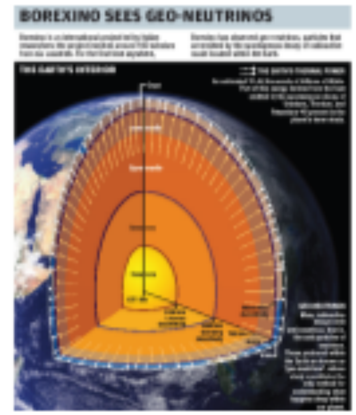
FY13 PHY MRI award: Facility for Laboratory Reconnection Experiments (FLARE) to study explosive release of magnetic energy in magnetized plasmas.

BOREXINO Geoneutrinos

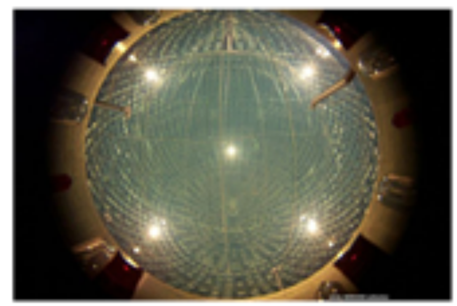
Spectroscopy of geoneutrinos from 2056 days of Borexino data

Geoneutrinos are electron antineutrinos produced by decays of long-lived isotopes, which are naturally present in the interior of the Earth, such as decays in the ^{238}U and ^{232}Th chains, and ^{40}K.

Borexino is an unsegmented liquid scintillator detector in operation at the underground Gran Sasso National Laboratory, Italy



These measurements (reported in Phys. Rev. D, August 7, 2015) of geo-neutrinos provide direct evidence that radioactivity within the Earth is a major contributor to its internal heating.

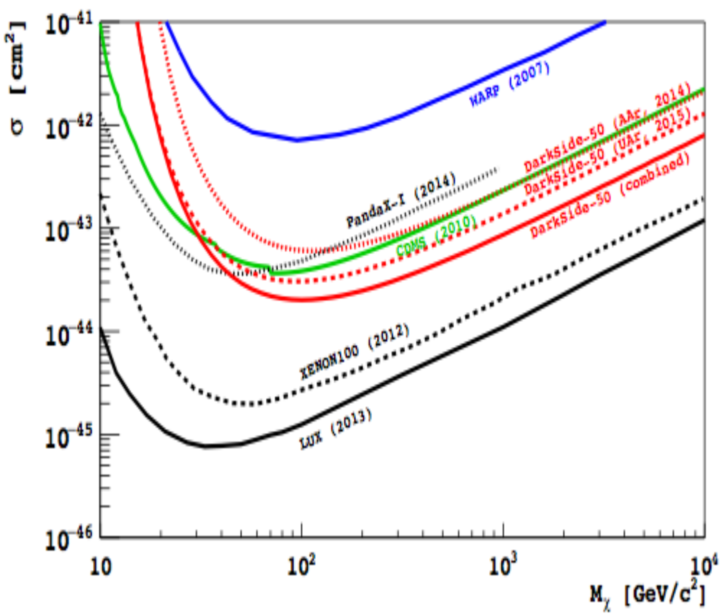


The present exposure is (5. 5 ± 0.3)x 10^{31} proton-yr. Assuming a chondritic Th/U mass ratio of 3.9, they obtain 23.7 +6:5 -5:7(stat) +0:9 -0:6(sys) geoneutrino events. The null observation of geoneutrinos with Borexino alone has a probability of 3.6×10^{-9} (5.9s).

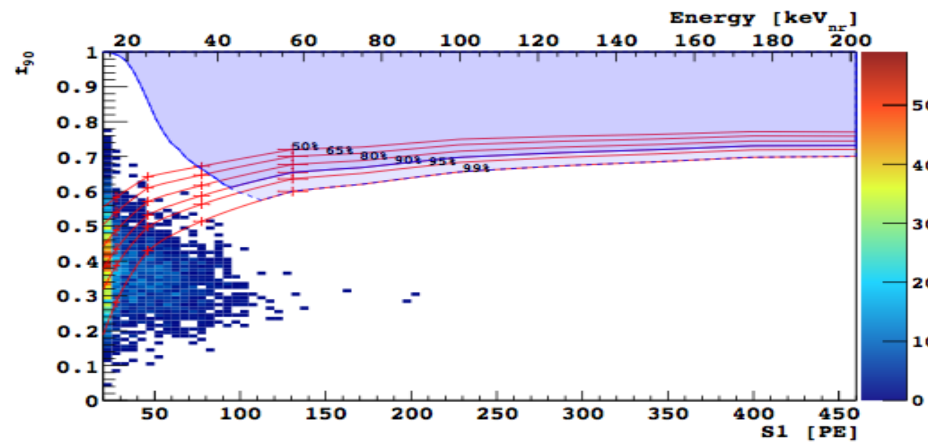
A geoneutrino signal from the mantle is obtained at 98% C.L. The radiogenic heat production for U and Th from the present best-fit result is restricted to the range 23-36 TW, taking into account the uncertainty on the distribution of heat producing elements inside the Earth.

DArkSide-50: Dark Matter search

The DA-50 dark matter search reports the first results obtained using a target of low-radioactivity argon extracted from underground sources. The experiment is located at the LNGS and uses a two-phase time projection chamber as a detector. A total of 155 kg of low radioactivity argon has been obtained, and they have determined that underground argon is depleted in ^{39}Ar by a factor (1.4 ± 0:2) x 10^3 relative to atmospheric argon. They find no evidence for dark matter in the form of WIMPs in 70:9 live-days of data with a fiducial mass of (36.9 ±0.6) kg.



The observed suppression is sufficient to allow multi-tonne-year exposures with this argon to be free of ^{39}Ar background.



National Science Foundation Budget

National Science Foundation
Summary Table
FY 2016 Request to Congress
(Dollars in Millions)

NSF by Account	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	FY 2016 Request over: FY 2014 Amount	FY 2014 Percent	FY 2015 Amount	FY 2015 Percent
BIO	$720.84	$731.03	$747.92	$27.08	3.8%	$16.89	2.3%
CISE	892.60	921.73	954.41	61.81	6.9%	32.68	3.5%
ENG	833.12	892.31	949.22	116.10	13.9%	56.91	6.4%
Eng Programs	*673.13*	*715.20*	*754.86*	*81.73*	*12.1%*	*39.66*	*5.5%*
SBIR/STTR	*159.99*	*177.11*	*194.36*	*34.37*	*21.5%*	*17.25*	*9.7%*
GEO	1,321.32	1,304.39	1,365.41	44.09	3.3%	61.02	4.7%
MPS	1,267.86	1,336.72	1,366.23	98.37	7.8%	29.51	2.2%
SBE	256.84	272.20	291.46	34.62	13.5%	19.26	7.1%
OISE[1]	48.31	48.52	51.02	2.71	5.6%	2.50	5.2%
IA[1]	433.12	425.34	459.15	26.03	6.0%	33.81	7.9%
U.S. Arctic Research Commission	1.30	1.41	1.48	0.18	13.5%	0.07	5.0%
Research & Related Activities	**$5,775.32**	**$5,933.65**	**$6,186.30**	**$410.98**	**7.1%**	**$252.66**	**4.3%**
Education & Human Resources	**$832.02**	**$866.00**	**$962.57**	**$130.55**	**15.7%**	**$96.57**	**11.2%**
Major Research Equipment and Facilities Construction	**$200.00**	**$200.76**	**$200.31**	**$0.31**	**0.2%**	**-$0.45**	**-0.2%**
Agency Operations and Award Management	**$305.95**	**$325.00**	**$354.84**	**$48.89**	**16.0%**	**$29.84**	**9.2%**
National Science Board	**$4.25**	**$4.37**	**$4.37**	**$0.12**	**2.8%**	**-**	**-**
Office of Inspector General	**$13.84**	**$14.43**	**$15.16**	**$1.32**	**9.5%**	**$0.73**	**5.1%**
Total, NSF	**$7,131.39**	**$7,344.21**	**$7,723.55**	**$592.16**	**8.3%**	**$379.34**	**5.2%**

Totals may not add due to rounding.

[1] This table reflects the realignment, expected in FY 2015, of the Office of International Science and Engineering (OISE) and Integrative Activities (IA) as separate budget activities. All data are presented in the FY 2015 structure for comparability.

MPS/PHY Budget

Mathematical and Physical Sciences (MPS) Funding
(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	Change Over FY 2015 Estimate Amount	Change Over FY 2015 Estimate Percent
Astronomical Sciences (AST)	$238.36	$244.16	$246.55	$2.39	1.0%
Chemistry (CHE)	235.18	243.85	251.20	7.35	3.0%
Materials Research (DMR)	267.09	306.99	315.80	8.81	2.9%
Mathematical Sciences (DMS)	224.97	231.73	235.47	3.74	1.6%
Physics (PHY)	267.09	274.99	277.37	2.38	0.9%
Office of Multidisciplinary Activites (OMA)	35.17	35.00	39.84	4.84	13.8%
Total, MPS	**$1,267.86**	**$1,336.72**	**$1,366.23**	**$29.51**	**2.2%**

Totals may not add due to rounding.

Physics (PHY) Funding
(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request	Change Over FY 2015 Estimate Amount	Change Over FY 2015 Estimate Percent
Total, PHY	**$267.09**	**$274.99**	**$277.37**	**$2.38**	**0.9%**
Research	**163.82**	**176.05**	**176.19**	**0.14**	**0.1%**
CAREER	8.57	7.44	7.45	0.01	0.1%
Centers Funding (total)	0.02	0.02	-	-0.02	-
Nanoscale Science & Engineering Centers	0.02	0.02	-	-0.02	-
Education	**5.38**	**5.56**	**5.32**	**-0.24**	**-4.3%**
Infrastructure	**97.89**	**93.38**	**95.86**	**2.48**	**2.7%**
IceCube Neutrino Observatory	3.45	3.45	3.45	-	-
Large Hadron Collider (LHC)	17.37	18.00	18.00	-	-
Laser Interferometer Grav. Wave Obs. (LIGO)	36.43	39.43	39.43	-	-
National Superconducting Cyclotron Laboratory (NSCL)	22.50	22.50	22.50	-	-
Research Resources	11.56	-	-	-	N/A
Midscale Research Infrastructure	6.58	10.00	12.48	2.48	24.8%

Totals may not add due to rounding.

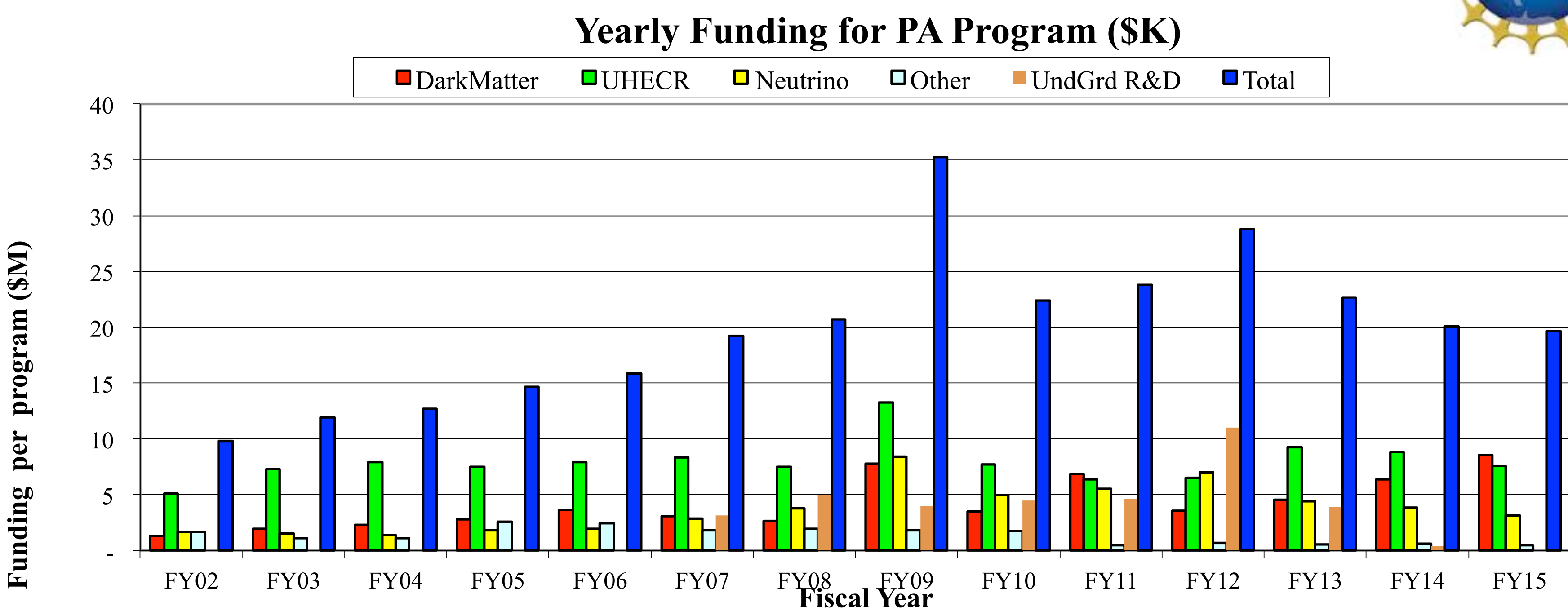
"Physics of the Universe" Funding Details

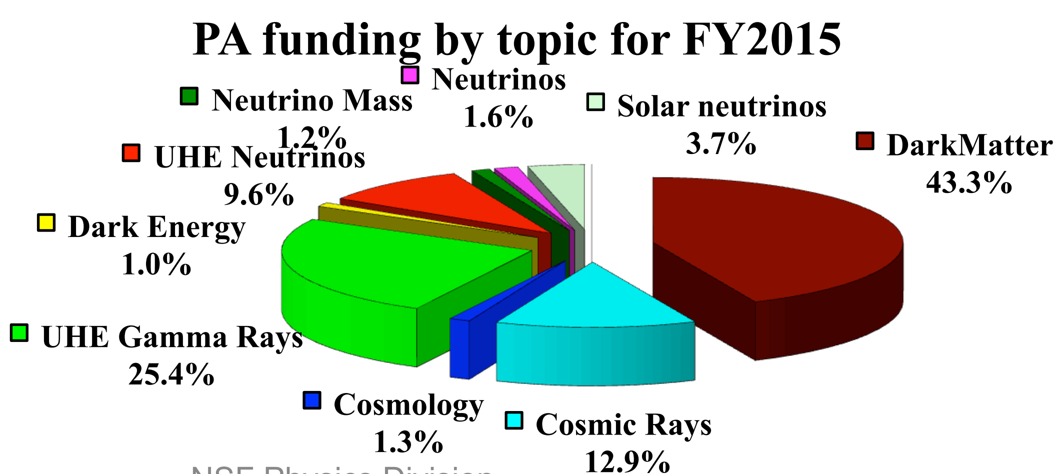
Experimental Particle Astro

Experimental Gravitational Phys

(in $M)	FY 2010 Actuals	FY 2011 Actuals	FY 2012 Actuals	FY 2013 Actuals	FY 2014 Actuals	FY 2015 Actuals
Particle Astrophysics	9.7	9.6	11.5	12	11.2	8.6
IceCube Ops	2.2	3.5	3.5	3.5	3.5	3.5
Underground R&D	4.6	6	11	3.9	0.4	0
Underground Physics	3.6	8.4	6.3	6.8	8.5	9.6
THY - Astro/Cosmo	0.8	1.4	1.1	0.9	1.5	1.3
THY - Gravitational Phys	4.7	3.9	4.4	4.8	5.2	4.7
Exp. Gravitational Phys	2.2	2.4	2.4	1.7	2.3	1.7
LIGO Research Support	8.4	8.7	8	7.3	6.8	7.8
LIGO M&O	28.5	30.3	30.4	30.5	36.4	33
Physics Frontier Centers	5.9	6	6	6	6	8
Total	70.6	80.2	84.6	77.4	81.8	78.2
Total Physics Division	307.8	280.3	277.4	247.4	261.6	275
% of Physics Division	22.94%	28.61%	30.50%	31.29%	31.27%	28.44%
Adv LIGO MREFC	46.4	23.6	21	15.2	14.9	0

PA Program FY2015





Continuing: Midscale Instrumentation

One of the most critical needs of research projects funded through the Physics Division is that of having cutting-edge instrumentation that enables investigators to remain competitive in a rapidly-changing scientific environment.

- The Physics Division has established a Midscale Instrumentation Fund.
  - Dear Colleague Letter *NSF 13-118*: "Announcement of Instrumentation Fund to Provide Midscale Instrumentation for FY2014 Awards in Physics Division"
- This is not a separate program to which investigators can apply directly. PIs should request funding for specialized equipment as part of a regular proposal to a disciplinary program in the Division. The Program Officer can then request funds be provided through the Midscale Instrumentation Fund.
- Resources from the Midscale Instrumentation Fund can be used for off-the-shelf purchases or for construction of specialized equipment.
- Midscale Instrumentation Fund resources are non-renewable and are intended to be one-time investments in the research project.

PHY Partnerships and Advisory Committees

- **NSF-DOE**
  - Particle Physics
    - HEPAP (P5) and MPSAC
    - LHC (ATLAS and CMS)
      - JOG
    - Dark Matter
  - Nuclear Physics
    - NSAC
    - NSCL-FRIB (JOG)
    - NLDBD
  - Plasma Physics: joint solicitation
- **Physics of Living Systems**
  - NIH
  - Stand Up To Cancer