NSF
Particle Astrophysics
(PA) Program

NSF Cosmic Frontier Particle Astrophysics Projects
(MPS/PHY Division Activities)

Jim Whitmore, Program Director for the PA program

Theme: Physics of the Universe: to support Particle Astrophysics projects doing world-leading, potentially transformative science – at any location (in/out of the US)

Outline:

- **Process, Advice, Agency Discussions**
- **Past funding, statistics**
  - **Dark Matter**
  - **UHE Cosmic Rays, Gamma Rays and Neutrinos**
  - **Neutrino Properties and Solar Neutrinos**
  - **Structure of the Universe (CMB Polarization and Dark Energy)**
  - **R&D**
  - **E&O, Broader Impacts for all**
- **Future Funding issues**

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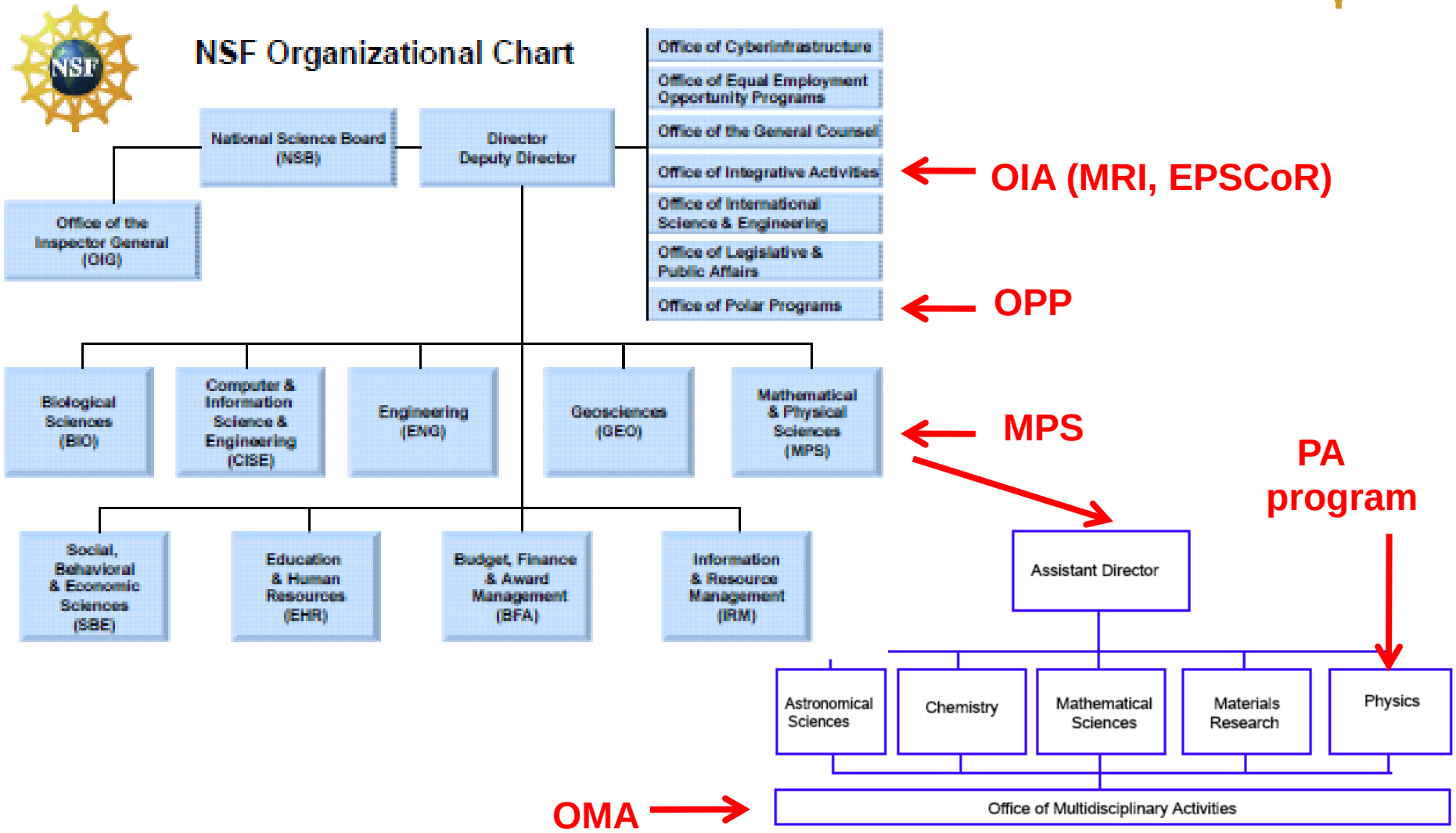
Mathematical and Physical Sciences Directorate



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PHY – PA
Process and Advice

We respond to proposals

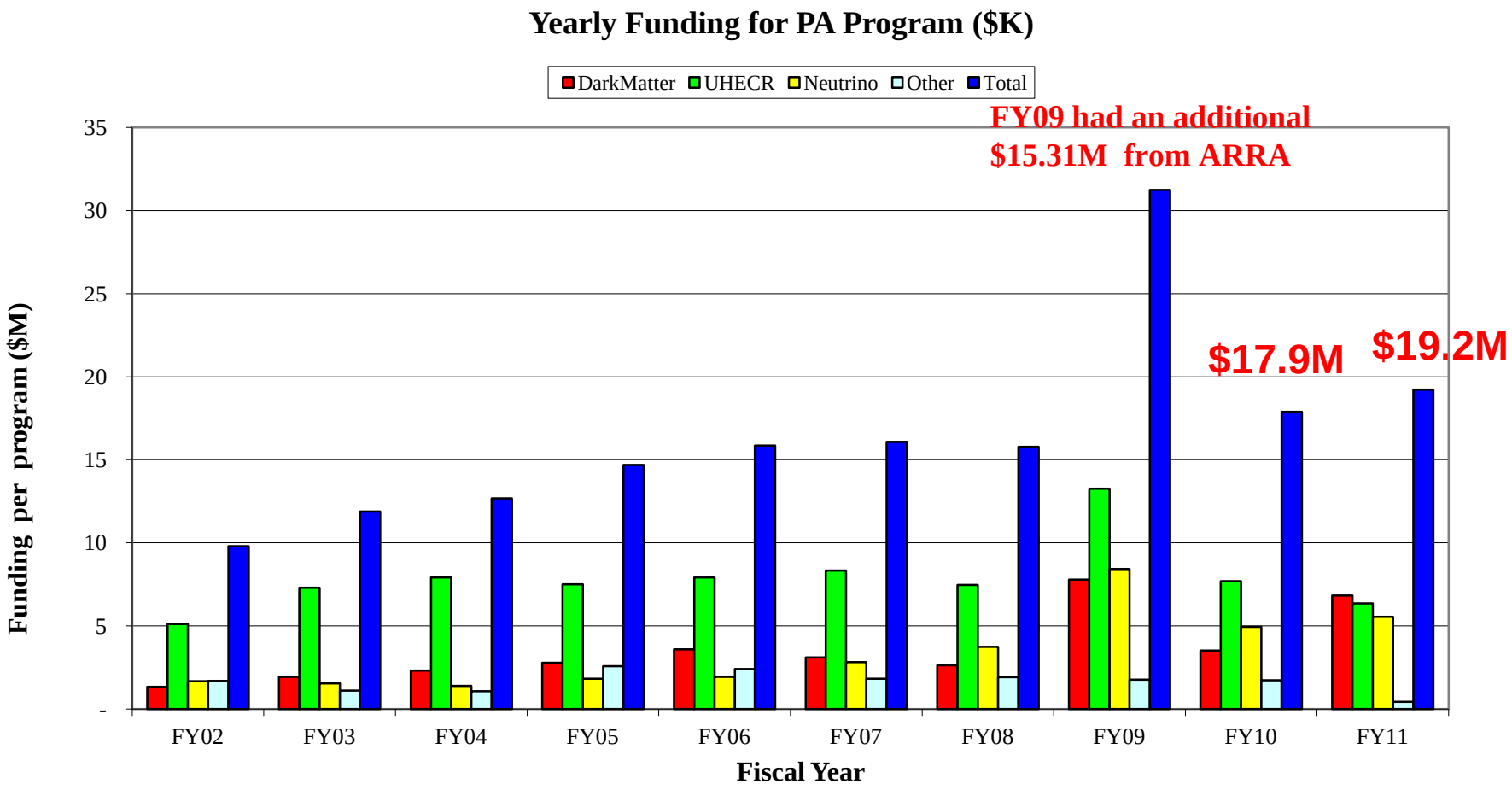
- Different programs (also apply to Particle Physics):
  - Career – July deadline
  - PA – Oct 26 target date (Now require Data Management section)
  - MRI – Jan deadline (internal University competition)
- Merit Reviews (email)
- Site Visits/Cost, Schedule, & Technical Reviews (for large requests)
- FACA Panel (gives advice, 14-15 experts, now in early February)

- HEPAP and its sub-panels (PASAG, DMSAG, NUSAG,…) give advice
- Also others (ASTRO2010, NAS,…)

Discussions with other Agencies

- We discuss programs with DOE OHEP & ONP
- We discuss projects with other International Agencies
- Respect confidentiality – get PI's permission
- International Finance Boards
- OECD-GSF-Astrophysics Working Group
- Bi-national Discussions (INFN, IN2P3)
- Attend Lab Scientific Committee meetings (PACs)

PA Funding FY02-FY11



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Construction and R&D Funding levels ($M)

FY	Undrgnd R&D	PHY	MPS OMA	MRI PHY	MRI OPP	EPSCoR	Sum		PA program
07	3.11						3.11		2.20
08	4.96	2.00	1.90	0.61			9.47		1.89
09	4.00	2.00		2.22	2.80		11.02		2.37
10	4.50	2.18		1.63			8.31		1.49
11	4.59	4.05		0.20	0.86	0.26	9.96		0.47

- **R&D: MJD, MiniLENS, DA-50, ADMX-HF, EXO Ba, LUX**
- **PHY: Double Chooz/CDMS/CUORE/HAWC/TA/ADMX-HF**
- **MPS (OMA): XENON/LUX/CDMS**
- **MRI is Major Research Instrumentation:**
  MJD electroform/ATTA(XENON)/VERITAS(Upgrade)/HAWC/ ARIANNA/RADAR-TA

Construction Funds only

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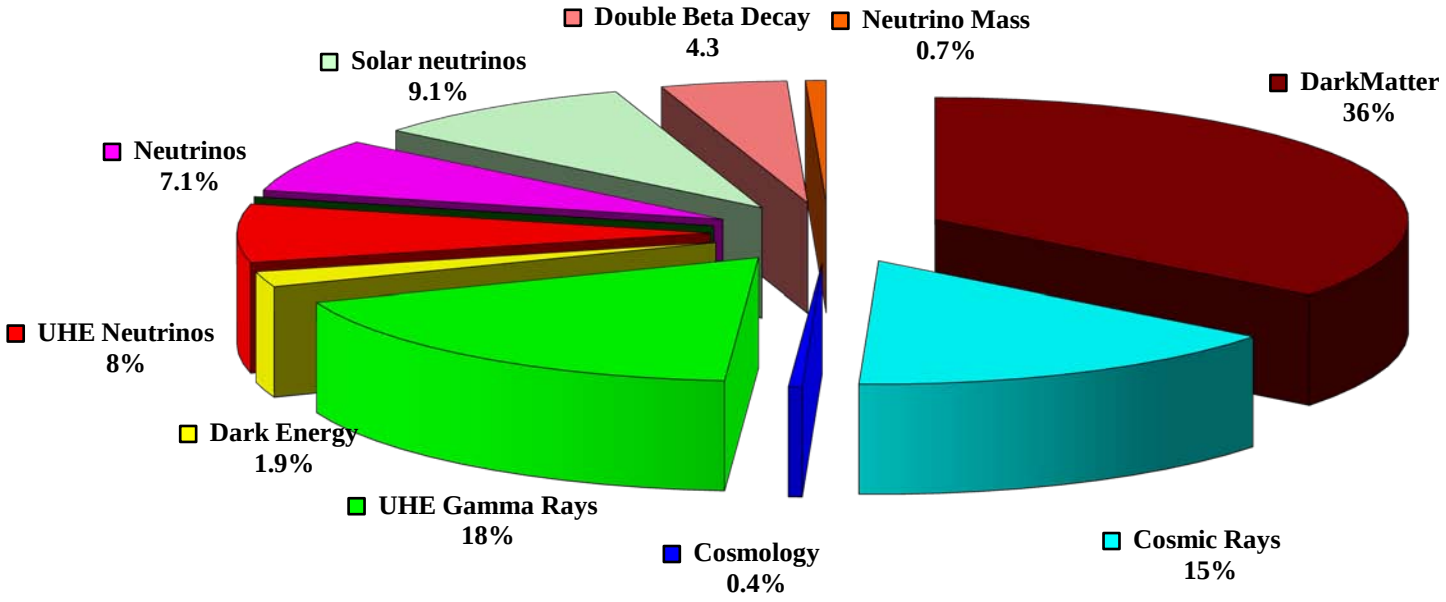
PA Funding FY11



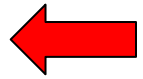
-- Search for **Dark Matter (35.5% of the funding);**
-- Study of the particles comprising the **UHE Universe** (ultra-high energy cosmic rays, gamma-rays and neutrinos) **(41%);**
-- Detection of solar neutrinos and the attempts to determine the absolute value of the mass of **Neutrinos** as well as some of their elusive properties **(21.2%);**
-- Search for understanding **Dark Energy, Cosmology (2.4%)**

Personnel supported by PNA

In FY2010:

62 different institutions (may have more than 1 group)
98 total funding actions (incl. CGIs)
140 PIs/Co-PIs
52 postdocs
118 graduate students
98 undergrads

More than 50% of the PIs work on more than one project



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PASAG Oct 23, 2009
Dark Matter

[1] A complete technical review of the G2 level should happen in the next 1-2 years.

This is expected to happen in 2012 (see Kathy's talk)

PA will coordinate/co-review with DOE-OHEP

[2] PASAG recommends a technical review of SuperCDMS in FY2010 to evaluate the performance of the new detectors currently in operation at Soudan

A DOE-NSF Review was carried out in August 2009 and subsequent mini-reviews were held in March and July 2010. Funding has been approved to complete the five towers at Soudan, including some of the new iZIP detectors.

[3] A future xenon program that avoids duplicate efforts

Efforts to combine continue, but not before the G3 level

[4] The use of depleted argon should also be explored

We funded DarkSide-50 with a start in FY10, and upgrades to DAr extraction

[5] All scenarios support the continued R&D into detectors with directional sensitivity.

We continue to support DRIFT-II and made an award in FY10 to DMTPC.

PASAG Oct 23, 2009
HE Gamma Rays

--PASAG recommends significant funding for AGIS in Scenarios B, C, and D. PASAG also strongly encourages the AGIS and CTA groups to work together

(Merger has happened)

We (DOE and NSF) are considering our next steps for the CTA project.

--PASAG recommends the construction of HAWC and the funding of the VERITAS upgrade in all four budget scenarios.

We (DOE and NSF) made a decision to fund the HAWC project, starting with FY11 funding from NSF

NSF funded the VERITAS upgrade with an MRI award in FY2010.

National Academy of Sciences Report

National Academy of Sciences: An Assessment of the Deep Underground Science and Engineering Laboratory (Board on Physics and Astronomy, **July 2011**)

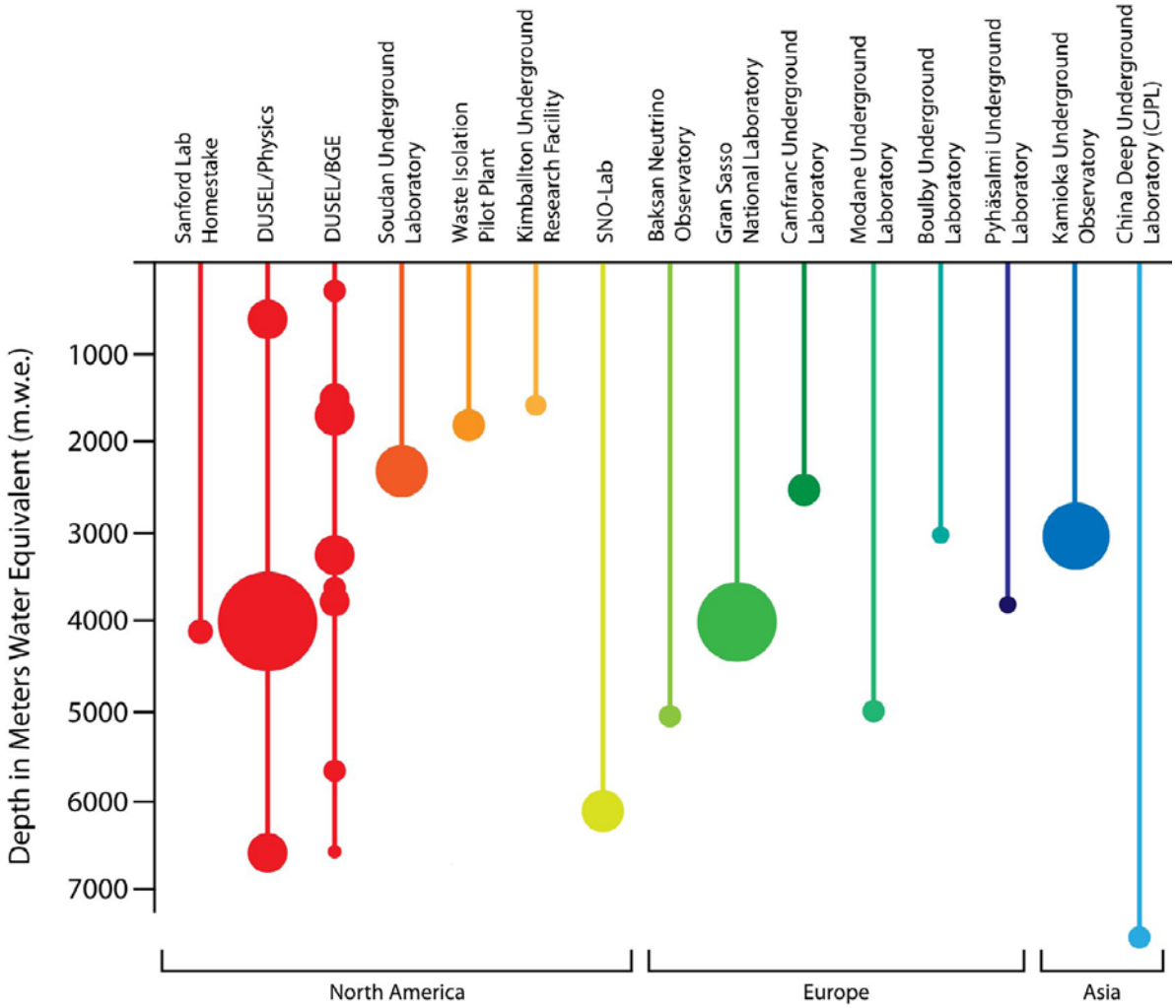
This study … identifies the most important questions and experiments that could be addressed by the proposed program of research.

From the list of proposed experiments, the study identified three as the top priorities:

- **The direct detection dark matter experiment;**
- **The long baseline neutrino oscillation experiment; and**
- **The neutrinoless double beta decay experiment**

Because these three experiments address fundamental questions at the forefront of physics research, all could produce a breakthrough discovery upon which the future of particle, nuclear, and astrophysics will be built. For this reason, and to foster future U.S. leadership in the expanding field of underground science**, the committee concluded that United States should proceed with plans to conduct the above three experiments, even if they must take place in a facility other than DUSEL**.

Location of PA projects



Of the 31 projects supported by PA, **11** are located in the US (two are planning to move out with their next upgrade) and **20** are located outside the US in Italy (underground), Canada (ug), UK (ug), Argentina, Mexico, Antarctica (ug), France (ug), China (ug), Japan (ug) and Chile.

Of the **13** underground labs shown, the PA program supports activities at **9** of them.

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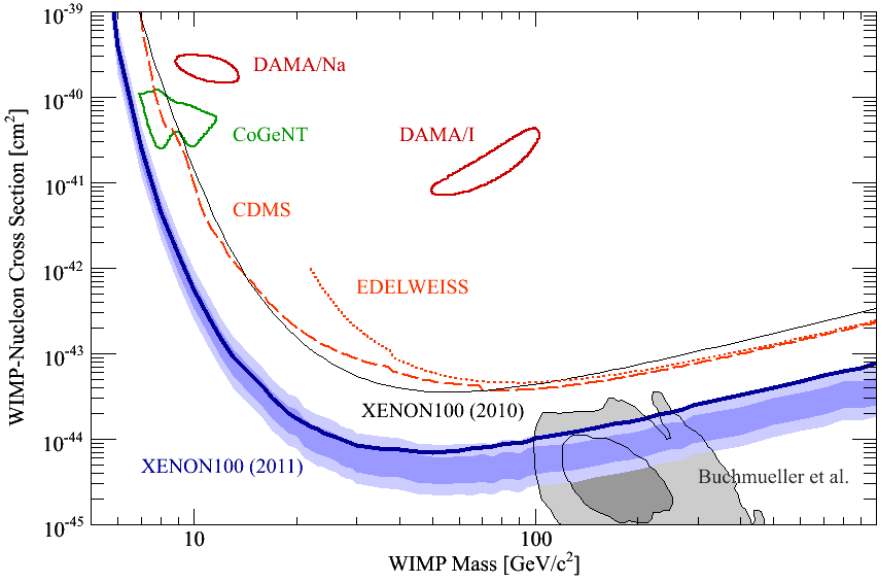
Dark Matter – 1 (35.5%)

Direct Detection WIMP searches

XENON100 and CDMS have the world's best limits as of today.

S-CDMS – at Soudan/SNOLab? Constr/Ops + 6 groups (Ge)
XENON – 100 at LNGS Constr/Ops and 3 groups (Xe)
WARP – 1 group, at LNGS (Ar)
LUX – Constr/2 groups support at SURF (Xe)
COUPP – 2 groups support – at SNOLab
PICASSO – 1 group at SNOLab
CoGeNT – 1 group base, at Soudan
DarkSide – Constr. + 6 groups at LNGS (DAr)
MiniCLEAN – 1 group, at SNOLab (Ar)

Directional projects:
DRIFT – Constr/Ops and 3 groups at Boulby
DMTPC – Constr only, at WIPP



Axion searches

ADMX-HF – Axion Dark Matter eXperiment – High Frequency – Constr. (Yale)
(1 Group) this is the first axion search funded (2011) by the PA program
(DOE-OHEP, INFN, UK, Canada, Germany, Poland)

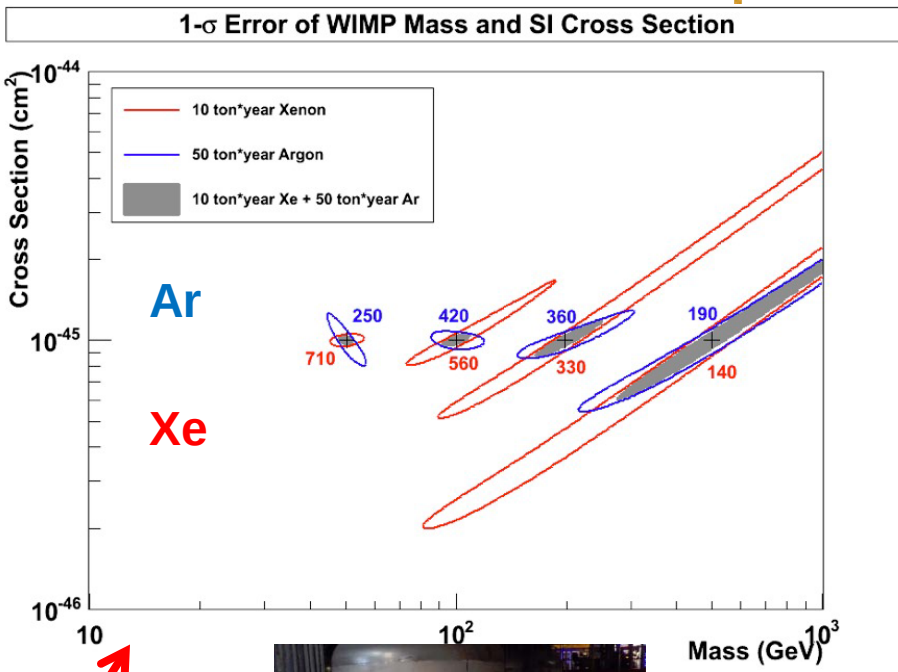
Dark Matter – 2 (35.5%)

-- XENON100 will lead to XENON1T --
approved at LNGS, significant US and non-US funding already obtained

-- PA has provided funding to collect depleted argon from underground sources that is greatly reduced in the radioactive component (^{39}Ar). This makes it an excellent choice for very low background experiments.

--It is important to have at least two different technologies, e.g. Xe and Ar: in FY2010 PA funded the DarkSide-50 project to go inside the Borexino CTF (~fully funded) 10^{-45} cm^2

Expect to start taking data at end of 2012



DA-10
LNGS

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UHE Cosmic Rays – 1 (15.1%)

S. AUGER – Constr complete/Ops and base support (10 groups)
(DOE-OHEP and 17 more countries)

Currently have 1639 working stations and only 5 not (99.7%)
All 5 fluoresence detectors are working

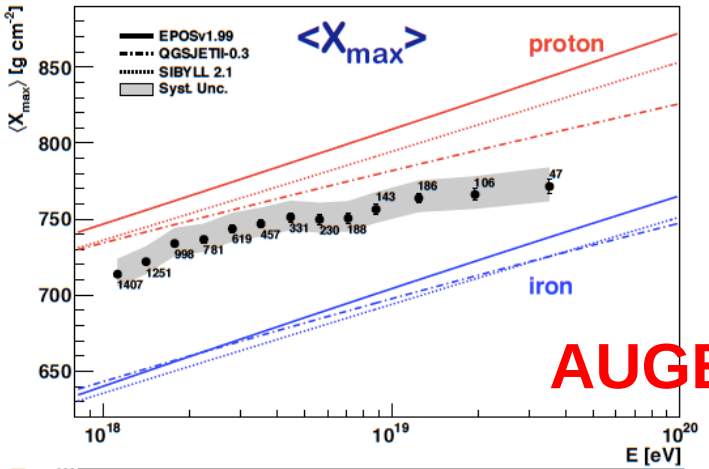
TA (Telescope Array) –
Constr/Ops/base support (1 group)

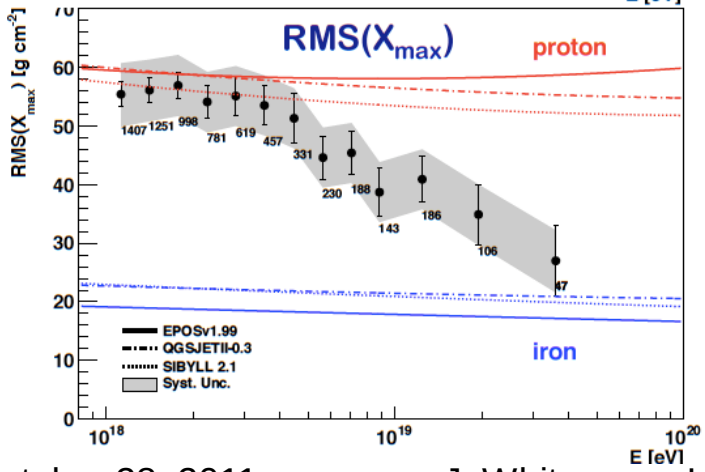
Located near Delta, south of Salt Lake City

(Japan, Korea)

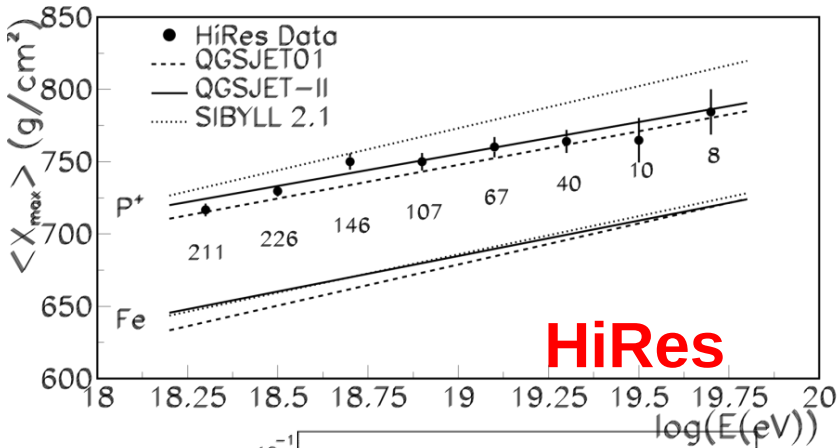
UHE Cosmic Rays – 2 (15.1%)

Cosmic Rays – AUGER and TA: need two different experiments since some of the results are different!

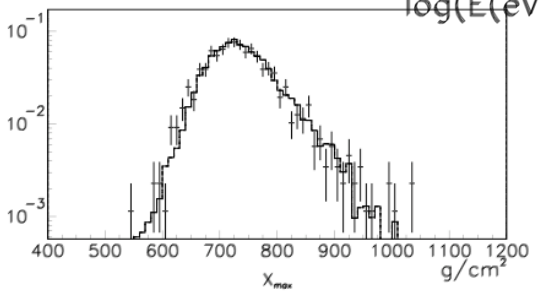




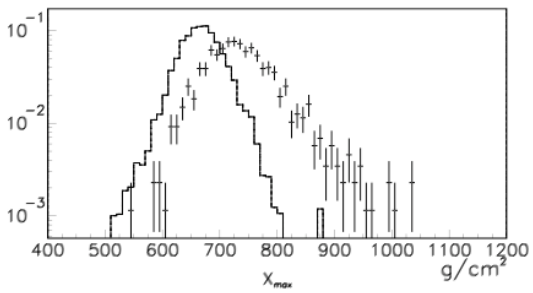
AUGER



HiRes



X_{max}



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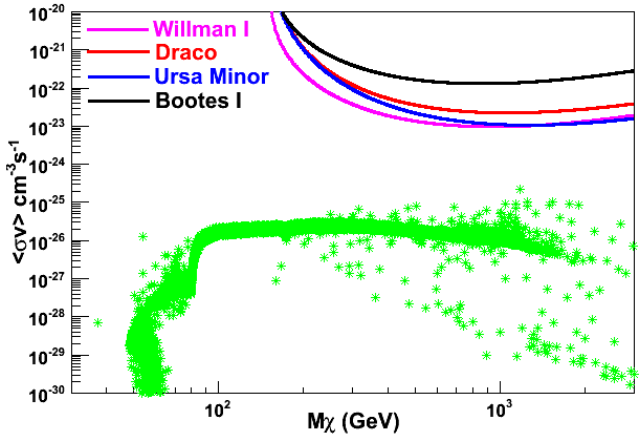
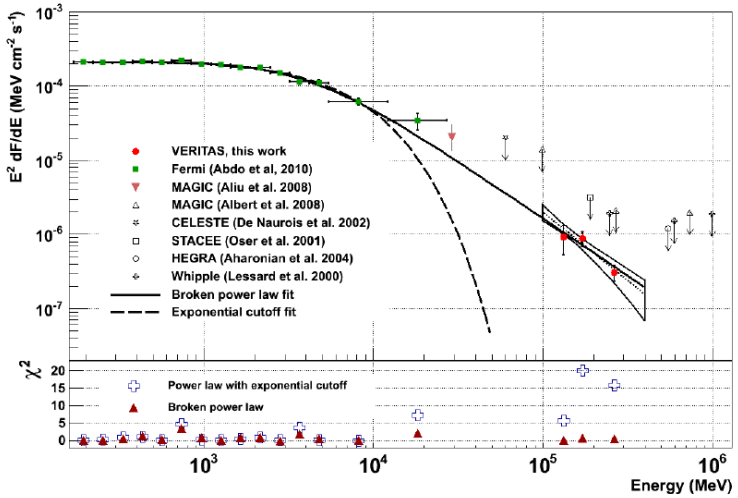
UHE Gamma Rays – 1 (18%)

VERITAS – Upgrade/Ops/support
(10 groups)
--Discoveries of TeV sources of γ-rays
--Indirect DM limits from Dwarf Spheroidal Galaxies



They have just published in *Science* (Oct 7): "Detection of Pulsed Gamma Rays above 100 GeV from the Crab Pulsar".
They are the highest energies (by an order of magnitude) ever detected from a pulsar; their **energy spectrum** indicates a completely new and unexpected component; and it is coming from a new location, more than 10 stellar radii from the neutron star.



(DOE-OHEP, Canada, Ireland, Smithsonian)

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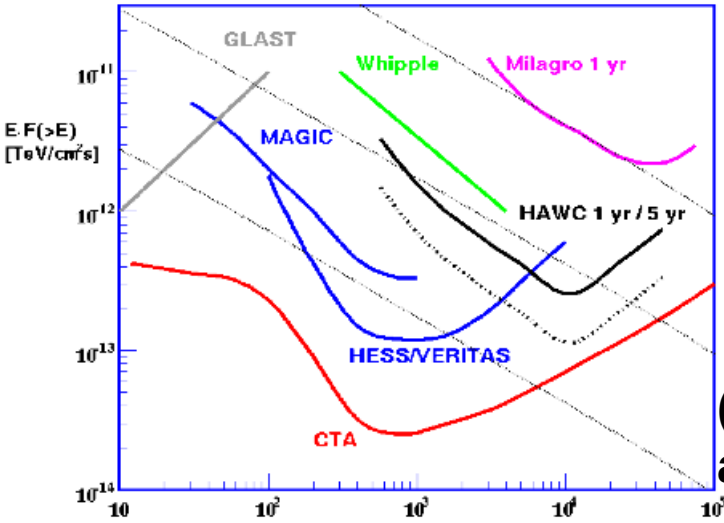
UHE Gamma Rays – 2 (18%)

HAWC PHY started construction with $3.7M in FY11 and will provide $6.7M out of about $12M total

Also base support (9 groups)

- **300 large water Cherenkov tanks**
- **Each tank is 7.3m diam, 5m deep**
- **At high altitude (4100m, Sierra Negra)**
- **7 tanks complete (MRI)**

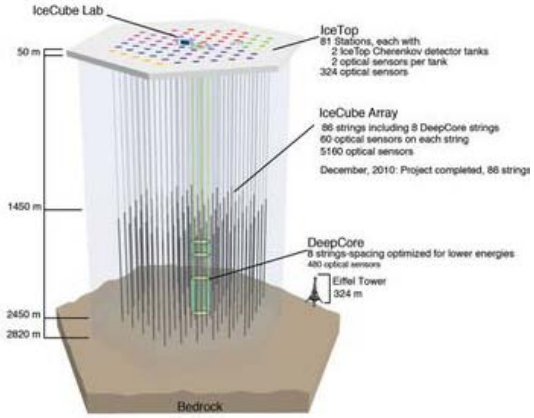


CTA

(DOE-OHEP and Mexico)

UHE Neutrinos (7.7%)

IceCube (funded 50-50 with OPP) Construction was completed at the South Pole on December 18, 2010 New Zealand time. The main IceCube detector now contains 5,160 optical sensors on 86 strings embedded two kilometers below the NSF's Amundsen-Scott South Pole Station.
Includes 6 strings of Deep Core (low energy).
(MREFC with Germany, Sweden, Belgium)



DOMs between 1,450 and 2,450 meters

Neutrino Properties – 1 (12.1%)

(Non-accelerator physics)

Reactor Neutrinos: (θ_{13})

Double Chooz – Constr/Ops/4 groups support; taking data with 1 (far) detector since April 13, 2011 (~5000 ν)

Daya Bay – 3 groups base support only. Data-taking started August with 2 near detectors

DC Outer veto (complete)
(Also FEE)

Neutrino mass measurements:

Mare-II (2 groups) cryogenic microcalorimeters measuring beta decay of ^{187}Re Sensitivity goal of 0.1-0.2 eV/c^2

INFN U. Genoa

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Neutrino Properties – 2 (12.1%)

Neutrinoless double beta decay searches:

CUORE (LNGS): 4 groups; NSF is funding the construction, testing and installation of the electronics (Milano design) Tech support for CUORE-0 (DOE-ONP)

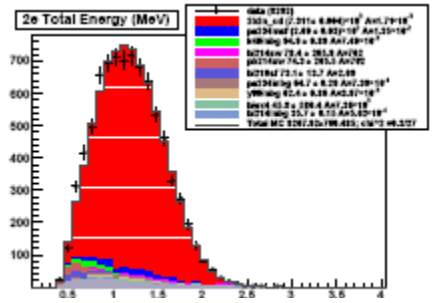
MJD at Homestake; providing funds to import ~60 kg of germanium enriched to ~86% in ^{76}Ge in the form of GeO_2, reduce it, purify it, and zone refine it to the level of ~10^{13} electrically active impurities/cm^3, normally accepted by the germanium detector manufacturers. (DOE-ONP)

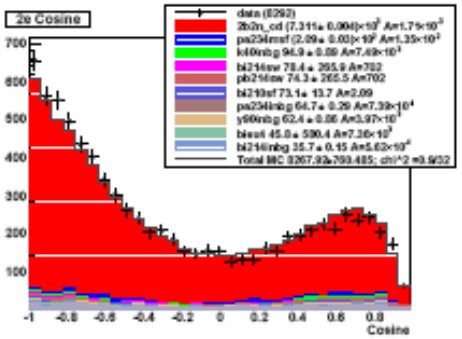
NSF is also funding R&D into P-type Point Contact (PPC) Ge detectors

EXO-200 WIPP (2ν DBD result: $T_{½}$ (^{136}Xe) = 2.11x10^{21} yrs)

Base support for 2 groups and Ba Tagging R&D

both Liquid and Gas Xe





NEMO-3 (Modane Underground Laboratory in the Fr´ejus Tunnel under the French-Italian Alps) support 1 group
combines tracking, calorimetry and ToF
For Super-NEMO: ^{82}Se 0.04-0.14 eV (>1.5x10^{26} yr)

Solar Neutrinos (9.1%)

Borexino (3 groups)

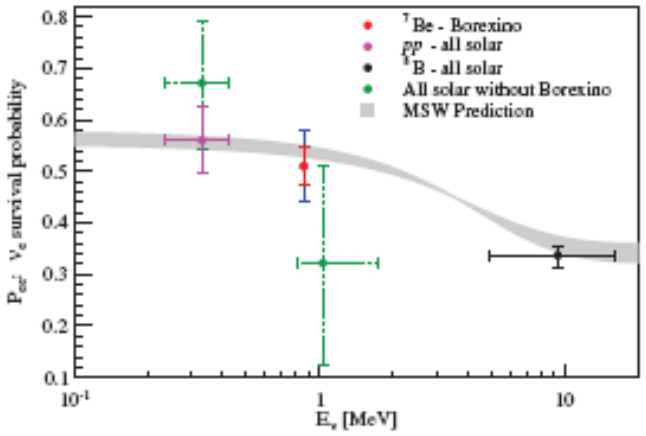
Geoneutrinos: radioactivity produces all internal heat of Earth

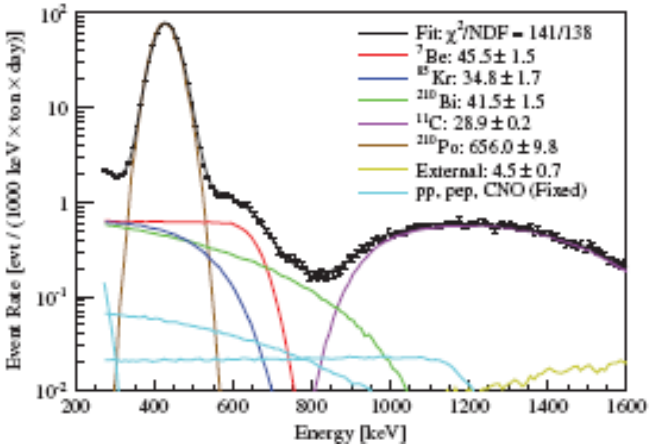
^{8}B and ^{7}Be real time spectra of solar neutrino fluxes

ν-oscillations

pep neutrinos

(co-fund with Italian groups)





Mini-LENS Neutrinos from the Sun are ideal for studying ν–flavor phenomena and astrophysics. A precision measurement of the neutrino-derived luminosity of the Sun is possible only by the detection of low-energy (<2 MeV) solar neutrinos that contain > 99.9% of the flux. The indium-based Low Energy Solar Neutrino Spectrometer, LENS will uniquely provide a nearly background-free complete spectral image of solar neutrinos using CC-based neutrino detection **(VTU)**

Structure of the Universe (2.5%)

ACT – Constr/Ops (Mostly NSF/AST)

QUIET – Constr/Ops (Mostly NSF/AST)

Results:The QUIET Collaboration has released its first measurement of the Cosmic Microwave Background polarization spectra using the data from its Q-band (43 GHz) receiver. The E-mode spectrum is consistent with the LCDM model, confirming the only previous detection of polarization at the first acoustic peak. The B-mode spectrum is consistent with zero.

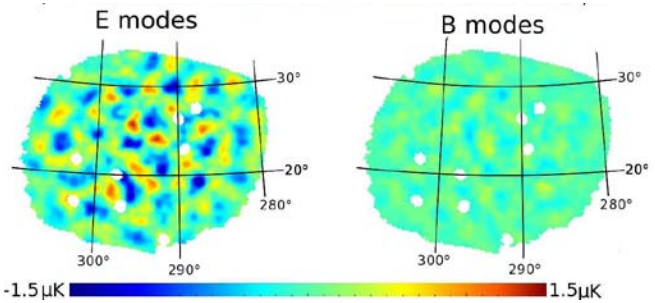


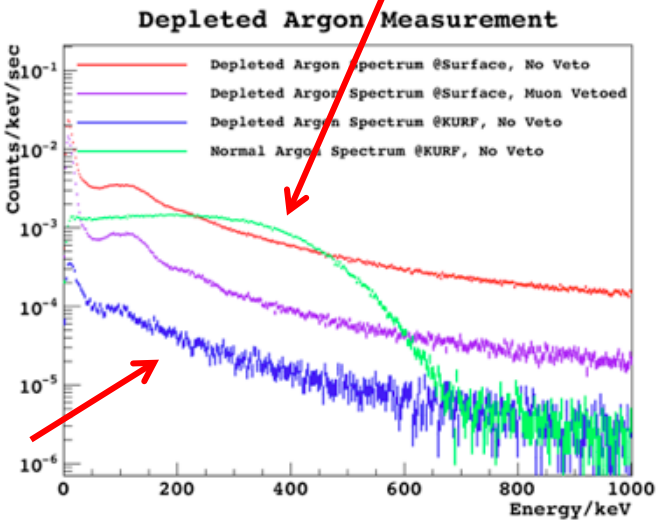
Figure 2: QUIET observing the CMB at the Chajnantor Test Facility in northern Chile.

LSST – PA: only PI support for 3 particle physics groups on LSST; aiming for possibility of MREFC start in FY 2014 or later

Underground Physics R&D

- Ba tagging (liquid and gas) for EXO
- Depleted underground Argon (Princeton):
  - Absence ^{39}Ar (<1%)
  - Depletion factor > 100
  - Peak prod. ~1 kg/day -> ~10 kg/day
  - To date have ~80 kg
- NaI in Borexino CTF for a DM search
- Ge Purification – MJD

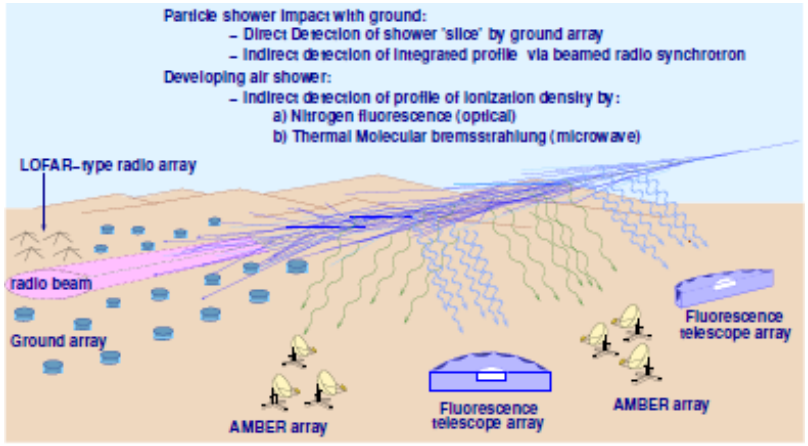
Decay shape from ^{39}Ar in normal Ar



Depleted Ar

HE Cosmic Rays R&D – 1

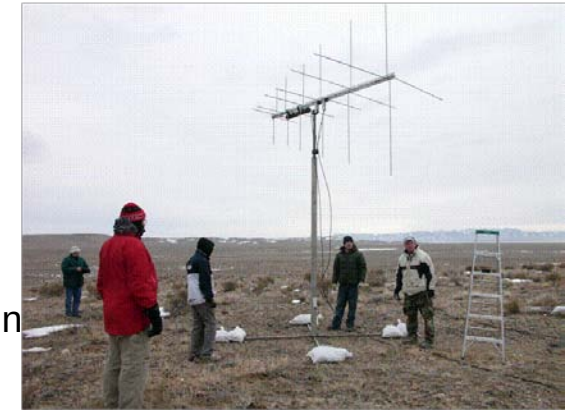
AMBER (Airshower Microwave Bremsstrahlung Experimental Radiometer) The indirect observation of secondary emission from the residual tenuous gas of excited particles and plasma left when the shower of particles transits the atmosphere is currently applied only to optical fluorescence of molecular nitrogen. AUGER is studying the feasibility of observing UHE cosmic rays via microwave molecular bremsstrahlung radiation (DOE-OHEP)



Bistatic radio detection in TA

The collaboration has successfully commissioned a 2 kW bistatic radar transmitter station, in Delta, Utah. The receiver station is under construction, and they have begun characterizing the transmitter output. (Ionization plasma reflects radio waves – amplitude largest in forward direction)

With an FY11 MRI they can now operate a donated 20 kW analog transmitter



HE Cosmic Neutrinos R&D – 2

Askaryan Effect: When ultra-high energy neutrinos interact in a dense medium, such as ice, the enormous cascade of secondary particles emit an intense sub-nanosecond pulse of coherent Cherenkov radiation at *radio wavelengths.*

ARIANNA (Radio reflection in Antarctic – **UHE νs**) **(with OPP)** the first prototype for the proposed Antarctic Ross Ice Shelf Antenna Neutrino Array (near McMurdo) of neutrino detectors was successfully installed. The interface between ice and liquid water below acts as an excellent surface for reflecting radio waves.

ARA (Askaryan Radio Array) R&D (MRI with OPP) To detect the RF emission from neutrino induced showers in RF transparent media. The receivers installed in IceCube boreholes were designed to be sensitive in the range of 100 MHz - 1 GHz. 14 receivers 40 m under ice and two additional ones on surface at S. Pole.

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FY2012 Funding for NSF R&RA

Current status: **Research and Related Activities**

(The FY 2010 appropriation was **$5,615.3 M**)

The FY 2011 appropriation was **$5,563.9 M**

The FY 2012 Administration request was **$6,253.5 M**

The House Appropriations Committee recommends **$5,607.0 M**, an increase of $43.1 million or 0.8%

The Senate Appropriations Committee recommends **$5,443.0 M**, a decline of $120.9 million or 2.2%.

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MPS FY2012 Budget Request

FY 2012 NSF request was **$7,767M ;13%** above the FY2010 Enacted amount

MPS Funding

(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 ARRA Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
Division of Astronomical Sciences (AST)	**$246.53**	**-**	**$245.69**	**$249.12**	**$3.43**	**1.4%**
Division of Chemistry (CHE)	233.68	15.70	233.73	258.07	24.34	10.4%
Division of Materials Research (DMR)	302.57	-	302.67	320.79	18.12	6.0%
Division of Mathematical Sciences (DMS)	244.92	-	241.38	260.43	19.05	7.9%
Division of Physics (PHY)	**301.66**	**-**	**290.04**	**300.91**	**10.87**	**3.7%**
Office of Multidisciplinary Activities (OMA)	38.58	-	38.33	43.41	5.08	13.3%
Total, MPS	**$1,367.95**	**$15.70**	**$1,351.84**	**$1,432.73**	**$80.89**	**6.0%**

Totals may not add due to rounding.

PHY

PHY will focus on three major areas for FY 2012: 1) providing continued support for individual investigator awards, especially in those areas that are priorities for the division, including physics of the universe, quantum information science, and the physics-biology interface; 2) ensuring that sufficient funding is available for investigators using the major facilities sponsored by the division; and 3) ensuring sufficient funding to support operations and maintenance of these facilities as they transition to a new era of operations. (LHC, IceCube, LIGO, NSCL)

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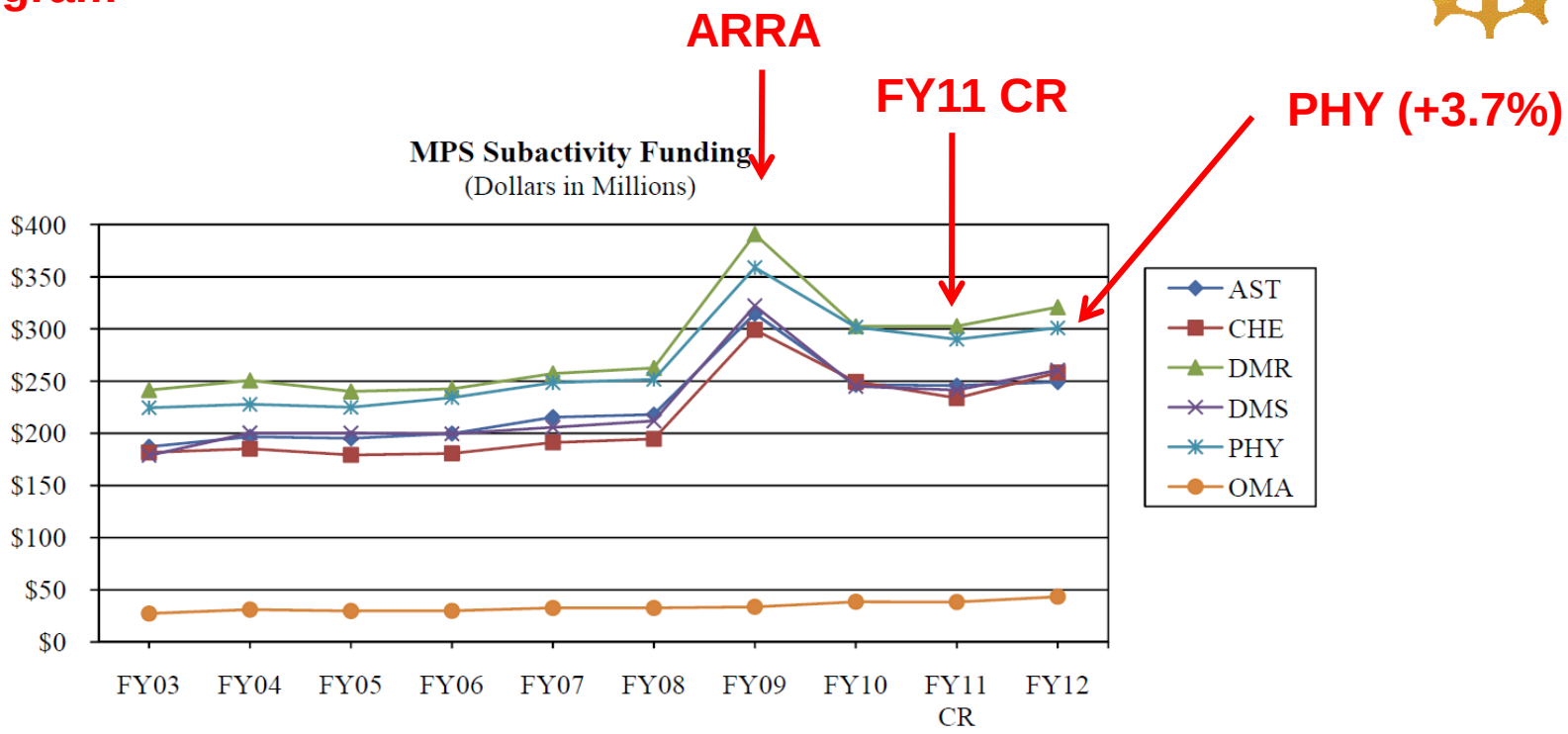
MPS FY2012 Budget Request



FY 2012 President's Budget under Terminations, Reductions and Savings

NSF will continue to solicit grant proposals for future particle physics research, including small-scale underground experiments that might be conducted at Homestake (should DOE decide to support the core infrastructure there) or at other existing sites in the United States and around the world.

Comments/ Future

- Oversight – periodic reviews of fabrication projects (usually with DOE, both OHEP and ONP)
- To start new projects, under flat funding, we obviously need to end others
- With DOE/OHEP, we are starting to review all major projects to re-evaluate:
  - their science
  - their goals
  - the length of running needed to achieve those goals

Looking ahead to FY2013: OMB Issues Budget Guidance:

An Office of Management and Budget memo instructed the heads of departments and agencies to submit FY 2013 budget requests lower than FY 2011 levels, while stressing the importance of investments critical to job creation and economic growth.

Backup slides

NSF Funding (total)

- Current status:
- The FY 2011 appropriation was **$6,859.9** million
  The FY 2012 Administration request was
  $7,767.0 million

- The House Appropriations Committee recommends **$6,859.9** million – level funding
- The Senate Appropriations Committee recommends **$6,698.1** million, a decline of $161.8 million or 2.4 percent.

NSF
Particle Astrophysics
(PA) Program

PASAG Oct 23, 2009
Dark Matter

[1] A complete technical review should be organized as soon as scalability to the G2 level is demonstrated by any of the present-day projects. This should happen in the next 1-2 years. (p.17)

[2] PASAG recommends a technical review of SuperCDMS in FY2010 to evaluate the performance of the new detectors currently in operation at Soudan. Funding for the 100-kg SuperCDMS-SNOLAB experiment should begin as soon as the detectors meet the design requirements. Tests of the iZIP detectors in SuperCDMS-Soudan are also highly desirable. (p.18)

[3] A future xenon program that avoids duplicate efforts and meets the technical requirements for low background should be supported in any of the funding scenarios. (p.19-20)

[4] The liquid argon technique may be especially promising with the use of depleted argon and should also be explored in any of the funding scenarios. (p.22)

[5] R&D should be conducted on all techniques with potential for scalability and/or background control (such as true directionality). (p.24) All scenarios support the continued R&D into detectors with directional sensitivity. (p.26)

NSF
Particle Astrophysics
(PA) Program

PASAG Oct 23, 2009
HE Gamma Rays

--Given its exciting science case covering topics of importance in astrophysics and particle physics, PASAG recommends significant funding for AGIS in Scenarios B, C, and D that would enable the construction of the prototype telescope and strong U.S. participation in a large array of atmospheric Cherenkov telescopes. PASAG also strongly encourages the AGIS and CTA groups to work together to develop a coordinated global effort to build the next major groundbased VHE gamma-ray facility.

--PASAG recommends the construction of HAWC and the funding of the VERITAS upgrade in all four budget scenarios. HAWC is a moderate-priced initiative that will carry out excellent astrophysics using a novel technique; there is also the possibility of surprising results of relevance for particle physics. The upgrade of VERITAS is a relatively low-cost way to improve the performance of an existing instrument to allow it to remain world-leading during the upcoming five to six years.

National Academy of Sciences Report

National Academy of Sciences: An Assessment of the Deep Underground Science and Engineering Laboratory (Board on Physics and Astronomy, **July 2011**)

Laboratories located deep under the surface provide a unique environment where scientists can study the behavior of the smallest subatomic components of matter, shielded from the cosmic rays and other environmental "noise" that permeate the environment on the surface. ….. The research pursued in these laboratories has the potential to make profound contributions to our understanding of nuclear and particle physics. ….. This study … identifies the most important questions and experiments that could be addressed by the proposed program of research.

From the list of proposed experiments, the study identified three as the top priorities:

- **The direct detection dark matter experiment;**
- **The long baseline neutrino oscillation experiment; and**
- **The neutrinoless double beta decay experiment**

Because these three experiments address fundamental questions at the forefront of physics research, all could produce a breakthrough discovery upon which the future of particle, nuclear, and astrophysics will be built. For this reason, and to foster future U.S. leadership in the expanding field of underground science**, the committee concluded that United States should proceed with plans to conduct the above three experiments, even if they must take place in a facility other than DUSEL**.