U.S. DEPARTMENT OF ENERGY

OFFICE OF SCIENCE

# Office of High Energy Physics Report to HEPAP on the Cosmic Frontier

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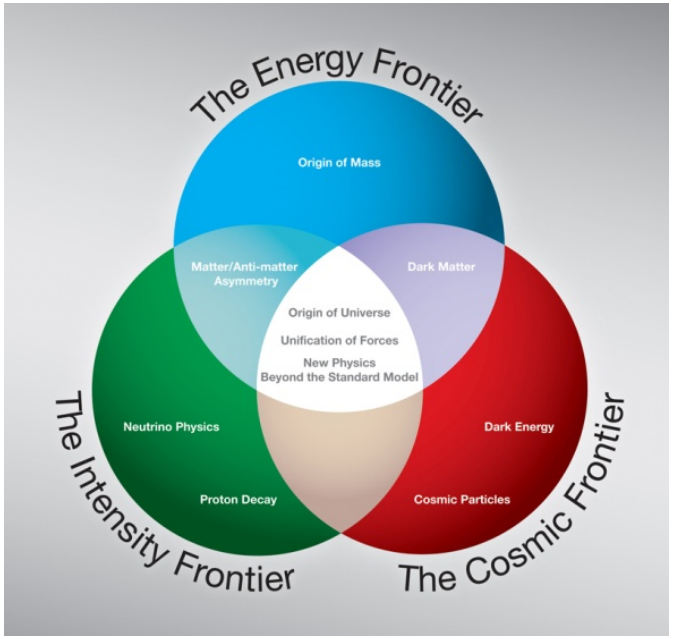
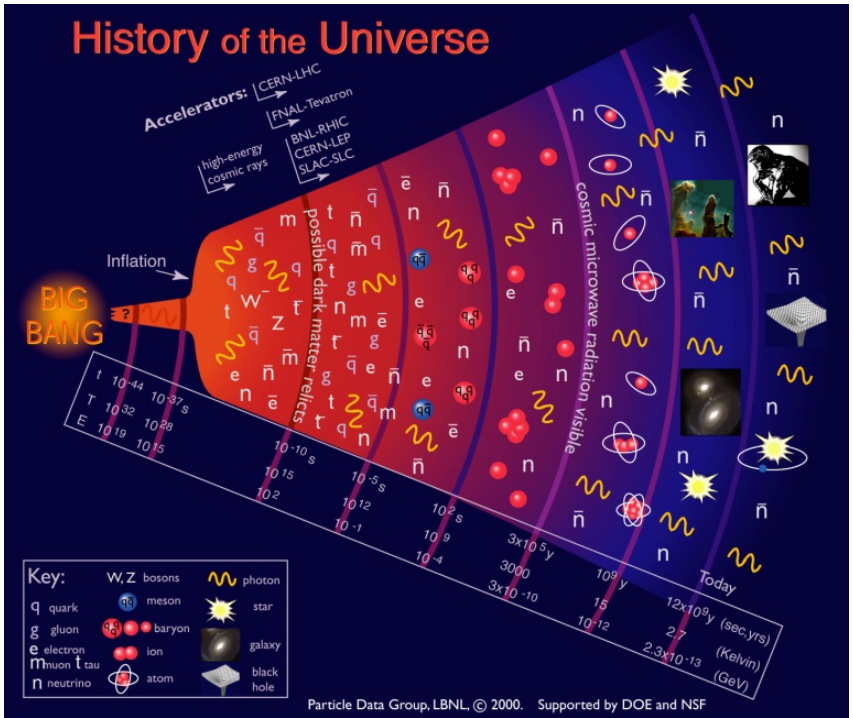
# HEP Strategic Plan (P5 report)

**The High Energy Physics program's mission is to understand how our universe works at its most fundamental level.**

**Progress in achieving the mission goals requires advancements at the**

– **Energy**, **Intensity** and **Cosmic** **Frontiers**




- Cosmic Frontier – science thrusts
  - Dark matter
  - Dark energy
  - High Energy Cosmic & Gamma rays
  - CMB and Other

# Cosmic Frontier

- Program Planning
- Program Status
- Budget
- Future

# The Cosmic Frontier - Program Guidance

Oct. 2009 - Received guidance from HEPAP (PASAG)

- Recommended an optimized program over the next 10 years in 4 funding scenarios
- Defined Prioritization Criteria for Contributions to Particle Astrophysics Projects
  - The science addressed by the project is necessary
  - Particle physicist participation is necessary
  - Scale matters, particularly for projects at the boundary between particle physics and astrophysics.
  - Programmatic issues

- Dark matter & dark energy remain the highest priorities
- Dark energy funding shouldn't compromise US leadership in dark matter
  - These should not completely zero out other activities

- Pursue at least 2 technologies for the direct detection of dark matter

- HAWC and VERITAS-upgrade recommended in any funding scenario; can only do Auger-North and AGIS/CTA in higher funding scenarios

# Cosmic Frontier: Program Guidance

August 2010 - Received guidance from Astro2010

Recommendations to DOE as part of a coordinated ground/space-based Dark Energy program

with NSF and NASA:

- The optimistic (doubling) funding profile allows investment in:
  - LSST (partner with NSF)
  - WFIRST (contribute to NASA mission)
- At lower funding level
  - LSST is recommended as the priority because DOE role is critical

- Other identified opportunities
  - 2nd priority ground based
    - » contributions to NSF mid-scale experiments
    - » e.g. BigBOSS, CMB, HAWC experiments, etc.
  - 4th priority ground-based
    - » NSF & DOE contribute as a minor partner to a European-led CTA ground-based gamma-ray

# The Cosmic Frontier - Program Planning & Coordination

Principles:

- Balanced cosmic frontier program
- Priority for Dark Matter & Dark Energy
- Staged implementation
- Cooperative multi-agency development as necessary
- Global coordination

In addition to HEPAP:

Astronomy and Astrophysics Advisory Committee (AAAC) – FACA committee that reports to NASA,NSF and DOE on areas of overlap and monitors status of Decadal Surveys

OECD Global Science Forum

- Astro-Particle Physics Working Group
  - Extended ASPERA (European roadmap) to coordinate with Americas and Asia
  - 2-year study of global coordination and planning of astro-particle physics experiments (report Dec. 2010

- A follow on, Astro-Particle International Forum (APIF) started in spring 2011 – continued coordination

# Direct-Detection Dark Matter – Current

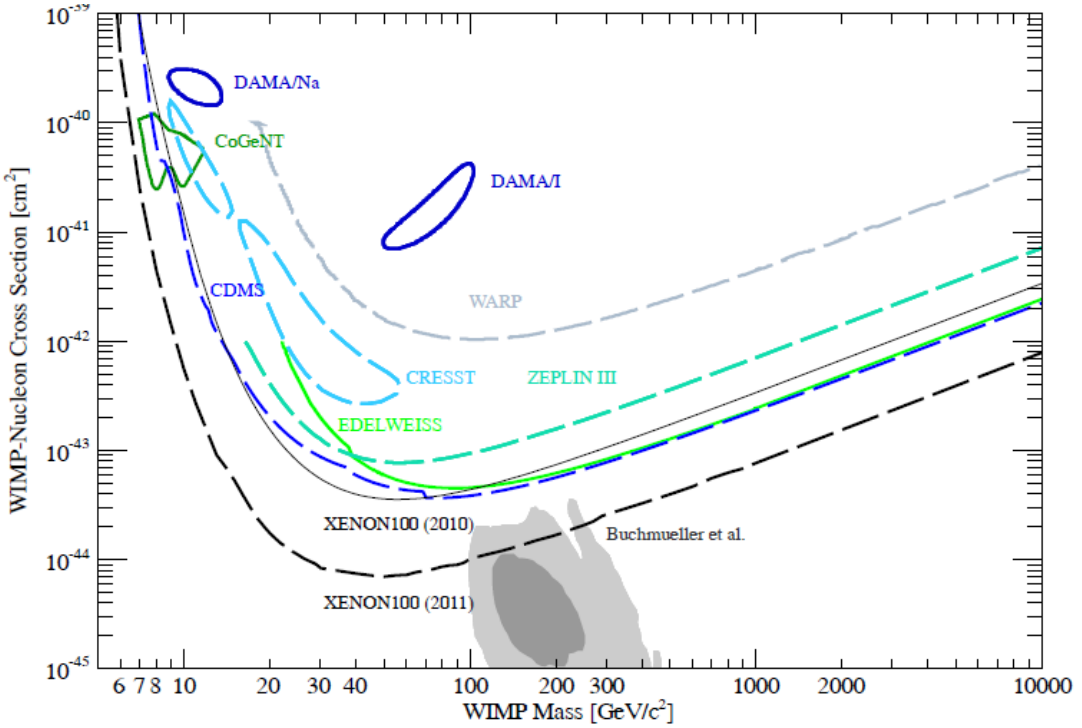
- WIMP and Axion direct-detection experiments

- Many creative approaches: Technologies include cryogenic germanium detectors, liquid xenon, liquid argon, and bubble chambers.

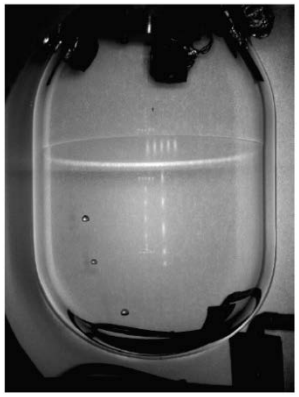
- Working in partnership/coordination with NSF-PHY on current efforts and future planning

## Current "Generation 1" (DM-G1) experiments funded by HEP:

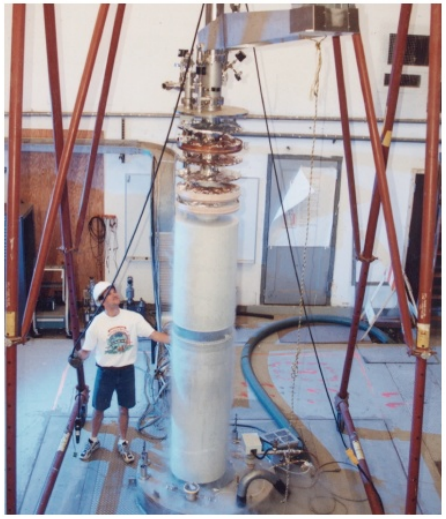
- **SuperCDMS-Soudan**: Ge detectors, at Soudan mine
- **LUX-350**: Liquid Xe, Homestake mine
- **COUPP 60**: Bubble Chamber, at NuMI tunnel and SNOLab
- **DarkSide-50**: Liquid Ar, at Gran Sasso
- **ADMX**: Axion detector, at U. Washington
- **XENON-100**: Liquid Xe, at Gran Sasso
- Other efforts (**DAMIC, DMTPC**, …)



# Direct-Detection Dark Matter – Current

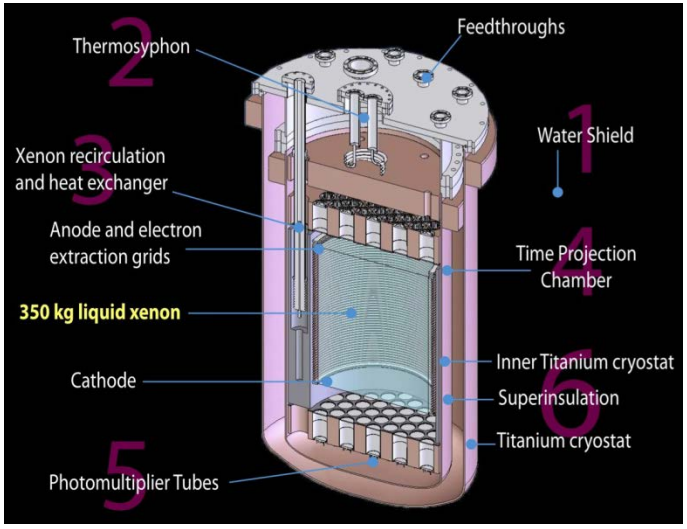


COUPP Bubble Chamber – Fermilab, SNOLab
(FY12 - commissioning, ops, move to SNOLab)



CDMS-germanium detectors at Soudan mine (FY12 – commissioning, operations)

Axion Dark Matter eXperiment (ADMX) Phase-2a at U.Washington
(FY12 – fabrication, commissioning)




LUX – Xenon detector, Sanford Lab, Homestake mine
(FY12 – commissioning, ops on surface, then move underground; FY13 ops underground)

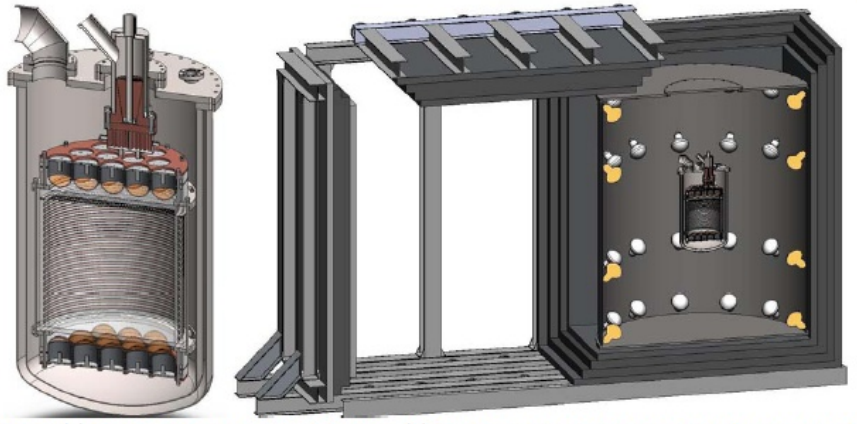


FIG. 5: **(a)** The DarkSide-50 internal detector. **(b)** The DarkSide-50 detector within the active liquid scintillator neutron veto and the passive shield.

DarkSide-50 – Dual-Phase liquid argon TPC at LNGS Gran Sasso
(FY12 – fabrication, commissioning)

# 2011 NOBEL PRIZE for Dark Energy Discovery

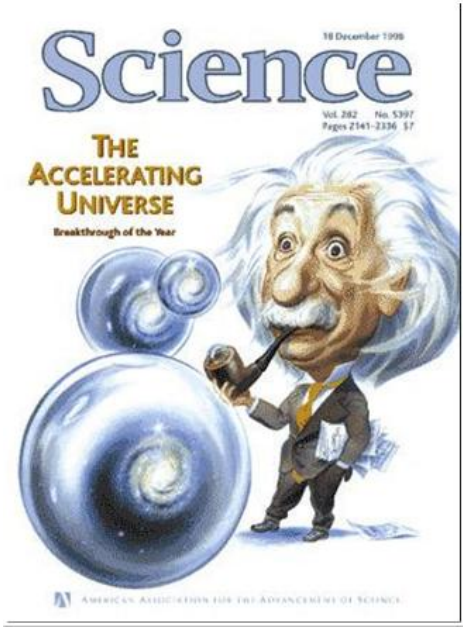
**Congratulations to:**

**Saul Perlmutter**

**Adam Riess**

**Brian Schmidt**

**…on their 2011 Nobel Prize in Physics "for the discovery of the accelerating expansion of the Universe through observations of distant supernovae."**




**In Saul's press conference at Berkeley, he noted some things that enabled this work:**

- **Lab environment with a variety of resources needed**
- **Lab infrastructure, including computing facilities**
- **Long term support**
- **Field that encourages collaboration, including international efforts**

**<u>Important for the field to convey its strengths</u>**

- **instrumentation, computing, collaborations, lab infrastructure**
- **partnerships between agencies and other offices within agencies can provide additional resources and provide opportunity for increased science (but can also be more difficult to execute)**

# Dark Energy - Current

Experiments using a variety of methods – supernovae, baryon acoustic oscillations, galaxy clustering, etc.

Working in partnership/coordination with NSF-Astronomy

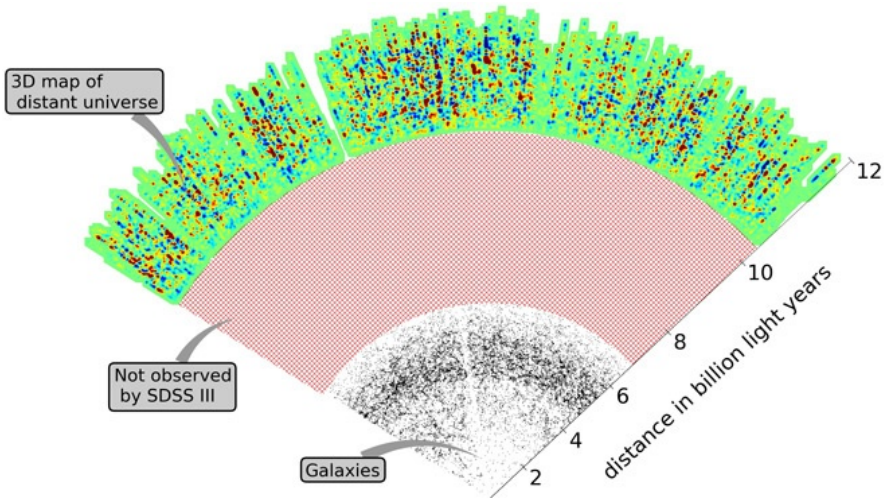
<u>Operating</u>

Baryon Oscillation Spectroscopic Survey (BOSS) – currently in operations (2 of 5 years)
-Planning to show dark energy results at AAS.

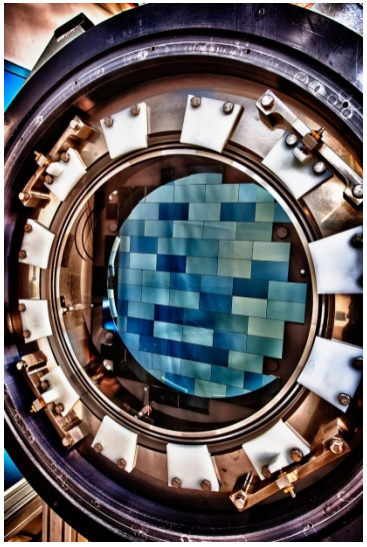
Supernova Cosmology Project, Nearby Supernova Factory + involvement in a few other supernova surveys

<u>R&D, Fabrication</u>

Dark Energy Survey (DES) - finishing fabrication in early FY12, then installing and commissioning; start taking data at the end of FY 2012.




**BOSS** - Has shown that they can use quasars to explore large scale structure at high z

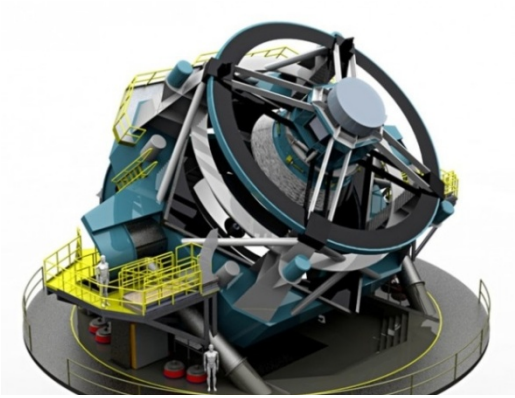


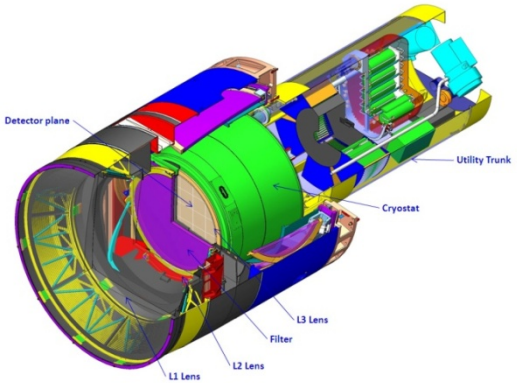
**DES** – Telescope simulator and completed imager

# Dark Energy – LSST (Large Synoptic Survey Telescope)

Following Astro2010 recommendation – top ranked ground-based project; priority for DOE

- Stage IV dark energy experiment using all 4 methods
- HEP is coordinating project planning with NSF
  - •DOE will be responsible for the camera; NSF leads the projects and is responsible for telescope facility and data management system
  - • Holding regular meetings of the Joint Oversight Group (JOG)
  - • MOU nearly complete
  - • planning our funding and schedule that assumes LSST camera starts fabrication in FY 2013 and NSF MREFC starts in FY 2014



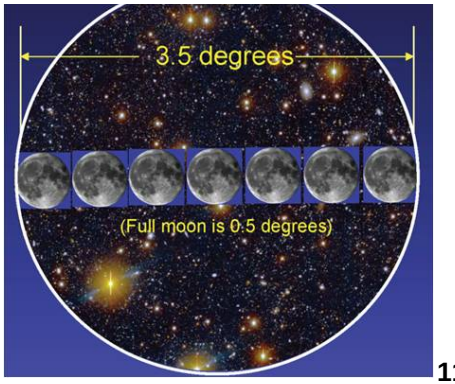



June 2011 - Mission Need Statement signed for a “Stage IV” experiment and Critical Decision 0 (CD-0) approved

Aug. 2011 – NSF Preliminary Design Review successful

Nov. 2011 - A “Lehman” review of the camera project, in preparation for requesting CD-1 approval, will be held at SLAC

FY 2012 - funding is provided for LSST R&D



# Dark Energy
# Discovery of Type Ia SN 2011fe →Palomar Transient Factory

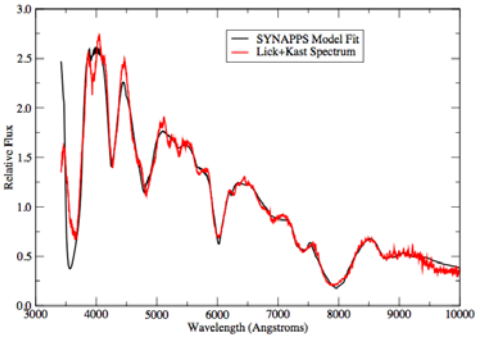
Type-Ia SN 2011fe was discovered by Peter Nugent (LBNL), leader of the type-Ia supernova group on PTF, less than 12 hours after explosion; closest supernova to earth in over 25 years.

Discovery & Follow up used multi-agency resources & world-wide collaboration:

- **DOE**: Scientific leadership and support, NERSC computing facilities, SCiDAC, contribution to PTF operations

- **NSF**: Direct support of PTF and support from the Cyber Enabled Discovery and Innovation Program - real-time classification.

- **NASA**: Swift, Chandra and HST for both pre-explosion imaging (optical and x-ray) and follow-up after discovery in the ultra-violet.




Early discovery allowed precision measurements to be made during the entire explosion → enabled strong constraints to be placed on progenitor systems.

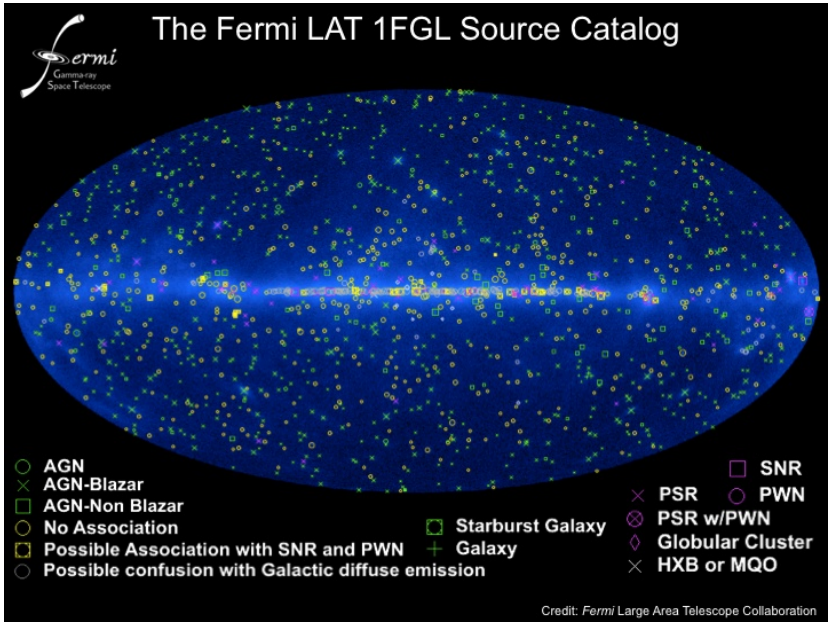
# Cosmic-ray, Gamma-ray experiments

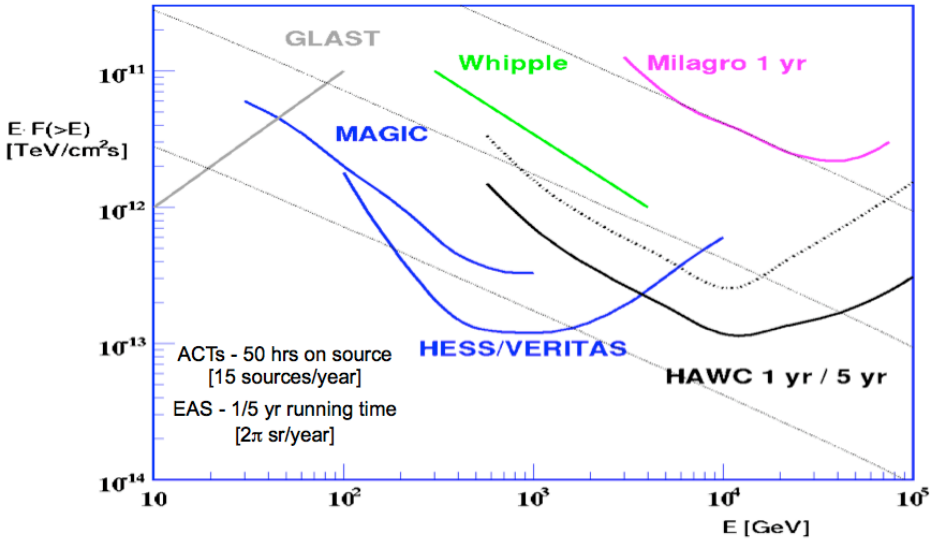
## Operating

- Pierre Auger cosmic ray observatory in Argentina – now doing R&D on radio and microwave detection
- VERITAS – high energy gamma rays in Arizona
- Fermi Gamma-ray Space Telescope
- Alpha Magnetic Spectrometer (AMS)

## R&D, Fabrication

High Altitude Water Cherenkov (HAWC) detector




2012 Panofsky prize to Bill Atwood (SLAC → UCSC) "for his leading work on the design, construction, and use of the Large Area Telescope on the Fermi Gamma-ray Satellite, enabling numerous new results in gamma-ray astrophysics and fundamental physics."

Atwood and Peter Michelson and FGST/LAT team won the 2011 Bruno Rossi Prize

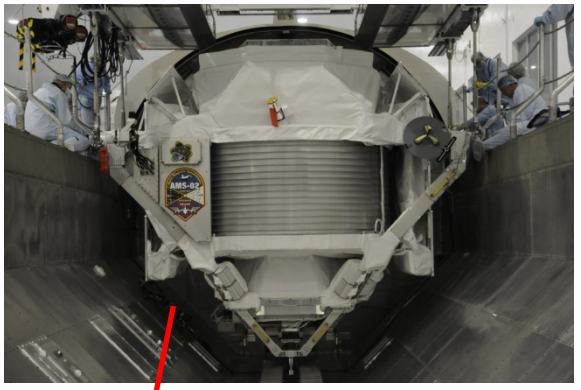
# AMS status

- Launched on May 16, 2011, (Endeavor, STS-134) and installed on Space Station

- Science goal of searches for antimatter in space, searches for dark matter, and searches for other new forms of matter like strange quark matter (strangelets)
  - Will open up new vistas in high energy particle astrophysics.

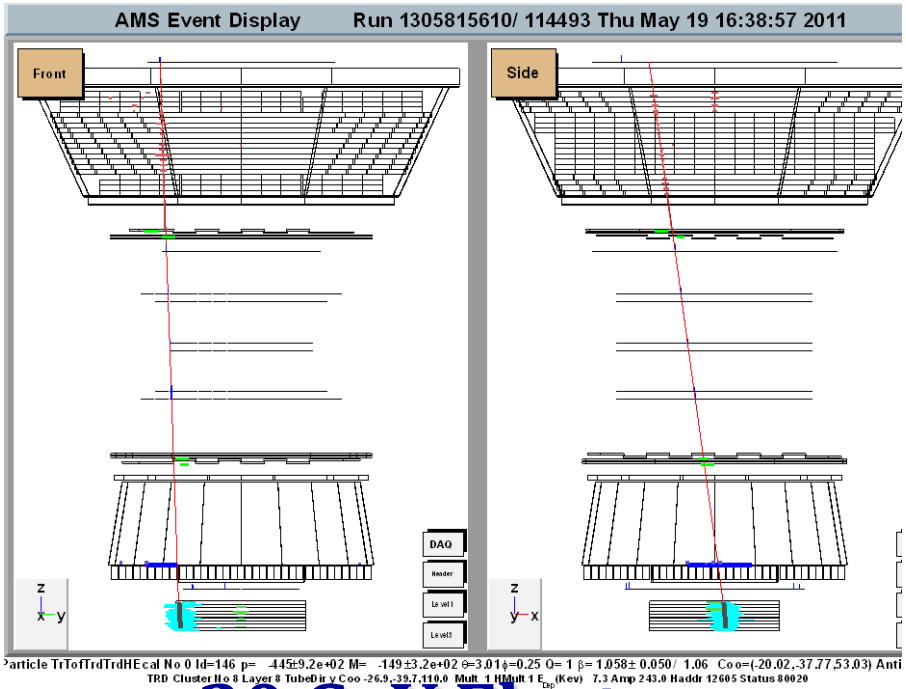
- It is a DOE HEP-led large, international collaboration, although most of the total cost for the instrumentation was provided by foreign collaborators

  - NASA is the lead in providing ISS laboratory, Shuttle mission, and associated infrastructure

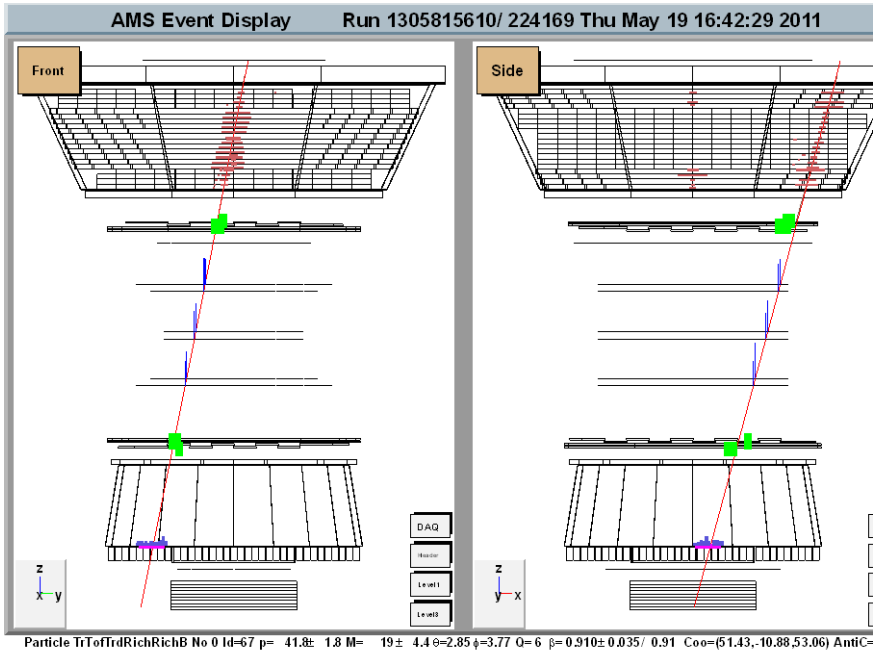


# AMS – results

**AMS is performing as expected and has collected and has collected more than 6 billion cosmic ray events since installation.**




20 GeV Electron




42 GeV carbon

# VERITAS, HAWC

VERITAS in Science Magazine: unexpected detection of pulsed (periodic) gamma-ray emission from the Crab Pulsar between 150 GeV and 40 GeV.

**HAWC – follow-on to Milagro**

- PASAG recommended in any funding scenario
- 300 tank array to be built in Mexico
- HEP, NSF-PHY, Mexico partnership

**FY11 R&D**

-- the 7-tank prototype array is complete and being commissioned

**FY12**

– "baseline" review in Nov. 2011

- Fabrication can start when CR is lifted

# Cosmic Frontier – other efforts

## Cosmic Microwave Background:

- HEP has small research efforts on a few experiments

- South Pole Telescope (SPT)
  - CMB polarization measurements to study inflationary era
  - HEP funding hardware contribution (Argonne) based upon 2010 Non-Accelerator Laboratory review
  - Several ANL Divisions worked together to design next-generation transition edge sensors

- ESA/NASA Planck mission – HEP has MOU with NASA to provide computing resources at NERSC in Berkeley for data processing and analysis

## Holographic Interferometry:

Aaron Chou won an Early Career award to develop the Holometer experiment at Fermilab – will provide direct experimental access to the Planck scale and probe the microscopic quantum nature of space and time.

# Cosmic Frontier Budget

The Cosmic Frontier is a subset of the Non-Accelerator Research funding line.

| Cosmic Frontier Funding (in $K) | FY10 actual | FY11 actual | FY12 Request | FY12 under CR |
|---|---|---|---|---|
| Research | 55161 | 57112 | 52419 | 54427 |
| Grants Research | 11674 | 11975 | 15385 | 12030 |
| Lab Research | 34145 | 36091 | 37034 | 34770 |
| Exp Ops & Commissioning | 9342 | 9046 | | 7627 |
| Projects | 20155 | 17652 | 14000 | 14000 |
| MIE's | 10110 | 5900 | 1500 | 7000 |
| MIE - DES | 8610 | 4000 | | |
| MIE - SuperCDMS Soudan | 1500 | | | |
| MIE - LSST | | 1900 | | 5500 |
| MIE - HAWC | | | 1500 | 1500 |
| Small + R&D | 10045 | 11752 | 12500 | 7000 |
| TOTAL | 75316 | 74764 | 66419 | 68427 |

**There is a decrease in project funding as DES and SuperCDMS-Soudan complete. LSST and HAWC become MIE's in FY12: HAWC starts fabrication (assuming successful baseline review); LSST still in R&D (doesn't have fabrication start approval in FY12)**

# Direct-Detection Dark Matter - Future

Most Collaborations are planning their next step.

Technology choices will need to be made going forward in the next phases

→ DM-G2, -G3

Now planning process for DM-G2 experiments

- ~10x greater sensitivity than G1
- Most if not all of the above G1 collaborations are planning G2 versions

DOE planning for DM-G2 process:

- Anticipate that (FOA) solicitation for R&D for G2 experiments will be announced within a few months, with proposals due 3-4 months after the announcement.
- Working towards a schedule of selecting experiment(s) in late FY 2012 that will then move to the next stage in development (R&D in FY13)
- Will be done in coordination with NSF; also will need global coordination

# Dark Energy – Future Possibilities

## BigBOSS

→ Primary method is Baryon Acoustic Oscillations (BAO): Fluctuations in the early universe imprinted on galaxy distributions.

→ Proposal is to fabricate a new 5000 fiber spectrograph covering a 3-degree field to mount on an existing telescope

→ NOAO reviewed and accepted the proposal for the Stage IV experiment on the Mayall telescope at Kitt Peak in late 2010.

→ A proposal has been submitted to DOE

– Plan a December 2011 review of the science case and R&D effort

– Depending on outcome and potential funding availability, we would then approach NSF for discussions

## Space-based Dark Energy:

– JDEM R&D has been closed out.

– Several of our scientists are participating on the WFIRST SDT. We have no current plans for participation in WFIRST.

– Several of our scientists joined the Euclid science team in August 2011 (no hardware contributions are planned). Euclid was approved to move forward for development by ESA in October 2011.

# Gamma-ray Astrophysics – Future Possibilities

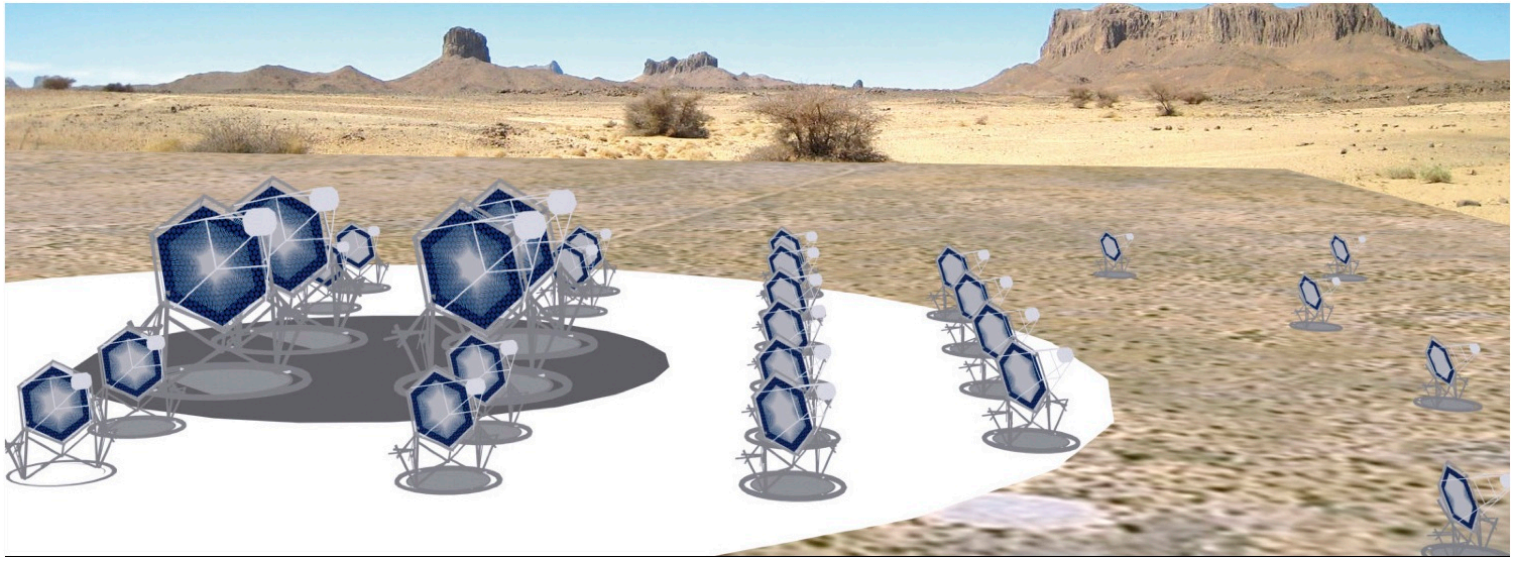
Cherenkov Telescope Array (CTA)

– Europe-led experiment

– next generation gamma-ray experiment

– US-collaboration (ANL, SLAC, Universities) submitted proposal for R&D program leading to fabrication with several options

We are coordinating with NSF – determining how to review & respond.



# Cosmic Frontier – Future planning

## Dark Matter – planning

- We have many options on the table!  This is a good thing.
- Need information on coordination and complementarity of different methods of dark matter detection so we can plan a coordinated strategy
- direct detection, indirect using gamma-ray experiments, LHC
- HEP plans a coordinated strategy for dark matter research – need to be able to describe program
- Investigating most effective and expedient strategy to get community input
  - Start with workshop?

## Dark Energy – planning

- LSST is our priority for the next experiment to be developed.
- Have near-term efforts – BOSS, DES, supernova searches
- Want to be pro-active in developing a robust dark energy program  – need input e.g., Near term and low cost options; What experiments require other agencies and at what level?
- NSF-AST undergoing Portfolio Review in FY12

# The Cosmic Frontier - Program Management

DOE-HEP Cosmic Frontier program is planning a review process to start in spring 2012 – based on recommendations from Committee of Visitors, etc.

- Will accomplish the necessary oversight of efforts and funds
- Will allow longer range planning of the program

~ March to May, we will have 2 reviews of projects

- Reviews in partnership/coordination with NSF for joint projects

<u>Review of Current Projects and R&D efforts – R&D, Fabrication</u>

For all experiments, we will continue to have monthly or quarterly reports and discussions to agencies as appropriate

- Process based on phase and size of project

Standard joint panel review - Projects below MIE limit ($2M equipment, $5M total project cost)

- Panel review of each experiment/effort's Project Execution Plan - status of technical, cost, schedule, management

Individual reviews - Projects above MIE limit but below the "Lehman" limit of $20M

- Will have individual R&D and "baseline" review before moving to Standard process (e.g. HAWC)

Lehman reviews - Projects above the $20M "Lehman" limit

- May choose to have independent review of the pre-conceptual R&D phase, science (e.g. BigBOSS) before moving to Lehman review process (if we go forward)

# The Cosmic Frontier - Program Management

Review of Operating Experiments – may do this every 2 or 3 years

For all experiments, we will continue to have monthly or quarterly reports & discussions to agencies as appropriate

Individual panel review - Projects above the "Lehman" limit:

- Prior to the operating phase, we plan an independent review of their Project Operations Plan – science plan, data collection schedule, technical aspects, cost, schedule, management
- After they move into operations, they can move into the standard operations review below

Standard Operations panel review – projects below "Lehman" limit or ones above after their initial operations plan has been reviewed and approved

Starting now, ask each experiment to provide a Project Operations Plan

For experiments within their agreed-upon operating phase:

- Panel reviews the status of science results, data collection, technical ops, cost, schedule, management

For experiments nearing the end of their operating phase:

- Panel reviews their status and proposal for continued operations in terms of science case and cost, schedule