

Cosmic Frontier Research at Fermilab

Status Update after the Astro 2010 panel report and the DOE
Non-Accelerator Physics Review

Dan Bauer, Deputy Director
for Craig Hogan, Director
Fermilab Center for Particle Astrophysics (FCPA)

Physics Advisory Committee Meeting, Nov. 2010

Current Core FCPA Experimental Program

Dark Energy

Dark Energy Survey (DES)

Sloan Digital Sky Survey (SDSS)

Dark Matter

Cryogenic Dark Matter Search (CDMS)

Chicago and Observatory for Underground Particle Physics (COUPP)

Ultra high energy cosmic rays

Pierre Auger Observatory (PAO)

Dark Energy Survey

Next big step in cosmic surveys after SDSS

DE Camera under construction at Fermilab

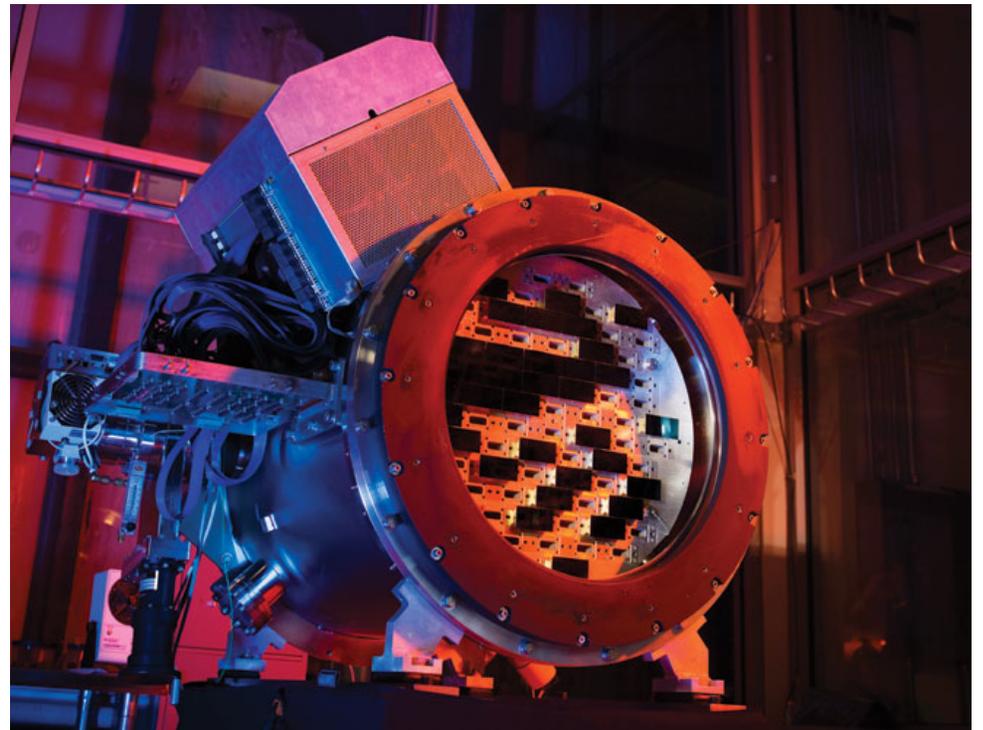
New Director: Josh Frieman, succeeds John Peoples

Survey starts in 2012, then runs 5 years



4m Blanco telescope at CTIO

DECam under construction at Fermilab



Dark Energy Camera Deployment

DECam in the past year

Passed Lehmann review (June): on track

All CCDs verified

Built telescope simulator, testing components

Now shipping parts to Chile

DECam in 2011

All parts arrive at CTIO

Assembly and commissioning start; first light in 2012

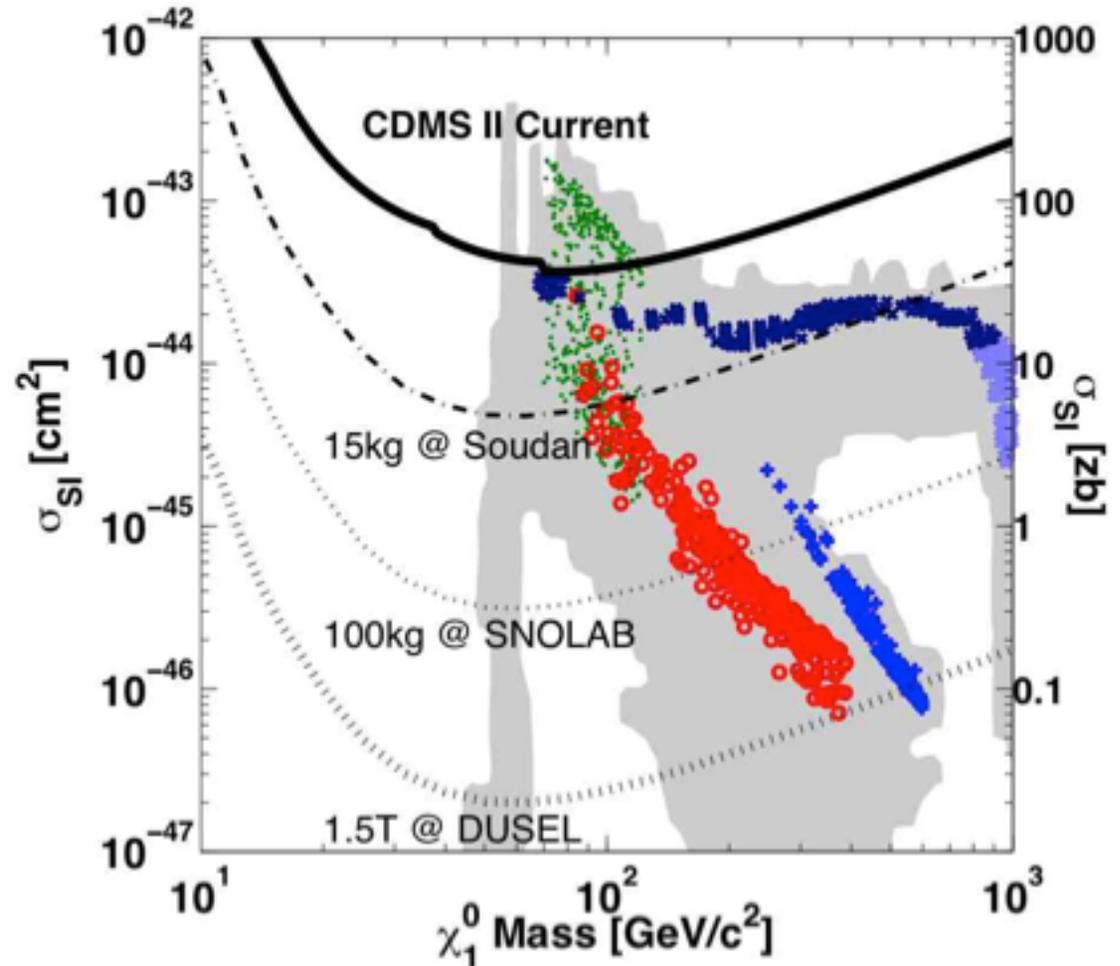
Have \$1.2M from DOE OHEP and \$0.8M internal lab funds identified for FY2011 DES operations.

Cryogenic Dark Matter Search (CDMS)

Search for rare collisions of Galactic halo dark matter particles with nuclei

State of the art in direct detection and background rejection

Near future: x4 sensitivity improvement with new detectors at Soudan



CDMS Technology Breakthrough

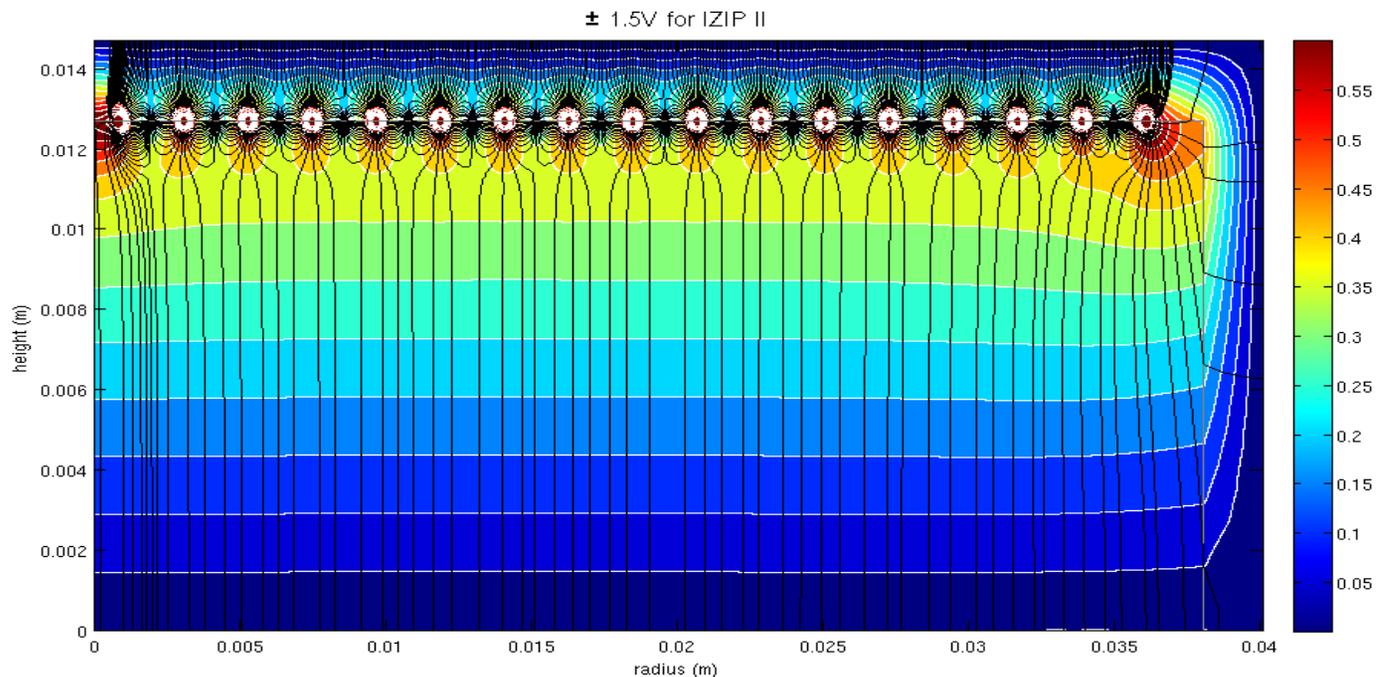
New symmetric detectors, with interleaved charge and phonon sensors (iZIP), have demonstrated a surface background rejection improvement of at least x30 compared with CDMS II

First trial run in Soudan this fall. Science run at Soudan 2011-2013

Larger iZIPs planned for SuperCDMS SNOLAB 100 kg project

Goal is another x10 improvement in sensitivity

Expect CD-0 soon, construction start in FY2012, operations in FY2014



Dark Matter with Bubble Chambers: COUPP

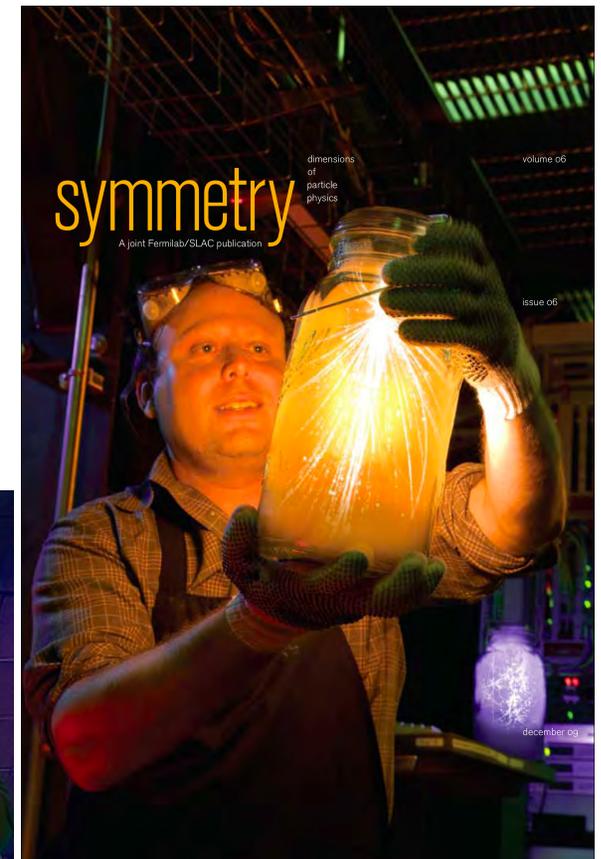
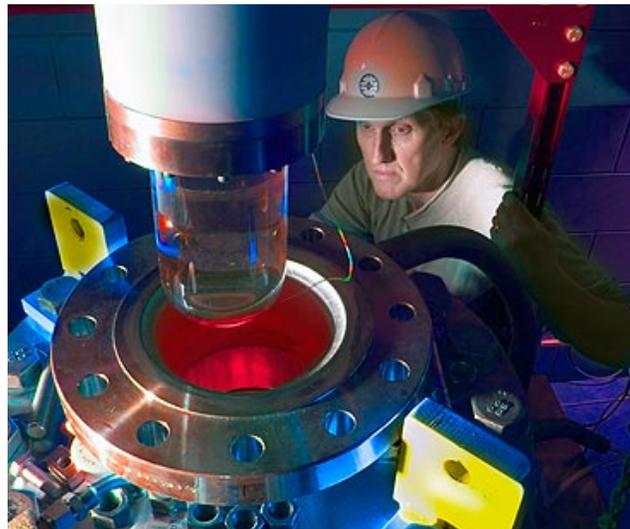
High-purity 4kg and 60kg chambers, new
acoustic rejection of alpha particles

Now: 4kg at SNOLab, 60kg at FNAL

Future: 60kg to SNOLab, then 500 kg

4kg run at SNOLAB will demonstrate power of new
acoustic sensors and actual background levels

Successful 60 kg run at SNOLAB would clear the
way for larger chambers

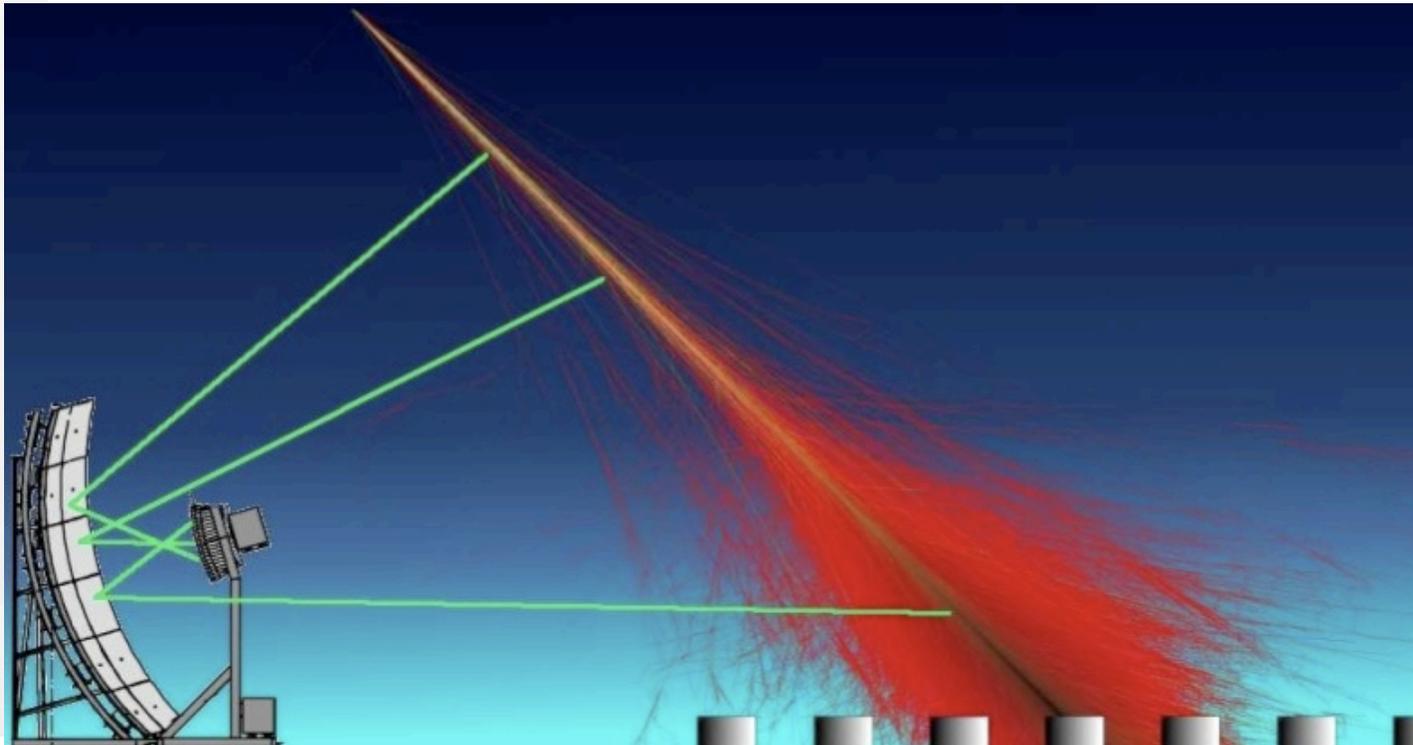


Pierre Auger Observatory

World's leading observatory for highest energy particles

US agencies plan at least 5 more years of operations, with modest upgrades to the array (but no Auger North)

Discoveries: high energy spectral cutoff from CMB interactions, anisotropy from sources, new composition puzzle



ermilab

HEPAP Particle Astrophysics Scientific Assessment Group (2009): Concise summary

“Dark matter and dark energy remain extremely high priorities.”

“Dark energy funding, which receives the largest budget portion, should not significantly compromise U.S. leadership in dark matter, where a discovery could be imminent.”

“Dark energy and dark matter funding together should not completely zero out other important activities in the particle astrophysics program.”

Astro 2010: DOE/HEP projects on top

“The top rank of LSST is a result of its capacity to address so many of the identified science goals and its advanced state of technical readiness.”

“DOE is a minor partner in the two largest projects that the survey committee has recommended—LSST and WFIRST—and it is likely that the phasing will involve choices by NSF and NASA, respectively. Other considerations being equal, **the recommended priority order is to collaborate first on LSST because DOE will have a larger fractional participation in that project, and its technical contribution is thought to be relatively more critical.**”

LSST is the top priority for DOE

WFIRST is the top priority for NASA

DOE role not yet defined; ESA collaboration also possible

Mission not yet defined

Medium-scale program also recommended, at lower priority for DOE

Brief Version of KA13 DOE review

Review of non-accelerator physics program at five national laboratories supported by OHEP

FNAL, SLAC, LBNL, BNL, ANL

Panel charged with evaluating lab programs in DOE thrusts (Dark Matter, Dark Energy, High Energy Particles, Neutrino Mass/Mixing, Other)

Specific evaluation requested on:

1. The quality and impact of the research by the group in the recent past
2. The scientific significance, merit, and feasibility of the proposed research
3. The competence and future promise of the group for carrying out the proposed research
4. The adequacy of resources for carrying out the proposed research, and cost-effectiveness of the research investment
5. The quality of the support and infrastructure provided by the laboratory
6. How well the group's activities relate to the overall HEP mission.

Future FCPA Dark Matter Program

SuperCDMS SNOLAB 100 kg -> GEODM 1500 kg

Demonstrated control of backgrounds with new iZIPs

SNOLAB removes cosmogenic neutron background

COUPP 60 -> 1000 kg

Acoustic sensors open the door towards larger chambers

Best spin-dependent sensitivity

DarkSide 50 -> 1000 kg

^{39}Ar reduction allows larger liquid argon volumes

Novel approach to active neutron veto

Fermilab is in a unique position to lead the field

Future FCPA Dark Energy Program

LSST: next major advance after DES

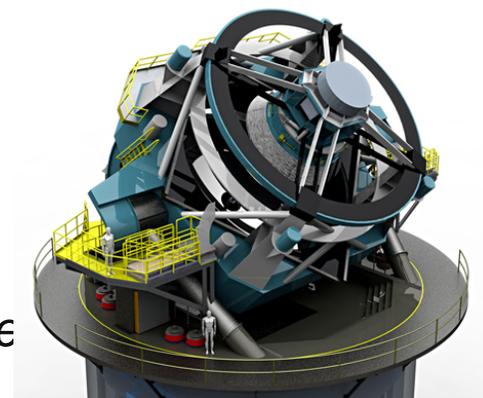
Work on defining Fermilab role

Slow start until DES is underway

Possible Fermilab roles in camera, calibration, data access, database architecture, analysis

Builds on SDSS/DES experience, large scale computing expertise

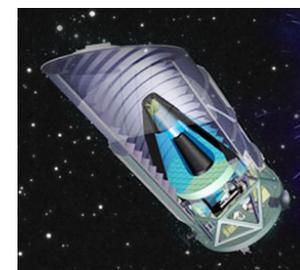
Have applied for membership in LSST Corporation



JDEM (WFIRST): wide field IR, spectra

Fermilab will continue to participate in mission definition, science analysis plans if DOE supported

JDEM Science Operations Center may merge with DES and LSST Dark Energy analysis support



Future Dark Energy: medium scale possibilities

21cm BAO “intensity map”

Map atoms (not galaxies) over very large volume

Angular and spectral resolution sufficient for BAO

Fermilab R&D on concept, technical feasibility

Awaits formation of viable collaboration and funding model

Big Boss

Collaboration with LBNL just formed

FNAL contributes to telescope interface

Dark Energy Camera Spectrograph (DESPEC)

Upgrade to DECam after DES completion: add new multi-fiber focal plane and spectrographs

Southern hemisphere followup to DES, LSST

conceptual design and costing

Laboratory probes beyond the Terascale

Non-accelerator laboratory experiments can address new fundamental physics (matter, energy, space and time), far beyond the TeV scale (the Unification Frontier)

At Fermilab, we are pursuing a program using laser cavities and interferometers

Axion searches (GammeV -> REAPR)

Holographic Interferometry (Holometer)

as well as CMB (QUIET II)

Responsive to high-level PASAG criteria:

Addresses fundamental physics

Possibility to achieve a compelling result

Discovery space, possible important surprises

DOE lab leadership and critical role

Small projects, high science per dollar

Axion-like particle searches: GammeV

Mediate interactions of light with magnetic fields

This year: chameleon search (CHASE); trapped particle afterglow, results pending

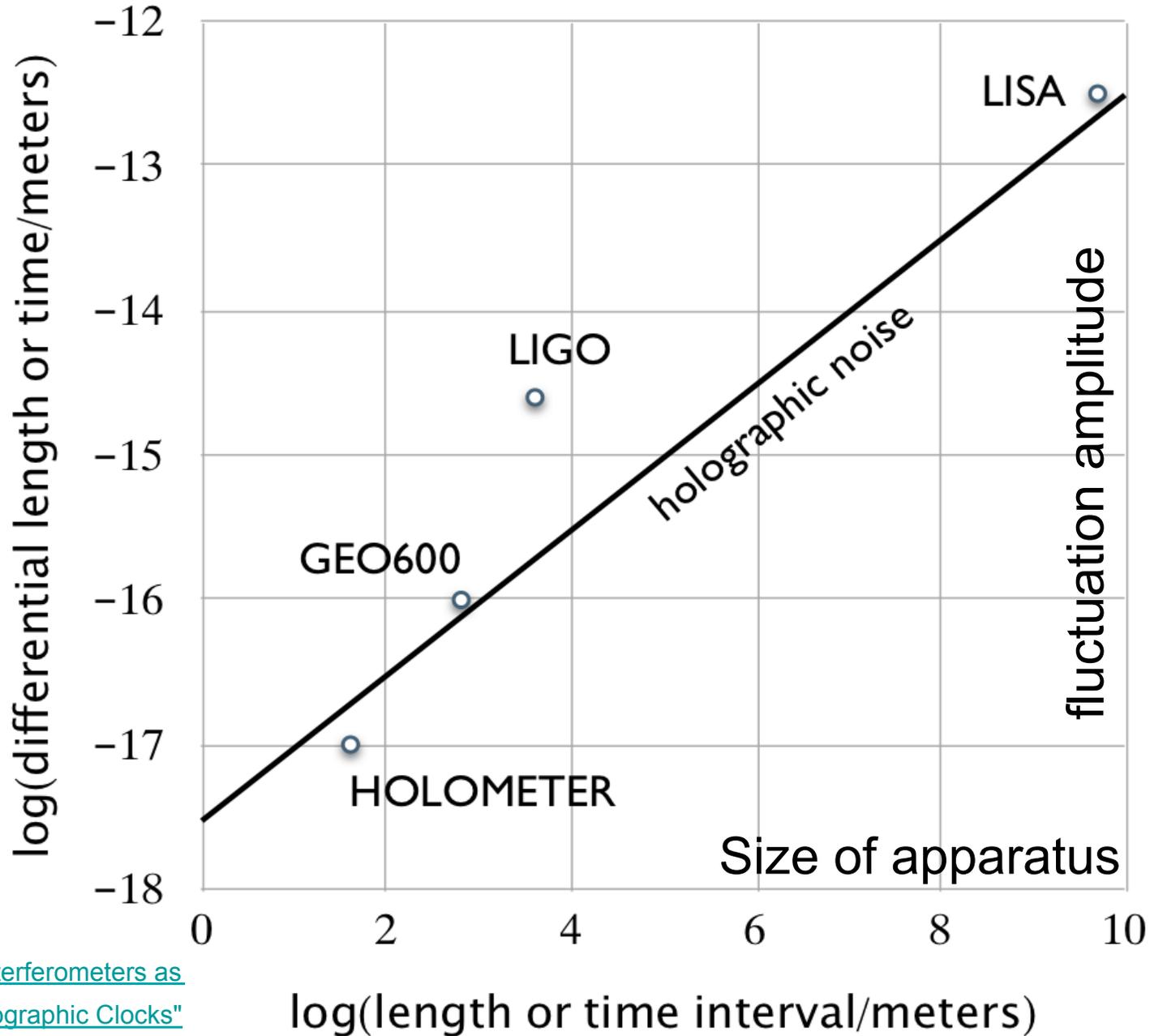
Future: resonant regeneration (REAPR), “light through a wall”, laser cavities in Tevatron magnets

Reach to $\sim 10^{11}$ GeV scale in the lab

requires development of high Q optical cavity technology



Probe of Planckian fluctuations: Fermilab Holometer



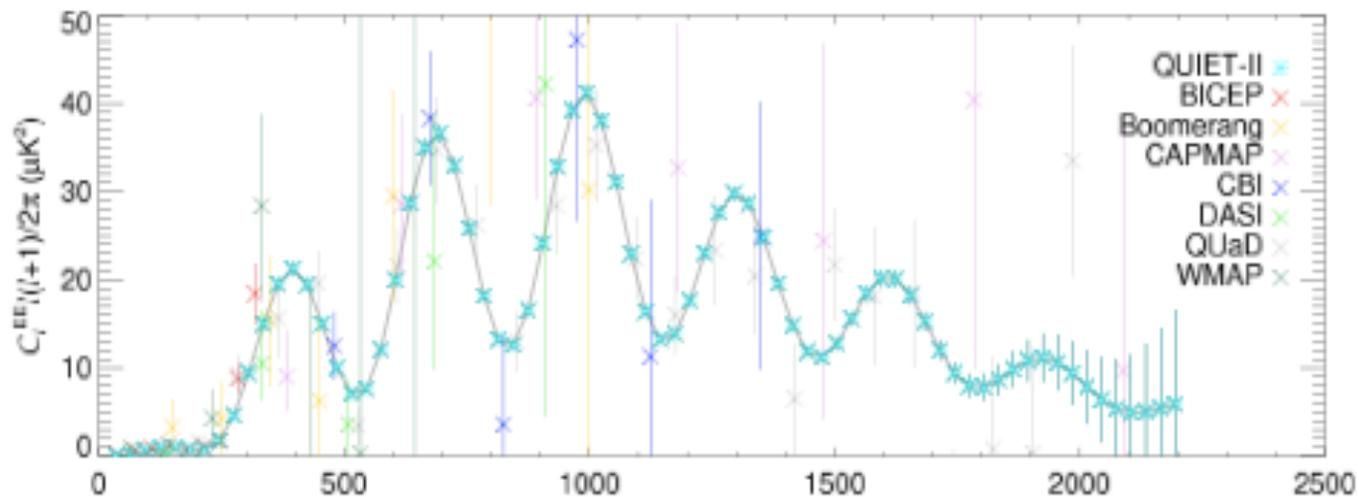
Cosmic Microwave Background : QUIET-II

Next generation CMB polarization experiment
led by B. Winstein (U Chicago)

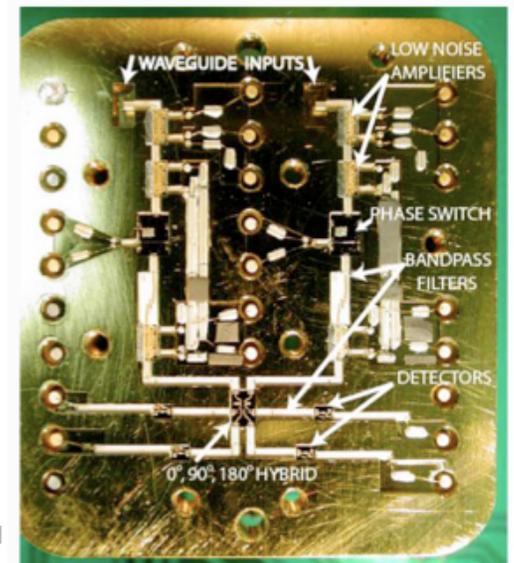
Probes cosmic inflation

Contingent on NSF funding; await concrete plan

Possible Fermilab roles: assembly of detector
modules, focal plane elements (SiDet facility),
science analysis



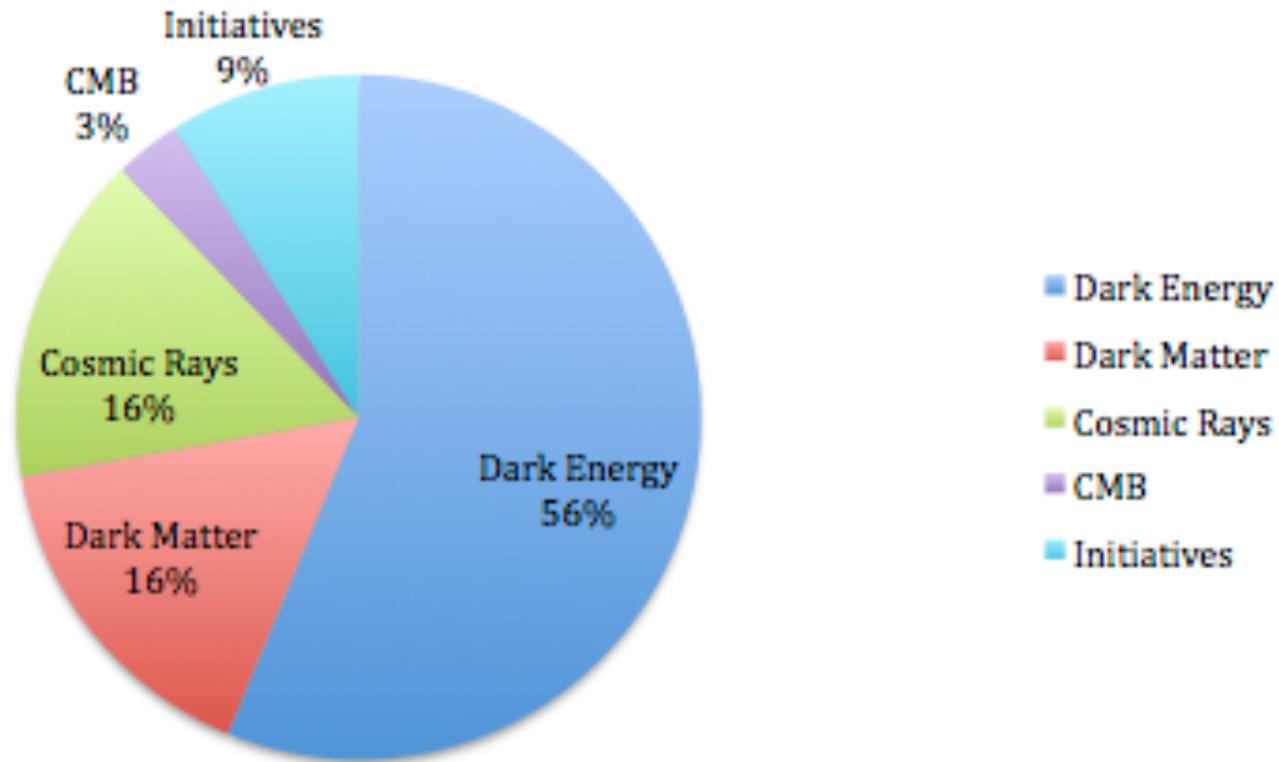
Particle Astrophysics at Fermilab-- September 2010-- Craig Hogan at



FCPA Program balance by thrust

Staff scientist FTEs indicate areas of emphasis

Project and non-scientist detector R&D costs are not included



Why does the Cosmic Frontier need Fermilab?

History as anchor institution for large projects

SDSS, DES, Auger, CDMS

Excellent technical support, lab infrastructure

Dark Energy Camera: silicon detector technology, CCD packaging, focal plane, electronics, large scale mechanical & cryogenics,.....

COUPP: on-site underground tunnel testing

CDMS: cryogenic engineering, assembly, electronics

LAr: purification and handling facilities, distillation column

Pierre Auger: large scale engineering, test beam

many projects: large-scale computing support

All projects: management within DOE project system

These functions need top quality engineers, technicians, and lab scientists

Informal Feedback from the DOE Non-Accelerator Review

- Dark Matter program got high marks
 - Recommend SuperCDMS program continue through 100 kg at SNOLAB
 - COUPP is unique and worth pursuing, but needs to concentrate on developing the technology
 - Take advantage of liquid argon technology base at FNAL to pursue DarkSide
 - Consider ways to help the community achieve greater coherence
 - Possible Soudan low-background and detector development facility

Informal Feedback from the DOE Non-Accelerator Review

- Dark Energy program also very good
 - DES will be the premier survey for the next 5 years and FNAL has shown good leadership
 - Collaborate with other labs and universities on developing the next dark energy mission
 - Join LSST and work with LBNL on planning BAO survey (BigBoss or DESpec, not both)
 - 21 cm radio telescope effort should be reduced

Informal Feedback from the DOE Non-Accelerator Review

- Pierre Auger South leadership recognized
 - More work needed to pin down correlations with matter and puzzling composition results
 - Need to reduce operations costs and develop plan for reviewing any array enhancements
 - Review in 3-5 years to determine when DOE operations support should end
 - Auger North is off the table for the foreseeable future

Informal Feedback from the DOE Non-Accelerator Review

- Most of our initiatives were interesting to the panel
 - Holometer and Axion initiatives unique and generally thought worth pursuing at a low level
 - Continue low-level detector R&D efforts like solid Xenon
 - QUIET effort was not considered to be very compelling and should not be pursued unless NSF funds the project

Our Reaction to the Panel Comments

- Consider the core program to have passed muster and priorities are correct
- Have already been reducing effort in the weakest areas (Auger enhancements, QUIET, 21 cm) and this process will continue
- Need to encourage DOE to fully-fund key Dark Matter and Dark Energy experiments

Planning for the Future

Experiments on the Cosmic Frontier symposium

Fermilab, March 23 to 26, 2011

Community planning effort, post-Astro 2010

Organized with other HEP labs and particle
astrophysics university community

Dialog and Debate to help shape future program in
Particle Astrophysics

**DOE OHEP has contributed funding for this
symposium**

Response to the June PAC report

It is important for Fermilab to articulate a clear vision for the FCPA program at the review. As this is a national program, there is also great value in the national laboratories presenting a unified effort, and the FCPA Director should be proactive to ensure this coordination happens well in advance of the review.

We worked hard to coordinate with the other labs in advance, and were largely successful with SLAC, ANL and BNL, not as much with LBNL (they were understandably distracted by the Astro 2010 report).

Response to the June PAC report

The Committee is concerned that the planning and budget for the commissioning and operations phases of the DES are not yet defined. The Committee advises the Laboratory to investigate this situation immediately. More generally, the Committee encourages the Laboratory to be more proactive in reviewing all high-priority FCPA projects over their entire lifecycle, including all aspects of the operation plans.

We have largely succeeded in patching the funding ‘gap’ for DES commissioning and operations in FY2011. We are also scheduling a review in early 2011 of the Auger South operations plans.

Response to the June PAC report

The Committee strongly encourages the DECSpec group to discuss collaboration with the BigBOSS groups now so the development can be coherent.

We are working on this with LBNL. Our goal is to arrive at one coherent proposal. However, we do not feel the same urgency as they do to converge immediately, since we believe such an experiment will likely not happen until DES has first results and LSST is well underway.

Response to the June PAC report

The science that would be enabled by the Joint Dark Energy Mission (JDEM) is compelling, and the Committee reiterates its view that the JDEM Science Operations Center is an appropriate role for Fermilab. The future of JDEM is presently unclear, however, both in scope and in possible international partnerships. Hopefully with the release of the Astro2010 Decadal Survey report on astronomy and astrophysics later this year, the situation will be clearer.

While Astro 2010 clarified some things, the status of JDEM/WFIRST still depends mainly on NASA. DOE may not even be involved at this point.

Response to the June PAC report

A coherent FCPA strategy in direct detection of dark matter should now be clearly articulated. The unique and essential roles of Fermilab and the coordination and collaboration with other laboratories and universities should be included. Within this overall vision, it should be a priority for the Fermilab dark matter effort to expand as necessary to support the national dark matter program...

We believe that we articulated a coherent FCPA strategy at the non-accelerator review, with participation in three technologies that have the best intrinsic background discrimination. The review panel also recommended that we take a larger role in coordinating the dark matter community, and we are exploring ways to do that.

Response to the June PAC report

The FCPA is involved in a number of other important programs. The Laboratory cannot continue all of these other efforts under the anticipated budgetary constraints. Difficult choices would have to be made, within a coherent strategy following the guidance of the PASAG, P5, and Decadal Survey reports, while preserving some capability for new initiatives. The Laboratory should give significantly lower priority to programs whose scope at Fermilab decreases below the point at which the FCPA can make an outstanding contribution commensurate with a national laboratory role. This may have painful national/international consequences. Thus, the Committee encourages Laboratory management to consider attempts to obtain budgetary increases within the context of an expanding national Cosmic Frontier program.

We are making the difficult choices, guided by the various review panels. We are also lobbying for increased funding, but this must be a community effort to be successful.

Response to the June PAC report

Per previous PAC reports, the Committee recommends that the Laboratory provide a written summary of the recent informal holometer theory review.

This one is for Pier.

The computing needs at all levels (cosmological simulations, data analysis, facility development, etc.) should be clearly articulated by the FCPA and the Computing Division, and the plans should be updated regularly.

We are working with the Computing Division and the Directorate on these issues.

Summary

- The FNAL program in particle astrophysics was favorably reviewed by DOE and is aligned with national priorities
- We will have world-leading dark matter, dark energy and cosmic ray experiments for at least the next five years.
- It is important to maintain a small program of innovative research in other areas of non-accelerator research at Fermilab.