The Future on the Cosmic Frontier

Summary of Snowmass Activities

S. Ritz and J. Feng
For the Cosmic Frontier Group

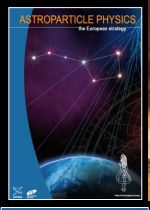
The Future in the Past

- Lots of planning and prioritization work already done (PASAG, NWNH, ApPEC…). Field is very much discovery driven, and evolves rapidly.

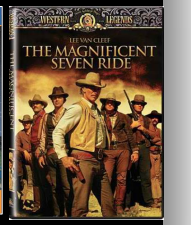
Roadmaps

APPEC

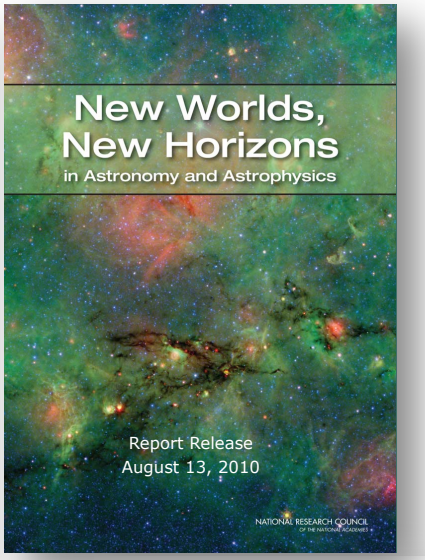
✓2008 The first Roadmap (the definition of the field):
➔ Dark matter/energy, Neutrino mass and properties
➔ Gravitational waves, High energy photons and neutrinos and Ultra high Energy Cosmic rays, dubbed : the 7 magnificent (we either hang together or…)
➔ No CMB (despite many agency links) To reconsider ?



✓2011 The Roadmap update
➔Prioritisation introduced (time ordering)
➔Interface with European Strategy
➔See next slides



✓2010 A global vision document in the context of OECD GSF, basis of APIF ➔ same topics



http://www.appec.org

http://sites.nationalacademies.org/bpa/BPA_049810

http://science.energy.gov/~/media/hep/pdf/files/pdfs/PASAG_Report.pdf

PASAG Prioritization Criteria

- The science addressed by the project is necessary
  - Address fundamental physics (matter, energy, space, time).
  - Expect either at least one compelling result or a preponderance of solid, important results. Check that anticipated results would not be marginal, either in statistics or in systematic uncertainties, relative to the needed precision for clear science results.
  - Discovery space: large leap in key capabilities and significant possibility of important surprises.
- Particle physicist participation is necessary
  - Transformative techniques and know-how to have a major, visible impact; project would not otherwise happen.
  - Leadership is higher priority than participation
- Scale matters, particularly for projects at the boundary between particle physics and astrophysics.
  - Relatively small projects with high science per dollar help ensure scientific breadth while maintaining program focus on the highest priorities.
- Programmatic issues:
  - International context: cooperation vs. duplication/competition.

13 February 2010 PASAG Report, APS Session on International Programs 5

And now…Snowmass

Snowmass on the Mississippi a.k.a CSS 2013

A detailed Wiki for activities and drafts of all the subgroups and working groups

Quick Links

- **TWiki registration**
- **Pre-meetings**
  - Community Planning Meeting
  - All pre-Snowmass Meetings
- **Big Questions**

Groups

- Energy Frontier
- Intensity Frontier
- Cosmic Frontier
- Frontier Capabilities
- Instrumentation Frontier
- Computing Frontier
- Education and Outreach
- Theory Panel

Google Search

www.snowmass2013.org
WWW

Cosmic Frontier

Conveners: Jonathan Feng (UC Irvine), Steve Ritz (UC Santa Cruz)

ANNOUNCEMENTS

July 23, 2013: Useful Documents for Snowmass in Minnesota: Indico Program, Printed Program (July 22), Program At A Glance, and Colloquium Questions.

June 11, 2013: The Snowmass in Minnesota agenda is online and under construction.

May 28, 2013: Snowmass on the Pacific takes place this week at KITP Santa Barbara. For the talks and discussions, see the videos and slides.

May 15, 2013: Registration for Snowmass in Minnesota is now open for non-DOE lab employees.

May 7, 2013: Dark Matter in the Coming Decade: Complementary Paths to Discovery and Beyond now available at arxiv:1305.1605.

February 14, 2013: Cosmic Frontier Workshop participants are encouraged to register as soon as possible. For the meeting schedules, see the Cosmic Frontier Workshop agenda (Wed-Fri) and the DURA Annual Meeting agenda (Tues) and the AARM Agenda (Monday). The Intensity Frontier's Neutrino Subgroup Workshop (Wed-Thu) will also be running concurrently with the Cosmic Frontier Workshop.

October 20, 2012: The Cosmic Frontier Workshop will be held March 6-8, 2013 at SLAC. SLAC Guest House rooms may be reserved now through the workshop website; registration will be open in December. The meeting will be joint with the Non-Accelerator Subgroup of Frontier Capabilities, and is being organized in coordination with meetings of DURA on March 5 and AARM on March 4.

October 13, 2012: Thanks to all who participated in the Cosmic Frontier sessions of the Community Planning Meeting. Talks given there are posted on the CPM agenda page.

October 3, 2012: Drafts of all subgroup charges are posted. Comments to subgroup conveners welcome.

August 3, 2012: Subgroup Conveners are now posted. Many thanks to all who provided inputs and especially to all those who have agreed to serve as conveners.

June 20, 2012: We are currently soliciting community input for subgroup conveners, topics, and experiments (see below).

CHARGE

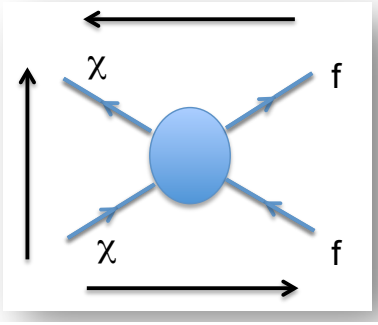
The Cosmic Frontier working group is charged with summarizing the current state of knowledge and identifying the most promising future opportunities at the interface of particle physics, astrophysics, and cosmology. Topics include dark matter, dark energy, the matter--anti-matter asymmetry, cosmic particles, and astrophysical probes of fundamental physics.

- **Huge amount of work over a year!**
- Many group and subgroup telecons and pre-meetings to spread the word and define the work, including
  - October Community Planning Meeting at FNAL
  - March Cosmic Frontier Workshop at SLAC
  - March SnowDARK (non-WIMP DM)
  - May EF/IF/CF Theory Workshop KITP
  - …

http://www.snowmass2013.org/tiki-index.php?page=Cosmic%20Frontier

Organization (1)

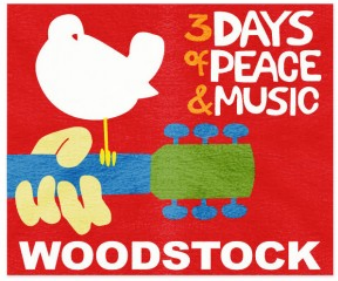
- **CF1: WIMP Dark Matter Direct Detection** – Priscilla Cushman, Cristiano Galbiati, Dan McKinsey, Hamish Robertson, Tim Tait
  - A: Status and Science Case (Dan Bauer)
  - B: Defining the Parameter Space (Tim Tait)
  - C: Enabling Technology and Infrastructure (Bob Jacobsen)
- **CF2: WIMP Dark Matter Indirect Detection** – Jim Buckley, Doug Cowen, Stefano Profumo
- **CF3: Non-WIMP Dark Matter** – Alex Kusenko, Leslie Rosenberg
- **CF4: Dark Matter Complementarity** – Dan Hooper, Manoj Kaplinghat, Konstantin Matchev



Organization (2)

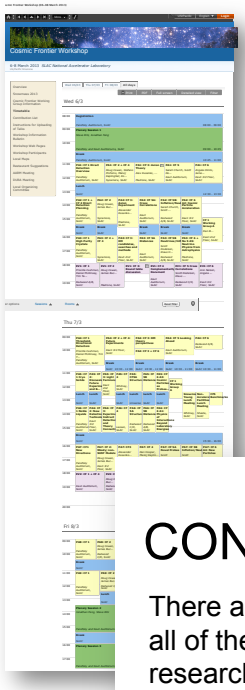
- **CF5: Dark Energy and CMB** – Scott Dodelson, Klaus Honscheid, and Sarah Church
  - Cosmological Distances (Alex Kim, Nikhil Padmanabhan)
  - Growth of Cosmic Structure (Dragan Huterer, David Kirkby)
  - Cross Correlations Exploiting Multiple Probes (Jason Rhodes, David Weinberg)
  - Novel Probes of Gravity and Dark Energy (Bhuv Jain)
  - Inflation Physics from CMB and Large Scale Structure (John Carlstrom, Adrian Lee)
  - Neutrino Physics from CMB and Large Scale Structure (Kev Abazajian, John Carlstrom, Adrian Lee)
  - Facilities (David Weinberg)
- **CF6: Cosmic Particles and Fundamental Physics** – Jim Beatty, Ann Nelson, Angela Olinto, Gus Sinnis
  - Cosmic Rays, Gamma Rays, Neutrinos (Gus Sinnis, Tom Weiler)
  - The Matter of the Cosmological Asymmetry (Ann Nelson)
  - Exploring the Basic Nature of Space and Time (Aaron Chou, Craig Hogan)

March CF Workshop at SLAC



Cosmic Frontier Workshop

- Intensive three-day workshop 6-8 March
  - 338 Registrants; 200 talks + panels, roundtable discussions,…
  - very broad range of topics; many new and exciting opportunities with close connections to the other Frontiers. Stimulating and FUN!
- Work planned and underway for deliverables
- Planning for the summer meeting
  - more time for discussions
  - cross-cutting interests with the other Frontiers
  - join together to promote the whole program



CONNECTIONS TO OTHER FRONTIERS

There are important connections to all of the other frontiers and to other research communities. For example:

- Assay and Acquisition of Radiopure Materials (AARM), Monday
- Deep Underground Research Association (DURA) Annual Meeting, Tues
- Frontier Capabilities: Non-Accelerator Facilities, Wed-Fri (see Gil Gilchriese talk)
- Intensity Frontier: Neutrino Subgroup, Wed-Thurs (see Kate Scholberg talk)
- Snowmass Young, Wed-Fri (see Marcelle Soares-Santos talk)

- **Energy Frontier**
  - Chip Brock (Michigan State), Michael Peskin (SLAC)
- **Intensity Frontier**
  - JoAnne Hewett (SLAC), Harry Weerts (Argonne)
- **Cosmic Frontier**
  - Jonathan Feng (UC Irvine), Steve Ritz (UC Santa Cruz)
- **Frontier Capabilities**
  - William Barletta (MIT), Murdock Gilchriese (LBNL)
- **Instrumentation Frontier**
  - Marcel Demarteau (ANL), Howard Nicholson (Mt. Holyoke), Ron Lipton (Fermilab)
- **Computing Frontier**
  - Lothar Bauerdick (Fermilab) and Steven Gottlieb (Indiana)
- **Education and Outreach**
  - Marge Bardeen (Fermilab), Dan Cronin-Hennessy (U of M)
- **Theory Panel**
  - Michael Dine (UC Santa Cruz)

- Instrumentation Frontier, Wed-Fri (see Clarence Chang talk on Friday)

"The main goal of the instrumentation frontier is to study the long-term instrumentation needs for the various frontiers: What technology development and innovation program, guided by the science questions, is needed for the decade after next! We kindly ask the various conveners to make this an integral part of their discussions in the parallel sessions and include it in the summary at the end of the workshop."

Tough Questions (aka Colloquium Questions)

- Was useful to ask ourselves and the other Frontier groups tough questions
  - Capabilities, missing pieces, importance of specific opportunities to HEP, how topics connect,…
  - Invited other Frontiers to do the same
  - We use the questions **to** CF to help organize our sessions and documents
- We don't have all the answers yet. Much to do at this meeting!
- A model: Snowmass process generates and answers the questions, and P5 uses the answers to help decide and articulate priorities.
- Some examples:
  - What would it take to convince ourselves that we have:
    - a discovery of dark matter?
    - discovered two different species of DM?
    - discovered ALL of the dark matter?
    - a false signal of a dark matter discovery?

http://www.snowmass2013.org/tiki-download_file.php?fileId=246

  - The study of cosmic structure may allow us to measure neutrino masses sufficiently accurately to determine the hierarchy. How realistic is this, what assumptions are needed, and when is this likely to happen?
  - What are the roles of cosmic-ray, gamma-ray, and neutrino experiments for particle physics? What future experiments are needed in these areas and why?

This Week: Types of Sessions (1)

Check Indico for updates!

- **CF subgroup parallel sessions to complete the work**
  - Tuesday morning:
    - CF1A+B & CF4 work on documents, subgroup C joint Underground Capabilities session
    - CF2+CF6 joint discussion of facilities
    - CF3 work on report
    - CF5: DE goals and systematics
    - Joint w/Computing and Cosmic Frontier
    - Joint w/Frontier Capabilities on underground experiments
  - Wednesday morning:
    - CF1 Discussion of report
    - CF2 Discussion of report
    - CF3+CF4 joint discussion
    - CF5 Neutrinos, DE+CMB, Facilities [including a talk on **recent SPT B-mode detection**]
    - Joint w/Instrumentation CF1 and CF2
  - Wednesday evening:
    - CF5 Inflation and CMB, panel discussion
- **CF-level plenaries: summaries and answers to Tough Questions (target audience non-specialists – all invited!):**
  - Thursday morning: CF5 Dark energy and CMB summary
  - [Thursday evening: CF session with DOE and NSF]
  - Friday morning: Joint EF/IF/CF on Baryogeneis, followed by CF6 Cosmic Particles summary
  - Saturday morning: DM CF1234 summary

All these meetings are completely open

This Week: Types of Sessions (2)

- **Colloquia and Panels (for non-specialists!)**
  - Monday (today) afternoon: Dark Matter from all perspectives:
    - Evidence and candidates, experimental probes, putting it all together: info from colliders, space, and underground, tough questions, discussion
  - Tuesday afternoon
    - Panel: Must there be new physics?
  - Wednesday afternoon
    - Colloquium: Neutrino Mass, Mixing, and Grand Unification
    - Panel: What can we learn about short-distance physics without discovering new particles?
  - Thursday afternoon
    - Colloquium: Cosmic Surveys – Dark Energy, Inflation, and Neutrino Properties
  - Saturday afternoon
    - Colloquium: High Energy Cosmic Particles
    - Panel: Domestic/Off-shore
  - Monday morning
    - Cosmic Frontier Summary

Deliverables

- Documents and Summary Talks
  - Contributed white papers, including cross-cutting science, techniques, and technology development
  - Working group and subgroup summary talks and documents
  - CF summary talk and documents
  - Sections of Snowmass-wide summary document
- Surveys of facilities, current and future
- Dark Matter Complementarity Document
- Issues and opportunities
- All linked to the Wiki

- **We are trying to write these with P5 in mind.**

WIMP Direct Detection Census

1. Experiment Status, Target Mass
2. Fiducial target mass
3. Backgrounds after passive and active shielding.
4. Detector Discrimination
5. Energy Threshold
6. Sensitivity versus WIMP mass
7. Experimental Challenges
8. Annual Modulation
9. Unique Capabilities
10. Determining WIMP properties and astrophysical parameters

http://www.snowmass2013.org/tiki-index.php?page=SLAC

Cryogenic Solid State

CDMS/SuperCDMS
EDELWEISS/CRESST/EURECA
CoGeNT/C4
TEXONO/CDEX

Liquid Xenon

LUX/LZ

XENON
PandaX
XMASS

Liquid Argon

ArDM
Darkside
DEAP
CLEAN

Crystal and Annual Modulation

DAMA/LIBRA
KIMS
ELEGANT
ANAIS
CINDMS
Princeton NaI
DM-Ice

Threshold Detectors

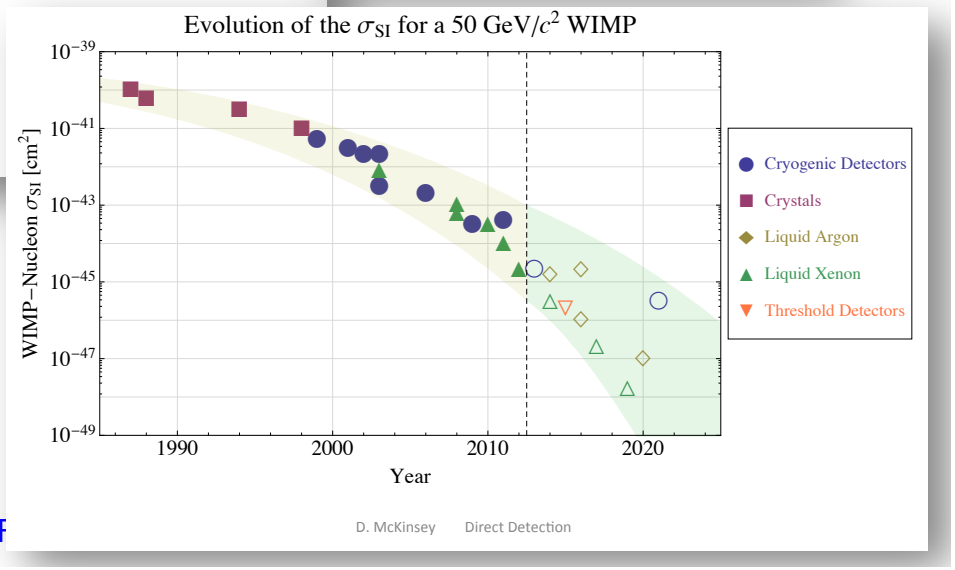
Technology Description
PICASSO
SIMPLE
COUPP

Directional Detection

DRIFT
Newage
DMTPC
MIMAC
D3

New Ideas

DAMIC
Liquid helium-4
NEXT
Nuclear emulsions (Naka, Japan)
DNA & Nano-explosions (Drukier/Cantor)



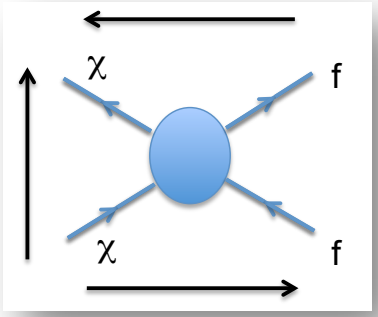
Indirect Detection and Cosmic Particles Facilities

Indirect Detection Experiments

Status	Experiment	Target	Location	Major Support	Comments
Current	AMS	e+/e-, anti-nuclei	ISS	NASA	Magnet Spectrometer, Running
	Fermi	Photons, e+/e-	Satellite	NASA, DOE	Pair Telescope and Calorimeter, Running
	HESS	Photons, e-	Namibia	German BMBF, Max Planck Society, French Ministry for Research, CNRS-IN2P3, UK PPARC, South Africa	Atmospheric Cherenkov Telescope (ACT), Running
	IceCube/ DeepCore	Neutrinos	Antarctica	NSF, DOE, International: Belgium, Germany, Japan, Sweden)	Ice Cherenkov, Running
	MAGIC	Photons, e+/e-	La Palma	German BMBF and MPG, INFN, WSwiss SNF, Spanish MICINN, CPAN, Bulgarian NSF, Academy of Finland, DFG, Polish MNiSzW	ACT, Running
	PAMELA	e+/e-	Satellite		
	VERITAS	Photons, e+/e-	Arizona, USA	DOE, NSF, SAO	ACT, Running
	ANTARES	Neutrinos	Mediter-ranean	France, Italy, Germany, Netherlands, Spain, Russia, and Morocco	Running
Planned	CALET	e+/e-	ISS	Japan JAXA, Italy ASI, NASA	Calorimeter
	CTA	Photons	ground-based (site TBD)	International: MinCyT, CNEA, CONICET, CNRS-INSU, CNRS-IN2P3, Irfu-CEA, ANR, MPI, BMBF, DESY, Helmholtz Association, MIUR, NOVA, NWO, Poland, MICINN, CDTI, CPAN, Swedish Research Council, Royal Swedish Academy of Sciences, SNSF, Durham UK, NSF, DOE	ACT
	GAMMA-400	Photons	Satellite	Russian Space Agency, Russian Academy of Sciences, INFN	Pair Telescope
	GAPS	Anti-deuterons	Balloon (LDB)	NASA, JAXA	TOF, X-ray and Pion detection
	HAWC	Photons, e+/e-	Sierra Negra	NSF/DOE	Water Cherenkov, Air Shower Surface Array
	IceCube/ PINGU	Neutrinos	Antarctica	NSF, Germany, Sweden, Belgium	Ice Cherenkov
	KM3NeT	Neutrinos	Mediter-ranean	ESFRI, including France, Italy, Greece, Netherlands, Germany, Ireland, Romania, Spain, UK, Cyprus	Water Cherenkov
	ORCA	Neutrinos	Mediter-ranean	ESFRI, including France, Italy, Greece, Netherlands, Germany, Ireland, Romania, Spain, UK, Cyprus	Water Cherenkov

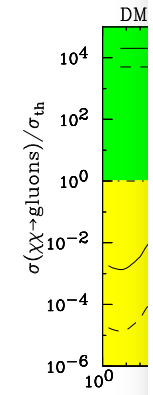
http://www.snowmass2013.org/tiki-index.php?page=WIMP+Dark+Matter+Indirect+Detection

Now entering very interesting sensitivity range – thermal production natural scale for WIMPs $\langle\sigma v\rangle \sim 3\times10^{-26}$ cm^3/s



Dark Matter Complementarity

See arXiv:1305.1605



Dark Matter in the Coming Decade: Complementary Paths to Discovery and Beyond

Daniel Bauer, Fermilab; **James Buckley**, Washington University; **Matthew Cahill-Rowley**, SLAC; **Randel Cotta**, University of California, Irvine; **Alex Drlica-Wagner**, SLAC; **Jonathan Feng***, University of California, Irvine; **Stefan Funk**, SLAC; **JoAnne Hewett**, SLAC; **Dan Hooper**, Fermilab; **Ahmed Ismail**, SLAC; **Manoj Kaplinghat***, University of California, Irvine; **Alexander Kusenko**, University of California, Los Angeles; **Konstantin Matchev***, University of Florida; **Daniel McKinsey**, Yale University; **Tom Rizzo**, SLAC; **William Shepherd**, University of California, Santa Cruz; **Tim M.P. Tait***, University of California, Irvine; **Alexander M. Wijangco**, University of California, Irvine; **Matthew Wood**, SLAC

on behalf of the Snowmass 2013 Cosmic Frontier Working Groups 1-4

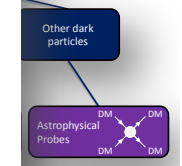
(Dated: 7 May 2013)

I. INTRODUCTION

Dark matter is five times as prevalent as normal matter in the Universe, but its identity is unknown. Its mere existence implies that our inventory of the basic building blocks of nature is incomplete, and uncertainty about its properties clouds attempts to fully understand how the universe evolved to its present state and how it will evolve in the future. Dark matter is therefore a grand challenge for both fundamental physics and astronomy. At the same time, groundbreaking experiments are set to transform the field of dark matter in the coming decade. This prospect has drawn many new researchers to the field, which is now characterized by an extraordinary diversity of approaches unified by the common goal of discovering the identity of dark matter.

As we will discuss, a compelling solution to the dark matter problem requires synergistic progress along many lines of inquiry. Our primary conclusion is that the diversity of possible dark matter candidates requires a balanced program based on four pillars: direct detection experiments that look for dark matter interacting in the lab, indirect detection experiments that connect lab signals to dark matter in our own and other galaxies, collider experiments that elucidate the particle properties of dark matter, and astrophysical probes sensitive to non-gravitational interactions of dark matter such as dark matter densities in the centers of galaxies and cooling of stars.

In this Report we summarize the many dark matter searches currently being pursued in each of these four approaches. The essential features of broad classes of experiments are described, each



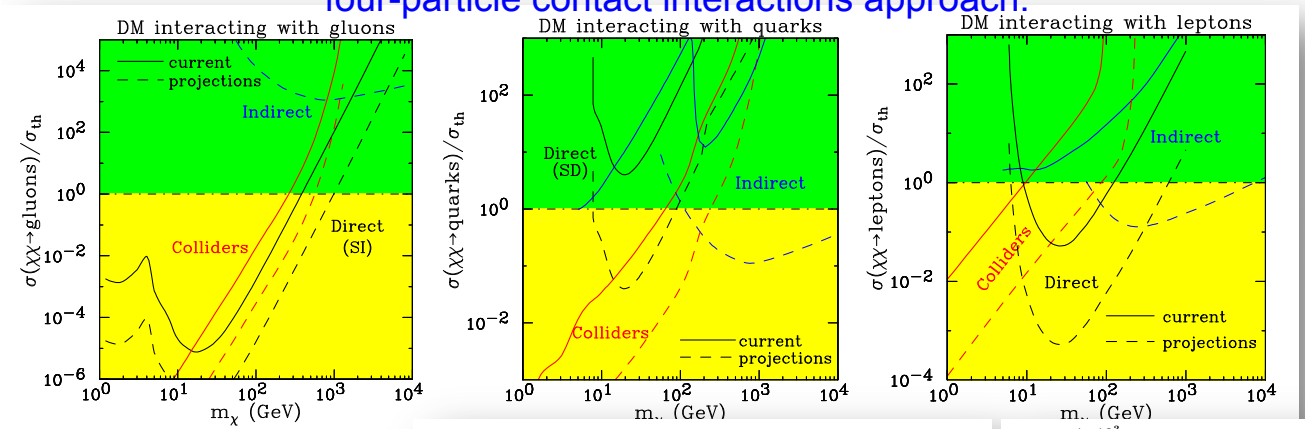
Dark Matter Complementarity

See arXiv:1305.1605

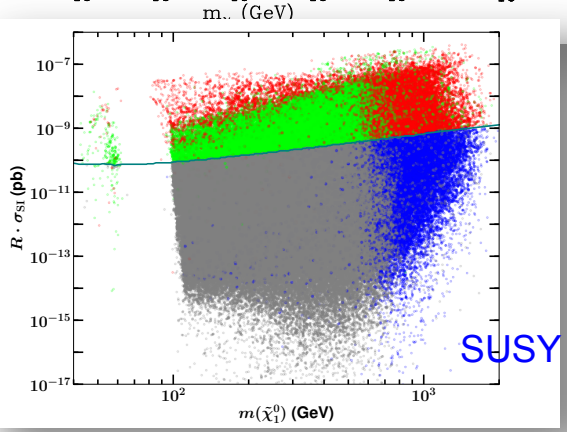
Direct Detection

Relic scattering locally, at low energy. Push to larger target mass, lower backgrounds, directional sensitivity

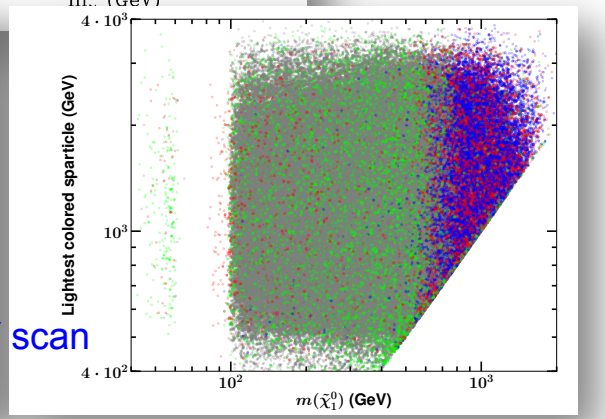
four-particle contact interactions approach:



future direct detection, indirect detection or both. Plus maybe upgraded LHC only.

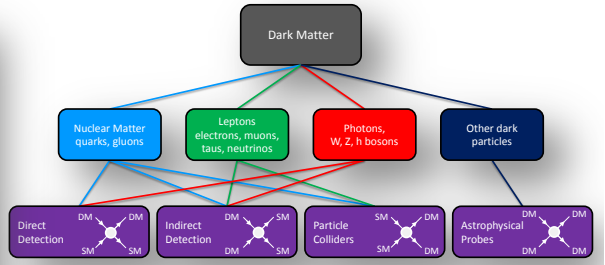


SUSY scan



Accelerators

Direct production. Push to higher energy



Observations

Push toward finding and studying galactic halo objects and large scale structure.

Indirect Detection

Interactions (via annihilations, decays) with SM particles. Understand the astrophysical backgrounds in signal-rich regions, and reveal the distribution of dark matter.

Simulations

Large scale structure formation. Push toward larger simulations, finer details.

Dark Matter Complementarity

See arXiv:1305.1605

Direct Detection

Relic scattering locally, at low energy. Push to larger target mass, lower backgrounds, directional sensitivity

Accelerators

Direct production. Push to higher energy

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Dark Energy and CMB Reports and Facilities Documents Complete and Posted on Twiki

Dark Energy and CMB

Conveners: S. Dodelson (FNAL/Chicago), K. Honscheid (Ohio State)

Click here to send email to the conveners

SNOWMASS CF5 PAPERS (TOPICAL CONVENERS IN PARENTHESES)

Distances (Alex Kim and Nikhil Padmanabhan)

Growth of Cosmic Structure: Probing Dark Energy Beyond Expansion (Dragan Huterer and David Kirkby)

Cross Correlations: Exploiting Multiple Probes, Surveys, and Techniques (Jason Rhodes and David Weinberg)

Novel Probes of Gravity and Dark Energy (Bhuvnesh Jain)

Inflation Physics from the Cosmic Microwave Background and Large Scale Structure (John Carlstrom and Adrian Lee)

Neutrino Physics from the Cosmic Microwave Background and Large Scale Structure (Kev Abazajian, John Carlstrom, Adrian Lee)

Dark Energy Facilities (David Weinberg)

LETTERS OF INTEREST

Why Study Dark Energy from a Broad Spectrum of Researchers

Support for Studies of Inflation from High Energy Theorists

WHITE PAPERS

MKIDS for the Dark Sector

Time Delays

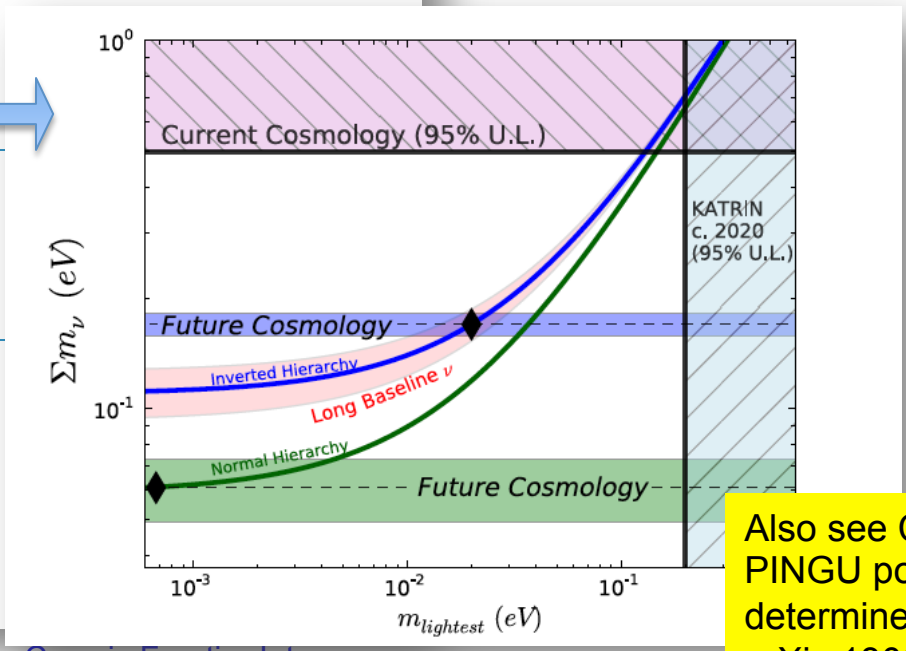
Clusters

Spectroscopic Needs for Imaging Dark Energy Experiments

DESI - Dark Energy Spectroscopic Initiative

Many contributions, new developments:

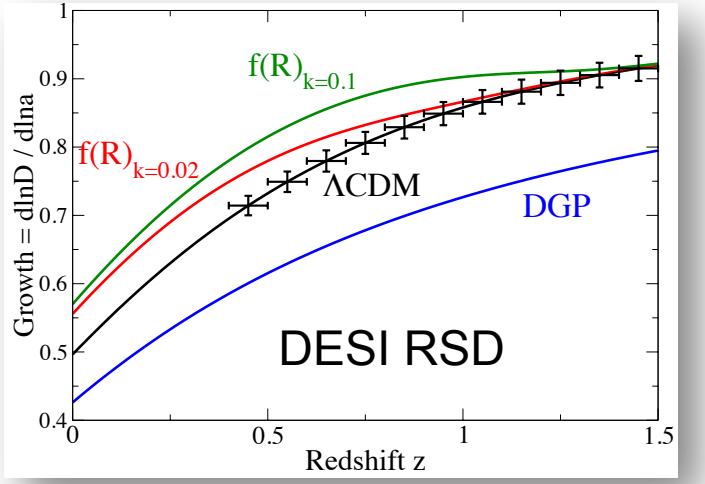
- **Dark Energy**
- **Inflation**
- **Facilities, techniques, opportunities, issues**
- **Neutrino physics from cosmic surveys (important cross-frontier complementarity!):**



Also see CF6: PINGU potential to determine hierarchy arXiv:1306.5846v1

CF5 Work on Dark Energy

- Highlights include
  - **Strategies to distinguish dark energy from modified gravity**
  - **Importance of upcoming complementary probes for determining the key cosmological parameters**
  - **Techniques and Issues**
  - **Facilities**
  - **"Why Study Dark Energy?"**
    - **A set of brief, thoughtful paragraphs by a wide range of researchers (post-docs through senior leaders) on what they personally find compelling.** ***A great read!***



Technology! (One example, March Workshop talk by J. Estrada)

MKID: new detectors

Semiconductor (CCDs)

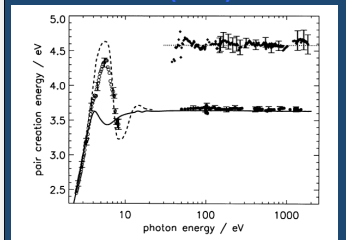
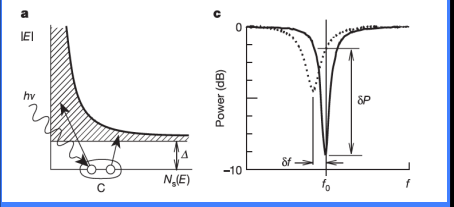


Fig. 5. Mean energy W required for creating an electron-hole pair determined from s_e and s: for silicon in the soft X-ray region [14] (closed circles) and UV and VUV region [21] (open circles) and for GaAsP in the soft X-ray region (diamonds). Typical experimental uncertainties are indicated. For silicon, calculations from Ref. [14] are shown as solid line and dashed line (see text). The points indicate the mean value of 4.58 eV for GaAsP.

1e- / red photon
No energy information

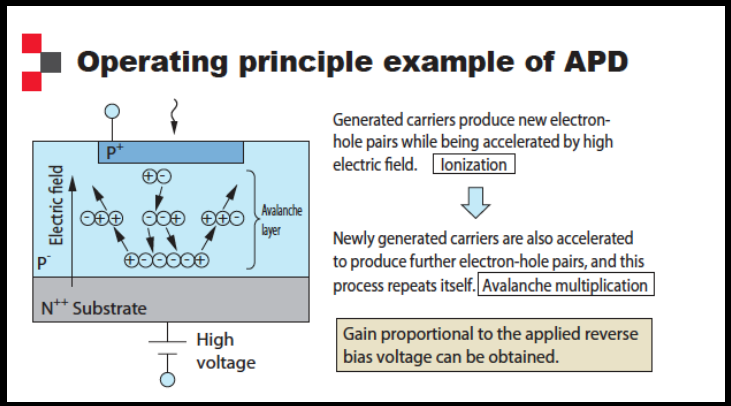
Superconductor
$N_{qp} = \eta h\nu/\Delta$,
Δ : gap parameter of the superconductor
η: is an efficiency factor (about 0.6)
Δ is meV instead of eV (this is why we like them!)
For Al Δ= 0.18 meV

Microwave Kinetic Inductance Detector



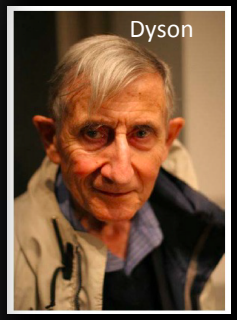
5000 qp / red photon
Energy resolution

SiPM: array of Avalanche Photodiodes



Conclusion

- If you are working on technology innovations to enable your DE science, please get in contact with us (gaston@fnal.gov, estrada@fnal.gov) to be included in the instrumentation document.
- Keep an eye on MKIDs as a tool for wide field low resolution spectroscopy.
- Keep an eye on SiPMs as a new detector for astronomical imaging pushing opening a new window for high time resolution.



"New directions in science are launched by new tools much more often than by new concepts.

The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained"

Freeman Dyson

Additional Documents Posted

CF6 Cosmic Particles

White Papers Completed and in Progress

Cosmogenic Neutrino Detection with the ARIANNA High Energy Neutrino Project **Steve Barwick**
Fundamental Physics via Charged Particles with the Cherenkov Telescope Array **Brian Humensky**
Gamma Ray Signatures of Ultra High Energy Cosmic Ray Line-of-sight Interactions **J. Dumm and L. Fortson**
Quark Anti-Nugget Dark Matter **K. Lawson and A. Zhitnitsky**

CF3 Non-WIMP DM

TOWARD THE SUMMARY DOCUMENT

The building block of the summary document are contributed by working groups.

Introduction and table of contents

Axion dark matter; lead writers: R. Peccei, L. Rosenberg

Asymmetric dark matter; lead writer: K. Petraki

Mirror dark matter; lead writers: R. Foot and R. Volkas

Primordial black holes; lead writer: K. Griest

SUSY Q-balls; lead writer: I. Shoemaker

CF2 Indirect WIMP DM

Whitepapers

- ``White Paper: Prospects for Indirect Searches for Dark Matter wit Neutrinos'', C. Rott, D. Cowen, D. Grant, F. Halzen, et al., Draft 1 - pdf
- *Prospects for Indirect Detection of Dark Matter with CTA*, M. Wood, J. Buckley, S. Funk, D. Nieto, M. Sanchez-Conde, et al., Draft 1 - pdf
- *CF2 White Paper: Status and Prospects of the VERITAS Indirect Dark Matter Detection Program*, A. W. Smith, R. Bird, J. Buckley, K. Byrum, J. Finley, A. Geringer-Sameth, J. Holder, D. Kieda, S. Koushiappas, R. Ong and B. Zitzer, Incorrect parameter fileId
- ``Dedicated Indirect Searches for Dark Matter Using Antideuterons'', C. Hailey, T. Aramaki, P. von Doetinchem, and R. Ong, Draft 1 - pdf

A Big Message

- **The future is very bright!**
- **<u>Together with the other Frontier areas</u>**, the Cosmic Frontier provides to HEP:
  - Clear evidence for physics Beyond the Standard Model
  - Many surprises. Profound questions of popular interest.
  - Frequent new results, with broad impacts.
  - Large discovery space.
  - Important cross-frontier topics (*e.g.*, neutrinos, DM, …)
  - Full range of project scales, providing flexible programmatic options.
  - **US Leadership**
- **<u>Join the fun!</u>**