Cosmic Frontier 1
WIMP Dark Matter Direct Detection
Working Group A Status Report

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SLAC Cosmic Frontier Workshop

CF1 Working Group A

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Working group A formed on January 17, 2013
- Email listserv created January 24, 2013
- Discussions mainly by email; first telecon last Friday
- First face-to-face meeting today

Task is to produce white paper sections for the following charge:

Charge 1: Summarize the state of direct searches for dark matter.

Charge 2: Review the motivation for future generations of direct searches for WIMP dark matter.

Charge 3: Develop criteria and figures of merit by which future generations of direct dark matter search experiments can be evaluated in terms of sensitivity and discovery potential.

CF1 Working Group A Charge

Charge 1: Summarize the state of direct searches for dark matter.

Describe the technology classes being used today for direct detection of dark matter.

Create an up-to-date summary of current limits and detection claims for the following set of experiments:

SuperCDMS, CoGeNT, COUPP, CRESST, DAMA, DAMIC, Darkside, DEAP-3600, DMIce, DMTPC, DRIFT, Edelweiss, LUX, MiniCLEAN, PANDA-X, Picasso, WARP, XENON, XMASS, ZEPLIN.

CF1 Working Group A Charge 1

- We have spent most of our effort thus far on Charge 1.
- Although much of the necessary information exists, it is scattered in numerous proposals, review reports, papers,…
- This meeting provided an opportunity to systematically gather the information
- Asked every current experiment to provide written background information and answers to 10 detailed questions we developed
- The intent of the questions is to extract what has been demonstrated for each experiment and the basis for projections
  - We are NOT a review panel
  - We will NOT be making comparisons between experiments
  - We are NOT (yet) considering costs
- Hear short presentations from the experiments over the next two days
  - Many of these questions are difficult, and we realize the experiments do not necessarily have complete answers; do the best you can.

CF1 Working Group A Charge 1

1) **Experiment Status and Target Mass**
Is your experiment currently operating, and with what total target mass?

If not, when do you expect to operate, and with what total target mass?

What total target mass do you expect to have operating 10 years from now?

2) **Fiducial target mass**
What is your current ratio of fiducial target mass to total target mass?

How to you expect that ratio to scale in the future? Describe briefly the basis for this scaling.

3) **Backgrounds after passive and active Shielding**
What is the current demonstrated background level, in both your total volume and in your fiducial volume, **before detector discrimination is applied** for each type of background (gamma, beta, alpha, radiogenic neutrons, cosmogenic neutrons)? Please quote in units of events/kev/kg/day and specify the energy range your are using (preferably 10-100 keV). Use either kevee (electron equivalent) or kevnr (nuclear recoil) as appropriate for the type of background.

Is your dominant background from the active target material, the experiment materials surrounding the active target, or from the environment (including cosmic rays)?

By what factor do you need to reduce these backgrounds for future experiments? Describe briefly how you would achieve such reductions.

CF1 Working Group A Charge 1

4) **Detector Discrimination**

What is your current demonstrated experiment discrimination factor, in both your total volume and in your fiducial volume, for each type of background (gamma, beta, alpha, radiogenic neutrons, cosmogenic neutrons)? Please quote these at 100 kevnr, and for 10 kevnr, or the lowest energy you have measured them.

By what factor might these improve in the future? Describe briefly how you would achieve any improvements.

Do you have "outlier" events that cannot be described by your simulations or calibrations?

5) **Energy Threshold**

What are your current demonstrated energy thresholds (trigger and analysis) for electron recoils and nuclear recoils?

Specify the nuclear recoil acceptance at your energy thresholds and describe briefly how you expect the thresholds and acceptance to evolve in the future.

6) **Sensitivity versus WIMP mass**

What are your current demonstrated SI and SD sensitivities as a function of WIMP mass, at least for 5, 10, 100, 1000 and 10000 GeV?

What sensitivities do you project in the next 5, 10 and 15 years?

Do you expect to develop sensitivity to WIMPS with masses < 5 GeV and, if so, how?

CF1 Working Group A Charge 1

7) **Experimental Challenges**
What are the main physics and engineering challenges you currently face in getting your experiment to work?

What physics and engineering challenges do you expect to face for improving the sensitivity of the experiment?

Is there detector R&D needed to enable a future experiment?

What are the facility requirements (size, depth, ...) for your next generation experiment?

8) **Annual Modulation**
Have you demonstrated experiment stability at the level needed to study annual modulation, and for what nuclear recoil energy energy threshold?

If not, what are the main obstacles you face?

9) **Unique Capabilities**
Do you have unique capabilities to identify whether a signal is due to WIMPs, aside from the standard event by event discrimination and multiple scattering?

Does your technology allow different targets in the same experiment? If so, what changes are required to make use of these?

Does your experiment have sensitivity to dark matter interactions other than spin-independent or spin-dependent?

10) **Determining WIMP properties and astrophysical parameters**
If a signal is detected, what information does your experiment provide about WIMP properties (especially WIMP mass), and about dark matter distribution in the galaxy?

CF1 Working Group A Charge 1

- During, and after, this workshop, we will cross check and summarize the information provided
  - This will likely take the form of tables and charts
  - Need a concise way to summarize experimental reach beyond the simple minima of cross section vs mass
- We will then draft the white paper text corresponding to this charge
  - Shoot for a first draft within the next two months
  - Iterate and converge by Snowmass

CF1 Working Group A Charge 2

Charge 2: Review the motivation for future generations of direct searches for WIMP dark matter.

Given standard assumptions of spin-independent or spin-dependent coupling, what do recent experimental constraints imply about the existence of WIMPs and their nature?

How do these conclusions change for non-standard assumptions?

What are the likely regions of WIMP-nucleon cross sections?

What WIMP masses are implied by these models?

Do the planned next-generation direct searches cover these likely regions?

What other physics (axion etc) might be explored with such searches (Liason with CF3)

Do we need to reach the irreducible neutrino floor?

Is our enthusiasm for WIMP searches modulated by LHC results? Should it be?

What about other dark matter candidates and methods?

What does the decision tree for this area look like? What are key results and outcomes?

What would be the impact of an LHC or indirect detection discovery?

CF1 Working Group A Charge 2

- The goal of Charge 2 is to make the best case for future direct detection experiments
  - However, the questions need some refinement
    - Many are requesting opinions rather than facts
    - Many also require significant interaction with CF1 Working Group B, CF2 and CF4
  - First working group A telecon made progress
    - Try to make progress on the complementarity questions at this meeting
    - Focus on the main question of what physics will be done by future direct detection experiments

CF1A Draft Revised Charge 2

Charge 2: Review the motivation for future generations of direct searches for WIMP dark matter.

Given current theoretical input and experimental constraints, what are the allowed regions in WIMP-nucleon scattering cross section and mass?

- Will the planned direct detection searches cover these likely regions in the next 10-20 years?
- What other physics might be explored with such searches?
- What would be the impact on planned direct detection searches if strong evidence for WIMPS emerges from the LHC or indirect detection?

CF1 Working Group A Charge 3

Charge 3: Develop criteria and figures of merit by which future generations of direct dark matter search experiments can be evaluated in terms of sensitivity and discovery potential.

Explore the future using these criteria and figures of merit.

What would it take to convince the community that WIMP dark matter has been discovered?

How many confirmations, and of what type, are required?

What targets should be set for WIMP-nucleon cross-section sensitivity as a function of WIMP mass in the next generation?

If WIMPs are discovered in the next generation, what further information is provided by the subsequent experiments?

How well could the WIMP mass be determined by direct searches?

What precision is required in the WIMP-nucleon cross section to constrain models?

How much information would be gained from annual or daily modulation experiments?

What angular resolution is required from directional detection experiments to do "WIMP astronomy"?

CF1 Working Group A Charge 3

- Charge 3 is our hardest, and most contentious task
  - Nobody has yet produced a figure of merit that is acceptable to the dark matter community
    - By default the figure of merit tends to be raw target mass, but this is clearly incorrect
    - Some combination of fiducial target mass, background performance is needed
  - We will likely instead focus on developing criteria for different WIMP mass regions, interactions, and detection methods
  - We think it would be especially useful to focus on the questions of what would be learned from a WIMP signal
- Again, we have started this discussion by telecon and will continue at this workshop

CF1A Draft Revised Charge 3

Charge 3: Develop criteria and figures of merit by which future generations of direct dark matter search experiments can be evaluated in terms of sensitivity and discovery potential.

Is a figure of merit possible for WIMP direct detection?

- Develop criteria for background systematics that can be used to evaluate sensitivity and discover potential
- Attempt to construct a "decision tree" for dark matter direct detection

What targets should be set for WIMP-nucleon cross-section sensitivity as a function of WIMP mass in the next generation?

- Is it important to reach the "neutrino floor" for all WIMP masses?

What would it take to convince the community that WIMP dark matter has been discovered?

- What are the criteria for "evidence for" and "discovery of" WIMPS?
- How many confirmations, and of what type, are required?

If WIMPs are discovered in the next generation, what further information can be gained from subsequent experiments?

- How well could the WIMP mass be determined by direct searches?
- How much additional information would be gained from annual modulation experiments?
- At what cross section scale would directional detection experiments be feasible?
  - What would such experiment be able to do in the way of WIMP astronomy?

CF1A Agenda for this afternoon

1) Discuss how to gather, validate and summarize the info from experiments, in response to our questions

- Take notes especially to capture verbal Q&A
- Decide what follow up ?'s might be needed
- Let's also talk about how we can best summarize the input in a useful form (tables, charts, figures, concise text) and how to split up the task

2) Refining the charge 2 and charge 3 questions

- Discuss draft of the revised charge ?'s
  - Are we getting the key info needed for the white paper?