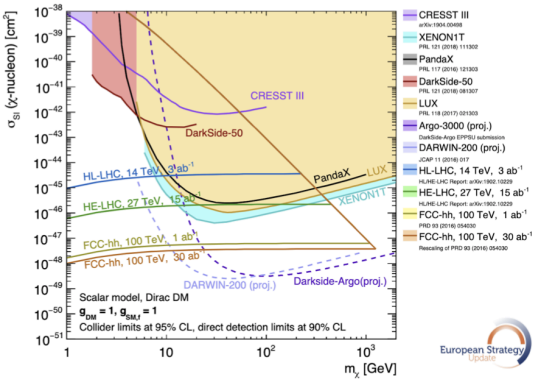
DM Complementarity: panel questions

Add your discussion points and questions here:

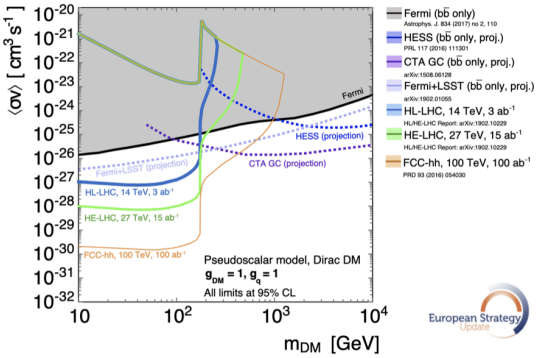
CF+EF-related discussion points

Panelists to be asked first: Hugh Lippincott, Alex Drlica-Wagner, Suchita Kulkarni
Discussion on plots shown so far by EF (and some CF experiments)

Direct detection



Indirect detection



Message of these plots: *complementary discoveries where >1 experiment is sensitive*
Shortcomings *according to plot creators:*

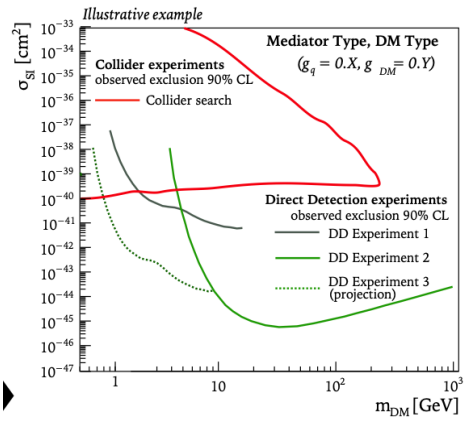
- Collider limits make no assumptions regarding relic density (we can't do much about this, we think)
- Even though assumptions are specified as clearly as possible, collider limits are still model-dependent
- DD and colliders are at different energy scales → https://arxiv.org/abs/1605.04917 but not a huge effect in a sketch

Shortcomings according to CF participants? → discuss

Discussion points (we will choose some during the session):

Are simple WIMP models / simplified models [Dark Matter Working Group] / portals [Physics Beyond Colliders] OK for these sketches , and is specification of assumptions sufficient?

What do you think of having a sketch like the one below, where we show sensitivity to varying couplings/masses/model parameters (not available for DD/ID, since at lower energies one can use EFT)



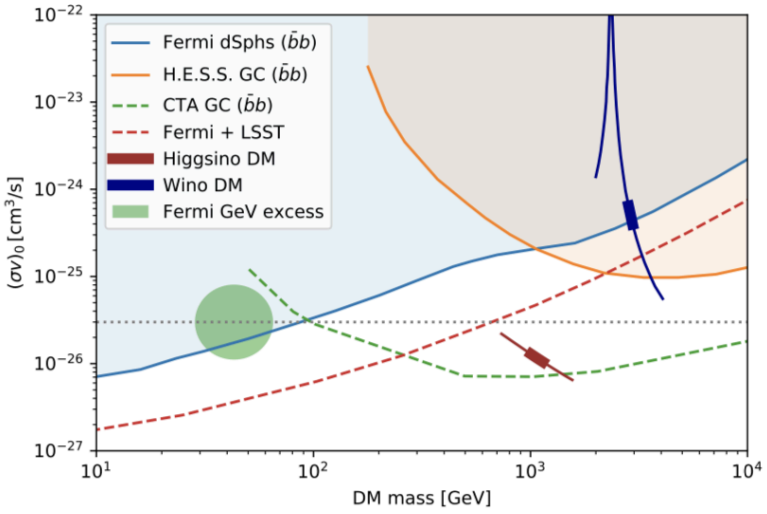
Is extending collider limits for thermal relics below 1 GeV in summary plots theoretically sound, and welcome by other communities?

Other ways to consider a wider breadth of searches (ie wave-like DM/axions, dark sector framework) in summary plots?

What would be the best way to display uncertainties for the experiments involved, and is it worth putting work into this?

Is a sketch following the plot about the minimal WIMP going to give a good picture about complementarity? From complementarity discussions, we had a comment from Rebecca Leane:

Rebecca Leane: these plots normally are restricted to DM annihilation into bb. It may be better to compare with the combined final state limit instead, like Fig. 9 of https://arxiv.org/abs/1805.10305. The bb line alone can be misleading in that it is only one final state, and when in reality the WIMP mass+cross section is so far much less probed than implied in the shaded region. Of course the plot does say "into bb", but people tend to map this sort of plot to the status of the WIMP overall.



Panelists to be asked first: Natalia Toro, Suchita Kulkarni, Lindley Winslow (discussion point already covered in discussion?)

With WLDM detection, a host of new massive particles is discoverable (heavy quarks, extended Higgs sector). Would these particles be accessible by current colliders? Future colliders?

- Depends on properties of WLDM and its couplings
- Cross-checks with colliders can confirm whether detected WLDM has appropriate couplings to be QCD axion

RF+EF-related discussion points

Panelists to be asked first: Natalia Toro, Suchita Kulkarni

Do you think the connection between RF (low mass dark photon) and EF (higher mass dark photon) makes a strong case for complementarity between the two frontiers, in terms of covering a large DM mass range?

EF-related discussion points

Panelists to be asked first: Jessie Shelton, Suchita Kulkarni, audience
Most of what we have done in EF (but also in other Frontiers) revolves around specific theory frameworks for DM. In the complementarity whitepaper, how can we show the breadth of possible cases for DM models while at the same time giving concrete examples? Are those good examples? What may be good benchmarks or common working points?

- Minimal benchmark models could be useful - probably late to make a new model from scratch for snowmass papers but for complementarity could be extra helpful
    - Could be harder to make strong statements about complementarity without benchmarks
    - Likely a work beyond the scope of snowmass
- Would need multiple specific models for full complementarity - not every frontier could contribute to every benchmark
    - DM broadly is the high-level message to push, not one specific model
- As a community, define what is a “good” example - make this point/definition clear
- Potential emphasis on non-minimal models (in the longer term) - makes benchmarking difficult

Some notes from the pre-Snowmass-break complementarity meeting: we classified DM into the following. Do we want to keep this classification somehow/somewhere (if we manage to - problem of this kind of whitepaper may be mission creep given the few weeks we have to write it)?

1. Thermal WIMP DM
    a. Including TeV scale particles even if non-thermal
2. Light hidden sector DM
    a. Including thermal, much lighter than WIMP DM
    b. Including hidden sectors with very light mediators (could also fit in 4)

    c. Self-interaction / warm DM / primordial couplings to proton constraints (CF3)
3. Sterile neutrino
4. Wave-like DM, axions and hidden photons (as DM and as mediator)
    a. (Maybe this should be split up)
5. Very heavy DM (both particles and macroscopic objects)
6. DM with gravitational interactions only
7. DM that we don't yet know about / for which we don't have a theory

RF/NF-related discussion points

CF-related discussion points

TF-related discussion points

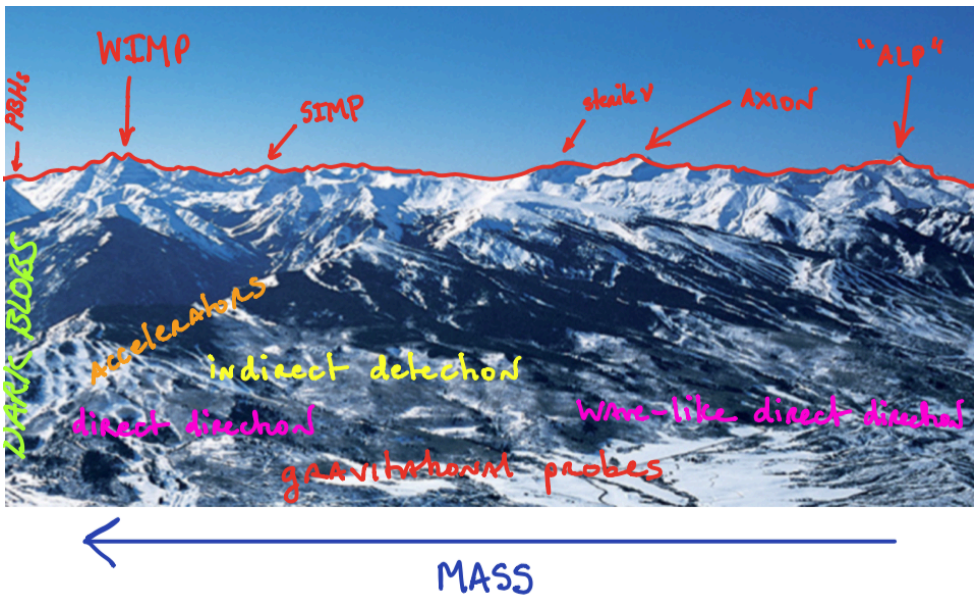
Panelists to be asked first: Susan Gardner, Hai-Bo Yu
We know dark matter is there, but it may not interact with the standard model other than through gravity. What can we learn in this case?

- "What have we missed in our considerations up to date?"
- Gravitational waves, diffuse GW background, compact object populations - all speak toward aspects of DM models
- Use GW to test models of leptogenesis but also DM/hidden sector particles inducing phase transitions to extended dark sector
- DM capture by neutron star leads to black hole development? Population studies could inform
- matter/power spectrum from cosmic probes, can tease out velocity distributions for example
- Gravitational lensing signatures

Big picture

Panelists to be asked first: Susan Gardner
During the meetings before the Snowmass break, we have thought of preparing a "big picture" graphics to represent the breadth of DM experiments/theoretical directions. This is what we came up with (note that it also looks a bit like this figure: https://indico.fnal.gov/event/22915/). What are your thoughts?

(follow-up for whitepaper: could you help us by taking responsibility to put together such a picture in the next 2-3 weeks?)



How can (and should) we encourage complementarity between experiment/theory/instrumentation (beyond experimental method complementarity)?

- Less about “complementarity” and more “fruitful exchange of ideas”

What is the role of small experiments in DM discovery and complementarity? Should the role be emphasized?

- Can be used as drivers to justify the next bigger experiment while they push DM science/discovery forward
- Can be used to justify development/testing of new technology
- DM could be used as a case study to show how these small experiments can be fruitful and informative for a physics search as a whole
- Not the job of snowmass to prioritize, but we can emphasize the utilization to the rest of the community as a fruitful path forward

Is there a point when we have “dug deep” enough? Can we search too far?

- At some point perhaps the sight of the goal post is missing. After much exclusion, the theory could become less motivated.

Overarching DM strategy/plan?

- “Drill deep, prospect far” isn’t infinite but could show guiding strategy

What is the purpose of the complementarity write-up. Summarize the complementarity OR outline the strategy for DM, what are the clear goals and requests from the community?

- Lindley:
    - Need a mixture of scale of experiment and supporting theory
    - Where is the best motivation? How do astrophysics/cosmology confine our models?
    - Focus complementarity on goals a little less broad
- Hugh:
    - DM is THE goal for particle physics in the next decade and we have a strategy

    - Convince community that we have a path we're following to cover this intimidating but exciting region of parameter space
- Audience (Dan):
    - Ultimate goal = full story of DM detection but also how it plays into full understanding of particle physics / big bang / etc
    - It's the community as a whole that will make progress on this front, not just one frontier
- Natalia:
    - Strategy: cast a wide discovery net and then later figure out how to construct story. Is this a reliable strategy considering complementarity? Maybe requires more forethought.
    - A wider net provides a higher probability of detection
    - Maybe better framing = more detection abilities implies more ways to understand it
- Audience (Prisca)
    - Don't promise too much in terms of delivery
- Audience
    - Valuable to create common vernacular between different domains
        - How can results be compared / plotted together, what cannot be compared directly
    - Deliverable = communication mechanisms between different DM communities
    - Strategy beyond just exploring all of parameter space - want to cross frontiers