Snowmass 2021: Dark matter at colliders

Caterina Doglioni (Lund University)
Liantao Wang (University of Chicago)
Energy Frontier Topical Group convenors (EF10)

2020/06/18 - Bi-weekly meeting

Snowmass topics #1: Testing (simple) WIMP Models

1. **Electroweak multiplet.**
   a. Electroweak multiplet: higgsino/wino(minimal DM). Mediator W/Z/h.
   b. Target: TeV-scale DM masses, motivated by relic density

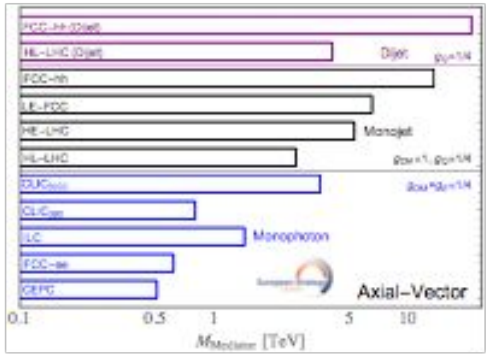
2. **Simplified mediator models.**
   a. S-channel and t-channel mediators. Well established benchmarks for LHC.
   b. Target: > GeV-scale DM masses, simple benchmarks for comparisons

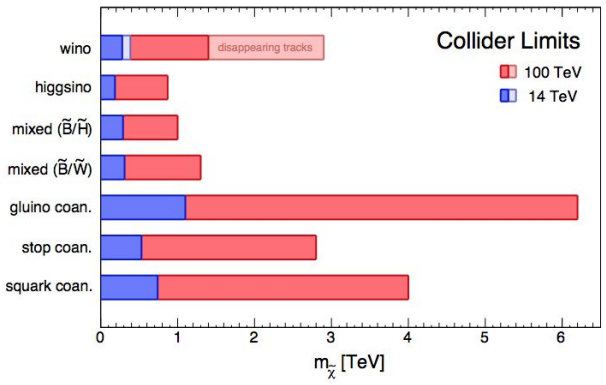
3. **Higgs portal**
   a. Well motivated coupling between SM to the dark world.
   b. Target: > GeV-scale DM masses

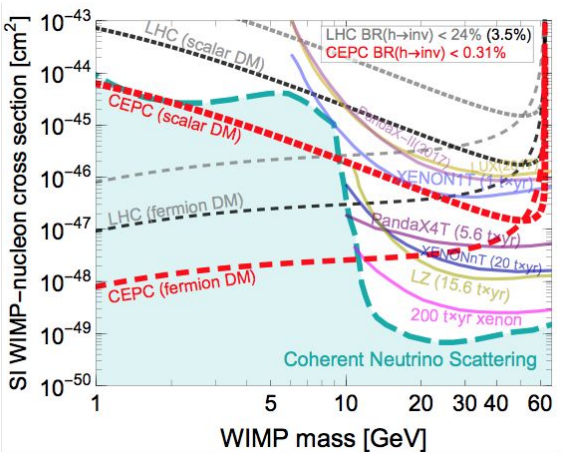
Testing Simple WIMP Models: Results

A number of results are available for simple WIMP-like models

https://arxiv.org/abs/1910.11775







Questions:

- Any obvious case missing?
- What kind of refinement of analysis/projections are needed?
- What are the challenges for controlling systematic uncertainties, trigger/detector/machine design?

Current status: synergies

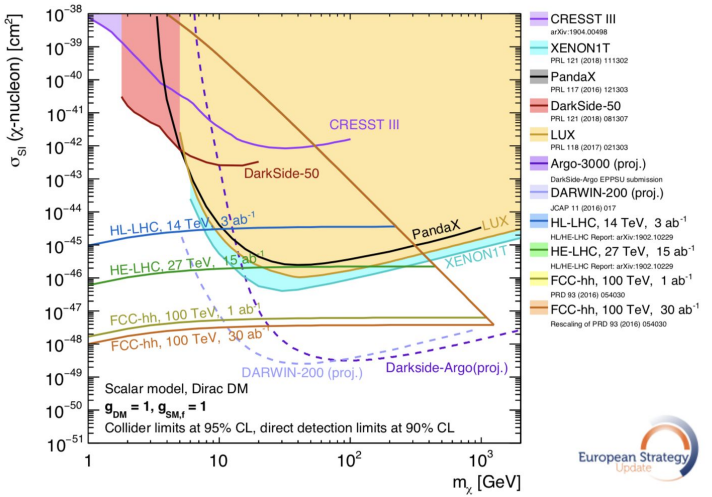
Work resulting from European Strategy from BSM DM@colliders subgroup:

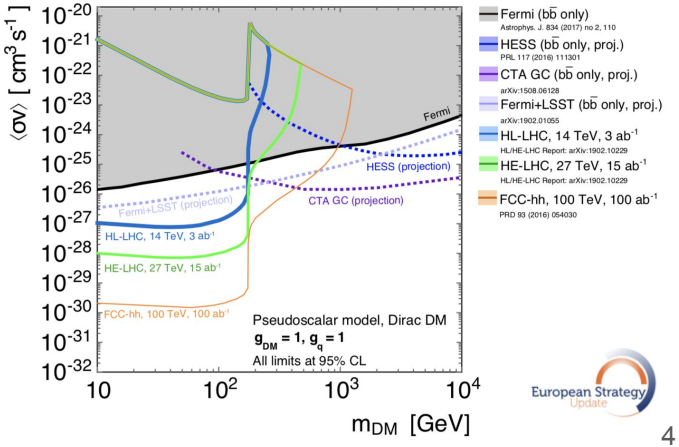
- plots including collider / direct / indirect detection, using a simple model scenario (pseudo/scalar with o(1) couplings)

Dark matter chapter conclusions (p of Briefing Book) emphasized synergies:

- What can we learn from
  - Dark sector (non-collider) experiments, Feebly Interacting DM
  - Astrophysics and nuclear physics
- How can we work together towards the same physics goals
  - In collaboration with **theory**
  - in terms of **instrumentation & computing**

http://cds.cern.ch/record/2691414/files/Briefing_Book_Final.pdf





Summary of pre-meeting discussions

Discussion notes and transcript for kick-off can be found at this link

- Wish to update summary plots of WIMP/non-WIMP with more recent results
  a. Joint work with EF09 / RP6
  b. Will cooperate with LHC Dark Matter and Long Lived Particles Working Group
- Wish to move away from “fixed coupling” plot for a bigger picture on simplified models (additional coverage of the phase space)
- Wish to connect vector models and dark photon models

Note: simplified models are just a part of our Snowmass work that helps developing a representative *big picture* set where we can highlight different aspects, but other more complete models are integral part of that big picture as well!

Synergies with other EF groups/frontiers

1. Astro/Cosmology (CF, **liaison Caterina Doglioni**).
2. DM models (TF)
3. Future colliders (AF)
4. Direct detection (Underground Facilities)
5. Small exp, Dark sector at Low energies (RF, in particular RF06)
6. Triggering, systematics… Instrumentation and computation frontiers
7. Within EF:
    a. EF01/02: Higgs portal
    b. EF08: SUSY models
    c. EF09: dark sector, LLP.
    d. MC task force

Our focus: MET+X searches, dark matter interpretation of models/searches, placing collider limits in context w/other experiments

Will coordinate and liaise with other frontiers and groups (stay tuned for meeting on LLP with EF09/RF06).

An idea to be discussed in future meetings

High Energy Physics - Phenomenology

[Submitted on 7 May 2013 (v1), last revised 3 Jul 2015 (this version, v2)]

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

Daniel Bauer, James Buckley, Matthew Cahill-Rowley, Randel Cotta, Alex Drlica-Wagner, Jonathan L. Feng, Stefan Funk, JoAnne Hewett, Dan Hooper, Ahmed Ismail, Manoj Kaplinghat, Alexander Kusenko, Konstantin Matchev, Daniel McKinsey, Tom Rizzo, William Shepherd, Tim M.P. Tait, Alexander M. Wijangco, Matthew Wood

In this report we summarize the many dark matter searches currently being pursued through four complementary approaches: direct detection, indirect detection, collider experiments, and astrophysical probes. The essential features of broad classes of experiments are described, each with their own strengths and weaknesses. The complementarity of the different dark matter searches is discussed qualitatively and illustrated quantitatively in two simple theoretical frameworks. Our primary conclusion is that the diversity of possible dark matter candidates requires a balanced program drawing from all four approaches.

Comments: Report prepared for the Community Summer Study (Snowmass) 2013, on behalf of Cosmic Frontier Working Groups 1-4 (CF1: WIMP Dark Matter Direct Detection, CF2: WIMP Dark Matter Indirect Detection, CF3: Non-WIMP Dark Matter, and CF4: Dark Matter Complementarity); published version

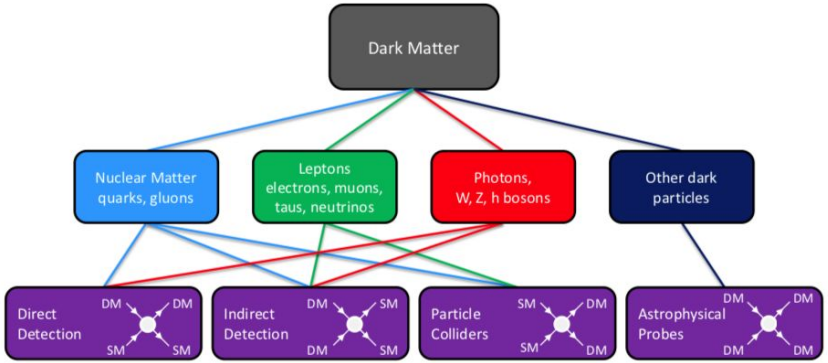
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; Cosmology and Nongalactic Astrophysics (astro-ph.CO); High Energy Astrophysical Phenomena (astro-ph.HE); Instrumentation and Methods for Astrophysics (astro-ph.IM); High Energy Physics - Experiment (hep-ex)

Journal reference: Phys. Dark Univ. vol. 7-8 (2015) 16-23

DOI: 10.1016/j.dark.2015.04.001

Cite as: arXiv:1305.1605 **[hep-ph]**

(or arXiv:1305.1605v2 **[hep-ph]** for this version)



Many updates, e.g. a new "box" for accelerator-based DM searches (RF06/EF05) / large progress in all other probes

Is there an interest in pursuing an update of this Snowmass2013 paper?
Will coordinate and liaise with other frontiers and groups

Coming up next

Initial focus: broadly agree on benchmarks to study and why → focused questions
- need input from theory/experiments/other Topical Groups & frontiers

Ongoing goal: offer a discussion platform for ongoing studies
Overall goal: propose and answer focused questions with studies on DM benchmarks

EF 10 **Bi-weekly meetings** with the community are focusing on **more specific topics.**

Every other Thursday, 12:00 -1 pm (US Eastern time).
Next meeting: July 2nd
Topics: Follow-up on Wino/Higgsino models

For most up to date info, see our webpage and slack channel

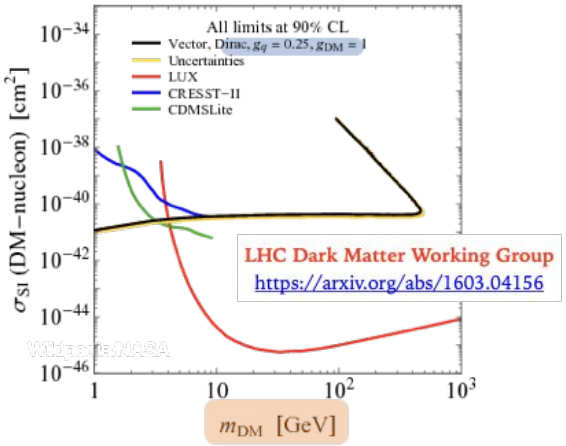
Energy frontier workshop: TBC in July, 2020
Joint meeting on LLP and DM interpretations: tentatively July 16-17

Backup slides

See summary at kick-off meeting - Notes can be found [at this link]

Status of DM@collider from the European Strategy

- European Strategy Update prompted conceptual design studies for HL-LHC and future collider proposals including DM/invisible particle signatures
- DM@colliders **focused on WIMP scenarios**
  - Full list of inputs to European Strategy is here: https://indico.cern.ch/event/765096/contributions/
  - Benchmark scenarios covered:
    - **SUSY Wino/Higgsino**
    - **Vector/scalar mediators with o(1) couplings** (DM Forum / WG, Phys. Dark Univ. 26 (2019) 100371)
    - **Higgs portal**
  - List of *European Strategy Big Questions* in backup slides
- Emphasis on **Synergies** within the Dark Matter community



Snowmass EF10: building, expanding and innovating upon this work

Snowmass topics #2: going beyond WIMP

1. **Different DM masses and couplings** with respect to the WIMP
   a. E.g. strongly interacting DM; light DM (< GeV)

2. **Different portals** with respect to LHC simplified models:
   a. dark photon and generic dark scalar/pseudoscalar (including rare decays)

Questions:

- what are the most relevant benchmarks? To be decided together with EF09/RP06
- are we missing any new ideas?

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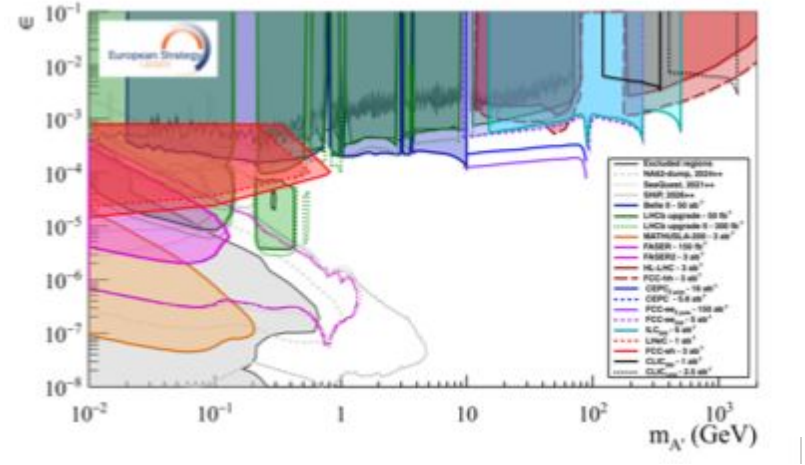
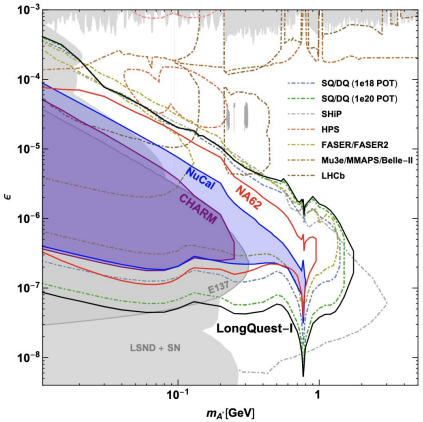


https://arxiv.org/abs/1908.07525



Join us and give input!

Webpage of EF 10: https://snowmass21.org/energy/dark_matter

Slack channel: #ef10-dark_matter under https://snowmass2021.slack.com

Email list: SNOWMASS-EF-10-DARK_MATTER@FNAL.GOV

Instructions on how to join: https://snowmass21.org/energy/start#communications

Give your input for our next discussion (same link will work for every meeting):

https://docs.google.com/document/d/1MWH4W1PAs4xKzWBJVzP3fBU8Z06aEsVvorGa2Frjljw/edit#

Expression of Interest form:

https://docs.google.com/forms/d/e/1FAIpQLSeFRaT5iUx4GYrypEiM-T6VId1b8y8Isqaruk714Yomw-9mOQ/viewform?usp=sf_link