

Snowmass: Dark matter at colliders

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2020/04/28 - DMWG meeting

The Snowmass process - <https://snowmass21.org>

Goal:

*The Snowmass Process is organized by the Division of Particles and Fields (DPF) of the American Physical Society. Snowmass is an opportunity for the entire HEP community to come together to **identify and document a vision for the future of particle physics in the U.S. and its international partners.***

Organization:

LHC = **Energy Frontier** (EF), but many other Frontiers, e.g. **Cosmic Frontier, Underground Frontier...**
Each Frontier has Topical Groups on a given topic with 2 conveners, e.g. EF10 = Dark Matter at Colliders

How to get involved:

Mailing list, Slack channels, upcoming meetings: see & click on first backup slide

Current call for Letters of Interest and Papers:

- <https://snowmass21.org/loi>

- <https://snowmass21.org/submissions/start>

There may be other more informal ways to get involved...stay tuned.

Physics plan in the making: what to cover?

Keep testing the WIMP paradigm, SUSY and generic models

- Continued exploration at HL-LHC
- Future colliders:
 - hadron colliders: 100(-ish) TeV
 - lepton colliders: exotic decays, higher energy lepton collider
 - lepton-hadron colliders

Put results into context of direct/indirect detection but also beyond-colliders & astro

- Liaising with other frontiers will be necessary/interesting! E.g. if they ask for plot updates...

We could also beyond the available results

- We could see what colliders can do on light dark matter (or dark sector particles)
- We could add new “non-standard” benchmarks: e.g. SIMPs, ALPs

Topical group EF10: tentative logistical plan

First stage: EF10 facilitates understanding of existing results to build on

First meeting (mid-May, date TBC)

- Overview of European Strategy work
- Discussion on community feedback: e.g. what would you like to add? What would you like to see done differently?
- Discuss call for broad community input (LoI, white papers)
 - Forward LOI invitation and talk to groups & initiatives, e.g. LHC Dark Matter WG, [iDMEu](#)

At a later date: EF10 provides a forum for the community to present new / work-in-progress results towards the final Snowmass workshop / whitepapers

→ How can we best interact with the Dark Matter Working Group?

Backup slides

Snowmass: how to get involved (and you don't need to be from the US to contribute!)

Starting point: <https://snowmass21.org/start>

Slack: <https://snowmass2021.slack.com/>

- There is a catch-all #dark_matter channel, our channel is #ef10-darkmatter
- Feel free to DM Caterina for guidance on what channels to subscribe if you're interested in dark matter (there are many! But generally they follow the Frontier-TG nomenclature e.g. #ef10-darkmatter)

Mailing lists

- General for energy frontier: SNOWMASS-ENERGY-FRONTIER-GROUP@fnal.gov
- Dark matter at colliders: SNOWMASS-EF-10-DARK_MATTER@FNAL.GOV

Calendar for meetings: [Link](#)

Current status of physics cases

Large body of work available:

- European Strategy studies asked for conceptual design studies for HL-LHC and future collider proposals, focusing on WIMP scenarios
 - Full list of proposals is here: <https://indico.cern.ch/event/765096/contributions/>
 - Benchmark scenarios covered: **SUSY Wino/Higgsino, Vector/scalar mediators with $o(1)$ couplings** (Dark Matter Forum / WG, [Phys. Dark Univ. 26 \(2019\) 100371](#)), **Higgs portal**
 - List of *European Strategy Big Questions* in backup slides
 - CD had an equivalent role as Snowmass subconvener for BSM subgroup DM @ colliders and as “liaison” to Dark Matter and Dark Sector WG
 - Work spanned a few months, can still contact groups for updates of studies if needed
- Emphasis on **Synergies** within the Dark Matter community
 - liaising with other WGs and frontiers, also backup slides

Inter-frontier connections of Dark matter study

Caterina Doglioni (Lund University), Liantao Wang (University of Chicago),
Conveners of Energy Frontier Subgroup 10 “*Dark Matter at colliders*” (EF10)

- Many experimental probes and observations are necessary for a comprehensive search for dark matter, given our ignorance of what DM is:
 - Examples: High energy Collider, direct and indirect detection, intensity frontier for rare processes, neutrino detectors, fixed-target experiment, table top experiments, cosmic ray, CMB, 21 cm, gravitational wave detectors...
 - New theory and experimental ideas continue to emerge
- Synergies crucial for a successful program
 - Connections with **all** frontiers identified!
- How can we efficiently communicate and exchange ideas throughout the Snowmass process?

Synergies within EF

Higgs (EF01/02): Higgs portal models

Top (EF03): Dark matter + heavy flavor (SUSY/generic scalar models favouring 3rd generation)

General exploration (EF09)

- Generic searches for new physics (New resonances, MET excesses)
- Dark sectors and long lived scenarios (no 1:1 mapping signature/model)

Model-specific exploration (EF08): SUSY and SUSY-like WIMP scenarios

EW/QCD & MC production (EF04-06)

- Precision backgrounds for MET+X searches (including PDFs)
- In general, precision backgrounds for high-background searches

Synergies with other frontiers

Underground frontier (description on the wiki is missing, so this is a guess)

- Direct detection complementarity, but also studies with novel materials

Accelerator frontier

- Dark matter is a major physics goal for future accelerator planning, including lepton vs hadron, energy vs luminosity, etc.

Cosmic frontier (CF1: particle-like dark matter, CF2: wave-like DM, CF3: astrophysical probes)

- Indirect detection complementarity
- Astrophysics inputs

Synergies with other frontiers

Rare events and precision frontier (RF6: dark sector studies at low energy)

- Accelerator-produced DM
- Feebly interacting models

Theory frontier (CFX: BSM model building, Astroparticle physics & cosmology)

- Model-building, model parameters, relic density targets...

Instrumentation / computing frontier

- Generic searches with high-rate backgrounds, Higgs searches: triggering
- Systematics-dominated searches

Sources of studies

- Lepton collider studies
 - CEPC conceptual design report <https://arxiv.org/abs/1811.10545>
 - ILC physics studies <https://arxiv.org/pdf/1506.05992.pdf>
 - CLIC <https://arxiv.org/pdf/1812.06018.pdf>
 - Muon collider, 50-100 TeV lepton collider
- Hadron collider studies
 - FCC
 - HL-LHC

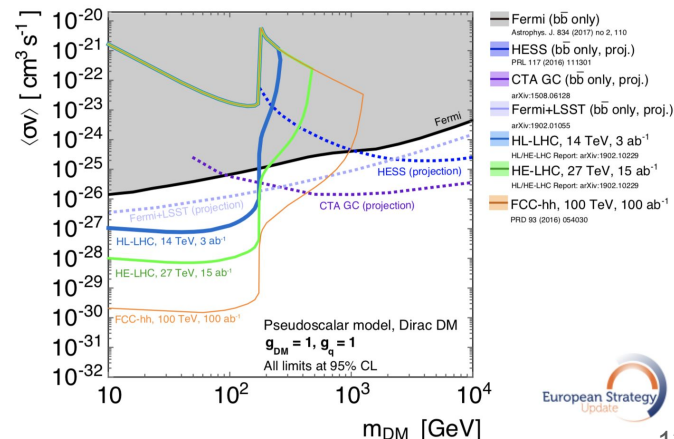
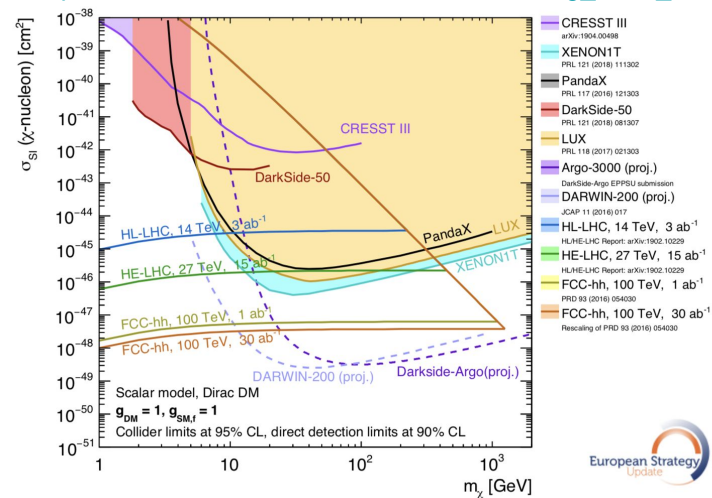
Current status: synergies

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

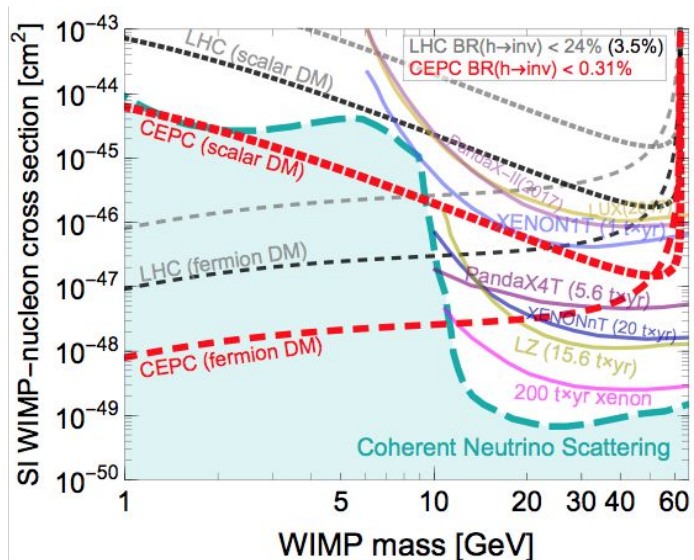
- plots including collider / direct / indirect detection, using a simple model scenario (pseudo/scalar with $o(1)$ couplings)

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

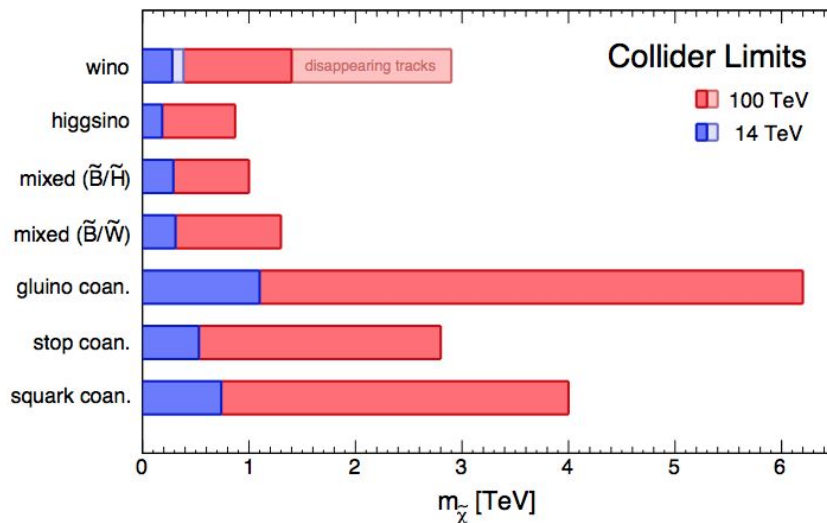
- What can we learn from
 - Dark sector (non-collider) experiments, Feebly Interacting DM
 - Astrophysics and nuclear physics
- How can we work together towards the same physics goals
 - In collaboration with **theory**
 - in terms of **instrumentation & computing**



Current status: benchmarks

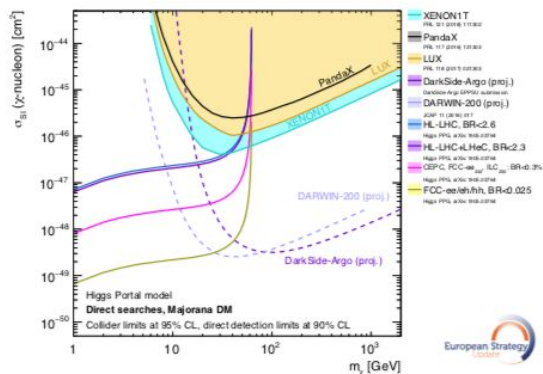


Higgs portal dark matter from Higgs rare decay



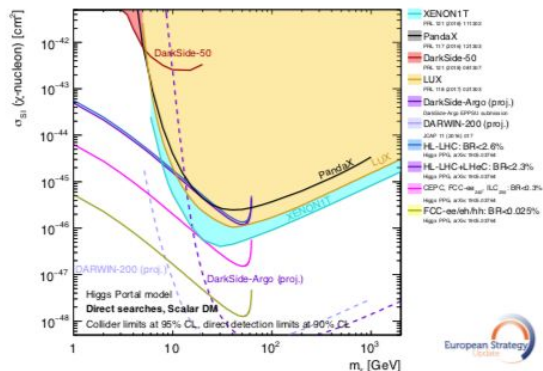
SUSY WIMP

Current status: benchmarks



Higgs portal dark matter from Higgs rare decay

<https://arxiv.org/pdf/1910.11775.pdf>



Big questions from European Strategy related to DM

What cases of thermal-relic particles are still unprobed and can be fully covered by future collider searches?

To what extent can current or future accelerators probe feebly-interacting sectors?

A subconvenor view of ESG work (community view needed)

On **benchmarks**:

- Somewhat missing in terms of benchmark models:
 - Strongly interacting scenarios (SIMPs)
 - Long lived collider signatures beyond disappearing track
 - Connections to EF8 and EF9

On **comparison plots**:

- Having a single model/coupling is not representative and can be misleading
→ work ongoing in Dark Matter Working Group to improve those plots
- Can we solve the “can colliders go below 1 GeV WIMP” question?
- Note that there were many other comments that we could not take into account because of time constraints → we will contact those people again