RF6: Dark Sector Studies at High Intensities

https://snowmass21.org/rare/dark

Topic Conveners: Stefania Gori, Mike Williams

Sub-topics/sub-conveners:

1. Theory of dark sectors (Brian Batell, Philip Schuster)
2. Dark sectors at electron-positron colliders (Chris Hearty)
3. Dark sectors at fixed target / beam dump experiments (electron, positron, proton, and muon beams) (Gordan Krnjaic, Phil Harris, Natalia Toro)
4. Dark sectors at kaon factories (Babette Dobrich, Jure Zupan)
5. Low-mass dark sectors at energy-frontier facilities (cross-group with EF09 - BSM: More general explorations / EF10 - BSM: Dark Matter at colliders) (Phil Ilten)
6. Dark sectors at neutrino experiments (cross-group with NF03 - Neutrino physics - BSM) (Pilar Coloma, Lisa Koerner)
7. Other experimental opportunities

What is a Dark Sector?

- Set of new particles which do not experience the known forces.
- Weakly coupled to visible sector through a mediator or "portal".

Why Dark Sectors?

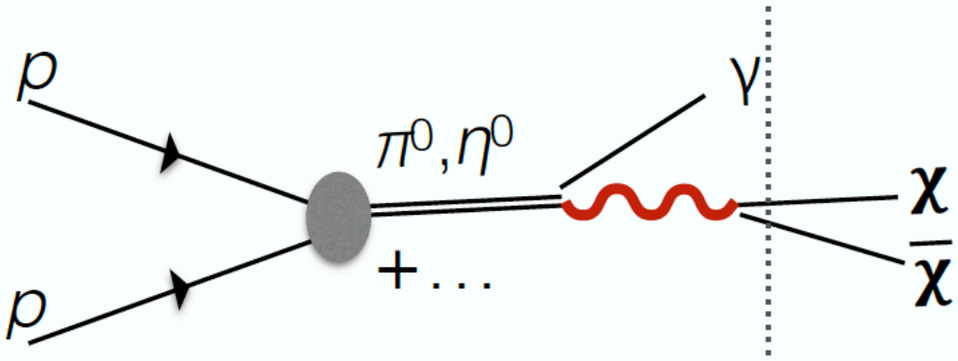
- Dark matter may reside in the dark sector. Simple (thermal) and novel cosmologies are possible.
- Dark sectors may play a role in addressing other puzzles, e.g., neutrino masses, matter-antimatter asymmetry, naturalness, …
- Experimental anomalies often interpreted in context of dark sectors.

Why high intensities?

- High intensities allow probes of weak portal couplings.
- Past/existing high intensity experiments already provide leading constraints.
- Great potential to discover dark sectors and discern their structure with new searches and experiments in the coming years.

Benchmark studies

- One natural way to organize benchmarks is according to final state signatures
- This scheme aligns well with the science case



"Once you get in to the dark sector, what do you look for?"

non-SM	SM	mixed
Dark Matter Production	**Portal-Mediator Decays to SM**	**Structure of the Dark Sector**
Producing stable particles that could be (all or part of) the Dark Matter	Systematically explore the minimal couplings of SM to dark sectors	There could be a rich sector of new physics under our noses

from talk by N. Toro, Dark Sectors and Light Long-Lived Particles cross frontier meeting

https://indico.fnal.gov/event/44030/

From N. Toro

Benchmarks in Final State x Portal Organization

	DM Production	Mediator Decay Via Portal	Structure of Dark Sector
Vector	*m_χ vs. y [$m_{A'}/m_\chi$=3,α_D=.5]* **$m_{A'}$ vs. y** [α_D=0.5, 3 m_χ values] m_χ vs.α_D [$m_{A'}/m_\chi$=3, y=y_{fo}] m_χ vs. m_A [α_D=0.5, y=y_{fo}] *Millicharge m vs. q*	$m_{A'}$ vs. ϵ [decay-mode agnostic] ***$m_{A'}$ vs. ϵ [decays]***	**iDM m_χ vs. y [$m_{A'}/m_\chi$=3,α_D=.5] (anom connection)** **SIMP-motivated cascades [slices TBD]** $U(1)_{B-L\,/\,\mu-\tau\,/\,B-3\tau}$ (DM or SM decays)
Scalar	m_χ vs. sinθ [**λ**=0, fix m_S/m_χ, g_D] (thermal target excluded 1512.04119, should still include) Note secluded DM relevance of S→SM of mediator searches	*m_S vs. sinθ* [**λ**=0] *m_S vs. sinθ* [**λ**=s.t. Br(H→ϕϕ ~10^{-2})]?	Dark Higgssstrahlung (w/vector) scalar SIMP models? Leptophilic/leptophobic dark Higgs?
Neutrino	e/μ/τ a la1709.07001?	*m_N vs. U_e* *m_N vs. U_μ* *m_N vs. U_τ* Think more about reasoanble flavor structures	Sterile neutrinos with new forces?
ALP	m_χ vs. fq/l [**λ**=0, fix m_a/m_χ, g_D] (thermal target excluded) What about f_γ, f_G?	*m_a vs. f_γ* *m_a vs. f_G* *m_a vs. f_q=f_l* (separate?) Think more about reasoanble coupling relations including $f_{W/Z}$	FV axion couplings

\+ Neutron portal? Hidden valleys (or are these out-of-scope?)? See e.g. 2003.02270

Bold = BRN benchmark, *italic=PBC benchmark.* others are new suggestions. Underline=CV benchmarks that were not used in BRN

Slide from Stefania Gori

RF6 “Big ideas” solicited papers

- Organization around science goals/questions.
- Arrange the breadth of RF6 science so that all the main techniques have a chance to shine.
- Span ≳95% of white-paper interests

1. Detect dark matter particle production (production reaction or through subsequent DM scattering), with a focus on exploring sensitivity to thermal DM interaction strengths.
Editors: Gordan Krnjaic, Natalia Toro — **Jan. 20, https://indico.fnal.gov/event/52857/**

2. Explore the structure of the dark sector by producing and detecting unstable dark particles: Minimal Portal Interactions.
Editors: Brian Batell, Chris Hearty —**Jan. 27, https://indico.fnal.gov/event/52858/**

3. New Flavors and Rich Structures in Dark Sectors.
Editors: Phil Harris, Philip Schuster, Jure Zupan — **Feb. 3, https://indico.fnal.gov/event/52859/**

4. Experiments/facilities/tools
Editors: Phil Ilten, Nhan Tran —**Feb. 10, https://indico.fnal.gov/event/52860/**

More details: https://docs.google.com/document/d/1R0O23wjGLxRzsc93a4pJlFn17yW9TCTq
(in our google drive folder, https://drive.google.com/drive/folders/1sMn1cWl2ddqzu46Yi4TcMIX7Cm2GUxO_)

Deadline: April 15

Areas of overlap, synergy, complementarity between NF03 and RF6

- Accelerator neutrino beam experiments are within the purview of both groups, but RF6 is emphasizing and exploring a wider variety of high intensity experiments (e.g., electron, muon, kaon, pion beams, missing energy/momentum, colliders, precision rare decays, …)

- One primary motivation guiding RF6 studies is dark matter:
  - Broader range of dark matter models under investigation
  - Closer connection with dark matter cosmological production targets
  - Less emphasis in RF6 on neutrino mass motivation, neutrino portal, neutrino-philic mediators, dark neutrinos, … and more emphasis on vector portal

- Distinct framings in motivations, approach, and scope:
  - NF03: what dark sector searches can we do with neutrino beam experiments? How might dark sectors impact neutrino physics?
  - RF6: what suite of experiments are needed to broadly test dark sectors and light dark matter?