Other accelerator-based BSM experiments

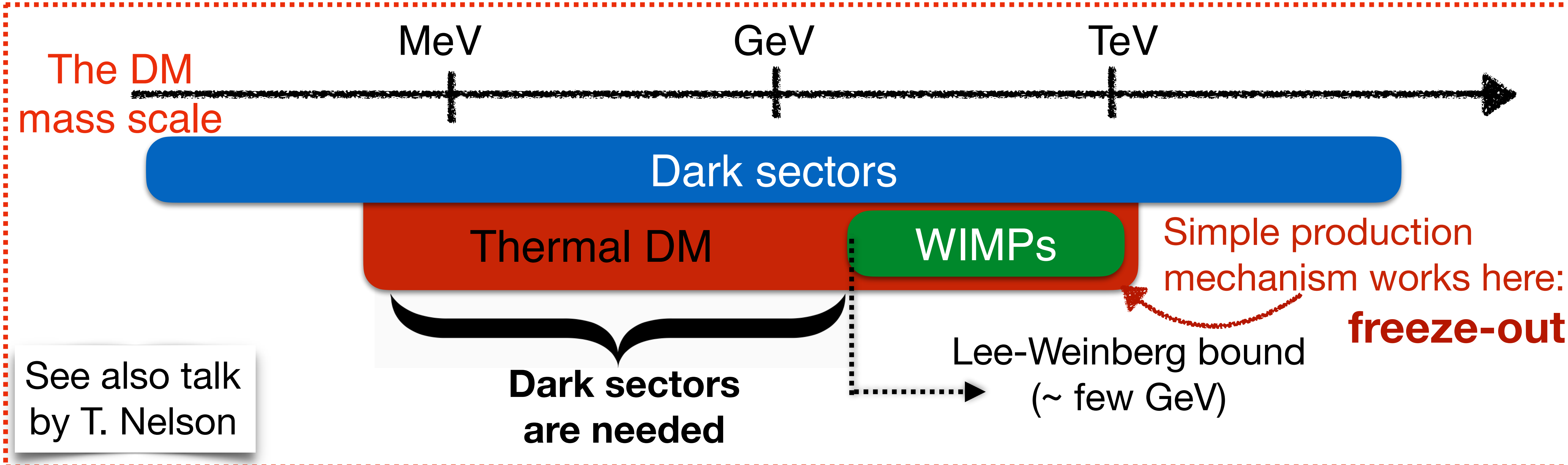
Stefania Gori
UC Santa Cruz

P5 Townhall meeting

Brookhaven

April 12, 2023

Dark Matter living in a dark sector



Dark Matter living in a dark sector

The DM mass scale

MeV GeV TeV

Dark sectors

Thermal DM

WIMPs

Simple production mechanism works here: **freeze-out**

Lee-Weinberg bound (~ few GeV)

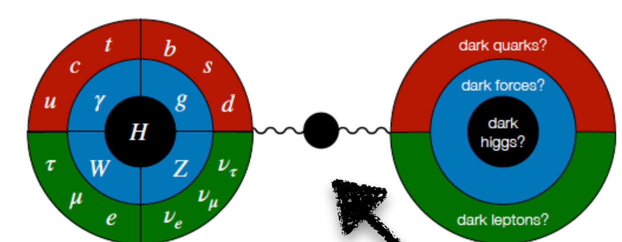
Dark sectors are needed

See also talk by T. Nelson

Beyond the DM motivation

Dark sectors are a generic feature of BSM theories

* Theories motivated by the hierarchy problem
* Theories that explain the baryon-antibaryon asymmetry
* Theories that address the strong CP problem
* Theories for the generation of neutrino masses



$\epsilon B^{\mu\nu} A'_{\mu\nu}$

$\kappa |H|^2 |S|^2$

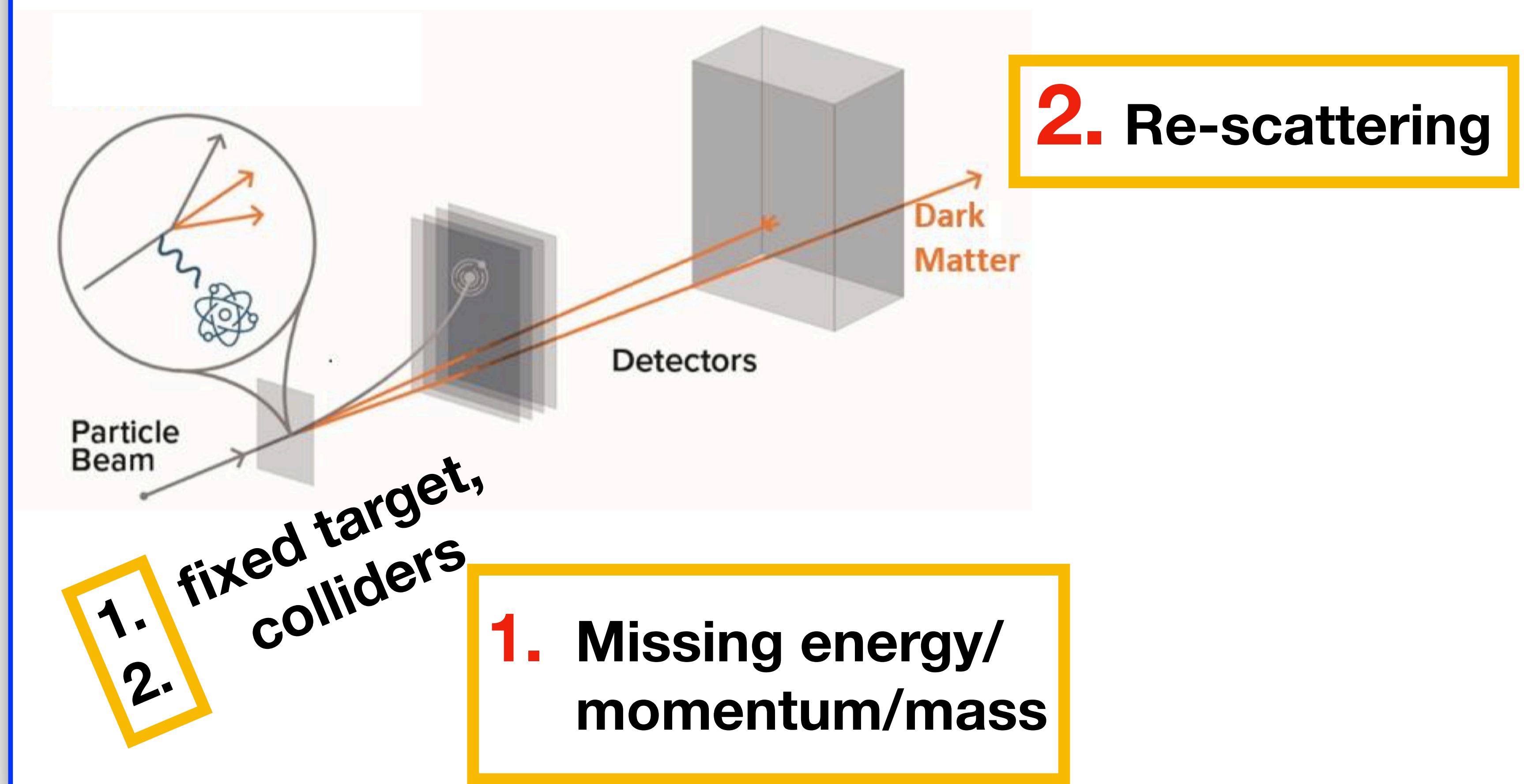
$y H L N$

$g_{a\gamma} \tilde{F}_{\mu\nu} F^{\mu\nu} a$

"mediator" particles

Search techniques for dark sectors at accelerators

Production of dark matter



The experimental techniques are only 3

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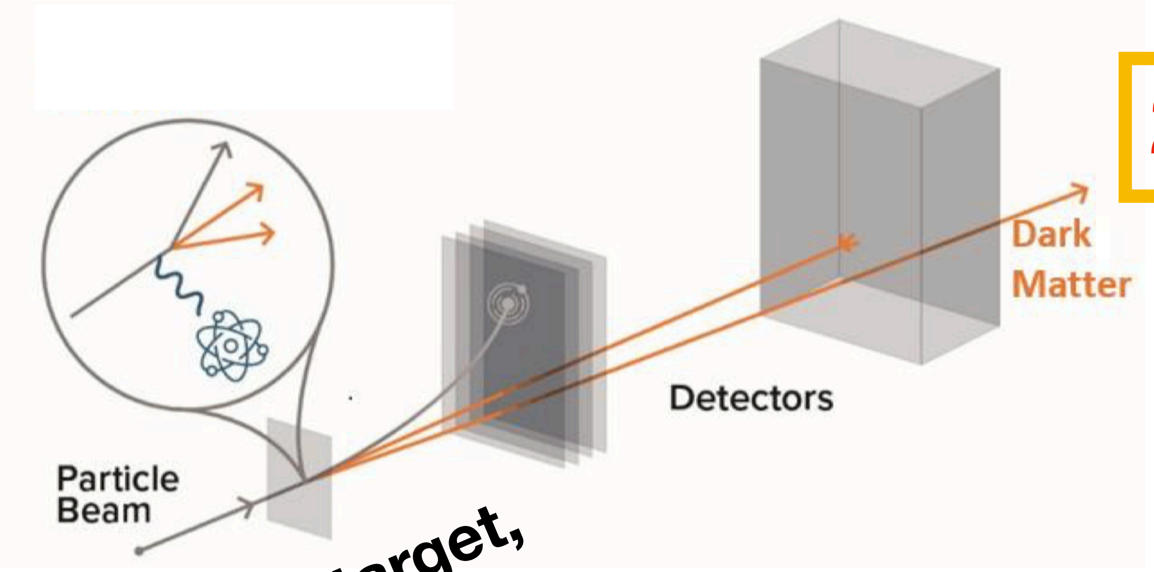


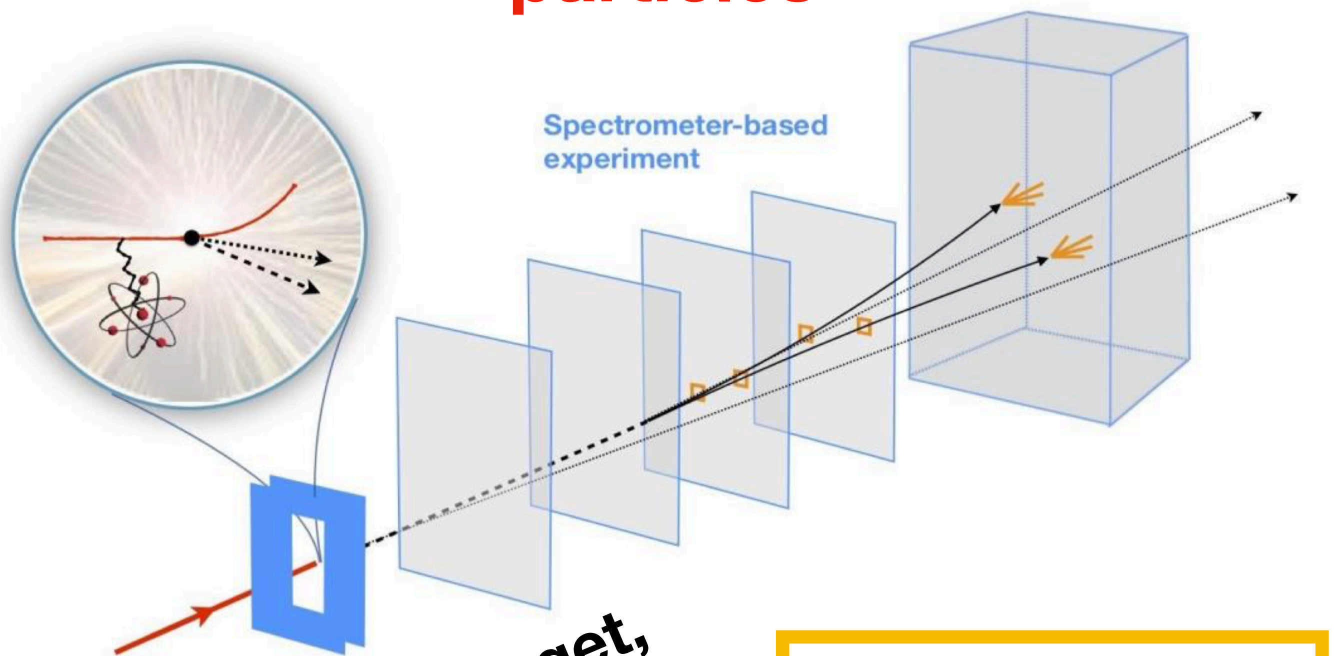
2. Re-scattering

1. fixed target,
2. colliders

1. Missing energy/
momentum/mass

The experimental techniques are only 3

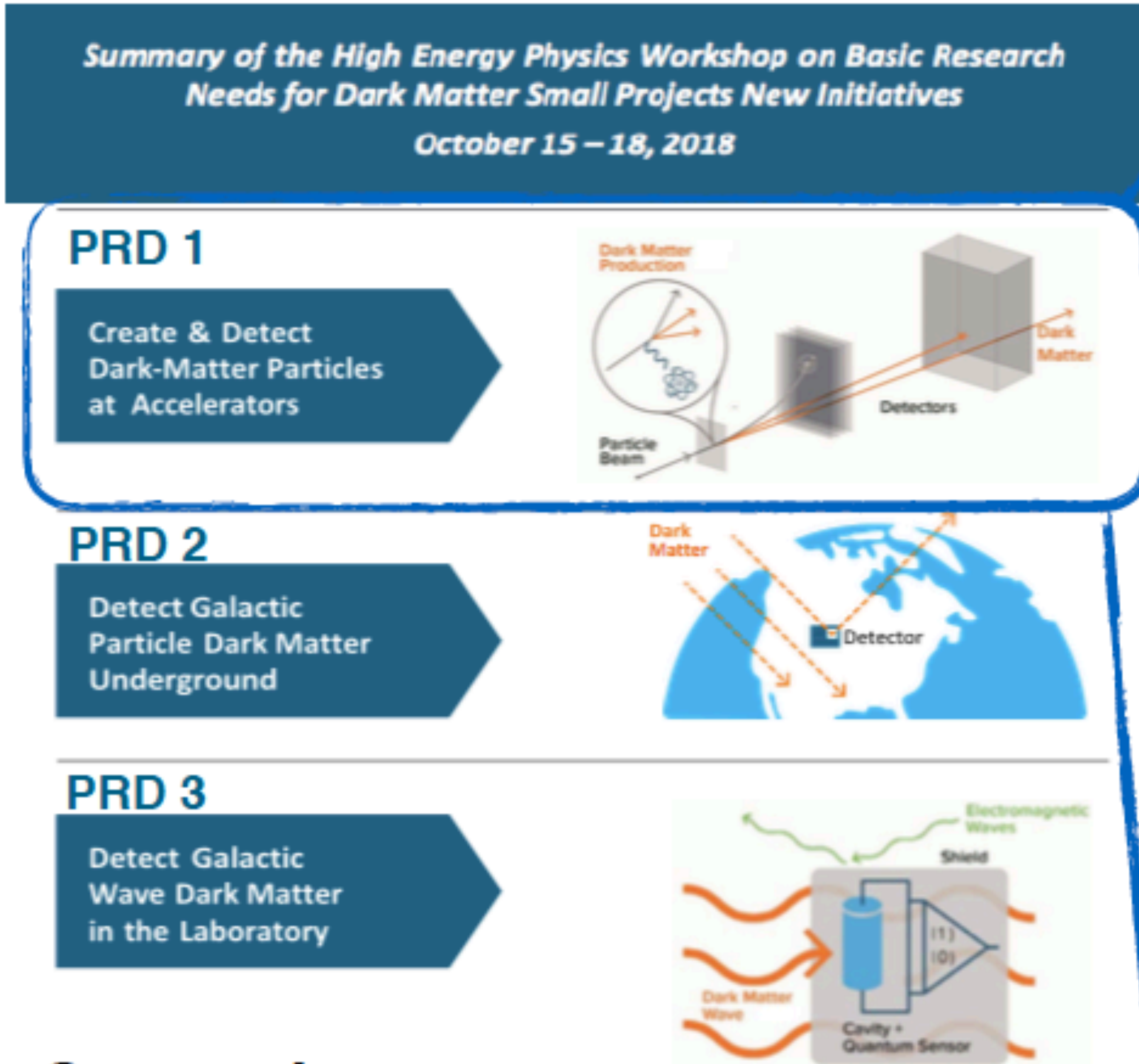
Production of unstable dark sector particles



1. fixed target,
2. colliders

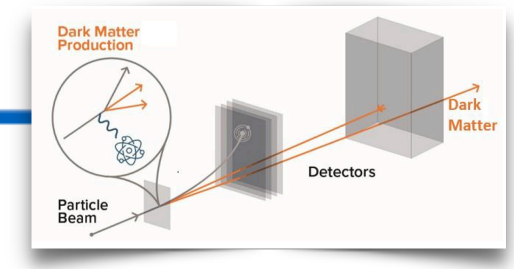
3. Visible decay products

DM New Initiatives (DMNI)



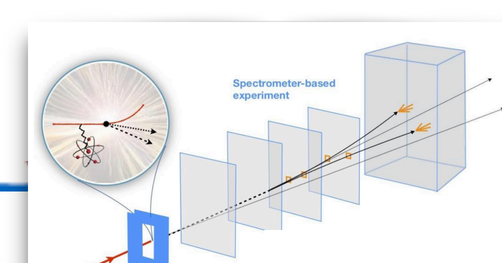
Success!

Experiments in all 3 PRDs received planning funds through 2019 FOA



Thrust 1 (near term):
Through 10- to 1000-fold improvements in sensitivity over current searches, use particle beams to explore interaction strengths singled out by thermal dark matter across the electron-to-proton mass range.
(CCM & LDMX got partial support)

Thrust 2 (near and long term):
Explore the structure of the dark sector by producing and detecting unstable dark particles.



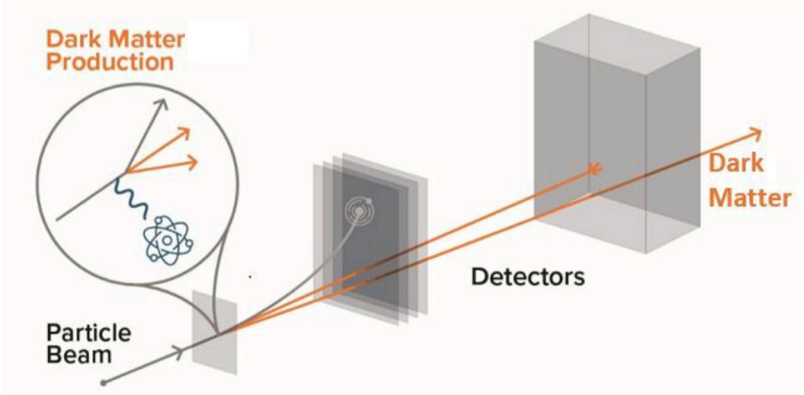
The physics goals (from Snowmass '21)

We (RF6) defined **three Big Ideas** each with associated ambitious —but achievable—goals for the next decade

1. Dark matter production at intensity-frontier experiments

Focus on exploring sensitivity to thermal DM interaction strengths.

https://arxiv.org/abs/2207.00597

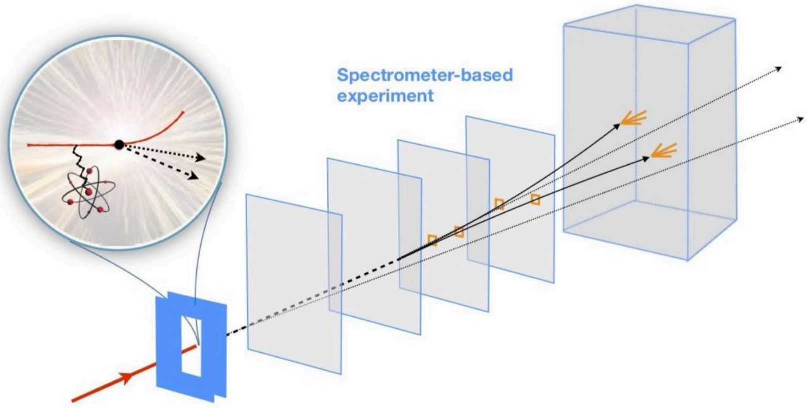


2. Exploring dark sector portals with intensity-frontier experiments

Focus on minimal portal interactions.

Prompt and long-lived mediators.

https://arxiv.org/abs/2207.06905



3. New flavors and rich structures of the dark sector at intensity-frontier experiments

Focus on beyond minimal models.

https://arxiv.org/pdf/2207.08990.pdf

Snowmass RF6 Report: SG, Williams et al., https://arxiv.org/pdf/2209.04671.pdf

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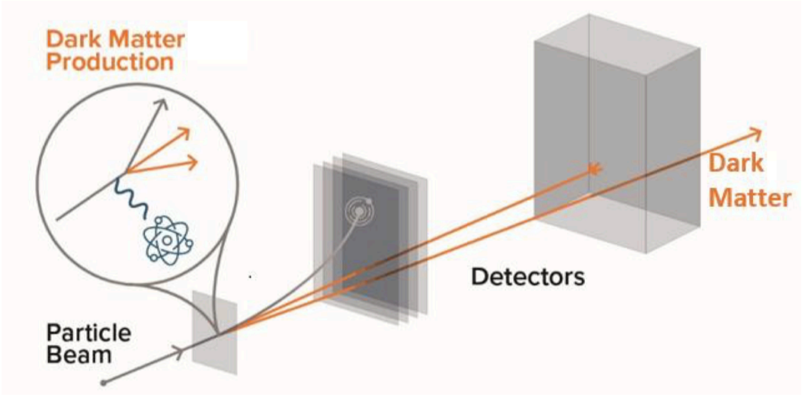

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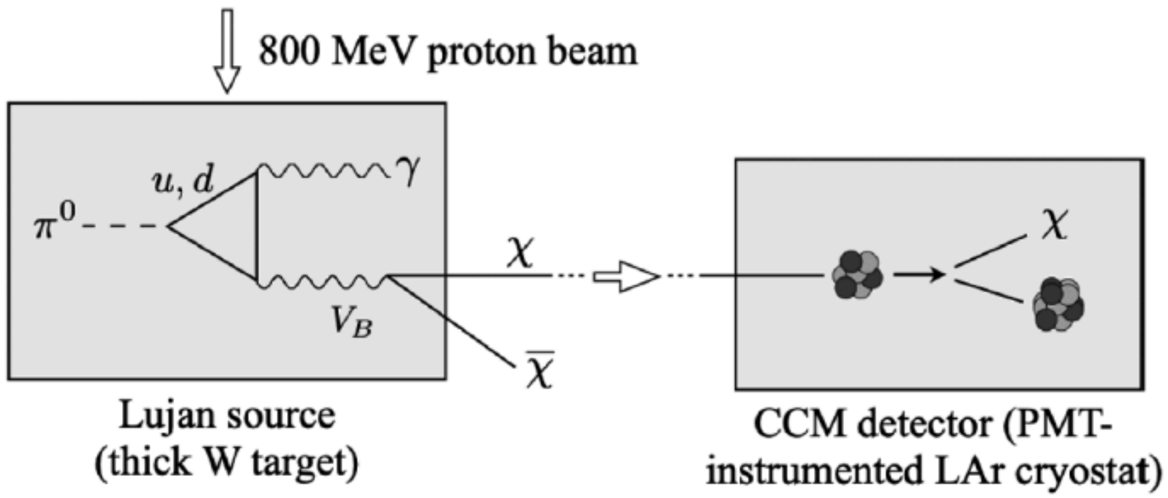
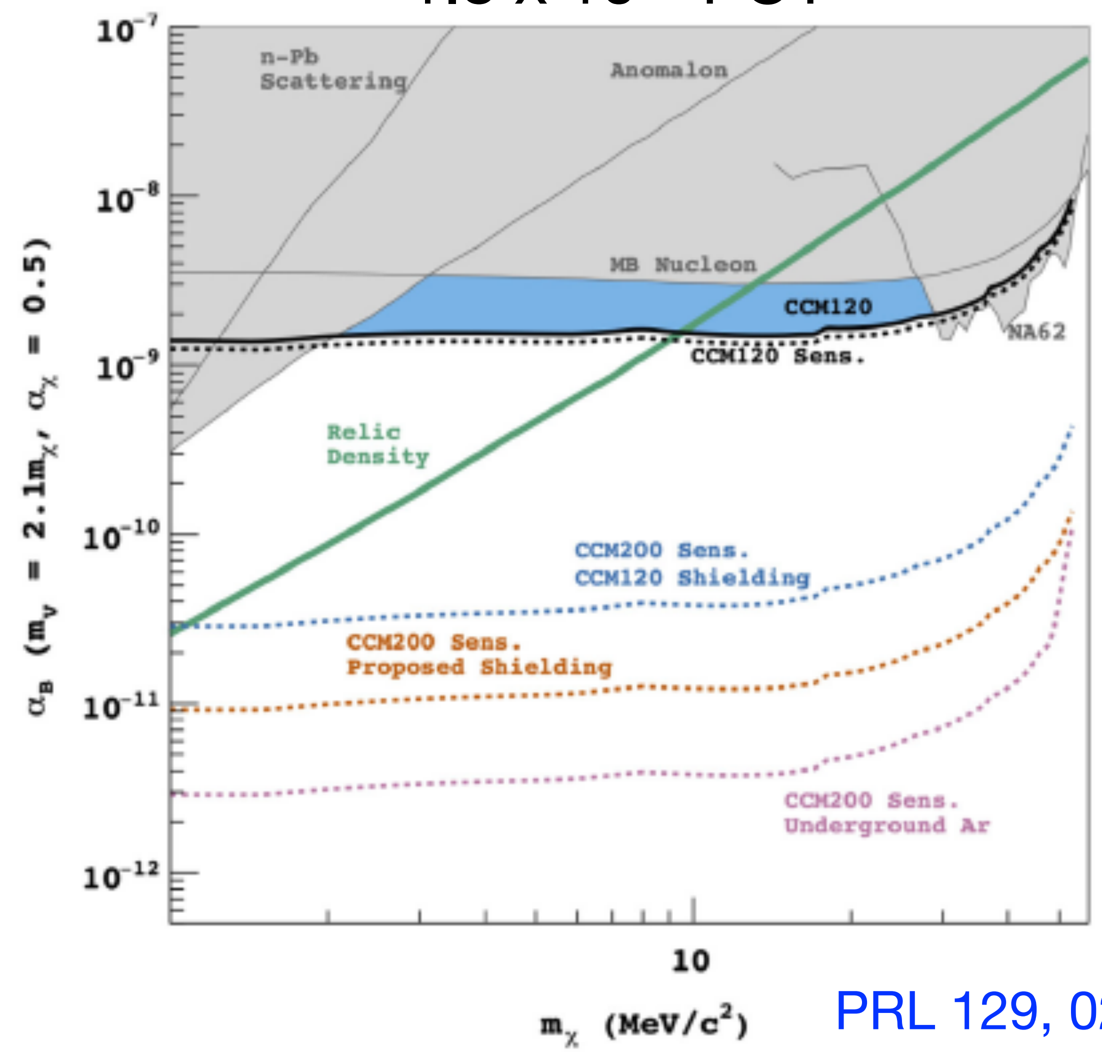
CCM, a DMNI success story

Coherent-CAPTAIN-Mills Liquid Argonne detector at Los Alamos



Leptophobic DM @ CCM120

1.8 x 10^{21} POT



PRL 129, 021801

LANL LDRD with DMNI funding.

Funded for another 3 years by the intensity program.

Upgrades: CCM200, 2.2 x 10^{22} POT. CCM scope expanded to inelastic DM, ALPs, and testing MiniBooNE anomaly via dark sector models.

Looking forward to new results!

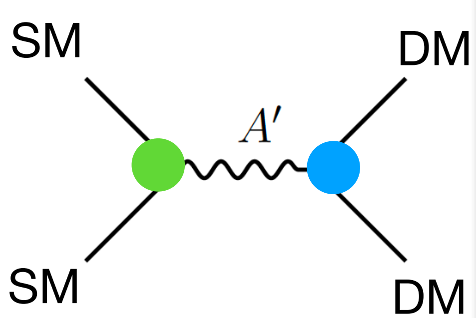
<u>Big idea 1:</u> thermal DM production

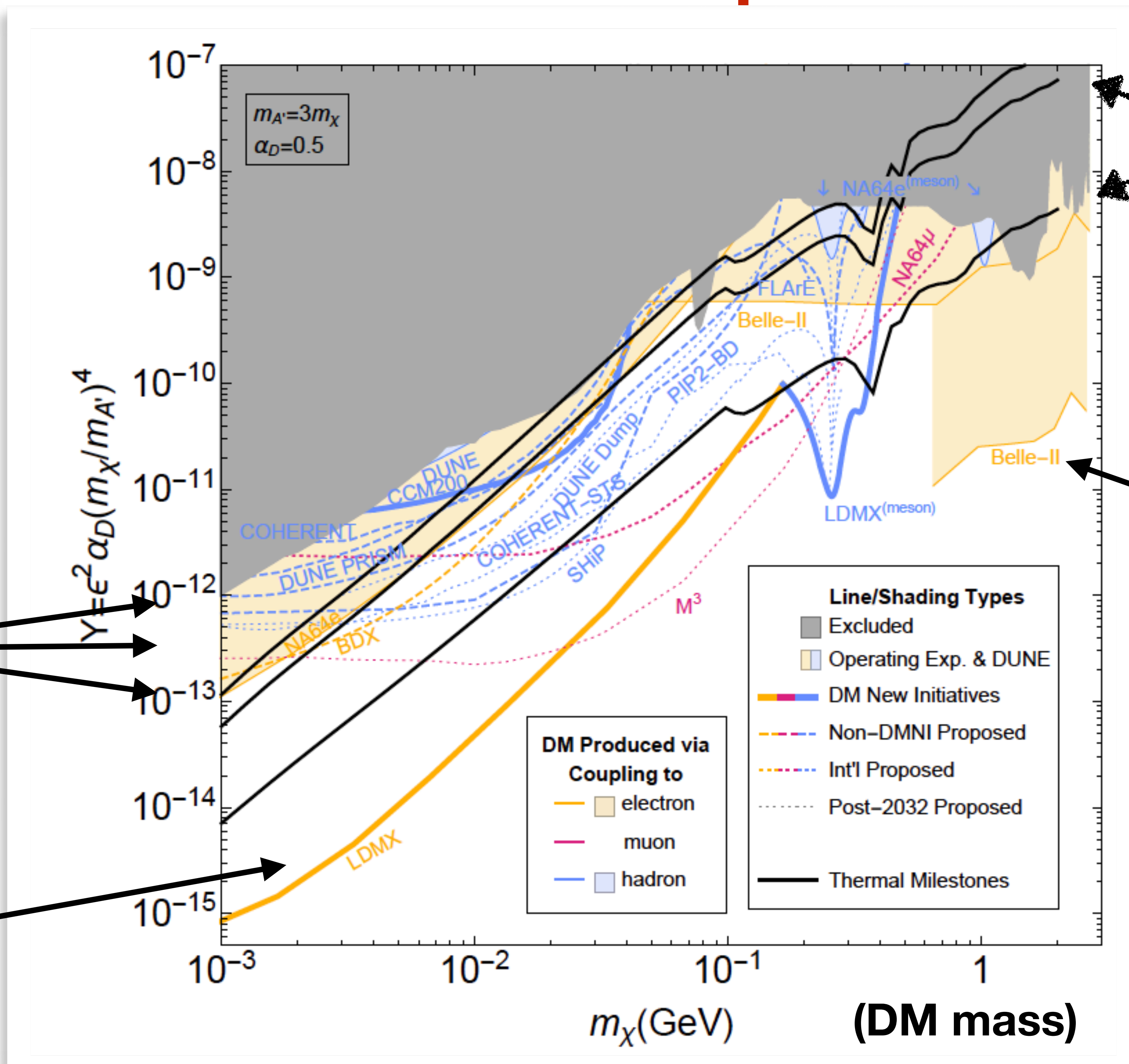
DM thermal milestones:

invisible dark photon

$\epsilon B^{\mu\nu} A'_{\mu\nu}$

A'→XX





(DM mass)

benchmarks for thermal DM

(1) Collider, mono-photon search (missing energy)

(2) Re-scattering

(1) Missing momentum

See talk by T. Nelson

DM thermal milestones:

invisible dark photon

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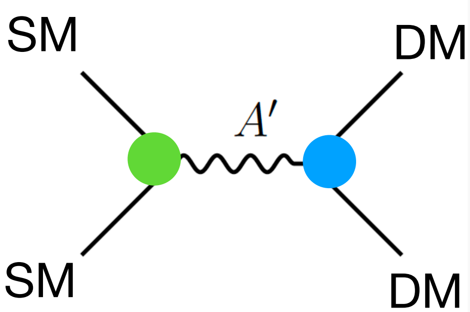

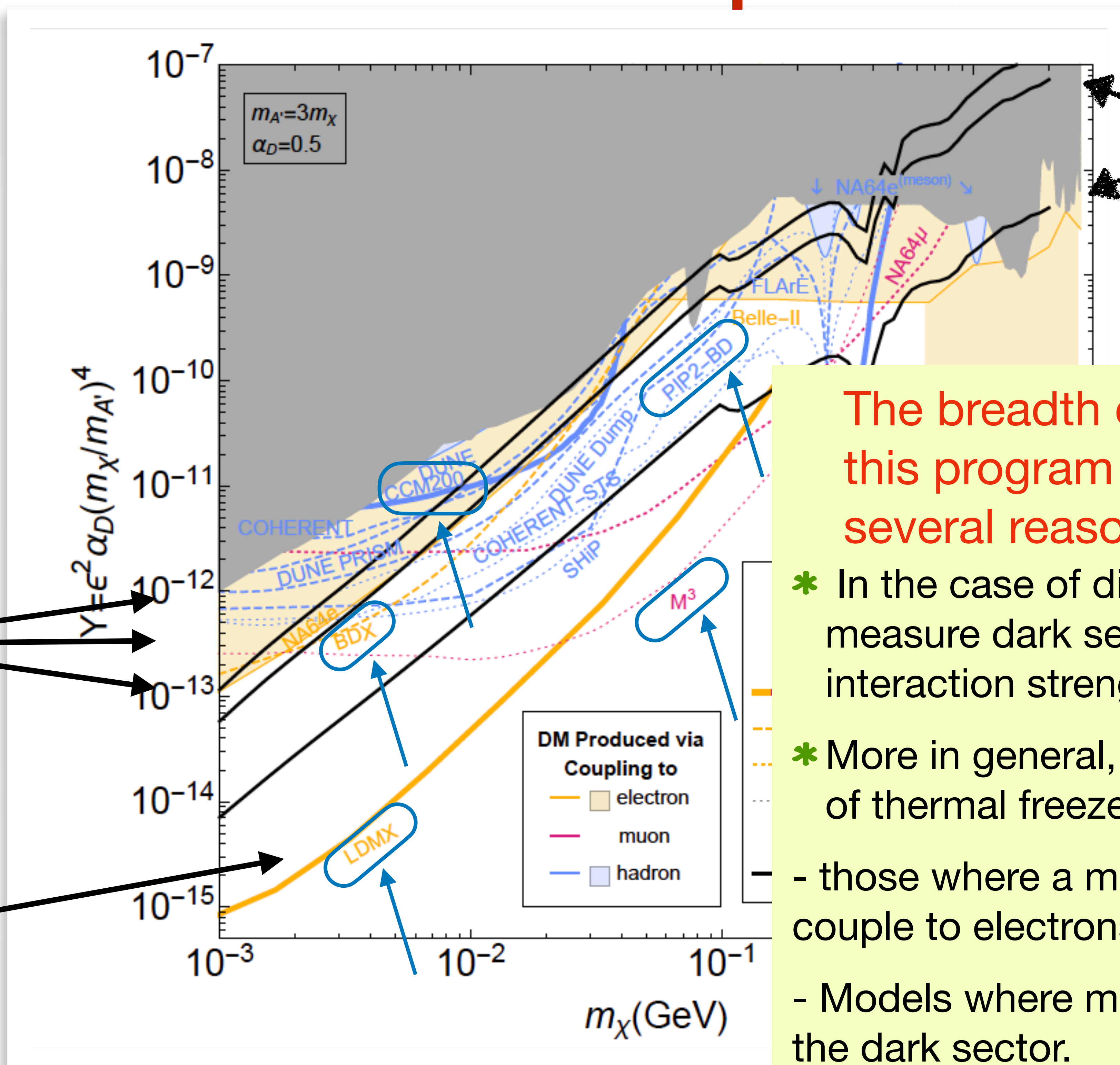

benchmarks for thermal DM

(2) Re-scattering

(1) Missing momentum

The breadth of ideas within this program is important for several reasons.

- In the case of discovery, the ability to measure dark sector masses and interaction strengths
- More in general, probe generalizations of thermal freeze-out, such as

- those where a mediator does not couple to electrons.

- Models where meta-stable particles in the dark sector.

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3. New flavors and rich structures of the dark sector at intensity-frontier experiments
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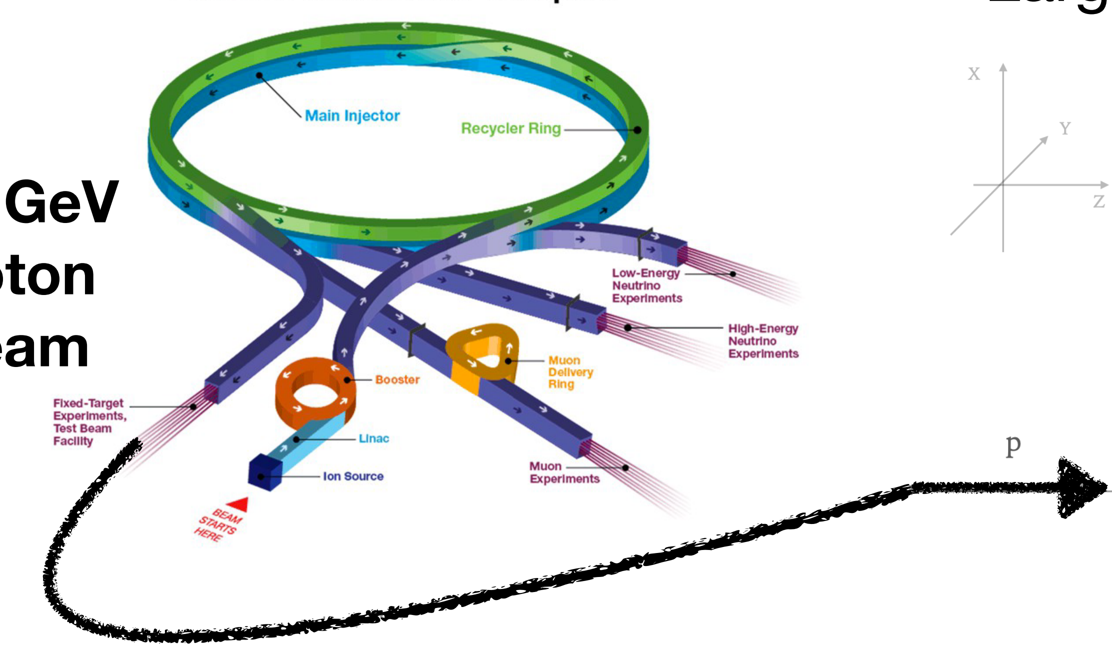
A generic feature is the appearance of long-lived particles

Snowmass RF6 Report: SG, Williams et al., https://arxiv.org/pdf/2209.04671.pdf

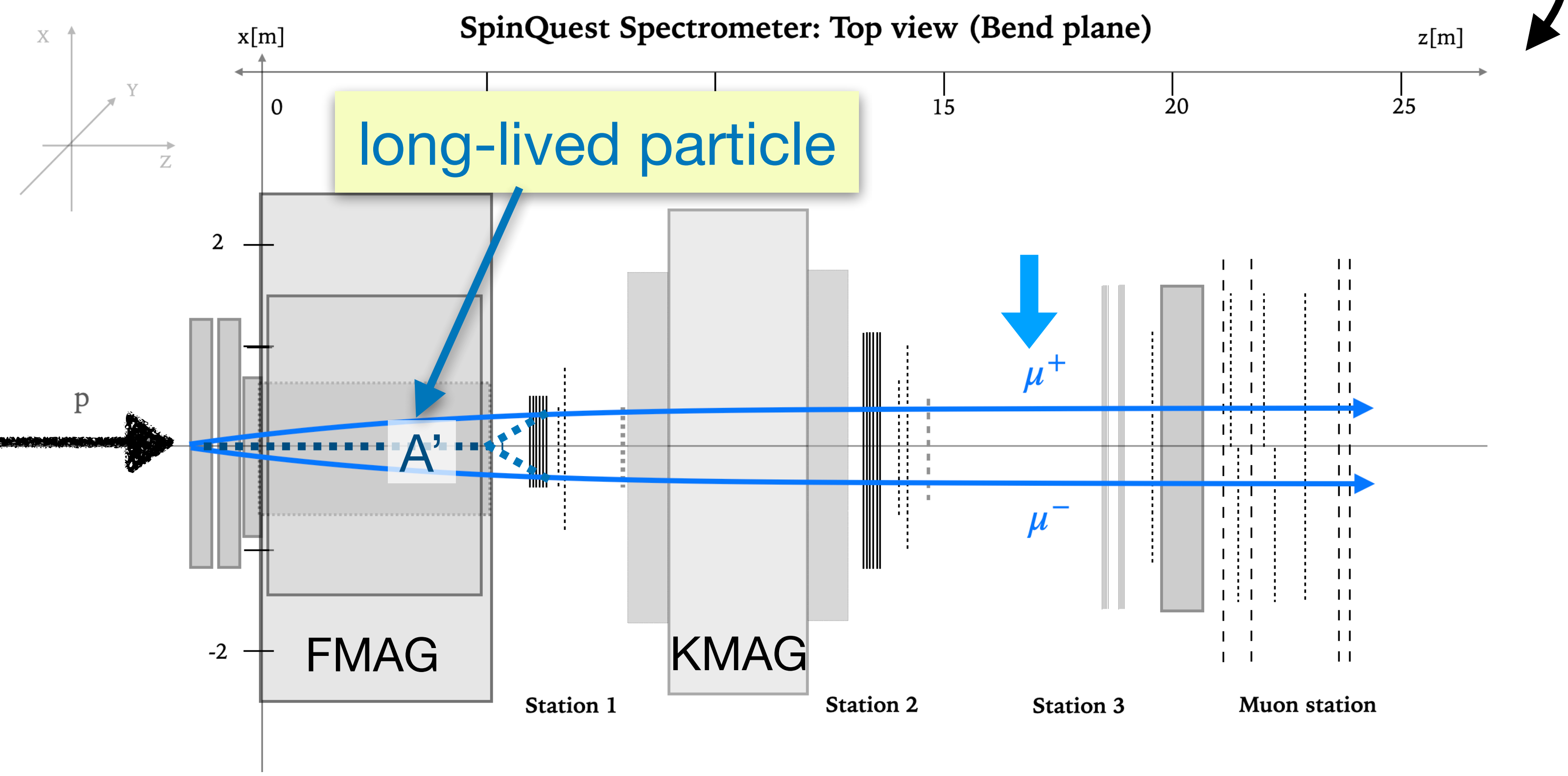
S.Gori

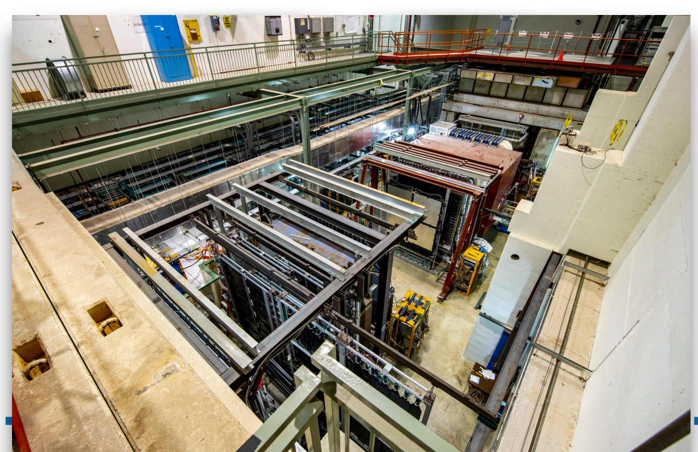
SpinQuest and DarkQuest

120 GeV proton beam



Large acceptance thanks to its **compact geometry**





SeaQuest → SpinQuest

1706.09990

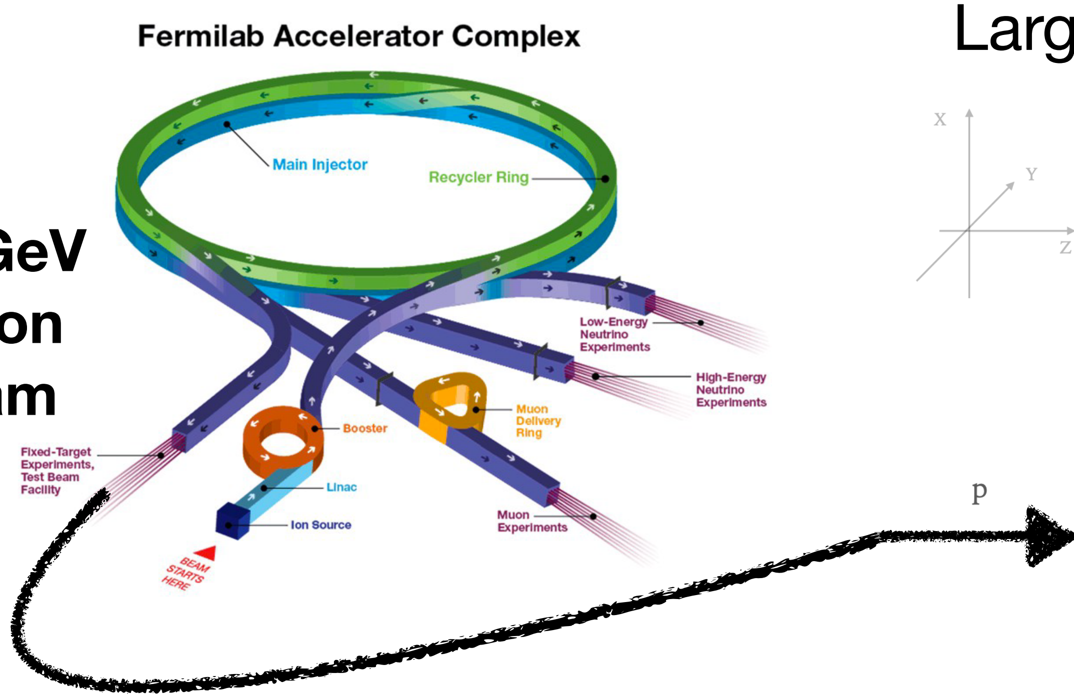
polarized target
+ displaced trigger

Nuclear physics: Measuring the Drell-Yan muon process for studies of the proton structure

Particle Physics: Visible dark sector searches (muons)

SpinQuest and DarkQuest

120 GeV proton beam



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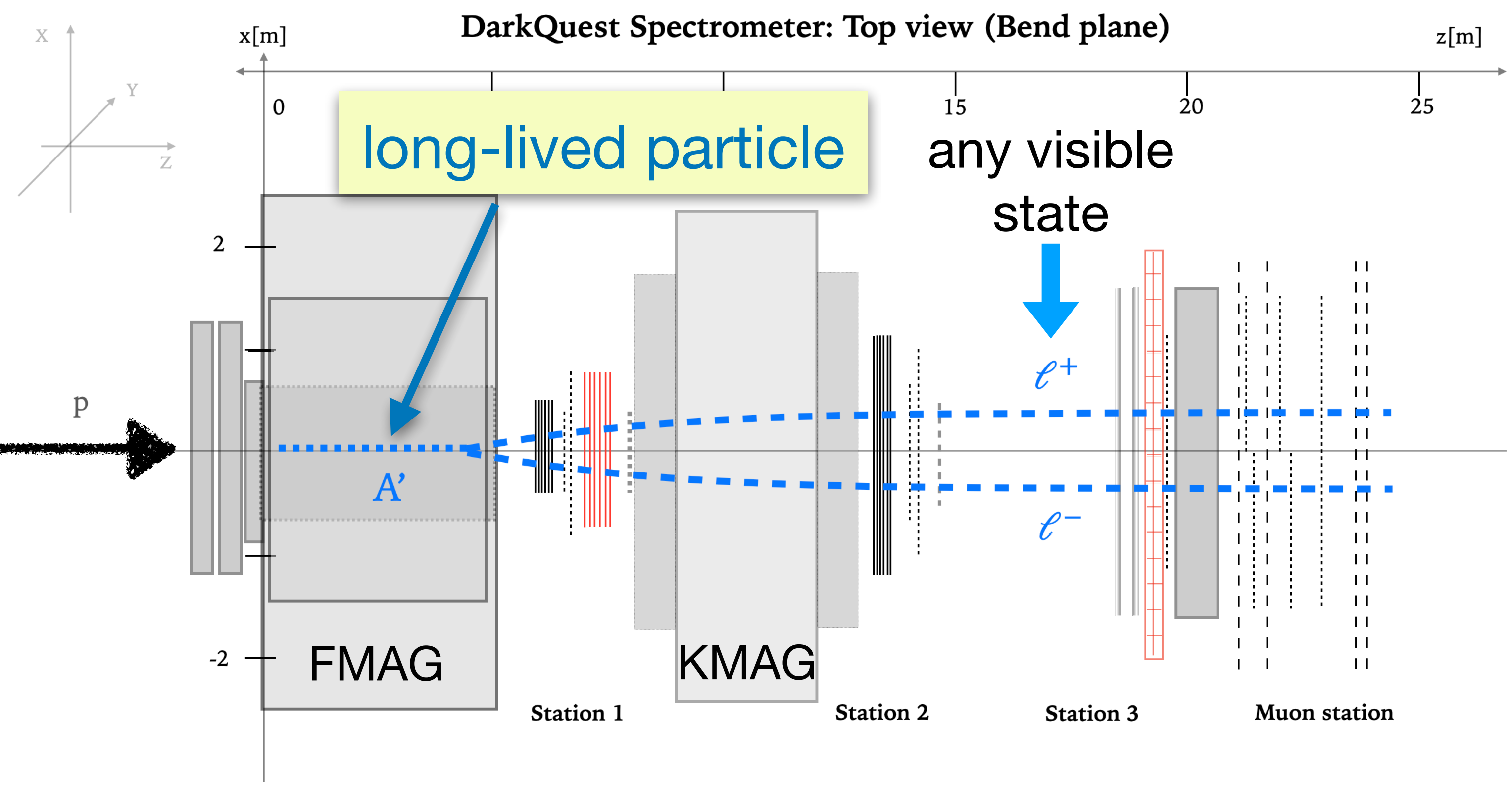
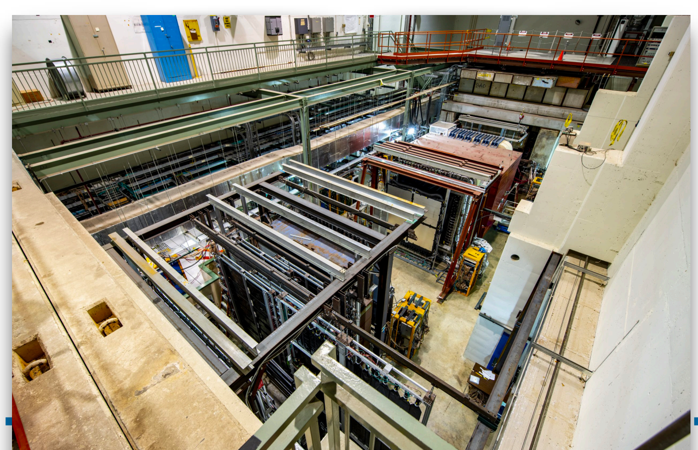




SeaQuest → SpinQuest → DarkQuest

SeaQuest: 1706.09990

SpinQuest: polarized target + displaced trigger

DarkQuest: **proposed upgrade** (calorimeter + more tracking layers + hodoscope for triggering)

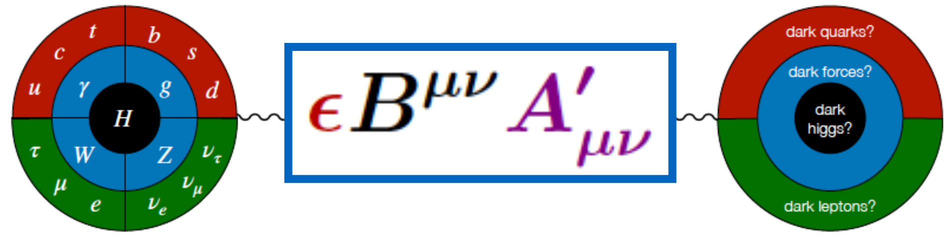
Nuclear physics: Measuring the Drell-Yan muon process for studies of the proton structure

Particle Physics: Visible dark sector searches (any visible: muons, electrons, photons, charged pions, …)

Initial proposal:
Gardner, Holt, Tadepalli, 1509.00050
Berlin, SG, Schuster, Toro, 1804.00661

Snowmass white paper: 2203.08322

Dark photons at DarkQuest

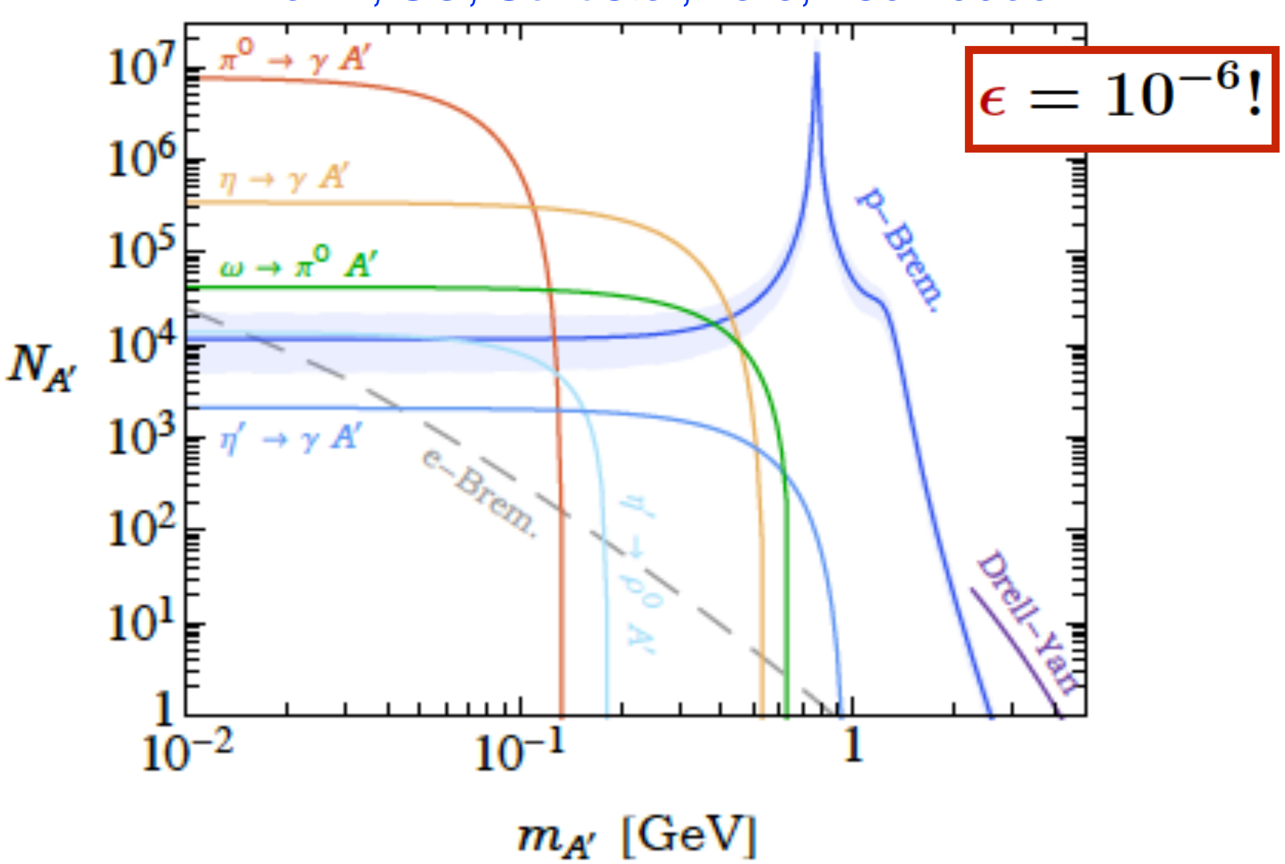


Dark photons are largely produced from high-energy and high-intensity proton beams.

(Larger production rates compared to electron beams.)

With 120 GeV and 10^{18} POT:

Berlin, SG, Schuster, Toro, 1804.00661



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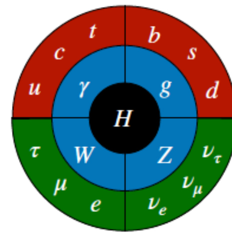

$$\epsilon B^{\mu\nu} A'_{\mu\nu}$$

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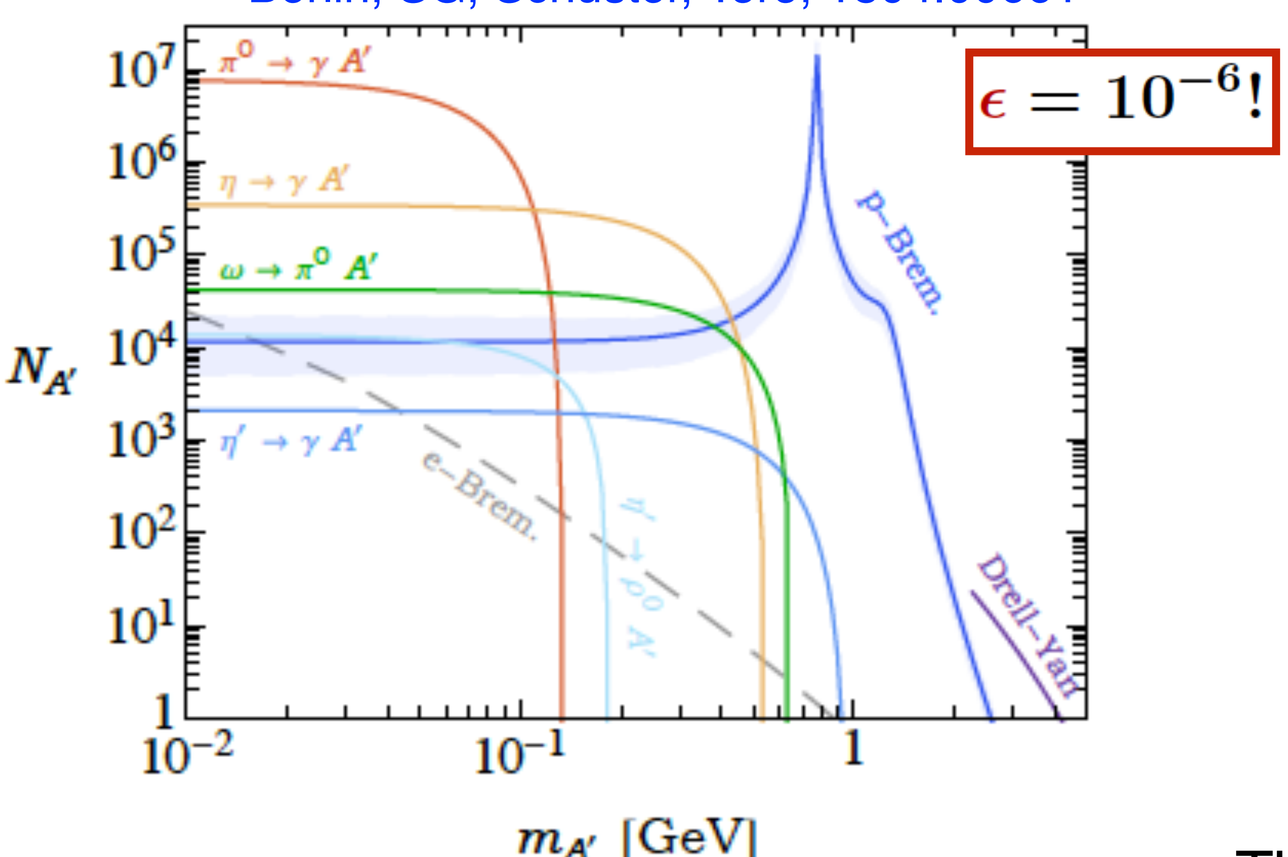
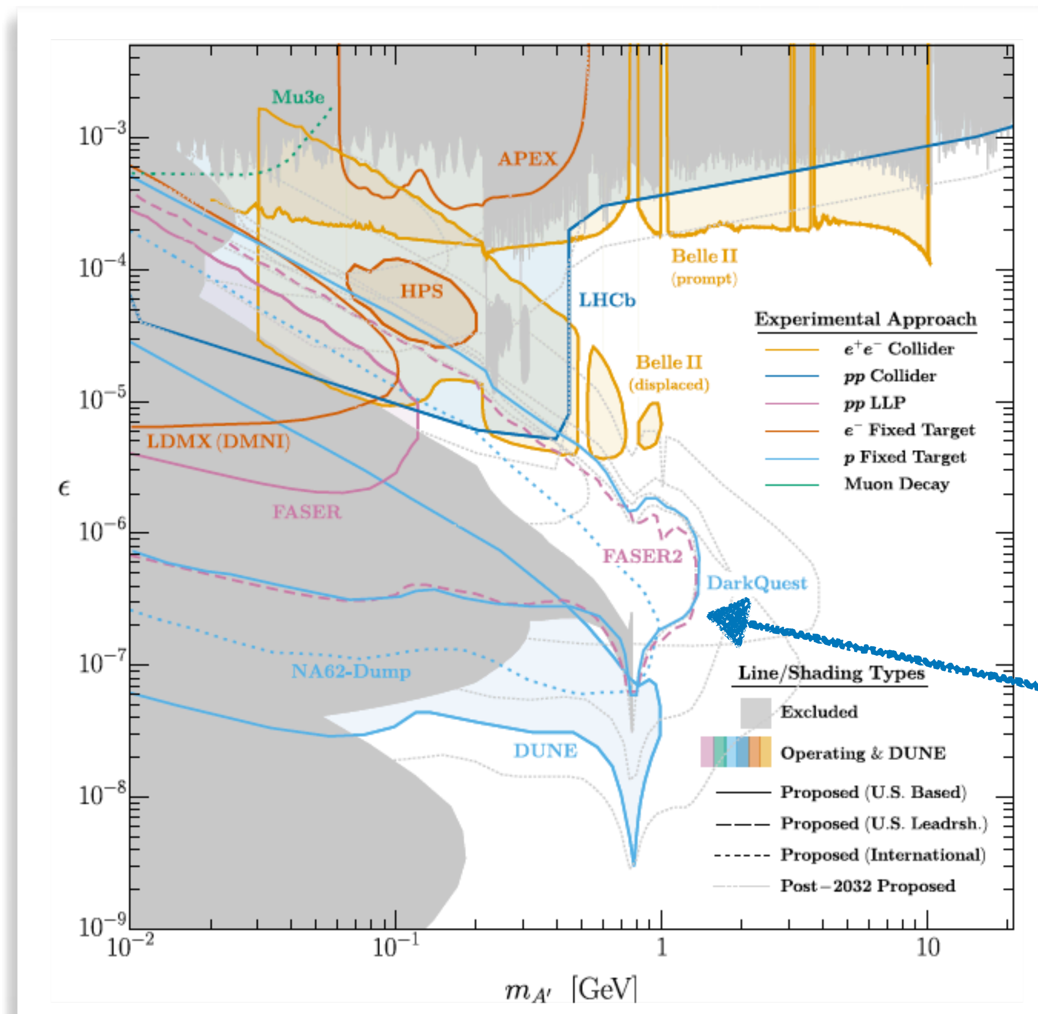




10^{18} POTs
~1-2 year running

This entire parameter space predicts a **dark sector in thermal equilibrium** with the SM

A broad physics program at DarkQuest

Multipurpose experiment. Any visible signature can be searched for.

A broad physics program at DarkQuest

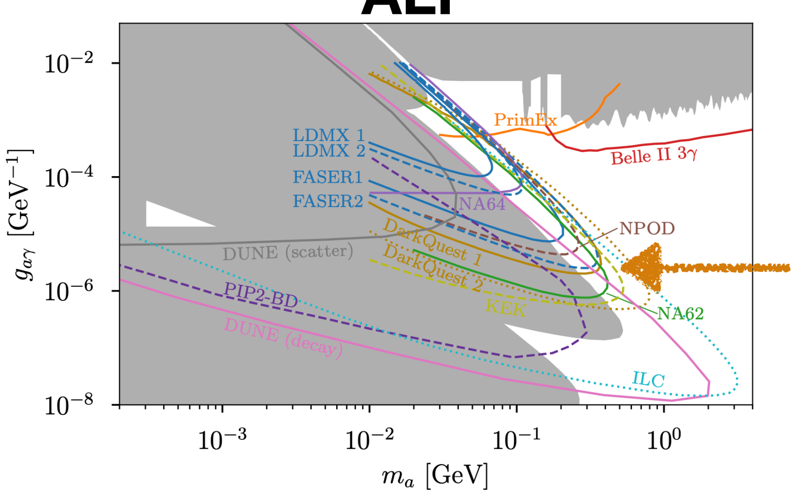
Multipurpose experiment. Any visible signature can be searched for.

Searching for the mediator

Big idea 2

* dark photon
* dark scalar
* sterile neutrino
* ALP
* New gauge symmetries: B-L, $L_\mu - L_\tau$, …

ALP

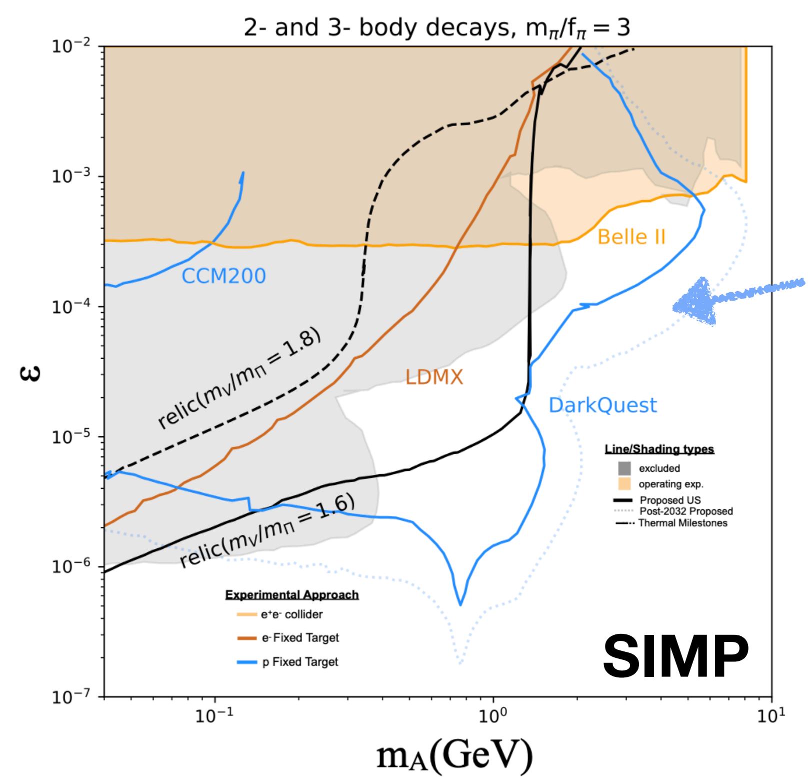


Batell et al., 2207.06905

Unveiling extended DM models

Big idea 3

* Inelastic Dark Matter
* Strongly interacting massive particles (SIMP)



Harris et al., 2207.08990

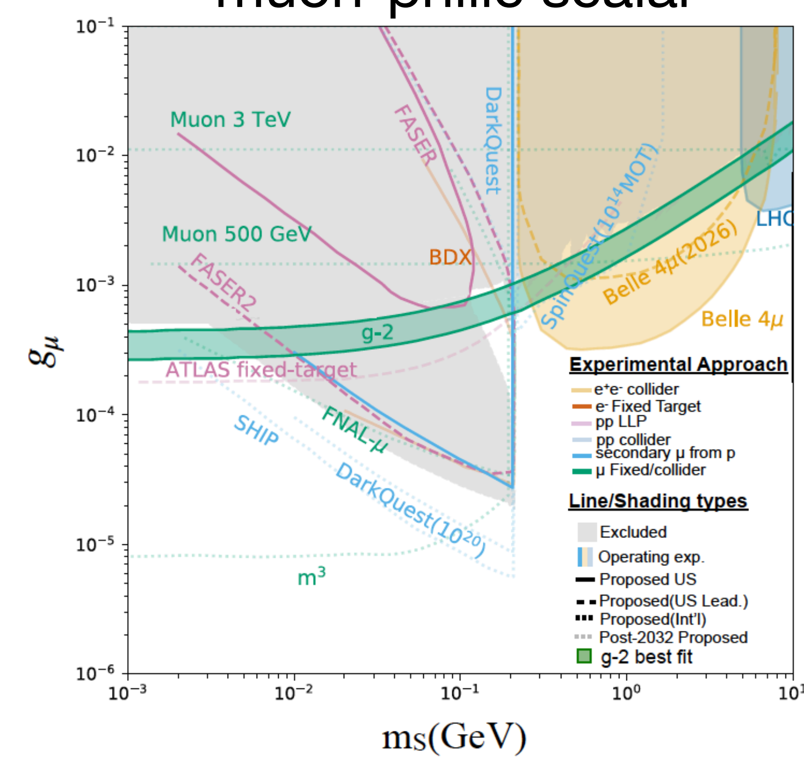
Addressing anomalies

Big idea 3

* $(g-2)_\mu$
* …

(secondary muon beam at DarkQuest)

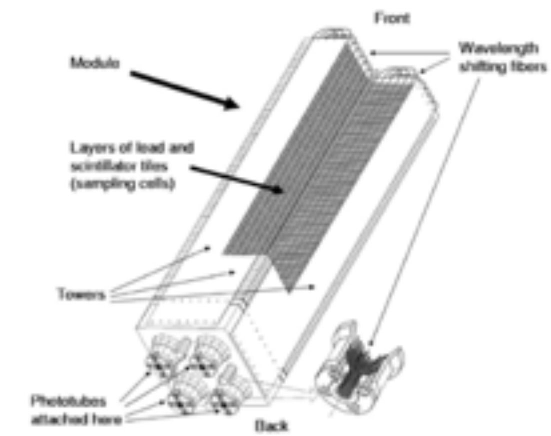
muon-philic scalar



Forbes et al., 2212.00033

List of experimental studies

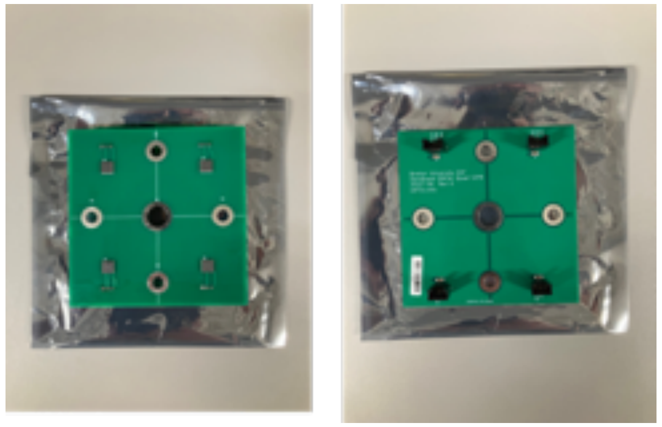
In the past two years a lot of progress has been made:



- Detector:
  - EMCal integration into the SpinQuest spectrometer
  - Extra Tracking layer integration into the SpinQuest spectrometer

- GEANT4 - based simulations:
  - EMCal simulations
  - Triggering
  - Tracking & vertexing
  - ParticleID: tracking + calorimeter information

Custom 4-ch SiPM Board



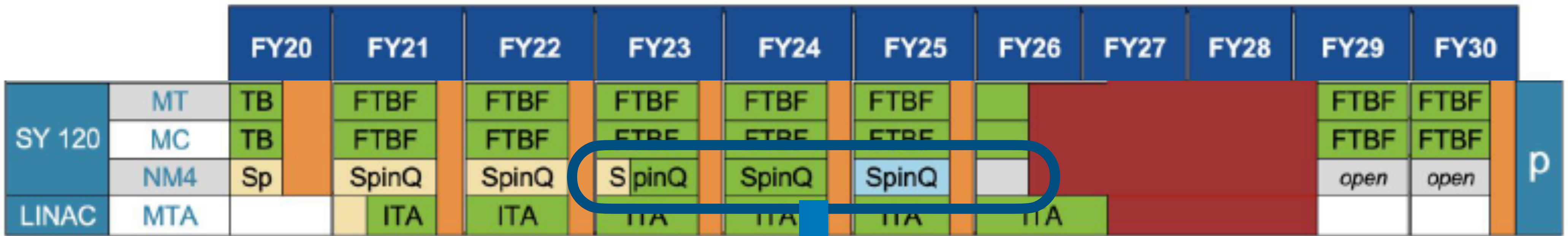
EMCal Test Stand at BU

Strong connections with the SpinQuest collaboration

~ 40 collaborators

see also short remark talk by P. McCormack tomorrow

SpinQuest/DarkQuest status and timeline



SpinQuest **DarkQuest**

FY23 | **FY24** | **FY25** | **FY26**

- Simulation studies
- Trigger tests
- Electronic designs

Data taking for Spin physics & dark sector physics (muon channel)

Approved

- Adding tracking layers
- EMCal installation

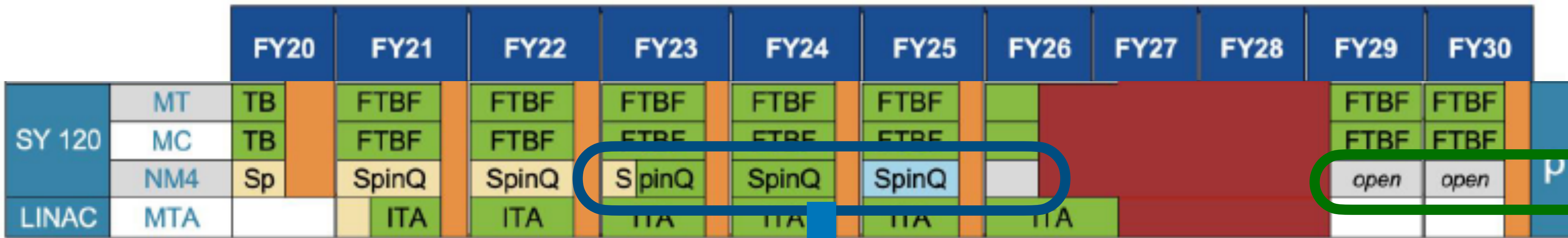
Proposed

Explore dark sector physics (all visible channels)

~10^{18} POT

Project cost: ~1.5M

SpinQuest/DarkQuest status and timeline



10^{20} POT?

SpinQuest

DarkQuest

FY23 FY24 FY25 FY26

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Approved

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~10^{18} POT

Project cost: ~1.5M

Possible long term project ahead for Fermilab.

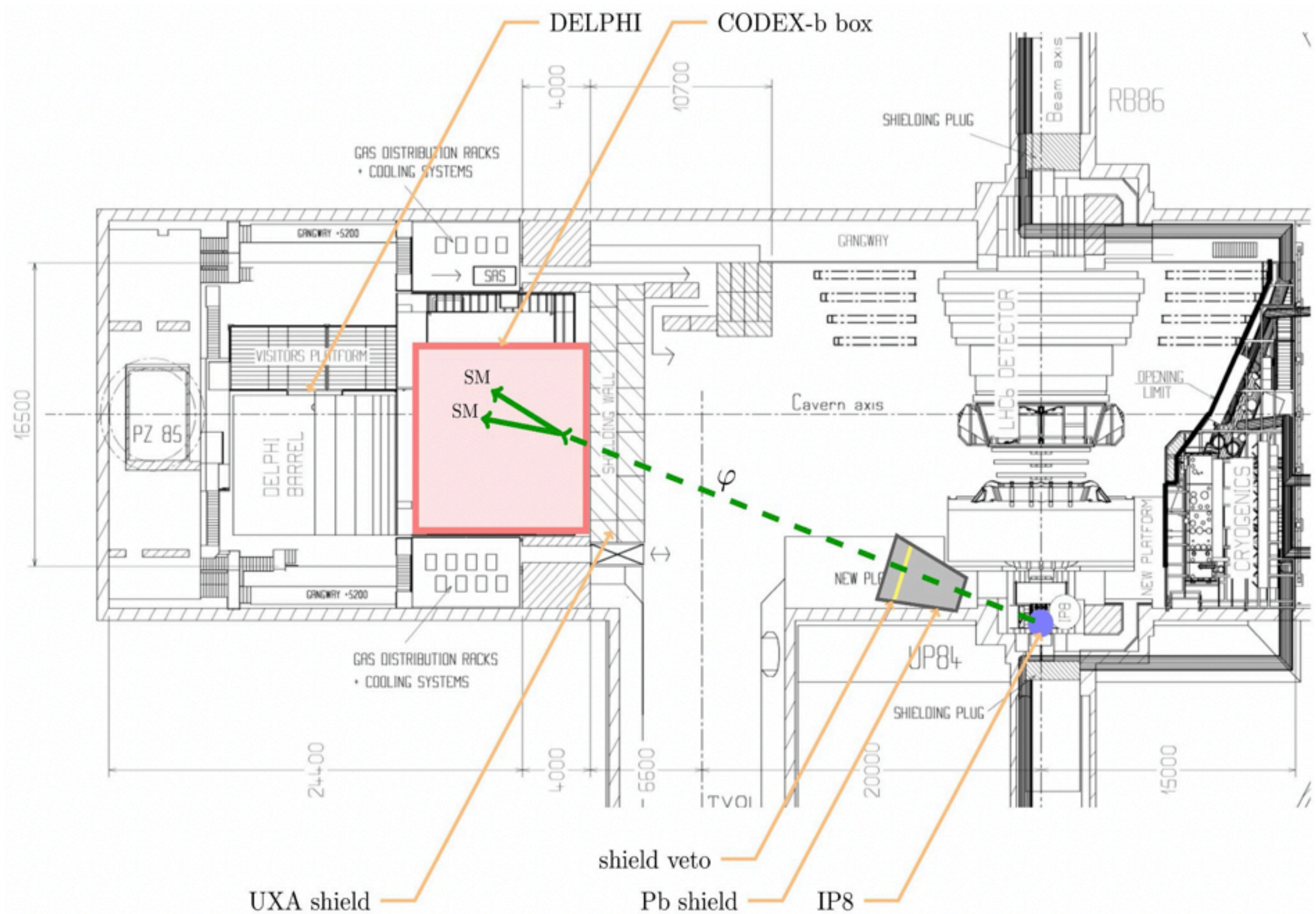
"A Booster replacement will enable the capability of the complex to serve precision experiments and searches for new physics with beams from 1-120 GeV"

Fleming, P5 Fermilab meeting

thanks to S. Knapen
for the slides

CODEX-b

COmpact Detector for EXotics at LHCb



Original proposal: 1708.09395
Expression of Interest: 1911.00481
Background studies: 1912.03846
Geometry optimization: 2211.08450
Snowmass contribution: 2203.07316

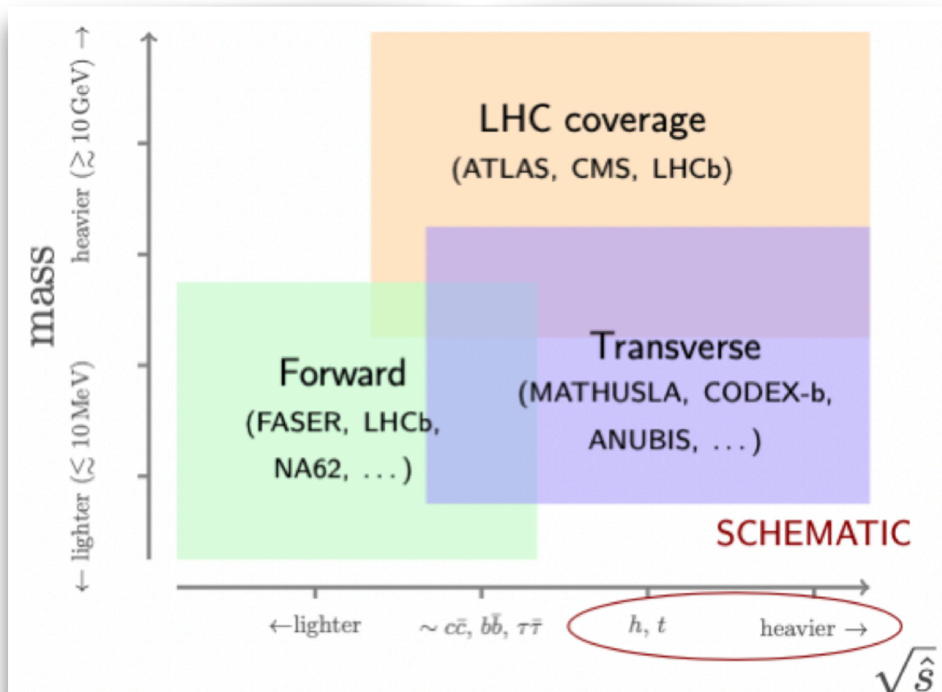
Baseline configuration:

- ~10m x 10m x 10m detector installed in available space near IP8
- Shielded by existing 3m wall plus additional 4m active shield near interaction point

Big idea 2: dark sector portals; Big idea 3: rich structures of the dark sector

CODEX-b physics targets

Ideal for low mass long-lived particles produced at medium to high center-of-mass energy



Signal models

- Exotic Higgs decays
- Exotic B-meson decays (dark scalars)
- Axion-like particles
- Heavy Neutral Leptons
- Hidden Valley models
- Inelastic Dark Matter
- …

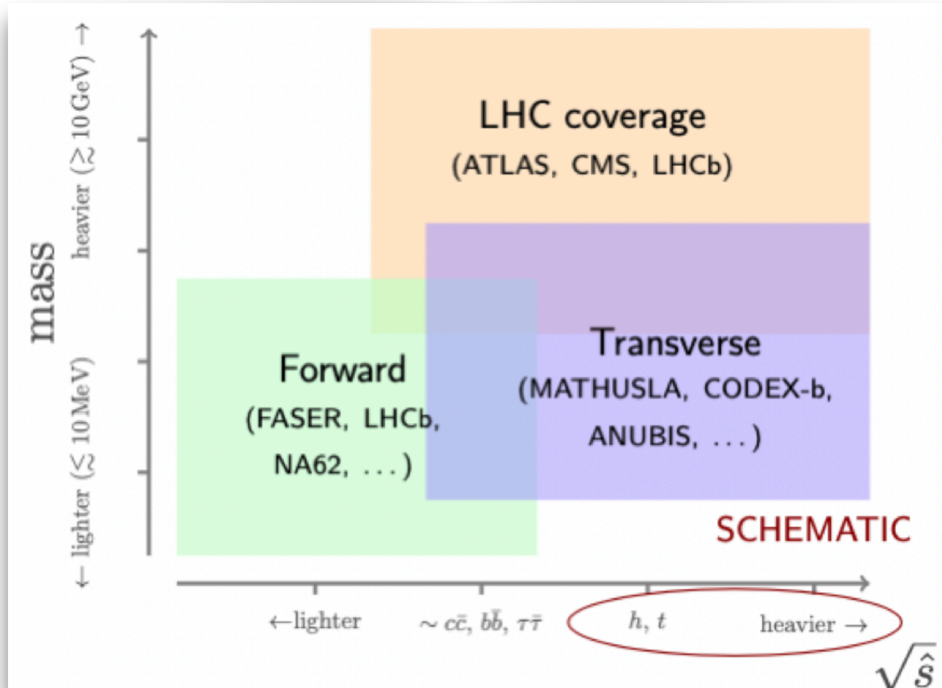
See 1911.00481 for exhaustive list

Backgrounds

- Extensive simulation studies support **achievable zero background environment**
- Requires additional data-driven inputs from CODEX-β demonstrator

CODEX-b physics targets

Ideal for low mass long-lived particles produced at medium to high center-of-mass energy



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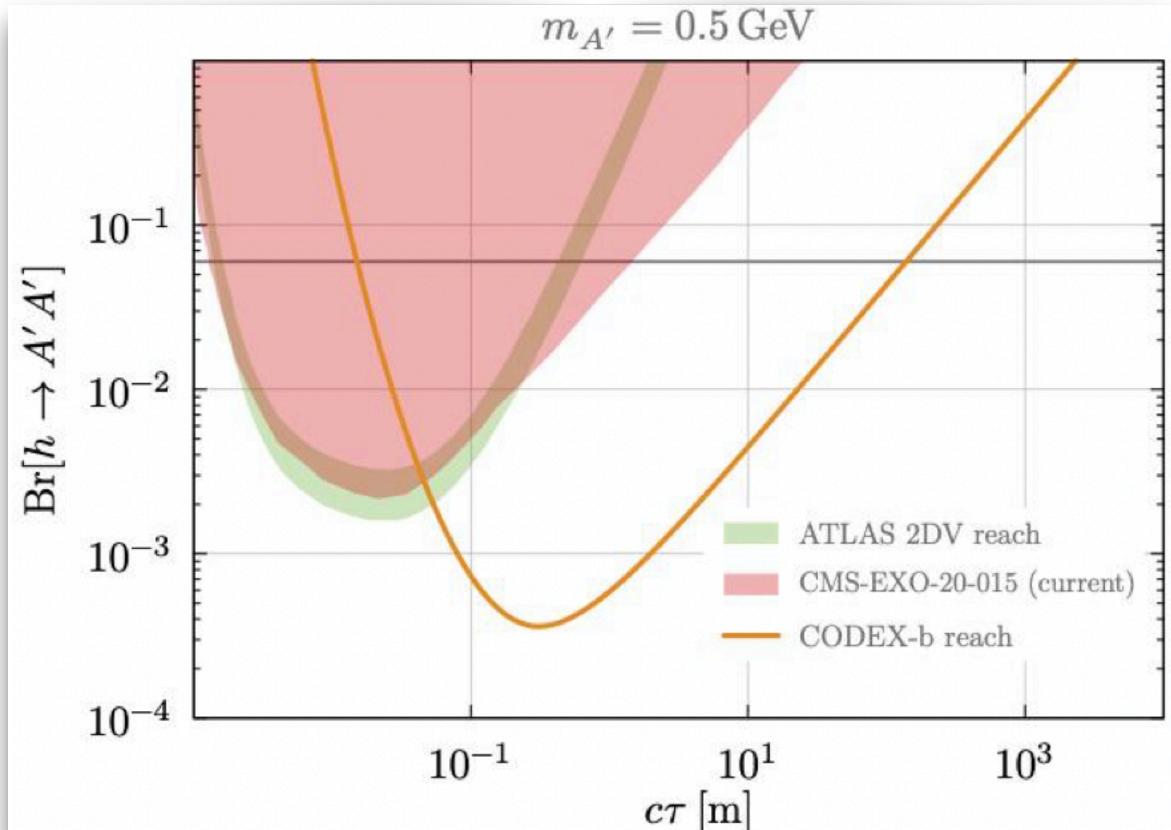
Competitive reach for exotic Higgs decays



Backgrounds

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- Requires additional data-driven inputs from CODEX-β demonstrator

CODEX-b status and timeline

CODEX-β prototype

- 2m x 2m x 2m detector
- Validate detector technology, reconstruction and background simulations
- Some limited physics reach
- CODEX-β construction underway, commissioning Winter 2023

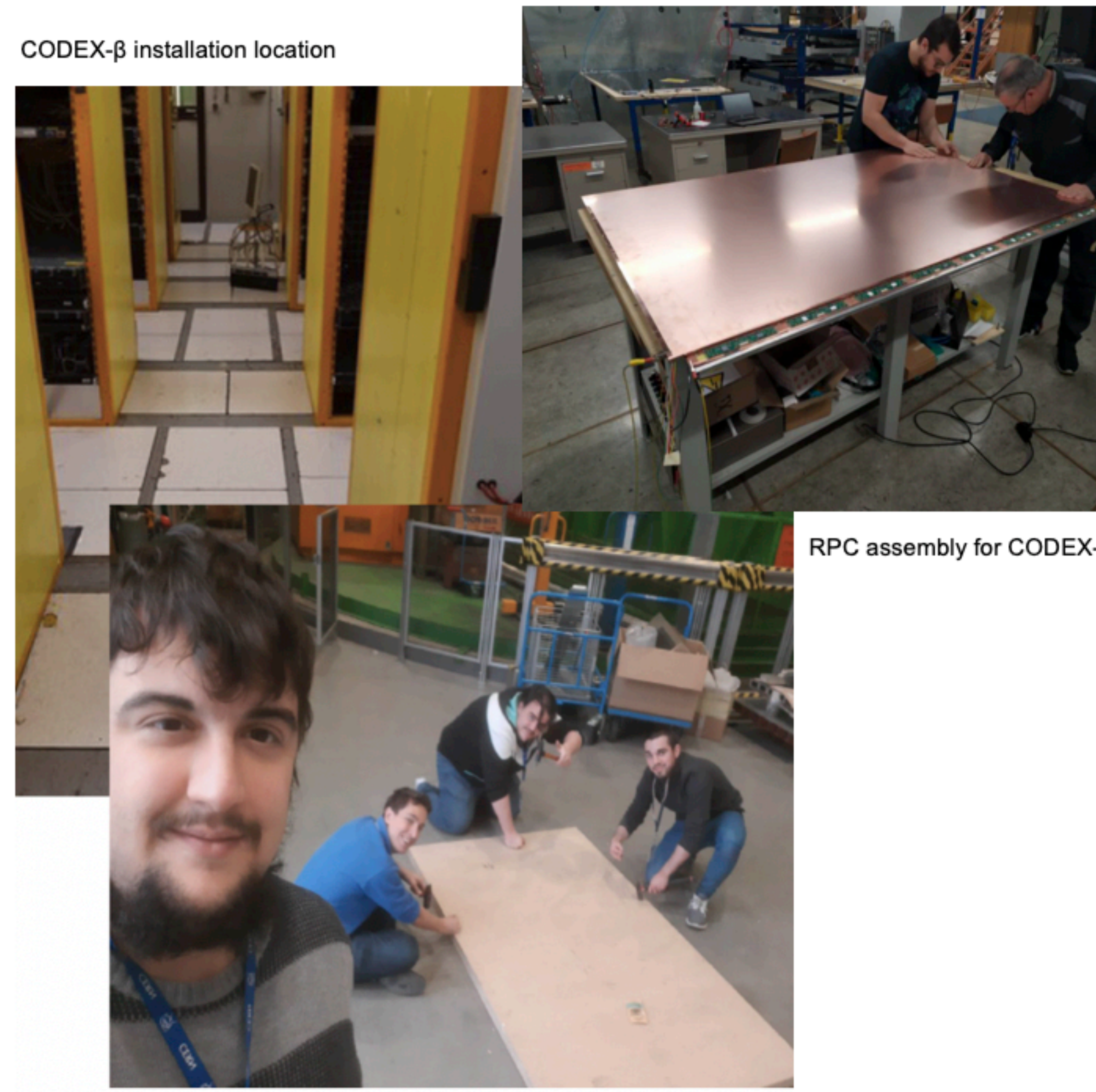
Full detector concept

- Existing RPC technology (ATLAS)
- Can do joint analysis with LHCb
- Affordable ~ few million $

Collaboration

- 40+ and growing (Europe + US)
- Members from ATLAS, CMS, LHCb, and theory

CODEX-β installation location



RPC assembly for CODEX-β

see also short remark talk
by M. Wilkinson tomorrow

Take home messages

Dark sector particles in the MeV-GeV range naturally appear in DM models, as well as many well-motivated extensions of the Standard Model.

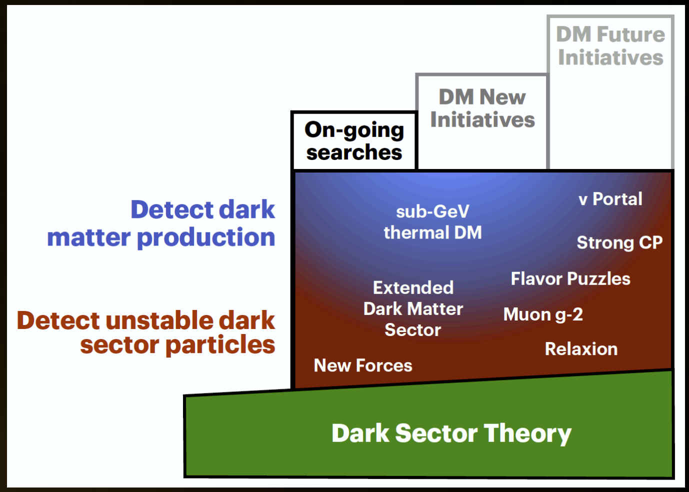
Very dynamic community

Unique role of **small scale** **accelerator experiments**

Support for this program:

- completion of the DM New Initiatives (DMNI) program. LDMX, CCM
- expand the program with a focus on complementary signals (focus on visible signals and long-lived particles). DarkQuest, CODEX-b, …
- Dark sector theory

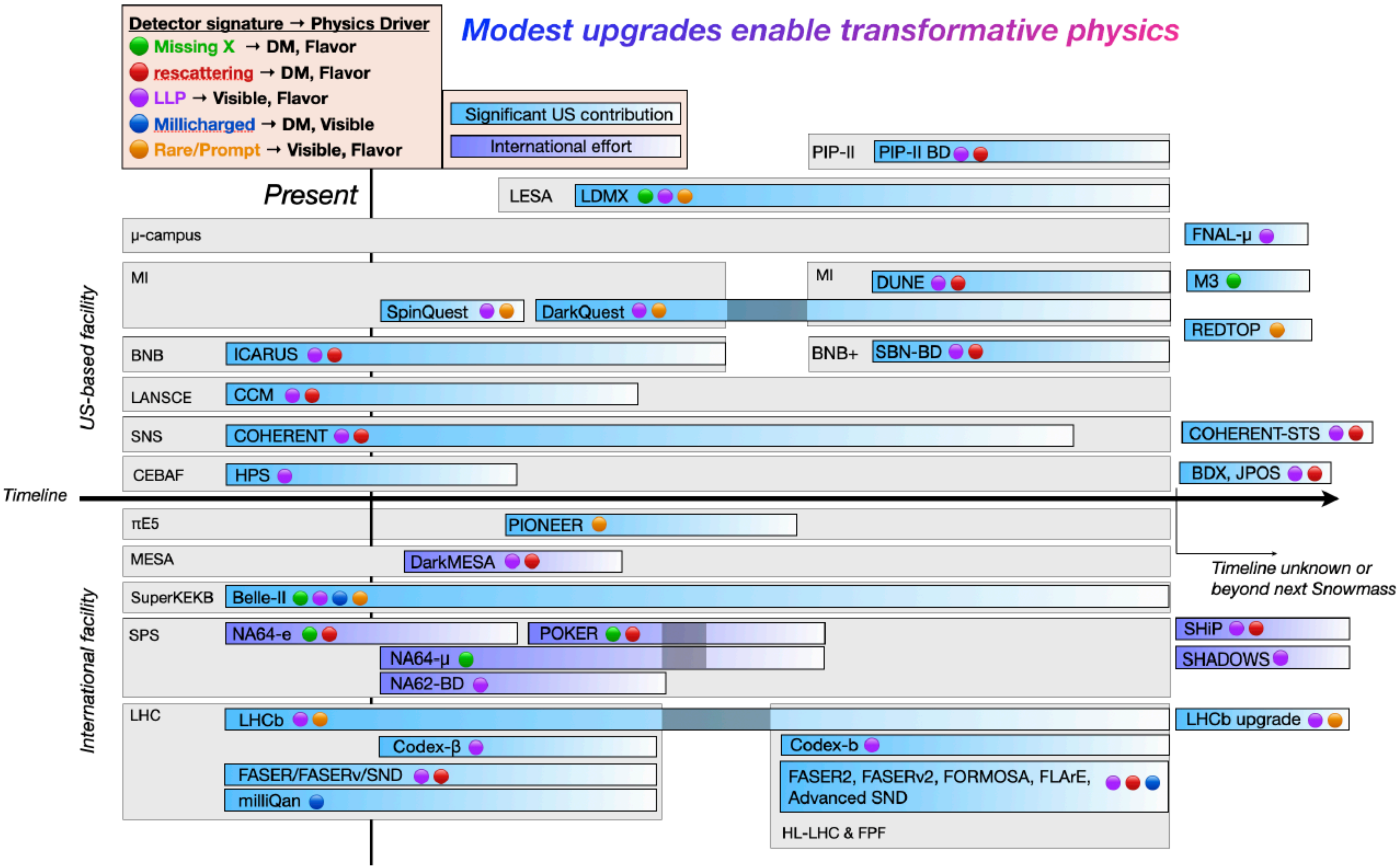
Well-defined science milestones that can be reached in the next decade (and beyond)



Backup

Experiments/facilities

https://arxiv.org/abs/2206.04220

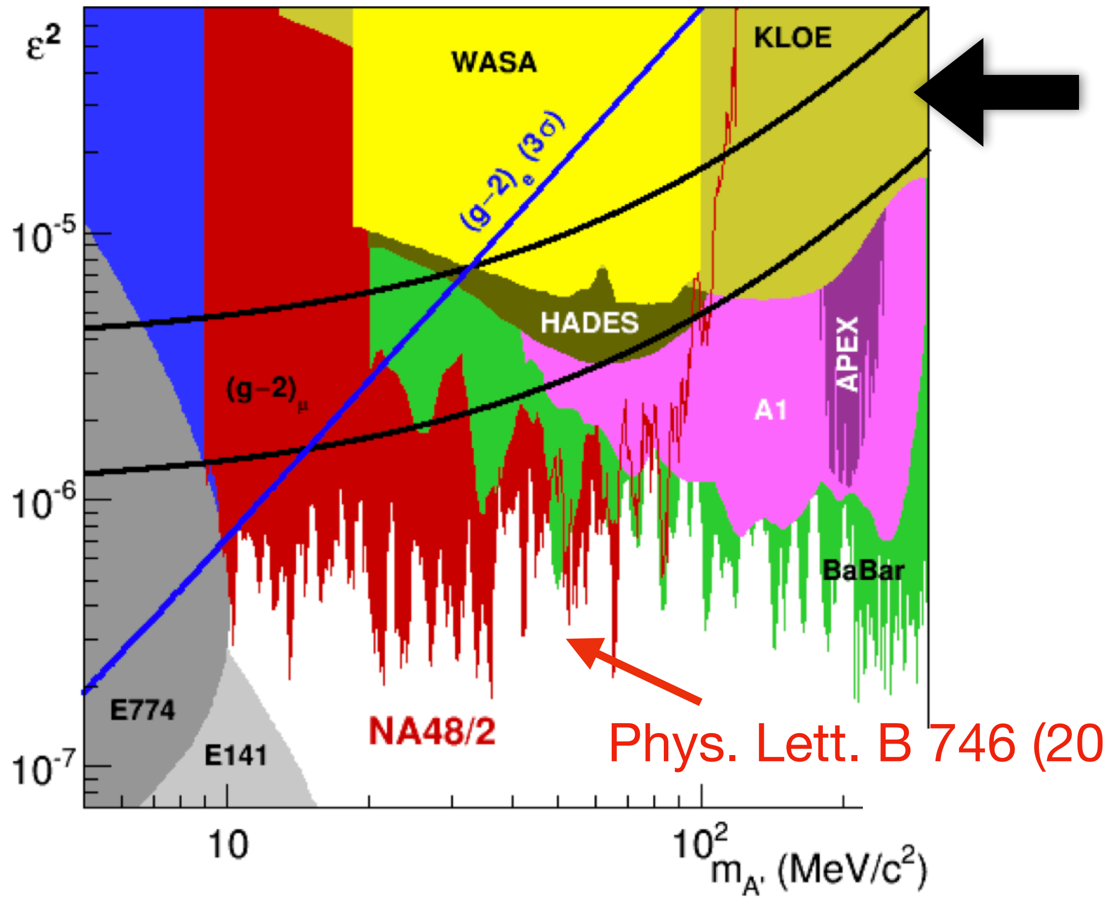


Experiments/facilities, key features

https://arxiv.org/abs/2206.04220

Experiment	Facility	Beam Config	Beam Energy	Det Signature	Timeline	Refs.
US-based						
HPS	CEBAF @ JLab	electron FT	1-6 GeV	LLP	running	section 3.15, [16]
COHERENT	SNS @ ORNL	proton FT	1 GeV	rescattering	running	section 4.5, [17]
CCM	LANSE @ LANL	proton FT	0.8 GeV	rescattering	running	[18]
SpinQuest/DarkQuest	MI @ FNAL	proton FT	120 GeV	LLP	construction, proposed upgrade	section 3.5, [19]
LDMX	LESA @ SLAC	electron FT	4-8 GeV	Missing X	R&D funding, 2024	section 3.17, [20]
BDX	CEBAF @ JLab	electron BD	11 GeV	rescattering, Millicharged	proposed	section 3.1, [21]
JPOS	CEBAF @ JLab	positron FT	11 GeV	Missing X	proposed	section 3.16, [22]
PIP-II BD	PIP-II @ FNAL	proton FT	1 GeV	rescattering, LLP	proposed (2029)	section 3.23, [23]
SBN-BD	Booster @ FNAL	proton BD	8 GeV	rescattering	proposed (2029)	[24]
REDTOP	TBD	proton FT	1-5 GeV	Missing X, LLP, Prompt	proposed	section 3.25, [25]
M^3	MI @ FNAL	muon FT	15 GeV muons	Missing X	proposed	[26]
FNAL-μ	muon campus @ FNAL	muon FT	3 GeV	LLP	proposed	section 3.13, [27]
International						
Belle-II	SuperKEKB @ KEK	e+e- collider	150 MeV	Missing X, LLP, Prompt	running	section 3.2, [28]
CODEX-β	LHC @ CERN	pp collider	6.5-7 TeV	LLP	construction (2023)	section 3.4, [29]
CODEX-b	LHC @ CERN	pp collider	6.5-7 TeV	LLP	proposed (2026)	section 3.3, [30]
LHCb	LHC @ CERN	pp collider	6.5-7 TeV	LLP, Prompt	running, future upgrade planned	section 3.18, [31]
NA62	SPS-H4 @ CERN	proton BD	400 GeV	LLP	dedicated running planned	[32]
FASERnu	LHC @ CERN	pp collider	6.5-7 TeV	rescattering	running	section 3.9, [33]
milliQAN	LHC @ CERN	pp collider	6.5-7 TeV	Millicharged	running	section 3.19, [34]
DarkMESA	MESA @ Mainz	Electron FT	150 MeV	rescattering, LLP	construction (2023)	section 3.6
NA64-e	SPS-H4 @ CERN	electron FT	100-150 GeV	Missing X, Prompt	running	section 3.20, [35]
NA64-mu	SPS-M2 @ CERN	muon FT	100-160 GeV	Missing X	commissioning	section 3.21
NA64/POKER	SPS-H4 @ CERN	positron FT	100 GeV	Missing X	planned (2024)	section 3.24, [35]
PIONEER	πE5 @ PSI	proton FT	10-20 MeV pions	Prompt	planned (2028)	section 3.22, [36]
FASER2	FPF @ CERN	pp collider	6.5-7 TeV	LLP	proposed (2029)	section 3.8 [37]
FORMOSA	FPF @ CERN	pp collider	6.5-7 TeV	Millicharged	proposed (2029)	section 3.14, [38]
FASERnu2	FPF @ CERN	pp collider	6.5-7 TeV	rescattering	proposed (2029)	section 3.10, [33]
FLArE	FPF @ CERN	pp collider	6.5-7 TeV	rescattering	proposed (2029)	section 3.12, [39]
SND@LHC	LHC @ CERN	pp collider	6.5-7 TeV	rescattering	running	section 3.27, [40]
Advanced SND@LHC	FPF	pp collider	6.5-7 TeV	rescattering	proposed (2029)	section 3.27, [40]

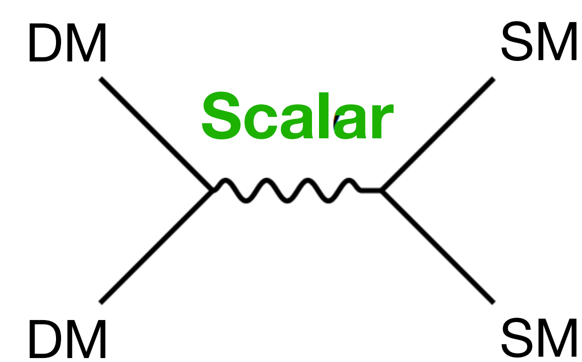
Several milestones were reached after 2013



Phys. Lett. B 746 (2015) 178

Dark photon explanation of
$(g - 2)_\mu$ is now fully probed

Scalar-mediated thermal DM
is now completely probed
Krnjaic, 1512.04119



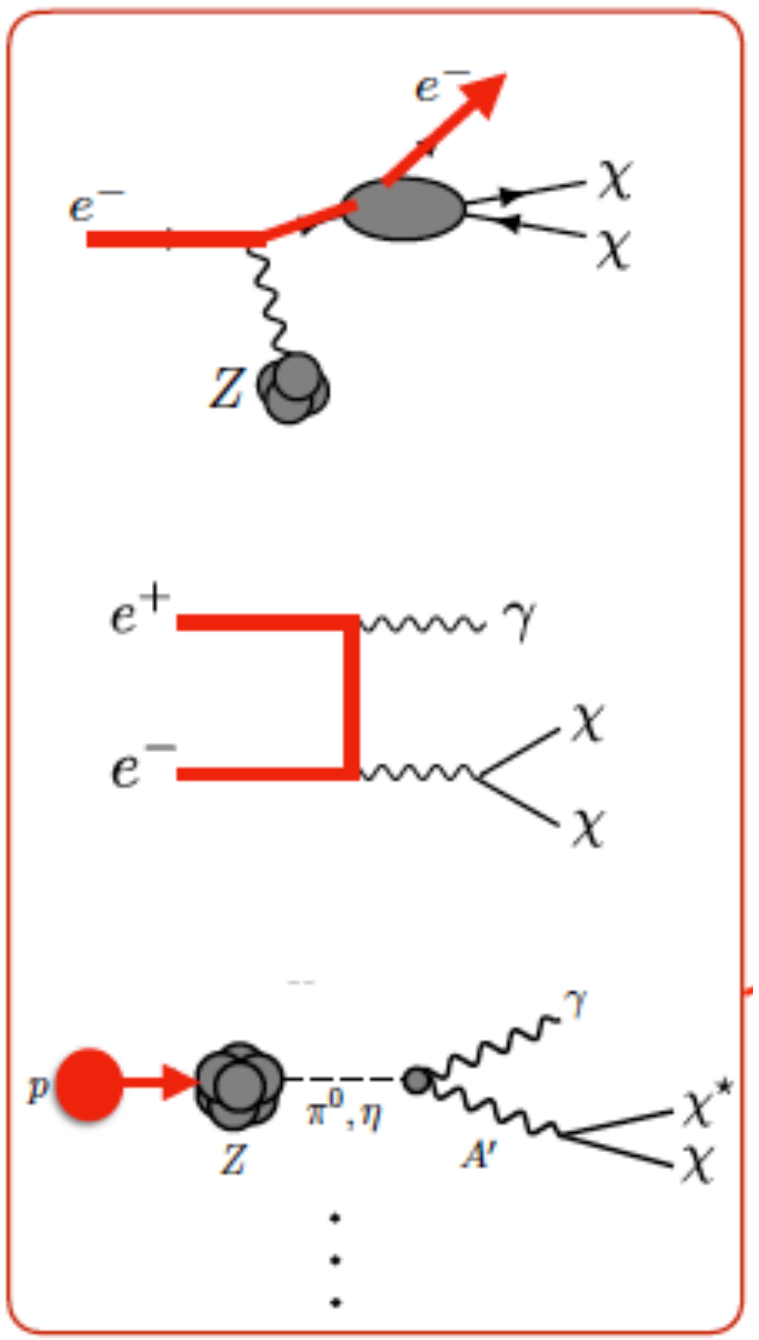
Rapid development of the field.

- New dedicated experiments (e.g. fixed targets, beam dumps, long-lived particle detectors, …);
- Novel analyses of data to discover dark sectors at multi-purpose experiments;

- New theories for DM (e.g. strongly interacting massive particles, Hochberg et al. 1411.3727);
- New theories to address the hierarchy problem (e.g. relaxion models, Graham et al. 1504.07551).
- New theories to address anomalies in data (e.g. $(g - 2)_\mu$, MiniBooNE, …)

Big idea 1: DM production at high intensities

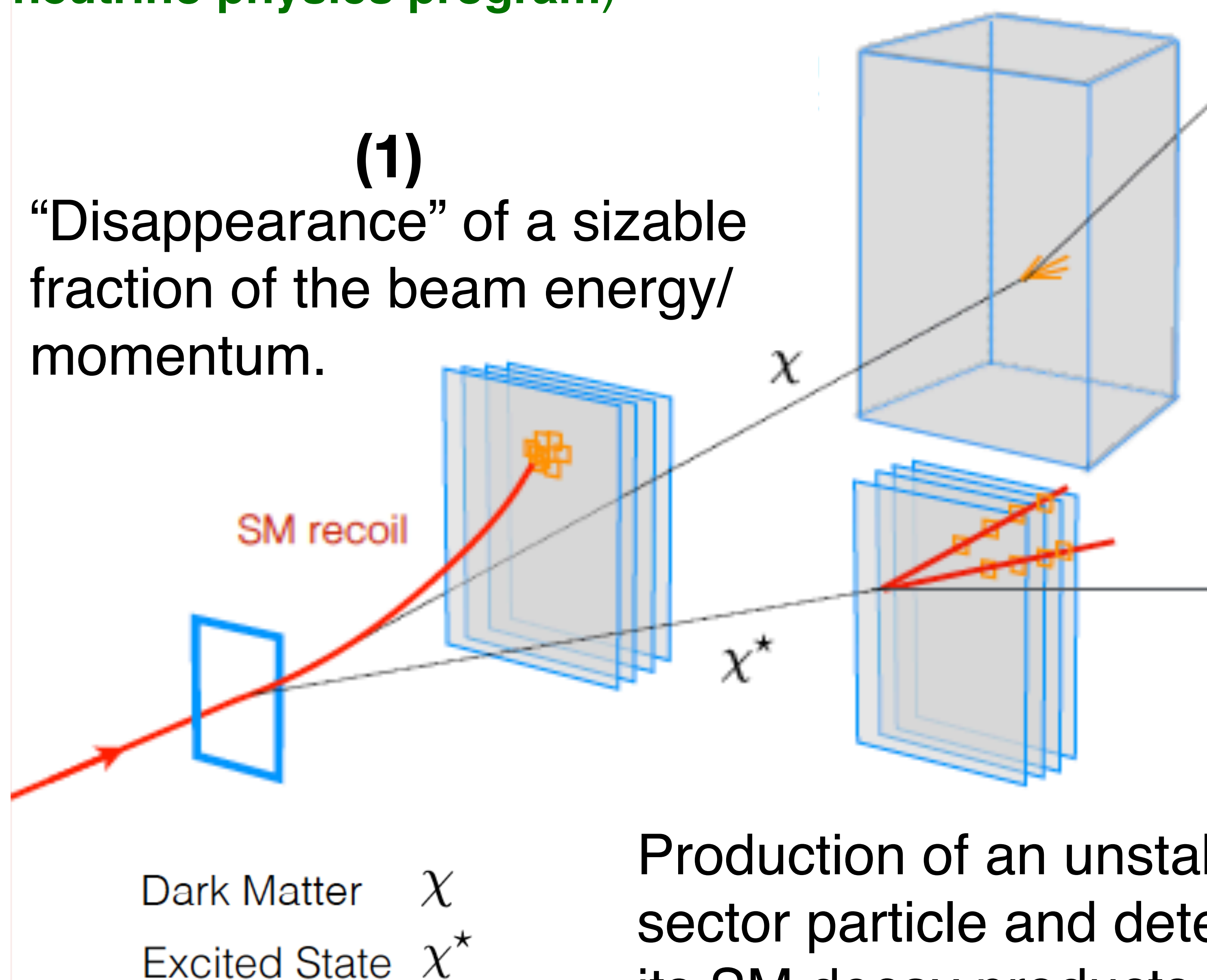
https://arxiv.org/abs/2207.00597



(proton beam: synergistic with the accelerator-based **neutrino physics program**)

Detection of DM scattering in forward detectors. **(2)**

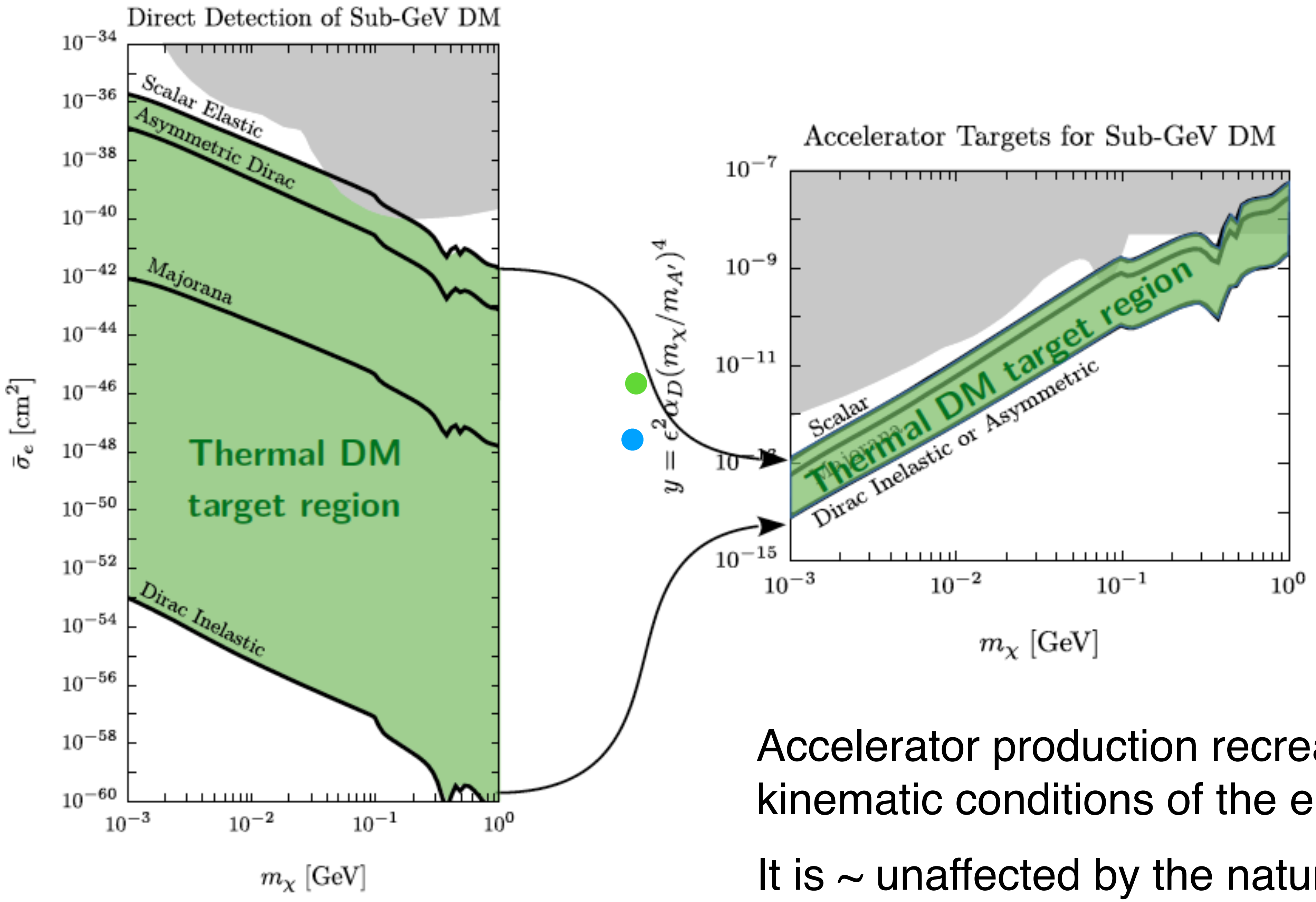
(1)
"Disappearance" of a sizable fraction of the beam energy/ momentum.

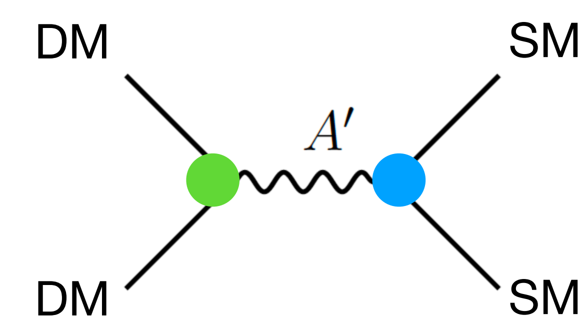


(3)
Production of an unstable dark sector particle and detection of its SM decay products.

Synergy with auxiliary detectors at collider experiments

Complementarity with DM direct detection





if $m_{A'} > 2m_{DM}$

$$\sigma \propto \frac{y}{m_{\rm DM}^2}, \qquad y \equiv \epsilon^2 \alpha_D \left(\frac{m_{\rm DM}}{m_{A'}}\right)^4$$

Accelerator production recreates the kinematic conditions of the early universe.

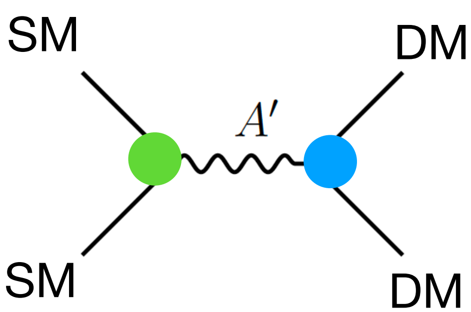
It is ~ unaffected by the nature of DM

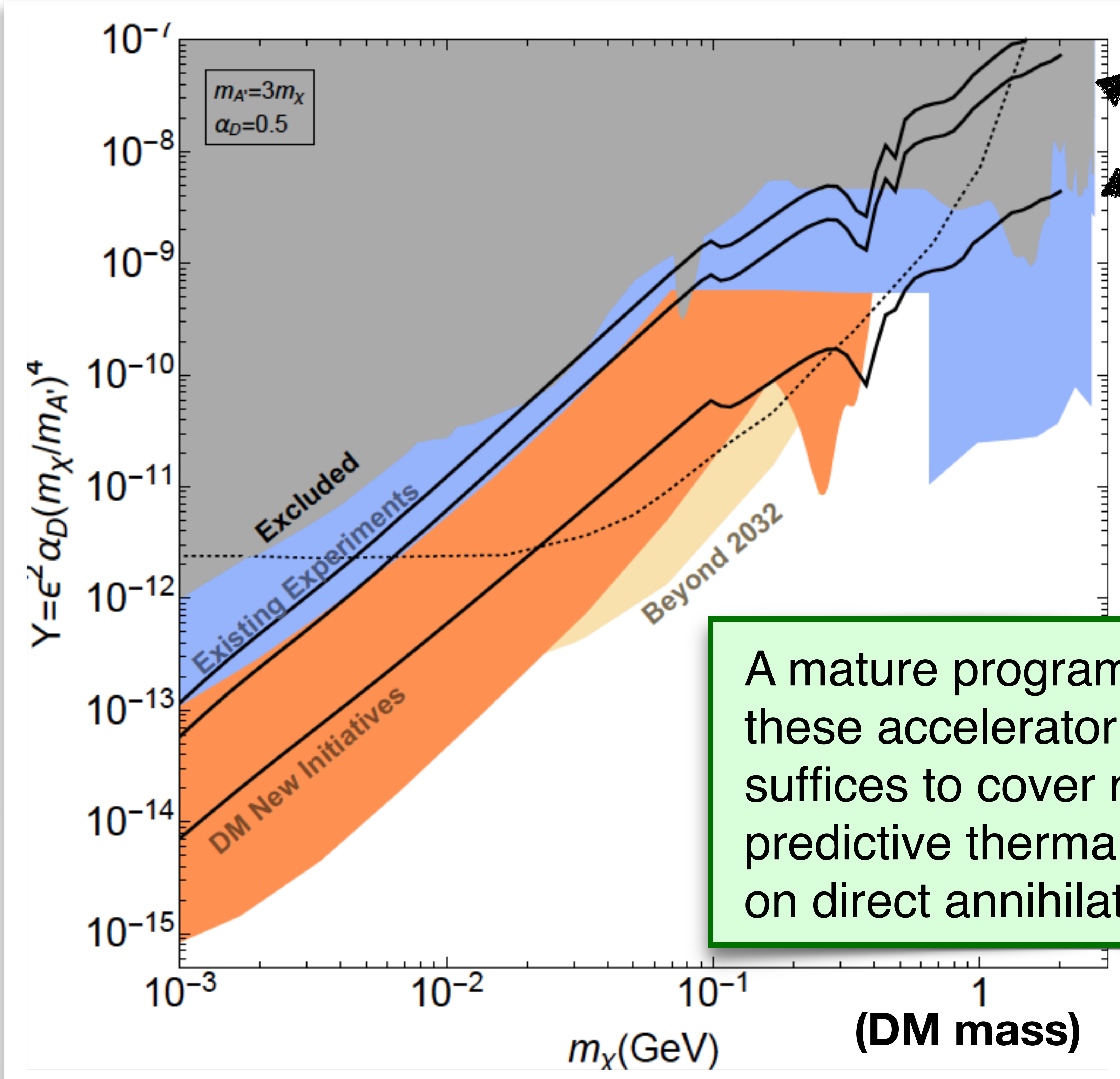
A broad experimental program encompassing both accelerator and direct detection searches is necessary

DM thermal milestones

$\epsilon B^{\mu\nu} A'_{\mu\nu}$

A'→XX





(DM mass)

benchmarks for thermal DM

A mature program that combines these accelerator based efforts suffices to cover nearly all of the predictive thermal targets based on direct annihilation

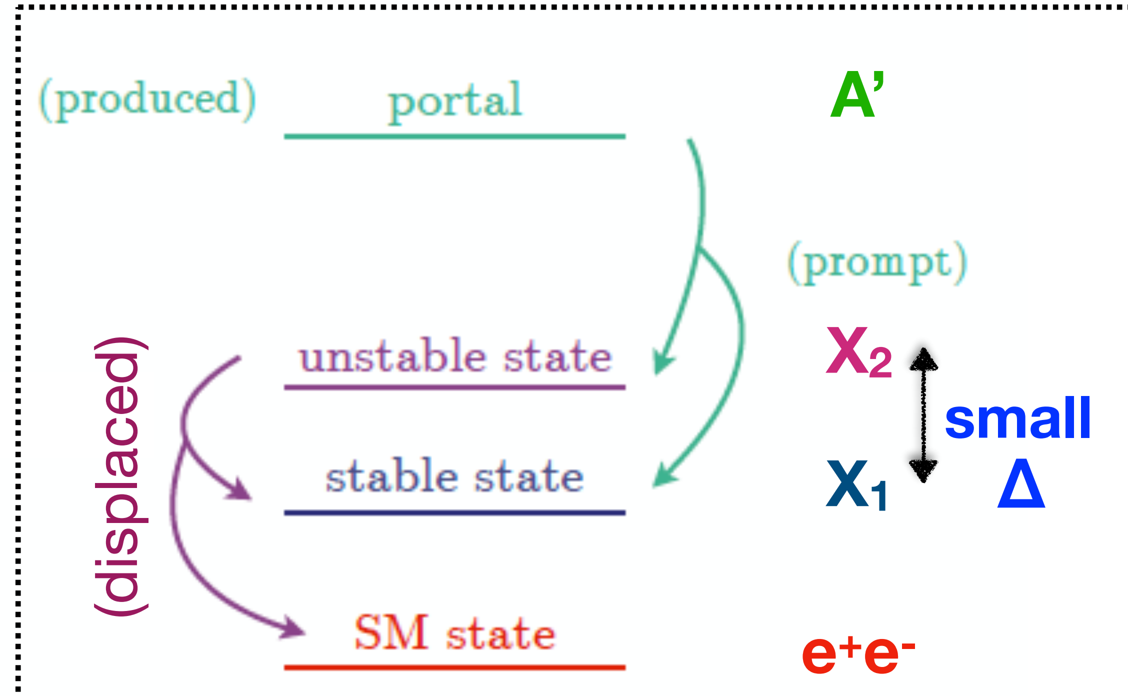
Dark photon mediated DM

DM models with metastable particles

Inelastic Dark Matter

Tucker-Smith, **Weiner**, 0101138

$$\mathcal{L} \supset \frac{i e_D \, m_D}{\sqrt{m_D^2 + (\delta_\xi - \delta_\eta)^2/4}} A'_\mu \left(\bar{\chi}_1 \gamma^\mu \chi_2 - \bar{\chi}_2 \gamma^\mu \chi_1\right)$$



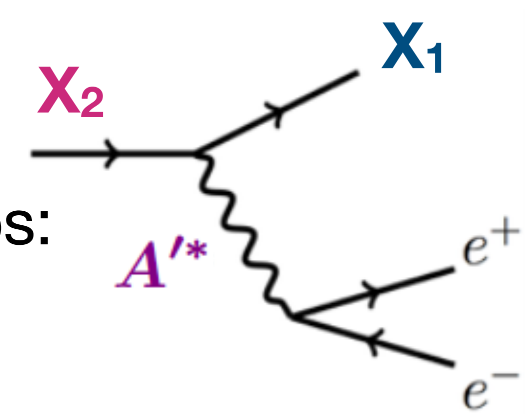
* A non-minimal freeze-out mechanism:

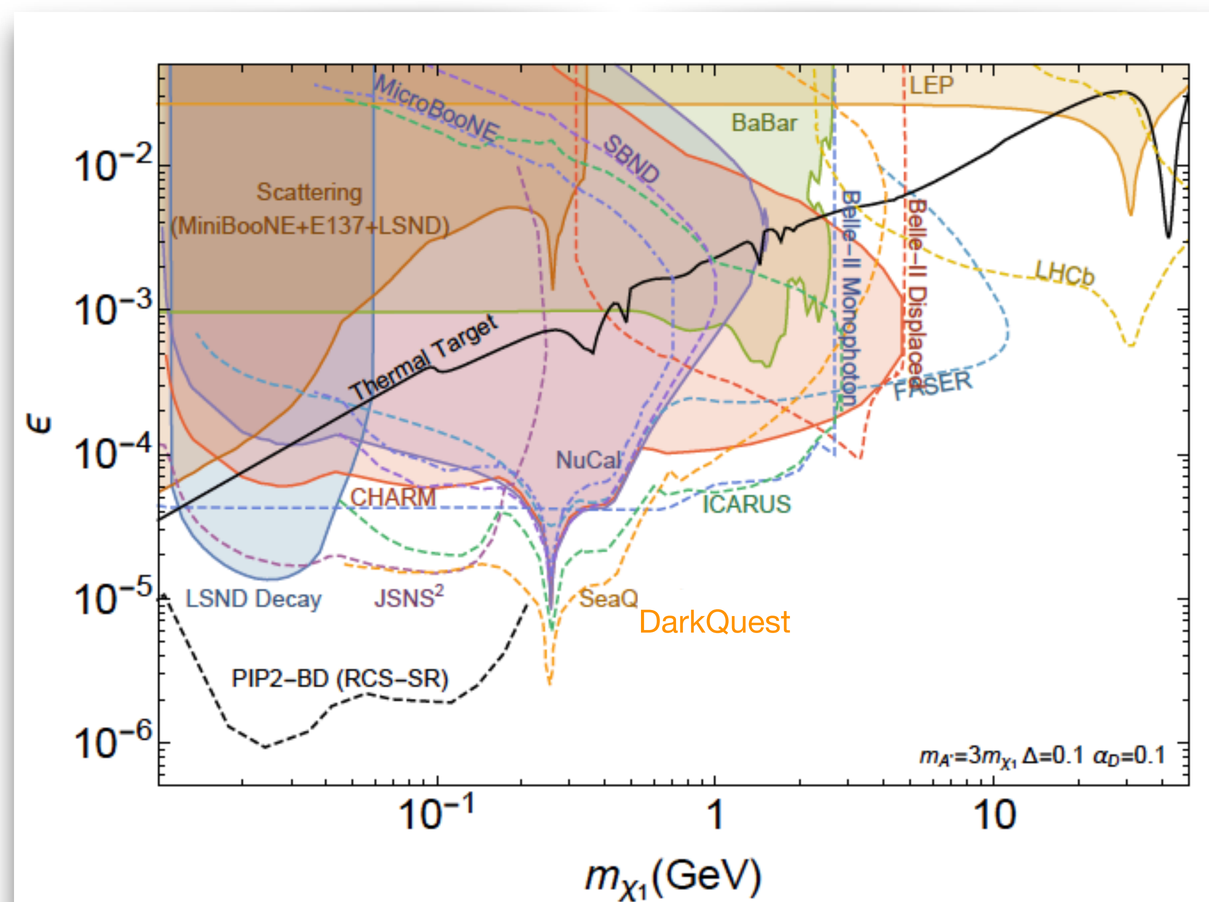
X_1 X_2 → SM

DM **DM excited state**

* Signatures in our labs:

X_2 → X_1 e^+ e^-





- Prompt visible decays
- Long lived particles
- Invisible component

Big idea 2: dark sector portals at high intensities

https://arxiv.org/abs/2207.06905

Explore the structure of the dark sector by producing and detecting unstable dark particles: Minimal Portal Interactions.

- dark photon $\epsilon B^{\mu\nu} A'_{\mu\nu}$
- dark scalar $\kappa |H|^2 |S|^2$
- sterile neutrino $y H L N$
- ALP $g_{a\gamma} a \tilde{F}_{\mu\nu} F^{\mu\nu}$
- New gauge symmetries: B-L, $L_\mu - L_\tau$, …

$A' \to \ell^+\ell^-, \ldots$

$S \to \mu^+\mu^-,\ \pi^+\pi^-, KK, \ldots$

$N \to \ell\pi, \ldots$

$a \to \gamma\gamma,$

$Z' \to \mu^+\mu^-, \ldots$

"visible" signatures

How to test these couplings?

Sizable coupling → **prompt** decay (generically larger backgrounds)

Small coupling → **displaced** decay (generically small backgrounds)

Experimental targets:

Secluded DM scenarios (Pospelov, Ritz, Voloshin, 0711.4866)

Forbidden DM scenarios (D'Agnolo, Ruderman, 1505.07107)

Big idea 3: richer dark sectors

https://www.dropbox.com/s/gksd3y43k0vtpyw/Snowmass_RF6_Big_Idea_3.pdf?dl=0

New Flavors and Rich Structures in Dark Sectors.

To-date, much of the emphasis for experimental work on dark sectors has been anchored to minimal models (i.e. minimal number of particles & flavor universality).

New necessary step: more complete coverage of non-minimal dark sector models

Richer phenomenology ➡ rethinking of experimental strategies for achieving optimized sensitivities

2 themes:

* Dark sector benchmarks that address anomalies in data
  E.g. $(g-2)_\mu$, flavor anomalies, Xenon 1T excess, MiniBooNE excess, …

* Commonly used benchmarks going beyond the assumption of minimality
  E.g. (1) flavor violating ALPs, (2) DM models with a DM excited state (inelastic DM, strongly interacting massive particles, …))

DM in a strongly interacting dark sector

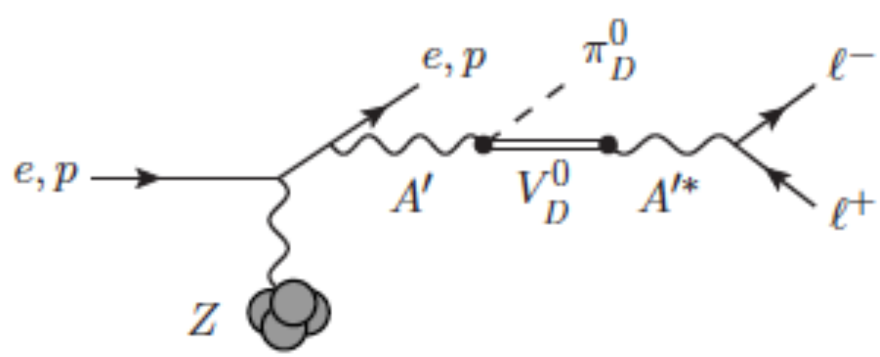
Dark Matter can be the lightest state of a dark QCD-like theory (e.g. a dark pion)

Novel process responsible of freeze-out: $3 \to 2$ annihilation

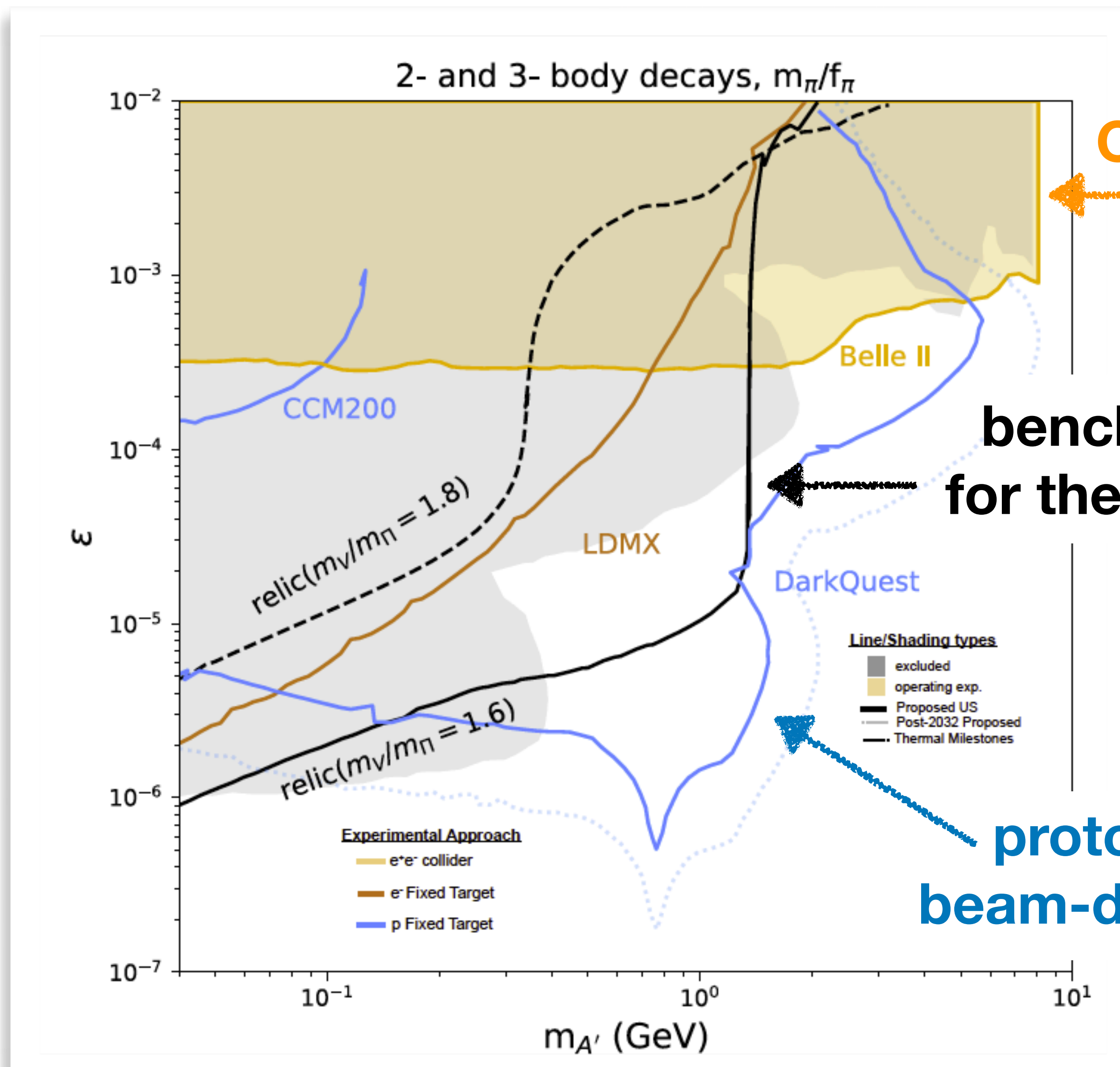
Motivation to consider MeV-GeV DM!

The additional dark states will lead to a richer phenomenology

For example:



Planned and proposal experimental program will remain robust to unexpected final states



Colliders

benchmarks for thermal DM

proton beam-dump

Theory

Theory is **essential** for the development of projects.

Continued support for leadership in dark sector theory will be **critical**.

1. **Theory**: Better understand which dark-sector scenarios can address (current and future) open problems in particle physics;

2. **Pheno**: Develop new ideas for exploring the phenomenology of dark sectors. Develop simulation / generator tools that can be integrated into experimental analyses

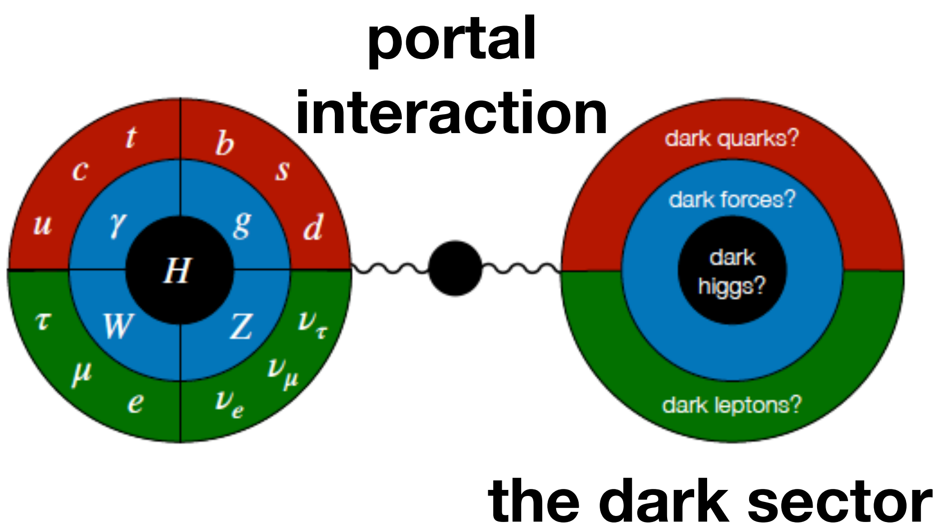
3. **Collaboration**: Collaborate at every stage of new dark-sector experiments, from design through interpretation of the data. This type of theory work has been at the foundation of essentially all ongoing and planned experimental activities in this growing field.

Examples: Proposal for

- LDMX Izaguirre, Krnjaic, Schuster, Toro, 1411.1404
- DarkQuest Berlin, SG, Schuster, Toro, 1804.00661
- M^3 Kahn, Krnjaic, Tran, Whitbeck 1804.03144
- Faser Feng, Galon, Kling, Trojanowski, 1708.09389
- CODEX-b Gligorov, Knapen, Nachman, Papucci, Robinson, 1708.09395
- Mathusla Chou, Curtin, Lubatti, 1606.06298

Dark Sectors at High Intensity

The existence of dark matter motivates a dark sector neutral under the SM forces



Dark sectors are a compelling possibility for new physics, with potential relevance to

lightness of SM neutrinos, baryon-antibaryon asymmetry,
hierarchy problem, strong-CP problem (e.g., axions, axion-like-particles),
anomalies in data

Dark sectors are generically weakly coupled to SM matter (via portal interactions) and can naturally have MeV-to-GeV masses.

→ Only mild constraints from precision atomic physics & high-energy colliders

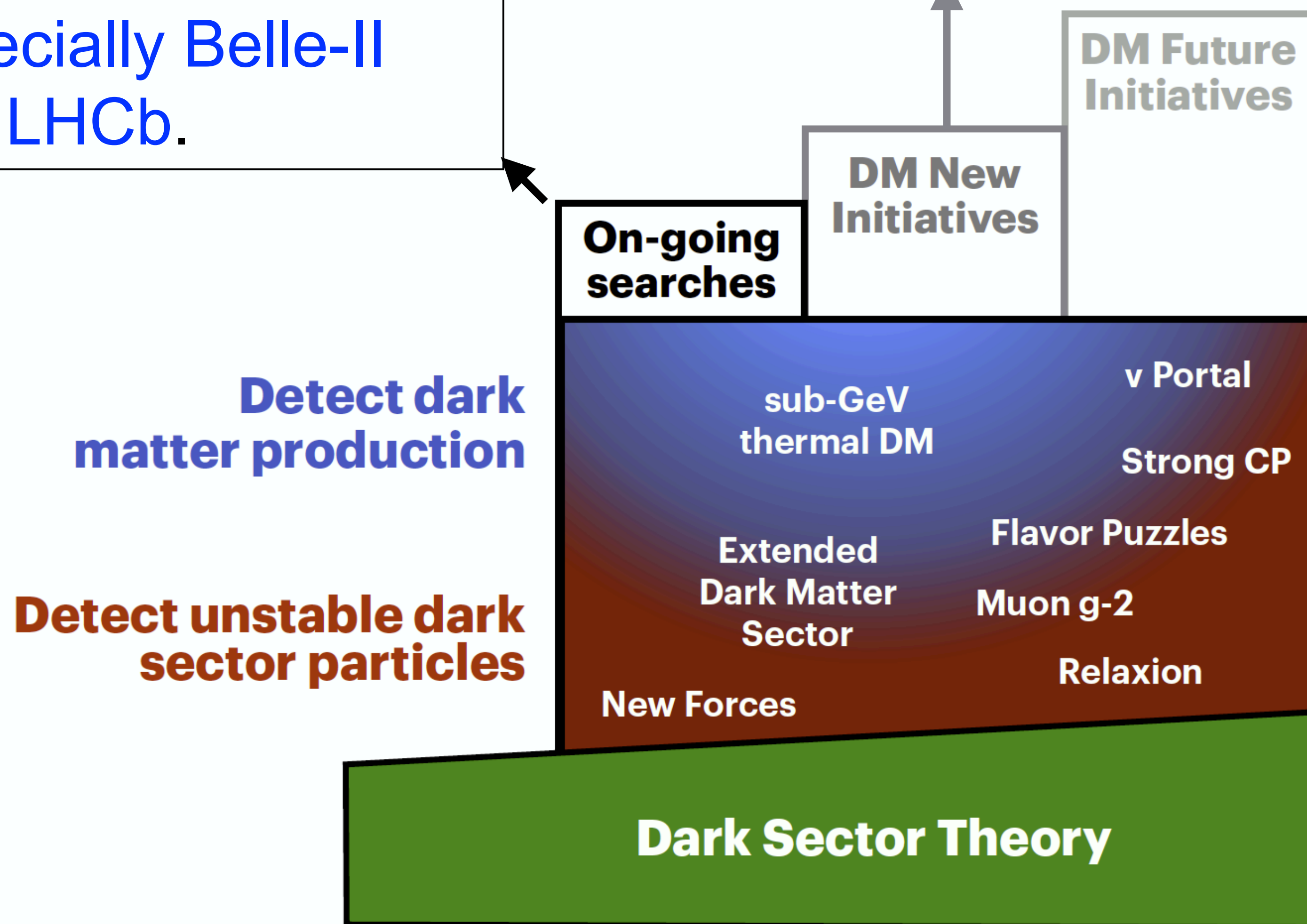
→ Intensity-frontier experiments offer unique and unprecedented access to:

Big idea 1	• Light dark matter production
Big idea 2	• Systematic exploration of dark sector portals
Big idea 3	• Searches for new flavors and rich structures in dark sectors

To promote US leadership in dark sector studies:

* Exploit the capabilities of existing multi-purpose detectors, especially Belle-II and LHCb.

* Invest in fully funding projects supported by “DM New Initiative”, LDMX and CCM



* Expand DMNI with focus on signals of visible decays of dark sector particles – proposals include proton and lepton beam-dump experiments, long-lived-particle detectors

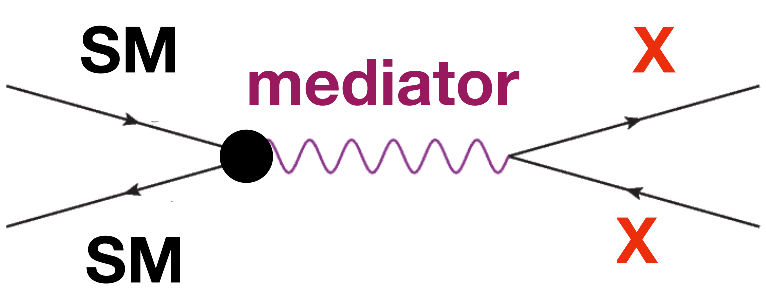
* Support theory efforts to explore dark sector models and collaborate in dark-sector experiments – this has been at the foundation of essentially all ongoing and planned experimental activities in this growing field.

Final states to look for

a. Invisible, non-SM

Dark Matter production

Producing stable particles that could be (all or part of) Dark Matter

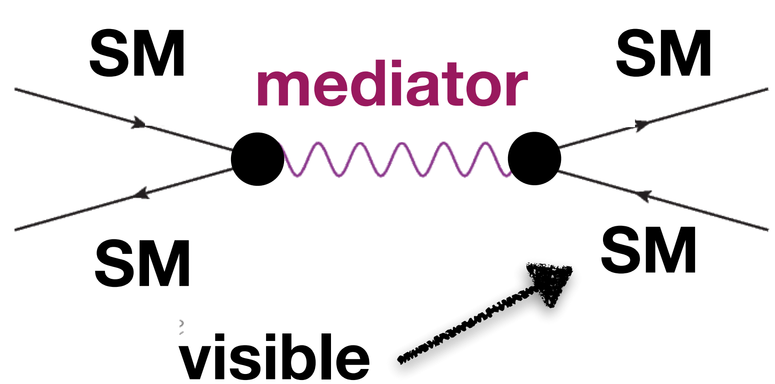


1. **Missing energy/ momentum**
2. **Scattering**

b. Visible, SM

Production of portal-mediators that decay to SM particles

Systematically exploring the portal coupling to SM particles

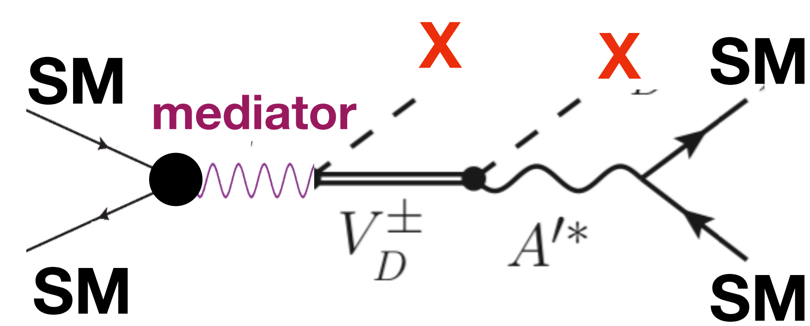


3. **Visible decay products**

c. Mixed visible-invisible

Production of "rich" dark sectors

Testing the structure of the dark sector

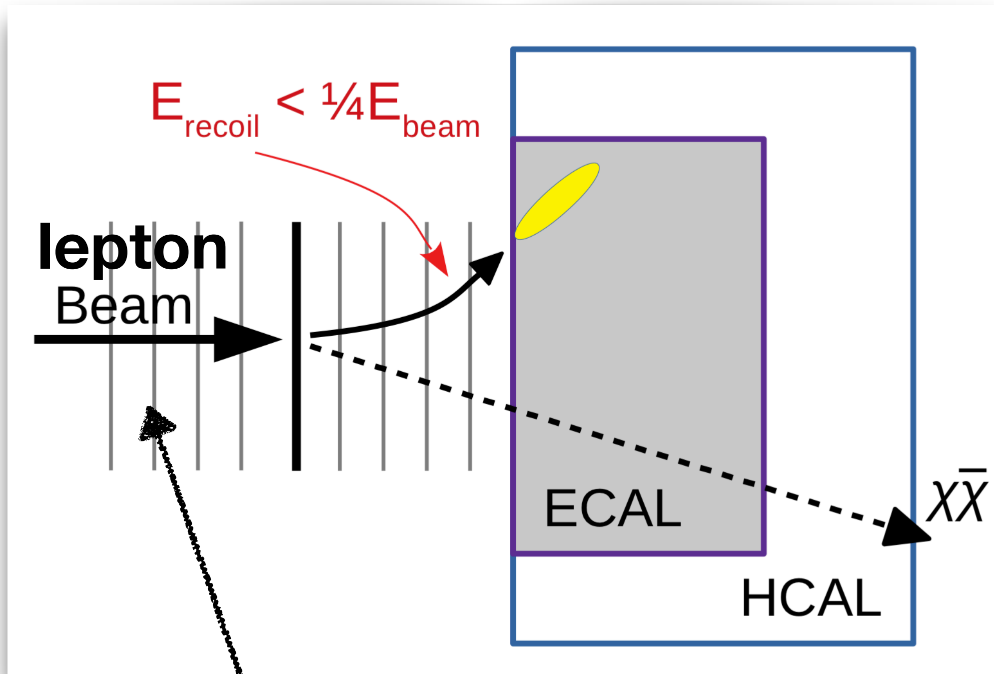


1. **Missing energy/ momentum**
2. **Scattering**
3. **Visible decay products**

S.Gori

Backup

1. Missing energy/momentum



Dark matter events can be kinematically characterized by the calorimetric "disappearance" of a sizable fraction of the beam energy. **Detection strategy**

e$^-$ beam for the **NA64** experiment,
Andreas et al., 1312.3309 Running at CERN

e$^-$ beam for the **LDMX** experiment,
Akesson et al., 1808.05219

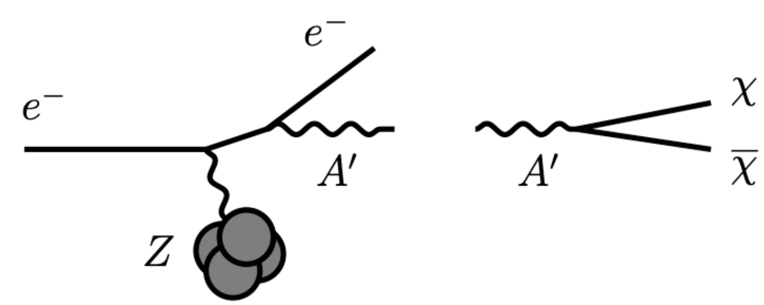
e$^+$ beam for the **POKER** experiment,
Andreev et al., 2108.04195

μ$^-$ beam for the **M^3** experiment,
Kahn et al., 1804.03144 Future experiments

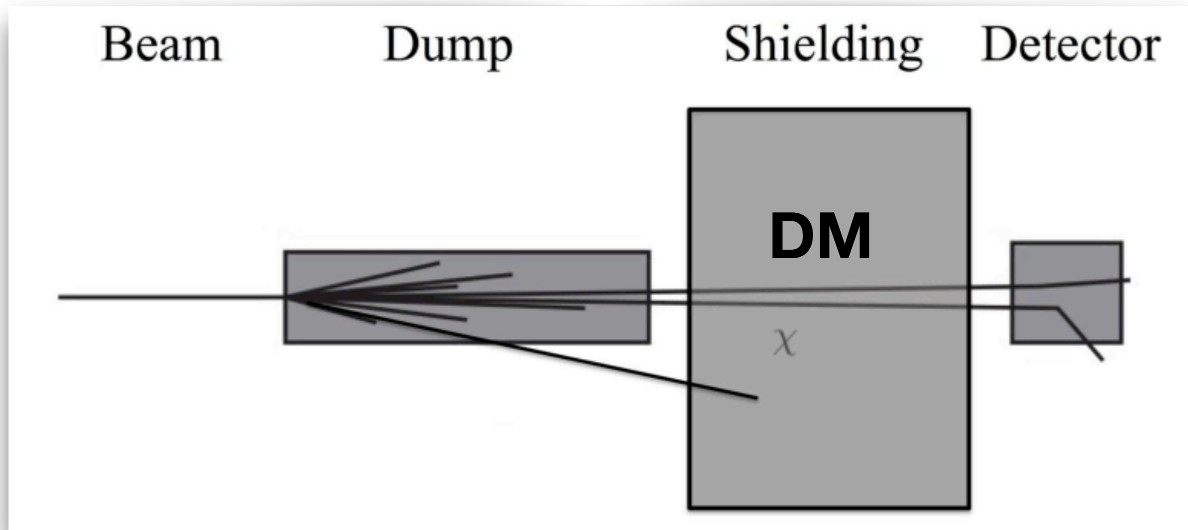
DMNI funding

Dark Matter can be produced through the mediation of a on-shell or off-shell mediator.

For example,



2. Re-scattering



Proton-beam experiments are highly synergistic with the accelerator-based neutrino physics program. They use the same beamlines and detectors:
LSND, MiniBooNE, COHERENT, CCM

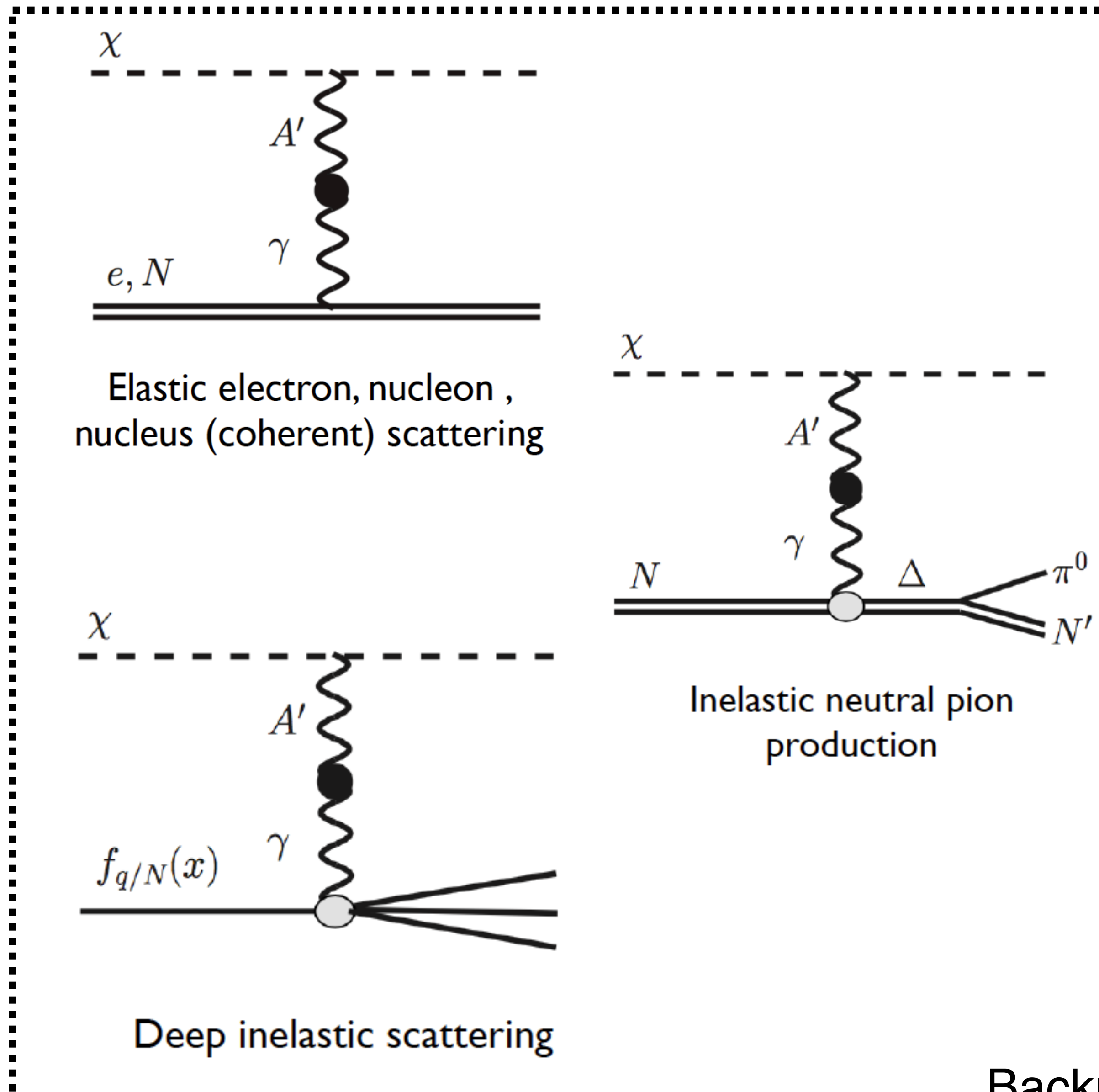
DMNI funding

Electron-beam experiments have the advantage of a more compact secondary DM beam (BDX experiment)

Synergy with beam dump-experiments that utilize high energy beams (forward facility, future colliders)

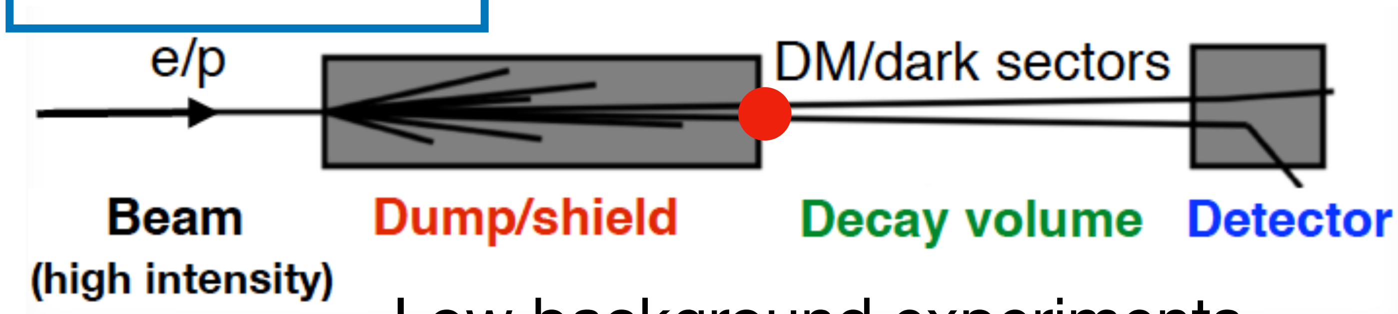
Production of dark matter in the dump and detection of its scattering in forward detectors.

Detection strategy



3. Visible signatures

DISPLACED



Low background experiments
(depending on the size of the dump)

Production of an unstable dark sector particle in the dump and detection of its SM decay products in forward detectors.

Detection strategy

p beam for the SeaQuest/DarkQuest experiment at Fermilab

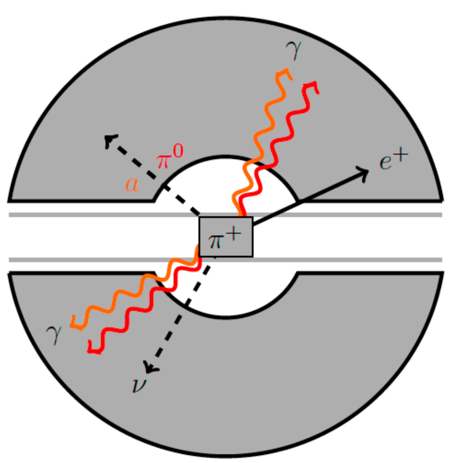
p beam for the NA62, KLEVER experiments at CERN

e- beam for the HPS experiment at JLAB

e- beam for the DarkLight experiment at TRIUMF

Running experiments

Future experiments



PROMPT

Production of an unstable dark sector particle from meson decay and detection of its SM decay products.

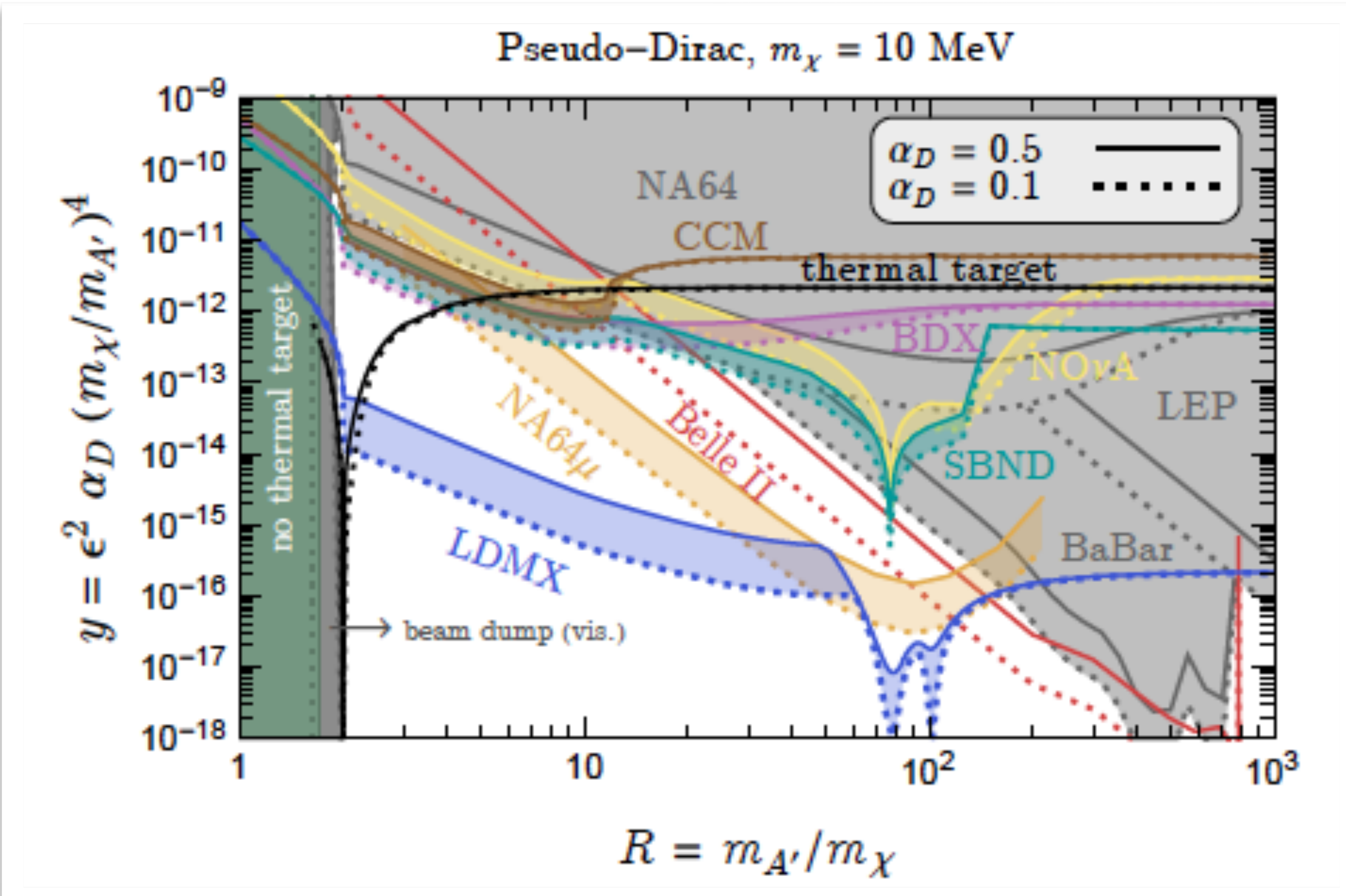
Detection strategy

Pion decaying at rest (PIONEER experiment)

Eta/eta' decaying (almost) at rest (REDTOP experiment)

Enormous synergy with collider experiments! Belle II, LHCb, …

Variations of the invisible dark photon scenario



Dark Matter living in a dark sector

The DM mass scale

MeV GeV TeV

Dark sectors

Thermal DM

WIMPs

Simple production mechanism works here

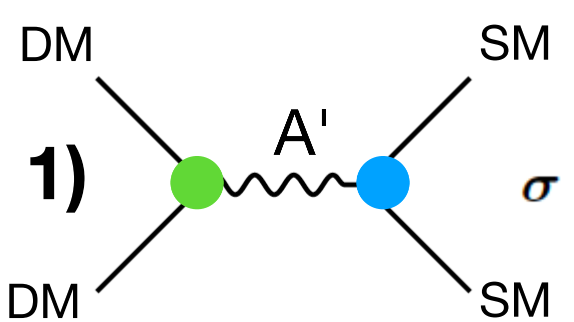
Dark sectors are needed

Lee-Weinberg bound (~ few GeV)

freeze-out

DM thermal freeze-out targets

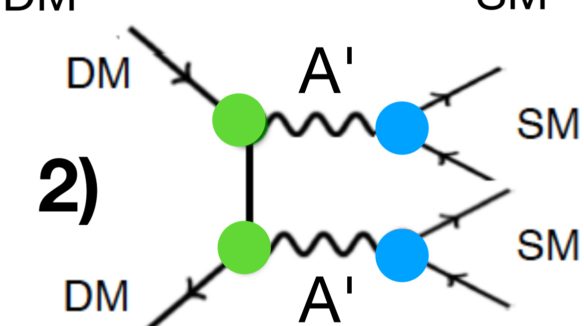
1)



if $m_{A'} > 2m_{DM}$

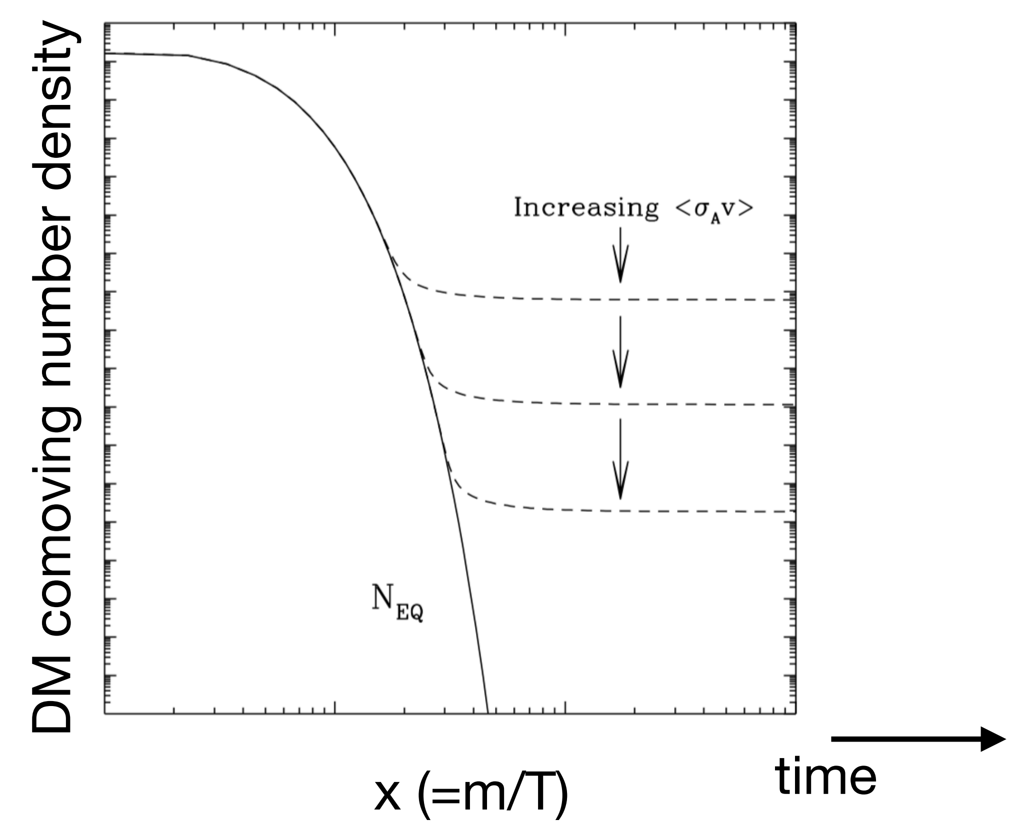
$$\sigma \propto \frac{y}{m_{DM}^2}, \quad y \equiv \epsilon^2 \alpha_D \left(\frac{m_{DM}}{m_{A'}}\right)^4$$

2)



if $m_{A'} < m_{DM}$

ε is lower bounded



S.Gori

Backup