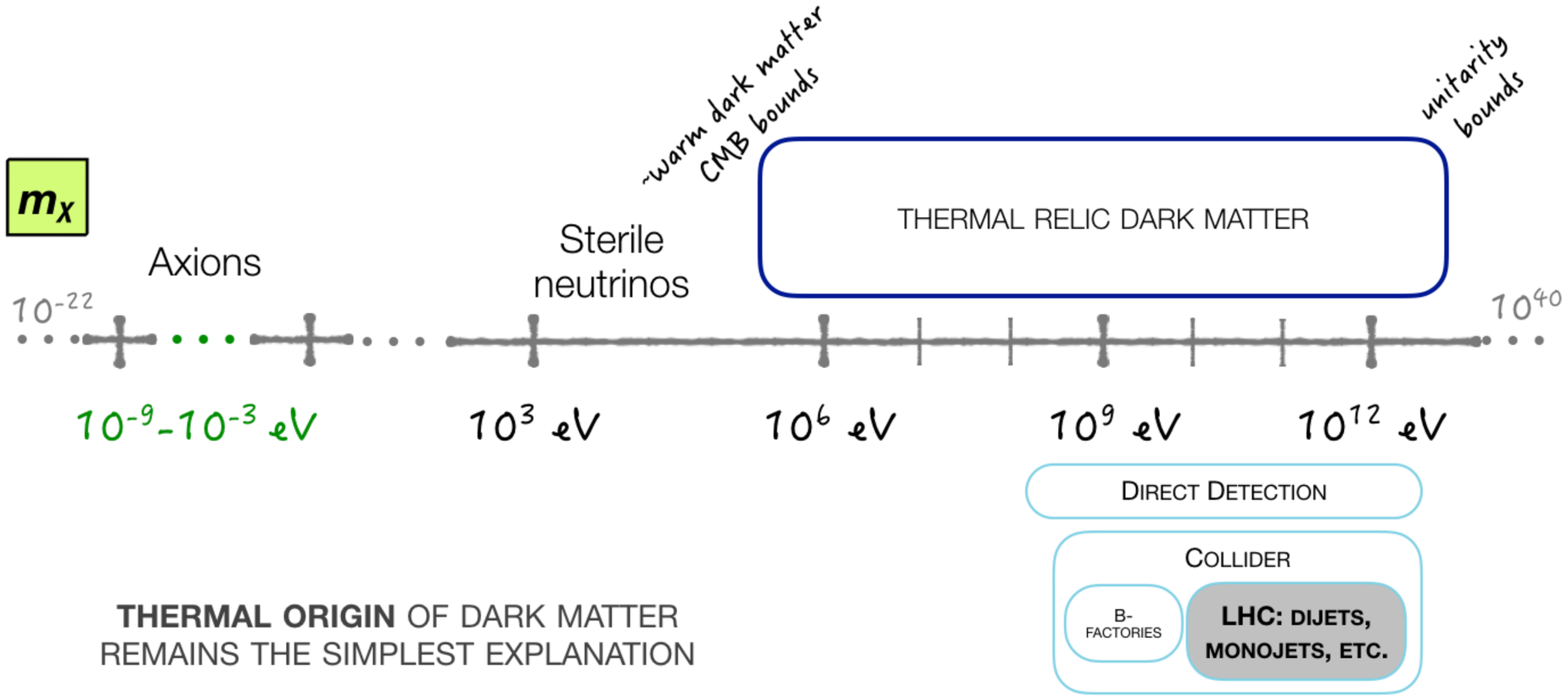
New ideas for hidden sector searches

Nhan Tran, Gordan Krnjaic, Andrew Whitbeck

Precision Working Group Meeting

April 20, 2017

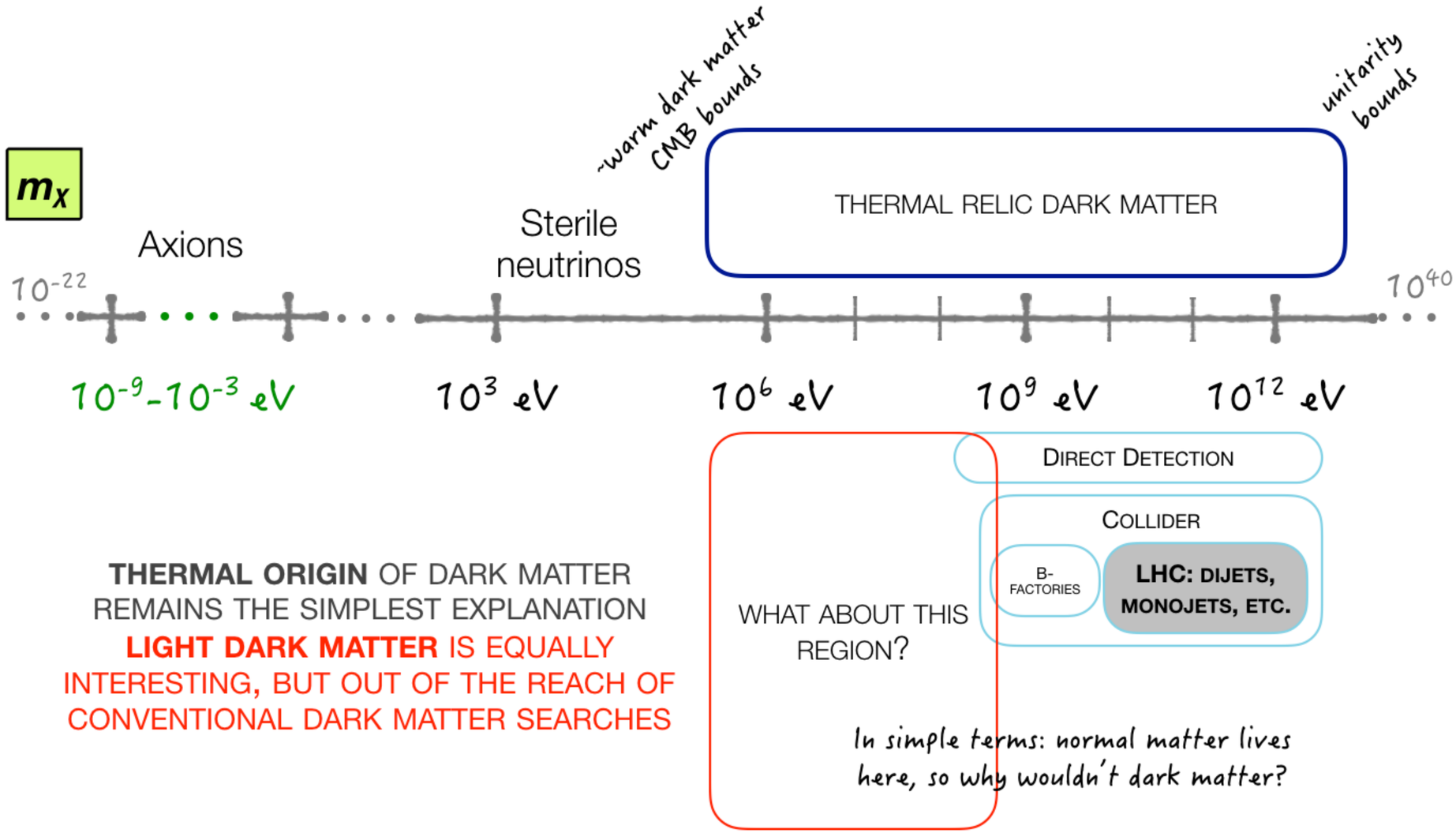
The dark matter parameter space…



THERMAL ORIGIN OF DARK MATTER
REMAINS THE SIMPLEST EXPLANATION

Fermilab

The dark matter parameter space…



THERMAL ORIGIN OF DARK MATTER REMAINS THE SIMPLEST EXPLANATION

LIGHT DARK MATTER IS EQUALLY INTERESTING, BUT OUT OF THE REACH OF CONVENTIONAL DARK MATTER SEARCHES

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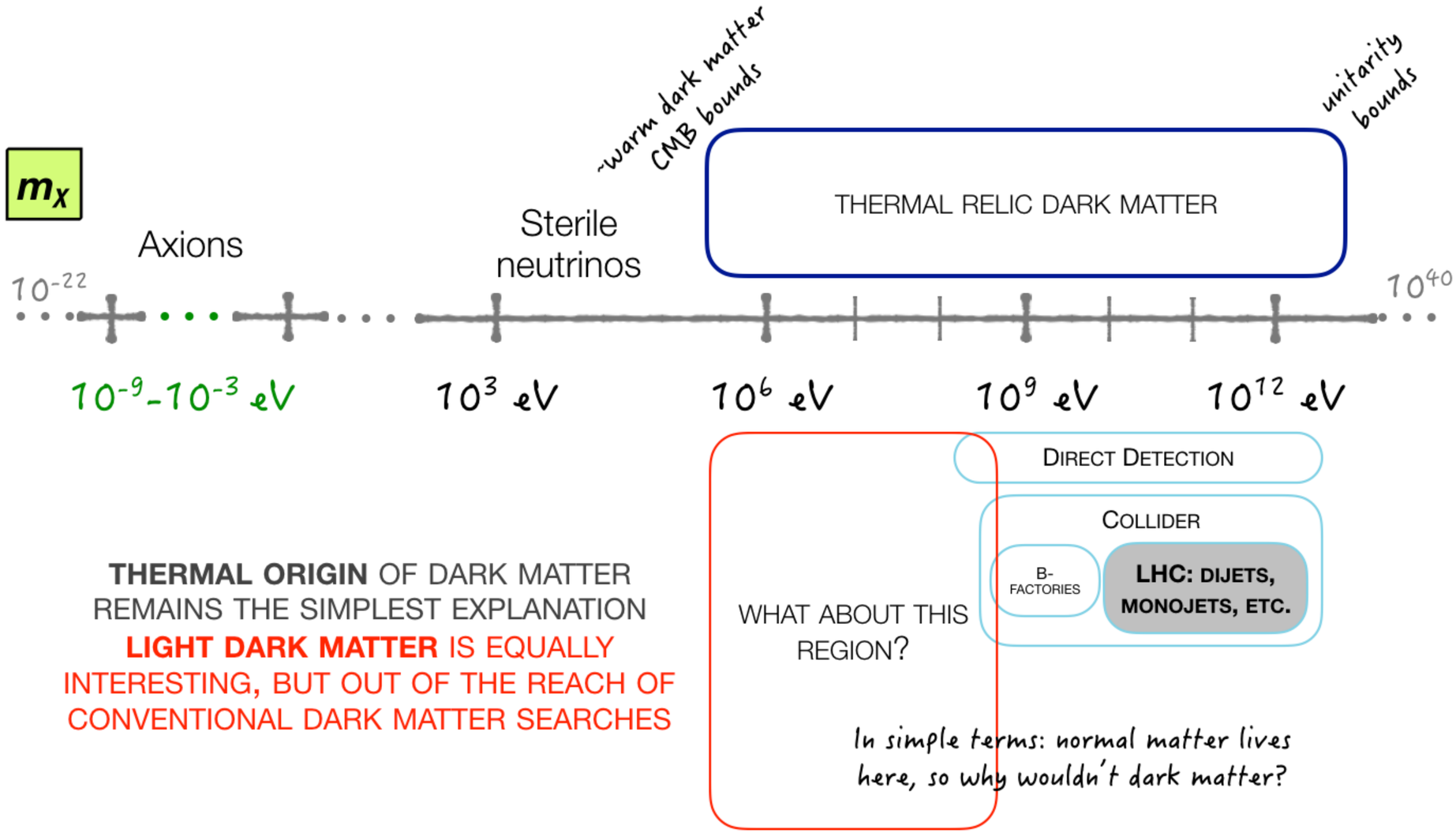

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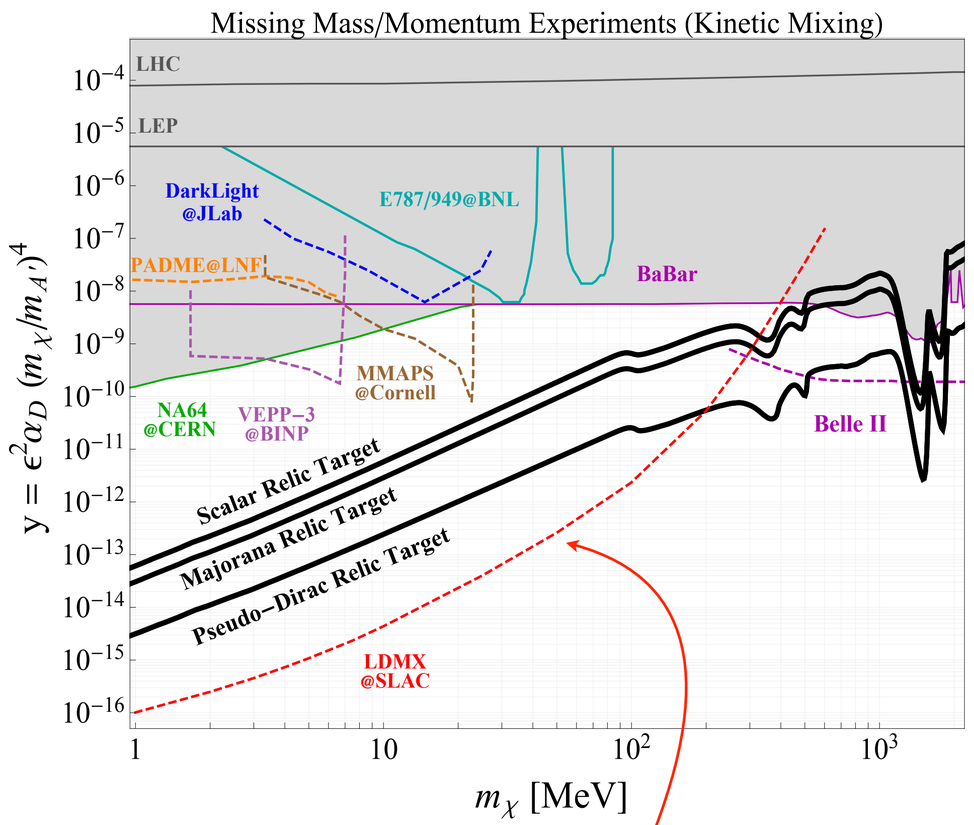
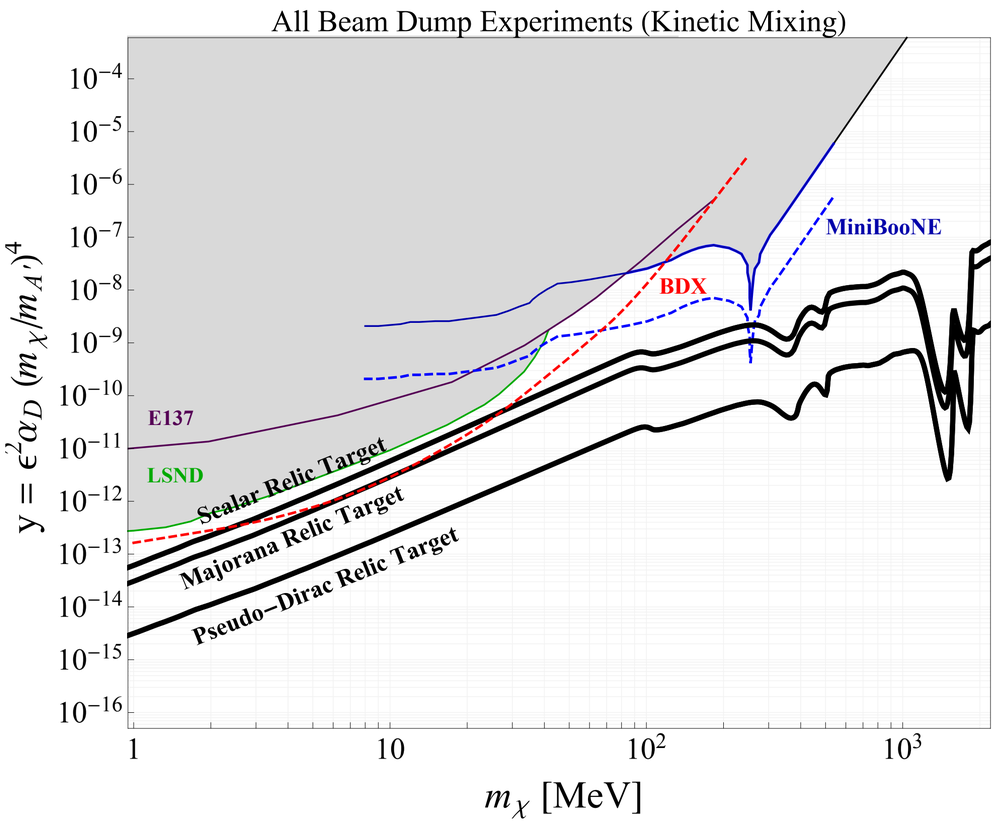
benchmarks

source

Missing mass / momentum / energy



Beam dump



electron fixed target missing momentum (LDMX) a strong candidate for achieving light thermal dark matter targets (based on 10^{16} EOT)

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LDMX

Beam requirements

LDMX requires a low current, high repetition rate electron beam

- Phase 1: **4x10^{14} EoT** ~ 1 e- / 25 ns in a year
- Phase 2: **1x10^{16} EoT** ~ 1 e- / ns in a year [or 5e-/5ns]

LHC BUNCH SPACINGS!

Beam energy,

- min: **few GeV,** to reliably veto soft backgrounds
- max: **O(10s of GeV)**, irreducible Moller/CCQE backgrounds too big

options:

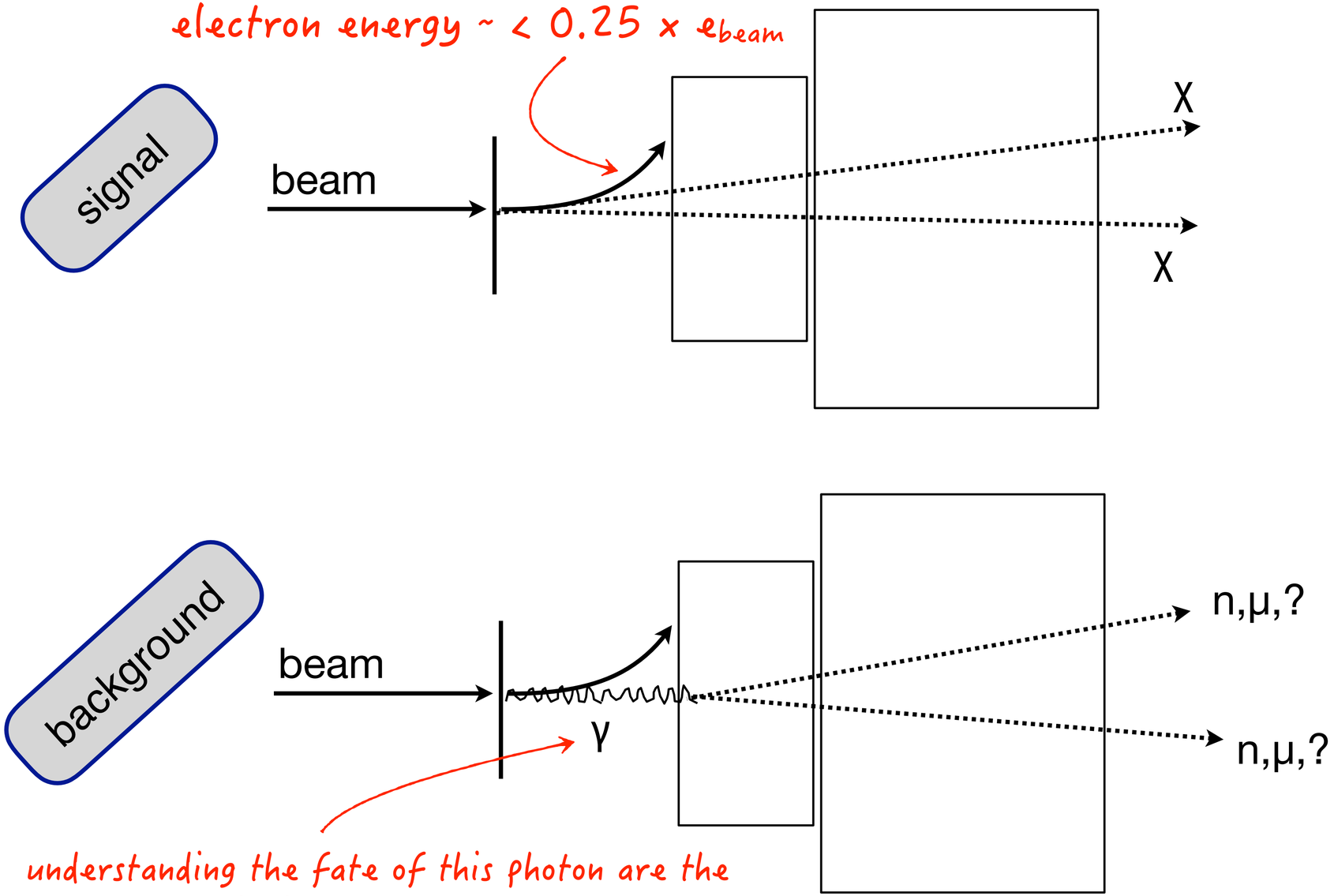
JLAB CEBAF, 12 GeV, 1.5 GHz CW beam (hall D)

- Challenge: very hard to get beam time, operation costs non-trivial

SLAC DASEL [proposed], 4/8 GeV Phase 1/2, (46/186 MHz)

- Parasitic to LCLS-II (< 1%), extracting bunches downstream

missing momentum basics



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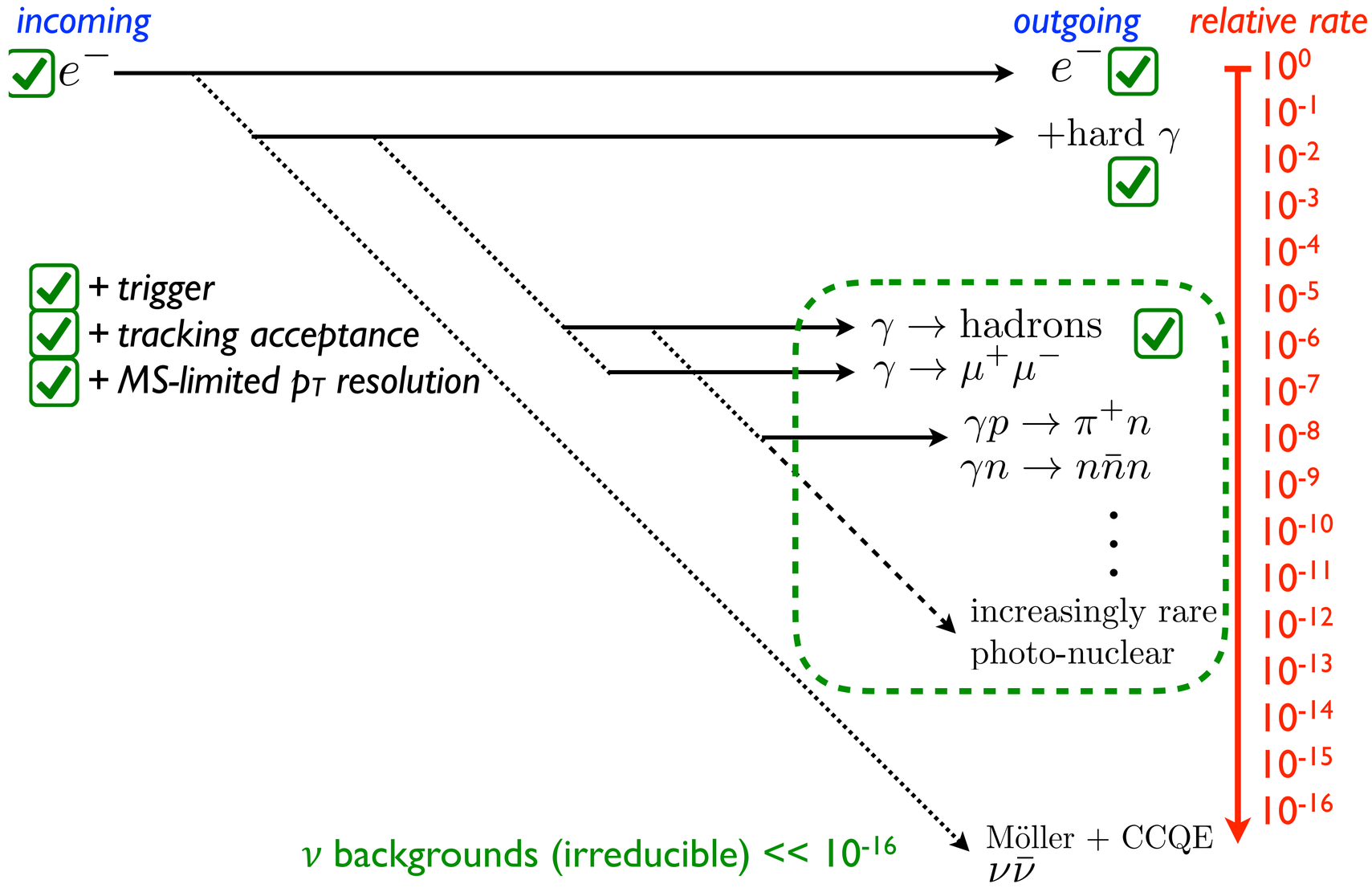
background reduction



ν backgrounds (irreducible) << 10^{-16}

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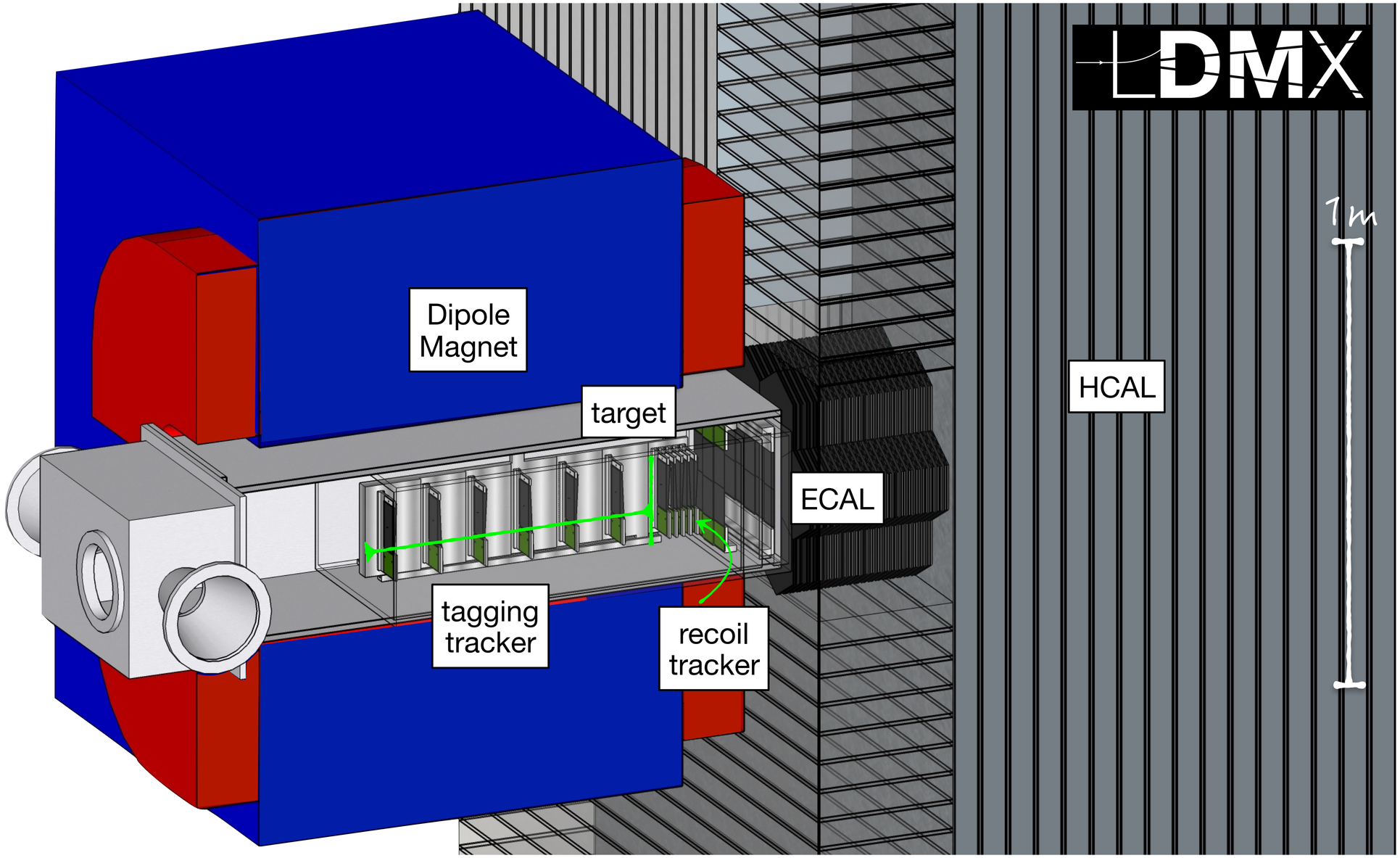

LDMX
Dipole Magnet
target
ECAL
HCAL
tagging tracker
recoil tracker
1m

Fermilab synergies

- **Tracker**: HPS tracker comes from Tevatron!
  - not much new to do, very similar to HPS, SLAC/UCSC expertise
- **ECal**: very similar to CMS Phase 2 HGCal
  - driven by UCSB group
  - FNAL involved in HGCal construction, potential to help out here if needed e.g. (testing/integration)
- **HCal**: readout electronics based on CMS Phase 1 HCal
  - FNAL expertise, ASIC and readout modules developed here
  - Largest detector subsystem
  - propose to drive this effort, collaborating with CalTech group
- **Trigger/DAQ**: CMS/FNAL expertise
  - CMS trigger development, algorithm development, firmware
  - SLAC has generic ATCA infrastructure (RCE), Minnesota expertise

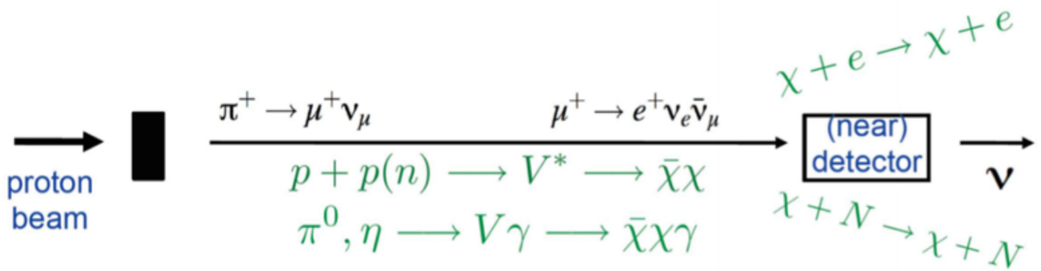
Beam dumps at FNAL

- What if couplings are leptophobic?

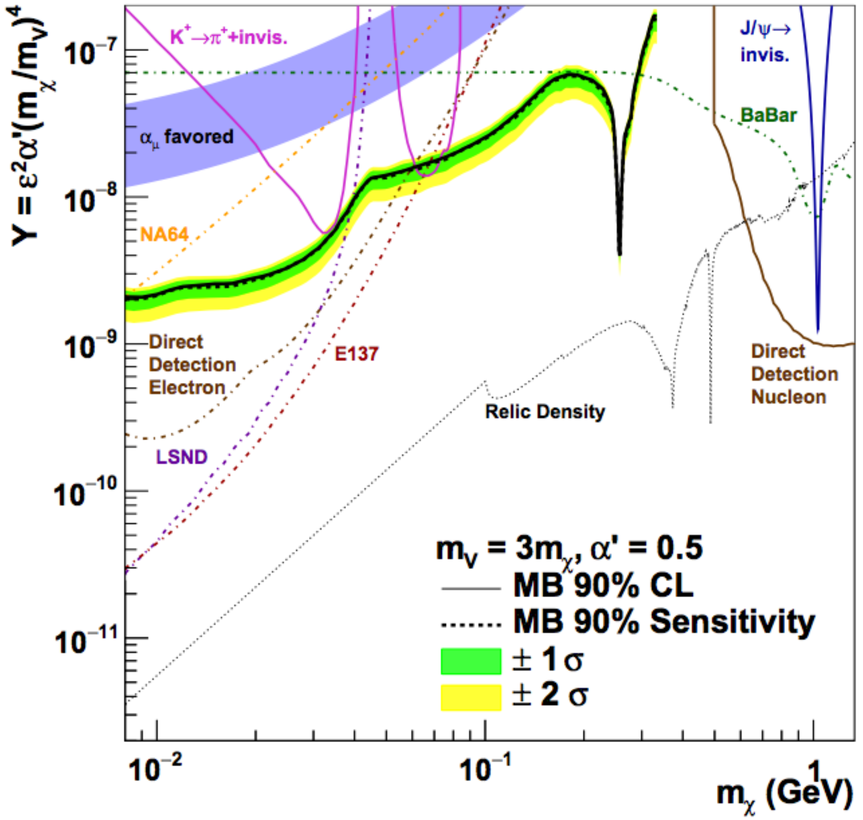
- What if muon couplings are enhanced?

Proton beam dumps

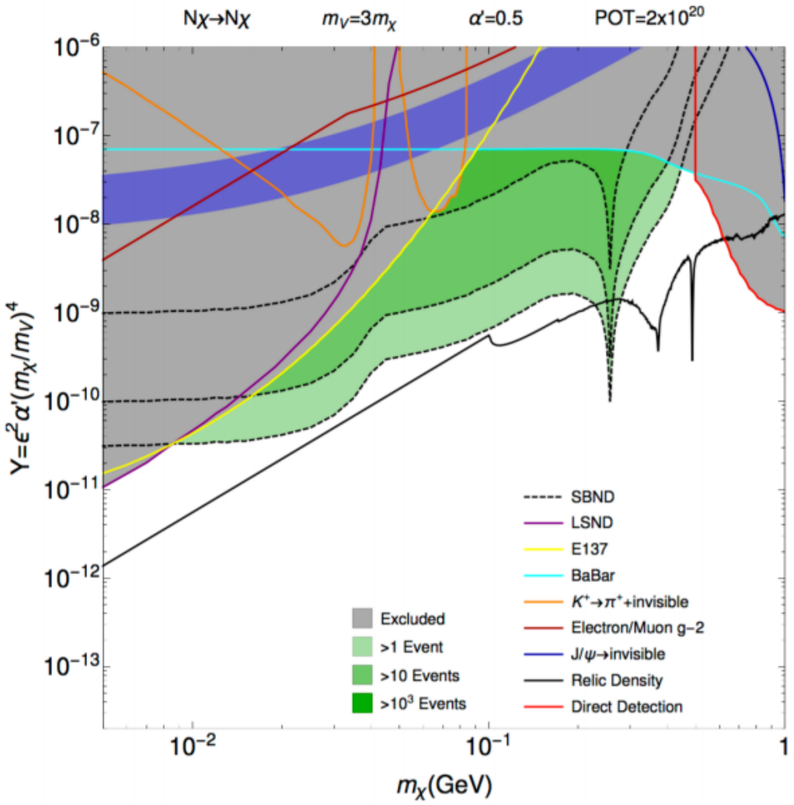
- Existing short baseline neutrino program is ideally suited for dark matter searches with proton beam dumps



arXiv:1702.02688



SBND with alterations to target



- **Option 1**
  - Design, optimize, build a target block (iron, tungsten, hybrid, etc) that replaces current horn/target (removable).
  - **Pros**: Inexpensive ~ $1M, excellent neutrino suppression
  - **Cons**: Can only run after SBN neutrino run > 3yrs.
- **Option 2**
  - Design, optimize, build a target block (iron, tungsten, hybrid, etc) and new target station on the beam line.
  - **Pros**: Run concurrently with neutrino run, more flexible design. Excellent neutrino suppression.
  - **Cons**: More expensive ~$5M, as extensive shielding required (new target station).

See R.G. Van de Water @ UMD cosmic visions

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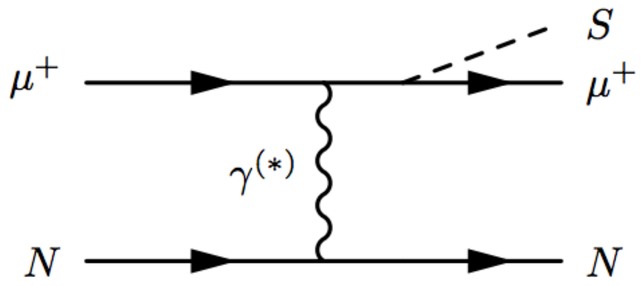
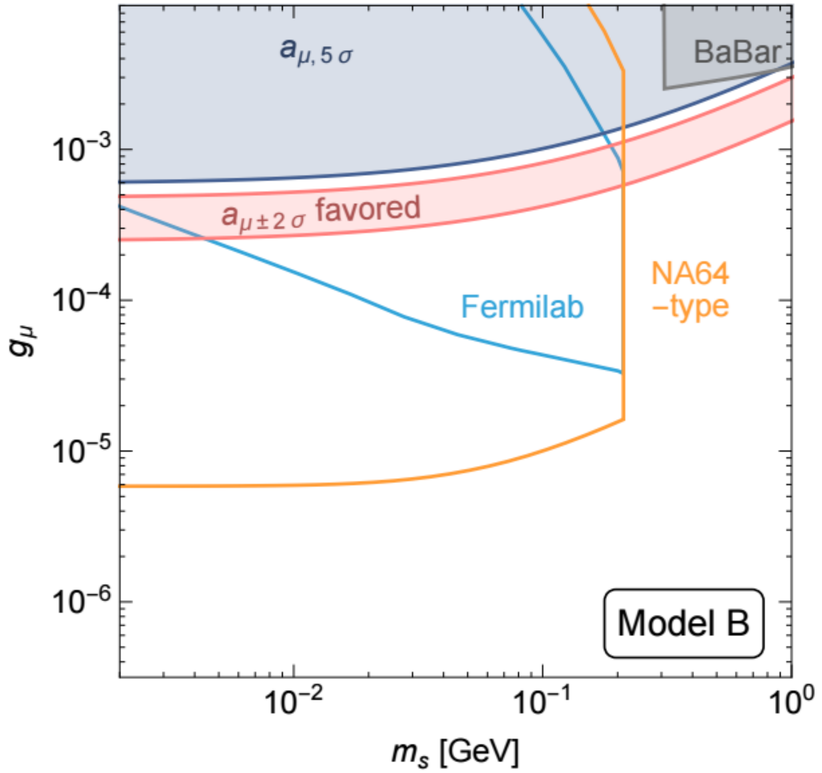
Muon beam dump

arxiv:1701.07437

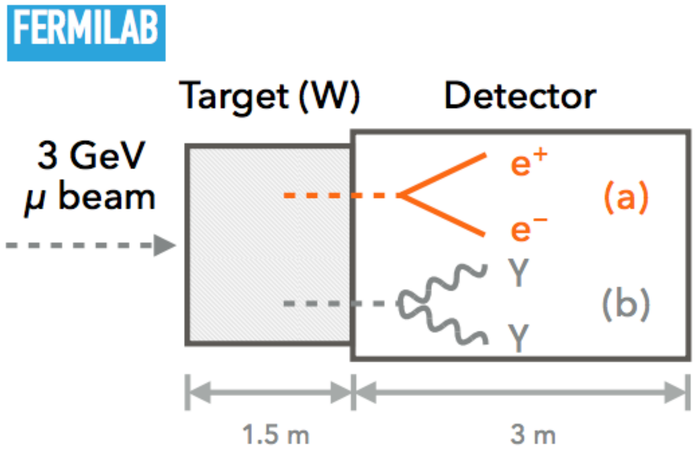
- Target muon anomalies (e.g. g-2) with hidden sector physics
  - suppress or turn off mediator coupling to electrons (and taus)
  - for $2m_e<m_S<2m_\mu$ decays will be displaced, but visible



- Whether muons can be delivered in bunches (Fermilab) or one-by-one will affect (NA64-type) the type of analysis done
  - these sensitivities assume there are no electron or tau couplings to the mediator



search for either
e^+e^- or $\gamma\gamma$
(mild bkg from K_L)



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Summary

- Physics case for accelerator based searches for hidden sectors is very strong (dark matter + anomalous measurements)

- LDMX is the single best accelerator based concept for probing invisible decays of mediators
  - can target most of the light thermal dark matter parameter space

- Other ideas (electron, muon, proton beam dumps) compliment existing programs and capitalize on existing infrastructure
  - should be part of the lab's future planning