The Light Dark Matter eXperiment LDMX @ INVISIBLES24

Einar Elén | On behalf of the LDMX collaboration

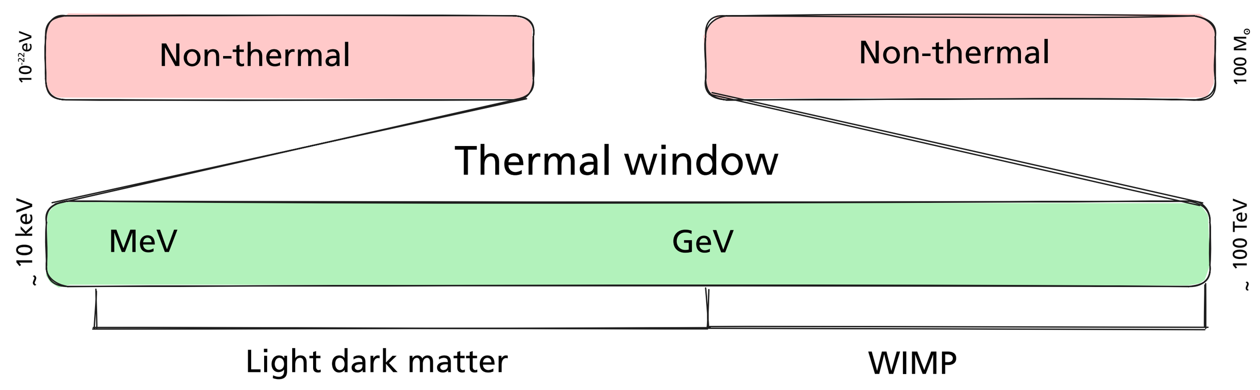
Background

While the allowed dark matter mass range is vast, the natural scenario where dark matter originates from thermal contact with familiar matter in the early Universe requires the DM mass to lie within about an MeV to 100 TeV. Considerable experimental attention has been given to exploring the WIMP regime (few GeV – ~TeV), while the region ~MeV to ~GeV is largely unexplored.

In the case of a thermal origin, then there necessarily is a production mechanism in accelerator-based experiments. The most sensitive way (if the interaction is not electron-phobic) to search for this production is to use a primary-electron beam to produce DM in fixed-target collisions. The Light Dark Matter eXperiment (LDMX) is a planned electron-beam fixed-target missing-momentum experiment at SLAC that has unique sensitivity to light DM in the sub-GeV range.

Light dark matter

- Well motivated and largely unexplored section of thermal relic dark matter.
- Well suited for accelerator experiments, since they are largely insensitive to spin and mass of DM particles.



LDMX lives here

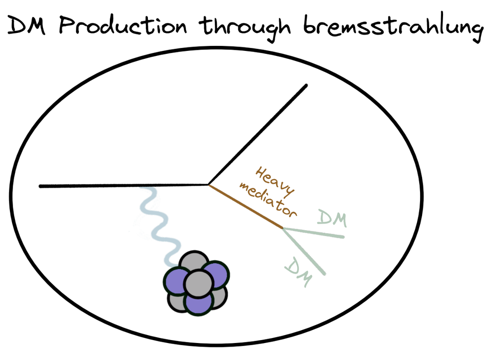
Production kinematics

Bremsstrahlung of a particle heavier than the electron has fundamentally different kinematics than SM bremsstahlung [1].

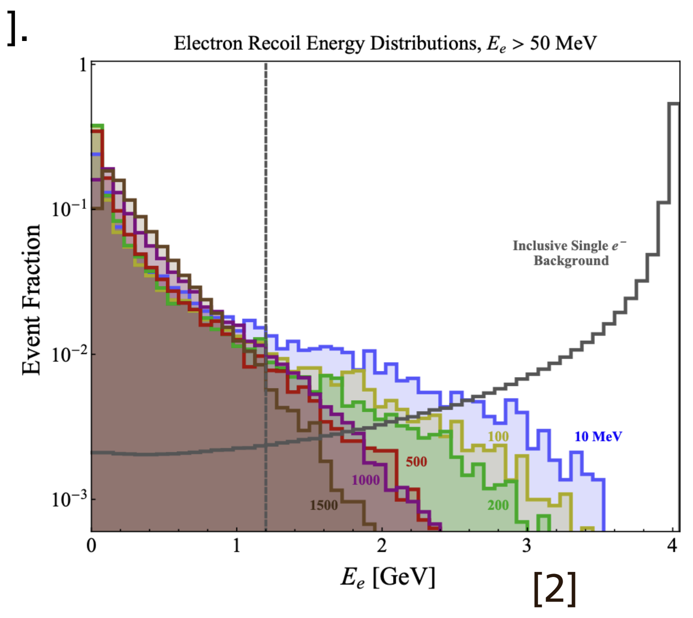
- Radiated particle carries most of the beam energy.
- Soft electron recoils at wide angle.

Opposite signature to SM bremsstrahlung.

DM Production through bremsstrahlung



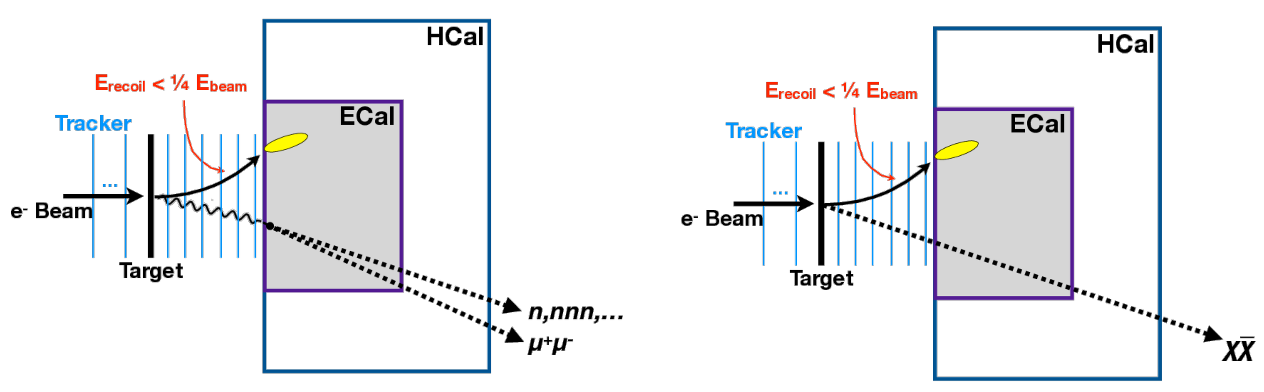
Thin target signature:
Missing momentum
&
Missing energy



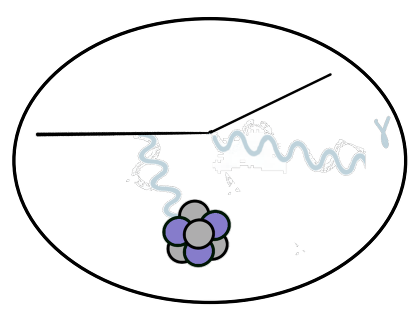
[2]

Photon induced background

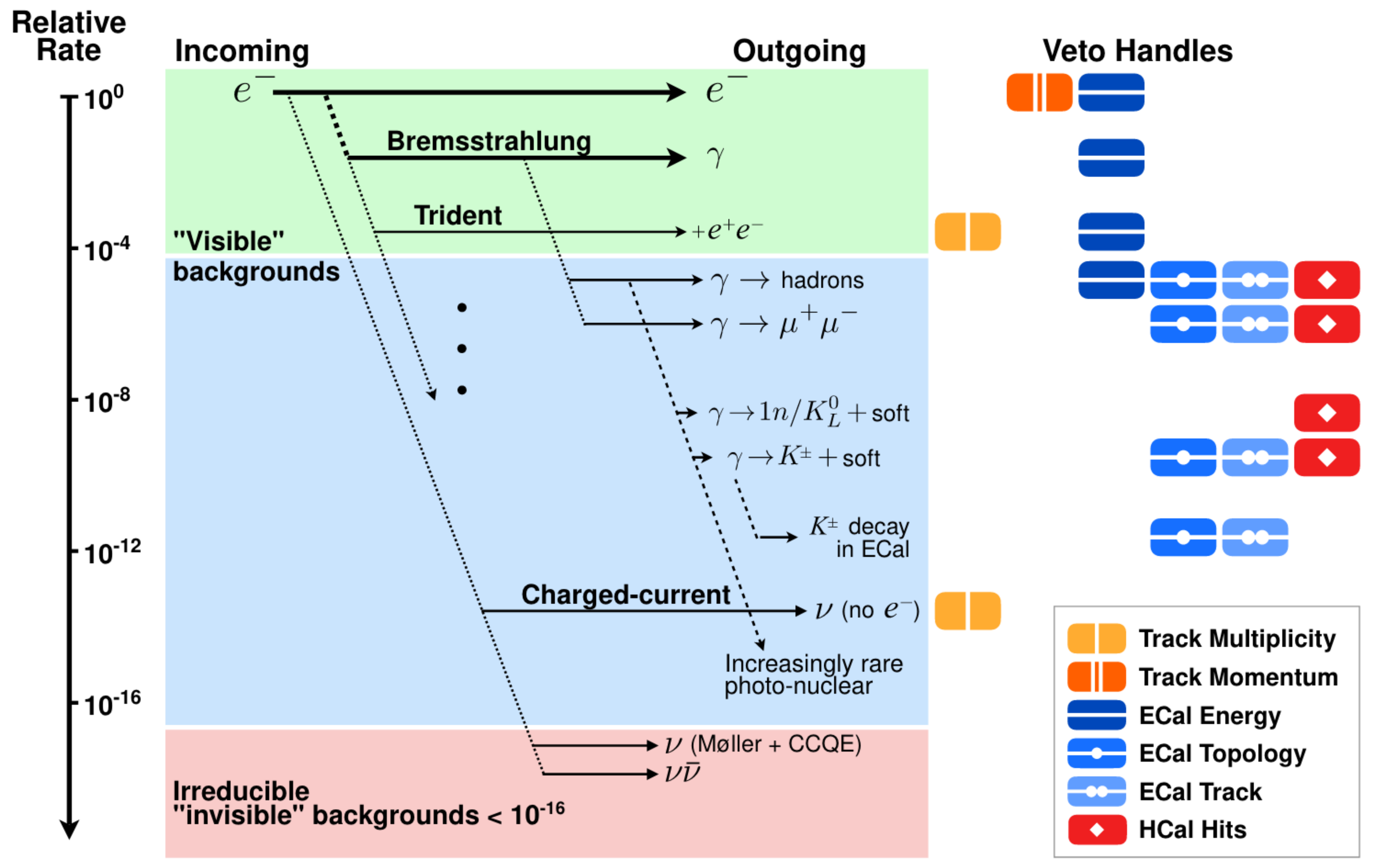
Ordinary standard model bremsstrahlung of a hard photon can mimic signal if not detected.



SM bremsstrahlung



Need veto handles for any final state that could mimic signal



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Acknowledgements

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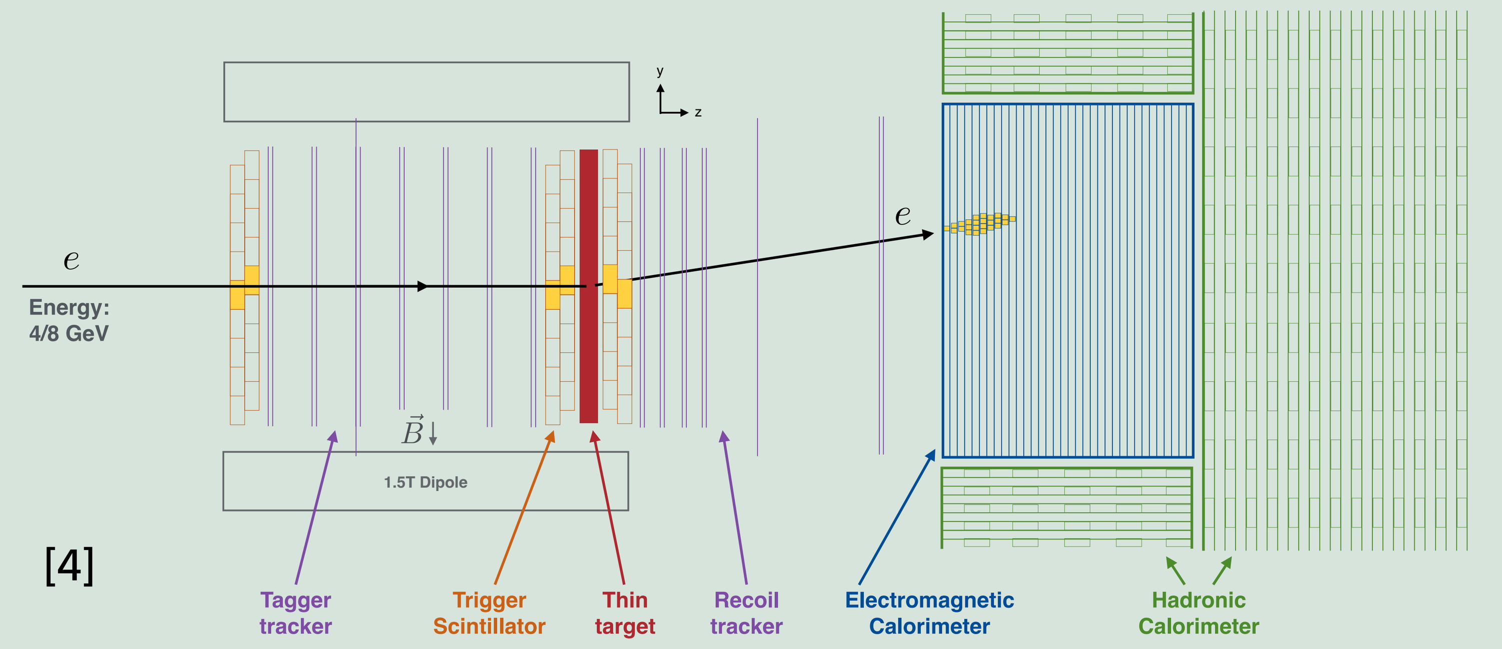
Experiment design

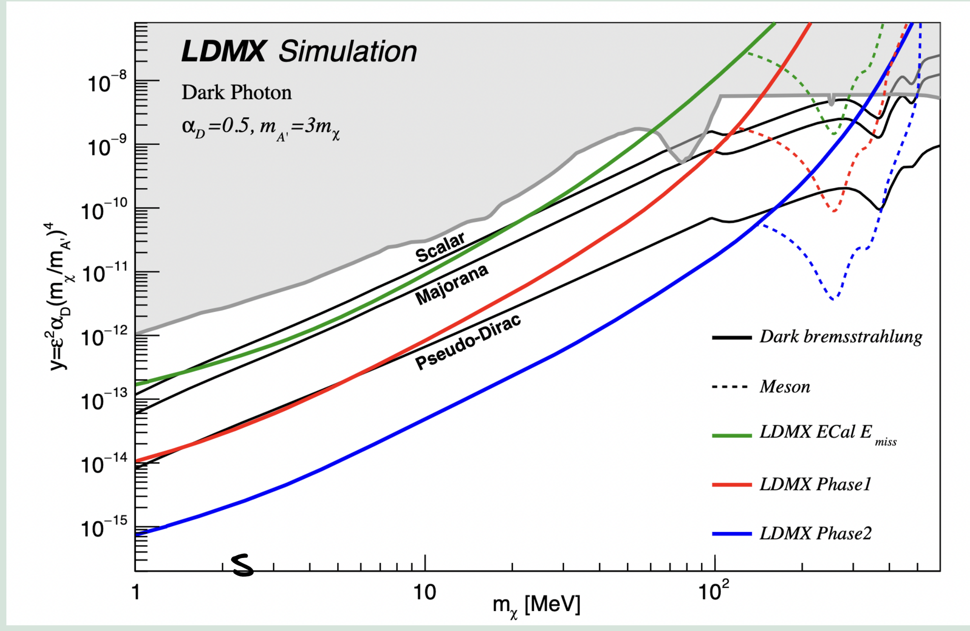


[4]

A recipe for discovering LDM with a fixed-target experiment

1) Find a suitable low current & high repetition rate electron beam.
2) Count incoming electrons & trigger on missing energy.
3) Require a recoiling electron with significant momentum loss & no extra tracks.
4) Use a high-granularity electromagnetic calorimeter to distinguish majority of photon-induced processes through e.g.
   - Shower features
   - Tracks from minimially ionizing particles
5) Finish with a low inefficiency hadronic veto for neutral final states (to taste).

Make sure to be below 1 background event for 10^{-16} electrons on target



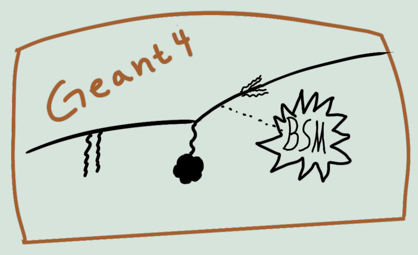
[4]

Model bridges across experiment scales

High statistics & zero background requirements

Stringent requirements for modeling subdominant components of rare processes lead to detailed scrutiny of modeling in tools like Geant4 & cross-comparisons with competing frameworks.

Large & well-controlled datasets of "background" events are a rich source of physics for constraining uncertainties in models for other experiments, e.g. electro-nuclear measurements @ LDMX for neutrino event generators [5].



Event generation cannot be factorized from detector simulation

DMG4 [6]: Direct implementation of models in Geant4

G4DarkBreM [7]: Scaling fixed energy events from tools like MG/ME

Pythia8/G4Apollo: Embed event generators directly in Geant4 (See also FLUKA/MOIRA [8])

- Upstream effects cannot be neglected.
- Fosters development of new techniques that benefit the wider HEP comunity.
- Brings otherwise disparate modeling communities closer together.

The LDMX collaboration

Caltech, Fermilab, Lunds Universitet, University of Minnesota, UCSB University of California Santa Barbara, Carnegie Mellon University, SLAC National Accelerator Laboratory, Stanford University, Texas Tech University, University of Virginia

[1] Bjorken et al., “New Fixed-Target Experiments to Search for Dark Gauge Forces.”
[2] Åkesson et al., “Light Dark Matter eXperiment (LDMX).”
[3] Åkesson et al., “Photon-Rejection Power of the Light Dark Matter eXperiment in an 8 GeV Beam.”
[4] Åkesson et al., “Current Status and Future Prospects for the Light Dark Matter eXperiment.”
[5] Ankowski et al., “Lepton-Nucleus Cross Section Measurements for DUNE with the LDMX Detector.”
[6] Bondi et al., “Fully Geant4 Compatible Package for the Simulation of Dark Matter in Fixed Target Experiments.”
[7] Eichlersmith et al., “Simulation of Dark Bremsstrahlung in Geant4.”
[8] Ahdida et al., “New Capabilities of the FLUKA Multi-Purpose Code.”

The light came in two
One was heavy, always shy
Hiding everywhere

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